DIRC R&D effort on the MCP-PMTs
(Log book #4)

J. Va’vra
Runs 176 – No Amplifier & timing with CFD/TAC/ADC 12.9.2006

- 2.80kV, 10µm hole 64 pad MCP-PMT (S/N 11180401), B = 0kG
- No amplifier; go directly to CFD via a SMA cable.
- Wait ~2 hours for the system to stabilize.
- Go from PiLas trigger to TTL/NIM convertor and then to a NIM discriminator = STOP of TAC.
- PiLas at 25%
- 3 Mylar attenuators => Npe ~20 (see page 82 in MCP-PMT_3 log book).
- Phillips 715 CFD, 25mV arming threshold, 1cm long delay jumper (assume a very fast signal), use it as a START of TAC 566.
- Ortec TAC 566:
  
  TAC OUTPUT: Amplitude 0 V to +10 V proportional to Start/Stop input time difference. 
  Brief calibration with scope (a histogram mode), and Jeff’s pulser (pulses have 5ns delay): 
  Calibration with a scope: 5000ps/1.08V = ~4.630ps/mV
  The resulting resolution obtained with scope is very bad: σ ~17.2mV ~79.6 ps !!!
  (Jeff’s explanation: The scopes have only 8 bit ADC; they are made for timing measurements).

- Tektronix digital scope TDS-5104, 1GHz BW, software histogram option 2A.
- Ortec AD114 – a 14 bit ADC:
  ADC ANALOG INPUT: Accepts analog input pulses in the range from 0 to +10 V. The peak amplitude of an input pulse is converted to a digital value by a successive-approximation ADC with sliding scale linearization.
  RESOLUTION: 16,128 channels (0.625 mV/channel).
  - Difficulties to load the status register. Endup running the ADC in a mode set by power on conditions, which sets it into a mode where a local gate does not have to be present; it seems to work this way.
  - Start with a bad ground loop problem between a NIM and CAMAC crates:

  a) ADC spectrum is very wide spectrum due to a periodic noise in the TAC output:
b) ADC spectrum with a ground loop fixed – fix with a 1”-wide ground strap:

Ortec TAC 566/ADC 114 calibration:

a) Use a scope and pulser:
- Calculate rms resolution as follows: \( \sigma_{RMS} \approx 6.040 \text{ counts} \times 0.625 \text{mV/count} \times 4.630 \text{ps/mV} \approx 17.5 \text{ps}, \)

\[
\sigma_{RMS} \approx 6.040 \times 0.625 \times 4.630 \approx 2.89 \text{ ps/count}.
\]

- One can improve tiny bit it by taking a shorter time interval;

b) Use a delay cable:
- Use nominally a 1.1 ns cable and calibrate it with a scope: its length is really 1060 ps long

- Another way to calibrate: add \( \approx 1.1 \text{ns} \) to TAC STOP: \( 1060 \text{ps}/(1559-1552) \text{ counts} \approx 2.604 \text{ ps/count} \)

\( \sigma_{FIT} \approx 6.040 \text{ counts} \times 2.604 \text{ps/count} \approx 15.7 \text{ ps vs. } \sigma_{RMS} \approx 17.5 \text{ps}, \) which is more sensitive to a tail.

- Both calibrations, the scope&pulser and delay cable methods, are consistent with each other.
- Observe some instability as a function of time. Not sure what is the cause. But, it does not dominate the resolution result.
c) Using Jeff’s pulser:
- Pulser feeds START & STOP pulses to TAC; use AUX pulse to trigger the computer.
- Time interval between pulses: 5 ns. TAC full scale range selection: 50ns. Expect 9 peaks in TDC spectrum.
- **TAC output baseline problems.** Try everything suspecting a ground loop problems:
  a) Put AC power of CAMAC crate and NIM crate, where TAC is located, to the same spot.
  b) Use heavy ground straps connecting the two crates.
  c) Put an isolation transformer between AUX out signal and CAMAC entry.
  d) Run computer trigger off a pulser running on a battery (a complete isolation)
  e) Run TAC out directly to a scope (bypass the CAMAC crate completely). **Nothing worked.**

- **Finally a fix:** the pulser was running at a rate of 1 MHz, which was upsetting the TAC output baseline;
  Switch to a rate of 1 kHz (run198):

Vary number of photoelectrons @2.8kV & 2.604 ps/count calibration:
  a) 0 Mylar attenuator, Npe ~315

b) 1 Mylar attenuators, Npe ~134

Strange tail: repeated 3 times – something goes wrong with CFD/ADC at this setting

Runs (b) and (c) were done on a different day, and therefore they have slightly different systematics (PiLas offset, etc.) => do not use the data together with other points
c) 2 Mylar attenuators, Npe ~57

\[ \sigma_{\text{FIT}} \approx 13.1 \text{ ps} \]

d) 3 Mylar attenuators, Npe ~24-25

\[ \sigma_{\text{FIT}} \approx 13.9 \text{ ps} \]

e) 3.1 Mylar attenuators, Npe ~22

\[ \sigma_{\text{FIT}} \approx 14.2 \text{ ps} \]

f) 3.2 Mylar attenuators, Npe ~20

\[ \sigma_{\text{FIT}} \approx 18.2 \text{ ps} \]

g) 3.3 Mylar attenuators, Npe ~17

\[ \sigma_{\text{FIT}} \approx 24.9 \text{ ps} \]
Runs 206 – Amplifier & timing with CFD/TAC/ADC  

- 2.80kV, 10µm hole 64 pad MCP-PMT (S/N 11180401), B = 0kG
- Philips 2GHz BW 100x amplifier with 20dB in front = 10x gain
- Wait ~2 hours for the system to stabilize.
- PiLas trigger to TTL/NIM convertor and then to a NIM discriminator = STOP of TAC.
- PiLas at 25%
- Phillips 715 CFD, 25mV arming threshold, 1cm long delay jumper, use it as a START of TAC.
- Ortec TAC 566

σ_{FIT} \sim 22.2 \text{ ps}
2.0 att., CFD output

**Runs 213-225 – Ortec 9327 Amp/CFD, TAC566/ADC AD114** 2.3.2007

- 2.33kV, 10µm hole 64 pad MCP-PMT (S/N 11180401), B = 0kG
- 9327 settings: -100mV CFD th., -20mV walk th., SP3-SP4 jumper (att. in line with input signal)
- MCP-PMT voltage so that 9327 “over threshold” LED just flickers
- Wait ~4 hours for the system to stabilize.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- **PiLas at 25%, 1kHz**
- Ortec 9328 NIM output = START of TAC.
- Use the calibration (see page 3 for more): 2.604 ps/count
- **2 Mylar att. => ~ 50 photo-electrons**
- Monitor pulses at 2.33kV (21:1 attenuator, PiLas scope trigger):

**Ortec 9327 amp out, 10mV/div, 400ps/div**

**MCP-PMT raw signal, 10mV/div, 400ps/div**

Ortec 9327 amp out -> 6dB -> Phillips 779 10x amp -> scope
20mV, 1ns/div:

**Not very good for ADC monitoring**
- Some strange shift. Look how it affects the distribution. Worthwhile to remember!!
2.0 att. (Run 219)

\[ \sigma_{\text{FIT}} \approx 12.6 \text{ ps} \]

2.1 att. (Run 218)

\[ \sigma_{\text{FIT}} \approx 14.8 \text{ ps} \]

2.2 att. (Run 217)

\[ \sigma_{\text{FIT}} \approx 15.0 \text{ ps} \]

2.3 att. (Run 215)

\[ \sigma_{\text{FIT}} \approx 13.6 \text{ ps} \]
3.0 att. (Run 216)

4.0 att. (Run 220) – no output (below a threshold)

$\sigma_{\text{FIT}} \sim 16.1 \text{ ps}$
Time resolution:

- A goal to reach $\sigma < 15$ ps for Npe ~60 seems possible.
- The Ortec 9327-like performance is good. Would work even at B = 15 kG.

Time walk:

- Time-walk needs to be corrected for any variation of Npe, for all methods.
- Ortec 9327 time-walk is smallest, but still significant.
Repeat some points because there seems to be some inconsistencies when plotted with other data:

0 att. (Run 220)

Analyze the 2-nd half of run 213:

- From some reason a bit worse; more noise or drifts?; the fit would prefer two Gaussians probably.

0 att. (Run 221, repeat run 220 with 5k only)

0 att. (Run 221, repeat run 220 with 5k only)

1.3 att. (Run 222)

\[ \sigma_{\text{FIT}} \approx 10.7 \text{ ps} \]

\[ \sigma_{\text{FIT}} \approx 9.6 \text{ ps} \]

\[ \sigma_{\text{FIT}} \approx 10.1 \text{ ps} \]

\[ \sigma_{\text{FIT}} \approx 10.1 \text{ ps} \]

\[ \sigma_{\text{FIT}} \approx 10.1 \text{ ps} \]

1.3 att.  (Run 223, repeat run 222)
\begin{align*}
\sigma_{\text{FIT}} & \sim 12.7 \text{ ps} \\
\end{align*}

1.2 att.  (Run 224)
\begin{align*}
\sigma_{\text{FIT}} & \sim 13.2 \text{ ps} \\
\end{align*}

1.1 att.  (Run 225)
\begin{align*}
\sigma_{\text{FIT}} & \sim 12.4 \text{ ps} \\
\end{align*}

- Will not add these data points to the previous measurement as I have probably a different systematic error. Will resolve later.
Visit to Photonis, Brive, France  

2.26.2007

- Gave a talk to Photonis physicists and engineers describing the timing measurements and pointing out problems. Two main problems mentioned: (a) a huge charge spread at the anode plane, which in turn must influence timing resolution, and (b) a coherent oscillation, which we see when too many photons hit the MCP-PMT at the same time. Both problems must be fixed before this type of detector can be successful.

- After the talk talked to Paschal Lavoute, who is in charge of Photonis research, which includes all labs, including Burle. He could decide several things on the spot (see below).

- S-25 QE: a) There was no problem to get the curve, provided it that it will not be shared with others.  
  b) It has a lower max value, but it is extended to 900nm.  
  c) It would not be good for a RICH applications (too low photoelectron yield).  
  d) However, for a TOF counter it might be of some interest because all photoelectrons start from the rest (“equi-time” line). However, the yield would almost half (55 pe→ 32 for 1cm thick quartz radiator)

- GaArP: a) 2x more expensive  
  b) needs a protection film against aging (500-1000A thick)  
  c) max 18 mm dia.

- Aging: a) They do not like the protecting film solution  
  b) They prefer a 3 MCP solution, with a top MCP operating at a low gain  
  c) Total gain of $10^6$.  
  d) Cost increase: $4k →$4.5k

- Coherent oscillation: They believe that each pad has to be bypassed to ground to limit this effect. It turns out that the next Burle tube I get will have some of this.

- Charge sharing: a) They agree with my model that the electric field flares out causing a huge charge spread, and as a result much smaller number of photoelectrons participate in “good” timing.  
  b) They added to the above model that about ~20% of electrons will also recoil from the anode surface, which again reduces number of photoelectrons participate in “good” timing.  
  c) They think the best way is to reduce the MCP-to-anode gap to 1-2mm.  
  d) They offered a night vision geometry detector to test the ultimate timing resolution limit:
    i) S-25 photocathode  
    ii) 2 MCPs with 4 μm holes  
    iii) 1mm cathode-to-MCP gap  
    iv) 0.2mm MCP-to-anode gap  
    v) A fiber optics window  
    vi) 16 deg hole angle to minimize time spread  
    vii) Delivery time: ~3 months  
    viii) - Fiber optics radiator ? Part of the MCP-PMT window ?

- Immediately after the visit I have noticed much better response from Burle.
Photonis night vision photocathode:

Charge sharing:

Coherent oscillation:
Runs 226-242 – Ortec 9327 Amp/CFD, TAC566/ADC AD114

3.8.2007

- 2.30kV, 10µm hole 64 pad MCP-PMT (S/N 11180401), B = 0kG
- 9327 settings: CFD th. -10mV, vary walk threshold, SP3-SP4 jumper (att. in line with input signal)
- 2 Mylar att. ~ 50 pe; set MCP-PMT voltage so that 9327 “over threshold” LED just flickers
- Wait ~4 hours for the system to stabilize.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC.
- Use the calibration (as before): 2.604 ps/count

- 2 Mylar att.:

Run 226, 2 att., walk th. = -20mV

Run 227, 2 att., walk th. = -30mV

Run 228, 2 att., walk th. = -40mV
Run 229, 2 att., walk th. = -50mV

Run 230, 2 att., walk th. = -60mV

Run 231, 2 att., walk th. = -70mV

Run 232, 2 att., walk th. = -100mV

Run 233, 2 att., walk th. = -10mV

σ ~ 12.0 ps

σ ~ 12.3 ps

σ ~ 12.1 ps

σ ~ 12.1 ps

σ ~ 11.9 ps
Run 234, 2 att., walk th. = 0mV

Run 235, 2 att., walk th. = +10mV

Run 236, 2 att., walk th. = +20mV

Run 237, 2 att., walk th. = +5mV

- Select the walk threshold of +5mV
Run 238, 1 att., walk th. = +5mV

Run 239, 0 att., walk th. = +5mV

Run 240, 2.1 att., walk th. = +5mV

Run 241, 2.2 att., walk th. = +5mV

Run 242, 2.3 att., walk th. = +5mV

σ ~ 11.5 ps
σ ~ 9.2 ps
σ ~ 12.3 ps
σ ~ 12.77 ps
σ ~ 13.04 ps
New results for Ortec Amp/CFD 9327:

3.9.2007

![Graph showing σ vs. Number of photoelectrons with various configurations and their corresponding standard deviations.](image-url)

- No amplifier, No CFD, TDS5104 scope 'leading edge' timing
- No amplifier, Phillips 715 CFD, TDS5104 scope 'zero-crossing' timing
- No amplifier, Phillips 715 CFD, Ortec TAC566 & ADC114 'zero-crossing' timing
- Ortec 9327 Amp/CFD & TAC566 & ADC114 'zero-crossing' timing
- Hamamatsu amplifier 63x, Phillips 715 CFD, 25ps/ct TDC, 1-st electron timing

Design
Visit to Fermilab

3.14-16.2007

- I was invited by Andrew Brandt, Univ. of Arlington, TX to give a critique of his setup during the beam test of fast photon detector intended to be used at ATLAS experiment, to participate in mini-workshop at Fermilab on fast timing. This was quickly organized because of my visit.
- I was then invited by Karen Byrum and Gary Drake to Argonne lab on Friday to help to lunch a laser setup they are trying to create to develop fast photon detectors for astrophysics, etc.

- My critique of Andrew effort:
  a) No laser setup, so all debugging done during the beam test. If this was done with the Focusing DIRC prototype, it would never work.
  b) His setup suffers from the coherent oscillations. He will probably luck out during this beam test because he is taking only the first proton from a spill. This is the same oscillations I complained to Burle more than one year ago.
  c) He works only with 1-7 photoelectrons and does not measure pulse height; therefore he cannot correct for time-walk, which is crucial to get a good resolution. As a result of my visit, Luc, and engineer from Belgium, will create a circuit, which will provide an amplitude. We may benefit from it also.
  d) Poor efficiency is probably related to a wrong CFD setting (he tuned it on large pulses).
  e) There were some things in the setup, which may invite the ground loops.
  f) He wants to purchase a 4GHz BW scope for $44k. He is now renting it for $1k/month during the test. I doubt that he really needs it, but he wishes to have this toy. Impossible to argue…
  g) He does not always know what he is doing, but is persistent, and probably will make it.
  h) Presently he is barely reaching a resolution of $\sigma \sim 70$ps in one finger. He gets a $1/\sqrt{N_{\text{fingers}}}$ improvement.

- Workshop at Fermilab:
  a) People who came: Paul Hink from Photonis, Henry Frisch, Mike Albrow, Andrew Brandt, +10 people.
  b) Talks: myself, Paul Hink, Henry, Andrew, Tang, an engineer from Univ. of Chicago.
  c) Very lively discussion on all sort of aspects of the fast timing.
  d) I learned that:
     i) Photonis has decided to keep the MCP-PMT production in US in Lancaster.
     ii) Paul confirmed that he considers our 4 MCP purchased last year as a money in the bank, and will keep delivering new updated models as they come.
     iii) Paul outlined a plan what they want to do next.
     iv) Front MCP-PMT window and the anode plane may deflect as much as 4-5 mils!! This would have a disasterous effect on timing, and needs to be fixed by having thicker window & feedthrough anode

- Visit to Argonne Natl. lab:
  a) Setup is in early stages run by a student, who needs a help.
  b) I managed to teach him in 4 hours how to set it up and how to run a single photon spectra.
  c) We took some data, which will help him to learn how to do an analysis.
  d) However, the setup has some serious problems and MCP-PMT wire harness needs to be redone. I told him what I would do.
  e) Karen mentioned that there is a possibility to collaborate with VERITAS experiment, which will look at the sources found by GLAST (I think some people from SLAC and Santa Cruz are interested also).
Details:
- Detectors in the test beam setup:

- Andrew has a 4 GHz BW Tektronics scope DPO70404, 20ps/div, $44k, $1k/month renting charge. Two fingers showing a clear oscillations going for a long time (as I predicted):

- Luc’s CFD circuit:

- Amplifiers Luc is using:

Note: use a protection resistor (~4kΩ) to ground at the input:

- In Argonne’s setup they use an USB interface to control CAMAC: Wiener CC USB (~$2k).
- Paul Hink is suggesting this MCP-PMT as the next product (a general wish from a community):
  - Fiber optics window
  - Small gaps between cathode and top MCP, and bottom MCP and anode (~1mm).
  - Improvement of coupling to ground.
  - 256 pixels (3mmx3 mm).
  - 2 MCPs (possibly three, the first one with a low gain).
  - Access to all critical voltages ($V_{\text{cath}}$, $V_{\text{MCP_top}}$, $V_{\text{MCP_bot}}$, $V_{\text{anode}}$).
  - Hole angles: 16-19° (larger than what photonis is using presently).
  - Work to improve the detection efficiency (QE improvements, open up the MCP hole dia. at their entrance, etc.).
  - Borosilicate window (not use quartz window any longer – it was a mistake)
  - The present window is 2mm thick. It deflects by 2-3 mils under vacuum. They would increase the window thickness to 3-4mm, and the anode plate as well as, to prevent distortions.
  - The next generation MCP-PMT they are aiming for (will satisfy most of customers):
- This is an e-mail exchange between him and me about the above test:

Dear Prof. Va’vra,

I think, the pulse was not saturated. But, as you may think, the ADC dependence is not much for such a large pulse height. We used the special device, named SPC-134 by Becker&Hickl GMbH, which includes the CFD at the front-end.

Best regards, K.Inami

>>Thank you Kenji,
>>   if I may, I would like to ask one or two more questions. Did you operate in a linear mode with a CFD Mwaning, staying away from saturated pulses) ? I suppose that a number of photoelectrons did not vary much during the test, and that is probably why you did not need to correct it. I a real experiment, I am guessing, the number of photoelectrons could vary, and there could be some time-walk. What CFD did you use ?
>>   Thanks again. Regards, Jerry

Dear Prof. Va’vra,

Thank you very much for your interest and sorry for late reply.

>> Dear Kenji,
>>   I have a few questions about your impressive timing measurement, if I may:
>>   1. Was your electronics sensitive to the 1-st arriving photoelectron ?
   Yes. But:
>> 2. I actually do not know how did you do timing. With a digitized waveforms, or with a CFD, or with a leading edge & ADC ?
   We use CFD for 5ps TOF measurement. In this case, we did not measure the timing of 1-st arriving photoelectron.
>> 3. Did you do some pulse height time-walk correction ?
   No, when we use CFD. We also used the leading edge with ADC and check the the time-walk corrected timing. It is about 8ps, which is mainly due to the TDC jitter.
>> 4. The radiator was a 1cm-long quartz cylinder. Was it aluminized on sides ?
   Yes.
>> 5. Did you try to rotate the detector relative to the beam direction ?
   We tested other TOF counter. The beam attack the quartz from side. In that case, the time resolution became worse. As you expected, to obtain the good resolution, the beam need to attack the quartz from ~face.

Regards, K.Inami
Analyze again the calibration of the TAC/ADC system using a new Jeff’s pulser (Run 198, page 4):
- Jeff’s pulser provides START & STOP pulses to Ortec TAC 566.
- Pulser running at 1kHz.
- A new pulser (makes 20 pulses every 5ns, covering as range of 100ns:

- A departure from an ideal time (calibration done by Jeff using his Ortec 9308 TAC system):

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- The pulser delay is known to a few ps.
- Run 198:

- Time interval between pulses: 5 ns; TAC 566 full scale range: 50ns => expect 9 peaks in TDC spectrum.

- Calibration slope: 3.19 ps/count
- Electronics resolution for small ADC values: \( \sigma_{\text{double detector}} \sim 4 \text{ ps} \) or \( \sigma_{\text{single detector}} \sim 2.8 \text{ ps} \)
- However, the electronics resolution depends on the ADC value, it grows as ADC value increases!!
Tests of the TOF counter prototype with Pilas

- New MCP-PMT without a Quartz radiator initially:

![Diagram of TOF counter](image)

**TOF counter-no radiator**

- Connect together pads 23, 24, 25 and 26; all the rest are grounded.
- Both pictures are views from the pin side (back side):

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- Choosing an assymetric radiator location makes it easier to connect 4 pads together without creating an inductance problem.
- Center of the quartz radiator: [-6mm, 0mm], where [0,0] is the center of the tube.
Scott’s information (Burle):
The pins that you indicate have the shortest traces on the PCB. Channels 23 and 26 will have the same trace length as well channels 24 and 25. The difference in length between (23, 26) and (24, 25) is 2mm. The (23,26) pair is shorter

=> Design a PC board to correct this 2mm difference

Runs 243-250 – Ortec 9327 Amp/CFD, TAC566/ADC AD114

- 2-nd 10µm hole 64 pad MCP-PMT with 4 pads shorted together (the rest grounded), S/N 7300714

- 1.93kV max. voltage before an ugly double peak appears => the new tube has higher gain

- 1-st CFD 9327; settings: CFD threshold -100mV, walk th. +5mV, SP3-SP4 jumper (0-150 mV range)

- 2 Mylar att. ~ 50 pe

- Wait 1-2 hours for the system to stabilize.

- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.

- PiLas power at 25%, 1kHz trigger rate

- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.

- Use the calibration: 3.19 ps/count (page 26)

- Monitor signal from Ortec 9327 CFD (21:1 attenuator, no additional amplifier, PiLas scope trigger):

1.93 kV, 400ps/div, 10mV/div

1.93kV vs. 1.90kV vs. 1.86kV, 400ps/div, 10mV/div
Run 243, 2 Mylar att.

- Still much worse than what I had before. The reason is a worse noise despite the fact that this run has a tight ground connection between TAC and ADC. Hm…

Run 244, 2 Mylar att., 1.93kV

- Getting worse as S/N deteriorates.

\[ \sigma \approx 20.2 \text{ ps} \]

CFD monitor out, TAC Start and TAC Stop

CFD monitor out and TAC output to ADC

Run 245, 2 Mylar att., 1.90kV

- Getting worse as S/N deteriorates.

\[ \sigma \approx 18.8 \text{ ps} \]
Run 246, 2 Mylar att., 1.87kV

Run 246a, 2 Mylar att., 1.93kV, reduce TAC’s start-stop delay; still use 3.19ps/ct

Run 246a:
CFD monitor out, TAC Start and TAC Stop

CFD monitor out and TAC output to ADC

Run 247, 2 Mylar att., 1.93kV, modify the grounding (signal & HV % det. housing grounds connected)

A clear drift due to PiLas warming up – waited only an hour or so.

σ ~ 18.7 ps

σ ~ 20.6 ps

σ ~ 19.8 ps

7.28.2007
- Details of grounding:

Run 248, 2 Mylar att., 1.90kV

Still a significant PiLas drift & tail.

Run 249, 2 Mylar att., 1.93kV, in this run change CFD th. to –10mV

- A disaster: poor efficiency & bad resolution. Why? Is it due to a noise? => go back to –100mV

Run 250, 2 Mylar att., 1.87kV

Drift is smaller, though, probably still there (3-5 counts). However, still a tail on high count side.

Nevertheless, the best result so far with this device. So, the new grounding is probably of some benefit.
Runs 251-255 – Ortec 9327 Amp/CFD, TAC566/ADC AD114
- 1-st 10µm hole 64 pad MCP-PMT with 4 pads shorted together (the rest grounded), S/N 11180401
- 2.3-2.4 kV
- 1-st CFD 9327; settings: CFD threshold -100mV, walk threshold +5mV, SP3-SP4 jumper
- 2 Mylar att. => ~ 50 pe. However, the detector rotated by 90° => yield was smaller !!! (see page 39)
- Wait ~ 3-4 hours for the PiLas to stabilize.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)
- Monitor signal from Ortec 9327 CFD (21:1 attenuator, no additional amplifier, PiLas scope trigger):

CFD monitor output, 2.3 kV, 2ns/div, 5mV/div

2.3kV, CFD monitor out, TAC Start and TAC Stop

2.35kV, CFD monitor out, TAC Start and TAC Stop

CFD monitor output and TAC output to ADC

- Rise time is clearly dependent on the MCP voltage, and appears to be slightly worse than an old MCP-PMT coupled to a single pad. It appears that there is quite a PH variation, which might affect the timing resolution.
Run 251, 2 Mylar att., 2.30kV, CFD “over range” LED does not fire

PiLas is stable, but still some tail.

\[ \sigma \approx 17.4 \text{ ps} \]

Run 252, 2 Mylar att., 2.35kV, CFD “over range” LED on all the time

\[ \sigma \approx 19.4 \text{ ps} \]

Run 253, 2 Mylar att., 2.4kV, CFD “over range” LED on all the time

\[ \sigma \approx 19.0 \text{ ps} \]

- This indicates that increasing the voltage does not necessarily improve the resolution. One probably needs to tune an optimum point for the CFD “walk” threshold. The origin of tail unclear. Is it a Mylar absorber?
If one searches my log books we had this problem periodically.

Run 254, 2 Mylar att., 2.4kV, CFD “over range” LED on all the time

- Example of a “cold” ADC. After ~2000-3000 triggers it gets stabilized.
Runs 256-264 – Search for the best grounding – the 1-st MCP 7.31.2007
- 1-st 10µm hole 64 pad MCP-PMT with 4 pads shorted together (the rest is grounded), S/N 11180401
- 2.33 kV
- 1-st CFD 9327; settings: CFD threshold -100mV, walk threshold +5mV, SP3-SP4 jumper
- 2 Mylar att. => ~ 50 pe. However, the detector rotated by 90° => yield was smaller !!! (see page 39)
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)
- Monitor signal from Ortec 9327 CFD (21:1 attenuator, no additional amplifier, PiLas scope trigger):

Scope not grounded, 10ns/div
Periodic noise, 4ms/div, 1mV/div
Scope grounded, 10ns/div, 1mV/div

- Scope grounded means a ground strap used to ground CAMAC & NIM crates also goes to scope.

Run 256, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Ground strap not connected to TAC and NIM crate, only to scope.

Run 257, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Ground strap not connected to TAC, ADC, detector and crates, Detector covered with Al foil

Run 258, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Add a new Ortec unit with a dual PS – need for the beam test to run two 9327 CFDs. Add a clamp to connect ground strap to NIM crate better.

Run 259, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Disconnect the clamp.
Run 260, 2 Mylar att., **2.33kV, CFD “over range” LED just flickers a bit**
- Disconnect the ground strap from the amplifier ground.

Run 261, 2 Mylar att., **2.33kV, CFD “over range” LED just flickers a bit**
- Ground strap connects CAMAC and NIM crates, but **NOT** the BNC connector grounds at TAC and ADC.
They are supposed to have a separate ground to prevent the ground loop noise (insulated BNC connector).

**Finally a success !!**

**Run 261:** the 1-st mcp, scope triggered with PiLas trigger
CFD amp out, 10mV/div, 400ps/div

CFD amp out + ZX60-6013E⁺ amp, 50mV/div, 400ps/div

<table>
<thead>
<tr>
<th>CFD amp out</th>
<th>CFD amp out + ZX60-6013E⁺ amp + 16ns + transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.25, 2.3, 2.35, 2.4kV, 10mV/div, 400ps/div</td>
<td>2.25, 2.3, 2.35, 2.4kV, 50mV/div, 400ps/div</td>
</tr>
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</table>

\( \sigma \approx 14.2 \text{ ps} \)
Run 262, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Repeat run 261, but add more Al layers around the detector.

Run 263, 2 Mylar att., 2.33kV, CFD “over range” LED just flickers a bit
- Repeat run 262, add an ADC readout of the CFD amp. output (running with an extra amp).
Run 264, 2 Mylar att., 2.4kV, CFD “over range” LED is solidly on

Runs 265-267 – Final tests without a radiator – the 2-nd MCP 8.1.2007
- 2-nd 10µm hole 64 pad MCP-PMT with 4 pads shorted together (the rest is grounded), S/N 7300714
- 1.92 kV
- 2-nd CFD 9327; settings: CFD threshold -100mV, walk threshold +5mV, SP3-SP4 jumper
- 2 Mylar att. => ~ 50 pe
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)
- Monitor signal from Ortec 9327 CFD (21:1 attenuator, no additional amplifier, PiLas scope trigger):

Run 265, 2 Mylar att., 1.92kV, CFD “over range” LED just flickers a bit

Run 265: the 2-nd MCP, scope triggered with PiLas trigger, 9327 CFD amp out:
1.92 kV, 10mV/div, 400ps/div
1.85, 1.9, 1.95, 2.0kV, 10mV/div, 400ps/div
CFD amp out + ZX60-6013E\textsuperscript{+} amp, 50mV/div, 400ps/div
1.92 kV, 50mV/div, 400ps/div

Run 266, 2 Mylar att., 1.95kV, CFD “over range” LED is on all the time

\[ \sigma \approx 16.0 \text{ ps} \]

A clear drift. Run taken in the morning, and PiLas may not be stable even though it is running all the time.

Run 267, 2 Mylar att., 2.0kV, CFD “over range” LED is on all the time

\[ \sigma \approx 18.2 \text{ ps} \]

Still a drift, plus the resolution is actually worse at this voltage.

Run 266a (repeat run 266 a few hours later), 2 Mylar att., 1.95kV, CFD “over range” LED is on all the time

\[ \sigma \approx 12.8 \text{ ps} \]

Much better.
Find a mistake: The 1-st MCP was rotated by 90° in its holder by mistake – this affected a photon illumination

Runs 268-269 – Final tests without a radiator – the 1-st MCP 8.2.2007
- 1-st 10μm hole 64 pad MCP-PMT with 4 pads shorted together (the rest is grounded), S/N 11180401
- 2.27 kV – it does not want to run at 2.33 any more !!
- 1-st CFD 9327; settings: CFD threshold -100mV, walk threshold +5mV, SP3-SP4 jumper
- 2 Mylar att. => ~ 50 pe. The rotation problem is fixed now. We get a larger # of photons.
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)
- Monitor signal from Ortec 9327 CFD (21:1 attenuator, no additional amplifier, PiLas scope trigger):

Run 268: the 1-st MCP, scope triggered with PiLas trigger, CFD amp out:
2.27 kV, 10mV/div, 400ps/div
2.2, 2.25, 2.3kV, 10mV/div, 400ps/div

Indeed, one should not run at this voltage.
CFD amp out + ZX60-6013E' amp + 16ns + transformer
2.27 kV, 50mV/div, 400ps/div

2.27 kV, CFD “over range” LED just flickers a bit
\[ \sigma \approx 13.4 \text{ ps} \]

- Both tubes achieved the same resolution: \(~12.7 \text{ ps}\).

Run 269, 2 Mylar att., 2.30kV, CFD “over range” LED is on all the time
\[ \sigma \approx 12.7 \text{ ps} \]

Run 270-275 – Final tests with a radiator (no grease yet)
- 2 Mylar att. => \(~50 \text{ pe}\)
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: \(3.19 \text{ ps/count}\) (page 26)
- The new MCP: S/N 7300714
Run 270, the 2-nd MCP, 2 Mylar att., 1.95kV, CFD “over range” LED is on all the time, S/N 7300714

The signal is larger, which means that we collect more photons (compare to page 38). The effect of mirror on the quartz cylinder walls?
Run 270:

Run 271, the 2-nd MCP, 2 Mylar att., 1.92kV, CFD “over range” LED is on all the time, S/N 7300714

Run 271: CFD amp out + ZX60-6013E’ amp, 50mV/div, 400ps/div

The signal is larger, which means that we collect more photons (compared to page 38). The effect of mirror on the quartz cylinder walls?

- Leave the tube running over night at 1.92kV.

Run 272: the 1-st MCP, 2 Mylar att., 2.27kV, CFD “over range” LED is on all the time

σ ~ 15.2 ps

σ ~ 13.4 ps
Run 272: CFD amp out + ZX60-6013E+ amp, 50mV/div, 400ps/div
Put in longer HV cable harness

Run 273, the 1-st MCP, 2 Mylar att., 2.3kV, CFD “over range” LED is on all the time

Run 273: CFD amp out + ZX60-6013E+ amp, 50mV/div, 400ps/div

Run 271a (repeat run 271), the 2-nd MCP, 2 Mylar att., 1.92kV, CFD “over range” LED is just flickering
- Replace a signal wire
- Run in more stable temperature environment

There is a curvature !! => still some instability.
Run 271a: CFD amp out + ZX60-6013E^+ amp, 50mV/div, 400ps/div

Run 272a (repeat run 272), the 1-st MCP, 2 Mylar att., 2.27kV, CFD “over range” LED is just flickering
- Run in more stable temperature environment (after ~3pm)

A final arrangement of two TOF counters:
Run 274, the 1-st MCP, 2 Mylar att., 2.29kV, CFD “over range” LED is on all the time

A clear drift.

\[ \sigma \sim 15.4 \text{ ps} \]

Run 274, the 1-st MCP, 2 att.:
CFD amp out + ZX60-6013E* amp + 16ns + transformer
2.29 kV, 50mV/div, 400ps/div

2.25, 2.29, 2.33 kV, 50mV/div, 400ps/div

Run 275, the 2-nd MCP, 2 Mylar att., 1.910kV, CFD “over range” LED is on all the time

Still noticeable drift.

\[ \sigma \sim 13.6 \text{ ps} \]

Run 275, the 2-nd MCP, 2 att.:
CFD amp out + ZX60-6013E* amp + 16ns + transformer
1.91 kV, 50mV/div, 400ps/div

1.88, 1.91, 1.93 kV kV, 50mV/div, 400ps/div
Run 275, the 2-nd MCP, 2 att.:
raw MCP signals, ~50 pe, TOF#2:
1.91 kV, 10mV/div, 400ps/div
1.85, 1.88, 1.91, 1.93 kV, 10mV/div, 400ps/div

Run 276-280 – Final tests with a radiator (with a grease) 8.7.2007
- 2 Mylar att. => ~ 50 pe
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM converter and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)
Run 276, the 2-nd MCP, 2 Mylar att., 1.85kV, CFD “over range” LED is off, S/N 7300714

Very big drift initially ("cold" ADC effect). Cut the first 1200 triggers off.

Run 276, CFD amp out + ZX60-6013E+ amp + 16ns + transformer:
1.91 kV, 50mV/div, 400ps/div

Run 277, the 2-nd MCP, 2 Mylar att., 1.88 kV, CFD “over range” LED is flickering

σ ~ 13.1 ps

Run 278, the 2-nd MCP, 2 Mylar att., 1.91 kV, CFD “over range” LED is on all the time

σ ~ 12.6 ps

σ ~ 13.1 ps
Run 278, raw MCP signals:
1.91 kV, 10mV/div, 1ns/div

Run 278, CFD amp out + ZX60-6013E' amp + 16ns + transformer:
1.91 kV, 50mV/div, 400ps/div
1.85, 1.88, 1.91, 1.93 kV, 50mV/div, 400ps/div

Run 279, the 1-st MCP, 2 Mylar att., 2.29 kV, CFD “over range” LED is on all the time

Run 279, raw MCP signals, ~50 pe, TOF#1:
2.29 kV, 10mV/div, 400ps/div

\[ \sigma \sim 14.8 \text{ ps} \]
Run 279, raw MCP signals:
2.2, 2.25, 2.29 kV, 10mV/div, 400ps/div

Run 279, CFD amp out + ZX60-6013E+ amp + 16ns + transformer:
2.29 kV, 50mV/div, 400ps/div
2.2, 2.25, 2.29, 2.32 kV, 50mV/div, 400ps/div

Run 280, the 1-st MCP, 2 Mylar att., 2.26 kV, CFD “over range” LED is on all the time
σ ~ 14.6 ps

8.9.2007

The 1-st MCP tripped at 2.29kV this morning. In addition, its resolution is typically 1-2ps worse, and pulses seem to have bigger spread. What is going on? Is it perhaps due to Burle HV divider? Let’s investigate.
Run 281-286 – Test my HV divider for the 1-st MCP 8.9.2007
- Build a new HV divider a'la the one for the 2-nd MCP, S/N 7300714
- 2 Mylar att. \(\Rightarrow \sim 50\) pe
- Run PiLas continuously for a week to keep it stable.
- PiLas trigger to TTL/NIM convertor and then to a Phillips 716 CFD discriminator = STOP of TAC.
- PiLas power at 25%, 1kHz trigger rate
- Ortec 9327 NIM output = START of TAC, Pilas trigger = STOP of TAC.
- Use the calibration: 3.19 ps/count (page 26)

Run 281, the 1-st MCP, 2 Mylar att., 2.27 kV, CFD “over range” LED is on all the time

Run 281, raw MCP signals:
2.2, 2.27 kV, 10mV/div, 400ps/div

Run 281, raw MCP signals:
2.0, 2.25, 2.30 kV, 50mV/div, 400ps/div

Run 281, CFD amp out + ZX60-6013E* amp + 16ns + transformer:
2.27 kV, 50mV/div, 400ps/div

Slightly larger gain with my HV divider. Pulses look the same otherwise.
Run 282, the 1-st MCP, 2 Mylar att., 2.25 kV, CFD “over range” LED is flickering

Run 284, the 1-st MCP, 2 Mylar att., 2.20 kV, CFD “over range” LED is off

Run 285, the 1-st MCP, 2 Mylar att., 2.20 kV, CFD “over range” LED is off

Run 286, the 1-st MCP, 2 Mylar att., 2.20 kV, CFD “over range” LED is off

Run 286, raw MCP signals: 2.15, 2.2 kV, 10mV/div, 400ps/div

Run 286, CFD amp out + ZX60-6013E+ amp + 16ns + transformer: 2.15, 2.2 kV, 50mV/div, 400ps/div
The new HV divider did not help. In fact, it seems to be slightly worse. Go back to the old Burle HV divider.

Run 287, the 1-st MCP, 2 Mylar att., 2.27 kV, CFD “over range” LED is flickering

Run 287, raw MCP signals:
2.27 kV, 10mV/div, 400ps/div

There is a drift because several things got switched on. Probably the same result as with my divider. Oh well, the culprit is somewhere else.

σ ~ 17.3 ps

Move things to the ESA test
**TOF counters:**

8.9.2007

- S/N 7300714 has an old ground plane, attached to the back of the tube (S/N 11180401 does not)
- Burle 85013 MCP-PMT product has the new ground plane attached as a standard feature.
- See more on page 99 (e-mails from Scott Mouzolf).
Check pulses using the PiLas laser diode:

8.11.2007

- Use three scopes for cross-calibration: (a) 1GHz BW Tektronics, 0.3GHz HP, 0.1GHz HP in bldg 420
- 1 Mylar att. plus 3-way splitter (80%, 10%, 10%)
- Retune the ESA PiLas laser diode (x&y stage), and connect fibers on 10% branches (shorter and without a variable optical attenuator; this changes timing). The aim is to increase the TOF counter photoelectron yield. At 25% PiLas power setting, there is too high rate in the prototype. At 12% it gets acceptable.

- Trailer 233 tests: CFD amp out + ZX60-6013E+ amp + 16ns + transformer & 1GHz BW scope
  Run 281, TOF start (the 1-st MCP)
  2.0, 2.25, 2.30 kV, 50mV/div, 400ps/div
  Run 278, TOF stop (the 2-nd MCP)
  1.85, 1.88, 1.91, 1.93 kV, 50mV/div, 400ps/div

- ESA tests: TOF counter signal: CFD amp out + ZX60-6013E+ amp + 16ns + 64ns (no transformer)
  a) PiLas at 25%, ext. trigger from MCC (30Hz), 300MHz BW HP scope
  TOF Start, 2.26kV, 50mV/div, 1ns/div
  TOF Stop, 1.88kV, 50mV/div, 1ns/div
  TOF Start and ADC gate
  TOF Stop and ADC gate
b) PiLas at 12%, ext. trigger from MCC (30Hz)
TOF Start, 2.26kV, 50mV/div, 1ns/div
TOF Stop, 1.88kV, 50mV/div, 1ns/div
ADC Ad114 input, 1V/div, 1µs/div

- ESA (next to test): TOF counter signal: CFD amp out + ZX60-6013E+ amp + transformer
a) PiLas at 25%, ext. trigger from MCC (30Hz), 1 thick Mylar attenuator (here we have 80:10:10 splitter
1GHz BW Tek scope
TOF Start, 2.26kV, 50mV/div, 400ps/div., transformer, 20ns cable from the amplif.
TOF Start, 2.26kV, 50mV/div, 400ps/div., transformer, 16+46ns cable from the amplif.

- This is the crucial cross-calibration between the trailer and ESA !!!! (see run 281, page 50, @2.27kV0
- Adding a cable delay of 64 ns makes a big difference.
- Number of photoelectrons at 25% power setting is consistent with tests in the trailer (Npe ~50).
TOF Start, 2.26kV, 50mV/div, 400ps/div., no transformer, 16+46ns cable from the amplif.

TOF Stop, 1.18kV, 50mV/div, 400ps/div., transformer, 20ns cable from the amplif.

TOF Start, 1.18kV, 50mV/div, 400ps/div., no transformer, 20ns cable from the amplif.

- **Bldg 420**: TOF counter signal: CFD amp out + ZX60-6013E^+ amp + 16 + 64 + a very long cable

TOF Start, 2.26kV, 50mV/div, 400ps/div., transformer
Monitoring HP scope (~0.2GHz BW)
TOF Start, 2.26kV, 100mV/div, 10ns/div
TOF Start, 2.26kV, 50mV/div, 10ns/div
TOF Stop, 1.88kV, 100mV/div, 10ns/div
TOF Stop, 1.88kV, 50mV/div, 10ns/div

Tests with PiLas in trailer:
TOF Start:
Run 268, the 1-st MCP, 2.27 kV
σ ~ 13.4 ps

TOF Stop:
Run 277, the 2-nd MCP, 1.88 kV
σ ~ 12.6 ps
PiLas tests in ESA using a fiber splitter:

Run 288, 1-st MCP at 2.27 kV, 2-nd MCP at 1.88 kV, PiLas on ext. trigger from MCC (30Hz)
ESA, TAC start: TOF Start, TAC stop: TOF Stop, use a fiber splitter to feed both detectors
Comparable number of photoelectrons as I had in the trailer (Npe ~50)

Run 289, the same as run 288, but add a ground strap between TAC & ADC crates

\[ \sigma_{\text{single detector}} \approx \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \approx 7.2 \text{ ps} \]
Alignment prior to test.  
(T-469/492 test)

8.10.2007

- With a help of surveyors, align the following counters in x & y:
  hodoscope #2, TOF_start and TOF_stop, and check alignment of the hodocope #1.

Results:
- Hodoscope 1: elevation +0.110”, horizontal: +0.127” (+ means that counter is towards North).
- Hodoscope 2: elevation -0.035”, horizontal: +0.020”.
- TOF-Start: elevation +0.016”, horizontal: +0.009”.
- TOF-Stop: elevation -0.016”, horizontal: +0.000”.

<table>
<thead>
<tr>
<th>Station</th>
<th>Y Deviation</th>
<th>Y Angle</th>
<th>X Deviation</th>
<th>X Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam 1</td>
<td>+0.110</td>
<td>+0.127</td>
<td>+0.016</td>
<td>+0.009</td>
</tr>
<tr>
<td>Beam 2</td>
<td>-0.035</td>
<td>+0.020</td>
<td>-0.016</td>
<td>+0.000</td>
</tr>
<tr>
<td>TOF Start</td>
<td>+0.016</td>
<td>+0.009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOF Stop</td>
<td>-0.016</td>
<td>+0.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Beam 1 is the beam on the left, and Beam 2 is the beam on the right.

80.04.2008
Beam test of the TOF counter in 10 GeV/c electron beam:

- Joe was unable to read the Ortec ADC114 unfortunately. Bring a MAC 2CX. It means we will not be able to take a benefit of our beam telescope background rejection capability.

- Configuration in the beam:

How many photoelectrons do we expect in the beam from the quartz radiator?

Expect ~30 pe- in TOF1 counter (Bi-alkali photocathode) for a 1 cm quartz radiator (+ 2 mm window)

- This information was known much later – see page 28 in log book 5 for more details.
Run 291, Trigger: ADC114 conversion valid, counter sits at the position surveyors told us => it is misaligned with the beam at this point so that the beam is missing it completely !!!
TAC start: TOF 1-st (2.23kV), TAC stop: TOF 2-nd (1.80kV)

Run 294, Trigger: ADC114 conversion valid, move the TOF counter 10mm south => it is still misaligned in y respective to the beam at this point so that the beam is missing it completely !!!

Paw fitting:
TAC start: TOF 1-st (2.23kV), TAC stop: TOF 2-nd (1.80kV)

Root fitting(g+g):

Run 295, Trigger: ADC114 conversion valid, counter misaligned with the beam at this point
TAC start: TOF 1-st (2.20kV), TAC stop: TOF 2-nd (1.80kV)
Run 296, Trigger: ADC114 conversion valid, counter misligned with the beam at this point
TAC start: TOF 1-st (2.20kV), TAC stop: TOF 2-nd (1.80kV)
Paw fitting:

σ_single detector ~ 25.6 ps

σ ~ 38.4 ps

σ_single detector ~ (1/2) σ_double detector
~ 27.2 ps

Run 297, Trigger: [finger 8 from hodoscope 1]*[ADC114 conversion valid]
TAC start: TOF 1-st (2.20kV), TAC stop: TOF 2-nd (1.80kV), counter misligned at this point
Paw fitting:

σ_single detector ~ 24.2 ps

σ ~ 36.0 ps

σ_single detector ~ (1/2) σ_double detector
~ 25.4 ps

- Move the counter 6mm up, and 2mm north at this point ⇒ To get the TOF counters into the beam, it was necessary to move them up 6-7mm and to south horizontally by 8mm compared to their original alignment by surveyors. The counter is aligned at this point, hopefully.
- Setup the lead glass veto (check signals in bldg 420):  
  Lead glass:  
  5ns/div, 50mV/div  
  Lead glass timing with the beam gate in bldg 420:  
  50ns/div, 50mV/div  
  Hodoscope#1 finger 8 timing with the beam gate in bldg 420:  
  50ns/div, 50mV/div

- Set the lead glass discriminator’s threshold to -250mV to discriminate against the multiples.
- Bring TOF amplifier signals to bldg 420, and steer the beam with x32 & y33 correctors by 1-2 mm:
  - This is a quick check if we sit on an edge
  Top: TOF Start (the 1-st), 50mV/div, 400ps/div, Bot: TOF Stop (2-nd), 20mV/div, 400ps/div
  The scope trigger is top trace, i.e. nothing sophisticated (accept all)
  TOF 1-st (2.26kV) – top trace, TAC stop: TOF 2-nd (1.89kV) – bottom trace
  Nominal values: x32 = 0.075, y33 = -0.025  
  x32 = 0.125, y33 = -0.025  
  x32 = 0.025, y33 = -0.025

  x32 = 0.075, y33 = -0.015  
  x32 = 0.075, y33 = -0.035  
  Nominal values again: x32 = 0.075, y33 = -0.025

- Notice that the 2-nd TOF counter has much smaller response in the beam !!! Why ? Misalignment ? Poor Al coating of the quartz radiator ? In addition, not a clear unique amplitude. Is it because of a too simple trigger, which does not select pristine single tracks ?
- For comparison, PiLas laser creating ~50 photoelectrons, looks like this in the bldg 420 (see page 72):

- **Bldg 420**: TOF counter signal: CFD amp out + ZX60-6013E’ amp + 16 + 64 + a very long cable

  TOF Start (the 1-st), 2.26kV, 50mV/div, 400ps/div.

  ![Graph of TOF counter signal in Bldg 420]

- **Run 304, Trigger**: [finger 8 from hodoscope 1]*[ADC114 conversion valid]*[Lead glass veto]

  TAC start: TOF 1-st (2.26kV), TAC stop: TOF 2-nd (1.89kV)

  - Remove the fiber connectors, including a lens. This improves the lead glass considerably (peak moves from 118 to 149, i.e. 25% !!)

  - Remove all connections to the bldg 420 during the run, to eliminate possible noise sources.

  Paw fitting:

  ![Paw fitting graph]

  - Clearly, much better, but far from my goal.

  - Actually, the veto did not help much compared to run 297, which had a trigger on one finger.

  - We would probably benefit, however, if we could create a single track trigger, which would require to read out the whole hodoscope.

  \[
  \sigma \sim 34.5 \text{ ps} \quad \text{single detector} \sim (1/\sqrt{2}) \sigma \text{ double detector} \sim 24.4 \text{ ps}
  \]
Run 305, PiLas at 15%, 1 att., TAC start: TOF 1-st (2.26kV), TAC stop: TOF 2-nd (1.89kV)

8.20.2007

Find that the TOF counters are not leveled. Apparently, they have tilted when shimming & clamping. The 1-st one is higher than the 2-nd one. Is this a smoking gun? Put in better shims. The counters are now leveled, and ~7-8 mm higher than the original alignment by surveyors.

- Joe is finally able to read the Ortec ADC114 !! He could reproduce my MAC results with PiLas. TAC start: TOF 1-st (2.26kV), TAC stop: TOF 2-nd (1.89kV)

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \]

\[ \sigma \sim 10.8 \text{ ps} \]

\[ \sim 7.6 \text{ ps} \]
- Tune X32 & Y33 correctors to maximize a “TOF/Lead glass” ratio.

- Use a “wobbler” display to tune the “TOF/Lead glass” ratio:

### Run 1
TAC start: TOF 1-st (2.26kV), TAC stop: TOF 2-nd (1.89kV), correctors: x32 = 0.05, y33 = 0

#### a) One finger (vert. #7) & lead glass singles:

\[
\sigma \approx 37.5 \text{ ps}
\]

#### b) Various pairs of fingers & lead glass singles:

\[
\sigma \approx 36.6 \text{ ps}
\]

\[
\sigma_{\text{single detector}} \approx \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \approx 26.5 \text{ ps}
\]

**Hodoscope 2:**

- Double detector \(\sigma \approx 36.6 \text{ ps}\)
- Single detector \(\sigma \approx \frac{1}{\sqrt{2}} \sigma \approx 25.8 \text{ ps}\)
b1) Single hodoscope finger & lead glass singles & fit with a double Gaussian:

```
root [7] -> Draw("adc8_5>>h1(25,3550.5,3750.5","(adc3_5>130.)&&(adc3_5<180.)&&(adc5_6>20.)&&(adc5_7<20.)&&(adc5_8<20.)&&(adc5_9<20.)&&(adc6_10<20.)&&(adc7_1<20.)&&(adc7_2<20.)&&(adc7_3<20.)||(adc5_6>20.)&&(adc7_1>20.)&&(adc5_6>20.)&&(adc6_10>20.)")
```

```
/u2/data/testrun_20070823_0139_100000.root
```

Root fitting (g+g):

```
TF1 F2g("F2g","[0]*exp(-.5*(x-[1])**2/[2]**2)+[3]*exp(-.5*(x-[4])**2/[5]**2),3620,3720); F2g.SetParNames("N1","m1","s1","N2","m2","s2"); F2g.SetParLimits(0,50,70) F2g.SetParameter(0,63); F2g.SetParLimits(1,3620,3720) F2g.SetParameter(1,3674); F2g.SetParLimits(2,10,12) F2g.SetParameter(2,11); F2g.SetParLimits(3,2,8) F2g.SetParameter(3,5); F2g.SetParLimits(4,3640,3680) F2g.SetParameter(4,3680); F2g.SetParLimits(5,10,20) F2g.SetParameter(5,15); h1->Fit(&F2g);
```

```
c) Various pairs of fingers (others empty) & lead glass singles – this is about a maximum # of conditions:
```

```
root [7] -> Draw("adc8_5>>h1(25,3550.5,3750.5","(adc3_5>130.)&&(adc3_5<180.)&&(adc5_6>20.)&&(adc5_7<20.)&&(adc5_8<20.)&&(adc5_9<20.)&&(adc6_10<20.)&&(adc7_1<20.)&&(adc7_2<20.)&&(adc7_3<20.)&&(adc5_6>20.)&&(adc7_1>20.)&&(adc5_6>20.)&&(adc6_10>20.)")
```

```
/u2/data/testrun_20070823_0139_100000.root
```

```
σ single detector ~ 23.7 ps
```

- This result appears to be close to that obtained with a MAC & with hardware trigger (see page 63)
- Run 2, TAC start: TOF 1-st (2.28kV), TAC stop: TOF 2-nd (1.92kV), correctors: x32 = 0.05, y33 = 0

Beam:
TOF_start & TOF_stop in bldg 420 (rise time degradable because of a long cable connection)
50mV/div., 1ns/div, Trigger: top channel, time: 3:40am

- Confirm that a response of TOF_stop counter is indeed smaller. If it is due to misalignment, then it was not fixed. However, I suspect it is due to a poor Al-coating of the quartz radiator. I think this also creates a very poor pulse height spread when running in a beam compared to a laser induced spectrum for Npe ~ 50 pe. We do not trigger on single electrons in the beam !!!

- To verify that the TOF_stop counter does not have lower gain or poor quartz radiator transmission use a PiLas laser with identical fiber for both counters:

PiLas (15%, 1 att.):
TOF_start & TOF_stop in bldg 420
Fibers 1 & 2 in respective counters
50mV/div., 1ns/div

Using a fiber 1
50mV/div., 1ns/div

Using a fiber 1 again (move it from counter 1)
50mV/div., 1ns/div

\[ \sigma \sim 37.2 \text{ ps} \]
\[ \sigma_{\text{single detector}} \sim (1/2) \sigma_{\text{double detector}} \sim 26.3 \text{ ps} \]
- Run 3, TAC start: TOF 1-st (2.28kV), TAC stop: TOF 2-nd (1.98kV), correctors: x32 = 0.05, y33 = 0
  Increase a voltage on TOF stop to compensate for smaller pulse height
  TOF start & TOF stop in bldg 420
  50mV/div., 1ns/div, time: 5:18am

- We do not trigger the scope on single electrons in the beam.

a) One finger (vert. #7) & lead glass singles:

\[
\sigma \sim 37.2 \text{ ps} \\
\sigma \sim 39.1 \text{ ps} \\
\sigma \sim 40.3 \text{ ps}
\]

\[\sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 26.3 \text{ ps}\]

b) Two finger (vert.#7&horiz.#7)& lead glass singles:

\[
\sigma \sim 37.2 \text{ ps} \\
\sigma \sim 39.1 \text{ ps} \\
\sigma \sim 40.3 \text{ ps}
\]

\[\sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 26.3 \text{ ps}\]
c) Single hodoscope finger & lead glass singles & fit with a double Gaussian:

Fit with a double Gaussian fctn:

\[
\text{TF1} \text{F2g}^{*} [0] \exp(-0.5(x-[1])**2/[2]**2)+[3] \exp(-0.5(x-[4])**2/[5]**2),3620,3720); \\
\text{F2g.SetParNames}("N1","m1","s1","N2","m2","s2"); \\
\text{F2g.SetParLimits}(0.5,70) \\
\text{F2g.SetParameter}(0.63) \\
\text{F2g.SetParameter}(1.3620,3720) \\
\text{F2g.SetParameter}(1.3674); \\
\text{F2g.SetParameter}(2.11) \\
\text{F2g.SetParameter}(3.2,8) \\
\text{F2g.SetParameter}(3.5); \\
\text{F2g.SetParameter}(4.3640,3680) \\
\text{F2g.SetParameter}(4.3680); \\
\text{F2g.SetParameter}(5.10,20) \\
\text{F2g.SetParameter}(5.15); \\
\text{h1->Fit}(\text{&F2g}); \\
\]

Further off-line analysis of the data with the TOF counters (run 36):
- Lead glass:
- Hodoscope 1:
  a) Single hits:
  b) Single hits + require that TOF_ADC is on:

- Hodoscope 2:
  c) Single hits:
  d) Single hits + require that TOF_ADC is on:
Conditions during the TOF counter run:

a) **Condition 1**, TAC start: TOF 1-st (2.26kV), TAC stop: TOF 2-nd (1.89kV), correctors: \(x_{32} = 0.05\), \(y_{33} = 0\)

b) **Condition 2**, TAC start: TOF 1-st (2.28kV), TAC stop: TOF 2-nd (1.92kV), correctors: \(x_{32} = 0.05\), \(y_{33} = 0\)

c) **Condition 3**, TAC start: TOF 1-st (2.28kV), TAC stop: TOF 2-nd (1.98kV), correctors: \(x_{32} = 0.05\), \(y_{33} = 0\)

Conditions & cuts within:

```c
if (z_coord > 6. && z_coord < 8. && y_coord > 3. && y_coord < 5. && z_coord_2 > -5. && z_coord_2 < -3. && y_coord_2 > -3.5 && y_coord_2 < -0.5)
    tightest_hit_12 = true;

if (good_hit && event_time > 80. && event_time < 150. && tightest_hit_12) h_tof_adc1->Fill(tof_adc);
if (good_hit && event_time > 150. && event_time < 250. && tightest_hit_12) h_tof_adc2->Fill(tof_adc);
if (good_hit && event_time > 250. && event_time < 350. && tightest_hit_12) h_tof_adc3->Fill(tof_adc);
```

![Event time vs. TOF counter resolution (counts)](image-url)

TOF counter resolution - condition 1

- Entries: 185
- Mean: 36.75
- RMS: 12.61
- Integral: 196
- $\chi^2$/ndf: 0.638/13
- Narrow Norm: 17.20 $\pm$ 2.58
- Narrow Mean: 36.75 $\pm$ 1.33
- Narrow Sigma: 0.96 $\pm$ 0.30
- Background: 0.60 $\pm$ 0.04

$\sigma$ single detector ~ 22.4 ps

TOF counter resolution - condition 2

- Entries: 324
- Mean: 36.71
- RMS: 13.15
- Integral: 281
- $\chi^2$/ndf: 0.160/12
- Narrow Norm: 18.66 $\pm$ 4.11
- Narrow Mean: 36.70 $\pm$ 0.77
- Narrow Sigma: 0.65 $\pm$ 0.05
- Background: 1.24 $\pm$ 0.20

$\sigma$ single detector ~ 22.6 ps

TOF counter resolution - condition 3

- Entries: 517
- Mean: 35.53
- RMS: 15.29
- Integral: 519
- $\chi^2$/ndf: 19.61/11
- Narrow Norm: 14.85 $\pm$ 4.91
- Narrow Mean: 36.94 $\pm$ 0.88
- Narrow Sigma: 0.31 $\pm$ 0.31
- Background: 1.17 $\pm$ 0.82

$\sigma$ single detector ~ 25.5 ps

TOF counter resolution - all conditions (aligned)

- Entries: 1006
- Mean: 36.54
- RMS: 12.56
- Integral: 887
- $\chi^2$/ndf: 21.86/13
- Narrow Norm: 15.46 $\pm$ 6.7
- Narrow Mean: 36.50 $\pm$ 0.76
- Narrow Sigma: 0.85 $\pm$ 0.36
- Background: 1.03 $\pm$ 0.72

$\sigma$ single detector ~ 24.5 ps
Tests with PiLas: Resolution $= f(N_{pe})$ for 100mV CFD thresholds

Run 306 & 307, PiLas at 12%, 2 att., TAC start: TOF 1-st (2.28kV), TAC stop: TOF 2-nd (1.92kV)

8.23.2007

![Graph showing data](image1)

$\sigma_{\text{single detector}} \sim (1/\sqrt{2}) \sigma_{\text{double detector}} \sim 15.8 \text{ ps}$

$\sigma \sim 22.3 \text{ ps}$

Run 308, PiLas at 15%, 1 att., TAC start: TOF 1-st (2.27kV), TAC stop: TOF 2-nd (1.88kV)

-100mV 9327 CFD threshold, +5mV walk threshold

8.28.2007

![Graph showing data](image2)

$\sigma_{\text{single detector}} \sim (1/\sqrt{2}) \sigma_{\text{double detector}} \sim 8.1 \text{ ps}$

$\sigma \sim 11.4 \text{ ps}$

Run 309, PiLas at 15%, 0 att., -100mV CFD threshold, +5mV walk threshold

8.30.2007

![Graph showing data](image3)

$\sigma_{\text{single detector}} \sim (1/\sqrt{2}) \sigma_{\text{double detector}} \sim 7.6 \text{ ps}$

$\sigma \sim 10.7 \text{ ps}$

Run 310, PiLas at 15%, 1.2 att., -100mV CFD threshold, +5mV walk threshold

9.2.2007

![Graph showing data](image4)

$\sigma_{\text{single detector}} \sim (1/\sqrt{2}) \sigma_{\text{double detector}} \sim 9.3 \text{ ps}$

$\sigma \sim 13.2 \text{ ps}$
Run 311, PiLas at 15%, 2.0 att., -100mV CFD threshold, +5mV walk threshold

Run 312, PiLas at 15%, 2.2 att., -100mV CFD threshold, +5mV walk threshold

Run 313 & 315, PiLas at 15%, 3.2 att., -100mV CFD threshold, +5mV walk threshold
Trigger on ch.1: Trigger on Linac pulse:

Run 316, PiLas at 15%, 4.2 att., -100mV CFD threshold, +5mV walk threshold
Trigger on Linac pulse:

Run 317, PiLas at 15%, 5.2 att., -100mV CFD threshold, +5mV walk threshold
Trigger on Linac pulse:
Run 318, PiLas at 15%, 6.2 att., -100mV CFD threshold, +5mV walk threshold
Trigger on Linac pulse:

Looks like a single electron mode, but need further steps.

Run 319, PiLas at 15%, 6.2 att., 2.35 & 2.0 kV, -100mV CFD threshold, +5mV walk threshold
Trigger on Linac pulse:

This is clearly a single photoelectron mode (mostly empty traces with ext. trigger)

Tests with PiLas: Resolution = f(Npe) for 20mV CFD thresholds
Run 320, PiLas at 15%, 2.27kV & 1.88kV, 0 att., -20mV 9327 CFD threshold, +5mV walk threshold

σ \sim 10.3 \text{ ps} 

σ_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 7.3 \text{ ps}

Run 321, PiLas at 15%, 1 att., -20mV CFD threshold, +5mV walk threshold

σ \sim 10.4 \text{ ps} 

σ_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 7.4 \text{ ps}
Run 322, PiLas at 15%, 1.2 att., -20mV CFD threshold, +5mV walk threshold

\[ \sigma \approx 12.4 \text{ ps} \]

Run 323, PiLas at 15%, 2.0 att., -20mV CFD threshold, +5mV walk threshold

\[ \sigma \approx 19.7 \text{ ps} \]

Run 324, PiLas at 15%, 2.2 att., -20mV CFD threshold, +5mV walk threshold

\[ \sigma \approx 25.3 \text{ ps} \]

Run 325, PiLas at 15%, 3.0 att., -20mV CFD threshold, +5mV walk threshold

\[ \sigma \approx 47.7 \text{ ps} \]

Run 326, PiLas at 15%, 3.2 att., -20mV CFD threshold, +5mV walk threshold

\[ \sigma \approx 62.2 \text{ ps} \]

Run 327, No events, PiLas at 15%, 4.0 att., 20mV CFD threshold, +5mV walk threshold

\[ \sigma_{\text{single detector}} \approx (1/\sqrt{2}) \sigma_{\text{double detector}} \approx 8.7 \text{ ps} \]

\[ \sigma_{\text{single detector}} \approx (1/\sqrt{2}) \sigma_{\text{double detector}} \approx 13.9 \text{ ps} \]

\[ \sigma_{\text{single detector}} \approx (1/\sqrt{2}) \sigma_{\text{double detector}} \approx 17.9 \text{ ps} \]

\[ \sigma_{\text{single detector}} \approx (1/\sqrt{2}) \sigma_{\text{double detector}} \approx 33.7 \text{ ps} \]

\[ \sigma_{\text{single detector}} \approx (1/\sqrt{2}) \sigma_{\text{double detector}} \approx 44.0 \text{ ps} \]
\( \sigma_{\text{single MCP \ [ps]} \)}

Number of photoelectrons

20mV CFD threshold
100mV CFD threshold
A cross-talk and ringing test in Andrew Brandt’s new MCP (10 &mu;m holes) tube with a better grounding
- Vertical scale is 200mV/div for a primary signal and 20mV/div for the cross-talk
- The primary signal is equivalent to 5-10 photoelectrons
Ringing

-2.4kV on the new MCP from Andrew Brandt -> gain of 5x10^5 (?)
Avalanche formed from 5-10pe/laser shot
The frequency of this ringing is close to ~150 MHz.
Use a 1GHz BW Tek scope and Hamamatsu 1.5 GHz BW amplifier.
All unused pads are terminated in 50 Ohms

Run 331, Andrew’s CFD, ~50 photoelectrons (PiLas at 15%, 1.0 att.), 50mV CFD threshold, Linac pulse is a start & external trigger to PiLas, , TOF_start is stop, Ortec TAC566 & ADC114, **2.30kV** on TOF_start

\[ \sigma \approx 16.5 \text{ ps} \]

Run 332, Andrew’s CFD, ~50 photoelectrons (PiLas at 15%, 1.0 att.), 50mV CFD threshold, Linac pulse is a start & external trigger to PiLas, TOF_start is stop, Ortec TAC566 & ADC114, **2.35kV** on TOF_start

\[ \sigma \approx 19.0 \text{ ps} \]
Calibration in ESA:  
9.4.2007

Run 333, Calibration of Amp/CFD9327 + TAC566 + ADC114 with Jeff’s pulser
- add 20dB attenuator between the pulser’s NIM outputs and Amp/CFD entry

ESA tests with PiLas: Resolution = f(Npe) for -10mV CFD thresholds  
9.18.2007

Run 334, 1 att., PiLas at 15%, 2.27kV & 1.88kV, -10mV 9327 CFD threshold, +5mV walk threshold
Because of the power outage, run PiLas on internal trigger => so, repeat run 321 first; check the pulse height using a slow HP54510B scope – both start & stop have approx. 150mV peak pulse height

\[ \sigma \sim 3.42 \text{ ps} \]

Run 335, 1att., PiLas at 15%, 2.27kV & 1.88kV, -10mV 9327 CFD threshold, +5mV walk threshold
PiLas on internal trigger.

\[ \sigma \sim 11.2 \text{ ps} \]

Run 336, 0 att., PiLas at 15%, 2.27kV & 1.88kV, -10mV 9327 CFD threshold, +5mV walk threshold
PiLas on internal trigger.

\[ \sigma \sim 9.2 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \sim 7.9 \text{ ps} \]
Run 337, PiLas at 15%, 2.27kV & 1.88kV, 1.2 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger.

Run 338, PiLas at 15%, 2.27kV & 1.88kV, 2.0 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger.

Run 339, PiLas at 15%, 2.27kV & 1.88kV, 2.2 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger.

Run 340, PiLas at 15%, 2.27kV & 1.88kV, 3.0 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger.

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

~ 9.5 ps

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

~ 15.3 ps

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

~ 21.1 ps

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

~ 40.5 ps

**Run 341**, PiLas at 15%, 2.27kV & 1.88kV, 3.2 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger.

\[ \sigma \sim 90.8 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \sim 64.2 \text{ ps} \]

**Run 342**, PiLas at 15%, 2.27kV & 1.88kV, 4.0 att., -10mV 9327 CFD threshold, +5mV walk threshold PiLas on internal trigger. ADC114 LED just occasionally flickers – obviously close to threshold

\[ \sigma \sim 150.3 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \sim 106.3 \text{ ps} \]

**Run 343**, Repeat run 335, PiLas at 15%, 2.27kV & 1.88kV, 1 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

\[ \sigma \sim 10.2 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \sim 7.2 \text{ ps} \]

**Run 344**, Repeat run 336, PiLas at 15%, 2.27kV & 1.88kV, 0 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

\[ \sigma \sim 9.1 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \left( \frac{1}{\sqrt{2}} \right) \sigma_{\text{double detector}} \sim 6.4 \text{ ps} \]
Modify the resistor voltage divider

Voltage divider used so far (values suggested by Burle):

Measurements so far were done with these parameters:

1) TOF 1, V = 2.27 kV ⇒ I_{chain} \sim \frac{2270}{(0.5+4.12+0.5) \times 10^6} \sim 443.4 \mu A
   ⇒ \Delta V_{MCP} \sim 443.4 \mu A \times 4.12 \times 10^6 \sim 1826.6 V and E_{MCP} \sim 1826.6/0.2 \sim 9.1 kV/cm
   ⇒ \Delta V_{MCP-to-Anode} \sim 443.4 \mu A \times 500 \Omega \sim 222 V and E_{MCP-to-Anode} \sim 222/0.5 \sim 444 V/cm

2) TOF 2, V = 1.88 kV ⇒ I_{chain} \sim \frac{1880}{(0.5+4.12+0.5) \times 10^6} \sim 367.2 \mu A
   ⇒ \Delta V_{MCP} \sim 367.2 \mu A \times 4.12 \times 10^6 \sim 1512.8 V and E_{MCP} \sim 1512.8/0.2 \sim 7.6 kV/cm
   ⇒ \Delta V_{MCP-to-Anode} \sim 367.2 \mu A \times 500 \Omega \sim 183.6 V and E_{MCP-to-Anode} \sim 183.6/0.5 \sim 367 V/cm

Loaded by the MCP resistance to a value of \sim 4.12 M\Omega
⇒ R_{MCP} \sim 23.4 M\Omega (voltage off)
New parameters intend to improve the MCP rise time:  
New voltage divider (need to increase cathode voltage to maintain the same $E_{MCP}$):

1) TOF 1, $V = 2.50 \text{ kV}$  
$\Rightarrow I_{\text{chain}} \approx 2500/[(0.5+4.12+1.0)*10^6] \approx 444.8 \mu\text{A}$  
$\Rightarrow \Delta V_{\text{MCP}} \approx 444.8 \mu\text{A}*4.12 \text{ M}\Omega \approx 1832.7 \text{ V}$ and $E_{MCP} \approx 1832.7/0.2 \approx 9.16 \text{ kV/cm}$  
$\Rightarrow \Delta V_{\text{MCP-to-Anode}} \approx 444.8 \mu\text{A}*1.0 \text{ M}\Omega \approx 444.8 \text{ V}$ and $E_{MCP-to-Anode} \approx 444.4/0.5 \approx 890 \text{ V/cm}$

2) TOF 2, $V = 2.07 \text{ kV}$  
$\Rightarrow I_{\text{chain}} \approx 2070/[(0.5+4.12+1.0)*10^6] \approx 368.3 \mu\text{A}$  
$\Rightarrow \Delta V_{\text{MCP}} \approx 368.3 \mu\text{A}*4.12 \text{ M}\Omega \approx 1517.5 \text{ V}$ and $E_{MCP} \approx 1517.5/0.2 \approx 7.6 \text{ kV/cm}$  
$\Rightarrow \Delta V_{\text{MCP-to-Anode}} \approx 368.3 \mu\text{A}*1.0 \text{ M}\Omega \approx 368.3 \text{ V}$ and $E_{MCP-to-Anode} \approx 368.3/0.5 \approx 737 \text{ V/cm}$

However, find that both MCP-PMTs have almost no gain at these voltages $\Rightarrow$ increase cathode voltage:  
(this is done by looking at max. amplitude for Npe $\approx 50$ photoelectrons)

1) TOF 1, $V = 2.85 \text{ kV}$  
$\Rightarrow I_{\text{chain}} \approx 2850/[(0.5+4.12+1.0)*10^6] \approx 507.1 \mu\text{A}$  
$\Rightarrow \Delta V_{\text{MCP}} \approx 507.1 \mu\text{A}*4.12 \text{ M}\Omega \approx 2089.3 \text{ V}$ and $E_{MCP} \approx 1832.7/0.2 \approx 10.4 \text{ kV/cm}$  
$\Rightarrow \Delta V_{\text{MCP-to-Anode}} \approx 507.1 \mu\text{A}*1.0 \text{ M}\Omega \approx 507.1 \text{ V}$ and $E_{MCP-to-Anode} \approx 444.4/0.5 \approx 1014 \text{ V/cm}$

2) TOF 2, $V = 2.43 \text{ kV}$  
$\Rightarrow I_{\text{chain}} \approx 2430/[(0.5+4.12+1.0)*10^6] \approx 432.4 \mu\text{A}$  
$\Rightarrow \Delta V_{\text{MCP}} \approx 432.4 \mu\text{A}*4.12 \text{ M}\Omega \approx 1781.4 \text{ V}$ and $E_{MCP} \approx 1517.5/0.2 \approx 8.9 \text{ kV/cm}$  
$\Rightarrow \Delta V_{\text{MCP-to-Anode}} \approx 432.4 \mu\text{A}*1.0 \text{ M}\Omega \approx 432.4 \text{ V}$ and $E_{MCP-to-Anode} \approx 368.3/0.5 \approx 865 \text{ V/cm}$

- One possible explanation of this increase of voltages: MCP resistance goes down as one increase $E_{MCP}$. 

\[\text{Change to } \sim 1.0 \text{ M}\Omega\]
Run 345, PiLas at 15%, 2.85kV & 2.43kV, 1 att., Npe ~ 50 pe, -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

Run 346, PiLas at 15%, 2.85kV & 2.43kV, 0 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

Run 347, PiLas at 15%, 2.85kV & 2.43kV, 1.2 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.
Run 348, PiLas at 15%, 2.85kV & 2.43kV, 2.0 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

\[ \sigma \sim 19.1 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

\[ \sim 13.5 \text{ ps} \]

Run 349, PiLas at 15%, 2.85kV & 2.43kV, 2.2 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

\[ \sigma \sim 26.5 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

\[ \sim 18.7 \text{ ps} \]

Run 350, PiLas at 15%, 2.85kV & 2.43kV, 3.0 att., -10mV 9327 CFD th., +5mV walk th., PiLas on internal trigger.

\[ \sigma \sim 49.7 \text{ ps} \]

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \]

\[ \sim 35.2 \text{ ps} \]

- There does not seem to be much benefit from an increase of the MCP-to-anode field.
Mutliple-threshold timing with Ortec 9327’s:

**Splitter 4.2GHz:**

![Diagram of ORTEC 9327s with Splitter 4.2GHz](image)

Run 352, 1 att., Npe ~ 50 pe, TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch 9327 #3 (Camden’s CFD) has -20mV threshold, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, all CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. All 9327 have amplifier gains set to low values (as I had before), i.e., run MCP at higher voltages.

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- This is worse than we had before (effect of splitter or lower voltage ?).

2) TOF1(th1) - TOF1(th2) measurement:

400ps/div, 10mV/div, 9327 CFD amp. monitor out, trigger on PiLas trigger out

\[ \sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 8.1 \text{ ps} \]
Multiple-threshold timing with Phillips 708’s:

Run 357, Introduce Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 1 att., ~50 pe, TOF #1: 2.73kV, passive 4.2 GHz BW splitter, one branch 9327 #1 (old #1) has -10mV threshold, the second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) with 10 and 200 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low values (as I had before), modified resistor chain, Hamamatsu amp. gain is 63x.

1) TOF1(low th.) -TOF2(low th.) measurement (as before):

\[ \sigma \sim 11.8 \text{ ps} \]

- This is worse than we had before (effect of a splitter ???).

2) TOF1(th1) -TOF1(th2) measurement and corrected distribution:

\[ \sigma_{\text{corr}} \sim 11.1 \text{ ps} \]

- Switch to Root analysis (program written by Camden)
Run 369, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 3 att., TOF #1: 2.88kV, passive 4.2 GHz BW splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) with 10 and 25 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is worse than that in run 350 ($\sigma \sim 66.9$ ps vs. $\sigma \sim 49.7$ ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

3) Profile of “TOF1(low) – TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

Run 370, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 2.2 att., TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) with 10 and 150 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low
1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is slightly better than that in run 349 (σ ~ 26 ps vs. σ ~ 26.5 ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

3) Profile of “TOF1(low) – TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

Run 371, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 2.0 att., TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV thresh second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 200 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is slightly worse than that in run 348 (σ ~ 21.9 ps vs. σ ~ 19.1 ps).
2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

3) Profile of "TOF1(low) – TOF2(low) vs. TOF1(low)-TOF1(high)" measurement:

Run 372, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 1.2 att., TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 500 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is slightly better than that in run 347 (σ ~ 13.6 ps vs. σ ~ 14.5 ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:
3) Profile of “TOF1(low) –TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

Run 373, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 1.0 att., TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 800 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) -TOF2(low th.) measurement (as before):

- Uncorrected result is slightly worse than that in run 345 ($\sigma \sim 12.1$ ps vs. $\sigma \sim 10.9$ ps).

2) TOF1(th1) -TOF1(th2) measurement and corrected distribution:

3) Profile of “TOF1(low) –TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:
Run 374, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, add 20dB in front of the Hamamatsu amplifier to prevent its saturation, 0 att., TOF #1 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) with 10 and 400 mV thresholds, TC 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is slightly worse than that in run 345 (σ ~ 12.1 ps vs. σ ~ 10.9 ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

σ_{single detector} ~ (1/√2) σ_{double detector} ~ 5.8 ps \rightarrow 5.1

3) Profile of “TOF1(low) - TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

TOF1(low th.) – TOF1(high th.)

σ_{corr} ~ 7.2 ps

Run 375, Repeat run 373 with a 20dB attenuator in front of the hamamatsu amplifier to prevent its saturation, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 1.0 att., TOF #1: 2.88kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) with 10 and 800 mV thresholds, TOF 2: 2.43kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low
1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is slightly worse than that in run 345 ($\sigma \sim 11.4$ ps vs. $\sigma \sim 10.9$ ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

$$\sigma_{\text{single detector}} \sim \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \sim 8 \text{ ps} \rightarrow 7.4$$

3) Profile of “TOF1(low) – TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

- No improvement compared to the CFD-only method, when doing the pulse height correction the way we did it. However, the correction, when applied, always improves the resolution.
Look at pulses for small Npe:

Run 376, 3 att., still the same circuit as previous runs, TOF #1: 2.88kV, PiLas at 15%, 50Hz, PiLas on internal trigger, modified resistor chain, Hamamatsu amp. C5594-44 gain is 63x, 20dB att. out.

Splitter 4.2GHz:

- Looks pretty linear to me. Do not see why CFD would have problems with it. S/N is worse, of course, for 3 att.
The first look at the rate response of MCP-PMT:

Run 378, 0 att., Check the photon yield of PiLas by the Si diode as we change the frequency, PiLas at 15% PiLas on internal trigger. Above 50Hz, Pilas chooses its own power setting. Spot size of the light on the MCP face is about a mm in dia. Calibrate the photon yield with the Si diode:

a) Calibration of light yield = f(rate):

<table>
<thead>
<tr>
<th>Rate [Hz]</th>
<th>Si diode response [mV]</th>
<th>MCP amplitude [mV]</th>
<th>MCP normalized output [mV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>85</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>100</td>
<td>78</td>
<td>74</td>
<td>80.6</td>
</tr>
<tr>
<td>200</td>
<td>86</td>
<td>84</td>
<td>84.9</td>
</tr>
<tr>
<td>500</td>
<td>58</td>
<td>60</td>
<td>87.9</td>
</tr>
<tr>
<td>1000</td>
<td>30</td>
<td>30</td>
<td>85</td>
</tr>
<tr>
<td>2000</td>
<td>13</td>
<td>13</td>
<td>85</td>
</tr>
</tbody>
</table>

- Looks good over this range: up to ~2kHz/mm², which would mean ~200kHz/cm² (???)

b) MCP amplitude response measurement = f(rate):

Run 379, 1 att., ~50 pe, Check the the MCP response as we change the frequency, PiLas at 15%:

- Do not know what is causing a wiggle. A bad SMA cable contact?
Go back to original 1st resistor chain

Run 380, 1.0 att, original 1st resistor chain, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 20dB attenuator in front of the Hamamatsu amplifier to prevent its saturation. TOF #1: 2.27kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 100 mV thresholds, TOF #2: 1.88kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low.

Splitter 4.2GHz:
ZFRSC-42+

![Diagram of the circuit](image)

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

\[ \sigma \approx 10.7 \text{ ps} \]

- Uncorrected result is slightly worse than that in run 343 (\( \sigma \approx 10.7 \text{ ps} \) vs. \( \sigma \approx 10.2 \text{ ps} \)).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

\[ \sigma_{\text{single detector}} \approx \frac{1}{\sqrt{2}} \sigma_{\text{double detector}} \approx 7.5 \text{ ps} \rightarrow 7.1 \]

\[ \sigma_{\text{corr}} \approx 10.1 \text{ ps} \]
3) Profile of “TOF1(low) –TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

Run 381, 0 att., original 1st resistor chain, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 20dB attenuator in front of the Hamamatsu amplifier to prevent its saturation, TOF #1: 2.27kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 100 mV thresholds, TOF 2: 1.88kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) -TOF2(low th.) measurement (as before):

- Uncorrected result is much worse than that in run 344 ($\sigma \sim 11.9$ ps vs. $\sigma \sim 9.1$ ps).

2) TOF1(th1) -TOF1(th2) measurement and corrected distribution:

3) Profile of “TOF1(low) –TOF2(low) vs. TOF1(low)-TOF1(high)” measurement:

The correction does not work because thresholds are too close to each other !!!!
Run 382, 0 att., original 1st resistor chain, Hamamatsu amplifier & Phillips 708 (300MHz) leading edge discriminator to do the double threshold timing, 20dB attenuator in front of the Hamamatsu amplifier to prevent its saturation, TOF #1: 2.27kV, passive splitter, one branch 9327 #1 (old #1) has -10mV threshold, second branch goes to Hamamatsu amplifier, another splitter, and two Phillips 708 discriminators (300MHz) w 10 and 400 mV thresholds, TOF 2: 1.88kV, no splitter, 9327 #2 (old #2) has -10mV threshold, both CFDs have +5mV walk th., PiLas at 15%, PiLas on internal trigger. Both 9327’s have amplifier gains set to low

1) TOF1(low th.) - TOF2(low th.) measurement (as before):

- Uncorrected result is much worse than that in run 344 ($\sigma \sim 11.9$ ps vs. $\sigma \sim 9.1$ ps).

2) TOF1(th1) - TOF1(th2) measurement and corrected distribution:

- The overall conclusion remains: although the correction works, the final result is not better than their original CFD timing.
- The best correction is achieved if the two thresholds are separated as much as possible.

Program originally written by Camden – the following version is for run 382:

```c
#include "Riostream.h"
#include "math.h"

/* This program consists of two parts. Part one (treeFill) creates the histograms and part two (treeHist) draws them.
   In part one the xlow, xhigh, bins, and nuevents parameters will need to be set.
   In part two the fitmin and fitmax parameters will need to be set.
*/
To run the program
root [0] .x tree.C

To run part one by itself
root [0] .L tree.C
root [1] treeFill()

To run part two by itself
root [0] .L tree.C
root [1] treeHist()

*/

void treeFill()
{
    gROOT->Reset();  // Reset ROOT

    ifstream in;
    Float_t r1ch1,r1ch2,r1ch3,r1ch4,r1ch5,r1ch6,r1ch7,r1ch8,r1ch9,r1ch10,r2ch1,r2ch2,r3ch1,r3ch2,r3ch3,r3ch4,r3ch5,r3ch6,r3ch7,r3ch8,r3ch9,r3ch10,r4ch1,r4ch2,r5ch1,r5ch2,r5ch3,r5ch4,r6ch1,r6ch2,r6ch3,r6ch4;

    char line[256];

    // Open data file
    in.open("run382.dat");

    int numevents = 5000;  // Number of events
    int taccmean = 1816;  // Mean value of timing resolution
    float p0 = 1.414;      // Fit constant
    float p1 = 0.7808;     // Fit constant
    float p2 = -0.0003674; // Fit constant
    float taccorrected;   // Corrected timing resolution

    int h1xlow = 1700;     // Min histogram value to be graphed
    int h1xhigh = 1900;    // Max histogram value to be graphed
    int h1xbins = (h1xhigh - h1xlow) / 1; // Number of histogram bins

    int h2xlow = 1480;     // Min histogram value to be graphed
    int h2xhigh = 1580;    // Max histogram value to be graphed
    int h2xbins = (h2xhigh - h2xlow) / 1; // Number of histogram bins

    int h3xlow = 0;        // Min histogram value to be graphed
    int h3xhigh = numevents; // Max histogram value to be graphed
    int h3ylow  = h1xlow; // Min histogram value to be graphed
    int h3yhigh = h1xhigh; // Max histogram value to be graphed
    int h3xbins = (h3xhigh - h3xlow) / 1; // Number of histogram bins
    int h3ybins = (h3yhigh - h3ylow) / 1; // Number of histogram bins

    int h4xlow = h2xlow;  // Min histogram value to be graphed
    int h4xhigh = h2xhigh; // Max histogram value to be graphed
    int h4ylow  = h1xlow; // Min histogram value to be graphed
    int h4yhigh = h1xhigh; // Max histogram value to be graphed
    int h4xbins = h2xbins; // Number of histogram bins
    int h4ybins = h1xbins; // Number of histogram bins

    int h5xlow = h1xlow;  // Min histogram value to be graphed
    int h5xhigh = h1xhigh; // Max histogram value to be graphed
    int h5xbins = (h5xhigh - h5xlow) / 1; // Number of histogram bins

    int h6xlow = h2xlow;  // Min histogram value to be graphed
    int h6xhigh = h2xhigh; // Max histogram value to be graphed
    int h6ylow  = h1xlow; // Min histogram value to be graphed
    int h6yhigh = h1xhigh; // Max histogram value to be graphed
    int h6xbins = h2xbins; // Number of histogram bins
    int h6ybins = h1xbins; // Number of histogram bins

    // Create a root file

TFile *f = new TFile("test.root","RECREATE");

// Create a 1D Histogram for the TAC data
TH1F *h1 = new TH1F("h1","MCP Resolution - [TOF1(low th)-TOF2(low th)]",h1xbins,h1xlow,h1xhigh);

// Create a 1D Histogram for the TAC data
TH1F *h2 = new TH1F("h2","Leading edge slope",h2xbins,h2xlow,h2xhigh);

// Create a 2D Histogram for the Drift plot
TH2F *h3 = new TH2F("h3","MCP Drift",h3xbins,h3xlow,h3xhigh,h3ybins,h3ylow,h3yhigh);

// Create a 2D Histogram for the Correlation Plot
TH2F *h4 = new TH2F("h4","[TOF1(low th)-TOF2(low th)] vs Leading edge slope",h4xbins,h4xlow,h4xhigh,h4ybins,h4ylow,h4yhigh);

// Create a TH1F plot of ADC1 vs ADC2
TH1F *h5 = new TH1F("h5","MCP Resolution - corrected",h5xbins,h5xlow,h5xhigh);

// Create a 2D Histogram for the Corrected Correlation Plot
TH2F *h6 = new TH2F("h6","Corrected [TOF1(low th)-TOF2(low th)] vs Leading edge slope",h6xbins,h6xlow,h6xhigh,h6ybins,h6ylow,h6yhigh);

// Create a TProfile plot of ADC1 vs ADC2
TProfile *h1prof = new TProfile("h1prof","Profile [TOF1(low th)-TOF2(low th)] vs Leading edge slope",h2xbins,h2xlow,h2xhigh);

// Create a 2D Histogram for the TAC data
TH2F *h7 = new TH2F("h7","MCP Resolution - corrected",h5xbins,h5xlow,h5xhigh);

// Get the first line w/ run information
in.getline (line,256);

// Loop over events
int i = 1;
while (1) {

    // Row 1
    in >> r1ch1 >> r1ch2 >> r1ch3 >> r1ch4 >> r1ch5 >> r1ch6 >> r1ch7 >> r1ch8 >> r1ch9 >> r1ch10;
    if (!in.good()) break;
    h1->Fill(r1ch1);
    h3->Fill(r1ch1);
    h2->Fill(r1ch2);
    h4->Fill(r1ch2,r1ch1);
    h1prof->Fill(r1ch2,r1ch1);
    taccorrected = tacmean + (r1ch1 - ((p2 * r1ch2 * r1ch2) + (p1 * r1ch2) + p0));
    h5->Fill(taccorrected);
    h6->Fill(r1ch2,taccorrected);
    h2prof->Fill(r1ch2,taccorrected);
    ntuple->Fill(r1ch1,r1ch2,r1ch3,r1ch4,r1ch5,r1ch6,r1ch7,r1ch8,r1ch9,r1ch10);

    // Row 2
    in >> r2ch1 >> r2ch2;
    if (!in.good()) break;
    //ntuple->Fill(r2ch1,r2ch2); If there is useful info in this row remove comment

    // Row 3
    in >> r3ch1 >> r3ch2 >> r3ch3 >> r3ch4 >> r3ch5 >> r3ch6 >> r3ch7 >> r3ch8 >> r3ch9 >> r3ch10;
    if (!in.good()) break;
    //ntuple->Fill(r3ch1,r3ch2,r3ch3,r3ch4,r3ch5,r3ch6,r3ch7,r3ch8,r3ch9,r3ch10); If there is useful info in this row remove comment

    // Row 4
    in >> r4ch1 >> r4ch2;
    if (!in.good()) break;
    //ntuple->Fill(r4ch1,r4ch2); If there is useful info in this row remove comment

    // Row 5
in >> r5ch1 >> r5ch2 >> r5ch3 >> r5ch4;
if (!in.good()) break;
//ntuple->Fill(r5ch1,r5ch2,r5ch3,r5ch4); If there is useful info in this row remove comment

// Row 6
in >> r6ch1 >> r6ch2 >> r6ch3 >> r6ch4;
if (!in.good()) break;
//ntuple->Fill(r6ch1,r6ch2,r6ch3,r6ch4); If there is useful info in this row remove comment

i++;
}

printf("Found %i points\n",i);

in.close(); // Close the data file
f->Write(); // Write the root file
//f->Close(); // Close the root file

}

void treeCorrected()
{
extern TStyle* gStyle;

int fitmin1 = 1743;
int fitmax1 = 1766;
int fitmin2 = 1495;
int fitmax2 = 1530;
int fitmin3 = 1806;
int fitmax3 = 1825;

TFile *f = new TFile("test.root");
TAC = (TH1F*)f->Get("h1;1"); // Get the 1D histogram
COR_TAC = (TH1F*)f->Get("h5;1"); // Get the 1D histogram
SLOPE = (TH1F*)f->Get("h2;1"); // Get the 1D histogram
TACvsSLOPE = (TH2F*)f->Get("h4;1"); // Get the 2D histogram
CTACvsSLOPE = (TH2F*)f->Get("h6;1"); // Get the 2D histogram
PROFILE = (TProfile*)f->Get("h1prof;1");
CPROFILE = (TProfile*)f->Get("h2prof;1");

//ROOT Plotting Options
//**************************
// Set histogram plotting options
//**************************
gStyle->SetOptStat(2211);
gStyle->SetOptFit(11);
gStyle->SetFuncColor(1);
gStyle->SetFrameFillColor(10);
//gStyle->SetHistFillColor(3);
gStyle->SetLabelSize(0.03,"XYZ");
gStyle->SetStatColor(0);
gStyle->SetStatFont(0.03);
gStyle->SetSetTitleColor(2);
gStyle->SetTitleW(0.5);
//gStyle->SetMarkerColor(6);
//gStyle->SetMarkerSize(0.25);
//gStyle->SetMarkerStyle(8);
gStyle->SetPageSize(20,20);

TCanvas *MyC1 = new TCanvas("MyC1","Canvas",1200,800); // Create a canvas for our graphs
MyC1->Divide(2,2); // Divide the canvas into two pads
MyC1->cd(1); // pad 1
TAC->SetXTitle("TOF1-low - TOF2-low");
TAC->GetXaxis()->SetTitleColor(2);
TAC->GetYaxis()->SetTitleColor(2);
TAC->GetYaxis()->SetTitleOffset(1.2);
TF1 *myfit = new TF1("myfit","gaus",fitmin1,fitmax1);
myfit->SetParName(0,"Norm");
myfit->SetParName(1,"Mean");
myfit->SetParName(2,"Sigma");
TAC->Draw(); // Draw the 1D histogram
TAC->Fit("myfit","R"); // use this to fit over a range and comment out previous

MyC1->cd(4); // pad 2
COR_TAC->SetXTitle("Pulse(TOF1-low - TOF1-high)");
COR_TAC->GetXaxis()->SetTitleColor(2);
COR_TAC->SetYTitle("Events");
COR_TAC->GetYaxis()->SetTitleColor(2);
COR_TAC->GetYaxis()->SetTitleOffset(1.2);
TF1* myfit = new TF1("myfit","gaus",fitmin3,fitmax3);
myfit->SetParName(0,"Norm");
myfit->SetParName(1,"Mean");
myfit->SetParName(2,"Sigma");
COR_TAC->Draw(); // Draw the 1D histogram
COR_TAC->Fit("myfit","R"); // use this to fit over a range and comment out previous

MyC1->cd(2); // pad 1
SLOPE->SetXTitle("TOF1-low - TOF1-high");
SLOPE->GetXaxis()->SetTitleColor(2);
SLOPE->SetYTitle("Events");
SLOPE->GetYaxis()->SetTitleColor(2);
SLOPE->GetYaxis()->SetTitleOffset(1.2);
TF1* myfit = new TF1("myfit","gaus",fitmin2,fitmax2);
myfit->SetParName(0,"Norm");
myfit->SetParName(1,"Mean");
myfit->SetParName(2,"Sigma");
SLOPE->Draw(); // Draw the 1D histogram
SLOPE->Fit("myfit","R"); // use this to fit over a range and comment out previous

MyC1->cd(3); // pad 2
TACvsSLOPE->SetStats(kFALSE);
TACvsSLOPE->SetXTitle("TOF1-low - TOF1-high");
TACvsSLOPE->GetXaxis()->SetTitleColor(2);
TACvsSLOPE->GetYTitle("TOF1-low - TOF2-low");
TACvsSLOPE->GetYaxis()->SetTitleColor(2);
TACvsSLOPE->GetYaxis()->SetTitleOffset(1.2);
TACvsSLOPE->Draw("SCAT"); // Draw the 2D histogram as a scatter plot

TCanvas *MyC2 = new TCanvas("MyC2","Canvas",300,10,1200,800); // Create a canvas for our graphs
MyC2->Divide(2,2); // Divide the canvas into two pads

MyC2->cd(3); // pad 2
PROFILE->SetXTitle("TOF1-low - TOF1-high");
PROFILE->GetXaxis()->SetTitleColor(2);
PROFILE->GetYTitle("TOF1-low - TOF2-low");
PROFILE->GetYaxis()->SetTitleColor(2);
PROFILE->GetYaxis()->SetTitleOffset(1.2);
PROFILE->Draw();

MyC2->cd(2); // pad 2
CTACvsSLOPE->SetStats(kFALSE);
CTACvsSLOPE->SetXTitle("TOF1-low - TOF1-high");
CTACvsSLOPE->GetXaxis()->SetTitleColor(2);
CTACvsSLOPE->GetYTitle("TOF1-low - TOF2-low");
CTACvsSLOPE->GetYaxis()->SetTitleColor(2);
CTACvsSLOPE->GetYaxis()->SetTitleOffset(1.2);
CTACvsSLOPE->Draw("SCAT"); // Draw the 2D histogram as a scatter plot

MyC2->cd(4); // pad 2
CPROFILE->SetXTitle("TOF1-low - TOF1-high");
CPROFILE->GetXaxis()->SetTitleColor(2);
CPROFILE->GetYTitle("TOF1-low - TOF2-low");
CPROFILE->GetYaxis()->SetTitleColor(2);
CPROFILE->GetYaxis()->SetTitleOffset(1.2);
CPROFILE->Draw();

MyC2->cd(1); // pad 2
TACvsSLOPE->SetStats(kFALSE);
TACvsSLOPE->SetTitle("TOF1-low - TOF1-high");
TACvsSLOPE->GetXaxis()->SetTitle("TOF1-low - TOF2-low");
TACvsSLOPE->GetYaxis()->SetTitle("TOF1-low - TOF2-low");
TACvsSLOPE->GetYaxis()->SetTitleColor(2);
TACvsSLOPE->Draw("SCAT"); // Draw the 2D histogram as a scatter plot

void treeHist()
{
    extern TStyle* gStyle;
    int fitmin1 = 1760;
    int fitmax1 = 1778;
    int fitmin2 = 1454;
    int fitmax2 = 1490;

    TFile *f = new TFile("test.root"); // Open the root file
    TAC = (TH1F*)f->Get("h1;1"); // Get the 1D histogram
    EVENTS = (TH2F*)f->Get("h3;1"); // Get the 2D histogram
    SLOPE = (TH1F*)f->Get("h2;1"); // Get the 1D histogram
    TACvsSLOPE = (TH2F*)f->Get("h4;1"); // Get the 2D histogram
    PROFILE = (TProfile*)f->Get("hprof;1");

    //**************************
    // ROOT Plotting Options
    //**************************
    gStyle->SetOptStat(2211);
    gStyle->SetOptFit(11);
    gStyle->SetFuncColor(1);
    gStyle->SetFrameFillColor(10);
    //gStyle->SetHistFillColor(3);
    gStyle->SetLabelSize(0.03,"XYZ");
    gStyle->SetStatColor(0);
    gStyle->SetStatFontSize(0.03);
    gStyle->SetTitleColor(2);
    gStyle->SetTitleW(0.5);
    //gStyle->SetMarkerColor(6);
    //gStyle->SetMarkerSize(0.25);
    //gStyle->SetMarkerStyle(8);
    gStyle->SetPaperSize(20,20);

    TCanvas *MyC1 = new TCanvas("MyC1","Canvas",600,800); // Create a canvas for our graphs
    MyC1->Divide(1,2); // Divide the canvas into two pads

    TAC->GetXTitle("MCP Timing Resolution            ADC Counts");
    TAC->GetXaxis()->SetTitle("MCP Timing Resolution");
    TAC->GetYTitle("Events");
    TAC->GetYaxis()->SetTitleOffset(1.2);
    TF1* myfit = new TF1("myfit","gaus",fitmin1,fitmax1);
    myfit->SetParName(0,"Norm");
    myfit->SetParName(1,"Mean");
    myfit->SetParName(2,"Sigma");
    // myfit->SetParameter(1, mean);
    // myfit->SetParameter(2, rms);
    TAC->Draw(); // Draw the 1D histogram
    TAC->Fit("myfit",R); // use this to fit over a range and comment out previous

    EVENTS->GetXTitle("MCP Drift            Event Number");
    EVENTS->GetXaxis()->SetTitle("MCP Drift");
    EVENTS->GetYTitle("ADC Counts");
    EVENTS->GetYaxis()->SetTitle OFFSET(1.2);
    EVENTS->Draw("SCAT"); // Draw the 2D histogram as a scatter plot
}

TCanvas *MyC2 = new TCanvas("MyC2","Canvas",610,0,600,800); // Create a canvas for our graphs
MyC2->Divide(1,2); // Divide the canvas into two pads

MyC2->cd(1); // pad 1
SLOPE->SetXTitle("MCP Slope ADC Counts");
SLOPE->GetYaxis()->SetTitleColor(2);
SLOPE->SetYTitle("Events");
SLOPE->GetYaxis()->SetTitleColor(2);
SLOPE->GetYaxis()->SetTitleOffset(1.2);
TF1* myfit = new TF1("myfit","gaus",fitmin2,fitmax2);
myfit->SetParName(0,"Norm");
myfit->SetParName(1,"Mean");
myfit->SetParName(2,"Sigma");
// myfit->SetParameter(1, mean);
// myfit->SetParameter(2, rms);
SLOPE->Draw(); // Draw the 1D histogram
// SLOPE->Fit("gaus"); // use this to fit over a range and comment out previous

MyC2->cd(2); // pad 2
TACvsSLOPE->SetStats(kFALSE);
TACvsSLOPE->SetXTitle("MCP TAC vs SLOPE TAC");
TACvsSLOPE->GetYaxis()->SetTitleColor(2);
TACvsSLOPE->SetYTitle("SLOPE");
TACvsSLOPE->GetYaxis()->SetTitleColor(2);
TACvsSLOPE->GetYaxis()->SetTitleOffset(1.2);
TACvsSLOPE->Draw("SCAT"); // Draw the 2D histogram as a scatter plot

/*

TCanvas *MyC3 = new TCanvas("MyC3","Canvas",300,200,600,400); // Create a canvas for our graphs
PROFILE->SetTitle("MCP TAC vs SLOPE Profile TAC");
PROFILE->GetXaxis()->SetTitleColor(2);
PROFILE->SetYTitle("SLOPE");
PROFILE->GetXaxis()->SetTitleColor(2);
PROFILE->SetYTitle("SLOPE");
PROFILE->GetXaxis()->SetTitleOffset(1.2);
PROFILE->Draw();
*/

void tree()
{
  treeFill();
treeCorrected();
}
Ortec info about the 9327 amplifier gain factors (got it via Camden):
- 32dB +/- 4dB in high gain mode
- 20dB +/- 2dB in low gain mode

Burle information about the grounding:

Dec. 3, 2007

Jerry,

I've attached a picture of the ground plane board. This board sits directly against the back of the anode ceramic and the 64 anode pins go through the holes. Nearly the entire surface of the board is metalized and grounded. The anode ceramic is 1.5mm thick so this is the distance between the ground plane and the metalized anode pads inside the tube.

Best regards,

-Scott

S/N 7300714:

Scott,

any chance to get a drawing of those ground planes so I can think about them a bit better? I would appreciate.

Thanks, Jerry

Quoting "Moulzolf, Scott" <s.moulzolf@usa.photonis.com>:

Jerry,

Your 64-anode Planacon with serial number 7300714 has a ground plane board attached to the back of the tube. The other tube (11180401) does not. Our 85013 product has the ground plane as a standard feature.

The 1024 anode tubes that we have supplied to Henry have a similar anode as those that you have tested. The anode plate on these tubes is just a simple land-grid-array with no intrinsic ground plane - the ground reference is left up to the customer to add externally.

Best regards, Scott

>> Hello Scott,
>> sorry to hear that you are leaving Burle. It is always a loss if a hardware expert leaves. I hope the void can be filled.
>> Your numbers match numbers of my tubes, so they are indeed 10 micron tubes. One last question. Do you provide now a more complex anode with ground close to pads to all your tubes, or it was used only in Henry’s tube?
>> Regards, Jerry
>>
>> Quoting "Moulzolf, Scott" <s.moulzolf@usa.photonis.com>:
>>
>
It's good to hear from you and I hope that all is well.

According to my records, the tubes that you refer to have 10um MCPs. To confirm, they should have the following serial numbers: 11180401, 7300714

I'm confused about the geometry of the 85011-501-P01 tube. I think it is of the improved open-area-ratio type, but we hadn't determined the new nomenclature before we sent it to you. Could you take a picture of the tube and send it to me so that I can provide you with the correct information?

FYI: I have decided to leave Burle and pursue a new job. My last day will be Dec 7th, after which you should refer questions to Paul Hink. I have had an excellent Senior Technician working with me for a couple of years now and he is very capable of processing the standard Planacon product and has done work on many customized Planacons. It has been a real pleasure to collaborate with you over the years and I enjoyed meeting you at the IEEE meeting and at SLAC.

Best regards, Scott

I am writing up a paper about my results and want to make sure that I understand differences between two tubes (85013-501 and 85011-501-001), which I was using. I am assuming that they are both 10 micron hole tubes. What are the internal differences apart from the resistor chain arrangement?

Thanks, Je

A circuit with Jeff’s new QTNT module:

Jeff’s price of 4-channel QTNT unit: $996/unit (+$100 for accessible test points, +$250 for a possibility to cancel it if it does not work).

Wiggles may cause afterpulses:
However, one should be able to tune the QTNT threshold high enough until the afterpulses disappear.

**Chicago workshop**

Based on discussion with P. Hink: The grounding in the 85013 series MCP-PMTs

- The getter is heat activated (no external leads)
Next two tubes

- Starting parameters, which Burle/Photonis is willing to try next:
  - 10 μm dia. hole MCP
  - 7 mm quartz drop face plate window - will be the radiator as well
  - 0.10" anode-to-MCP distance (this still allows a placement of a getter);
    oldest tube was 0.2", newer improved “open arc ratio” tube is 0.14”
  - 0.03” (864 microns) cathode-to-MCP distance; currently it is 5-6 mm ?
  - 64 pads, 6x6 mm.

A modular structure for future photon detectors?

- Manufacturer would come up with a modular detector vacuum containers
- Depending on “wishes” of a customer, they would drop in into a standard support structure inserts with MCPs, which would form a coaxial structure
- A schematic description:

- A size of the vacuum vessel is variable
- It seems to me that somebody should think about this…

- This is the way to go.
Run 383, original 1st resistor chain, TOF #1: 2.22kV, TOF 2: 1.88kV, no splitter, both CFDs have --10mV arming th., and +5mV walk th., PiLas at 18%, 10Hz (adjusted to get the same amplitude as in 268), internal trigger. Both 9327’s have amplifier gains set to low

- From some reason the response of two counters is not the same as before => reduce HV on TOF1 to 2.22kV from 2.27kV. Try to tune the x-y stage, but it does not help.

400ps/div, 10mV/div, 9327 CFD amp. monitor outputs from TOF1 (yellow) & TOF2 (blue), 1 & 2 Mylar att.

9327 CFD amplifier monitor output + 6dB + Hamamatsu Amplifier, TOF2, 1 & 2 Mylar att.,
400ps/div, 200mV/div

~1.4ns

~2.5ns

Peak ratio (blue) ~ 44/12 ~ 3.6 !?!
Expect ~2.3 (log book 3, page 75)
Check the Mylar calibration:
1) MCP-PMT without an amplifier, log book 3, page 75:

<table>
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<th>Attenuator</th>
<th>Amplitude [mV]</th>
<th>Ratio per Mylar sheet</th>
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<tbody>
<tr>
<td>0</td>
<td>760</td>
<td>1.490196078</td>
</tr>
<tr>
<td>1</td>
<td>510</td>
<td>1.821428571</td>
</tr>
<tr>
<td>2</td>
<td>280</td>
<td>2.333333333</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>2.5</td>
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<tr>
<td>4</td>
<td>48</td>
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<tr>
<td>5</td>
<td>14</td>
<td>2.916666667</td>
</tr>
<tr>
<td>6</td>
<td>4.8</td>
<td>1.92</td>
</tr>
<tr>
<td>7</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

Average: 2.344313725
(Compares well with my earlier estimate of 2.4)

2) Run 384, Repeat with a Si diode:
   a) Thick Mylar sheets:
      250ps/div, 20mV/div, 0 & 1 thick Mylar att.
      250ps/div, 20mV/div, 1 & 2 thick Mylar att.
      250ps/div, 2mV/div, 2 & 3 thick Mylar att.
      250ps/div, 2mV/div, 3 & 4 thick Mylar att.
b) Thin Mylar sheets:
250ps/div, 20mV/div, 0 & 1 & 2 thin Mylar att.

<table>
<thead>
<tr>
<th>Thick Mylar att</th>
<th>Amplitude [mV]</th>
<th>Ratio</th>
<th>Scope scale</th>
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<tbody>
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<td>90</td>
<td>4.090909091</td>
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<td>1</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>27.5</td>
<td>3.666666667</td>
<td>5 mV/div scale</td>
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<tr>
<td>2</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7.3</td>
<td>3.041666667</td>
<td>2 mV/div scale</td>
</tr>
<tr>
<td>3</td>
<td>2.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average:** 3.599747475

(Earlier estimate from the trailer setup: 2.34 and it agrees with the run 383 result)

<table>
<thead>
<tr>
<th>Thin Mylar att</th>
<th>Amplitude [mV]</th>
<th>Ratio</th>
<th>Scope scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>92</td>
<td>1.210526316</td>
<td>20 mV/div scale</td>
</tr>
<tr>
<td>1</td>
<td>76</td>
<td>1.333333333</td>
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</tr>
<tr>
<td>2</td>
<td>57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average:** 1.271929825

(Earlier estimate from the trailer setup: 1.095)
With the new calibration some plots have changed:

![Graph 1](image1)

![Graph 2](image2)

![Graph 3](image3)