DIRC R&D effort on the MCP-PMTs
(Log book #2)

J. Va’vra
Run 15 – **MCP-3 with Gholam’s old CFD (50mV thresh.)**: J.V., 3.1.2004

Files: mcp-3d_Gholam.dat, 20390 triggers, 62.5 µm dia. multi-mode fiber, PiLas laser diode at ~8.8%, 1kHz internal trigger, New Elantec EL2075C amplifier (Gcharge ~ 400x, Gvoltage ~ 130x).
Gholam’s old CFD with 50mV threshold and 1ns delay cable, The circuit has been fixed with a wrong value of resistor, after the module fell, and as a result the circuit was functioning as a simple leading edge discriminator, Probability of a hit ~10%, 24 psec/count TDC.

**Input to Gholam’s CFD:**
50mV/div, 1ns/div, Trigger: TDC start (from PiLas laser diode trigger)

![Graph showing Time vs. Intensity](image)

σ ~ 267 ps
Run 16 – **MCP-3 with Gholam’s old CFD (30mV thresh.):** J.V., 3.1.2004

Files: mcp-3d_Gholam.dat, 53250 triggers, MCP at \(-2.4\)kV; 
62.5 \(\mu\)m dia. multi-mode fiber, PiLas laser diode at \(~10.6\)%, 1kHz internal trigger, 
New Elantec EL2075C amplifier (\(G_{\text{charge}} \approx 400\times\), \(G_{\text{voltage}} \approx 130\times\)).

Gholam’s old CFD with 30mV threshold and 1ns delay cable, 
The circuit has been fixed with a wrong value of resistor, after the module fell, and as a result the circuit 
was functioning as a simple leading edge discriminator, 
Probability of a hit \(~9.1\)%, 24 psec/count TDC.

**Input to Gholam’s CFD:**

50mV/div, 1ns/div, Trigger: TDC start (PiLas laser diode trigger)

\(\sigma \approx 202\) ps 
& 
390 ps
Run 17 – **MCP-3 with Phillips CFD (30mV thresh.)**:  
J.V., 3.2.2004

Files: mcp-3e_Philips.dat, 63221 triggers, MCP at ~2.4kV,  
62.5 µm dia. multi-mode fiber, PiLas laser diode at ~8.8%, 1kHz internal trigger,  
New Elantec EL2075C amplifier (G\text{charge} ~ 400x, G\text{Voltage} ~ 130x).  
Phillips CFD with 30mV threshold and 1ns delay cable, Too low – picking up a noise (outside the peak region), Probability of a hit <10%, 24 psec/count TDC.

**Input to Phillips CFD together with the TDC start pulse:**  
50mV/div, 1ns/div, Trigger: TDC start (PiLas laser diode trigger)

**Fit: G1+G2+P2 (1 bin = 1 count):**

**Fit: G1+G2+P2 (1 bin = 80 psec):**

**Fit: G1+G2+P2 (1 bin = 25 psec):**
Run 18 – **MCP-3 with Phillips CFD (50mV thresh.):**

J.V., 3.2.2004

Files: mcp-3f_Philips.dat, 63221 triggers, MCP at –2.4kV, 62.5 µm dia. multi-mode fiber, PiLas laser diode at ~8.8%, 1kHz internal trigger, New Elantec EL2075C amplifier (G\text{charge} ~ 400x, G\text{voltage} ~ 130x). Phillips CFD with 50mV threshold and 1ns delay cable, Probability of a hit ~6.1%, 24 psec/count TDC.

Fit: G1+G2+P2 (1 bin = 1 count):

\[ \sigma \approx 105 \text{ ps} \]

As one increase the threshold and duration of run (?) the resolution gets worse.

Fit: G1+G2+P2 (1 bin = 80 psec):

\[ \sigma \approx 388 \text{ ps} \]
Run 19 – **MCP-3 with the new CFD (50mV thresh.):**

Files: mcp3j_new_cfd.dat, 74119 triggers, MCP at ~2.4kV,
62.5 µm dia. multi-mode fiber, PiLas laser diode at ~9.8%, 1kHz internal trigger,
The new Elantec EL2075C amplifier (G\text{charge} \sim 400x, G\text{Voltage} \sim 130x),
Gholam’s new CFD board with 50mV threshold and 1ns delay cable. **Resistor error on the board fixed !!!!**
Probability of a hit ~7.9%, 24 psec/count TDC.

**Input to and output from the Gholam’s new CFD:**

<table>
<thead>
<tr>
<th>50mV/div, 1ns/div, CFD input &amp; TDC start</th>
<th>50mV/div, 1ns/div, CFD output &amp; TDC start</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Input" /></td>
<td><img src="image2.png" alt="Output" /></td>
</tr>
</tbody>
</table>

Fit: G1+G2+P2 (1 bin = 1 TDC count)

\[
\sigma \sim 105 \text{ ps}
\]

Fit: G1+G2+P2 (1 bin = 25 psec):

\[
\sigma \sim 108 \text{ ps}
\]

Fit: G1+G2+G3 (1 bin = 25 psec):

\[
\sigma \sim 94 \text{ ps} \quad \text{&} \quad 239 \text{ ps}
\]

3-Gaussian fit not much different if one uses the correct binning
For comparison, I show the old way of fitting with coarse binning:

Fit: G1+G2+P2 (1 bin = 80 psec):

\[ \sigma \sim 106 \text{ ps} \]

Fit: G1+G2+G3 (1 bin = 80 psec):

\[ \sigma \sim 50 \text{ ps} \& 144 \text{ ps} \]

- A fit with a function G1+G2+P2 is not doing “visually” as well as with a function G1+G2+G3.
- Fitting with coarse binning and 3 gaussian function is somewhat dangerous, if there is a spike in one channel. A fit with G1 + G2 + P2 does not seem to suffer that much from this problem. In the past, I have always used the “G1 +G2 +P2” fit function. But, will check our published data.

Run 20 – Repeat conditions of run 19:

Files: mcp3j1_new_cfd.dat, 68901 triggers, MCP at –2.4kV,
Gholam’s new CFD board with 50mV threshold and 1ns delay cable,
Probability of a hit ~16.1% (hot !!), 24 psec/count TDC.

Fit: G1+G2+P2 (1 bin = 1 TDC count)

\[ \sigma \sim 107 \text{ ps} \]

Fit: G1+G2+P2 (1 bin = 25 psec):

\[ \sigma \sim 96 \text{ ps} \]

- We seem to get ~100psec resolution with MCP #3 running at –2.4 kV. Similar result to that of the Phillips CFD.
Run 21 – MCP-3 with the new CFD:

File: mcp3k_cfd_adc.dat, MCP3 at ~2.2 kV because it is tripping.
62.5 μm dia. multi-mode fiber, PrLs laser diode at ~9.8%, 1kHz internal trigger.
The new Elantec EL2075C amplifier ($G_{\text{charge}} \sim 400x$, $G_{\text{Voltage}} \sim 130x$).
Gholam’s new CFD board with 50mV threshold and 1ns delay cable.
Probability of a hit (a) ~6.1%, and (b) ~5.8%, 24 psec/count (TDC).

a) TDC: File: mcp3k_cfd_adc.dat: 
Fit (TDC): G1+G2+P2 (1 bin = 1 TDC count)

b) TDC: File: mcp3k1_cfd_adc.dat: 
Fit (TDC): G1+G2+P2 (1 bin = 1 TDC count)
Run 22a&b – MCP3 with TDC&ADC in Common Stop:  
J.V., 3.25.2004

Files: test9_com_stop.dat, test10_com_stop.dat (add 8 ns)
MCP3 at −2.17 kV because it is tripping, LRS 2249A ADC in COMMON STOP, 998 µsec VETO for 1kHz trigger rate, 12 ns ADC gate, 62.5 µm dia. multi-mode fiber, PiLas laser diode at ~9.8%, 1kHz internal trigger, the new Elantec EL2075C amplifier (G_{charge} ~ 400x, G_{Voltage} ~ 130x).
Gholam’s new CFD board with 50mV threshold and 1ns delay cable.
Probability of a hit ~9.2%, 24 psec/count (TDC).

A lot of problems:

a) **Trivial**: cold solders, wrong resistor values, wrong ADC (LRS ADC 2249W is AC coupled; need to use a DC-couples one, i.e., 2249A – however, this one is only a 10 bit ADC !!!), not properly working gate generator, 60 Hz noise, etc.

b) **Less trivial**: we found that it is necessary to block the PMT pulses by a VETO, otherwise we upset ADC input level; this works in the COMMON STOP mode, however, it does not work in the COMMON START mode – would need more work)

Verify by a scope that the circuit works:
a) TDC: File: test9_com_stop.dat:
Fit (TDC): G1+G2+P2 (1 bin = 1 TDC count)

σ ~ 127 ps

b) TDC: File: test9_com_stop.dat:
Fit (TDC): G1+G2+P2 (1 TDC count = 24 ps)

σ ~ 127 ps

a) ADC: File: test9_com_stop.dat:
Fit (TDC): G1+G2+P2 (1 bin = 1 ADC count)

b) ADC: File: test10_com_stop.dat:
Fit (ADC): G1+G2+P2 (1 bin = 1 ADC count)

Add 8 ns

- Calibration: 1 ADC count = 1.562ns !!! => the resolution is bad
## Summary of scans:

<table>
<thead>
<tr>
<th>MCP #</th>
<th>Pads</th>
<th>Burle S/N</th>
<th>HV [kV]</th>
<th>Required red laser power to get a 10% prob. of a hit [%]</th>
<th>Response (white) [uA/Lm] (Burle)</th>
<th>Response (blue) [uA/bLm] (Burle)</th>
<th>Gain @ a voltage specified (Burle)</th>
<th>P/V Ratio a voltage specified (Burle)</th>
<th>Value of mean/RMS for the best 90% of the efficiency points</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2x2</td>
<td>08290202</td>
<td>-2.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No scan</td>
</tr>
<tr>
<td>2</td>
<td>8x8</td>
<td>01150302</td>
<td>-2.3</td>
<td>28</td>
<td>6.3</td>
<td>3.39x10^3</td>
<td>3.4</td>
<td>6.79</td>
<td>Reasonably uniform, low efficiency</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8x8</td>
<td>05220304</td>
<td>-2.3</td>
<td>53</td>
<td>8.3</td>
<td>6.96x10^1</td>
<td>2.8</td>
<td>17.4</td>
<td>Our reference: very uniform, 60% of the Photonis PMT efficiency.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8x8</td>
<td>09130305</td>
<td>-2.3</td>
<td>47</td>
<td>38</td>
<td>6.3</td>
<td>3.13x10^2</td>
<td>1.5</td>
<td>Low efficiency</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8x8</td>
<td>07030301</td>
<td>-2.3</td>
<td>48</td>
<td>45</td>
<td>6.7</td>
<td>3.48x10^2</td>
<td>1.8</td>
<td>Higher efficiency around the edges, low efficiency</td>
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<td>09050302</td>
<td>-2.3</td>
<td>48</td>
<td>41</td>
<td>5.2</td>
<td>2.18x10^2</td>
<td>1.4</td>
<td>Non uniform, low efficiency</td>
<td></td>
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<td>7</td>
<td>8x8</td>
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<td>-2.3</td>
<td>48</td>
<td>36</td>
<td>6.3</td>
<td>1.91x10^3</td>
<td>1.6</td>
<td>Relatively uniform, low eff.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8x8</td>
<td>09130303</td>
<td>-2.3</td>
<td>49</td>
<td>38</td>
<td>6.3</td>
<td>1.91x10^3</td>
<td>1.6</td>
<td>Relatively uniform, low eff.</td>
<td></td>
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<tr>
<td>9</td>
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<td>04290301</td>
<td>-2.3</td>
<td>47</td>
<td>?</td>
<td>?</td>
<td>2.78x10^1</td>
<td>1.1</td>
<td>2.33 Extremely non uniform; Returned</td>
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<tr>
<td>10</td>
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<td>12040301</td>
<td>-2.3</td>
<td>48</td>
<td>50</td>
<td>7.8</td>
<td>4.6x10^2</td>
<td>4.2</td>
<td>5.15 This is a Burle replacement for the failed tube; very non uniform, especially near edges.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>8x8</td>
<td>09130301</td>
<td>-2.3</td>
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<td>37</td>
<td>6.1</td>
<td>2.52x10^2</td>
<td>3.3</td>
<td>9.02 Relatively uniform, low eff.</td>
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<td>-2.3</td>
<td>48</td>
<td>29</td>
<td>4.3</td>
<td>4.0x10^3</td>
<td>1.3</td>
<td>5.47 Very non uniform, low eff. Returned</td>
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</tr>
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<td>8x8</td>
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<td>-2.3</td>
<td>44</td>
<td>54</td>
<td>6.2</td>
<td>4.26x10^2</td>
<td>2.1</td>
<td>1.43 Extremely non uniform, two dead pads; Returned</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>8x8</td>
<td>12110303</td>
<td>-2.3</td>
<td>44</td>
<td>55</td>
<td>7.9</td>
<td>3.0x10^3</td>
<td>1.5</td>
<td>Reference #4 for us</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>8x8</td>
<td>12110302</td>
<td>-2.3</td>
<td>44</td>
<td>55</td>
<td>7.9</td>
<td>2.5x10^3</td>
<td>1.5</td>
<td>Reference #3 for us</td>
<td></td>
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<td>16</td>
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<td>02010410</td>
<td>-2.66</td>
<td>62</td>
<td>8.5</td>
<td>4.8x10^3</td>
<td>1.5</td>
<td>Reference #2 for us</td>
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<td></td>
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<tr>
<td>DIRC 1&quot; dia</td>
<td>9125B</td>
<td>65 typ.</td>
<td>11 typ.</td>
<td>2.0</td>
<td>Reference #1 for us</td>
<td></td>
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<tr>
<td>Photonis 2&quot; dia</td>
<td>XP2262B</td>
<td>70 typ.</td>
<td>11.2 typ.</td>
<td>3.0</td>
<td>Reference #2 for us</td>
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<tr>
<td>#1</td>
<td>8x8</td>
<td>H8500</td>
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<td>53.9</td>
<td>7.4</td>
<td>0.8x10^6</td>
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<td>1-st Hamamatsu MAPMT</td>
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<tr>
<td>#2</td>
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<td>H8500</td>
<td>-1.0</td>
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<td>7.9</td>
<td>1.57x10^6</td>
<td>1.5</td>
<td>2-nd Hamamatsu MAPMT</td>
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<td>#4</td>
<td>8x8</td>
<td>H8500</td>
<td>-1.0</td>
<td>64.2</td>
<td>8.86</td>
<td>1.46x10^6</td>
<td>1.5</td>
<td>New Hamamatsu MAPMT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition we had these tubes breaking down:

- MCP-PMT, S/N 09130306, breaking down at –2.2kV, returned already. This tube was replaced with a new one, called MCP 10.
Typical conditions during the scan of the latest MCP-PMTs

- People doing it: J.Schwiening, T. Hadig, J.Va’vra
- Elantec EL2075C amplifier (charge gain: ~400, voltage gain: ~130),
- LeCroy 4413 discriminators with 100mV threshold, LeCroy TDCs with 0.5ns/count,
- MCP-PMT at –2.4kV, chain current ~300uA,
- X-step: 0.1mm, Y-step: 1mm, Events/point: 20000, Probability of a hit: ~10-15%,
- The normalization is done to 2” dia. XP 2262B Photonis tube, i.e., Burle tube is ~65% of its efficiency at 635nm (the end of bandwidth). The DIRC tube efficiency is about 60% of the Photonis tube.

1. MCP #2 (S/N 01150302)
   (very uniform, 60% of the Photonis PMT efficiency, if one believes the normalization at 635nm)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:

2. MCP #3 (S/N 05220203) - the best tube so far
   (very uniform, 60% of the Photonis PMT efficiency, if one believes the normalization at 635nm)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:
A method to judge the non-uniformity of the response:

- **Value of mean/RMS for the best 90% of the efficiency points:**
  - Take all measurements of the efficiency at 635nm relative to the Photonis PMT as long as the laser was nominally on an MCP pad (52x52mm, 520*52 measurements) and fill them into a one-dimensional histogram.
  - That is plotted in the histogram on the left side.
  - Next I find the efficiency value that contains the highest 80% and the highest 90% of all measurements. (The 80% value is given at the top of the page.)
  - The measurements that belong to the 90% highest values are then put into a new histogram that is plotted on the right side. For those 90% highest points I take the mean and RMS from the histogram and calculate $x$ equals to mean divided by RMS.

3. **MCP #4 (S/N 09130305)**
   - (reasonably uniform, but lower overall efficiency, if one believes the normalization at 635nm)

   a) Normalize to best spot in the tube:

   b) Normalize to Photonis PMT at 635nm:
      - (normalization point taken from the MCP#3 run)
4. **MCP #5 (S/N 07030301)**

(higher efficiency around the edges, lower overall efficiency)

a) **Normalize to best spot in the tube:**

b) **Normalize to Photonis PMT at 635nm:**

(normalization point taken from the MCP#3 run)
5. MCP #6 (S/N 09050302)  
(higher efficiency around the edges, lower overall efficiency)

a) Normalize to best spot in the tube:  
b) Normalize to Photonis PMT at 635nm:  
(normalization point taken from the MCP#3 run)

6. MCP #7 (S/N 08220302)  
(Non uniform, lower overall efficiency)

a) Normalize to best spot in the tube:  
b) Normalize to Photonis PMT at 635nm:  
(normalization point taken from the MCP#3 run)
7. MCP #8 (S/N 09130303)
(relatively uniform, lower overall efficiency)

a) Normalize to best spot in the tube:
b) Normalize to Photonis PMT at 635nm:
(normalization point taken from the MCP#3 run)

8. MCP #9 (S/N 04290301)
(extremely nonuniform)

a) Normalize to best spot in the tube:
b) Normalize to Photonis PMT at 635nm:
9. MCP #10 (S/N 12040301)
(nonuniform, especially along the edges, low efficiency)

a) Normalize to best spot in the tube;  
b) Normalize to Photonis PMT at 635nm:
10. MCP #11 (S/N 09130301)
   (relatively uniform)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:

11. MCP #12 (S/N 05070305)
   (very nonuniform)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:
12. MCP #13 (S/N 04290302) 
(exremely nonuniform, two dead pads)

a) Normalize to best spot in the tube: 

- Two dead pads inside MCP !! The amplifier and the connector are OK.

b) Normalize to Photonis PMT at 635nm:

We definitely would like to return these MCPs:
- MCP #13 (two dead pads, very non-uniform),
- MCP #12 (very non-uniform, low efficiency),
- MCP #9 (very non-uniform, low efficiency relative to Photonis),

These tubes have low efficiency relative to the Photonis PMT and may be considered for the replacement (they have low efficiency, but they are more uniform though):
- MCP #10, MCP #8, MCP #6, MCP #5 (has already RMA AW605531) and MCP #4.
Run 23 – Russian MCPs: J.V., 3.30.2004

Input from S. Kononov:

Cathode type:
Tri-alkali photocathode (extends the response to red region a bit),

Geometry:
Photocathode-to-MCP distance: 0.1-0.2mm (possible deviation from parallelism 0.05mm),
A single MCP thickness: 0.45mm, gap between two MCPs: 0.1mm,
MCP-to-anode distance: 0.2-0.4mm (deviation 0.05mm),

Cathode-MCP voltage:
The initial guess from Sergey was 200-600 Volts. Half way through the measurement a new limit of 400 Volts was suggested. The initial measurements exceeded this voltage. Collection efficiency of photoelectrons is determined by the voltage applied to photocathode-MCP gap. It saturates at voltages above 200V. We have chosen nominal voltage 300V for this stage. Also noise rate is strongly depends on the photocathode-MCP voltage. And some tubes that reveal too large noise rate (>100kHz at the level of 400V (+100 to the nominal) are considered to be waste and rejected. However some tubes happen to sustain even 700V showing still low noise. Until I inquired my colleagues, I didn’t know how much voltage we can apply for the particular tubes you have. Then I found out that for the both samples the maximum voltage is 400V. So the working range of photocathode-MCP voltage for the samples you have is from 200V to 400V.

Voltage across MCP:
Voltage applied to the micro-channel plates determines gain and it happens to affect noise rate too. According to our procedure we tune this voltage to achieve 10^6 still keeping the noise rate below 100kHz. We calibrate gain using a known capacity to generate certain amount of charge and feed it to the amplifier used and charge digitizer, then we compare this measurement with single photoelectron mean pulse height. Working values of voltages at MCP may vary from tube to tube, I do not know exactly what is the highest value we observed, but I think it is no more than 2600V.

Operating points (arrived half way through the measurement):
Working voltages according to Novosibirsk measurements:

<table>
<thead>
<tr>
<th>S/N</th>
<th>MCP voltage(10^6 gain)</th>
<th>Photocathode-MCP Voltage</th>
<th>Noise at 400V</th>
<th>MCP-Anode (not critical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1446</td>
<td>2160 V</td>
<td>200-400 V</td>
<td>95 kHz</td>
<td>~100 V</td>
</tr>
<tr>
<td>3548</td>
<td>2000 V</td>
<td>200-400 V</td>
<td>100 kHz</td>
<td>~100 V</td>
</tr>
</tbody>
</table>

Other parameters all these tests:
62.5 μm dia. multi-mode fiber, PiLas laser diode at 7-10%, 1kHz internal trigger,
Two Elantec EL2075C amplifiers in tandem (G_{V_{oltage}} ~ 10x10 ~ 100x).
Gholam’s old CFD with a 20 mV threshold and 1ns delay cable, 24 psec/count TDC.

a) Try initially recommended voltages (from Sergey):

<table>
<thead>
<tr>
<th>Last version of the voltage divider:</th>
<th>3.31.2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{oc} [V]</td>
<td>250 V</td>
</tr>
<tr>
<td>G_{v}</td>
<td>3.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R0 (source)</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
</tr>
<tr>
<td>R2</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
<td>2 V</td>
</tr>
<tr>
<td>R3 (source)</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
<td>0 V</td>
</tr>
<tr>
<td>Total [V]</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
<td>15.5 V</td>
</tr>
</tbody>
</table>

- For this setting, we are within the limits, which arrived from Novosibirsk later. I get only small pulses compared to the Burle MCP by a factor of 3-4.
MCP #1 (S/N 3548)  
20mV/div, 2ns/div, CFD input & TDC start

Smaller average gain than that of Burle MCP !!!

Notice a lot of after-pulses (Are they ions ?)

Catch one after-pulse (it often has a larger amplitude)

- CFD does not trigger reliably if pulses are small (20-30mV and a few ns long). This cause apparent inefficiency and too good timing resolution. Must increase voltage.

b) Increase voltage to –2.8kV:

- This exceeds the cathode-MCP voltage max rating by ~50 Volts (at this point I did not know).

Noise rate (after the CFD): ~48kHz
Take data under this condition. File: Russian-1_1.dat, 80000 triggers, Probability of a hit ~7.8%.
J.Va’vra, 2003-2004, the last entry 2.10. 2005

MCP #1 (S/N 3548)
20mV/div, 2ns/div, CFD input & TDC start

Fit: G1+G2+P2 (1 bin = 1 TDC count)
σ ~ 106 ps

File: Russian-1_2.dat, 80000 triggers, Probability of a hit ~6.3%.

- Time [ns]
  - σ ~ 106 ps
  - σ ~ 97 ps

2 ad version of the voltage divider:

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Voltage</th>
<th>R1</th>
<th>R2</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1 [ohms]</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>3.5</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td>E2 [ohms]</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>3.5</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td>E3 [ohms]</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>3.5</td>
<td>2.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- This exceeds the cathode-MCP voltage max rating by ~120 Volts (at this point I did not know).

Noise rate (after the CFD with a 20mV threshold): ~450kHz (after the voltage has been set) → 8.7 kHz (the end of run).
Take data under this condition. File: Russian-1_2.dat, 80000 triggers,
Probability of a hit ~6.3%.
MCP #1 (S/N 3548)
20mV/div, 2ns/div, CFD input & TDC start

Initial noise rate on the 10µsec/div scale (amp output)

Fit: G1+G2+P2 (1 bin = 1 TDC count)

\[ \sigma \sim 124 \text{ ps} \]

Fit: G1+G2+P2 (1 bin = 25 psec):

\[ \sigma \sim 124 \text{ ps} \]

- At this point the new instruction arrived from Novosibirsk not to exceed 400 Volts on cathode-MCP gap.

d) Make a new resistor chain to reduce the cathode-MCP voltage:

i) 

### 2-ad version of the voltage divider:

<table>
<thead>
<tr>
<th>Voltage Dividers</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value [V]</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistors</th>
<th>[Ohms]</th>
<th>Voltage [V]</th>
<th>[%]</th>
<th>[%]</th>
<th>[%]</th>
<th>TDC counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0 (hand)</td>
<td>25.83</td>
<td>2900</td>
<td>3.94</td>
<td>3.39</td>
<td>0.02</td>
<td>20-25</td>
</tr>
<tr>
<td>R1</td>
<td>25.83</td>
<td>1500</td>
<td>1.99</td>
<td>1.70</td>
<td>0.01</td>
<td>20-25</td>
</tr>
<tr>
<td>R2</td>
<td>25.83</td>
<td>750</td>
<td>0.99</td>
<td>0.85</td>
<td>0.00</td>
<td>20-25</td>
</tr>
<tr>
<td>R3</td>
<td>25.83</td>
<td>375</td>
<td>0.49</td>
<td>0.43</td>
<td>0.00</td>
<td>20-25</td>
</tr>
<tr>
<td>R4</td>
<td>25.83</td>
<td>187.5</td>
<td>0.05</td>
<td>0.04</td>
<td>0.00</td>
<td>20-25</td>
</tr>
<tr>
<td>Total Req</td>
<td>119.25</td>
<td>5250</td>
<td>6.94</td>
<td>5.78</td>
<td>0.02</td>
<td>20-25</td>
</tr>
</tbody>
</table>

Aim:
Want to achieve an average pulse height, which would be similar to that of Burle MCP, while keeping the cathode-MCP voltage within 300 V limit. After ~10 minutes, the tube trips and after that we have small pulses only again. When this starts happening, we get also a shift in timing. This means that the tube will not stand over-voltage across MCP.

Noise rate (after the CFD with a 20mv threshold): ~170kHz (after the voltage has been set).
ii) - See a bad timing resolution for this setting. Do not take data.

iii) - See only small pulse height for this setting.

Secondary ionic processes at this setting?
e) What about the second Russian MCP?:

i) MCP #2 (S/N 1446)
20mV/div, 2ns/div, CFD input & TDC start

<table>
<thead>
<tr>
<th>Resistors</th>
<th>[Ohms]</th>
<th>Voltages</th>
<th>[V]</th>
<th>dV</th>
<th>[V]</th>
<th>E</th>
<th>[V/cm]</th>
<th>100u/cm thickness [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0 (anode)</td>
<td>6.5</td>
<td>V-mcp_bot</td>
<td>105</td>
<td>94</td>
<td>105</td>
<td>1.06</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>10</td>
<td>V-mcp_top</td>
<td>222.2</td>
<td>212.2</td>
<td>212.2</td>
<td>21.2</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>V-mcp</td>
<td>2550</td>
<td>424</td>
<td>424</td>
<td>21.2</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>R3 (ground)</td>
<td>0</td>
<td>V-mcp supply</td>
<td>2550</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total R-chain</td>
<td></td>
<td></td>
<td>12.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Again, see only small pulse height for this setting, even though that we are within Novosibirsk’s specs.
- These pulses are smaller than Burle MCP pulses by a factor of 2-3.

ii) Add a new resistor divider:
- File: Russian-2_1
- PiLas laser diode at ~8% of power (a bit smaller compared to Burle because this MCP has a better QE near red).
- Probability to get a hit: ~12% (a bit hot compared to a usual setting)

<table>
<thead>
<tr>
<th>Resistors</th>
<th>[Ohms]</th>
<th>Voltages</th>
<th>[V]</th>
<th>dV</th>
<th>[V]</th>
<th>E</th>
<th>[V/cm]</th>
<th>100u/cm thickness [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0 (anode)</td>
<td>1</td>
<td>V-mcp_bot</td>
<td>112.2</td>
<td>112.2</td>
<td>112.2</td>
<td>1.12</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>20</td>
<td>V-mcp_top</td>
<td>3100</td>
<td>2875</td>
<td>2875</td>
<td>21.25</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>2.5</td>
<td>V-mcp</td>
<td>2650</td>
<td>261.9</td>
<td>261.9</td>
<td>14.1</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>R3 (ground)</td>
<td>0</td>
<td>V-mcp supply</td>
<td>2650</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total R-chain</td>
<td></td>
<td></td>
<td>23.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The new resistor chain is “cleaner” and has capacitors across R0, R1 and R3.
MCP #2 (S/N 1446)
20mV/div, 1.25ns/div, CFD input & TDC start

- Pulses are too small for a 20mV threshold to work reliably. Expect poor efficiency at this setting. Not enough gain for this choice of amplifier.

iii) Increase the voltage across anode-MCP gap:
- File: Russian-2_2
- PiLas at ~7.8% of power (a bit smaller compared to Burle because this MCP has a better QE near red).
- Probability to get a hit: ~12% (a bit hot compared to a usual setting)

**σ ~ 144 ps**
MCP #2 (S/N 1446)
20mV/div, 1.25ns/div, CFD input & TDC start

V_{ps} = -2.75 \text{kV}:

- Pulses are too small for Elantek amplifier (voltage gain 100x).
- A sign of after-pulses about 2-3 and 7-8ns later.
- Not good enough at present.

V_{ps} = -2.8 \text{kV}:

Run at V_{ps} = -2.9 \text{kV}:

\sigma \sim 132 \text{ ps}
Burle tube: **Vary MCP voltage, CFD threshold & delay**

e-mail a week ago from Burle:

Jerry,
All of the 85011 (64 anode) tubes that you have can be run at a max voltage of -2.6 kV. I don't know if you have any 85001 (4 anode) tubes, but they have a max voltage specification of -2.4 kV.

Scott

Run 24 – **MCP-3**

- 62.5 µm dia. multi-mode fiber, PiLas laser diode at ~9.4%, 1kHz internal trigger.
- New Elantec amplifier ($G_{\text{charge}} \sim 400x$, $G_{\text{Voltage}} \sim 130x$), “old” CFD made by Gholam.

Input to CFD together with the TDC start pulse:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Dividers</th>
<th>Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 kV</td>
<td>50mV/div, 1ns/div</td>
<td>Trigger: TDC start</td>
</tr>
<tr>
<td>2.2 kV</td>
<td>50mV/div, 1ns/div</td>
<td></td>
</tr>
<tr>
<td>2.3 kV</td>
<td>50mV/div, 1ns/div</td>
<td></td>
</tr>
<tr>
<td>2.4 kV</td>
<td>50mV/div, 1.25ns/div</td>
<td></td>
</tr>
<tr>
<td>2.5 kV</td>
<td>100mV/div, 1ns/div</td>
<td></td>
</tr>
<tr>
<td>2.6 kV</td>
<td>100mV/div, 1ns/div</td>
<td></td>
</tr>
</tbody>
</table>
- Vary MCP voltage, 30mV threshold, Pad #62 (however, some signal on pad #61, i.e., not completely centered), “old” CFD, Fit: G1+G2+P2 (1 bin = 1 count).

2.6kV, 8.8%, file: mcp3_2.6kV_30mV.dat

2.5kV, 10.3%, file: mcp3_2.5kV_30mV.dat

2.4kV, 10.3%, file: mcp3_2.4kV_30mV.dat

2.3kV, 7.1%, file: mcp3_2.3kV_30mV.dat

2.2kV, 6.7%, file: mcp3_2.2kV_30mV.dat

- Why the resolution at highest voltage is so bad?
- **Vary MCP voltage, 50mV** threshold, Pad #62 (however, some signal on pad #61, i.e., not completely centered), “old” CFD, Fit: G1+G2+P2 (1 bin = 1 count).

### 2.6kV, 7.7%, file: mcp3_2.6kV_50mV.dat

σ ~ 113 ps

### 2.5kV, 7.9%, file: mcp3_2.5kV_50mV.dat

σ ~ 120 ps

### 2.4kV, 6.5%, file: mcp3_2.4kV_50mV.dat

σ ~ 120 ps

### 2.3kV, file: mcp3_2.3kV_50mV.dat

σ ~ 148 ps

### MCP #3 Timing resolution

- Why the resolution at highest voltage is so bad?
Search for the explanation of a poor timing resolution:

- **Center the laser light on the center of Pad #62** (minimize the signal on pads 61 and 63)
- 50mV threshold, “old” CFD

2.5kV, 6.2%, file: mcp3_2.5kV_a.dat

\[\sigma \sim 123 \text{ ps}\]

- **Center the laser light between Pads #62 & 61** (share the charge), 50mV threshold, Pad 62

2.5kV, 5.5%, file: mcp3_2.5kV_b.dat

\[\sigma \sim 133 \text{ ps}\]

- **Increase PiLas power to 11%** (to get the same rate, put absorbers between the fiber and the laser head)
- 50mV threshold, center of Pad #62, “old” CFD.

2.5kV, 8.4%, file: mcp3_2.5kV_c.dat

\[\sigma \sim 89 \text{ ps}\]

**Eureka:**

We have to keep the Pilas laser above a certain power to get a good timing resolution.
- Vary MCP voltage, increase the Pilas power to 11% and add optical absorbers:
- 50mV threshold, center on Pad #62, “old” CFD.

- Clearly, the PiLas laser diode needs a minimum power to minimize its timing jitter.
- When I checked the Pilas laser timing with a fast APD, the PiLas power was set at 11.4%.
MCP#3 Pulses with PiLas at 11%:

Input to CFD together with the TDC start pulse:

2.2kV, 100mV/div, 1ns/div, Trigger: TDC start

2.3kV, 100mV/div, 1ns/div

2.4kV, 50mV/div, 1.25ns/div

2.5kV, 100mV/div, 1ns/div

2.6kV, 100mV/div, 1ns/div
- **Vary MCP voltage.** Increase the Pilas power to 16% and add optical absorbers.
- 50mV threshold, center on Pad #62, “old” CFD

**2.6kV, 12.2%, file: mcp3_2.6kV_16.dat**

- σ ~ 87 ps

**2.6kV, 12.2%, file: mcp3_2.6kV_16.dat**

- σ ~ 83 ps

**2.4kV, 11.1%, file: mcp3_2.4kV_16.dat**

- σ ~ 86 ps

**2.3kV, 10.4%, file: mcp3_2.3kV_16.dat**

- σ ~ 108 ps

**MCP #3 Timing resolution**

- Not much improvement by running at 16%. Running at ~11% power setting is sufficient.
- Not much improvement by running the tube above 2.4kV.
MCP#3 Pulses with PiLas at 16%:

Input to CFD together with the TDC start pulse:

2.2kV, 100mV/div, 1ns/div, Trigger: TDC start

2.3kV, 100mV/div, 1ns/div

2.4kV, 50mV/div, 1.25ns/div

2.5kV, 100mV/div, 1ns/div

2.6kV, 100mV/div, 1ns/div
- **Vary CFD delay cable.** 50mV th., center on Pad #62, Pilas power at 16%, “old” CFD:

- **0.7ns, 2.5kV, 12.2%, mcp3_2.5_16_5.dat**
  \[\sigma \sim 73 \text{ ps}\]

- **1.2ns, 2.5kV, 12.2%, mcp3_2.5_16_1.0.dat**
  \[\sigma \sim 81 \text{ ps}\]

- **1.8ns, 2.5kV, 11.4%, mcp3_2.5_16_1.5.dat**
  \[\sigma \sim 71 \text{ ps}\]

- **2.3ns, 2.5kV, 11.1%, mcp3_2.5_16_2.0.dat**
  \[\sigma \sim 73 \text{ ps}\]

- **2.9ns, 2.5kV, 11.4%, mcp3_2.5_16_1.5.dat**
  \[\sigma \sim 84 \text{ ps}\]

- **3.4ns, 2.5kV, 11.0%, mcp3_2.5_16_2.0.dat**
  \[\sigma \sim 81 \text{ ps}\]

- Assume that a LEMO union is 0.1ns, and the internal time offsets are 0.1+0.1ns.
- It seems that we want ~1.5ns, which is close to the pulse’s rise time.
- **Vary CFD delay cable**, 50mV th., center on Pad #62, Pilas power at 16%, “old” CFD:

<table>
<thead>
<tr>
<th>Time (ns)</th>
<th>Voltage (kV)</th>
<th>MCP (%)</th>
<th>File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>2.4</td>
<td>12.2</td>
<td>mcp3_2.4_16_5.dat</td>
</tr>
<tr>
<td>1.2</td>
<td>2.4</td>
<td>12.2</td>
<td>mcp3_2.4_16_10.dat</td>
</tr>
<tr>
<td>1.8</td>
<td>2.4</td>
<td>11.4</td>
<td>mcp3_2.4_16_15.dat</td>
</tr>
<tr>
<td>2.3</td>
<td>2.4</td>
<td>11.1</td>
<td>mcp3_2.4_16_20.dat</td>
</tr>
<tr>
<td>2.9</td>
<td>2.4</td>
<td>11.4</td>
<td>mcp3_2.4_16_15.dat</td>
</tr>
<tr>
<td>3.4</td>
<td>2.4</td>
<td>11.0</td>
<td>mcp3_2.4_16_20.dat</td>
</tr>
</tbody>
</table>

- Assume that a LEMO union is 0.1ns, and the internal time offsets are 0.1+0.1ns.
- Again, it seems that we want ~1.5ns, i.e. lose to the pulse rise time value.
- I will set the delay to 1.5ns.

- **Vary CFD threshold**, Delay: 1.5ns, Center on Pad #62, Pilas power at 16%, “old” CFD:

  30mV, 2.4kV, 11.1%, mcp3_2.4_16_30.dat

  - Time [counts] \(\sigma \approx 72\) ps

  40mV, 2.4kV, 11.2%, mcp3_2.4_16_40.dat

  - Time [counts] \(\sigma \approx 74\) ps

  50mV, 2.4kV, 10.8%, mcp3_2.4_16_50.dat

  - Time [counts] \(\sigma \approx 74\) ps

  60mV, 2.4kV, 10.7%, mcp3_2.4_16_60.dat

  - Time [counts] \(\sigma \approx 72\) ps
70mV, 2.4kV, 10.4%, mcp3_2.4_16_70.dat

\[ \sigma \sim 72 \text{ ps} \]

80mV, 2.4kV, 10.1%, mcp3_2.4_16_80.dat

\[ \sigma \sim 76 \text{ ps} \]

90mV, 2.4kV, 10.1%, mcp3_2.4_16_90.dat

\[ \sigma \sim 76 \text{ ps} \]

100mV, 2.4kV, 9.5%, mcp3_2.4_16_100.dat

\[ \sigma \sim 73 \text{ ps} \]

- Set the threshold to 50mV.

J.V., 5.14.2004
Run 25 – MCP 14&15 (replacements for a bad & returned MCPs):
- -2.4 kV, 50mV threshold, “old” MCP design, “old” CDF:

**MCP#14**, probability 5.9%, PiLas at 15.6%:

- **σ ~ 71 ps**

**MCP#15**, probability 4.6%, PiLas at 17.8%:

- **σ ~ 74 ps**

Run 26 – MCP 16 (replacements for a bad & returned MCPs): J.V., 5.15.2004

- **New design:** MCP-to-cathode distance is 750 μm (the old design has 6mm); it has larger MCP-to-cathode voltage; however, it still has 25 μm hole dia., i.e., tube is not good for the magnetic field yet; can operate up to 2.8 kV; S/N number 85011-430.

2.4kV, 100mV/div, 1ns/div

2.5kV, 100mV/div, 1ns/div

2.6kV, 100mV/div, 1ns/div
- **Vary MCP voltage.** CFD delay 1.5ns, Center on Pad #62, Pilas power at 15.2%, 50mV threshold:

- **2.4kV, probability 8.0%, mcp16_2.4kV.dat:**

  ![Graph 2.4kV](image)

  - σ ~ 64 ps

- **2.5kV, 8.3%, mcp16_2.5kV.dat:**

  ![Graph 2.5kV](image)

  - σ ~ 64 ps

- **2.6kV, 8.9%, mcp16_2.6kV.dat:**

  ![Graph 2.6kV](image)

  - σ ~ 62 ps

- **2.7kV, 8.6%, mcp16_2.7kV.dat:**

  ![Graph 2.7kV](image)

  - σ ~ 65 ps

- **2.8kV, 8.9%, mcp16_2.8kV.dat:**

  ![Graph 2.8kV](image)

  - σ ~ 67 ps

- Set the voltage to –2.6 kV.
- The tube has indeed much smaller tail, as expected. Almost a Gaussian shape.
Run 26 – MCP 15

- Test of a new “final” CFD (analog part only).
- 2.4 kV, 50mV threshold.
- See some wiggles in the output:

Old CFD output, 200mV/div, 1ns/div

![Image of Old CFD output]

New CFD output, 200mV/div, 1ns/div

![Image of New CFD output]

- This wiggle probably does not matter for to the TDC start.

a) MCP#15, probability 7.2%, PiLas at 18.6%,
33 Ohm cable in CFD, mcp15_new_cfd.dat:

![Image of mcp15_new_cfd.dat]

σ ~ 108 ps

b) MCP#15, 7.0%, PiLas at 18.6%,
50 Ohm cable in CFD, mcp15_new_cfd_a.dat:

![Image of mcp15_new_cfd_a.dat]

σ ~ 81 ps

- A 33 Ohm cable is probably causing a tiny reflection, which is disturbing the zero-crossing timing.
- Use one solid cable (no joints).
- **Vary CFD delay cable.** 50mV th., Center on Pad #62, Pilas power at 18.6%, New CFD

1.2ns, 2.4kV, 7.1%, mcp15_new_cfd_b.dat

<table>
<thead>
<tr>
<th>Time [counts]</th>
<th>σ ~ 90 ps</th>
</tr>
</thead>
</table>

1.8ns, 2.4kV, 6.5%, mcp15_new_cfd_c.dat

<table>
<thead>
<tr>
<th>Time [counts]</th>
<th>σ ~ 72 ps</th>
</tr>
</thead>
</table>

2.4ns, 2.4kV, 6.4%, mcp15_new_cfd_d.dat

<table>
<thead>
<tr>
<th>Time [counts]</th>
<th>σ ~ 72 ps</th>
</tr>
</thead>
</table>

2.9ns, 2.4kV, 6.1%, mcp15_new_cfd_e.dat

<table>
<thead>
<tr>
<th>Time [counts]</th>
<th>σ ~ 89 ps</th>
</tr>
</thead>
</table>

3.4ns, 2.4kV, 6.0%, mcp15_new_cfd_f.dat

<table>
<thead>
<tr>
<th>Time [counts]</th>
<th>σ ~ 109 ps</th>
</tr>
</thead>
</table>

- Assume that a LEMO union is 0.1ns, and the internal time offsets are 0.1+0.1ns.
- The result is consistent with the tuning of the old CFD. Let's have a 1.8ns cable in the new CFD.
We used to claim a better resolution. Why? What changed, if anything?

**Run 9c (log book 1, File: mcp-1_3a.dat):**

62.5 µm dia. multi-mode fiber, the 2-nd new PiLas laser diode at 9.2%, 1kHz internal trigger, Elantec EL2075C amplifier (40x =13x), add a 275MHz BW Philips 779 amplifier (10x); total gain AC coupling between amplifiers and after the 779 amplifier with 1uF capacitors, Gholam’s CFD after a few fixes, with 40mV threshold and 1ns delay cable, Probability of a hit ~ 10263/100000 ~ 10.3%, Burle 4-channel MCP-PMT at –2.4kV, chain current ~300uA.

**Original analysis (fit the binned distribution):**

\[ \sigma \sim 54\text{ ps} \quad \& \quad 240\text{ ps} \]

**New analysis (fit raw data):**

\[ \sigma \sim 67\text{ ps} \quad \& \quad 206\text{ ps} \]

- I have re-fitted the old data again.
A final check the TAC & ADC performance of the final CFD board.

Timing sequence:

- Conversion for 12 bit ADC: 2.5 Volts/2048 = 1.22 mV/count.
- 1 count = 25psec.
- Peak-to-peak noise: ~5mV in both measurements.
- Conversion for 12 bits: 2.5 Volts/2048 = 1.22 mV/count.
- 1 count = 25psec.
- Sigma (noise) ~ $5/\sqrt{12} \sim 1.44$ mV \sim 1.1 count \sim 27psec.
- Could be worse if we do not clean the 60Hz noise in the final setup.
Run 27 – MCP 4

- Test of a thin 33 Ohm cable again with the new “final” CFD (analog part only).
- 2.4 kV, 50mV threshold.
- 1.5 + 0.1 + 0.1 + 0.1 = 1.8ns

a) MCP#4, probability 5.4%, PiLas at 18.6%, 33 Ohm cable in CFD, mcp4_33_Ohm.dat:

\[ \sigma \approx 86 \text{ ps} \]

- Hm, it is not as good. Perhaps, due to a different MCP?
Final report to Burle:

<table>
<thead>
<tr>
<th>MCP #</th>
<th>Pads</th>
<th>Burle S/N</th>
<th>HV [kV]</th>
<th>Required red laser power to get a 10% prob. of a hit [%]</th>
<th>Response (white) [uA/Lm] (Burle)</th>
<th>Response (blue) [uA/bLm] (Burle)</th>
<th>Gain @ a voltage specified (Burle)</th>
<th>P/V Ratio a voltage specified (Burle)</th>
<th>Value of mean/RMS for the best 90% of the efficiency Points: Red &amp; blue</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2x2</td>
<td>08290202</td>
<td>-2.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No scan</td>
</tr>
<tr>
<td>2</td>
<td>8x8</td>
<td>01150302</td>
<td>-2.3</td>
<td>51</td>
<td>6.96x10^4</td>
<td>2.8</td>
<td>17.4 &amp; 8.55</td>
<td>6.06 &amp; 3.91</td>
<td>Non uniform</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8x8</td>
<td>05220304</td>
<td>-2.3</td>
<td>53</td>
<td>6.3</td>
<td>3.39x10^4</td>
<td>3.4</td>
<td>6.79 &amp; 10.3</td>
<td>Requiring uniform, 60% of the Photonis PMT efficiency.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8x8</td>
<td>09130305</td>
<td>-2.3</td>
<td>38</td>
<td>6.3</td>
<td>3.39x10^4</td>
<td>3.4</td>
<td>6.79 &amp; 10.3</td>
<td>Reasonably uniform, low efficiency</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8x8</td>
<td>07030302</td>
<td>-2.3</td>
<td>45</td>
<td>5.7</td>
<td>3.13x10^4</td>
<td>1.5</td>
<td>8.36 &amp; 10.1</td>
<td>Low efficiency</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>8x8</td>
<td>09050302</td>
<td>-2.3</td>
<td>41</td>
<td>6.7</td>
<td>3.48x10^4</td>
<td>1.8</td>
<td>10.7 &amp; 3.67</td>
<td>Higher efficiency around the edges, low efficiency</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8x8</td>
<td>08220302</td>
<td>-2.3</td>
<td>36</td>
<td>5.2</td>
<td>2.18x10^4</td>
<td>1.4</td>
<td>6.79 &amp; 5.10</td>
<td>Non uniform, low efficiency</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8x8</td>
<td>09130303</td>
<td>-2.3</td>
<td>38</td>
<td>6.3</td>
<td>1.91x10^4</td>
<td>1.6</td>
<td>7.37 &amp; 10.5</td>
<td>Relatively uniform, low eff.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>8x8</td>
<td>04290301</td>
<td>-2.3</td>
<td>?</td>
<td>?</td>
<td>2.78x10^4</td>
<td>1.1</td>
<td>2.33 &amp; Extremely non uniform; Returned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8x8</td>
<td>12040301</td>
<td>-2.3</td>
<td>50</td>
<td>7.8</td>
<td>4.6x10^4</td>
<td>4.2</td>
<td>5.15 &amp; 8.42</td>
<td>This is a Burle replacement for the failed tube; very non uniform, especially near edges.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>8x8</td>
<td>09130301</td>
<td>-2.3</td>
<td>37</td>
<td>6.1</td>
<td>2.52x10^4</td>
<td>3.3</td>
<td>9.02 &amp; 10.5</td>
<td>Relatively uniform, low eff.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>8x8</td>
<td>05070305</td>
<td>-2.3</td>
<td>29</td>
<td>4.3</td>
<td>4.0x10^3</td>
<td>1.3</td>
<td>5.47 &amp; Very non uniform, low eff. Returned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>8x8</td>
<td>04290302</td>
<td>-2.3</td>
<td>54</td>
<td>6.2</td>
<td>4.26x10^4</td>
<td>2.1</td>
<td>1.43 &amp; Extremely non uniform, two dead pads; Returned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>8x8</td>
<td>12110303</td>
<td>-2.3</td>
<td>55</td>
<td>7.9</td>
<td>3.0x10^3</td>
<td>1.5</td>
<td>7.44 &amp; 8.46</td>
<td>Very uniform, High efficiency</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>8x8</td>
<td>12110302</td>
<td>-2.3</td>
<td>55</td>
<td>7.9</td>
<td>2.5x10^4</td>
<td>1.5</td>
<td>12.8 &amp; 9.83</td>
<td>Very uniform, High efficiency</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>8x8</td>
<td>02010410</td>
<td>-2.66</td>
<td>62</td>
<td>8.5</td>
<td>4.8x10^4</td>
<td>1.5</td>
<td>2.17 &amp; 3.05</td>
<td>Very non uniform along edge pads</td>
<td></td>
</tr>
</tbody>
</table>

Typical conditions during the scan of the latest MCP-PMTs

- People doing it & principal responsibility: J.Schwiening (analysis), T. Hadig (DAQ), J.Va’vra (hardware).
- Elantec EL2075C amplifier (charge gain: ~400, voltage gain: ~130),
- LeCroy 4413 discriminators with **100mV threshold**, LeCroy TDCs with 0.5ns/count,
- Quoted voltages are Burle values and they correspond to quoted gain values. We have run all MCP-PMTs at –2.4kV, chain current ~300uA. MCP #16 was run at –2.6kV.
- X-step: 0.1mm, Y-step: 1mm, Events/point: 20000, Probability of a hit: ~10-15%
- The normalization is done to either to its max value or to a 2" dia. XP 2262B Photonis tube.
1. MCP #2 (S/N 01150302)
   a) Red PiLas Laser (635nm)
      (relatively uniform, 50% of the Photonis PMT efficiency)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:

   b) Blue PiLas Laser (430nm, borrowed from T. Sumyioshi)
      (the same uniformity as in red, ~35% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:

Timing resolution with red PiLas, 2.4kV:

\[ \sigma \sim 75 \text{ ps} \]
2. MCP #3 (S/N 05220203) - the best tube so far
   a) Red PiLas Laser (635nm)
      (very uniform, 60% of the Photonis PMT efficiency)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

   b) Blue PiLas Laser (430nm)
      (very uniform, ~60% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:

Timing resolution with red PiLas, 2.4kV:

\[ \sigma \approx 71 \text{ ps} \]
3. MCP #4 (S/N 09130305)
   a) Red PiLas Laser (635nm)
      (quite uniform)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

   b) Blue PiLas Laser (430nm)
      (quite uniform, ~50-60% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:

Timing resolution with red PiLas, 2.4kV:
\[ \sigma \approx 86 \text{ ps} \]
4. MCP #5 (S/N 07030301)
a) Red PiLas Laser (635nm)
(higher efficiency around the edges, lower overall efficiency)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)
(quite uniform, ~40% of the Photonis PMT efficiency at 430nm)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT:
5. MCP #6 (S/N 09050302)
a) Red PiLas Laser (635nm)
(higher efficiency around the edges, lower overall efficiency)

a) Normalize to best spot in the tube:  
b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)
(quite uniform, ~50% of the Photonis PMT efficiency at 430nm)

a) Normalize to best spot in the tube:  
b) Normalize to Photonis PMT:  

---

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6. MCP #7 (S/N 08220302)
   a) Red PiLas Laser (635nm)
      (Non uniform, lower overall efficiency)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

   b) Blue PiLas Laser (430nm)
      (not uniform, ~35% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:
7. MCP #8 (S/N 09130303)
   a) Red PiLas Laser (635nm)
      (relatively uniform, lower overall efficiency)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

   b) Blue PiLas Laser (430nm)
      (very uniform, ~40% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:
8. MCP #9 (S/N 04290301)
a) Red PiLas Laser (635nm)
(Extremely nonuniform)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT at 635nm:

- Returned, no scan in blue.
9. MCP #10 (S/N 12040301)
a) Red PiLas Laser (635nm)
(not very uniform, especially along the edges, low efficiency)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)
(quite uniform, ~60% of the Photonis PMT efficiency at 430nm)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT:
10. MCP #11 (S/N 09130301)
   a) Red PiLas Laser (635nm)
      (relatively uniform)
      
      a) Normalize to best spot in the tube:

      b) Normalize to Photonis PMT at 635nm:

   b) Blue PiLas Laser (430nm)
      (relatively uniform, ~40% of the Photonis PMT efficiency at 430nm)
      
      a) Normalize to best spot in the tube:

      b) Normalize to Photonis PMT:
11. MCP #12 (S/N 05070305)
a) Red PiLas Laser (635nm)
   (very non uniform)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:

- Returned, no scan in blue.

12. MCP #13 (S/N 04290302)
a) Red PiLas Laser (635nm)
   (extremely non uniform, two dead pads)
   a) Normalize to best spot in the tube:
   b) Normalize to Photonis PMT at 635nm:

- Returned, no scan in blue.
13. MCP #14 (S/N 12110303)

**a) Red PiLas Laser (635nm)**
(qite uniform)

- a) Normalize to best spot in the tube:

**b) Blue PiLas Laser (430nm)**
(qite uniform, ~60% of the Photonis PMT efficiency at 430nm)

- a) Normalize to best spot in the tube:

**b) Normalize to Photonis PMT at 635nm:**

Timing resolution with red PiLas, 2.4kV:

\[ \sigma \approx 71 \text{ ps} \]
14. MCP #15 (S/N 12110302)
   a) Red PiLas Laser (635nm)
      (very uniform)
      a) Normalize to best spot in the tube:

   b) Blue PiLas Laser (430nm)
      (very uniform, ~50% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:

Timing resolution with red PiLas, 2.4kV:
\[ \sigma \sim 72 \text{ ps} \]
15. MCP #16 (S/N 02010410)

a) Red PiLas Laser (635nm)
(relatively uniform, except the edge pads)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)
(very uniform, except the boundary pads, ~70% of the Photonis PMT efficiency at 430nm)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT:

Timing resolution with red PiLas, 2.6kV:

\[ \sigma \sim 62 \text{ ps} \]
1. Hamamatsu H8500, PMT #1 (S/N ZA0154)
   a) Red PiLas Laser (635nm)
      (not very uniform)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

      \[
      \sigma \sim 138 + 244 \text{ ps}
      \]

   b) Blue PiLas Laser (430nm)
      (not very uniform, except the boundary pads, 10-25% of the Photonis PMT efficiency at 430nm)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT:

   Timing resolution with red PiLas, 1.0kV:
2. Hamamatsu H8500, PMT #2 (S/N ZA1930)

a) Red PiLas Laser (635nm)

(not very uniform)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)

(relatively uniform, except the boundary pads, ~40-50% of the Photonis PMT efficiency at 430nm)

a) Normalize to best spot in the tube:

b) Normalize to Photonis PMT:
3. Hamamatsu H8500, PMT #3 (S/N …)
   a) Red PiLas Laser (635nm)
      (relatively uniform in red)
      a) Normalize to best spot in the tube:
      b) Normalize to Photonis PMT at 635nm:

Returned to Hamamatsu and exchanged for PMT#4
4. Hamamatsu H8500, PMT #4 (S/N ZA2968)

a) Red PiLas Laser (635nm)
(not very uniform)

- a) Normalize to best spot in the tube:
- b) Normalize to Photonis PMT at 635nm:

b) Blue PiLas Laser (430nm)
(not very uniform, except the boundary pads, 40-70% of the Photonis PMT efficiency at 430nm)

- a) Normalize to best spot in the tube:
- b) Normalize to Photonis PMT:
Run 28 – MCP 16 (test of a final cfd):

- **New design**: MCP-to-cathode distance is 750 µm (the old design has 6mm); **it has larger MCP-to-cathode voltage**; however, it still has 25 µm hole dia., i.e., tube is not good for the magnetic field yet; can operate up to 2.8 kV; S/N number 85011-430.

2.6kV, 100mV/div, 1ns/div

- New CFD, S/N #1, Vary PiLas power, MCP 16, 2.6kV:
  - ch.2, 13.2%:
    - σ ~ 110 ps + sig. 2-nd comp.

- Old NIM CFD, PiLas at 25%, MCP 16, 2.6kV:
  - σ ~ 96 ps
- New CFD, S/N #1, PiLas at 25%, MCP 16, 2.6kV:
- Vary CFD channel number, first from one PCB side:

**ch.1:**

\[\sigma \sim 101 \text{ ps} \quad + \text{tail}\]

**ch.2:**

\[\sigma \sim 110 \text{ ps} \quad + \text{sig. 2-nd comp.}\]

**ch.3:**

\[\sigma \sim 94 \text{ ps} \quad + \text{sig. 2-nd comp.}\]

**ch.4:**

?????

**ch.5:**

\[\sigma \sim 110 \text{ ps} \quad + \text{tail}\]

**ch.6:**

\[\sigma \sim 105 \text{ ps} \quad + \text{tail}\]
ch. 7:

- The other PCB side:

ch. 17:

ch. 18:

ch. 19:

ch. 20:

\[ \sigma \approx 56 \text{ ps} + \text{tail} \]

\[ \sigma \approx 86 \text{ ps} + \text{tail} \]
ch.22:

\[ \sigma \sim 111 \text{ ps} + \text{tail} \]

ch.30:

\[ \sigma \sim 130 \text{ ps} + \text{tail} \]

ch.31 – Clearly see a satellite pulses (trig: Pilas):

\[ \sigma \sim 132 \text{ ps} + \text{tail} \]

ch.32, add tape to hold the output cable:
ch.21:

\[ \sigma \sim 88 \text{ ps} + \text{tail} \]

ch.21, 2.6kV (nominal running):

- Blue: CFD output, Violet: PiLas trigger, Yellow: MCP-PMT pulse.

ch.21, 2.8kV (force PMT to large pulses):

- It seems that a frequency of earlier CFD outputs is enhanced at lower voltage (pulse is also delayed because the PMT is slower). At larger voltage, the frequency of small pulses is smaller. Somehow, CFD does not work properly for small pulses?
Tune CFD threshold on CFD#1, ch.21:

**ch.21 - with tape holding the analog twisted pair cable down to ground to stop slight oscillation:**

- **σ ~ 77 ps + tail**

**ch.21 - Add damping resistor, 50 Ohm on neighbors, better grounding, add stop, clean up delay cable:**

- **σ ~ 50 ps + tail**

**The effect is not sensitive to threshold**
ch.21 – Clearly see a satellite pulses ~1ns apart; trigger on Pilas; CFD input and output pulses: 

ch.21 – Trigger on CFD output; 250mV CFD th. some large pulses are shifted: 

ch.21 – Trigger on CFD output; 250mV CFD th. some large pulses are shifted: 

ch.21 – Trigger on CFD output; 250mV CFD th. some large pulses are shifted: 

ch.21 – Trigger on CFD output; 250mV CFD th. some large pulses are shifted:
ch.21 – Trigger on CFD output; 250mV CFD th.
some pulses are shifted:

ch.21 – Trigger on CFD output; 100mV CFD th.
some pulses are shifted:

ch.21 – Attenuate pulses by 6dB; Trigger on CFD
output; 100mV CFD th.; see no shifted pulses:
Tune CFD threshold on CFD#1, ch.2:

ch.2, 100mV, PiLas 25%:

\[ \sigma \approx 116 \text{ ps} \]
+ sig. 2-nd comp.

ch.2 - with tape holding the analog twisted pair cable down to ground to stop slight oscillation:

\[ \sigma \approx 97 \text{ ps} \]
+ sig. 2-nd comp.

- This distribution actually consists of two peaks very close to each other !!!

ch.2 - 175mV CFD threshold:

\[ \sigma \approx 109 \text{ ps} \]
+ sig. 2-nd comp.

ch.2 - 200mV CFD threshold:

\[ \sigma \approx 116 \text{ ps} \]
+ sig. 2-nd comp.

- Did not improve !! So far no solution at hand.
**Try CFD board #2:**

**CFD#2, ch.2 – 100mV CFD threshold:**

- CFD function doesn’t work on this channel

**CFD#2, ch.2 – trigger on CFD output;**

**CFD input and output pulses:**

- CFD#2, ch.2 – Trigger on Pilas; 100mV th.

**CFD#2, ch.2 – trigger on CFD output**
Go back to our reference CFDs:

**CFD#0, ch.1 – 100mV CFD threshold:**

- \( \sigma \sim 67 \text{ ps} \)

**CFD#0, ch.1 – trigger on CFD output:**

This CFD works perfectly

**Old CFD – 100mV CFD threshold:**

**Old CFD – trigger on CFD output:**

This CFD works perfectly
Tune zero-crossing threshold:

**CFD#1, ch.2, CFD:100mV, 40 Ohms, Zero-crossing res. & threshold: 40Ω & 10mV**

\[ \sigma \approx 67 \text{ ps} \]

**CFD#1, ch.2, CFD:100mV, Zero-crossing res. & threshold: 51Ω & 13mV**

\[ \sigma \approx 59 \text{ ps} + 123 \text{ ps} \]

**CFD#1, ch.21, CFD th.:100mV, 40 Ohms, Zero-crossing res. & threshold: 40Ω & 10mV**

\[ \sigma \approx 39 \text{ ps} + 116 \text{ ps} \]

**CFD#1, ch.21, CFD th.: 100mV, Zero-crossing res. & threshold: 51Ω & 13mV**

This solution seems to work better, but it is not 100% perfect.
Continue tuning the zero-crossing threshold:

CFD#1, ch.2, CFD: 100mV,
Zero-crossing res. & threshold: 56.5Ω, 13.9mV:

$$\sigma \sim 46\ \text{ps} + 128\ \text{ps}$$

CFD#1, ch.21, CFD: 100mV,
Zero-crossing res. & threshold: 56.5Ω, 14.5mV:

$$\sigma \sim 50\ \text{ps} + 123\ \text{ps}$$

CFD#1, ch.21, CFD th.: 150mV,
Zero-crossing res. & threshold: 56.5Ω, 14.5mV:

$$\sigma \sim 57\ \text{ps} + 130\ \text{ps}$$

Not much improvement by increasing the CFD threshold to 150mV. It seems to me that we should stay with 50Ω resistor, yielding ~13mV zero-crossing threshold, and 100mV for the CFD threshold.
CFD2 – Final evaluation (after setting zero-crossing th. to 13mV):

**ch.1**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 113 \text{ ps} + 160 \text{ ps} \]

**ch.2**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 104 \text{ ps} \]

**ch.3**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 85 \text{ ps} + 109 \text{ ps} \]

**ch.4**, CFD th.100mV, zero-cross th. 13mV:

Did not work

**ch.5**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 117 \text{ ps} \]
ch.6, CFD th.100mV, zero-cross th. 13mV:

σ ~ 69 ps + 140 ps

ch.7, CFD th.100mV, zero-cross th. 13mV:

σ ~ 91 ps

ch.8, CFD th.100mV, zero-cross th. 13mV:

σ ~ 95 ps

ch.9, CFD th.100mV, zero-cross th. 13mV:

σ ~ 97 ps

ch.10, CFD th.100mV, zero-cross th. 13mV:

σ ~ 106 ps

ch.11, CFD th.100mV, zero-cross th. 13mV:

σ ~ 116 ps
ch.12, CFD th.100mV, zero-cross th. 13mV:

<table>
<thead>
<tr>
<th>Channel</th>
<th>RMS</th>
<th>UDFL</th>
<th>GVEL</th>
<th>ALLOCAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex 1</td>
<td>100</td>
<td>2084</td>
<td>650</td>
<td>14.10</td>
</tr>
<tr>
<td>Ex 2</td>
<td>7.96</td>
<td>11.00</td>
<td>950</td>
<td>2.00</td>
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<tr>
<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
</tr>
</tbody>
</table>

\[ \sigma \approx 98 \text{ ps} + 108 \text{ ps} \]

ch.13, CFD th.100mV, zero-cross th. 13mV:

<table>
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<td>7.96</td>
<td>11.00</td>
<td>950</td>
<td>2.00</td>
</tr>
<tr>
<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
</tr>
</tbody>
</table>

\[ \sigma \approx 48 \text{ ps} + 120 \text{ ps} \]

ch.14, CFD th.100mV, zero-cross th. 13mV:

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<th>UDFL</th>
<th>GVEL</th>
<th>ALLOCAN</th>
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<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
</tr>
</tbody>
</table>

\[ \sigma \approx 70 \text{ ps} + 132 \text{ ps} \]

ch.15, CFD th.100mV, zero-cross th. 13mV:

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<th>UDFL</th>
<th>GVEL</th>
<th>ALLOCAN</th>
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<td>650</td>
<td>14.10</td>
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<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
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</tbody>
</table>

\[ \sigma \approx 40 \text{ ps} + 126 \text{ ps} \]

ch.16, CFD th.100mV, zero-cross th. 13mV:

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<tr>
<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
</tr>
</tbody>
</table>

\[ \sigma \approx 88 \text{ ps} + 144 \text{ ps} \]

ch.17, CFD th.100mV, zero-cross th. 13mV:

<table>
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<tr>
<th>Channel</th>
<th>RMS</th>
<th>UDFL</th>
<th>GVEL</th>
<th>ALLOCAN</th>
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<tbody>
<tr>
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</tr>
<tr>
<td>Ex 3</td>
<td>660</td>
<td>3.00</td>
<td>2016</td>
<td>7.96</td>
</tr>
</tbody>
</table>

\[ \sigma \approx 62 \text{ ps} + 122 \text{ ps} \]
ch.18, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 71 \text{ ps} + 147 \text{ ps} \]

ch.19, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 81 \text{ ps} + 145 \text{ ps} \]

ch.20, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 96 \text{ ps} \]

ch.21, CFD th.100mV, zero-cross th. 13mV:

Did not work

ch.22, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 106 \text{ ps} \]

ch.23, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 117 \text{ ps} \]
ch.24, CFD th.100mV, zero-cross th. 13mV:  
\[ \sigma \approx 77 \text{ ps} + 117 \text{ ps} \]

ch.25, CFD th.100mV, zero-cross th. 13mV:  
\[ \sigma \approx 44 \text{ ps} + 123 \text{ ps} \]

ch.26, CFD th.100mV, zero-cross th. 13mV:  
\[ \sigma \approx 42 \text{ ps} + 135 \text{ ps} \]

ch.27, CFD th.100mV, zero-cross th. 13mV:  
\[ \sigma \approx 46 \text{ ps} + 118 \text{ ps} \]

ch.28, CFD th.100mV, zero-cross th. 13mV:  
\[ \sigma \approx 99 \text{ ps} \]

ch.29, CFD th.100mV, zero-cross th. 13mV:  
Did not work
\[ \sigma \approx 52 \text{ ps} + 128 \text{ ps} \]

\[ \sigma \approx 70 \text{ ps} + 119 \text{ ps} \]
CFD1 – Final evaluation (after setting zero-crossing th. to 13mV):

**ch.1**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 56 \text{ ps} + 128 \text{ ps} \]

![Graph for ch.1](image1.png)

**ch.2**, CFD th.150mV, zero-cross th. 13mV:

\[ \sigma \approx 77 \text{ ps} + 161 \text{ ps} \]

![Graph for ch.2](image2.png)

**ch.9**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 42 \text{ ps} + 115 \text{ ps} \]

![Graph for ch.9](image3.png)

**ch.16**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 51 \text{ ps} + 140 \text{ ps} \]

![Graph for ch.16](image4.png)

**ch.17**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 48 \text{ ps} + 112 \text{ ps} \]

![Graph for ch.17](image5.png)

**ch.25**, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \approx 47 \text{ ps} + 123 \text{ ps} \]

![Graph for ch.25](image6.png)
ch.32, CFD th.100mV, zero-cross th. 13mV:

\[ \sigma \sim 43 \text{ ps} + 137 \text{ ps} \]

Analysis of Josef Uher, 10.16.2004
 Calibration of a contribution to the timing resolution from the electronics:

- Feed PiLas start pulse to CFD input.
- Old Gholam’s CFD, 15mV threshold.
- It is hard to fit (too narrow). Use the RMS value to estimate sigma.

\[ \sigma \approx 15 \text{ ps} \]
Run 29 – **New Russian MCP (S/N 1440):**

(Obtained three MCP-PMTs from A. Onuchin on Dec 8. 2004)

**Operating points based on Novosibirsk data sheet:**
- Quoted QE @ 400nm: ~17.3%
- Resistor chain number: 246

**Working voltages of MCP-PMT (S/N 1440) according to Novosibirsk measurements:**

<table>
<thead>
<tr>
<th>MCP voltage</th>
<th>Gain($\times 10^6$)</th>
<th>Noise rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 V</td>
<td>0.5</td>
<td>10.7kHz</td>
</tr>
<tr>
<td>2700 V</td>
<td>1.0</td>
<td>14.6kHz</td>
</tr>
<tr>
<td>2900 V</td>
<td>2.11</td>
<td>18.9kHz</td>
</tr>
<tr>
<td>3100 V</td>
<td>3.8</td>
<td>26.7kHz</td>
</tr>
<tr>
<td>3300 V</td>
<td>5.8</td>
<td>34.7kHz</td>
</tr>
</tbody>
</table>

Their “SHV connector” is not the same thing as ours, had to replace it. Their “BNC connector” is also different:

- Initial testing is done without the Lucite radiator and metallic enclosure.
a) Other parameters in the initial test:

- 62.5 \mu m dia. multi-mode fiber, PiLas laser diode at 23%, 1kHz internal trigger,
- Two Elantec EL2075C amplifiers in tandem (G_{\text{charge}} \sim 10x10 \sim 100x).
- Gholam’s old CFD with a 15 mV threshold, 2ns delay cable, 24 psec/count TDC.
- Probability of a hit <10%.

Run initially with \(-3.1\)kV:

MCP (S/N 1440) raw pulses (scope trigger: PiLas)
50mV/div, 2ns/div, CFD input:

A single shot: see \sim 70kHz noise equiv.:

CFD output, 1ns/div, 200mV/div:

Fit: G1+G2+P2 (1 bin = 1 TDC count), File: rus_mcp_1440_3.1kV_23\%_15mV.log = run_3.dat

\[ \sigma < 83 \text{ ps} \]

Not very good fit. It looks that the major component is better than \(\sigma \sim 83\text{ps}\) (from FWHM one gets \(\sigma \sim 50\text{ps}\)). The shoulder is coming from the threshold effect (small pulses are comparable to threshold). It gets larger as one increases the CFD threshold. Therefore one needs a larger amplification. The MCP noise does not allow it, as it gets very noisy. So, I will try higher amplifier gain.
b) $-3.2\text{kV}$:

MCP (S/N 1440) raw pulses (scope trigger: PiLas)
50mV/div, 2ns/div, CFD input:

If we will run this tube for a long time like this it will surely die. Therefore, this result cannot be considered real. But, let’s measure anyway.

Fit: G1+G2+P2 (1 bin = 1 TDC count), File: rus_mcp_1440_3.2kV_23%-15mV.log = run_4.dat

Again, the major component is better than $\sigma \sim 76\text{ps}$ (from FWHM one gets $\sigma \sim 50\text{ps}$). The shoulder is again coming from the threshold effect (small pulses are comparable to threshold).
c) **Runs with much larger electronics amplification:**

**Change of several parameters:**
- Add Philips 779, 10x amplifier to two Elantec EL2075C amplifiers, all in tandem (G\textsubscript{charge} \sim 1000x).
- Gholam’s old CFD, 2ns delay cable, 24 psec/count TDC.
- PiLas laser diode at 23%, 1kHz, filters to attenuate to a probability of an event to be <10%.

**–2.9kV & 100mV CFD threshold:**

MCP (S/N 1440) raw pulses (scope trigger: PiLas)

- 200mV/div, 1ns/div, CFD input:
- 500mV/div, 10ns/div, CFD input:

A single shot: see \sim 30kHz noise equiv.:  

200mV/div, 1ns/div, CFD output:

Fit: G1+G2+P2 (1 bin = 1 TDC count), File: rus_mcp_1440_2.9kV_1000x_100mV.log = run_5.dat

\[\sigma < 56 \text{ ps}\]

Getting better. I think we need a good ratio between the amplitude and CFD threshold. Will aim for \sim 1/10 in the following tests.
-3.1kV & 100mV CFD threshold:
Fit: G1+G2+P2 (1 bin = 1 TDC count),
rus_mcp_1440_3.1kV_1000x_100mV.log = run_6.dat

\[ \sigma < 59 \text{ps} \]

-3.2kV & 100mV CFD threshold:
Fit: G1+G2+P2 (1 bin = 1 TDC count),
rus_mcp_1440_3.2kV_1000x_100mV.log = run_7.dat

\[ \sigma < 75 \text{ps} \]

-3.1kV & 50mV CFD threshold:
Fit: G1+G2+P2 (1 bin = 1 TDC count),
File: rus_mcp_1440_3.1kV_1000x_50mV.log = run_8.dat

\[ \sigma < 49 \text{ps} \]

-3.2kV & 50mV CFD threshold:
Fit: G1+G2+P2 (1 bin = 1 TDC count),
File: rus_mcp_1440_3.2kV_1000x_50mV.log = run_9.dat

\[ \sigma < 57 \text{ps} \]

-2.9kV & 50mV CFD threshold:
Fit: G1+G2+P2 (1 bin = 1 TDC count),
File: rus_mcp_1440_2.9kV_1000x_50mV.log = run_10.dat

\[ \sigma < 58 \text{ps} \]

-3.1kV & 50mV & multiple pe/trigger:
Remove 3 Mylar attenuators to simulate the beam,
File: rus_mcp_1440_3.1kV_1000x_50mV_3att_rem.log = run_11.dat, Ugly tail!!!
Single photoelectron mode:
500mV/div, 1ns/div, S/N1440:

500mV/div, 2ns/div, S/N1440:

500mV/div, 10ns/div, S/N1440:

500mV/div, 20ns/div, S/N1440:

Remove 3 Mylar attenuators to simulate the multiple photoelectron mode:
1V/div, 2ns/div, S/N1440:

1V/div, 10ns/div, S/N1440:

- Amplifier saturates a portion of the time.
- 3.1kV & 56mV threshold with LeCroy “amplitude corrected discriminator”:
  Fit: G1+G2+P2 (1 bin = 1 TDC count), File: rus_mcp_1440_3.1kV_1000x_56mV_LeCroy.log = run_12.dat

A disaster!!

Time [TDC counts]

- Lower the electronics amplification to prevent the saturation:
  - Two Elantec EL2075C amplifiers +12dB attenuator + Philips 779 10x amplifier (G_charge ~ 250x).
  - Gholam’s old CFD, 50mV threshold, 2ns delay cable, 24 psec/count TDC.
  - PiLas laser diode remains at 23%, 1kHz, filters to attenuate to a probability of an event to be <10%.

- 3.1kV & single photoelectron pulses:
  MCP (S/N 1440) raw pulses (scope trigger: PiLas)
  CFD input, 1ns/div, 200mV/div:

- 3.1kV & 5 Mylar attenuators out:
  Fit: G1+G2+G3 (1 bin = 1 TDC count), File: rus_mcp_3.1kV_1000x_12dB_50mV_5att.log = run_13.dat
  σ ~ 36ps (Joe: ~35ps)

Time [TDC counts]

- 3.2kV & 4 Mylar attenuators out:
  Fit: G1+G2+G3 (1 bin = 1 TDC count), File: rus_mcp_3.1kV_1000x_12dB_50mV_4att.log = run_14.dat
  σ ~ 50ps (Joe: ~39ps)

Time [TDC counts]
–3.1kV & 3 Mylar attenuators out:
Fit: G1+G2+G3 (1 bin = 1 TDC count), File:
rus_mcp_3.1kV_1000x_12dB_50mV_3att.log = run_15.dat

σ ~35ps  
(Joe: ~34ps)

–3.2kV & 2 Mylar attenuators out:
Fit: G1+G2+G3 (1 bin = 1 TDC count), File:
rus_mcp_3.1kV_1000x_12dB_50mV_2att.log = run_16.dat

σ ~50ps  
(Joe: ~34ps)

–3.1kV & 1 Mylar attenuator out:
N_ave ~
Fit: G1+G2+G3 (1 bin = 1 TDC count), File:
rus_mcp_3.1kV_1000x_12dB_50mV_1att.log = run_17.dat

σ ~42ps  
(Joe: ~35ps)

–3.2kV & single photoelectron mode:
N_ave ~
Fit: G1+G2+G3 (1 bin = 1 TDC count), File:
rus_mcp_3.1kV_1000x_12dB_50mV_0att.log = run_18.dat

σ ~44ps  
(Joe: ~35ps)

3V, 1.25.2005

Russian MCP S/N 1440

- Why do not I see a dependence on number of photoelectrons? There must be a noise.
- Problem: have an unstable base line due to a 60Hz noise, which may influence the resolution.
Russian MCP-PMT fiber and Lucite radiator connection:
- **This tube goes to ESA test beam**
MCP-PMT S/N 1448 – a version intended for the test beam,
Lucite radiator is captured on the window: MCP is on springs to absorb a mismatch in depth:

Lucite radiator on the window:
Fiber ends with a lens to make the beam parallel:

With Matt’s help, I have added the fiber holder to the Russian MCP. Shown solution has a lens at the end of the fiber
Try to remove the 60Hz noise by moving the HV PS to the electronics rack:

–3.1kV & 2 Elantek amplifiers in tandem (10x10x), AC coupled, + Philips amp. (10x) + 12 dB attenuator, 50mV threshold on the old Gholam’s CFD, internal 1kHz trigger, single photoelectron mode:

200mV/div, 1ns/div, S/N1448:

–3.1kV & 1 Mylar attenuator out (still ~single photoelectron mode):

\[ \sigma \approx 33 \text{ps} \]

\[ \text{Fit: G1+G2+G3 (1 bin = 1 TDC count), File: rus_1448_3.1kV_1000x_12dB_50mV.log = run_19.dat} \]

- However, in ESA, with external trigger of 10Hz, we got \( \sigma > 300 \text{ps} \) !!!
- What is the culprit? Bring the PiLas laser back to the lab.
Try the 3-rd Russian MCP-PMT (S/N 1992):

-3.1kV & 3 Elantek amplifiers in tandem (10x10x10), AC coupled, 50mV threshold on the old Gholam’s CFD, internal 1kHz trigger, single photoelectron mode:

200mV/div, 1ns/div, amplify. output:

-3.1kV & 1 Mylar attenuator out (still ~single photoelectron mode):

\[ \sigma_1 \sim 51\text{ps} \quad \sigma_2 \sim 116\text{ps} \]

Fit: G1+G2+G3 (1 bin = 1 TDC count), File:
rus_1992_3.1_10x10x10_50mV.log = run_20.dat

Fit: G1+G2+P2 (1 bin = 1 TDC count), File:
rus_1992_3.1_10x10x10_50mV.log = run_20.dat

- It is worse than what I got with S/N 1442, but it is not as bad as in ESA!!!

\[ \sigma_1 \sim 57\text{ps} \quad \sigma_2 \sim 129\text{ps} \]
Try the Russian SiPM (a gift from Dolgoshein):
+32Volts & Elantek amplifiers AC coupled in tandem (10x10x10), 50mV threshold on the old Gholam’s CFD, internal 1kHz trigger, single photoelectron mode:

- I can’t get to work !!