Understanding The Focusing DIRC Prototype And The Beam Test

Jose Benitez
5/19/2006

Outline

Part I:

Cherenkov ring focusing study: Trying to focus the outer slots.

Part II:

Event selection and start time resolution in the beam test.

Part III:

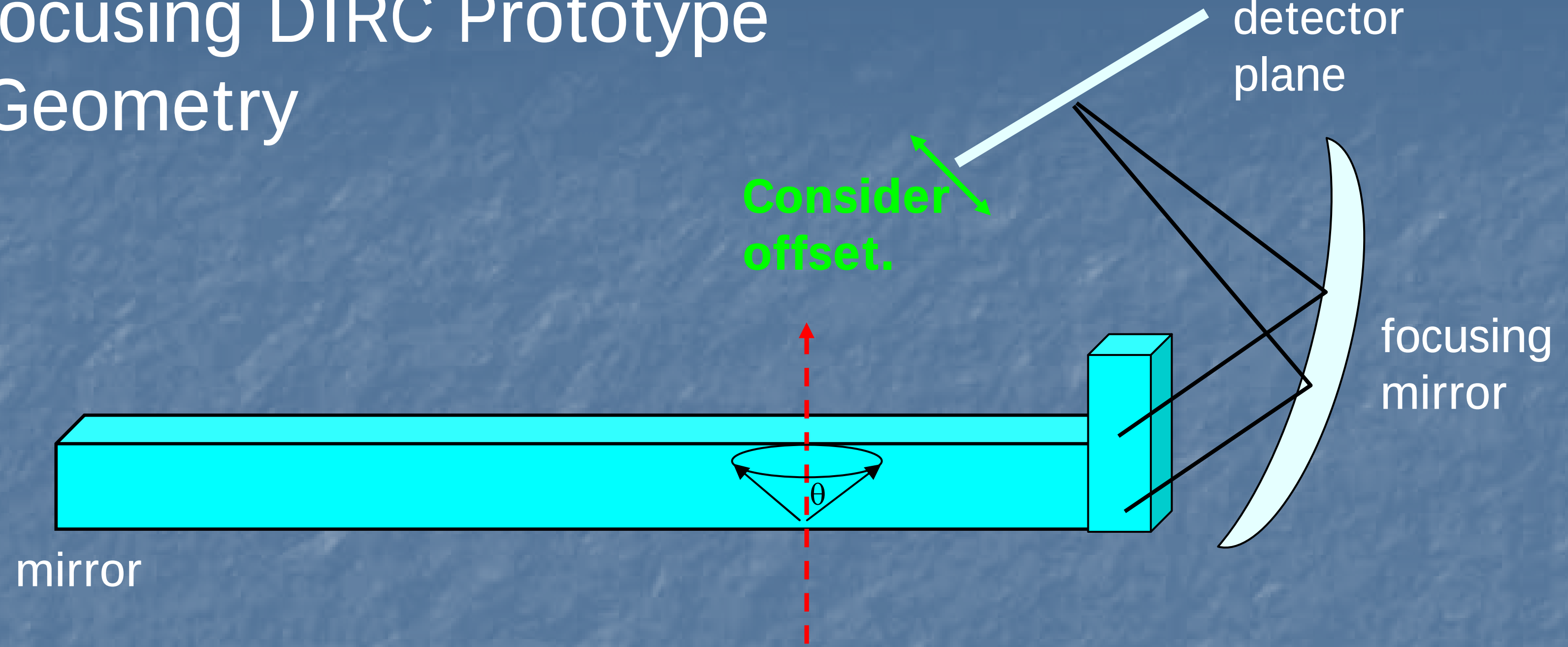
Study of the contributions to the Cherenkov angle resolution measured with time using a simple toy Monte Carlo.

PART I

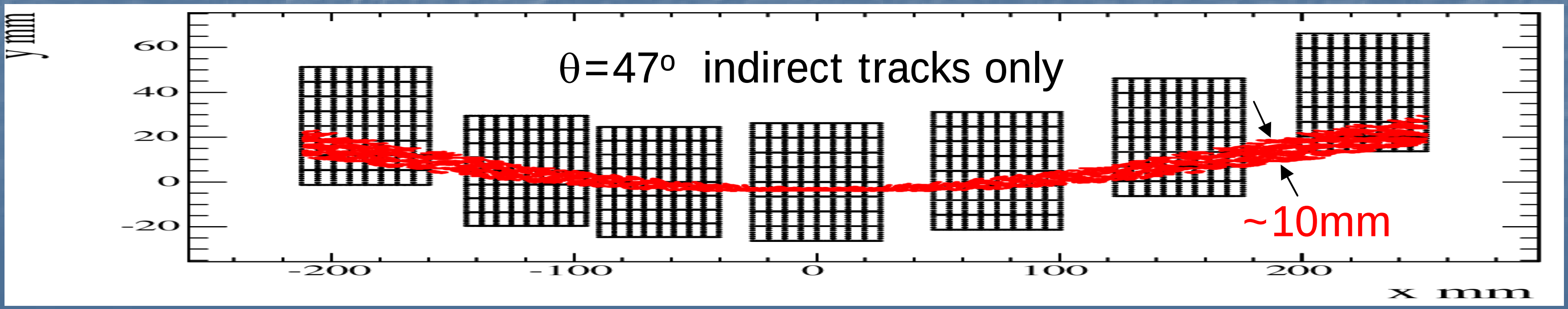
Cherenkov ring focusing study: Trying to focus the outer slots.

- Prototype Geometry
- Outward shifts of the detector plane.
- Inward shifts of the detector plane.

Focusing DIRC Prototype Geometry



Cherenkov ring image ray traced* from inside the bar is blurred in the outer slots.



*** The formulas used to ray trace photons can be found in my logbook.**

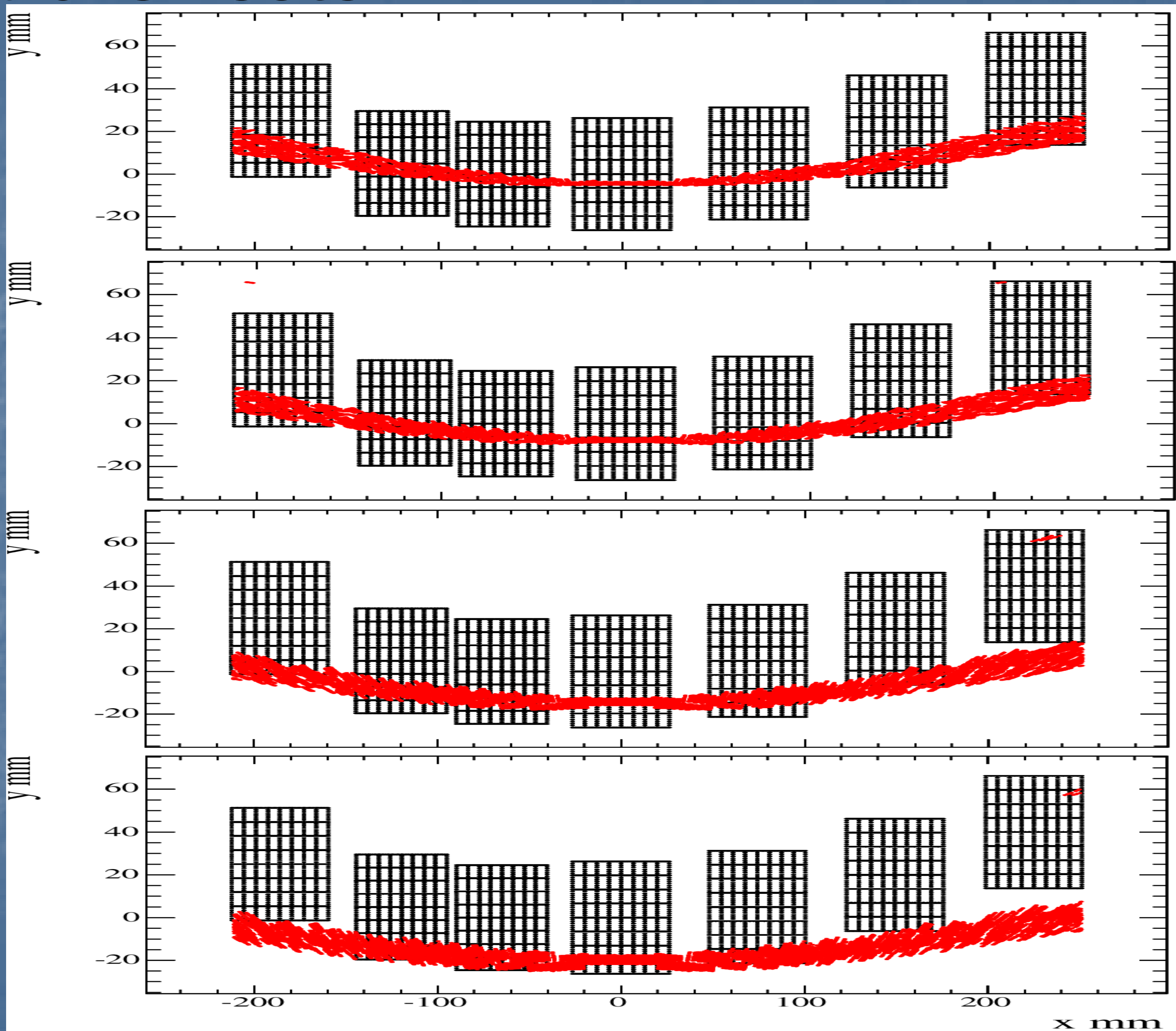
Outward Offsets

5mm

20mm

50mm

75mm



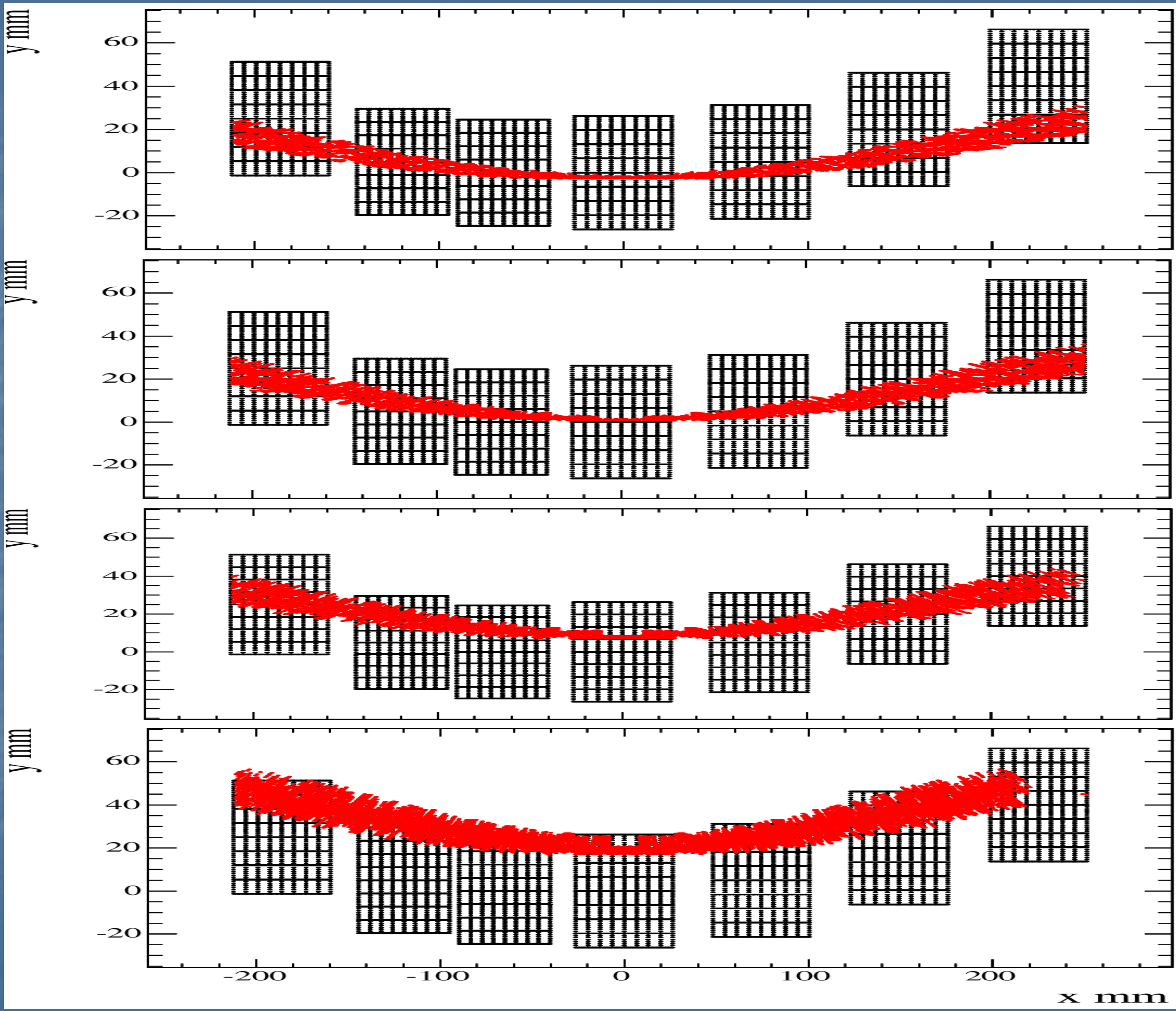
Inward Offsets

5mm

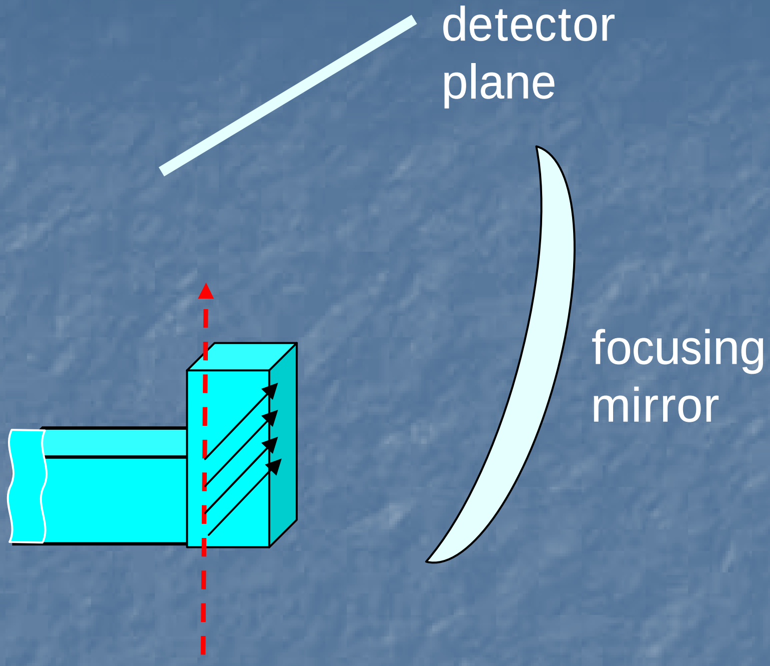
20mm

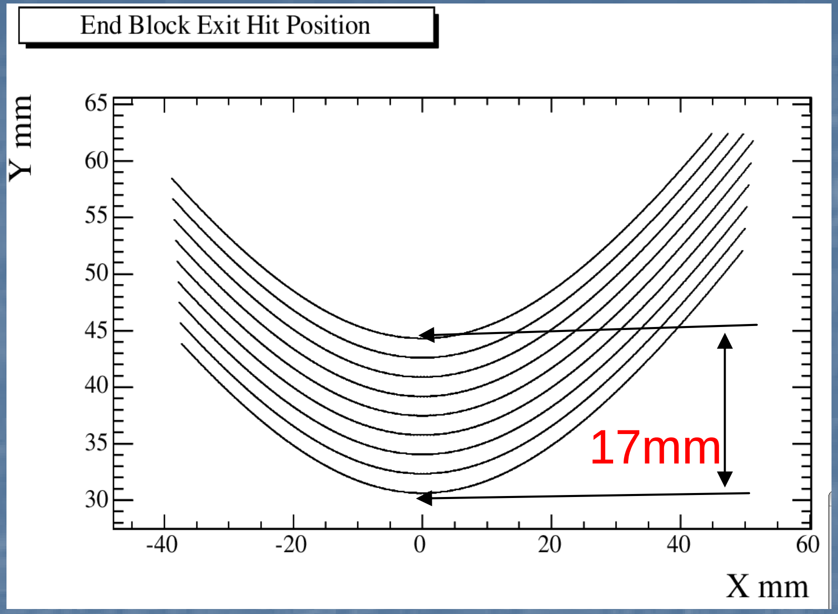
50mm

100mm

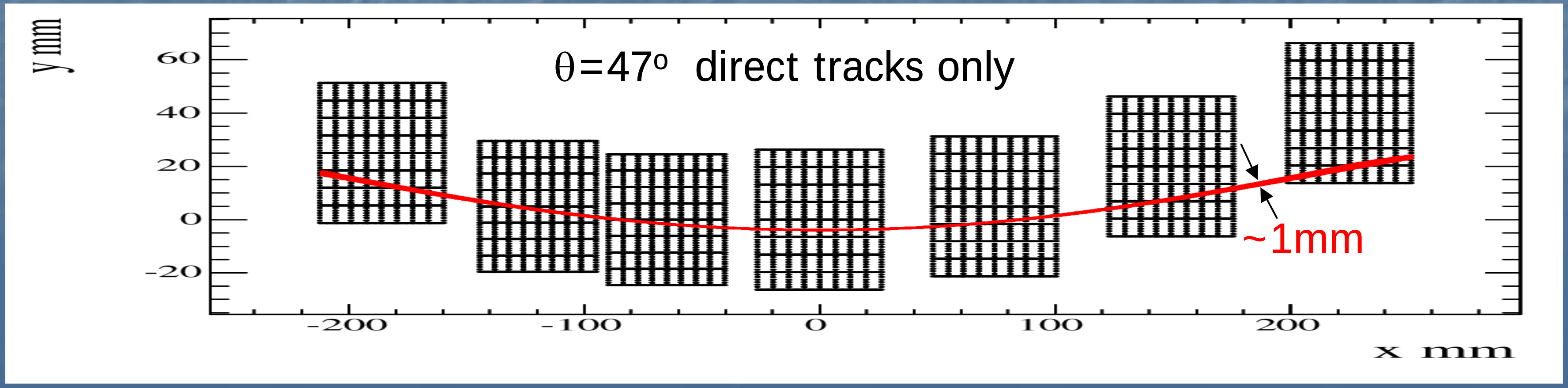


Rings from outside bar are well focused





Cherenkov rings ray traced from outside the bar.



Part I: Conclusions

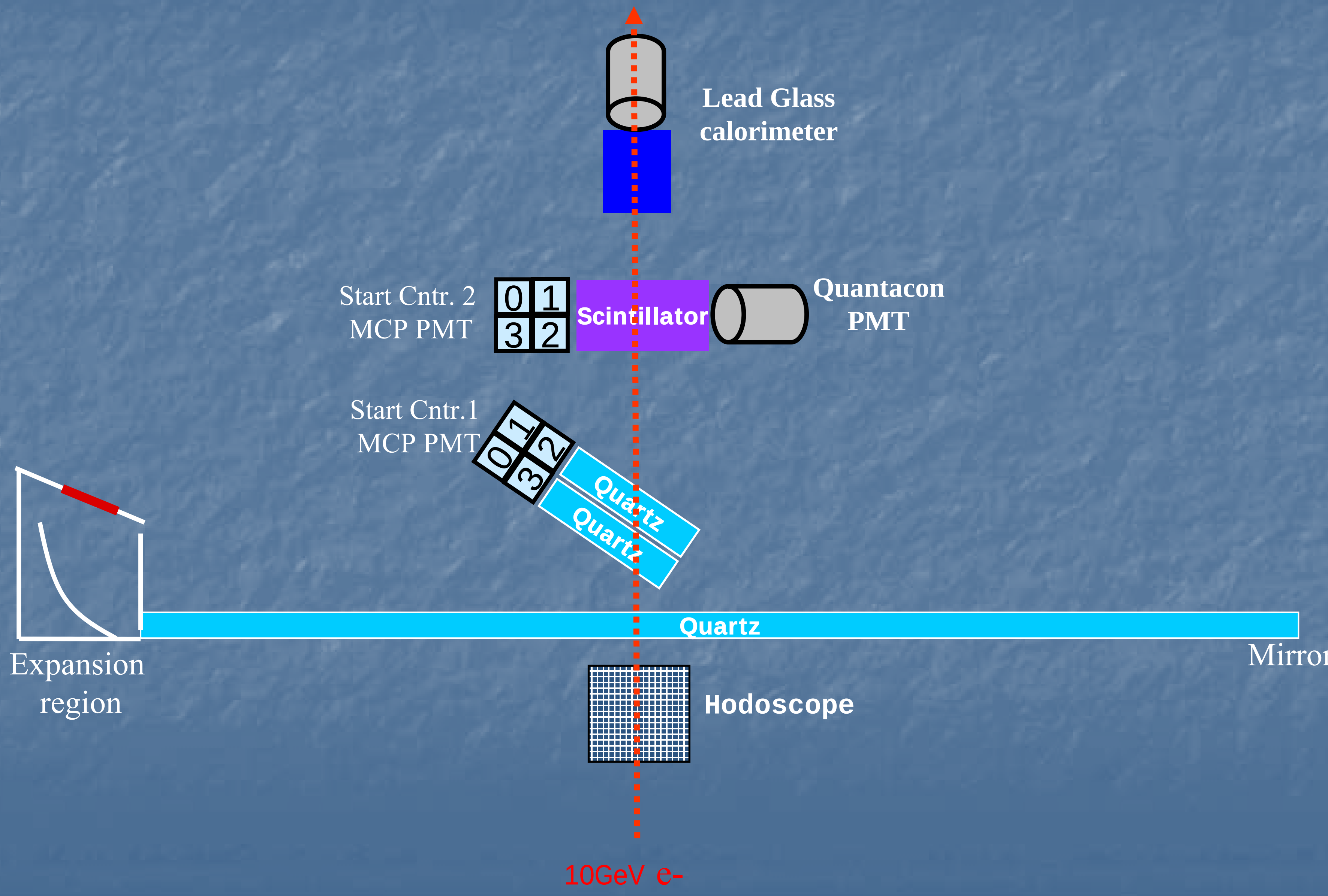
- The detector plane is placed at an optimal position. Offsetting the detector plane does not help in focusing the outer slots.
- Ring aberration is mainly due to bar effects.

PART II

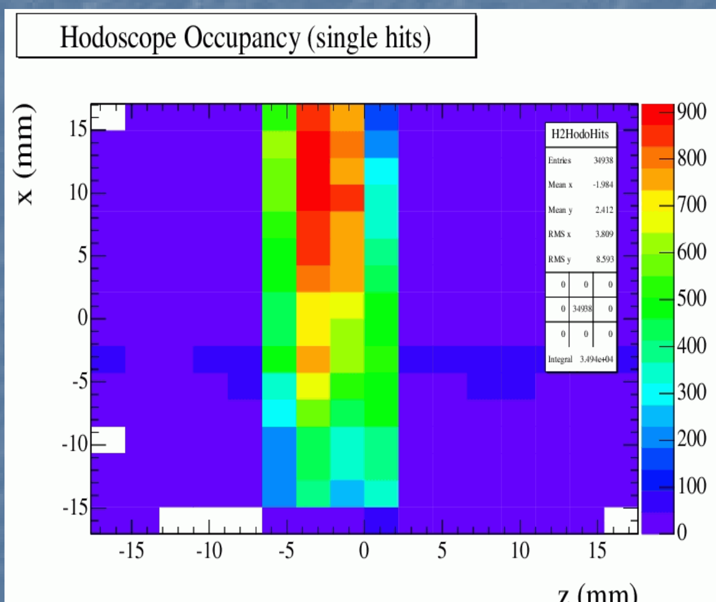
Event selection and start time resolution in the beam test.

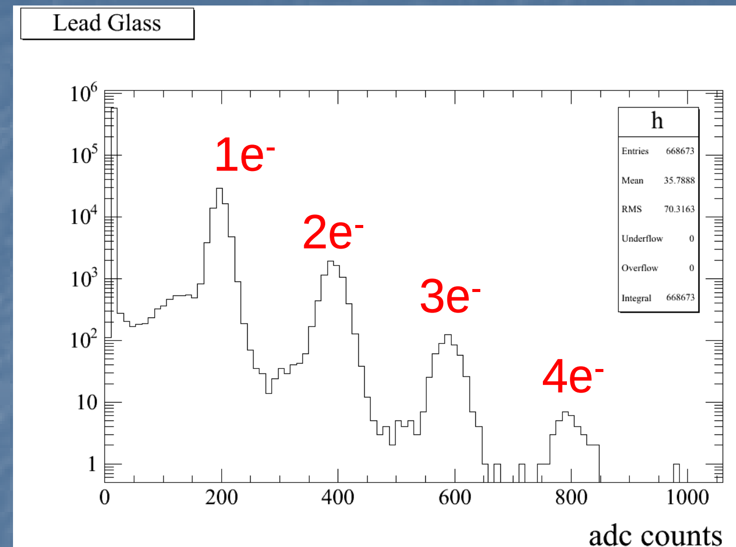
- Event Selection.
- Start Counter 1.
- Start Counter 2.
- Quantacon.
- Precise Start Time.
- Resolutions for different runs.

End Station A Set Up

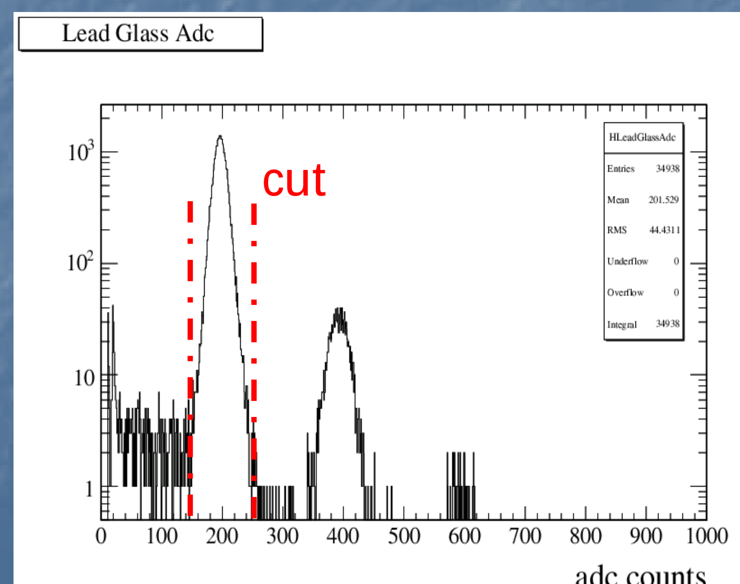


Event Selection





Before single hit hodoscope cut

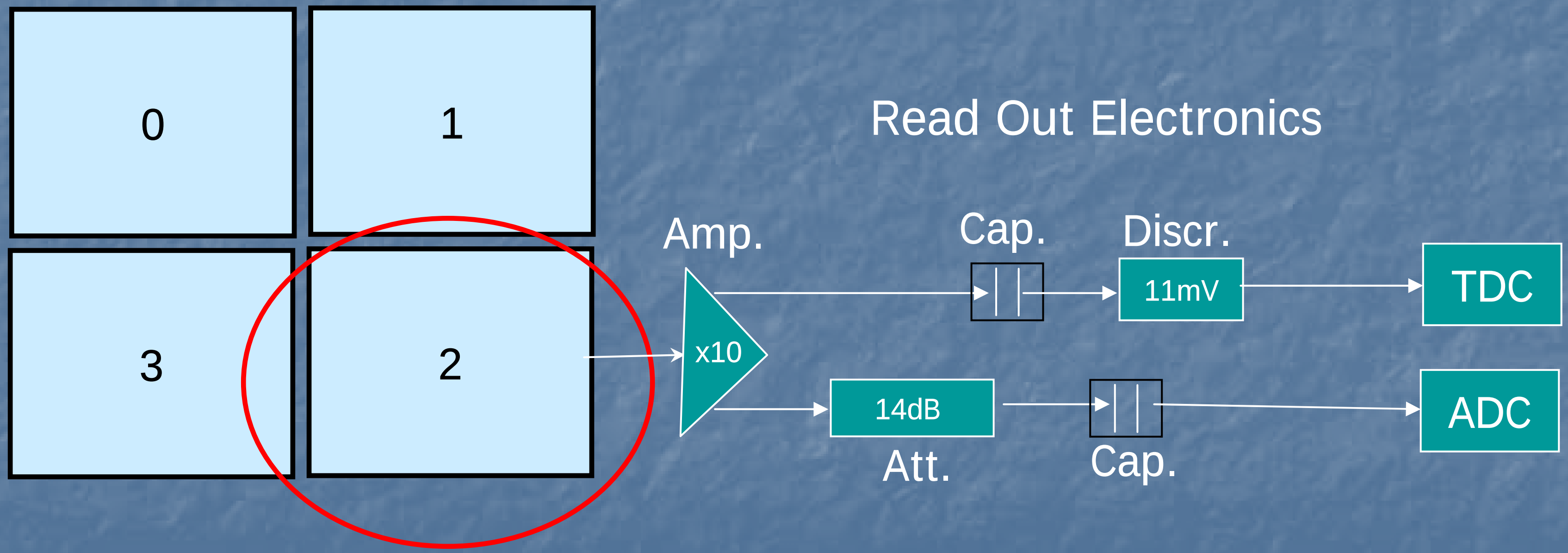


After single hit hodoscope cut

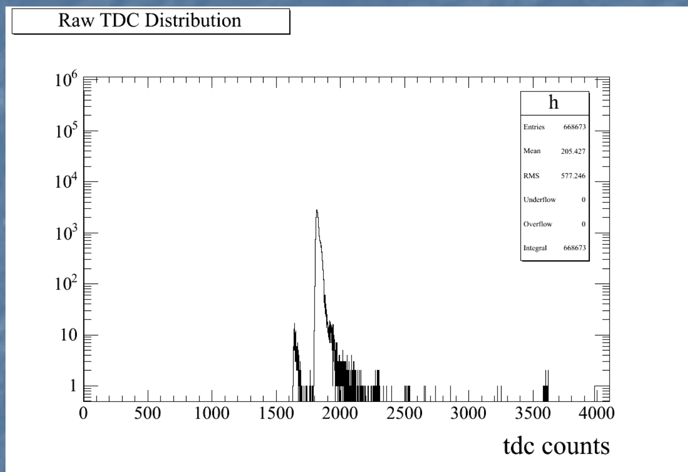
Data From Run 12

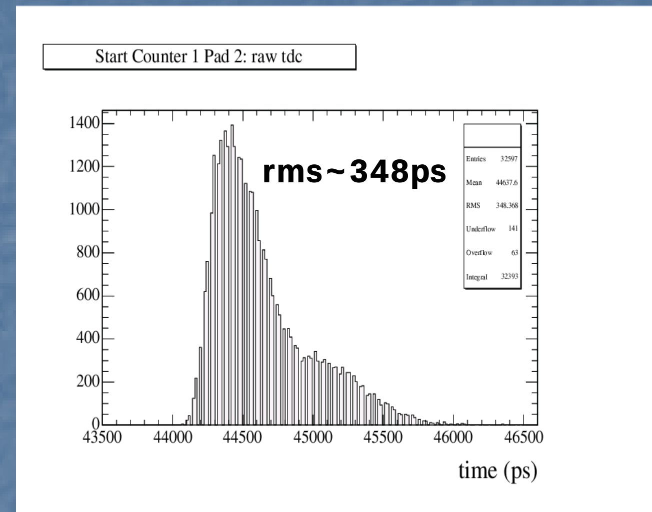
Start Time Resolution

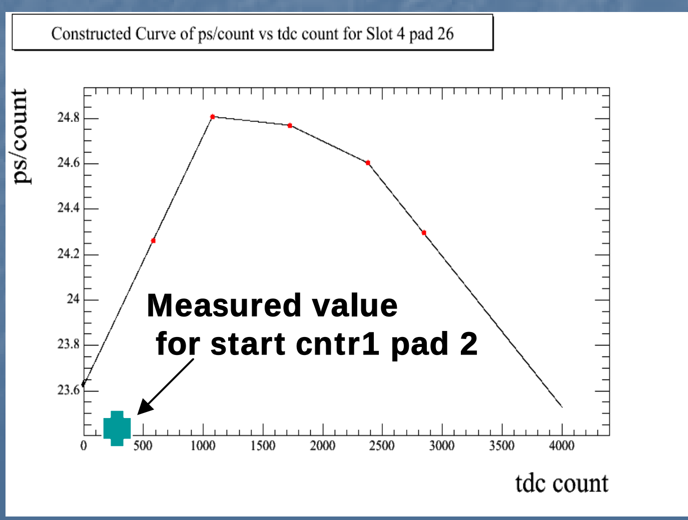
Consider analysis of one pad:
Start Counter 1 Pad#2



Conversion From TDC counts To Time





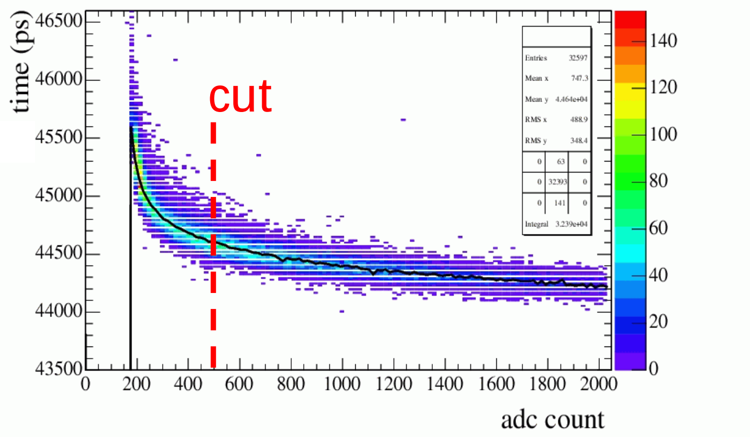


The ps/count calibration for this TDC channel was measured to be ~23 ps/count at about 300 tdc counts. This value is approximately consistent with the full calibration curves from the Prototype TDC's, therefore one of these calibration curves will be used to convert to time.

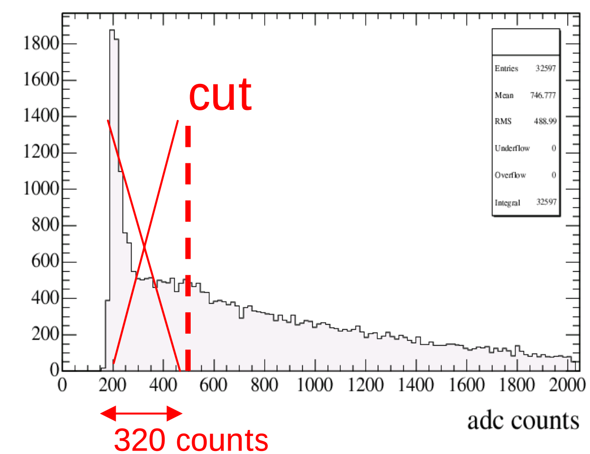
Data From Run 12

ADC Correction

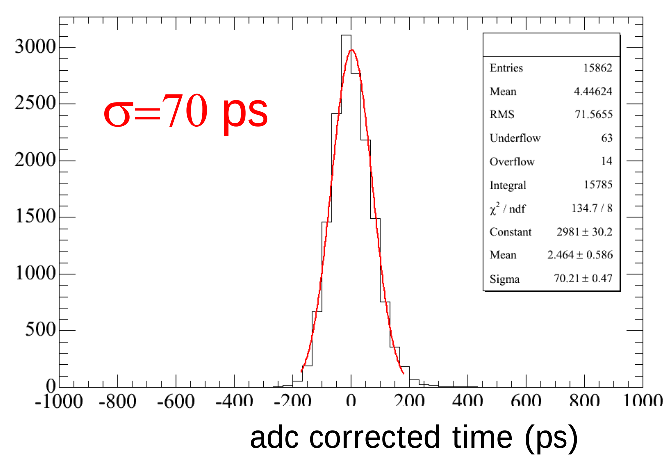
adc dependence



adc distribution



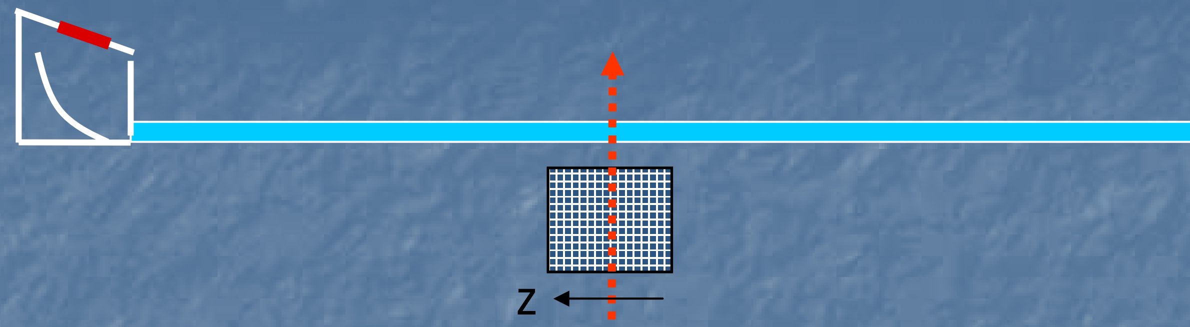
adc corrected time

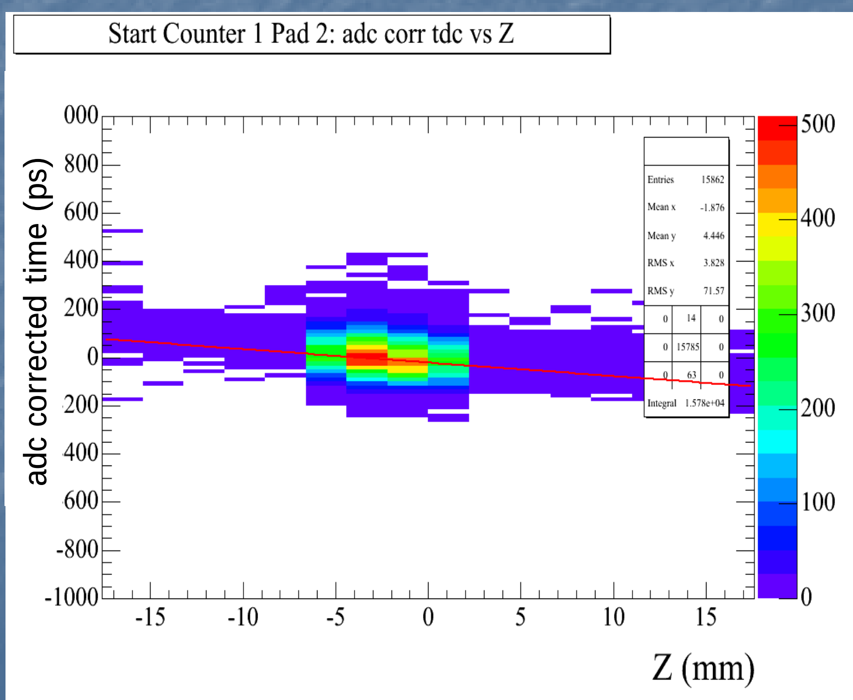


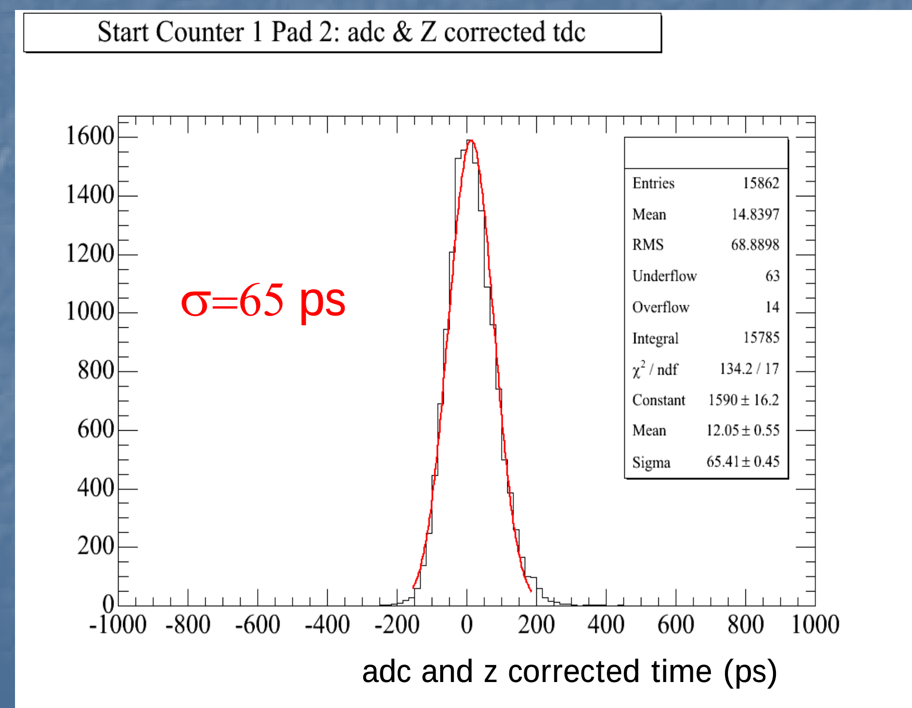
Data From Run 12

Track Position Correction

The start time should not depend on the track position.

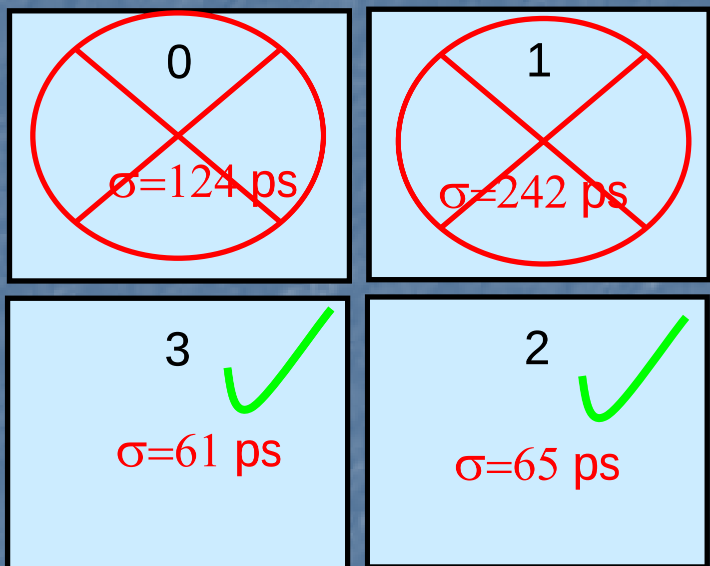


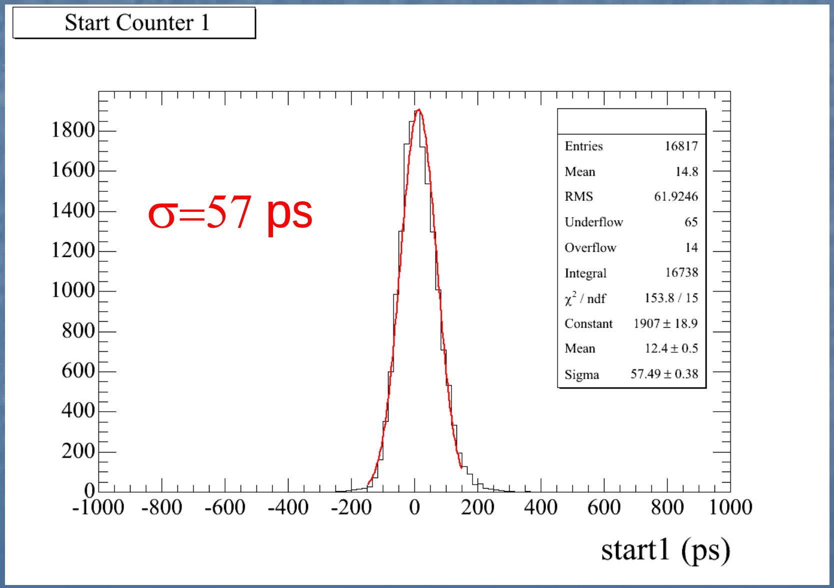




Data From Run 12

Start Counter 1 Final Pad Resolutions



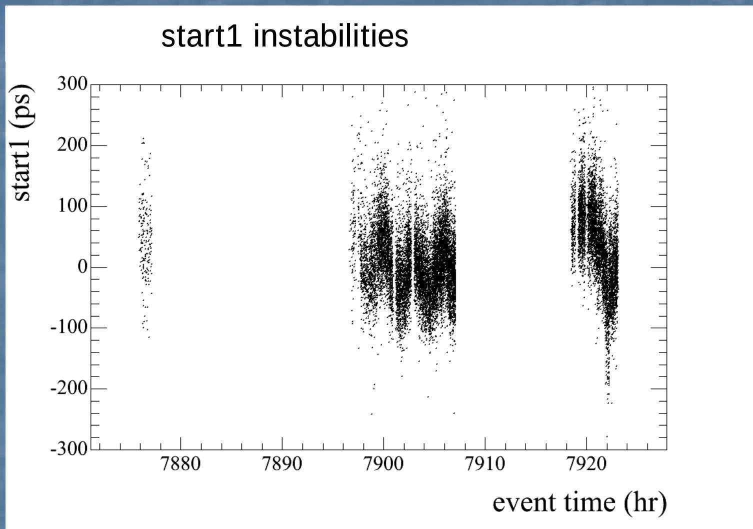


Use the 2 good pads:

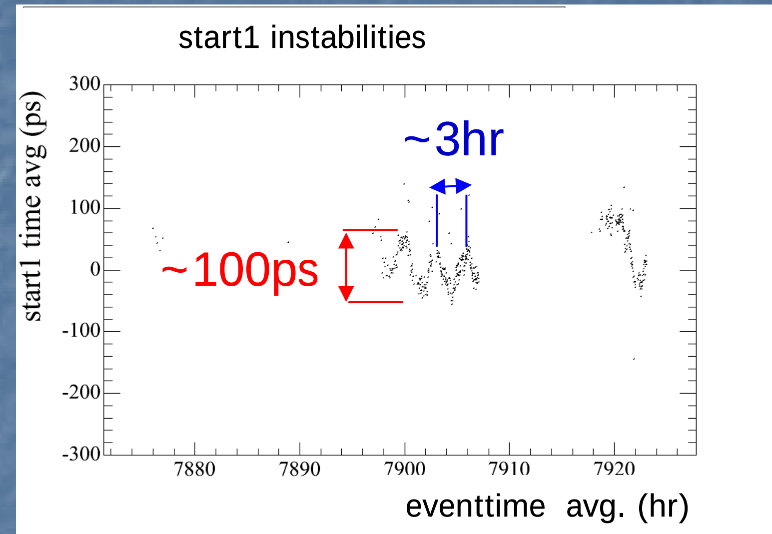
start1= avg. of pads which fire.
(require at least one hit)

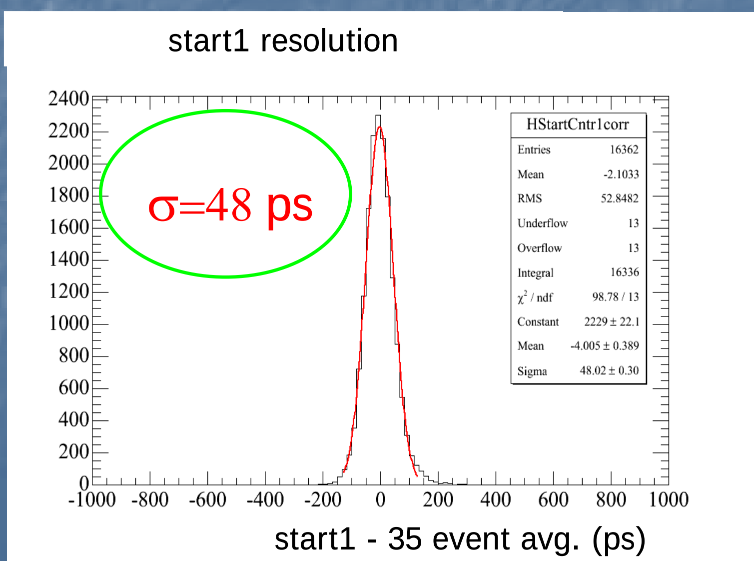
Data From Run 12

Instabilities in the start time.



Avg. every 35 events





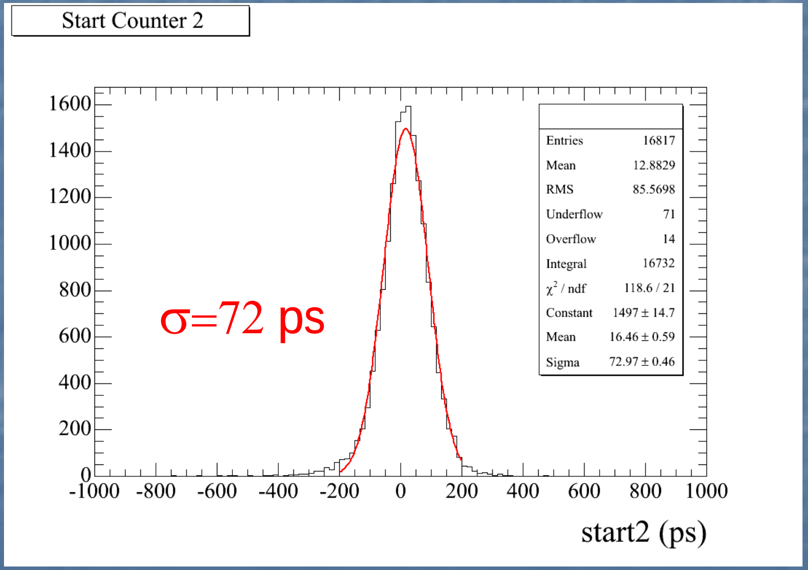
This is the resolution with which start counter 1 measures the instabilities.

Data From Run 12

The Start Counter 2

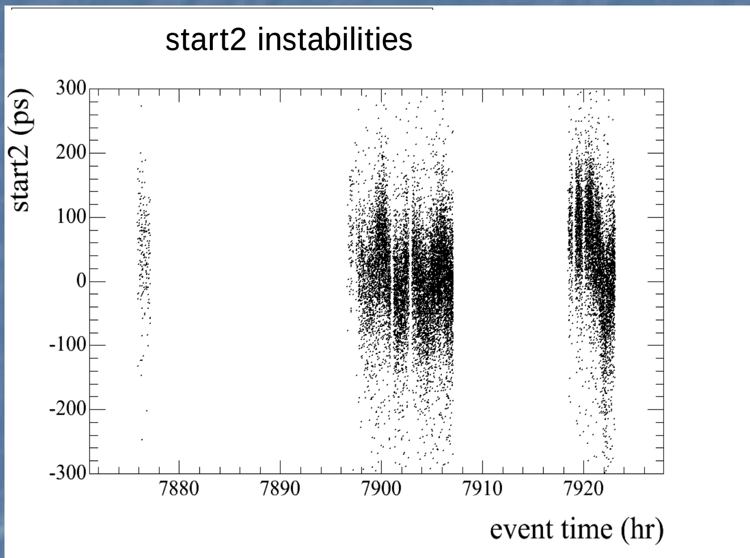
Use all 4 pads:

start2= Avg. of pads which fire.
(require at least one hit)

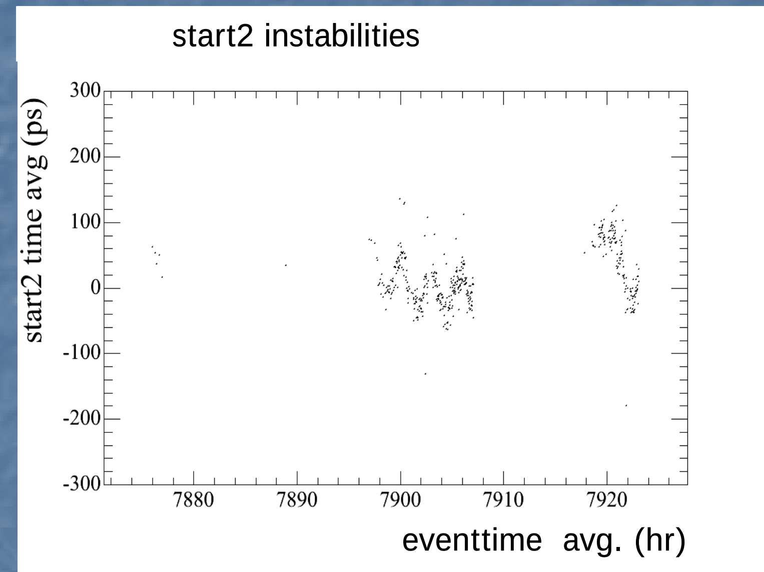


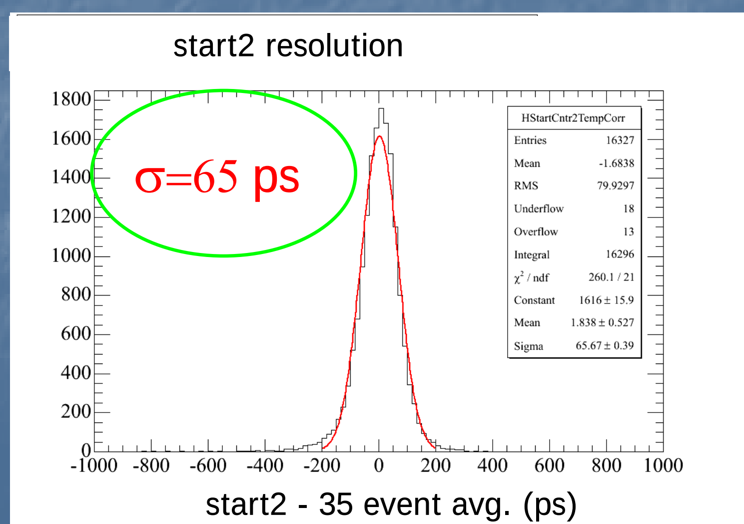
Data From Run 12

Instabilities Observed



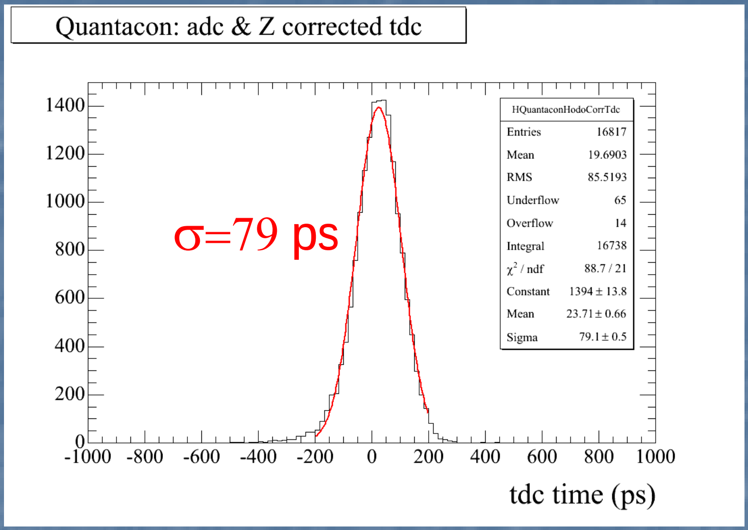
Avg. 35 events

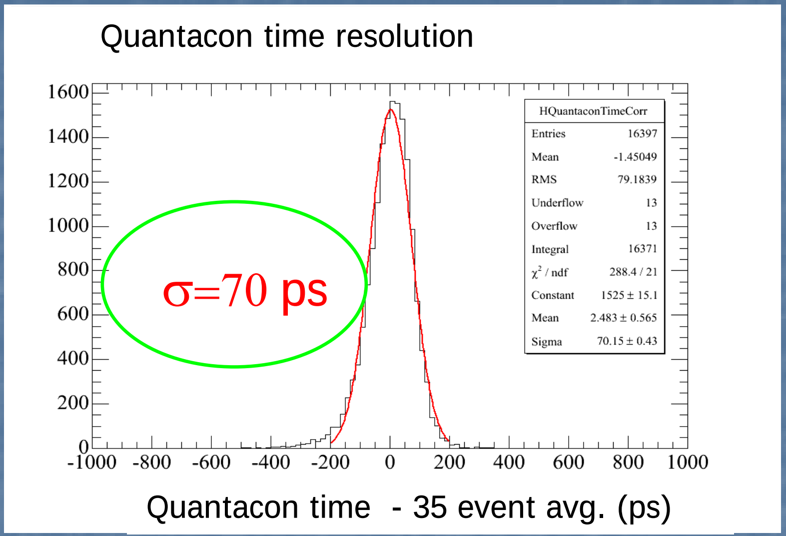


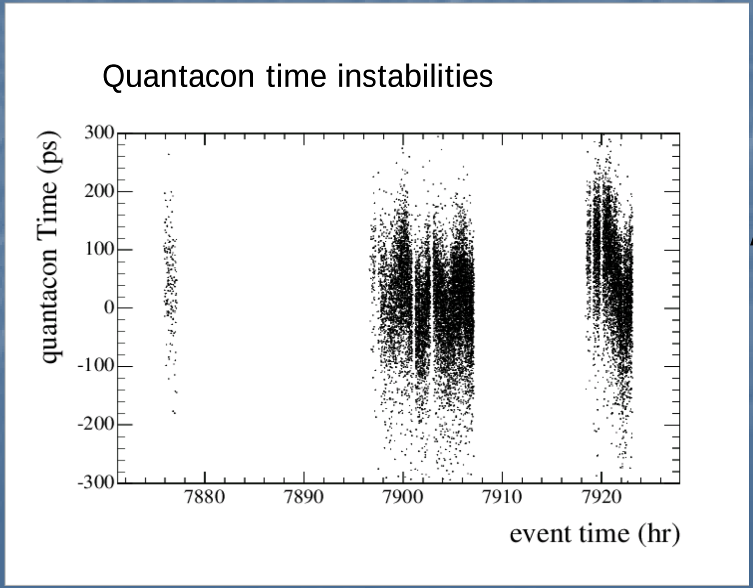


Data From Run 12

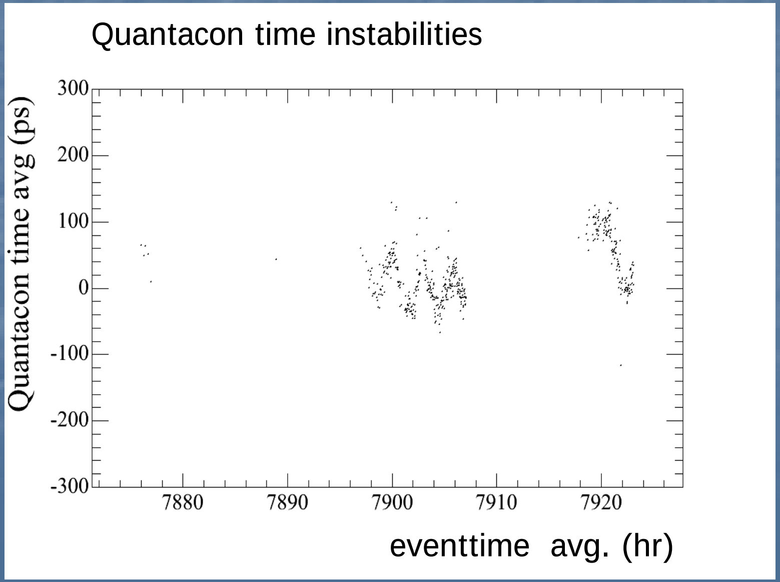
The Quantacon PMT





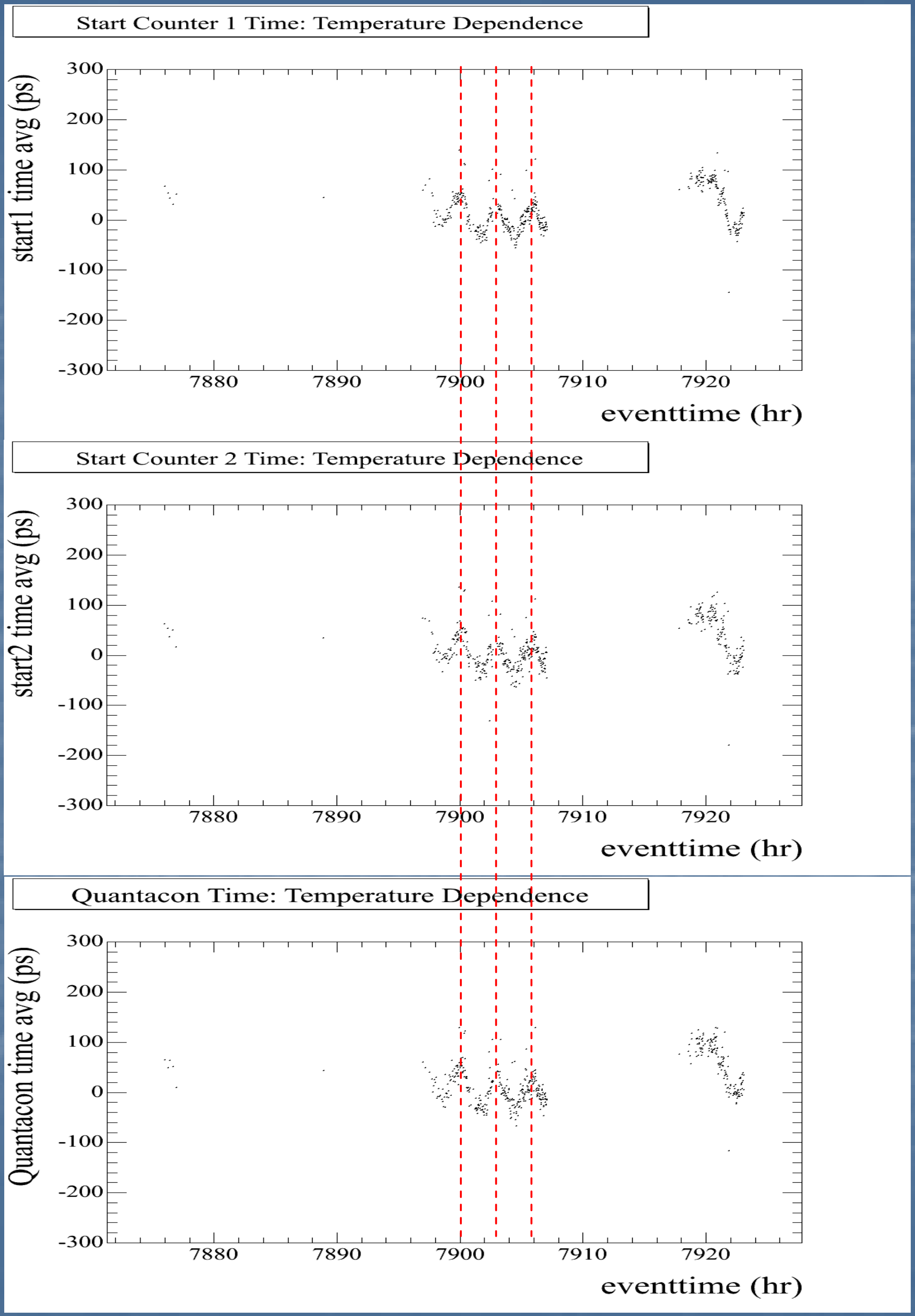


Avg. 35 events



Data From Run 12

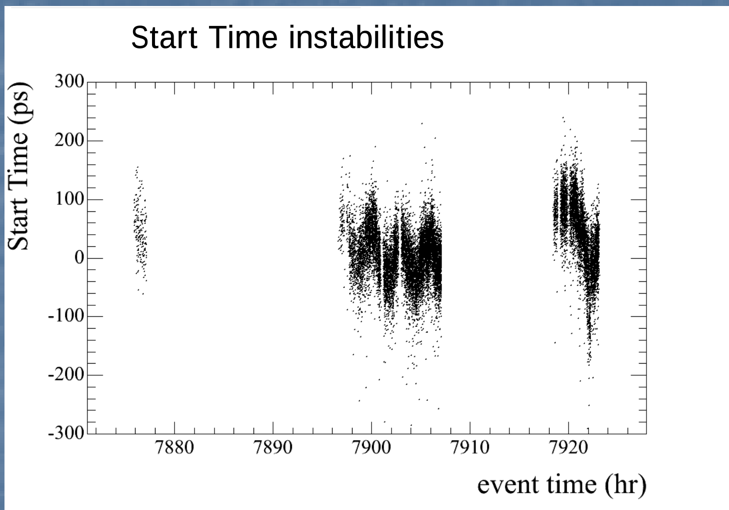
A closer look at the instabilities



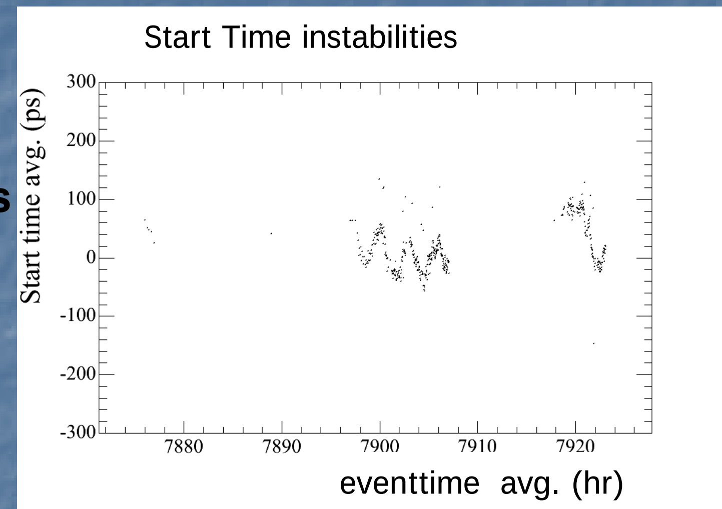
- All Beam detectors capture the instabilities.
- We can combine all three detectors and form a single start time.

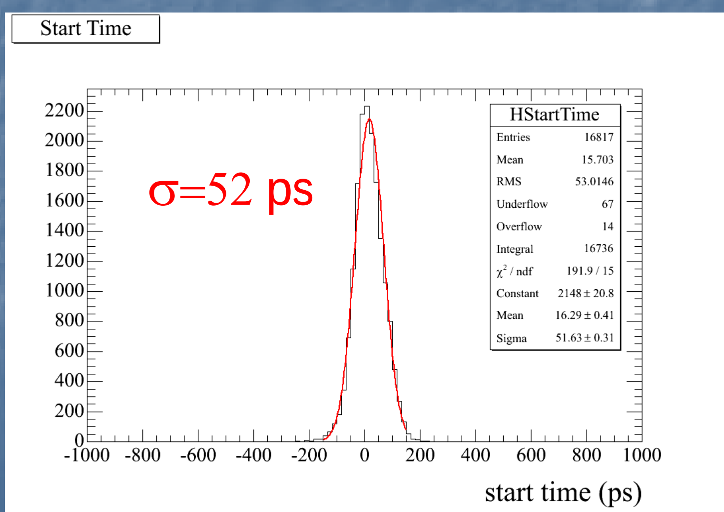
Precise Start Time

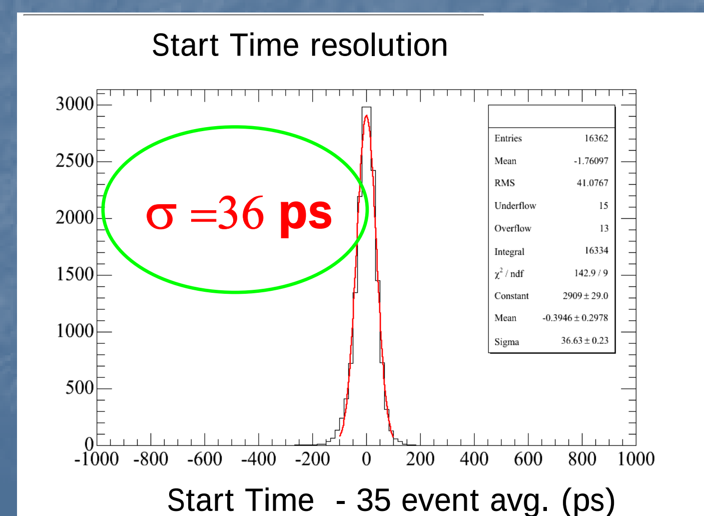
Start Time = (start1+start2+Quantacon)/3



Avg. 35 events



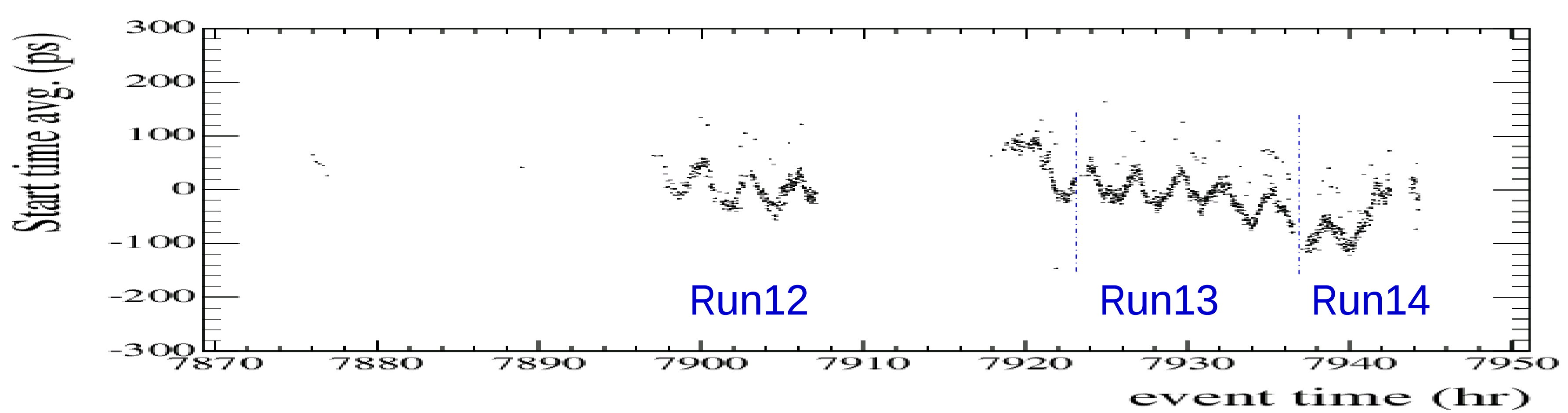




Data From Run 12

Time Resolution For All Nov. Runs

	Run12 (beam pos. 1)	Run13 (beam pos. 3)	Run14 (beam pos. 5)
Start1	48 ps	48 ps	69 ps
Start2	65 ps	65 ps	82 ps
Quantacon	70 ps	70 ps	73 ps
Start Time	36 ps	36 ps	50 ps



Part II: Conclusions

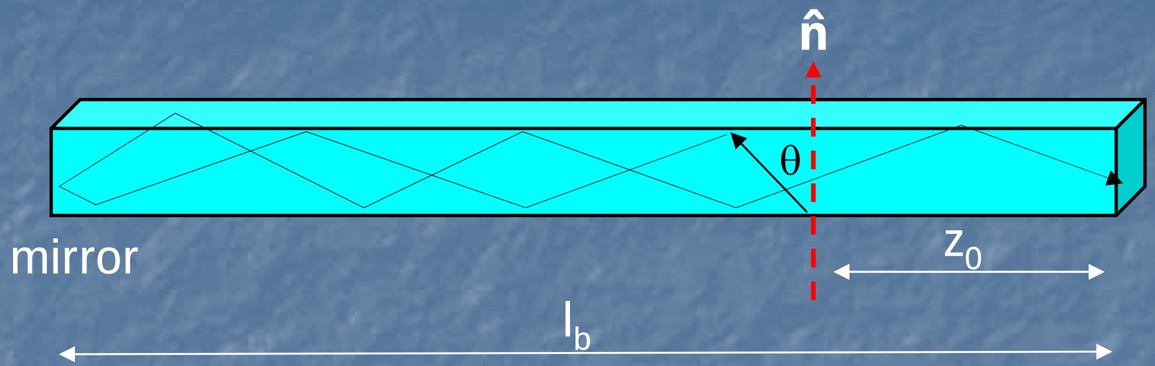
- The Start Counter 1 , Start Counter 2 and Quantacon all provide good start time resolution and work in phase with each other. When combined we can get up to 36 ps resolution in the beam test start time. This is, however, with a loss of ~50% in statistics after the hodoscope and lead glass cuts.
- The first two November runs (run12 and 13) show better time resolution than the last run (run14). This is correlated with pedestal instabilities in some adc channels also observed.
- At the moment it is not clear that the instabilities observed in the start time are actually in the signal from MCC. This start time correction does not seem to help the time resolution of the Prototype MCP's

PART III

Study of the contributions to the Cherenkov angle resolution measured with time using a simple toy Monte Carlo:

- Photon Generation.
- Two methods for reconstruction.
- Contributions to the ThetaC resolution.

Photon Track Descrition



The photon track is described by the following variables.

$$\mathbf{z_0}\ ,\ \hat{\mathbf{n}}\ ,\ \beta,\ \lambda,\ \theta,\ \varphi,\ \mathbf{L},\ \mathbf{v},\ \mathbf{T}$$

not all independent.

In this toy Monte Carlo specialize to photons with the following parameters:

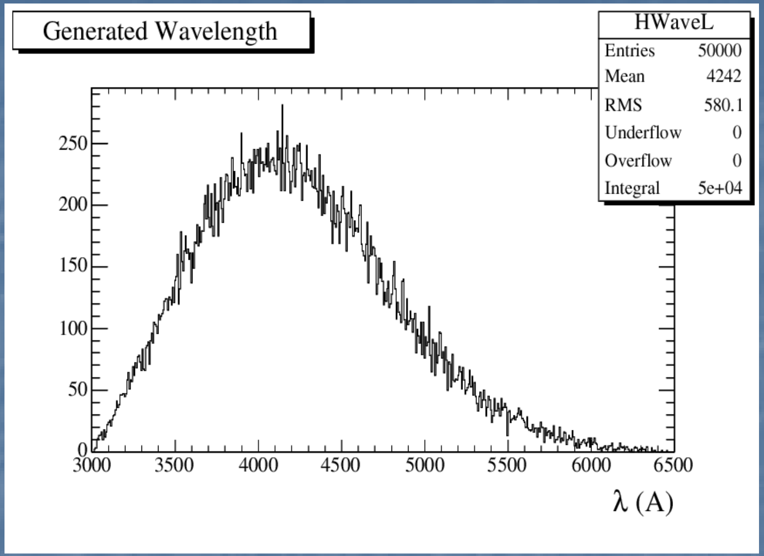
1. z_0 for beam position 1
2. $\hat{n}$ normal to the bar.
3. $\beta=1$ for 10GeV electrons
4. φ fixed for indirect photons traveling straight down the bar

these parameters are adequate for photons detected in slot 4.

We are left with the following variables to vary: λ, θ, **L, v, T**

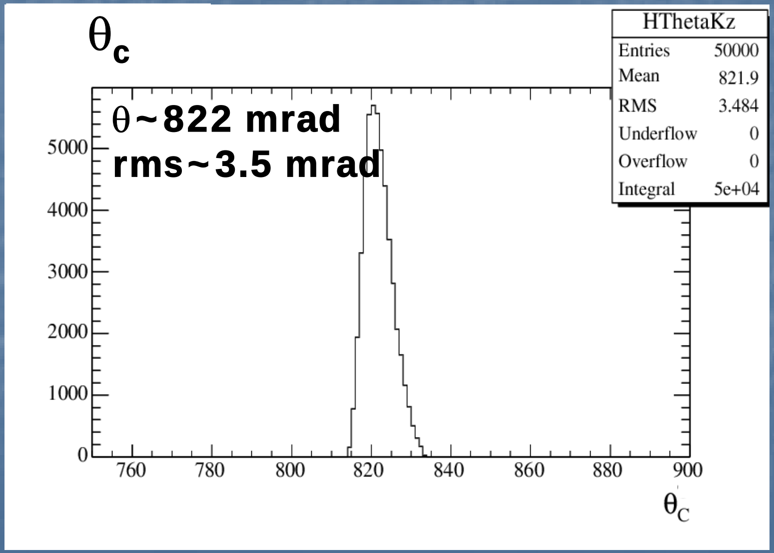
Photon Track Generation

1. Produce λ according weight function*:



2. Calculate θ using Cherenkov equation:

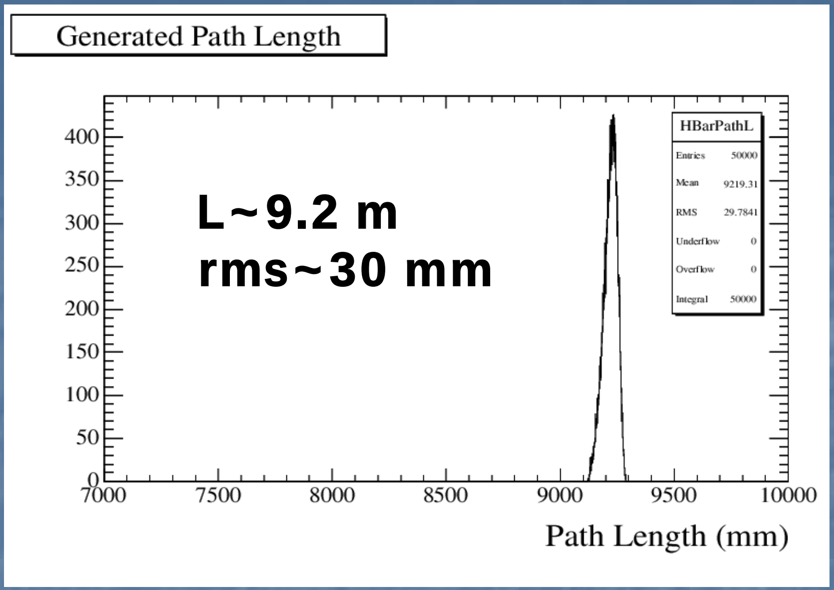
$$\theta_c = \cos^{-1}\left(\frac{1}{\beta n(\lambda)}\right)$$



* Derivation of Weight function can be found in my logbook

3. Calculate the path length:

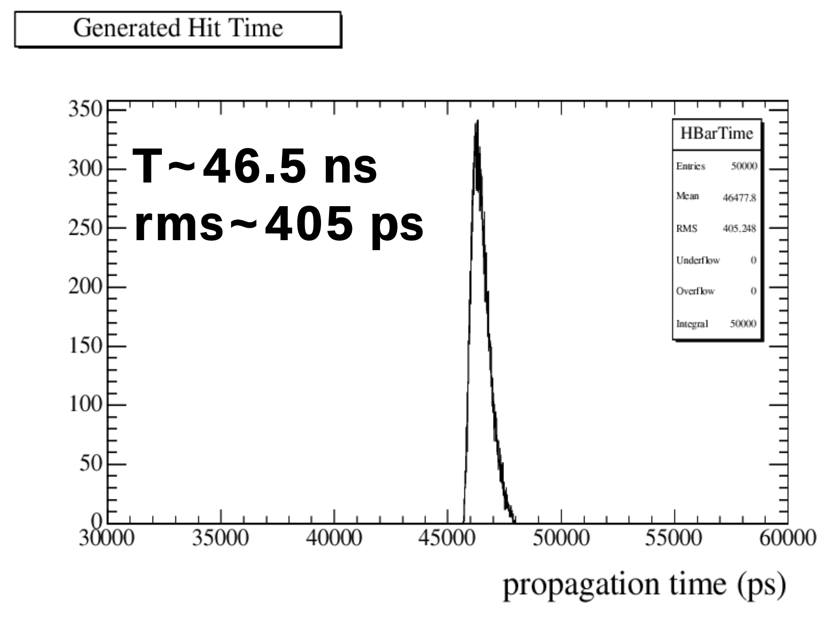
$$L = (2\, l_b - z_0) / \sin\theta$$

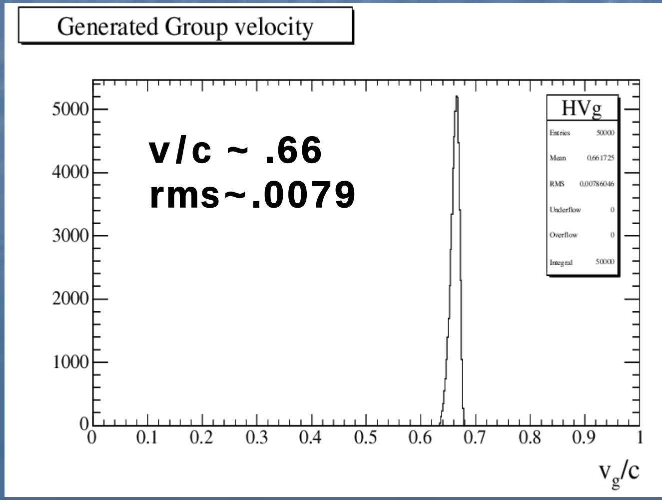


4. Calculate time T:

$$T = L / v$$

where $v = c / n_g(\lambda)$

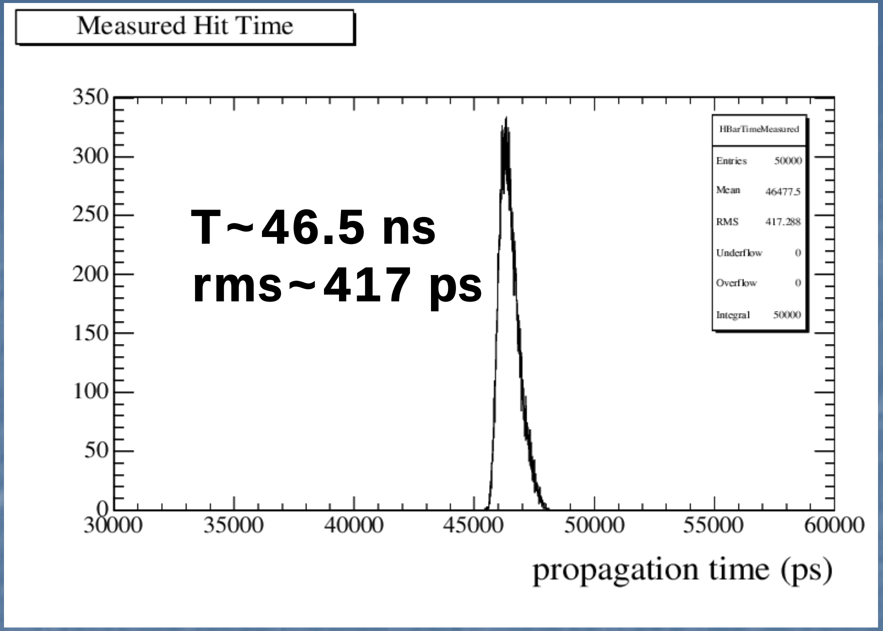




Measurement and Reconstruction: Method 1

1. In this method the only variable we measure is T.

   Assume our time resolution is
   100 ps
   and smear T using a Gaussian distribution.

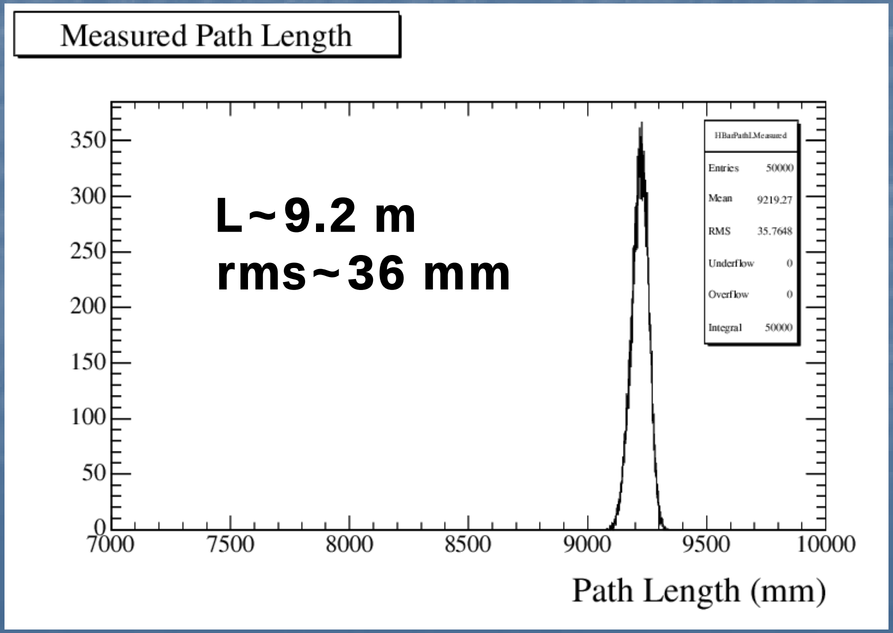


2. Assume all photons have same speed

   $v = \langle v \rangle = c/n_g(\lambda=410\text{nm}) = \textit{constant}$

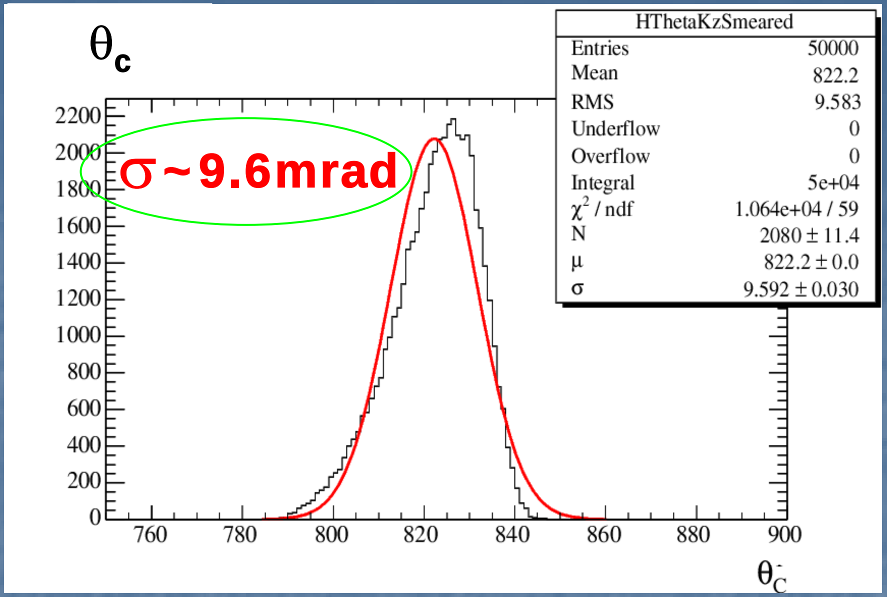
   then estimate the path length

   $L = T\langle v \rangle$



3. Calculate θ_c :

$$\theta_c = \sin^{-1}\left(\frac{2l_b - z_0}{L}\right)$$



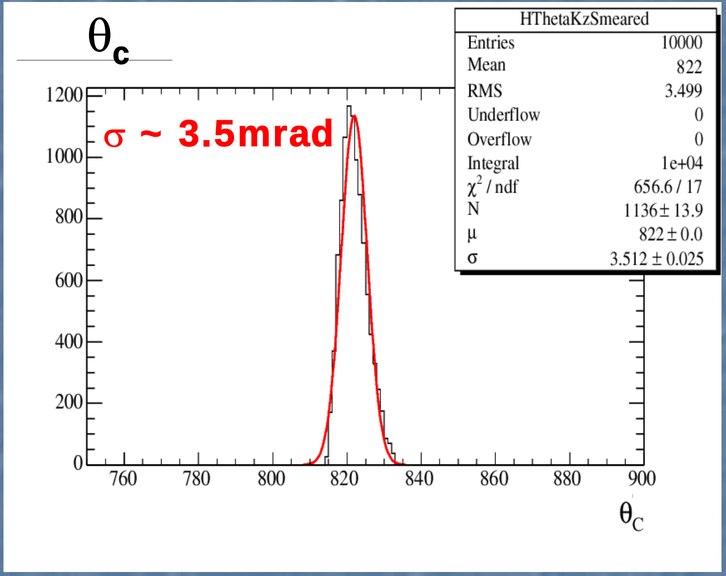
θ_c resolution as a function of time resolution

SigmaT (ps)	SigmaThetaC (mrad)
100	9.6
200	10.4
300	11.6
400	13
500	13.8

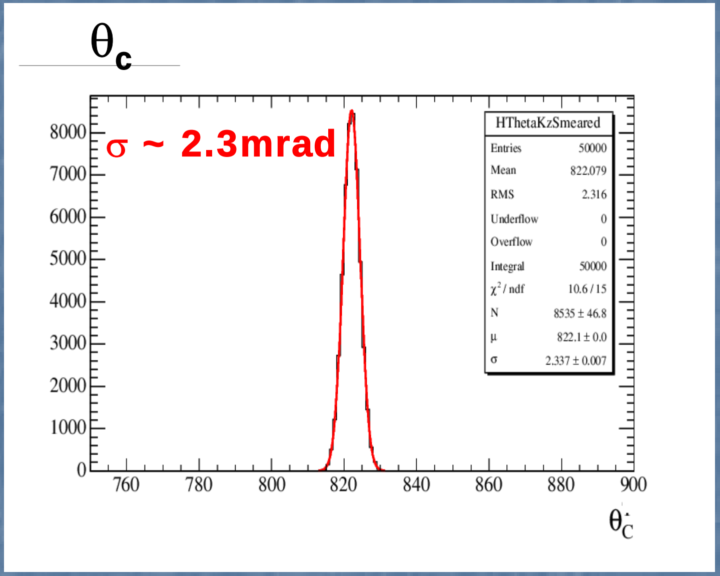
Contributions to the ThetaC resolution in Method 1

Monte Carlo settings:

- **Generate full λ distribution**
- **v=proper**
- **time error=0**



- **Generate only λ=410nm**
- **v=proper**
- **time error=100ps**



From these numbers we can deduce the contribution to the thetaC resolution from using a constant photon speed: v=<v>.

sqrt(9.6^2-3.5^2-2.3^2) = 8.6 mrad

Measurement and Reconstruction: Method 2

1. In this we method we measure two variables:

   T and L

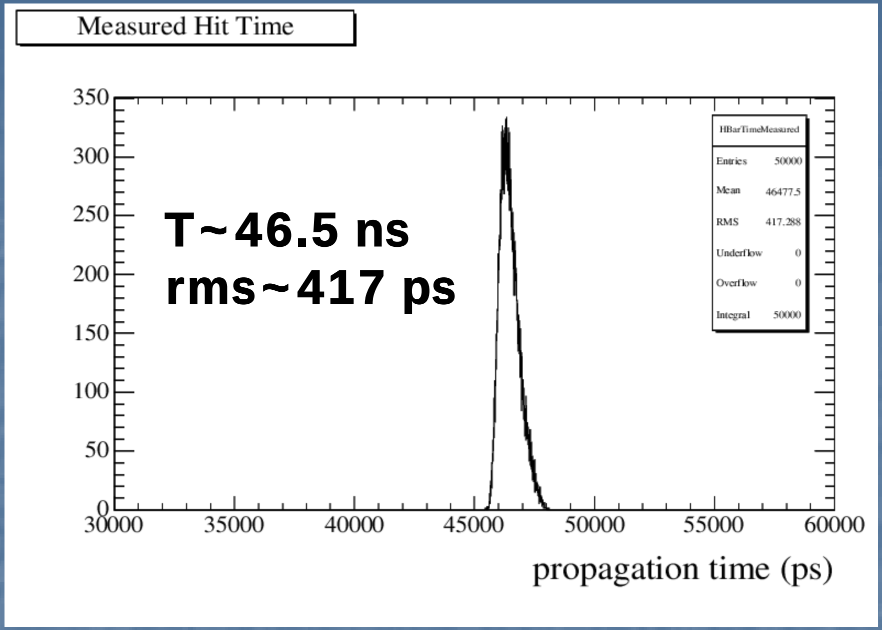
Assume our time resolution is

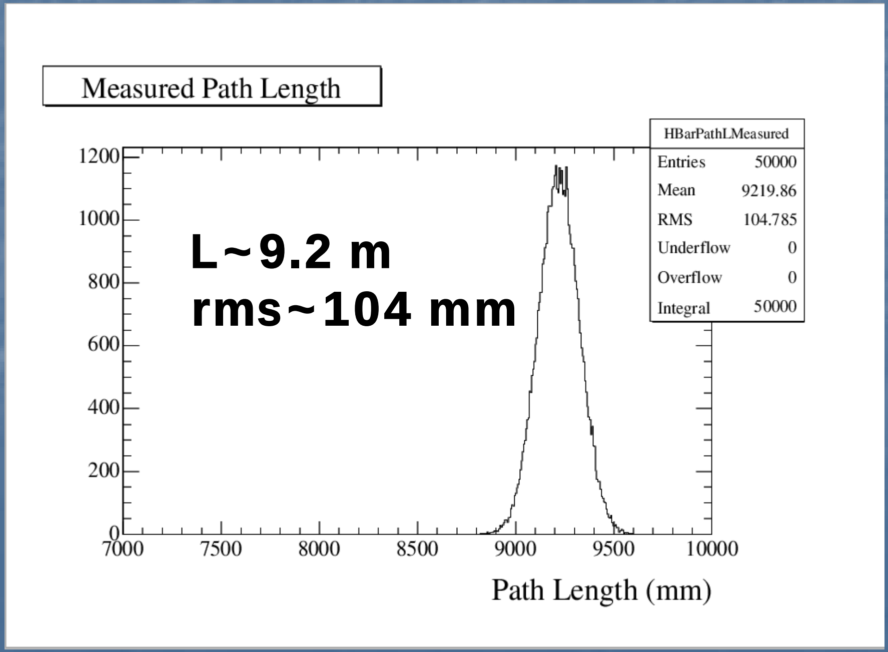
100 ps

also assume our path length resolution is

10cm

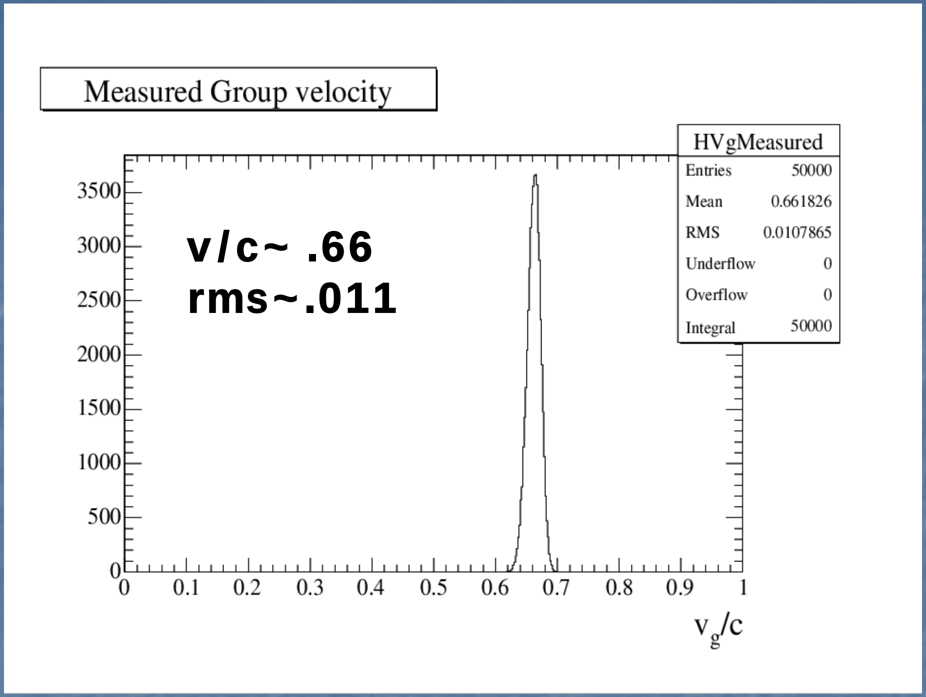
then smear T and L accordingly.





2. Calculate the velocity of the photon:

$v = L/T$



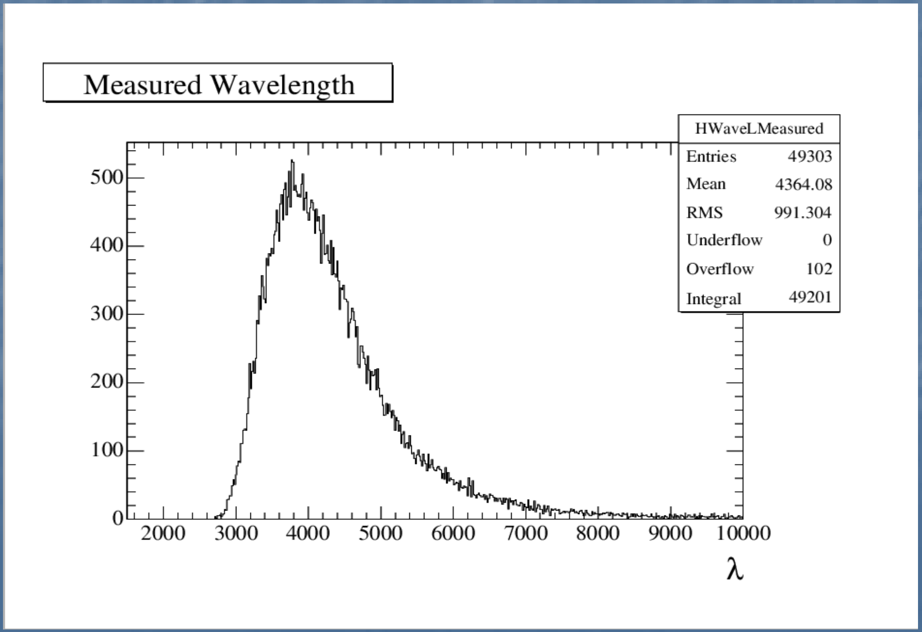
3. Deduce the wavelength of the photon from the formula

$v = c \, / \, n_g(\lambda)$

where

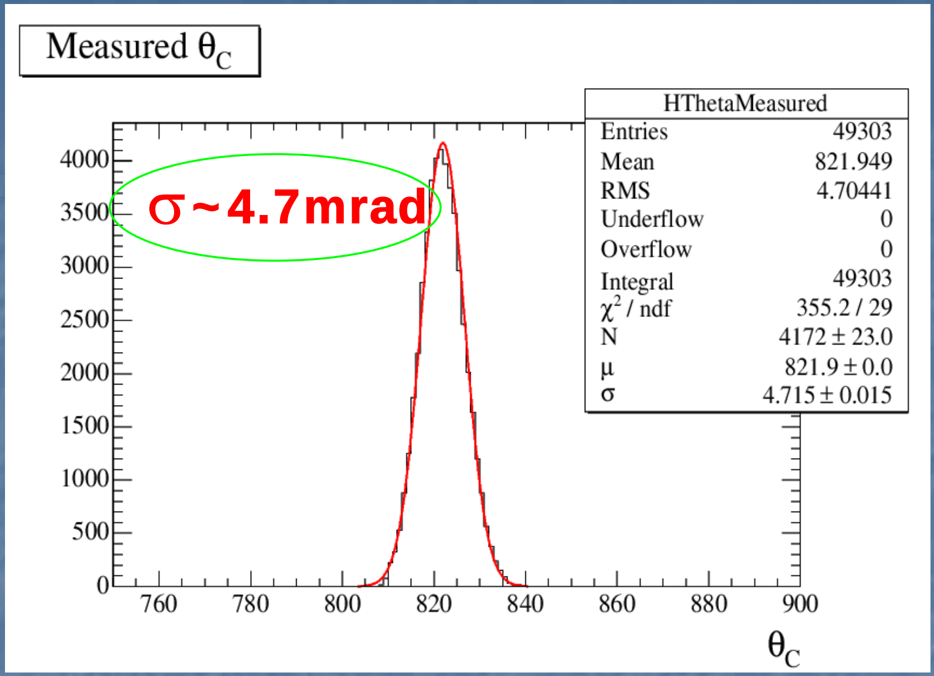
$$n_g \equiv \frac{n}{1 + \frac{\lambda}{n}\frac{dn}{d\lambda}}$$

and $n(\lambda)$ is the index of refraction of the quartz bar.



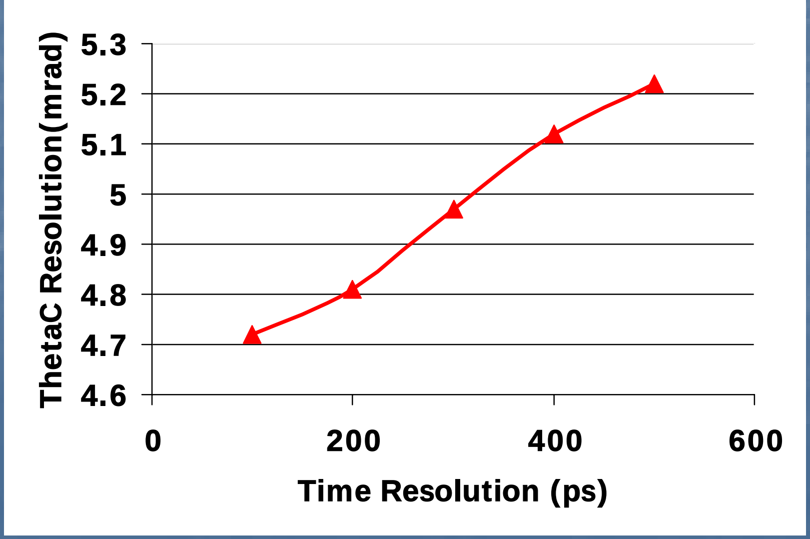
4. Finally, assuming we know the beta of the particle that produced the photon, calculate the Cherenkov angle.

$$\theta_c = \cos^{-1}\left(\frac{1}{\beta n(\lambda)}\right)$$



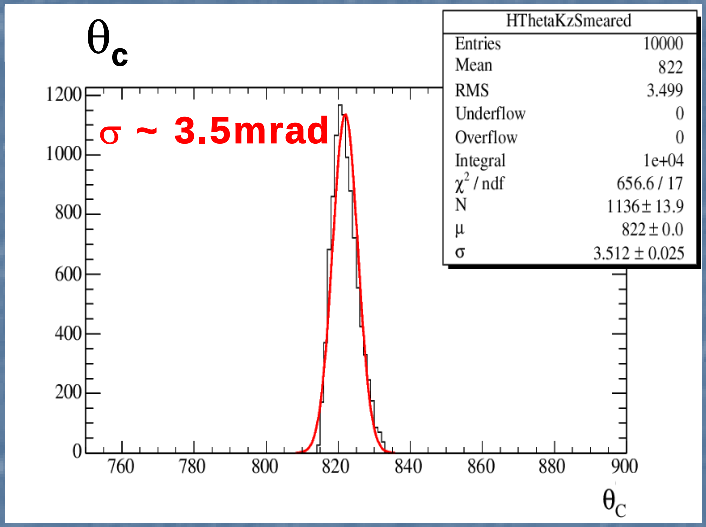
<u>ThetaC resolution vs. time resolution</u>

sigmaT (ps)	sigmaThetaC (mrad)
100	4.72
200	4.81
300	4.97
400	5.12
500	5.22

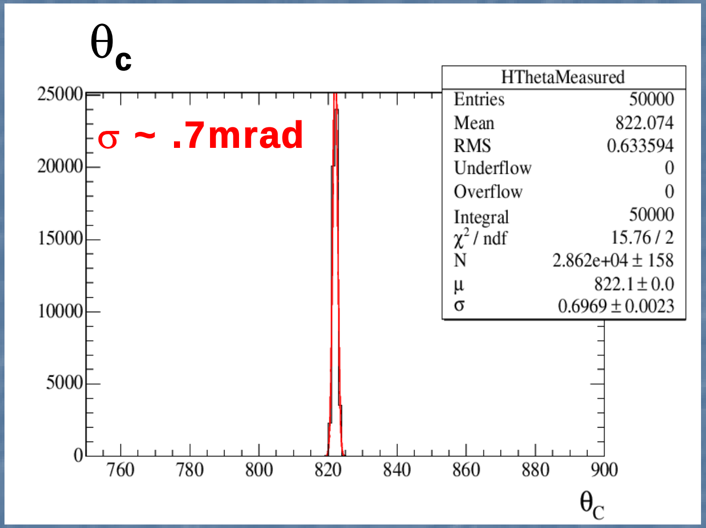


Contributions to the ThetaC resolution

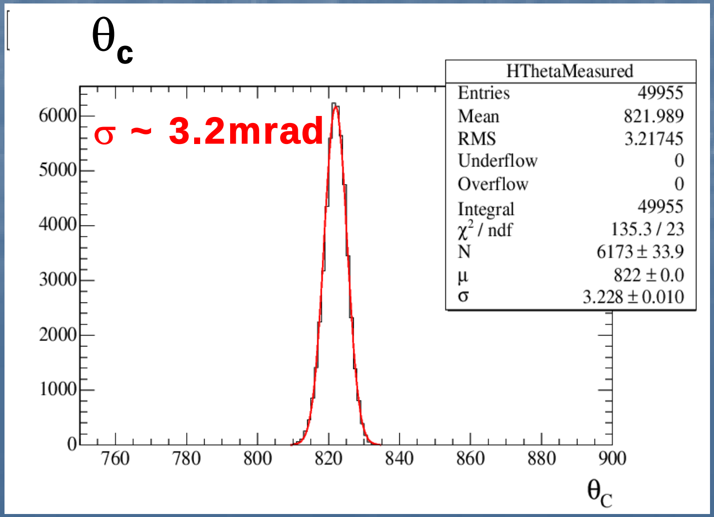
- Generate full λ distribution
- path length error=0
- time error=0



- λ = 410 nm
- path length error=0
- time error=100ps



- λ=410 nm
- path length error=10cm
- time error=0



Part III: Conclusions

- Generation of Cherenkov photons in this toy Monte Carlo is a simple process, and it will be extended to include the outer slots. To include different beam positions however may require to modify the weighting function for the wave length and to recalculate the error in the path length.
- Reconstruction Method 1 relies on the fact that the Cherenkov pulse travels down the bar at a speed determined by the opening angle of the Cherenkov cone. In this method the main contribution to the error comes from the fact that we don’t know the speed of the photon.
- Reconstruction Method 2 provides a precise measurement of the Cherenkov angle by assuming we know the β of the particle that produced the photon. In this example the main contribution to the thetaC resolution comes from production and the error in the path length.
- In both of these methods the time error does not play a significant role for the path length considered here, however at smaller path lengths the time error will give an important contribution to the thetaC resolution.