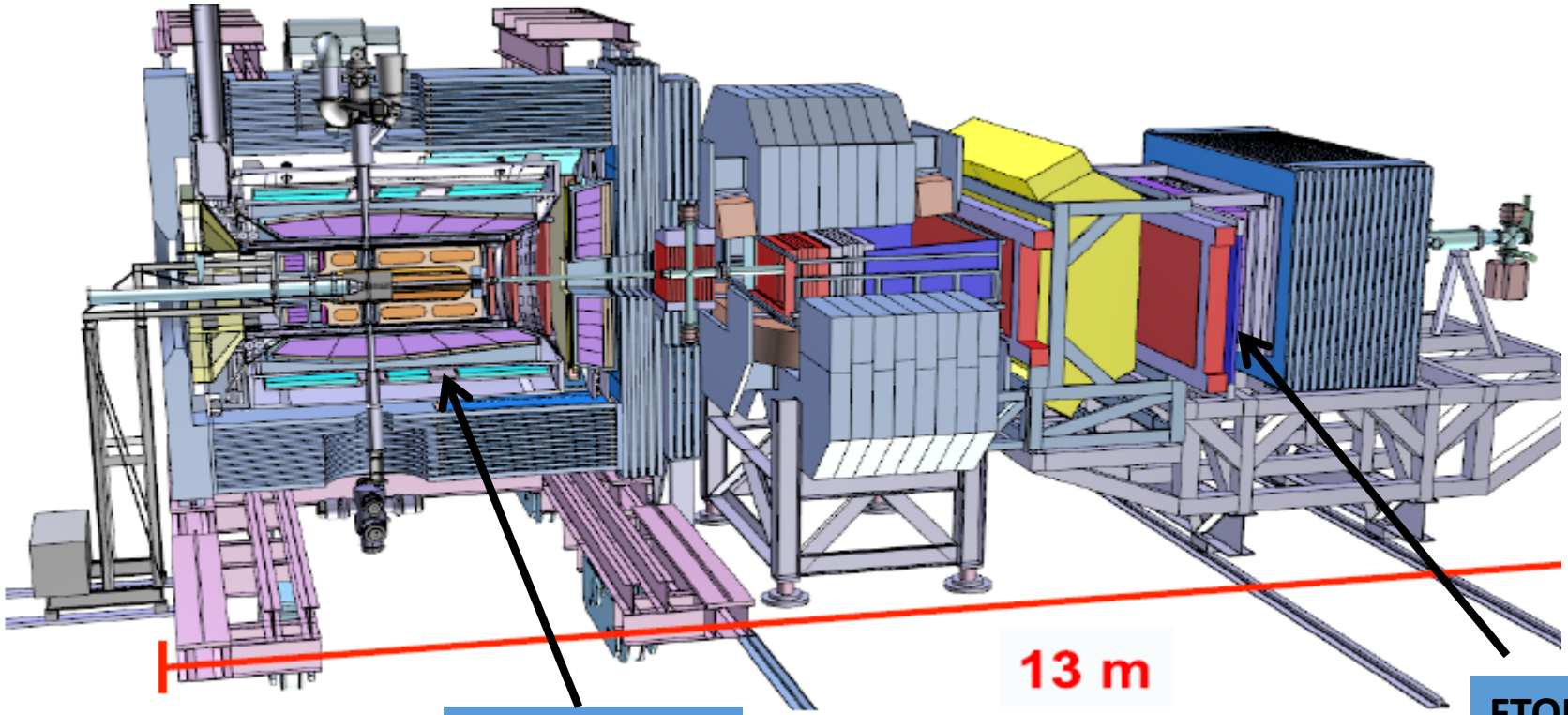
FTOF Wall: A slab testing with picosecond pulsed diode laser

Gleb Fedotov

Petersburg Nuclear Physics Institute

Panda Collaboration meeting
PID TOF session

PANDA FTOF Wall Detector



Time resolution below 100 ps

FS acceptance 10 deg.x 5 deg about 50%
produced particles detected

FTOF Wall Functions

- **PID of forward emitted particles using time-of-flight information for low momentum hadrons**

  protons < 4.GeV/c, kaons < 3. GeV/c, pions < 2.5 GeV/c
  close to or below forward RICH threshold
  provided
  time resolution is about 50-100 ps
  FS momentum resolution must be no worse 0.01,
  FT reconstruction δL_{track} ~ few mm

- **Event start stamp reference time T_0**

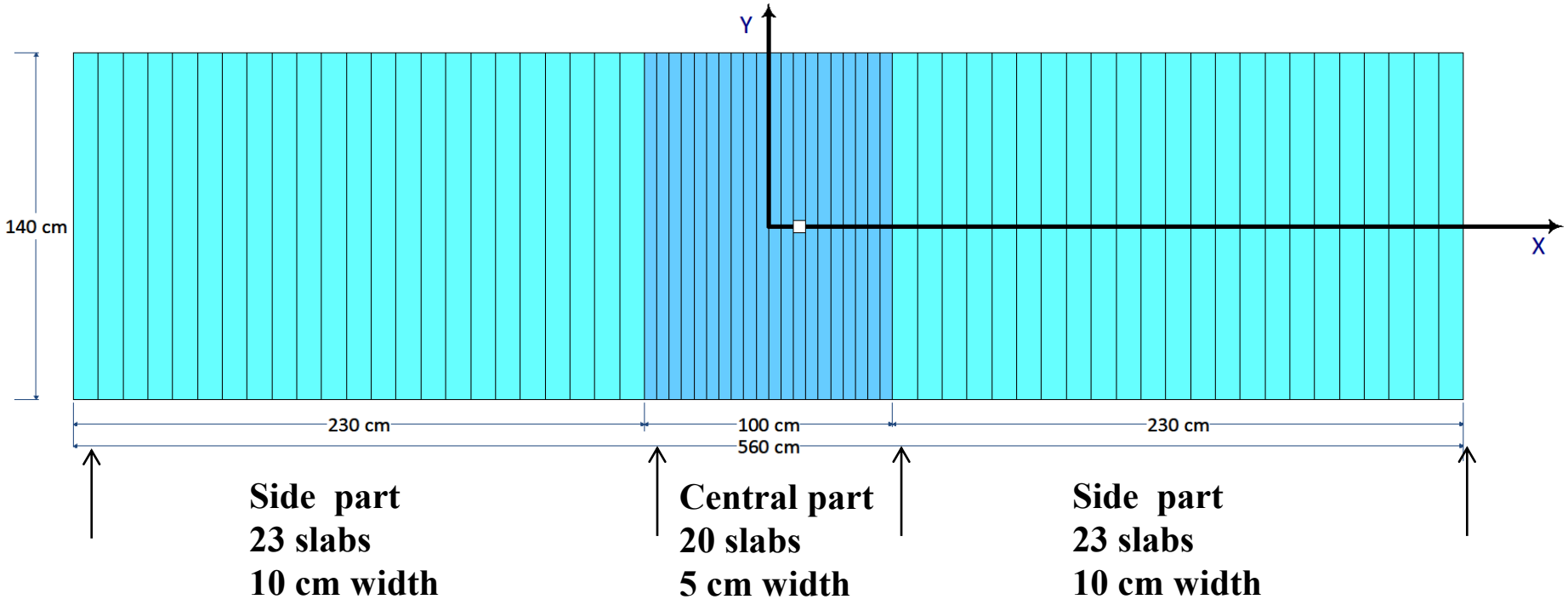
  provided a particle independently identified
  e.g. with FRICH or EMC(FSC) or Forward muon system

- **Energy deposition information**

  expected energy deposition range
  from 5 to 50 MeV

FTOF Wall Design

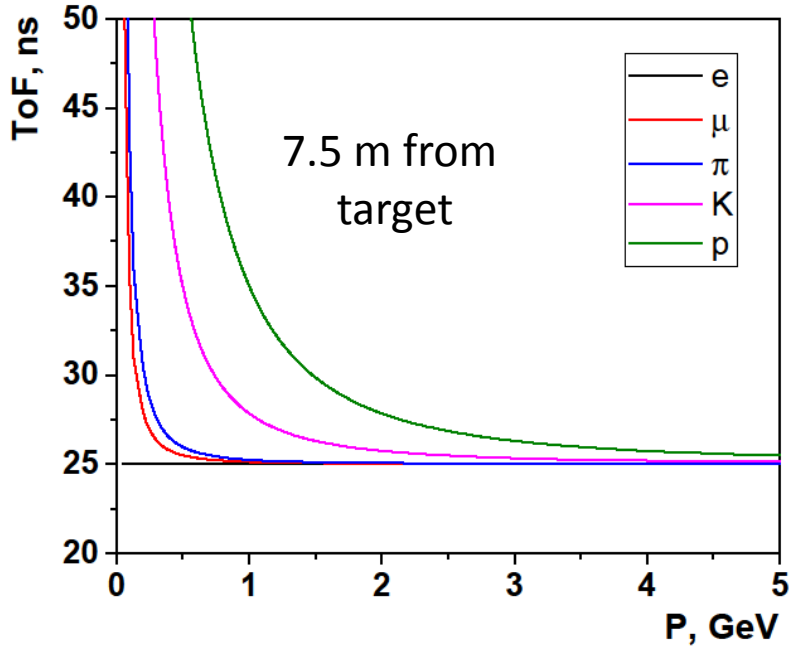
The wall can be built of commercially available plastic scintillation slabs and fast photodetectors. Sensitive area is 560 cm (width) x 140 cm (height)



Granularity : counting rate below 1 MHz at HL PANDA regime

Comment. The beam pipe diameter at this z-location is 180 mm. i.e. 4 slabs to be cut.

FTOF Wall Hadron Id



$$m = p\sqrt{\frac{t^2}{t_c^2} - 1}, \qquad \frac{\delta m}{m} = \sqrt{\left(\frac{\delta p}{p}\right)^2 + \gamma^4\left(\frac{\sigma_{TOF}}{t}\right)^2}$$

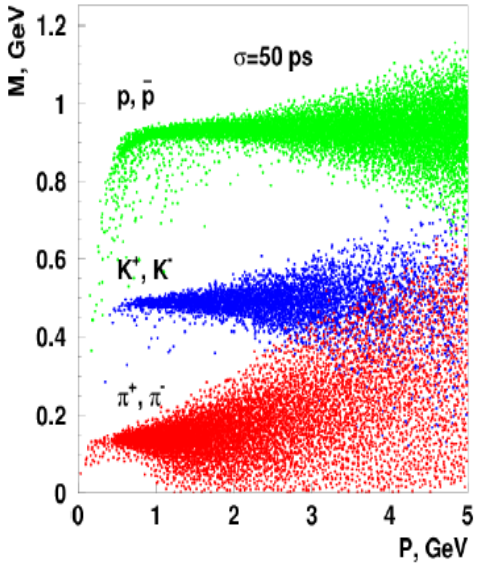
$$t_c = L_{track} / c$$

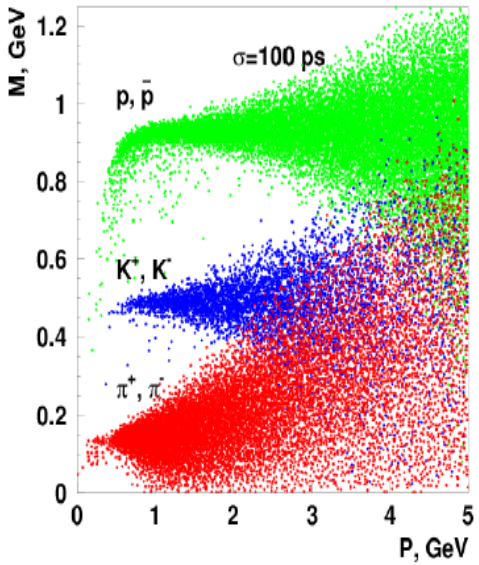
At FS momentum resolution $\Delta p/p=0.01$

TOF resolution σ_{TOF} = 50 or 100 ps

σ=50 ps
Proton/ kaon separation < 4.5 GeV/c
Kaon/pion separation < 3 GeV/c

σ=100 ps
Proton/ kaon separation < 3.5. GeV/c
Kaon/pion separation < 2.5 GeV/c





TDR Status

Technical Design Report for:

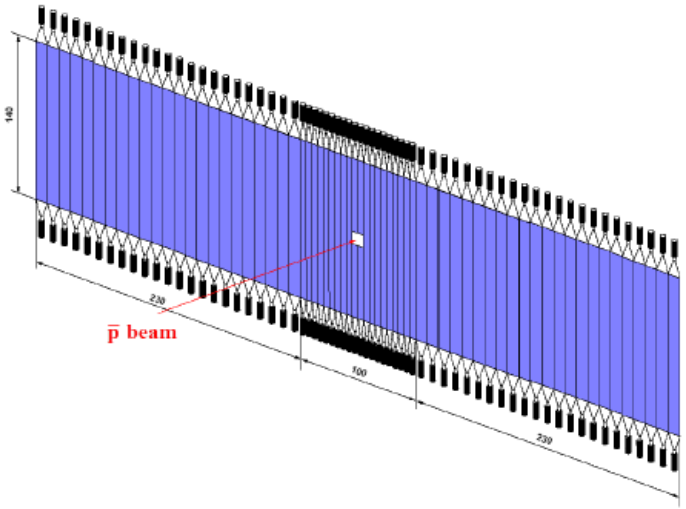
$\overline{\text{P}}$ANDA
Forward Time of Flight detector (FToF wall)

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

$\overline{\text{P}}$ANDA Collaboration

January 19, 2018



The FtoF wall TDR approved by the FAIR ECE.

Editors
Stanislav Belostotski
Oleg Miklukho
Yuri Naryshkin
Denis Veretennikov
Andrei Zhdanov
Anton Izotov

Technical Coordinator
Lars Schmitt
Deputy of TC
Anastasious Belias

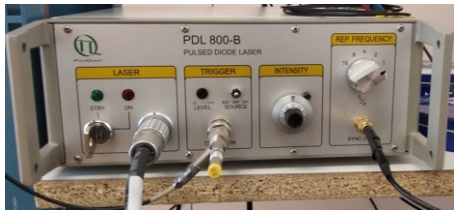
Spokesperson
Klaus Peters
Deputy of SP
Tord Johansson

Test Room Overview

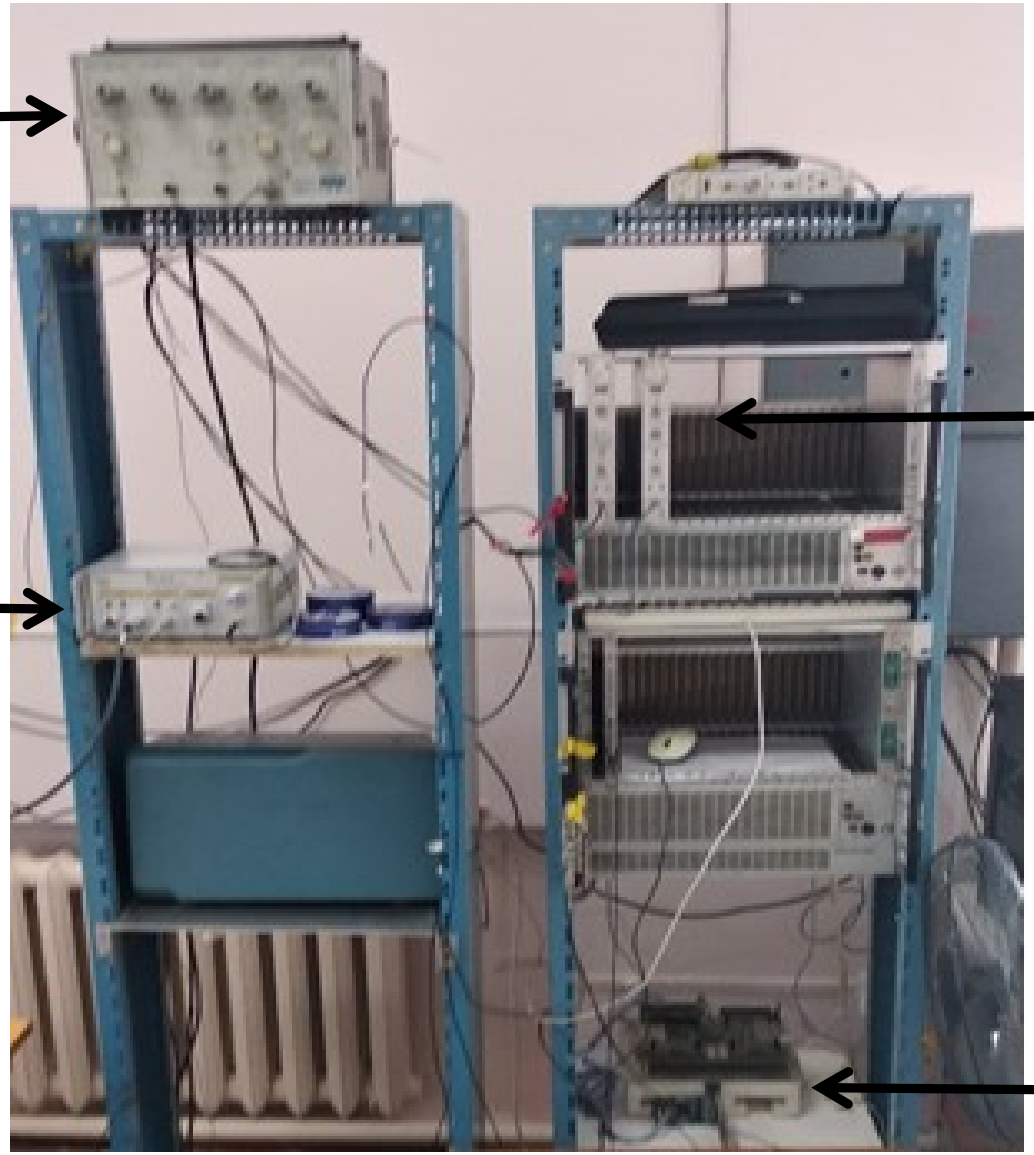
The Testing Electronics

Pulse generator

Picosecond pulsed diode laser started from the pulse generator



Laser specifications
Wave length 372 nm
Pulse width ~ 50 ps
Peak power – 1 W
Frequency 1Hz – 40 MHz

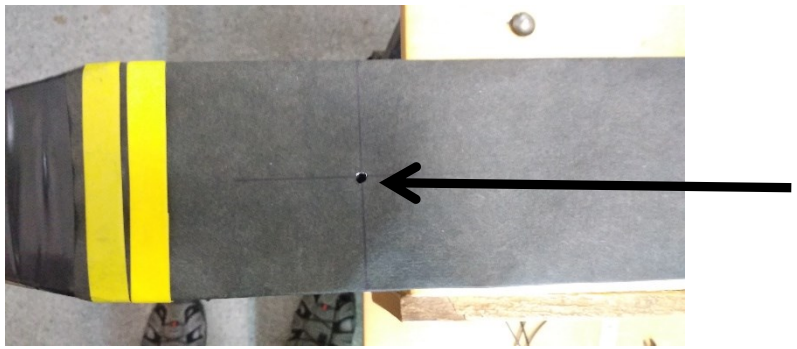


Two HV modules inserted in the crate

TRB3

The Investigated Slab

140x10x2.5 cm slab with lightguides and PMTs attached from both sides.
PMT 1 (left side of the plot) – Hamamatsu R2083 (HV was set to 2.7 kV)
PMT 2 (right side of the plot) – Hamamatsu R9779 (HV was set to 1.6 kV)



Three 5mm diameter holes in the wrapping materials were made along the slab. One in the center and one at a distance of 10 cm from each side.

PMTs properties

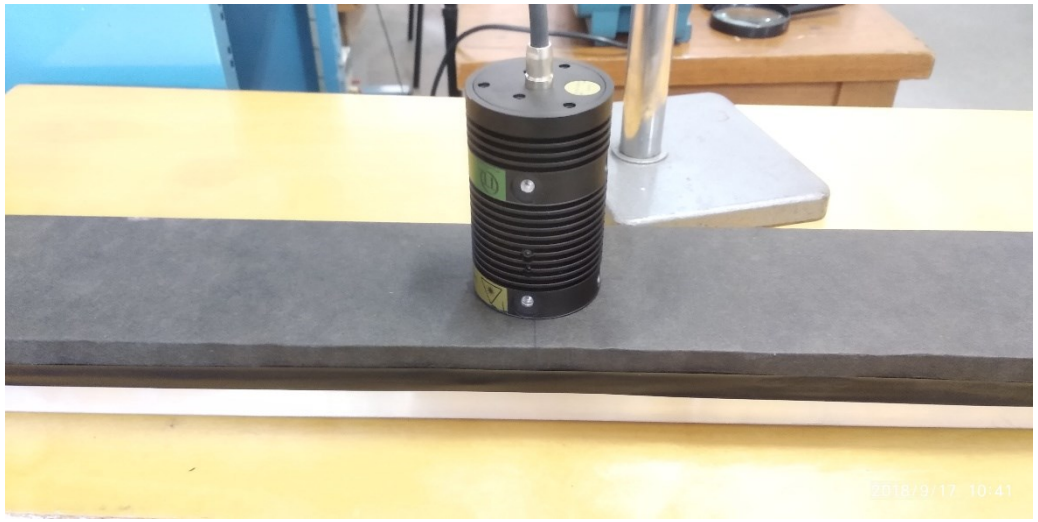
CHARACTERISTICS (at 25 °C) R2083

Parameter			Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856 K)		60	80	—	μA/lm
	Radiant at 420 nm		—	80	—	mA/W
	Blue Sensitivity Index (CS 5-58)	R2083	—	10.0	—	—
		R3377	—	9.5	—	—
Anode Sensitivity	Luminous (2856 K)		50	200	—	A/lm
Gain			—	2.5×10^6	—	—
Anode Dark Current (after 30 min storage in darkness)			—	100	800	nA
Time Response	Anode Pulse Rise Time		—	0.7	—	ns
	Electron Transit Time		—	16	—	ns
	Transit Time Spread		—	0.37	—	ns
Pulse Linearity at 2 % Deviation			—	100	—	mA

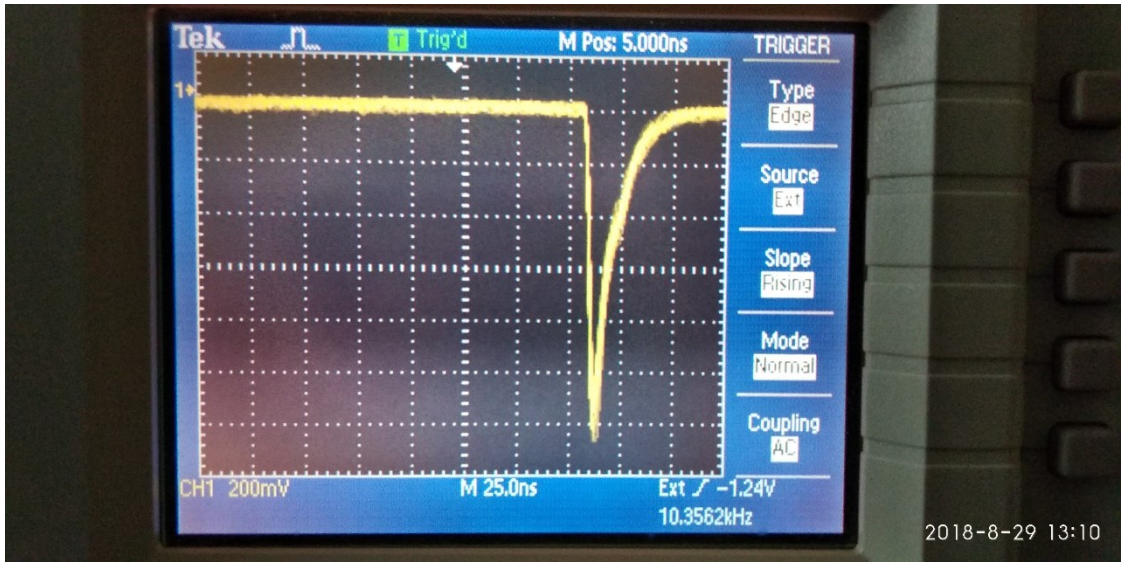
CHARACTERISTICS (at 25 °C) R9779

Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856 K)	—	95	—	μA/lm
	Blue Sensitivity Index (CS 5-58)	—	11	—	—
Anode Sensitivity	Luminous (2856 K)	—	47.5	—	A/lm
Gain		—	5.0×10^5	—	—
Anode Dark Current (After 30 minute storage in darkness)		—	15	100	nA
Time Response	Anode Pulse Rise Time	—	1.8	—	ns
	Electron Transit Time	—	20	—	ns
	Transit Time Spread (FWHM)	—	250	—	ps
Pulse Linearity (±2 % deviation)		—	50	—	mA

Initial Test With Oscilloscope

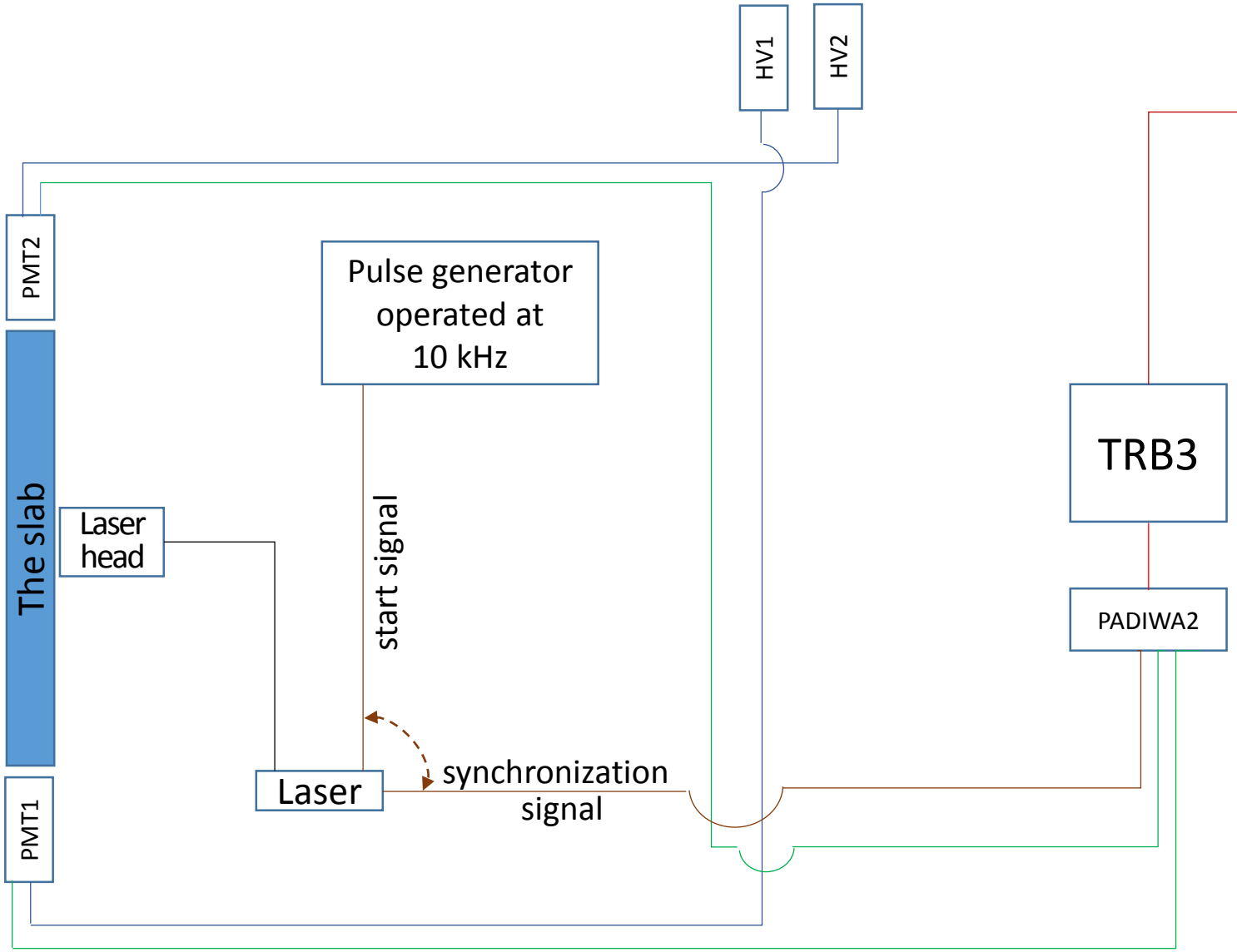


The laser head on top of the slap (central point).



A screenshot of the signal from PMT 1 (R2083) from the laser set at the center of the slab.

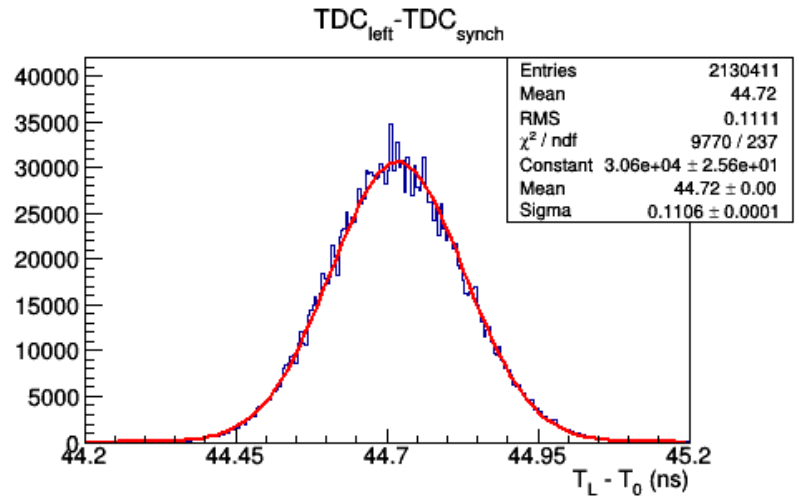
Flowchart of The Experiment

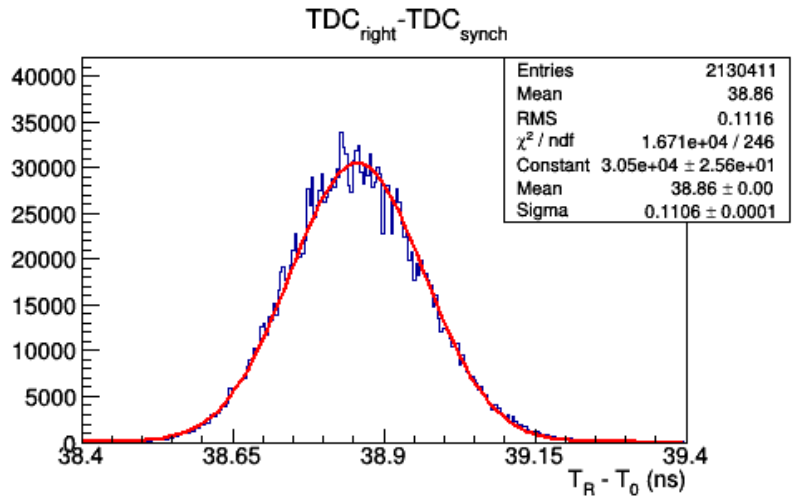


computer

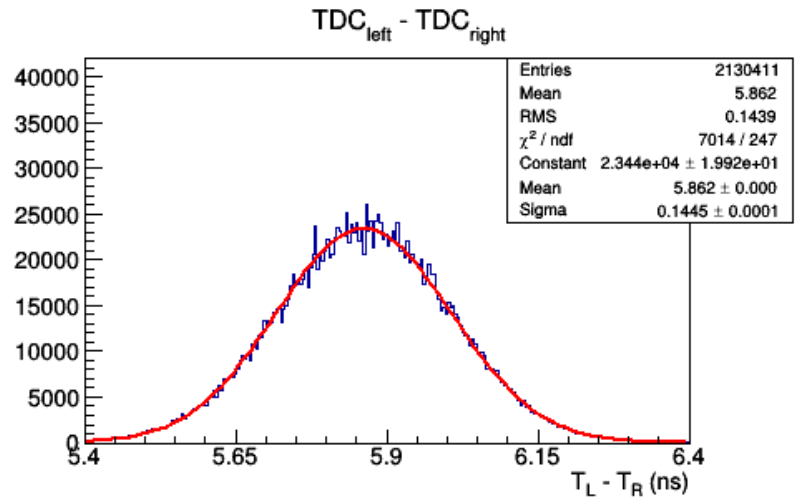
Synchronization signal from the laser is treated in the same way as the signals from PMTs

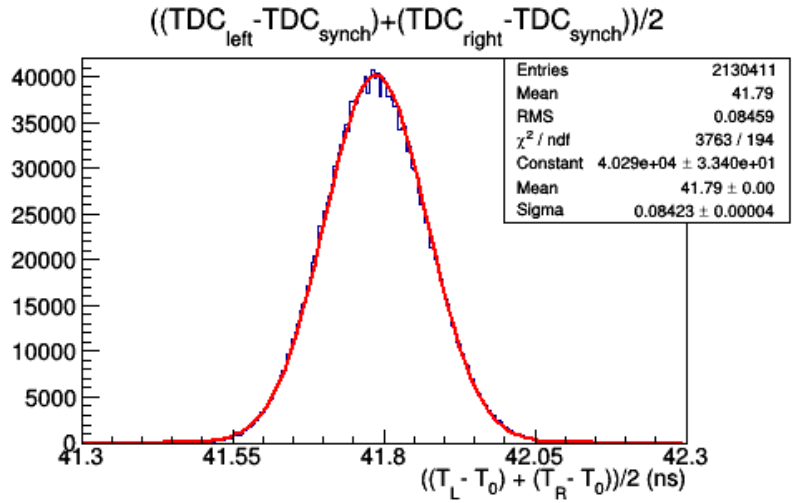
Measurement at The Center Point





σ_L = 102.2 ps; σ_R = 102.2 ps; σ_0 = 43.4 ps; $\sigma_{\frac{L+R}{2}}$ = 72.3 ps



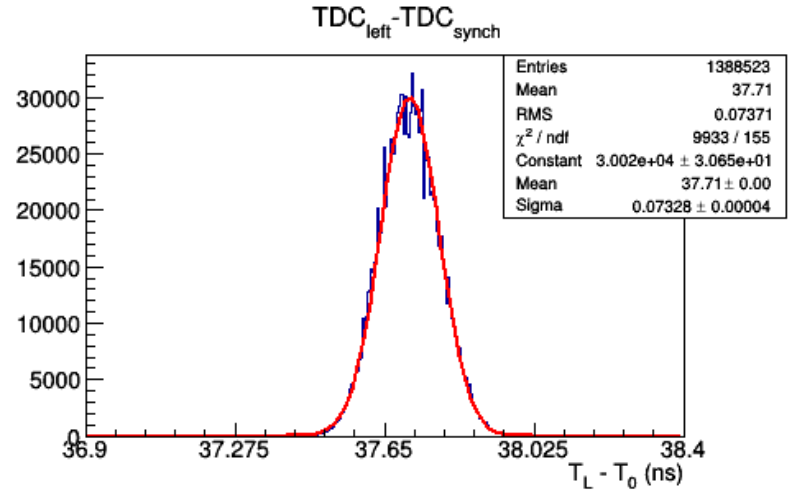


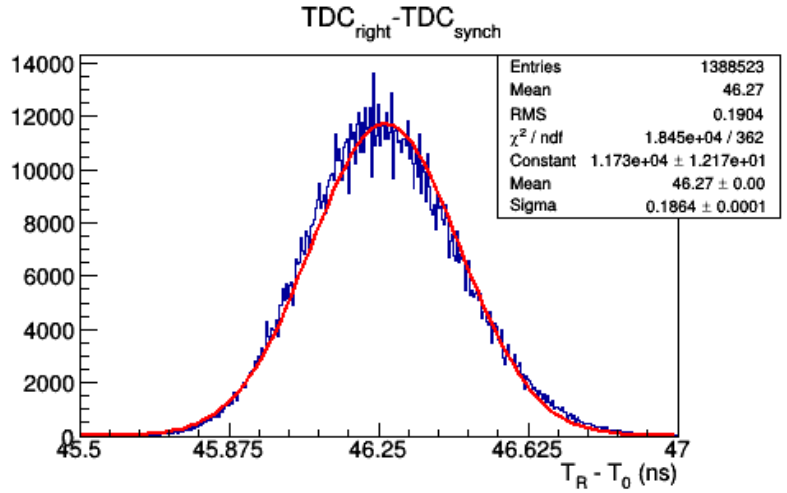
The laser synchronization has its own resolution

Measured observables connected with real resolutions via the following relations

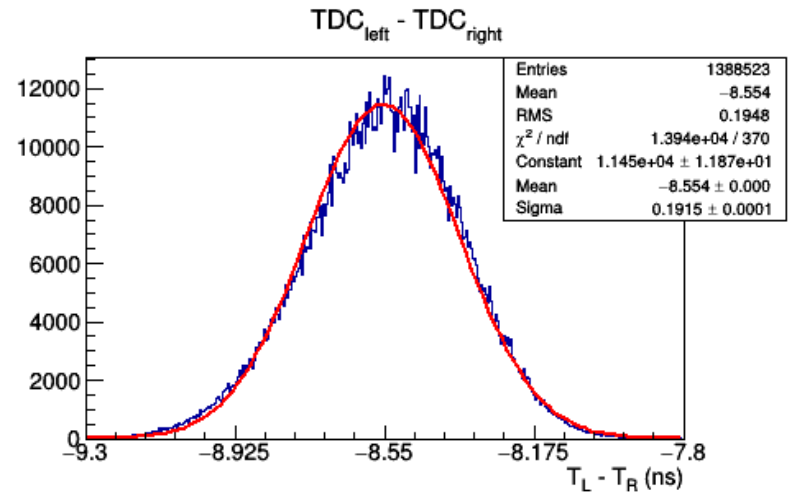
$$\sigma^2_{T_L - T_0} = \sigma^2_L + \sigma^2_0$$
$$\sigma^2_{T_R - T_0} = \sigma^2_R + \sigma^2_0$$
$$\sigma^2_{T_L - T_R} = \sigma^2_L + \sigma^2_R$$
$$\sigma^2_{\frac{(T_L - T_0)+(T_R - T_0)}{2}} = \frac{\sigma^2_L + \sigma^2_R}{4} + \sigma^2_0$$

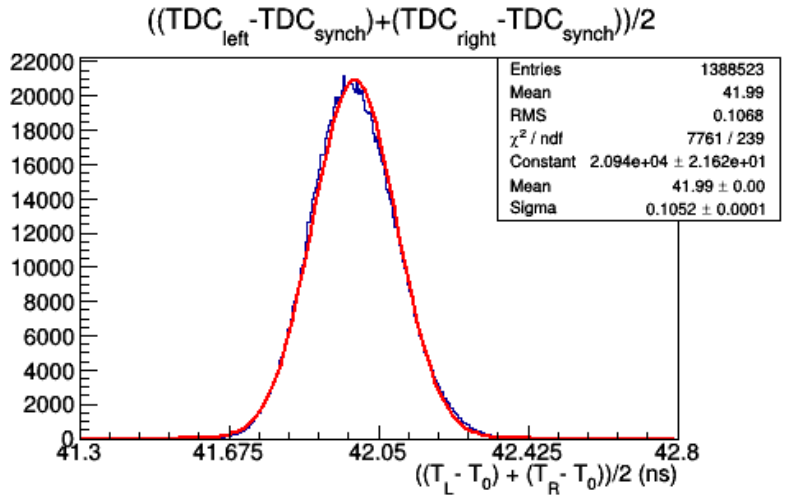
Measurement at The Left Point



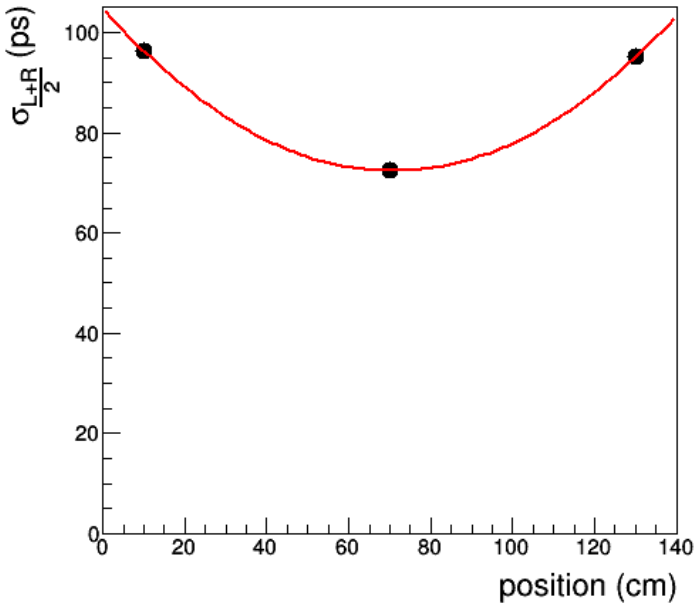


σ_L = 60.5 ps; σ_R = 181.8 ps; σ_0 = 43.6 ps; $\sigma_{\frac{L+R}{2}}$ = 95.8 ps





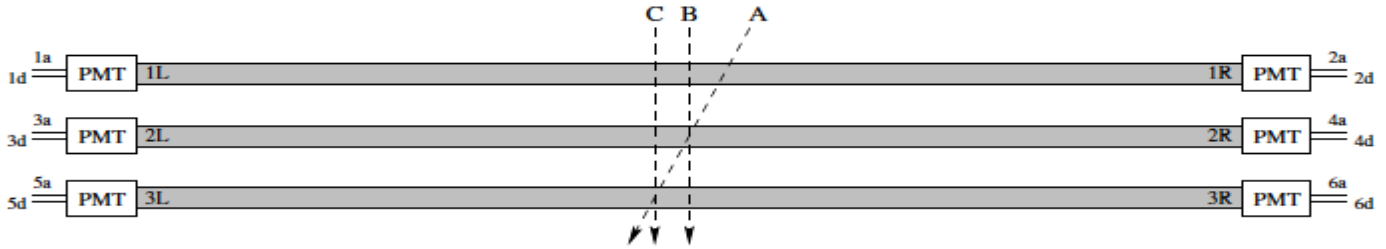
As is expectable the resolution for the PMT that closer to the measurement point is better than for another one.



Expectable parabola-like shape for resolution vs position distribution.

Outlooks

Three-bar method



The time at which the particle interacts with i^{th} scintillator $t_i = \frac{t_{iL}+t_{iR}}{2} - \frac{L}{2v_{eff}}$, where $t_{iL,R} = t_{raw} - t_{ref}$ with t_{raw} is the raw time reported by TDC and t_{ref} is the reference time.

Counter interaction time for each of the three counters (t, m, and b) is finally given by

$$t_t = \tau + \varepsilon_t$$
$$t_m = \tau + \varepsilon_m + \delta$$
$$t_b = \tau + \varepsilon_b + 2\delta$$

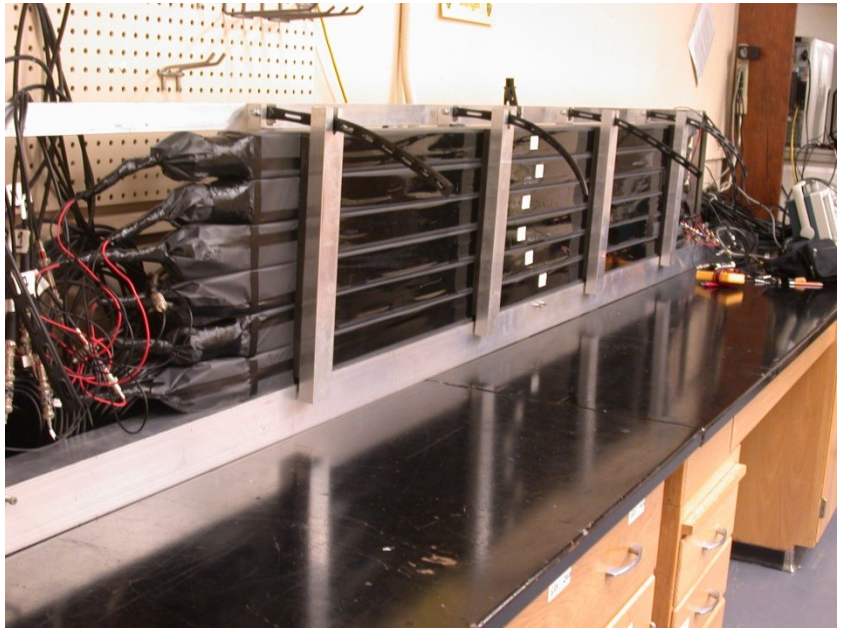
τ is the actual time at which the particle interacts with top counter.
δ is the time that particle travels between adjacent counters.
ε_i are all uncertainties that contribute to the measured time.
σ_ε is the resolution of the corresponding counter.

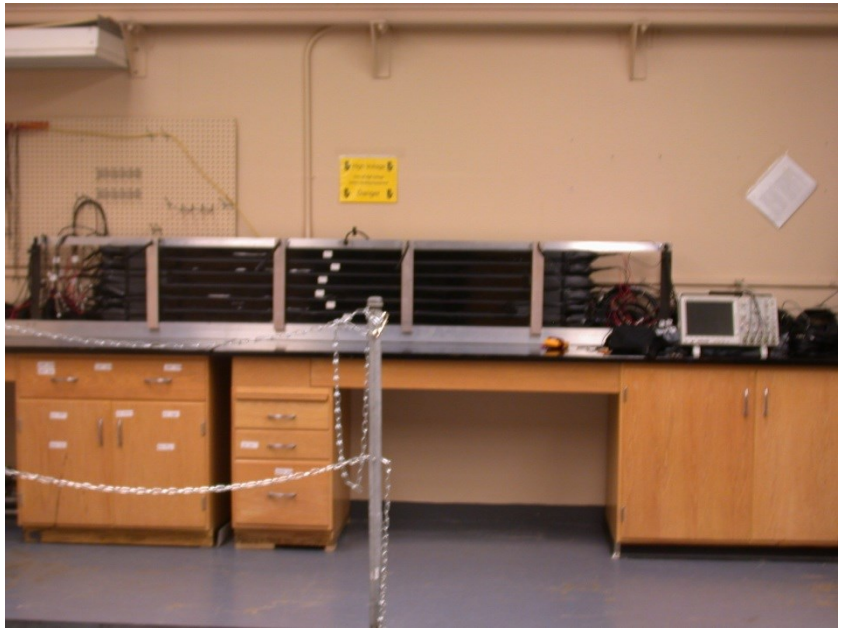
The quantity $T = \frac{t_t+t_b}{2} - t_m = \frac{\varepsilon_t+\varepsilon_b}{2} - \varepsilon_m$ is composed to be constant, only smeared by ε_i

The statistical uncertainty in T is defined by $\sigma_T^2 = (\sigma_{\varepsilon_t}^2 + \sigma_{\varepsilon_b}^2)/4 + \sigma_{\varepsilon_m}^2$

Assuming all counters are identical, the resolution is $\sigma_\varepsilon = \sqrt{\frac{2}{3}}\sigma_T$

Six-Bar method (CLAS12 FTOF)



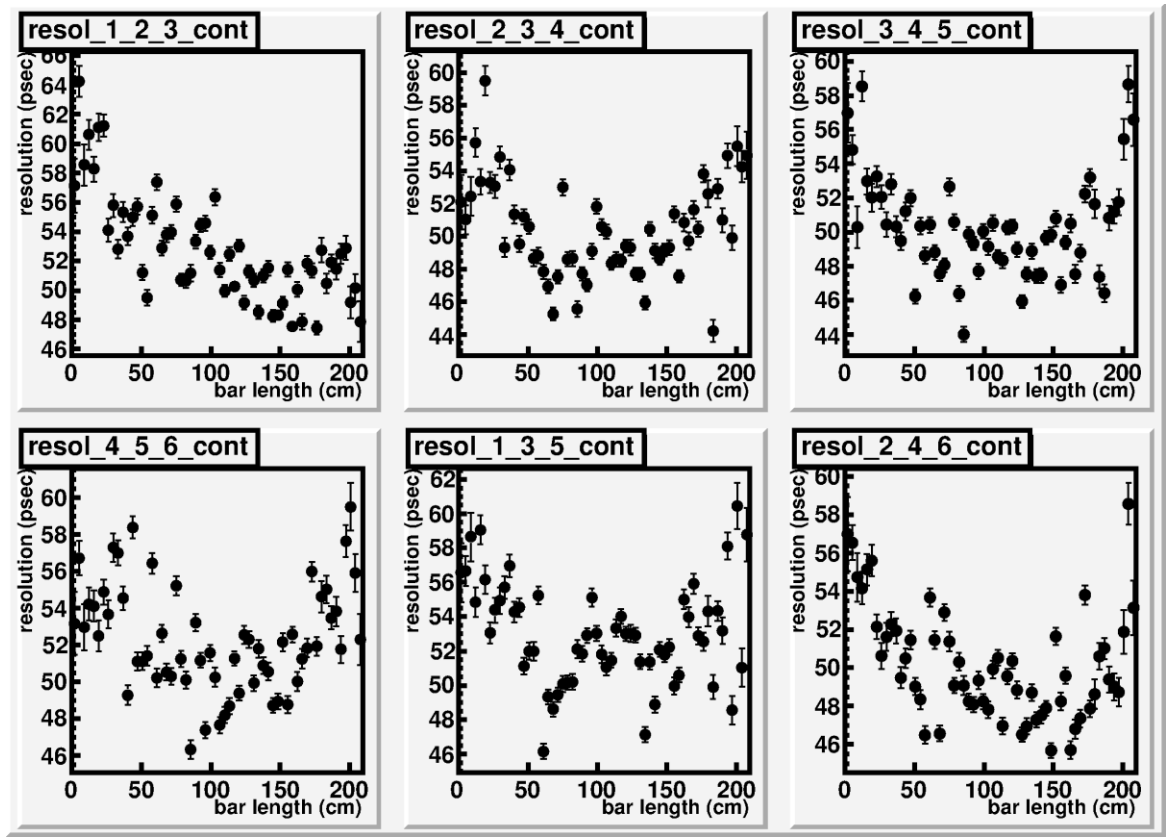


Resolution analyses were performed using the three-bar cosmic ray method. To speed-up the analysis process we run with six bars on top of each other and then select equidistant combinations of three bars for the analysis.

The pictures show the experimental setup for 210 cm long bars with 6 possible bar combinations for the analysis:

1-2-3	4-5-6
2-3-4	1-3-5
3-4-5	2-4-6

Resolution of Three-Bar Combinations (CLAS12 FTOF)



Example for 210 cm bars set

Parabola-like shape of the resolution vs position distributions looks similar to one obtained using laser measurements.

Conclusions

- A preliminary test of the 140 cm slab with picosecond diode laser is done.
- The measurements provide better than 100ps $\sigma_{\frac{L+R}{2}}$ resolution and its predictable shape as a function of the position along the bar.
- The laser measurements will be compared with the cosmic ray ones.