Current Status of the PANDA FTOF Wall Detector

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PNPI HEPD Seminar February 2021

Project Participants

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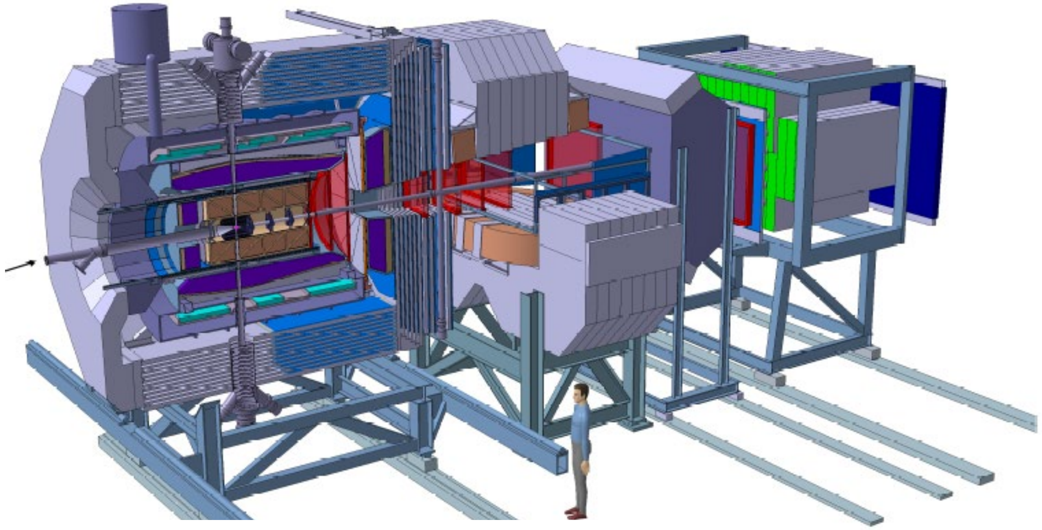
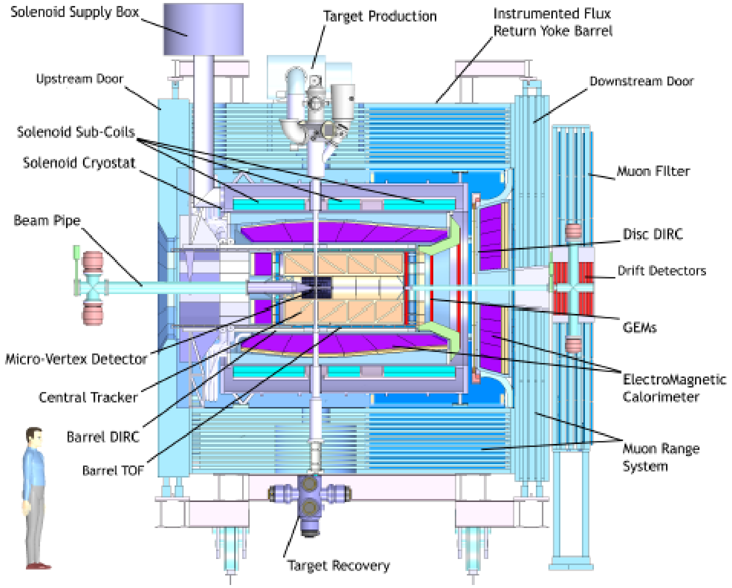
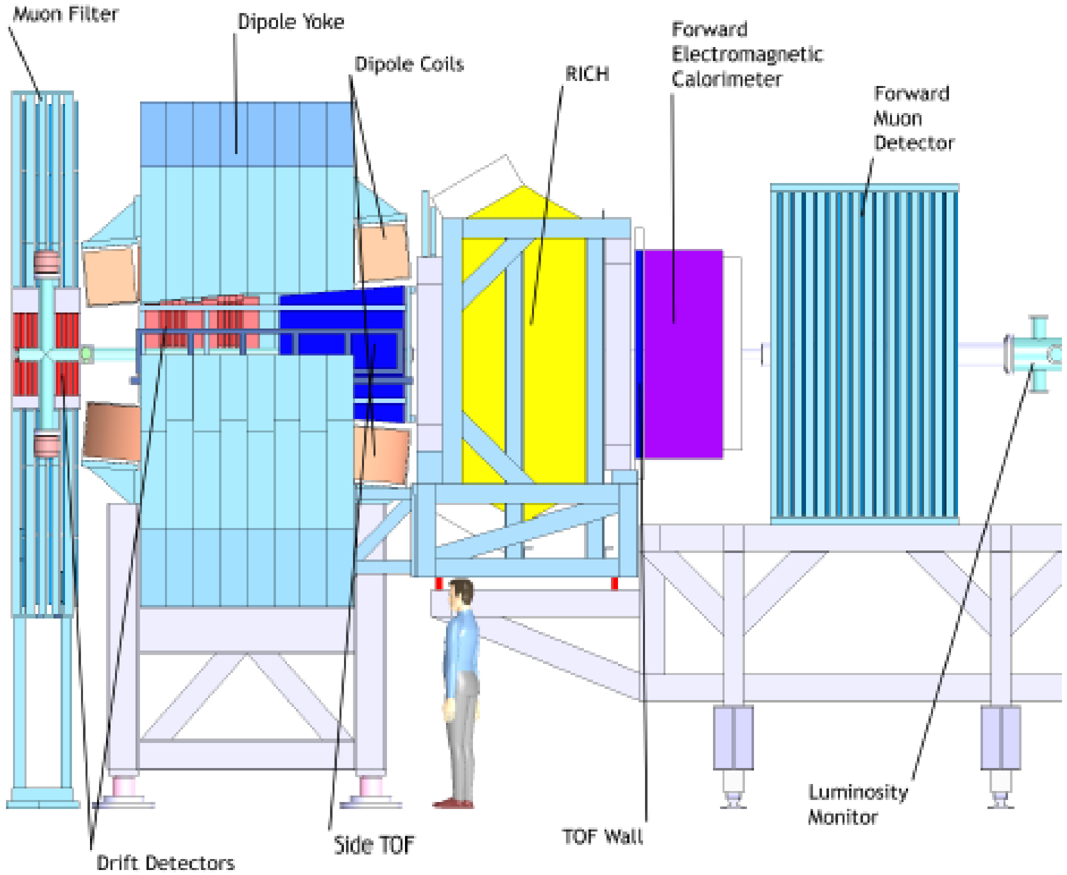
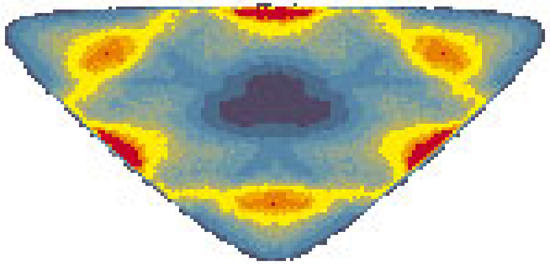
The PANDA Detector



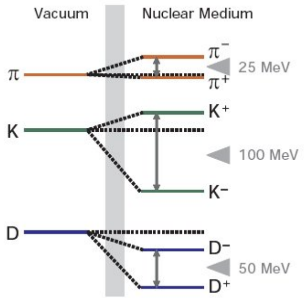




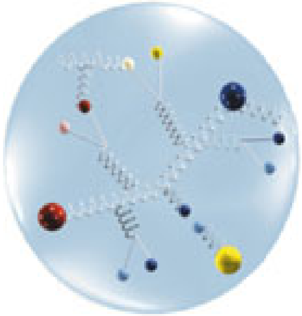
PANDA Physics



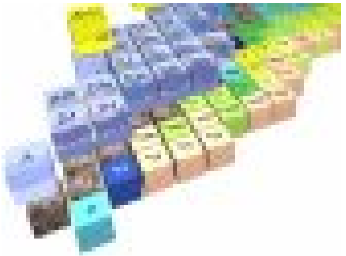
Hadron Spectroscopy
Search for exotic particles and measurement of hadron properties



Hadrons in Matter
Study in-medium effects of hadronic particles



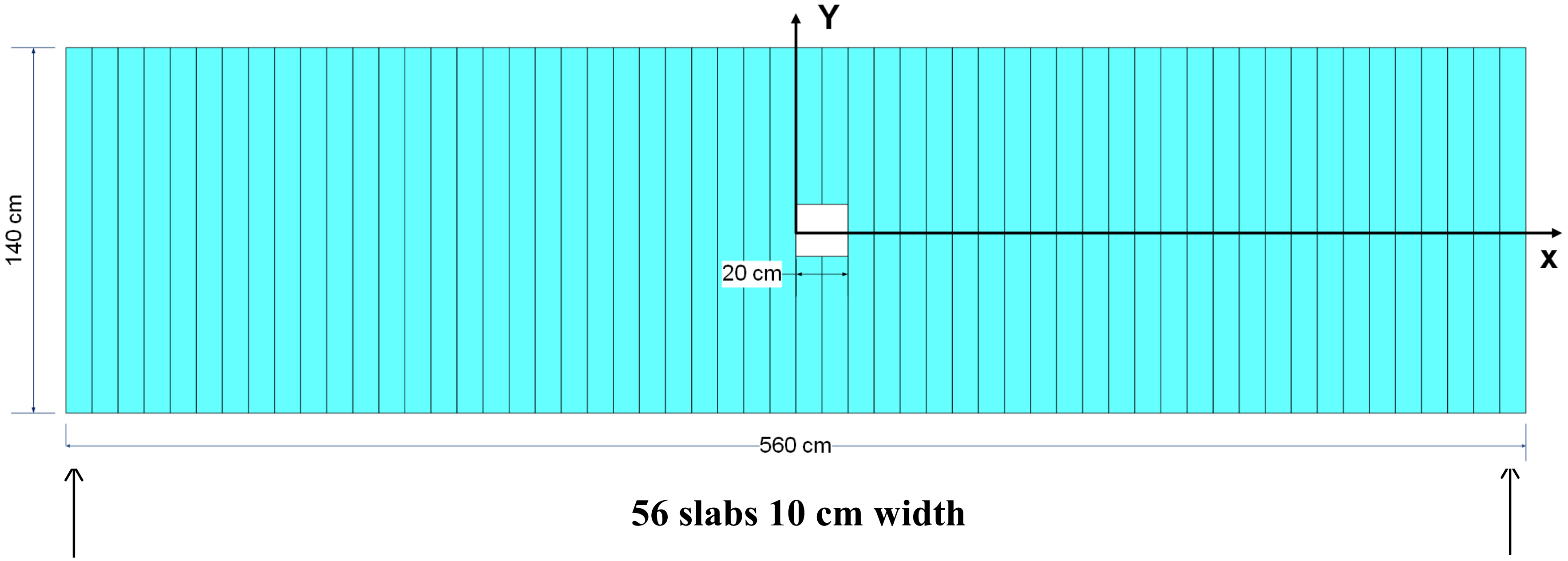
Nucleon Structure
Generalized parton distribution, Drell-Yan processes and time-like form factor of the proton



Hypernuclei
Measurement of nuclear properties with an additional strangeness degree of freedom

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)



56 slabs 10 cm width

Comment. The beam pipe diameter at this z-location is 180 mm. i.e. 2 slabs to be cut.

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

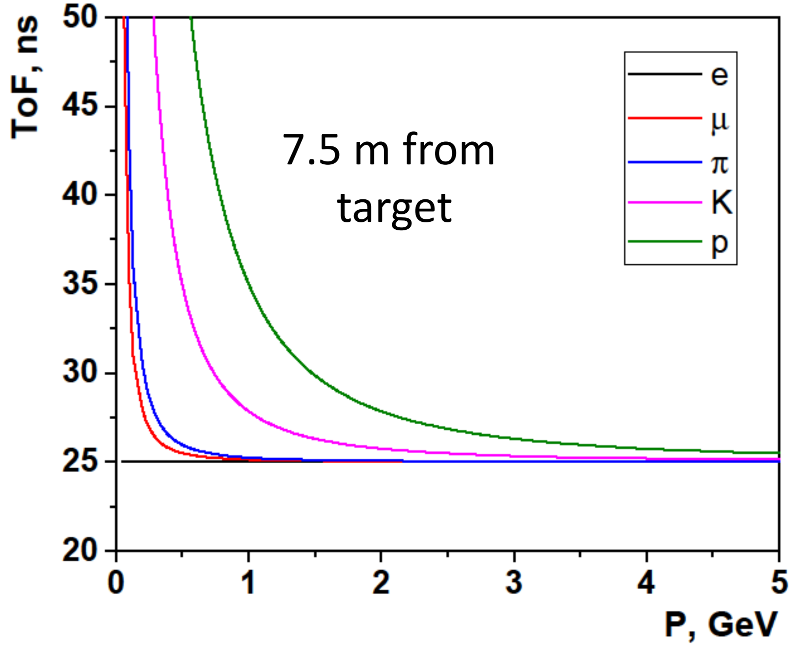
- **Energy deposition information**

  expected energy deposition range
  from 5 to 50 MeV

- **Track position**

  expected precision few centimeters vertically and 10 centimeters horizontally

FTOF Wall Hadron Id



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

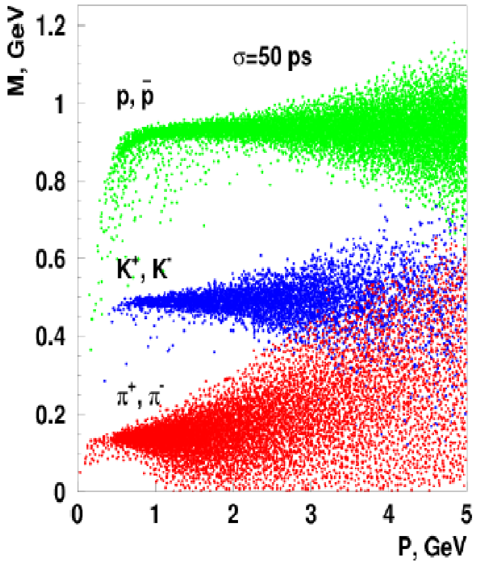
$$t_c = L_{track} / c$$

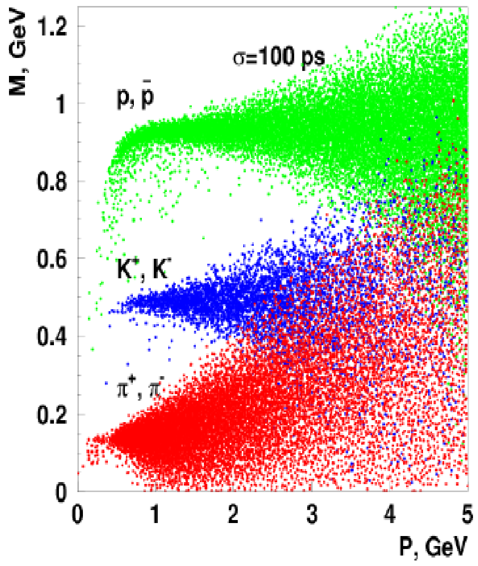
At FS momentum resolution Δp/p=0.01

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:

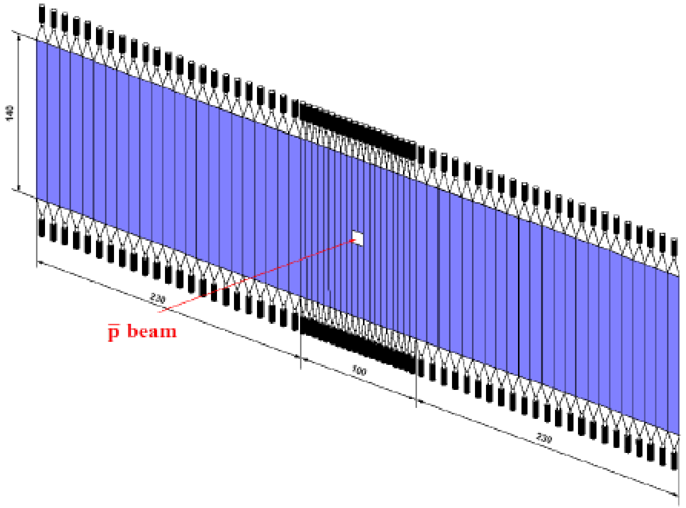
$\overline{\text{P}}$ANDA
Forward Time of Flight detector (FToF wall)

(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.

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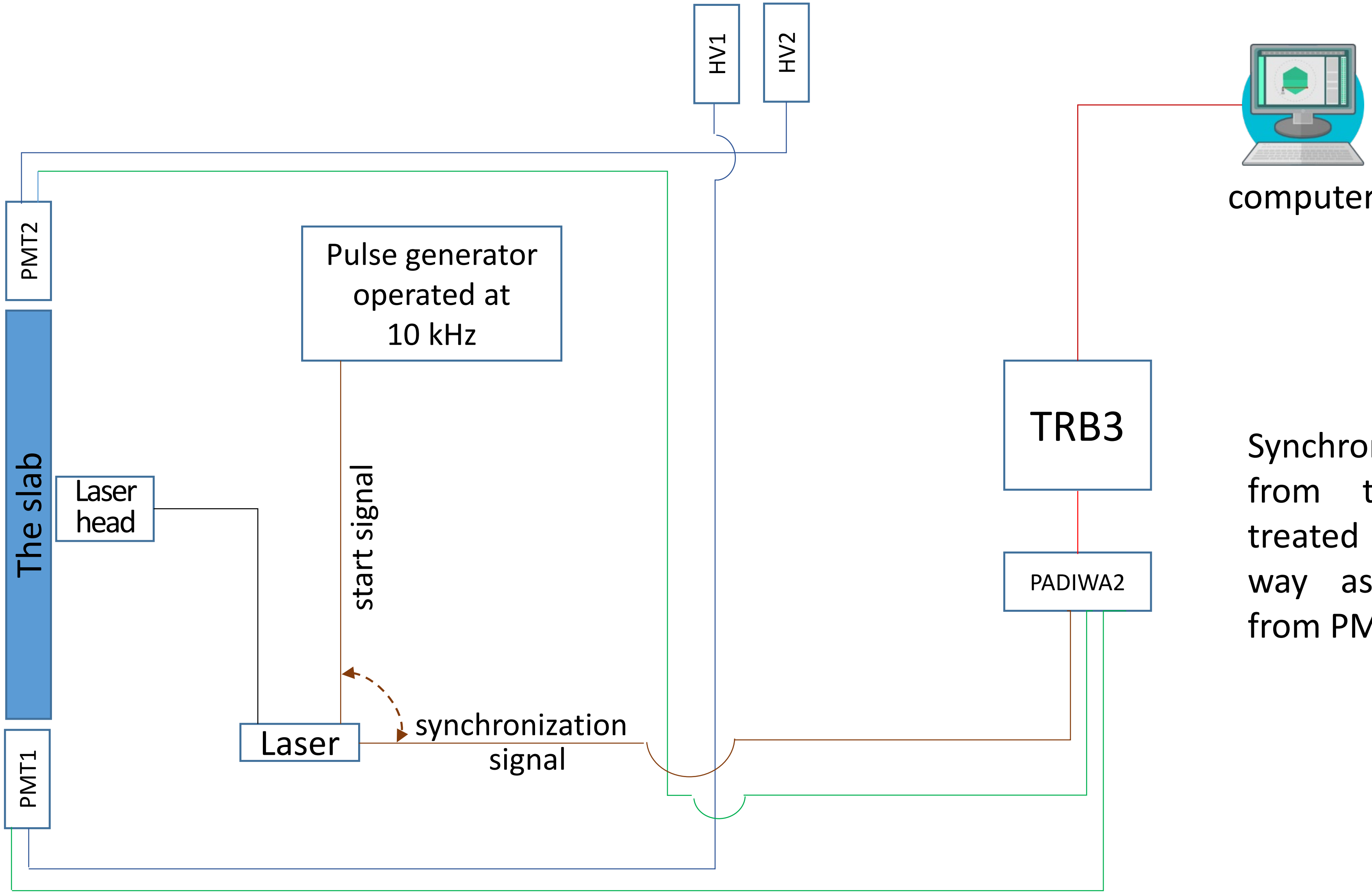
Flowchart of The Experiment



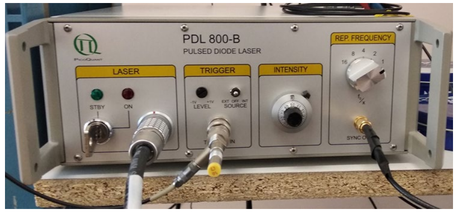
Synchronization signal from the laser is treated in the same way as the signals from PMTs

Test Lab Overview

The Testing Electronics

Pulse generator

Picosecond pulsed diode laser started from the pulse generator



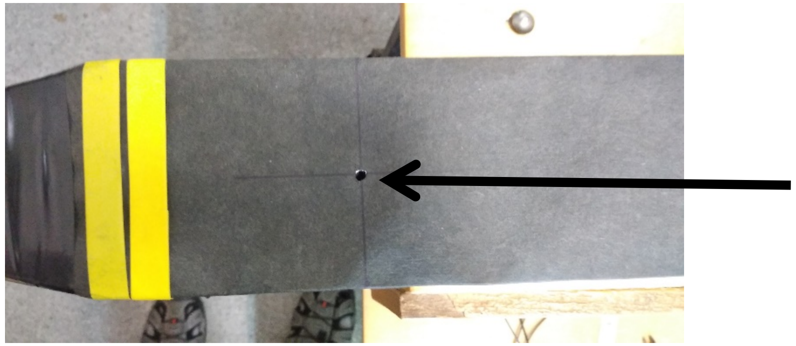
Laser specifications
Wave length 372 nm
Pulse width ~ 50 ps
Peak power – 1 W
Frequency 1Hz – 40 MHz

Two HV modules inserted in the crate

TRB3

The Investigated Slab

140x10x2.5 cm EJ-200 slab with lightguides and PMTs attached from both sides.



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.

Additional Procurements

- In order to test the exact same prototype that we are going to use in actual development one EJ-200 slab and two Hamamatsu R13435 PMTs were ordered. *This additional procurement was made PNPI HEPD financial support.*

- HV dividers for the new PMTs were developed by our electronics department.

Comparison of R13435 and R2083 PMTs

R13435

GENERAL

Parameter			Description / Value	Unit
Spectral Response			300 to 650	nm
Wavelength of Cathode Radiant Sensitivity			420	nm
Window Material			Borosilicate glass	-
Photocathode	Material	R13435	Bialkali	-
		R13435-100	Super Bialkali	-
	Minimum Effective Area		ϕ46	mm
Dynode Structure / Number of Stages			Linear Focused / 10	-
Base			JEDEC No. B20-102	-
Operating Ambient Temperature		Tube	-30 to +50	°C
		Assembly Type	0 to +50	°C
Storage Temperature		Tube	-80 to +50	°C
		Assembly Type	0 to +50	°C
Suitable Socket			E678-20B (supplied)	-
Recommended Supply Voltage Between Anode and Cathode			1750	V

CHARACTERISTICS (at 25 °C)

Parameter			Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856 K)	R13435	-	95	-	μA/lm
		R13435-100	-	130	-	μA/lm
Cathode Blue Sensitivity Index (Cs 5-58)		R13435	9	10	-	-
		R13435-100	12.5	13.5	-	-
Anode Sensitivity	Luminous (2856 K)	R13435	80	400	-	A/lm
		R13435-100	80	550	-	A/lm
Gain			-	4.2×10^6	-	-
Anode Dark Current (After 30 min storage in darkness)			-	30	200	nA
Anode Pulse Rise Time			-	2.0	-	ns
Electron Transit Time			-	23 (24)	-	ns
Transit Time Spread (FWHM)			-	230 (280)	-	ps
Pulse Linearity (+/-2 % deviation)			-	30 (100)	-	mA

R2083

GENERAL

Parameter		Description/Value	Unit
Spectral Response		300 to 650	nm
Wavelength of Maximum Response		420	nm
Photocathode	Material	Bialkali	—
	Minimum Useful Diameter	46	mm dia.
Window Material		Borosilicate glass	—
Dynode	Structure	Linear focused	—
	Number of Stages	8	—
Base		19-pin glass base with SMA output connector	—
Socket		E678-19C	—

Parameter		Value	Unit
Supply Voltage	Between Anode and Cathode	3500	Vdc
	Between Anode and Last Dynode	1000	Vdc
Average Anode Current		0.2	mA
Ambient Temperature		-30 to +50	°C

CHARACTERISTICS (at 25°C)

Parameter		Min.	Typ.	Max.	Unit
Anode Sensitivity	Luminous (2856K)	50	200	—	A/lm
Cathode Sensitivity	Luminous (2856K)	60	80	—	μA/lm
	Radiant at 420nm	—	80	—	mA/W
	Blue (CS 5-58 filter)	—	10.0	—	μA/lm-b
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
	Transmit Time Spread	—	0.37	—	ns
Pulse Linearity at 2% Deviation		—	100	—	mA

Comparison of EJ-200 and BC-408 scintillators

EJ-200 PLASTIC SCINTILLATOR

This plastic scintillator combines the two important properties of long optical attenuation length and fast timing and is therefore particularly useful for time-of-flight systems using scintillators greater than one meter long. Typical measurements of 4 meter optical attenuation length are achieved in strips of cast sheet in which a representative size is 2 cm x 20 cm x 300 cm.

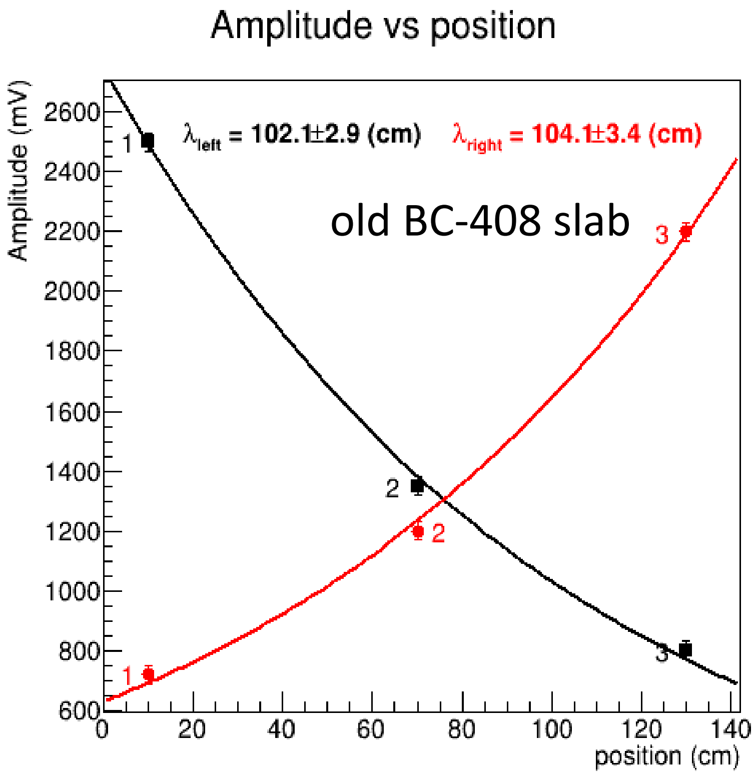
Physical and Scintillation Constants:

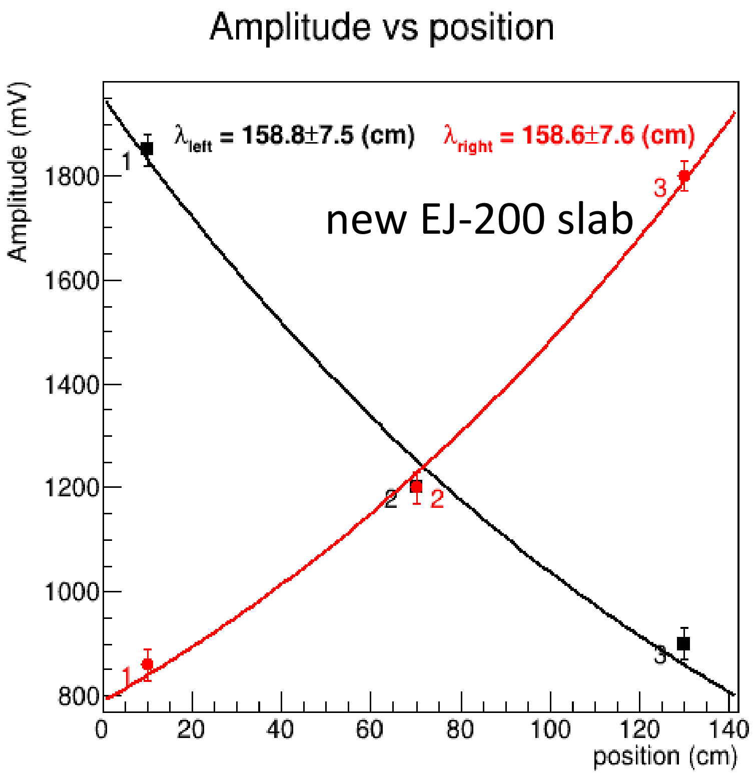
Light Output, % Anthracene	64
Scintillation Efficiency, photons/1 MeV e^-	10,000
Wavelength of Max. Emission, nm	425
Rise Time, ns	0.9
Decay Time, ns	2.1
Pulse Width, FWHM, ns	~2.5
No. of H Atoms per cm^3, x 10^{22}	5.17
No. of C Atoms per cm^3, x 10^{22}	4.69
No. of Electrons per cm^3, x 10^{23}	3.33
Density, g/cc:	1.023

	BC-400	BC-404	BC-408	BC-412	BC-416
Radiation Detected					
<100keV X-rays			X		
100keV to 5MeV gamma rays				X	
>5MeV gamma rays	X				
Fast neutrons				X	X
Alphas, betas	X	X	X		
Charged particles,cosmic rays, muons, protons, etc.			X	X	X
Principal Uses/Applications	general purpose	fast counting	TOF large area	large area	large area economy
Scintillation Properties					
Light Output, %Anthracene	65	68	64	60	38
Rise Time, ns	0.9	0.7	0.9	1.0	-
Decay Time (ns)	2.4	1.8	2.1	3.3	4.0
Pulse Width, FWHM, ns	2.7	2.2	~2.5	4.2	5.3
Wavelength of Max. Emission, nm	423	408	425	434	434
Light Attenuation Length, cm*	160	140	210	210	210
Bulk Light Attenuation Length, cm	250	160	380	400	400
Atomic Composition					
No. H Atoms per cc ($x10^{22}$)	5.23	5.21	5.23	5.23	5.25
No. C Atoms per cc ($x10^{22}$)	4.74	4.74	4.74	4.74	4.73
Ratio H:C Atoms	1.103	1.100	1.104	1.104	1.110
No. of Electrons per cc ($x10^{23}$)	3.37	3.37	3.37	3.37	3.37

*The typical 1/e attenuation length of a 1x20x200cm cast sheet with edges polished as measured with a bialkali photomultiplier tube coupled to one end.

Attenuation Length Measurement



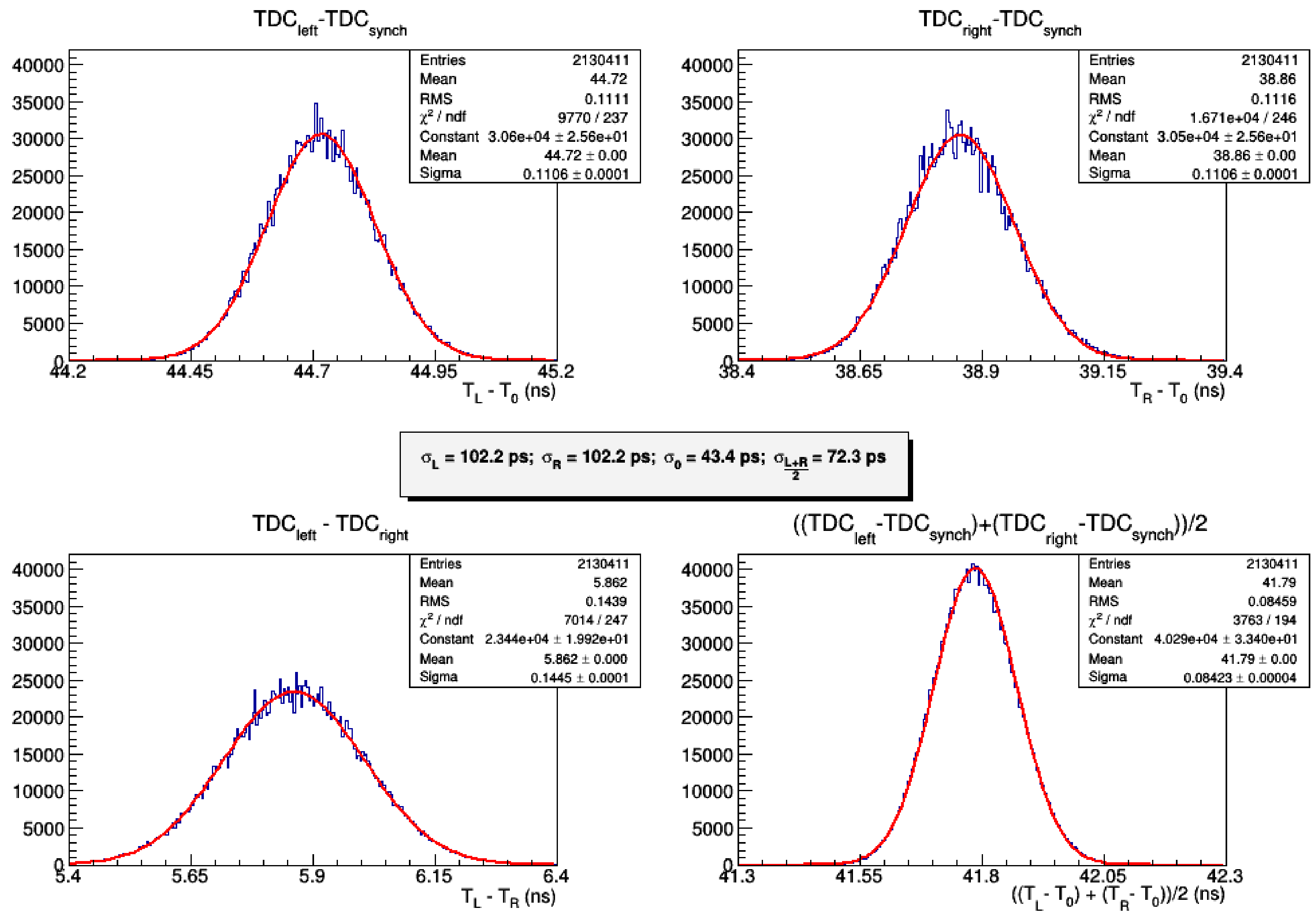


mean λ_{old} = 102.9 +- 2.2 cm

mean λ_{new} = 158.7 +- 5.3 cm

The measured attenuation length for new slab is about 1.5 times longer. That is in coincidence with scintillator material datasheets.

The Measurement method



The laser synchronization has its own resolution

Measured observables connected with real resolutions via the following relations

$$\sigma^2_{T_L - T_0} = \sigma^2_L + \sigma^2_0$$

$$\sigma^2_{T_R - T_0} = \sigma^2_R + \sigma^2_0$$

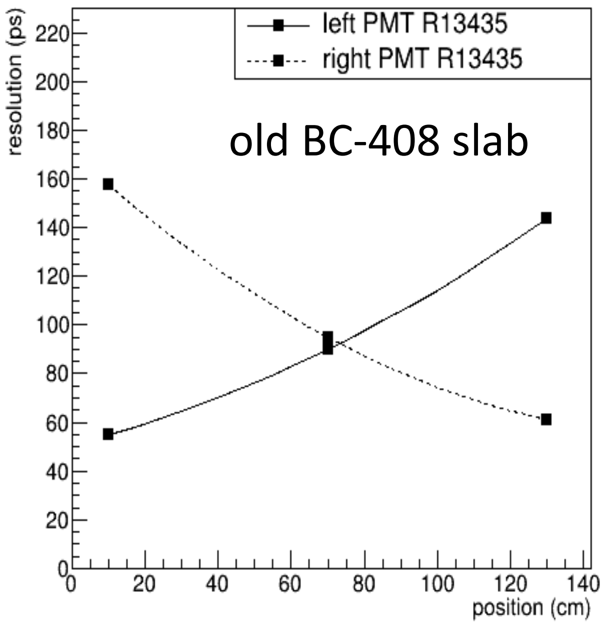
$$\sigma^2_{T_L - T_R} = \sigma^2_L + \sigma^2_R$$

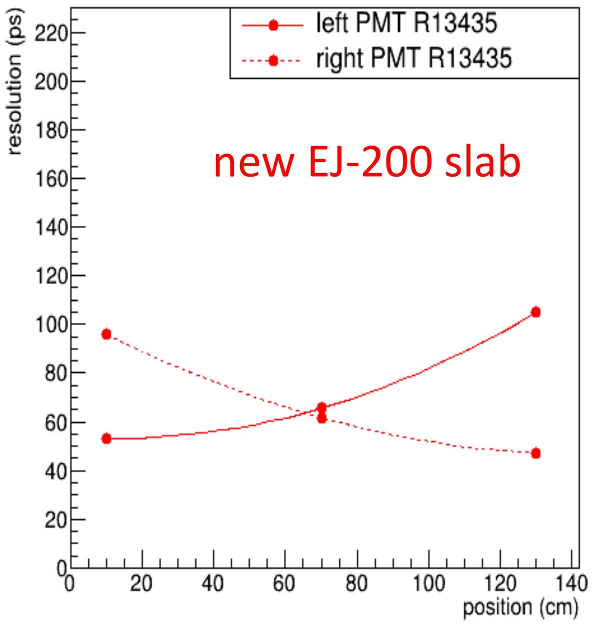
$$\sigma^2_{\frac{(T_L - T_0)+(T_R - T_0)}{2}} = \frac{\sigma^2_L + \sigma^2_R}{4} + \sigma^2_0$$

Weighted Mean Method

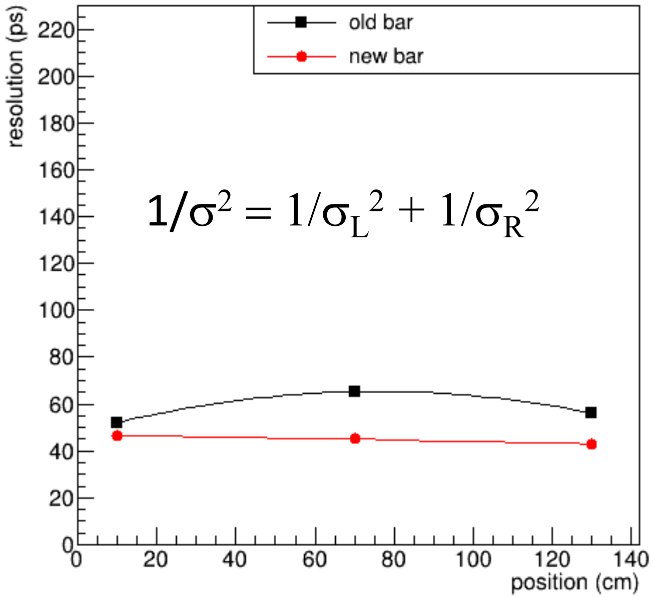
Can be used if the hit position is measured with the precision about 2mm

Timing resolution for various scintillation counter prototypes vs position along the slab.

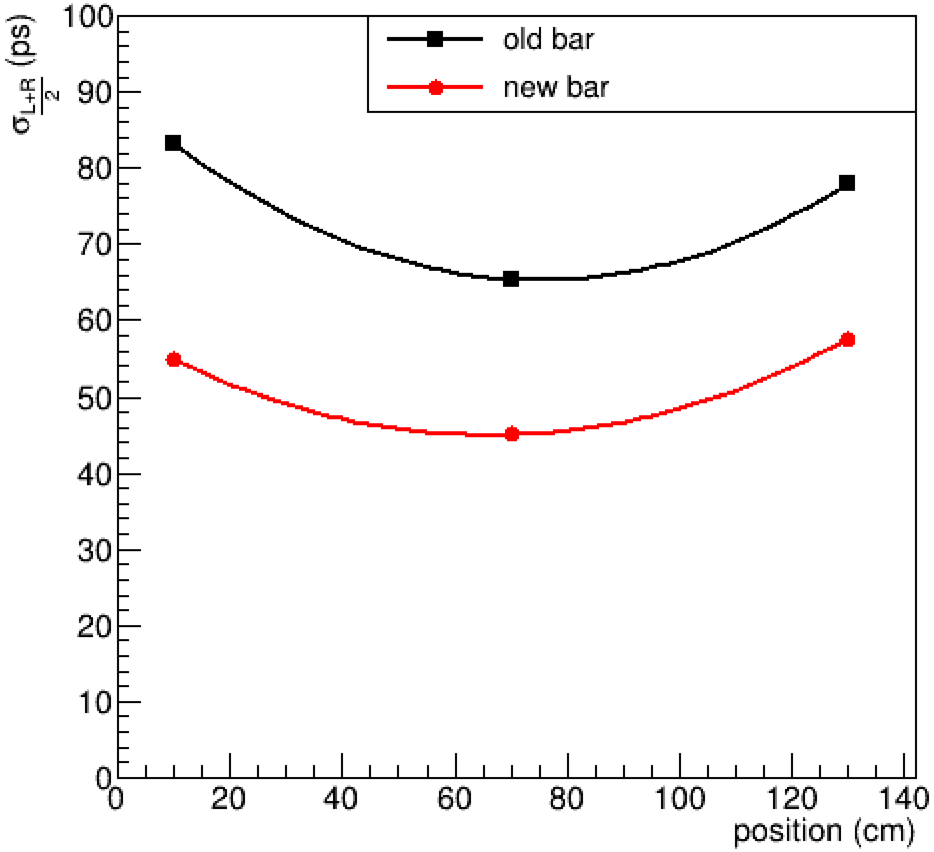




The corresponding weighted mean vs position along the slab

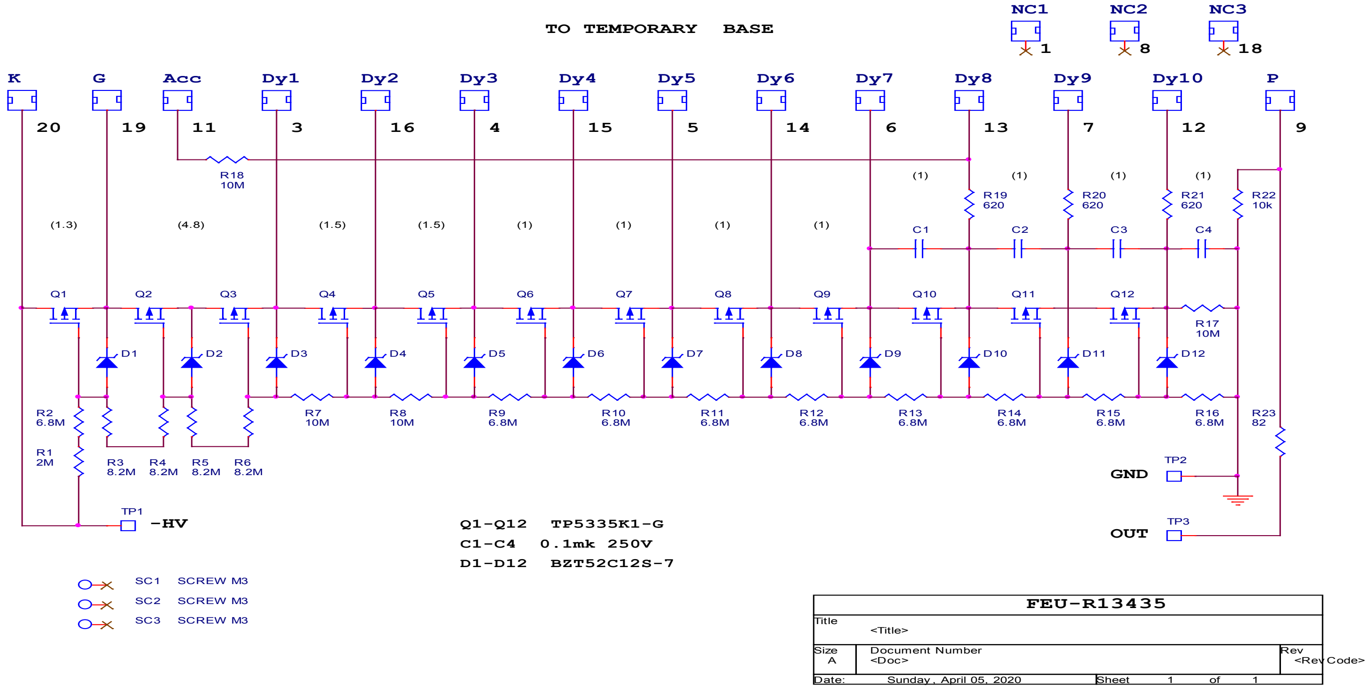


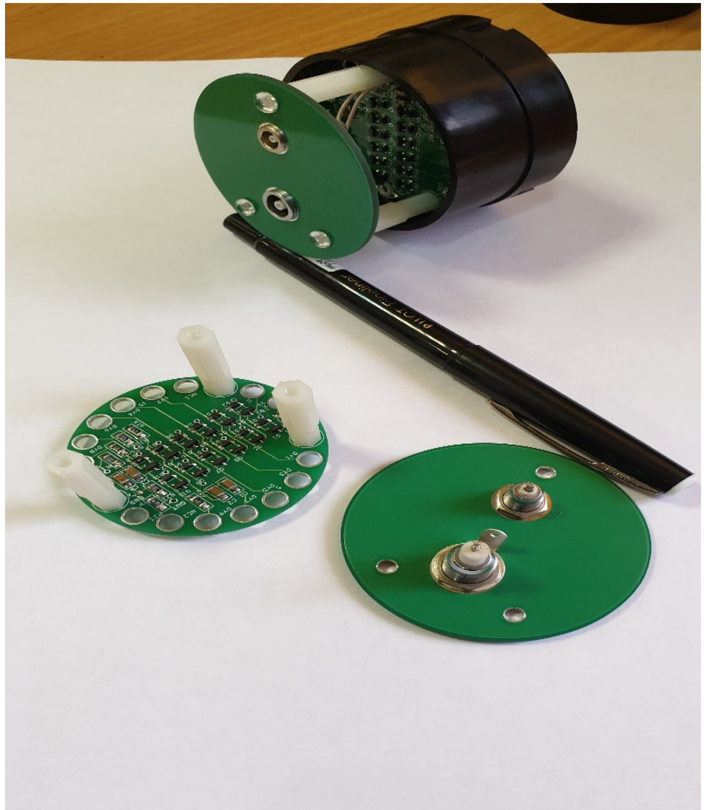
Not sensitive to the hit position method



Active Dividers

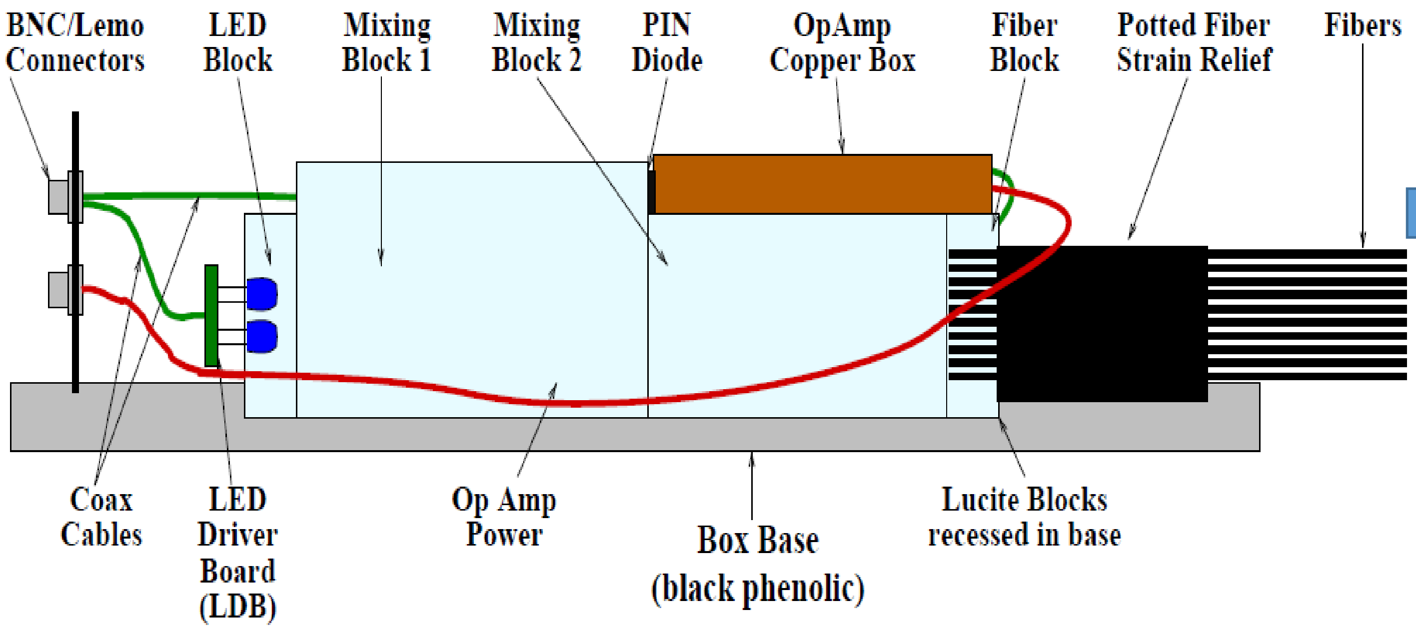
New Active Divider prototype for Hamamatsu R13435
Is developed by the PNPI Electronics department



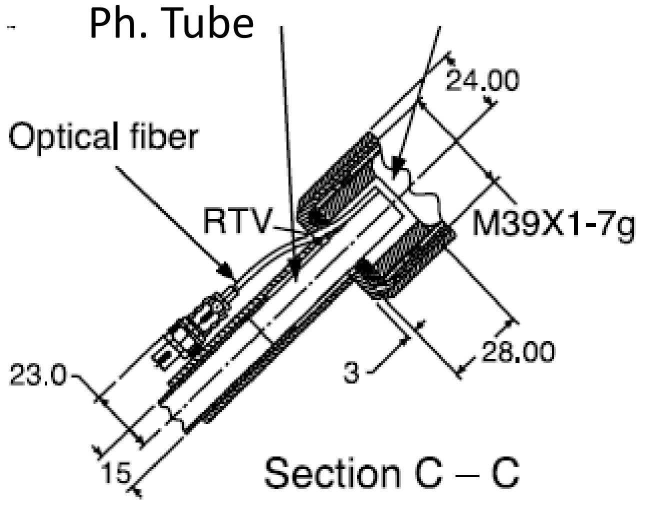


LED Based Calibration System

LEDIS (Led Imitator of scintillation) system that will be used for the time calibration is currently under development by our Electronics department



To Ph. Tube



Conclusions and Outlooks

- As it is expected, the measured attenuation length for the new scintillation slab turned out to be significantly longer than that for old one.
- The new slab has significantly (more than 1.4 times !!!) better resolution, than old one.
- The resolution better than 50 ps can be achieved even without well knowledge about hit position.
- The laser measurements will be compared with ones at PNPI proton beam.
- The development of the calibration system based on the ultra-bright blue LEDs is underway with the help of the PNPI Electronics Department.
- Our Electronics department will also provide us with HV system.
- Continue work on modeling the registration of θ^+ production in PANDA.
- The signing of MoU between FAIR and PNPI.