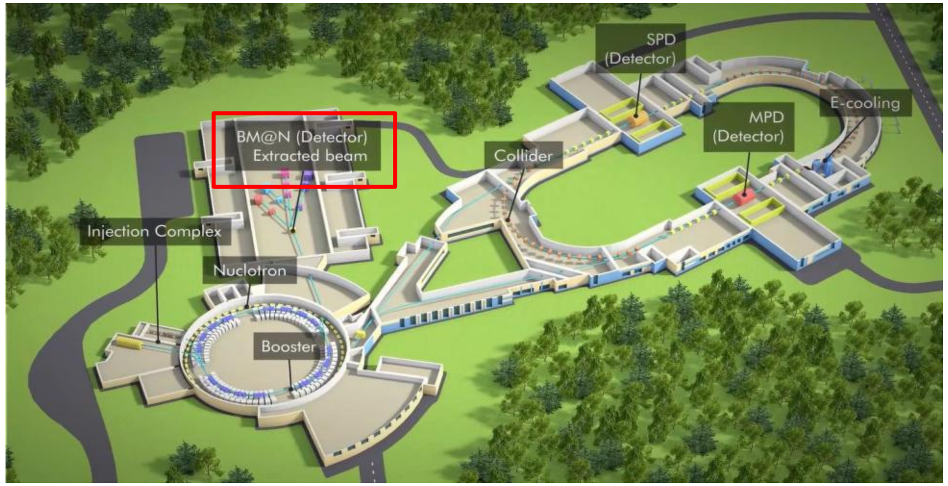
Upgrade of the trigger detectors for the BM@N experiment

Valyo Velichkov

for the BM@N trigger group



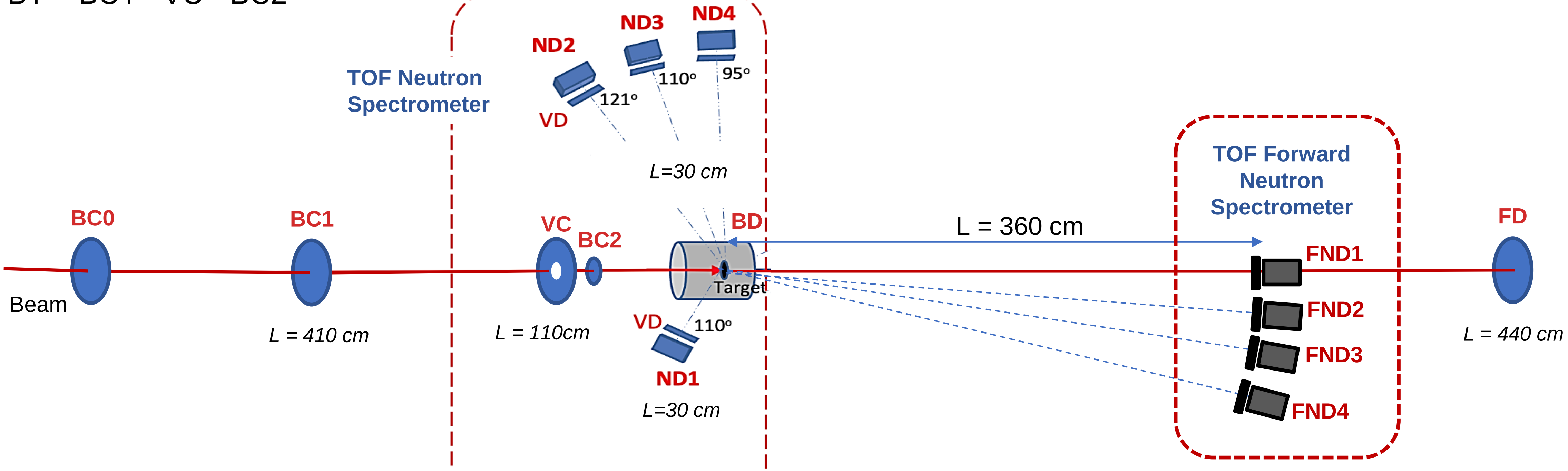
Analysis and Detector Meeting of the BM@N Experiment at NICA,

March 4, 2025

Overview of the trigger detectors in the BM@N experiment

Beam trigger

BT = BC1 • $\overline{VC}$ • BC2



Centrality trigger 1

CCT1 = BT • BD (n ≥ 4)

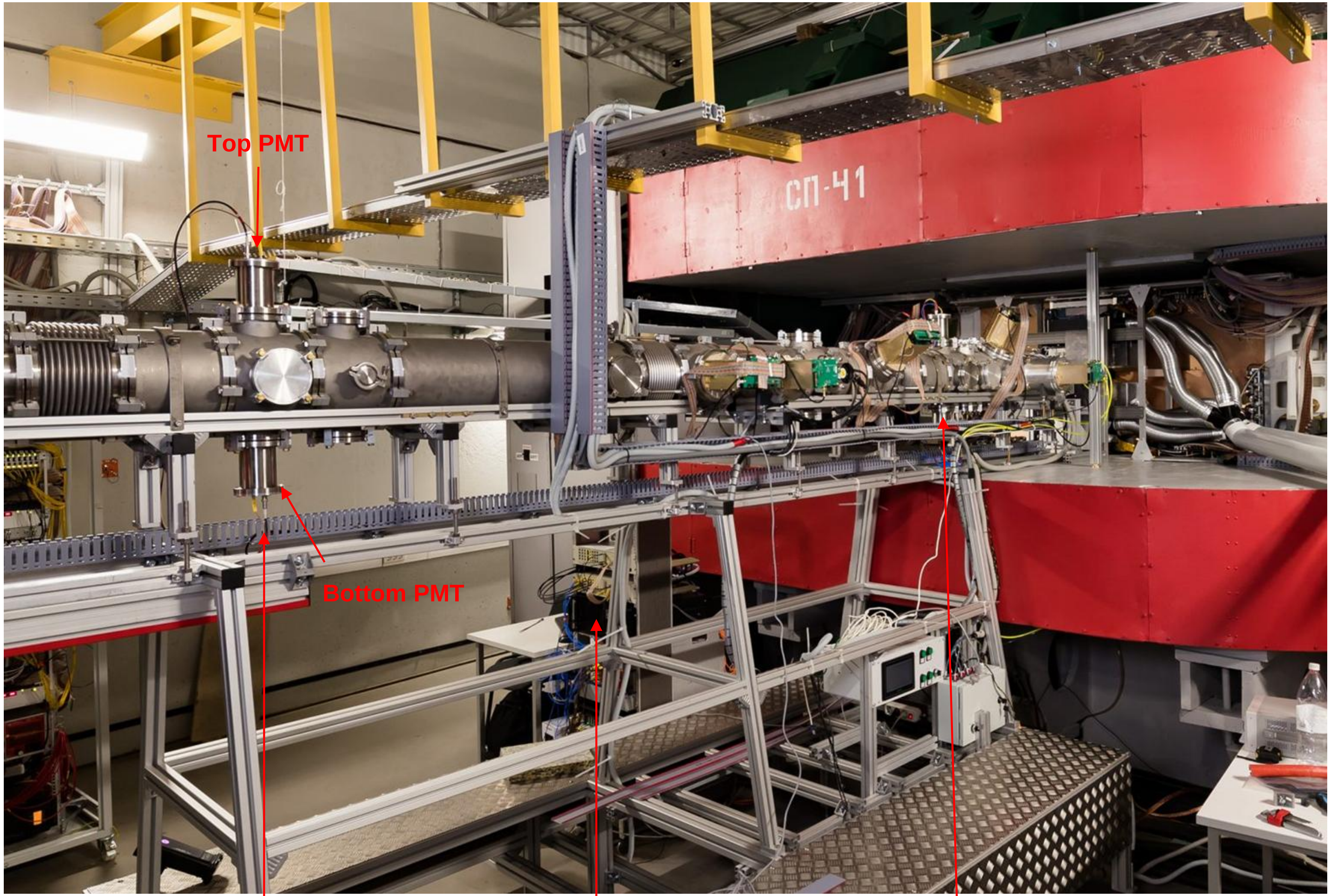
Minimum bias, non-interaction, centrality trigger 2

MBT = BT • $\overline{FD}$

NIT = BT • FD

CCT2 = BT • $\overline{FD}$ • BD (n ≥ 4)

Beam pipe and detectors upstream of the target



BC1 Trigger electronics VC, BC2

Vacuum for heavy ion runs

2020-2023: new vacuum elements in nearly entire beam transport line from Nuclotron to BM@N

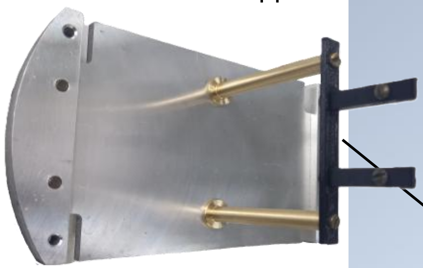
Radiators of BC1, BC2, VC are placed in the vacuum,

BC2 and VC PMTs are capable to work in the magnetic field

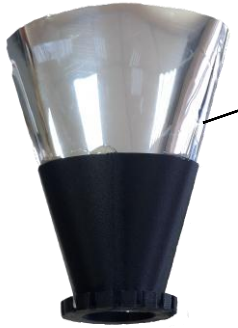
Status of the beam counters upgrade

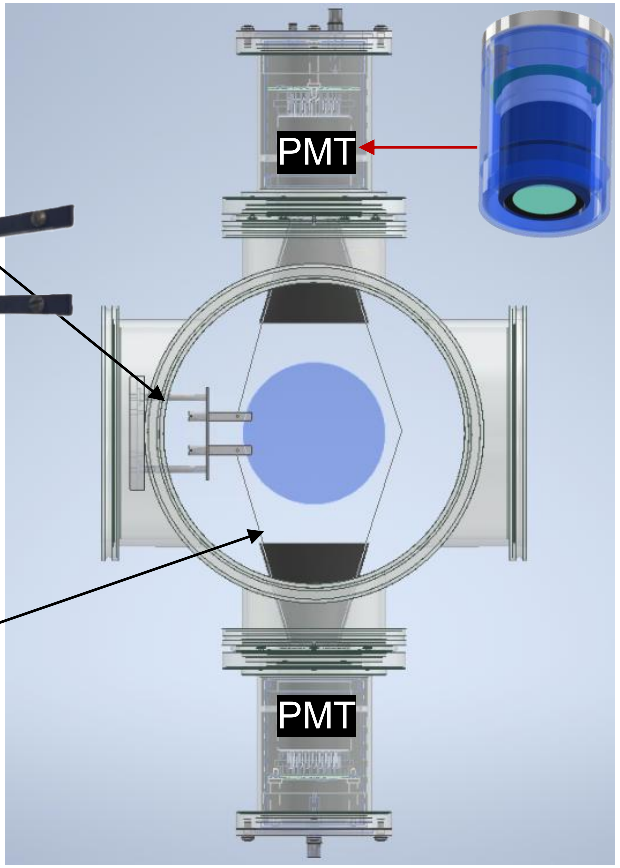
Detector	PMT (mesh dynodes)	Radiator
BC0, BC1	Hamamatsu R2490-07	Scint. BC400B Ø 100 x 0.25 mm³
VC	Hamamatsu R2490-07	Scint. Ø 100 x 0.25 mm³ Ø 25 mm hole

Scintillator support



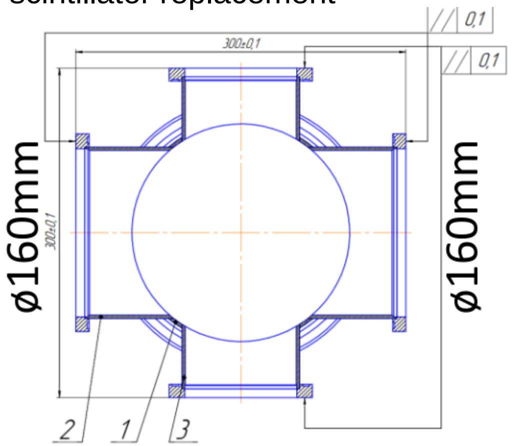
Al-mylar light guide

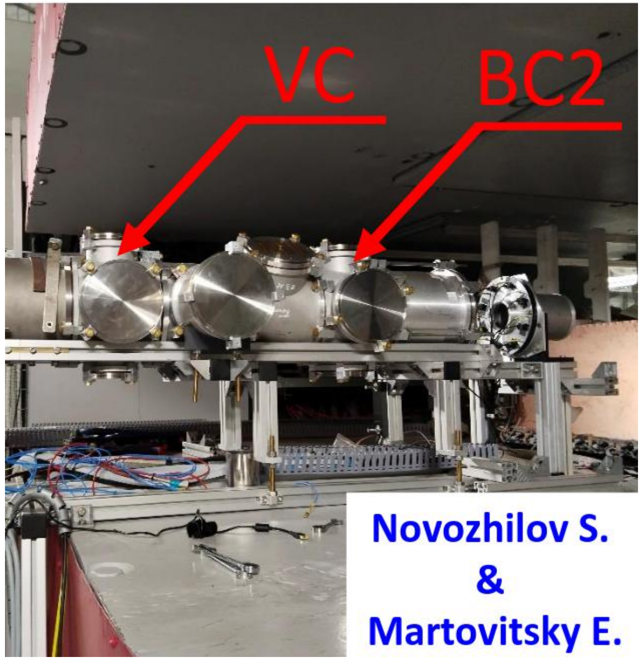




New vacuum boxes

- wider side tubes which will facilitate scintillator replacement





Novozhilov S.
&
Martovitsky E.

New counter BC0 - the same as BC1: ready

New vacuum boxes for BC0, BC1, VC, BC2: ready, installed
(Belgorod team, the team of S. Piyadin)

New scintillator mounts for BC0, BC1, VC, BC2: design completed,
preparation done (V. Velichkov, V. Azorskiy)

FEE : done (V. Rogov)

3D printed parts: done (A. Timoshenko)

New scintillators: available
Mylar light guides: done

Upgrade of BC2 (T0)

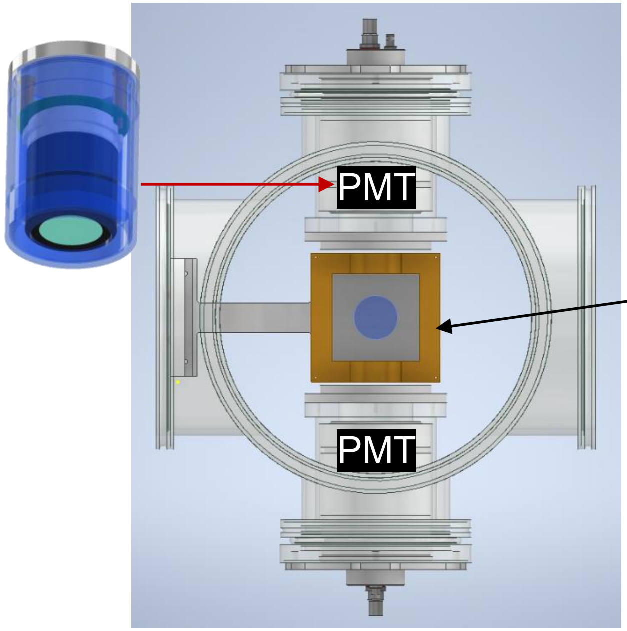
Long negative tail in BC2 pulses complicates analysis of pile-up events.
Reason for PMTs change from
Photonis XPM85112/A1 Q400
to Hamamatsu R2490-07 (BC1 type).

Detector	PMT (mesh dynodes)	Radiator
BC2	Hamamatsu R2490-07	Scint. BC400B Ø 25 x 0.125 mm^3

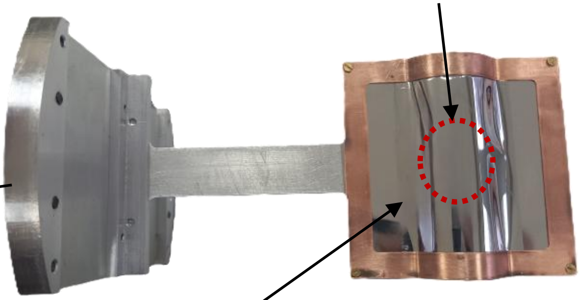
New parts for BC2

- PMTs change to R2490-07 (BC1 type)
- New design of mylar light guide

Light guide support



Scintillator
Ø 25x0.125 mm^3



Al-mylar "mirror"
and light guide

<u>TQDC</u>
Multihit
ADC precision:14 bit
Sampling rate:125 MS/s
TDC time bin 25 ps

New vacuum box: ready, installed
(Belgorod team, the team of S. Piyadin)

Adaptation of BC2 to Hamamatsu R2490-07 PMT: ready (V. Velichkov)

Scintillator mount: completed (V. Velichkov, V. Azorskiy)

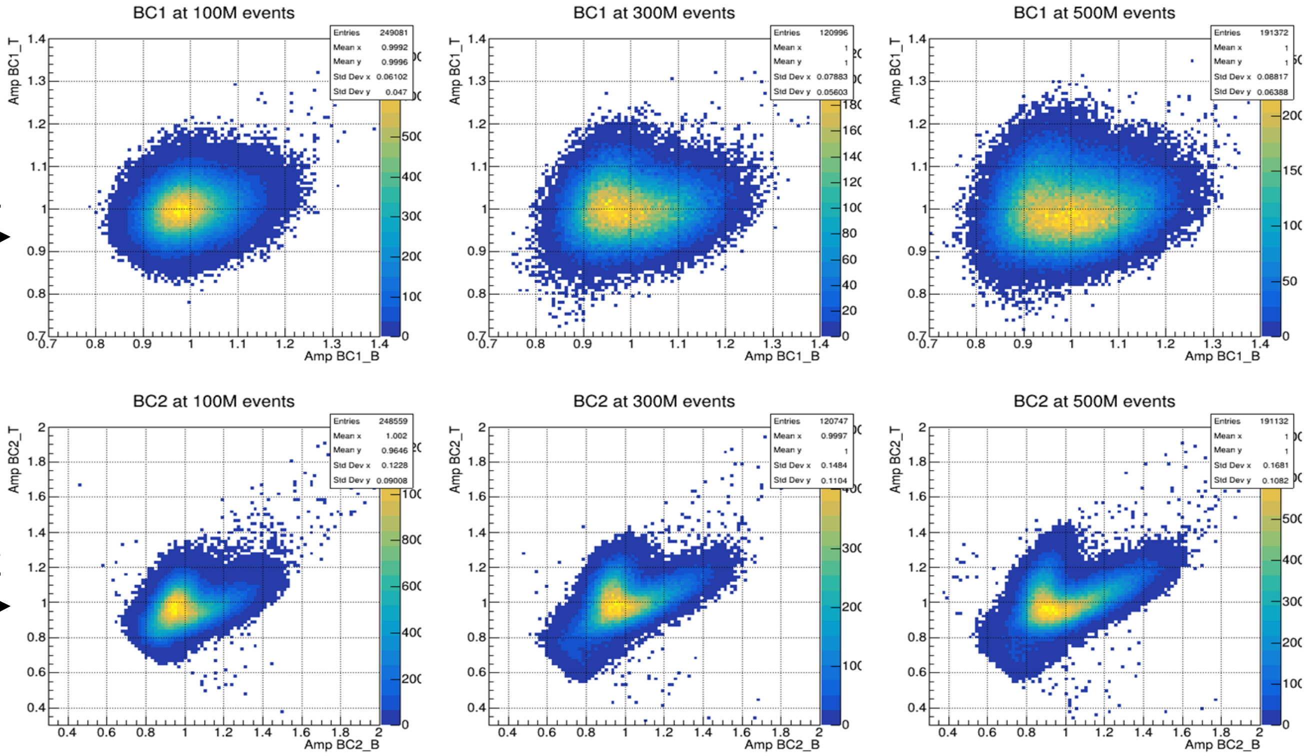
Scintillators: available
Mylar light guides: done

Indication of radiation damage in BC1 and BC2

2D plot of Top versus Bottom amplitude

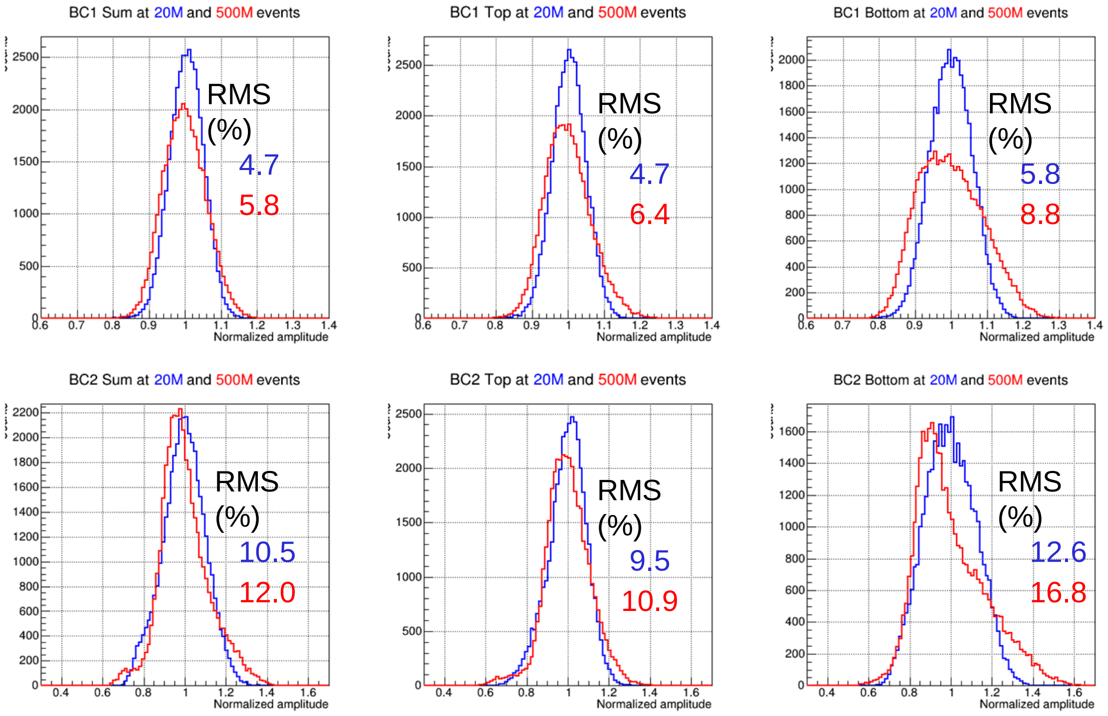
BC1

BC2



1D plot for the individual amplitudes

Blue - in the beginning of the run, Red - end of the run



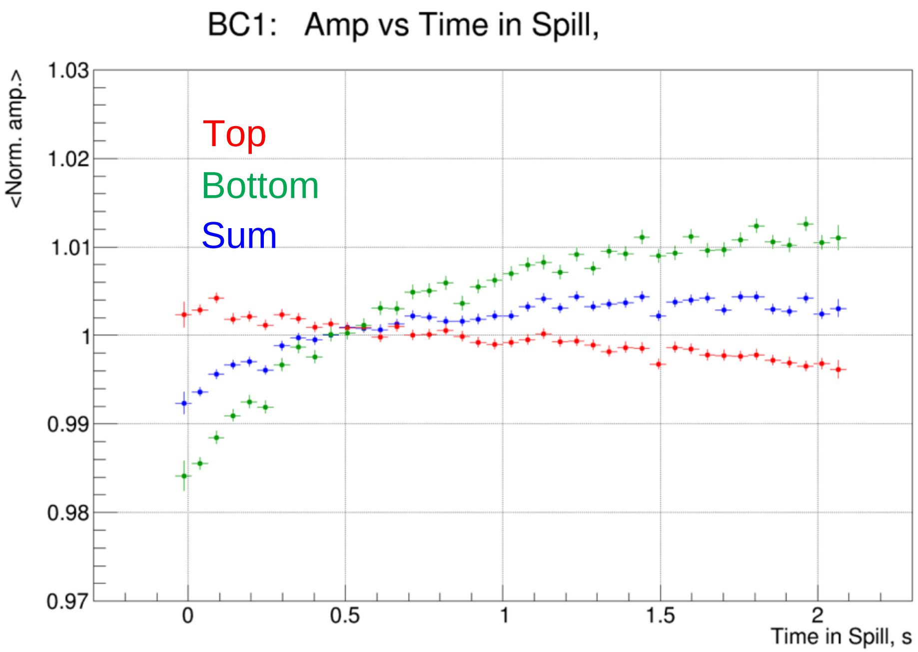
Sum →Trigger

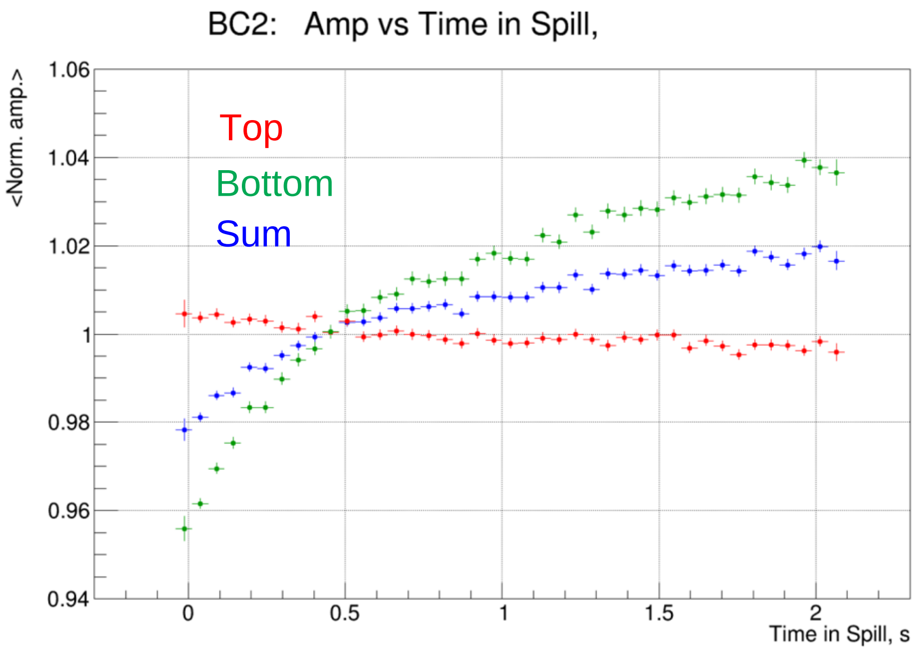
Top

Bottom

We see some degradation of the signals, which results in larger RMS at the end of the run – in BC1 Sum, BC2 Sum and individual signals.

BC1 and BC2: Amplitude and stability





BC1, BC2 response in spill

- stable at 1-2 % level for the sum signal
- stable at 2-4 % level for the individual signals
- sensitive to (X,Y) beam movement

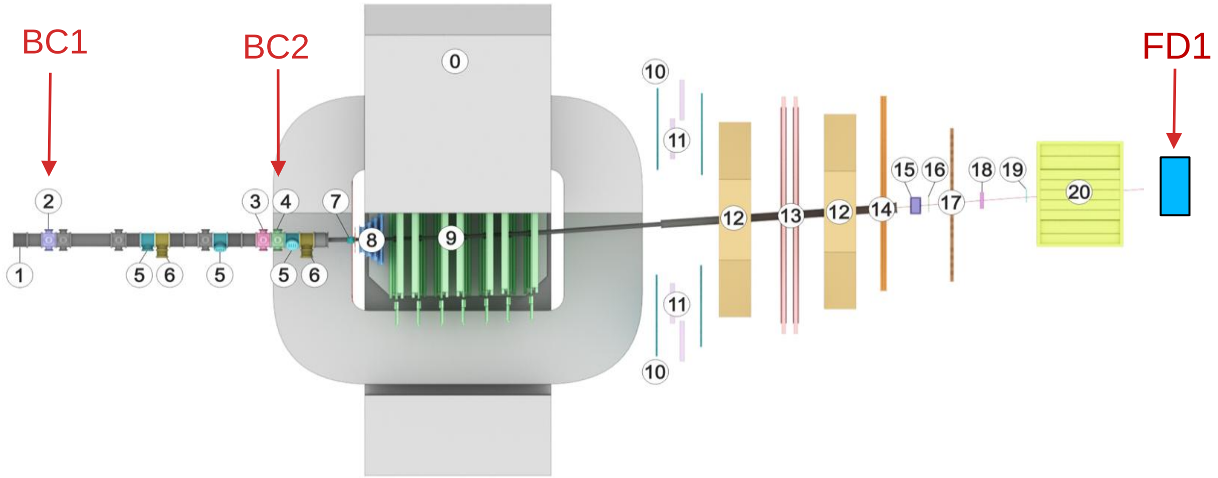
*spill duration ~ *2.2 s*

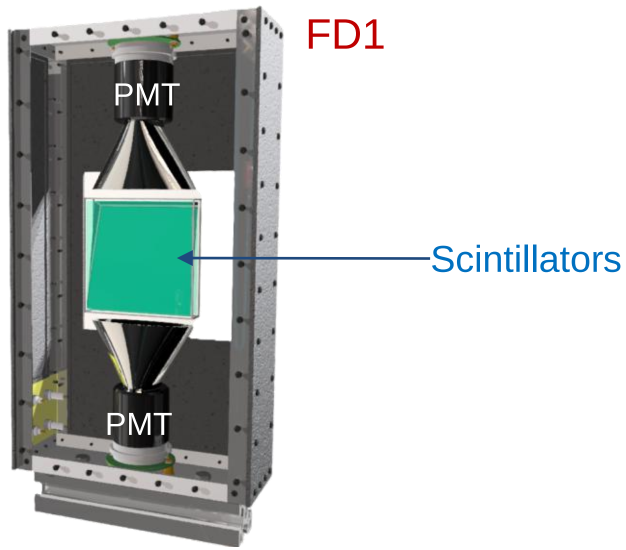
Offline amplitude resolution

Detector	Before corrections σ (%)	After corrections σ (%)
BC1	5.4	4.8
BC2	8.0	7.1

Corrections:
1)Top Amp versus Bottom Amp
2)TQDC binning

Time resolution of BC1, BC2





Measured with additional FD1 counter, placed behind the FHCal hole.
FD1 is similar to BC1 in design - has exactly the same PMTs and scintillator.

$\Delta t_{ij} = t_i - t_j$

$\sigma_{ij}^2 = \sigma_i^2 + \sigma_j^2$

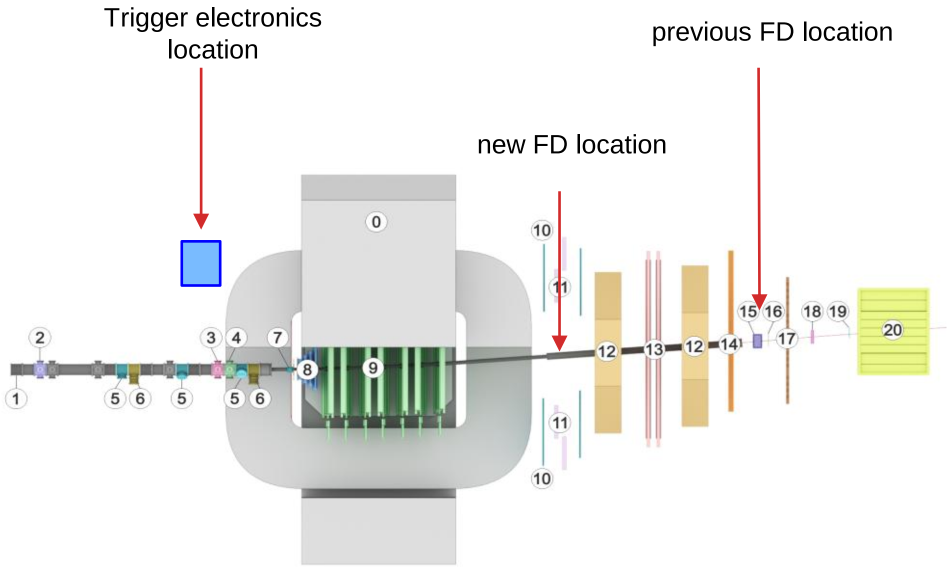
i,j: BC1, BC2, FD1

Detectors	σ_{ij}, ps
BC1 - BC2	57
BC1 - FD1	61
BC2 - FD1	58
(BC1&BC2) - FD1	52

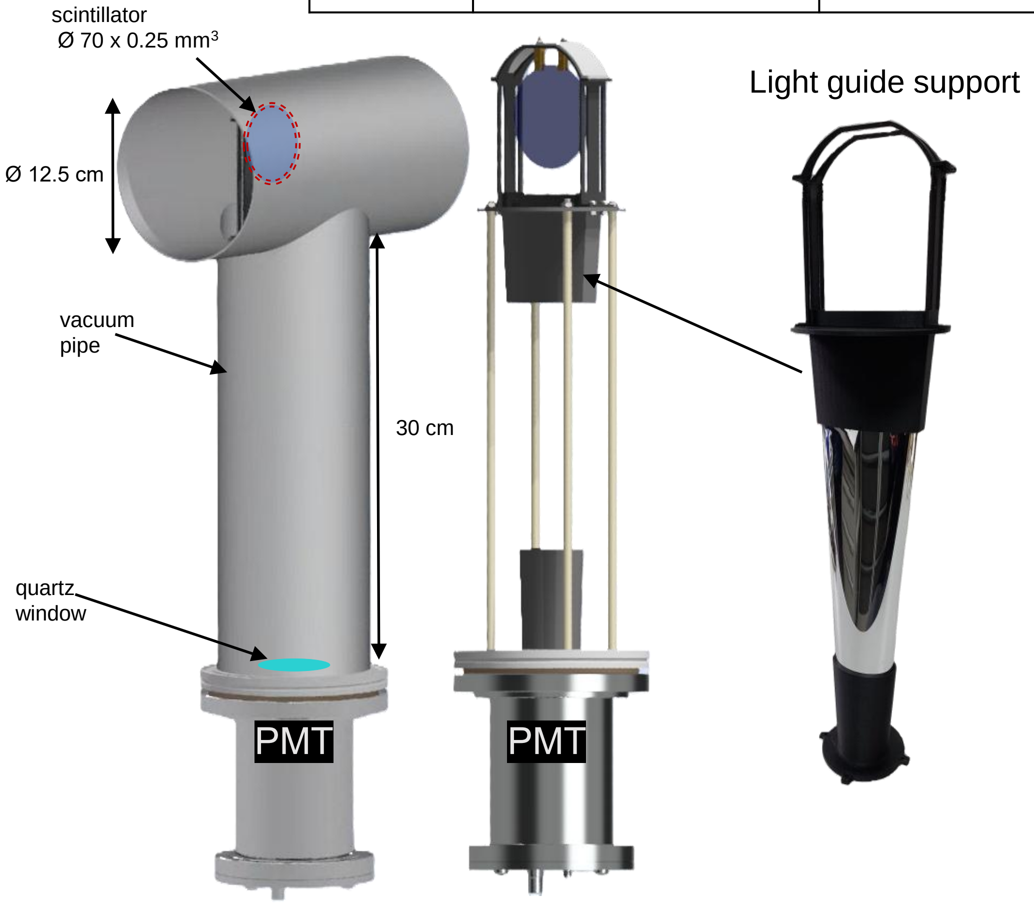
Detectors	σ_i, ps
BC1	43
BC2	38
FD1	44
(BC1&BC2)	28.2
	28.5

BC0 will be used to measure the time resolution of BC1 and BC2.

New Fragment Detector



Detector	PMT (mesh dynodes)	Radiator
FD	Hamamatsu R2490-07	Scint. BC400B Ø 70 x 0.25 mm^3



Vacuum box: ready
(Belgorod team, the team of S. Piyadin)

Design of the detector: completed
(V. Velichkov, *V.Yurevich,* V. Azorskiy)
Scintillator mount: design completed,
preparation done (V. Velichkov, V. Azorskiy)
Mechanics: done (V. Azorskiy)

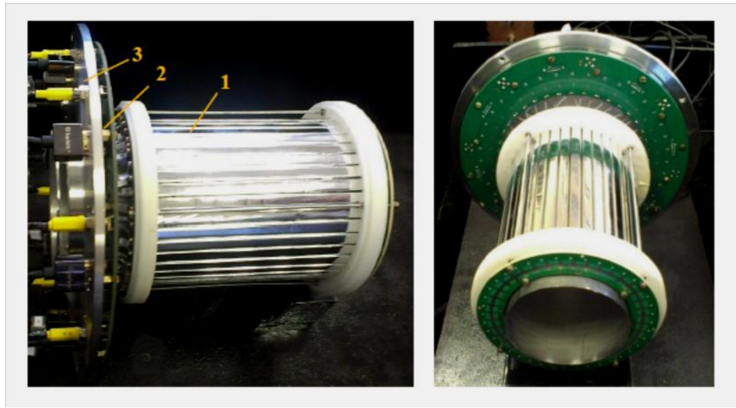
FEE : done (V. Rogov)
3D printed parts: done (A. Timoshenko)

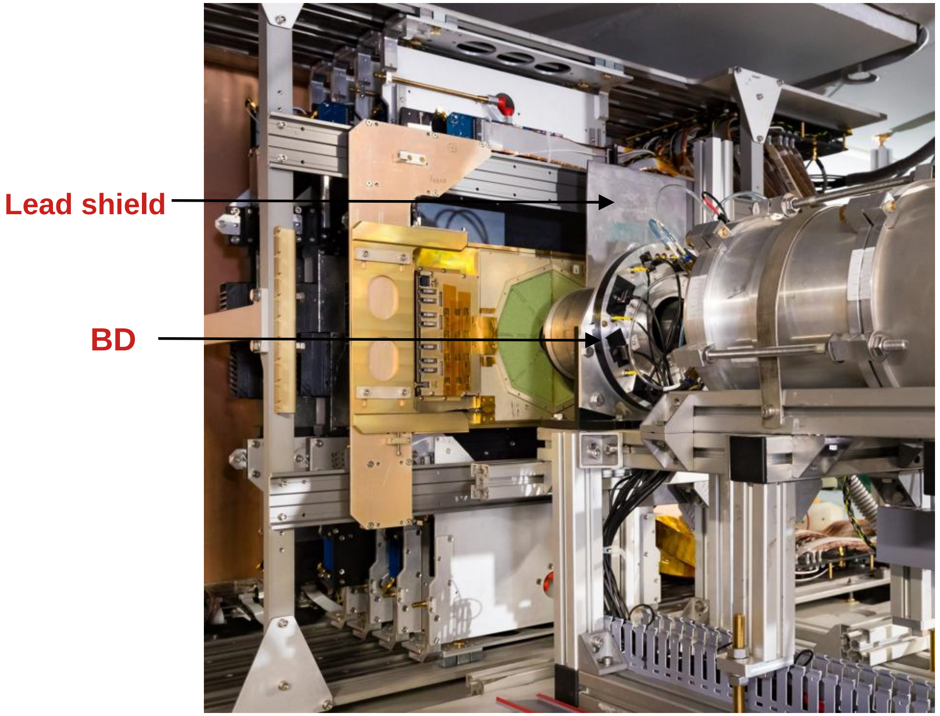
New scintillator: available
Mylar light guide: done

1. FD radiator in vacuum, i.e. min. material between target and FD
2. Shorter distance between target and FD, shorter cable between FD and trigger electronics
3. Rejection of close pile-up in the T0U

Barrel detector as multiplicity counter

Target is located inside the BD



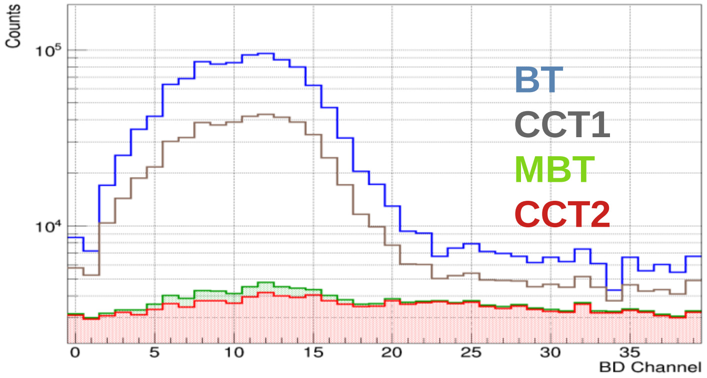


Barrel Detector (BD):
1 – 40 scintillation strips, 150 x 7 x 7 mm, BC418
2 – the board with SiPMs, Sensl C-series, 6 x 6 mm
3 – the board of front-end electronics.

Readout:
signals from every channel in BD are digitized by multihit TDC providing time and time-over-threshold width

Strong background hits from δ – electrons, curved in the magnetic field and hitting right side of the BD.

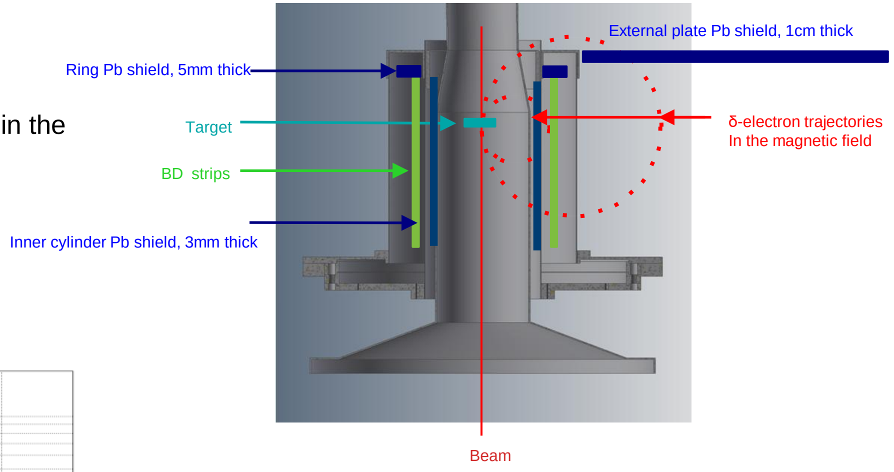
Distribution of hits in BD strips for different triggers



Settings in Xe 2023 run:

CCT1 = BT * BD(≥4)

Main physics trigger - CCT2 = MBT * BD(≥4)

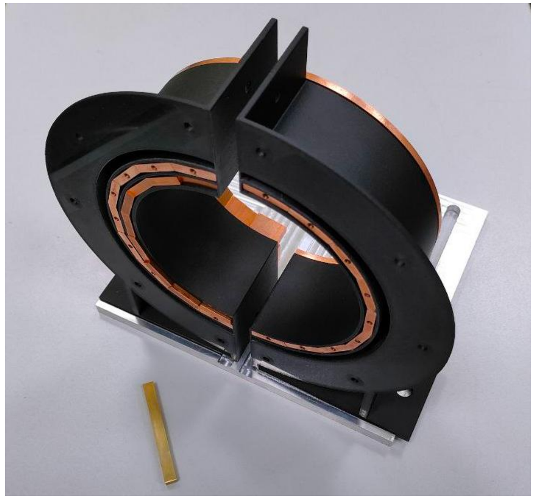


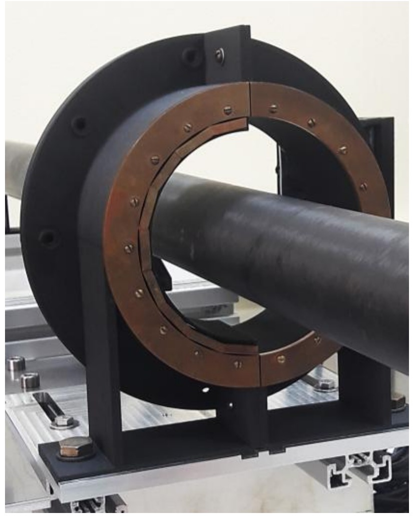
Target section of carbon vacuum pipe and BD

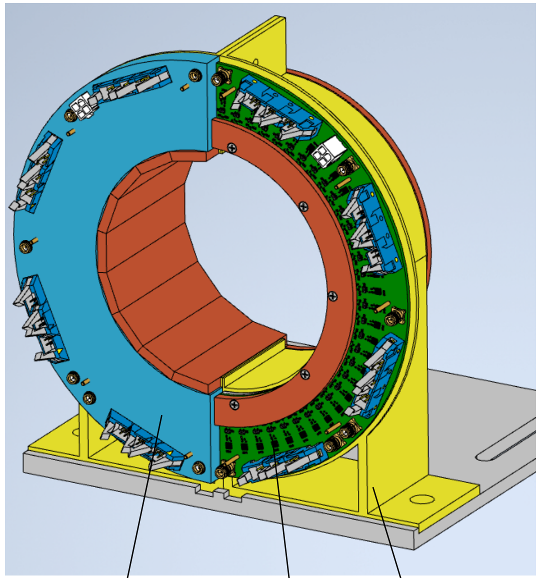
New Barrel Detector

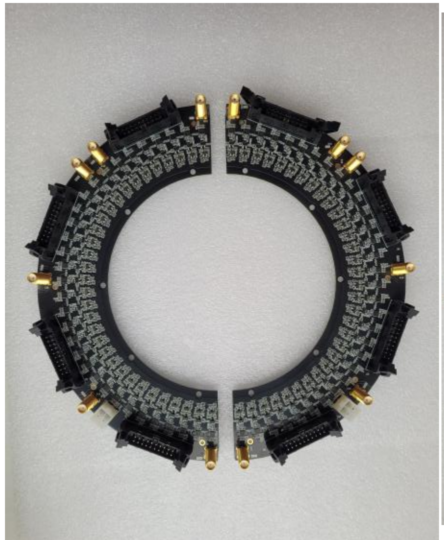
Upgrades for future runs with heavier beam ions (Bi)

- Larger number of channels - 64 scintillation strips 57×7×5 mm^3
- readout by 3×3 mm^2 SiPMs (J-ser. SensL)
- Cu layer inside BD for delta-electron absorption
- Shorter strips, easier to protect and position
- Larger inner diameter
- Consists of two parts (left /right) for simple installation

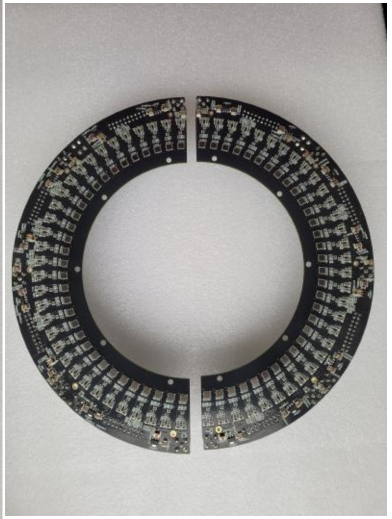








FEE PCB connectors side



FEE PCB SiPM side

Mechanics (*V.Tikhomirov, V.* Azorskiy, *A.Timoshenko*): completed, assembled

FEE : completed, currently been tested (*V.Rogov*)

Multiplicity logic module (*S.Sergeev, V.Rogov, P. Grigoriev*): components available, about half a year needed for production

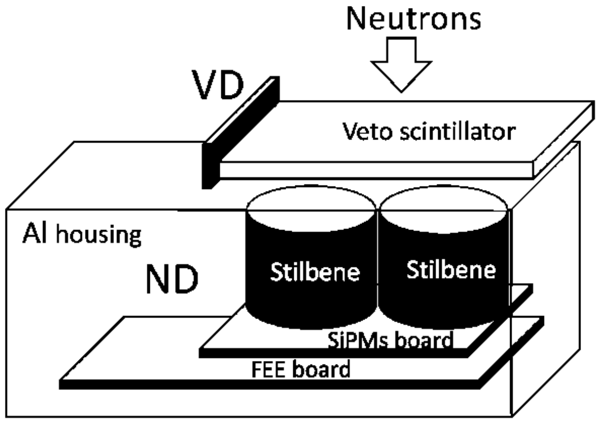
Scintillators, SiPMs : available (*V.Yurevich*)

Simulation: done (*N.Lashmanov)*

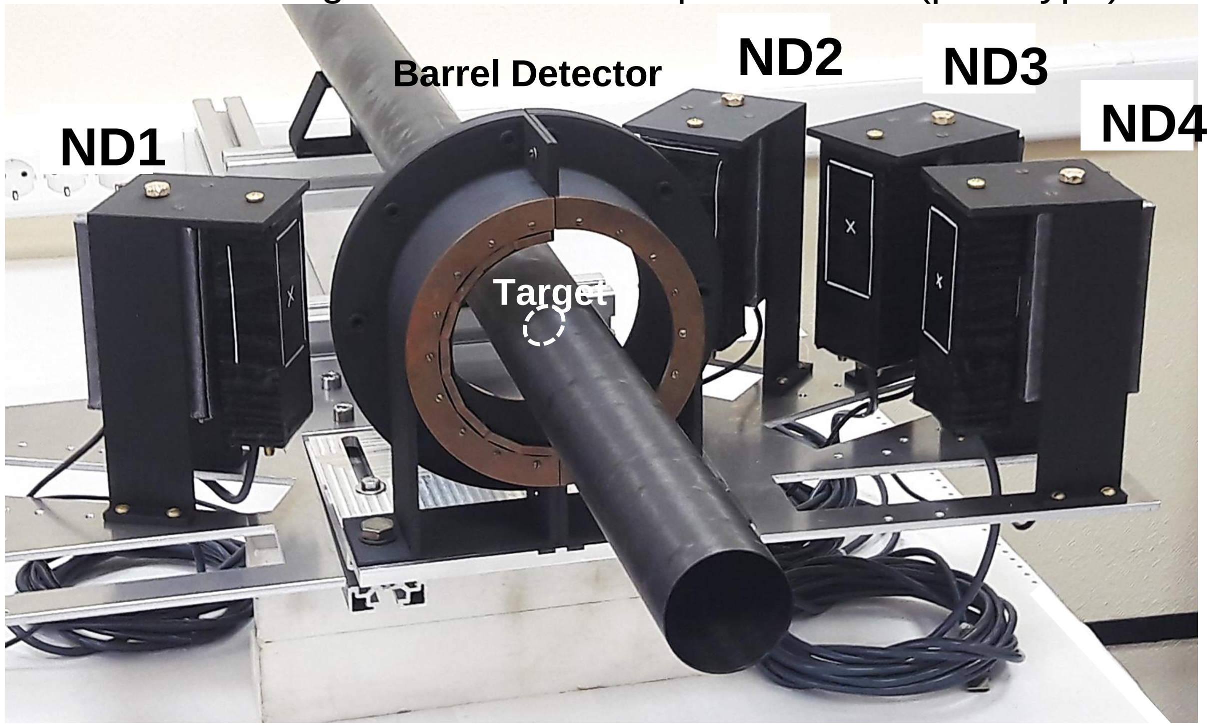
The compact TOF Neutron Spectrometer 2024

Neutron Detectors

Detector	θ (deg.)	L (cm)	Stilbene (mm)
ND1	**110º**	**20**	**D30×10**
ND2	**121º**	**30**	**D25.4×25.4**
ND3	**110º**	**30**	**D25.4×25.4**
ND4	**95º**	**30**	**D25.4×25.4**



A new design of the neutron spectrometer (prototype)



Compact time-of-flight spectrometer. Range of neutron energies from 1 to 200 MeV. With this spectrometer the neutron emission from target spectators in Xe + CsI collisions at 3.8 *A* GeV was studied by measuring double-differential neutron production cross section.

Mechanics: completed, assembled
(*V. Tikhomirov, V. Azorskiy, A. Timoshenko)*

FEE : done (*V. Rogov*)

Simulation: done (*N.Lashmanov*)

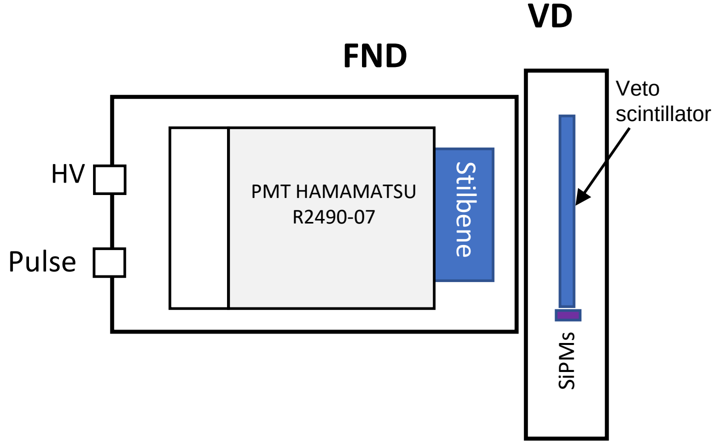
Analysis of the data: (*N.Lashmanov*)

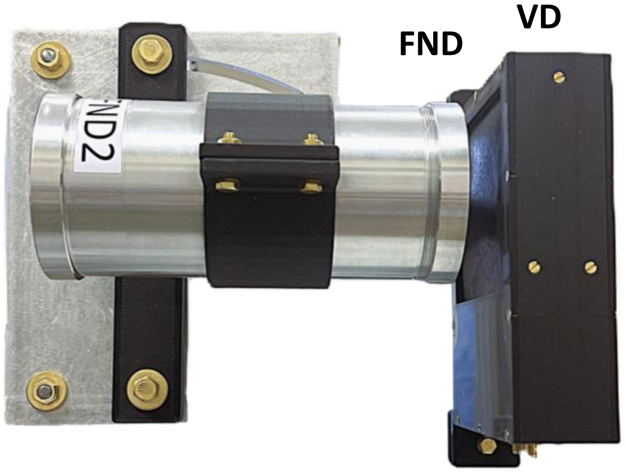
New neutron detectors for measurements at small angles

Forward Neutron Detectors

Detector	Stilbene	Angle
FND1	D31 × 31 mm	3°
FND2	D31 × 31 mm	6°
FND3	D40 × 20 mm	9°
FND4	D40 × 20 mm	12°

Energy range: 50 – 5000 MeV





Aim of the measurements

- ✓ Study neutron emission from beam spectators and comparison with theoretical models and results of the compact TOF spectrometer
- ✓ To get reference data for HGND project
- ✓ Study of energy and angular distribution of neutrons coming to nZDC

Design of the detector: completed
(V. Velichkov, *V.Yurevich,* V. Azorskiy)

Radiators mounts and assembly: design completed,
preparation done (V. Velichkov)

Mechanics: done (V. Azorskiy)

FEE : done (V. Rogov)

3D printed parts: done (A. Timoshenko)

Bosch profile holders: in progress

Summary and outlook

- Amplitude resolution of the BC1, BC2 and FD (~5-7 %) met the requirements for the event selection at the trigger level and at the later offline event analysis.

- Time resolution of BC1 and BC2 (~40 ps) is sufficient for a precise start time determination in the time of flight measurements.

- Some radiation damage of the scintillators is observed in the 2023 Xe run. The scintillators will be replaced.

Upgrades:

- **New counter BC0**
- **New vacuum boxes** for the beam counters
- **New scintillator supports** for the beam counters
- **New PMTs for BC2**
- **New FD** with the scintillator placed in vacuum.
- **New neutron detectors** for measurements at small angles

Upgrades for future runs with heavier beam ions (Au, Bi)

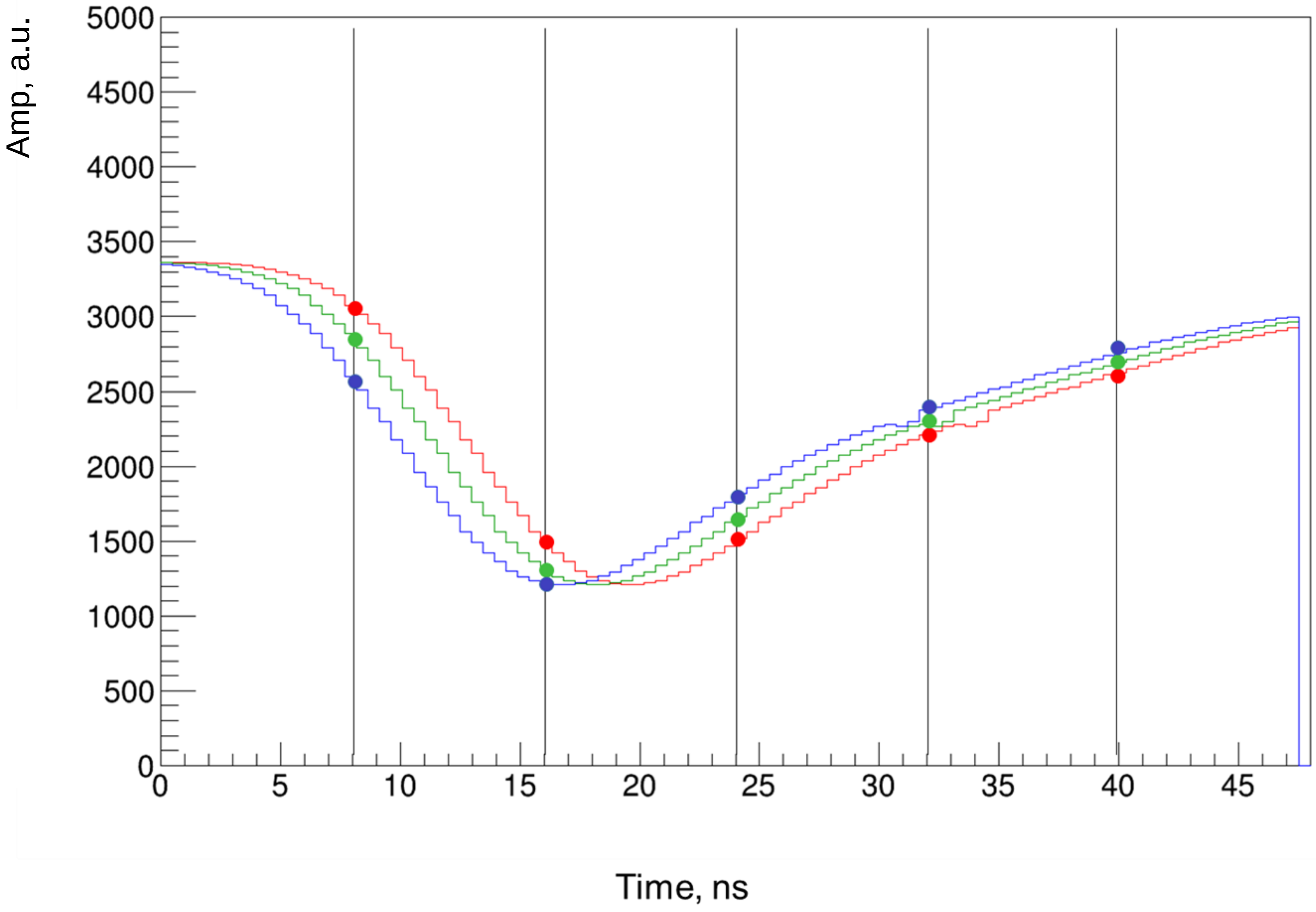
- **New Barrel detector**

Tests of quartz radiators for BC1, BC2, FD

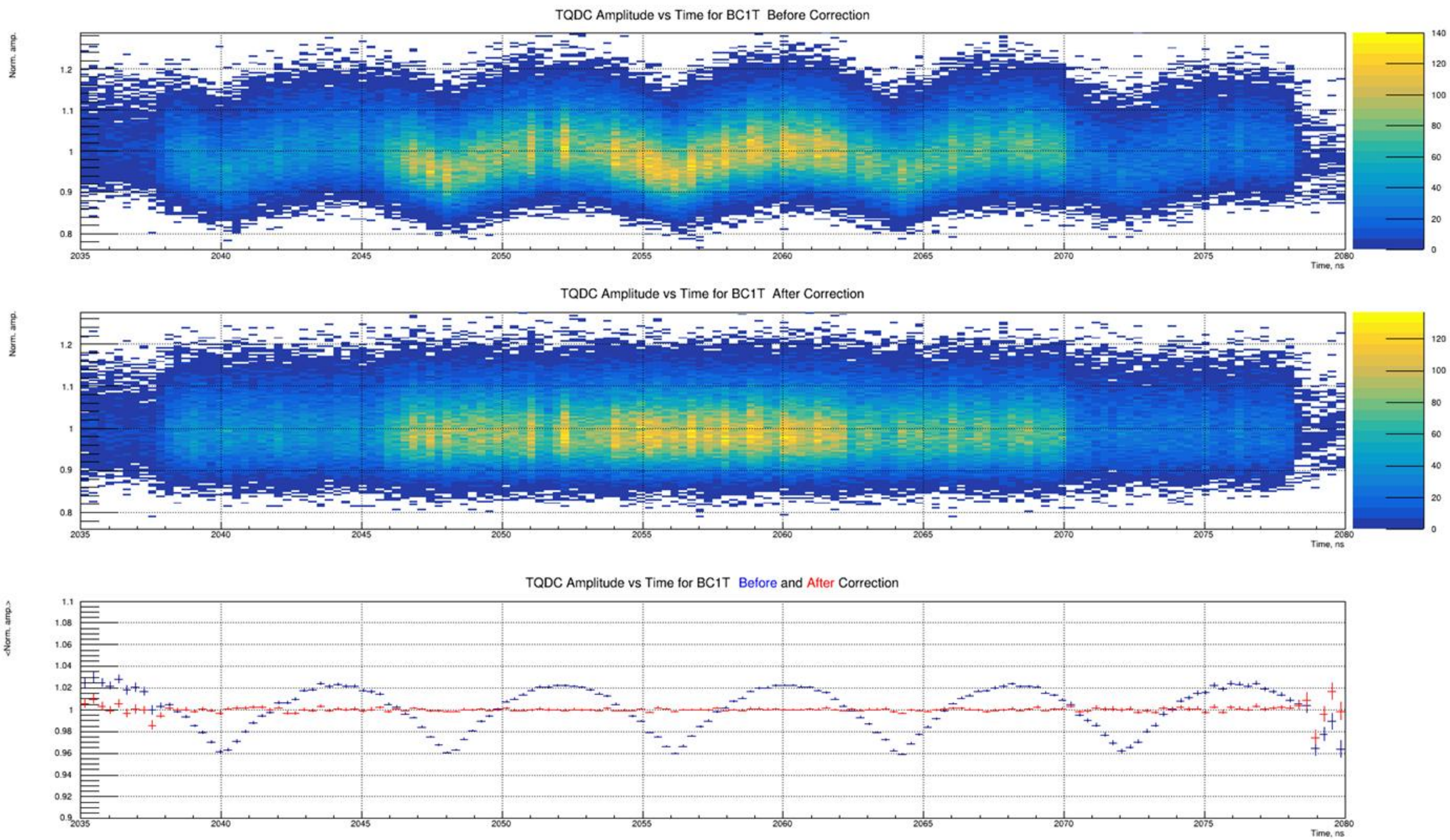
Thank you for your attention!

Backup slides

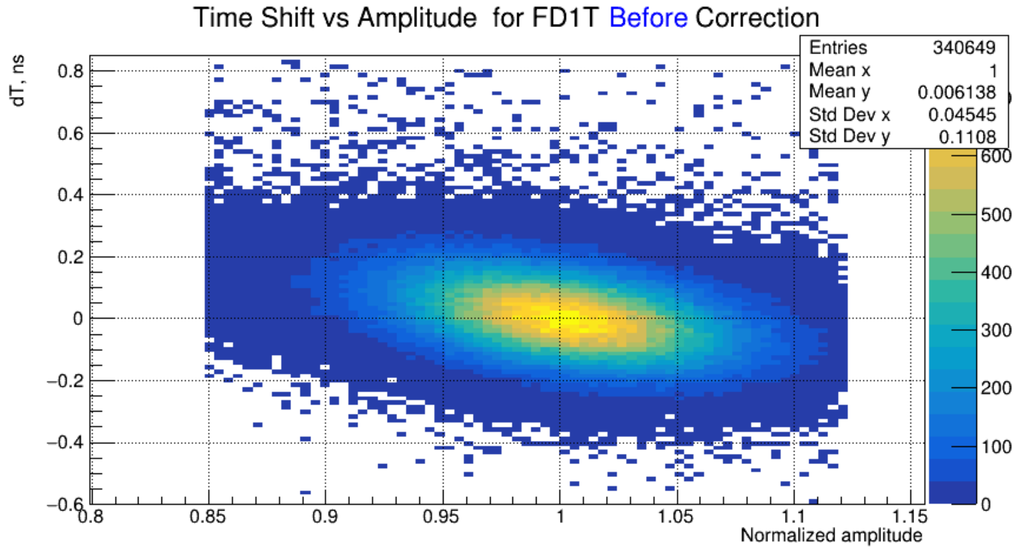
TQDC_Digit → GetPeak() will return different values,
depending on the pulse phase with respect to the 8ns binning grid

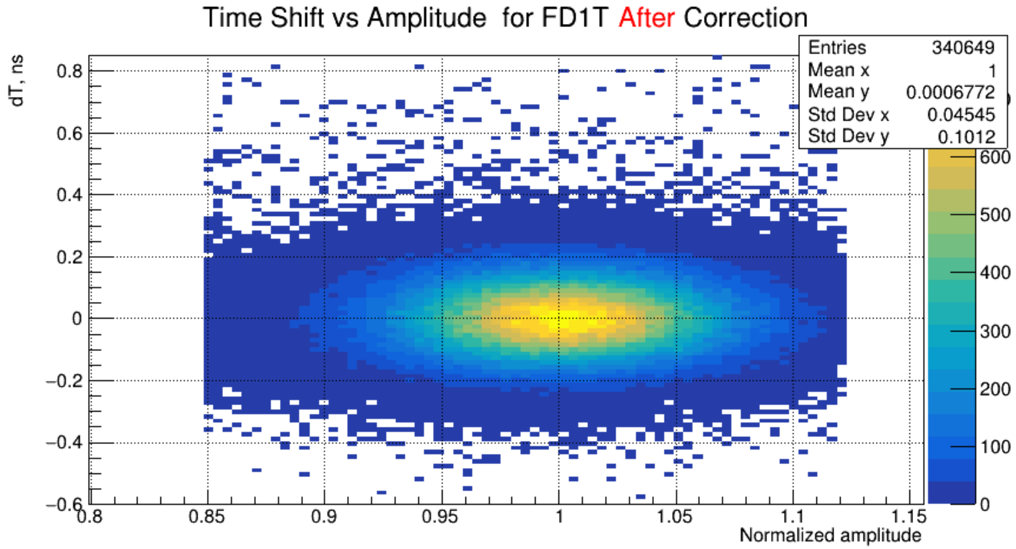


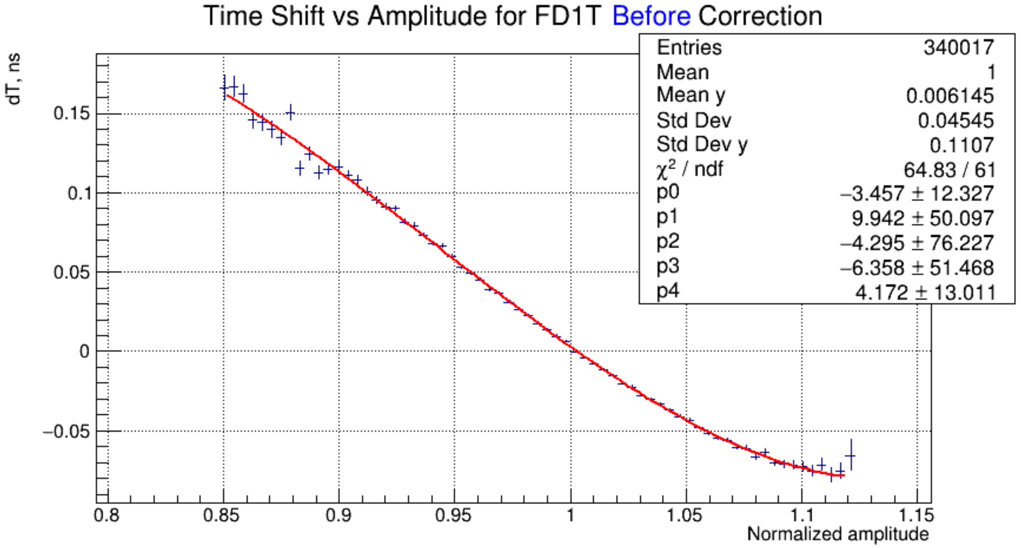
TQDC “8ns binning” correction for amplitude resolution

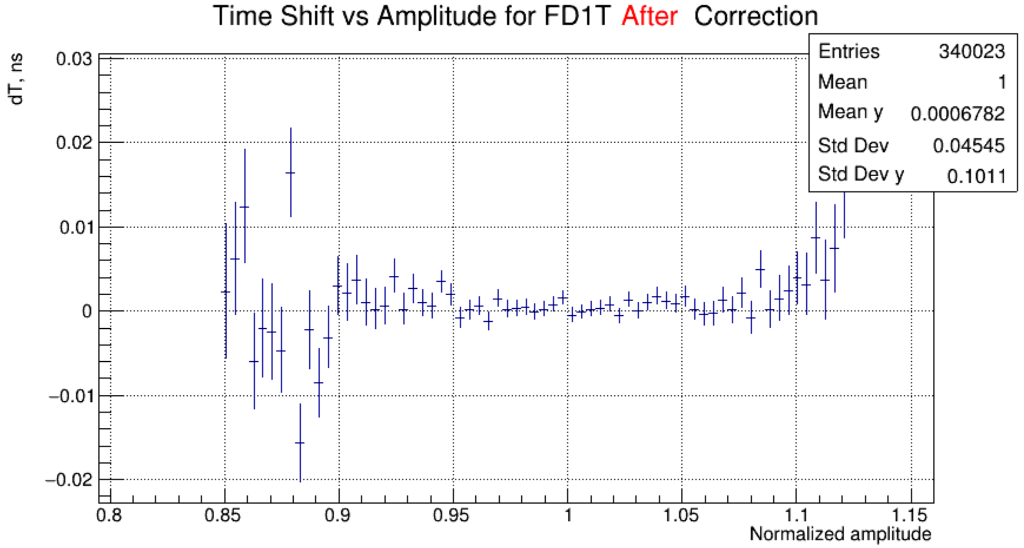


Before and after time-walk correction for FD1T

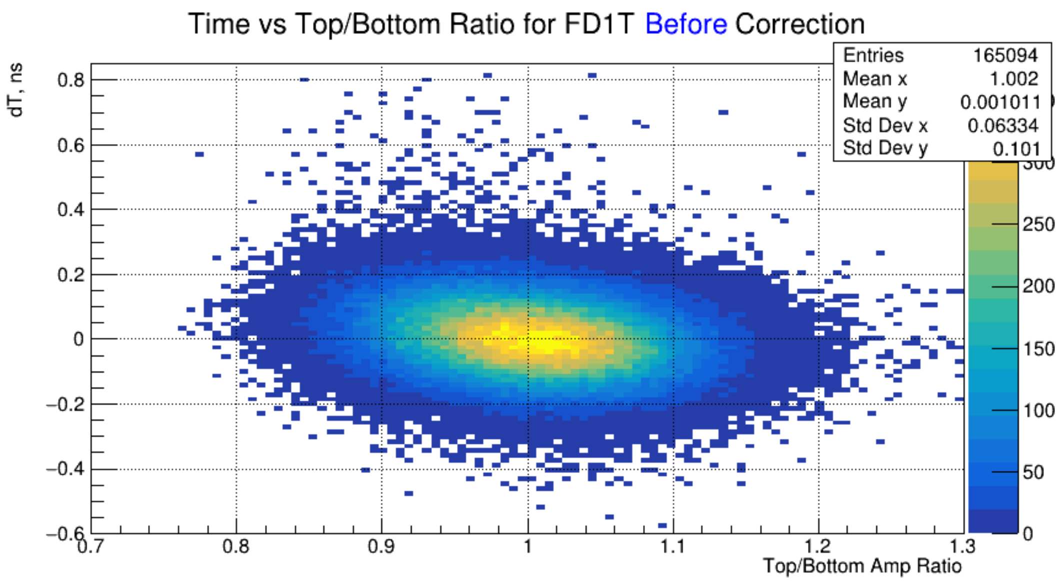


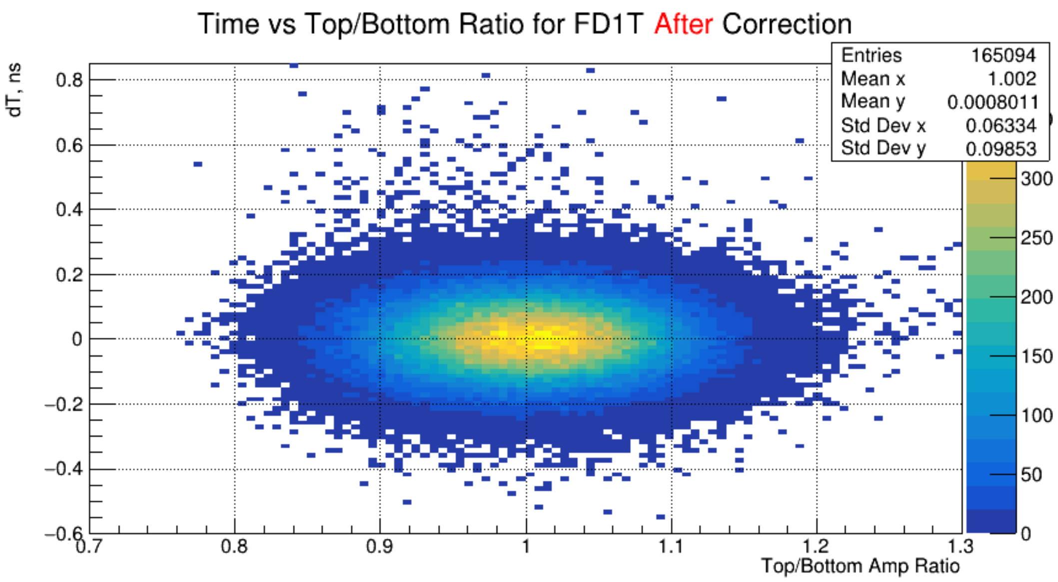


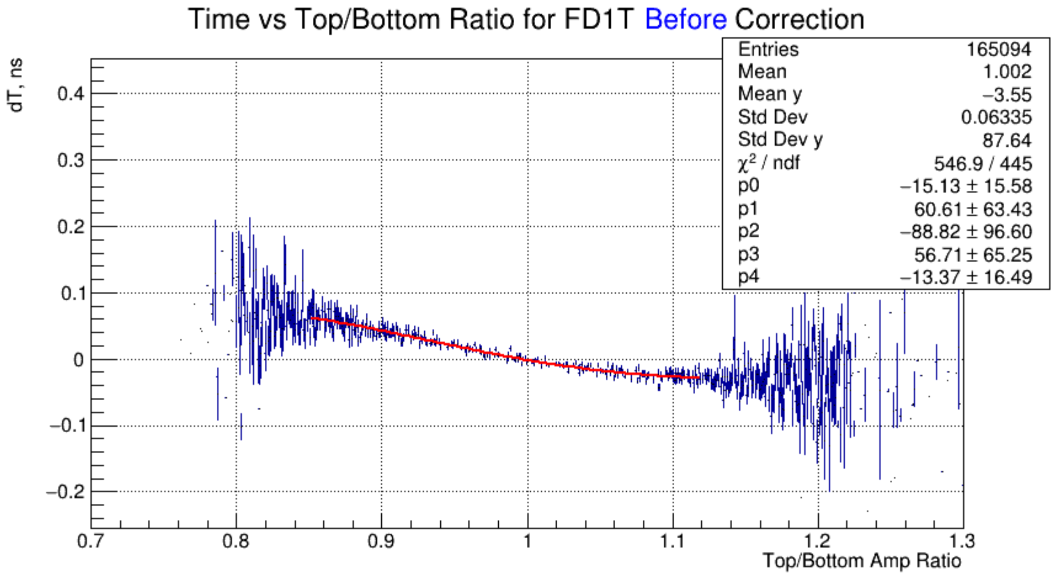


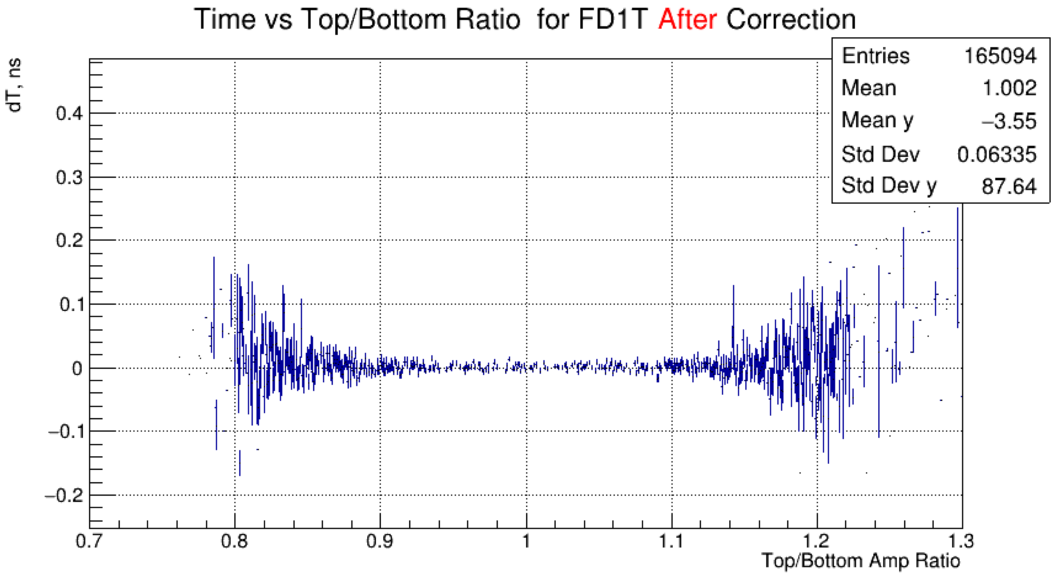


Top/Bottom correction for time resolution analysis



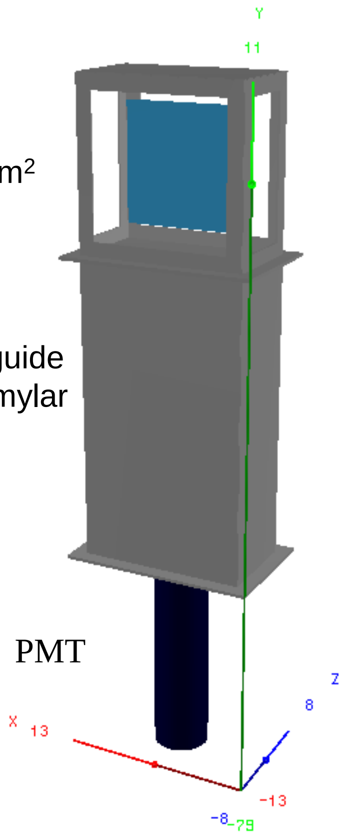




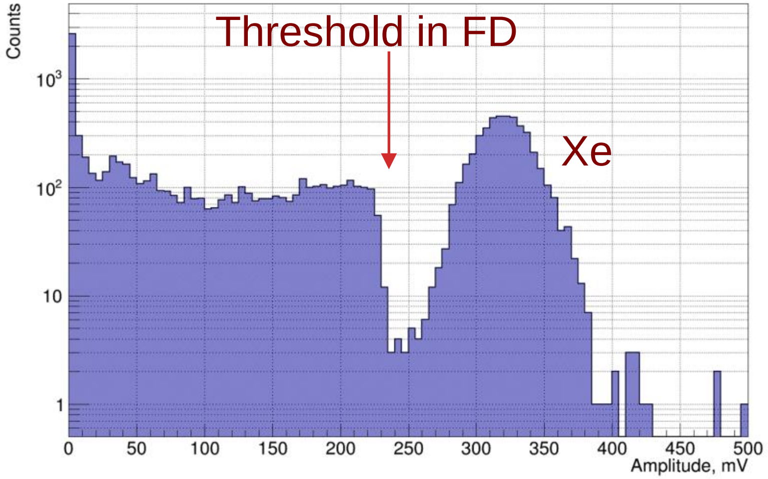


Fragment Detector

PMT	Radiator	σ/A (%)
XP2020	Scint. 0.5 mm	6.0
XP2020/Q	Quartz 1 mm	11.7
R2490-07	Scint. 0.5 mm	5.3



Significantly better resolution with scintillator radiator.
Less than expected photoelectron statistics with quartz radiator.



~65-70% centrality was selected by the threshold in FD