Development of beam trigger detectors for the BM@N experiment

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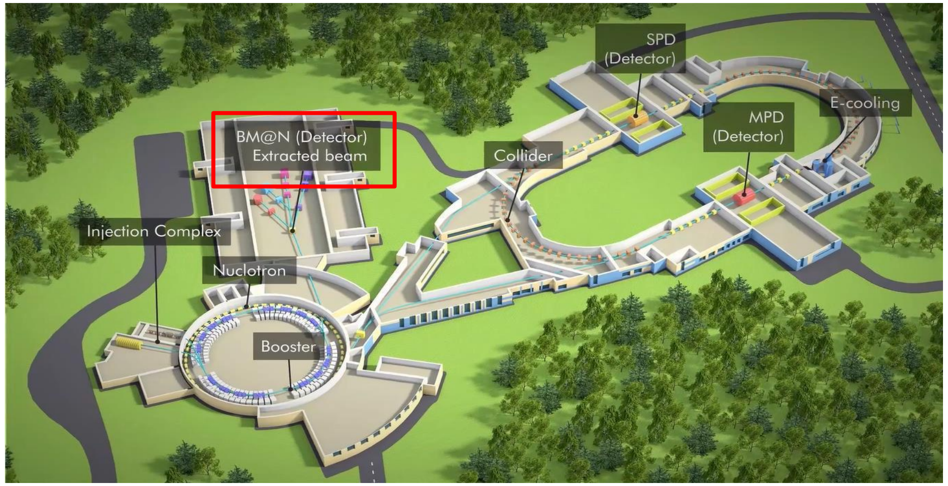
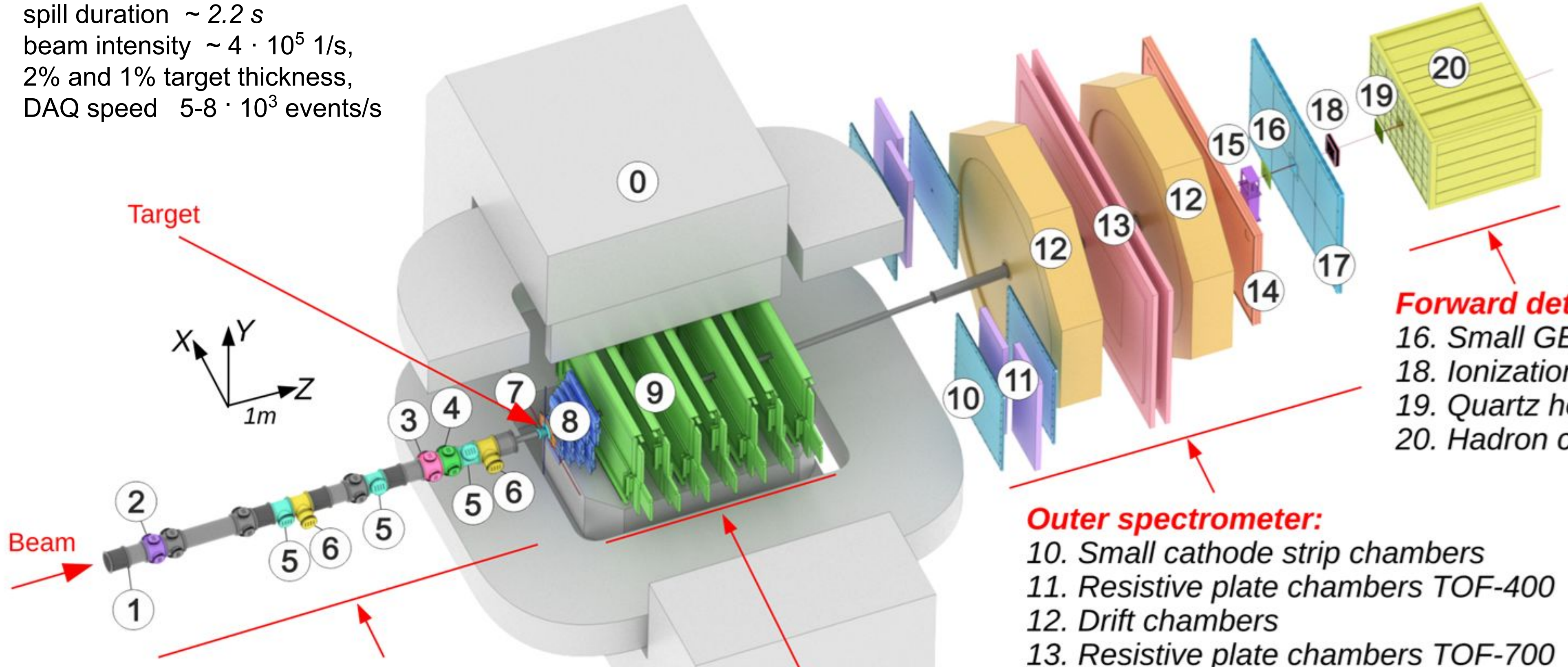


BM@N spectrometer in 2023 ^{124}Xe run

Conditions in 2023 Xe run, *3.8 GeV/n*:
spill duration ~ *2.2 s*
beam intensity ~ 4 · 10^5 1/s,
2% and 1% target thickness,
DAQ speed 5-8 · 10^3 events/s



Beam tracking system:
1. Vacuum beam pipe
5. Silicon beam tracker
6. Beam profilometers

Central tracking system:
0. Analysing magnet
8. Silicon strip detectors
9. GEM detectors

Outer spectrometer:
10. Small cathode strip chambers
11. Resistive plate chambers TOF-400
12. Drift chambers
13. Resistive plate chambers TOF-700
14. Scintillation Wall
17. Large cathode strip chamber

Forward detectors:
16. Small GEM chamber
18. Ionization chamber
19. Quartz hodoscope
20. Hadron calorimeter

Forward spectrometer, typical tasks for heavy ion physics:
- *particle yield and their spectra,*
- *of a particular interest strange particles,*
- *particle flow, correlations, etc.*

Overview of the trigger detectors and trigger logic in the 2023 Xe run

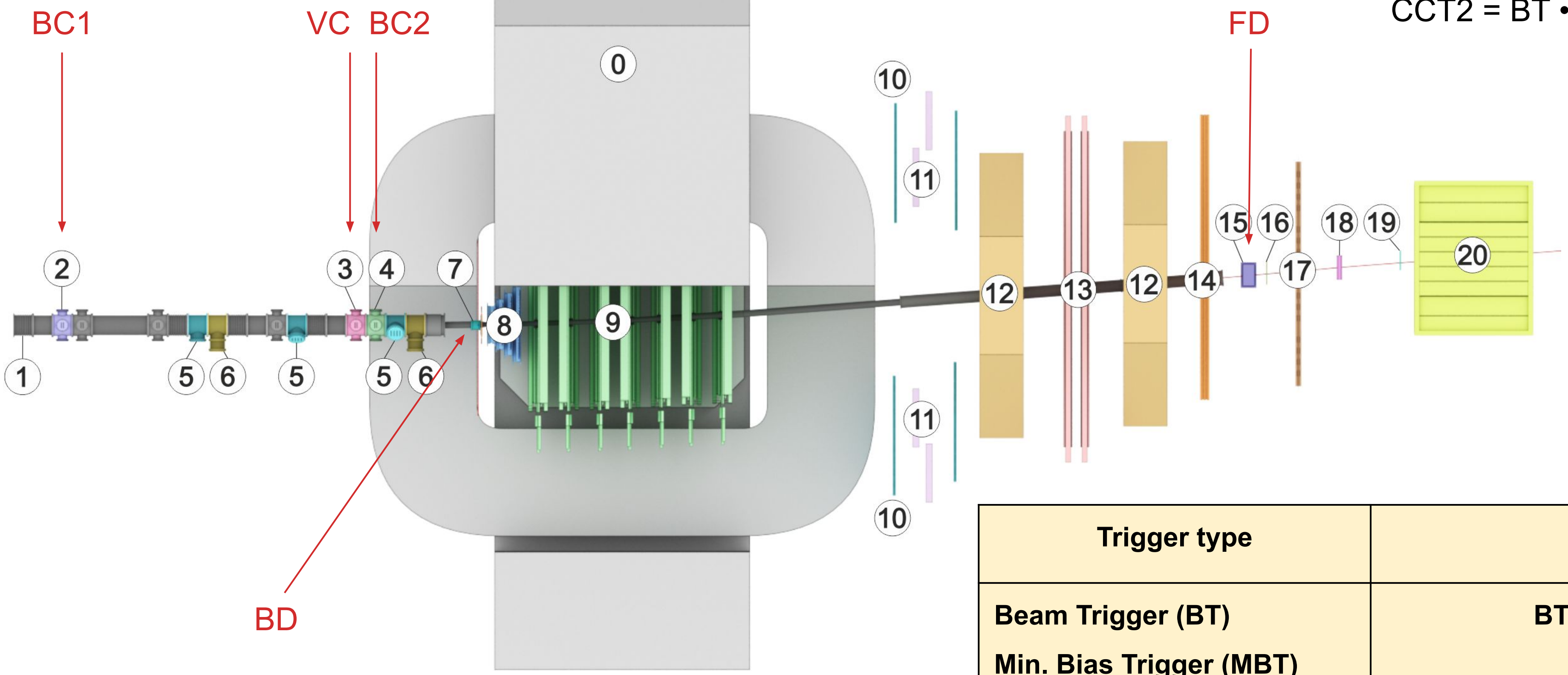
<u>Beam trigger</u>

$BT = BC1 \bullet \overline{VC} \bullet BC2$

<u>Minimum bias, centrality trigger 2</u>

$MBT = BT \bullet \overline{FD}$

$CCT2 = BT \bullet FD \bullet BD\ (n \geq 4)$

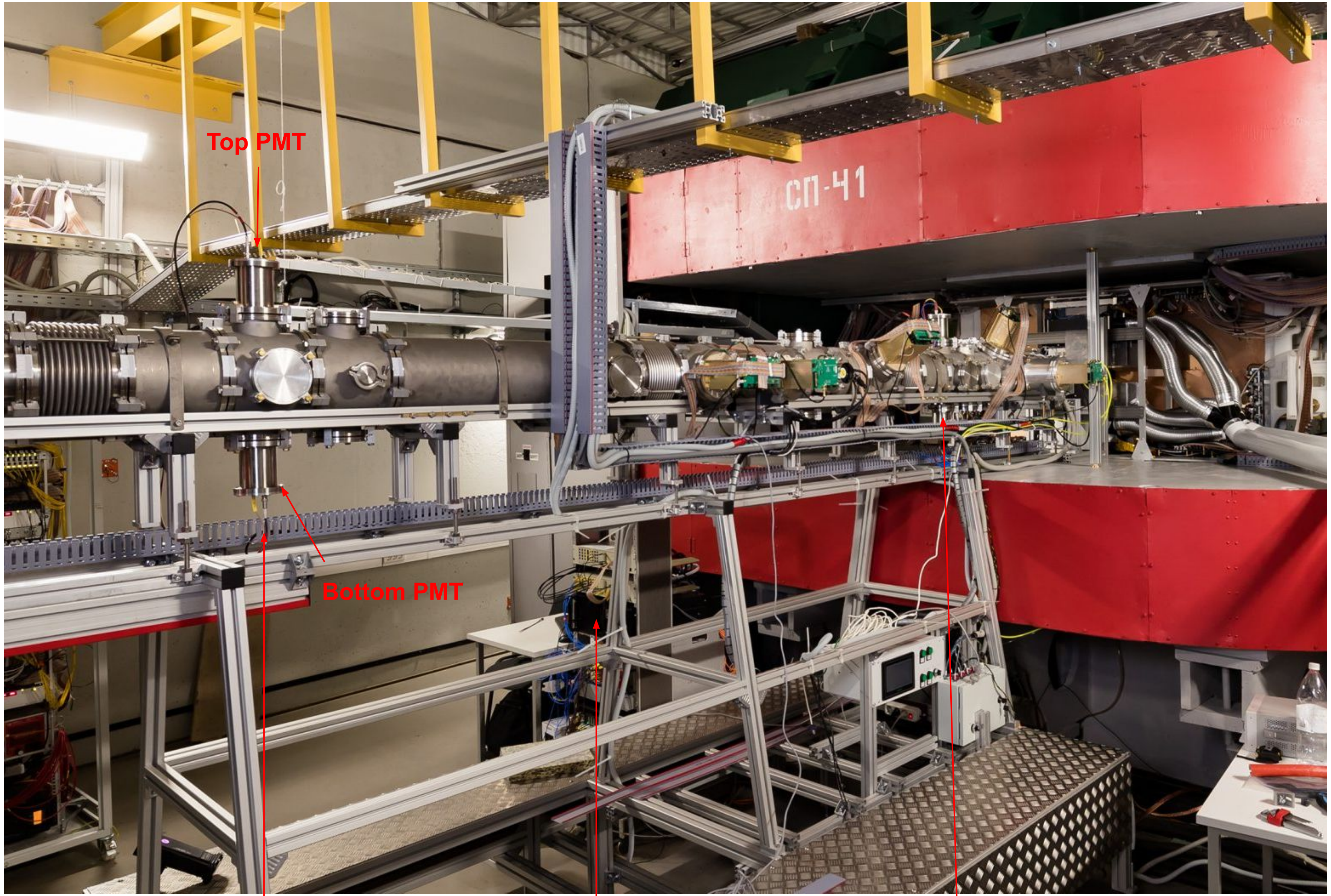


<u>Centrality trigger 1</u>

$CCT1 = BT \bullet BD\ (n \geq 4)$

Trigger type	Trigger logic
Beam Trigger (BT)	**$BT = BC1 * BC2 * \overline{VC}$**
Min. Bias Trigger (MBT)	**$MBT = BT * \overline{FD}$**
Centrality Trigger 1 (CCT1)	**$CCT1 = BT * BD(n \geq 4)$**
Centrality Trigger 2 (CCT2)	**$CCT2 = BT * BD\ (n \geq 4) * \overline{FD}$**

Beam pipe and detectors upstream of the target



BC1 Trigger electronics VC, BC2

Vacuum for heavy ion runs

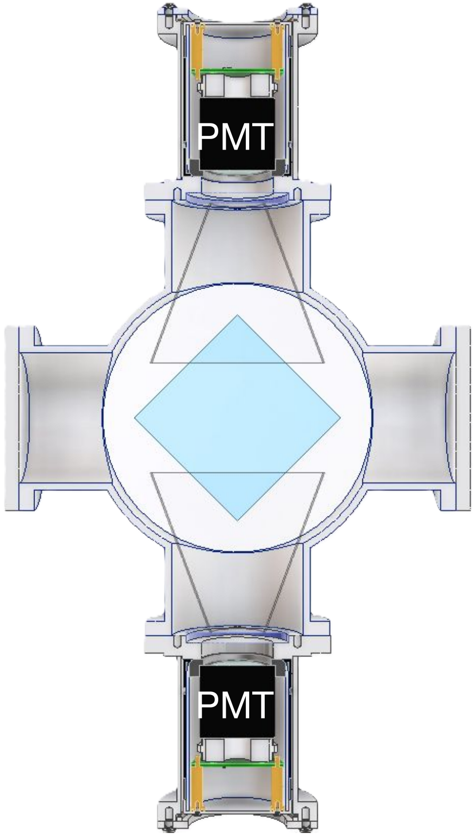
2020-2023: new vacuum elements in nearly entire beam transport line from Nuclotron to BM@N

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

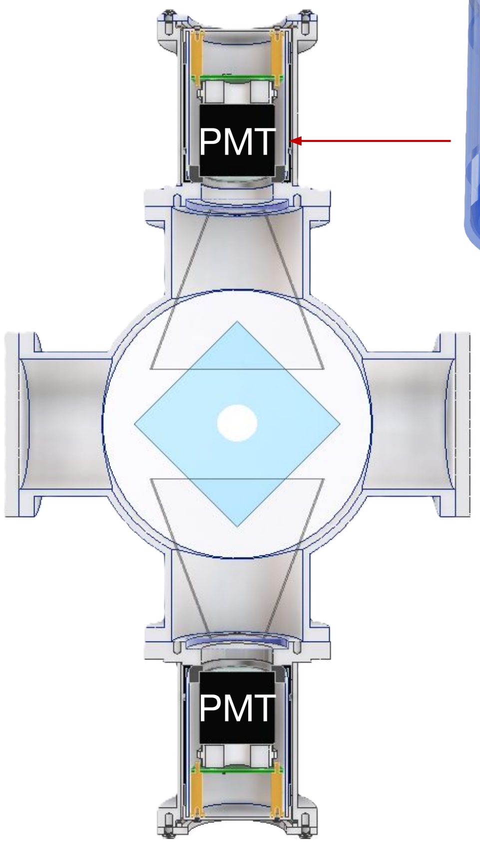
BC2 and VC PMTs are capable to work in the magnetic field

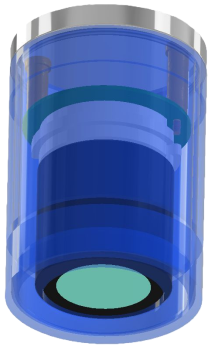
Design and read-out of BC1, VC

BC1



VC

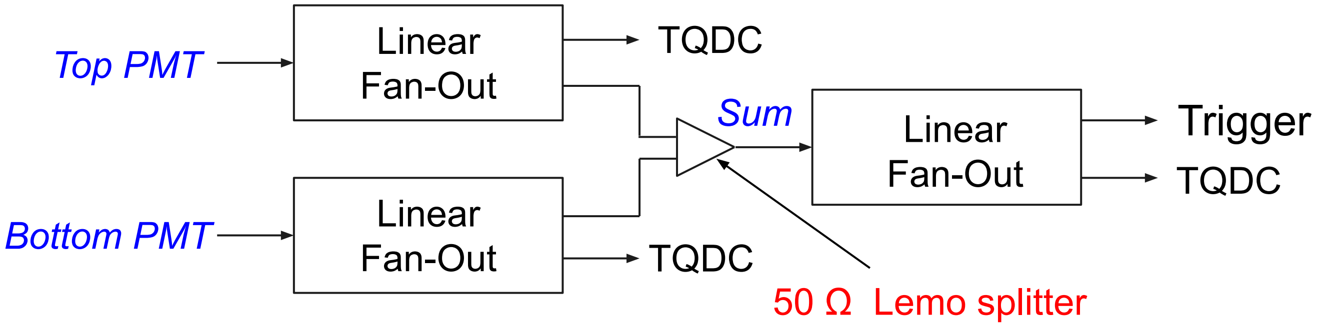




Detector	PMT (mesh dynodes)	Radiator
BC1	Hamamatsu R2490-07	Scint. BC400B 100 x 100 x 0.25 mm^3
VC	Hamamatsu R2490-07	Scint. 113 x 113 x 4 mm^3 Ø 25 mm

“Air”-lightguides from Al-mylar

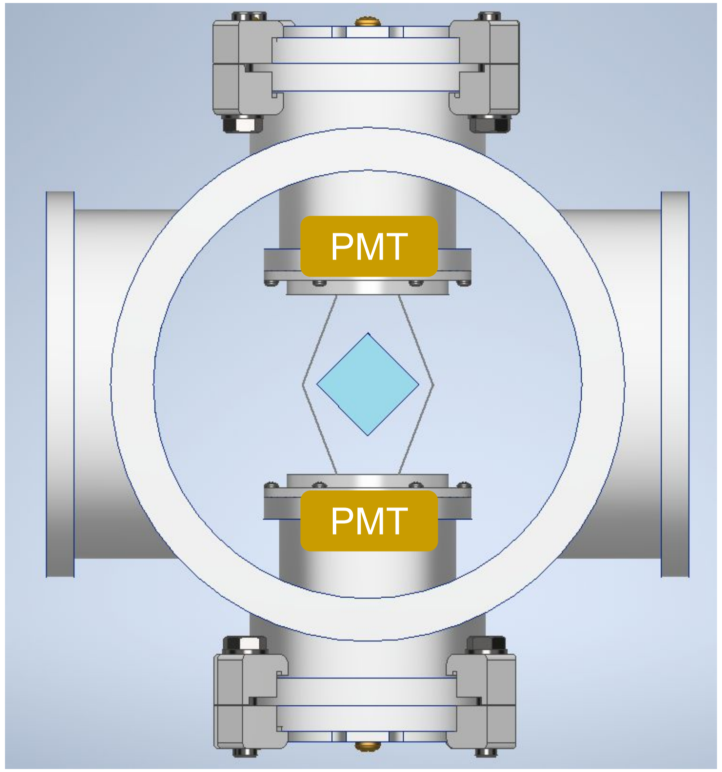
<u>TQDC</u>
Multihit
ADC precision:14 bit
Sampling rate:125 MS/s
TDC time bin 25 ps



Design and read-out of BC2

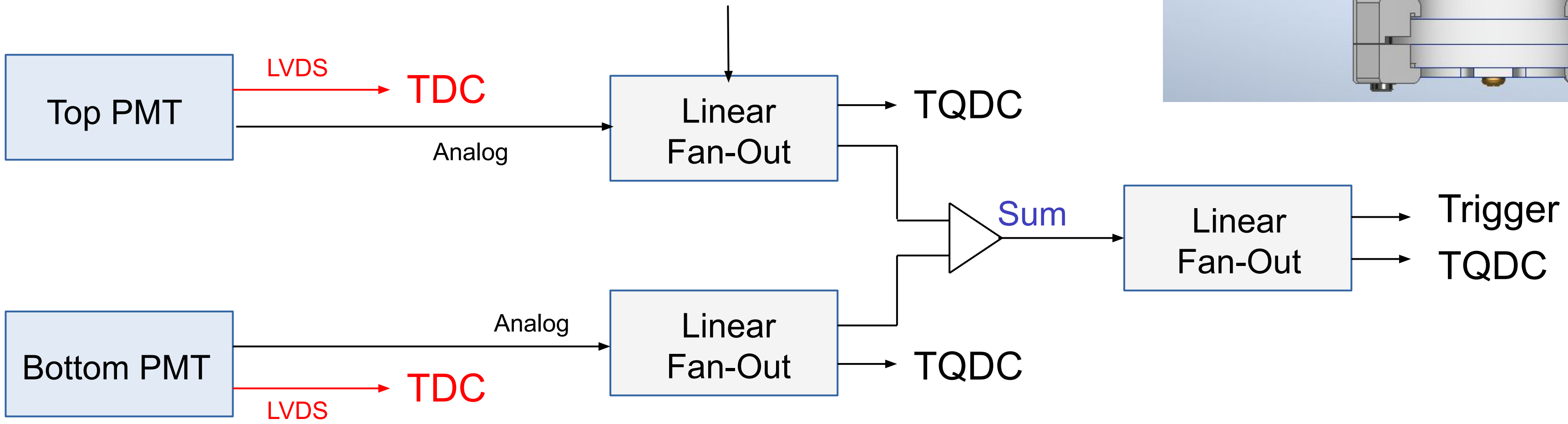
Detector	PMT (MCP)	Radiator
BC2	Photonis XPM85112/A1 Q400 25x25 mm^2	Scint. BC400B 34 x 34 x 0.15 mm^3

"Air"-lightguides from Al-mylar



<u>TDC</u>
Multihit
TDC time bin 25 ps
Time over threshold

High quality linear fan-outs are "custom made" , time jitter ~*11 ps*.



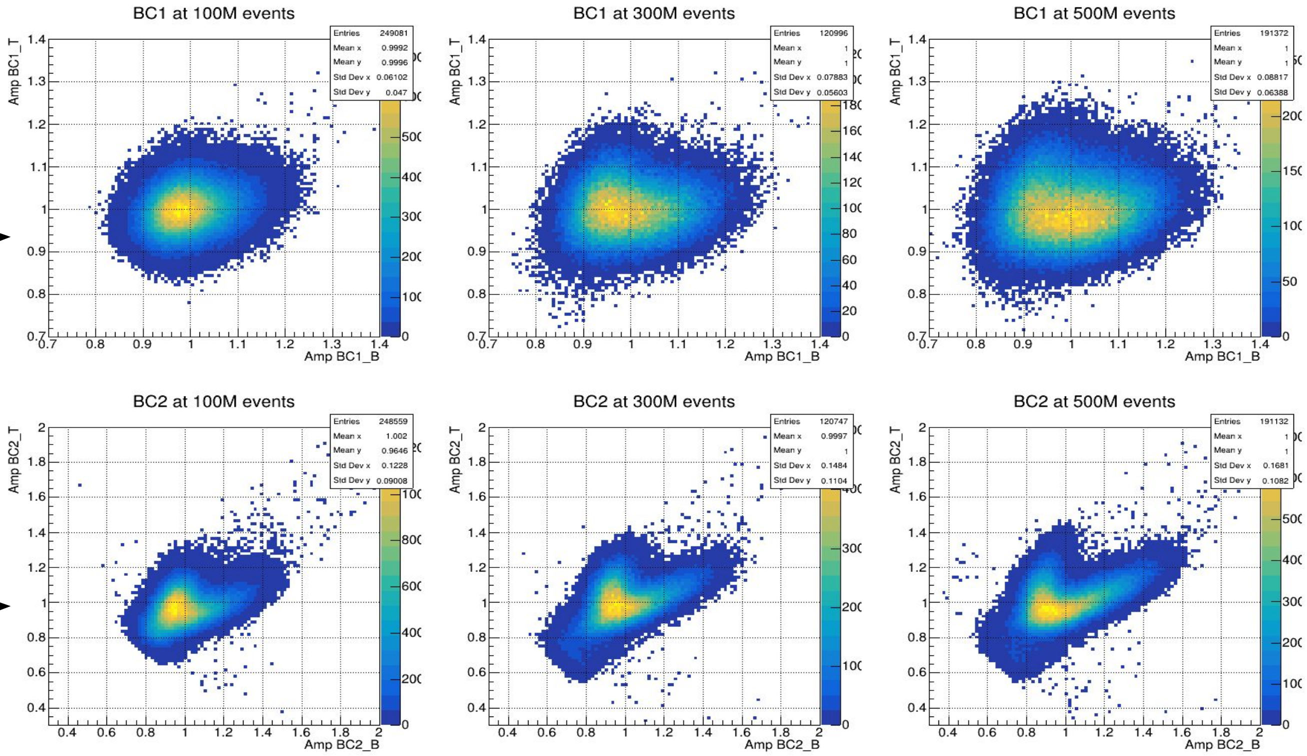
Indication of radiation damage in BC1 and BC2

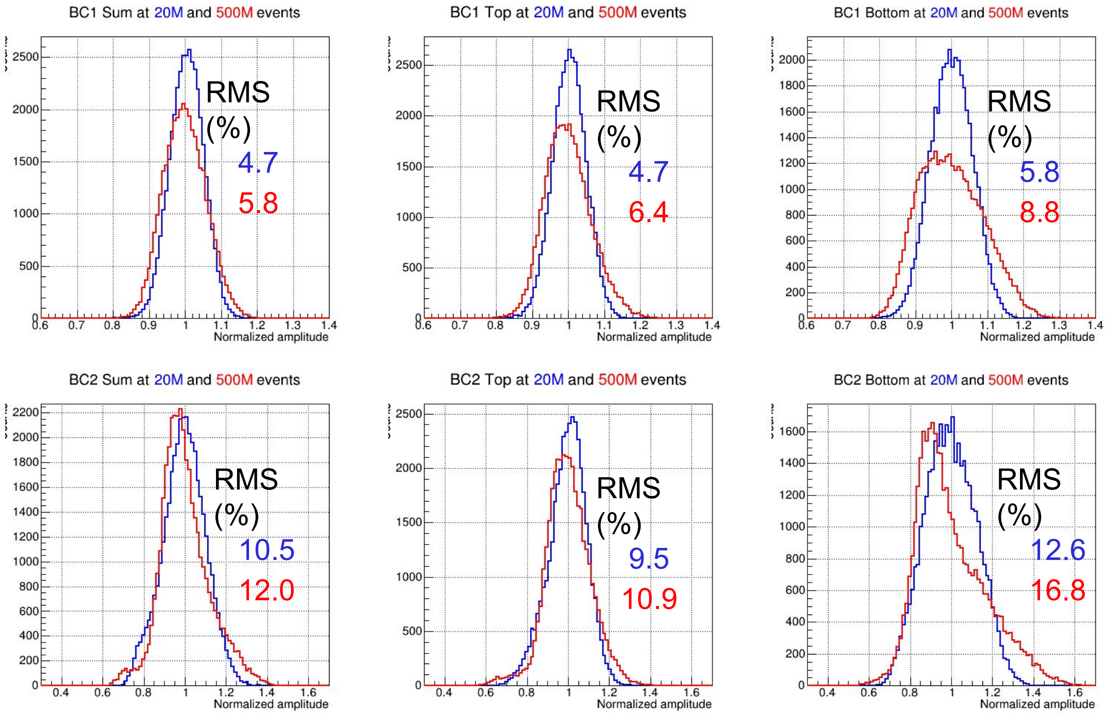
2D plot of Top versus Bottom amplitude

1D plot for the individual amplitudes
Blue - in the beginning of the run, Red - end of the run

BC1

BC2





Sum →Trigger

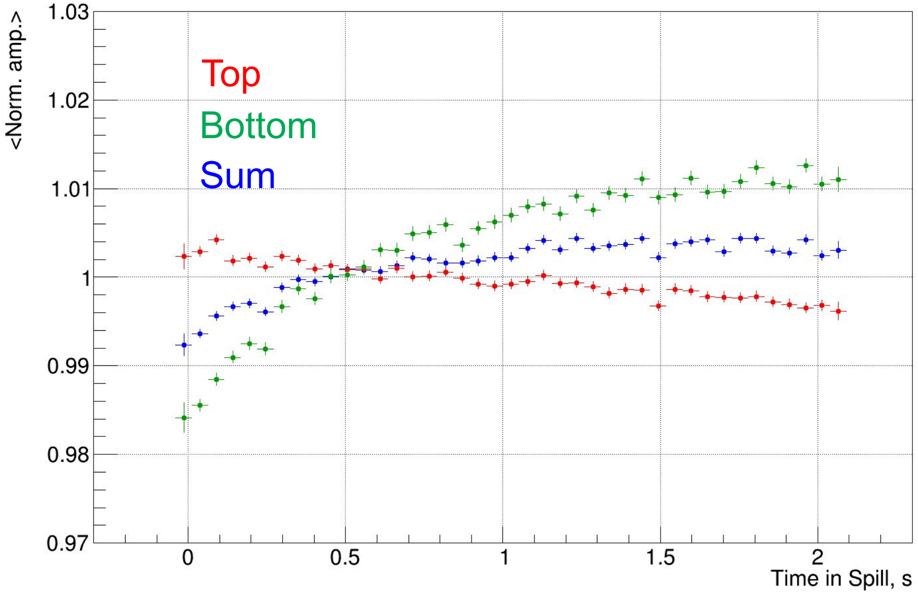
Top

Bottom

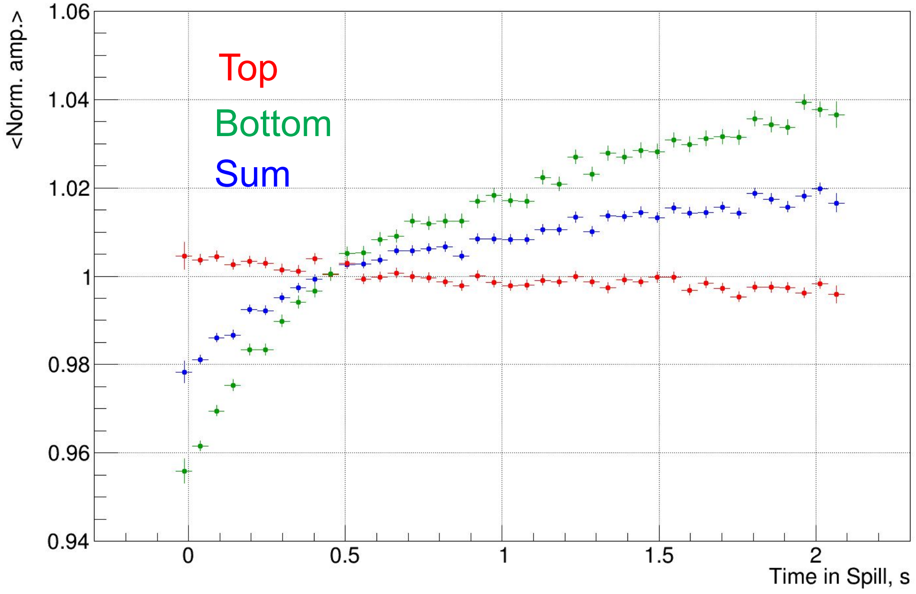
We see some degradation of the signals, which results in larger RMS at the end of the run – in BC1 Sum, BC2 Sum and individual signals.

BC1 and BC2: Amplitude and stability

BC1: Amp vs Time in Spill,



BC2: Amp vs Time in Spill,



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

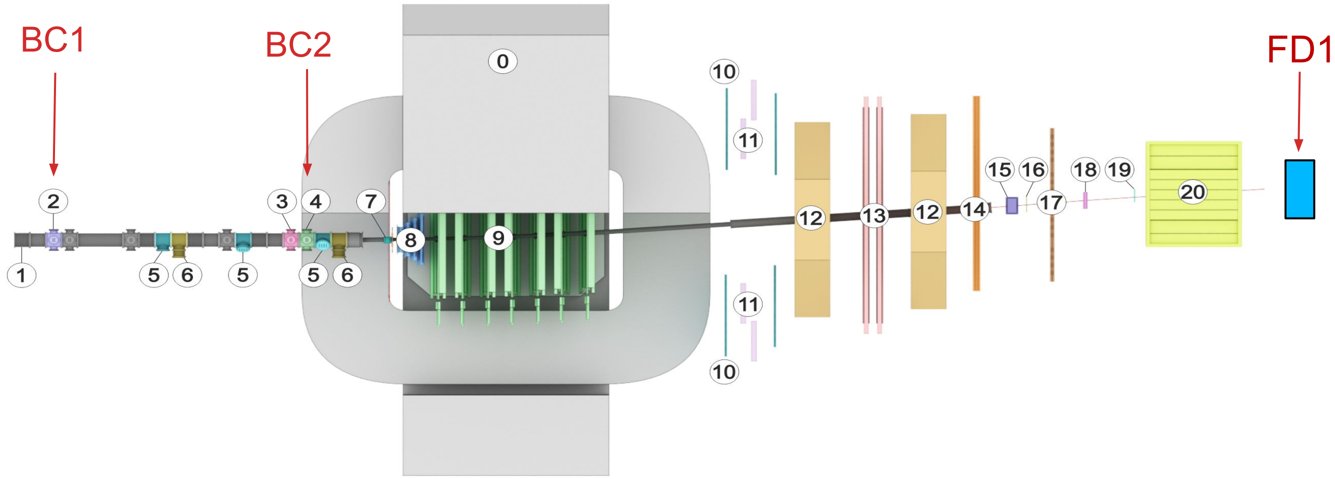
*spill duration ~ *2.2 s*

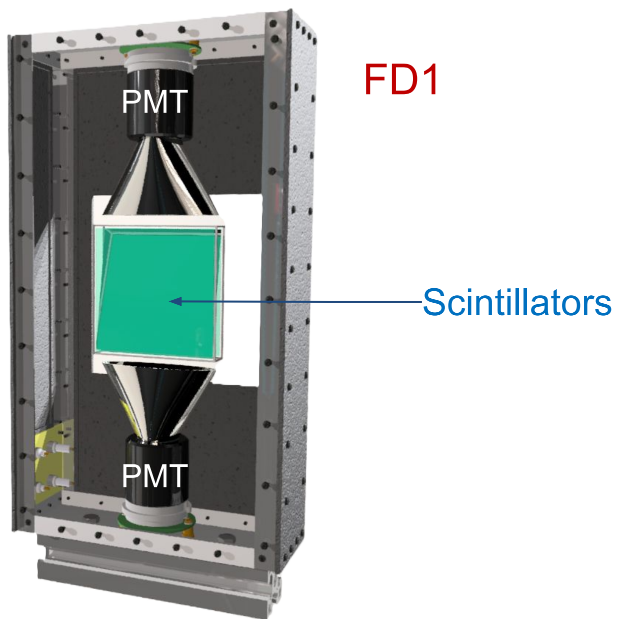
Offline amplitude resolution

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

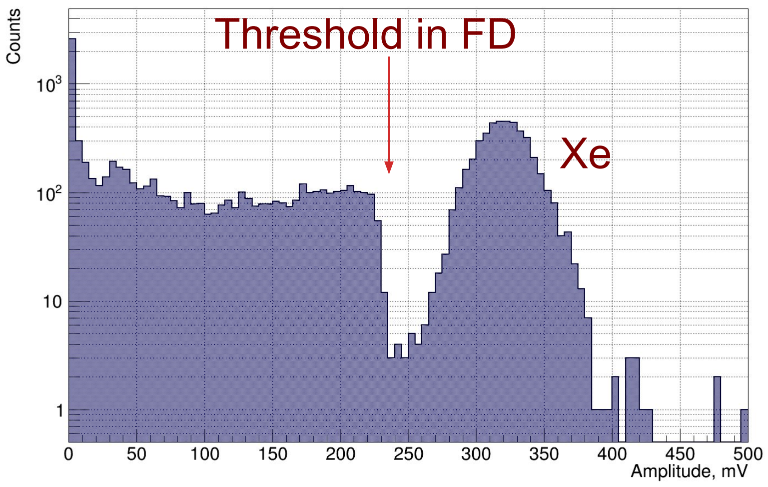
Detectors	σ_{ij}, ps
BC1 - BC2	57
BC1 - FD1	61
BC2 - FD1	58
(BC1&BC2) - FD1	52

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

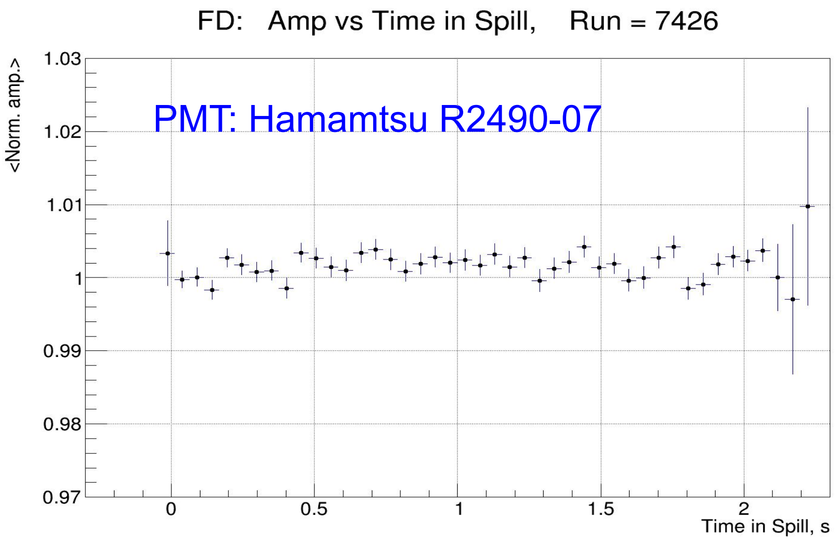
FD design and response

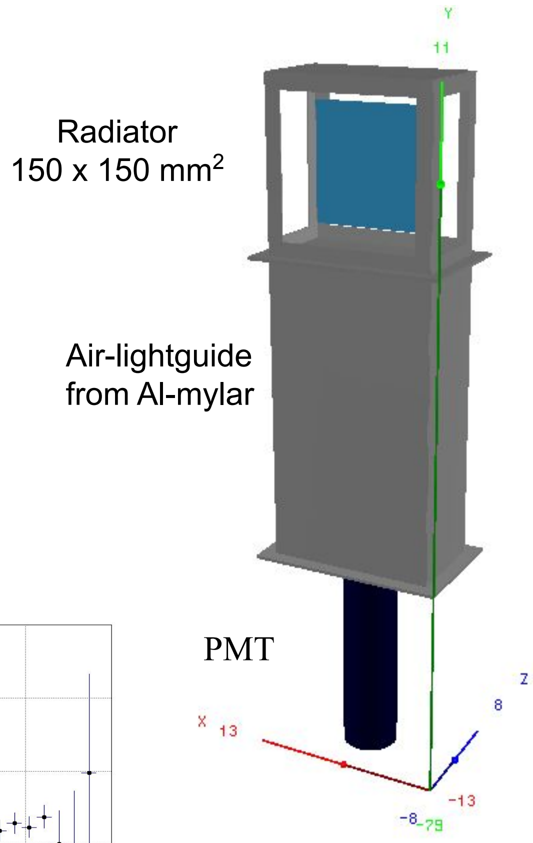
PMT	Radiator	σ/A (%)
XP2020	Scint. 0.5 mm	6.0
XP2020/Q	Quartz 1 mm	11.7
R2490-07	Scint. 0.5 mm	5.3

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



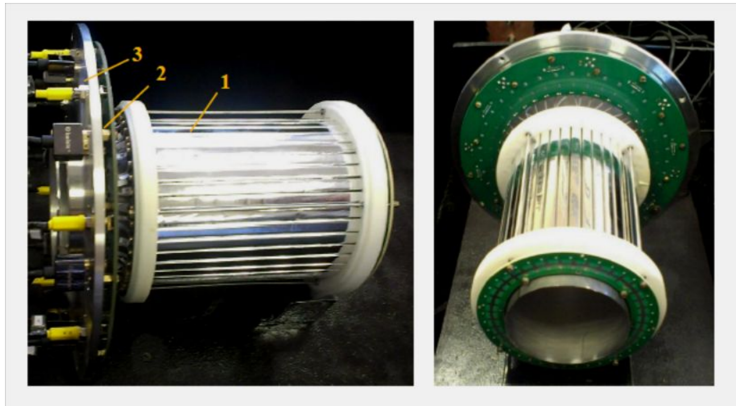
~65-70% centrality was selected by the threshold in FD





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

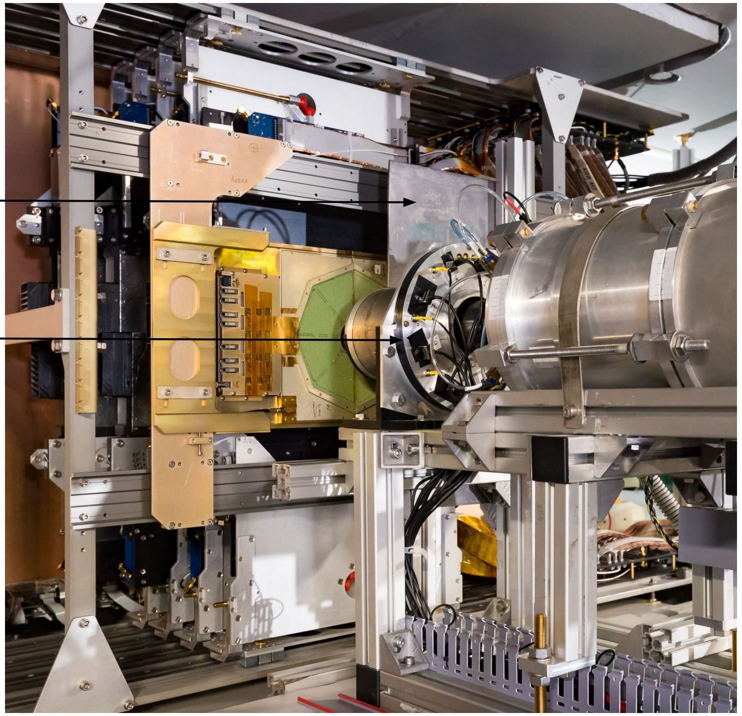
Settings in Xe 2023 run:

CCT1 = BT * BD(≥4)

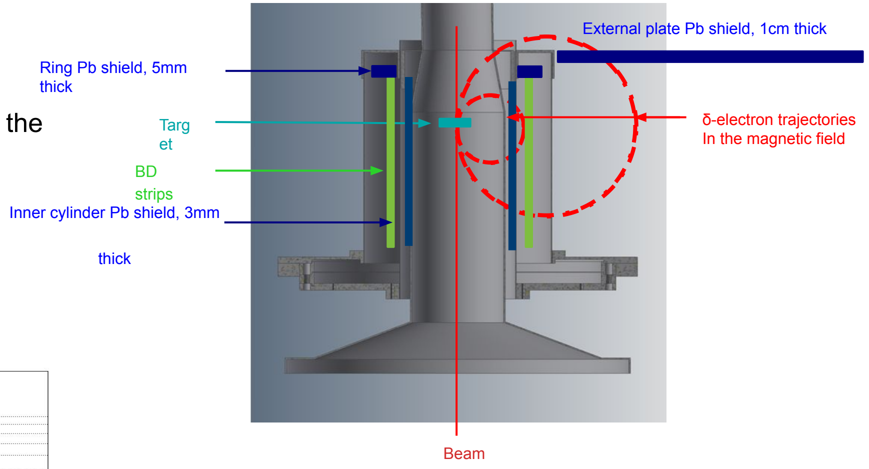
Main physics trigger - CCT2 = MBT * BD(≥4)

Lead shield

BD

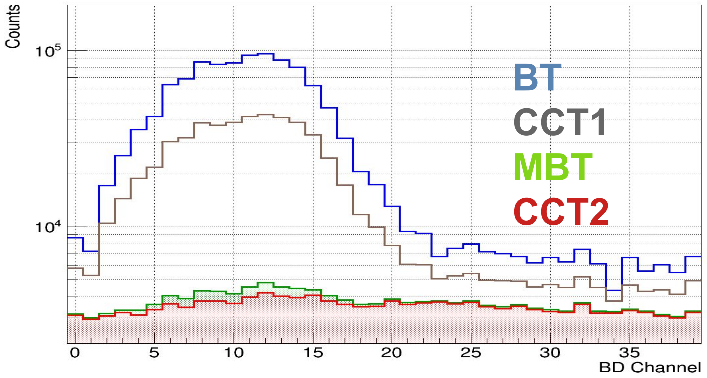


Strong background hits from δ – electrons, curved in the magnetic field and hitting right side of the BD.



Target section of carbon vacuum pipe and BD

Distribution of hits in BD strips for different triggers



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 between the runs.

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

New FD:

Placement of the scintillator in vacuum.

New Barrel detector:

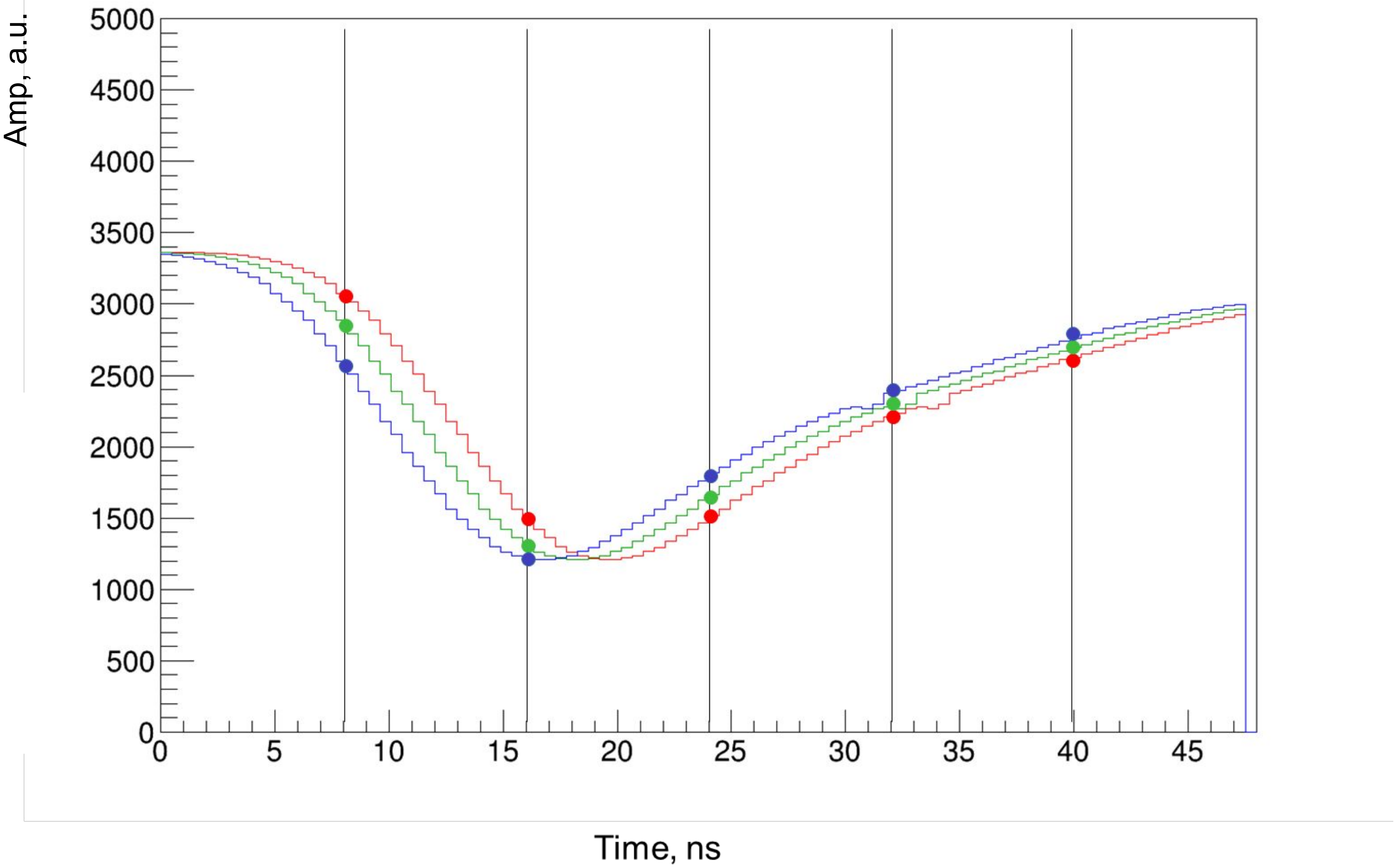
- two halves for easier installation;
- larger beam opening to add space for extra δ-electrons inner shielding;
- shorter (5 cm) strips in order to further reduce δ-electron background;
- larger number of strips (40 → 64) to accommodate larger hit multiplicity in heavy ion collisions.

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