Status of the trigger system

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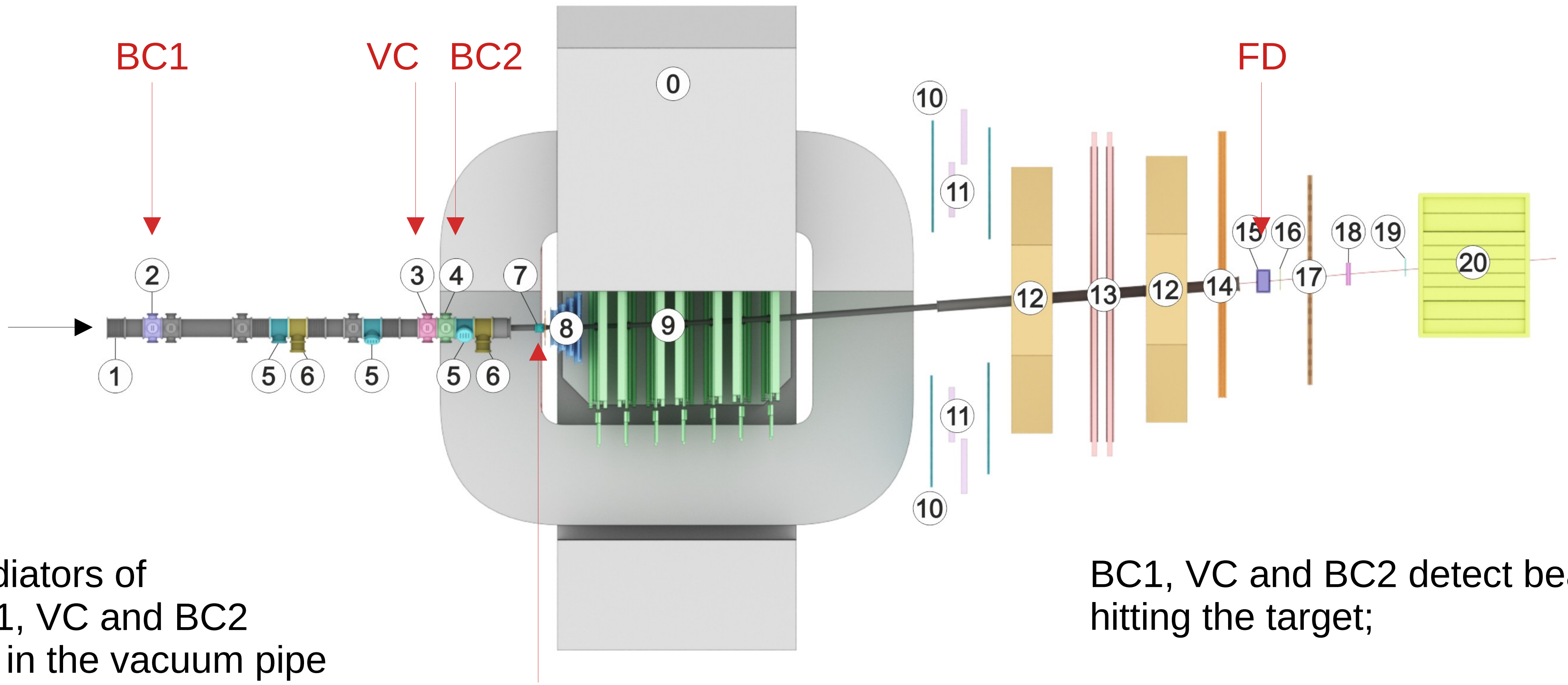
for the BM@N trigger group

12th Collaboration meeting of the BM@N experiment
May 14, 2024

Trigger detectors in Xe 2023 run



Target, BD and SiMD

Radiators of
BC1, VC and BC2
are in the vacuum pipe

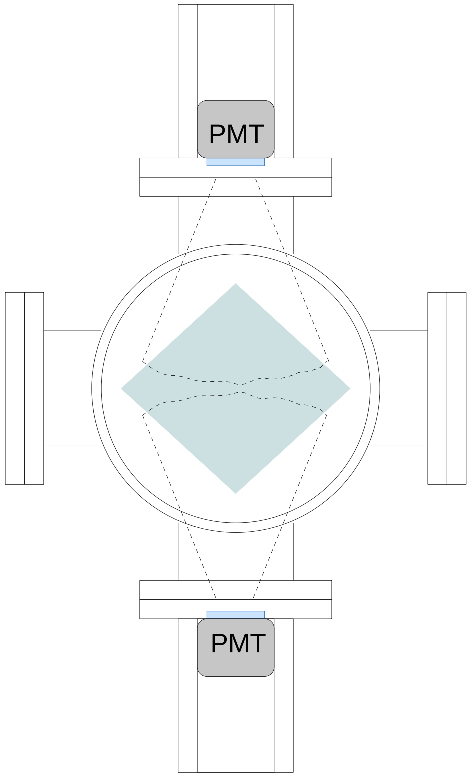
FD is positioned
right after the end
of the vacuum pipe

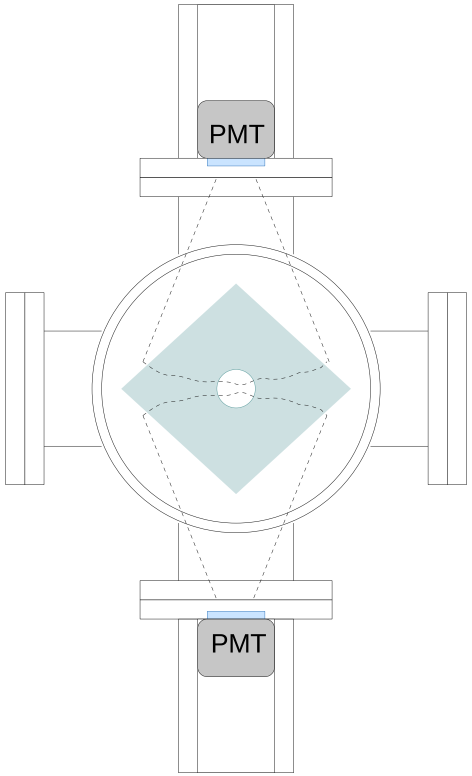
BC1, VC and BC2 detect beam ions hitting the target;

BD and SiMD are sensitive to secondary particles produced in the collision;

FD determines that the beam ion is not present downstream the target.

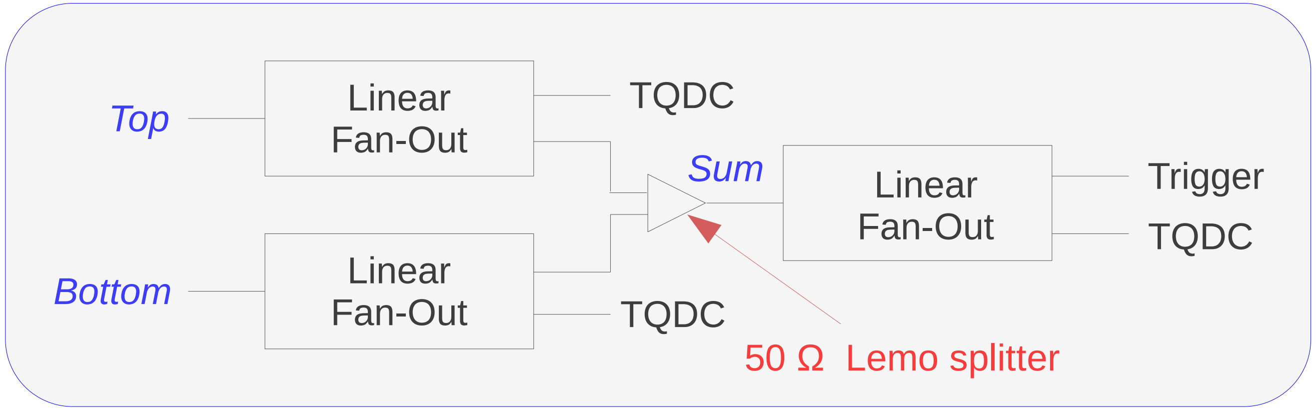
Design and read-out of BC1, VC





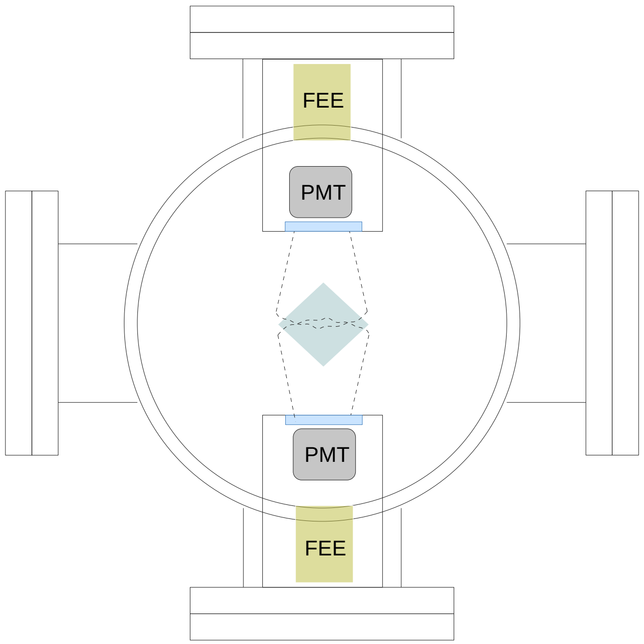
Detector	PMT	Radiator
BC1	Hamamatsu R2490-07	Scint. BC400B 100 x 100 x 0.25 mm^3
VC	Hamamatsu R2490-07	Scint. 113 x 113 x 4 mm^3 Ø 25 mm

“Air”-lightguides from Al-mylar



Planned upgrade:
(*group of S.Piyadin and Belgorod team*)
new vacuum box for BC1
with wider side tubes to facilitate
scintillator replacement

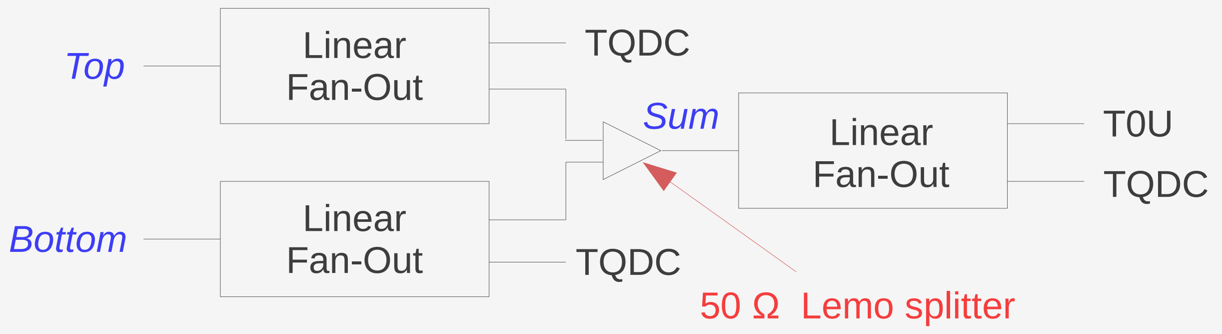
Design and read-out of BC2



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

"Air"-lightguides from Al-mylar

Two signals from each PMT: Anode and MCP



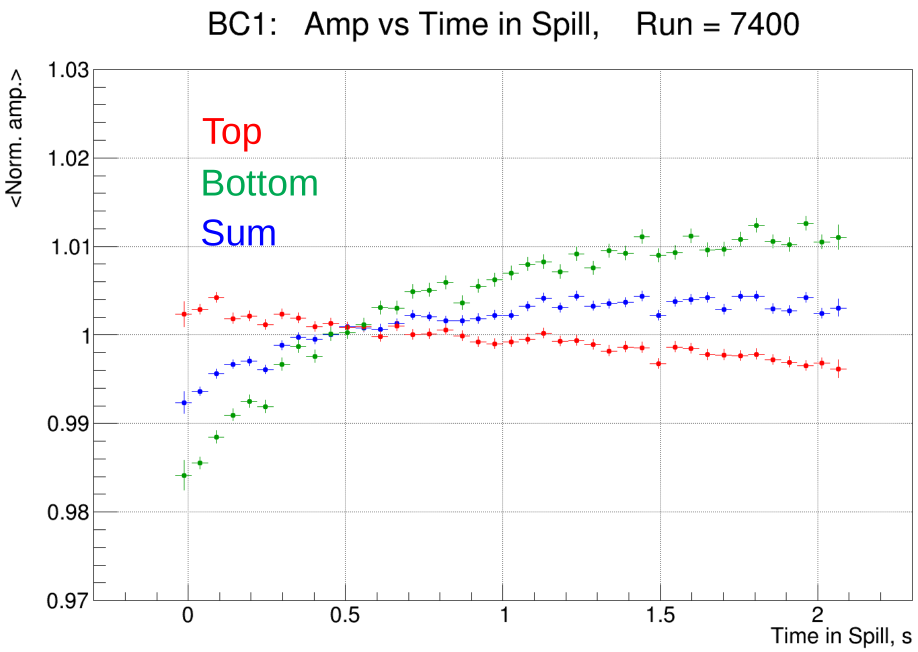
Upgrade:
PMT change to Hamamatsu R2490-07 (*ready, V.Velichkov*)

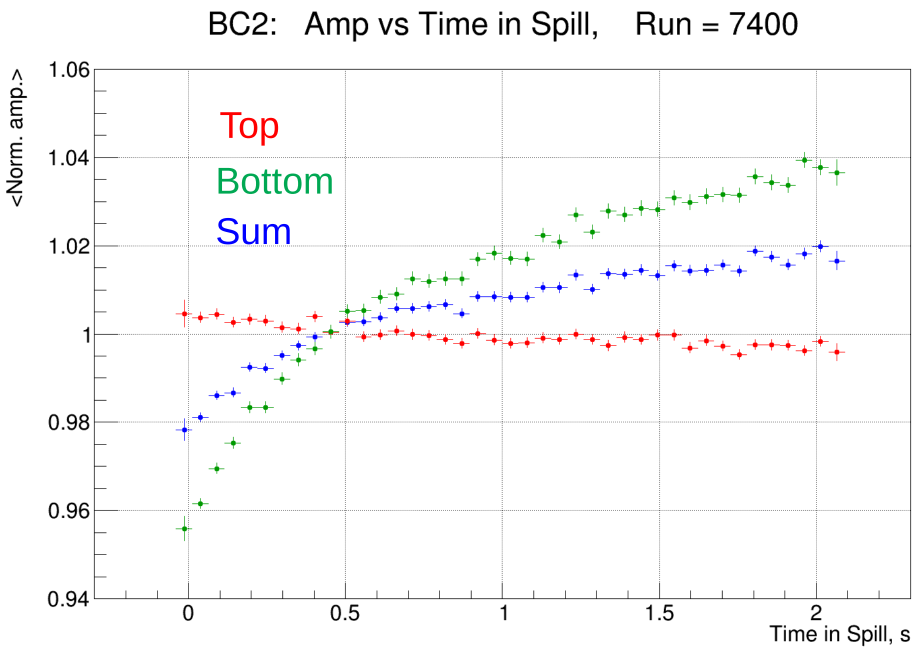
no TDC72VHL readout, TQDC for T0

new scintillator mount

Additional read-out of LVDS signals from FEE into TDC72VHL.
Both, TQDC and TDC provide high resolution timing.

BC1 and BC2: Amplitude and time resolution





BC1, BC2 response in spill

- stable at 2-4 % level
- sensitive to (X,Y) beam movement

Offline amplitude resolution

Detector	σ (%)
BC1	4.8
BC2	7.1

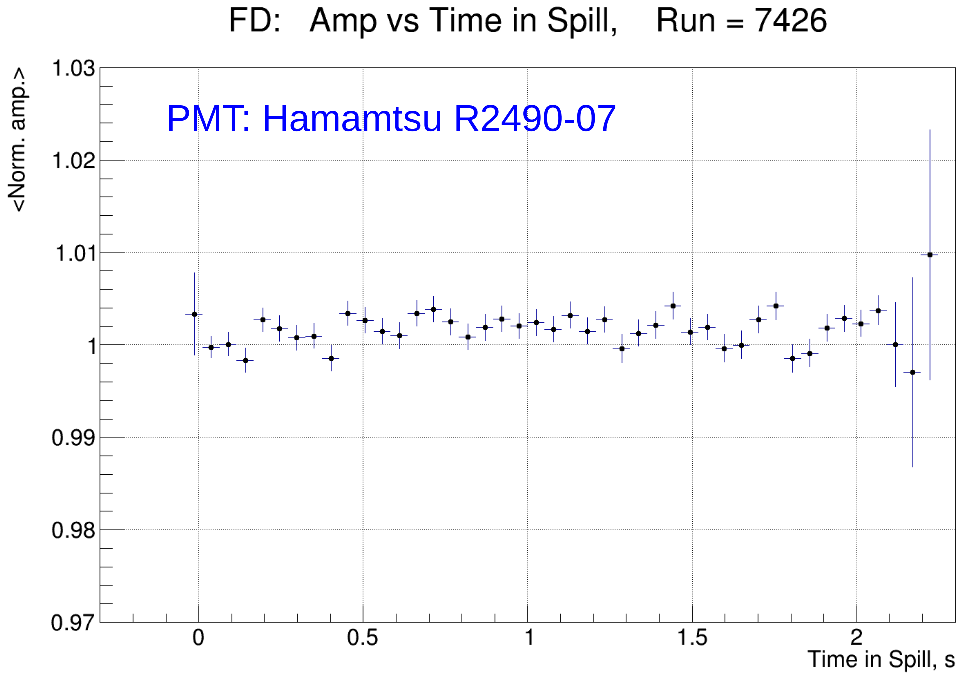
Time resolution

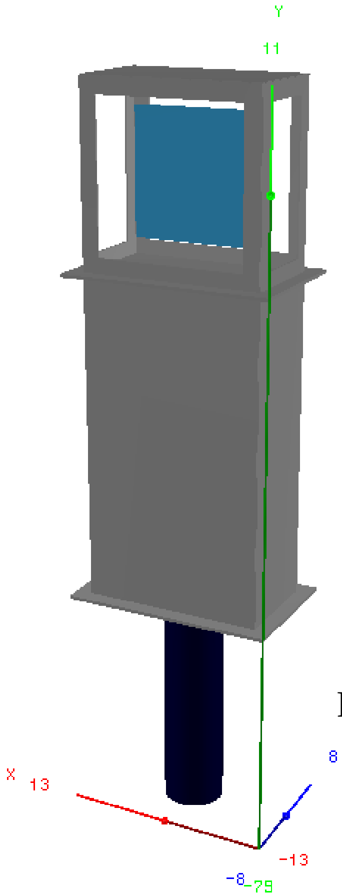
Detectors	σ, *ps*
BC1	43
BC2	38
BC1&BC2	28

FD design and response

Nikita Lashmanov
Vladimir Yurevich

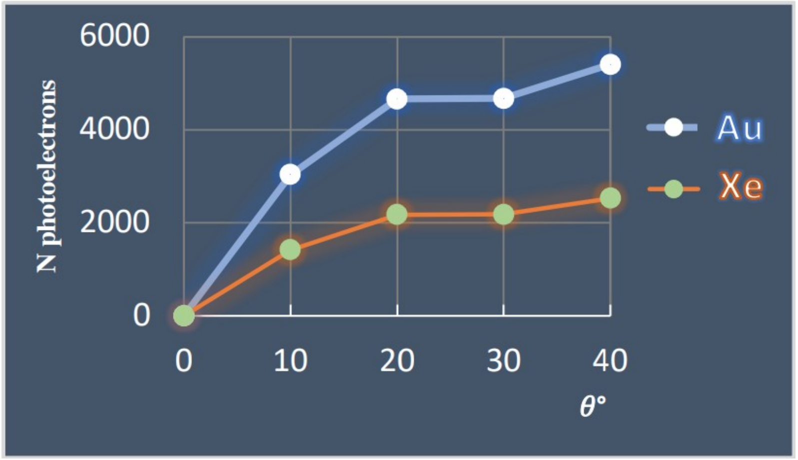
PMT	Radiator	σ/A (%)
XP2020	Scint. 0.5 mm	6.0
XP2020/Q	Quartz 1 mm	11.7
R2490-07	Scint. 0.5 mm	5.3





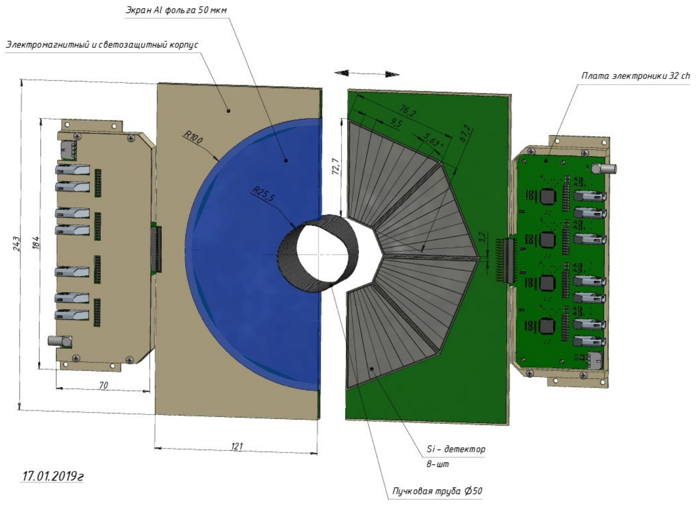
Significantly better resolution with scintillator radiator

Less than expected photoelectron statistics with quartz radiator

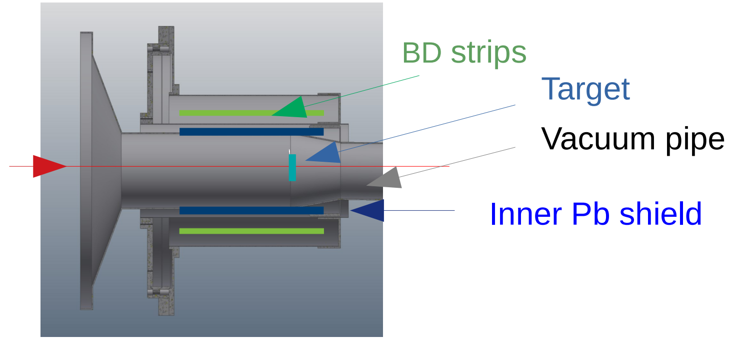


No. of p.e. as a function of quartz tilt (simulation by *N.Lashmanov*)

Trigger multiplicity detectors

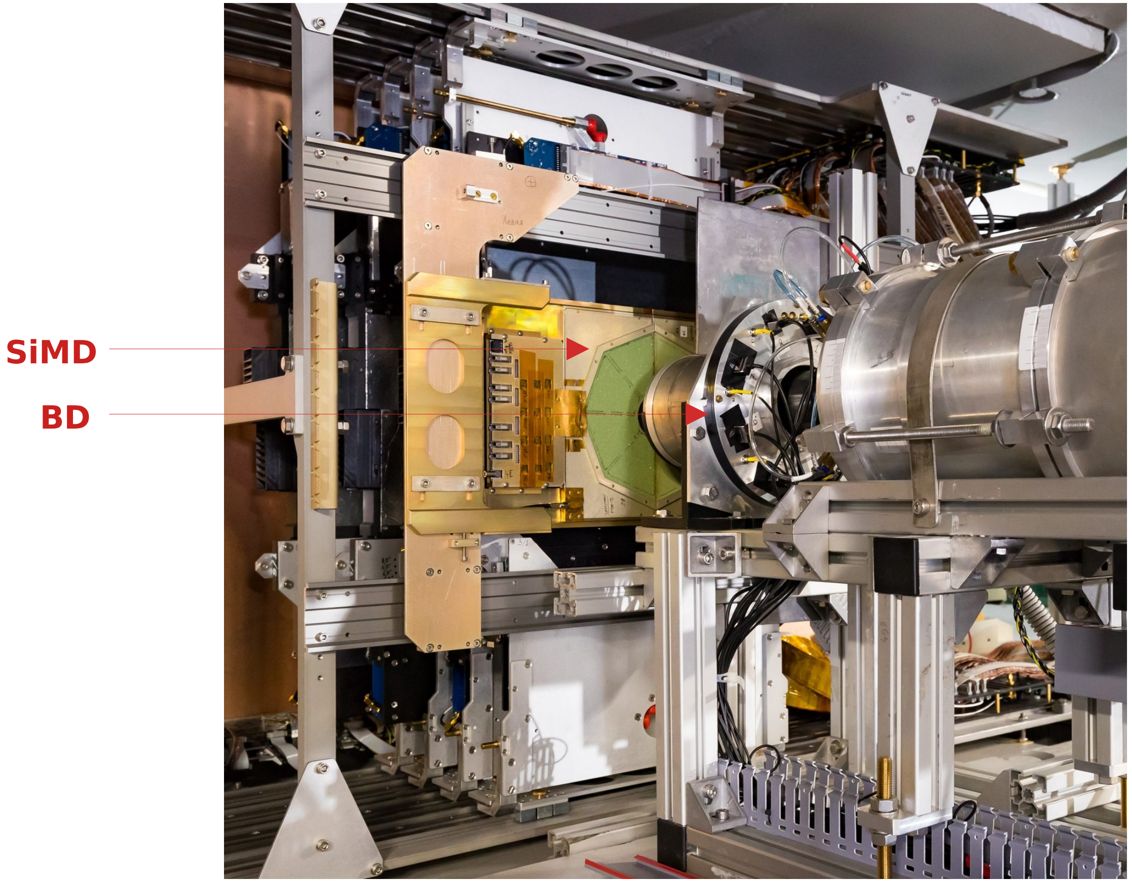


SiMD: 525 µm thick; 64 radial strips



Target section of carbon vacuum pipe and BD

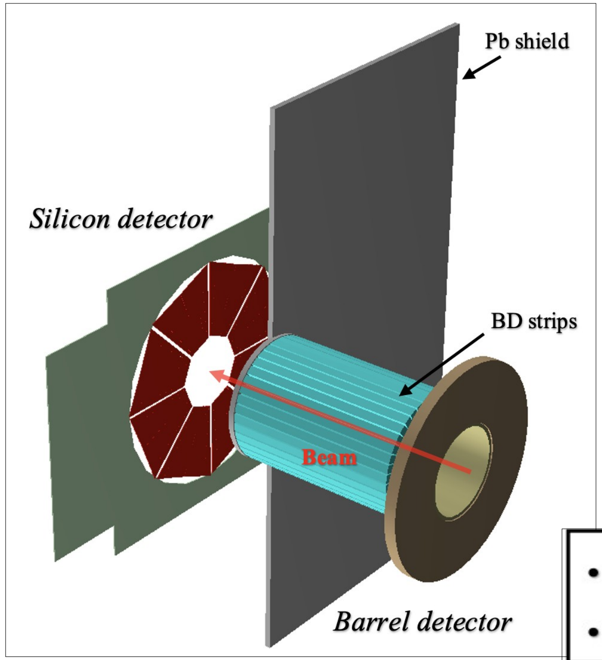
BD: 40 strips, 150x7x7 mm, BC418
SiPMs, Sensl C-series, 6 x 6 mm



Target is located inside the BD

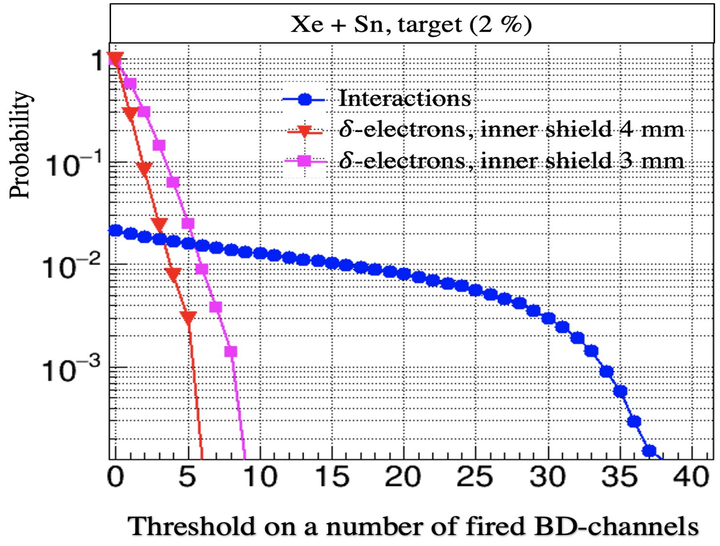
Readout:
signals from every channel in BD and SiMD are digitized by multihit TDC providing time and time-over-threshold width

δ-electron background in Barrel Detector

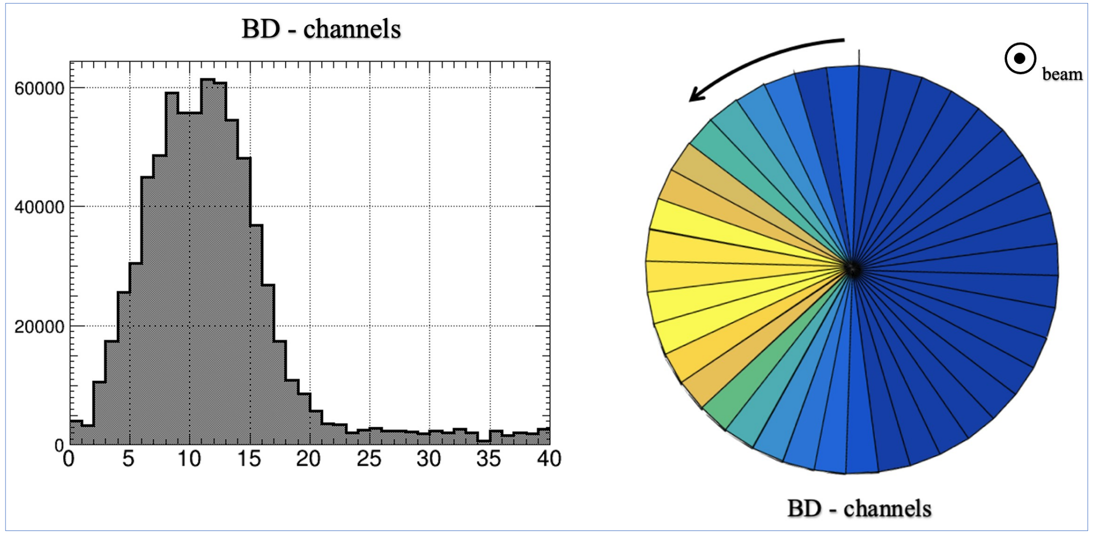


Even with Pb-shielding,
the background from δ-electrons
is significant and larger,
than predicted by Geant4 simulations.

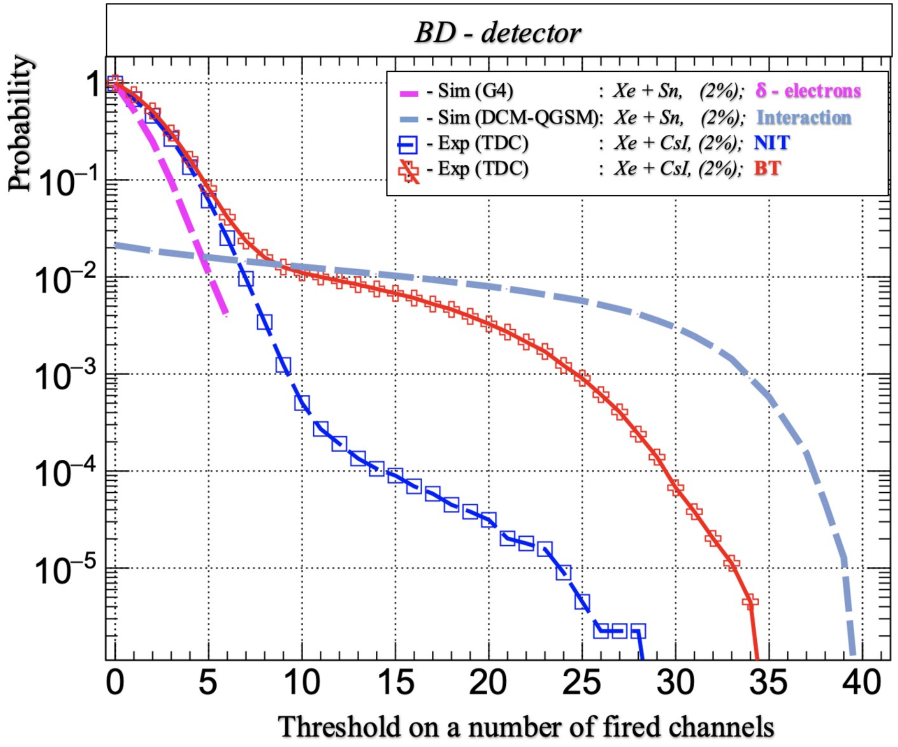
Tight space between BD and beam pipe
prevents adding thicker Pb layer



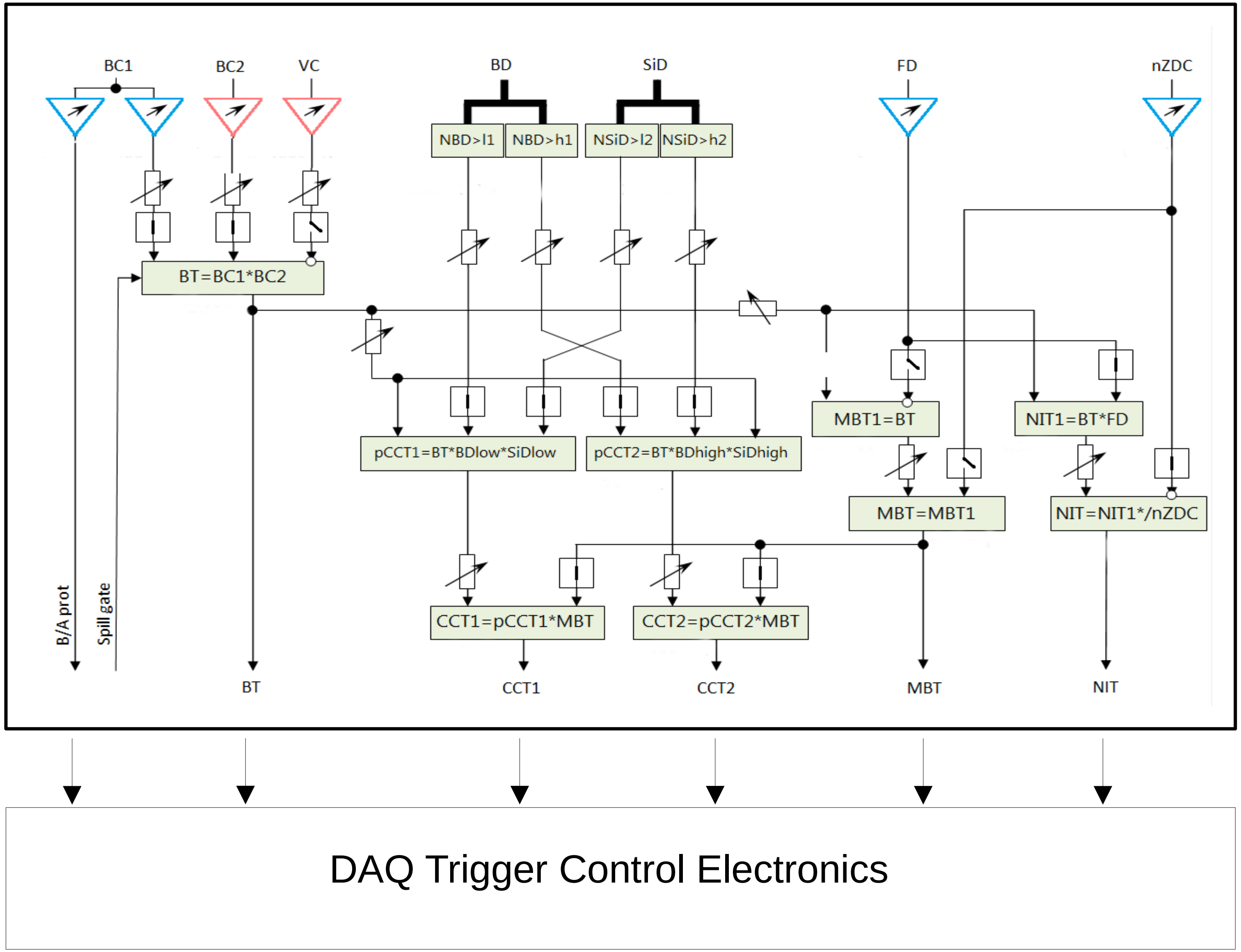
- *Inner shield*: Pb - cylinder 0.3 cm thick;
- *Outer shield*: 25 x 50 cm², L = 0.5 cm.



NIT
events



Trigger electronics



T0U module (*S.Sergeev, V.Rogov*)

- implements trigger logic in FPGA.
- threshold levels, delays, pulse width, coincidence switches are adjustable via user interface.
- internal scalers (counts per spill)

Trigger Control and Distribution modules (*DAQ group, A.Shutov, A.Shchipunov*):

- triggers can be activated/disabled;
- downscaling factors are set;
- Before/After protection is implemented
- calibration triggers are added

Multihit scalers (*DAQ group)*
continuous count during spill

Triggers used in 2023 Xe run

Trigger	Logic	Reduction factor	Fraction in recorded events (%)
BT	$BC1 \cdot BC2 \cdot \overline{VC}$	2000	3
MBT	$BT \cdot \overline{FD}$	35	7
CCT2	$MBT \cdot BD\ (n \geq 4)$	1	85
CCT1	$BT \cdot BD\ (n \geq 4)$	230	5
pBT	$BC1 \cdot BC2$	-	-
NIT	$BT \cdot FD$	-	-
BC1L	BC1	-	-

In the last run the DAQ normally operated in the “mixed” trigger mode.

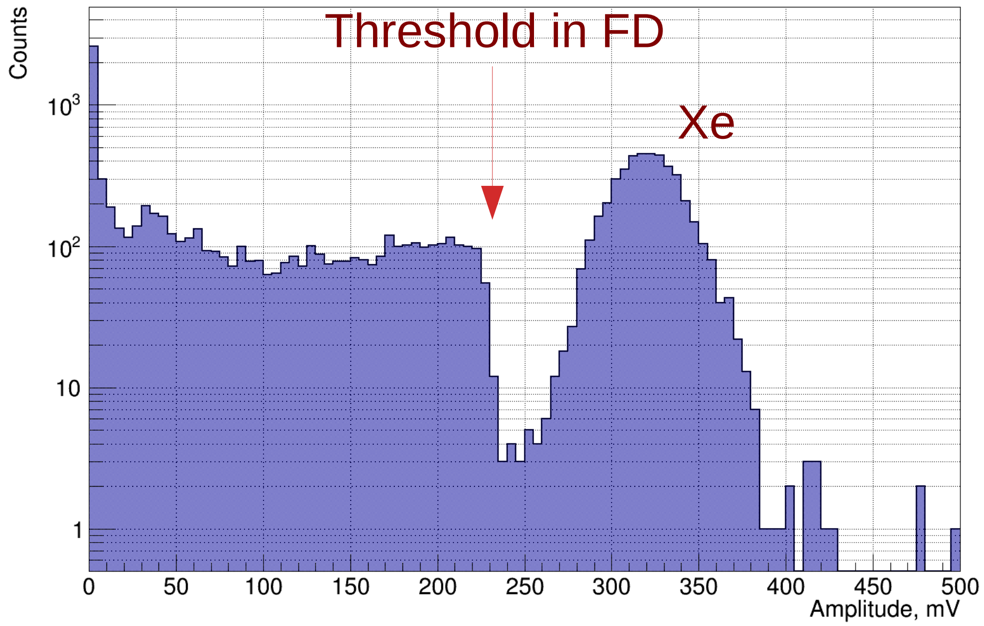
Trigger masks “Before reduction” (BR) and “After reduction” (AR) are used to control downscaling process in the trigger mix.

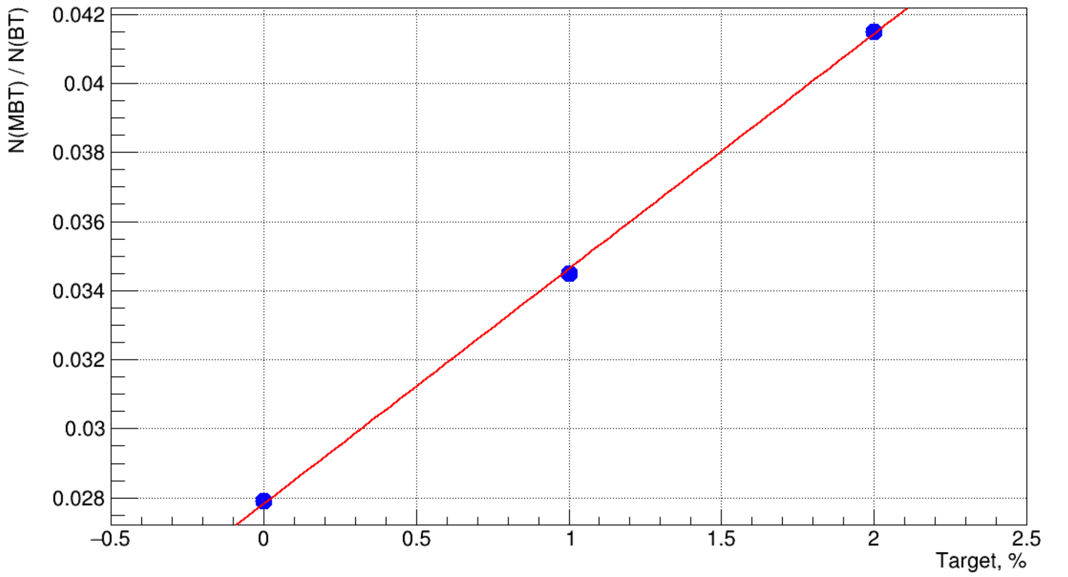
An activated trigger sets corresponding bit to *1* or *0* if its condition is met or not met in the recorded event.

BR bit is set independently of the event count. AR in addition to the trigger requirements checks if the downscaling condition for this trigger is satisfied.

Possible additions to the trigger set:
- second threshold in FD
- “halo interaction” ($BC1 \cdot VC \cdot \overline{FD}$)

Minimum Bias Trigger (MBT = BT • FD_{veto})





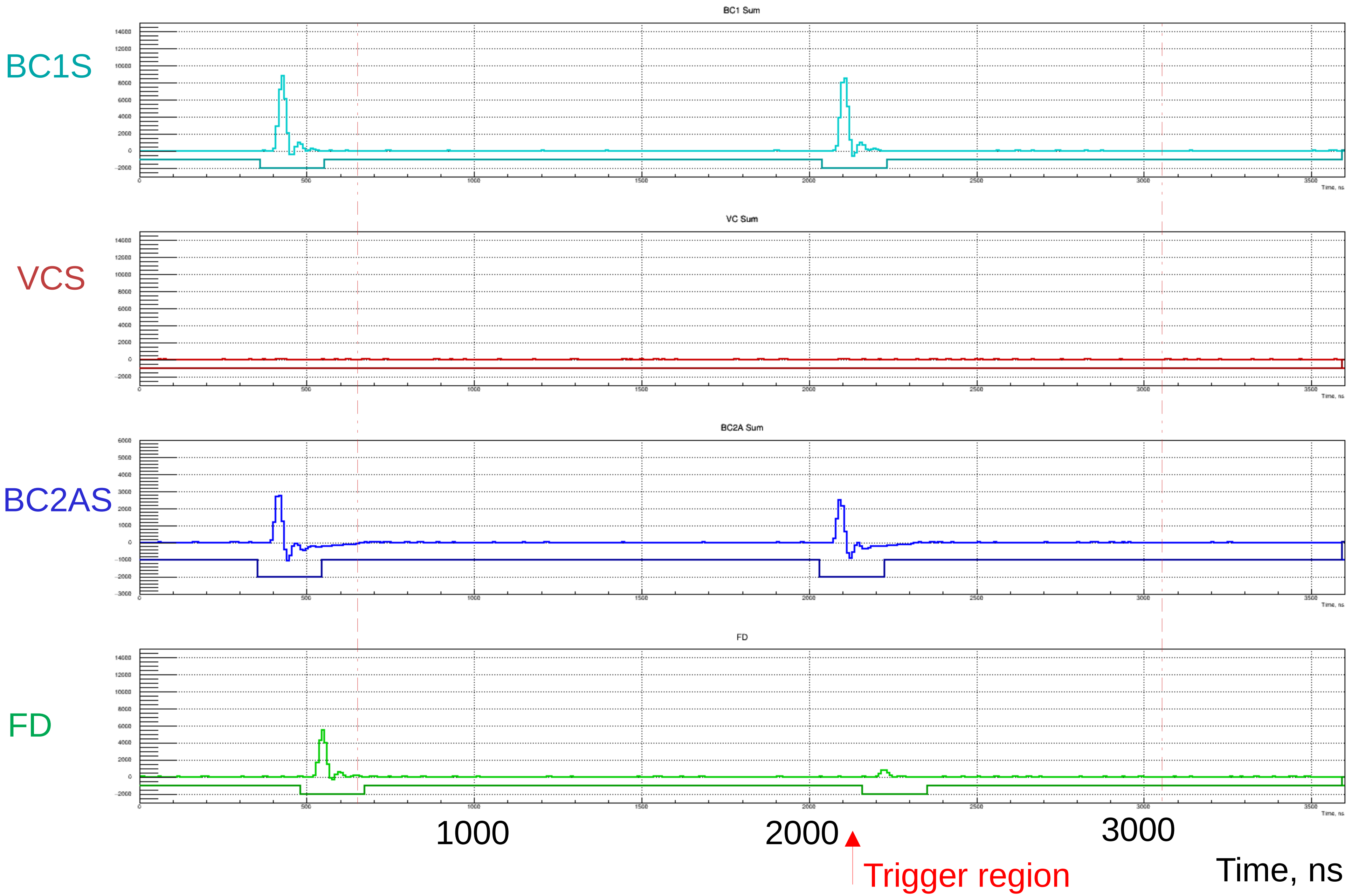
Even with conservatively low threshold in FD amplitude, typical ratio of N(MBT) / N(BT) for 2% target was ~0.04, i.e. with significant background

Good linearity with Empty, 1%, 2% targets; N(MBT) / N(BT) for “empty target” ~0.028

Contribution of close pile-up events in MBT trigger was studied with high statistics BT run. Confirmed pile-up contribution ~0.8%.

Material	Thickness, mm	Interaction probability %
Si BeamTracker	0.175	0.30
Ti vacuum window	0.08	0.17
FD, black tape, etc.	0.5	0.94
Air	150	0.21
FD, scint.	~0.1	~0.2
BC2, scint.+Mylar	~0.04	~0.1
		Total ~1.9

TQDC and TDC read-out without Zero-Suppression



Wide time range (*3.6 μs*) covers trigger time window (*~150 ns*) and Before/After protection zones

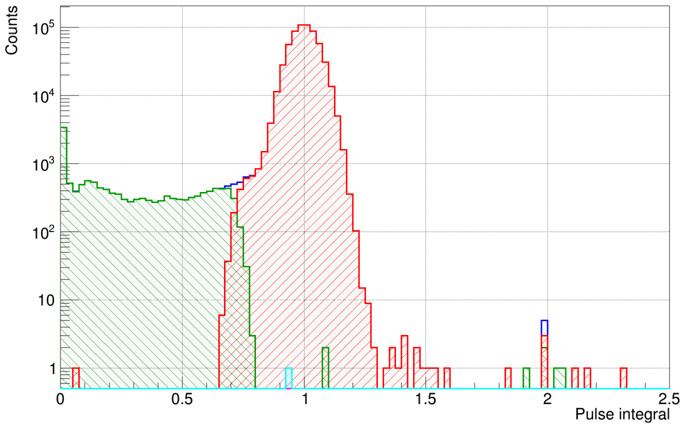
Used in analysis to check interaction or non-interaction in recorded event and to estimate influence of pile-up beam ions

Study of MBT and NIT triggers in BT run 8281 (1M events)

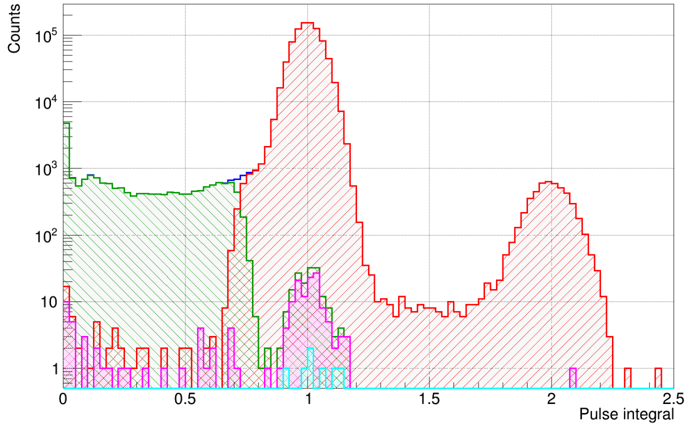
Integral of FD pulse in the “trigger window” as a function of “software” B/A protection

MBT bit = 1
NIT bit = 1
both bits = 0
both bits = 1

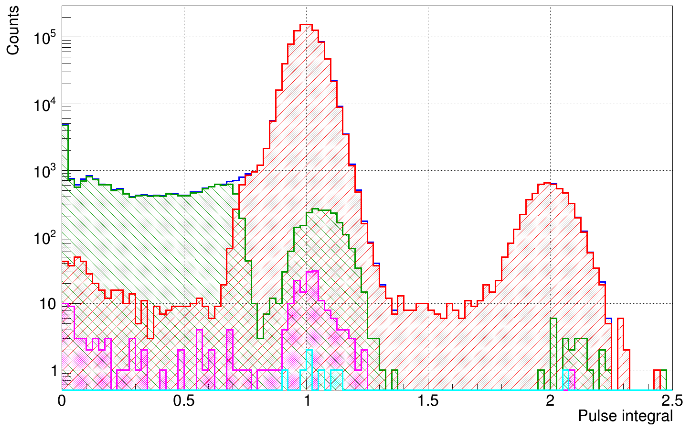
“single BC1”
B/A = [2000,1600] ns



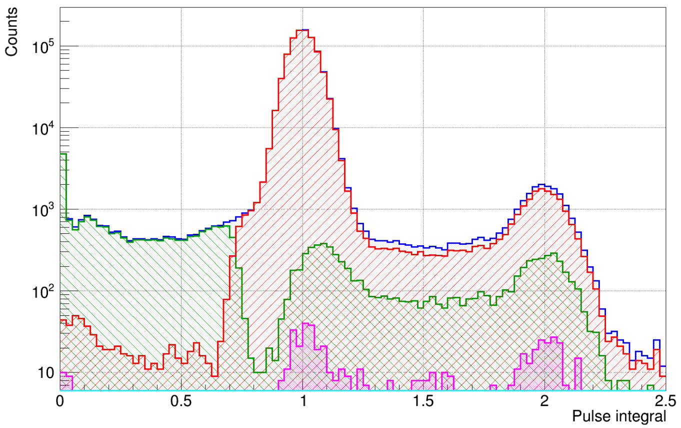
B/A = [150,150] ns



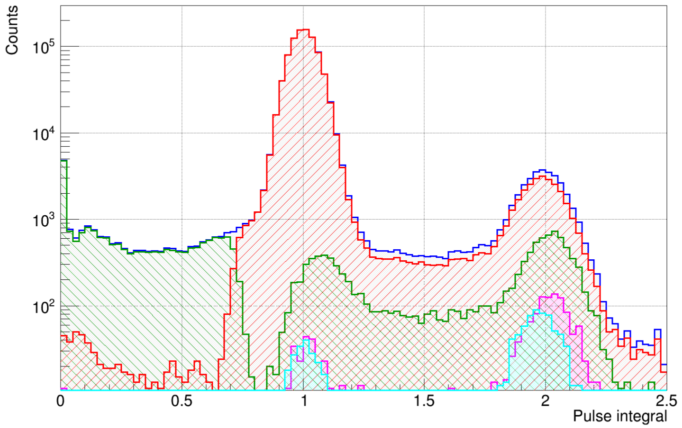
B/A = [100,100] ns



B/A = [50,50] ns



all events

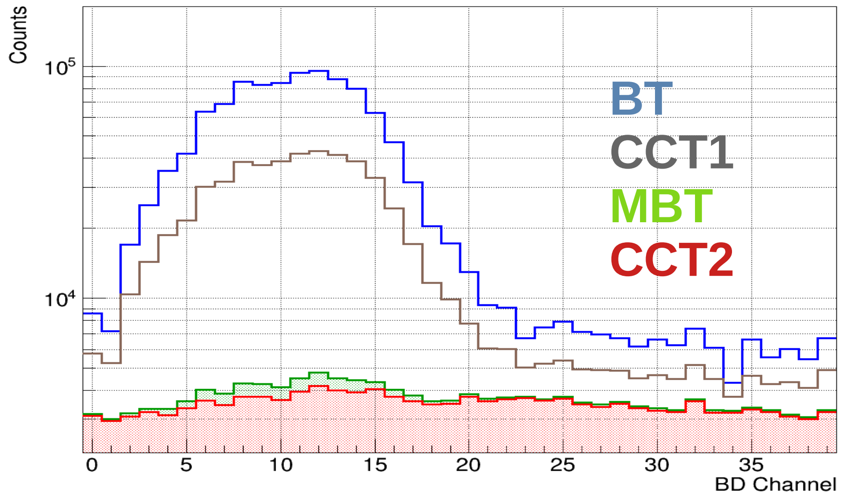


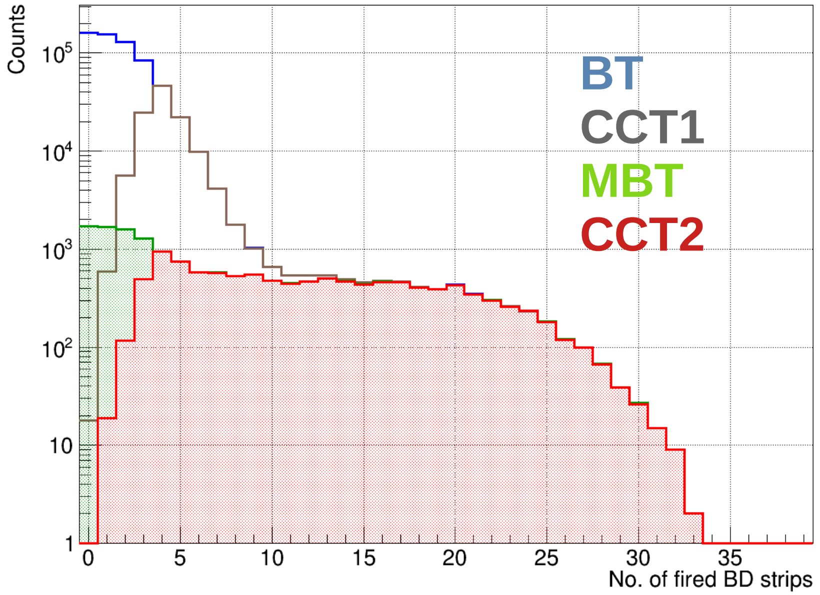
Comment: better handling of close pile-up events should be organized in T0U

Trigger studies using BT run 8281 (cont.)

Influence of close pile-up on the MBT, CCT1 and CCT2

Before / After [ns,ns]	Statistics (%)	MBT (%)	CCT2 (%)	CCT1 (%)
BC1 ≥ 1	100%	3.5	1.9	21
[50,50]	98 %	3.3	1.9	21
[100,100]	95 %	2.8	1.8	20
[150,150]	92 %	2.7	1.8	20
Single BC1	65 %	2.7	1.8	20





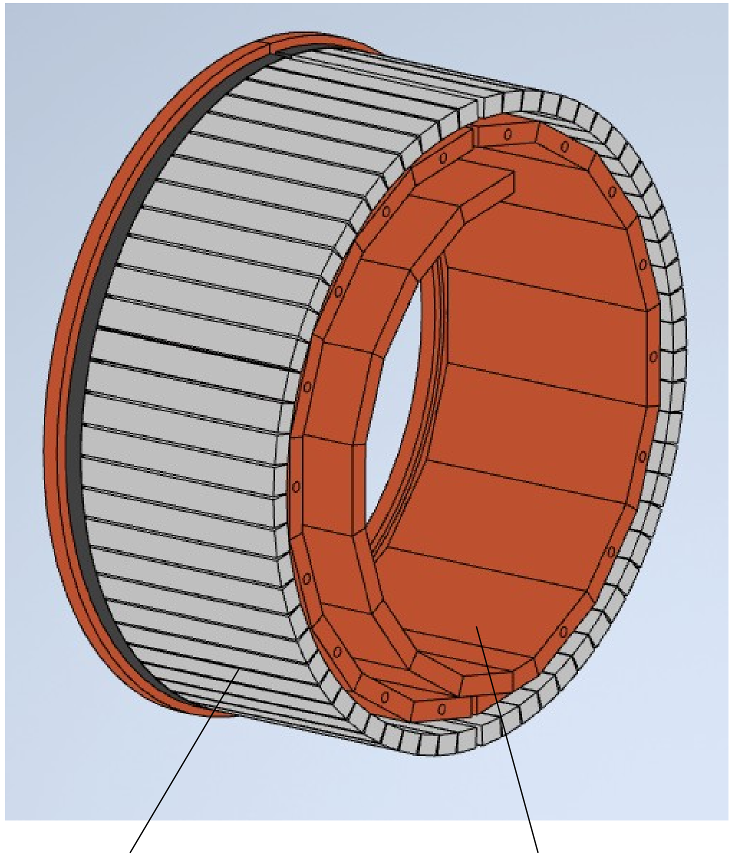
Verification of trigger bits using events in BT run

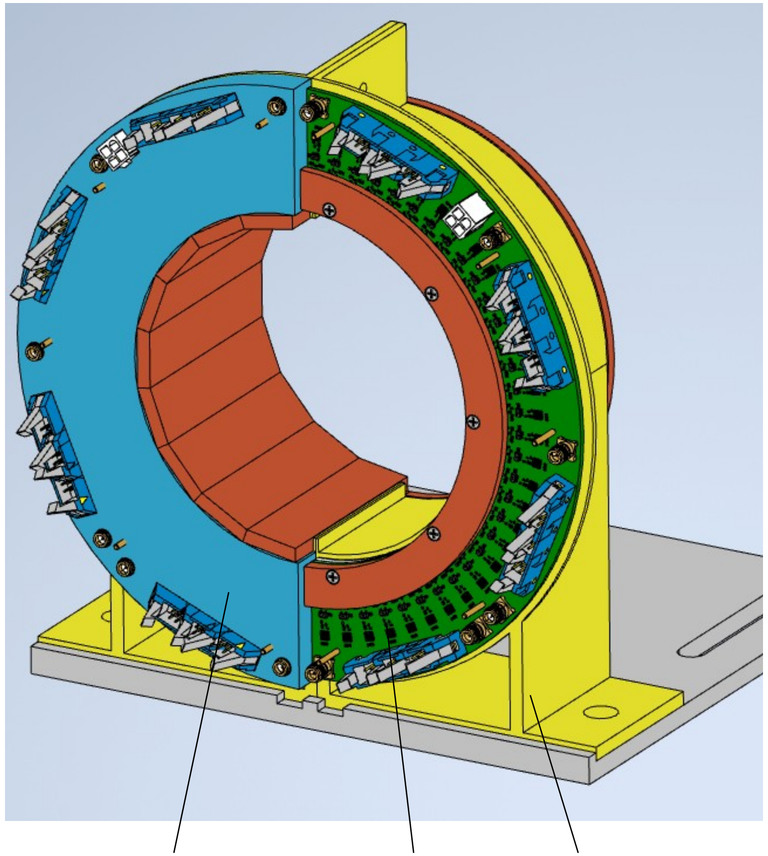
Trigger bit	bit = 1	bit = 0
BC1L	0.0002	0.9998
pBT	1.	$4 \cdot 10^{-6}$
BT	1.	0
BT (Mask AR)	1.	0

Trigger	Event selection	Trigger bit = 1 (%)
CCT1	BT && (TDC BD ≥ 4)	99.7
CCT2	MBT && (TDC BD ≥ 4)	99.6
MBT	BT && (FD < 0.80 “Xe”)	89.8
MBT	BT && (FD < 0.75 “Xe”)	96.2
MBT	BT && (FD < 0.70 “Xe”)	99.7

In general trigger bits show high consistency (>99.6%) except for always missing BC1L.

New Barrel Detector

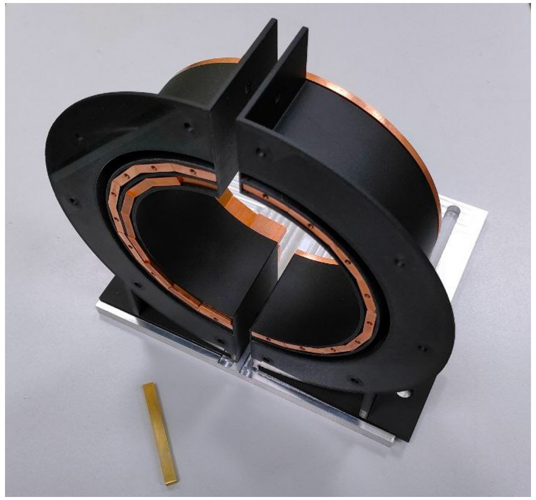




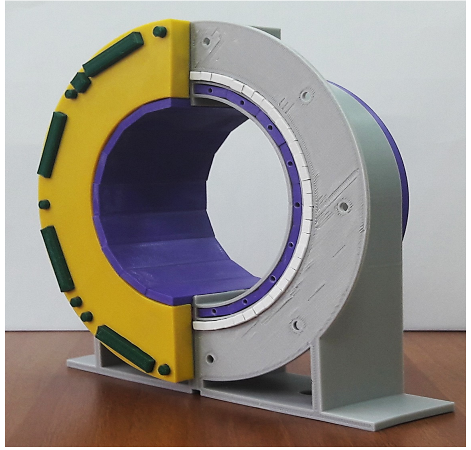
- Cu layer inside BD for delta-electron absorption
- Shorter strips, easier to protect and position
- Larger inner diameter
- Consists of two parts (left and right) for simple installation
- Larger number of channels for Bi runs

- 64 scintillation strips $57\times7\times5$ mm^3
- readout by 3×3 mm^2 SiPMs (J-ser. SensL)

New Barrel Detector (current status)



Mechanical parts prototype



3D model

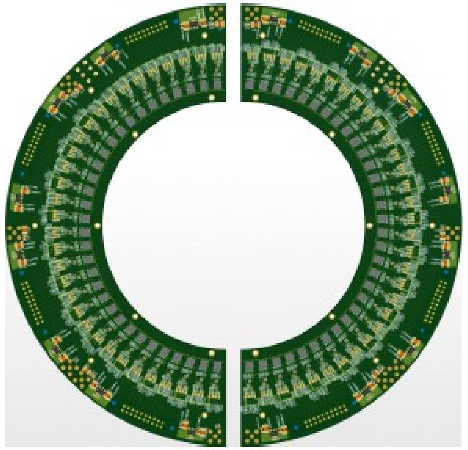
Mechanics (*V.Tikhomirov, V.Azorskiy, A.Timoshenko*): design completed, expected production Jun-Jul.2024

FEE (*V.Rogov*): design completed, all parts available

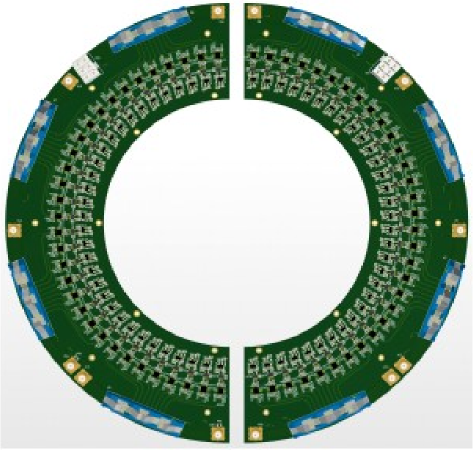
New T0U (*S.Sergeev, V.Rogov, P.Grigoriev*): some parts need to get, might be delayed

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

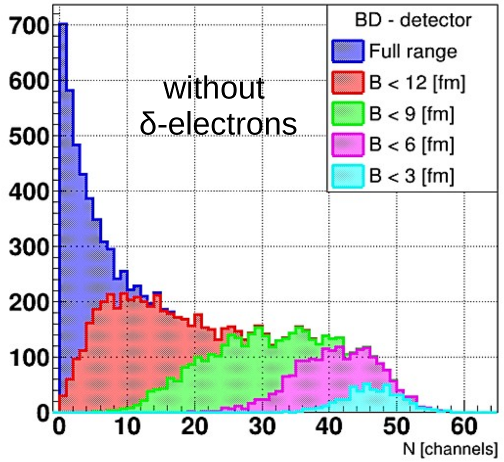
Simulation (*N.Lasnmanov*): ongoing

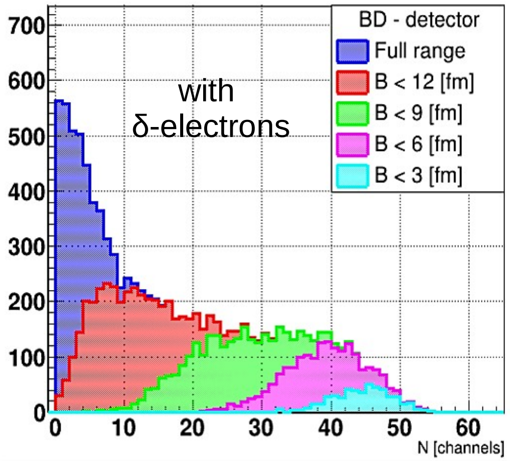


FEE PCB SiPM side (design)



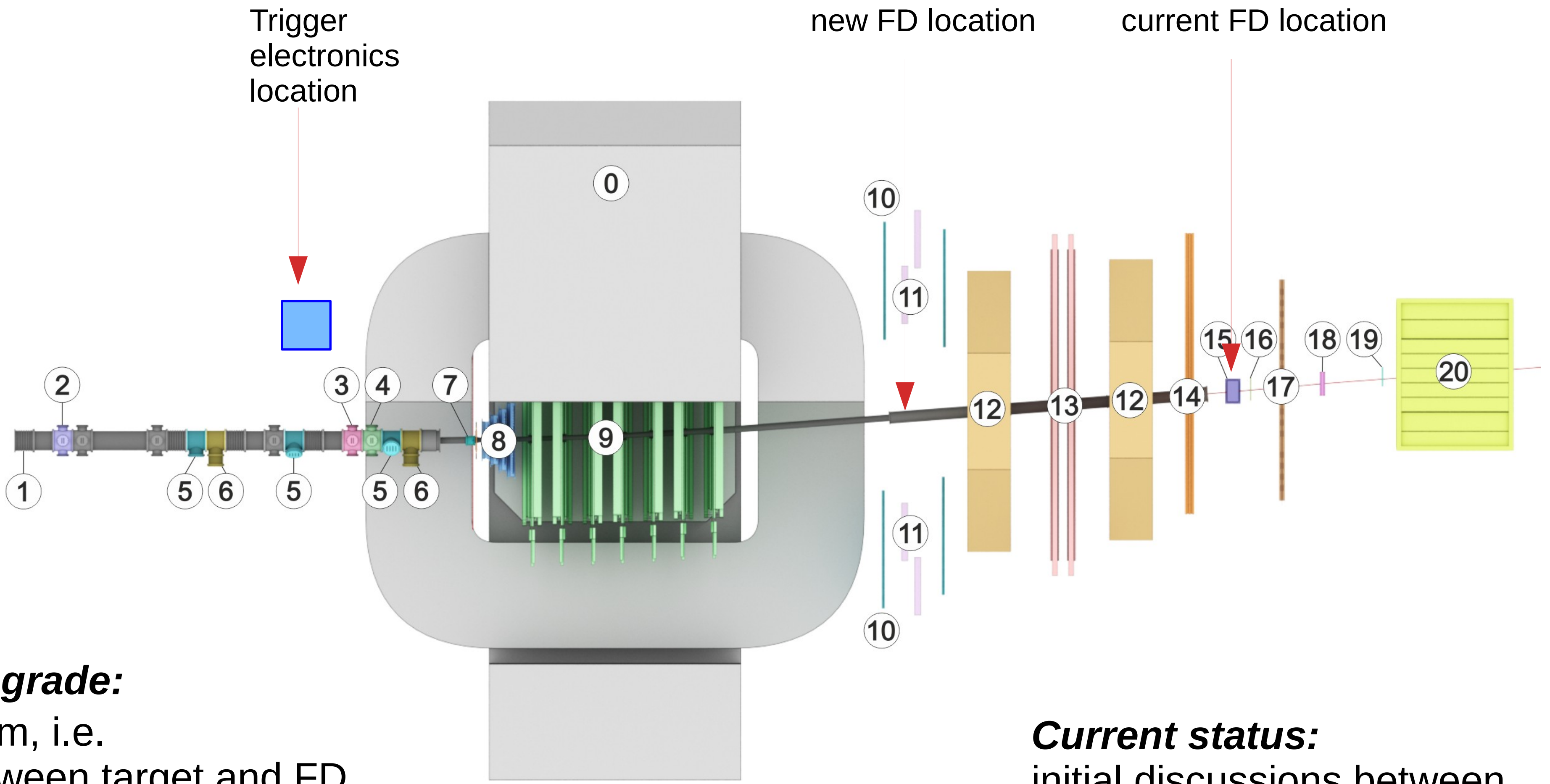
FEE PCB connectors side (design)





Au+Au, 3.8 AGeV, 2%

New or additional FD



Main points for upgrade:

1) radiator in vacuum, i.e.
   min. material between target and FD
2) shorter distance between target and FD
3) shorter cable between FD and trigger
   electronics (faster trigger)

Current status:
initial discussions between S.Pyadin, Belgorod group and trigger group

Thank you for your attention