Performance of the trigger system in the BM@N run with Xe beam

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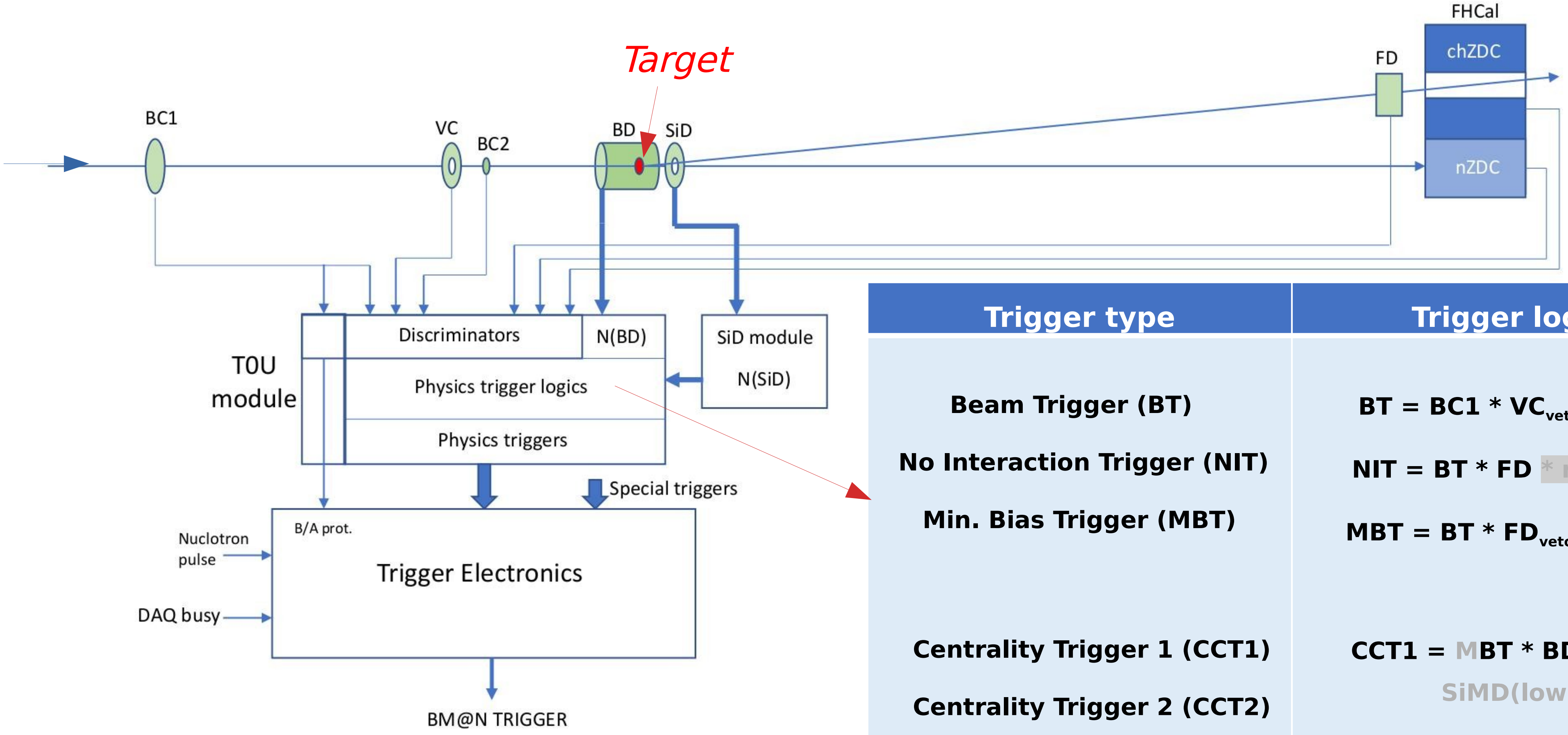
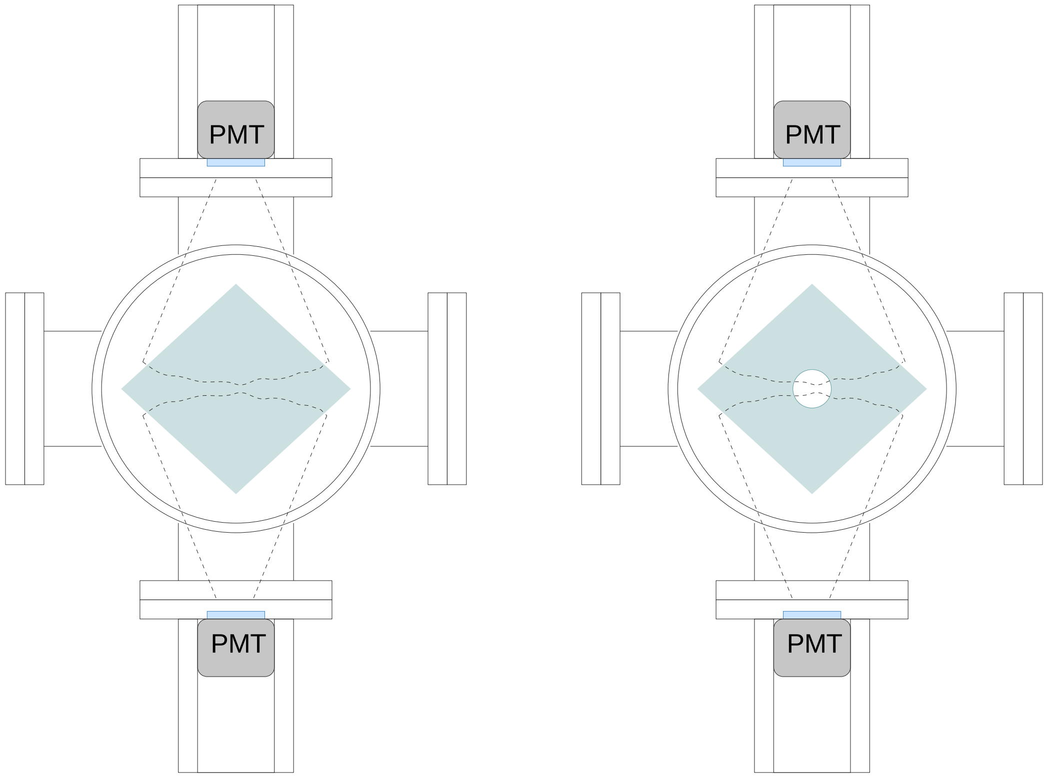
10th Collaboration meeting of the BM@N experiment
May 16, 2023

Overview of the trigger scheme



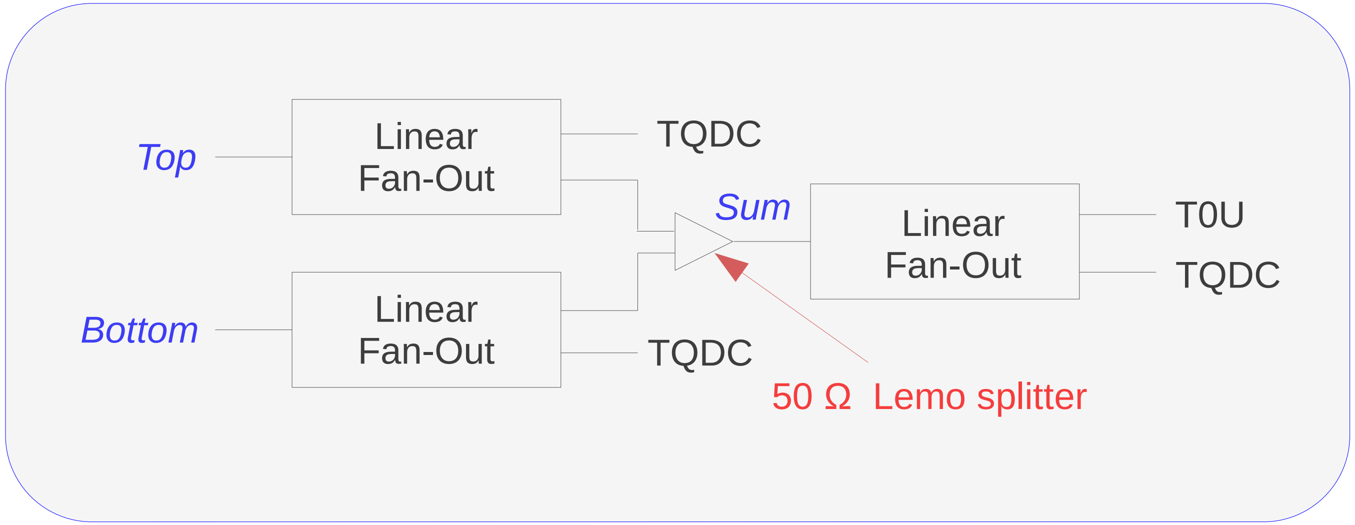
Trigger type	Trigger logic
Beam Trigger (BT)	**BT = BC1 * VC_{veto} * BC2**
No Interaction Trigger (NIT)	**NIT = BT * FD * $nZDC_{veto}$**
Min. Bias Trigger (MBT)	**MBT = BT * FD_{veto} * nZDC**
Centrality Trigger 1 (CCT1)	**CCT1 = MBT * BD(low) * SiMD(low)**
Centrality Trigger 2 (CCT2)	**CCT2 = MBT * BD(high) * SiMD(high)**
	Actual BD setting: low = high

Design and read-out of BC1, VC

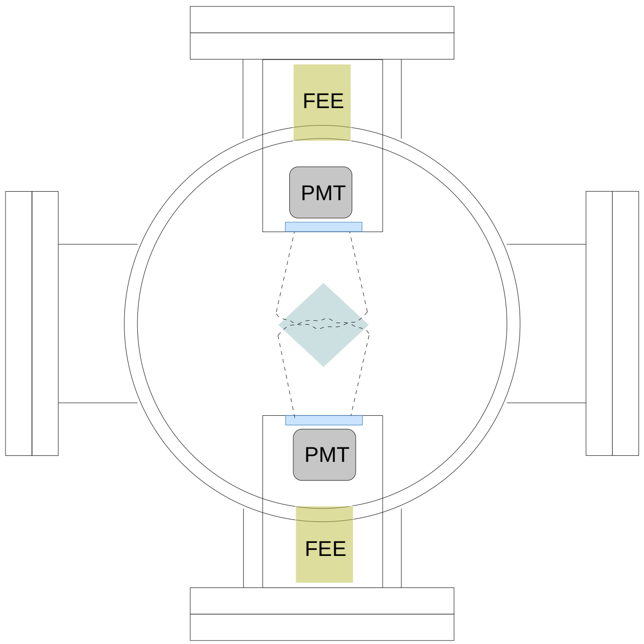


Detector	PMT	Radiator
BC1	Hamamatsu R2490-07	Scint. BC400B 100 x 100 x 0.25 mm^3
VC	Hamamatsu R2490-07	Scint. 113 x 113 x 4 mm^3 Ø 25 mm

“Air”-lightguides from Al-mylar

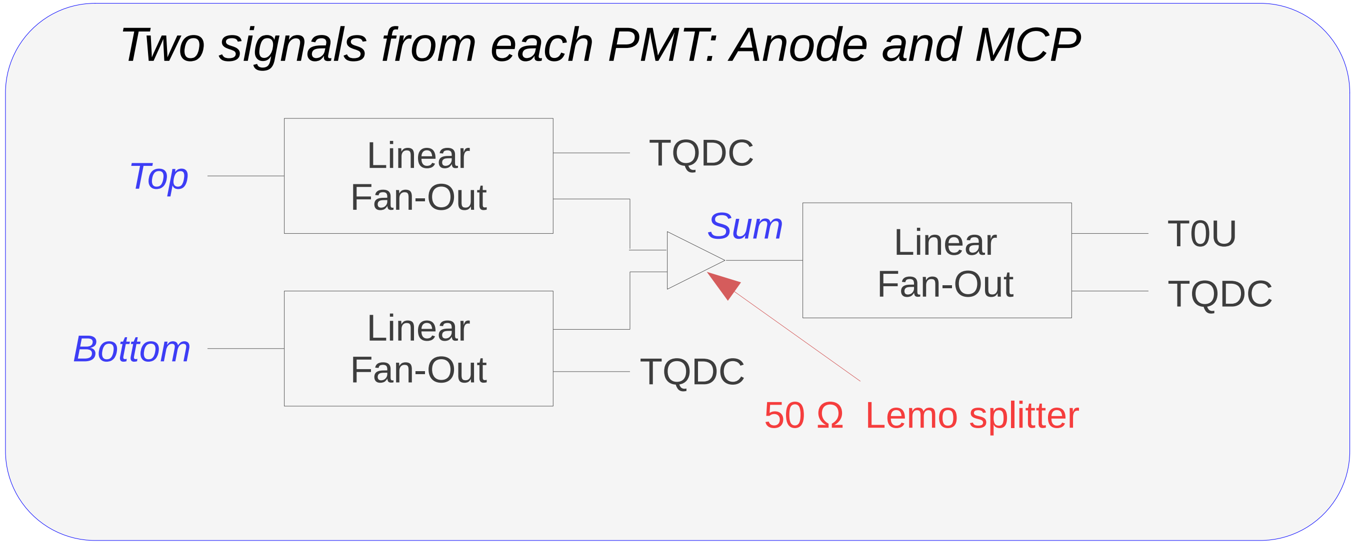


Design and read-out of BC2



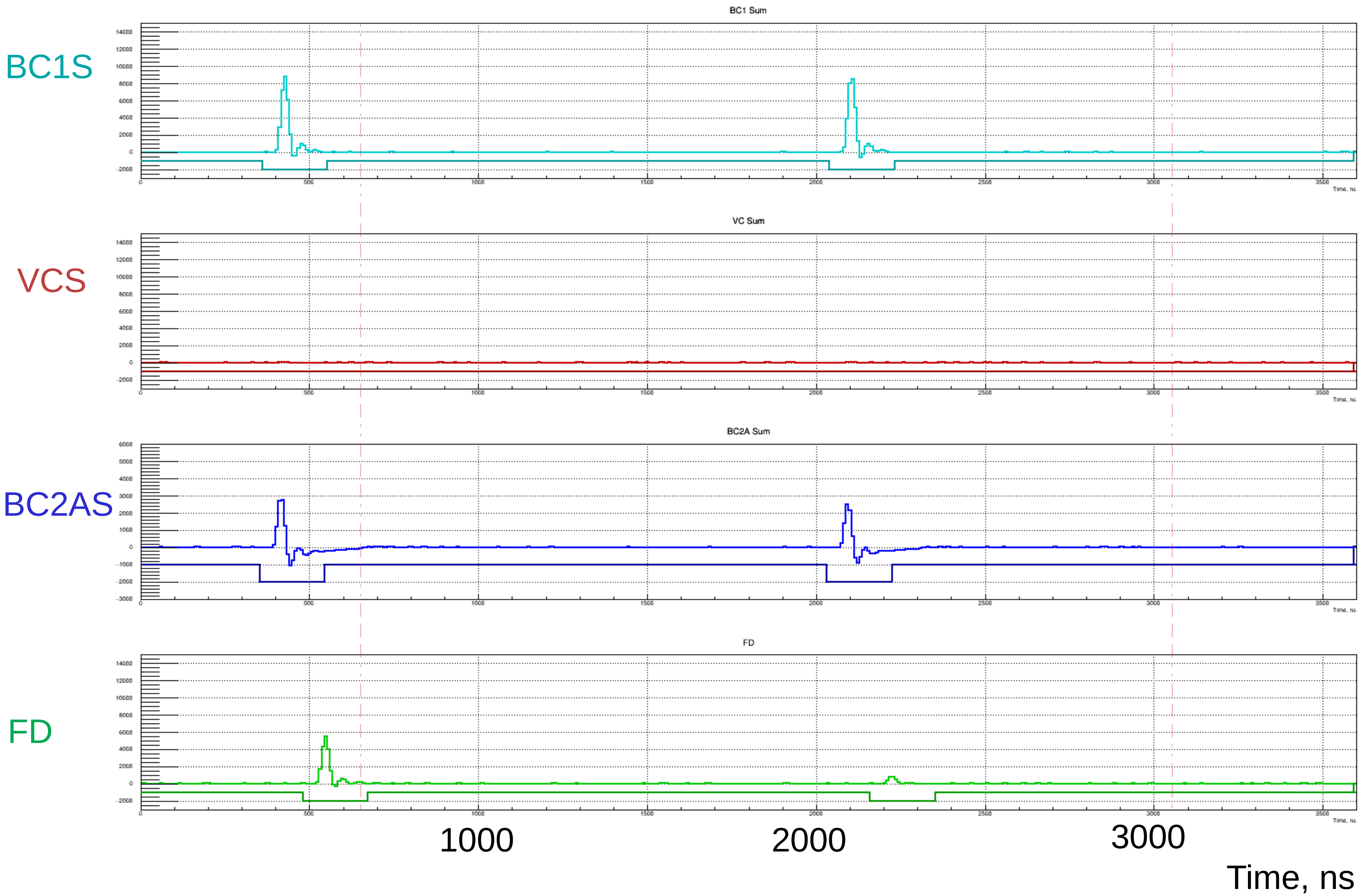
Detector	PMT	Radiator
BC2	Photonis XPM85112/A1 Q400 25x25 mm^2	Scint. BC400B 34 x 34 x 0.15 mm^3

“Air”-lightguides from Al-mylar



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

3.6 μs TQDC read-out without Zero-Suppression



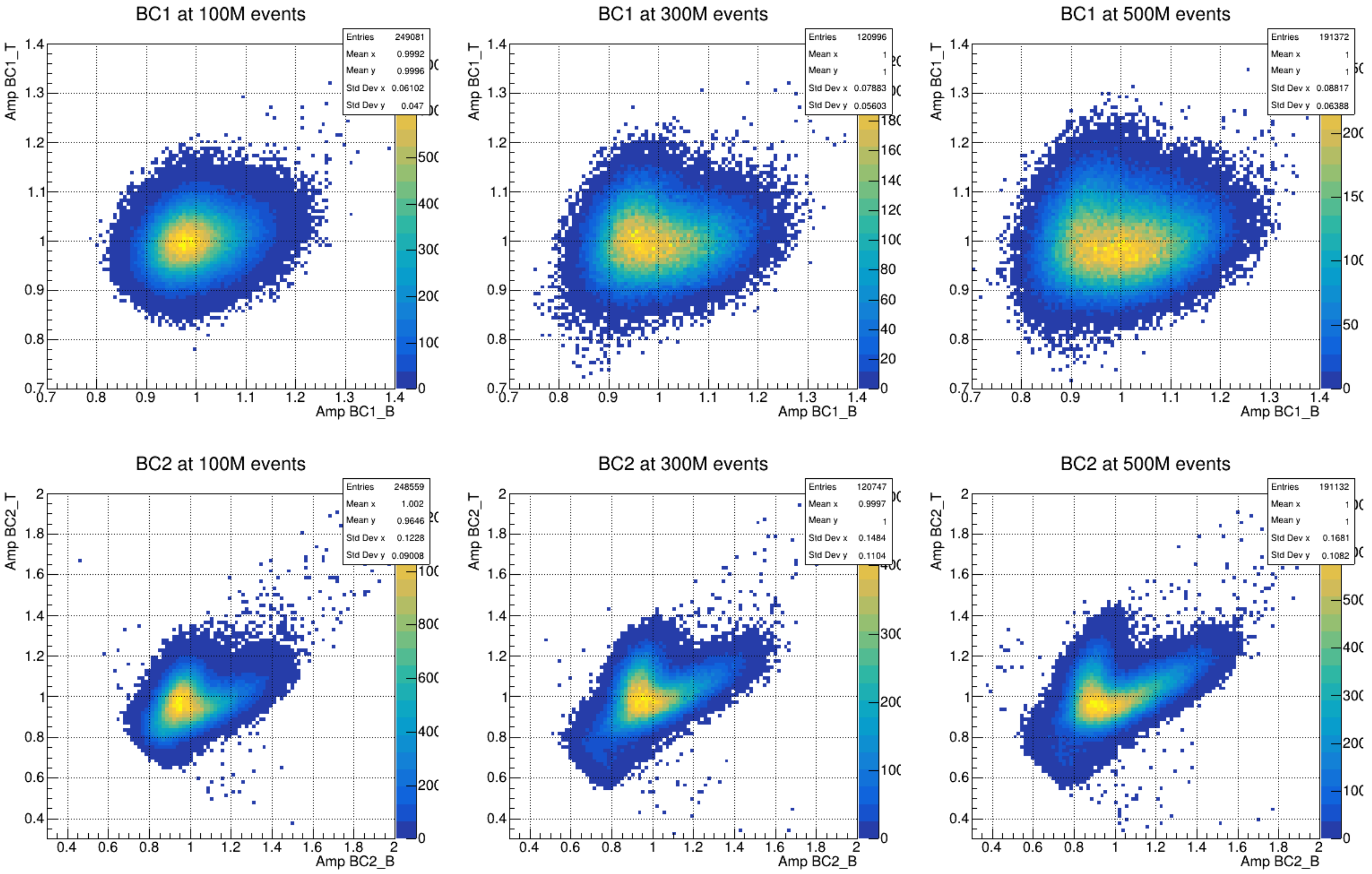
Required software adaptation

Efficient detection of small pulses

ADC info is independent of TDC threshold

Extra info outside of Before/After time window (useful for beam composition and beam counter response studies)

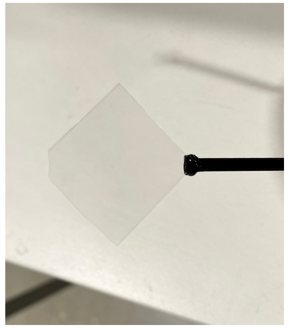
Indication of radiation damage in BC1 and BC2



More pronounced in BC2

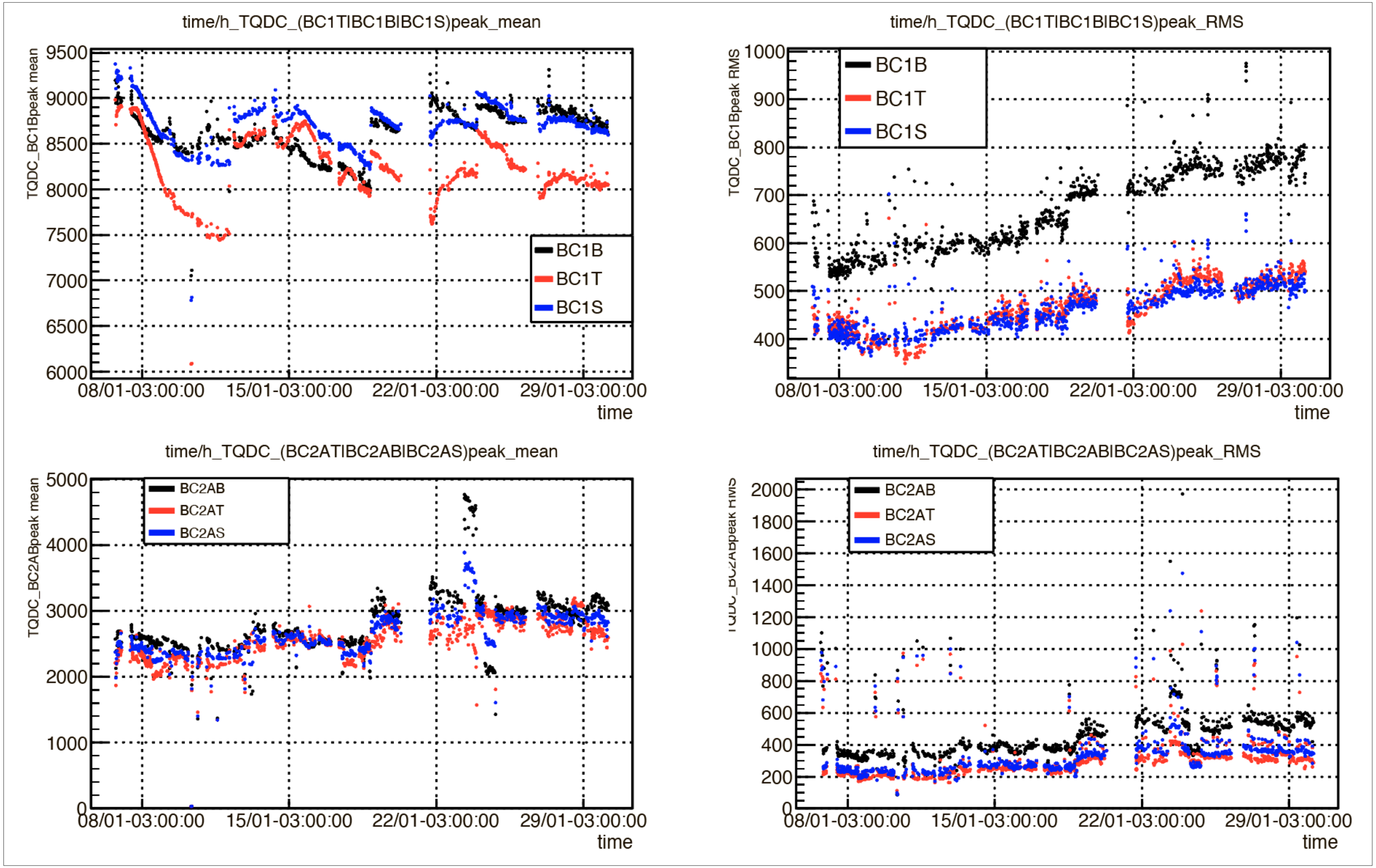
Might require scintillator change during the run

Cherenkov prototypes are hard to test without heavy ion beams



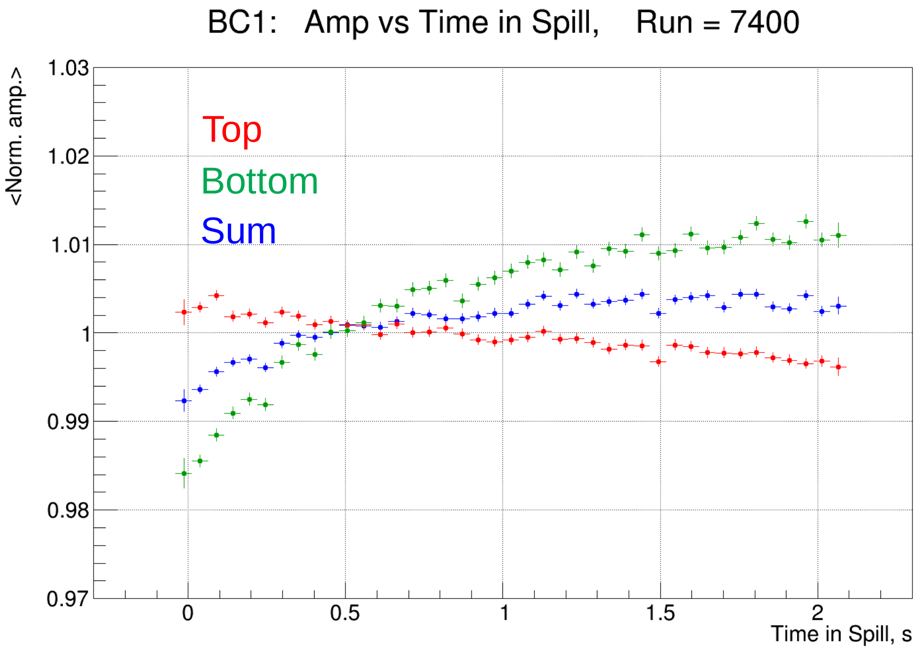
No visible loss in transparancy of the BC2 scintillator. Study is planned by the LPI RAS group

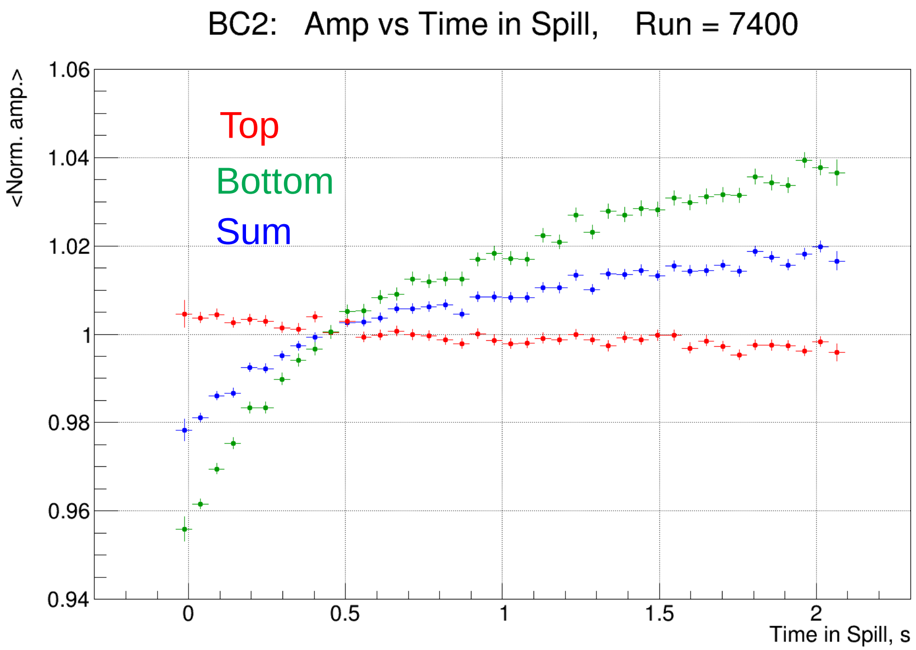
Monitoring of BC stability during the run



Oleg Golosov
MEPhI-group

BC1 and BC2: Amplitude stability in spill. Offline resolution





- stable at 2-4 % level
- can be sensitive to (X,Y) beam movement during spill
- next step is to add Beam Tracker into analysis

Offline amplitude resolution

Detector	σ (%)
BC1	4.8
BC2	7.1

Good resolution of BTr3 is very important for offline rejection of upstream interactions

Time resolution of BC1 and BC2

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

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

i,j: *BC1, BC2, FD1*

Measured with additional FD1 counter, placed behind the FHCal hole. FD1 is similar to BC1 in design, PMTs and scintillator (prepared by V.Velichkov).

Each of BC1 and BC2 have ≤ 45 ps resolution. Combined, they can provide ≤ 30 ps resolution.

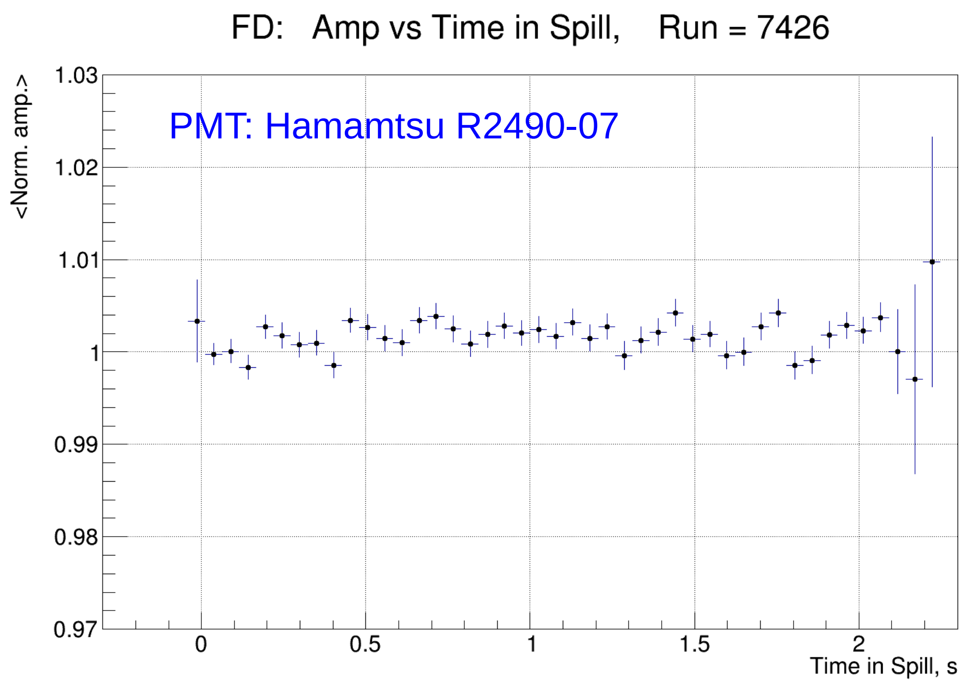
Resolution of BC2 is good enough, but poorer than expected for this type of PMT.

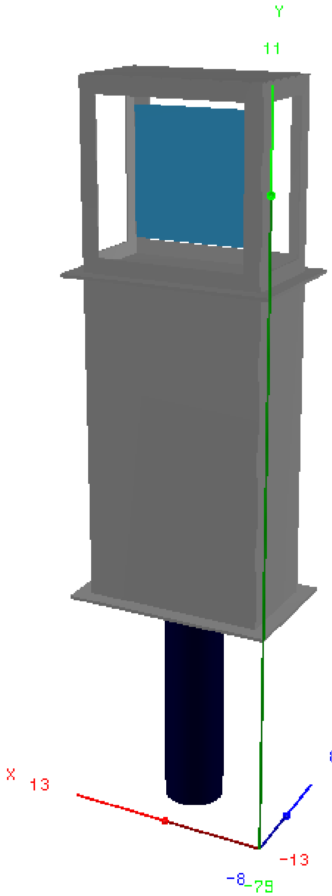
Detectors	σ_{ij}, ps
BC1 - BC2	57
BC1 - FD1	61
BC2 - FD1	58
(BC1&BC2) - FD1	52

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	Quartz 1 mm	17.0
XP2020/Q	Quartz 1 mm	11.7
R2490-07	Scint. 0.5 mm	9.1 → 6.7 → 5.3





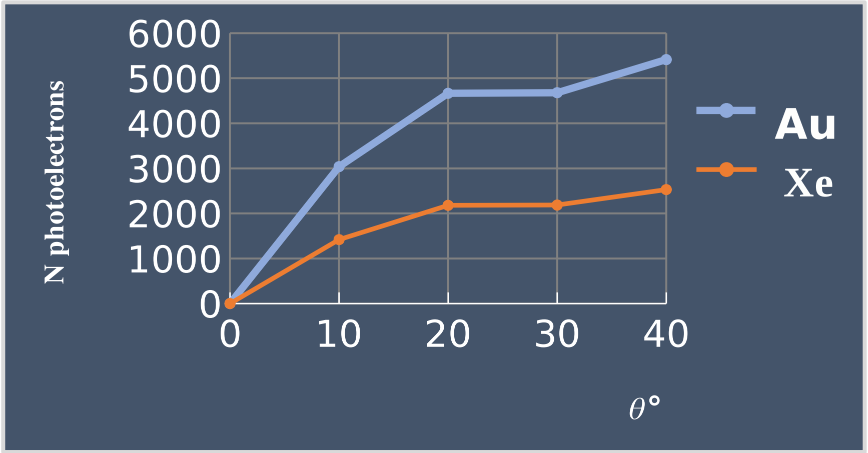
Non-stable base for XP2020 at the beginning of the spill

Significantly better resolution with scintillator radiator

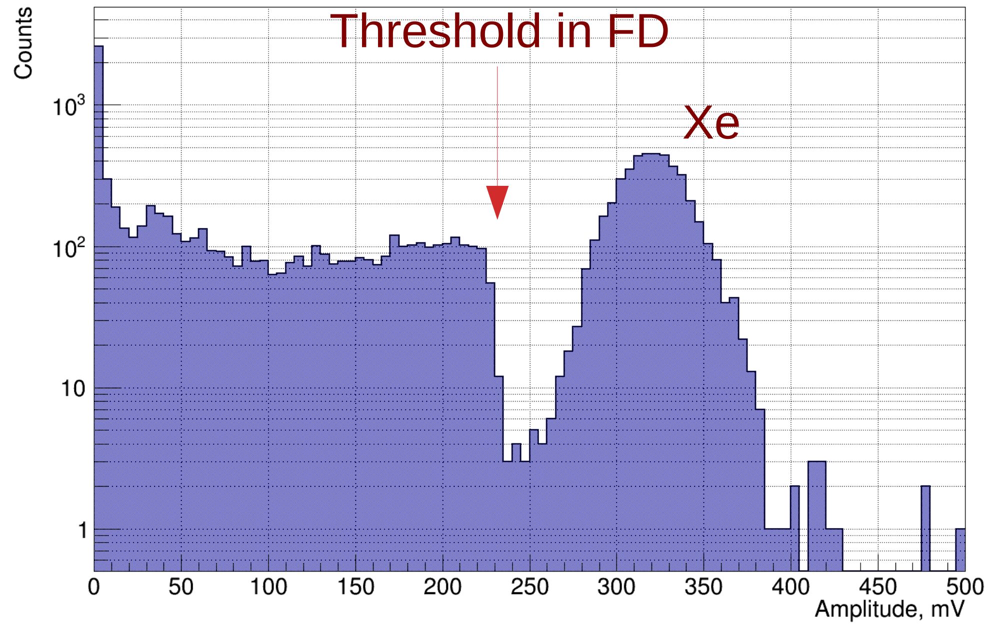
Less than expected photoelectron statistics with the quartz radiator

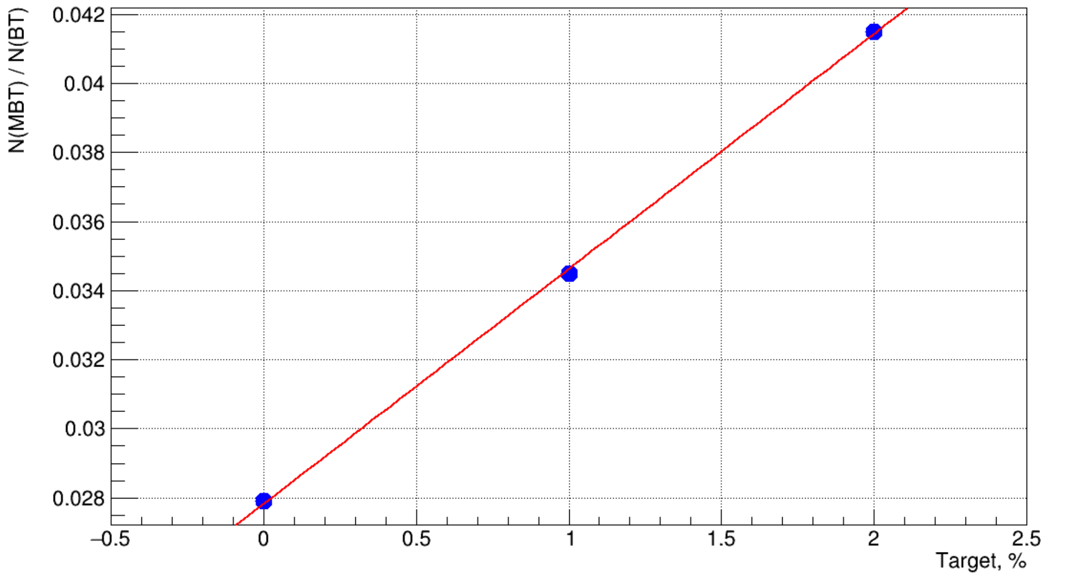
Quartz hodoscope has 2% resolution (FHCal group) and will be used in offline analysis

Simulation (N.Lashmanov)



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





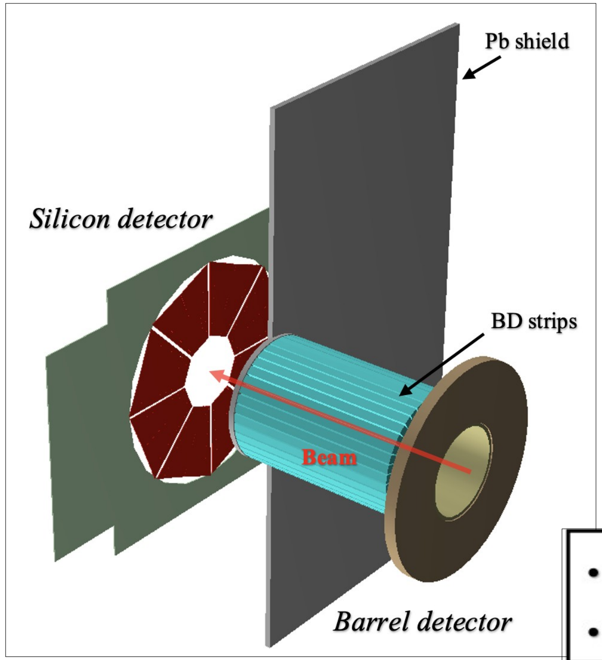
Even with conservatively low threshold
in FD amplitude, typical ratio of N(MBT) / N(BT)
for 2% target was ~0.04,
i.e. with significant background

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

To check: contribution from interactions upstream of BC2

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

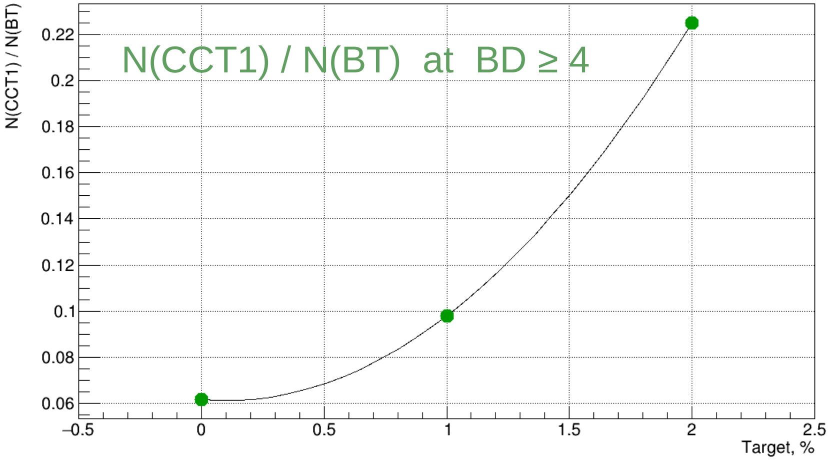
Response of Barrel Detector and trigger CCT1 = BT • (BD≥n)



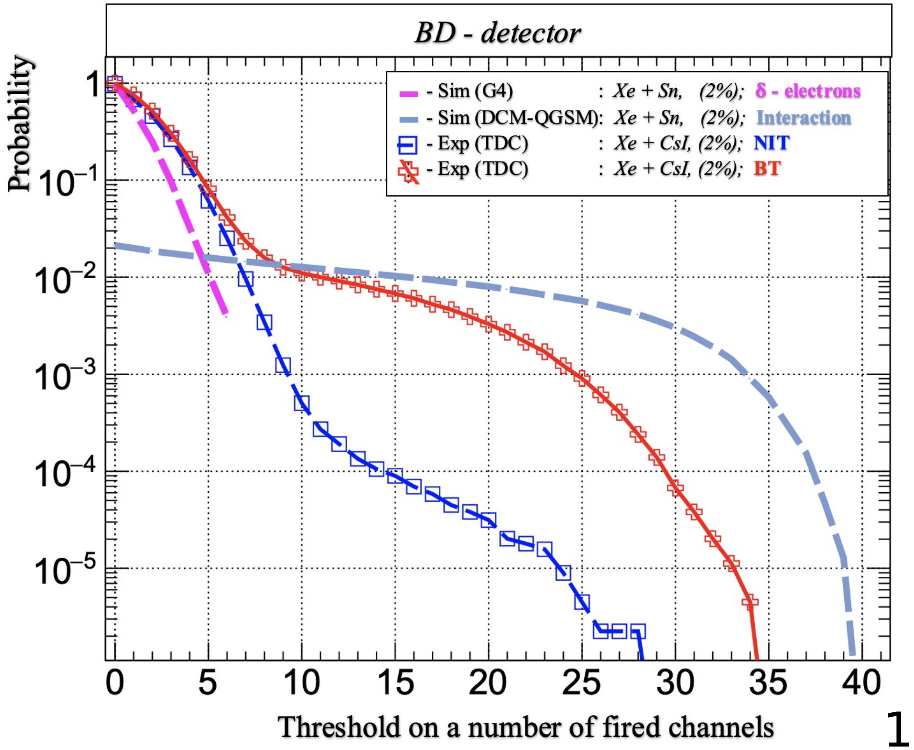
Even with added Pb-shielding,
the background from δ-electrons is significant
and larger, than predicted by Geant4 simulations

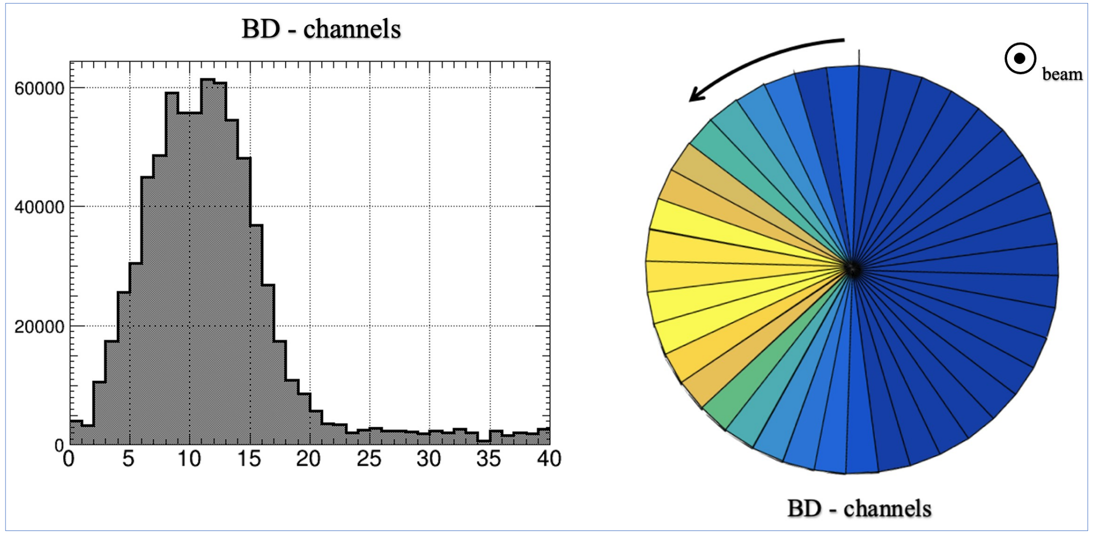
At BD ≥ 4 and 2% target,
N(CCT1) / N(BT) is 0.22,
while 0.02-0.04 was expected.

In addition, CCT1 rate is very non-linear
with 1% and 2% targets, indication of
high sensitivity to pile-up of beam ions



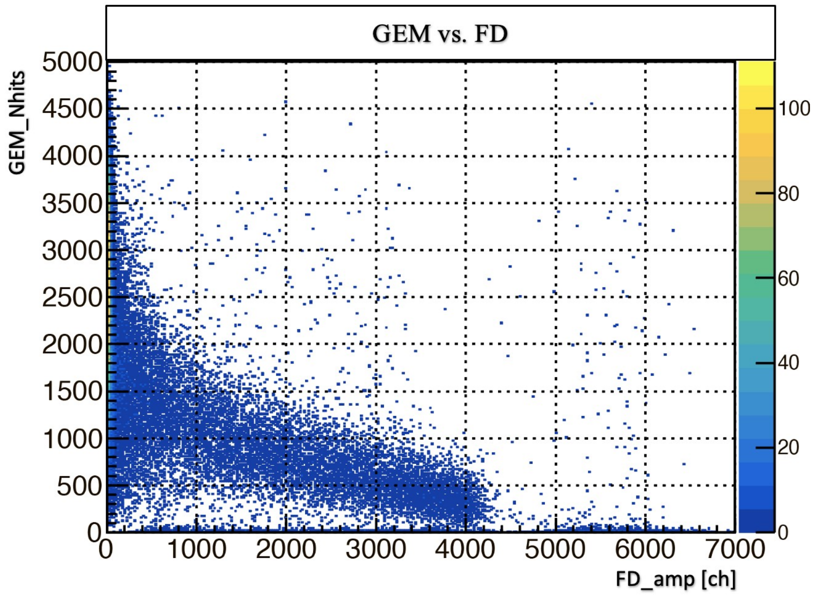
- *Inner shield*: Pb - cylinder 0.3 cm thick;
- *Outer shield*: 25 x 50 cm², L = 0.5 cm.





NIT
events

Central collisions trigger CCT2 = MBT • (BD≥n)

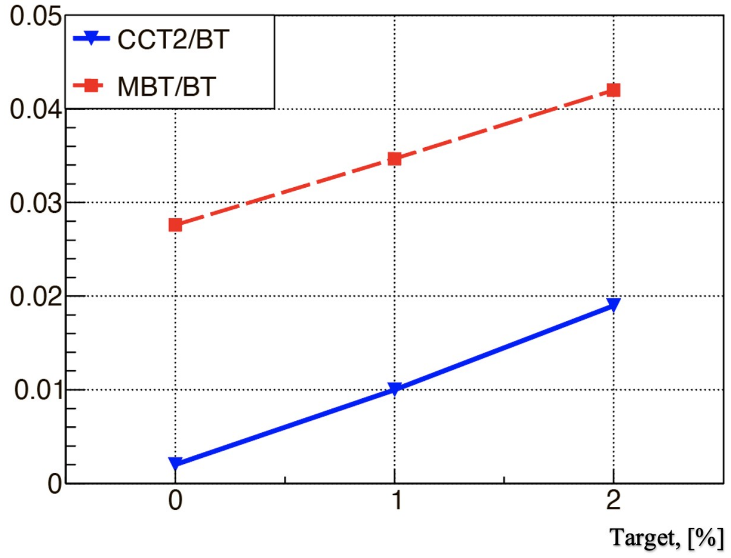


The backgrounds in triggers MBT and CCT1 are suppressed when MBT and CCT1 are combined in CCT2

Some non-linearity with 1% and 2% targets remains in CCT2, but becomes much smaller

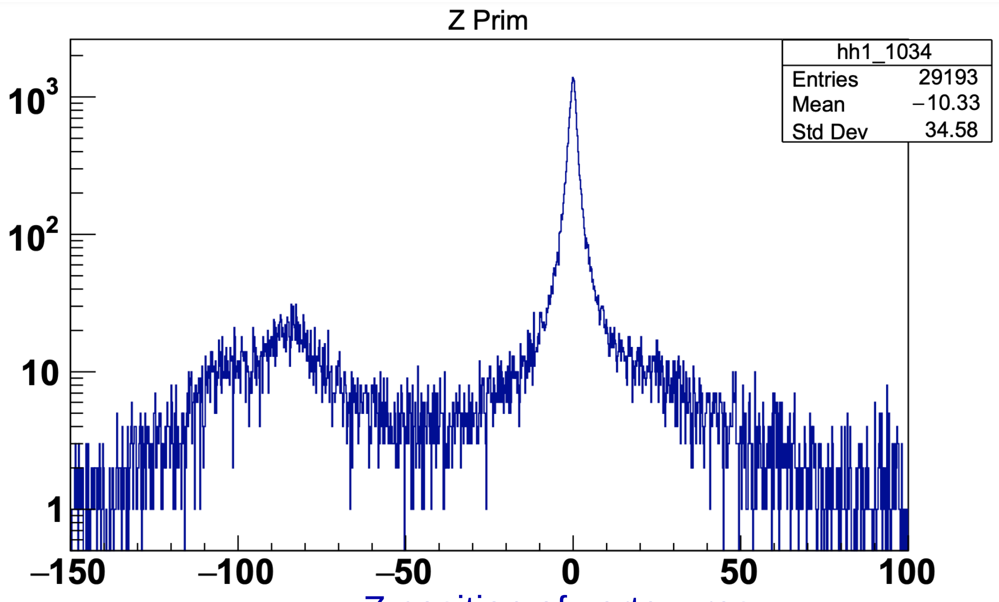
Correlation plots in various detectors were used in order to confirm the validity of the trigger

N(CCT2) / N(BT) at BD ≥ 4



“Regular” mix of triggers used in data taking

Trigger	Downscaling factor	Fraction, %
BT	2000	3
MBT	35	7
CCT1	230	5
CCT2	1	85



Outlook

In general, so far it looks that the trigger system can be used in the next run (assuming, Xe 2024) without major changes. However, there are points for improvement (currently under discussion):

BC2: -- replace scintillator with a fresh one;
-- modify mount in vacuum box to allow easy scintillator replacement during the run;

-- investigate the effect of amplitude drop in the presence of a close preceding pulse (within few tens of nanoseconds). Can be studied with the laser system
-- test if different operation mode (higher voltage,different FEE) improves time resolution;

-- prepare mount for different PMT (BC1 type R2490-07, this will remove negative tail overshoot).

FD: -- prepare stable base for XP2020/Q and test it with the laser system.

BD: -- major redesign for Bi runs: two halves, more inner Pb-shielding, shorter scintillator strips

SiMD: -- it was not used in the last run, but test data were taken with 3 GeV/n beam, quick look at the data shows normal response of the detector, but further analysis is needed.

Beam trigger: -- additional threshold on BC1 amplitude in order to veto pile-up of beam ions.
MBT: -- add second threshold on FD amplitude and use “soft” threshold in MBT and “hard” in CCT2.
CCT1: -- check if currently used full DAQ read-out is actually needed, perhaps, the trigger mask in BT events is enough for the analysis tasks

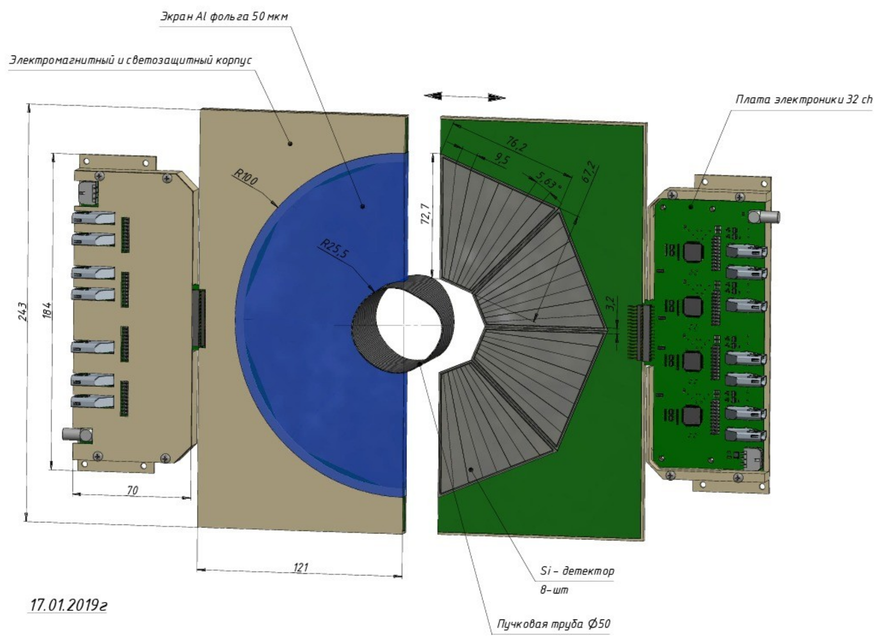
Prototypes with Cherenkov radiators in BC1, BC2 and FD: design and prepare for testing in the next run.

Thank you for your attention

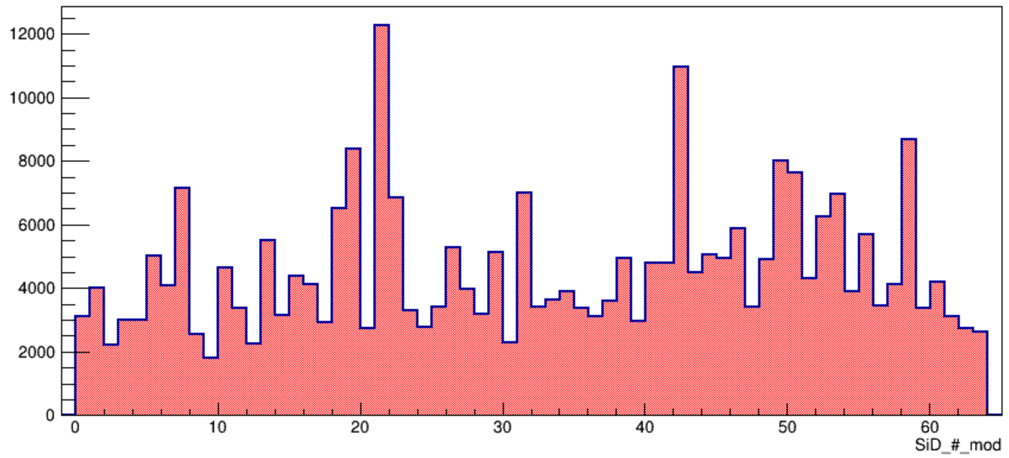
Group of N.Zamjatin

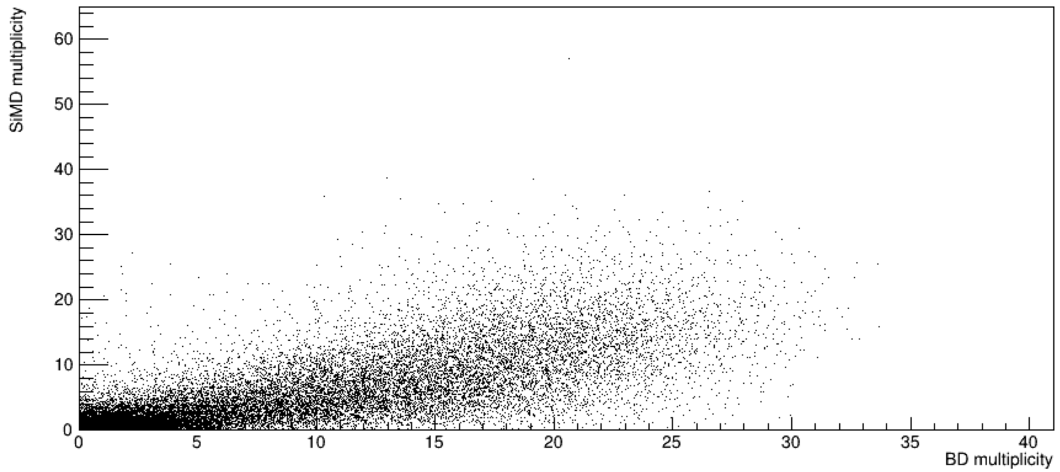
Response of Si Multiplicity Detector

Xe Beam 3 GeV/n, data taking with MBT trigger



- all 64 channels are working
- clear correlation of hits multiplicity in SiMD and BD



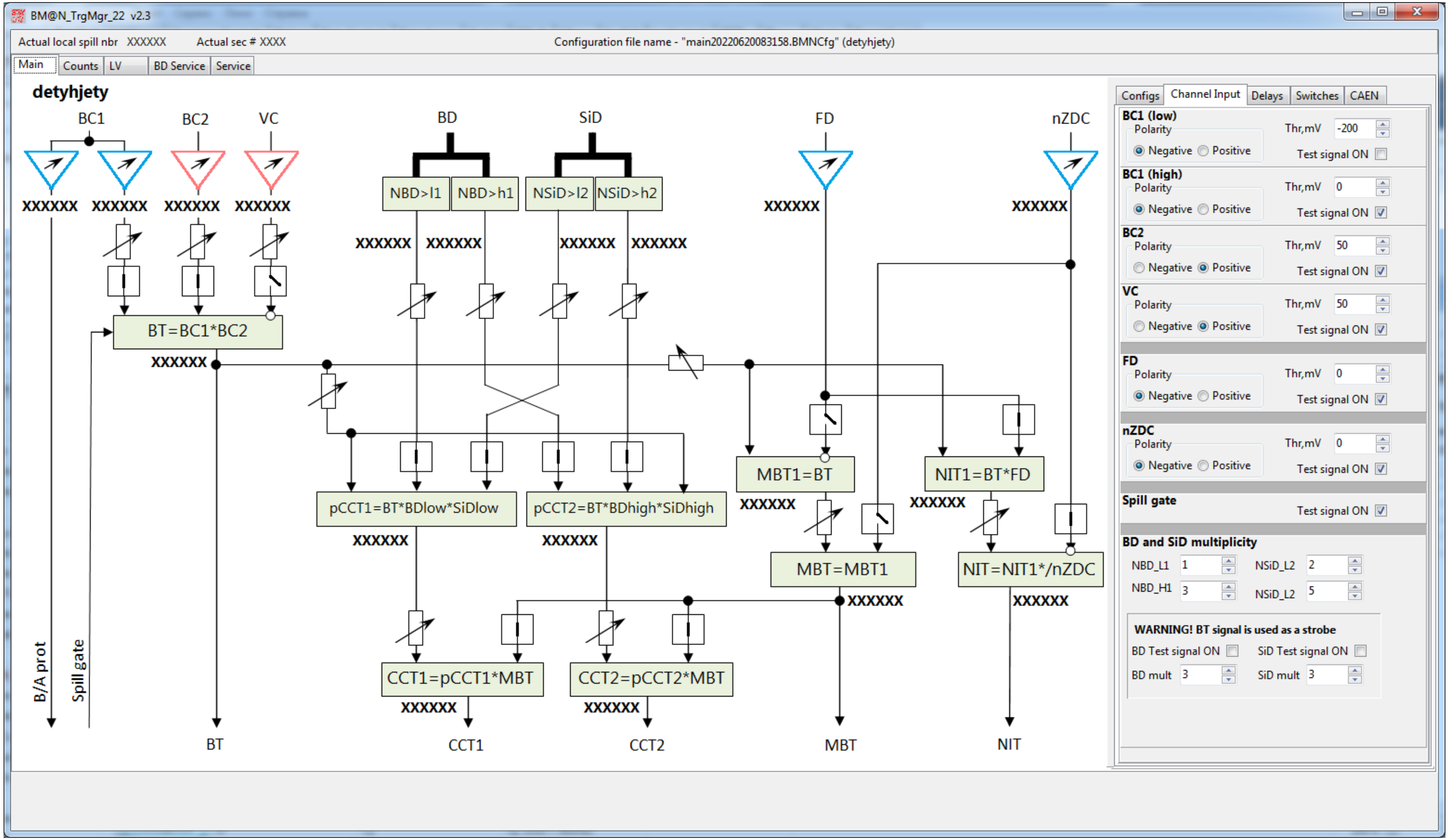


Detector parameters:

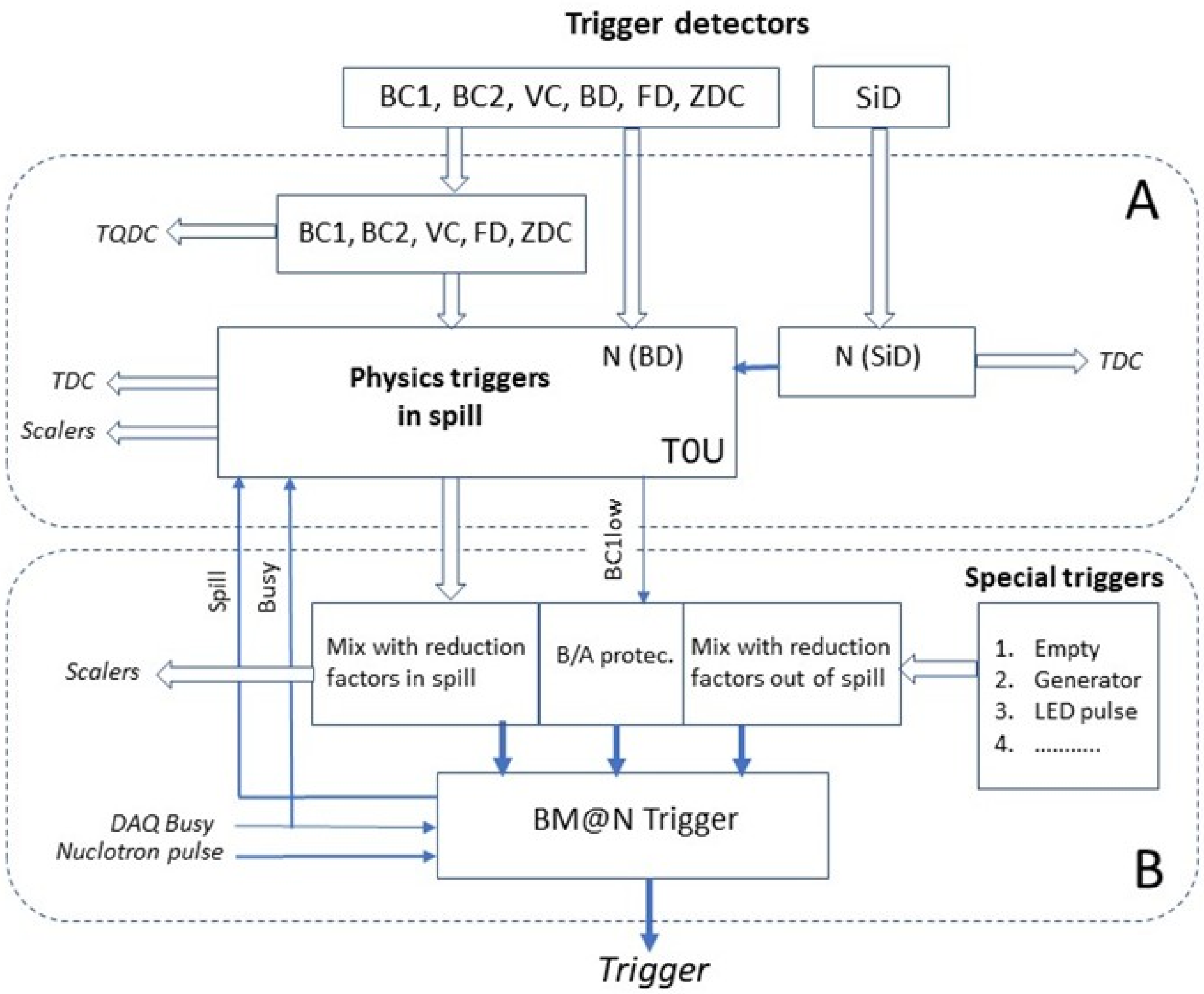
– opening for the beam. Dia. 50 mm
– 8 trapeziodal detectors
– 64 strips in total
– 525 μm thick

First look analysis by N. Lashmanov

T0U trigger logic scheme



Sub-parts in trigger electronics



Part A
(managed by the trigger group):

generates physics triggers.

Part B
(managed by the DAQ group):

makes downscaling of
the physics triggers (up to 16 triggers can be provided);

makes Before/After protection;

generates special triggers.