Status of the trigger system

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for the BM@N trigger group

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Trigger detectors preparation for 2025 Xe Run (Run 9)

BC0: new upstream counter (inserted in the beam during beam tuning):
vacuum part - ready (groups of A.Kubankin and S.Piyadin)
scintillator assembly – ready (+ V.Velichkov, V.Azorskiy)
PMTs with bases – ready (V.Velichkov, V.Rogov)
cables – ready (V.Rogov)

BC1, VC: same as in 2023 Xe Run (Run 8)
new scintillator mounts and lightguides – ready (V.Velichkov, V.Azorskiy)

BC2: same as in Run 8
new scintillator mounts and lightguides – ready (V.Velichkov, V.Azorskiy)
new type of PMTs with bases – ready (V.Velichkov, V.Rogov)
cables – ready (V.Rogov)

BD: no changes compared to Run 8

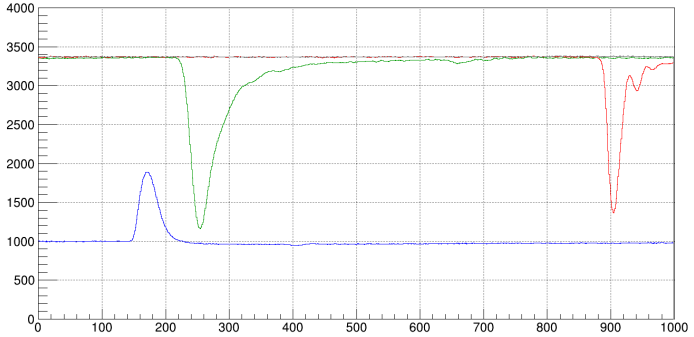
FD: same function as in Run 8, but in a new position and made out of new parts
vacuum part – ready (groups of A.Kubankin and S.Piyadin)
scintillator assembly – ready (+ V.Velichkov, V.Azorskiy)
cables – ready (V.Rogov)

FHCal: new trigger detector
electronic module for summed signal – ready for trigger tests (Troitsk group)
cable (as short as possible) – ready (S.Piyadin, S.Novozhilov, V.Rogov)

FHCal Signal in CAEN data in Run 8

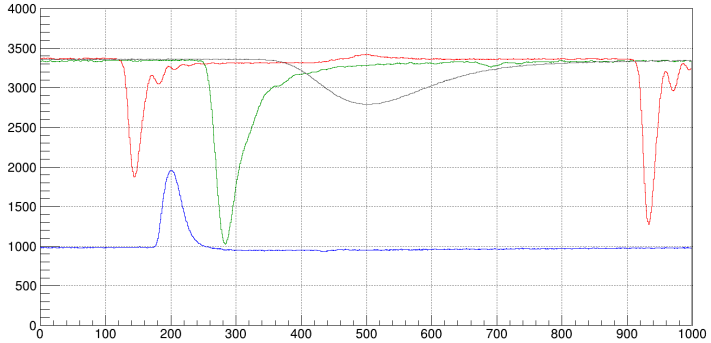
Input to T0U was out of expected trigger time window
TQDC output was never properly read-out
only CAEN data in pile-up events can provide some info

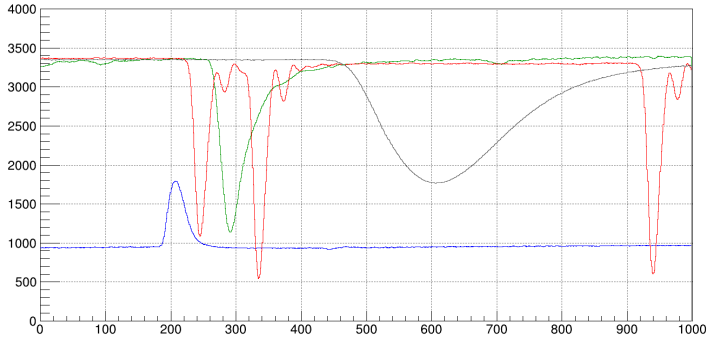
Typical event with BC1, BC2, FD

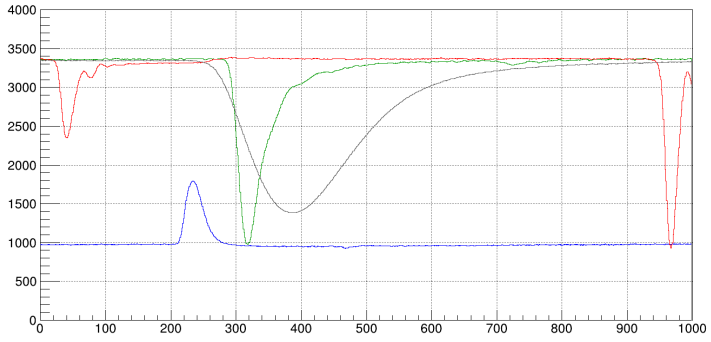


Time window 200 ns

Pile-up with additional FD and FHCal







FHCal signal parameters:

Delay with respect to FD was ~70 ns;

BC2 ~220 ns (will be shorter with new cables)

Front duration ~25 ns
at low fixed threshold this will be the signal “time walk”

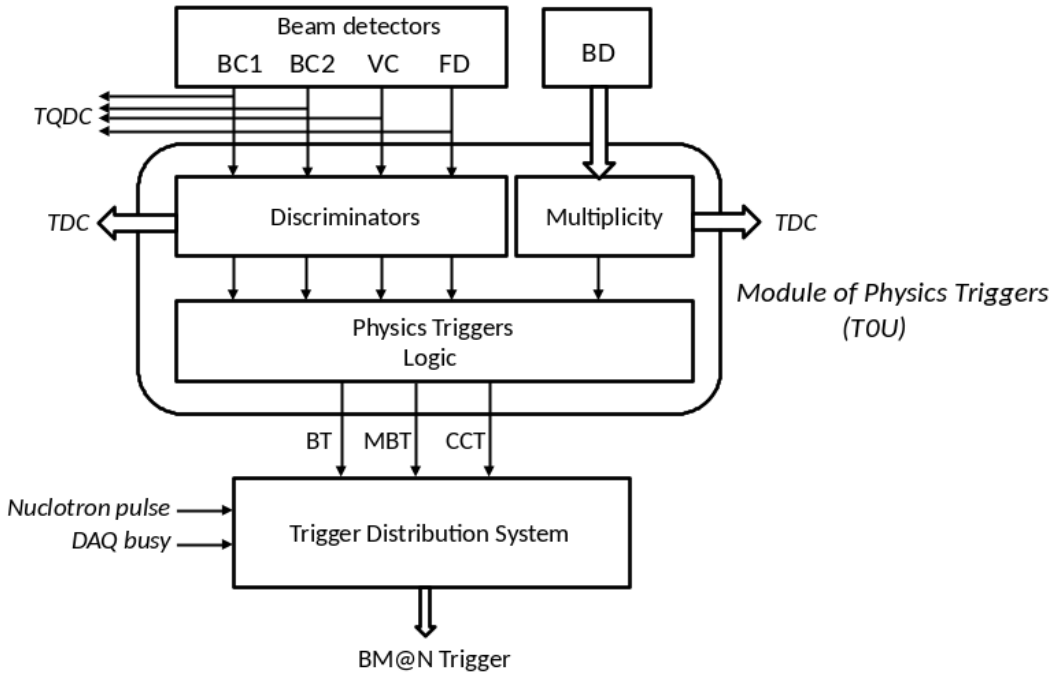
Pulse duration ~80 ns

The idea is to use FHCal signal in combination with BD multiplicity.

Perhaps, the FHCal response is too slow for the BM@N, but test of this trigger might be useful as a prototype for “MPD fixed target” trigger.

Electronics overview

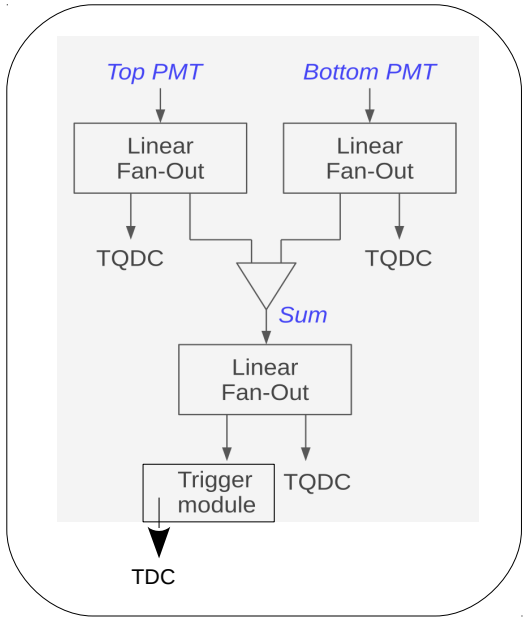
Trigger scheme in 2023 Xe Run



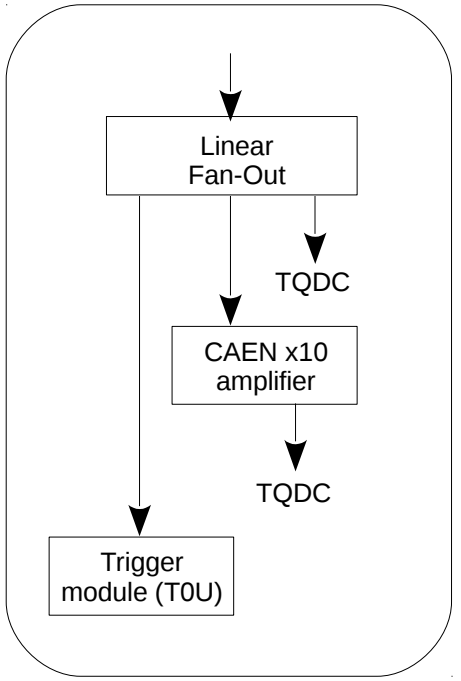
One signal from BC0, BC1, BC2, VC is sent to the trigger T0U.

This will be linear sum of the two PMTs (as in Run 8).

BC0, BC1, BC2, VC read-out scheme



FD, FHCal read-out scheme

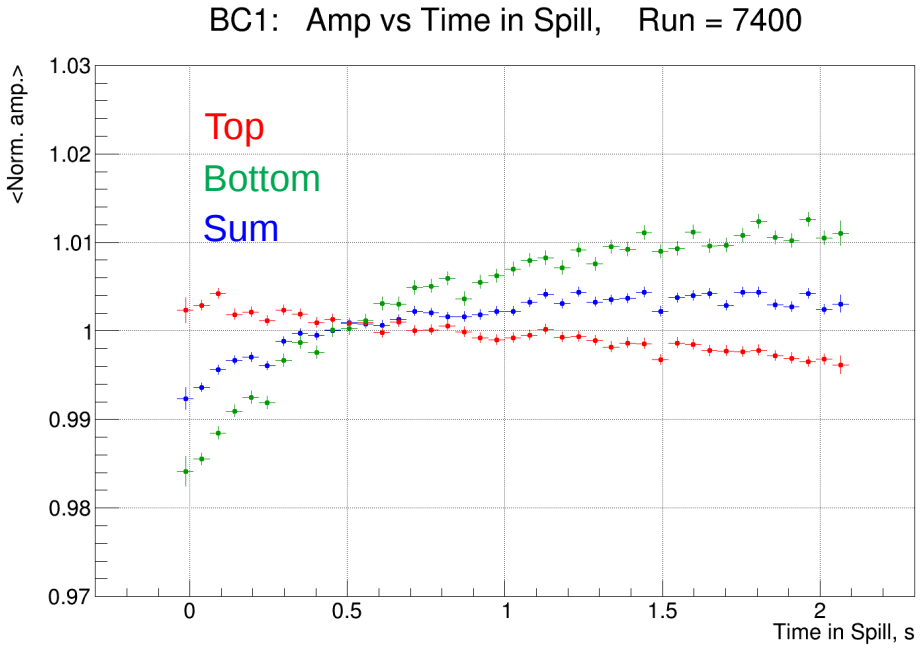


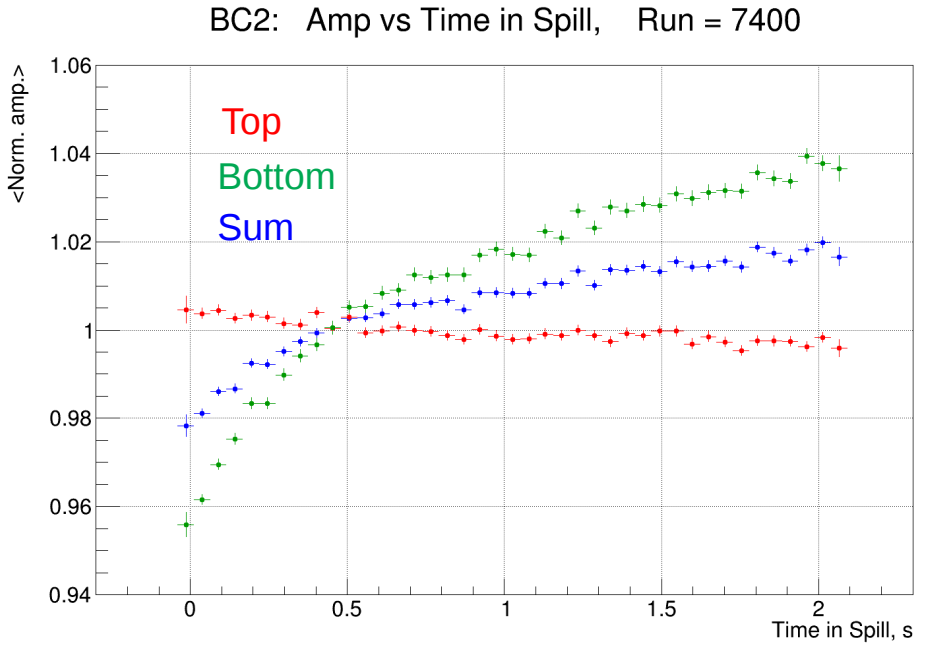
In addition, output of the Fan-Out signal are sent to CAEN Waveform digitizer (not shown).

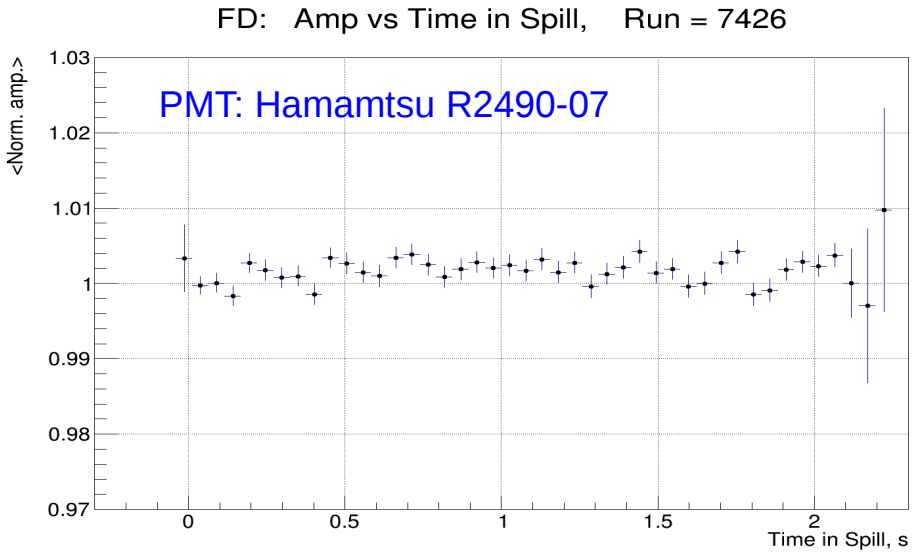
50 Ω LEMO “Fan-in / Fan-out” will be replaced by new Fan-In / Fan-Out module – ready (V.Rogov).

If needed, individual signals can be sent to CAEN x10 amplifiers (under discussion).

BC1, BC2 and FD: gain stability during spill (Run 8)







- similar signal changes in BC1 (fine-mesh PMT) and BC2 (MCP PMT) suggest sensitivity to (X,Y) beam movement;
- high stability of FD response (fine-mesh PMT);
- in Run 9 all counters have Hamamatsu R2490-07;
- amplifiers don't seem to be needed, and might affect time resolution;
- start without amplifiers, but can add them if needed.

Detector read-out electronics

TQDC

BC1, VC, BC2: same read-out as in Run 8, i.e. individual PMTs, and linearly summed signals

FD, FDx10: same read-out as in Run 8

FD1: test detectors downstream of FHCal, same as in Run 8

FHCal, FHCalx10: will be added

T0U triggers: will be added

TDC

BD: same as in Run 8

BC1, BC2: no read-out for individual BC2 PMTs (not available with new PMTs and bases)
read-out of linearly summed signals will be activated in order to provide T0 for TOF

VC, FHCal: can be easily activated, but will provide the same info as TQDC, so, not needed.

MSC

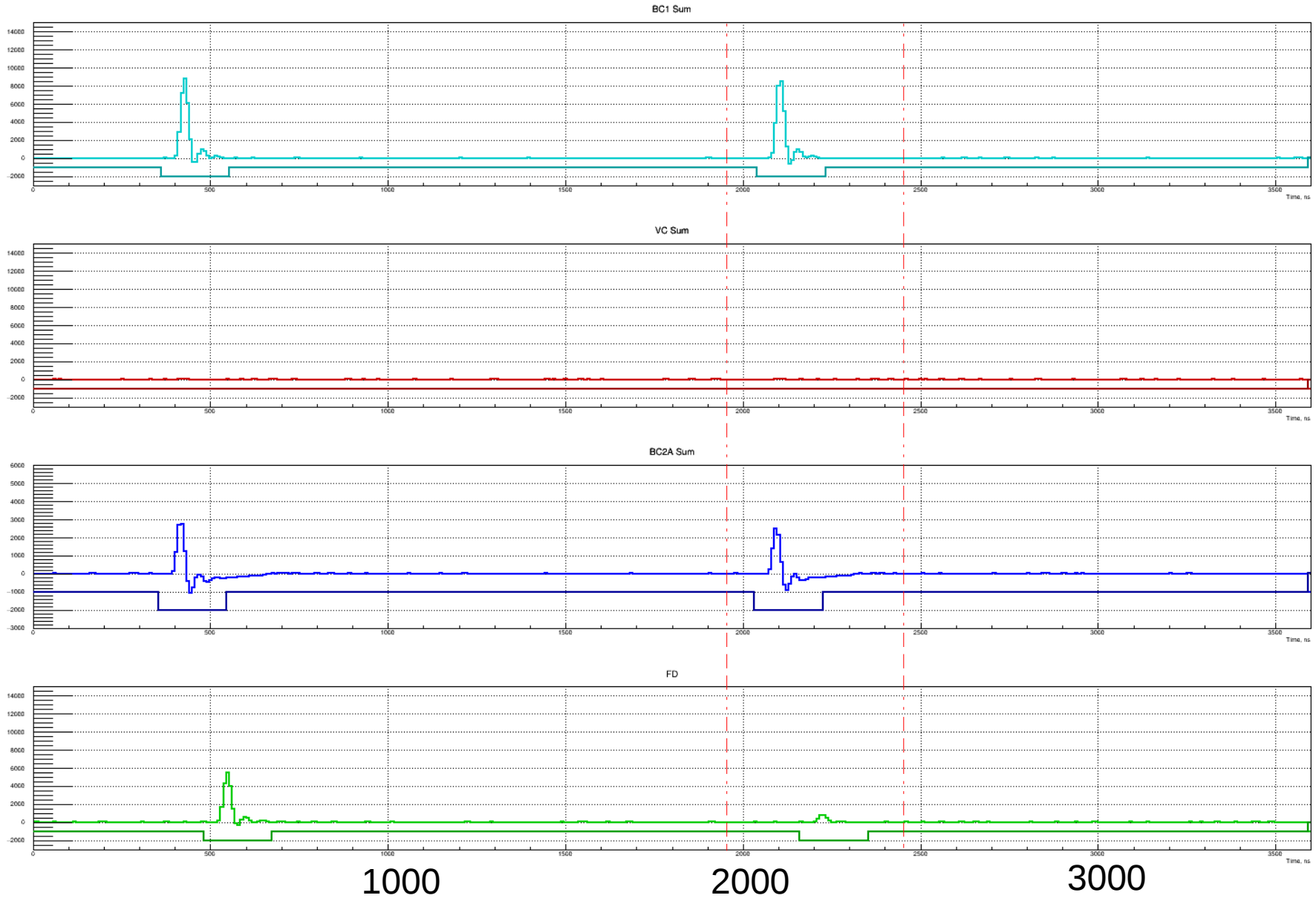
T0U triggers: same as in Run 8, but with finer 25 ns time bins – ready (DAQ group, A.Shchipunov)

Combined for Trigger and Compact Neutron Spectrometer: 5 TQDC and 1 TDC modules – ready (DAQ group)

Plan to configure extended time window compared to Run 8: (-2000, +1500) ns → (-3500, +1500) ns

In order to address pile-up effects it would be useful to have the same extended read-out time window for all fast detectors: TOF400, TOF700, SciWall, Quartz Hodoscope

3.6 µs TQDC read-out without Zero-Suppression



TQDC16VS-E

Main tool to study trigger features

waveform sampling
by 125 MS/s ADC (8ns bins)

25 ps bin TDC

wide time window is used for offline Before/After protection analysis

Long negative tail in BC2 pulses complicates analysis of pile-up events. Reason for PMT change to R2490-07 (BC1 type).

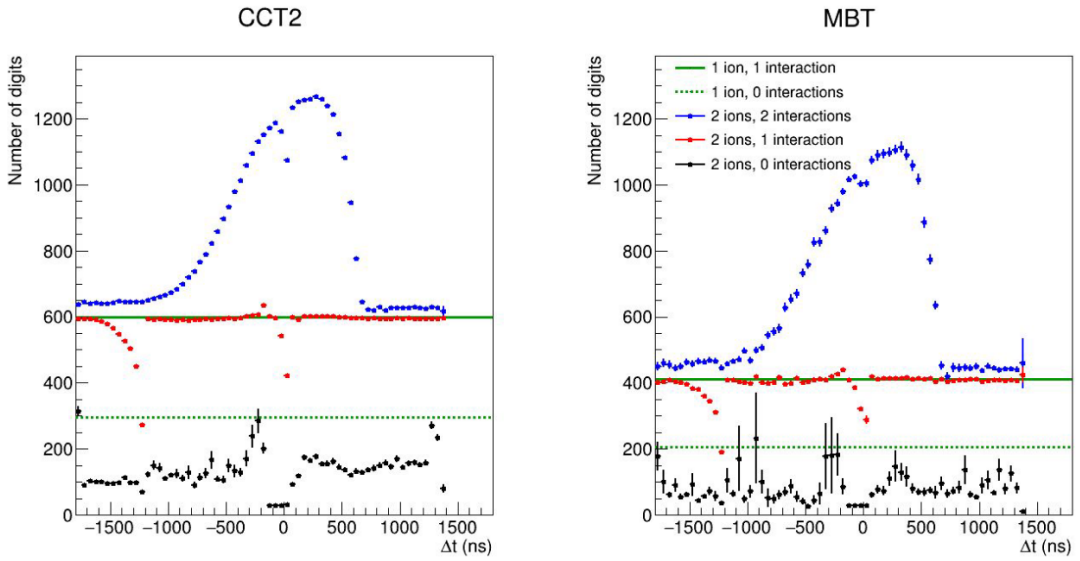
“Close pile-up”: ± 60 ns with respect to trigger time

“Distant pile-up:
(- 2000, -60 ns)
(+60, +1600 ns)

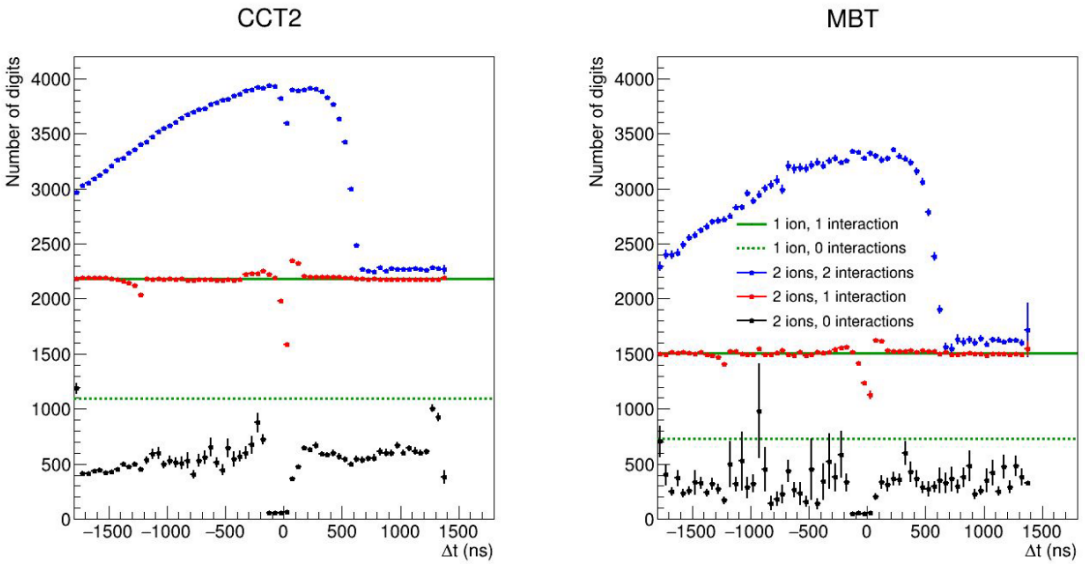
Reason to extend TQDC time window to cover more “Before” time

Additional hits in tracking detectors if there is a second interaction (studied by O.Golosov)

FSD



GEM



How many extra hits are visible in tracking detectors if there was additional beam ion interaction before or after trigger interaction.

Based on observed extra hits in GEM it might be good to add about 1.5 μs “before” time in the TQDC and TDC time windows.

Information about presence or absence of additional hits in “fast” detectors (TOF, SciWall, QHD) at the time of pile-up beam ion can provide information how far downstream the target the pile-up ion interacted.

The data will not increase DAQ load by much, but might be useful.

Changes in the trigger logic implemented in T0U

Time difference between incoming signals from upstream and downstream trigger detectors is significantly reduced by moving FD closer to the target and using shorter signal cable (10 m).

For FHCal signal also the shortest possible cable is used (17 m).

T0U trigger logic for Run 8 was developed expecting strict Before/After protection in ±1.5 μs for all incoming BC1 ions, so delays introducing “dead time” were used in the scheme. This led to difficulties in pile-up handling when Before/After protection was switched off during the run.
For Run 9 all delays are of “no dead time” type.

Before/After protection for BC1 pulses in ± 40 ns is implemented in T0U, while “wider” Before/After protection (~2 μs) will be set in TRC as in Run 8.

Rejection of overlapped BC1 pulses is added (especially needed for trigger with FHCal).

SiMD is removed from the trigger logic.

Two thresholds for FD: “Low bias trigger” (far from Xe peak) and “Minimum bias trigger” (closer to Xe peak)

Time delay for BT is extended to allow coincidence with FHCal signal.

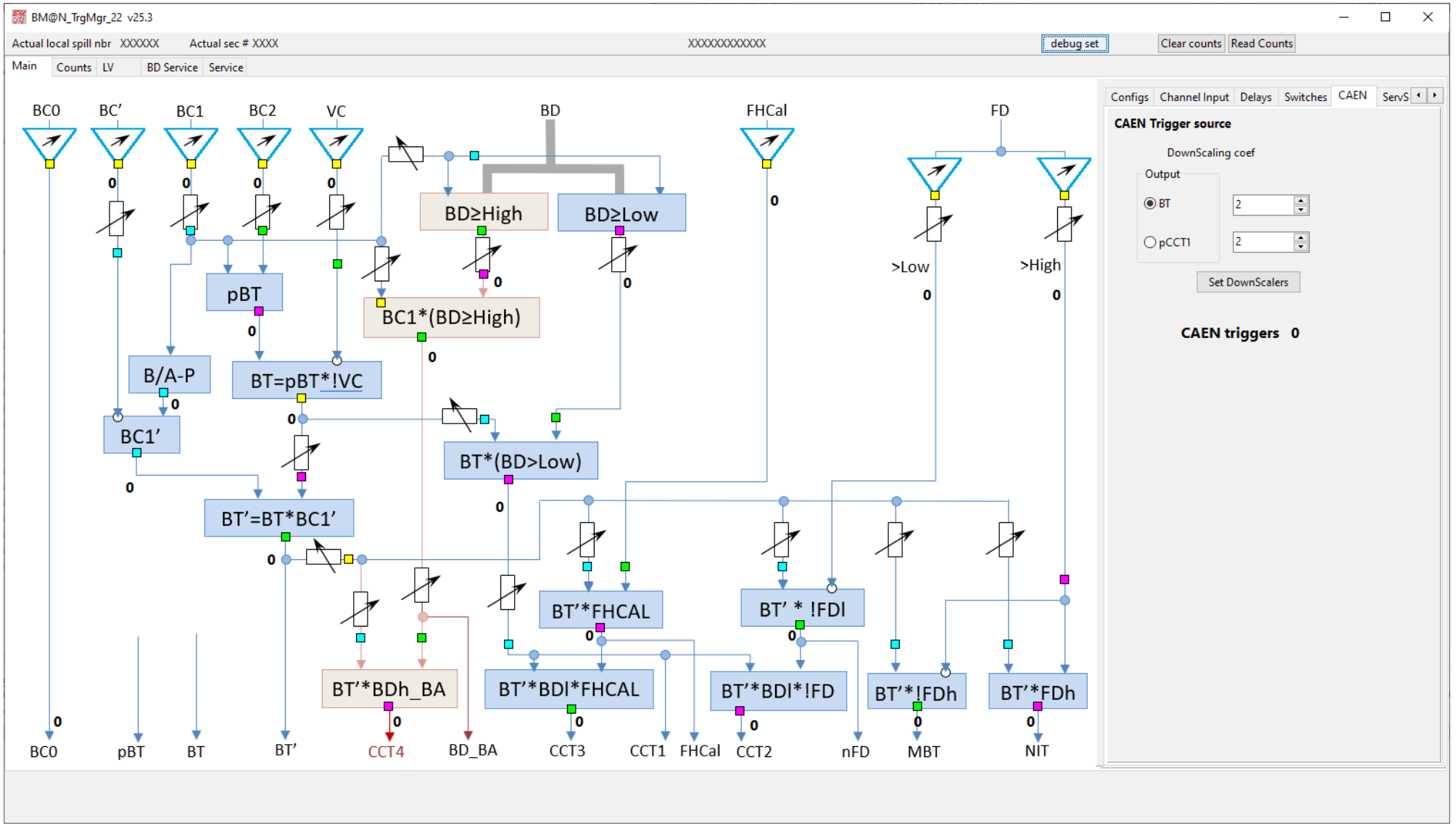
(BC1 • BD>High) coincidence is added in order to provide additional signal for Before/After protection.

Status: FPGA programming is done (P.Grigoriev), interface programming is done (S.Sergeev),
Testing with the external generator or/and laser system is planned starting next week
(S.Sedykh, N.Lashmanov)

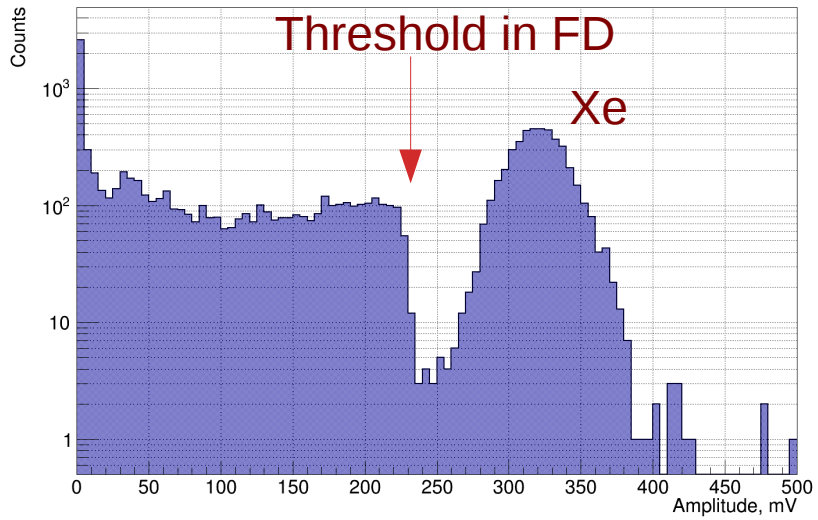
List of trigger signals sent from T0U to TRC

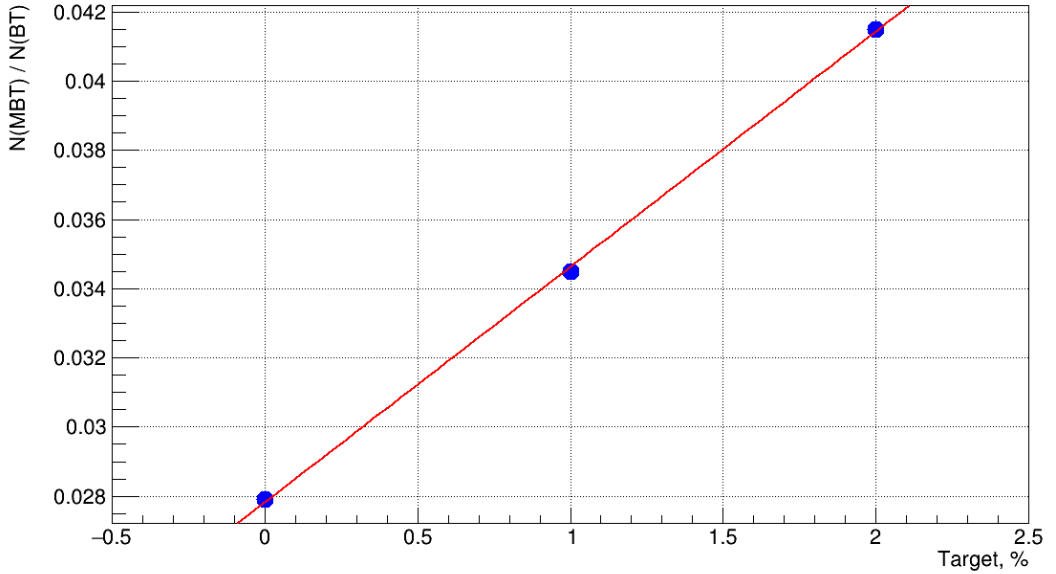
	Trigger	Logic	Scale factor	B/A	Comment
1	BC0	BC0			Stand alone trigger
2	pBT	BC1 • BC2			Same as in Run8
3	BT	pBT • !VC			Same as in Run8
4	BT’	BT • BC1’	$n \cdot 10^3$		BT with “single” BC1 (B/A protection ± 40 ns)
5	CCT1	BT • (BD > Low)	$n \cdot 10^2$		Same as in Run8
6	LowBias	BT’ • !(FD > Low)	$n \cdot 10^2$	+	Similar to Run8 MBT
7	CCT2	CCT1 • LowBias	1		Similar to Run8, but with single BC1
8	FHCal	FHCal > Thr.	$n \cdot 10^2$	-	FHCal Sum > some threshold
9	CCT3	CCT1 • FHCal	1	-	Similar to CCT2, but with FHCal instead of nFD
10	MinBias	BT’ • !(FD > High)	1	+	Similar to nFD and Run8, but with “softer” threshold in FD
11	NIT	BT’ • (FD > High)			Similar to Run8
12	BD_BA	BC1 • (BD > High)	$n \cdot 10^2$	+	Before/After protection based on BC1 and high count in BD
13	BDHigh	BT’ • BD_BA	1		Added to help CCT3 for most central events
14	BC1	BC1			Beam tuning and MSC

T0U Trigger Scheme



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





Two main sources of background in the MBT:

1) additional material between BC2 and FD adds ~1.9%
2) close pile-up withing ± 50 ns, adds ~0.8% (presumably due to dead time in the T0U elements)

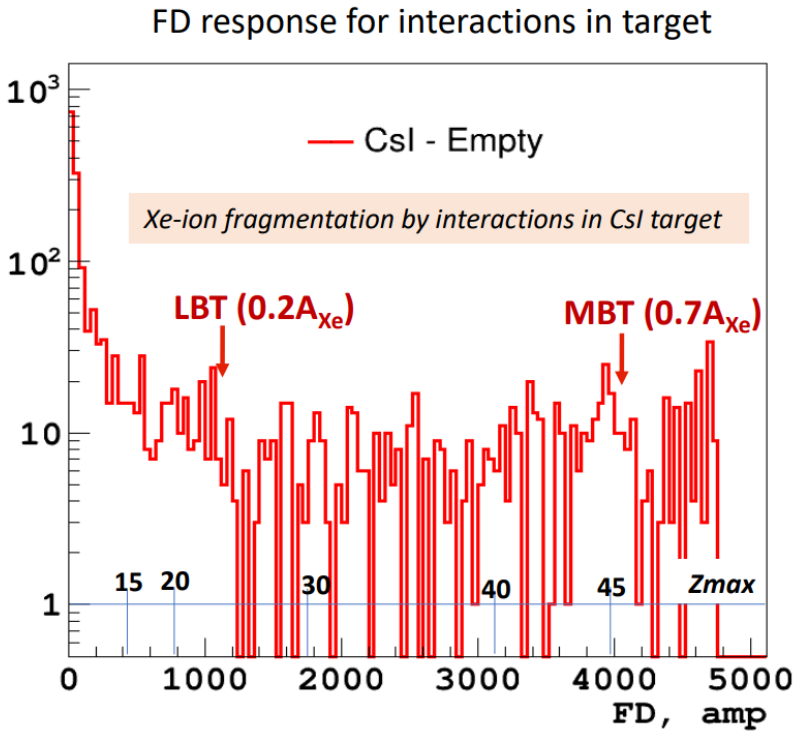
By suppressing events with close pile-up, and by placing FD radiator in vacuum and swapping BC2 with SiBT3, one might expect reduction in MBT background from 2.7% to 0.3%,

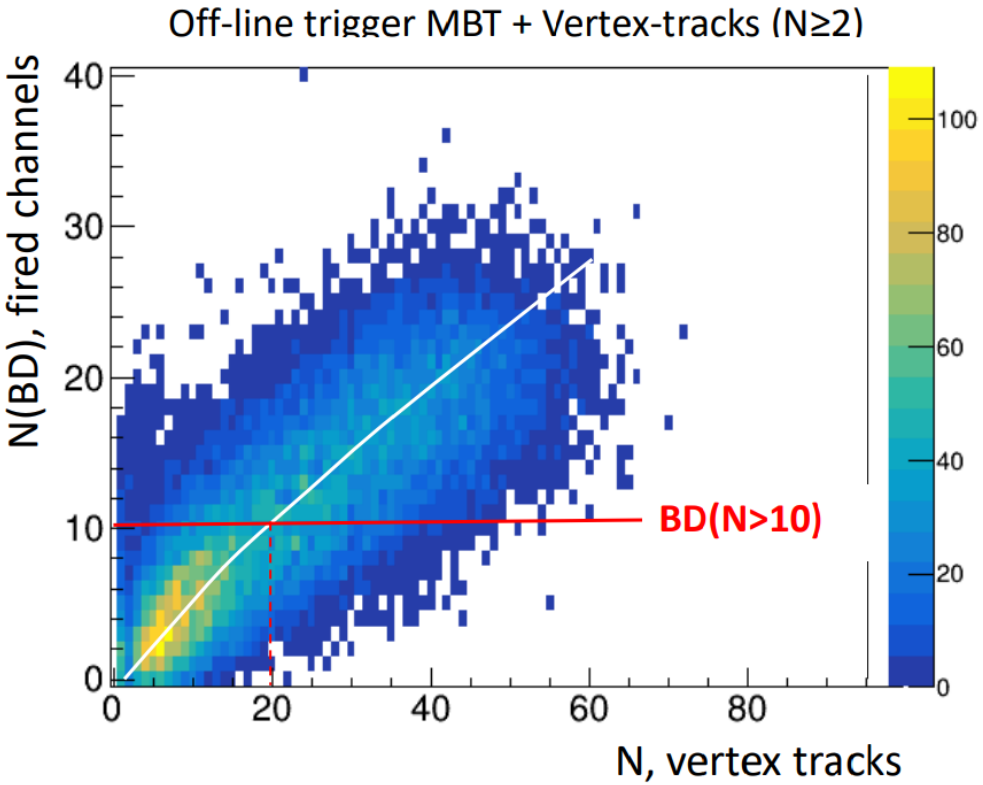
i.e. for 2% target and 70% centrality selected by MBT:

2023, actual: 1.4% signal + 2.8% background
2025, expected: 1.4% signal + 0.3% background

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

Choice of settings: thresholds, downscaling factors





Ongoing discussions involving M.Kapishin, V.Yurevich, and members of analysis groups.

Of particular interest is how far we can go towards setting MBT better than ~70% centrality selection.

Actual settings will depend on amplitude resolution of the new FD, and on background conditions for BD, FD, FHCal.

In Run 8 N(CCT1) / N(BT) at (BD ≥ 4) dropped from 0.2 to 0.1 when we switched from 3.8 GeV to 3.0 GeV Xe beam. This background from δ-electrons will be even lower for 2.5 GeV Xe.

Thank you for your attention