Analysis of beam conditions, trigger performance and proposal of advanced detector system of BM@N trigger

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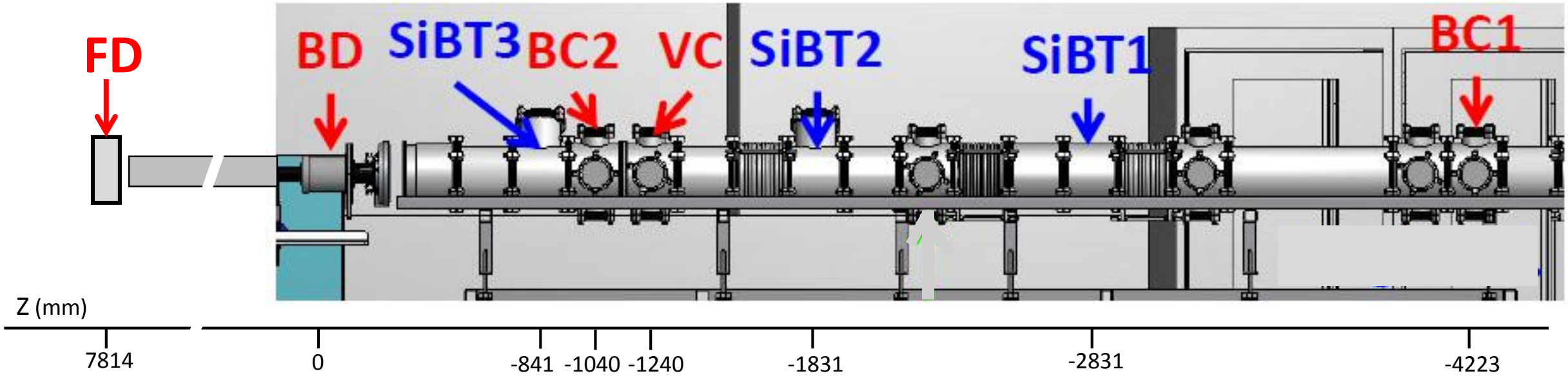
Beam line and trigger detectors 2022



Pileup problem at high beam intensity

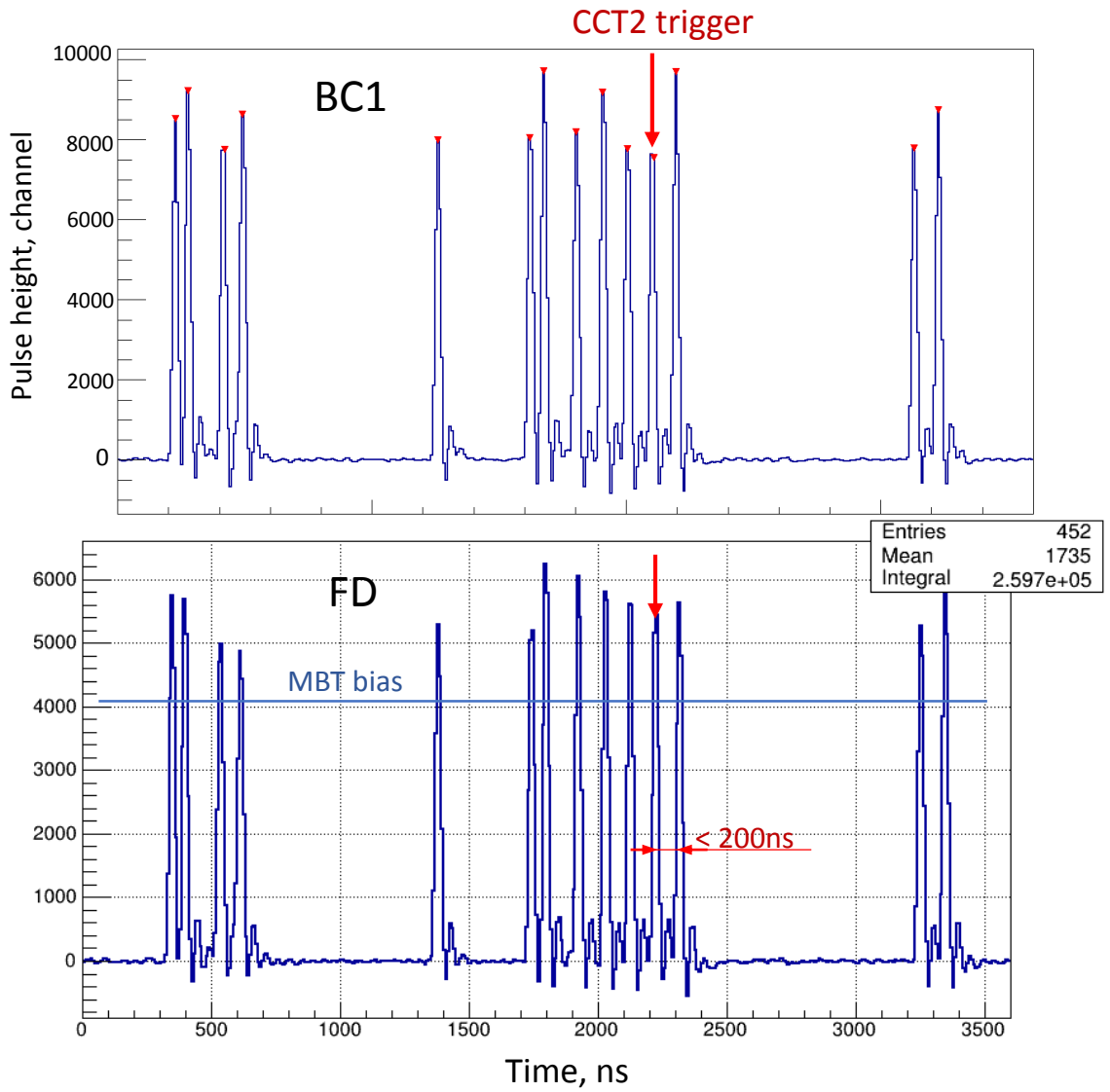
Current situation

An example of event where multiple BC1 pulses with small time intervals between them can provide the CCT2 trigger in despite of registration the same ions in FD.
The possible reason is the dead time of T0U module due to FD digital delay and pulse duration.

⇩ *Solution*

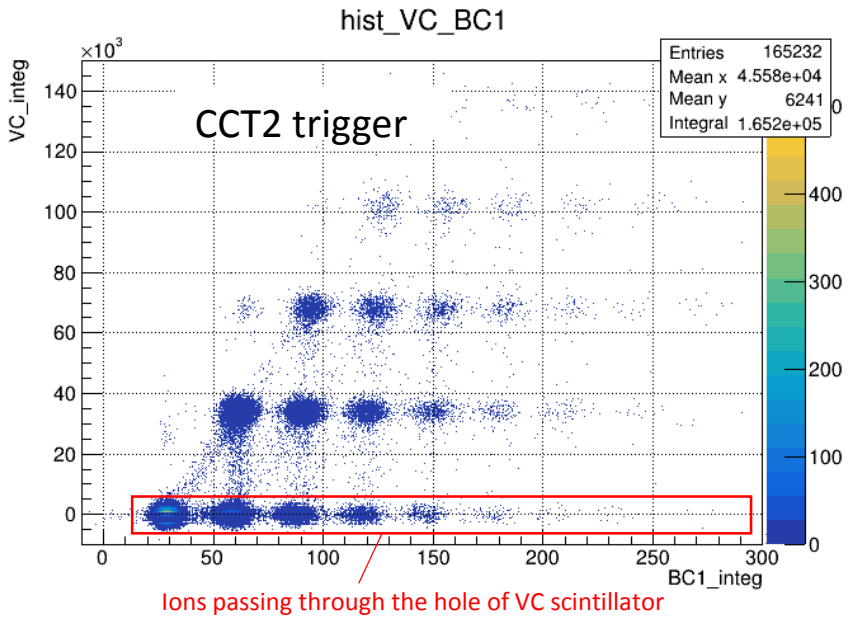
Apply offline B/A protection of 200 - 250 ns with BC1 pulse to exclude such problem and unstable operation of T0U.

New design of FD with small delay and with new advanced T0U delay will exclude this effect in future BM@N runs



Selection of events for analysis

Total charge of BC1 and VC pulses over a 3.6 μs interval

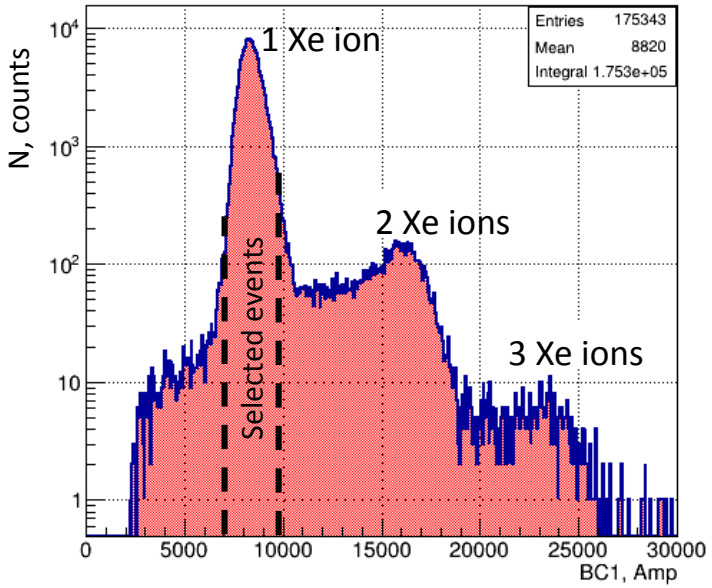


All these ions are far from the beam axis and can produce background interactions in beam line materials including the 3-mm scintillator of VC

⇩ *Solution*

To solve this problem we can use a condition "BC1 plus non FD" for offline B/A protection over 3.6 μs interval.

Time selection of 1 ion in BC1 into TDC time interval of 3.6 μs



Some Xe ions are very close in time and its pulses are overlapping. In this case the observed amplitude is higher of typical Xe amplitude.

⇩ *Solution*

To discriminate such events, one has to make a selection of events with BC1 amplitudes corresponding to single Xe-ion

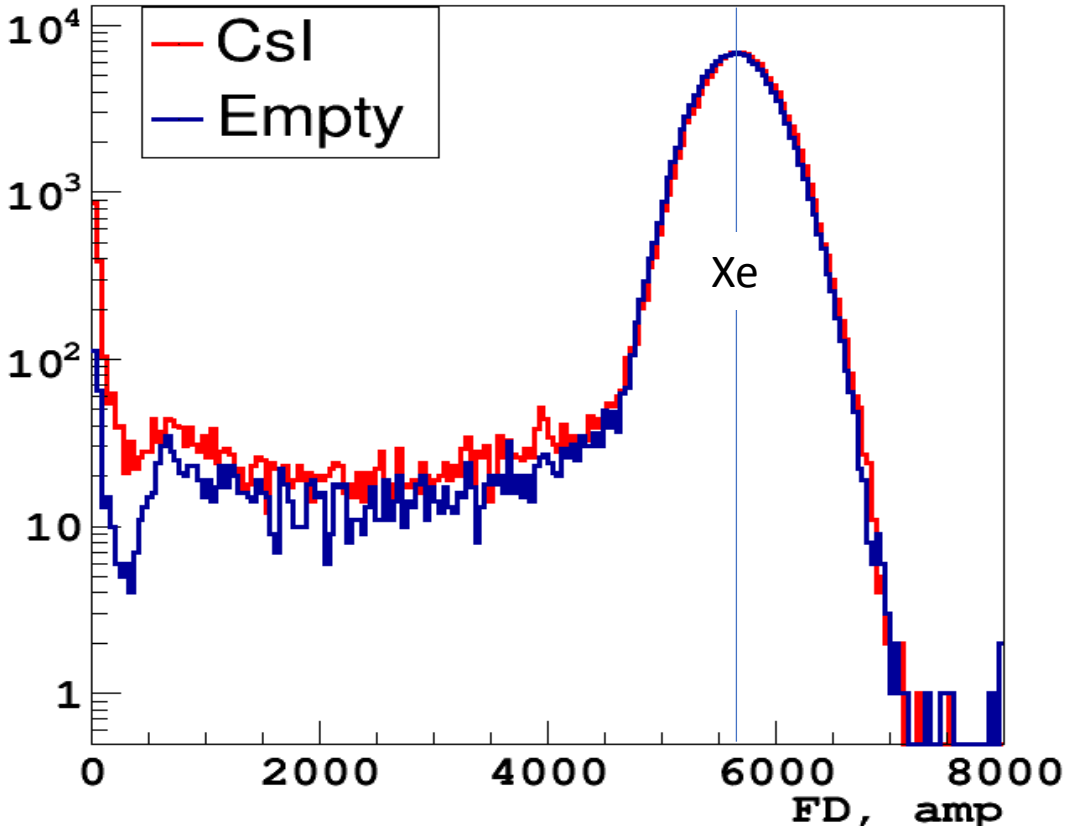
CCT2 trigger

Offline Conditions	N, events	N(track>1)
–	103726	79904 (77%)
BC1 B/A prot. ±250ns	66584 (64%)	58455 (56%)
BC1*$\overline{FD}$ B/A prot. 3.6 μs	65762 (63%)	

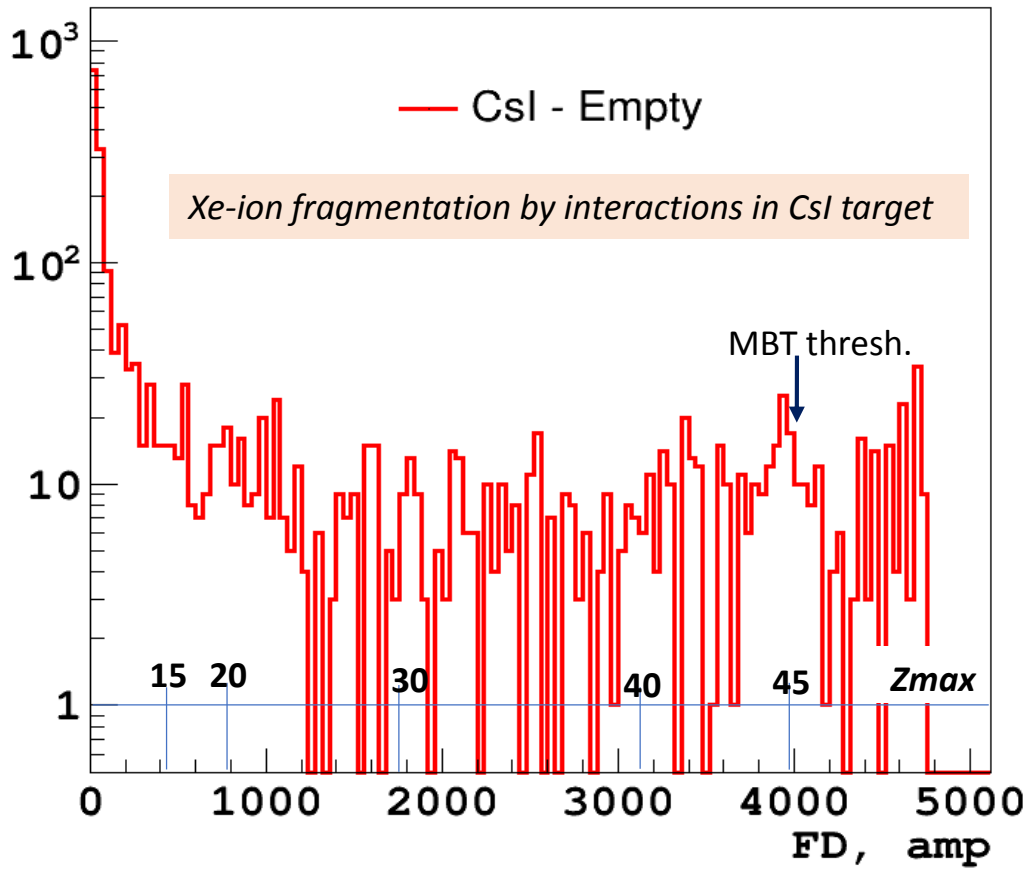
Inefficiency of Min Bias Trigger due to interactions in beam line materials

Fragment Detector (FD) response with BT trigger

FD response with/without target



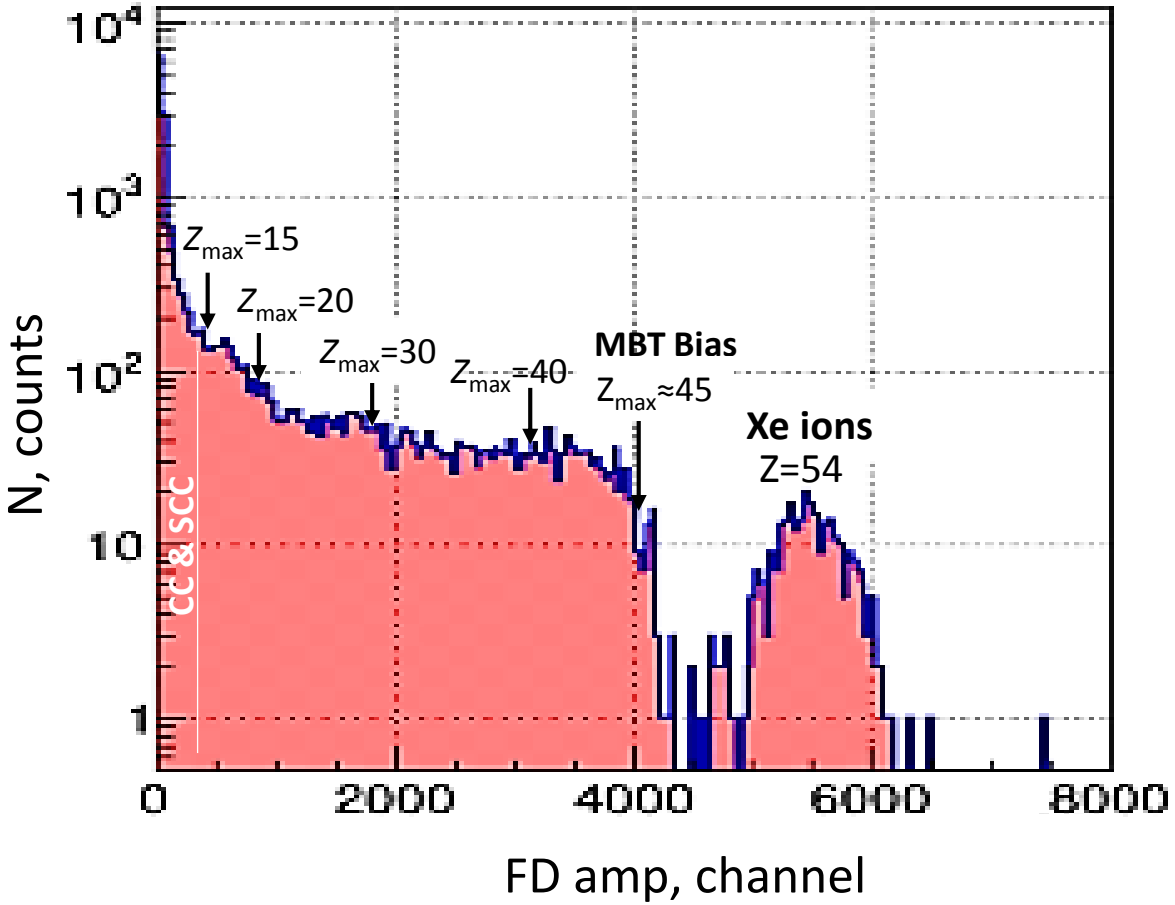
FD response for interactions in target

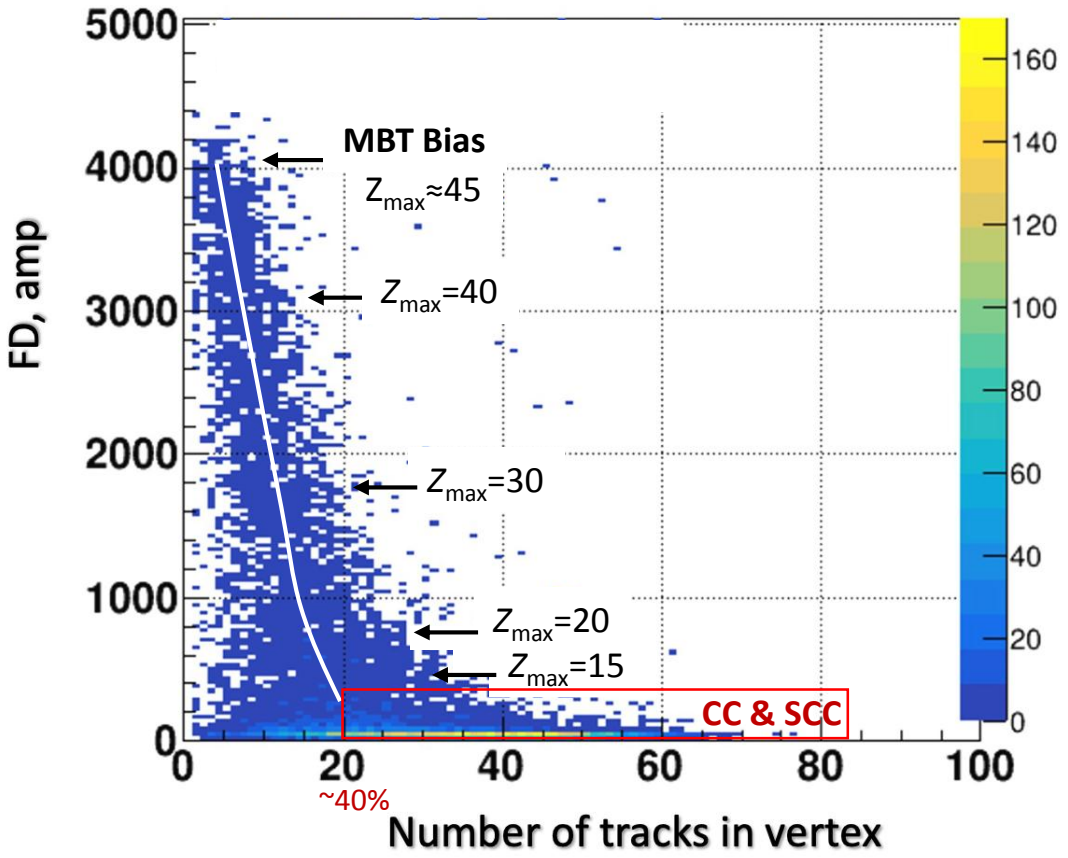


Fragment Detector (FD)

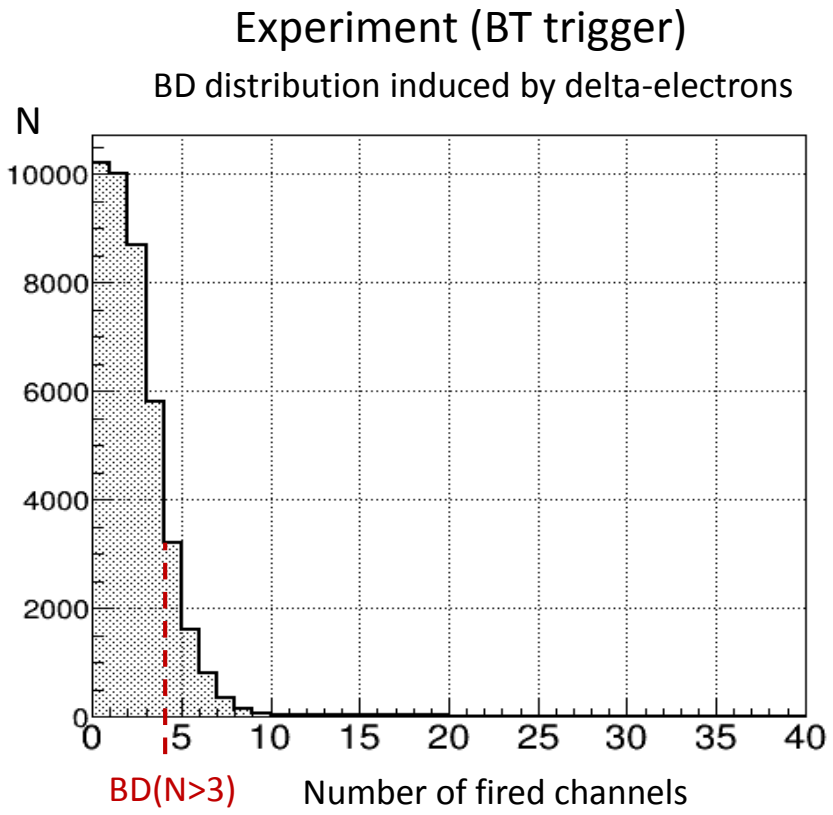
CCT2 trigger

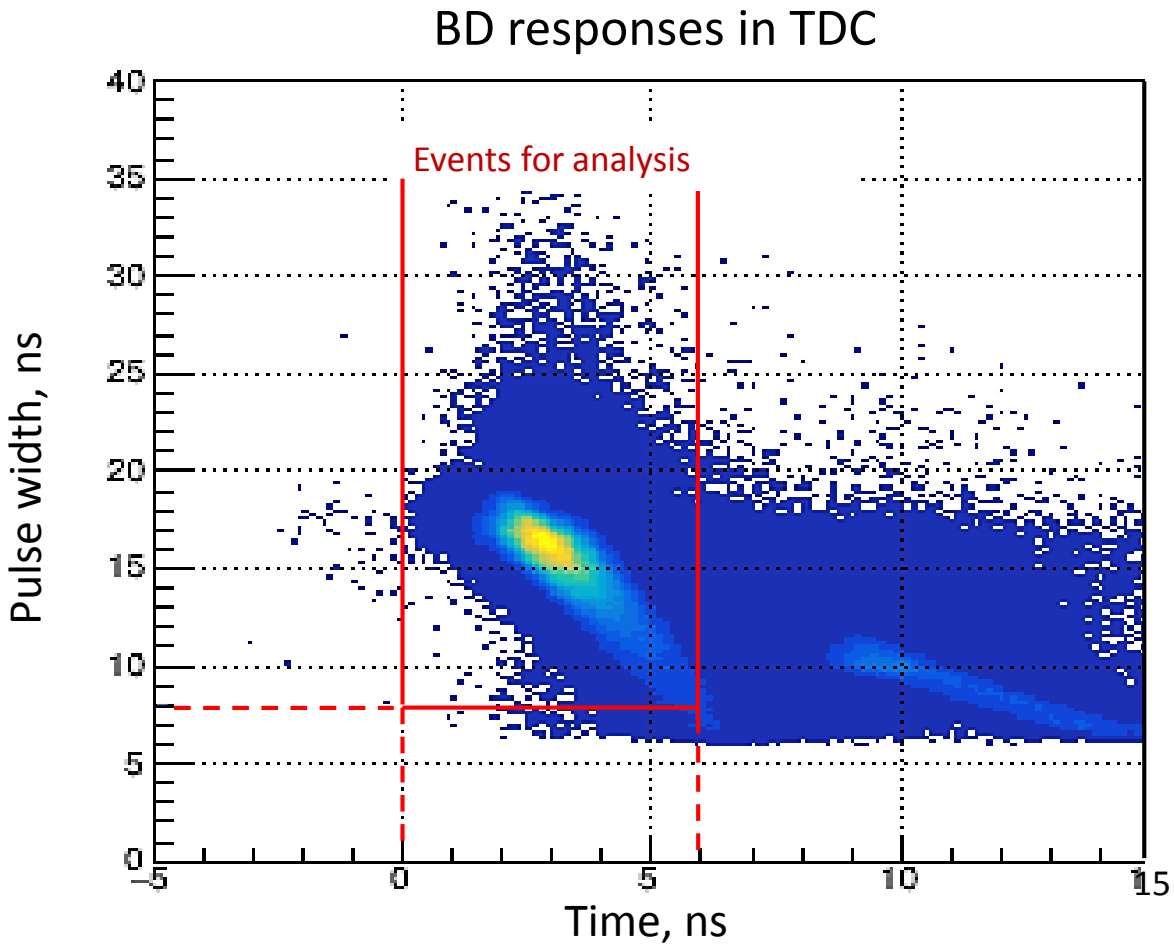
1 ion in BC1 into time interval of 3.6 μs





Inefficiency of CCT2 trigger with low BD threshold

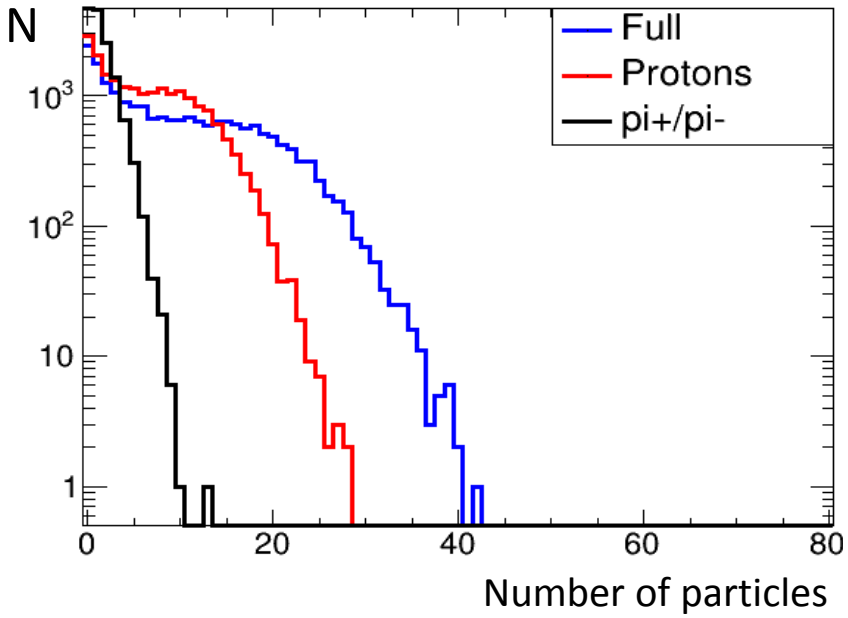




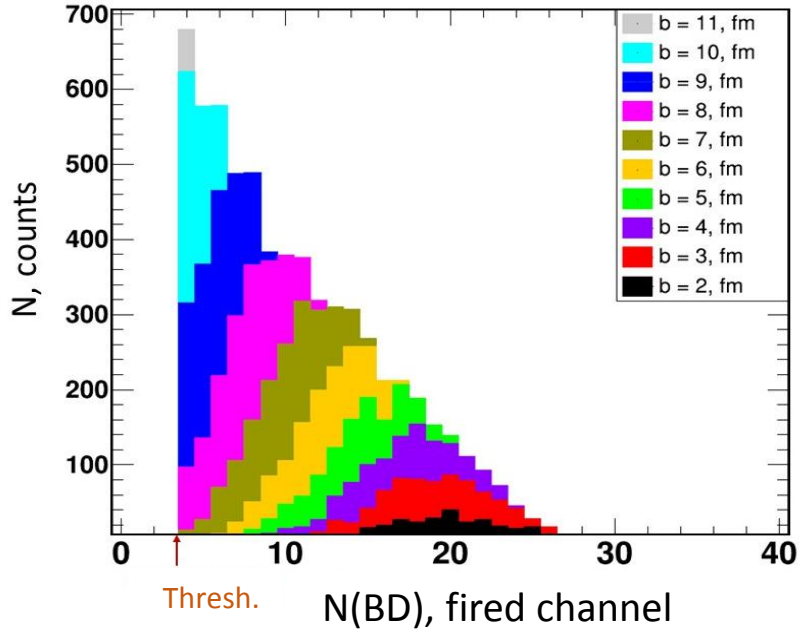
Low particle multiplicity into the BD acceptance in peripheral collisions

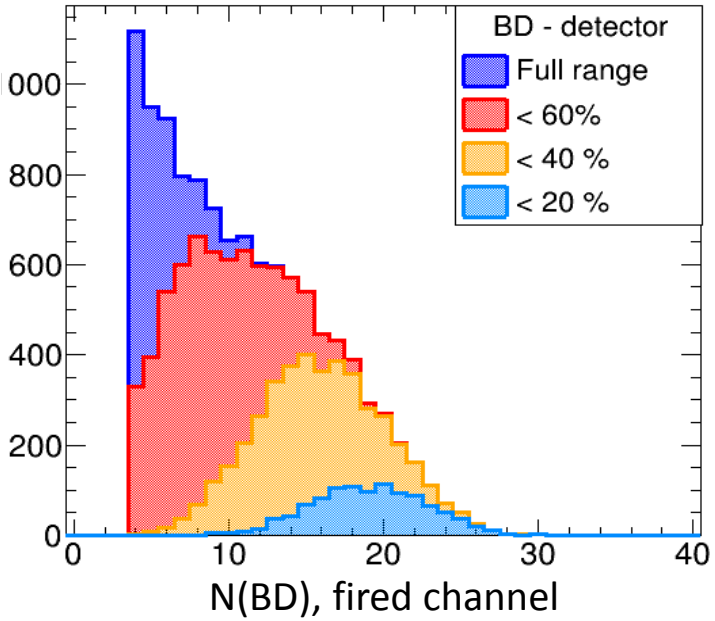
Simulation
DCM-QGSM-SMM + GEANT4

Charged particles detected in BD



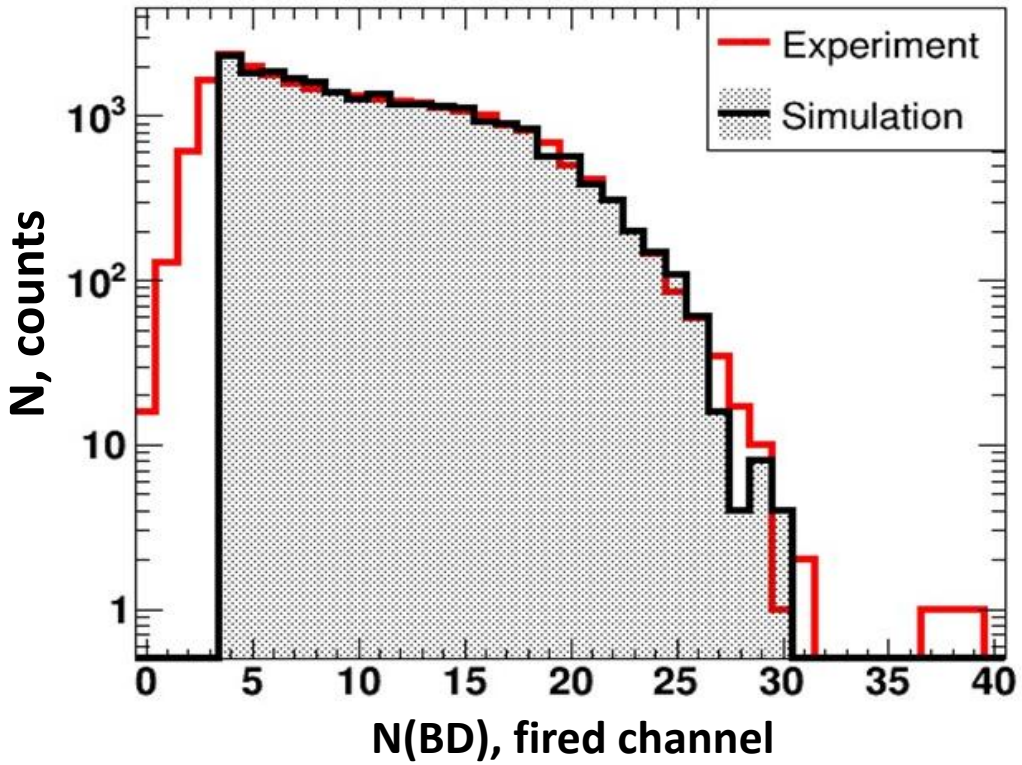
BD response for different centrality

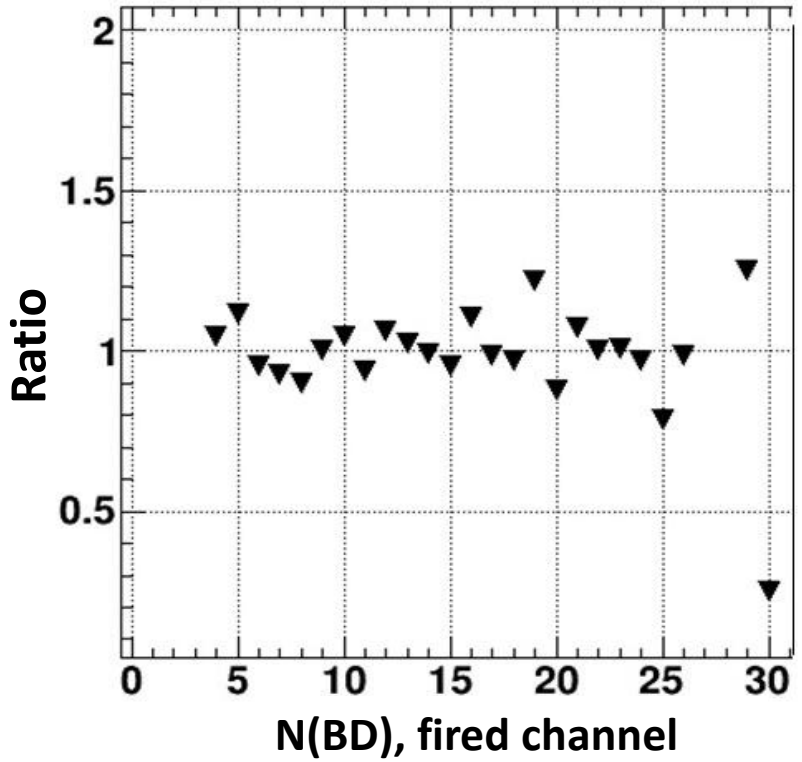




Study of Barrel Detector

Simulation
DCM-QGSM-SMM + GEANT4

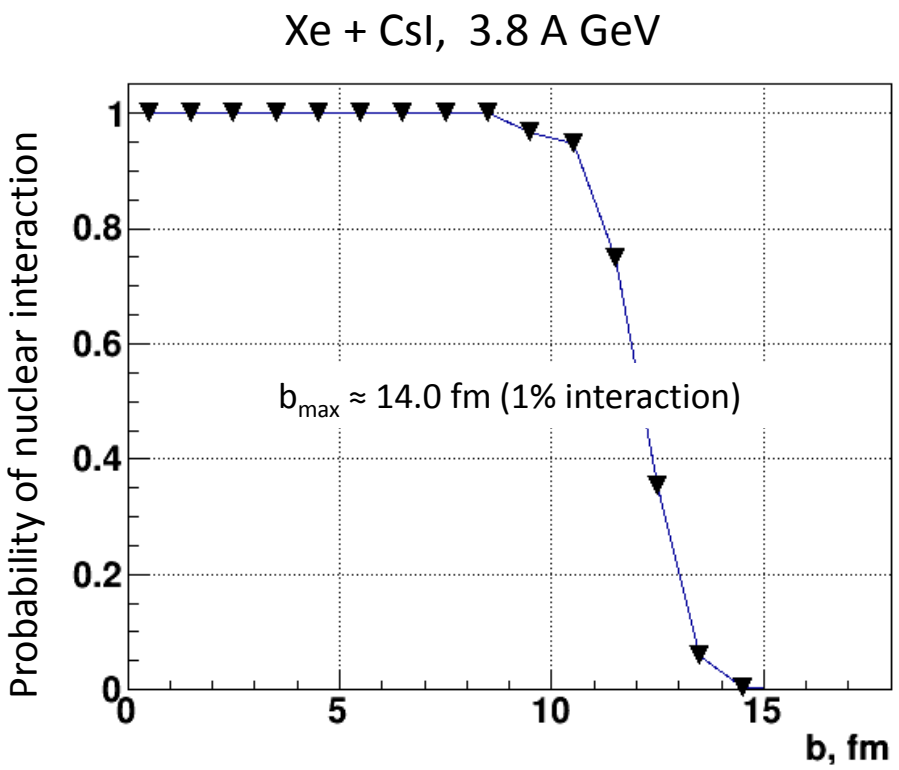


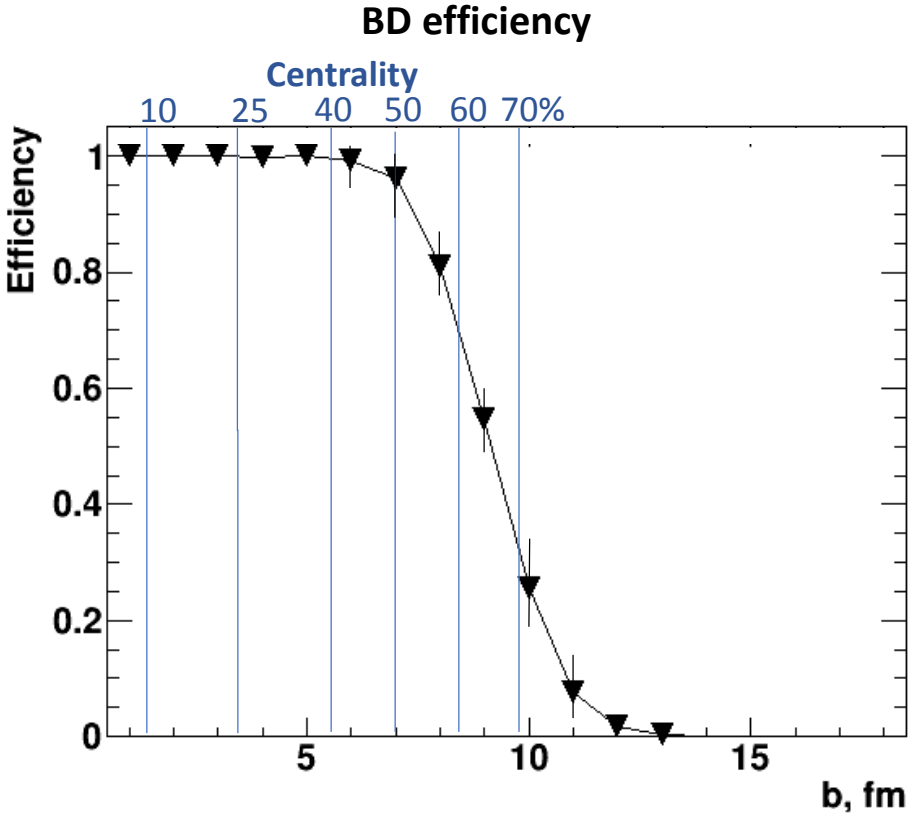


Study of Barrel Detector efficiency

Simulation
DCM-QGSM-SMM + GEANT4

BD efficiency depends on N_{ch} into the detector acceptance and it decreases in peripheral collisions with impact parameter *b*



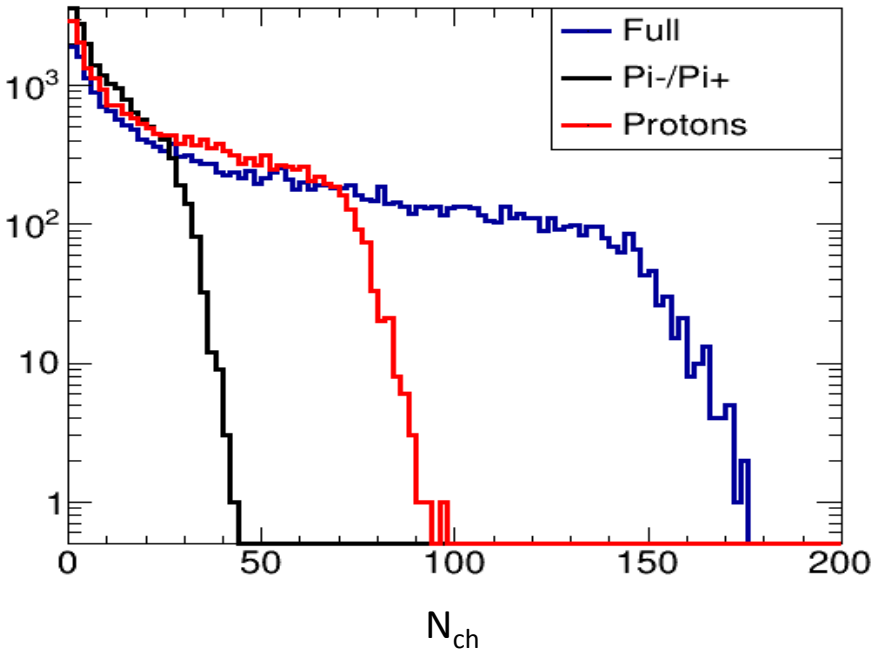


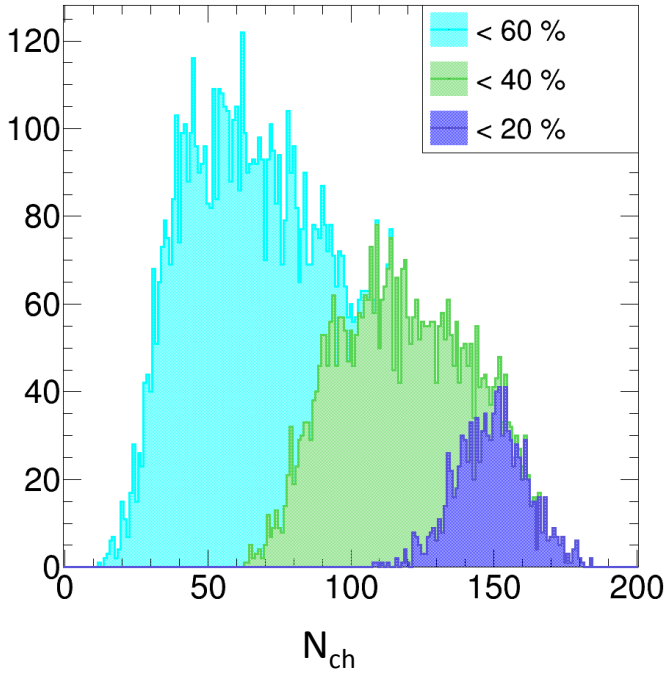
Poisson probability distribution for N(BD) well describes this dependence

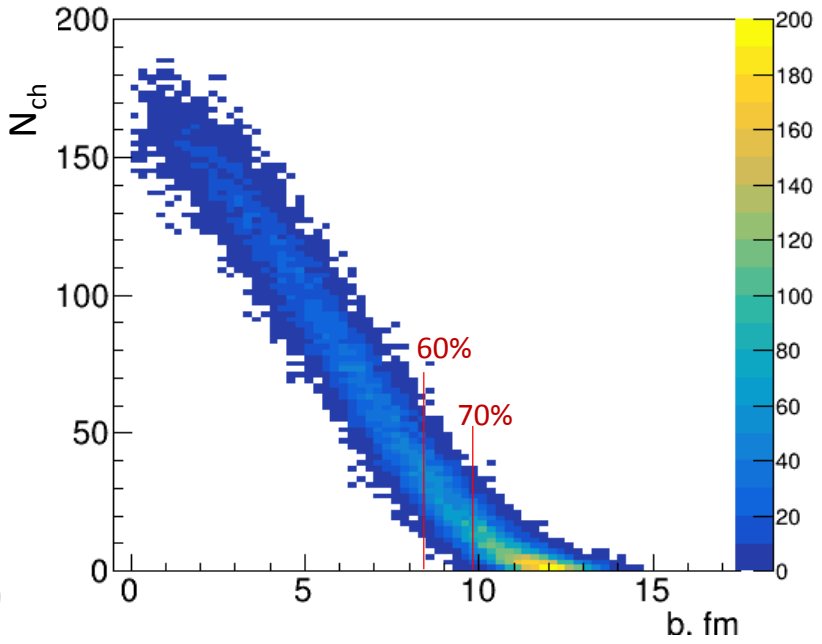
Simulation of charged particles in BM@N acceptance

Xe + CsI, 3.8 AGeV
p > 0.3 GeV/c
$3^o < \theta < 35^o$

Simulation
DCM-QGSM-SMM

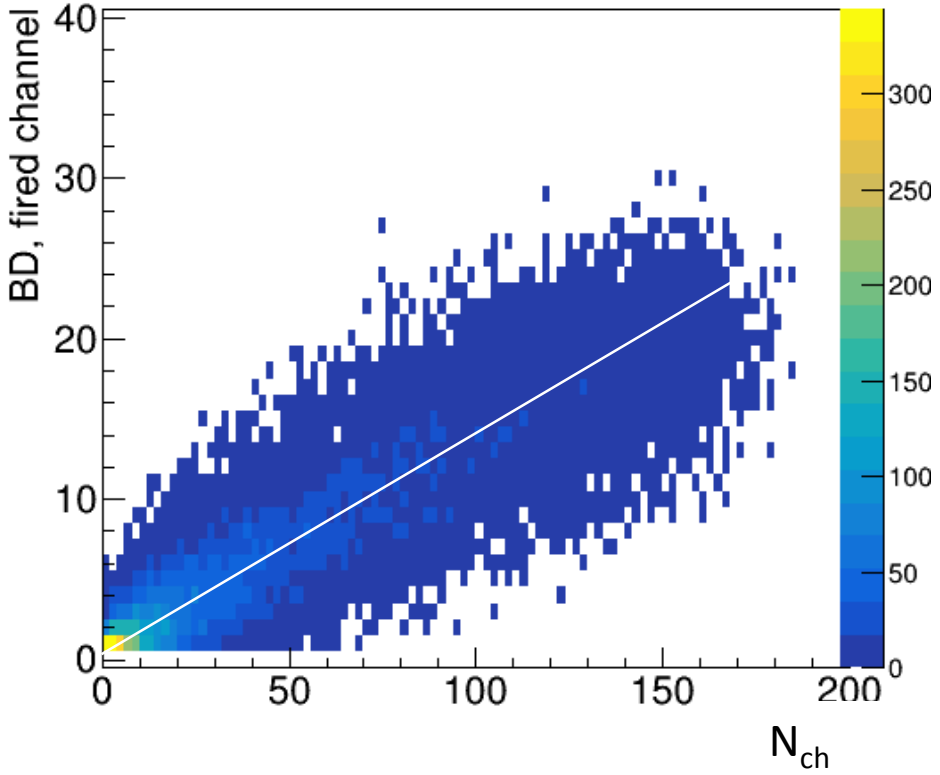


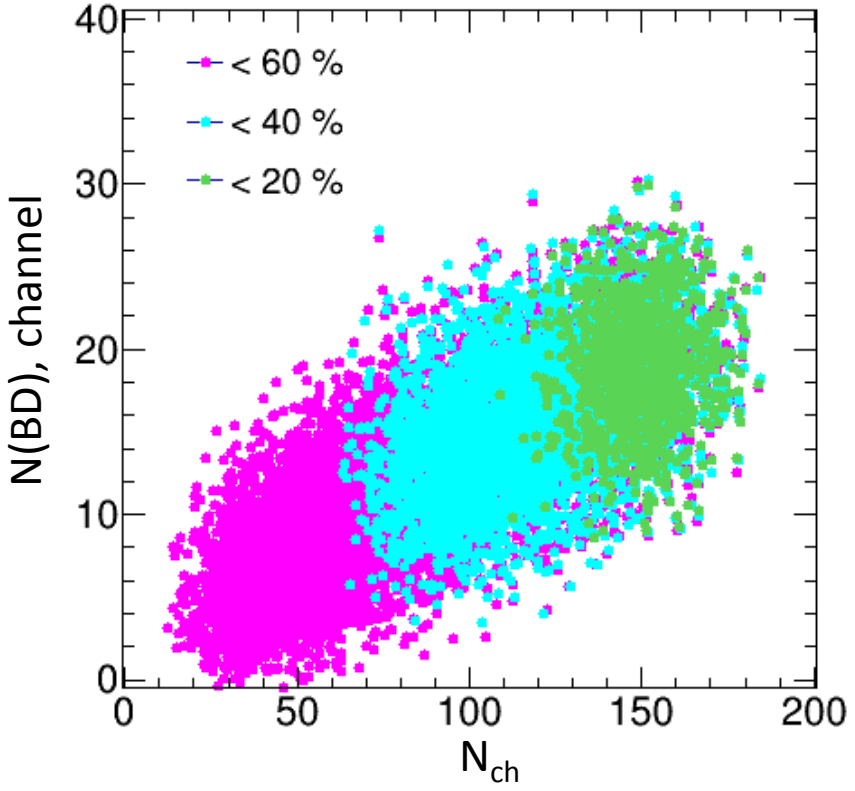




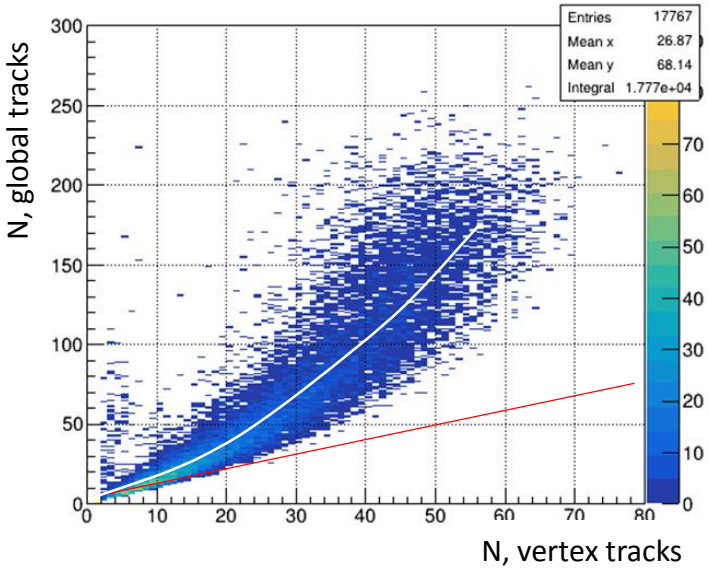
Correlation between BD response and track multiplicity

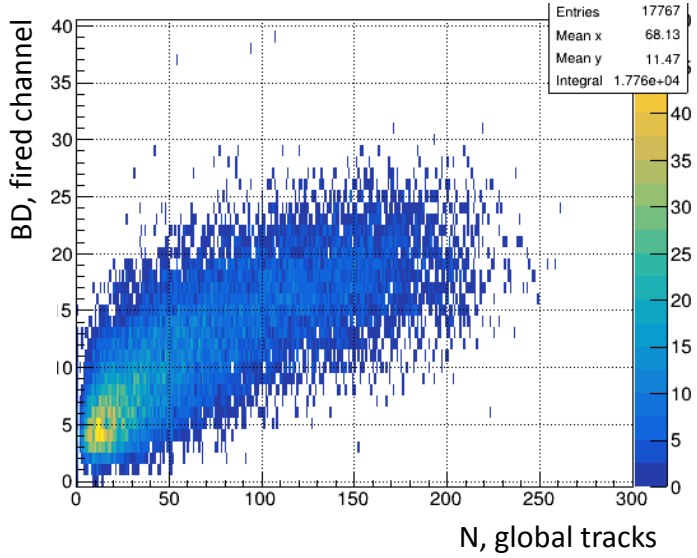
Simulation
DCM_QGSM_SMM + GEANT4





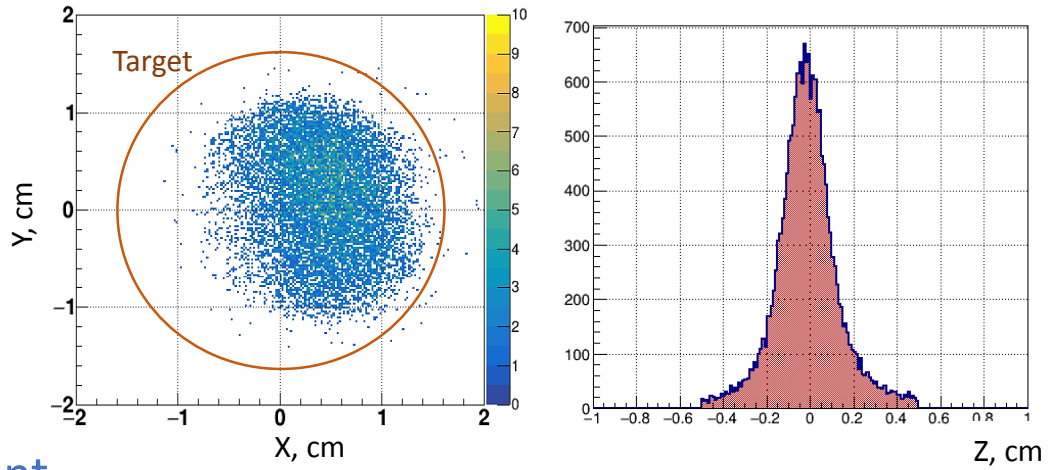
Tracks in Target position





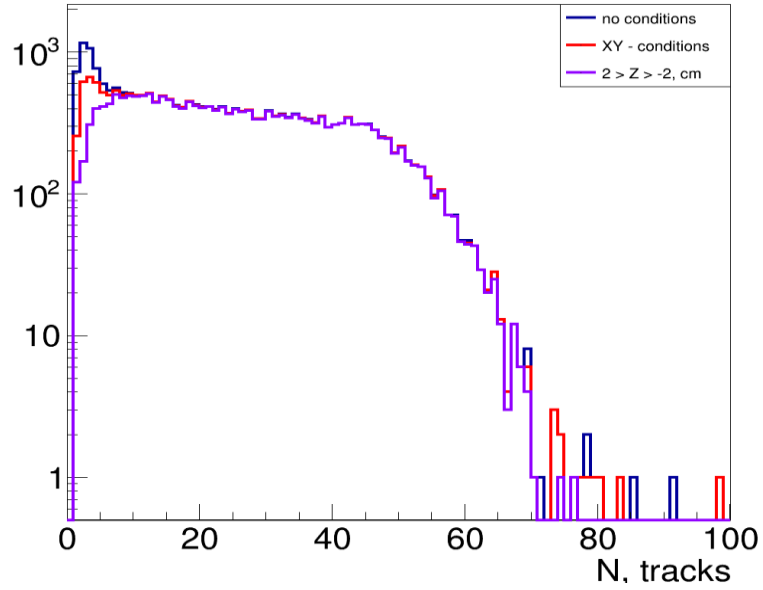
CCT2 trigger

Primary vertex tracks

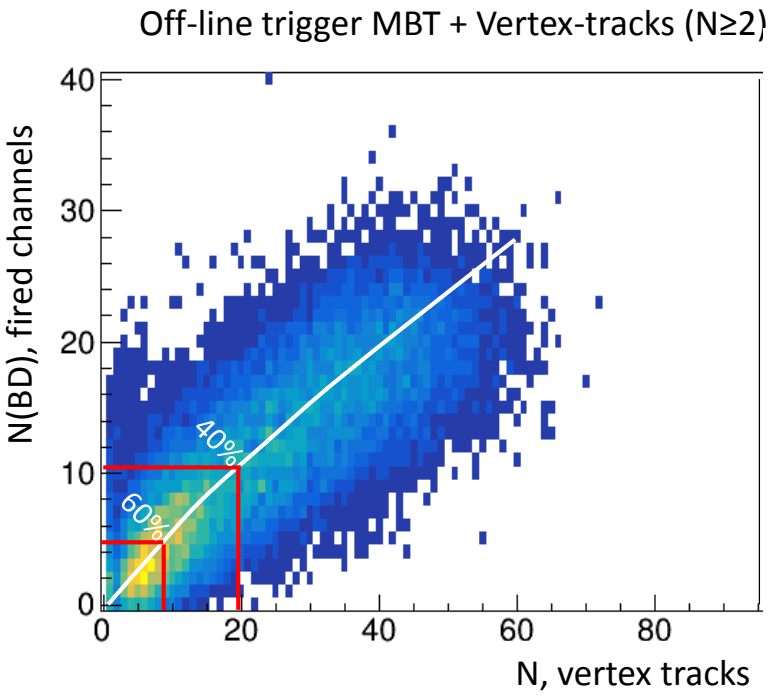


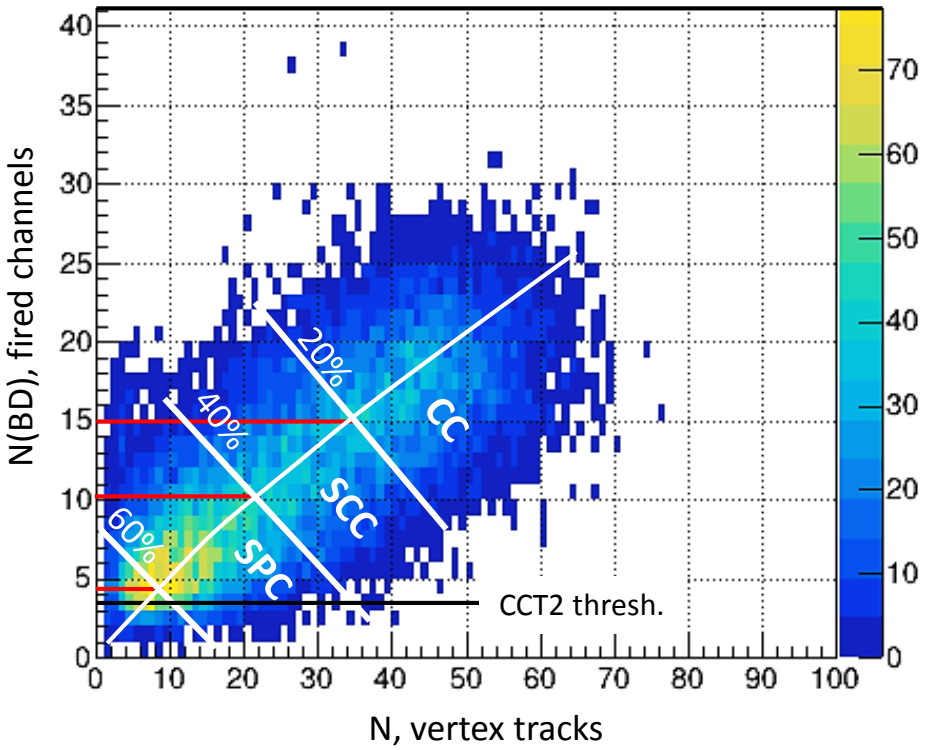
Experiment

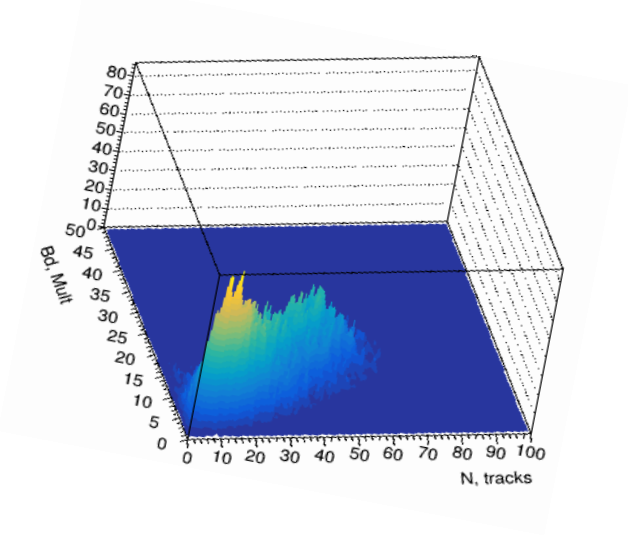
1 Xe-ion in BC1 in
3.6-μs TDC interval



Possible Approach for Event Selection on Centrality







SPC – Semi-Peripheral Collisions,
40 – 60% (5.6< b <8.4 fm)

SCC – Semi-Central Collisions
20 – 40% (2.8< b <5.6 fm)

CC – Central Collisions
0 – 20% (0< b <2.8 fm)

Proposal of Advanced Detector System of the BM@N Trigger

Modernization of the beam detectors

The goal is to reduce the contribution of background interactions to the trigger

- ✓ Replacement of VC scintillator with thinner one – 0.5 mm
- ✓ BC2 upgrade:

  Short distance from target ~500 – 600 mm

  New small size scintillator with diameter 25 mm

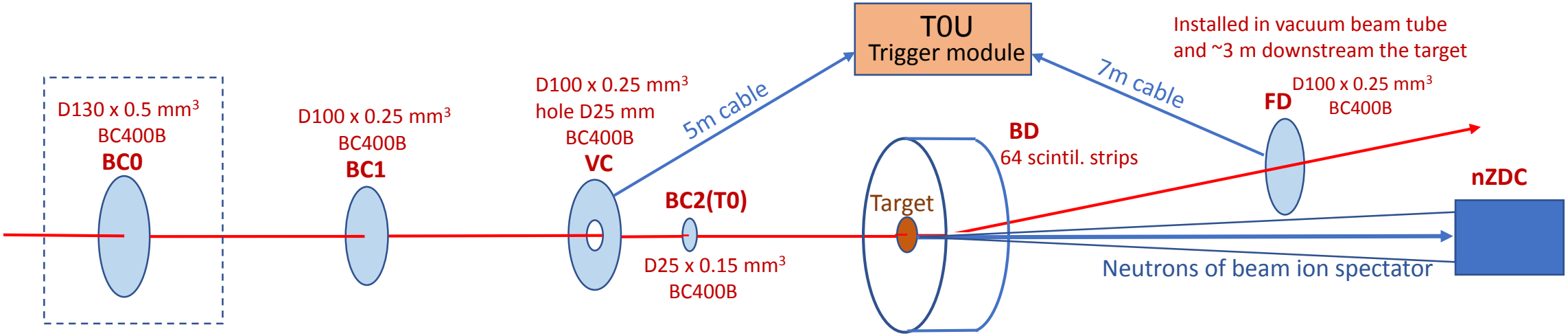
  Replacement of PMT with Hamamatsu R2490-07
- ✓ Put the FD scintillator inside vacuum tube (new FD design)
- ✓ Use round scintillators with new Al mylar light guides in all detectors

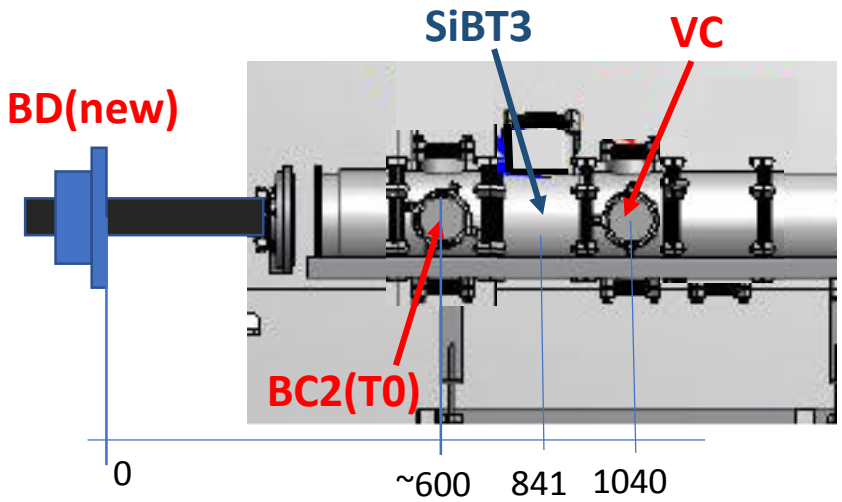
New detectors

The goal is to improve trigger performance for collisions of heavy nuclei

- ✓ New Barrel Detector with 64 scintillation strips
- ✓ New FD in vacuum beam tube closer to BM@N target
- ✓ New BC0 in the entrance to the BM@N zone
- ✓ Add to the trigger scheme nZDC (a part of FHCal) as the main detector for triggering peripheral collisions

Proposal of New Trigger Detector System





BM@N Triggers

BT = BC1 * BC2 * VC(*veto*)

MBT = **BT** * FD(*veto*)

CCT = **MBT** * BD($N>N_{th}$)

PCT = **BT** * nZDC(E > *15 GeV*)

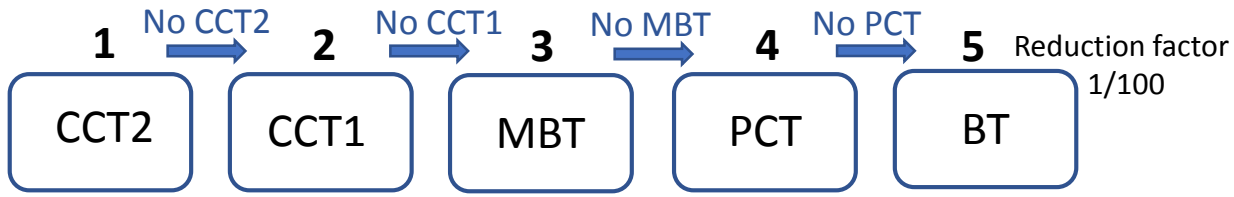
B/A protection (offline)

BC1 – interval ±50 ns

No ions

BC1 * FD(veto) – interval ±1.5 μs

No interactions



Trigger priority

Reduction of background interactions in beam line

1. Materials between Target and FD scintillator has to be removed.
   Solution – to make new design of the FD with thin scintillator into vacuum beam tube.
2. New position of the BC2 – between SiTr3 and Target (it will reduce by factor of 1.5 the MBT rate)

List of all materials(without target)
making background contribution to MBT trigger

Now

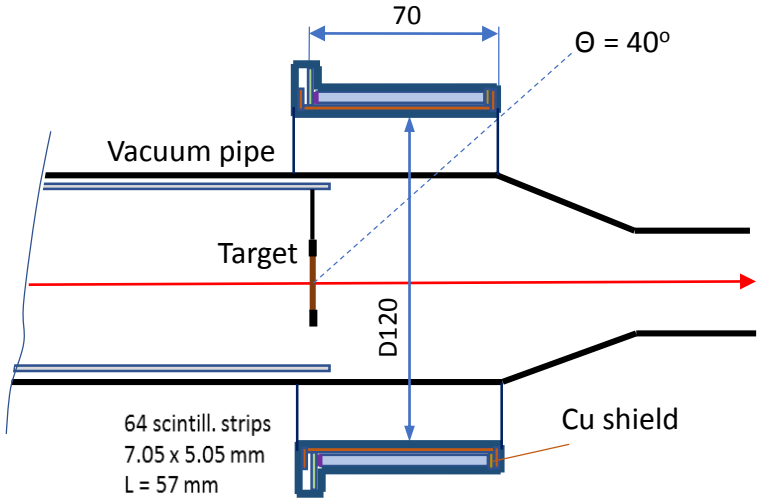
Material	Thickness (mm)	Probability of interaction (%)
Scintillator BC2	~0.03	0.06
Mylar BC2	0.0125	0.025
Si Tr 3	0.175	0.3
Ti window	0.08	0.17
Air	150	0.21
Paper+Mylar FD	0.2 + 0.05	0.2
Scintillator FD	0.8	1.5
Sum		**2.47%**

New

Material	Thickness (mm)	Probability of interaction (%)
Si Tr 3	0.175	0.3
Scintillator BC2	~0.03	0.06
Mylar BC2	0.0125	0.025
Mylar FD	0.025	0.05
Scintillator FD	0.25	0.5
Sum		**0.635%**

4 times less !!

New Barrel Detector



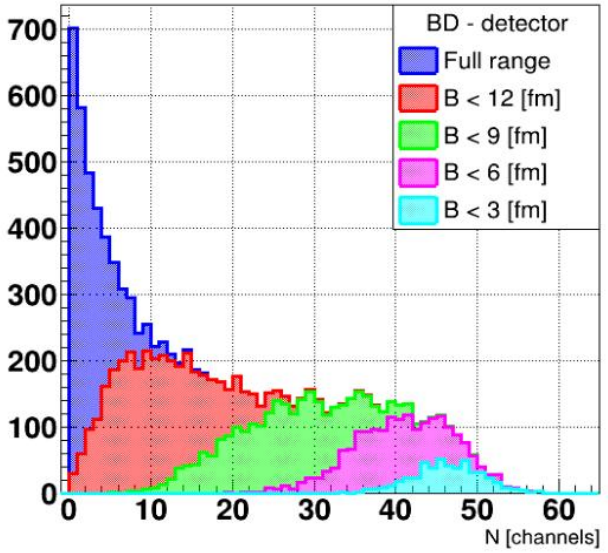
Study of new BD performance

N. Lashmanov

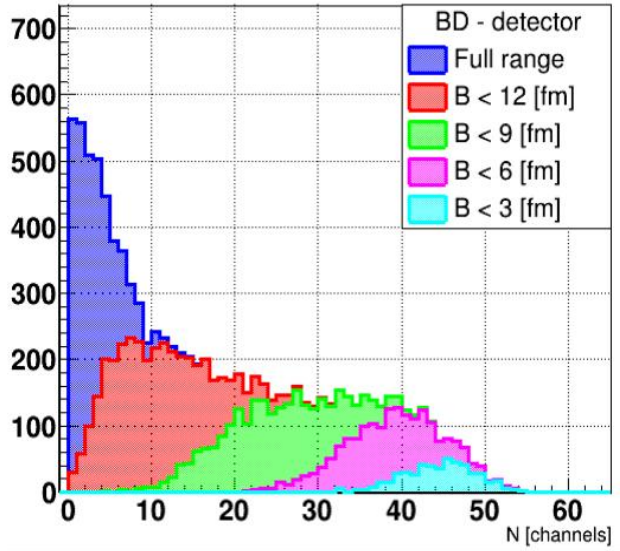
DCM-QGSM-SMM + GEANT4 simulation

Au + Au, 3.8 *A* GeV

without delta-electrons



with delta-electrons

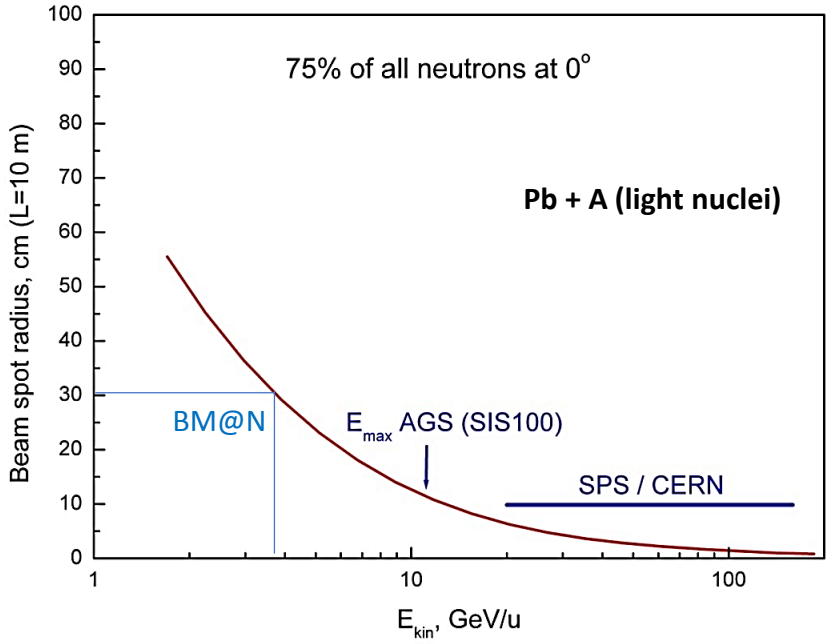


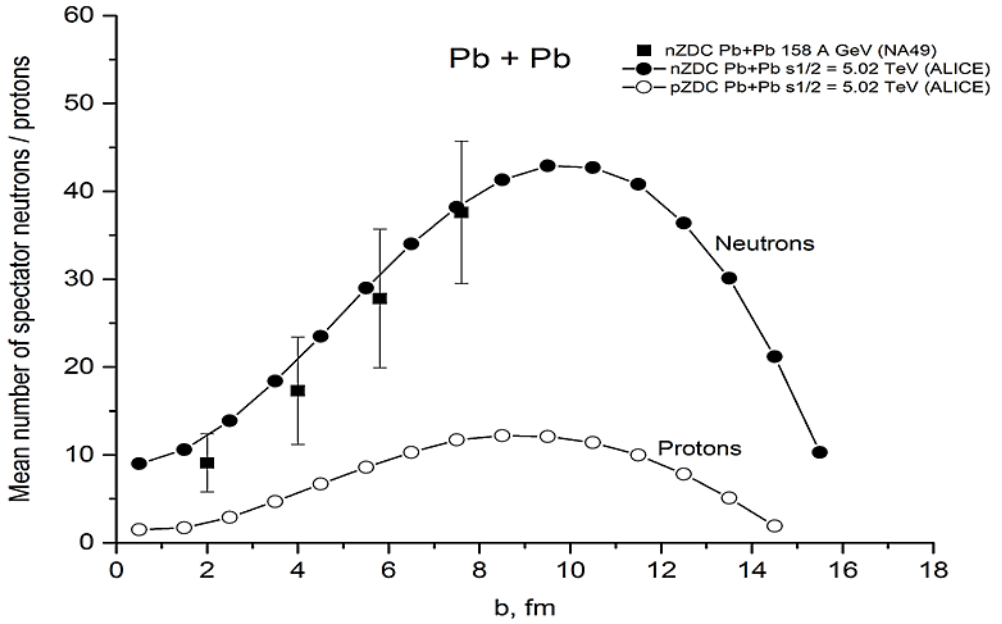
Detector with electronics will be ready for installation in the BM@N setup in September 2025

nZDC in Trigger

For study AA- collisions in peripheral region will be useful to add fast response from nZDC (a part of FHCal modules) to the trigger. For Bi +Bi peripheral collisions the expected neutron multiplicity in nZDC acceptance is <Mn> > 5 neutrons with > 20 GeV of total kinetic energy.

Note: This value is higher of the number of neutrons producing in EM- collisions.





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Conclusion

Current Analysis of Xe + CsI data

CCT2 interaction trigger

1. 2- level B/A protection:

   B/A protection ± 200 ns for beam ions with BC1 pulses

   B/A protection ± 1.5 μs for interactions between BC1 and FD (BC1 * FDveto)

2. Selection of events with vertex in the target position
3. Analysis of BD response in the first 6-ns interval
4. The trigger efficiency as a function of centrality was estimated using MC simulation of BD response
5. The plot N(vertex tracks) – N(BD) might be used for estimation of centrality
6. Important task – to study background in Si and GEM track detectors with BT trigger in dependence of the number of ions in spill passing the BM@N area without interaction (with and without target)

Conclusion

Trigger detector upgrade for future runs

1. Change of the BC2 position – its scintillator must be the last material in front of the target
2. Change of size of the BC2 scintillator (25 mm in diam.) with new PMTs
3. New FD detector in vacuum beam tube, new position provides smaller delay
4. New BD detector with higher granularity (64 scintillation strips), improved mechanics and better shielding from delta-electrons
5. Decreasing the VC scintillator thickness to 0.25 mm
6. A new beam counter BC0 has to be installed in entrance to the BM@N zone
7. nZDC (a part of FHCal) has to be included in trigger scheme for triggering peripheral collisions

Electronics upgrade

1. Upgrade T0U – for pulses with long delay to use a pipe-line regime and implement a new scheme of pulse processing
2. Development, production and testing electronics for new Barrel Detector