Trigger efficiency, luminosity and fluxes in argon run

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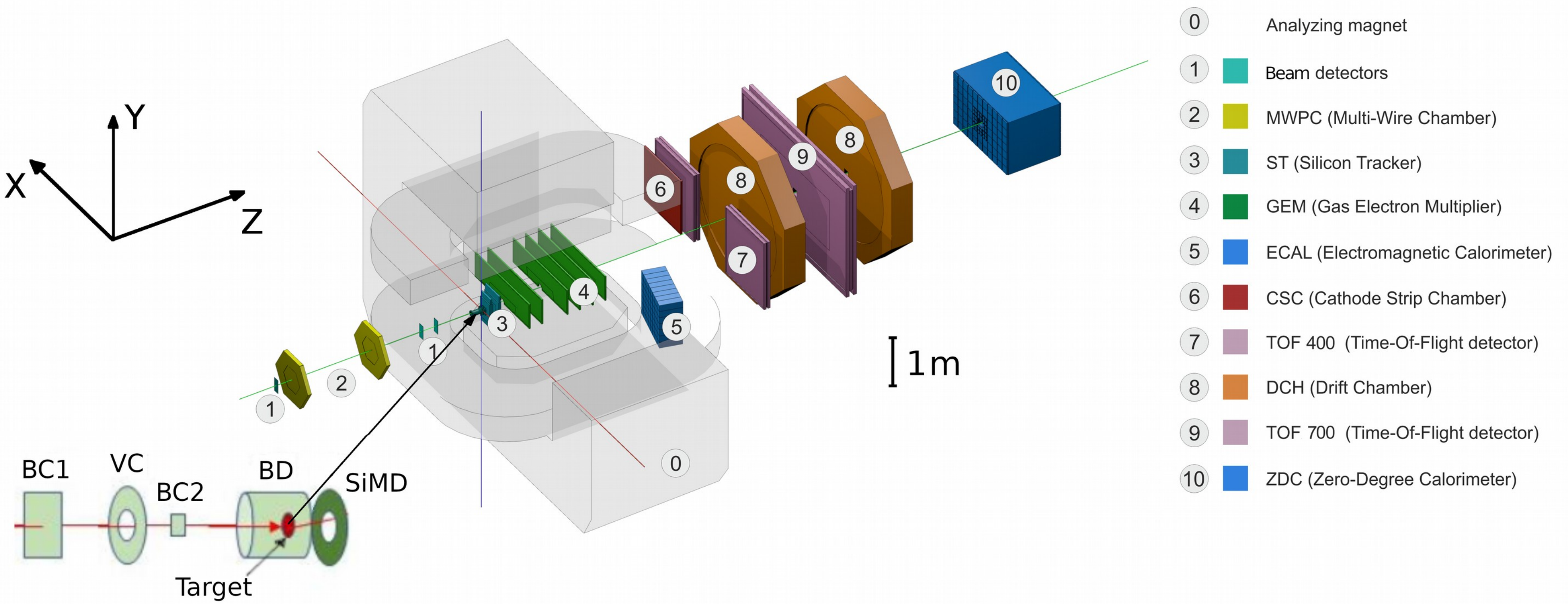
Seminar on Trigger Efficiency, Luminosity and Fluxes
08.02.2023

Outline

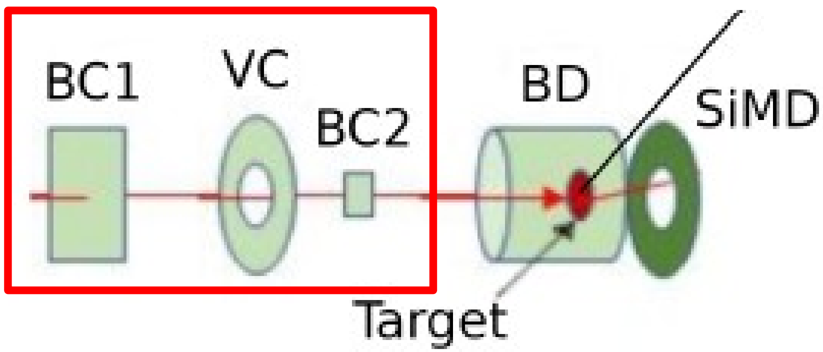
1. Luminosity and fluxes
2. Trigger efficiency

BM@N set-up in Ar run



Detectors used in the analysis: Beam detectors (1), Multiplicity Detectors (BD and SiMD), ST (3), GEM (4), CSC (6), TOF 400 (7), DCH (8), TOF 700 (9).

Luminosity and fluxes

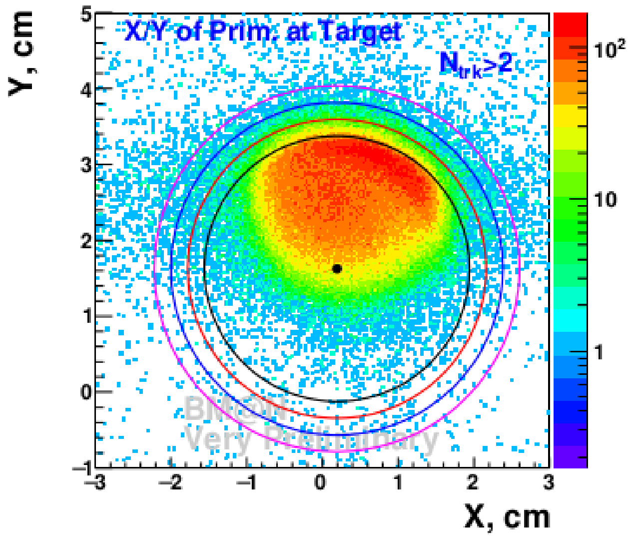


$L = N_b \cdot N_A \cdot \rho \cdot l / A \cdot corr = N_b \cdot coeff$

- ✓ N_b – integrated ion flux through the target
- ✓ N_A – Avogadro number
- ✓ $\rho \cdot l$ – target thickness (g/cm²)
- ✓ A – target atomic weight
- ✓ corr = 0.865±0.02 – correction (see below)
- ✓ coeff – transformation coefficient

- ✓ To count the beam flux (N_b) we use BT
- ✓ $BT = BC1 \otimes \overline{VC} \otimes BC2$
- ✓ Beam halo, pile-up suppression within the readout time window, number of signals in the start detector: BC1=1, number of signals in the beam counter: BC2=1, number of signals in the veto counter around the beam: VC=0;
- ✓ Beam flux for active (not busy) time of DAQ was integrated spill by spill for each target (C, Al, Cu, Sn, Pb)

Luminosity and fluxes



Run-7, X-Y of the primary vertices (PV) within 3−σlimits around the target (Fig.6 taken from lumi.pdf). Target (black circle), target + 1σ X-Y PV uncertainty (red circle), target + 2σ X-Y PV uncertainty (blue circle), target + 3σ X-Y PV uncertainty (magenta circle)

- ✓ 13.5% of the beam is missed the target by the edge of the target due to shifted beam position.
- ✓ The systematic uncertainty for this measurement do not exceed 2% (the number of PV outside the magenta circle divided by the number of PV inside the magenta circle).
- ✓ The probability of passing 2 ions in the same trigger time window is about 0.7%.

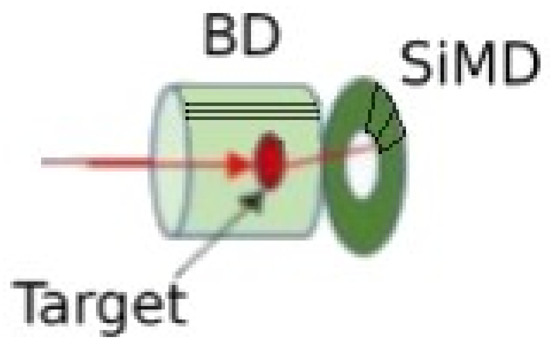
Luminosity and fluxes

Number of triggered events, transformation coefficients, beam fluxes and integrated luminosities collected for the argon beam of 3.2A GeV (*ToF-400* (*ToF-700*)).

Interactions (target thickness)	**Number of triggers / 10^6**	**coeff**	**Integrated beam flux / 10^7**	**Integrated luminosity / 10^{30} cm^{-2}**
Ar+C (2mm)	9.5 (9.4)	0.2256	9.1 (8.7)	2.06 (1.97)
Ar+Al (3.33mm)	24.1 (21.6)	0.2006	11.5 (10.2)	2.30 (2.05)
Ar+Cu (1.67mm)	24.5 (21.0)	0.1411	12.7 (11.3)	1.79 (1.60)
Ar+Sn (2.57mm)	23.8 (19.0)	0.0954	11.6 (9.5)	1.11 (0.91)
Ar+Pb (2.5mm)	11.7 (9.7)	0.0824	6.1 (4.9)	0.50 (0.40)

Trigger efficiency

- ✓ BD: 40 strips
- ✓ SiMD: 60 azimuthal segmets



The efficiency to get a trigger signal based on multiplicities of fired channels in the BD (SiMD) detectors ε_{trig} was calculated for events with reconstructed π^+ and K^+ mesons using experimental event samples recorded with an independent trigger based on the SiMD (BD) detectors:

$$\varepsilon_{trig}(BD \geq m) = N(BD \geq m, SiMD \geq n)/N(SiMD \geq n),$$

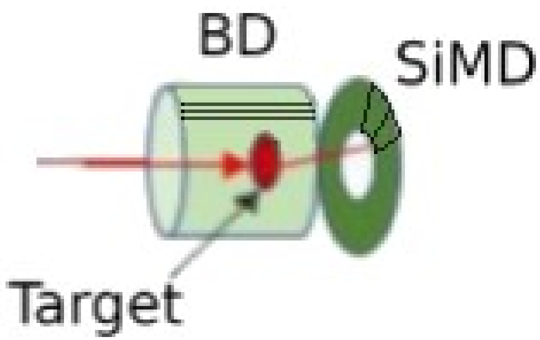
$$\varepsilon_{trig}(SiMD \geq n) = N(SiMD \geq n, BD \geq m)/N(BD \geq m),$$

$$\varepsilon_{trig}(BD \geq m \; \& \; SiMD \geq n) = \varepsilon_{trig}(BD \geq m) \cdot \varepsilon_{trig}(SiMD \geq n),$$

where m and n are the minimum number of fired channels in BD and SiMD varied in the range from 2 to 4 (run dependent). The dependences of the trigger efficiency on the track multiplicity in the primary event vertex and the X/Y vertex position were taken into account.

Trigger efficiency

- ✓ BD: 40 strips
- ✓ SiMD: 60 azimuthal segmets



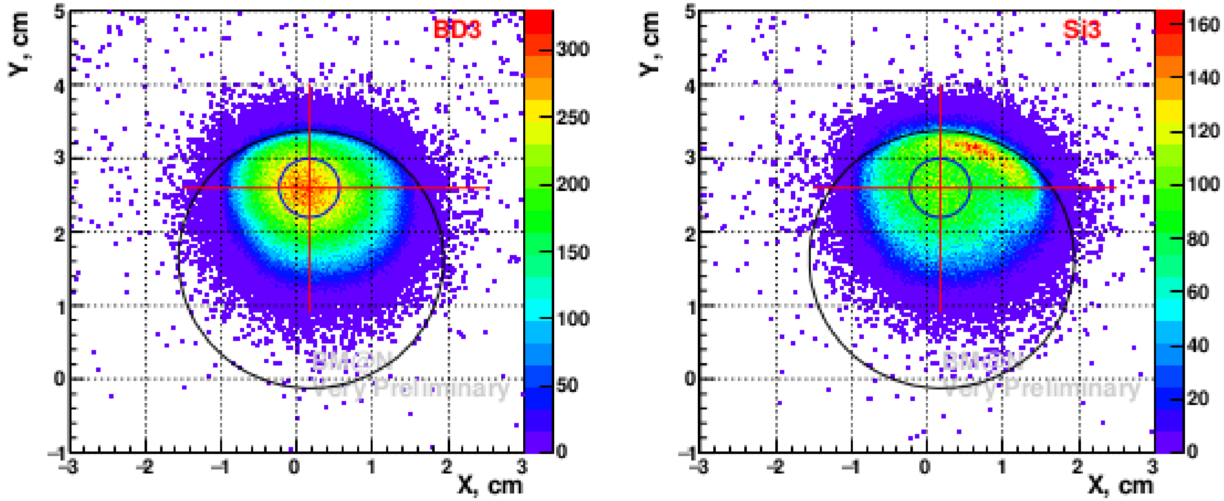
The following logic conditions were applied to generate the trigger signal: 1) BT⊗(BD≥m); 2) BT⊗(SiMD≥n); 3) BT⊗(BD≥2)⊗(SiMD≥3). The trigger conditions were varied to find the optimal ratio between the event rate and the trigger efficiency for each target. Condition 1 was applied for 60% of data collected with the carbon target. This trigger fraction was continuously reduced with the atomic weight of the target down to 26% for the Pb target. The fraction of data collected with trigger condition 2 was rising from 6% for the carbon target up to 34% for the Pb target. The rest of data were collected with trigger condition 3.

The systematic errors evaluated in the analysis cover the differences in the π^+, K^+ signals obtained by using the mean values of the trigger efficiency values instead of the efficiency dependences on the number of vertex tracks and primary vertex position. The systematic errors also include the following checks made on limited statistics:

$$\varepsilon_{trig}(BD \geq m) = N(BD \geq m, BT)/N(BT),$$
$$\varepsilon_{trig}(SiMD \geq n) = N(SiMD \geq n, BT)/N(BT),$$
$$\varepsilon_{trig}(BD \geq m \ \&\ SiMD \geq n) = N(BD \geq m \ \&\ SiMD \geq n)/N(BT).$$

where runs with only BT in online trigger are used.

Trigger efficiency

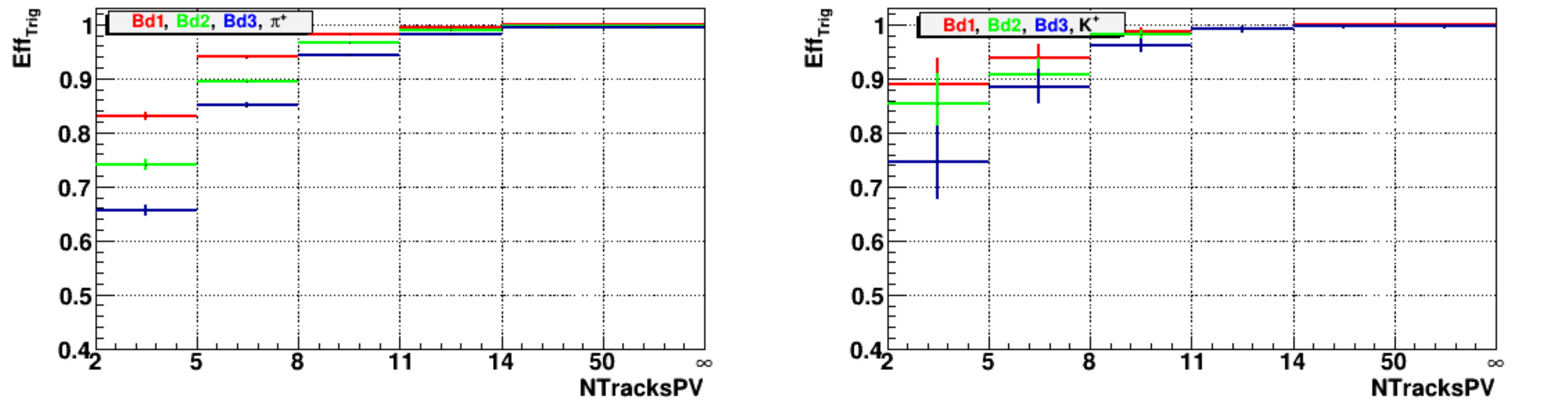


Run-7, X-Y of the primary vertices for different trigger conditions. Left: $BD \geq 3$, Right, $SiMD \geq 3$ (Fig.5 taken from lumi.pdf).

✓ The events collected with the Si-trigger near the upper edge of the target were recorded with higher efficiency relative the rest of the beam spot.

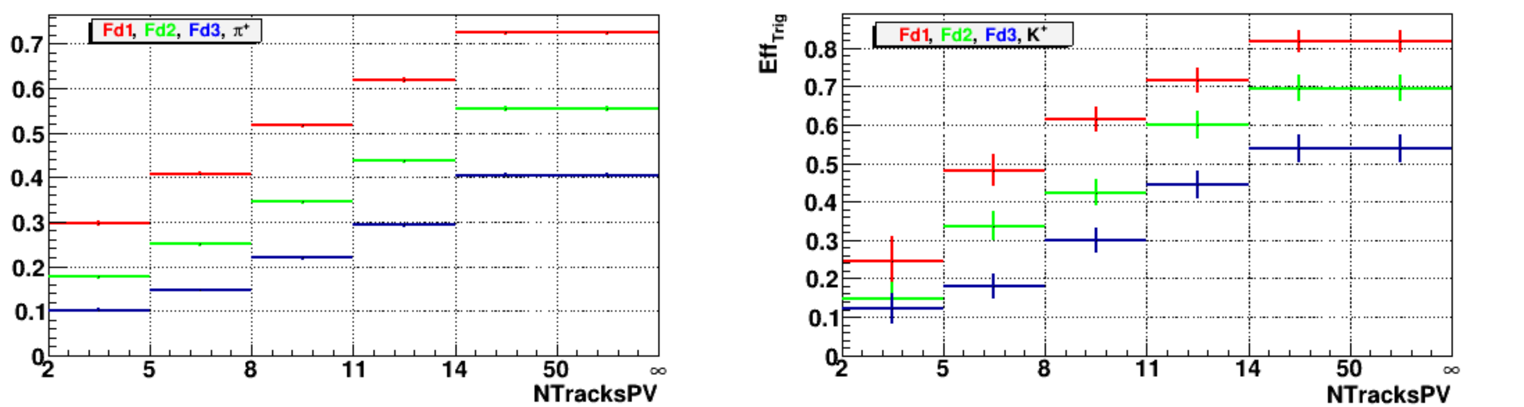
Trigger efficiency

Bd1=BD≥1
Bd2=BD≥2
Bd3=BD≥3



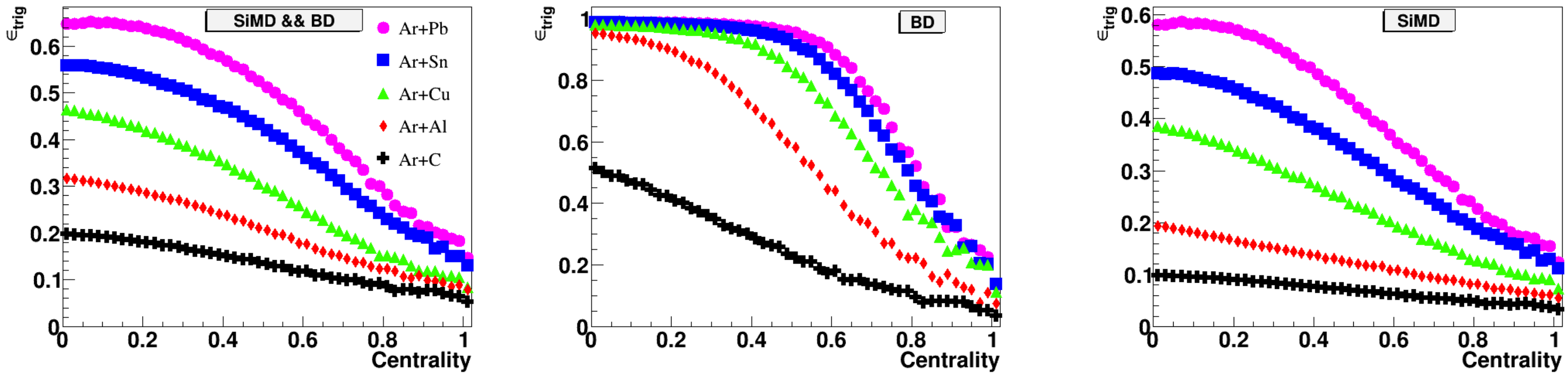
Dependence of the BD trigger efficiency on the number of tracks from the primary vertex calculated in events with π^+ (left plot) and K^+ (right plot) produced in interactions of the argon beam with the C, Al, Cu, Sn, Pb targets.

Fd1=SiMD≥1
Fd2=SiMD≥2
Fd3=SiMD≥3



Dependence of the SiMD trigger efficiency on the number of tracks from the primary vertex calculated in events with π^+ (left plot) and K^+ (right plot) produced in interactions of the argon beam with the C, Al, Cu, Sn, Pb targets.

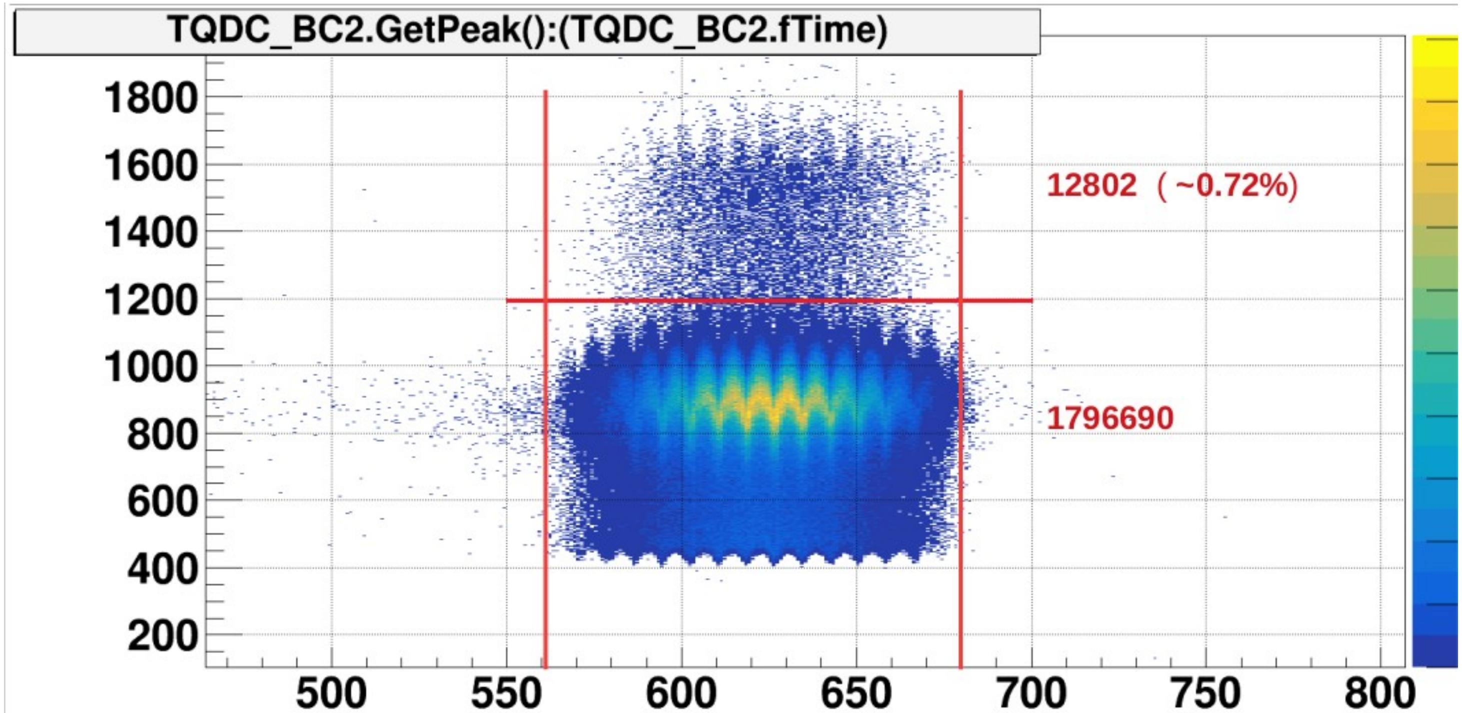
Trigger efficiency



Dependence of the SiMD && BD (left plot), BD (middle plot) and SiMD (right plot) trigger efficiency on the centrality in interactions of the argon beam with the C (black), Al (red), Cu (green), Sn (blue), Pb (magenta) targets.

Backup

Luminosity and fluxes



BT signal within 20 ns of BT coincidence time window. The BT signal is determined by the BC2 signal due to the fact that the BC2 trigger size is smaller than the BC1 trigger size.

✓ The probability of passing 2 ions in the same trigger time window is about 0.7% (it is within 2% taken as the systematic uncertainty of the beam flux measurement).

Trigger efficiency for BD

Mean BD trigger efficiency evaluated for events with reconstructed π^+/K^+ in interactions of the argon beam with the whole set of *C*, *Al*, *Cu*, *Sn*, *Pb* targets.

Trigger / Target π^+ **mesons**	***C***	***Al***	***Cu***	***Sn***	***Pb***
ε_{trig} (BD>=2)	0.80±0.03	0.96±0.01	0.98±0.01	0.99±0.01	0.99±0.01
ε_{trig} (BD>=3)	0.66±0.02	0.92±0.01	0.97±0.01	0.98±0.01	0.99±0.01
ε_{trig} (BD>=4)	0.48±0.02	0.88±0.01	0.95±0.01	0.97±0.01	0.98±0.01

Trigger / Target K^+ **mesons**	***C***	***Al***	***Cu***	***Sn***	***Pb***
ε_{trig} (BD>=2)	0.67±0.15	0.97±0.02	0.98±0.01	0.99±0.01	0.99±0.01
ε_{trig} (BD>=3)	0.67±0.15	0.96±0.02	0.97±0.01	0.99±0.01	0.99±0.01
ε_{trig} (BD>=4)	0.67±0.15	0.94±0.02	0.95±0.02	0.99±0.01	0.98±0.01

Trigger efficiency for SiMD

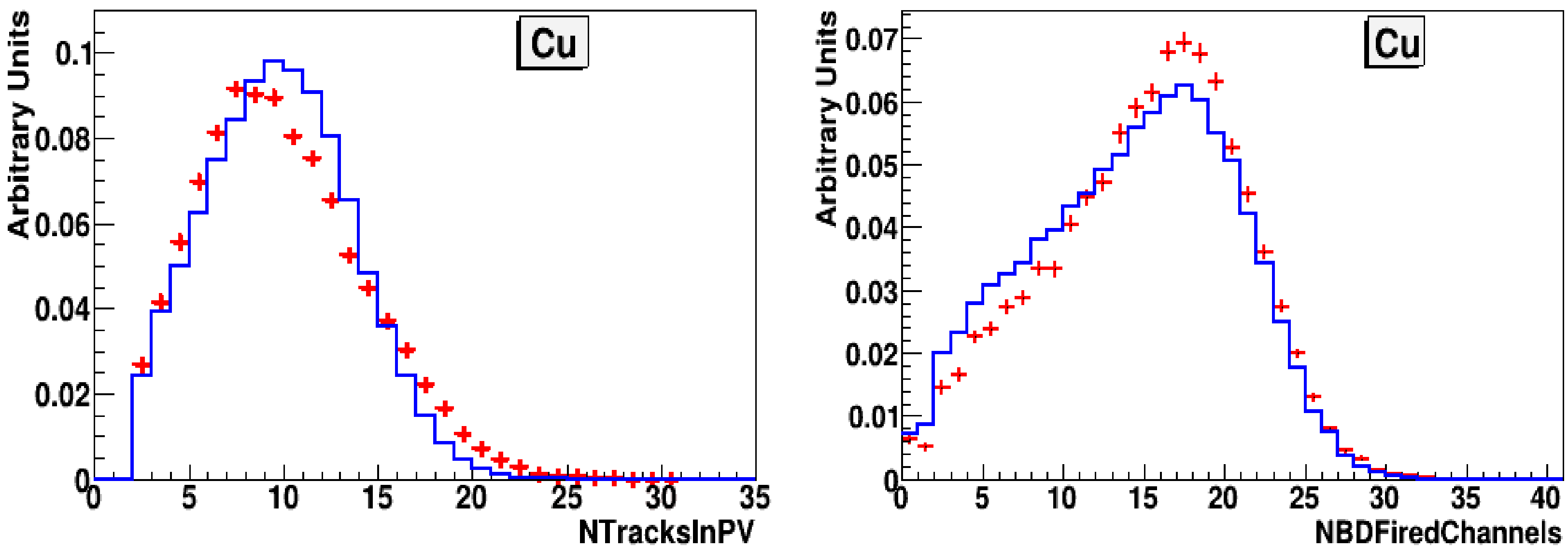
Mean SiMD trigger efficiency evaluated for events with reconstructed π^+ and K^+ in interactions of the argon beam with the whole set of *C*, *Al*, *Cu*, *Sn*, *Pb* targets.

Trigger / Target π^+ **mesons**	***C***	***Al***	***Cu***	***Sn***	***Pb***
ε_{trig} (SiMD>=2)	0.28±0.01	0.40±0.01	0.56±0.01	0.65±0.01	0.72±0.01
ε_{trig} (SiMD>=3)	0.14±0.01	0.22±0.01	0.37±0.01	0.49±0.01	0.58±0.01
ε_{trig} (SiMD>=4)	0.08±0.01	0.11±0.01	0.23±0.01	0.34±0.01	0.46±0.01

Trigger / Target K^+ **mesons**	***C***	***Al***	***Cu***	***Sn***	***Pb***
ε_{trig} (SiMD>=2)	0.30±0.06	0.40±0.03	0.64±0.03	0.74±0.03	0.82±0.03
ε_{trig} (SiMD>=3)	0.17±0.04	0.23±0.02	0.45±0.03	0.61±0.03	0.73±0.03
ε_{trig} (SiMD>=4)	0.08±0.03	0.12±0.02	0.35±0.03	0.44±0.03	0.58±0.03

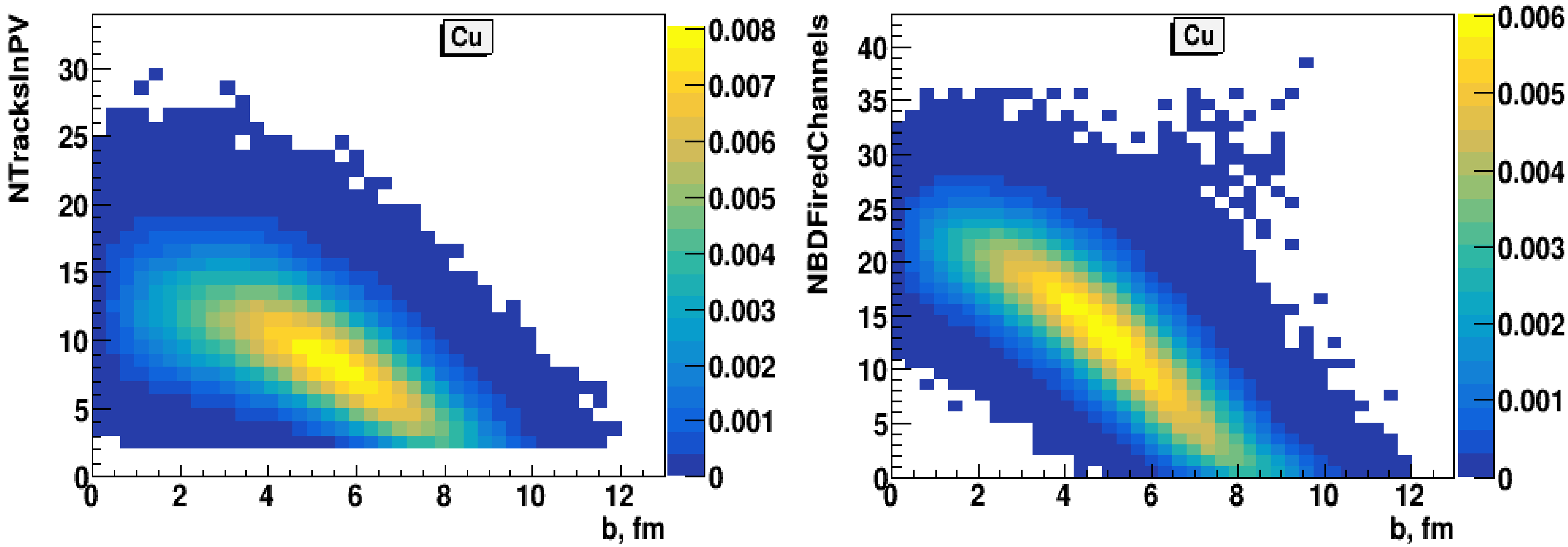
Comparison of experimental data and MC

Multiplicity distributions



Comparison of the experimental distributions (red crosses) and reconstructed Monte Carlo GEANT distributions of events generated with the DCM-SMM model (blue lines): number of tracks reconstructed in the primary vertex; number of fired BD channels.

MC



Correlation obtained from the DCM-SMM model of the number of tracks in the primary vertex (left) and the number of fired channels in the BD with impact parameter.