PETERSBURG NUCLEAR PHYSICS INSTITUTE
NAMED BY B.P. KONSTANTINOV
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JINR grant (#5, trigger) Intermediate report: Final results and summary

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MPD Cross-PWG Meeting
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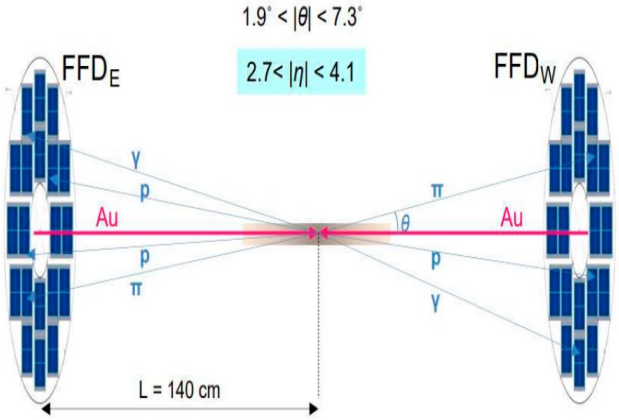
Project goals

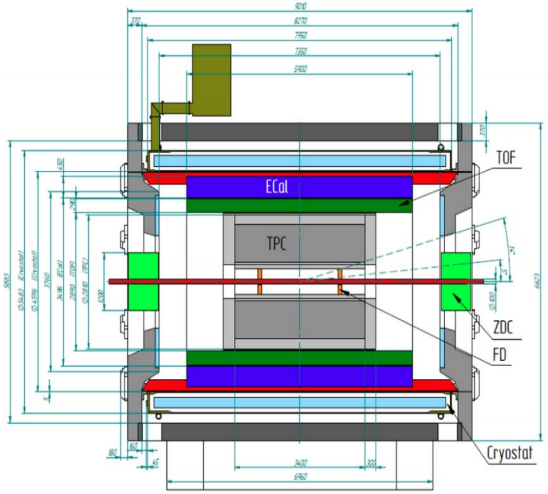
- Systematic study of the MPD trigger system (stage 1, collider mode) and T_0 measurement capability in p+p, p+Bi, C+C, Xe+Xe, Bi+Bi collisions at $\sqrt{s_{NN}}$ = 4 – 11 GeV. What collisions can be measured and what trigger logic for event selection can be used.
- Full-scale simulation (DCM-QGSM-SMM, PYTHIA8 → MPDRoot) of the MPD detector in p+p, p+Bi, C+C, Xe+Xe, Bi+Bi collisions at $\sqrt{s_{NN}}$ = 4 – 11 GeV.
- Optimization of trigger logic algorithms and determination of the maximum achievable characteristics of the MPD trigger system in p+p, p+Bi, C+C, Xe+Xe, Bi+Bi collisions at $\sqrt{s_{NN}}$ = 4 – 11 GeV.
- Determination of the limits of the MPD trigger system for the purpose of efficient selection of events and the start time T_0 measurement depending on the size, energy and centrality of a colliding system.
- Adjustment of the trigger logic algorithms in accordance with the development of trigger electronics.

Trigger detectors

Fast forward detector (FFD)



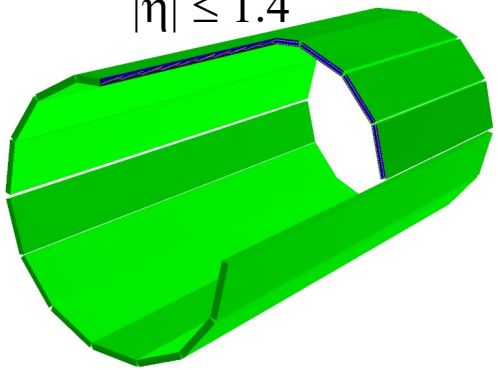
- 2×20 Cherenkov modules. 2×80 channels.
- Specially designed for event selection.
- Good time and vertex resolutions.
- Provides T_0 for TOF and ECal. Designed time resolution ≤ 50 ps.



Stage 1

Time of flight system (TOF)

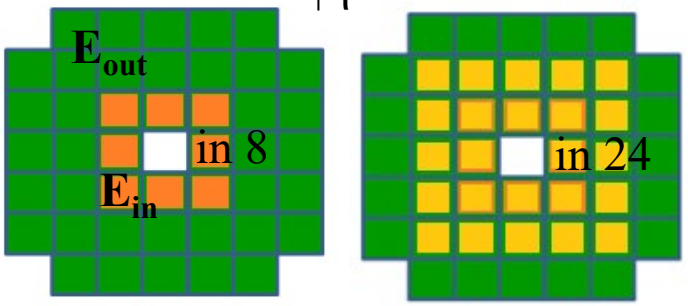
$|\eta| \leq 1.4$



- 14×2×10 MRPC detectors.
- Fast enough for event triggering.

Forward Hadron Calorimeter (FHCal)

$2 < |\eta| < 5$



- 2×48 equivalent sampling lead/scintillator calorimeter modules.
- Time and event vertex resolutions are not good enough compared to FFD.
- Fast enough for event triggering.

MPD Trigger

FFD: $|\Delta\varphi| < 2\pi$, $2.7 < |\eta| < 4.1$

FHCAL: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

TOF: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.4$

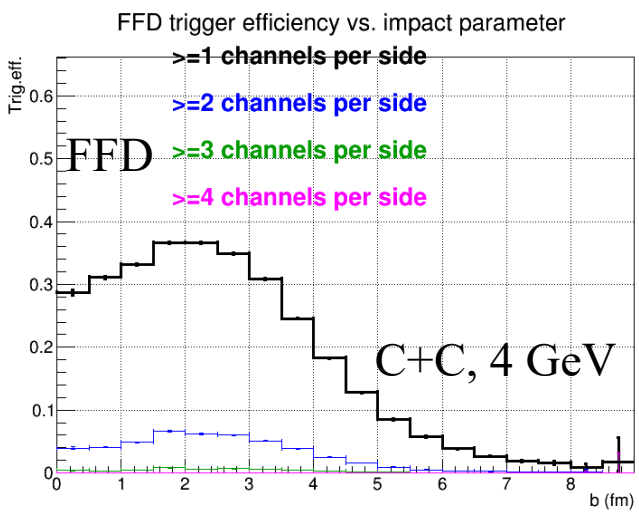
- Fast enough.
- Have suitable electronics.
- Cover different rapidity ranges.
- Measure different signals.
- Complement each other.

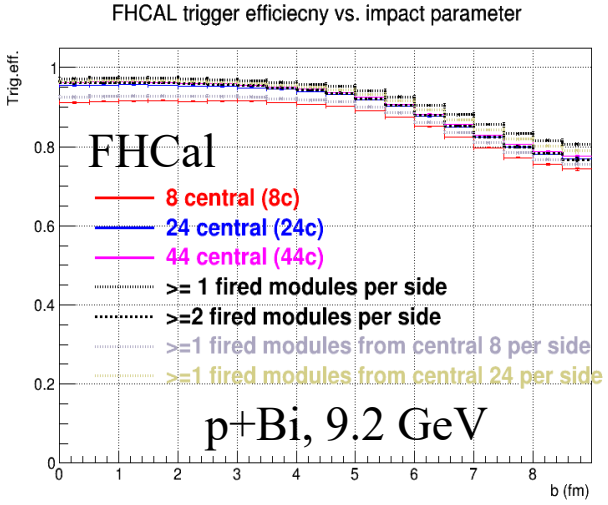
Full-scale simulation

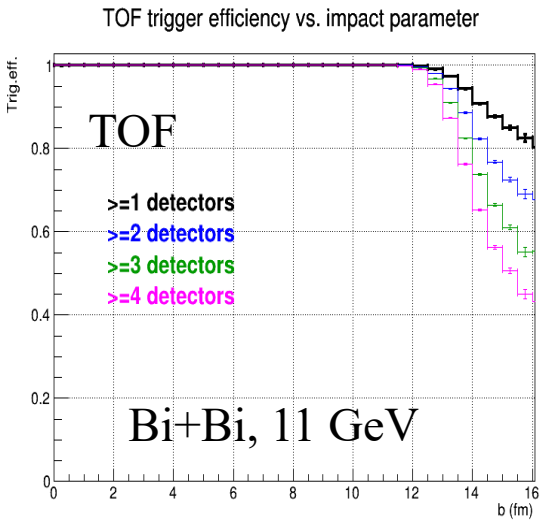
- **Collision systems:**
  - p+p, p+Bi, C+C, Xe+Xe and Bi+Bi.
  - $\sqrt{s_{NN}}$ = 4, 7 and 11 GeV (9,2 GeV for results validation).
- **Event generators:**
  - DCM-QGSM-SMM for p+Bi, C+C, Xe+Xe, Bi+Bi.
    - realistic z-vertex distribution (±200 cm) with $\sigma_z \sim 50$ cm.
    - inelastic collisions with b ~ 0–16 fm (~ 0.5×10^6 - 1×10^6 events for every collision system).
  - PYTHIA8 for p+p and p+Bi (TOF).
- **Particles propagation through MPD:**
  - Full event reconstruction with default MpdRoot.
  - Geant-4.
  - FFD, FHCal and TOF standard procedures as described in Victor Riabov presentations: (https://indico.jinr.ru/event/3448/contributions/18622/attachments/14091/23624/TriggerMassProductions.pdf)
- **Trigger configurations and definition:**
  - Different combinations of FFD, FHCal and TOF detectors
  - FFD
    - Default is ≥ 1 fired channel per side for symmetric and on one side for asymmetric collision system.
    - Optional: ≥ 2, 3 or 4 modules per or on one side.
    - |z-vertex| < 140 cm (should be wider by 10 – 20 cm during online selection).
  - FHCal:
    - Default is ≥ 1 fired module per side for symmetric and on one side for asymmetric collision system.
    - Optional (per or on one side): ≥ 2 modules, ≥ 1 module in inner region 8, ≥ 1 module in inner region 24.
    - Optional: ≥ 1 modules in 8, 24 or 44 inner region, ≥ 1 modules in 8 or 24 or 44 inner regions.
    - |z-vertex| < 150 cm (should be wider by 20 – 30 cm during online selection).
  - TOF:
    - Default ≥ 1 fired detector.
    - Optional: ≥ 2, 3, 4 fired detectors.

Trigger efficiency

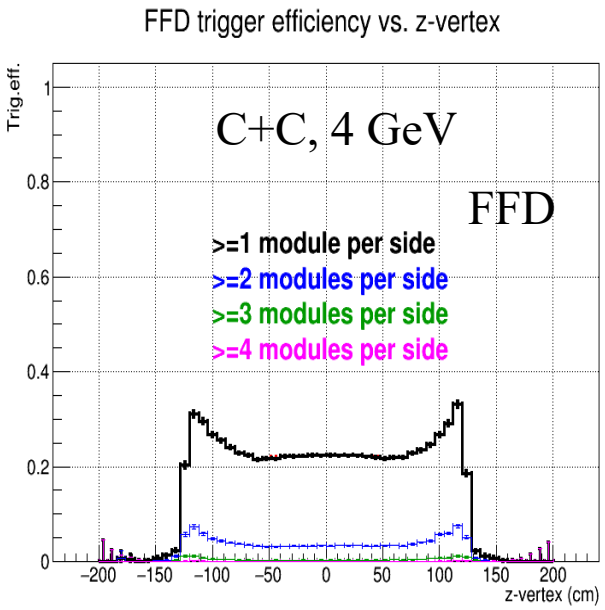
Trigger efficiency vs impact parameter b (fm)

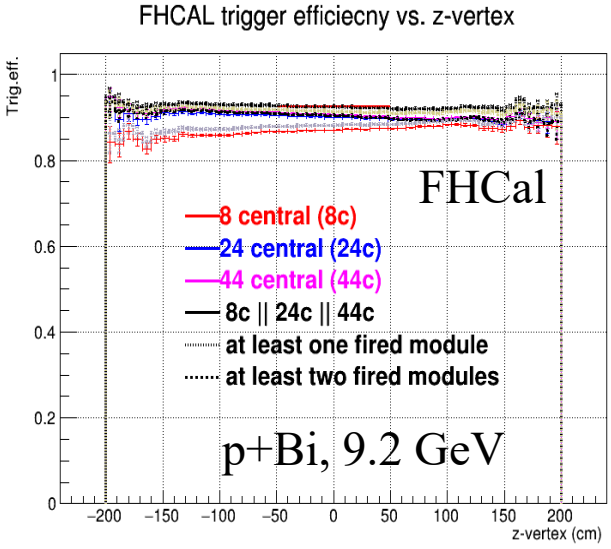


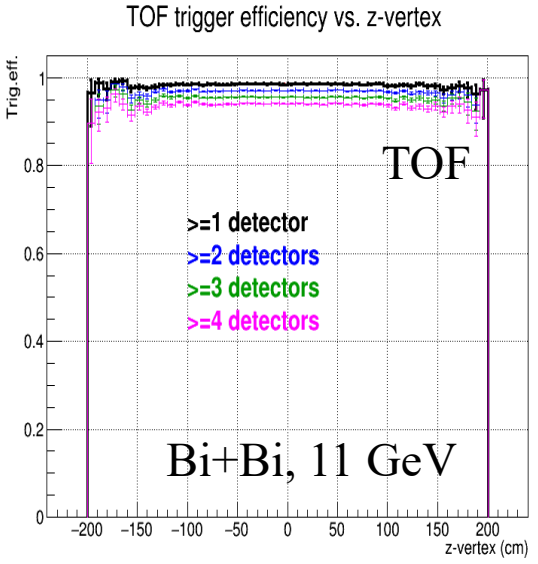




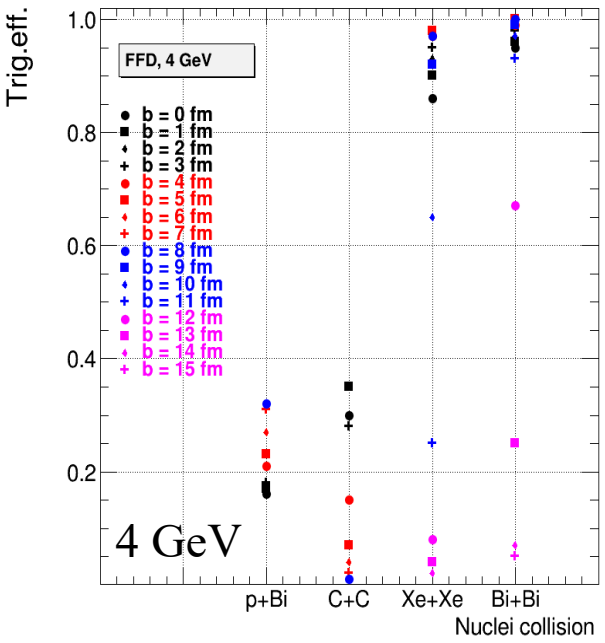
Trigger efficiency vs z-vertex (cm)

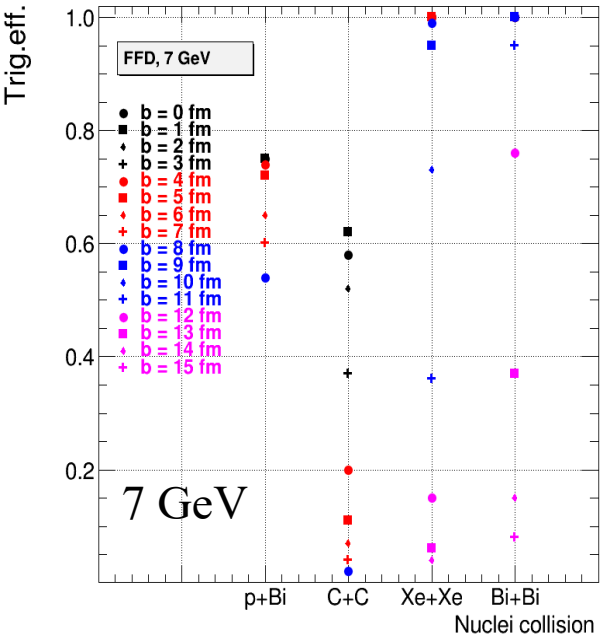




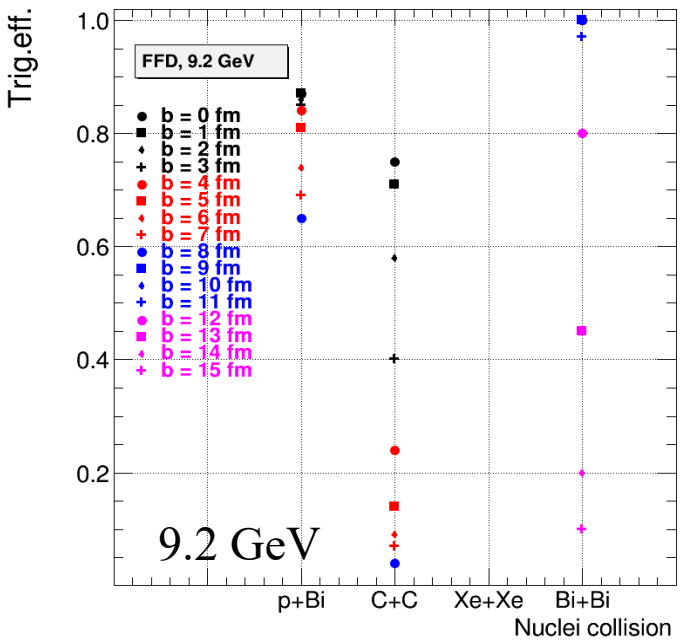


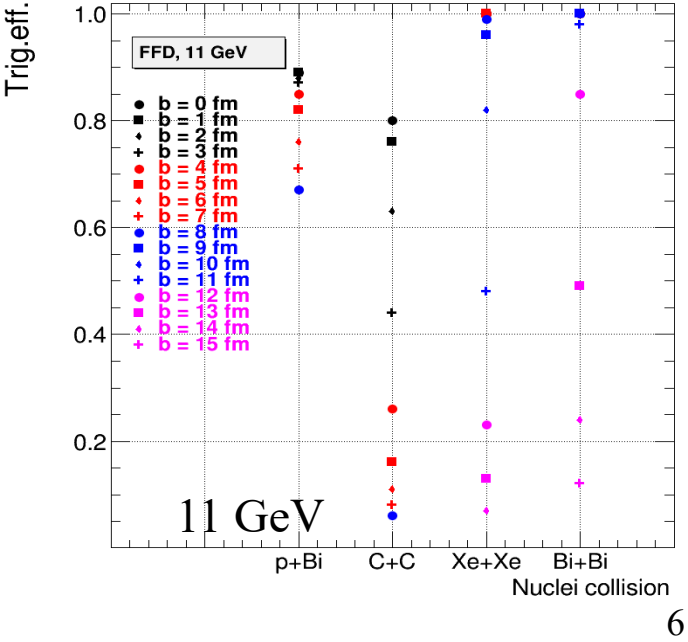
Trigger efficiency vs b (FFD)



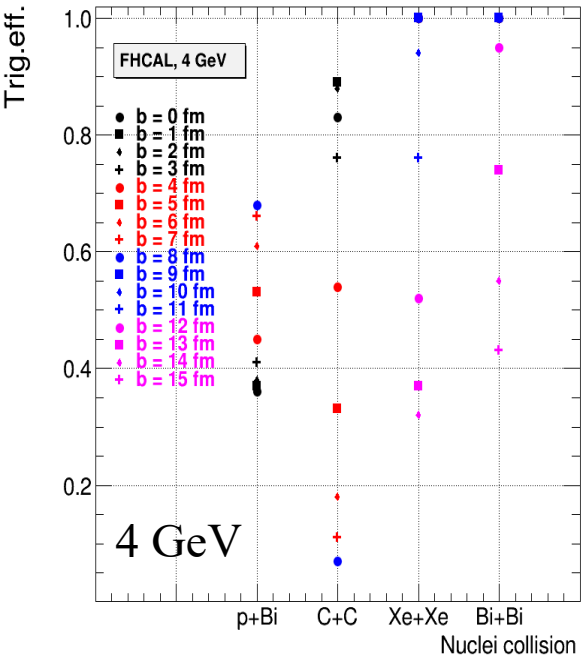


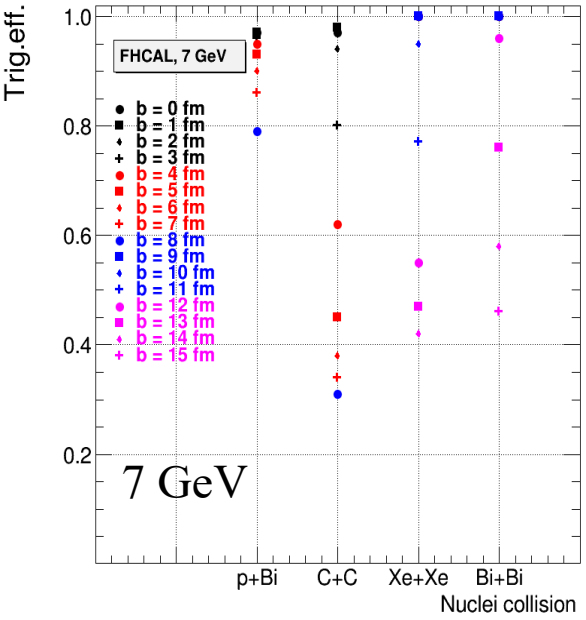
- Default trigger configuration.
- Trigger efficiency is decreasing with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- 100% for central and semi-central Xe+Xe and Bi+Bi collisions, except Xe+Xe 4 GeV. ~ 10% in peripheral collisions.
- <90% For C+C and p+Bi collisions. ~ few percent in peripheral collisions.
- FFD is ok for Bi+Bi and Xe+Xe selection.
- FFD is not good enough for selection of p+Bi, C+C and low energy Xe+Xe.



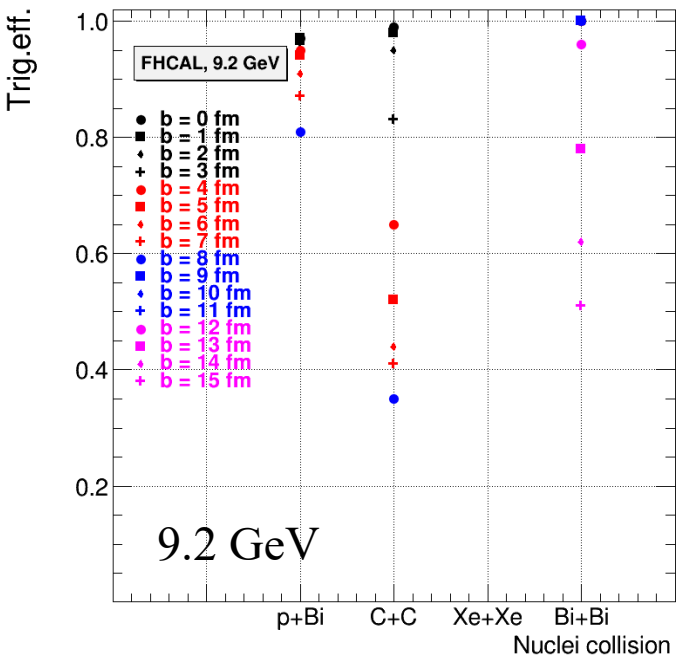


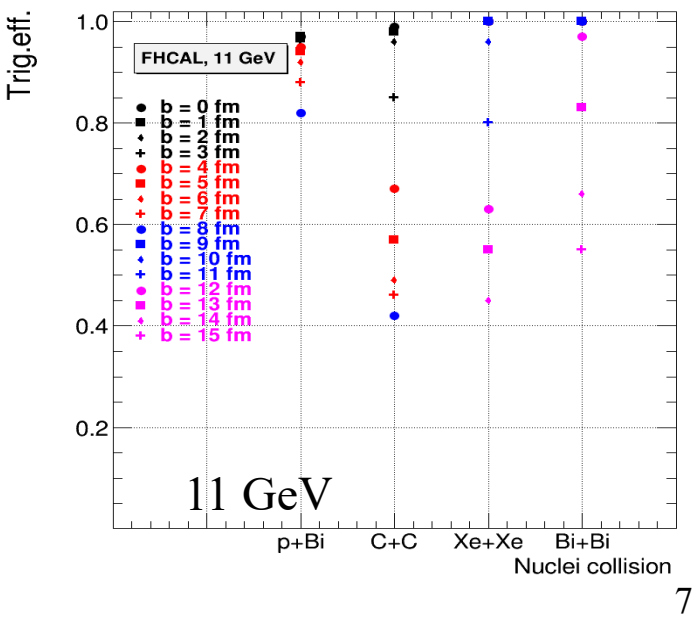
Trigger efficiency vs b (FHCal)



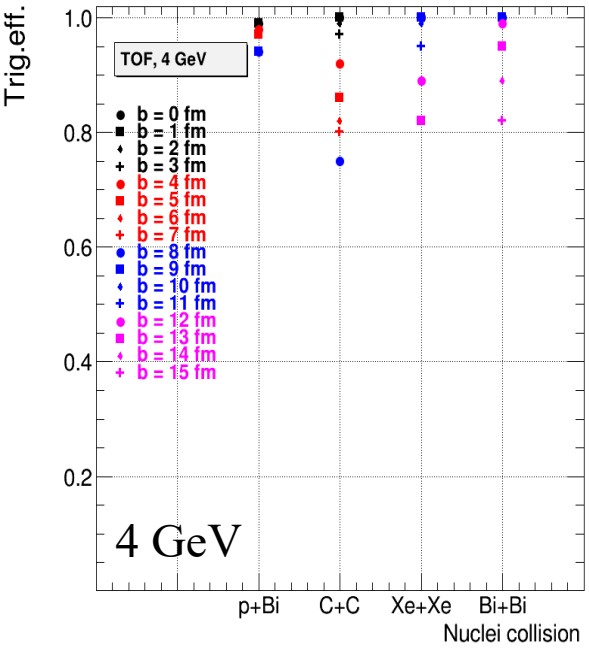


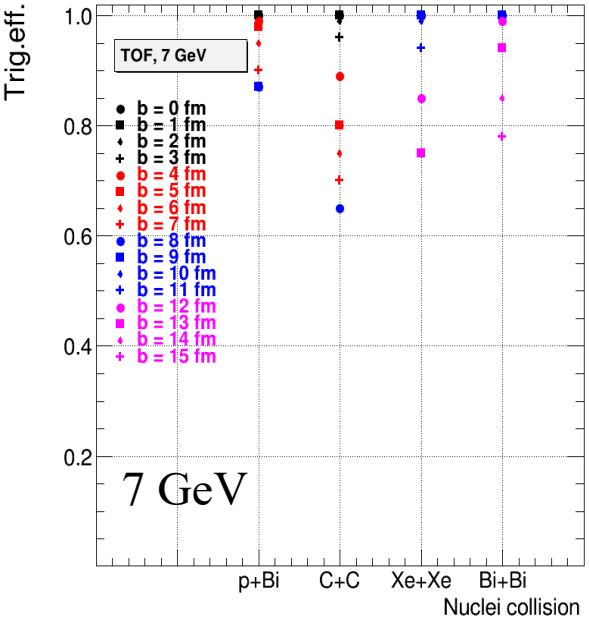
- Default trigger configuration.
- Trigger efficiency is decreasing with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- 100% for central and semi-central Xe+Xe and Bi+Bi collisions. >30% in peripheral collisions.
- <100% For C+C and p+Bi collisions. >10% in peripheral collisions.
- FHCal is ok for Bi+Bi and Xe+Xe selection.
- FHCal is not good enough for selection of p+Bi and C+C.



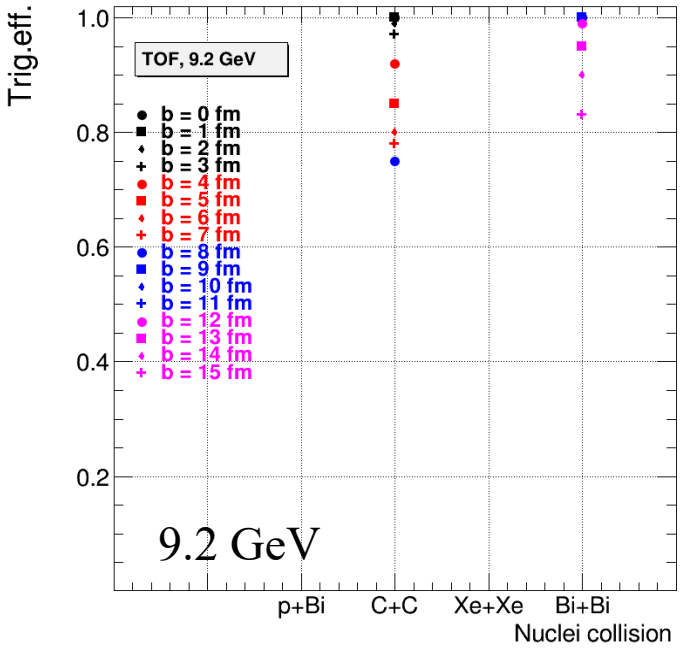


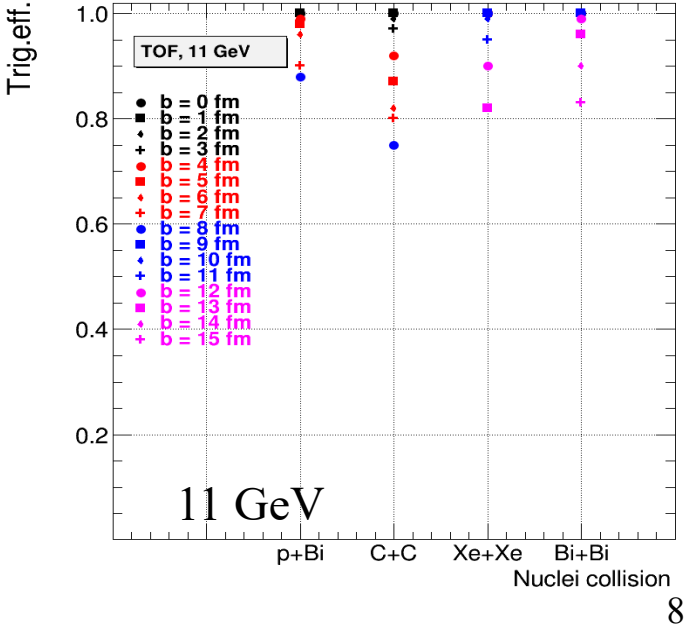
Trigger efficiency vs b (TOF)



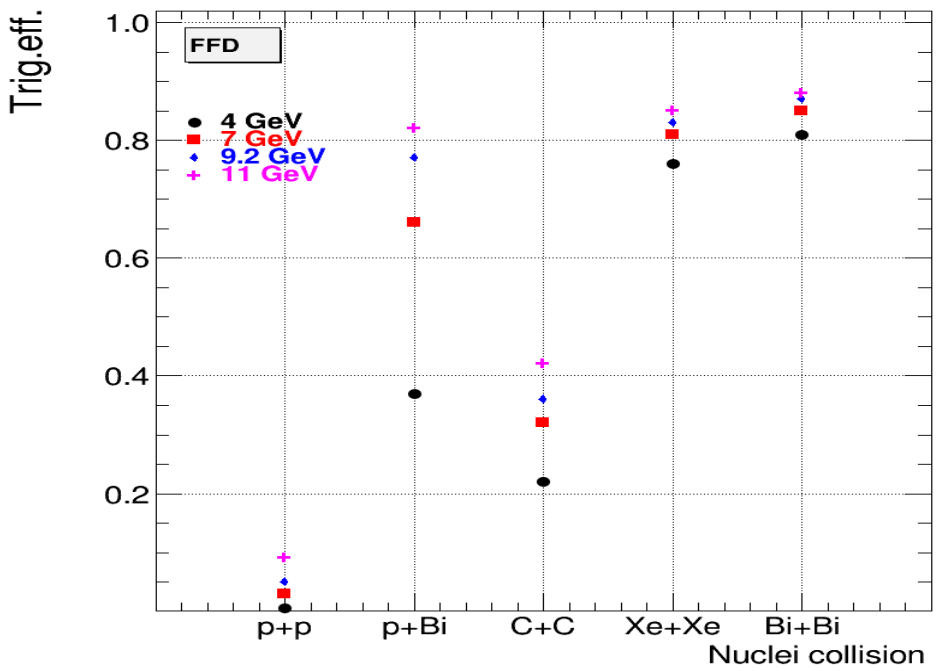


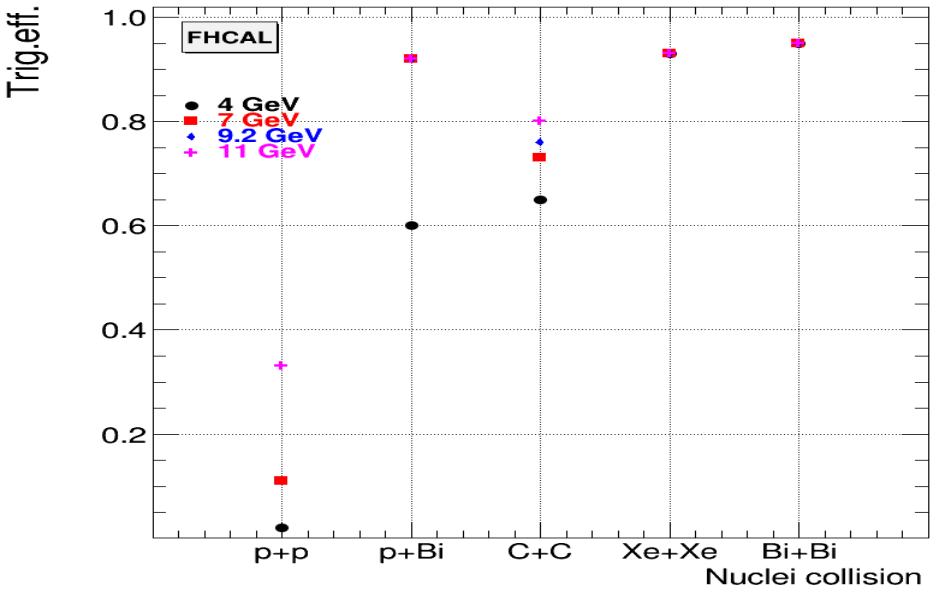
- Default trigger configuration.
- Trigger efficiency is decreasing with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- 100% for central and semi-central Xe+Xe and Bi+Bi collisions. >70% in peripheral collisions.
- 100% For C+C and p+Bi collisions. >60% in peripheral collisions.
- TOF is fine for selection of Bi+Bi and Xe+Xe and is crucial for p+Bi and C+C selection.

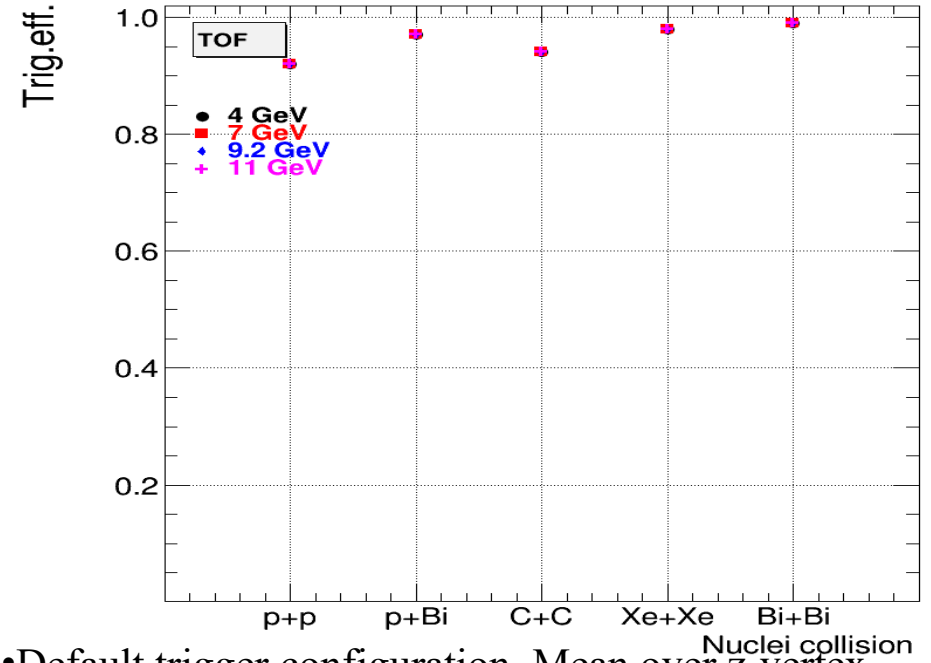




Comparison of trigger efficiencies







- Default trigger configuration. Mean over z-vertex.
- Trigger efficiencies are decreasing with decreasing $\sqrt{s_{NN}}$ except TOF and FHCal in Xe+Xe and Bi+Bi.
- Xe+Xe and Bi+Bi:

TOF(98-99%)>FHCal(93-95%)>FFD(76-88%).

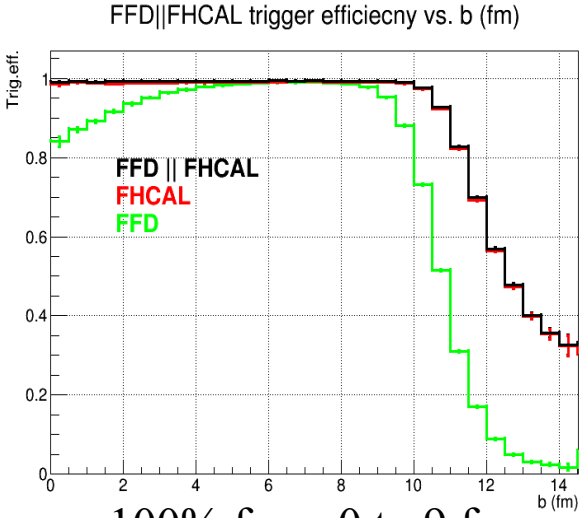
- p+p, p+Bi and C+C:

TOF(92-97%)>FHCal(2-92%)>FFD(0.5-82%).

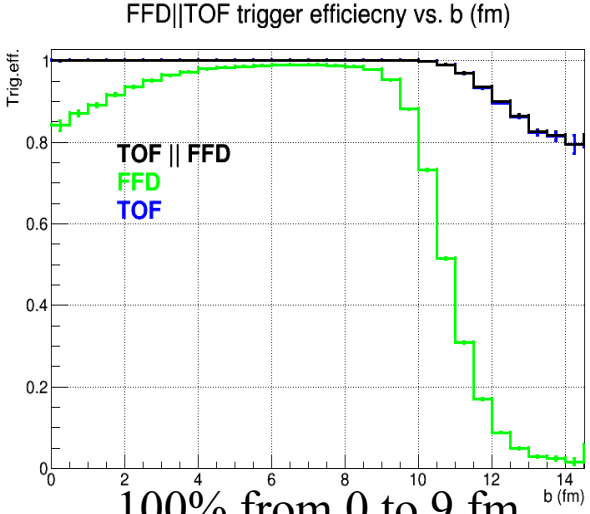
Combinations of trigger detectors

Xe+Xe, 4 GeV

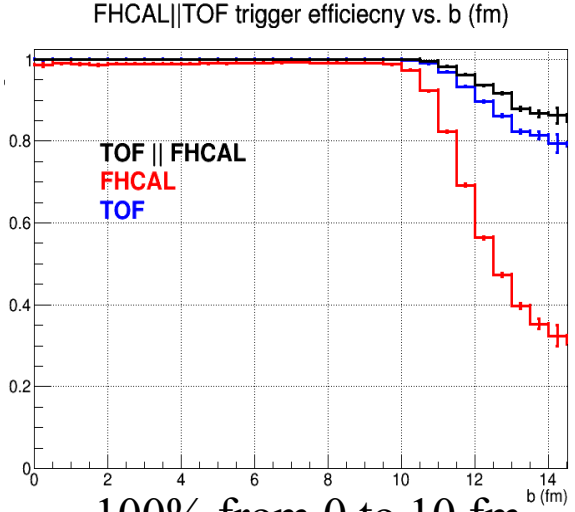
Trigger efficiency vs impact parameter b (fm)



100% from 0 to 9 fm

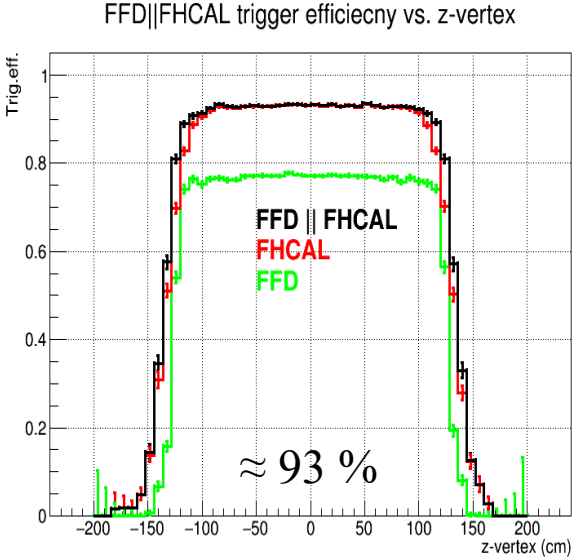


100% from 0 to 9 fm

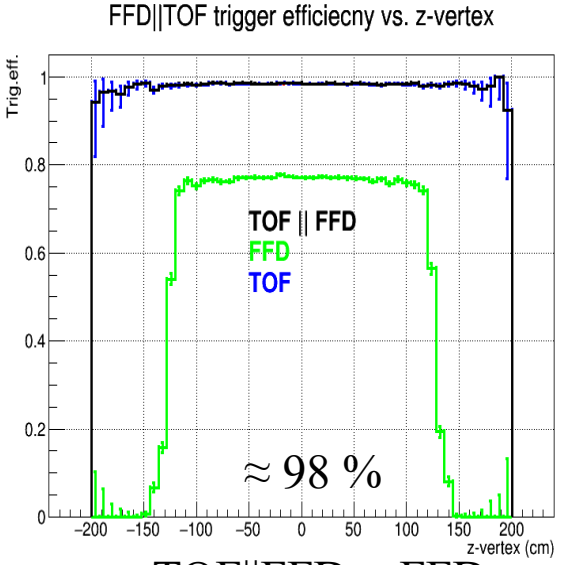


100% from 0 to 10 fm

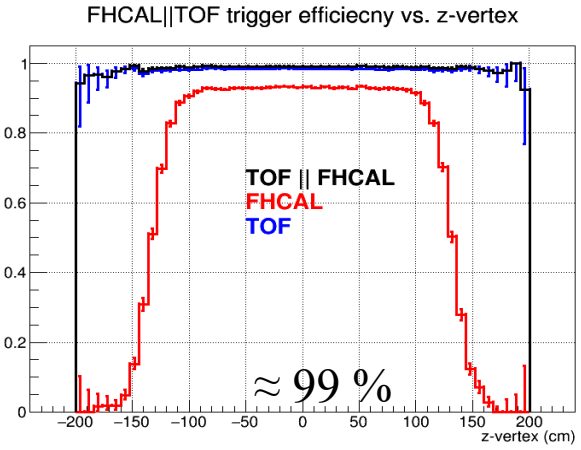
Trigger efficiency vs z-vertex (cm)



FFD||FHCal ~ FHCal



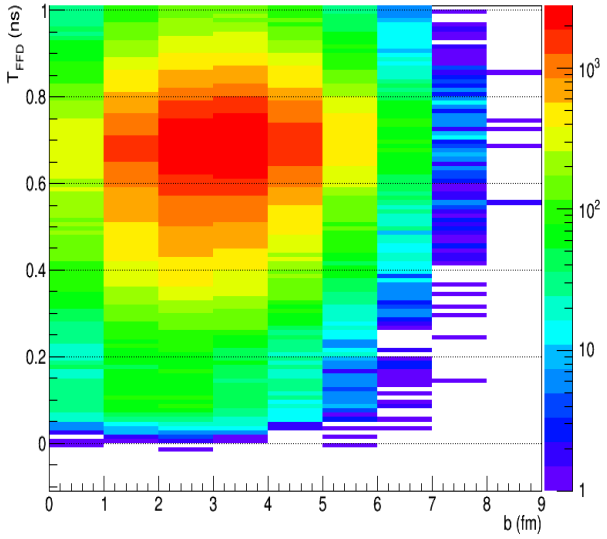
TOF||FFD ~ FFD



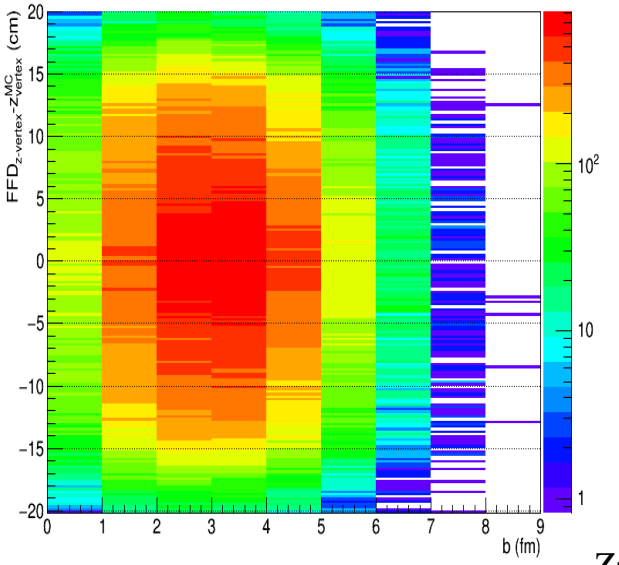
TOF||FHCAL > TOF, especially in the region of the most peripheral collisions

T_0 and z-vertex resolutions

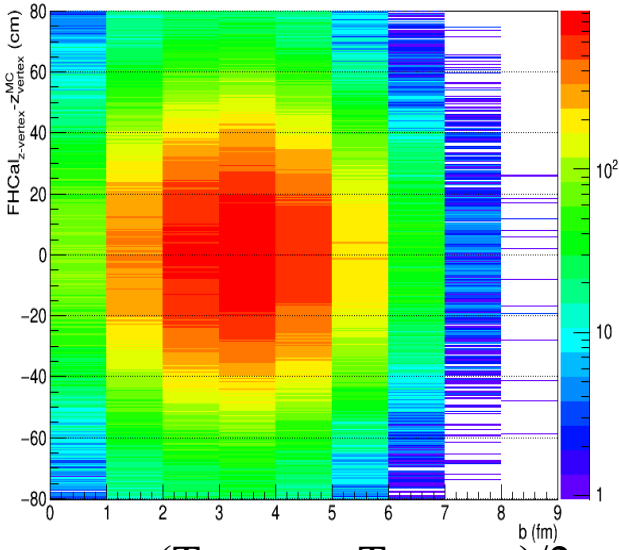
FFD, T_0



FFD, z-vertex



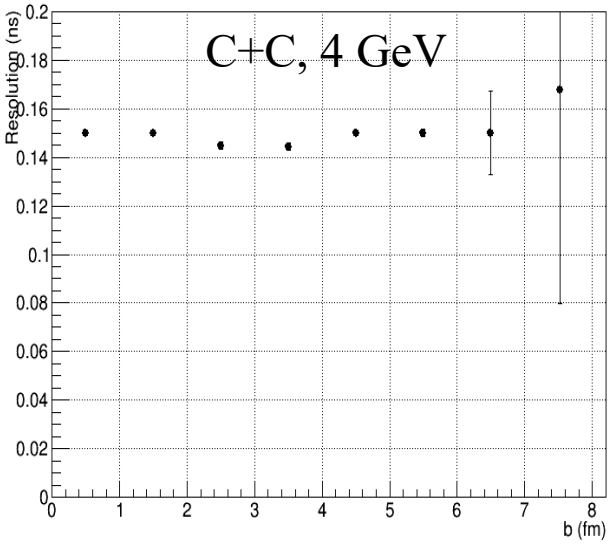
FHCal, z-vertex

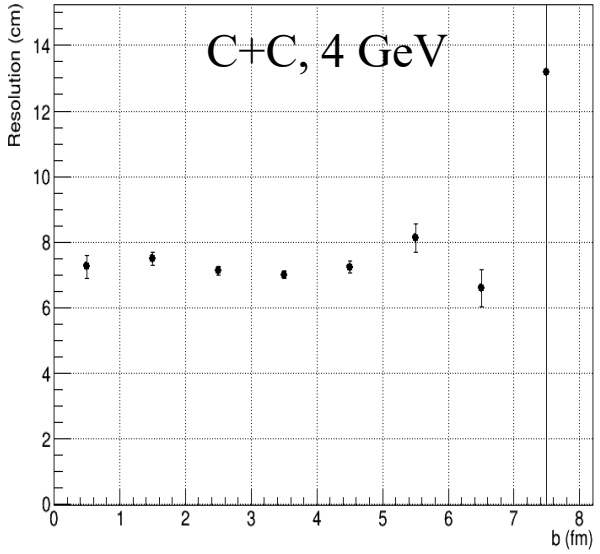


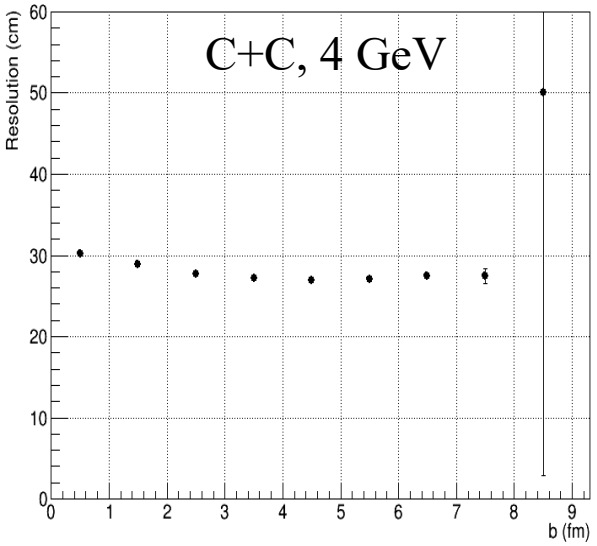
$T_0 = (T_{FFDE}+T_{FFDW})/2 - L/c$

z-vertex$= (T_{FFDW}-T_{FFDE})/2 \times c$

z-vertex$= (T_{FHCALW}-T_{FHCALW})/2 \times c$

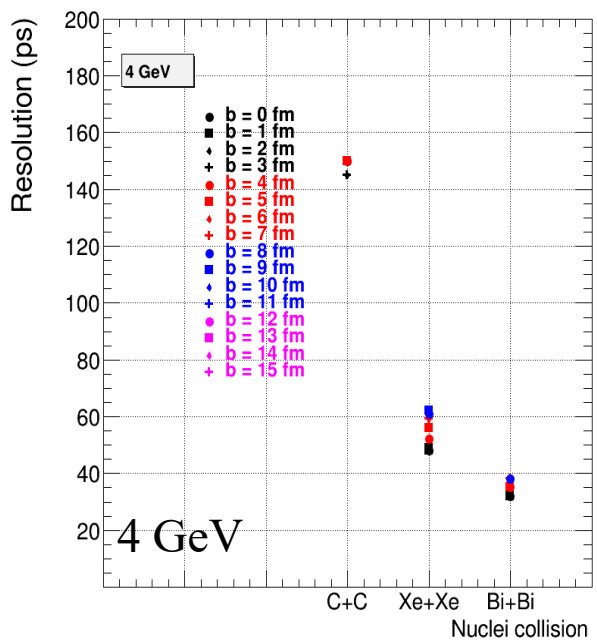




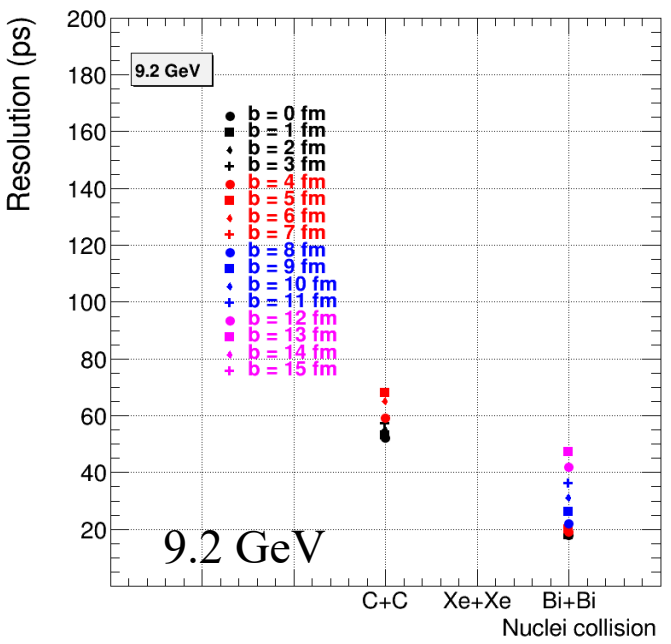


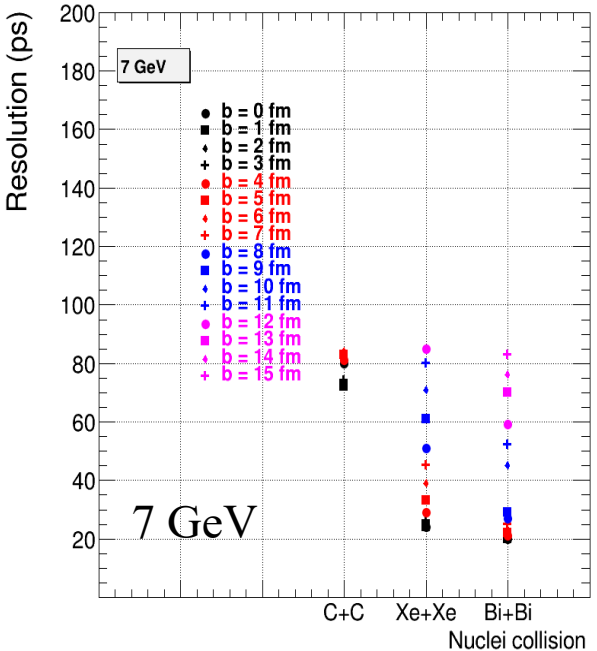
Vertex resolution

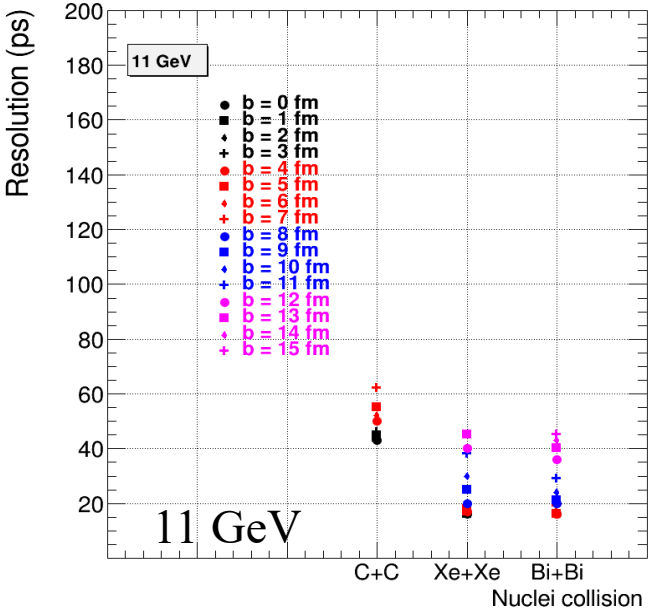
T_0 resolution vs b



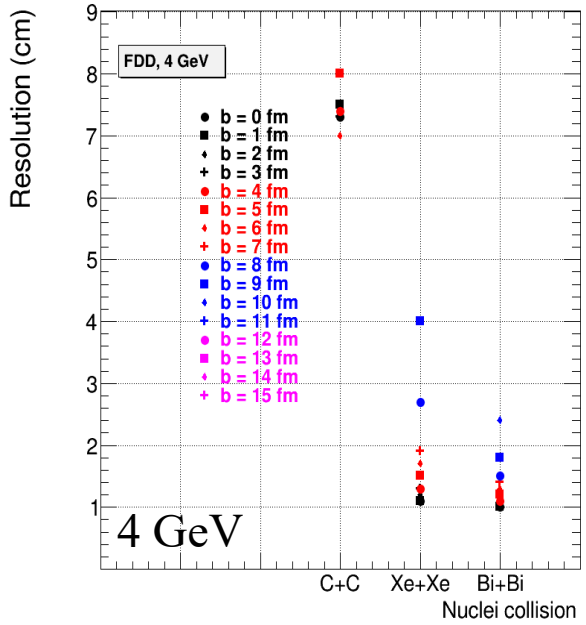
- T_0 resolution is worsen with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- Bi+Bi and Xe+Xe: > 15 – 50 ps for the most central and < 45 – 85 ps for the most peripheral collisions.
- C+C: > 40 – 140 ps for the most central and < 60 – 150 ps for semi-central collisions.

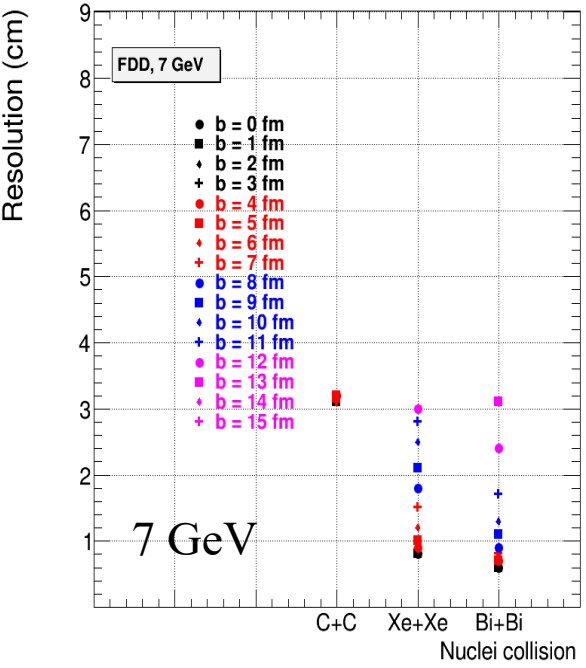




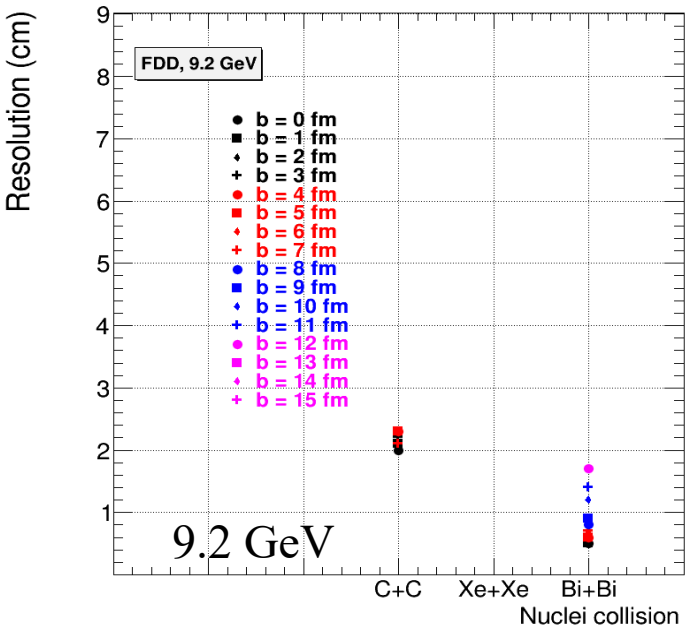


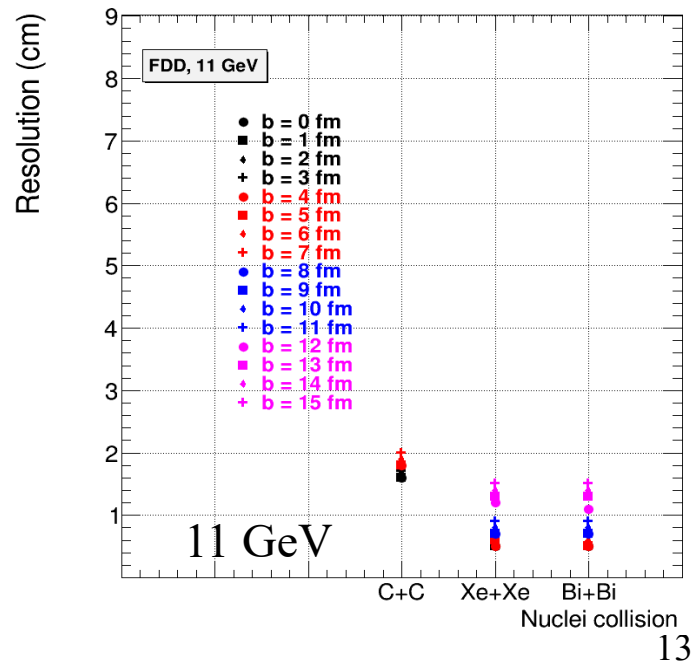
FDD z-vertex resolution vs b



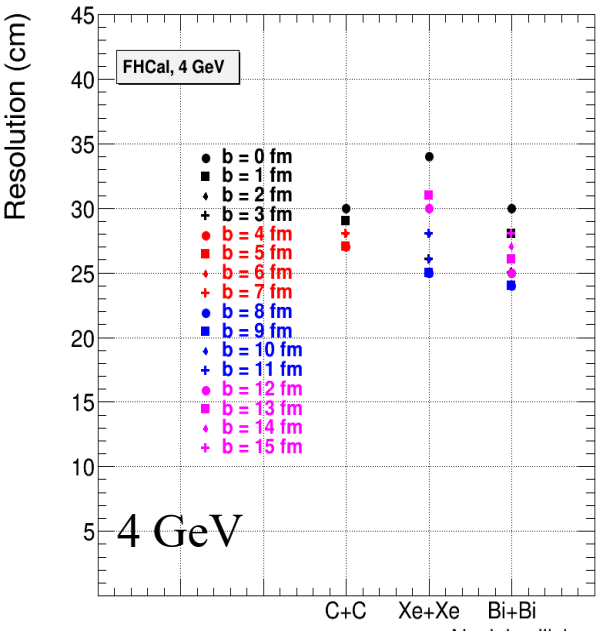


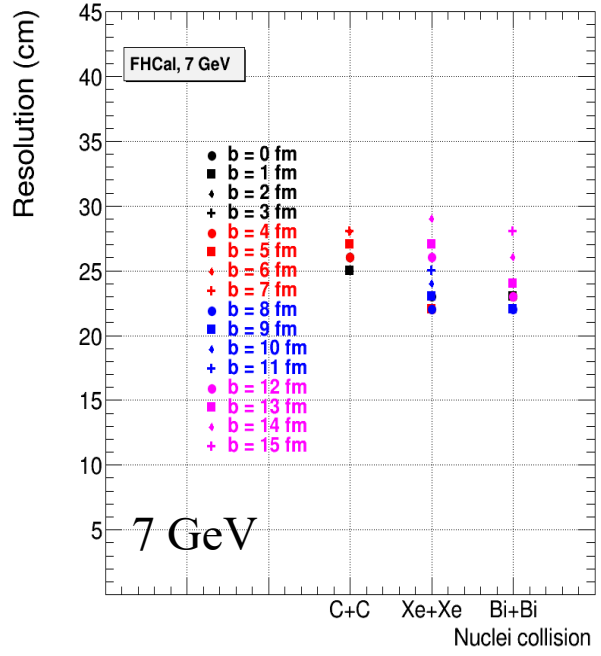
- z-vertex resolution is worsen with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- Bi+Bi and Xe+Xe: > 0.5 – 1 cm for the most central and < 1.5 – 4 cm for the most peripheral collisions.
- C+C: > 1.5 – 7 cm for the most central and < 2 – 8 cm for semi-central collisions.



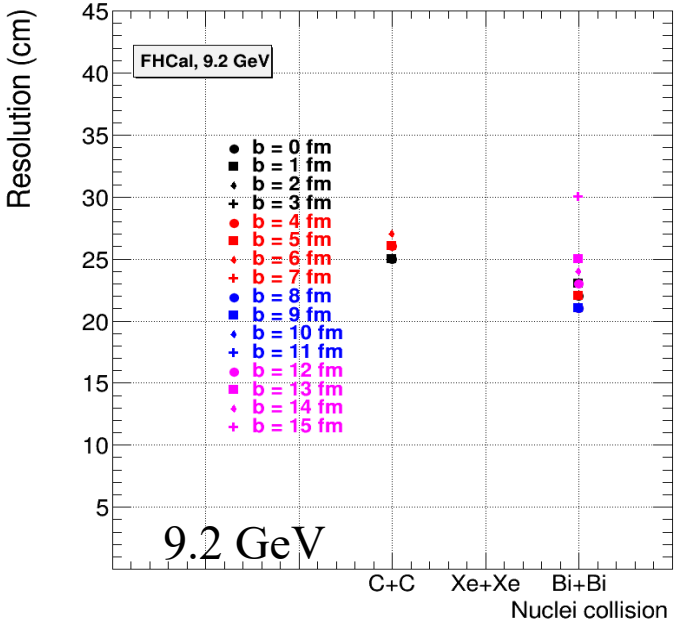


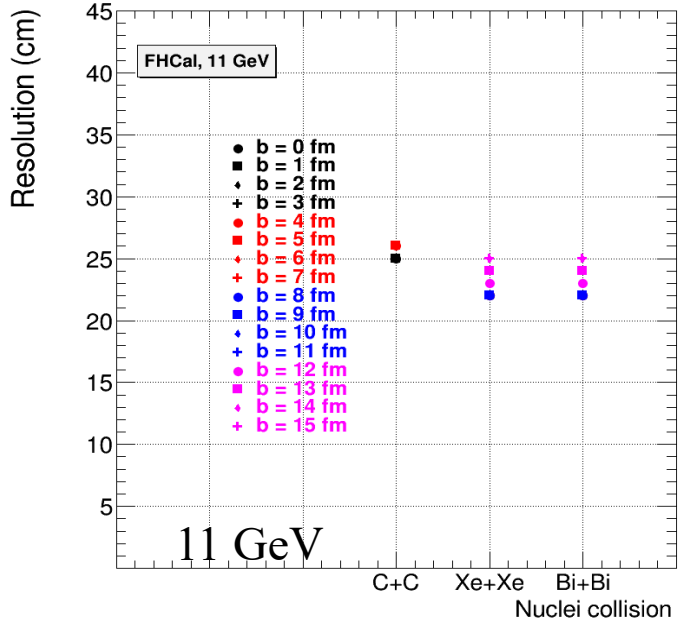
FHCal z-vertex resolution vs b





- z-vertex resolution is worsen with increasing impact parameter and decreasing $\sqrt{s_{NN}}$.
- Bi+Bi and Xe+Xe: > 22 – 25 cm for the most central and < 25 – 35 cm for the most peripheral collisions.
- C+C: > 25 – 27 cm for the most central and < 25 – 30 cm for semi-central collisions.





Conclusions and outlook

- Result on the MPD trigger efficiency, T_0 and z-vertex systematic study in the collider mode in p+p, p+Bi, C+C, Xe+Xe and Bi+Bi collisions at $\sqrt{s_{NN}}$ = 4, 7, 9.2 and 11 GeV were presented.
- Full-scale simulation of the MPD detector in p+p, p+Bi, C+C, Xe+Xe, Bi+Bi collisions at $\sqrt{s_{NN}}$ = 4 – 11 GeV was done using DCM-QGSM-SMM event generator for all collision systems except p+p and PYTHIA8 for p+Bi (TOF) and p+p collisions.
- The study of the trigger efficiency was done for different trigger systems based on combination of trigger detectors and their configurations.
- Event selection of heavy nuclei (Bi + Bi) and intermediate-mass nuclei (Xe + Xe) at $\sqrt{s_{NN}}$ = 4, 7, 9.2 and 11 GeV can be done with FFD, FHCAL and TOF subsystems and their combinations except collisions of Xe + Xe at $\sqrt{s_{NN}}$ = 4 GeV where FDD doesn't have a region with 100% efficiency in the dependence of trigger efficiency on impact parameter.
- FFD and FHCal trigger performance is not good enough for event selection in light and asymmetric light-heavy collision systems (p+p, p+Bi and C+C). TOF is crucial for event selection in such systems.
- The trigger logic which is based on the combination of TOF and FHCAL in default configuration is the most promising. Adding FFD to this combination increases efficiency negligibly.
- FFD T_0 resolution: 15 – 150 ps depending on the centrality and the collision system. FFD z-vertex resolution: 0.5 – 8 cm. FHCAL z-vertex resolution is about 20 – 40 cm.