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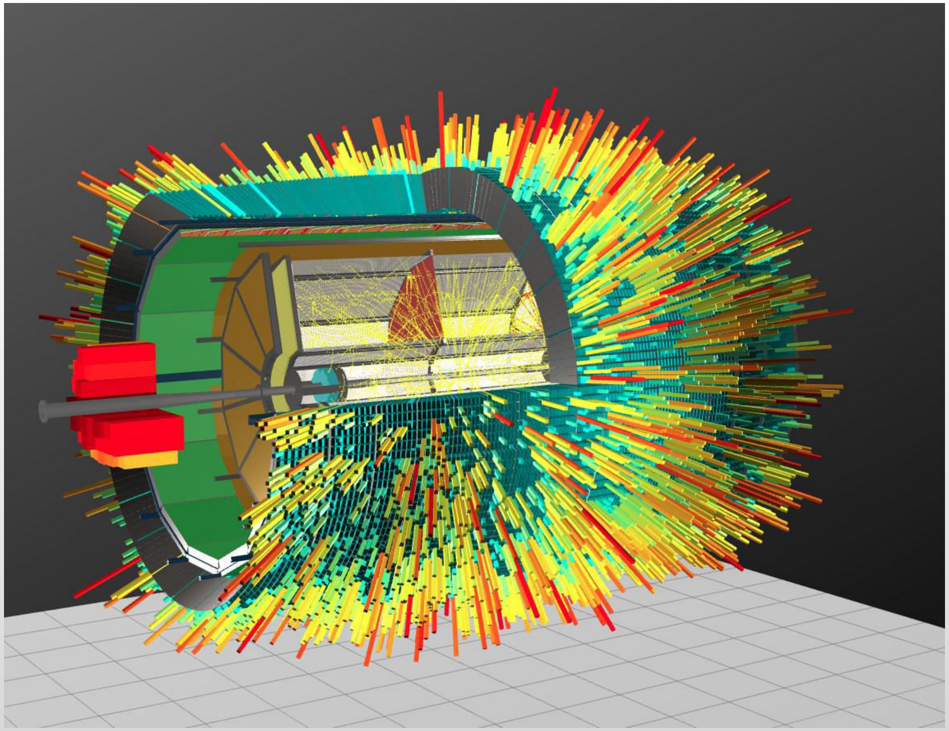
# Performance of the trigger system of the MPD experiment

V. Riabov for the MPD Collaboration



The work has been supported by the Ministry of Science and Higher Education of the Russian Federation, Project "Fundamental and applied research at the NICA megascience experimental complex" № FSWU-2024-0024

# MPD @ NICA

- One of two experiments at NICA collider to study heavy-ion collisions at $\sqrt{s_{NN}}$= 4−11 GeV

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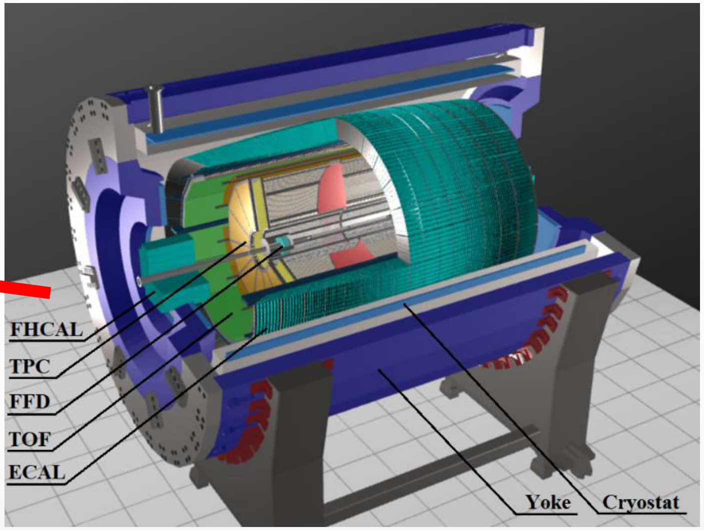
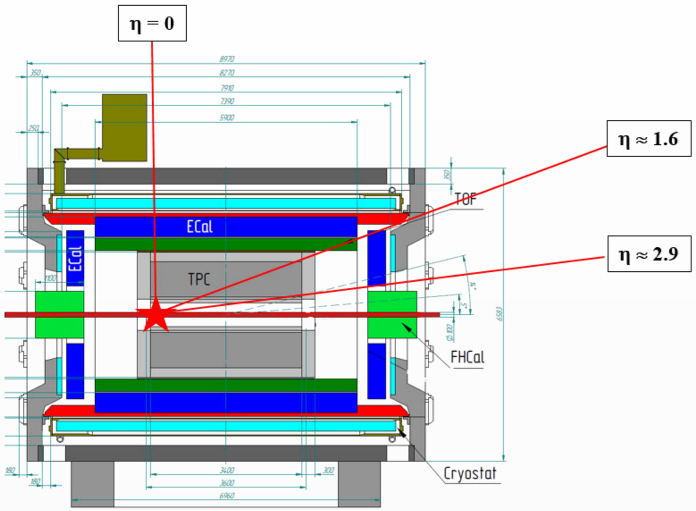
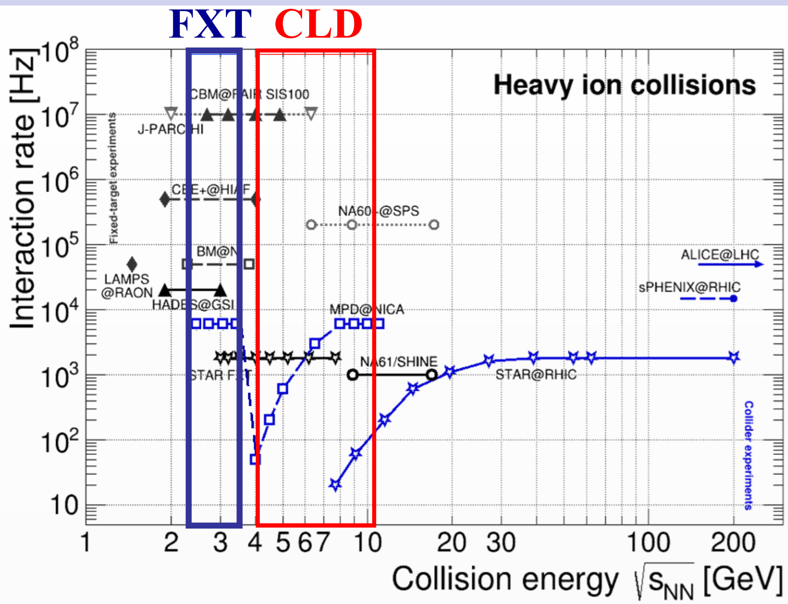



**TPC**: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.6$; **TOF, EMC**: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.4$; **FFD**: $|\Delta\varphi| < 2\pi$, $2.9 < |\eta| < 3.3$; **FHCAL**: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

- MPD strategy − high-luminosity scans in **energy** and **system size** to measure a wide variety of signals:
  - ✓ order of the phase transition and search for the QCD critical point → structure of the QCD phase diagram
  - ✓ hypernuclei and equation of state at high baryon densities → inner structure of compact stars, star mergers
- Scans to be carried out using the **same apparatus** with all the advantages of collider experiments:
  - ✓ maximum phase space, minimally biased acceptance, free of target parasitic effects
  - ✓ correlated systematic effects for different systems and energies → simplified extraction of physical signals

# CLD and FXT operation at NICA

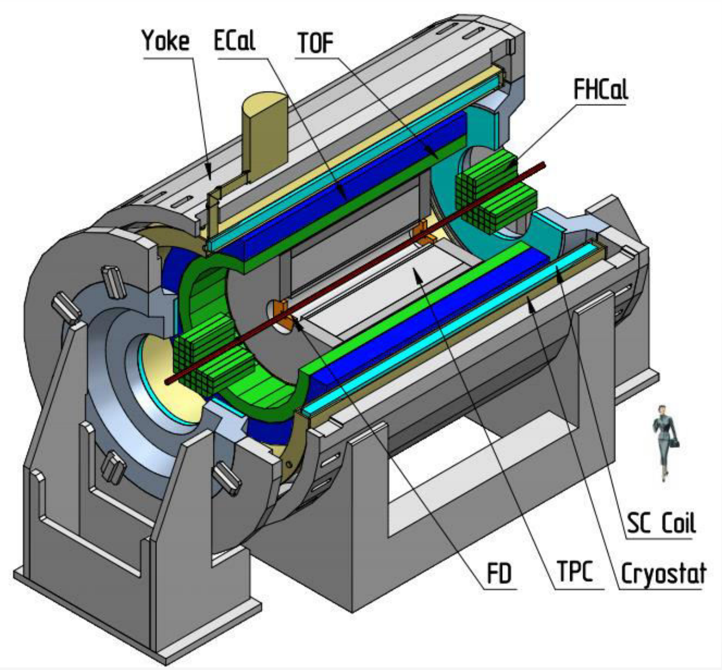


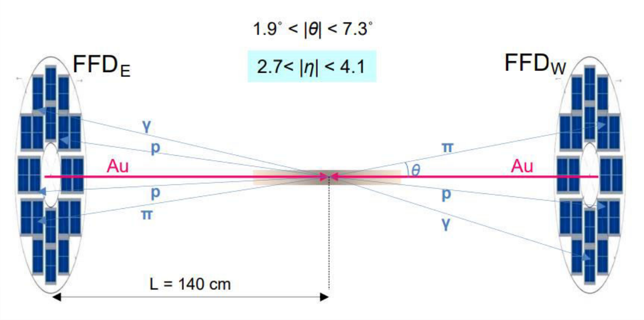

- MPD-CLD and MPD-FXT options approved by accelerator department (default option from start-up)
- Collider mode: two beams, $\sqrt{s_{NN}}$ = 4-11 GeV
- Fixed-target mode: one beam + thin wire (~ 50-100 μm) close to the edge of the MPD central barrel:
  - ✓ extends energy range of MPD to $\sqrt{s_{NN}}$ = 2.4-3.5 GeV (overlap with HADES, BM@N and CBM)
  - ✓ solves problem of low event rate at lower collision energies (only ~ 50 Hz at $\sqrt{s_{NN}}$ = 4 GeV at design luminosity)
- Expected beam condition for the first year(s):
  - ✓ MPD-CLD: Xe+Xe/Bi+Bi at $\sqrt{s_{NN}}$ ~ 7 GeV, reduced luminosity → collision rate ~ 50 Hz
  - ✓ MPD-FXT: Xe/Bi+W at $\sqrt{s_{NN}}$ ~ 3 GeV

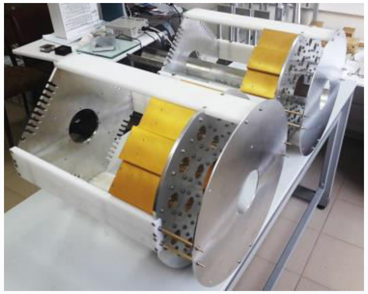
**Trigger system of the MPD should be effective for <u>different collision systems and energies</u> as well as for <u>different operation modes</u> (MPD-CLD vs. MPD-FXT)**

# Trigger detectors



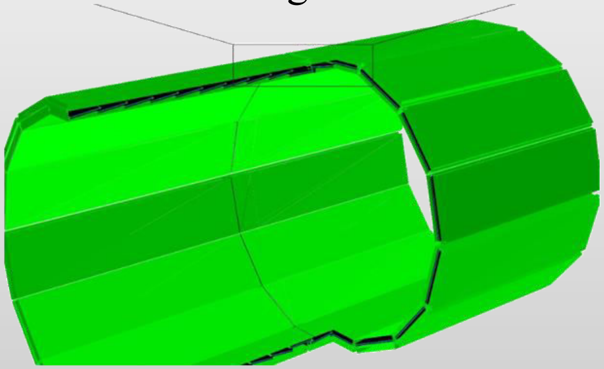

- FFD (Fast Forward Cherenkov Detector):
  - ✓ fast (~ 50 ps) event triggering → photons from $\pi^0$'s
  - ✓ $T_0$ for time-of-flight measurements (TOF and ECAL)



- FHCAL (Forward Hadron Calorimeter):
  - ✓ Fast signals for event triggering
  - ✓ poor $T_0$ (~ 1 ns) and event z-vertex resolution

- TOF ($|\eta| < 1.5$):
  - ✓ 280 fast signals for each MRPC chamber
  - ✓ no online timing information



two FHCAL detectors
at $2 < |\eta| < 5$,
~ 1x1 m$^2$ each

# Simulation chain

- Event generators: DCM-QGSM-SMM*:
  - ✓ inelastic collisions (~0-16 fm), realistic z-vertex with $\sigma \sim 50$ cm
- All detectors are simulated in the framework of the MpdRoot (Geant-4)
- Trigger logic depends on the configuration :
  - ✓ CLD mode: coincidence of signals, East & West

    $T_0 = (T_{East} + T_{West}) / 2 – L/c$

    $\text{z-vertex} = (T_{East} - T_{West}) / 2 * c$

  - ✓ FXT mode: only one side is used → only rough online $T_0$ and z-vertex
- Different trigger thresholds are considered, depend on background situation

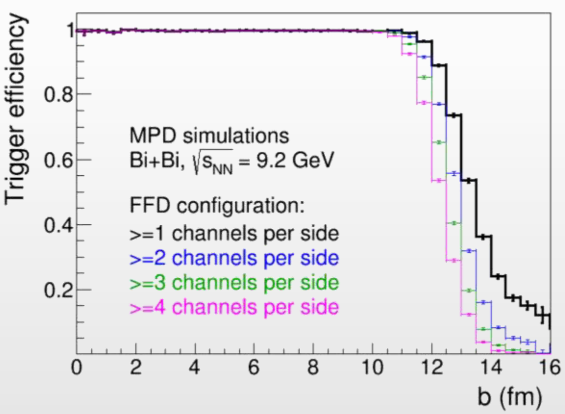
* Statistical Multifragmentation Model (**SMM**)

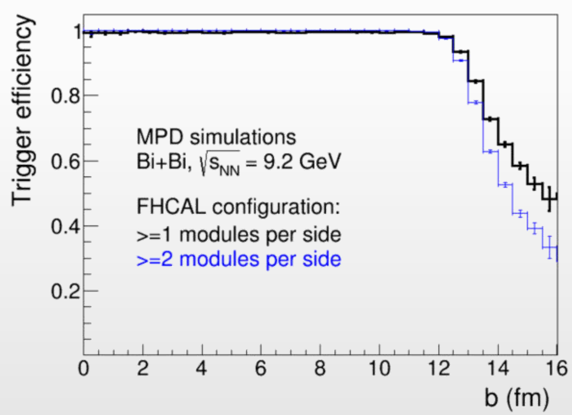
# Collider mode

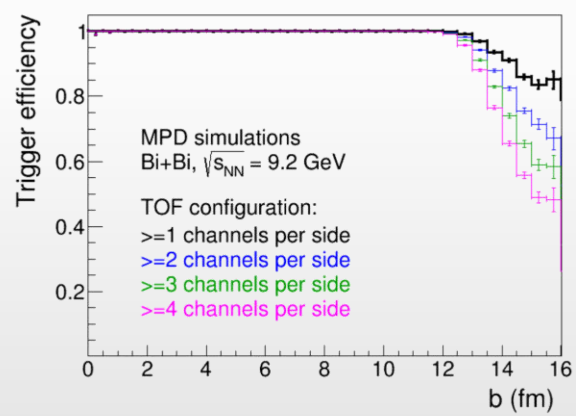
# CLD: trigger simulation, BiBi@9.2 GeV

- ❖ Trigger system consists of FFD (2.7 < |η| < 4.1), FHCAL (2 < |η| < 5) and TOF (|η| < 1.5)
- ❖ MPD trigger system challenges at NICA energies:
  - ✓ low multiplicity of particles produced in heavy-ion collisions
  - ✓ particles are not ultra-relativistic (even the spectator protons)
  - ✓ wide z-vertex distribution, σ ~ 20 cm (σ ~ 50 cm at start-up)
- ❖ DCM-QGSM-SMM, BiBi@9.2: trigger efficiency is 87-98% for different trigger configuration

- FFD trigger definition:
  - ✓ at least one fired module per side
  - ✓ meaningful times, 0 < time $_{E,W}$ < 50 ns
  - ✓ reconstructed |z-vertex| < 140 cm
- FHCAL trigger definition:
  - ✓ at least one fired module per side
  - ✓ meaningful times, 0 < time $_{E,W}$ < 50 ns
  - ✓ reconstructed |z-vertex| < 150 cm
- TOF trigger definition:
  - ✓ at least one fired MRPC




- ❖ Trigger system of the MPD based on FFD, FHCAL and TOF detectors provides high efficiency in HIC
- ❖ Efficiency ~ 100% efficiency for (semi)central collisions, drops for peripheral collisions
- ❖ FFD and FHCAL show lower efficiency compared to TOF located ta central rapidity

# CLD: trigger simulation, BiBi@9.2 GeV

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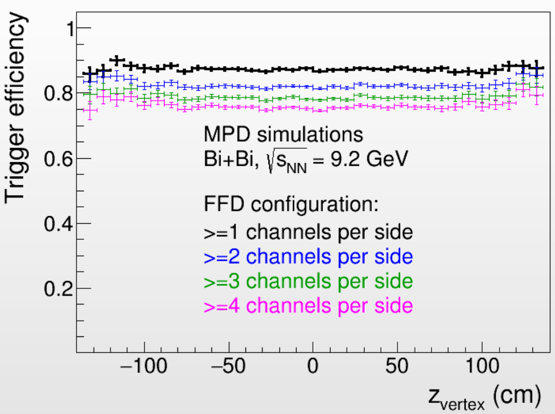
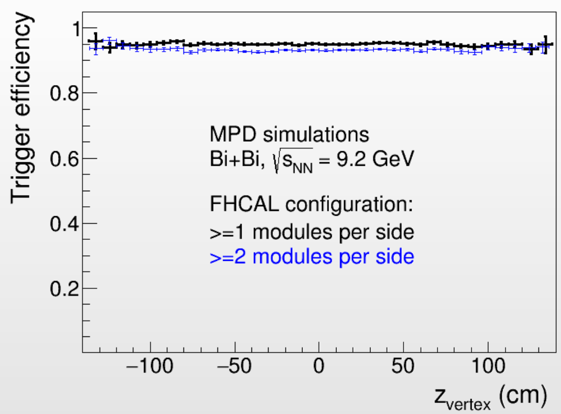
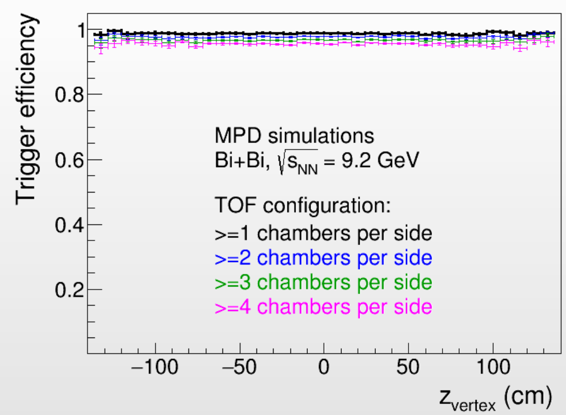
  - ✓ at least one fired MRPC



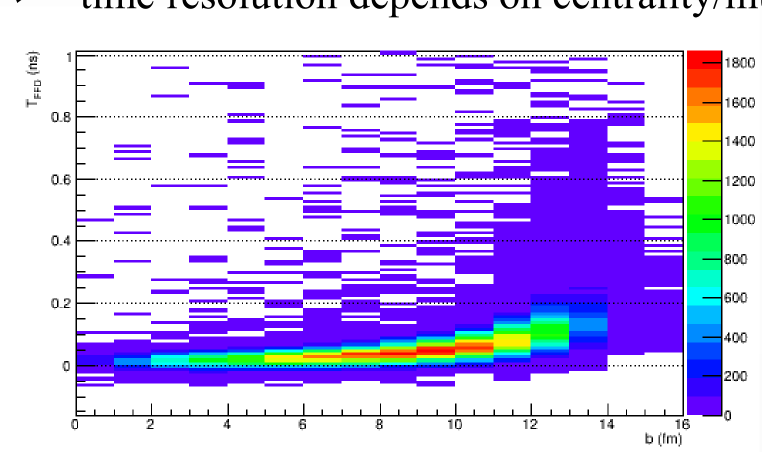



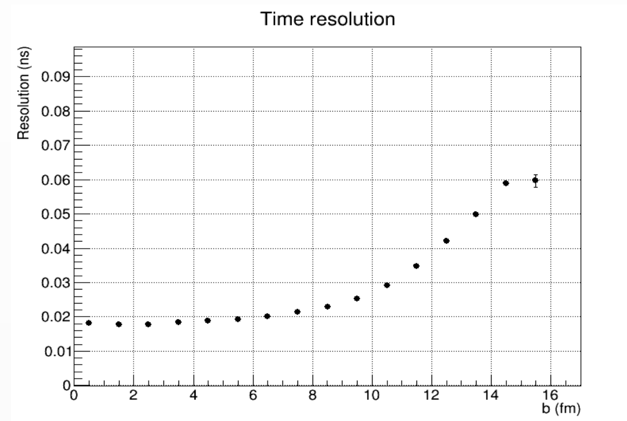

- Trigger efficiency is ~ constant in a wide range of |z-vertex| < 130 cm
- Similar analyses for light collision systems: ~ 50% for C+C, vanishingly small for d+d

**Need different solutions for triggering of light collision systems (forward detectors are not enough)**

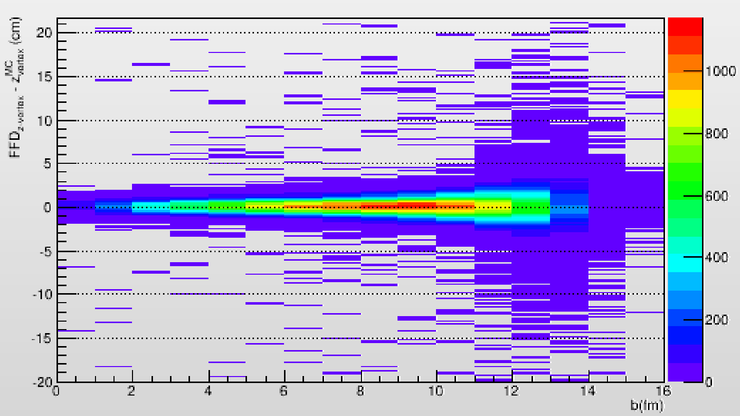
# FFD resolution

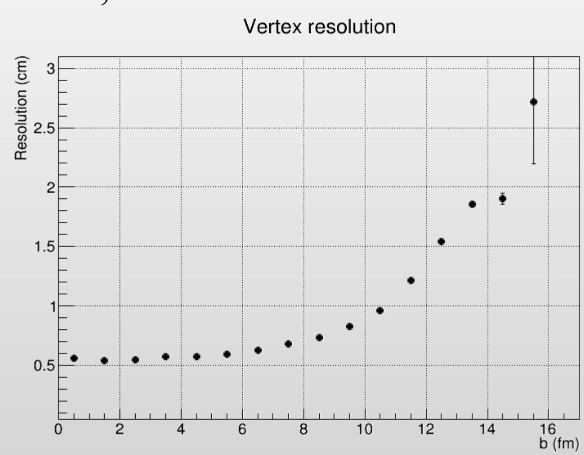
- $T_0$ resolution: $T_0 = (T_{FFDE} + T_{FFDW}) / 2 - L/c$
  - ✓ centrality bias
  - ✓ time resolution depends on centrality/multiplicity, <= 60 ps



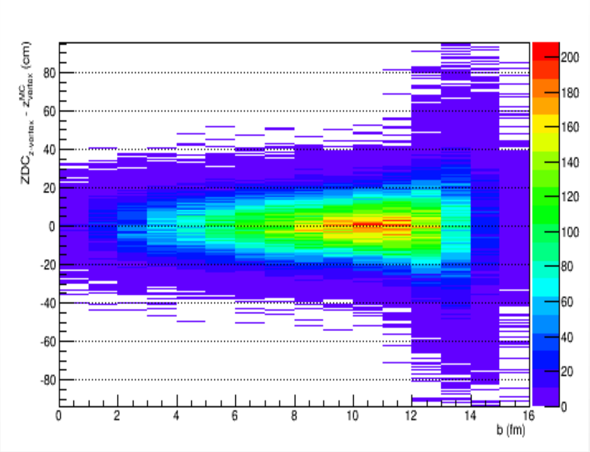

- Z-vertex resolution: z-vertex = $(T_{FFDW} - T_{FFDE}) / 2 * c$
  - ✓ no centrality bias
  - ✓ z-vertex resolution is worsens in peripheral collisions, 0.5-2 cm

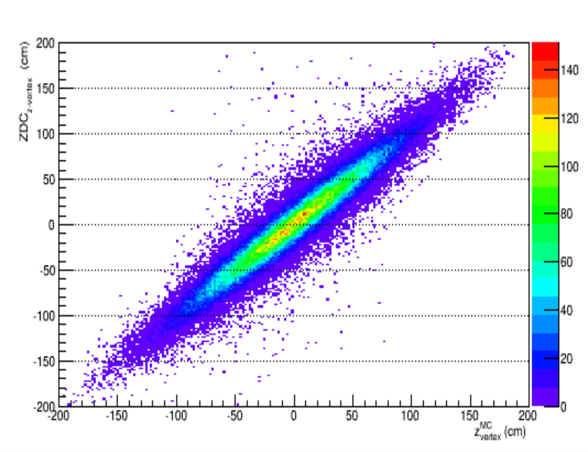


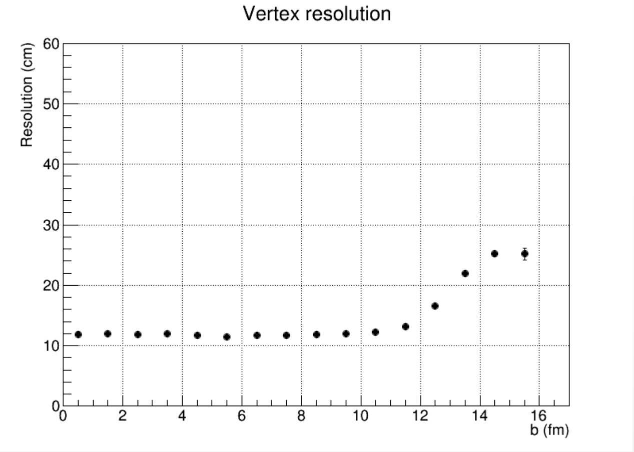



# FHCAL resolution

- $T_0$ resolution:
  - ✓ meaningless with module resolution of ~ 1 ns → no PID possible (TOF $T_0$??? - unlikely)
- z-vertex resolution:
  - ✓ no bias, no limitations for z-vertex range
  - ✓ vertex resolution is very modest, worse in peripheral collisions, 10-30 cm cm





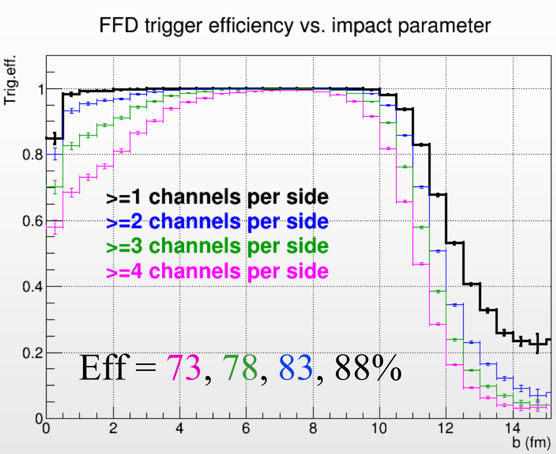

- Even rather poor resolution of the FHCAL is useful for background rejection

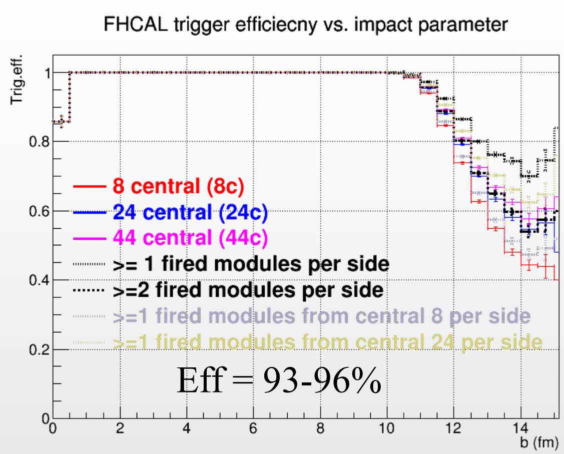
# Fixed-target mode

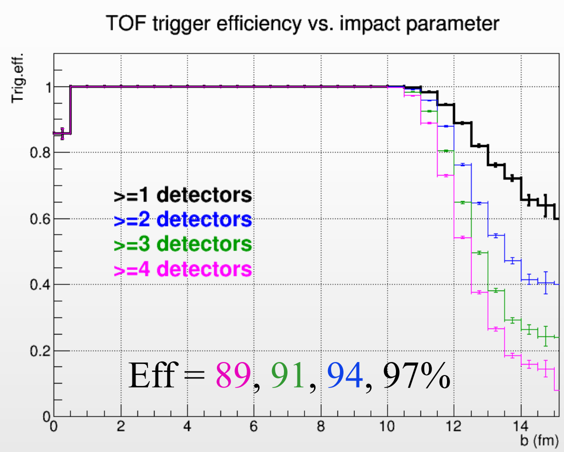
# FXT: trigger simulation, XeW@2.9 GeV

- Trigger system consists of FFD ($2.7 < |\eta| < 4.1$), FHCAL ($2 < |\eta| < 5$) and TOF ($|\eta| < 1.5$)
- MPD trigger system challenges at NICA energies:
  - ✓ no coincidence signals for East and West trigger detectors
  - ✓ particles are not ultra-relativistic (even spectator protons)
- DCM-QGSM-SMM, XeW@2.9: trigger efficiency is 87-98% for different trigger configuration

- FFD trigger definition:
  - ✓ at least one fired module (East)
  - ✓ meaningful times, $0 < time_E < 50$ ns
- FHCAL trigger definition:
  - ✓ at least one fired module (East)
  - ✓ meaningful times, $0 < time_E < 50$ ns
- TOF trigger definition:
  - ✓ at least one fired MRPC




- Trigger system of the MPD based on FFD, FHCAL and TOF detectors remains efficient in FXT

**Need to better understand background (beam-gas, beam-pipe, EM, etc.) and noise situation**

# Summary

- Trigger system of MPD is based on thee subsystems: FFD, FHCAL and TOF covering different rapidity and measuring different particles
- Existing trigger system is sufficient to trigger on heavy-ion collisions, event in the FXT mode
- Existing trigger system shows low efficiency for light collision systems → new solutions are required, especially for pp-like collisions
- Real performance of the trigger system is yet to be evaluated based on real data measurements, depends on background situation

The work has been supported by the Ministry of Science and Higher Education of the Russian Federation, Project "Fundamental and applied research at the NICA megascience experimental complex" № FSWU-2024-0024

# BACKUP

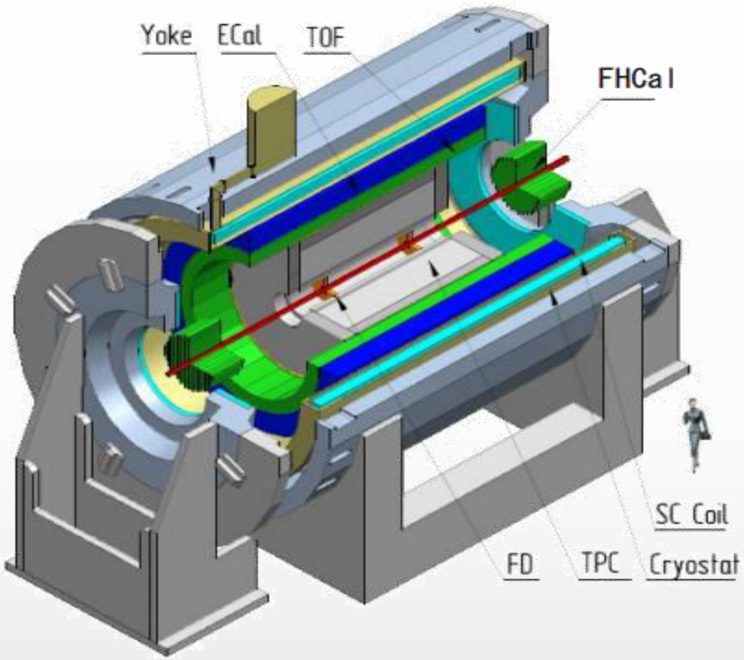
# Multi-Purpose Detector (MPD) Collaboration

***MPD*** *International Collaboration was established in* ***2018***
*to construct, commission and operate the detector*

***12*** *Countries,* ***>500*** *participants,* ***38*** *Institutes and* ***JINR***

## Organization

| | |
|---|---|
| *Acting Spokesperson:* | ***Victor Riabov*** |
| *Deputy Spokespersons:* | ***Zebo Tang, Arkadiy Taranenko*** |
| *Institutional Board Chair:* | ***Alejandro Ayala*** |
| *Project Manager:* | ***Slava Golovatyuk*** |

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*University of Science and Technology of China, Hefei,* ***China****;*
*Huzhou University, Huzhou,* ***China****;*
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*Shandong University, Shandong,* ***China****;*
*University of Chinese Academy of Sciences, Beijing,* ***China****;*
*University of South China,* ***China****;*
*Three Gorges University,* ***China****;*
*Institute of Modern Physics of CAS, Lanzhou,* ***China****;*
*Tbilisi State University, Tbilisi,* ***Georgia****;*
*Institute of Physics and Technology, Almaty,* ***Kazakhstan****;*
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