XV Latin American Symposium on High Energy Physics (SILAFAE)

Status of the MPD experiment at NICA.

Ivonne Maldonado

November 4th, 2024

Outline

1. Introduction
2. NICA complex
3. MPD experiment
4. MBB sub-detector
5. MPD physics program
6. Participation of Mexican Group
7. Summary

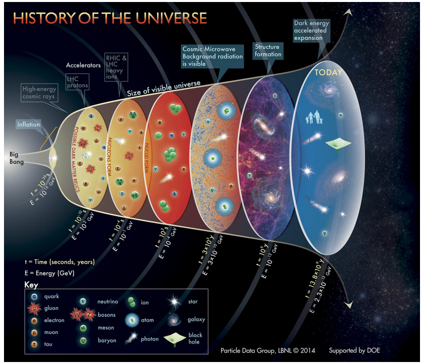
Heavy Ion Collisions (HIC)

- ★ QCD is a fundamental theory of the strong interactions
- ★ Only colorless particles are observed in the experiment » Confinement
- ★ QGP is a state of matter in which quarks and gluons are free to move in space » size of the nucleon

Two recipes for QGP Formation:

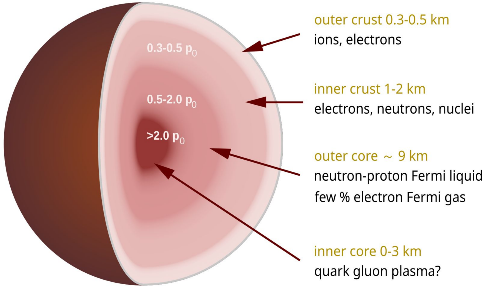
★ at high T, $\mu_B \approx 0$ » Early Universe

$\sqrt{s_{NN}} > 100$ GeV

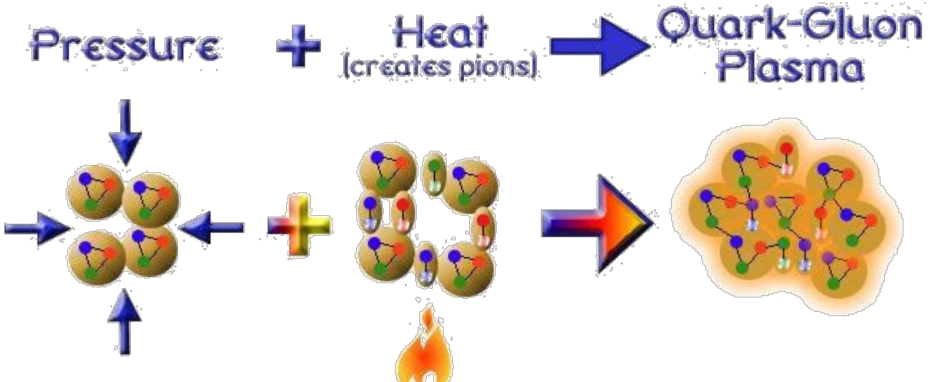


★ at intermediate T, high baryon density μ_B - Inner structure eof the compact stars and neutron STARS mergers

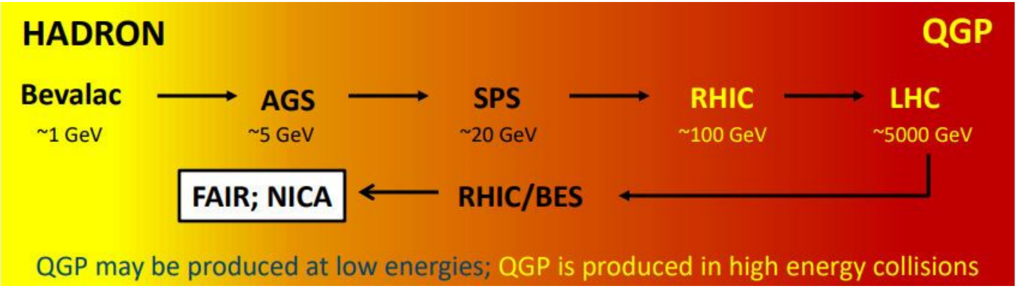
$2.4 \text{ GeV} < \sqrt{s_{NN}} < 11 \text{ GeV}$



Relativistic heavy Ion collisions - a combination of the two recipes



Short Heavy Ion-physics history



FXT
- **BEVALAC- LBNL** 1972 -1984 max. $\sqrt{s_{NN}}$ = 2.2 GeV
- **SPS - CERN** 1986 -2000 $\sqrt{s_{NN}}$ = 17.3 GeV
- **AGS - BNL** 1988 -1996 $\sqrt{s_{NN}}$ = 4.8 GeV
- **SIS 18 - GSI** 1990» $\sqrt{s_{NN}}$ = 2.4 GeV

Coll.
- **RHIC -BNL** 2000-2025 $\sqrt{s_{NN}}$ = 200 GeV
- **LHC - CERN** 2010 » $\sqrt{s_{NN}}$ = 5.02 TeV

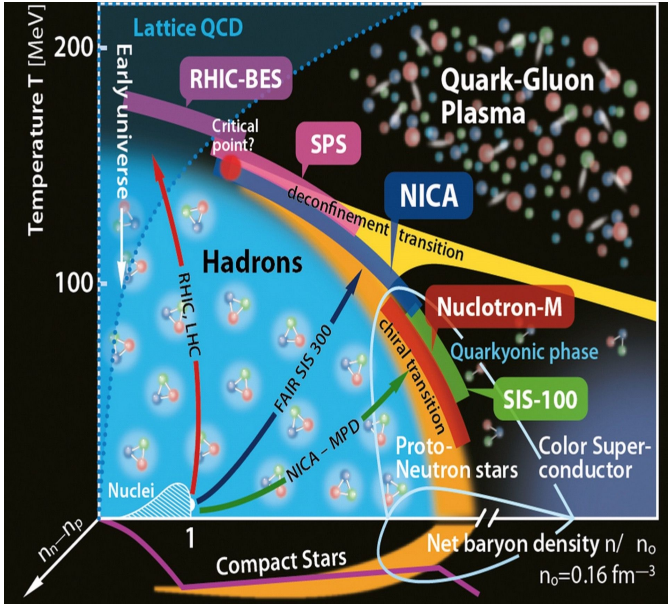
Near Future

FXT & Coll NICA -JINR 2024 $\sqrt{s_{NN}}$ = 11 GeV

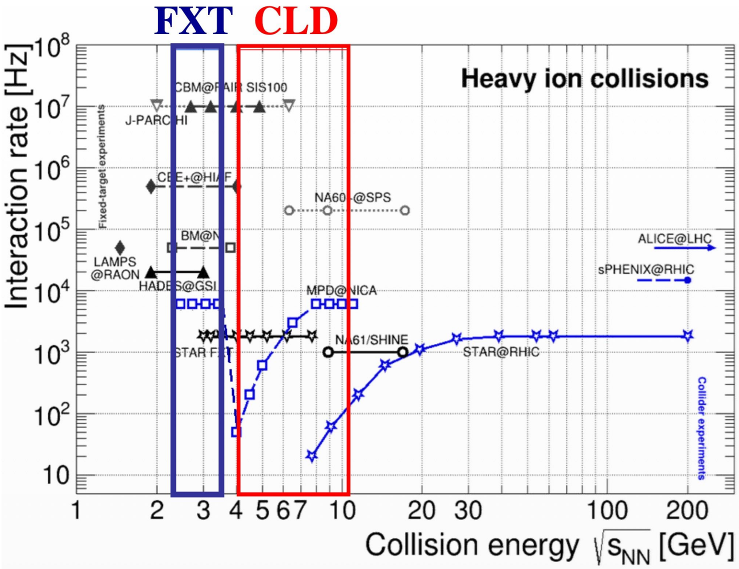
FXT SIS 100 - FAIR 2028? $\sqrt{s_{NN}}$ = 5 GeV

1970-2000 – nuclear equation of state (EoS), search for the quark-gluon plasma (QGP)
2005 – QGP formation was observed at RHIC and it behaves as almost perfect liquid
2005-2010 – LQCD predicts crossover phase transition at top RHIC and LHC (high T, μ ! ≈ 0)
Since 2010 – Beam energy scans to study QCD phase diagram: search for the 1st order phase transition and CEP at Intermediate T, high μ !

NICA: unique and complementary



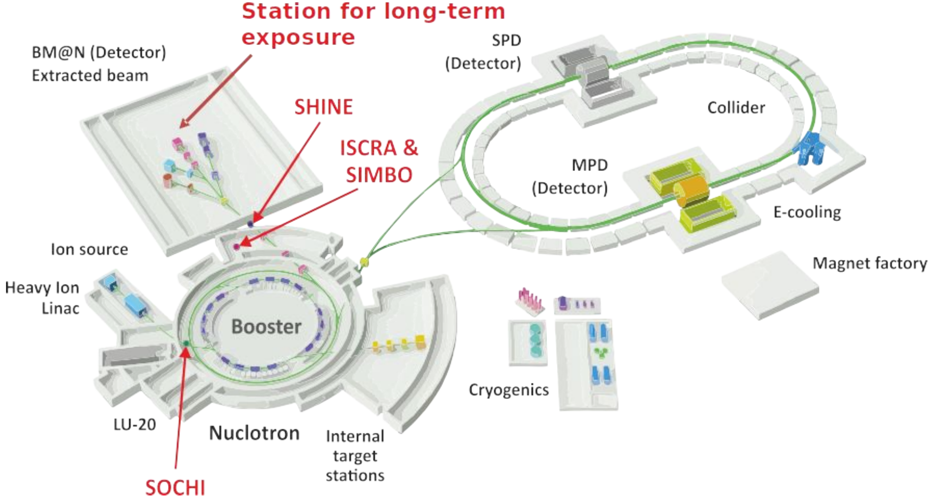
- At μ B ~ 0, smooth crossover (lattice QCD + data)
- At large μ B , we expect 1st order phase transition » QCD critical point
- Thermal model indicates that highest baryon density is achieved at NICA energy
- Energy range $\sqrt{s_{NN}}$ < 6 GeV » most appropriate to search CEP

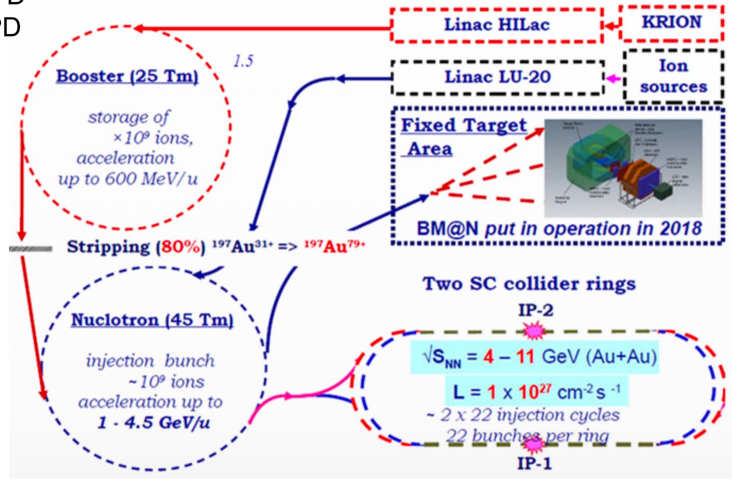


BM@N and MPD will study QCD Medium at extreme net baryon densities.
Many ongoing (NA61/Shine, STAR-BES) and future experiments (CBM at FAIR) in the same energy range

MPD at NICA Complex in Dubna

- Two injection chains
  - Ion sources (A/Z ≤ 3) → LINAC LU-20 (5 MeV/u) → Nuclotron
  - 1 ESIS KRION sources (A/Z ≤ 6) → HILAc (3.24 MeV/u) → Booster
- SC Booster synchrotron
  injection up to $2 \cdot 10^9$ accelerated up to ~ 600 MeV/u ions of $^{197}Au^{31+}$
- Nuclotron synchrotron
  injection up to $1 \cdot 10^9$ ions accelerated up to 1 − 4.5 GeV/n
  - BM@N
- Two Collider superconducting storage rings
  - MPD
  - SPD
- ARIADNA





Megascience project in Russia, which is approaching its full commissioning:

- ❖ Baryonic Matter at Nuclotron (**BM@N**) – fixed-target experiment, first physics run Xe+CsI 2022–2023
- ❖ Multi-Purpose Detector (**MPD**) – start of operation in 2025–2026
- ❖ Spin Physics Detector (**SPD**) – operating on polarized deuterons later on
- ❖ Applied Research Infrastructure for Advanced Developments at NICA fAcility (**ARIADNA**)

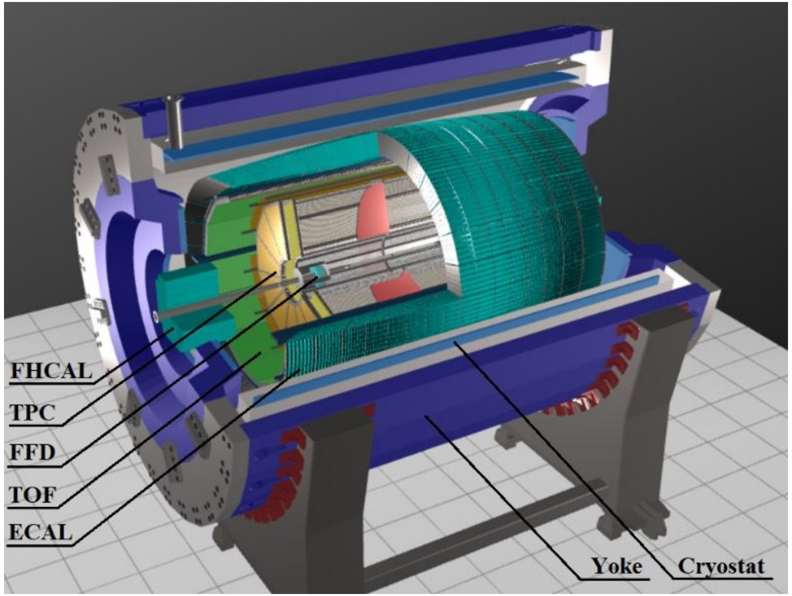
NICA Accelerator Complex

Multi-Purpose Detector (MPD) at NICA

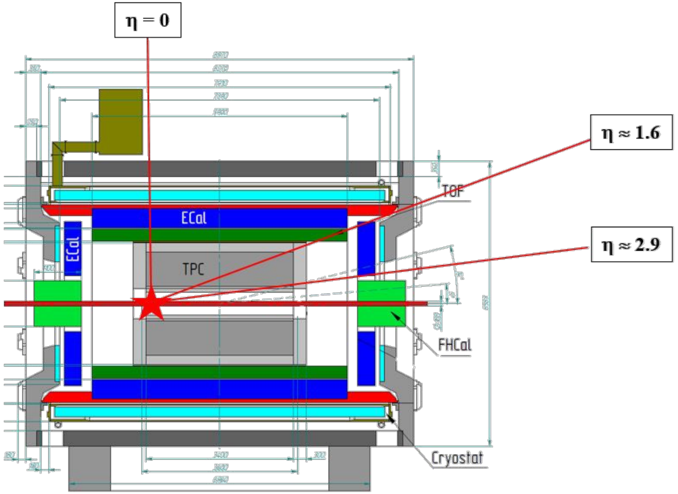
The central barrel of the MPD is built as a classical magnetic spectrometer with a full coverage in azimuthal angle ($|\Delta\varphi| < 2\pi$) and a wide coverage in pseudorapidity ($|\Delta\eta| < 1.5$)

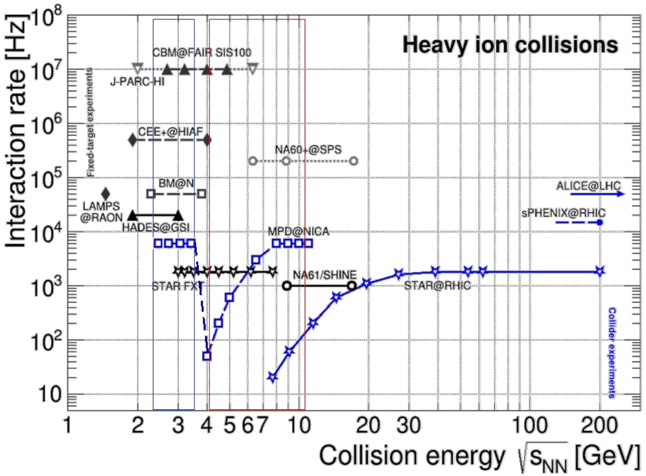
Main subsystems at Stage-I:

★ **TPC** ($\eta \leq 1.6$): charged particle tracking + momentum reconstruction + dE/dx identification
★ **TOF** ($\eta \leq 1.4$): charged particle identification
★ **ECal** ($2.9 < \eta < 1.4$): energy and PID for $\gamma/e\pm$
★ **FHCal** ($2 < \eta < 5$) and **FFD** ($2.9 < \eta < 3.3$): event triggering + event geometry



Fixed Target Operation





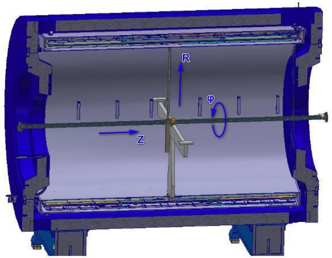
- MPD-CLD (Collider) and MPD-FXT (Fixed Target) options approved by accelerator department
- Collider mode: two beams, $\sqrt{s_{NN}}$ = 4-11 GeV
- Fixed-target mode: one beam + thin wire (~ 100 μm) close to the edge of the MPD central barrel:
  - extends energy range of MPD to $\sqrt{s_{NN}}$ = 2.4-3.5 GeV (overlap with HADES, BM@N and CBM)
  - high event rate

Expected beams at the first year(s) of operation (Stage-I):

- MPD-CLD: Xe/Bi + Xe/Bi at $\sqrt{s_{NN}}$ ~ 7 GeV, reduced luminosity collision rate ~ 50 Hz
- MPD-FXT: Xe/Bi + W at $\sqrt{s_{NN}}$ ~ 3 GeV

Detector Construction

SC Solenoid + Iron Yoke + Mapper



- Test cooling performed to 70°K in March 2024
- Start of cooling to LHe and magnetic field measurements in the second half of the 2024
- Magnetic field mapper is ready

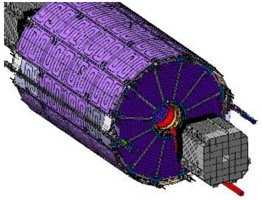
Support structure

Carbon fiber support frame delivered and ready to use

TOF - ready

28 modules are produced and ready for installation

TPC - Central Tracking System

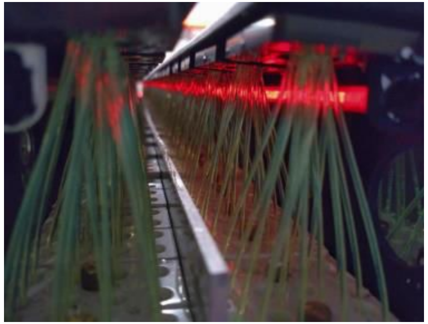


TPC cylinders, central membrane, service wheels, rails, readout chambers, gas system – ready; TPC gas volume assembly and HV/leakage tests – ongoing

• TPC + ECAL cooling systems commissioned in early 2025

ECal

Produced in consortium with China institutes



83% of calorimeter will be ready in 2024 the rest of the modules will be ready by the April 2025

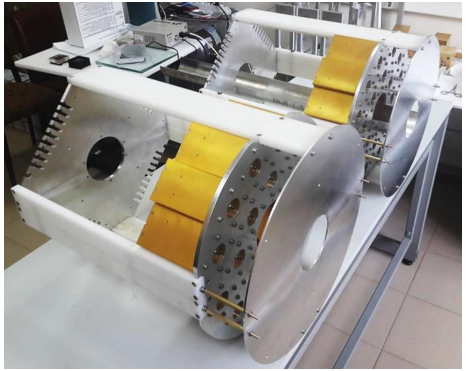
Forward subsystems in production

FHCal

FHCal assembled on the platform, ready to be installed in the Poles (modules are equipped with FEE)

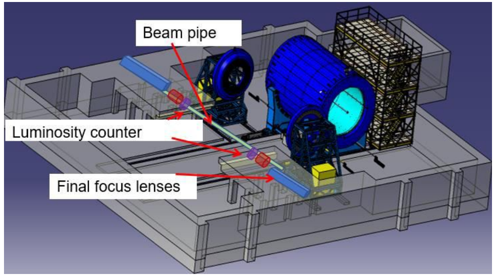
FFD

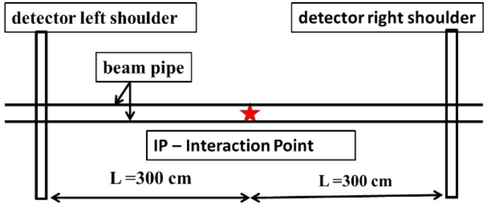
Cherenkov modules of FFDE and FFDW, mechanics for installation in container with beam pipe are available, Long term tests with cosmic rays & laser ongoing

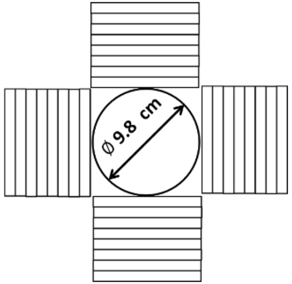


FHCAL modules have been produced and tested installation in autumn 2024

Beam and luminosity monitoring







Measurement of transverse sizes of the bunches
Transverse and longitudinal convergence of bunches
Vertices distribution along the beam

Assembly of the main components of the detector for the Run on the collider beam – June 2025

Mini BeBe

ITS-miniBeBe cooperation - development for different stages

- MiniBeBe detector was proposed as a wake-up trigger for TOF detector.

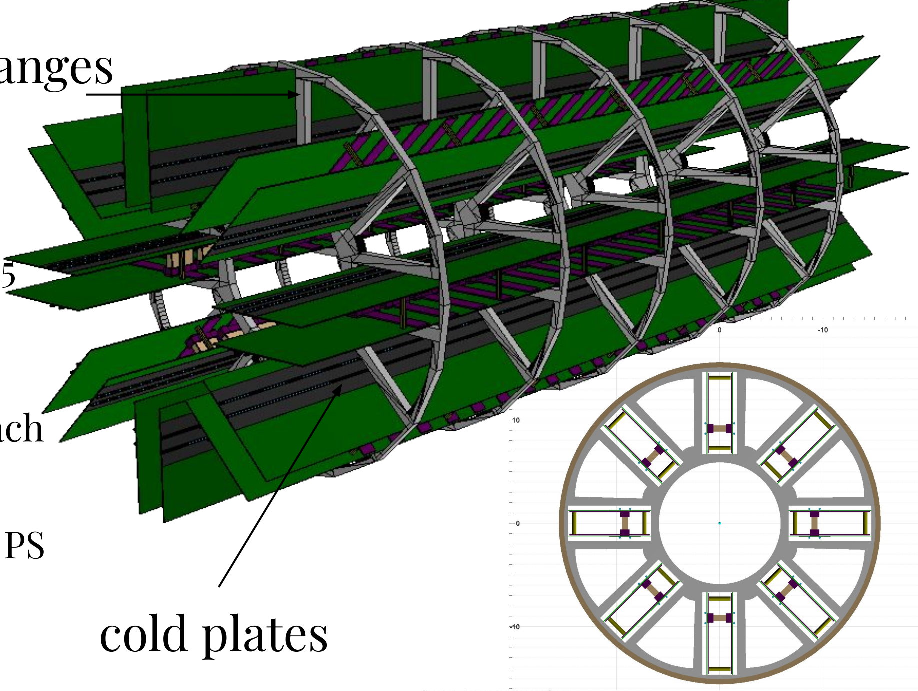
- Should be efficient for low multiplicity events like p+p, p+A and A+A.

  In which other systems are not efficient

- Designed to be used only in Phase 0, before ITS installation

Team: M. Herrera, M.E. Patiño, M. Alvarado, I. Maldonado, A. Ayala, W. Bietenholz, E. Cuautle, I. Domínguez, L. A. Hernández, I. Luna, P. Martínez-Torres, A. Raya, U. Sáenz-Trujillo, M.E. Tejeda-Yeomans, G. Tinoco

MiniBeBe - Geometry



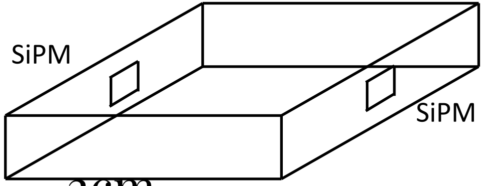
It consist on **160 plastic scintillators (PS) EJ232** - 20x20x5 mm³ » covering an area of 64000 mm² in a coaxial symmetry.

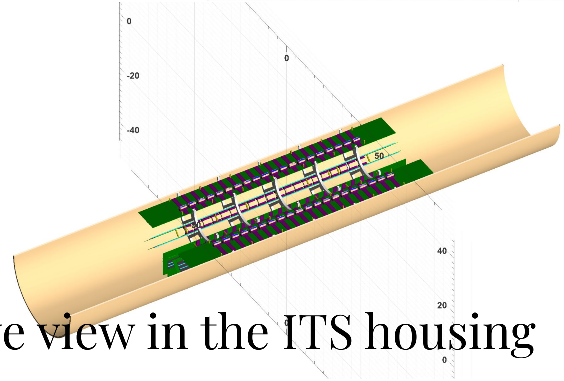
Each **PS** has two **SiPM Hamamatsu S13360-3050PE** at each side 3.07x3.07 mm²

The PCBs are connected to the SiPMs at each side of the PS providing an **H-shaped** rail (80 x 800 mm²).

Each SiPM-PS-SiPM element is fixed to the PCBs with a carbon fiber supports.

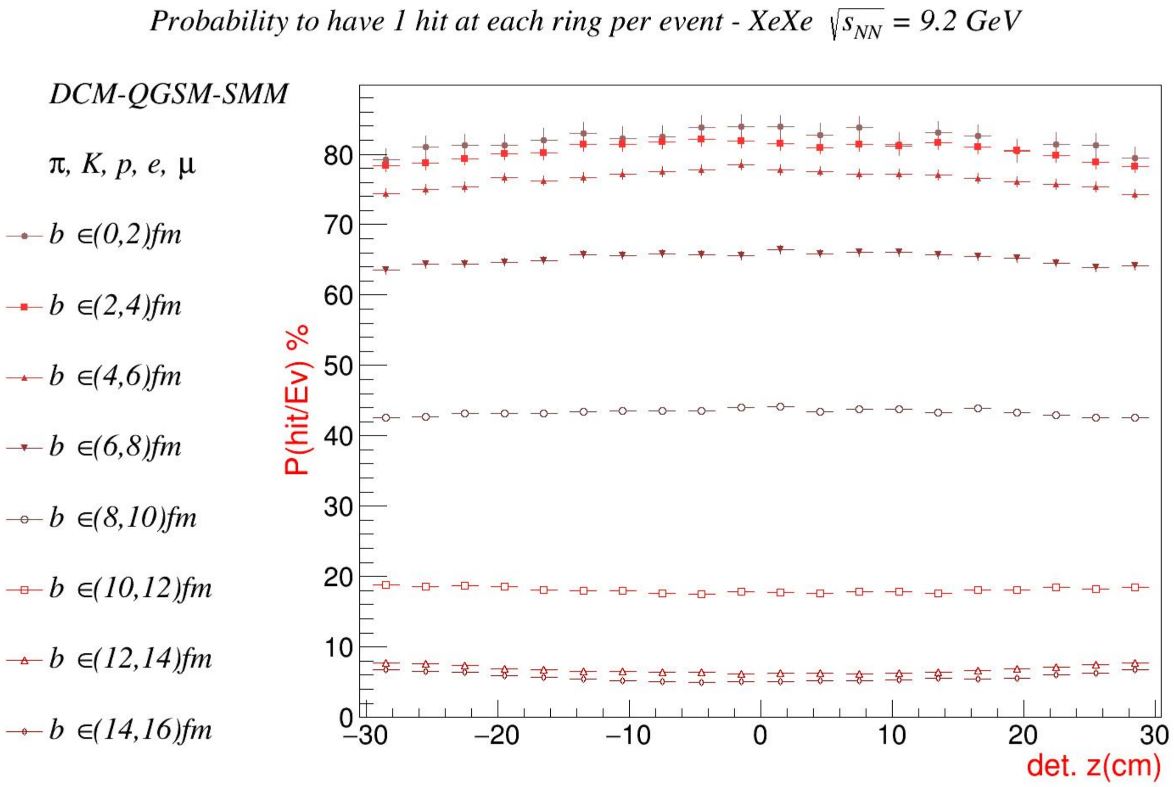
Attached to PCBs are the Carbon Fiber cold plates (same of ITS)





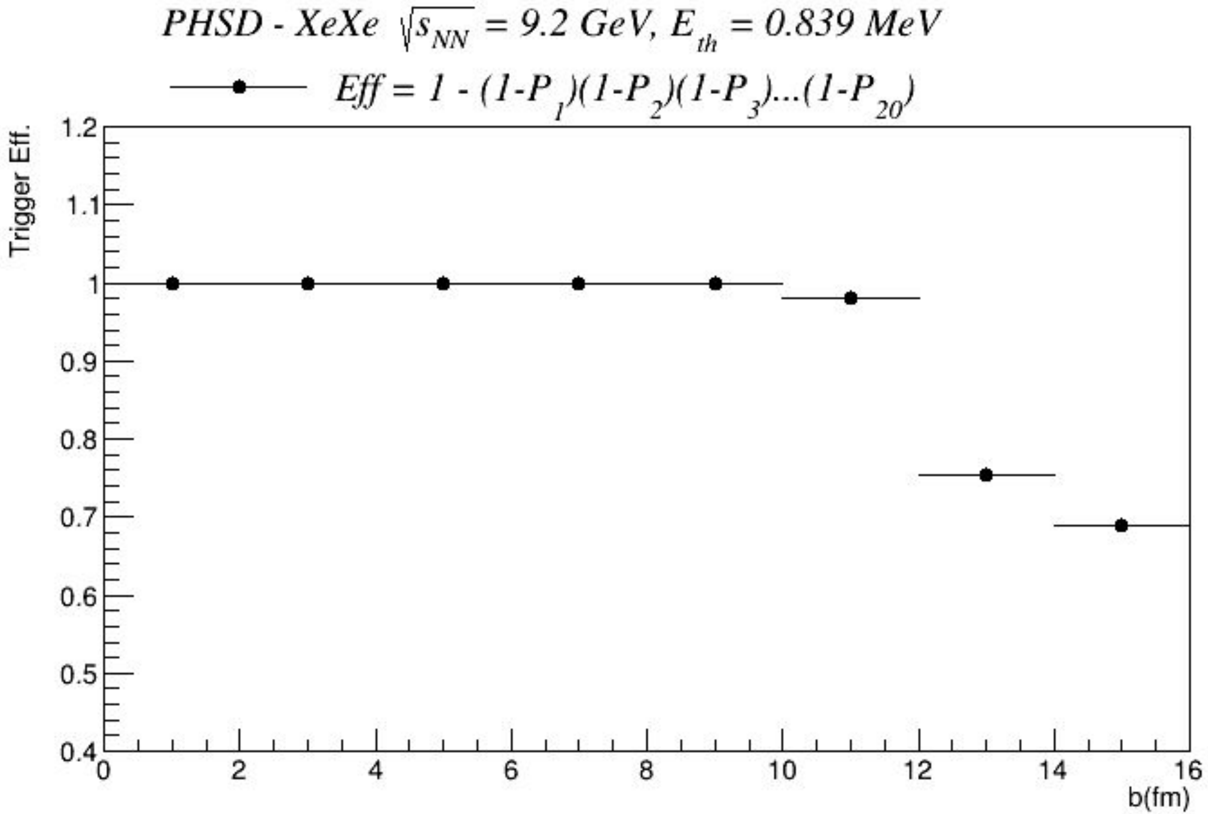
Perspective view in the ITS housing

Xe+Xe collisions, Probability to 1 hit as a function of z - position

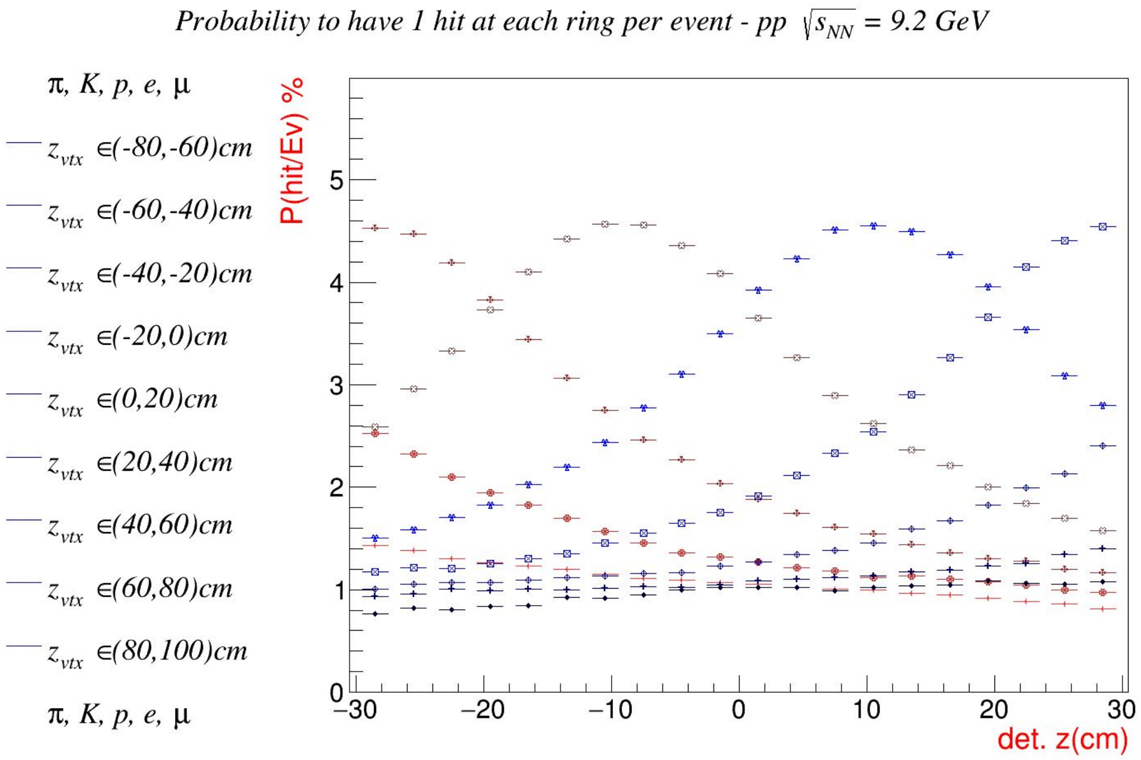


At least one charged MbbPoint at each ring, for events with different impact parameter

Trigger Efficiency as a function of Impact Parameter for Xe+Xe



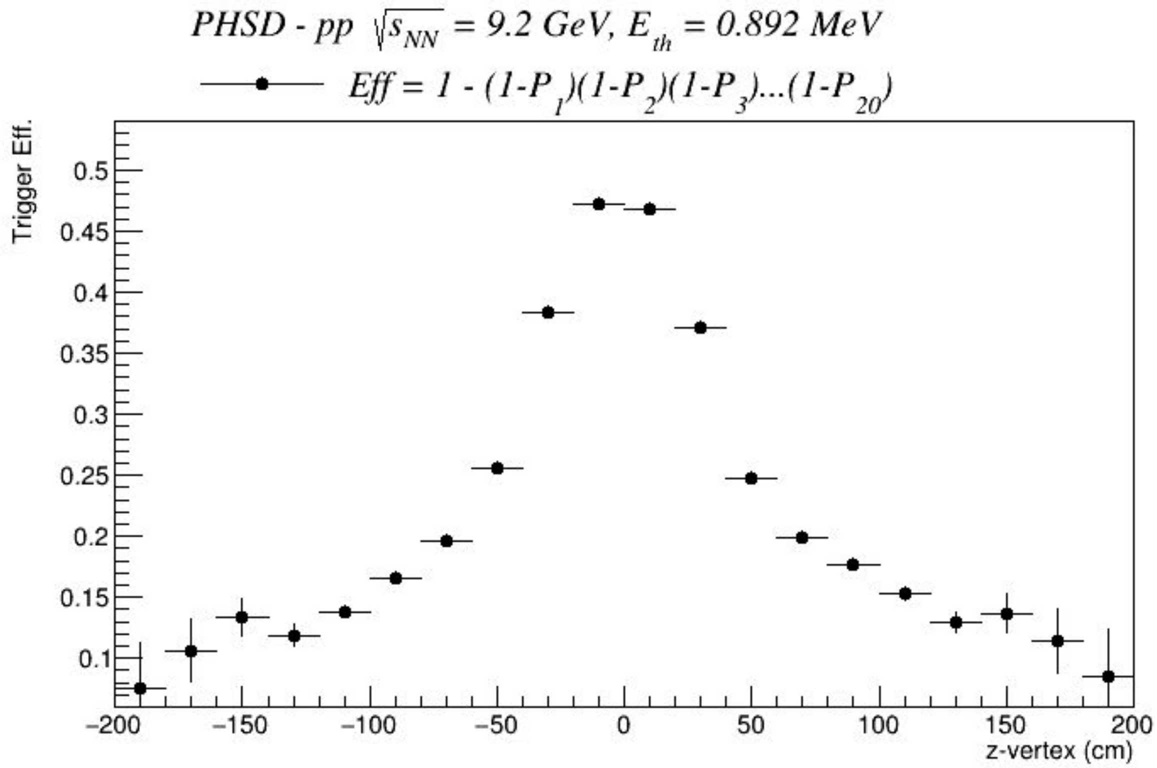
p+p collisions, Probability to 1 hit as a function of z - position



The smallest collision system

At least one charged MbbPoint at each ring, for events with different primary vertex position

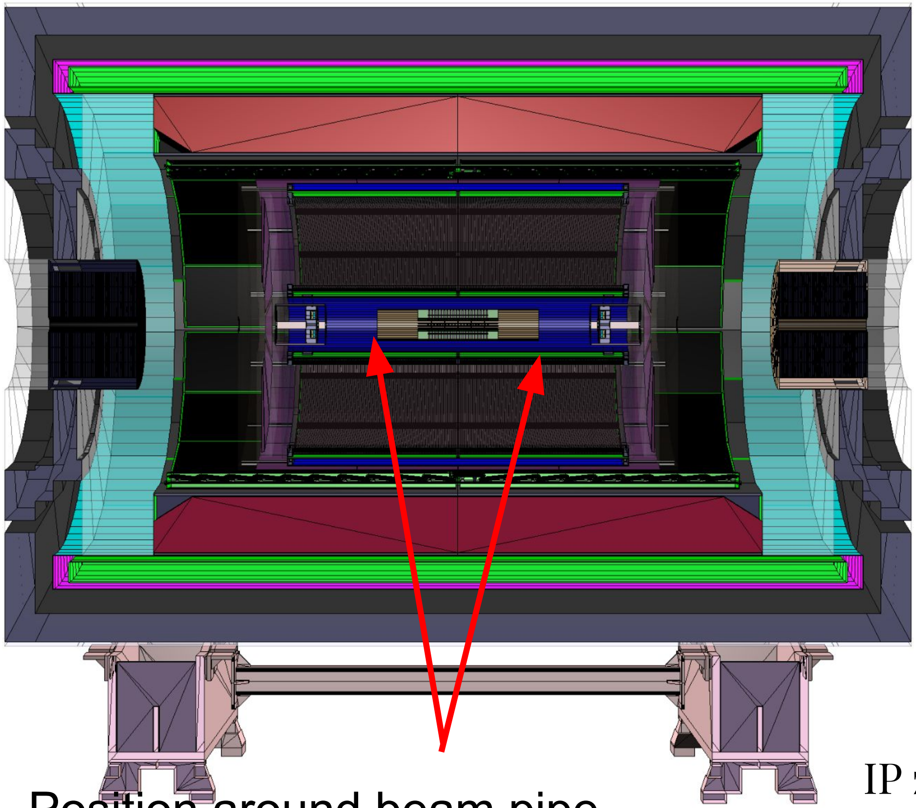
Trigger Efficiency as a function of Impact Parameter for p+p



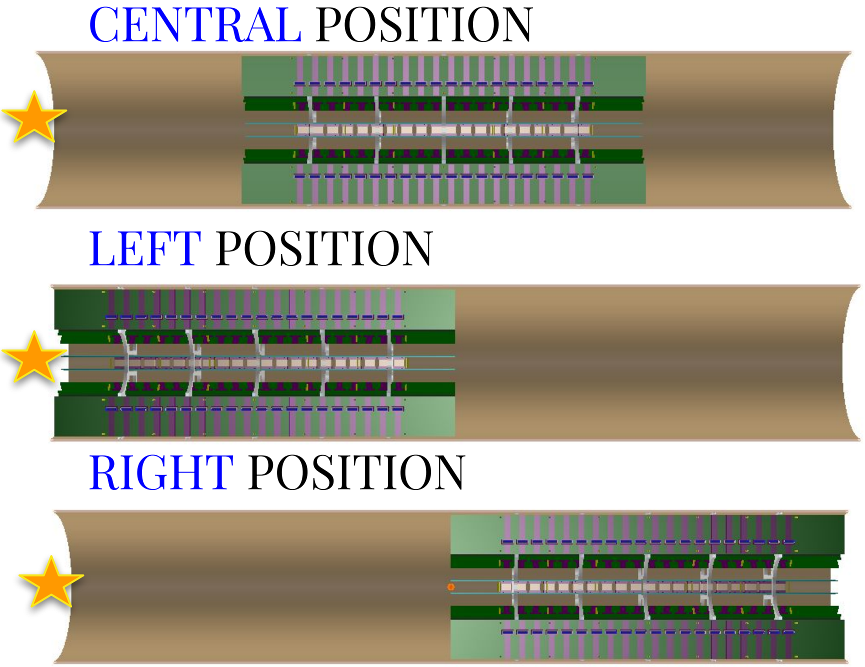
Trigger efficiency is not uniform

Trigger Efficiency > 35% only for events with primary vertex ∈ (-40,40)cm

Position in the MPD has been tested for Fixed Target Mode

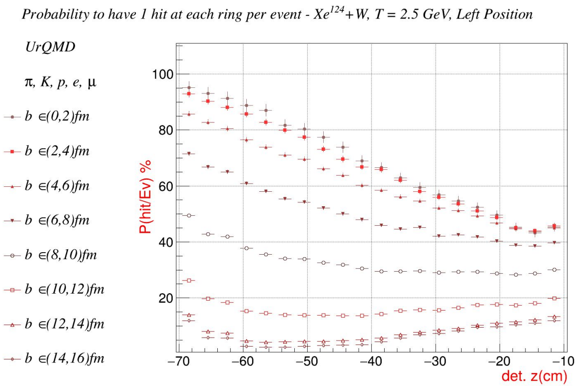


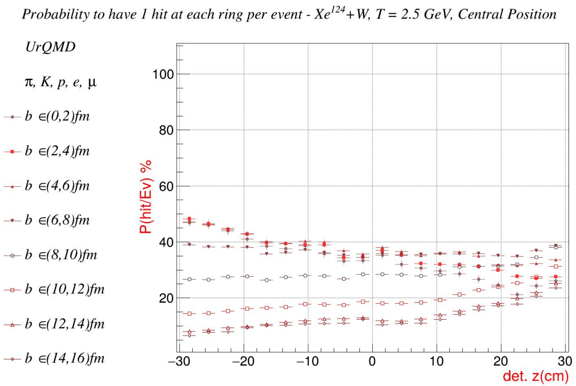
Position around beam pipe
in Central Position

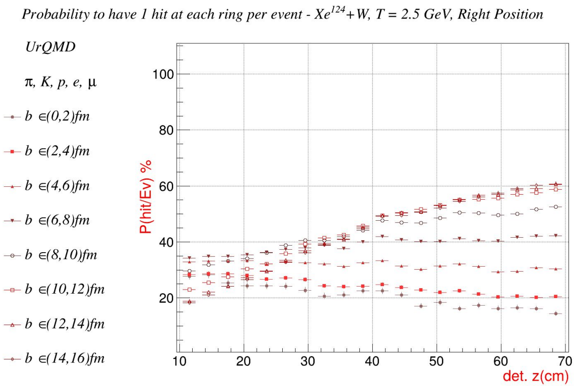


IP z=-85cm distance between IP and center of MBB:
central ↠ 85cm, left ↠ 45 cm and right ↠ 125cm

Probability to 1 hit at each ring as a function of impact parameter







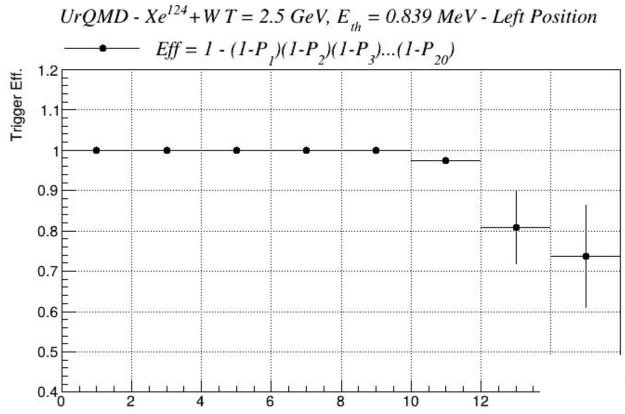
MbbHit at each ring, for LEFT Position

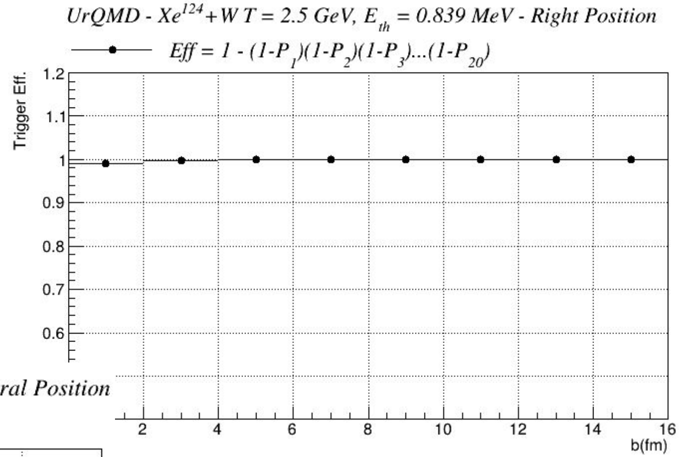
Each ring corresponds to position on z direction of the plastic scintillators

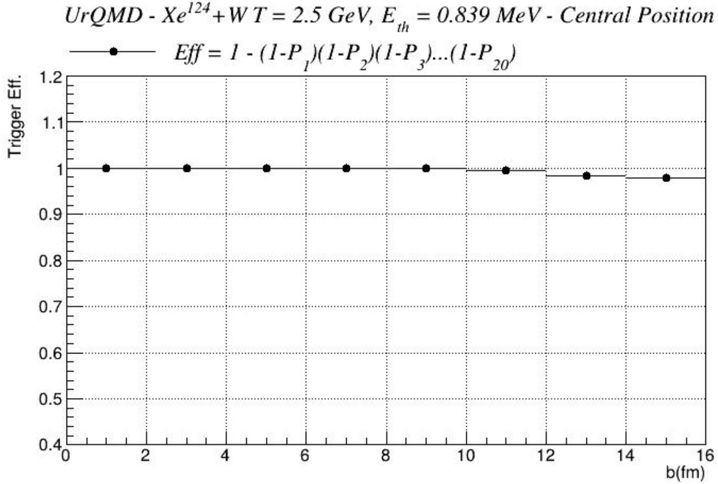
At least one charged MbbHit at each ring, for CENTRAL Position

At least one charged MbbHit at each ring, for RIGHT Position

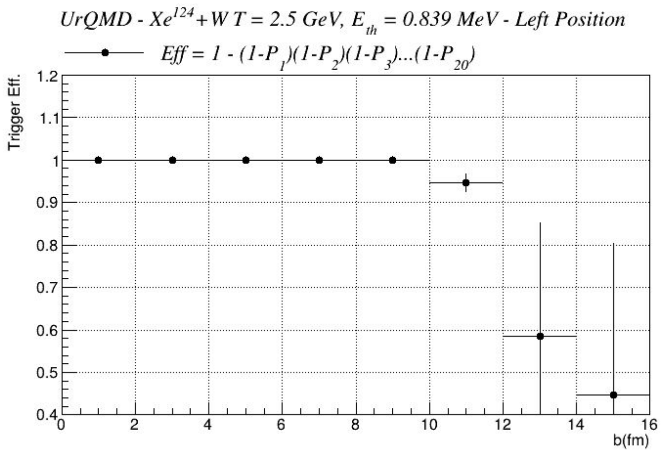
Trigger Efficiency as a function of Impact Parameter with 1 hit

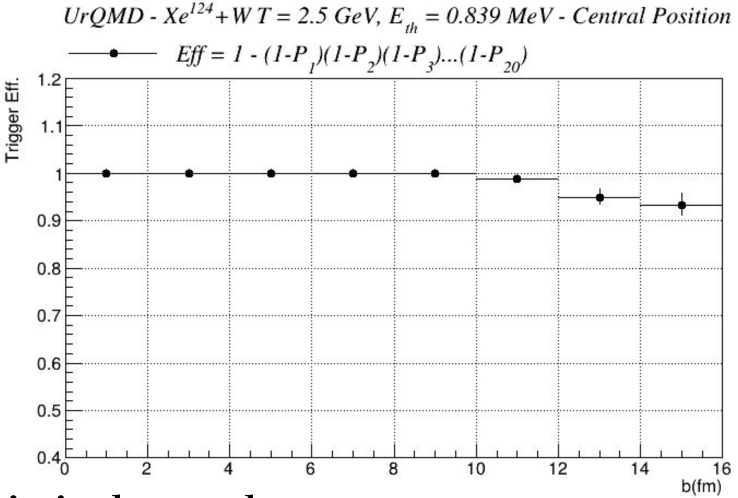




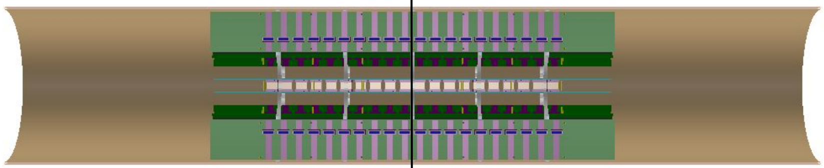


Trigger Efficiency as a function of b with 1 hit at each side

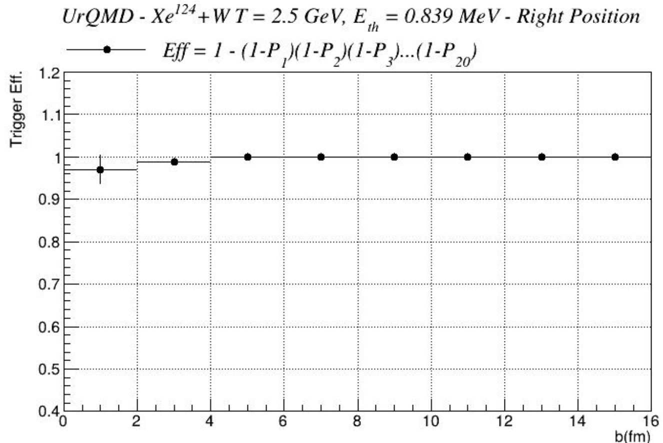




Modules are divided: read out is independent

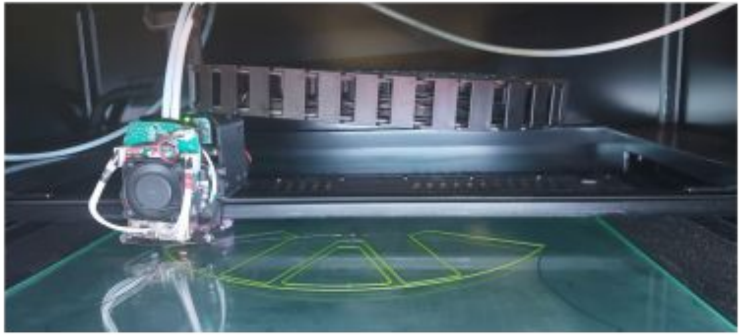


We can get the efficiency with 1 hit at each half



Mechanical Support

Prototype -printed at JINR

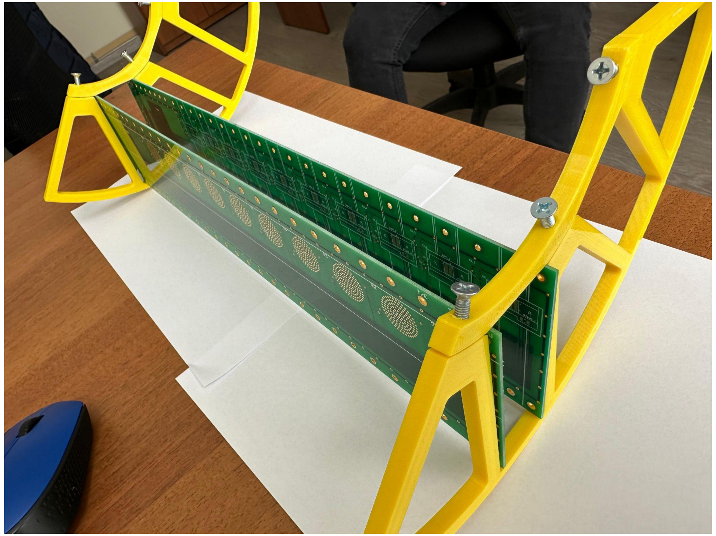


3D printing

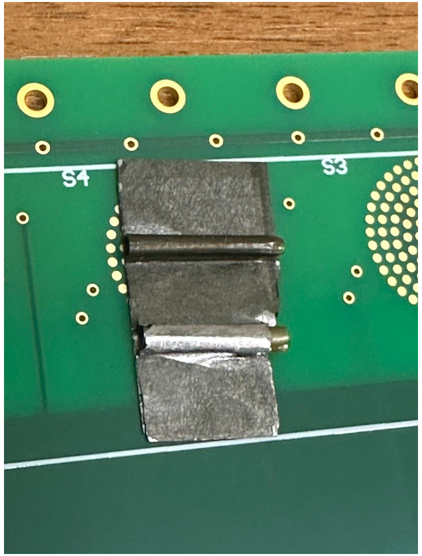
Filaments

Flanges for rails support

Prototype - half module



Half module fixed with the flanges

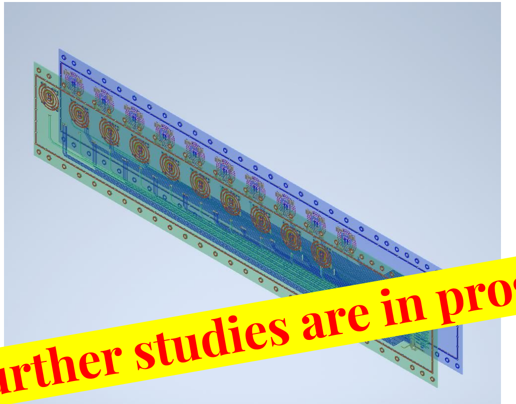


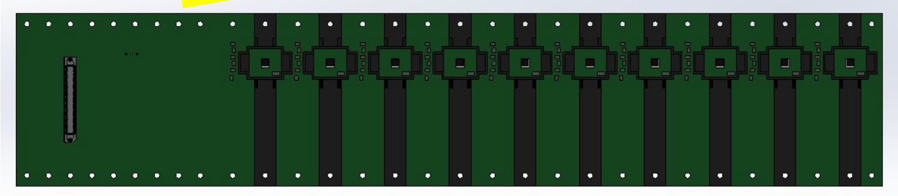
Cooling plates superposition

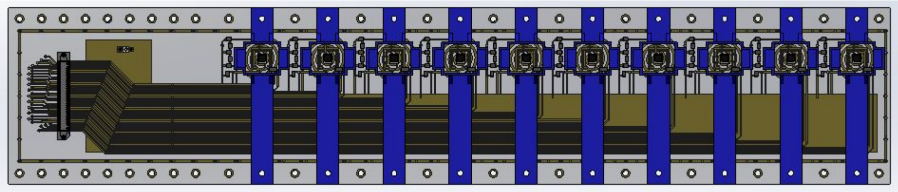
Frontal view, PS and screws

Electronic Module

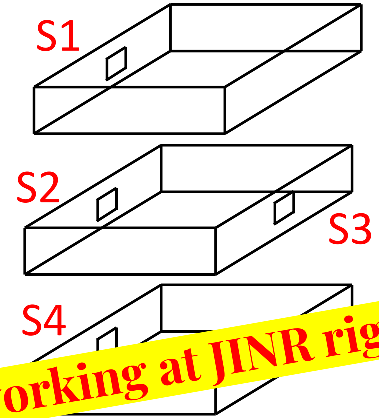
Electronic board right and left for 10 plastic scintillators. Half module

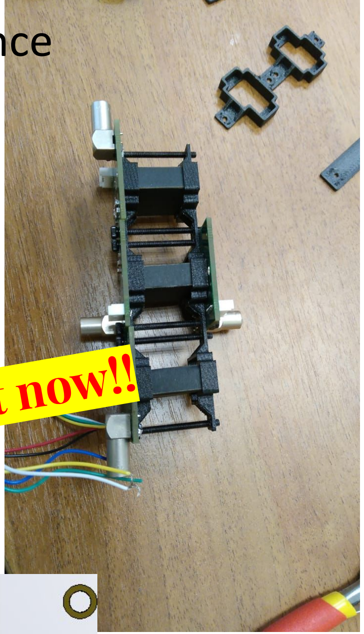




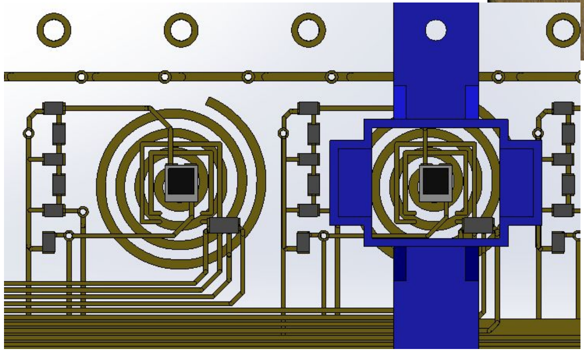


Array to test time coincidence





Further studies are in progress by team working at JINR right now!!



Circular copper heatsink that connects the SiPM to the cooling plate

Multi-Purpose Detector (MPD) Collaboration

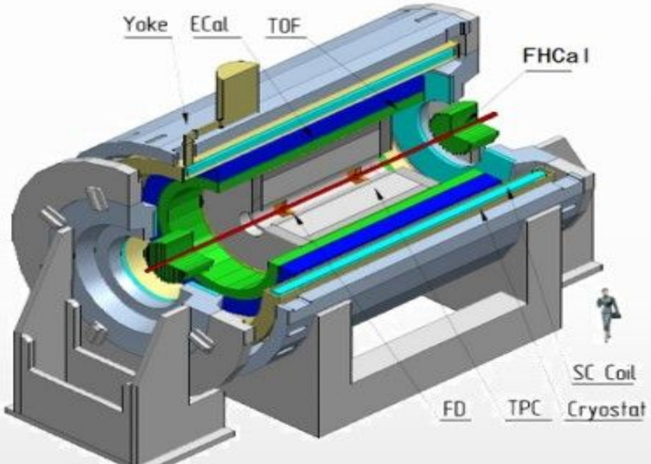
MPD

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

12** Countries, **>500** participants, **39** Institutes and **JINR

Organization

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



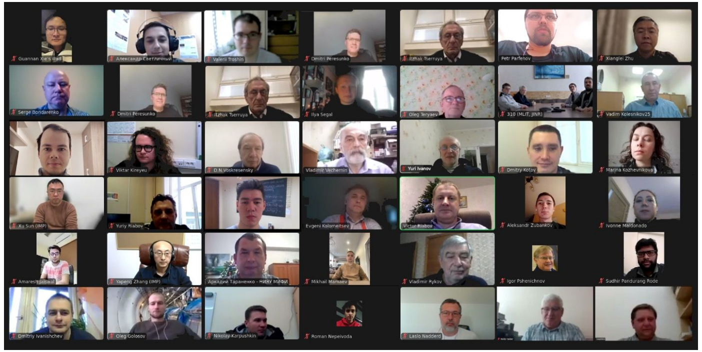
***Joint Institute for Nuclear Research, Dubna**;*
*A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;***
*SSI "Joint Institute for Energy and Nuclear Research – Sosny" of the National Academy of Sciences of Belarus, Minsk, **Belarus***
*University of Plovdiv, **Bulgaria;***
*Tsinghua University, Beijing, **China**;*
*University of Science and Technology of China, Hefei, **China**;*
*Huzhou University, Huzhou, **China**;*
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;*
*Central China Normal University, **China**;*
*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**;*
*Benemérita Universidad Autónoma de Puebla, **Mexico**;*
*Centro de Investigación y de Estudios Avanzados, **Mexico**;*
*Instituto de Ciencias Nucleares, UNAM, **Mexico**;*
*Universidad Autónoma de Sinaloa, **Mexico**;*
*Universidad Autónoma Metropolitana, **Mexico**;*
*Universidad de Colima, **Mexico**;*
*Universidad de Sonora, **Mexico**;*
*Universidad Michoacana de San Nicolás de Hidalgo, **Mexico***
*Institute of Applied Physics, Chisinev, **Moldova**;*
*Institute of Physics and Technology, **Mongolia**;*

*Belgorod National Research University, **Russia**;*
*D.V.Skobeltsyn Institute of Nuclear Physics, Moscow, **Russia**;*
*High School of Economics University, Moscow, **Russia**;*
*Institute for Nuclear Research of the RAS, Moscow, **Russia**;*
*Moscow Institute of Physics and Technology, **Russia;***
*National Research Nuclear University MEPhI , Moscow, **Russia**;*
*National Research Center "Kurchatov Institute", **Russia;***
*North Osetian State University, **Russia**;*
*Peter the Great St. Petersburg Polytechnic University Saint Petersburg, **Russia**;*
*Petersburg Nuclear Physics Institute, Gatchina, **Russia**;*
*Plekhanov Russian University of Economics, Moscow, **Russia**;*
*SaintPetersburg State University, **Russia**;*
*Vinča Institute of Nuclear Sciences, **Serbia**;*
*Pavol Jozef Šafárik University, Košice, **Slovakia***

NICA

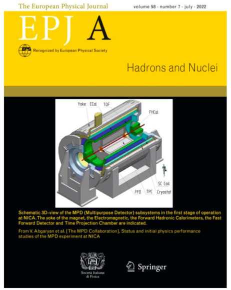
MPD publications, conferences and workshops

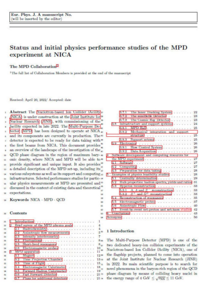
- International Workshop on physics performance studies at NICA
  - http://indico.oris.mephi.ru/event/301
  - 5 workshops since 2019



2nd China-Russia Joint Workshop on NICA Facility
indico.jinr.ru/event/4642

Over 50 reports at international conferences and workshops





Status and initial physics performance studies
of the MPD, Eur.Phys.J.A 58 (2022) 7, 140

MPD Physics Program

G. Feofilov, P. Parfenov

Global observables

- Total event multiplicity
- Total event energy
- Centrality determination
- Total cross-section measurement
- Event plane measurement at all rapidities
- Spectator measurement

V. Kolesnikov, Xianglei Zhu

Spectra of light flavor and hypernuclei

- Light flavor spectra
- Hyperons and hypernuclei
- Total particle yields and yield ratios
- Kinematic and chemical properties of the event
- Mapping QCD Phase Diag.

K. Mikhailov, A. Taranenko

Correlations and Fluctuations

- Collective flow for hadrons
- Vorticity, Λ polarization
- E-by-E fluctuation of multiplicity, momentum and conserved quantities
- Femtoscopy
- Forward-Backward corr.
- Jet-like correlations

D. Peresunko, Chi Yang

Electromagnetic probes

- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

Wangmei Zha, A. Zinchenko

Heavy flavor

- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF electrons
- Explore production at charm threshold

Big Data Production

Physics feasibility studies using centralized large-scale MC productions ↠ consistent picture of the MPD physics capabilities with the first data sets, preparation for real data analyses.

A new cycle of productions (https://mpdforum.jinr.ru/c/mcprod/26):

Centralized Analysis Framework for access and analysis of data ↠ Analysis Train:

Regular runs on request since September, 2023 ↠ ~12 hours to process 50M events for 10-15 wagons

Many new services and improvements (improved PID parametrizations, new wagons):

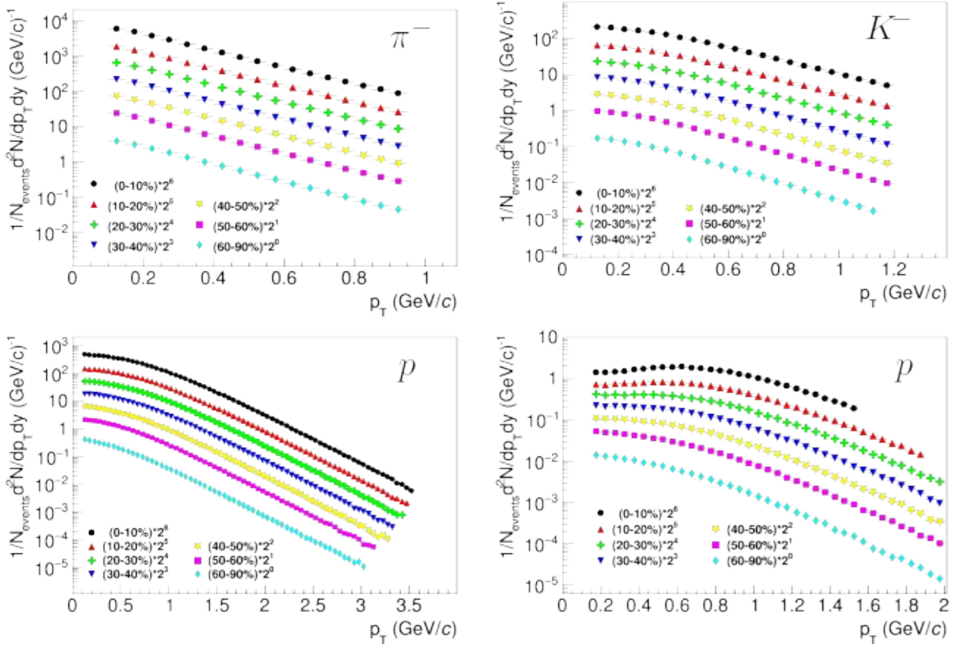
New standard for physics feasibility studies ↠ ideally all analysis codes should be committed to MpdRoot as Wagons

Physics feasibilities studies

Identified charged hadrons (π/K/p)

BiBi@9.2 GeV (UrQMD), 50 M events ↣ full event/detector reconstruction

π/K/p identification based on n-sigma selections in the TPC/TOF ↣ good for the first day measurements



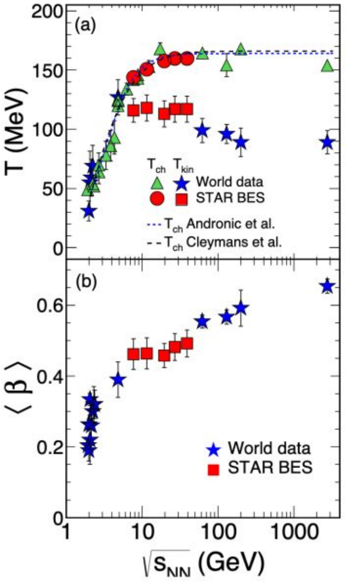
Good enough coverage for dN/dy, <pT> and β/T (BW-fits) measurements.

Unmeasured low-pT range is as small as possible with the existing track reconstruction methods

Sampled yields > 92% for all species

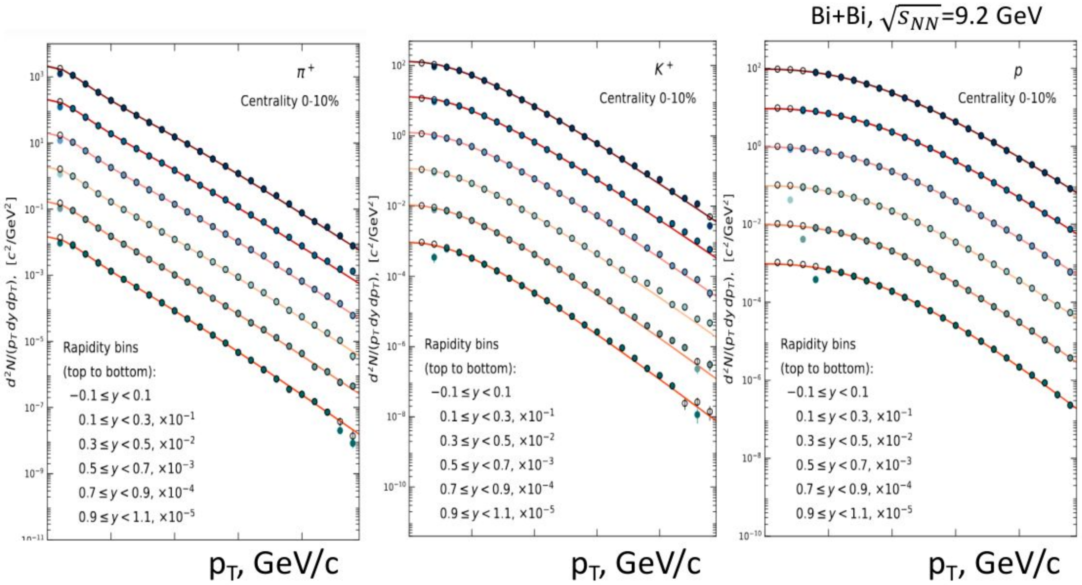
Identified charged hadrons

Phys.Rev.C 96 (2017) 4, 044904



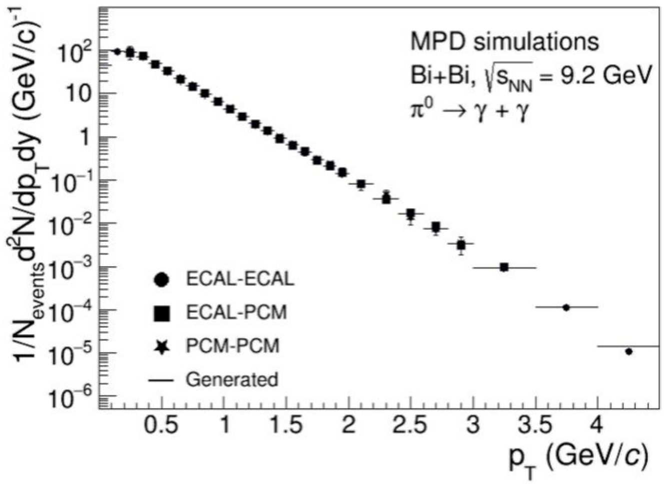
Particle yields allow to extract information about (μ_B,T_{ch})

Particle spectra allow to extract information about (<β>,T_{kin})

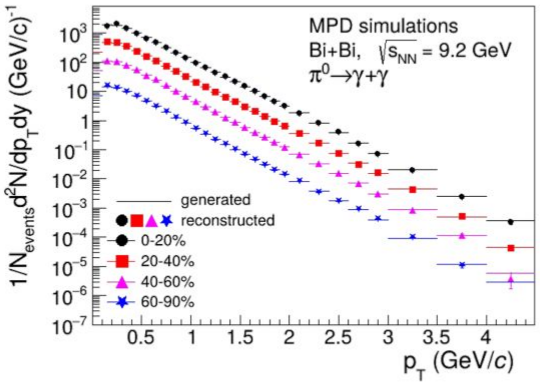


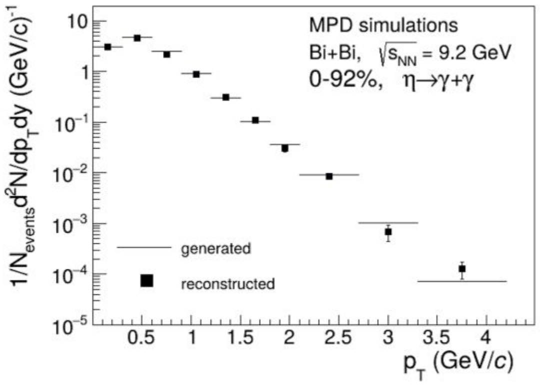
- Probe freeze-out conditions, collective expansion, mechanisms, strangeness production, parton energy loss, etc. with particles of dihadronizationfferent masses, quark contents/counts → **requirements on MPD acceptance and PID capabilities**
- **Charged hadrons**: large (~70% of π/K/p) and uniform acceptance + excellent PID capabilities of TPC and TOF from p_T~0.1 GeV/c

Neutral identified hadron production



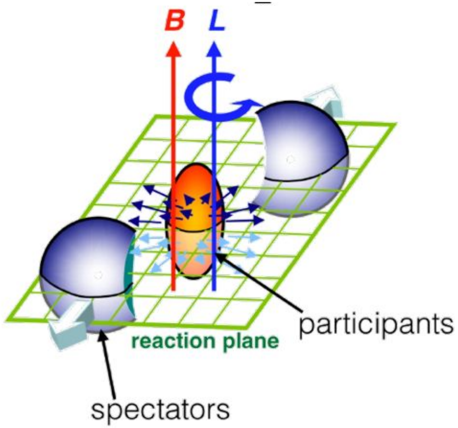
BiBi@9.2 GeV (UrQMD), 50 M events → full event/detector reconstruction





- MPD will be able to measure differential production spectra, integrated yields and $\langle p_T \rangle$, particle ratios, multiplicity distributions for a variety of identified hadrons ($\pi, K, \eta, \omega, \rho$, …)
- Neutral mesons ($\pi^0, K_S, \eta, \omega, \eta'$) : ECAL reconstruction + photon conversion method (PCM)
- Will be helpful to extend p_T ranges of charged particle measurements and assess systematics

Hyperon Global Polarization



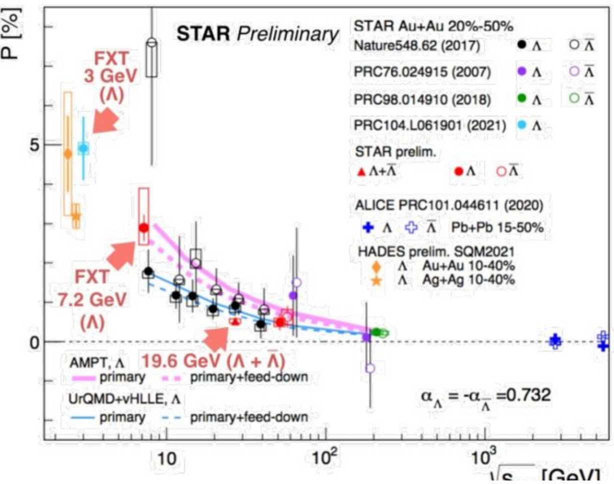
Can be defined as: $\frac{dN}{d\cos(\phi_\Lambda - \phi_p^*)} = \frac{1}{2}\left(1 + \alpha_\Lambda |P_\Lambda| \cos\left(\phi_\Lambda - \phi_p^*\right)\right)$

Invariant mass fit method can be used to measure P_Λ:

$$P^{obs}(m_{inv}, p_T) = P^{sig}(p_T)\frac{N^{sig}(m_{inv}, p_T)}{N^{tot}(m_{inv}, p_T)} + P^{bg}(m_{inv}, p_T)\frac{N^{bg}(m_{inv}, p_T)}{N^{tot}(m_{inv}, p_T)}$$

$$\frac{8}{\pi \alpha_\Lambda R_{EP}} P^{sig}(p_T) = \mathbf{P_\Lambda} + c\sin\left(\phi_\Lambda - \phi_p^*\right)$$

α_Λ - hyperon decay const., R_{EP} - EP resolution, ϕ_Λ, ϕ_p^* - azimuthal angles of Λ, p



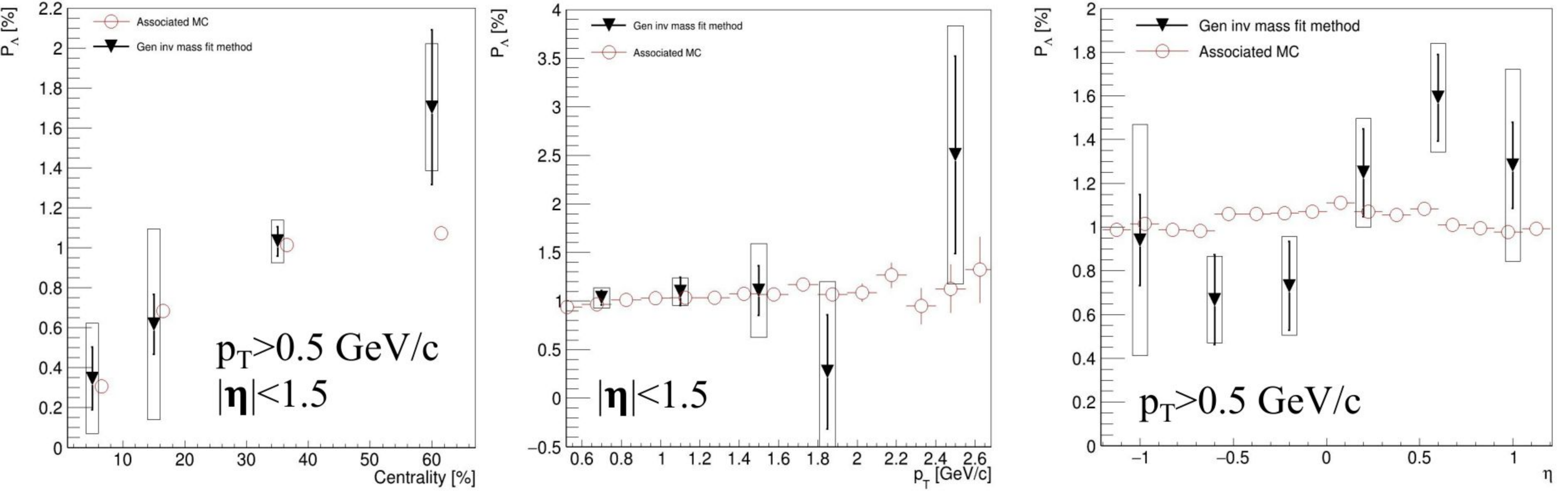
Focus is to see the effect of large angular momentum and magnetic field in heavy-ion collisions

- Global polarization of hyperons experimentally observed, decreases with $\sqrt{s_{NN}}$
  - reproduced by AMPT, 3FD, UrQMD+vHLLE

P_Λ at **NICA:** **<u>extra points in the energy range 2-11 GeV</u>**
centrality, p_T and rapidity dependence of polarization,
not only for Λ, but other (anti)hyperons (Λ, Σ, Ξ)

Global Polariation in MPD

Performance study of the hyperon global polarization measurements with MPD at NICA, Eur.Phys.J.A 60 (2024) 4, 85



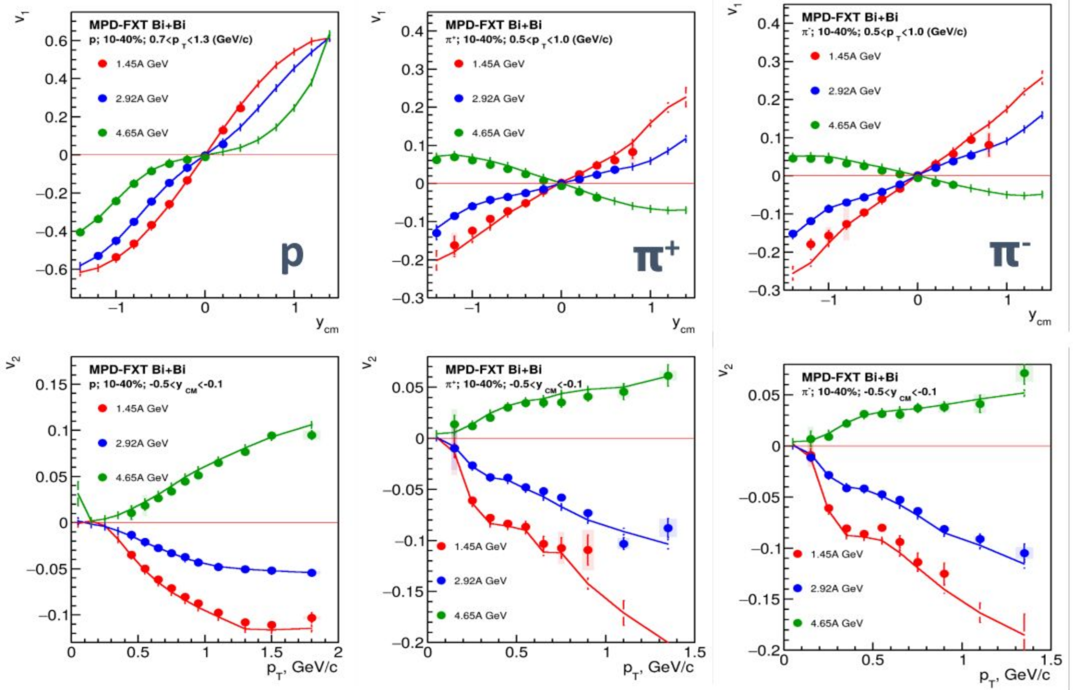
Good performance of MPD for P_Λ measurements

More statistics needed for differential (p_T,**η**) measurements and other hyperons

First results are to be expected at ~100M events

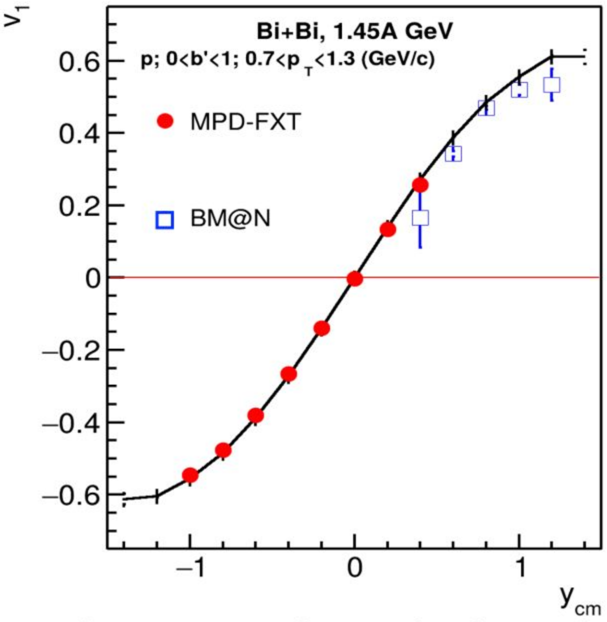
Anisotropic flow in MPD-FXT

❖BiBi @ 2.5, 3.0 and 3.5 GeV (UrQMD mean-field, fixed-target mode)
❖Realistic PID (TPC+TOF); efficiency corrections; centrality by TPC multiplicity



Reconstructed v_1 & v_2 are quantitatively consistent with truly generated signals

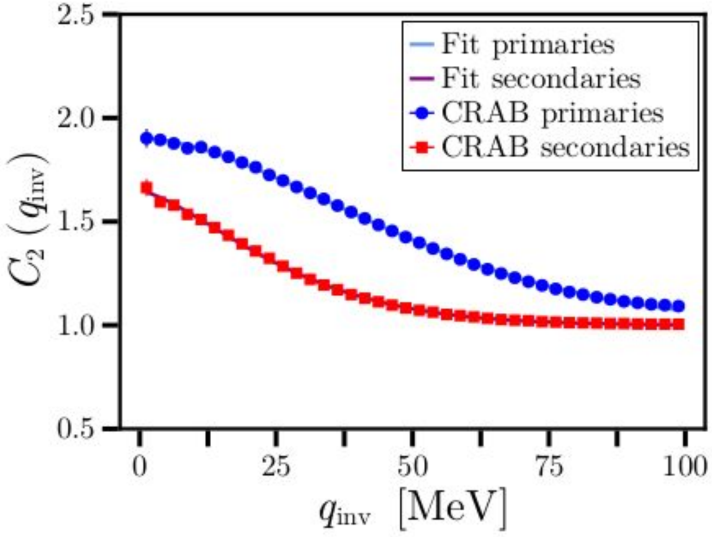
MPD vs. BM@N performance

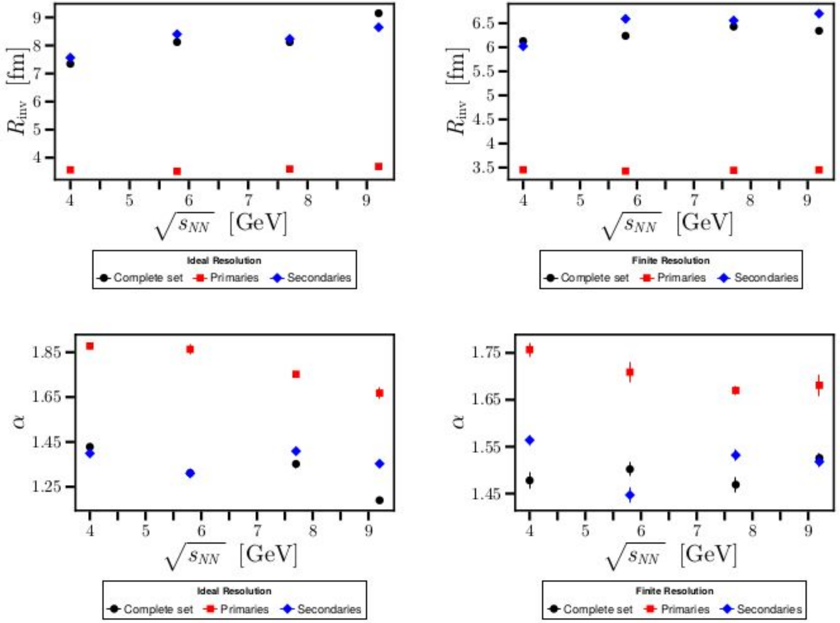


MPD and BM@N complete each other with a small overlap

Measurement techniques were tested on experimental data from BM@N

Two pion correlation function and Levy shape analysis





the core pion sample has a large component that comes from the decay of long-lived but slow moving resonances, as well as a small component of pions coming from primary processes

Eur.Phys.J.A 60 (2024) 6, 135 e-Print:[2401.00619](2401.00619) [hep-ph]

High-energy heavy-ion reaction data

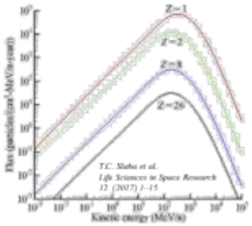
Galactic Cosmic Rays composed of nuclei (protons, … up to Fe) and E/A up to 50 GeV

Cosmic rays are a serious concern to astronauts, electronics, and spacecraft

The damage is proportional to Z^2, therefore the damage from p, d, t, ^{3}He, and ^{4}He is important

Need input information for transport codes for shielding applications (Geant-4, Fluka, PHITS, etc.):

- total, elastic/reaction cross section
- particle multiplicities and coalescence parameters
- outgoing particle distributions: $d^2N/dEd\Omega$

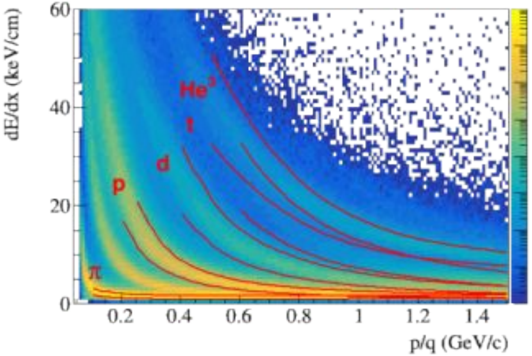


NICA can deliver different ion beam species and energies:

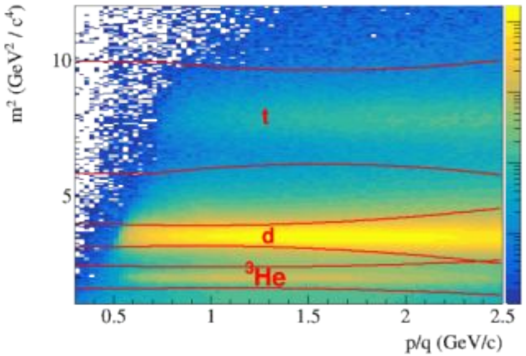
- Targets of interest (C = astronaut, Si = electronics, Al = spacecraft) + He, C, O, Si, Fe, etc.

No data exist for projectile energies > 3 GeV/n

dE/dx vs momentum in TPC



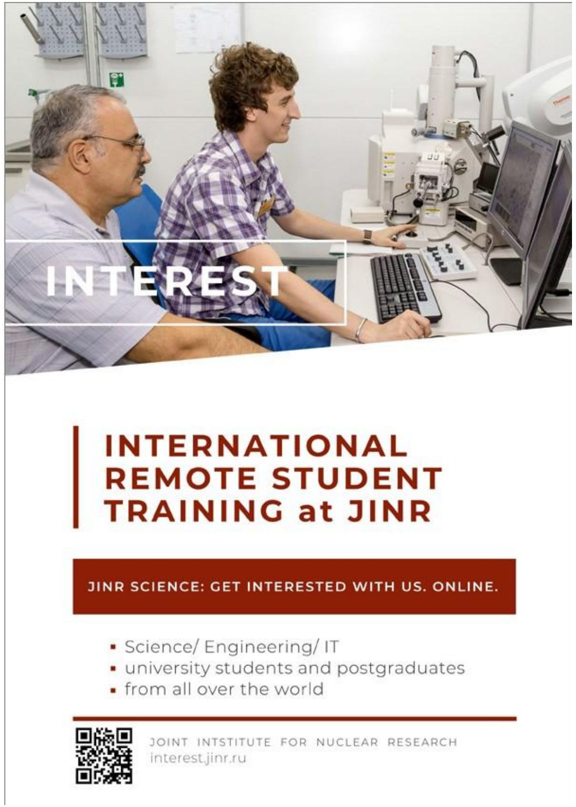
m² vs. momentum in TOF



Excellent light fragment identification capabilities in a wide rapidity range

⇒ important potential contribution to applied research

Opportunities at JINR for students



More info at the following links

INTEREST
https://interest.jinr.ru/index.php

START
https://start.jinr.ru/

Summary

Preparation of the MPD detector and experimental program is continued

Start of the MPD commissioning in 2025 is the main goal

Develop physics program of the experiment, prepare tools and methods for data analysis

Thanks for your attention!

Anisotropic flow of V0 particles

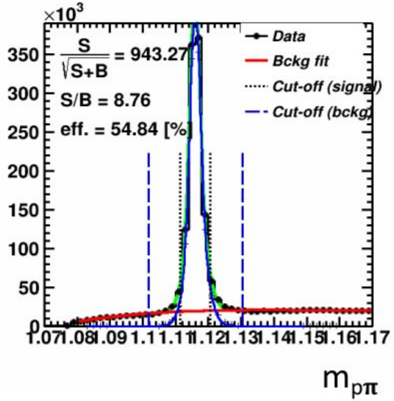
Differential flow can be defined using the following fit:

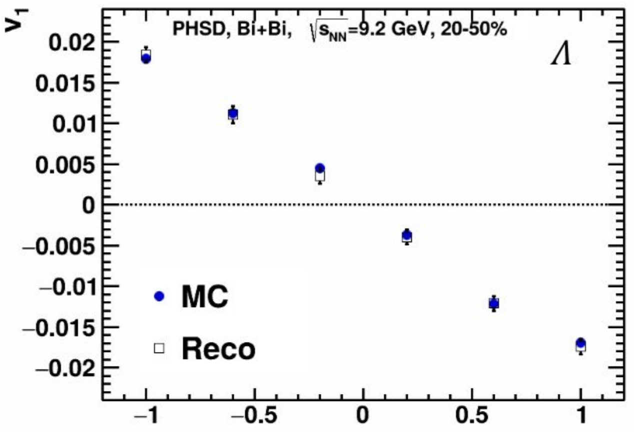
$$v_n^{SB}(m_{inv}) = v_n^S \frac{N^S(m_{inv})}{N^{SB}(m_{inv})} + v_n^B(m_{inv}) \frac{N^B(m_{inv})}{N^{SB}(m_{inv})}$$

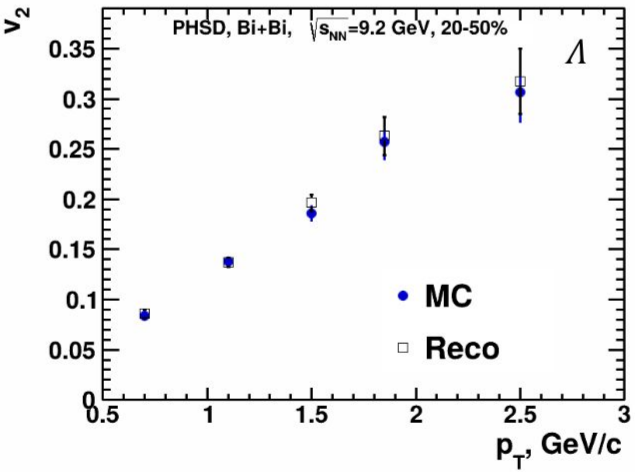
where:

- v_n^S - signal anisotropic flow (set as a parameter in the fit)
- $v_n^B(m_{inv})$ - background flow (set as polynomial function)
- $N^{SB}(m_{inv})$ - m_{inv} distribution (signal + background)
- $N^S(m_{inv})$ - m_{inv} signal distribution
- $N^B(m_{inv})$ - m_{inv} background distribution

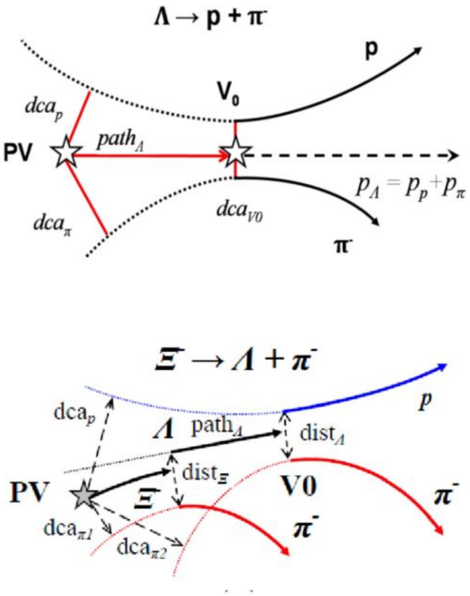
Good performance for v_1, v_2 using invariant mass fit and event plane methods

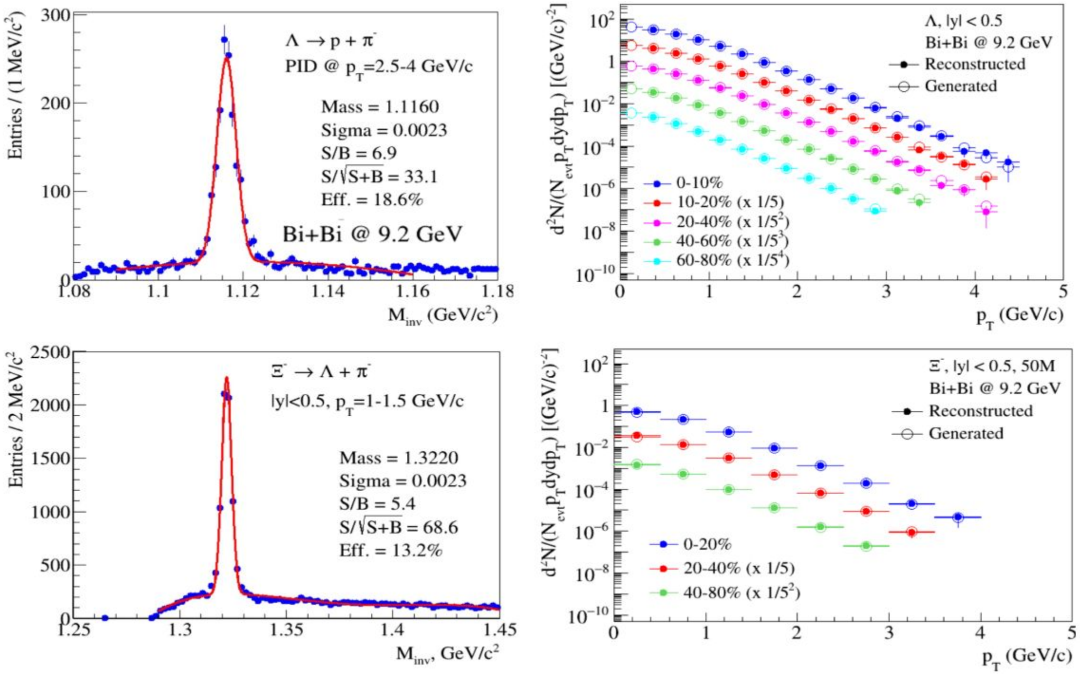






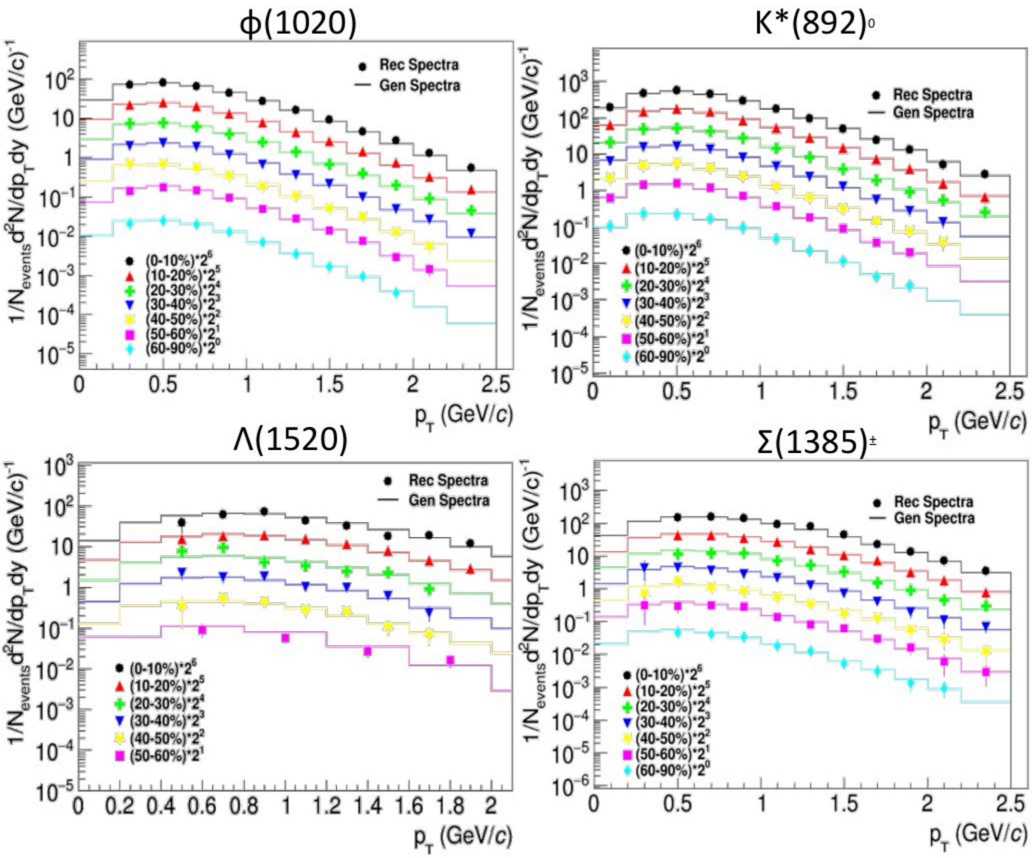
Hyperon production





- Strangeness enhancement is considered to be a signature of the QGP formation with no consensus on the dominant mechanisms of strangeness enhancement – precise measurements are needed in pp, pA, AA
- Strange baryons can be reconstructed with a good level of significance (S/B ratios) with PID using TPC+TOF and different topology selections

Resonance production in MPD



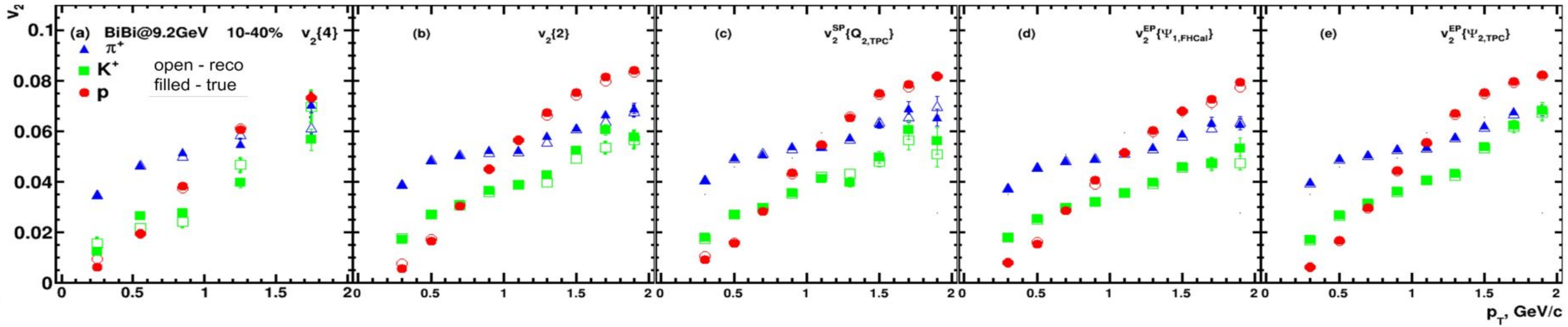
Short-lived resonances are sensitive to rescattering and regeneration in the hadronic phase

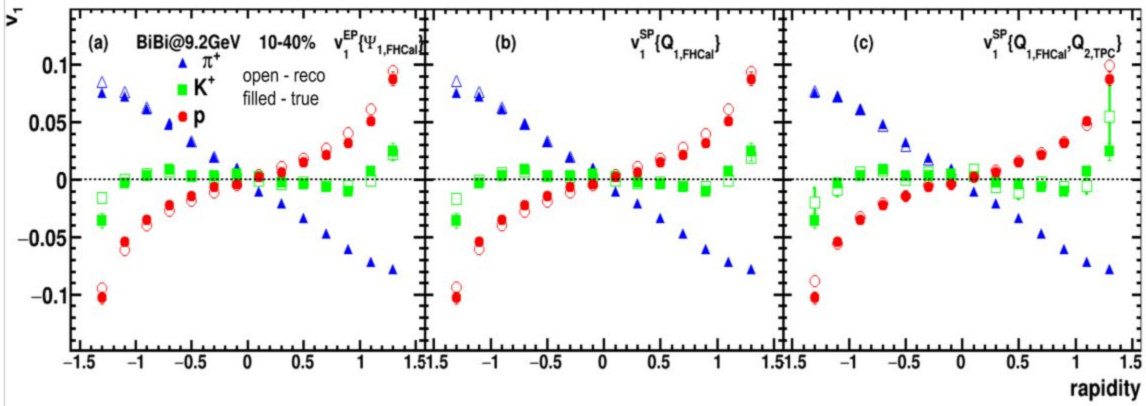
Most realistic approach to data analysis, centrality dependence

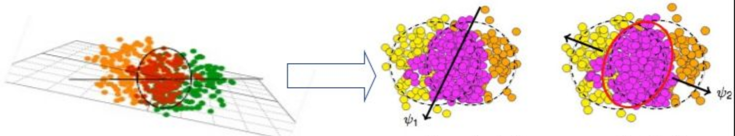
MPD is capable of resonance reconstruction using TPC and TOF for PID and selection based on the topology of the decay

First measurements are feasable with 10M events

Anisotropic flow of identified charged hadrons







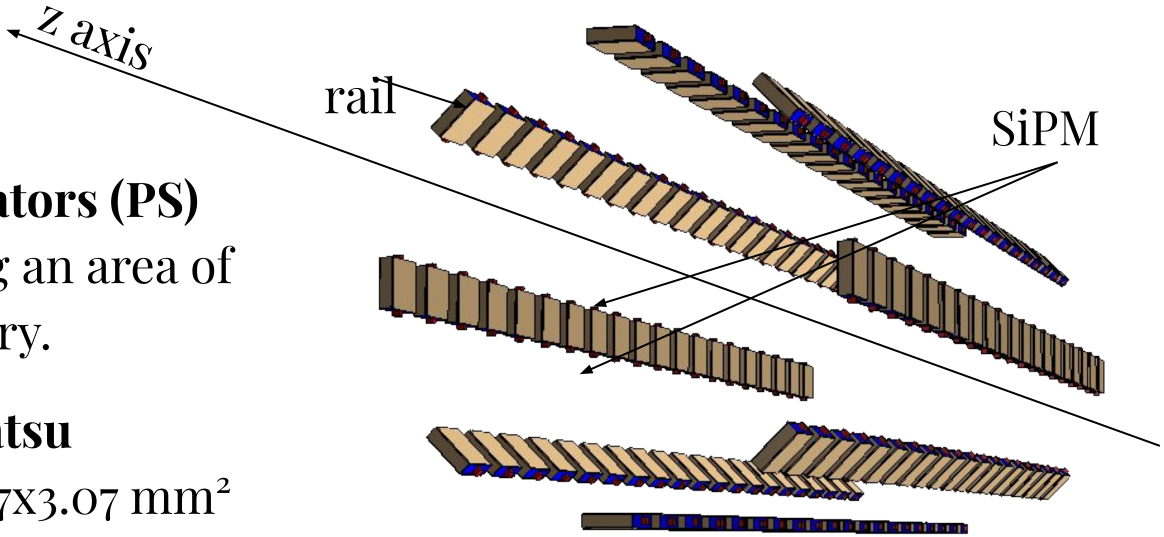
v_1 - directed flow v_2 - elliptic flow

$$\frac{dN}{d\phi} \propto \left(1 + 2\sum_{n=1} v_n \cos\left[n\left(\phi - \Psi_n\right)\right]\right)$$

$$v_n = \langle \cos[n(\phi - \Psi_{RP})] \rangle$$

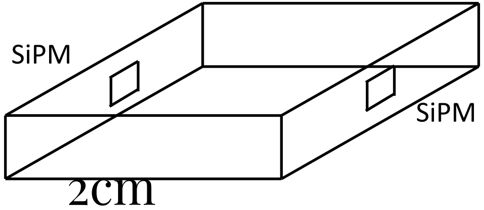
Good performance for flow measurements for all methods used (EP, SP, Q-cumulants)

MiniBeBe - Geometry



It consist on **160 plastic scintillators (PS) EJ232** - 20x20x5 mm^3 ↠ covering an area of 64000 mm^2 in a coaxial symmetry.

Each **PS** has two **SiPM Hamamatsu S13360-3050PE** at each side 3.07x3.07 mm^2

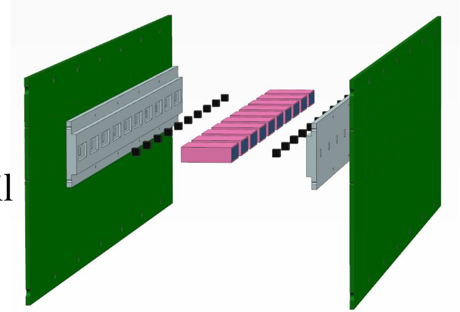


MiniBeBe - Geometry

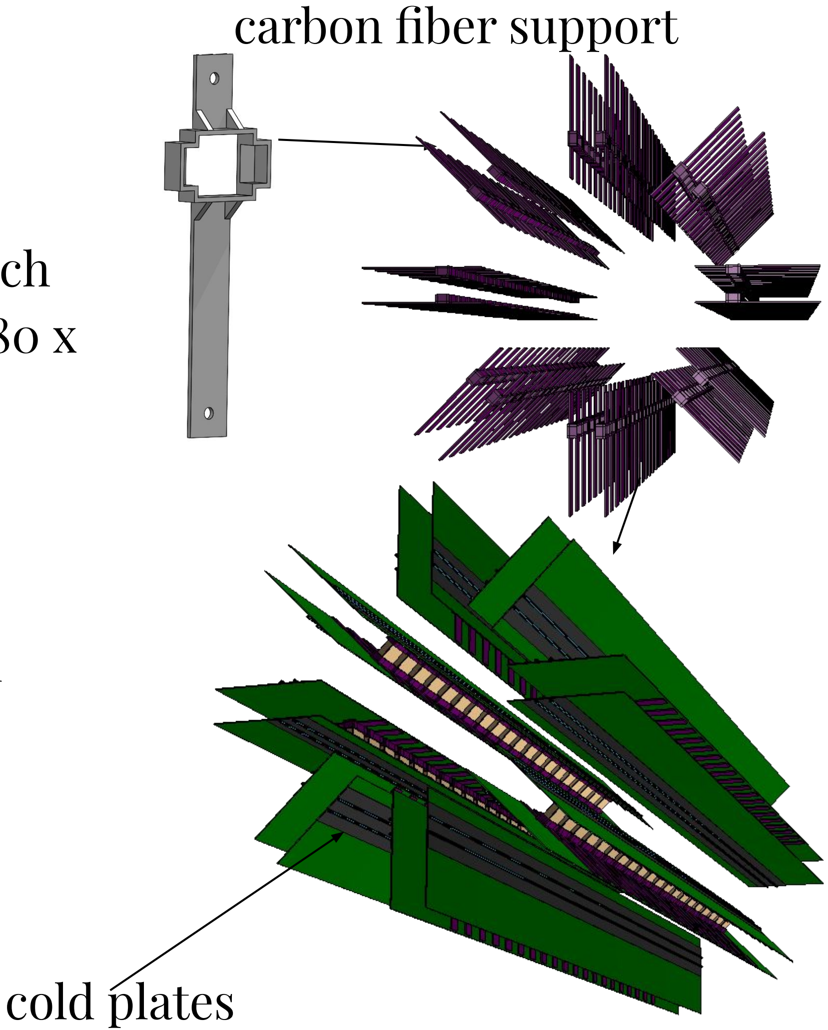
The PCBs are connected to the SiPMs at each side of the PS providing an **H-shaped** rail (80 x 800 mm²).

Each SiPM-PS-SiPM element is fixed to the PCBs with a carbon fiber supports.

Attached to PCBs are the Carbon Fiber cold plates (same of ITS)

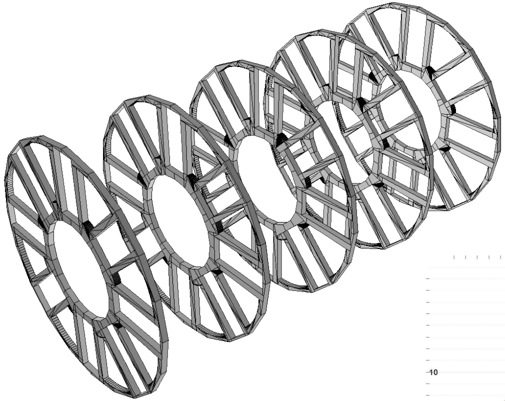


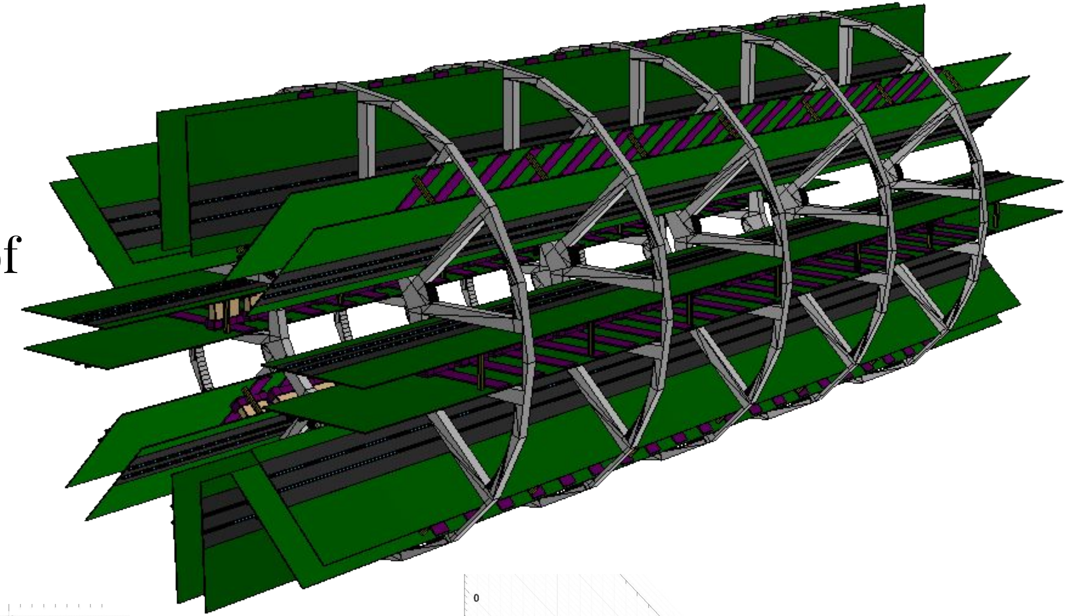
exploded view diagram of H-rail

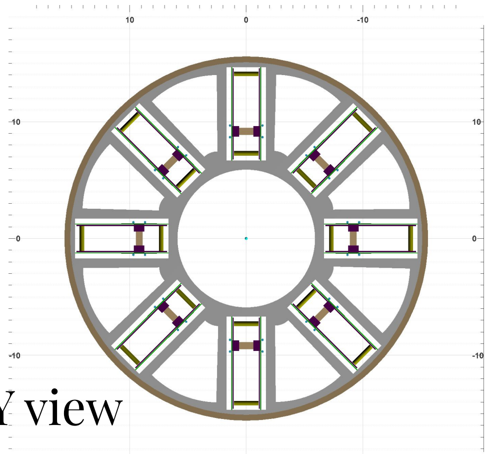


MiniBeBe - Geometry

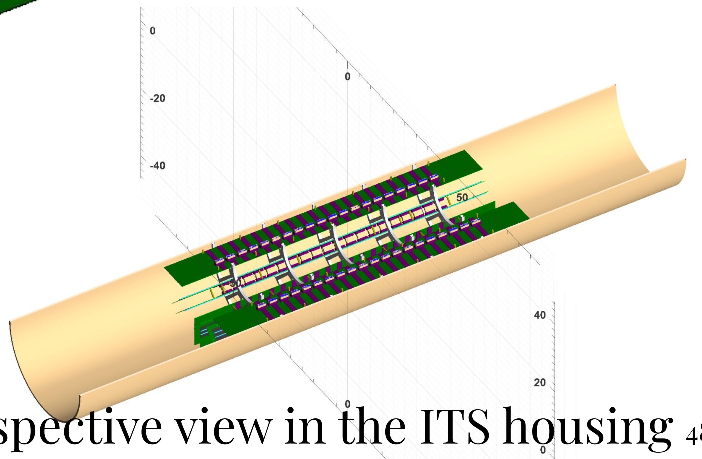
Modules are fixed to the Inner Barrel of the ITS with Aluminum flanges





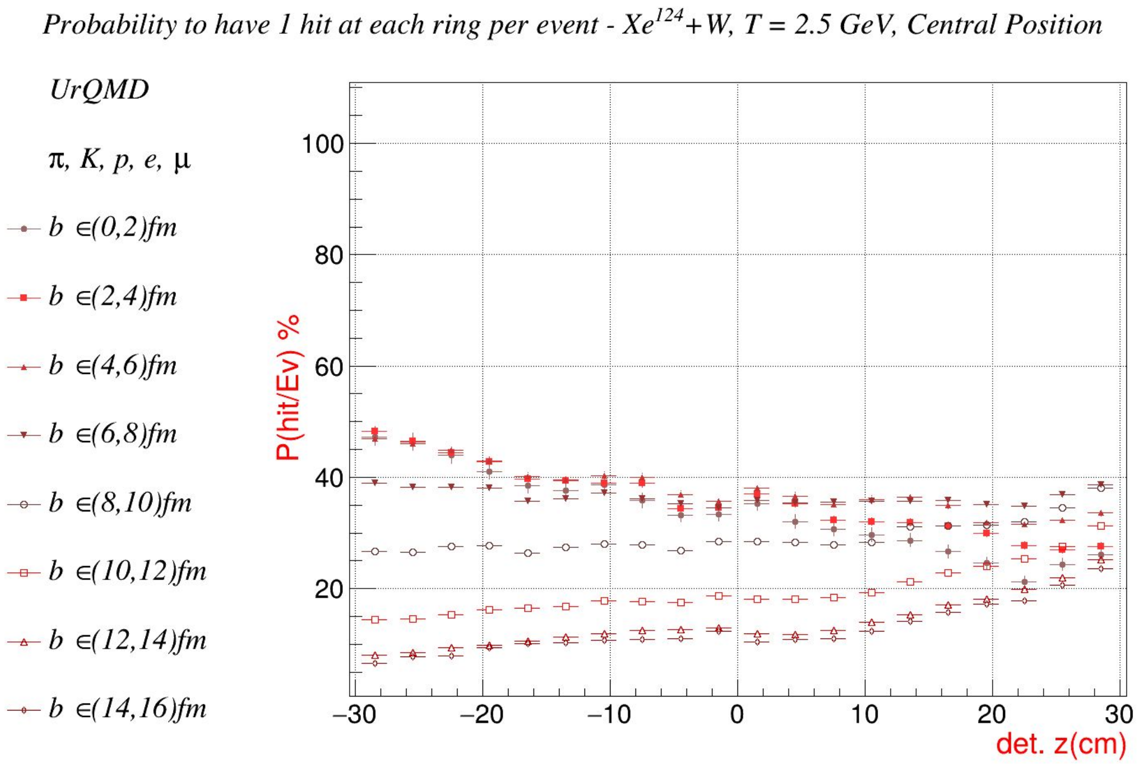


XY view



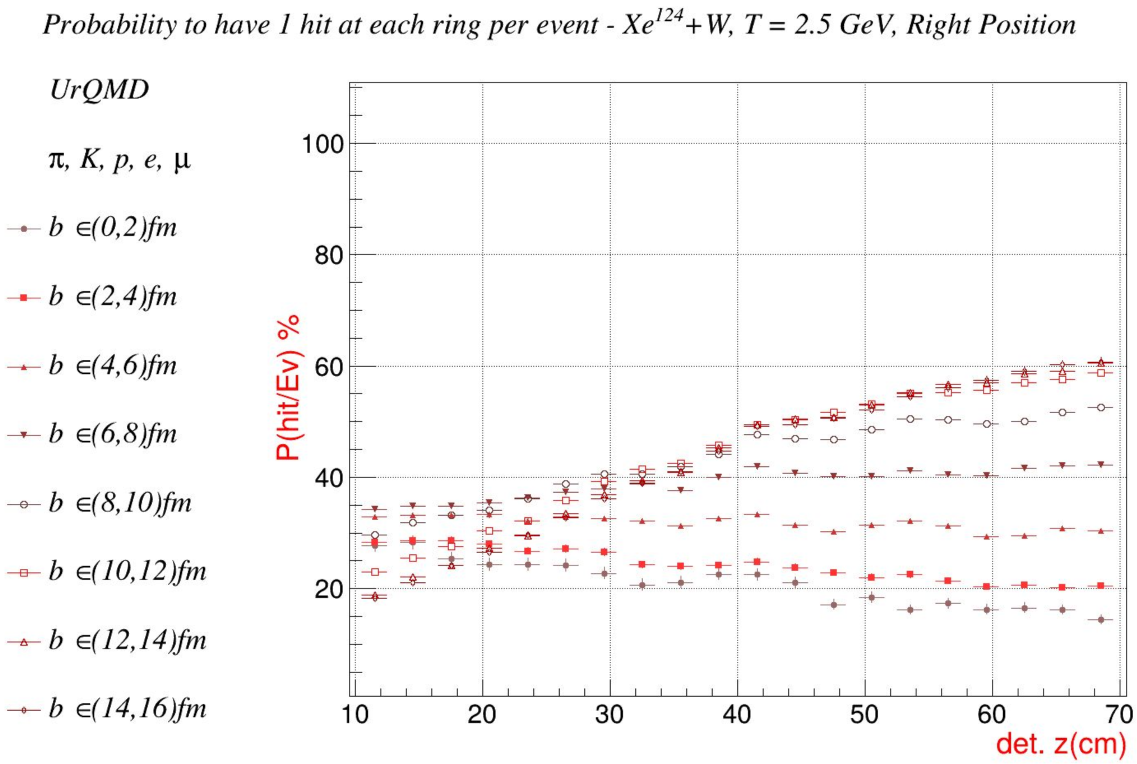
Perspective view in the ITS housing

Probability to 1 hit as a function of impact parameter



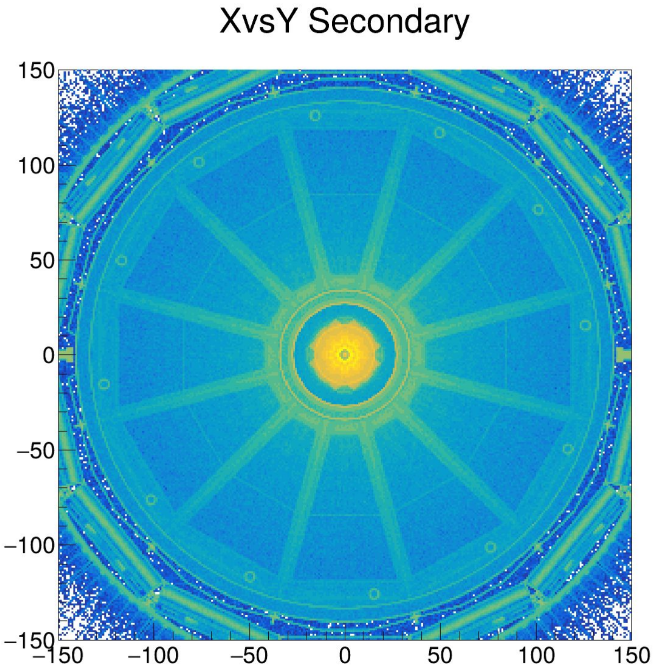
At least one charged MbbHit at each ring, for CENTRAL Position

Probability to 1 hit as a function of impact parameter

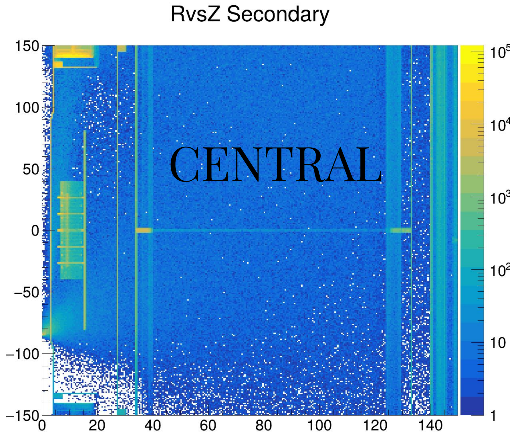


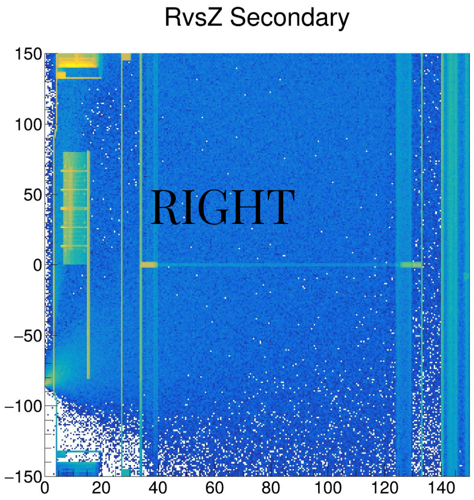
At least one charged MbbHit at each ring, for RIGHT Position

Secondary particle production



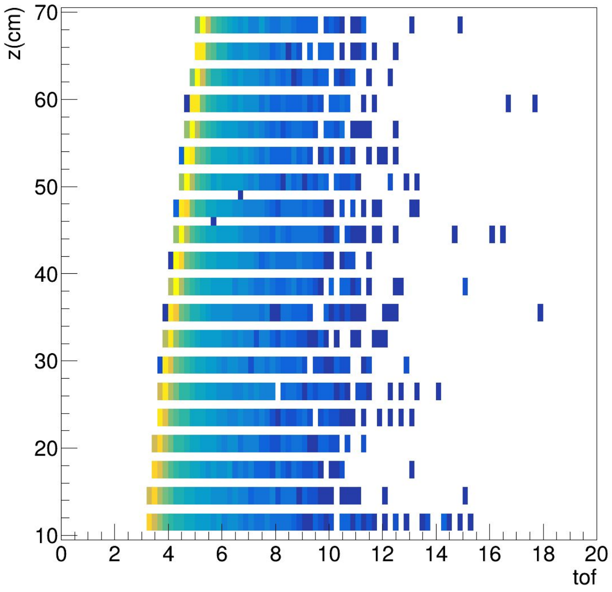
Study of secondary particles in the other detectors is work in progress



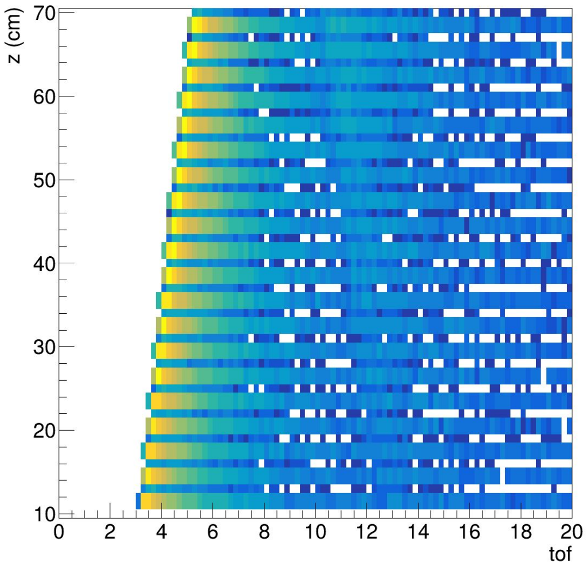


Reaching Time

Primary particles



Secondary particles



Material Budget

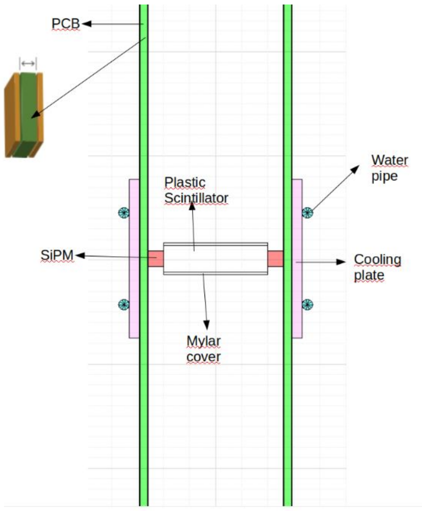
Radiation Length

The radiation length can be approximated by:

$$X_0 = \frac{716.4 \times A}{Z(Z+1)ln(\frac{287}{\sqrt{Z}})} \quad \left[\frac{g}{cm^3}\right] \tag{1}$$

For different materials:

$$\frac{W_0}{X_0} = \sum_i \frac{W_i}{X_i} \tag{2}$$



(a) perspective view

Element	Dimensions
Plastic Scintillator	20x20x5 mm^3
SiPM	3x3x3 mm^3
Mylar cover	thickness = 0.5 mm
FR4	800x100x1.4 mm^3
Copper	800x10x0.1 mm^3
Cooling plate	800x30.6x2 mm^3
Water pipe	radius = 1.025 mm

(b) Dimensions of material in the rail used for material budget simulation.

Element	X_0 (g/cm^2)	ρ (g/cm3)	$\bar{X}$ (cm)	Average Mat. Budget %
Plastic Scintillator & SiPM	43.3886	1.032	0.57	1.31
Mylar	39.69	1.39	0.07	0.25
FR4	288.67	1.86	1.25	0.80
Copper	12.86	8.96	0.10	6.83
Carbon-Fiber	42.11	1.383	1.30	3.09
air	1.205E-3	36.66	7.08	0.02
water	35.758	1.	0.253	0.7

Table 1: Radiation Length X_0 and density ρ of materials used in simulation. Also is shown the average distance $\bar{X}$ traveled by particles on each material and the corresponding material budget.

Material Budget

Radiation Length

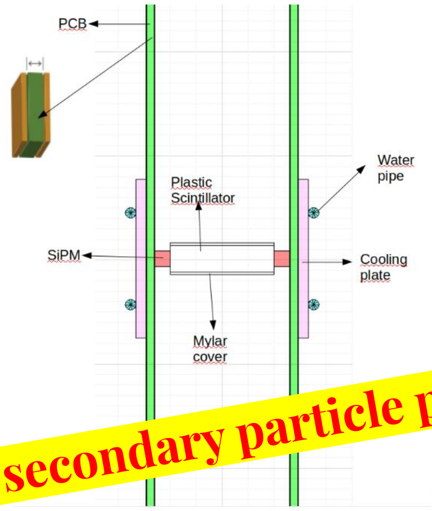
The radiation length can be approximated by:

$$X_0 = \frac{716.4 \times A}{Z(Z+1)ln(\frac{287}{\sqrt{Z}})} \quad \left[\frac{g}{cm^3}\right] \qquad (1)$$

For different materials:

$$\frac{W_0}{X_0} = \sum \frac{W_i}{[illegible]}$$

How is going to affect tracking the secondary particle production?!!
Studies under development



(a) perspective view

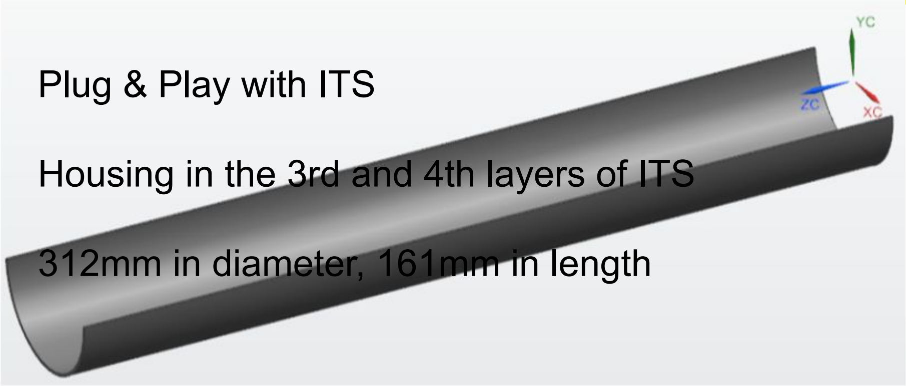
Element	Dimensions
Plastic Scintillator	[illegible]5 mm^3
[illegible]	[illegible] mm^3
[illegible]	[illegible]ness = 0.5 mm
[illegible]	800x100x1.4 mm^3
Copper	800x10x0.1 mm^3
Cooling plate	800x30.6x2 mm^3
Water pipe	radius = 1.025 mm

(b) Dimensions of material in the rail used for material budget simulation.

[illegible]	[illegible]	ρ (g/cm3)	$\bar{X}$ (cm)	Average Mat. Budget %
Plasti[illegible]	43.3886	1.032	0.57	1.31
Mylar	39.69	1.39	0.07	0.25
FR4	288.67	1.86	1.25	0.80
Copper	12.86	8.96	0.10	6.83
Carbon-Fiber	42.11	1.383	1.30	3.09
air	1.205E-3	36.66	7.08	0.02
water	35.758	1.	0.253	0.7

Table 1: Radiation Length X_0 and density ρ of materials used in simulation. Also is shown the average distance $\bar{X}$ traveled by particles on each material and the corresponding material budget.

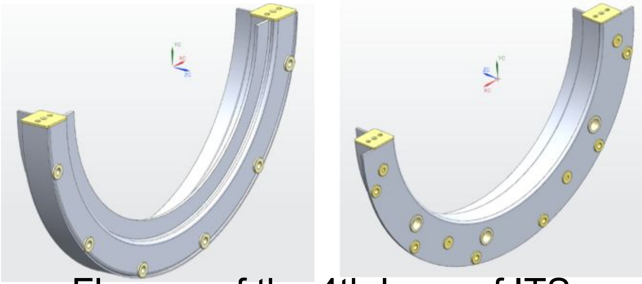
Mechanical support - Plug & Play MPD-ITS Mechanical Support



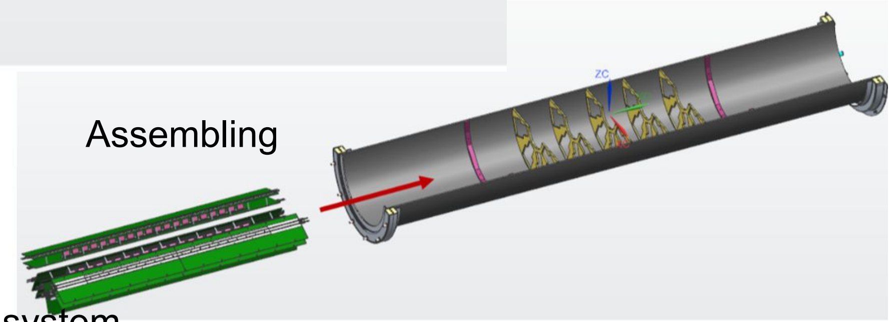
Plug & Play with ITS

Housing in the 3rd and 4th layers of ITS

312mm in diameter, 161mm in length

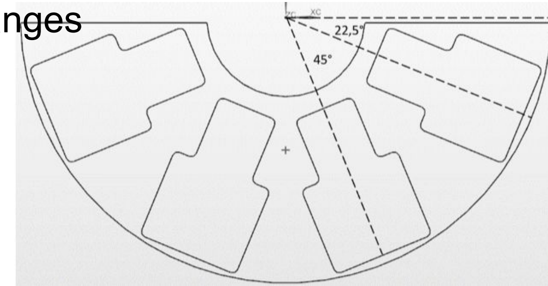


Flanges of the 4th layer of ITS were redesigned
Bushings of 9.3mm



Assembling

Electronic modules fixed with flanges



Supports fit the cooling system