Summary report from PWG1
Global observables

Reported by Alexey Aparin
XI Collaboration Meeting of the MPD Experiment
20.04.20223

PWG1 conveners
A.Aparin (JINR), G. Feofilov (SPbSU)

Results since the last meeting

Previous collaboration meeting took place at 8.11-10.11 2022

Since then we had 9 Cross-PWG meetings ~ 20 talks concerning PWG1
Several talks on ICPPA (December)
Some talks on other occasions

Only one talk was fully presented to PWG prior to the presenting at the conference

Institutions contributing to the PWG1 workflow:
JINR, NRNU (MEPhI), INR, SPbSU, some people from MexNICA ~ 20 people
MPD collaboration list > 500 people

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Where is everyone??

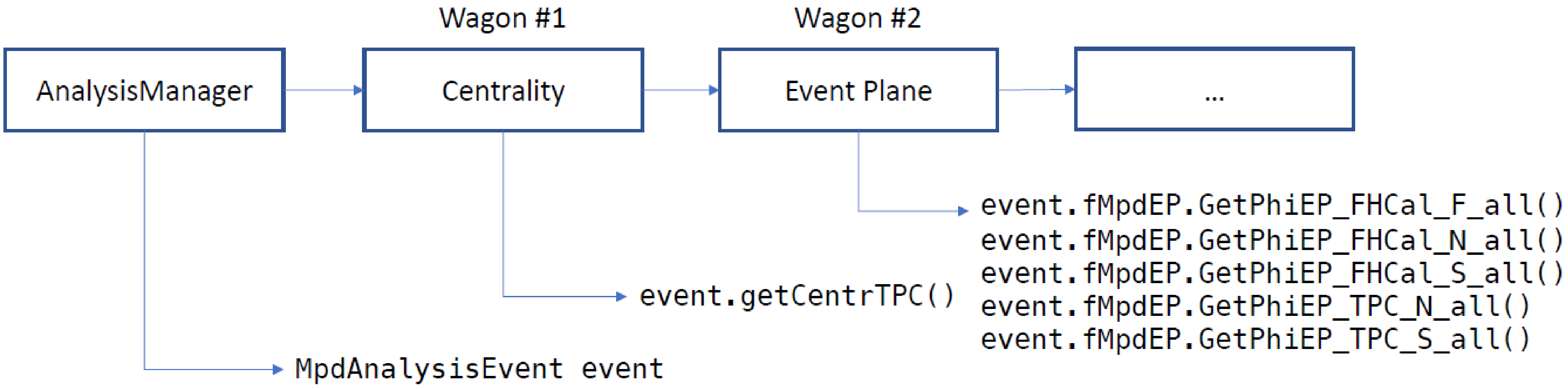
Centralized Analysis Framework

Analysis manager reads event into memory and calls wagons one-by-one to modify and/or analyze data:

Proposal is to move to a centralized Analysis Framework:

- all analyses codes are saved (archived) in the MpdRoot -> easier sharing of codes and methods
- all analyses codes have a similar structure -> easier reading of codes, cross checks
- all analyses use the same global variables for centrality, T0, z-vertex, reaction plane, matching for tracks to external detectors, etc. (input from TaskForces) -> consistent approach
- analyses are easily grouped in a train, analyses are run simultaneously with a single access to data for all of them -> reduced number of input/output operations for disks and databases, easier organization of data storage

Centralized Analysis Framework



- Centrality wagon: mpdroot/physics/evCentrality
- Currently works with Request25_UrQMD, Request26_DCM-SMM and Request31_PHSD
- Other productions/event generators can be added by request
- Calculates TPC centrality for all accepted events

Centralized Analysis Framework

- Example codes are available in MpdRoot @ mpdroot/physics, originally committed by D. Peresunko:

  MpdAnalysisEvent.cxx MpdAnalysisManager.cxx MpdAnalysisTask.cxx
  MpdAnalysisEvent.h MpdAnalysisManager.h MpdAnalysisTask.h

- Class **MpdAnalysisManager** requires list of input files, list of branches to be used for analysis and list of tasks (wagons) to process. In the end, **MpdAnalysisManager** takes care of writing output objects for each task (wagon)

```
void RunAnalyses(){

  gROOT->LoadMacro("mpdloadlibs.C");
  gROOT->ProcessLine("mpdloadlibs()");

   MpdAnalysisManager man("ManagerAnal") ;
   man.InputFileList("list.txt") ;
   man.ReadBranches("*") ;
   man.SetOutput("histos.root") ;

   MpdCentralityAll pCentr("pCentr","pCentr") ;
   man.AddTask(&pCentr) ;

   MpdConvPi0 pDef("pi0Def","ConvDef") ; //name, parametes file
   man.AddTask(&pDef) ;

   MpdPairKK pKK("pKK","pKK") ;
   man.AddTask(&pKK) ;

   man.Process() ;

}
```

Text file with a list of input DST files

Wagon # 1 - centrality

Wagon # 2 – Pi0 by ECAL and PCM

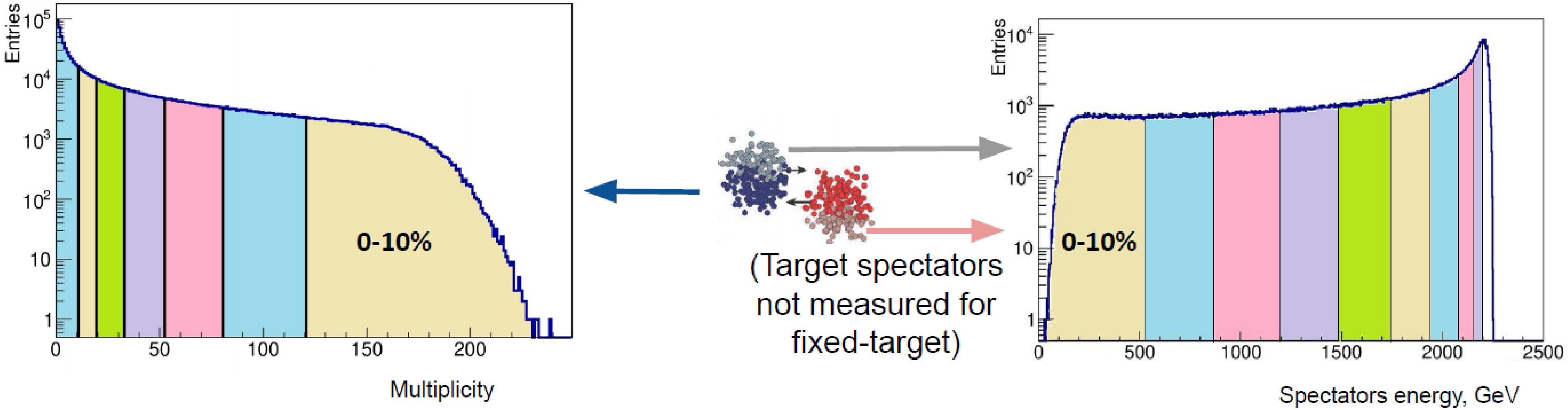
Wagon # 3 – phi -> KK

Centrality estimations

Types of centrality estimators

Produced charged particles

Spectators



Glauber model

MC Glauber model provides a description of the initial state of a heavy-ion collision

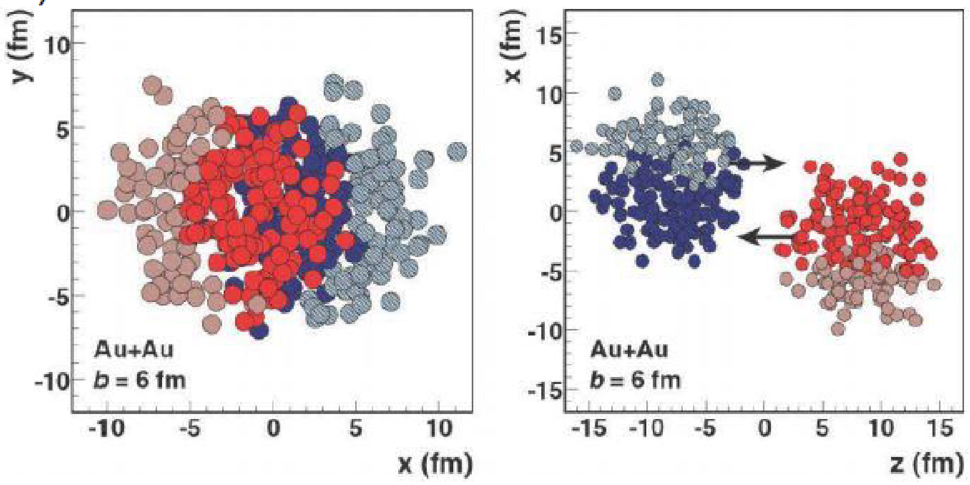
- Independent straight line trajectories of the nucleons
- A-A collision is treated as a sequence of independent binary NN collisions
- Monte-Carlo sampling of nucleons position for individual collisions

Main model parameters

- Colliding nuclei
- Inelastic nucleon-nucleon cross section (σ^{NN}_{inel}) (depends on collision energy)
- Nuclear charge densities (Wood-Saxon distribution)

$$\rho(r) = \rho_0 \cdot \frac{1 + w(r/R)^2}{1 + \exp\left(\frac{r-R}{a}\right)}$$

Glauber Modeling in High Energy Nuclear Collisions: ARNPS57:205-243,2007



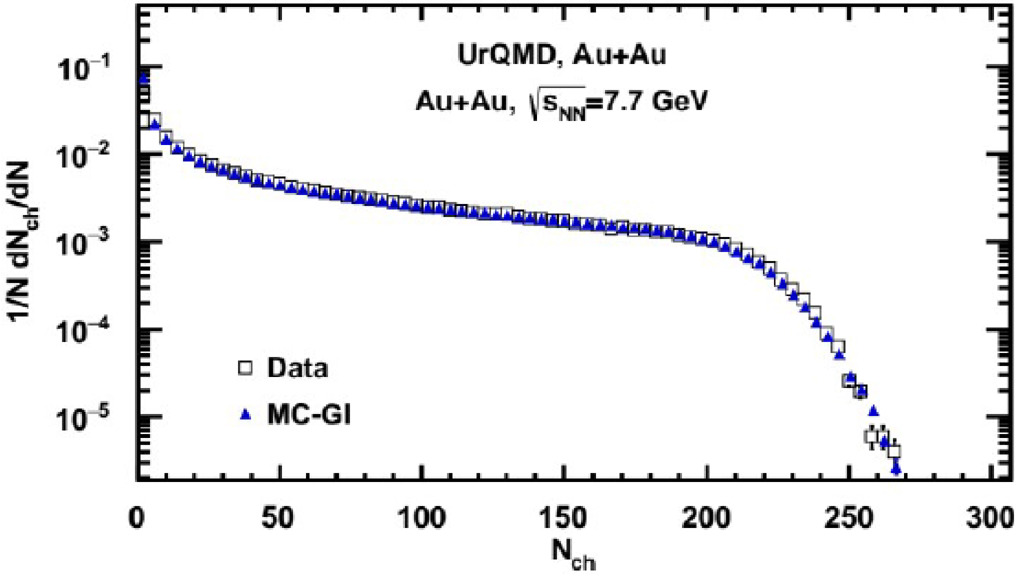
Geometry parameters

b – impact parameter
N_{part} – number of nucleons participating in the collision
N_{spec} – number of spectator nucleons in the collision
N_{coll} – number of binary NN collisions

Centrality from TPC multiplicity

MC Glauber data → Evaluate N_a: $N_a = fN_{part} + (1-f)N_{coll}$ → Call $NBD(\mu,k) \times N_a$ → Build multiplicity fitting function

Build multiplicity fitting function + Input multiplicity distribution → Evaluate χ^2 → Minimize χ^2 to find f, μ, k



NBD – negative binomial distribution
Parameters of the fit:

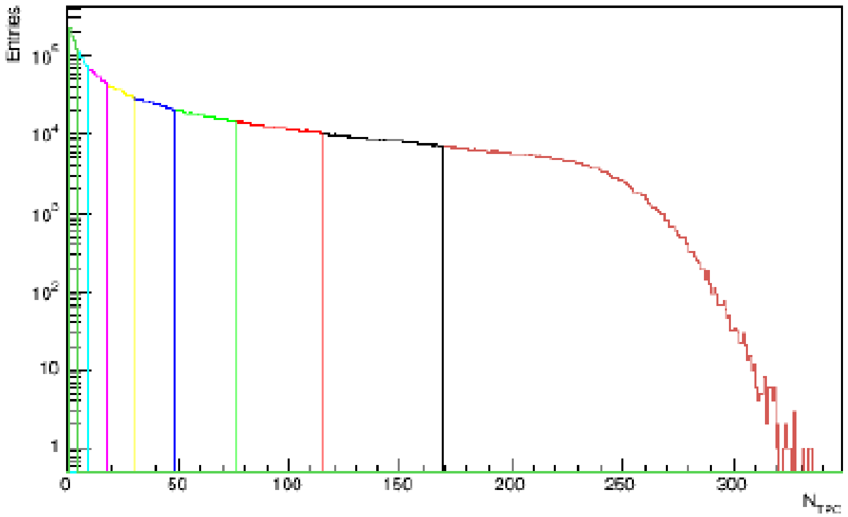
- **f** – fraction of the production from the soft component
- **μ** – mean multiplicity value
- **k** – width of the multiplicity distribution, can be connected to the fluctuations

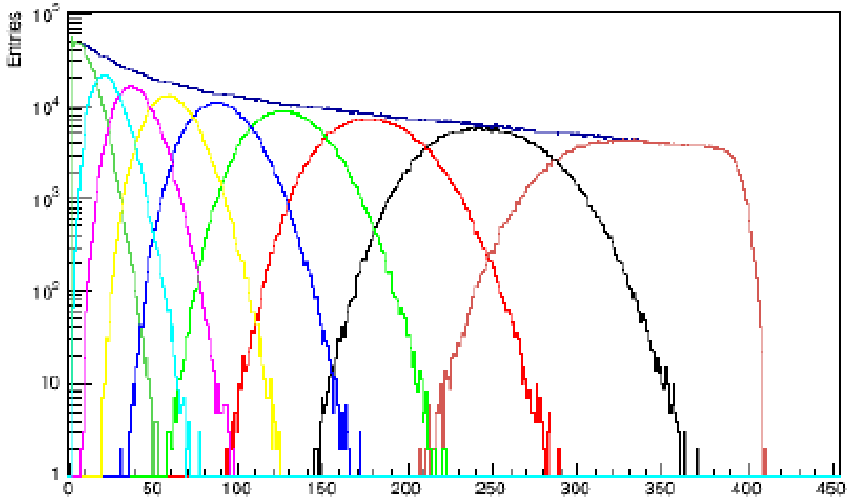
Centrality from TPC multiplicity

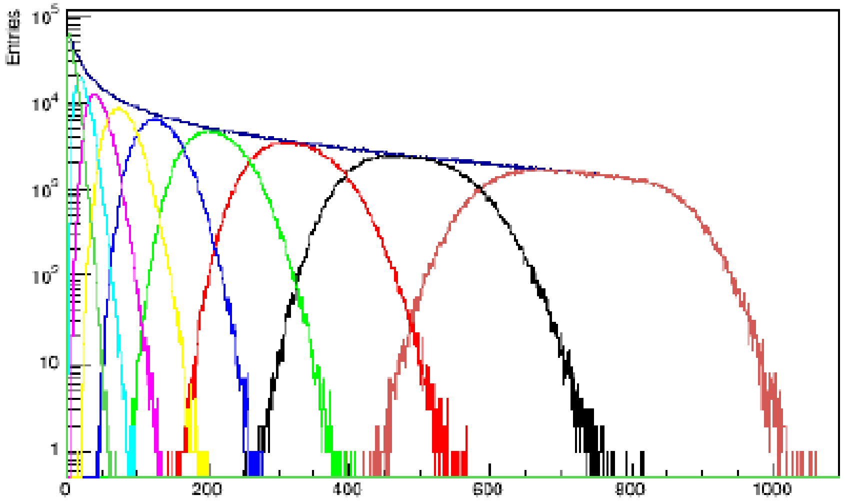
We need to keep in mind the parameters N_{part} and N_{coll} meaning in the MC Glauber function and consequent quantities which we get from fit if charged particle multiplicity

Thus, the centrality class can be narrow, but corresponding N_{part} and N_{coll} can still be rather wide

$$\left.\frac{dN_{ch}}{d\eta}\right|_{\eta=0} = n_{pp}\left[(1-x)N_{part}/2 + xN_{coll}\right]$$

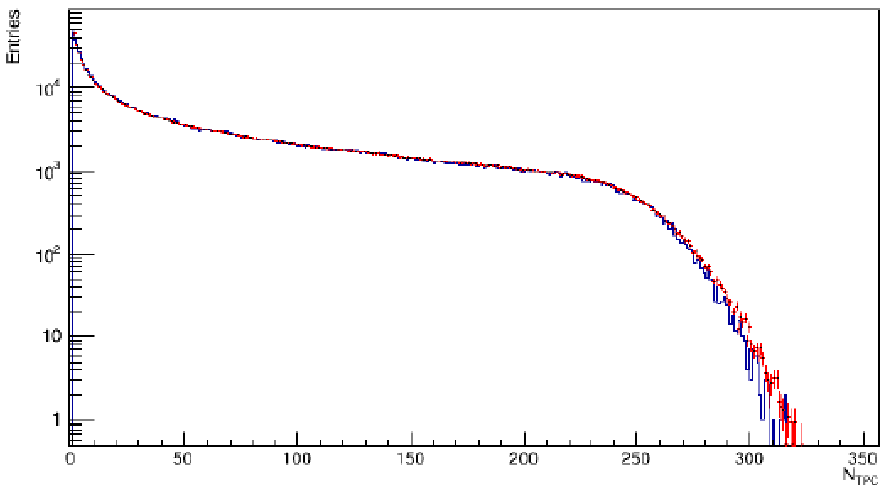


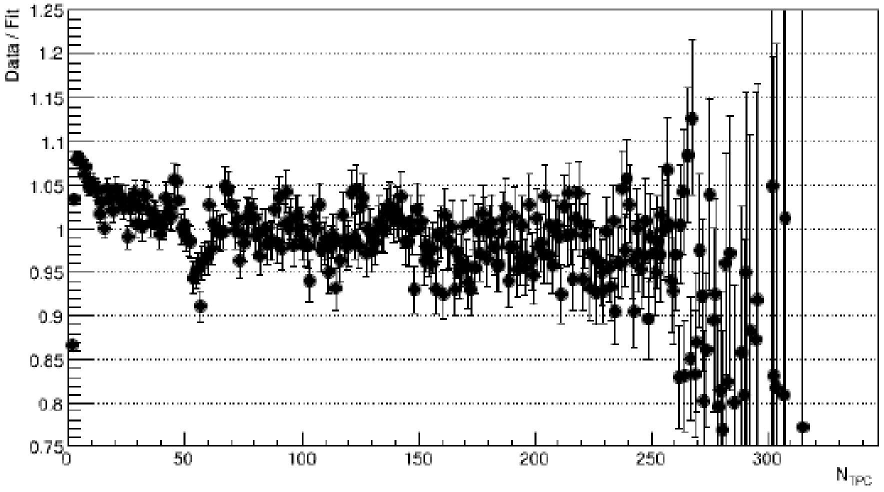


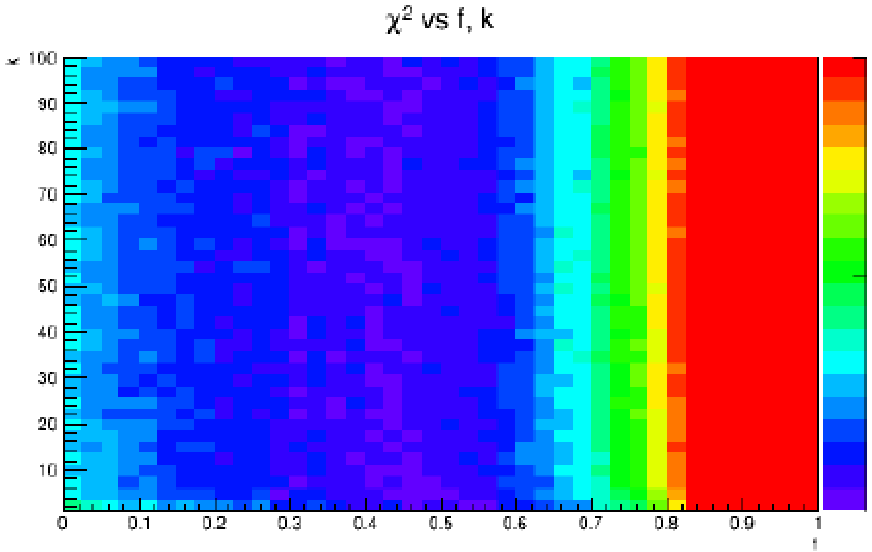


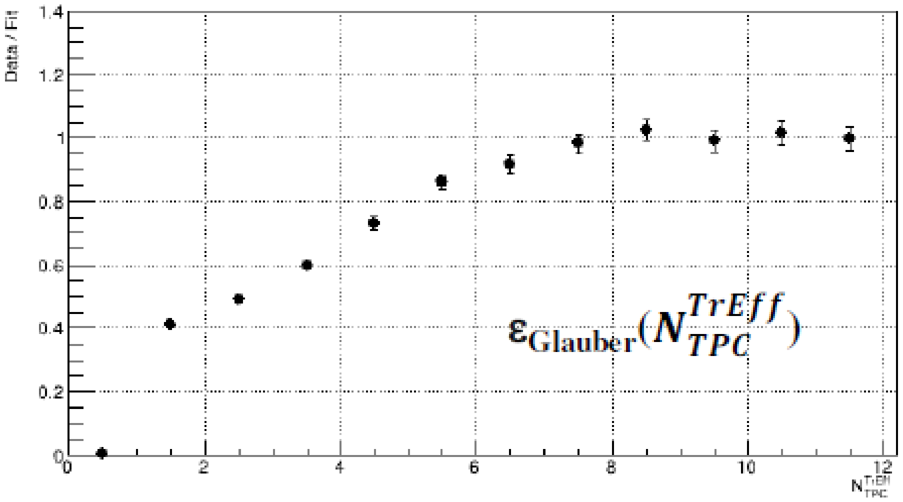
Weighted Glauber fit for TPC N_{tracks}

- With efficiency correction: f = 0 mu = 0.29 k = 87 chi2 = 1.5

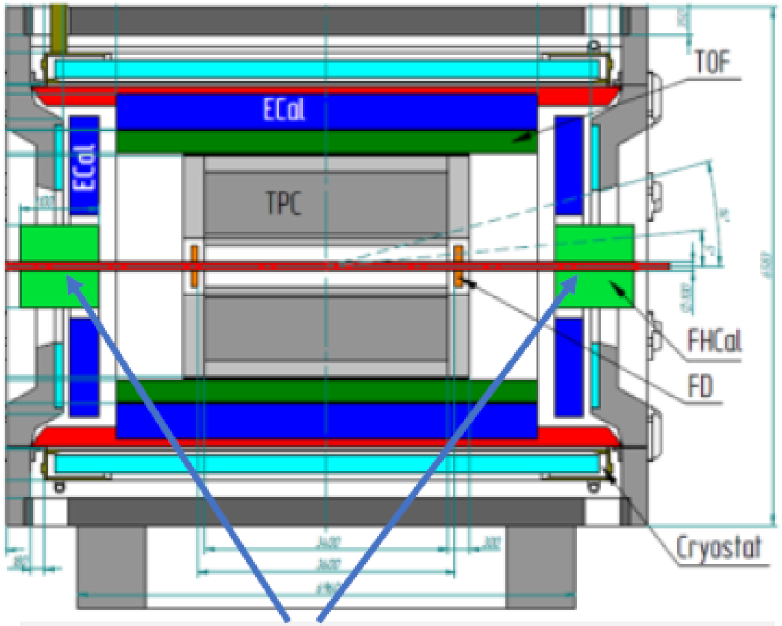




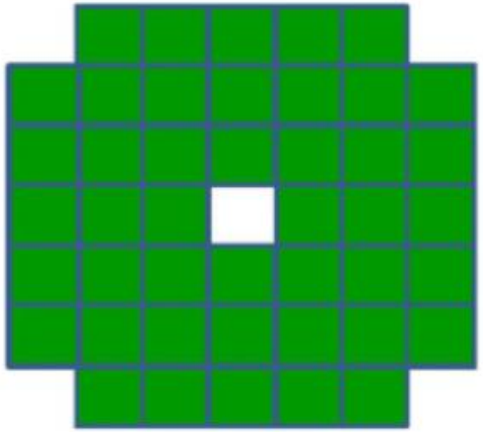




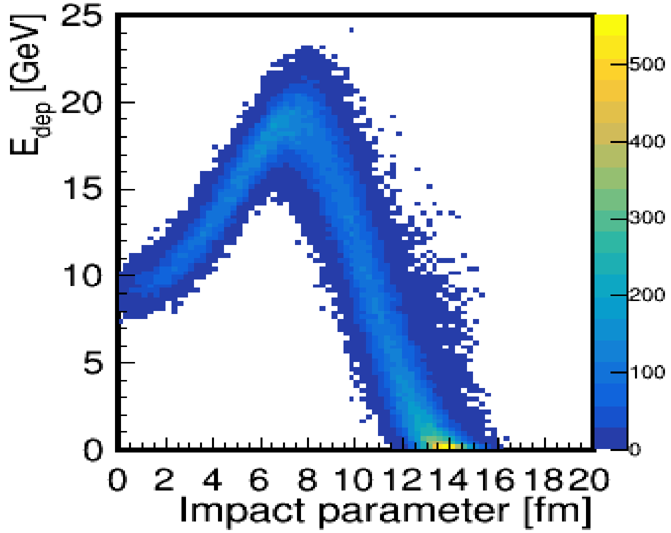
FHCal for centrality



Two upstream/downstream parts

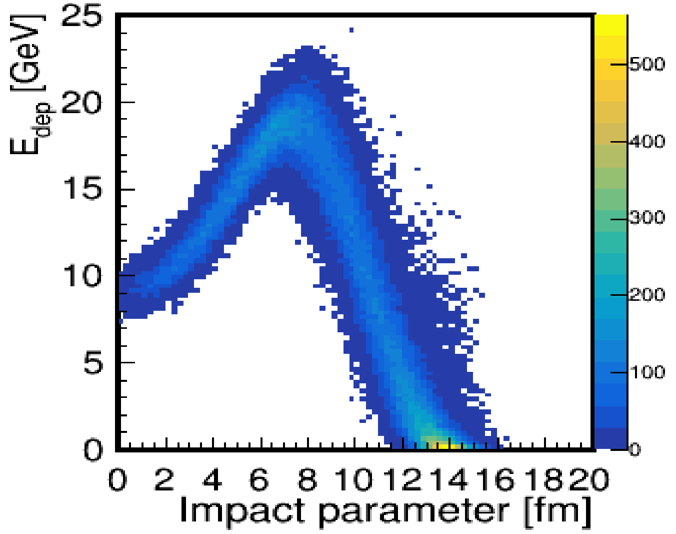


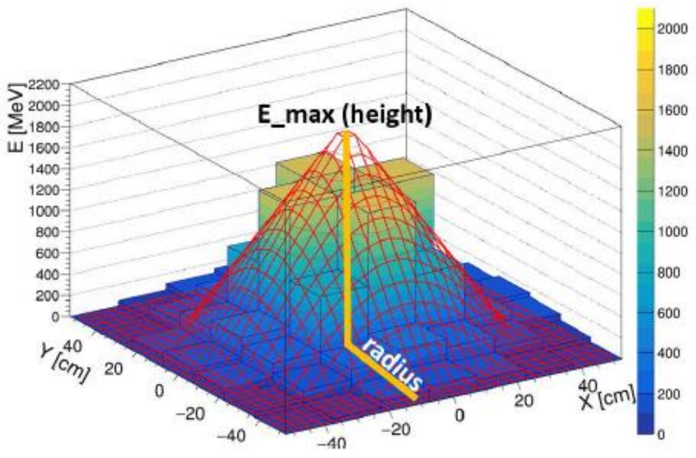
FHCal modules

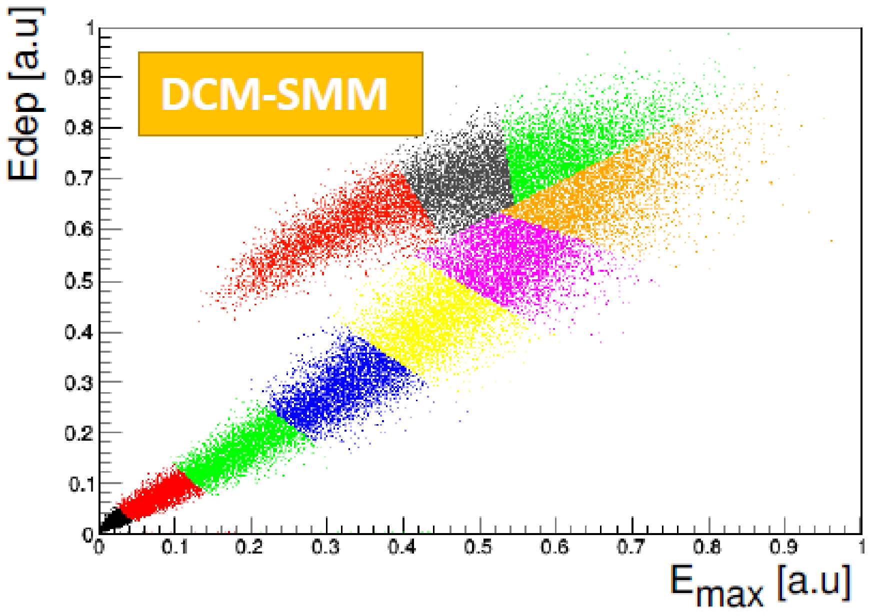


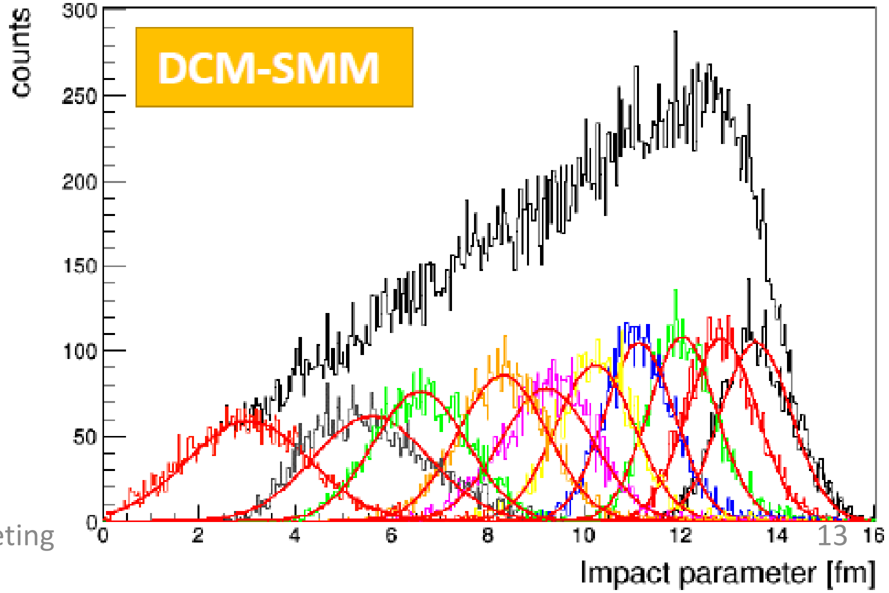
Due to the central hole in FHCal for the beam pipe some spectators can escape detection which will lead to the horn shape in the total deposited energy distribution

FHCal for centrality









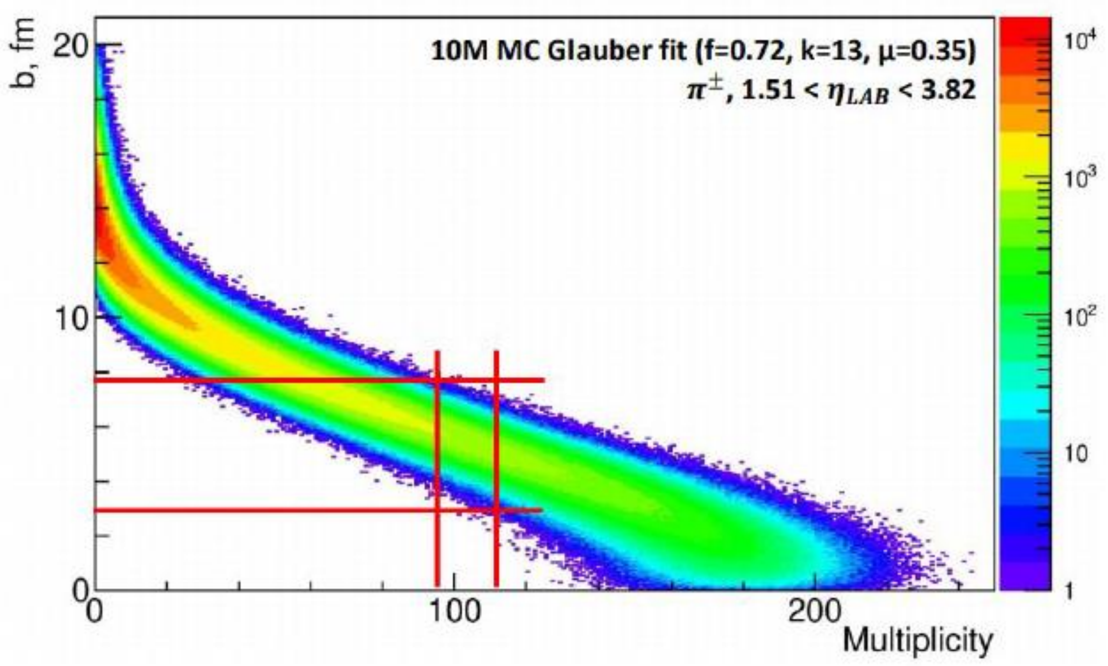
The main smearing factor in the spectator energy deposit estimator for the centrality would be the spectators which escaped detection.

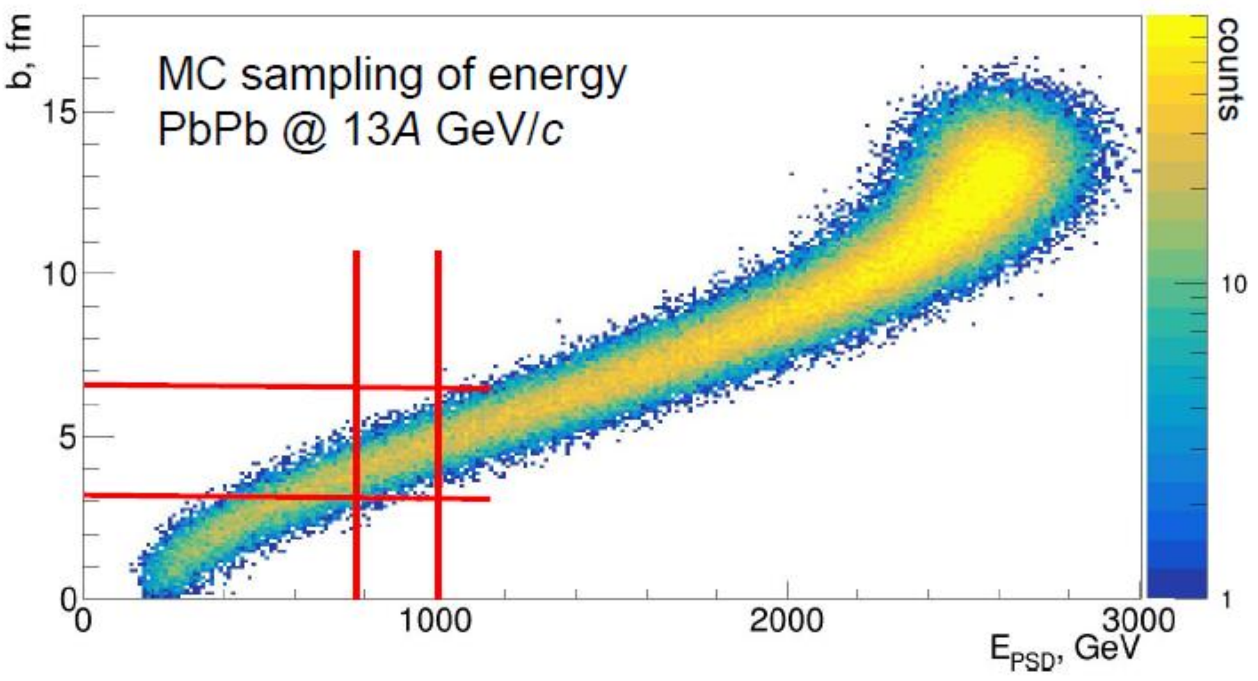
This leads to the possibility of mismatching centrality classes from very central with very peripheral events

Centrality estimations vs. impact parameter

Centrality estimators based on charged track multiplicity in TPC and spectator energy deposit in FHCal both give only a rather wide estimation of actual impact parameter of the collision

It can be worth it to have a method of combined estimation of the centrality to reduce these fluctuations of the centrality vs. impact parameter





Centrality class width

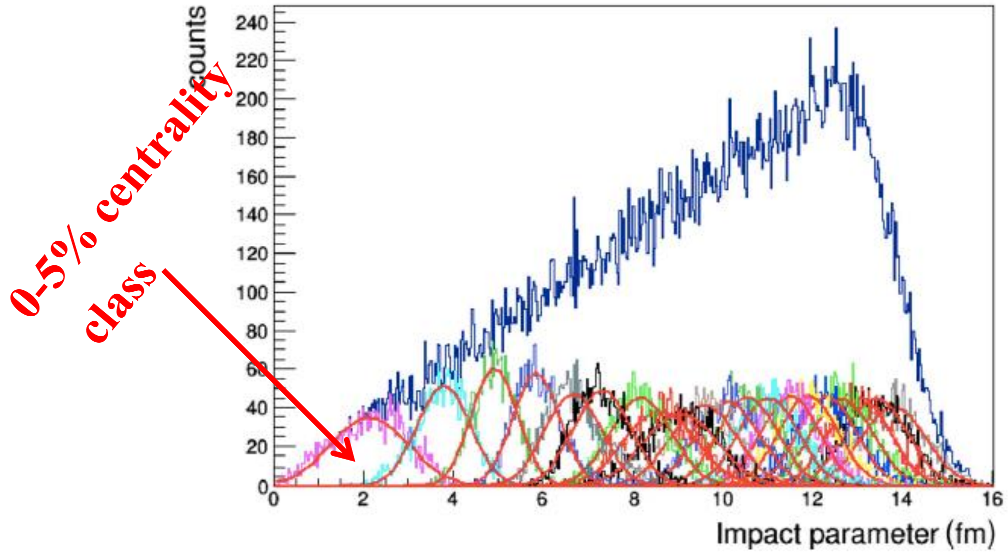
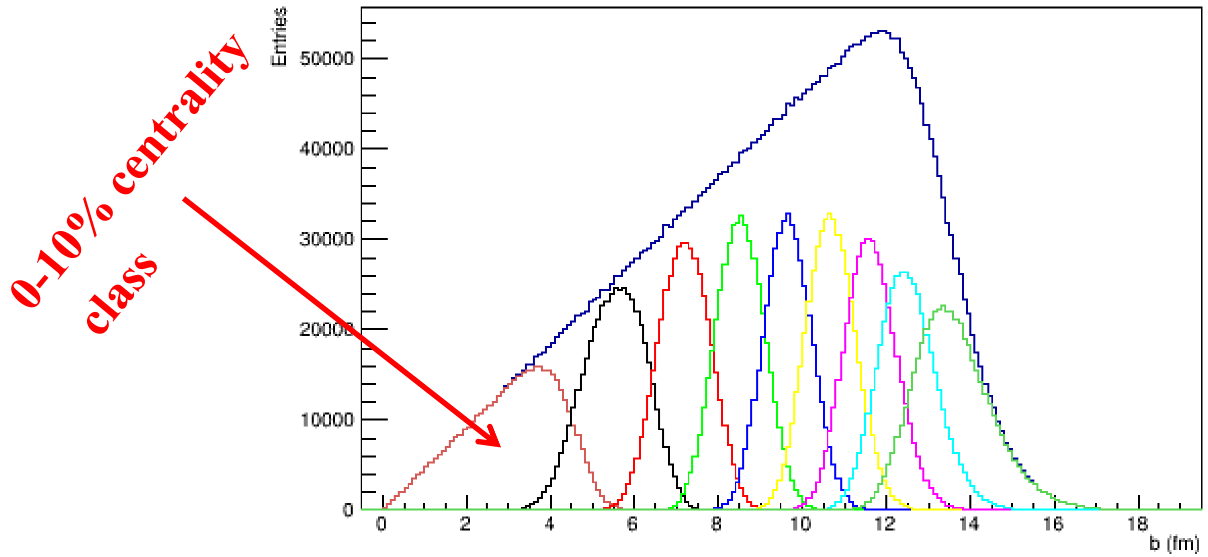


Fig. 44 Top: correlation of the energy deposition in the FHCal and the height of the cone, obtained from the linear fit of the two two-dimensional energy distributions in the FHCal modules. The different colors indicate groups of events within 5% centrality ranges. Bottom: distributions of the MC-generated impact parameters for each 5% group of events fitted to a Gaussian



- we need more precise selection of centrality classes
- we need events with well defined initial conditions and optimized class width
- we need combination of several observables – proxies of centrality, capable to minimize trivial volume fluctuations

Reaction plane

Reaction plane (RP) – plane formed by impact parameter *b* and beam line
RP cannot be measured in the experiment since we cannot measure *b*

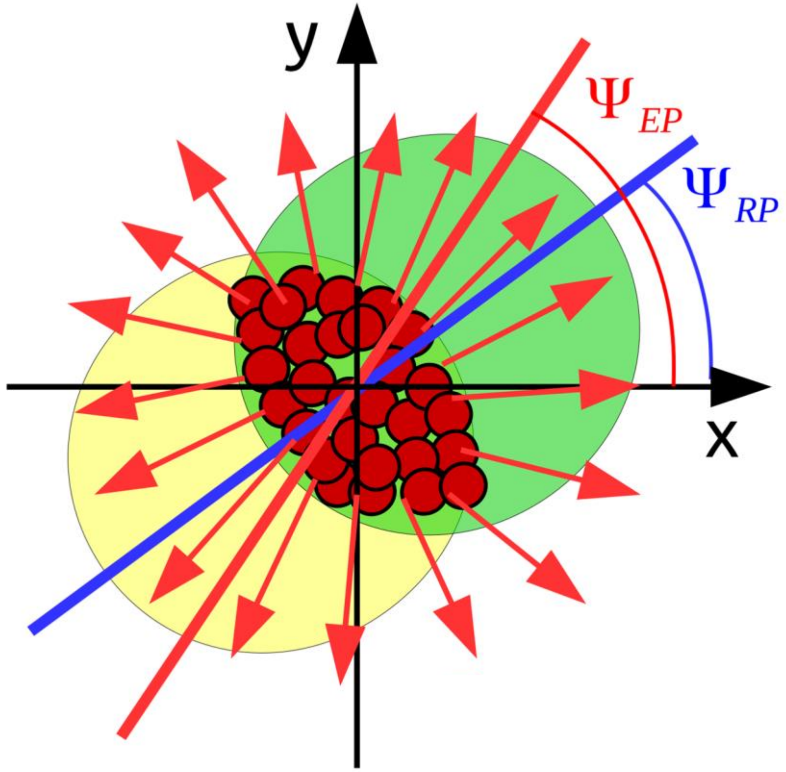
Event plane (EP) is the observable estimation of the reaction plane

$$\Psi_n^{EP} = \frac{1}{n}\tan^{-1}\left(\frac{Q_{n,Y}}{Q_{n,X}}\right)$$

$$v_n = \frac{\left\langle \cos\left(n\left(\varphi - \Psi_{n,EP}\right)\right)\right\rangle}{R_{n,EP}}$$

$$R_{n,EP} = \left\langle \cos\left(n\left(\Psi_{n,EP} - \Psi_{RP}\right)\right)\right\rangle$$

$$R_{n,EP} - \text{Resolutioncorrectioinfactor}$$



Calculation of the Event Plane

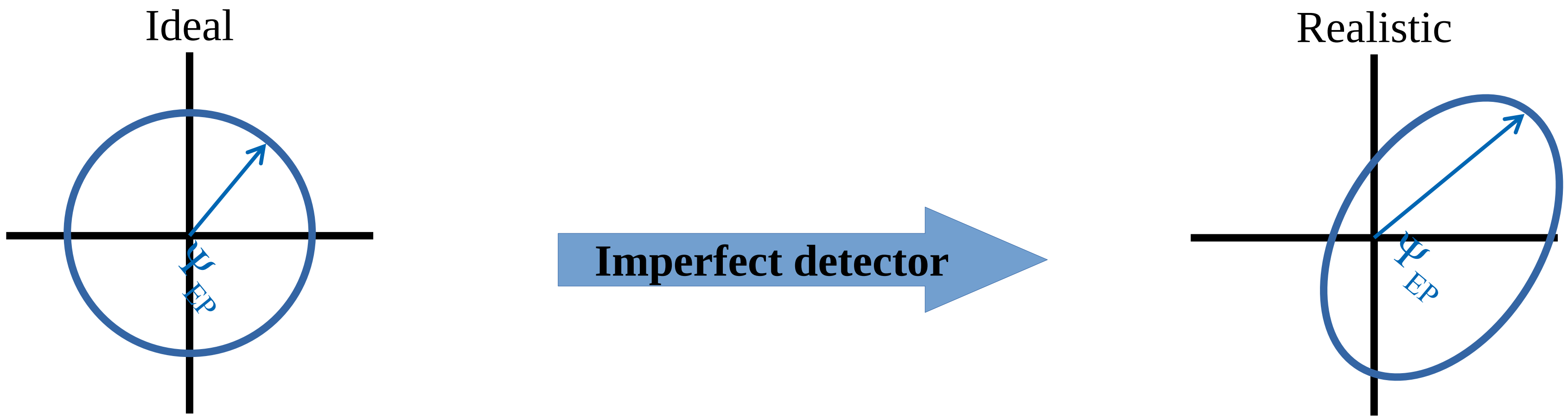
- EP angle is measured using Q-vectors from FHCal and TPC:

$$Q_{1,x}^{\mathrm{FHCal}} = \frac{1}{\sum E_{dep,i}} \sum E_{dep,i} \cos \phi_i \, , Q_{1,y}^{\mathrm{FHCal}} = \frac{1}{\sum E_{dep,i}} \sum E_{dep,i} \sin \phi_i$$

$$Q_{2,x}^{\mathrm{TPC}} = \sum p_{T,i} \cos 2\varphi_i \, , Q_{2,y}^{\mathrm{TPC}} = \sum p_{T,i} \sin 2\varphi_i$$

$$\Psi_1^{\mathrm{FHCal}} = \tan^{-1} \frac{Q_{1,y}^{\mathrm{FHCal}}}{Q_{1,x}^{\mathrm{FHCal}}}, \qquad \Psi_2^{\mathrm{TPC}} = \frac{1}{2} \tan^{-1} \frac{Q_{2,y}^{\mathrm{TPC}}}{Q_{2,x}^{\mathrm{TPC}}}$$

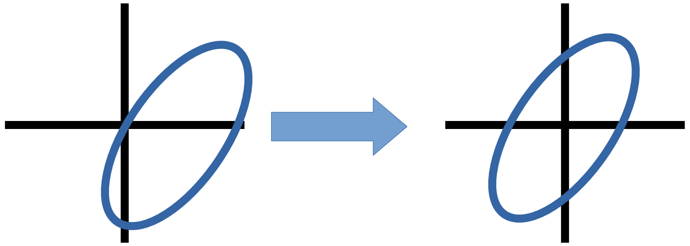
EP correction factors



Most common methods for the acceptance corrections are:

Recentering

$$Q^{Corrected} = Q - \langle Q \rangle$$



Flattening – removes contribution from higher harmonics

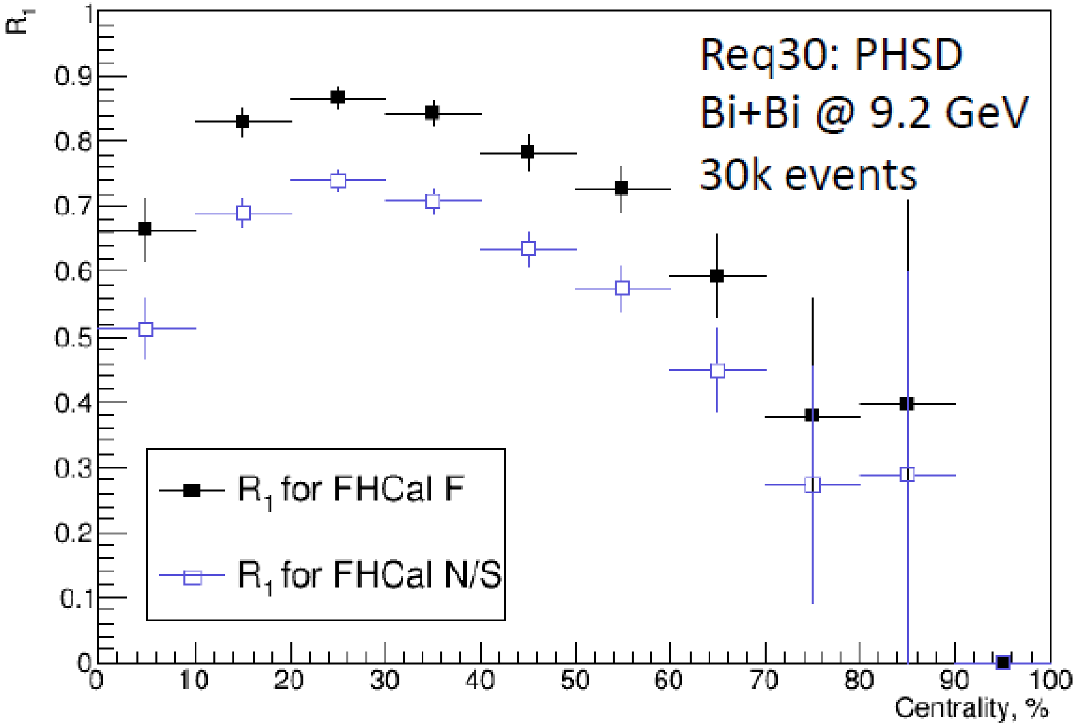
$$\Psi_{n,EP}^{Corrected} = \Psi_{n,EP} - n\Delta\Psi_n$$

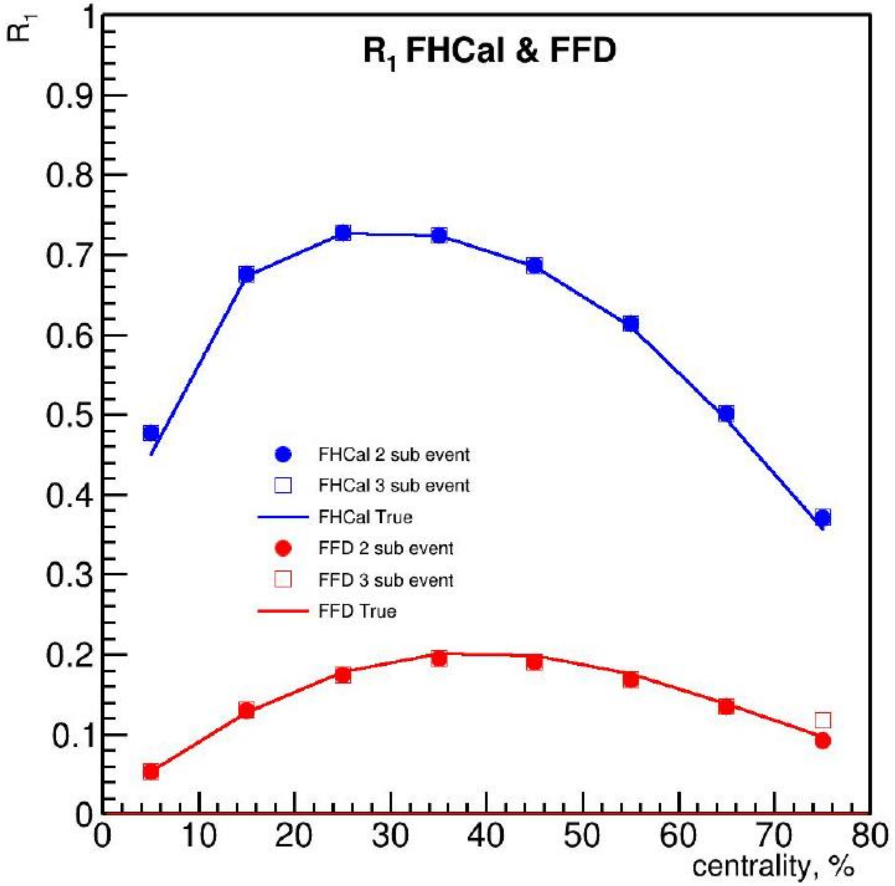
$$n\Delta\Psi_n = \sum_{i=1}^{i_{max}} \frac{2}{i}\left(-\langle \sin(in\Psi_n)\rangle \cos(in\Psi_n) + \langle \cos(in\Psi_n)\rangle \sin(in\Psi_n)\right)$$

Event plane resolution

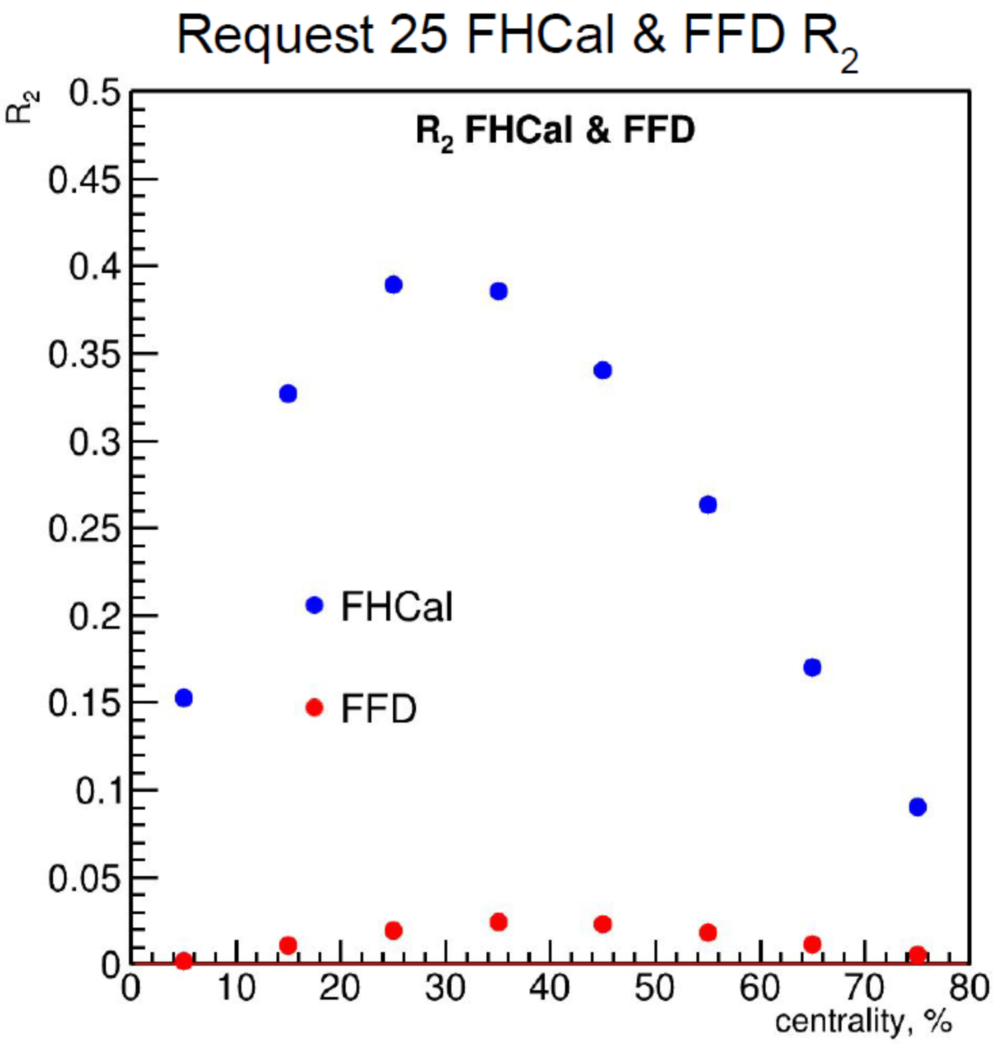
An unexpected? jump in reaction plane resolution from request 25 to request 30

Difference in UrQMD and PHQMD in FHCAL response?





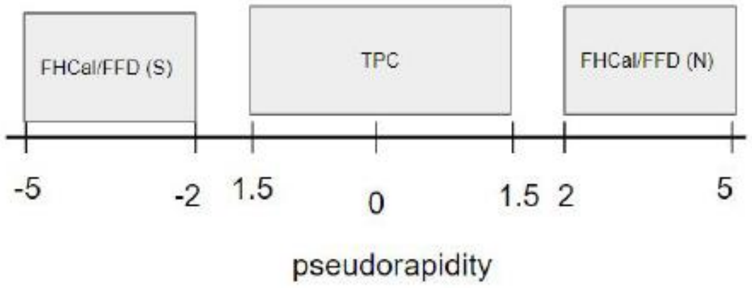
Event plane resolution



2 sub event

$$R_{1,i} = \sqrt{\langle Q^N_{1,i} Q^S_{1,i} \rangle}, i = x, y$$

$$R^{True}_{1,i} = \langle Q_{1,i} \Psi_{RP} \rangle$$



3 sub event

$$R^N_{1,i} = \sqrt{\frac{2\langle Q^N_{1,i} Q^S_{1,i} \rangle \langle Q^S_{1,i} Q^{TPC}_{1,i} \rangle}{\langle Q^N_{1,i} Q^{TPC}_{1,i} \rangle}}$$

- FFD resolution are smaller than FHCal
- 2 and 3 sub event has good agreement with True Resolution

Asymmetric nuclear collisions

A recent interest by Qazaqstan group

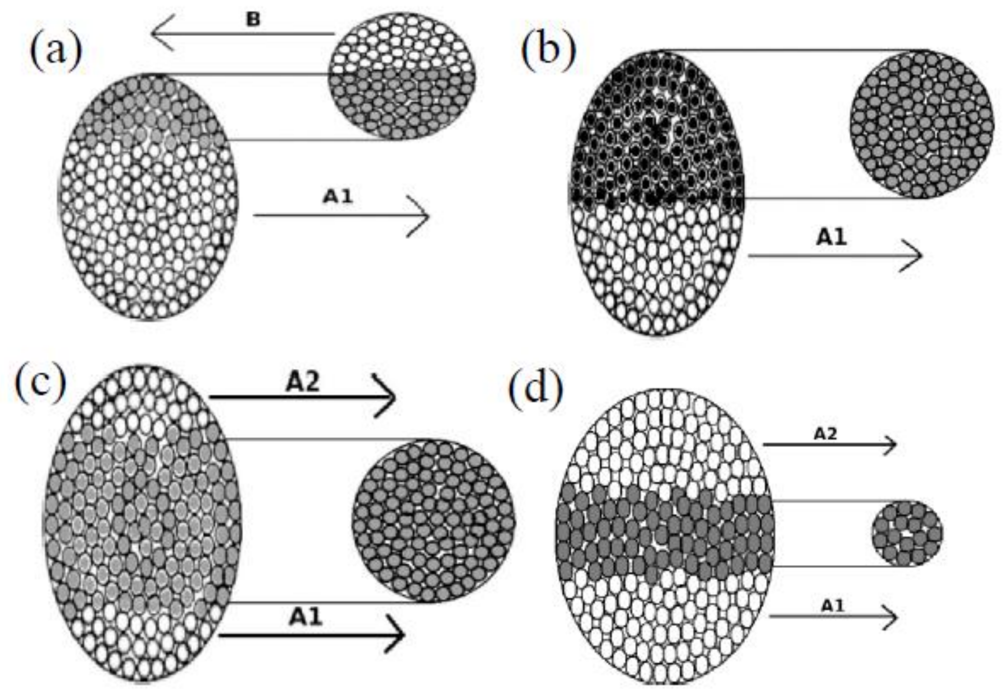


Figure 2 – Schematic representation of the interaction of nuclei with different degrees of centrality. Participating nucleons are marked in dark color (based on geometric representations). The light color indicates spectator nucleons that form fragments of the projectile and target nuclei.

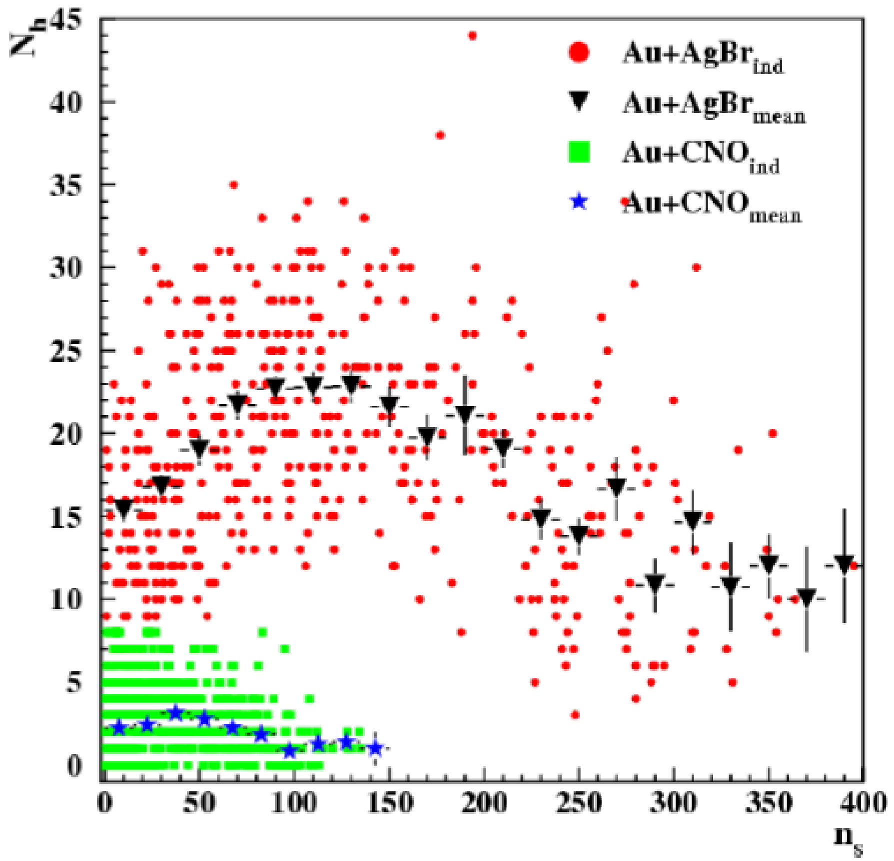
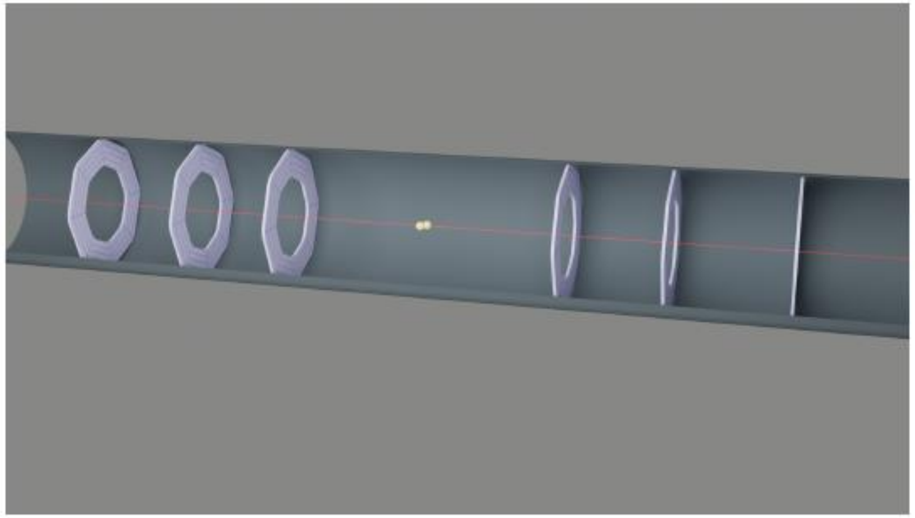
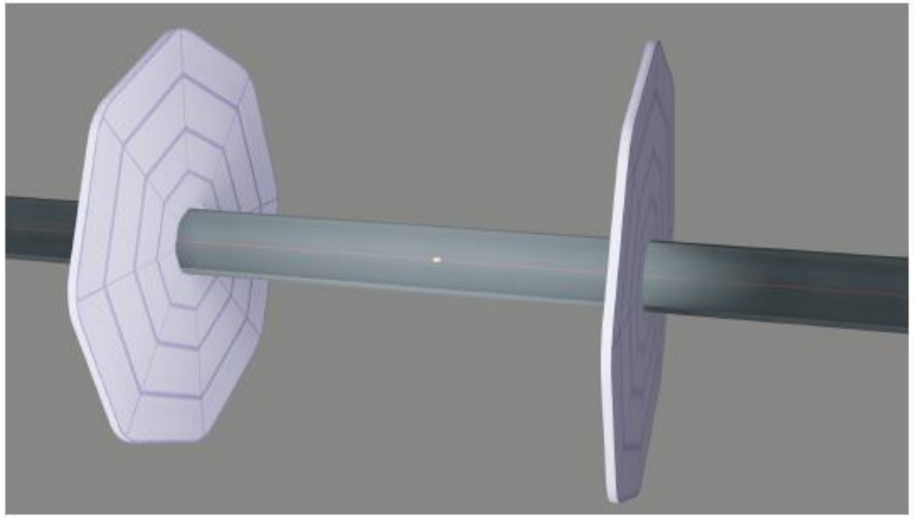


Figure 3 – Dependence of the total number of fragments of the target nucleus ($N_h=n_b+n_g$) and the number of shower particles n_s for the interaction of projectile-nucleus with heavy (AgBr) and light (CNO) target-nuclei.

Microchannel plate detector modeling





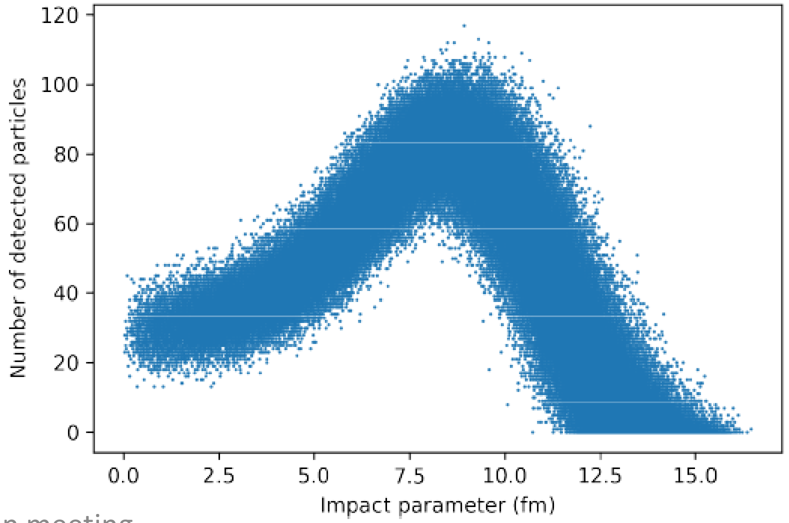
A proposition from SPbSU to use Artificial Neural Network ANN to model the layout of segmented microchannel plate detector for the MPD

Big detectors geometry:

- 300 - 400 floating point multiplications
- Preprocessing: number of particles and mean angle
- 2 x 352 cells

Small detectors geometry:

- 10000 - 80000 floating point multiplications
- Preprocessing: time-of-flight evaluation
- 6 x 32 cells



How to keep in touch

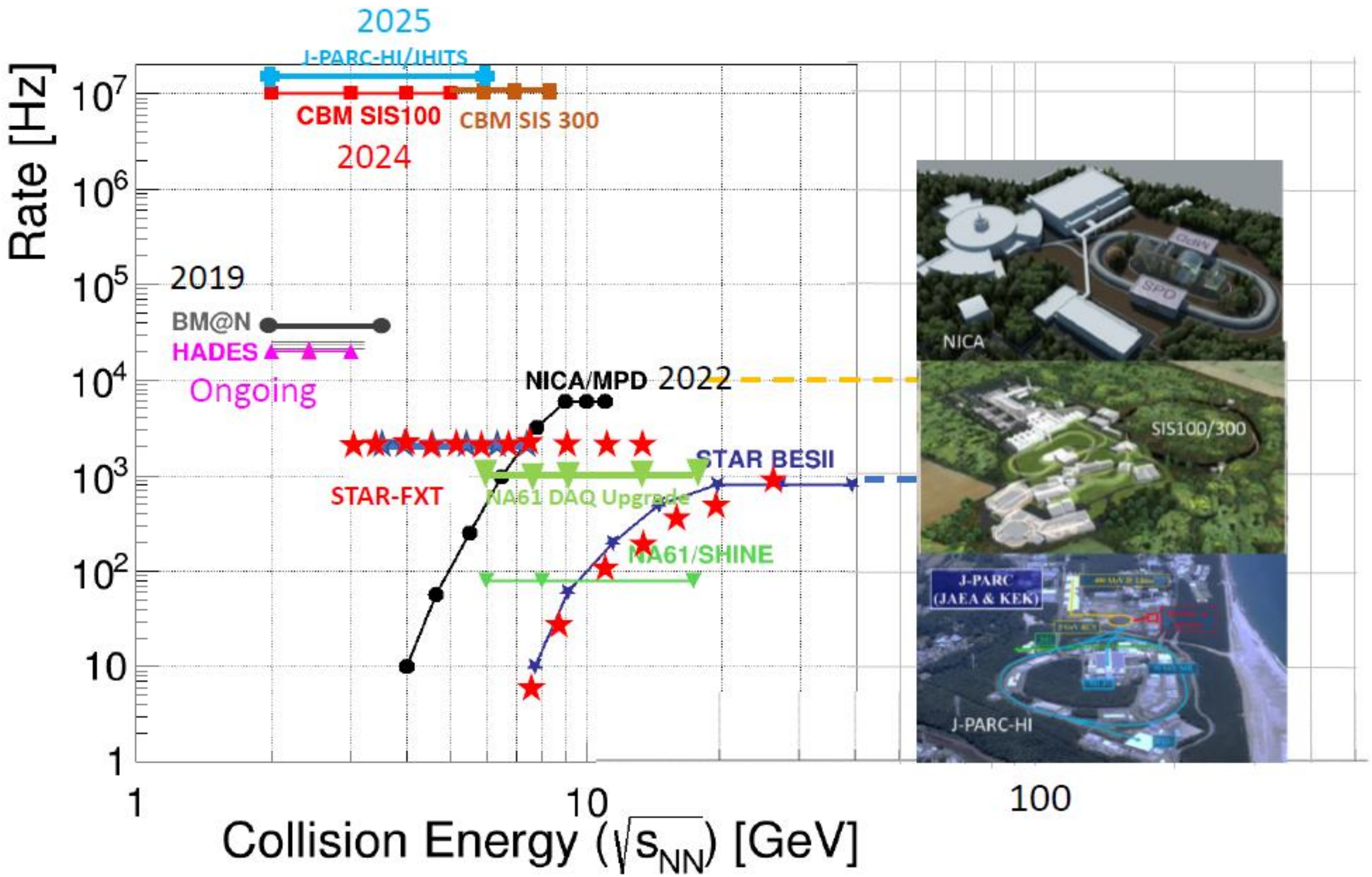
Physics Working Group 1

conveners:
Alexey Aparin (JINR) aparin@jinr.ru
Grigory Feofilov (SPbSU) grigory-feofilov@yandex.ru

PWG specific mailing list mpd_pwg1@maillist.jinr.ru
currently 29 active e-mails in this list
If you want to subscribe to PWG1 mailing list, please, contact the conveners

Meeting of the group can be organized if needed in addition to the cross-PWG meetings

HIC facilities and experiments



SPS up to 160 GeV

NICA/MPD is a Collider exp.
NICA single beam of about 10 GeV

Nuclotron reaches up to 3.5 GeV

JPARC up to about 18 GeV

BES-II data collection at STAR

STAR ☆

Recent BES-II, FXT and 200 GeV datasets (years 2018-2021)

$\sqrt{s_{NN}}$ (GeV)	Beam Energy (GeV/nucleon)	Collider or Fixed Target	$y_{center\ of\ mass}$	μ_B (MeV)	Run Time (days)	No. Events Collected (Request)	Date Collected
200	100	C	0	25	2.0	138 M (140 M)	Run-19
27	13.5	C	0	156	24	555 M (700 M)	Run-18
19.6	9.8	C	0	206	36	582 M (400 M)	Run-19
17.3	8.65	C	0	230	14	256 M (250 M)	Run-21
14.6	7.3	C	0	262	60	324 M (310 M)	Run-19
13.7	100	FXT	2.69	276	0.5	52 M (50 M)	Run-21
11.5	5.75	C	0	316	54	235 M (230 M)	Run-20
11.5	70	FXT	2.51	316	0.5	50 M (50 M)	Run-21
9.2	4.59	C	0	372	102	162 M (160 M)	Run-20+20b
9.2	44.5	FXT	2.28	372	0.5	50 M (50 M)	Run-21
7.7	3.85	C	0	420	90	100 M (100 M)	Run-21
7.7	31.2	FXT	2.10	420	0.5+1.0+ scattered	50 M + 112 M + 100 M (100 M)	Run-19+20+21
7.2	26.5	FXT	2.02	443	2+Parasitic with CEC	155 M + 317 M	Run-18+20
6.2	19.5	FXT	1.87	487	1.4	118 M (100 M)	Run-20
5.2	13.5	FXT	1.68	541	1.0	103 M (100 M)	Run-20
4.5	9.8	FXT	1.52	589	0.9	108 M (100 M)	Run-20
3.9	7.3	FXT	1.37	633	1.1	117 M (100 M)	Run-20
3.5	5.75	FXT	1.25	666	0.9	116 M (100 M)	Run-20
3.2	4.59	FXT	1.13	699	2.0	200 M (200 M)	Run-19
3.0	3.85	FXT	1.05	721	4.6	259 M -> 2B(100 M -> 2B)	Run-18+21

Summary

- Statistics for Bi+Bi collisions at 9.2 GeV: **~ 300M** min. bias events in different MC generators
- **More precise selection of the centrality class** in the MPD vs. STAR will provide more accurate determination of the number of binary collisions and of the R_{AA} factor
- Classes with narrow width of central collisions will eliminate considerably the trivial volume fluctuations and allow **to get new results** at the NICA energy
- We need to intensify organizational efforts prior to the actual data taking in order to effectively use working time
- We need to deliver **new physics message** from the MPD taking into account the huge amount of data from BES-II program at STAR

Thank you for the attention!

Backup slides

MC Glauber model provides a description of the initial state of a heavy-ion collision

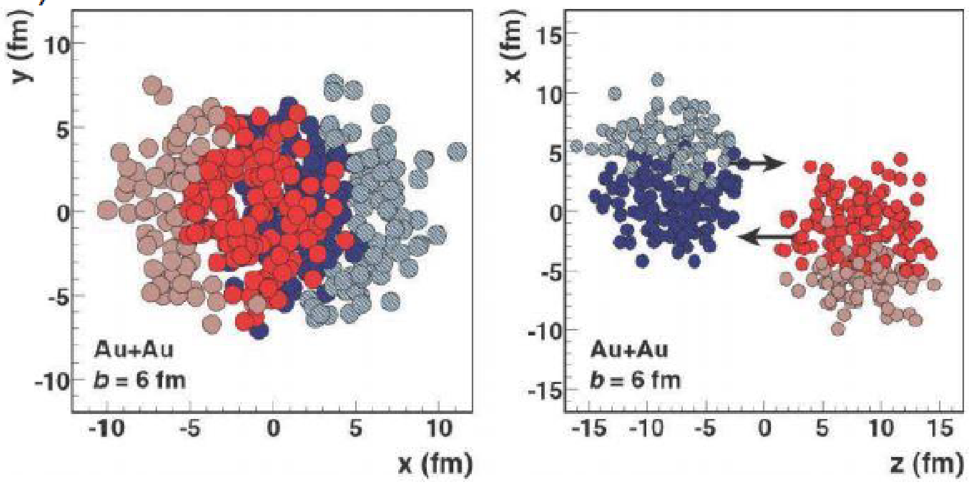
- Independent straight line trajectories of the nucleons
- A-A collision is treated as a sequence of independent binary NN collisions
- Monte-Carlo sampling of nucleons position for individual collisions

Main model parameters

- Colliding nuclei
- Inelastic nucleon-nucleon cross section (σ^{NN}_{inel}) (depends on collision energy)
- Nuclear charge densities (Wood-Saxon distribution)

$$\rho(r) = \rho_0 \cdot \frac{1 + w(r/R)^2}{1 + \exp\left(\frac{r-R}{a}\right)}$$

Glauber Modeling in High Energy Nuclear Collisions: ARNPS57:205-243,2007



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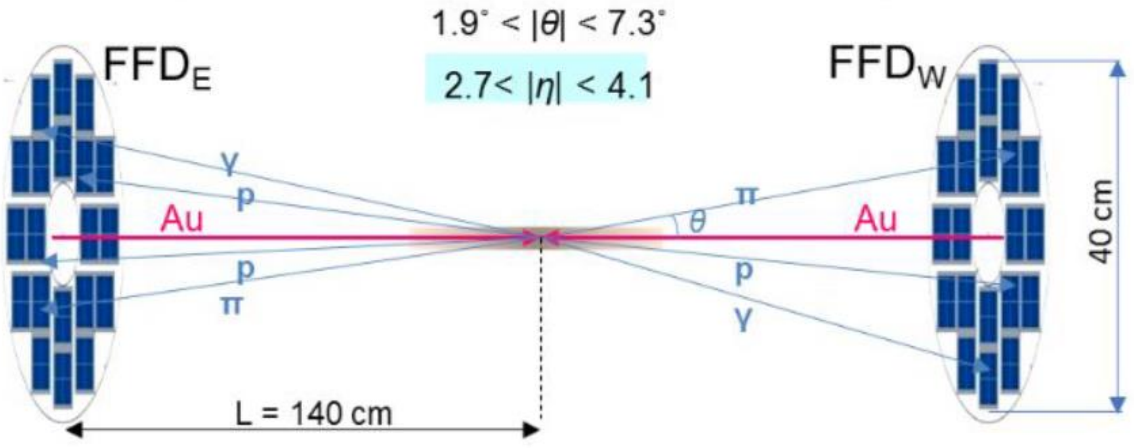
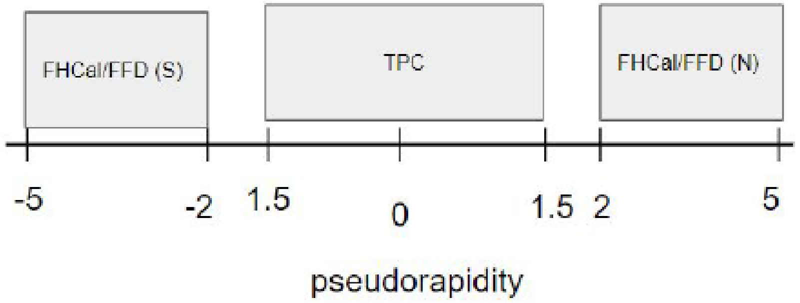


2 sub event

$$R_{1,i} = \sqrt{\langle Q^N_{1,i} Q^S_{1,i} \rangle}, i = x, y$$

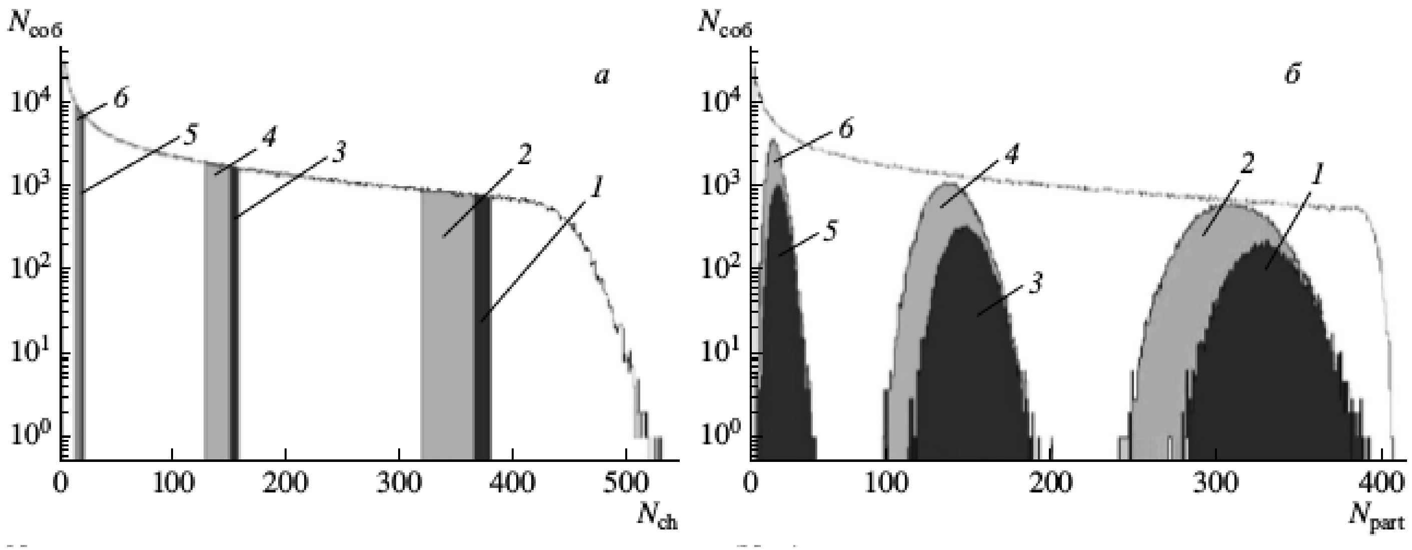
$$R^{True}_{1,i} = \langle Q_{1,i} \Psi_{RP} \rangle$$



3 sub event

$$R^N_{1,i} = \sqrt{\frac{2\langle Q^N_{1,i} Q^S_{1,i} \rangle \langle Q^S_{1,i} Q^{TPC}_{1,i} \rangle}{\langle Q^N_{1,i} Q^{TPC}_{1,i} \rangle}}$$

- Event plane Resolution of FFD is much more smaller than FHCal resolution;
- Good agreement for 2 and 3 sub event methods
- FFD has extremely small Resolution for 2-nd harmonic
- FFD needs more statistics than FHCal for flow measurements
- FHCal are better than FFD for flow measurements



$N_{соб}$
а
6
5
4
3
2
1
N_{ch}
б
N_{part}