Global observables in heavy-ion collisions at NICA
PWG1 Summary

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

Reported by G. Feofilov (SPbSU)
X Collaboration Meeting of the MPD Experiment at the NICA Facility
10.11.2022

https://indico.jinr.ru/event/3251/timetable/#20221109

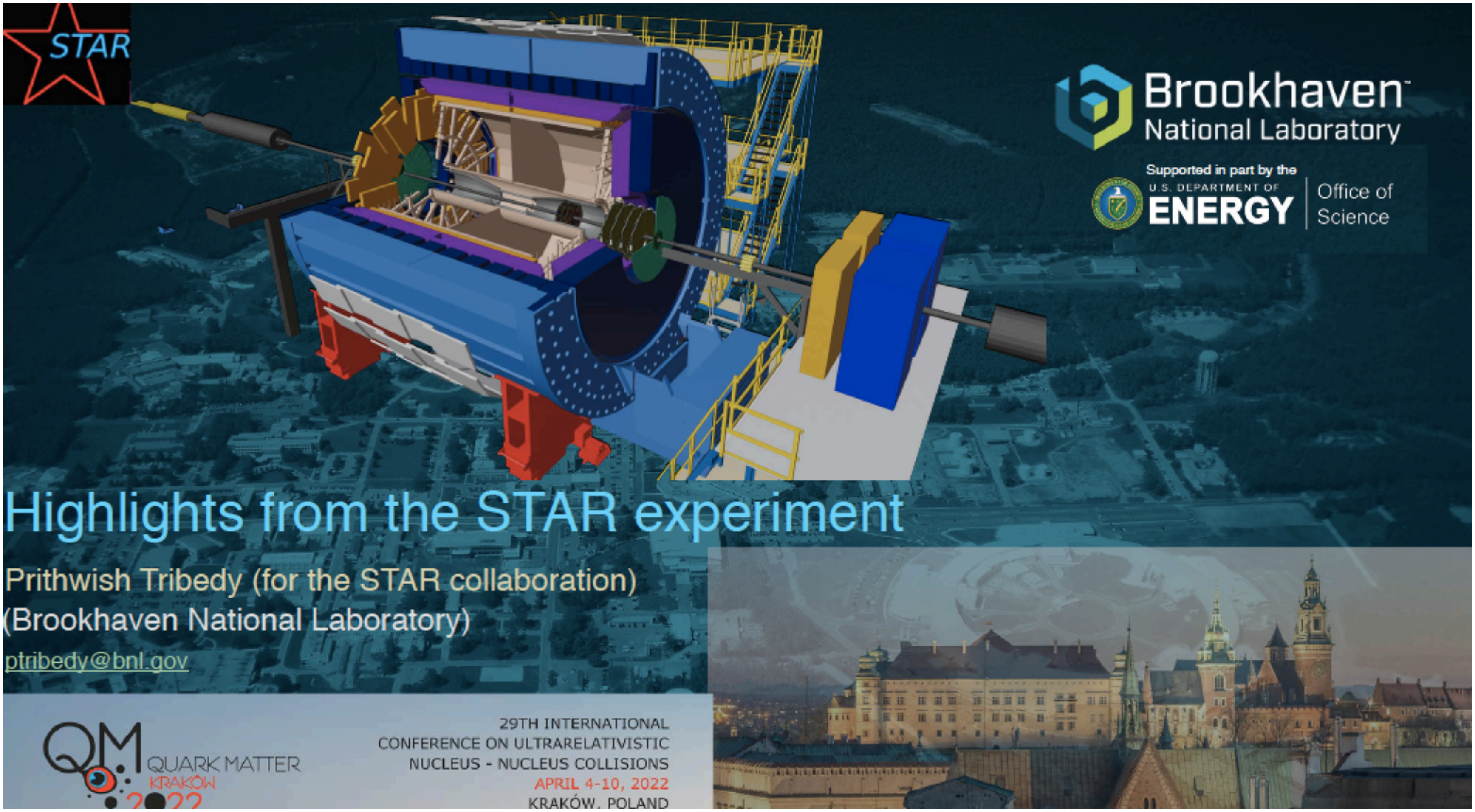
Layout of the talk

- **Introduction. Where we are today.**
- **Overview of some reports at Cross-PWG meetings in summer-autumn 2022**
- **Activity needed for the Physics Paper**

Where are we today?

➢ There is a very strong competition between STAR@RHIC (BES 1 and BES II) and NA61/SHINE@SPS…and CBM@FAIR and MPD@NICA!

Some highlights from STAR@RHIC presented at QM-2022



https://indico.cern.ch/event/895086/contributions/4314628/

Some highlights from STAR@RHIC presented at QM-2022

Outline of STAR highlights

- Isobar collisions & strong field effects
  1. Chiral magnetic effects — Slide #5-7
  2. Directed flow splitting — Slide #8
  3. Global polarization — Slide #9, 17
  4. Spin alignment — Slide #10
  5. Photoproduction — Slide #11-12
- New Insights on collective effects
  6. Nuclear shape & structure — Slide #14
  7. Longitudinal dynamics — Slide #15
- Prerequisites for phase transitions & freezeout
  8. Baryon stopping — Slide #18-19
  9. Strangeness production — Slide #20
  10. Hyper-nuclei formation — Slide #21
  11. Nuclei formation — Slide #22
  12. Hadron & nuclei femtoscopy — Slide #23
- Critical phenomena & mapping phase diagram
  13. Net-proton fluctuations — Slide #25
  14. Deuteron fluctuations — Slide #25
  15. Search for chiral crossover — Slide #26
  16. Di-lepton as QGP thermometer — Slide #27
- Hard probes in the medium
  17. J/ψ suppression — Slide #29
  18. High p_T hadron R_{AA} — Slide #30
  19. Heavy flavor jet shape — Slide #31
  20. Broadening of γ/π^0+jets — Slide #32
- Upgrades and future program
  21. Forward upgrade of STAR — Slide #34

STAR results are being presented in 21 parallel talks and 47 posters at this Quark Matter

STAR overview, P. Tribedy, QM 2022, Krakow, Poland 3

https://indico.cern.ch/event/895086/contributions/4314628/

Very reach harvest by STAR@RHIC **[1]**

6 / Nuclear Physics A 00 (2020) 1–8

$\sqrt{s_{NN}}$ (GeV)	Minbias (millions)	new detectors	year
200	138	EPD+iTPC	2019
54.4	835		2017
27	557	EPD	2018
19.5	582	EPD+iTPC	2019
14.6	324	EPD+iTPC	2019
11.5	235	EPD+iTPC+eTOF	2020
9.2	45*	EPD+iTPC+eTOF	2020
7.7	2.9**	EPD+iTPC	2019
31.2 FXT	112	EPD+iTPC+eTOF	2020
26.5 FXT	155		2017
19.5 FXT	118	EPD+iTPC+eTOF	2020
13.5 FXT	103	EPD+iTPC+eTOF	2020
9.8 FXT	108	EPD+iTPC+eTOF	2020
7.3 FXT	117	EPD+iTPC+eTOF	2020
5.75 FXT	116	EPD+iTPC+eTOF	2020
4.59 FXT	201	EPD+iTPC	2019
3.85 FXT	258	EPD	2018

Table 2. Major datasets at different energies in last 4 RHIC runs (2017 to early 2020) related to the beam energy scan with minimum-bias selection of Au+Au collisions at collider mode and FXT mode. The value for FXT mode is the single beam energy and not the $\sqrt{s_{NN}}$. 9.2 GeV will continue in the next run, and 7.7 was a commissioning run in 2019.

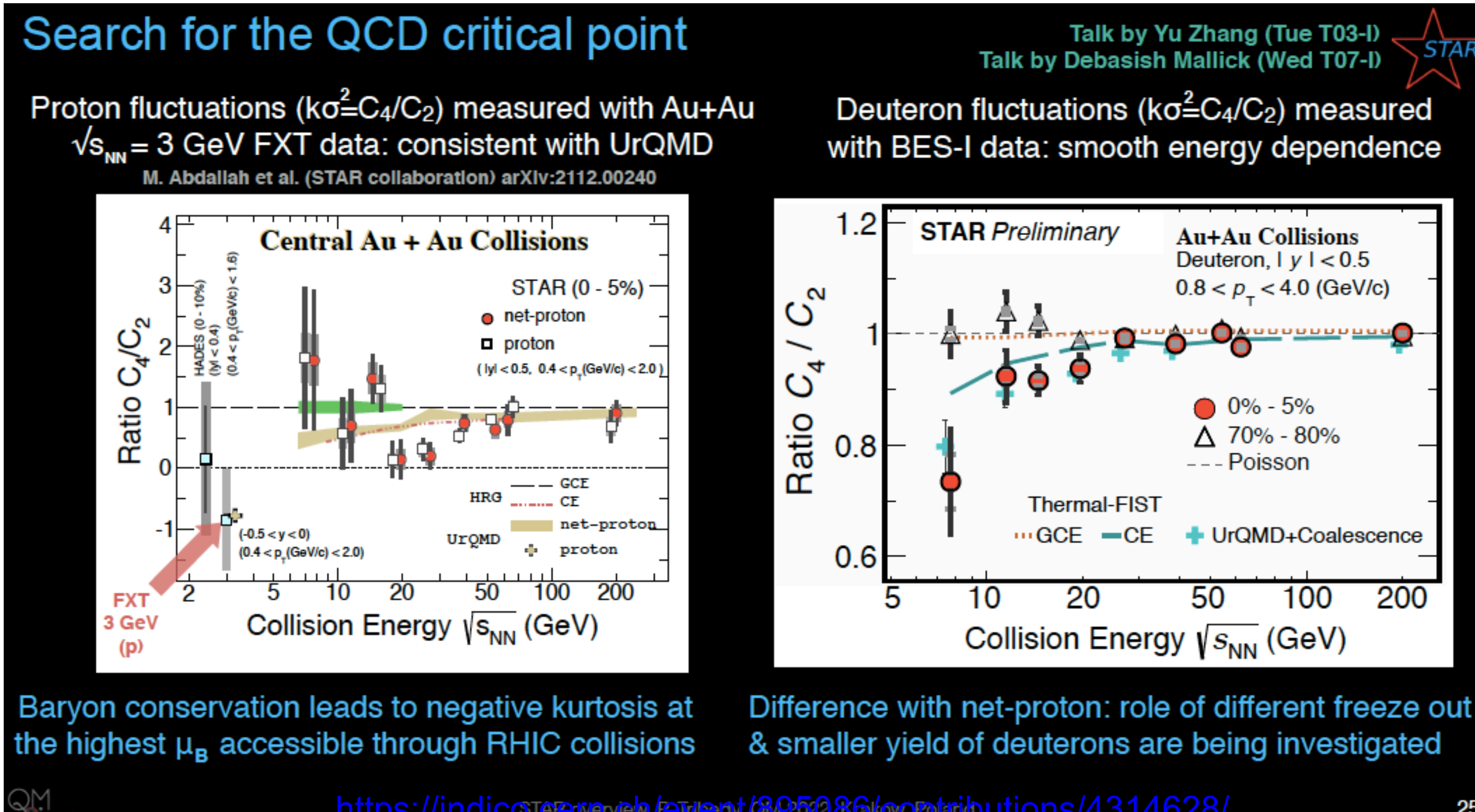
- [1] https://www.osti.gov/servlets/purl/1762771
- **See also later today the talk by Alexey Aparin :**

  "Identified particle production at STAR (BES)"

Important questions:

- **What is expected to be new by the MPD, compared to STAR ?**
- **What are the tasks needed for the Physics Paper in view of the Global Observables?**

Some new STAR data:
role of proton fluctuations



https://indico.cern.ch/event/895086/contributions/4314628/

- ➢ **Non-monotonic energy dependence of net-proton $k\sigma^2$ for 5% most central events**
- ➢ **Not decribed by the HRG model**

NEW!

NICA

- Deviations from the HRG behavior by STAR
- One of the possible theoretical explanations -

(by inclusion of the strongly interacting plasma screening properties)
-- could be found in the approach by Alejandro Ayala
using LSMq (the Linear Sigma Model with quarks) as an effective QCD model.

.

Talk by A.Ayala at NUCLEUS-2022:
https://events.sinp.msu.ru/event/8/contributions/604/attachments/586/1067/The_role_of_screening_Nucleus_2022_talk.pdf

Eur. Phys. J. A 58 (2022), 87; e-Print:2108.02362 [hep-ph]

From the talk by A.Ayala at NUCLEUS-2022:

Cumulants

For the HRGM,
ratios of cumulatns of even order are equal to 1

In particular, for the square of the variance σ^2 and the kurtosis κ
$\langle N^4 \rangle_c / \langle N^2 \rangle_c = \kappa\sigma^2$

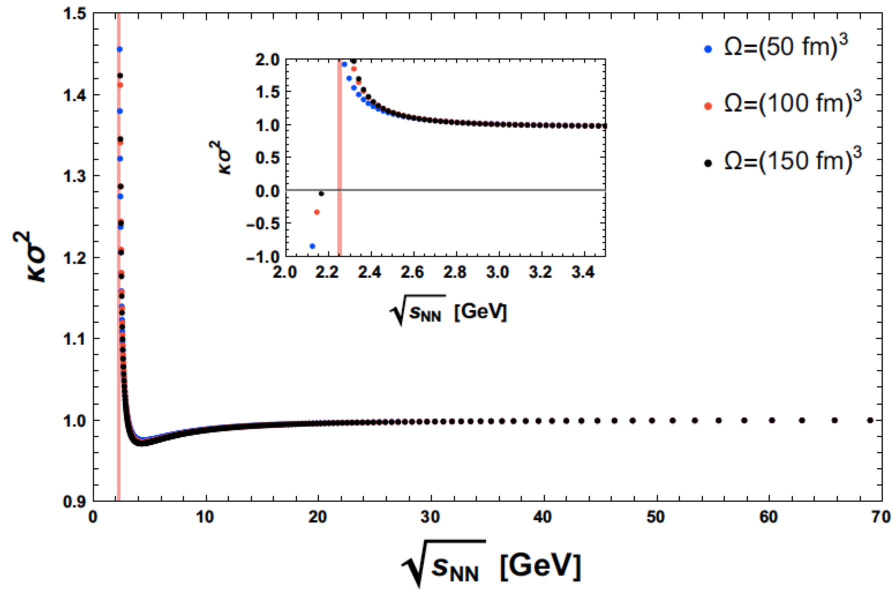
Look for deviations from 1 in $\kappa\sigma^2$ as a function of collision energy as a signal of the CEP.

https://events.sinp.msu.ru/event/8/contributions/604/

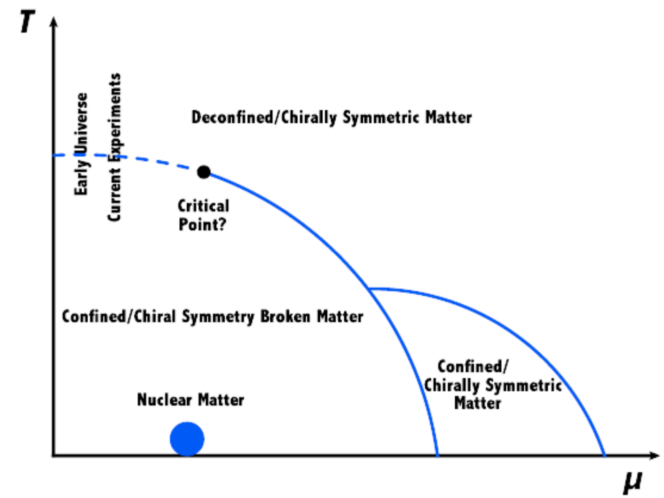
NEW!

From the talk by A.Ayala at NUCLEUS-2022:

Baryon number fluctuations in the LSMq



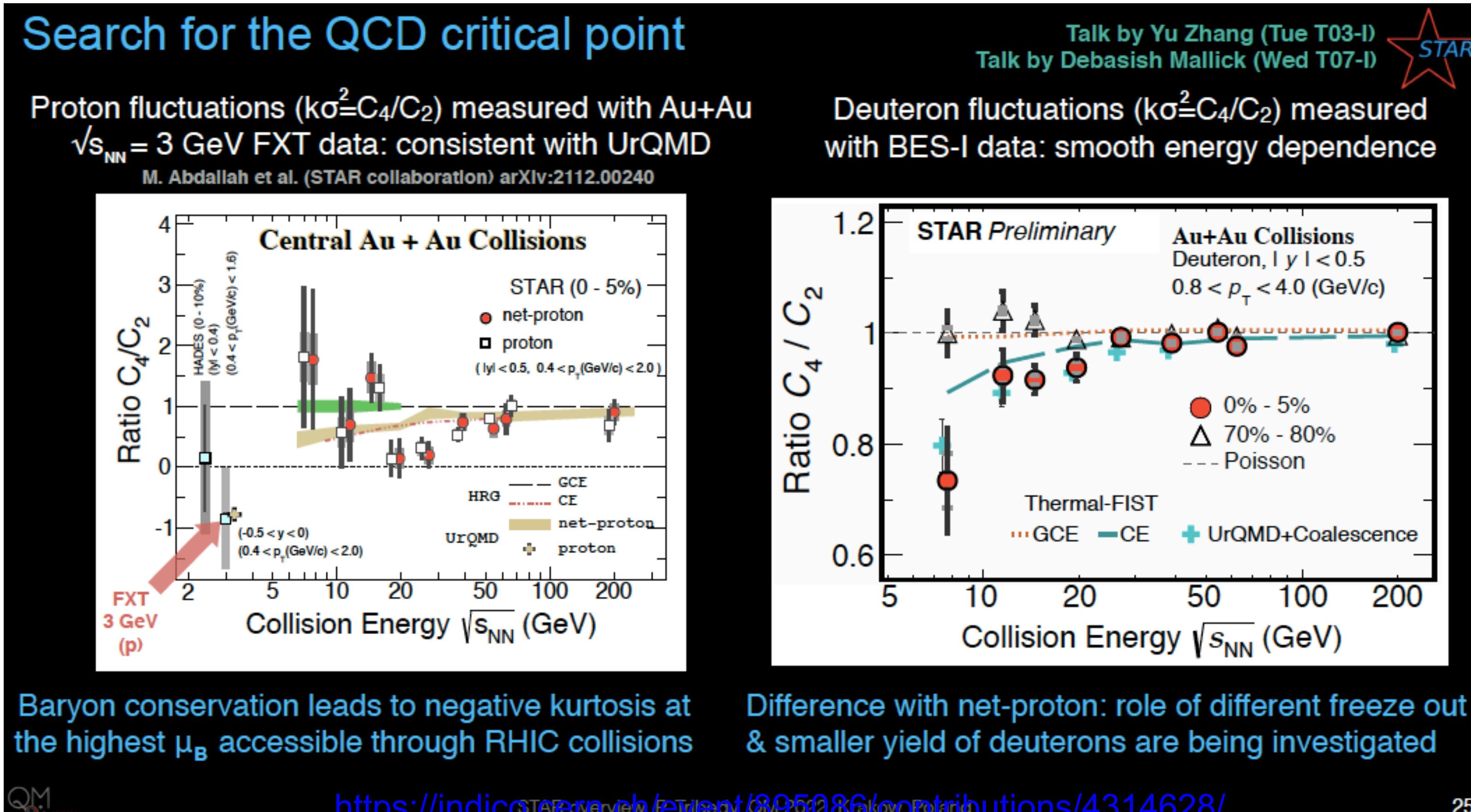
The QCD phase diagram



https://events.sinp.msu.ru/event/8/contributions/604/

- **The CEP can be located for collision energies of ~ 2 GeV per nucleon**

A closer look at STAR data:
role of fluctuations



https://indico.cern.ch/event/895086/contributions/4314628/

➢ **Class of 0-5% most central events – is it too narrow or too wide for studies of fluctuations?**

What is expected to be new by the MPD from the point of view of Global Observables?

0-5% centrality class is a mixture of different events, where the volume fluctuations are dominant, so:

- **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**

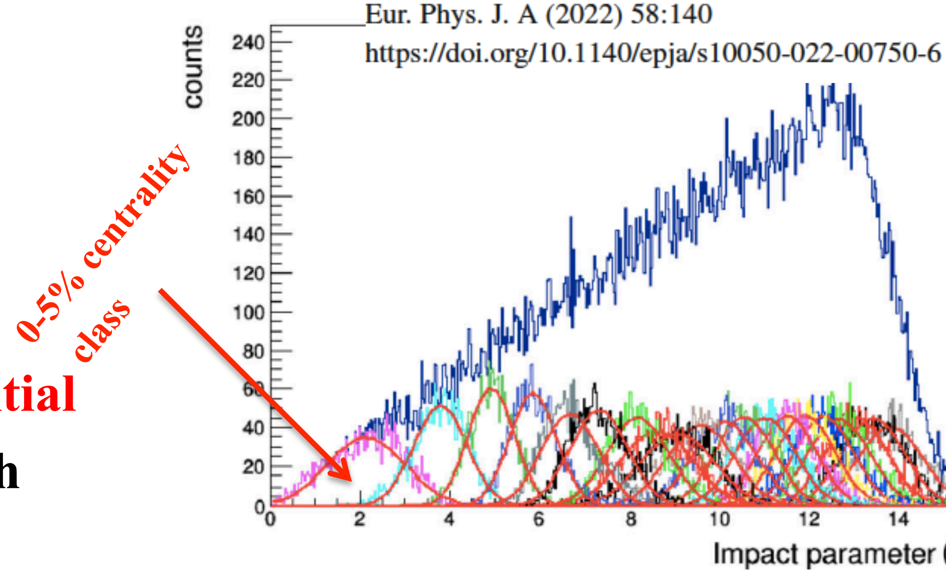
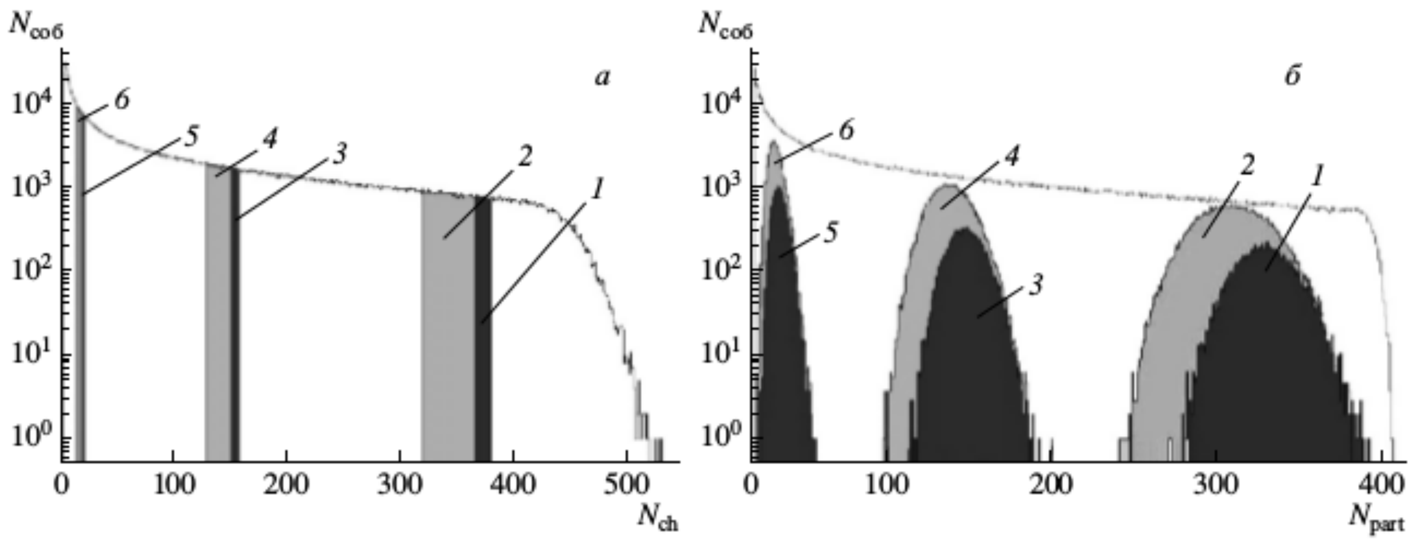


Fig. 44 Top: correlation of the energy deposition in the FHCa the height of the cone, obtained from the linear fit of the two dimensional energy distributions in the FHCal modules. The dif colors indicate groups of events within 5% centrality ranges. Bo distributions of the MC-generated impact parameters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

Centrality and multiparticle production in ultrarelativistic nuclear collisions



COMMENT : **Narrow distribution in Nch DOES NOT mean narrow distribution in Npart!**
https://link.springer.com/journal/11450

- Centrality determination and selection of classes by STAR should be taken with definite concern!

[1] T. A. Drozhzhova,V. N. Kovalenko,A. Yu. Seryakov,G. A. Feofilov, Physics of Atomic Nuclei, September 2016, Volume 79, Issue 5, pp 737–748

Question: with very reach harvest of STAR data at RHIC what is expected to be new by the MPD?

- Classes of central collisions with optimized width [1] will eliminate considerably the trivial volume fluctuations and allow **to get new results** at the NICA energy:
  - in flucand long-range correlations) tuations and correlation measurements (including short- range
  - in elliptic flow measurements, flow fluctuations, analysis of cumulant ratious, in studies with strongly intensive observables, etc.

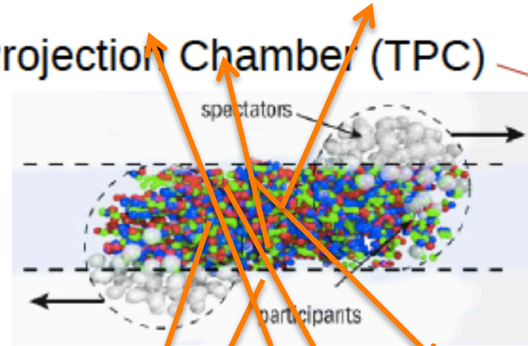
[1] T. A. Drozhzhova,V. N. Kovalenko,A. Yu. Seryakov,G. A. Feofilov, Physics of Atomic Nuclei, September 2016, Volume 79, Issue 5, pp 737–748

Current approaches to centrality class selection:

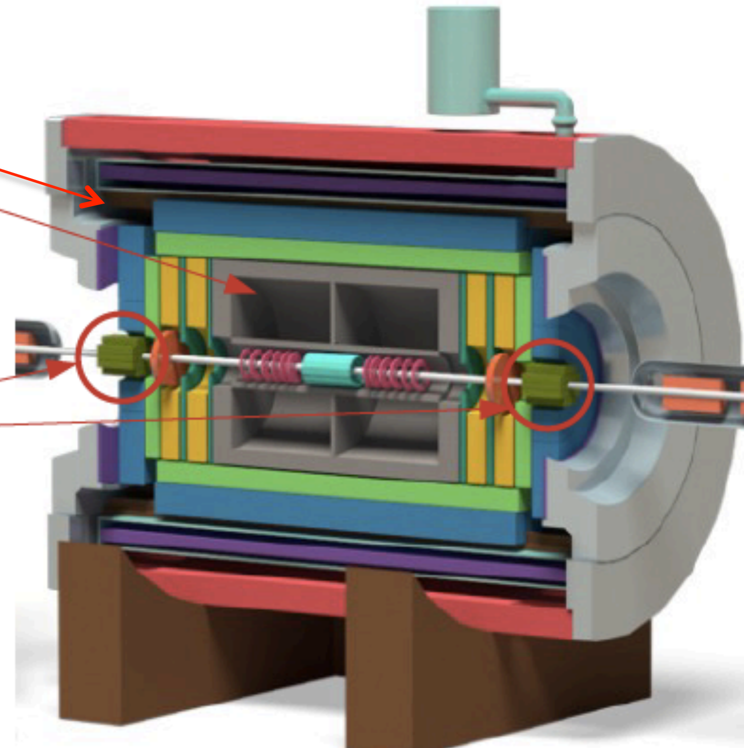
(1) Charged particle Multiplicity classes by the TPC
(2) Spectator energy classes by FHCal
(3) Transverse energy classes by the ECAL
NEW! (4) Machine learning with TOF MCP

- Time Projection Chamber (TPC)

$|\eta|<1.5$

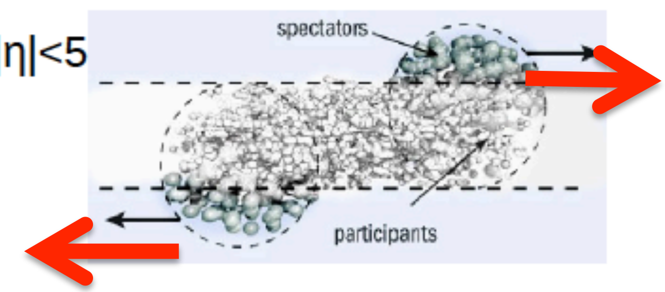


ECAL



- Forward Hadron Calorimeter (FHCal)

$2<|\eta|<5$



PWG1 meetings: Sept.2021- March 2022

24 March 2022 Speaker: I.Maldonado (Universidad Autónoma de Sinaloa) ,"Update BiBi Collisions at 9.2 GeV

27 Jan 2022, A.Seryakov (SPbSU)," Influence of different centrality methods on multiplicity fluctuations: MPD case"

20 Jan 2022

- G.Feofilov and A.Aparin. "PWG1: planning of activity for 2022"
- I.Maldonado (Universidad Autónoma de Sinaloa)"BiBi collisions at 9.2 GeV"

18 November 2021,

- Dr. G.Musulmanbekov, "Nuclear fragments deposited in FHCal. DCM-QGSM or DCM-SMM?"
- A.Aparin "Discussion concerning a way to establish a standartized procedure for basic QA",

09 Sept. 2021

- Pedro Antonio Nieto Marín "Centrality determination in MPD at NICA"¶ 20m by "Centrality determination in MPD at NICA".

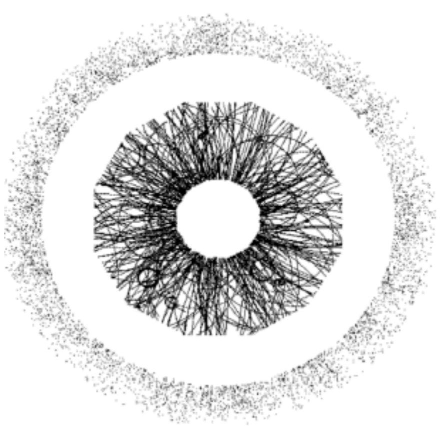
Centrality related reports at Cross-PWG meetings in summer-autumn 2022

1) **Andrey Seryakov, 31.05.2022,** "Influence of different centrality methods on multiplicity fluctuations: MPD case " https://indico.jinr.ru/event/3098/
2) **Valerii Troshin**, 14.06.2022, "Study of the systematics in determining the symmetry plane for Bi-Bi collision", https://indico.jinr.ru/event/3120/
3) **Viktor Riabov,** 14.06.2022, "E_T distributions and event centrality", https://indico.jinr.ru/event/3120/
4) **Victor Riabov, 12.07.2022,** "Event centrality with TPC, ECAL and FHCAL" , **https://indico.jinr.ru/event/3192/**
5) **Grigory Feofilov, 31.05.2022,** Fast Beam–Beam Collision (FBBC) monitor based on Micro Channel Plate detectors (MCPs) https://indico.jinr.ru/event/3098/
6) **Kirill Galaktionov, 18.10.2022,** "Machine learning based study of microchannel plate detector configurations for future NICA experiments", https://indico.jinr.ru/event/3279/

NEW!

Andrey Seryakov, 31.05.2022, “Influence of different centrality methods on multiplicity fluctuations: MPD case “

https://indico.jinr.ru/event/3098/



Influence of different centrality methods on multiplicity fluctuations MPD case

Andrey Seryakov
LUHEP SPbSU
andrey.seryakov@cern.ch

LUHEP SPb SU

Andrey Seryakov, 31.05.2022, "Influence of differ
centrality methods on multiplicity fluctuations: MPD case
https://indico.jinr.ru/event/3098/

- 4 centrality methods (more information is on the next slides):
  - Impact parameter – ideal, unrealistic case
  - Number of nucleon participants – realistic, but currently unreachable
  - FHCall pyramid algorithm
  - Multiplicity in a separate rapidity window
- a bunch of fluctuations quantities:
  - First 4 moments of multiplicity distributions
  - Strongly intensive $\Delta[Pt, N], \Sigma[Pt, N]$
  - First 4 factorial moments of net charge distributions

➢ **What**

Andrey Seryakov, 31.03.2022, "Influence of differ
centrality methods on multiplicity fluctuations: MPD case
https://indico.jinr.ru/event/3098/

Data set

90k events DCM-CMM min.bias Au+Au 11A GeV produced by INR

Only FHCal was simulated (GEANT 4)

No reconstruction was done not to interfere with centrality effects.

Therefore measured multiplicity is a pure one from MC:
pi+/-, p+/-, K+/- $|\eta|<0.8$, $0.15<pt<2$

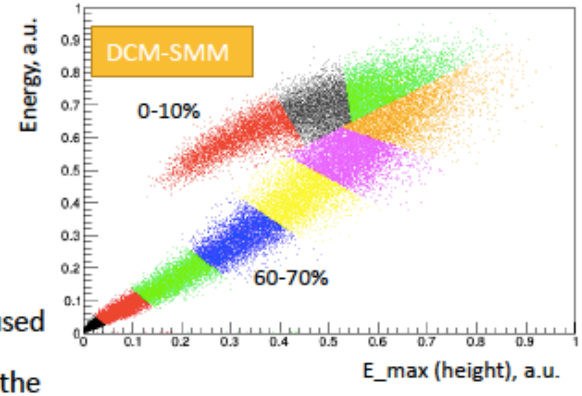
- **What**

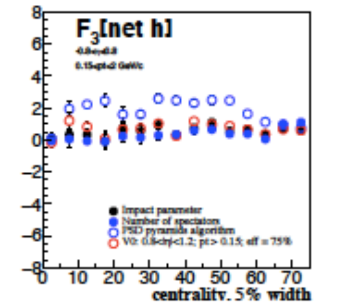
centrality methods on multiplicity fluctuations: MPD case

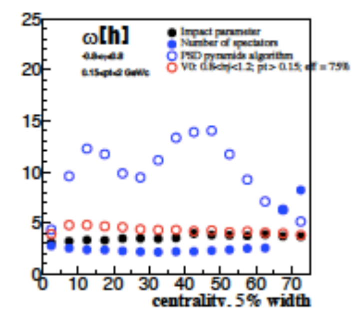
https://indico.jinr.ru/event/3098/

Conclusions

- The current state of the pyramid procedure:
  - Can't be reproduced in pure MC by people from outside the collaboration, so it may be used only as a proxy to Npart or b.
  - Doesn't restrict volume fluctuations enough to measure multiplicity fluctuations, except the most central point (0-1%). Although I would expect this region to become narrower with statistic and better calorimeter description (effects of electronics).
  - A further development is needed
    - Maybe a 3rd axis (multiplicity) has to be introduced to increase resolution capability between very central and very peripheral events.
    - A different fit instead of the pyramid?
  - We have to be very careful with this procedure as:
    - MC generators are usually having a much worse description of the forward region compare to the central rapidity
    - GEANT 4 description of FHCal doesn't not include effects of electronic, which can be very significant (based on my experience of analyzing data from PSD at NA61/SHINE)
- Contrary to FHCal, the multiplicity based procedure shows close results to Npart and b and can be easily reproduced by people from outside MPD.
- Considering all of the above, I would recommend using FHCal for fluctuation measures only for the most central events and to study a possibility of using simultaneously both centrality proxies – multiplicity and FHCal.







NEW!

Victor Riabov, 12.07.2022, "Event centrality with ECAL and FHCAL" , https://indico.jinr.ru/event/3192/

Selection cuts

NEW

- Event selections:
  - ✓ BiBi@9.2, DCM-QGSM-SMM (for central and forward rapidities)
  - ✓ b = 0-17 fm
  - ✓ inelastic collisions
  - ✓ z-vertex = 0 to avoid efficiency corrections

- Track selections (for centrality by TPC multiplicity):
  - ✓ n-hits > 10
  - ✓ $|\eta| < 0.5$
  - ✓ $|DCA_{x,y,z}| < 2$ cm

- ECAL cluster selections:
  - ✓ $E_\gamma > 50$ MeV
  - ✓ n-towers > 1

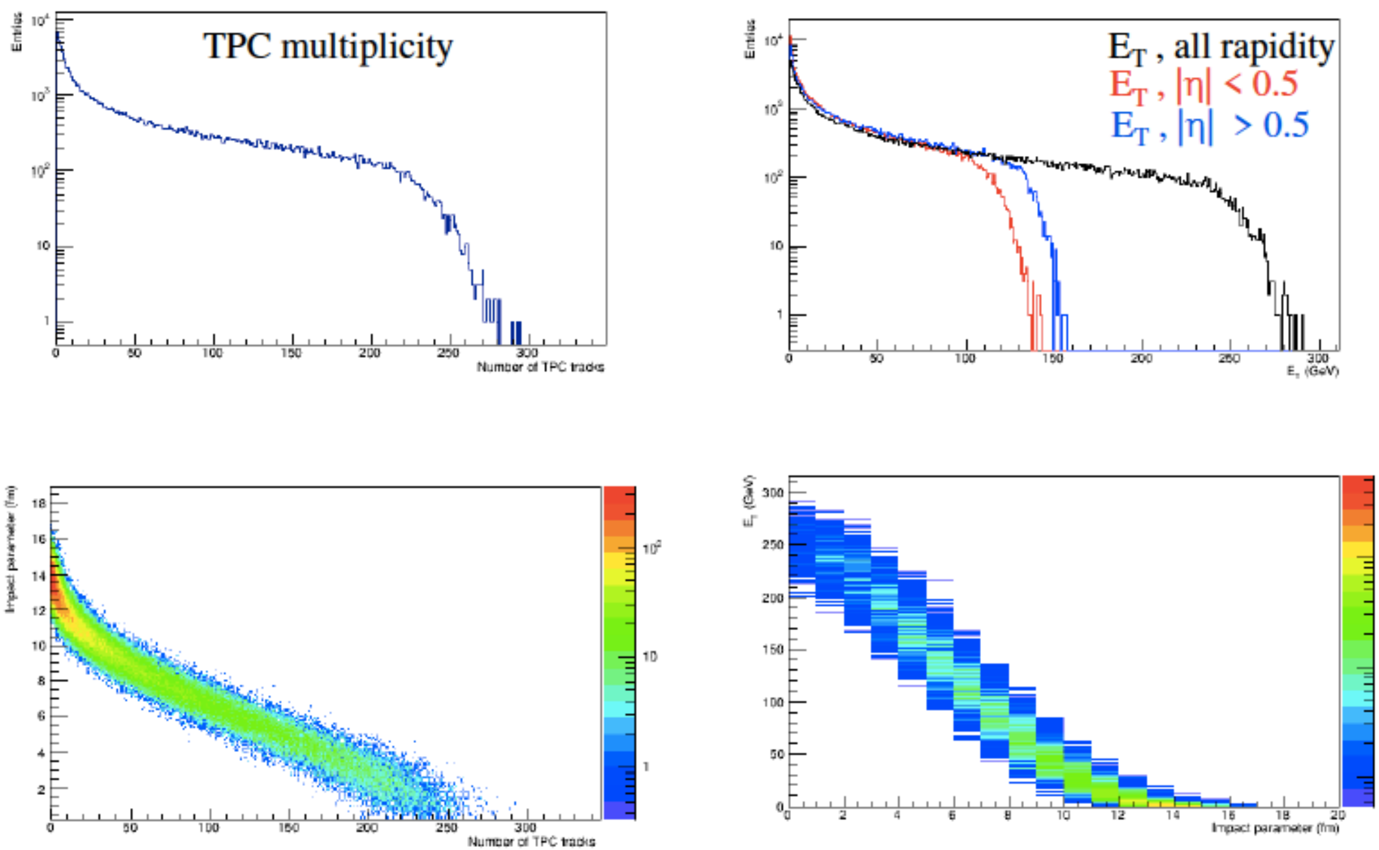
- FHCAL:
  - ✓ standard centrality with event distribution by E_{tot} vs. $E_{\_max\_cone}$

Victor Riabov, 12.07.2022, “Event centrality with ECAL and FHCAL” ,

NEW!

https://indico.jinr.ru/event/3192/

N_{TPC}, E_T distributions

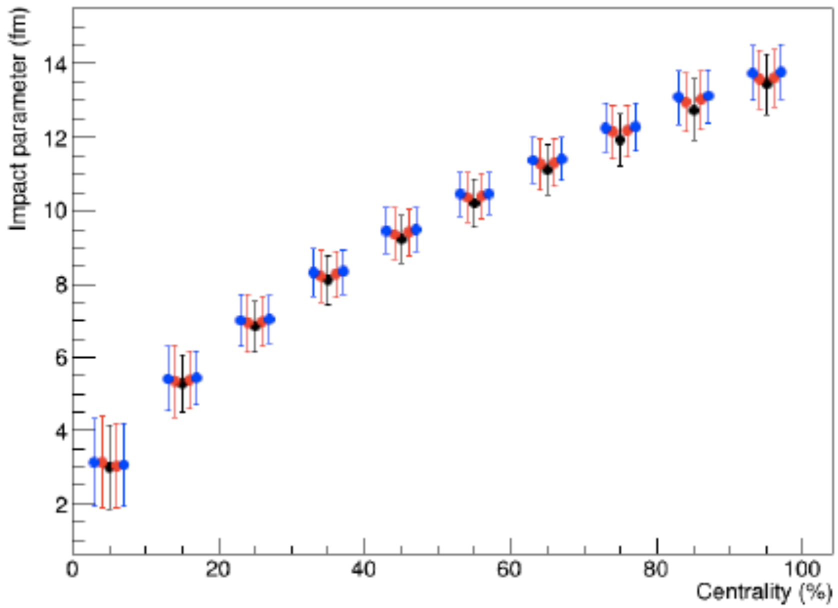


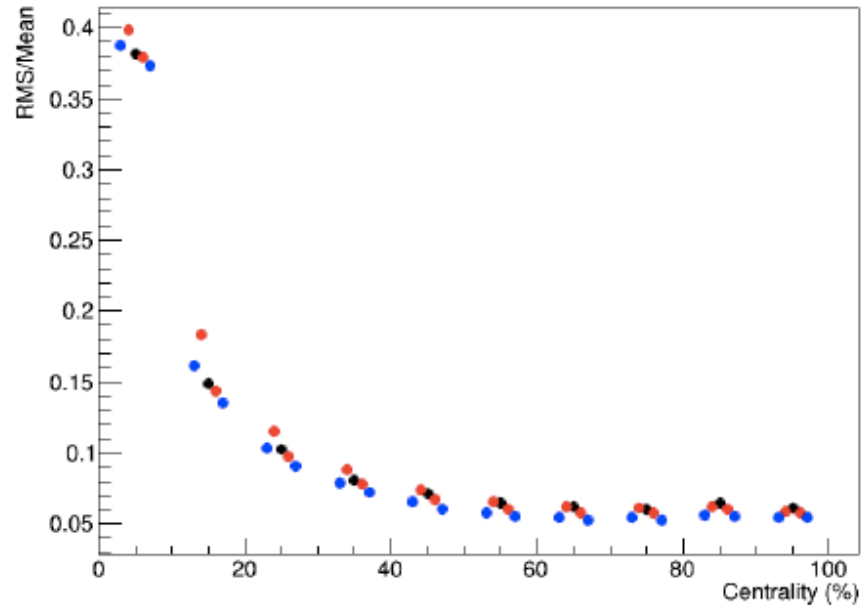
Victor Riabov, 12.07.2022, "Event centrality with ... ECAL and FHCAL" ,

NEW!

Sampled impact parameter distributions

E_T-CPV, |η|> 0.5, E_T-CPV, |η|< 0.5, TPC centrality, E_T, |η|< 0.5, E_T |η|> 0.5



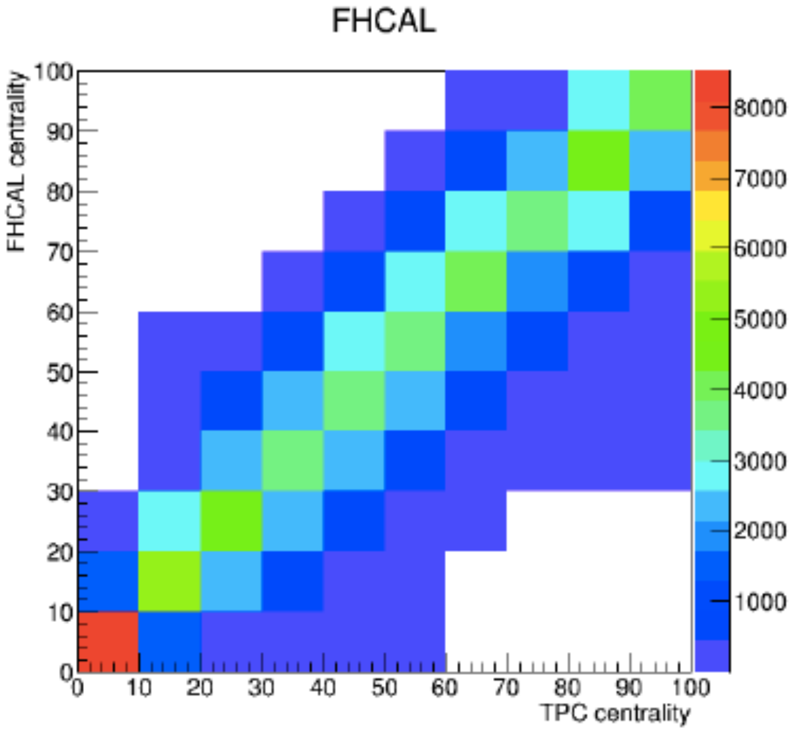


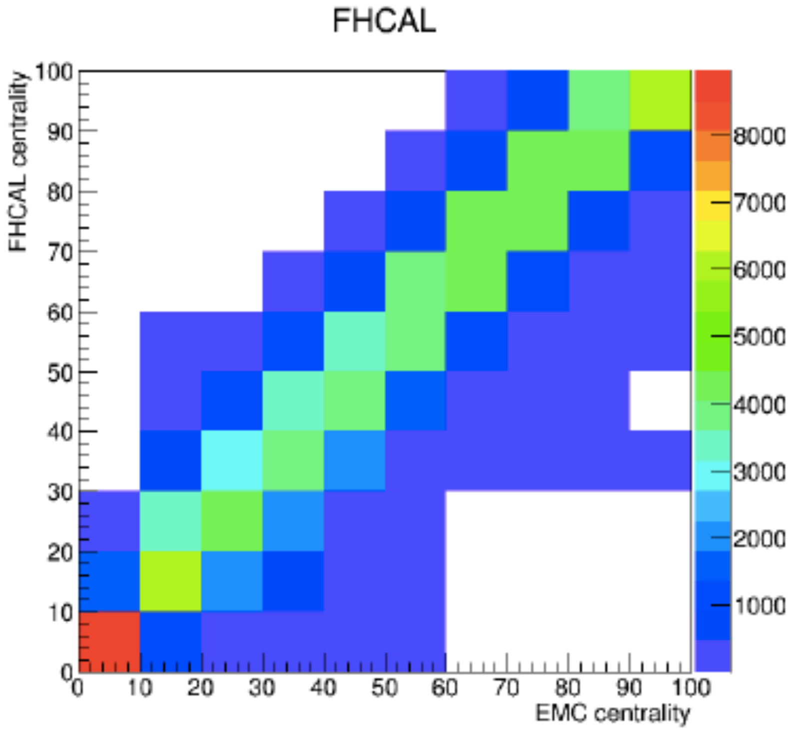
- Sampled impact parameter distributions are similar but event samples are different

Victor Riabov, 12.07.2022, "Event centrality with TPC, ECAL and FHCAL".

NEW!

Centrality by FHCAL vs. centrality by TPC/ECAL





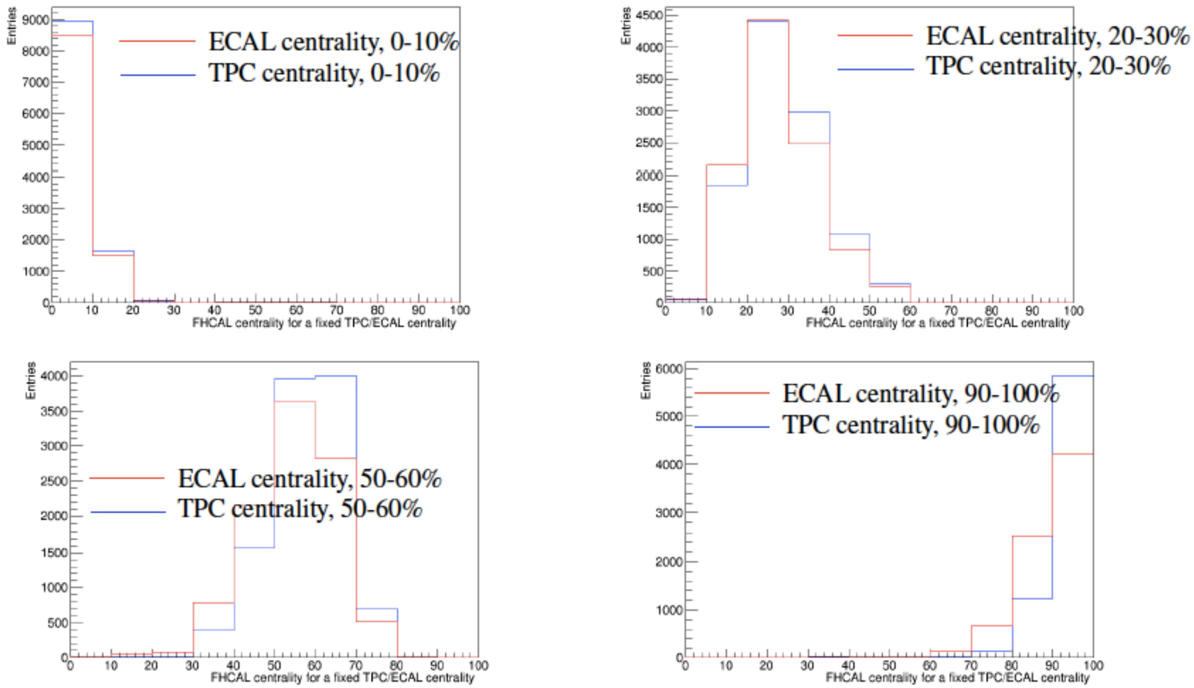
- Very wide correlations between FHCAL centrality and TPC/ECAL centralities

Victor Riabov, 12.07.2022, "Event centrality with ECAL and FHCAL",

NEW!

https://indico.jinr.ru/event/3192/

Centrality by FHCAL vs. centrality by TPC/ECAL



- Very wide distributions (much wider compared with ECAL-TPC centralities)
- FHCAL-TPC correlation is slightly narrower

V. Riabov, Cross-PWG Meeting, 12.07.2022 17

➢**Note: the event samples appear to be different for different proxies of centrality!**

Victor Riabov, 12.07.2022, "Event centrality with T... ECAL and FHCAL" ,

https://indico.jinr.ru/event/3192/

NEW!

Conclusions

- TPC and E_T can be used for centrality measurements, produce similar results
- FHCAL centrality has a very wide correlation with the TPC/E_T centrality; resolution by impact parameter is worse

➢ **Note: these conclusions are in line with Andrey Seryakov estimates**

Kirill Galaktionov, 18.10.2022, ”Machine learning based study of MCP detector configurations for future NICA experiments”

NEW!

https://indico.jinr.ru/event/3279/

Microchannel plate detectors

Some features of these detectors:

- Variability in size
- Registration of charged particles
- Time of flight resolution $\approx$ 50 - 100 ps

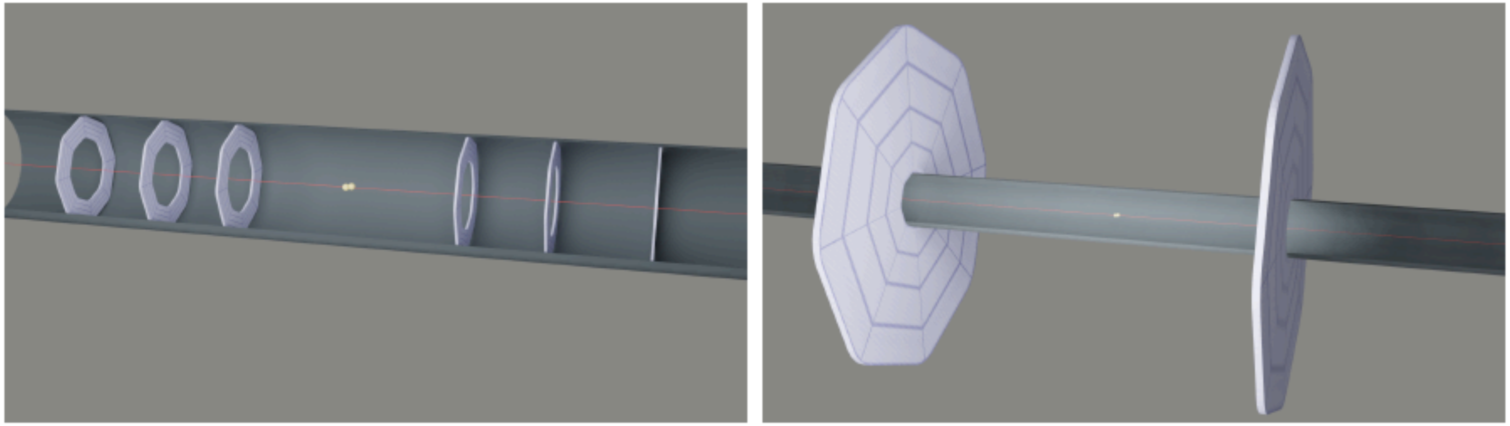


Fig. 1 Scheme of modeled detector configurations (not to scale). (left) - three pairs of small rings ($d = 3$ cm, $D = 5$ cm), (right) - one pair of big rings ($d = 5$ cm, $D = 50$ cm).

Research method

1. The QGSM model of gold nuclei collisions ($\sqrt{(s)} = 11\text{GeV/nucleon}$) is used as a source data.
2. Spacial and temporal data for the detector hits is generated according to the detector configuration.
3. The detector data is used for the neural network training.

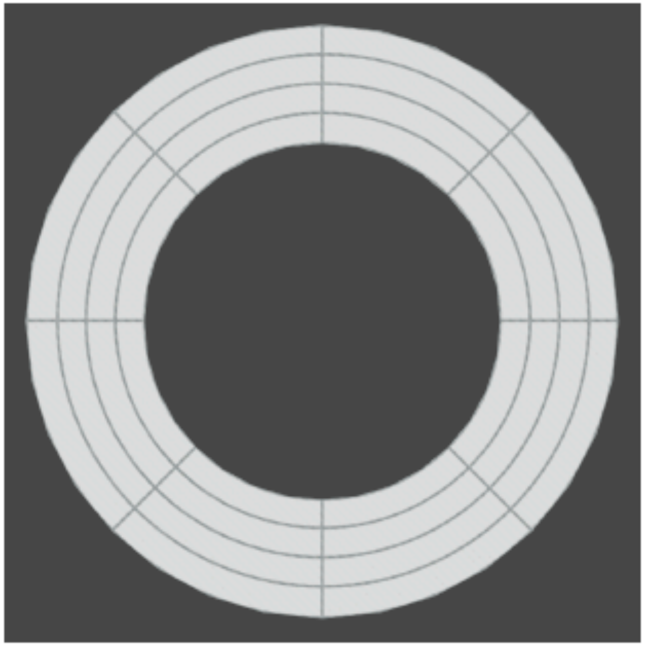


Fig. 2 Example of partitioning the detector into cells by radius and angle

Artificial neural networks (ANN)

ANN - an example of supervised learning.
Formula describing a dense layer of a neural network.

$$y = \theta(x * A^T + b) \tag{1}$$

Formula describing a convolutional layer of a neural network.

$$out(N_i, C_{out_j}) = \theta(bias(C_{out_j}) + \sum_{k=0}^{C_{in}-1} weight(C_{out_j}, k) \star input(N_i, k)) \tag{2}$$

Where: y, out - outputs of layer; $x, input$ - inputs of layer; A^T - transpose of a matrix of weights; $weight$ - convolution kernel; b, bias - biases of layer, $\theta(x)$ - activation function.

Kirill Galaktionov, 18.10.2022, ”Machine learning based study of microchannel plate detector configurations for future NICA

https://indico.jinr.ru/event/3279/

EXAMPLE:

NEW!

One pair of big rings. Classification results, distributed coordinate

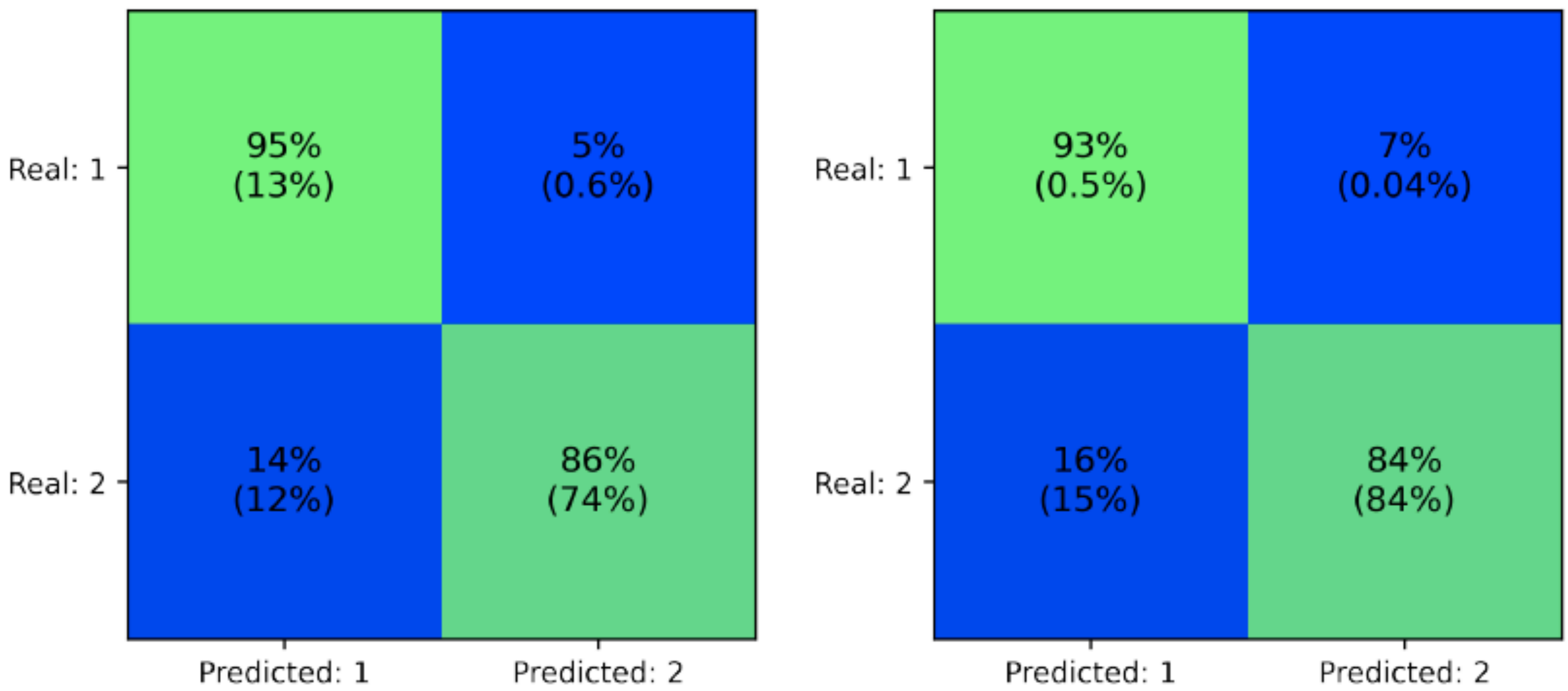


Fig. 6 Confusion matrices: (left) - threshold = 5 fm. Overall accuracy

https://indico.jinr.ru/event/3279/

Overall comparison table

Detector type	Small rings detector	Big rings detector
Regression result (σ fm)	1.7	0.78
Regression (var. coord.) (σ fm)	2.4	0.80
5 fm classification, true positive	93.1 %	96.6 %
5 fm classification, true negative	88.6 %	84.9 %
1 fm classification, true positive	86.4 %	97.6 %
1 fm classification, true negative	90.1 %	82.0 %

MC simulations and our activity needed for the Physics Paper

- Statistics for Bi+Bi collisions at 9.2 GeV: **~ 100 mln** min bias events
- Central pseudorapidity intervals for TPC physics analysis:
  |η|<0.5 and |η|<1.0
- Pseudorapidity intervals should be considered, for multiplicity and E_T classes selections, **outside the midrapidity region** − this is in order to avoid trivial autocorrelations :

  TPC tracks in 0.5 <|η|<1.5

  ECAL data in 0.5 <|η|<1.5
- Other pseudorapidity intervals: e.g. FFDs, which are symmetrically placed to the MPD center along the beam line 2.5 ≤| η |≤ 3.2 (also mini-BeBe – ?) could be aslo considered for the multiplicity classes selection
- Class-wise **optimization of the class width:** MC simulations fo Bi+Bi collisions at 9.2 GeV for 0-1%, 0-3%, 0-5%, 0-7%, 0-10%, 0-20% multiplicity based centrality classes (**and similar optimization for the FHCal classes is needed**)
- Z-position of the interaction vertex should be taken into account in the new MC simulations production. Studies of z-cuts are needed.

Institutes – PWG1 participants

SPbSU (St.Petersburg),
JINR (Dubna)
INR RAS (Troitsk, Moscow),
MEPhI (Moscow) and
MexNICA Collaboration (Mexica)

PWG1 co-conveners:

Alexey Aparin (JINR) aparin@jinr.ru
Grigory Feofilov (SPbSU,RF) g.feofilov@spbu.ru

PWG1: 6 meetings in the period October 2021 –April 2022

Please, visit our PWG1 WEB page:

https://indico.jinr.ru/category/343/

➢ *Send us an e-mail to join the group!*

Institutes – PWG1 participants

- We have the following **experts** today – Petr Parfenov, Vadim Volkov, Pedro Nieto, Mike Medina and Ivonne Maldonado ……
- They may trigger via the PWG1 the requests on MC production at NICA clusters

Please, visit our PWG1 WEB page:

https://indico.jinr.ru/category/343/

- *Send us an e-mail to join the group!*

Thank you for your attention!

MPD physics program

NICA

G. Feofilov, A. Aparin

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

V. Riabov, 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

Move to cross-PWG format of meetings
See PWG1-PWG5 status reports on Wednesday

AS

- **What**

AS

- **What**

What are the novel studies and new results expected from the MPD@NICA?

- **What**

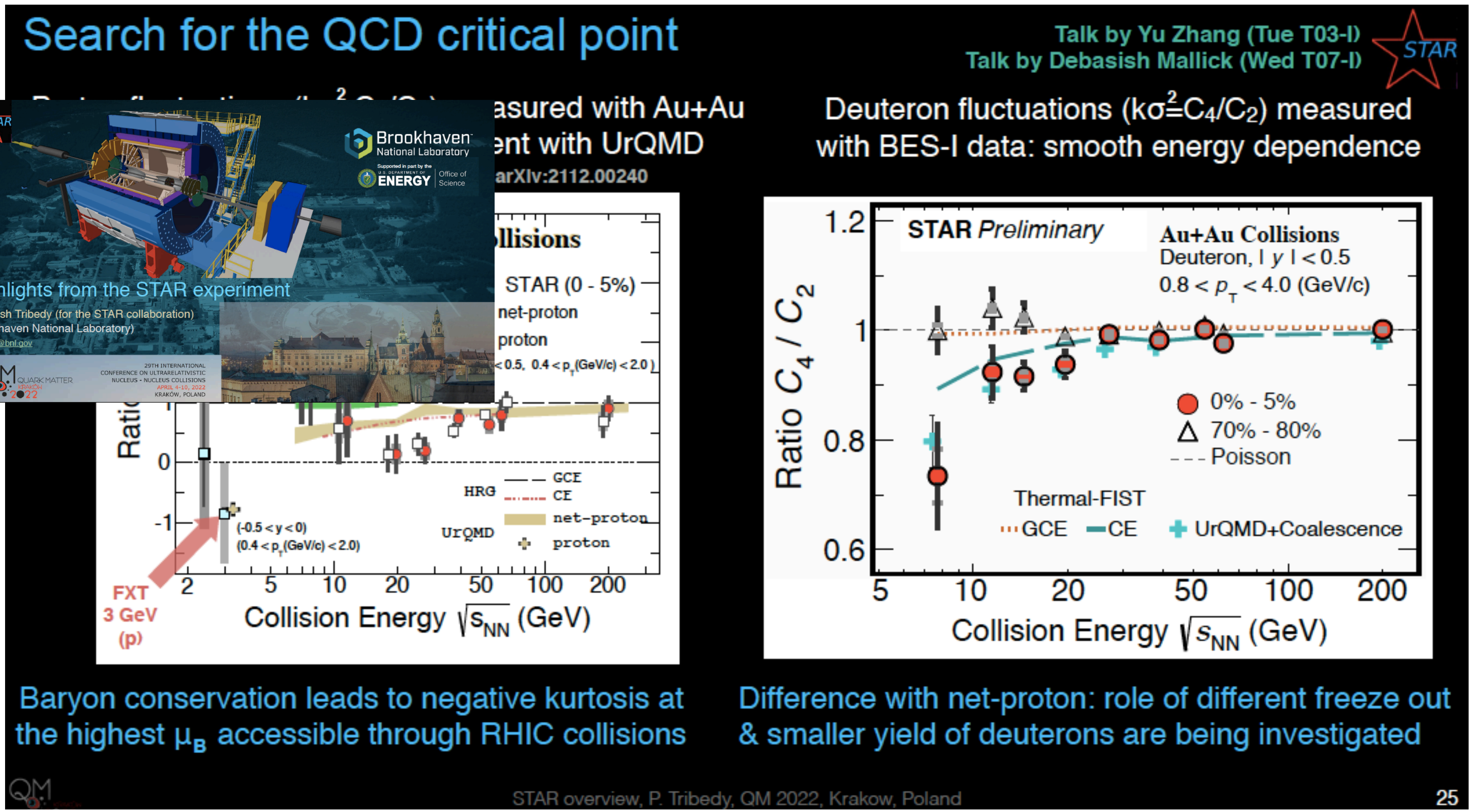
What are the novel studies and new results expected from the MPD@NICA?

- **What**

Organization of workflow:

- PWG1 should prepare to provide expertise on global observables for other physics groups as soon as data are recorded
- We need intensify efforts prior to the actual data taking in order to effectively using working time to prepare for that
- Need to decide on effective way of communication of different analysis groups in PWG1 and with other PWG's. Would it be mailing, forum, wiki-like structure, mattermost, etc.
- Need to find people who will lead different analysis topics. Centrality calculation has volunteers, what else?

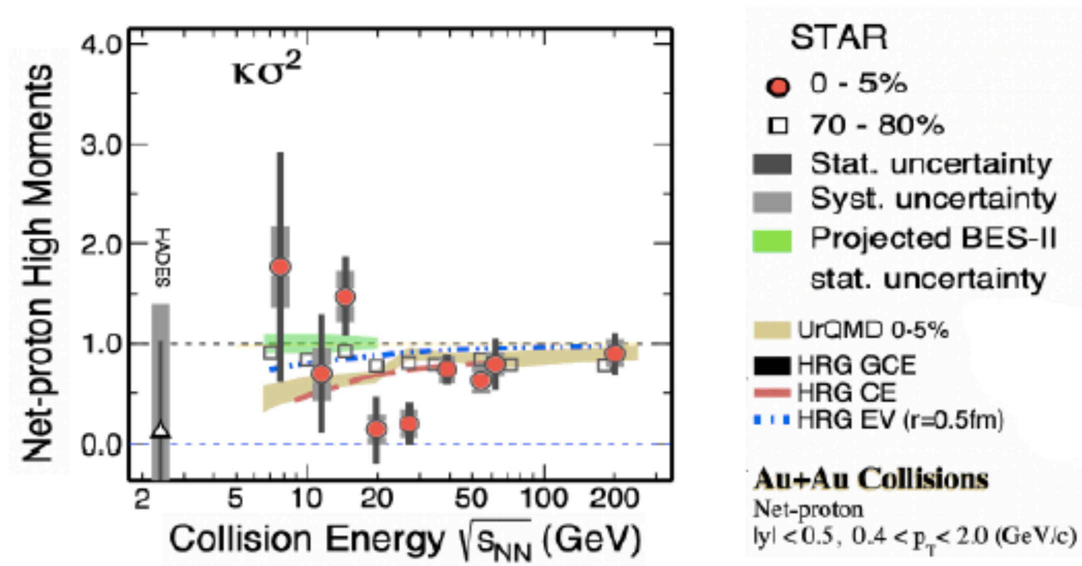
https://indico.cern.ch/event/895086/contributions/4314628/



STAR and HADES recent results

Result 1: Net-proton C_4/C_2 from BES-I

J. Adam *et al.* (STAR Collaboration) Phys. Rev. Lett. **126**, 092301; long version paper: arXiv:2101.12413



- Non-monotonic energy dependence of net-proton $\kappa\sigma^2$ is shown in top 5% from BES-I data which is not reproduced by various models.
- More statistics below 20 GeV are needed to confirm the non-monotonic trend.
- Measurement from new dataset in fixed target experiment at $\sqrt{s_{NN}} = 3$ GeV is on the way!

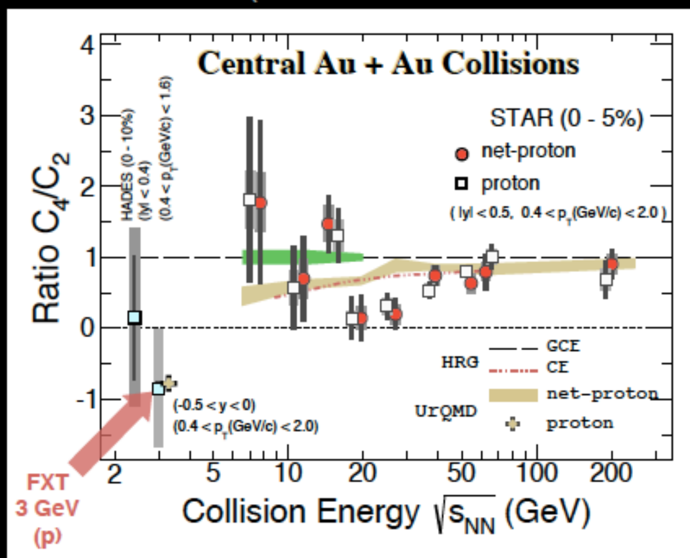
ch/event/895086/contributions/4314628/

al point

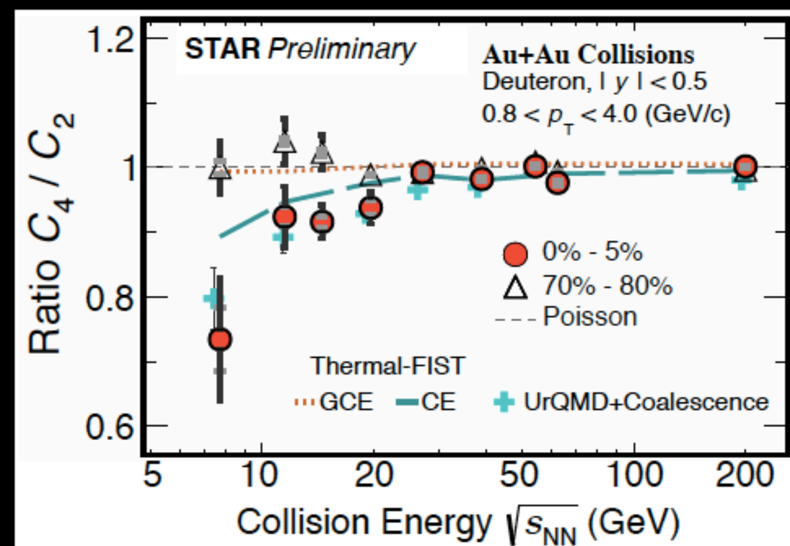
Talk by Yu Zhang (Tue T03-I)
Talk by Debasish Mallick (Wed T07-I)

Proton fluctuations ($\kappa\sigma^2$=C_4/C_2) measured with Au+Au $\sqrt{s_{NN}}$ = 3 GeV FXT data: consistent with UrQMD

M. Abdallah et al. (STAR collaboration) arXiv:2112.00240



Deuteron fluctuations ($\kappa\sigma^2$=C_4/C_2) measured with BES-I data: smooth energy dependence



Baryon conservation leads to negative kurtosis at the highest μ_B accessible through RHIC collisions

Difference with net-proton: role of different freeze out & smaller yield of deuterons are being investigated

STAR overview, P. Tribedy, QM 2022, Krakow, Poland 25

Study of the systematics in determining the symmetry plane for Bi-Bi collisions at $\sqrt{S_{NN}}$ 9.2 GeV in the DCM-QGSM-SMM model

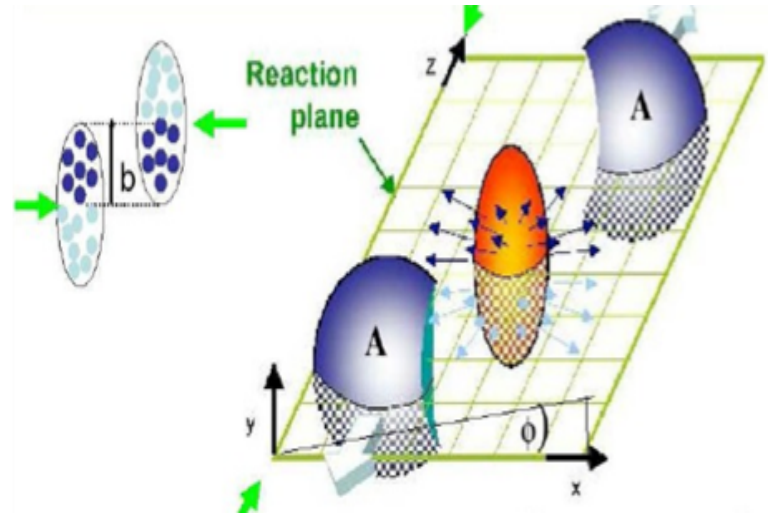
Valerii Troshin NRNU MEPhI

Cross-PWG meeting in MPD
14.06.2022

Collective anisotropic flow

The spatial asymmetry of the energy distribution at the initial moment of the collision of nuclei is transformed, through the strong interaction, into the momentum anisotropy of the produced particles

Fourier series expansion of particle distribution in azimuthal angle with respect to the reaction plane angle



$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_{RP}))\right)$$

The expansion coefficients:

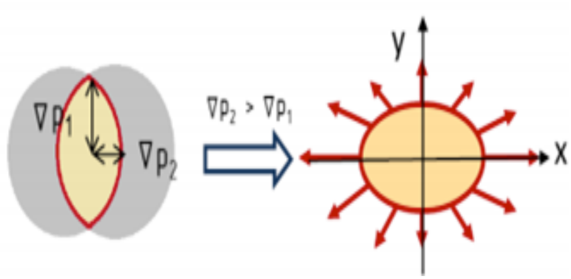
$$v_n = \langle\cos(n(\phi - \Psi_{RP}))\rangle$$

In the experiment, we can get the event plane angle Φ_n , relative it:

$$v_n = \frac{\langle\cos n(\phi - \Phi_n)\rangle}{R_n}$$

R_n — Resolution of Φ_n
for the reaction plane angle Ψ_{RP}:

$$R_n = \langle\cos n(\Phi_n - \Psi_{RP})\rangle$$



Scalar product method

Each particle with an azimuthal angle ϕ is assigned a vector u:

$$u_n = x_n + iy_n = \cos(n\phi) + i\sin(n\phi) = exp(in\phi)$$

The sum of these vectors determines the Q-vector of the event

$$Q_n = \sum u_n = \sum(\cos n\phi + i\sin n\phi) = X_n + iY_n = |Q_n| exp(in\Psi^n_{EP})$$

Event-averaged correlation of u-vectors with Q-vector depends on v_n

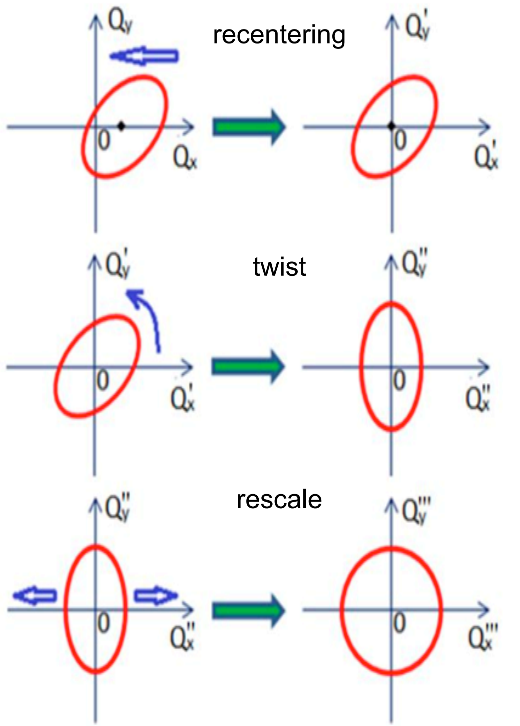
$$\langle u_n Q_n \rangle = \langle x_n X_n \rangle + \langle y_n Y_n \rangle = \int_0^{2\pi} \frac{d\Psi_{RP}}{2\pi} \langle u_n \rangle_{\Psi_{RP}} \langle Q_n \rangle_{\Psi_{RP}} = v_n V_n$$

$$\langle Q_n^a Q_n^b \rangle = \frac{1}{4} V_n^2$$

$$v_n = \frac{\langle x_n X_n \rangle}{\sqrt{2\langle X_n^a X_n^b \rangle}} = \frac{\langle y_n Y_n \rangle}{\sqrt{2\langle Y_n^a Y_n^b \rangle}}$$

a,b - sub-events

Corrections for non-uniform acceptance



The QnAnalysis package

Motivation:

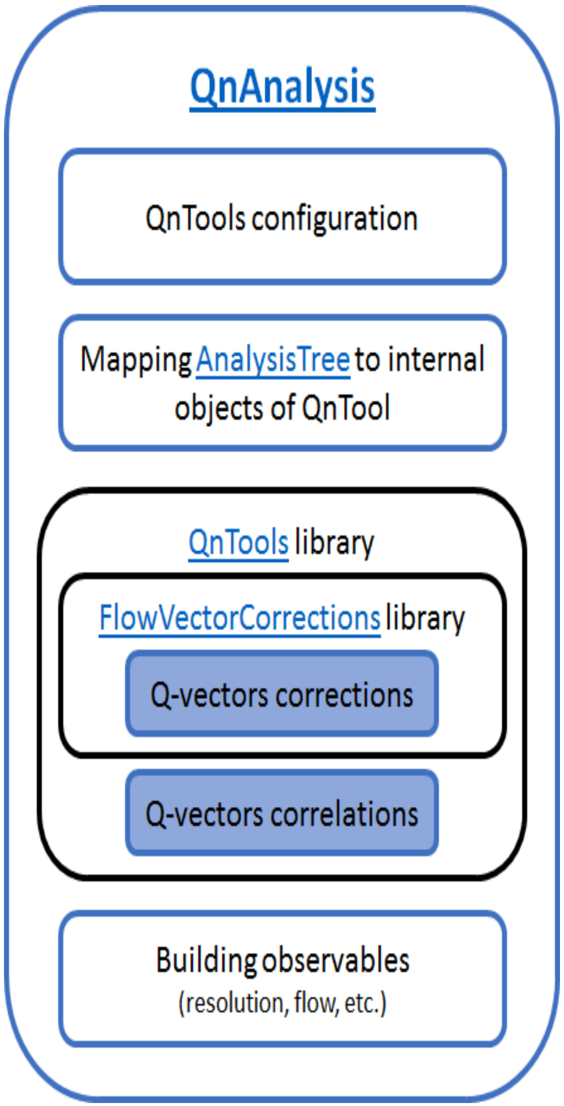
•Decoupling configuration from implementation

•Persistency of analysis setup

•Co-existence of different setups (easy systematics study)

•Unification of analysis methods

•Self-descriptiveness of the analysis results

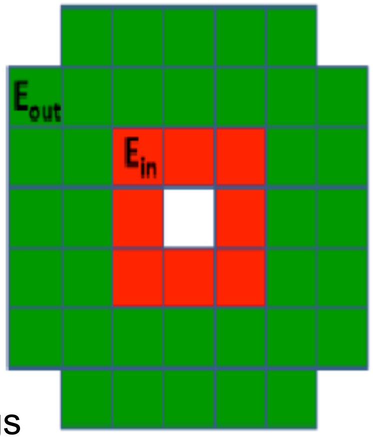


QnAnalysis requirements:
•ROOT ver. ≧ 6.20 (with MathMore library)
•C++17 compatible compiler
•CMake ver. ≧ 3.13
Can be easily installed on NICA cluster using ROOT and CMake modules

Git repository:
https://github.com/HeavyIonAnalysis/QnAnalysis

FHCal's role in scalar product method

FHCal is used to form Q-vectors of sub-events according to the angular distribution of spectator energy in modules:

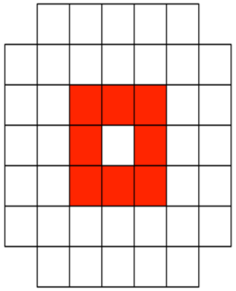


$$Q_{n,x} = \sum_i w_i \cos(n\phi_i) \quad Q_{n,y} = \sum_i w_i \sin(n\phi_i)$$

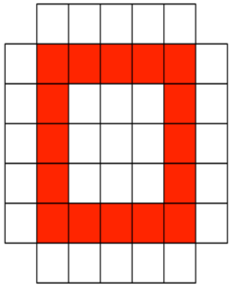
ϕ_i —azimuthal angle of modules № i in FHCal, w_i — energy in module

Sub-events can be formed by Right(South) and Left(North) FHCal and also by the rings of FHCal modules

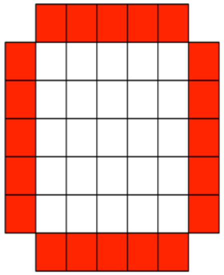
Inner



Middle



Outer



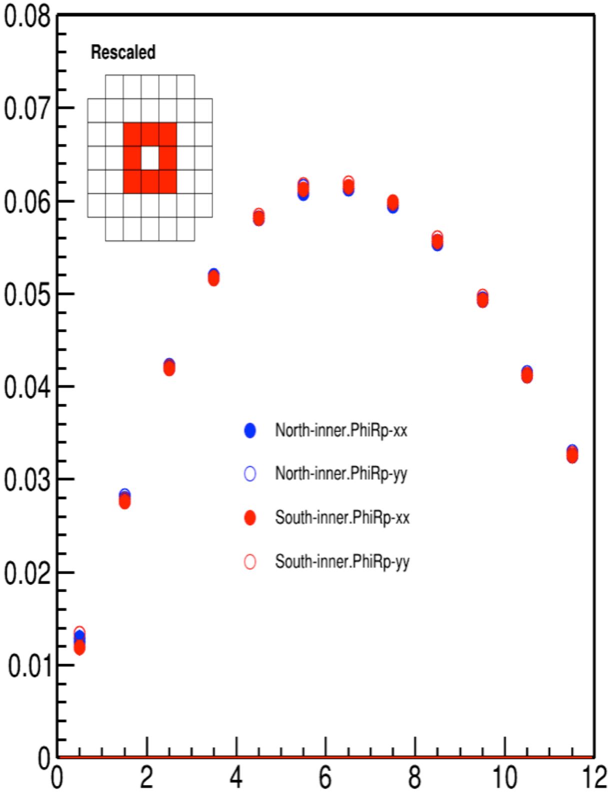
When studying correlations, the following values is also considered:

$$\frac{1}{2}R_n^T = \langle X_n^{a,b} X_{RP} \rangle = \langle Y_n^{a,b} Y_{RP} \rangle ; R_n^T - TrueResolution$$

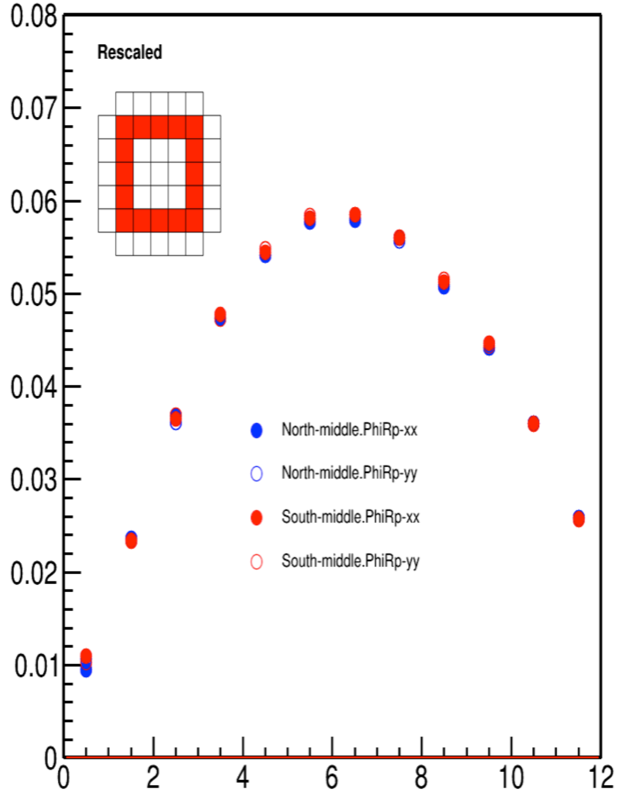
$$\frac{1}{2}R_n^2 = \langle X_n^a X_n^b \rangle = \langle Y_n^a Y_n^b \rangle ; R_n - RecoResolution$$

Correlation of Q-vectors in FHCal's rings with reaction plane angle PhiRp

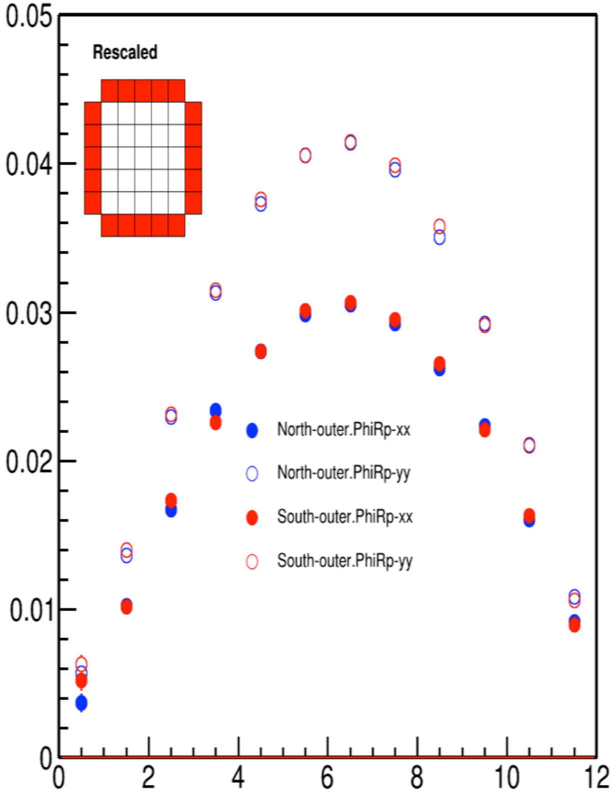
Inner ring



Middle ring

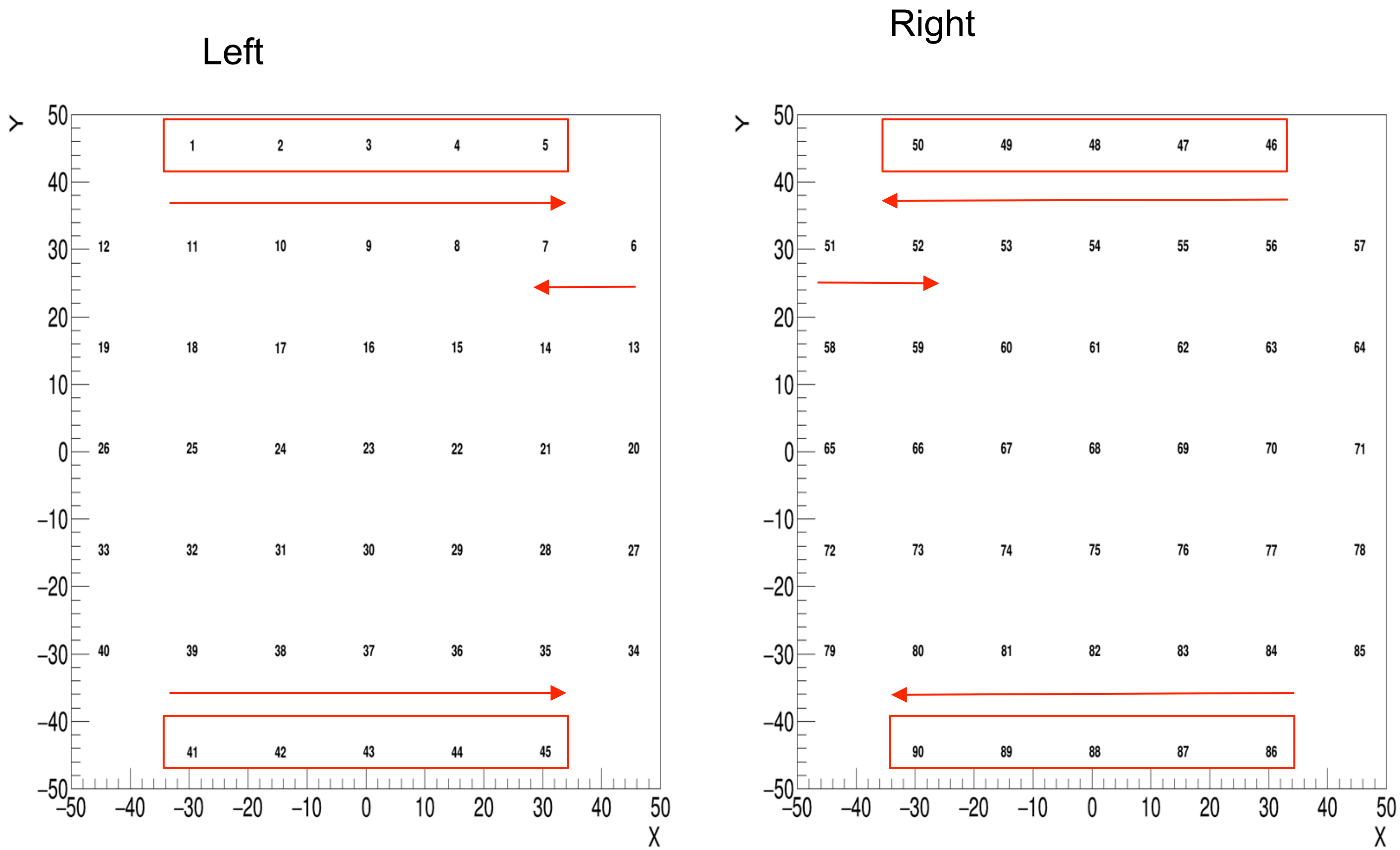


Outer ring



XX and YY components diverge for outer ring

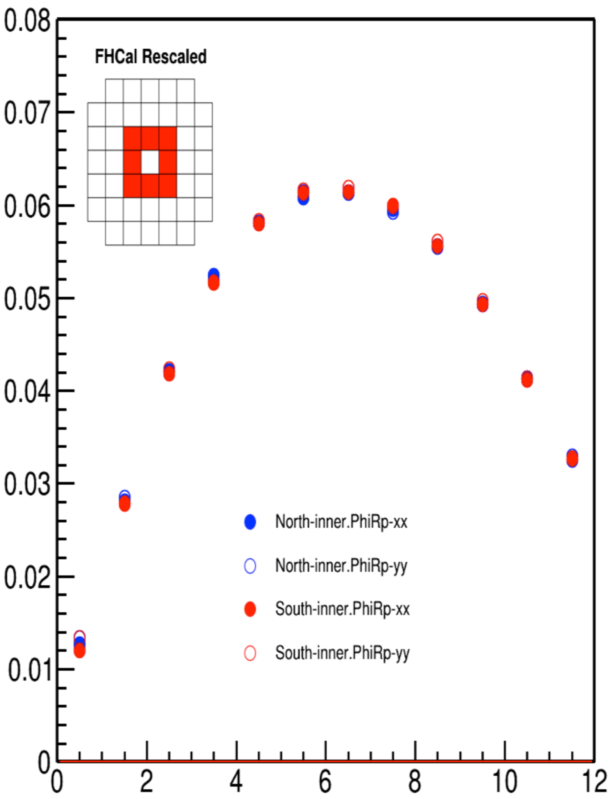
FHCal Module numbering



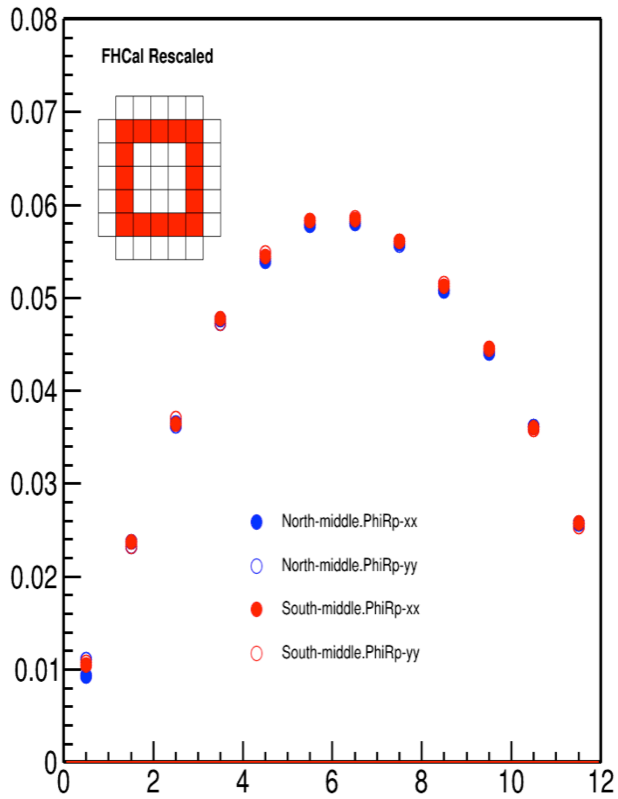
The first and last lines are numbered in the wrong direction. Can we obtain module coordinates from MPDROOT?

Correlation of Q-vectors in FHCal's rings with reaction plane angle PhiRp

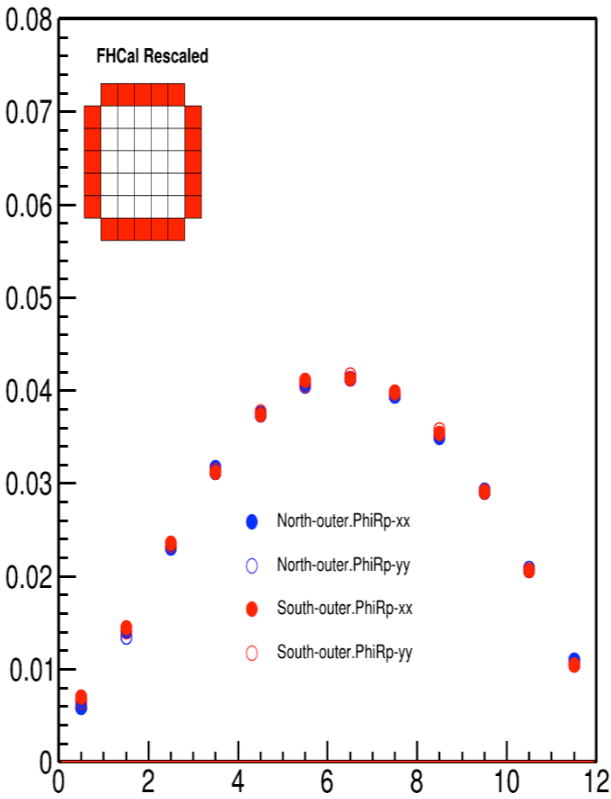
Inner ring



Middle ring

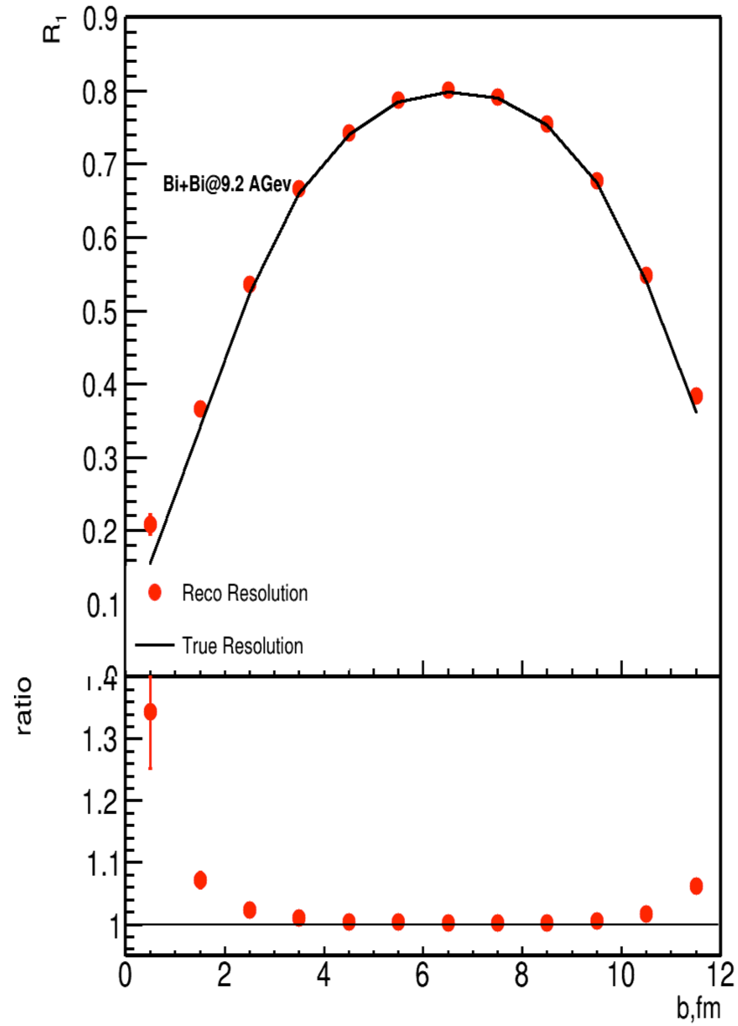


Outer ring



Ratio of True Resolution and Reco Resolution

$$R_1 = \langle \cos(\Phi_1 - \Psi_{RP}) \rangle$$



- good agreement for mid-central collisions
- necessary to study difference for central collisions

Summary

- An error was detected in the calculation of FHCal module coordinates
- Two sub-events method is applicable to calculate first harmonic Resolution for mid-central collisions
- It is necessary to study difference for central collisions
- Three sub-events method is needed to study further

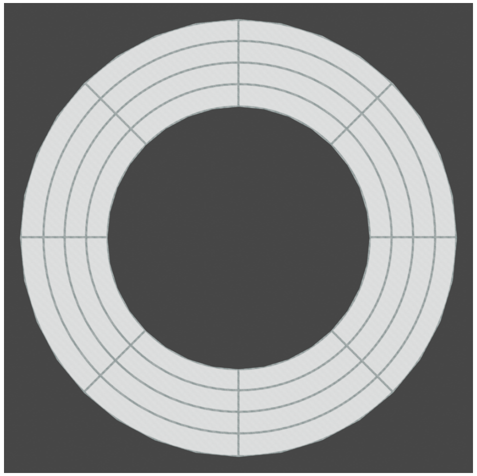
Thanks for your attention!

Application of neural networks for event-wise evaluation of the impact parameter

K.Galaktionov, V. Roudnev, F. Valiev
(St. Petersburg State University)
(Paper was submitted to PEPAN)

Evaluation of the impact parameter in a single event is crucial for correct and efficient data processing in collision-based nuclear and particle physics experiments. Real-time estimates of the impact parameter allows experimentalists to preselect the most informative events at the data acquisition stage, before any processing. The presented computational experiments prove application of neural network techniques for direct impact parameter evaluation useful for future experimental setups.

Application of neural networks for event-wise evaluation of the impact parameter



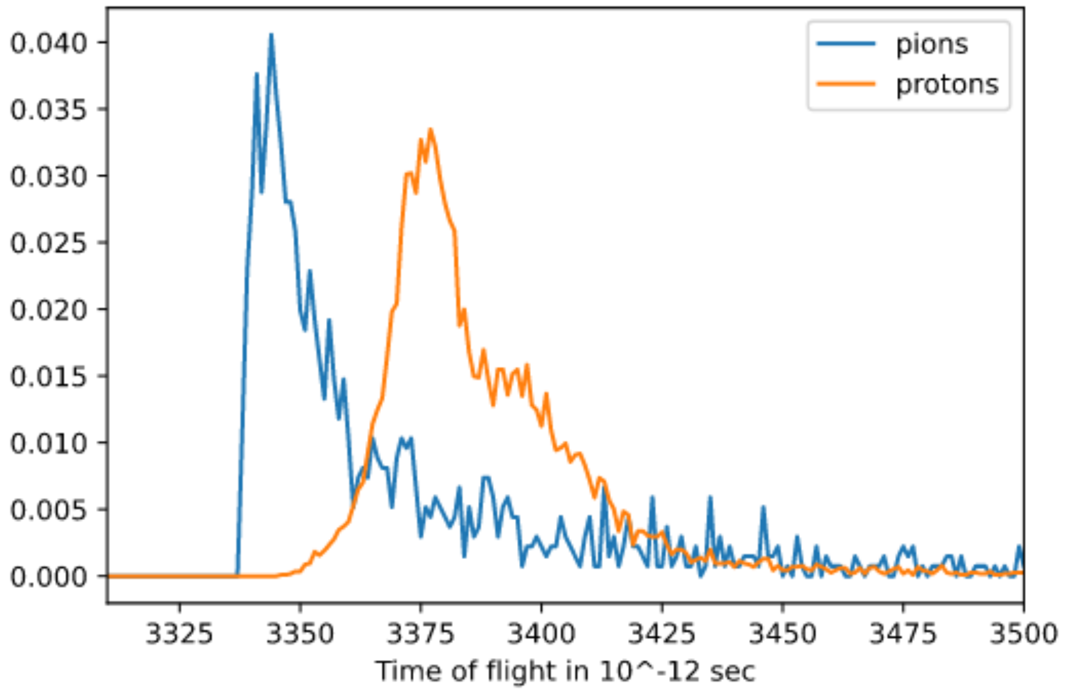
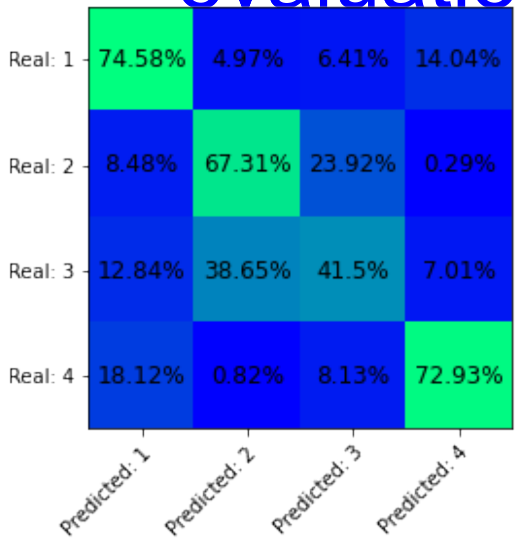


Fig.15.
(a)Segmentation according to angle and radius of ring MCP detector.
(b)Timing information obtained from detectors.

Application of neural networks for event-wise evaluation of the impact parameter



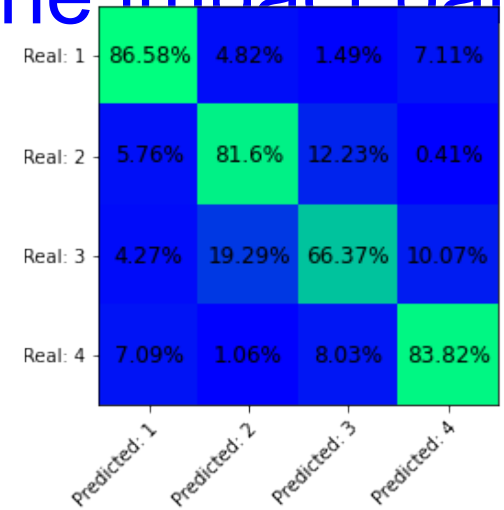


Рис.16. Матрицы ошибок: (а) - для сбора детектора в виде трех пар колец с учетом времени прилета, (б) - для сбора детектора в виде трех пар колец с учетом разниц времени прилета пионов и протонов.

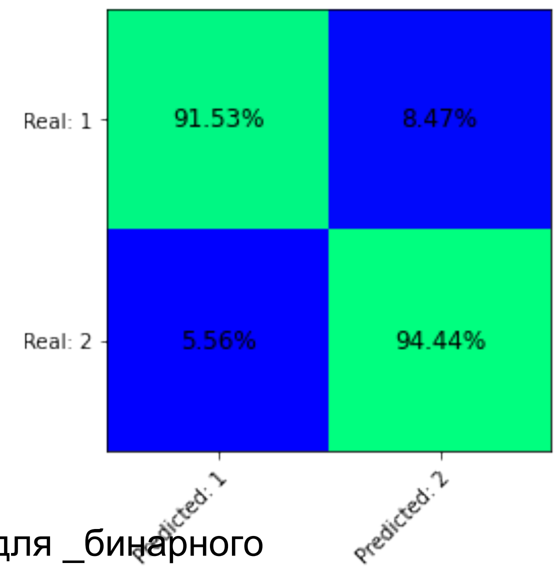


Рис._17. Матрица _ошибок._ _Матрица _ошибок _для _бинарного _классификатора _с _границей _между _классами _в _7_ _ферми._

Impact parameter.

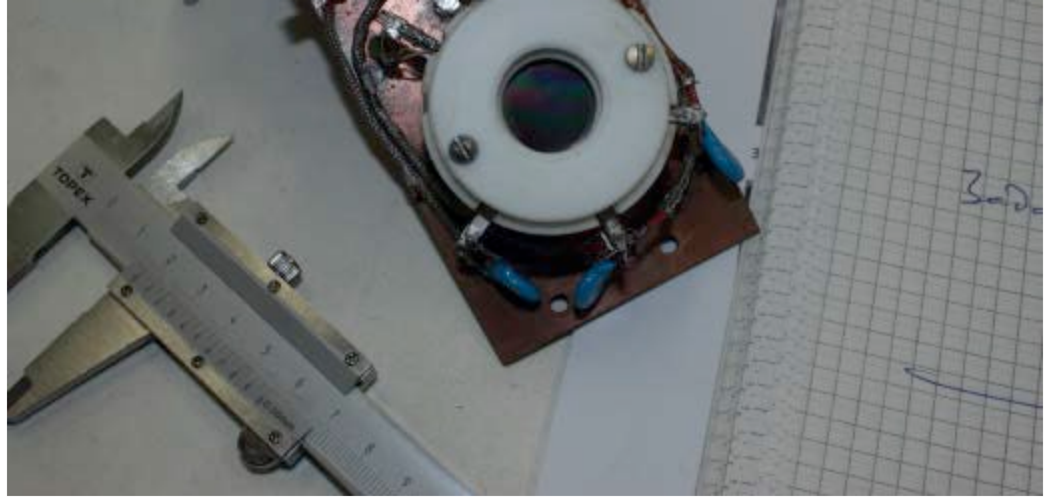
The application of neural networks for the event-wise estimation of the impact parameter from the data obtained from the MCP-based FBBC was tried out numerically. Au+Au collisions at $\sqrt{s}$=11 GeV were simulated using QGSM event generator. The simulated data set was divided into the reference and test samples with a ratio of 80/20. The reference sample was used to determination of the weights in the artificial neural network to match the given parameters in the best way. Then the network parameters were fixed and it was applied to processing the test sample. The obtained error matrix provided information on the network operation efficiency.

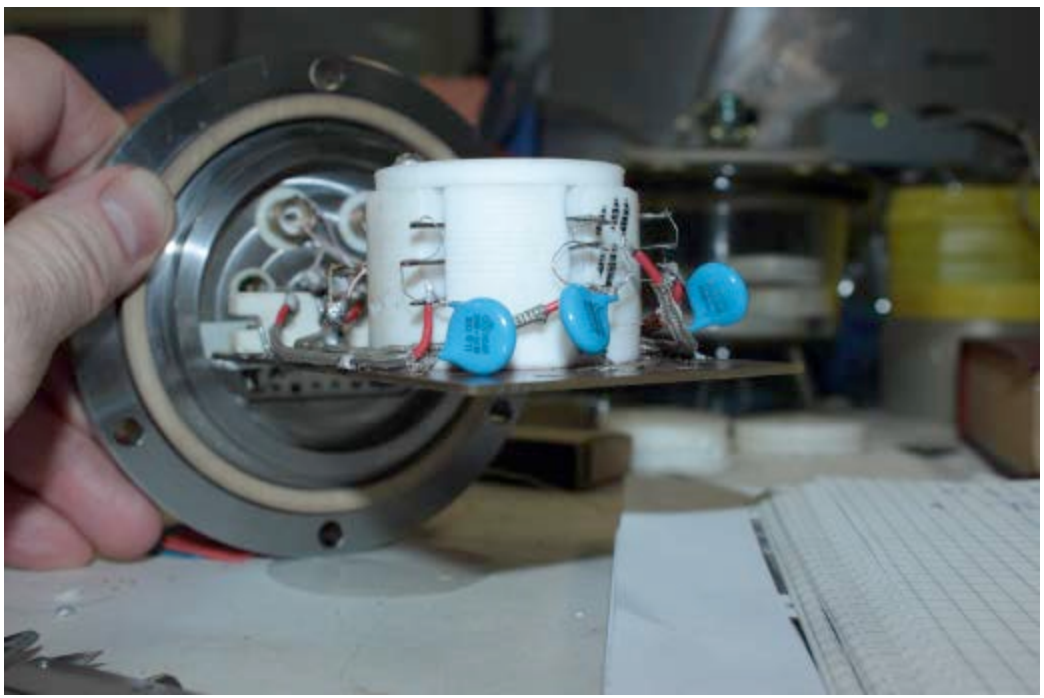
On the whole, the general accuracy of correct event identification in a certain class (part of the detector) was about 80%. Taking into account that average times of pion and proton arrival are close, an additional possibility of distinguishing between these types of particles would increase the network efficiency. It should also be noted that this approach proved quite efficient for separation between events with large and small impact parameters, demonstrating the highest error in the intermediate interval of impact parameters. For small impact parameters, which are of most interest in collision experiments, an additional binary classifier was constructed. This increased the accuracy of the network operation to 93%.

- Thus, it is possible to use the developed numerical tools for processing experimental data from MCP-based BBC detector at SPD in order to select central collisions both on-line and in post-processing.

Testing in-lab

Microchannel plates circular plates with diameters of 18 mm and 25 mm.
MCPs were manufactured by VTC “Baspik” (Vladikavkaz, Russia)
Chevron MCP setups.


TOPEX



FBBC developments

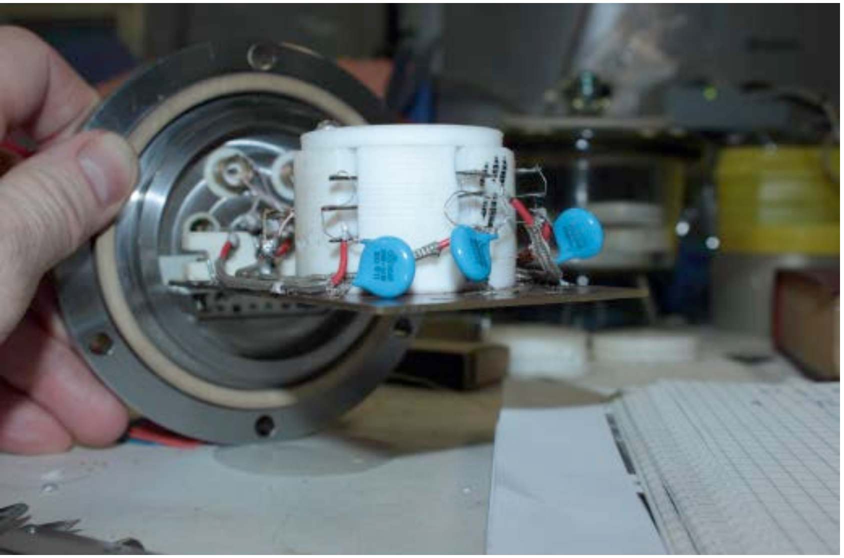


Fig.20. Photograph of three MCP detectors in a chevron assembly

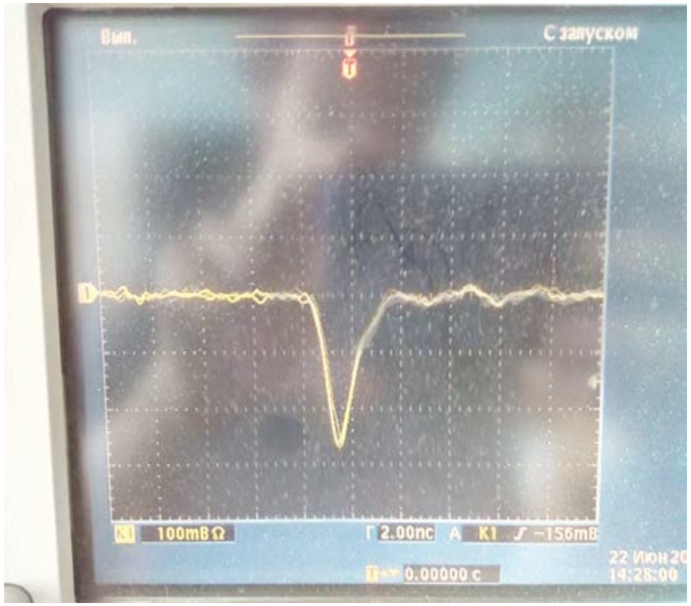
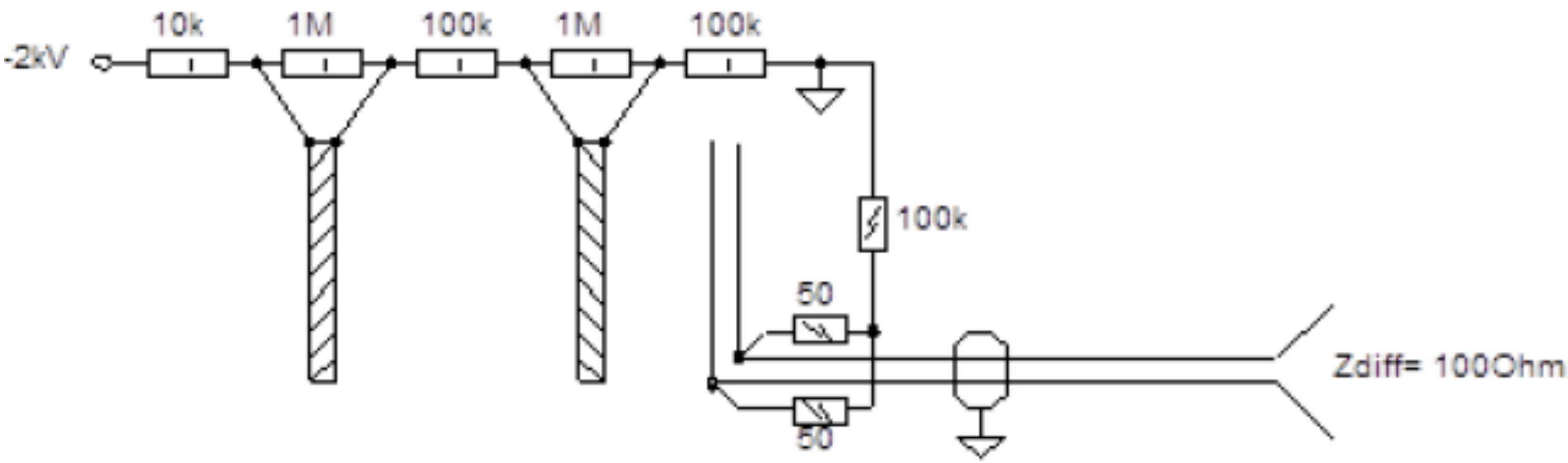


Fig.21. Pulse shape from MCP detector.
The voltage at the MCP assembly is 1.8 kV. The anode area is 0.25 cm2.
Signal edge <1 nsec, amplitude 300 **mV**

FBBC developments: electronics

A differential matched scheme is selected as a result of testing of the MCP detectors with different readout systems.

This choice is associated with a lower sensitivity
to pickups up of the UHF noise signals by the fast readout electronics.



FBBC developments: electronics

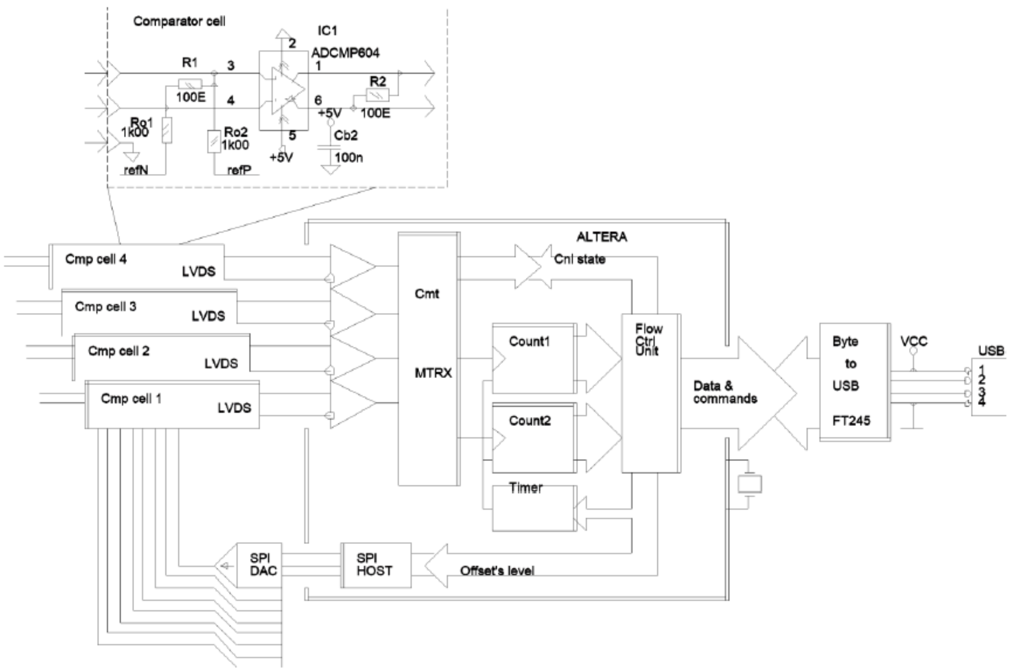


Fig. 26. Block diagram of fast electronics and detailed diagram of one registration channel

- We propose to develop a next prototype of a registration system basing on high-speed discrete comparators of the **ADCMP572 / ADCMP573 type** as primary recorders in a multichannel time-code converter based on the FPGA. These ADCMP572 / ADCMP573 type comparators feature a high switching rates (35 ps) with jitter of the order of 15 ps with a minimum signal duration of 85 ps.
- Work is in progress.

FBBC developments:
first prototypes of electronics

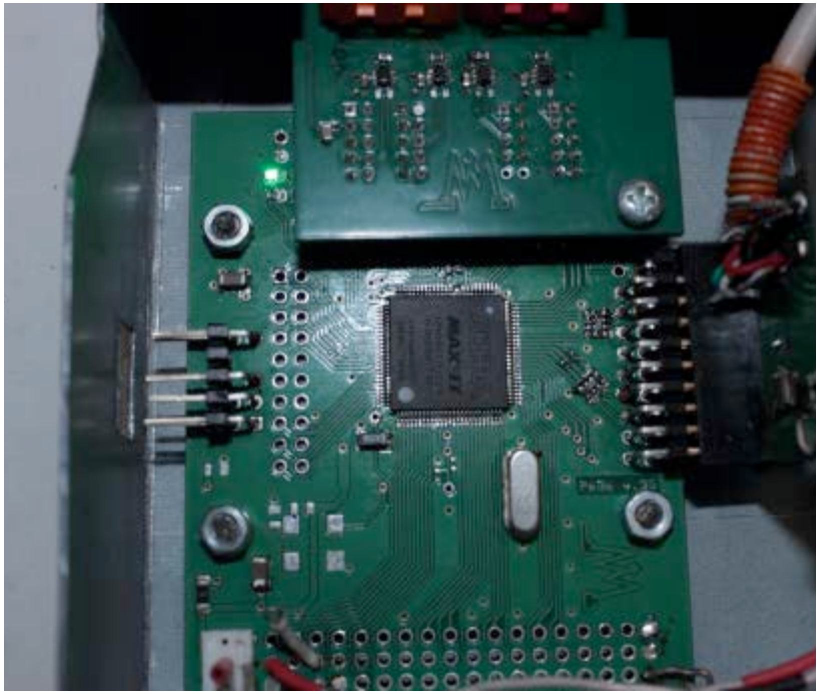


Fig.29. Four-channel electronics module on discrete comparators with differential inputs for timing measurements.

Fig.34. Photo of the device of the two-channel fast electronics module based on discrete comparators. Work is in progress.

Conclusions-1

- Two compact systems based on MCPs are proposed for the fast beam-beam collisions monitoring, event selection and determination of the precise timing signal (T0) of the collisions, We propose to use the MCP-based Beam Profilometer and the Fast Beam-Beam Collisions counters (FBBC) as devices potentially capable to extend the performance and the physics outreach of experiments at NICA.
- This includes the event-by-event measurements of:
  - Beam-beam IP location in z-coordinate
  - 3D-beam profile (2 dimensional + time structure)
  - Luminosity
  - Reaction plane
  - Event centrality class in A-A collisions
  - Precise timing signal (T0) of the collisions
  - Beam-gas events suppression

Conclusions-2

- We evaluated the effectiveness of the conceptual design of the proposed FBBC system using Monte Carlo simulation based on event generators SMASH, LAQGSM and UrQMD
- We show the possibility of increasing the acceptance of the SPD setup up to 6 units of pseudorapidity by using several MCP-based ring detectors located inside the beam pipe of the NICA collider. This also provides an extension of the possibilities for physical measurements.
- The Beam Profilometer was succesfully tested at the NUCLOTRON beams,
- At the end of December 2020, the first test of a prototype multi-anode detector of the MCP system, made in the design of ultrahigh vacuum, was carried out on the line of the circulating helium ion beam of the NICA collider booster
- Another test of a prototype was done during the latest Booster and Nuclotron run in January, 2022.

Conclusions-3

- The technology for ultra-high vacuum (UHV) design of MCP detectors was tested. It allows the application of the MCP detectors inside the vacuum beam line.
- The first prototypes were prepared in the UHV and UHF design. The in-lab and in-beam tests show subnanosecond MCP signal rise time (<800 ps)
- We produced, using modern high-speed discrete comparators, the prototype of a multichannel fast electronics module for time reference to signals from MCP detectors
- We proposed to develop a next prototype of a registration system basing on high-speed discrete comparators of the **ADCMP572 / ADCMP573 type** as primary recorders in a multichannel time-code converter based on the FPGA. These ADCMP572 / ADCMP573 type comparators feature a high switching rates (~35 ps) with jitter of the order of 15 ps with a minimum signal duration of 85 ps.
- We applied the machine learning method using event-by-event information from MCP detectors in our studies of event-by-event selection of the primary collision vertex and for the fast selection of collision centrality class. We show the method to be feasible for the bunch-by-bunch crossing analysis at NICA.

BACK-UP SLIDES

Micro Channel Plates (MCPs) as a MIP detector

[1]A.Baldin,G.Feofilov,F.F.Valiev et al. ,"Microchannel plates as a detector for 800 MeV/c charged pions and protons." // JINR Rapid Communications. 1991. No 4/50/-91. p.27-36.

[2] A.A.Baldin, G.Feofilov,Yu.Gavrilov, A.Tsvinev,F.Valiev, "Proposals for a new type of microchannel-plate-based vertex detector", // NIM A323. 1992. p. 439-444.

…

[3]V.Bondila, L.Efimov D.Hatzifotiadou, G.Feofilov, V.Kondratiev, V.Lyapin, J.Nysten, P.Otiougova, T.A.Tulina, W.H.Trzaska, F.Tsimbal, L.Vinogradov, C.Williams, Results of in-beam tests of an MCP-based vacuum sector prototype of the T0/centrality detector for ALICE, NIM A, Volume 478, Issues 1–2, 1 February 2002, Pages 220-224.

…

[4] G. Feofilov, V. Kondratev, O. Stolyarov, T. Tulina, F. Valiev, and L. Vinogradov, Development and Tests of MCP Based Timing and Multiplicity Detector for MIPs, ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2017, Vol. 14, No. 1, pp. 150–159. © Pleiades Publishing, Ltd., 2017.

…

[5] A. Baldin, G. A. Feofilov, P. Har'yuzov, F. F. Valiev
NIMA, 958, 162154, 2019, Reported at the VCI2019
DOI:10.1016/j.nima.2019.04.108

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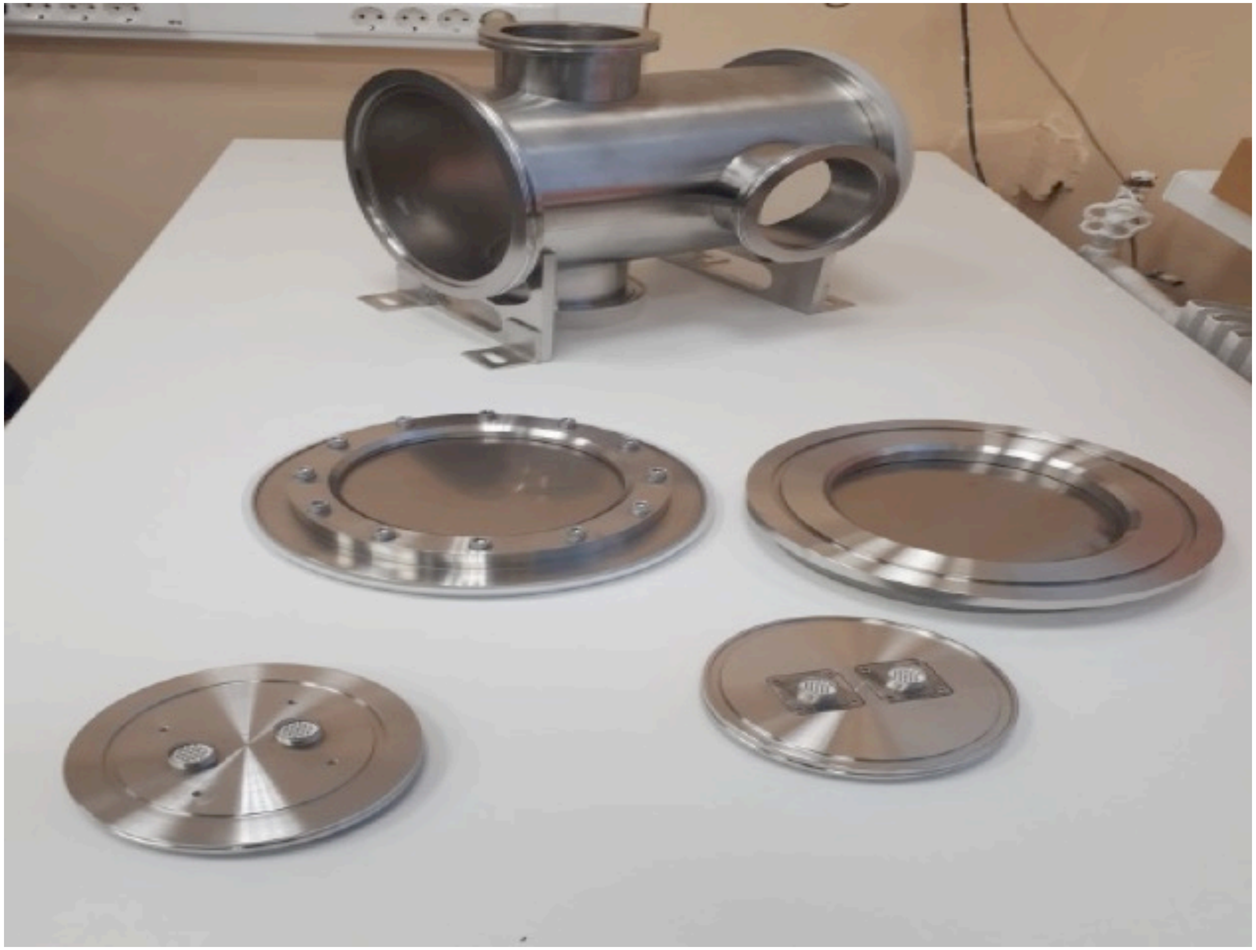
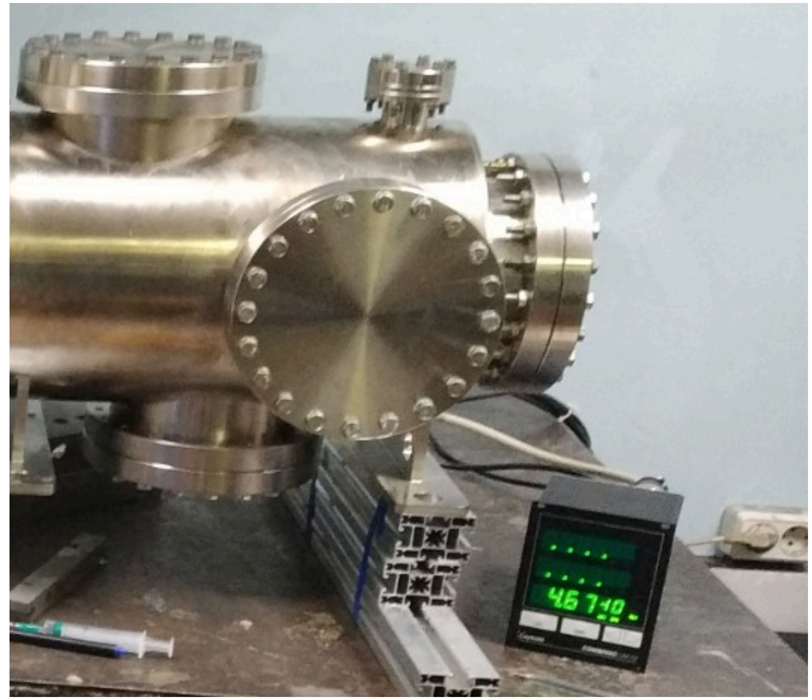
[6] NONDESTRUCTIVE DIAGNOSTICS OF ACCELERATED ION BEAMS
WITH MCP-BASED DETECTORS AT THE ACCELERATOR COMPLEX
NICA. EXPERIMENTAL RESULTS AND PROSPECTS
A. A. Baldin, V. I. Astakhov, A. V. Beloborodov, D. N. Bogoslovsky, A. N. Fedorov,
P. R. Kharyuzov, A. P. Kharyuzova, D. S. Korovkin, A. B. Safonov, Joint Institute for Nuclear Research, Dubna, Russia
27th Russian Particle Acc. Conf. RuPAC2021, Alushta, Russia JACoW Publishing
ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WED05

In 2021 : The loading characteristics were studied in a range from single pulses to $5 \cdot 10^6$ particles/cm^2 s. Thus, the possibility of application of detectors of this type for BBC SPD was demonstrated.

A specialized portable vacuum chamber with thin (50 mkm) Ti windows was manufactured for investigation of particle registration efficiency by chevron MCPs in the case of particles with minimum ionizing power; two independent prototypes of MCP detectors can be installed in this vacuum chamber. It is planned to perform full-scale testing of registration efficiency, time resolution, and loading characteristics of such detectors at extracted beams of Nuclotron and electron beams of the linear accelerator LINAC-200 (LNP JINR).

Figure
shows the photo of the specialized vacuum chamber and its flanges.





Вакуумные испытания камеры с прогревом.
Достигнут вакуум $5*10^{-10}$ Торр

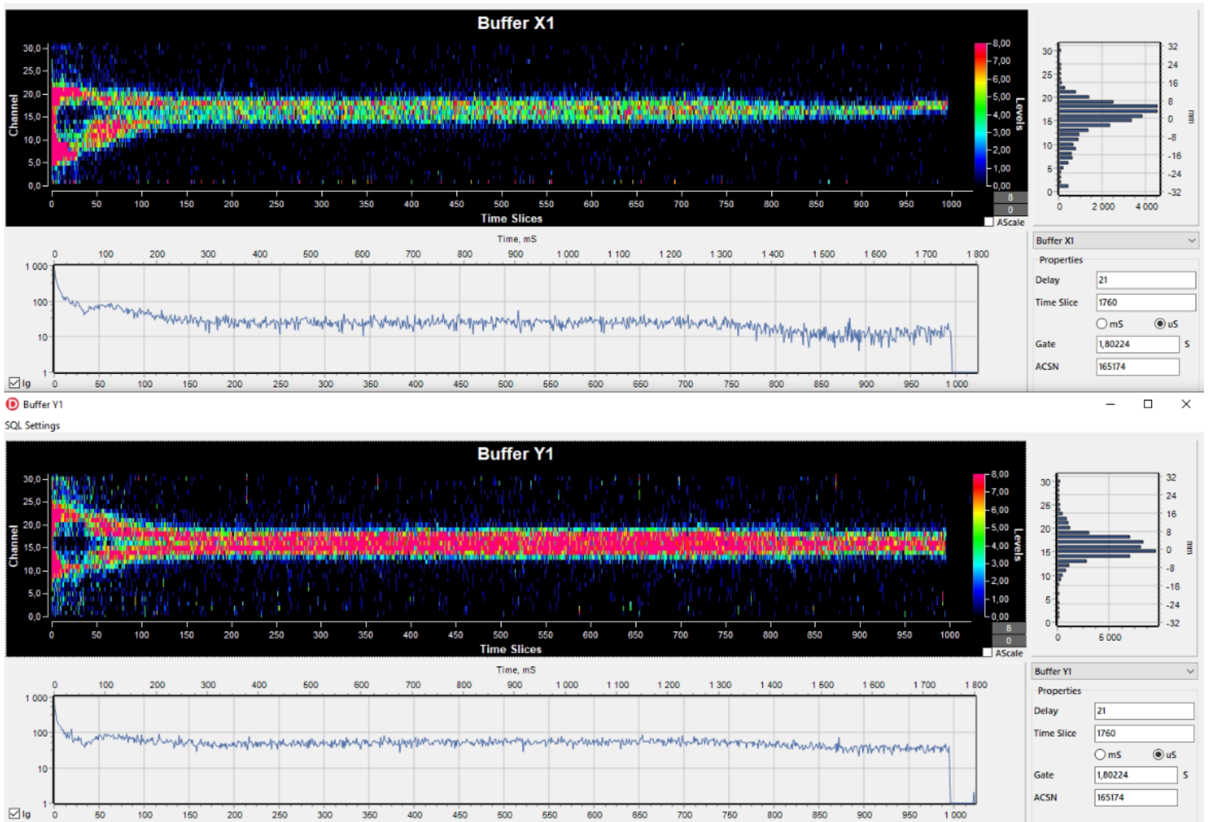


Figure 8 shows an example of C beam acceleration in the Booster from injection to transmission into Nuclotron (a total time of about 1.5 s).

Rice. Fig. 17. Horizontal (x) and vertical (y) beam profile versus time, measured with an MCP XY profilometer installed in the booster UHV beamline.

Distances / # Channels/anodes (Nang.sec.×Nrad.sec)	L1 = 900 mm	L2 = 1500 mm	L3 = 2500 mm
64 **($8_A \times 8_R$)**	0 miss: 70% 1 miss: 18% 2 miss: 7% 3 miss: 3% ≥ 4 miss: 2%	0 miss: 88% 1 miss: 10% 2 miss: 2% 3 miss: < 1% ≥ 4 miss: < 1%	0 miss: 99% 1 miss: < 1% 2 miss: < 1% 3 miss: < 1% ≥ 4 miss: < 1%
32 **($8_A \times 4_R$)**	0 miss: 57% 1 miss: 19% 2 miss: 11% 3 miss: 6% ≥ 4 miss: 7%	0 miss: 80% 1 miss: 13% 2 miss: 4% 3 miss: 1% ≥ 4 miss: 2%	0 miss: 97% 1 miss: 3% 2 miss: < 1% 3 miss: < 1% ≥ 4 miss: < 1%
16 **($4_A \times 4_R$)**	0 miss: 46% 1 miss: 16% 2 miss: 11% 3 miss: 9% ≥ 4 miss: 18%	0 miss: 70% 1 miss: 16% 2 miss: 7% 3 miss: 3% ≥ 4 miss: 4%	0 miss: 95% 1 miss: 5% 2 miss: < 1% 3 miss: < 1% ≥ 4 miss: < 1%
1 **($1_A \times 1_R$)**	0 miss: 23% 1 miss: 8% 2 miss: 7% 3 miss: 6% ≥ 4 miss: 56%	0 miss: 40% 1 miss: 12% 2 miss: 9% 3 miss: 8% ≥ 4 miss: 31%	0 miss: 73% 1 miss: 15% 2 miss: 8% 3 miss: 3% ≥ 4 miss: 1%
$<N_{ch}>$ per event for MCP ring	6,4	3,5	1,2

FBBC developments

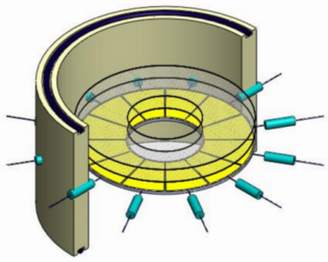
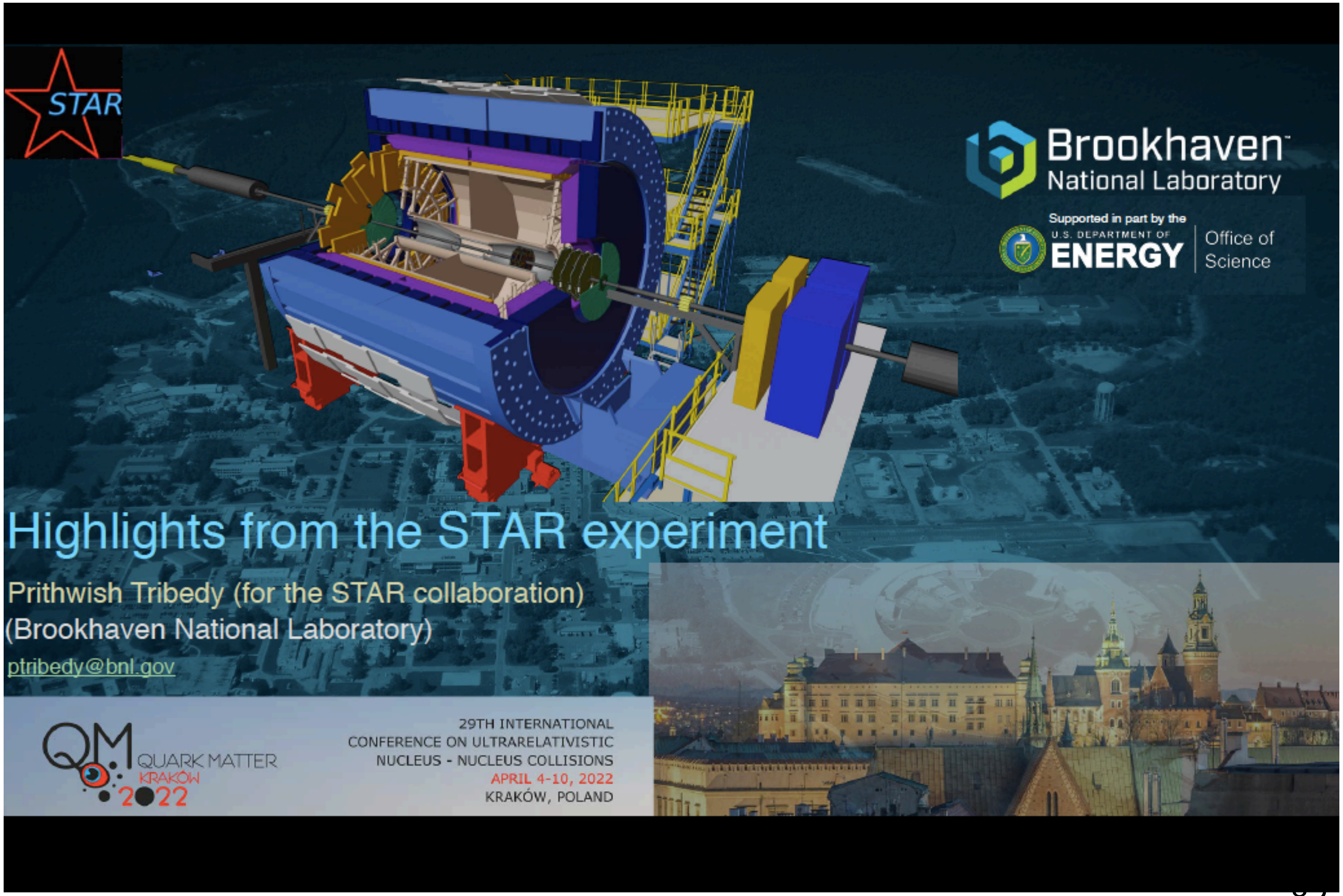


Figure : Compact module of the Fast Beam-Beam Collision Monitor (FBBC) based on the circular MCPs. Sector cathode readout pads and two MCP set-ups are embedded into a separate flange with hermetic 50 Ohm signal feedthroughs and
HV feedthroughs (the last ones are not shown).

Where are we today?

- ➢ **MPD collaboration is in preparations to start…**

Some highlights from STAR@RHIC
presented at QM-2022

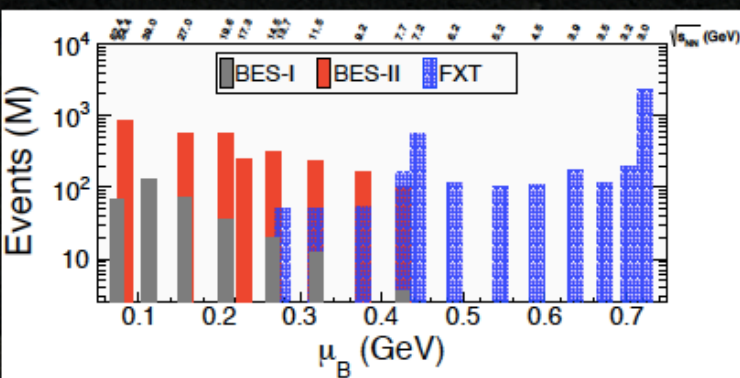


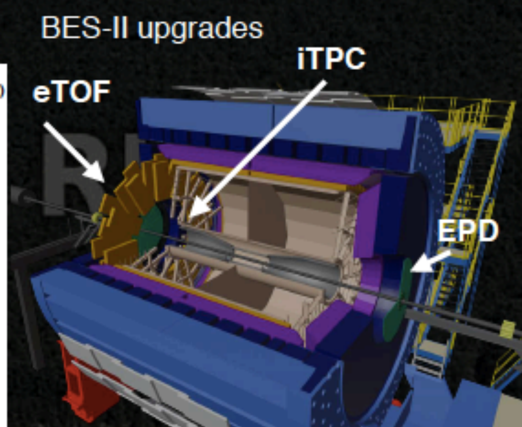
Some highlights from STAR@RHIC presented at QM-2022

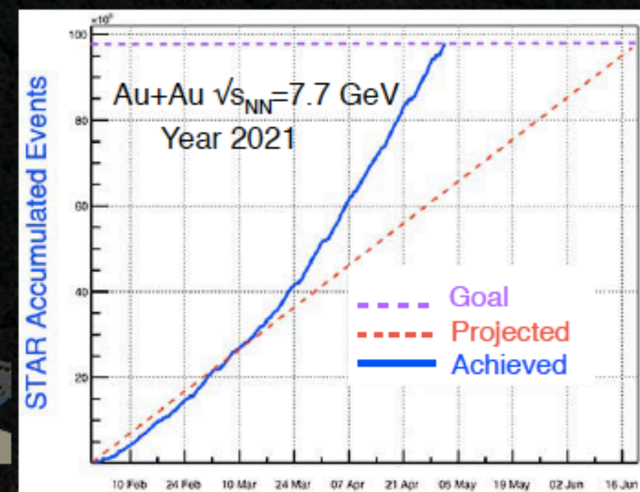
Successful Operation of STAR in Years 2020-21

Watch Live Collisions At STAR:
https://online.star.bnl.gov/aggregator/livedisplay/

Run 20 and 21 completed successfully: enhanced collision rates due to Low Energy RHIC Electron Cooling (LEReC) system, smooth & desired performance of BES-II upgrades (iTPC, eTOF, EPD)







7 energies between 7.7 - 27 GeV (collider mode)
12 energies between 3.0 - 13.7 GeV (FXT mode)

Early completion of BES-II data taking allowed O+O & d+Au runs in 2021

RHIC Beam Energy Scan II completed, p+p 510 run with fully installed forward upgrade is ongoing

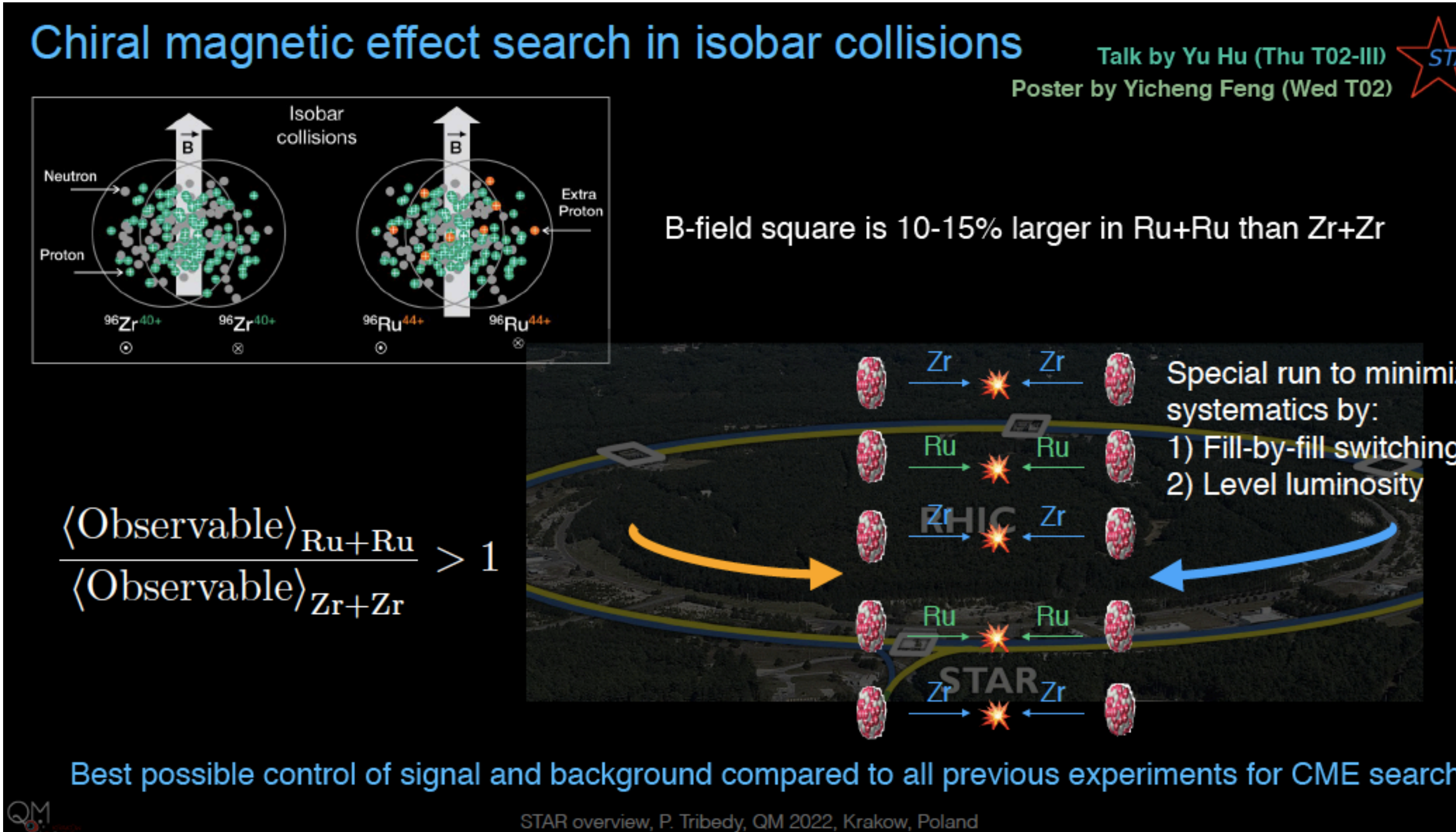
Some highlights from STAR@RHIC presented at QM-2022

Outline of STAR highlights

- Isobar collisions & strong field effects
  1. Chiral magnetic effects — Slide #5-7
  2. Directed flow splitting — Slide #8
  3. Global polarization — Slide #9, 17
  4. Spin alignment — Slide #10
  5. Photoproduction — Slide #11-12
- New Insights on collective effects
  6. Nuclear shape & structure — Slide #14
  7. Longitudinal dynamics — Slide #15
- Prerequisites for phase transitions & freezeout
  8. Baryon stopping — Slide #18-19
  9. Strangeness production — Slide #20
  10. Hyper-nuclei formation — Slide #21
  11. Nuclei formation — Slide #22
  12. Hadron & nuclei femtoscopy — Slide #23
- Critical phenomena & mapping phase diagram
  13. Net-proton fluctuations — Slide #25
  14. Deuteron fluctuations — Slide #25
  15. Search for chiral crossover — Slide #26
  16. Di-lepton as QGP thermometer — Slide #27
- Hard probes in the medium
  17. J/ψ suppression — Slide #29
  18. High p_T hadron R_{AA} — Slide #30
  19. Heavy flavor jet shape — Slide #31
  20. Broadening of γ/π^0+jets — Slide #32
- Upgrades and future program
  21. Forward upgrade of STAR — Slide #34

STAR results are being presented in 21 parallel talks and 47 posters at this Quark Matter

Some highlights from STAR@RHIC presented at QM-2022: example



Comments to STAR data on chiral magnetic effect search in isobar collisions

Comment 1: it is a very interesting idea!
Comment 2: but, as one may see, the narrow centrality class selection is important to ensure the high resolution

Comment 3: first of all, the MPD has to start and compare results of measurements in Bi+Bi collisions at 9.2 GeV with available Au+Au data by with STAR@RHIC

Very reach harvest of STAR data at RHIC [1]

6 / Nuclear Physics A 00 (2020) 1–8

$\sqrt{s_{NN}}$ (GeV)	Minbias (millions)	new detectors	year
200	138	EPD+iTPC	2019
54.4	835		2017
27	557	EPD	2018
19.5	582	EPD+iTPC	2019
14.6	324	EPD+iTPC	2019
11.5	235	EPD+iTPC+eTOF	2020
9.2	45*	EPD+iTPC+eTOF	2020
7.7	2.9**	EPD+iTPC	2019
31.2 FXT	112	EPD+iTPC+eTOF	2020
26.5 FXT	155		2017
19.5 FXT	118	EPD+iTPC+eTOF	2020
13.5 FXT	103	EPD+iTPC+eTOF	2020
9.8 FXT	108	EPD+iTPC+eTOF	2020
7.3 FXT	117	EPD+iTPC+eTOF	2020
5.75 FXT	116	EPD+iTPC+eTOF	2020
4.59 FXT	201	EPD+iTPC	2019
3.85 FXT	258	EPD	2018

Table 2. Major datasets at different energies in last 4 RHIC runs (2017 to early 2020) related to the beam energy scan with minimum-bias selection of Au+Au collisions at collider mode and FXT mode. The value for FXT mode is the single beam energy and not the $\sqrt{s_{NN}}$. 9.2 GeV will continue in the next run, and 7.7 was a commissioning run in 2019.

- [1] https://www.osti.gov/servlets/purl/1762771 -- **we have to check the data-sets available!**

Discussion of the MC production
Task 1: to start and compare with STAR@RHIC)

Selection of the pseudorapidity intervals and centrality classes with Bi+Bi at MPD to compare with STAR

STAR@RHIC: Au+Au collisions at $\sqrt{s}_{NN}$=9.2GeV, year 2008 , a short test run of ~3000 good events [2]

- Energy dependence of particle ratios,π−/π+, p/p, K−/K+ and K/π, plotted as a function of √sNN. **Results from 0–10%** central Au+Au collisions at 9.2 GeV at midrapidity (**|y|<0.5**) are compared with those from AGS, SPS and RHIC.
- Azimuthal anisotropy measurements
- Pion interferometry measurements

[2] **STAR Collaboration, Bulk Properties in Au+Au Collisions at $\sqrt{s_{NN}}$= 9.2 GeV in STAR Experiment at RHIC,** Nucl.Phys.A830:275c-278c,2009; arXiv:0907.1943v2

We have to start and compare with STAR@RHIC [2]

Energy dependence of particle ratios

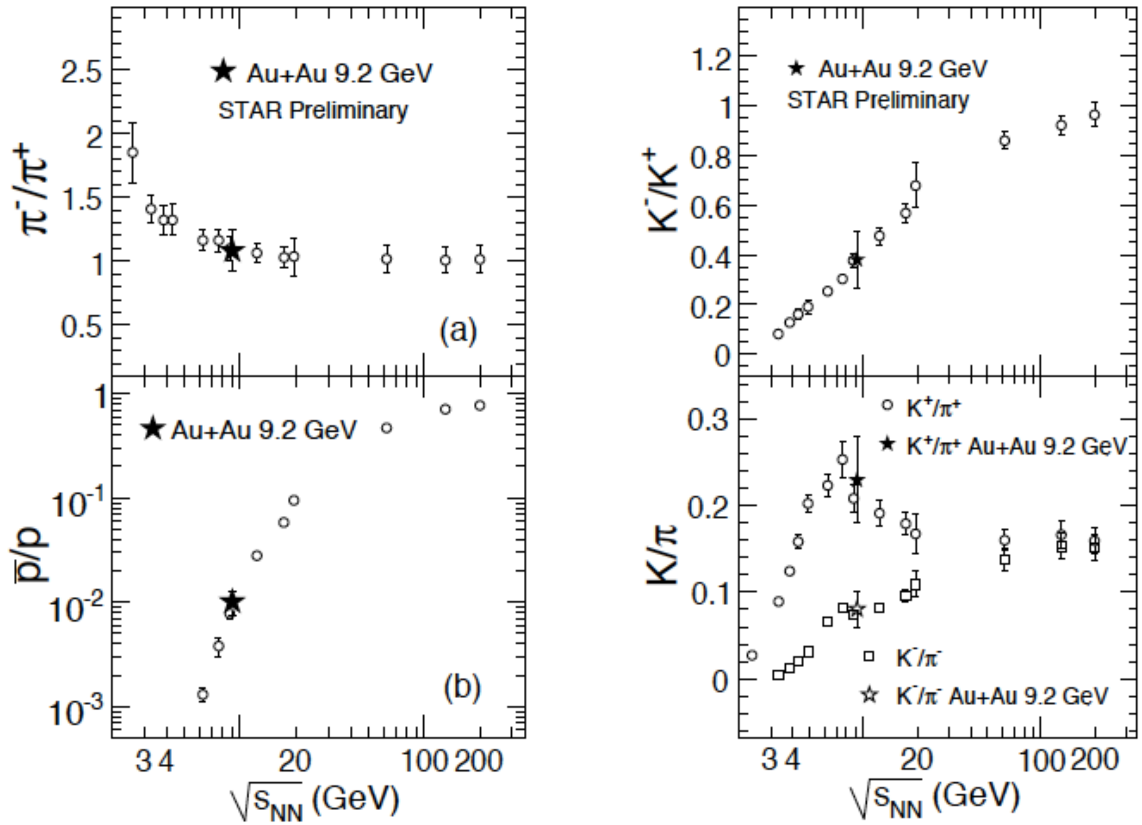


Figure 1: Left panel: (a) π^-/π^+ and (b) $\bar{p}/p$, plotted as a function of $\sqrt{s_{NN}}$. Right panel: (a) K^-/K^+ and (b) K/π, plotted as a function of $\sqrt{s_{NN}}$. Results from 0–10% central Au+Au collisions at 9.2 GeV (solid stars) are compared with those from AGS [4], SPS [5] and RHIC [6] (open symbols). Errors are statistical and systematic added in quadrature. See text for details.

At midrapidity (|y|<0.5)

Centrality Class 0-10%

·Au

ıt at

RHIC, Nucl.Phys.A830:275c-278c,2009,

arXiv:0907.1943v2

We have to start and compare with STAR@RHIC [2]

Pion interferometry measurements

Table 1: The HBT parameters for 0–30% central events and k_T = [150, 250] MeV/c.

λ	R_{out} (fm)	R_{side} (fm)	R_{long} (fm)
0.6 ± 0.1	4.8 ± 0.8	4.4 ± 0.5	5.1 ± 0.8

Centrality class 0-30%

[2] STAR Collaboration, Bulk Properties in Au+Au Collisions at $\sqrt{s_{NN}}$ = 9.2 GeV in STAR Experiment at RHIC, Nucl.Phys.A830:275c-278c,2009; arXiv:0907.1943v2

We have to start and compare with STAR@RHIC [2]

Azimuthal anisotropy measurements

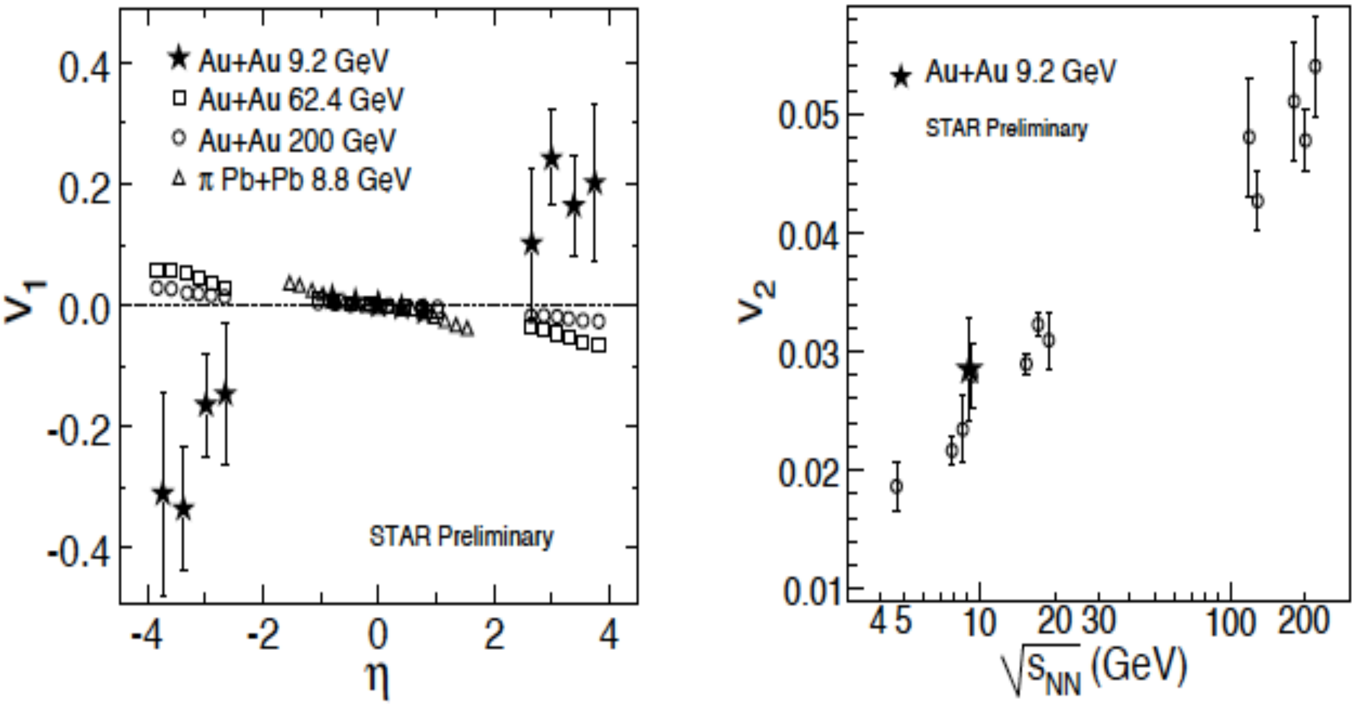


Figure 2: Left panel : Charged hadrons v_1 vs. η from 0–60% Au+Au collisions at 9.2 GeV (errors shown are statistical). See text for details. Right panel : Energy dependence of v_2 near mid-rapidity ($-1 < \eta < 1$). Errors are statistical only. See text for details.

At midrapidity (|η|<1.0) Centrality class 0-60%

[2] STAR Collaboration, Bulk Properties in Au+Au Collisions at √ s_{NN}= 9.2 GeV in STAR Experiment at RHIC, Nucl.Phys.A830:275c-278c, 2009; arXiv:0907.1943v2

Strange hadron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, and 39 GeV with STAR@RHIC [3]

STAR measurements of strange hadron (K^0_S, Λ, Λ, Ξ^-, Ξ^+, Ω^-, Ω^+, and ϕ) production

One may include later in the analysis recent STAR measurements of strange hadron (K^0_S and ϕ) production at mid-rapidity ($|y|<0.5$) in Au+Au collisions at from √sNN = 7.7 to 39 GeV

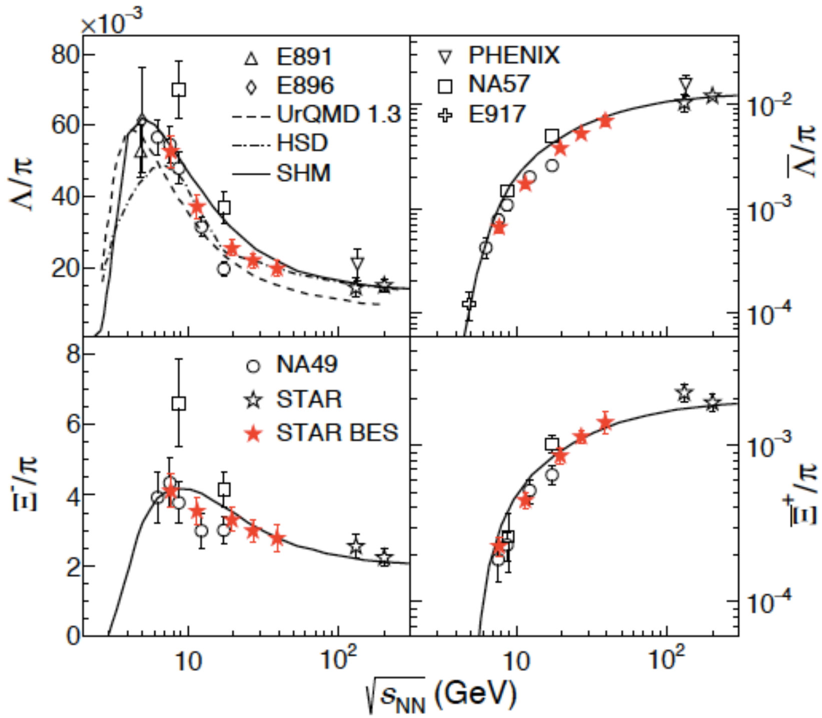
[3] STAR Collaboration: J. Adam, et al., Phys. Rev. C 102, 034909 (2020) Related DOI: https://doi.org/10.1103/PhysRevC.102.034909
https://arxiv.org/abs/1906.03732

Strange hadron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, and 39 GeV [3]

Strange

ha

oduction in Bi+Bi



at later stages and

[3

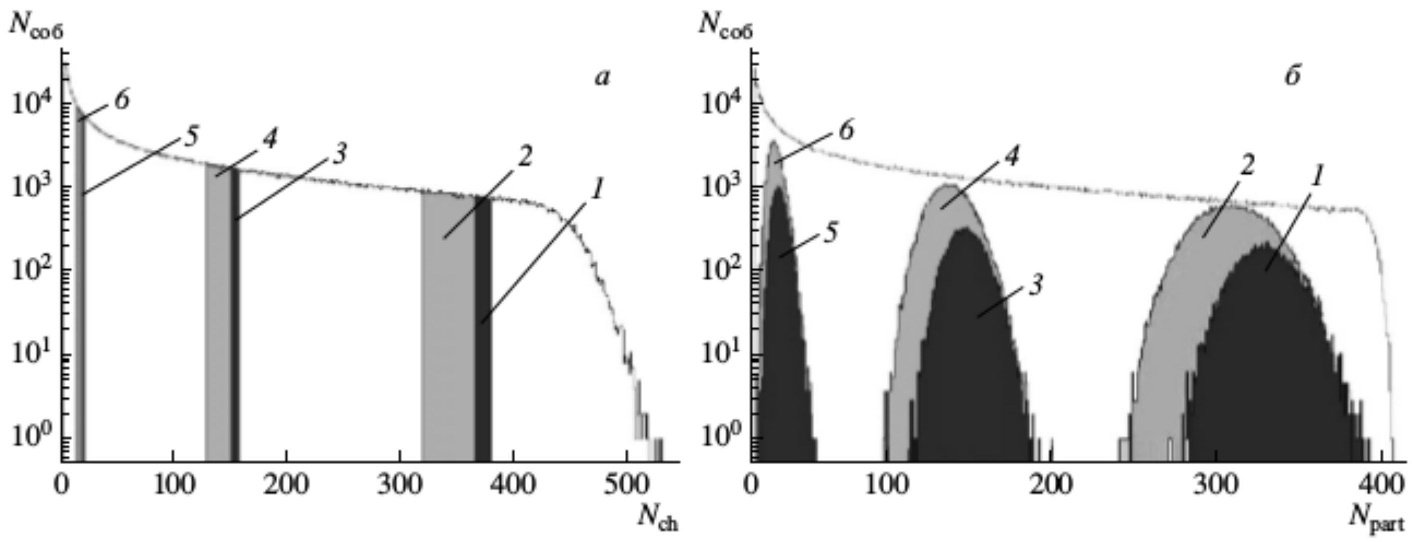
R

ys. Rev. C 102, 034909 (2020)

sRevC.102.034909

FIG. 27: Energy dependence of Λ, antiΛ--, Ξ⁻, antiΞ⁺, Ω⁻, antiΩ⁺ to pions ratios at mid-rapidity in central Au+Au collisions from STAR Beam Energy Scan (solid symbols). The STAR BES mid-rapidity pion yields are taken from [7].

Centrality and multiparticle production in ultrarelativistic nuclear collisions



COMMENT : Narrow distribution in Nch **D O E S N O T** mean narrow distribution in Npart!

https://link.springer.com/journal/11450

- So, centrality determination and selection of classes by STAR should be taken with definite concern!

T. A. Drozhzhova,V. N. Kovalenko,A. Yu. Seryakov,G. A. Feofilov, Physics of Atomic Nuclei, September 2016, Volume 79, Issue 5, pp 737–748

Question: with very reach harvest of STAR data at RHIC what is expected to be new by the MPD?

- **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 RAA 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:
  - in fluctuations and correlation measurements,
  - in elliptic flow measurements and flow fluctuations

Where are we today?

Where are we today? PWG1

meetings: Sept.2021- March 2022

24 March 2022 Speaker: I.Maldonado (Universidad Autónoma de Sinaloa) ,"Update BiBi Collisions at 9.2 GeV

27 Jan 2022, A.Seryakov (SPbSU),” Influence of different centrality methods on multiplicity fluctuations: MPD case”

20 Jan 2022

- G.Feofilov and A.Aparin. ”PWG1: planning of activity for 2022”
- I.Maldonado (Universidad Autónoma de Sinaloa)”BiBi collisions at 9.2 GeV”

18 November 2021,

- Dr. G.Musulmanbekov, “Nuclear fragments deposited in FHCal. DCM-QGSM or DCM-SMM?”
- A.Aparin “Discussion concerning a way to establish a standartized procedure for basic QA”,

09 Sept. 2021

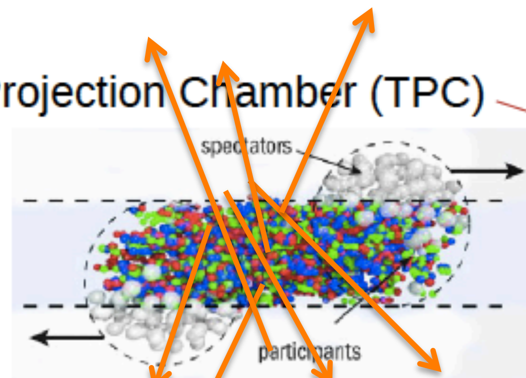
- Pedro Antonio Nieto Marín "Centrality determination in MPD at NICA"¶ T-20m by "Centrality determination in MPD at NICA”.

Two main approaches to centrality class(es selection:

1) Charged particle Multiplicity classes by the TPC (or…)
and
2) Spectator energy classes by FHCal

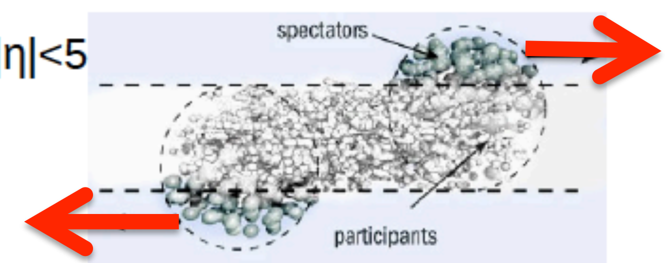
- Time Projection Chamber (TPC)

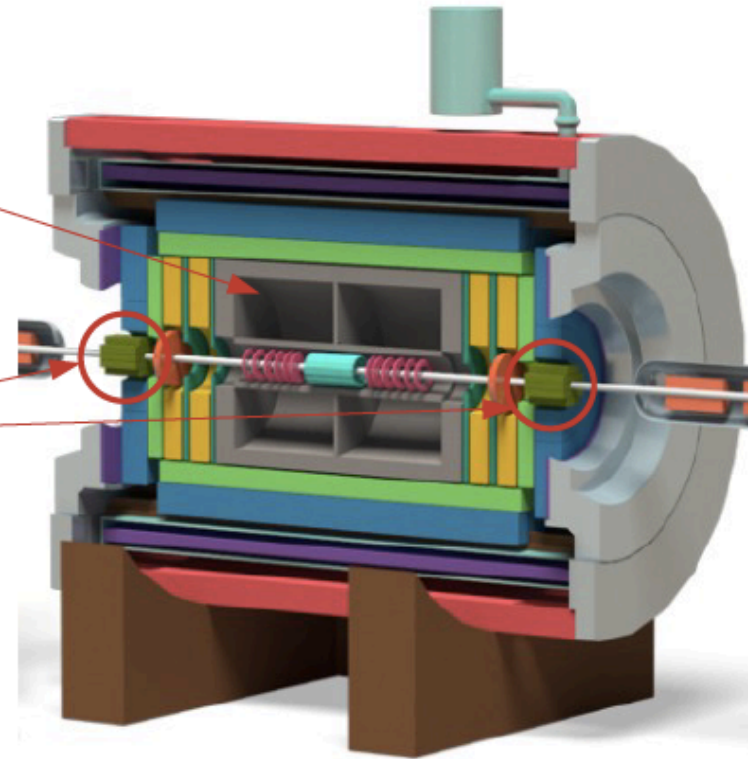
$|\eta|<1.5$



- Forward Hadron Calorimeter (FHCal)

$2<|\eta|<5$





Two main approaches to determination of classes of centrality

➢ Multiplicity in TPC as centrality class estimator

-- method was suggested by MEPHI/GSI team

Report by Petr Parfenov at the MPD Physics forum 15.04.2021г:

See https://indico.jinr.ru/event/2065/

https://github.com/FlowNICA/CentralityFramework

https://github.com/Dim23/GammaFit

Draft of analysis note:

https://github.com/FlowNICA/CentralityFramework/blob/master/Documentation/Centrality_AnalysisNote.pdf

➢ Spectator nucleons with FHCal

– by the INR RAS team, see the PWG1 meetings Report by Vadim Volkov at the PWG1 meeting **01 April 2021**

https://indico.jinr.ru/event/2066/

or RFBR conference:

https://indico.jinr.ru/event/1469/contributions/9905/attachments/8135/12126/ivashkin_RFBR_2020.pdf

Codes: https://github.com/qweek2/Centrality_NICA/tree/master

Two main approaches to determination of classes of centrality

- **Spectator nucleons with FHCal**

– by the INR RAS team, see the PWG1 meetings Report by Vadim Volkov at the PWG1 meeting **01 April 2021**
https://indico.jinr.ru/event/2066/
or RFBR conference:
https://indico.jinr.ru/event/1469/contributions/9905/attachments/8135/12126/ivashkin_RFBR_2020.pdf
Codes: https://github.com/qweek2/Centrality_NICA/tree/master

- **It is important to proceed with the results presented by Genis in the report**

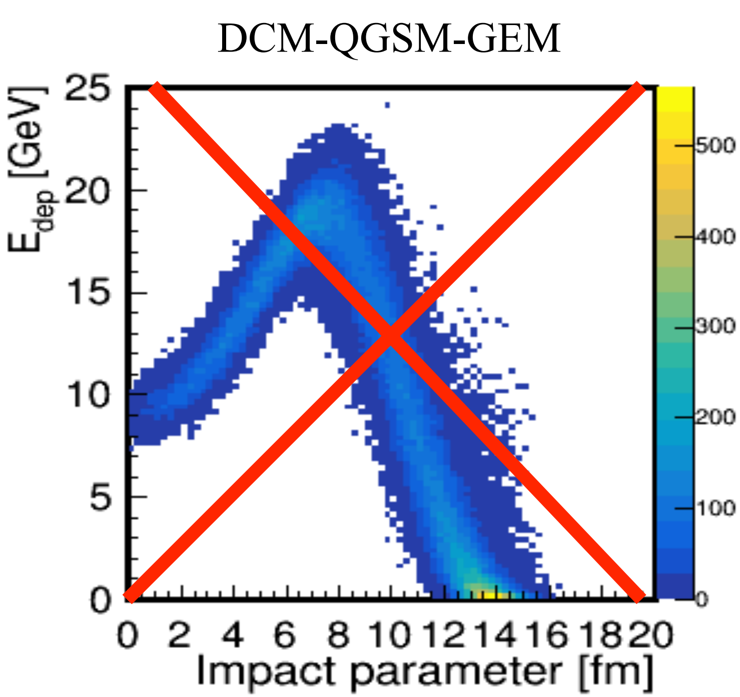
G. Musulmanbekov, V. Zhezher , **“Nuclear fragments deposited in FHCal. DCM-QGSM or DCM-SMM?”:**
“DCM-QGSM-SMM is more reliable than DCM-QGSM-GEM for description of spallation of excited **N**uclear **R**emnants”
see https://indico.jinr.ru/event/2658/

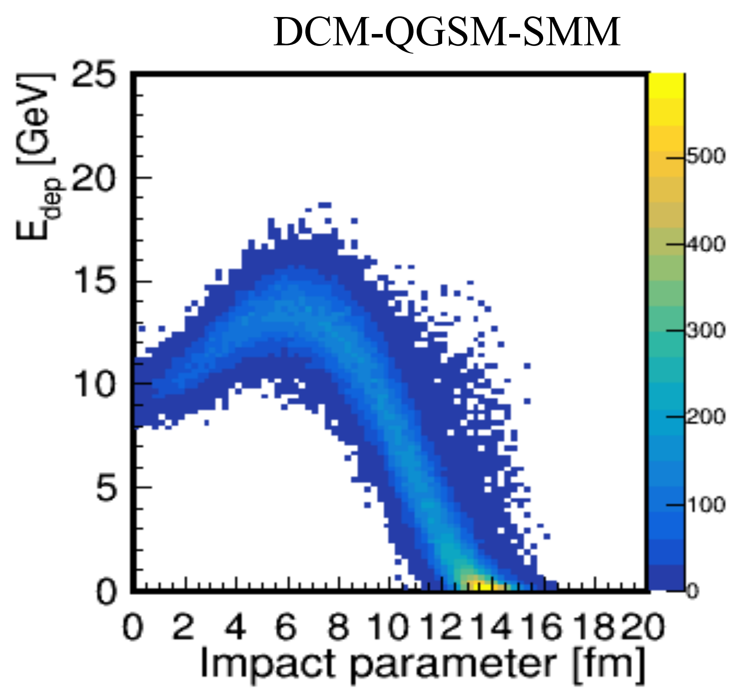
DCM-QGSM-GEM vs DCM-QGSM-SMM

DCM-QGSM-GEM	**DCM-QGSM-SMM**
Step 1	**Step 1**
• Intranuclear Cascade	• Intranuclear Cascade
Step 2	**Step 2**
• Coalescence	• Coalescence
Step 3 Residual Nucleus (**RN**)	**Step 3** Residual Nucleus (**RN**)
• Preequlibrium emission	• None
Step 4	**Step 4** Residual Nucleus **(RN)**
• Fermi-break-up if $A_{res} < 13$	• Fermi break-up if $A_{res} < 13$
• Generalized evaporation (GEM)	• Statistical Multifragmentation (SMM)
• Fission	• Secondary Fragmentation and Evaporation of excited fragments
	• Fission

see https://indico.jinr.ru/event/2658/

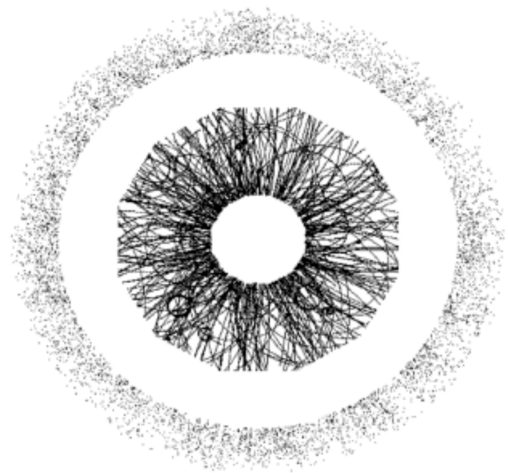
Conclusion





G. Musulmanbekov: **DCM-QGSM-SMM is more reliable for estimation E_{FHCal} and Centrality**

see https://indico.jinr.ru/event/2658/



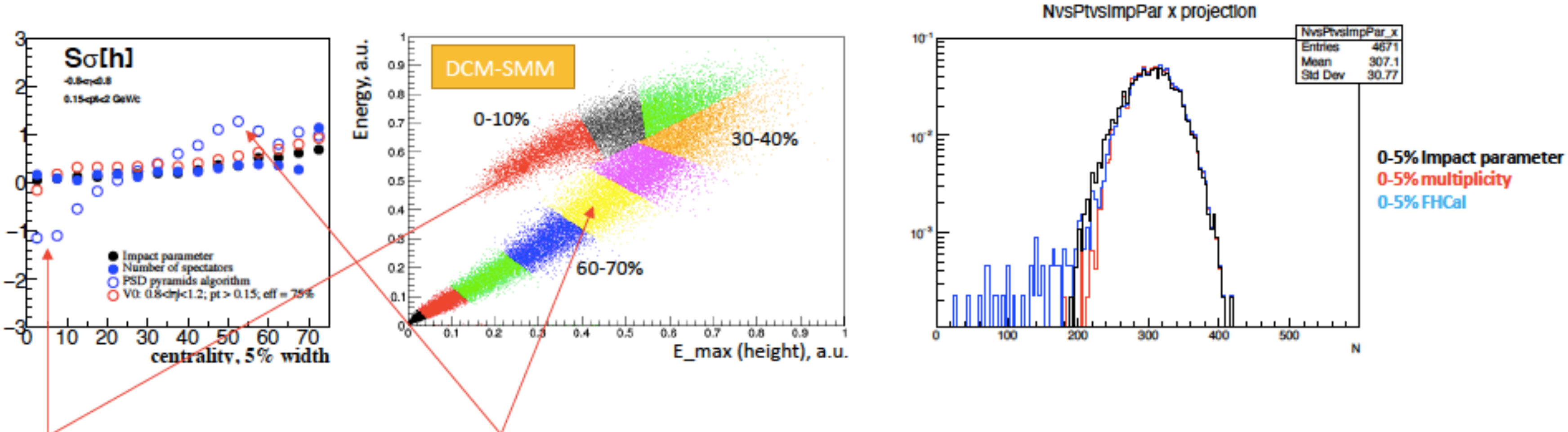
Influence of different centrality methods on multiplicity fluctuations MPD case

Andrey Seryakov
LUHEP SPbSU
andrey.seryakov@cern.ch

PWG1 meeting Thursday the 27th of Jan 2022
https://indico.jinr.ru/event/2794/

Discussion

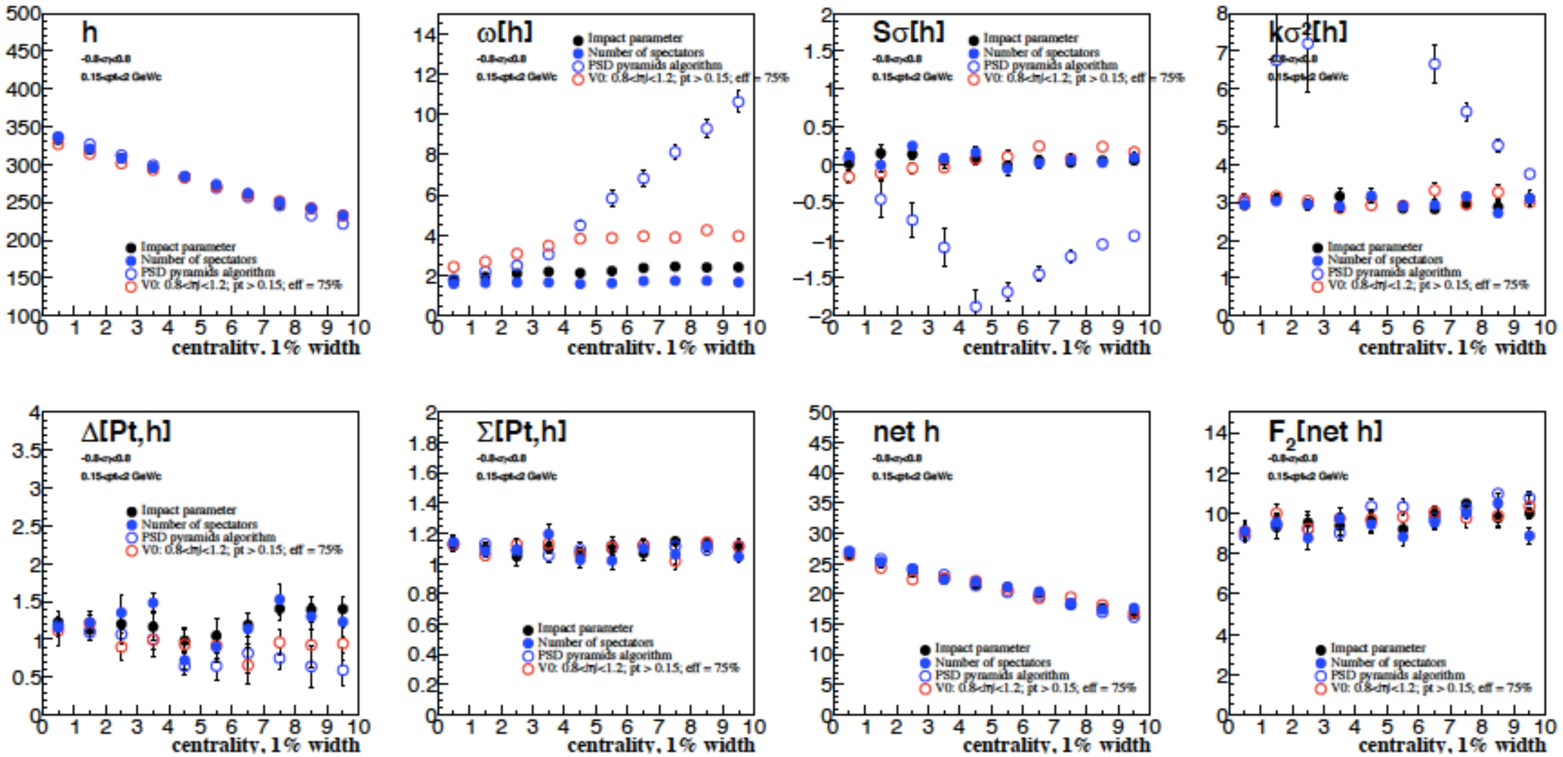
- Why FHCal pyramids are so far away from other methods



Central event with a small fraction of very peripheral

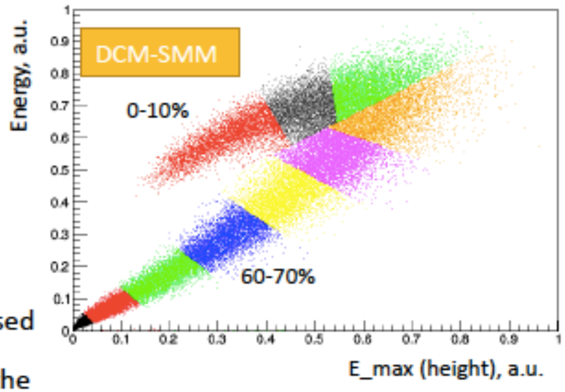
Peripheral events with a small fraction of very central

1% width

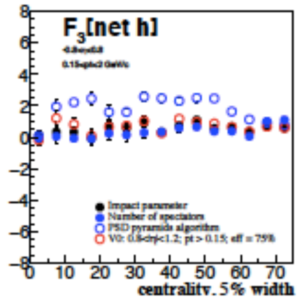


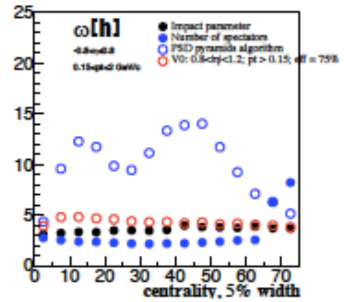
h
ω[h]
Sσ[h]
kσ²[h]
Δ[Pt,h]
Σ[Pt,h]
net h
F2[net h]
Impact parameter
Number of spectators
PSD pyramids algorithm
V0: 0.8<|η|<1.2; pt > 0.15; eff = 75%
centrality, 1% width

Conclusions



- The current state of the pyramid procedure:
  - Can't be reproduced in pure MC by people from outside the collaboration, so it may be used only as a proxy to Npart or b.
  - Doesn't restrict volume fluctuations enough to measure multiplicity fluctuations, except the most central point (0-1%). Although I would expect this region to become narrower with statistic and better calorimeter description (effects of electronics).
  - A further development is needed
    - Maybe a 3rd axis (multiplicity) has to be introduced to increase resolution capability between very central and very peripheral events.
    - A different fit instead of the pyramid?
  - We have to be very careful with this procedure as:
    - MC generators are usually having a much worse description of the forward region compare to the central rapidity
    - GEANT 4 description of FHCal doesn't not include effects of electronic, which can be very significant (based on my experience of analyzing data from PSD at NA61/SHINE)
- Contrary to FHCal, the multiplicity based procedure shows very close results to Npart and b and can be easily reproduced by people from outside MPD.
- Considering all of the above, I would not recommend using FHCal for fluctuation measures till it shows significantly better results than the multiplicity based approach.





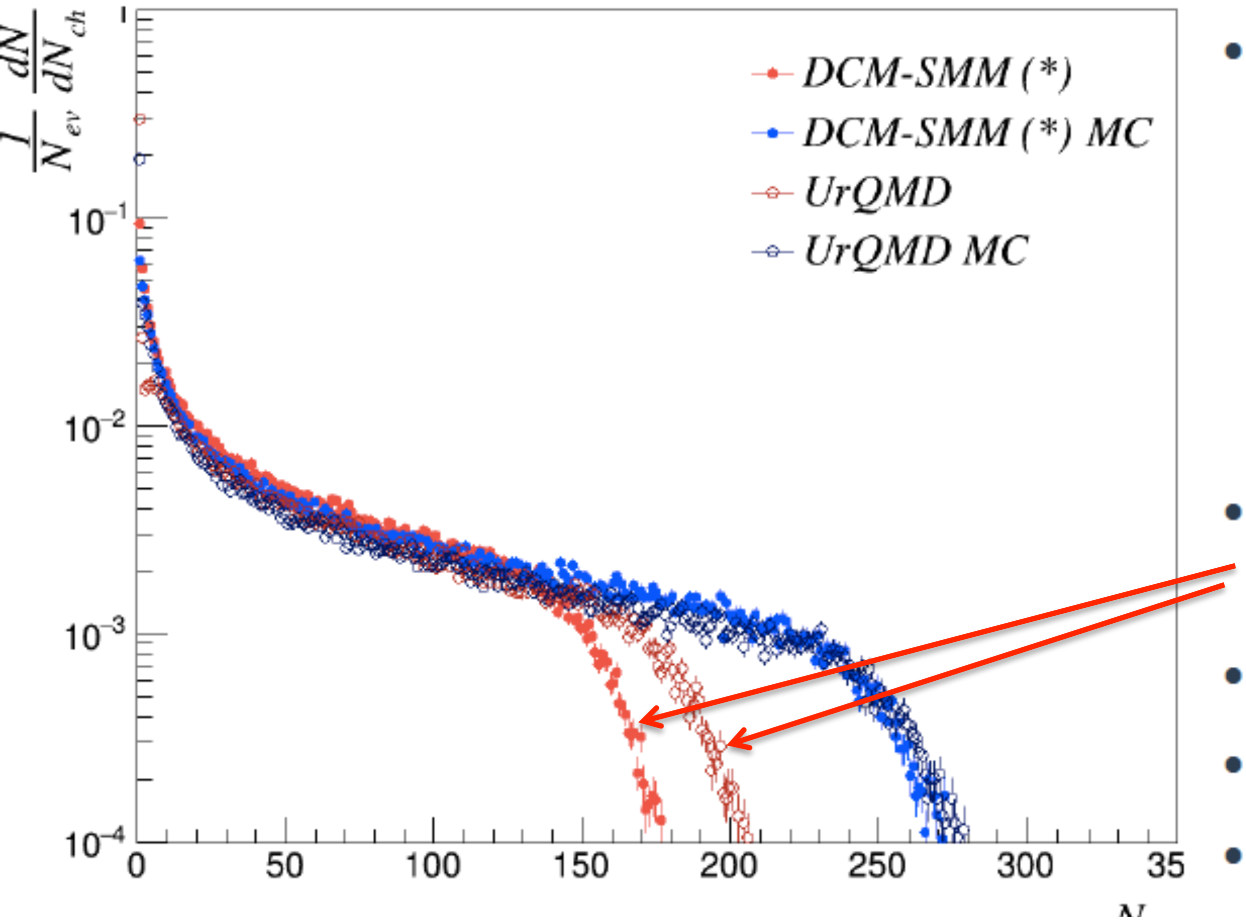
BiBi Collisions at 9.2 GeV

I. Maldonado

PWG1 meeting Thursday the 24th of March 2022

https://indico.jinr.ru/event/2781/

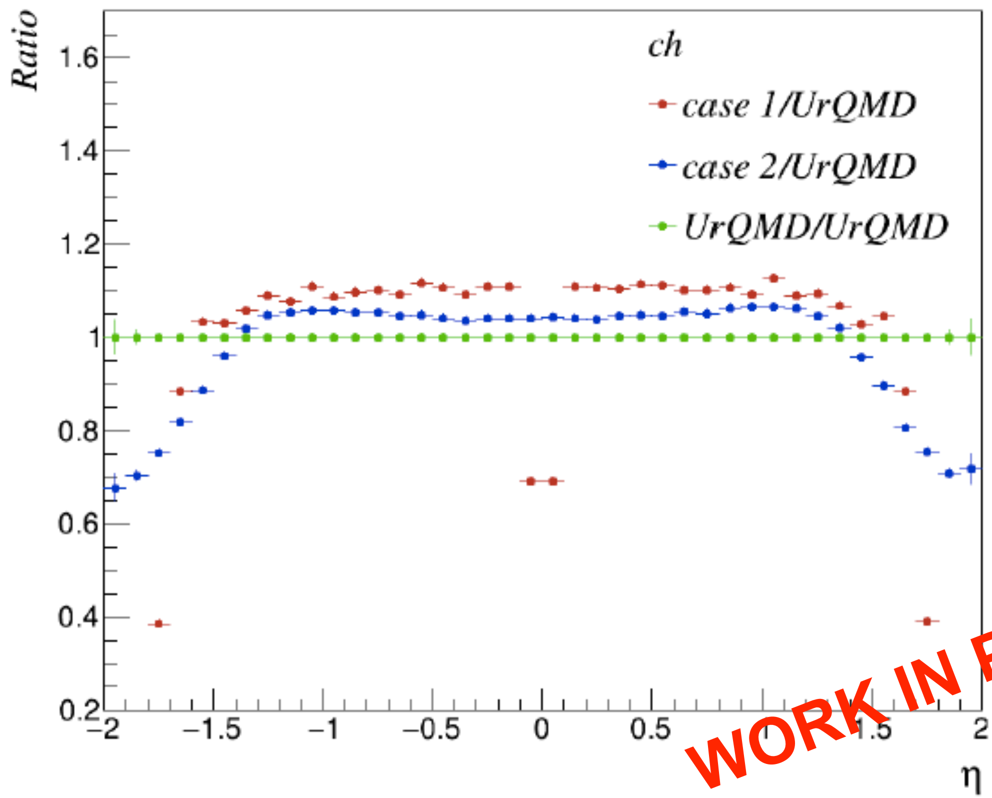
- **Analysis with mpddst.root files**
- **BiBi at 9.2 GeV**
- **Events analyzed ~ 100000 events**
  - **UrQMD:** /eos/nica/mpd/sim/data/exp/dst-BiBi-09.2GeV-mp06-21-500ev/BiBi/09.2GeV-mb/UrQMD/BiBi-09.2GeV-mp06-21-500ev/urqmd-BiBi-09.2GeV-mb-eos0-500-15.reco.root
  - **DCMSMM**: Local Transport and Reconstruction with pz of particles measured at CM system, which corrects shift in rapidity



- **MC → MCTracks with**
  - p_T>0.15 GeV/c
  - |η|<0.5
  - Primary π^+, π^-, K^+, K^-, p and p^-
- **Reconstructed Tracks**
- p_T > 0.15 GeV/c
- |η| <0.5
- N_{hits} > 16

- **Case 1: NO smearing selection**
- **Case 2: Smearing Selection**
  - primGen->SetBeam(0.0,0.0,0.1,0.1);
  - primGen->SetTarget(0.0,24.0);
  - primGen->SmearGausVertexZ(kTRUE);
  - primGen->SmearVertexXY(kTRUE);
- **UrQMD for comparison**

...or Pseudorapidity ch w.r.t UrQMD



- The smearing changes the value of pseudorapidity

WORK IN PROGRESS

- I show that in a strongly interacting plasma, the fluctuations responsible for deviations from those of a description based on a simple Hadron Resonance Gas Model naturally arise from the proper inclusion of the plasma screening properties. These are encoded in the contribution of the so called "ring diagrams" and thus in the introduction of a key feature of plasmas near phase transitions, namely, long-range correlations. I illustrate this property using the Linear Sigma Model with quarks which in the high temperature and chiral symmetry approximations renders analytical results. After fixing the model parameters using input from LQCD for the crossover transition at vanishing baryon chemical potential, I study the location of the Critical End Point (CEP) in the effective QCD phase diagram. I use the model to study baryon number fluctuations and show that in heavy-ion collisions, the CEP can be located for collision energies of order of 2 GeV per nucleon, namely, in the lowest NICA or within the HADES energy domain.