Status report from MexNICA group to PWG1

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V-th Collaboration Meeting of the MPD Experiment at the NICA Facility

April, 24th , 2020

Outline

The present slides summarize the activities of MexNICA group at PWG1. Some of the results have been already presented while others are new. The results are at different levels: generation and/or reconstruction in the pseudorapidity region covered by BeBe detector. Regarding phenomenology: magnetic fields and average transverse momentum. **All the analyses are at the early stage.**

- **Simulations using BeBe detector on MPD**
  1) BeBe detector with PHSD event generator
  2) Determination of centrality classes
  3) Event plane resolution
  4) Studies of Λ hyperon

- **Phenomenology**
  1) Magnetic fields at RHIC and NICA energies
  2) Average transverse momentum studies

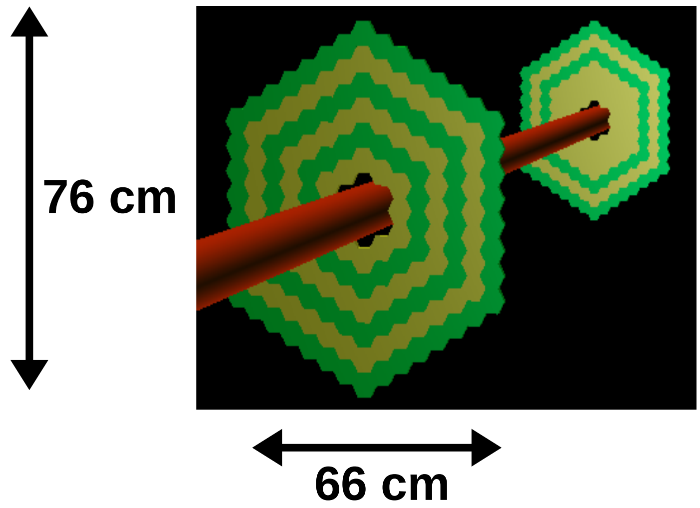
Simulation of Beam-Beam monitoring detector using Parton Hadron String Dynamics (PHSD)

Motivation

Beam-Beam (BeBe) Monitoring detector
It is being designed to provide zero level trigger for MPD. Each hodoscope is array of scintillators located on both sides of the interaction point.

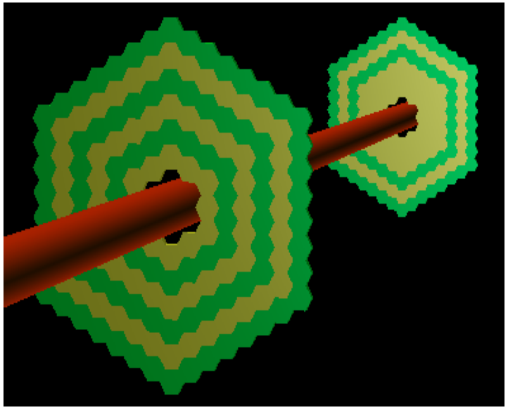
NIMA 953, 163150, 2020

$1.9 < |\eta| < 3.97$



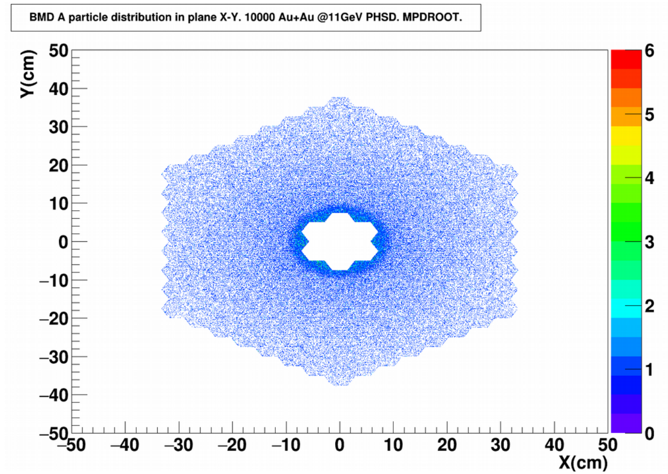
Geometry simulation of Beam-Beam monitoring detector

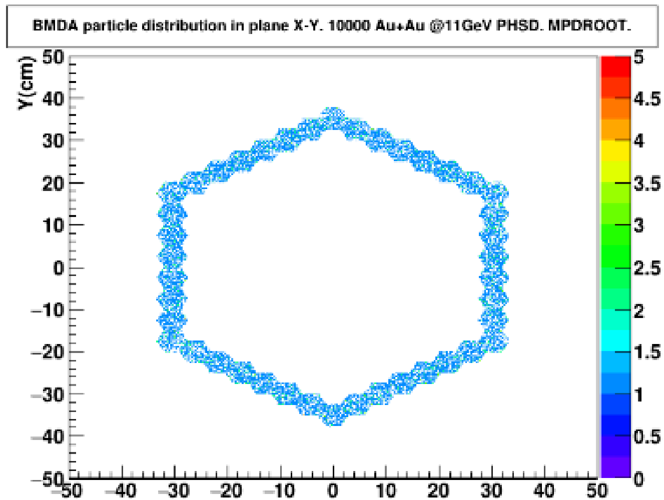
Beam-Beam (BeBe) Monitoring



1.9 < |η|<3.97

- ✔ Generator: PHSD
- ✔ 10000 events min.bias
- ✔ Impact parameter (0 - 14) fm
- ✔ $\sqrt{s_{NN}}$ = 11GeV
- ✔ Framework: MPDROOT

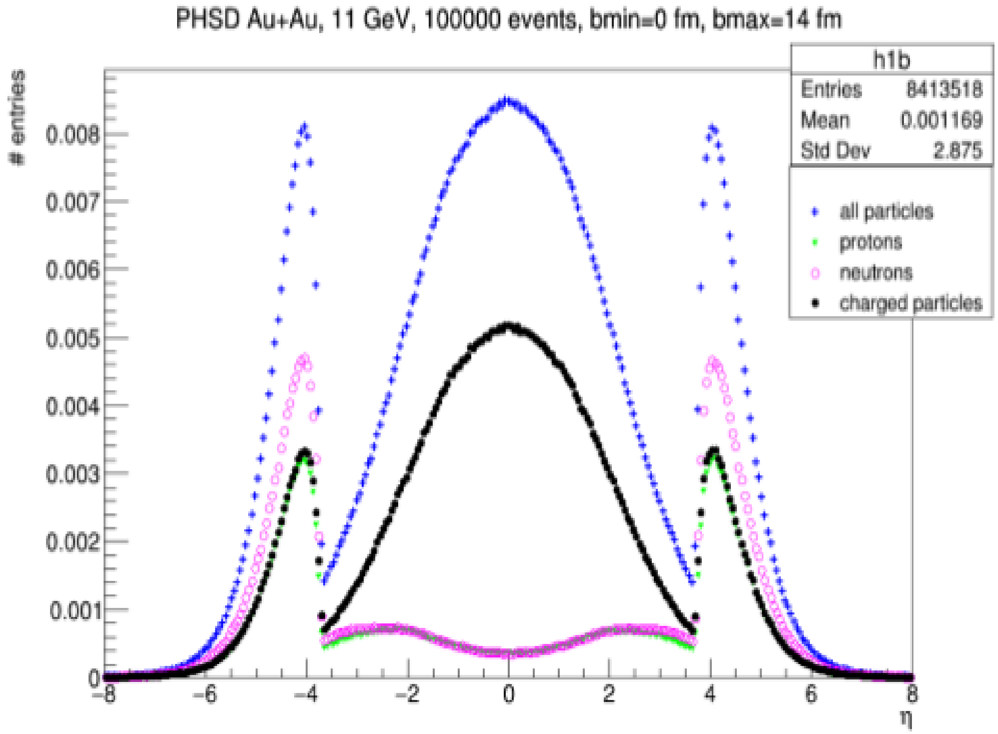


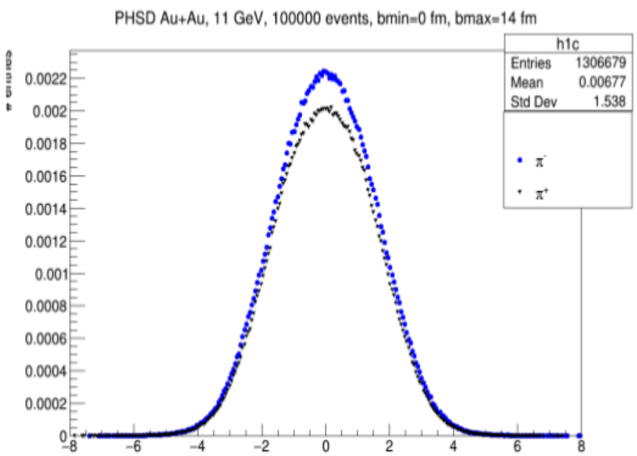


kinematic variables of identified particles

Generator: PHSD
10000 events
Impact parameter 0-14 fm
$\sqrt{s_{NN}}$ = 11GeV
Framework: ROOT

BeBe: 1.9 < |η|<3.97





Determination of centrality classes (using UrQMD)

Motivation

The centrality is a key parameter in the study of the properties of QCD matter at extreme temperature and energy density, because it is directly related to the initial overlap region of the colliding nuclei. Most of the measurements are reported as a function of the centrality classes

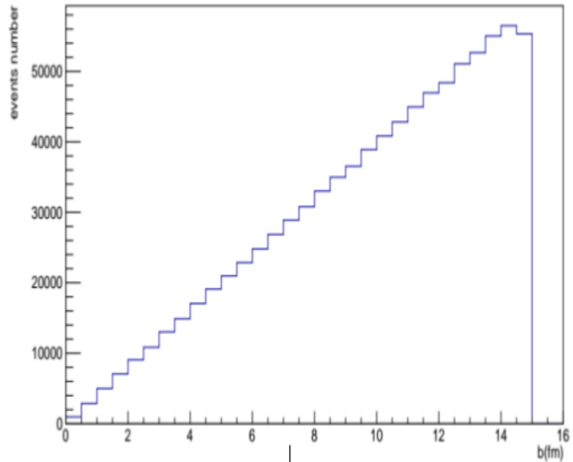
Determination of centrality classes
(using rings 3-6 from BeBe: 2.2 <|η|< 3.2)

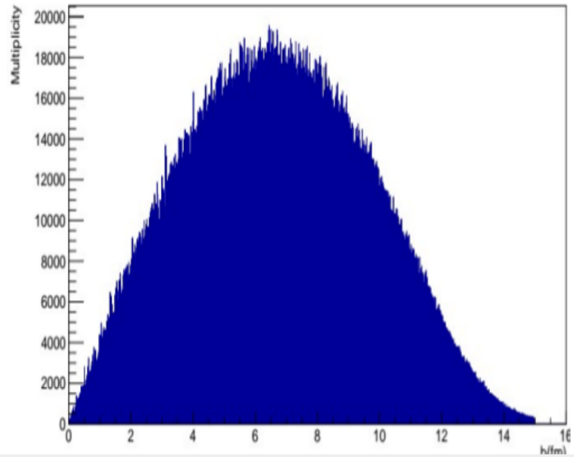
1.- Make the histogram of event numbers for each bin of impact parameter.

2.- Make histogram of number of particles for each event and bin of impact parameter.

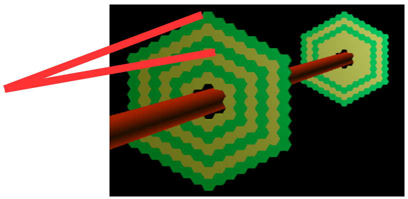
3.- Integrate over bins of impact parameter until the value for each centrality class has been determined

$$c = \frac{\int_0^b \frac{dN_{ch}}{db'} db'}{\int_0^{b_{max}} \frac{dN_{ch}}{db'} db'} = \frac{1}{N_{total}} \int_0^b \frac{dN_{ch}}{db'} db'$$

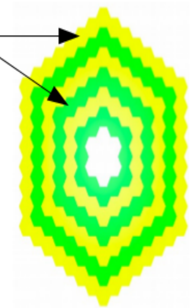




2.2 <|η|< 3.2
Ring 3-6



Determination of centrality classes
(using rings 3-6 from BeBe: 2.2 <|η|< 3.2)

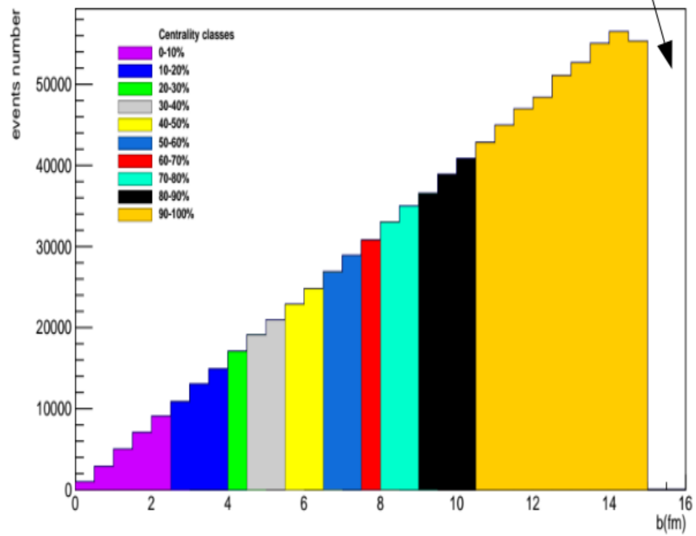


Class %	bi (fm)	bf (fm)
0-10	0	2.78
10-20	2.78	4.00
20-30	4.00	4.98
30-40	4.98	5.86
40-50	5.86	6.69
50-60	6.69	7.55
60-70	7.55	8.44
70-80	8.44	9.46
80-90	9.46	10.75
90-100	10.75	14.96

Simulation details

- Beam - target: Au-Au
- Generator: UrQMD v. 3.4
- Events: 1M mbias (0-16 fm)
- Energy: $\sqrt{s}$ = 11 GeV
- MPDROOT framework: BeBe

Loss of peripheral events with spectator protons



Event plane resolution

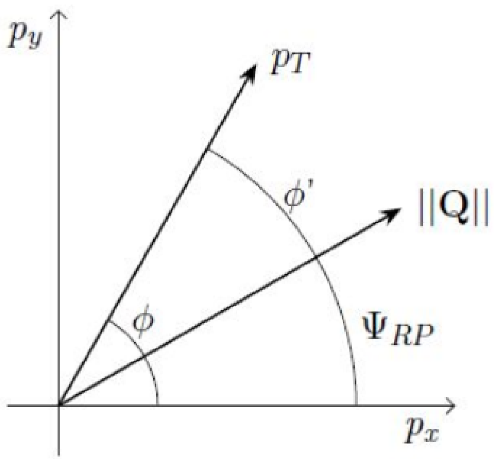
Motivation

distributions of produced particles and the spectator nucleons can be used to estimate the **collision geometry.**

Flow could be measured with the knowledge of the event plane resolution

The event-planes of this anisotropy **can be estimated via measured azimuthal distributions of particles produced in the collision**

Event plane resolution (with BeBe detector)



$$Q_{n,x} = \sum_i^N w_i \cos(n\phi_i) = \mathbf{Q}_n \cos(n\Psi_n)$$

$$Q_{n,y} = \sum_i^N w_i \sin(n\phi_i) = \mathbf{Q}_n \sin(n\Psi_n)$$

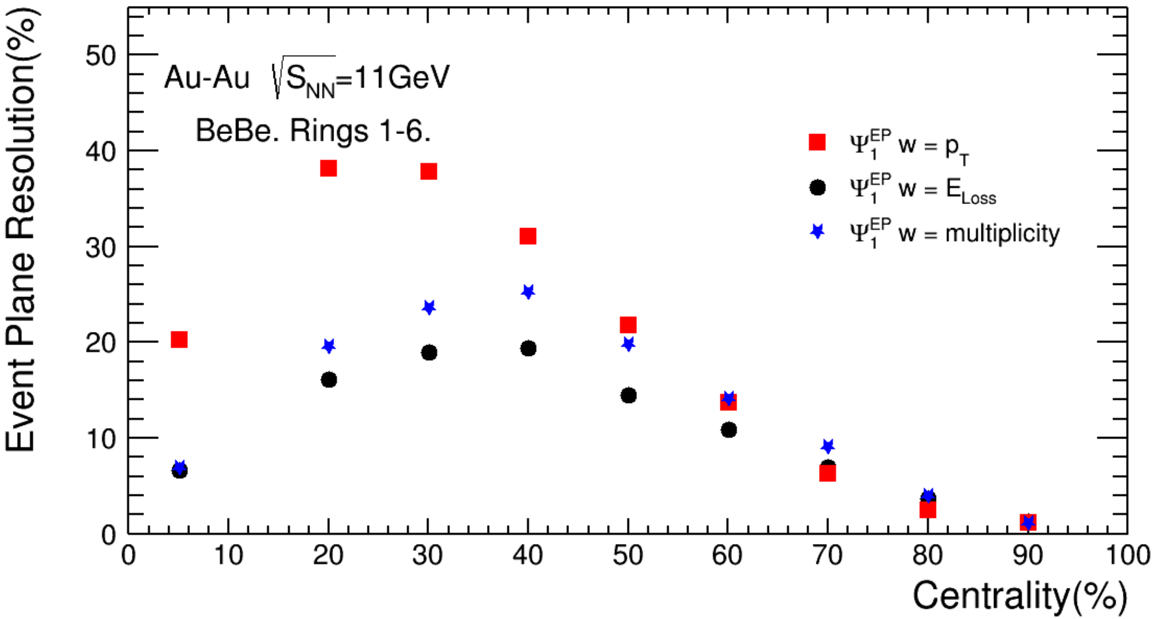
$$\frac{Q_{n,y}}{Q_{n,x}} = \frac{\sin(n\Psi_n)}{\cos(n\Psi_n)} \longrightarrow \Psi_n = \frac{1}{n}\tan^{-1}\left[\frac{Q_{n,y}}{Q_{n,x}}\right]$$

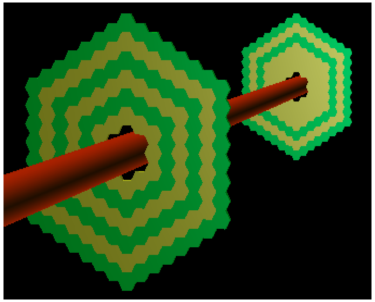
$$= \tan^{-1}\left[\frac{\sum_i^N w^i \sin(n\phi_i)}{\sum_i^N w^i \cos(n\phi_i)}\right]$$

$$R_1 = \langle\cos[\Psi_1 - \Psi_{RP}]\rangle$$

Event plane resolution for centrality range

Event plane resolution using BeBe detector



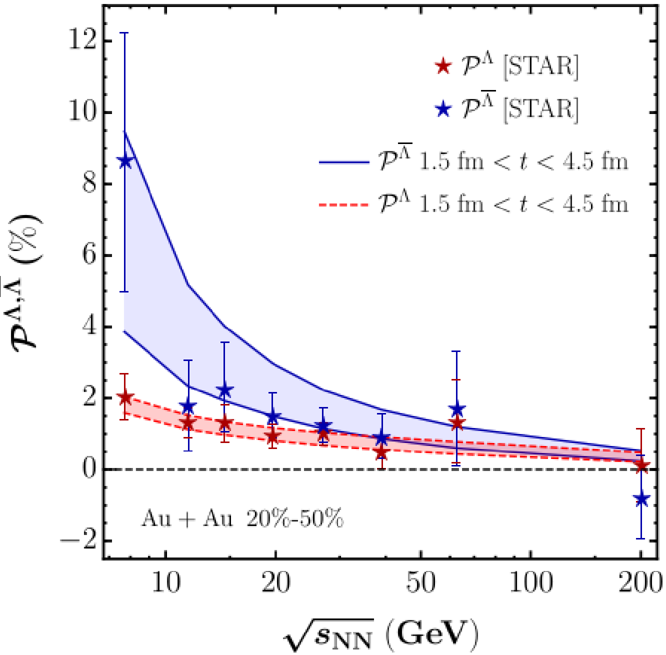


Located ~2m from the interaction point

Event plane resolution extracted with BeBe detector and calculated **using different weights: transverse momentum, energy loss, multiplicity.**

Studies of Λ hyperon

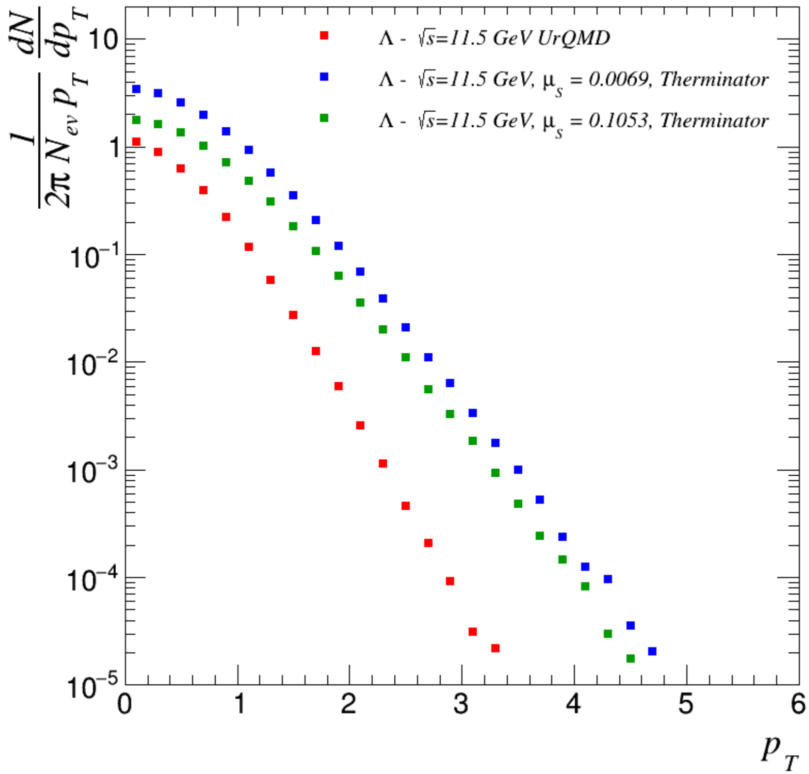
Motivation



when more Λ's than $\bar{\Lambda}$'s are produced in the corona, and this is combined with a smaller number of Λs coming from the core, as compared to those coming from the corona, an amplification effect for the $\bar{\Lambda}$ with respect to that of Λ polarization can occur. This amplification becomes more important for lower collision energies and quantitatively accounts for the Λ and Λ polarizations measured by the STAR beam energy scan.

arXiv:2003.13757 [hep-ph]

P_T from UrQMD vs Therminator at 11.5 GeV



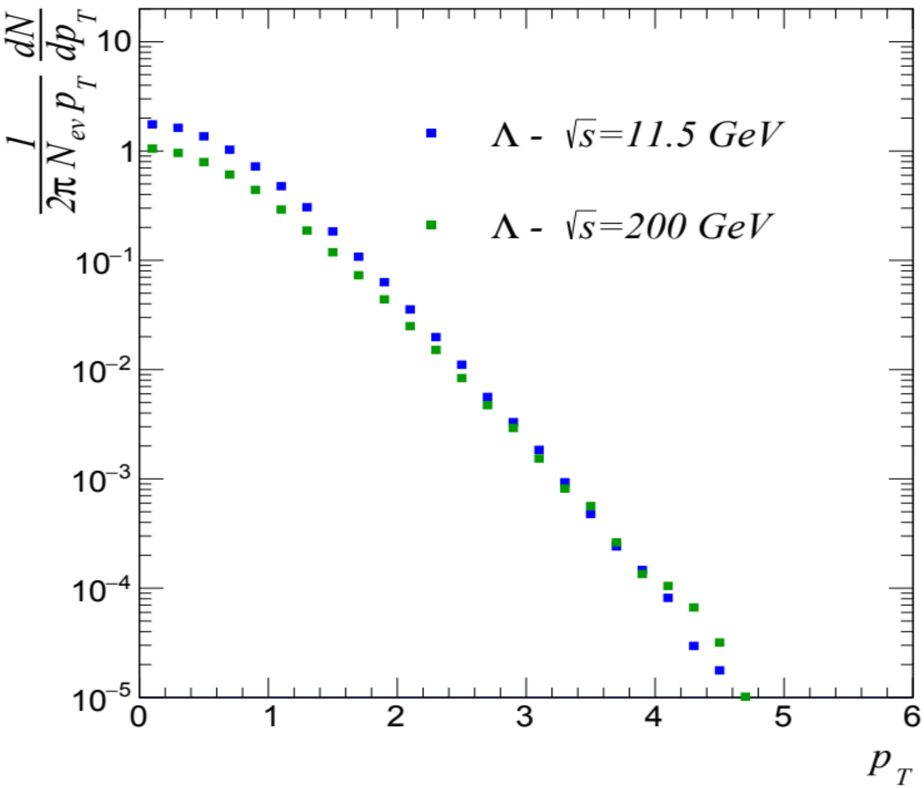
Changing μ_S, which is obtained from tables [1] or assuming $\mu_S = 1/3\ \mu_B$.

- The maximum increases when μ_S decreases, however this value should be determined by the condition of the overall strangeness neutrality and that the ratio of the electric to baryon charge density equals the initial ratio Z/A.
- The distribution obtained with UrQMD is different.

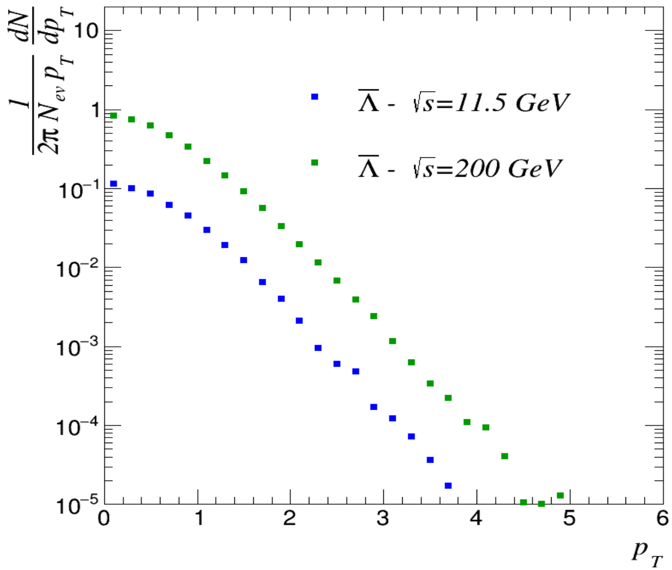
[1] Phys. Rev. C 96 (2017) 044904

Λ production at different energies

- Changing μ_B, and temperature T which are obtained from [2] according the energy of the collision and assuming the same μ_S .



- The yield decreases with energy for Λ and increases for $\overline{\Lambda}$.



[2] Eur. Phys. J 52 (2016) 218-219
Phys. Rev. C 74 (2006) 047901

Magnetic fields at RHIC and NICA energies

In the earliest moments after the collision, the system is subjected to what is expected to be the strongest magnetic field created in nature.

Develop a greater understanding of anomalous transport phenomena in heavy-ion collisions, like the Chiral Magnetic Effect (CME), ...

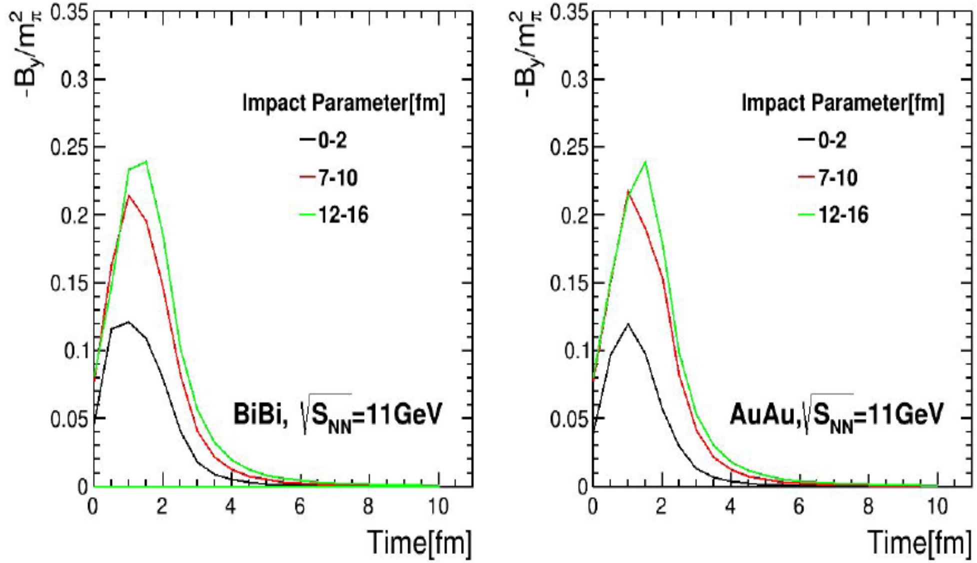
Magnetic Fields at NICA Energy

Lienard-Wiechert potential classically describes the electromagnetic fields of a moving charge distribution in terms of the vector (**A**) and scalar (Φ) potential.

$$\phi(\mathbf{r}, t) = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{R - \mathbf{R}\cdot\mathbf{v}(t)}\right]_{t=t_{ret}}$$

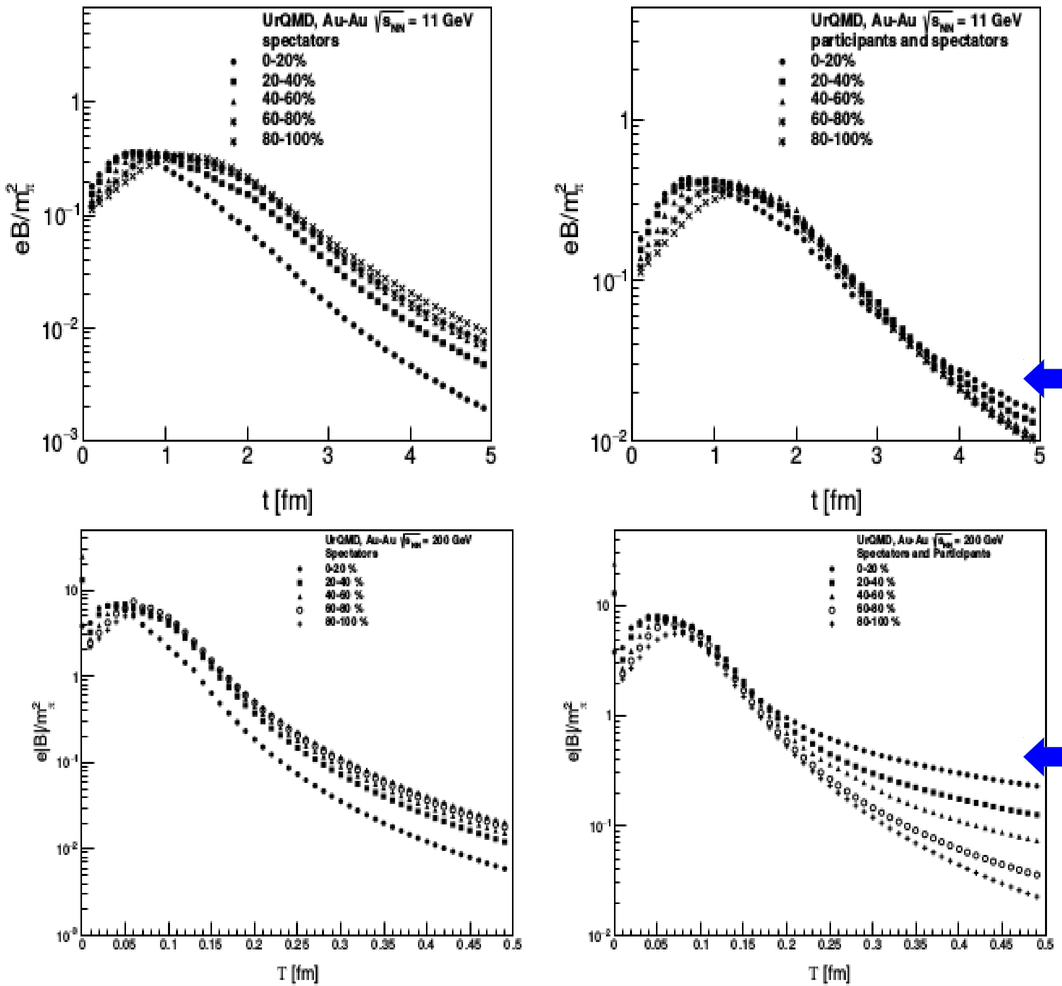
$$\mathbf{A}(\mathbf{r}, t) = \frac{\mu_0}{4\pi}\left[\frac{q\mathbf{v}(t)}{R - \mathbf{R}\cdot\mathbf{v}(t)}\right]_{t=t_{ret}}$$

$$t_{ret} = t - \frac{|\mathbf{r} - \mathbf{r}'|}{c} = t - \frac{|\mathbf{R}|}{c}$$



Magnetic fields on perpendicular direction to reaction plane, produced by spectator protons in Bi+Bi and Au+Au collisions at 11 GeV for 3 centrality ranges.

Magnetic Fields for Au+Au at 11 and 200 GeV



Mean magnetic field strength produced by spectators (left) and spectator+participants (right), for centrality bins.

Au+Au at 11 GeV

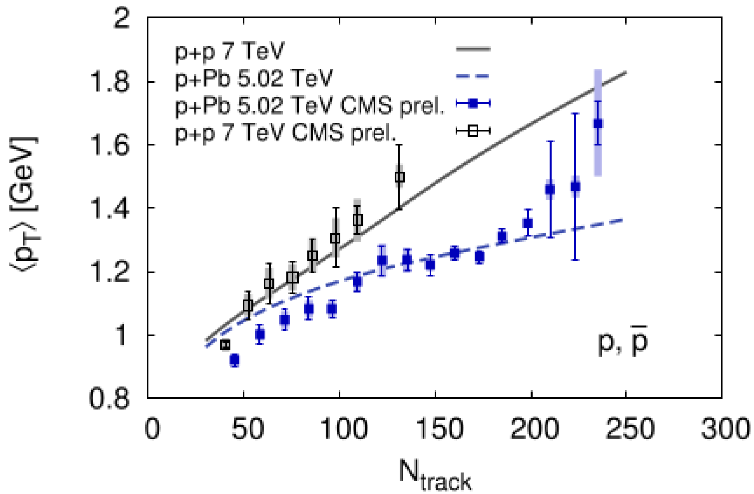
The intensity of B is higer for higher energy, but it reach its maximum in very short time.

Au+Au at 200 GeV

Average transverse momentum vs multiplicity

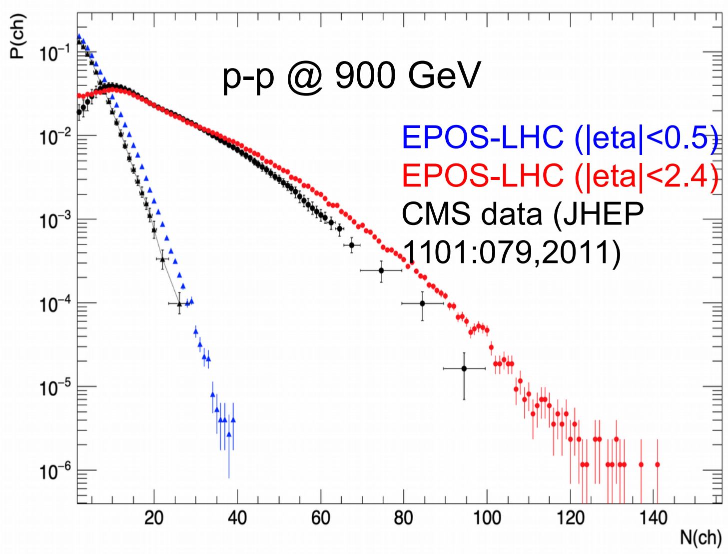
Motivation

The goal of the analysis is to investigate the average transverse momentum versus multiplicity. **There are discrepancies at low multiplicity between data and Color Glass Condensate which is attributed to flow effects.** We will investigate the flow effect with different event generators.

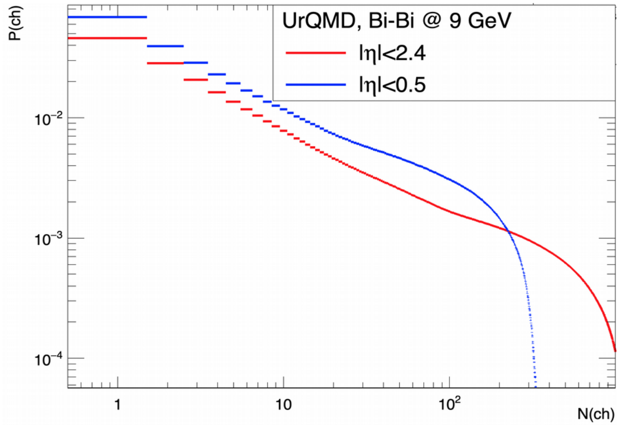


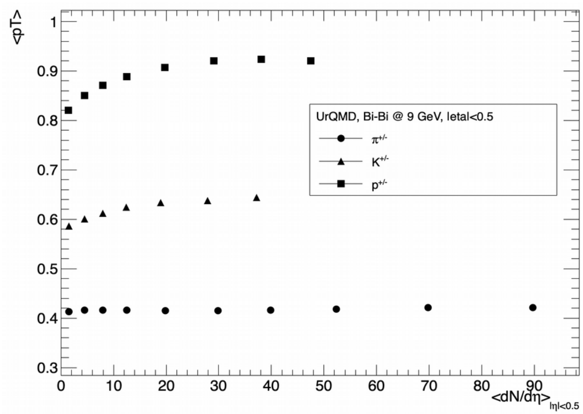
Multiplicity distributions with EPOS, Data and UrQMD

10^4 events with EPOS at 900 GeV.
It overestimates the charged particle multiplicity



UrQMD results at 9 GeV





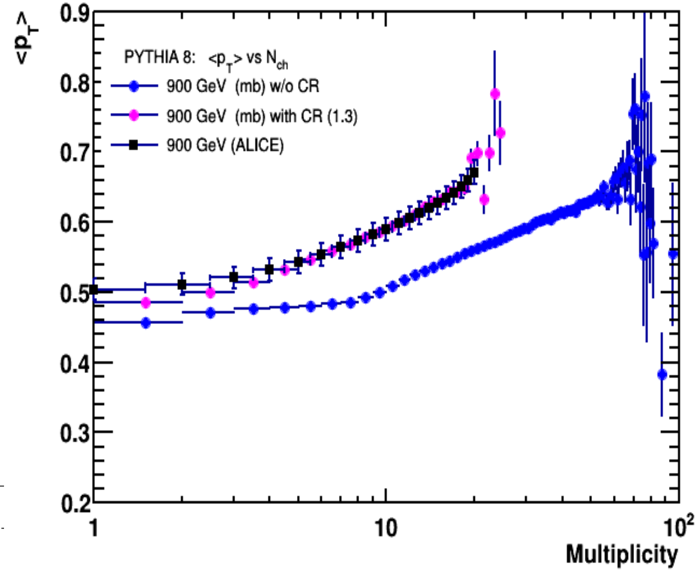
- Similar results for higher energies
- Other event generators produce disagreement with data

PYTHIA Average transverse momentum vs ALICE data

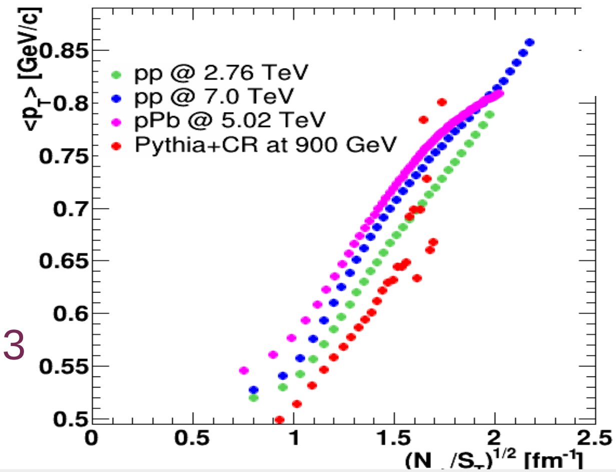
PYTHIA version 8.235
Soft QCD p+p at 900 GeV; 5 millions of events

Color reconnection produces flow-like effects and allow to explain ALICE $\langle p_T \rangle$ vs N_{ch}.
Phys. Rev. Lett. 111, 042001, 2013

We would like to study different event generators (EPOS, UrQMD) including hydrodynamic flow.



PLB727, 371, 2013



According to CGC model $\langle p_T \rangle$ seems to scale with transverse collision (S_T).

Conclusion

MexNICA group is working on different topics related to global observables by simulating BeBe detector (all the analyses are just beginning):

- Determination of centrality classes
- Pseudorapidiy distribution
- Event plane resolution

The group is also working on phenomenological topics like:

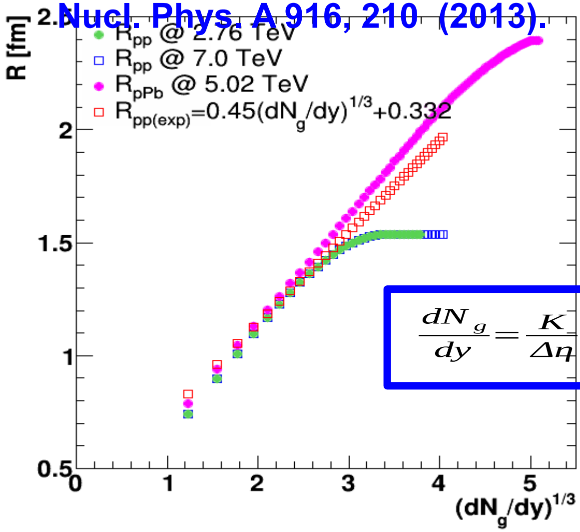
- Magnetic fields in heavy ion collisions
- Flow effects on average transverse momentum

MexNICA group working at PWG1:
Dario Chaires, Maria Elena Tejeda, Luis Valenzuela, Isabel Domínguez, Alejandro Guirado, Oleg, Ivonne Maldonado, Pedro Nieto, Isabel Dominguez, Valeria Reyna, Mario Rodriguez, Eleazar Cuautle

Backup

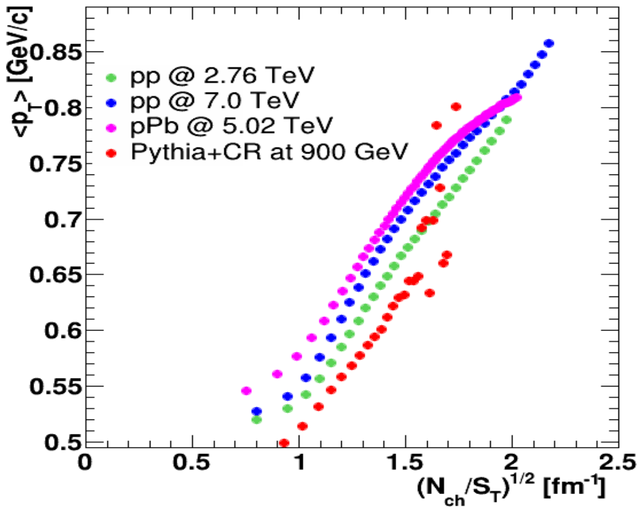
$\langle p_T \rangle$ vs multiplicity scaled to transverse area ($S_T = \pi R^2$) in pp, pPb collisions

Nucl. Phys. A 916, 210 (2013).



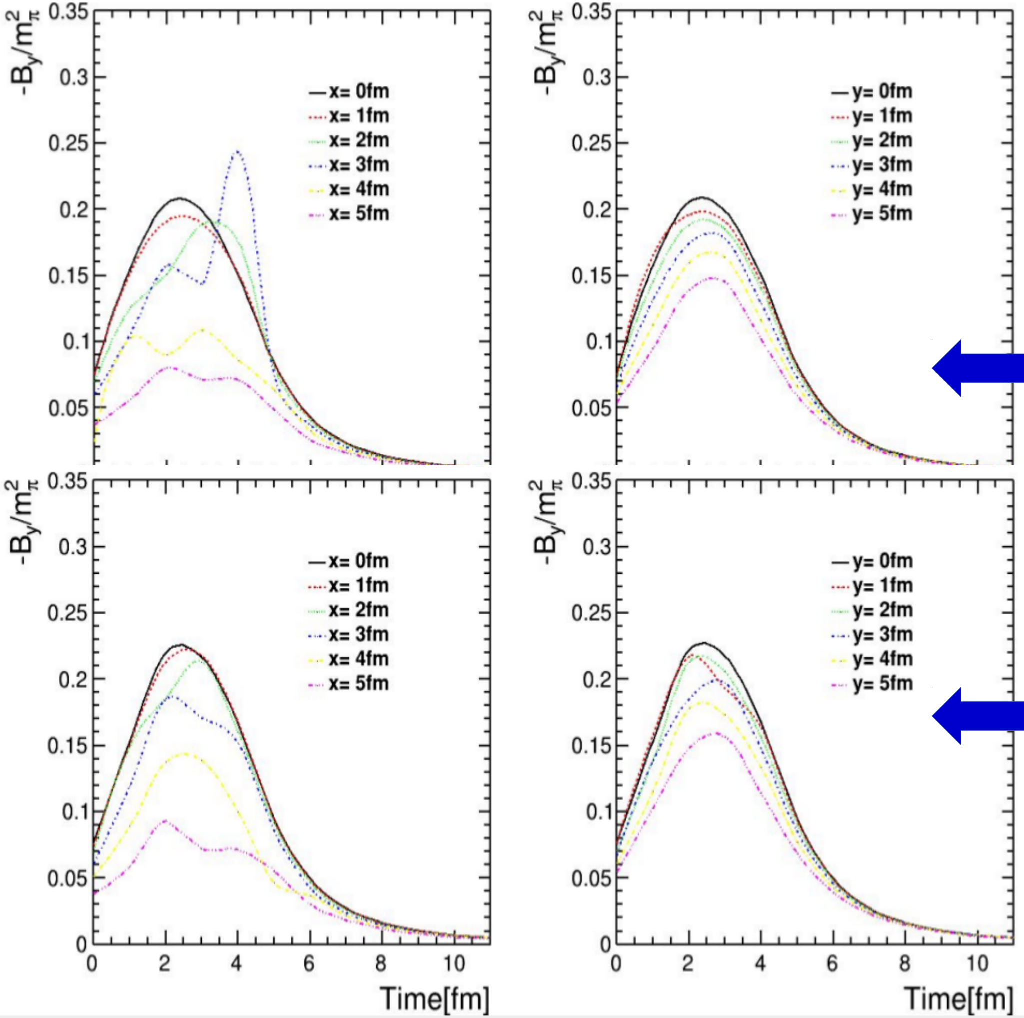
$$\frac{dN_g}{dy} = \frac{K}{\Delta\eta} \times \frac{3}{2}\left(\frac{dN}{d\eta}\right)^{1/3}$$

Our calculation with ALICE data



According to CGC model $\langle p_T \rangle$ seems to scale with transverse collision (S_T). At low multiplicity, flow effects could be relevant and should be investigated. Analyses are being done with ALICE data (PLB727, 371, 2013).

Magnetic Fields for Au+Au and Bi+Bi at 11 GeV



Magnetic field perpendicular to the reaction plane for different position values (x,y), produced by the proton spectator:

Au+Au collision at 11 GeV and impact parameter (0-16) fm

Bi+Bi collision at 11 GeV and impact parameter (0-16) fm

Transvere area ($S_T = \pi R^2$) in pp, pPb collisions

Our calculation with ALICE data

Nucl. Phys. A 916, 210 (2013).
CMS data

$$\frac{dN_g}{dy} = \frac{K}{\Delta\eta} \times \frac{3}{2}\left(\frac{dN}{d\eta}\right)^{1/3}$$

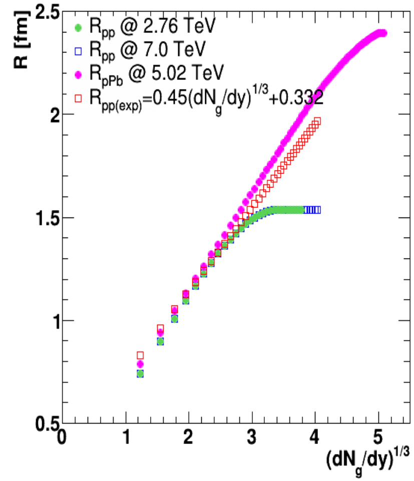
$$R_{\mathrm{pPb}} = 1\ \mathrm{fm} \times f_{\mathrm{pPb}}\left(\sqrt[3]{dN_g/dy}\right)$$

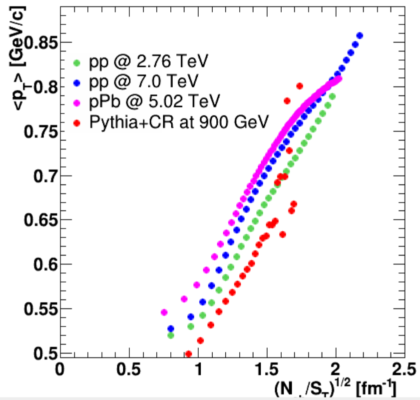
with

$$f_{\mathrm{pPb}}(x) = \begin{cases} 0.21 + 0.47x & \text{if } x < 3.5, \\ 1.184 - 0.483x + 0.305x^2 - 0.032x^3 & \text{if } 3.5 \leqslant x < 5, \\ 2.394 & \text{if } x \geqslant 5. \end{cases}$$

$$x = \left(\frac{dN_g}{dy}\right)^{1/3}$$

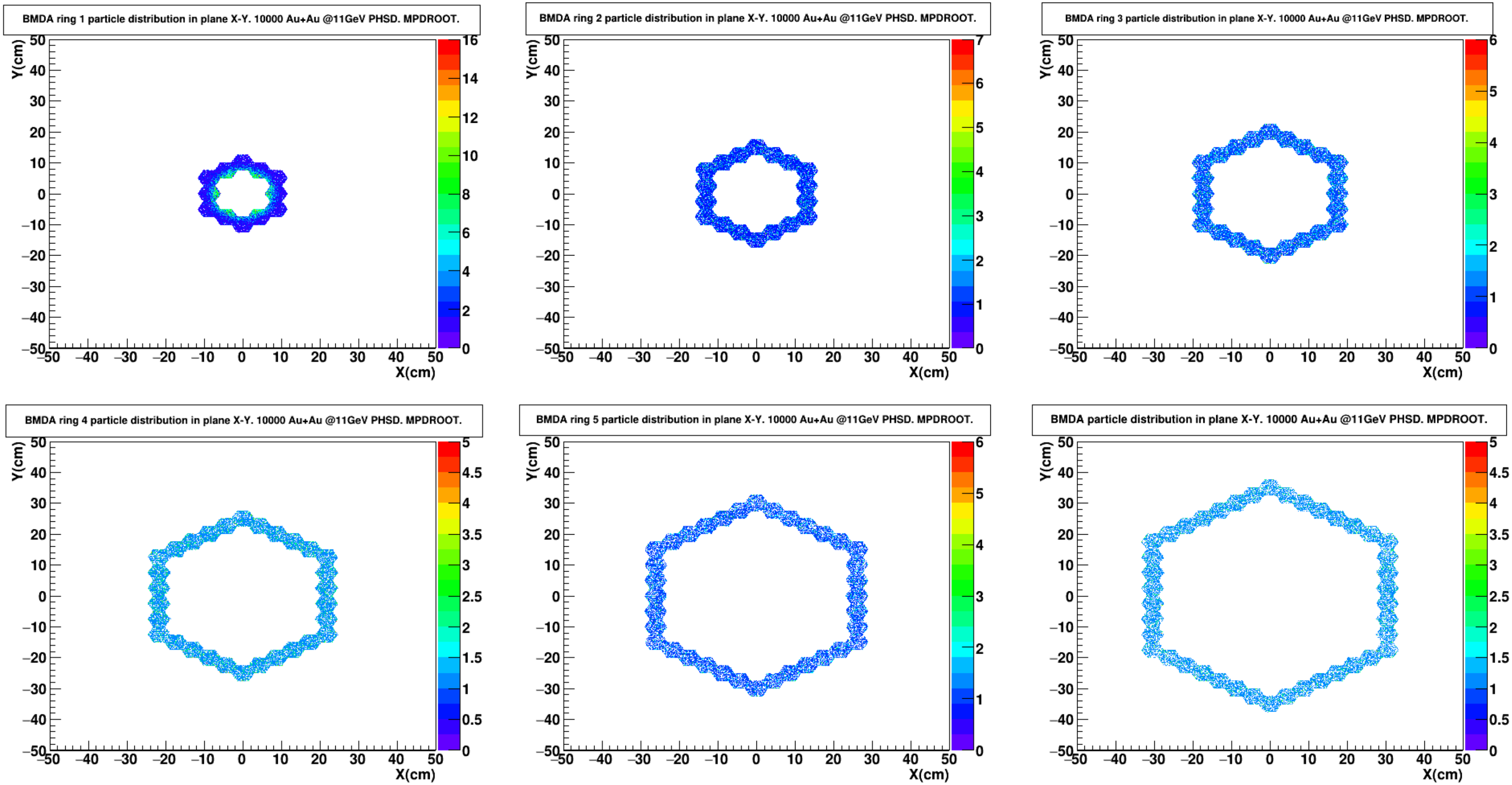
$$f_{\mathrm{pp}}(x) = \begin{cases} 0.387 + 0.0335x + 0.274x^2 - 0.0542x^3 & \text{if } x < 3.4, \\ 1.538 & \text{if } x \geqslant 3.4. \end{cases}$$





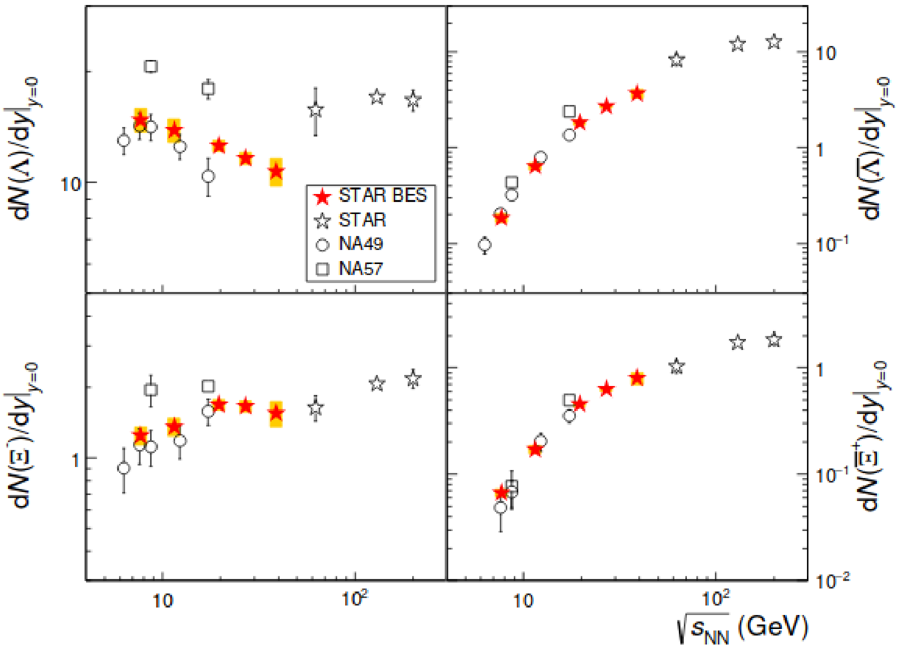
According to CGC model $<p_T>$ seems to scale with transverse collision (S_T). At low multiplicity, flow effects could be relevant and should be investigated. Analyses are

Hits distribution for each ring of BeBe detector



Studies of Λ hyperon at STAR BES

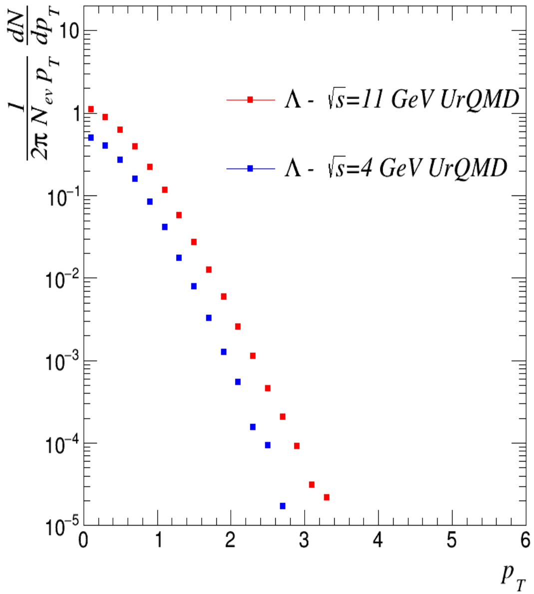
- The yield decreases with energy for Λ and increases for $\bar{\Lambda}$ which is consistent with experimental data [3] shown by BES-STAR at RHIC.



[3] ArXiv: 1906.03732 [nucl-ex]

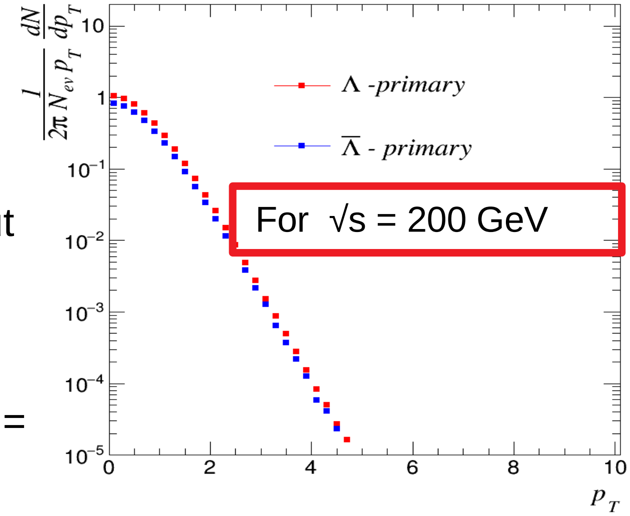
Study of hyperons: Production of Λ at different event generators and energies

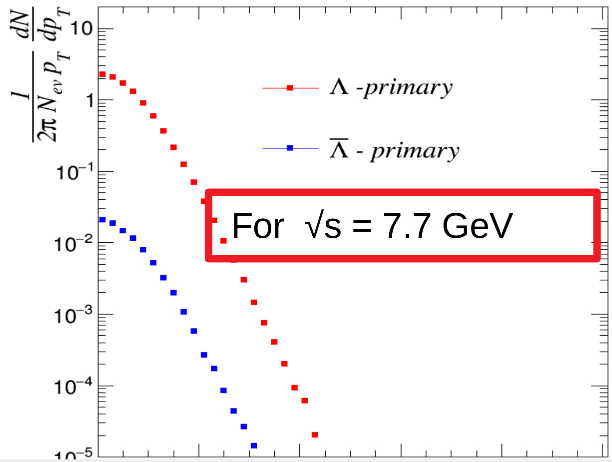
UrQMD input parameters:
4 and 11 GV



Therminator Input parameters:

- Events = 1×10^5
- FreezeOutModel = SingleFreezeOut
- τ = 9.74
- ρ_{Max} = 7.74

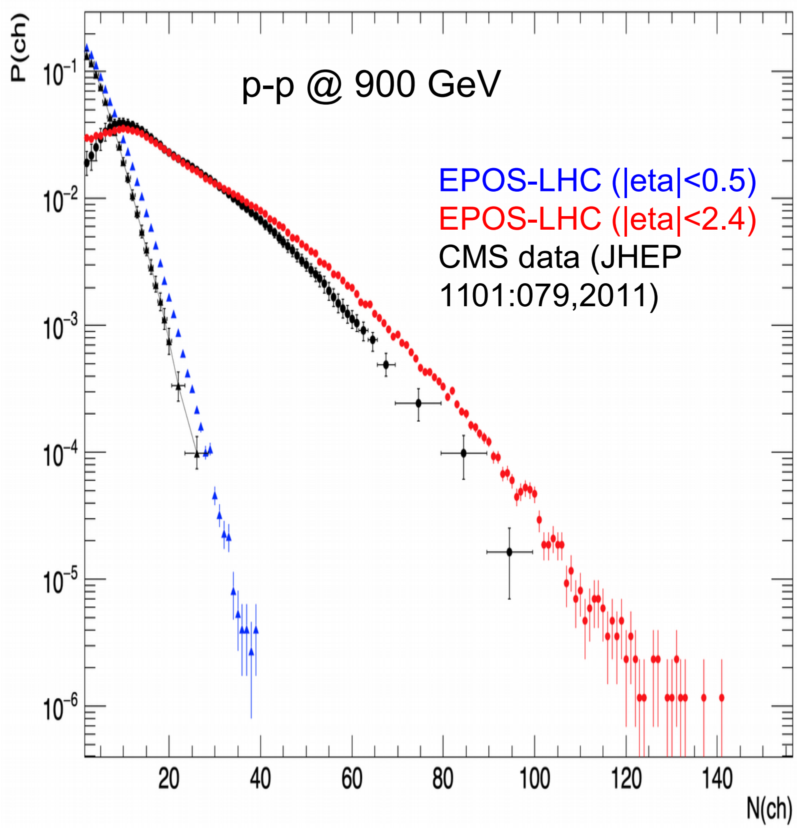


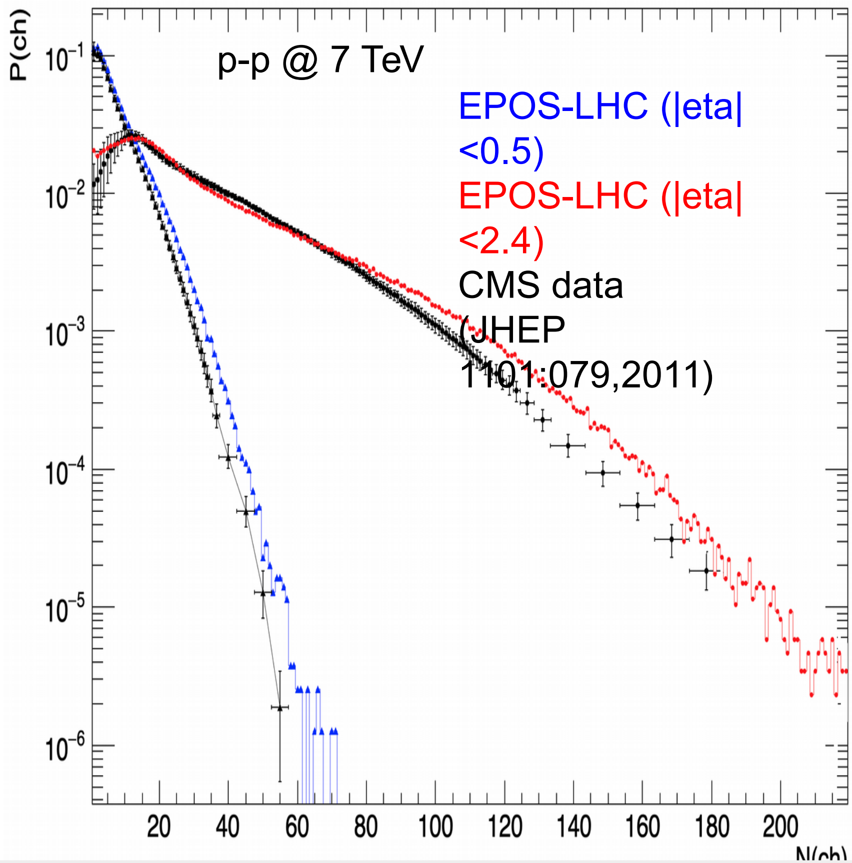


Λ production helps to understand production of strangeness, as well as polarization and spin alignment among

Multiplicity distribution with EPOS versus CMS data

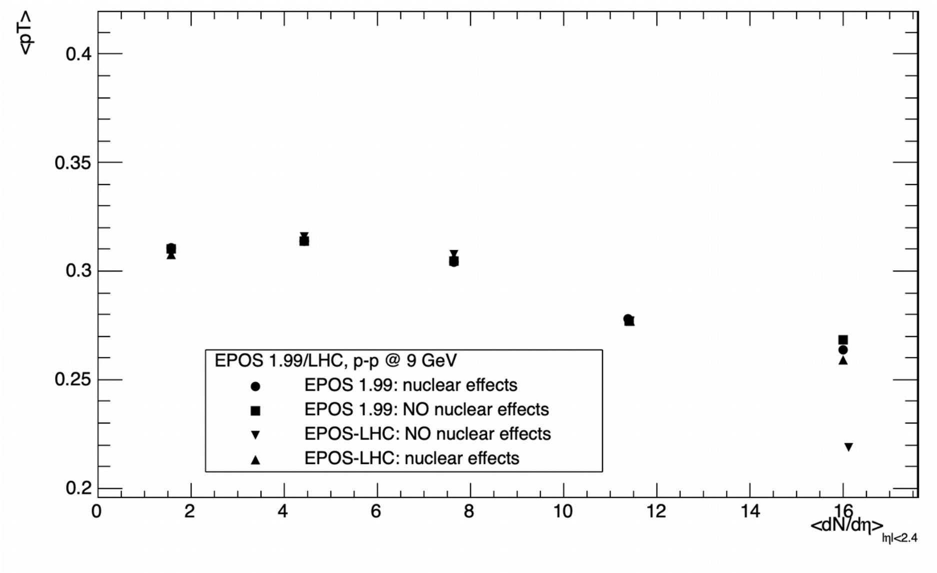
10^4 events with EPOS. It overestimates the charged particle multiplicity



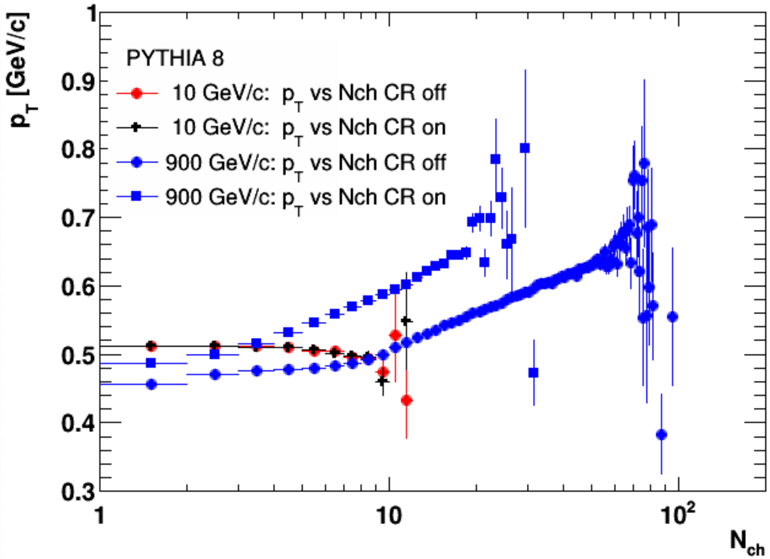


Average transverse momentum at NICA energy (on pp collisions)

EPOS LHC



PYTHIA 8



Particle identification with TPC of MPD

Identification of charged particles through deposition energy in the TPC.

After reconstruction 100 Au+Au events generated with UrQMD at 11 GeV.

Interesting to test alternative algorithms to identify particles.