Study of the MPD detector performance in pp collisions at NICA

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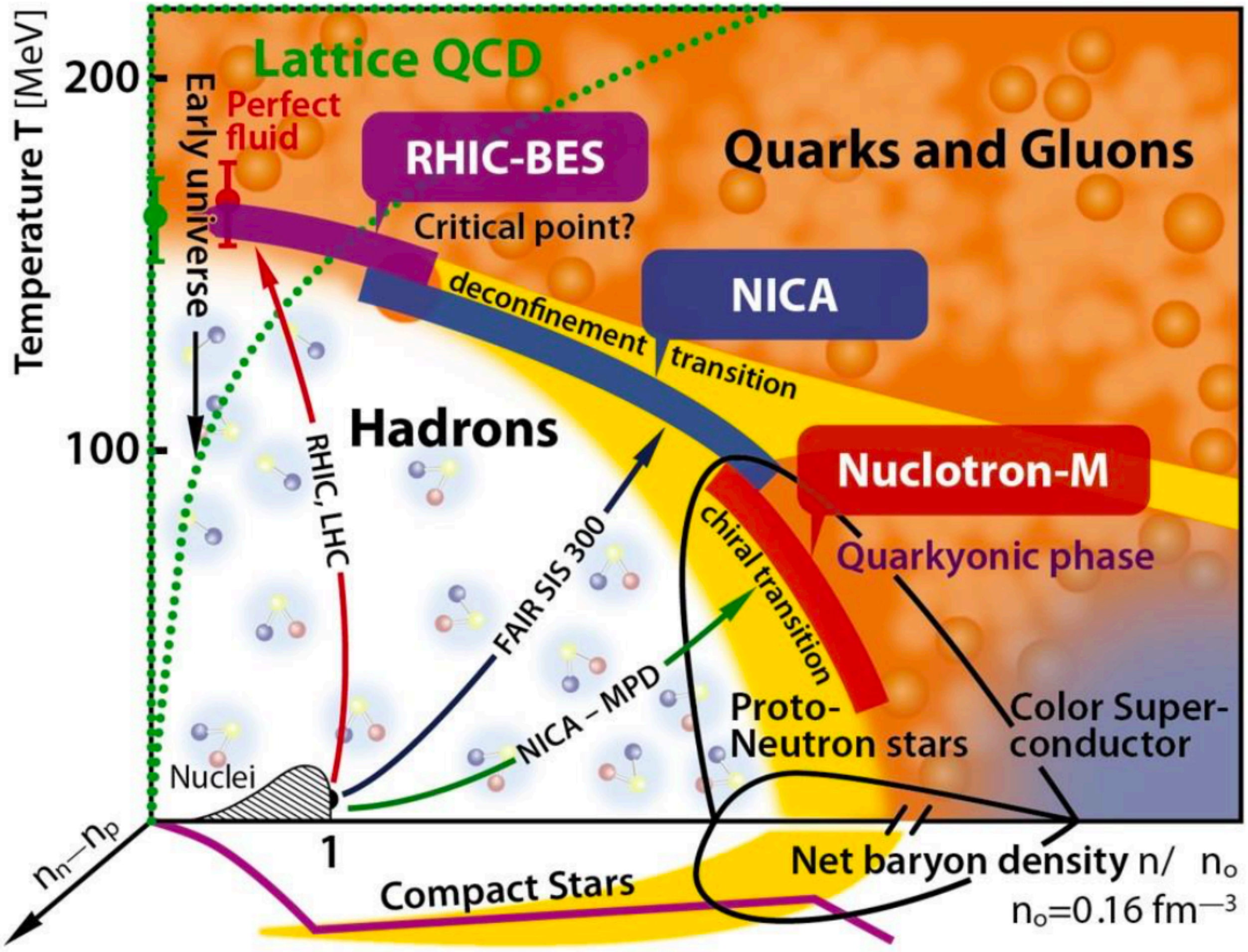
Introduction

Phase diagram of strongly interacting matter



The physics goals that are pursued in NICA will be complementary to the experimental program at CERN(LHC), RHIC(BES) and FAIR(CBM):

NICA MPD: Moderate temperature and much higher net baryon density in a mixed phase. Points to in-medium modification effects as signals of chiral symmetry restoration and phase transition.

Introduction

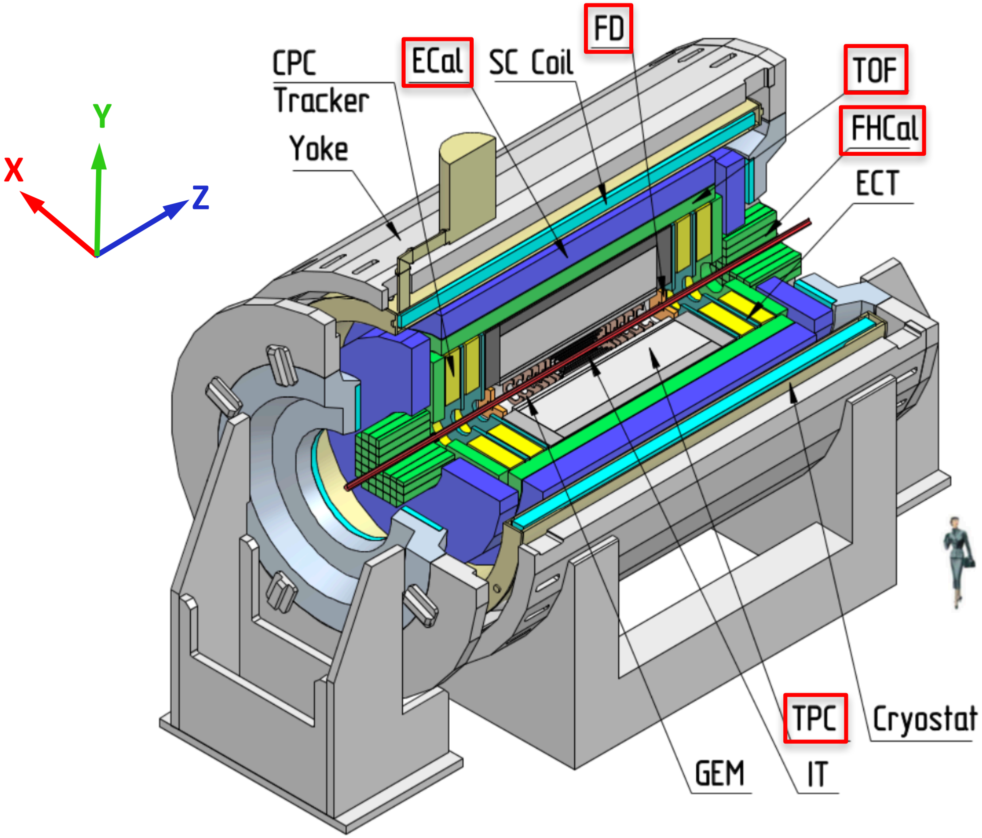
pp collisions

Basic measurements in p + p collisions are required:

- Reference data from light collision systems are needed for a complete picture of heavy ion collisions.
- Some signatures of in-medium modification effects reveal themselves though comparison of heavy-ion and p + p collisions, with appropriate scaling for the volumes.
- Better understanding of p + p collisions is just essential.

Multipurpose Detector (MPD)

MPD: designed to accomplish a wide range of tasks of the NICA physics program.
Provide collisions in a wide range of atomic mass: A = 1 – 197.
High-precision tracking and particle identification in the full space-phase under a high multiplicity environment is expected.



Maximum centre-of-mass energy	Average luminosity
$\sqrt{s_{NN}}$ = 11 GeV (Au^{79+})	L = 10^{27} $cm^{-2}s^{-1}$
$\sqrt{s_{NN}}$ = 20 GeV (p)	L = 10^{32} $cm^{-2}s^{-1}$

Stage I: barrel part (- 2020)

TPC:

- $\eta < |2.0|$
- Momentum resolution for charge particles < 3% at $0.1 < p_T < 1$ GeV/c
- Two track resolution ≈ 1 cm

TOF:

- $\eta < |1.4|$
- Large space-phase coverage.
- High granularity

p + p event simulation

Event generation
(HSD model)

MC transport
(*G3 - MpdRoot*)

Reconstruction
(*MpdRoot:*
CF - KF)

PHSD model (in **HSD** mode) was used to generate events
HSD mode => without partonic QGP phase.
High energy inelastic hadron – hadron collision in HSD is described by FRITIOF string model (including PYTHIA). The description of *p+p* reactions is almost equivalent to the Lund String model.

- 50000 events
- Point-like source
- Only primary tracks*
- Analyzed TPC Kalman Tracks also identified in TOF
- The reconstructed tracks are associated with the primary MC particle that ‘caused’ the reconstructed track.
- Number of Hits > 20

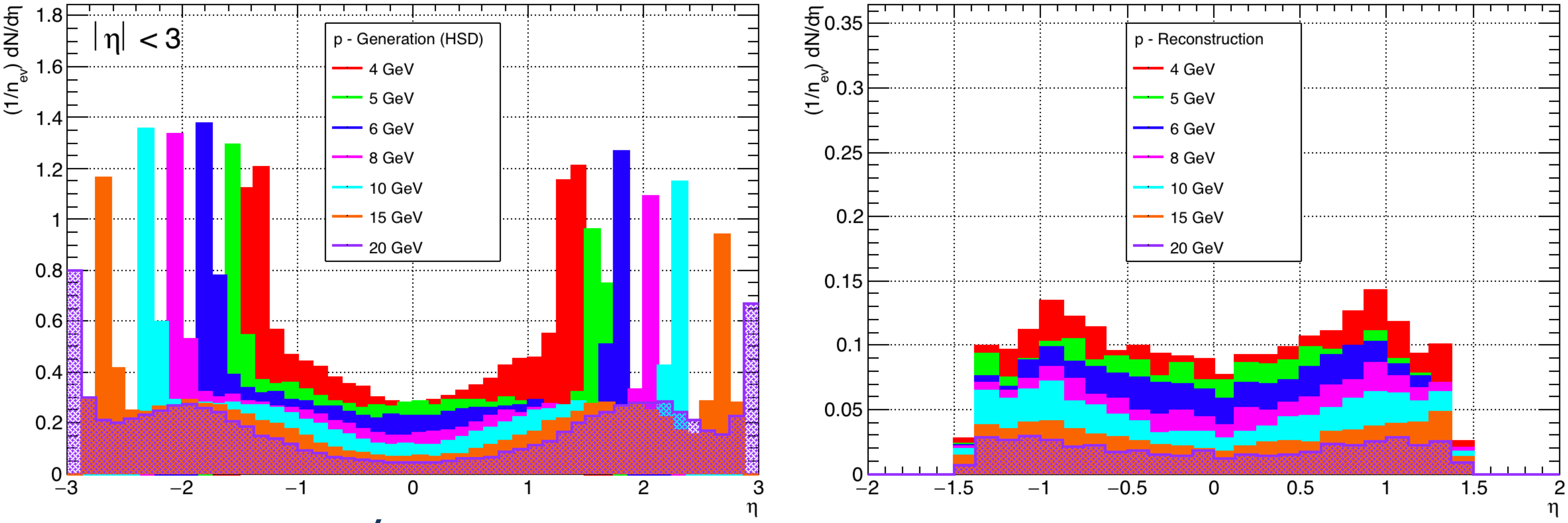
* **Primary particles** are defined as prompt particles produced in the collision including products of strong and electromagnetic decays, as well as weak decay of charmed and beauty particles except feed-down products from strange and other secondary particles.

Analysis

Protons from pp collisions

Generation (HSD)

Reconstruction (MPRRoot)



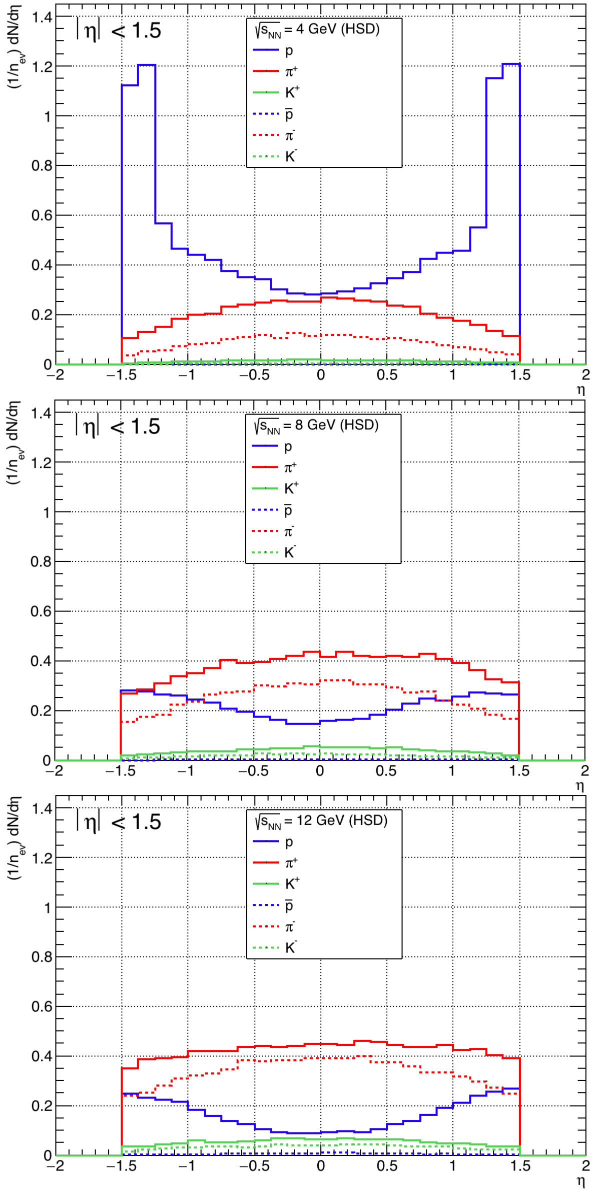
Increasing collision energy:

- pseudorapidity range of produced protons is enlarged
- proton multiplicity decreases

Analysis of reconstructed particles is constrained by the TOF identification $\Rightarrow |\eta| < 1.5$

Pseudorapidity distributions

Generation (HSD)

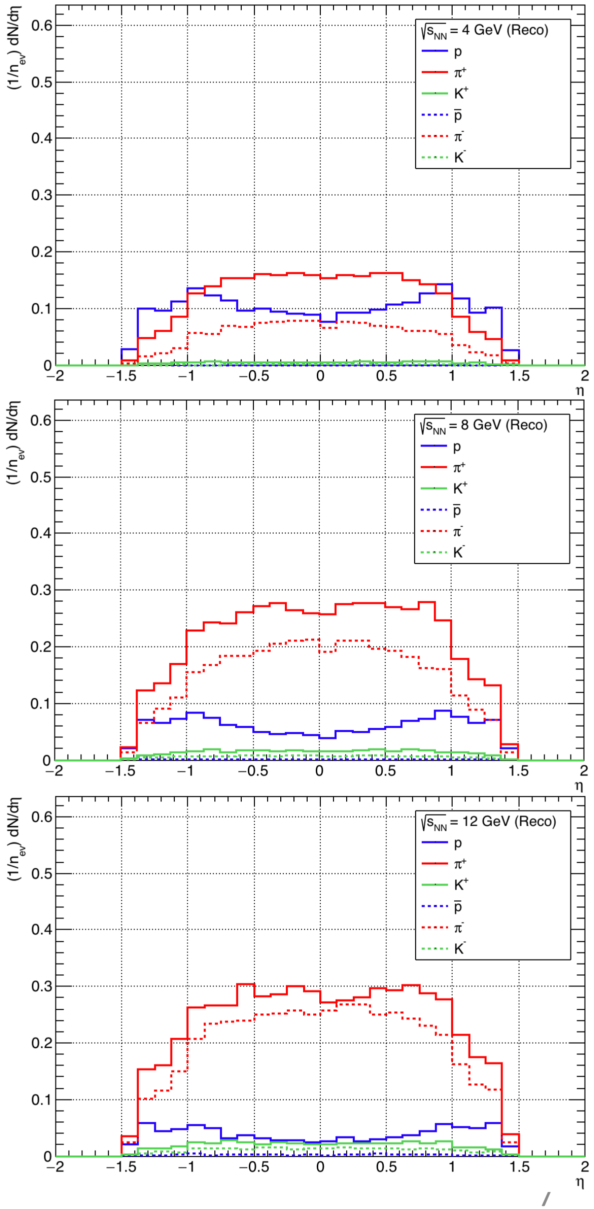


For $\sqrt{s_{NN}}$ = 4 GeV , the HSD model predicts a larger production of protons over π in all η range.

In the reconstruction this happens at large $|\eta|>1$.

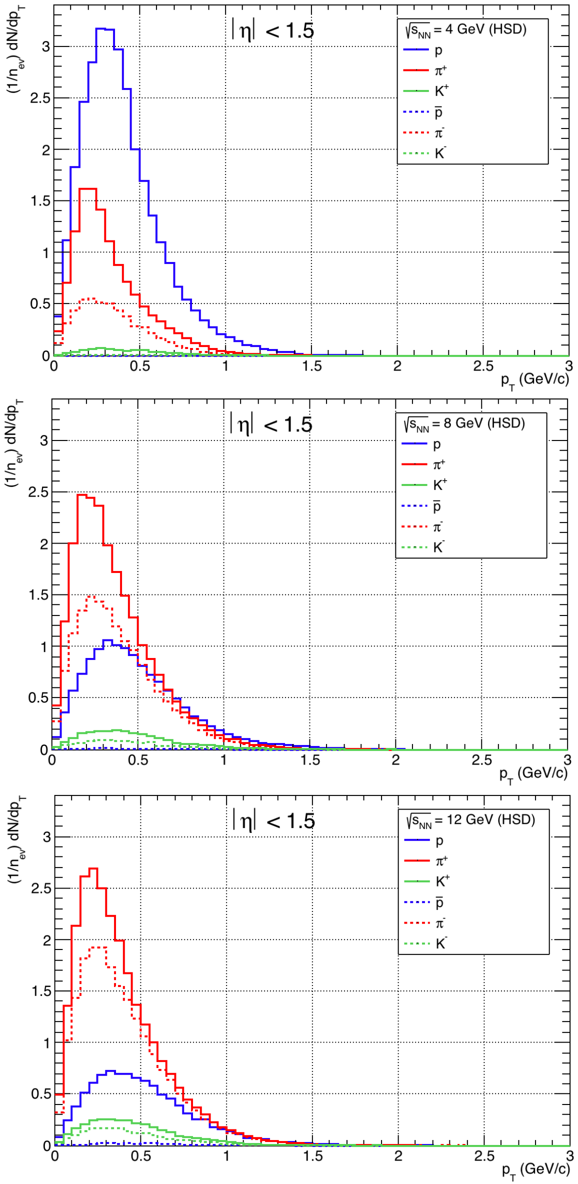
Both, model and reconstruction, show an enhanced production of pions over protons with the increasing collision energy.

Reconstruction (MPRRoot)

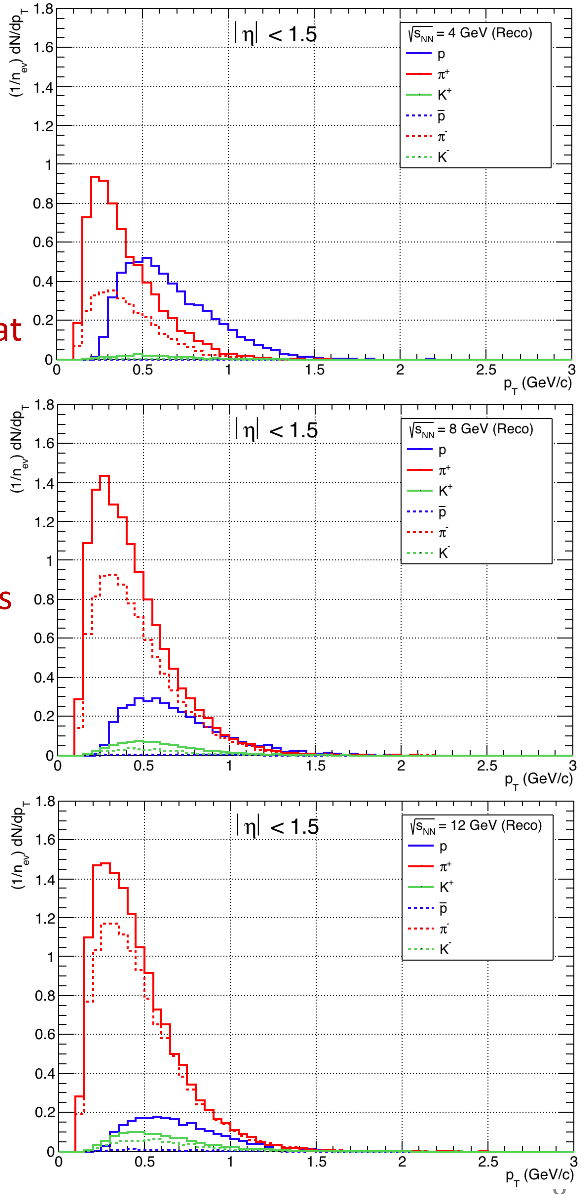


p_T distributions

Generation (HSD)



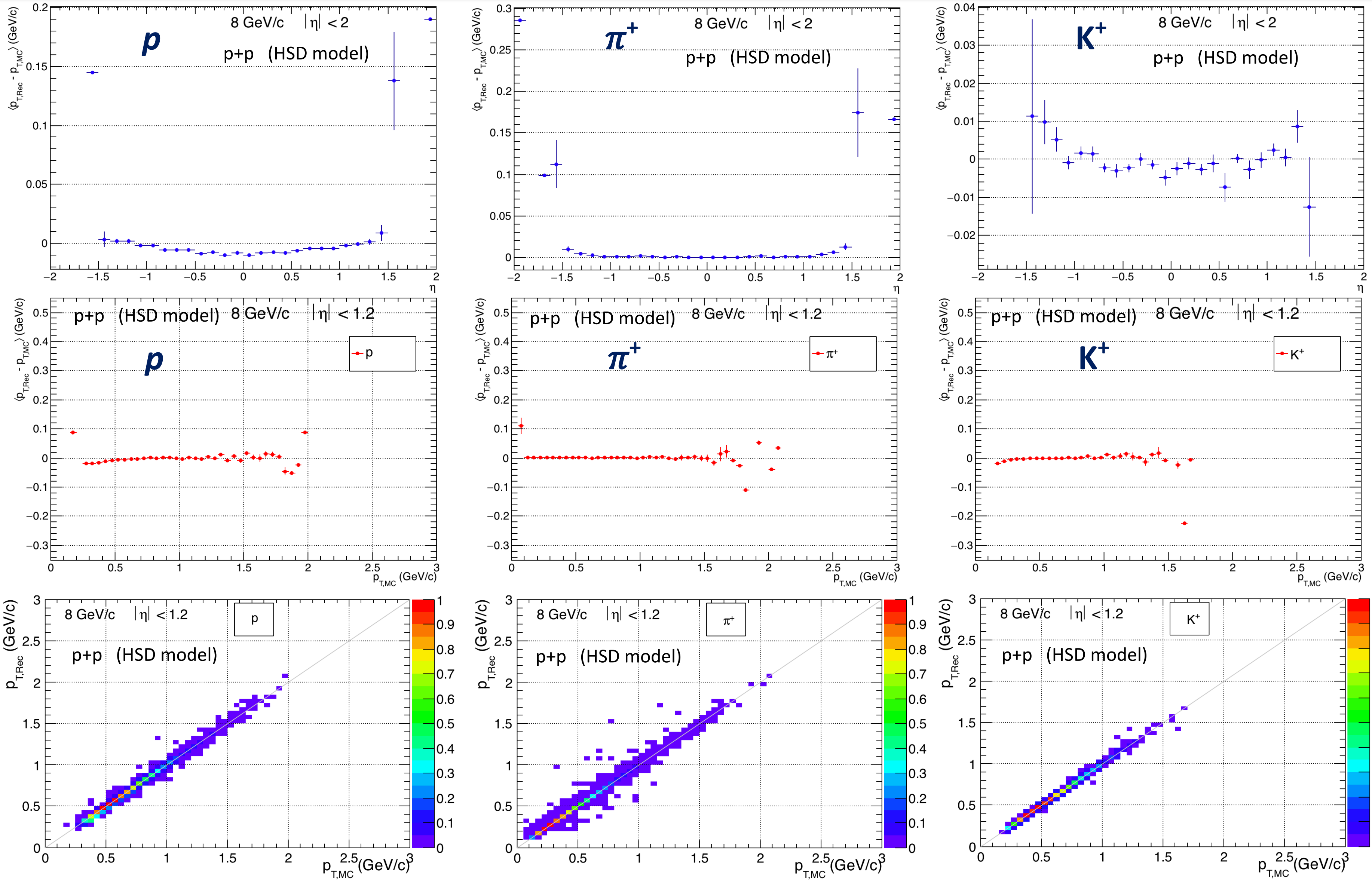
Reconstruction (MPRRoot)



For $\sqrt{s_{NN}}$ = 4 GeV , the HSD model predicts a larger production of protons over π^+ at all p_T range. In the reconstruction this happens at $p_T > 0.5$ GeV/c.

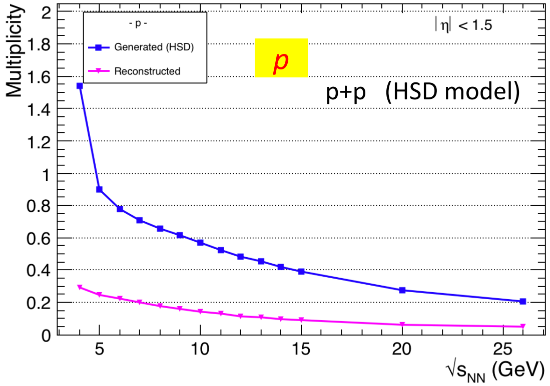
Both, model and reconstruction, show that $p_{T,\text{ pion}}$ distributions peaks at values lower than $p_{T,\text{ proton}}$. The pion and kaon production from p+p increases with the increasing collision energy while protons diminishes

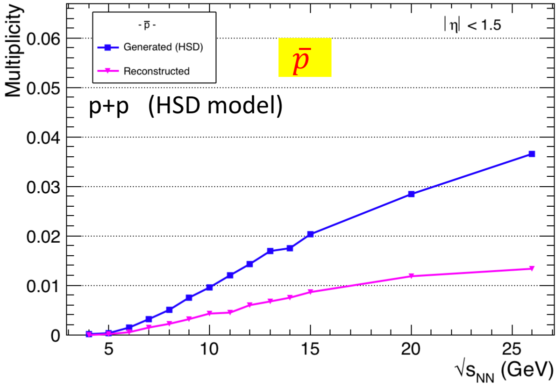
MC *vs.* Reconstruction



TProfile plots display the mean value $\langle p_{T,rec} - p_{T,MC} \rangle$ for each bin.

Multiplicity

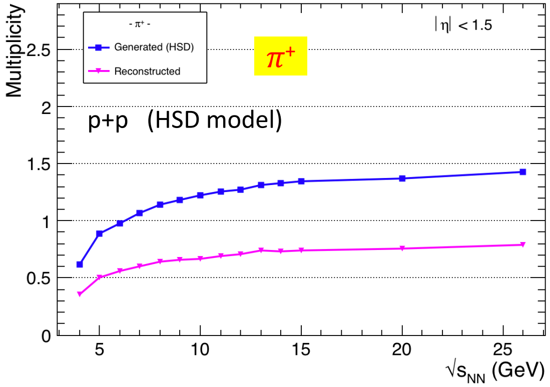


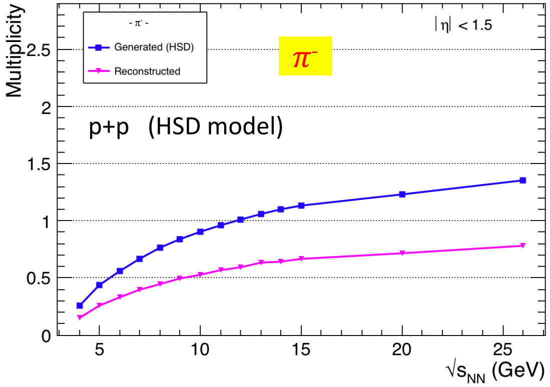


Multiplicity *vs.* $\sqrt{s_{NN}}$

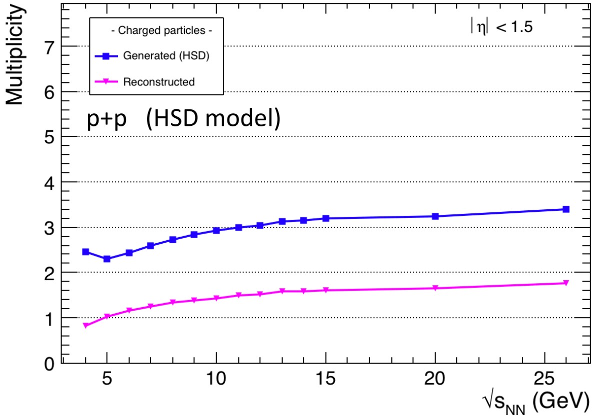
Obtained from $|\eta|$ and p_{T} density distributions:

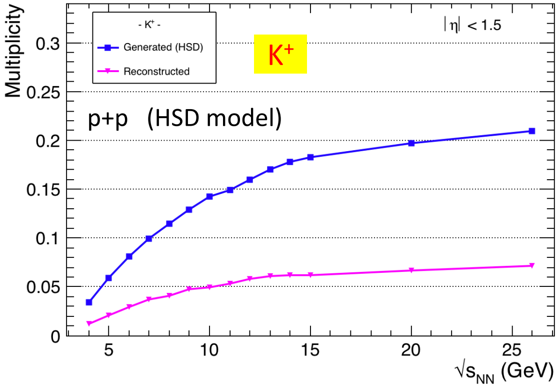
- Model
- Reconstruction

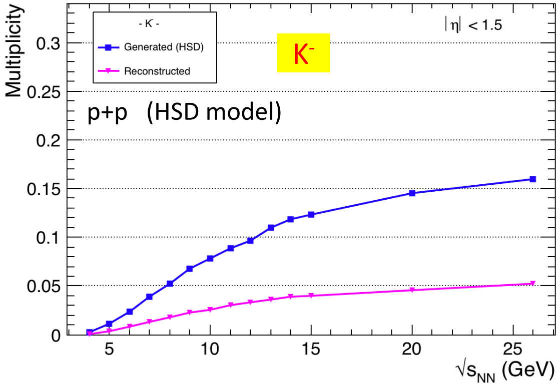




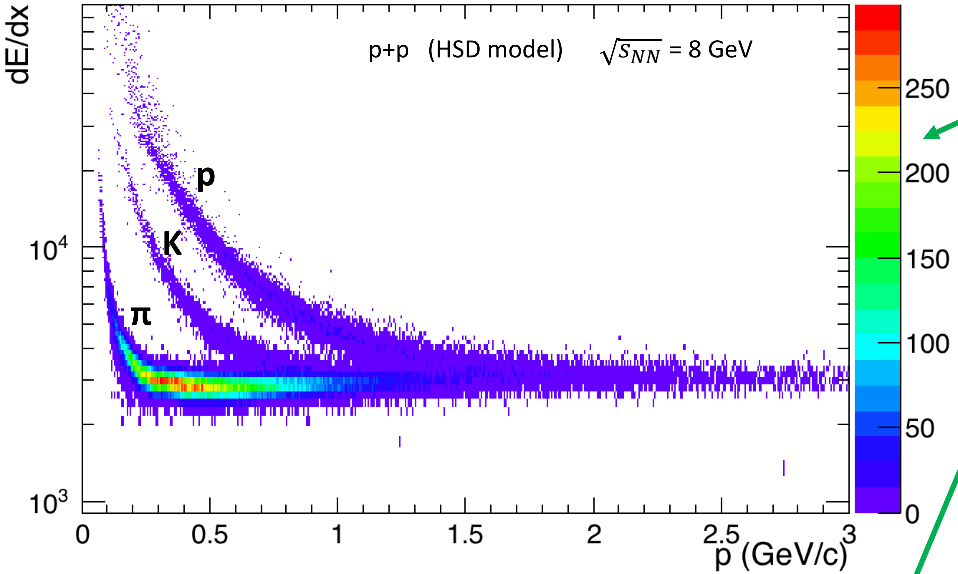
Charged particles
p , $\bar{p}$, π^+ , π^- , K^+ , K^-







PID

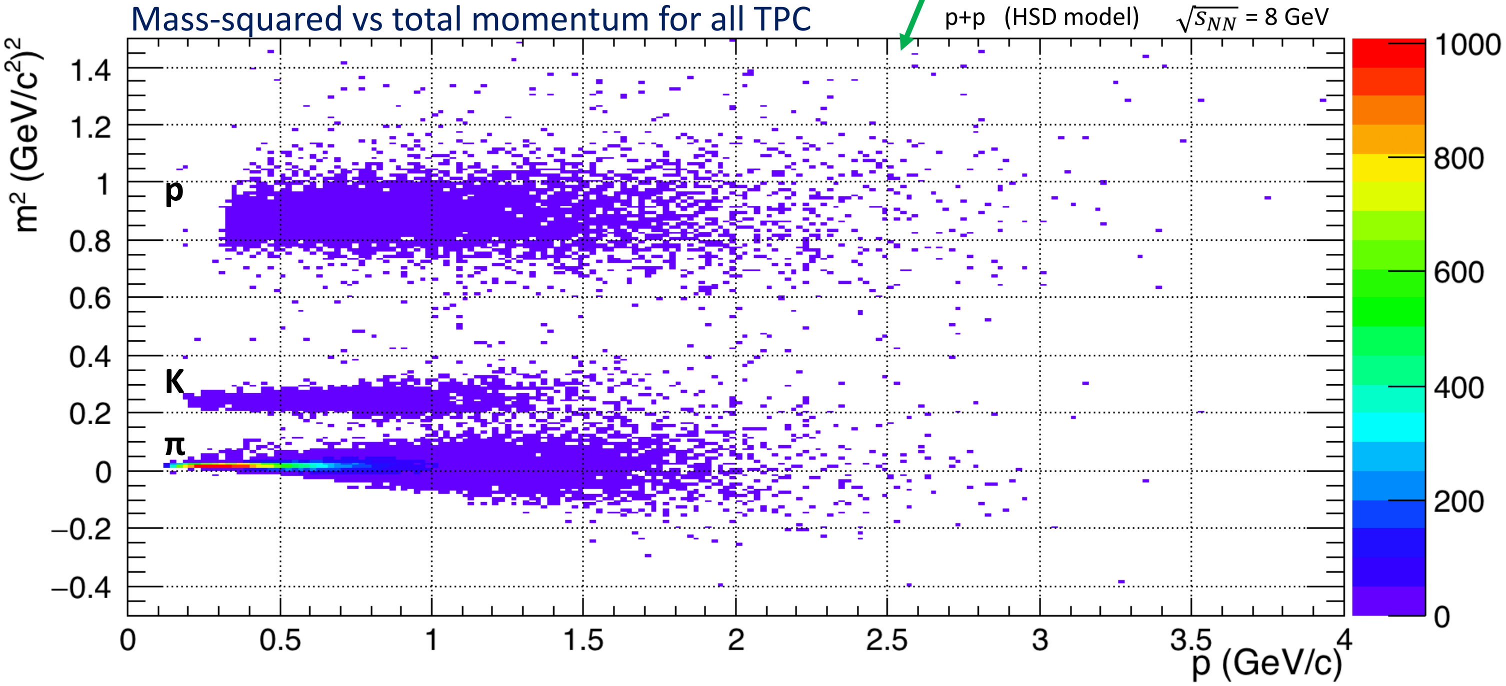


Hadrons and light nuclei can be identified using the dE/dx information from TPC:
Specific energy loss dE/dx ← truncated mean of charges of the TPC hits assigned to the track.

Mass separation capability of TOF is based on the reconstructed momentum, track length and time-of-flight from collision vertex to TOF hit.

MPD PID performance is considerably enhanced using the combination of TOF + TPC ⇒ must be able to identify charge hadrons in a broad rapidity range up to a total momentum of 3 GeV/c.

Mass-squared vs total momentum for all TPC

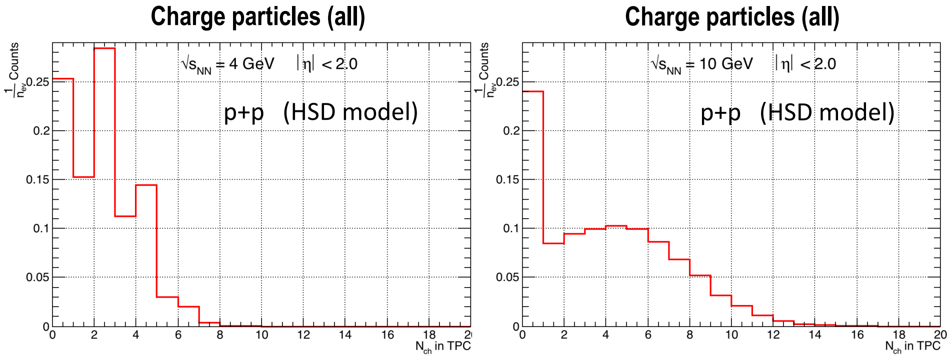


Good separation:

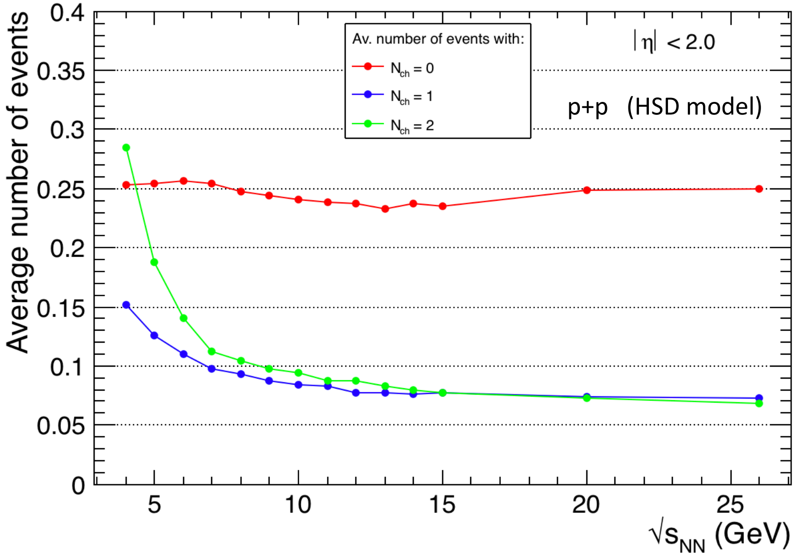
- π/K up to 1.5 GeV/c
- K/p up to 3 GeV/c

Occupancy of TPC

<Events> vs. # of charge tracks reconstructed in TPC



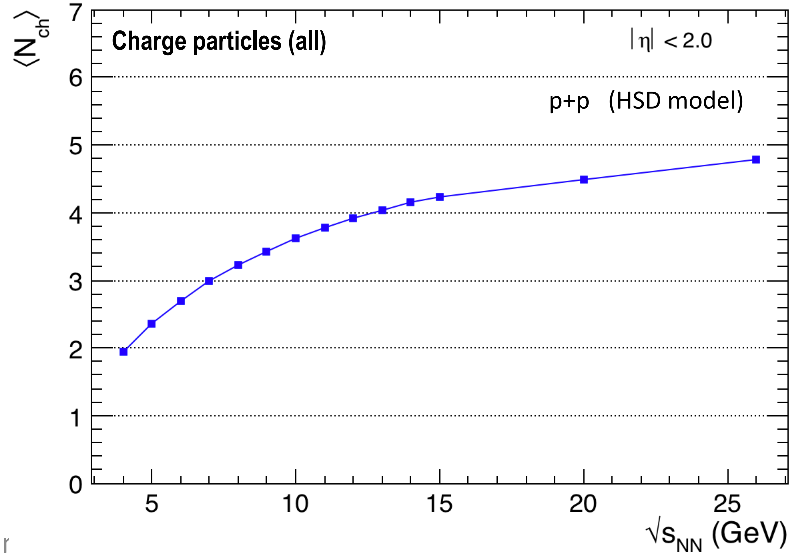
<Events> with charge track multiplicity = 0, 1, 2 in TPC *vs* $\sqrt{s_{NN}}$



- ➢ The average number of reconstructed tracks $\langle N_{ch} \rangle$ in TPC, from pp collisions, increases with $\sqrt{s_{NN}}$.
- ➢ $\langle N_{ch} \rangle = N_{ch}/ev \approx 1.8 - 5$ for $\sqrt{s_{NN}} = 4 - 26$ GeV
- ➢ The number of events with $N_{ch} = 0$ does not depend of the collision energy. $N_{ch} = 0$ in 25 % of events.
- ➢ The average number of events with 1 or 2 charge tracks reconstructed in TPC decreases with $\sqrt{s_{NN}}$, from 28% to 10% in the range $\sqrt{s_{NN}} \approx 4 - 10$.

The resolution of primary vertex reconstruction might get degraded for very low multiplicities.

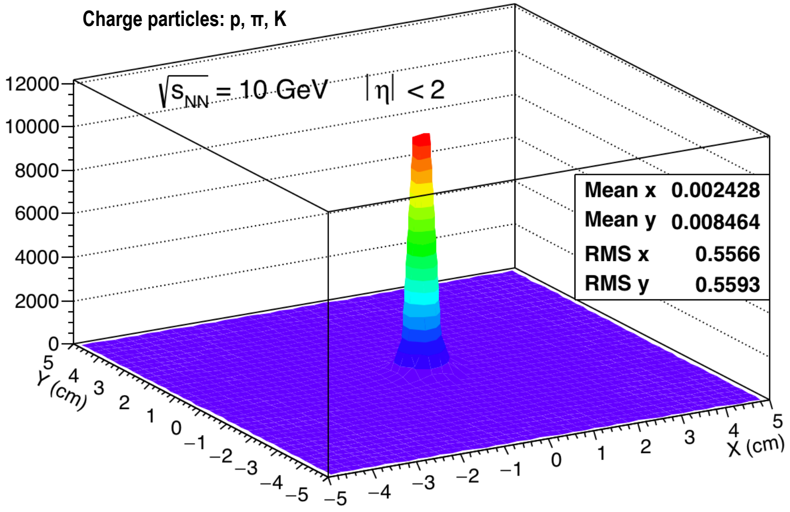
Average reconstructed multiplicity in TPC *vs* $\sqrt{s_{NN}}$



Primary Vertex

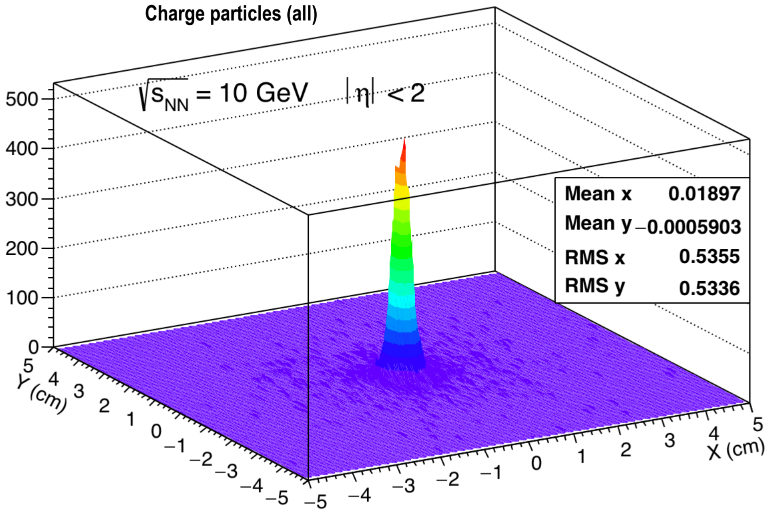
XY distribution (all tracks in TPC)

Charge particles: p + π + K

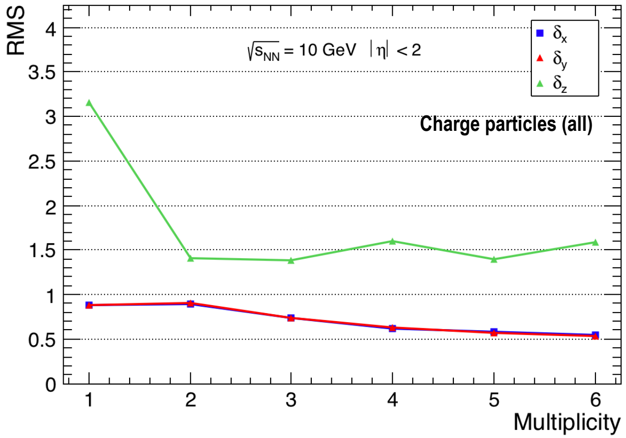


XY distribution (Ntrk $\leq$ 6 in TPC)

All charge particles!



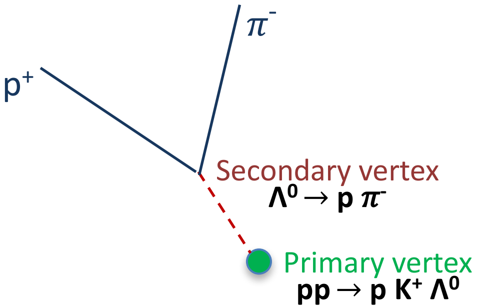
RMS of the primary vertex reconstruction perpendicular ($\delta_x\delta_y$) and along (δ_z) the beam direction for a primary track multiplicity in TPC ($1 \leq$ Ntrk $\leq$ 6).



Corrections for reconstruction effects due to acceptance, vertex reconstruction efficiency and tracking efficiency should be defined.

Events with low multiplicities in TPC ($\leq$ 3) might be compromised.

Neutral Lambda Baryon


p^+

π^-

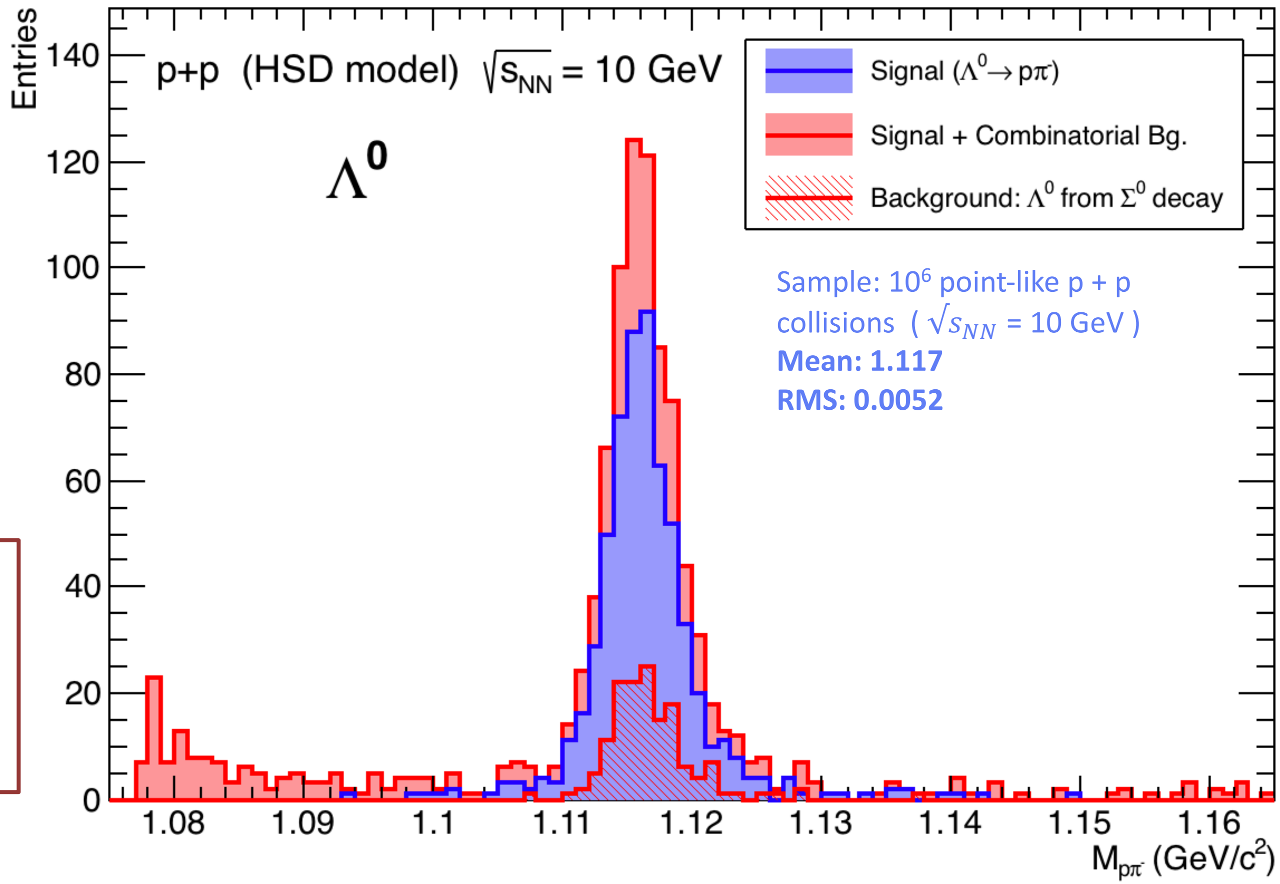
Secondary vertex
$\Lambda^0 \to p\,\pi^-$

Primary vertex
$pp \to p\,K^+\,\Lambda^0$

$m_{\Lambda^0} = 1116$ MeV

There is a weak combinatorial background due to the low multiplicity from p + p collisions.

Invariant mass spectrum of (p , π^-) pair



Sample: 10^6 point-like p + p collisions ($\sqrt{s_{NN}}$ = 10 GeV)
Mean: 1.117
RMS: 0.0052

Reconstruction of strange hyperons from p + p collisions in the MPD detector is possible by combining charged tracks reconstructed in the TPC.

Summary

- The performance studies of MPD, in its first stage, include the simulations of p+p collisions to estimate the feasibility of TPC as the main tracking detector for event reconstruction.

- Simulations indicates that the pseudorapidity and p_T density distributions as well as the multiplicity of charge hadrons from p+p collisions can be measured in MPD at collision energies $\sqrt{s_{NN}}$ = 4 – 20 GeV. Still fine-tuning of the analysis is required.

- Charge tracks from p+p collisions can be efficiently identified and separated. MPD PID performance is considerably enhanced using the combination TPC+TOF.

- Primary and secondary vertex identification in MpdRoot allows to detect Λ^0 baryon. A p+p collision system has the advantage of a weak p,π^- combinatorial background. However the low multiplicity of charge particles is a challenge.