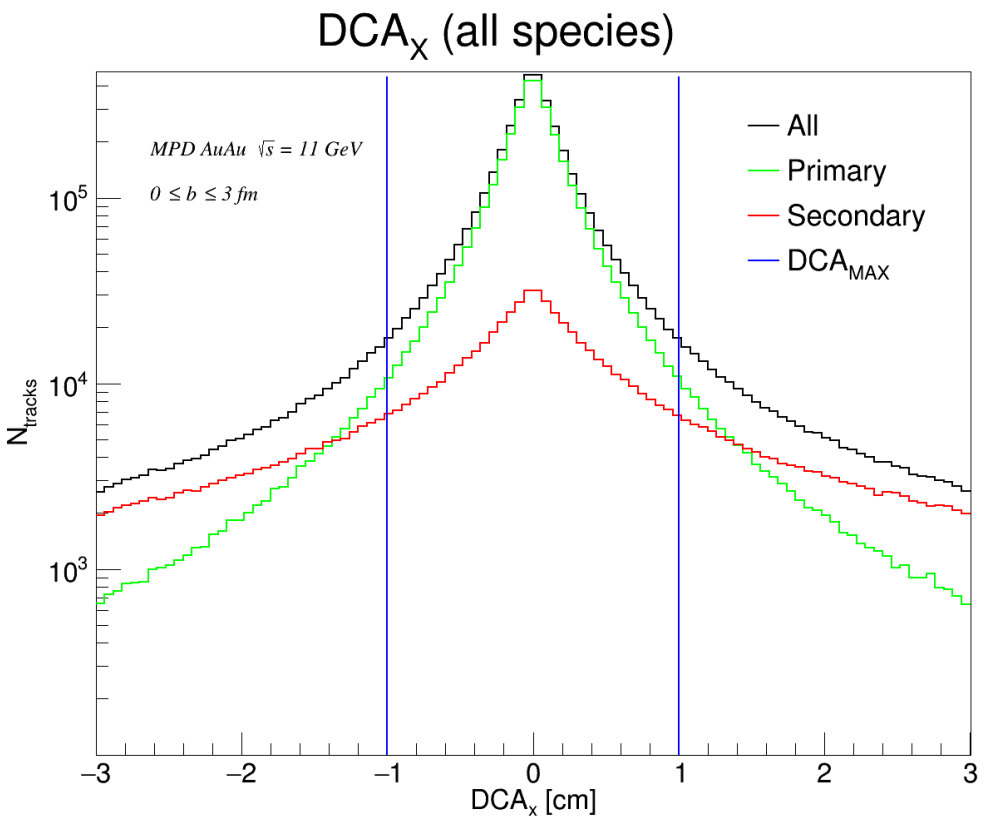
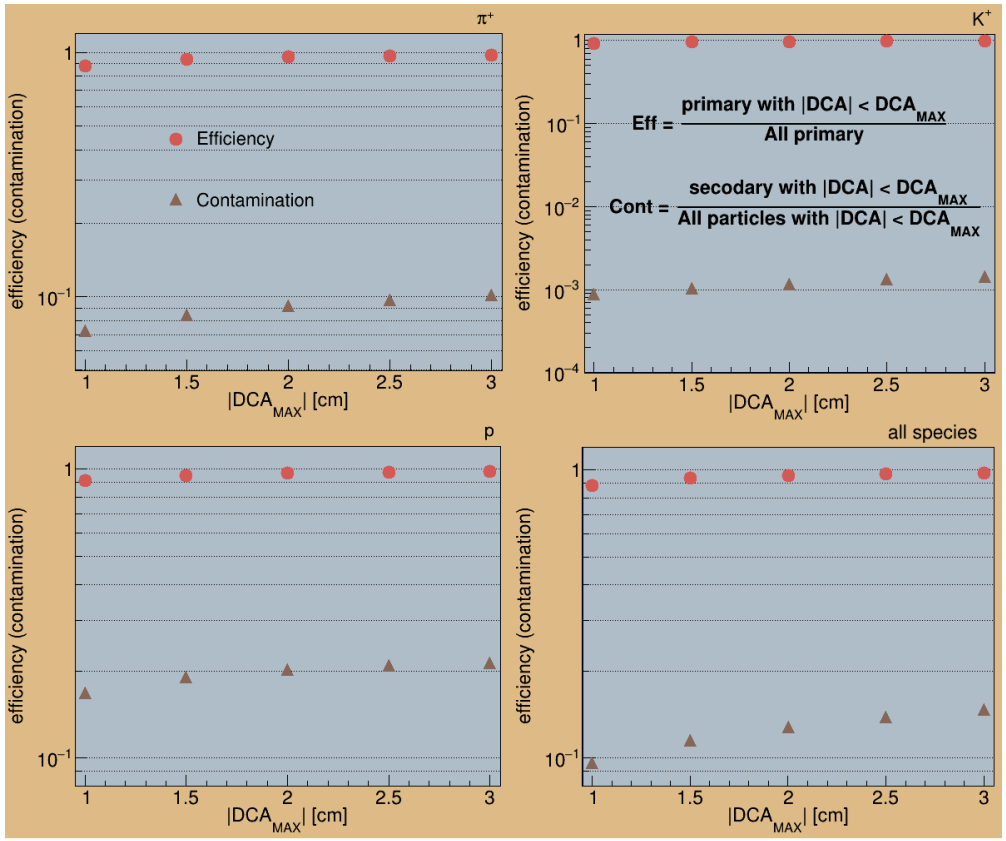
PID for charged hadrons and fluctuations

A. Mudrokh (VBLHEP)
on behalf of the MPD collaboration

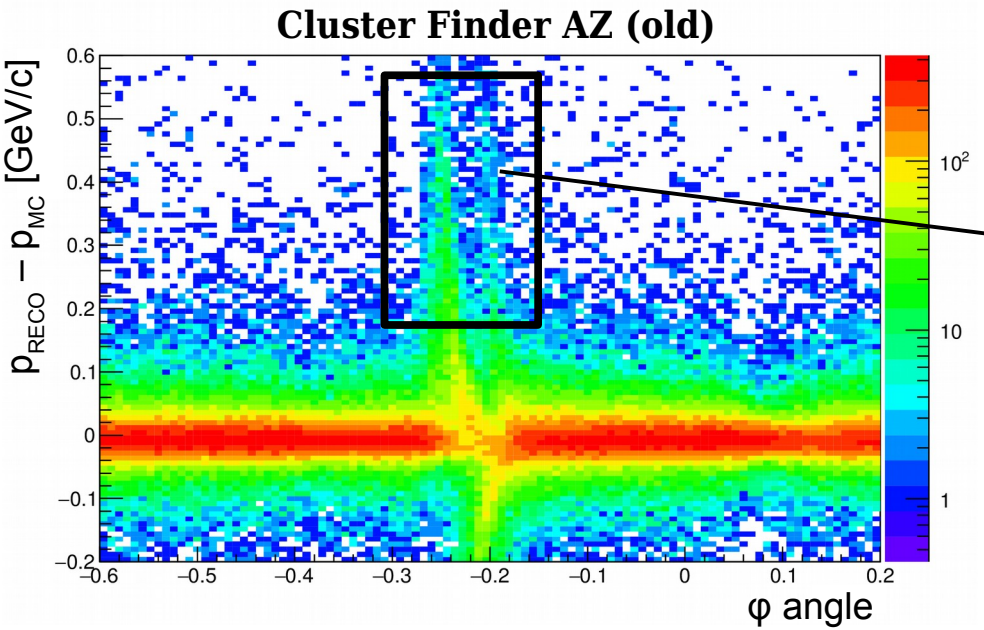
Track selection criteria for the analysis – DCA cut

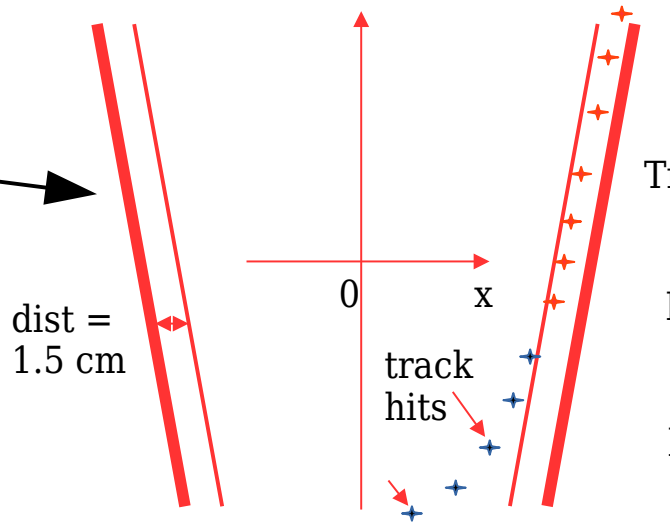




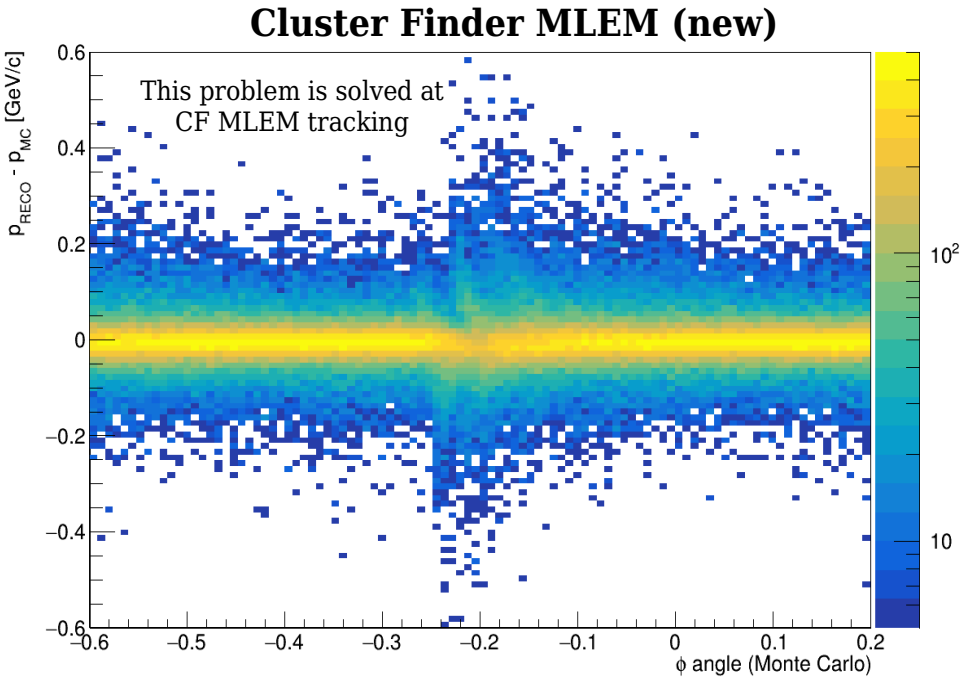
- Distance of the closest approach (DCA) cut between TPC tracks and primary vertex can be used instead of GEANT motherID signal
- Track is considered as primary if its $DCA_{X,Y,Z} < DCA_{MAX}$
- Values of DCA_{MAX} along *X*, *Y* and *Z* axes are identical
- Efficiency and contamination of DCA cut weakly depend on the chosen DCA_{MAX}

Track selection criteria for the analysis – TPC Edge cut





Tracks propagated close to the TPC sector boundaries usually had significant difference between p_{MC} and p_{RECO}

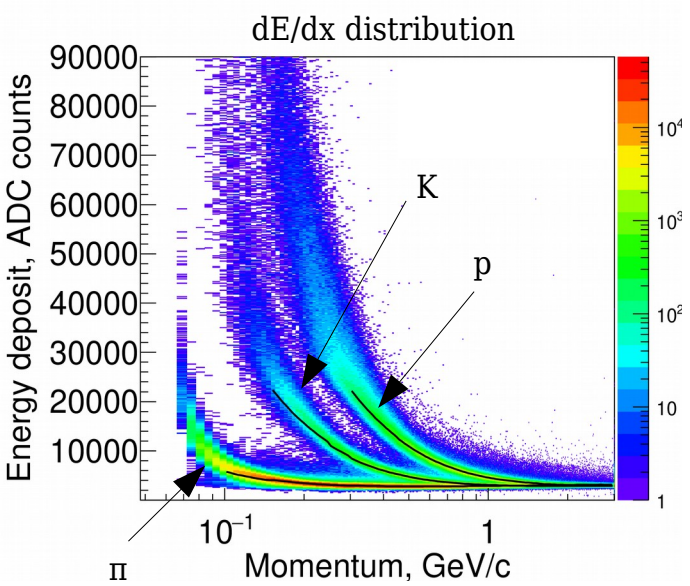


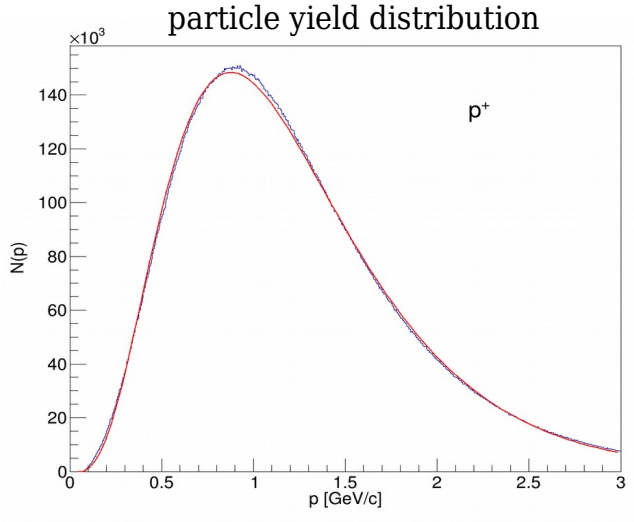
Old version of Cluster Finder tracking had difficulties of charge collection and momentum reconstruction in the region close to the TPC sector boundaries. In the new version of tracking, these difficulties have been corrected. **Thus TPC Edge cut becomes obsolete.**

Track selection criteria for analysis:

- $N_{hits} \geq 20$
- $|\eta| < 1.6$
- MotherID = -1 or |DCA| < 3 cm

PID methods: Bayesian approach and n_σ method





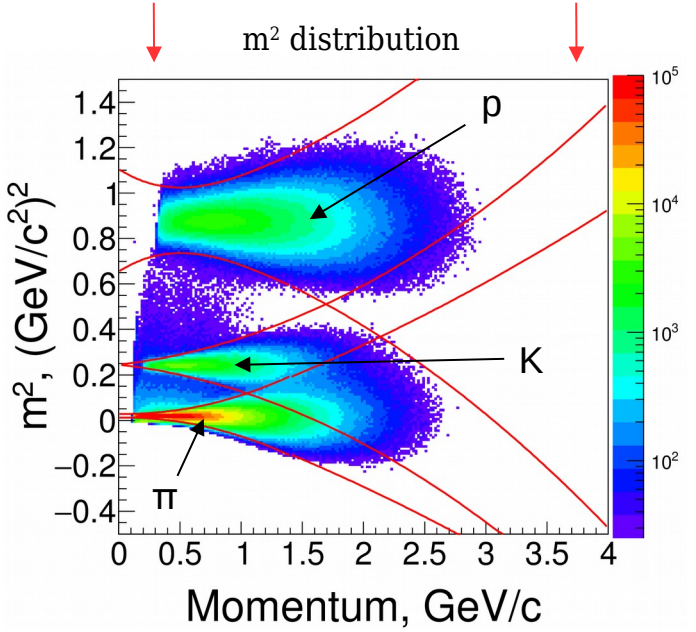
$$D_i \sim e^{-\frac{\left(dE/dx - \overline{dE/dx}_i\right)^2}{2\sigma_{TPC}^2(1+\delta)^2}} \cdot e^{-\frac{(m^2-\overline{m^2}_i)^2}{2\sigma_{TOF}^2}}$$

TPC TOF

D_i is the probability that a particle of species i will produce a signal dE/dx (m^2).
Then, according to the Bayes' theorem, the probability that the particle is of species i:

$$P_i = \frac{D_i C_i(p)}{\sum_i D_i C_i(p)}$$

Red lines depict 3σ bands



n_σ method:

$$N_{\sigma(TPC)} = \frac{\frac{dE/dx}{\langle dE/dx\rangle} - 1}{\sigma_{dE/dx}} \qquad N_{\sigma(TOF)} = \frac{m^2 - \langle m^2\rangle}{\sigma_{m^2}}$$

if $N_\sigma \leqslant \sqrt{N^2_{\sigma(TPC)} + N^2_{\sigma(TOF)}}$

then probability = 1
else probability = 0

If particle has several assigned species, PID sets all probabilities to zero (particle is not identified)

where C_i is an *a priori* probability of measuring the particle species i:

$$C_i(p) = \frac{N_i(p)}{\sum_i N_i(p)}$$

C_i are evaluated from the particle yield distribution function for each particle species i.

TOF reconstruction at STAR and MPD

STAR

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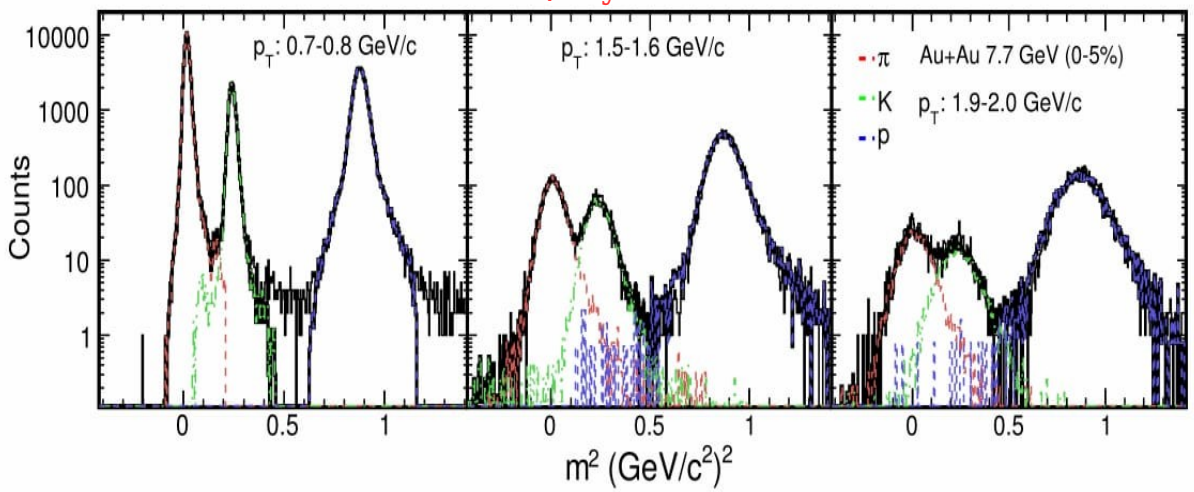


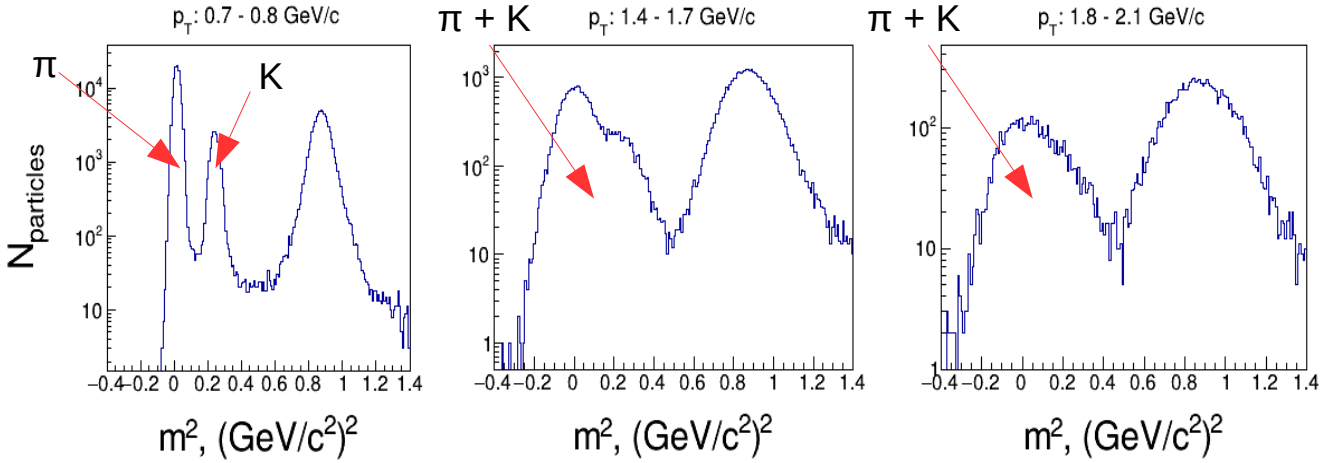
The m^2 distributions for positively charged hadrons used to extract raw yields for pions, kaons, and protons in $|y| < 0.1$ for Au+Au collisions at 7.7 GeV at three different p_T ranges. The curves are predicted m^2 fits representing contributions from pions (dashed-red), kaons (dashed-green), and protons (dashed-blue).

Particle separation properties (STAR):

Time resolution δt = 70 ps
Length uncertainty δL = 0.5 cm
Track length L = 110 cm
Momentum resolution δp = 3,5%

$$m^2 = p^2 \cdot \left(\frac{1-\beta^2}{\beta^2}\right) \qquad \beta = \frac{L}{ct}$$

MPD



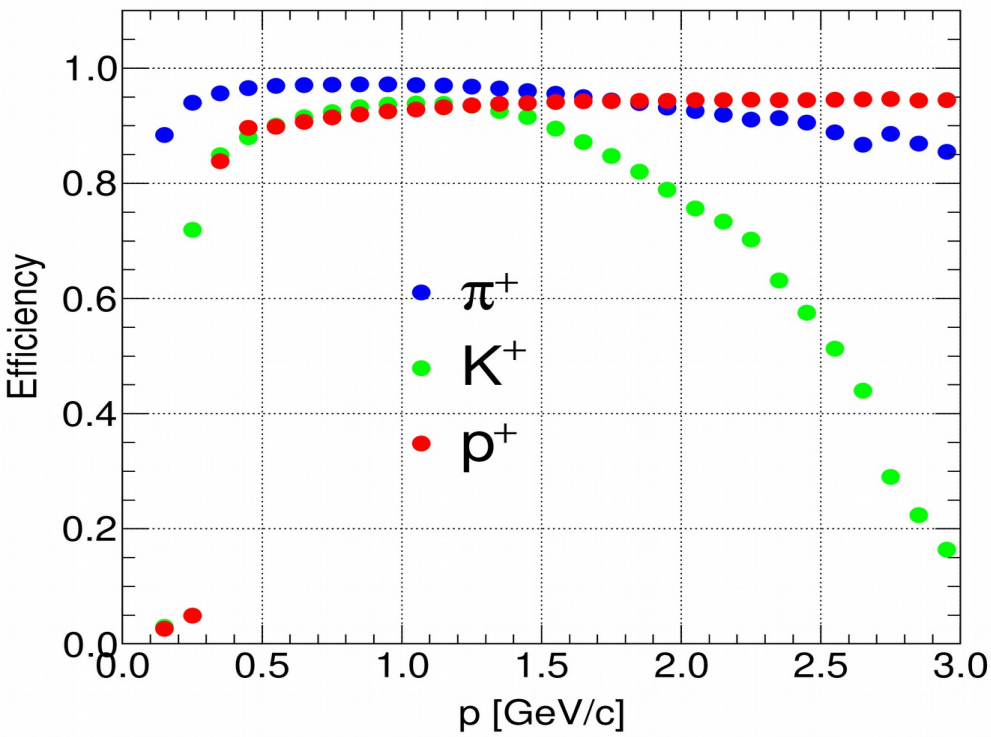
Particle separation properties (MPD):

Time resolution δt = 80 ps
Length uncertainty δL = 0.2 cm
Track length L = 130 cm
Momentum resolution δp = 3%

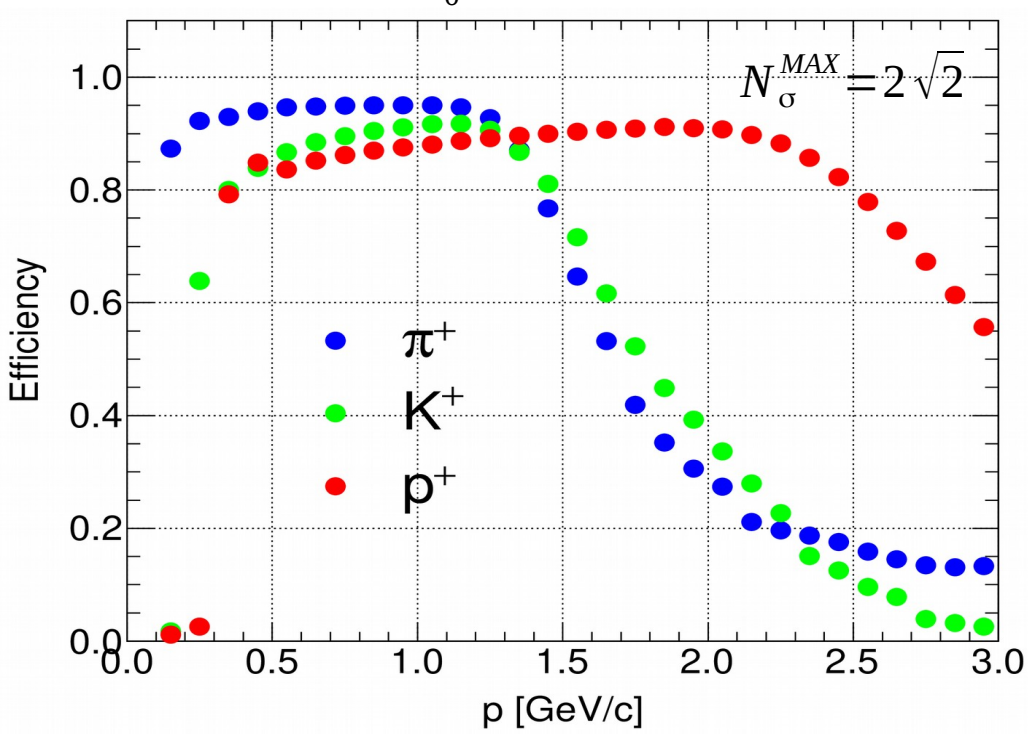
By now we do not have a clear view how to improve π-K separation

Combined (TPC + TOF) PID efficiency

Bayesian approach



n_σ method



Bayesian approach gives an array of probabilities P_i and assigns it to a track as PID result.
Species is defined as a maximum probability in this array.

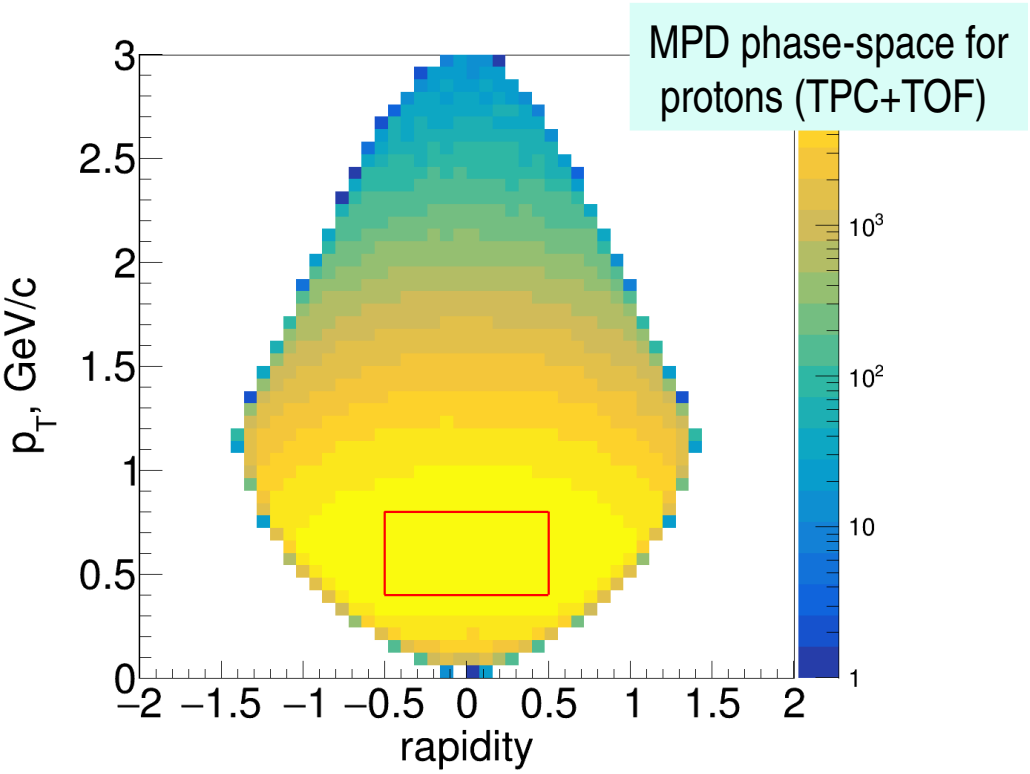
$$eff = \frac{particles\ which\ are\ correctly\ identified}{all\ particles\ of\ a\ given\ species}$$

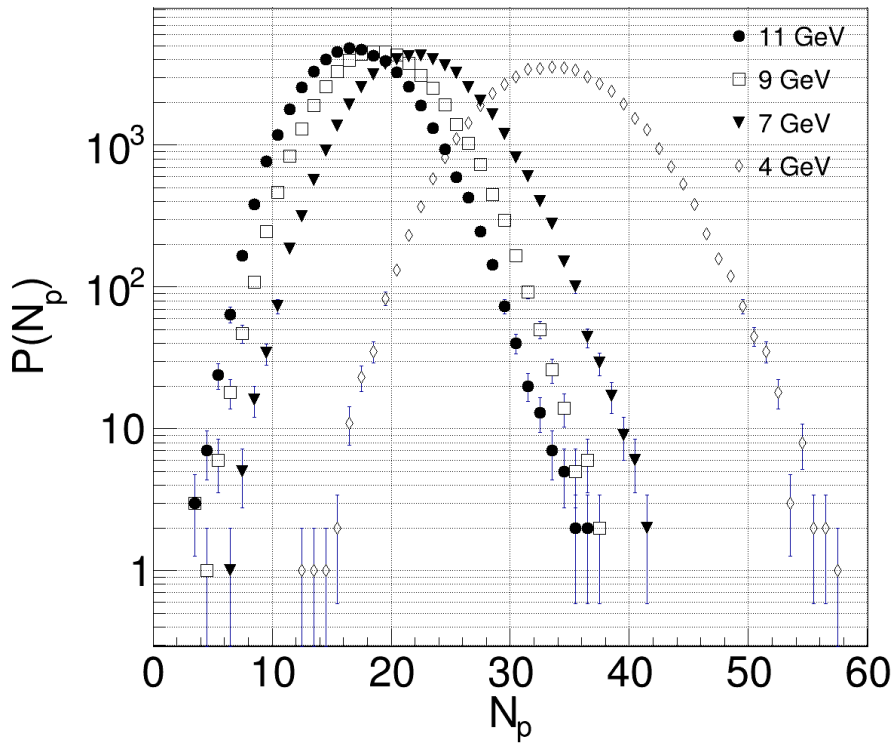
Set of cuts:

- primary particles (GEANT)
- $|\eta| < 1.6$
- $N_{hits} \geq 20$
- TOF point existence (GEANT)

Measurements of proton number distribution cumulants

- Cumulant measurements are carried out within $|y| < 0.5$ and $0.4 < p_T < 0.8$ GeV/c
- Measurements of proton multiplicity are carried out with dE/dx + TOF bayesian PID
- This p_T interval accounts for approximately 50% of the total uncorrected p + anti-p multiplicity at midrapidity (STAR paper)
- Typical value of detection efficiency ε in the given phase-space is 92% (protons are wasted due to tracking uncertainties, TPC-TOF mismatching, PID, cuts etc.)





Measured cumulants and moments (very preliminary)

Cumulants:

$k_1 = \langle N \rangle$

$k_2 = \langle (\delta N)^2 \rangle$

$k_3 = \langle (\delta N)^3 \rangle$

$k_4 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2$

Moments:

$\mu = k_1 \qquad \sigma^2 = k_2$

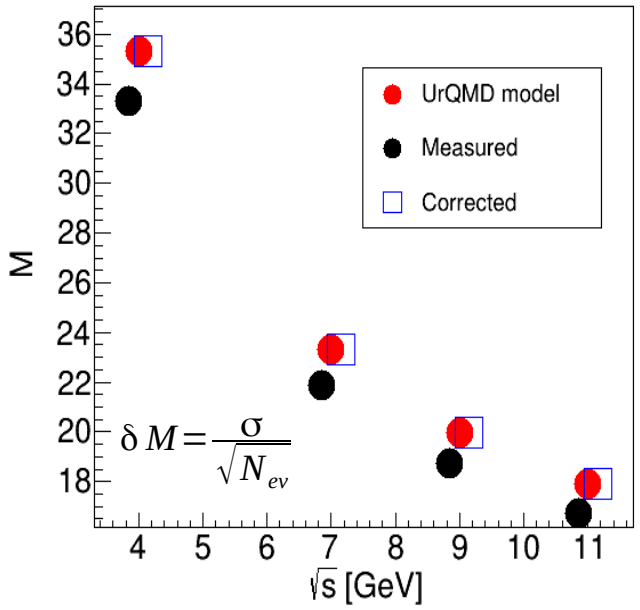
$S = \frac{k_3}{k_2^{3/2}}$

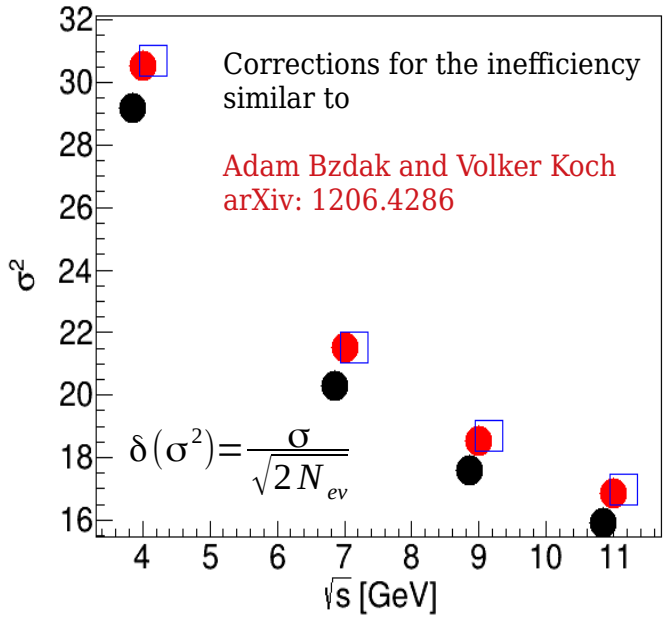
$K = \frac{k_4}{k_2^2}$

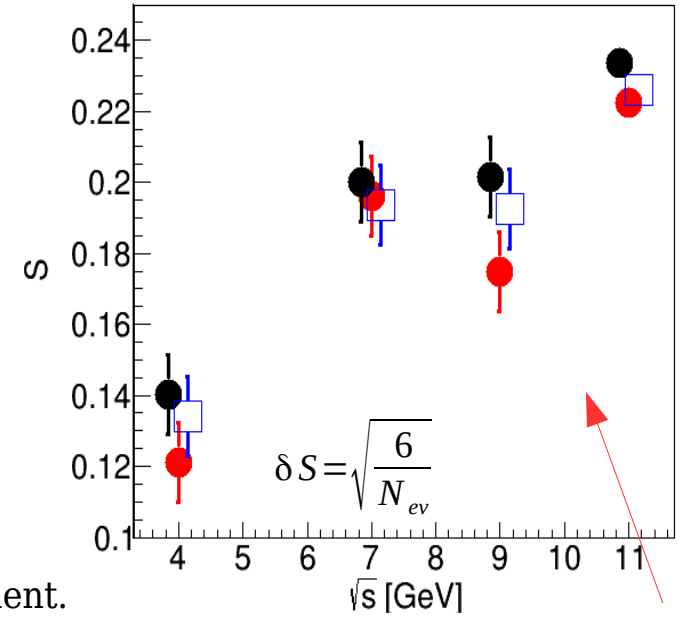
if $\boldsymbol{K_i}$ is a cumulant associated with MC-distribution and $\boldsymbol{c_i}$ with the measured one with detecting efficiency p, their relation is following:

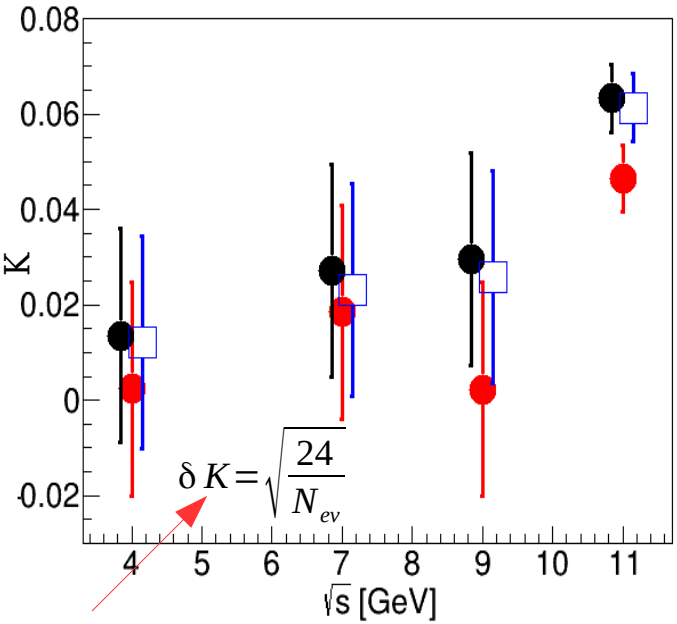
- $pK_1 = c_1$
- $p^2 K_2 = c_2 - c_1(1-p)$
- $p^3 K_3 = c_3 - c_1(1-p^2) - 3(1-p)(f_2 - c_1^2)$
- $p^4 K_4 = c_4 - c_1 p^2(1-p) - 3c_1^2(1-p)^2 - 6p(1-p)f_2 + 12c_1(1-p)f_2 - (1-p^2)(c_2 - 3c_1^2) - 6c_1(1-p)(c_1^2 - c_2) - 6(1-p)(f_2 + f_3)$

where $f_i = \langle \frac{N_p!}{(N_p - i)!} \rangle$ – factorial moment.







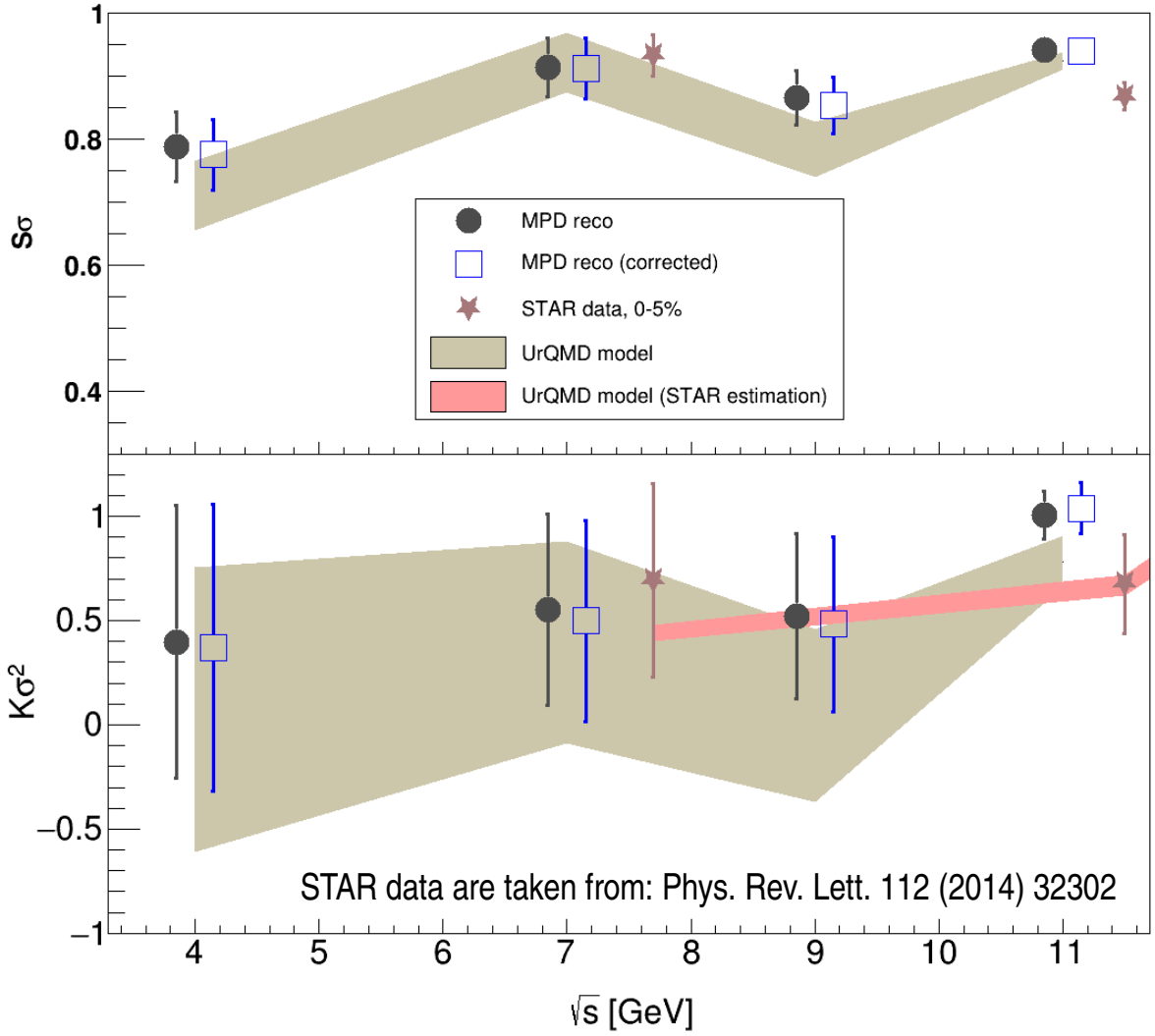


Statistical error bars only

Measured cumulants and moments (very preliminary)

Cumulant ratios are directly compared to susceptibilities and allow fireball volume cancellation

$$\frac{k_3}{k_2} = S\sigma \qquad \frac{k_4}{k_2} = K\sigma^2$$



$$\epsilon_K = \frac{\delta K}{|K|} \qquad \epsilon_{\sigma^2} = \frac{\delta \sigma^2}{|\sigma^2|}$$

$$\epsilon_{K\sigma^2} = \epsilon_K + \epsilon_\sigma$$

Statistics is not sufficient - large error bars

It is observed that this correction procedure does not work well. It can stem from our assumption that detection efficiency *p* is a single number. However, this does not imply that in each event *i* the number of observed particles is

$$n_i = pN$$

So, in order to improve correction results, local detection efficiency $p(y, p_T)$ has to be used instead of the global one.

Results

- Particle identification (PID) based on Cluster Finder MLEM tracking has been developed and implemented within the MpdRoot software package. Effective π/K separation is working up to 1.5 GeV, π/p separation is working up to 3 GeV.
- Cumulants of proton distribution are calculated within $|y| < 0.5$ and $0.4 < p_T < 0.8$ GeV/c.

Plans

- Increase of the event statistics for the ev-by-ev fluctuations study *(~10M min bias events per each energy)*
- Use realistic centrality determination
- To carry out a study of systematics (phase-space coverage, analysis details, corrections)
- Extend study to other conserved charges (strangeness, charged particles)