MPD@NICA: PHYSICS WE ARE AFTER AND PID TECHNIQUES
PHYSICS WORKING GROUP

MPD@NICA

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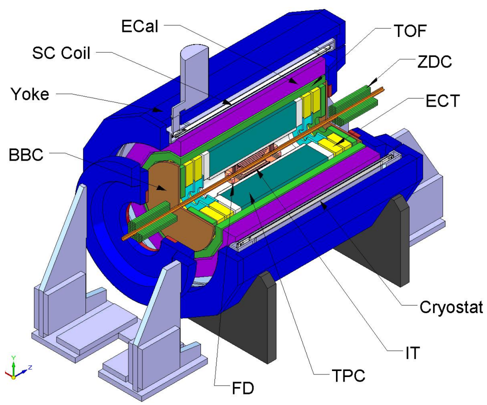
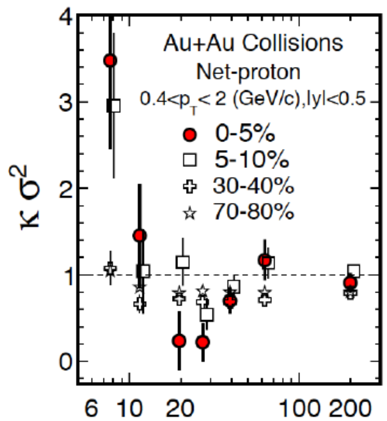
Physics cases

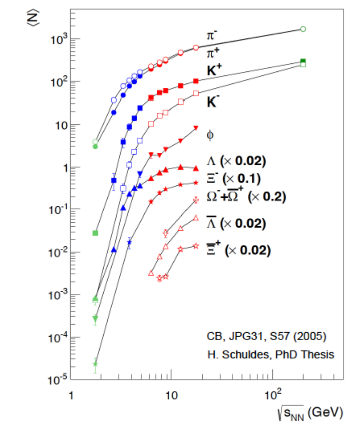
A.R. 122 JINR Scientific Council

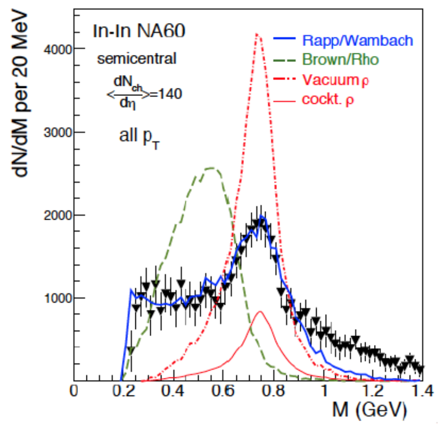
- *No clear signals for critical point*
- *No direct evidence for chiral symmetry restoration*
- *Missing hadron yields and spectra in the NICA energy range*
- *Additional phases at lower baryon chemical potential?*

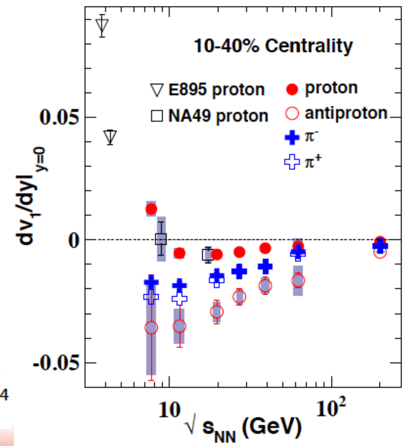
All these and other unresolved issues can and should be explored at the upcoming MPD@NICA

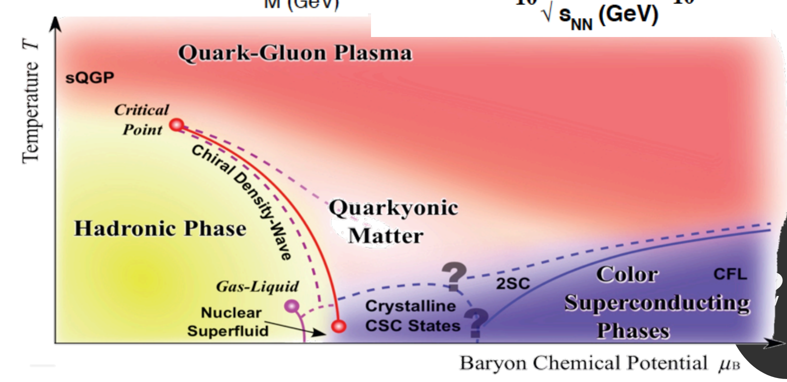












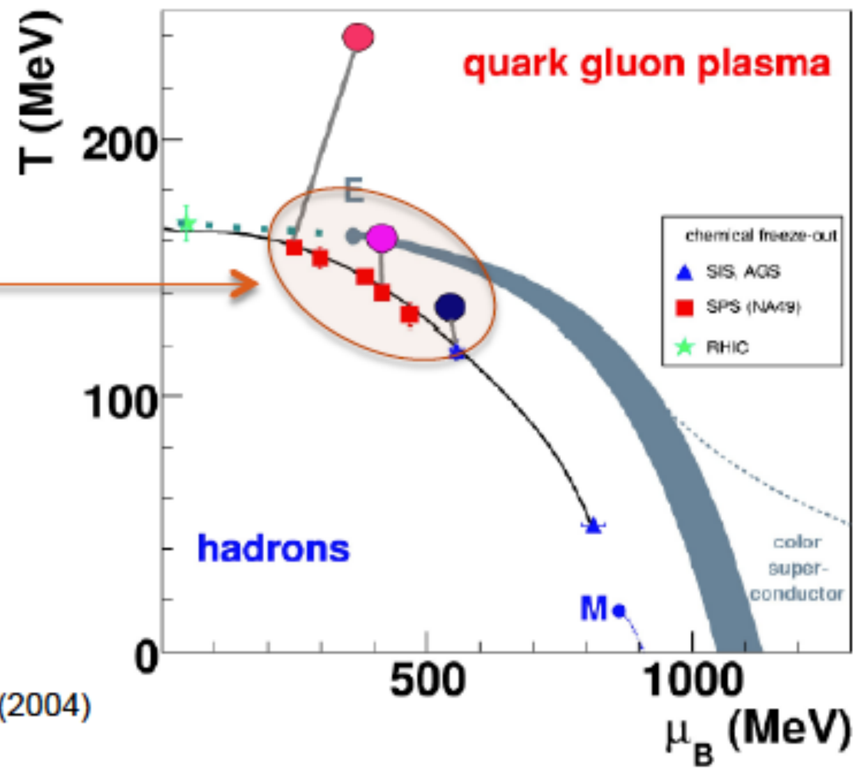
The Ultimate Goal

probes an interesting region on the phase diagram

for example:

T_c = 162±2MeV
μ_c = 360±40 MeV

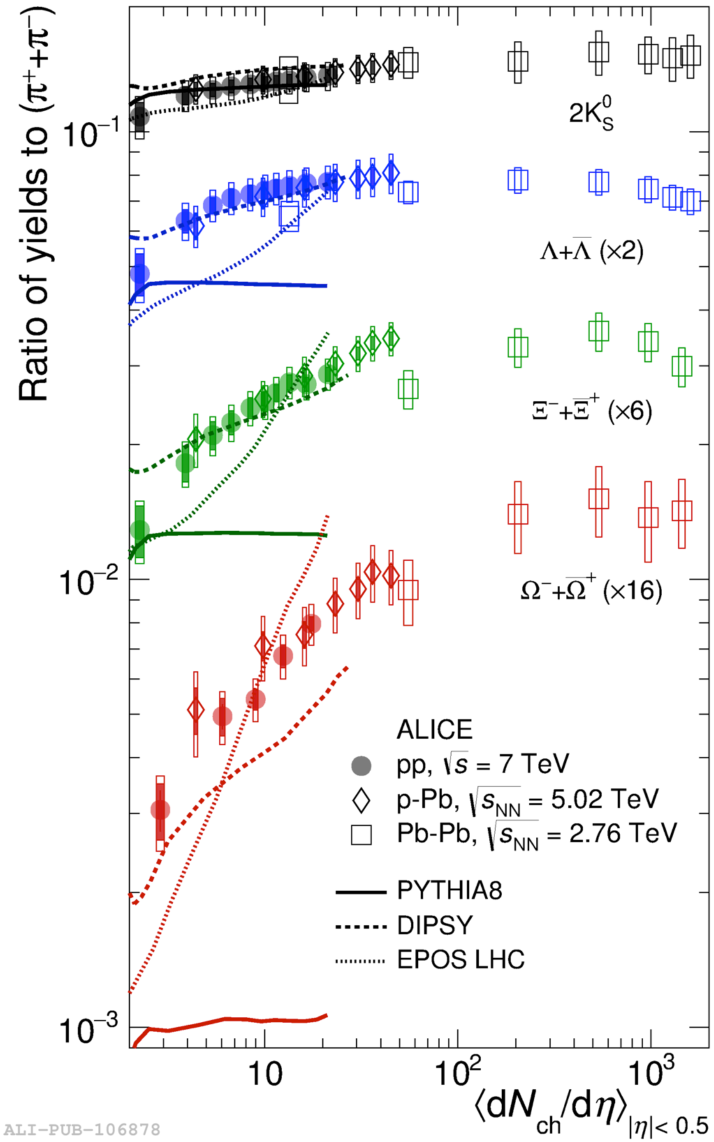
Z. Fodor S. D. Katz, JHEP 0404, 050 (2004)

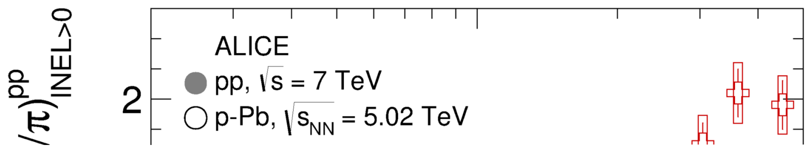


- To probe the structure of strongly interacting matter
  - Locate phase boundaries
  - Diagnose QGP phase
  - Search for critical phenomena
  - …

A.R. CPOD2013

Strangeness enhancement in p+p





ΔS=3

ΔS=2

ΔS=1

S=0

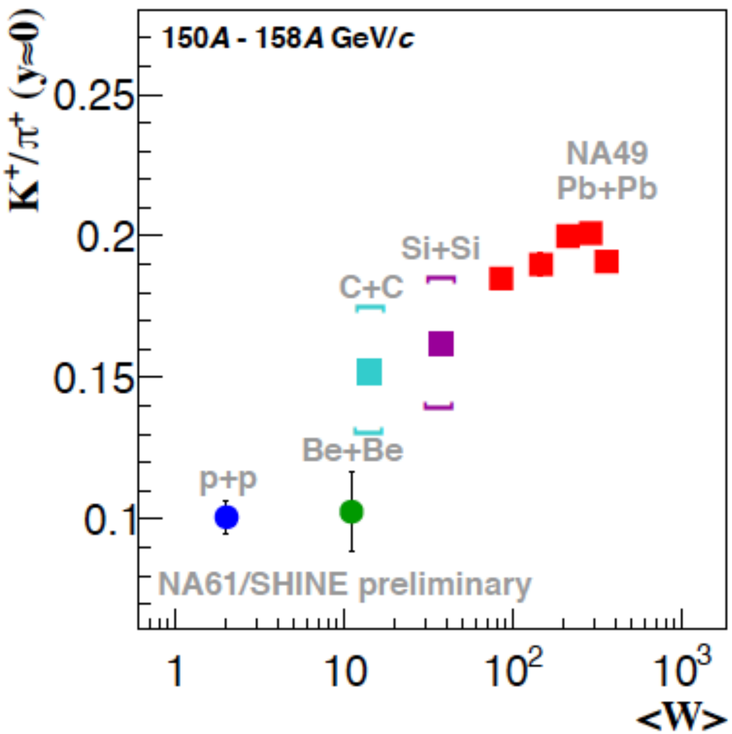
- ***Strange to non-strange ratios in p+p and p-Pb approaches the GCE limit for Pb+Pb***
- ***No dependence on energy and collision system***
- ***The enhancement hierarchy follows the strangeness content***

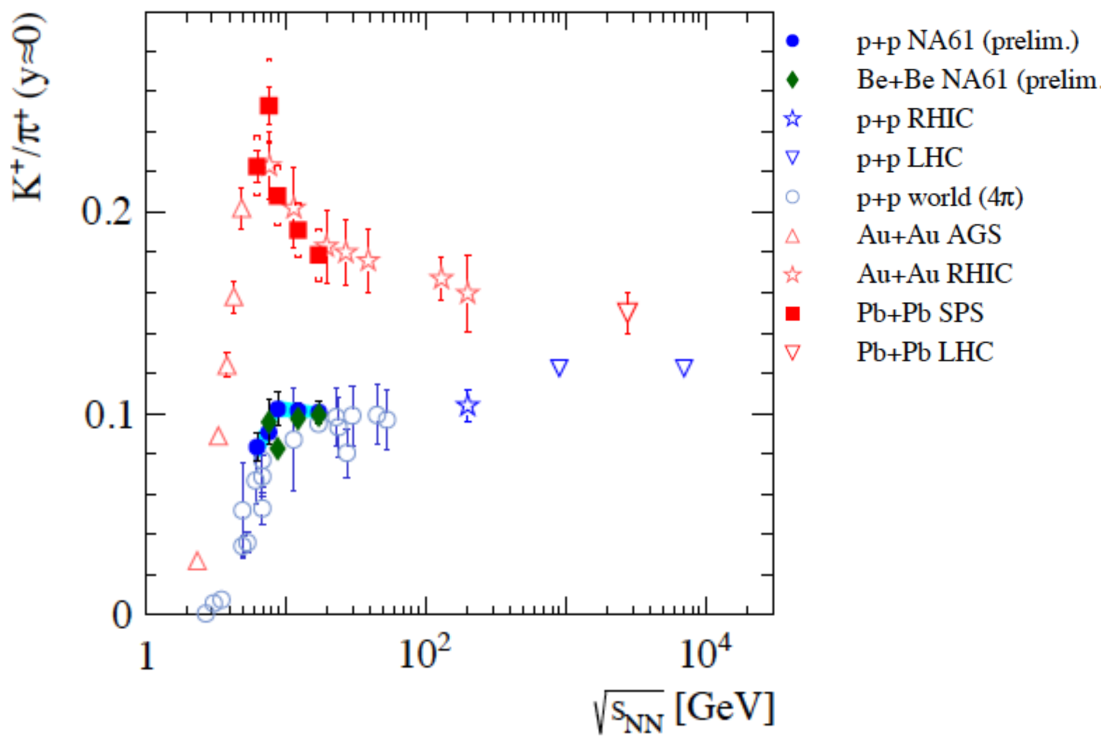
$F_s = I_s(x)/I_o(x)$ *-> 1 for large multiplicities*

ALICE, Nature Phys. 13, 535 (2017)

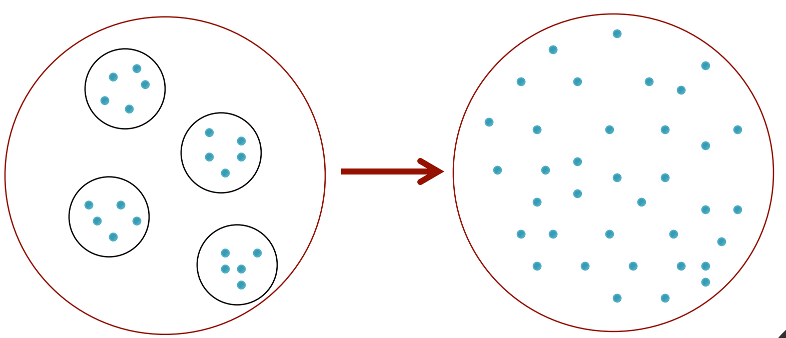
A.R. SQM 2017

Strangeness enhancement at SPS





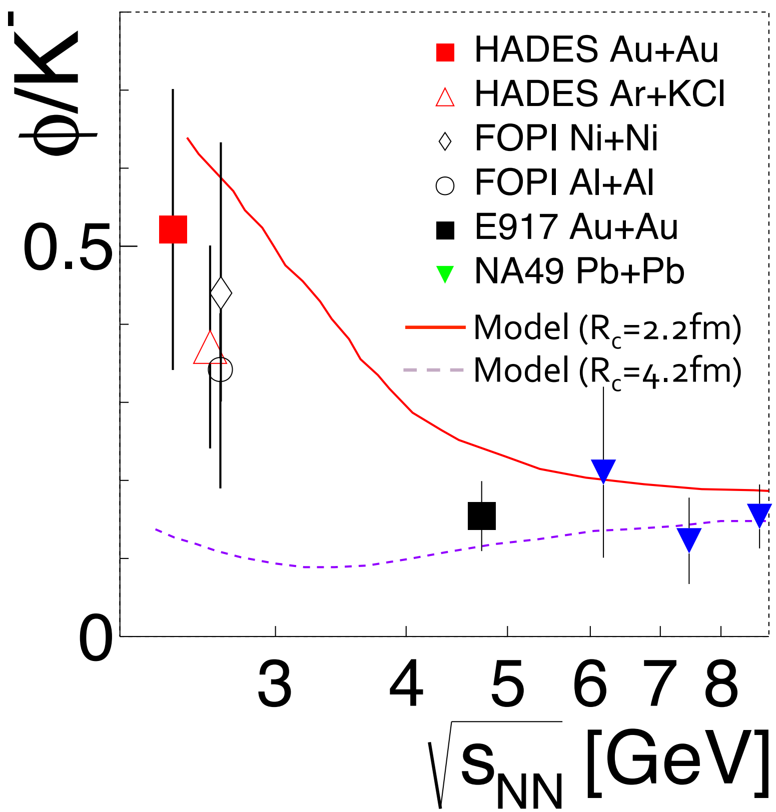
- Be+Be results are very close to p+p
- "Shadow of horn ?" in p+p collisions
- K/π for protons approaches Pb-Pb values at LHC

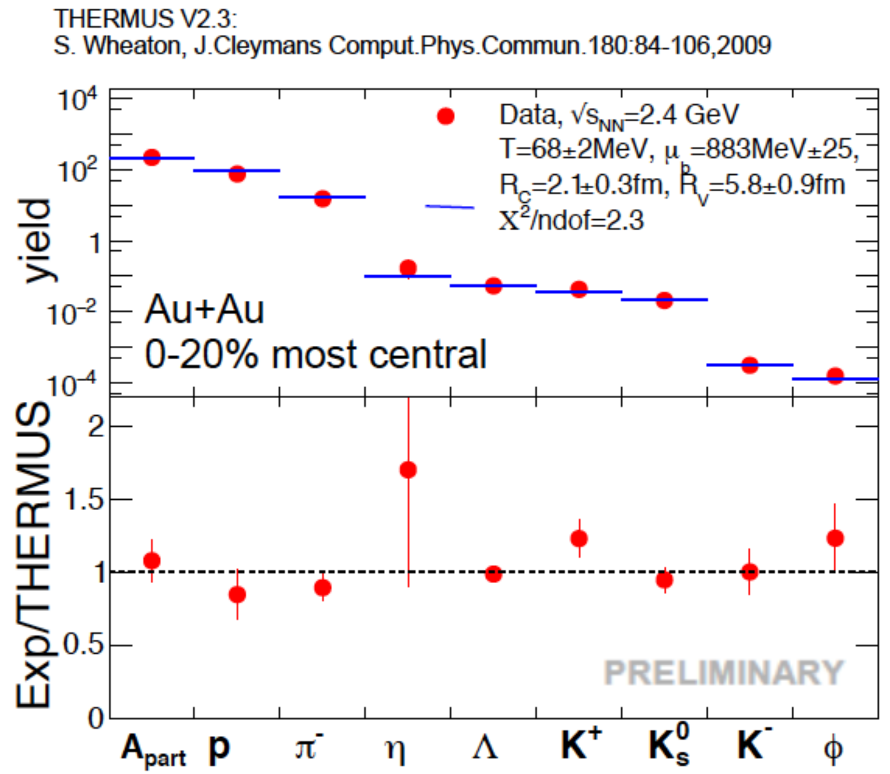


T. Susa, NA61/SHINE talk

A.R. SQM 2017

Hadron abundances at low energies





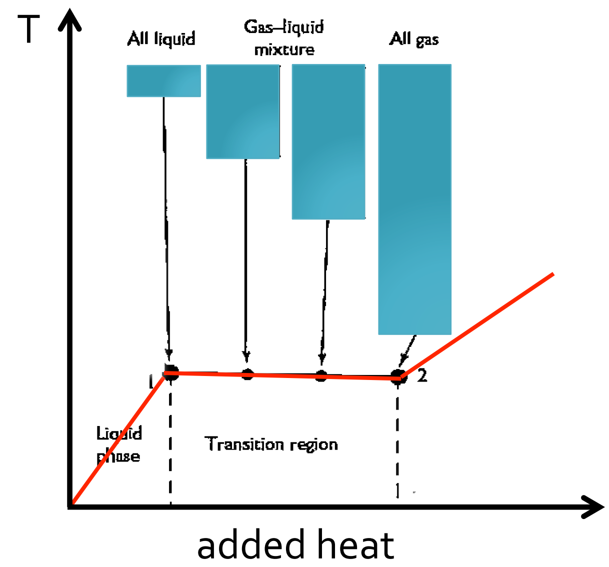
consistent with canonical suppression of K^-

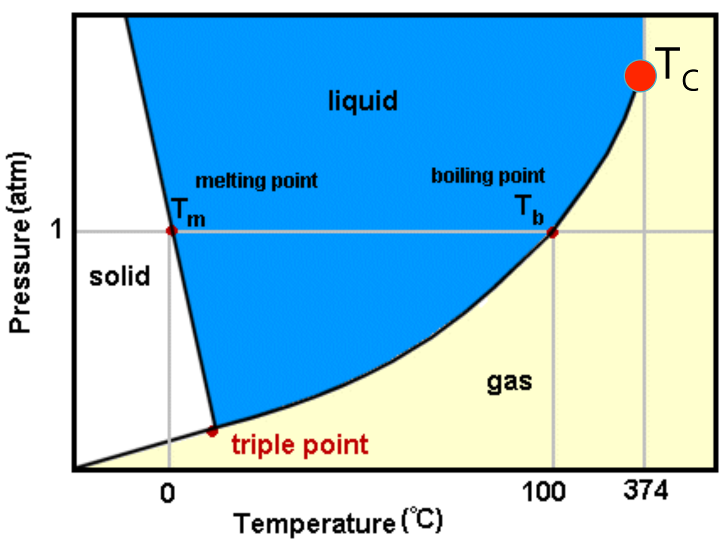
- Grand Canonical fit with T, μ_B, R_V
- strangeness in canonical volume ($R_C < R_V$)

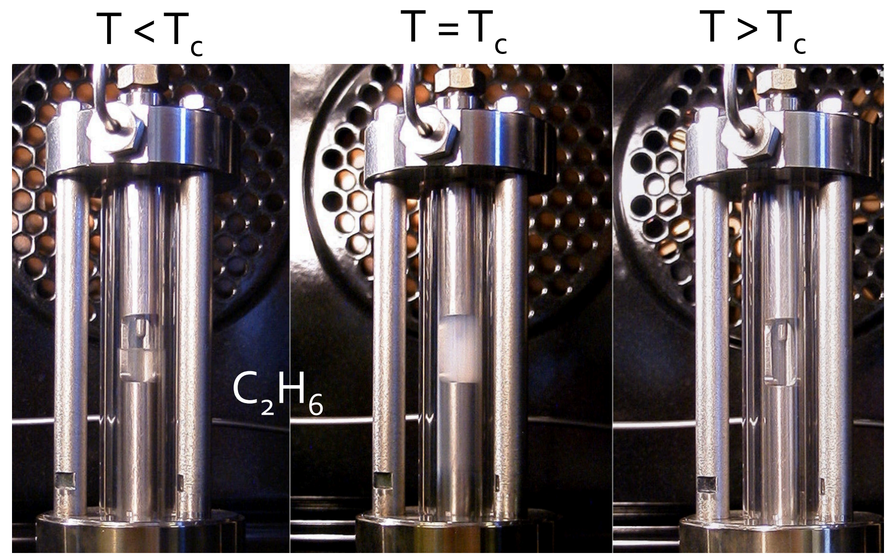
HADES, arXiv: 1703.08418
Model: J. Cleymans, H. Oeschler, K. Redlich, S. Wheaton, PRC 73, 034905 (2006)

M. Lorenz, QM 2017

Electromagnetically Interacting matter







$$\frac{\langle \rho^2 \rangle - \langle \rho \rangle^2}{\langle \rho \rangle^2} = \frac{T\chi}{V}, \quad \chi = -\frac{1}{V}\frac{\partial V}{\partial P}$$

Einstein, 1910

$$Rayleigh\,Ratio \propto \chi$$

probing phase transitions with E-by-E fluctuations

Strongly Interacting Matter

for a thermal system in a fixed volume V within the Grand Canonical Ensemble

$$\hat{\chi}_2^B = \frac{\langle \Delta N_B^2 \rangle - \langle \Delta N_B \rangle^2}{VT^3} = \frac{\kappa_2(\Delta N_B)}{VT^3}$$

$$\hat{\chi}_n^{N=B,S,Q} = \frac{\partial^n P/T^4}{\partial(\mu_N/T)^n} \qquad \frac{P}{T^4} = \frac{1}{VT^3}\ln Z(V,T,\mu_{B,Q,S})$$

- *In experiments*
  - *Volume (participants) fluctuates from E-to-E*
  - *Global conservation laws are important*

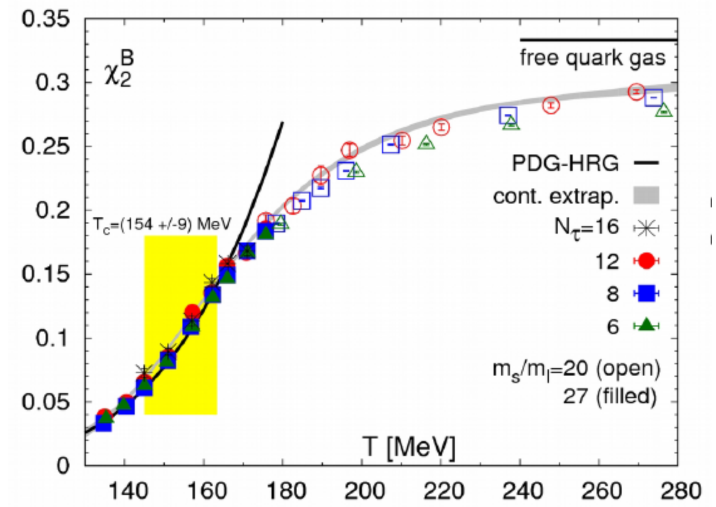
$$\hat{\chi}_n^B \neq \frac{\kappa_n(\Delta N_B)}{VT^3} \qquad \frac{\kappa_4(\Delta N_B)}{\kappa_2(\Delta N_B)} \equiv \gamma_2\sigma^2 \neq \frac{\hat{\chi}_4^B}{\hat{\chi}_2^B}$$

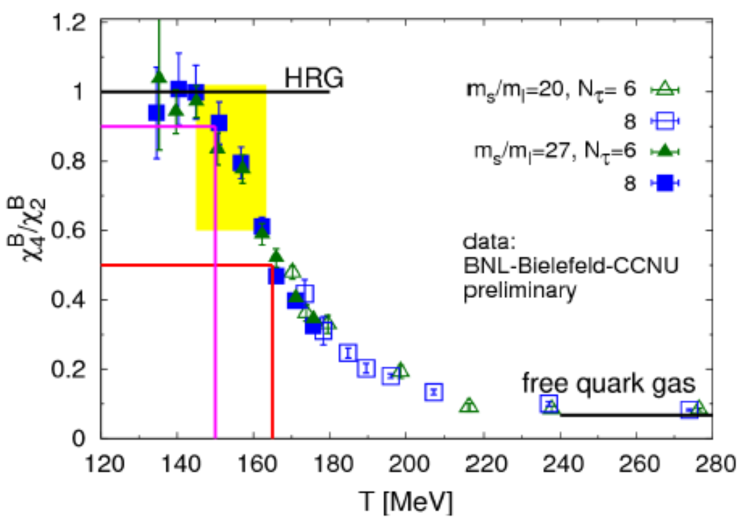
V. Skokov, B. Friman, and K. Redlich, Phys.Rev. C88 (2013) 034911

P. Braun-Munzinger, A. Rustamov, J. Stachel, arXiv:1612.00702, NPA 960 (2017) 114

At $s^{1/2}$ > 10 GeV net-proton is a reasonable proxy for the net-baryon

M. Kitazawa, and M. Asakawa, Phys. Rev. C86 (2012) 024904



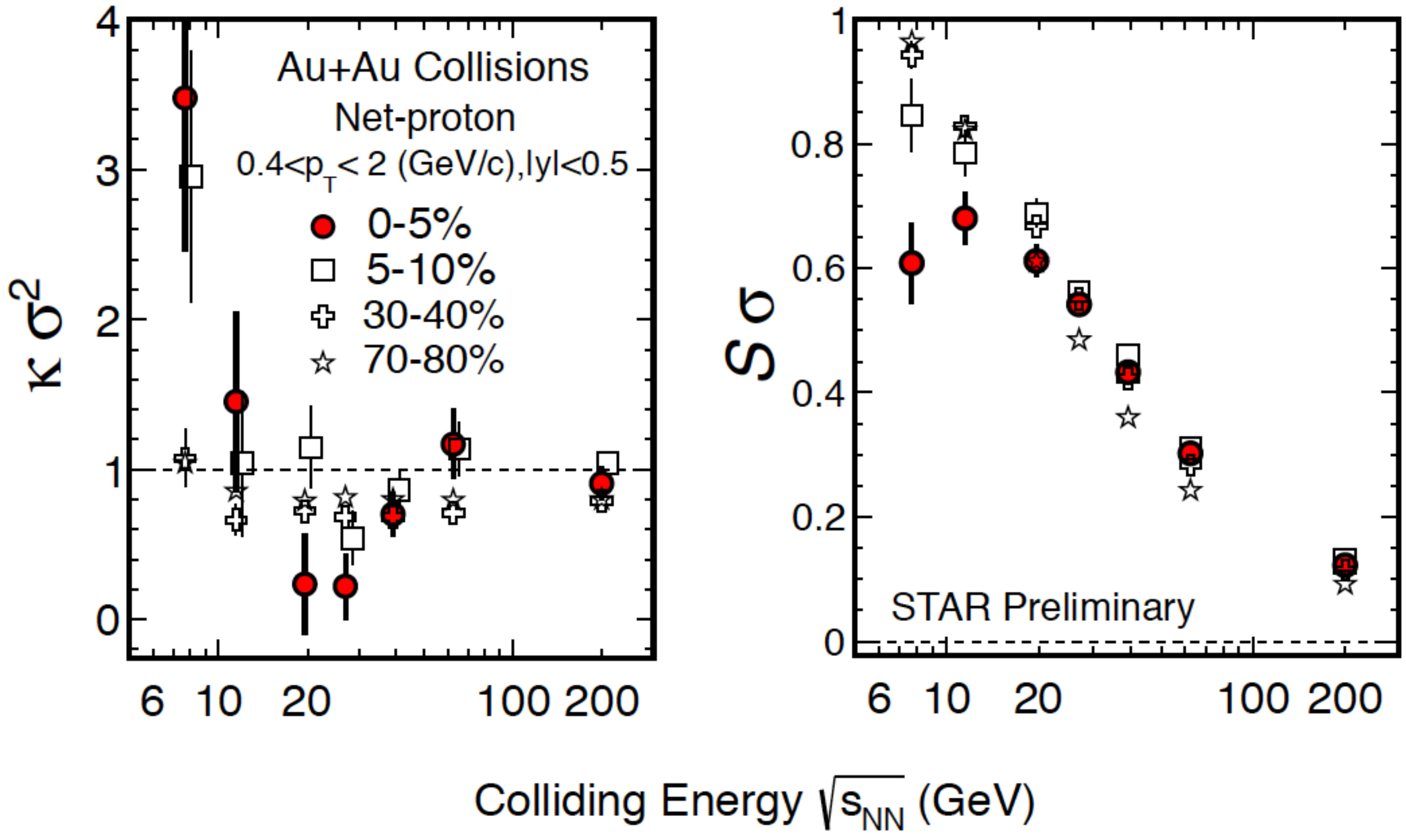


smaller than in HRG for T > 150 MeV

F. Karsch, QM17, arXiv:1706.01620
O. Kaczmarek, QM17, arXiv:1705.10682

A.R. Quark Mater, 2017

Results from STAR



- Close to unity for peripheral collisions
- Below 39 GeV hints for a non-monotonic behavior
- ***More statistics and precise control of systematics are needed to explore this region***

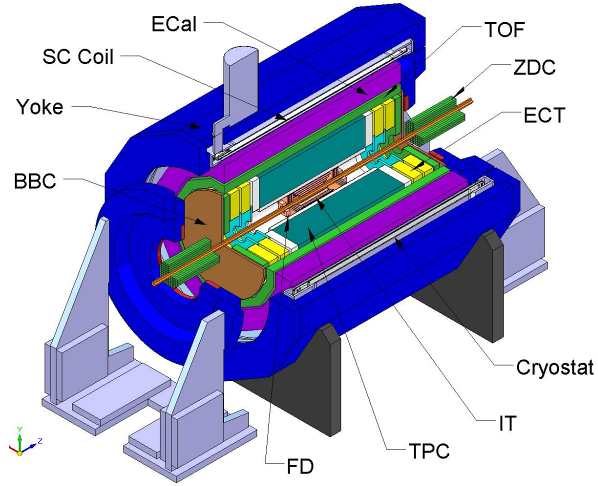
Drop at 7.7 GeV for central events

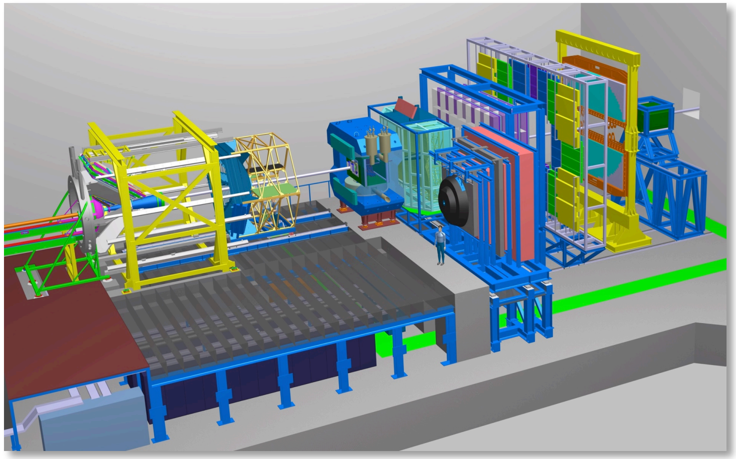
X. Luo, PoS CPOD2014, 019 (2015)
STAR: PRL 112, 032302 (2014)

NOTE: Only statistical uncertainties are presented!

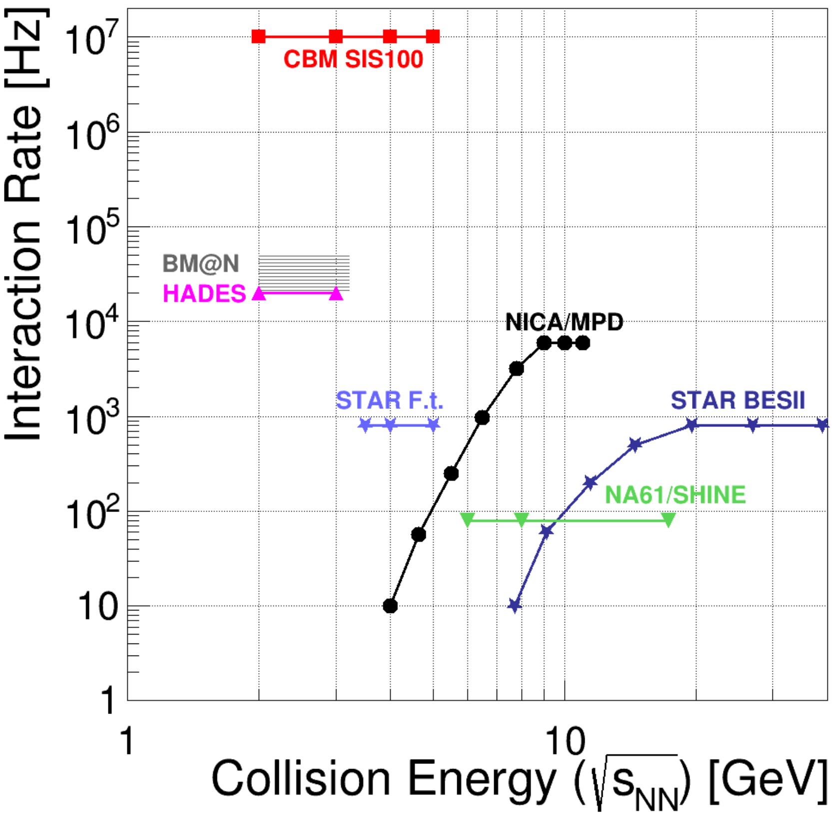
Near Future Experiments

MPD at NICA (collider mode)



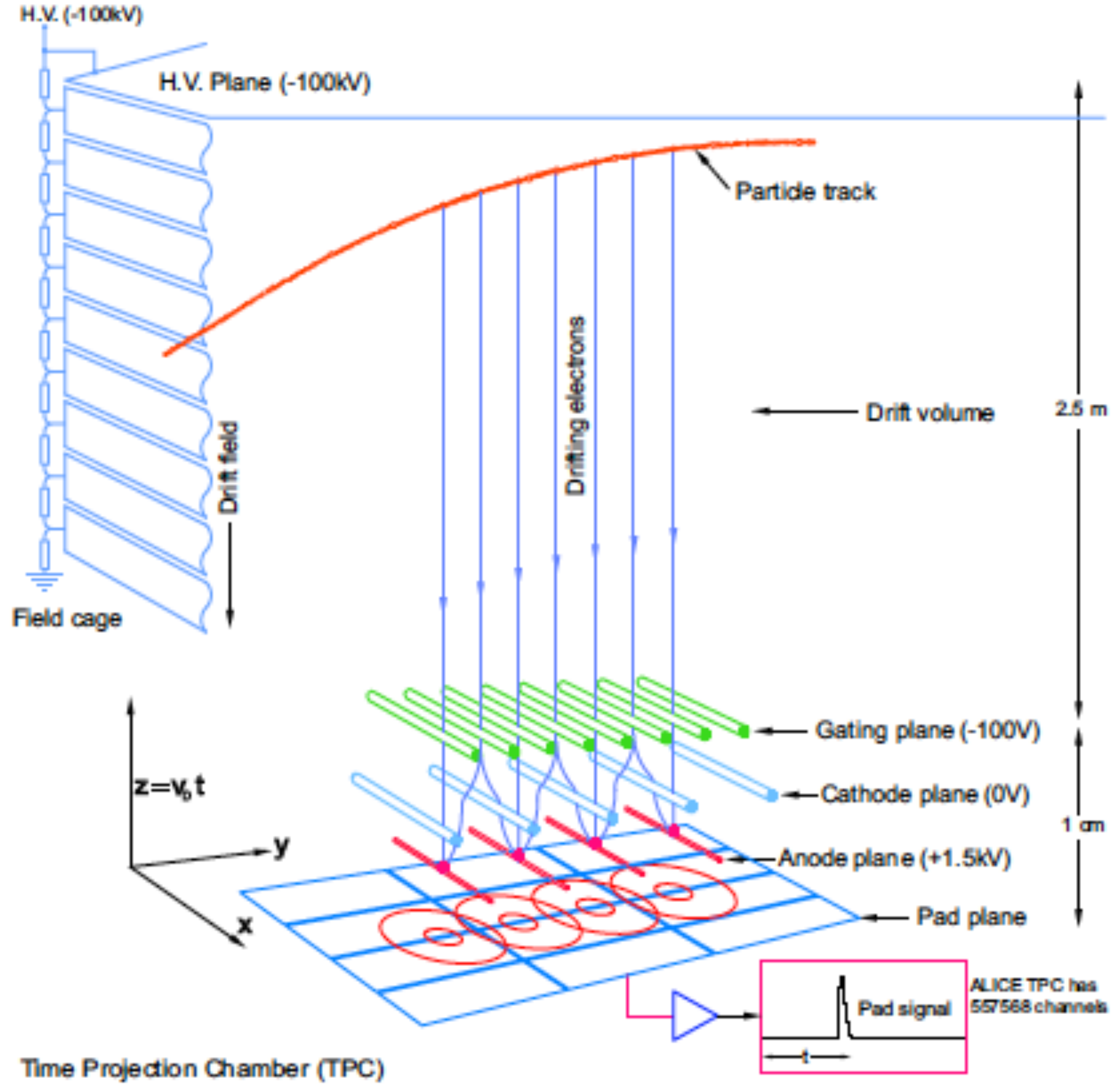


CBM at FAIR (fixed target)



V. Kekelidze, QM2017
P. Senger, QM2017

Time Projection Chamber



Particle Identification

$$\vec{p} = m\vec{\beta}\gamma$$

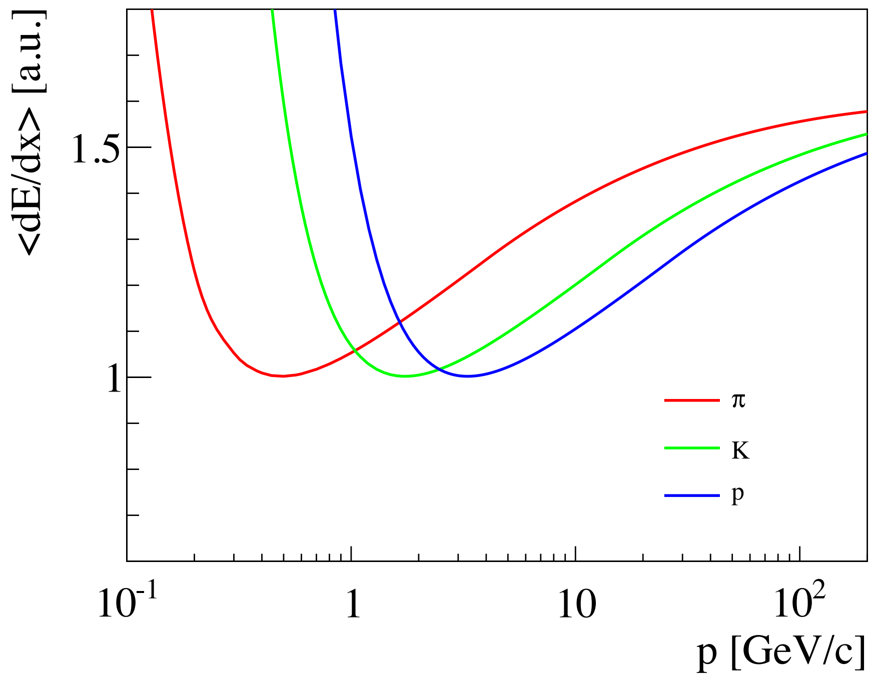
In order to identify the particle
at least two independent measures are needed

$$-\left\langle \frac{dE}{dx} \right\rangle (\beta\gamma) \propto \frac{z^2}{\beta^2} \ln(a\beta\gamma)$$

Momentum is obtained by solving the equation of motion in a magnetic field.

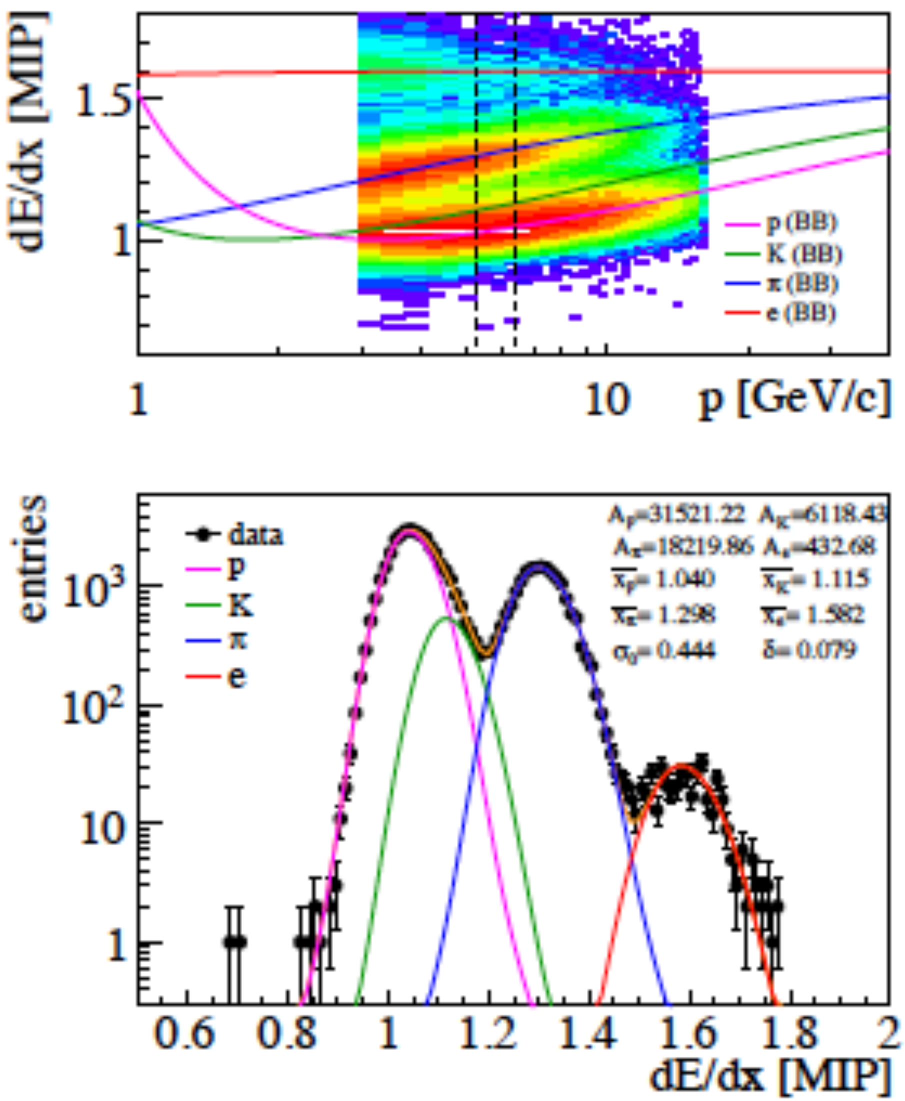
- ✓ Input:
  - ✓ set of measured points in space
  - ✓ magnetic field map (typically calculated)

$$\frac{d^2\vec{x}}{ds^2} = \frac{z}{|\vec{p}|}\left[\frac{d\vec{x}}{ds} \cdot \vec{B}(\vec{x})\right]$$



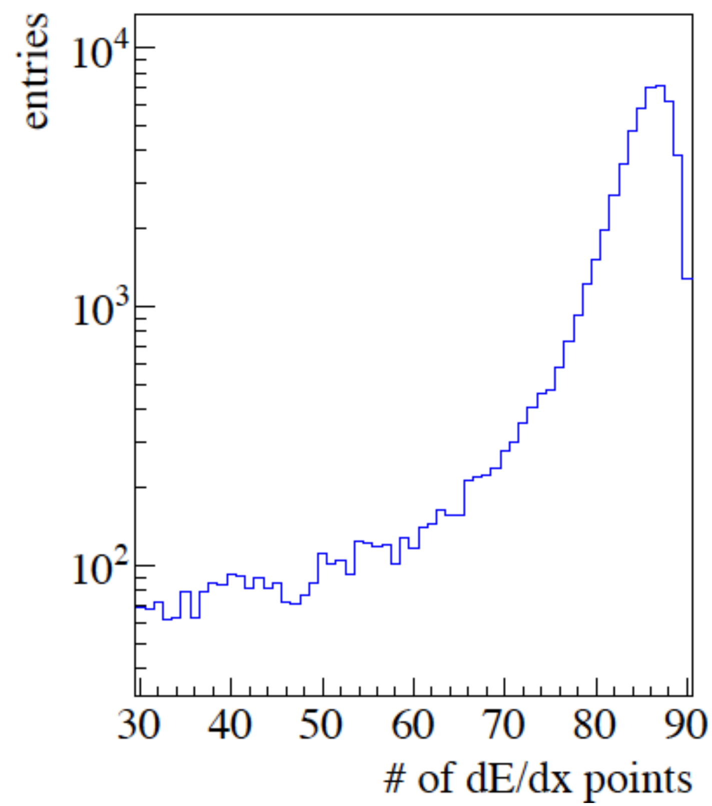
Simultaneous measurement of momentum and dE/dx allows to identify the identity (mass) of a particle

Particle Identification, Reality

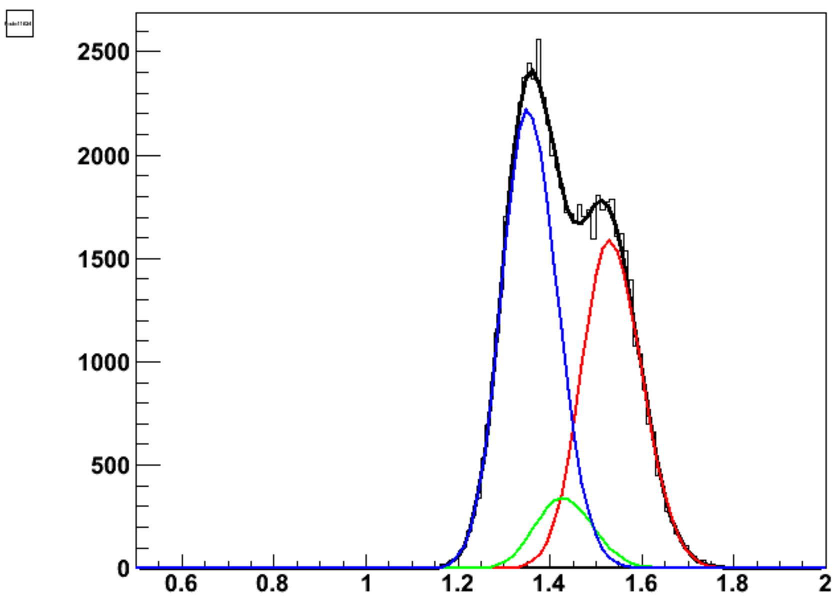


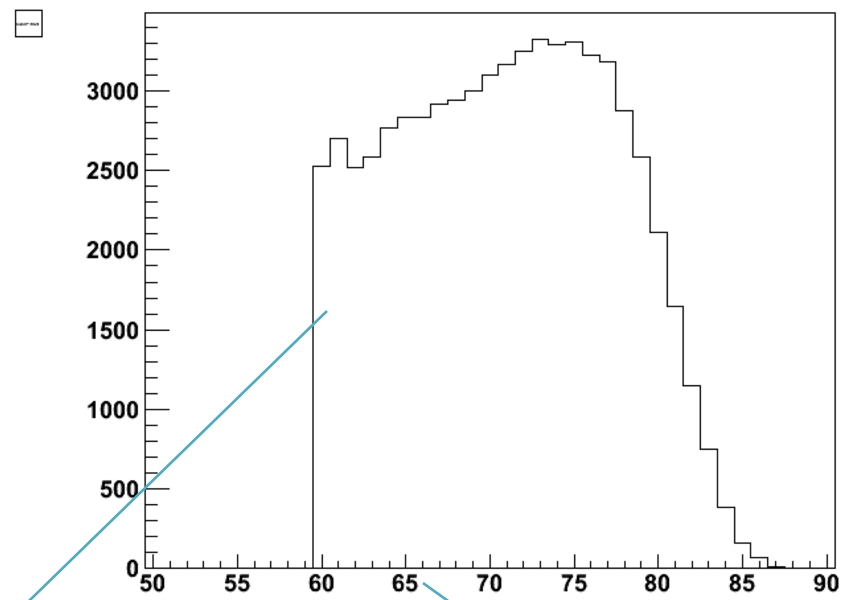
NA49: PRC 89 (2014), 054902

20A GeV Pb+Pb collisions



PID Technique, EPIZODE I





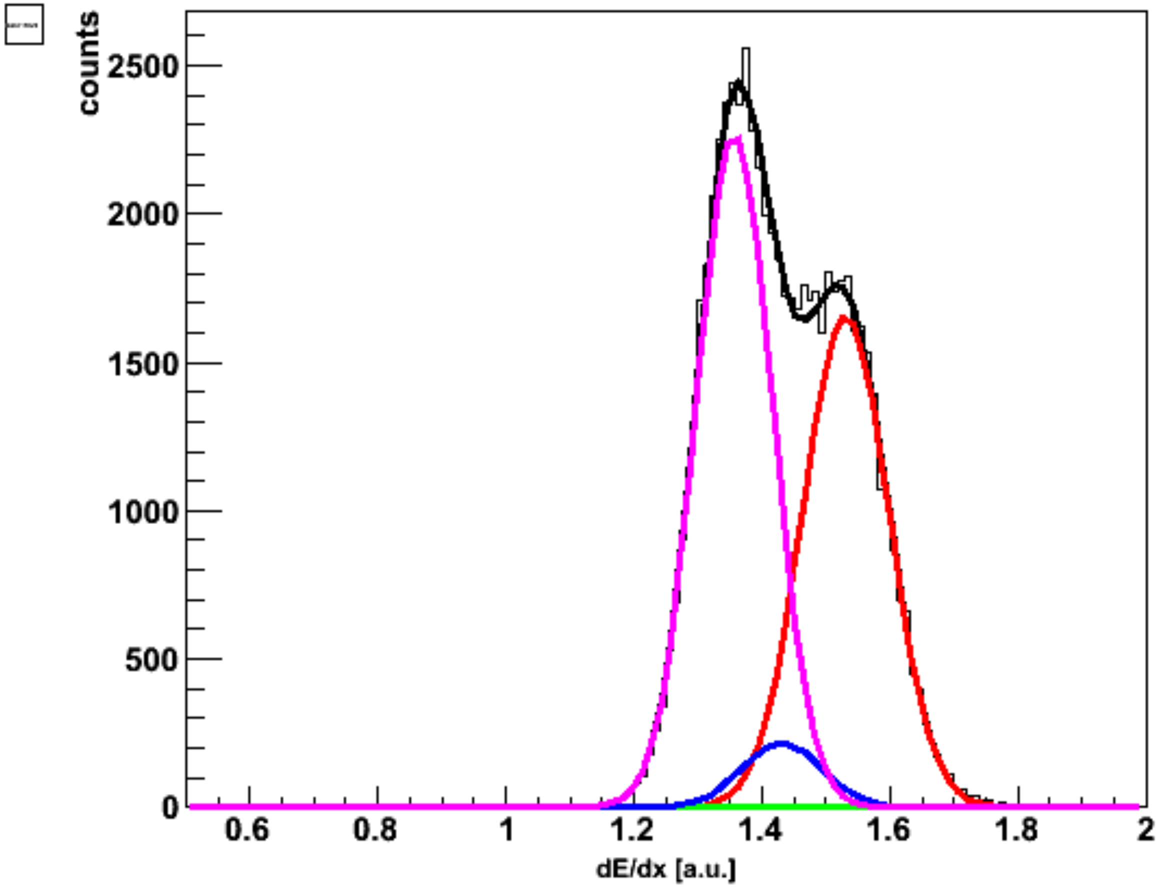
$$F(x) = \sum_{i=p,K,\pi,e} A_i \cdot e^{-\frac{1}{2}\left(\frac{x-\bar{x}_i}{\sigma_i}\right)^2}$$

$$F(x) = \sum_i A_i \cdot \frac{1}{\sum N_k} \sum \frac{N_k}{\sqrt{2\pi}\sigma_k^i} e^{-\frac{1}{2}\left(\frac{x-\bar{x}_i}{\sigma_k^i}\right)^2}$$

$$\sigma_k^i = \sigma_0 \cdot \left(\frac{\bar{x}_i}{\bar{x}_\pi}\right)^{0.625} \cdot (1 \pm \delta) \cdot \frac{1}{\sqrt{n_k}}$$

10 independent parameters

PID Technique, EPIZODE II



$$F(x) = \sum_{i=p,K,\pi,e} A_i \cdot e^{-\frac{1}{2}\left(\frac{x-\bar{x}_i}{\sigma_i}\right)^2}$$

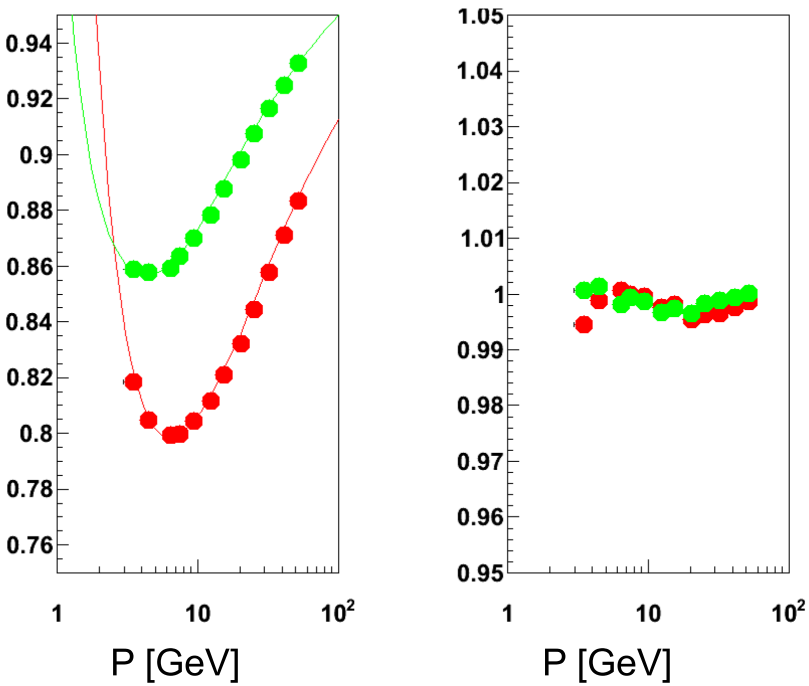
12 independent parameters
(in general no way to fit)

$$\sigma_i = \bar{x}_i \cdot \sqrt{\sigma_0}$$

9 independent parameters

EPIZODE I vs. EPOZIDE II, positives

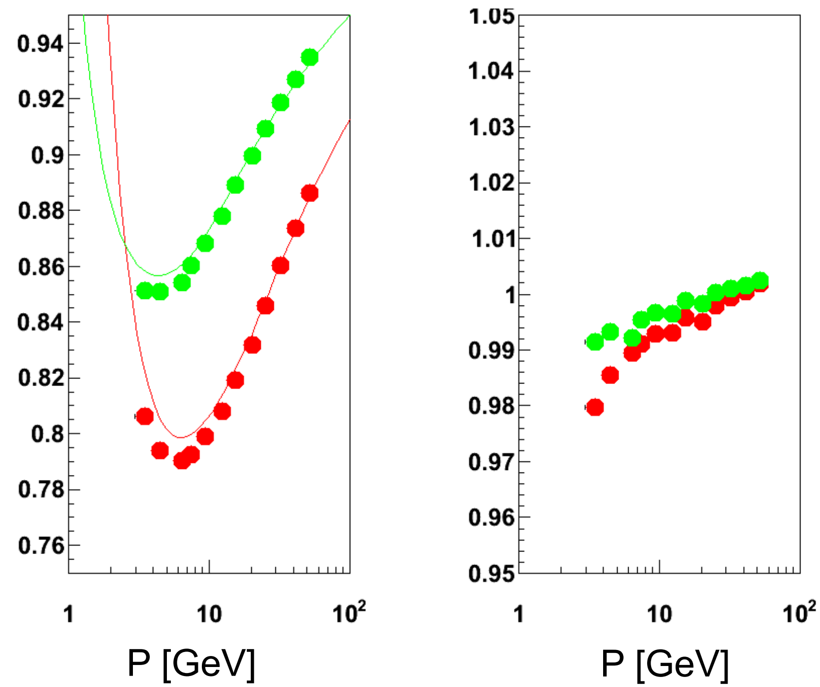
Episode I



Comparison of fitted positions to Bethe-Bloch curve

proton over pion and kaon over pion

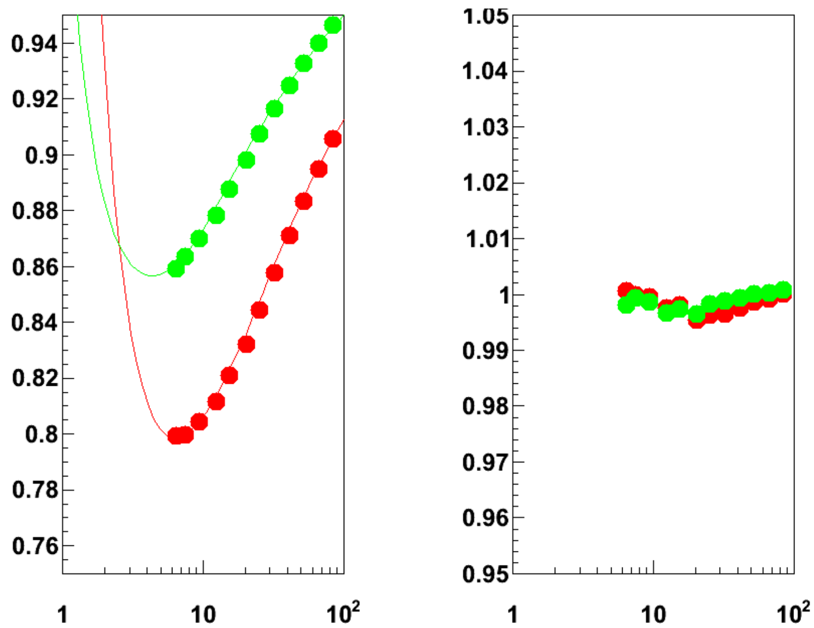
Episode II



Comparison of fitted positions to Bethe-Bloch curve

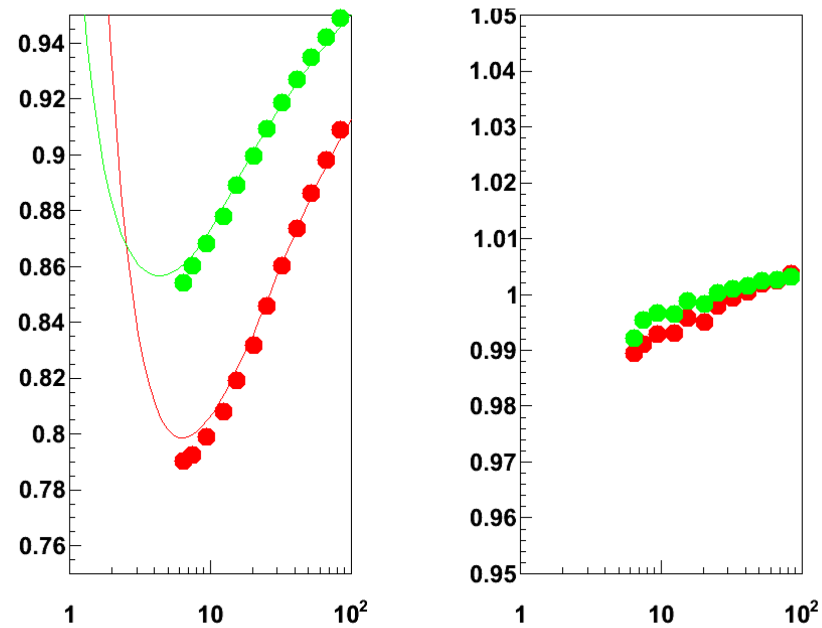
proton over pion and kaon over pion

EPIZODE I vs. EPOZIDE II, negatives



Comparison of fitted positions to Bethe-Bloch curve

similar to previous slide



Comparison of fitted positions to Bethe-Bloch curve

similar to previous slide

Separation Power