Hadron Production Ratio in Au+Au Collisions at RHIC-PHENIX

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- –Motivation
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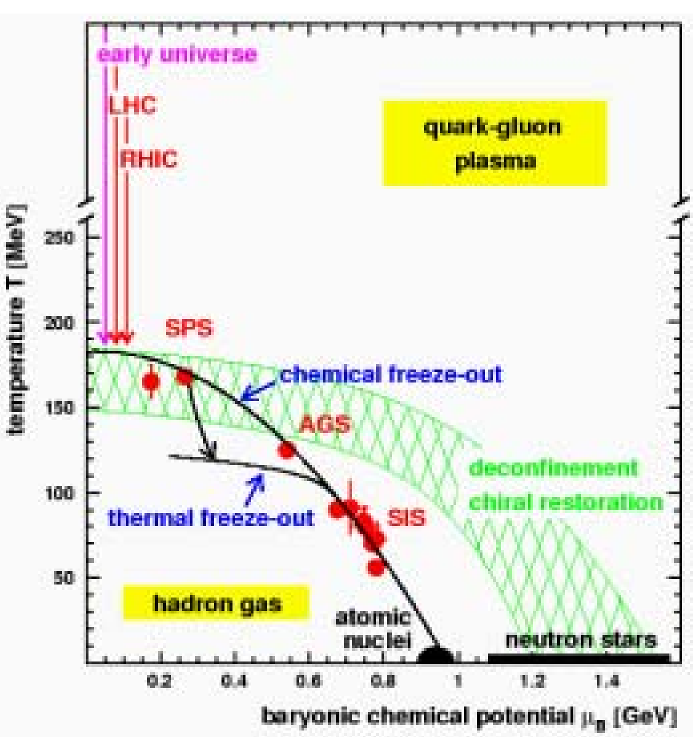
- –Status of hadron analysis in Au+Au at $\sqrt{s_{NN}} = 200\text{GeV}$ [Run-2]
- –Conclusion

Motivation

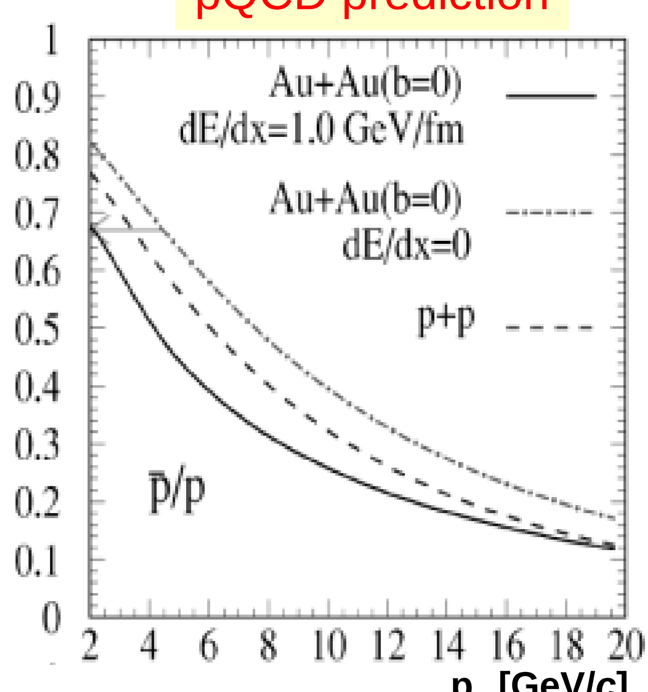
What do we learn from particle ratio?

- **Soft process**
  - Chemical freeze-out Temperature T_{ch}
  - Chemical potential μ_B, μ_s
    - SPS : T_{ch} **~ 170MeV,** μ_B **~ 270MeV**
    - AGS : T_{ch} **~ 130MeV,** μ_B **~ 500MeV**
  - Degree of baryon stopping power.

- **Hard process**
  - Contain earliest stage of collision.
  - Parton energy loss in hot and dense matter.
    - pbar/p ratio decreases with p_T.
    - Jet quenching moves the pbar/p ratio even below the pp value.

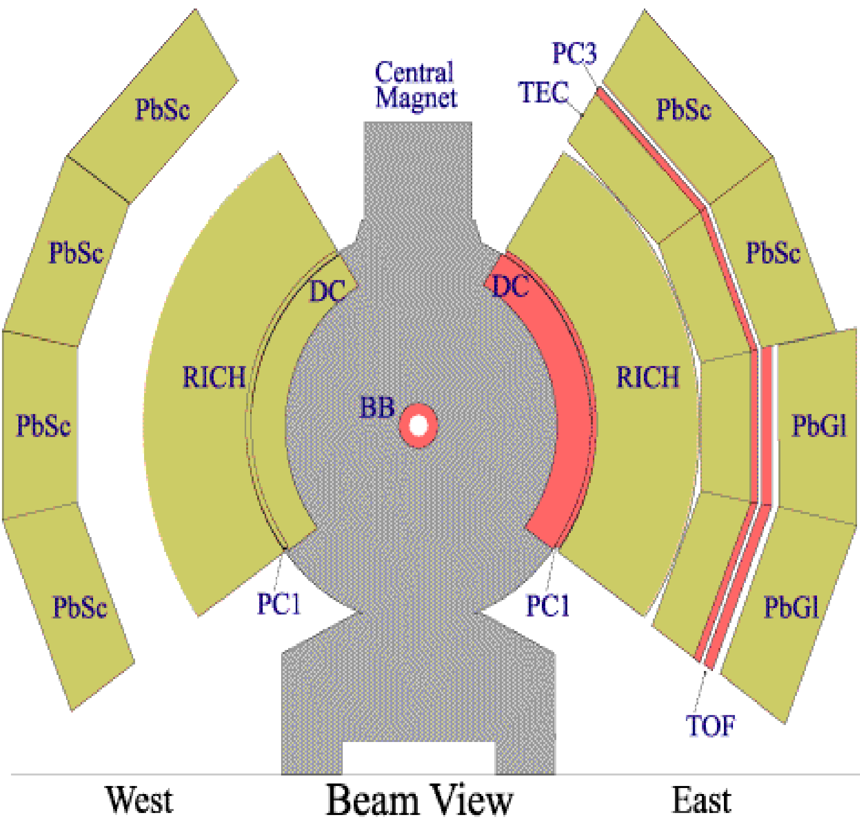


pQCD prediction



X.N.Wang, PRC58(1998)2321

PHENIX Detectors



In this analysis, we use

Beam-Beam Counter (BBC)
- *z vertex, start timing for TOF*

Time-of-Flight (TOF)
- *stop timing measurement*

Drift Chamber (DC)
- *momentum, flight path length*

Pad Chamber 1 (PC1)
- *additional track z information*

- **Momentum resolution :**
  $\delta p/p = 0.6\ \% \oplus 3.6\%\ p$ [GeV/c] (Run1)
- **TOF resolution : ~100 ps (Run1)**
- **Acceptance:**
  $\Delta\phi = 45$ deg
  $\Delta\eta = 0.7\ (\pm 0.35)$

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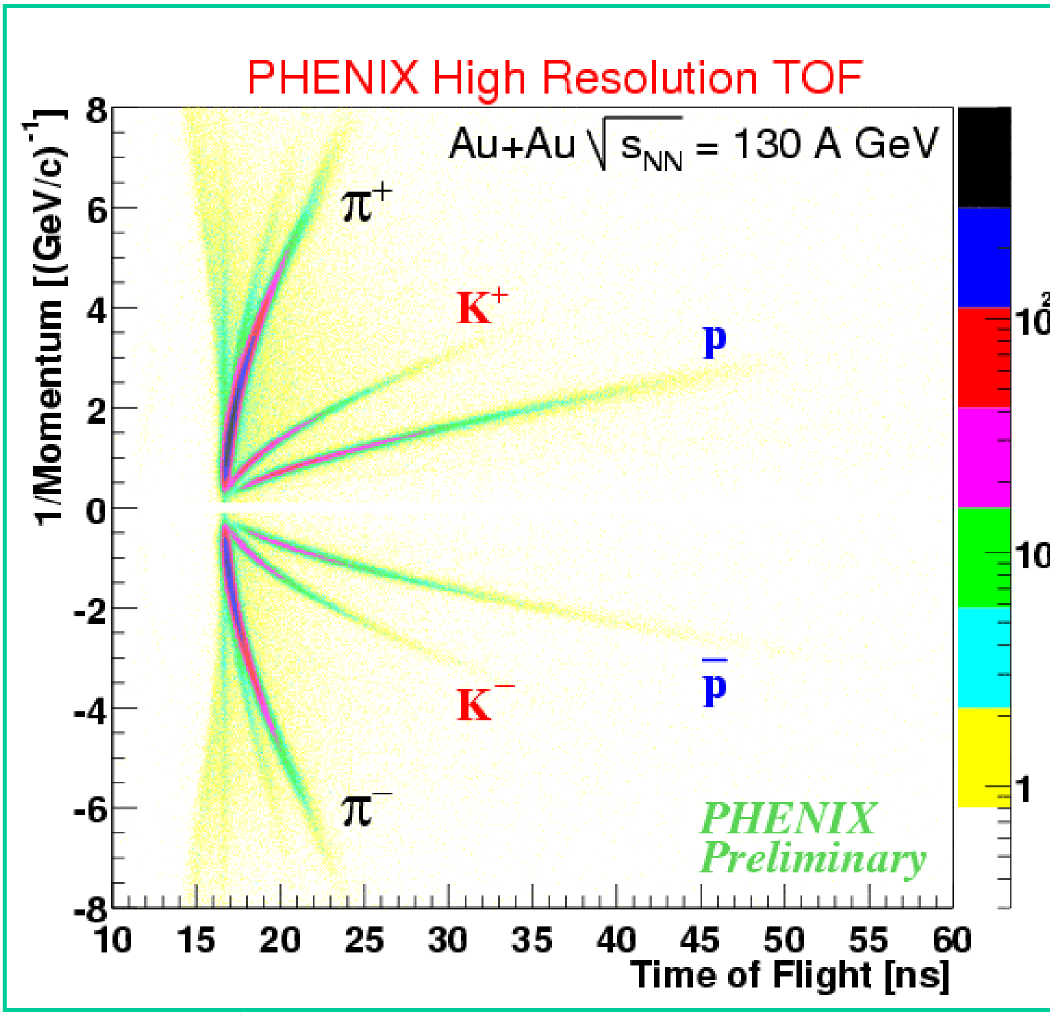
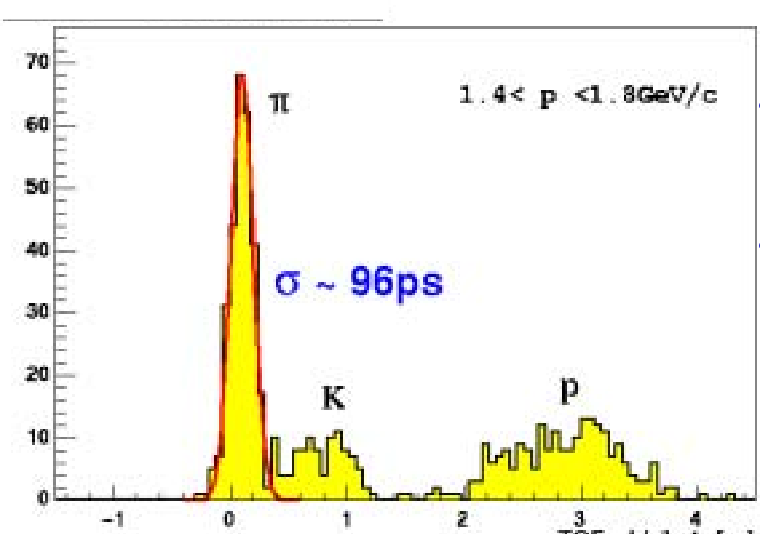
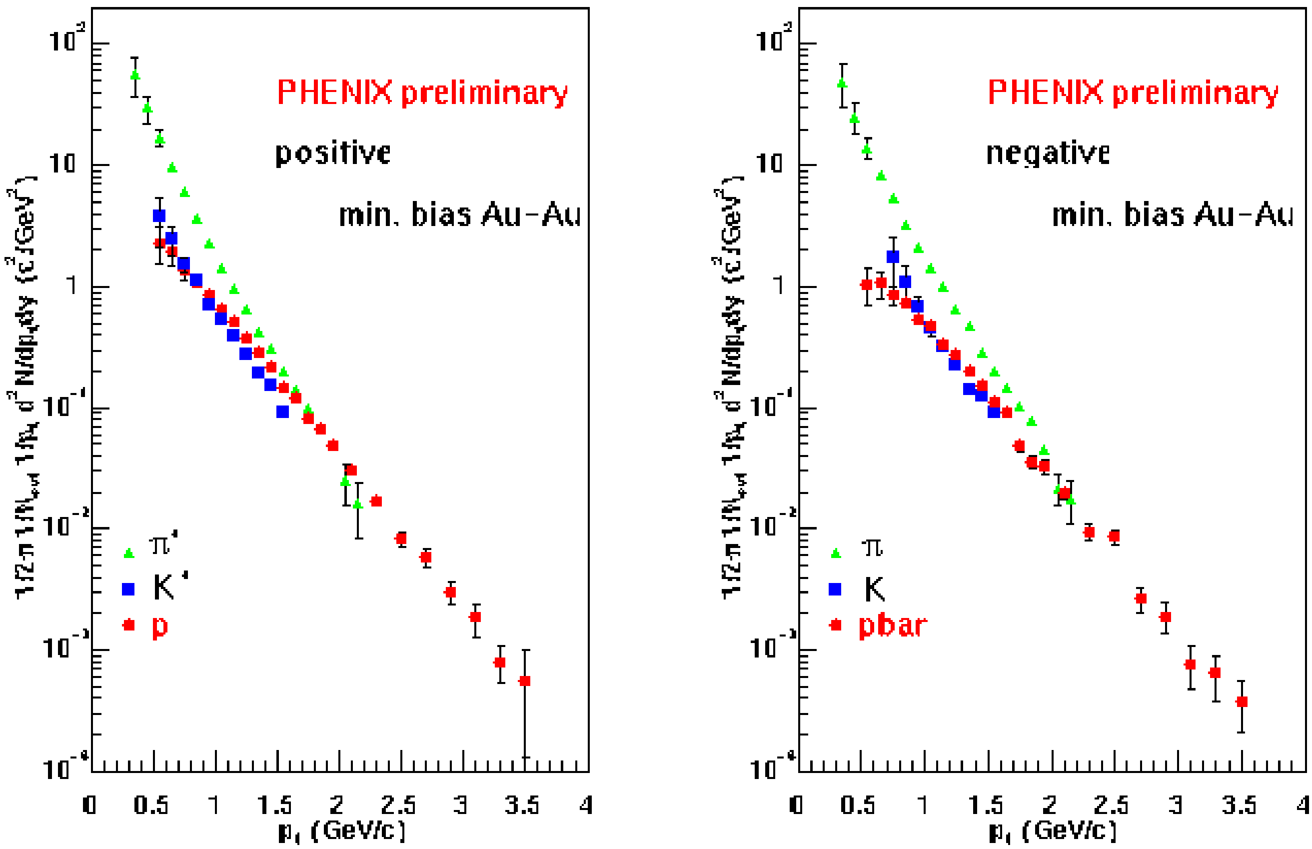
Particle Identification by TOF





- We can see clear π,K,p separation
- Particle separation
  - π/K < 2.0GeV/c
  - proton < 3.5GeV/c

Identified Particle Spectra at $\sqrt{s_{NN}} = 130\mathrm{GeV}$

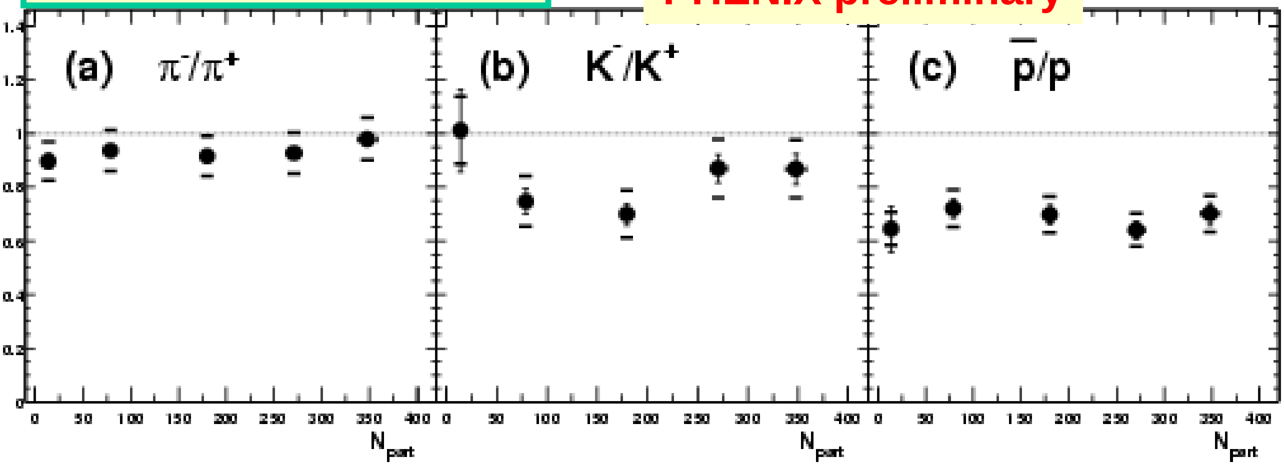


- Single particle spectra of pion, kaon, proton and their anti particles.

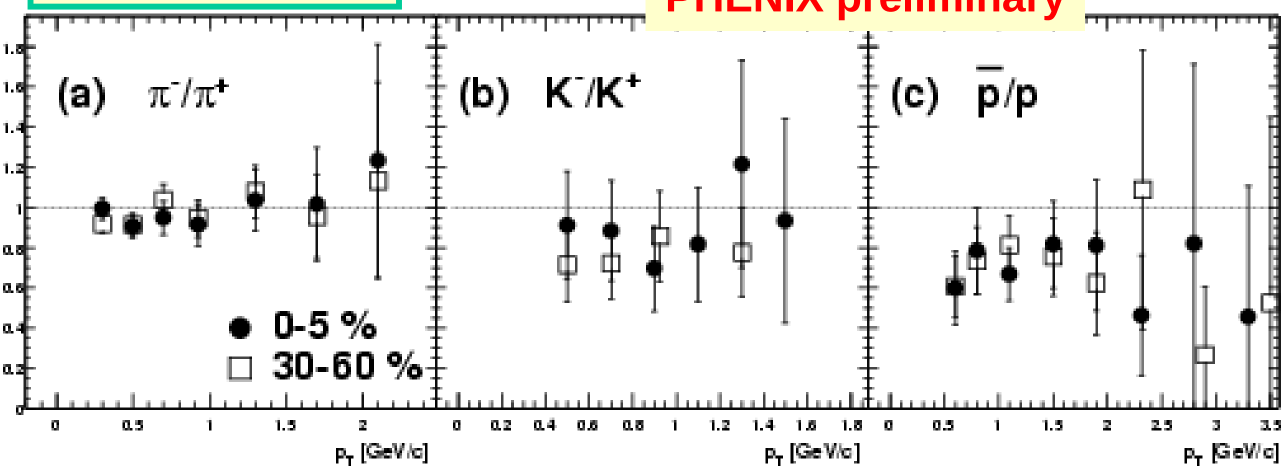
- Au+Au collisions at $\sqrt{s_{NN}} = 130\mathrm{GeV}$
  - Minimum bias data.

Anti-particle/particle ratios at $\sqrt{s_{NN}} = 130\text{GeV}$

Centrality dependence



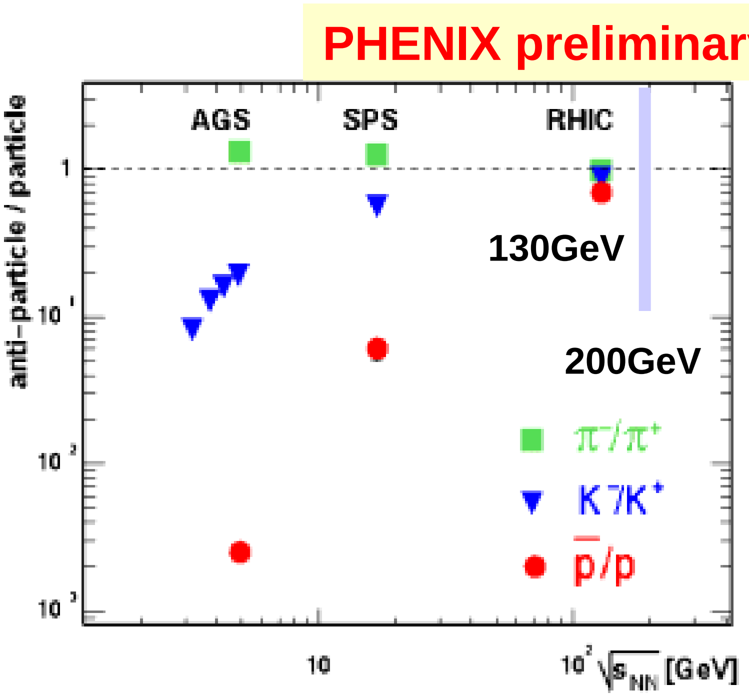
p_T dependence

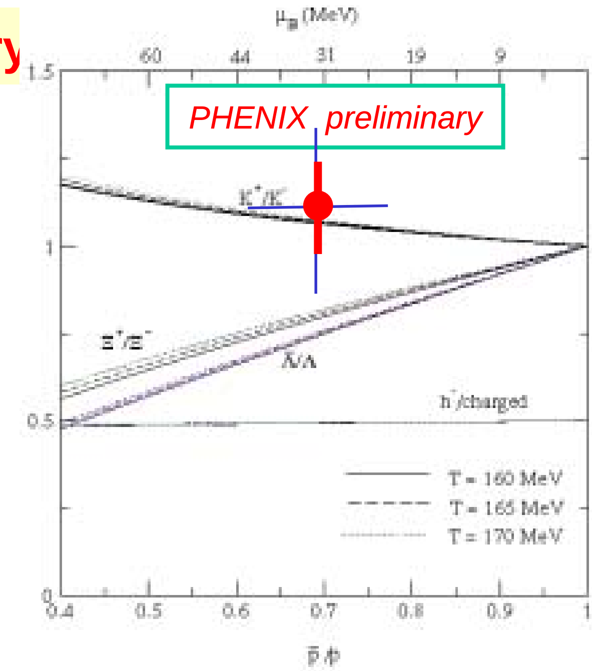


- No clear dependence as a function of centrality and p_T.

- π^-/π^+ **@5%central = 0.98 ±0.02(stat.) ±0.08(syst.)**
- K^-/K^+ **@5%central = 0.87 ±0.06(stat.) ±0.11(syst.)**
- $\bar{p}/p$ **@5%central = 0.70 ±0.04(stat.) ±0.07(syst.)**

Beam energy dependence



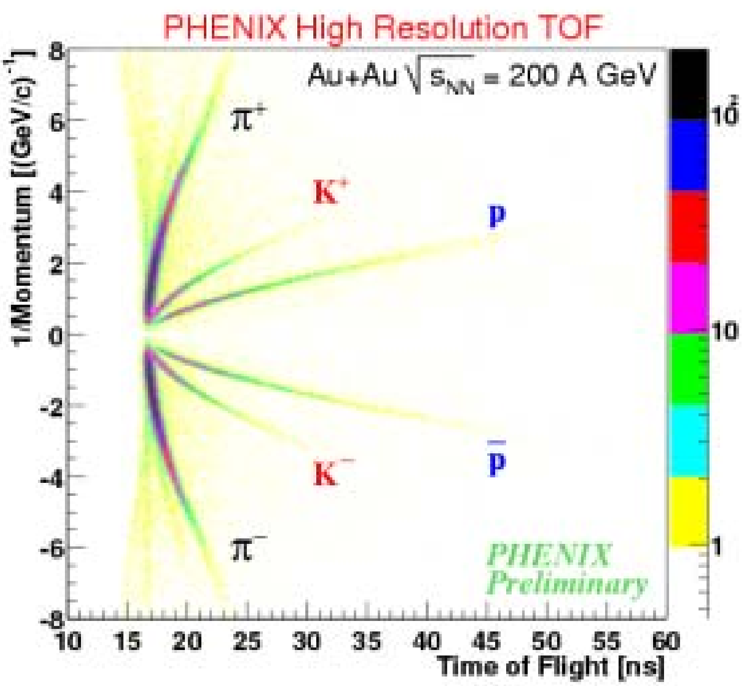


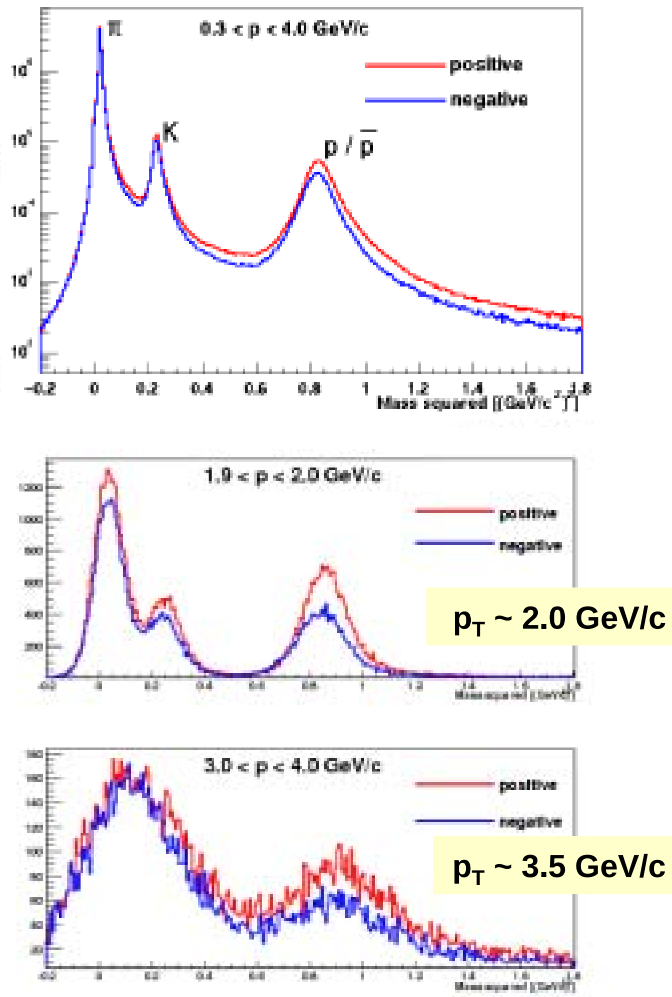
F.Becattini et al. Phys.Rev.**C60**,024901(2001)

- No strong energy dependence in π^-/π^+ ratio.
- K^-/K^+ and $\bar{p}/p$ ratios increase from SPS and AGS.
- Comparison with Thermal model:
  - Baryon chemical potential.: μ_B **~ 35MeV ±10MeV**
  - not baryon free at mid rapidity.
- Other Thermal Model calculation
  - P.Braun-Munzinger et al. Phys.Lett.B.518 41(2001)
  - **T_{ch} ~ 174MeV, μ_B ~ 46MeV**
  - Use result from RHIC four experiments.

- How about Au+Au 200GeV → analysis is on going
  - Close to baryon free? Temperature?

Status of Run-2 Analysis





- **Au+Au at** $\sqrt{s_{NN}} = 200\mathrm{GeV}$
- ~**92 million** minimum bias events.

- DST production is on going. about **15M** events are processed.

- **π/K separation ~ 2.0 GeV/c**
- **K/p separation ~ 4.0 GeV/c**

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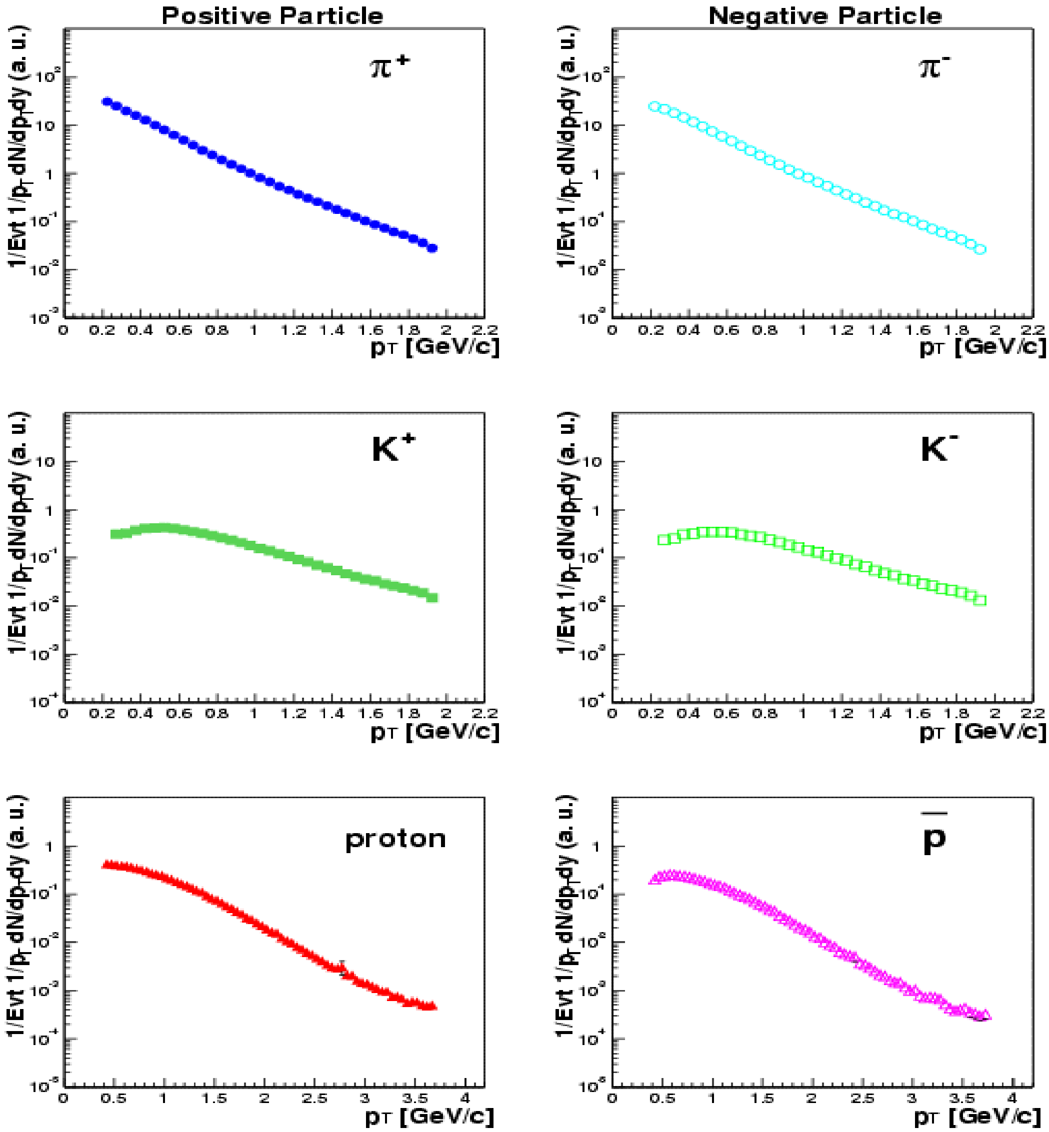
Un-corrected p_T spectra



- Acceptance, efficiency and decay corrections are not applied.
- Enough statistics at high p_T region.
  - proton, pbar candidate @3.0GeV/c<p_T<4.0GeV/c
    - **Run2 : ~5K count** (in15M events) → **~30K** in full event
    - **Run1 : ~0.1K count**
  - Increase the statistics by few hundred.

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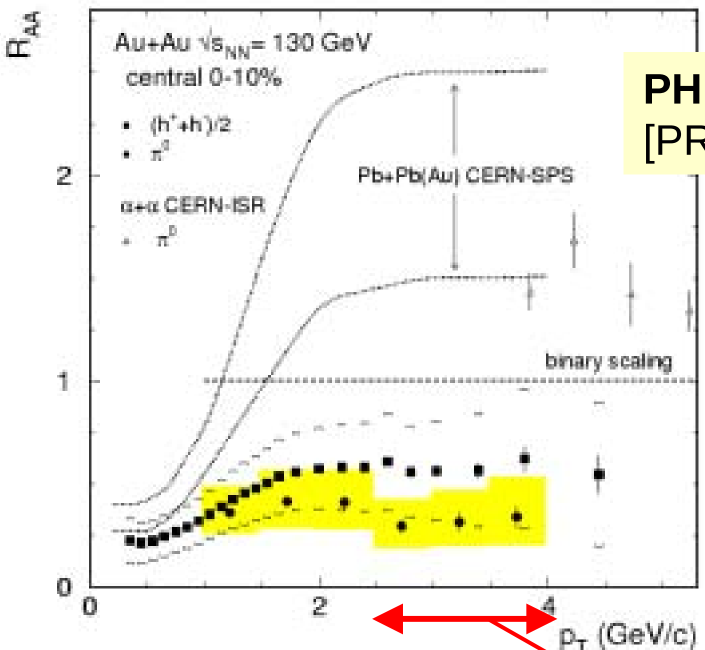
Hadron at high-p_T region

Result from Au+Au at $\sqrt{s_{NN}} = 130\text{GeV}$

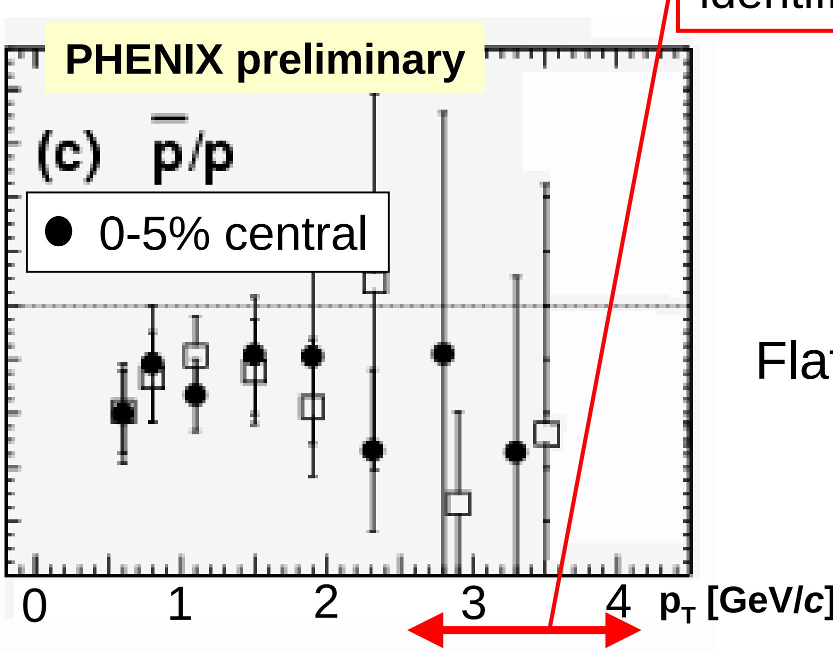
$$R_{AA} = \frac{\text{Yield}_{central} / \langle N_{coll} \rangle_{central}}{\text{Yield}_{pp}}$$



PHENIX published
[PRL88, 022301(2002)]

Different suppression for **h**$^{\pm}$ and π^0

We get enough statistics of identified hadron in Run-2



Flat or Falling?

- **PHENIX has ~300 more statistics in Run-2**

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Conclusion

Particle ratios in Au+Au collisions at 130GeV

- No clear centrality and p_T dependence.
- Particle ratio at 5% most central event
  - π^-/π^+ = 0.98 ± 0.02(stat.) ± 0.08(syst.)
  - K^-/K^+ = 0.87 ± 0.06(stat.) ± 0.11(syst.)
  - $\bar{p}/p$ = 0.70 ± 0.04(stat.) ± 0.07(syst.)
- Baryon density at RHIC is much less than AGS and SPS, but not baryon free at mid rapidity.
  - Thermal Model : T_{ch} ~ 174MeV, μ_B ~ 46MeV

Outlook for Au+Au collisions at 200GeV

- Precise measurement of hadron yield and spectra.
- Hadron suppression at high-p_T.
- pbar/p ratio up to 4.0GeV/c.
- Comparison with p+p collisions at 200GeV.

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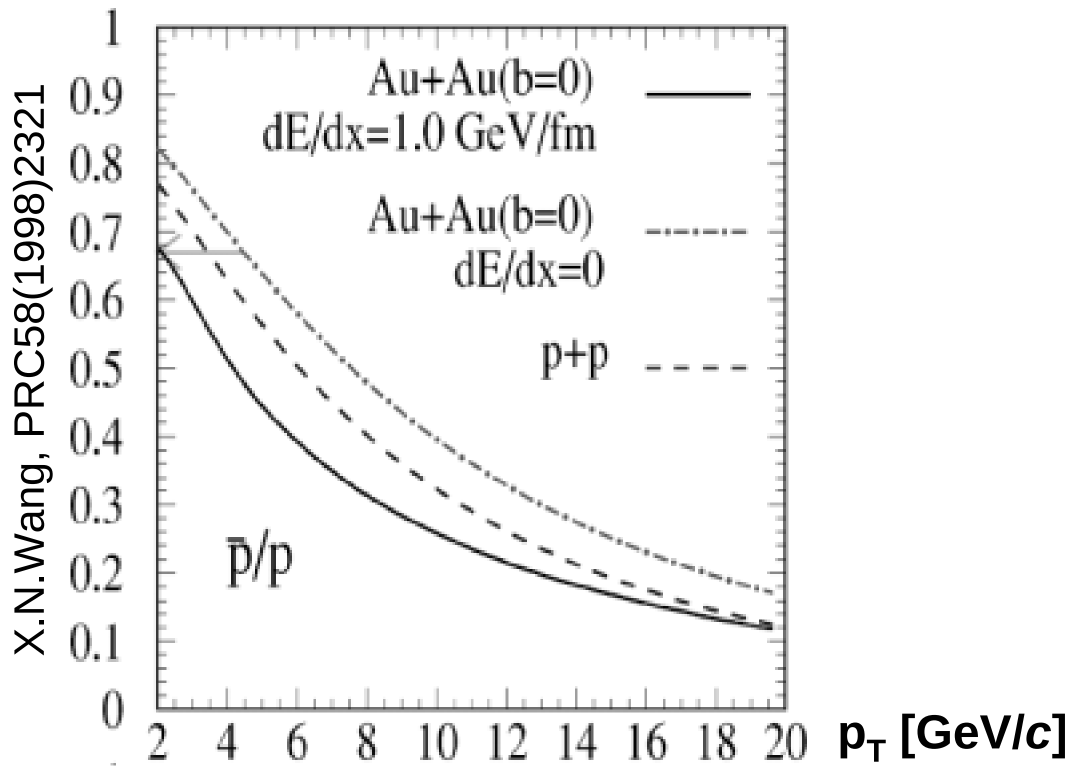
Backup Slides

Spare

Motivation (Hard process)

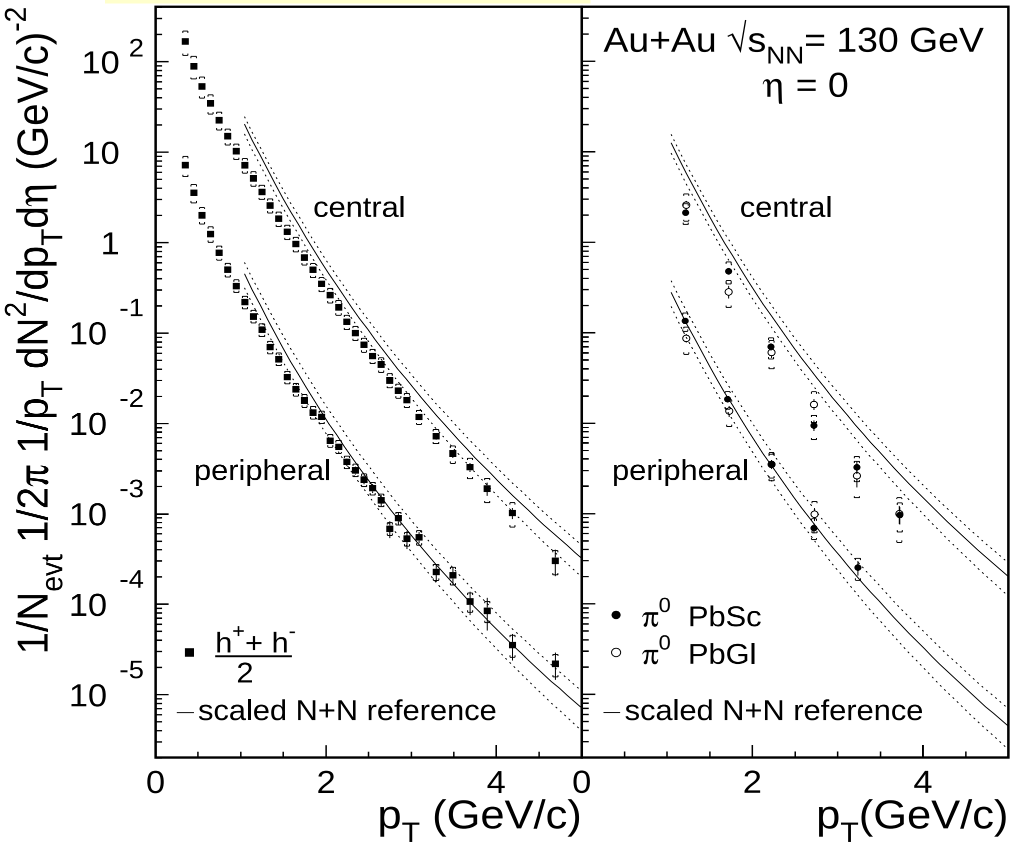


Theory prediction

- (u,d) quark jets likely produce a leading proton than antiproton.
  - Ratio decreases with pt.
- Gluon jets produce the same number of proton and antiproton with softer distribution.
  - At high pt, most of antiproton from gluons, while proton from both valence quark and gluon fragmentation.
  - If gluon jets lose more energy, then ratio behavior modified.

Compare $h^{\pm}$ and π^0

PHENIX published
[PRL88, 022301(2002)]



- Peripheral collisions
  ~ p-p scaled by <N bin coll> = 20 ± 6
- Central
  - Different shape for **h** and π^0
  - Below scaled p-p
  - <N bin coll> = 905 ± 96

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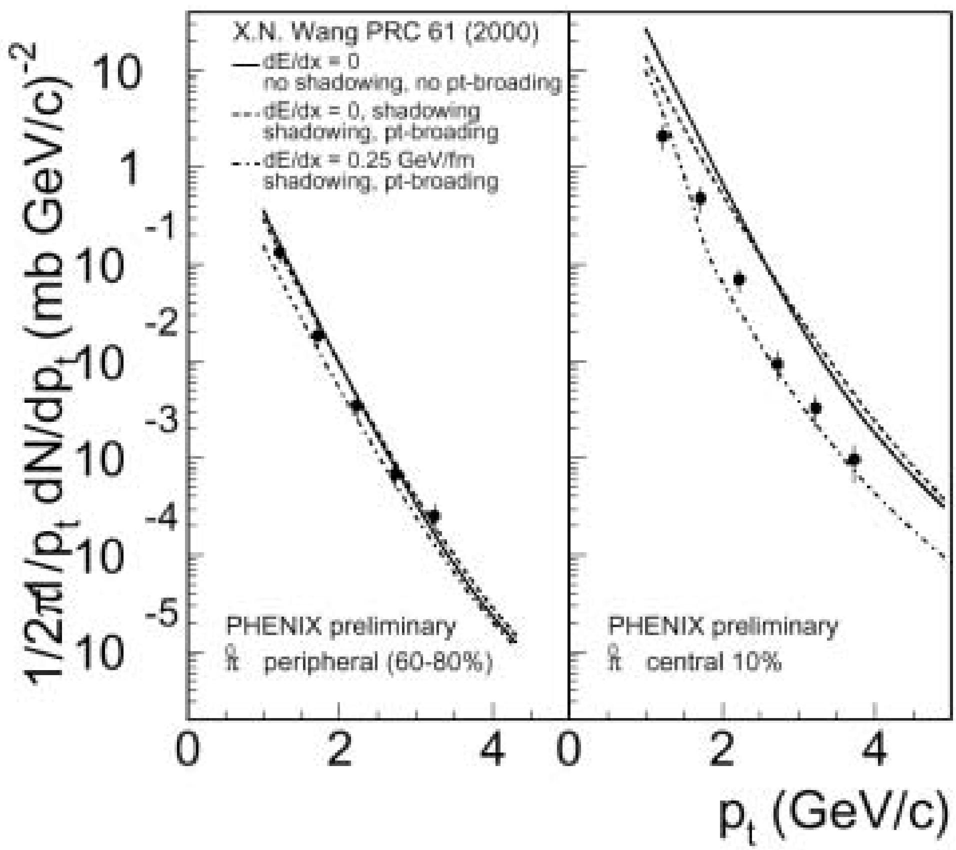
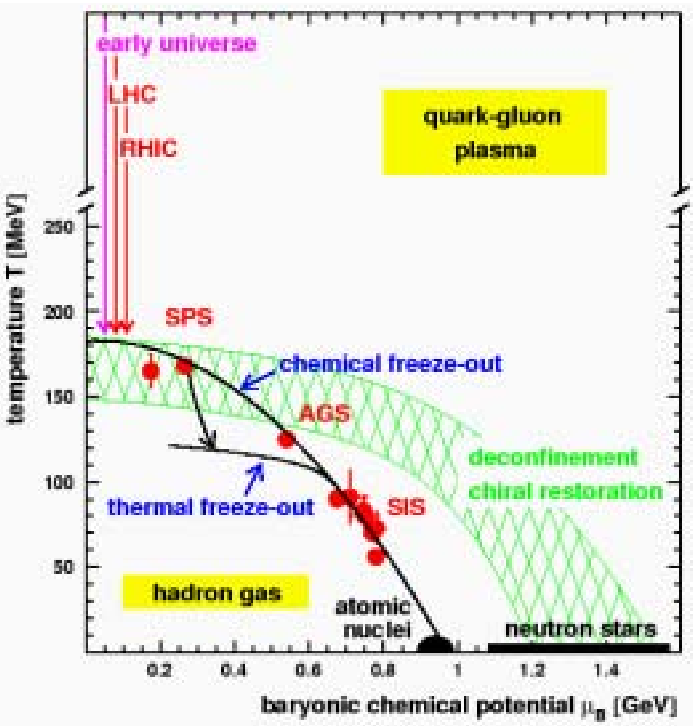
Jet Quenching via p_T distribution



- One straight way to see the effect
  - Extend the pt range helps!
  - May be difficult when the other effects involved

Motivation (Soft process)



From previous experiment

- SPS : T_{ch} ~ 170MeV
  μ_B ~ 270MeV
- AGS : T_{ch} ~ 130MeV
  μ_B ~ 500MeV

- Result from SPS and AGS
  - In agreement with predictions of a thermal model assuming chemical equilibration.
- Is the chemical equilibrium at RHIC energy?
  - If there, how about temperature and chemical potential.

- What do we learn from particle ratio?
  - **Chemical freeze-out Temperature T_{ch}**
  - **Chemical potential μ_B, μ_s**
  - **Degree of baryon stopping power**

Ratios contain basic information about collision dynamics

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Particle-ratio

Particle Density

$$\rho = \gamma^{|s|} \frac{g}{2\pi^2} \int_0^\infty \frac{p^2 dp}{\exp\left[(E-\mu)/T_{ch}\right] \pm 1}$$

γ : Strangeness suppression factor
g : spin-isospin freedom

$$\mu = B\mu_B + s\mu_s$$

B : Baryon number
s : Strange quantum number

μ_B : Baryon chemical potential
μ_s : Strange chemical potential

Particle Ratio

Example:

$$\frac{\bar{p}}{p} = \exp(-2\mu_B / T_{ch})$$

$$\frac{K^-}{K^+} = \exp(-\tfrac{2}{3}\mu_B / T_{ch}) \exp(2\mu_s / T_{ch})$$

$$\frac{\Lambda^-}{\Lambda^+} = \exp(-\tfrac{4}{3}\mu_B / T_{ch}) \exp(-2\mu_s / T_{ch})$$

- What do we learn from particle ratio?
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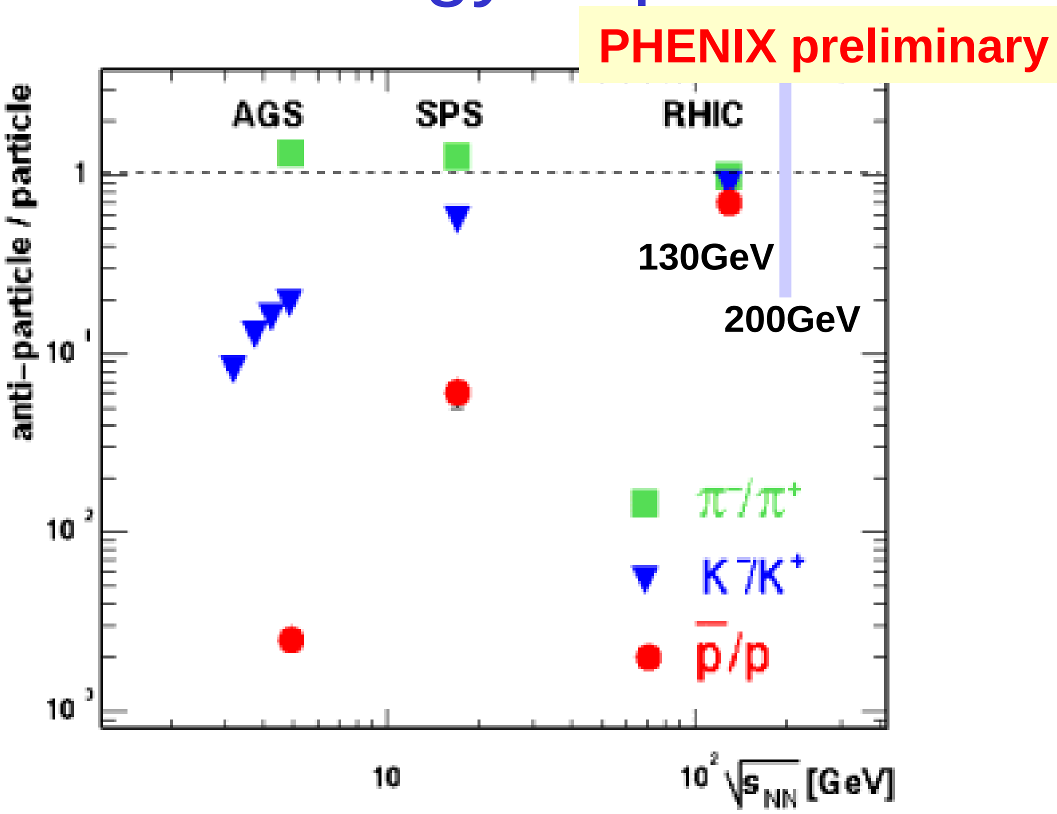
Beam energy dependence



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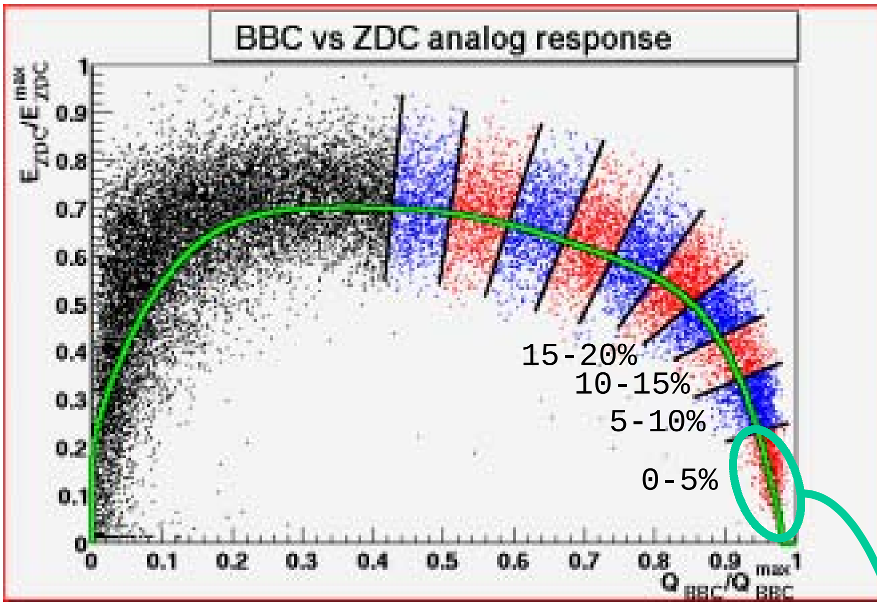
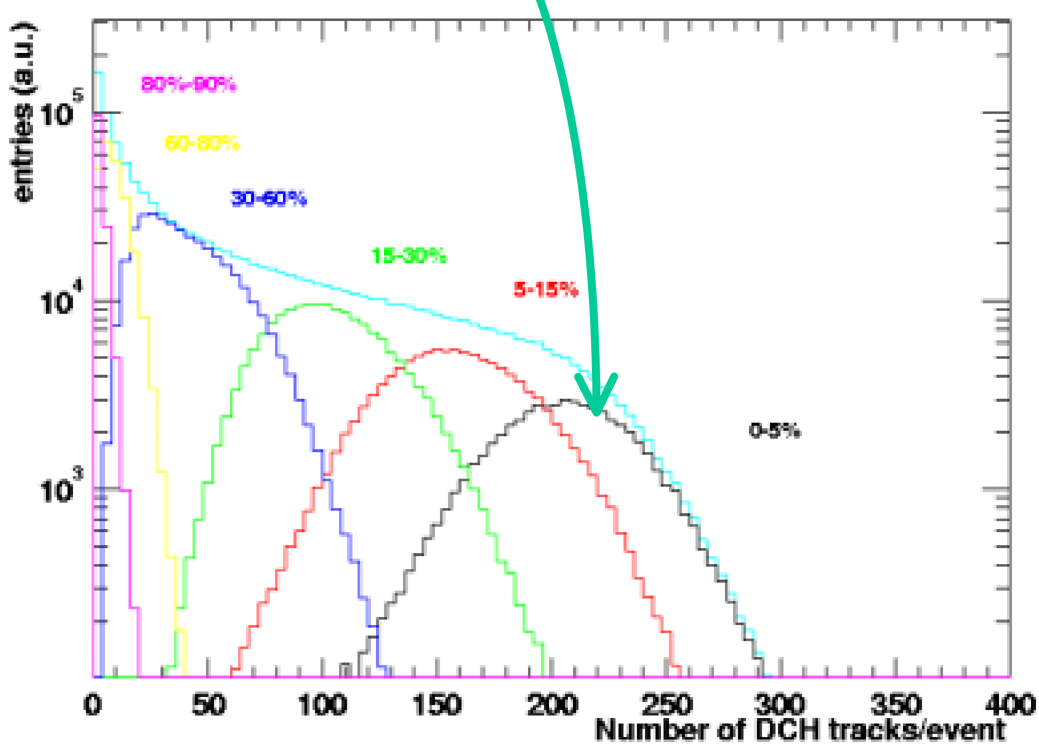
Centrality Selection



Centrality	Participants
0-5%	347 ± **15%**
5-15%	271 ± **15%**
15-30%	178 ± **15%**
30-60%	76 ± **15%**
60-80%	19 ± **60%**
80-92%	5 ± **60%**



- Use combination of BBC charge and ZDC energy.
- Extract N_{part} based on Glauber model.

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