QM2005 Review

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- NEWs from SPS (NA60)
  - $\mu\mu$ & J/Ψ production from InIn@158 AGeV
- NEWs from RHIC
  - Run-4 AuAu@200,62 AGeV
  - Run-5 CuCu@200,62,22 AGeV
- 25 experimental & 14 theoretical plenary talks
- 60 experimental & 55 theoretical parallel talks

- Signals of the 1st Order Phase Transition
- Properties of the Quark Matter beyond T_C

Signals of the 1st Order Phase Transition

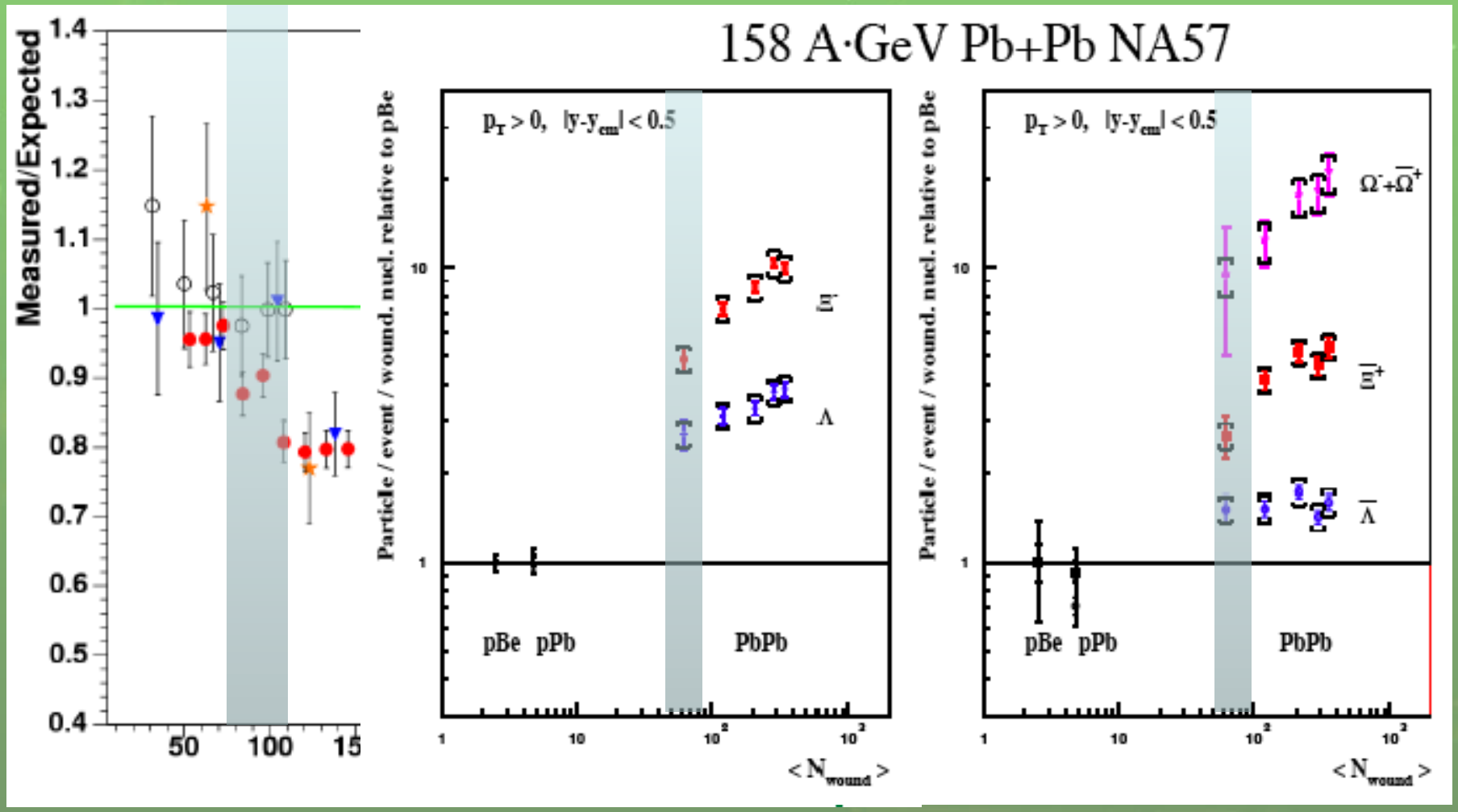
- J/Ψ Suppression at SPS
- Strangeness Enhancement at SPS
- Fluctuations etc.

Properties of the Quark Matter beyond Tc

- CuCu vs. AuAu
- Flow
- High p_T Suppression
- Heavy Quark
- J/Ψ at RHIC
- Jets Tomography
- Low-Mass Pairs, Open Charm, Direct Photons

Signals of the 1st Order Phase Transition

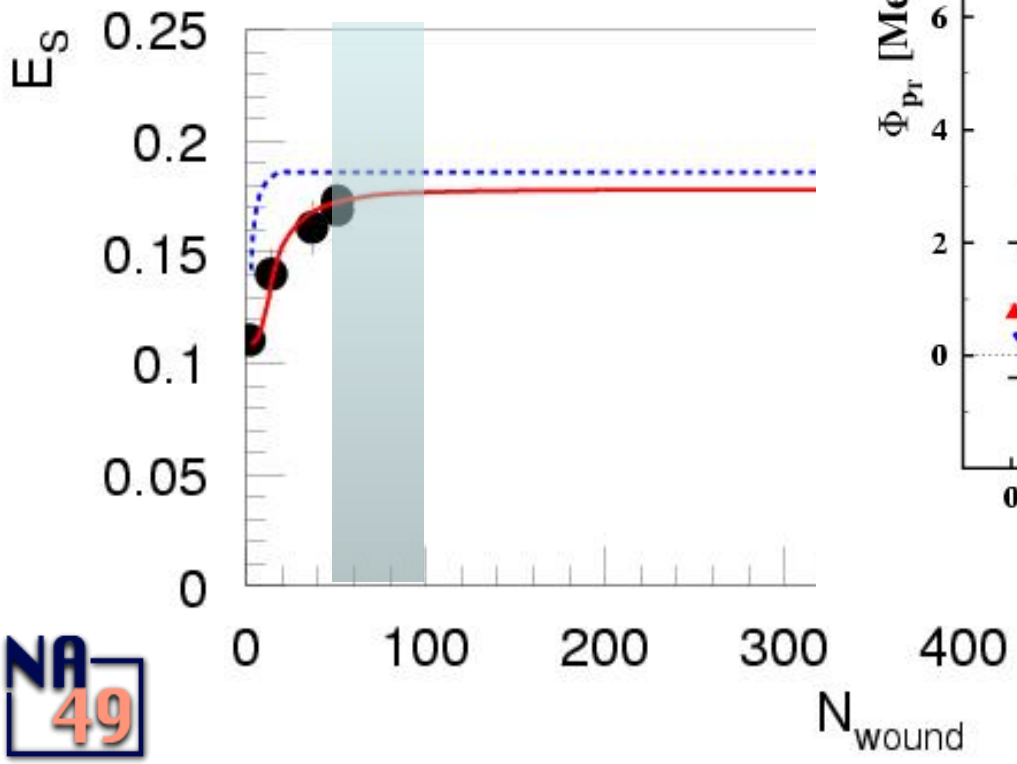
- J/Ψ Suppression at SPS
- Strangeness Enhancement

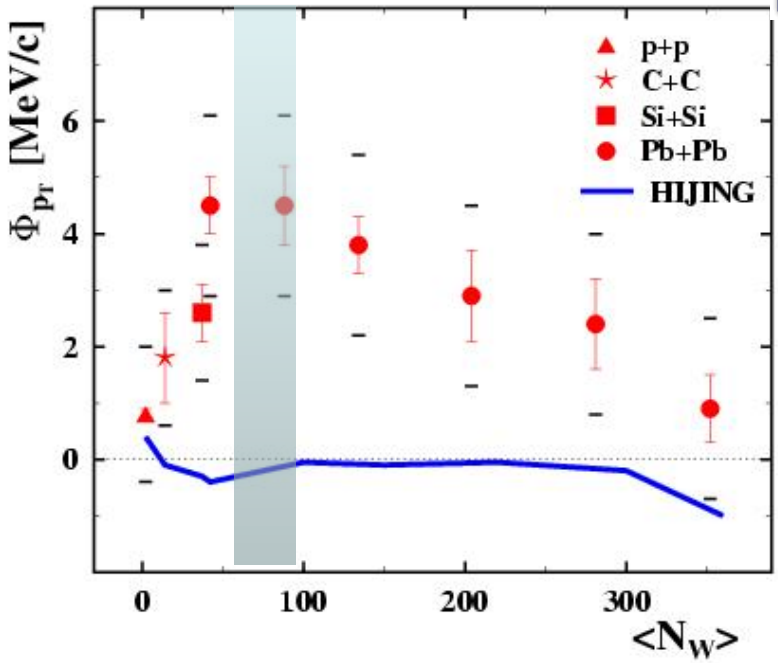


Signals of the 1st Order Phase Transition

- Strangeness Evolution
- Fluctuation

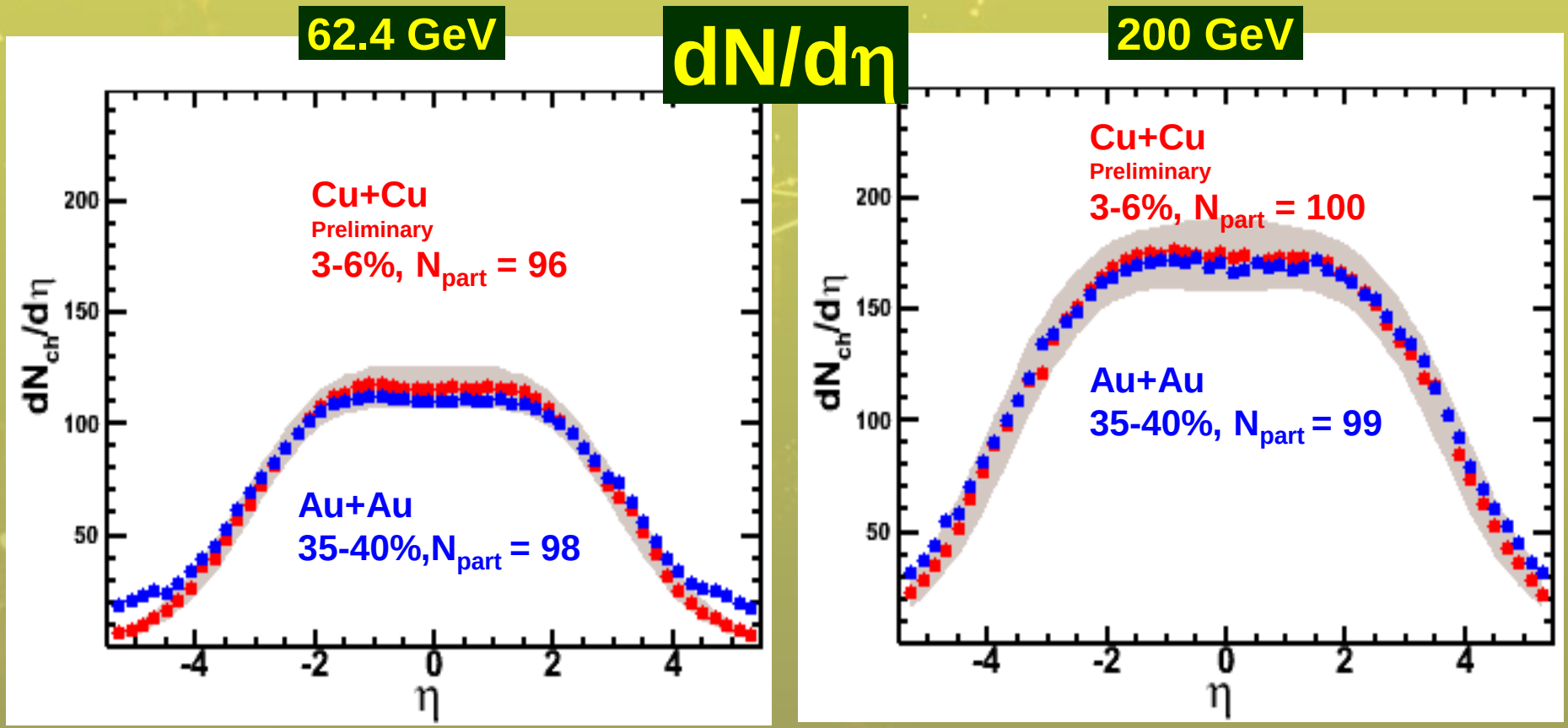
$$E_s = \frac{\langle \Lambda \rangle + 2\left(\langle K^+ \rangle + \langle K^- \rangle\right)}{\langle \pi \rangle}$$





Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy

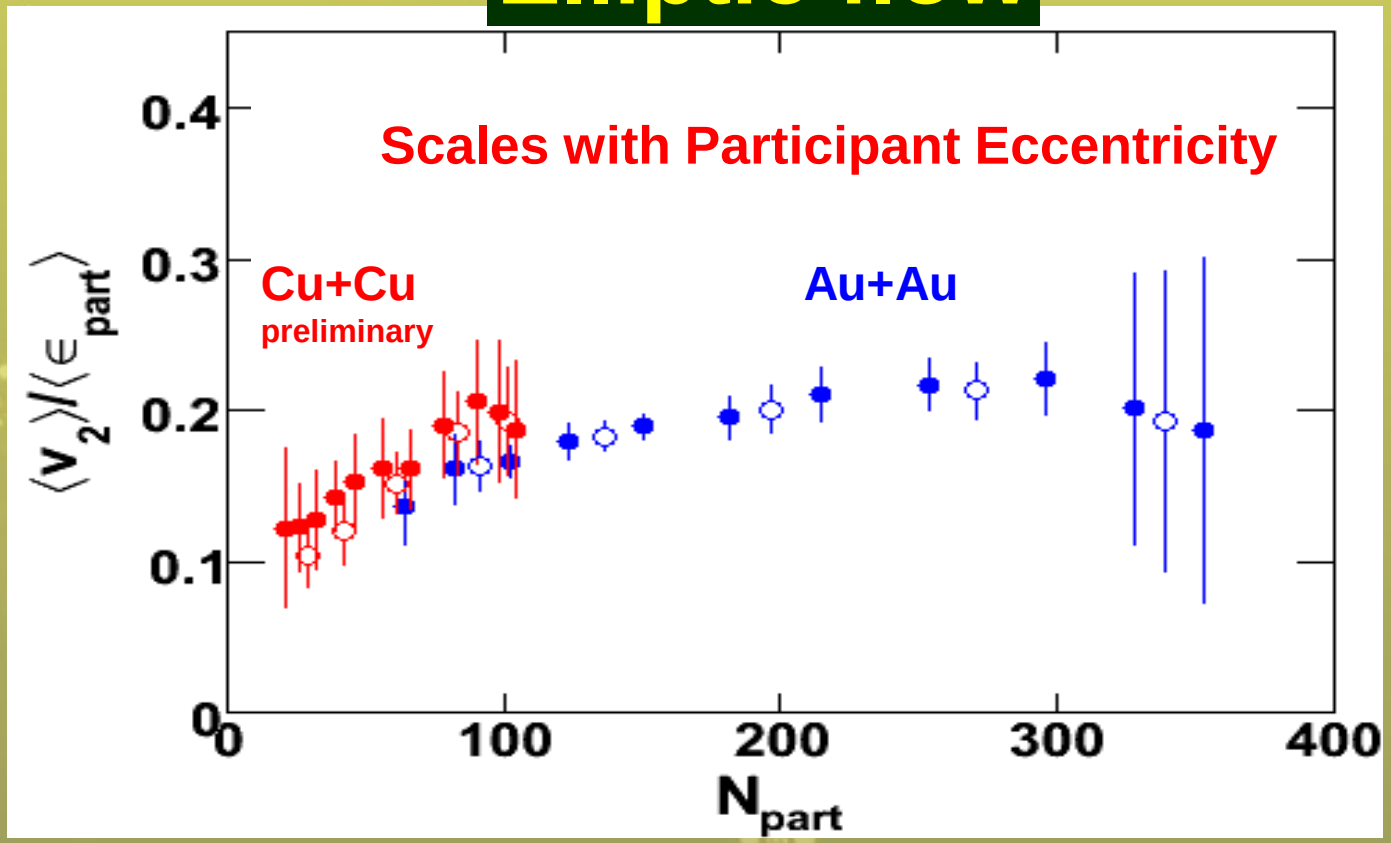


dN/dη scales with N_{part}

Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy

Elliptic flow

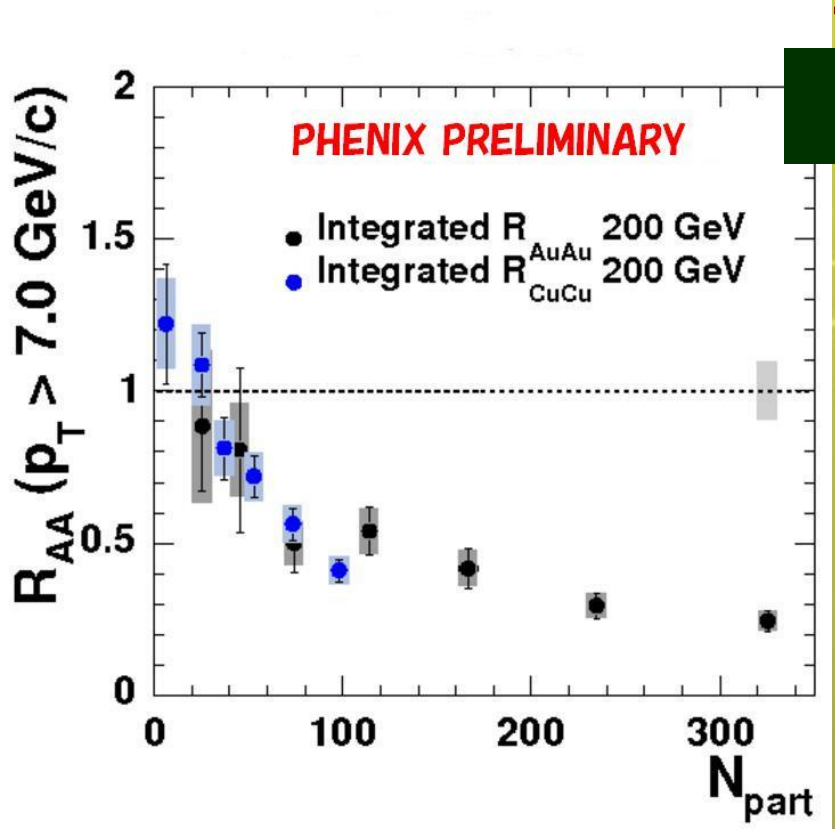


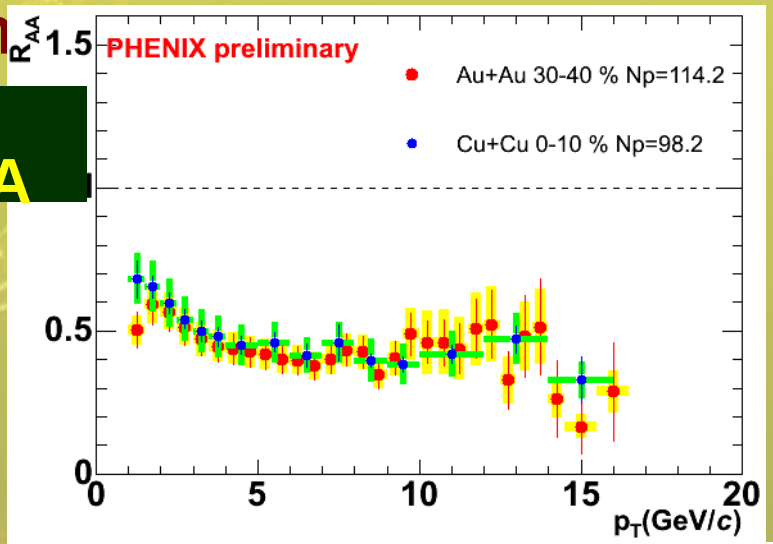
Elliptic flow scales with participant eccentricity

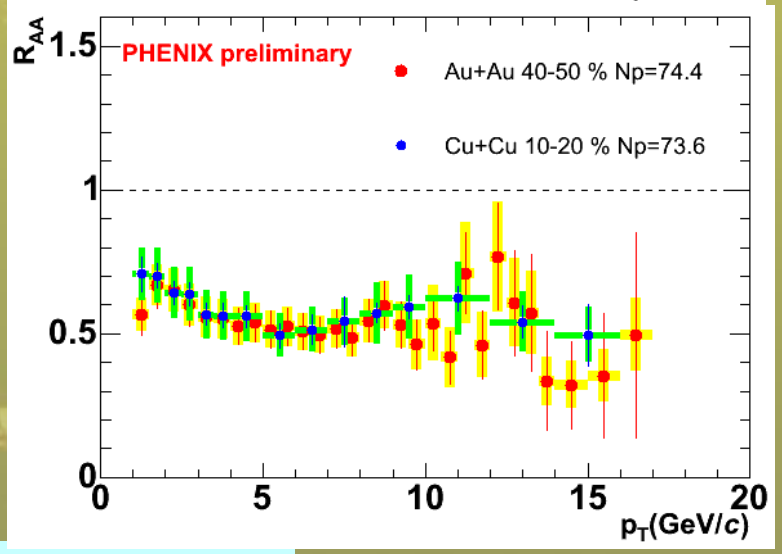
Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system

R_{AA}







Same behavior for same N_{part} but better accuracy in CuCu

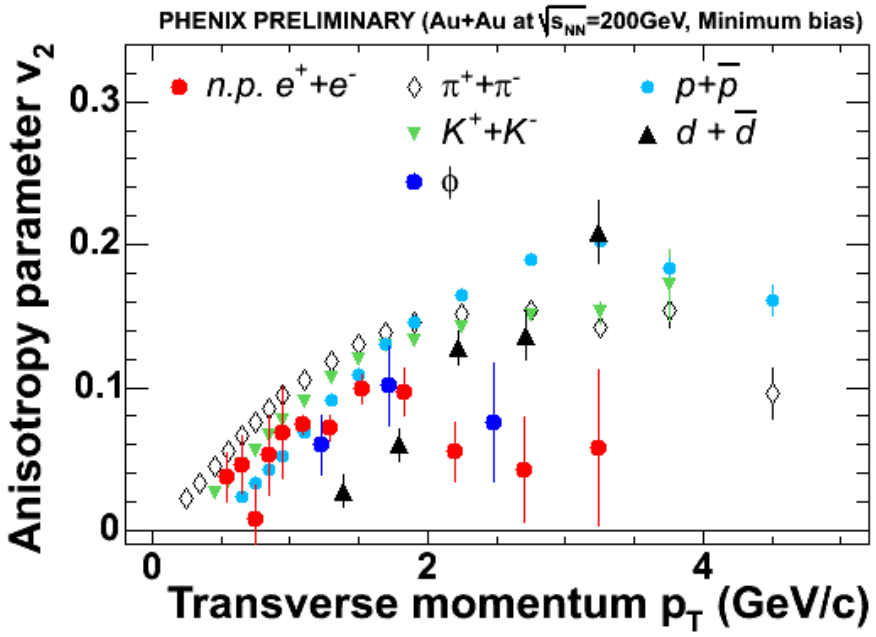
R_{AA} scales with N_{part}

Properties of the Quark Matter beyond T_C

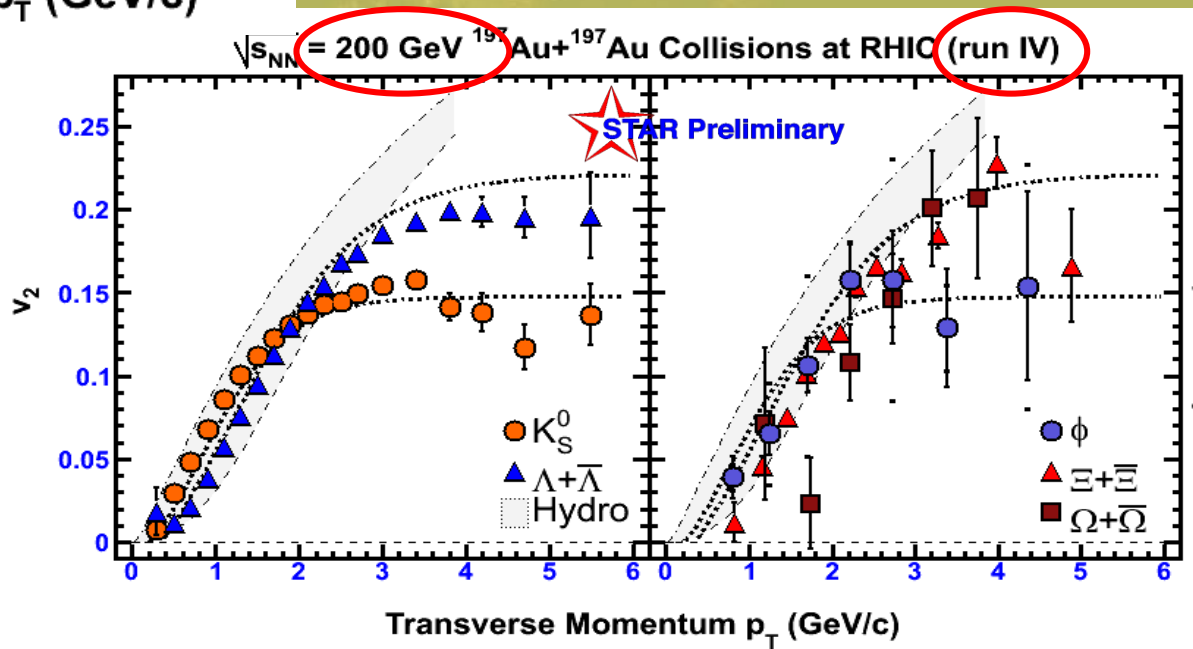
- CuCu vs AuAu : **Vary system size at same energy**

- **$dN/d\eta$ scales with N_{part}**
- **Elliptic flow scales with participant eccentrincity**
- **R_{AA} scales with N_{part}**
- **Smaller system size adds significant precision at $N_{part} \leq 100$**

Properties of the Quark Matter beyond T_C



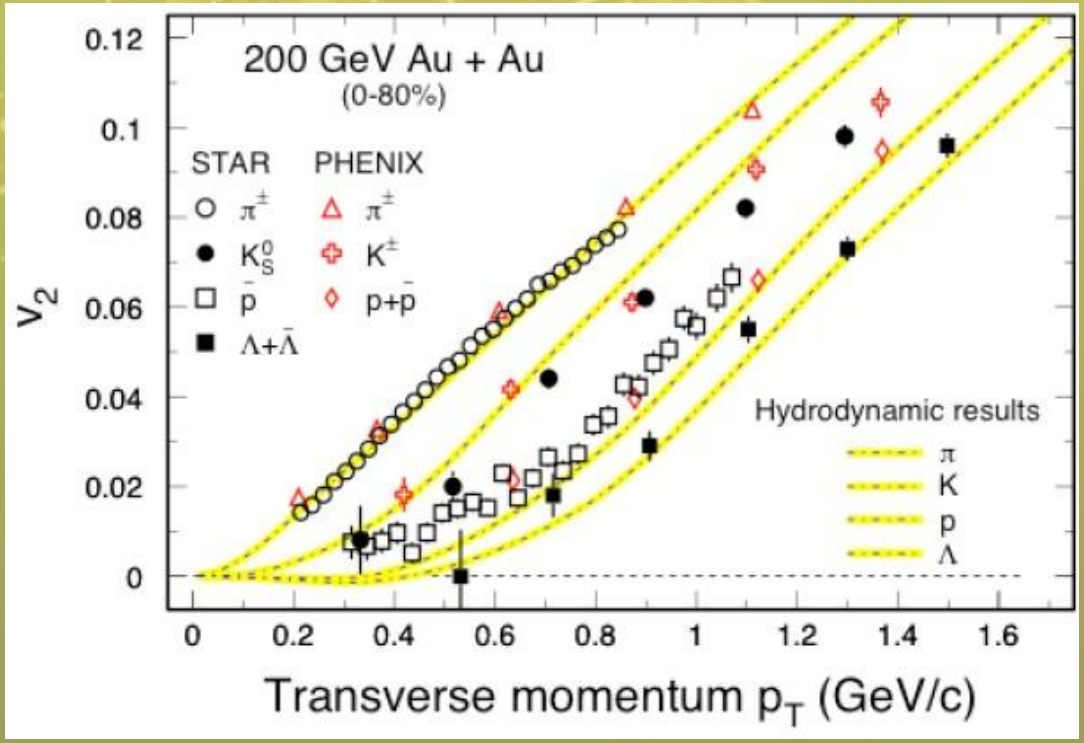
- Large v_2 of heavier particles: ϕ, Ξ, Ω, d.
- Even open charm flows (measured through single electrons)
- Strong interactions at early stage → early thermalization.



Properties of the Quark Matter beyond T_C

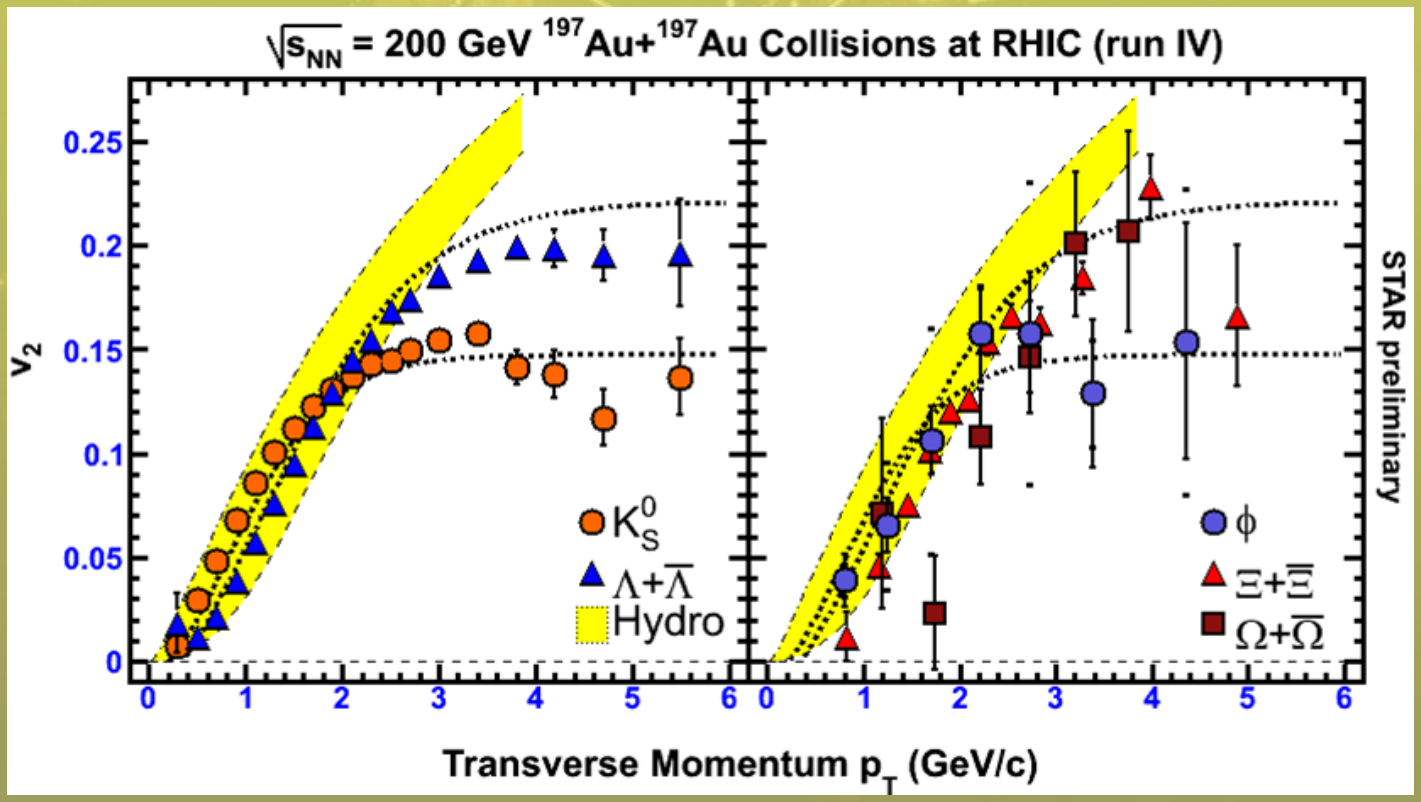
- CuCu vs AuAu : **Vary system size at same energy**
- Flow :

- **Hydro works at low p_T**



Properties of the Quark Matter beyond T_C

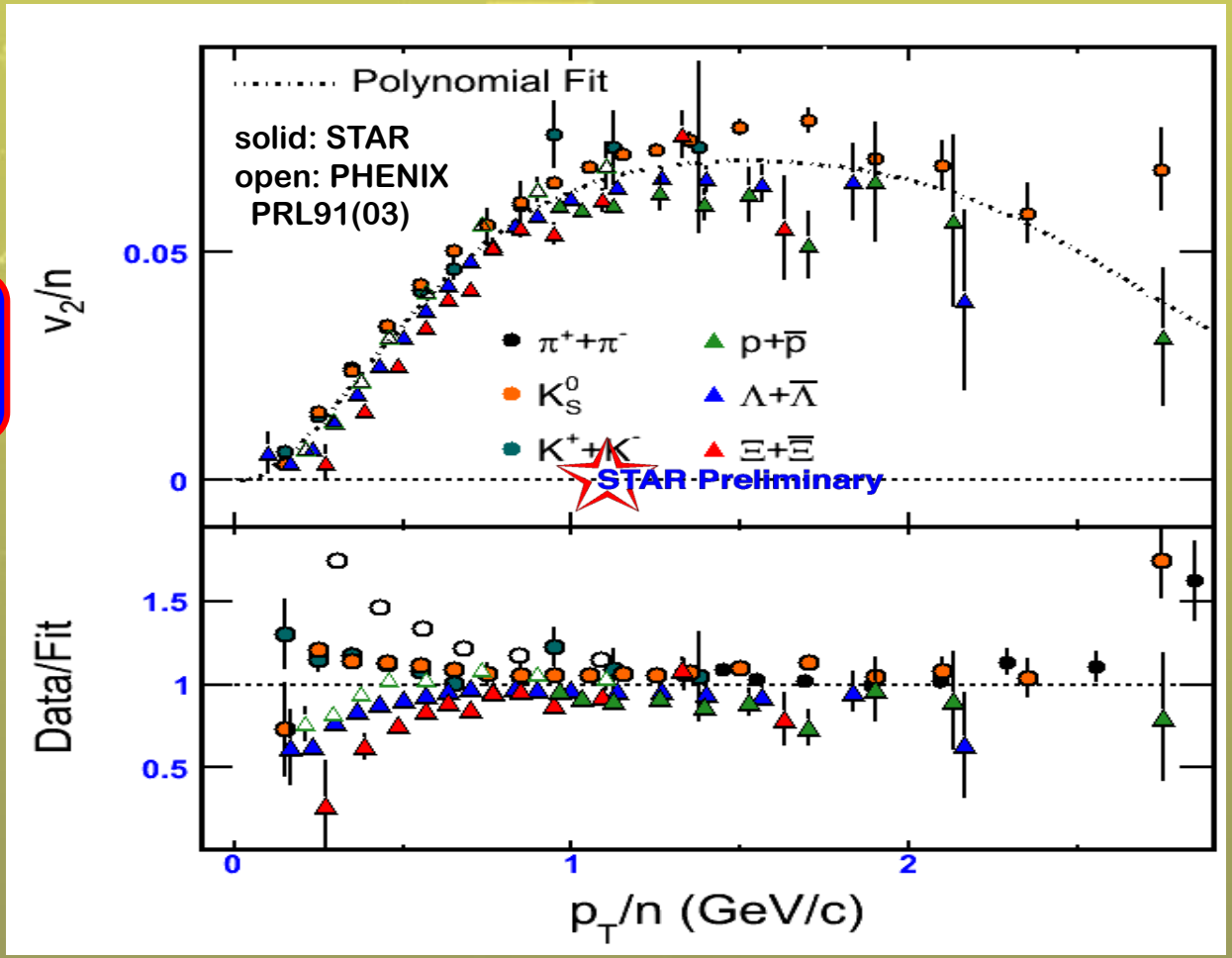
- CuCu vs AuAu : Vary system size at same energy
- Flow :
  - Also for heavier particles



Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : **Vary system size at same energy**
- Flow :

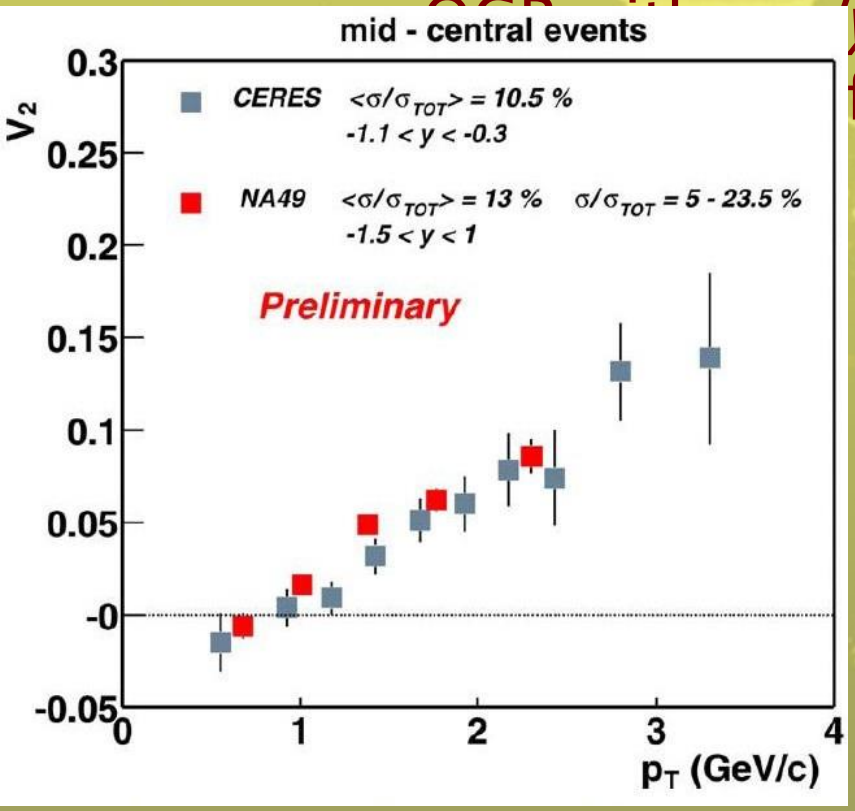
- Recombination works at intermediate p_T



Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy

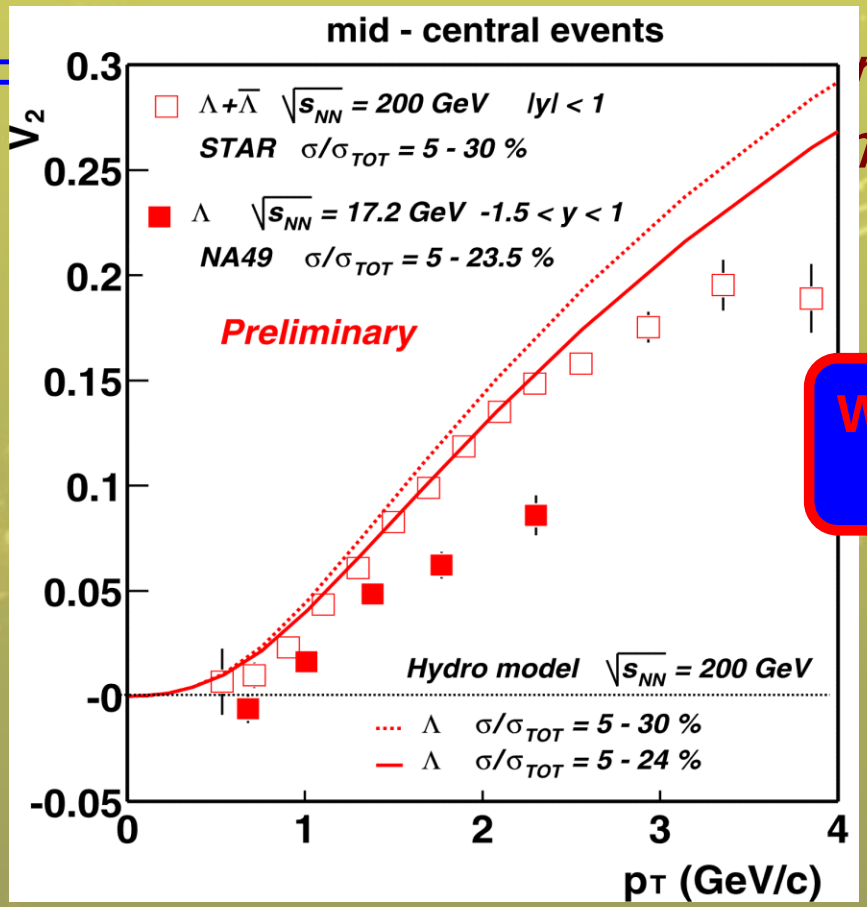
QGP with early *thermalization* of partonic
f *constituent quarks*



- Significant v_2
- CERES and NA49 in good agreement

Properties of the Quark Matter beyond T_C

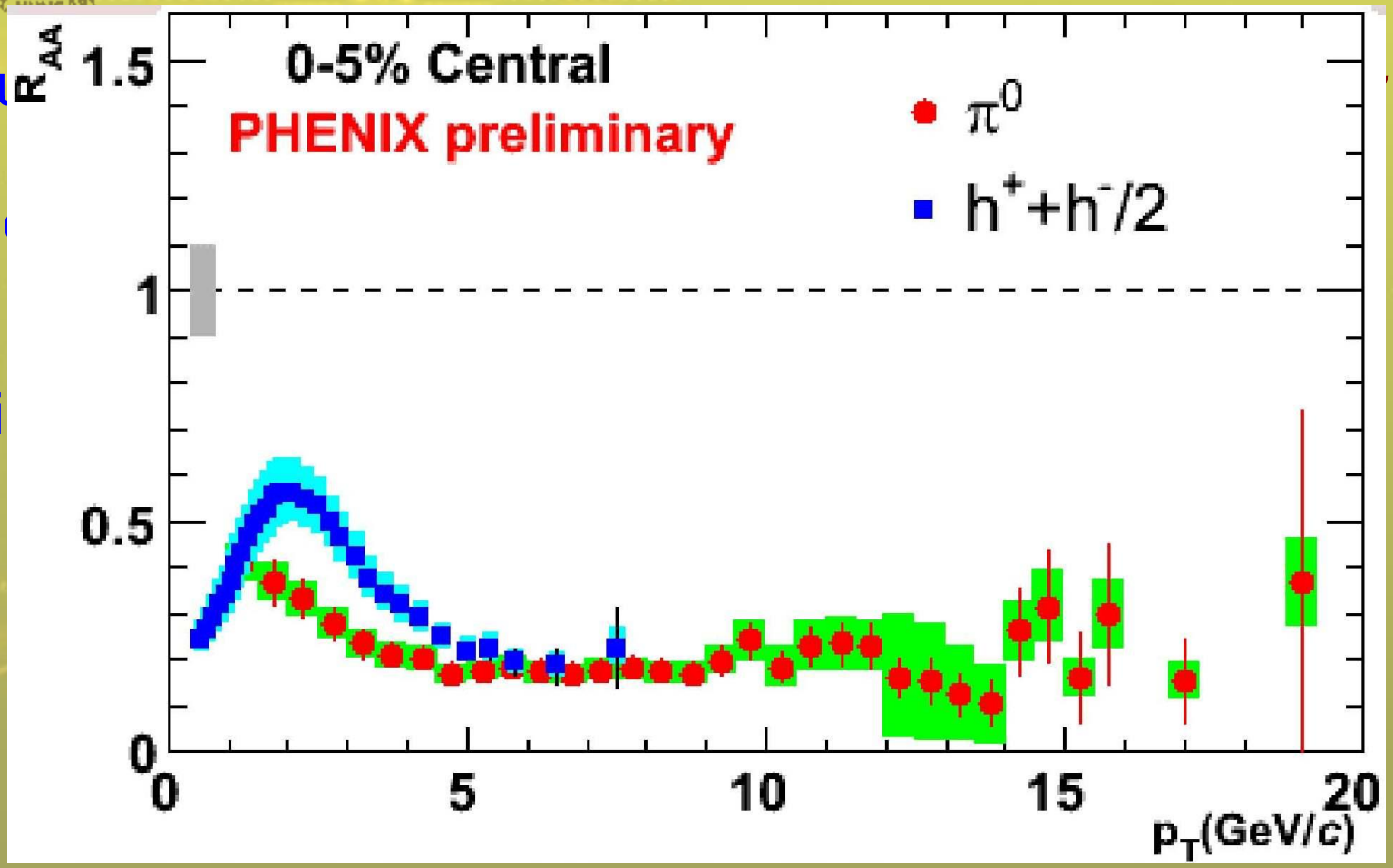
- CuCu vs AuAu : Vary system size at same energy
- F*rmalization* of partonic
  nstituent quarks



Weaker increase of $v_2(p_T)$ at SPS than at RHIC

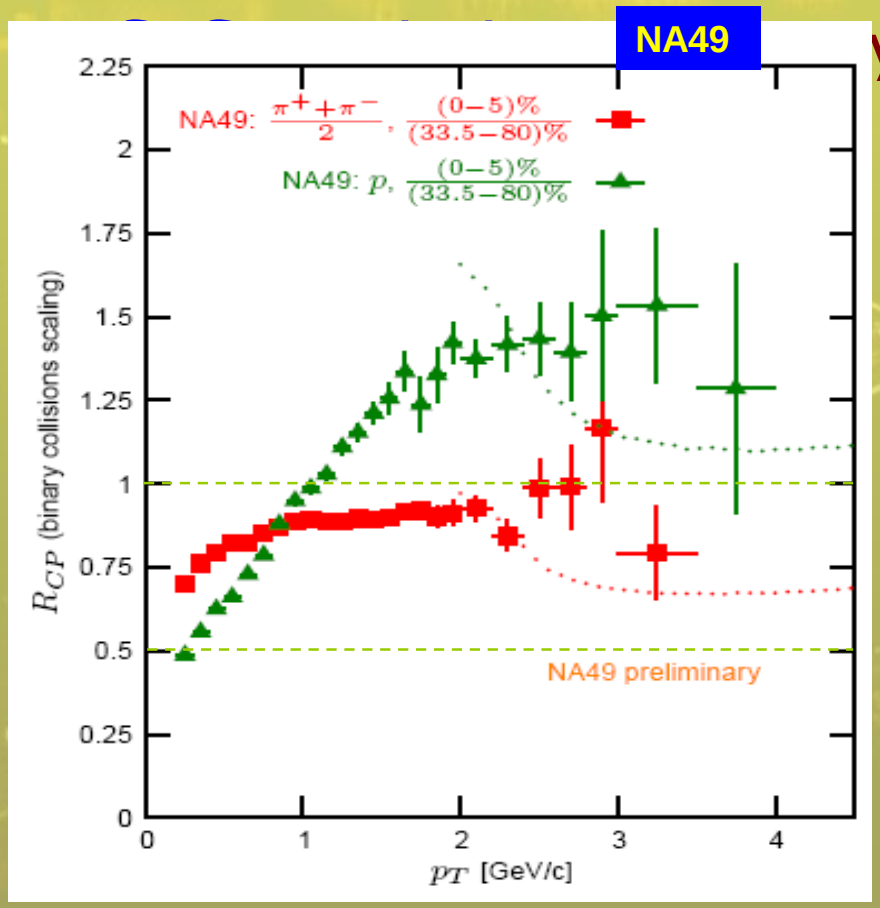
Properties of the Quark Matter beyond T_c

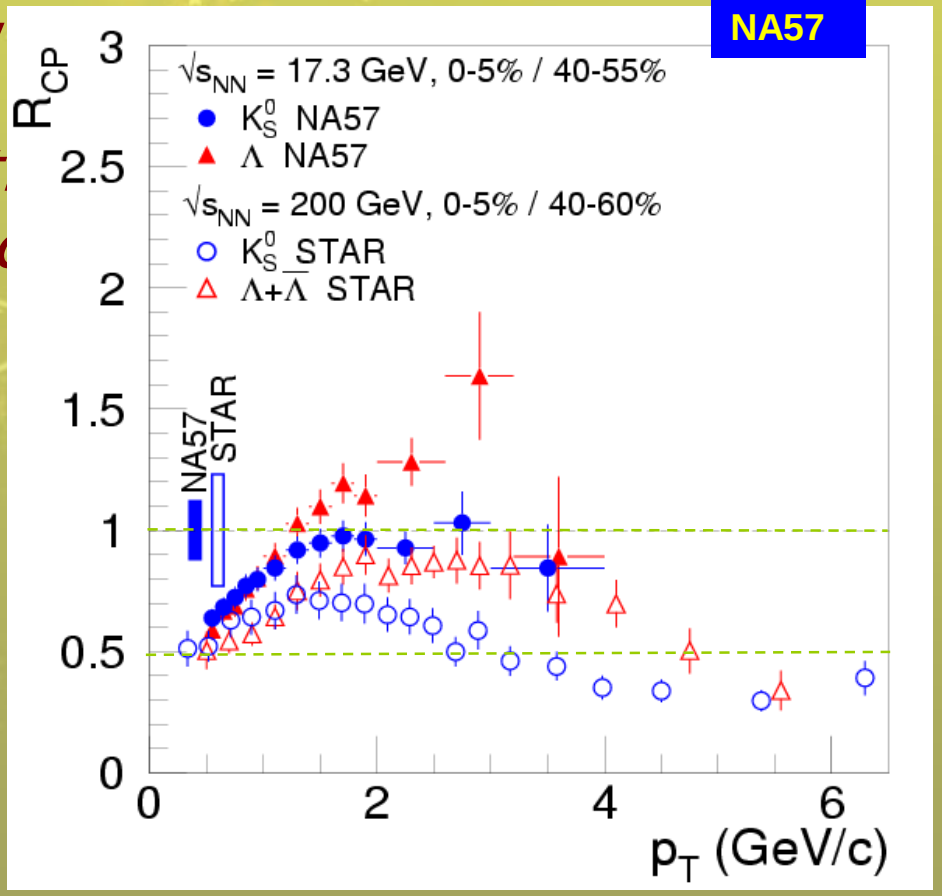
- Cu
- Fl
- hi



- Suppression is strong (R_{AA} =0.2!) and flat up to 20 GeV/c
- Matter is extremely opaque

Properties of the Quark Matter beyond T_c

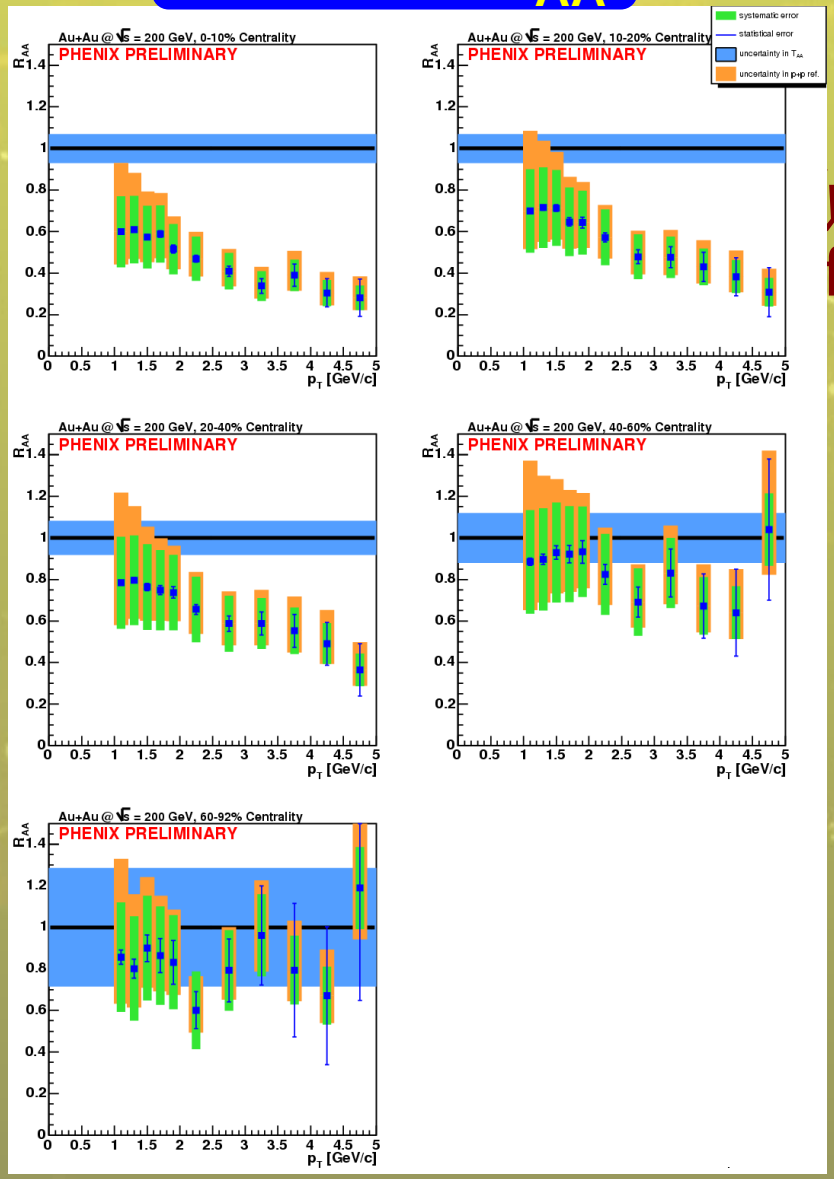




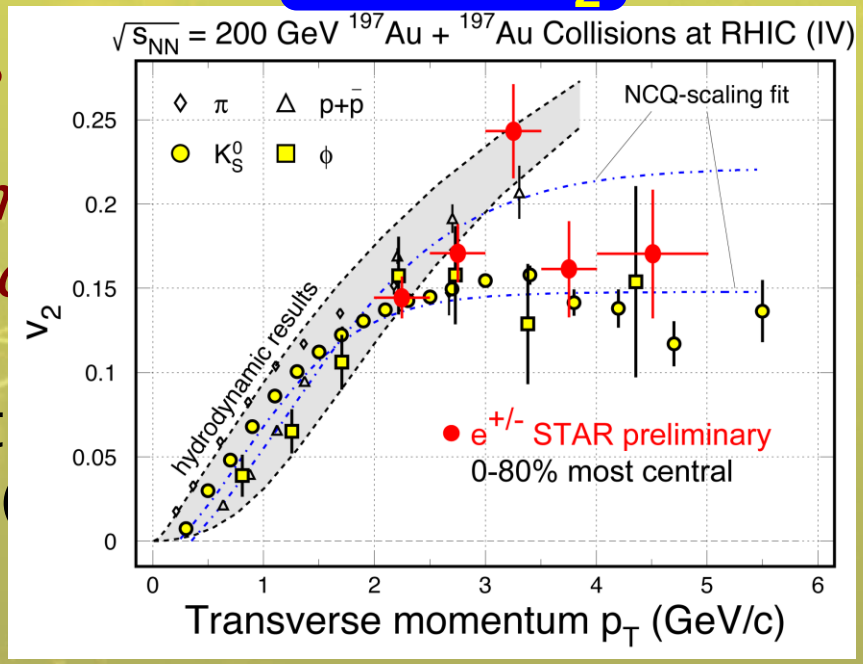
- R_{CP}(baryon)>R_{CP}(meson)
  - ⇒same systematics as original Cronin data at similar √s
  - ⇒same systematics as RHIC but scaled upward

Properties of the Quark Matter beyond T_C

PHENIX R_{AA}



STAR V_2

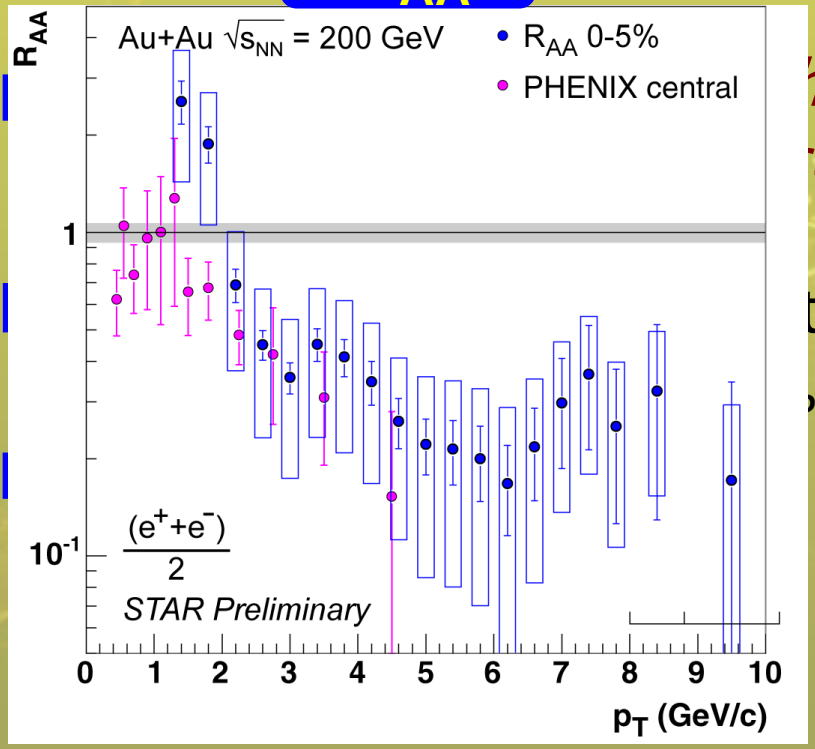


Charm quark is suppressed and it flows !!!

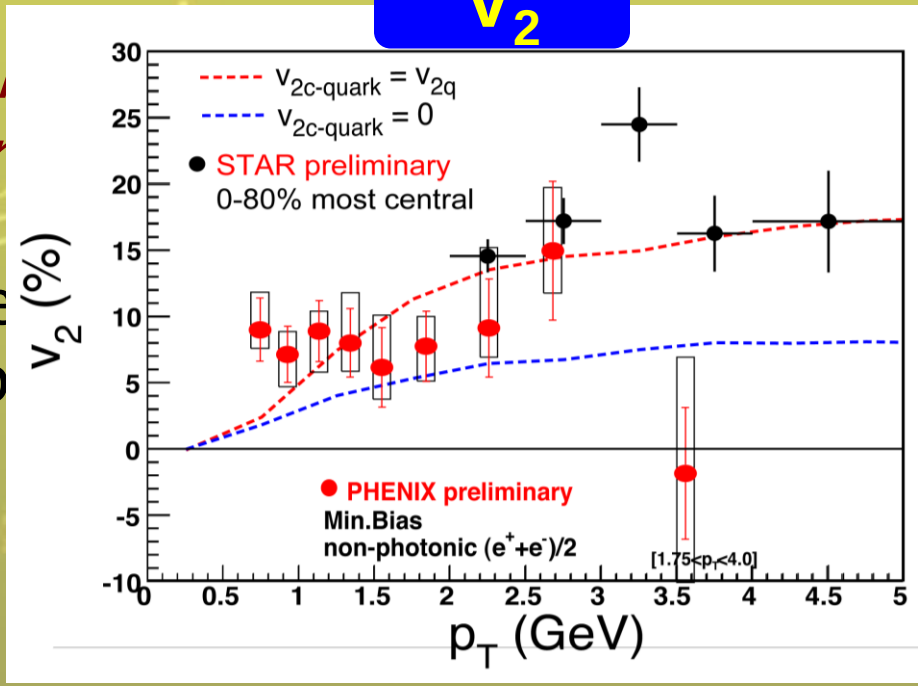
Properties of the Quark Matter beyond T_c

- CuCu vs Au Au Vary system size at same energy

R_{AA}



V_2

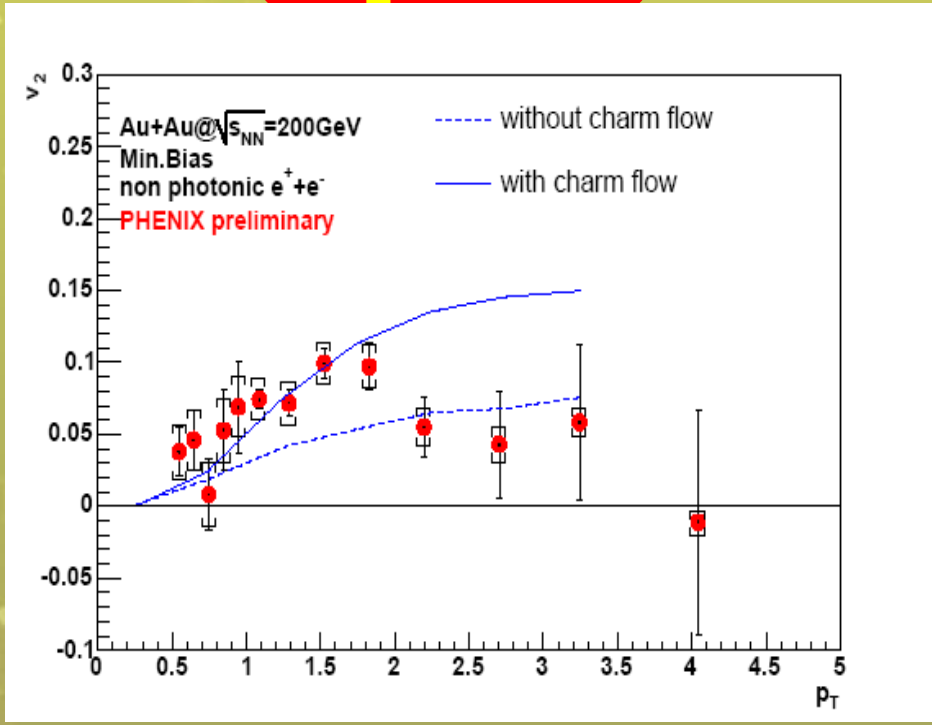


quite consistent !

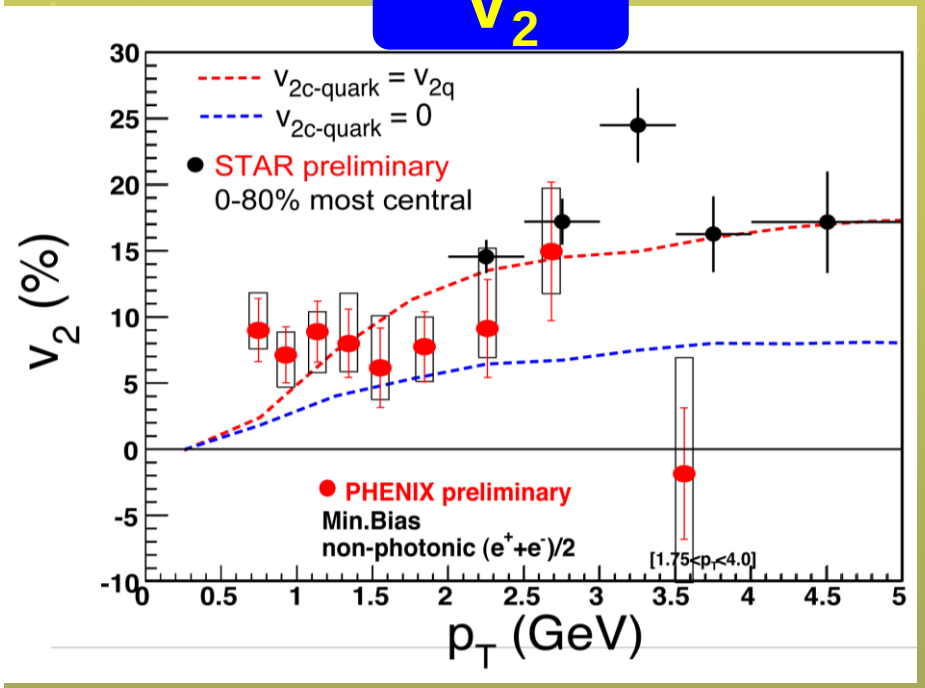
Properties of the Quark Matter beyond T_C

- CuCu, Au+Au Vary system size at same energy

V_2 Run4



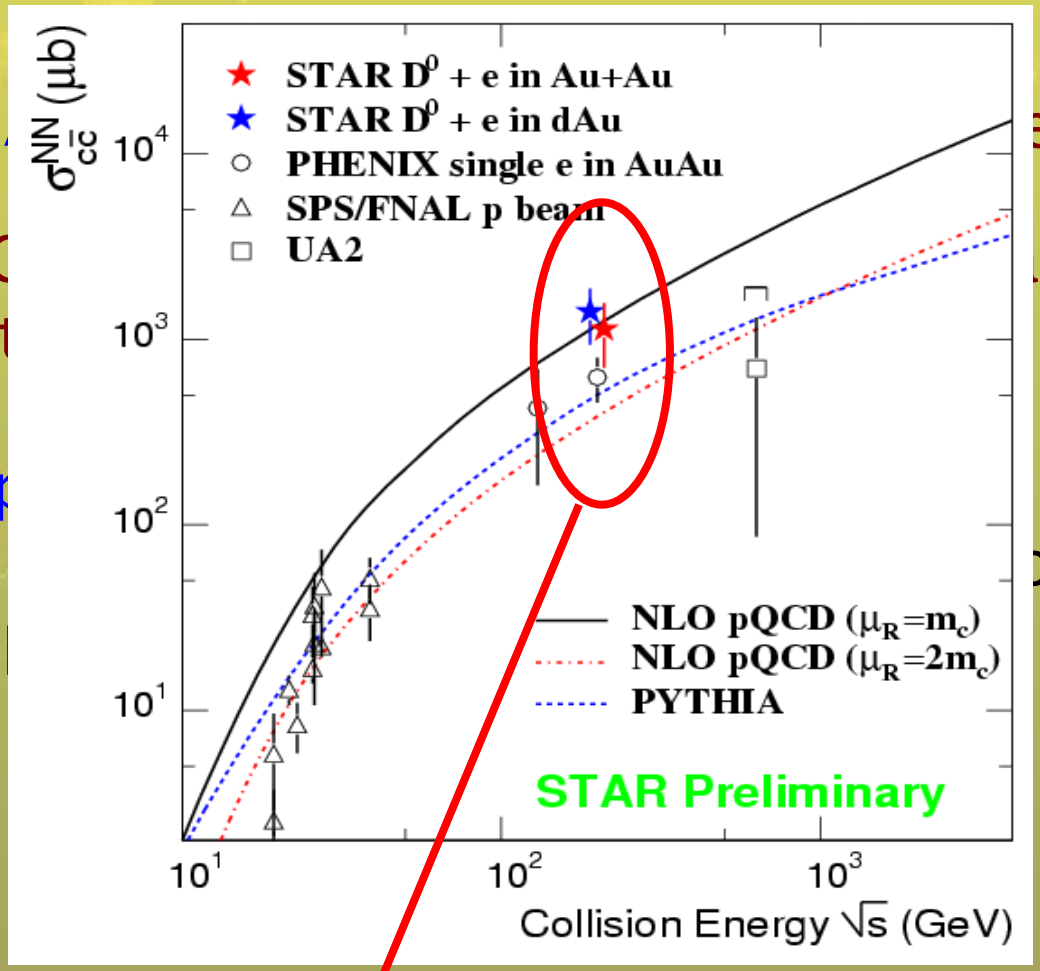
V_2



consistent ?

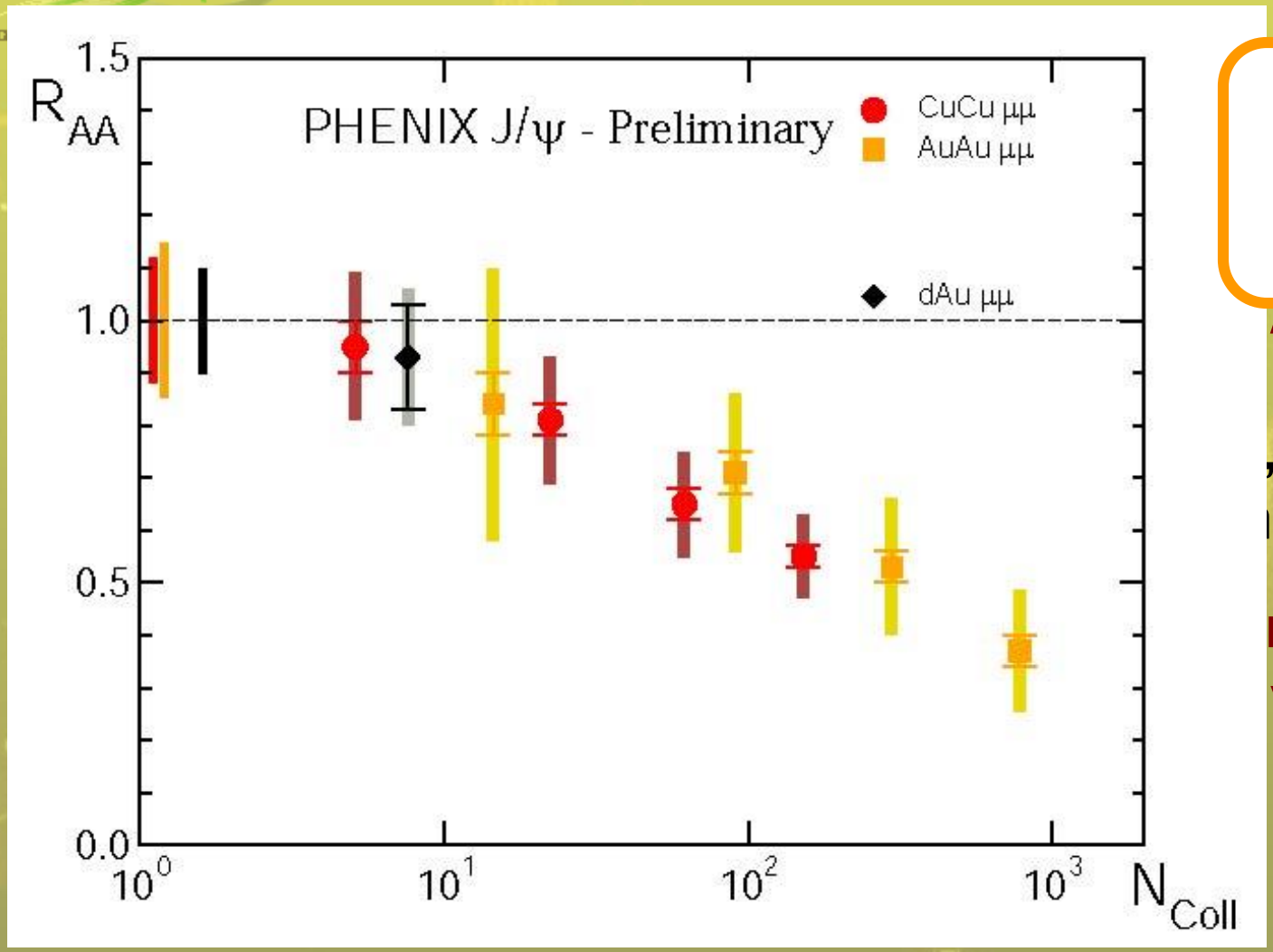
Properties of the Quark Matter beyond T_c

- CuCu vs Au
- Flow : sQ
  mat
- high-PT Sup
- Heavy Quar



Factor of two discrepancy in the charm cross sections measured by PHENIX and STAR.

Properties of the Quark Matter beyond T_C



J/ψ → μμ
muon arm
1.2 < |y| < 2.2

ks

,

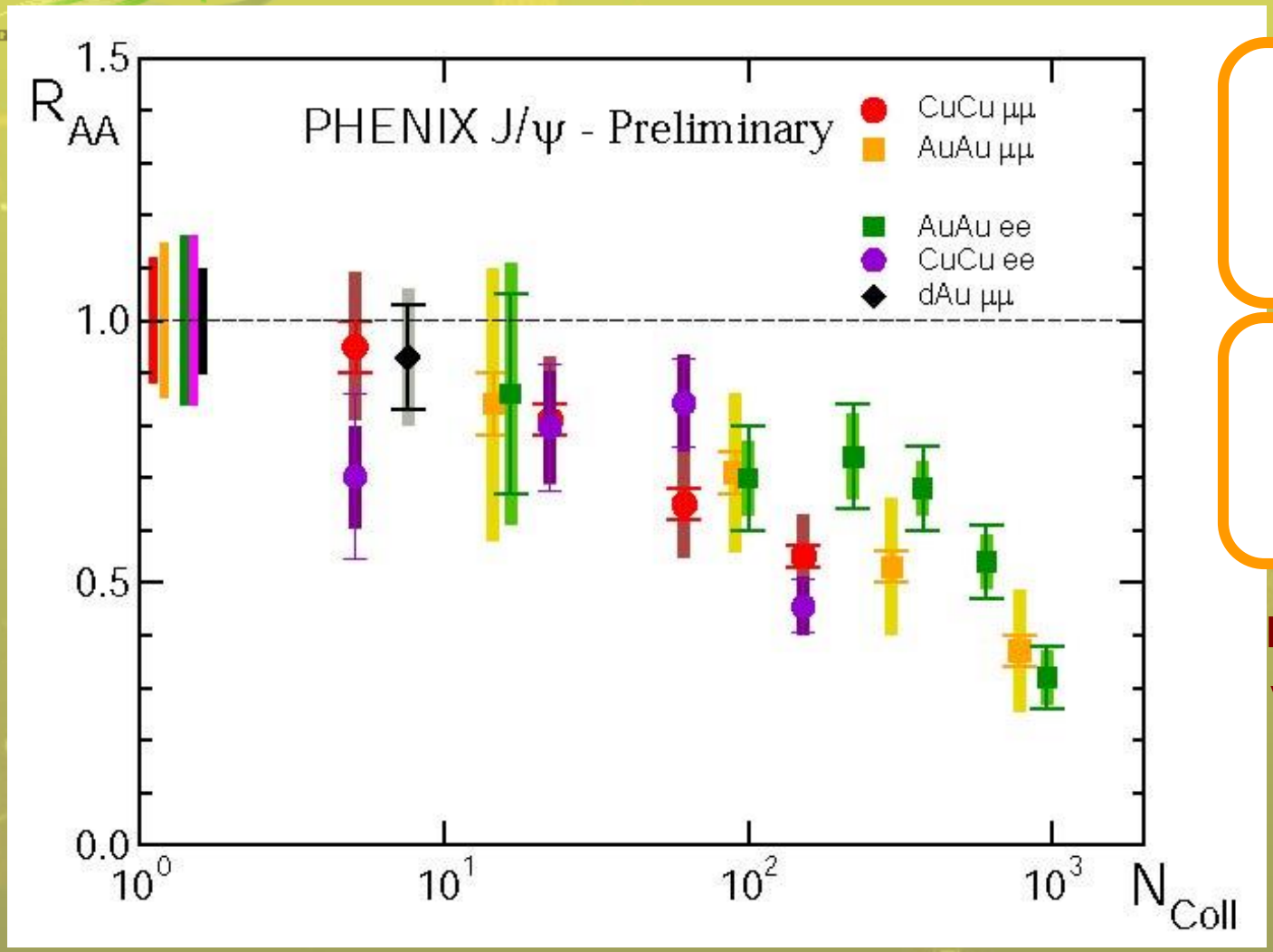
eson)

nd flows

y

dAu	AuAu	CuCu
μμ	μμ	μμ
200 GeV/c	200 GeV/c	200 GeV/c

Properties of the Quark Matter beyond T_C



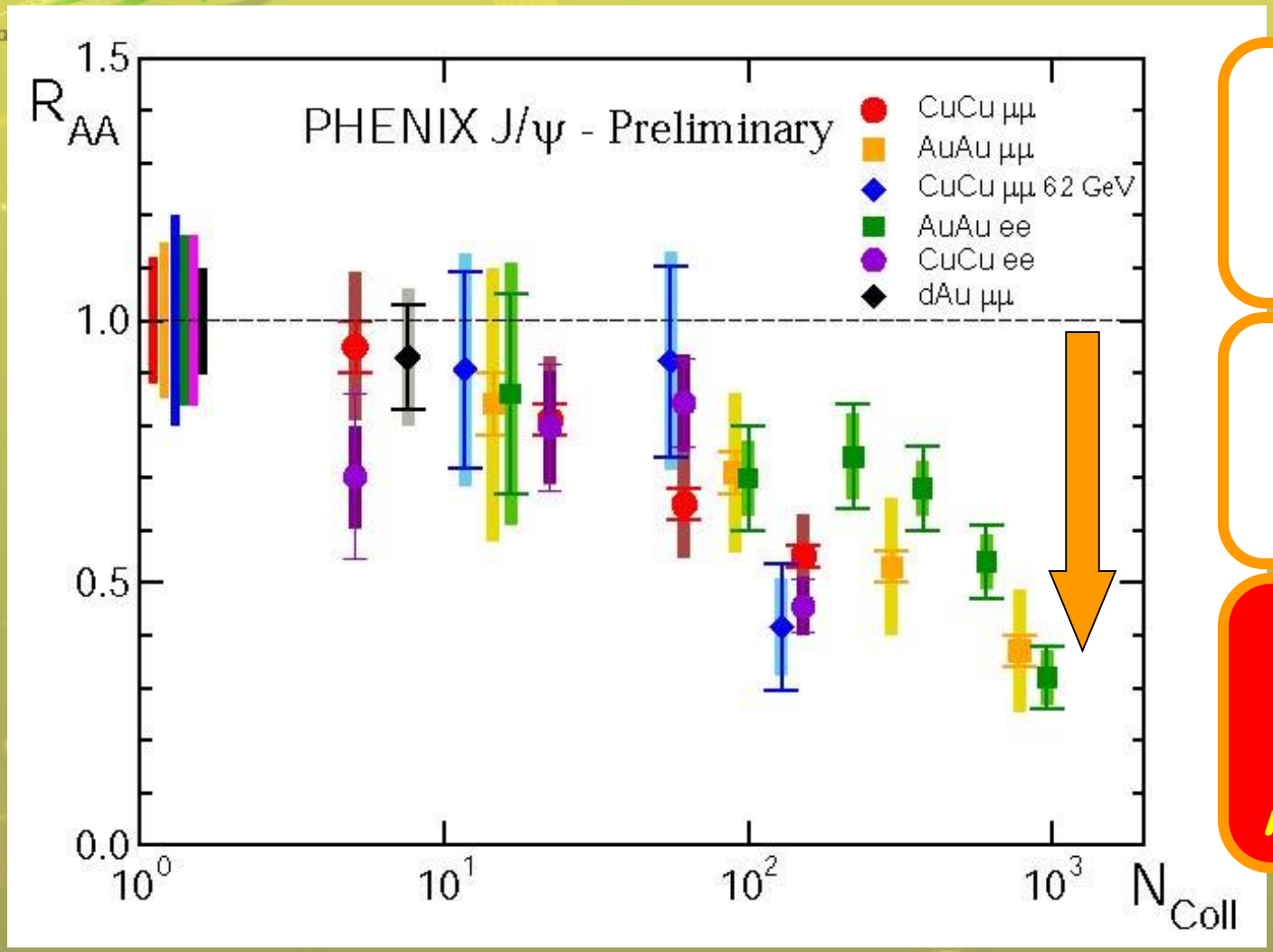
J/ψ → μμ
muon arm
1.2 < |y| < 2.2

J/ψ → ee
Central arm
-0.35 < y < 0.35

nd flows
y

dAu	AuAu	CuCu	AuAu	CuCu
μμ	μμ	μμ	ee	ee
200 GeV/c	200 GeV/c	200 GeV/c	200 GeV/c	200 GeV/c

Properties of the Quark Matter beyond T_C



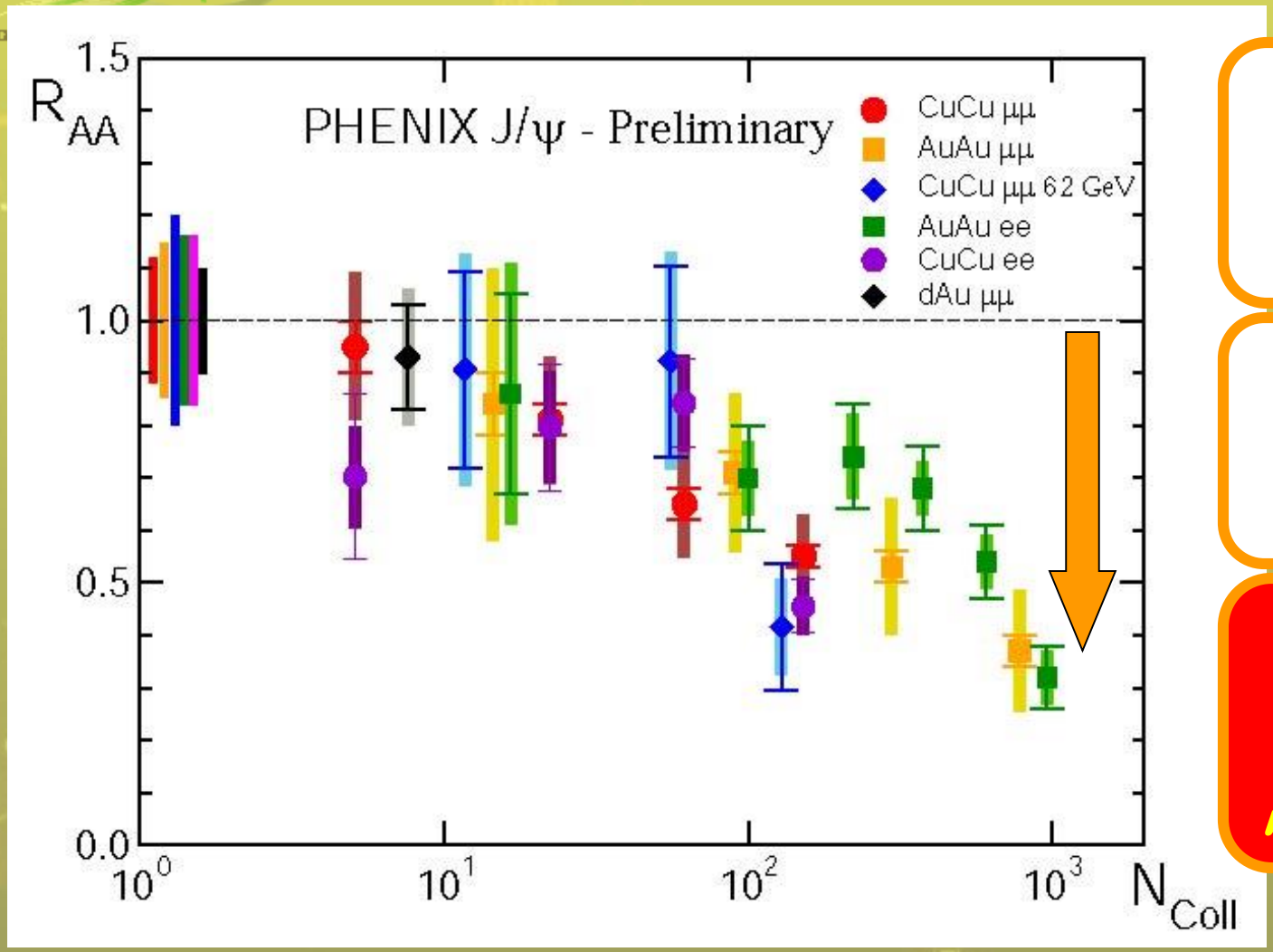
J/ψ → μμ
muon arm
1.2 < |y| < 2.2

J/ψ → ee
Central arm
-0.35 < y < 0.35

Factor ~3 suppression in central events

dAu	AuAu	CuCu	AuAu	CuCu	CuCu
μμ	μμ	μμ	ee	ee	μμ
200 GeV/c	200 GeV/c	200 GeV/c	200 GeV/c	200 GeV/c	62 GeV/c

Properties of the Quark Matter beyond T_C



J/ψ → μμ
muon arm
1.2 < |y| < 2.2

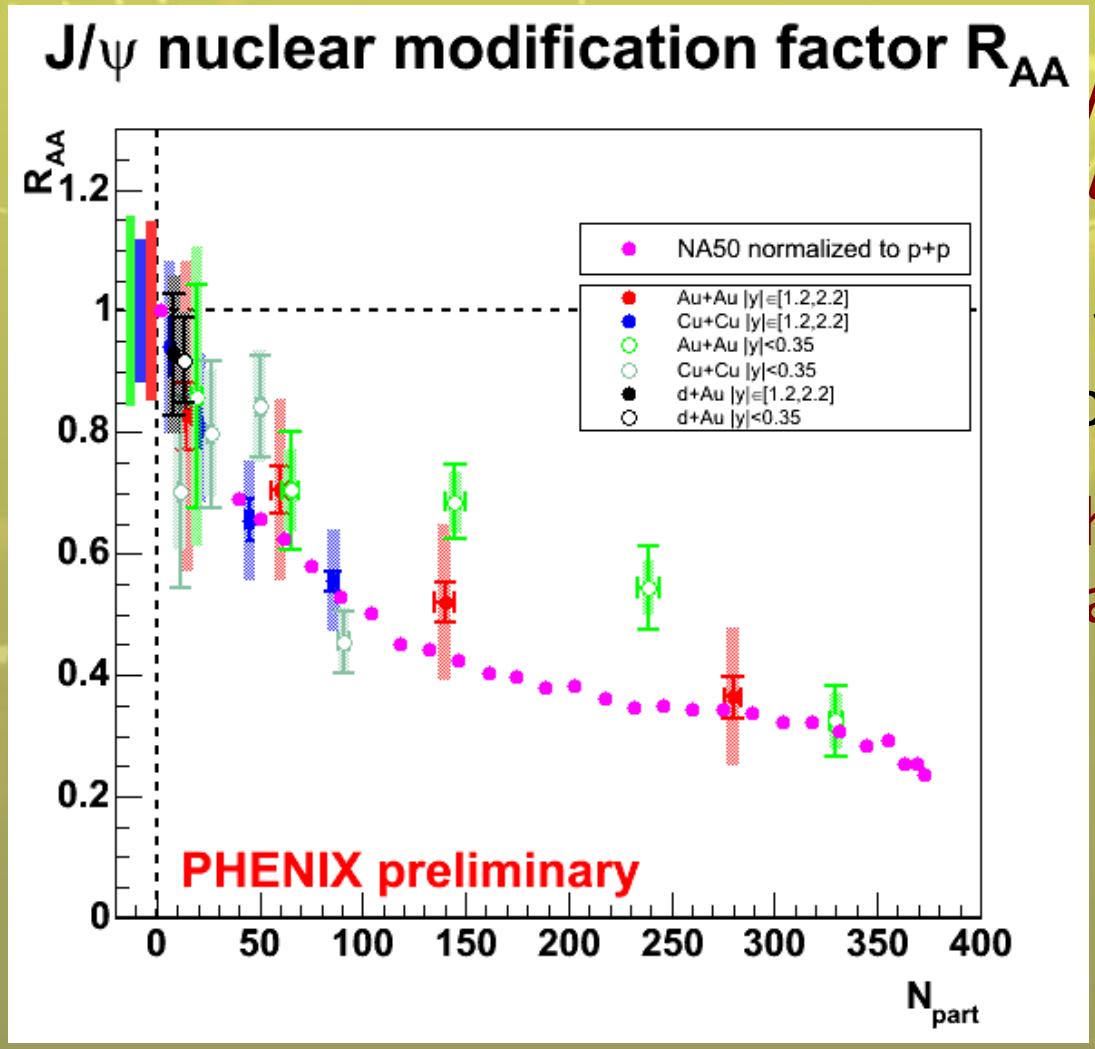
J/ψ → ee
Central arm
-0.35 < y < 0.35

Factor ~3 suppression in central events

Data show the same trend within errors for all species and even 62 GeV

Properties of the Quark Matter beyond T_c

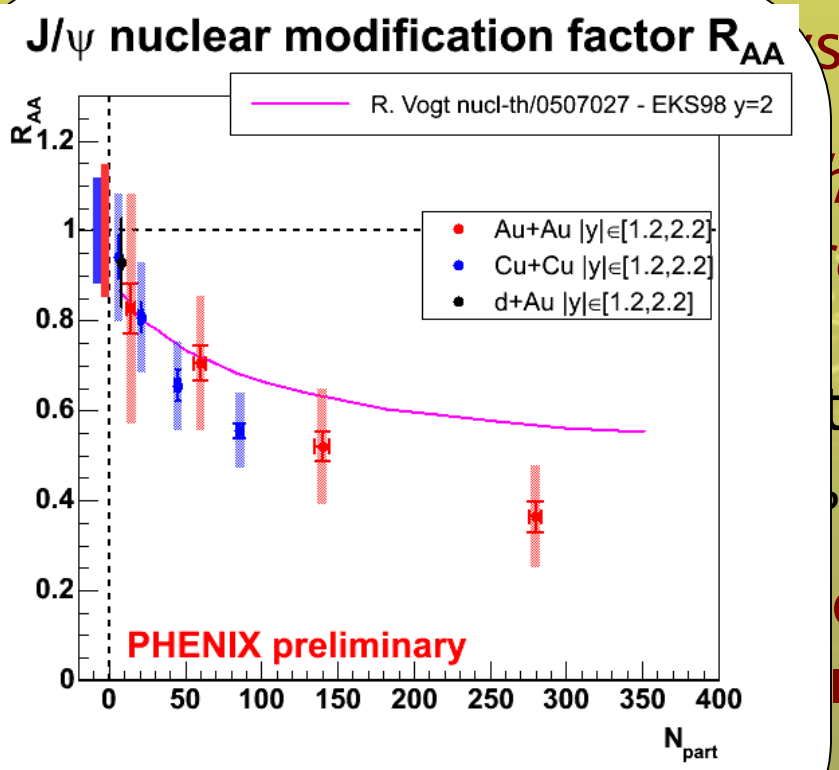
- CuCu vs AuAu : Vary system size at same energy



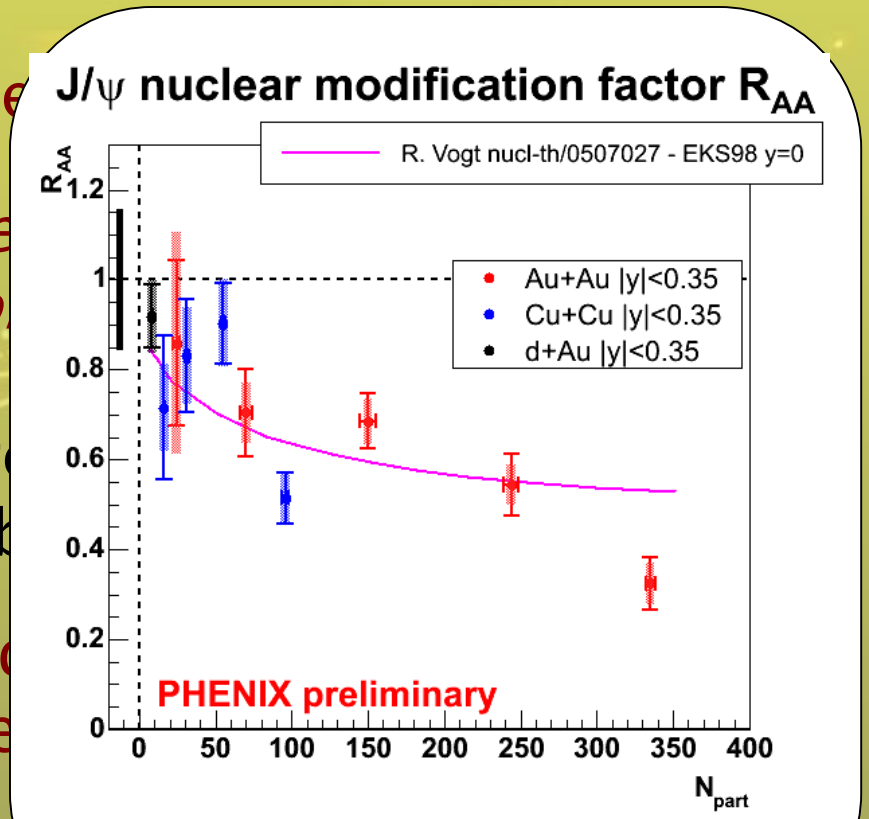
lization of partonic

- NA50 data normalized to NA50 p+p point.
- Suppression level is similar in the two experiments, although the collision energy is 10 times higher (200GeV in PHENIX wrt 17GeV in NA50)

Properties of the Quark Matter beyond T_c



Muon arm



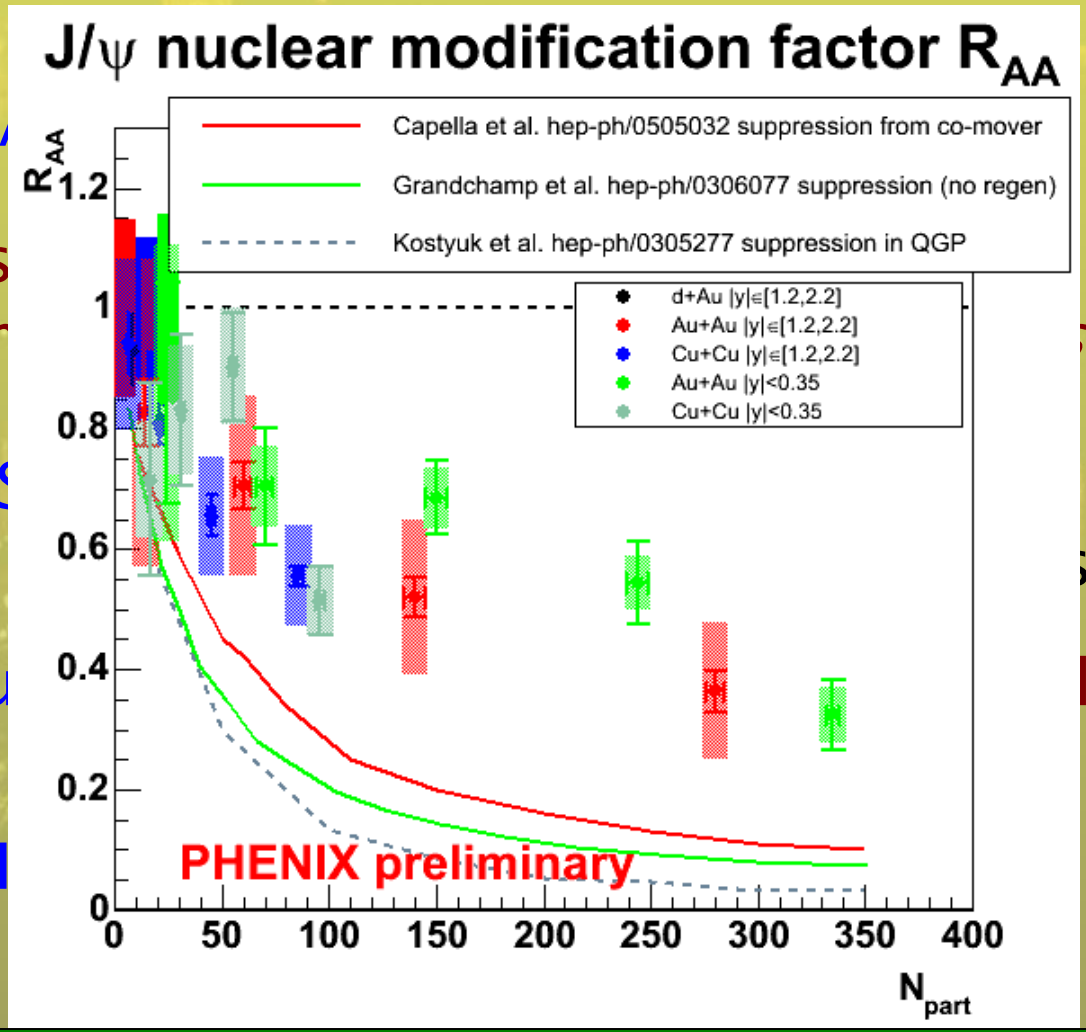
Central arm

Theory Vogt: nucl-th/0507027

Cold nuclear matter absorption model in agreement with dAu:
Tendency to underpredict suppression in most central AuAu and CuCu events

Properties of the Quark Matter beyond T_C

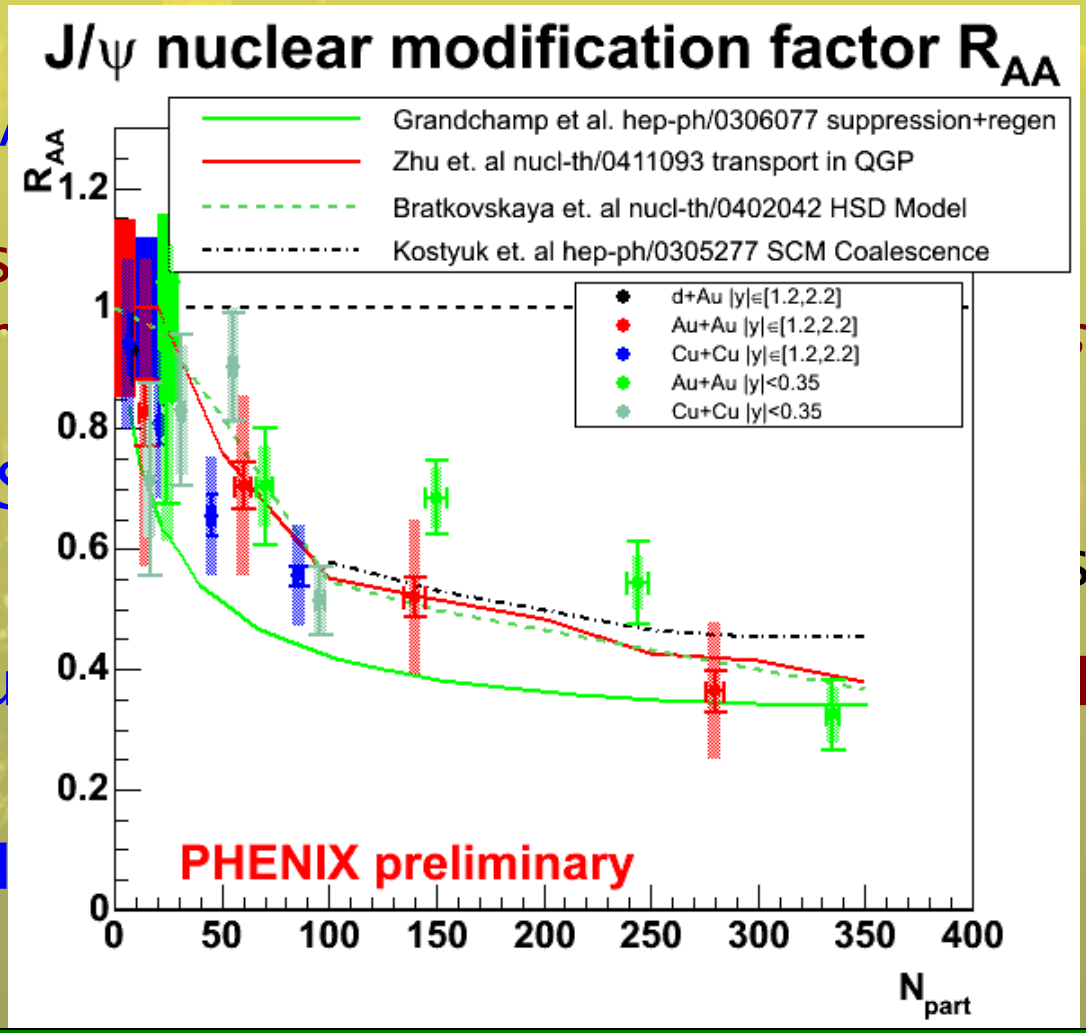
- CuCu vs A … energy
- Flow : s … artonic … r … s
- high-PT S … son)
- Heavy Qu … l flows
- J/Ψ @ RH …



Models that were successful in describing SPS data fail to describe data at RHIC - too much suppression -

Properties of the Quark Matter beyond T_C

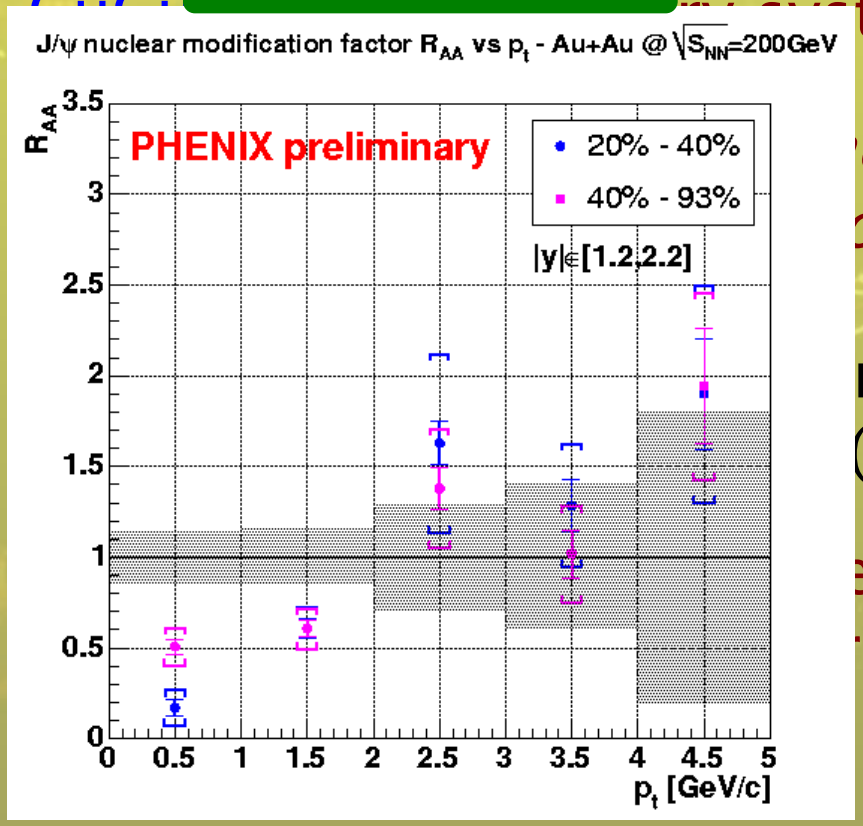
- CuCu vs A … energy
- Flow : s … artonic … r …
- high-PT S … son)
- Heavy Qu … l flows
- J/Ψ @ RH …



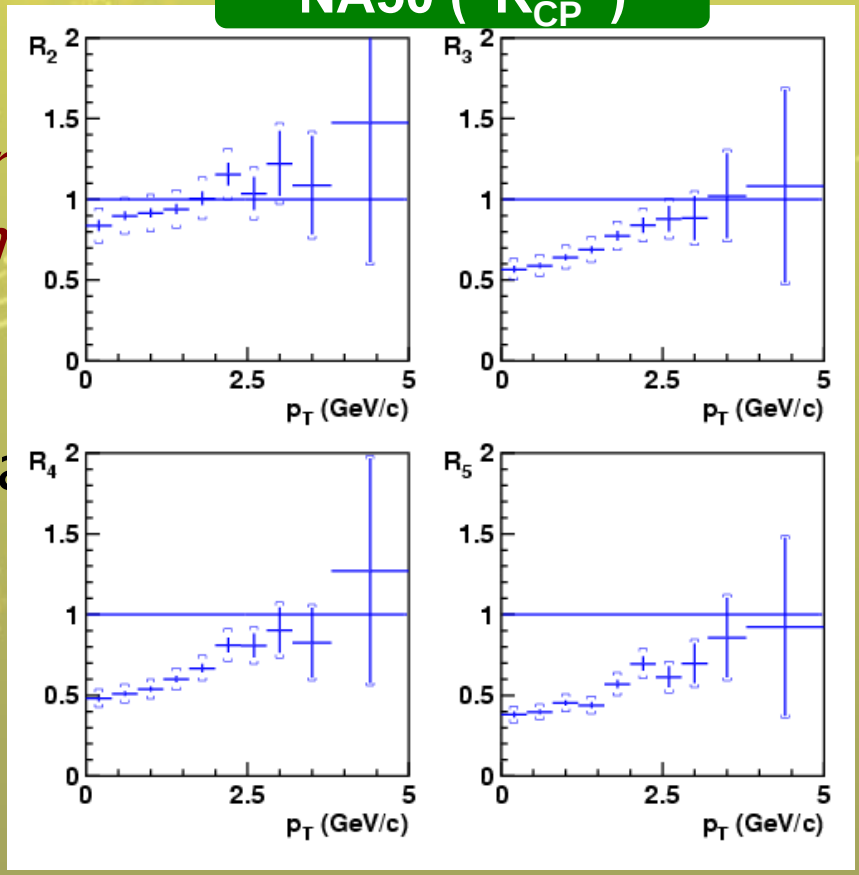
Adding recombination:
much better agreement with the data

Properties of the Quark Matter beyond T_C

PHENIX



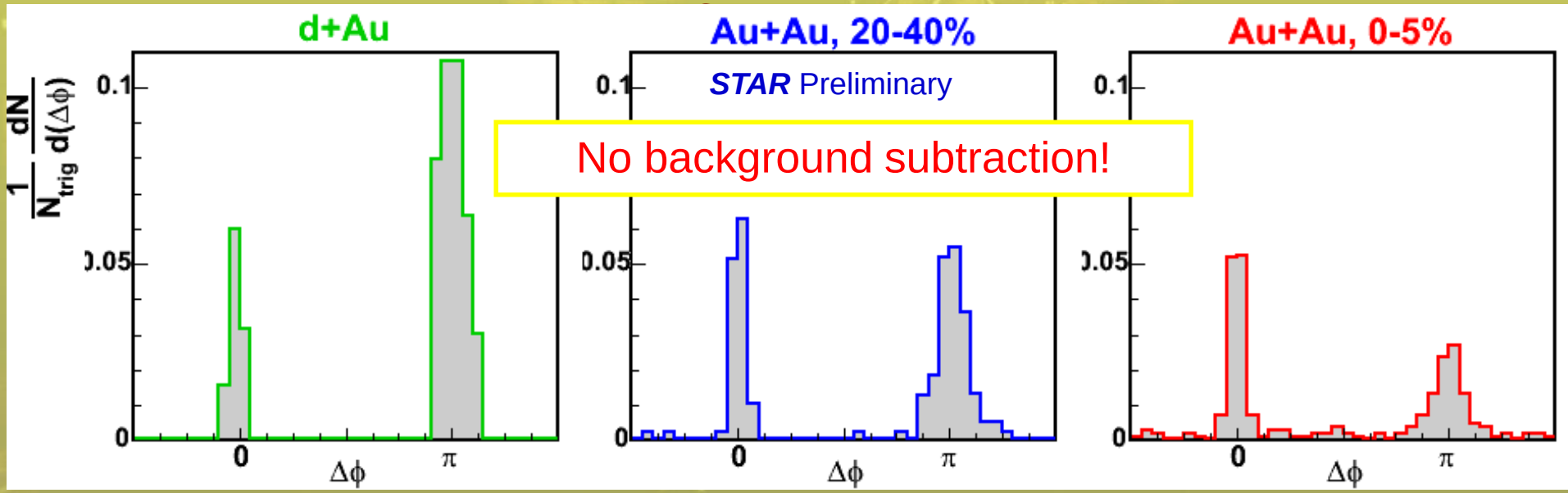
NA50 ("R_{CP}")



J/ψ suppressed at low-p_T.

Properties of the Quark Matter beyond T_c

- CuCu vs AuAu : Vary system size at same energy
- Flow : sQGP with *early thermalization* of partonic



- Je

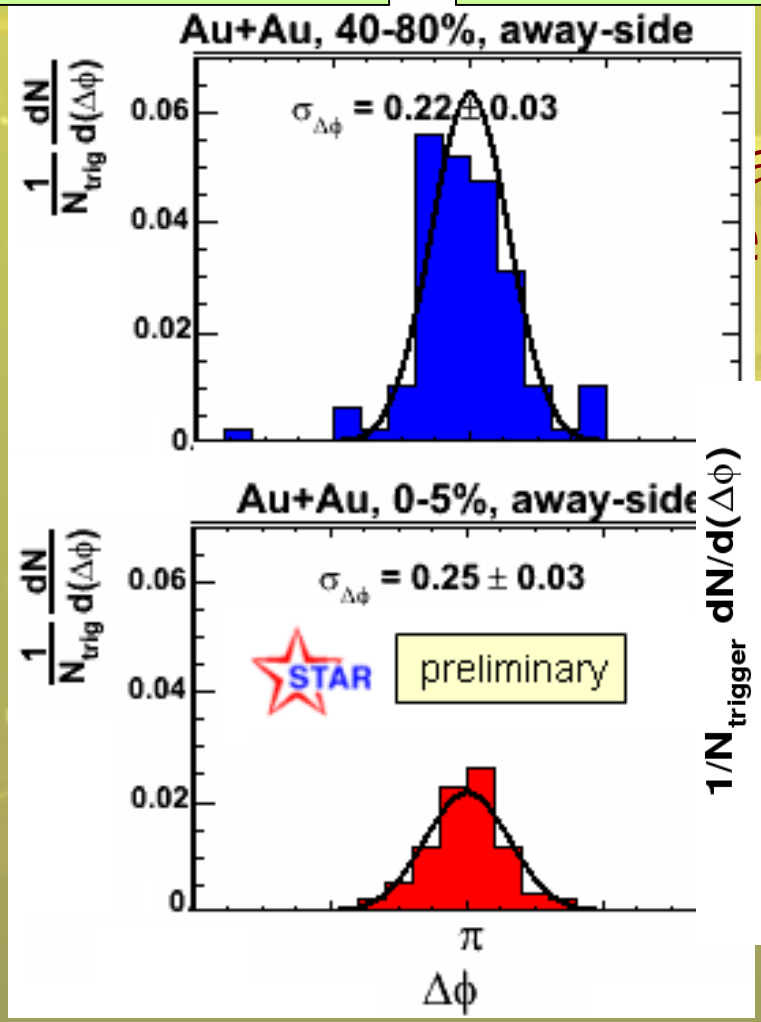
Clear emergence of the away-side jet

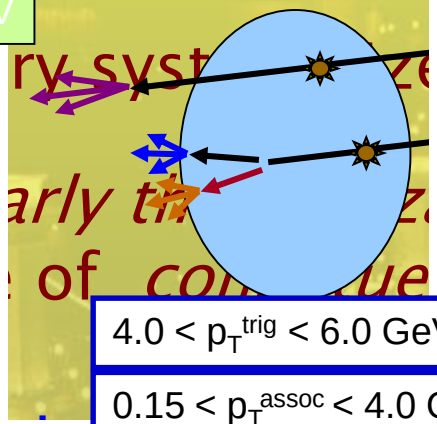
For the first time: jet-like peaks seen on near and away side in central Au+Au collisions

Properties of the Quark Matter beyond T_C

$8 < p_T(\text{trig}) < 15$ GeV/c

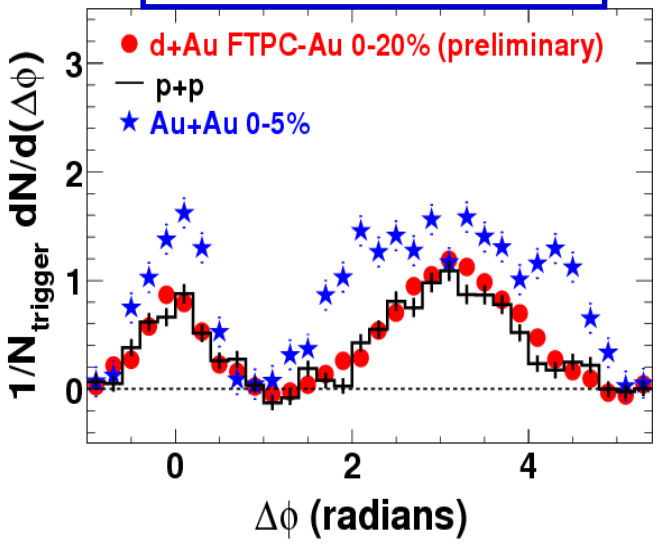
$p_T(\text{assoc}) > 6$ GeV

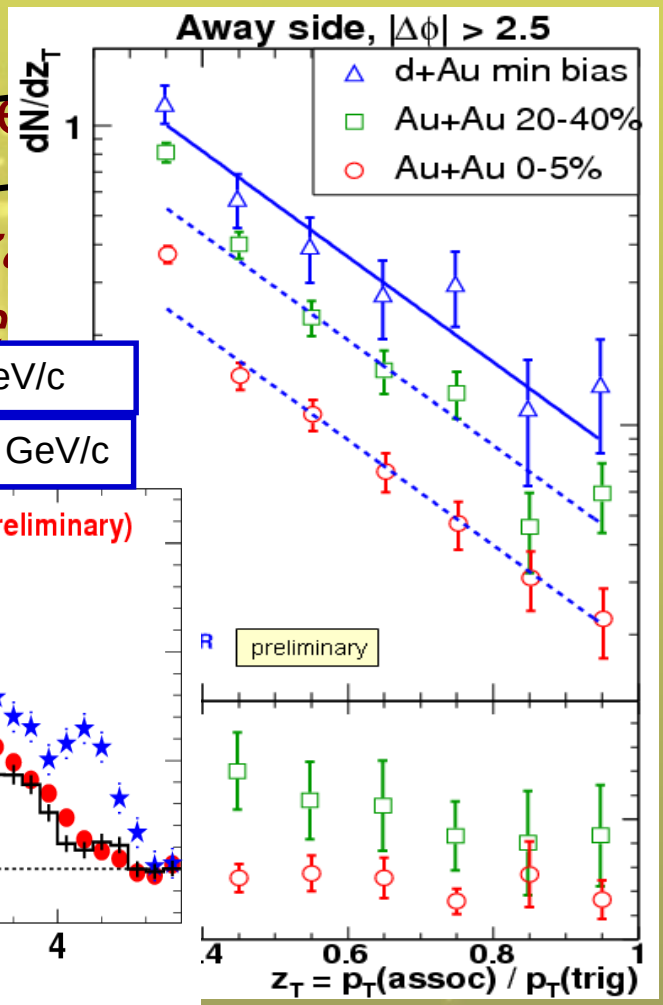




$4.0 < p_T^{trig} < 6.0$ GeV/c

$0.15 < p_T^{assoc} < 4.0$ GeV/c



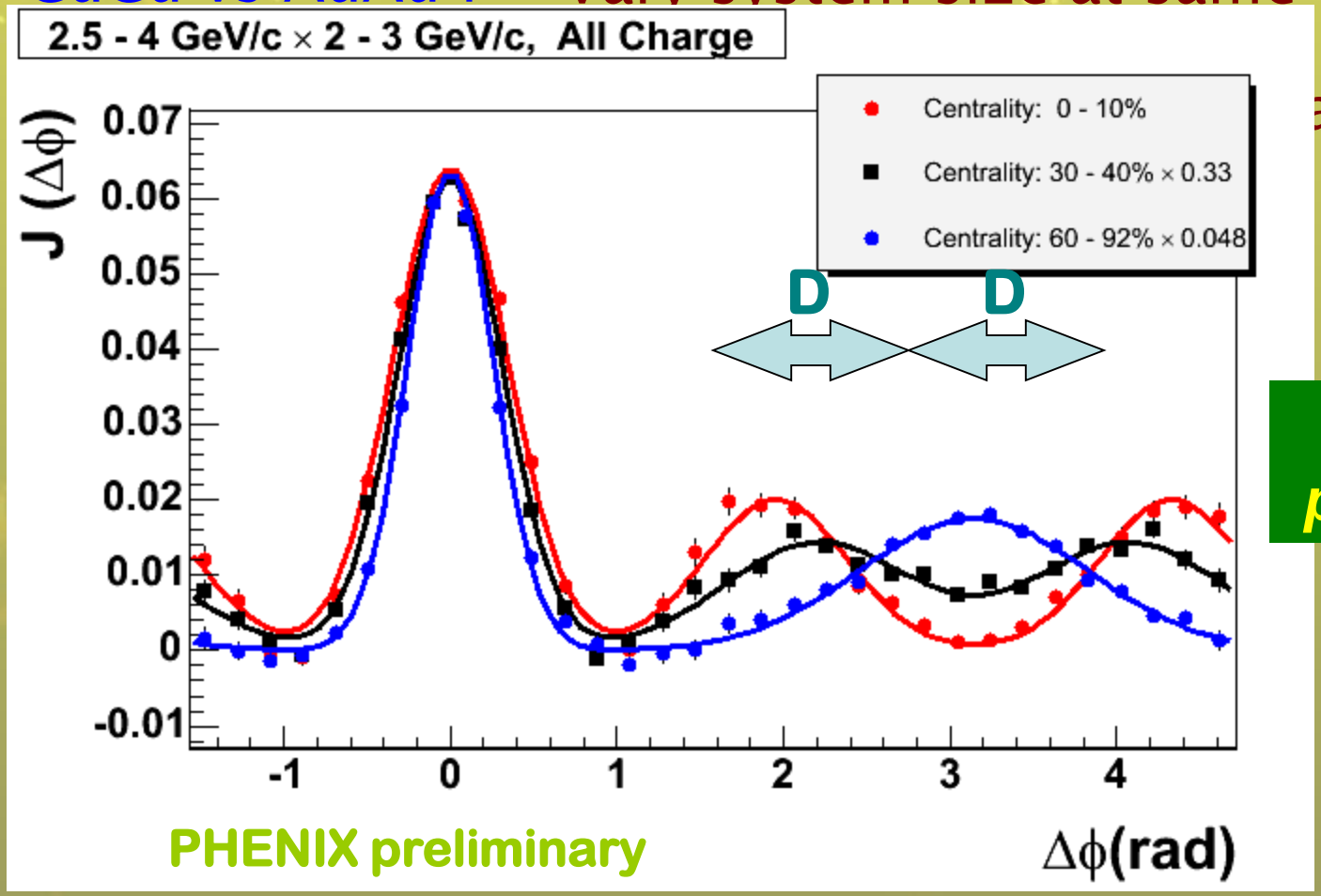


Width unchanged with centrality

Away side yield strongly suppressed to the level of R_{AA}

Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy
- artonic



Splitting parameter D

Intermediate p_T trigger: modification of away-side jets

Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy
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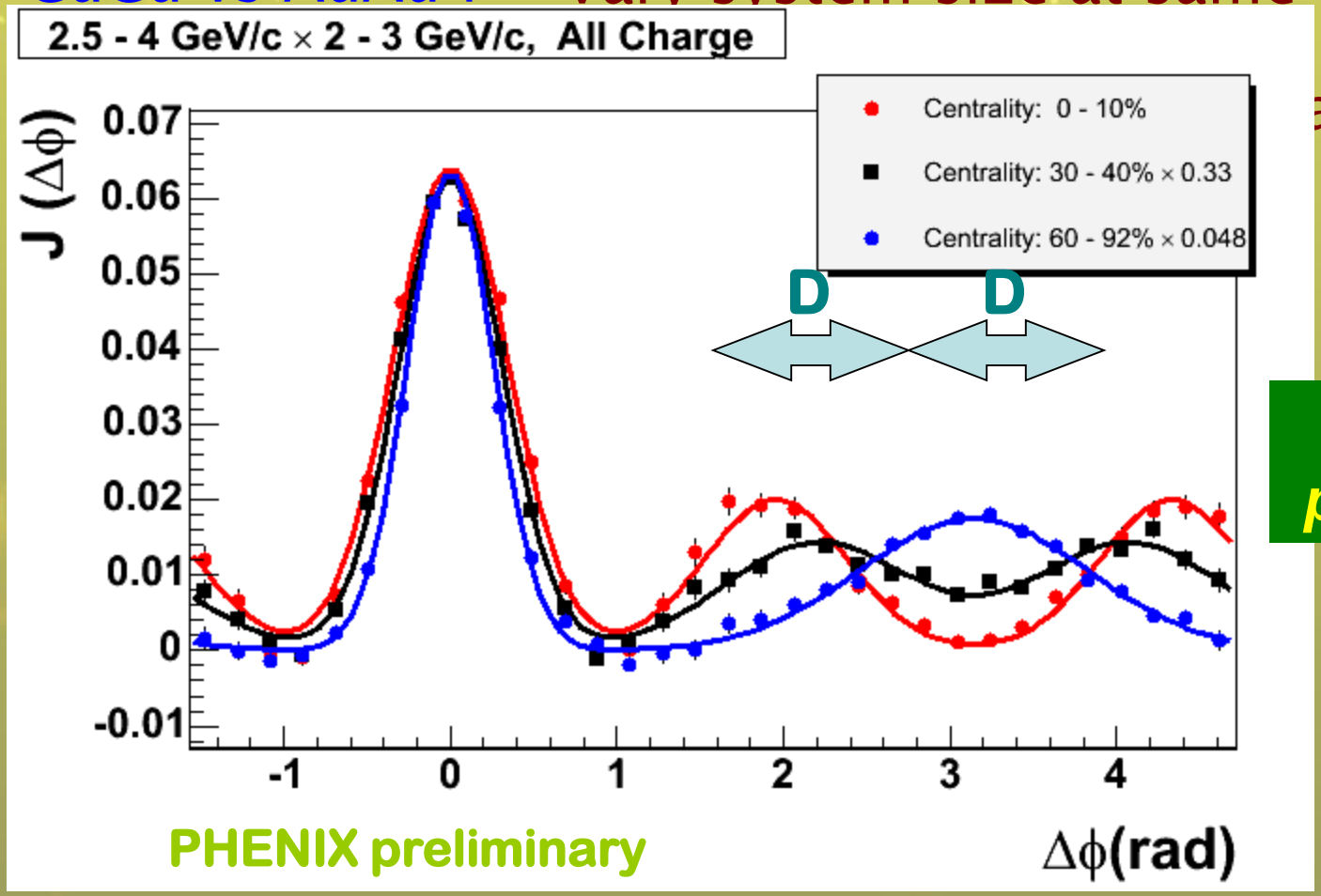

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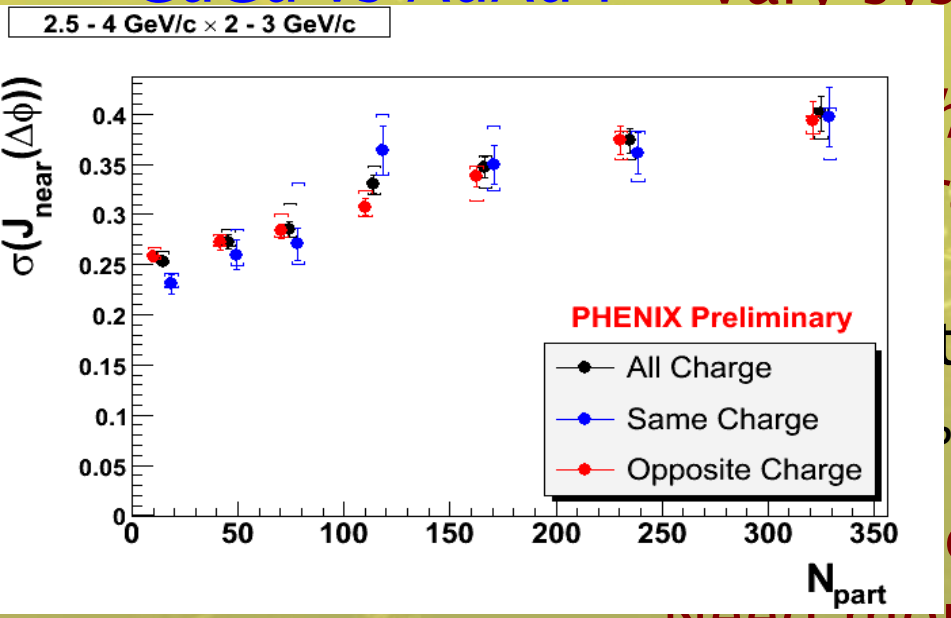
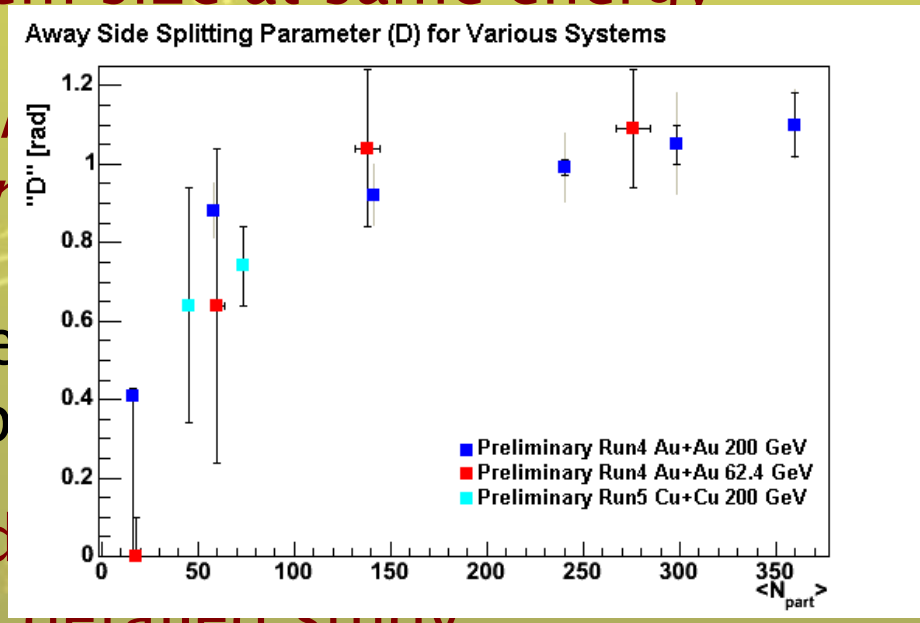
- CuCu vs AuAu : Vary system size at same energy



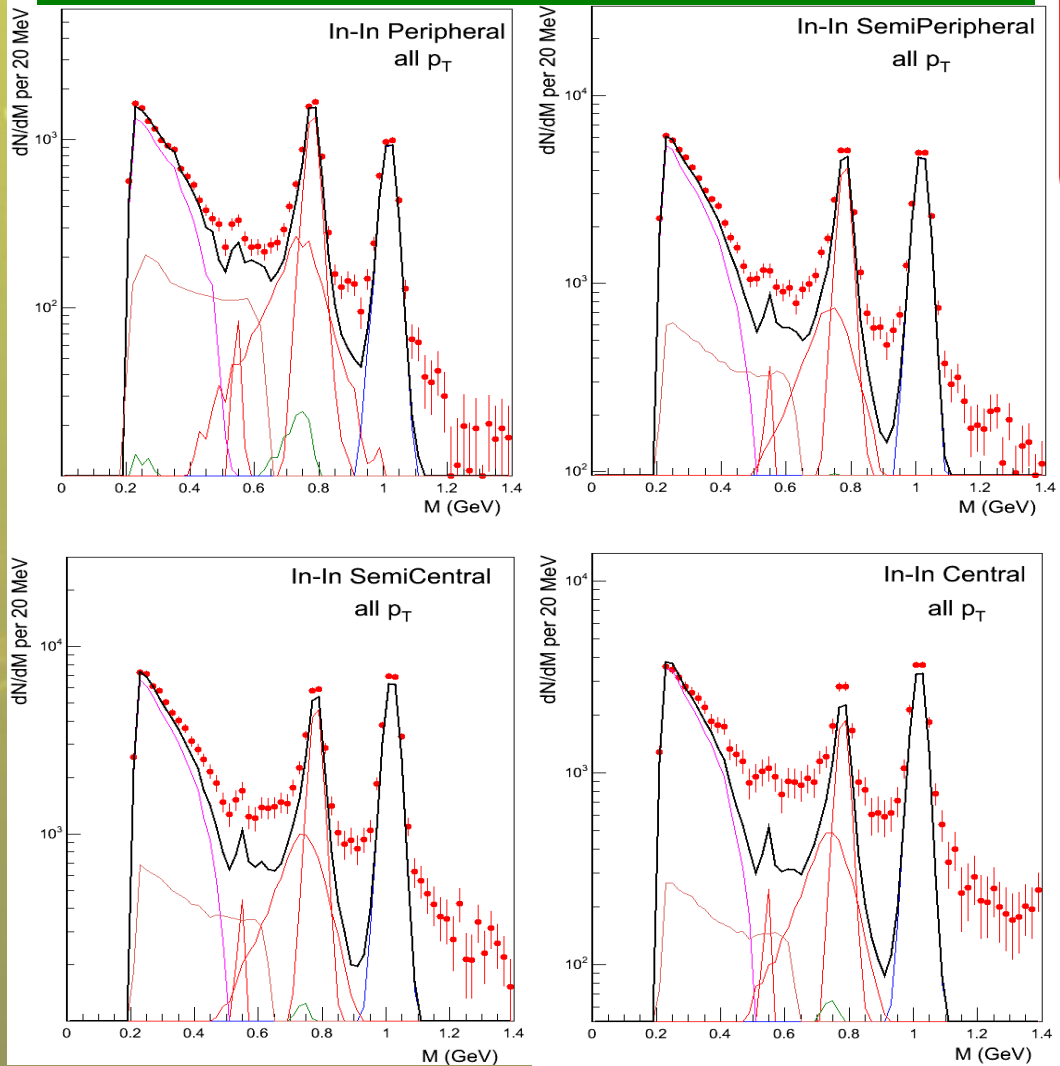


- J/Ψ @ RHIC : Comparable to NA50 results

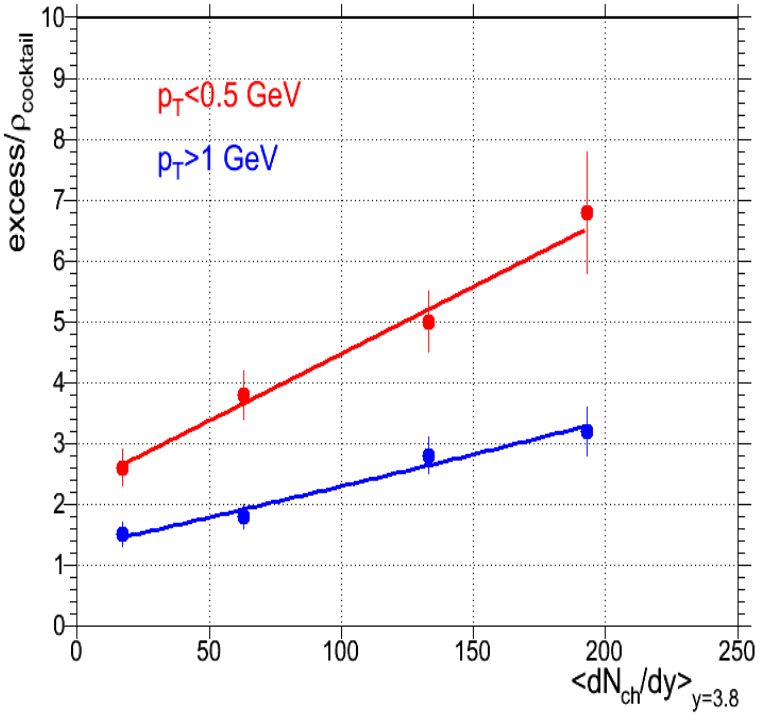
- Near side seems to broaden as function of centrality
- Splitting parameter D increases with centrality
- Similar trend for all systems and energies

Properties of the Quark Matter beyond T_C

NA60 very precise measurements in InIn

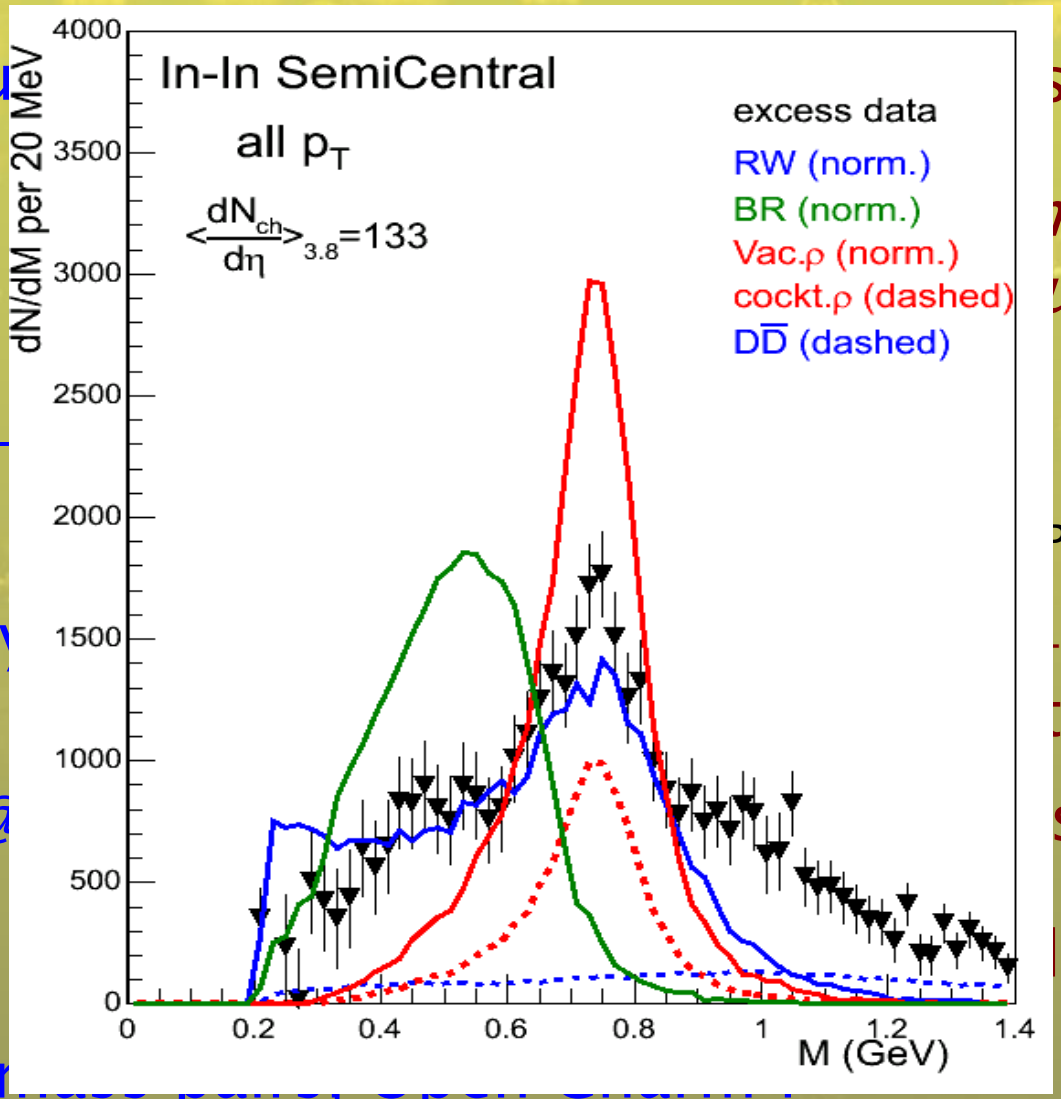


- ✓ *confirms and consistent with CERES*
- ✓ **rising with centrality**
- ✓ **more pronounced at low pT**



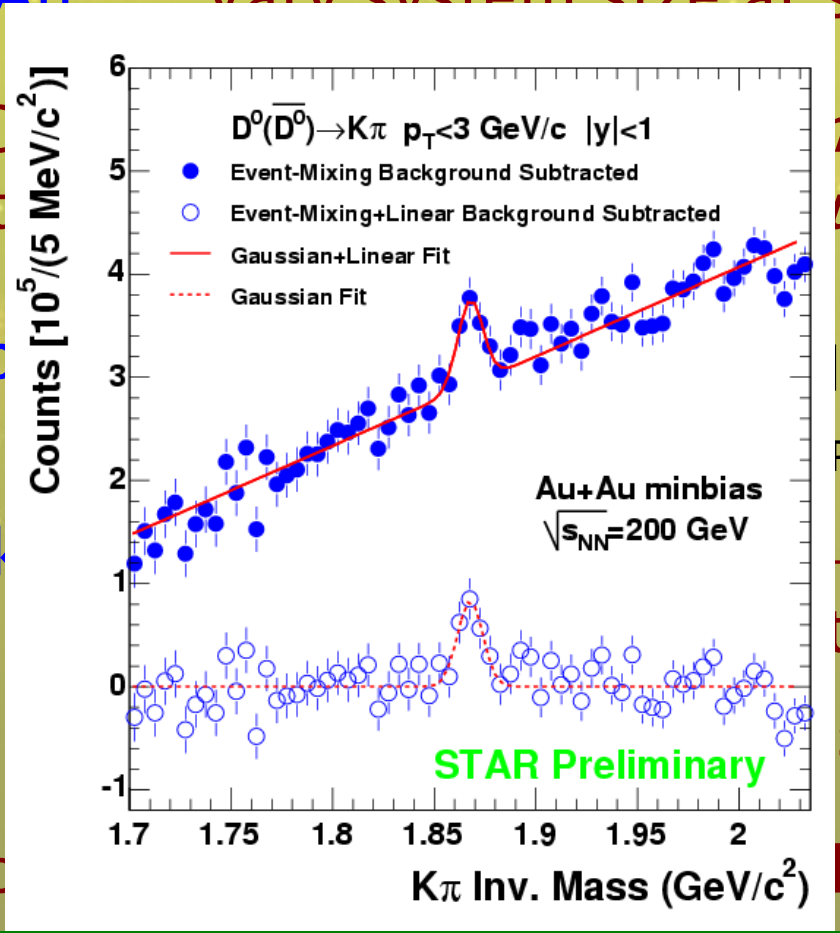
Properties of the Quark Matter beyond T_C

- CuCu … same energy
- Flow … of partonic … *quarks*
- high- … ue, … (meson)
- Heavy … , and flows … tudy
- J/Ψ @ … sults
- Jets : …
- low-…



Properties of the Quark Matter beyond T_C

- CuCu vs AuAu : Vary system size at same energy
- Flow : sQC … of partonic mat… *…uarks*
- high-PT Sup… …ue, …(meson)
- Heavy Quark… …, and flows …tudy
- J/Ψ @ RHIC … …sults
- Jets : Varic… …l



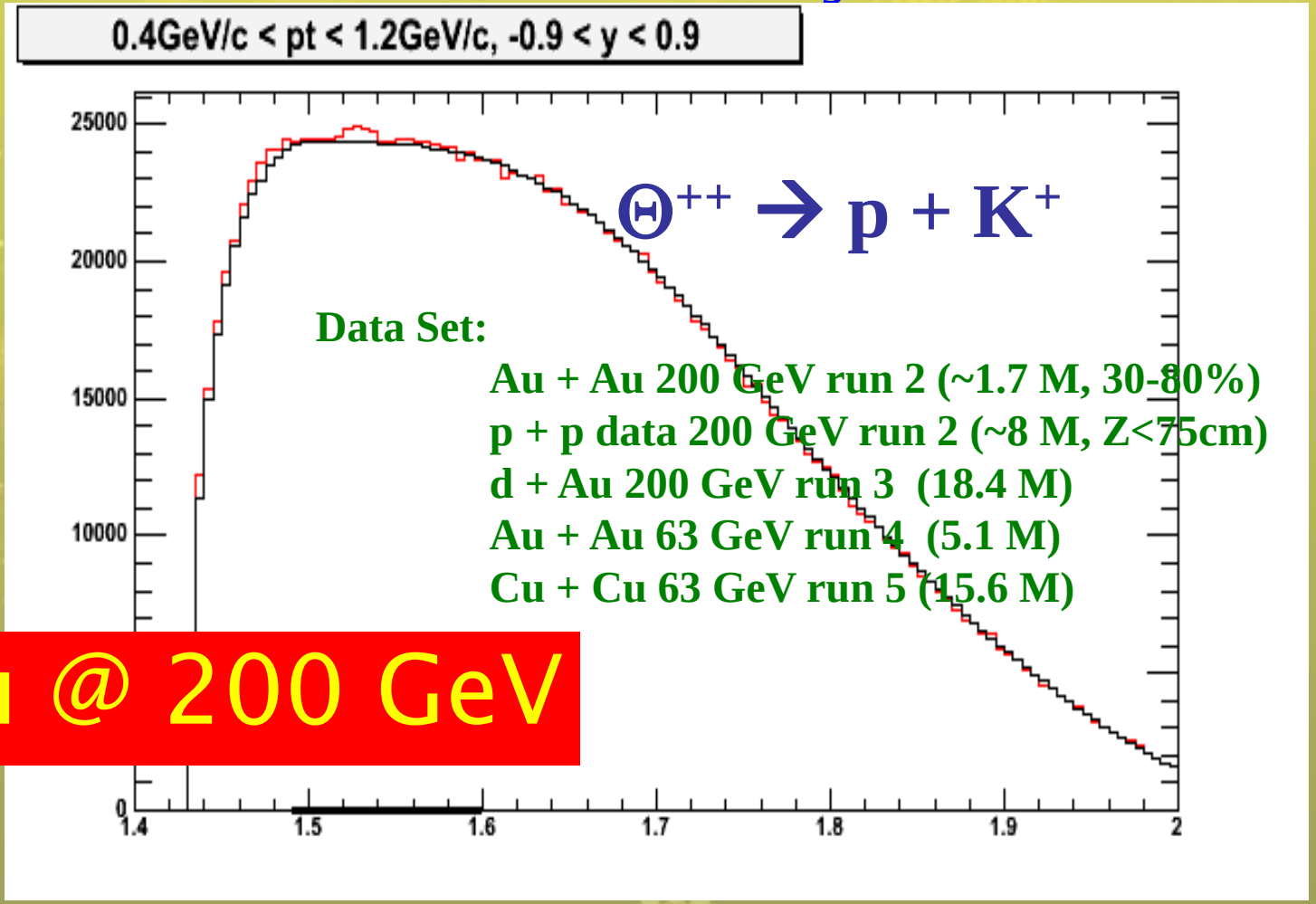
- The 1st direct Measurement of open charm in AuAu

Where we are, What to do

- SPS has returned !
  - The 1st Order Phase Transition
  - Looking for the 'critical' point
  - → SPS Program will be alive
- FAIR Project :
  - detailed study around the 'critical' point
  - study on 'dense' matter
- RHIC :
  - Study on properties of the 'Perfect Fluid' matter

Appendix (STAR Collab.)

Thanks to Huang & Ma



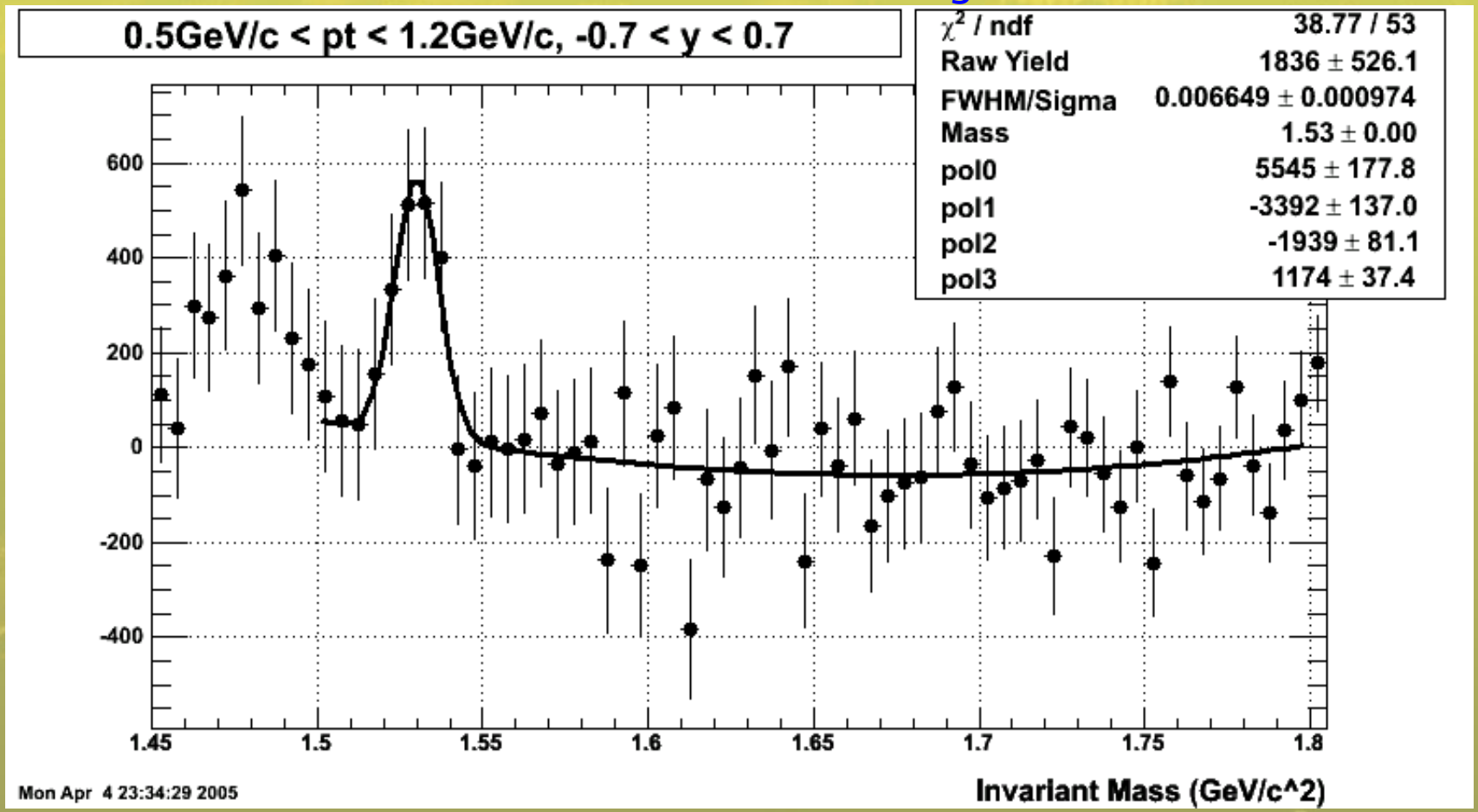
d+Au @ 200 GeV

pK^+ and $\bar{p}K^-$ from 18.4 M d+Au at 200 GeV

Background – Combinatorial and Correlated Pairs

Appendix (STAR Collab.)

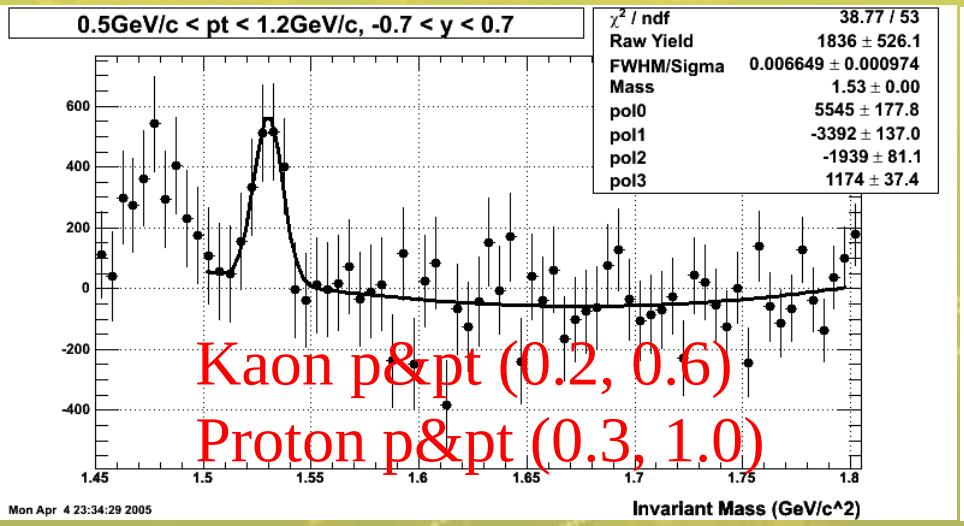
Thanks to Huang & Ma

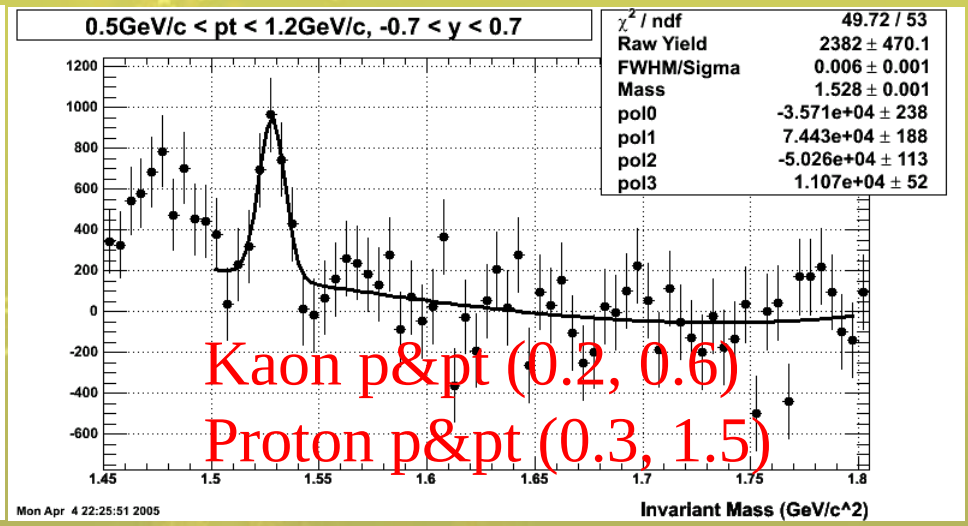


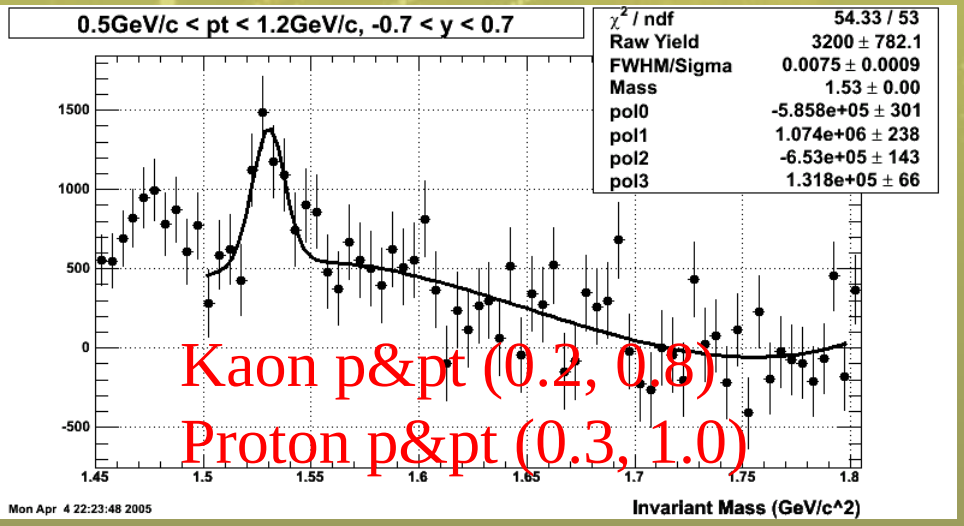
- 3.5–5.0 sigma signal.
- Measured mass ~ 1.53 GeV/c^2.
- Full width ~ 15 MeV

Appendix (STAR Collab.)

Thanks to Huang & Ma



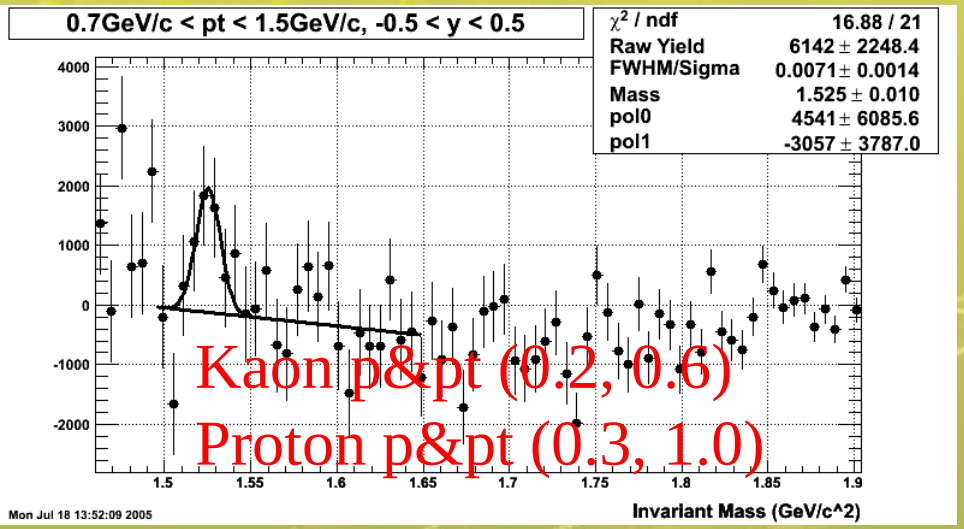


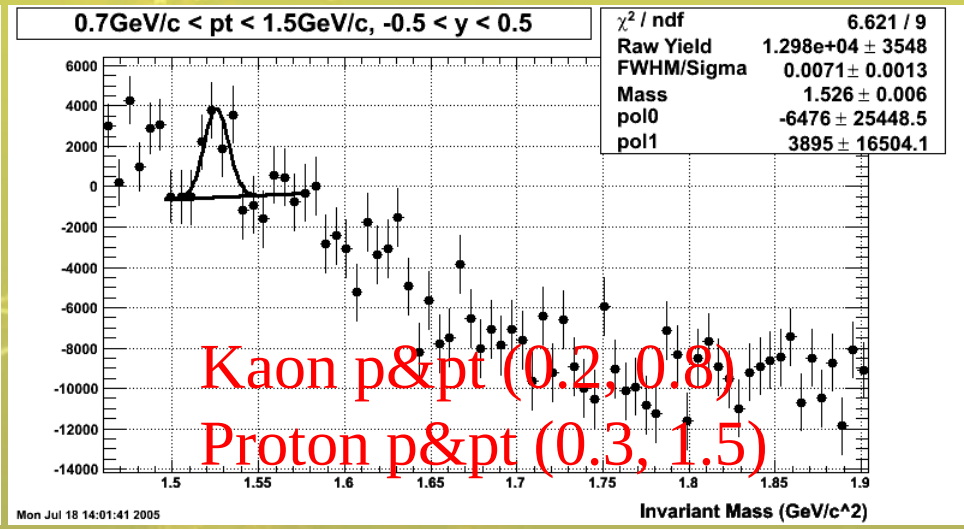


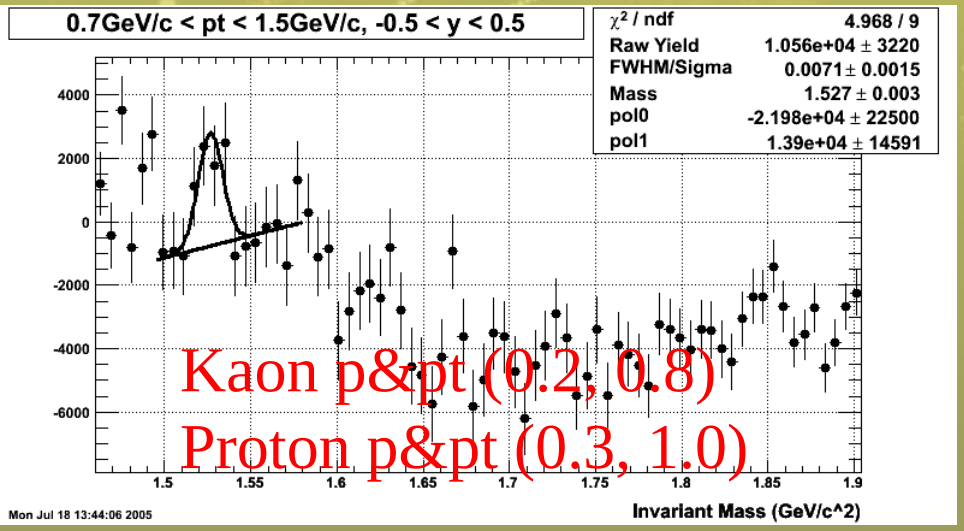
d+Au @ 200 GeV

Appendix (STAR Collab.)

Thanks to Huang & Ma



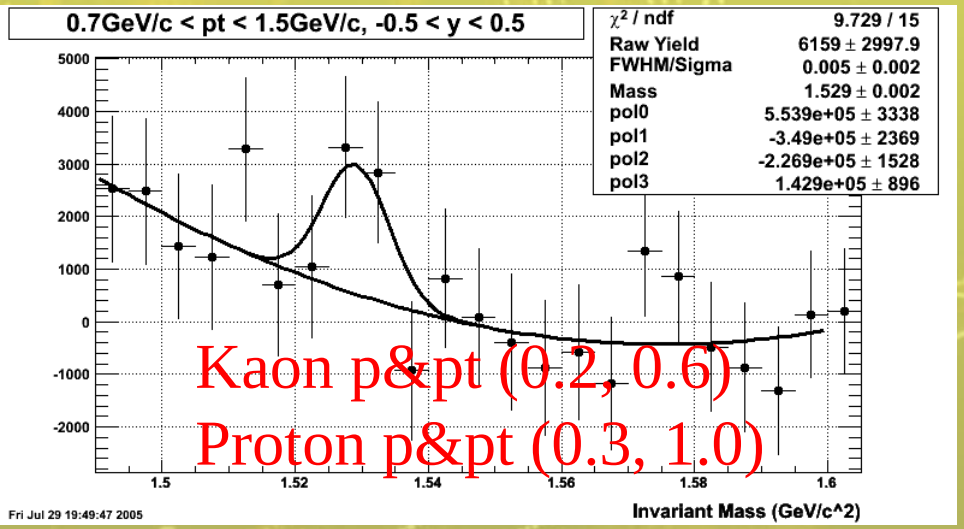


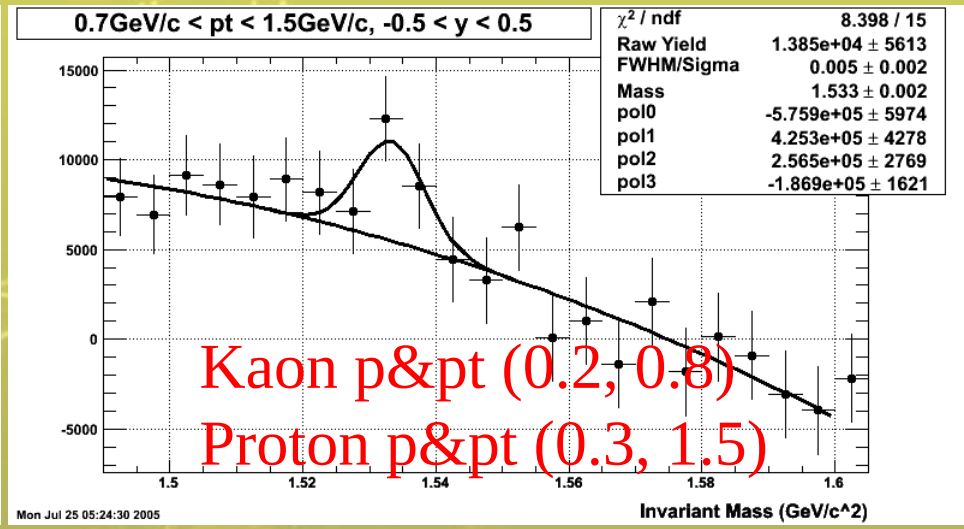


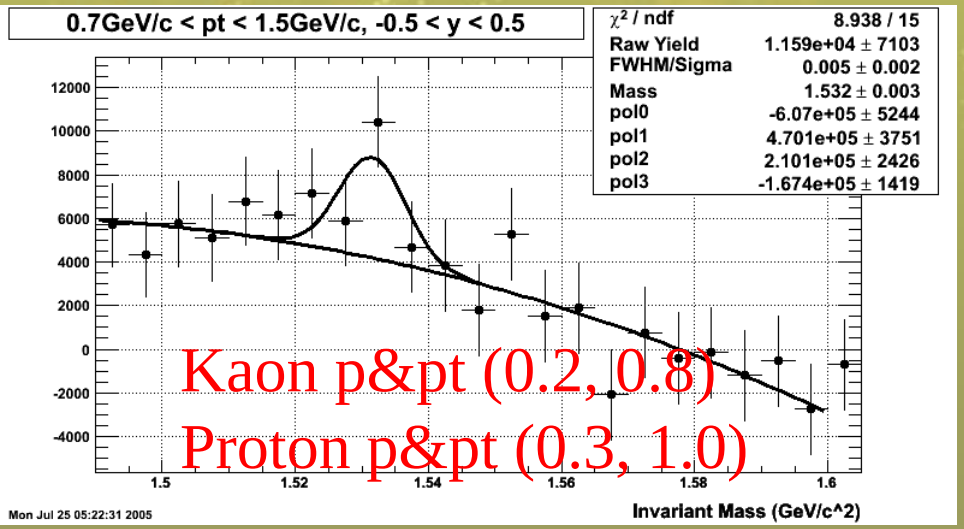
- AuAu 62 GeV data
- 20-80% centrality bin
- 5.6 M events
- 3-3.5 sigma signal

Appendix (STAR Collab.)

Thanks to Huang & Ma



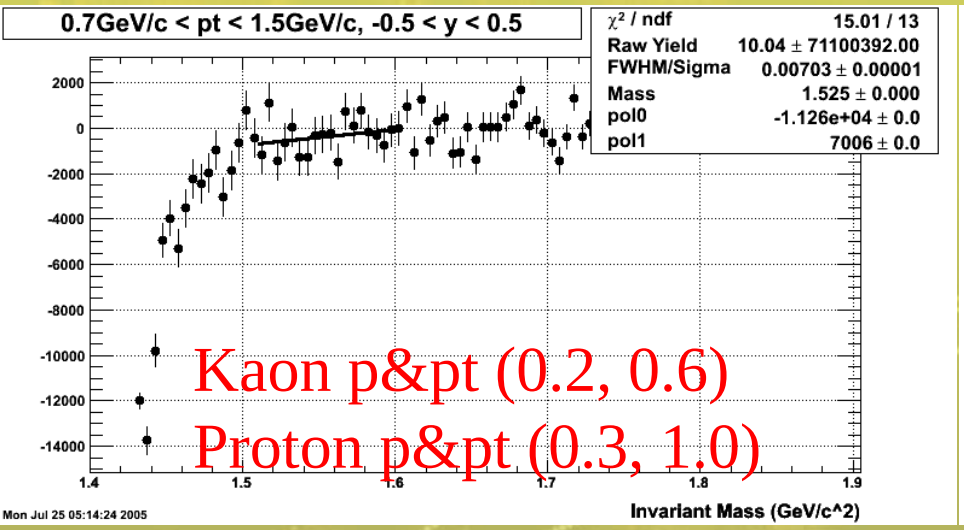


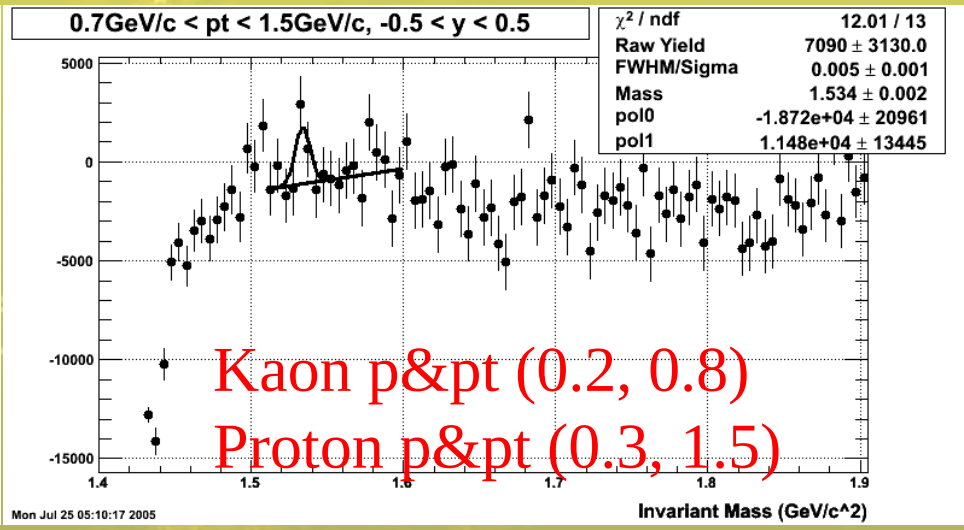


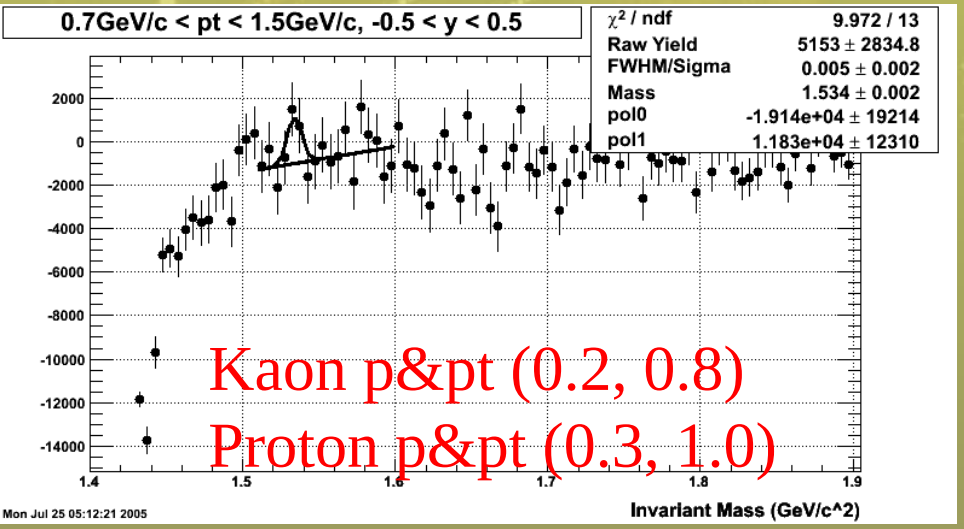
- Year 4 AuAu 200 GeV data
- 20-80% centrality bin
- 10.7 M events
- 2-2.5 sigma signal

Appendix (STAR Collab.)

Thanks to Huang & Ma







- Year 5 CuCu 62 GeV data
- 0-70% centrality bin
- 16.5 M events
- No signal with clean Kaon (p<0.6) cut

Appendix (STAR Collab.)

Thanks to Huang & Ma

1) If pK^+ peak at 1530 MeV/c^2 is a real pentaquark, then I = 1 likely, there must be a Θ^+. But the recent JLab null result on Θ^+ casts serious doubt on the observation of Θ^+.

2) The STAR observed yield is so small such that many experiments would not have the sensitivity to see it.

3) Within the STAR data we have not seen any significant peak signal in p+p (8M) data and Au+Au at 200 GeV (~10M).
What do these null observations mean?
Production dynamics or data set bias unknown to us?
What is so special about d+Au 200 GeV (18.4 M events) and Au+Au 62.4 GeV (5.1 M events) ?

4) More and more carefulness for any concrete conclusion !