Konferencja QM05 dźć

(dźć Bohusia)

Helena Białkowska

Bowne tematy na poprzednich QM:

1. Tzw ‘global characteristics’ oraz ‘flow’
2. ‘Penetrating probes’:
   - tłumienie jetów
   - open ?/hidden charm?
   - dileptony?
   - bezpośrednie ‘prompt’ fotony?

Na tej QM (Budapeszt, sierpie 05)

1. Global characteristics nadal ważne – wszędzie skalowanie!
2. Flow – wszystko płynie, różne charakterystyki
3. Znikają lub maleją znaki zapytania:
   - szczegóły gaszenia jetów
   - charm (flow, tłumienie Ψ)
   - ‘thermal photons?’

Komentarz lingwistyczny

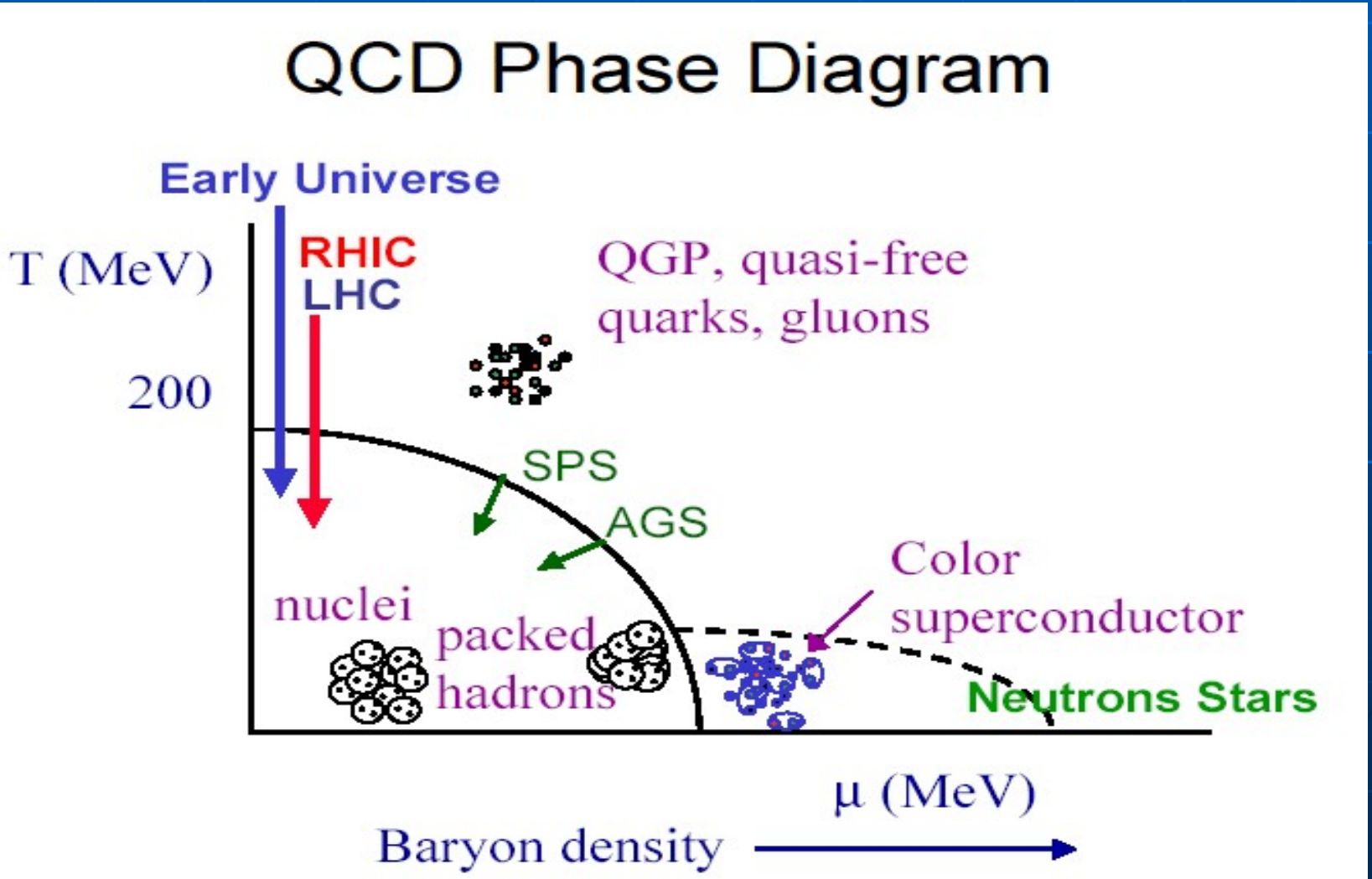
O plaźmie albo się nie mówi, tylko o ‘gęstej, gorącej materii’ (partonowej)

Albo ‘take it for granted’

A w każdym razie – ta plazma jest inna niż się spodziewaliśmy

Nowa mantra: sQGP albo ‘strongly coupled plasma with fluid-like properties’

Co jest plazma:



A Definition of the Quark-Gluon Plasma

(Tim Hallman, STAR spokesman)

QGP ≡ ***a (locally) thermally equilibrated state of matter in which quarks and gluons are deconfined from hadrons, so that color degrees of freedom become manifest over nuclear, rather than merely nucleonic, volumes.***

non-interacting quarks and gluons

Ale niekoniecznie

1st- or 2nd-order phase transition

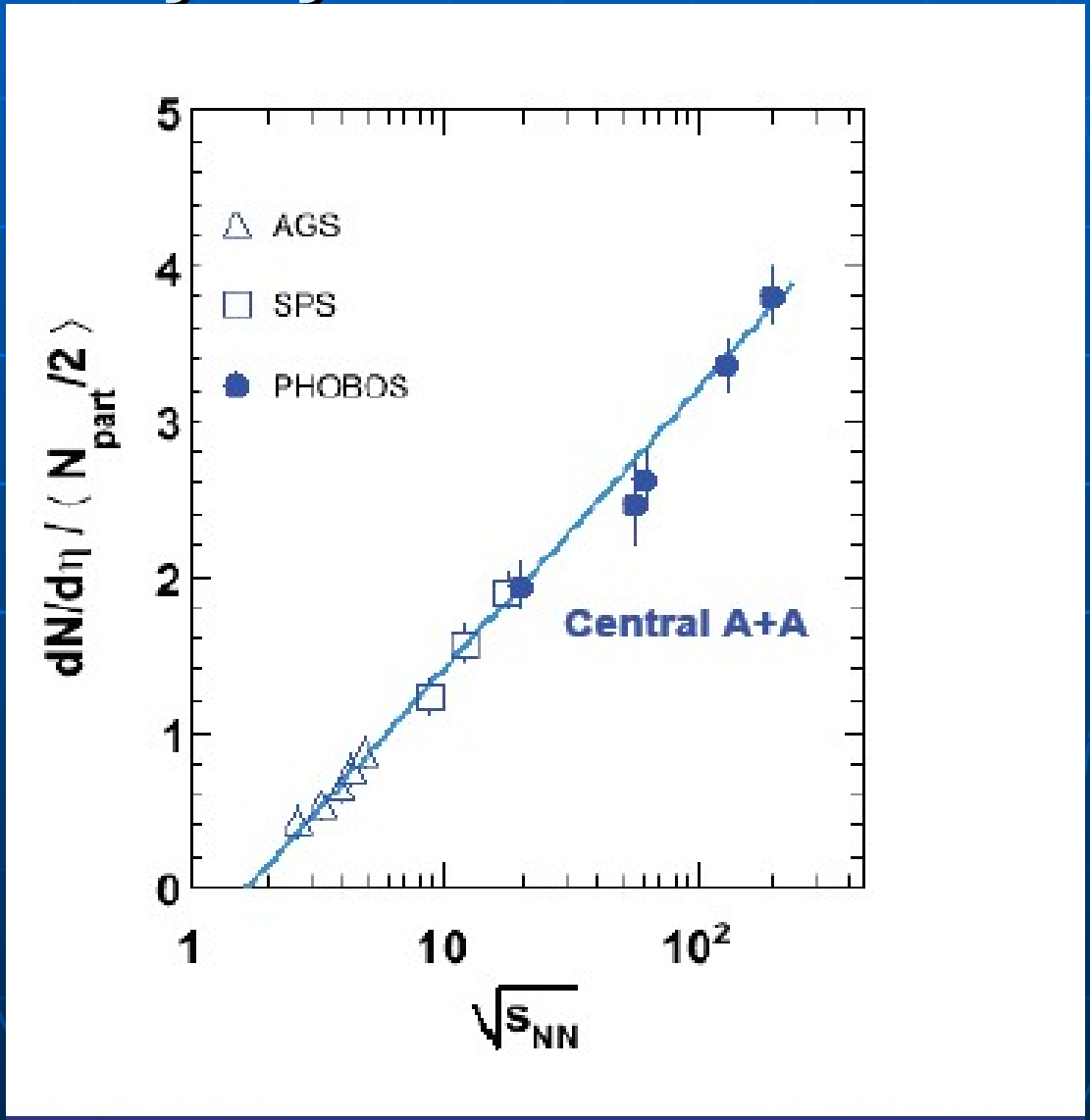
evidence of chiral symmetry restoration

Nowe dane z RHICa:

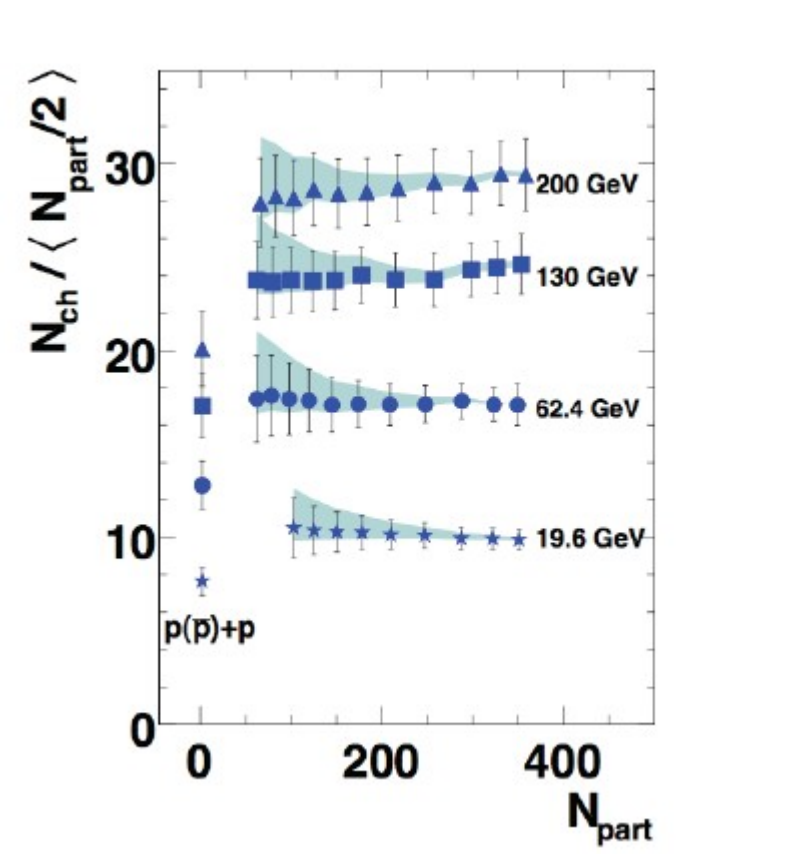
Run	Year	Species	$s^{1/2}$ [GeV]	∫Ldt
01	2000	Au+Au	130	1 μb^{-1}
02	2001/2	Au+Au	200	24 μb^{-1}
		p+p	200	0.15 pb^{-1}
03	2002/3	d+Au	200	2.74 nb^{-1}
		p+p	200	0.35 pb^{-1}
04	2003/4	Au+Au	200	241 μb^{-1}
		Au+Au	62	9 μb^{-1}
		Cu+Cu	22.5	2.7 μb^{-1}

A także nowe (NA60 In-In) i nowoopracowane (NA49, NA57) dane z SPS

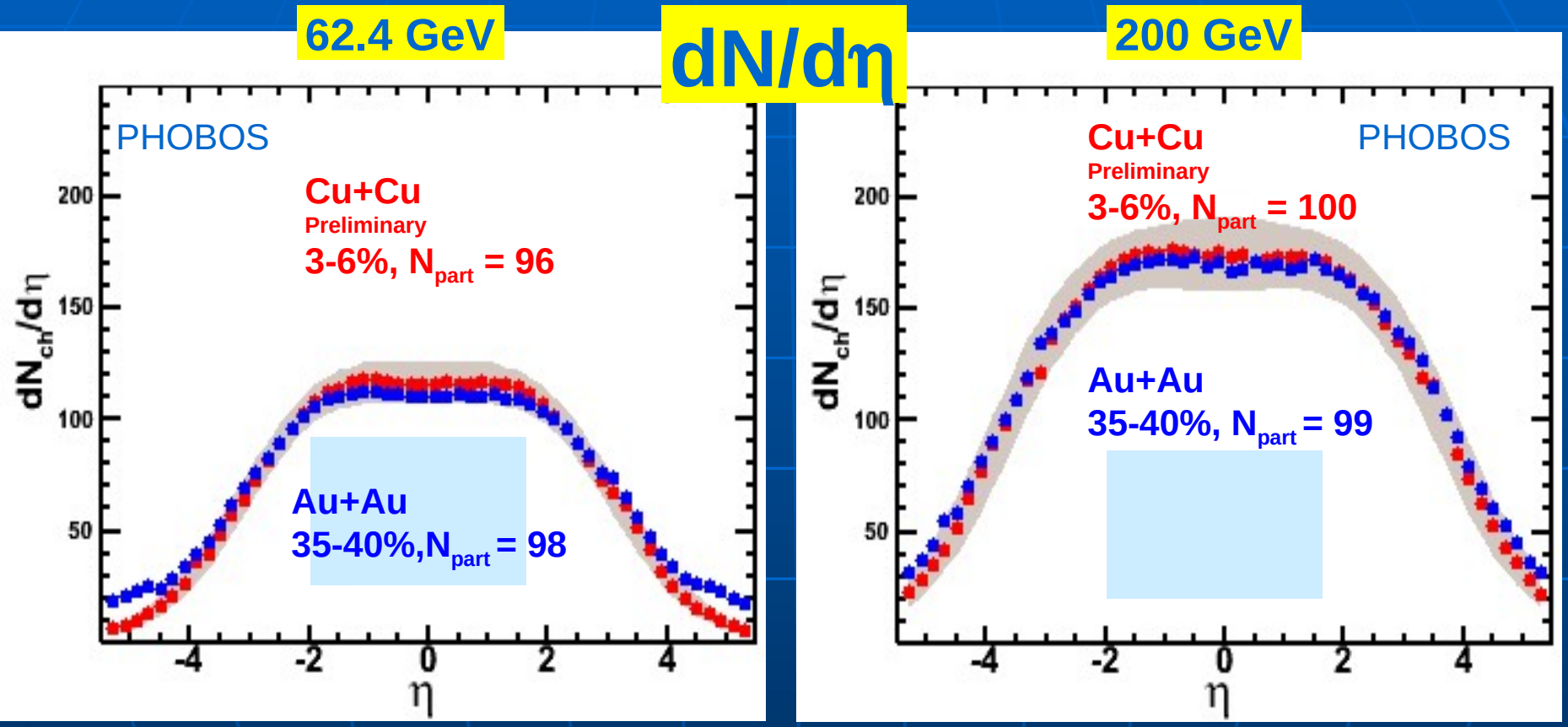
Zaczynamy od globalnych charakterystyk: krotno



śóvs centralno



Od Cu do Au: rozkłady pospieszności

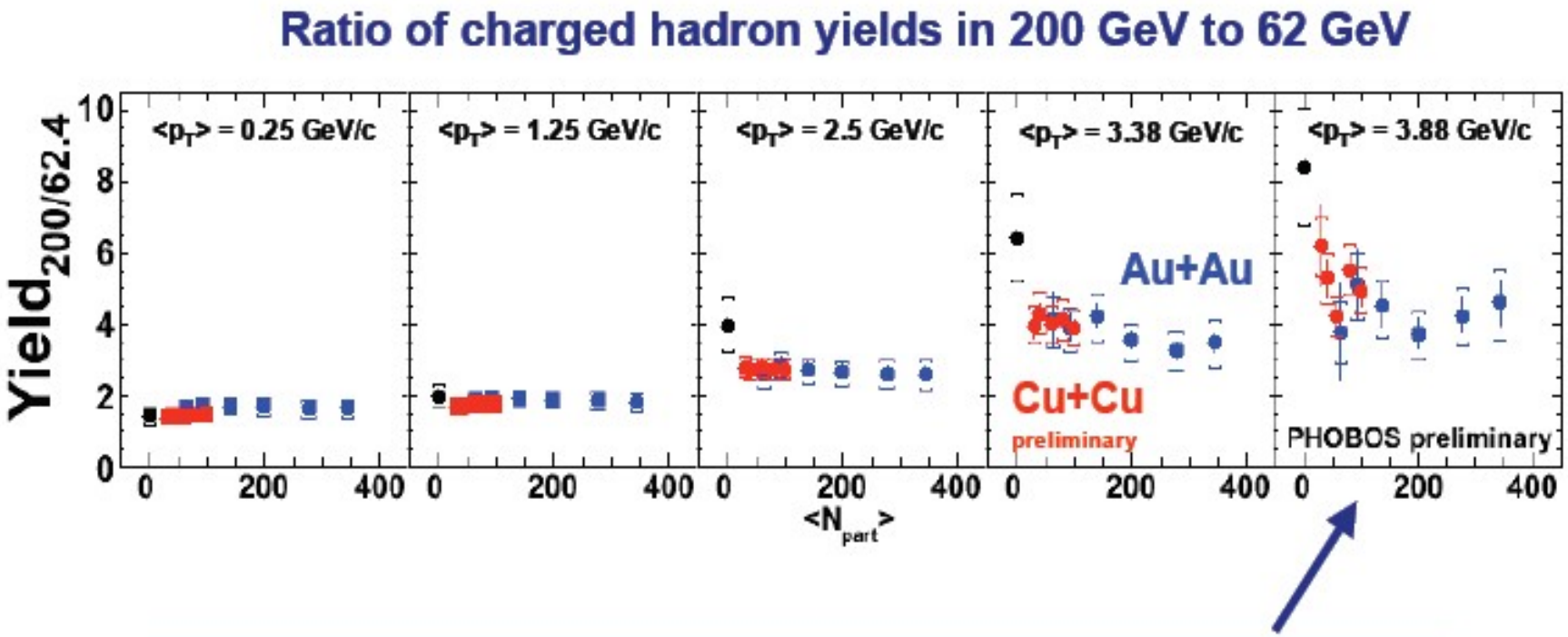


Skalowanie w N part

Przy danej energii i tej samej liczbie uczestników – wszystko jedno czy Cu czy Au

Rozkład poprzecznego:

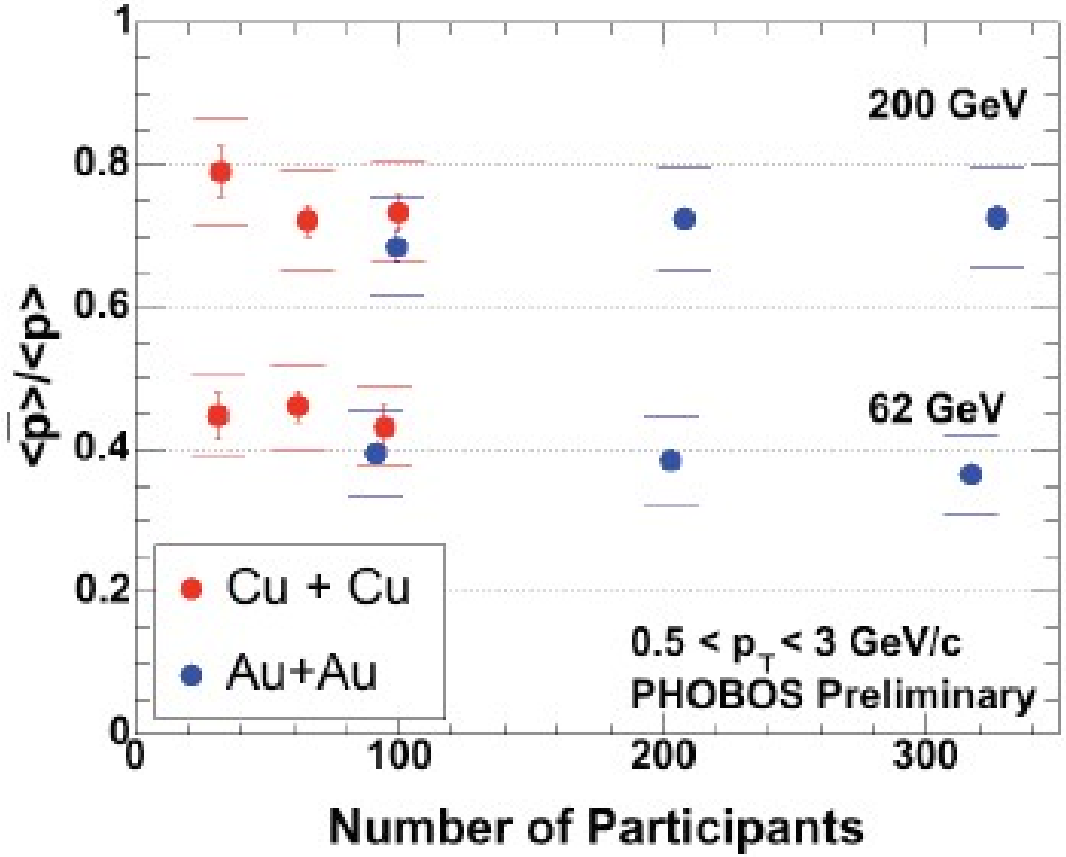
Factorization in p_T, I



Energy/centrality factorization up to $p_T \approx 4$ GeV/c for $N_{part} > 40$

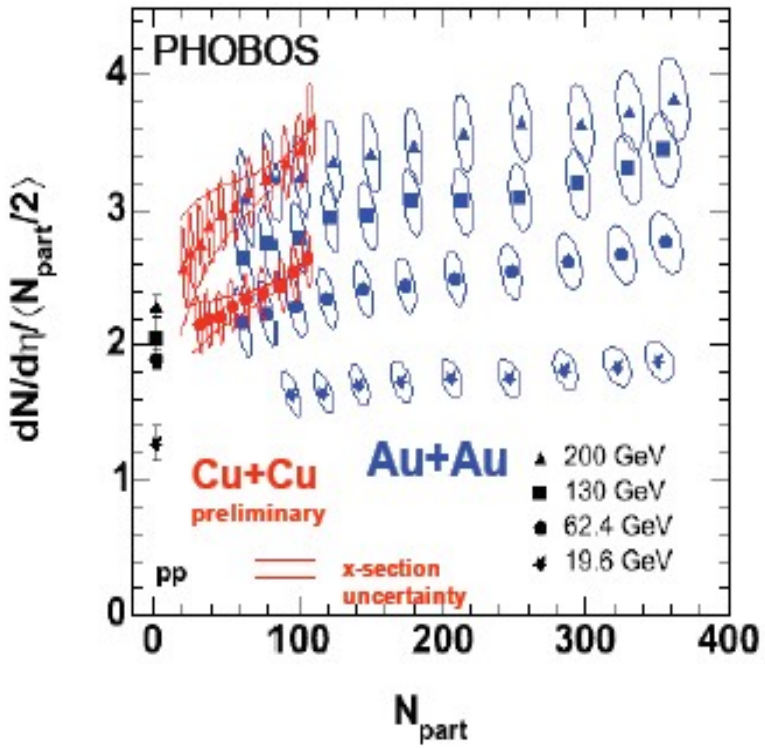
Stosunek produkcji barion/antybarion:

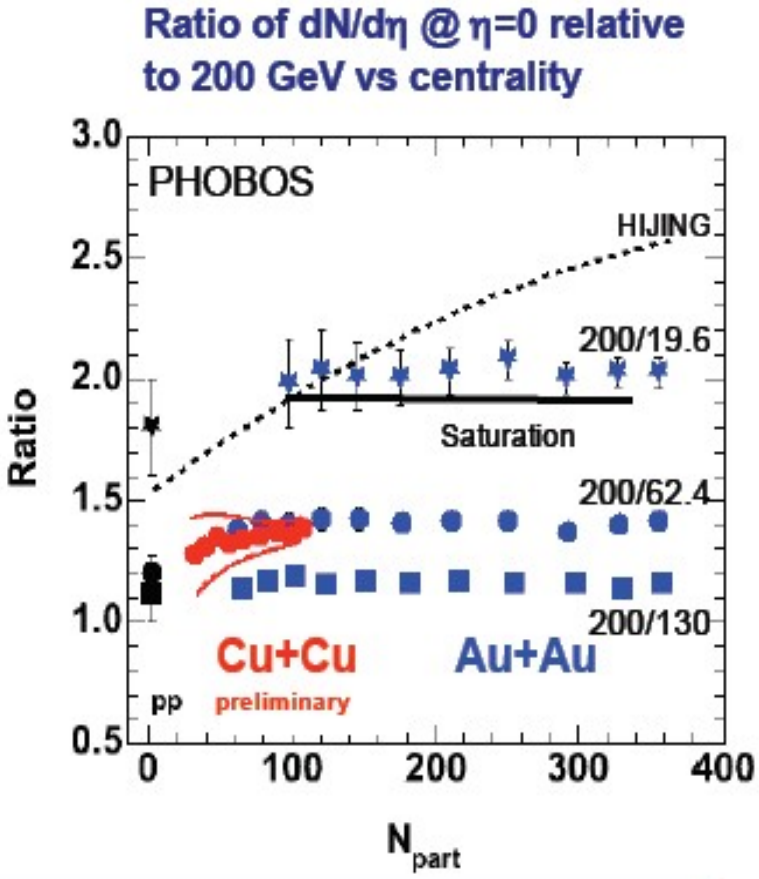
Anti-proton/proton ratio



$\bar{p}/p$ ratio very similar in Cu+Cu and Au+Au

Faktoryzacja?





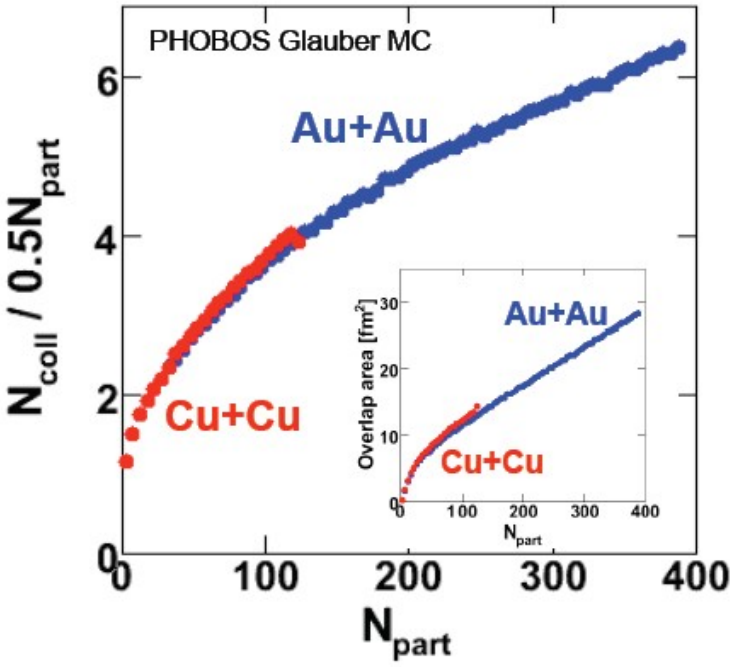
Factorization of energy and centrality dependence

Initial state effect?

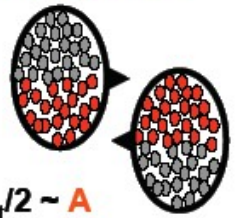
Ta faktoryzacja zależności od energii i od centralności sprzeczna z modelami dwuskładnikowymi typu ‘część miękka skalowana w liczbie uczestników i twarda – w liczbie zderzeń’; ta twarda miałaby rosnąć z energią (wzrost liczby mini-jetów)

Rola geometrii j

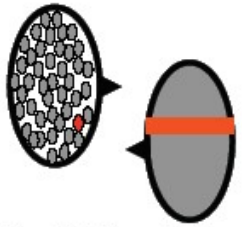
Collision Geometry



"Participants"



$N_{part}/2 \sim A$



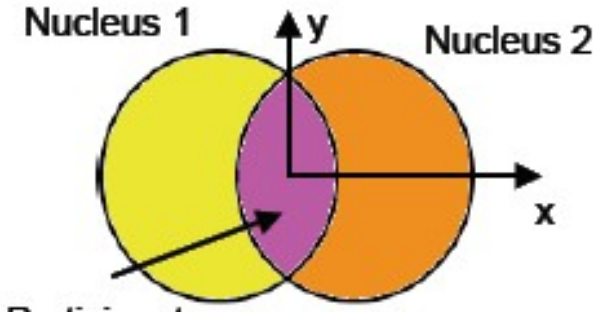
$L \sim A^{1/3}$

N_{coll} = # of NN collisions: $\sim A^{4/3}$

"Collisions"

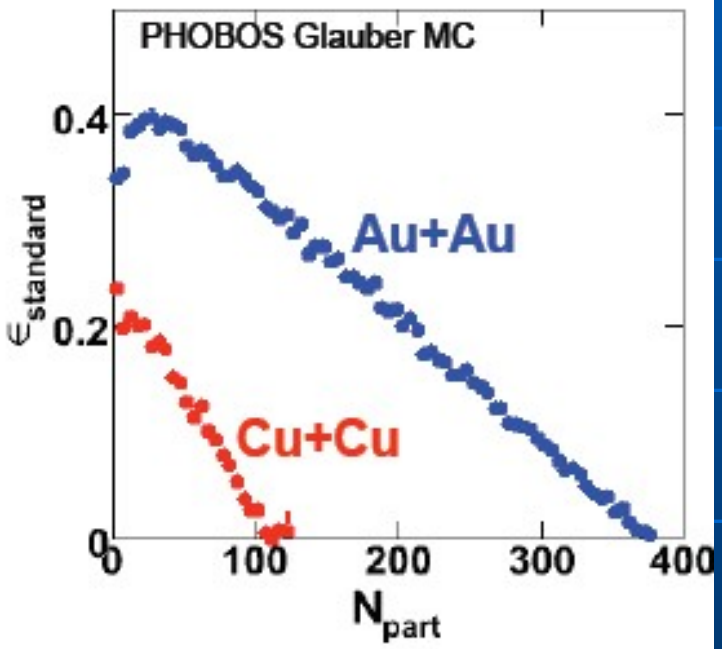
Geometria ‘poprzeczna’

Transverse Geometry



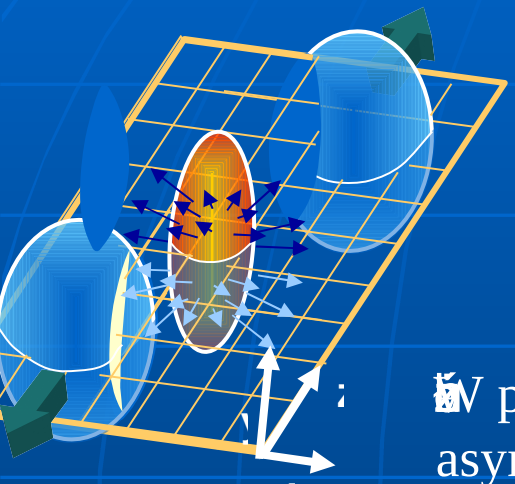
$$\varepsilon = \frac{\sigma_y^{\,2} - \sigma_x^{\,2}}{\sigma_y^{\,2} + \sigma_x^{\,2}}$$

wrt reaction plane

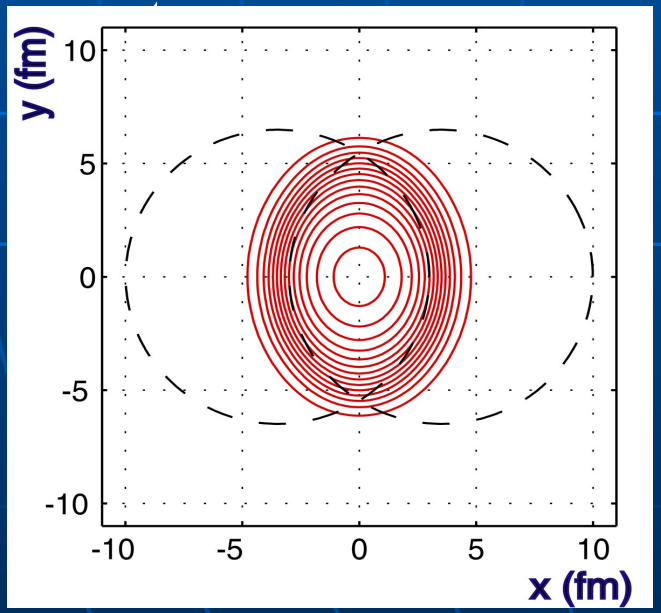


- **Au+Au vs Cu+Cu**
  - Interplay of initial geometry and initial density
  - Test ideas of early thermalization and collectivity

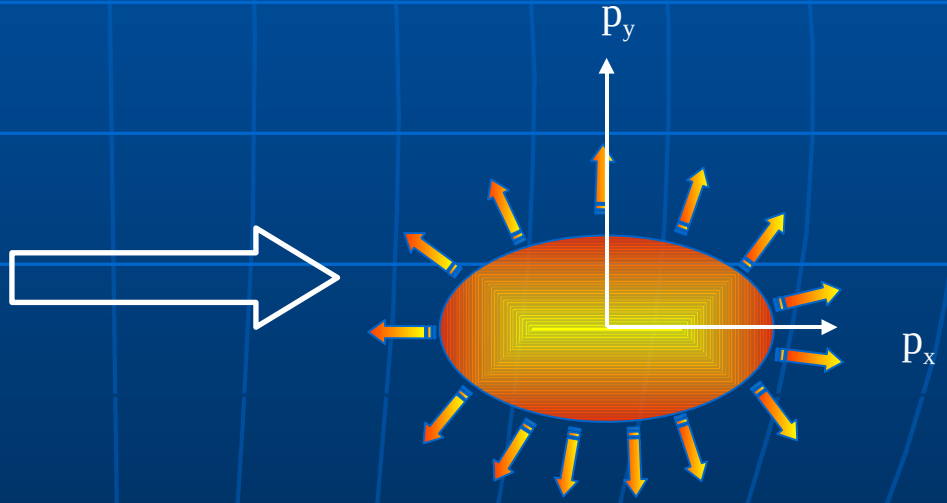
Teraz patrzymy na efekty kolektywne: flow



W przestrzeni po asymetria



W przestrzeni p asymetria



Jak mierzy ‘elliptic flow’:

Trzeba wyznaczyć płaszczyznę reakcji: intuicyjnie proste, ‘płaszczyzna wyznaczona przez wszystkie wyprodukowane cząstki’, prostopadle do wiązki pierwotnej

Wyznaczyć tę płaszczyznę dla każdego przypadku :Ψ

A dalej – zrobić rozkład kąta między pędem danej cząstki a wektorem płaszczyzny reakcji,

i rozwinąć go w szereg Fouriera

współczynnik przy cos $2(\phi - \Psi)$ to właśnie v_2 czyli ‘elliptic flow’

Opis hydrodynamiczny:

O czym mówi flow:

Skoro mamy dużą gęstość energii to możliwa ‘szybka termalizacja’

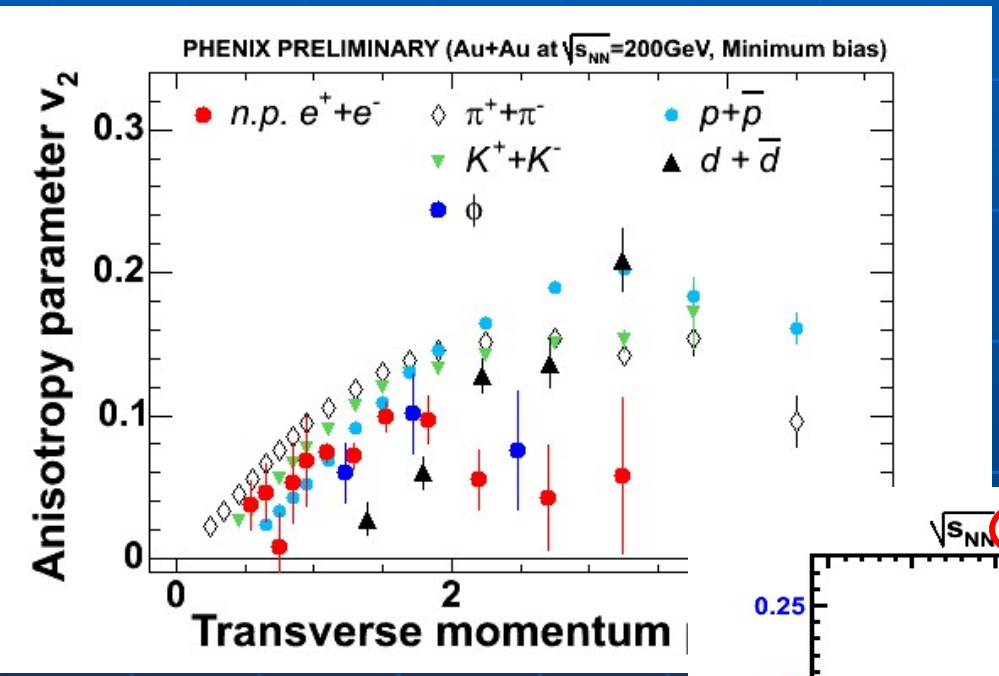
Wtedy duży gradient ciśnienia

Dla p_t < ~2-3 GeV/c dobry opis

Powyżej – inaczej

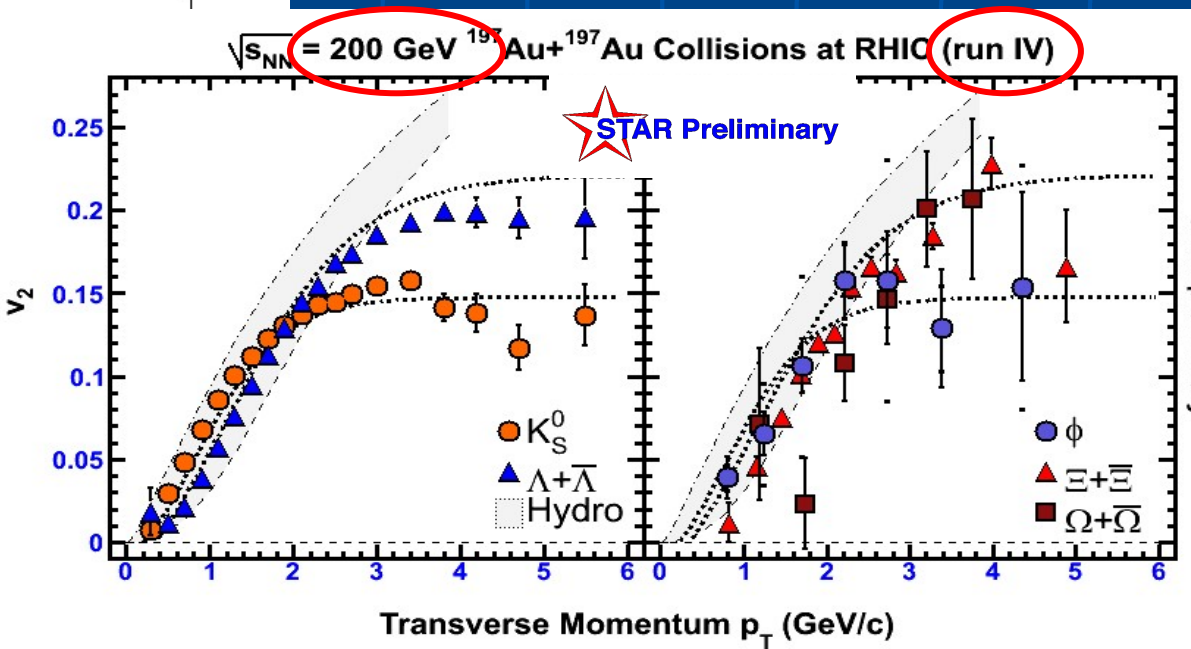
I nowa hipoteza (stara, ale nowa w tym zastosowaniu): koalescencja

Wiele nowych danych o flow:



'wszystko płynie'

różnica mezony – bariony

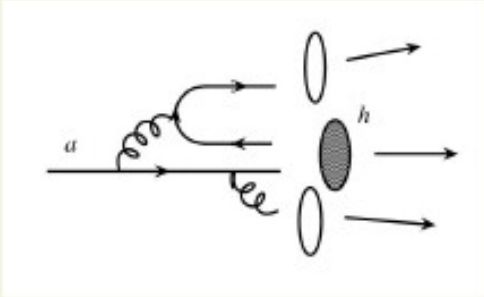


Inna interpretacja konkurencyjna do hydro:

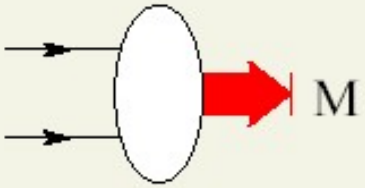
Parton coalescence

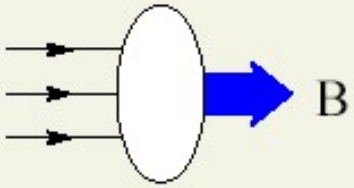
Hwa, Yang, Biró, Zimányi, Lévai, Csizmadia, Ko, Lin, Voloshin, DM, Greco, Fries, Müller, Nonaka, Bass, ...

In addition to jet fragmentation



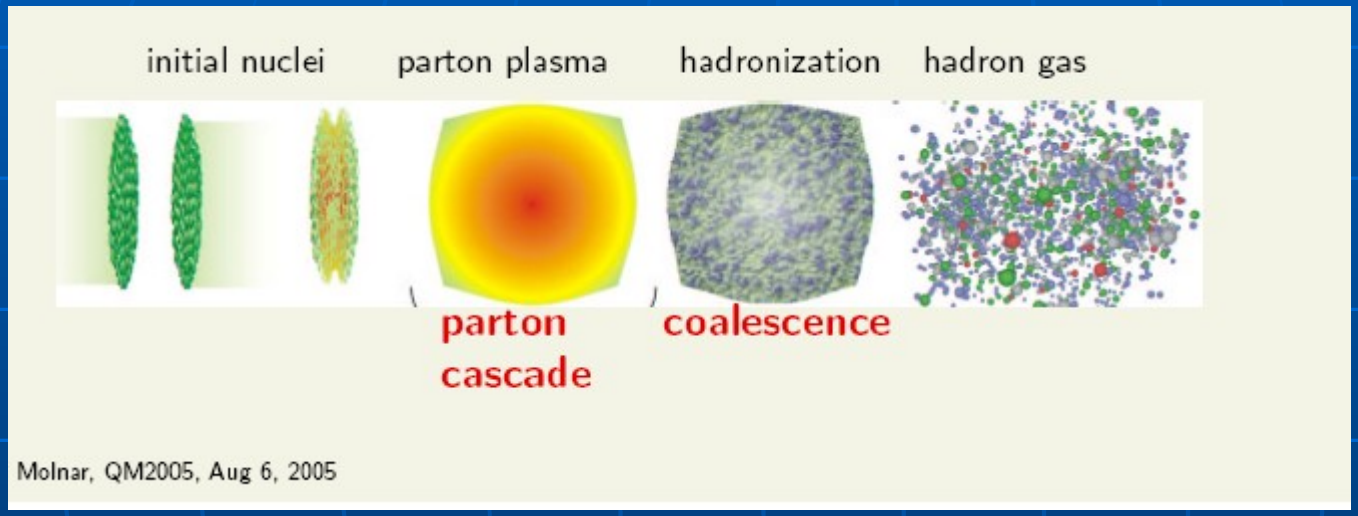
other hadronization channels via parton coalescence/recombination



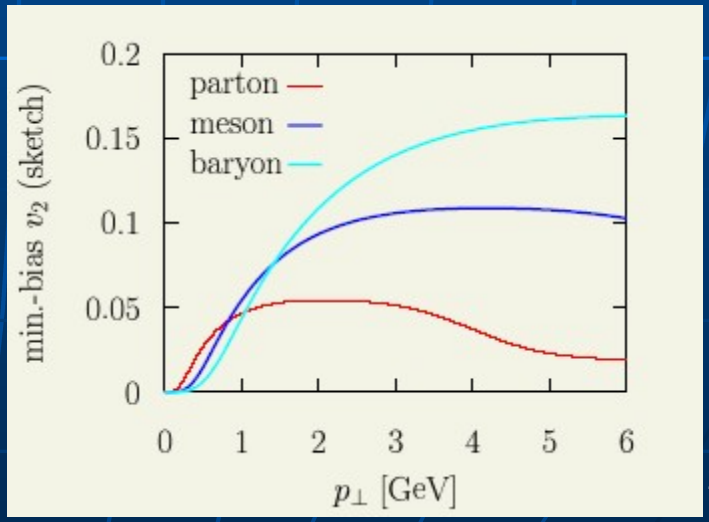


to lowest order $q\bar{q} \to M$, $qqq \to B$

Kiedy koalescencja mo



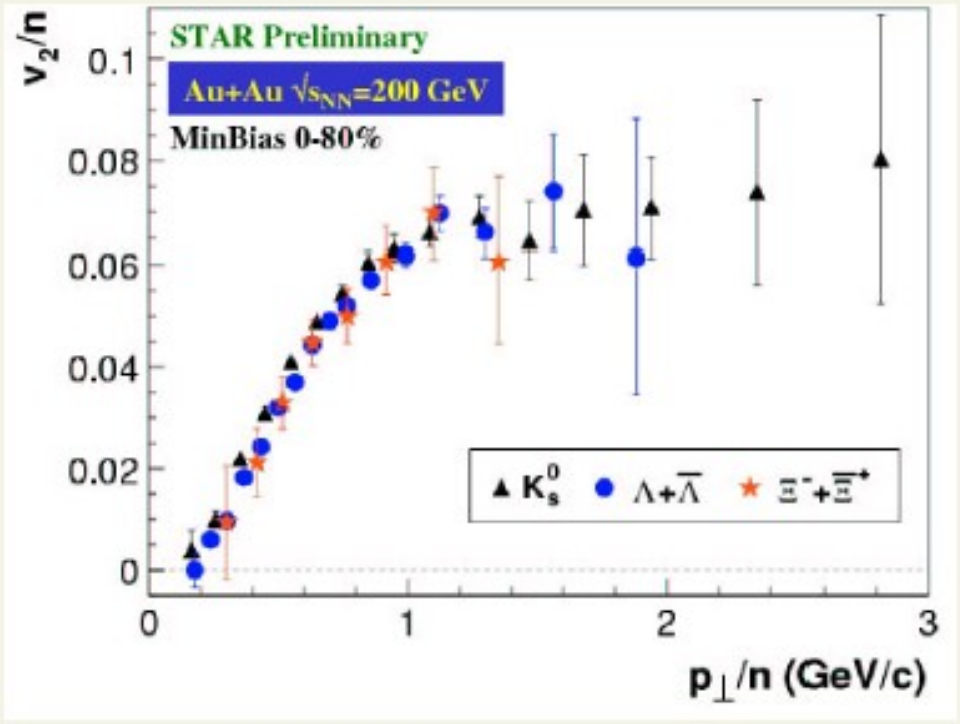
I jakie dać efekty dla mezonów
a jakie dla barionów



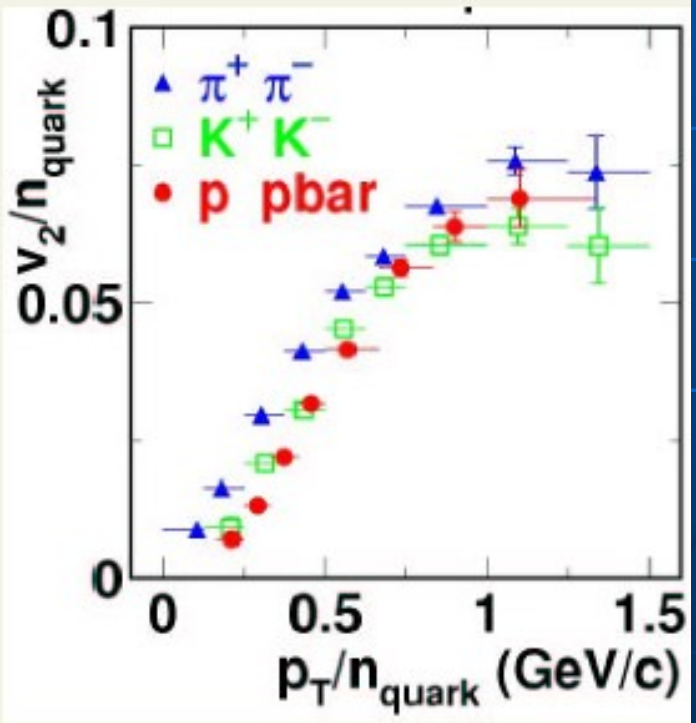
Śnieczywi

quark number scaling OBSERVED: v_2/n_v vs p_T/n_v universal

Castillo [STAR] '03



Esumi [PHENIX] '03

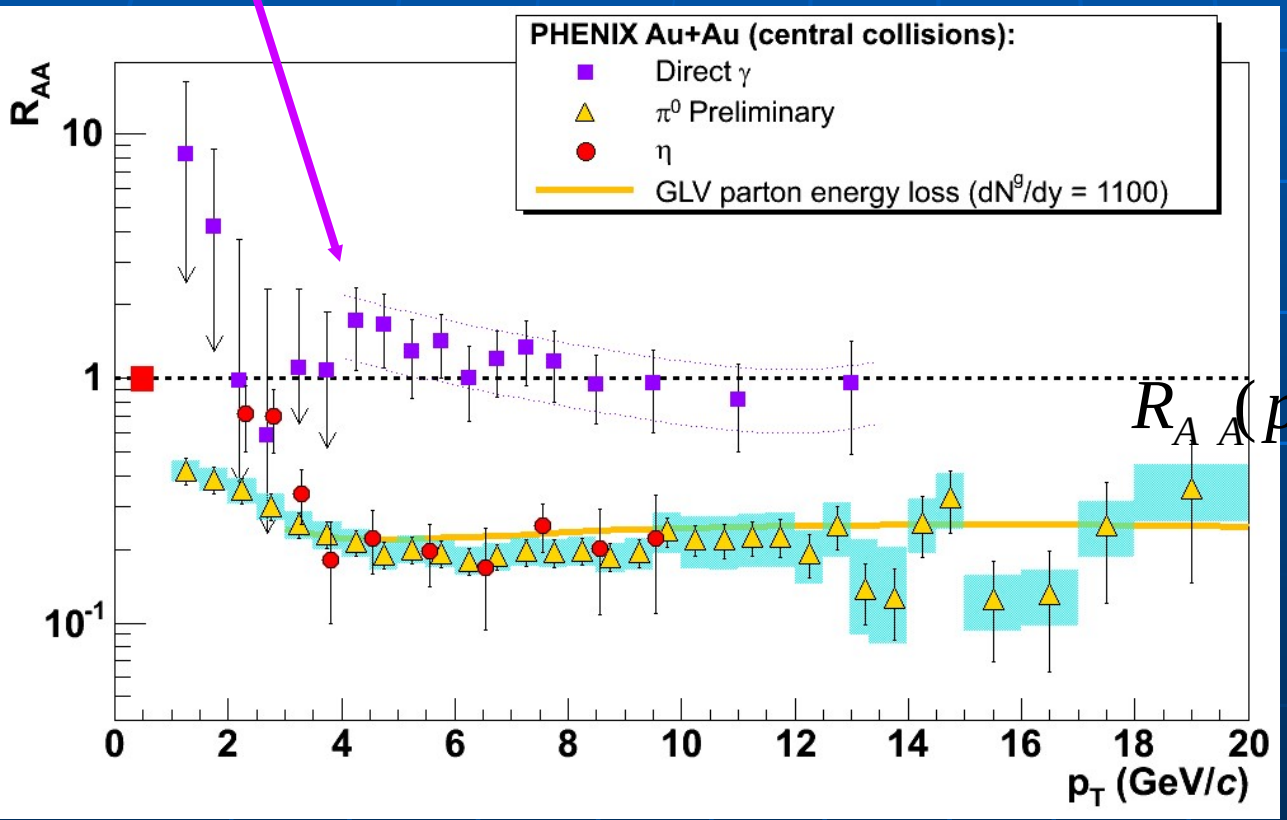


Wiele nowych danych o tej ‘kolektywnej materii partonowej’:

Cytaty za Y.Akiba, PHENIX

The matter is so opaque that even a 20 GeV π^0 is stopped

Fotony



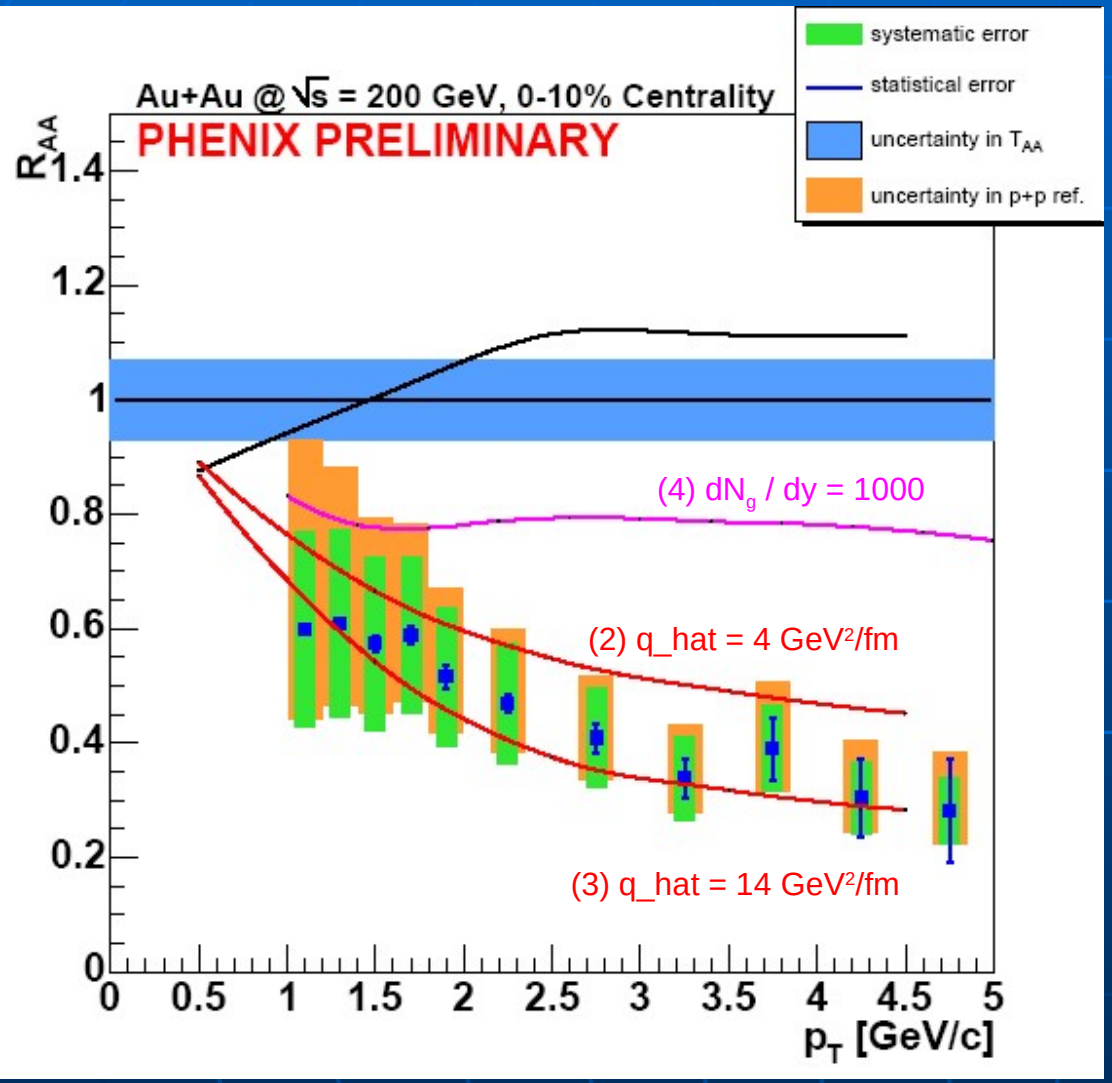
Więcej o tym 2 grudnia

$$R_{AA}(p_T) = \frac{d^2N^{AA}/d\,p_T d\eta}{T_{AA}\, d^2\sigma^{NN}/d\,p_T d\eta}$$

Gaszenie sięga 20 GeV/c!

η jak π!

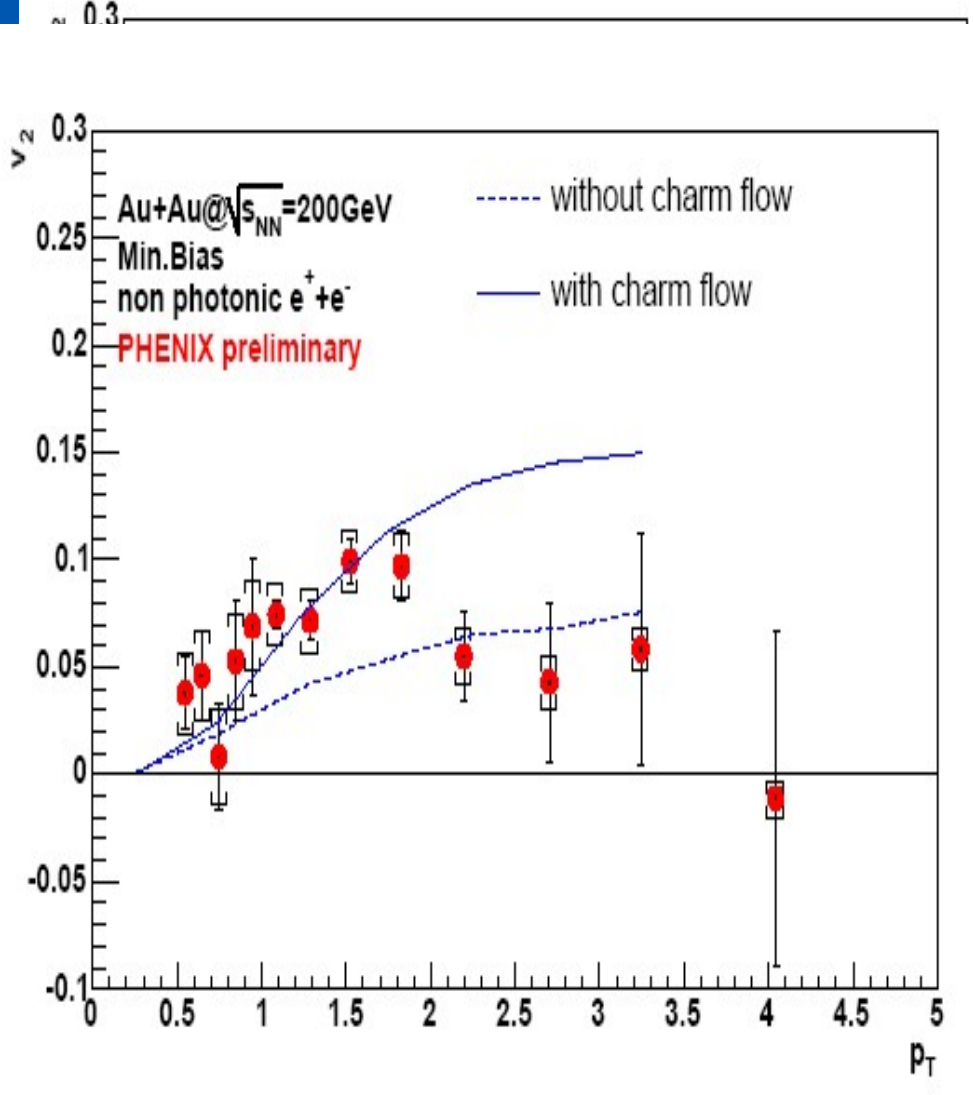
The matter is so dense that even heavy quarks are stopped



(skąd dane o c:
`non-photonic electrons'

The data suggest large c-quark-medium cross section; evidence for strongly coupled QGP?

The matter is so strongly coupled that even heavy quarks flow



Charm flows, but not as strong as light mesons.

Drop of the flow strength at high p_T. Is this due to b-quark contribution?

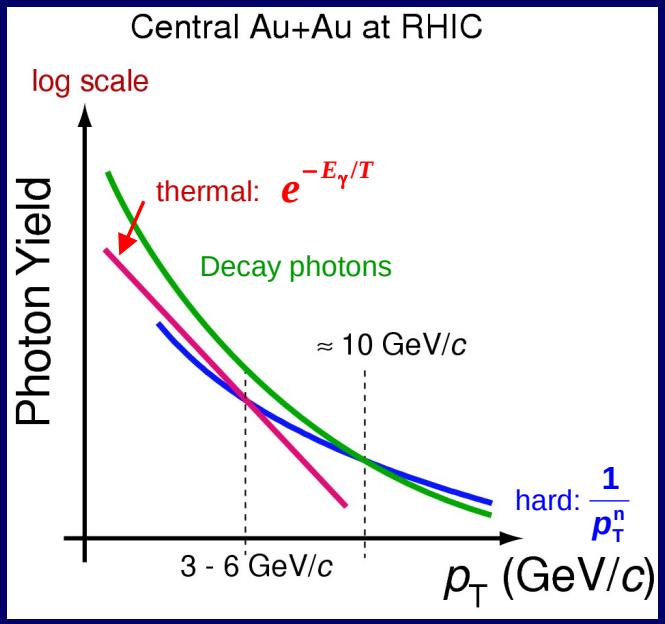
Charm flow supports high parton density and strong coupling in the matter.

Teraz o ‘prompt photons’: dlaczego takie wa?

- Fotony wodzą
- Fotony – pozwalają N_{col}
  - dla interpretacji t dla hadronów)
- Fotony ‘thermal’ – powinny nie zderzenia
- Wuporczywe,bardzo trudne technicznie, badanie γ ymp

Widmo fotonów z A-A:

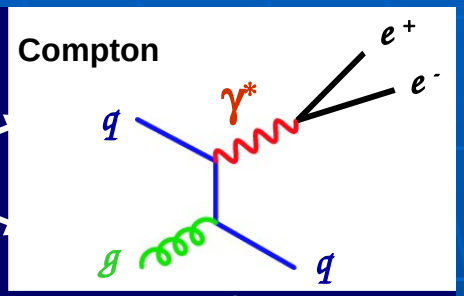
Schematic Photon Spectrum in Au+Au



Metoda PHENIXa: badanie par ee

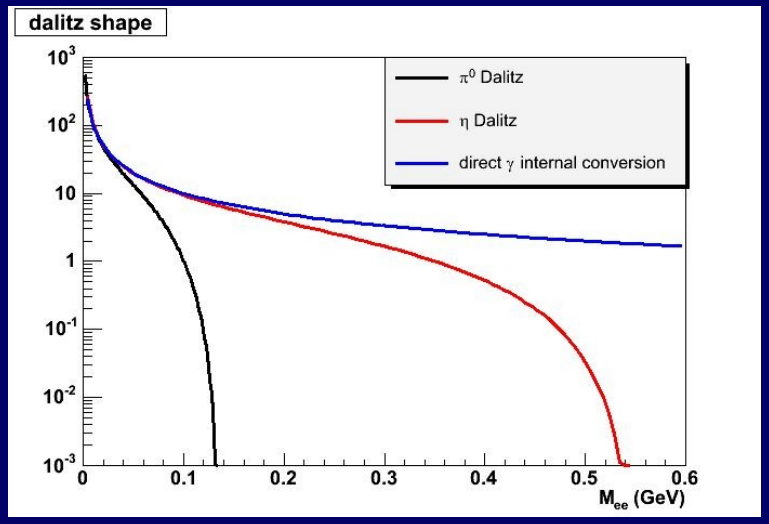
The Idea

- Start from Dalitz decay π^0
- Calculate invariant mass distribution of Dalitz pairs



$$\frac{1}{N_\gamma}\frac{dN_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)\frac{1}{m_{ee}}\left|F(m_{ee}^2)\right|^2\left(1-\frac{m_{ee}^2}{M^2}\right)^3$$

invariant mass of Dalitz pair	invariant mass of virtual photon	form factor	phase space factor



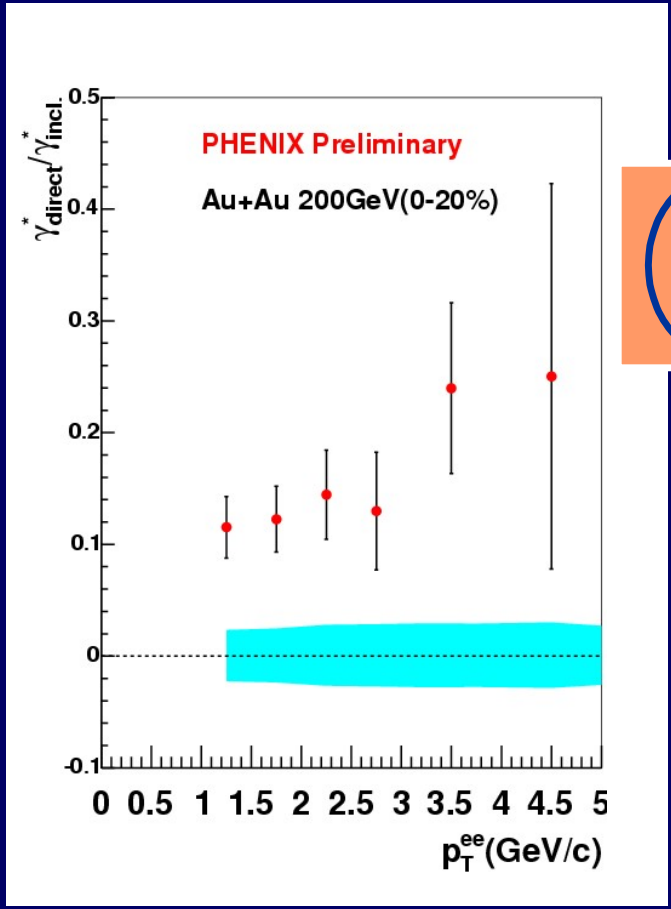
- Now direct photons
- Any source of real **γ** produces virtual **γ** with very low mass
- Rate and mass distribution given by same formula
  - No phase space factor for $m_{ee} << p_T$ photon

15

Bridge virtualnych (mierzonych z par Dalitza)

stosunek $\gamma_{direct}/\gamma_{inclusive}$ jest taki sam jak dla ‘prawdziwych’

$\gamma^*_{direct}/\gamma^*_{inclusive}$

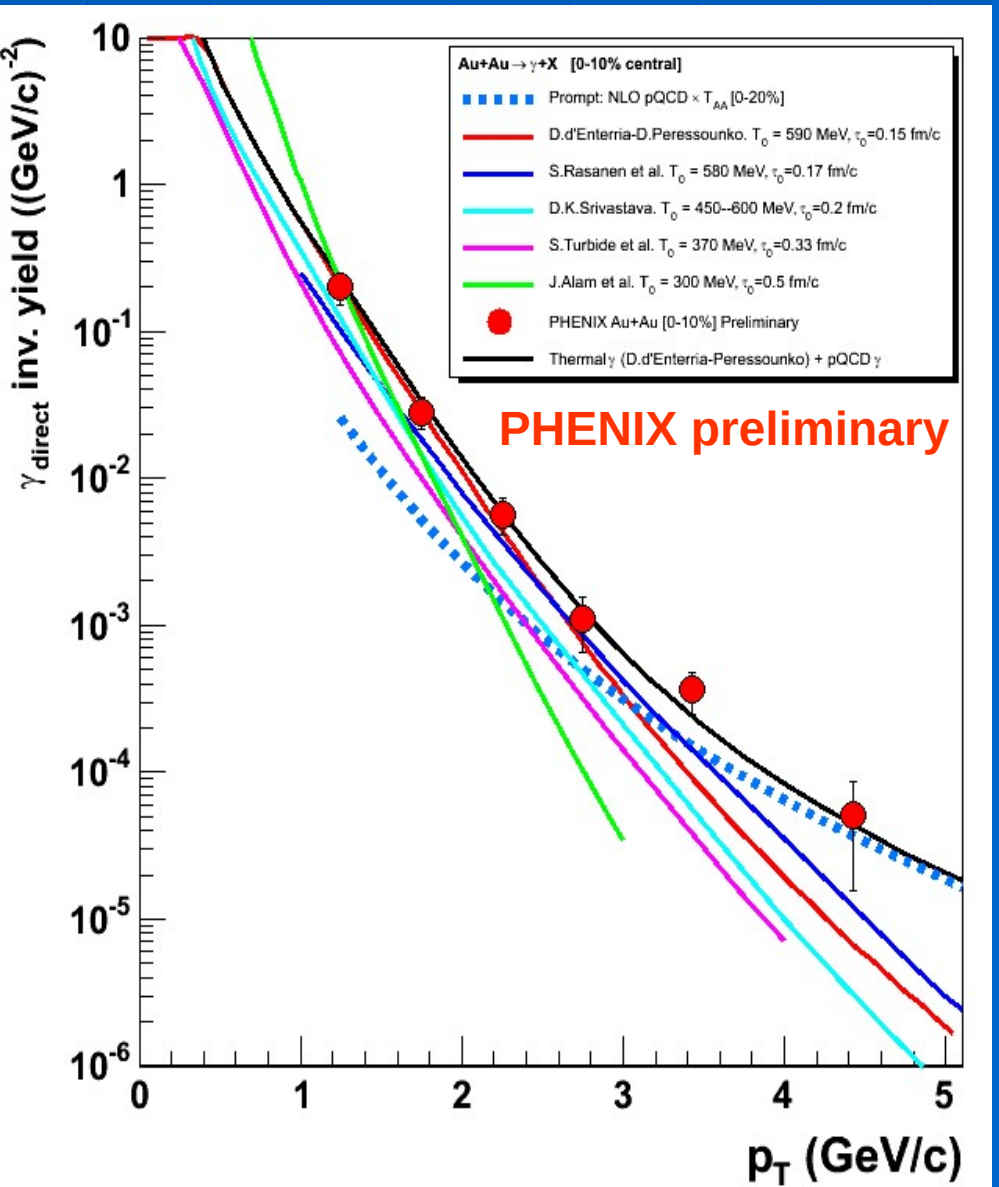


$$\frac{\gamma^*_{direct}}{\gamma^*_{incl.}} = \frac{R_{data} - R_{\pi^0+\eta}}{R_{direct} - R_{\pi^0+\eta}} = \frac{\gamma_{direct}}{\gamma_{incl.}}$$

0 - 20 %

Significant 10% excess of very-low-mass virtual direct photons

The matter is so hot that it emits (thermal?) photon copiously



The first promising result of direct photon measurement at low p_T from low-mass electron pair analysis.

Are these thermal photons? The rate is above pQCD calculation.

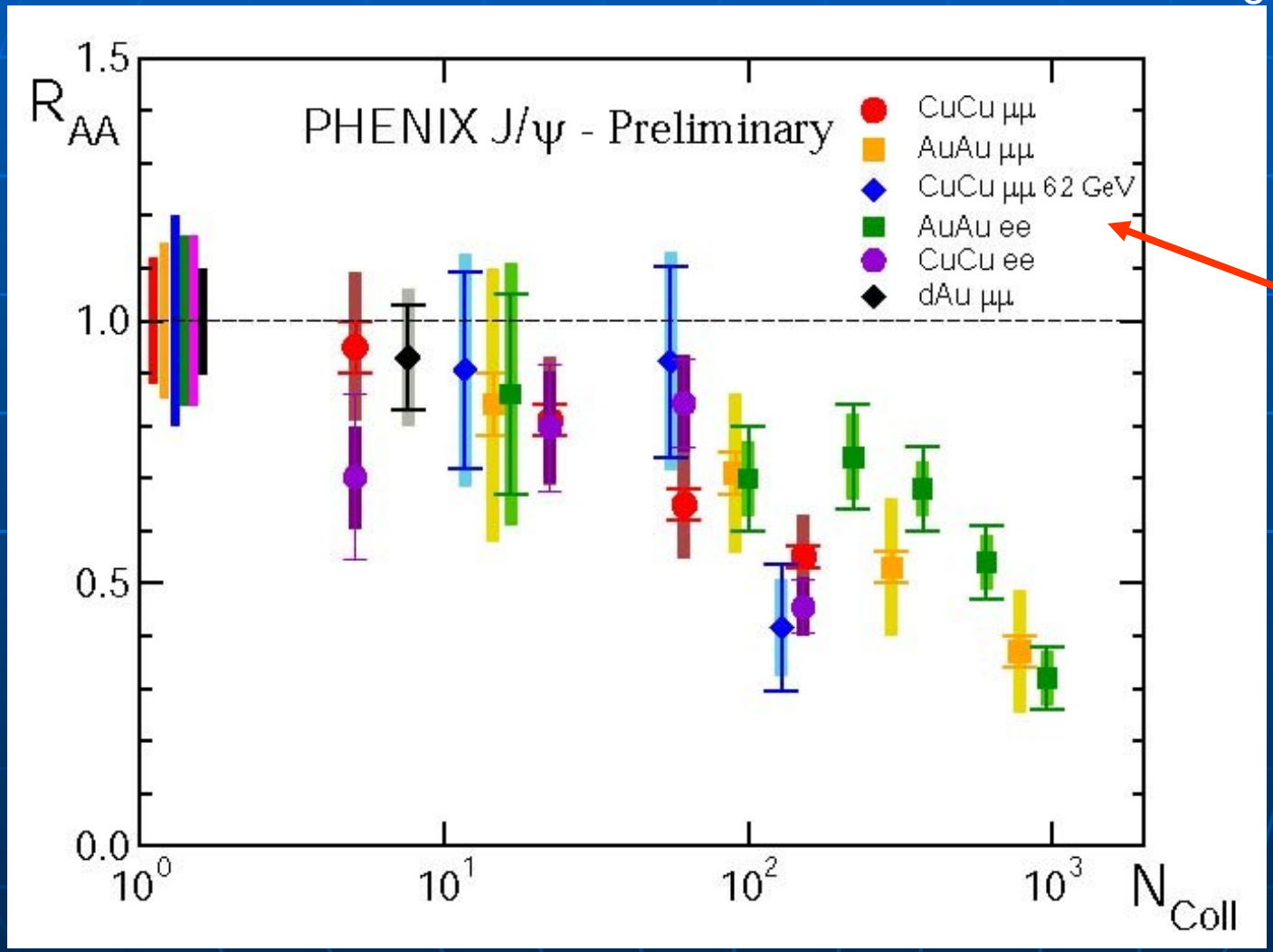
If it is due to thermal radiation, the data can provide the first direct measurement of the initial temperature of the matter.

T_0^{max} ~ 500-600 MeV !?

T_0^{ave} ~ 300-400 MeV !?

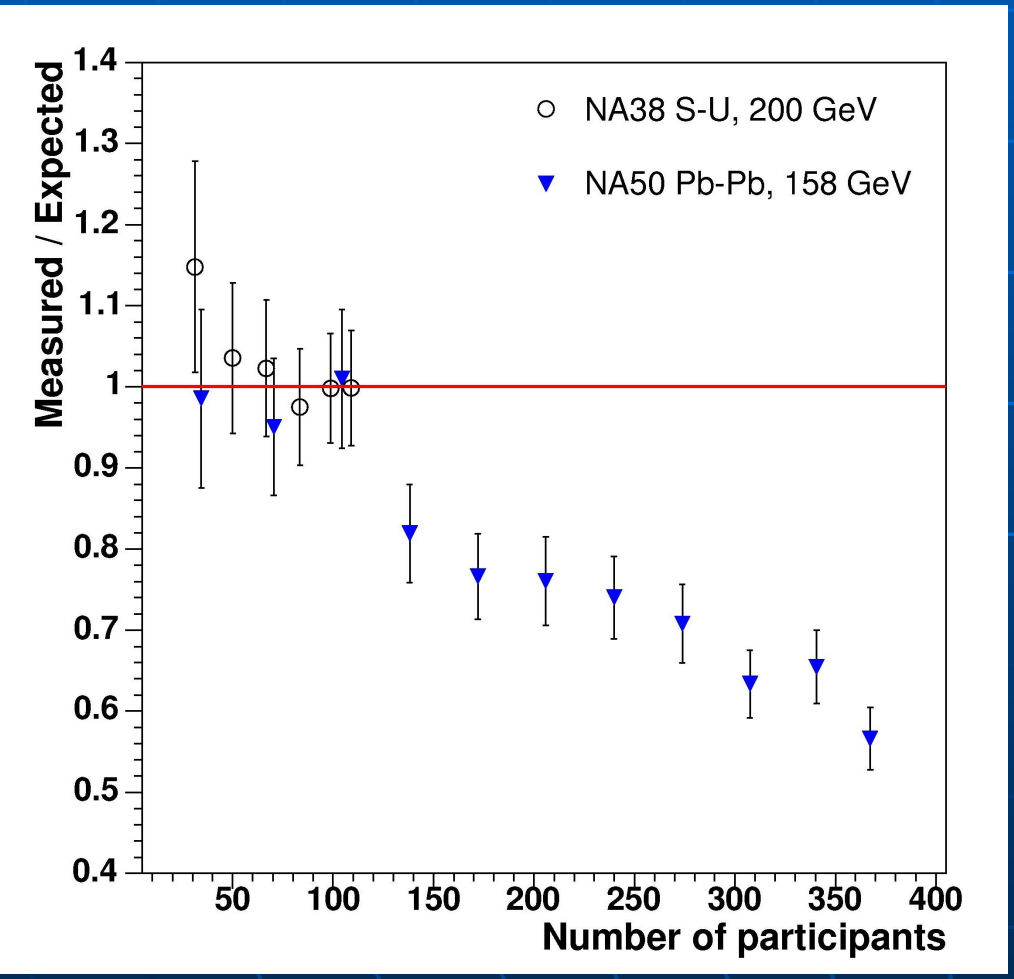
The matter is so dense that it melts(?) J/ψ (and regenerates it ?)

Pierwsze znaczące wyniki z RHIC o tłumieniu J/Ψ



Różne jądra
Różne kanały

Historia J/ Ψ (on SPS, NA50)



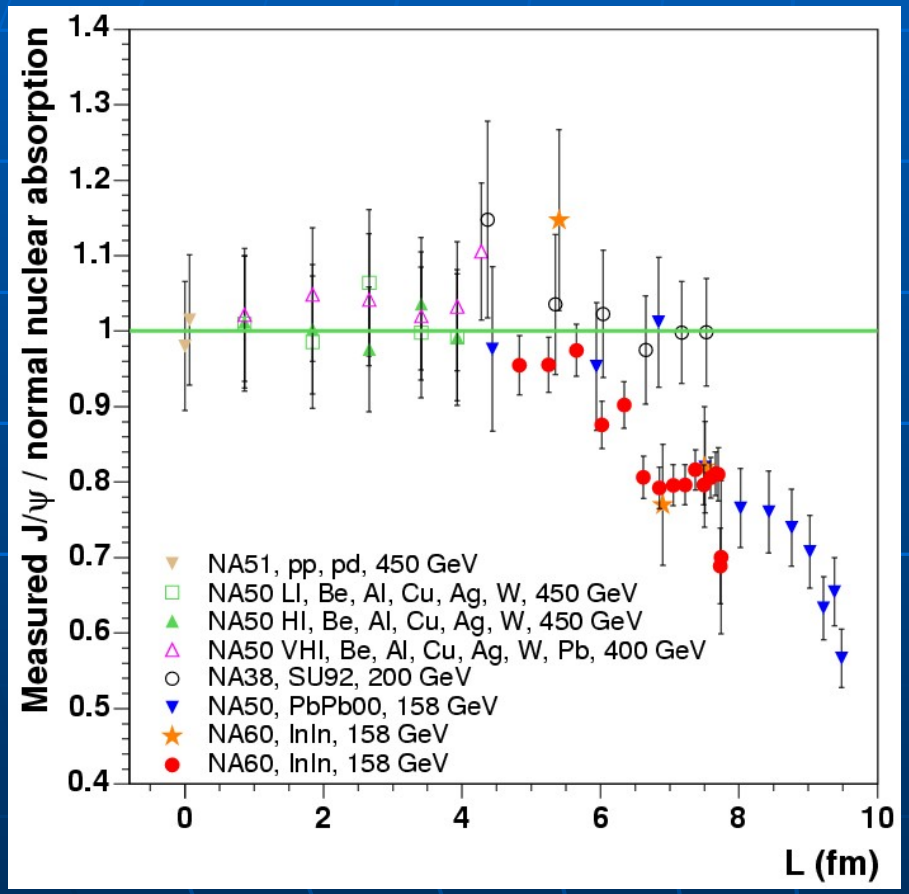
Reanalysis of data:

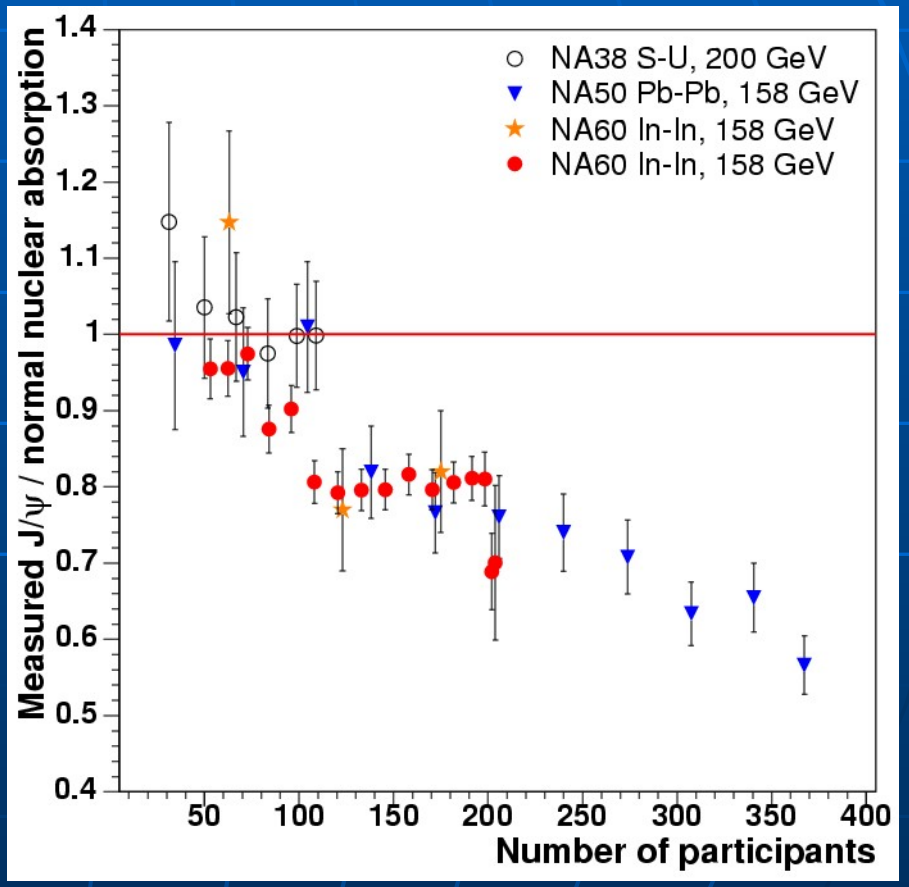
Normal nuclear absorption derived from pA data only $\sigma = 4.18 \pm 0.35$ mb

S-U consistent with normal nuclear absorption

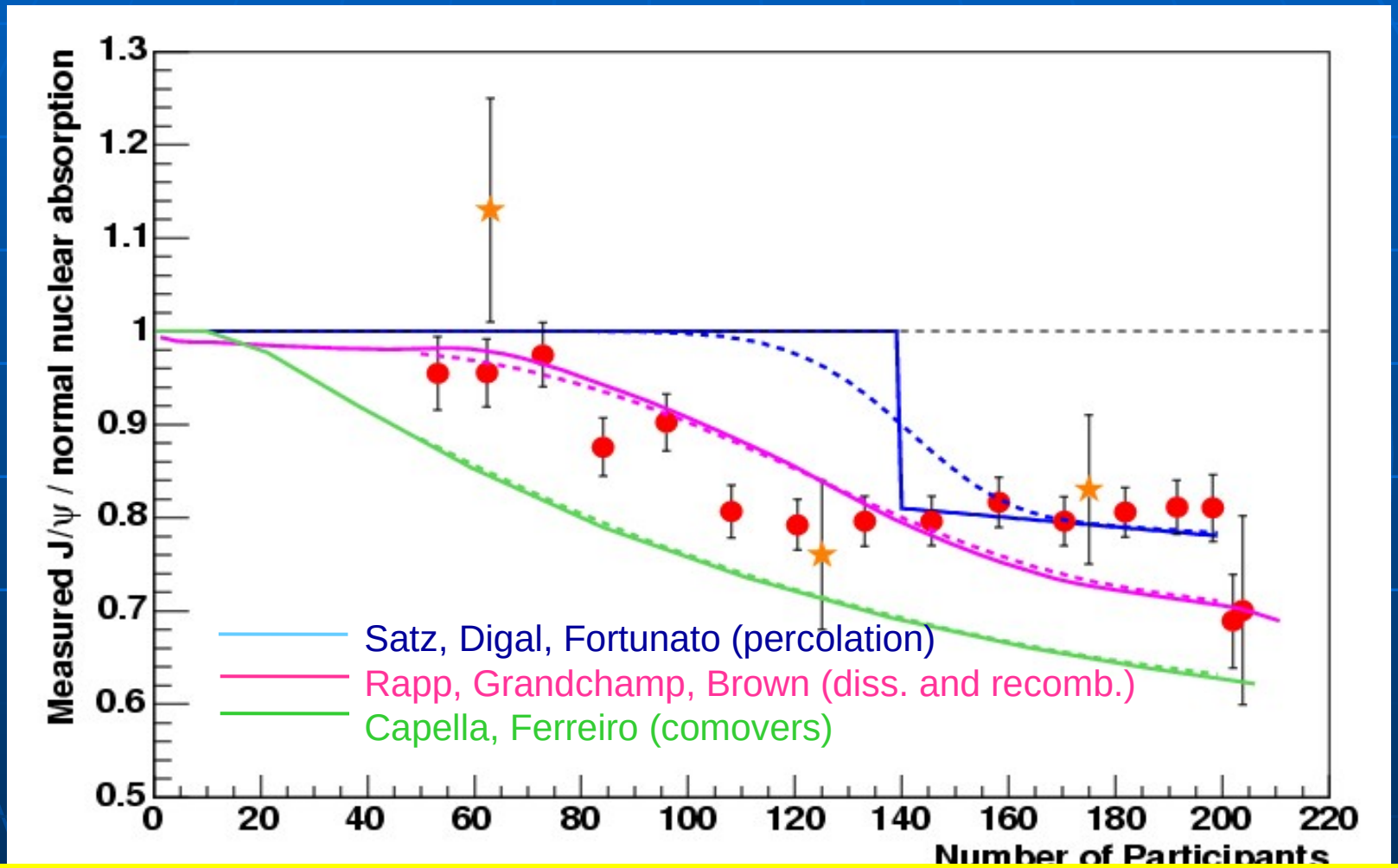
Only Pb-Pb shows additional suppression

A teraz nowe dane z In-In, NA60



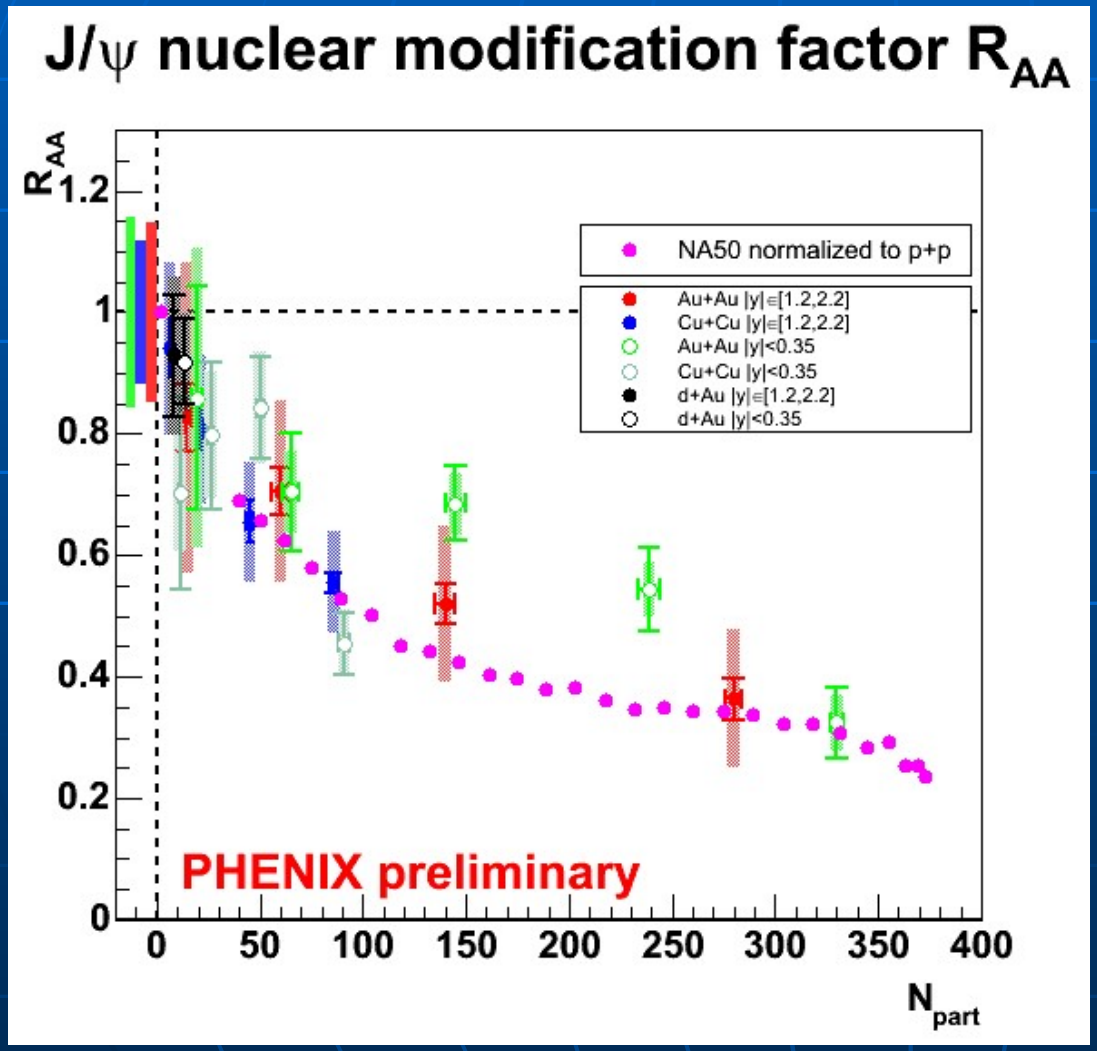


Rachunki modelowe



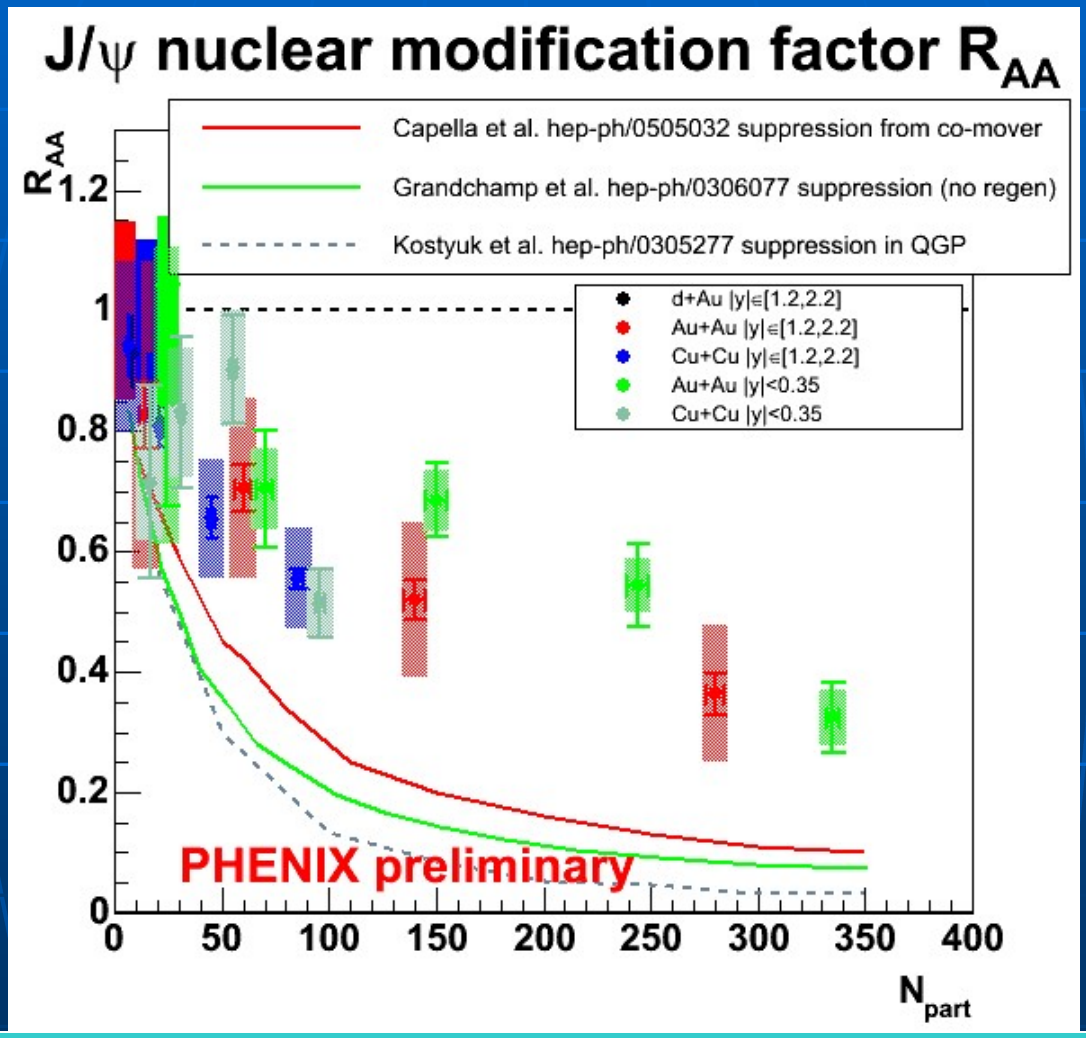
“None of the models (tuned to reproduce the NA50 data and with specific predictions for In-In) properly describes the observed suppression pattern.”

SPS vs RHIC:



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)



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

Cytat :Itzak Tserruya

Historical regression

(in the following CC stands for Cristobal Colon not for a pair of quarks)

In 1492 CC started a long journey with three flag ships –la Nina, la Pinta y la Santa Maria – in the quest for the predicted and expected alternative route to India.

It took quite some time to realize that he had discovered a totally unknown continent (CC actually died in 1506 without knowing it).

In 1986 we started a long journey with 2+1+(1) flag ships – AGS, SPS + RHIC + (LHC)– in the quest for the predicted and expected

~~QGP characterized by free quarks and gluons,~~

(deconfinement ,J/ψ, chiral symmetry restoration (low–mass dileptons)).

Are we discovering our America?

Prymitywne podsumowanie:

- ‘Proste charakterystyki ogólne’ – wciąż decyduje zwykła geometria jąder
- Intrygujące skalowanie
- Na pewno jednak więcej niż złożenie N–N
- Na pewno gęsta materia o intrygujących własnościach
- Na pewno – partonowa