Recent results from Nucleus-Nucleus Collisions at the CERN SPS

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and Świętokrzyska Academy, Kielce

- K*(890) production
- Production of light nuclei
- Medium p_T results
  - Scaling of identified particle spectra
  - Azimuthal correlations
- The Φ puzzle
- Lepton pair production
  - Low mass – modification of ρ spectral function
  - Intermediate mass enhancement
  - Charmonium suppression
- Evidence for deconfinement
- Future plans at the SPS

SPS Talks and Posters at QM2008

J/Ψ production:		
R.Arnaldi (NA60)	9/2,10:00	J/Ψ suppresion
C.Lourenco (NA60)	P150	nuclear effect in charmonium production
lepton pairs:		
S.Damjanovic (NA60)	8/2,12:00	thermal dileptons (plenary talk)
vector mesons:		
M.Floris (NA60)	5/2,14:20	Φ production in In+In
D.Jouan (NA50)	9/2,17:50	Φ and ω-ρ production in d+C,d+U,S+U,Pb+Pb
direct photons:		
C.Baumann (WA98)	8/2,17:50	search for direct photons in p+Pb
hadron production:		
M.Slodkowski (NA49)	P115	K*(890) production in Pb+Pb
M.Kalisky (NA45)	P142	neutral, charged K reconstruction in Pb+Au
high p_T results:		
A.Laszlo (NA49)	P151	nuclear modification in Pb+Pb at $\sqrt{s}$=17 GeV
S.Kniege (NA45)	P251	2- and 3-particle correlations
M.Szuba (NA49)	P263	2-particle correlations
fluctuations:		
M.Rybczynski (NA49)	8/2,14:00	energy dependence of fluctuations in Pb+Pb

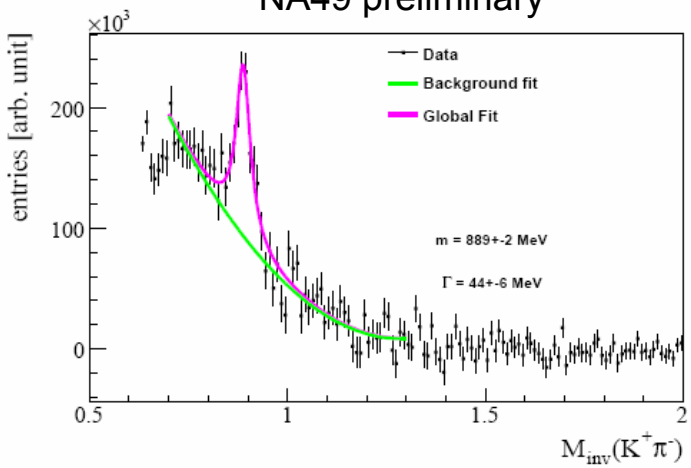
$K^*(890) \rightarrow K^+ + \pi^-$ in central Pb+Pb collisions at 158A GeV

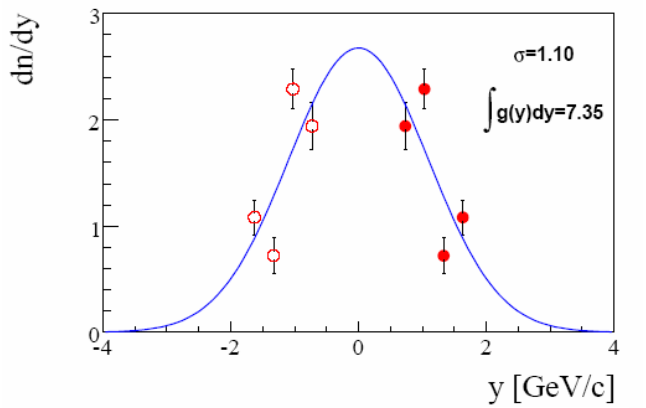
P115

- yield modified by K* destruction, regeneration and scattering of decay products
- sensitive to duration of hadronic stage of fireball

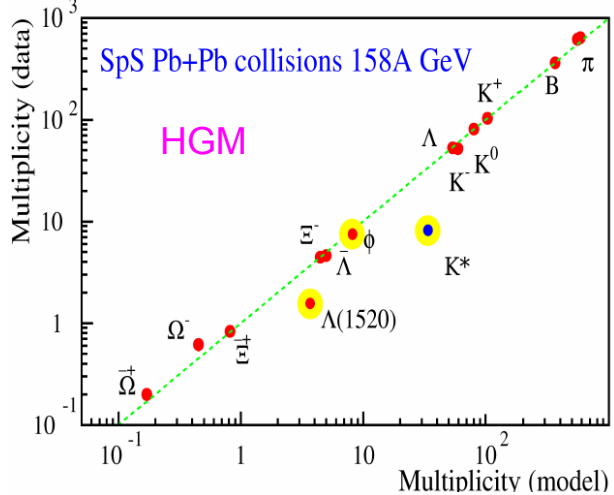
G.Torrieri,J.Rafelski: PLB509,239(2001)

NA49 preliminary

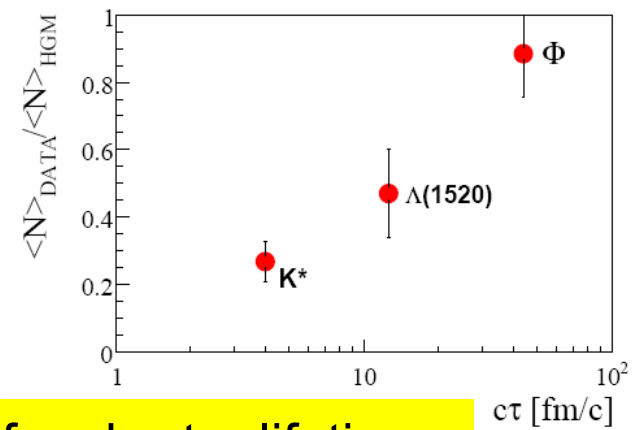




F.Becattini et al., PRC73,044905(2006)



T=157.8±1.9 MeV
μ_B=247.4±7.7 MeV
γ_s=0.843±0.033
χ^2=16.9/9 dof



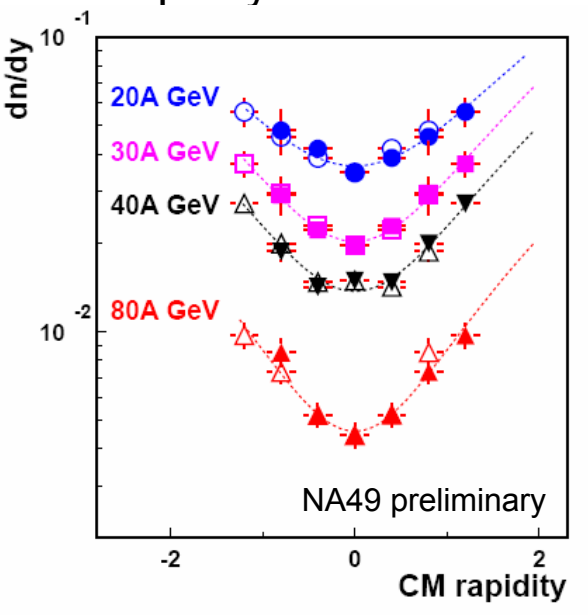
resonance yield suppression increases for shorter lifetimes

Production of light nuclei d, ^{3}He in central Pb+Pb collisions

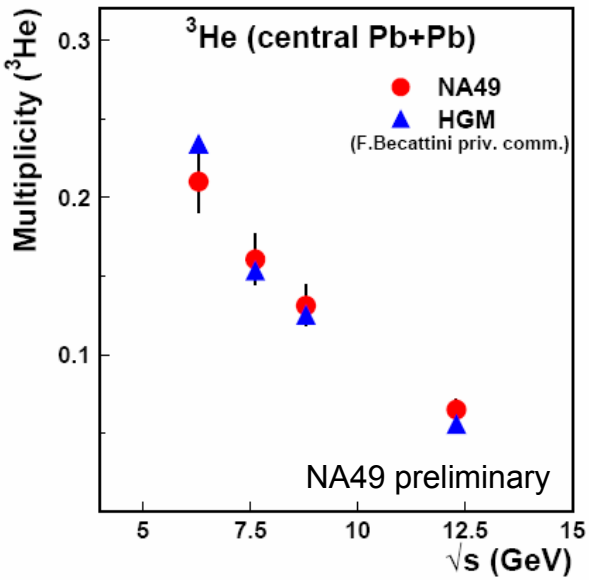
conventionally explained by nucleon coalescence

NA49 measurement of 4π yields for ^{3}He at SPS energies (arXiv:0710.5118)

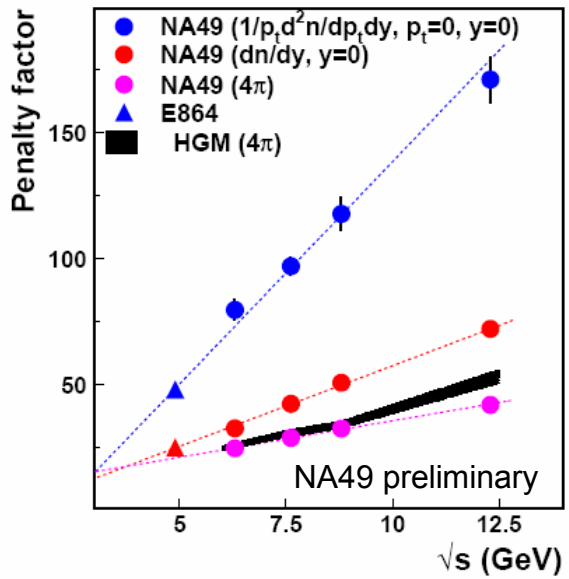
rapidity distributions



4π yields



penalty factor : $\frac{dn(A)}{dy} \propto p^{A-1}$



HGM: F.Becattini et al., PRC73,044905(2006)
Braun-Munzinger,Stachel, J.Phys.G28,1971(2002)

$p \approx e^{(m_N - \mu)/T}$

remarkable agreement of 4π yields and penalty factors with statistical hadron gas model

interpretation in context of the coalescence model

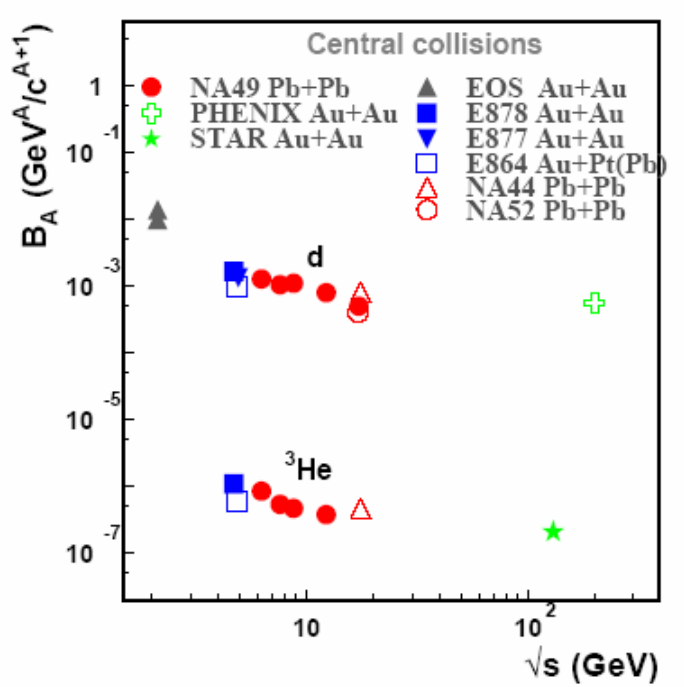
coalescence factor:

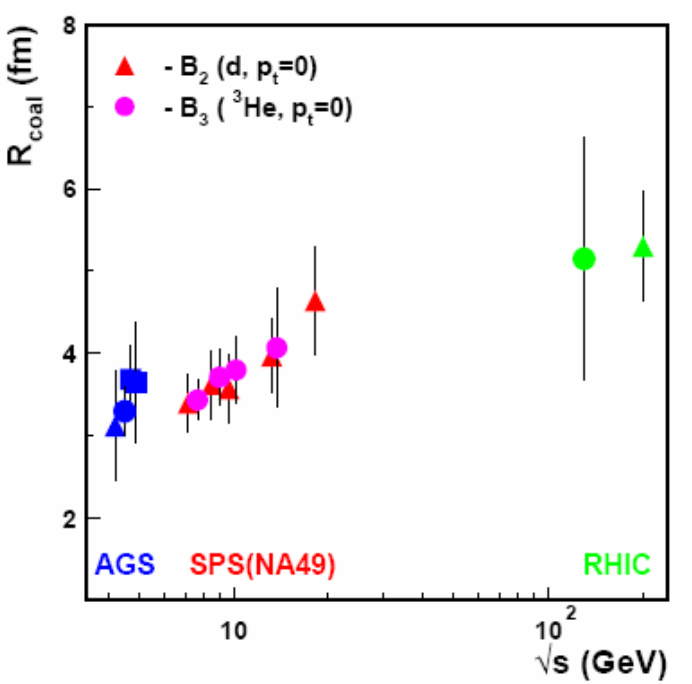
$$E_A \frac{d^3N_A}{dP_A^3} = B_A \cdot \left(E_p \frac{d^3N_p}{dP_p^3} \right)^A, \quad P_A = A \cdot P_p$$

coalescence volume:

$$V_{coal} = \frac{3\pi^{3/2}\langle C_A \rangle}{2 m_t B_A}$$

Scheibl,Heinz: PRC59,1585(1999)

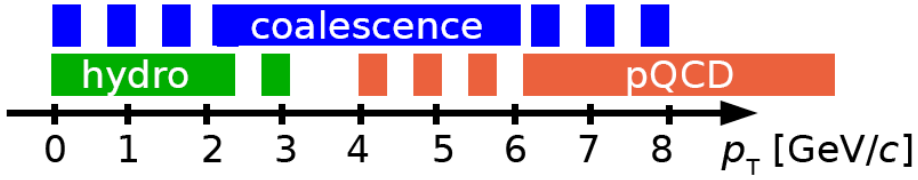




- gradual dercrease of B_A implies increase of coalescence volume
- same coalescence volume for d and ^{3}He

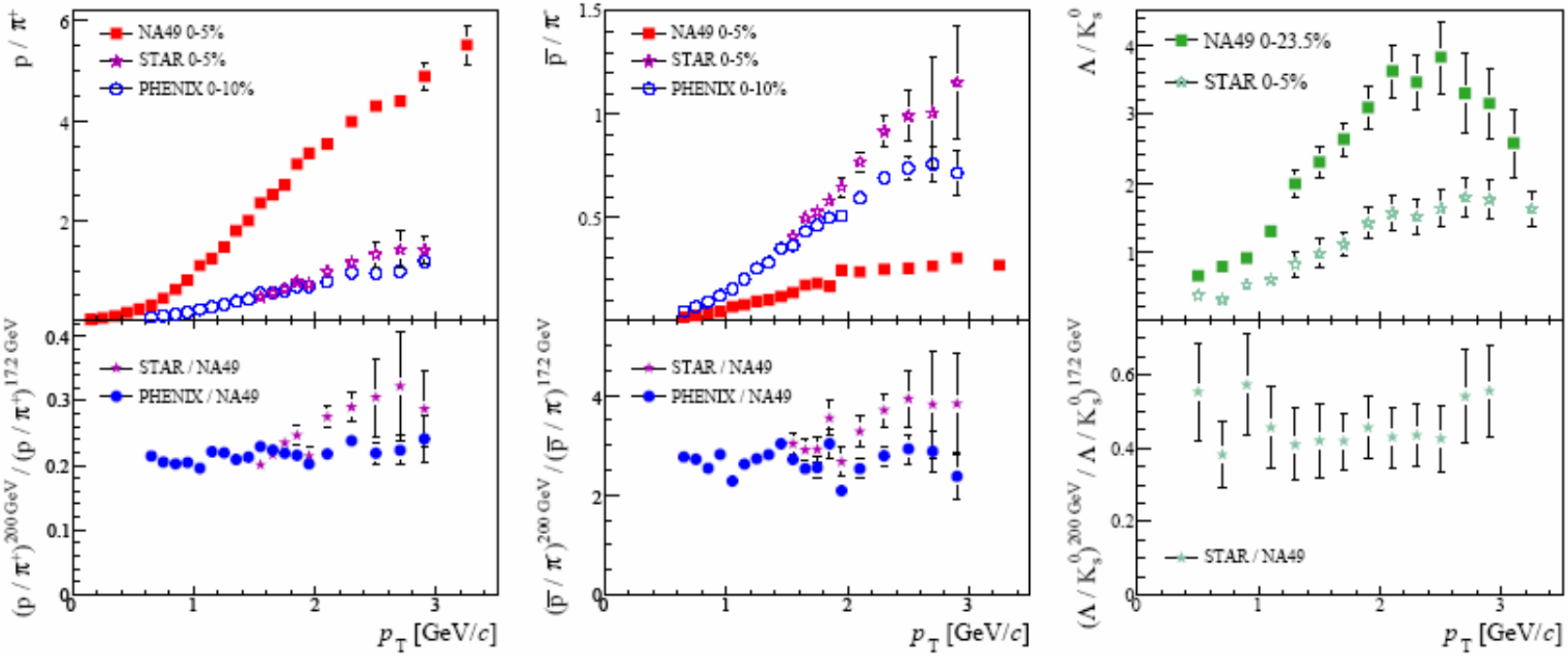
Intermediate p_T results at 158A GeV

(1) Baryon/Meson ratios in Pb+Pb:



NA49: arXiv:0711.0547

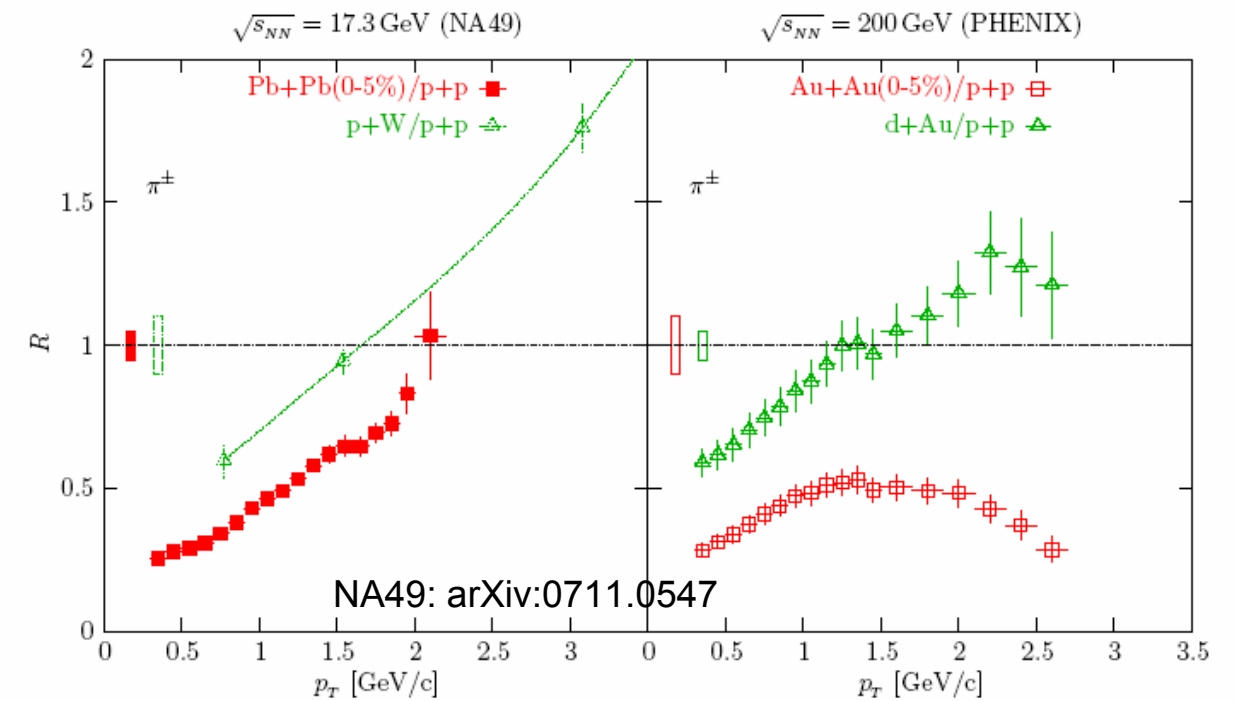
NA49 preliminary



- same relative increase of particle ratios with p_T at SPS and RHIC

(2) nuclear modification factor R_{AA} of pions at SPS and RHIC (p+p reference)

$$R_{AA}(p_t) = \frac{1}{\langle N_{coll}(AA)\rangle} \frac{d^2N_{AA}/(dp_t\,dy)}{d^2N_{pp}/(dp_t\,dy)}$$

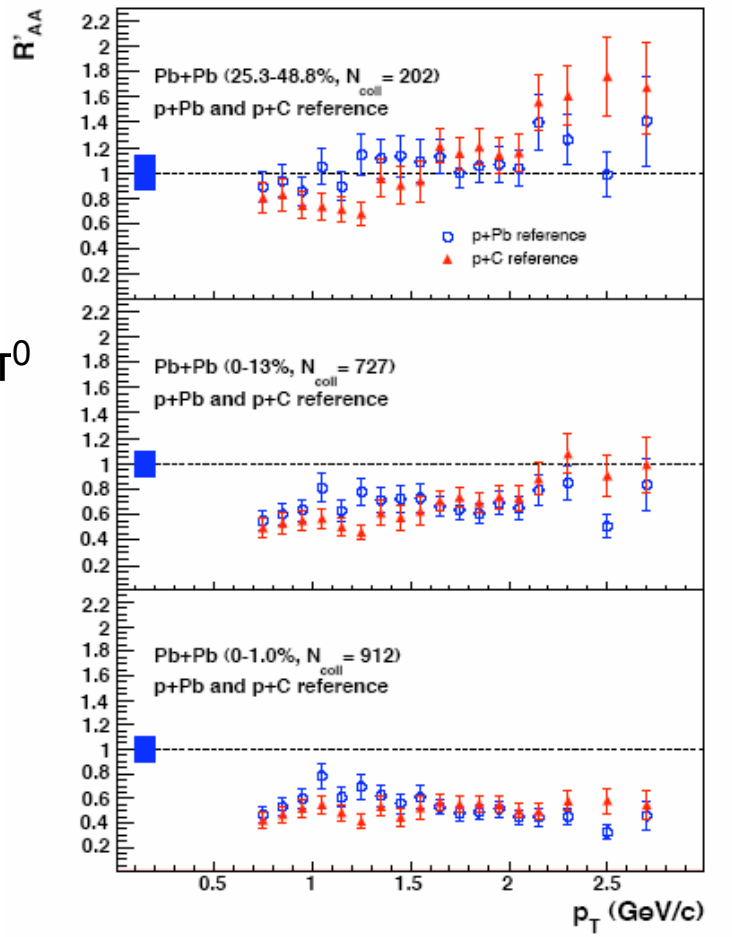


NA49: arXiv:0711.0547
and EPJC 45,343(2006)

- similar increase of ratio at SPS in p+Pb and Pb+Pb (Cronin effect)
- R_{PbPb} stays below binary scaling up to $p_T < 2$ GeV/c , but no decrease as for R_{AuAu} at RHIC

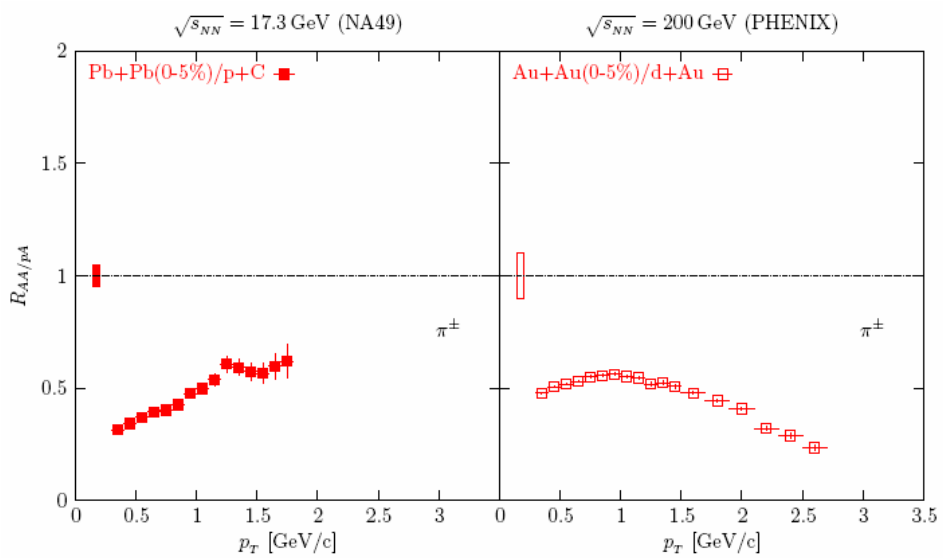
p+C / p+Pb reference → reduction of Cronin effect

WA98: arXiv:0708.2630



π^0

NA49: arXiv:0711.0547 and EPJC49,897(2007)



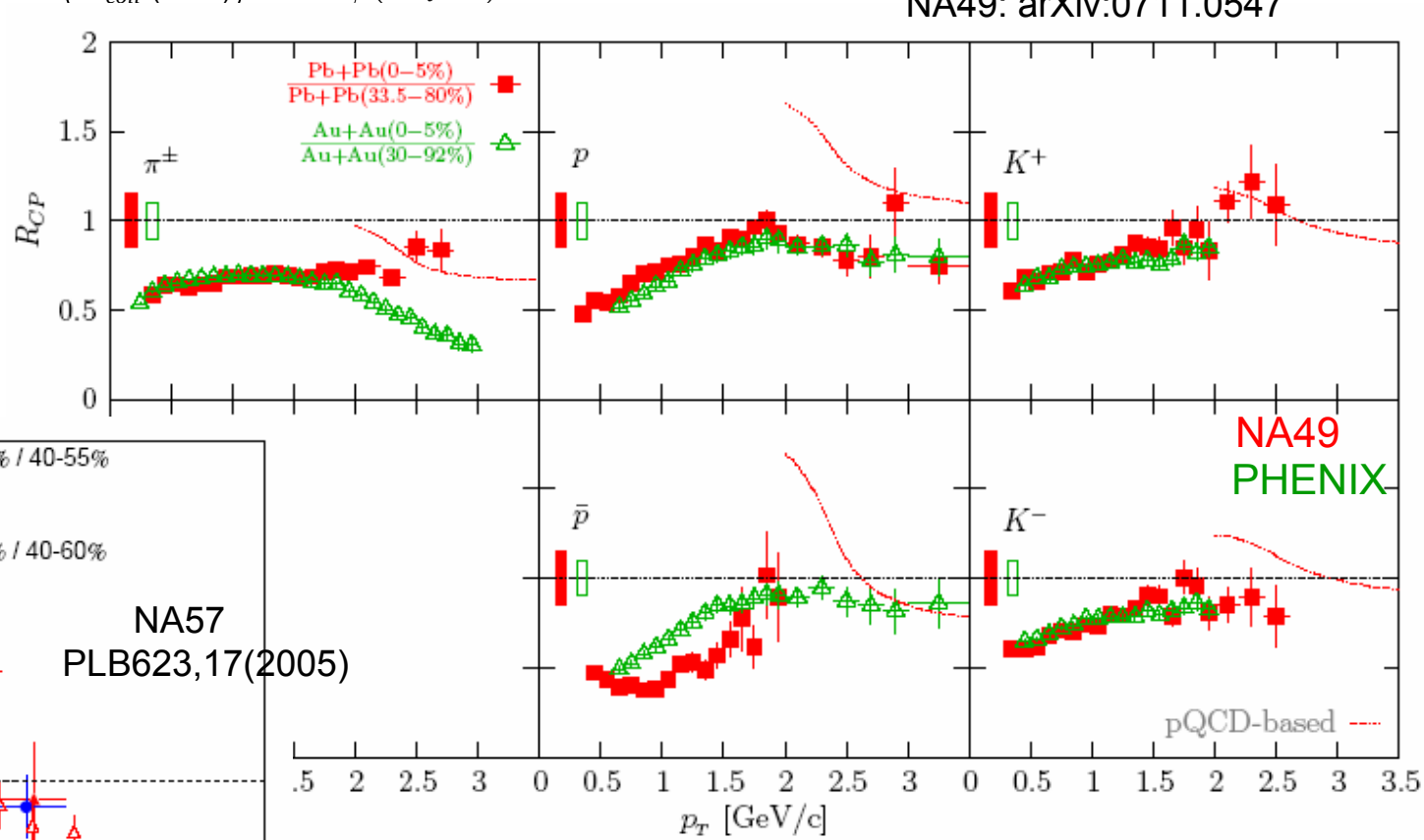
$\pi^{\pm}$

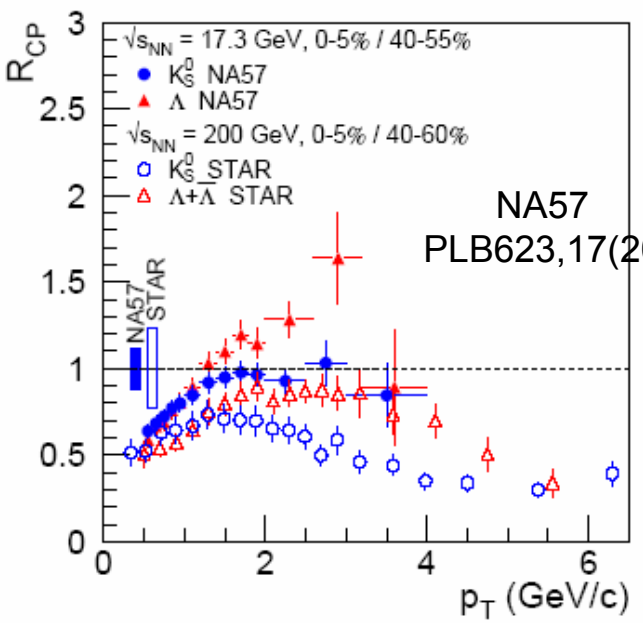
pion suppression similar at SPS and RHIC, no downturn yet at SPS

(3) nuclear modification factor R_{CP} at SPS and RHIC

$$R_{CP}(p_t) = \frac{\langle N^P_{coll}(AA)\rangle}{\langle N^C_{coll}(AA)\rangle} \frac{d^2N^C/(dp_t\,dy)}{d^2N^P/(dp_t\,dy)}$$

NA49: arXiv:0711.0547



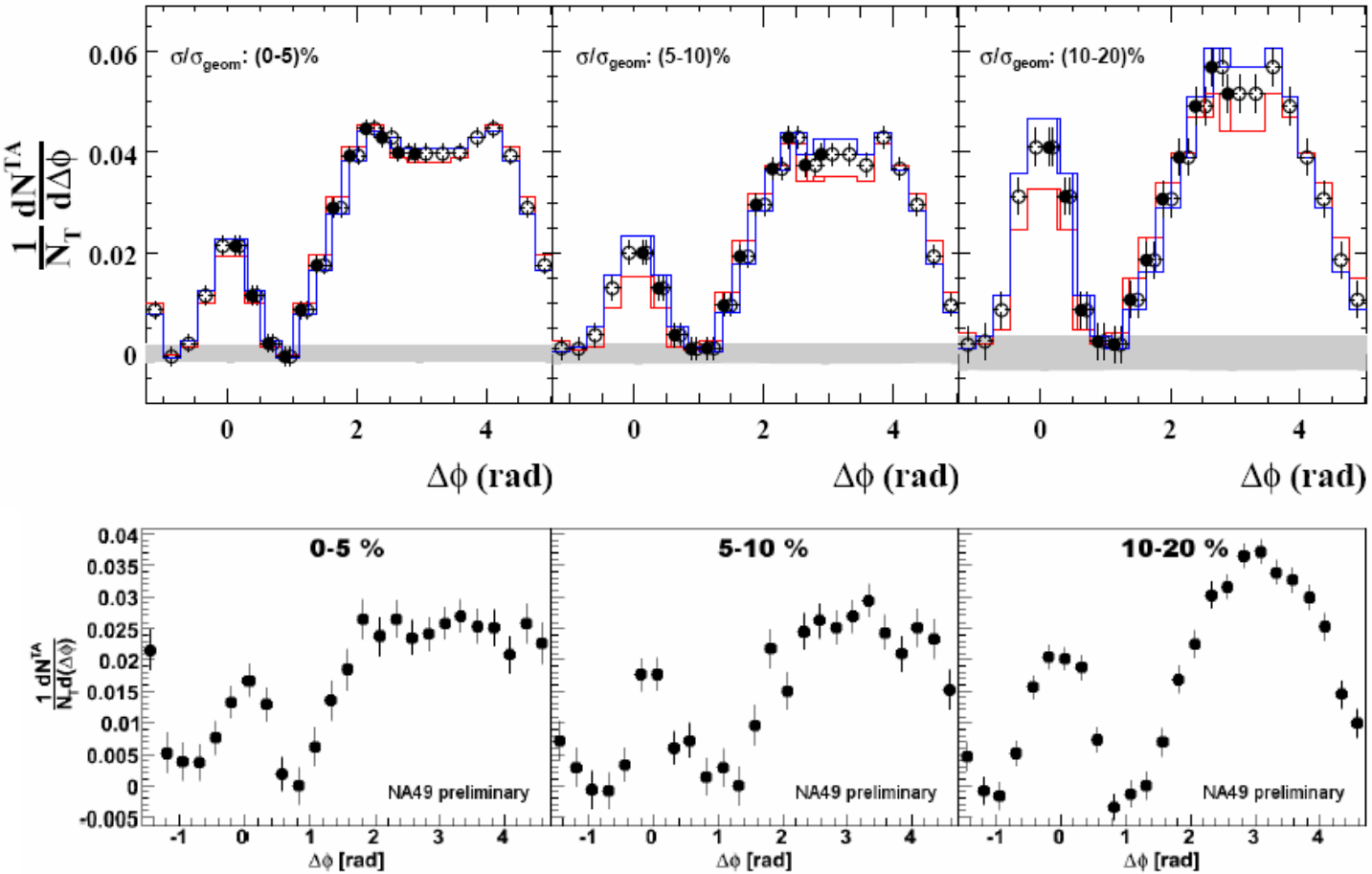


NA57
PLB623,17(2005)

- trends of R_{CP} quite similar at SPS and RHIC
- p_T range not sufficient to establish suppression

(4) Azimuthal 2-particle correlations in Pb+Au/Pb+Pb

P251
P263



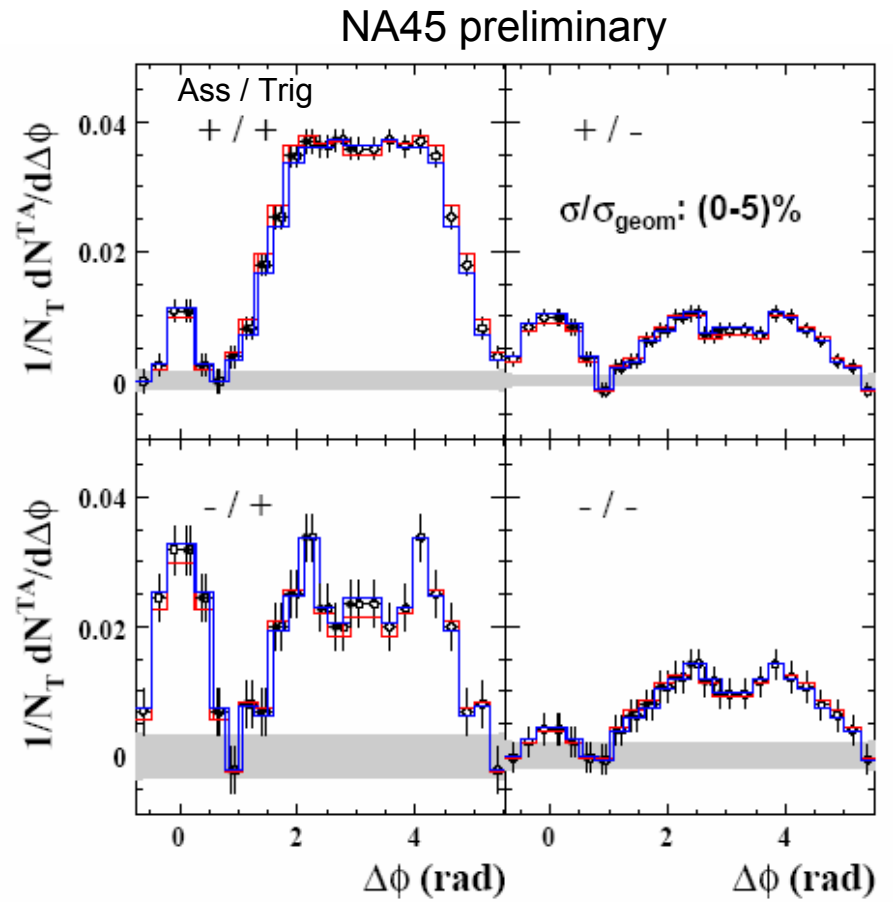
NA45
preliminary

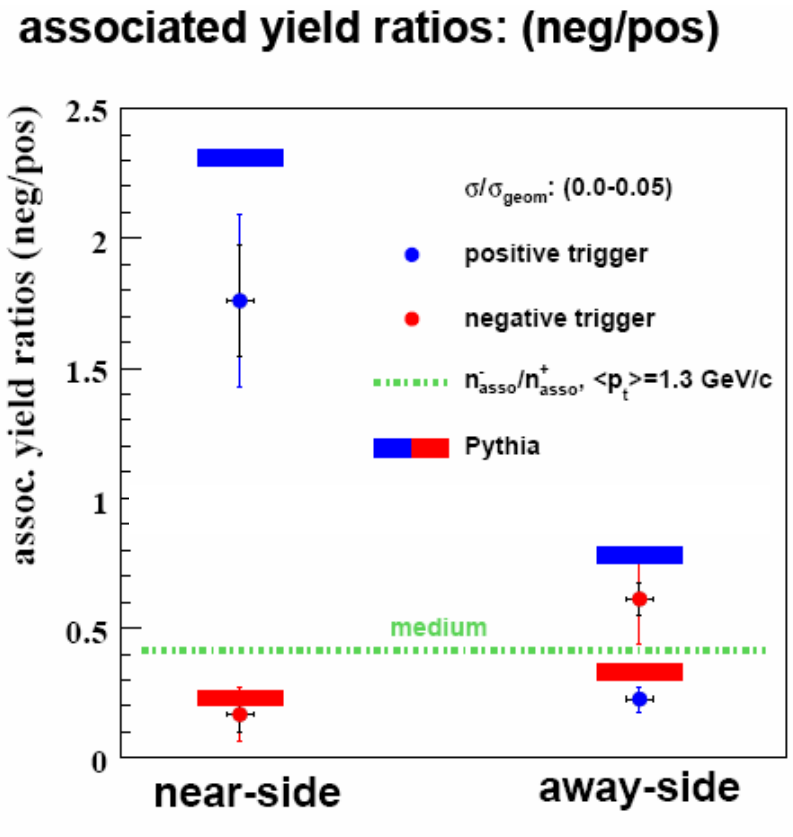
$2.5 < p_{t,trig} < 4$ GeV/c
$1 < p_{t,ass} < 2.5$ GeV/c

confirmed
by NA49

- away side broadens with increasing centrality of the collision
- previous CERES finding (PRL93,032301(2004)) confirmed

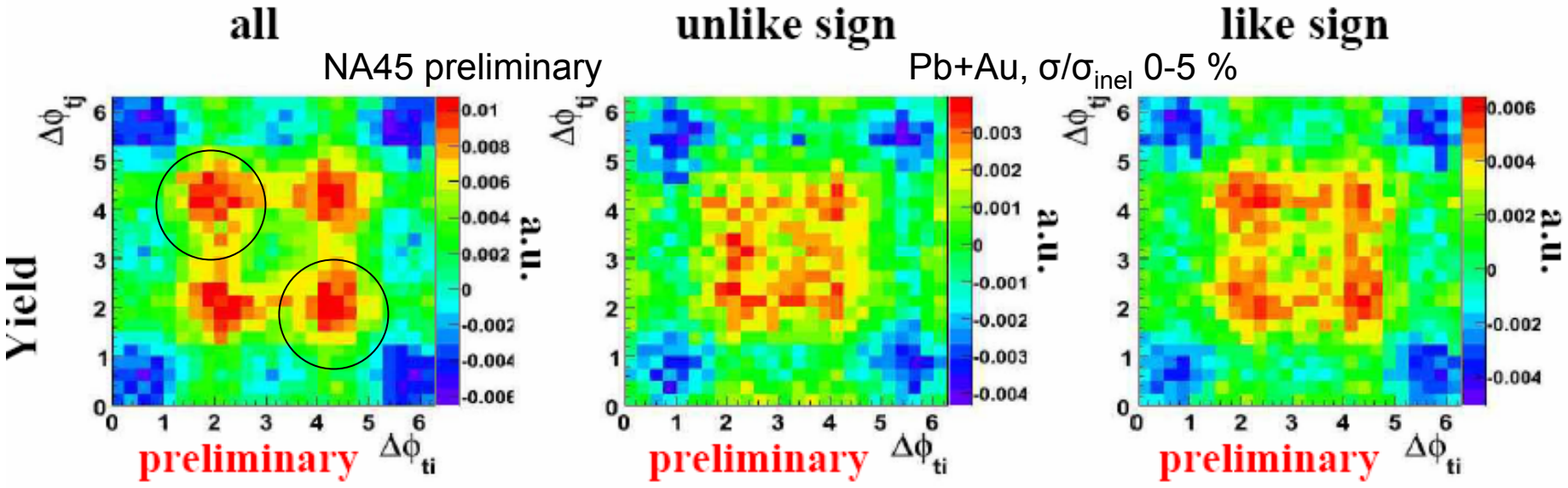
significant charge dependence of near and away side correlations

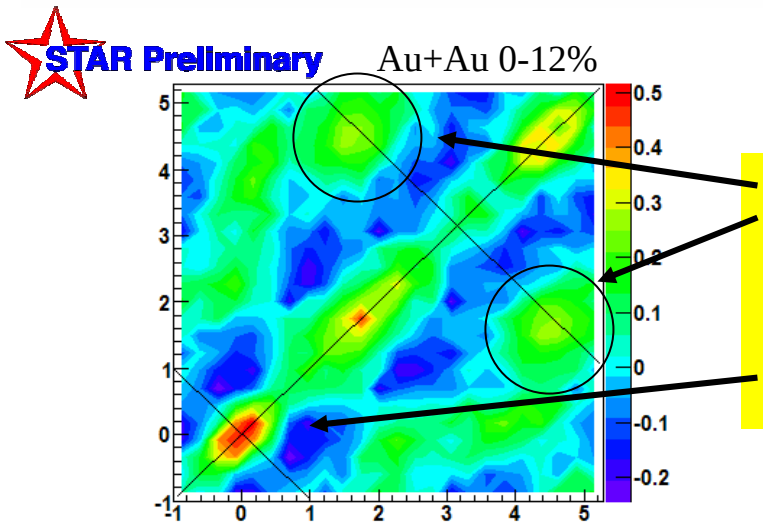




- near side ratios close to Pythia - hard scattering (jet) already at SPS
- away side ratios differ from Pythia - medium effect on away side

(5) Azimuthal 3-particle correlations in Pb+Au at SPS





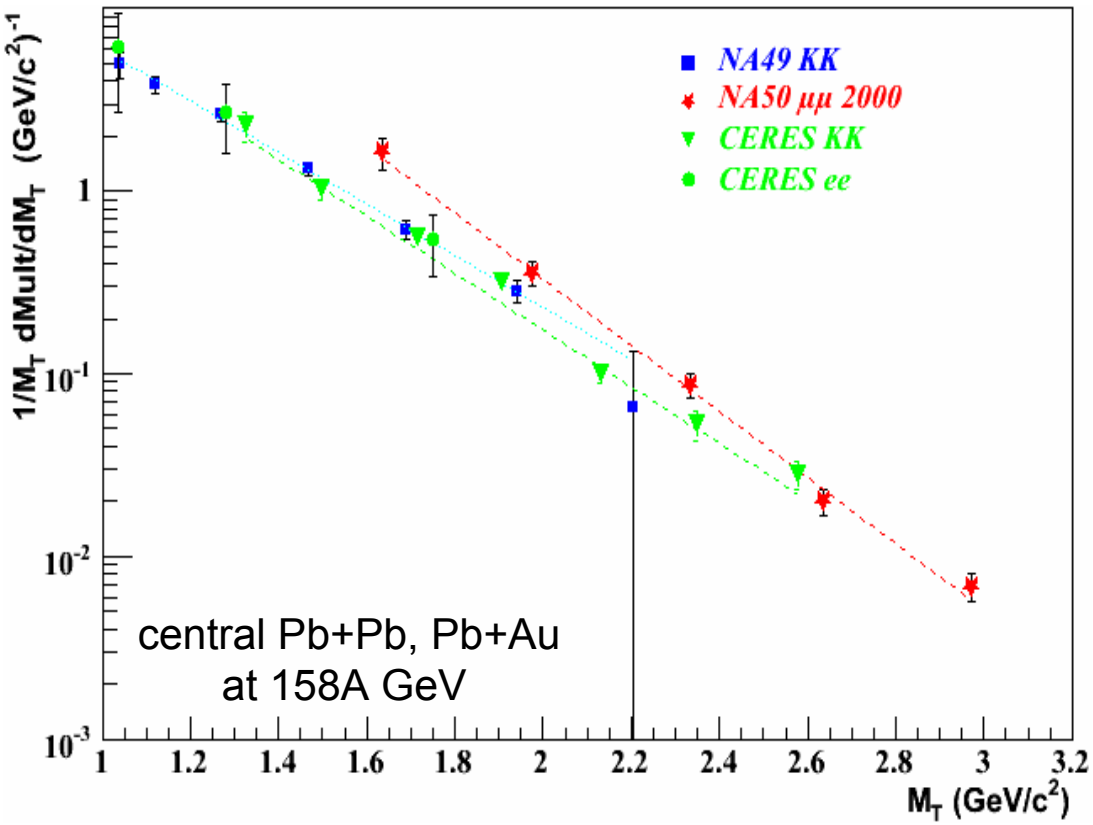
- cone like structure on the away side also observed at the SPS
- same side correlation not seen at SPS, effect of energy/momentum conservation ?

The Φ puzzle

Talks: M.Floris
D.Jouan

- measurements of $\Phi \rightarrow K^+K^-$ (NA49) and $\Phi \rightarrow \mu^+\mu^-$ (NA50) indicated different yields and T_{eff} although no mass shift observed
- effect of in medium Kaon absorption and rescattering ??

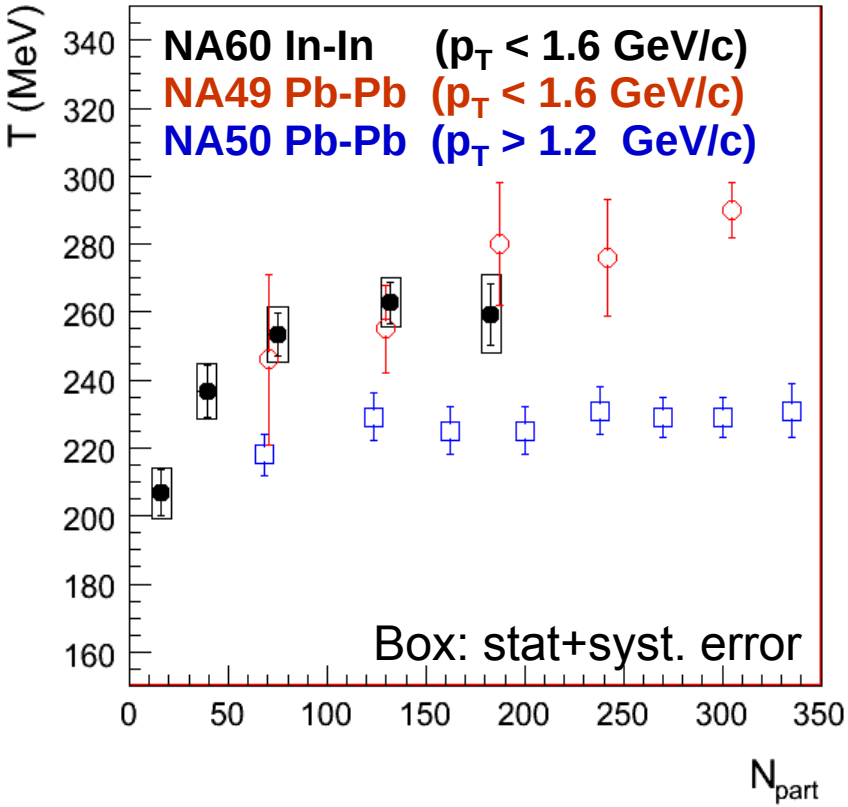
D.Lissauer,E.Shuryak, PLB253,15(1991)



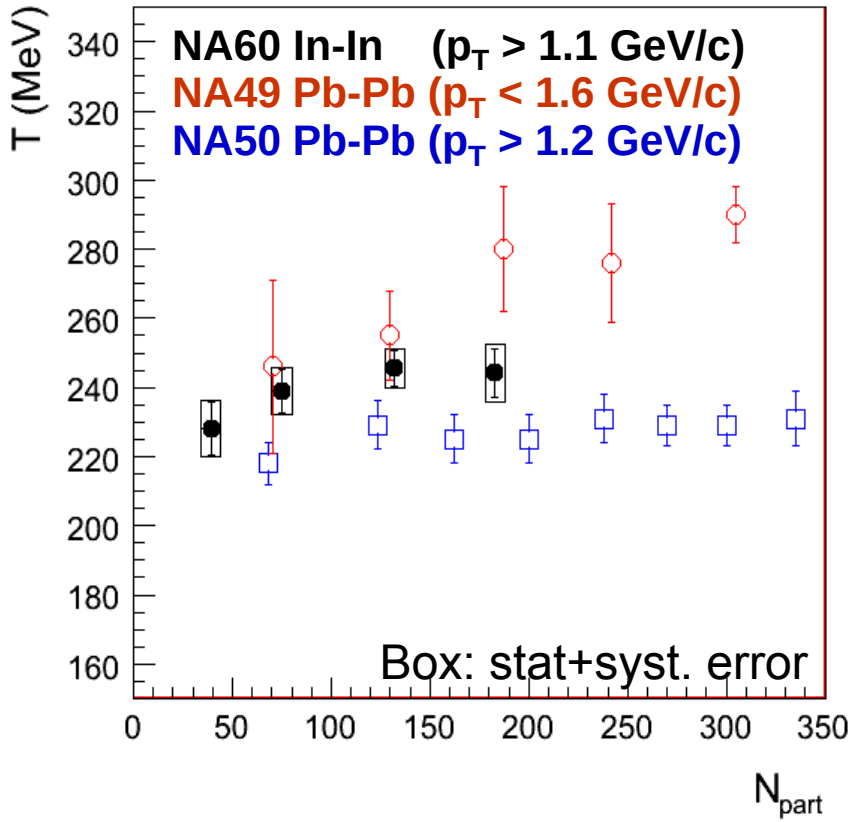
- new NA50 result 8% lower
- factor 2 discrepancy between KK and μμ channels remains
- discrepancy between ee and μμ channels now less significant

comparison of inverse slopes of m_T distributions

lower p_T range



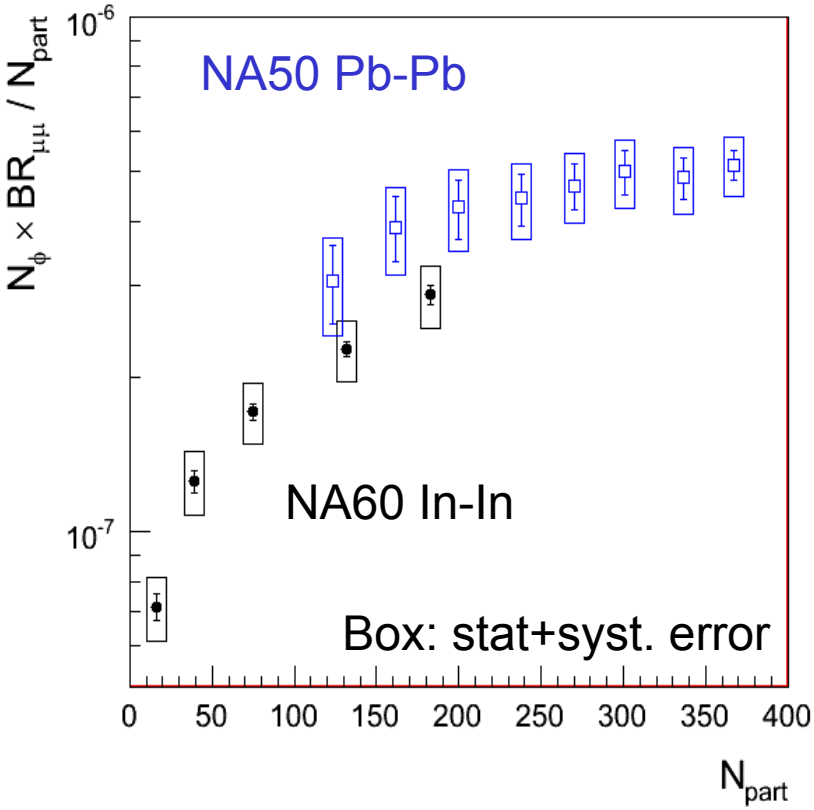
upper p_T range



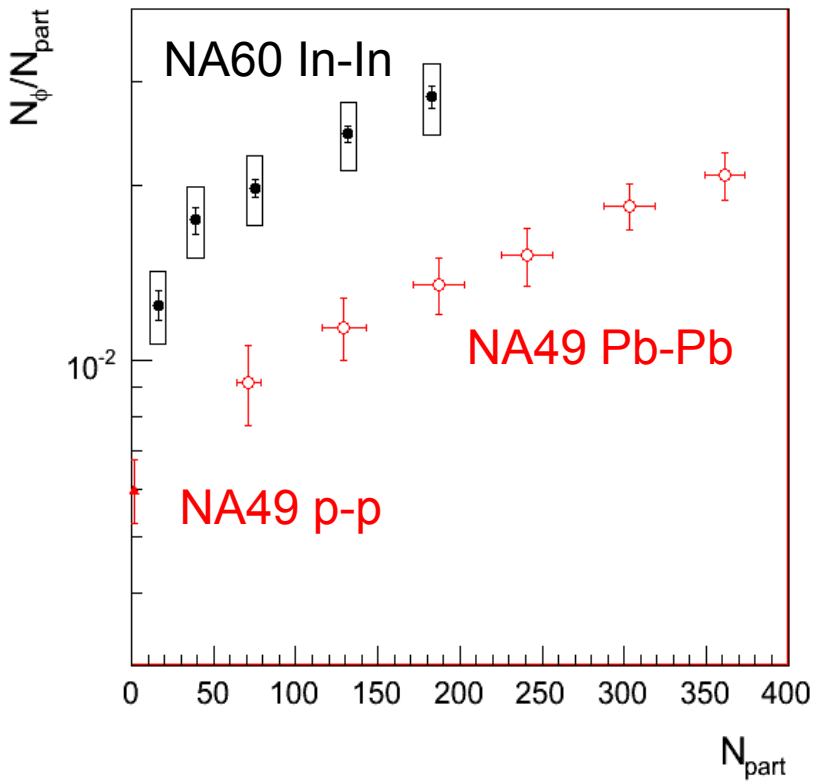
- T larger at low p_T (NA45,NA49,NA60) than at high p_T (NA50,NA60)
- expected effect of radial flow and/or in medium Φ decay with re-interaction of daughter Kaons

comparison of yields in μμ and KK channels

N_{part} scaling for μμ channel



factor 2 higher yield in μμ confirmed



looks qualitatively like predicted medium effect on Φ → KK
but only 20% of Φ decay in fireball

we can soon expect NA60 results in the KK channel

Lepton pair production in In+In at 158A GeV

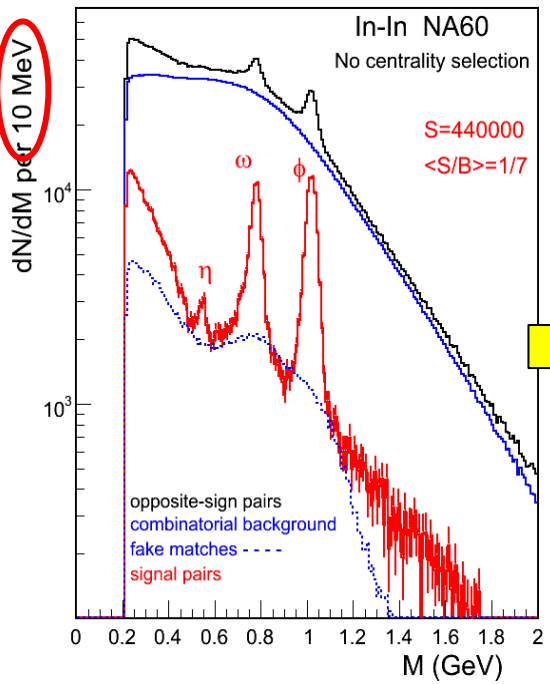
Plenary: Damjanovic

(1) Low mass – in medium modification of ρ spectral function

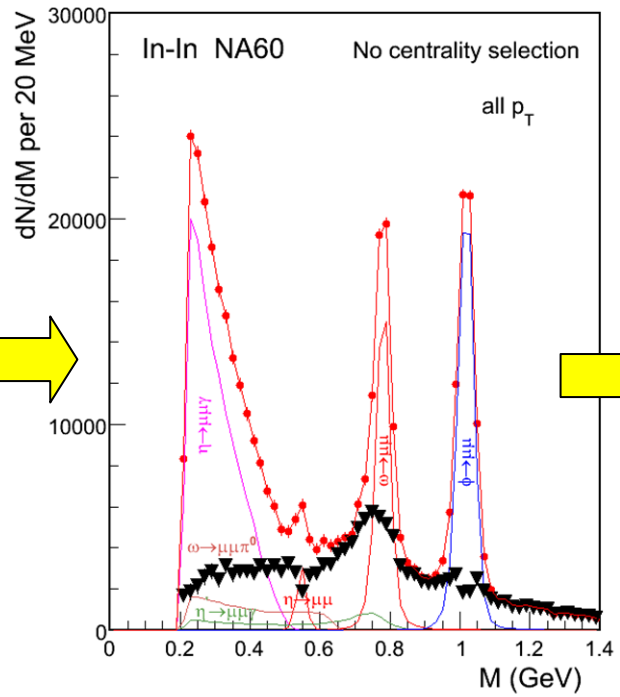
NA60 completed high resolution and statistics study of low-mass region

NA60: PRL 96, 162302 (2006)

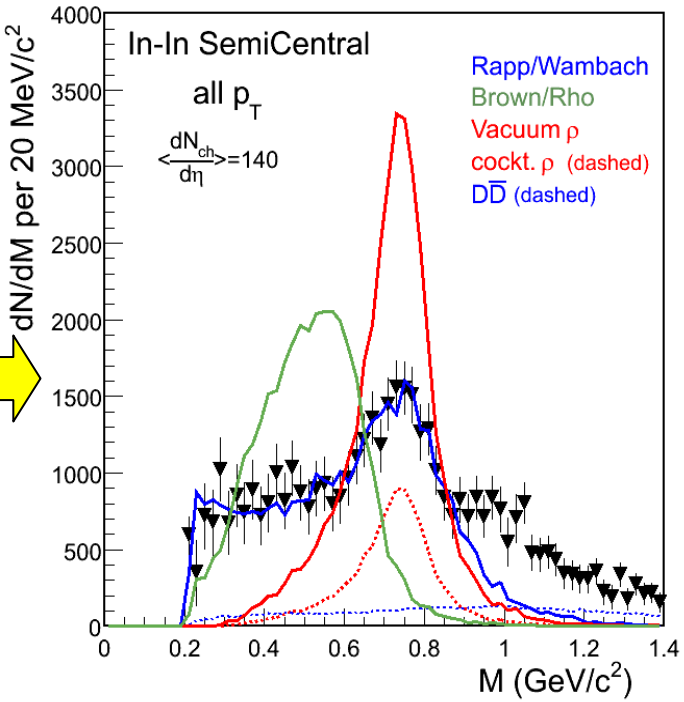
background subtraction



subtraction of non-ρ cocktail



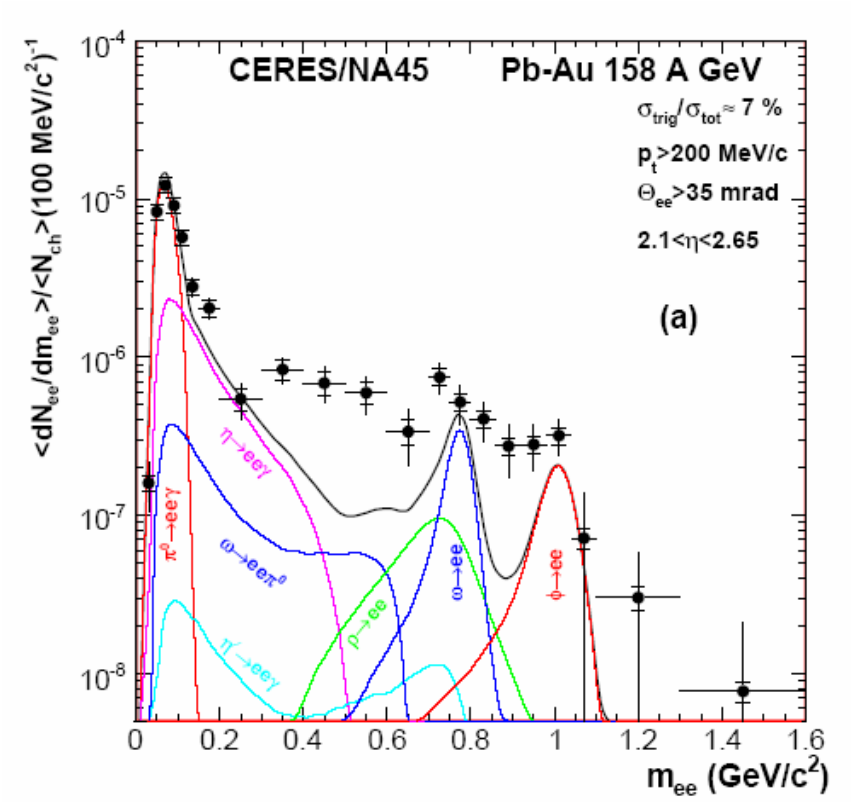
excess pairs including ρ

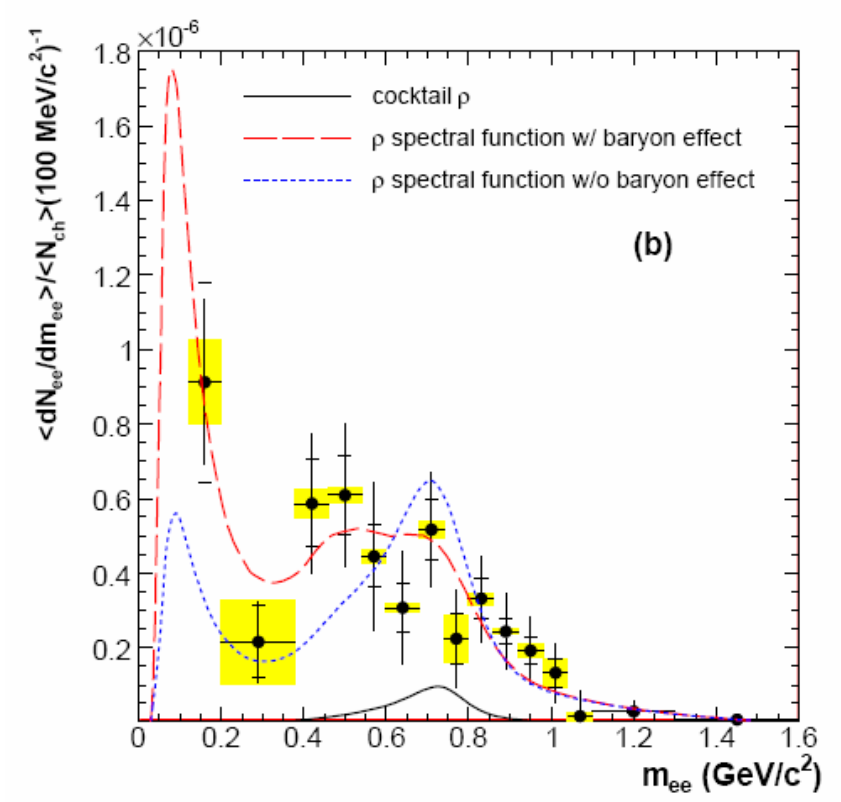


- mass shift of ρ ruled out, looks like suppressed ρ on a low mass continuum
- models of in medium spectral function modification describe data

Results of NA45/CERES from electron pairs in Pb+Au collisions

- improved mass resolution due to TPC compared to NA45/I
- sensitivity to smaller virtual photon masses than with μ-pairs



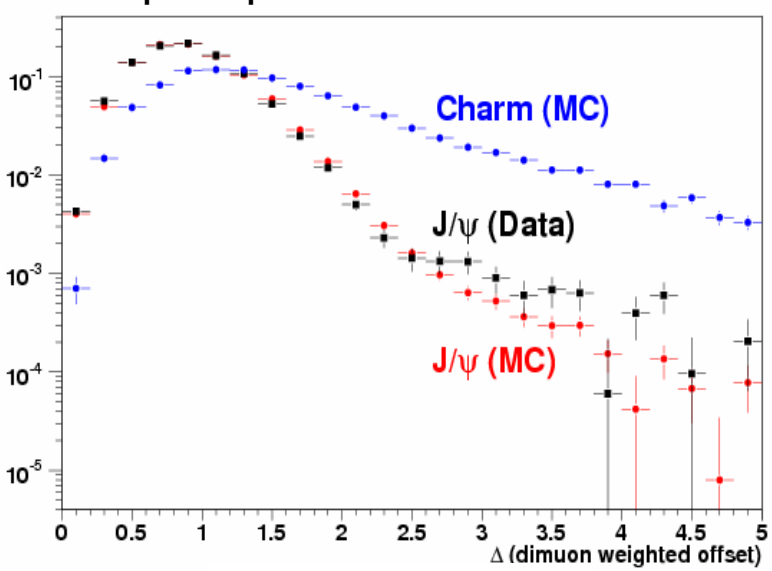


- results consistent with older NA45 and high statistics NA60 In+In results
- also observe the strong baryon effect in the ππ spectral function

(2) enhanced yield of intermediate mass $\mu^+\mu^-$ pairs

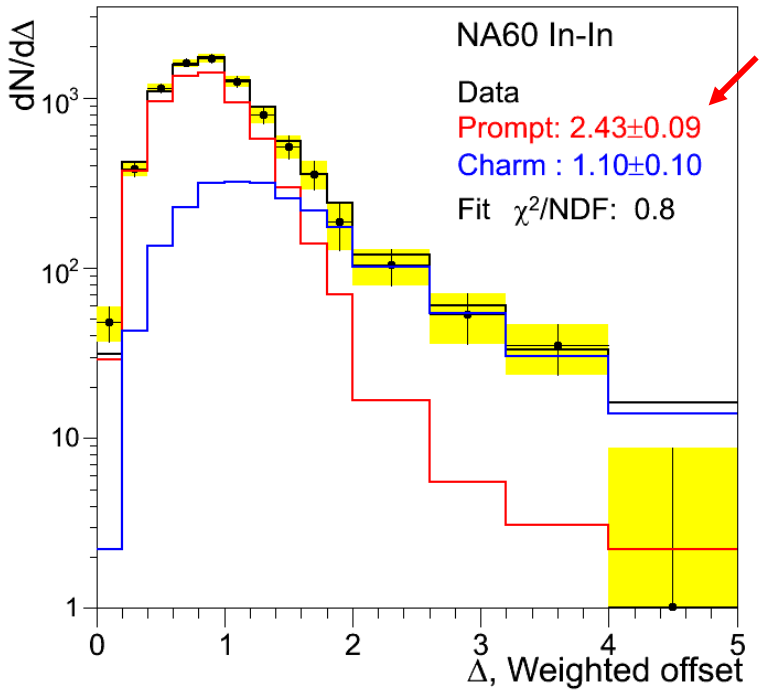
- First observed by HELIOS-3 (S+U) and NA50 (Pb+Pb): thermal dileptons or enhanced charm production ?
- vertex detector in NA60 provides required discrimination

impact parameter distributions



$$\Delta = \sqrt{(\Delta_{\mu 1}^2 + \Delta_{\mu 2}^2)/2}$$

decomposition of distributions

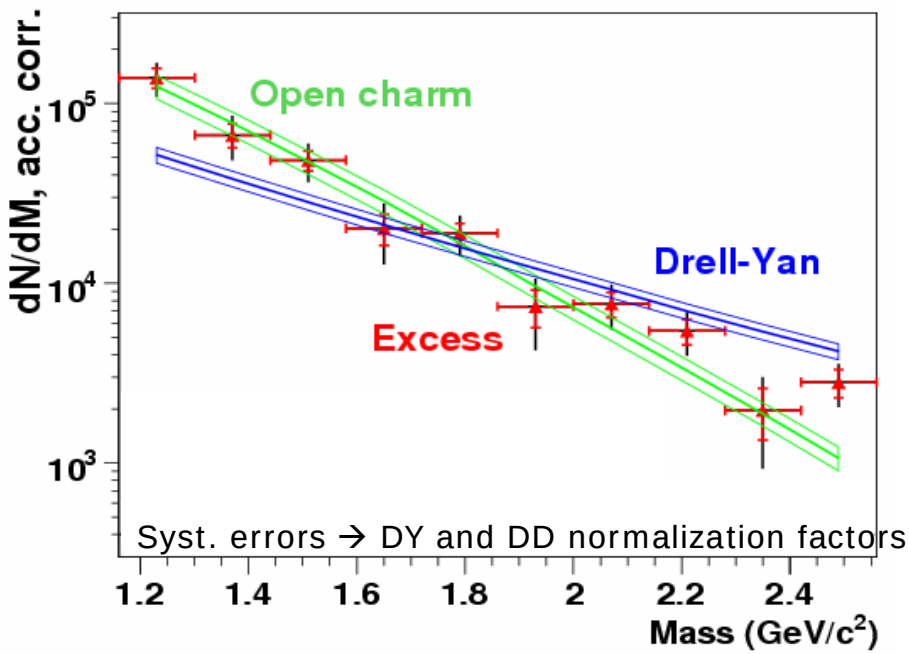


Excess + Drell-Yan

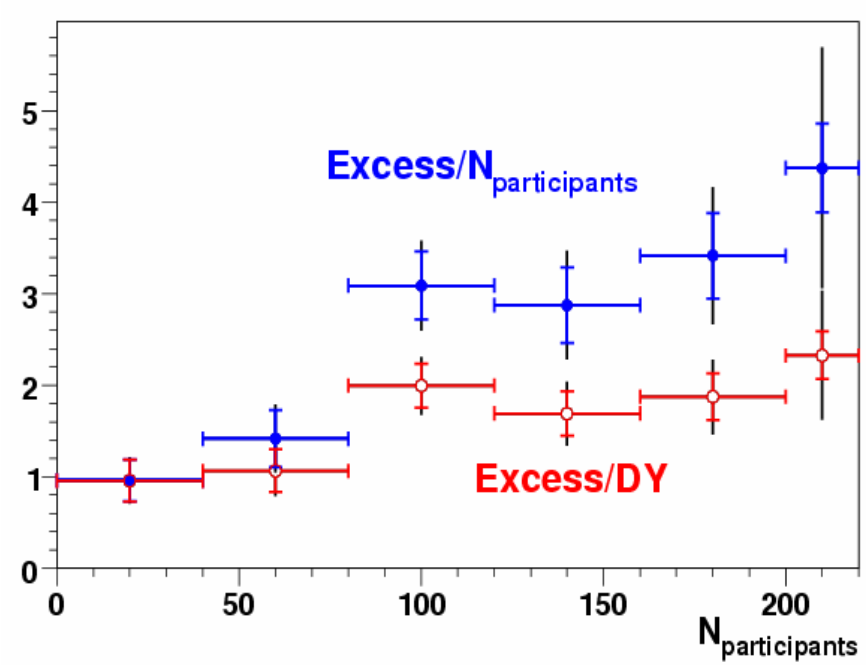
- non-prompt pair yield consistent with expectation for charm production
- intermediate mass excess due to prompt pairs in addition to Drell-Yan

prompt pair excess over Drell-Yan in In+In collisions

mass dependence



centrality dependence



- similar to open charm
- steeper than Drell-Yan

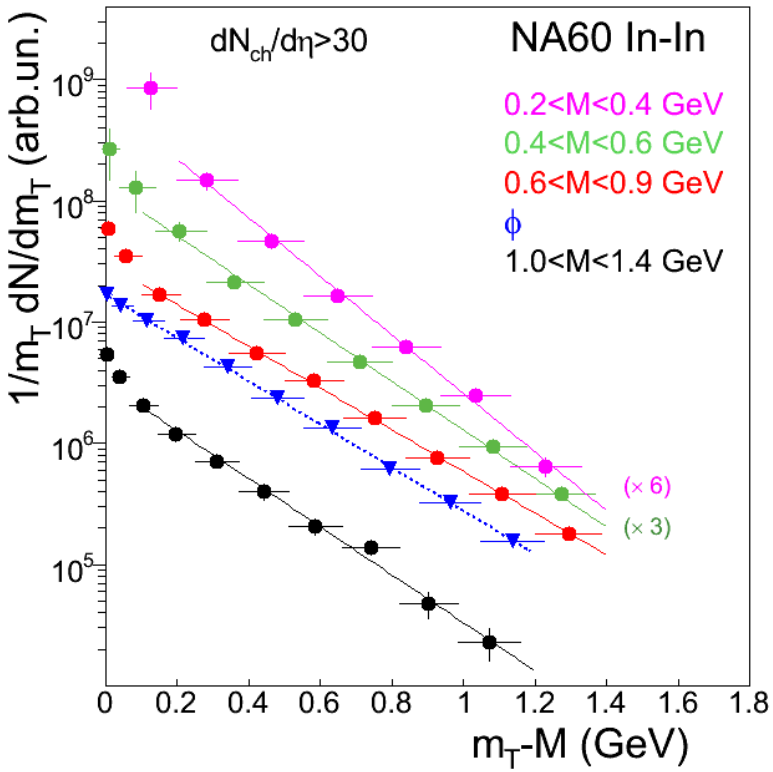
- rises faster than N_{part}
- probably faster than N_{coll} (DY)

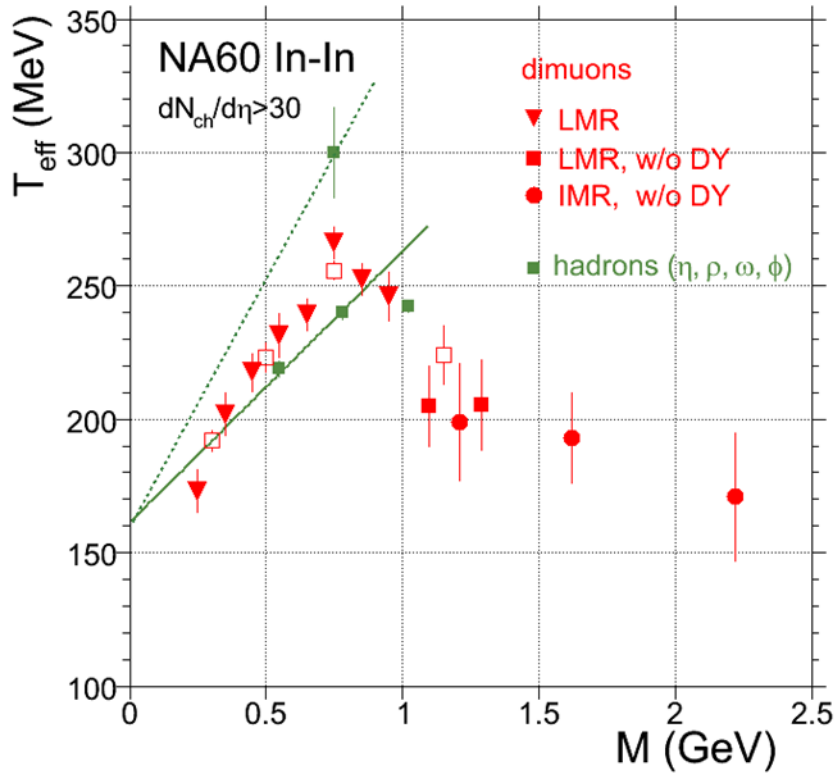
data at RHIC less precise, no definite conclusions yet (arXiv:0706.3034)

evolution of m_T distribution with pair mass

NA60: PRL 100,022302(2008)

parameterisation $\frac{1}{m_T}\frac{dN}{dm_T} \sim \exp\left(-m_T/T_{eff}\right)$





- T_{eff} rises in low-mass region → radial flow of a hadronic source
- sudden drop suggests transition to early (partonic) production process

first evidence for thermal radiation of partonic origin ?

(3) Charmonium suppression

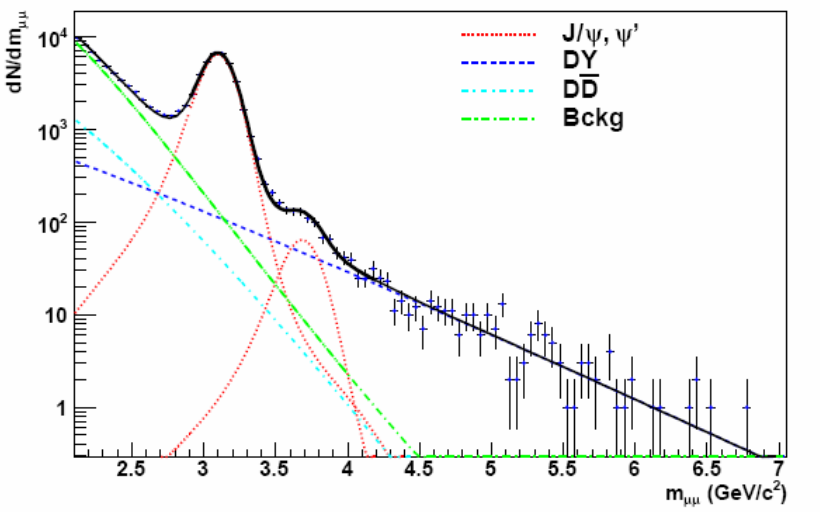
Talk: R.Arnaldi and P150

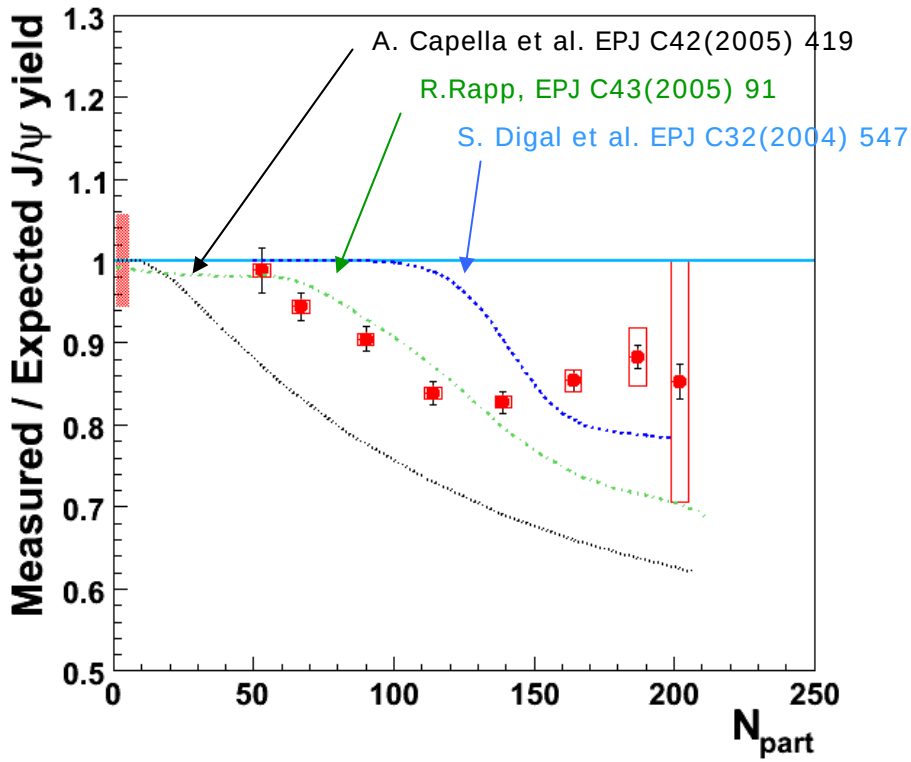
- once “smoking gun” of QGP
- complex interplay of QGP, initial and final state effects

no consistent and comprehensive theoretical interpretation yet

In+In results of NA60 now published

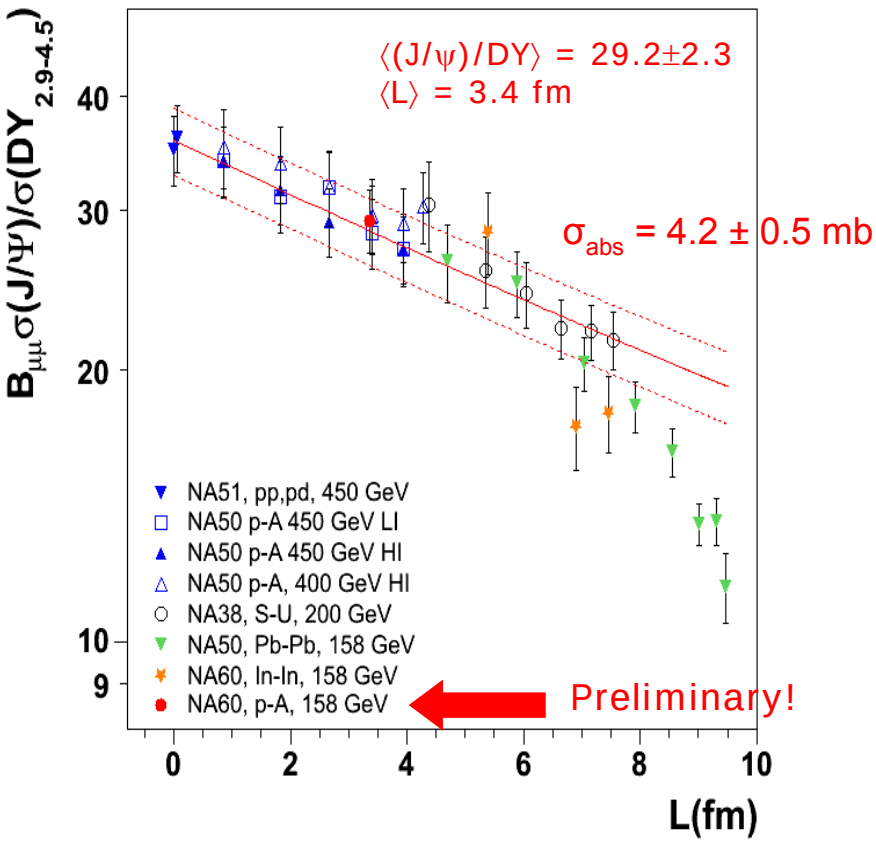
PRL 99, 132302 (2007)

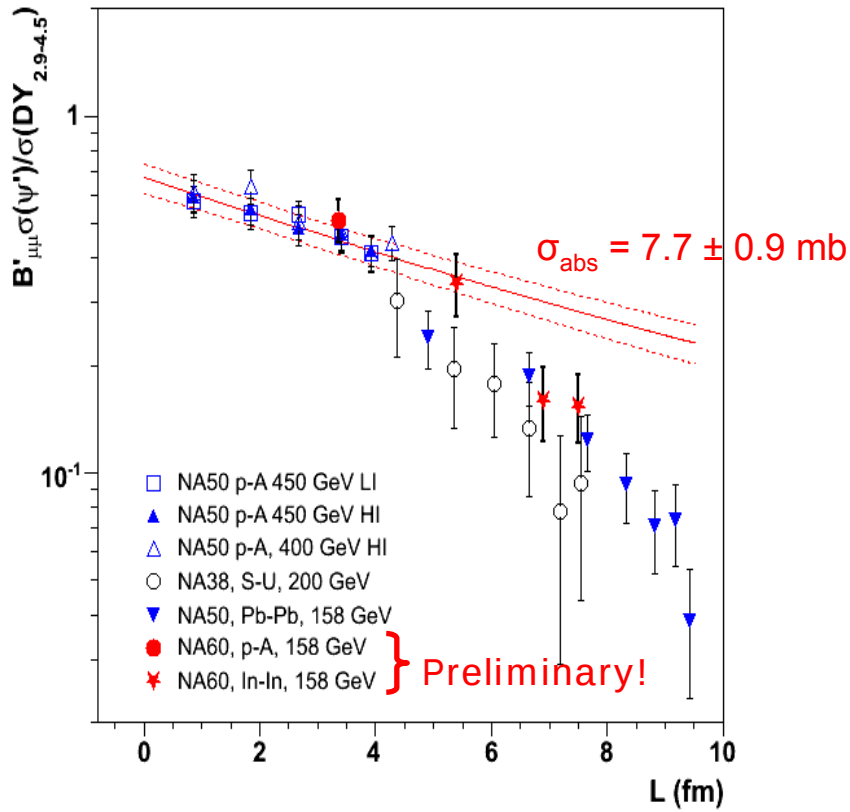




J/Ψ suppression at the SPS:

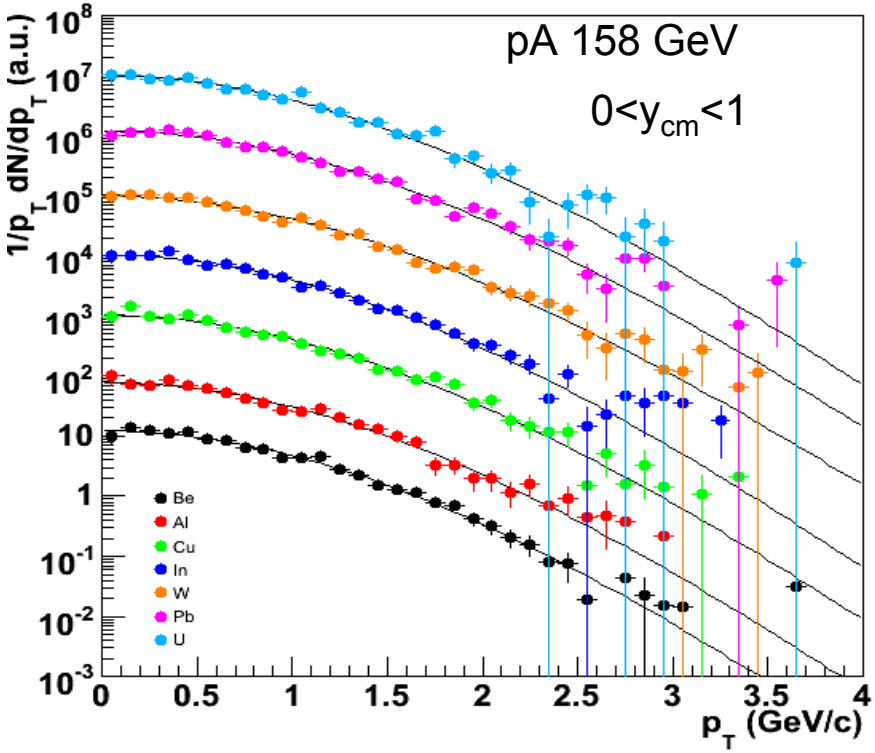
- suppression beyond absorption in cold nuclear matter
- additional absorption sets in earlier for Ψ' than J/Ψ
- remarkable scaling with L (thickness of traversed nuclear matter)



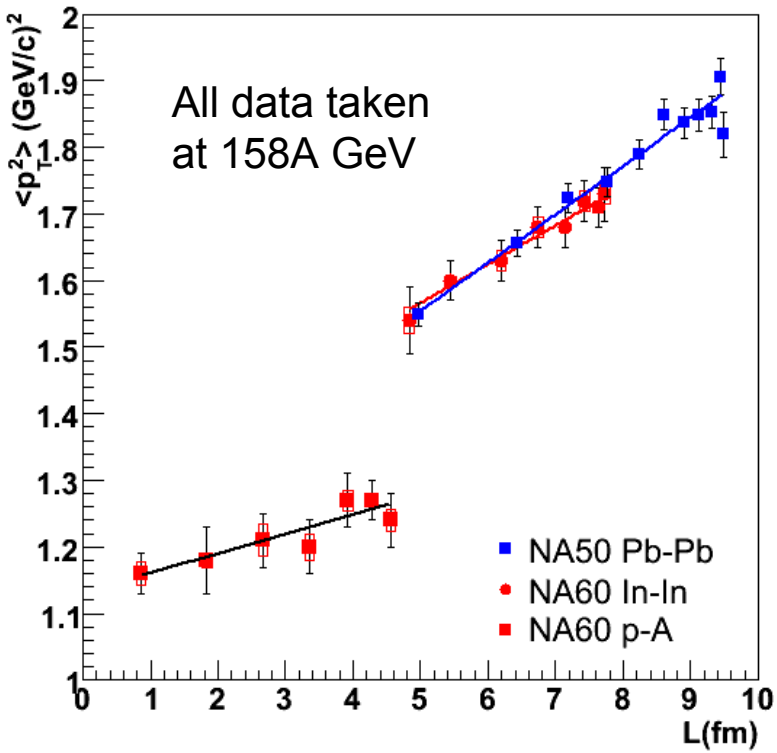


new J/Ψ data in p+A collisions at 158 GeV from NA60:

p_T distributions in p+A collisions



scaling of $\langle p_T^2 \rangle$ pathlength in nuclei

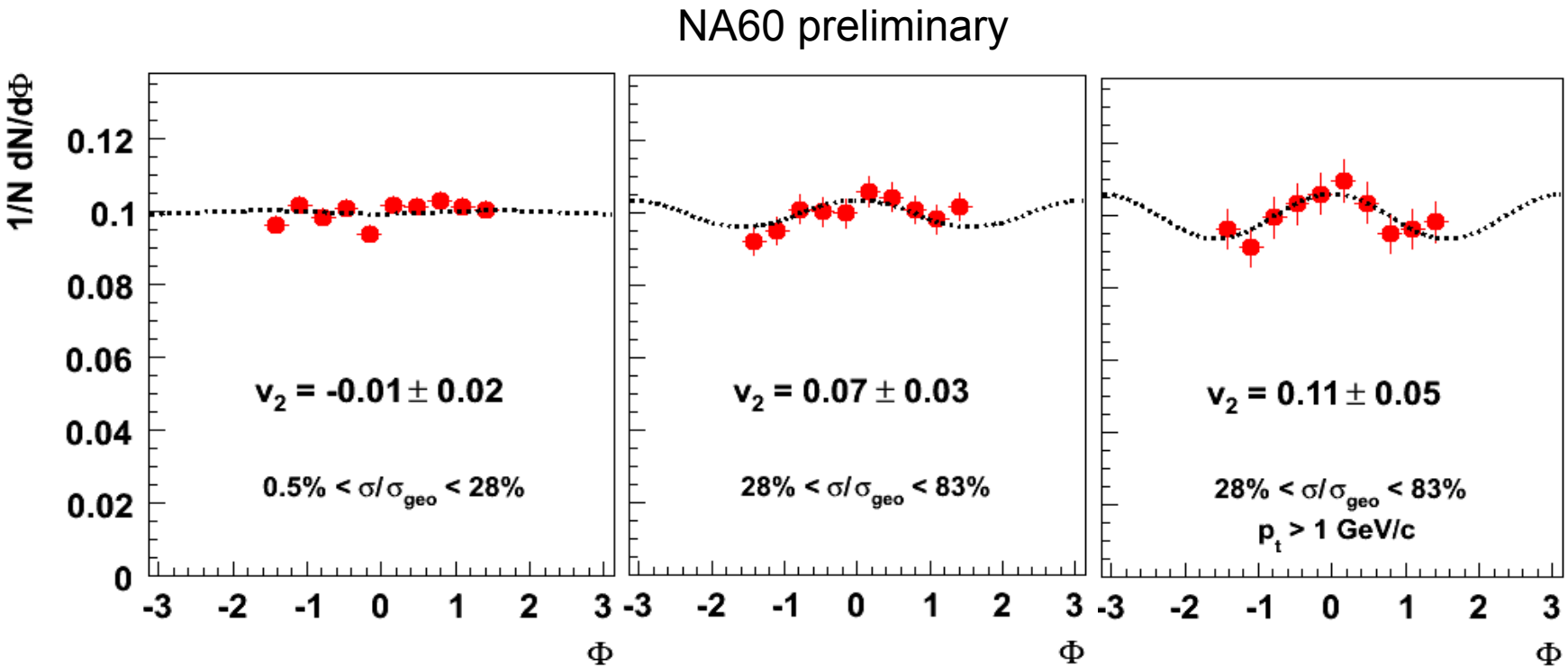


- linear increase of $\langle p_T^2 \rangle$ with L for both p+A and In+In, Pb+Pb
- L scaling breaks down between p+A and A+A

p_T distribution of J/Ψ affected not only by initial state effects

Talk: R.Arnaldi

azimuthal anisotropy of J/Ψ production in In+In collisions

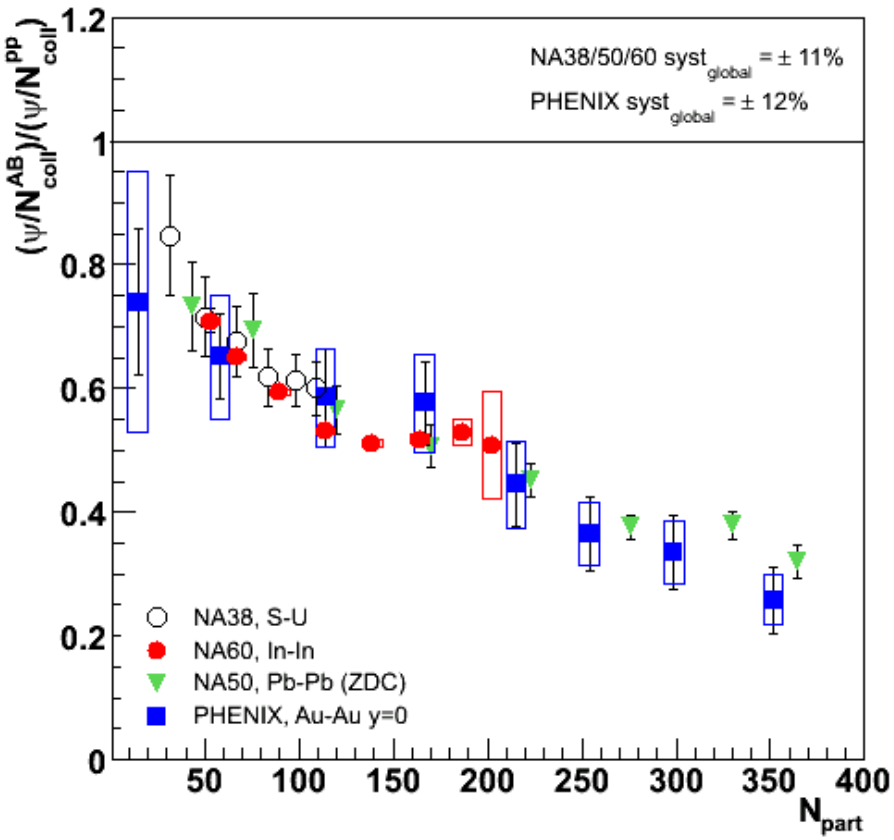


charmed quark recombination not believed to be a dominant source of J/Ψ yield → expect no significant v_2 elliptic flow signal

effect caused by anisotropic absorption in QGP or nuclear matter ?

suppression of charmonium production measured via R_{AA}

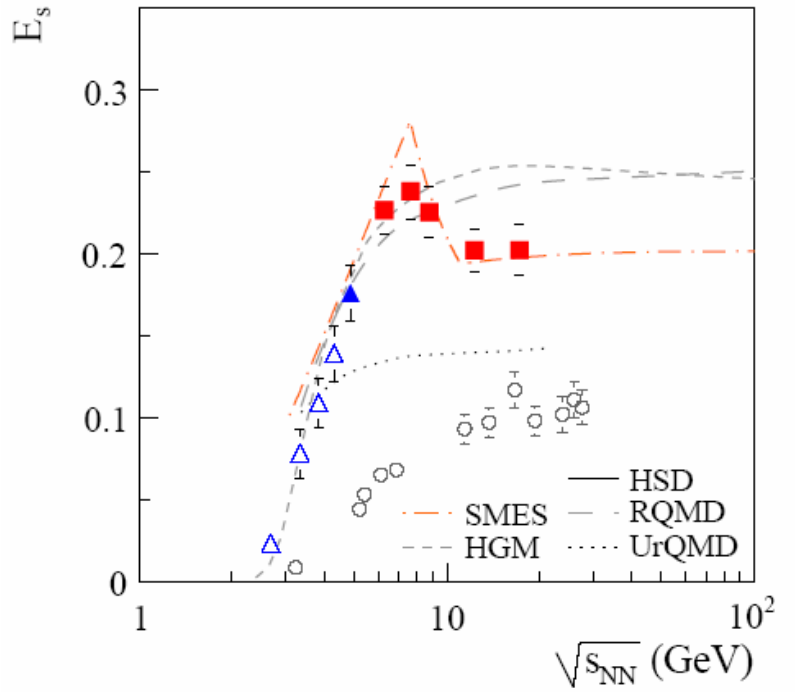
- similar in In+In, Pb+Pb, Au+Au at same N_{part}
- shows no increase from SPS to RHIC



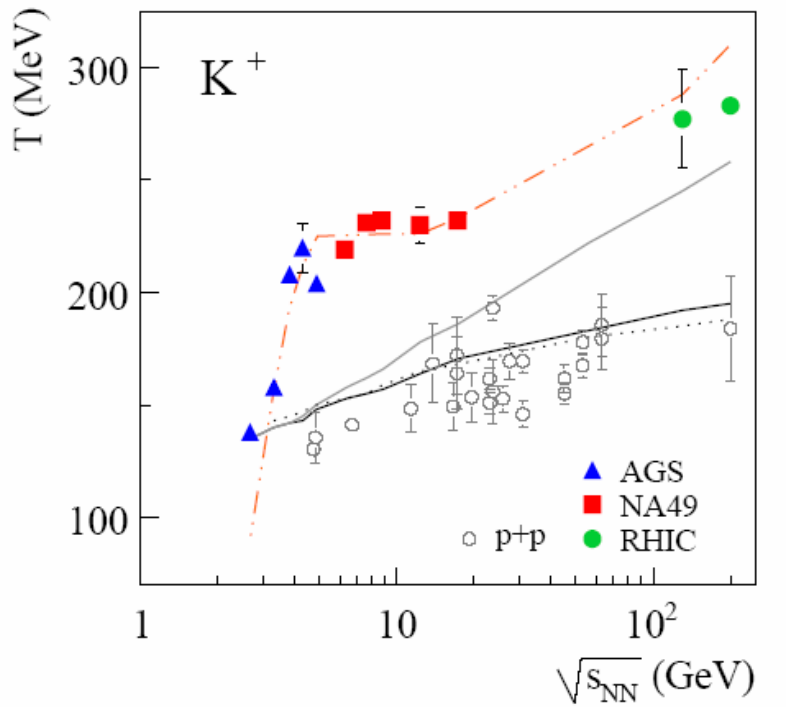
onset of deconfinement in central Pb+Pb collisions at the SPS

final NA49 results: arXiv:0710.0118

relative strangeness production



inverse m_T slope parameter

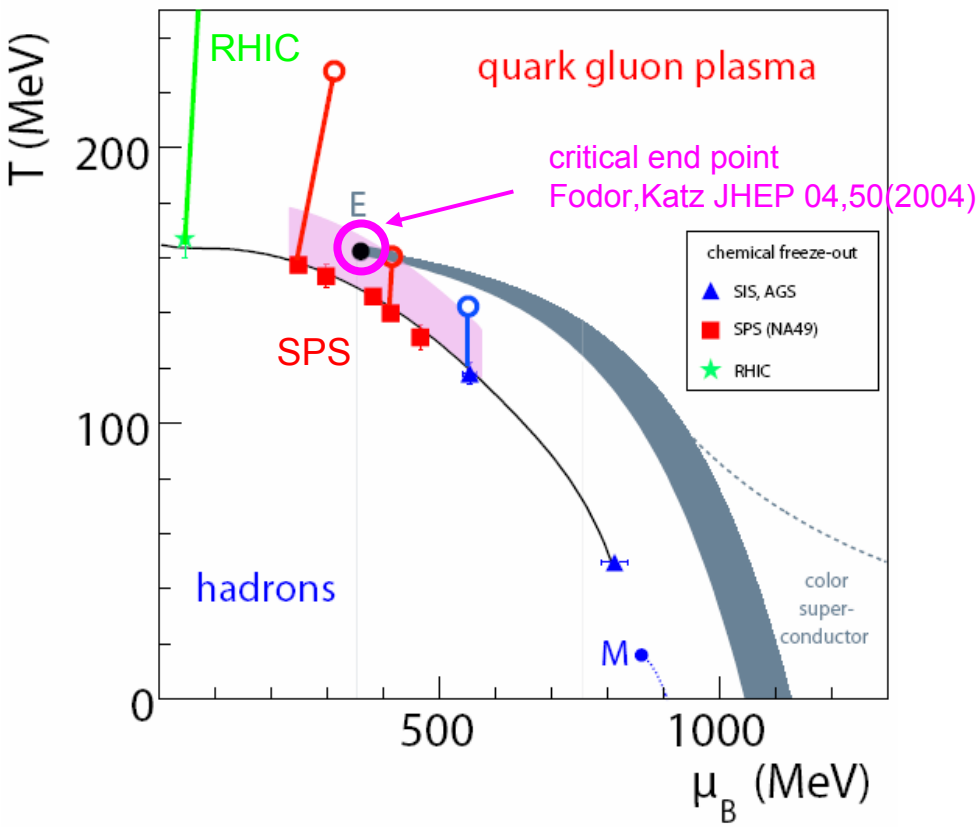


- rapid changes of hadron production properties at low SPS energy
- only models with deconfinement at the early stage describe data
- deconfinement reached in central Pb+Pb collisions above ≈ 30AGeV

Talk: Rybczynski

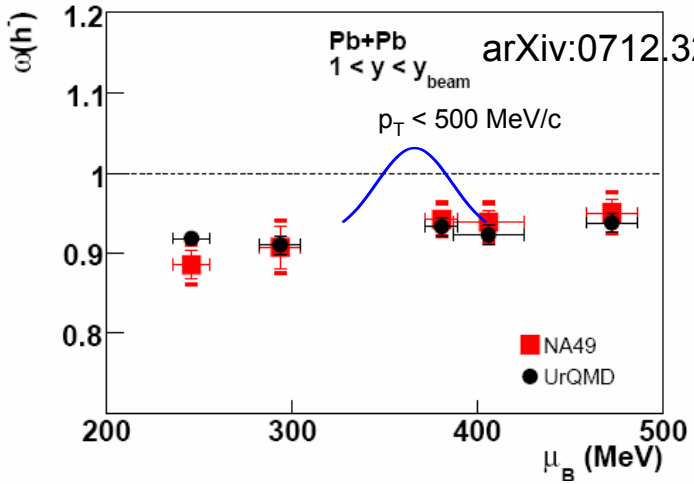
Lattice QCD predicts critical point of hadronic matter

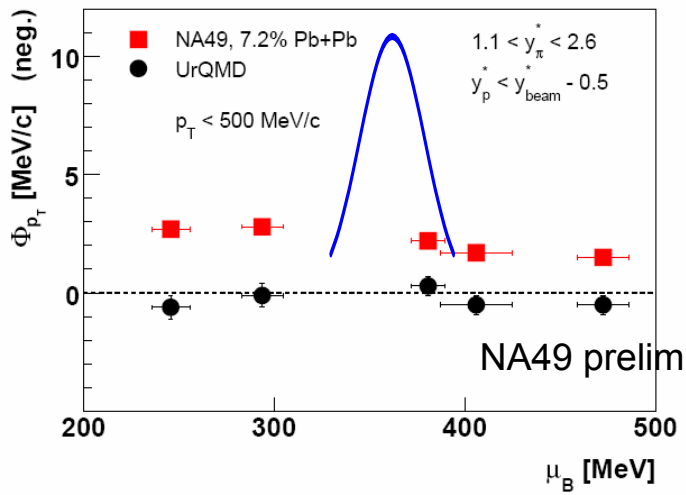
hadron composition freeze-out points



no indications in central Pb+Pb

Prediction: Stephanov et al.,PRD60,114028(1999)

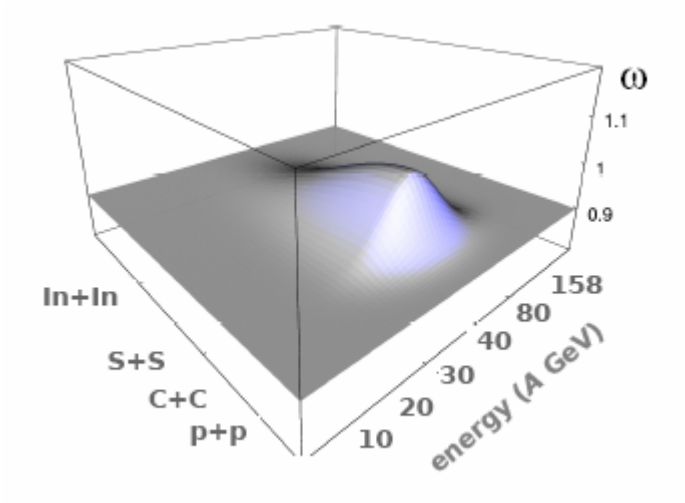




- at SPS access to predicted T, μ_B region
- scan with lighter nuclei seems promising

Future plans at the SPS:
search for critical point of hadronic matter

scan energies of SPS with
smaller size nuclei



- experiment NA61 (upgraded NA49) approved by CERN
- provision of ion beams at CERN requires coordination with LHC schedule

Conclusions

- heavy-ion data were last taken at the SPS in 2003, new results are still being produced
  - lepton pair production

    thermal dileptons: ρ spectral function m < 1GeV

    partonic origin m > 1GeV
  - charmonium production

    L scaling broken for $\langle p_T^2 \rangle$; azimuthal anisotropy
  - yield of K*, Φ resonances, light nuclei
  - high p_T phenomena
- deconfinement seems to be reached in Pb+Pb collisions at low SPS energy
- the predicted critical point of hadronic matter appears to be best accessible at SPS energies
- a systematic search for the critical point in A+A collisions is in preparation (NA61)