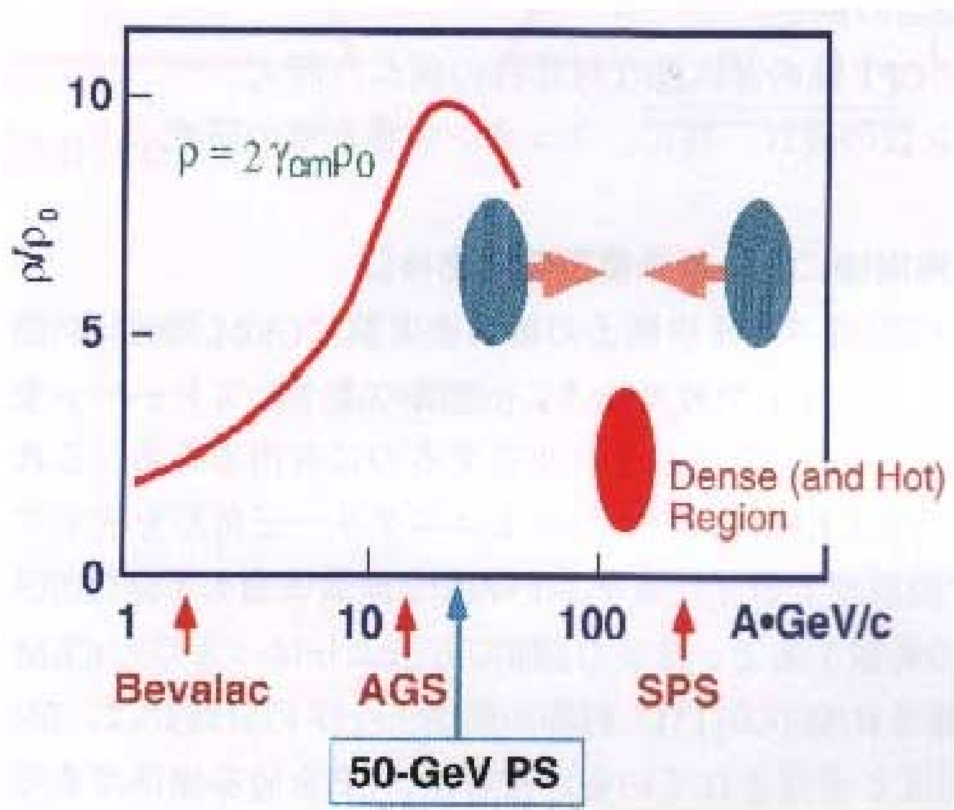
# Heavy-ion physics at JHF





ShinIchi Esumi
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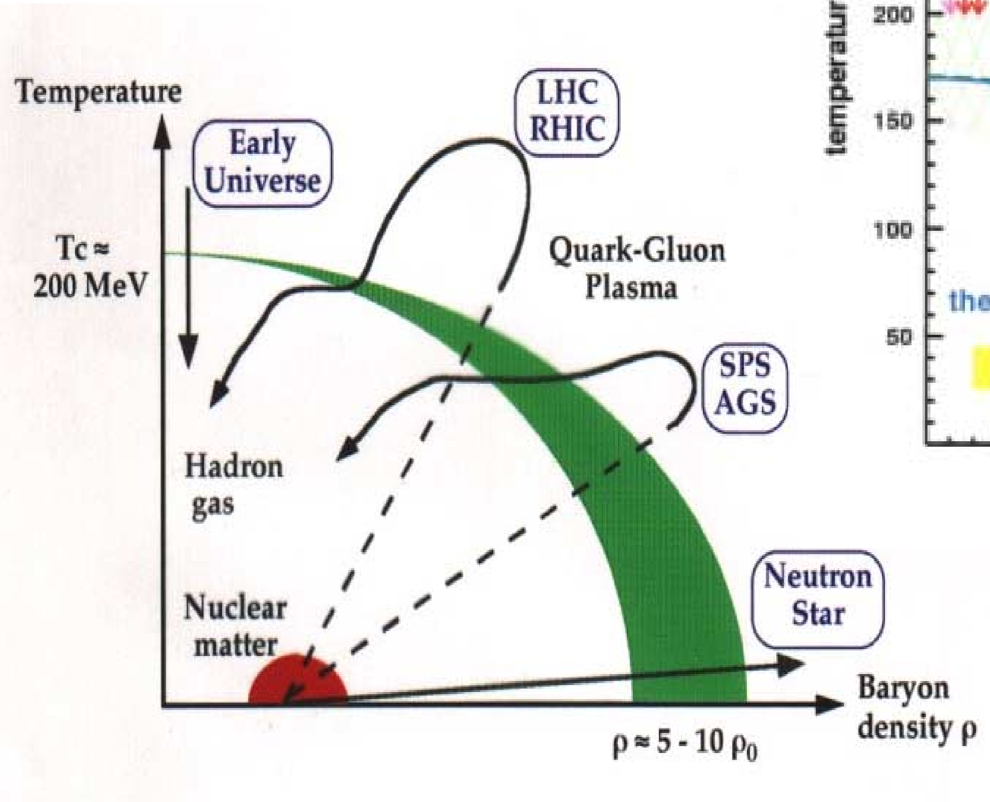
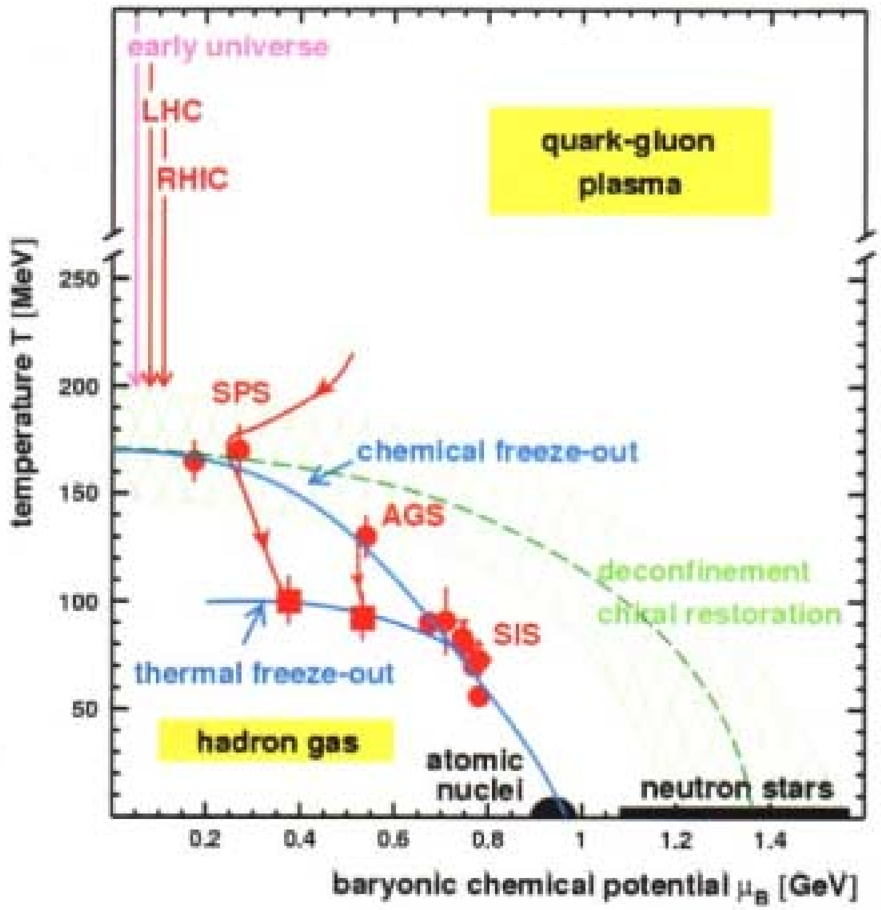
(1) the highest baryon density expected at JHF
(2) QGP exists at SPS, but not at AGS ?
(3) expansion and flow at freeze-out
(4) leptonic probes

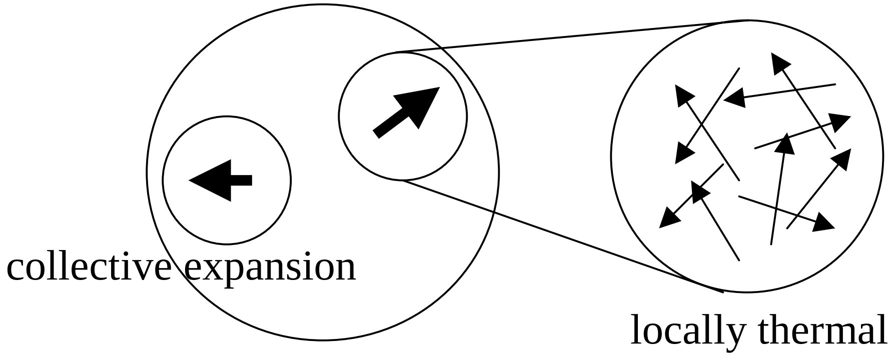
Phase diagram

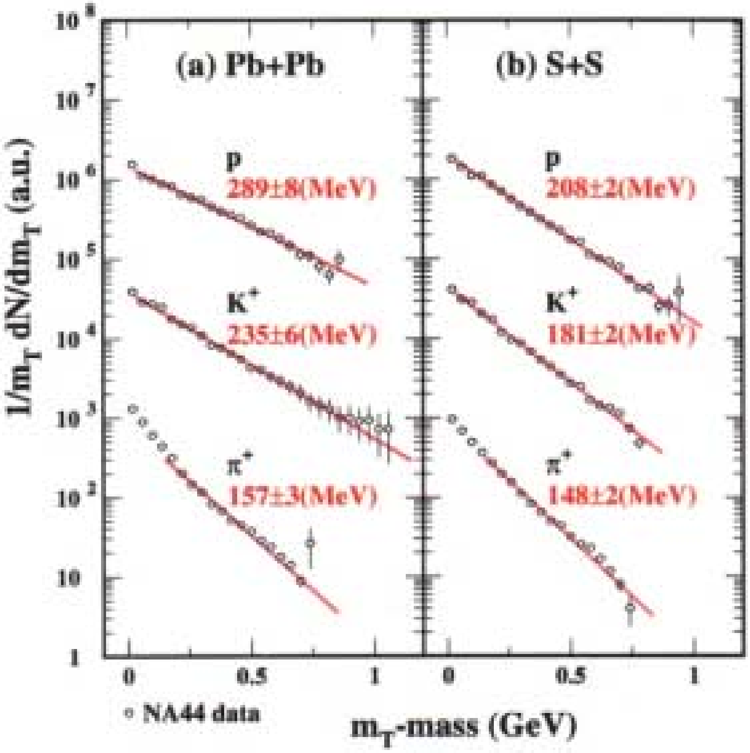


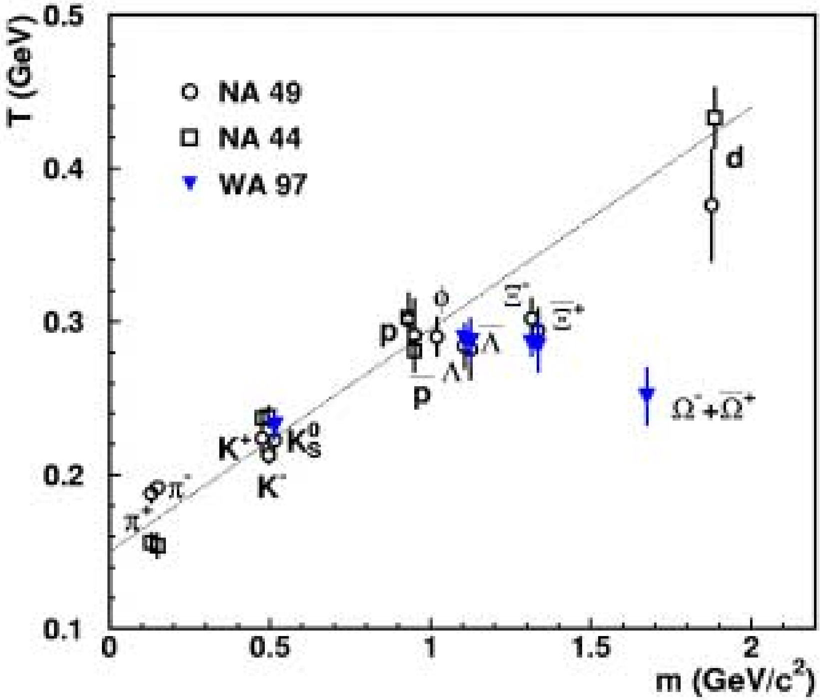



# thermal freeze-out

the end of elastic
interactions

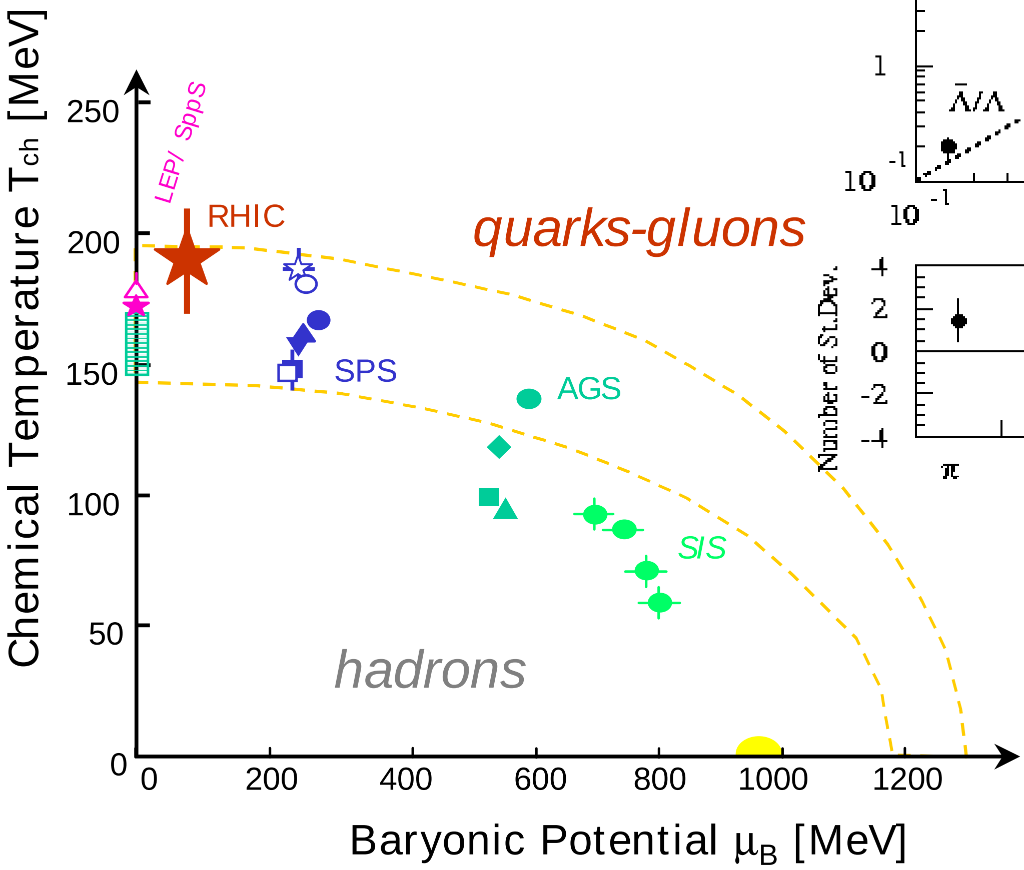


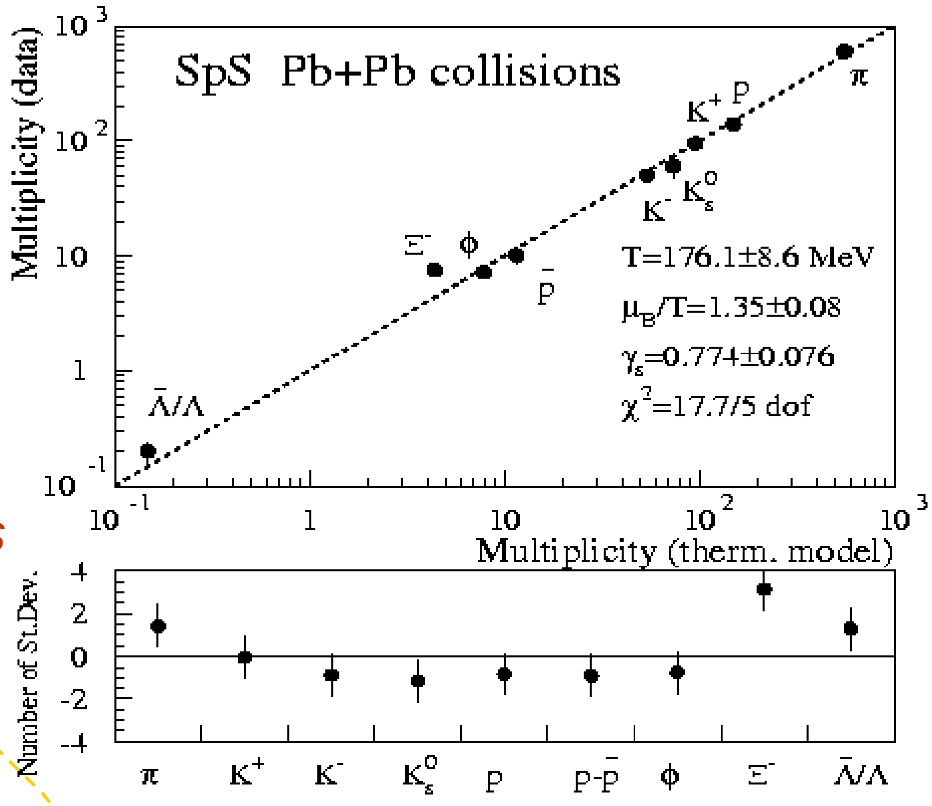



# chemical freeze-out

the end of inelastic interactions



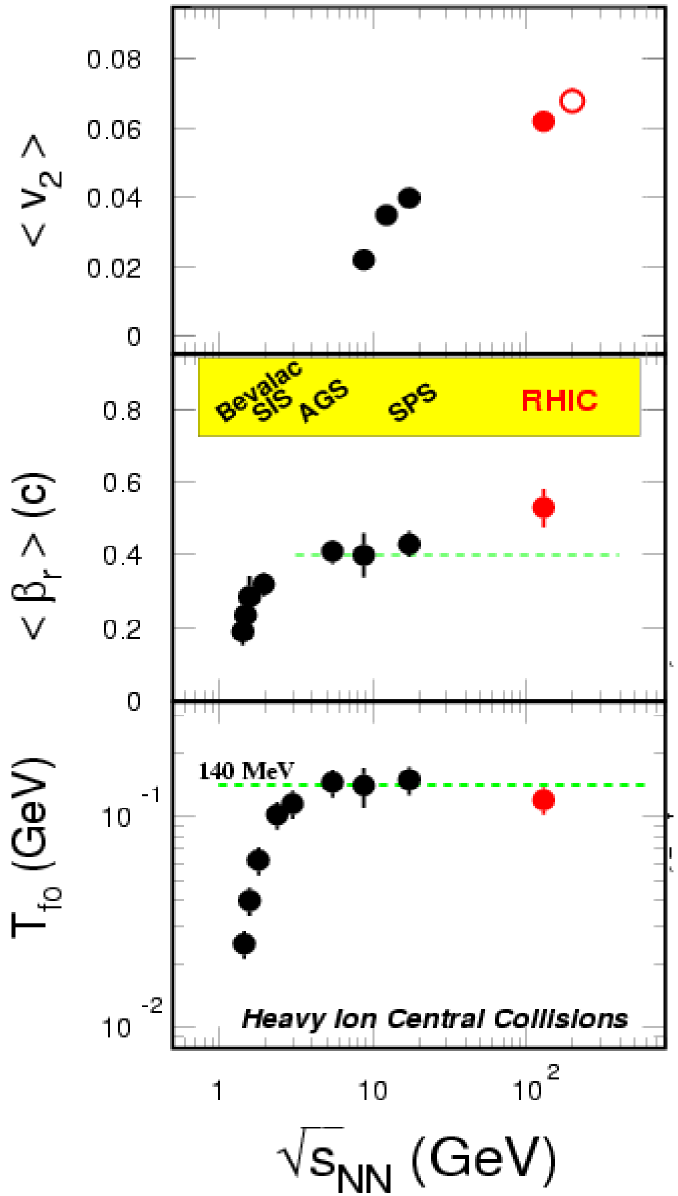

$$\rho = \frac{g}{2\pi^2}\int_0^\infty \frac{p^2\,dp}{\exp\left[(E-\mu)/T_{ch}\right] \pm 1}$$

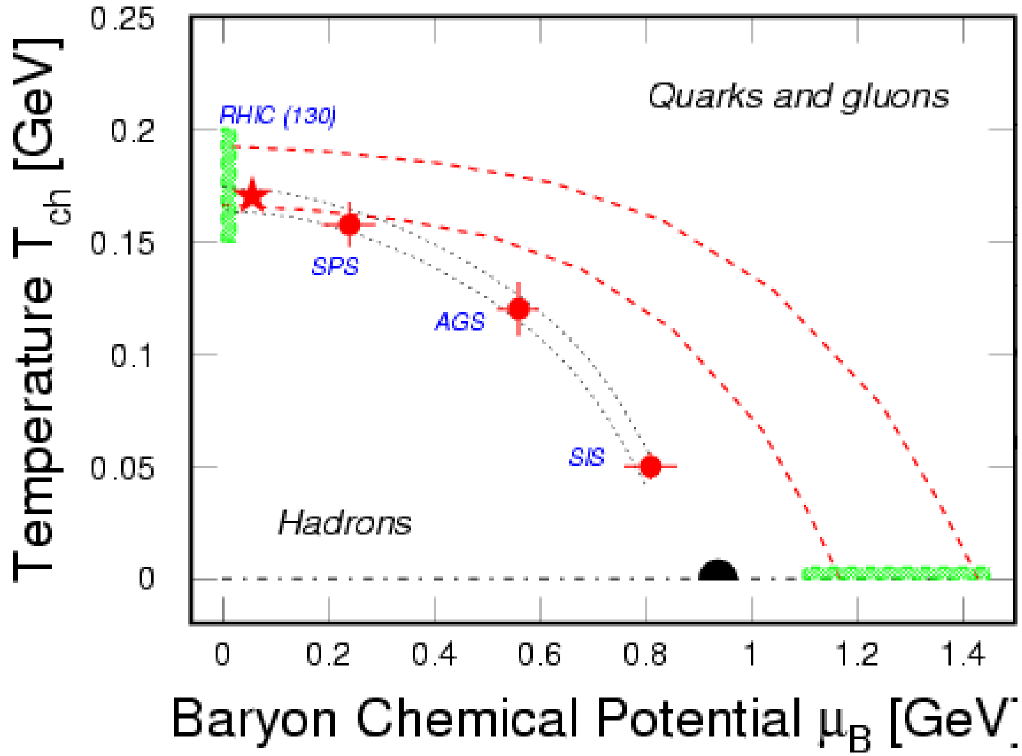
$\mu = q\mu_q + s\mu_s$: chemical quark potential

$T_{ch}$ : chemical freeze-out temperature

ρ : integrated particle yield over full phase space

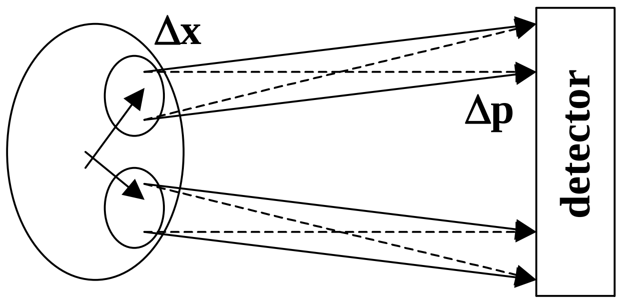
# expansion and freeze-out

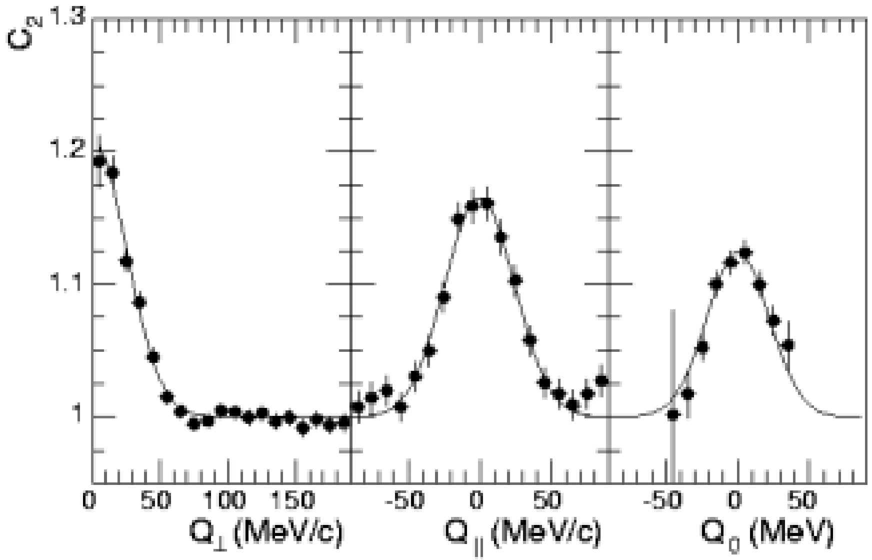


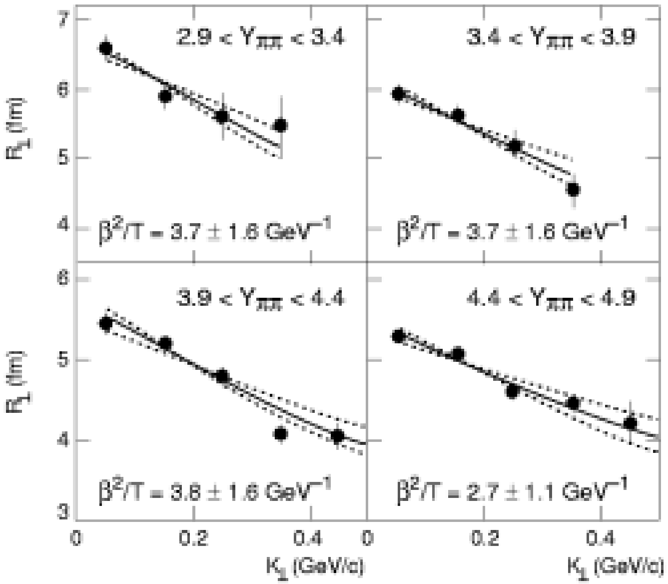




Thermal $T_f$ is saturating already at AGS.
Chemical $T_f$ is reaching the boundary.
Transverse and elliptic flows are still increasing.

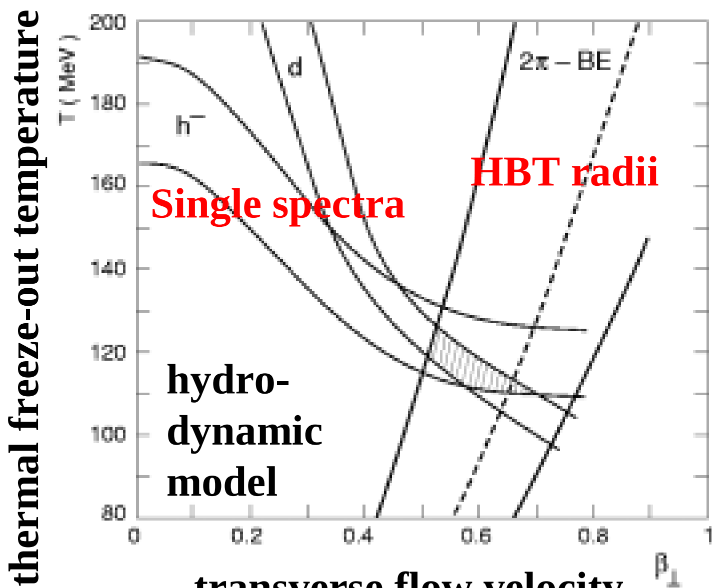
# HBT correlation




transverse momentum

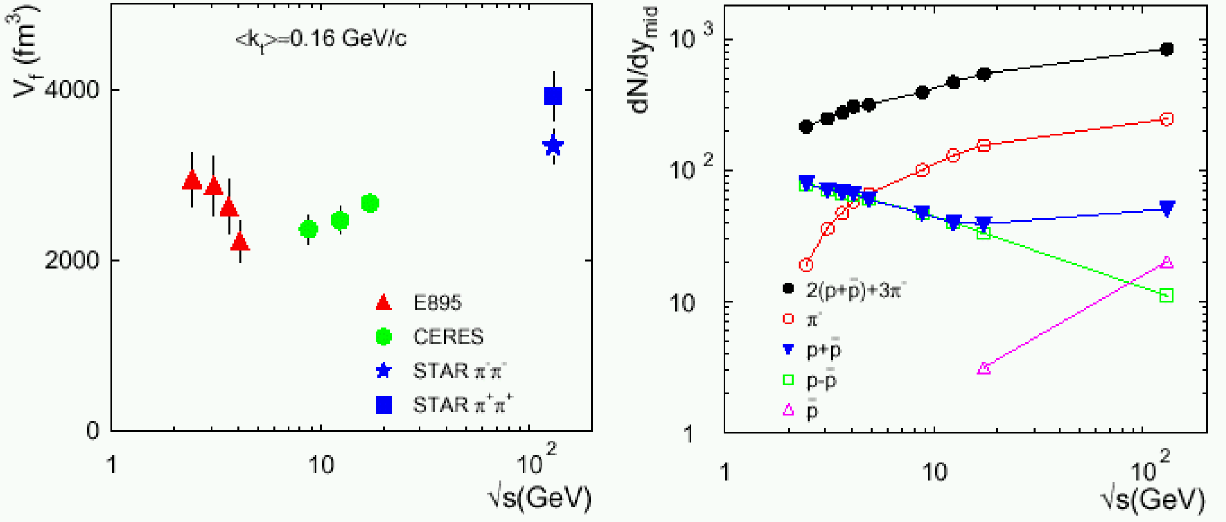



transverse flow velocity

# non-monotonic behavior of $V_f$

H. Appelshäuser, H. Tilsner

$$V_f = (2\pi)^{\frac{3}{2}} \cdot R_{long} \cdot R^2_{side}$$



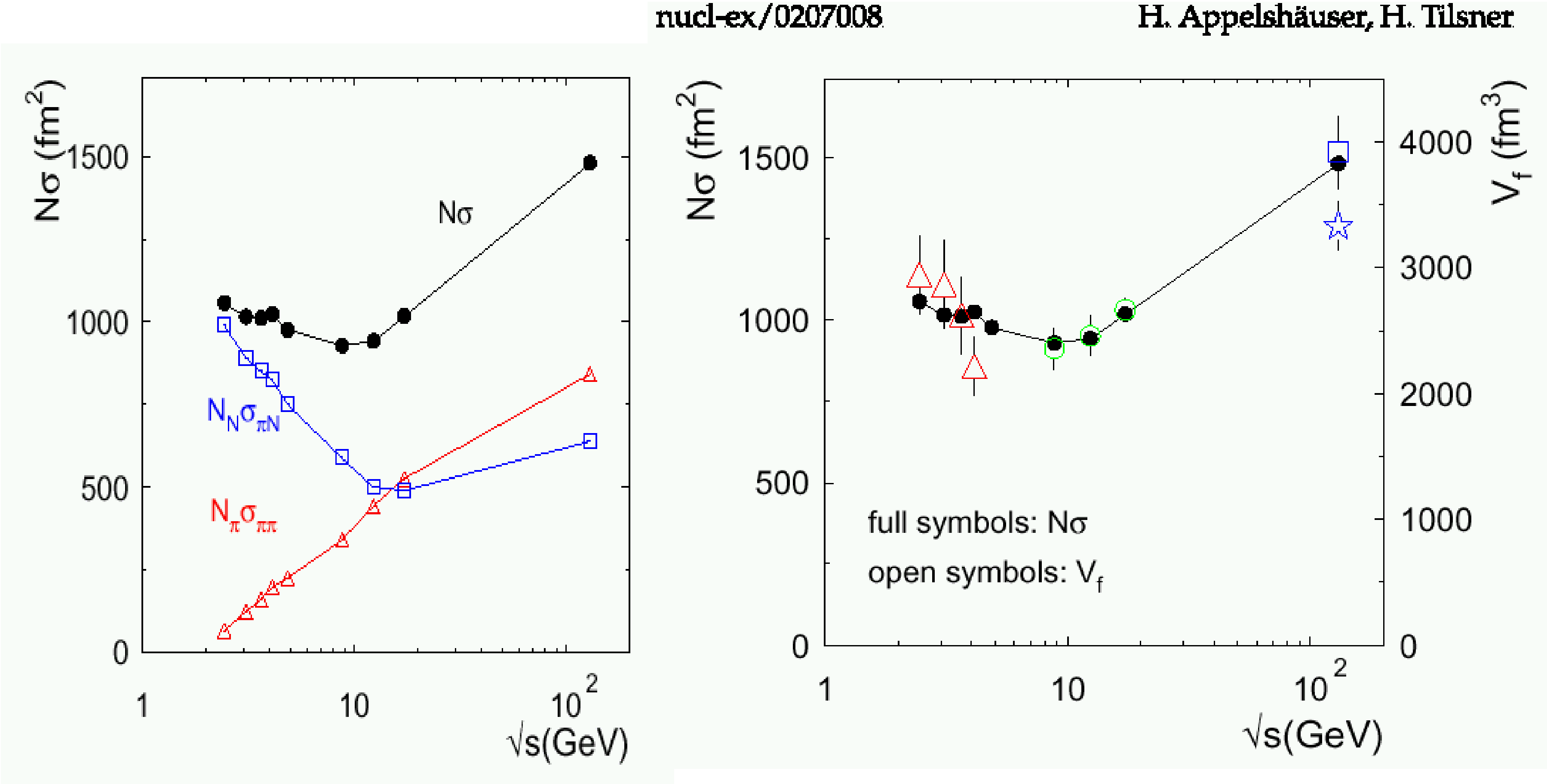

⇒ non-monotonic behavior of $V_f$ with beam energy

⇒ minimum of $V_f$ between AGS and SPS

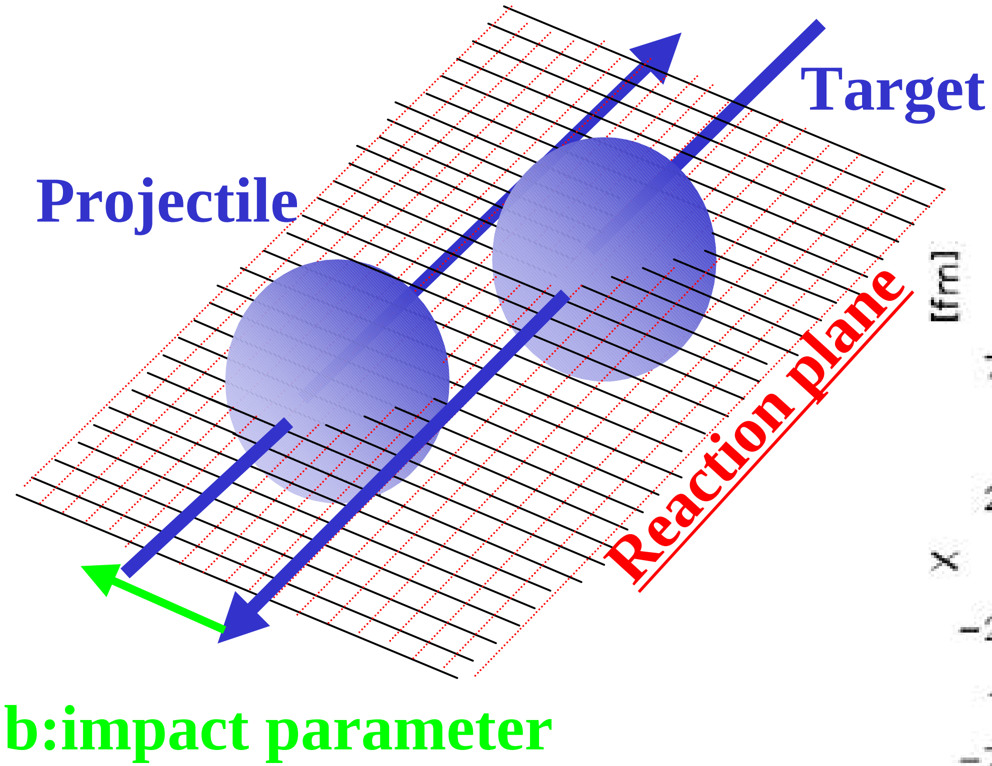
⇒ monotonic evolution of particle yields

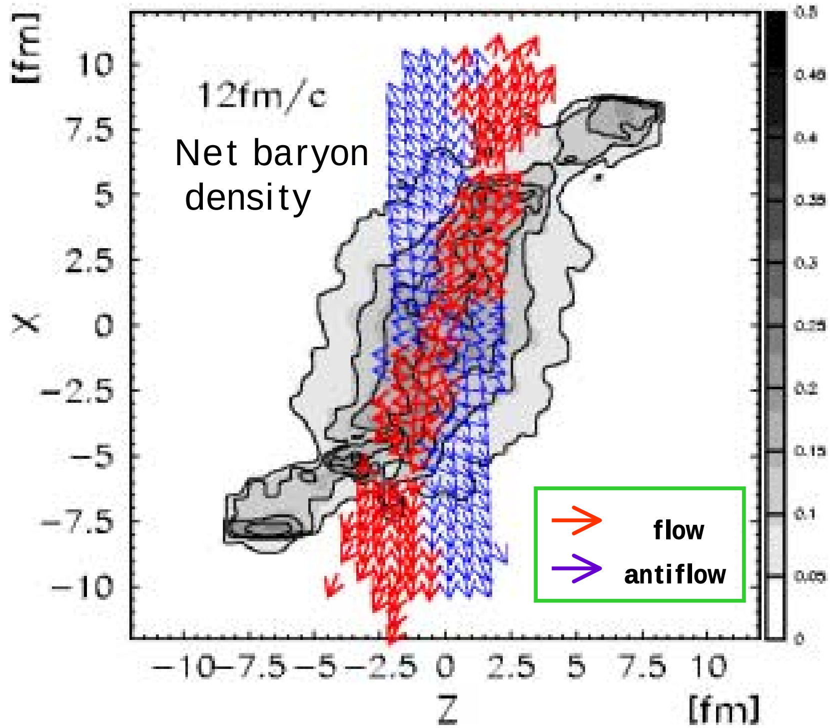
⇒ freeze-out not at constant particle density $\rho = \frac{V_f}{N}$

freeze-out at critical
mean free-path



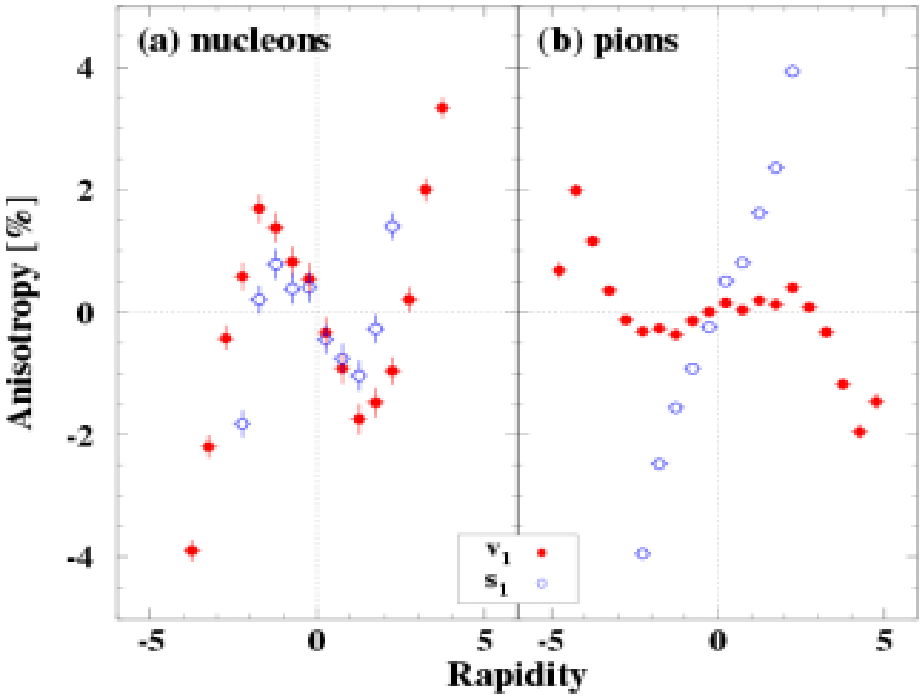
anisotropic flow



# the third flow component in $v_1$

RQMD v2.4




R. Snellings, A. Poskanzer, S.Voloshin., nucl-ex/9904003

R. Snellings, H. Sorge, S.V., F. Wang, Nu Xu, PRL 84 (2000) 2803

Bleicher, Stocker, PRB 526 (2002) 309

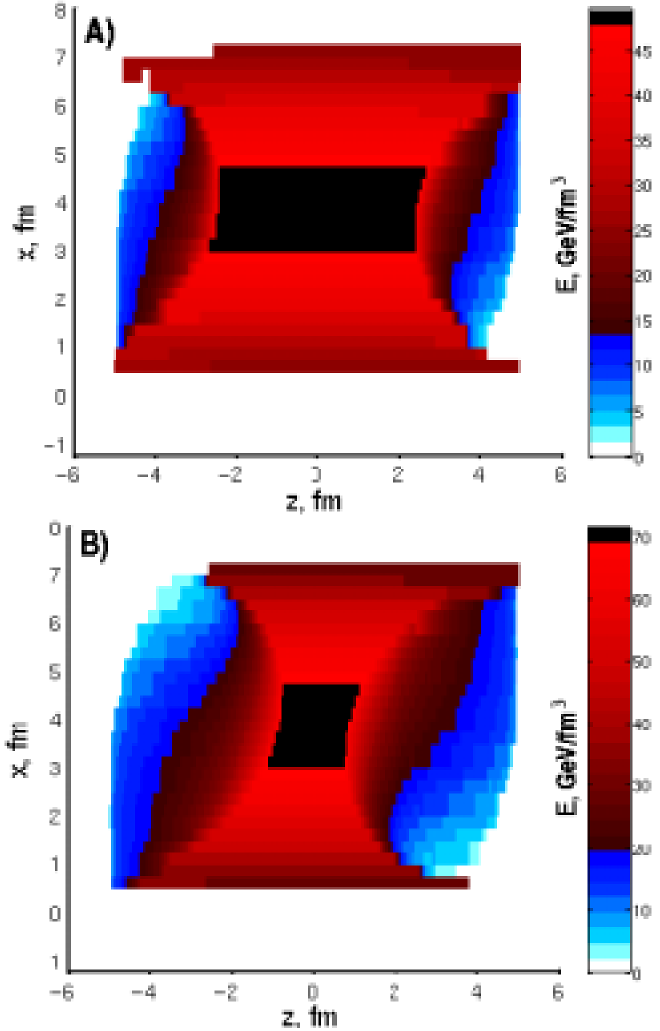
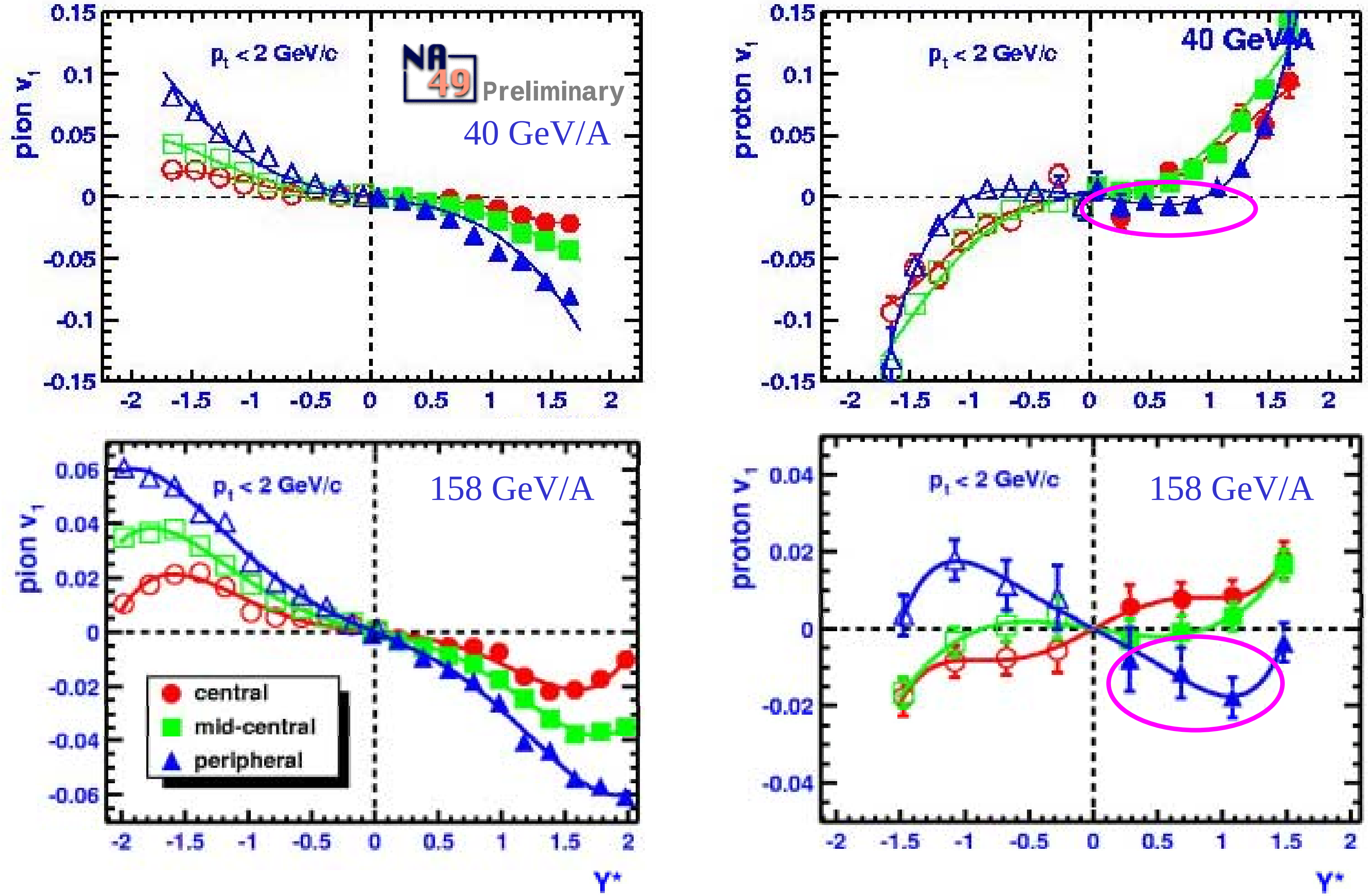


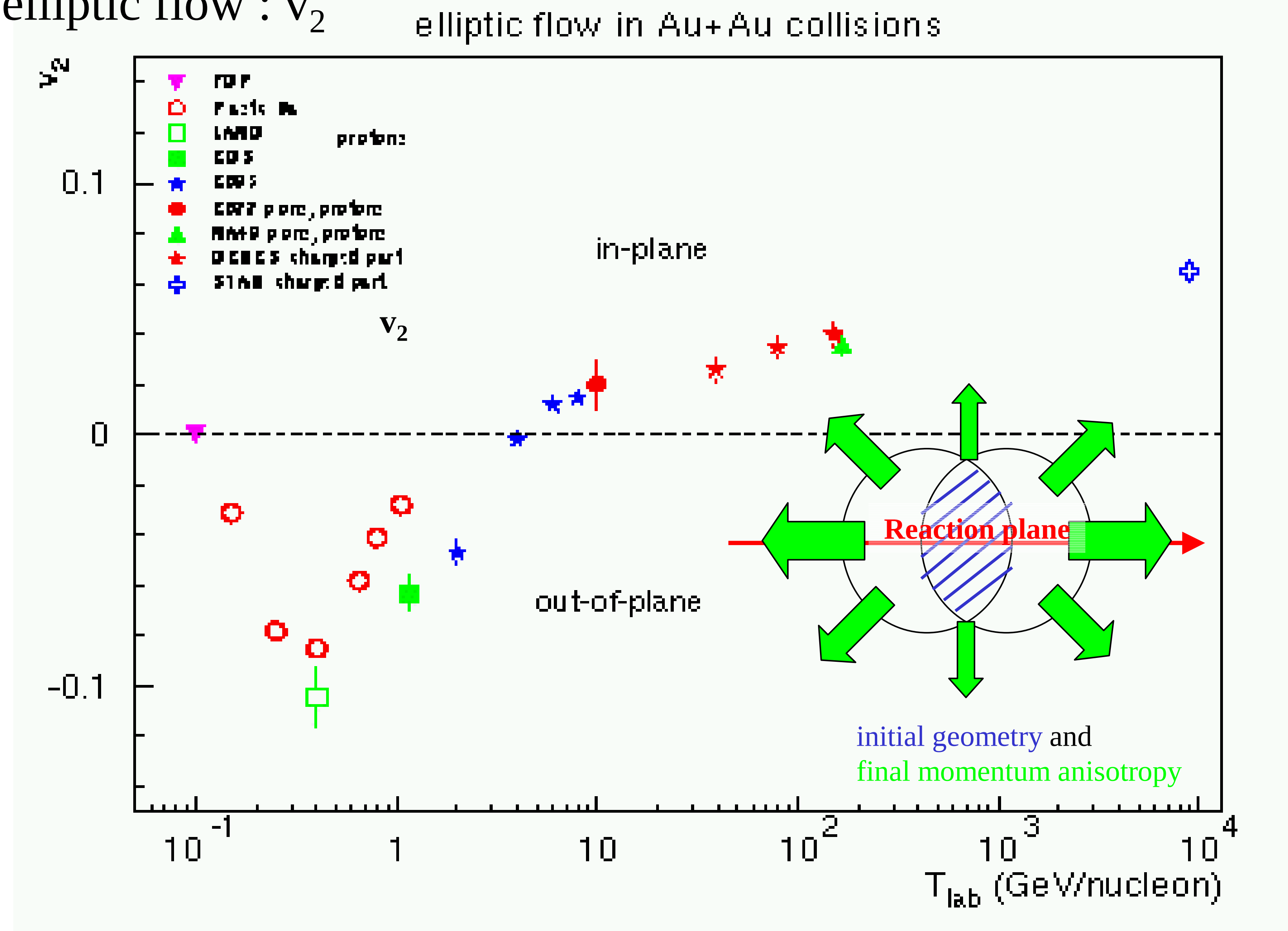

Figure 2: Au+Au collision at $\varepsilon_0 = 100\ GeV/nucl$, $(b = 0.5 \cdot 2\ R_{Au})$ , $E = T^{00}$ is presented in the reaction plane as a function of $x$ and $z$ for $t_h = 5\ fm/c$. Subplot A) $A = 0.065$, subplot B) $A = 0.08$. The QGP volume has a shape of a tilted disk and may produce a third flow component.

# The wiggle (the 3rd flow component) is there at SPS.

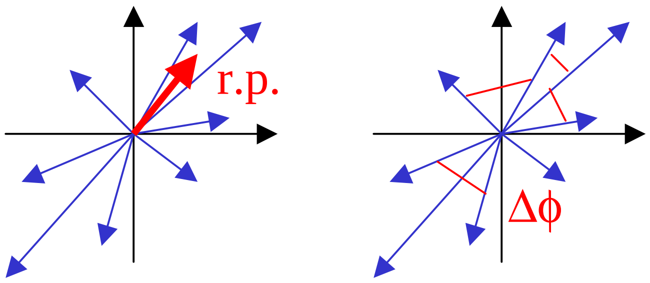
A. Wetzler (NA49)

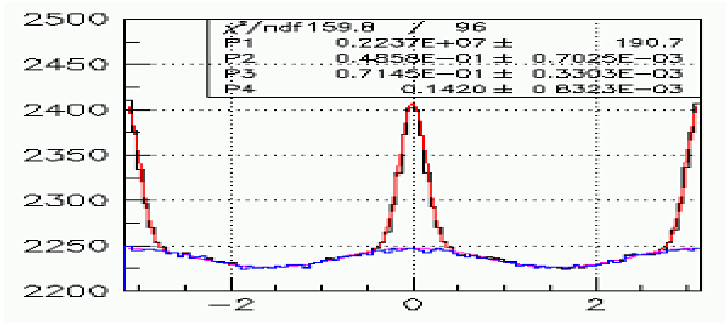


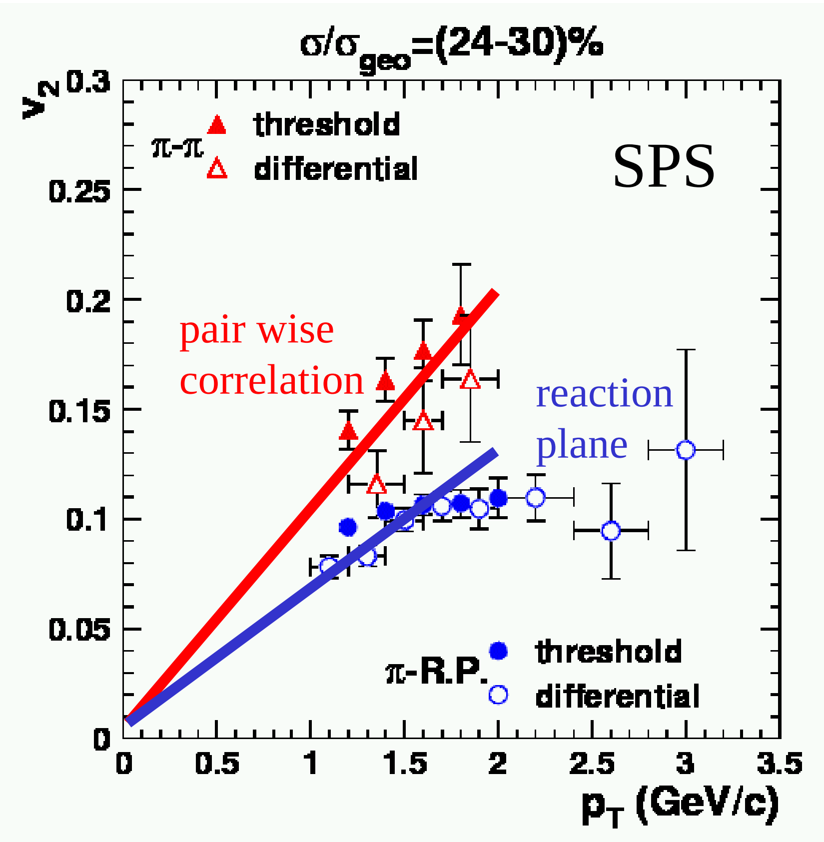
# elliptic flow : $v_2$



# reaction plane or pair correlation

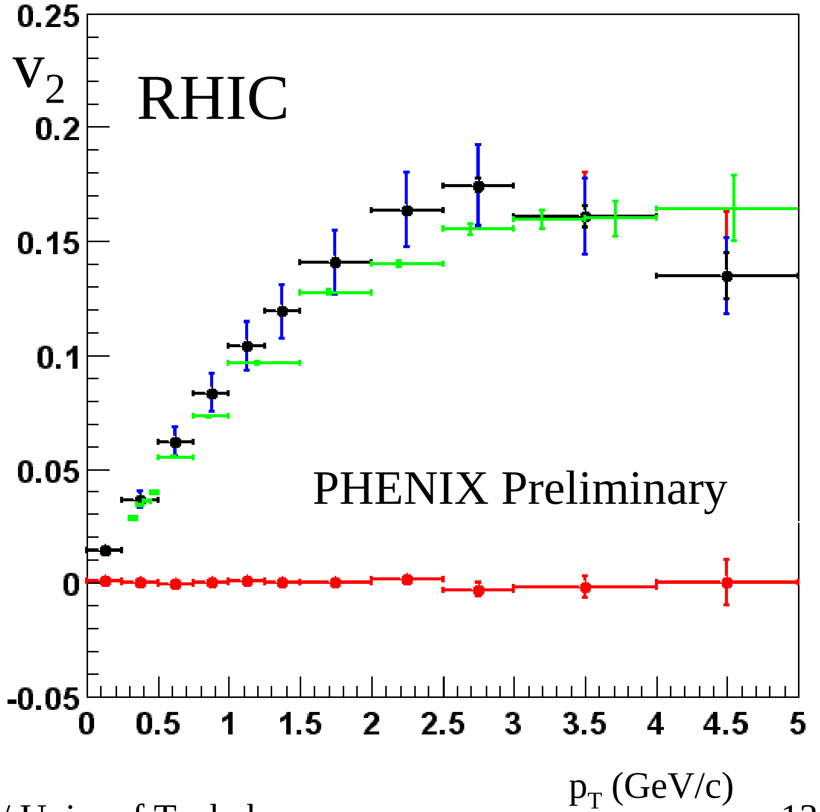


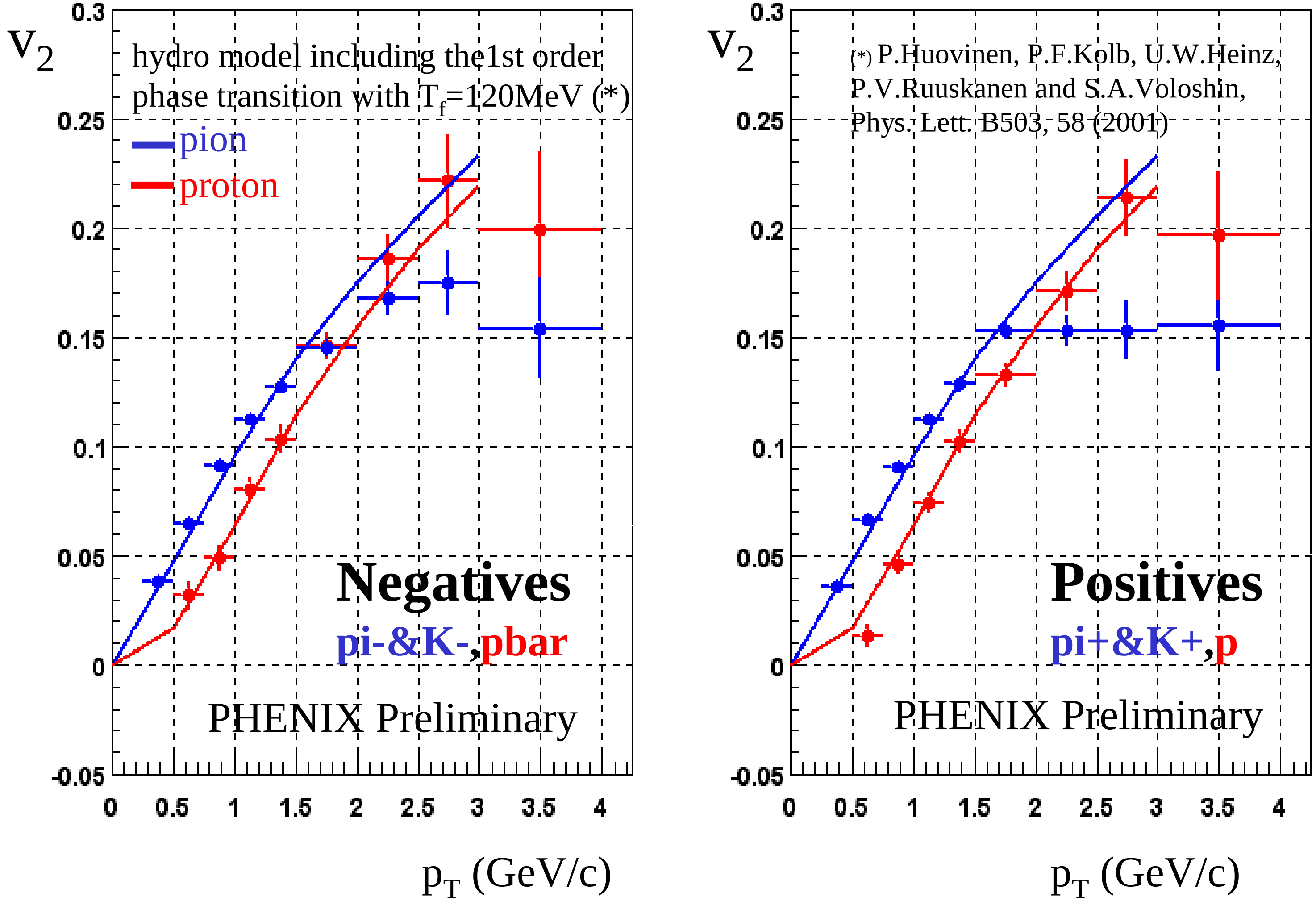

● reaction plane based analysis (r.p. |η|=3~4)

■ pair wise correlation analysis

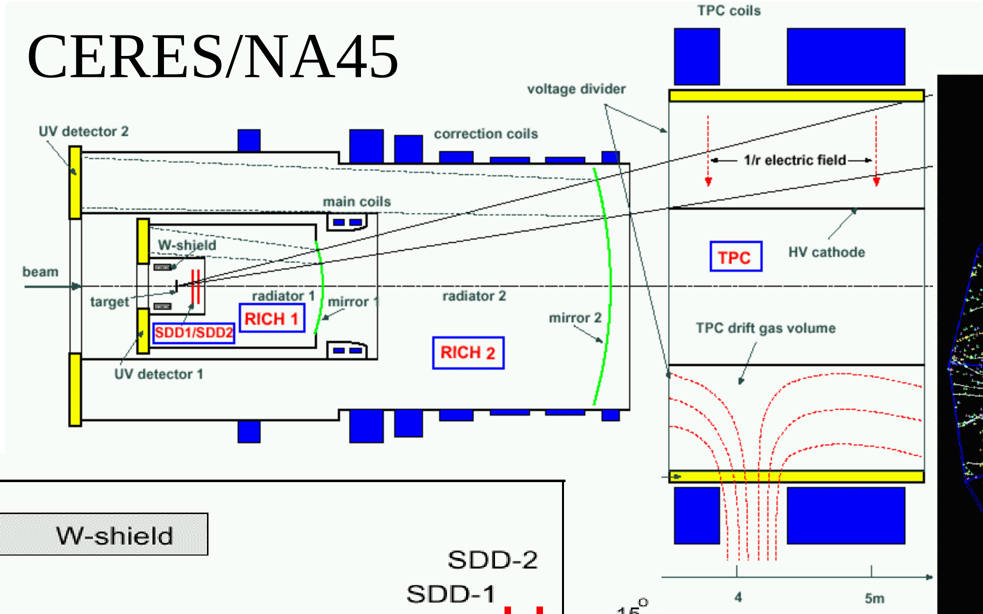


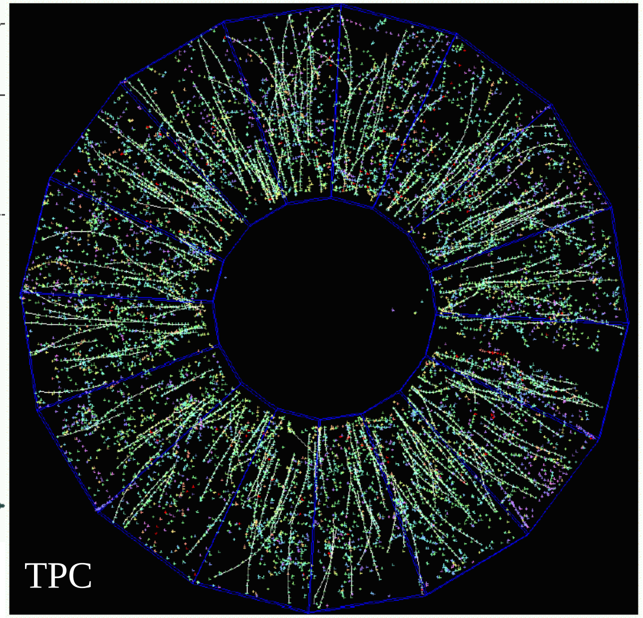
# $v_2$ of identified hadrons

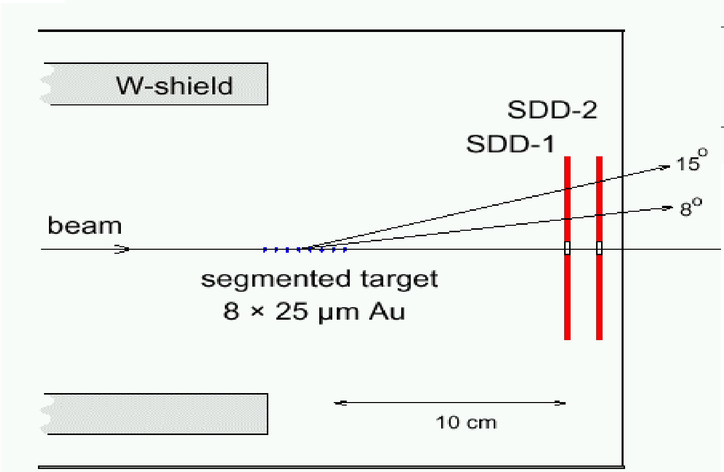
Au+Au at sqrt($s_{NN}$)=200GeV
min. bias r.p. |η|=3~4

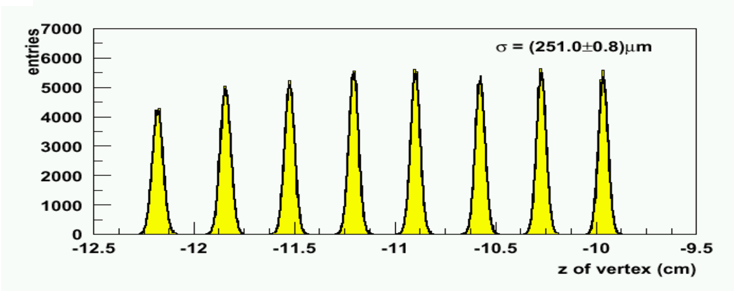


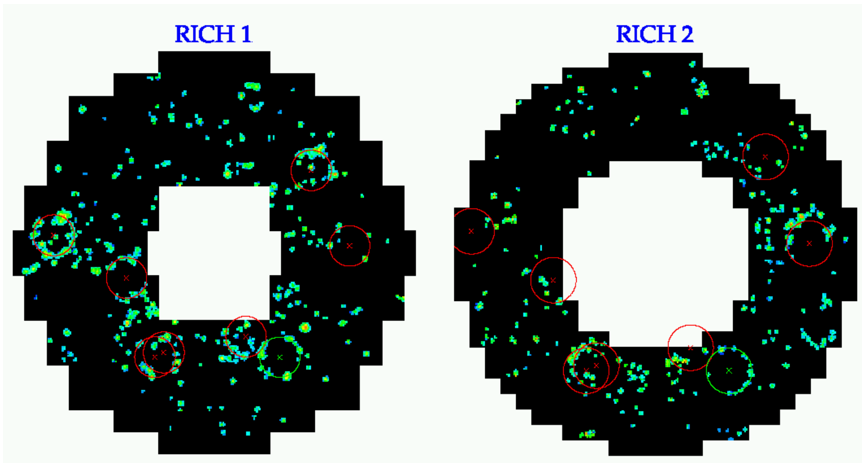
# CERES/NA45


TPC coils
voltage divider
UV detector 2
correction coils
1/r electric field
main coils
W-shield
TPC
HV cathode
beam
target
radiator 1
mirror 1
radiator 2
RICH 1
mirror 2
SDD1/SDD2
RICH 2
TPC drift gas volume
UV detector 1
4
5m

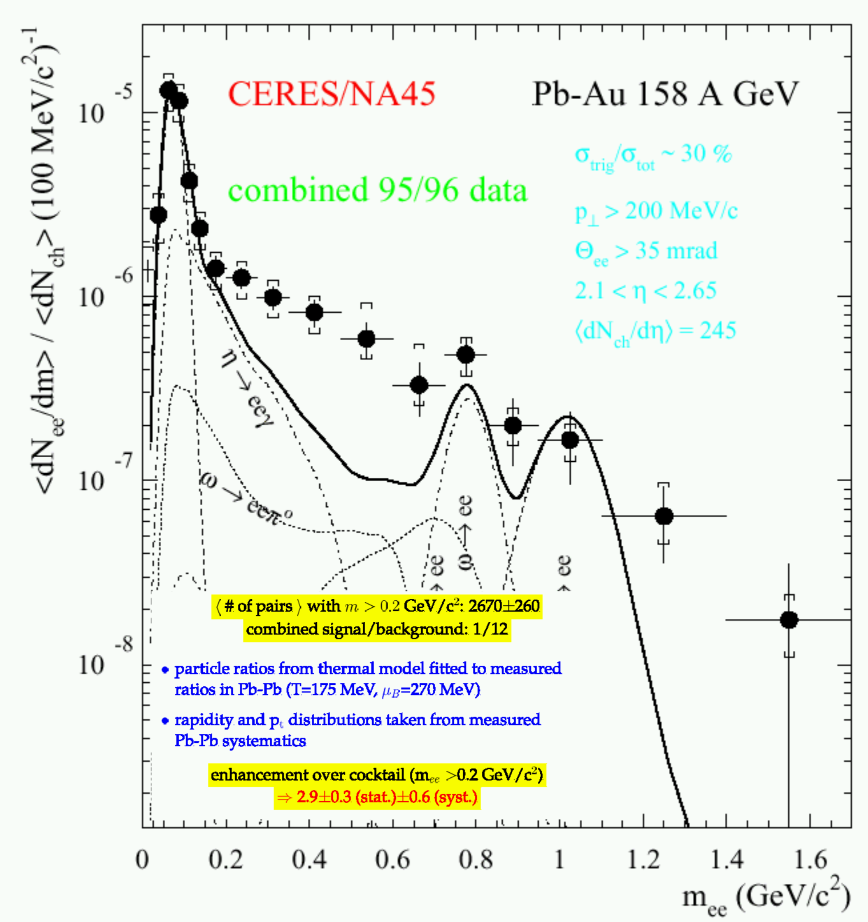

TPC

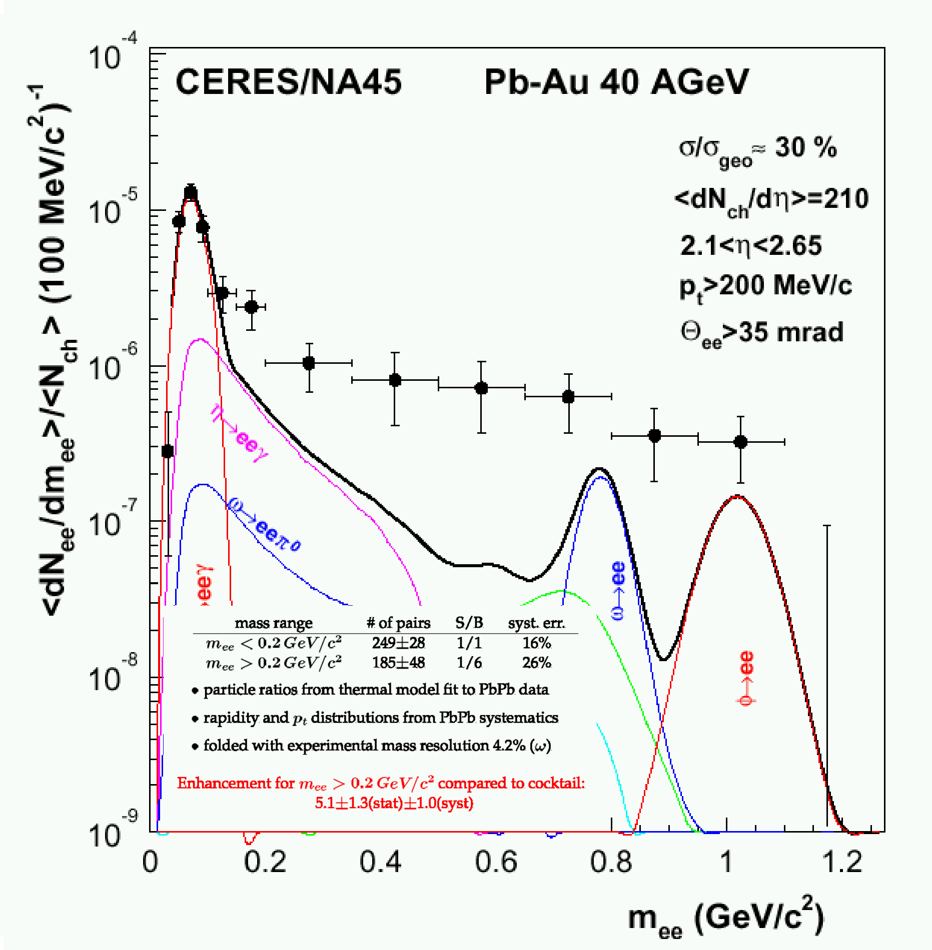

W-shield
SDD-2
SDD-1
15°
8°
beam
segmented target
8 × 25 μm Au
10 cm


entries
σ = (251.0±0.8)μm
z of vertex (cm)


RICH 1
RICH 2

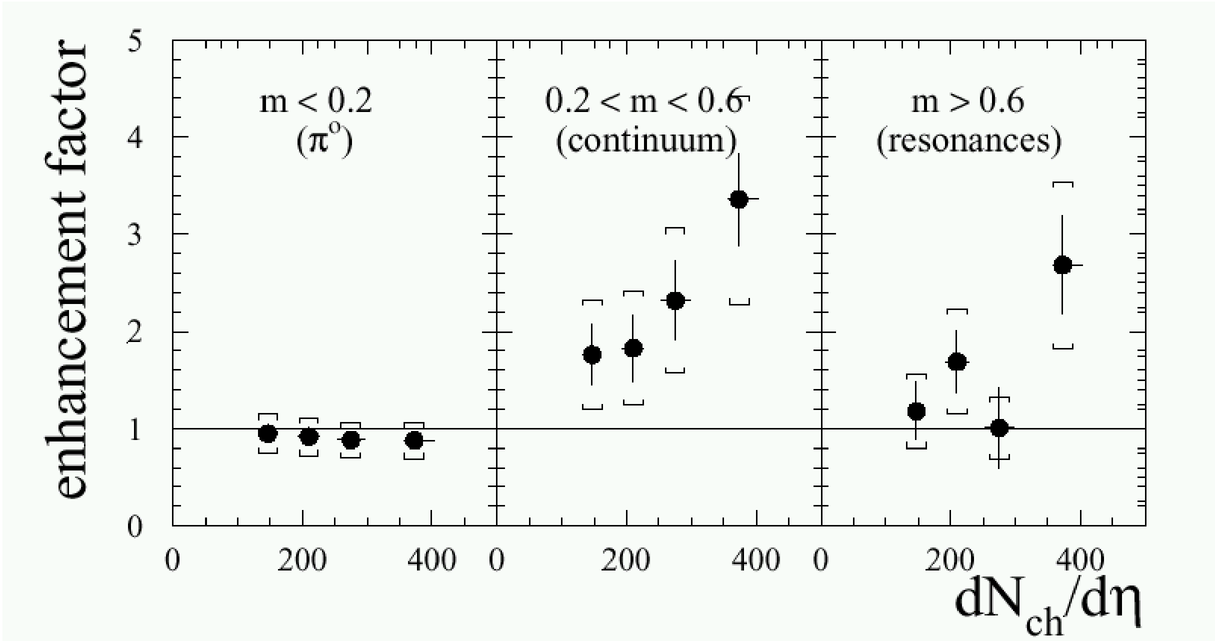
# low mass electron pair enhancement



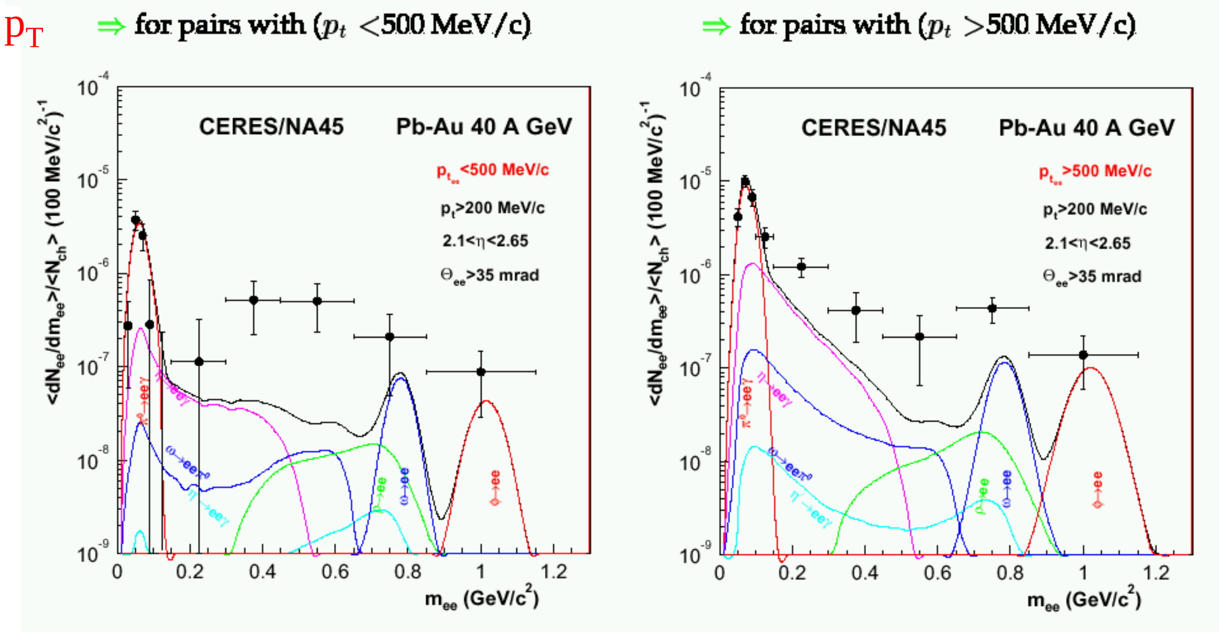




larger enhancement at lower energy in SPS

# centrality and $p_T$ dependence

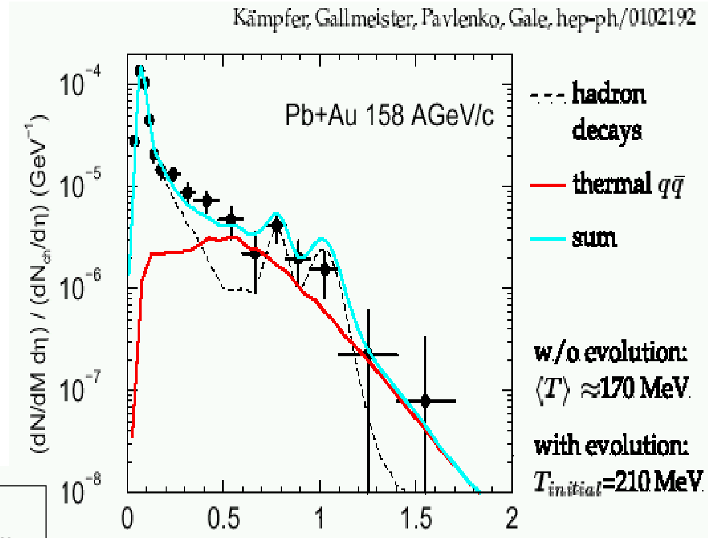


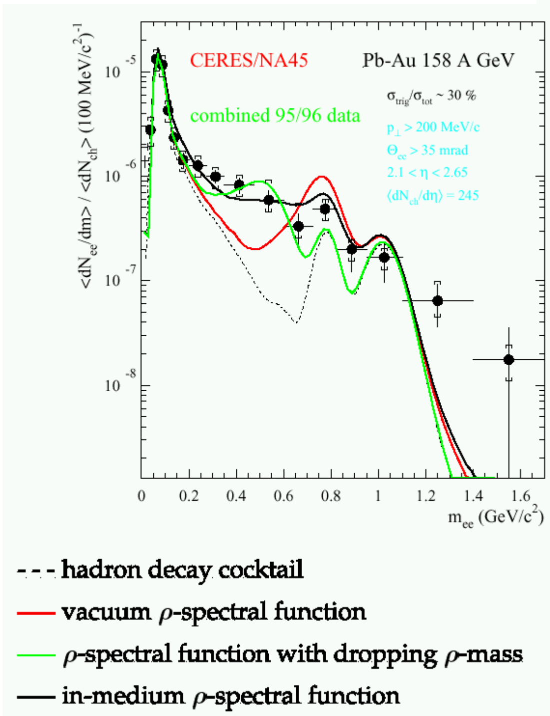

Enhancement factor increases with multiplicity and is higher for small pair $p_T$

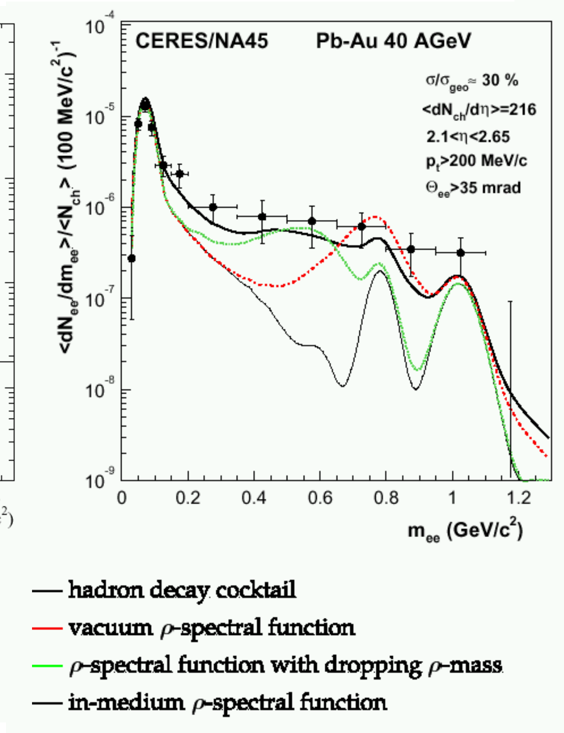


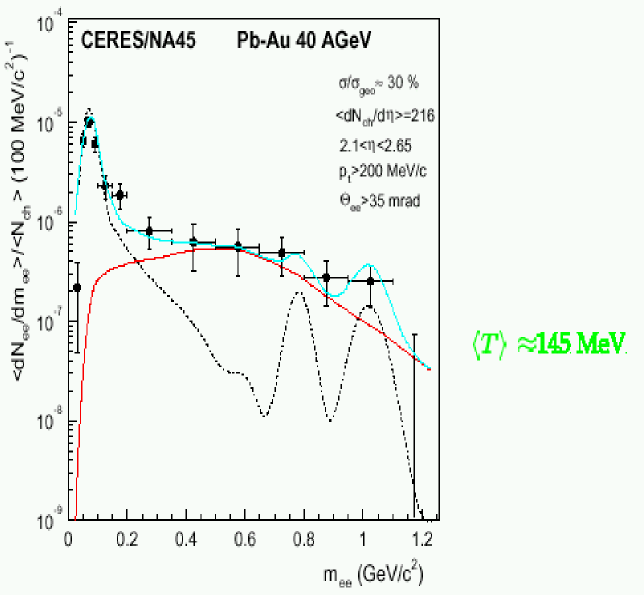
# comparison to models

in-medium modification of ρ or thermal radiation with $T>T_f$

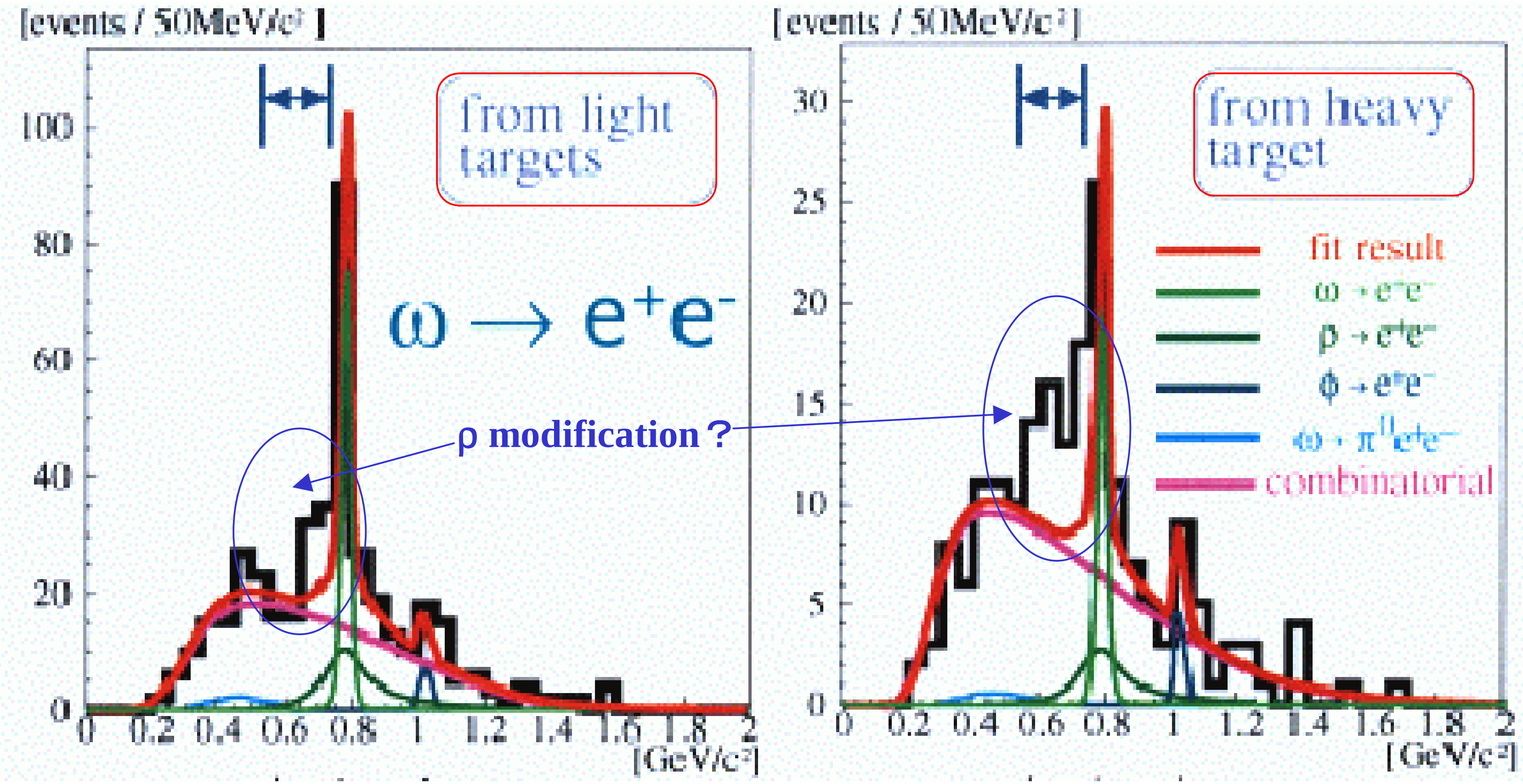


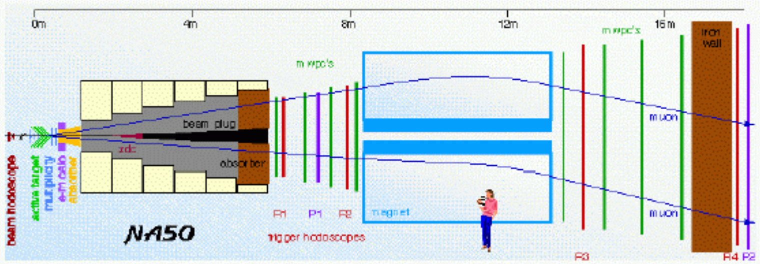



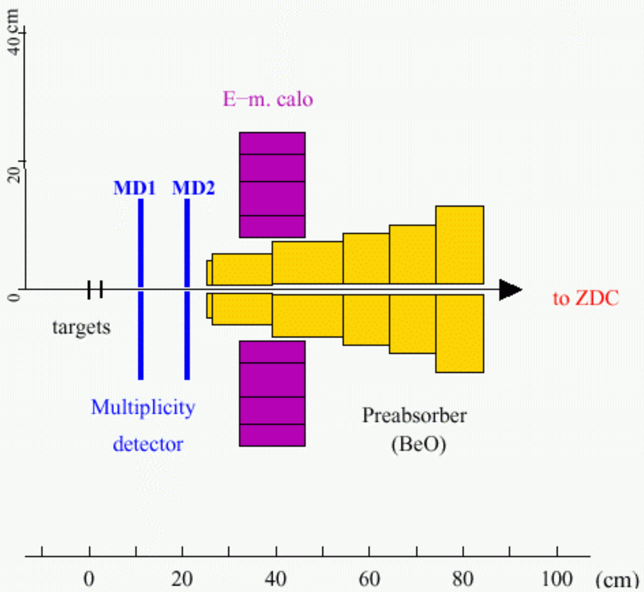
density effect seen in p+A collisions at KEK ps

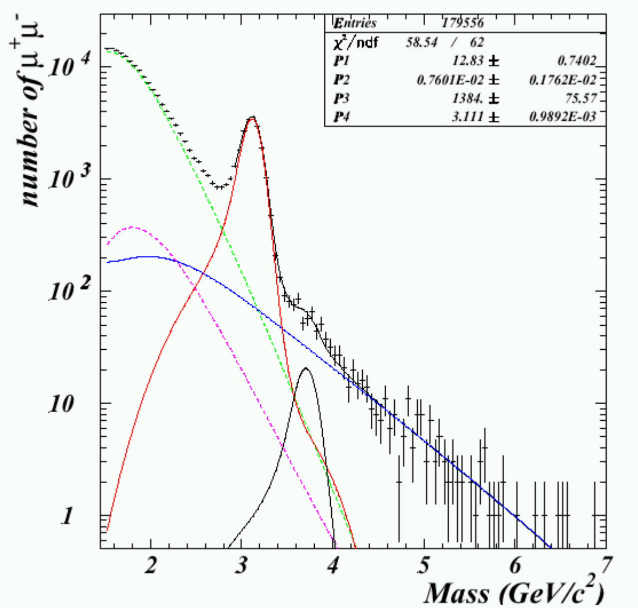


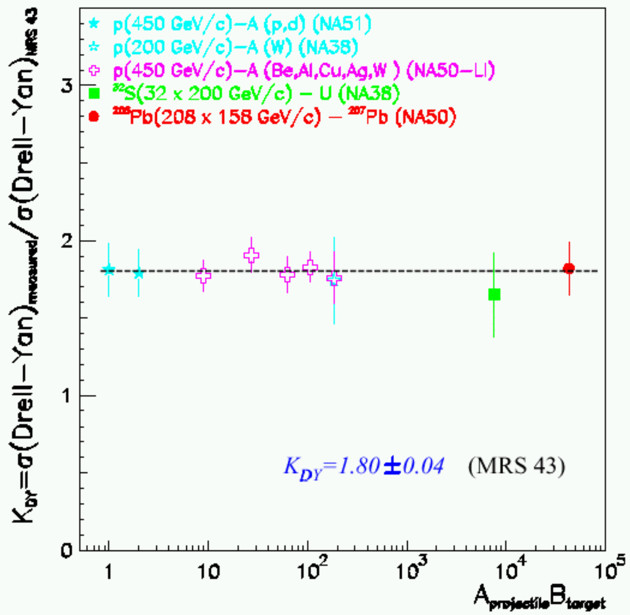
# J/ψ measurements with μμ




dimuon rapidity $(0 < y_{cm} < 1)$, polar angle $(-0.5 < \cos\theta_{CS} < 0.5)$

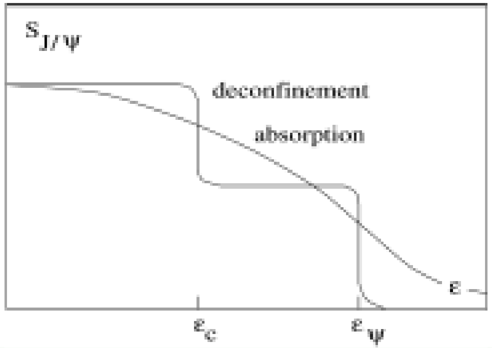


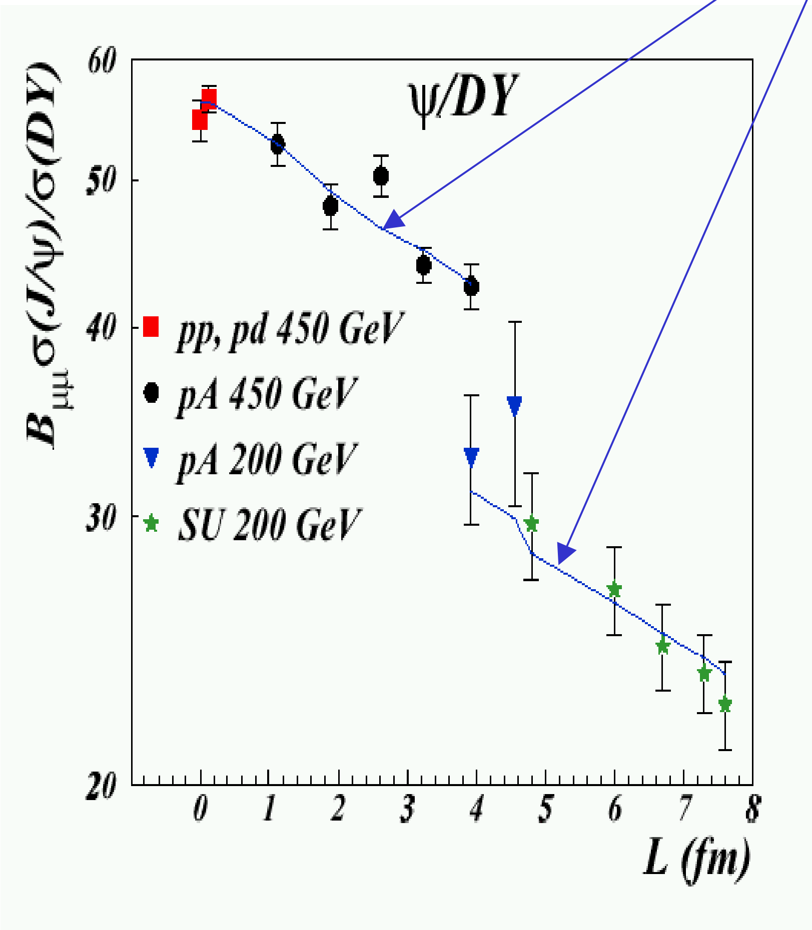



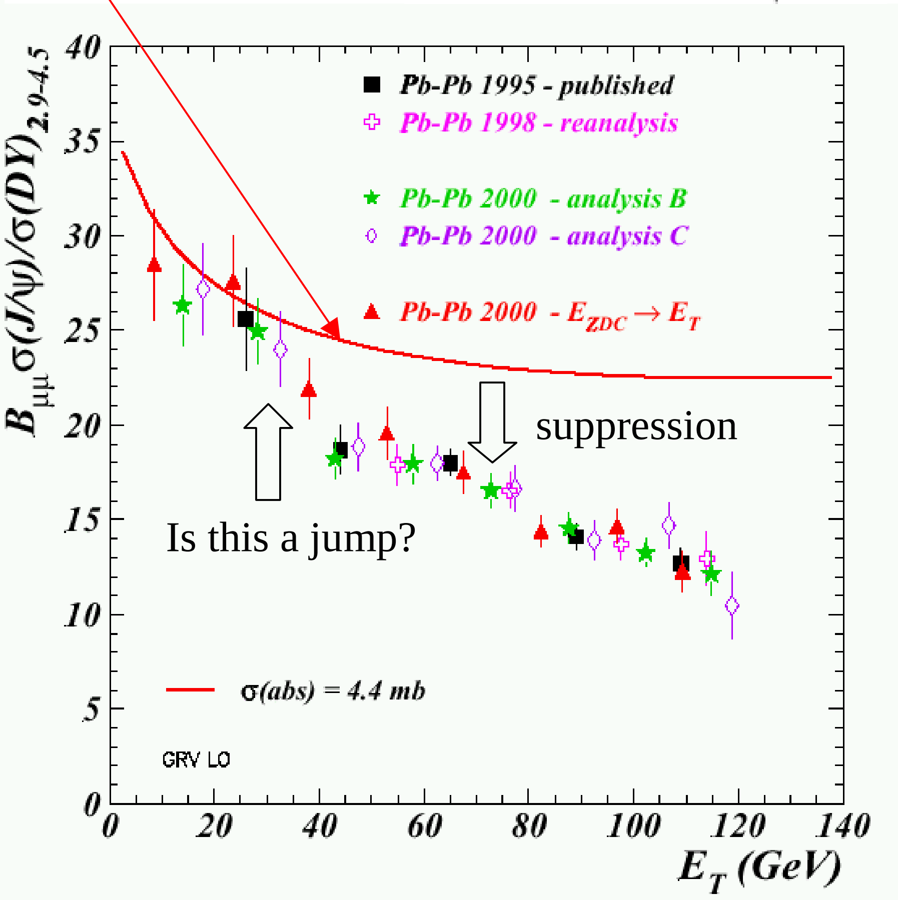



# J/ψ suppression as a signal of deconfinement

normal nuclear absorption



# Summary

(1) systematic study of freeze-out conditions
(2) detailed study of directed and elliptic flow
(3) low mass lepton pair measurements

can be done in order to understand QGP and/or high density nuclear matter and by

heavy-ion beam at JHF and/or GSI upgrade