Centrality dependence of hadrons in nuclear collisions

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NA52 Collaboration

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Issues

1 Why is the centrality dependence interesting ?

2 Experimental methods

3 Kaon yields as a function of participant nucleons

4 Comparison with other experiments at $\sqrt{s}$=5-19 GeV

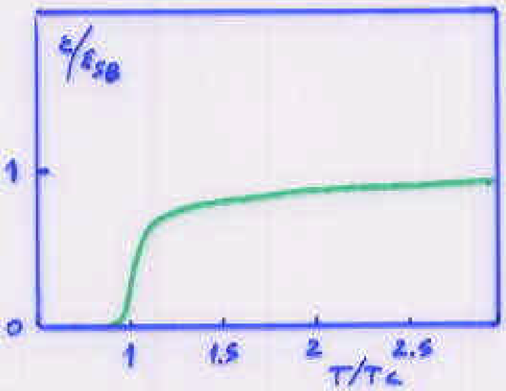
5 Quark flavour and mass and $\sqrt{s}$ dependence of centrality dependence

6 Comparison of strangeness and charm

7 Conclusions and outlook

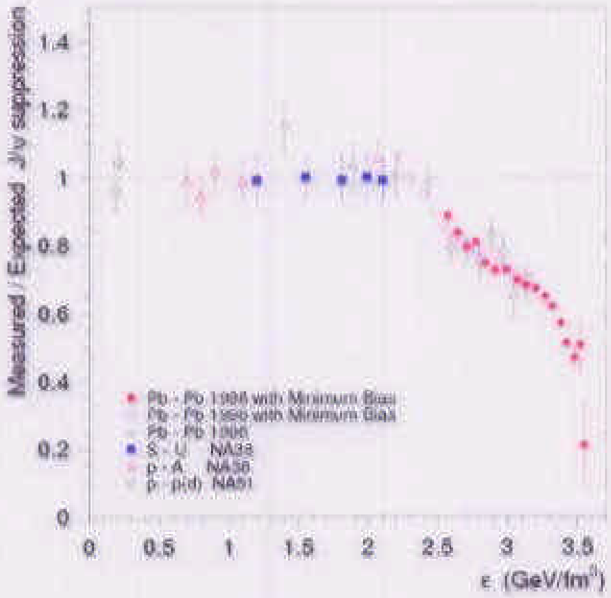
1 Why is the centrality dependence interesting ?

($\varepsilon_c \sim 1\ GeV/fm^3$)



A. Ukawa Nucl. Phys. A638 (98) 339

→ Search for discontinuous behaviour of relevant observables vs $\sqrt{s}$ and/or b   Major example: J/ψ / DY

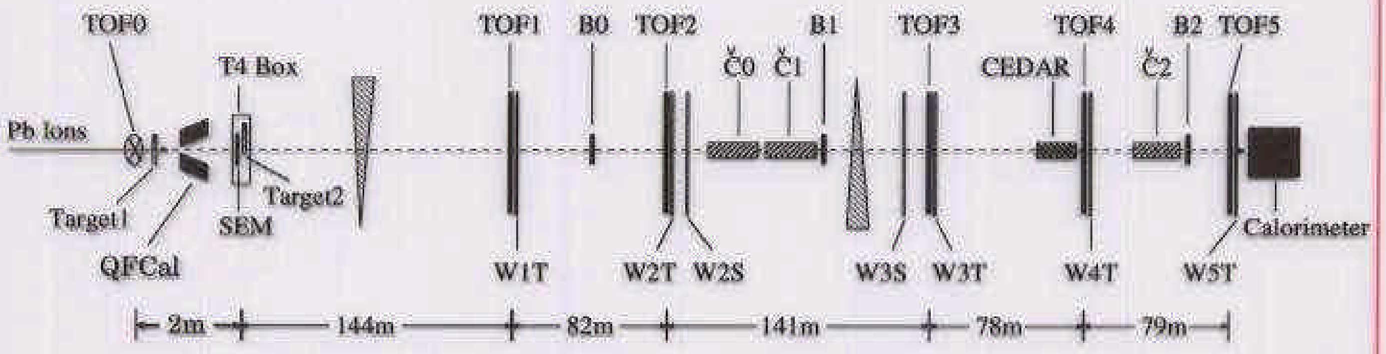


NA50
CERN-EP-2000-013

→ Is there a threshold in strangeness too?

2 Experimental methods

The NA52 experiment



NA52 philosophy: 1 particle per event in the spectrometer acceptance

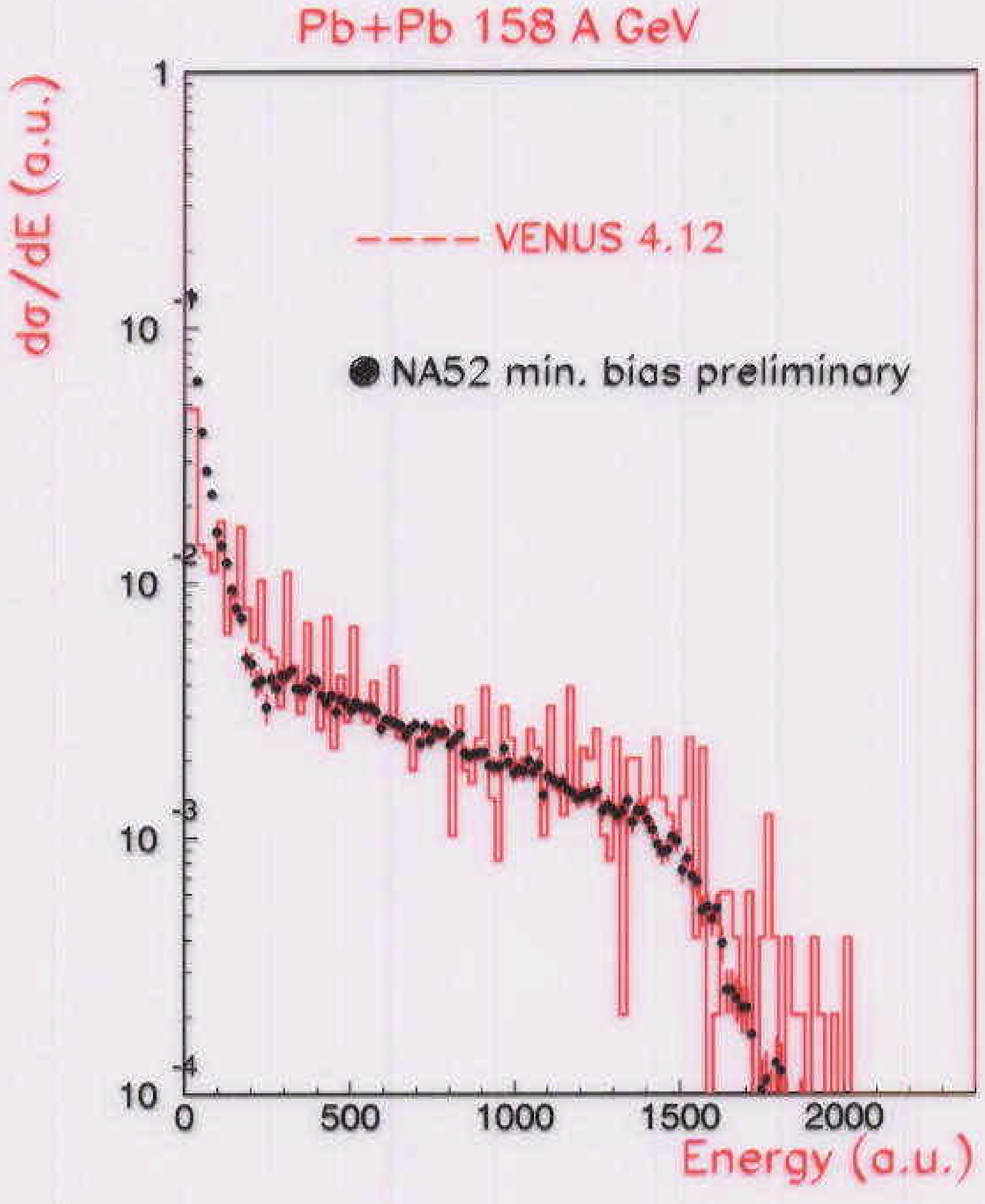
Centrality measurement: em calorimeter (QFCal)

1998 run :

- Factor 3 increase in the statistic of K at y=4, $p_T \sim 0$
- Different target thicknesses studied
- New calorimeter with full ϕ acceptance
- Factor 10 higher intensity: $\sim 10^8$ Pb/spill

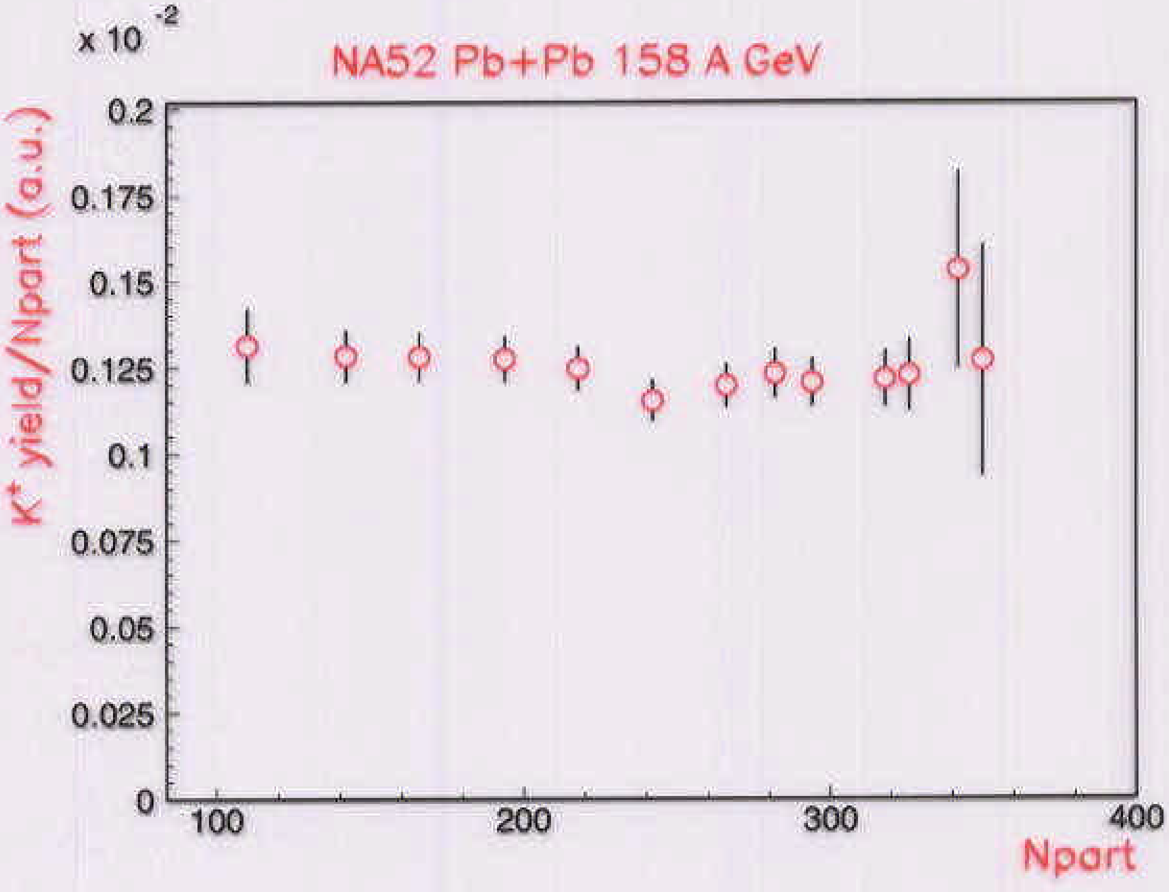
Determination of centrality in NA52 Quartz Fiber Calorimeter 1998

Comparison to VENUS 4.12 (K.Werner Phys. Rep. (93) 232 87)
($\pi \rightarrow \gamma\gamma$ in the QFC + exp. resol.) scaled in E by 0.77.



3 Kaon yields as a function of participant nucleons

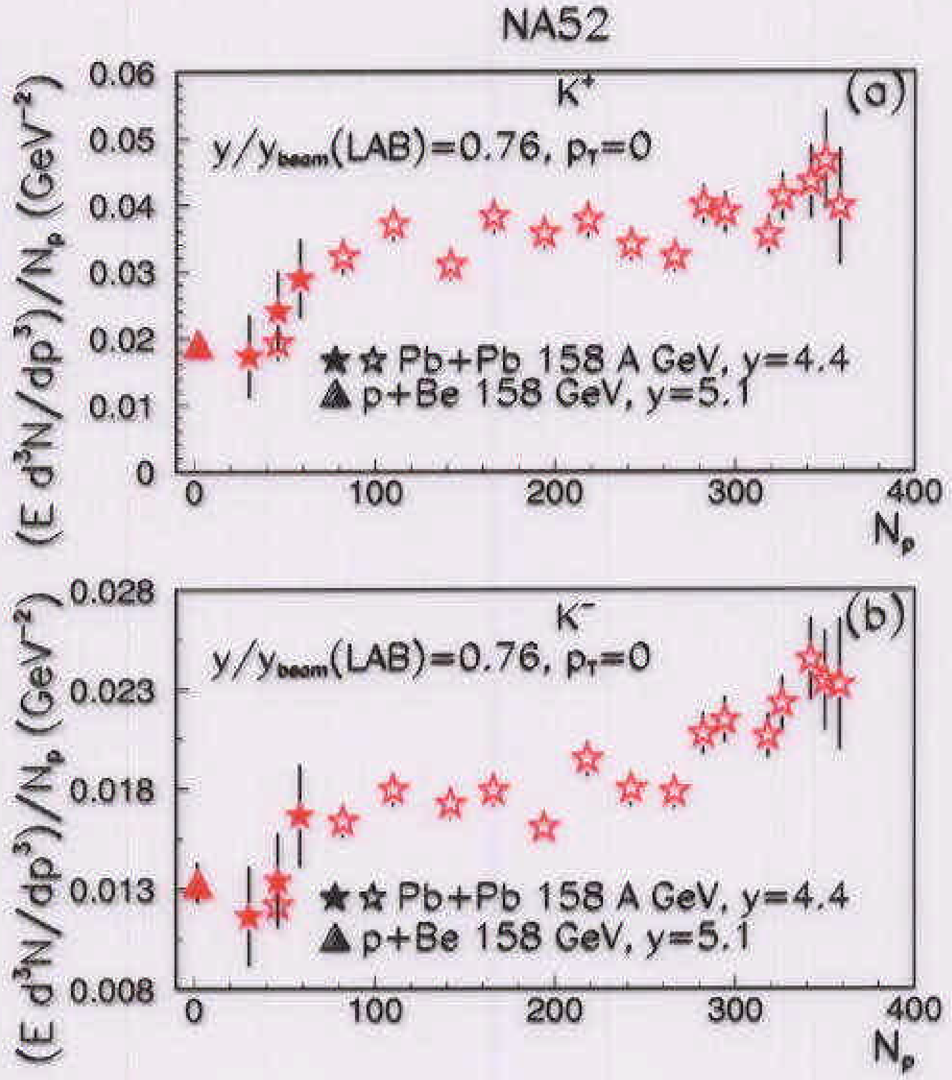
Preliminary



- K^+ **scale linearly with** N **above** $N \sim 100$

Kaon yields as a function of participant nucleons

G. Ambrosini et al, NA52 coll., New J. of Phys. 1 22 (1999)



$\varepsilon > 1.3$ GeV/fm³ ↑

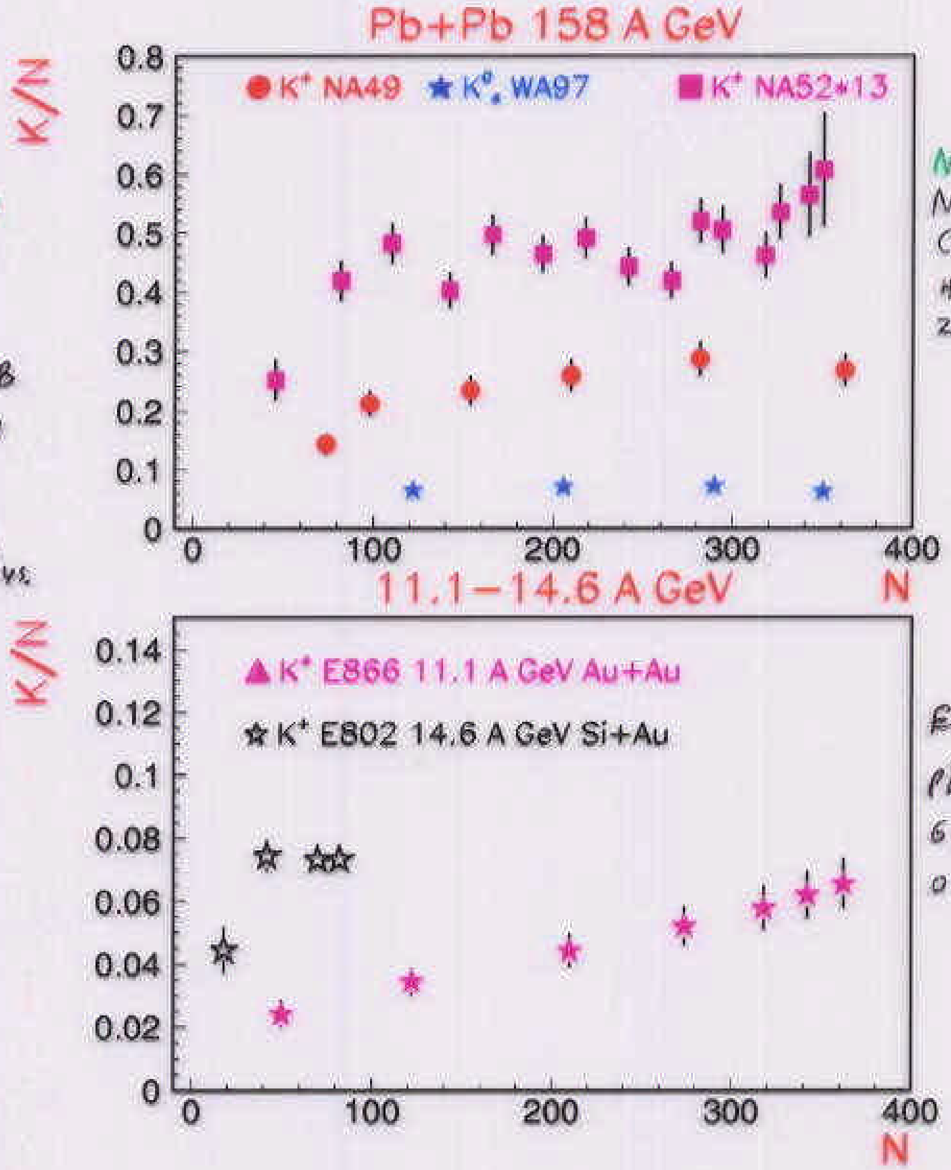
- Charged kaons scale almost linearly with N for $N > 100$

if N~V → higher degree of thermalization at high N

4 Comparison with other experiments at $\sqrt{s}$=5-19 GeV

Kaon yield per participant N versus N

N ≥ N_wounded



NA49: Nucl. Phys. A661 (99) 45, HI Forum 26.7.99

WA97: Phys. Lett. B 449 (99) 401

NA52: N.J.o.Phys. 1 22 (99)

E802/E866: Phys. Rev. C 60 (99) 044904

→ **Investigate the energy density as critical parameter**

Energy density calculation

(S. Kabana hep-ph/0004138)

- NA52 measures E_T near ycm. This is used to estimate ϵ as a function of N:

(J. D. Bjorken Phys.Rev.D 27 (1983) 140) :

$\epsilon = \frac{(dE_T/d\eta)_{ycm}}{\pi R^2_{proj} \tau_0}$

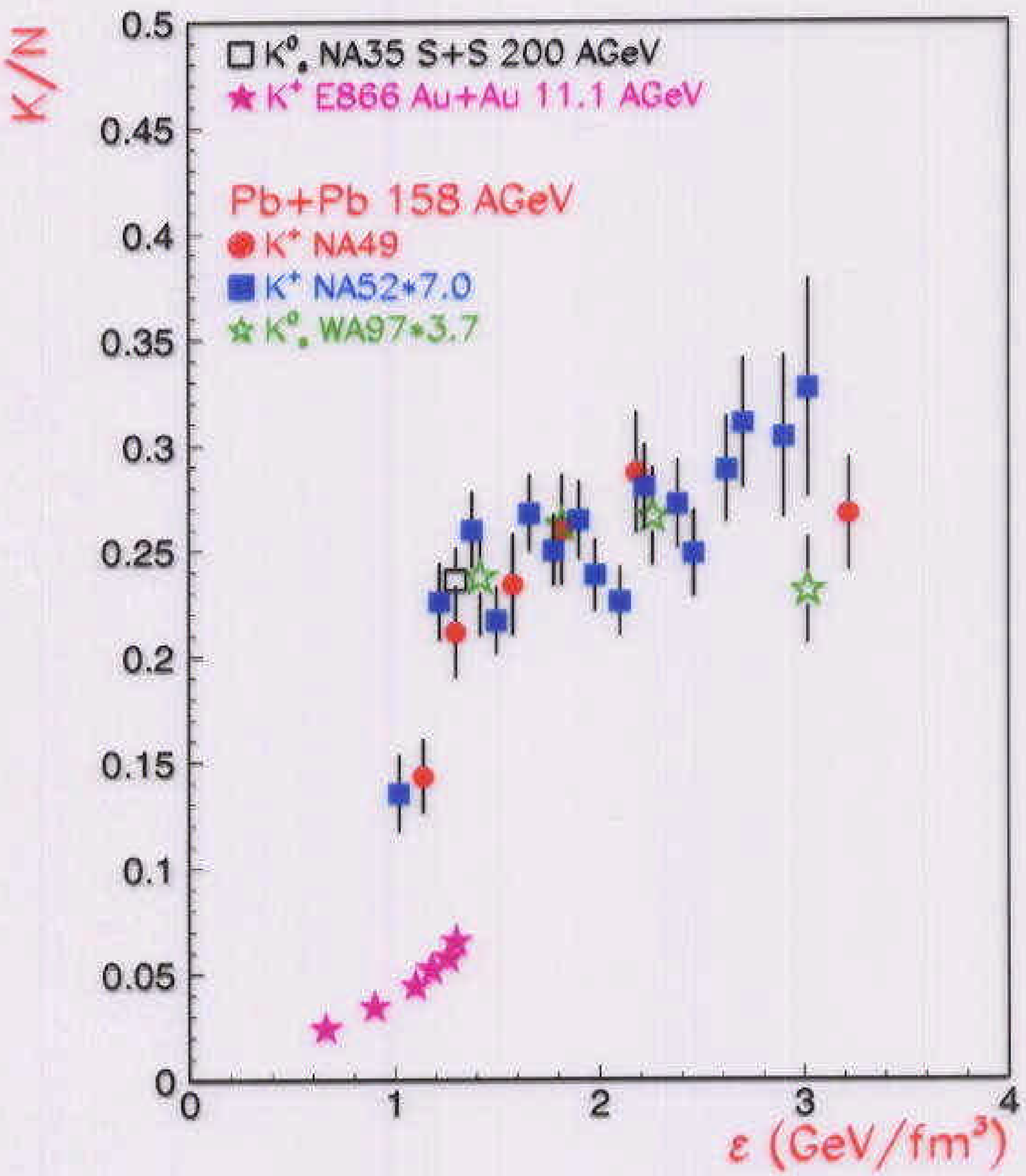
R: transverse radius of source, taken $1.2(N/2)^{1/3}$,
τ: formation time of the fireball, taken 1 fm/c.

- ϵ is normalised to ϵ_{max}(Pb+Pb)=3.2 GeV/fm^3 from NA49 Phys. Rev. Lett. 75 (1995) 3814.

The ϵ versus Npart distribution is parametrised with a polynomial function.

- The ϵ is then extracted for the N values estimated by NA49 in Pb+Pb and for N=2 for p+p data at 158 A GeV and by WA97 in Pb+Pb.
- ϵ at AGS has been estimated assuming E_{tot}(Npart) $\sim (dE_T/d\eta)_{ycm}$ and normalised to ϵ_{max}(Au+Au)=1.3 GeV/fm^3 (P.B. Munzinger et al Nucl. Phys. A 638 (1998) 3) and ϵ_{max}(Si+Au)=0.9 GeV/fm^3 (E802 Phys. Lett. B 332 (1994) 258, and M. Tannebaum priv. commun.)
- The systematic error of the calculated ϵ is estimated to $\sim$ 30%

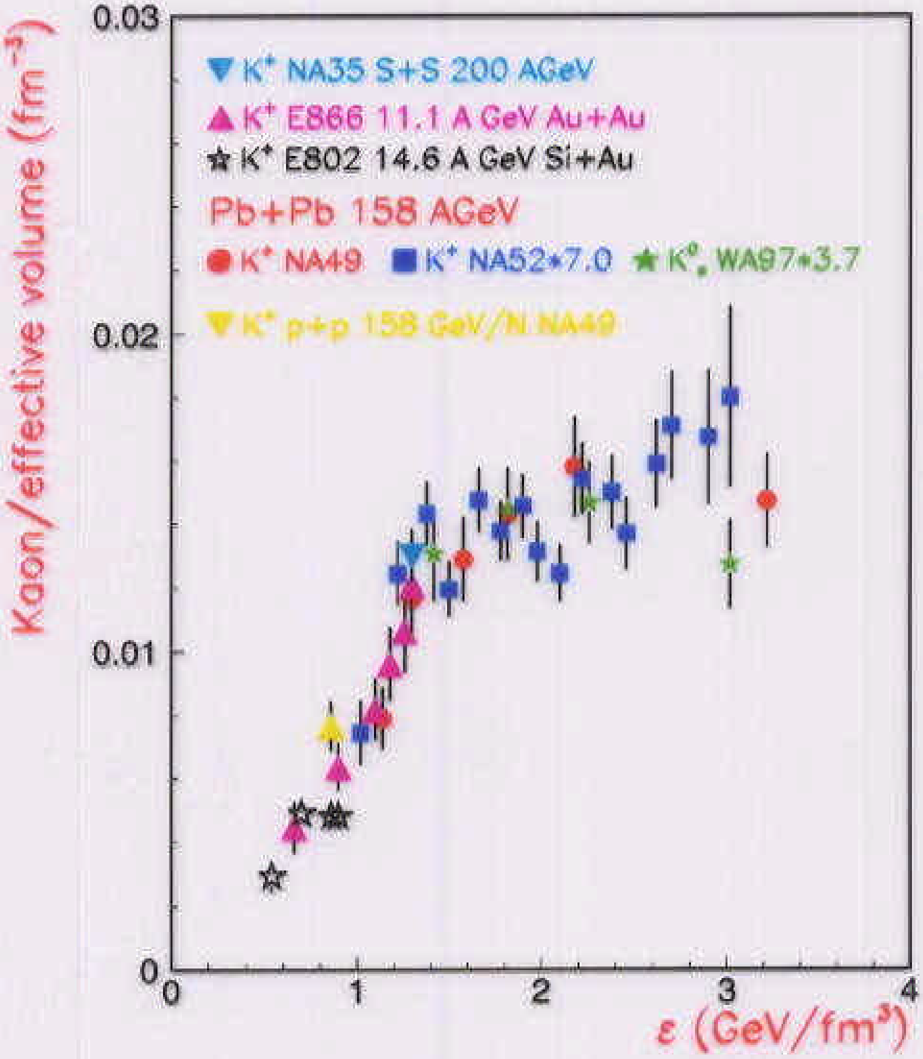
Kaon yield per participant versus ϵ



K number density versus ϵ

(hep-ph/0004138)

- Assume N ~ V. (Supporting evidence : R. A. Soltz (E866) QM99, R. Ganz (NA49) QM99, NA52 N. J. of Phys. (99) 1 22.)
- Use meas. of source radii to estimate for central events: $V_{thfreezeout,Au+Au(AGS)} = 1949 fm^3$, $V_{thfreezeout,Pb+Pb(SPS)} = 6532 fm^3$.



$V \sim T^{-3}$;

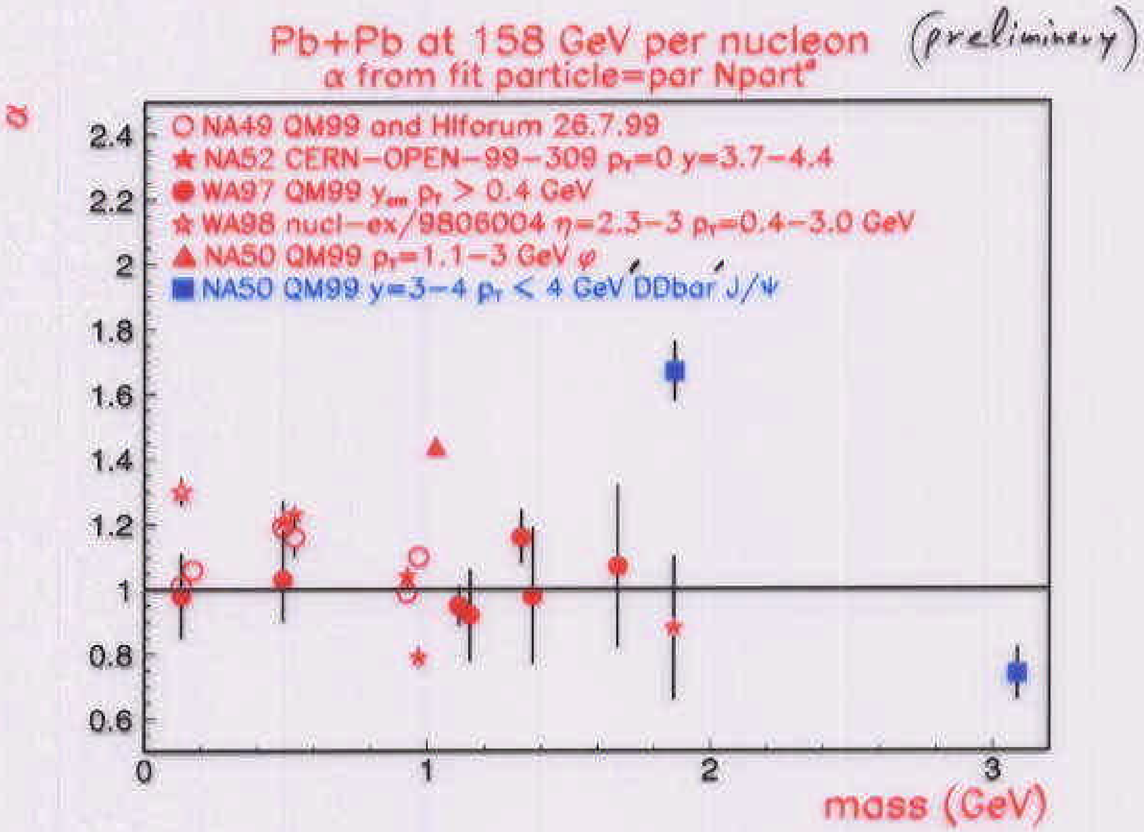
$\frac{V_{ch}}{V_{th}}$ AGS = 0.45

$\frac{V_{ch}}{V_{th}}$ SPS = 0.28

1.6

New with respect to hep-ph/0004138: p+p NA49: R. Ganz et al, QM99, Si+Au E802: L. Ahle et al, nucl-ex-9903009

5 Quark flavour and mass dependence of centrality dependence at $\epsilon > 1$ GeV/fm^3



- With the exception of $\overline{d}$ and some deviations among hadrons: $\overline{p}$, ϕ, π^0 at SPS:

α(u,d,s states) ~ 1

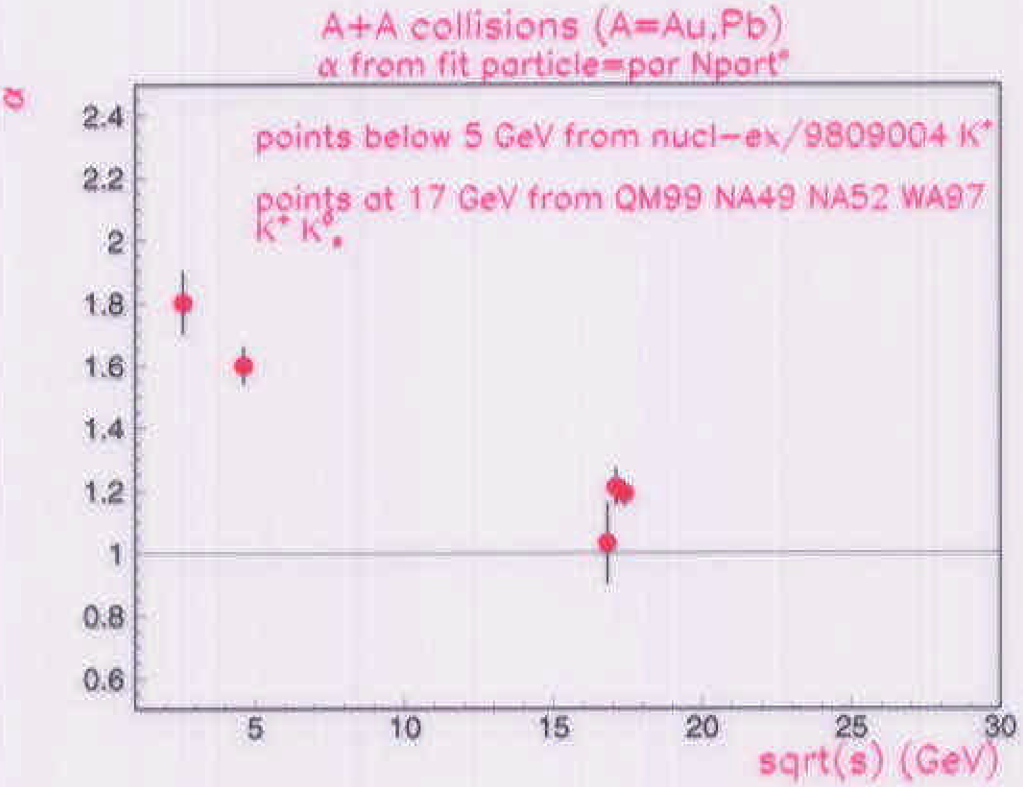
α(open charm) ~ 1.7 → $D\bar{D}$-like enhancement (NA50)

α(closed charm) ~ 0.7

This suggest →

- High degree of thermalization for light and strange hadrons
- open charm ($D\overline{D}$) not thermalized
- closed charm suppressed as compared to open charm

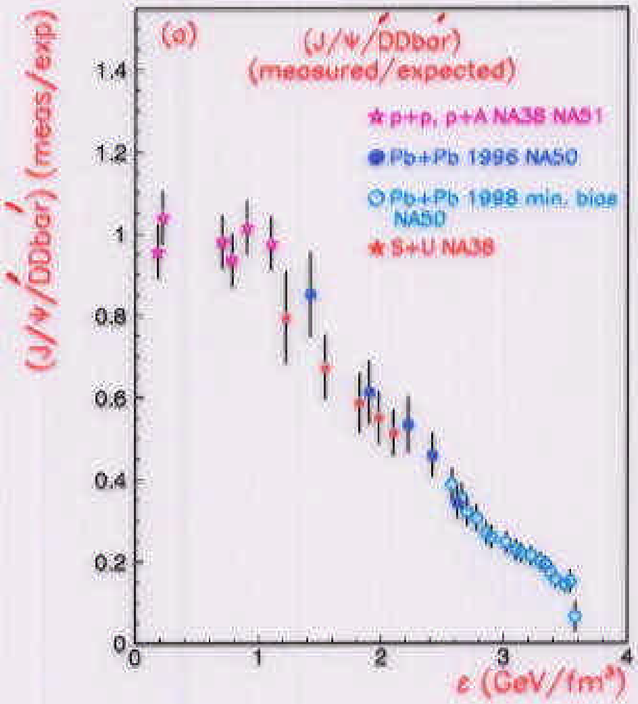
N^{α} dependence versus $\sqrt{s}$



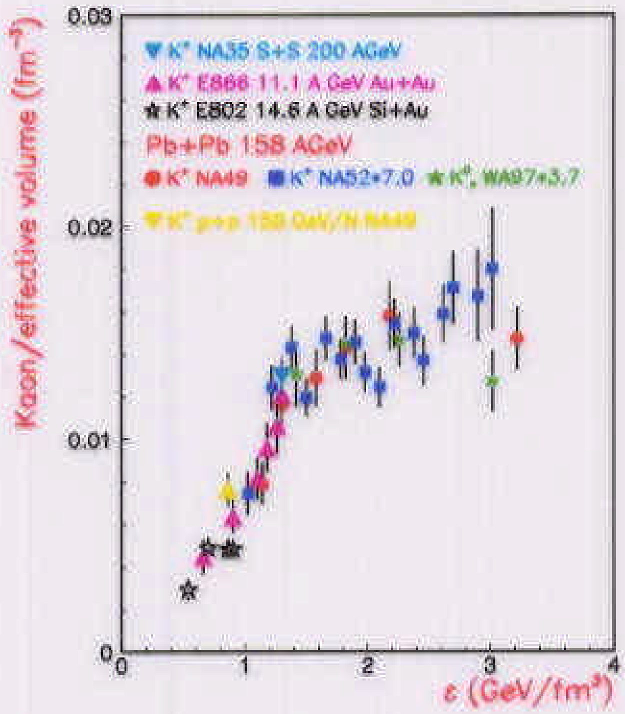
- α of kaons depends on $\sqrt{s}$, ϵ
- suggests increasing thermalization of Kaons with $\sqrt{s}$

6 Comparison of strangeness and charm

(hep-ph/0004138)



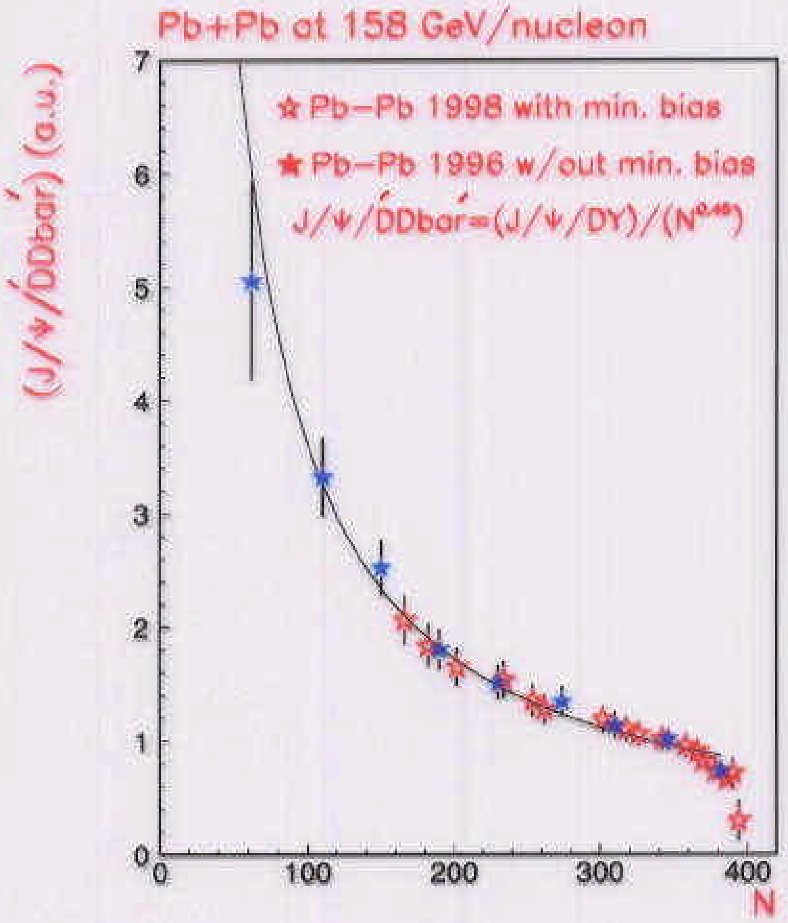
ε_c (QCD) ~ 1 GeV/fm³



Hadrons from quark coalescence

- **Strangeness:** (A. Bialas, Phys.Lett.B442(98)449)
Data ($\overline{\Lambda}/\Lambda$, $\overline{\Xi}/\Xi$,...) agree with hypothesis of hadron formation through coalescence of independent quarks
- **Charm:**

(hep-ph/0004138)



- $J/\Psi/D\overline{D} \sim 1/\mathrm{N}$ → compatible with J/Ψ formation from c and $\overline{c}$ quark coalescence

In plasma enhancement of open $q\bar{q}$ production

(S. Kabana, P. Minkowski work in progress)

$th_q = m_0 - m_q$
$m_{u,d}$ = 7 MeV
m_s = 175 MeV
m_c = 1.25 ± 0.15 GeV
m_0 : m (π, K, D)

$R_q = \sqrt{th_q / th_{u,d}}$

Quark flavour	th_q	R_q	$E\frac{(A+B)}{(N+N)}$	$E/E_{u,d}$
u,d	133	1	$\pi/N \sim$ 1.12 ± 0.092	1
s	320	1.55	$K/N \sim$ 2	1.79
c	615	2.15	$D\overline{D}$ meas/exp $\sim$ 3	2.68

- The enhancement factors of lightest mesons of u,d,s,c flavours scale similar to the mass gain of their production in plasma modes

7 Conclusions and outlook

Conclusions

- NA52 coll., New J. of Phys. (99) 1 22 → evidence for a change in $K^{\pm}/N$ above N=100.

- 1998 run: increase of K statistics by factor of 3, use of new calorimeter, 10^8 Pb/spill.
Preliminary results: $K^+ \sim N^1$, above N=100.

- K number density versus ϵ in NA52, E866, E802, NA49, NA35, WA97 → a change appears above ~ 1.3 GeV/fm^3.

- N^α ($\sim V^\alpha$) dependence: α depends on m_{quark}, ϵ, not on m(particle)
→ suggestive of u,d,s thermalisation at ϵ >1.3 GeV/fm^3, open c not thermalised.

- If $m(\mu^+\mu^-)$ (1.5-2.5 GeV) enh. is due to $D\overline{D}$:

I Enhancement factors of u,d,s,c hadrons scale similar to the mass gain in plasma

II Quark coalescence picture for c and s

III The kaon number density (K/V) and the $(J/\Psi/D\overline{D})$ exhibit both a threshold behaviour near $\epsilon = 1$ GeV/fm^3, similar to $\epsilon_{critical}(QCD)$.

Outlook

- NA52 experiment dismounted, analysis of 1998 data is ongoing for K at $\epsilon < 1.3$ GeV/fm^3

- Identification of open charm in A+B, $>$ and $< \epsilon \sim 1$ GeV/fm^3

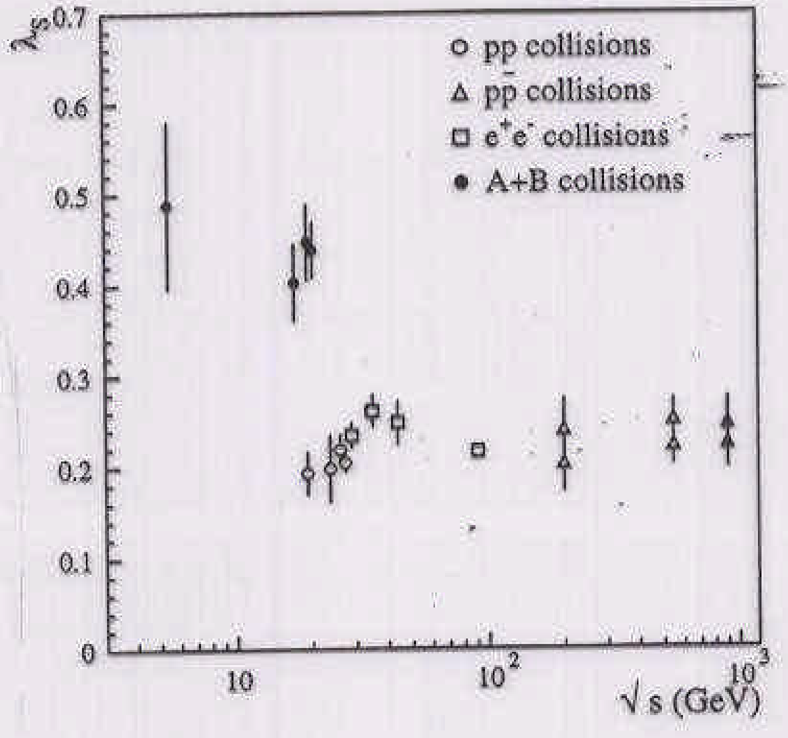
- A+B closed charm data below 1 GeV/fm^3 (Ag..., low N, low $\sqrt{s}$)

- More strangeness and π at $< \epsilon \sim 1$ GeV/fm^3 (40, 80 GeV run)

e^+e^- too

- $p\overline{p}$ open and closed charm data and better π and strangeness data needed well above 1 GeV/fm^3 to prove the change in A+B, and ϵ and/or V as critical parameters

- Open and closed charm and strangeness at $> \epsilon = 3$ GeV/fm^3 in RHIC !


λ_S
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
10^2
10^3
$\sqrt{s}$ (GeV)
pp collisions
$p\bar{p}$ collisions
e^+e^- collisions
A+B collisions