THEORETICAL SUMMARY

1. What is the quark-gluon plasma?

First principle calculations

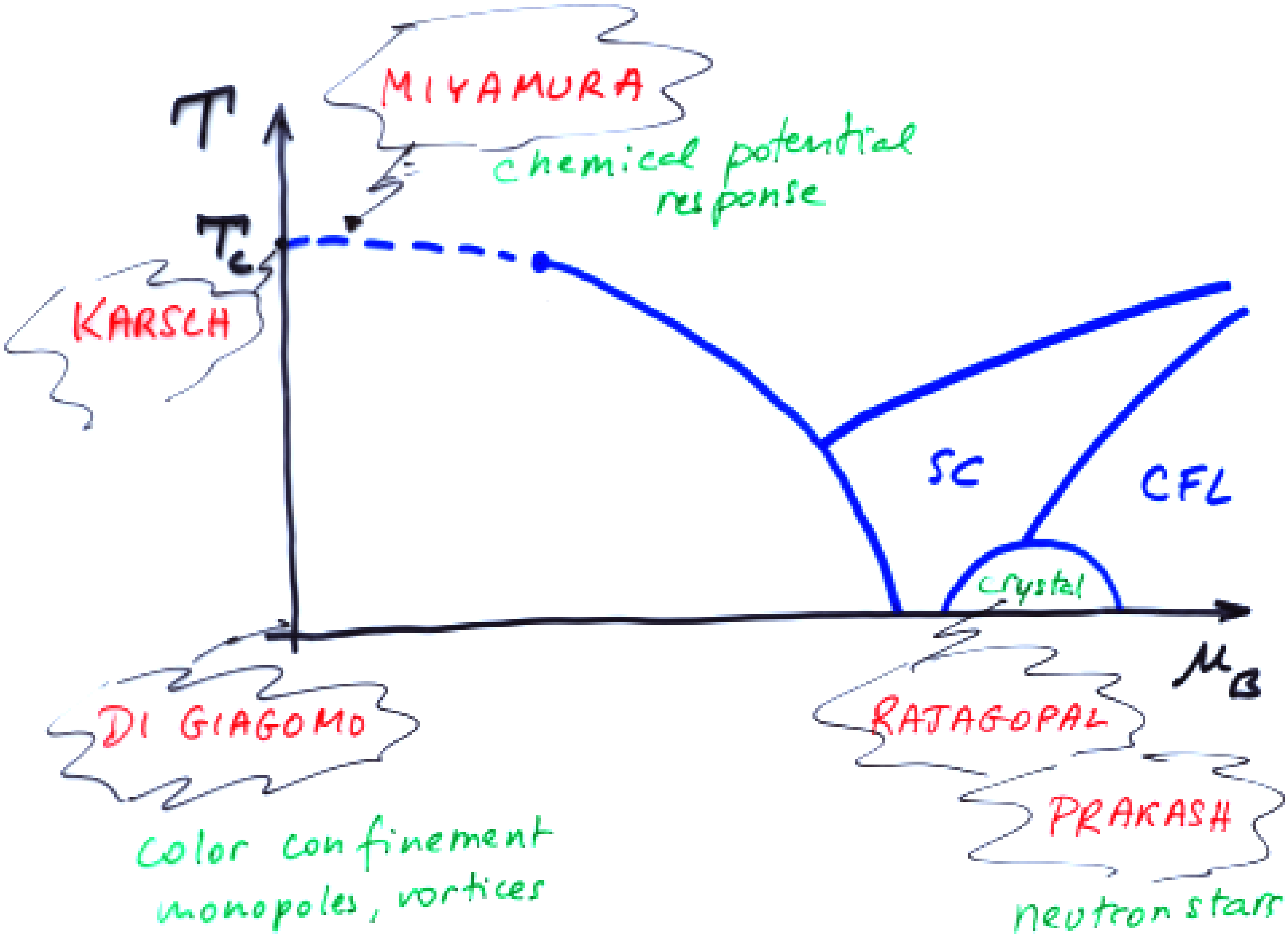
2. Nucleus-nucleus collisions. The standard picture

- Freeze out and hadronization
- Models and degrees of freedom
- Initial conditions

3. Specific signals / observables

- Fluctuations
- Elliptic flow
- Strangeness
- Dileptons
- J/ψ

THE PHASE DIAGRAM



II) QCD (phase) transition temperature

new results:

Clover-fermions ($\mathcal{O}(a)$ improved WF): CP-PACS, hep-lat/0008011v3
rot. sym. improved SF (p4-action): Bielefeld, hep-lat/0012023

- global symmetries control order of the transition for

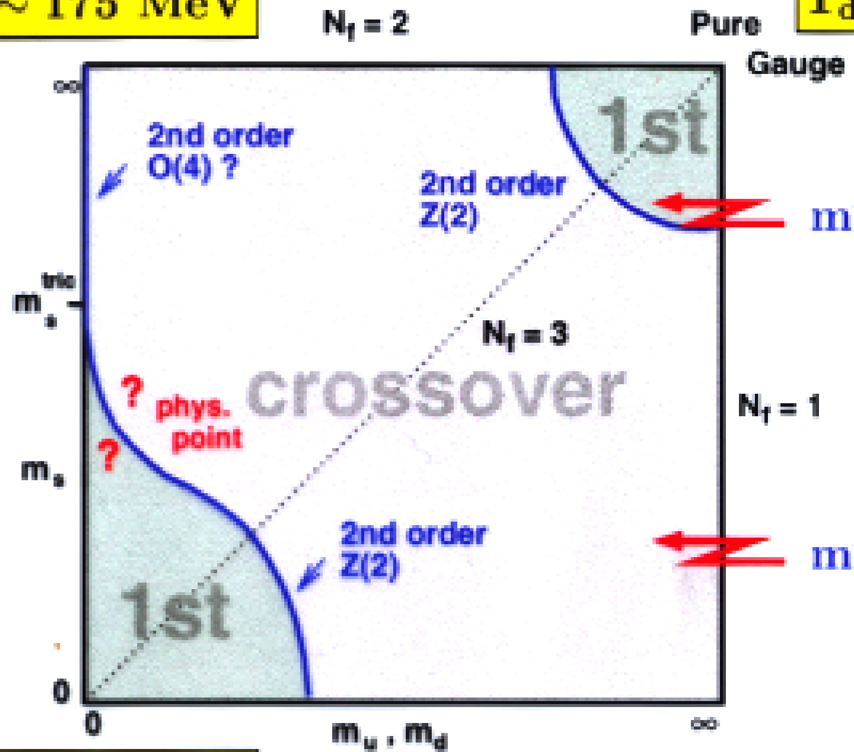
  $m_q \to \infty \Rightarrow$ deconfinement transition
  $m_q \to 0 \quad \Rightarrow$ chiral transition

- rapid crossover in ϵ/T^4; peaks in susceptibilities define transition temperatures for all m_q

3-flavor phase diagram

$T_\chi^{n_f=2} \sim 175$ MeV

$T_d \sim 270$ MeV



$m_{PS}^{crit} \simeq 2.5$ GeV

$m_{PS}^{crit} \simeq 300$ MeV

$T_\chi^{n_f=3} \sim 155$ MeV

- How to compare QCD calc. with varying m_q and n_f?

  $\Rightarrow$ assume exp. value for $m_\rho^{n_f}$ (or $\sqrt{\sigma}$) for all n_f

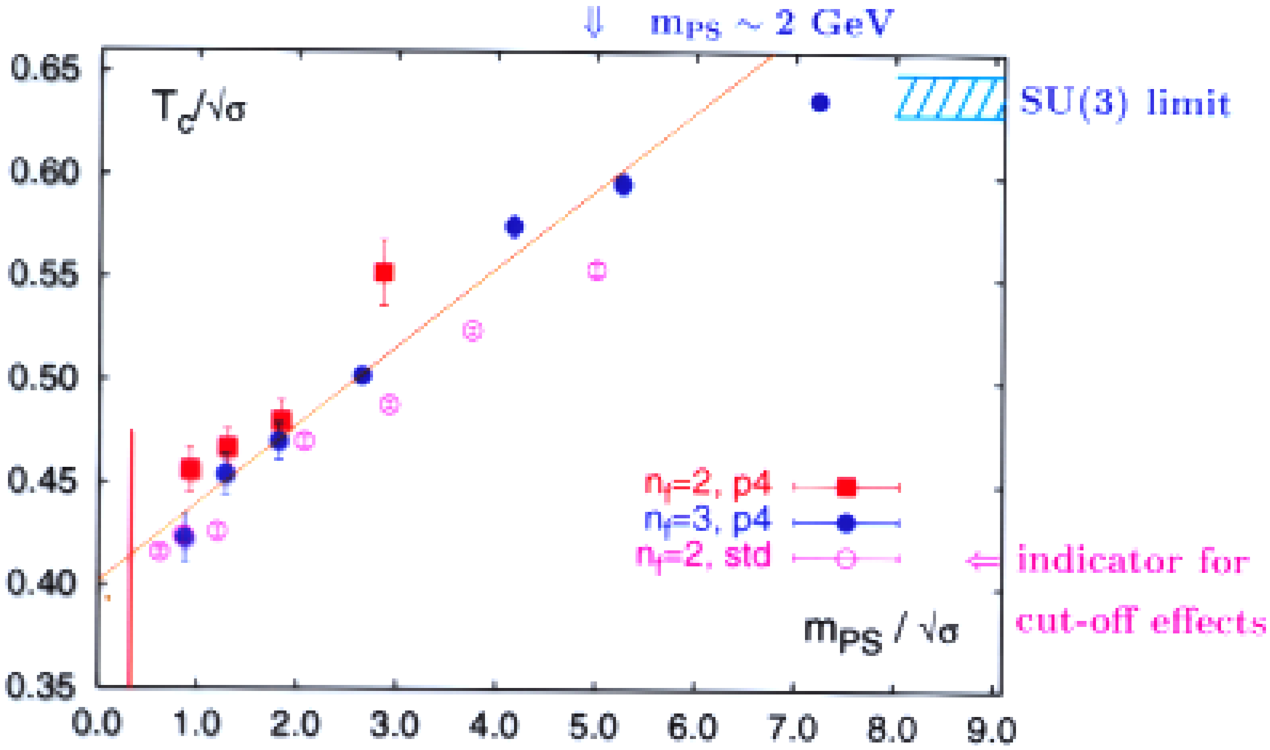
Quark Mass Dependence of T_c

need a m_q (and n_f) independent observable to set a scale

$$\frac{\sqrt{\sigma}}{m_\rho} = \begin{cases} 0.552(13) & \text{, quenched } (m_q \to \infty) \\ 0.532(18) & \text{, partially quenched, } m_q = 0.1,\ n_f = 3 \\ 0.53(3) & \text{, chiral limit, } n_f = 3 \end{cases}$$

$\Rightarrow$ $\sqrt{\sigma}$, quenched hadron masses are good scale parameters

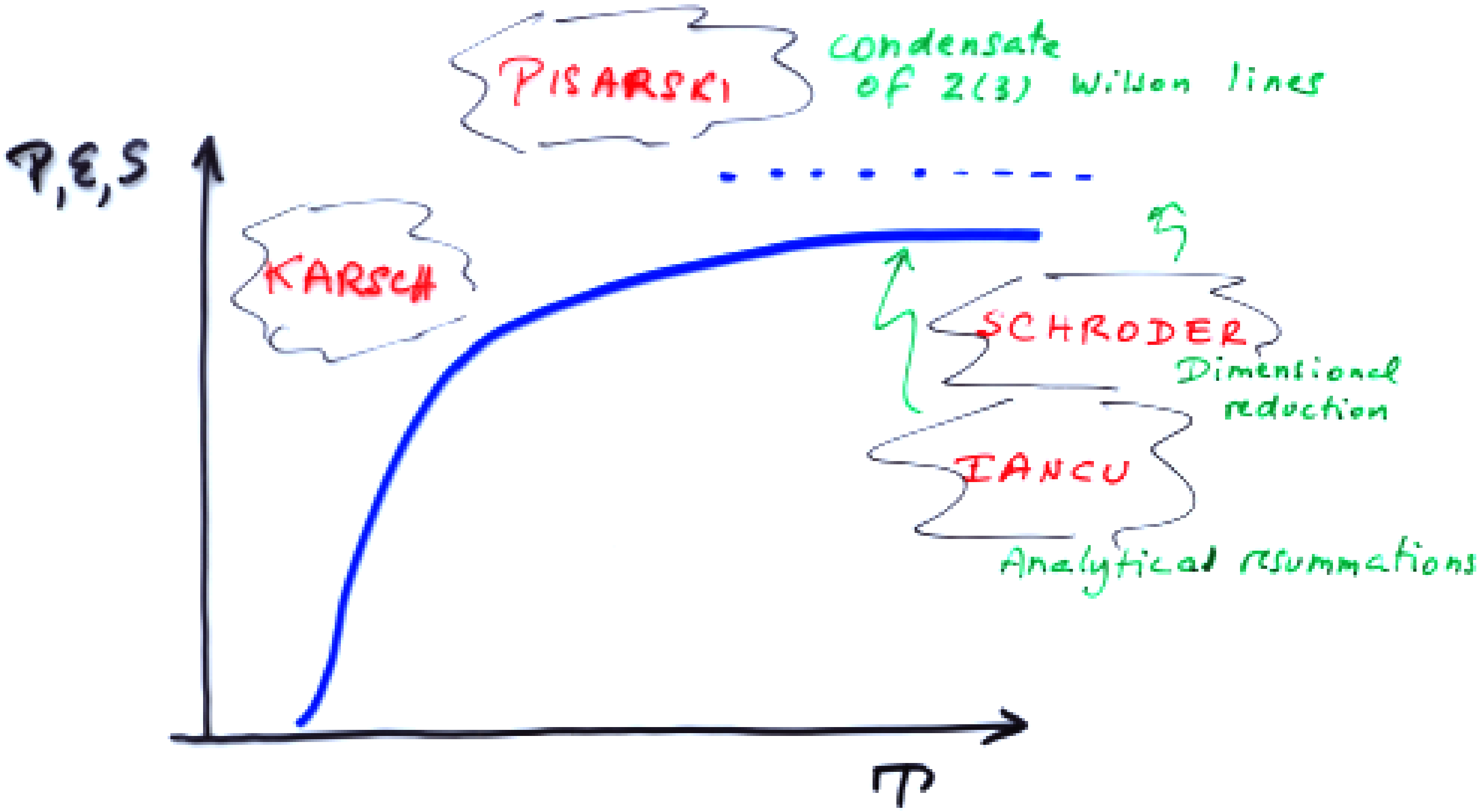
$$T_c(m_{PS}) \simeq T_c(0) + 0.04(1) m_{PS}$$



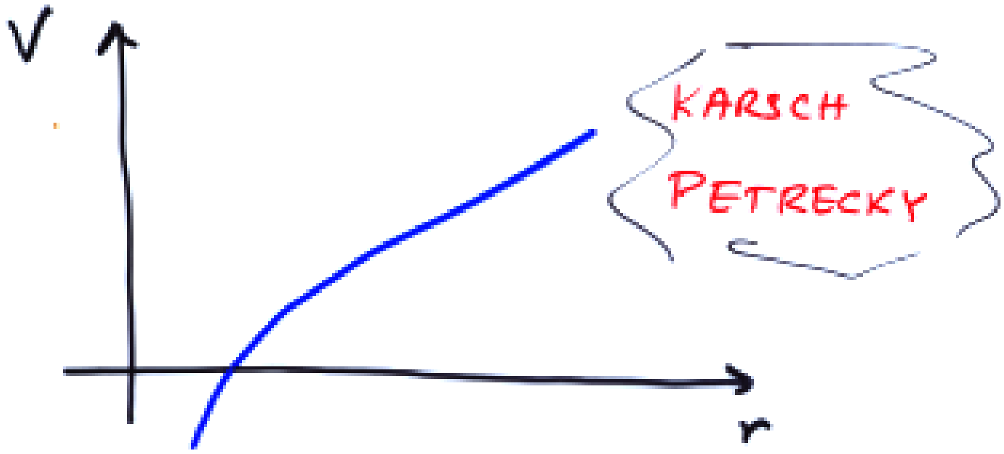
- weak quark mass dependence of $T_c/\sqrt{\sigma}$

$\Rightarrow$ gross features of the transition not controled by "light" mesons

EQUATION OF STATE



HEAVY QUARK POTENTIAL



III) QCD-EoS and critical energy density

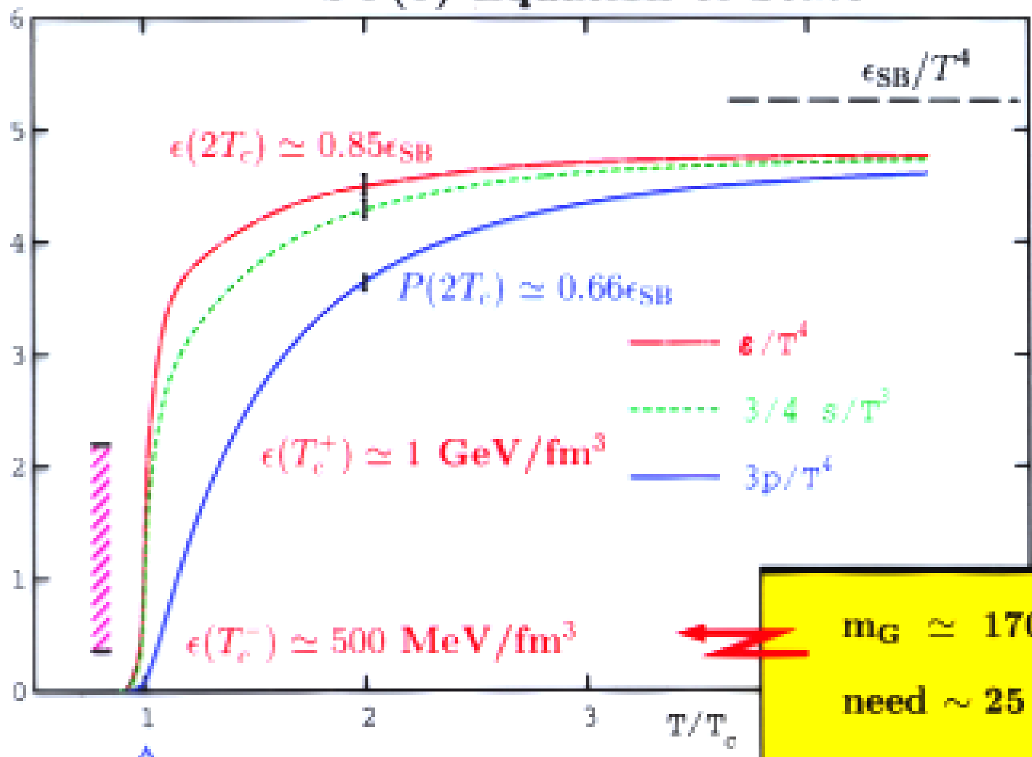
- $\epsilon_{SB} \sim T^4 \Leftrightarrow$ (relevant momenta) $\sim$ T

  - EoS is sensitive to short distance physics
  - Lattice calculations sensitive to cut-off effects

- experience gained in the pure gauge sector

  - improved actions mandatory
  - EoS non-perturbative even at $T \simeq 5T_c$

SU(3) Equation of State



$m_G \simeq 1700$ MeV

need ~ 25 d.o.f.

$\Rightarrow$ resonance gas

$\Uparrow$

$T_c \simeq (0.63 - 0.65)\sqrt{\sigma} \simeq 270$ MeV

high-T behaviour can be reproduced in continuum approaches

(HTL-resummed perturbation theory, quasi-particle models)

- J.O. Andersen et al., PR D61 (2000) 014017;
- J.-P. Blaizot, et al., PRL 83 (1999) 2906; PL B470 (1999) 181
- P. Lévai and U. Heinz, PR C57 (1998) 1879

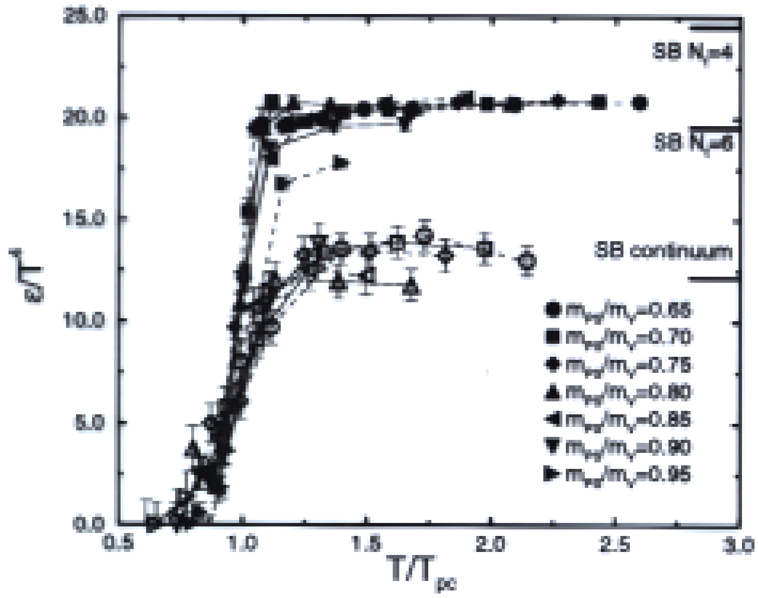
parallel session: E. Iancu, R. Pisarski, Y. Schroder

poster P037: A. Peshier

Energy Density

new results:

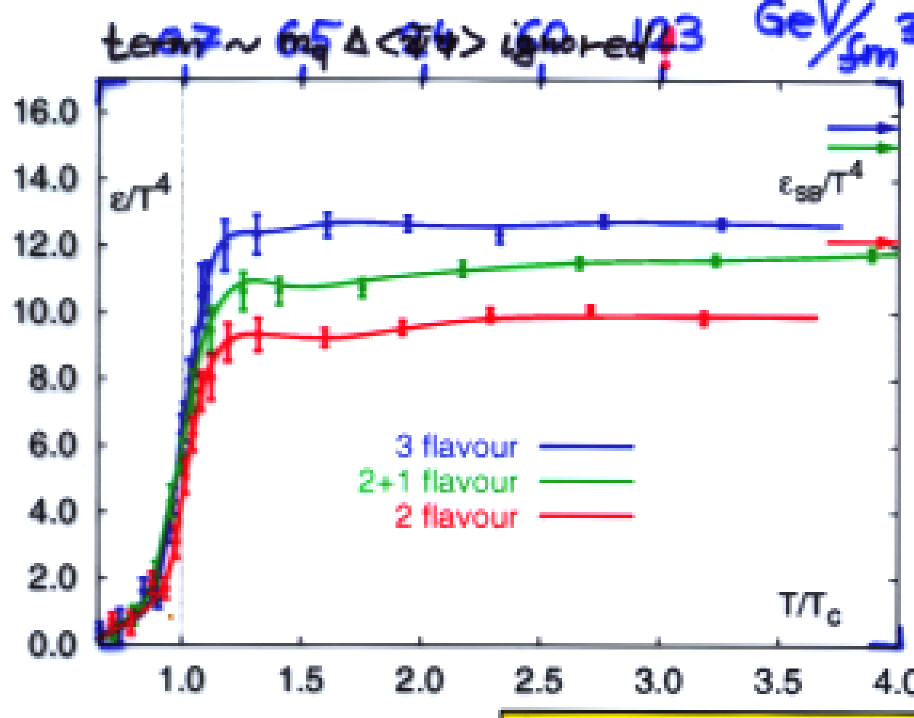
Clover improved WF (CP-PACS in prep.), S. Ejiri, hep-lat/0011006v2
rot. sym. improved SF (Bielefeld):
A. Peikert et al., Phys. Lett. B478 (2000) 447



$n_f = 2$ Clover fermions:

large cut-off dependence for $T > T_c$

small cut-off dependence at T_c



improved staggered fermions:

small cut-off dependence

40% error in ϵ_c, ϵ

10% error in T_c

critical energy density: $\epsilon_c \simeq (6 \pm 2)\ T_c^4$

even massless pions would contribute only [illegible]0% to this!

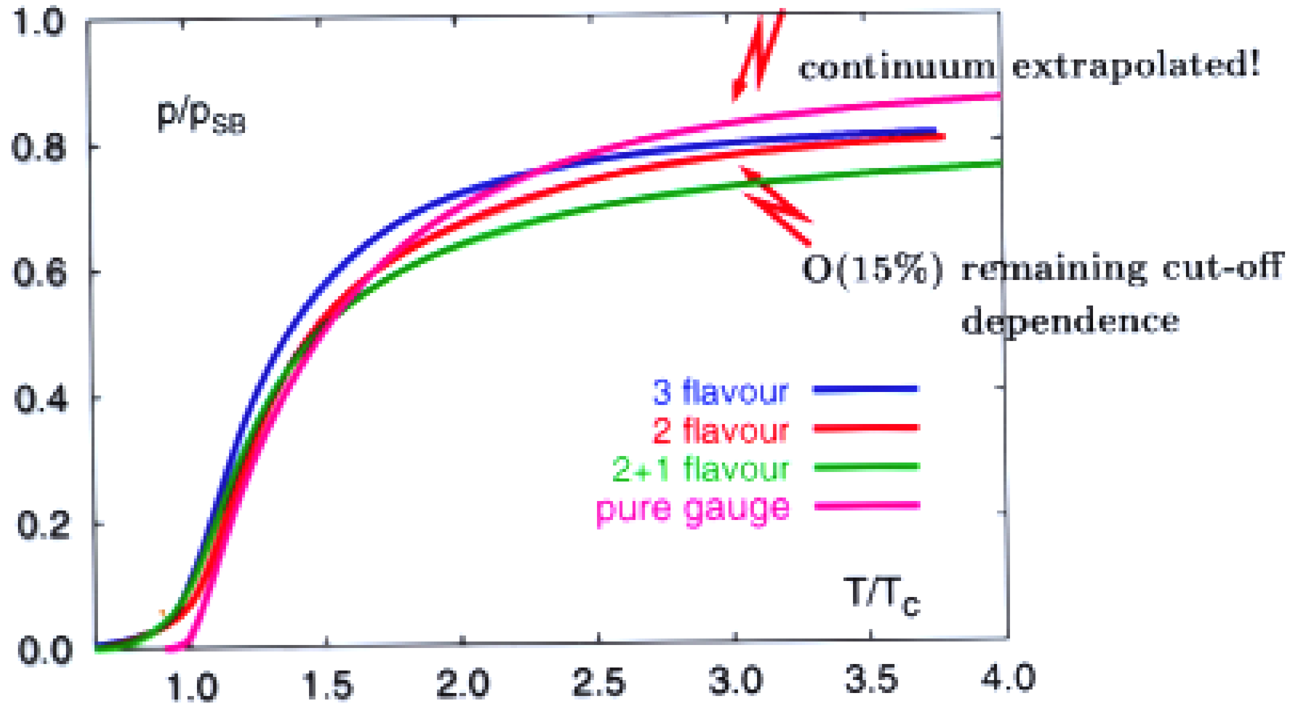
detailed analysis of volume and quark mass dependence still needed!

Flavor (IN)-dependence of the EoS

flavor dependence dominated by ideal gas term

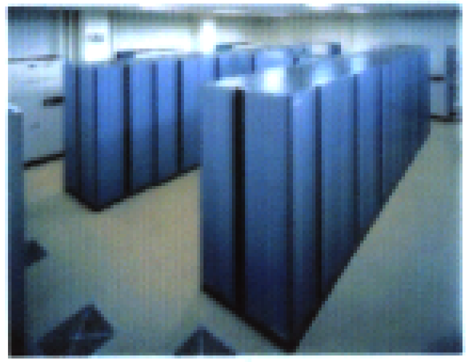
$$\frac{p(n_f, T)}{T^4} \simeq \left(16 + \frac{7}{8} \cdot\ 12 n_f\right) \frac{\pi^2}{90}\, f(T)$$

heavy quark contribution is slightly suppressed
relative to a massive ideal gas with $m/T \simeq 1$



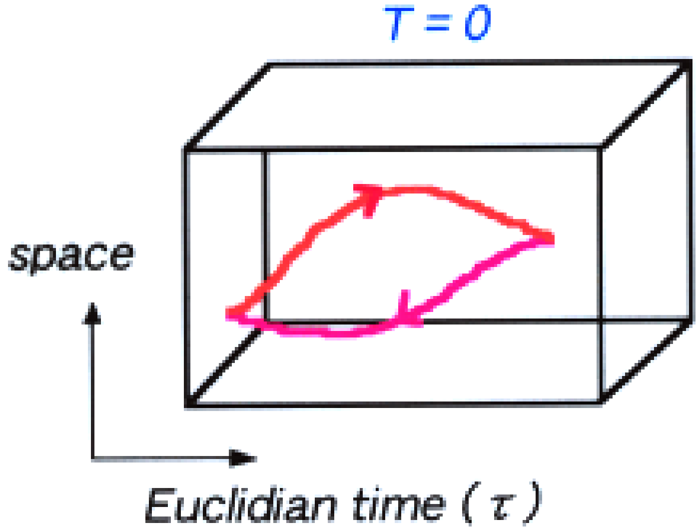
quark mass independence
examined for $n_f = 4$
and also for WF

Hadronic correlations in lattice QCD


CP-PACS @ Tsukuba

- Traditional tool : asymptotic analysis

$$D(\tau) = \int \langle H(\tau,\vec{x}) H(0) \rangle d^3x \underset{\tau \to \infty}{\sim} e^{-m\tau}$$



MEM ⇒ P[A|D]

(i) No parametrization of $A(\omega)$

(ii) unique solution for $D(\tau) \rightarrow A(\omega)$

(iii) Statistical significance of $A(\omega)$

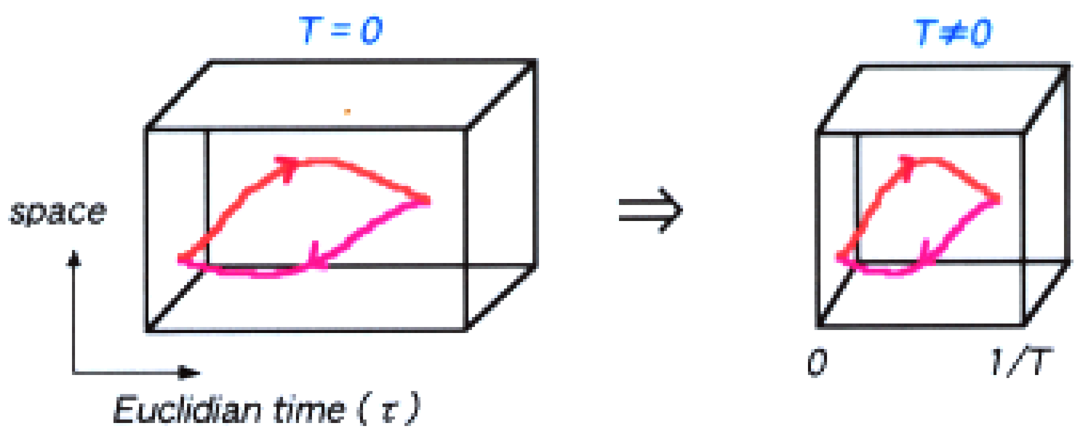
Asakawa, Nakahara & T.H., PRD ('99) , hep-lat/0011040

— MELQCD Collaboration —

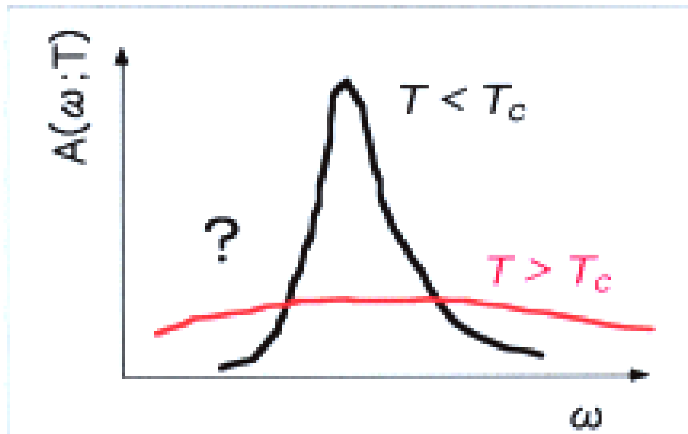
- New approach : Maximal Entropy Method (MEM)

$$D(\tau) = \int_0^\infty e^{-\omega\tau} A(\omega)\, d\omega \qquad (\text{use all } \tau)$$

Hadronic correlations at finite T in lattice QCD



$$D(\tau;T) = \int_0^\infty \frac{e^{-\omega\tau} + e^{+\omega(\tau - 1/T)}}{1 - e^{-\omega/T}} A(\omega;T)\, d\omega$$



Lattice QCD + MEM provides a clue to study in-medium hadrons (ρ , J/Ψ , ⋯)

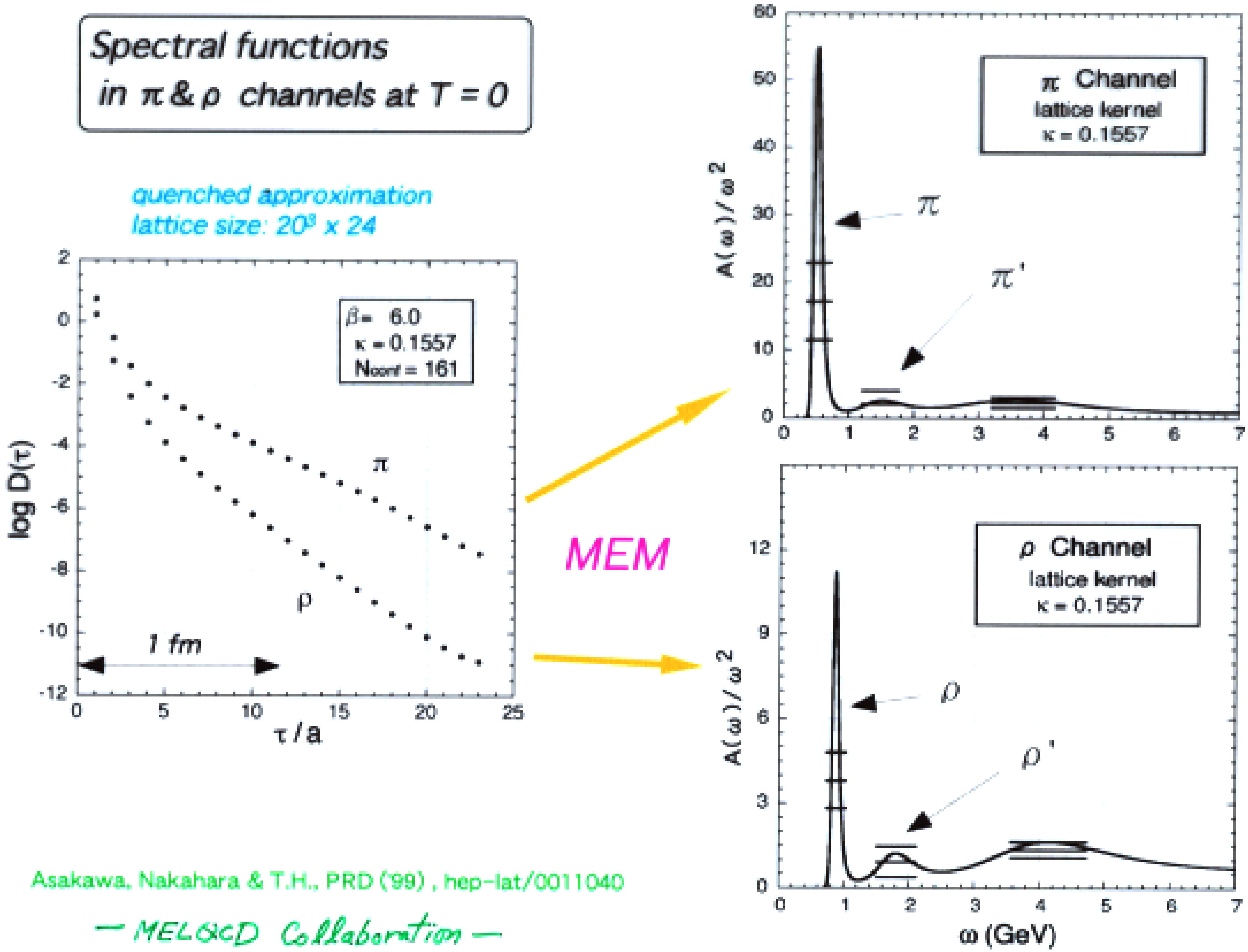
preliminary studies are started :

Asakawa, Nakahara & T.H., in progress.
Oevers, Davies & Shigemitsu, hep-lat/0009031,
Wetzorke & Karsch, hep-lat/0008008.

[$32^3 \times 32, 48, 64, 96$; $\beta = 7.0$; $a_\tau/a_s \sim 1/4$ on CP-PACS]

Spectral functions in π & ρ channels at $T = 0$

quenched approximation
lattice size: $20^3 \times 24$



Asakawa, Nakahara & T.H., PRD ('99), hep-lat/0011040

— *MEMQCD Collaboration* —

THE STANDARD PICTURE

HADRONIZATION and FREEZE-OUT

D. RISCHKE
K. REDLICH

MODELS and DEGREES OF FREEDOM

S. BASS
K. ESKOLA

INITIAL CONDITIONS

R. VENUGOPALAN
D. SON

HADRONIZATION and FREEZE-OUT

- Apparent chemical equilibrium
  Particle ratios are functions of T and μ_B only.
  (D. Rischke, K. Redlich, L. Bravina)

- In-medium modifications of hadrons may modify freeze out parameters
  (D. Rischke, G.E. Brown)

Statistical-Thermal Models

- At freeze-out: the available particle phase space is occupied according to statistical laws
  -> thermal distribution
- Chemical freeze-out: particle abundances are frozen in
- Thermal freeze-out: particle spectra are frozen in

Test of equilibration required to specify:

i) level of observation: (multiplicities, spectra, correlations,..)

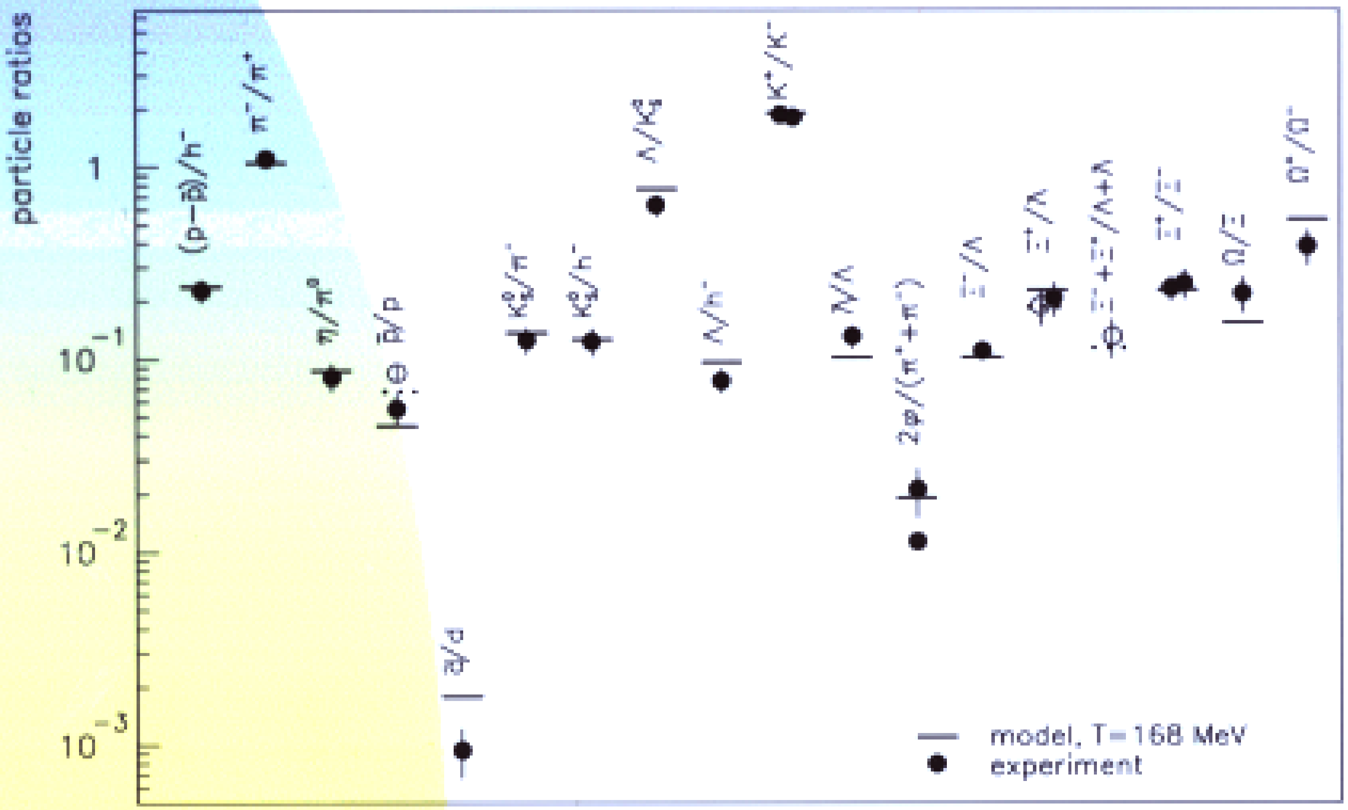
ii) Statistical operator:

$$Z^{GC}(T,\vec{\mu},V) = Tr[e^{-\beta(H-\mu_B B-\mu_S S-\mu_Q Q)}]$$

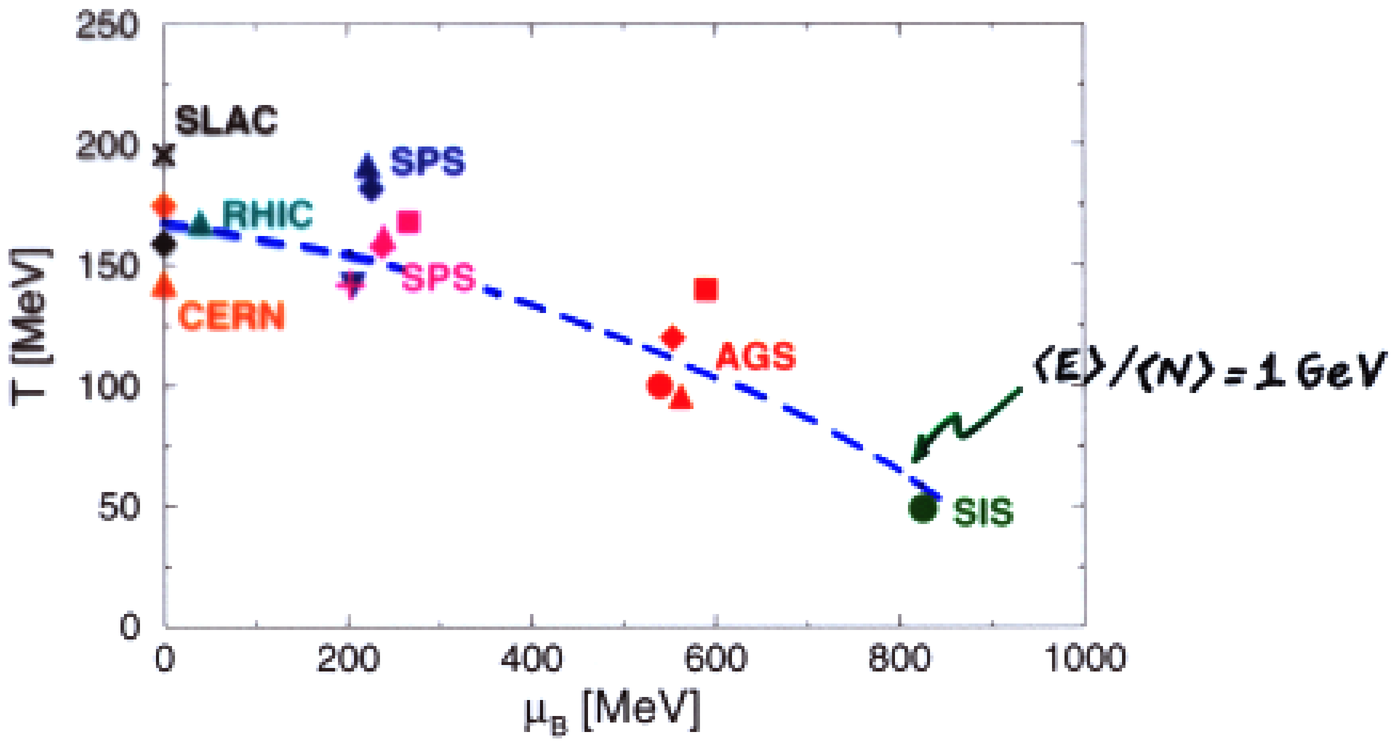
Test of chemical equilibrium for Pb-Pb at SPS

P. Braun-Munzinger, I. Heppe, J. Stachel

$$\varepsilon \approx 0.6 GeV / fm^3, \rho_B \approx 0.16 / fm^3$$



T, μ_B at freeze-out from particle ratios:



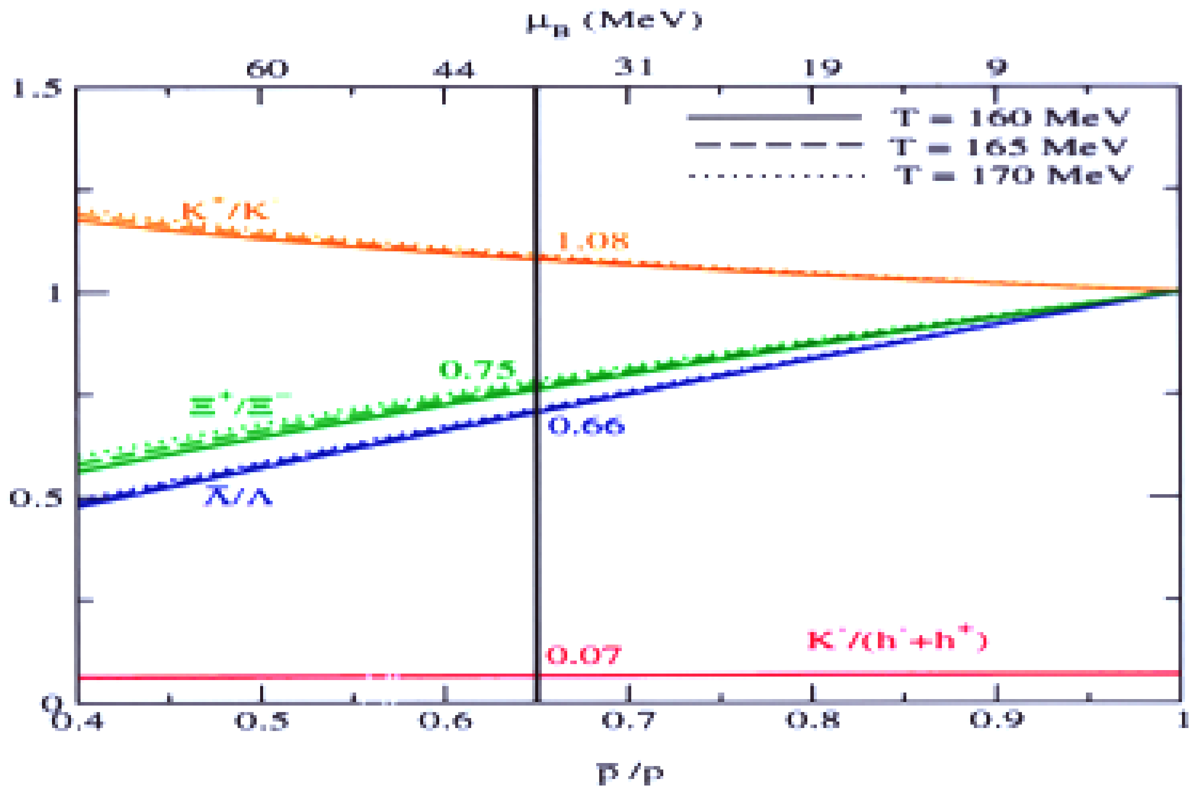
Au+Au, 2.3 AGeV	● [1] Cleymans et al., PRC 59 (99) 1663 ⟵ Exact charge conservation
	■ [2] Yen et al., JPG 24 (98) 1777 ⟵ excl. volume
Au+Au, 5 AGeV	◆ [3] Becattini et al., hep-ph/0002267 ⟵ $\gamma_s < 1$
	▲ [4] Kabana et al., hep-ph/0010247 ⟵ $\gamma_s = 1$
	● [5] Cleymans et al., PLB 388 (96) 5
S+S, 20 AGeV	◆ [6] Becattini, JPG 23 (97) 1933
	▼ [7] Sollfrank, EPJC 9 (9) 159 ⟵ hydro
	▲ [8] Panagiotou et al., PRC 53 (96) 1353
	■ [9] Braun-Munzinger et al., PLB 465 (9) 15
Pb+Pb, 17 AGeV	◆ [3]
	▲ [4]
	+ [10] Letessier et al., IJMPE 9 (00) 107 ⟵ $\gamma_s > 1$
Au+Au, 130 AGeV	▲ [4]
	◆ [11] Becattini et al., ZPC 74 (97) 319
p–pbar, 900GeV	▲ [4]
e^+e^-, 29GeV	× [12] Hoang et al., ZPC 38 (88) 603 ⟵ fit to $E\frac{d\sigma}{d^3p}$
	◆ [13] Becattini et al., hep-ph/0010221

cf. also: J. Sollfrank, J. Phys. G 23 (97) 1903

J. Cleymans, K. Redlich, PRC 60, 054908 (99)

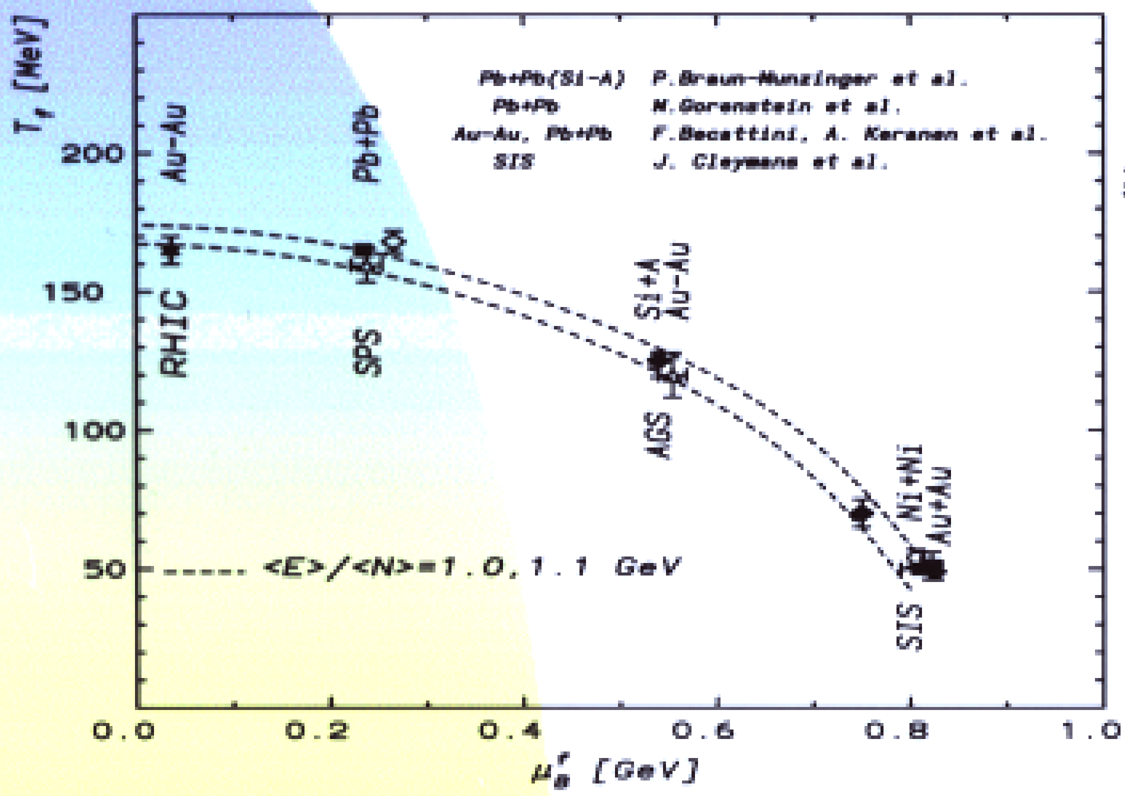
Thermal Model at RHIC

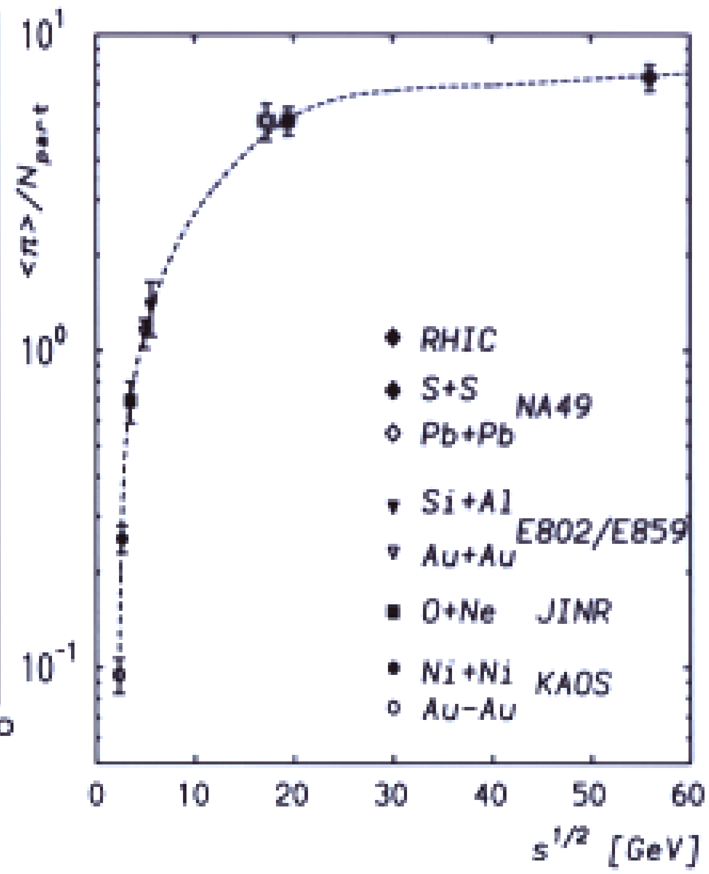
F. Becattini, J. Cleymans, A. Keranen, E. Suhonen, K. R



Unified freeze-out curve from SIS =>RHIC

J. Cleymans, K.R





$<E>/<N> \sim <m>+3T/2$

Models and degrees of freedom

- No single model for the entire collision process → various models best suited for different stages of the raction

①	SOFT	hadrons	S. Bass
		hadronic resonances	
③	↕		K. Werner
		hadronic strings	
			U. Wiedeman
			S. Vance
			G. Papp
②	HARD	Partons	P. Levai
			X.N. Wang
			K. Eskola

Some quotations:

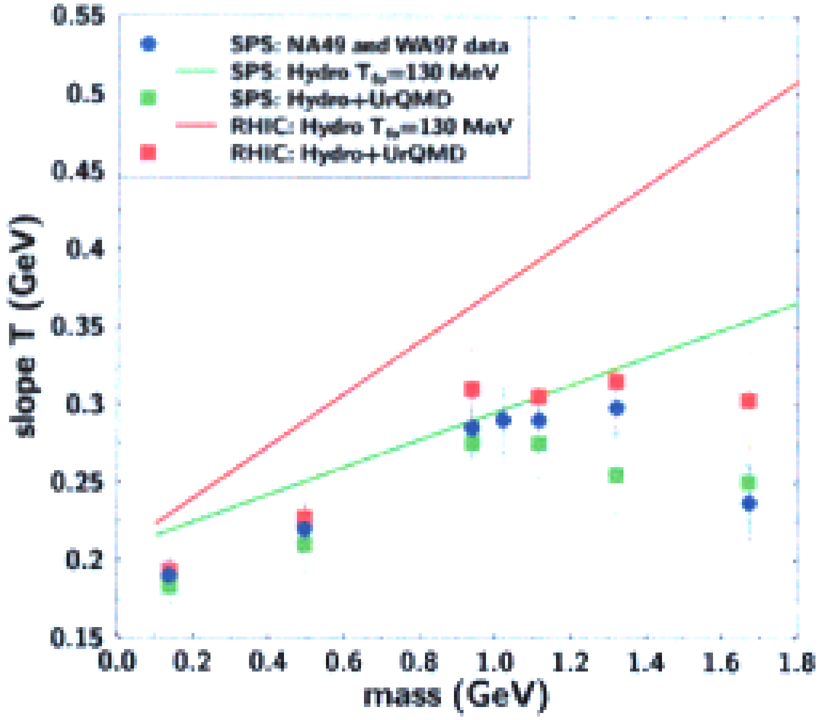
"Theoretical uncertainties are bigger than exp^{al} error bars"

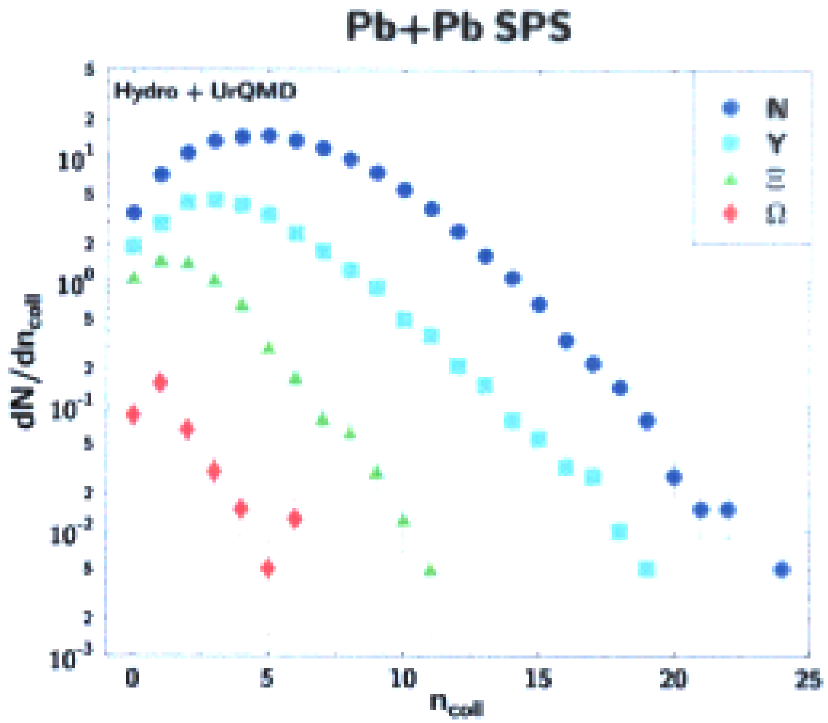
(K. ESKOLA)

"We have to be more concerned about the theoretical content of models: an ill-defined model which fits the data is quite useless"

(K. WERNER)

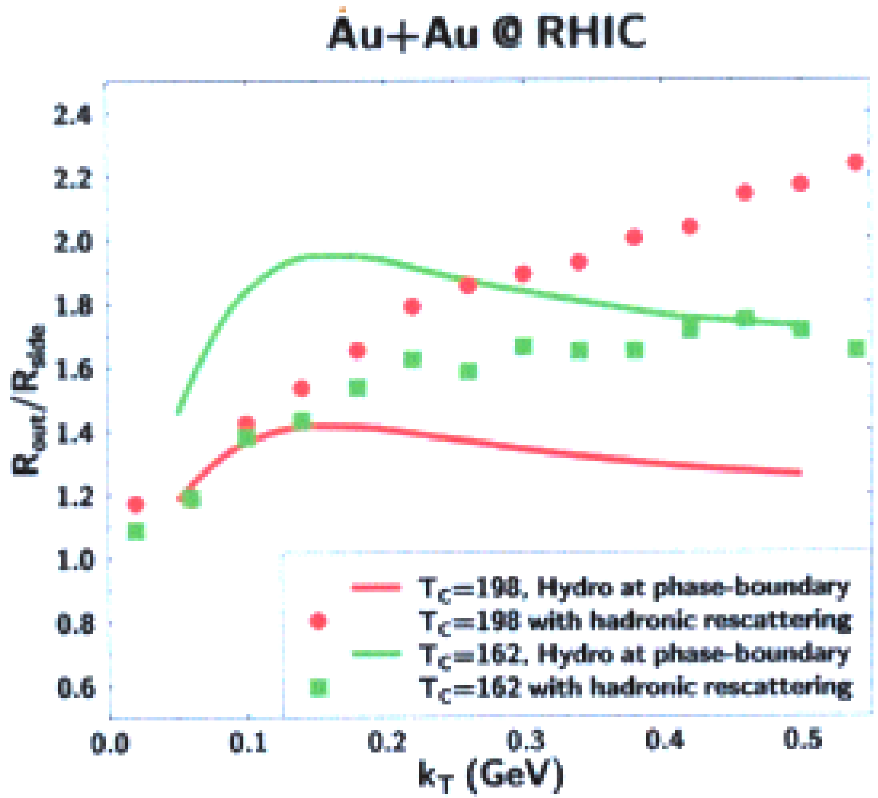
Flavor Dynamics: Radial Flow

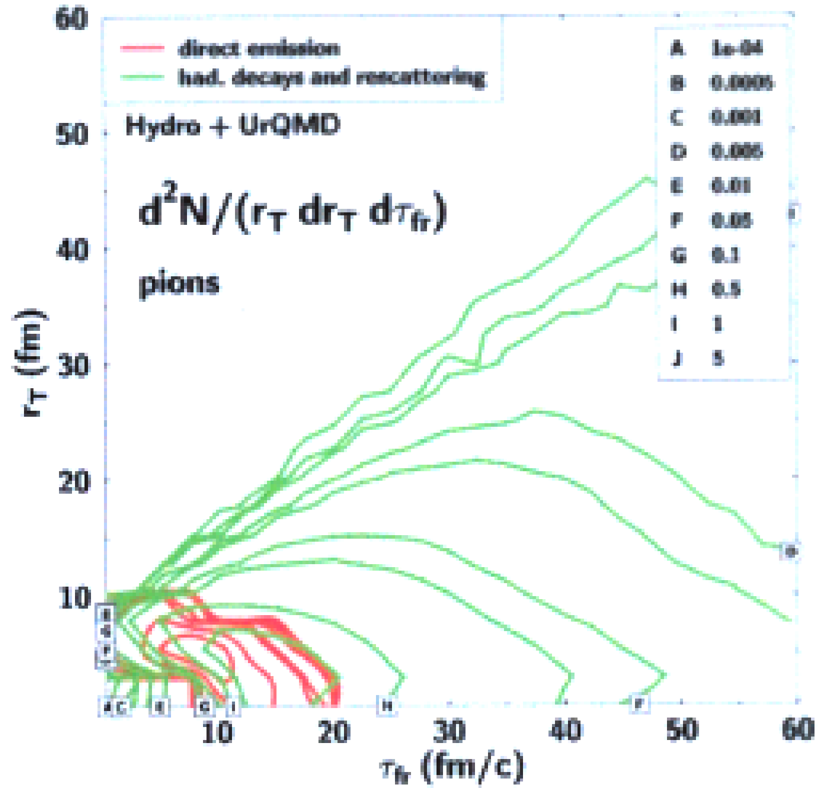




- Hydro: linear mass-dependence of slope parameter, strong radial flow
- Hydro+Micro: softening of slopes for multistrange baryons
  - early decoupling due to low collision rates
  - nearly direct emission from the phase boundary

HBT: QGP Lifetime vs. Hadronic Halo



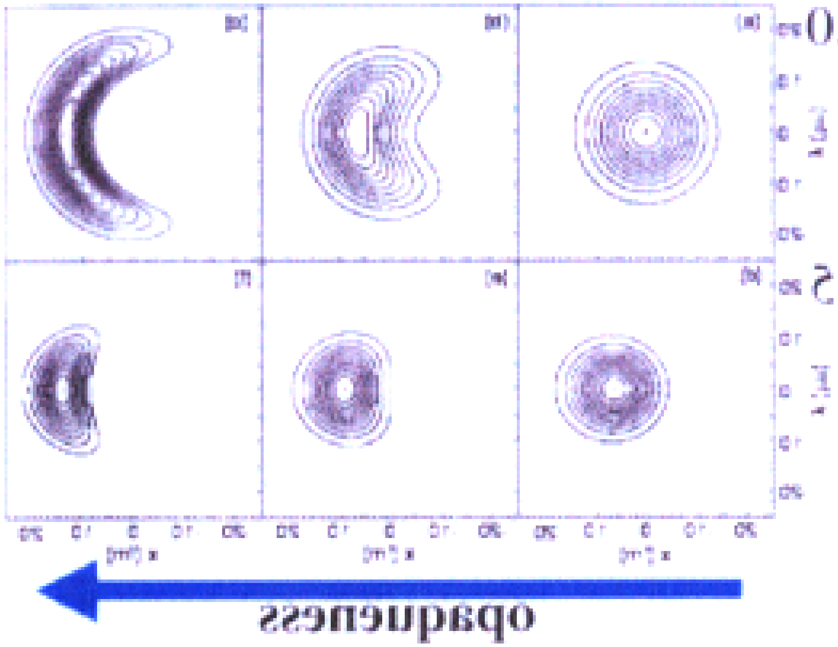


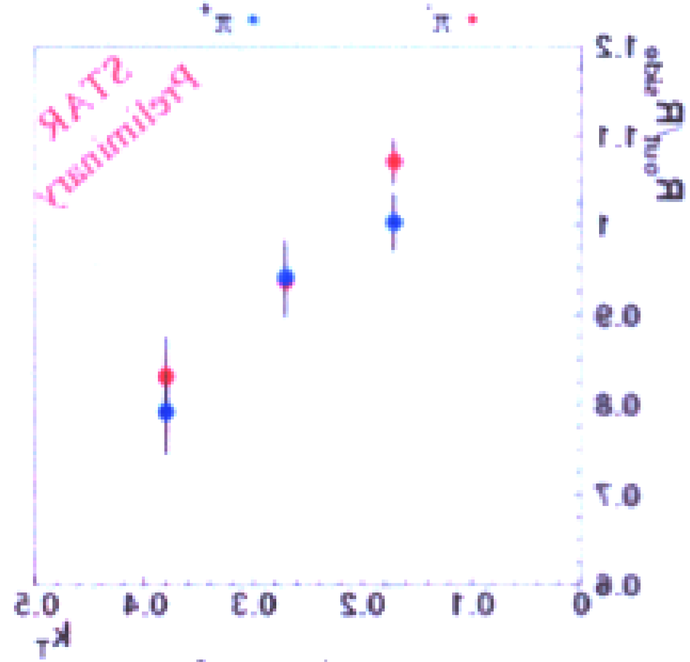
- large R_{out}/R_{side} has been proposed as indicator of long-lived QGP
- inclusion of hadronic phase: only weak sensitivity to initial conditions
- ➢ long-lived dissipative hadronic phase dominates correlation signal
- ➢ dissipative hadronic phase: unavoidable consequence of thermalized QGP

The R_{Out}/R_{Side} Ratio

emission duration for transparent sources: $\tau = \sqrt{R_{Out}^2 - R_{Side}^2} / \beta_T$

Tomášik, Heinz nucl-th/9805016

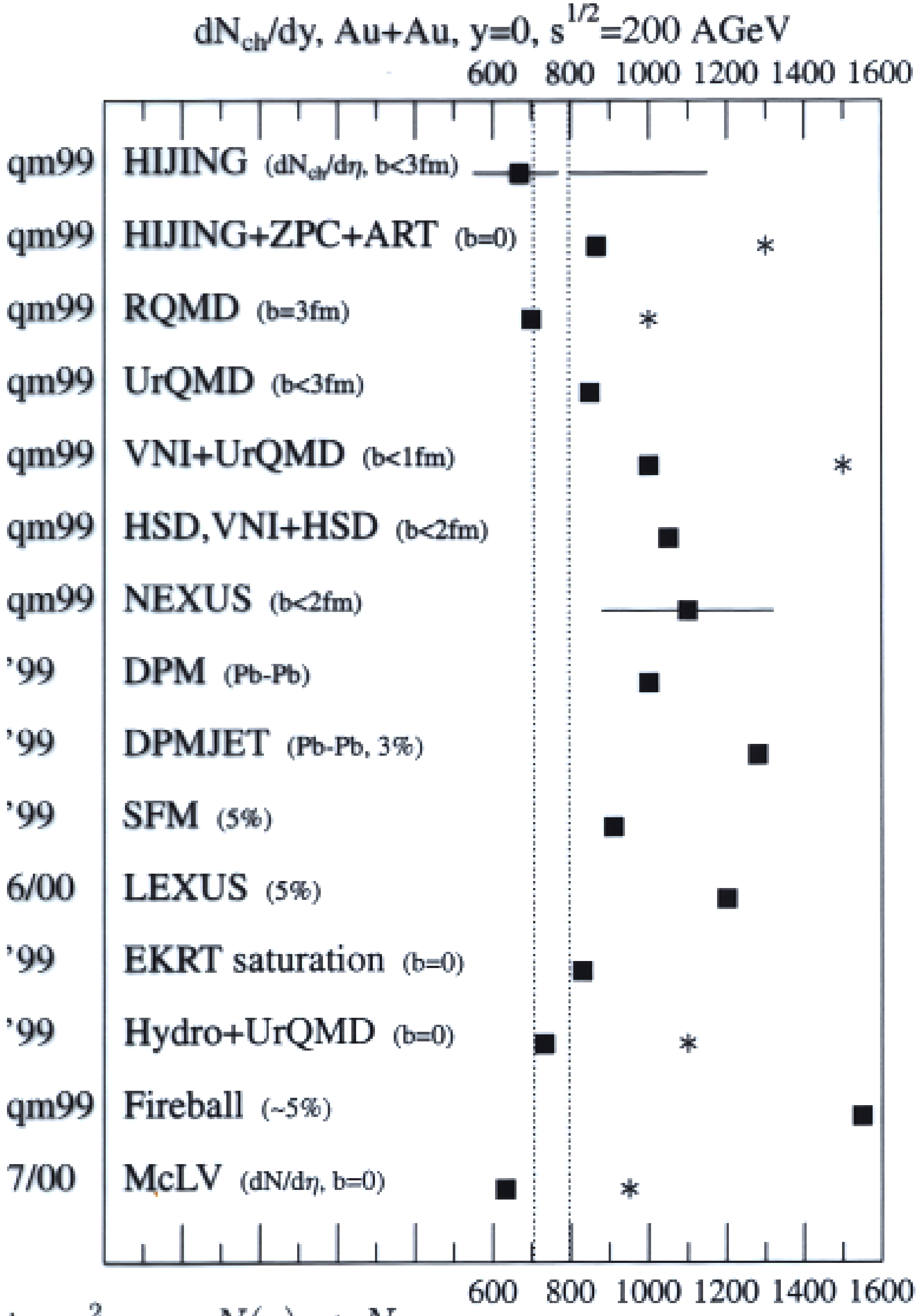




$K_T = (p_T^1 + p_T^2)/2$

Note: extremely strong flow at RHIC (close to hydro)

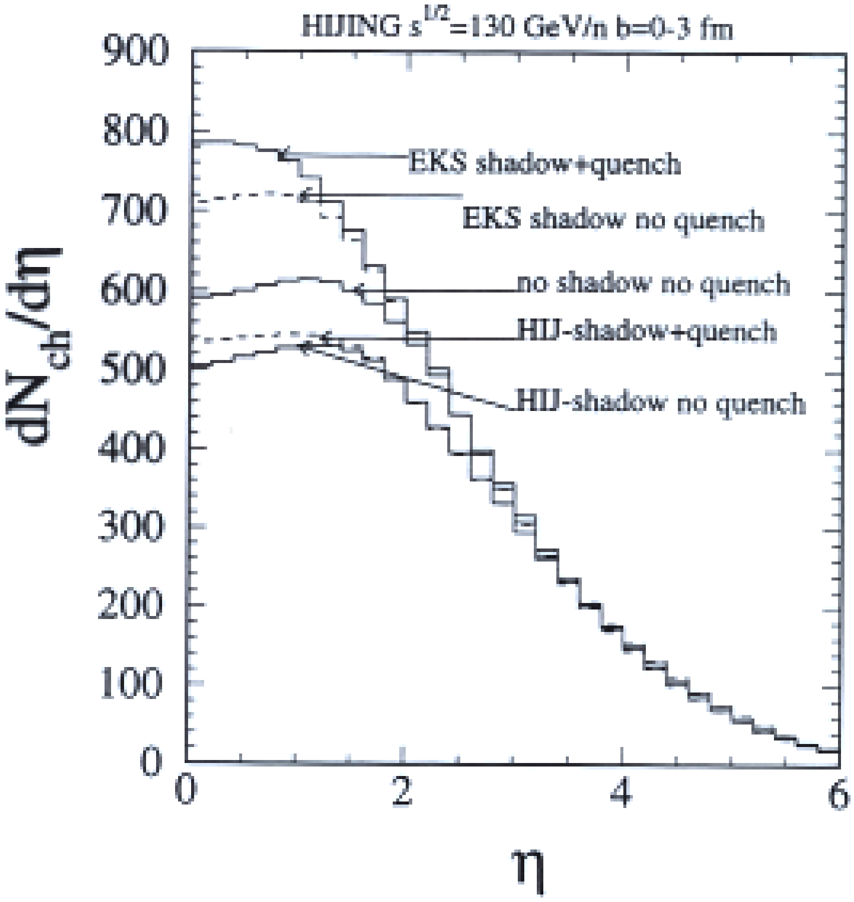
x-p correlations (flow / opaqueness) might change the homogeneity length



Applied $\sim \frac{2}{3}$: $N(*) \rightarrow N_{ch}$ ······· data $* (200/130)^{0.37} * 1.1$

Not applied above $\begin{cases} \sim 1.1: & \eta \rightarrow y \\ \sim 0.9: & b = 0 \rightarrow b \lesssim 3\,\mathrm{fm}(5\%) \end{cases}$

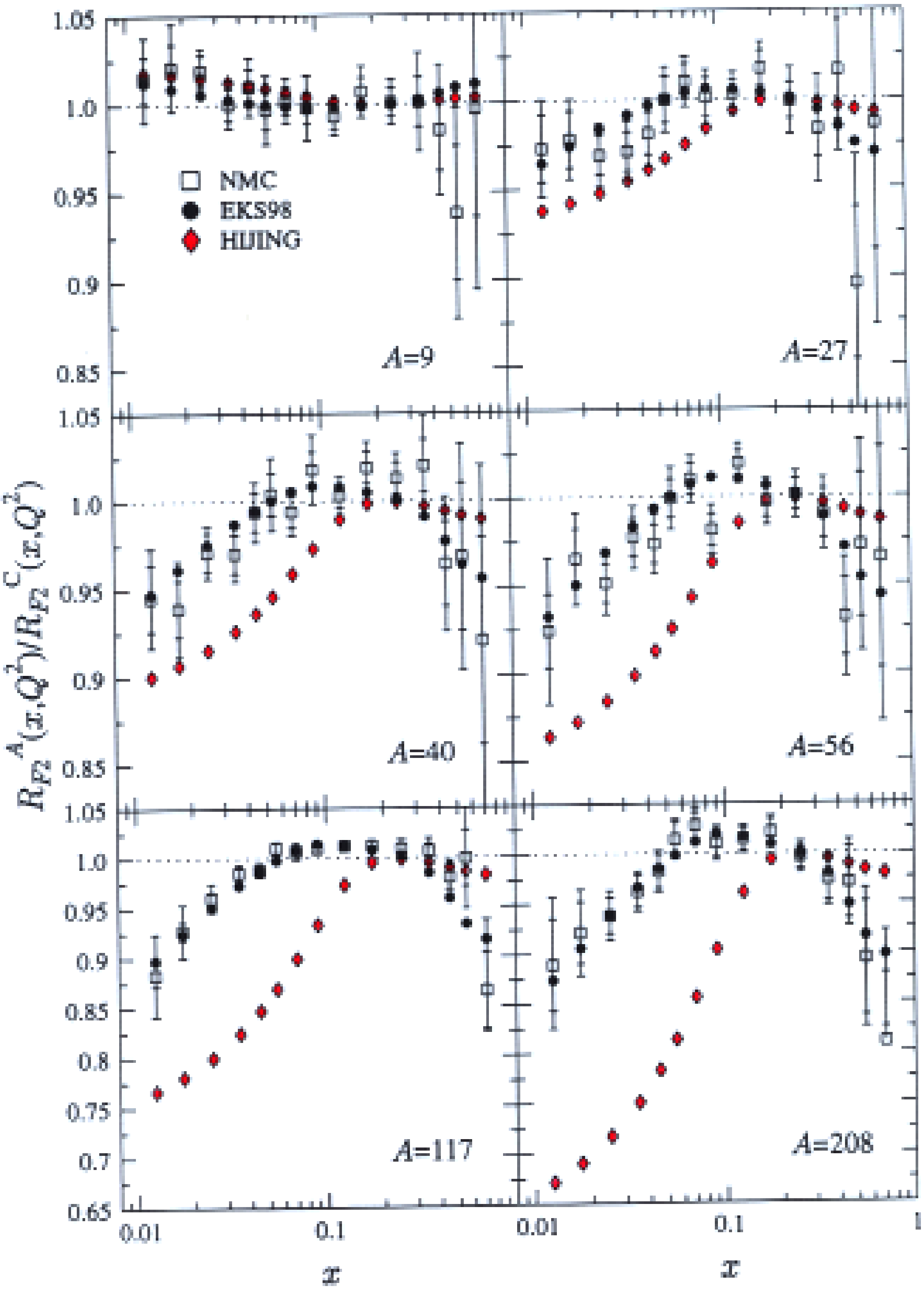
see [Armesto,Pajares, hep-ph/0002163]



HIJING prediction, from X.-N. Wang

EKS98 = DGLAP + constraints from DIS & DY, conservation of B & p

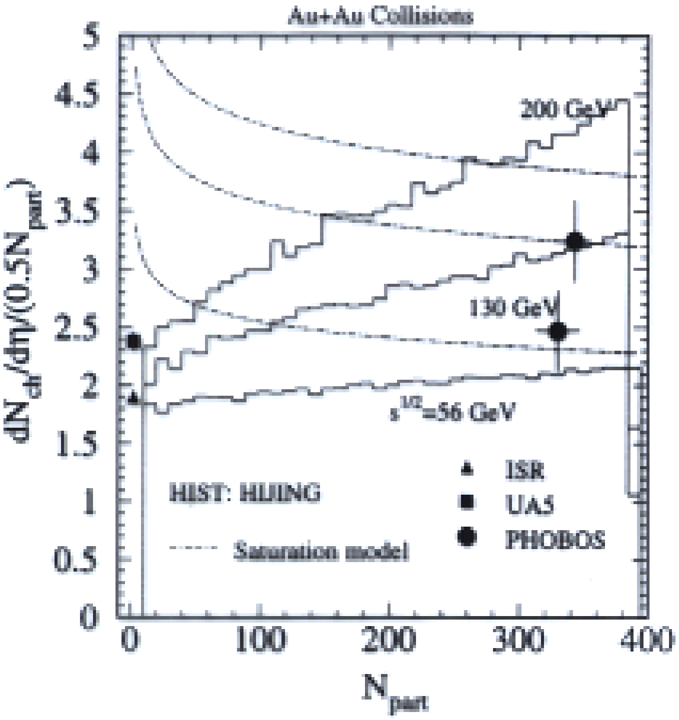
[Eskola, Kolhinen, Salgado, hep-ph/9807297]



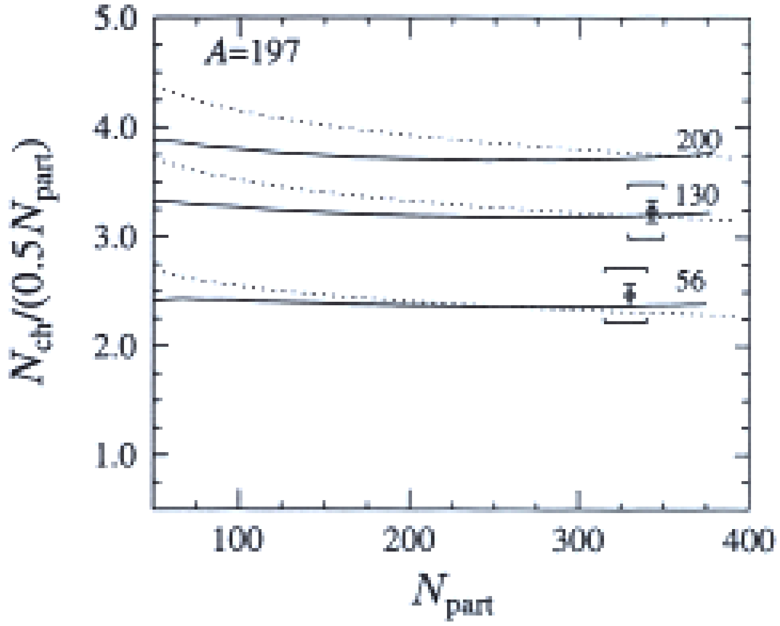
EVIDENCE FOR HARD SCATTERING ?

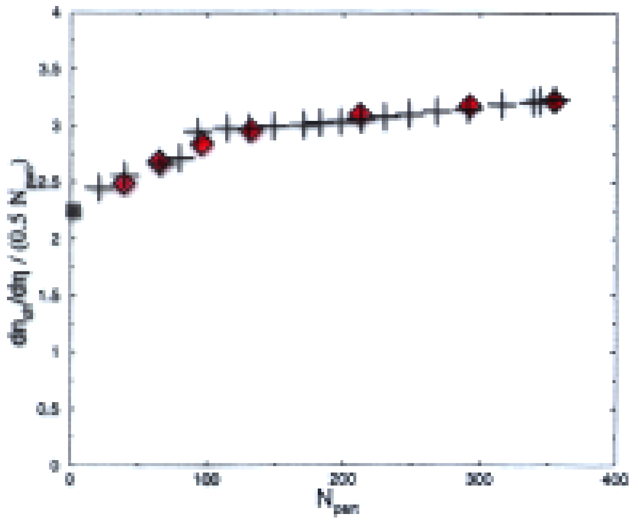
$$\frac{dN}{d\eta} = A \cdot N_{part} + B \cdot N_{coll}$$

HIJING

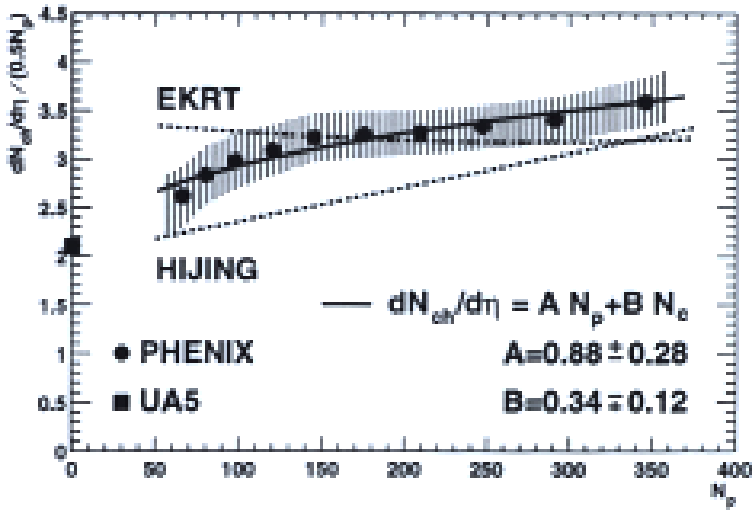


EKRT saturation





Kharzeev&Nardi



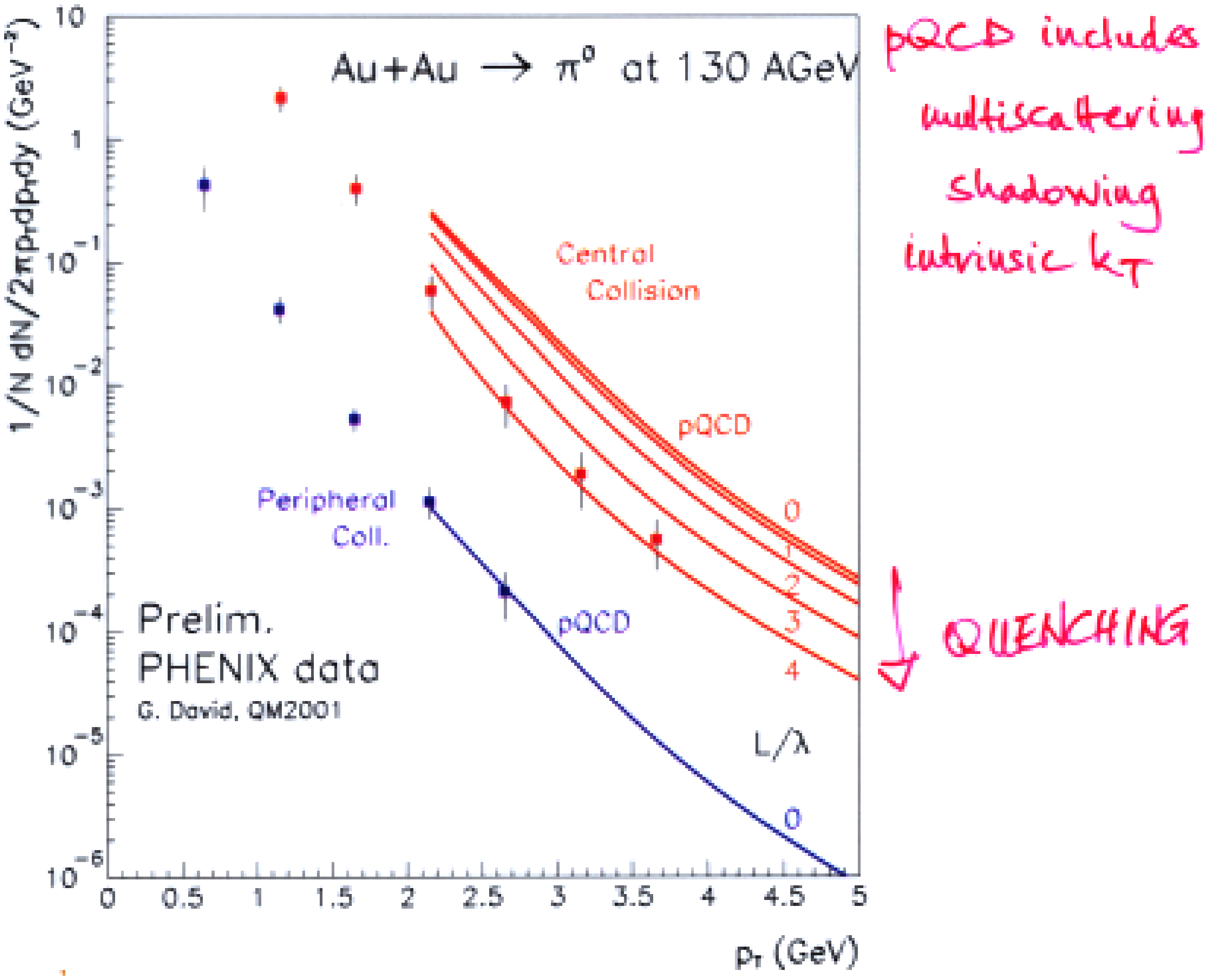
PHENIX

Jet quenching on hadron yields - 3

PHENIX prel. results at $\sqrt{s} = 130$ GeV G. David's talk

Periferial collisions (75-92 %; $< N_{coll} >= 5.5$)

Central collisions (10 %; $< N_{coll} >= 857$)



Factor 8-10 shift in central coll. $\Longleftrightarrow$ jet-quenching !!!!

INITIAL CONDITIONS

R. VENUGOPALAN

D. Son

(Y. Kovchegov, A. Dumitru)

IMAGINE

- VERY LARGE NUCLEI $A \to \infty$

  AND/OR

  VERY HIGH COLLISION ENERGY $s \to \infty$

$$\Downarrow$$

A CONTROLLED PERTURBATIVE REGIME

$$\alpha_s(Q_s) \ll 1$$

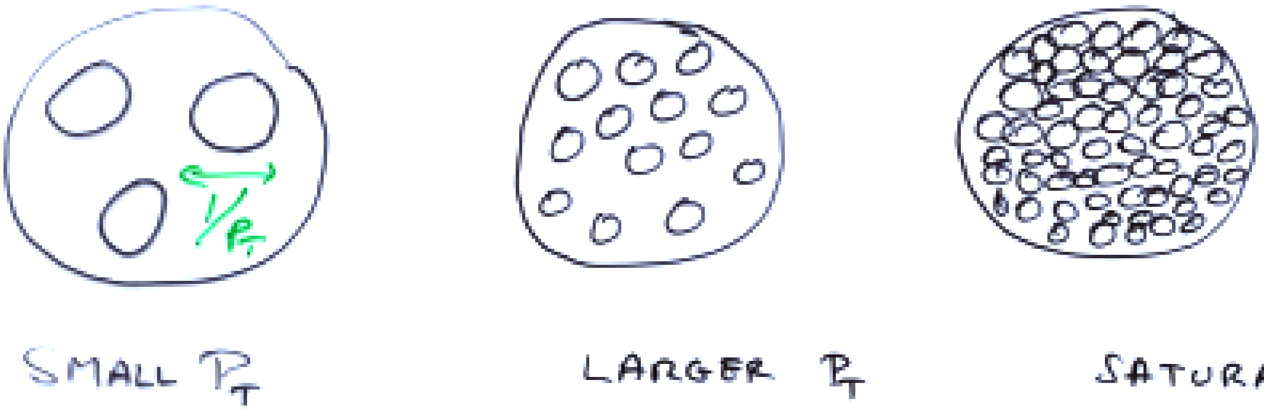
WHERE QUESTIONS CAN BE ANSWERED ...

SATURATION

Which partons contribute dominantly to energy density?

Partons must collide to get freed.

Optimum p_T given by saturation argt.



Growth of $xG(x, p_T^2)$ controlled by evolution equation. Enter non linear regime when

$$p_T^2 \propto \alpha_s \frac{A}{R^2} xG(x, p_T^2)$$

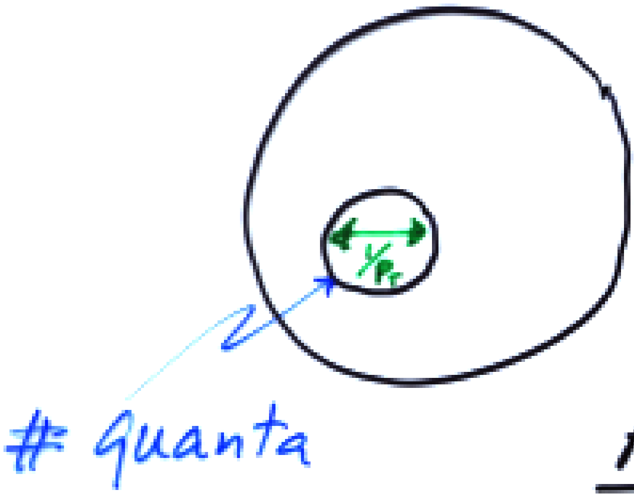
Then

$$\sigma \sim R^2 A x G$$

and

$$\frac{dN}{dy} = 2AxG \qquad \frac{dE_T}{dy} = 2p_T AxG$$

At saturation



$$\frac{A\,xG}{\pi R^2}\cdot\frac{\pi}{p_T^2}\sim\frac{1}{\alpha_s}$$

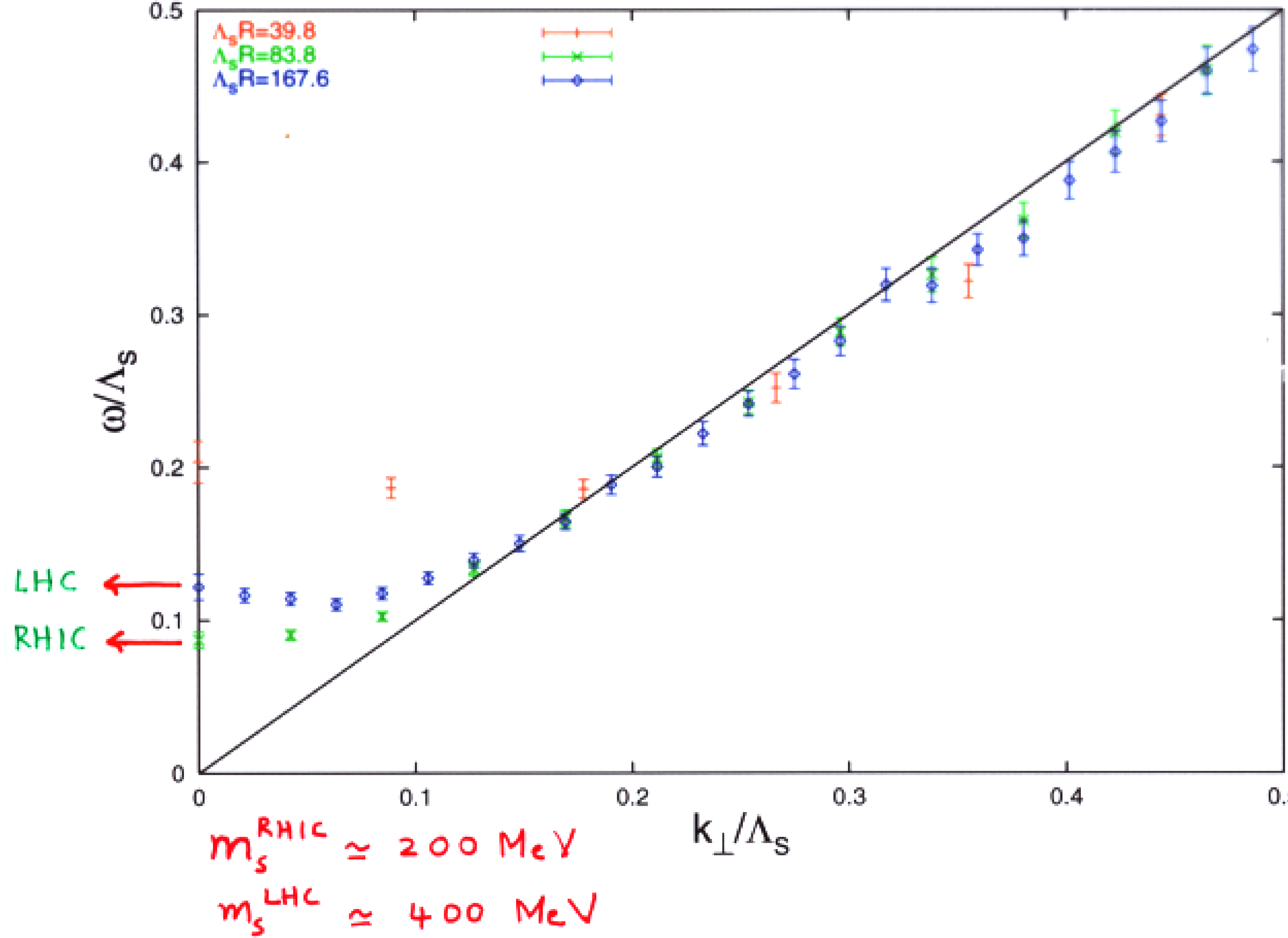
large nuclei (and high energy)

p_T^2 is large

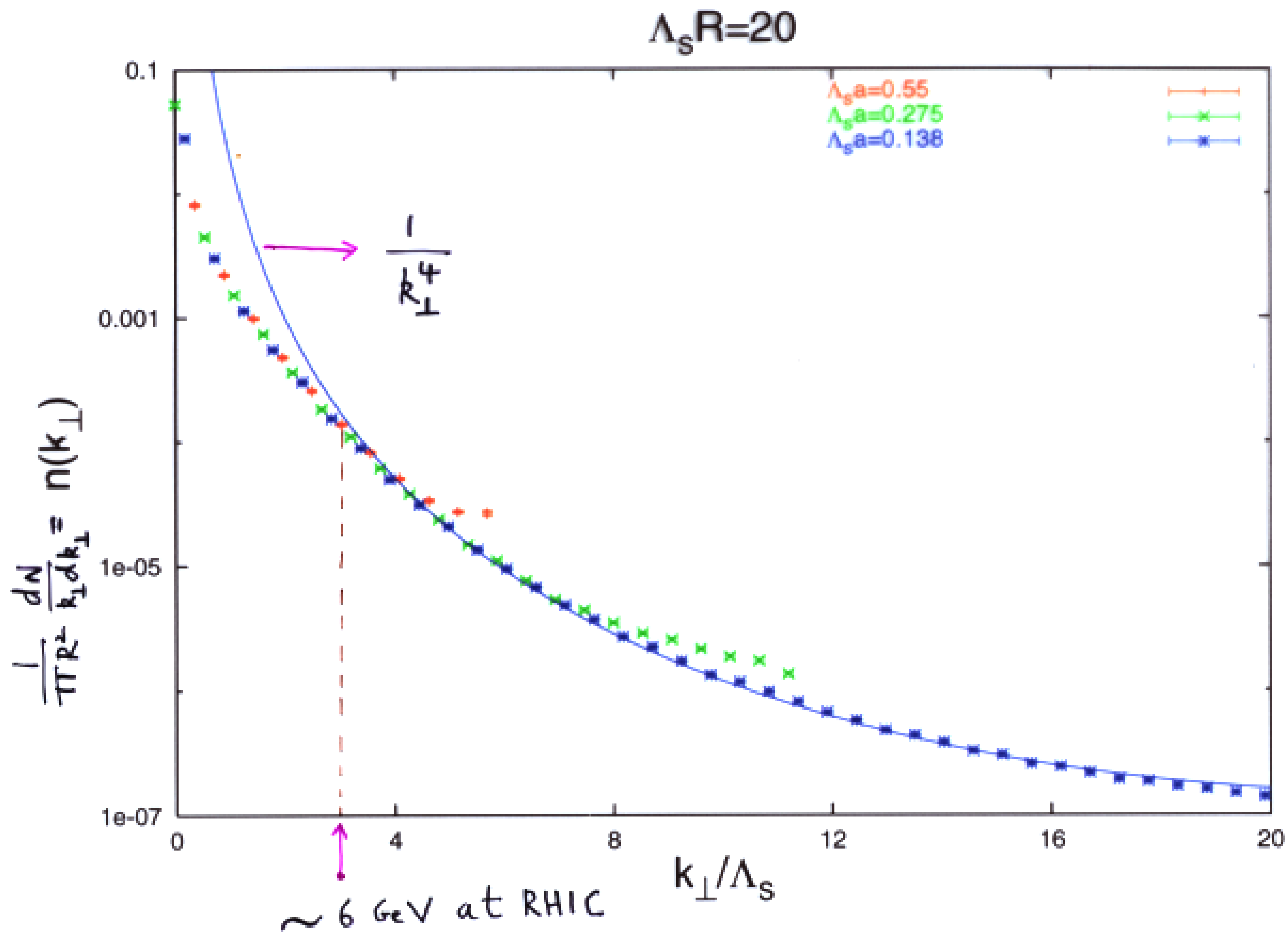
$\alpha_s(p_T^2)$ is small

⇒ many quanta. suggest classical approximation

(McLerran, Venugopalan)



$\Lambda_s R=39.8$
$\Lambda_s R=83.8$
$\Lambda_s R=167.6$
ω/Λ_s
$k_\perp/\Lambda_s$
LHC
RHIC
$m_s^{RHIC} \simeq 200$ MeV
$m_s^{LHC} \simeq 400$ MeV



$\Lambda_s R=20$
$\Lambda_s a=0.55$
$\Lambda_s a=0.275$
$\Lambda_s a=0.138$
$\frac{1}{k_\perp^4}$
$\frac{1}{\pi R^2}\frac{dN}{k_\perp dk_\perp} = n(k_\perp)$
$k_\perp/\Lambda_s$
~ 6 GeV at RHIC
0.1
0.001
1e-05
1e-07
0
4
8
12
16
20

Conclusions

When $\alpha_s(Q_s) \ll 1$:

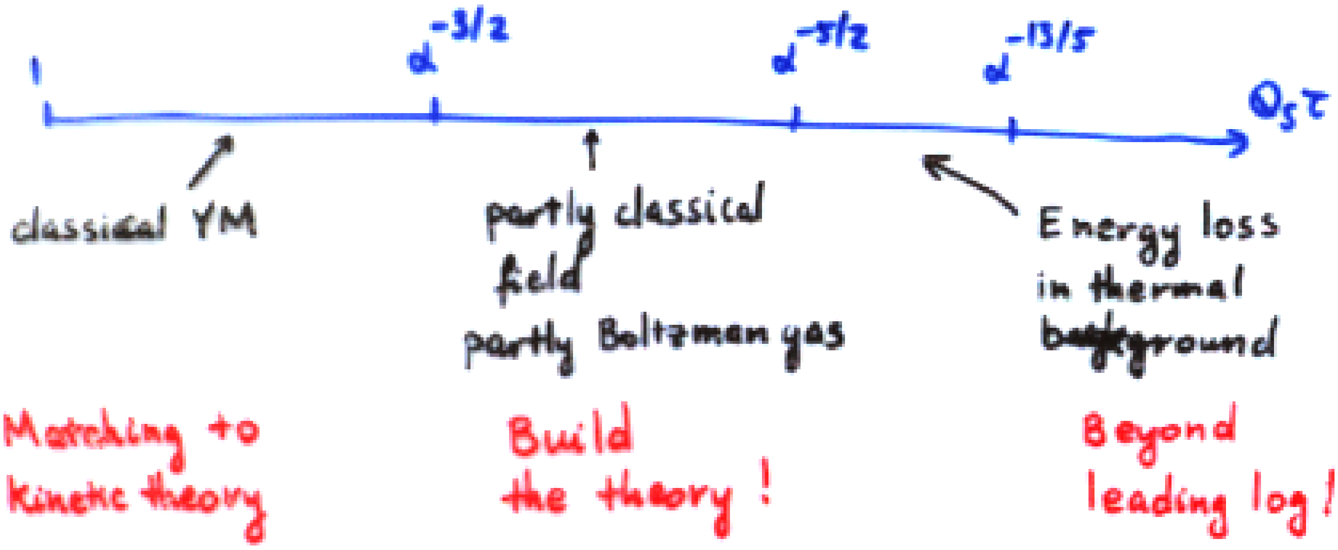
thermalization occurs

$$T \sim \alpha^{2/5} Q_s \quad \text{during} \quad \tau \sim \frac{1}{\alpha^{13/5} Q_s}$$

soft gluons thermalize *first*

$$\frac{N_{final}}{N_{initial}} \sim \frac{1}{\alpha^{2/5}}$$

- Three stages:



SPECIFIC OBSERVABLES

Fluctuations
V. Koch, M. Stephanov, A. Asakawa

Elliptic flow
P. Huovinen, D. Teaney, D. Molnar

Strangeness
K. Redlich, G.E. Brown

Dilepton
C. Gale, B. Kaempfer, R. Schneider, D. Srivastava, F. Gelis

J/ψ
J. Qiu, R. Thews, M. Dinh, A. Capella

FLUCTUATIONS

- "Interesting" sources of fluctuations
  (near phase transition (Gavin, Hama),
  DCC, ...)
  at large or small p_T.

- Fluctuations in conserved quantities (Koch, Asakawa, Stephanov)
  (NB. Related to correlator
  of conserved current)

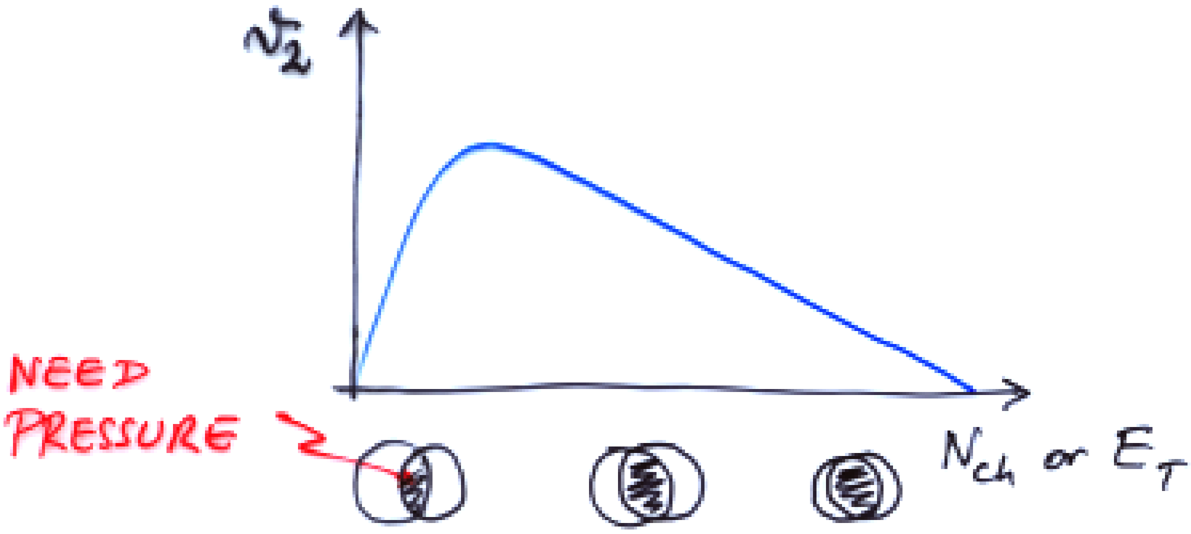
- Related work: "balance function"
  (S. Pratt)

In progress ...

"Absence of evidence is
not evidence of absence"

V. Koch

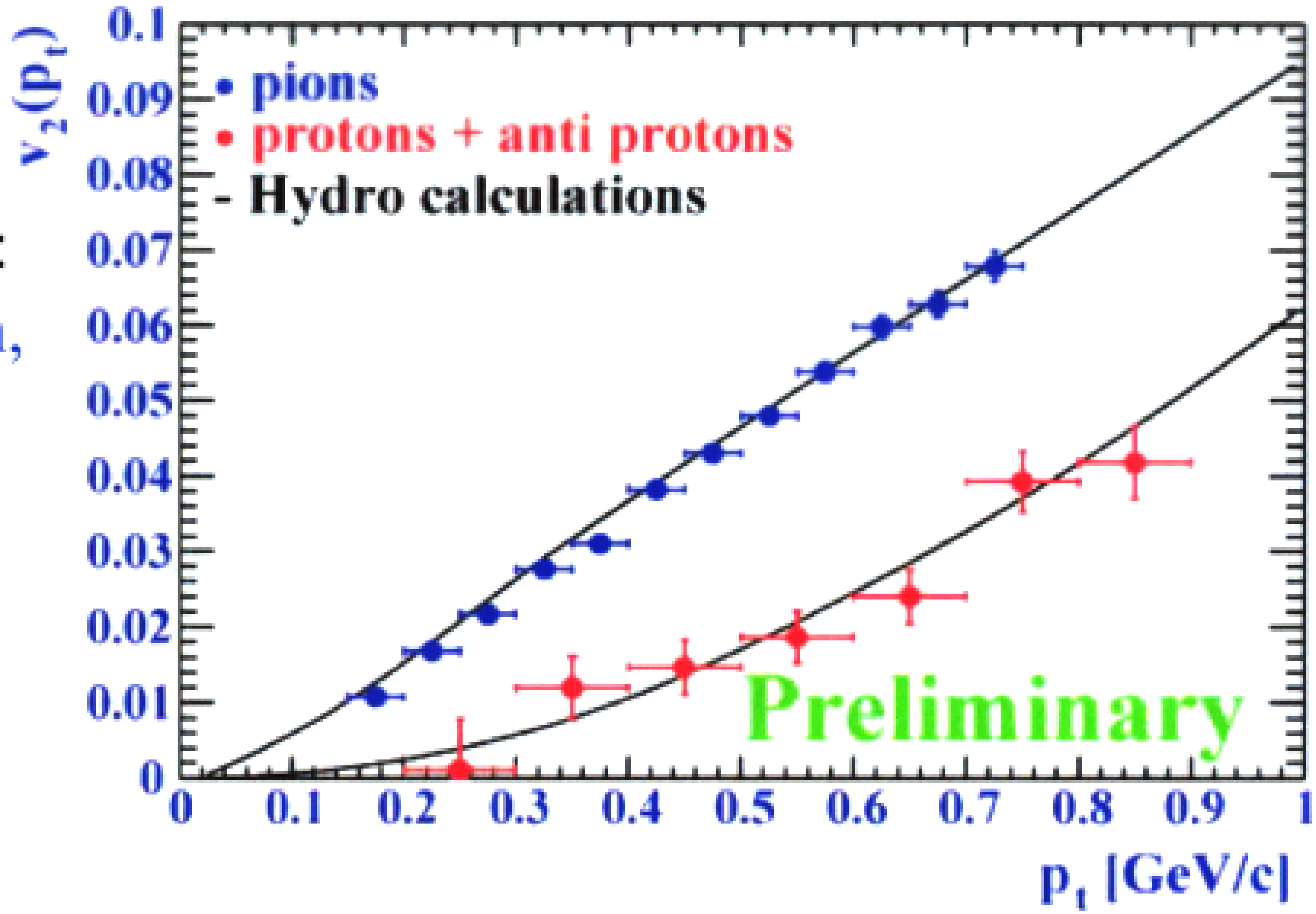
ELLIPTIC FLOW



- Linear decrease with centrality predicted by hydro (J.-Y. Ollitrault, 92)
- p_T dependence of v_2
  - effect of the mass
  - decrease at $p_T > 2$ GeV (predicted by X.N. Wang 09/00)
- QGP influence unclear
- Sensitivity to early times (?)

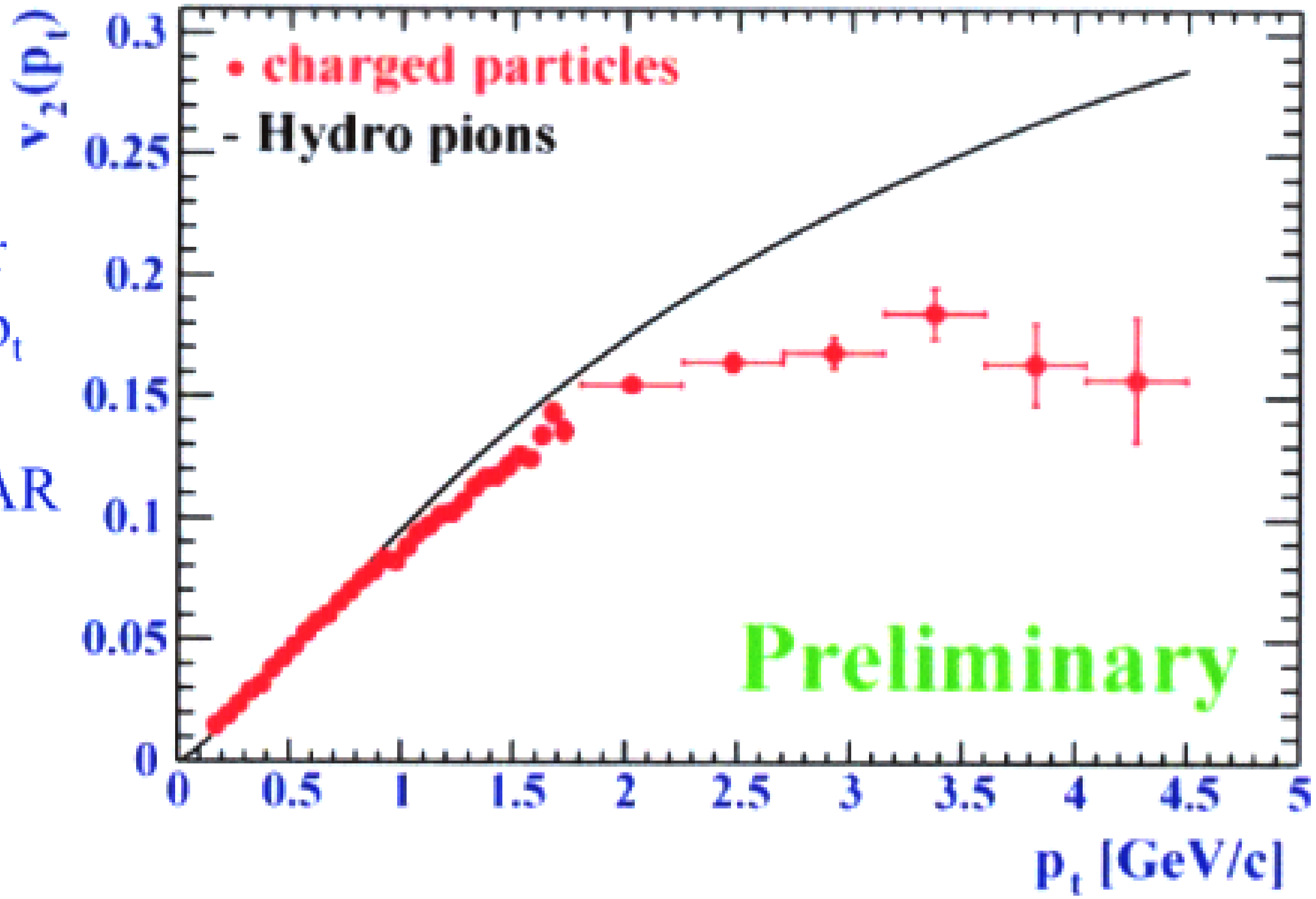
A Hydro view of the world

- Hydro calculations: P. Huovinen, P. Kolb and U. Heinz



Charged particle anisotropy
$0 < p_t < 4.5$ GeV/c

- Only statistical errors
- Systematic error 10% - 20% for $p_t = 2 - 4.5$ GeV/c
- More in the STAR high-pt talk (James Dunlop, PS2, this afternoon)

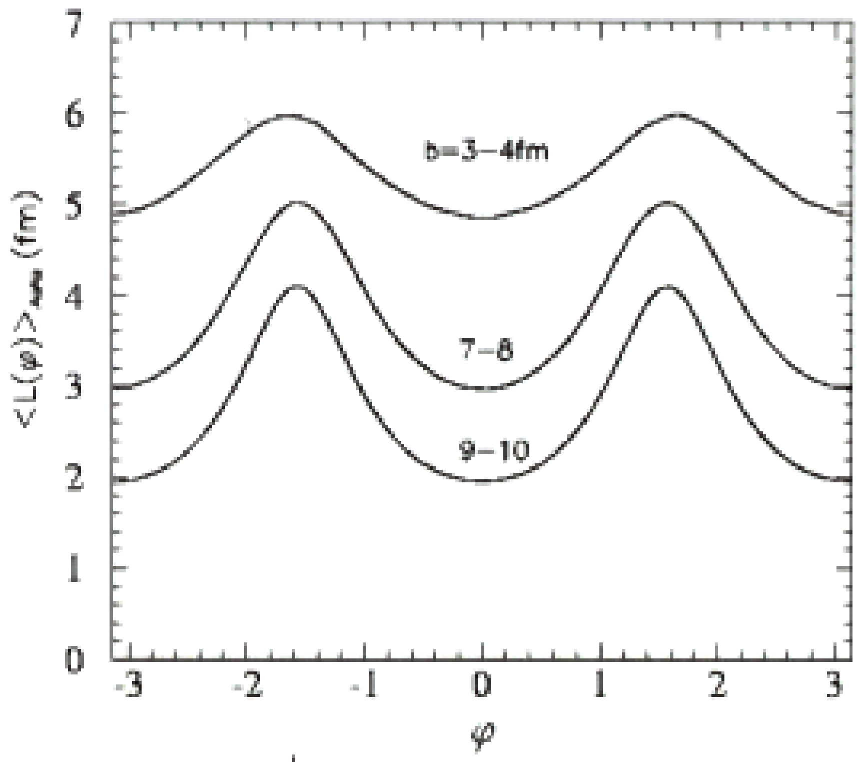


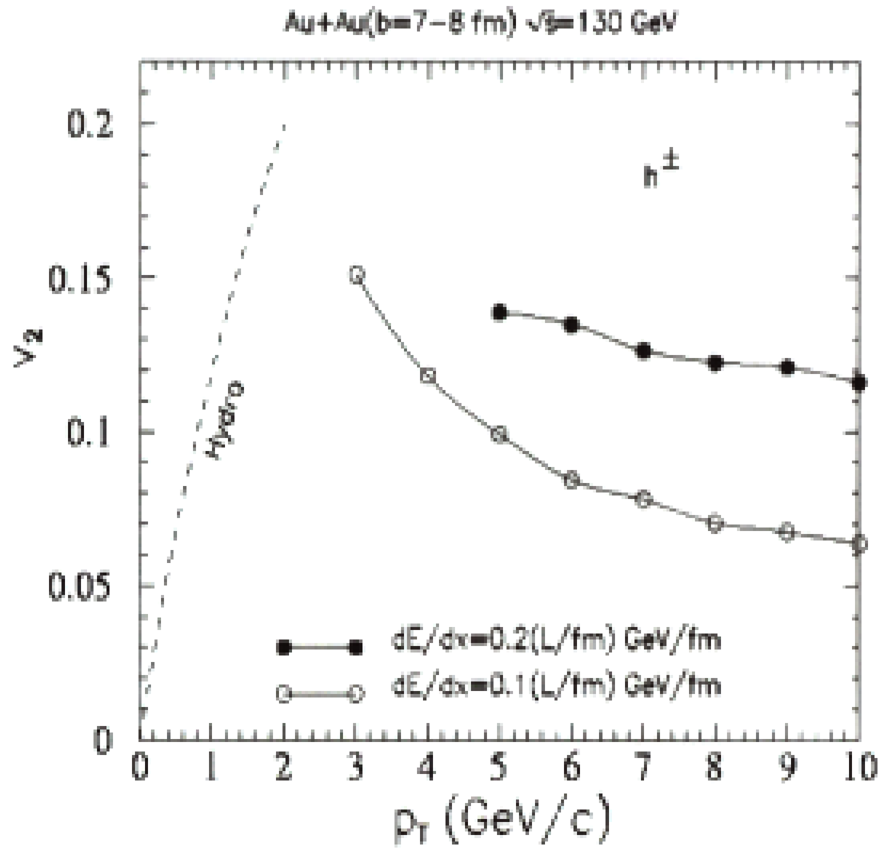
QM2001

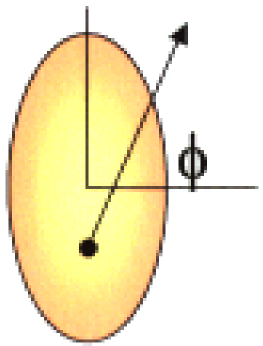
Azimuthal Anisotropy

Anisotropy in geometry:

nucl-th/0009019







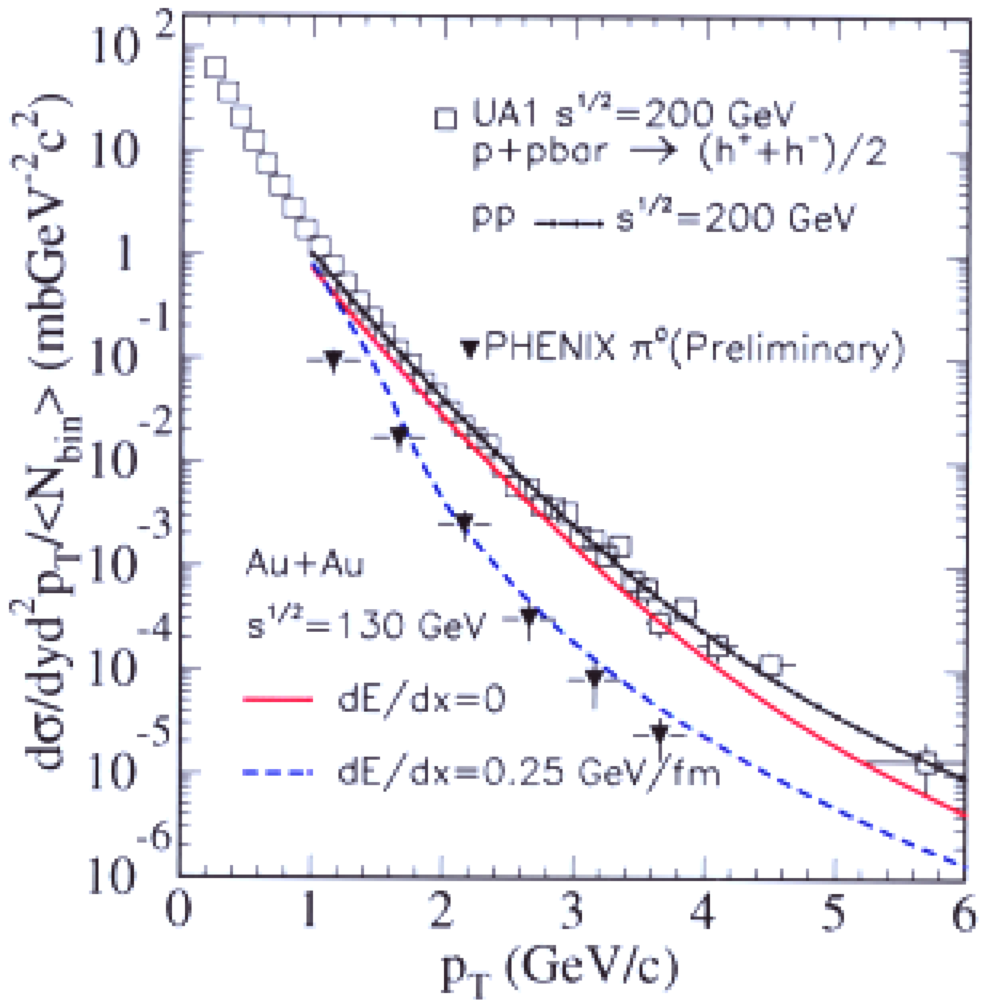
Anisotropy in jet quenching

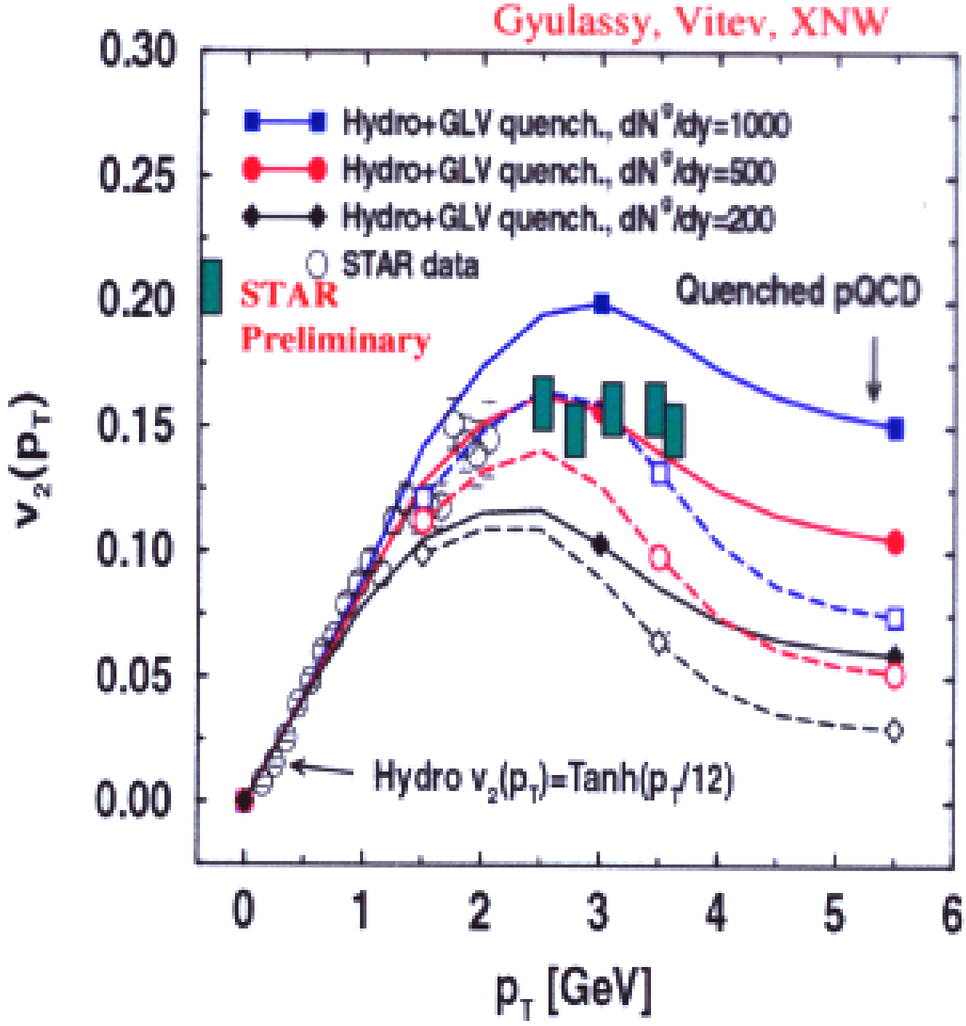
QM2001

Probes of initial parton density

$v_2(p_T)$ at large p_T is very sensitive to initial parton density

$\Delta E \propto \rho_g(\tau_0)$





STRANGENESS

- strangeness enhancement/suppression (K. REDLICH)

- how can we understand chemical equilibrium ?
  - role of n-body processes (Rapp)

    $$p\bar{p} \leftrightarrow n\,\pi$$

    $$\bar{Y} + p \leftrightarrow n_1\,\pi + n_2\,K \quad \text{(Greiner)}$$

  - also, dropping masses (G.E. Brown)

- threshold for onset of strangeness enhanament

Conclusions

SPS data are consistent with the predictions of QGP

However: these predictions are not a unique signal for deconfinement:

- Chemical equilibrium population of hadronic yields observed in A-A collisions from SIS, AGS, SPS to RHIC

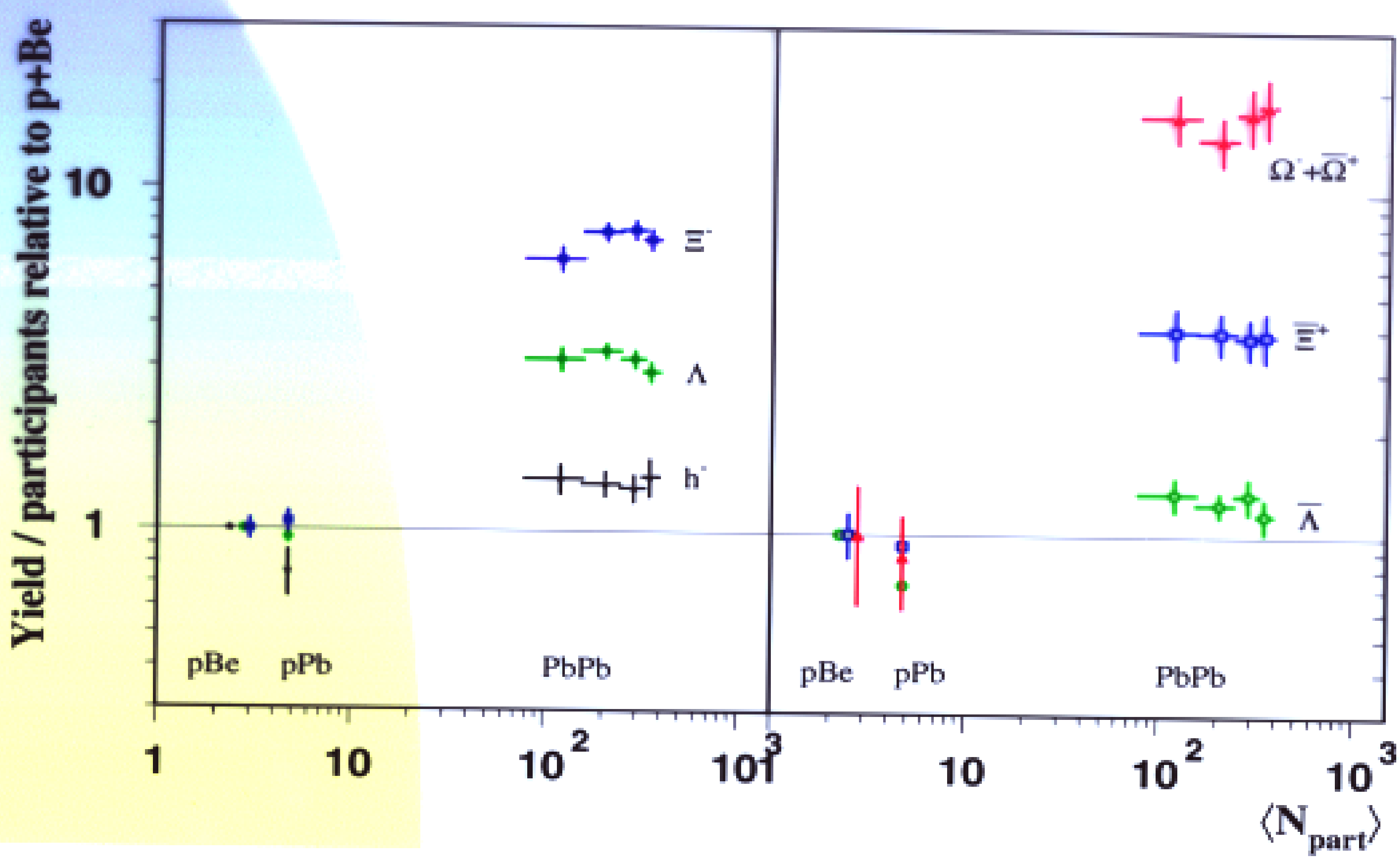
- Strangeness enhancement already appears in p-A
- Enhancement (K^+/π^+) from p-A to A-A collisions increases with decreasing $\sqrt{s}$

  the above also expected for multistrange baryons?

- Suppression of K^+/π^+ (NA49 4π data) from 40 =>158 AGeV Pb-Pb collisions could signal new dynamics

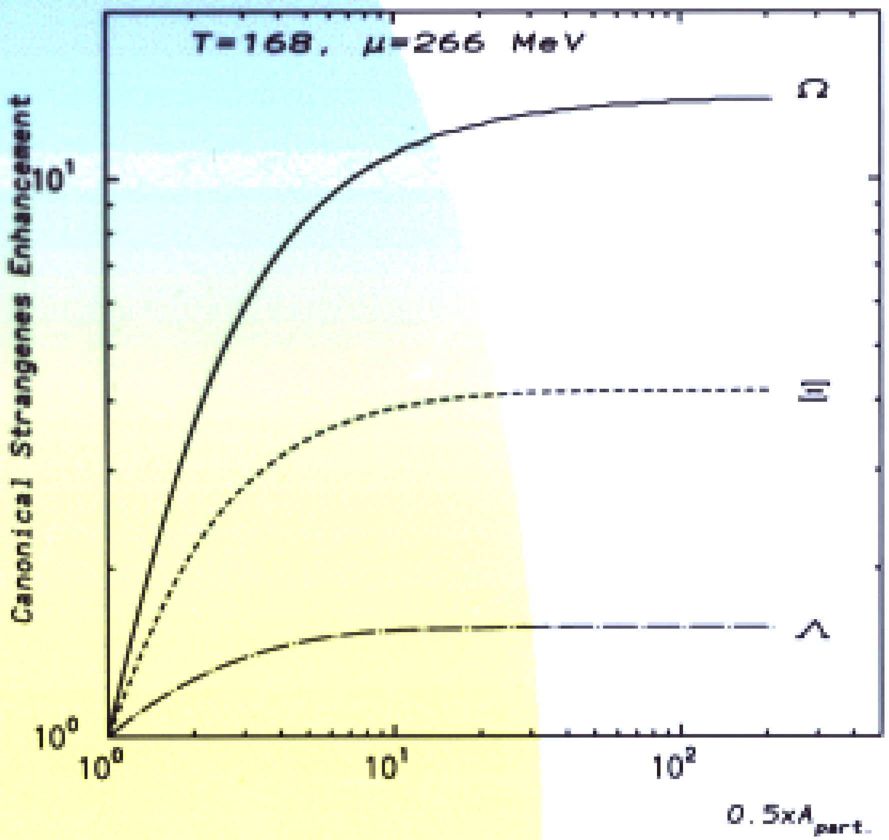
(Multi) Strange Baryons Enhancement

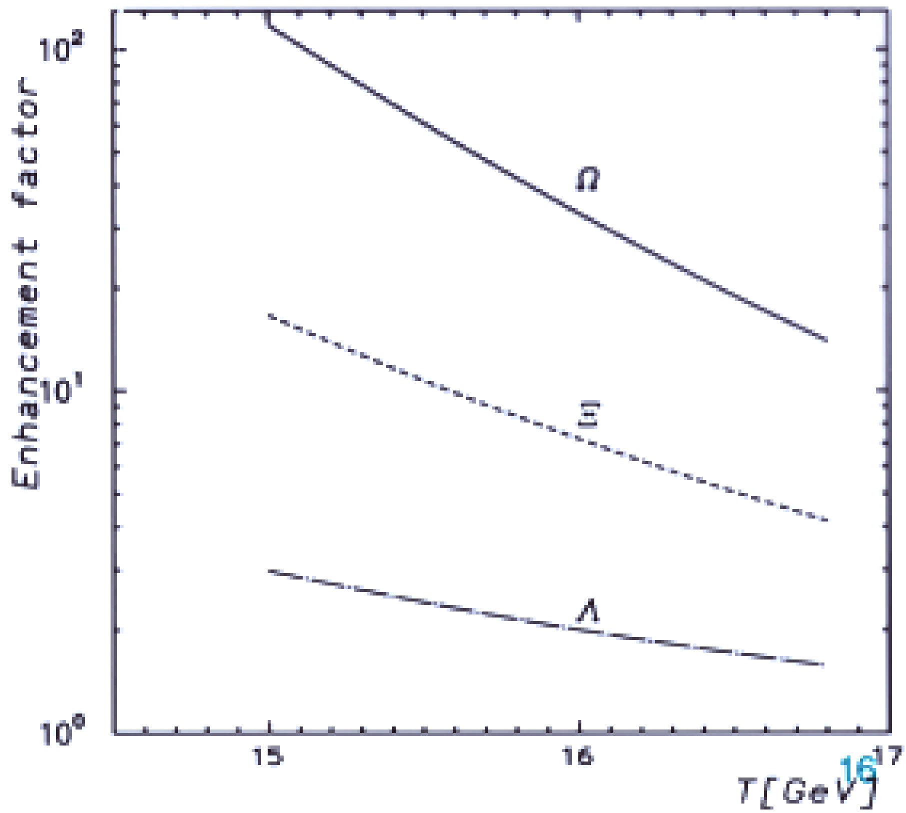
WA97



Statistical Model – Centrality Dependence

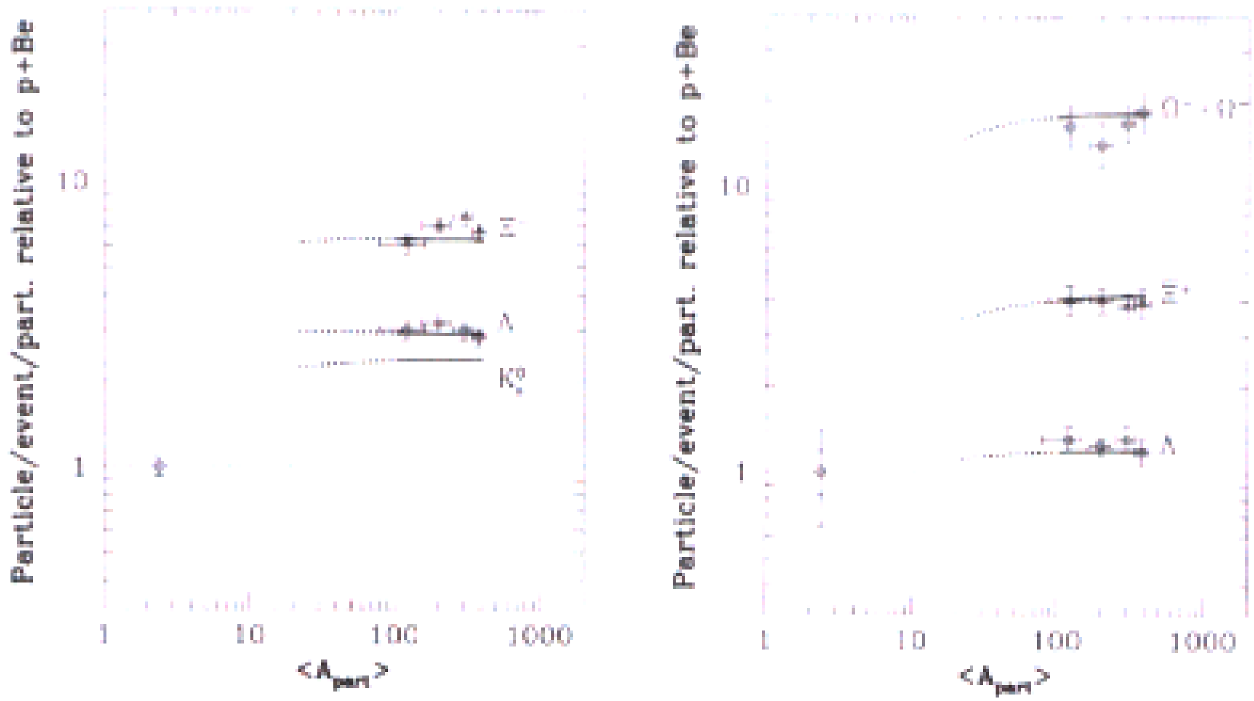
approaching asymptotic - grand canonical limit



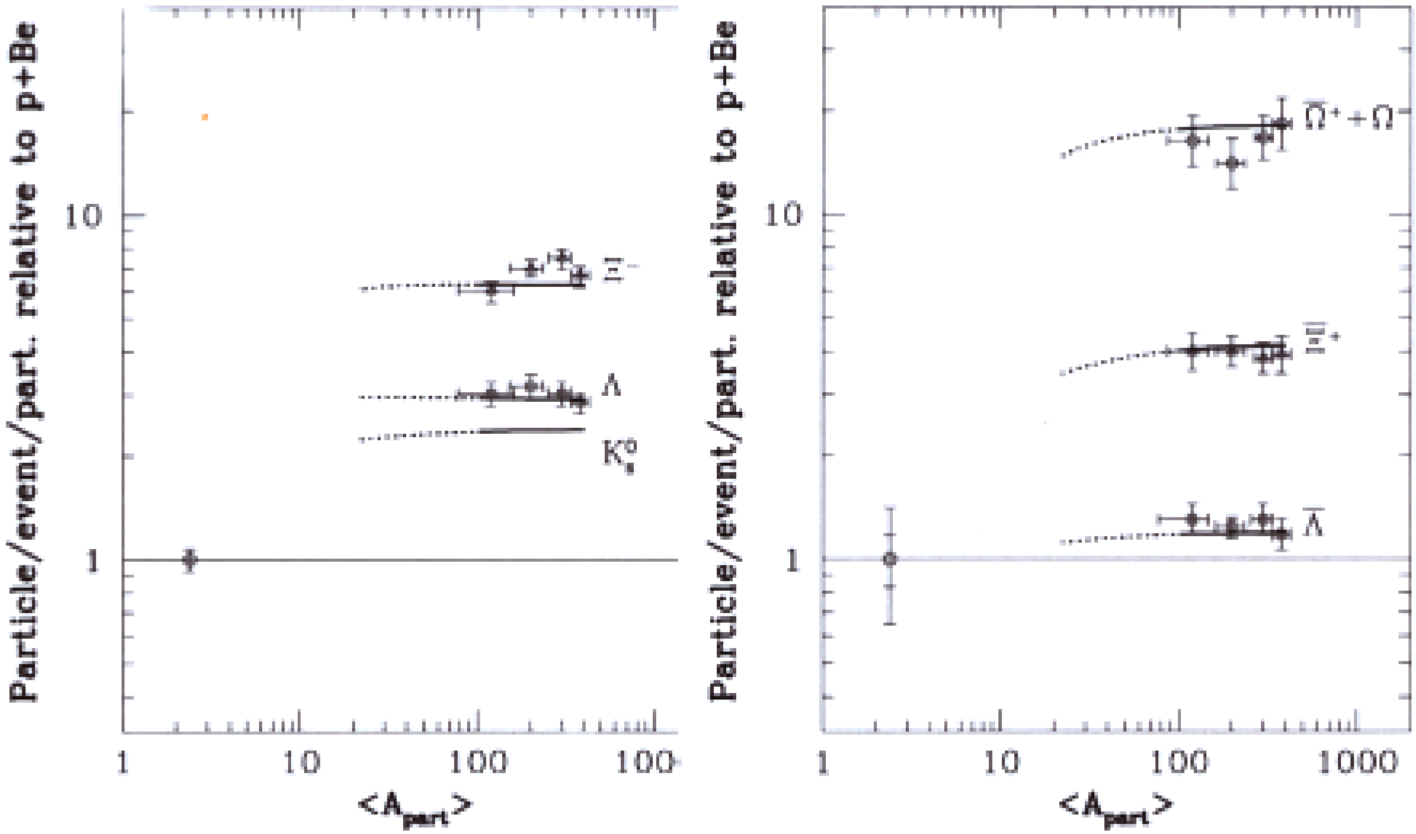


Statistical canonical model

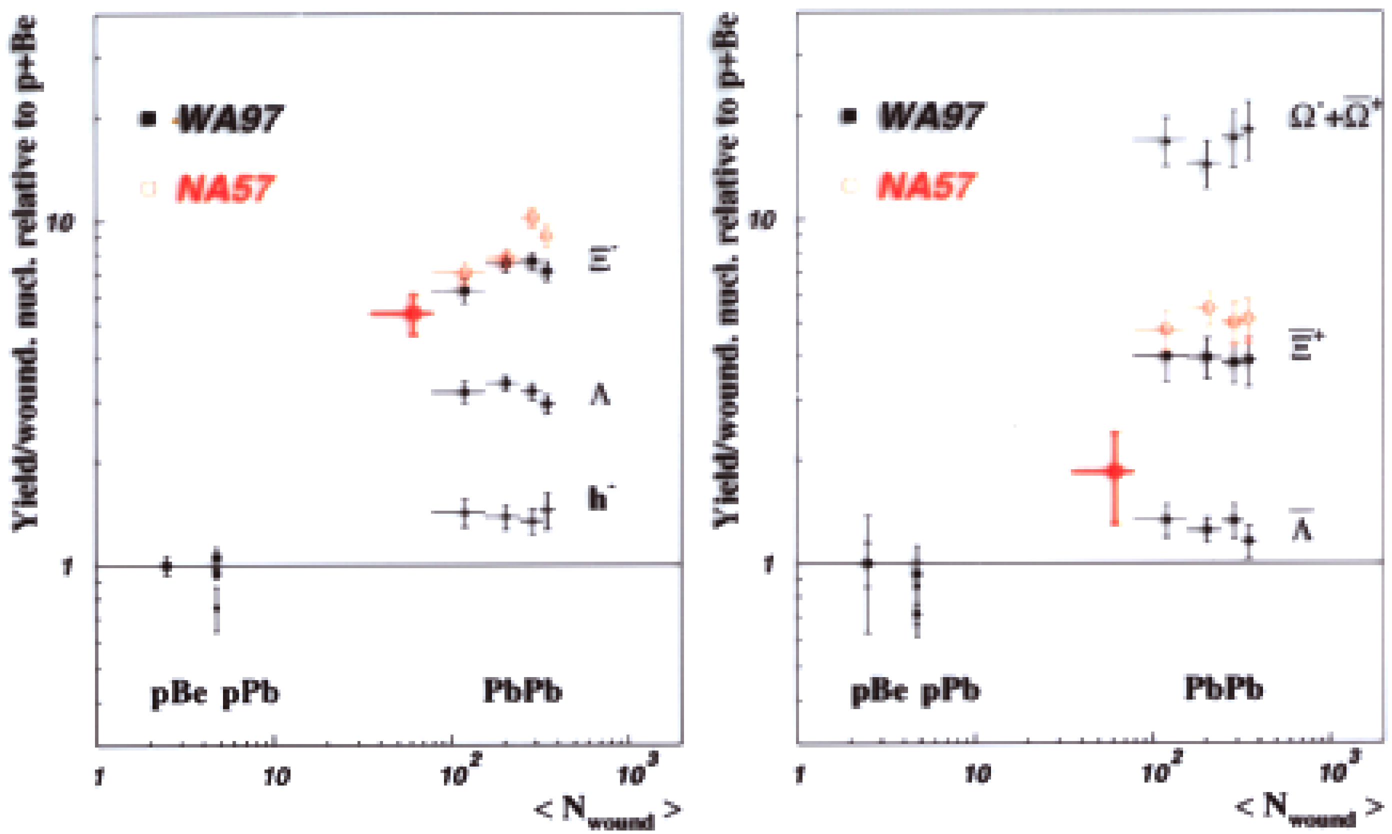
S. Hamieh, K. Redlich and A. Tounsi hep–ph/0006024



- Reproduces WA97 hyperon data
- Predicts enhancements ~saturated down to N_{wound}=20


Particle/event/part. relative to p+Be
10
1
1
10
100
100
$\langle A_{part} \rangle$
Ξ^-
Λ
K^0_s
Particle/event/part. relative to p+Be
10
1
1
10
100
1000
$\langle A_{part} \rangle$
$\bar{\Omega}^+ + \Omega^-$
$\bar{\Xi}^+$
$\bar{\Lambda}$

Yields per participant



- Yield per N_{wound} rises from $\langle N_{wound} \rangle = 62 \rightarrow 121$ both for Ξ^- and for $\bar{\bar{\Xi}}^+$
  - 2.6 for $\overline{\Xi}^+$ (3.5 σ effect)

PHOTONS - DILEPTONS

Reviewed by C. Gale

Low mass dileptons (Schneider, Kaempfer)

Some progress but new precision data are waited

Direct photons

QCD Calculation of the rate at 2 loop order (F. Gelis)

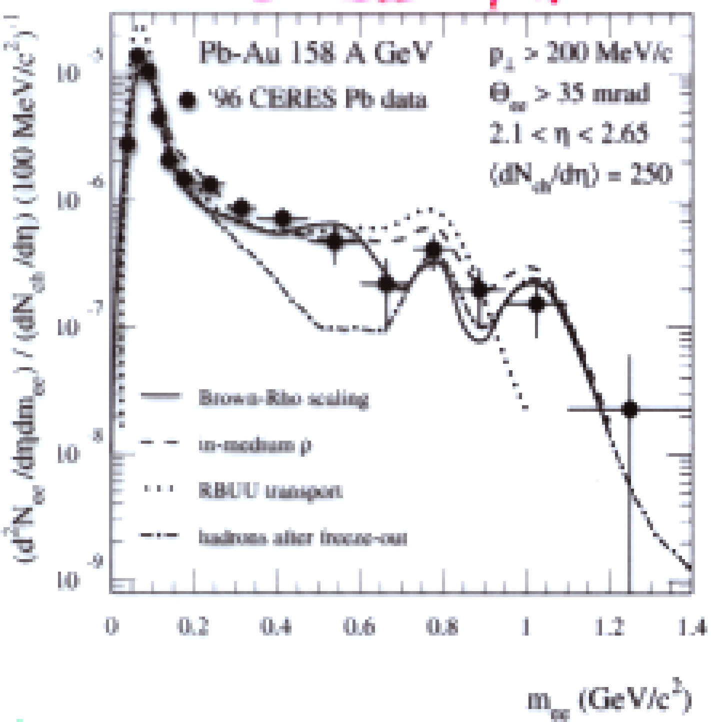
When included in hydro evolution, fit WA98 - But inconclusive. (D. Srivastava)

Intermediate mass dileptons

Role of thermal contributions (competing with open charm)

Dileptons: low mass

I. TSERRUYA, 99

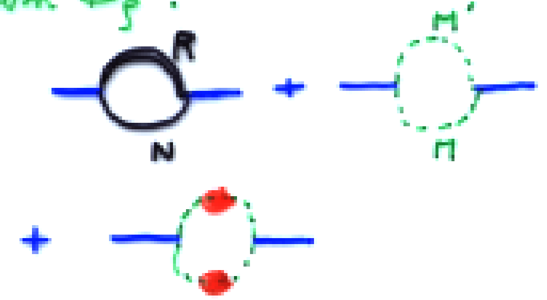


BR: BROWN, RHO, LI 1997

TRANSPORT: V. KOCH, 1999

CASSING & BRATKOVSKAYA 98

dm. D_ρ :



FRIMAN, PIRNER 97

HERRMANN, FRIMAN, NÖRENBERG 92

RAPP, CHANFRAY, WAMBACH 97

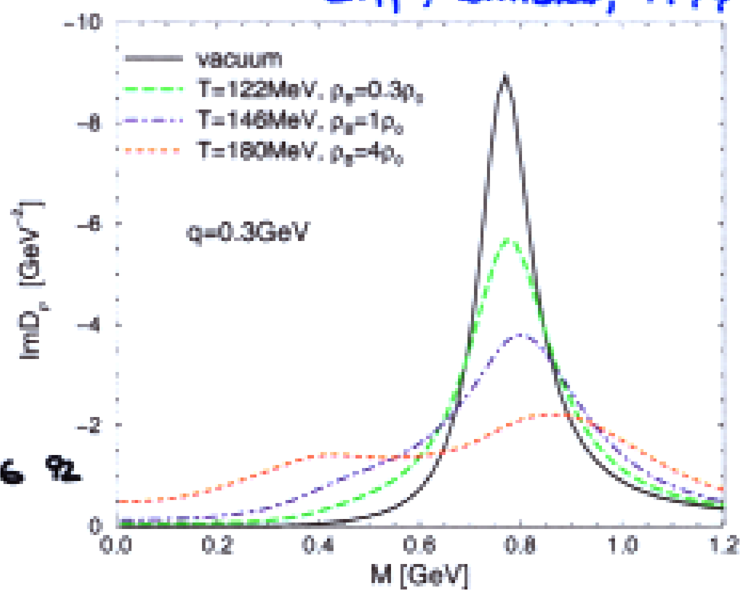
PETERS et al. 98

SIBIRTSEV, CASSING 98

ELETSKY, IOFFE, KAPUSTA 98

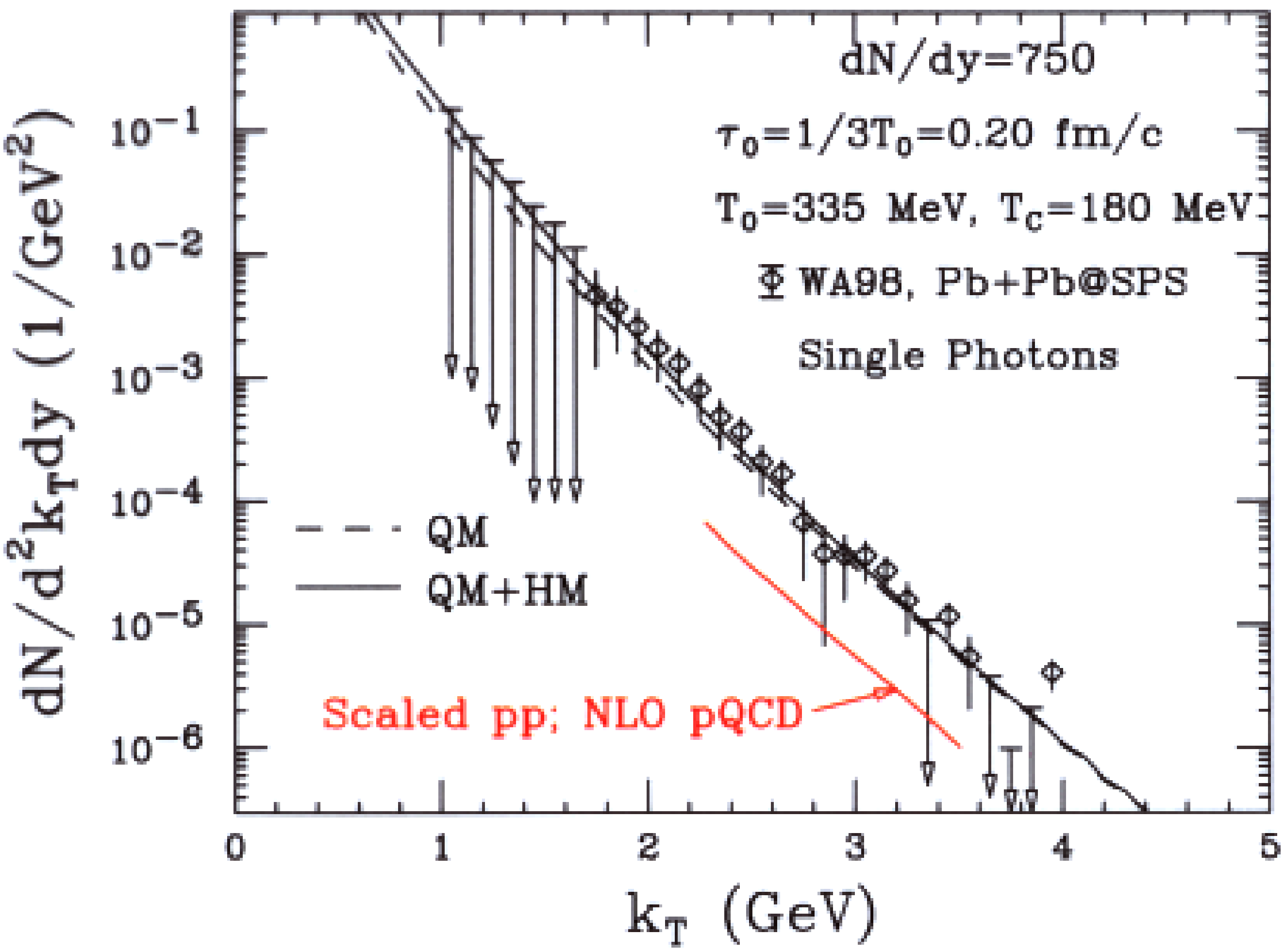
⋮

RAPP & WAMBACH, 1999



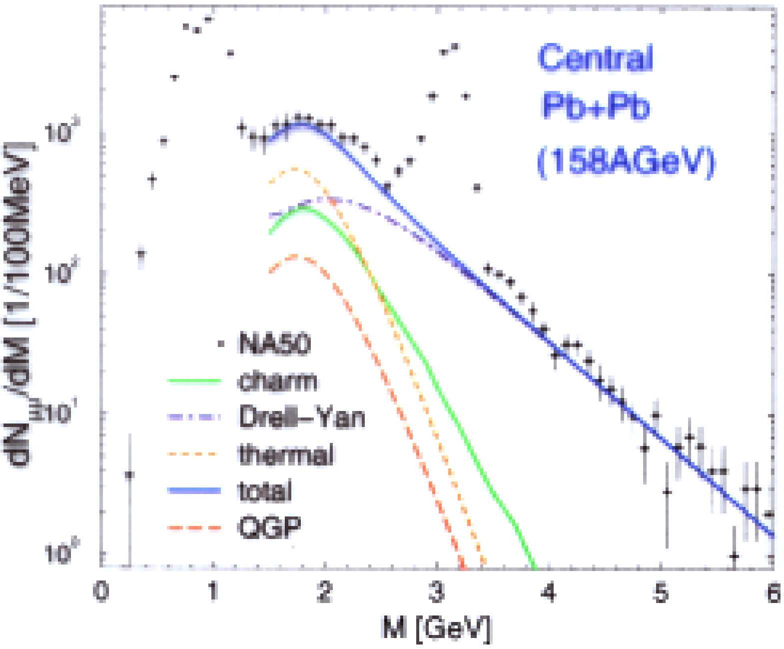
- γA DATA
- $p_\perp$ DEPENDENCE OF [illegible] EXCESS

D.K. SRIVASTAVA & B. SINHA, 2000

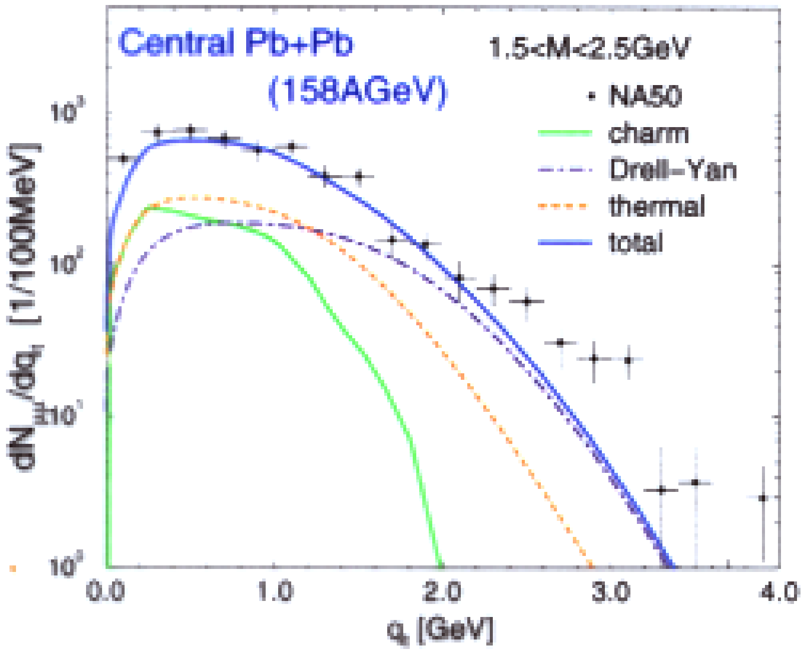


CONTAINS THE HIGHER ORDER α_s^2 RESULTS OF AURENCHE, GÉLIS et al.

Intermediate mass dileptons (II)



R. RAPP & E. SHURYAK,
PHYS. LETT. B473, 13
(2000).



THE INTERMEDIATE-MASS REGION "IS FILLED IN" BY THE "THERMAL" CONTRIBUTION.

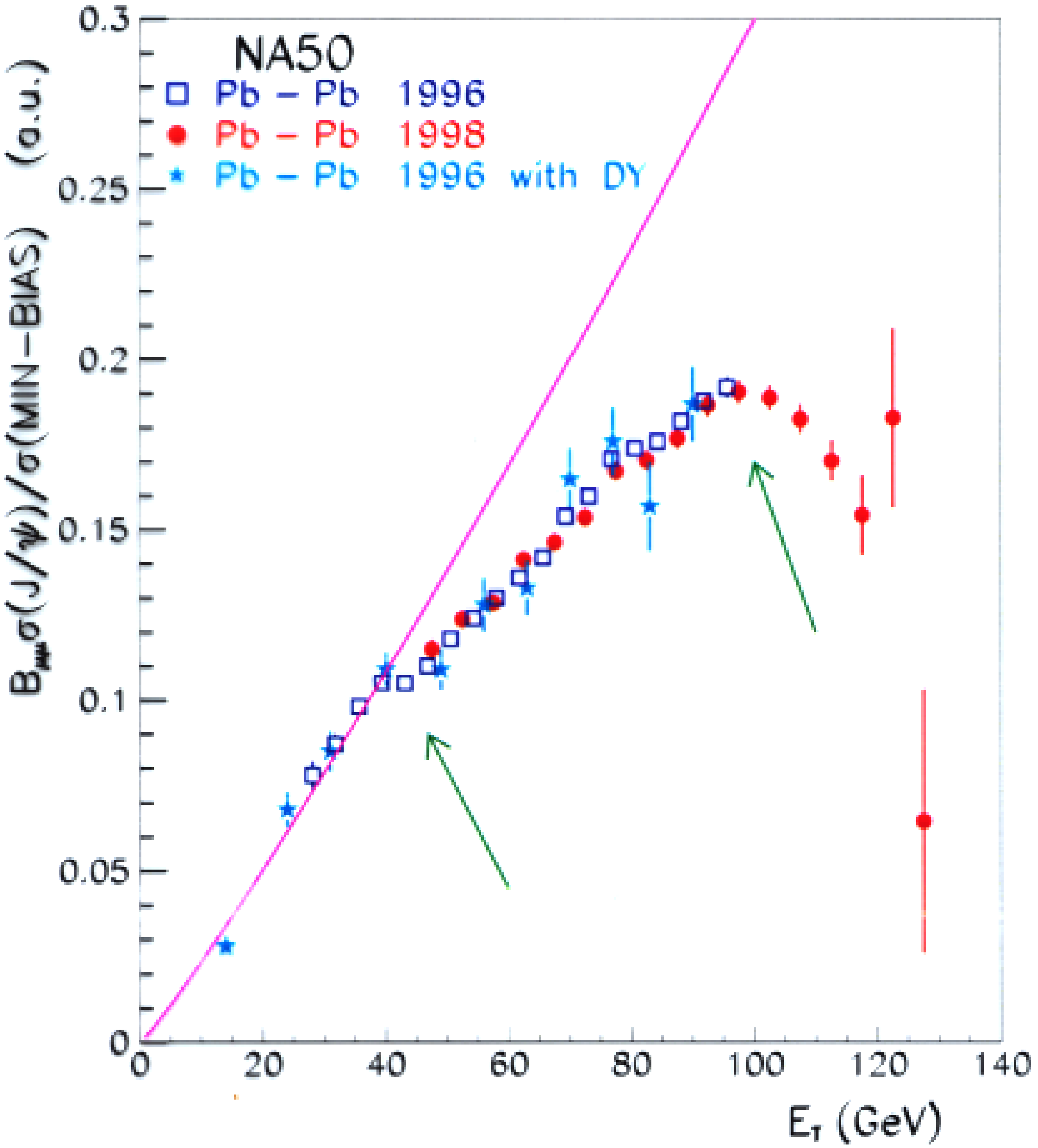
J/ψ

- New mechanism for "nuclear absorption" (J. Qiu)

- Role of transverse energy fluctuations (M. Dinh, A. Capella)

- J/ψ enhancement at RHIC ! (R. L. Thews)

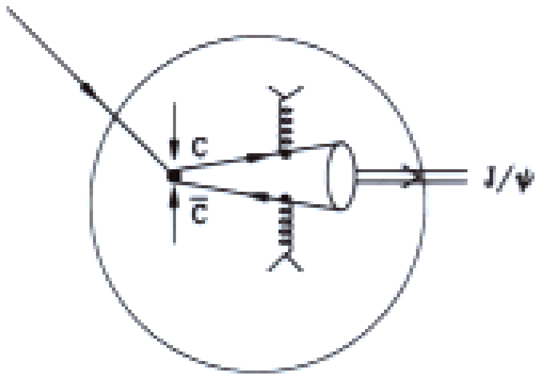
ψ/Minimum Bias as a function of E_T



Solid line: Absorption Model with $\sigma_{abs} = 6.4 \pm 0.8\ mb$ **as obtained from fit to p-A and S-U data (NA38 + NA51) with full calculation**

Pattern exhibits 2 "accidents"

New Suppression Mechanism

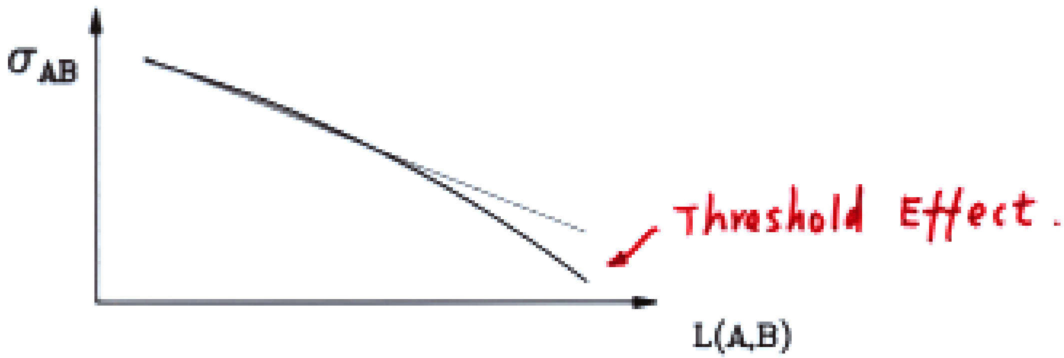


- J/ψ are not produced at the point of hard collision
  $\Rightarrow$ partonic $c\bar{c}$ states going through medium

- Multiple scattering with nuclear medium increase the invariant mass of the $c\bar{c}$ pairs
  $\Rightarrow$ push some $c\bar{c}$ pairs over the open charm threshold
  $\Rightarrow$ "suppress" the production of J/ψ (see figure)

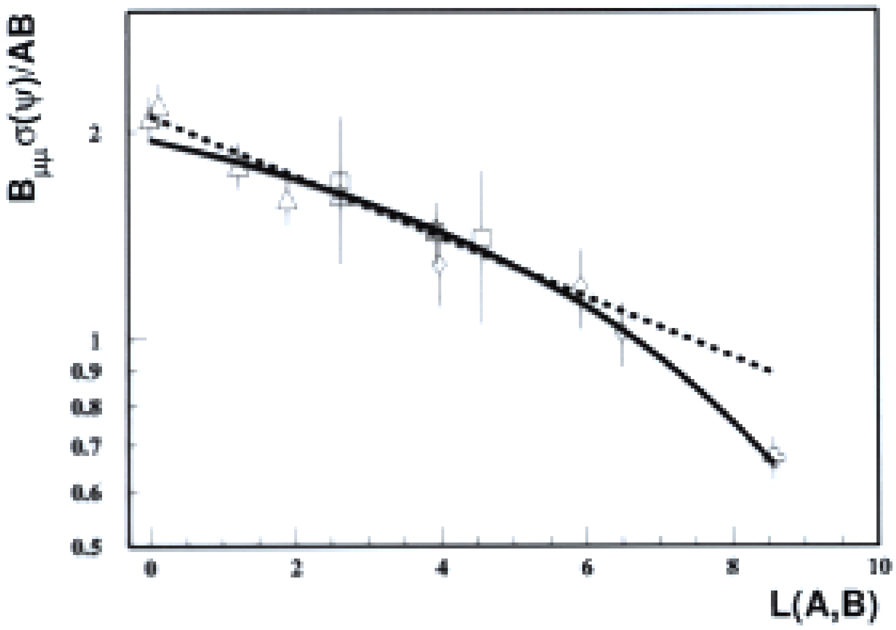
- The suppression rate depends on
  - Gain of invariant mass per medium length: ϵ
  - Functional form of the transition probability: $F_{[c\bar{c}]\to J/\psi}(m^2_{c\bar{c}})$
  - Functional form of the $c\bar{c}$ cross section: $\frac{d\sigma_{AB\to c\bar{c}}}{dm^2_{c\bar{c}}}$

- Expect a non-linear behavior on the semi-log plot

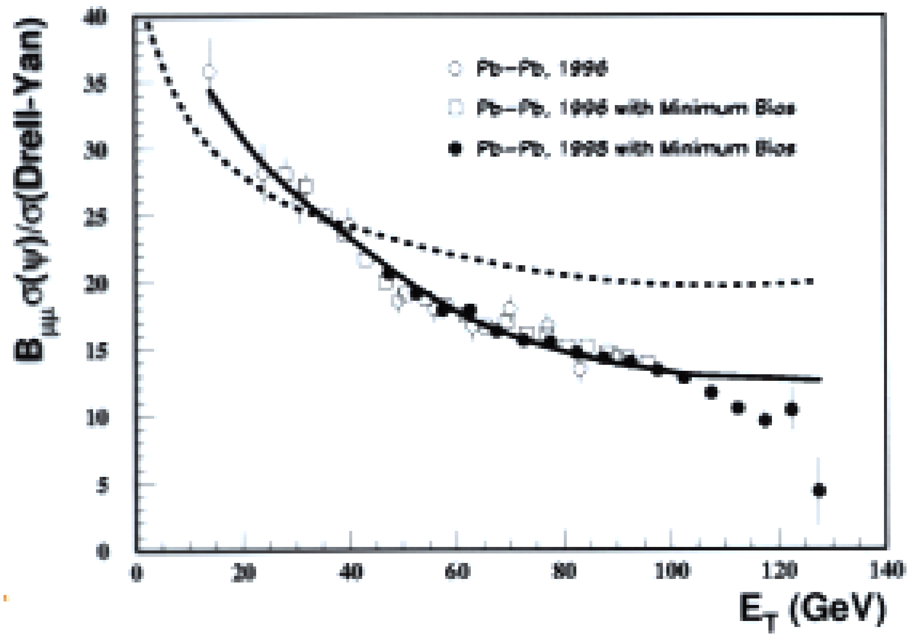


Comparison with J/ψ Suppresion Data*

- J/ψ production as a function of effective medium length:



- Ratio of J/ψ over Drell-Yan as a function of E_T:



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*Data from Phys. Lett. B410, 337 (1997); B477, 28 (2000)

Variations of $\langle\, p_T^2 \,\rangle$

Assumptions

- Initial state scattering

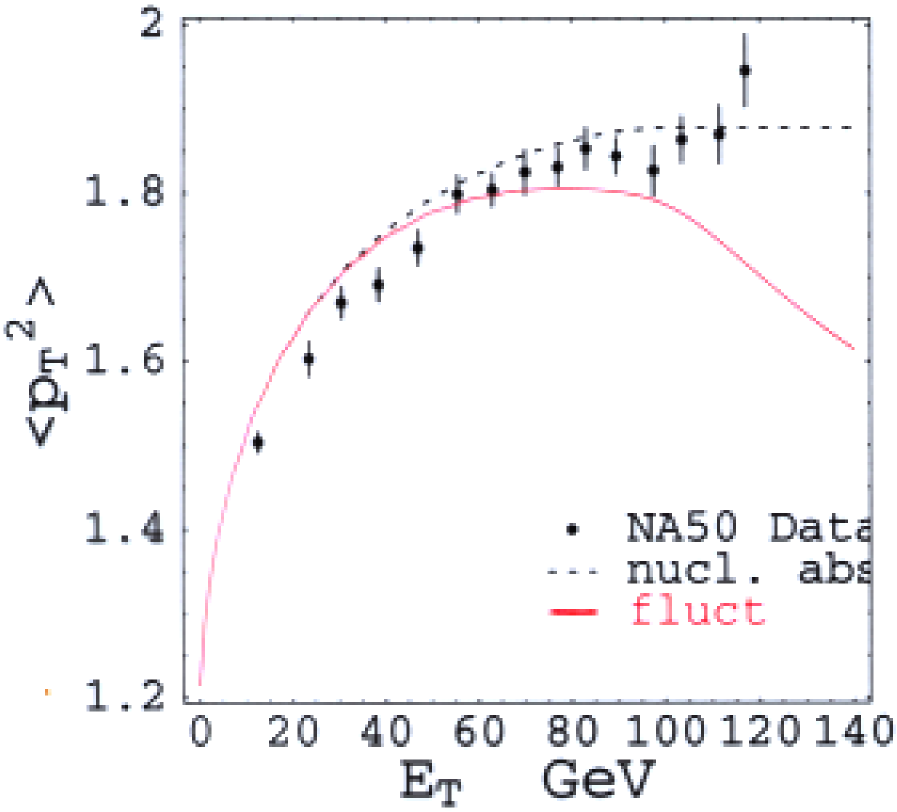
$$\langle\, p_T^2 \,\rangle_{AB} = \langle\, p_T^2 \,\rangle_{pp} + a\langle L\rangle$$

length of crossed matter $\hookleftarrow$

NA50, CERN-EP-2000-141 Nov 2, 2000

Kharzeev *et al*, Phys. Lett. **B405** (1997) 14

- Anomalous suppression taken p_T–independent



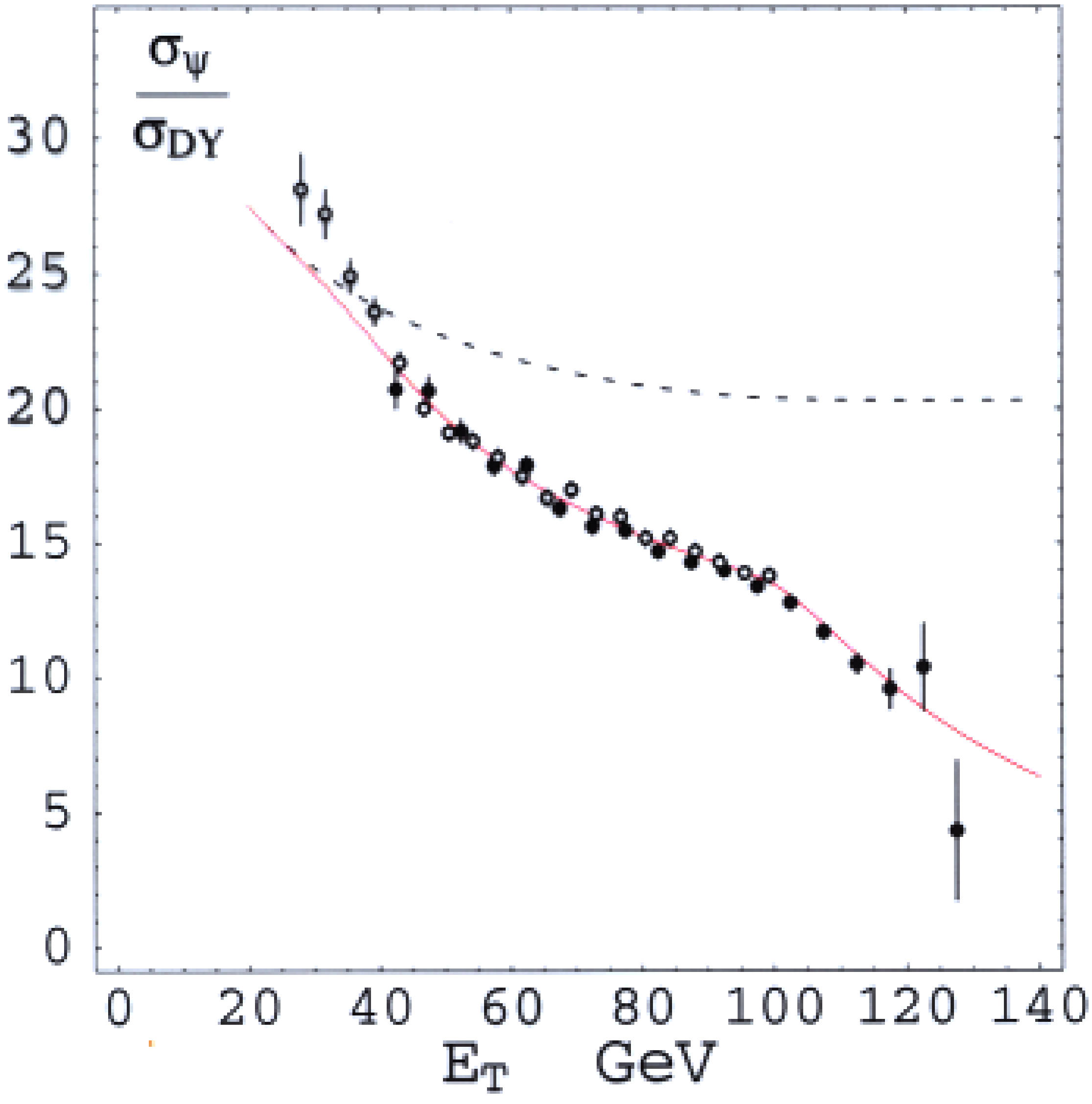
- Possible improvement

  consider less suppression at high p_T

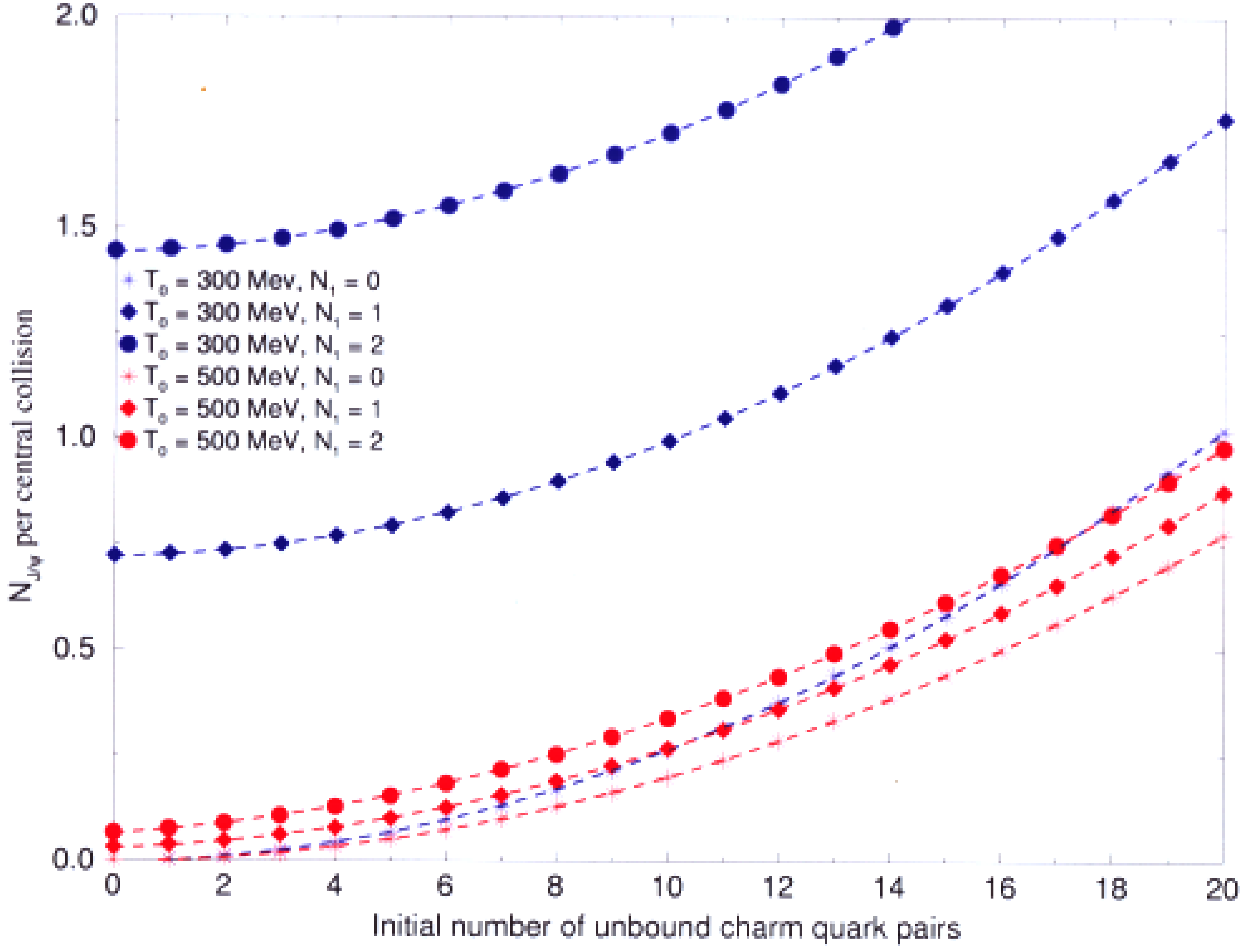
Fit to NA50 Data (2)

[M. Dinh]

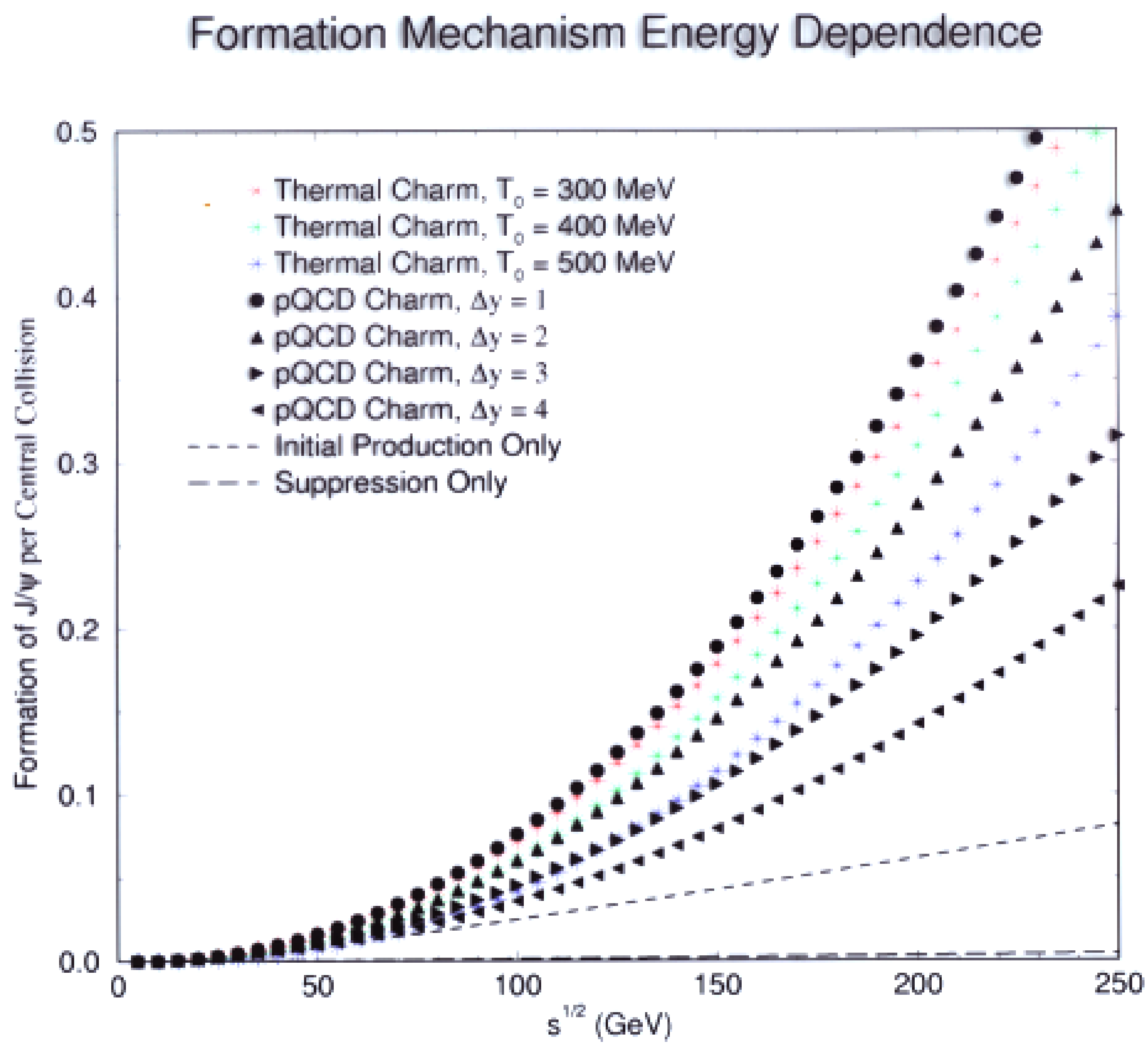
Two thresholds or gradual suppression



R. Thews.



2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
16
18
20
$N_{J/\psi}$ per central collision
Initial number of unbound charm quark pairs
T_0 = 300 Mev, N_1 = 0
T_0 = 300 MeV, N_1 = 1
T_0 = 300 MeV, N_1 = 2
T_0 = 500 MeV, N_1 = 0
T_0 = 500 MeV, N_1 = 1
T_0 = 500 MeV, N_1 = 2



Formation Mechanism Energy Dependence
Thermal Charm, T_0 = 300 MeV
Thermal Charm, T_0 = 400 MeV
Thermal Charm, T_0 = 500 MeV
pQCD Charm, Δy = 1
pQCD Charm, Δy = 2
pQCD Charm, Δy = 3
pQCD Charm, Δy = 4
Initial Production Only
Suppression Only
Formation of J/ψ per Central Collision
$s^{1/2}$ (GeV)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250