

Heavy Quark Probes of QCD Matter

International Symposium

On

The QCD Phase Diagram

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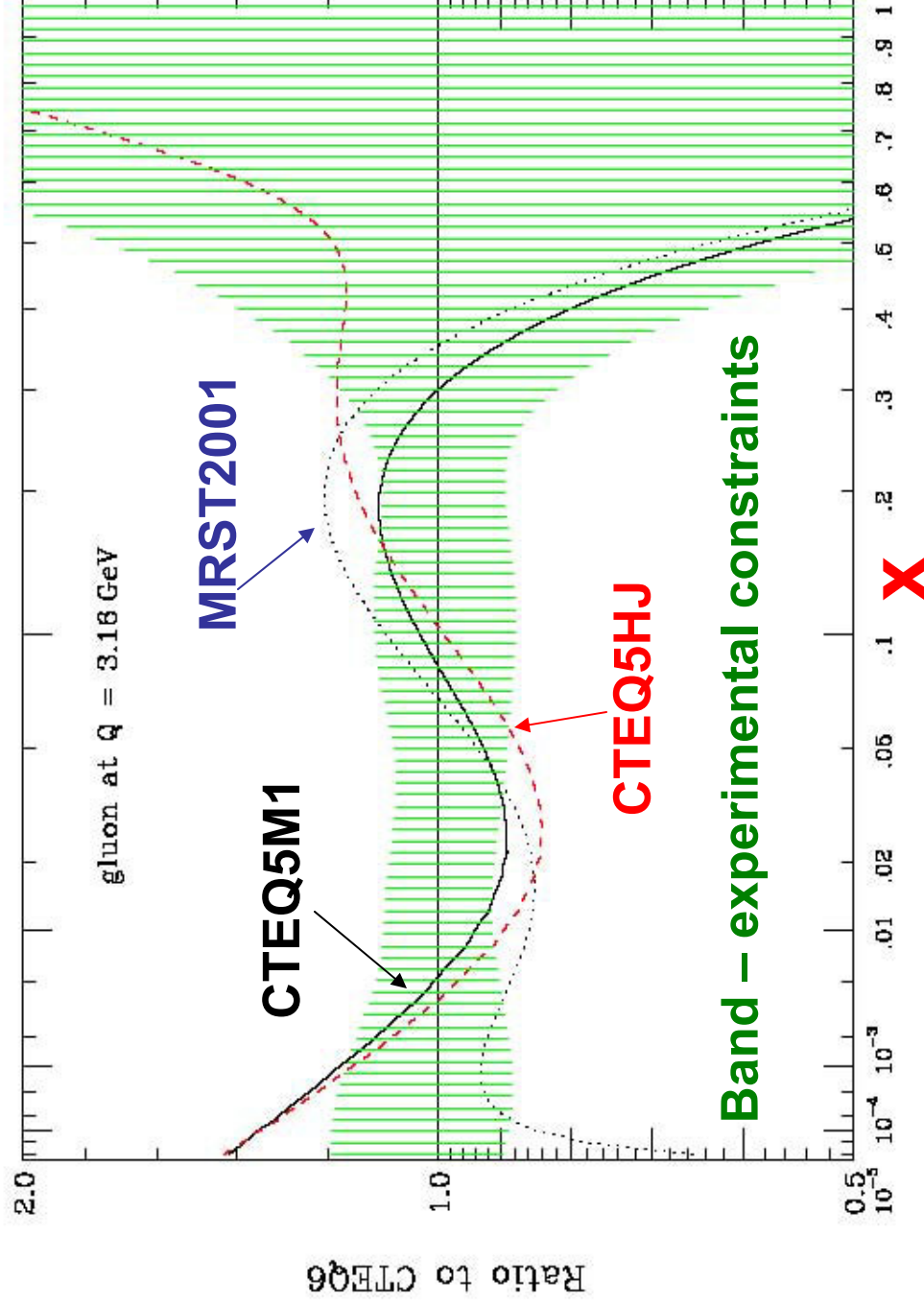
Thanks to An Tai, Zhangbu Xu, Hans Georg Ritter, Nu Xu, R. Vogt, Jingguo Ma

Outline

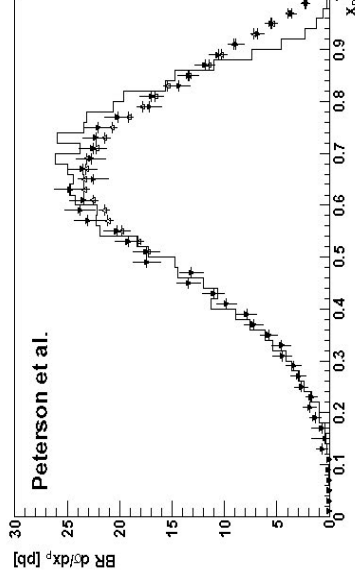
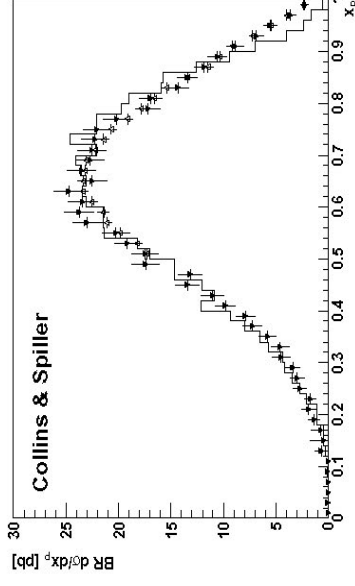
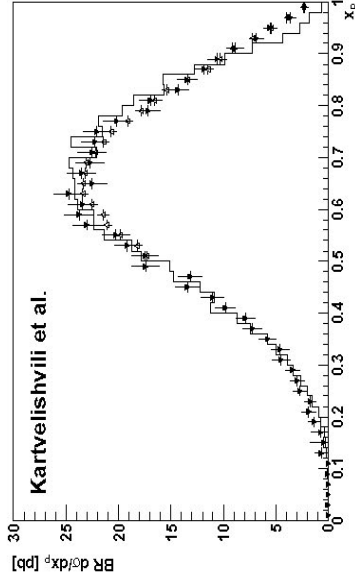
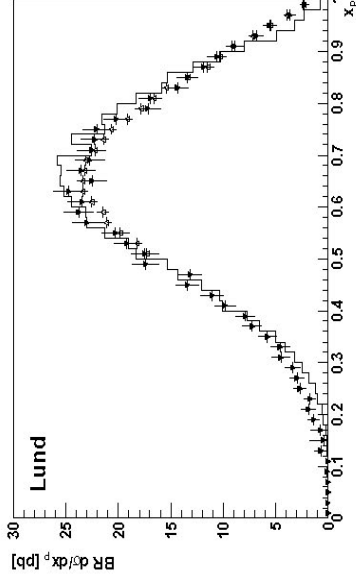
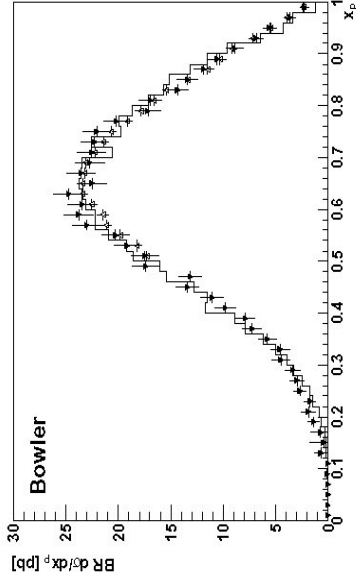
- 1) Charm quark fragmentation or else**
- 2) Charm at Intermediate p_T**
- 3) Charm Suppression and Enhancement**
- 4) Heavy Quark and QCD Properties of Matter**

Uncertainties in gluon structure function of the proton

J. Pumplin et al, JHEP07(2002)012

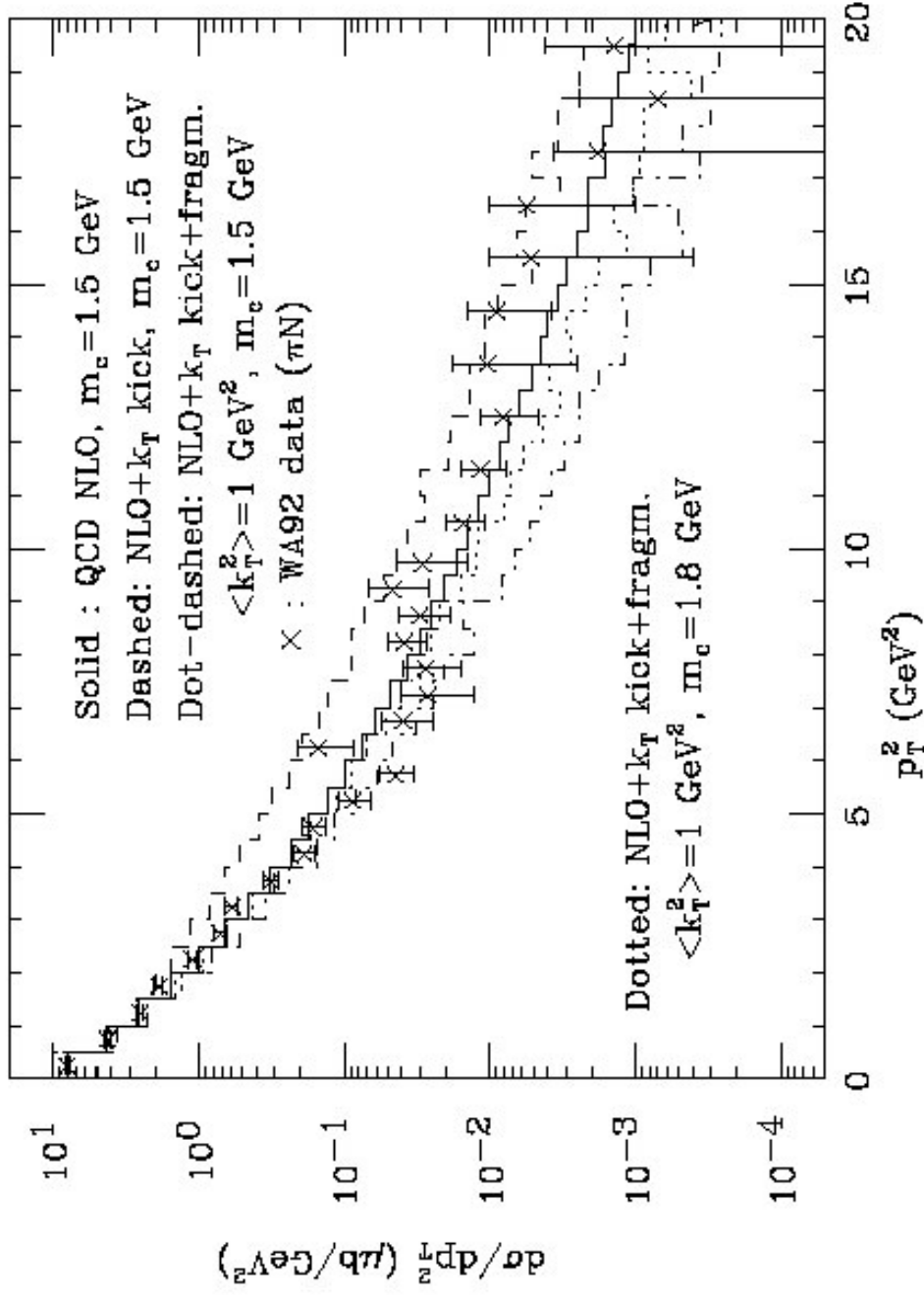


Fragmentation Functions from e+e- Collisions



Belle Data

Charm Mesons from Hadronic Collisions

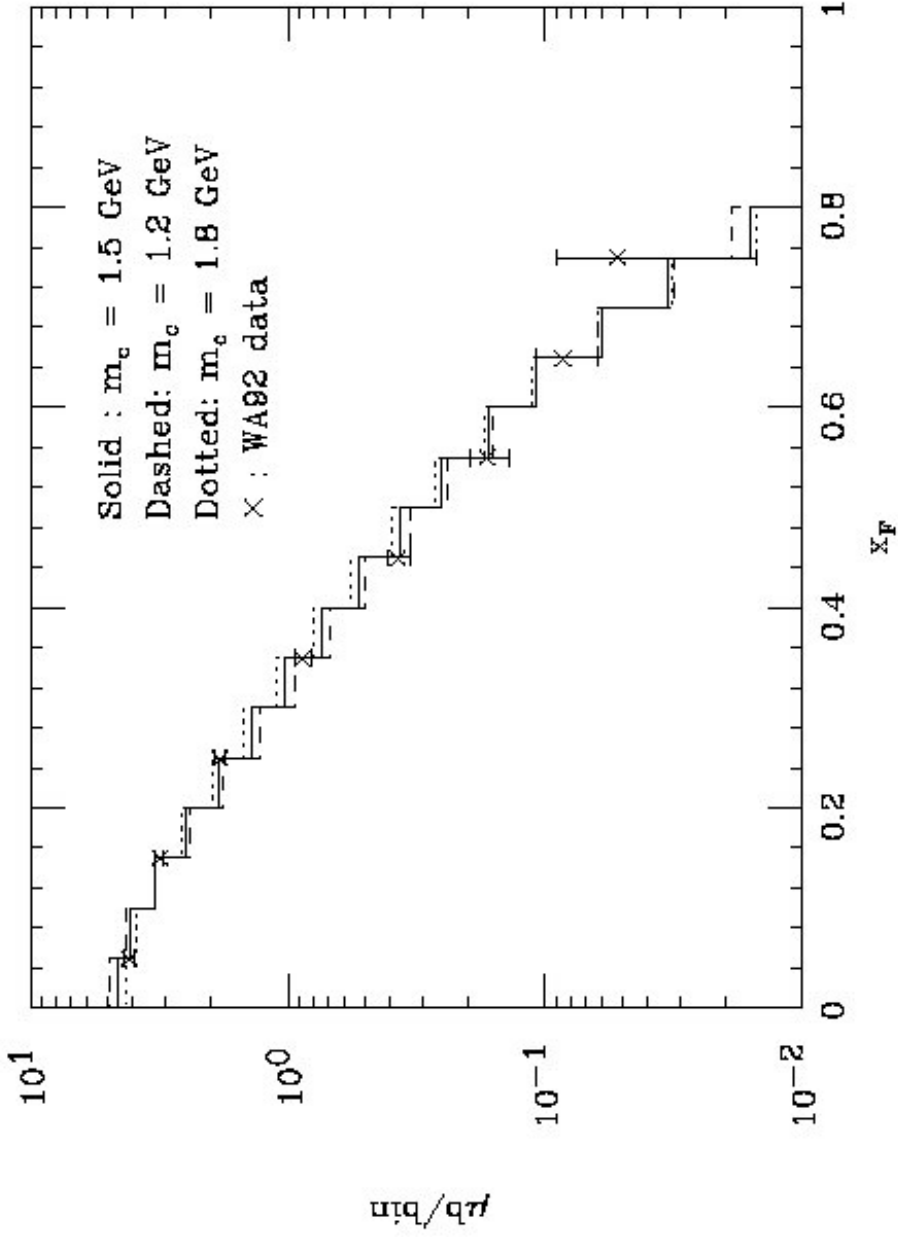


Charm meson $p_T \sim$ follow the NLO charm quark p_T

-- add k_T kick

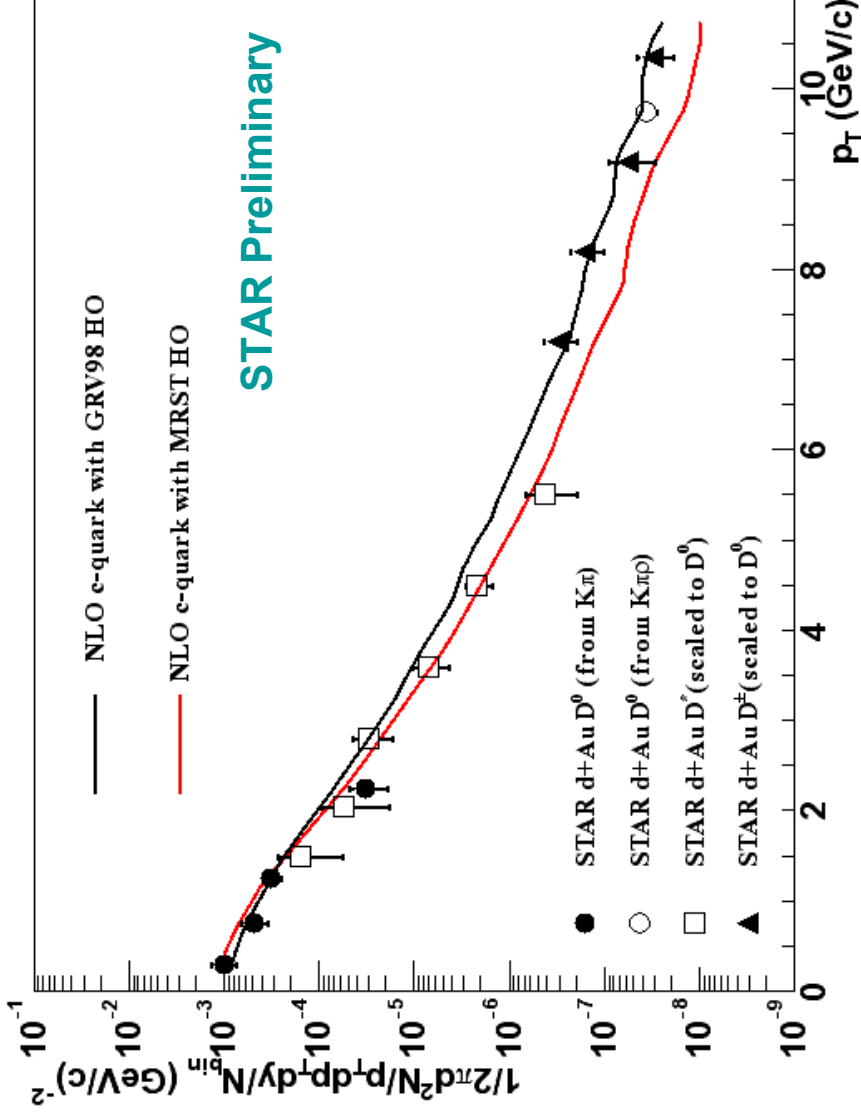
-- harder fragmentation (δ func or recombination scheme)

k_T Kick? What about k_L ?



The x_F distribution matches the NLO charm quark x_F !

The RHIC D meson $p_T \sim$ NLO charm quark too



NLO pQCD predictions are provided by R. Vogt, hep-ph/0203151

But NLO QCD calculation fits CDF data within a factor of 2

Belle Puzzle !

PRL 89, 142001 (2002)

$$\frac{\sigma(e^+e^- \rightarrow J/\psi c\bar{c})}{\sigma(e^+e^- \rightarrow J/\psi X)} = 0.59^{+0.15}_{-0.13} \pm 0.12$$

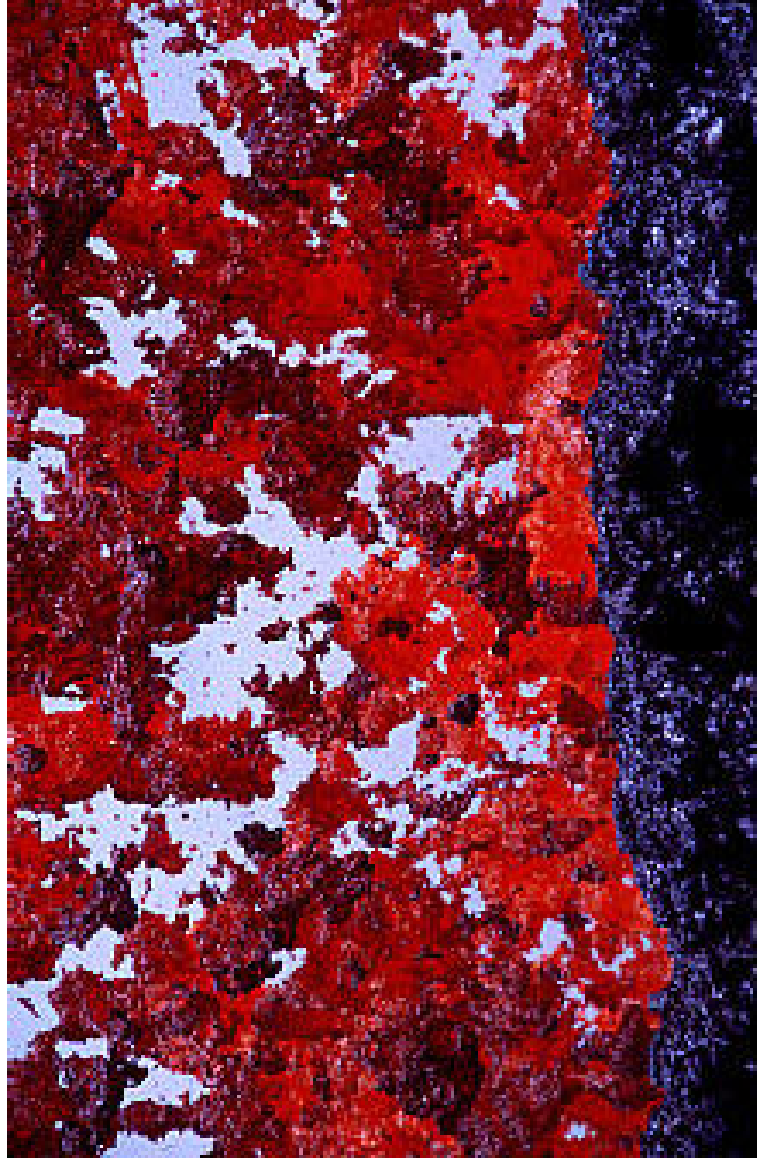
An order of magnitude higher than theoretical predictions

-- B.L. Ioffe and D.E. Kharzeev, PRD 69, 014016 (2004)

These results challenge our current understanding of how charm quarks/mesons are produced.

We may question our view for the underlying charm production process, e.g., the universality of fragmentation process and the fragmentation schemes !

Charm Probes of Bulk Partonic Matter at Intermediate p_T



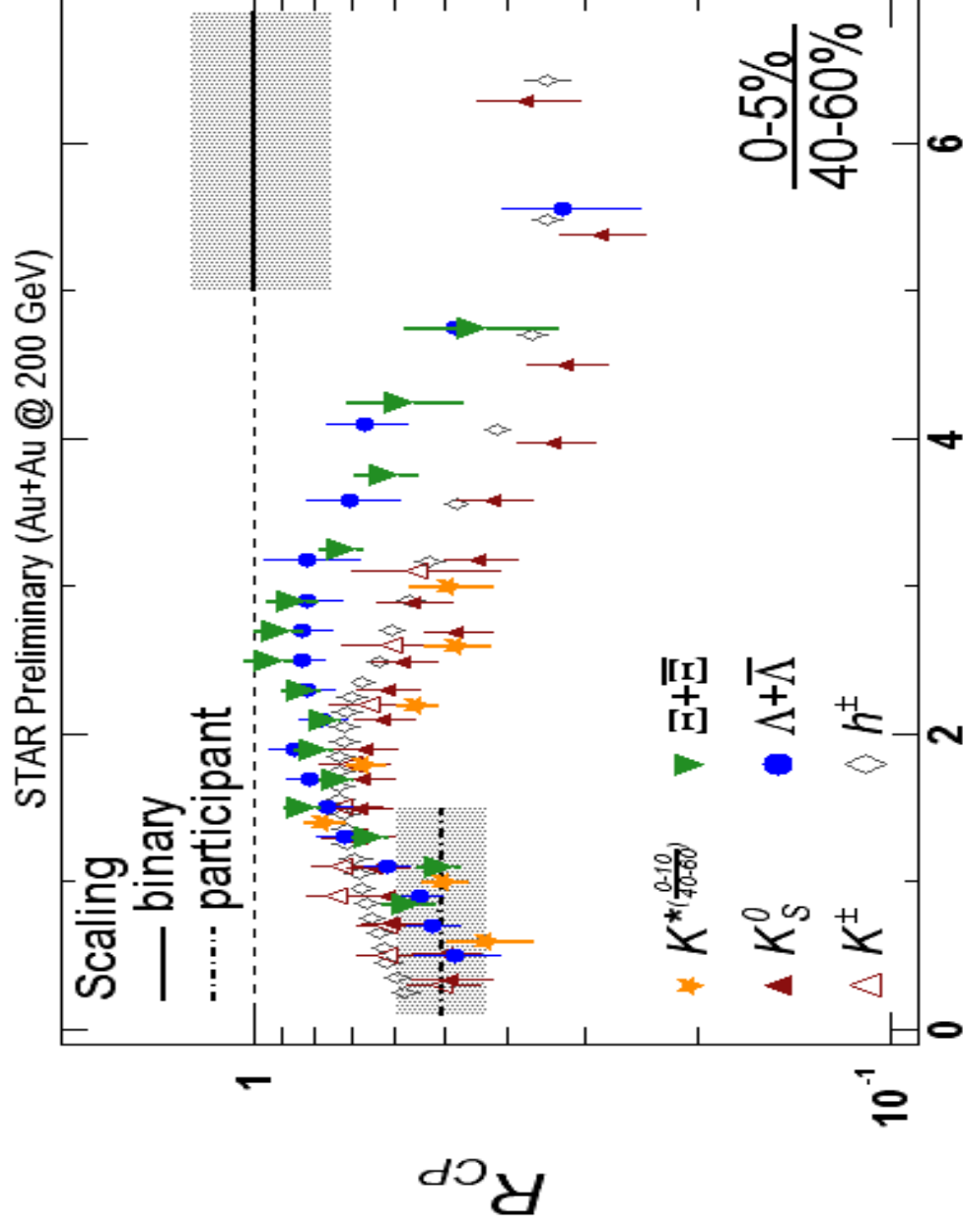
Volcanic mediate p_T – Spatter (clumps)

Does charm meson/baryon form from multi-parton dynamics?

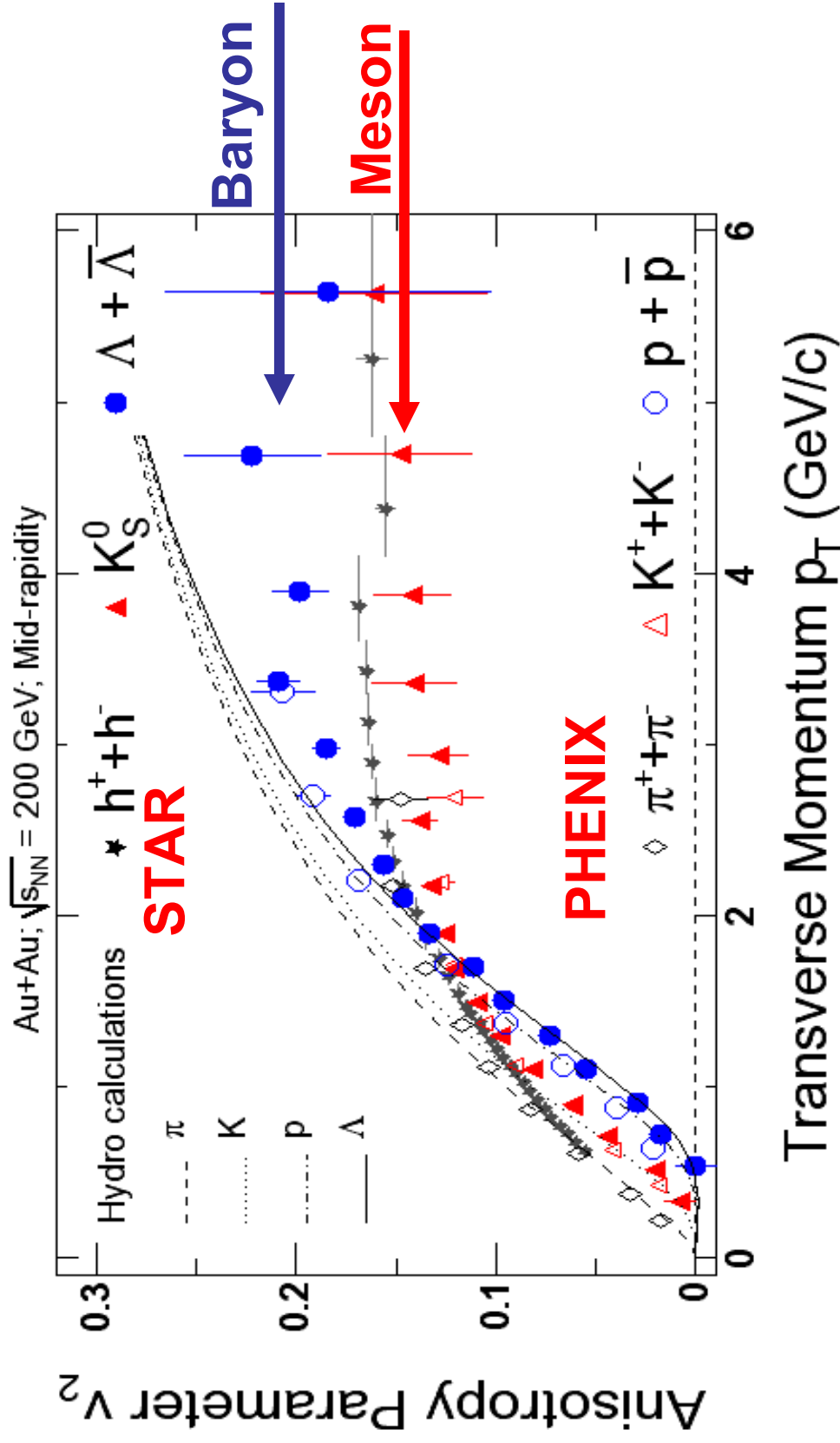
Constituent quark scaling for charmed baryon/meson ?!

Charm meson chemistry from strangeness equilibrated system – D_s/D^0 ?

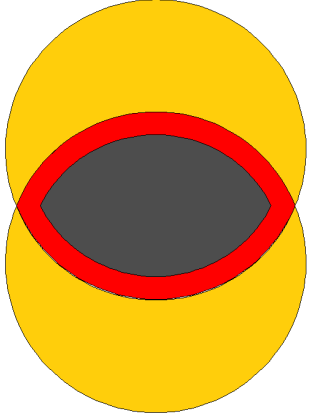
Particle Dependence of R_{CP}



Particle Dependence of v_2



Multi-Parton Dynamics

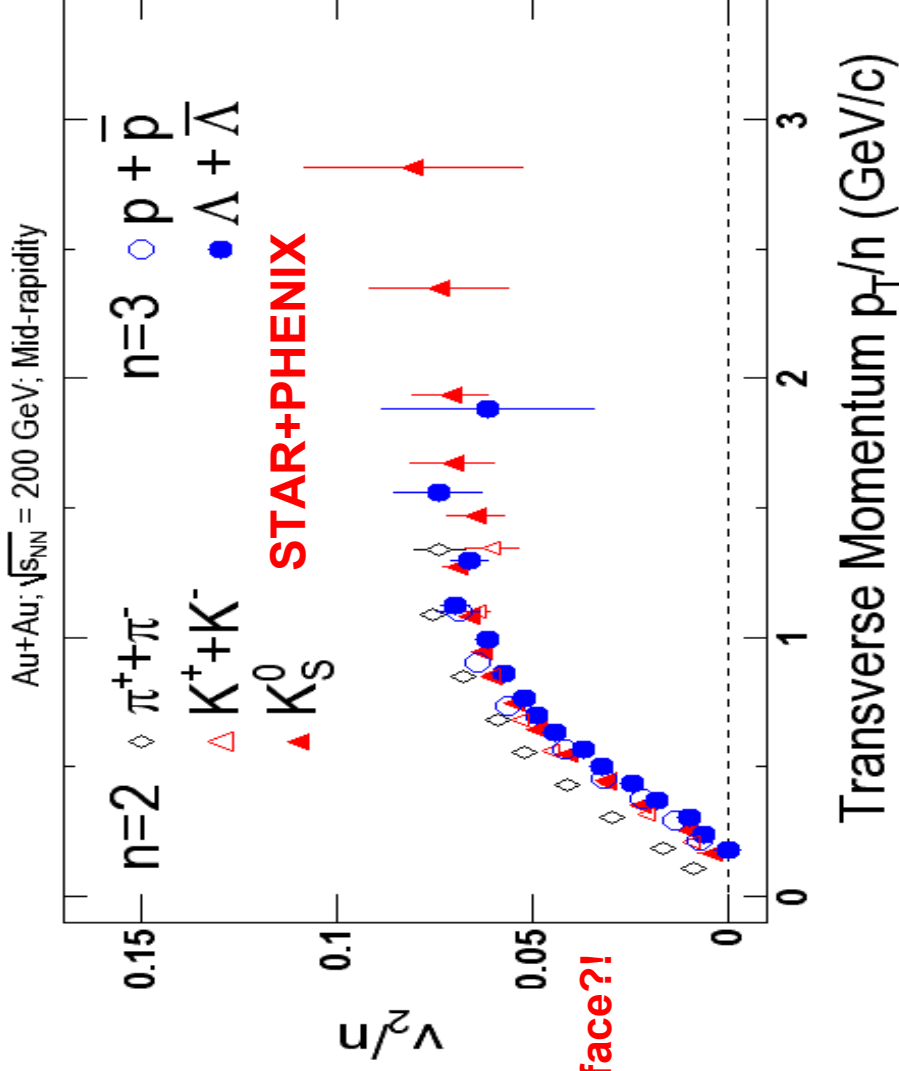


Hadronization Scheme for Bulk Partonic Matter:

K_S – two quark coalescence
 Λ – three quark coalescence
 from the partonic matter surface?!

Particle v_2 may be related to quark matter anisotropy !!

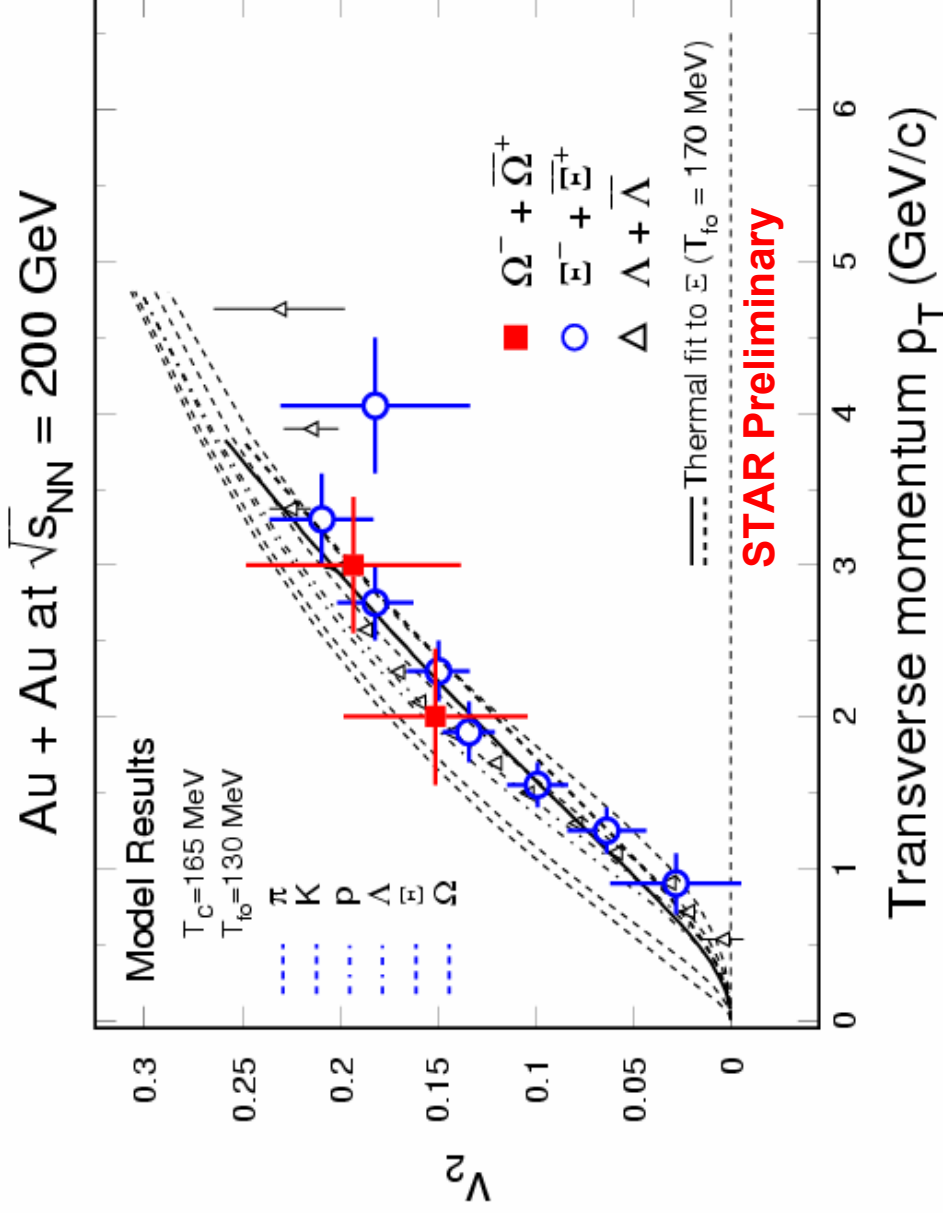
$p_T < 1$ GeV/c may be affected by hydrodynamic flow !



Quark Coalescence – (ALCOR-J.Zimanyi et al, AMPT-Lin et al,
 Rafelski+Danos, Molnar+Voloshin

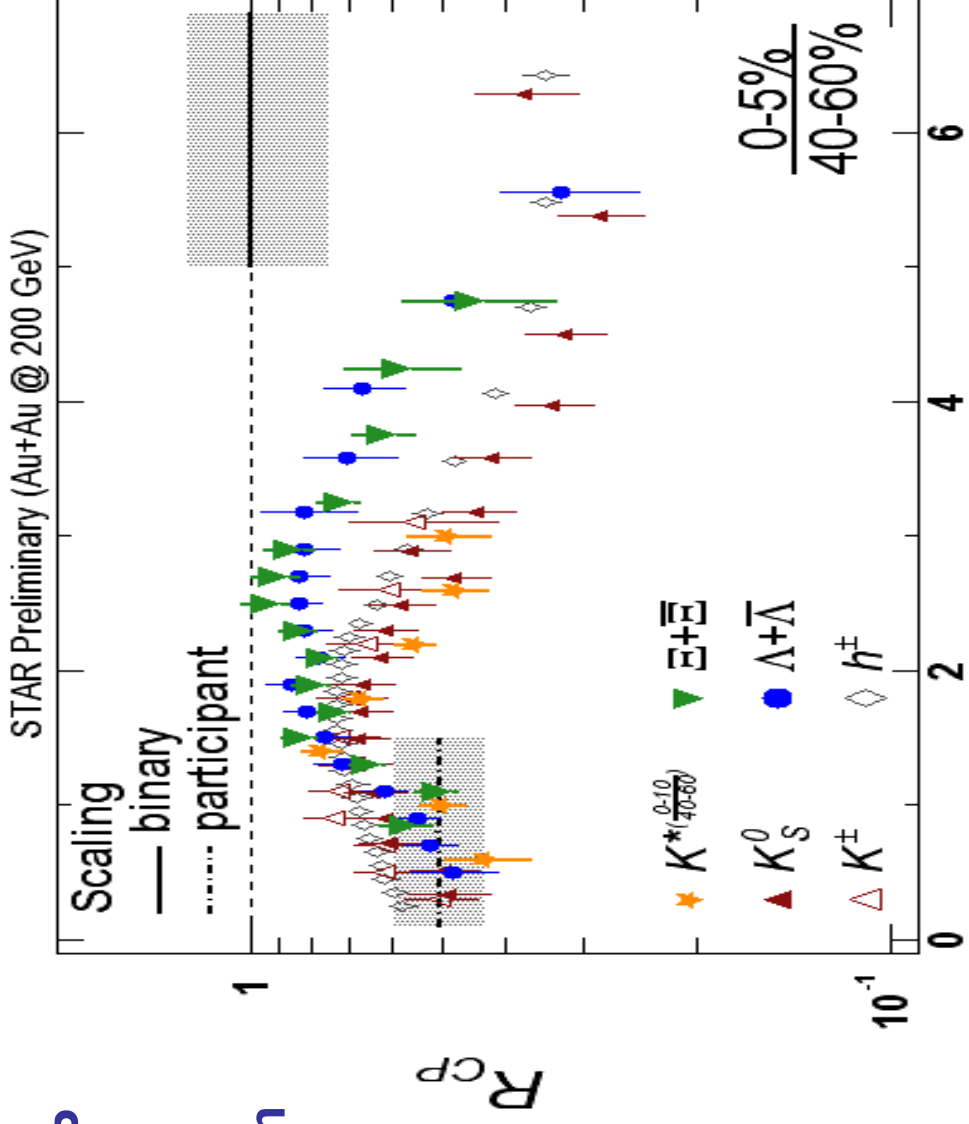
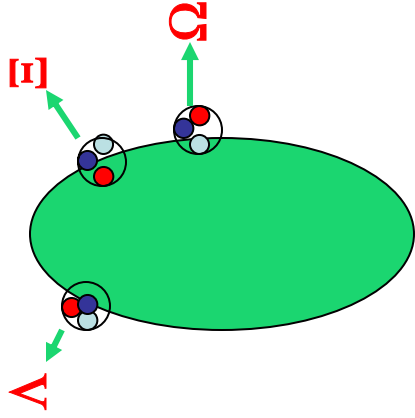
Quark Recombination – (R.J. Fries et al, R. Hwa et al)

Strange quark dynamics are not significantly different from light quarks

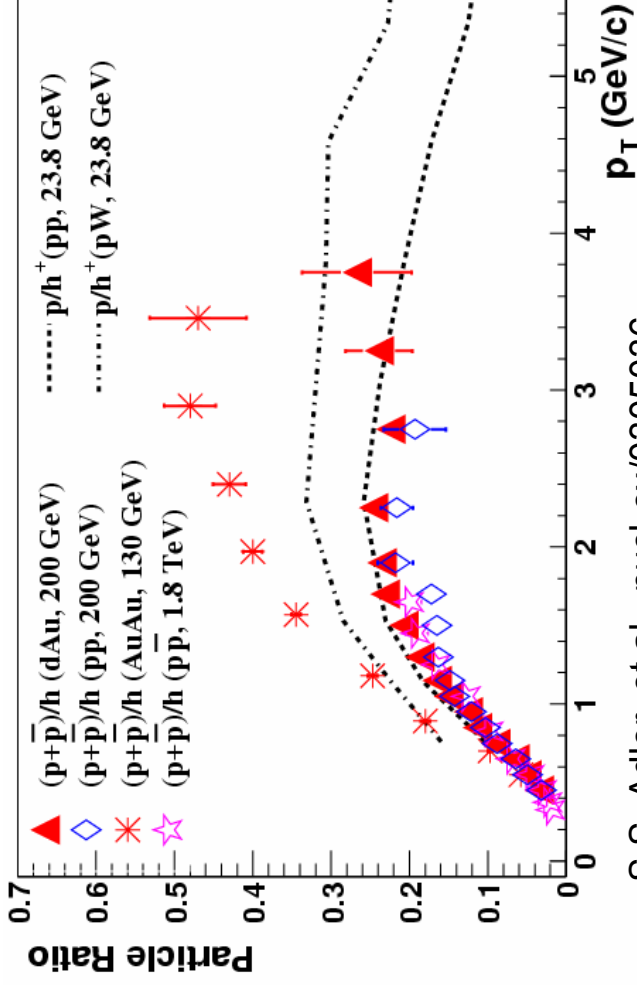


Strangeness from Bulk Partonic Matter

Strangeness enhancement from QGP is most prominent in the region where particle formation from quark coalescence is dominant !



Recombination as a hadronization scheme



S.S. Adler et al., nucl-ex/0305036.

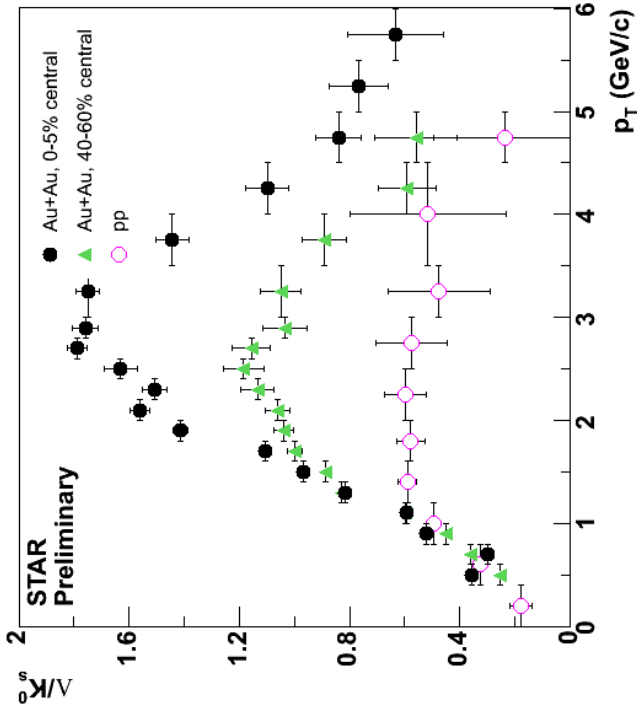
Essential difference:

Traditional fragmentation \rightarrow particle properties mostly determined by the leading quark !

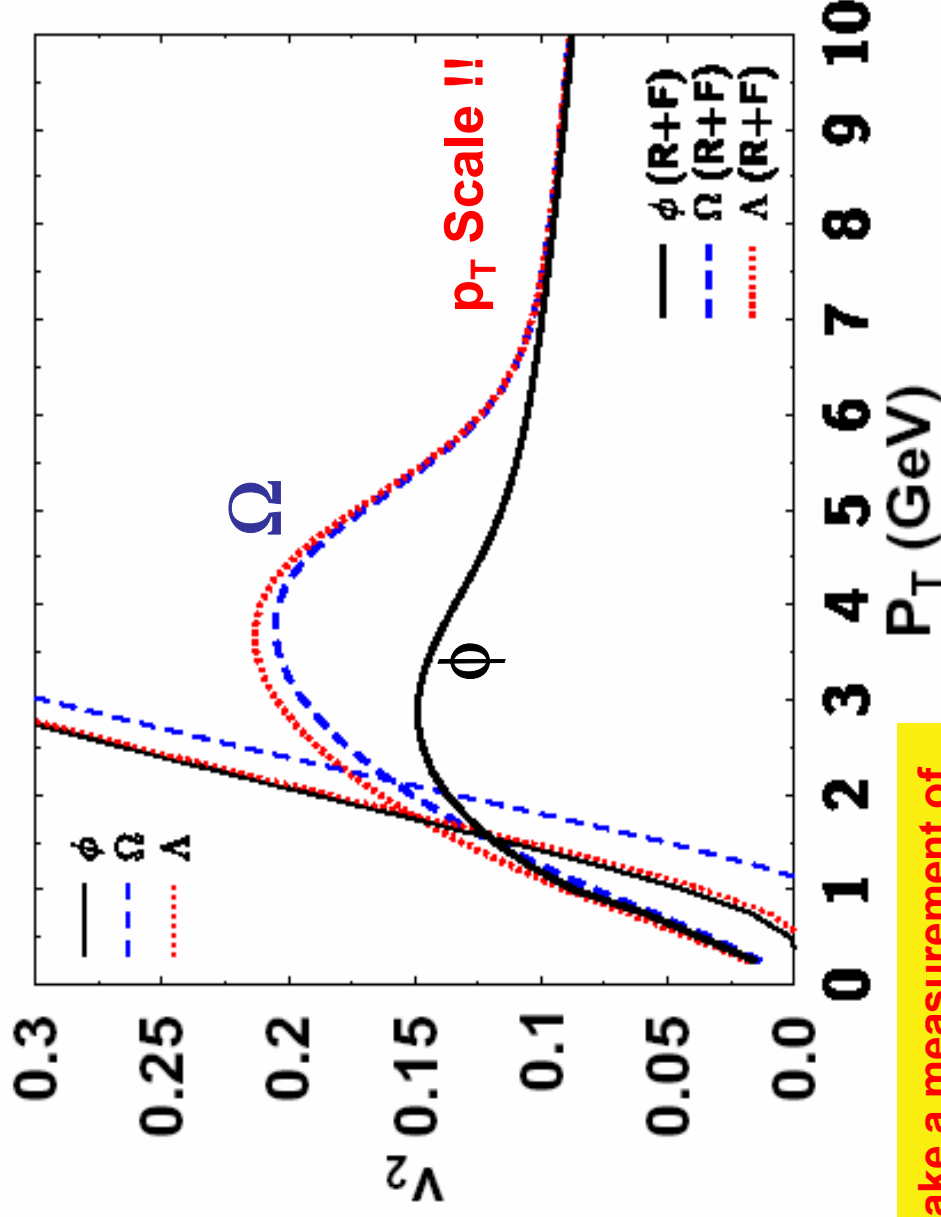
Emerging picture from RHIC data (R_{AA}/R_{CP} and v_2) \rightarrow all constituent quarks are almost equally important in determining particle properties !

Are constituent quarks the effective degrees of freedom for bulk partonic matter hadronization ?

How do we establish signatures for recombination with thermal constituent quarks or with shower partons ?

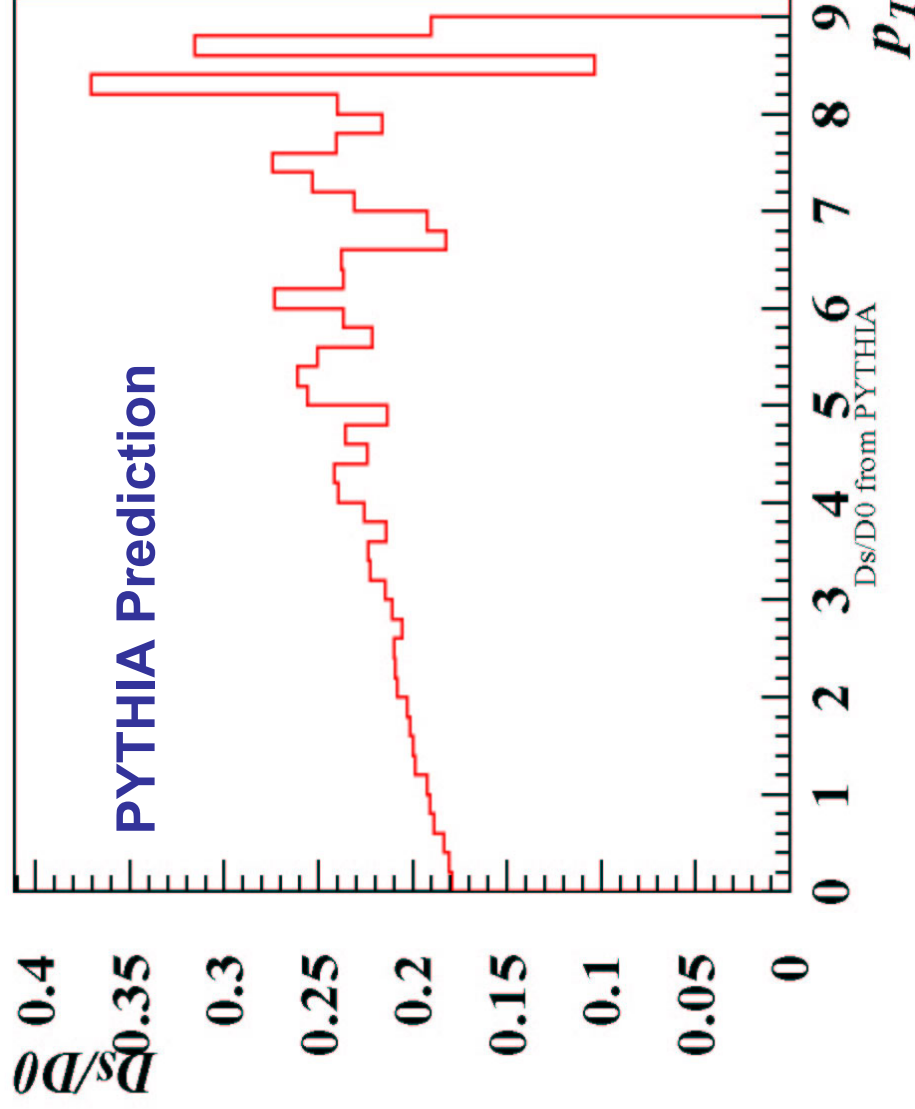


A Critical Test for Recombination And Strange Quark Dynamics in Bulk Matter



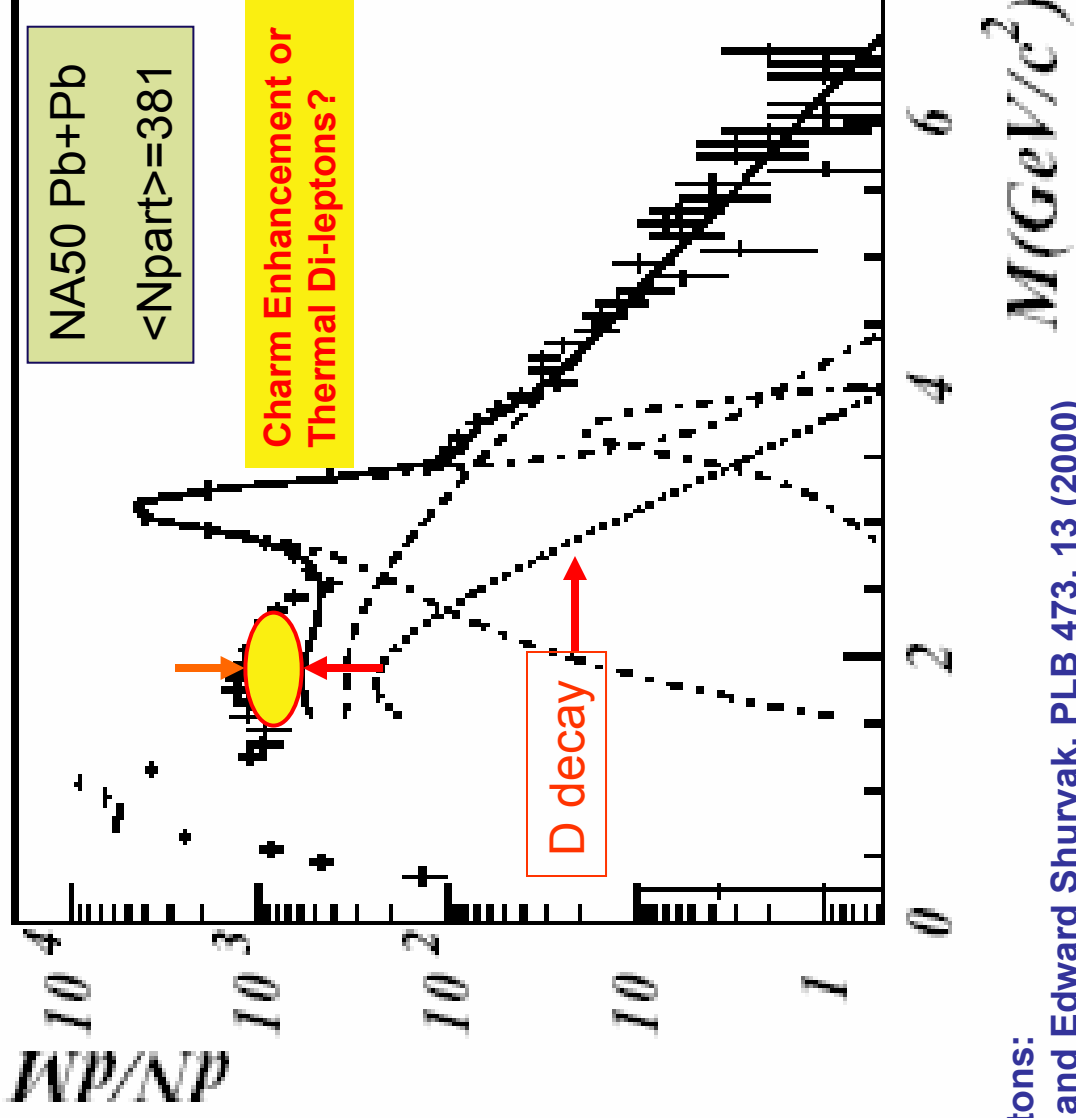
STAR will make a measurement of Ω and ϕ v_2 from run-4 Au+Au data !

Recombination $\rightarrow D_s/D^0$



Charm quark recombines with a light (u,d,s) quark from a strangeness equilibrated partonic matter $\rightarrow D_s/D^0 \sim 0.4-0.5$ at intermediate p_T !!!

Charm Enhancement in Heavy Ion Collisions ?

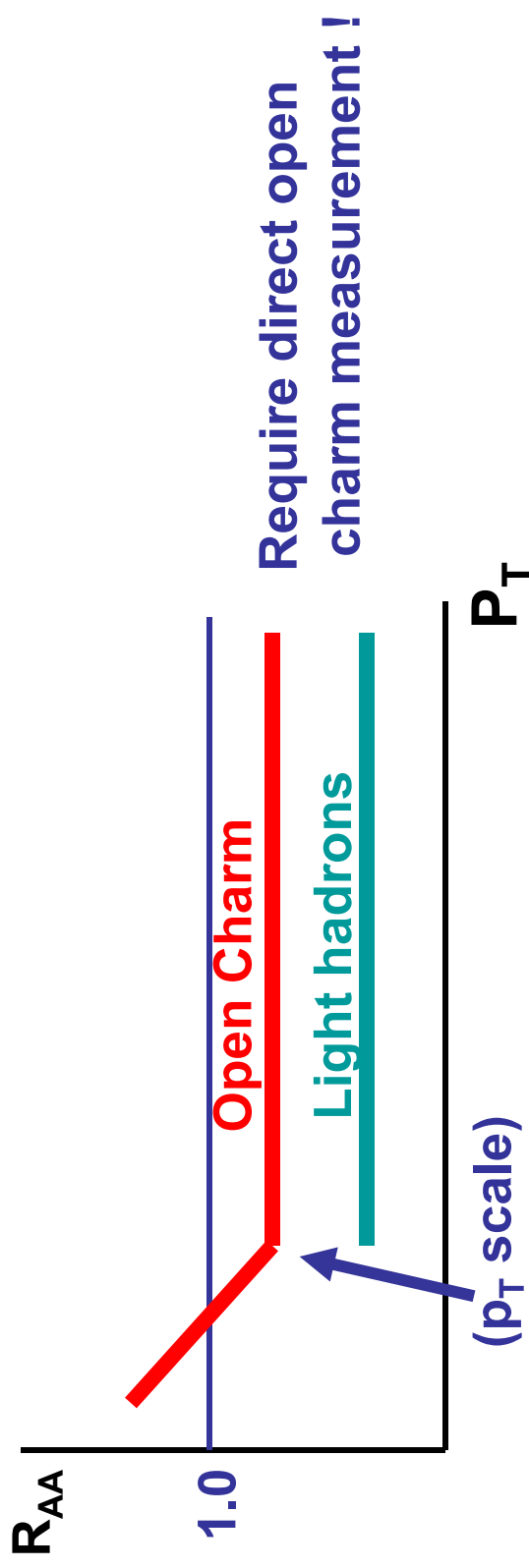


Thermal Di-leptons:
e.g., Ralf Rapp and Edward Shuryak, PLB 473, 13 (2000)

Heavy Quark in QCD Medium

- Heavy Quark energy loss in color medium !
 - dead cone effect (less than light quarks)
- Charm enhancement from high temperature gluonic matter ($T_{\text{init}} > 500$ MeV)!

An Intriguing Scenario ?!



Charm and Bulk Matter

Does Charm Flow?



Volcanic low p_T – Bulk matter flows

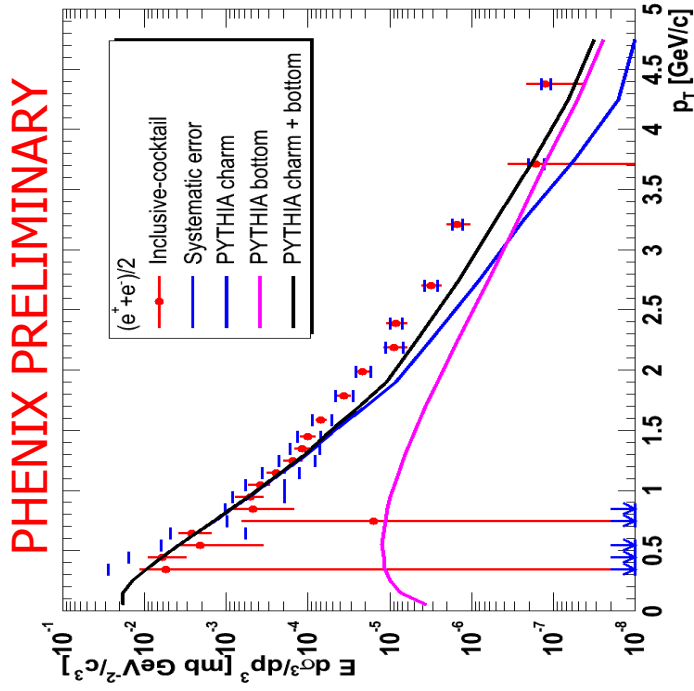
Thermalization of partonic matter

- charm elliptic flow v_2 !
- charm hadron chemistry !

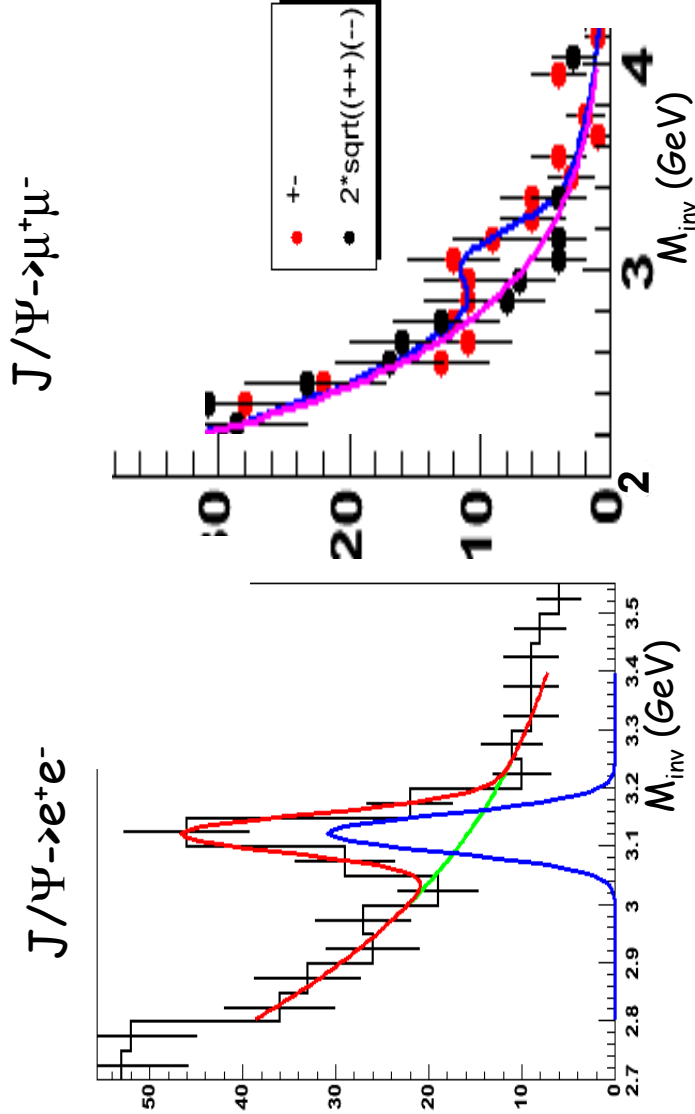
RHIC Heavy Quark Physics Program

PHENIX electron and J/Ψ measurement!

Clear J/Ψ signal already observed by muon and electron arms in a small subset of Run-4 Au+Au data.

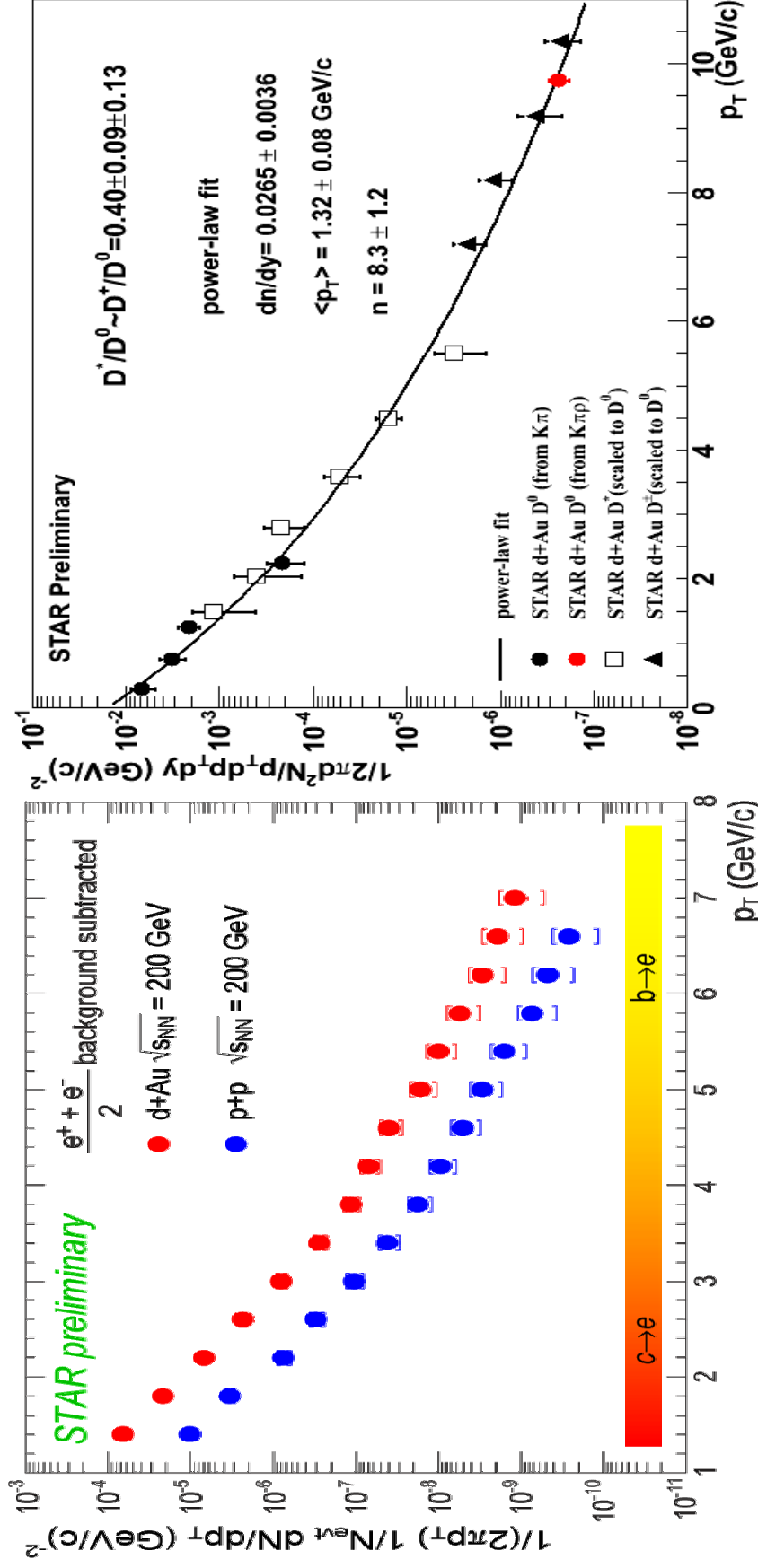


~ x100 more data in Run-4!



PHENIX data shown at RHIC User's meeting

RHIC Heavy Quark Physics Program



RHIC Exp Program from PHENIX and STAR:

Au+Au data on charm and beauty, Charm flow, J/ψ and Upsilon !

Detector Upgrade: PHENIX -- VTX

STAR -- TOF and microVertex Detector (MVD) !

**Charm and Beauty
reflect
QCD Properties of Matter**

- **Initial gluon flux and initial temperature of the gluon-dominated matter**
- **Transition temperature from partons to hadrons**
- **Color degree of freedom of the matter –
definement**
- **Heavy Quark in the forward region -- CGC**

The End