Au + Au physics topics with the μVertex detector

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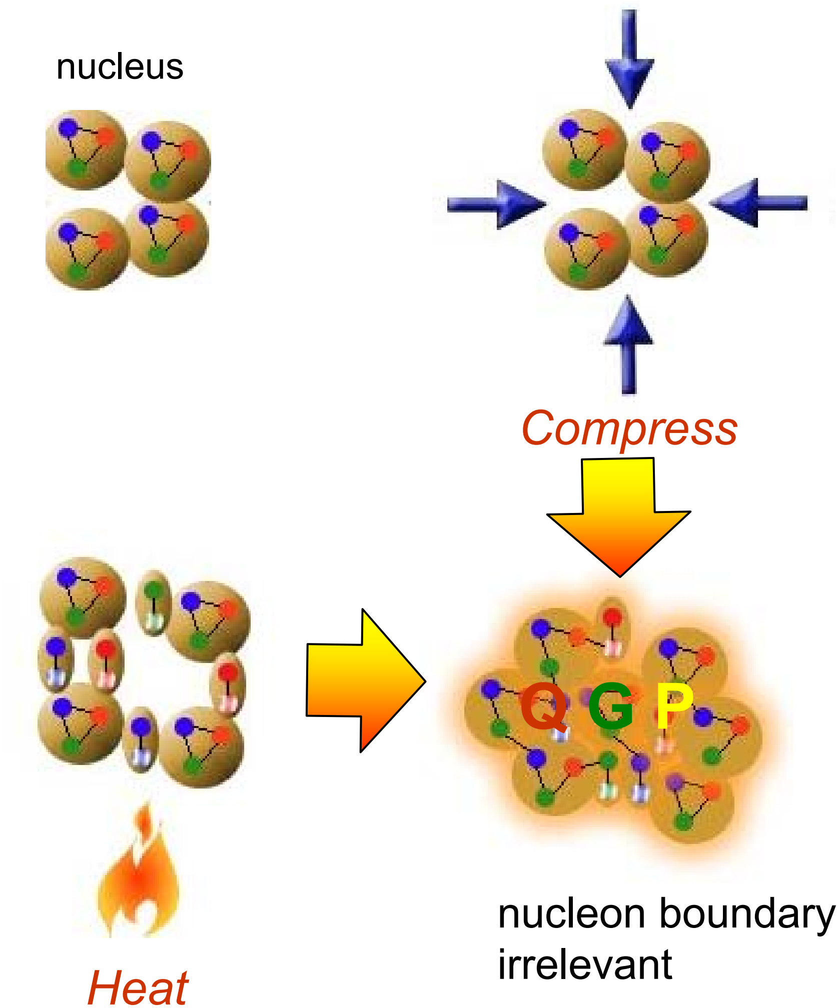
Outline

- ❑ Introduction / Motivation
- ❑ Multi-strange hadron spectra and partonic collectivity
- ❑ Open charm to probe thermalization
- ❑ Simulations of the μVertex detector
- ❑ Summary

Motivation



<u>Quark Gluon Plasma:</u>

Deconfined and thermalized state of quarks and gluons

❑ Equilibration:

- hadron yields

❑ Partonic Collectivity:

- Spectra of multi-strange baryons

❑ Thermalization:

- heavy charm quark
- (thermal photons, di-leptons)

J.C. Collins and M.J. Perry, Phys. Rev. Lett. 34 (1975) 1353.

Pressure, Flow, …

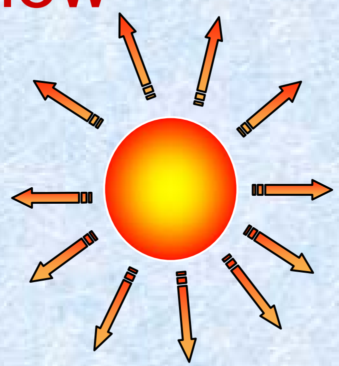
Thermodynamic identity

σ – entropy p – pressure
U – energy V – volume
$\tau = k_B T$, thermal energy per dof

$$\tau d\sigma = dU + pdV$$

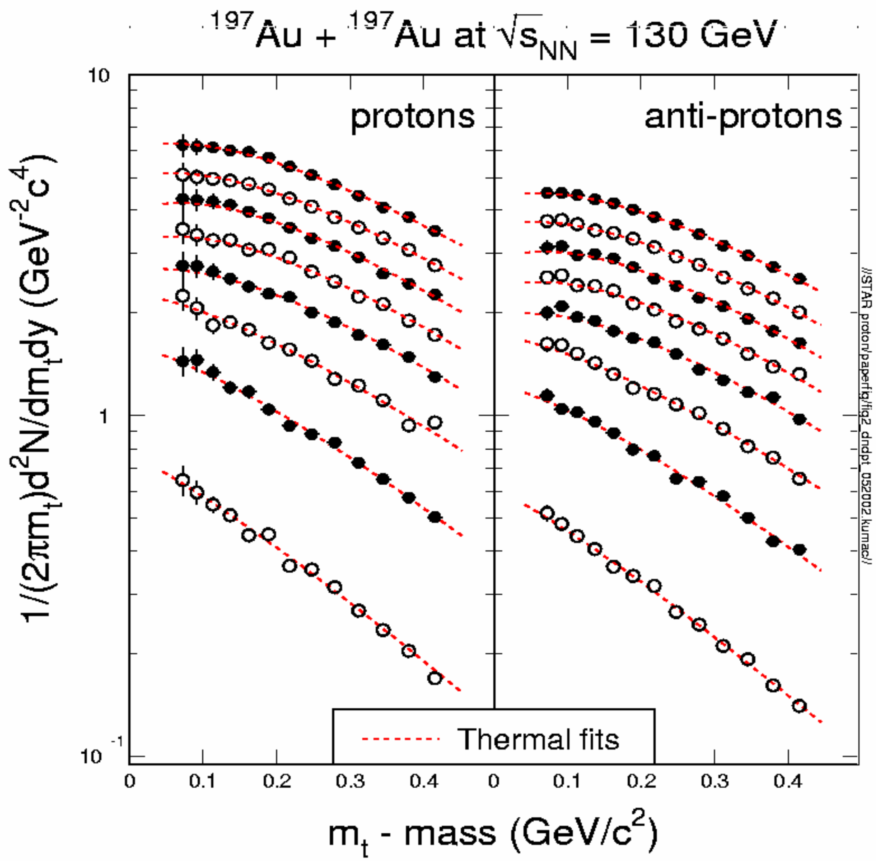
In A+A collisions, interactions among constituents *and* density distribution lead to:

pressure gradient ⇒ collective flow



⇔ number of degrees of freedom (dof)
⇔ Equation of State (EOS)
⇔ cumulative – *partonic* + *hadronic*

Transverse Radial Flow



$$\frac{dN}{m_T dm_T} \propto \int_0^R r dr m_T K_1\left(\frac{m_T \cosh\rho}{T_{fo}}\right) I_0\left(\frac{p_T \sinh\rho}{T_{fo}}\right)$$

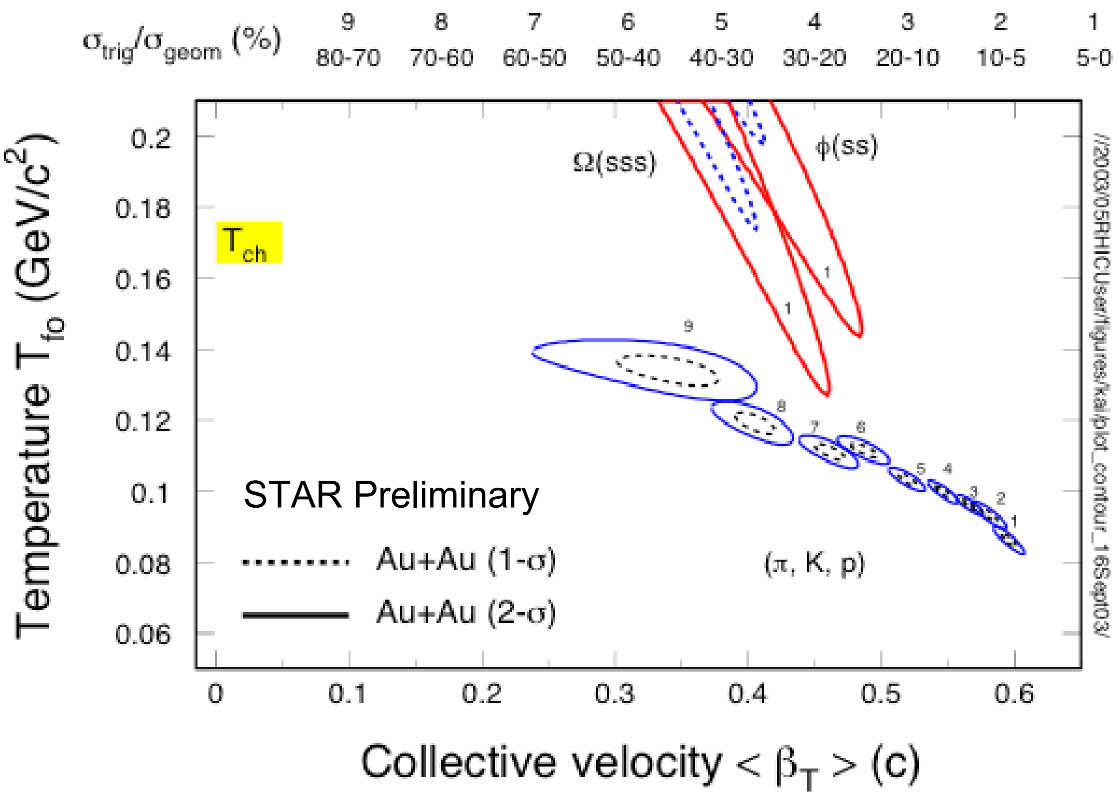
$$\rho = \tanh^{-1}\beta_r \qquad \beta_r = \beta_S\left(\frac{r}{R}\right)^{\alpha} \qquad \alpha = 0.5,1,2$$

T_{fo}: temperature parameter

β: collective flow velocity

- ***In more central collisions, m_t distributions become more convex $\Rightarrow$ collective flow !***

Kinetic Freeze-out



1) Compare to π, *K*, and *p*, multi-strange particles φ, Ω are found at higher T and lower <β_T>

⇨⇨ Collectivity prior to hadronization

2) Sudden single freeze-out* Resonance decay lower T_{fo} for (π, *K*, *p*)

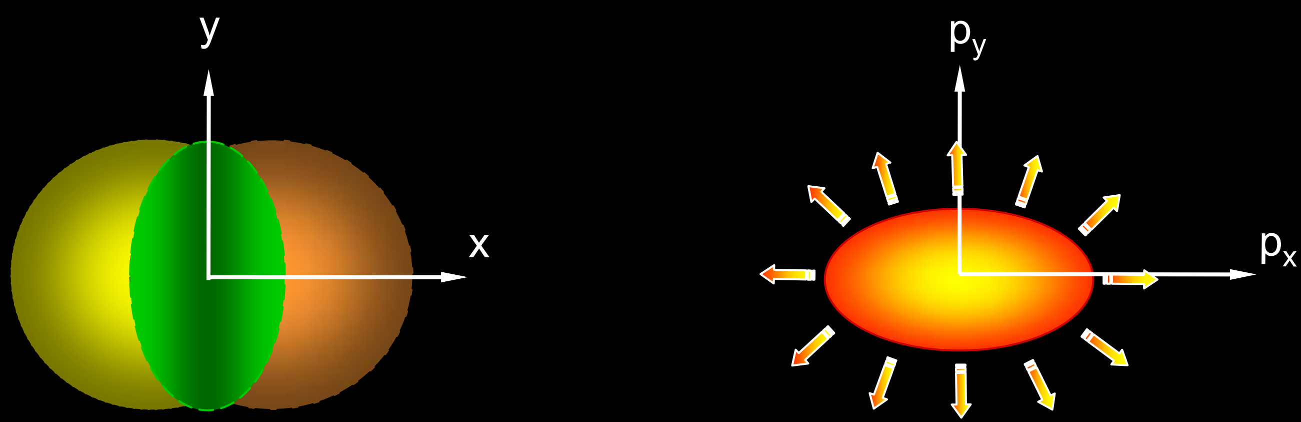
⇨⇨ Collectivity prior to hadronization

Partonic Collectivity !

Data: STAR preliminary Au+Au@200GeV: Nucl. Phys. A715, 129c(2003).
*A. Baran, W. Broniowski and W. Florkowski; nucl-th/0305075

Elliptic Flow, v_2

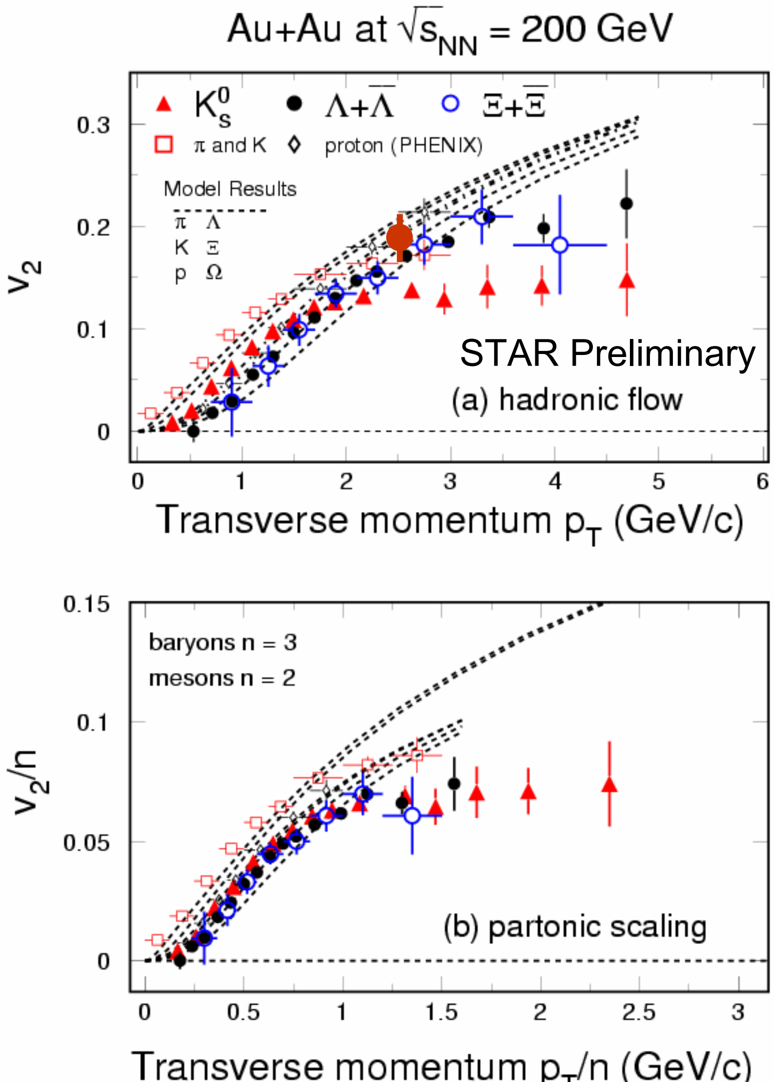
coordinate-space-anisotropy ⇔ momentum-space-anisotropy



Initial/final conditions, dof, EOS

$$\frac{dN}{p_t dp_t dy d\varphi} = \frac{1}{2\pi}\frac{dN}{p_t dp_t dy}\left[1 + \sum_{i=1} 2v_i \cos(i(\varphi - \Phi_R))\right]$$

Quark Coalescence



- ❑ Exp. data consistent with quark coalescence scenario
- ❑ ***Partonic collectivity at RHIC!***
- ❑ Pentaquark*

θ^+(uudd$\bar{s}$), n=5 ?

θ_c(uudd$\bar{c}$), $c\tau$ > 100μm ?

Z. Lin et al., Phys. Rev. Lett., 89, 202302 (2002)
R. Fries et al., nucl-th/0306027
D. Molnar and S.A. Voloshin, PRL 91, 092301 (2003)

*LEPS: Phys. Rev. Lett. 91, 012002-1 (2003)

Summary(i)

- ❑ Spectra and v_2 of multi-strange hadrons

→ Partonic Collectivity at RHIC !

- ❑ probe thermalization at RHIC with

- yields: hadro-chemistry with heavy flavor (c,b)

- spectra and v_2 of open charm

- energy loss of heavy flavor quarks

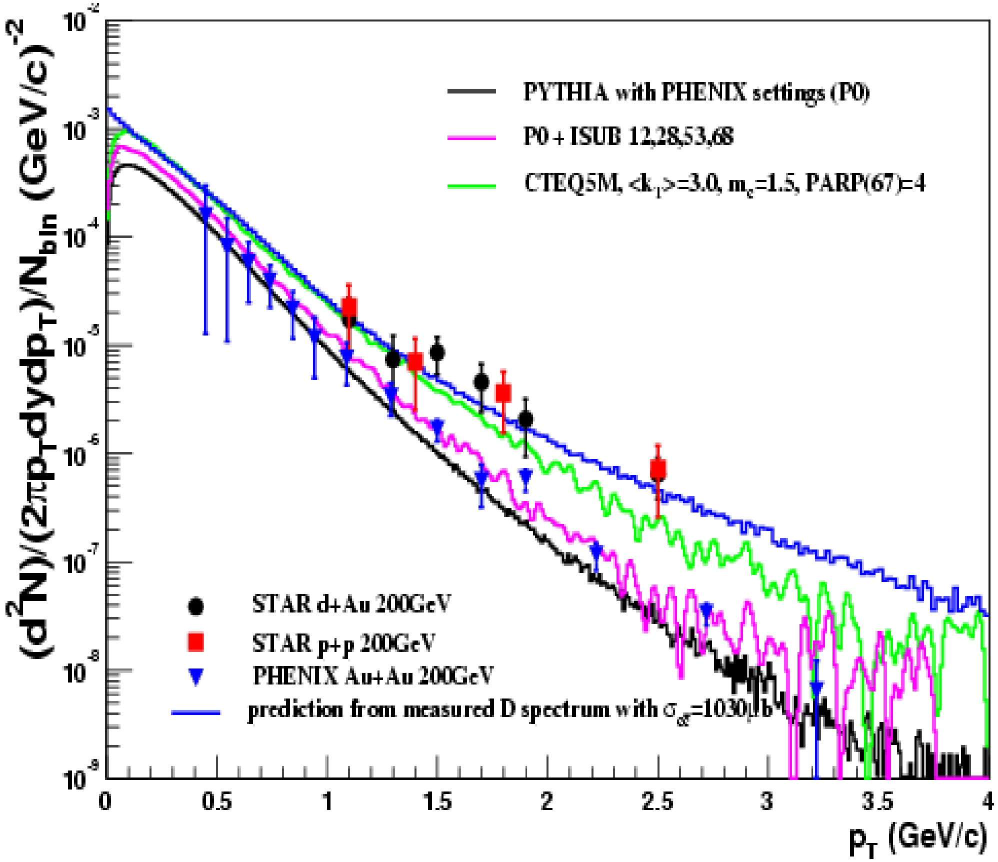
Charm Yields

- No thermal creation of c or b quarks; m(c) = 1.1GeV >> T
- c and b quarks interact with lighter quarks → thermal recombination ?
  - D_s^+ yield very sensitive !
  - J/ψ: suppression vs recombination ?

	Pythia p-p 200 GeV	Au-Au Thermal*
D^+/D^0	0.33	0.455
D_s^+/D^0	**0.20**	**0.393**
Λ_c^+/D^0	0.14	0.173
$J/\psi/D^0$	0.0003	0.0004 **No suppression**

* A.Andronic, P.Braun-Munzinger, K.Redlich, J.Stachel, nucl-th/030306.

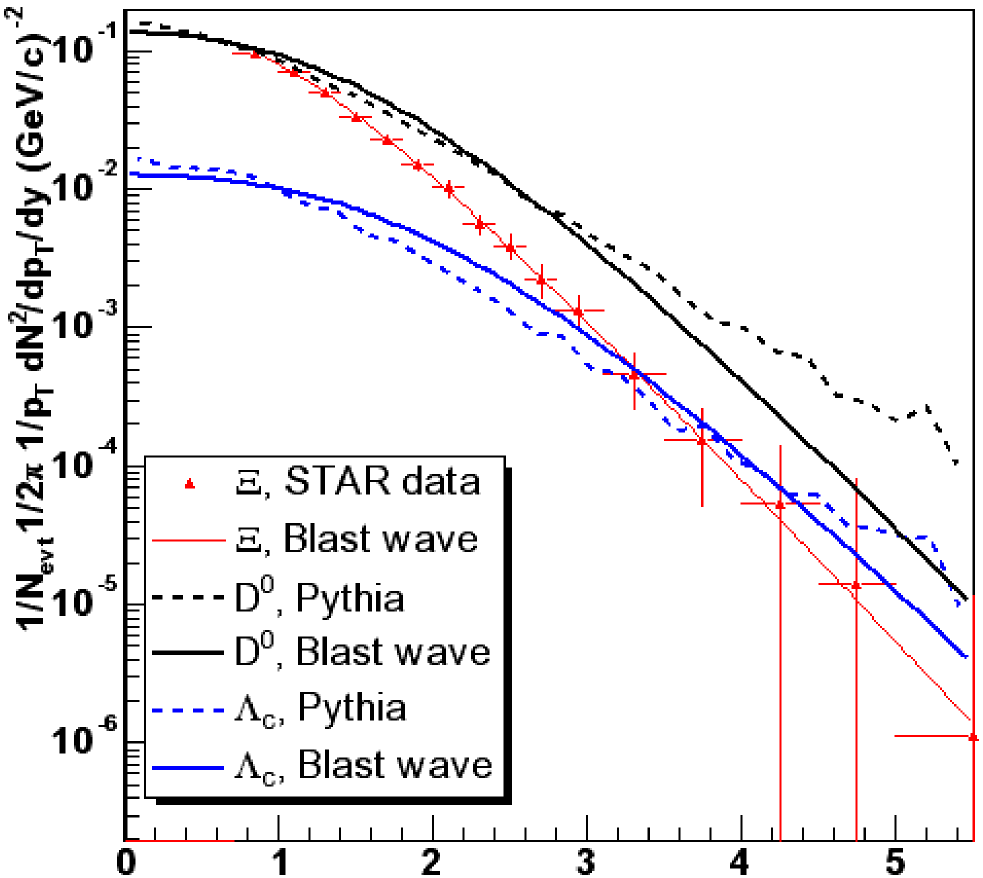
(Indirect) Charming Spectra



- ❑ single e- spectra
  - D → e- + nX
  - B → e- + nX
- ❑ d + Au: Electron spectrum is consistent with the D meson spectrum
- ❑ Au + Au: Electron spectrum is suppressed
- ❑ ***Heavy flavor energy loss(?) in heavy-ion collisions***
- ❑ ***Need direct measurement !***

Au+Au data: PHENIX, K. Adcox et al., Phys. Rev. Lett. 88 (2002) 192303.

Does Charm Flow ?



Blast wave: includes flow

PYTHIA: no flow!

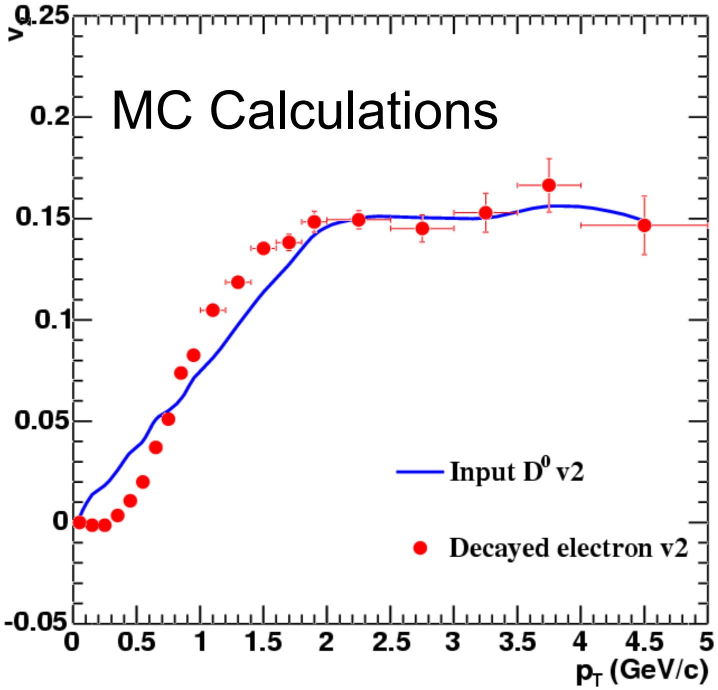
→At low momentum, differences in spectra small

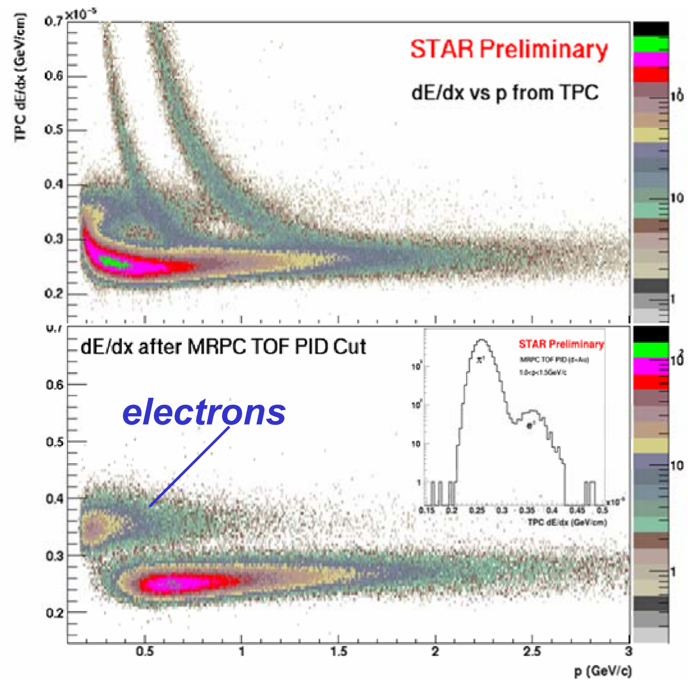
→ need high statistics !

→ need μVertex detector !

Calculations: F. Retiere, LBNL

Elliptic Flow of Charm – v_2

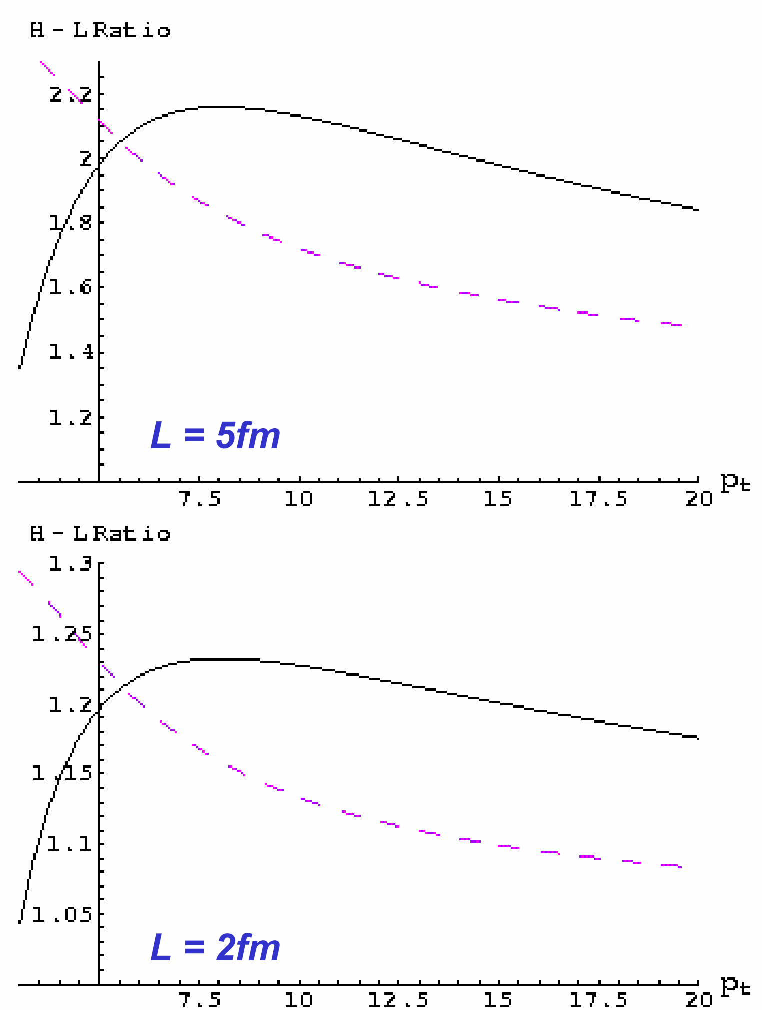




- ❑ ***Finite v_2 of D-mesons signals thermalization !***
- ❑ ***Remove electron background from $\pi^0 \rightarrow \gamma \rightarrow e^+e^-$ conversion***
  → measure thermal di-lepton spectra !

MC calculations: Xin Dong, USTC/LBNL

Heavy-Quark Energy Loss



- Heavy(H) quarks suffer smaller energy loss than light(L) quarks
  - Dead cone effect
  - QCD analog Ter-Mikayelian effect; nucl-th/0305062
- D/π ratio sensitive to color charge
- Differential study of energy loss

Yu.L. Dokshitzer and D.E. Kharzeev. Phys. Lett. B519 (2001) 199.

Summary(ii)

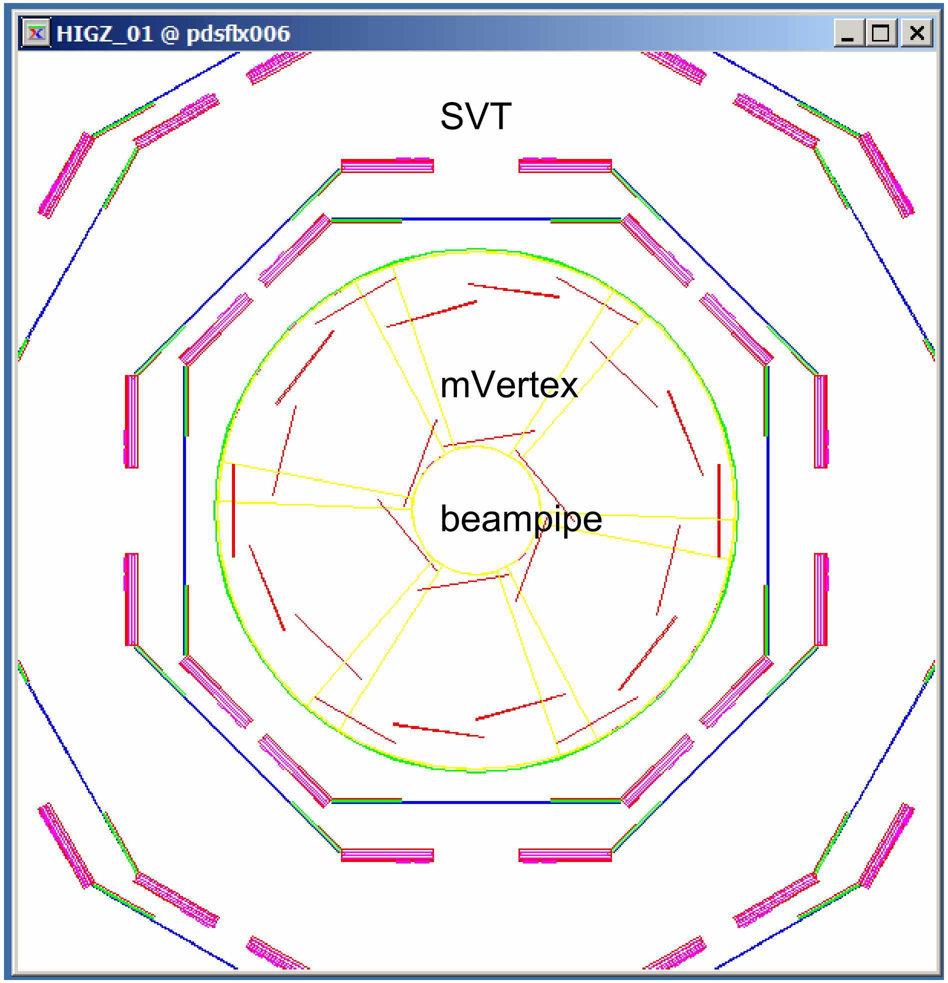
❑ probe thermalization at RHIC with

- yields: hadro-chemistry with heavy flavor (c,b)

- spectra and v_2 of open charm

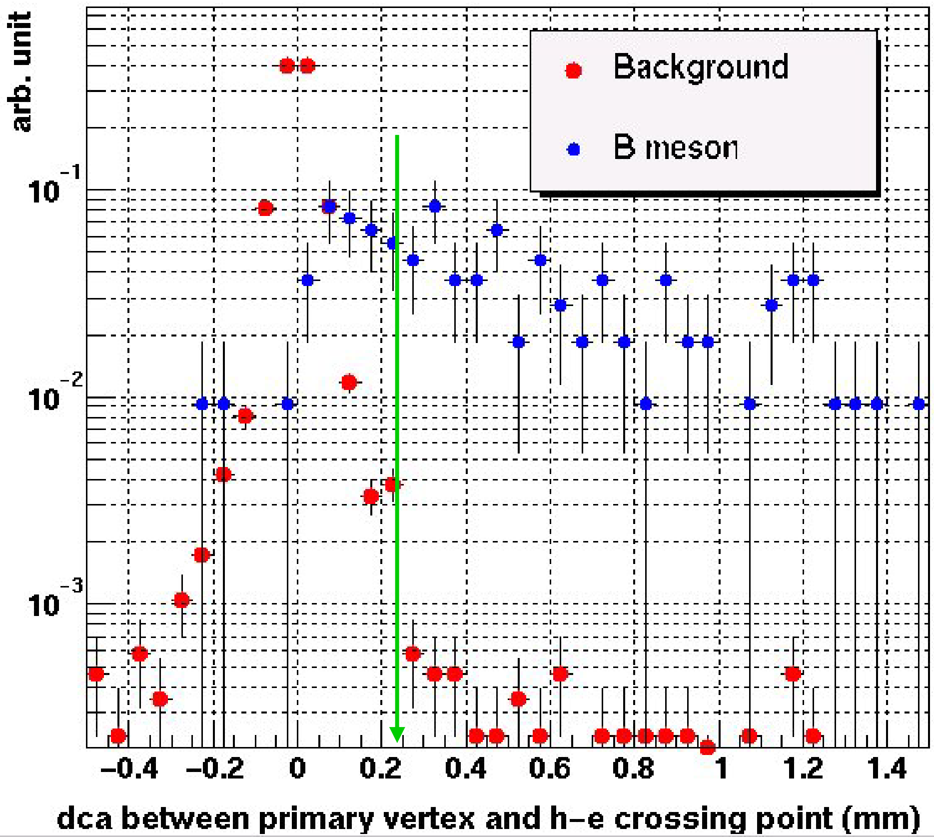
- energy loss of heavy flavor quarks

Simulations



- Two layers
- 24 ladders
- total length: 16cm
- inner radius: 1.4cm
- outer radius: 5.65cm
- new beampipe, 760μm Be
- position resolution: 3-10μm
- Δx~100μm Si-equivalent

Background Suppression



- B $\rightarrow$ $e^{+/-}$ + hadron + X
  - High pt $e^{+/-}$ triggered by EMC

→ Background-free at dca>200μm !

Reconstruct Charm

System	N events for 3 σ $\mathbf{D^0}$ signal	N events for 3 σ $\mathbf{D^0}$ **signal $\mathbf{p_T}$ > 2 GeV/c**	N events for 3 σ $\mathbf{D^+_s}$ signal
TPC+SVT	12.6 M (Evan Finch)	59 M	500 M (K^0_s + K^+) (Jeff Porter)
TPC+SVT+TOF	2.6 M	23 M	?
TPC+SVT+μVertex	0.1 M	0.6 M	50 M (ϕ+π^+)
TPC+SVT+μVertex+TOF	10 K	?	5 M (ϕ+π^+)

Uncertainty in N events: ±30%

Summary(iii)

- Spectra and v_2 of multi-strange hadrons

→ Partonic Collectivity at RHIC !

- Measure centrality dependence of spectra and v_2 of ϕ, Ξ, Ω, …, D^0, D_s, Λ_c, J/ψ, (θ^+)

– quantify partonic collectivity

– probe thermalization

→ ***Discover QGP !***

- thermal photons + di-leptons → plasma temperature