Overview of results from STAR

SQM 2007, Levoča, Slovakia

Lee Barnby

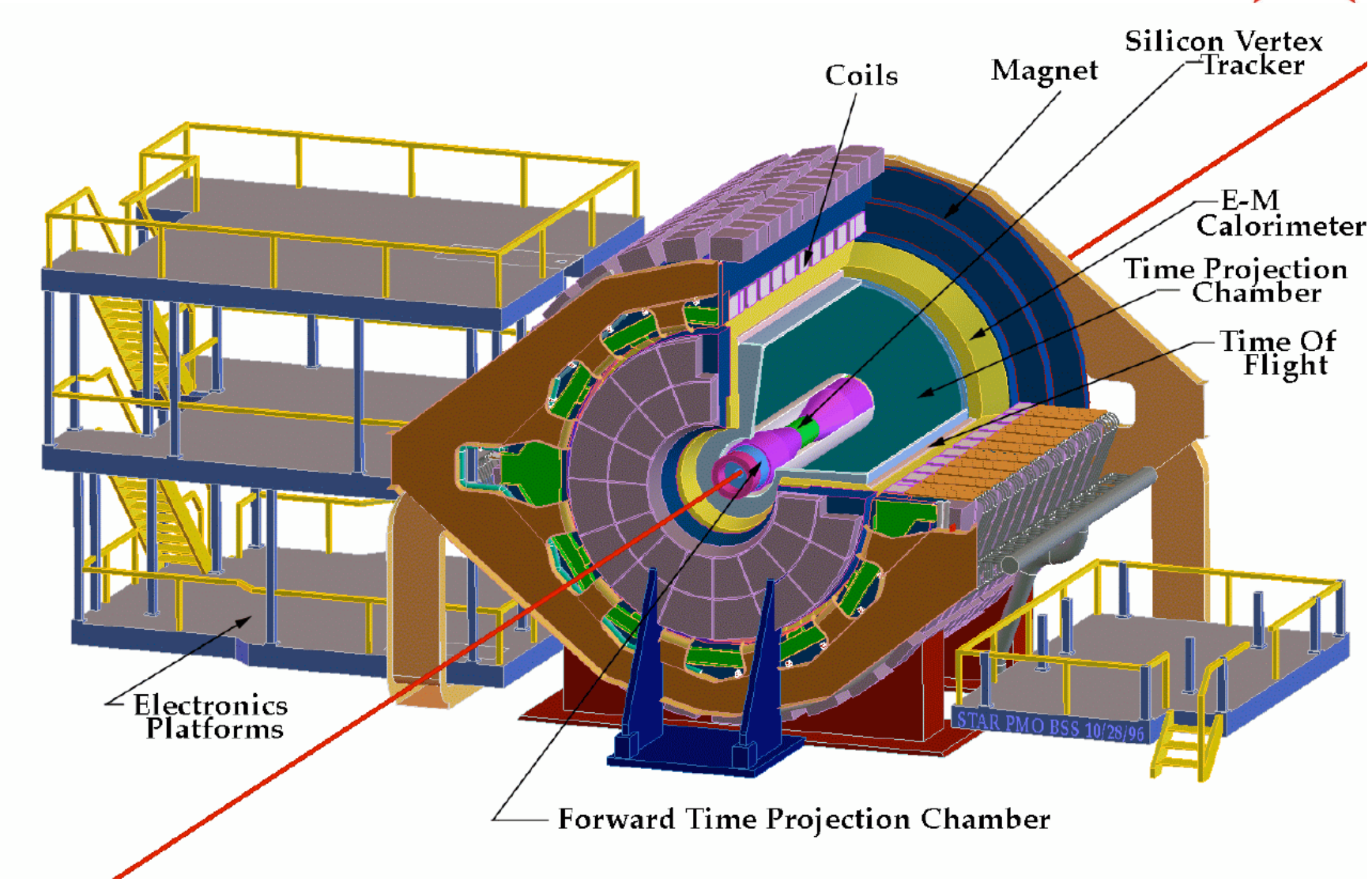
For the STAR Collaboration

UNIVERSITY OF BIRMINGHAM

Overview

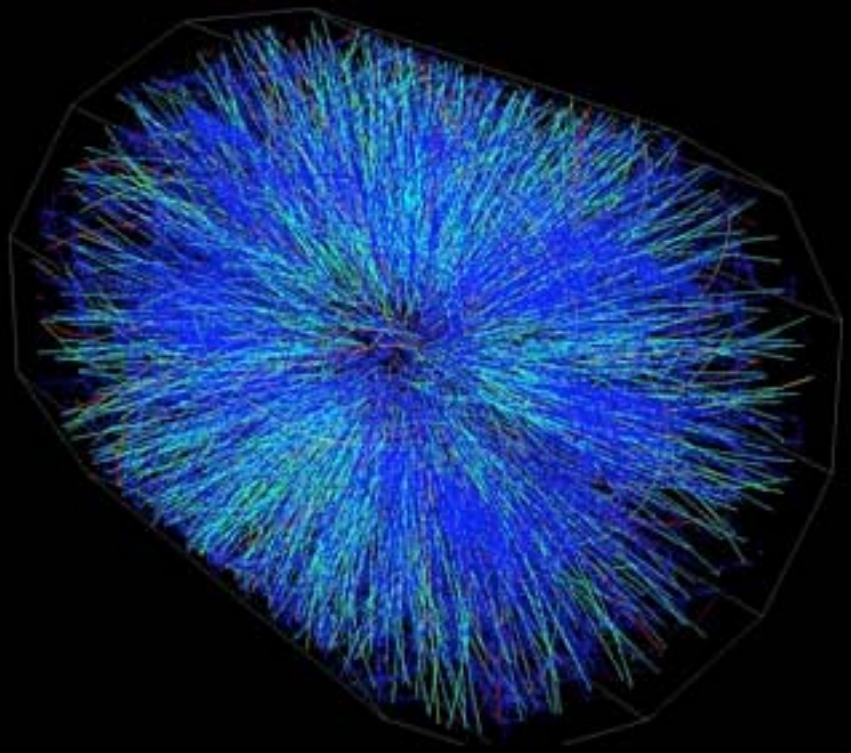
- Introduction
- Flow
- High- and intermediate-p_T triggered phenomena
- Strangeness
- Heavy Flavour

STAR Detector

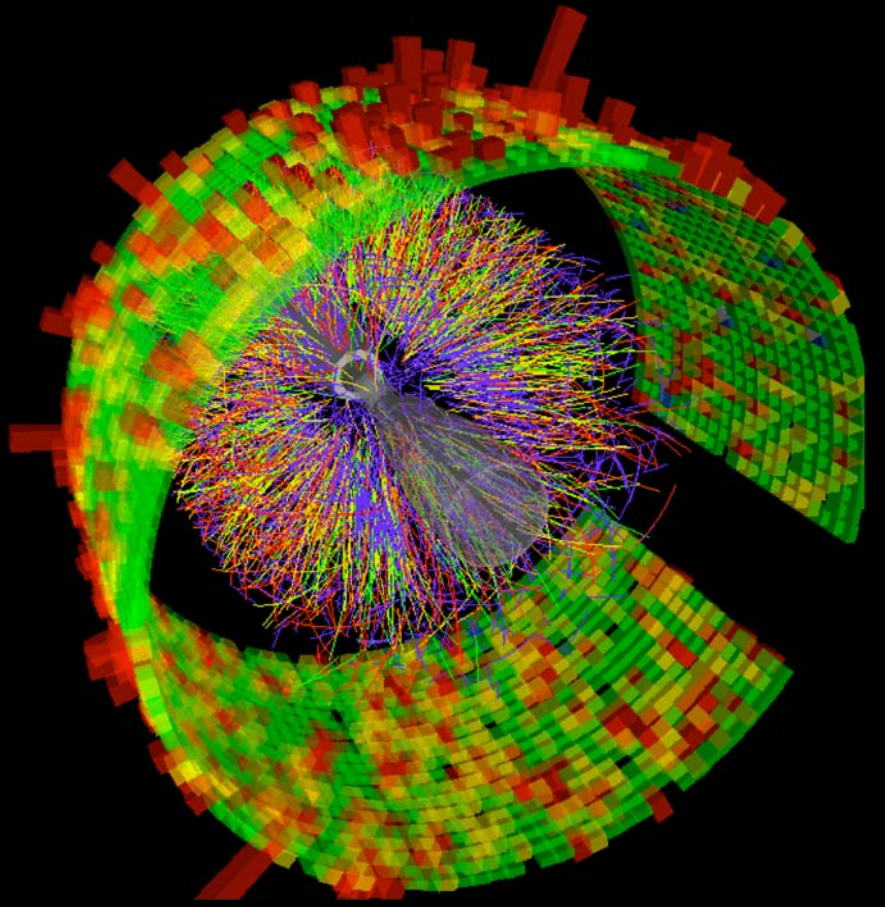


STAR Events

Classic STAR event picture



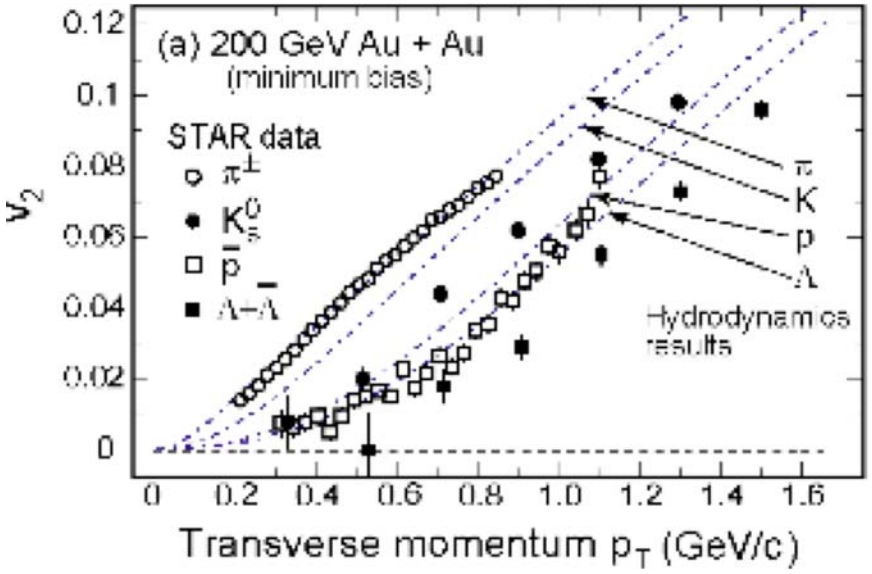
With EMC added

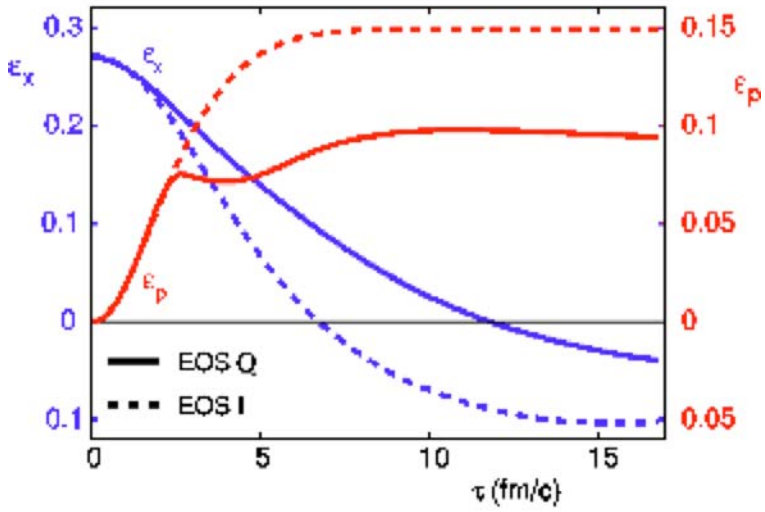


Key measurements to date

- Elliptic flow
  - Large values
  - Hydro-like scaling with mass
- High-p_T
  - Suppression w.r.t binary scaling
  - Disappearance of back-to-back di-hadron pairs

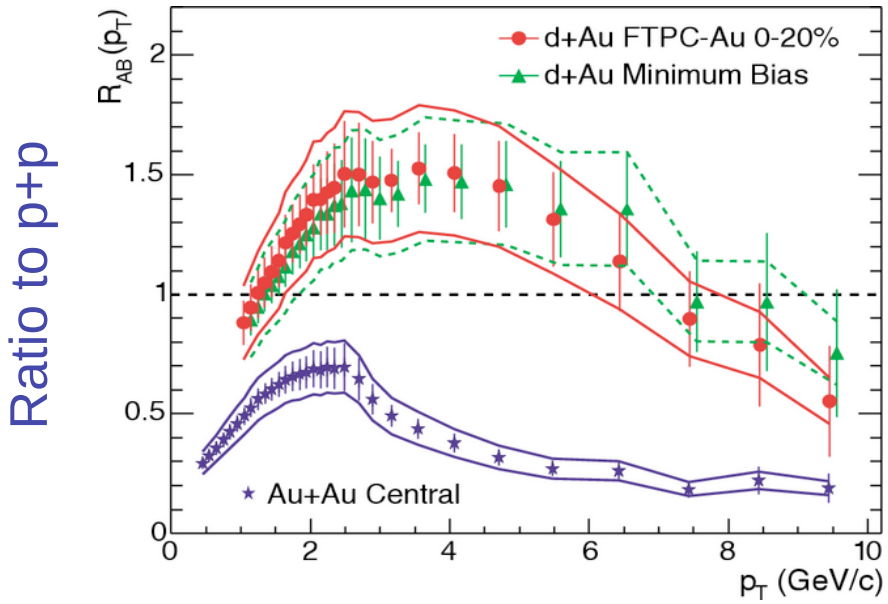
Elliptic flow



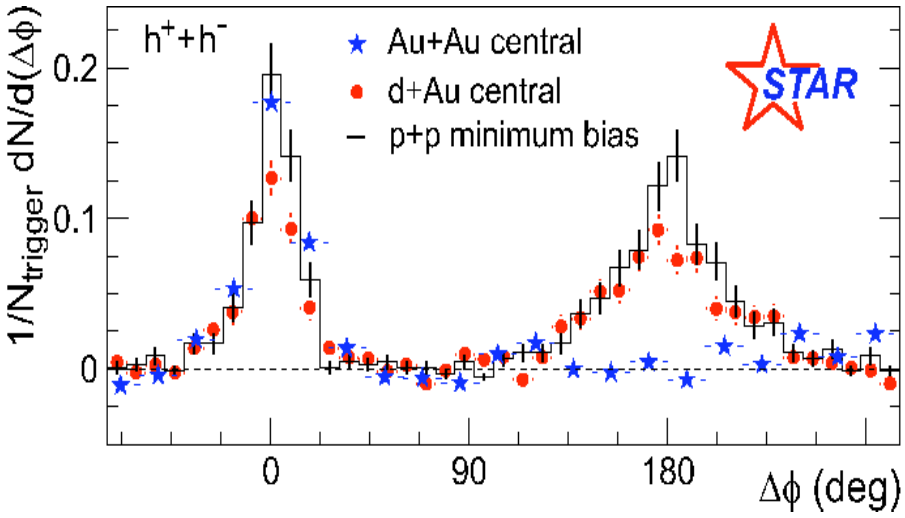


- Strong elliptic flow
  - Mass dependence signals common velocity
  - observed approaching hydro limit
- Modelled with hydro
  - Parton EoS + phase transition to hadron gas

High p_T and back-to-back suppression



PRL **91** (2003) 072304



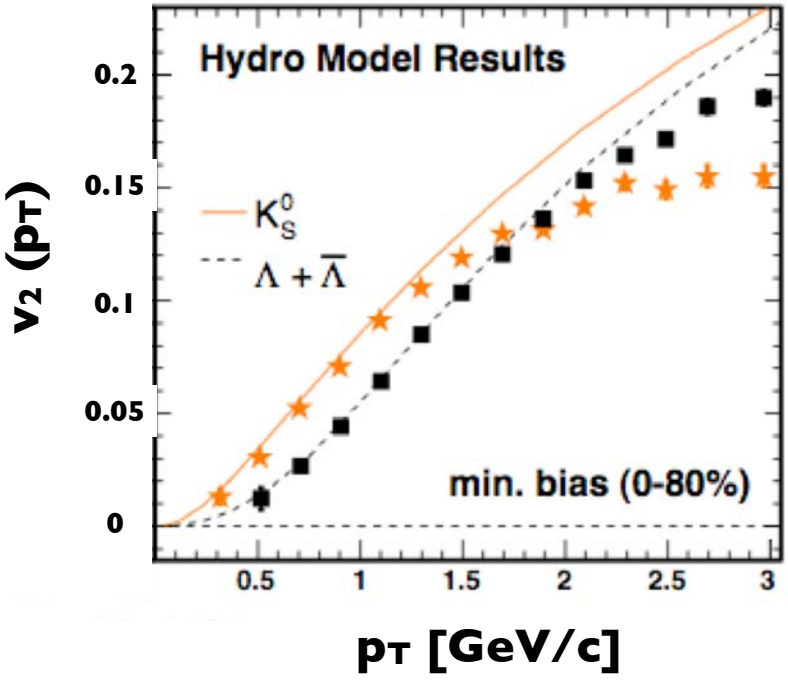
- Compare hadron spectra to p+p
  - d+Au and Au+Au scaled for system size
  - Central Au+Au factor 5 suppression at high p_T
- Absence of away side in back-to-back $\Delta\phi$ correlation

How to investigate the sQGP?

- Look more differentially
  - Change system size (centrality and $\therefore N_{part}$)
  - Look at identified hadrons
    - In particular if one can link a hadron to the parent parton (q, Q, g) giving mass or colour charge dependence
  - Change geometry
    - Cu+Cu vs Au+Au

v_2 of strange hadrons

- Mass ordering observed at lower p_T
- v_2 saturates for p_T > 3 GeV/c
- Clear baryon/meson difference at intermediate to high p_T observed
- High statistics measurement shows deviation from ideal scaling ...



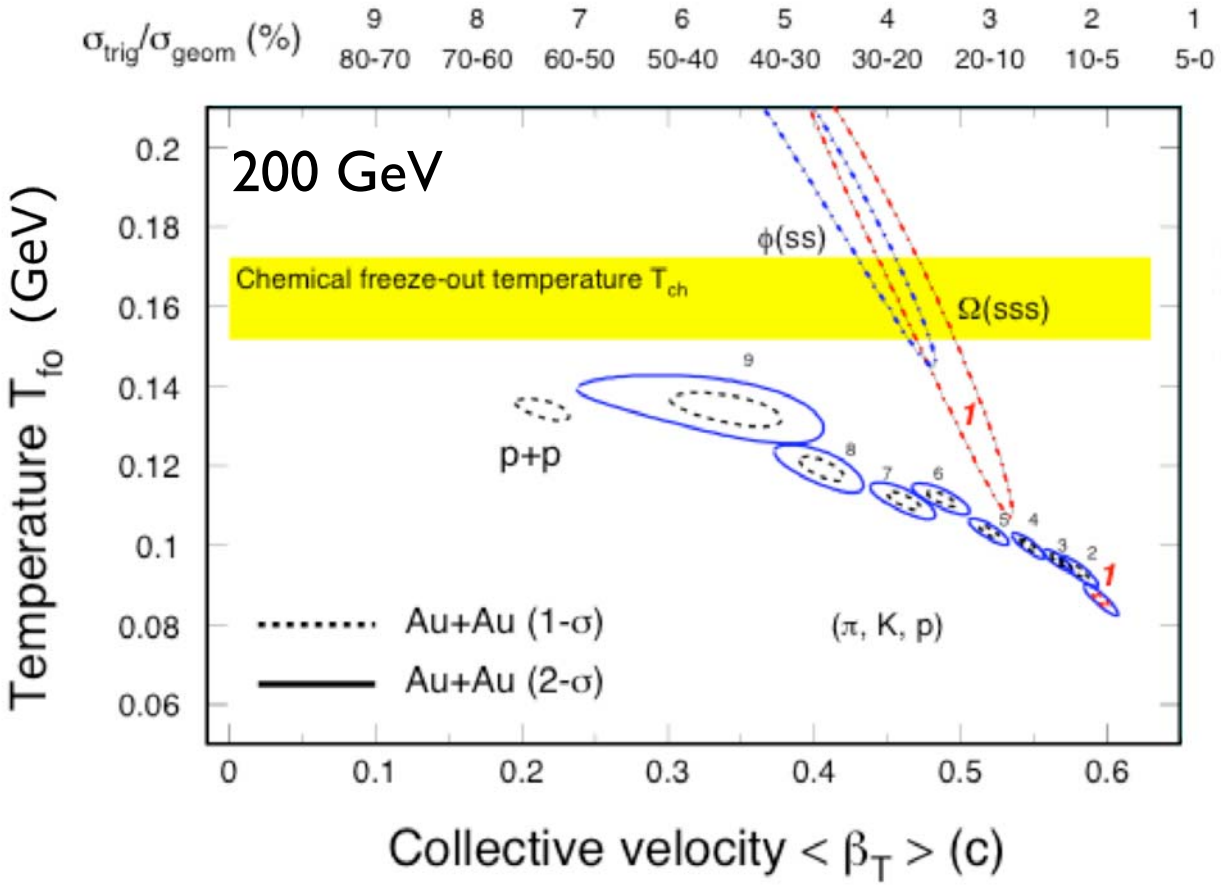
Radial flow - Blast wave fits to data

Strong centrality dependence on freeze out parameters for light hadrons

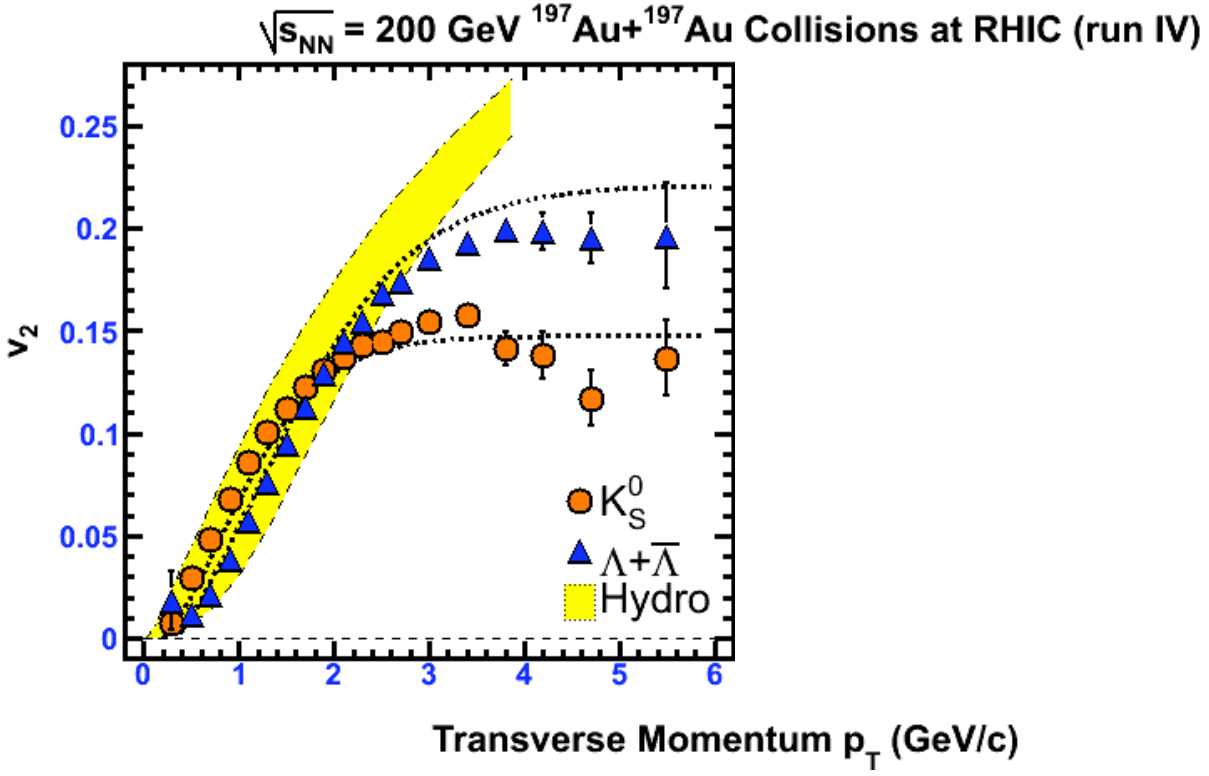
Multi-strange hadrons freeze out earlier, with a lower $<\beta_T>$

Indicative of smaller cross-section for interactions of multiply strange hadrons with lighter species.

Is this a signature of partonic collectivity?



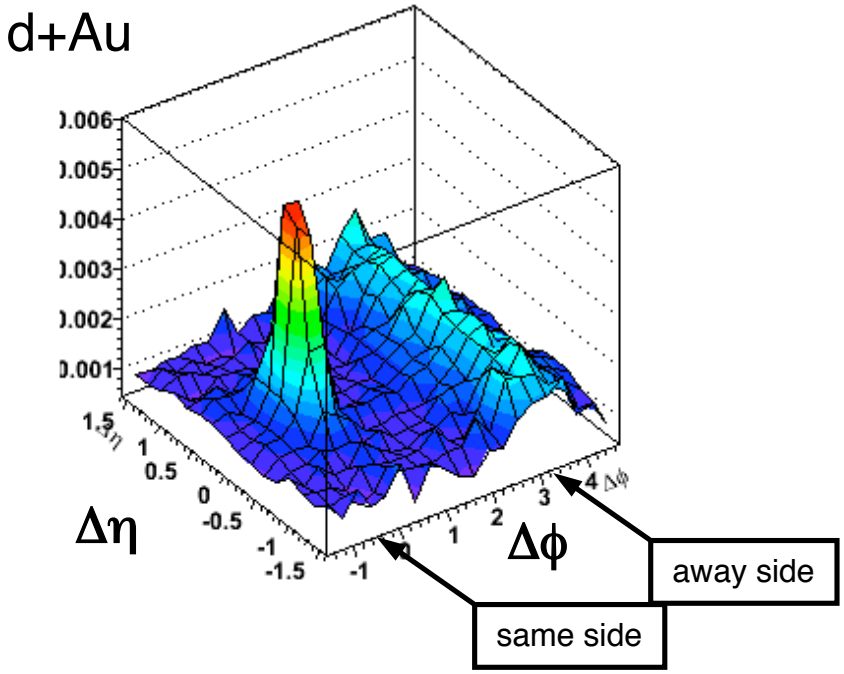
v_2 of multi-strange hadrons

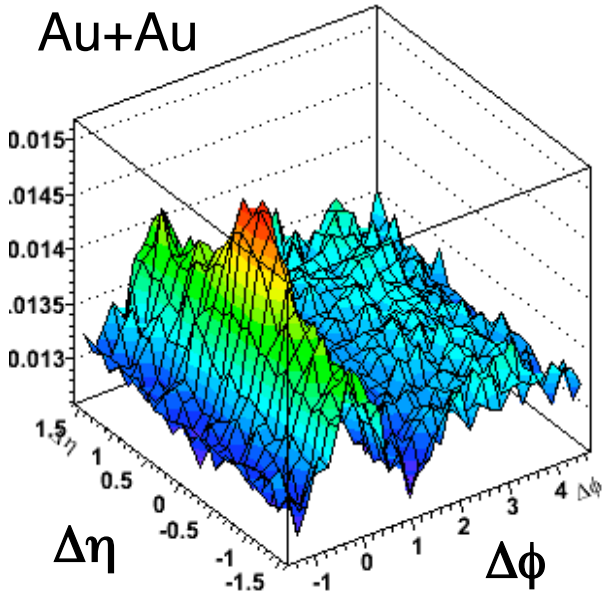


- Multi-strange hadrons flow just as well as other baryons and mesons
- Collective flow is developed early, during partonic stage

See Talk by N. Xu for detailed ϕ study.

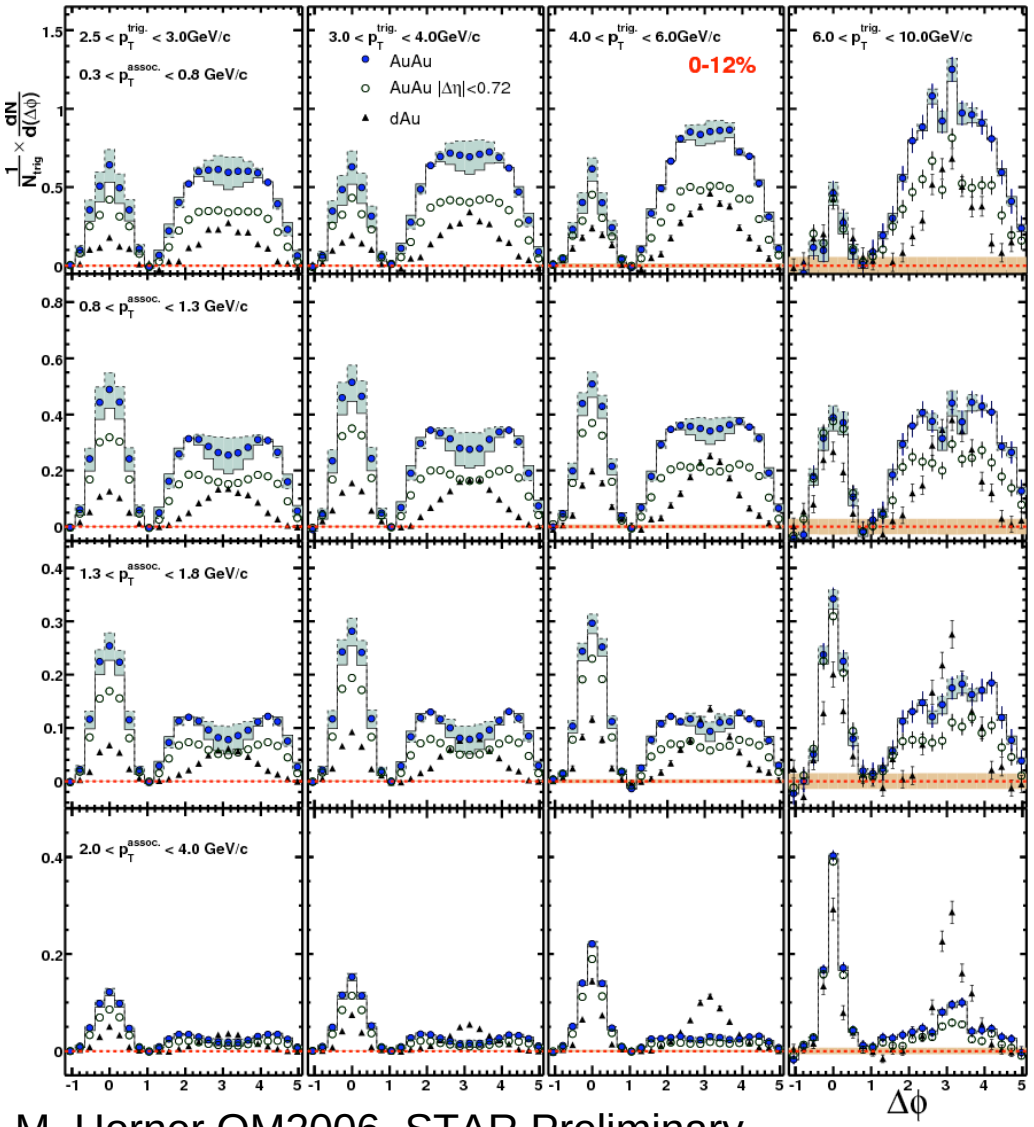
$\Delta\eta-\Delta\phi$ correlations





- Modifications d+Au → Au+Au
  - Disappearance of away side
  - Extended same side feature on $\Delta\eta$ - 'ridge'
- Explore dependence of jet-medium interaction on
  - trigger particle species, $p_{T,trig}$ $p_{T,assoc}$

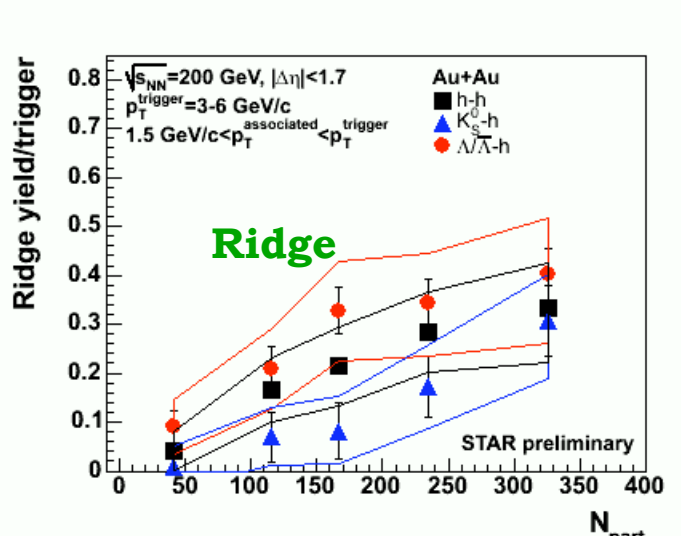
$\Delta\phi$ correlations: p_T dependence

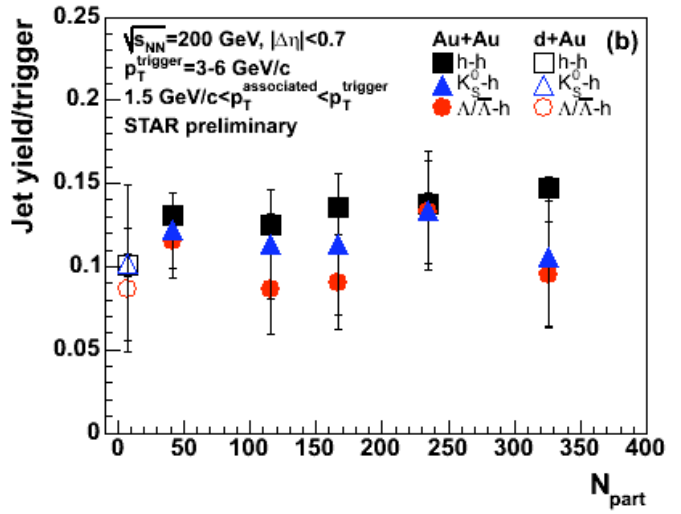


M. Horner QM2006, STAR Preliminary

- Full exploration of trigger- and associated-p_T dependence.
  - At lower $p_{T,assoc}$ away side enhanced and shape modified

$\Delta\phi$ correlations: species dependence

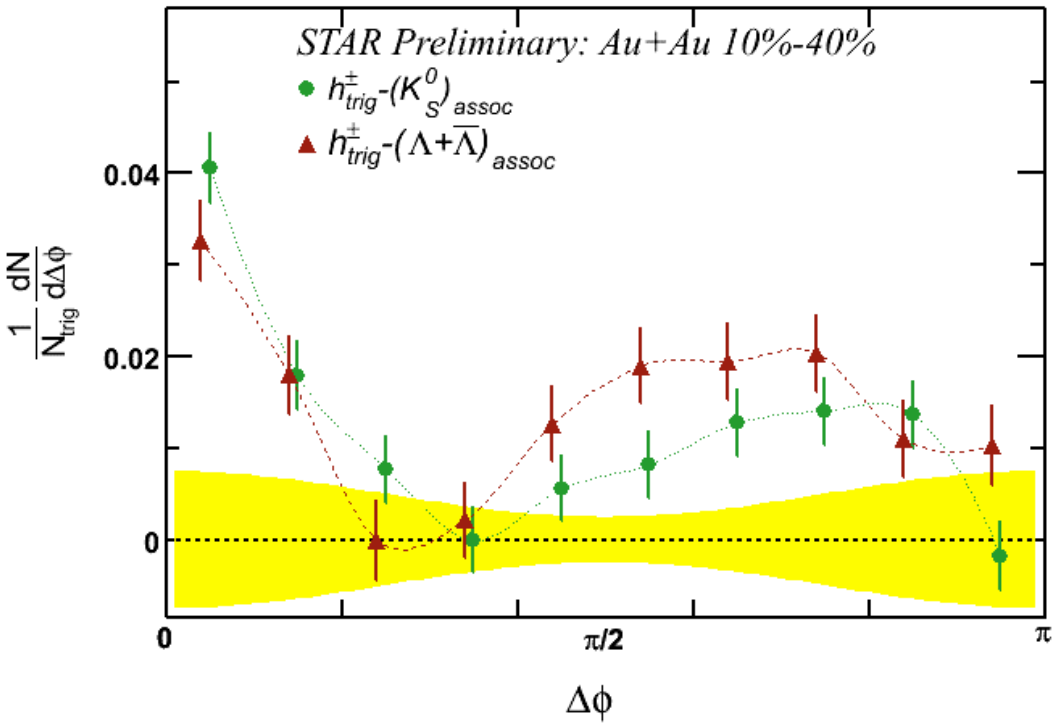




- Ridge yield growing as move to more central collisions
  - For all hadron species triggers
- Jet part ~ constant
- Also possible to use multi-strange triggers and inform recombination models

See Talk by B. Abelev for more details
Also C. Nattrass and A. Timmins from Sunday

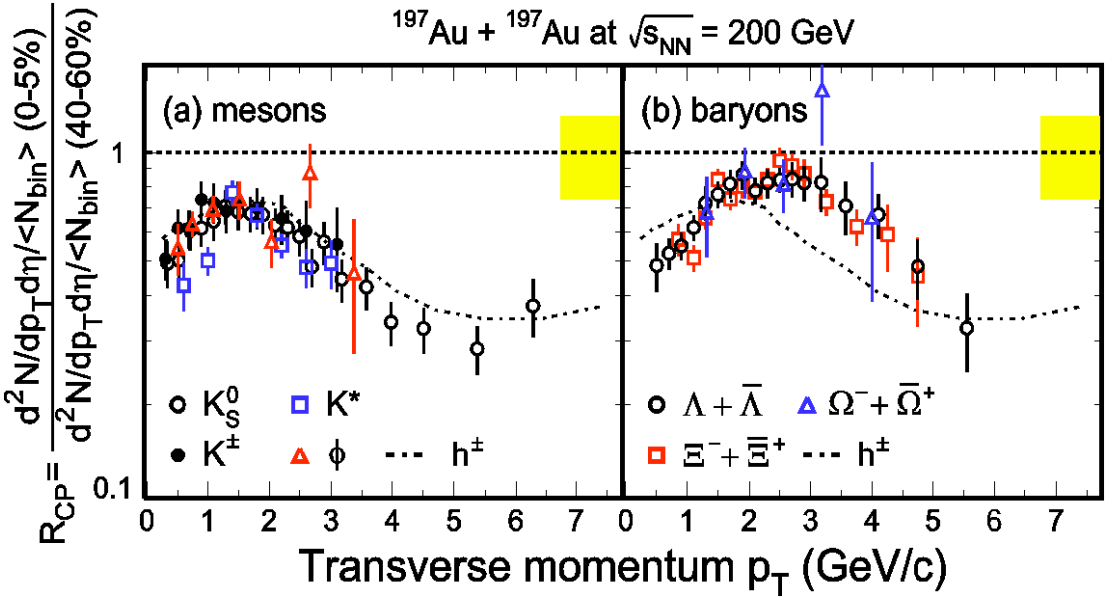
$\Delta\phi$ correlations: species dependence



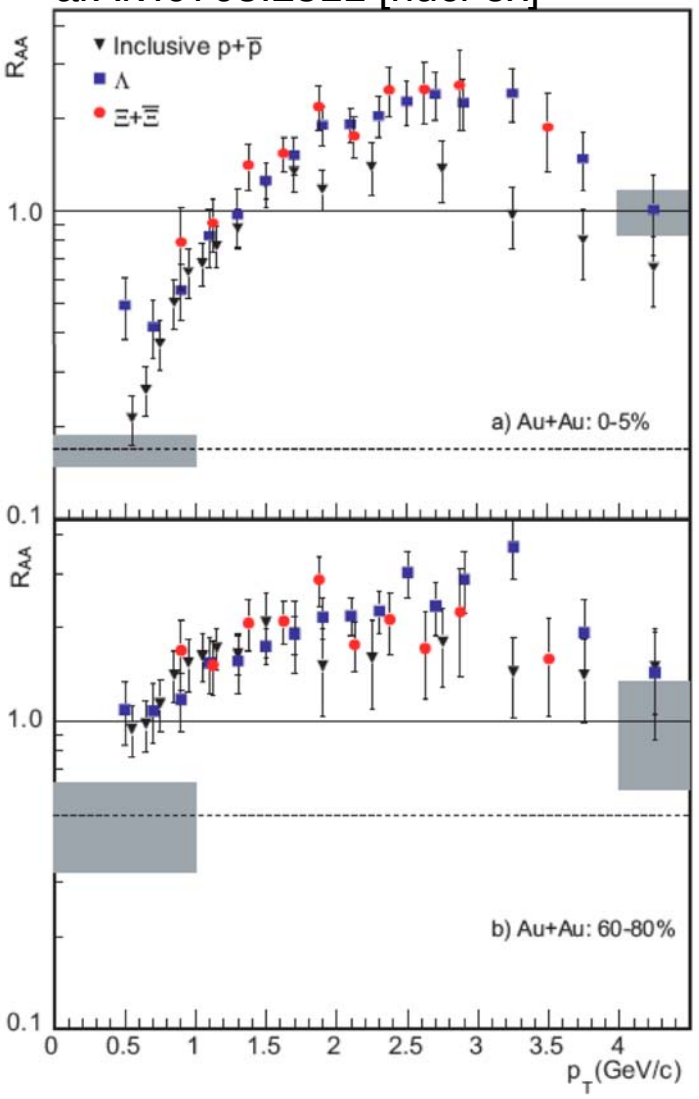
- Particle composition in the away side structures can be explored
  - Eg associated Λ and K^0 as a function of $\Delta\phi$ for a hadron-triggered correlation

See Talk by J. Zuo for more details.

Strange particle R_{CP} and R_{AA}

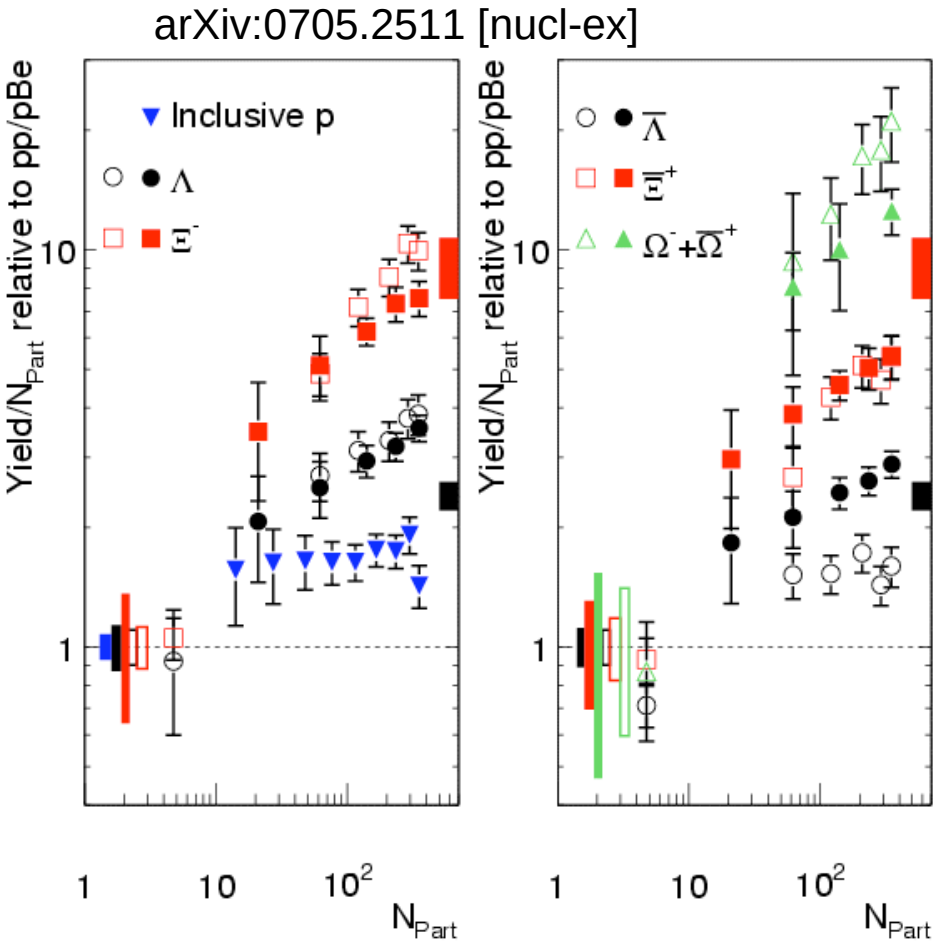


arXiv:0705.2511 [nucl-ex]



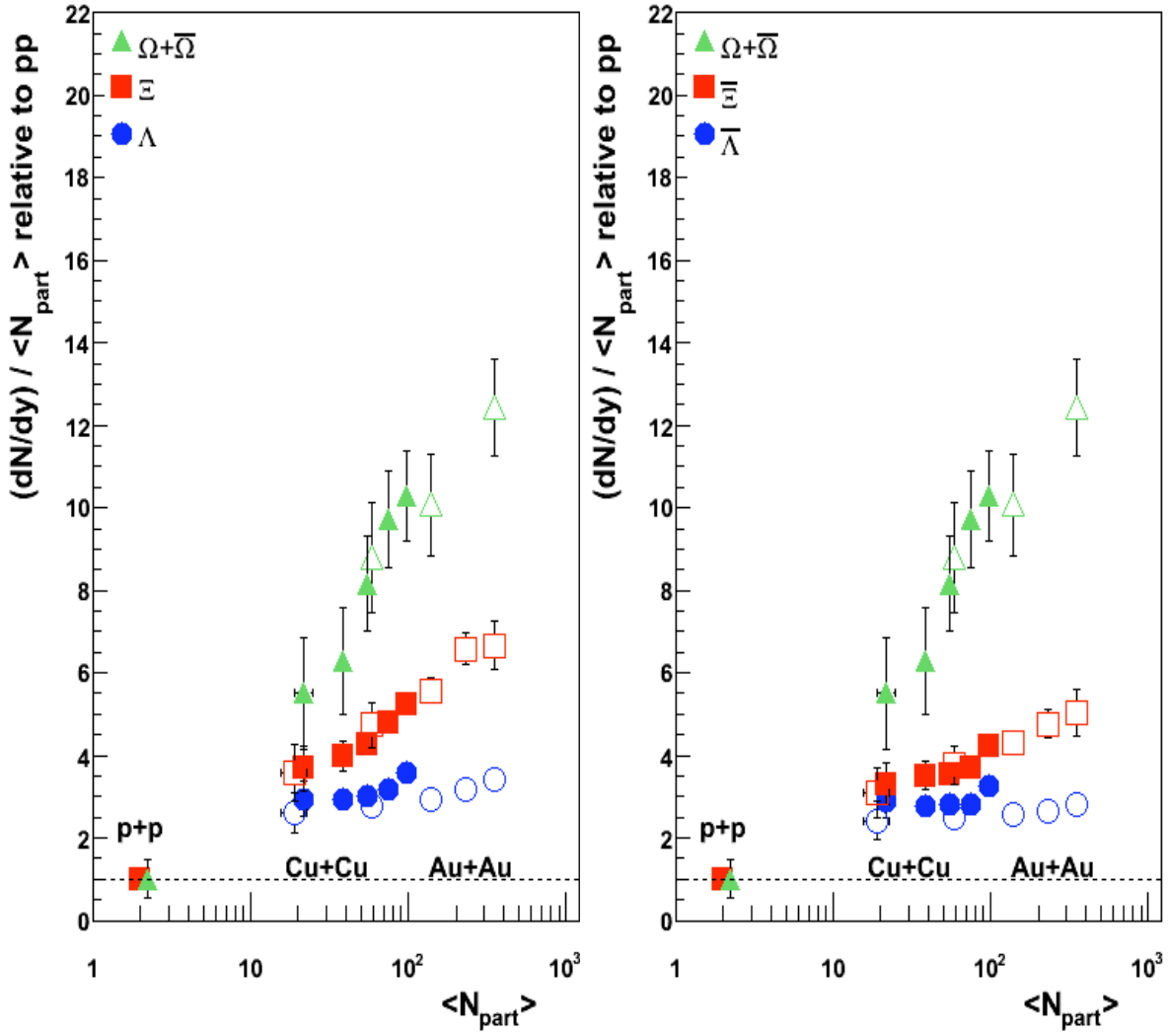
- R_{CP} reveals meson/baryon difference at intermediate p_T
  - Due to recombination , hard-soft interplay
- R_{AA} for strange baryons is higher though
  - Influence of strangeness enhancement (cannonical suppression) of soft ‘thermal’ distribution

Strangeness Enhancement



- Strange baryon yields per participant in Au+Au (Pb+Pb) relative to p+p (p+Be)
- Dependence on N_{part} in above ~20 not expected if N_{part} ∝volume

Strangeness Enhancement Cu+Cu

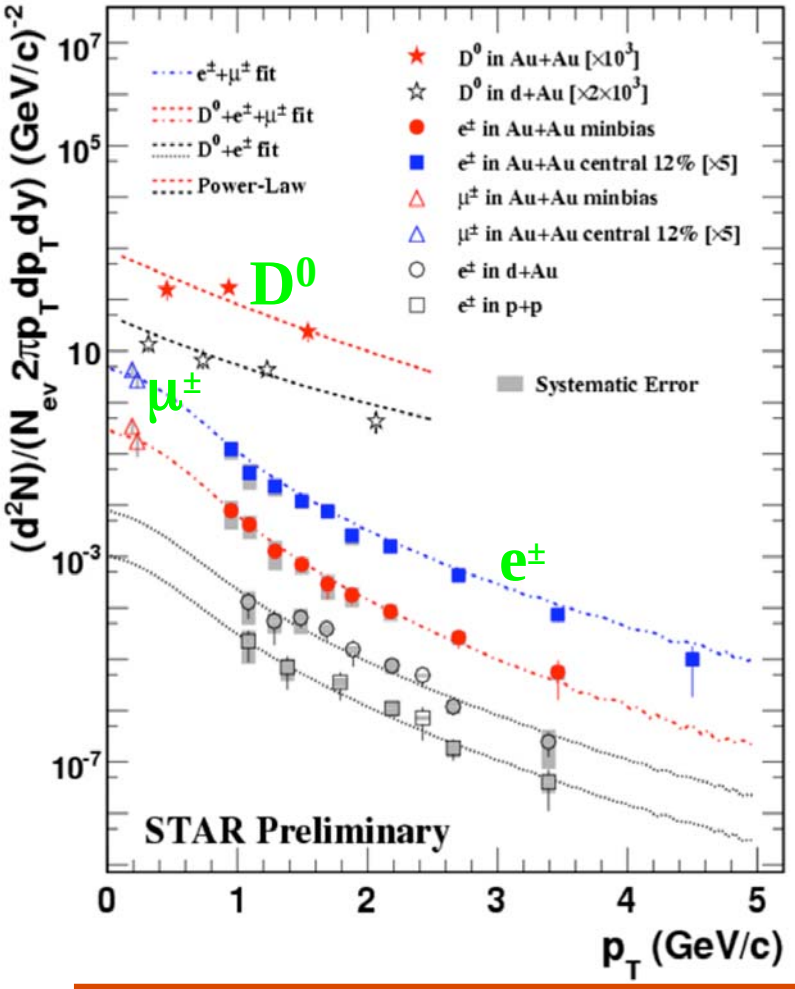


- Cu+Cu covers range where $N_{part} < 100$
- Broadly agrees with Au+Au
- Indications that for Λ and Λ-bar enhancement is larger than in Au+Au
  - Why? Greater overlap of small correlation volumes?

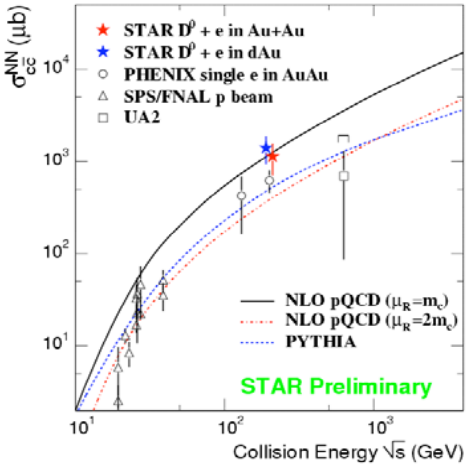
Heavy Flavour

- pQCD calculable process
- Varies mass of partonic probe of matter
- Quarkonium states disassociate in medium
  - Details depend on temperature compared to T_C

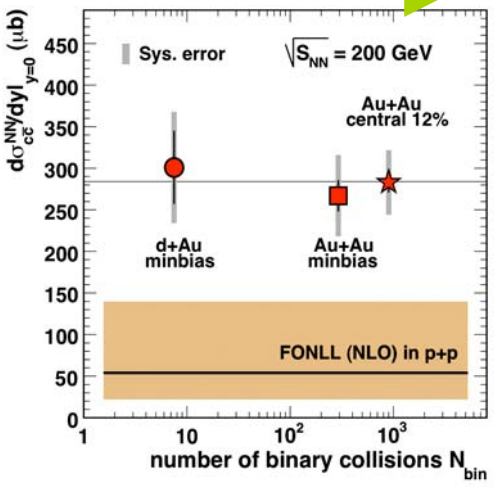
Charm cross section



$\sigma^{NN}_{c\bar{c}}$ = 1.40 ± 0.11 ± 0.39 mb
in 0-12% central Au+Au



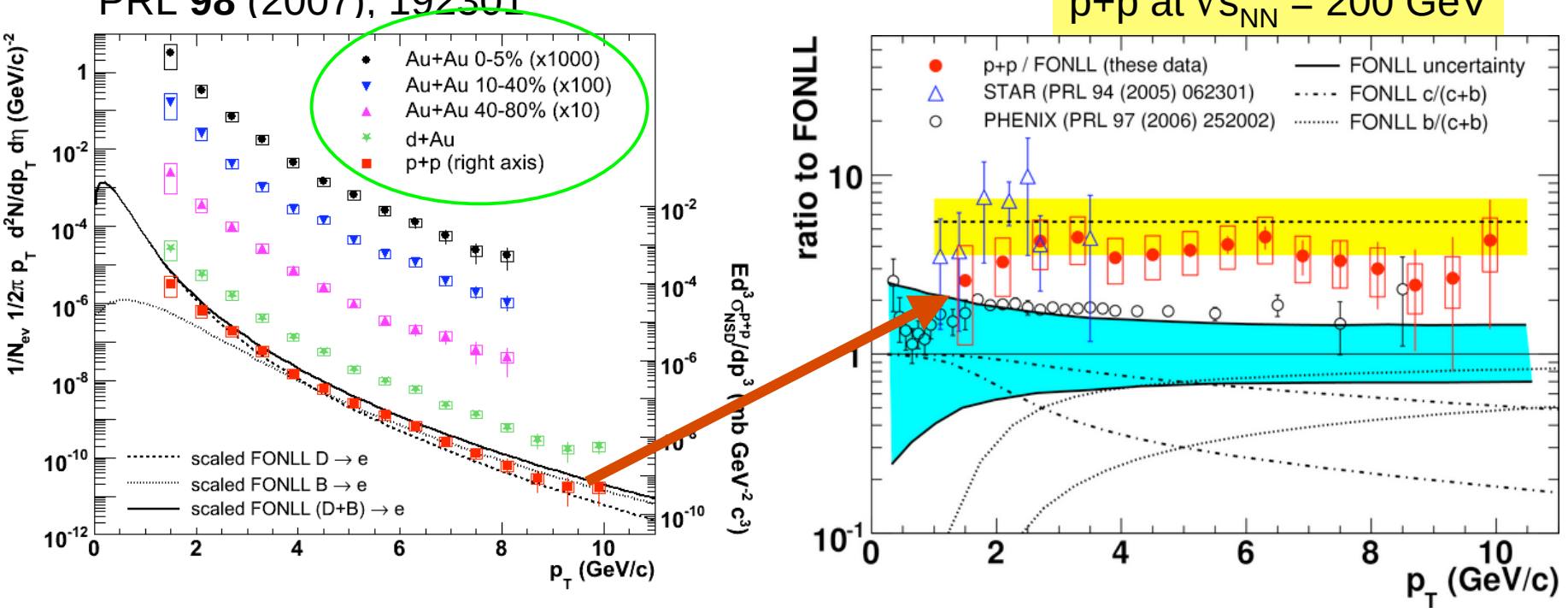
centrality



- D^0, $e^{\pm}$, and $\mu^{\pm}$ combined fit covering ~95% of cross section
- σ^{NN}_{cc} higher than NLO calculations
- $d\sigma^{NN}_{cc}/dy$ follows binary collision scaling (N_{bin}) → charm production from initial state, as expected

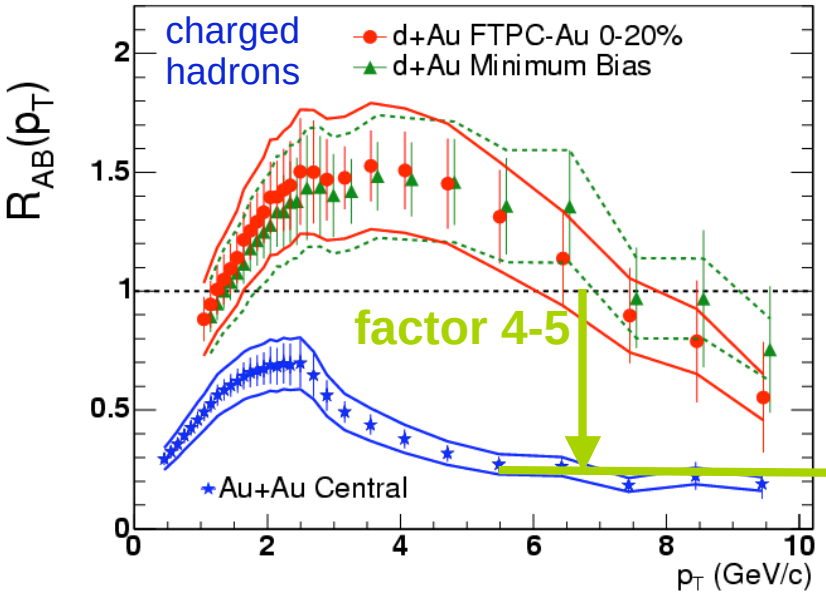
Non-photonic electron spectra

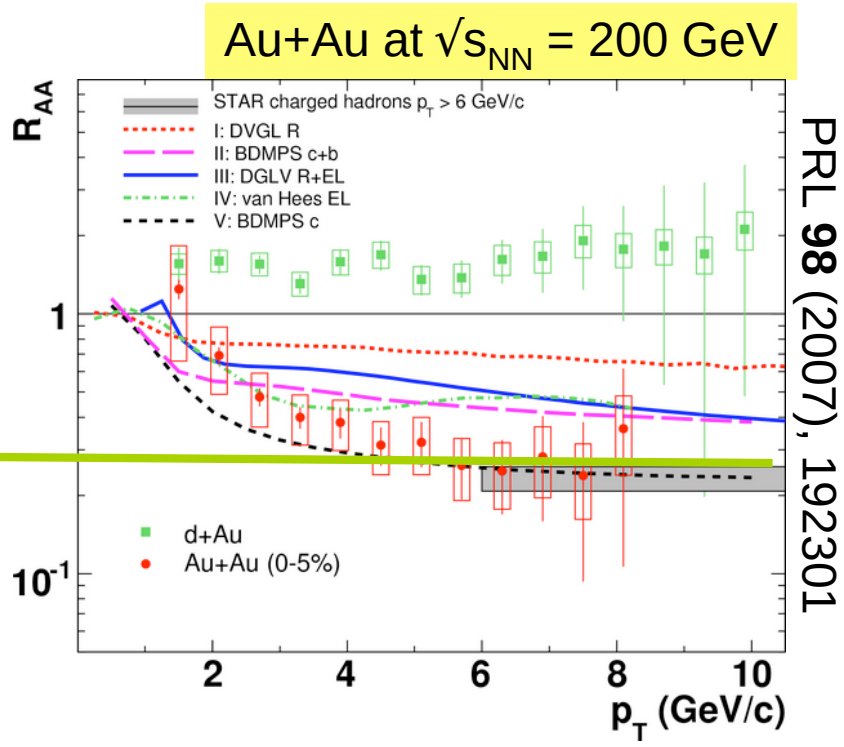
PRL **98** (2007), 192301



- FONLL calculation factor of about 5 lower
- Spectra *shape* well described

Nuclear modification factor R_{AA}





Nuclear modification factor:

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta}$$

where $T_{AA} = N_{Coll}/\sigma^{NN}_{inelast}$

- Non-photonic electrons at high-p_T are suppressed to the same extent as light quark hadrons in Au+Au
- Not expected due to dead-cone effect

Disentangle c and b: first approach

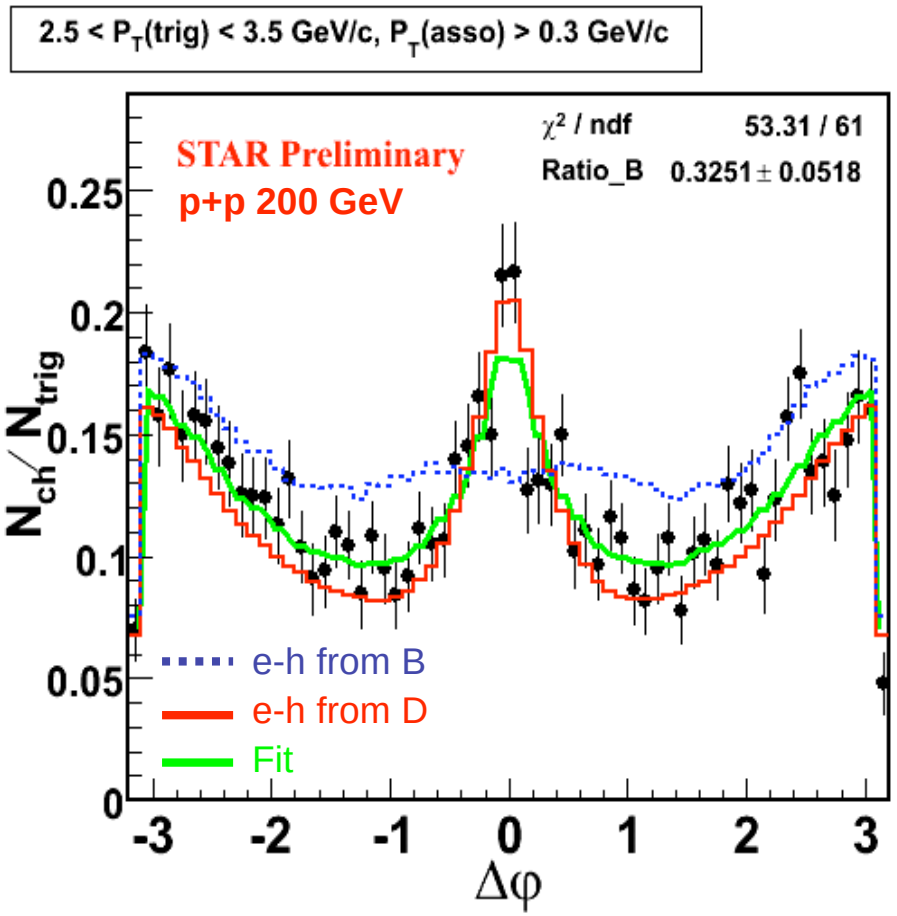
- Different fragmentation of associated jets
- Study non-photonic electron-hadron azimuthal correlations in p+p
- B much heavier than D mesons

→ sub-leading electrons get larger kick from B (decay kinematics)

→ near-side e-h correlation is broadened

- Extract relative bottom contribution using PYTHIA simulations:

$$\Delta\phi_{measured} = R \cdot \Delta\phi_B + (1-R) \cdot \Delta\phi_D$$



See Talk by X. Lin

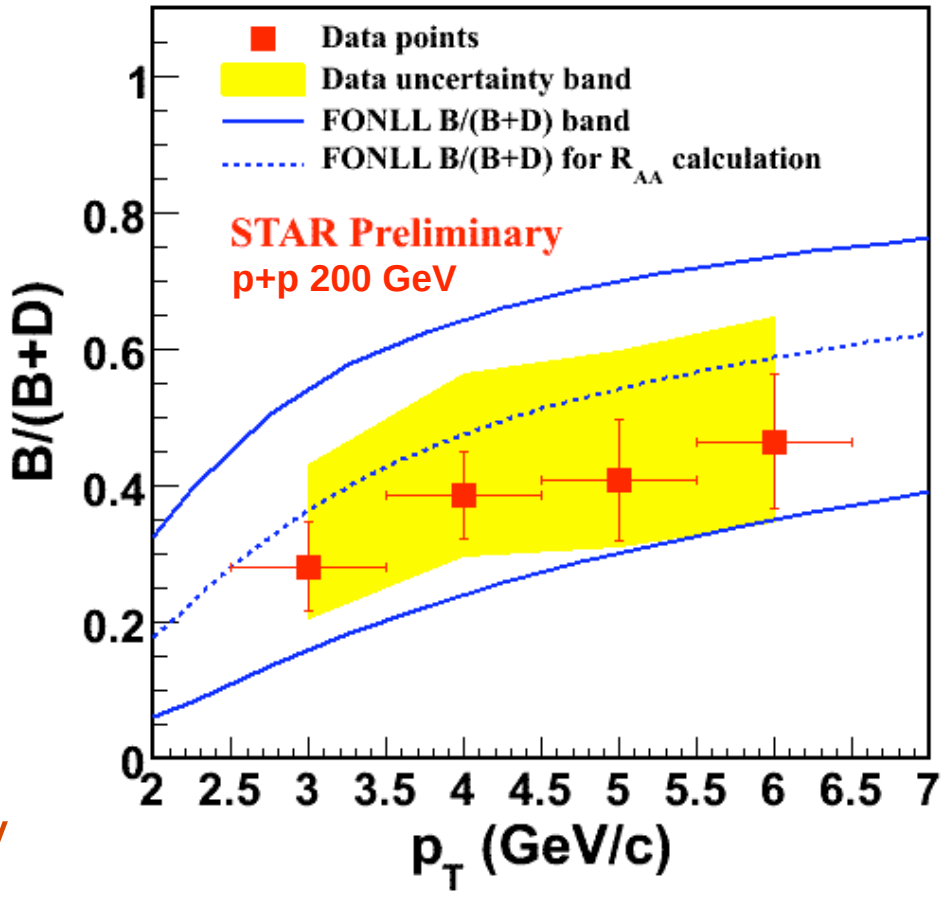
B contribution to np-electrons

- Non-zero bottom contribution observed
- Flavour contribution consistent with FONLL
- Caveats
  - subtraction of (large) back-ground
  - model dependent (PYTHIA)
  - photonic background rejection efficiency

Follow up with direct D/B meson measurements

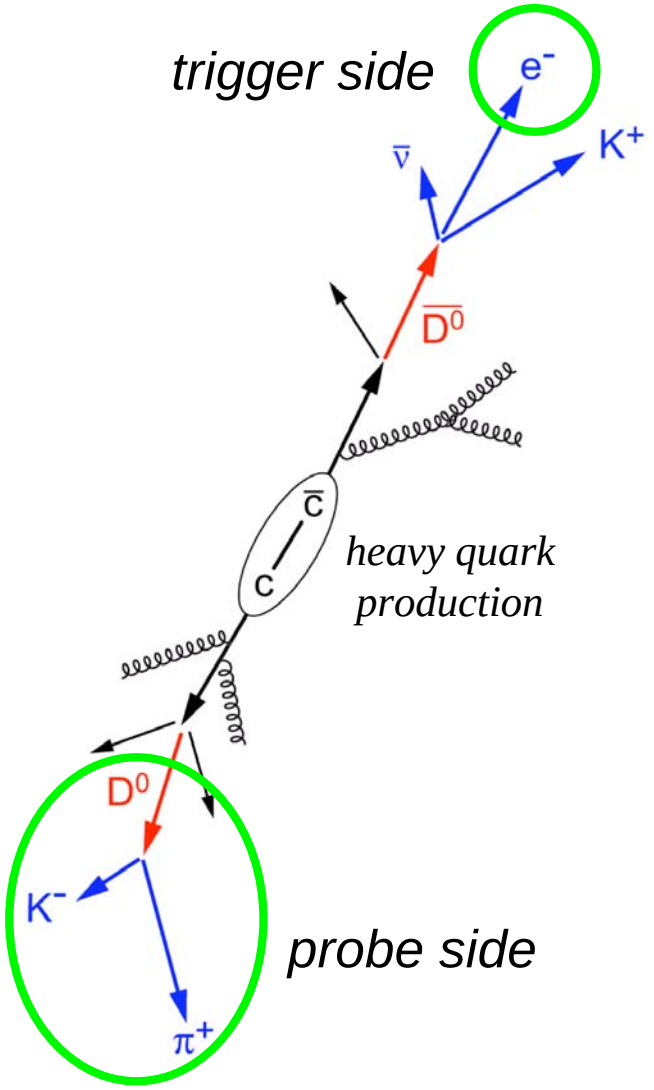
→ STAR detector upgrade: Heavy flavor tracker
(vertex resolution σ ≤ 50 μm)

X Lin (STAR), QM 2006



Heavy flavor tagged correlations

- Advantage: STAR has large acceptance ($|\eta| < 1$ and full azimuth)
- Underlying production mechanism can be identified using second charm/bottom particle
- Experimental approach
  - non-photonic electrons from semi-leptonic c/b decays are used to trigger on c-cbar or b-bbar pairs
  - associate D^0 mesons are reconstructed via their hadronic decay channel (probe)



See Talk by A. Mischke.

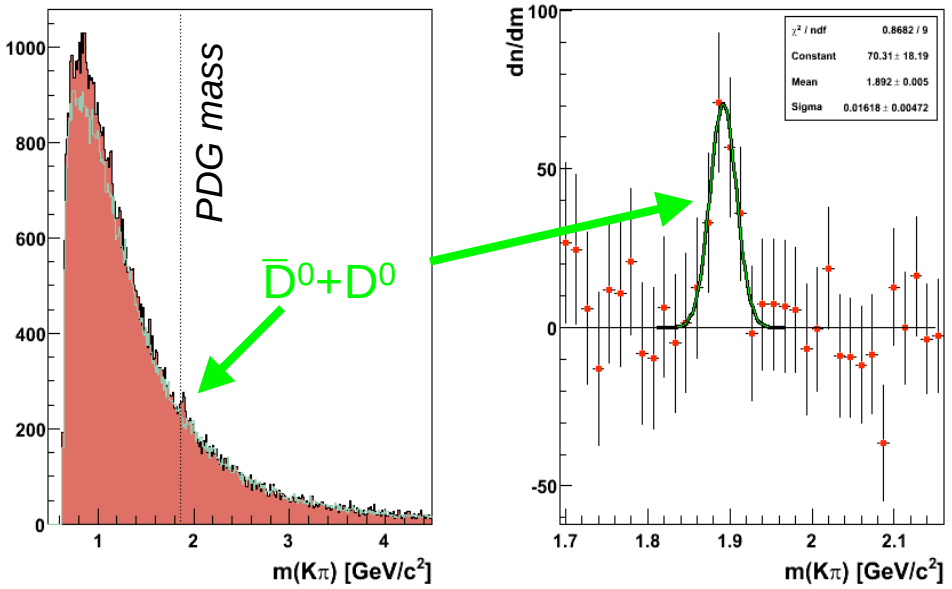
Electron-D^0 azimuthal correlations

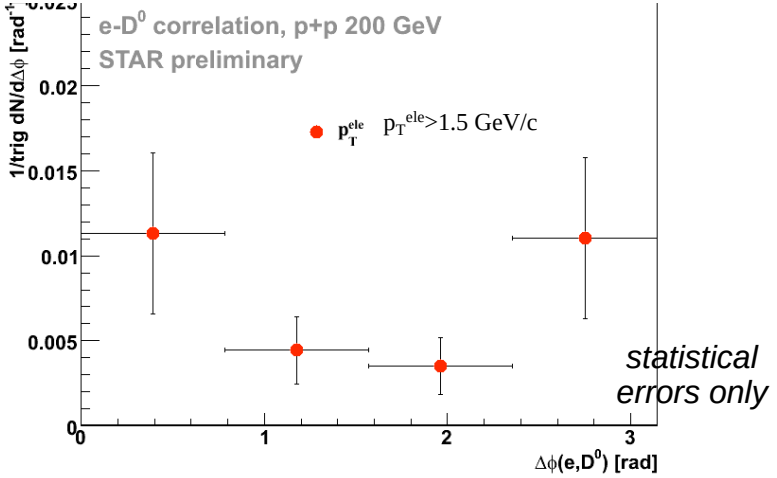
- Clear D^0 signal
  - S/B ratio factor ~100 better than signal w/o electron trigger
- Near- and away-side correlation peak with similar yields observed

→ Evidence for heavy flavor correlations

- Next: Separate charm and bottom contribution as well as sub-processes (e.g. gluon splitting) using
  - dedicated simulations
  - charge-sign requirement on (e, D^0) pairs

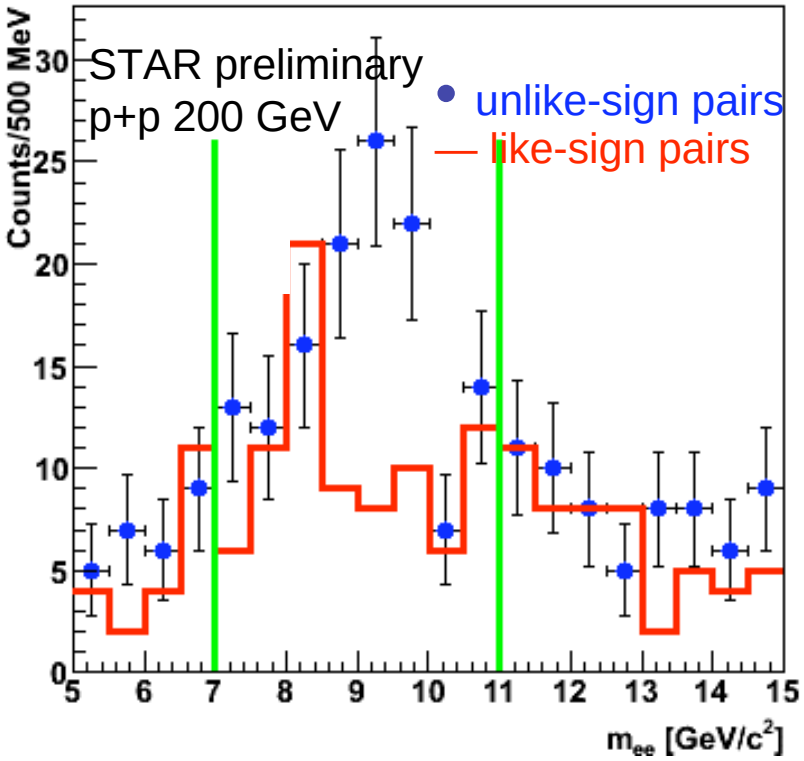
p+p $\sqrt{s_{NN}}$ = 200 GeV, $\int Ldt$ = 9 pb^{-1}

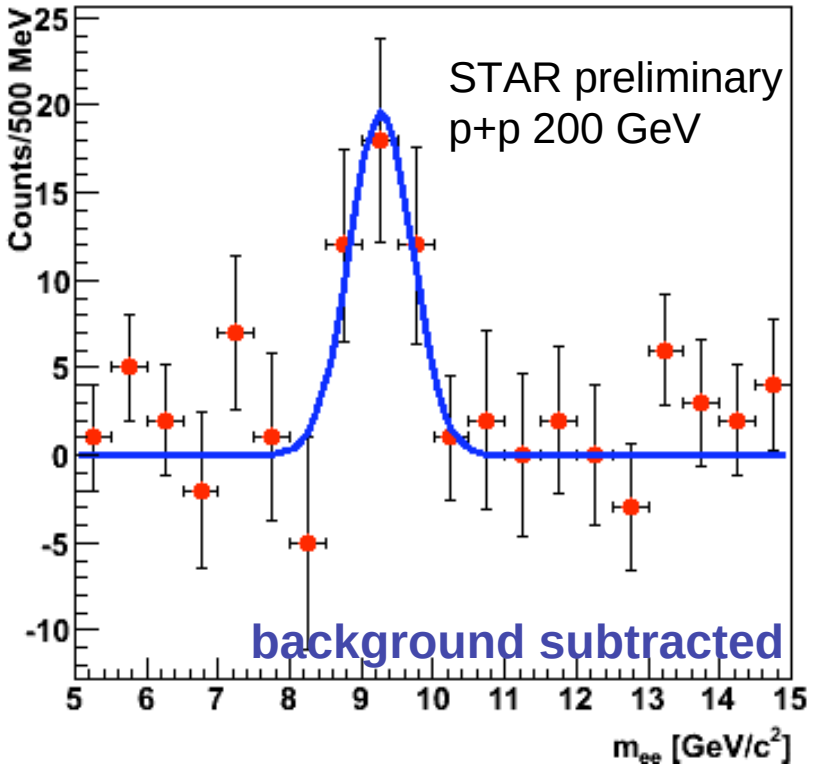




Quarkonia in STAR

QM 2006, nucl-ex/0701075



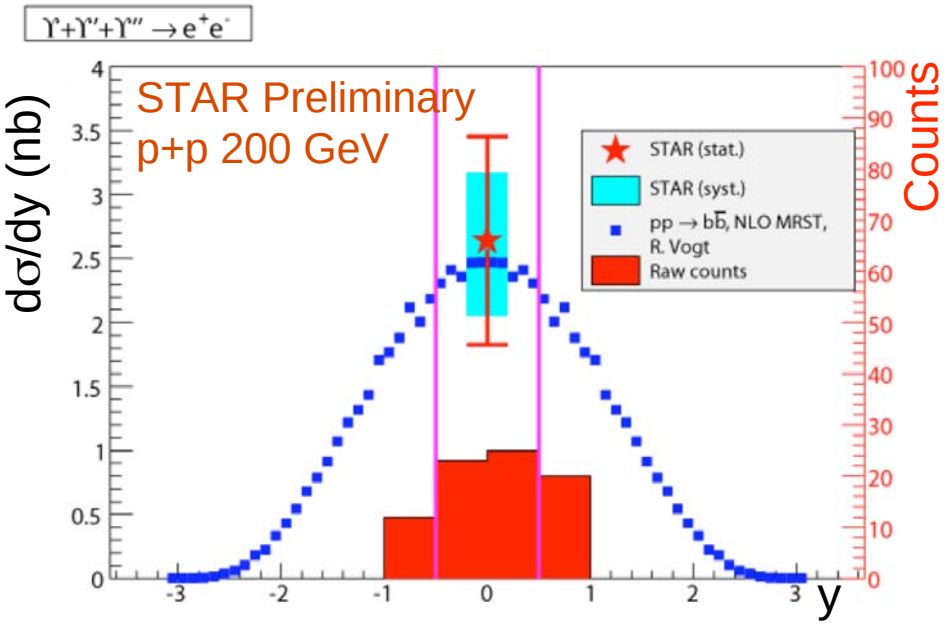


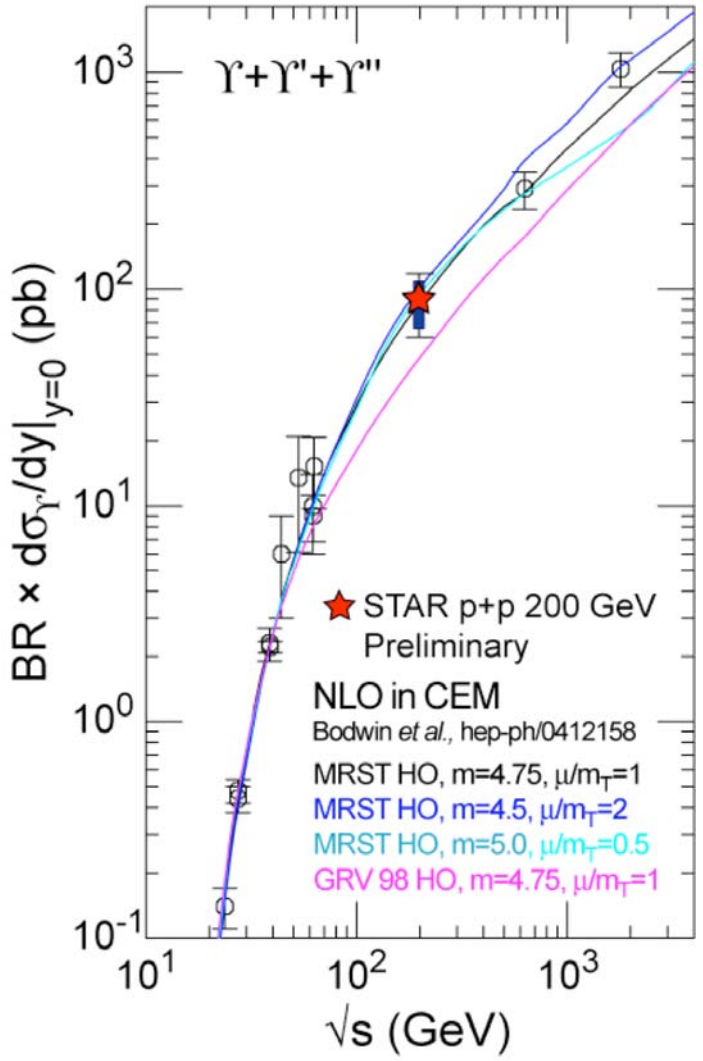
- Prediction: Melting of Quarkonia states in QGP phase
- Color screening between heavy quark pairs, e.g., J/ψ suppression

Matsui and Satz, PLB 178, 416 (1986)

- Large dataset sampled in Run VI
- Measure Υ(1s+2s+3s) $d\sigma/dy$ at y=0
- Peak width consistent with expected mass resolution

Mid-rapidity Υ(1s+2s+3s) cross-section





- Integrated yield at mid-rapidity: |y|<0.5
- Υ(1s+2s+3s) → e^+e^-:

  $BR_{ee} \times d\sigma/dy = 91 \pm 28(stat.) \pm 22(sys.)$ pb
- Consistent with NLO pQCD calculations and world data trend
- Next: Au+Au measurement in RHIC Run VII

Summary

- Rich data set now available.
- v_2 measurements support partonic picture
  - EoS, v_2/n_q scaling
- High-p_T measurements reveal areas of interplay between jet and medium.
  - Near-side ridge, away-side broadening
- Soft production continues to provide additional information, some puzzling.
  - strangeness suppression with N_{part}, Cu+Cu
- Heavy flavour has *some* of the expected features…
  - σ scales with N_{bin} *but* disagrees with FONLL calc.
- …and shows much promise for future
  - Υ programme, open charm V0


STAR