Jet studies in STAR via 2+1 correlations

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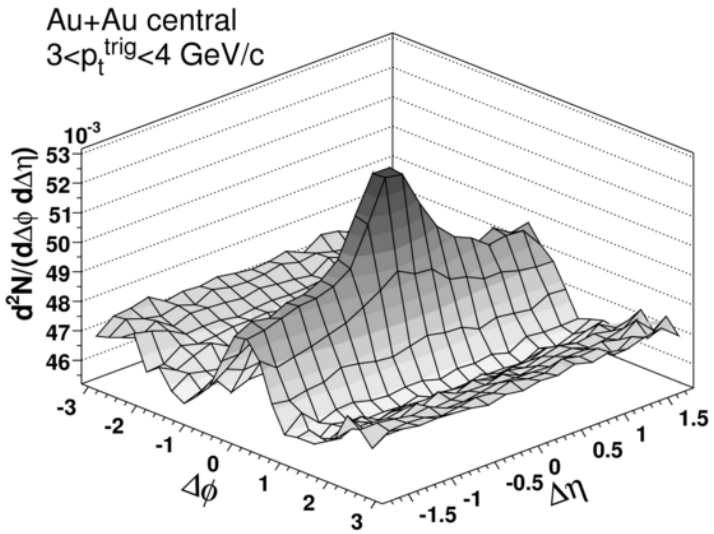
For the STAR Collaboration

Outline

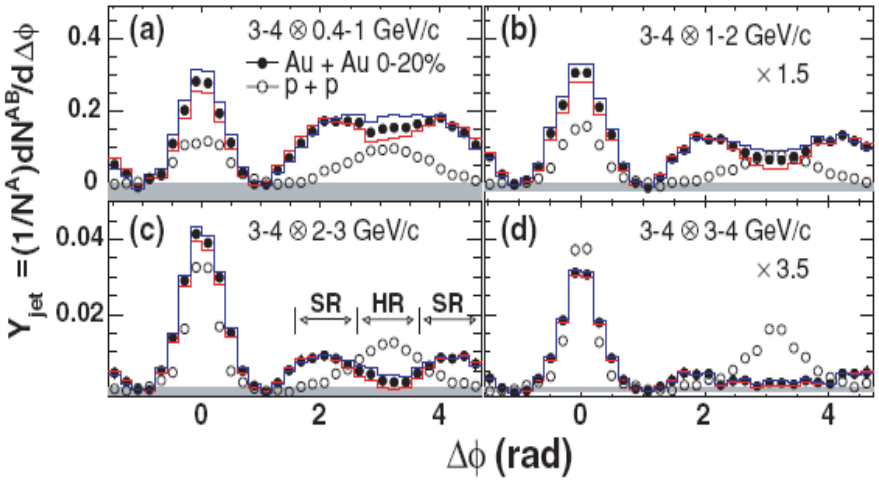
- **Jet quenching as a big discovery in heavy ion collisions**
- **Statistical studies of di-jets: 2+1 correlation technique, different to full jet reconstruction.**
  - **Analysis technique,** *background subtraction*
  - **High-energy photon and charged hadron triggered data**
  - **Jet shapes, spectra, and comparison between**
    - **d+Au analysis**
    - **Au+Au analysis**
  - **Preliminary test of theory models, comparison with samples.**
- **Outlook**

Start from 2-particle correlations

- p+p shows jet-like peaks on near- and away-side.
- Au+Au shows strong modification in shapes:
  - Ridge at near-side
  - Head-shoulder shape on the away-side, a “cone” structure?



Phys. Rev. C **80** (2009) 64912

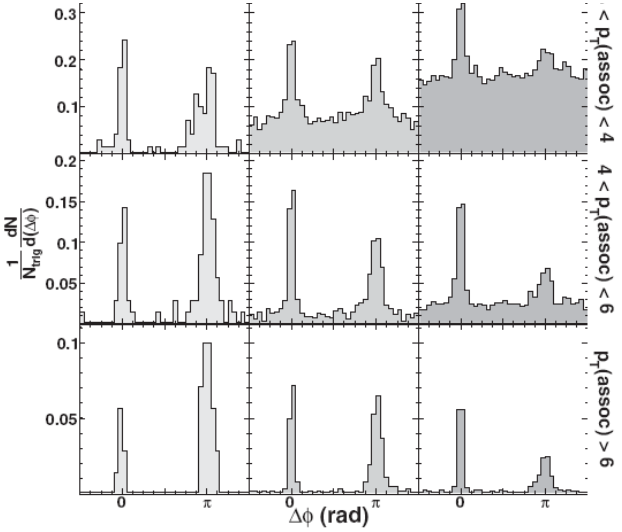


Phys. Rev. C **77**, 011901(R) (2008)

The long “Mach-cone” legend

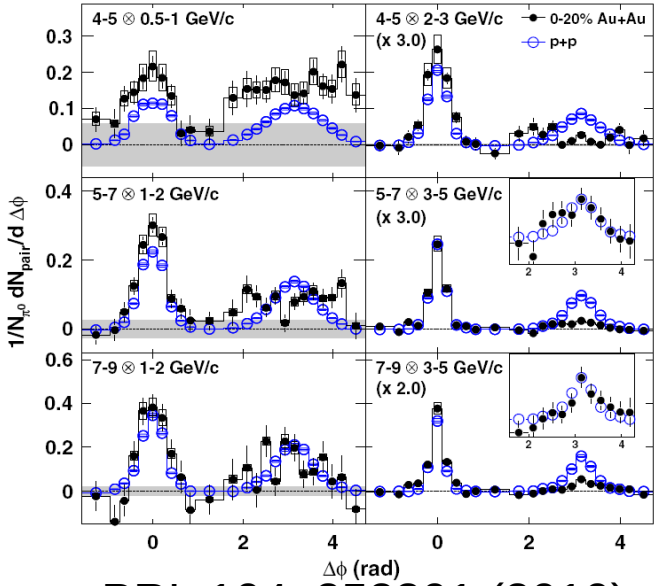
- Many theory models have calculated how parton-medium interaction (energy-loss) can form such “cone” structure.
- On the other hand, di-jet structure re-appear at high-p_T Au+Au correlations, with similar shapes to those in vacuum p+p.
  - A strong suppression, however: **jet quenched, energy lost**

d+Au ----> Central Au+Au



PRL **97,** 162301 (2006)

Associate p_T increase



PRL 104, 252301 (2010)

Introduction of "2+1" correlation

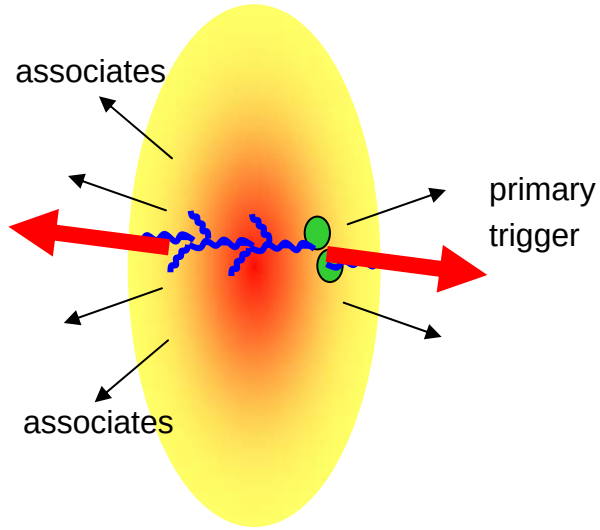
- If the 2-particle correlation of high-p_T particles indicates jet-like shape reappear at away-side while quenched, is it a "smaller jet per-trigger", or do some jets escape unmodified while others completely absorbed?

- And how will that test the existing theory models on energy-loss?

- Here we present analysis with a "2+1" technique, using a second high-p_T ("conditional") particle on the away-side of the first high-p_T trigger, then study the low-p_T associates around both high-p_T particles.

The “2+1” correlation

Courtesy of R .Hollis



- **Use two back-to-back high-p_T triggers as proxy of dijets**
  - **“pin” the ‘jet axis’ selecting back-to-back high-p_T triggers**
  - **Study all low-p_T particles correlation in the events, w.r.t. this axis**

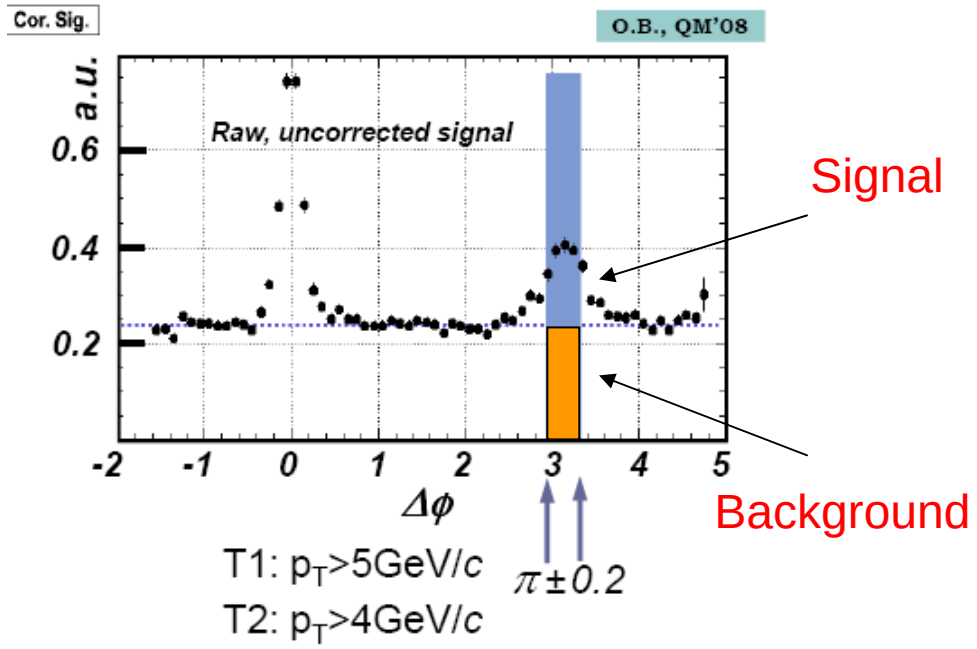
The “2+1” correlation technique

- The trigger-associated pairs include random combinatorics, which are subtracted in the analysis.

- The back-to-back trigger pairs also include random combinatorics.

  ➢ This probability is estimated from trigger-trigger correlation at the required back-to-back region.

  ➢ Such pairs will contribute two independent “normal” 2-particle correlation, which are subtracted.



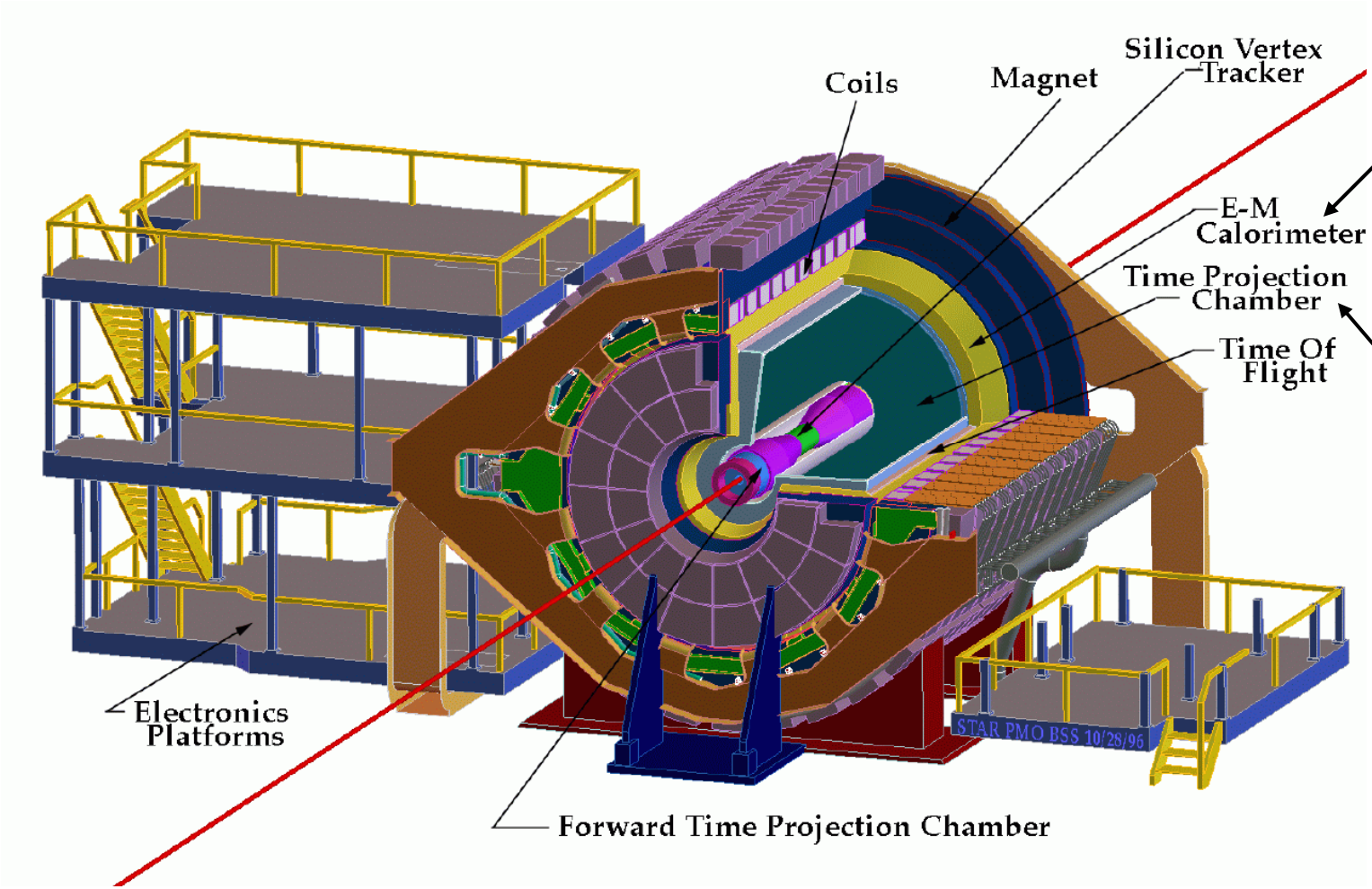
(S+B)/S * Raw 2+1 correlation (near-side)

– B/S * T1-A (near-side)

– B/S * T2-A (away-side)

= “True” 2+1 correlation (near-side)

STAR detector layout



High energy gammas

Charged tracks

Result of "2+1" correlation

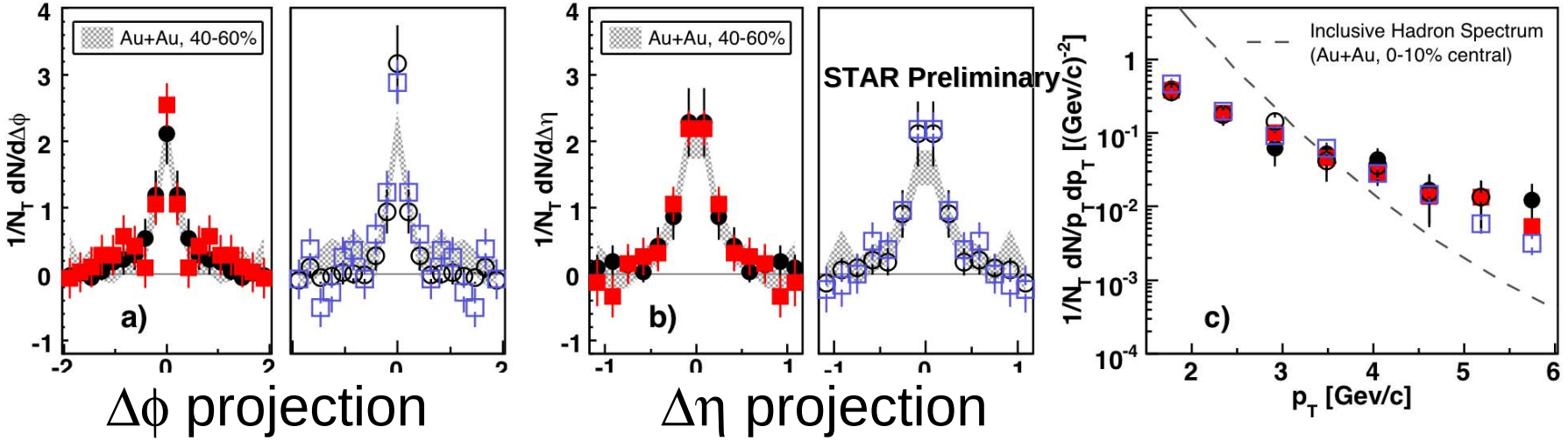
Au+Au vs. d+Au $\sqrt{s_{NN}} = 200GeV$

T1: 5 GeV/c < p_T < 10 GeV/c
T2: 4 GeV/c < p_T < p_T^{T1}
A1: 1.5 GeV/c < p_T < p_T^{T1}

arxiv.

1102.2669

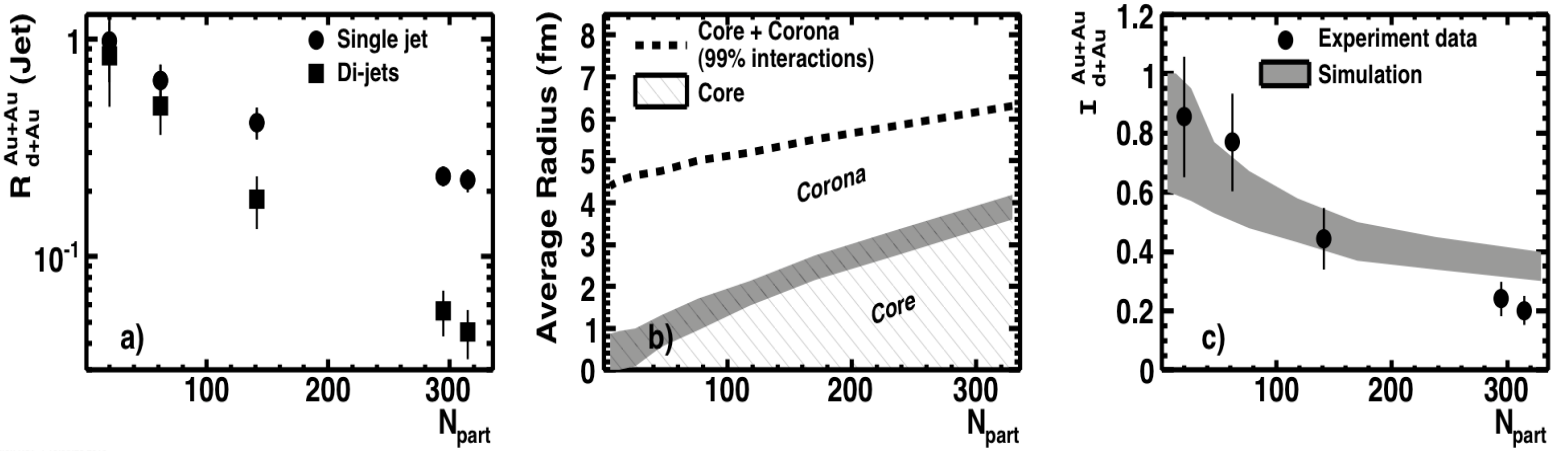
Near-side Away-side Near-side Away-side



Δφ projection Δη projection

- Significantly harder spectra than inclusive background (dash-line).
- If trigger pairs exist: No appreciable difference between same side and away side, or between Au+Au and d+Au. *Indication of source of jet quenching?*

A test of theory model – Surface emission



- If the jet-like structure from associate particles at this selected low-p_T region is intact even at away-side, how will these "dijet-like" event help to explore medium properties and explain observed jet quenching?
- A preliminary test: full parton-absorption/escape model (core/corona medium).
- **Go back to look at the back-to-back high-p_T trigger pairs.**
  - Use the single high-p_T rate to tune the size of core/corona (central panel),
  - Calculate the expected dijets absorption relative to single-jets (band at right panel).
  - *Other tuning methods exist:, e.g., K. Werner, Phys. Rev. C 82, 034906 (2010)*
- It agrees with data (points at right panel), the 2+1 measurement (ratio of points at left panel, high-p_T triggers with jet-like associates as proxy of jets).

Questions and answers

- Surface emission model works with correlation data. How will path-length dependent energy-loss models adapt to the 2+1 measurement?

- A possible explanation from path-length dependent models: By selecting trigger pairs of similar p_T (>5GeV/c vs. >4GeV/c), is it true that these triggers sample partons losing similar energy?

- Then not only away-side, but also near-side partons, are not fully surface biased. The two partons travel similar length of medium then fragment, to reach similar energy loss or survival probability.

- This can be tested by picking up those high-p_T trigger pairs of big asymmetry in energy. A relative difference shall happen between Au+Au & d+Au when we compare near-/away-sides.

Asymmetric triggers, correlation functions

RHIC Run 2007/2008,

High-Energy Tower trigger is applied to study associate particles.

Trigger$_1$: E_T>10 GeV (E-M calorimeter), mostly from γ pairs of same π^0

vs.

Trigger$_2$: p_T>4 GeV/c,

Associate: p_T>1.5 GeV/c

Large Δp_T between the two triggers.

Au+Au

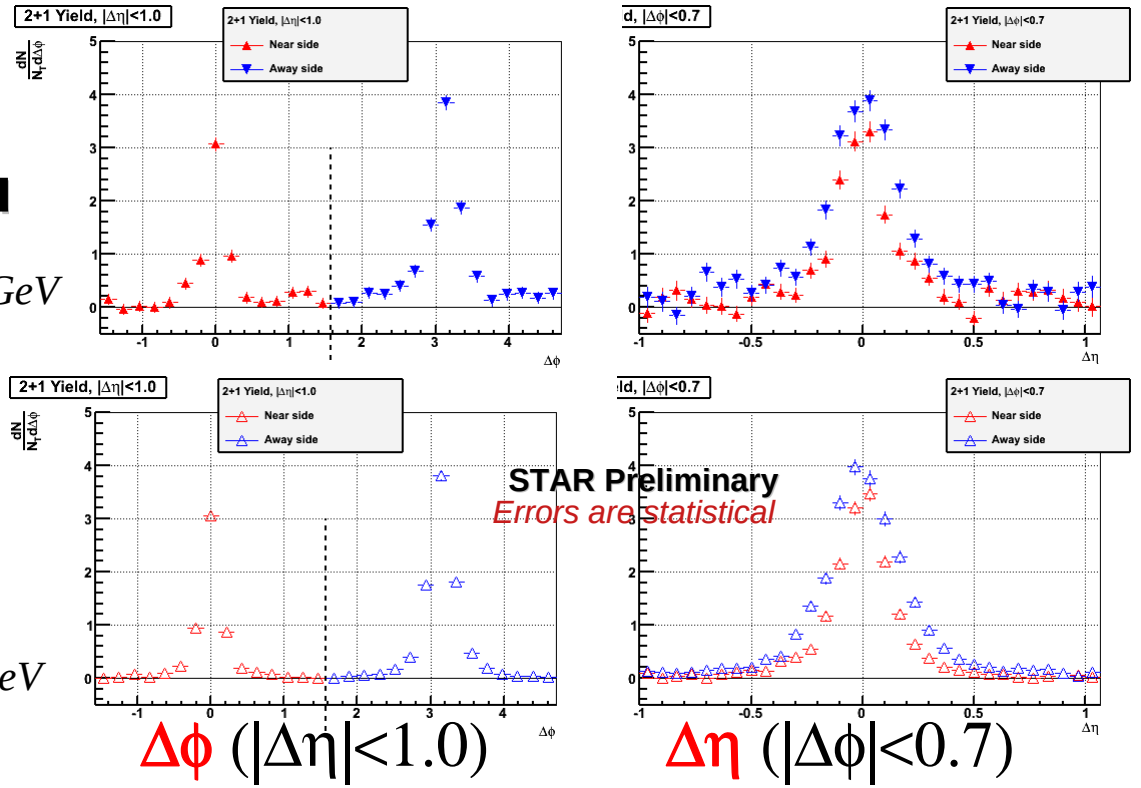
$\sqrt{s_{NN}} = 200GeV$

vs.

d+Au

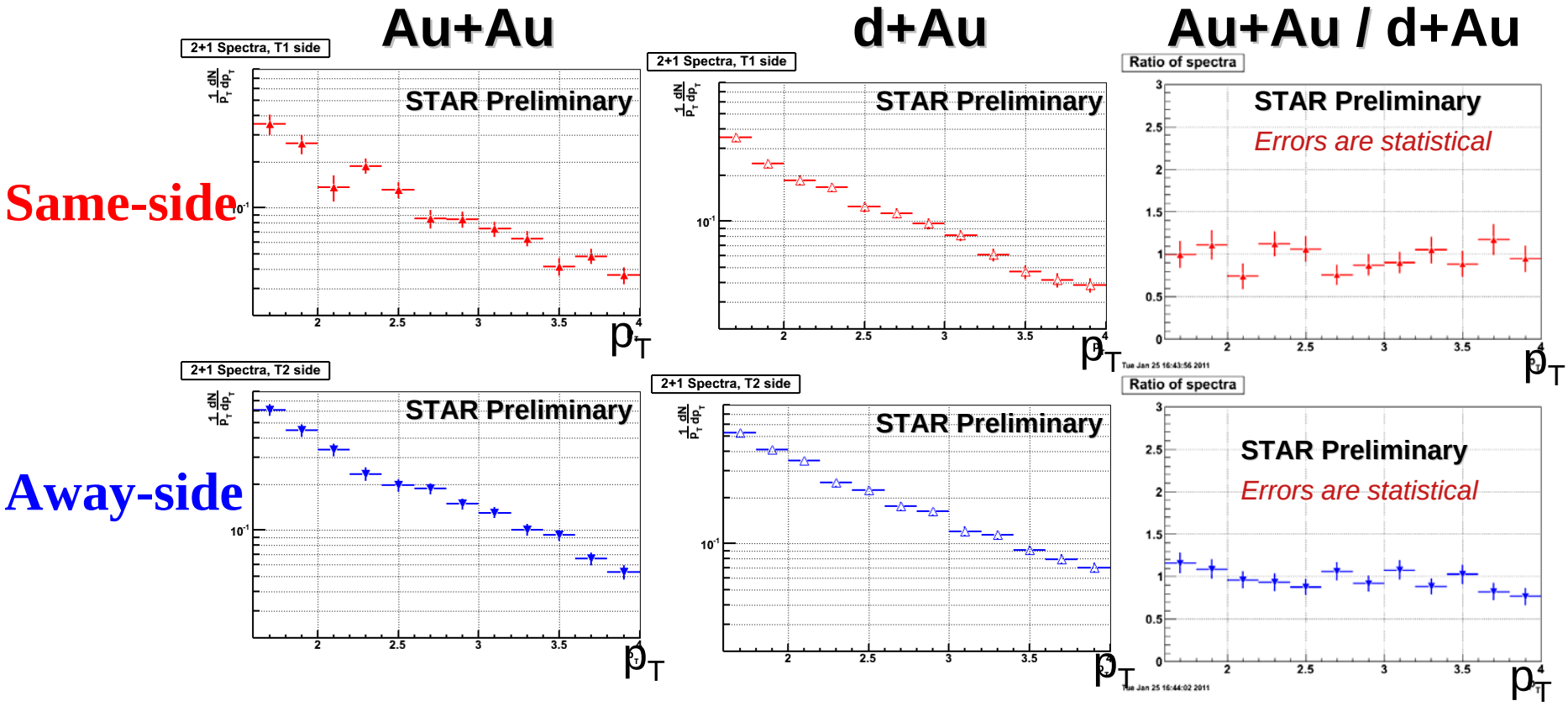
$\sqrt{s_{NN}} = 200GeV$

Red: Same-side, Blue: Away-side



The correlations are of close shape/level from d+Au to central Au+Au collisions, at both same-/away-sides

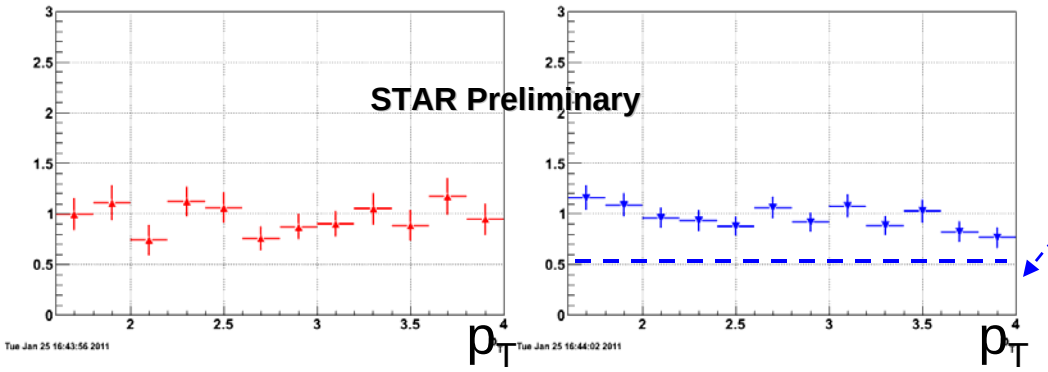
Asymmetric triggers, spectra

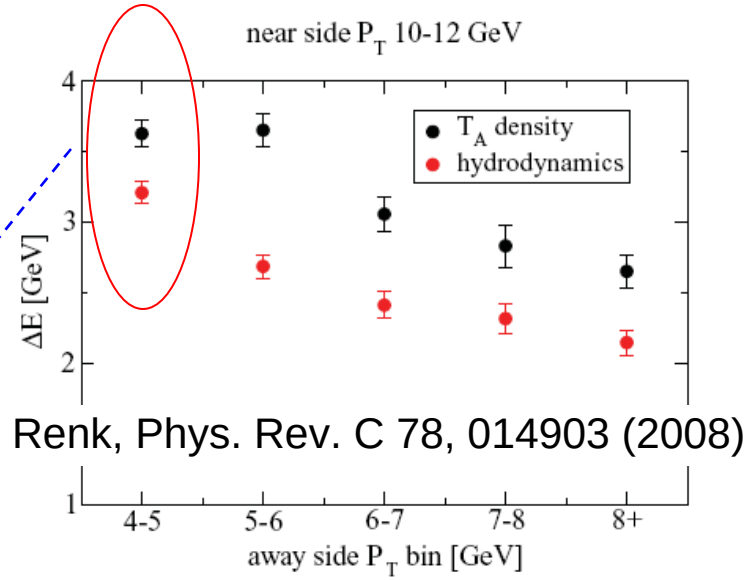


- The same-side spectra ratio is flat at unity.
- The away-side spectra ratio is also consistent with flat at unity.

Energy loss due to path-length dependence?

Spectra of Au+Au divided by d+Au





T. Renk, Phys. Rev. C 78, 014903 (2008)

Red: Same-side, Blue: Away-side

- One sample of path-length dependent E-loss model: the surviving dijets (jet-like structure sustained) mainly come from partons deposit energy into the medium then fragmentate in vacuum.
- At asymmetric trigger case, a big ΔE is predicted in Au+Au near-side minus away-side, comparing to d+Au.
- Thus at away-side, the spectra ratio of Au+Au/d+Au spectra (e.g. dash-line) must be evidently below unity, in contrary to the data.

Summary

- The 2+1 correlation are used as proxy of dijets to study parton-medium interaction.
- When two back-to-back high-p_T particles are triggered, the whole associated particles sustain jet-like structures, at a close shape and magnitude, on both correlation functions and spectra, at Au+Au to d+Au.
- Theory models are tested primarily:
  - Surface emission model (core/corona) agrees with data.
  - Path-length dependent energy loss mode are expected to:
    - Show a relative difference between near- and away-side Au+Au/d+Au (double ratio),
    - It is not observed in either symmetric or asymmetric trigger case.
- Detailed study is going on.