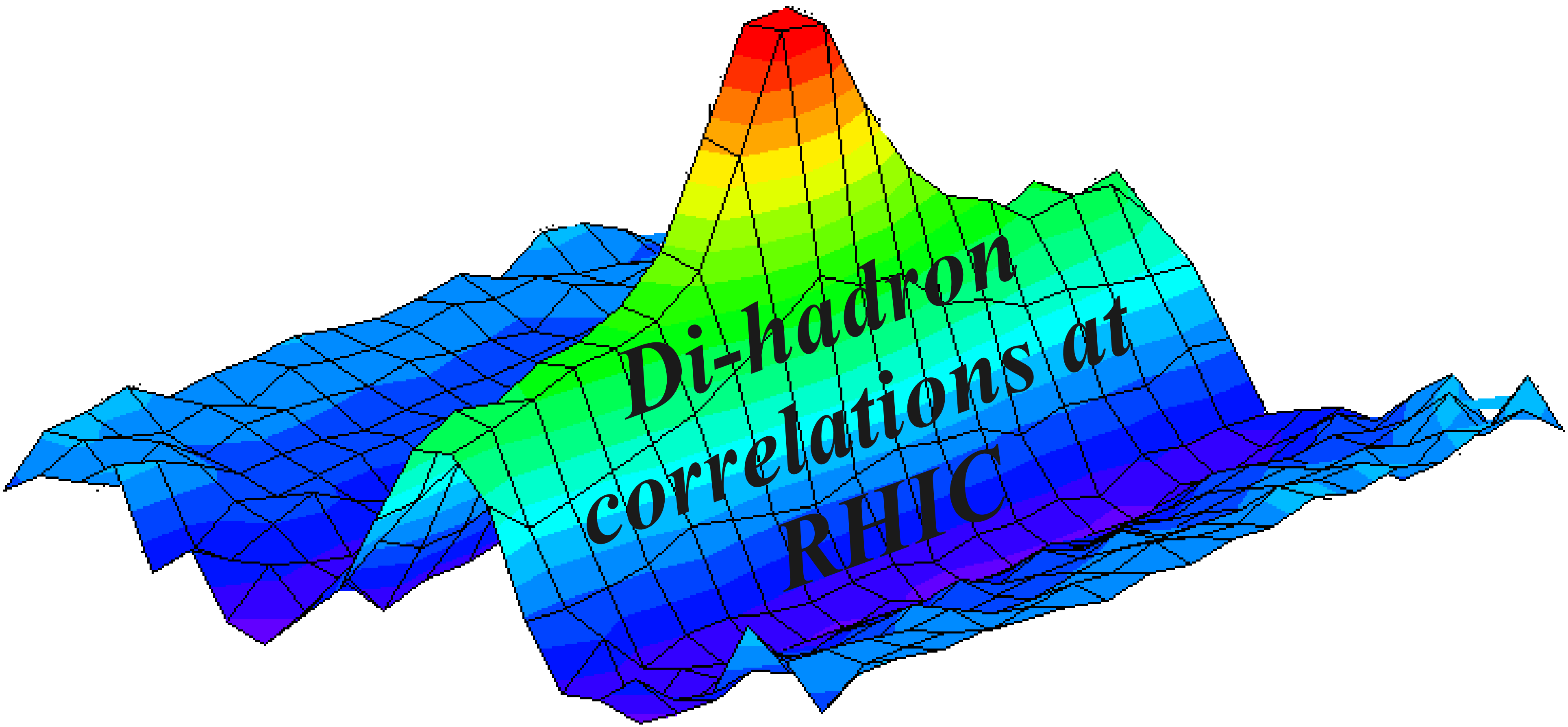
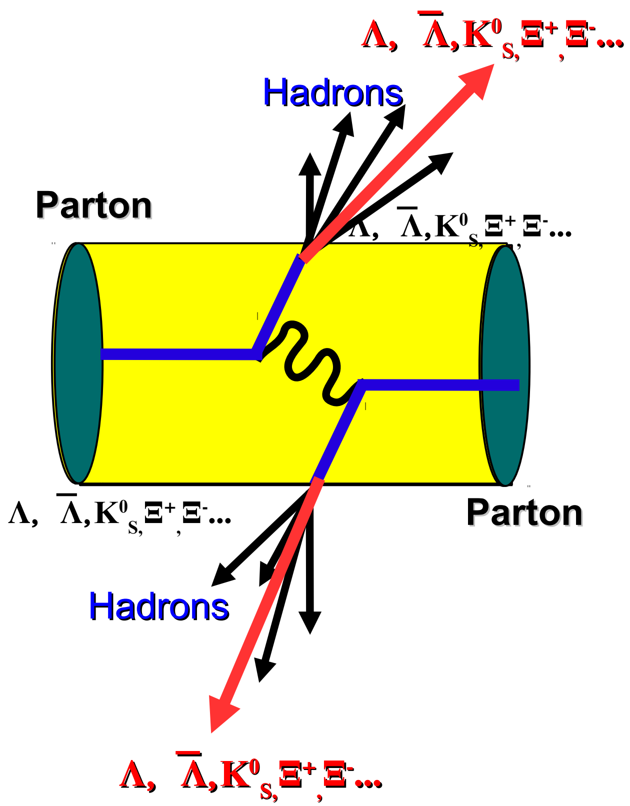
Di-hadron correlations at RHIC



Christine Nattrass

University of Tennessee at Knoxville

Di-hadron correlations



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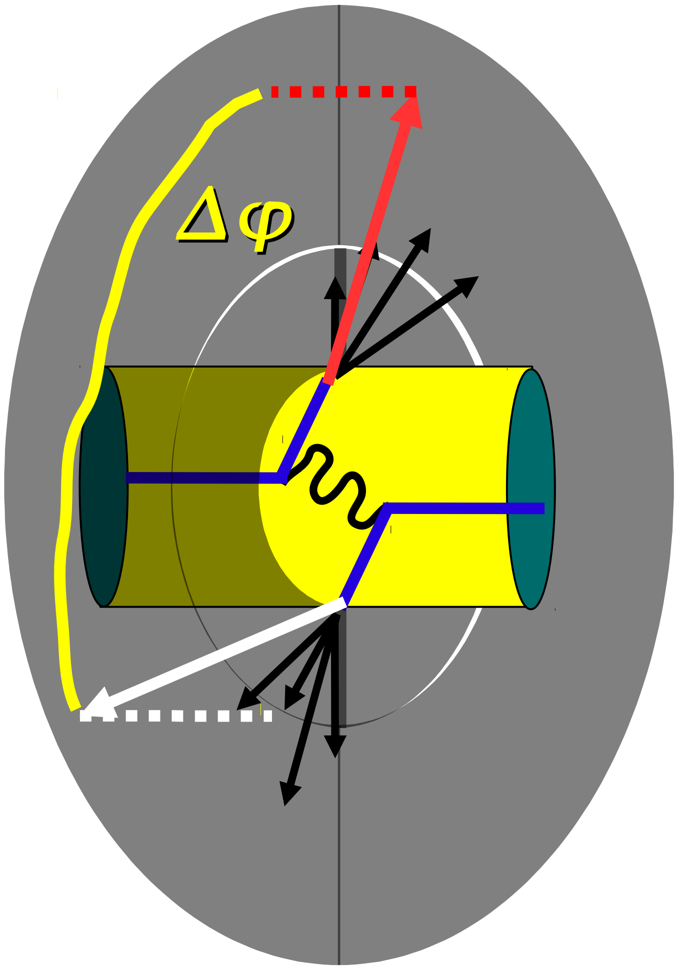

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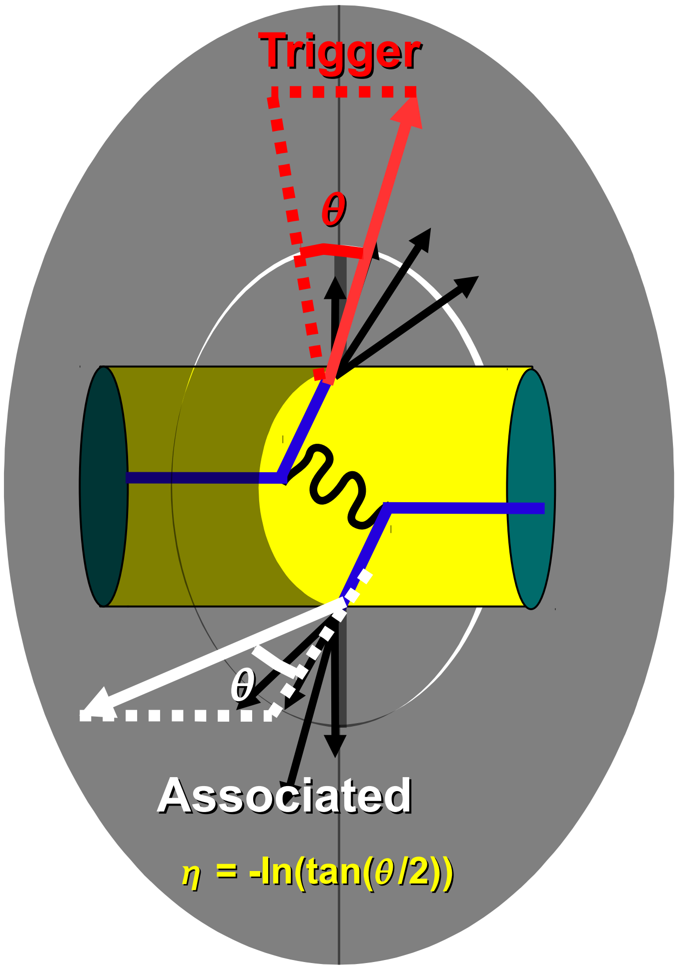
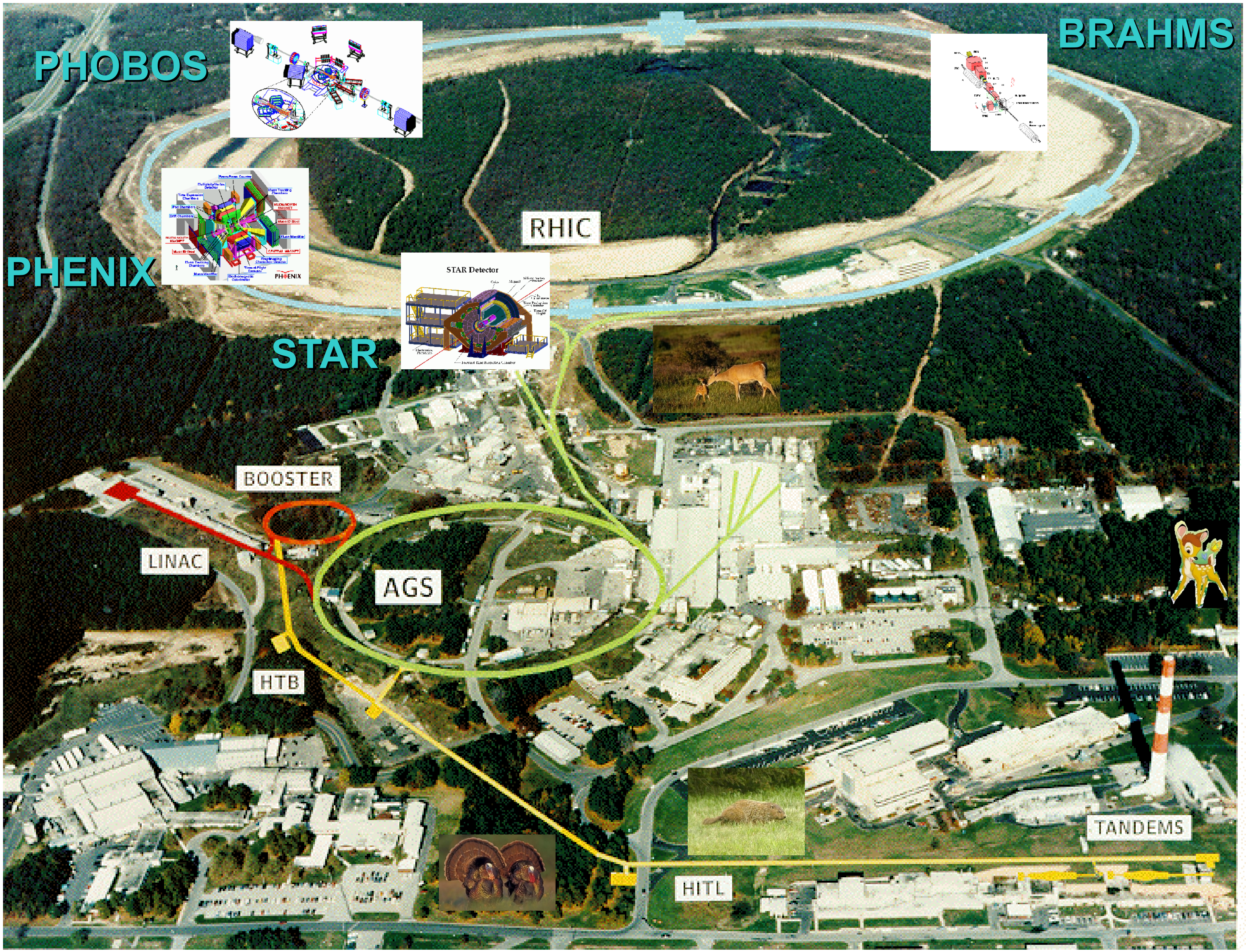


Relativistic Heavy Ion Collider



PHOBOS

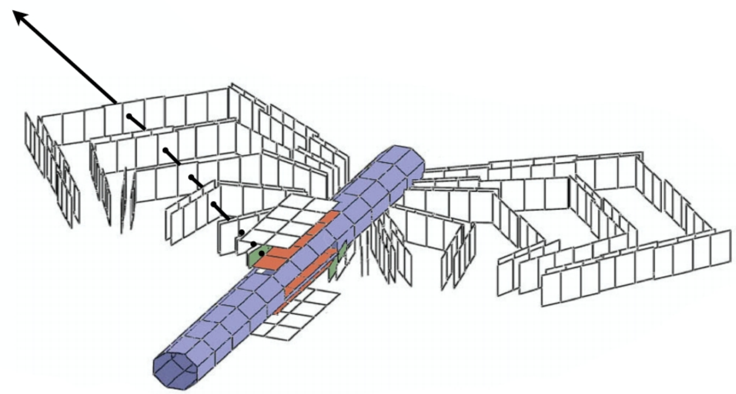
- Coverage:

  With tracking:

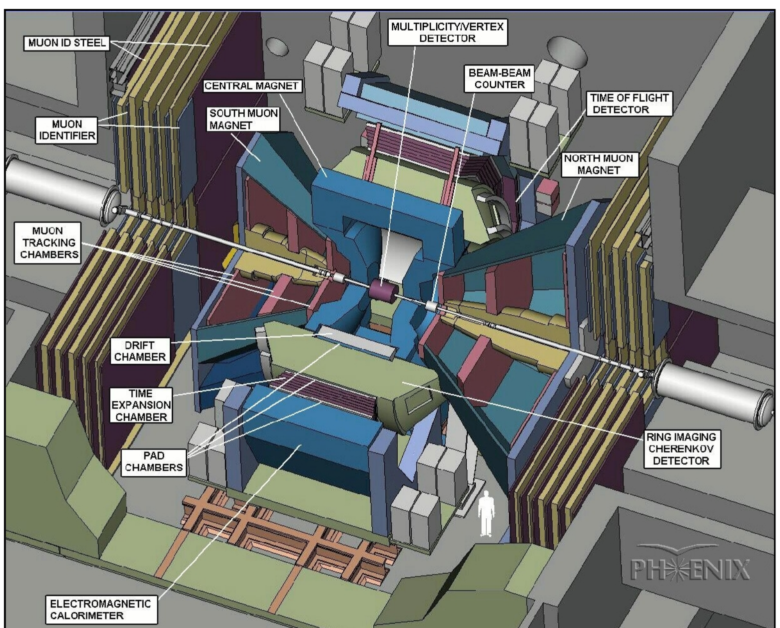
  2x ($0<\phi<0.2$); $0<\eta<1.5$

  Without tracking:

  $0<\phi<2\pi$; $-3<\eta<3$



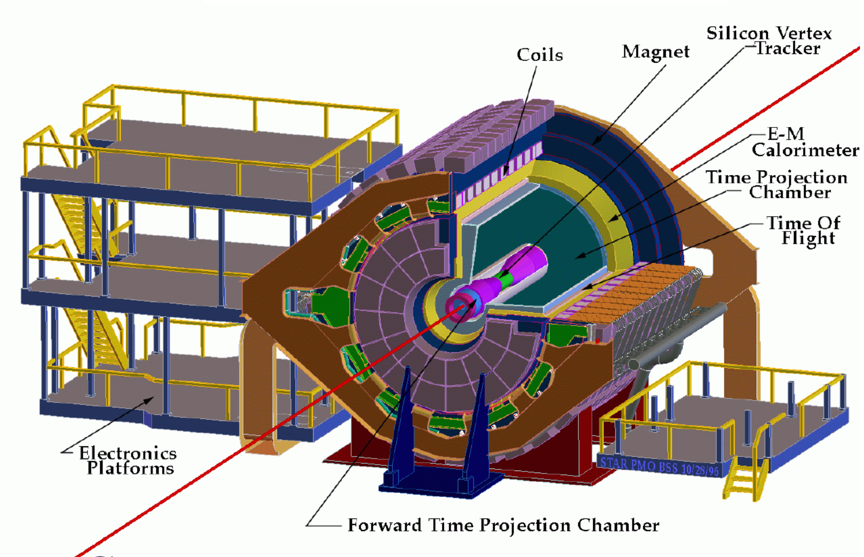
PHENIX



Coverage:

2x($0<\phi<\pi/2$);$-0.35<\eta<0.35$

STAR



- Coverage:

  $0<\phi<2\pi$; $-1<\eta<1$

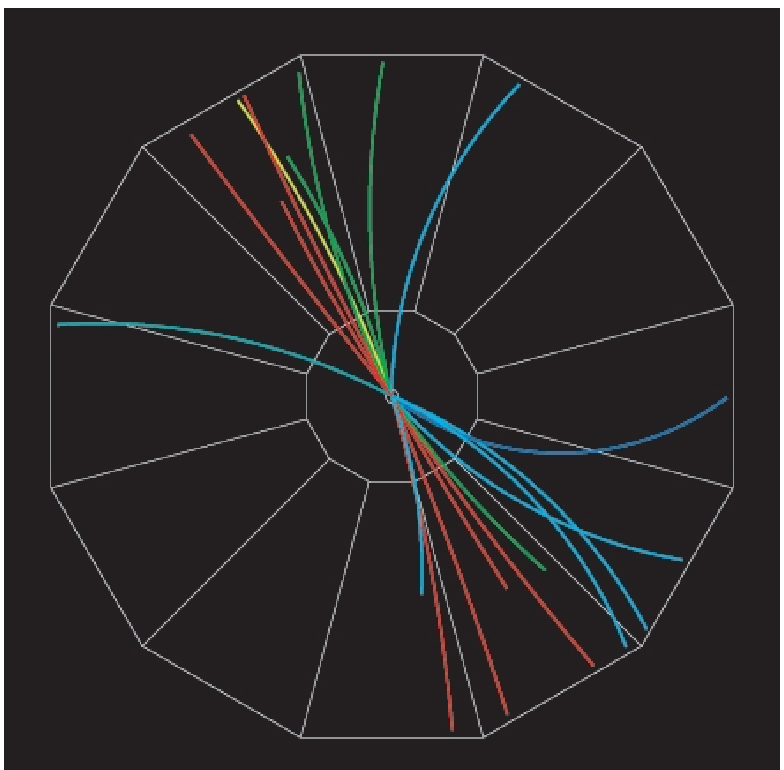
Jets – azimuthal correlations

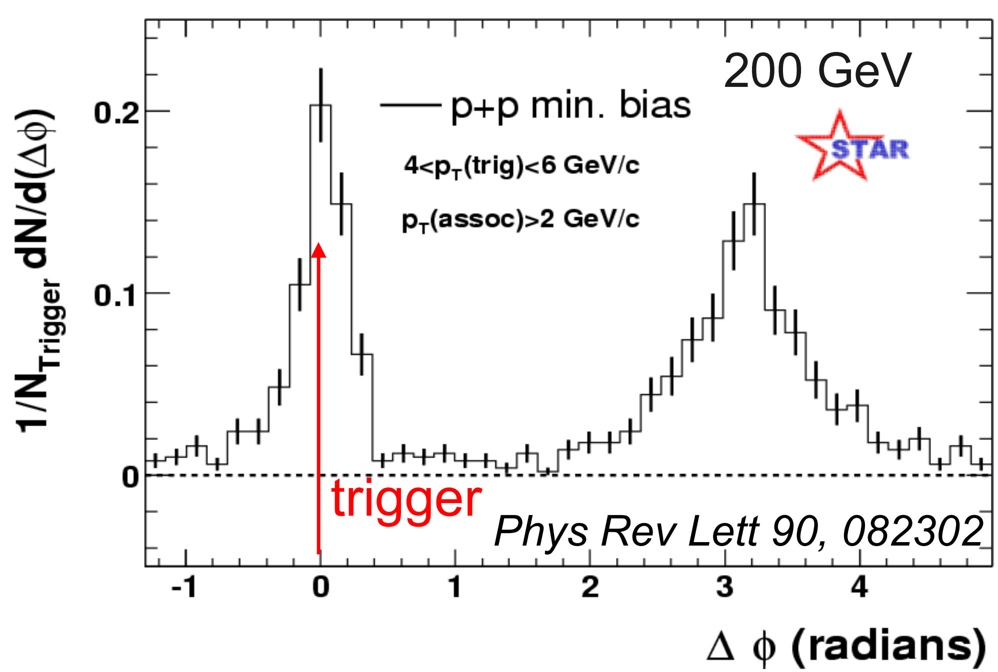
At RHIC energies, jets are dominantly produced as di-jets

Assume that a high-p_T trigger particle comes from a jet

Look at distribution of high-p_T associated particles relative to trigger

p+p → dijet





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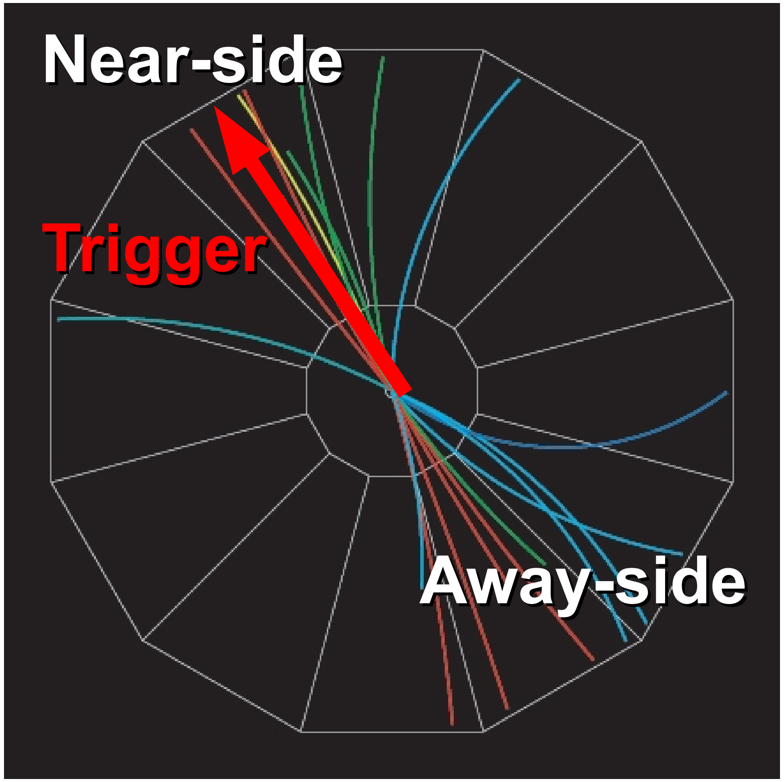

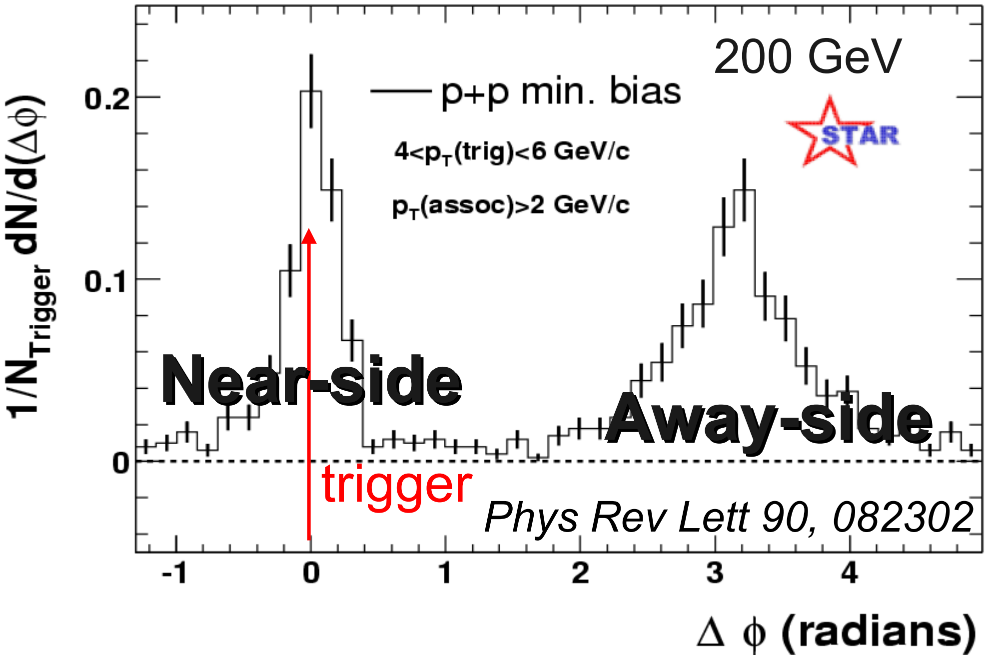

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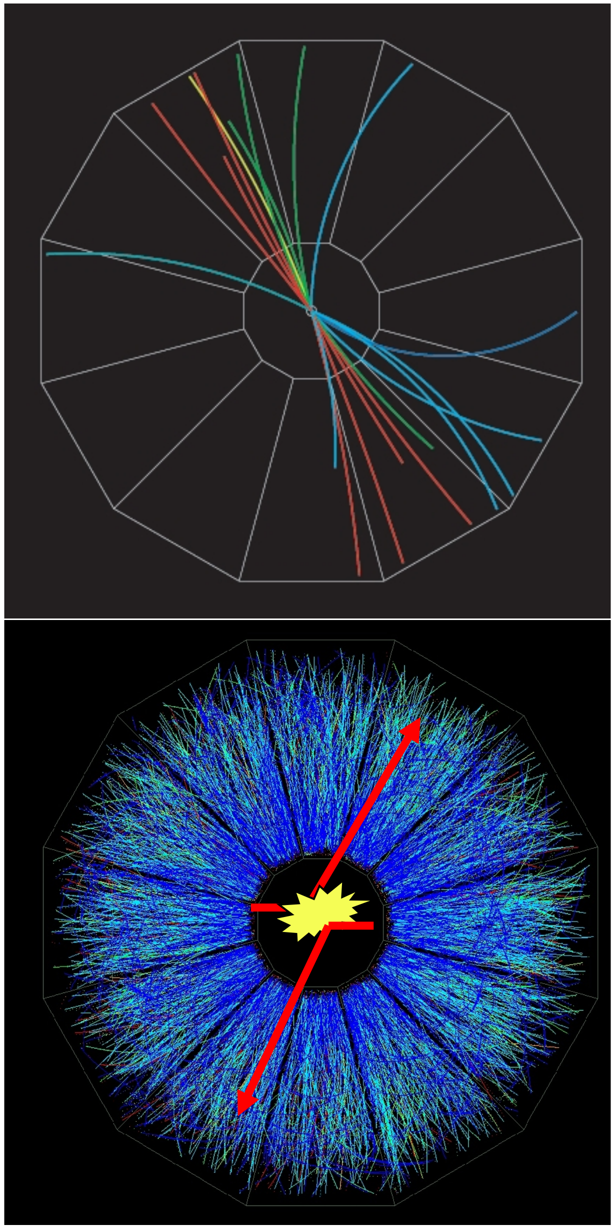
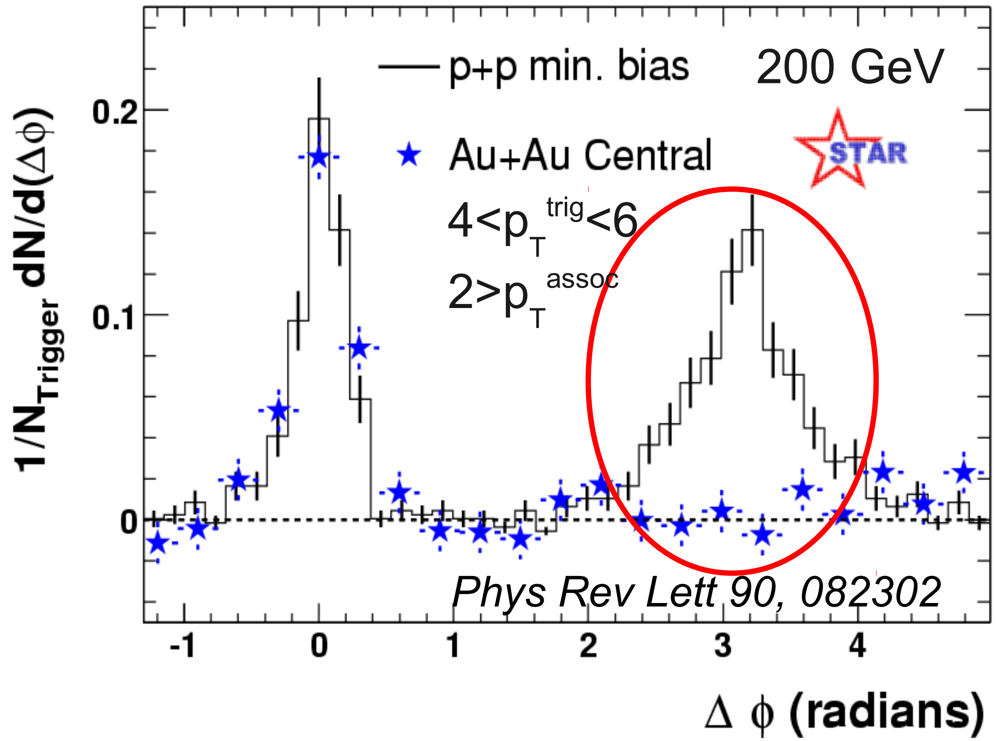
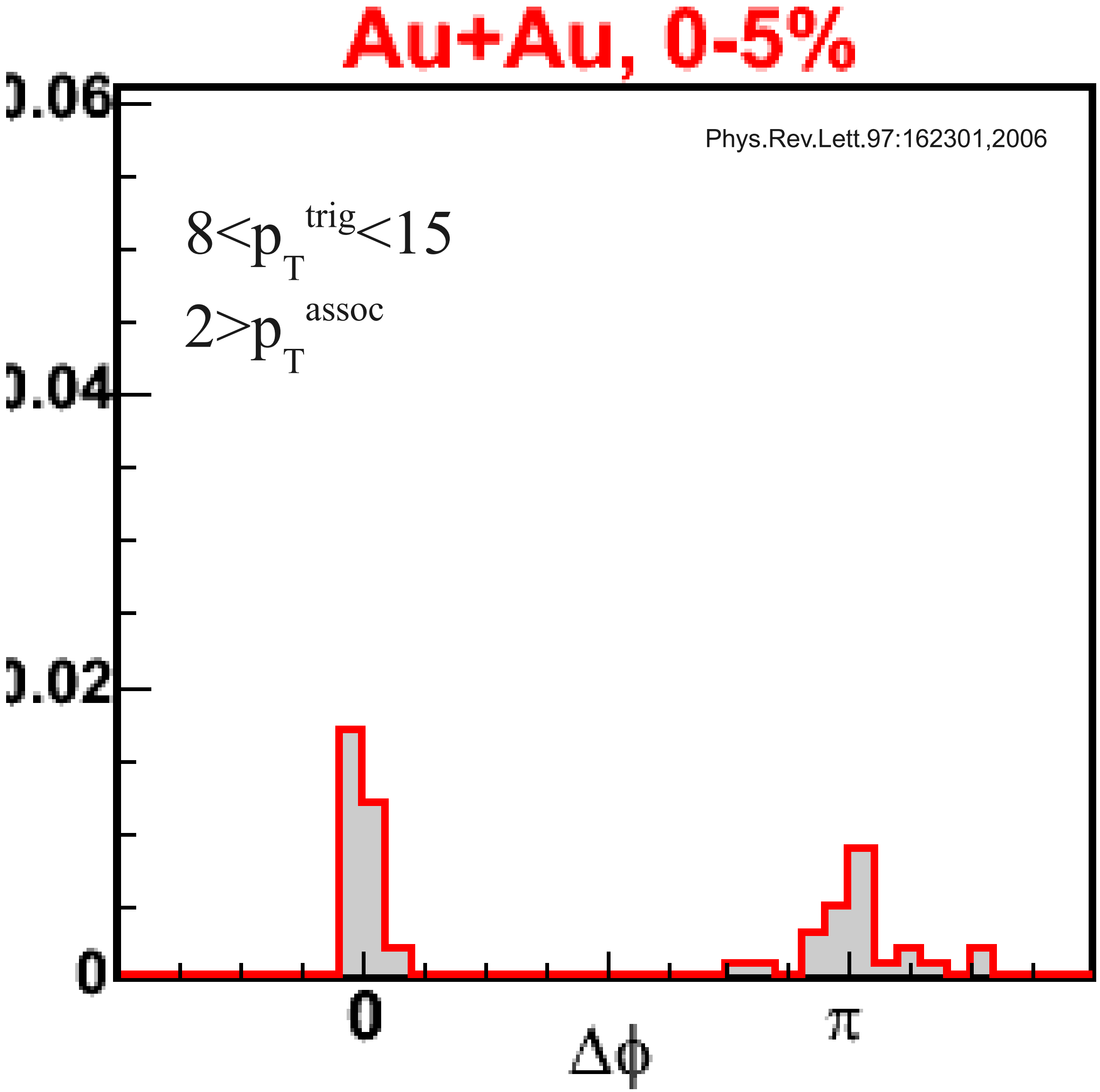




The away-side jet is quenched in Au+Au collisions

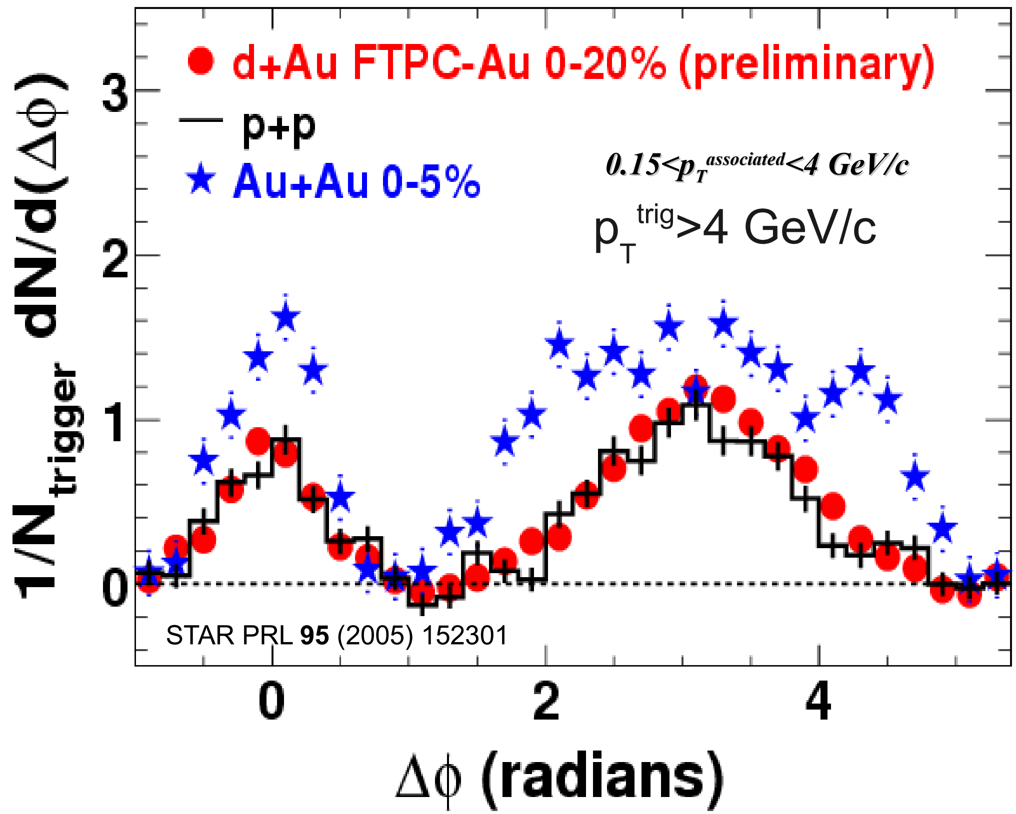
At higher p_T...



The away-side jet punches through the medium

But at lower p_T...

Near-side, away-side: excess yield in Au+Au relative to p+p



Near-side

Away-side

0

1.0

2.0

3.0

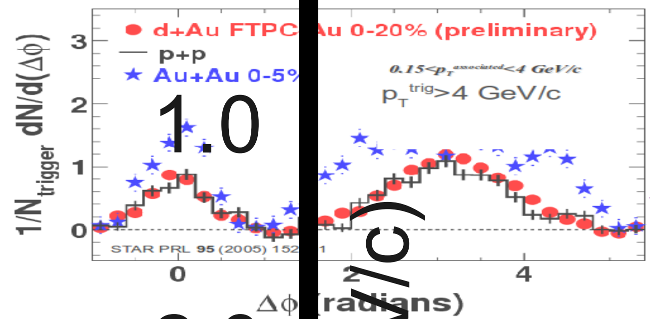
4.0

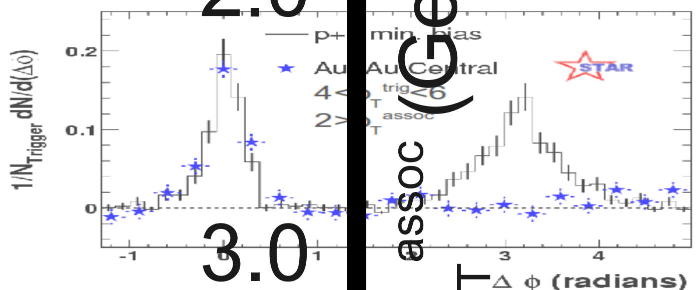
p_T^{assoc} (GeV/c)

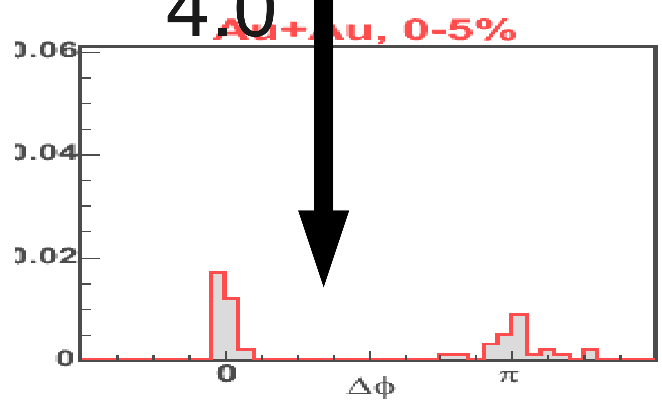
Ridge

Mach Cone

Quenching



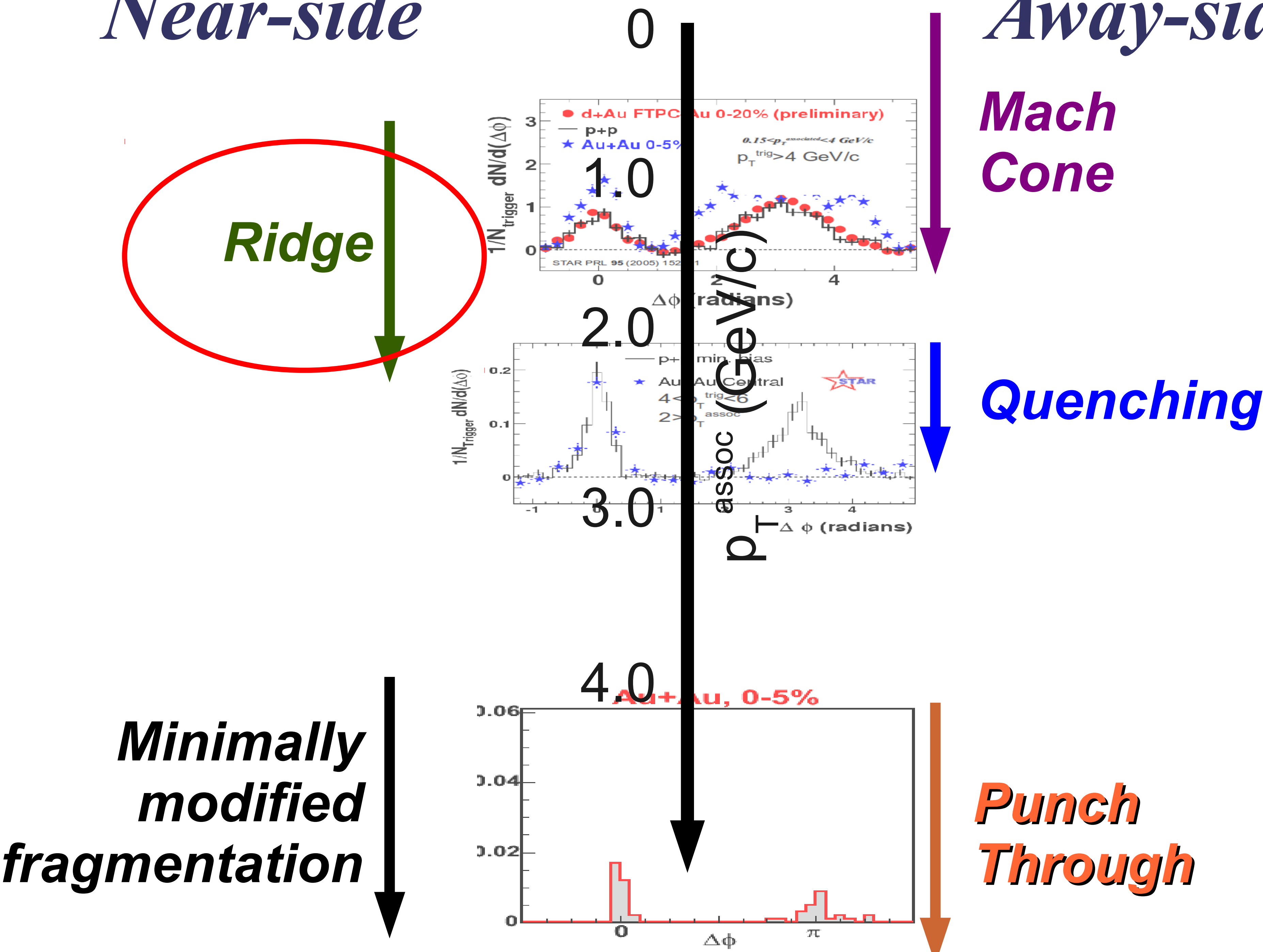




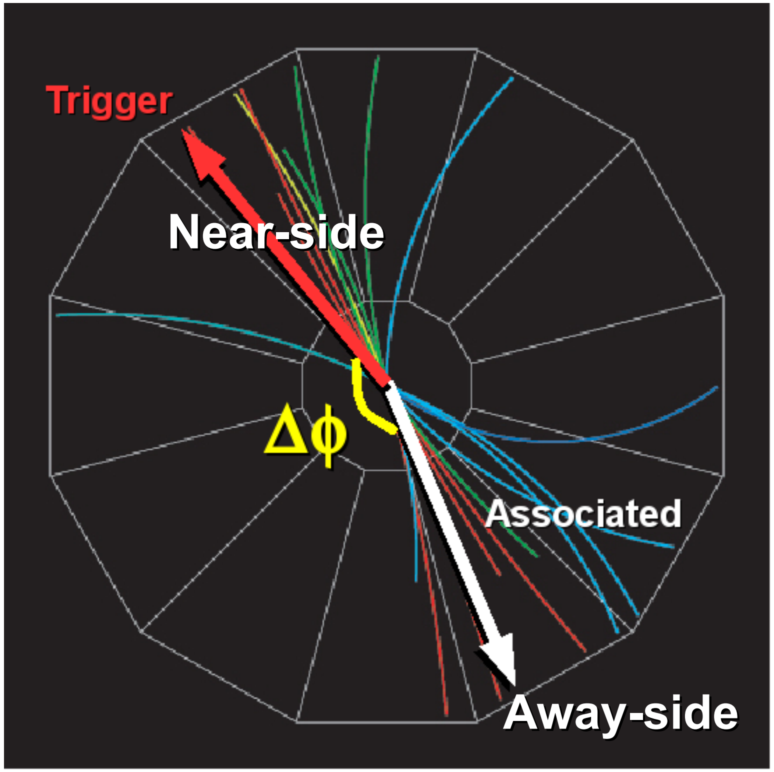
Minimally modified fragmentation

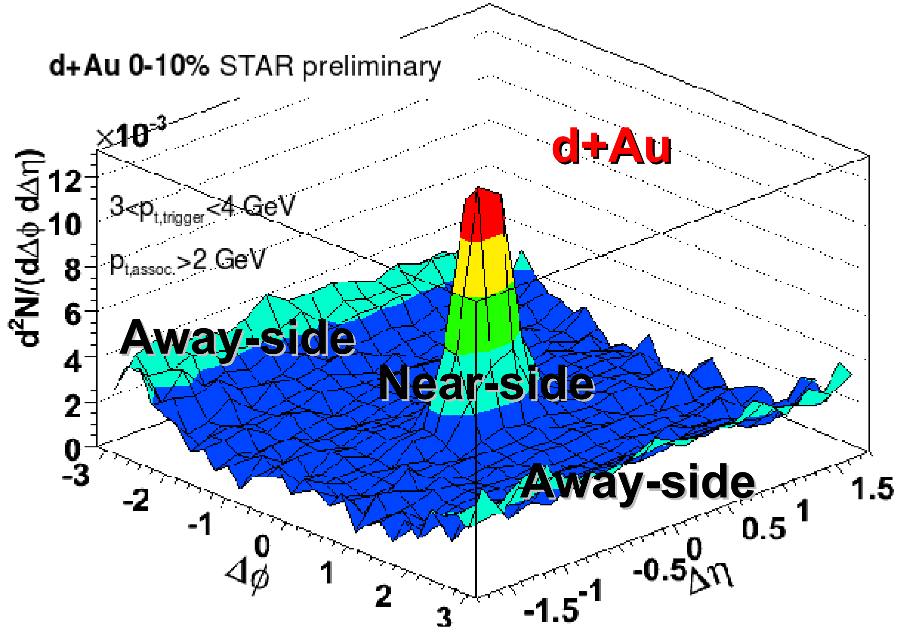
Punch Through

Near-side *Away-side*



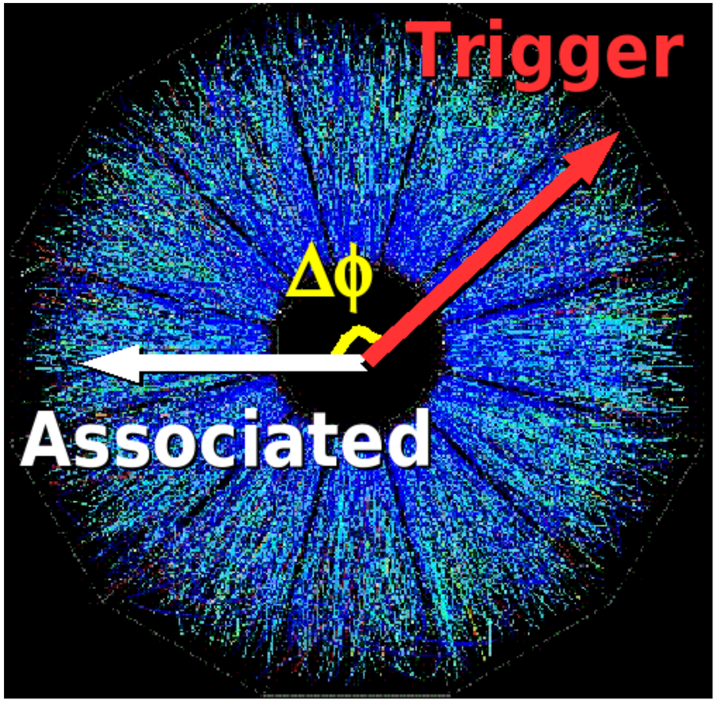
d+Au





Phys.Rev.C80:064912,2009

In two dimensions in Au+Au



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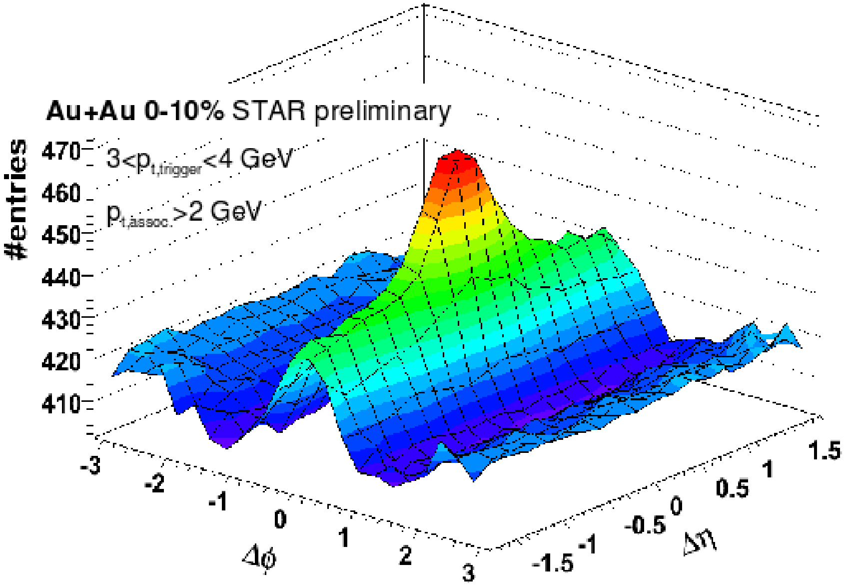

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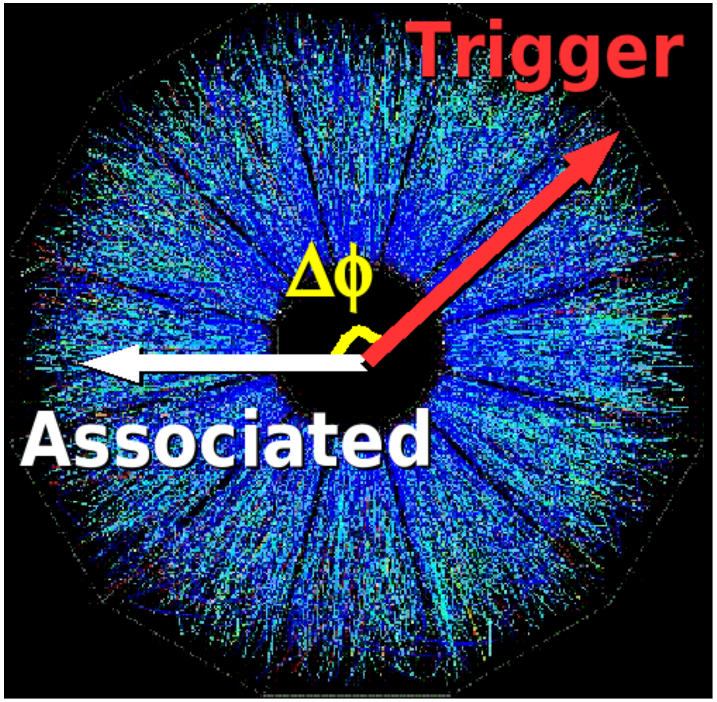

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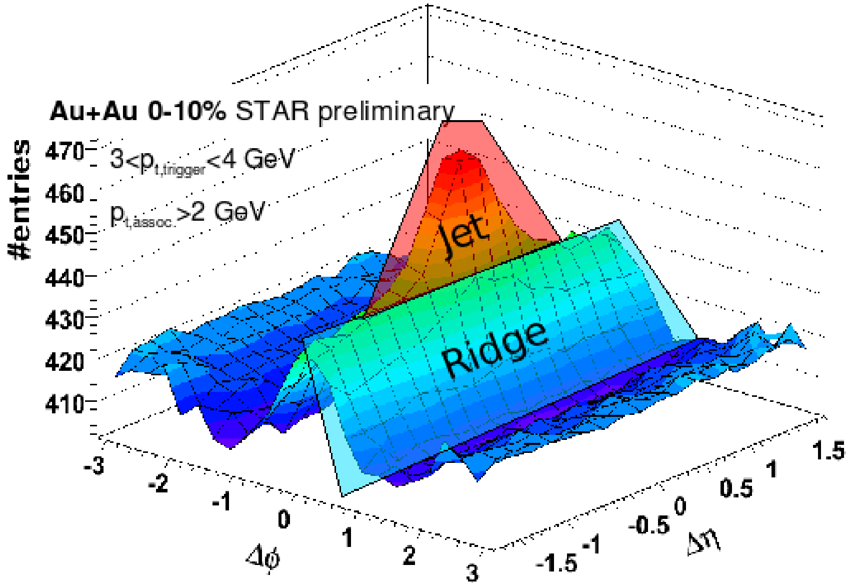
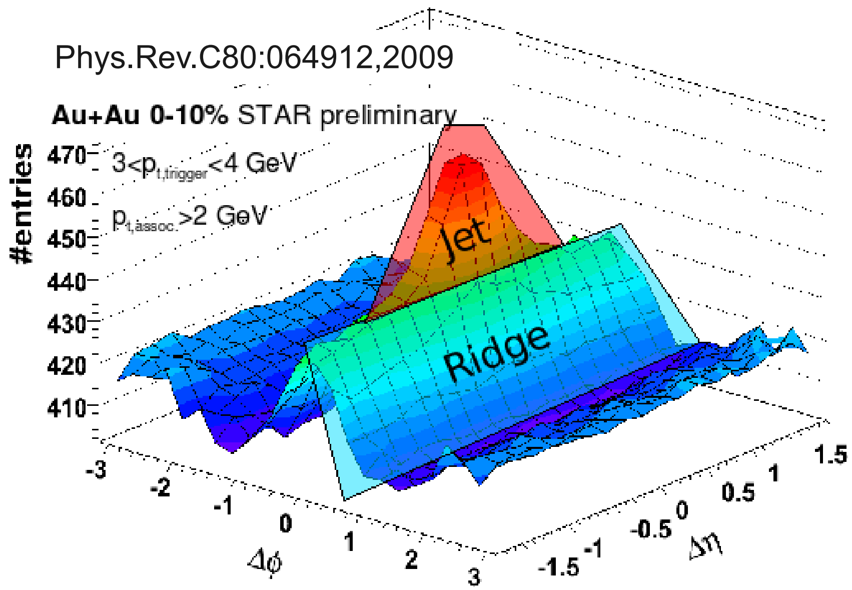
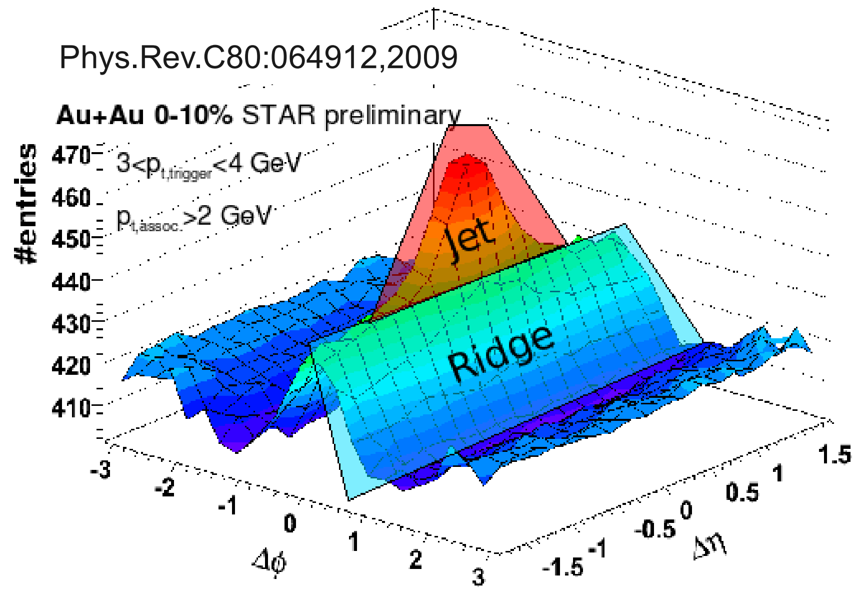


Simple picture



- Jet-like correlation: Dominantly produced by fragmentation

Simple picture



- Jet-like correlation: Dominantly produced by fragmentation
- Ridge: Two classes of models
  - Partonic energy loss in the medium
  - Correlation of trigger with bulk

ZYAM and the two-component model

- Two component model:

  Di-hadron correlations are composed of

  - Correlations arising from jet fragmentation
  - Correlations arising from elliptic flow (v_2)

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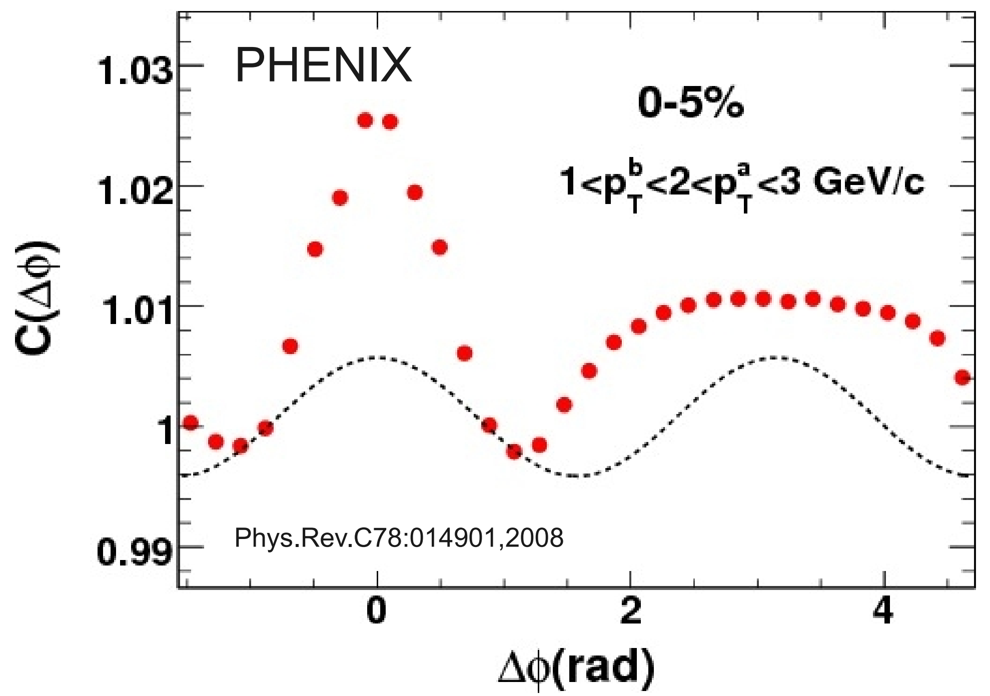
The background is then
$B(1+2\ v_2^{trig}\ v_2^{assoc}\ \cos(2\Delta\Phi))$
Phys.Rev. C69 (2004) 021901



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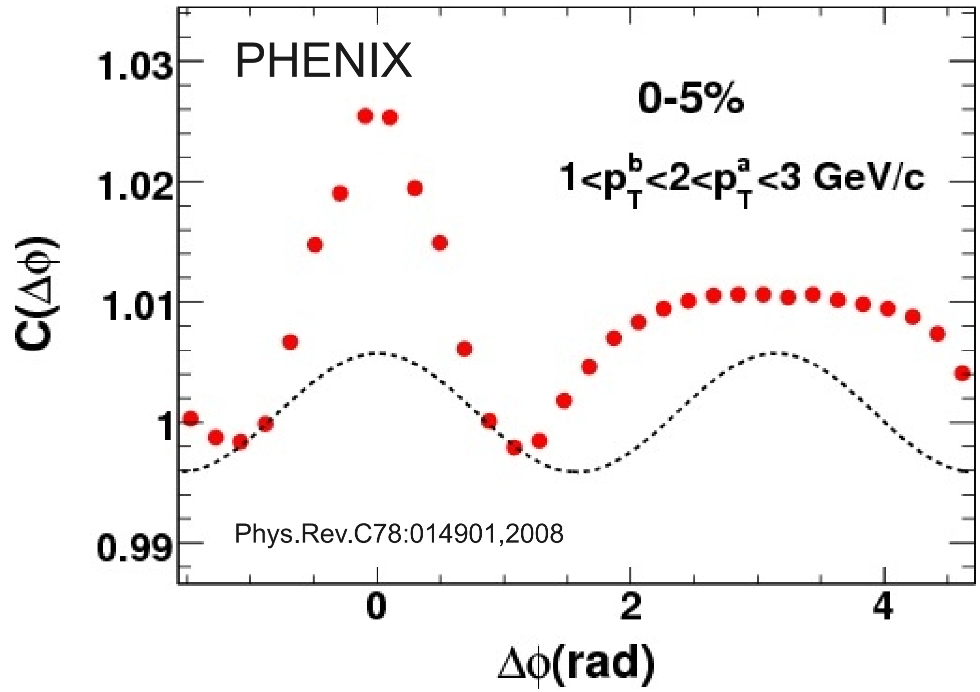
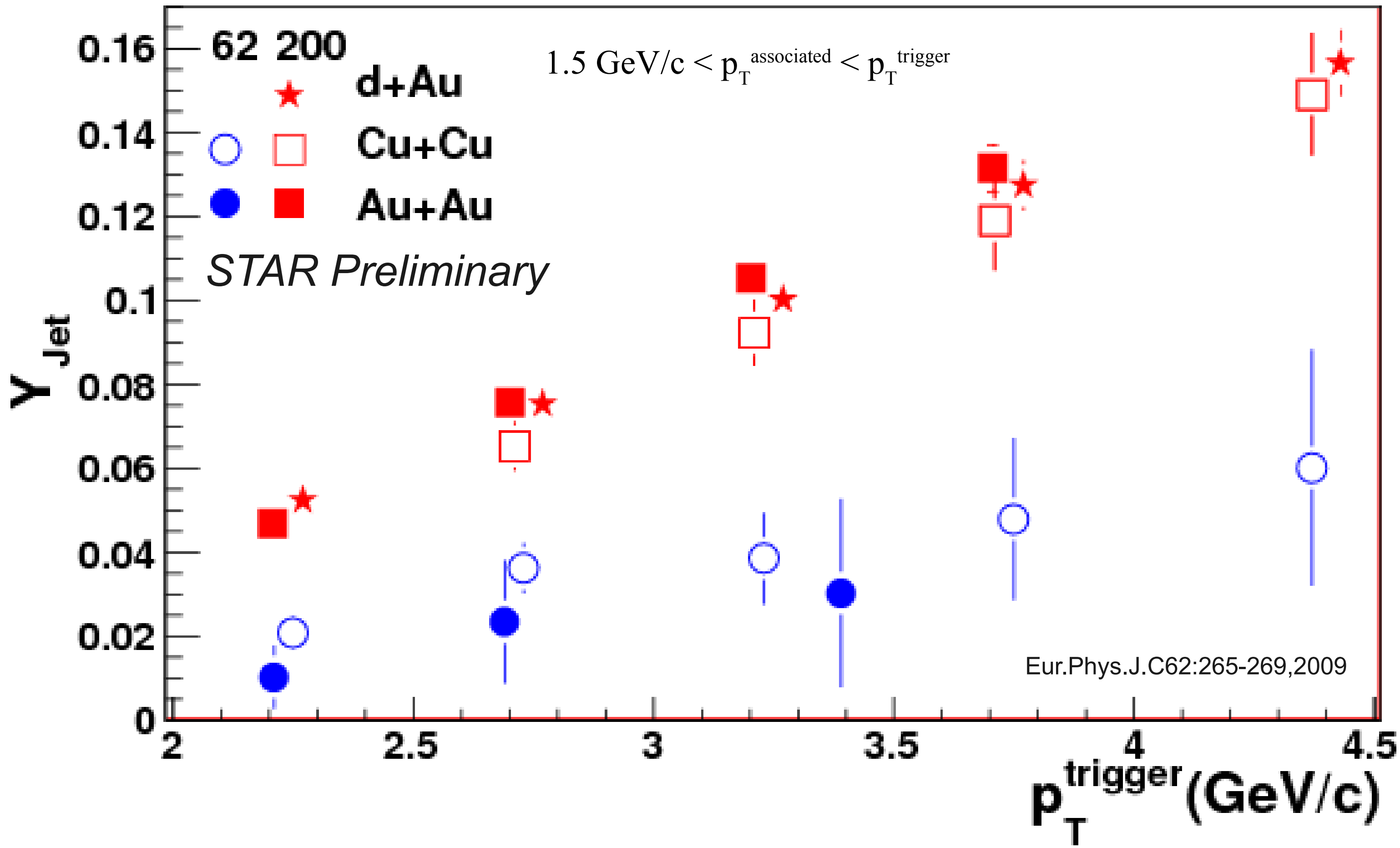
  Phys.Rev. C69 (2004) 021901

- Zero-Yield-At-Minimum (ZYAM)
  - Assumes there is a region where there is no signal
  - Fix B in this region assuming two component model
  - Use v_2 from independent measurements



Jet-like yield: $p_T^{trigger}$ dependence



Yield increases with $p_T^{trigger}$

No collision system dependence

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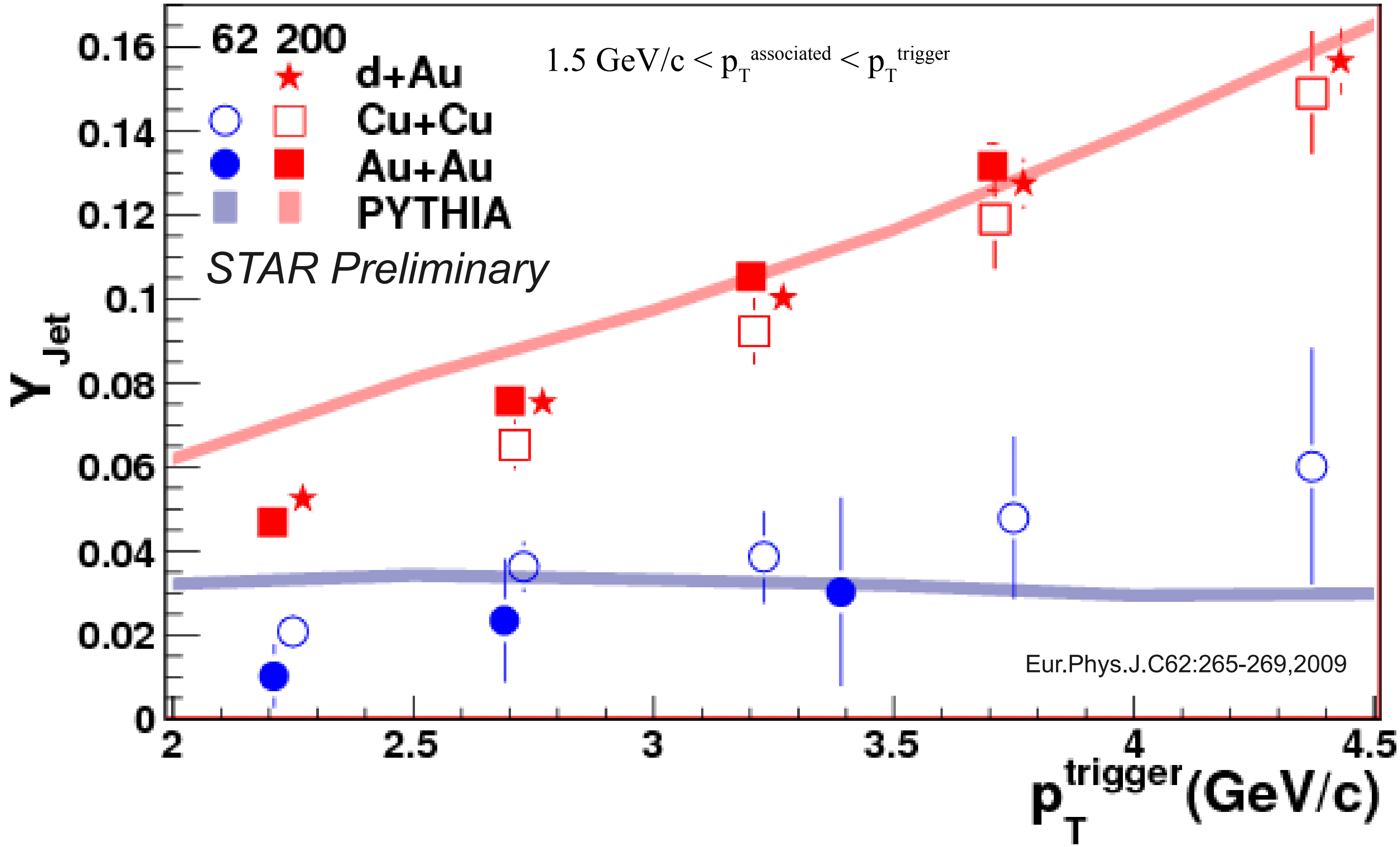

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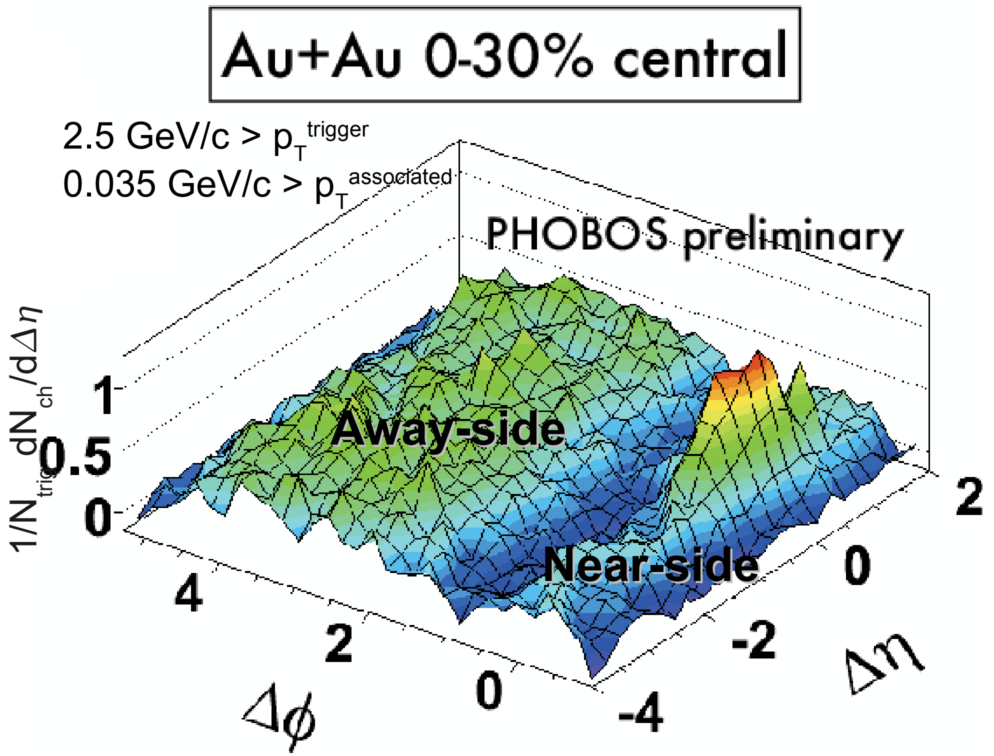
No collision system dependence

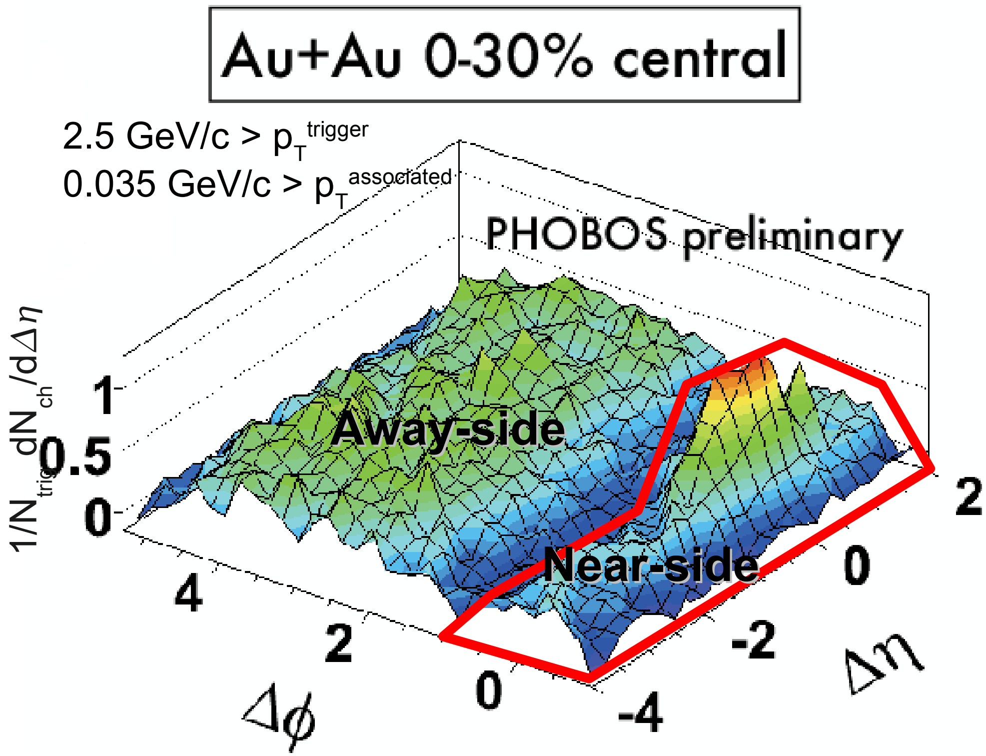
PYTHIA 6.4.10 Tune A– Monte Carlo p+p event generator tuned to data and incorporating many features of pQCD

Extent of ridge in $\Delta\eta$



Phys. Rev. Lett. 104, 062301 (2010)

Extent of ridge in Δη



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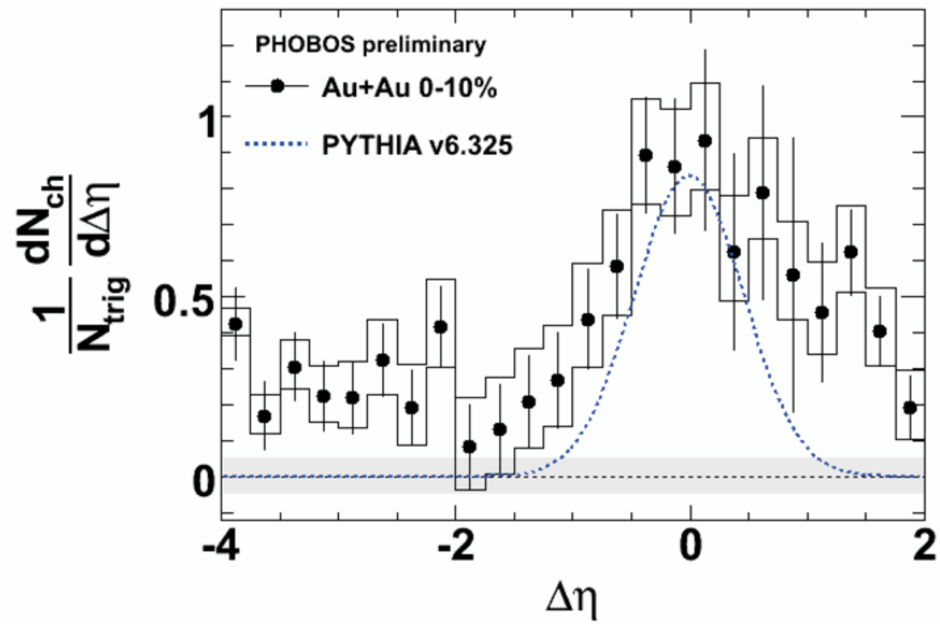

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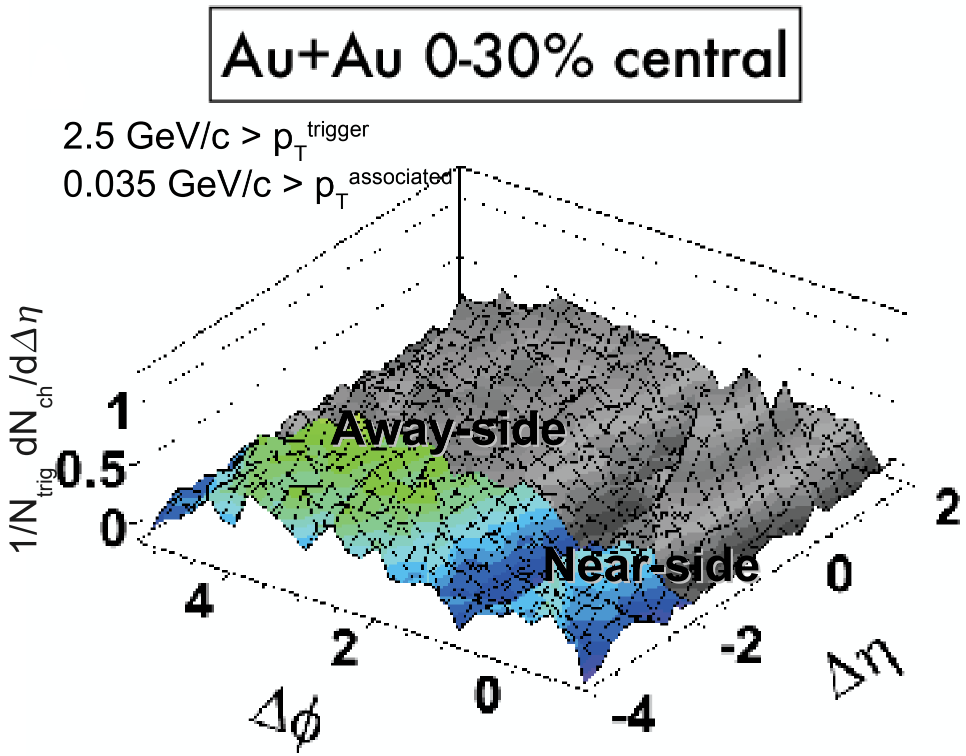

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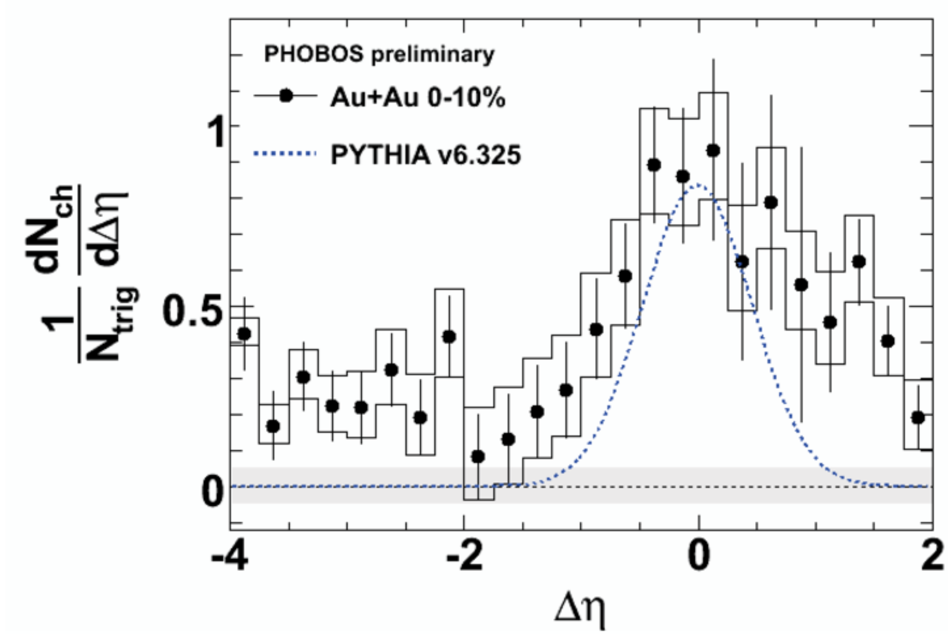

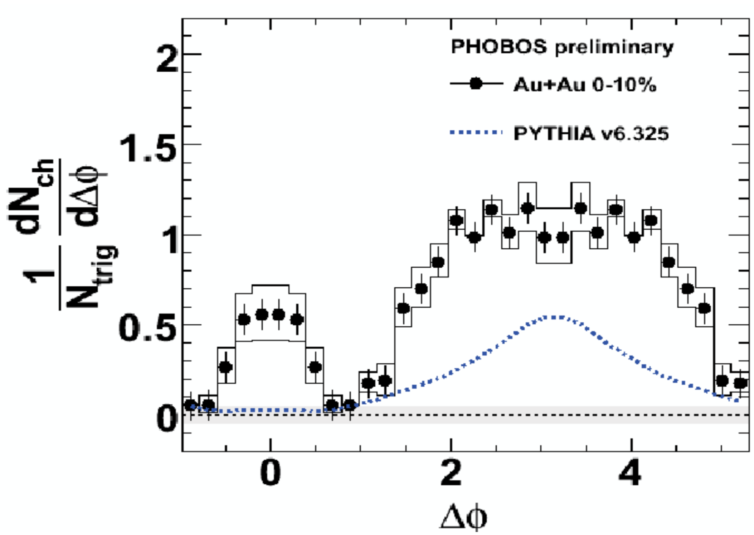

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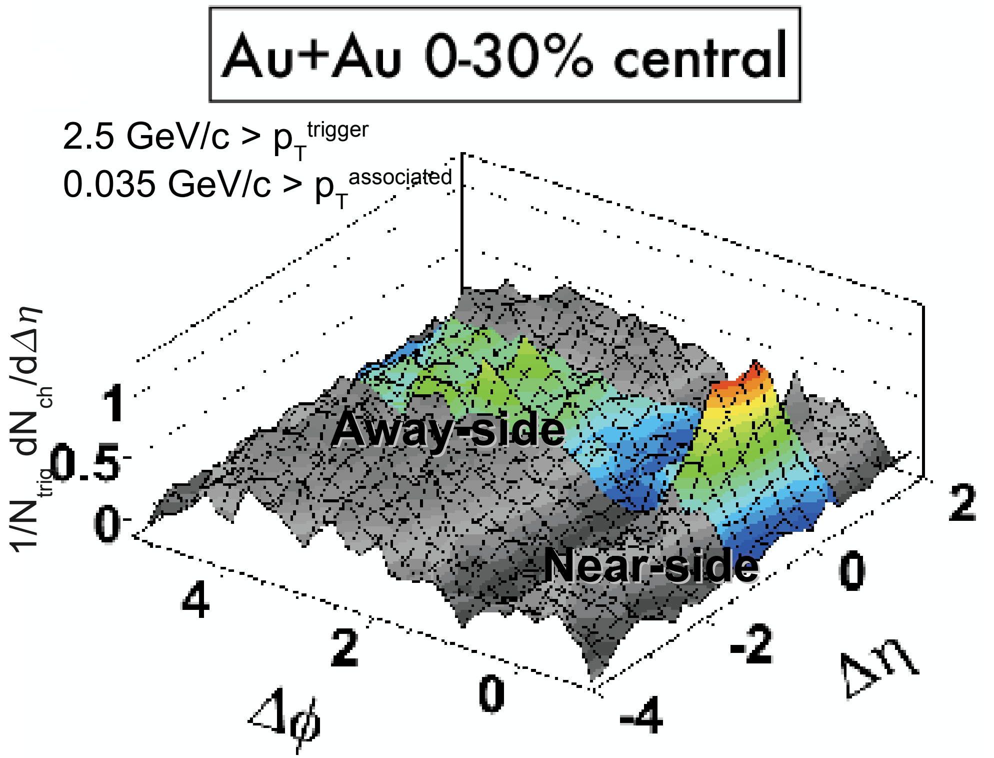

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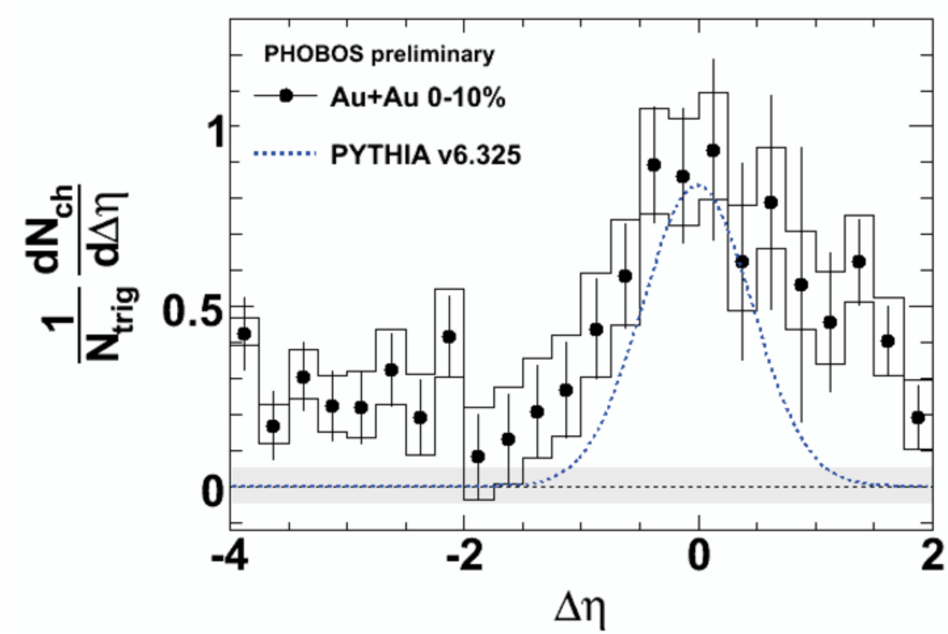
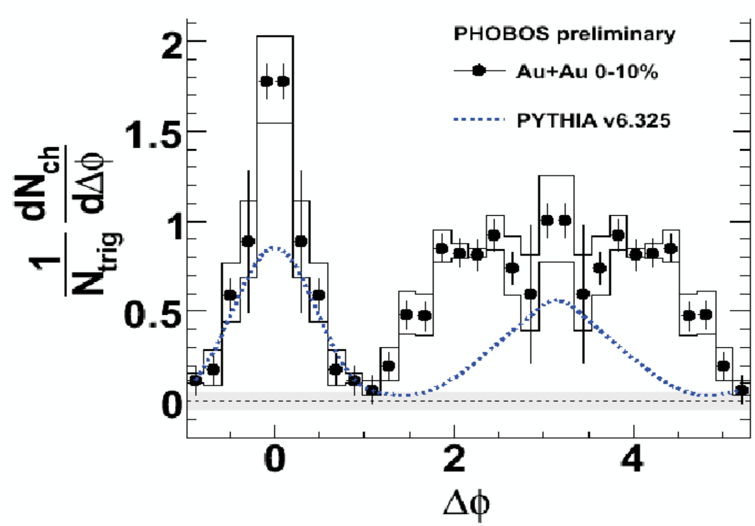
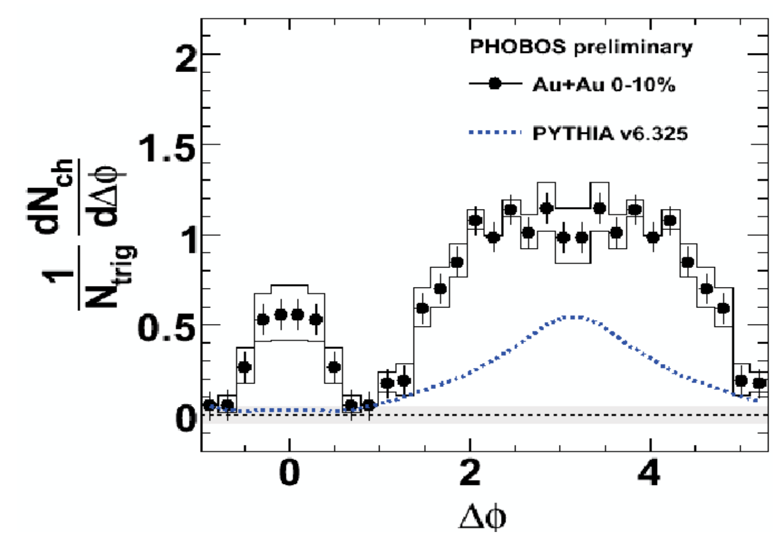
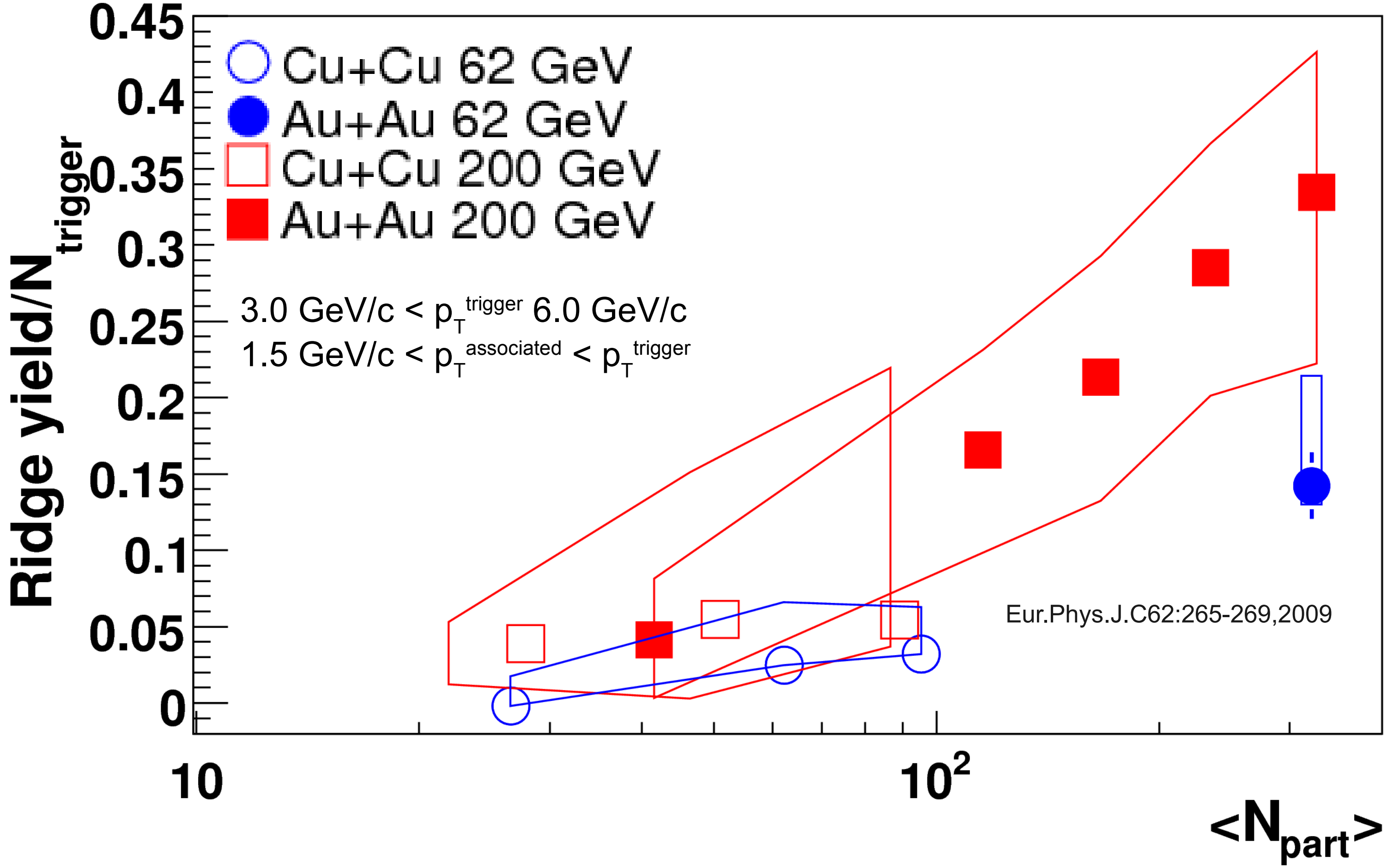






Ridge vs N_{part}



No system dependence at given N_{part}

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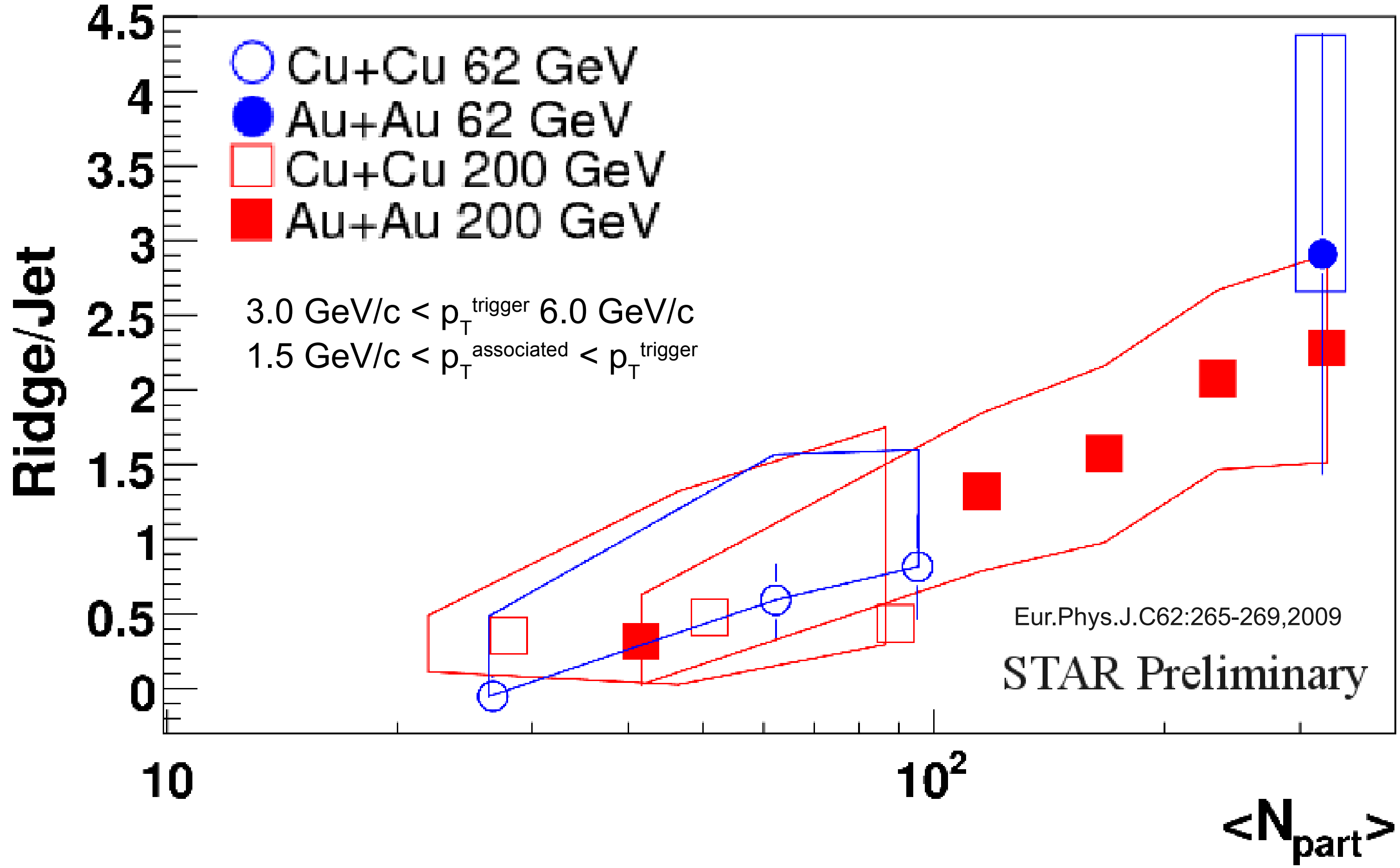


No system dependence at given N_{part}

Ridge/jet-like yield independent of energy*

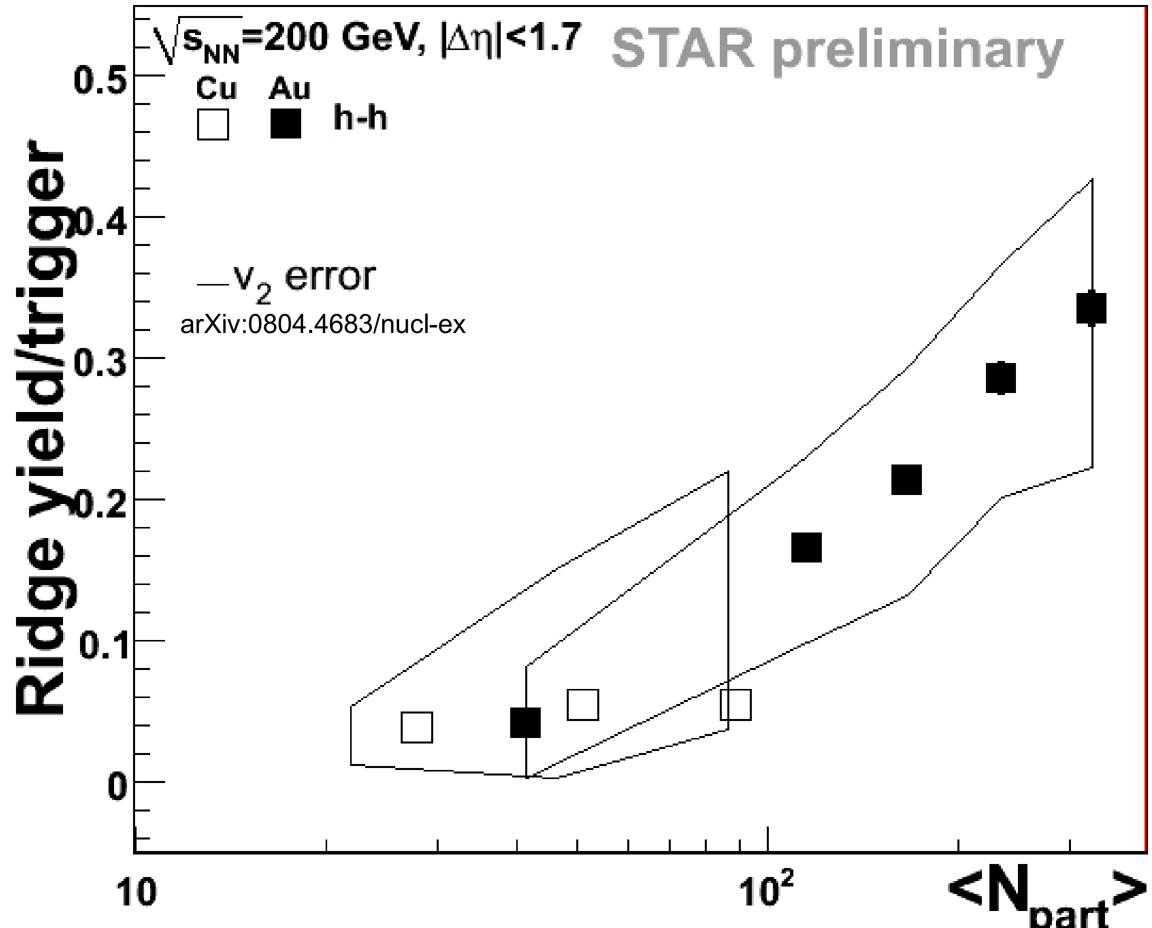
*Comparing these two energies in this kinematic region

arXiv:0806.2261/nucl-ex
arXiv:0804.4683/nucl-ex

Identified trigger: Near-side Yield vs N_{part}

3.0 GeV/c < $p_T^{trigger}$ 6.0 GeV/c; 1.5 GeV/c < $p_T^{associated}$ < $p_T^{trigger}$

Ridge yield -
No trigger type dependence



Au+Au $\sqrt{s_{NN}}$=200 GeV from nucl-ex/0701047
Cu+Cu $\sqrt{s_{NN}}$=200 GeV from SQM2007
Data points at same N_{part} offset for visibility

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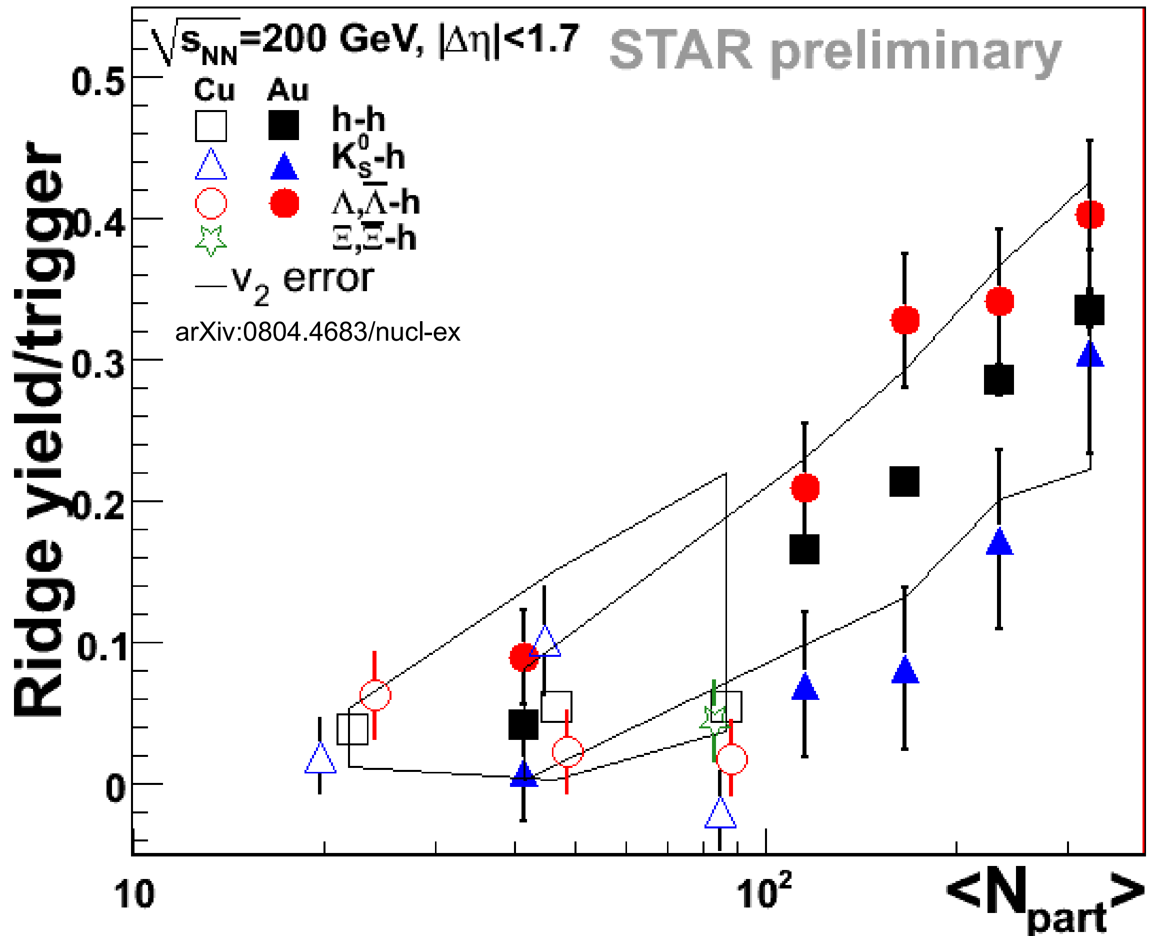

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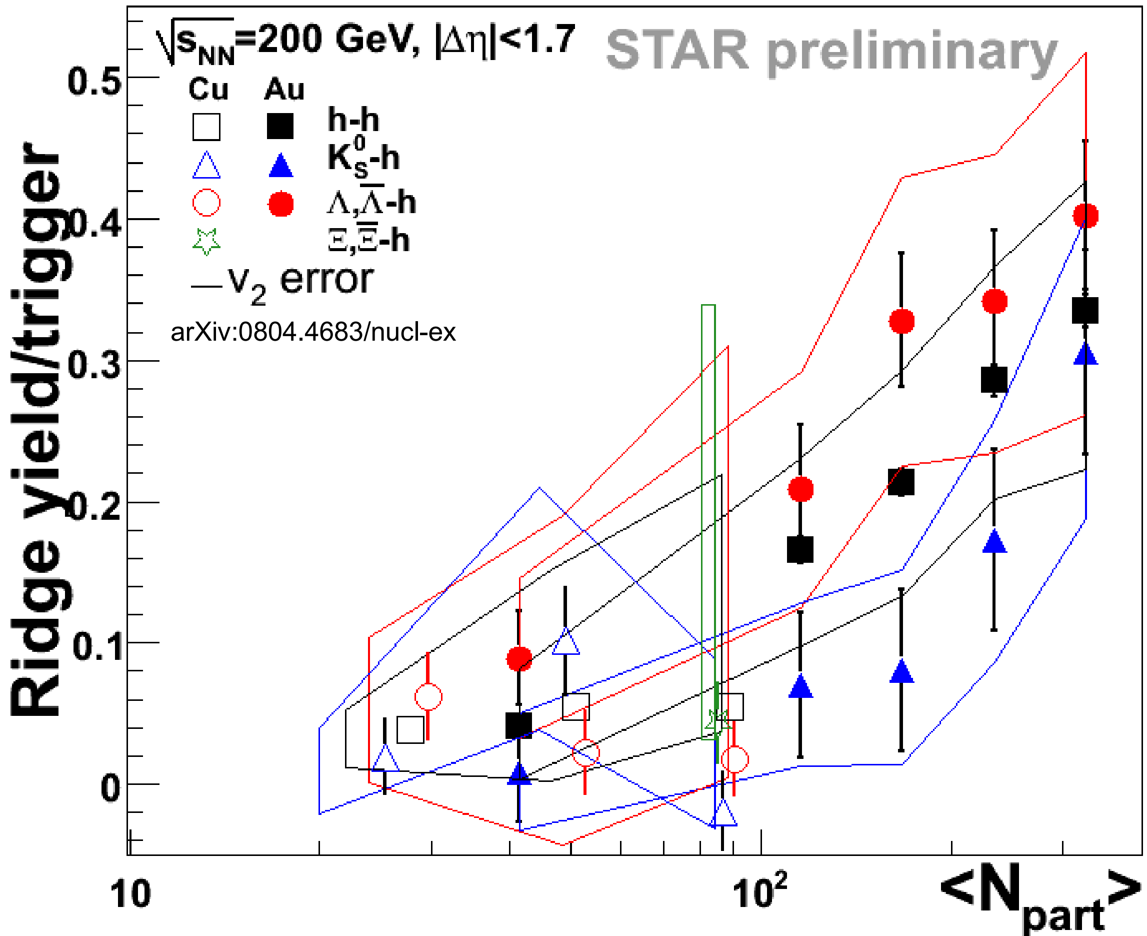

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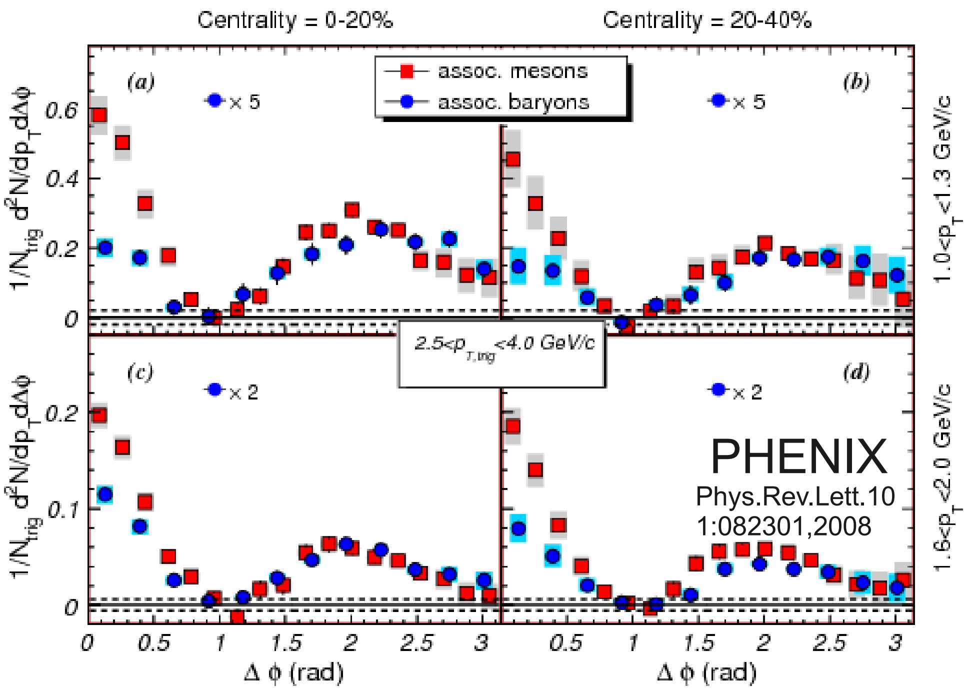
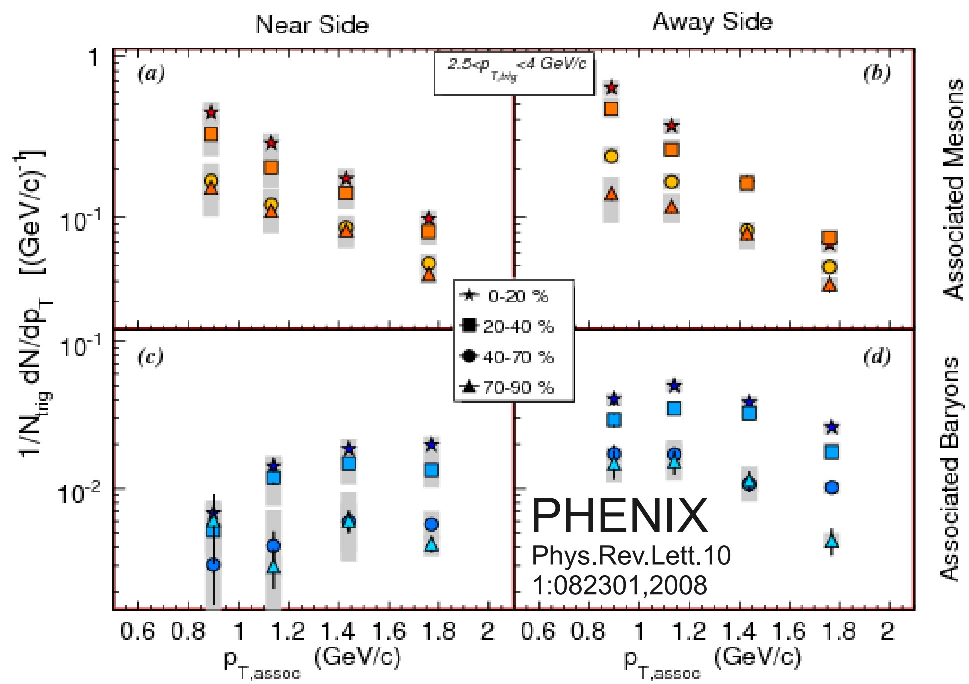
Cu+Cu $\sqrt{s_{NN}}$=200 GeV from SQM2007
Data points at same N_{part} offset for visibility

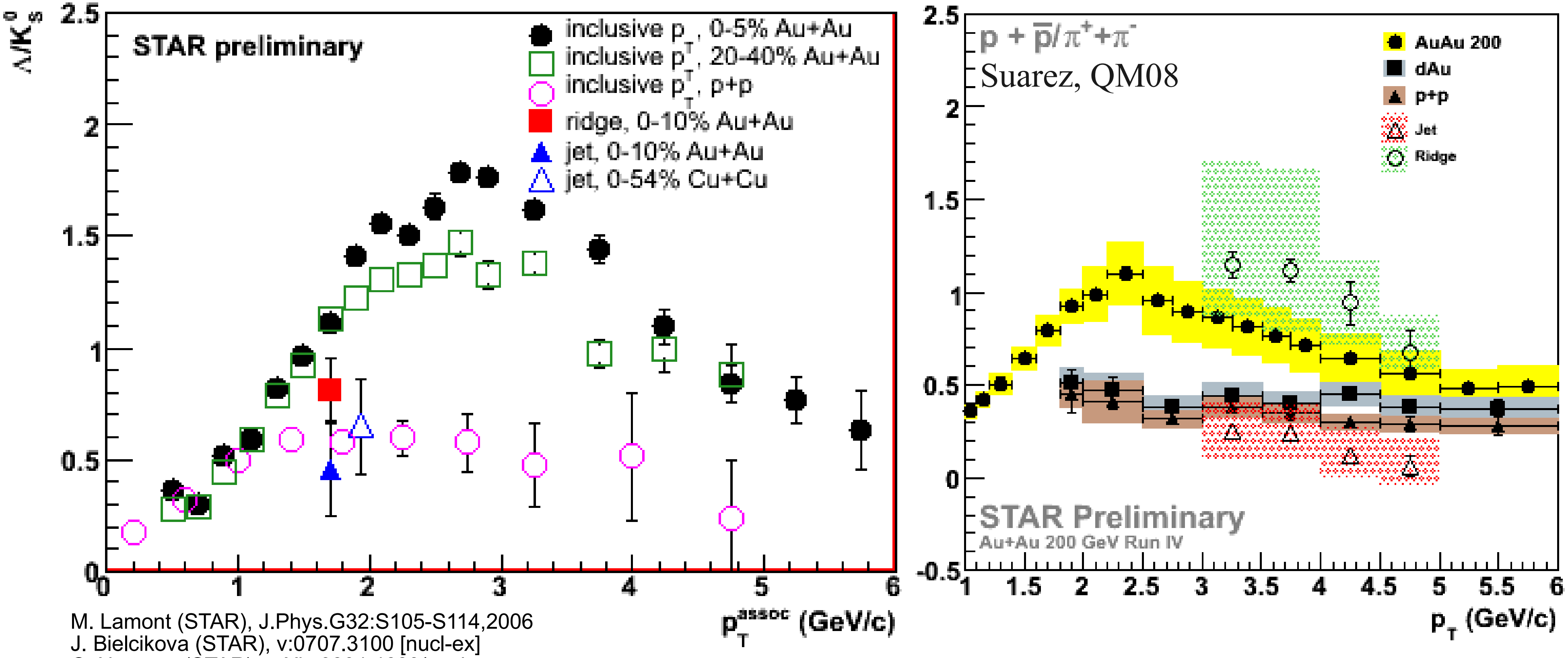
Baryon/meson ratios





- Clear evidence of different behavior for baryons and mesons
- For this kinematic region, baryon/meson ratio in bulk changing rapidly

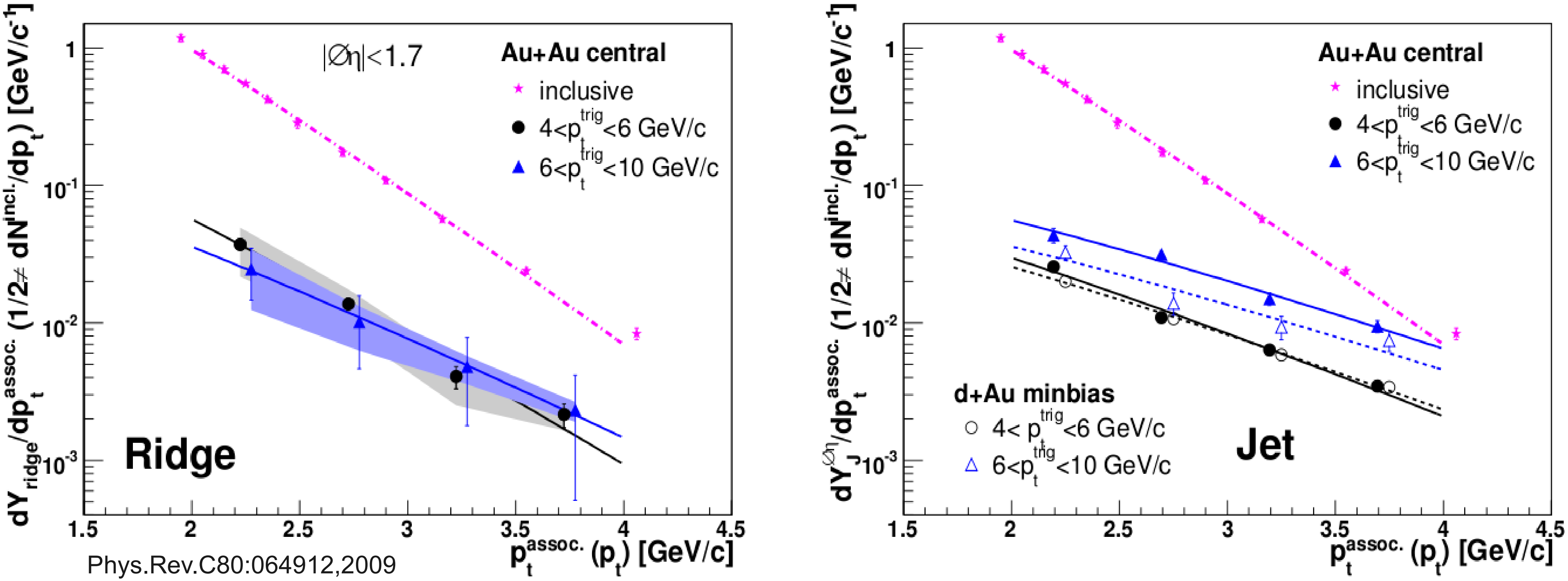
Jet-like correlation composition



M. Lamont (STAR), J.Phys.G32:S105-S114,2006
J. Bielcikova (STAR), v:0707.3100 [nucl-ex]
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

- Baryon/meson ratios in jet-like correlation in Cu+Cu and Au+Au similar to p+p for both strange and non-strange particles
- Baryon/meson ratios in ridge similar to bulk for both strange and non-strange particles

Jet-like correlation is like p+p, ridge is like bulk

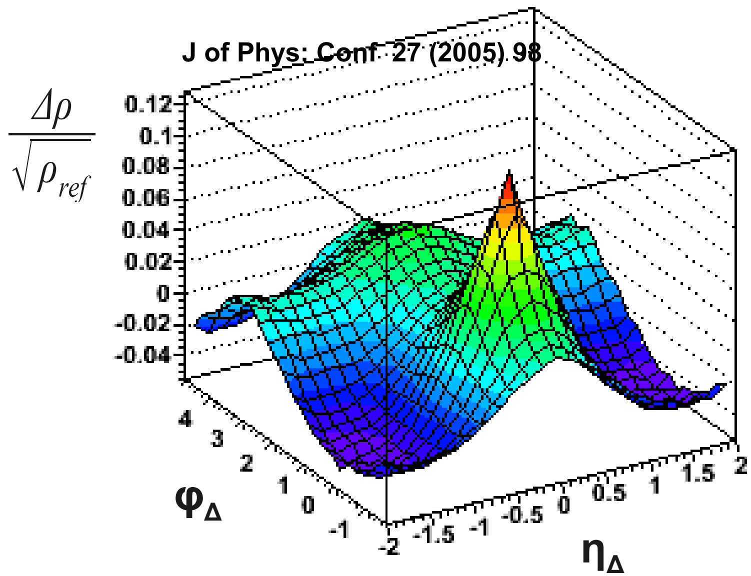


Phys.Rev.C80:064912,2009

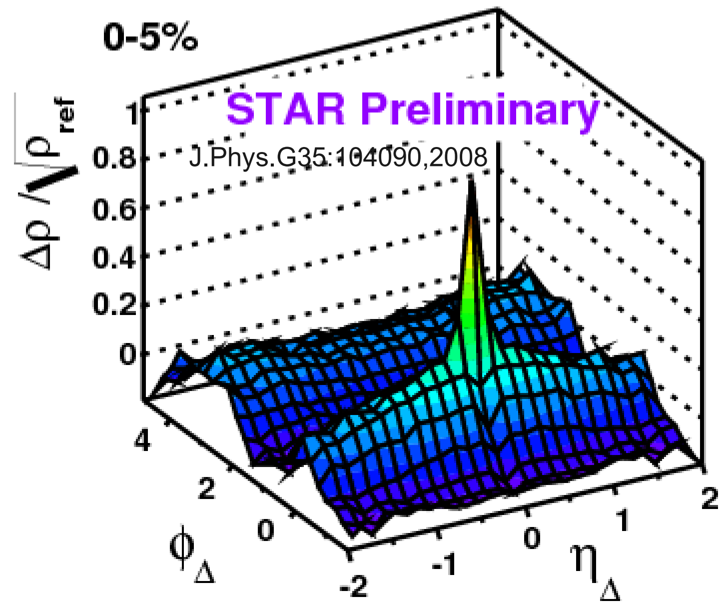
Spectra of particles associated with ridge similar to inclusive

Spectra of particles associated with jet-like correlation harder

The soft ridge



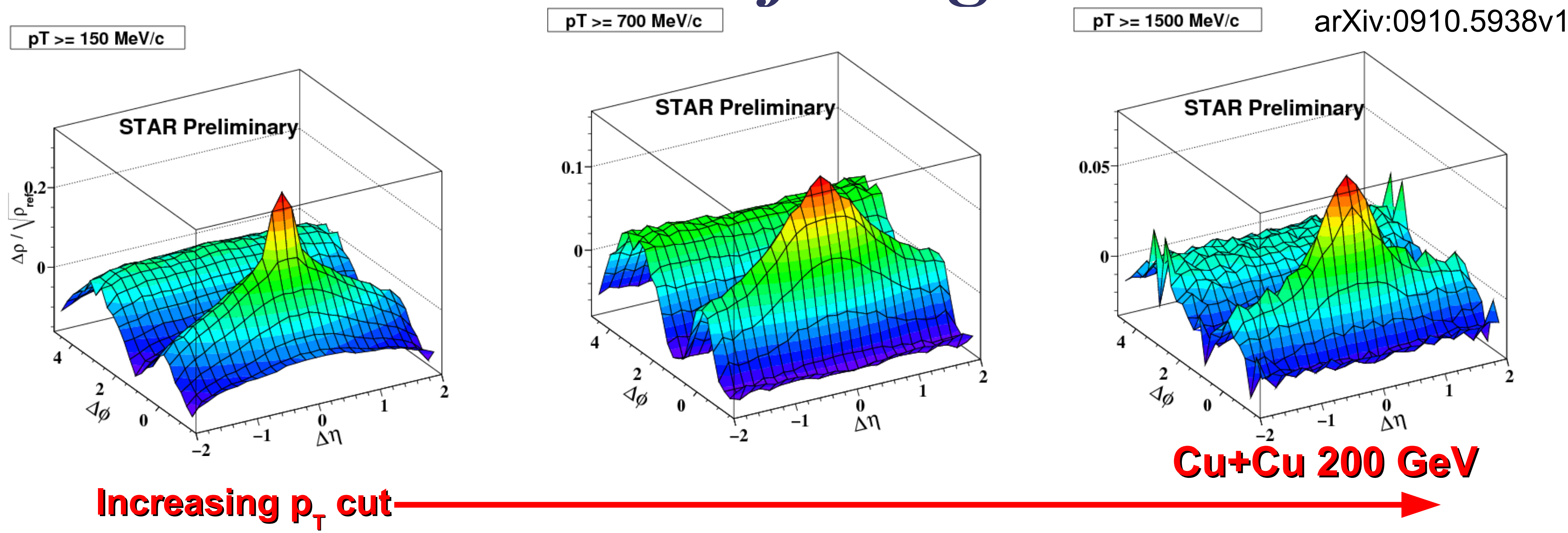
p+p 200 GeV



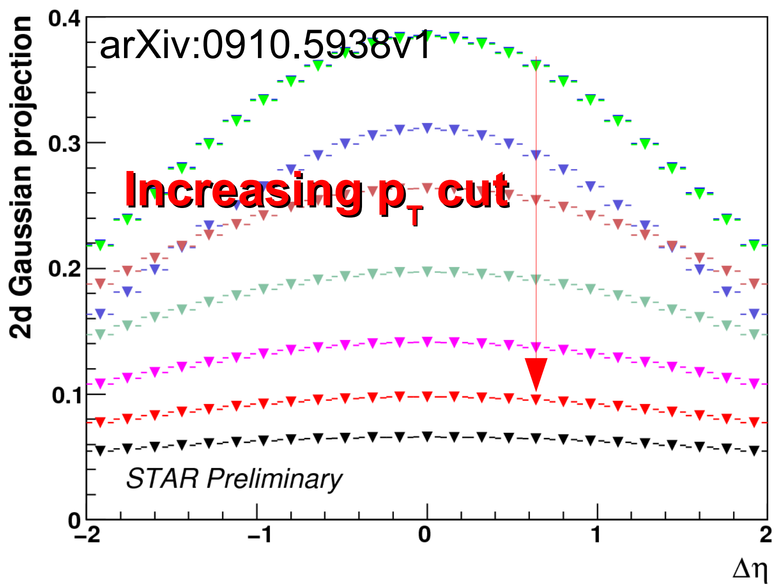
Au+Au 200 GeV

- Untriggered di-hadron correlations – no p_T cuts
- Similar structure on the near-side - “Soft Ridge”
- Are soft and hard ridge the same?

The soft ridge



- Soft ridge → hard ridge with increasing p_T
- Most likely two structures are the same



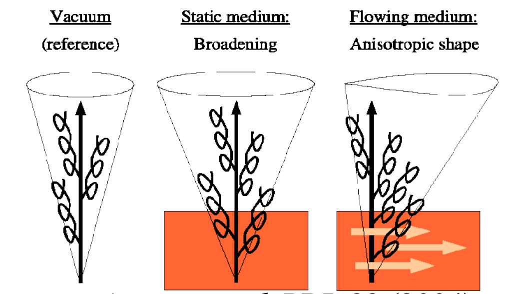
*Note the different normalizations for the hard and soft ridge

Models

- Radiated gluons broadened in pseudorapidity

  Longitudinal flow, Armesto et al, PRL 93 (2004)
  QCD magnetic fields, Majumder et al,Phys.Rev.Lett.99:042301,2007
  Anisotropic plasma, P. Romatschke, PRC,75014901 (2007)

  So far unable to make enough r*idge*



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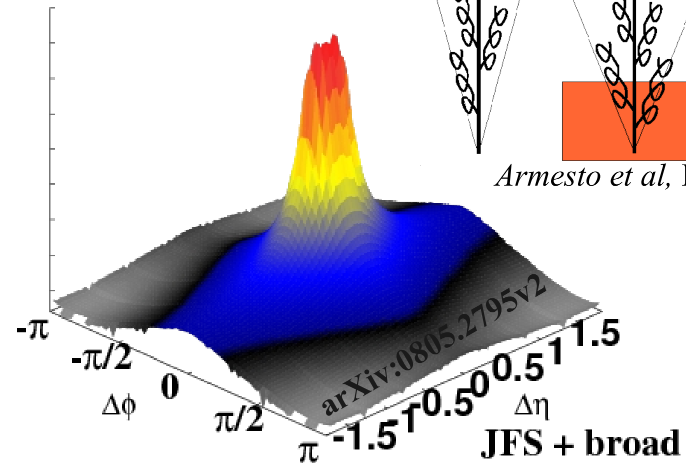

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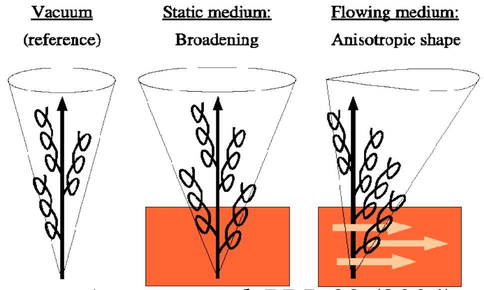
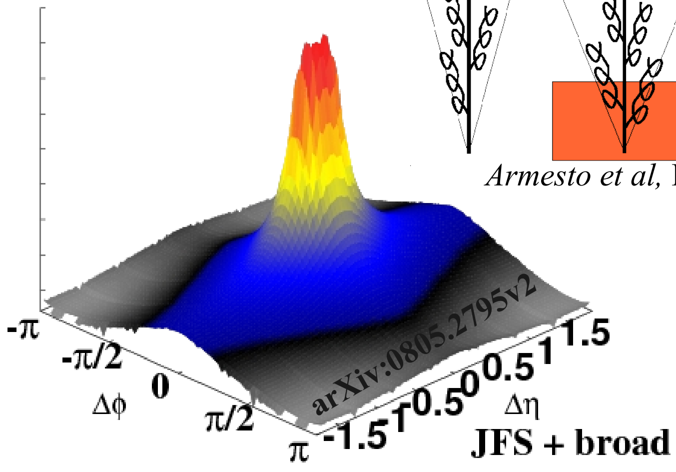
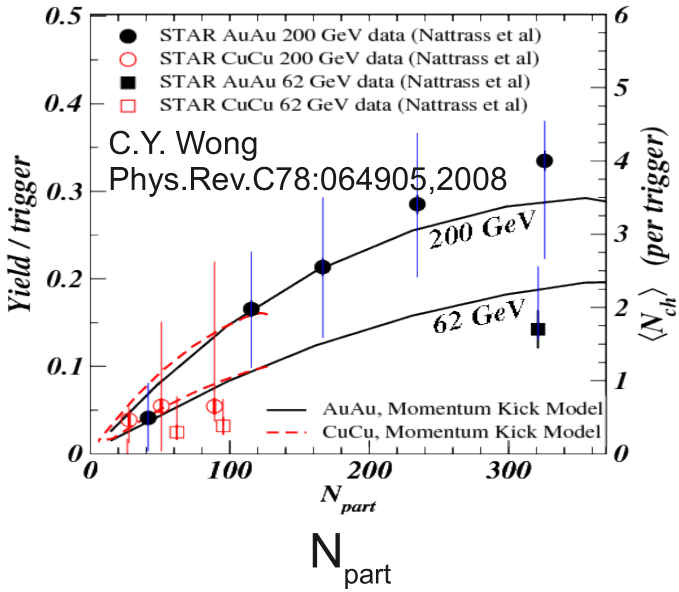
- Interaction of jet+medium
  Momentum kick from jet, C.-Y. Wong , Phys.Rev.C76:054908,2007
  Medium heating + recombination, Chiu & Hwa, PRC72, 034903
  Agrees with data but lots of fits to the data



Armesto et al, PRL 93 (2004)





Models

- Radiated gluons broadened in pseudorapidity
  Longitudinal flow, Armesto et al, PRL 93 (2004)
  QCD magnetic fields, Majumder et al,Phys.Rev.Lett.99:042301,2007
  Anisotropic plasma, P. Romatschke, PRC,75014901 (2007)
  So far unable to make enough *ridge*

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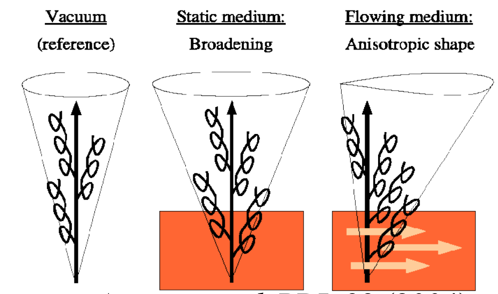
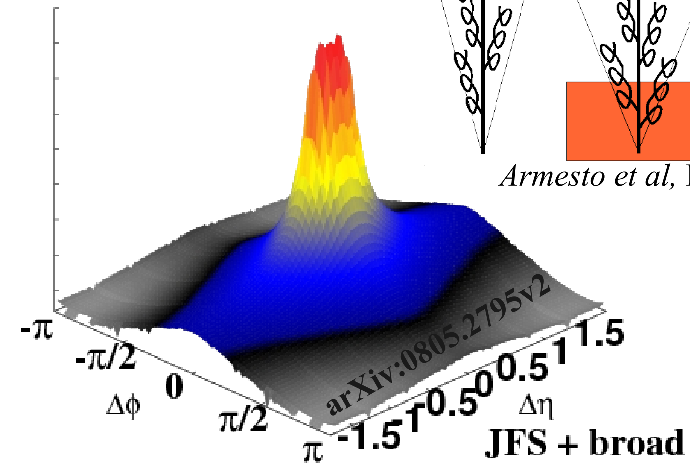
  Agrees with data but lots of fits to the data

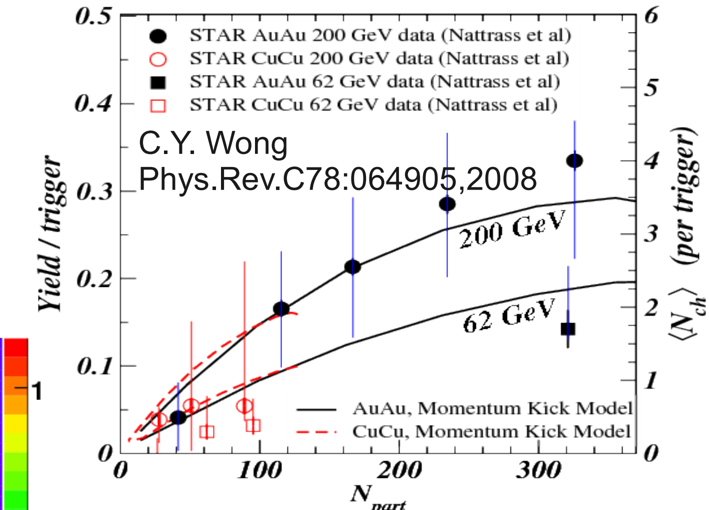
- Hydrodynamical flow
  Radial flow+trigger bias
  S. Voloshin, nucl-th/0312065, Nucl. Phys. A749, 287
  C.. Pruneau, S. Gavin, S. Voloshin, arXiv:0711.1991v2
  E. Shuryak, *Phys.Rev.C76:047901,2007*
  Triangular flow (v_3)
  B.Alver, G.Roland, Phys.Rev.C81:054905,2010
  P. Sorensen, arXiv:1002.4878v1

As an added bonus, these describe the away-side
How can we distinguish these?

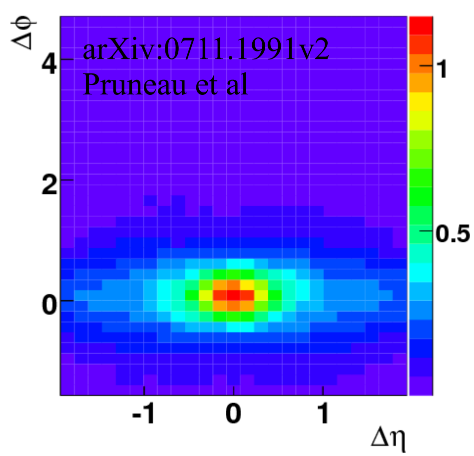


Armesto et al, PRL 93 (2004)

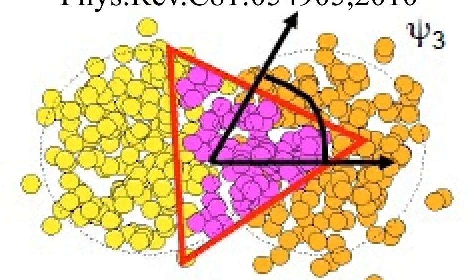




N_{part}



Phys.Rev.C81:054905,2010



Conclusions

- Lots of data
  - Jet-like correlation dominated by fragmentation
  - Ridge is bulk-like. From the bulk?
  - Hard and soft ridge most likely the same phenomenon

Conclusions

- Lots of data
  - Jet-like correlation dominated by fragmentation
  - Ridge is bulk-like. From the bulk?
  - Hard and soft ridge most likely the same phenomenon
- Theories
  - Causal: Have some difficulty reproducing the data
  - Non-causal/Hydrodynamical models: Good candidates

Outlook

- My prediction: There will be a ridge at the LHC
  - Hydro is mass dependent → need better mass dependent measurements
- Need to understand the ridge to understand fully reconstructed jets
  - – Is it background? Is it signal?
  - If the ridge isn't from jets, can we use it to learn something else?