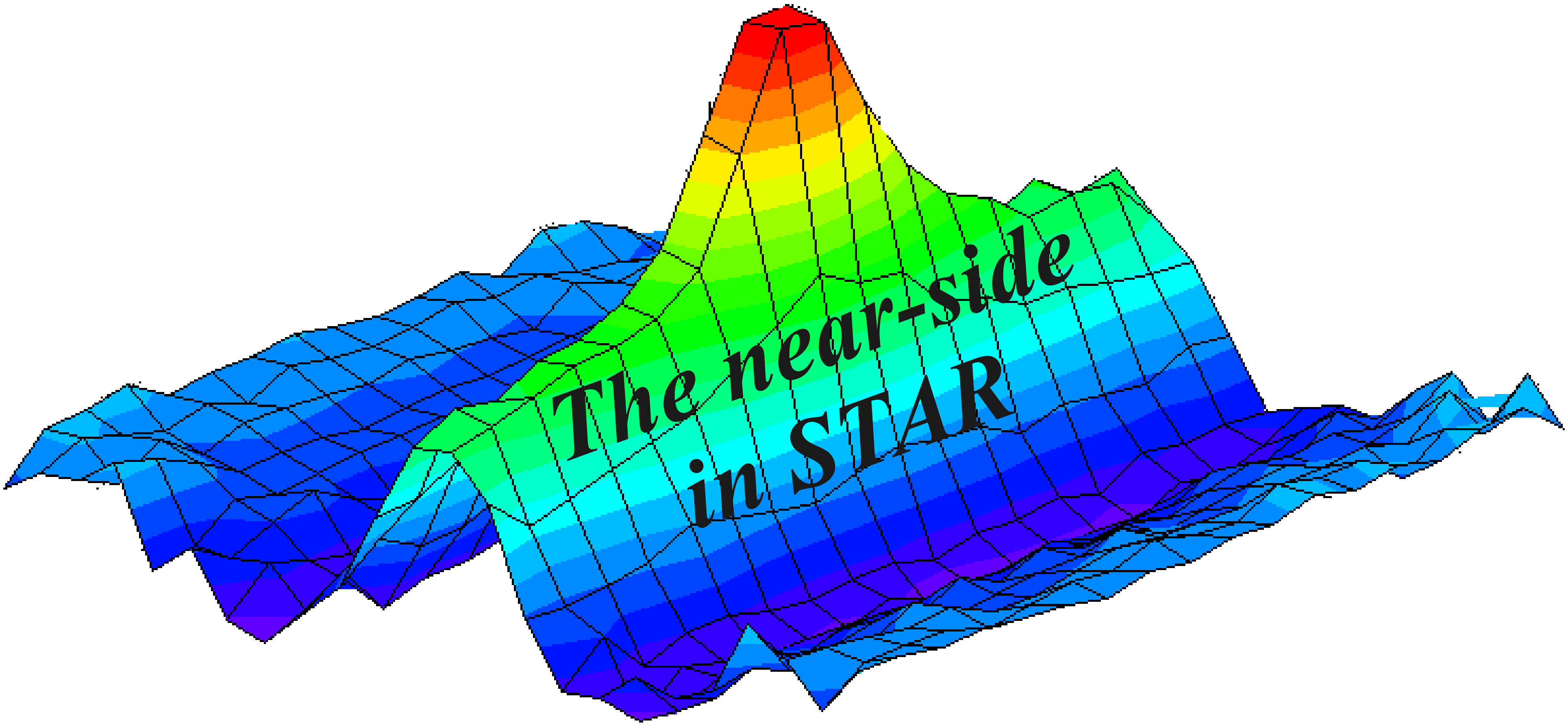


# The near-side in STAR


*Christine Nattrass (Yale University)*

*for the STAR Collaboration*

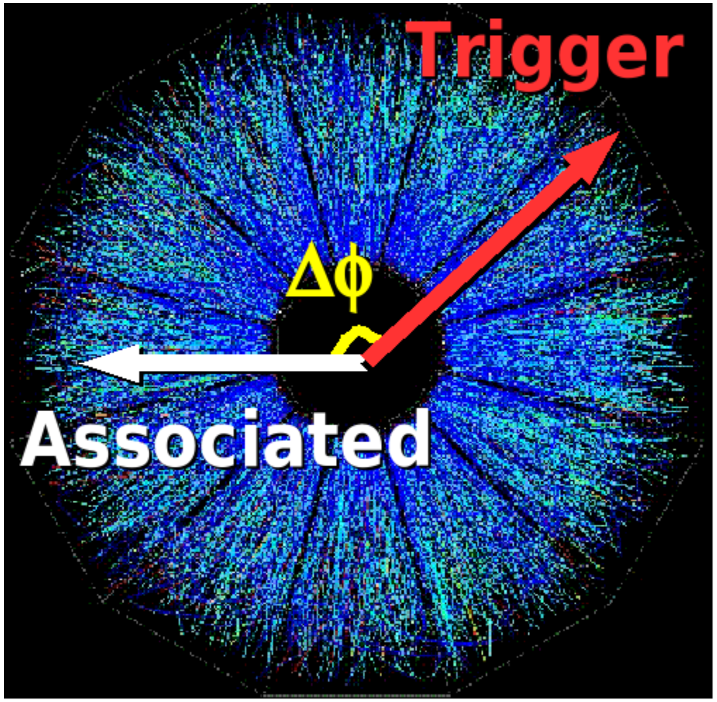
# *Outline*

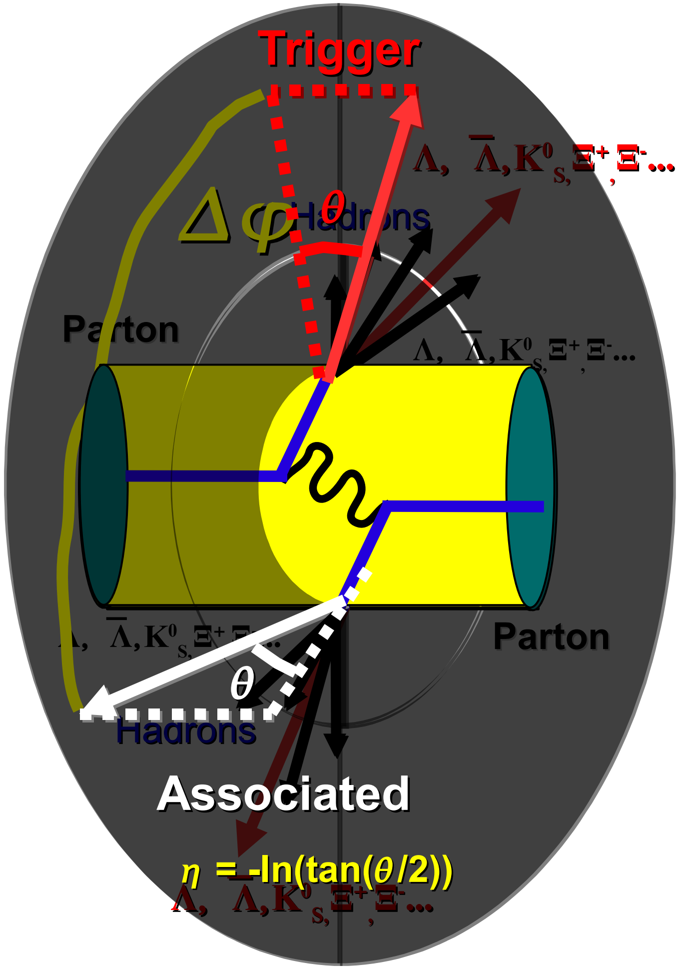
- Introduction
- The *Jet* – energy, system, and particle type dependence
- The *Ridge* – energy, system, and particle type dependence
- Comparison to models
- Conclusion

# Introduction

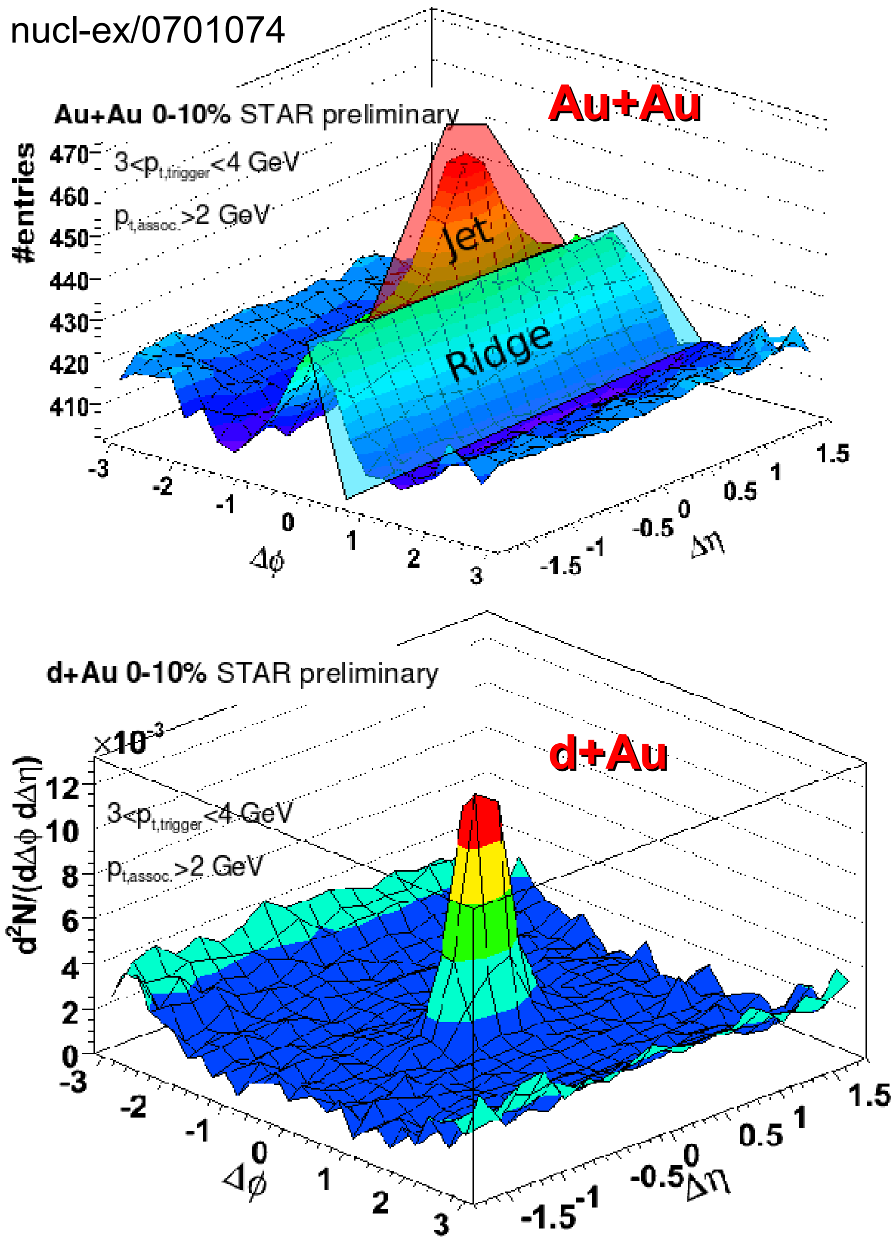
# *Di-hadron correlations*

- Define a high-pT trigger particle
- Look at the distribution of particles relative to that trigger particle



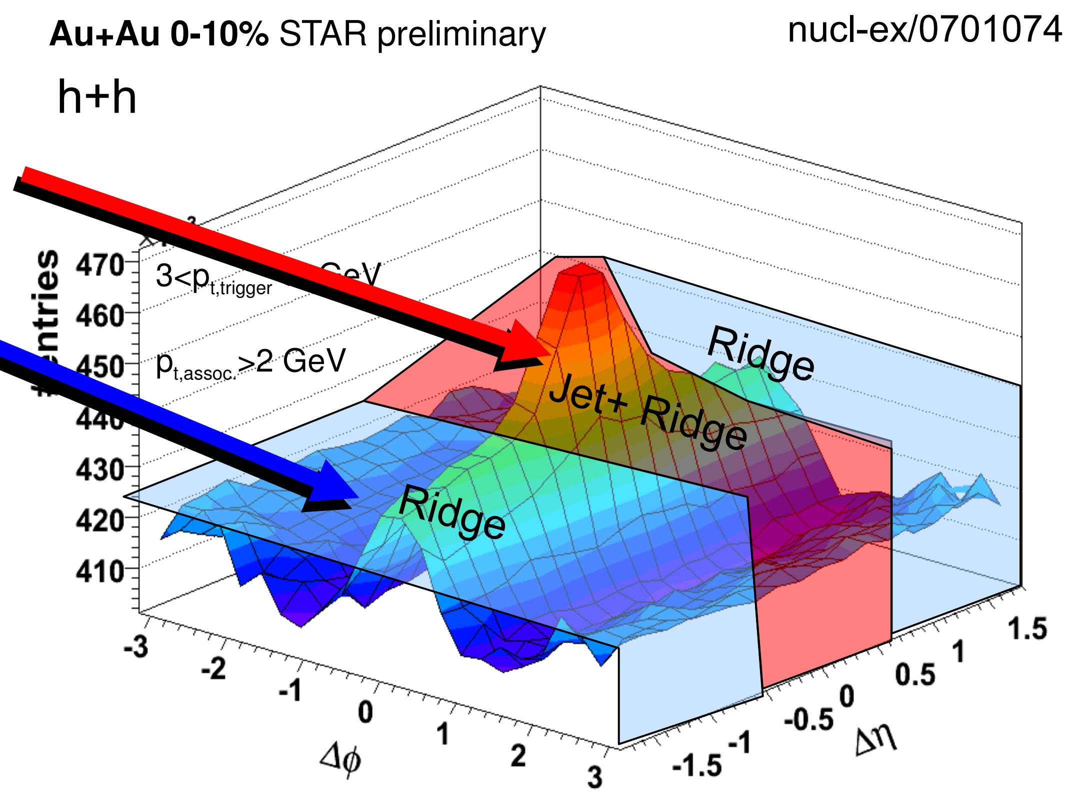
# *Motivation – Jet and Ridge*



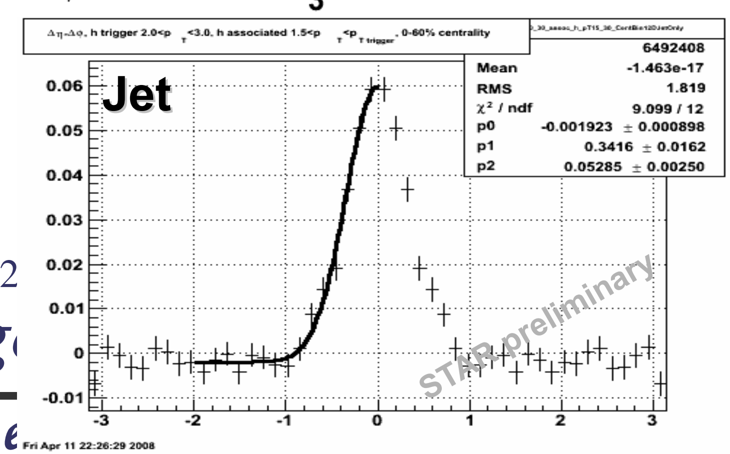

- Long-range pseudorapidity ($\Delta\eta$) correlations observed by STAR in Au+Au at intermediate $p_T$
- Near side jet peak sits on plateau (*Ridge*)
  - Significant contribution to the near-side yield in central Au+Au

# Method: Yield extraction

- *Ridge* previously observed to be independent in $\Delta\eta$ in Au+Au
- To determine relative contributions, find yields for near-side, take $\Delta\Phi$ projections in
  - $-0.75<\Delta\eta<0.75$ ***Jet + Ridge***
  - $0.75<|\Delta\eta|<1.75$ ***Ridge***
  - *Jet* = (*Jet+Ridge*) – *Ridge**.75/1.0
  - *Ridge* = yield from $-1.75<\Delta\eta<1.75$ – *Jet* yield

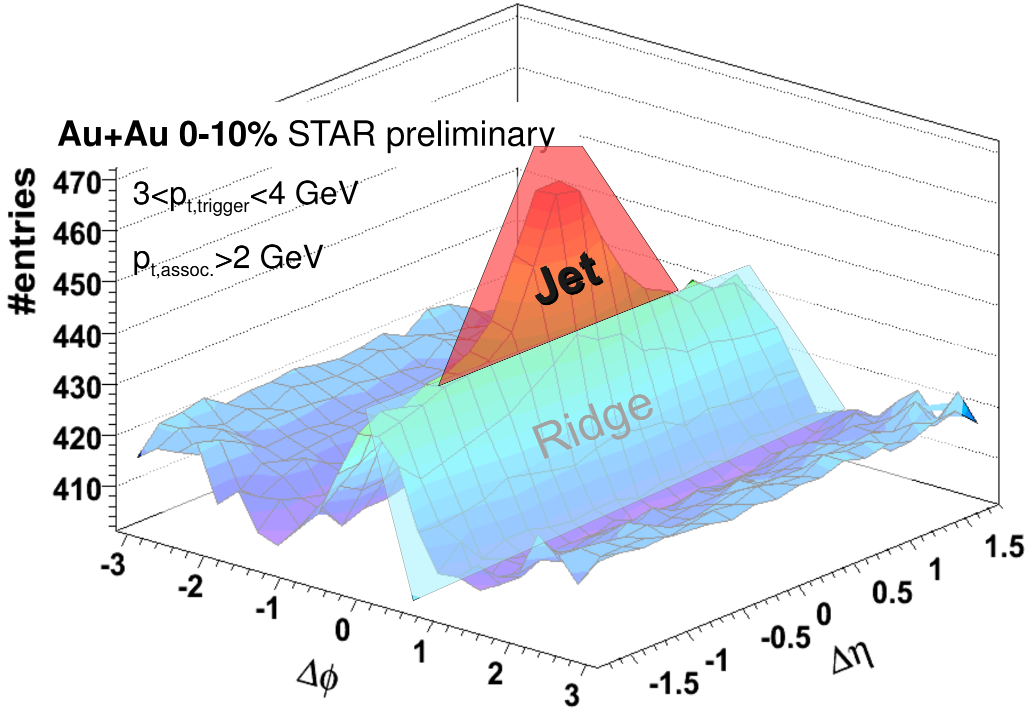



- Flow contributions to *Jet* cancel
  - $v_2$ independent of $\eta$ for $|\eta|<1$
    - Phys. Rev. C72, 051901(R) (2005), Phys. Rev. Lett. 94, 122



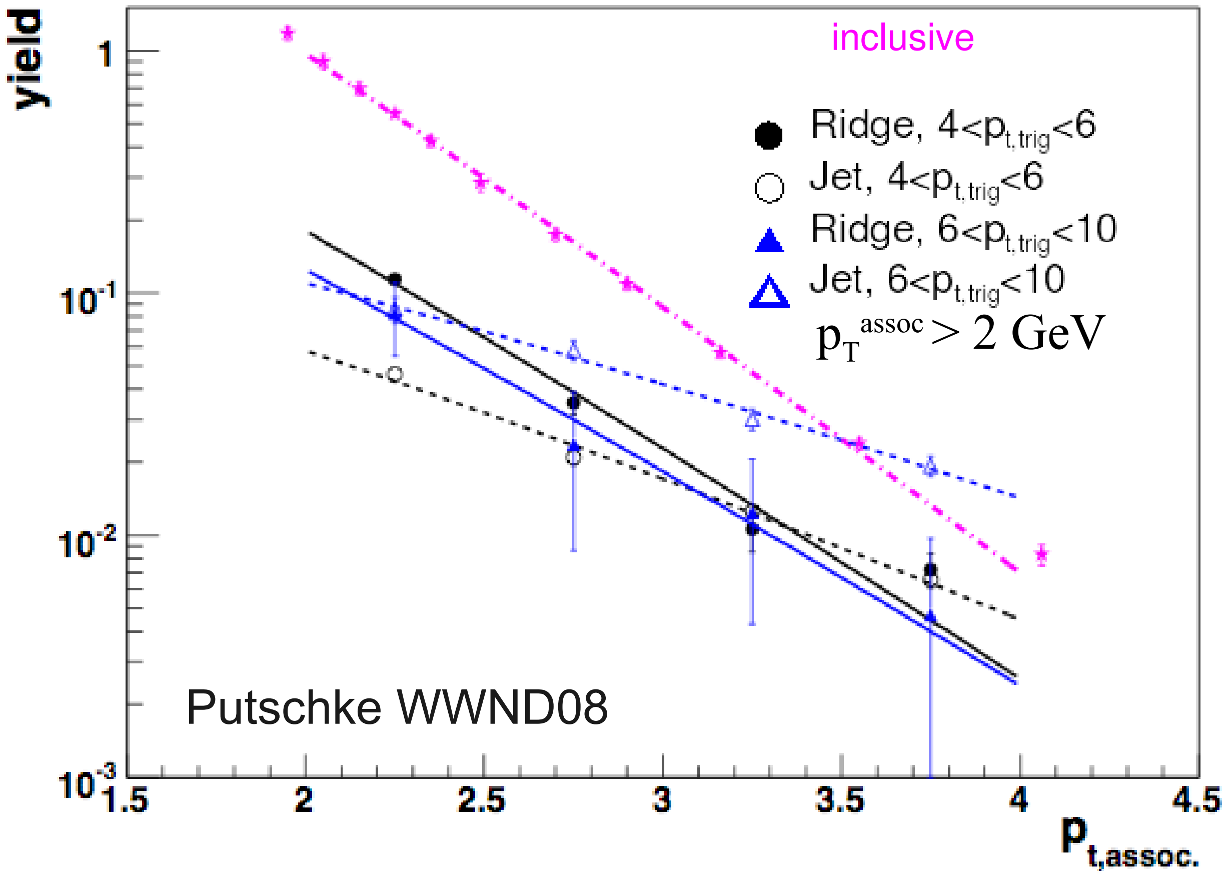

- Yield: number of particles in *Jet*, *Ridg*

# The *Jet*



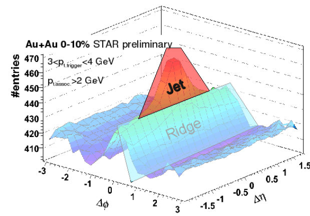
Au+Au 0-10% STAR preliminary
#entries
470
460
450
440
430
420
410
3<p t,trigger<4 GeV
p t,assoc.>2 GeV
Jet
Ridge
-3
-2
-1
0
1
2
3
Δφ
-1.5
-1
-0.5
0
0.5
1
1.5
Δη

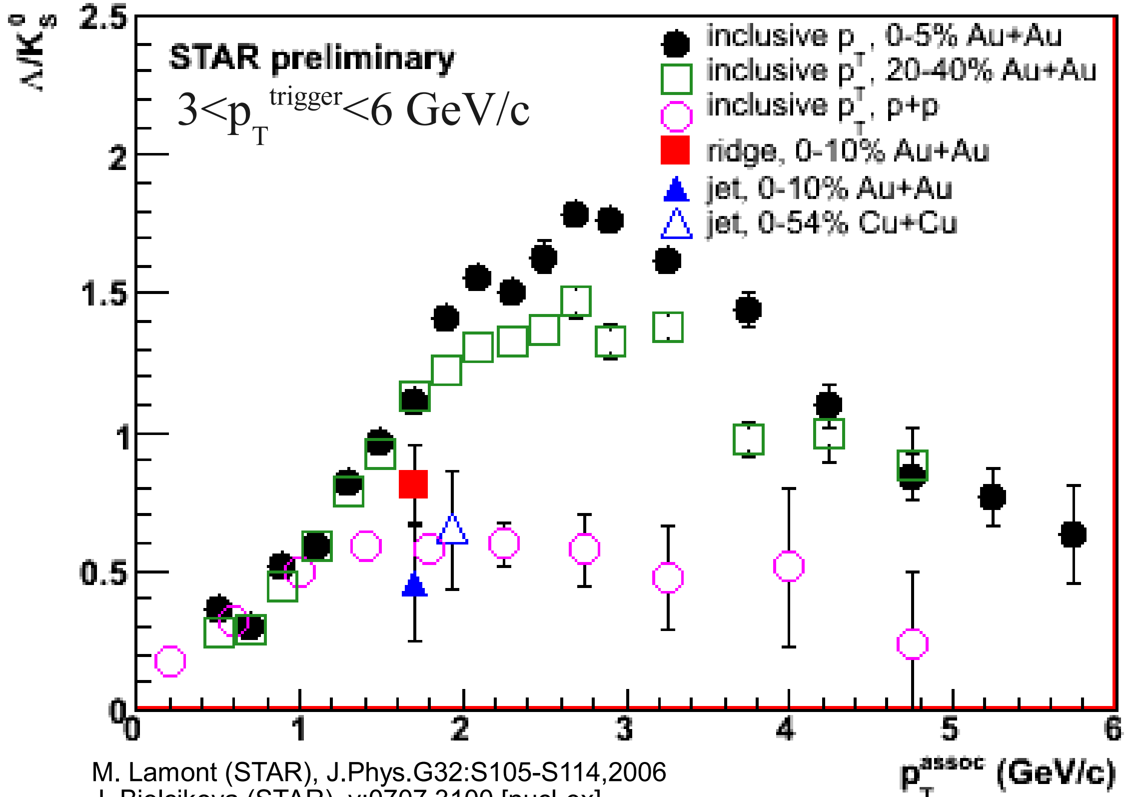
# *Jet is like p+p*



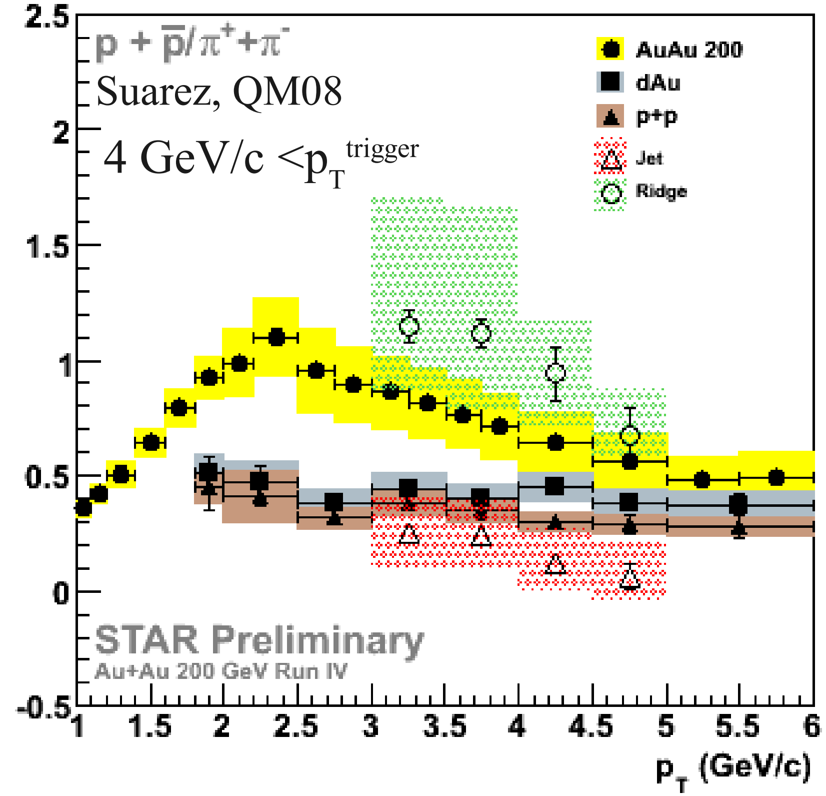

- Spectra of particles associated with *Jet* harder than inclusive

# *Jet composition*



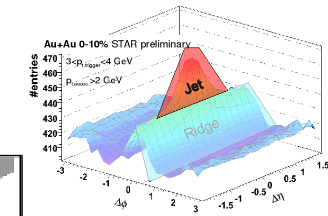


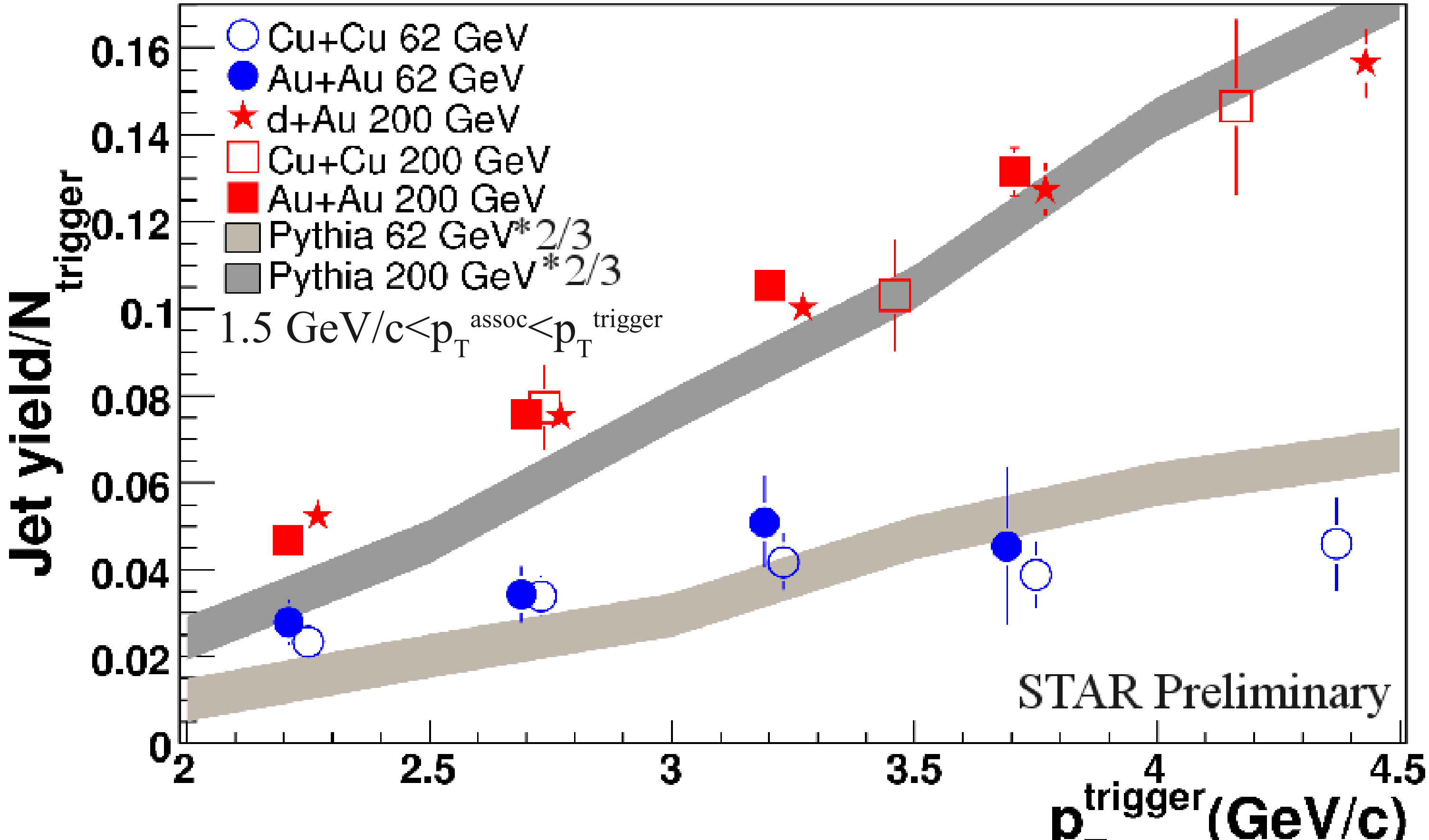

M. Lamont (STAR), J.Phys.G32:S105-S114,2006
J. Bielcikova (STAR), v:0707.3100 [nucl-ex]
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex




- Baryon/meson ratios in *Jet* in Cu+Cu and Au+Au similar to p+p for both strange and non-strange particles

# $p_T^{trigger}$ dependence

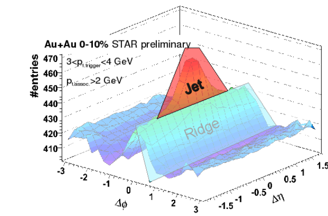


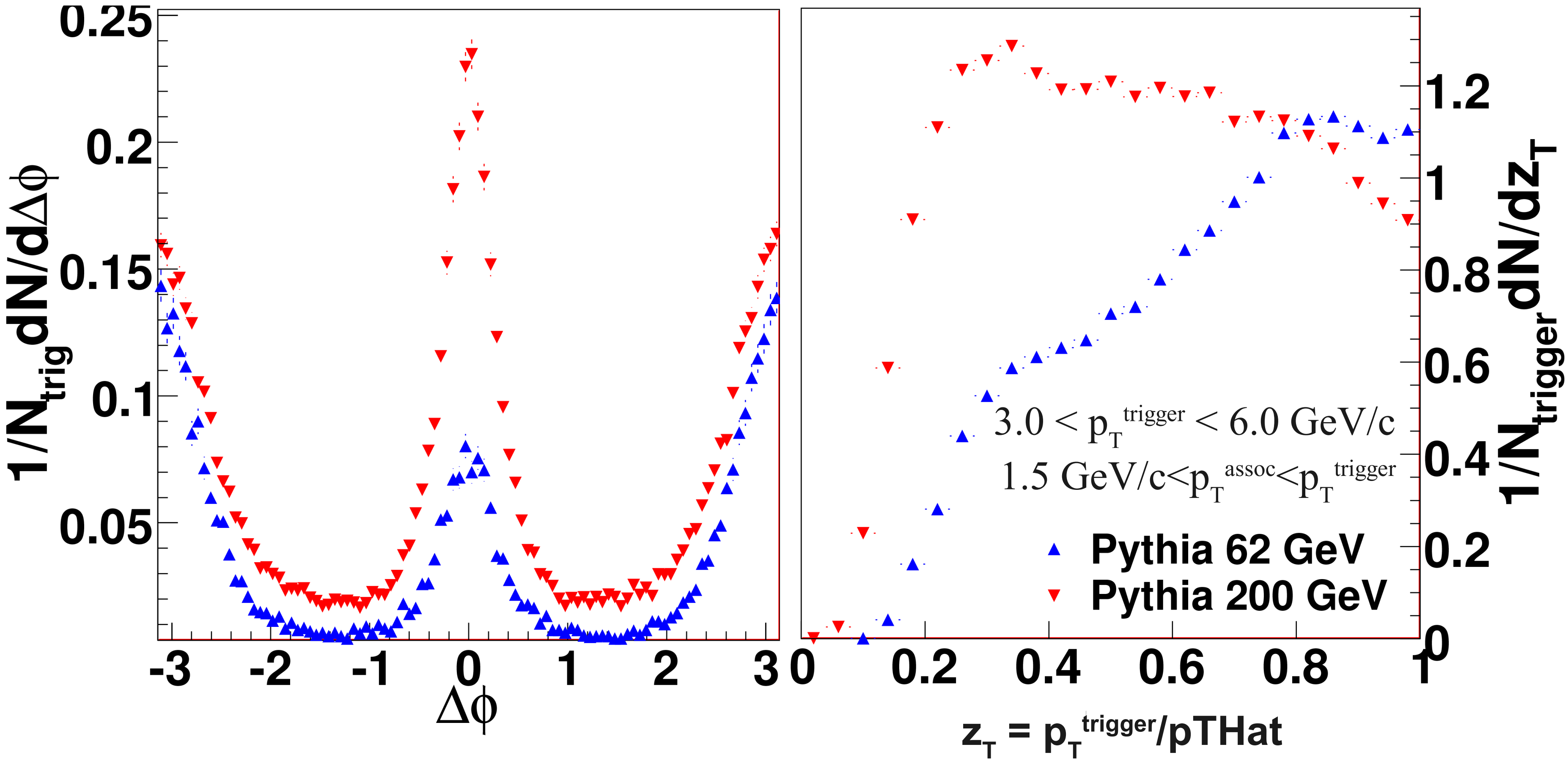




- No system dependence observed in the data
- Pythia 8.1 describes trends in data up to a scaling factor
  - Gets energy dependence right
  - Stronger deviations at low $p_T^{trigger}$, as expected

J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

# *Pythia comparisons*

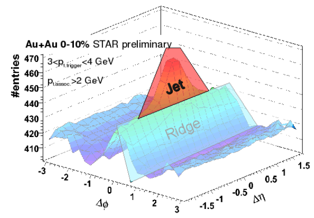


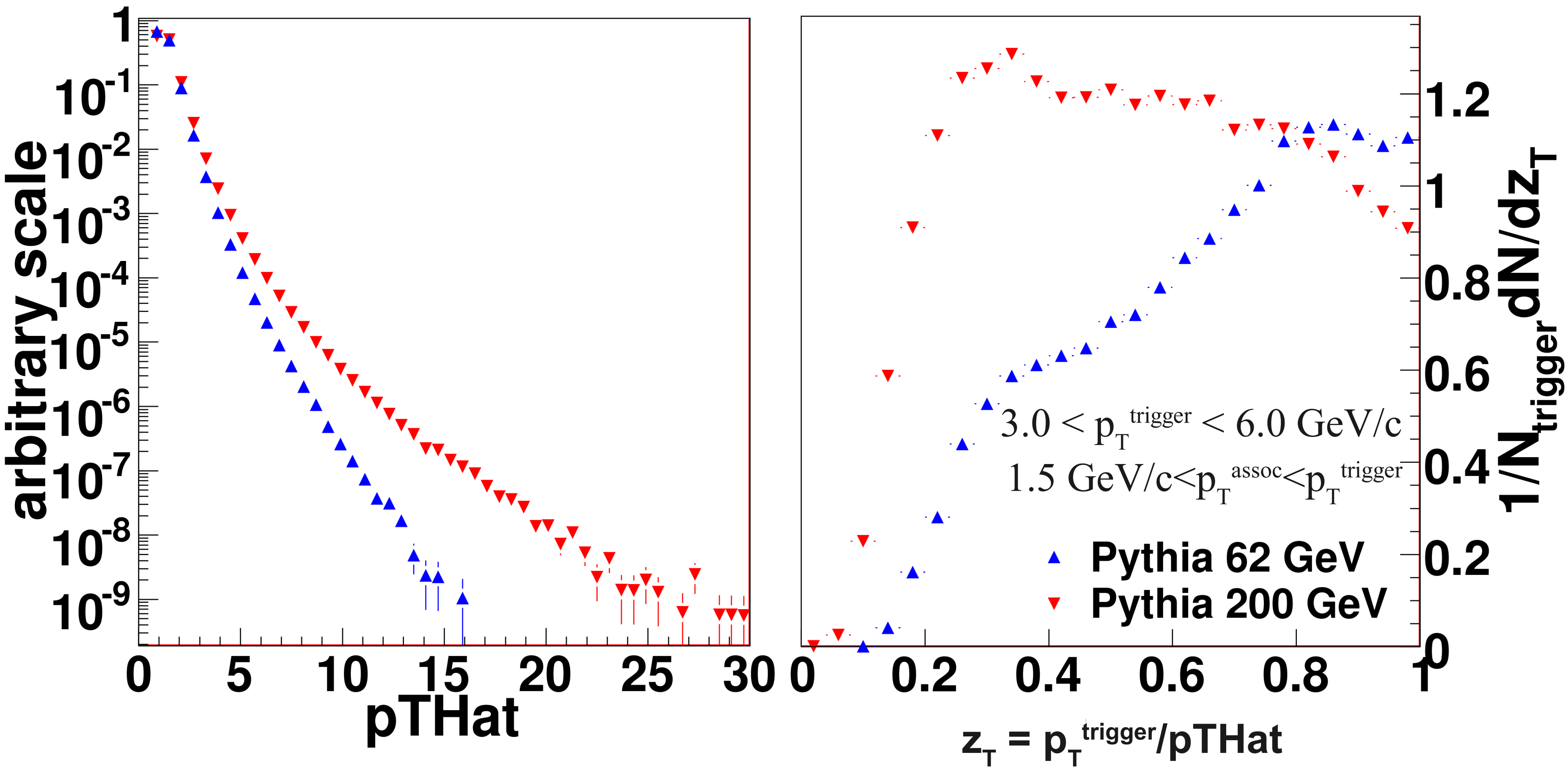




- What can Pythia tell us?
  - Higher $z_T$ (lower jet energy) in 62 GeV for same $p_T^{trigger}$

pTHat = the parameter in Pythia for the transverse momentum in the hard subprocess

# Pythia comparisons

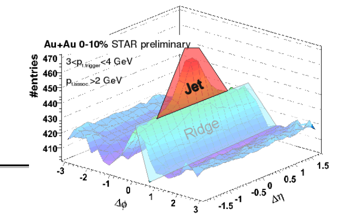


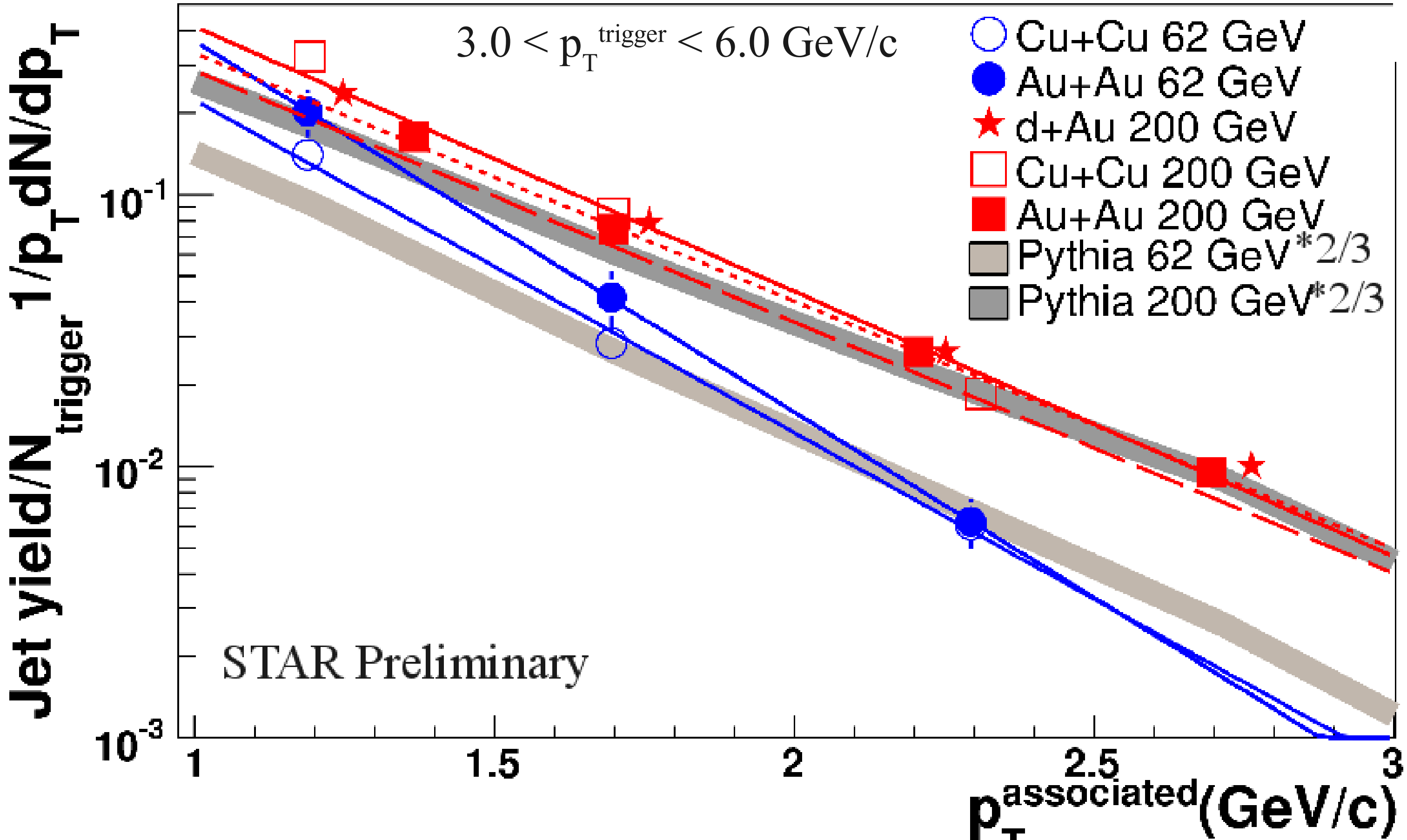



- What can Pythia tell us?
  - Higher $z_T$ (lower jet energy) in 62 GeV for same $p_T^{trigger}$

pTHat = the parameter in Pythia for the transverse momentum in the hard subprocess

# $p_T^{associated}$ dependence




- No system dependence
- Pythia 8.1 slightly harder than data
- Diverges slightly from Pythia 8.1 at lower $p_T^{associated}$

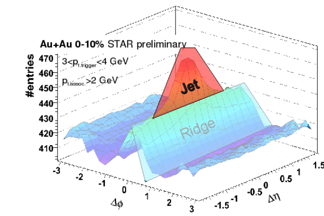
**Inverse slope parameter**

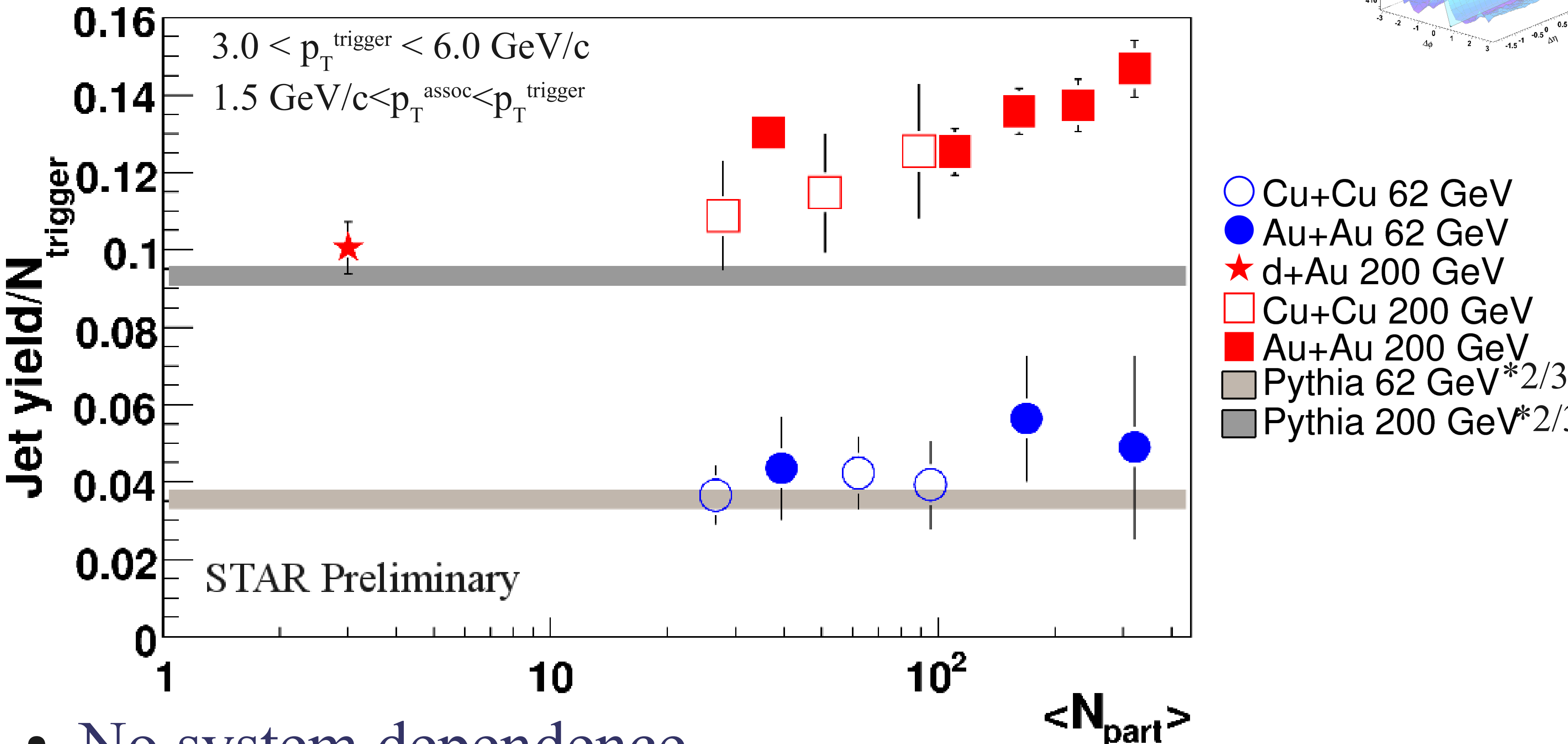
| | $\sqrt{s_{NN}}$ = 62 GeV | $\sqrt{s_{NN}}$ = 200 GeV |
|---|---|---|
| **Cu+Cu** | **317 ± 26** | **445 ± 20** |
| **Au+Au** | **355 ± 21** | **478 ± 8** |
| **d+Au** | | **469 ± 8** |
| **Pythia** | **417 ± 9** | **491 ± 3** |

Statistical errors only

J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

# $N_{part}$ dependence

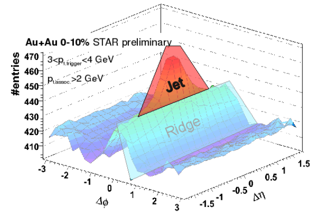



- No system dependence
- Some deviations from Pythia 8.1 with increase in $N_{part}$
  - Incomplete *Ridge* subtraction?
  - *Jet* modification at low $p_T$?

J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

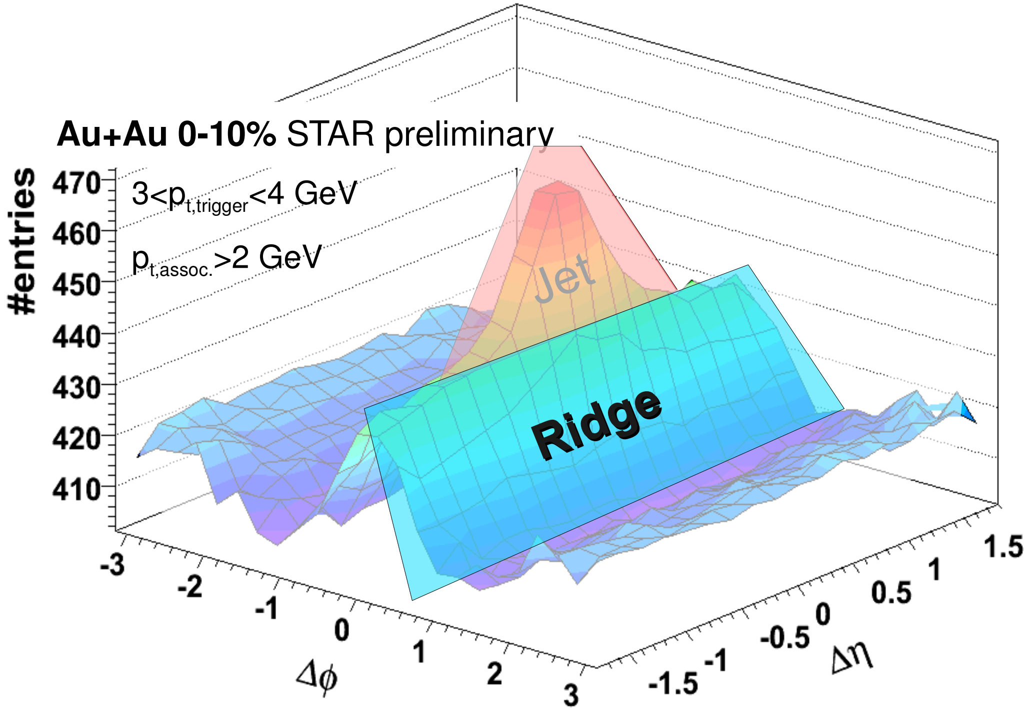
# *Conclusions: Jet*




- Particle ratios similar to p+p
  - Separation of *Jet* and *Ridge* works
  - Effects of triggers which don't come from jets small
  - Pythia can be used to estimate $z_T$ distributions, jet energy
- Pythia describes data well
  - Scaling factor needed but Pythia 8.1 is not as tuned as earlier versions
  - Energy dependence in *Jet* is described well in Pythia
  - Trends for $p_T^{trigger}$, $p_T^{assoc}$ dependence right

→ *Jet* production mechanism dominated by fragmentation

# The *Ridge*



Au+Au 0-10% STAR preliminary
#entries
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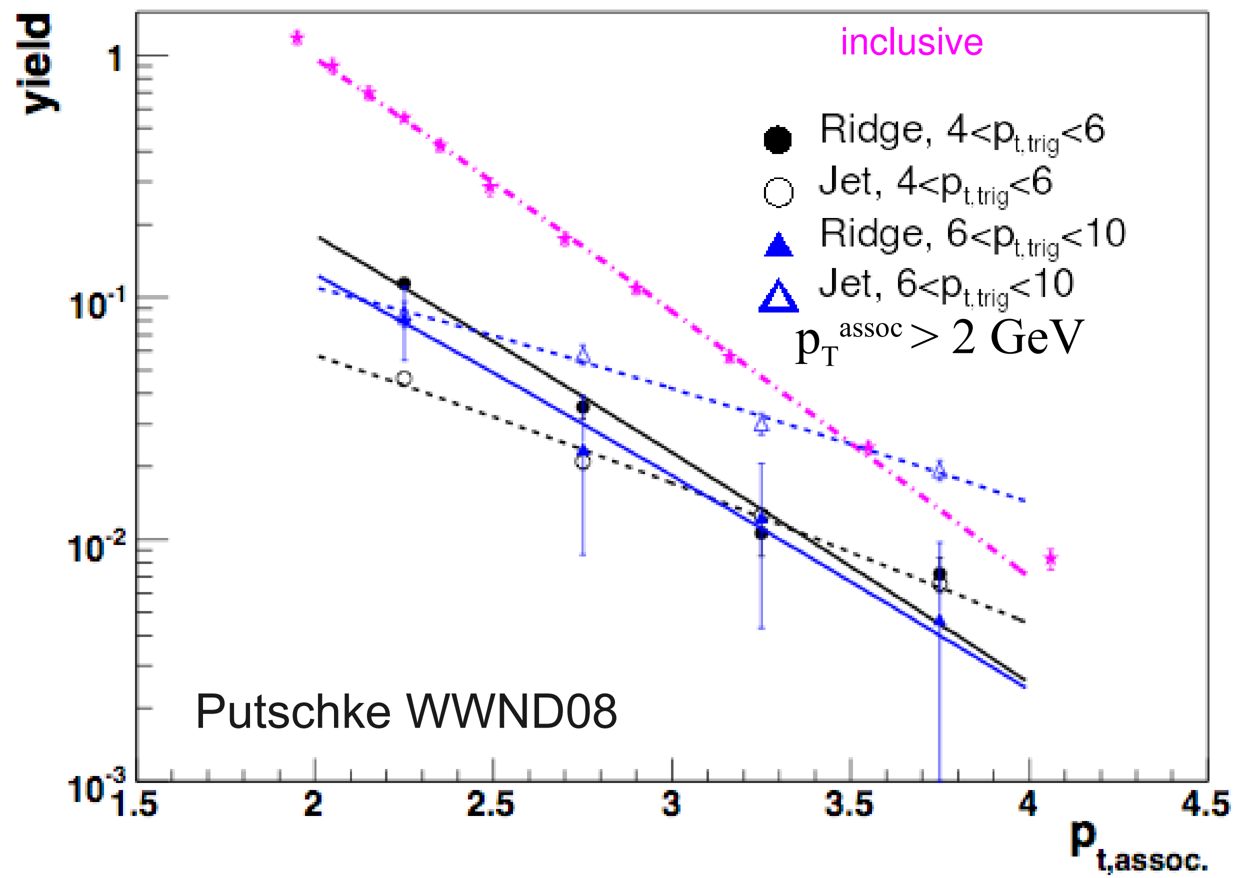
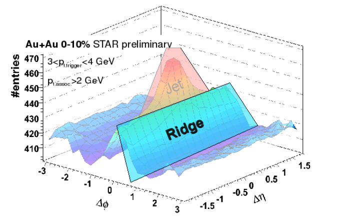
3<p t,trigger<4 GeV
p t,assoc.>2 GeV
Jet
Ridge
-3
-2
-1
0
1
2
3
Δφ
-1.5
-1
-0.5
0
0.5
1
1.5
Δη

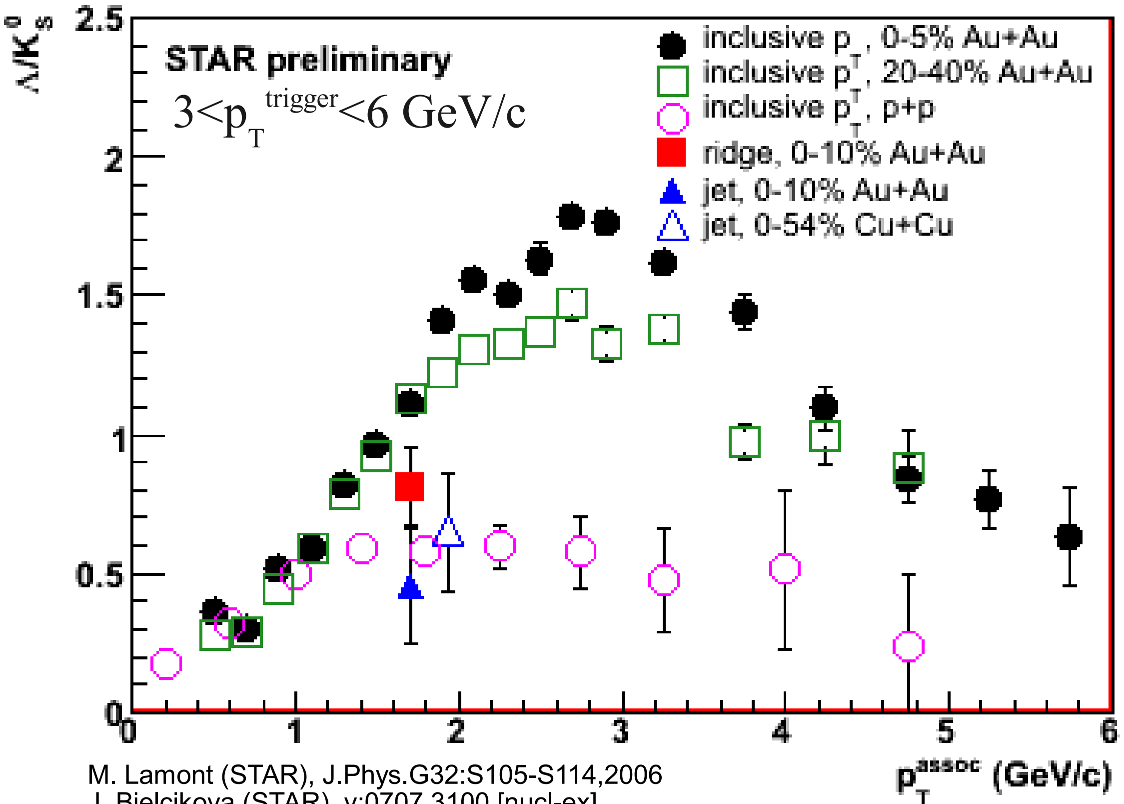
# *Ridge is like bulk*



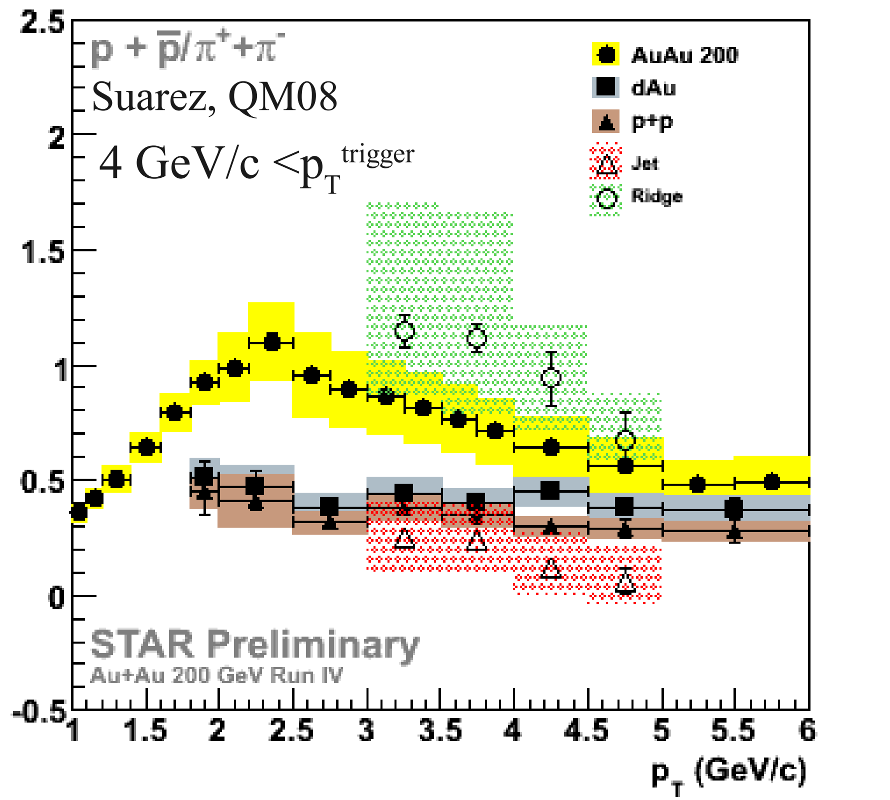

- Spectra of particles associated with *Ridge* similar to inclusive




# *Ridge composition*

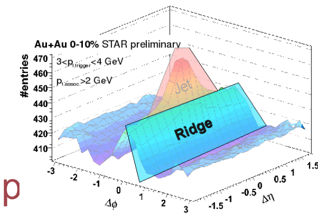



M. Lamont (STAR), J.Phys.G32:S105-S114,2006
J. Bielcikova (STAR), v:0707.3100 [nucl-ex]
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex



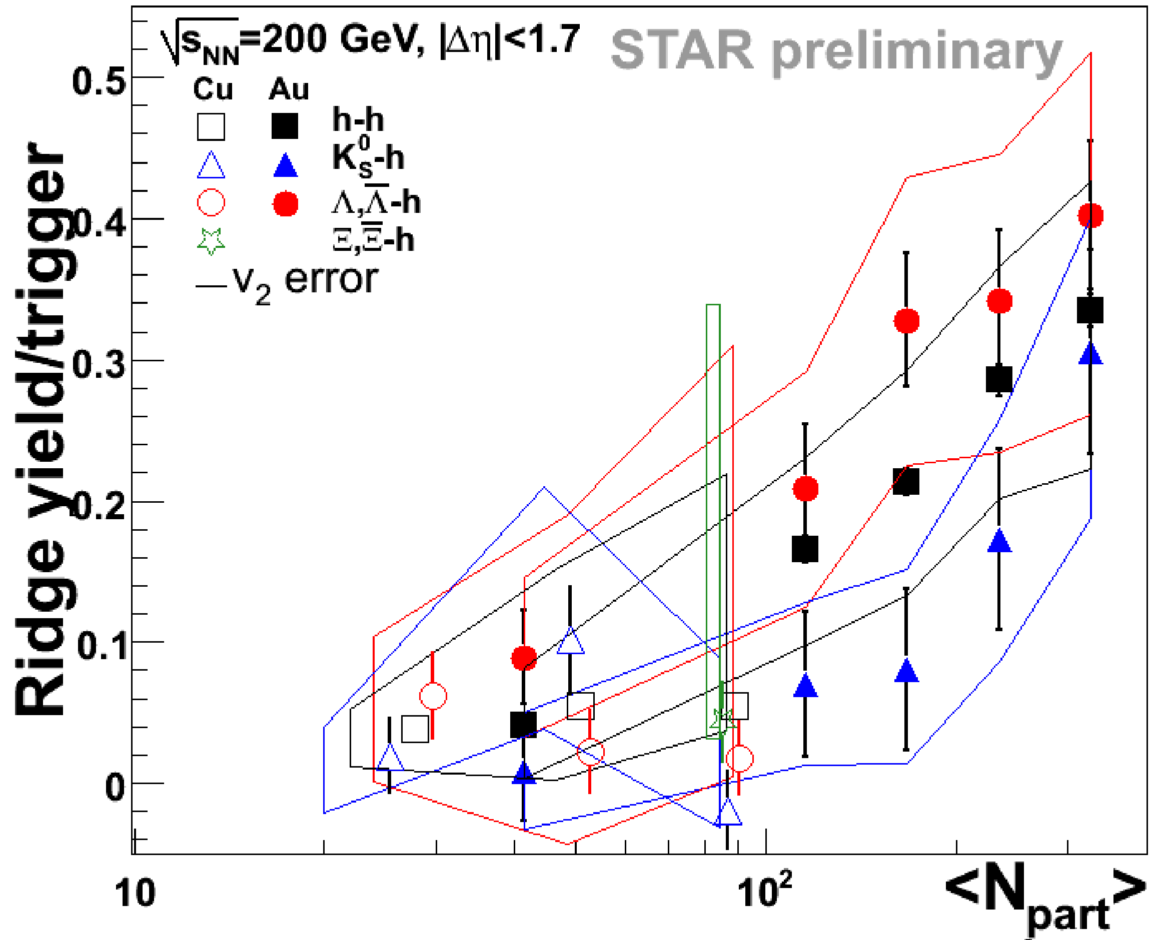

- Baryon/meson ratios in *Ridge* similar to bulk for both strange and non-strange particles

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



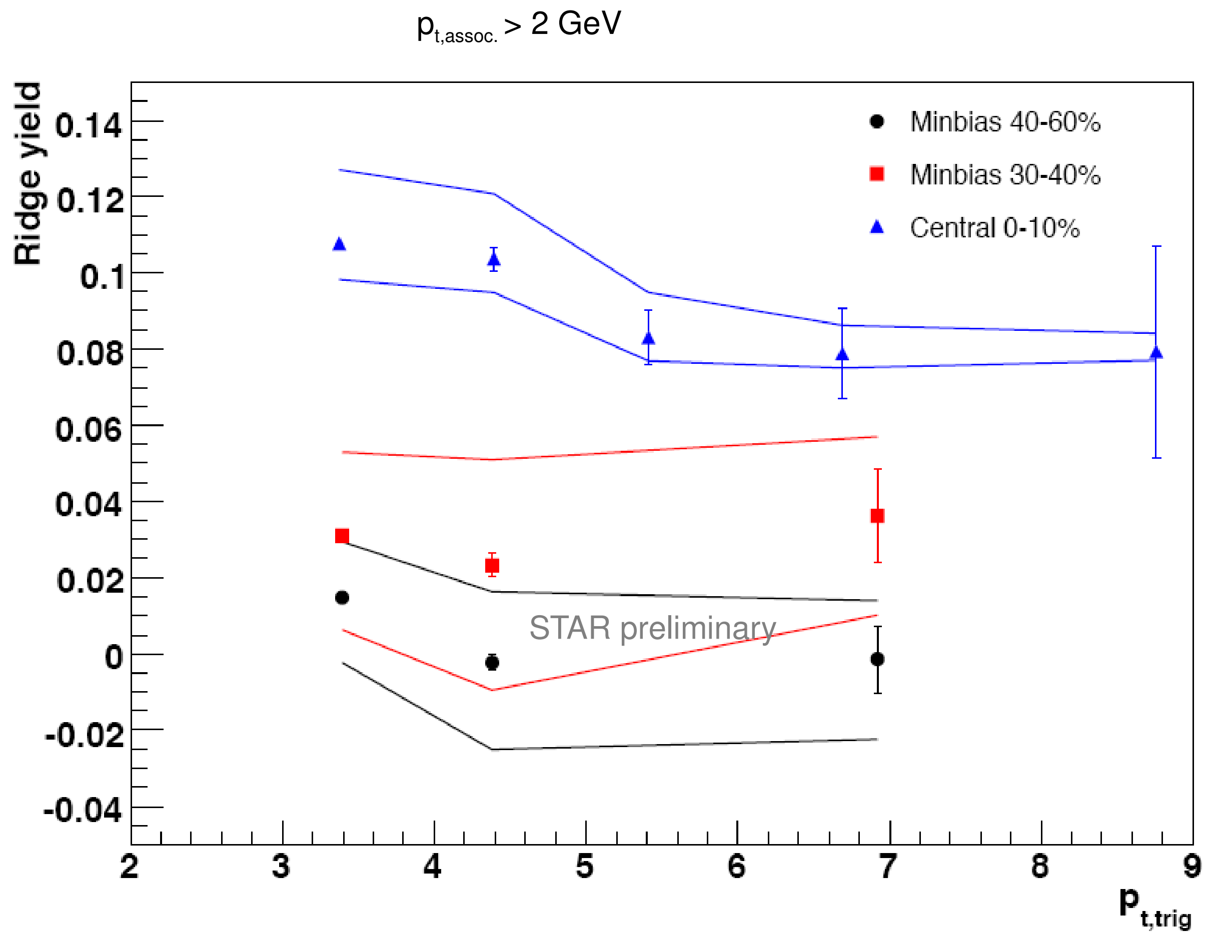

$3.0$ GeV/c < $p_T^{trigger}$ $6.0$ GeV/c; $1.5$ GeV/c < $p_T^{associated}$ < p

*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

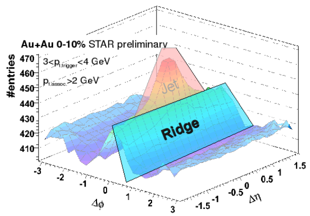
# *Ridge yield vs. pt,trig in Au+Au*

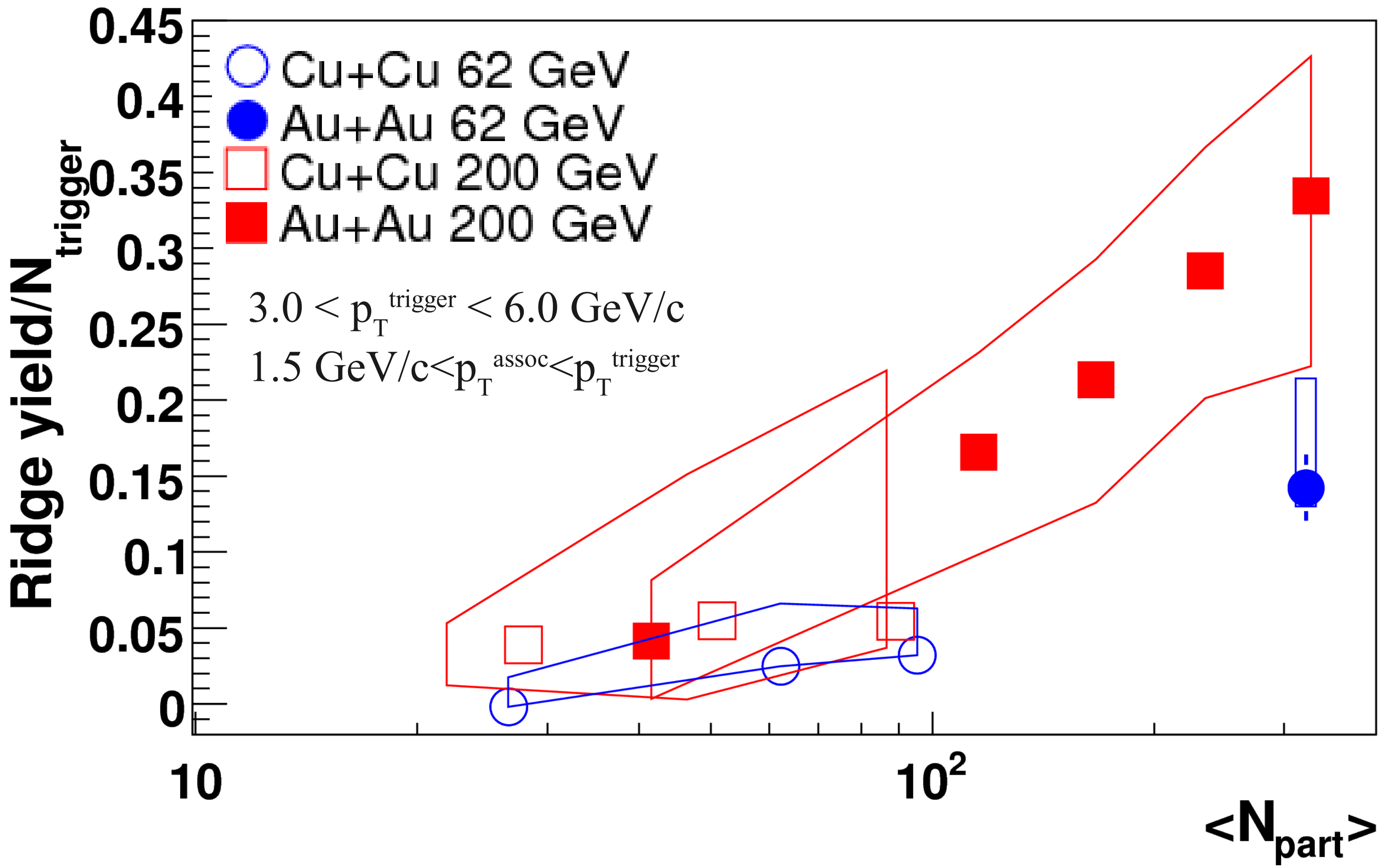



Putschke
WWND08

- *Ridge* yield persists to highest trigger pt ⇒ correlated with jet production

# *Ridge vs $N_{part}$*

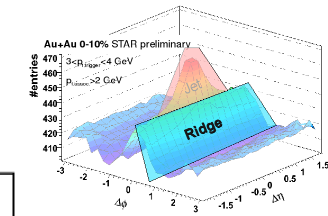


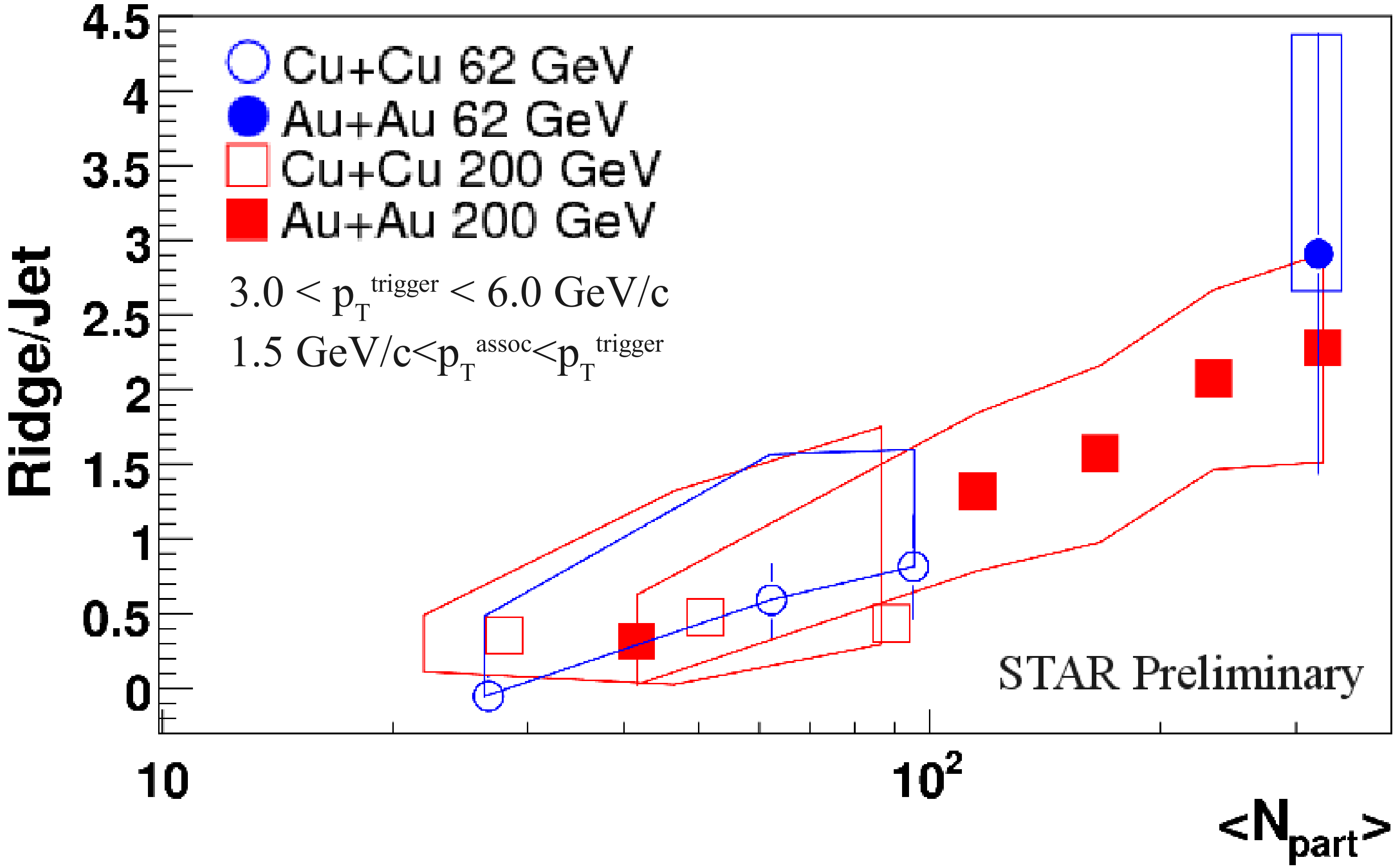




- No system dependence at given $N_{part}$

J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

# *Ridge vs $N_{part}$*



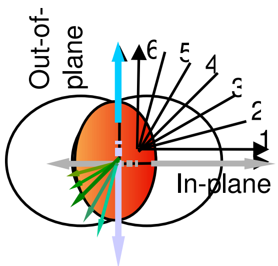




- No system dependence at given $N_{part}$
- *Ridge/Jet* Ratio independent of collision energy

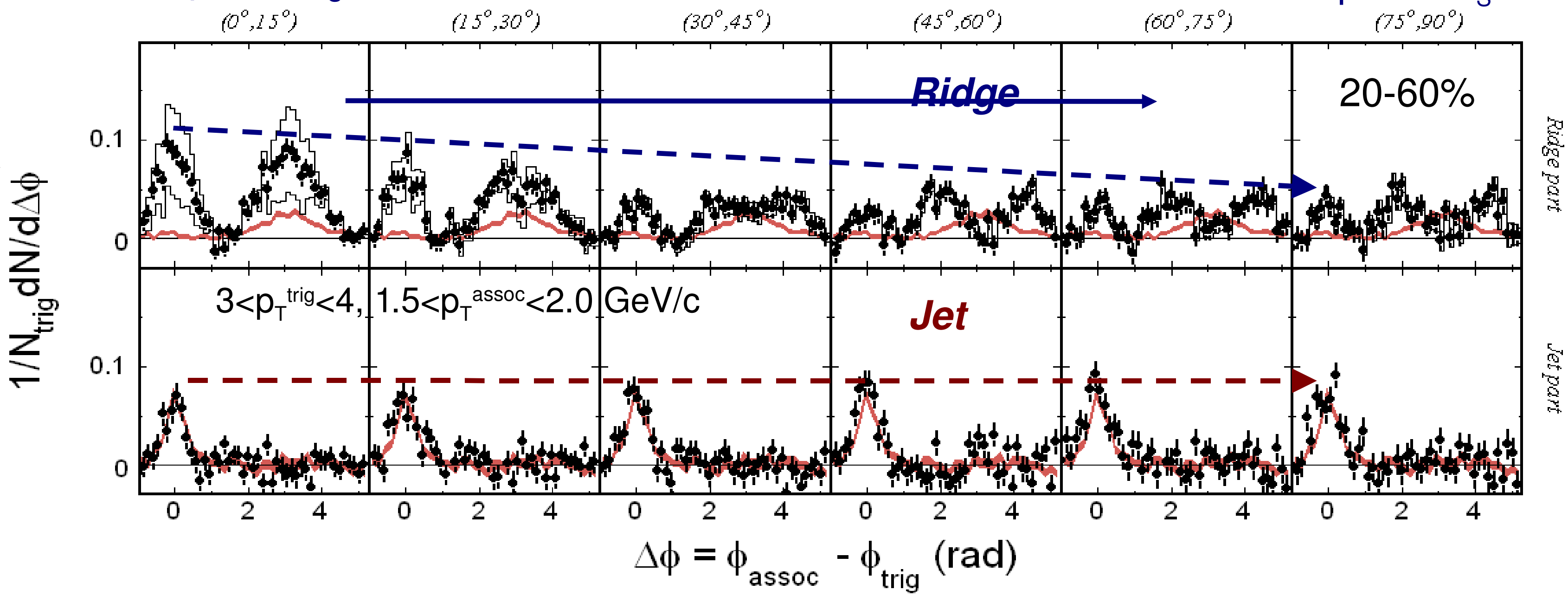
J. Bielcikova (STAR), arXiv:0806.2261/nucl-ex
C. Nattrass (STAR), arXiv:0804.4683/nucl-ex

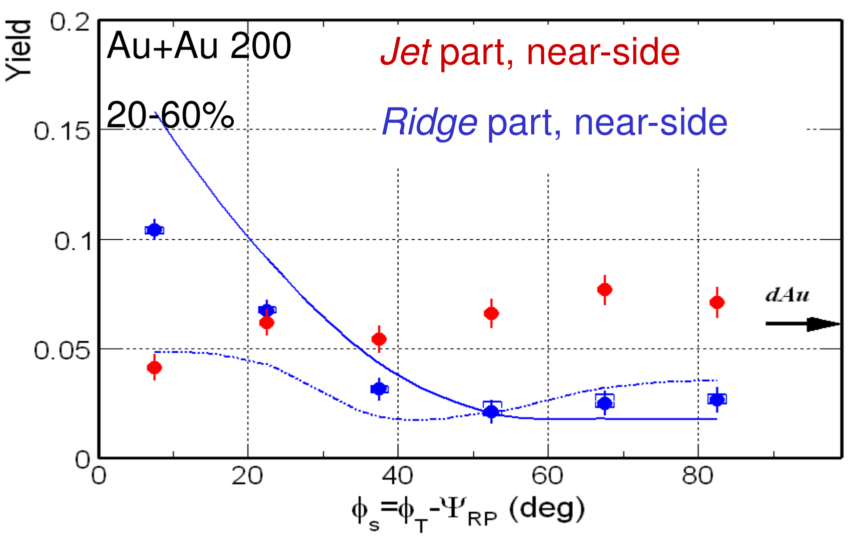
# *Jet/Ridge w.r.t. reaction plane*

Feng QM08
Konzer QM09




**20-60%**
**Au+Au**
**200 GeV**



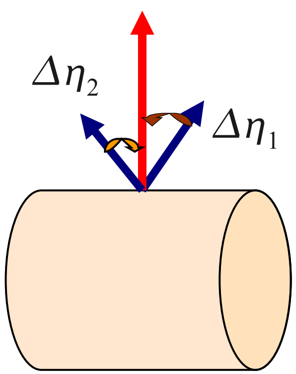




- *Ridge* yield decreases with $\Psi_S$. Smaller ridge yield at larger $\Psi_S$
- *Jet* yield approx. independent of $\Psi_S$ and comparable with d+Au

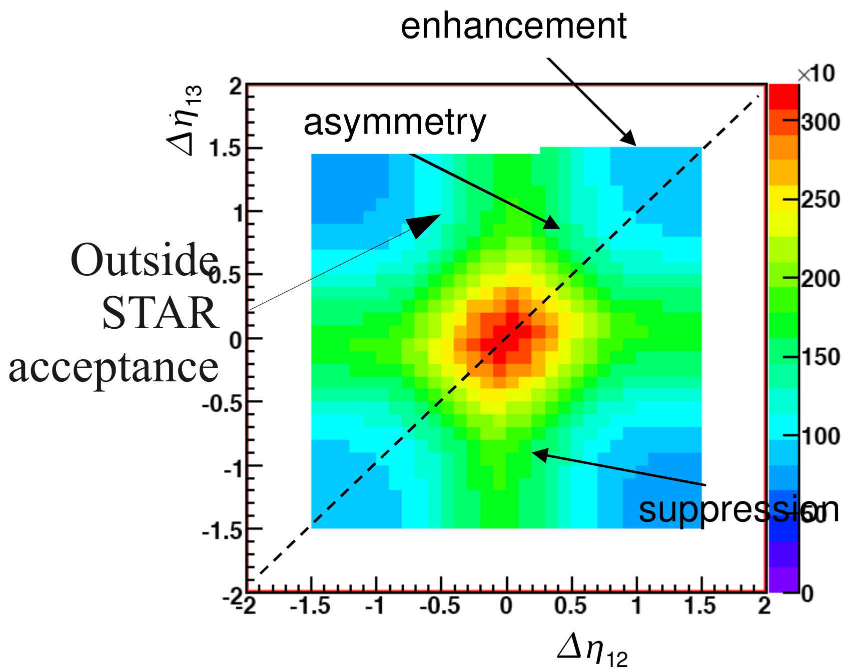
*Jet* yield independent of $\Psi_S$, consistent with vacuum fragmentation after energy loss and lost energy deposited in ridge, if medium is “black” out-of-plane and more “gray” in-plane for surviving jets.

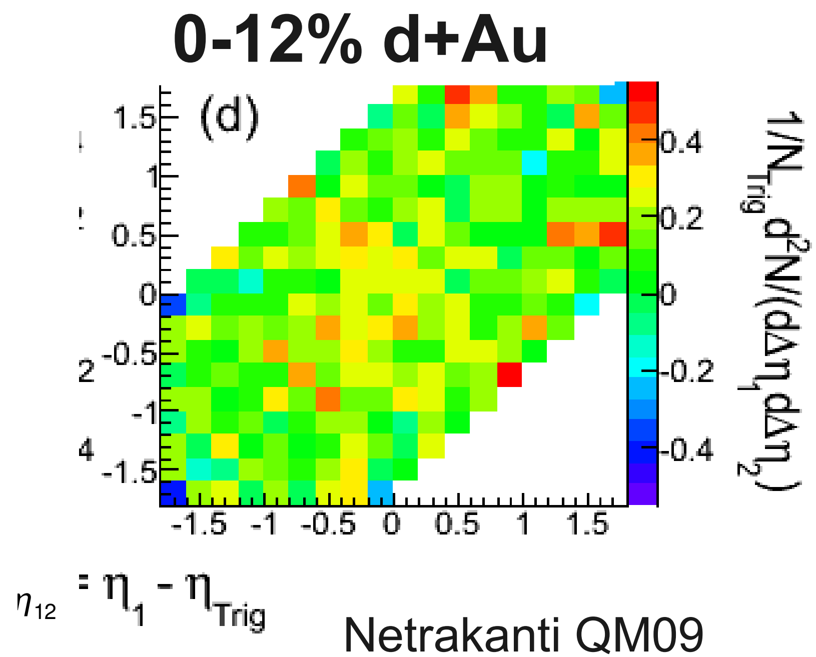
*Ridge* asymmetric in $\Delta\phi$, consistent with surface emission

# 3-particle correlations



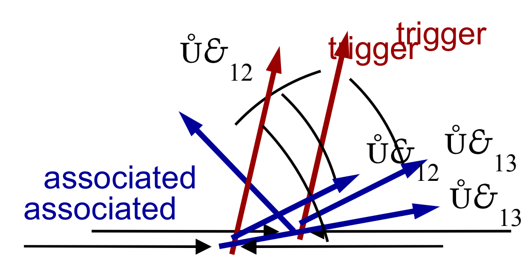

$\Delta\eta_1$ = A1-T
$\Delta\eta_2$ = A2-T



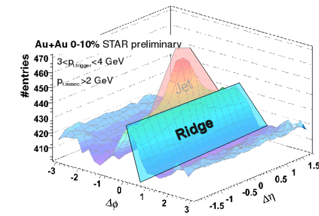




$3<p_T^{trigger}<10$ $1<p_T^{assoc}<3$ $|\Delta\phi|<0.7$

- *Ridge* appears uniform event-by-event within STAR acceptance
- Charge sign dependence:
  - All signs the same: no *Jet*, *Ridge* only
  - Friday Plenary session talk (Netrakanti)



# *Conclusions: Ridge*




- Extensive data on Ridge
  - Cu+Cu, Au+Au consistent at same $N_{part}$
  - *Ridge/Jet* ratio independent of energy
  - Persists to high $p_T^{trigger}$
  - *Ridge* looks like bulk
    - $p_T^{associated}$ dependence, particle composition
  - Appears isotropic in $\Delta\eta$

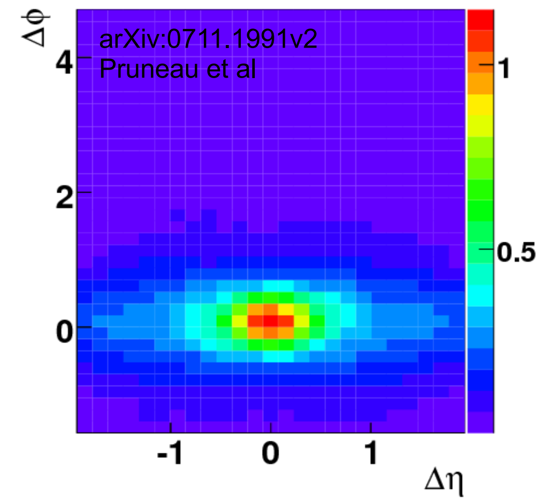
# Comparisons to models

# Models

- 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*

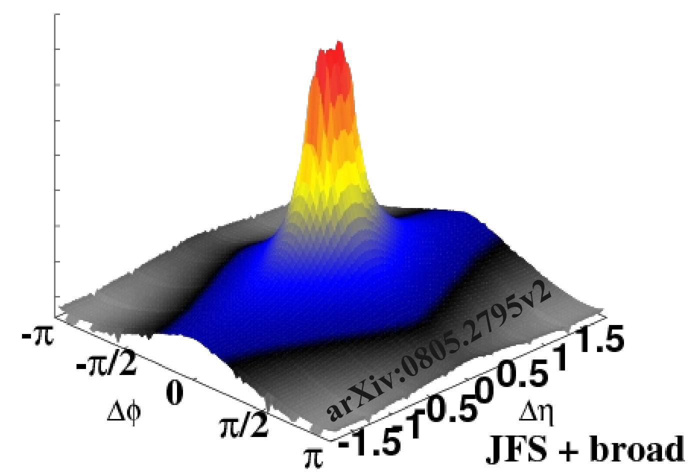
  - Works for one set of kinematic cuts in central Au+Au at 200 GeV
  - Need more detailed comparisons (energy dependence)
  - Model needs some refinements (momentum conservation)




- Plasma instability

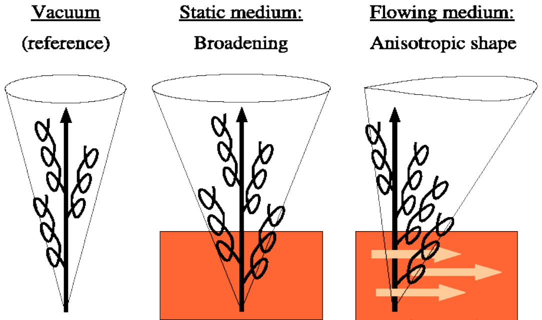
  QCD magnetic fields, Majumder et al,Phys.Rev.Lett.99:042301,2007
  Anisotropic plasma, P. Romatschke, PRC,75014901 (2007)

  - So far unable to make enough *Ridge* without Radial flow+trigger bias



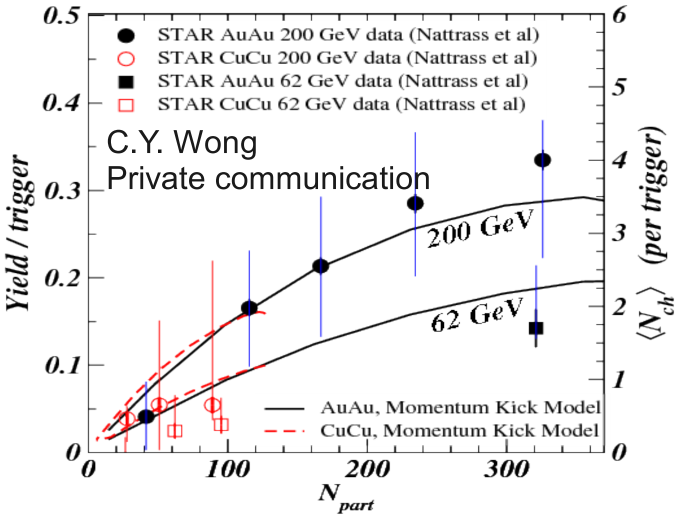
# Models

- Longitudinal flow
  Longitudinal flow, Armesto et al, PRL 93 (2004)
  - Problems due to Δη width




*Armesto et al,* PRL 93 (2004)

- Momentum kick
  Momentum kick from jet, C.-Y. Wong , Phys.Rev.C76:054908,2007
  - Fits data well, including energy dependence




- Recombination
  Medium heating + recombination, Chiu & Hwa, PRC72, 034903
  - No quantitative comparisons

# Conclusions

- Considerable evidence that *Jet* is dominantly produced by fragmentation
  - Can we use this information to learn more about the *Ridge*?
- Several models for the *Ridge*, few quantitative comparisons
  - Several depend on hydrodynamics
  - Need better calculations – more quantitative, more than central Au+Au
- Future:
  - More energy dependence (RHIC beam energy scan, LHC)
  - Jet reconstruction – more detailed studies of *Ridge*?
  - Ridge in $\gamma$-jet correlations?