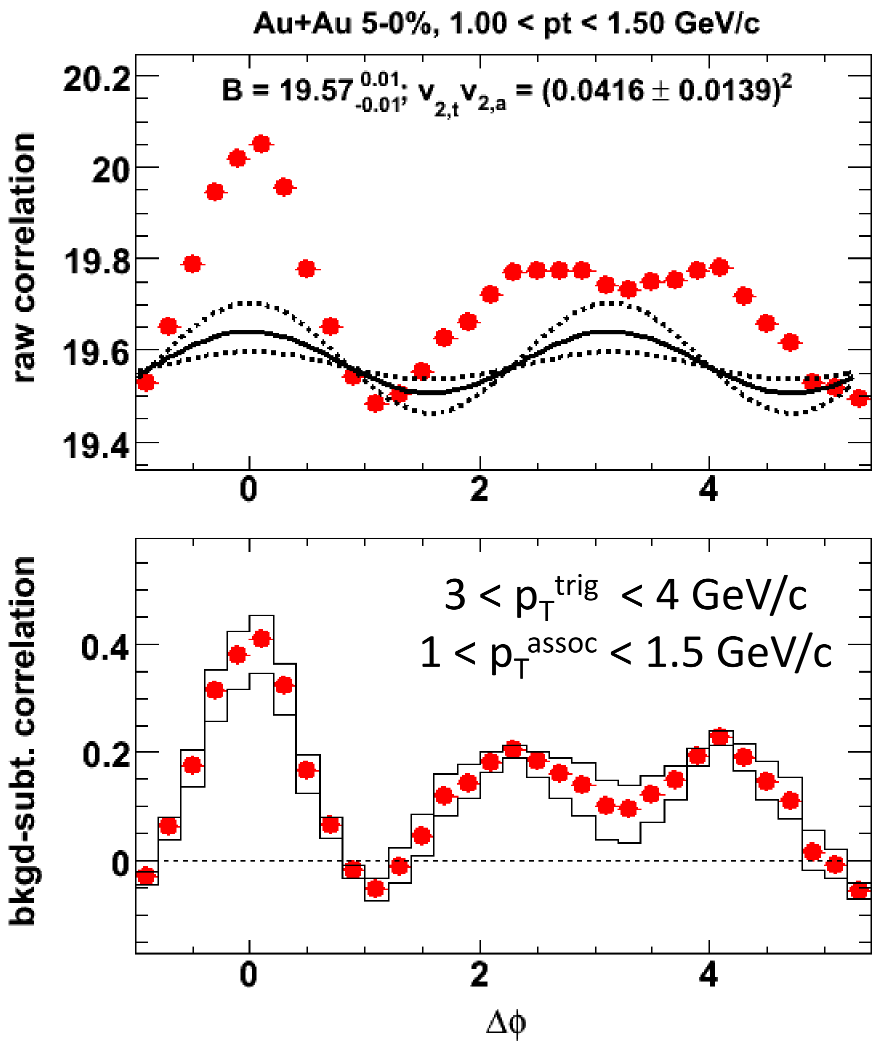
Geometrical Effect on Conical Emission of Correlated Hadrons

Fuqiang Wang
Purdue University
For the STAR Collaboration

Double-peak in dihadron corr.

Broad away-side, and for selected pt region even double-peaked.



Double-peak in raw corr.
in specific kinematic region
without any bkgd subtraction!

$v_2 = (v_2\{4\} + v_2\{2\}) / 2$
flow syst. = $v_2\{4\} : v_2\{2\}$
Large **flow syst.** applied: **± 30% !**

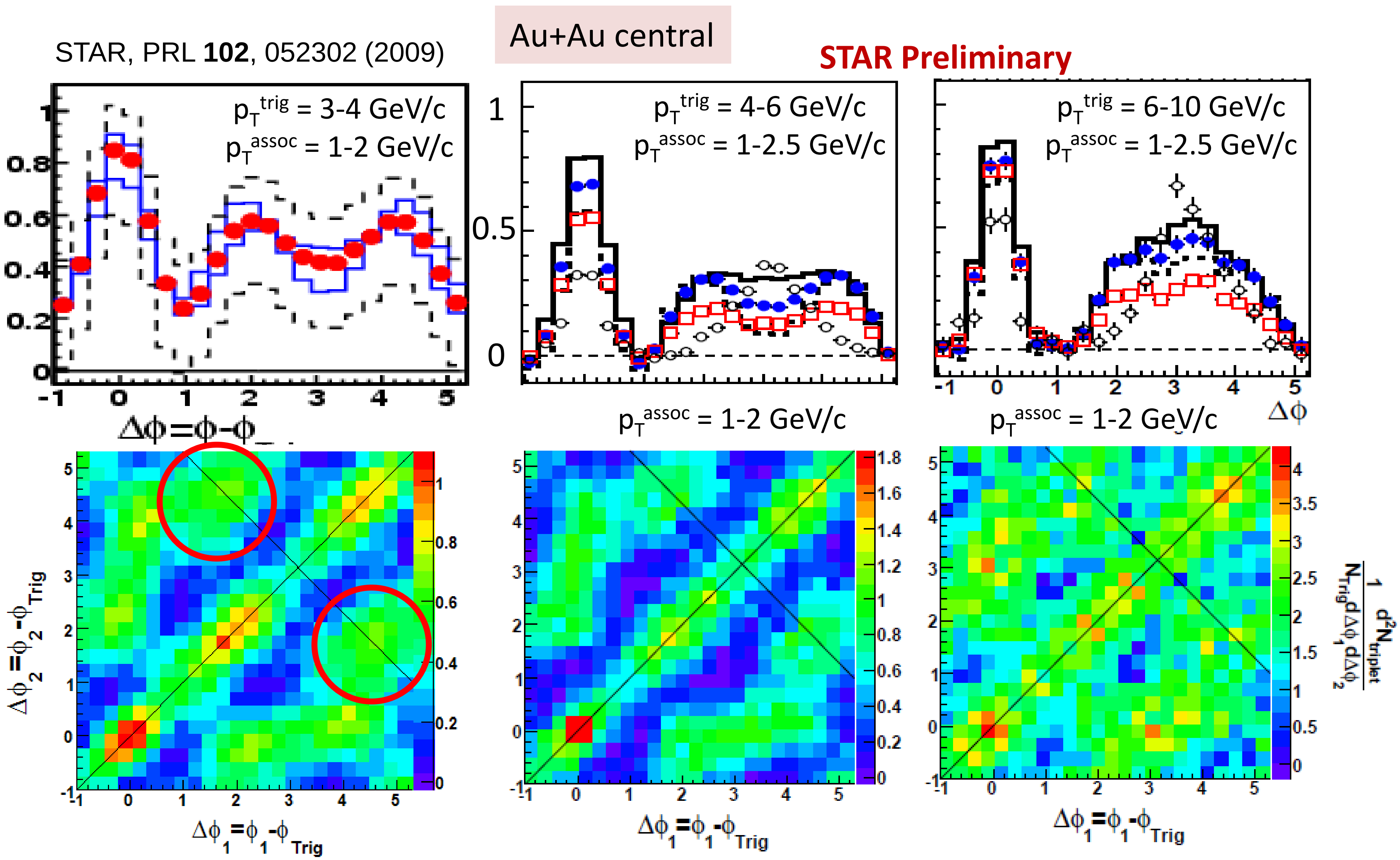
ZYAM: $B(1+2v_{2,t}v_{2,a}\cos 2\Delta\phi)$

$v_{2,t}v_{2,a}$ is small, ~< signal/bkgd

Even 10% uncertainty in **ZYAM does not introduce dip.**

Evidence of conical emission

Two-component model: event = correlated + uncorrelated (i.e. flow-bkgd)

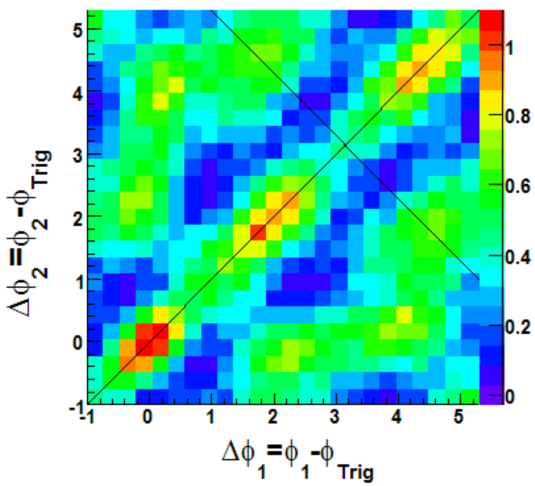


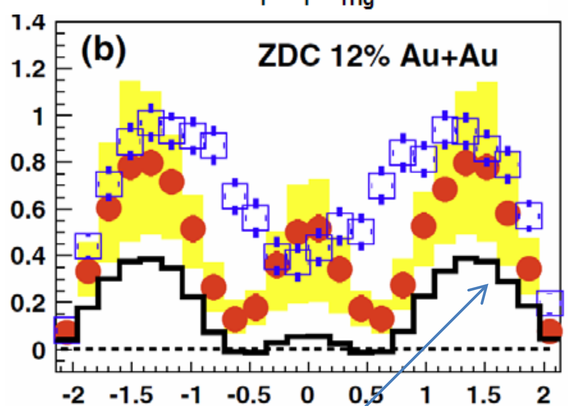
Cumulants

$$\hat{\rho}_3(\varphi_t,\varphi_1,\varphi_2)=\rho_3(\varphi_t,\varphi_1,\varphi_2)-\rho_2(\varphi_1,\varphi_2)\rho_1(\varphi_t)-\rho_2(\varphi_t,\varphi_1)\rho_1(\varphi_2)-\rho_2(\varphi_t,\varphi_2)\rho_1(\varphi_1)+2\rho_1(\varphi_t)\rho_1(\varphi_1)\rho_1(\varphi_2)$$

Jet-like 3-part. correlation

STAR, PRL **102**, 052302 (2009)



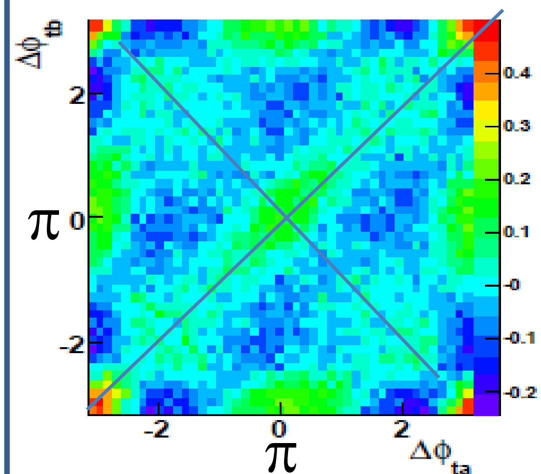


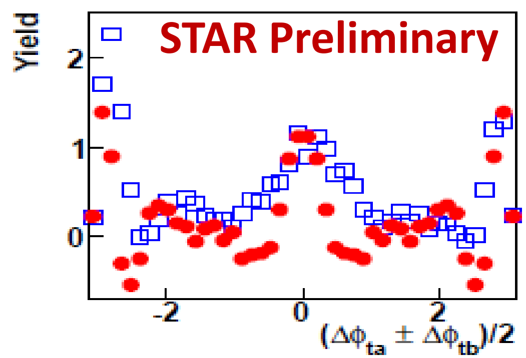
a=b=1

No ZYAM

Lab-frame cumulant

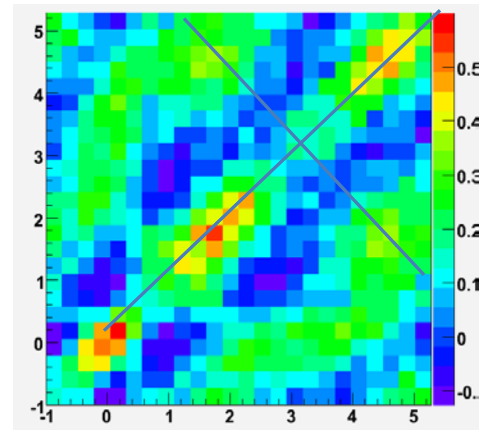
Pruneau (STAR), nucl-ex/0703010

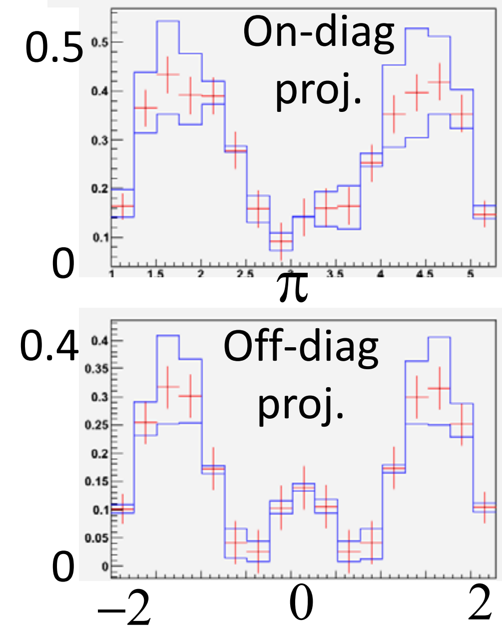




RP-frame cumulant

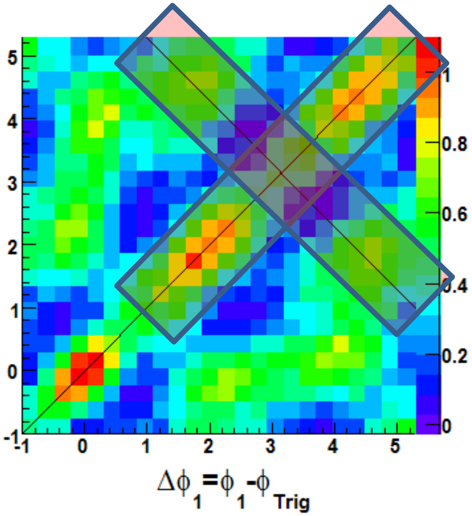
STAR Preliminary

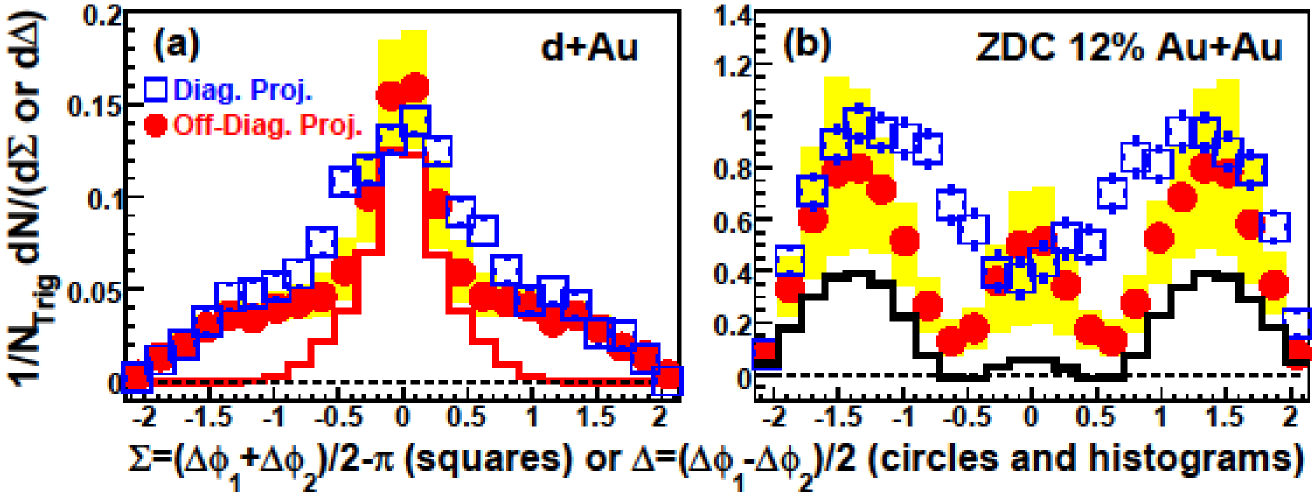


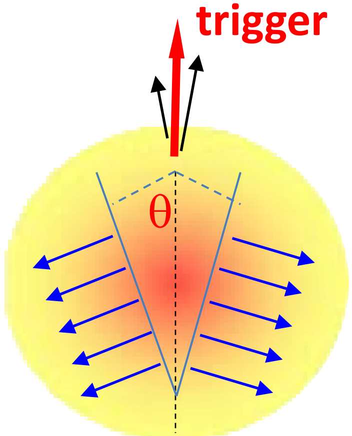


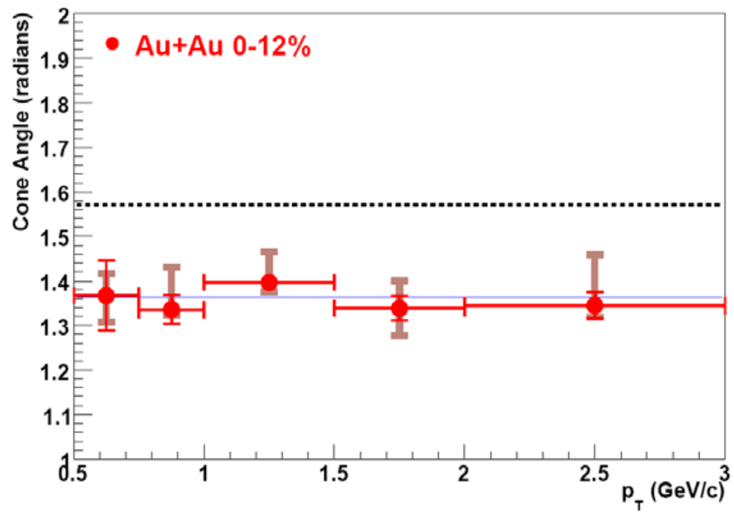
Conical emission angle

STAR, PRL **102**, 052302 (2009)





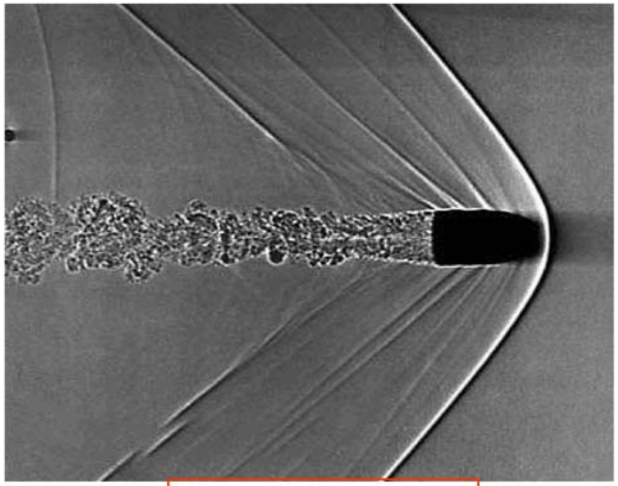




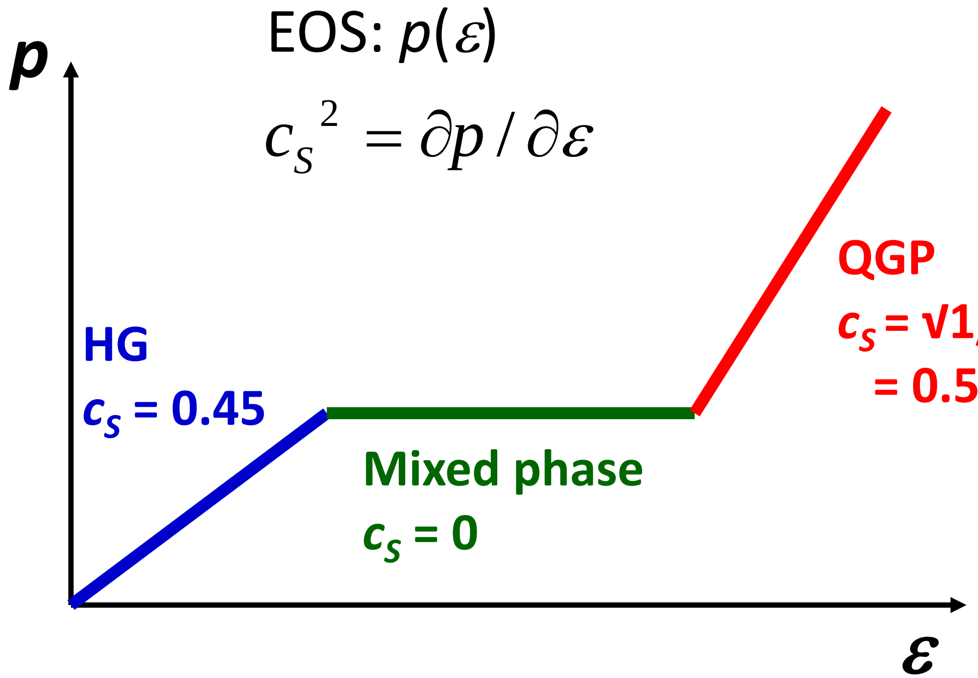
θ = 1.37 ± 0.02 (stat.) ± 0.06 (syst.)

Constant cone angle vs p_T suggests Mach Cone shock waves may be the underlying mechanism.

Speed of sound?



$\cos(\theta_M) = c_s$



Measured θ = 1.37

⬇

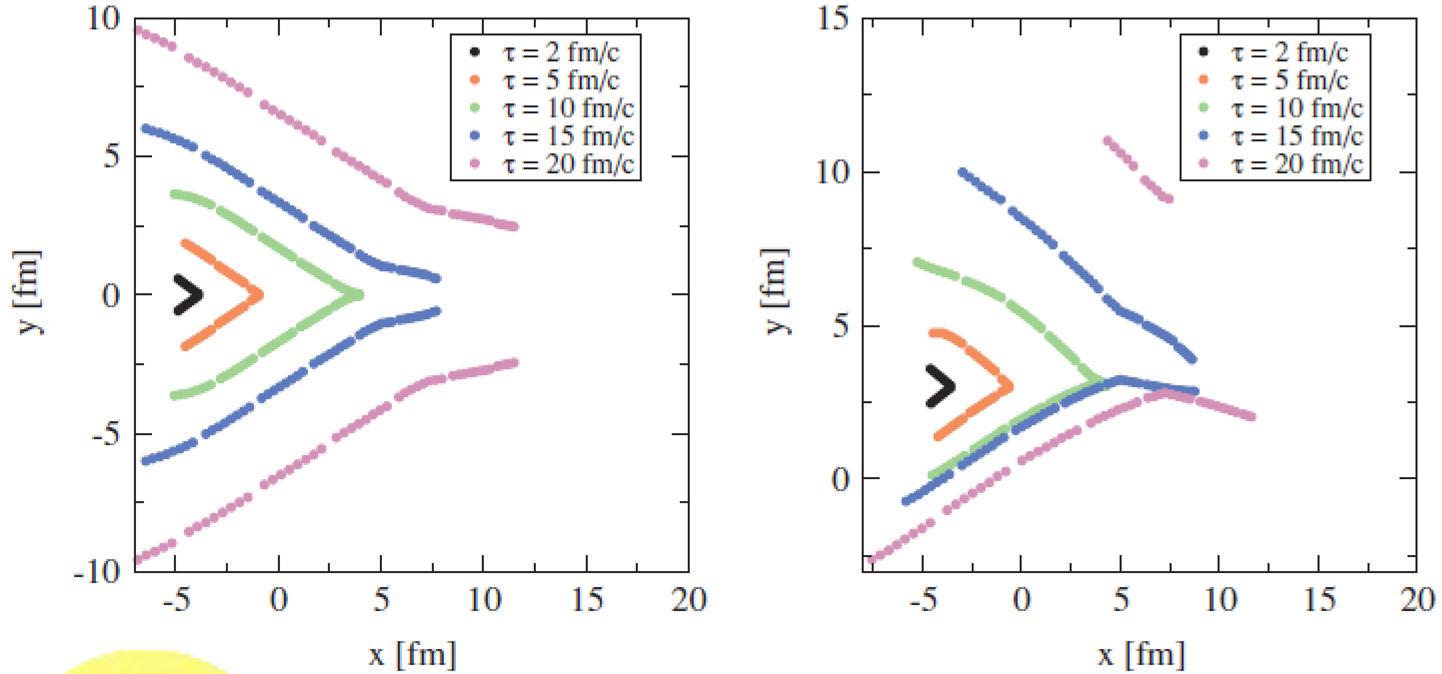
speed of sound
$c_s \sim 0.2$

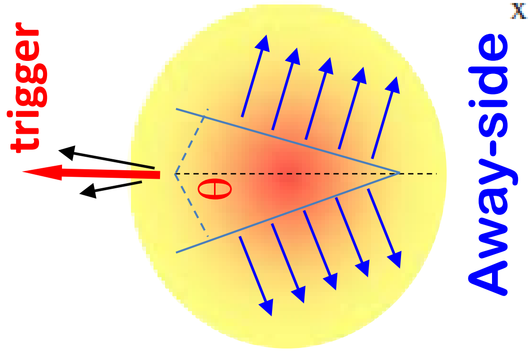
c_s far smaller than HG or QGP.
Must have mixed phase (phase transition).

However, model calculations indicate that Mach Cone angle can be altered by medium flow.

Model study of flow effect on Mach cone angle

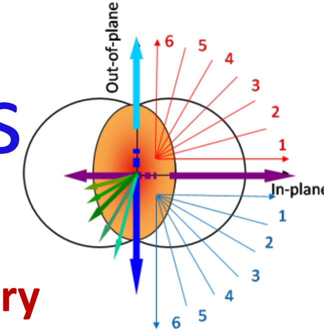
Renk, Ruppert, PRC 73 (2006) 011901(R)

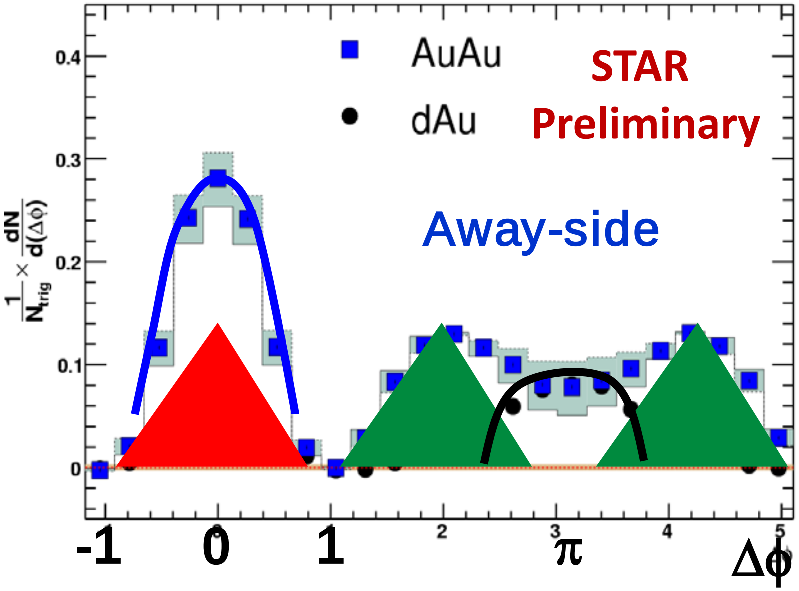


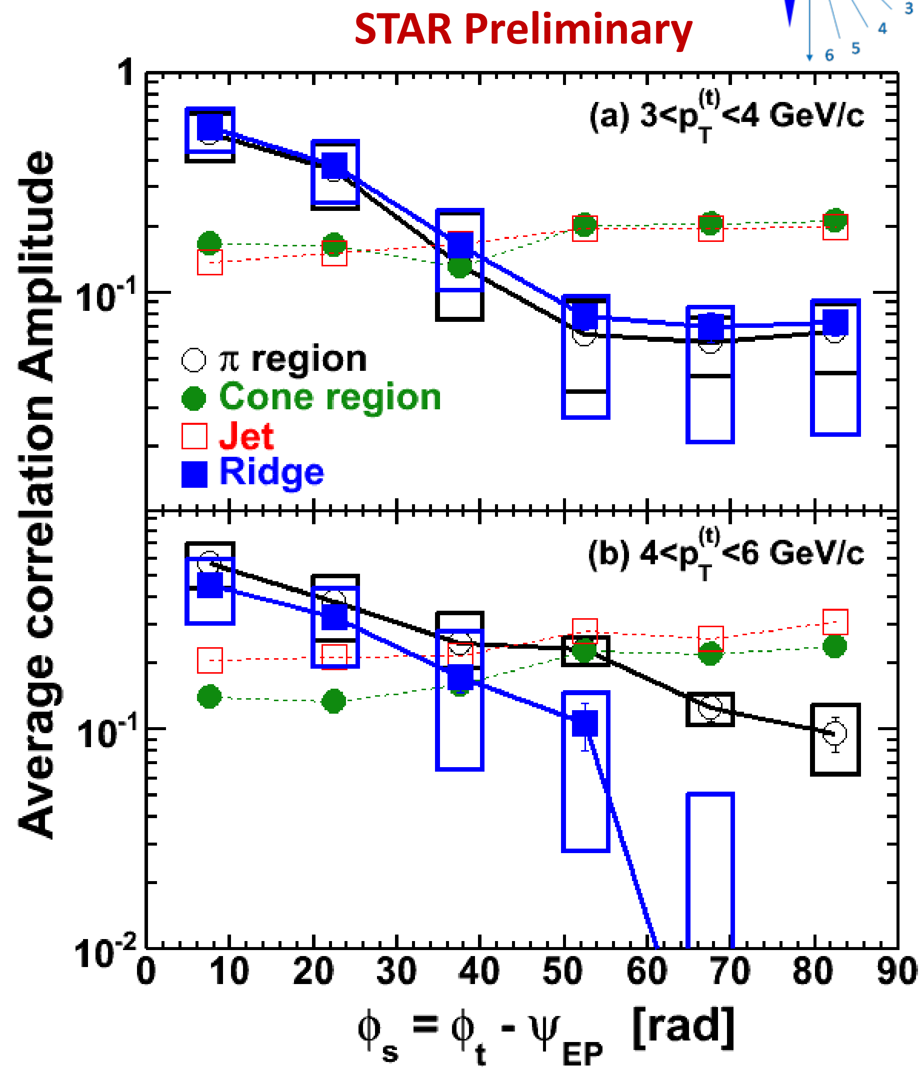


How to possibly investigate such effects experimentally?

Data suggest back-to-back ridges







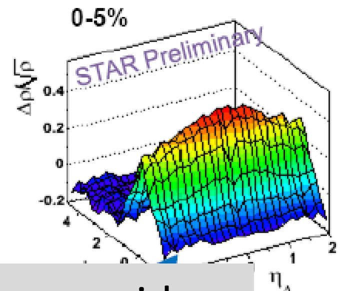
Near-side jet and ridge seem to come from different physics.

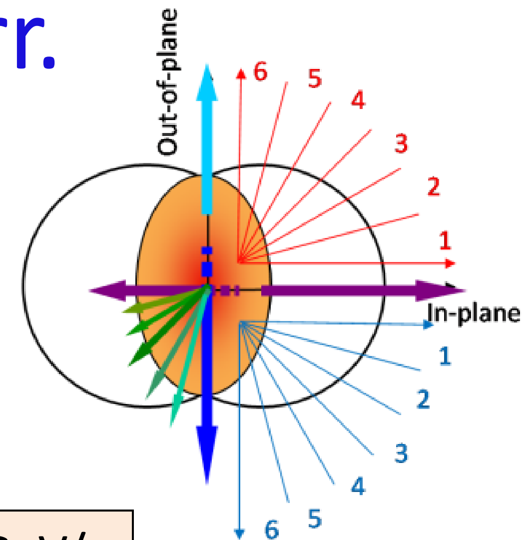
Ridge likely comes from the medium.

Then there ought to be a back-to-back ridge due to symmetry.

RP-dep. Large-Δη Azimuth. Corr.

Flow-bkgd subtracted by ZYAM.

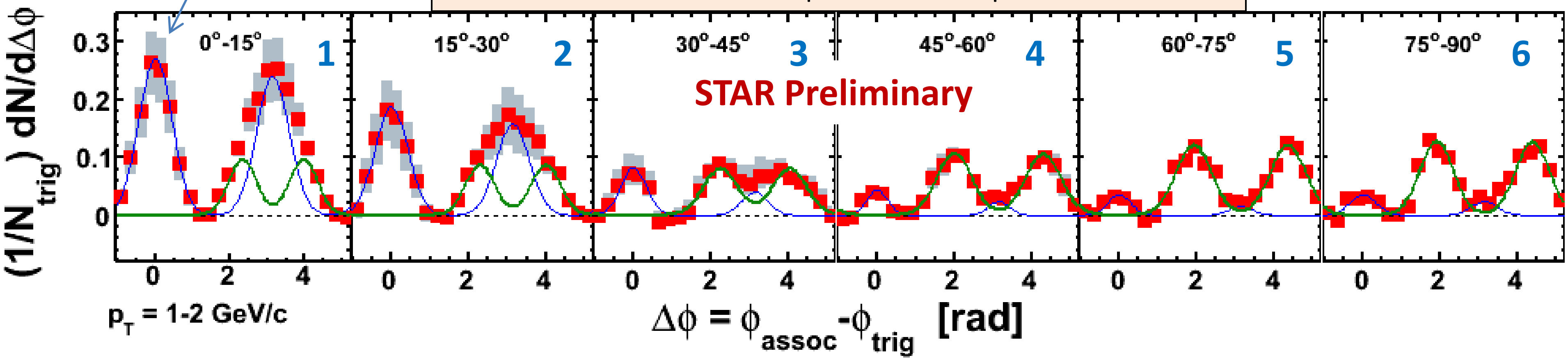




$v2 = (v_2\{4\}+v_2\{2,\text{away-side}\}) / 2$
flow syst. = $v_2\{4\} : v_2\{2,\text{away-side}\}$

To remove near-side minijet non-flow corr.

Au+Au 20-60%, $3<p_T^{trig}<4$, $1<p_T^{assoc}<2$ GeV/c

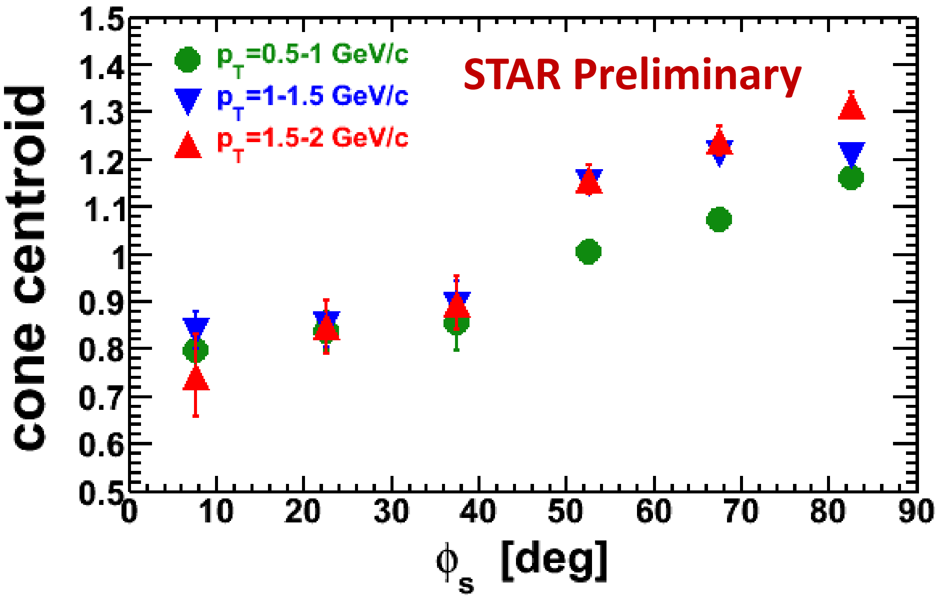


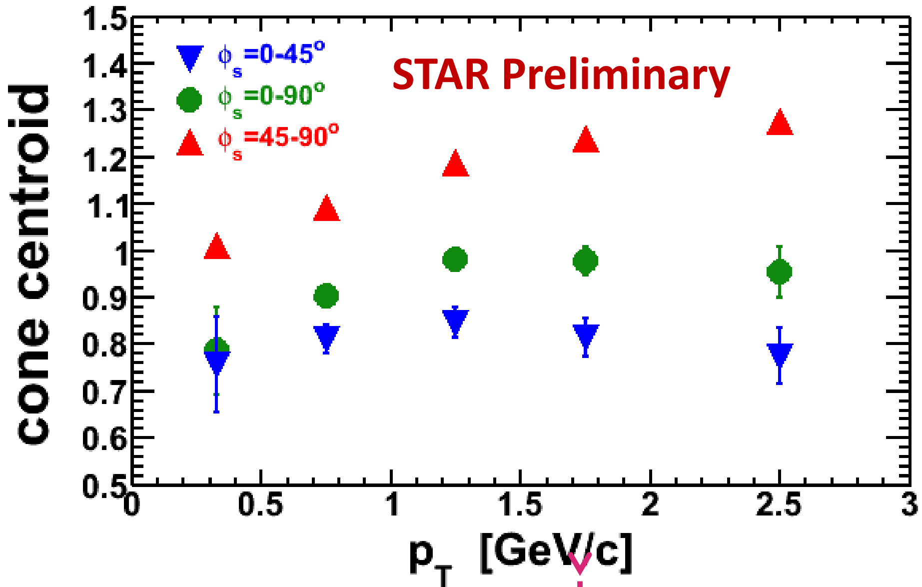
<u>Back-to-back ridge + Away conical emission</u>

2 Gaus: Ridge at 0 and ridge at π, same shape, diff. magnitudes

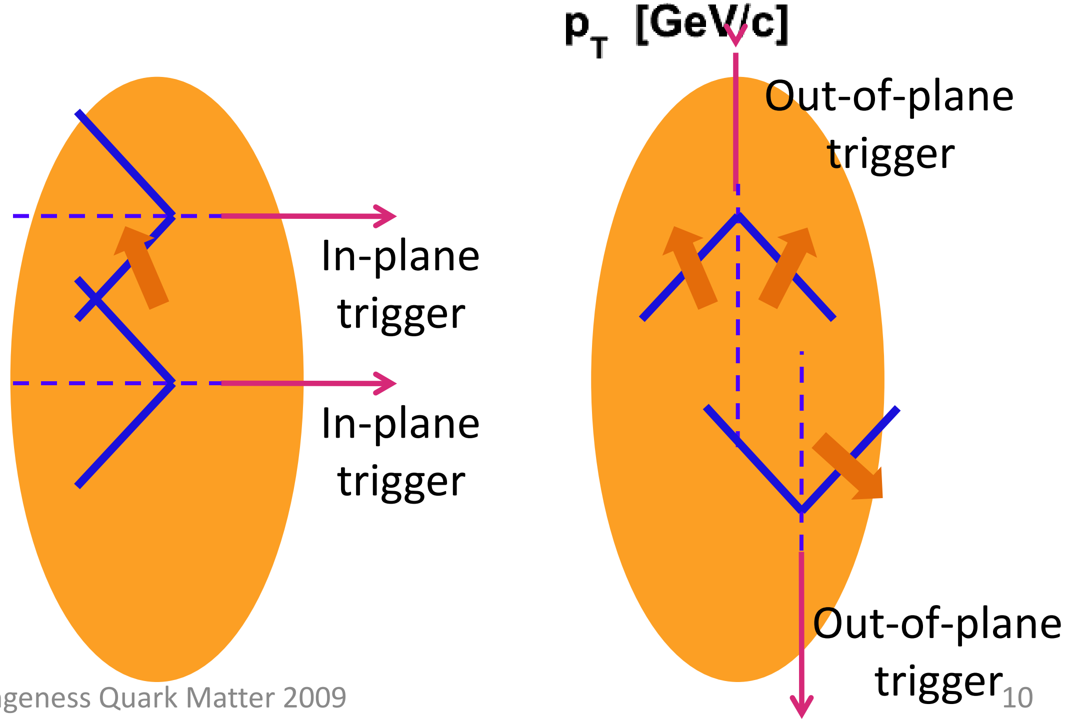
2 Gaus: identical conical emission peaks symmetric about π.

Away peak fit positions





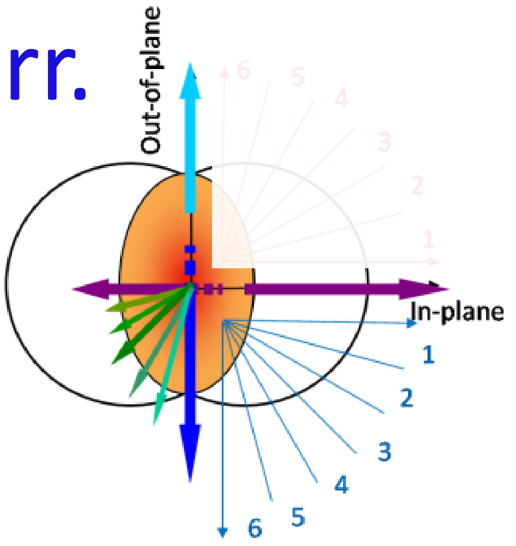
- Cone angle takes off after trigger ϕ_s=45°.
- Split in p_T after ϕ_s=45°.
- Cone angle ~constant over p_T at ϕ_s<45°.



RP-dep. Large-$\Delta\eta$ Azimuth. Corr.

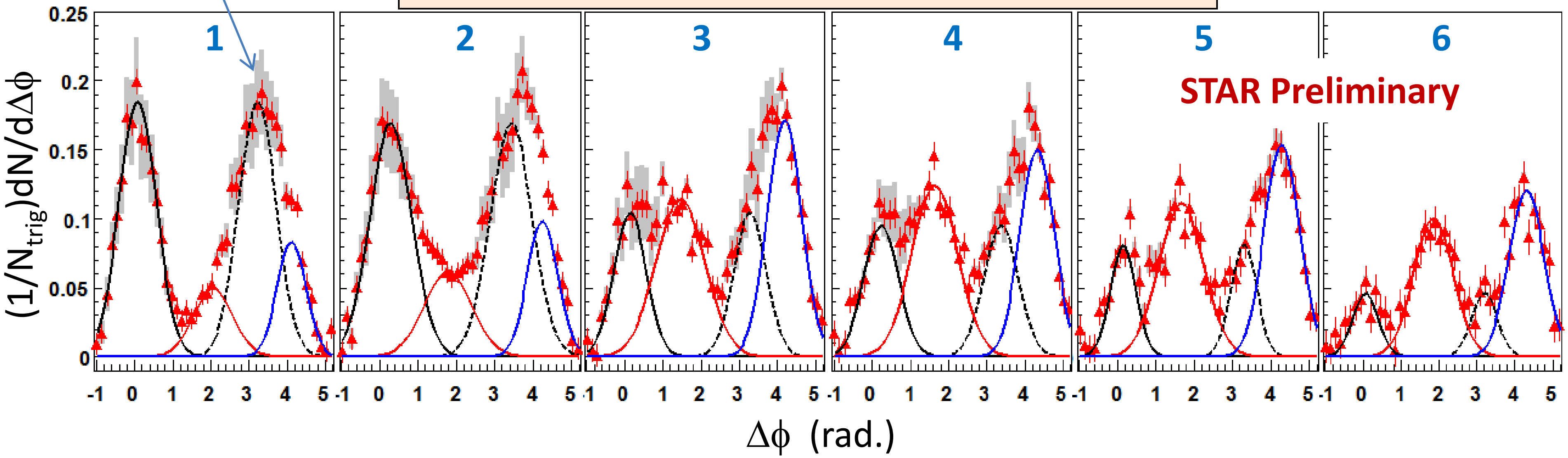
Flow-bkgd subtracted by ZYAM.

Azimuthal correlation for large $|\Delta\eta|>0.7$
Separate 1st and 4th quadrants trigger particles



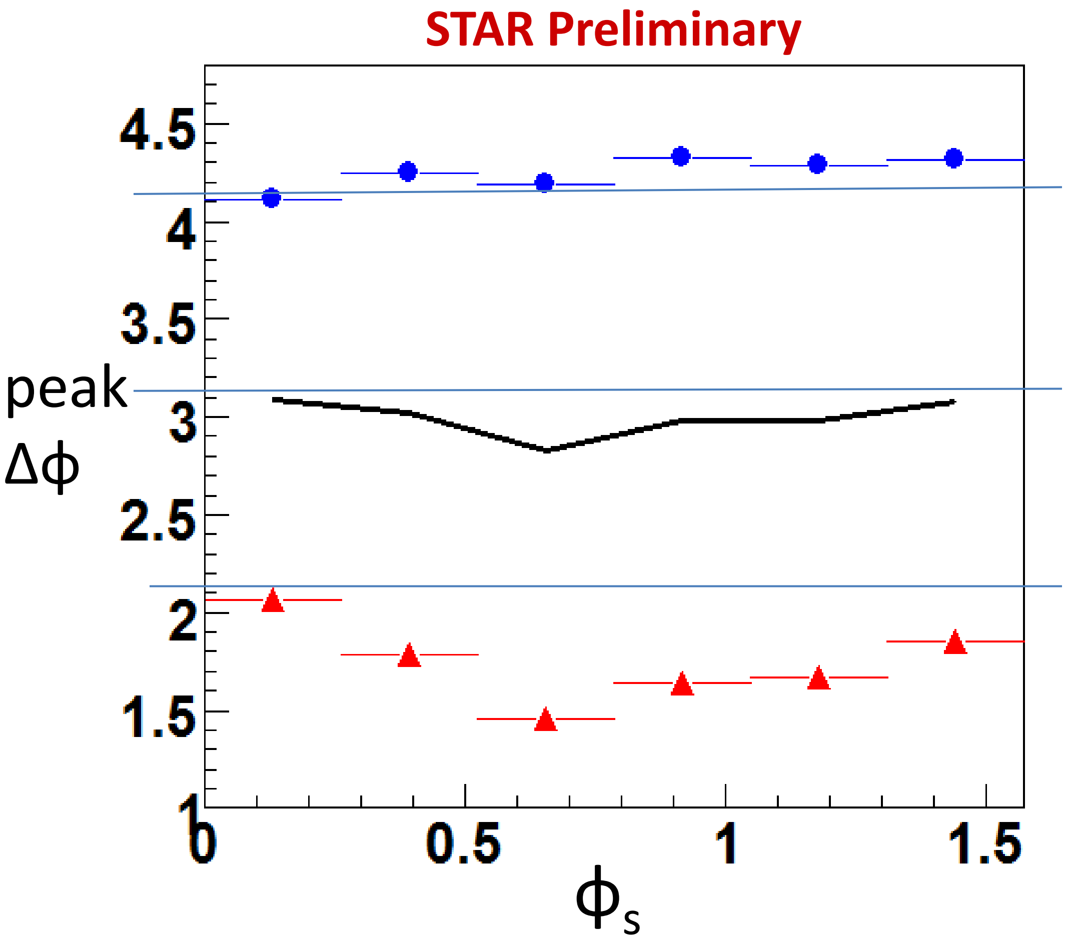
$v2 = (v_2\{4\}+v_2\{2,\text{away-side}\}) / 2$
flow syst. = $v_2\{4\} : v_2\{2,\text{away-side}\}$

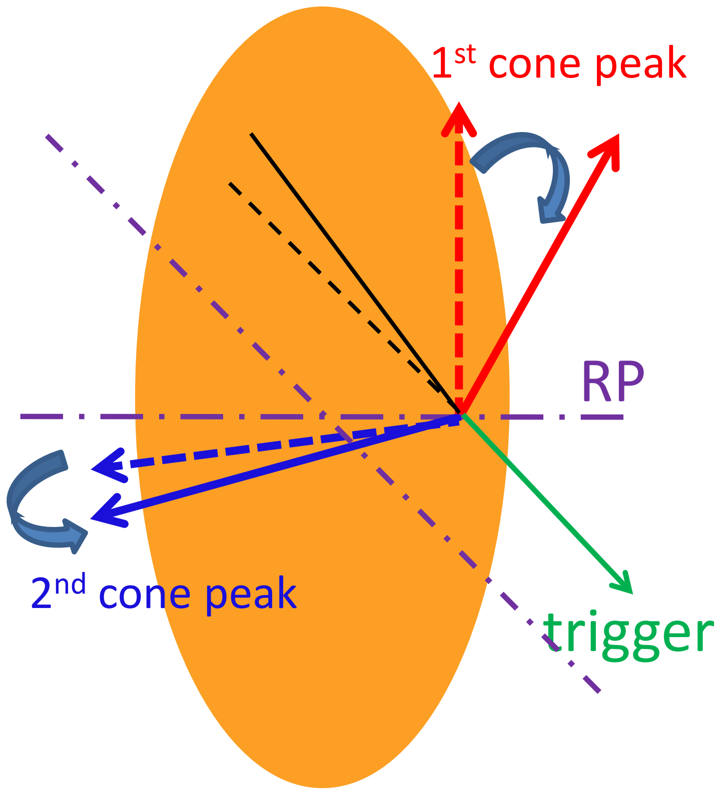
Au+Au 20-60%, $3<p_T^{trig}<4$, $1<p_T^{assoc}<2$ GeV/c



Fit: Back-to-back ridge + Away conical emission peaks

Away-side asymmetric cone positions

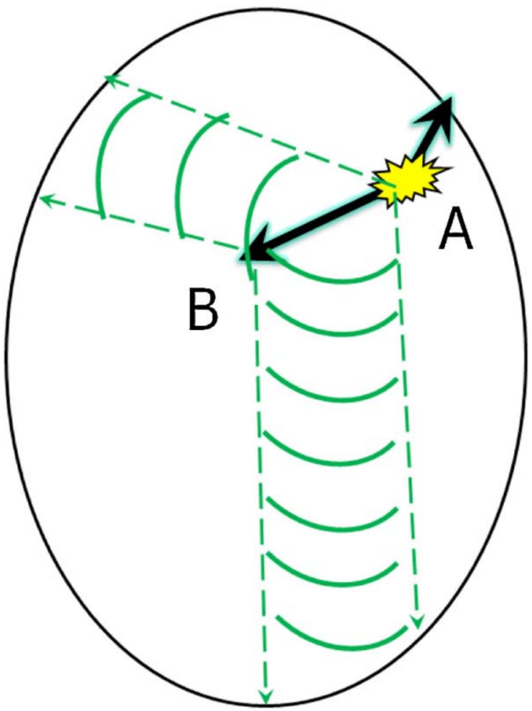


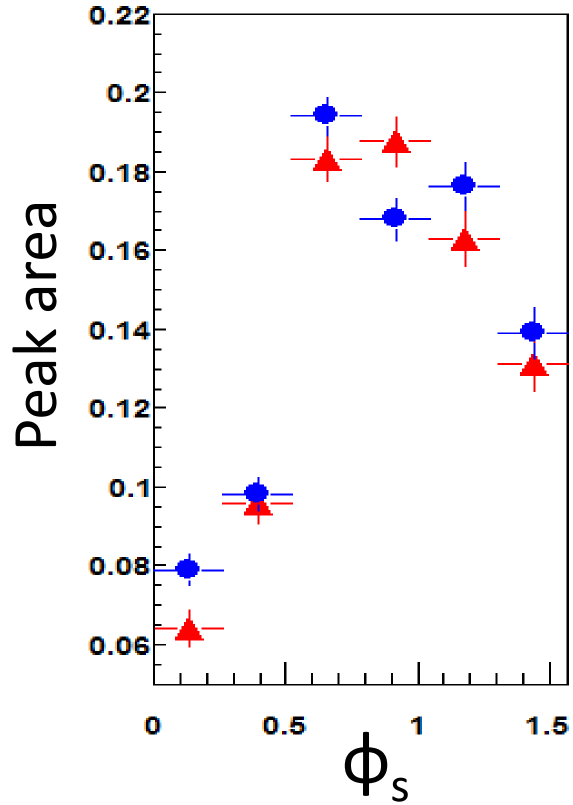


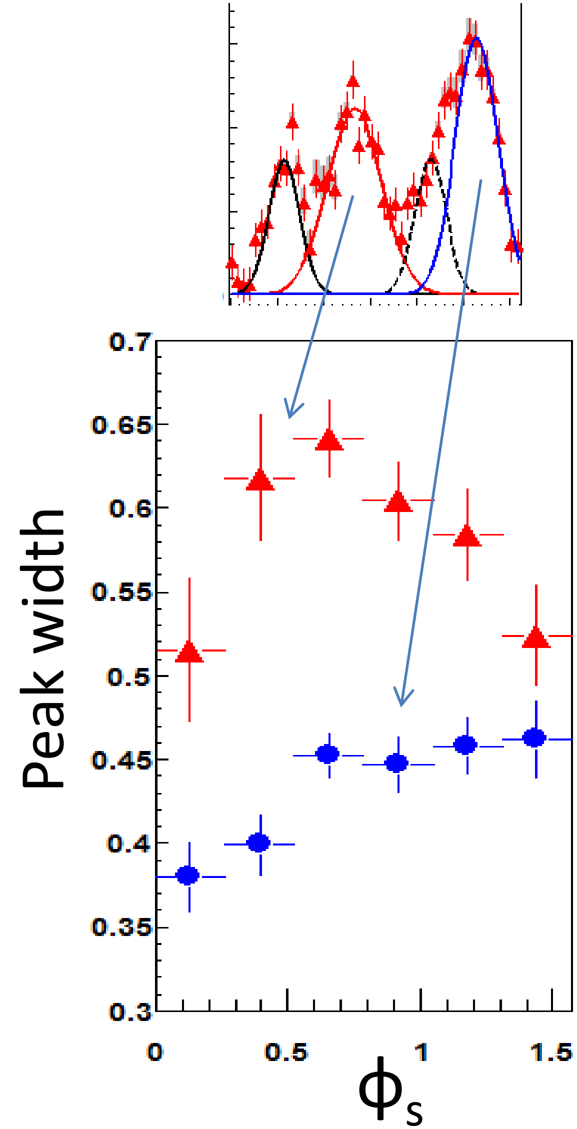
- Evidence of flow effect on conical emission.
- It appears that the conical emission "particles" are pushed by flow, perhaps not so much the away-side partner parton.

Medium absorption?

Jia et al, PRL 103 (2009) 022301







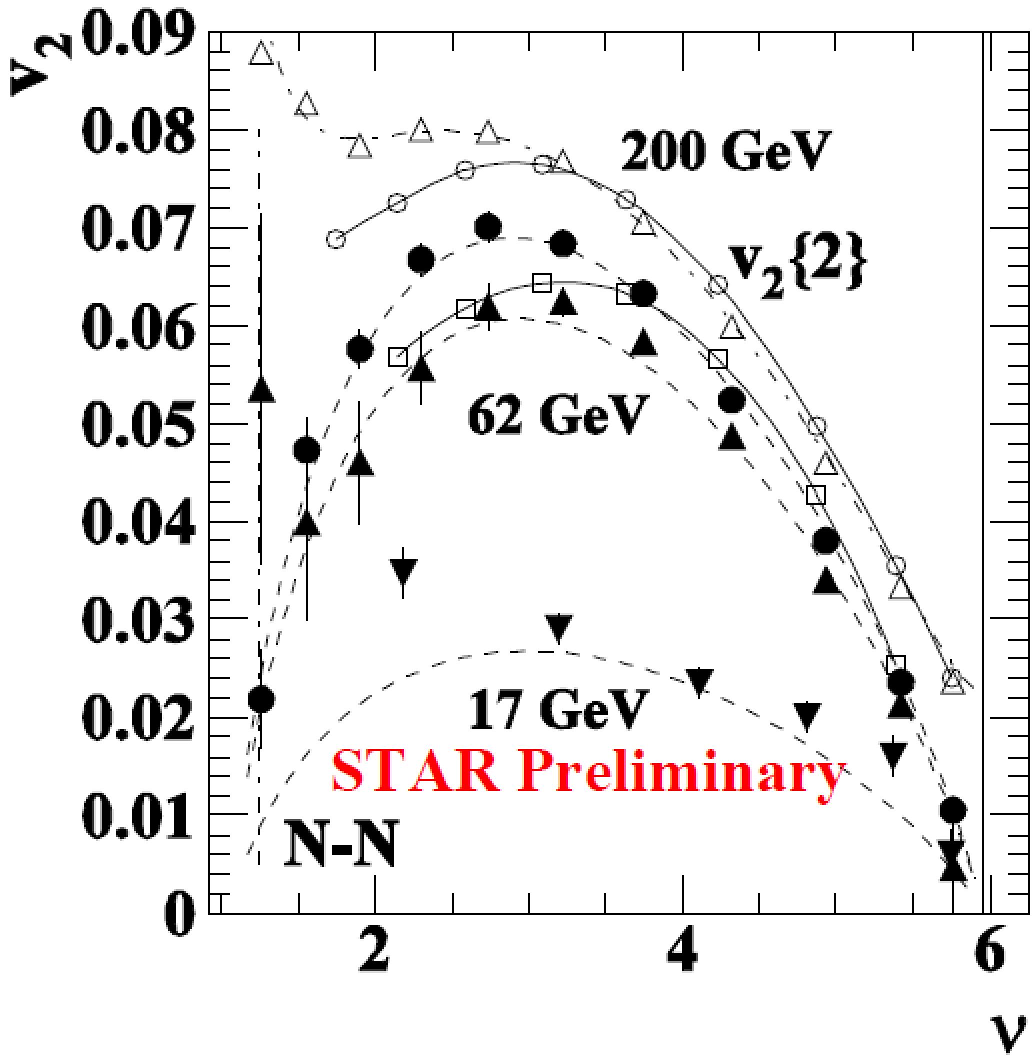
- **Conical emission peaks are broadened, but signal strengths appear symmetric.**
- **No evidence of medium absorption.**
- **It appears that conical emission "particles" are pushed by flow.**

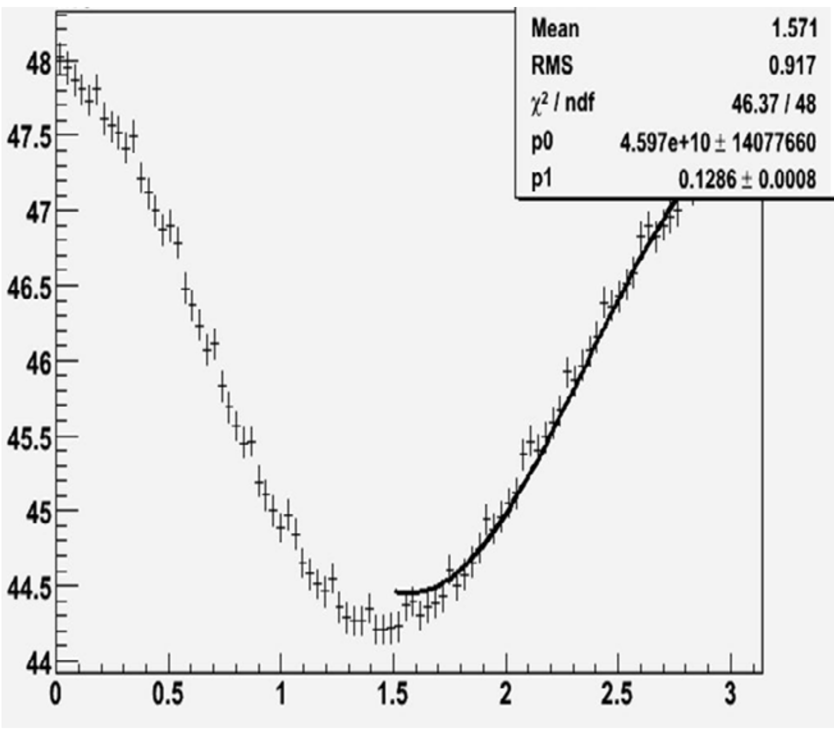
Summary

- Conical emission of correlated hadrons from 3-particle correlation measurement.
- Dihadron correlation relative to RP as a tool to study geometrical effects (medium flow).
- Evidence of flow effects on conical emission hadrons.
- No evidence for medium absorption.

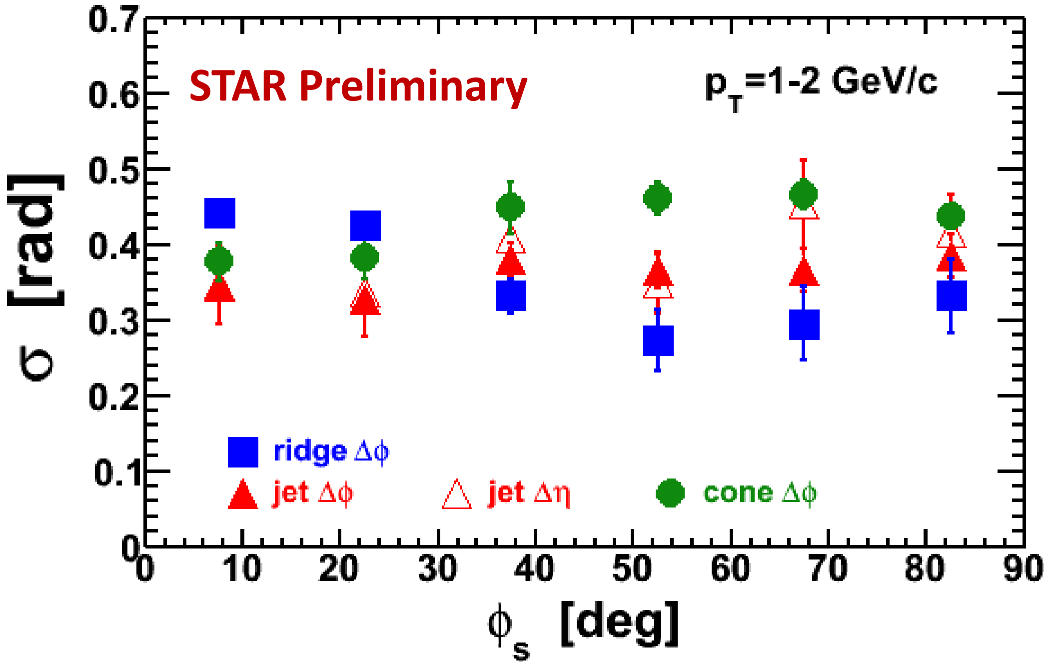
Backups

v2 systematic uncertainties

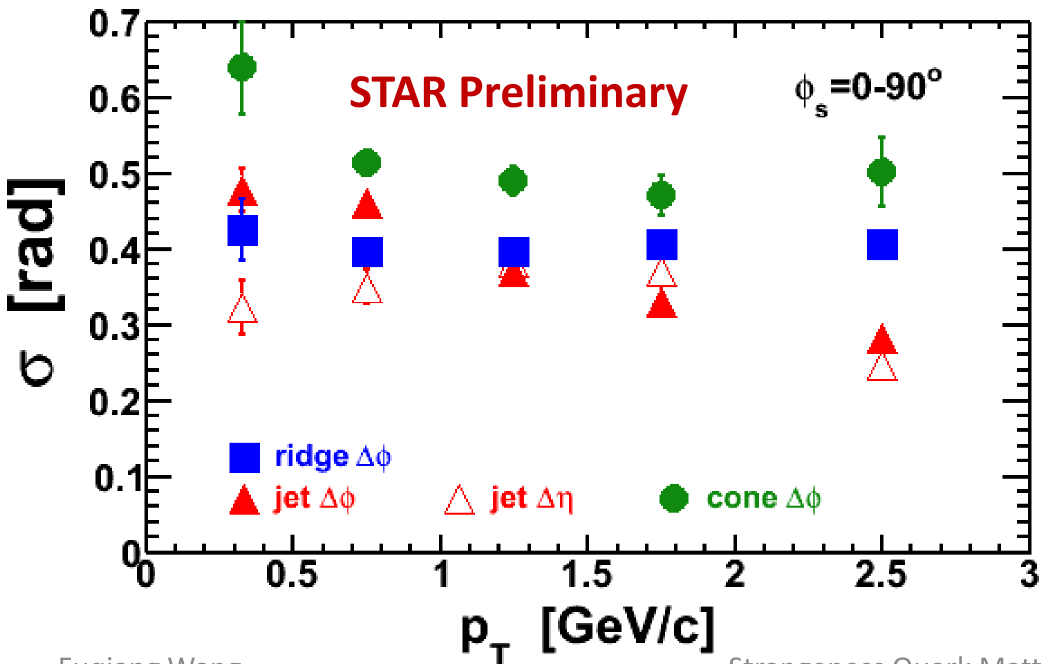




$v_2\{2,\text{away-side}\} = \sqrt{\langle\cos 2\Delta\phi\rangle_{\text{away-side}}}$



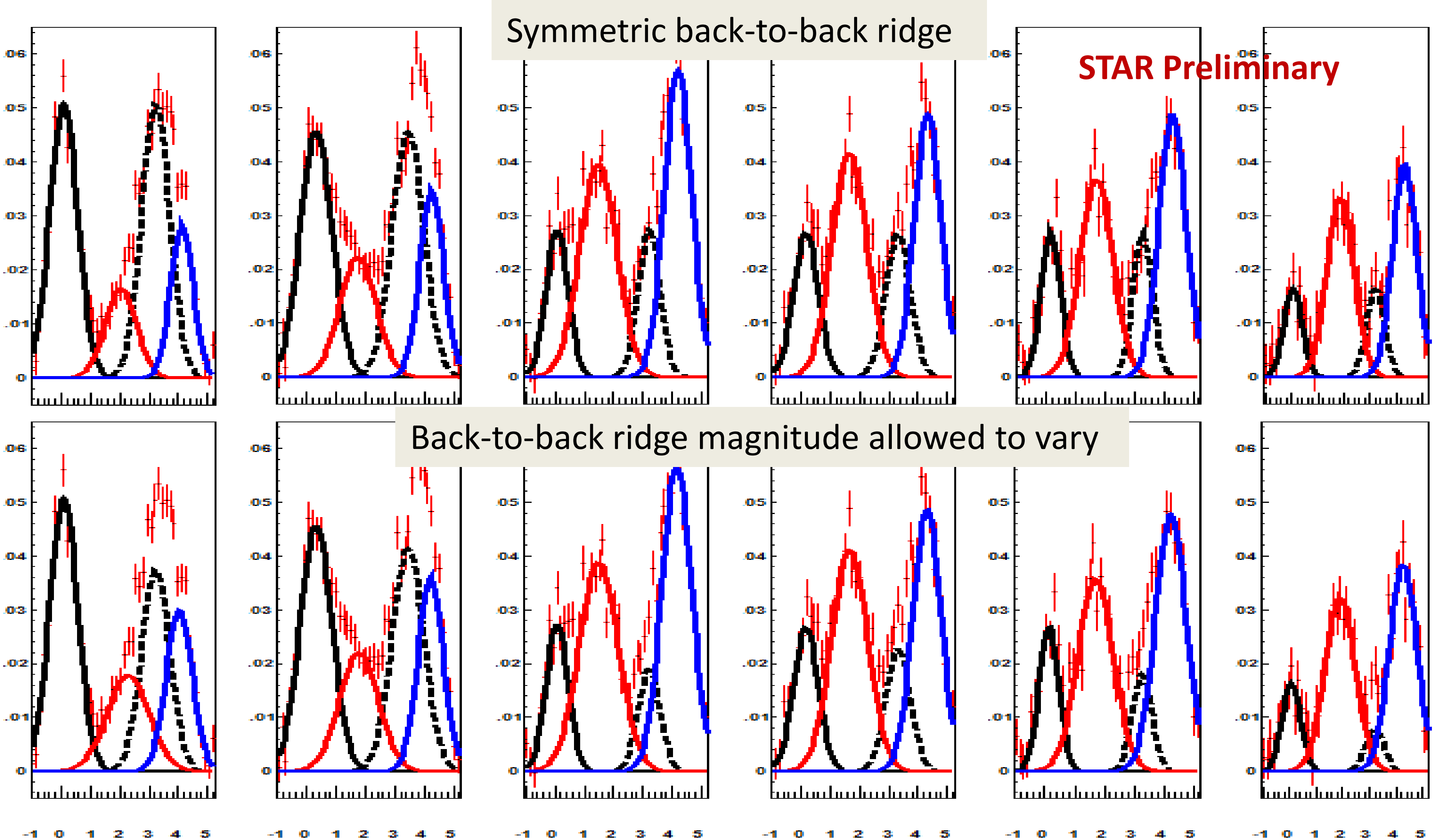
- Jet σ constant with ϕ_s.
- Ridge σ decreases with ϕ_s.
- Cone σ increases with ϕ_s.



- Jet σ decreases with p_T.
- Ridge σ constant with p_T.
- Cone σ decreases with p_T.

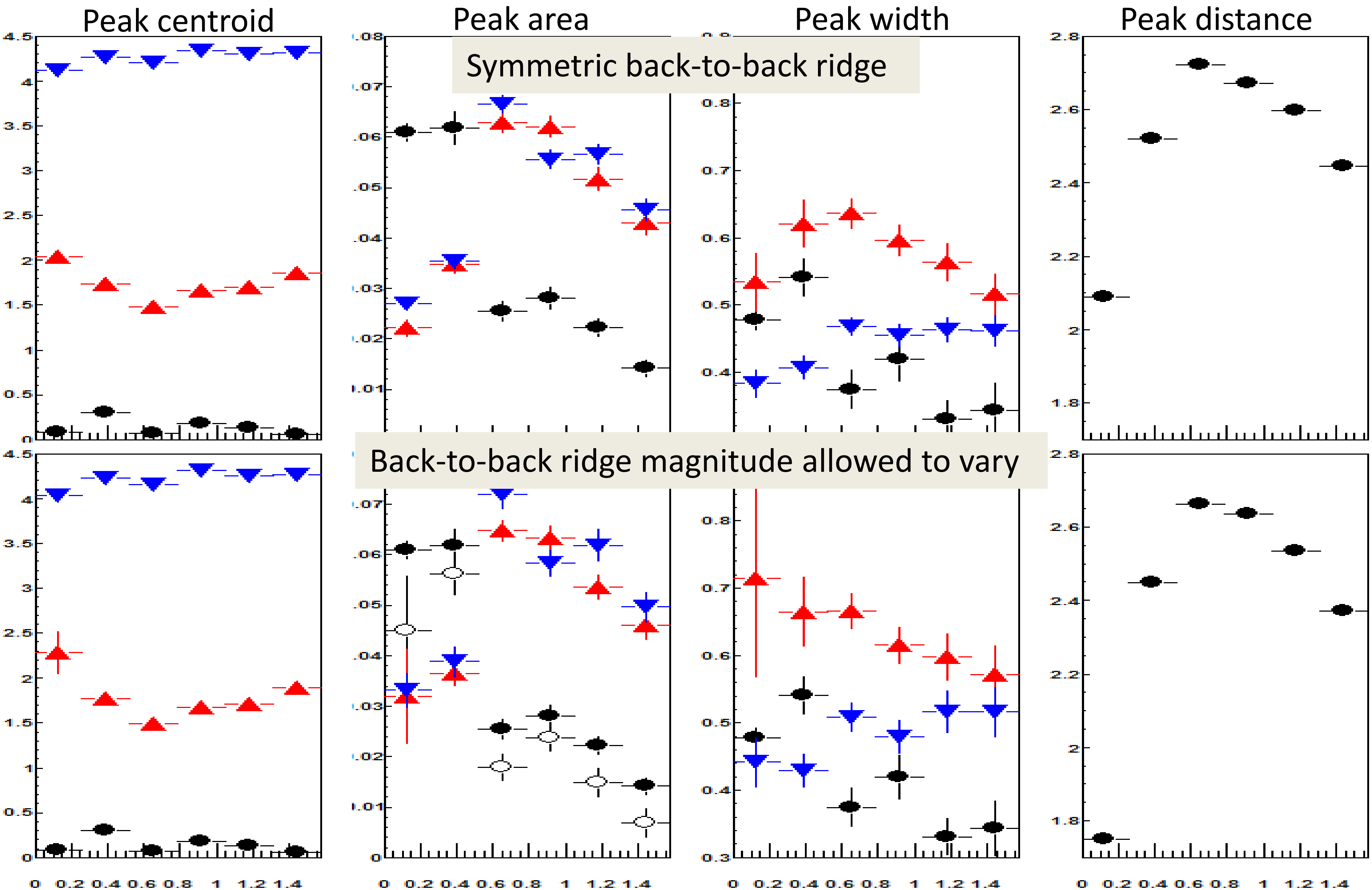
Back-to-back ridge + Away conical emission

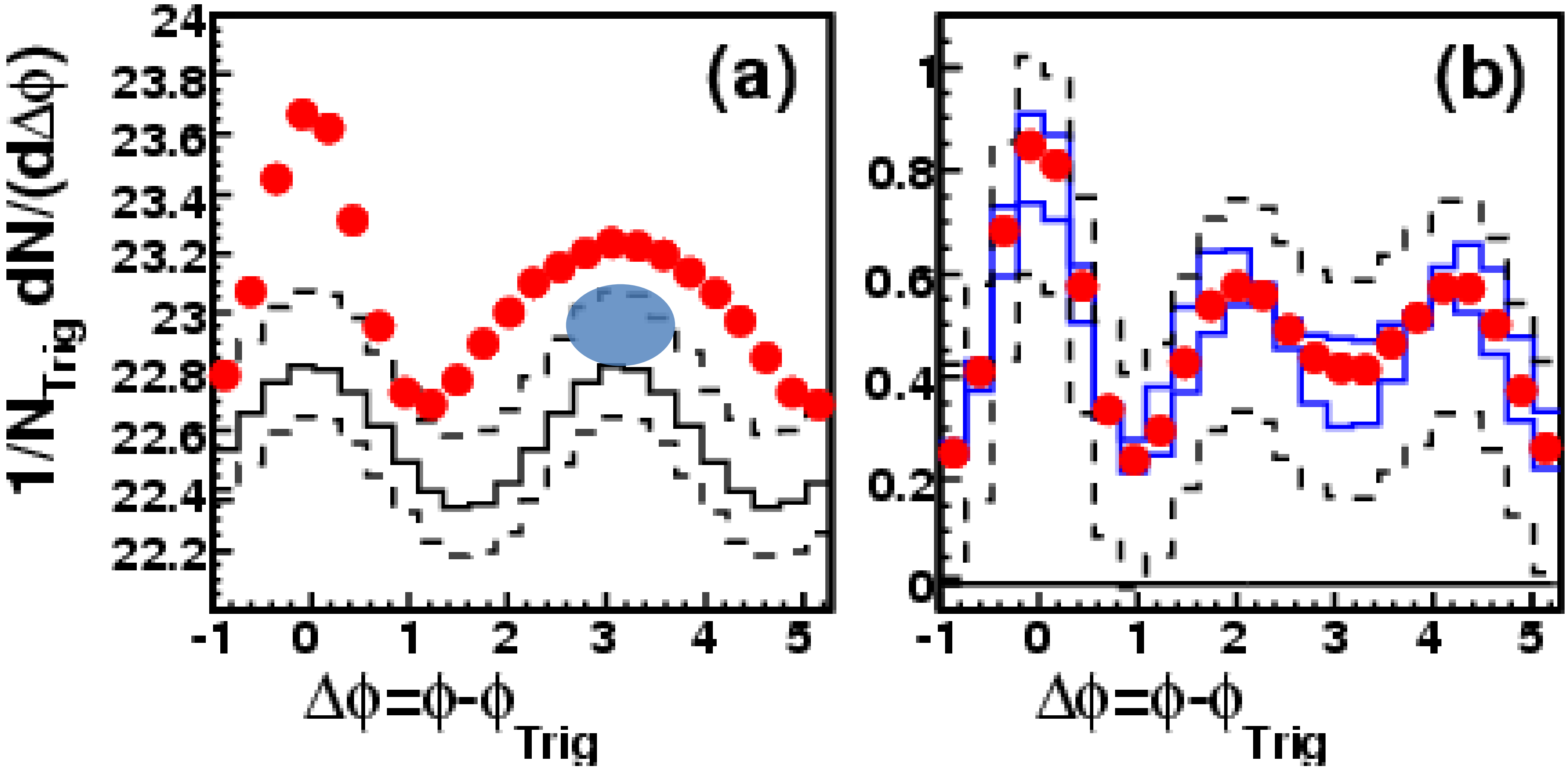
Azimuthal correlation for large $|\Delta\eta|>0.7$; Separate 1st and 2nd quadrants trigger particles



Fit parameters

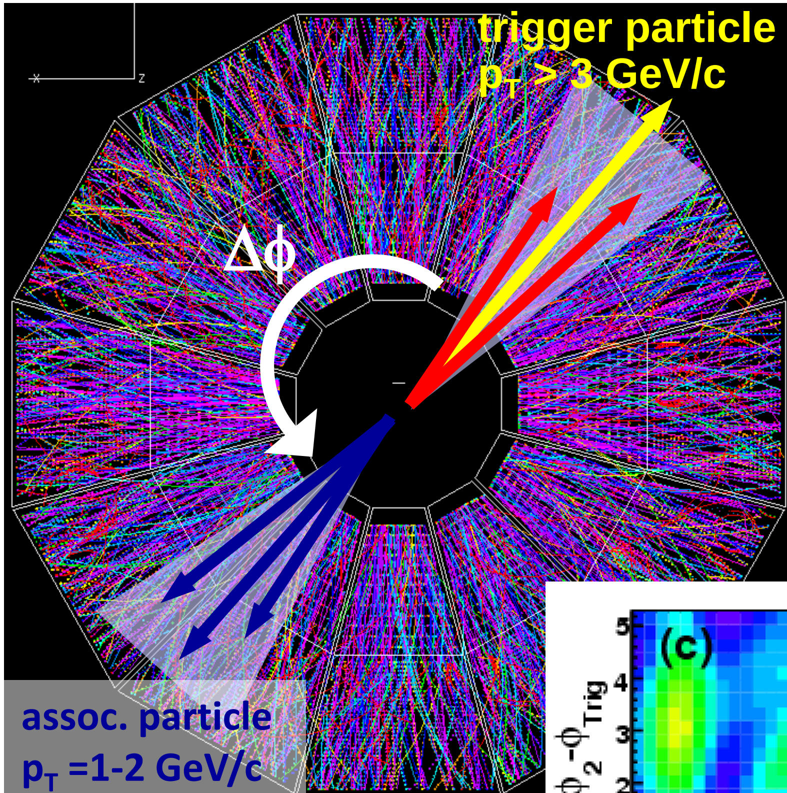
STAR Preliminary

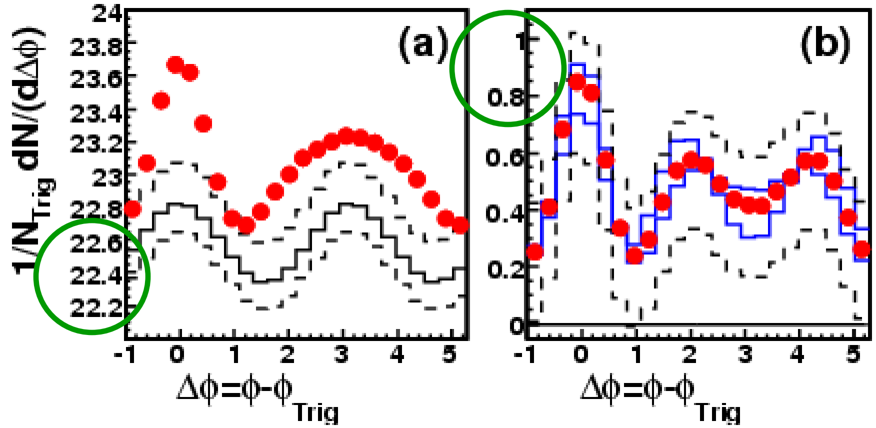



(a)
(b)
$1/N_{Trig}\, dN/(d\Delta\phi)$
24
23.8
23.6
23.4
23.2
23
22.8
22.6
22.4
22.2
1
0.8
0.6
0.4
0.2
0
-1
0
1
2
3
4
5
$\Delta\phi=\phi-\phi_{Trig}$
$\Delta\phi=\phi-\phi_{Trig}$

Large combinatorics

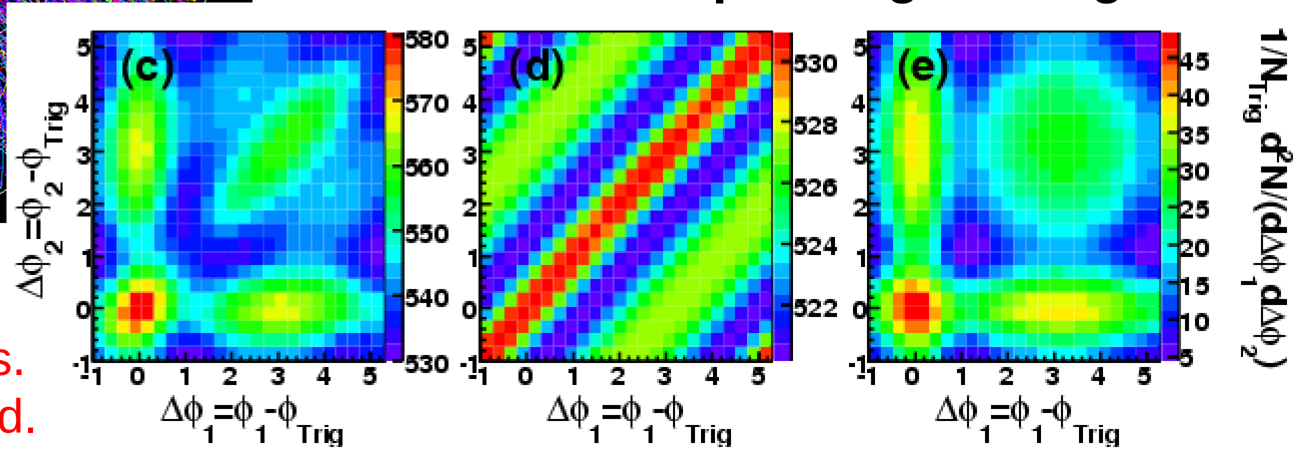
p_T^{trig}=3-4 GeV/c, p_T^{assoc}=1-2 GeV/c





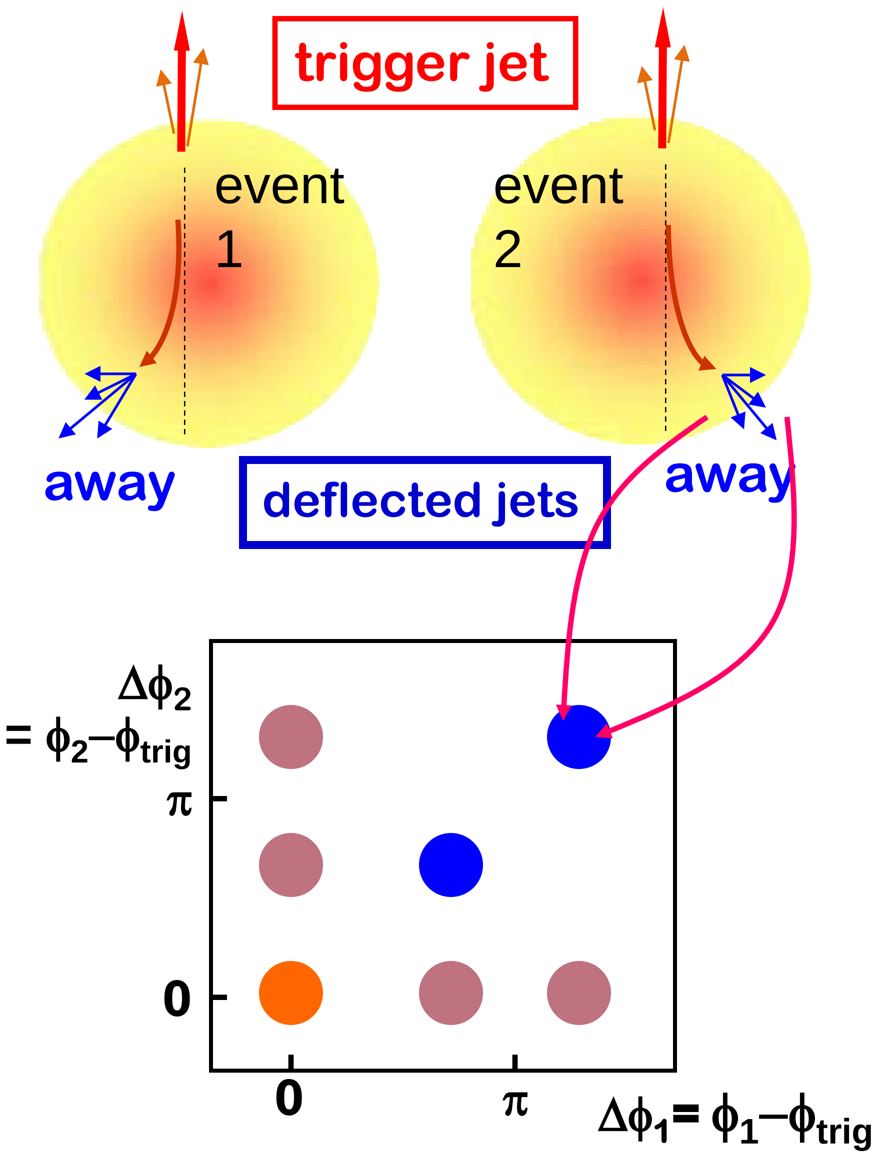
N jet particles ~ 1,   N bkgd particles ~ 20

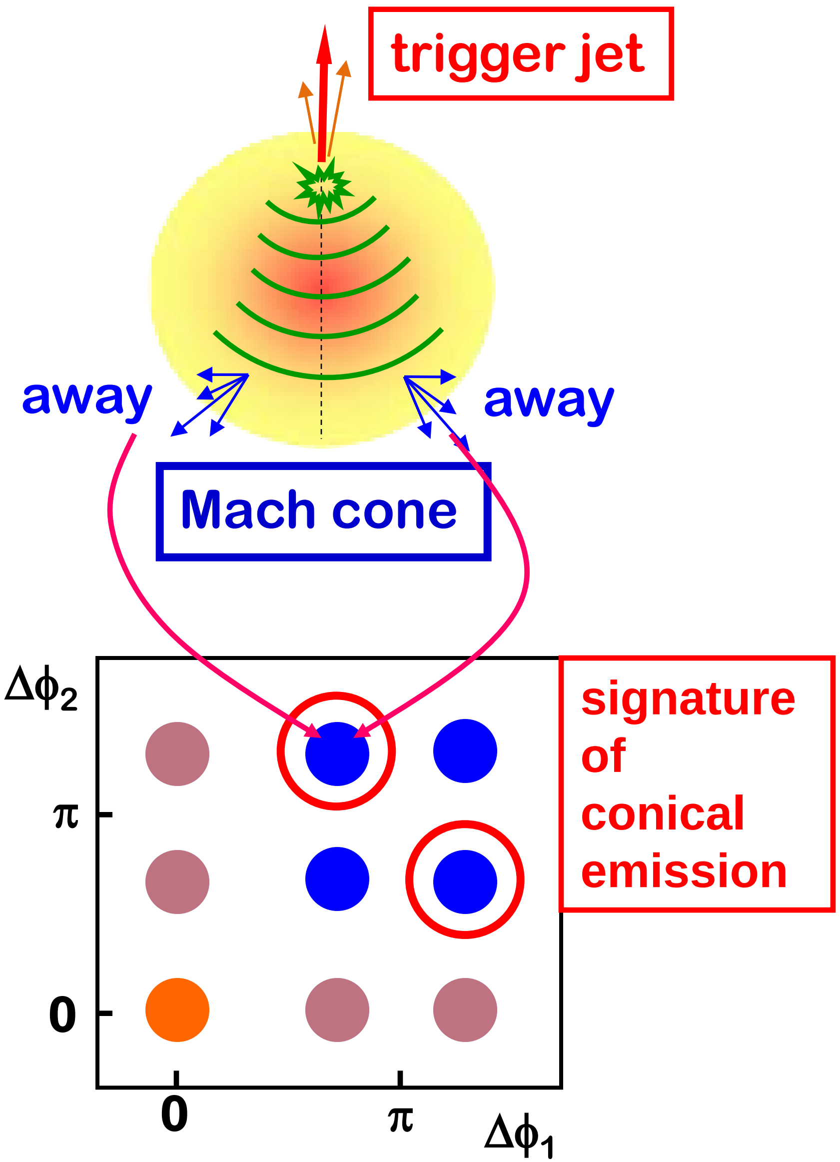
Combinatorial pair bkgd is huge!



Extremely difficult analysis.
Careful subtraction of bkgd.
Extensive assessment of systematics.

3-particle azimuthal correlation





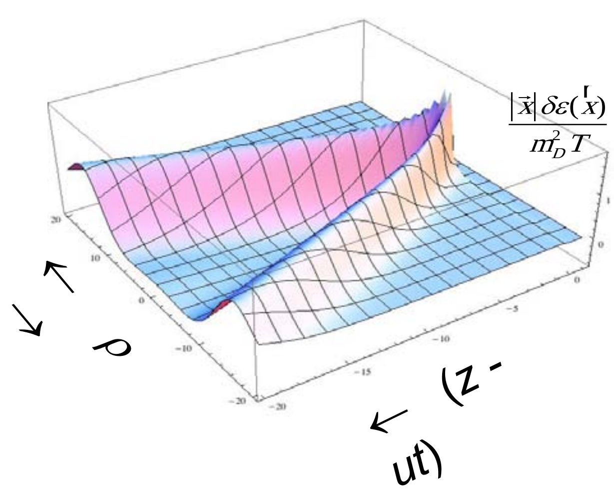
Theory calculations

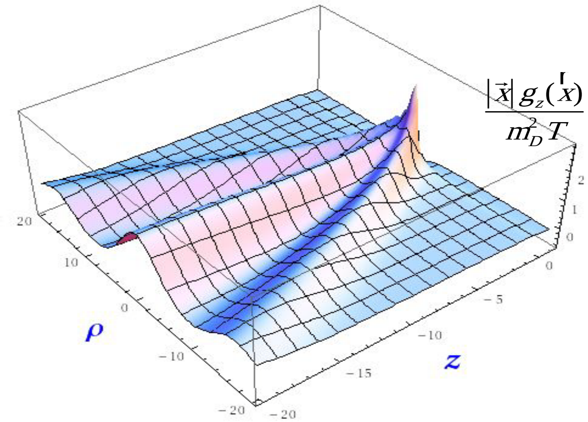
pQCD + hydro:

Neufeld et al.

arXiv:0807.2996

quark v = 0.99955

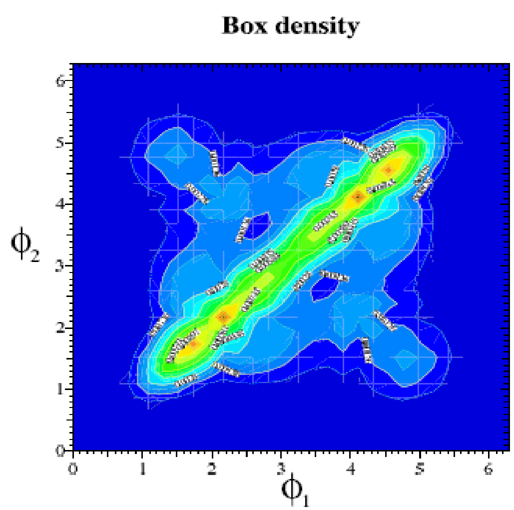


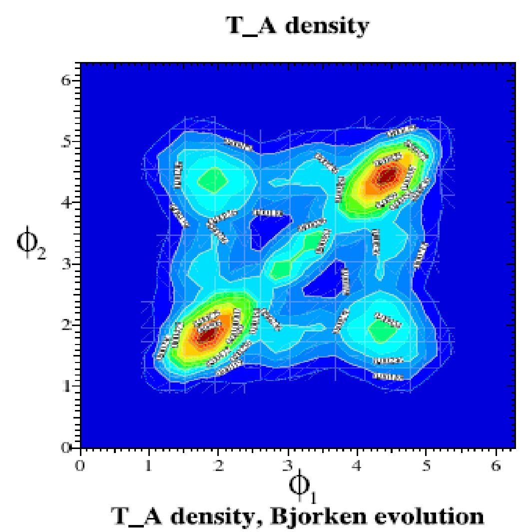


Parton energy loss:

Renk et al.

PRC 76, 014908 (2007)





AdS/CFT Correspondence

Maldacena (1997), Gubser, Klebanov,Polyakov; Witten (1998)

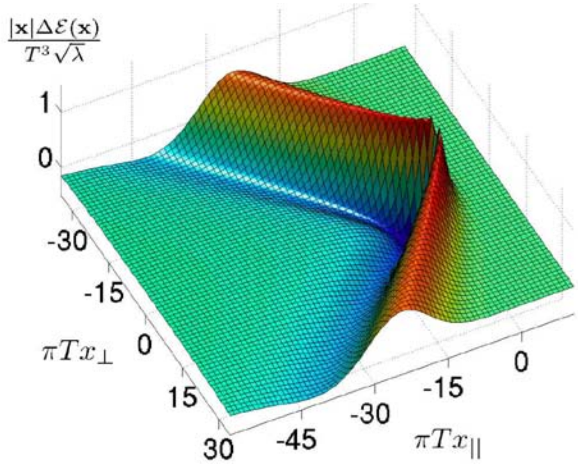
$\mathcal{N} = 4$ Super-Yang-Mills theory in 4d with SU(N_C) ⟺ **A string theory in 5d AdS**

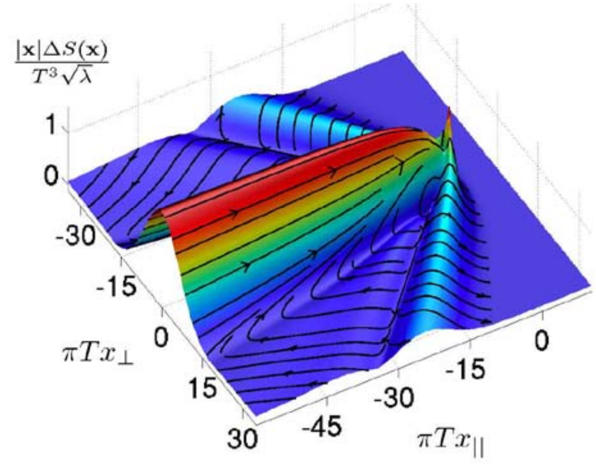
YM observables at infinite N_C and infinite coupling can be computed using classical gravity.

Chesler & Yaffe

arXiv:0712.0050

Heavy quark u = 0.75c





Measure heavy quark Mach-cone shock waves:

→ Experimental consequence of string theory?