Centrality Dependence of Δη-Δφ Correlations in Heavy Ion Collisions

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for the PHOBOS collaboration

PHOBOS Collaboration



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- In p+p collisions, 2-particle correlations elucidate the physics mechanisms responsible for particle production

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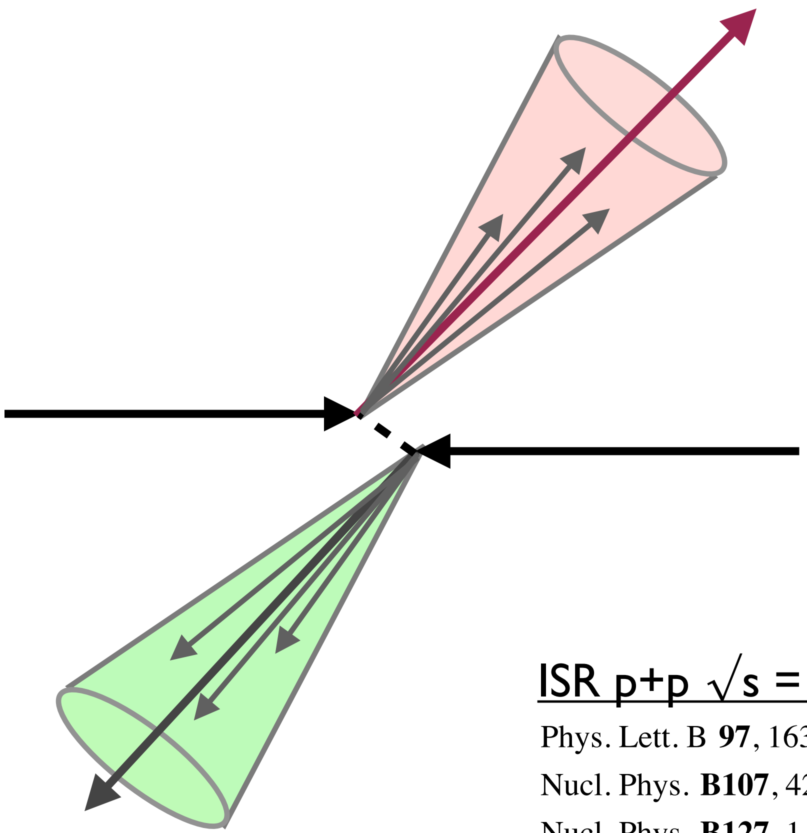
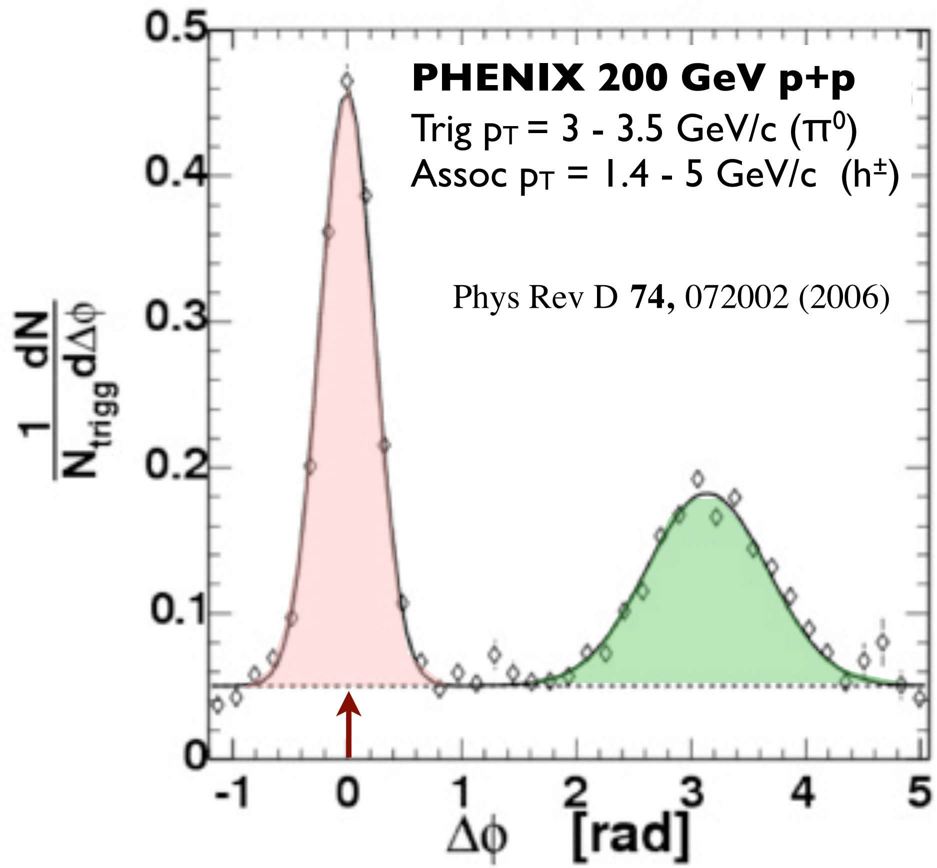


ISR p+p $\sqrt{s}$ = 63 GeV

Phys. Lett. B **97**, 163 (1980)

Nucl. Phys. **B107**, 429 (1976)

Nucl. Phys. **B127**, 1 (1977)



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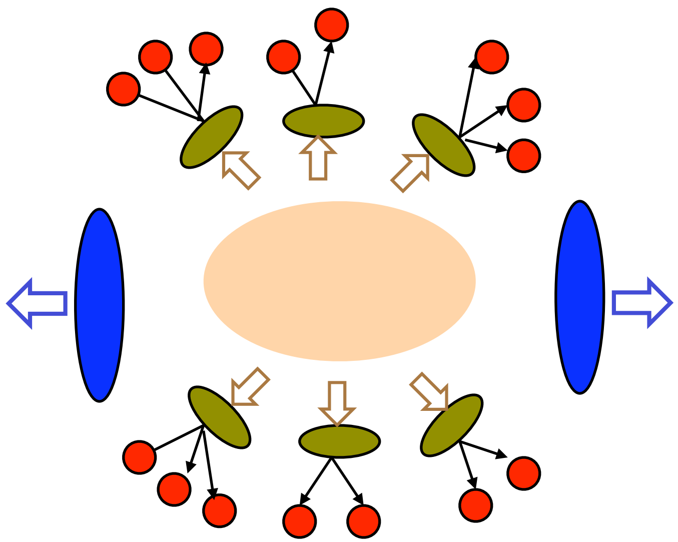
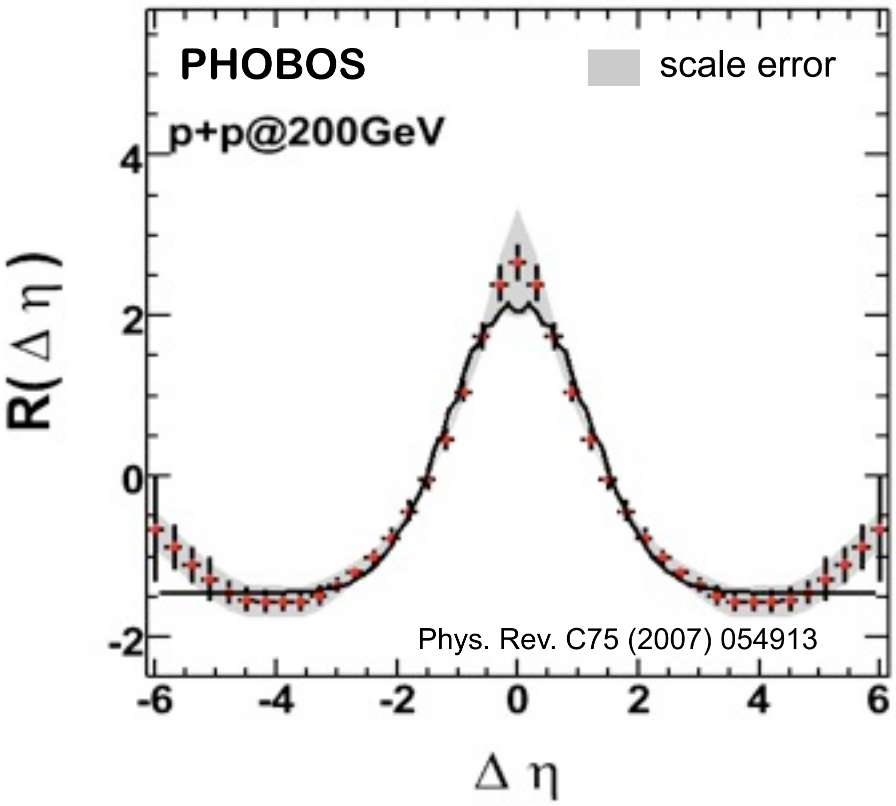
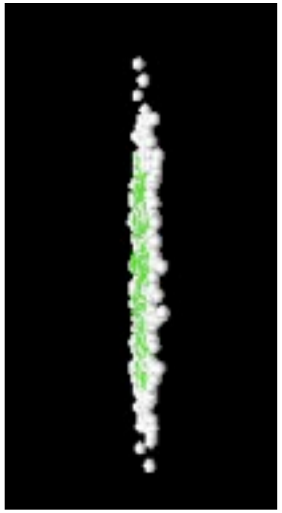


ISR: Nucl. Phys., B132:15, 1978
UA1: Z. Phys., C37: 191–213, 1988

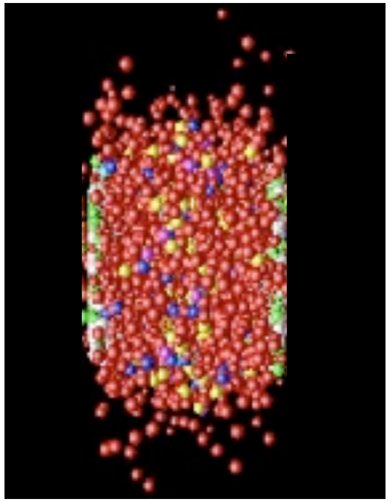


Heavy Ion Collisions

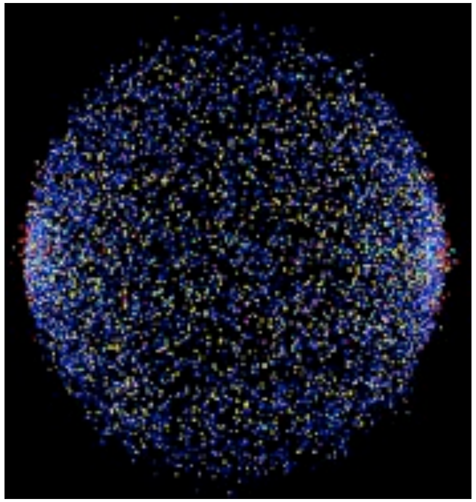
Insight into different stages of the system evolution



Initial geometry



Hydrodynamical evolution



Freeze-out

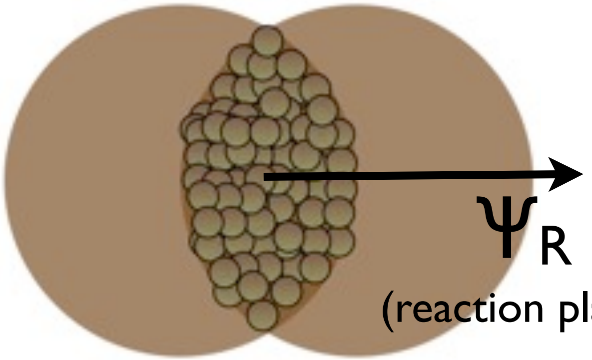
Elliptic Flow

Jet Quenching

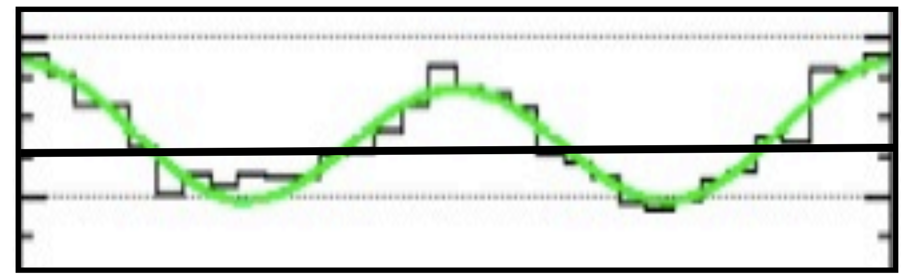
Hadronization from ‘clusters’

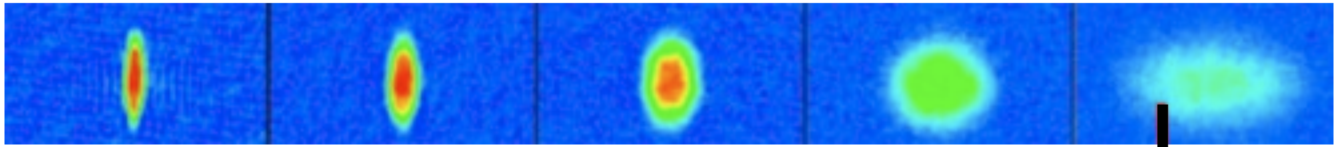
Elliptic Flow

Initial anisotropy



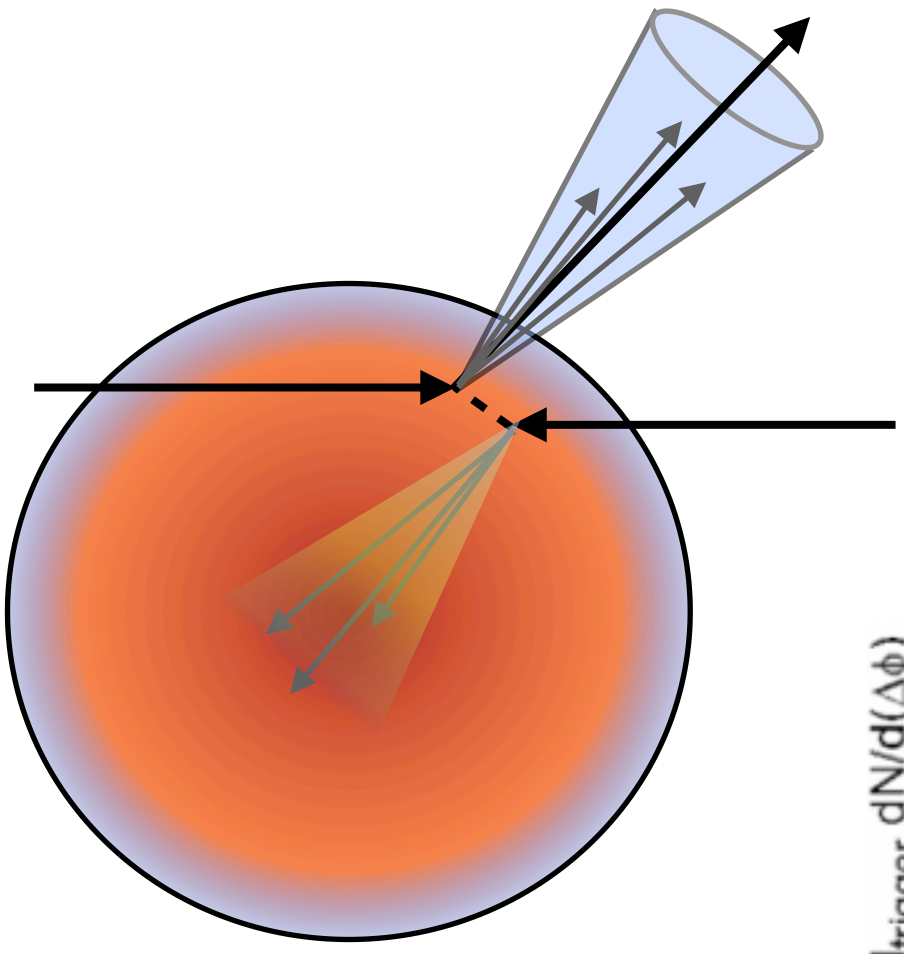
N_{part} = # of participating nucleons





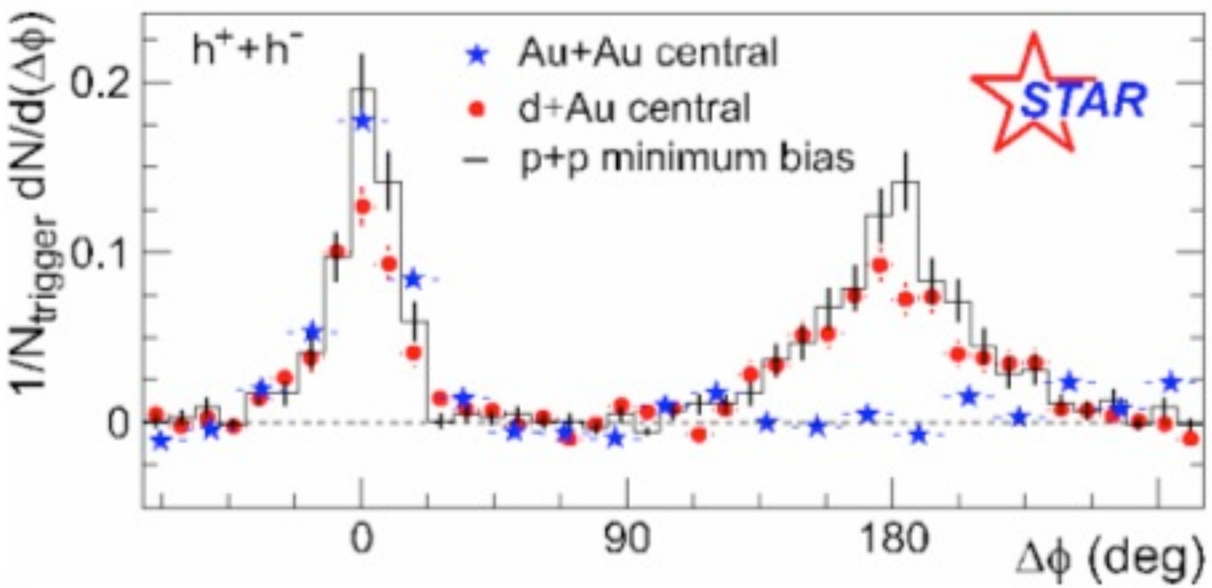
- Early equilibration
- Hydrodynamic expansion

Back-to-Back Jet Quenching

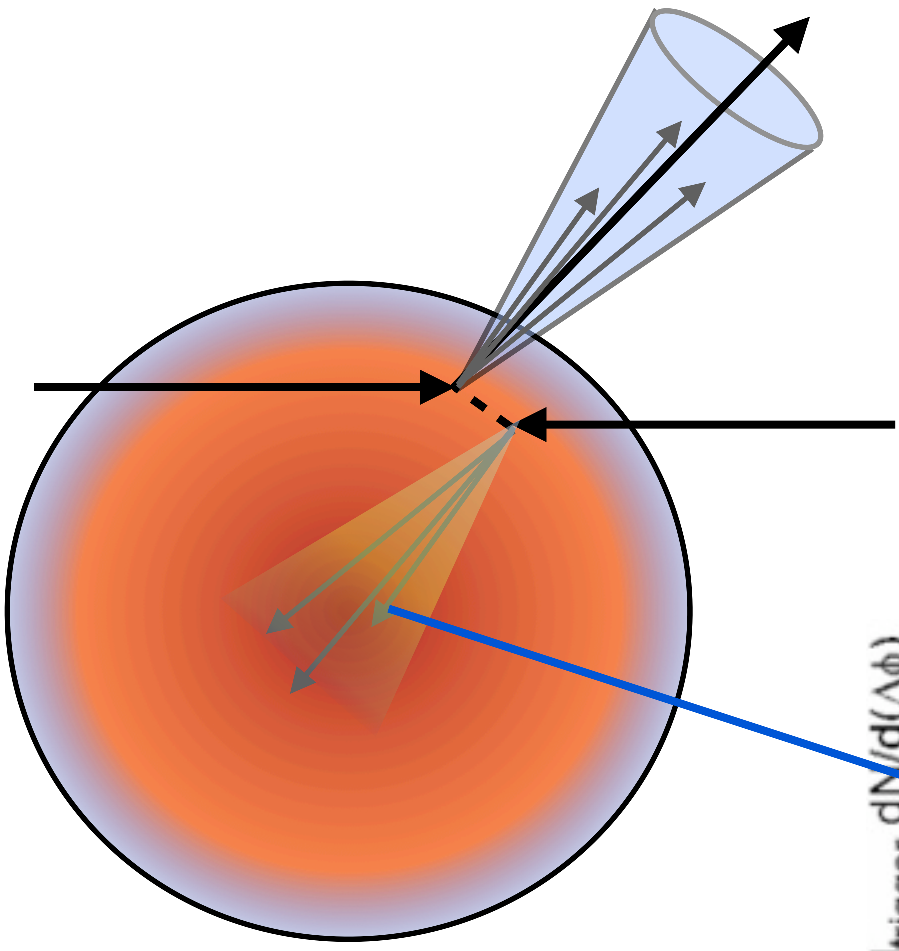


p_T^{trig} : 4 - 6 GeV/c
p_T^{assoc} : 2 - 4 GeV/c

STAR, PRL **91**, 072304 (2003)



Back-to-Back Jet Quenching



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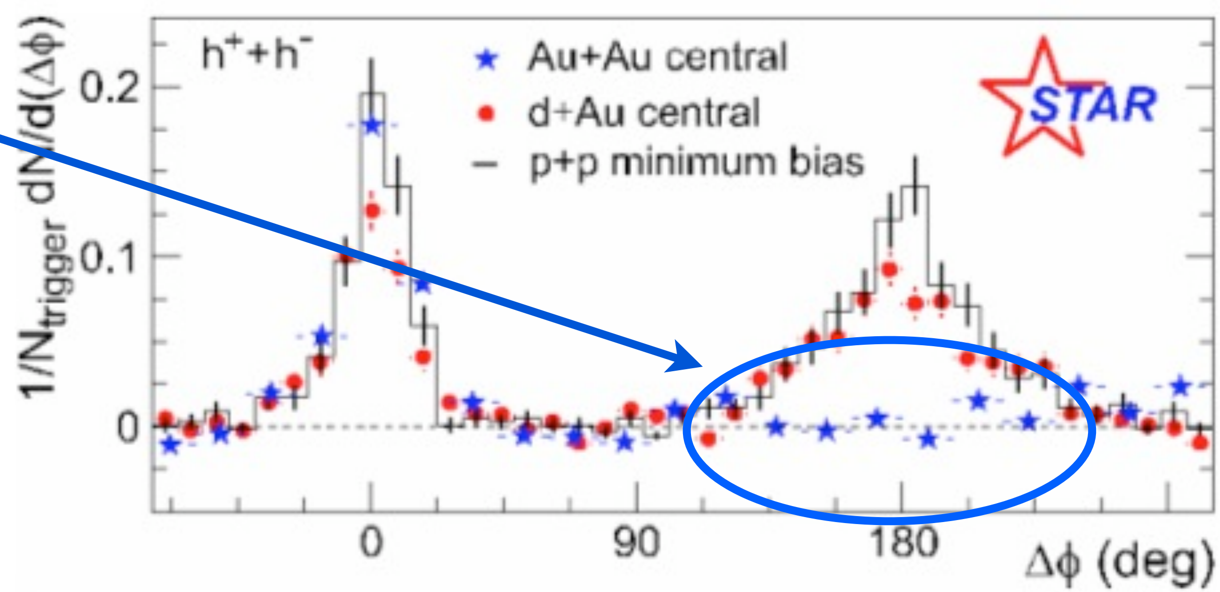
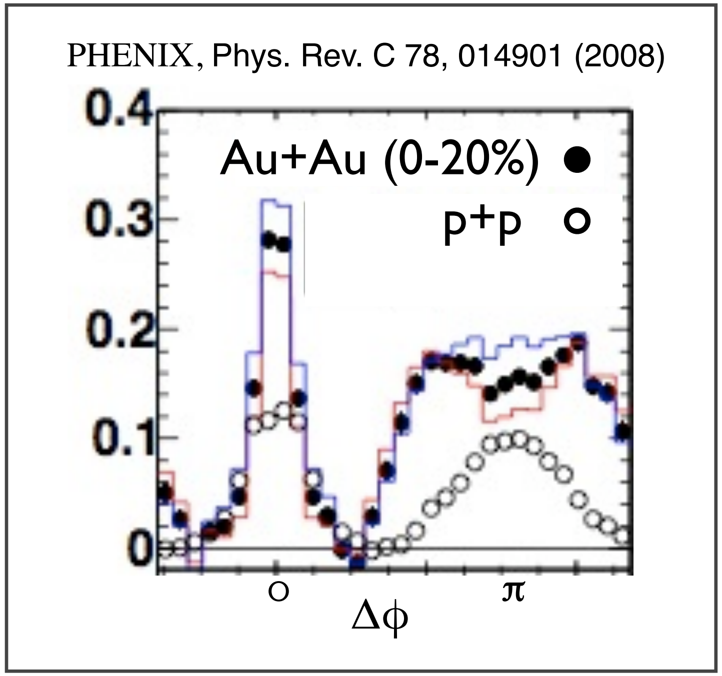
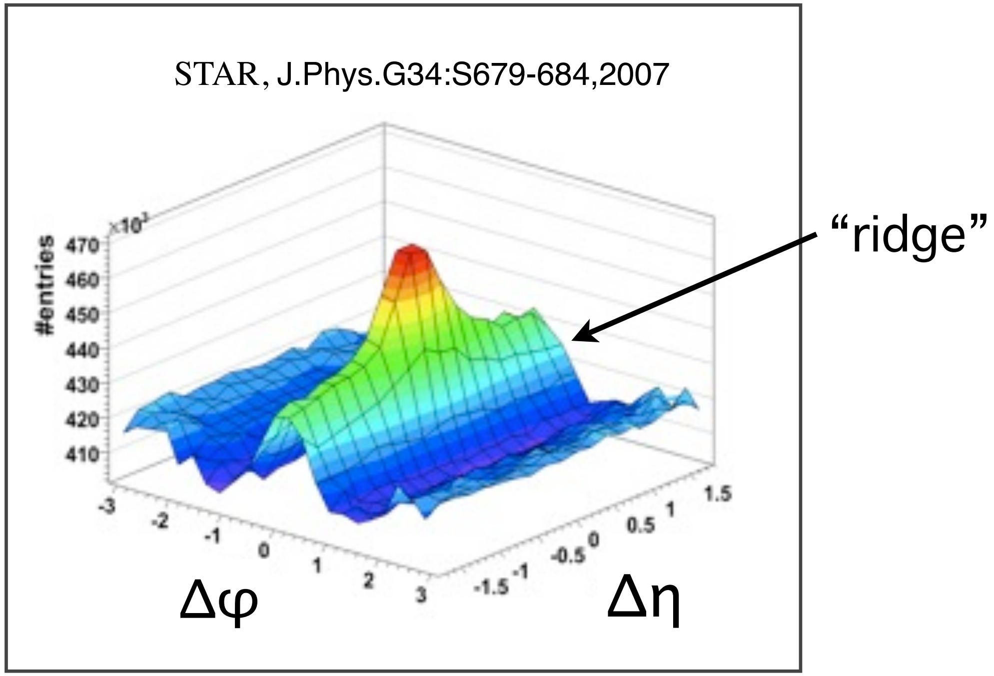


Where does the energy go?

p_T^{trig} : 3-4 , p_T^{assoc} : 0.1-1 GeV/c



p_T^{trig} : 3-4 , p_T^{assoc} : >2 GeV/c



Medium response to high-p_T probes near mid-rapidity

- ✓ broadening in Δφ of away-side compared to p+p
- ✓ enhanced correlation ("ridge") at Δφ=0 and large Δη

PHOBOS Experimental Setup

High p_T trigger tracks

$p_T > 2.5$ GeV/c

$0 < \eta_{trig} < 1.5$

Associated hits

Full ϕ coverage

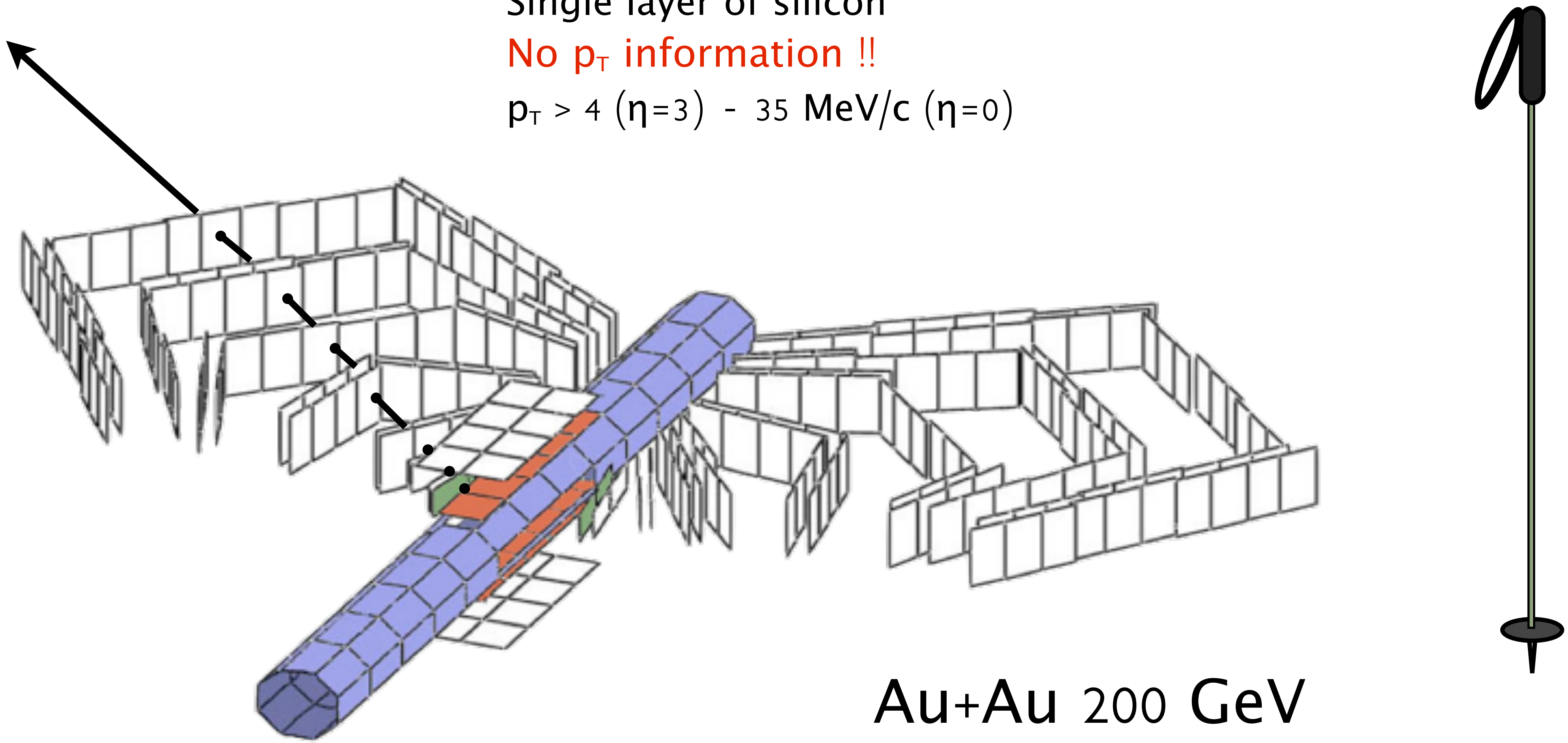
Broad η coverage ($-3<\eta<3$)

Single layer of silicon

No p_T information !!

$p_T > 4$ ($\eta=3$) - 35 MeV/c ($\eta=0$)

Octagon holes are filled using hits from the first layers of the Spectrometer and Vertex detectors



Au+Au 200 GeV

Construction of Correlated Yield

$$\frac{1}{N_{trig}} \frac{d^2N_{ch}}{d\Delta\phi\, d\Delta\eta} = B(\Delta\eta) \left\{ \frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)} - a(\Delta\eta) \left[1 + 2V(\Delta\eta) \cos(2\Delta\phi) \right] \right\}$$

$\frac{s(\Delta\phi,\Delta\eta)}{b(\Delta\phi,\Delta\eta)}$ **Raw correlation**: ratio of per-trigger same event pairs to mixed event pairs

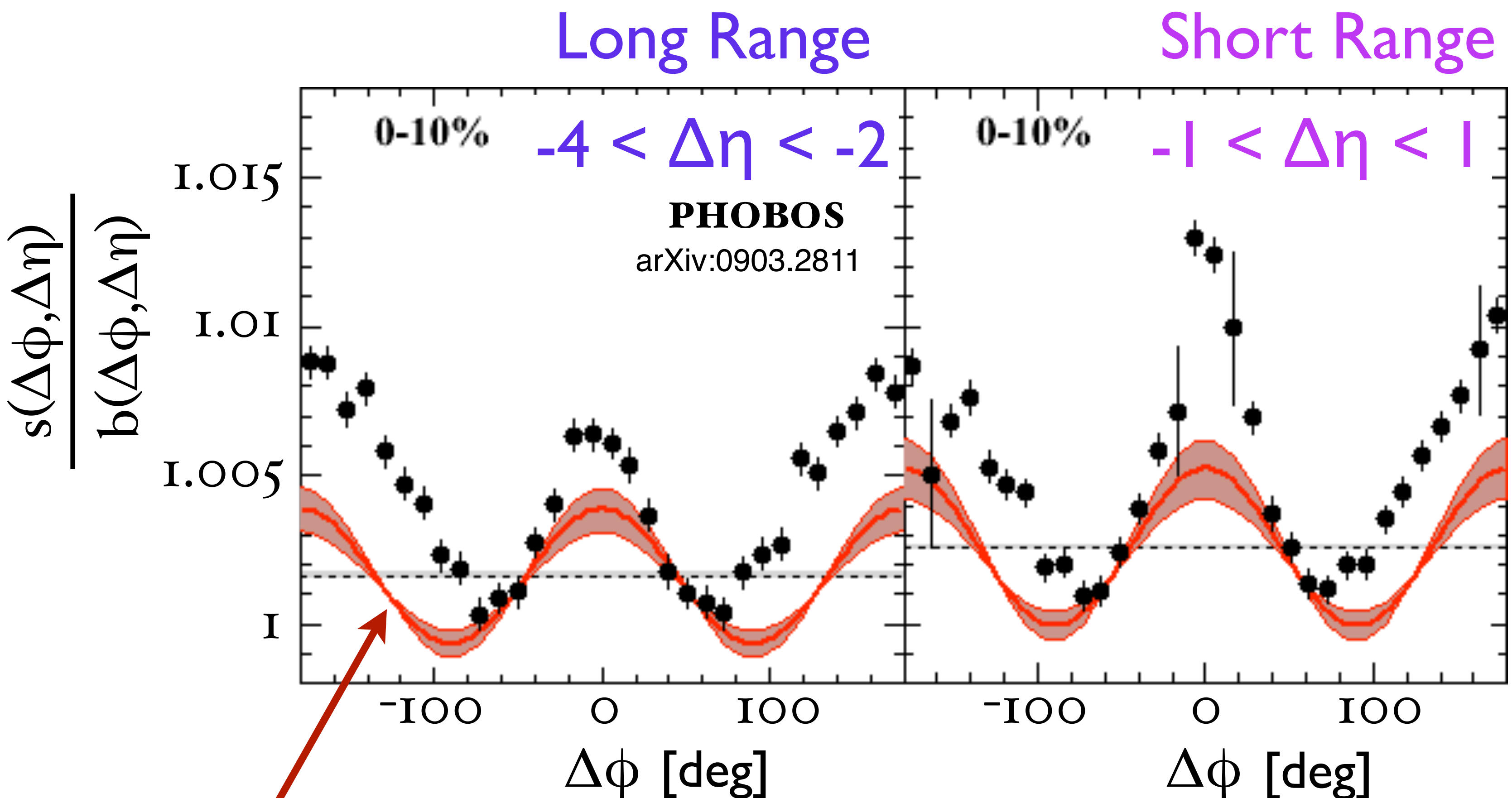
$1 + 2V(\Delta\eta)\cos(2\Delta\phi)$ **Elliptic flow**: $V(\Delta\eta) = \langle v_2^{trig} \rangle \langle v_2^{assoc} \rangle$

PHOBOS Phys. Rev. C **72**, 051901(R) (2005)

$a(\Delta\eta)$ **Scale factor**: accounts for small multiplicity difference between signal and mixed events

$B(\Delta\eta)$ **Normalization term:** relates flow-subtracted correlation to correlated yield

Subtraction of elliptic flow



Elliptic Flow

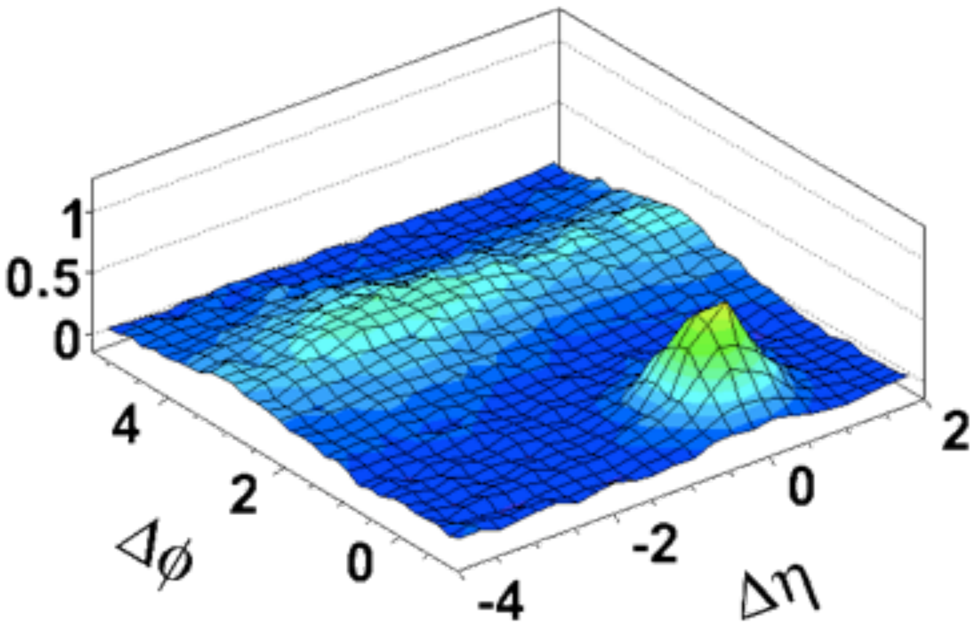
$a(\Delta\eta)\,[1 + 2V(\Delta\eta)\cos(2\Delta\phi)]$

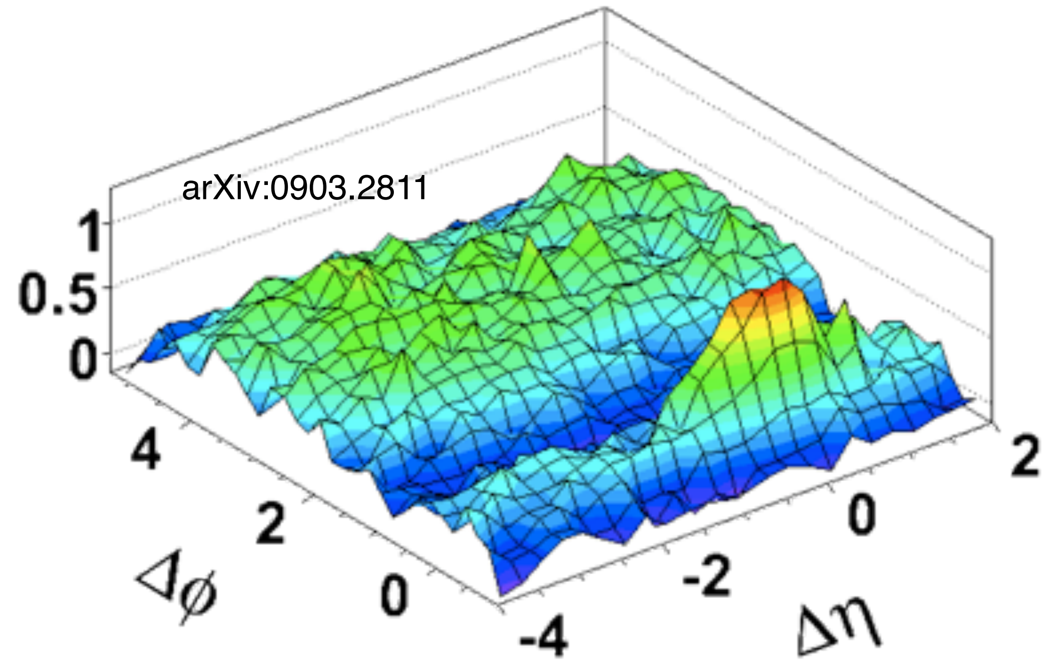
Correlated Yields in p+p and Au+Au

p+p
(PYTHIA)

$$\frac{1}{N_{trig}} \frac{d^2N_{ch}}{d\Delta\phi\, d\Delta\eta}$$

Au+Au 0-30%
(PHOBOS)

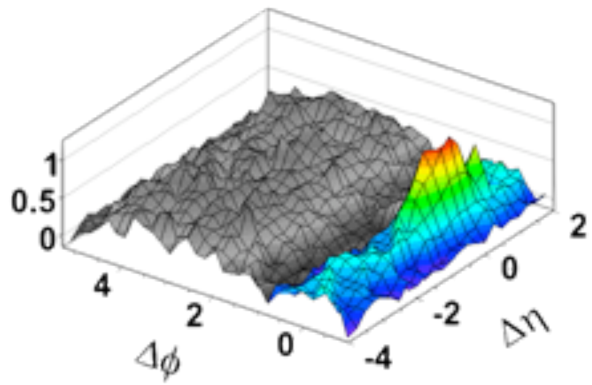


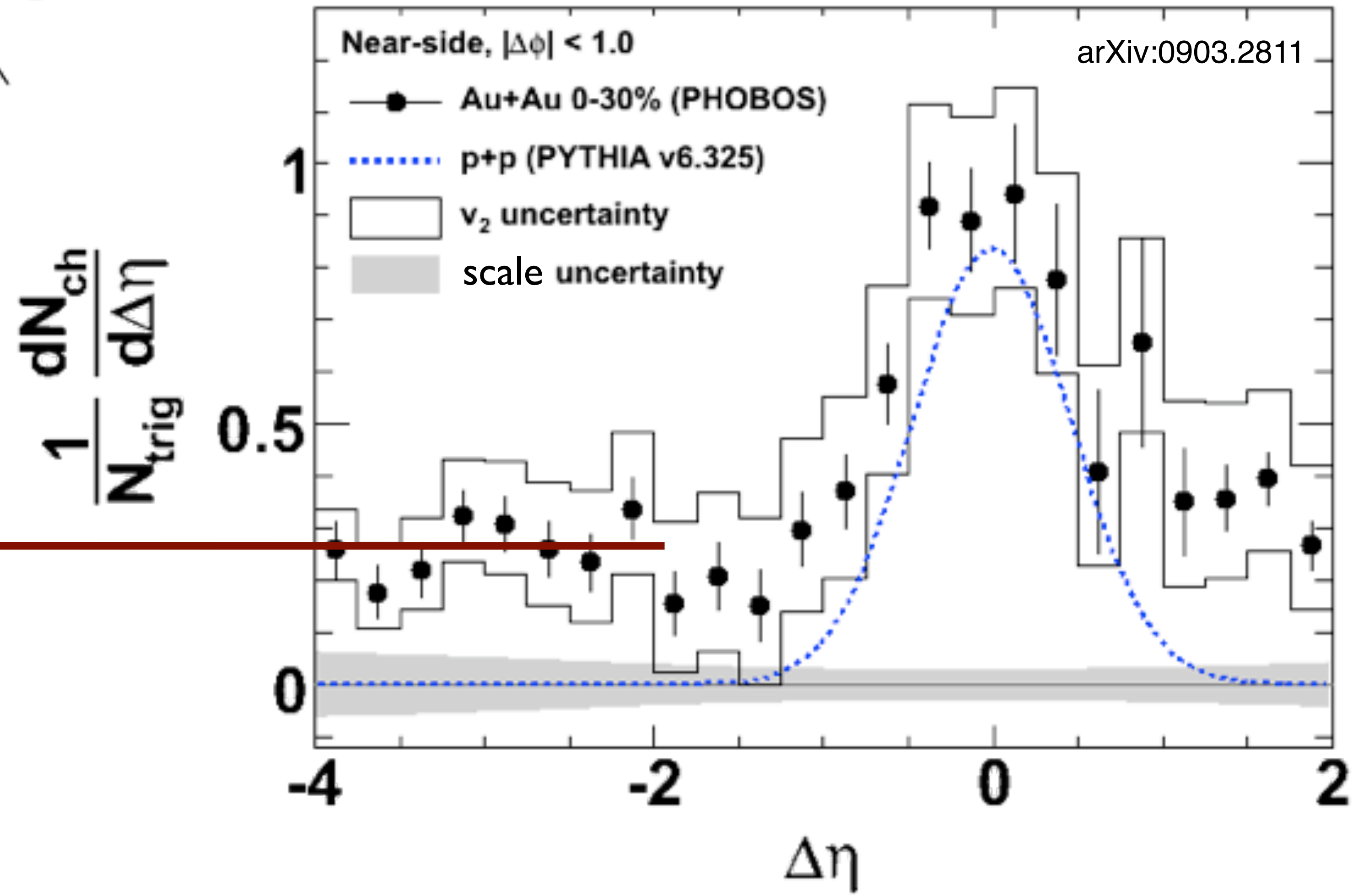


NB: PYTHIA agrees nicely with STAR at mid-rapidity for a similar set of p_T cuts

p_T^{trig} >2.5 GeV/c
p_T^{assoc} > 4 - 35 MeV/c

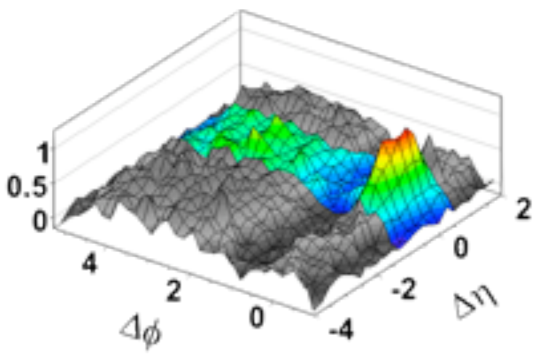
Ridge Extent in Δη





Long-range ridge yield

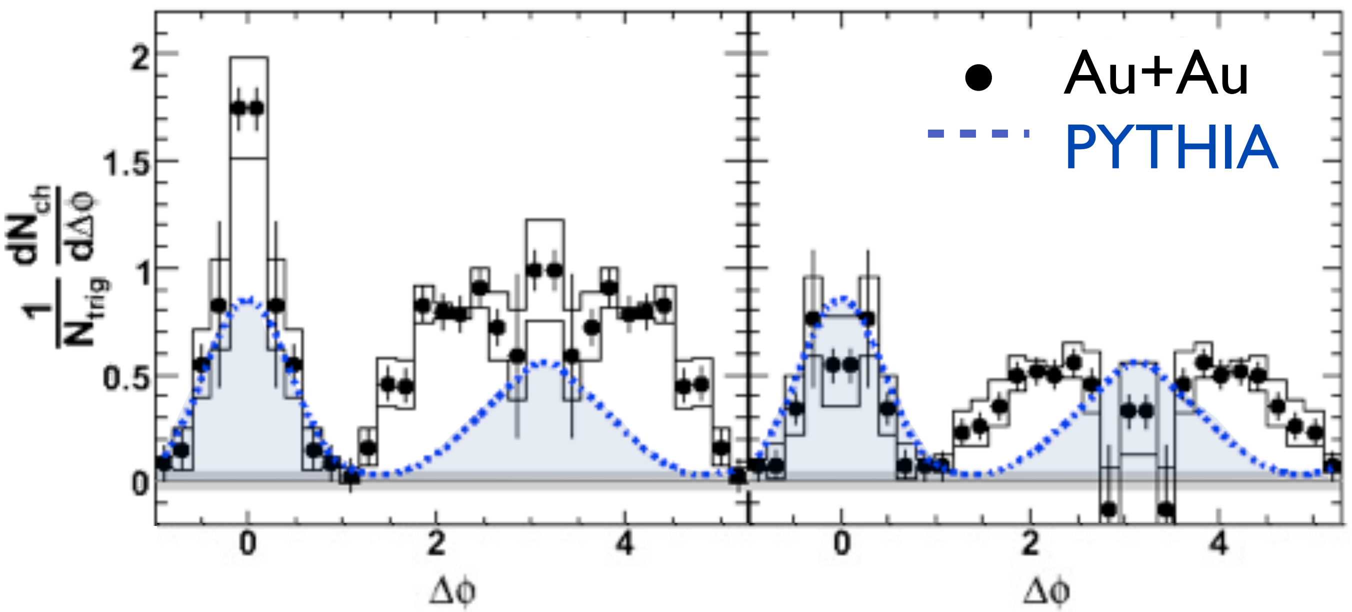
Projection of correlation in Δφ



Short-range
|Δη| <1

0-10%

40-50%



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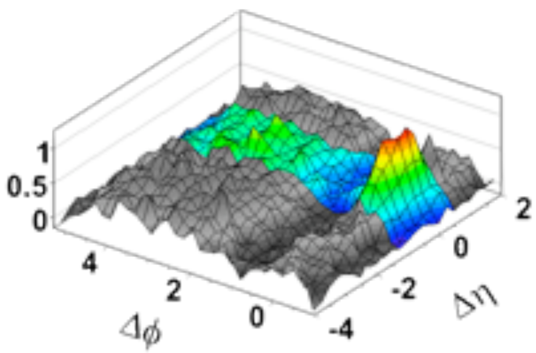
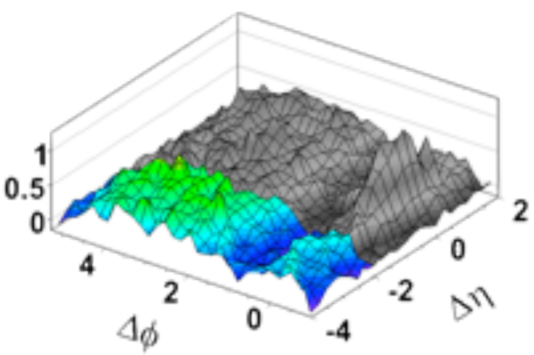
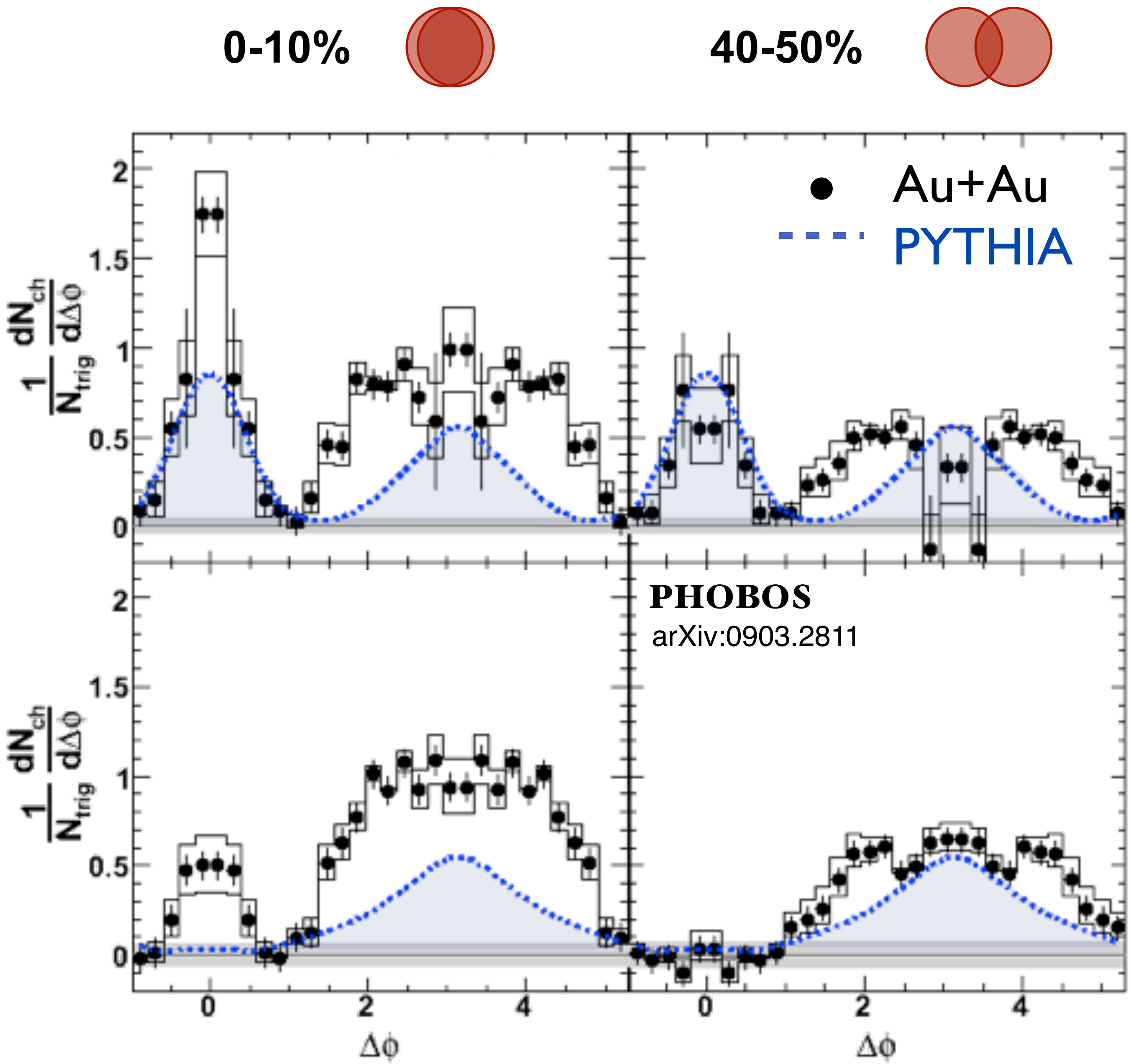


Short-range
|Δη| <1

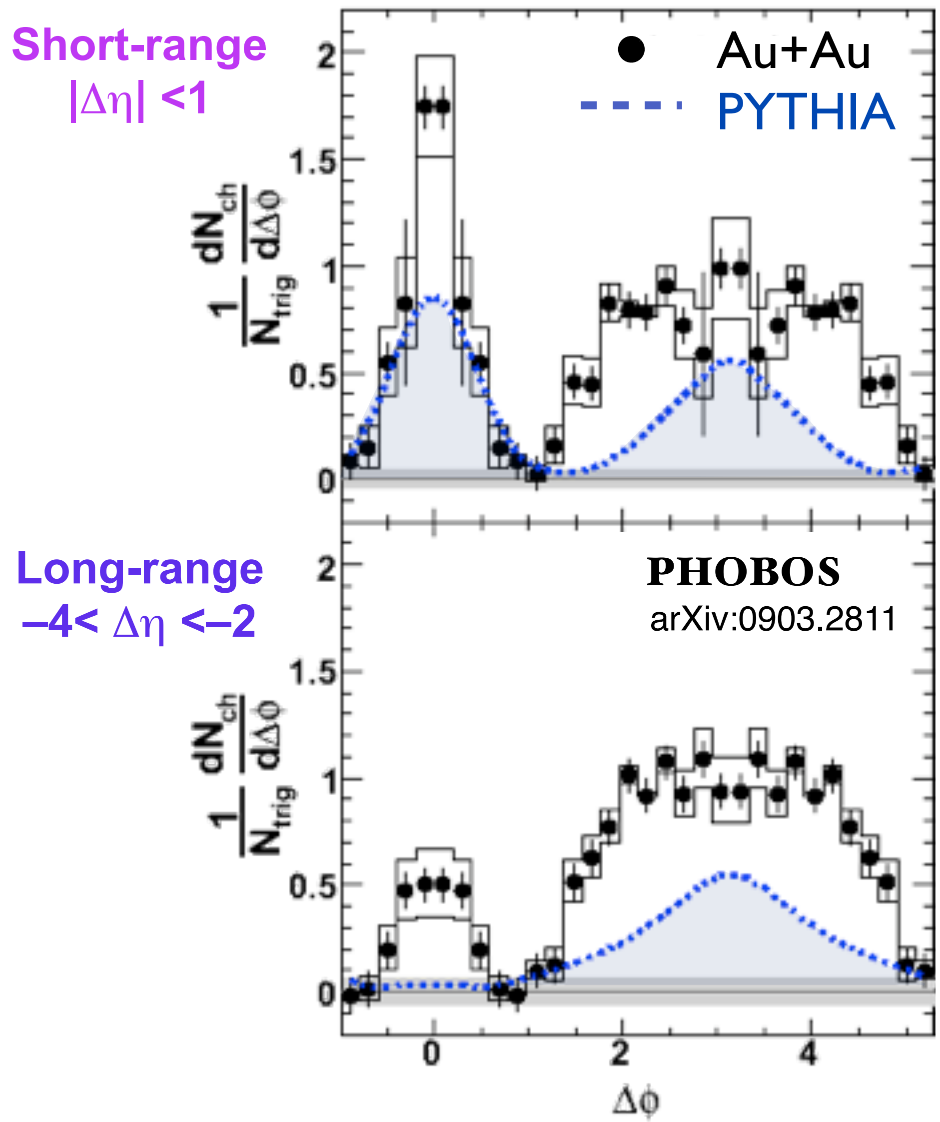


Long-range
–4< Δη <–2



Integrated Ridge Yield

0-10%



Integrated Ridge Yield

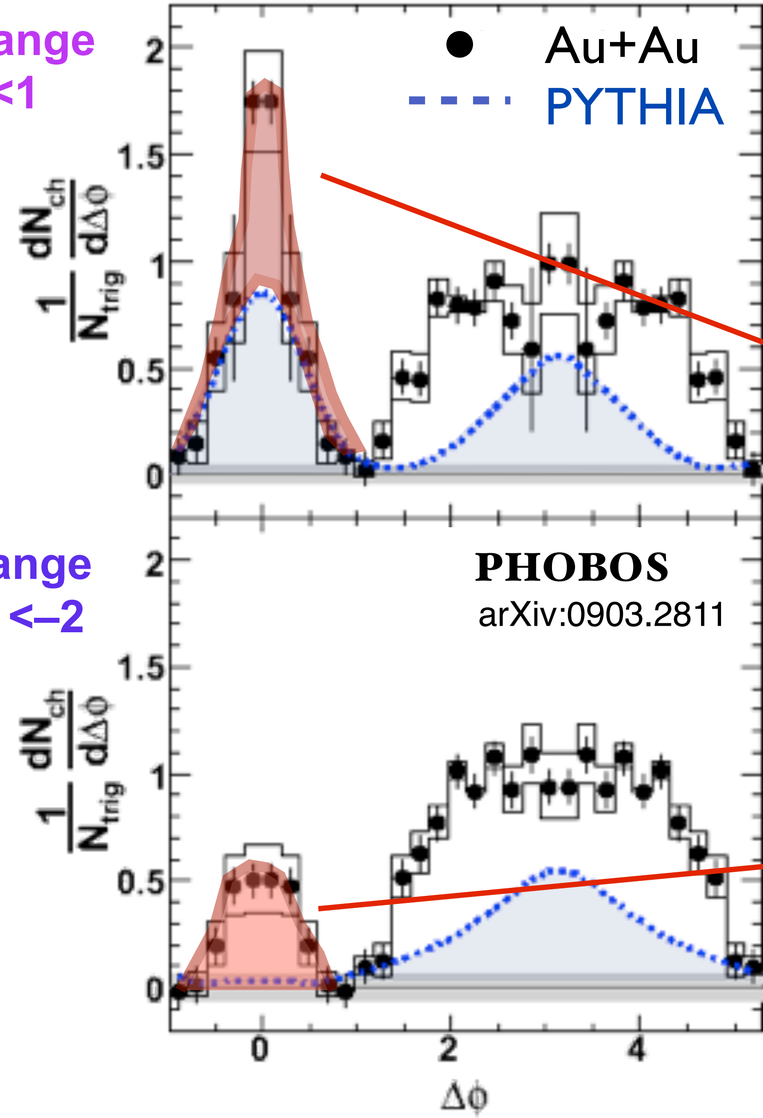
0-10%

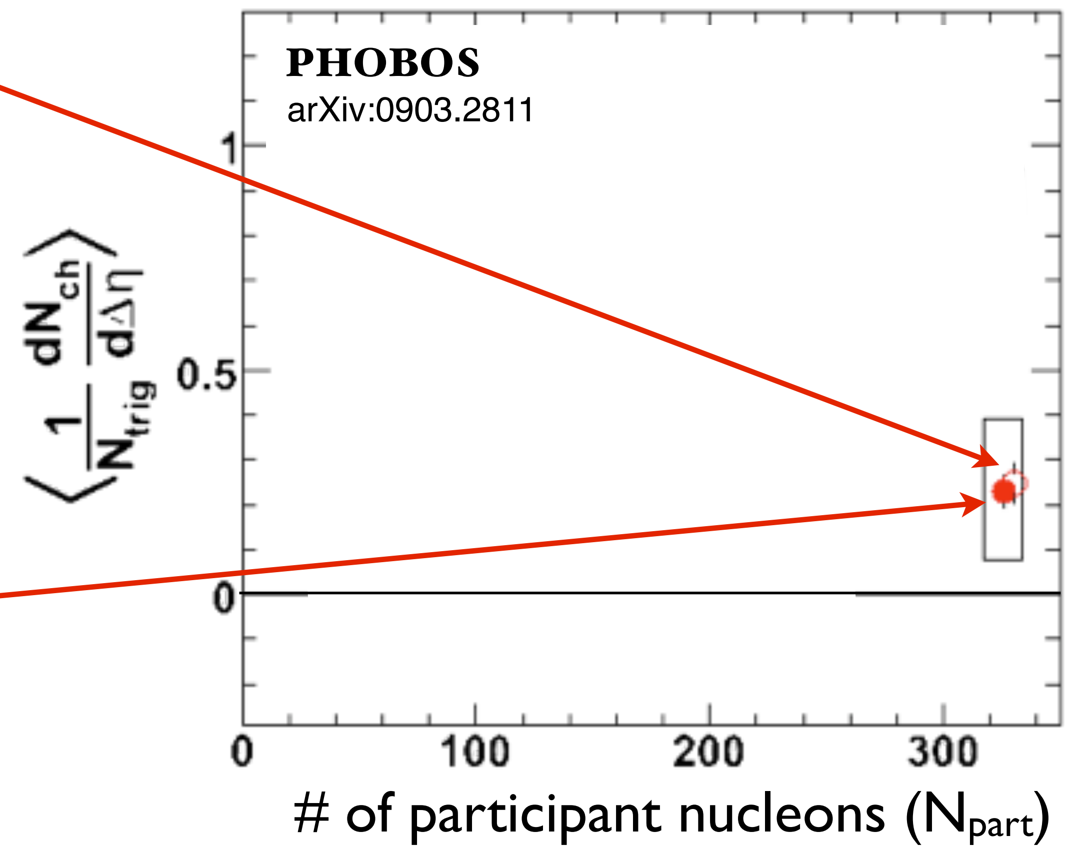
NEAR side

- ○ short-range minus PYTHIA
- ● long-range

Short-range
$|\Delta\eta| < 1$

Long-range
$-4 < \Delta\eta < -2$





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0-10%

Short-range
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Long-range
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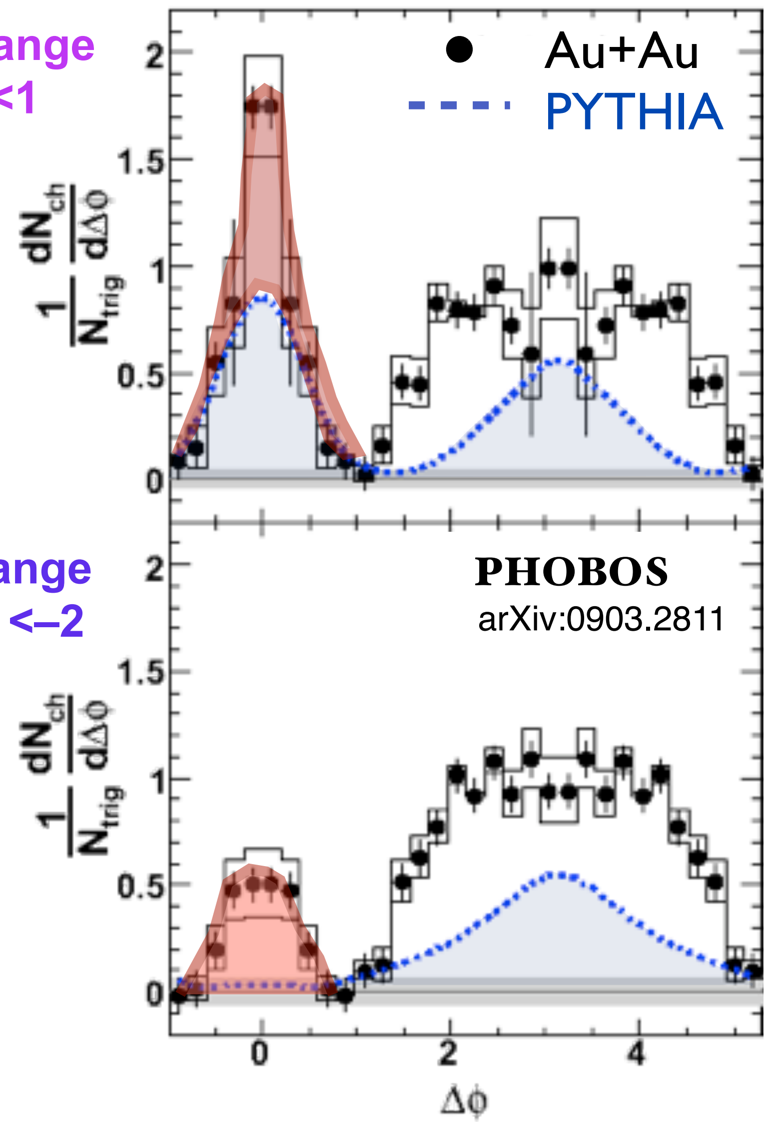

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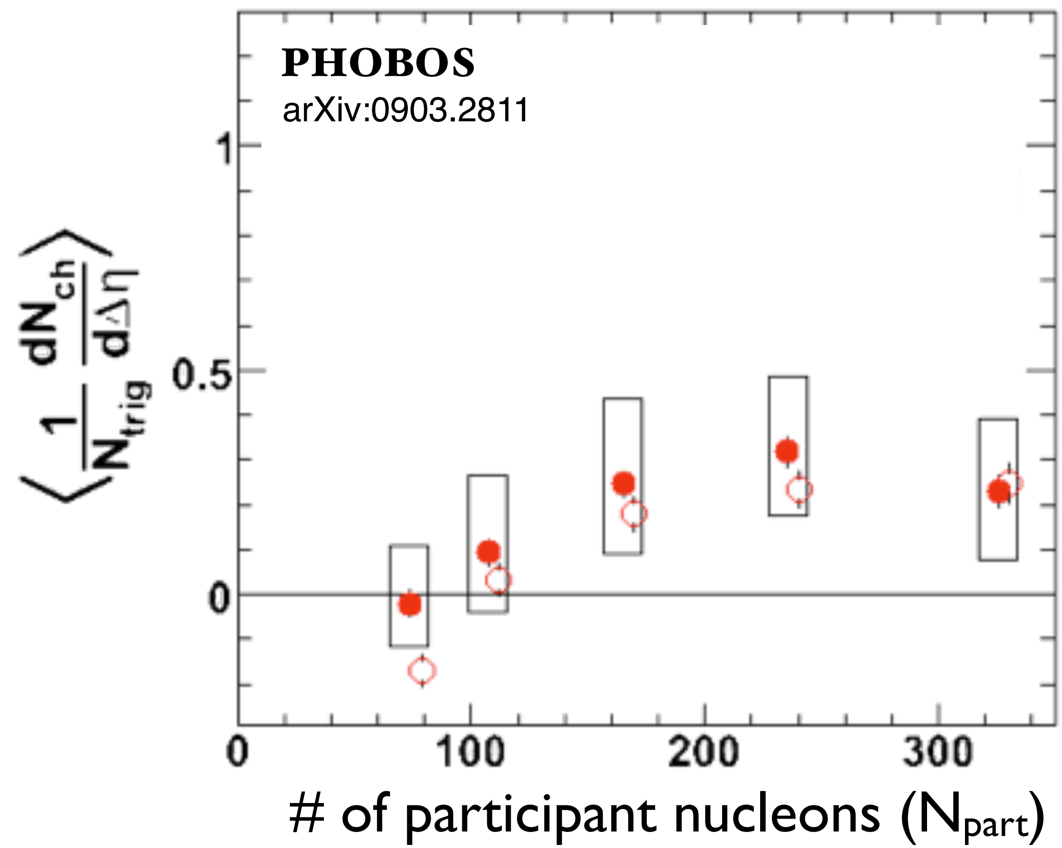

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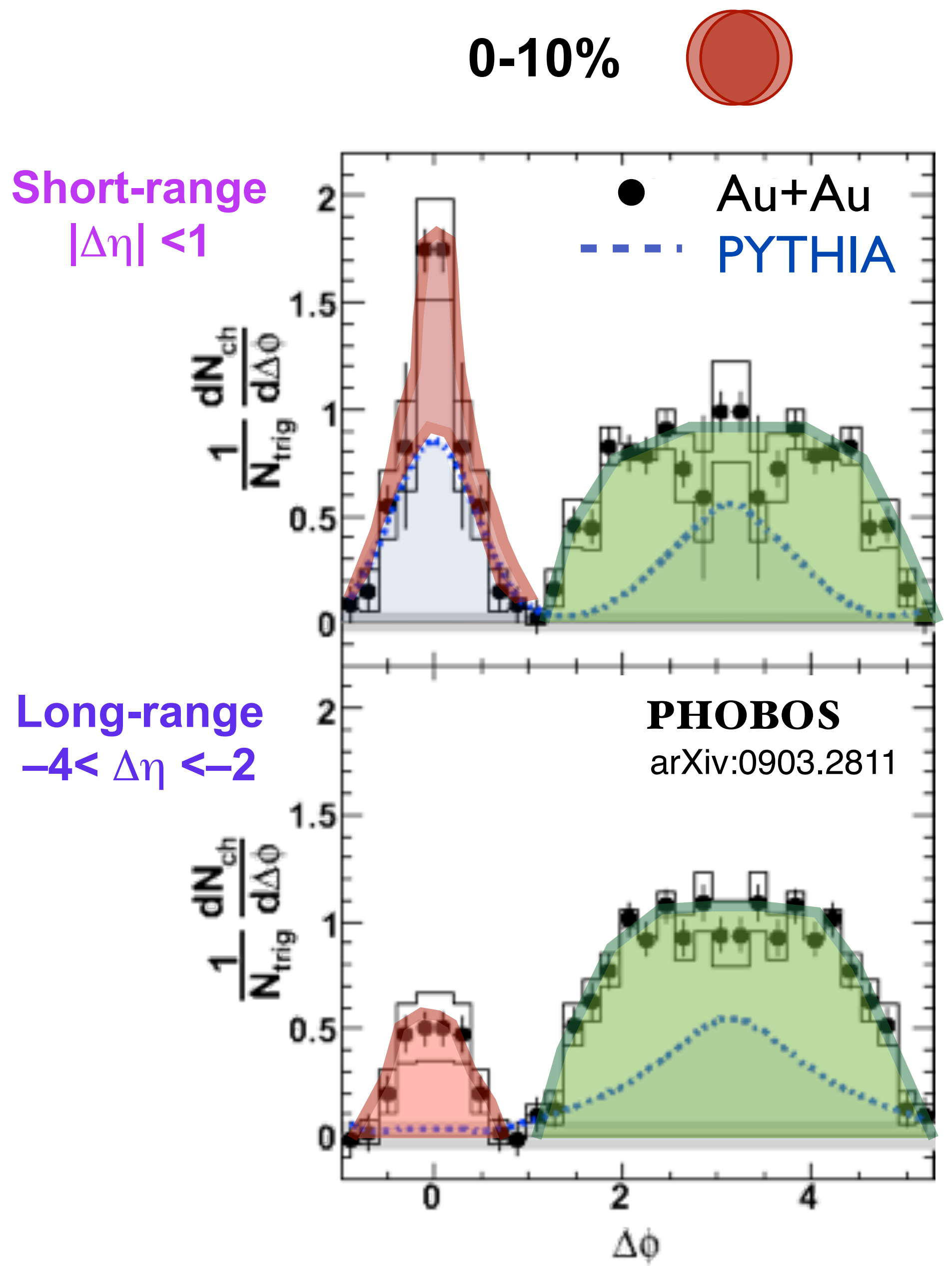

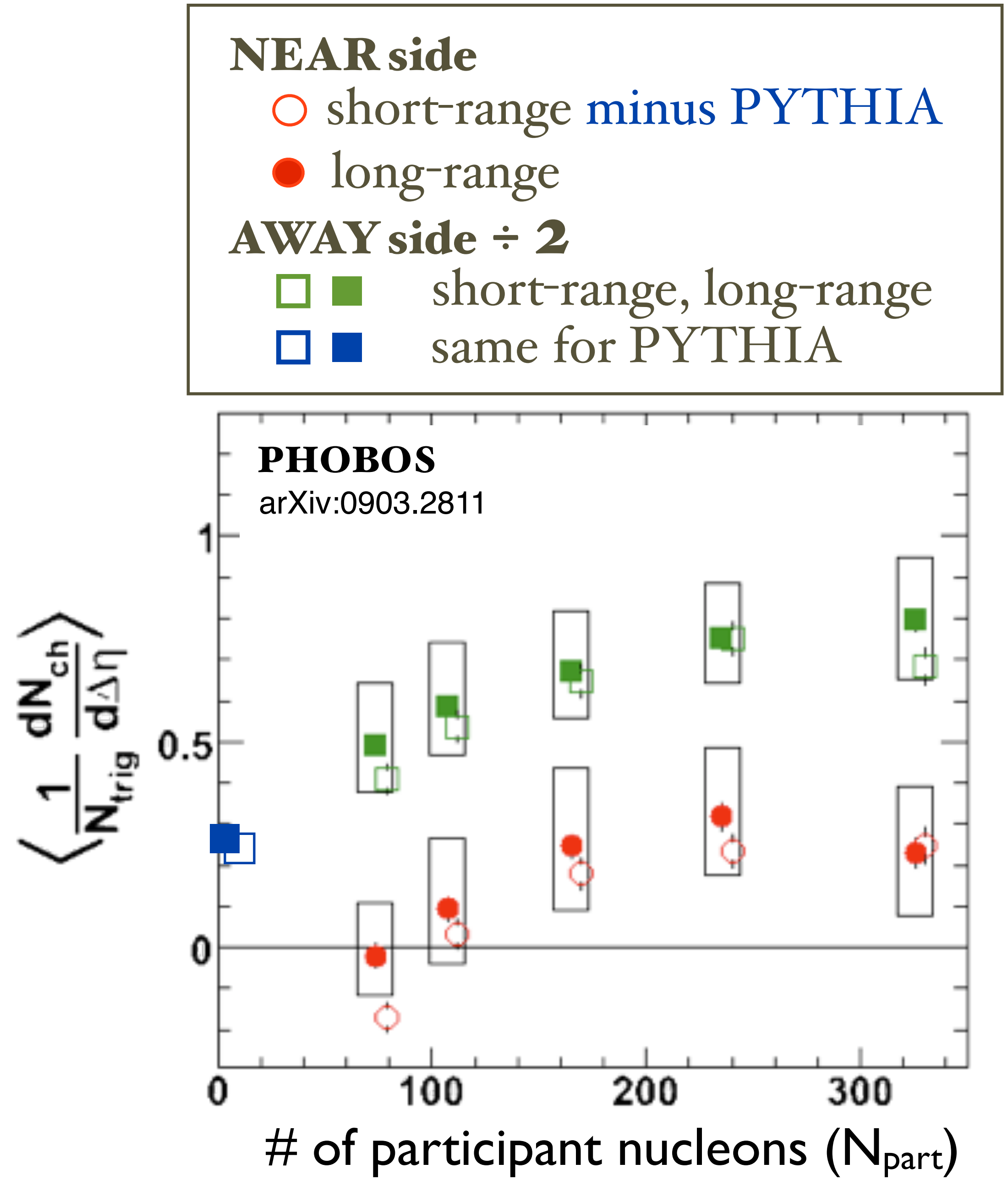

What is the “ridge” ?

- Near-side correlation persists out to at least $\Delta\eta = 4$
- Causality requires that the correlation be imprinted very early on

Dumitru, *et al,* arXiv:0804.3858

- Properties of particles in ridge similar to bulk (different from jet fragmentation)

Putschke, J. Phys., G34: S679–684, 2007 (STAR)

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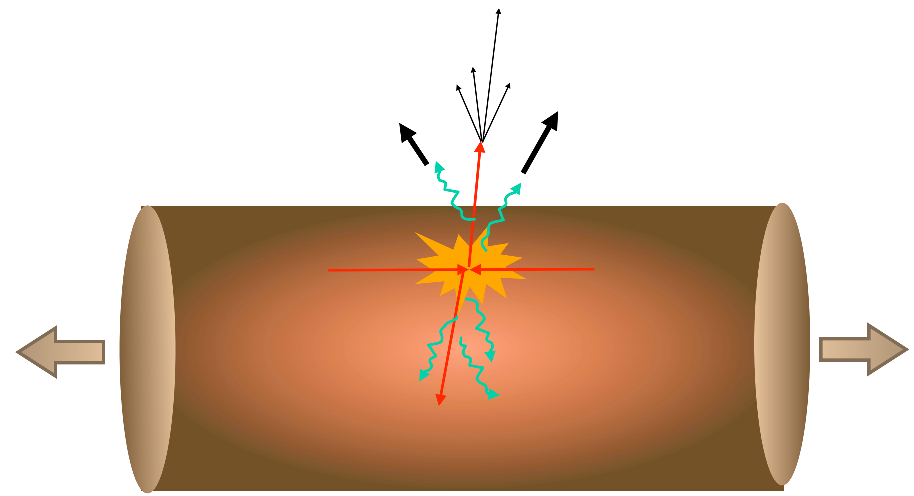
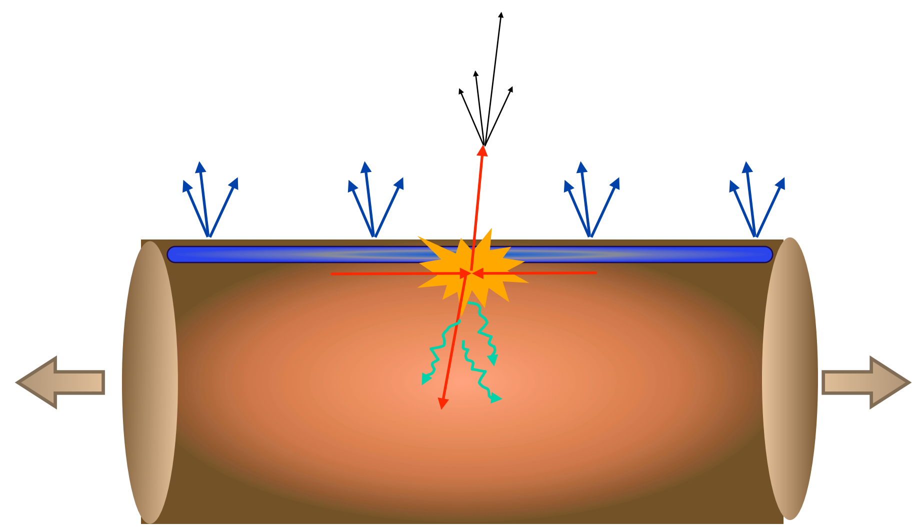
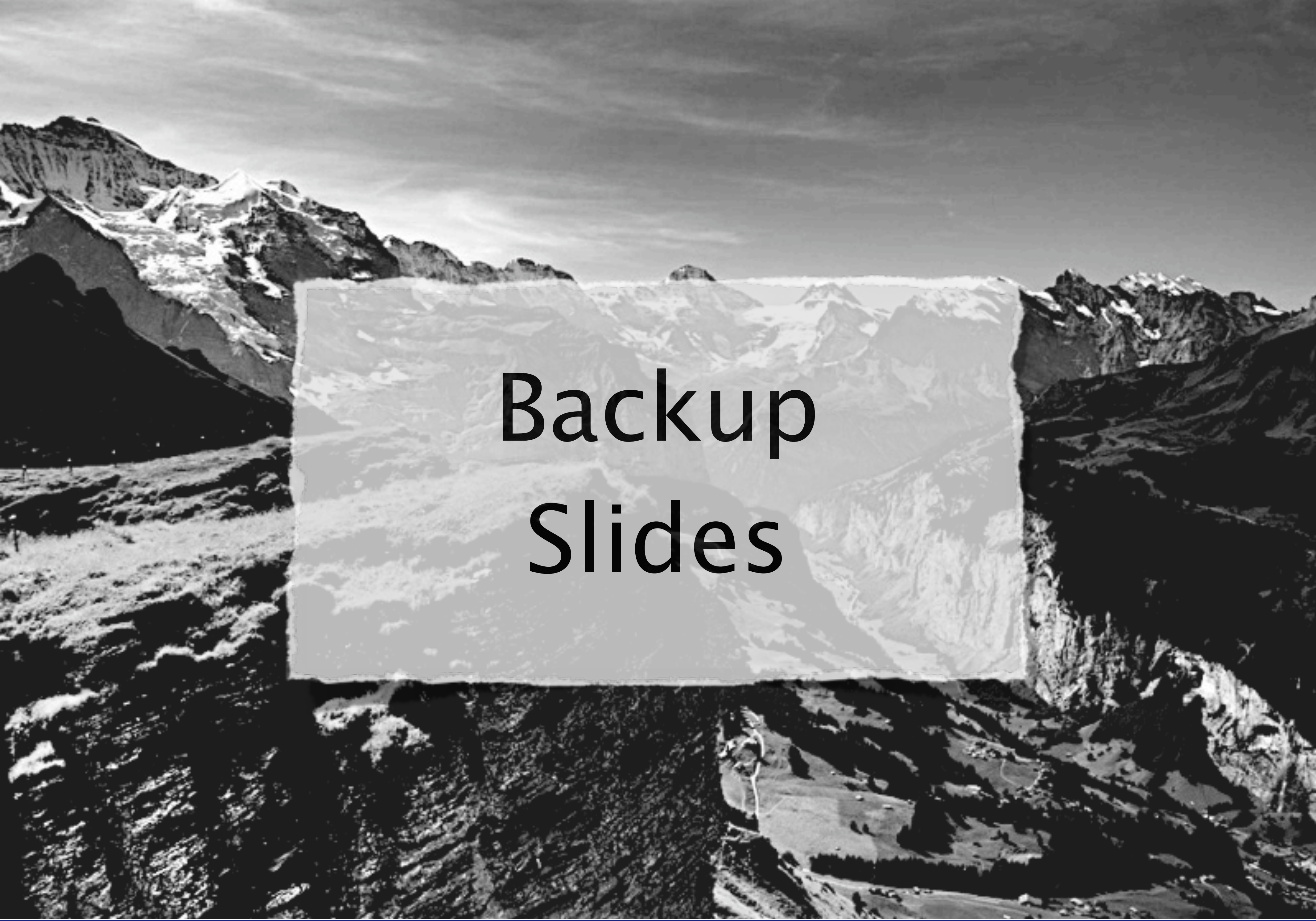




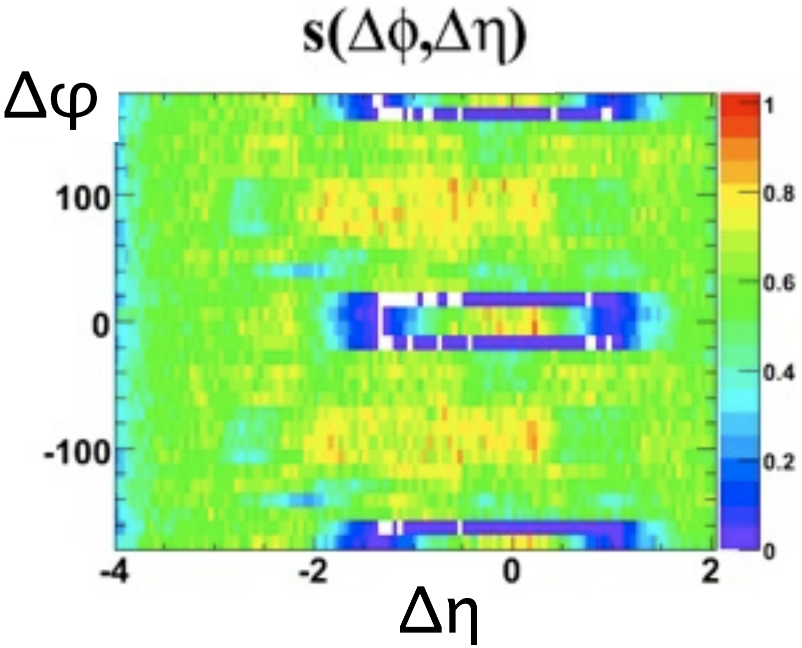
Summary

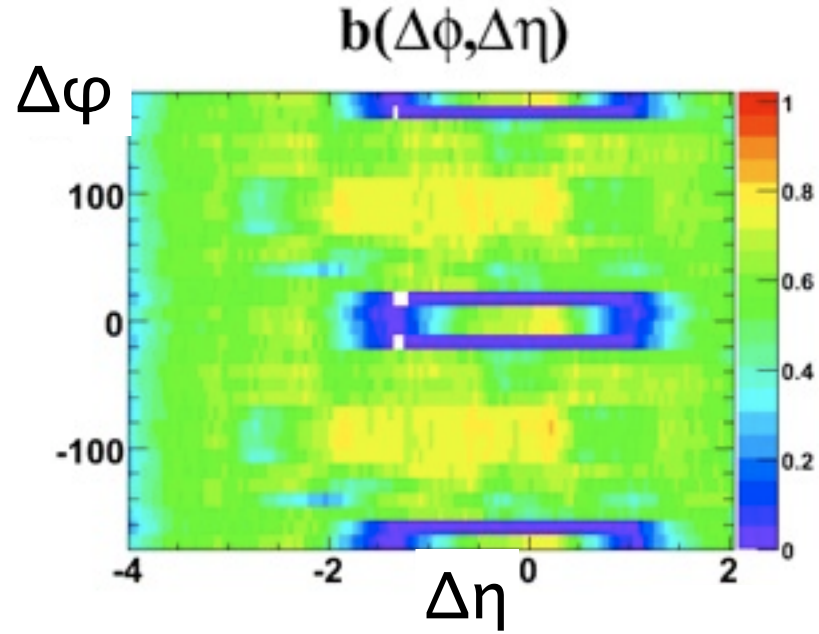
- PHOBOS measures a near-side 'ridge' in the 2-particle correlation structure in Au+Au collisions extending out to $\Delta\eta=4$
- The breath of the correlation suggests a mechanism other than medium-induced energy loss
- The magnitude of the correlation is consistent with zero for events with less than ~100 participating nucleons



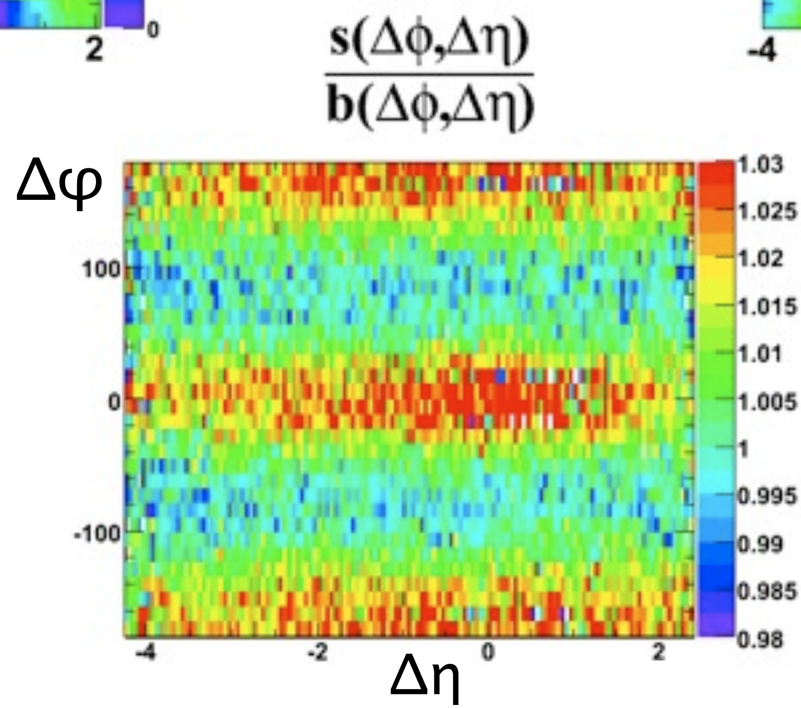
Backup Slides

Triggered Pair Acceptance





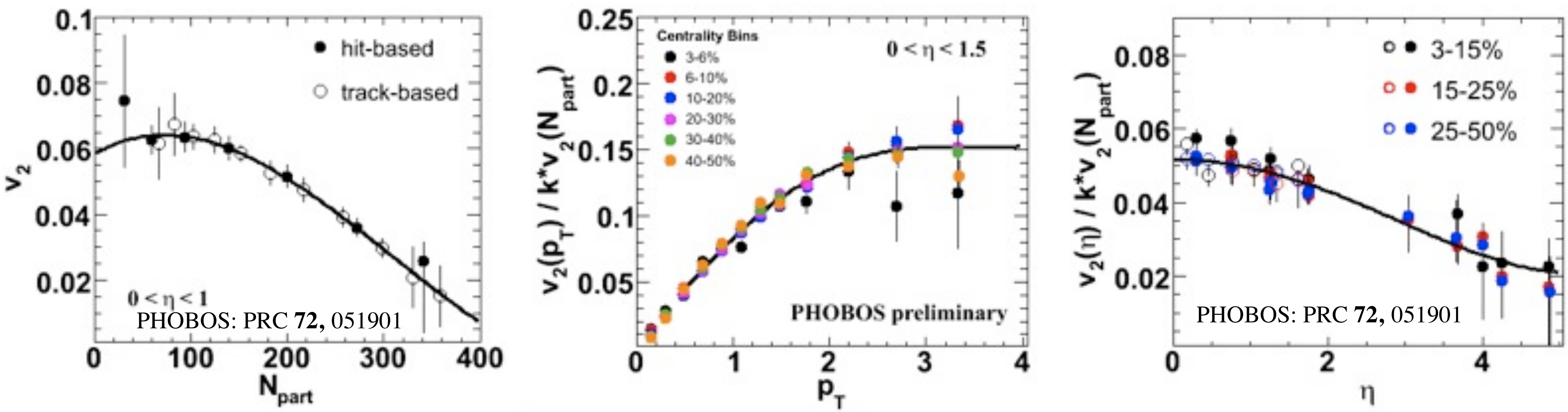
15-20% central
3mm < v_z < 4mm



averaged over
-15cm < v_z < 10cm

Estimating the Flow Term

- Parameterize published PHOBOS measurements as
  $v_2(N_{part}, p_T, \eta) \;=\; A(N_{part})\ B(p_T)\ C(\eta)$



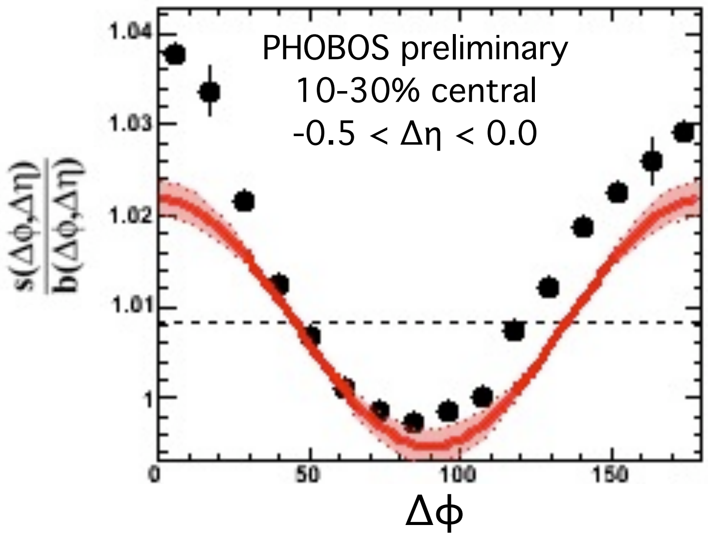
- Correct $v_2(N_{part}, \langle p_T^{trig} \rangle, \eta_{trig})$ for occupancy and $v_2(N_{part}, \langle p_T^{assoc} \rangle, \eta_{assoc})$ for secondaries

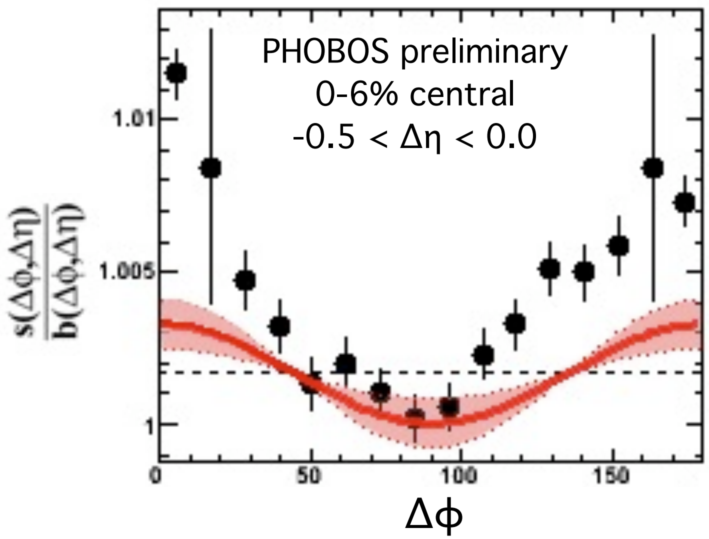
$$1 + 2V(\Delta\eta)\cos(2\Delta\phi)$$

$$V = \langle v_2^{trig} \rangle \langle v_2^{assoc} \rangle$$

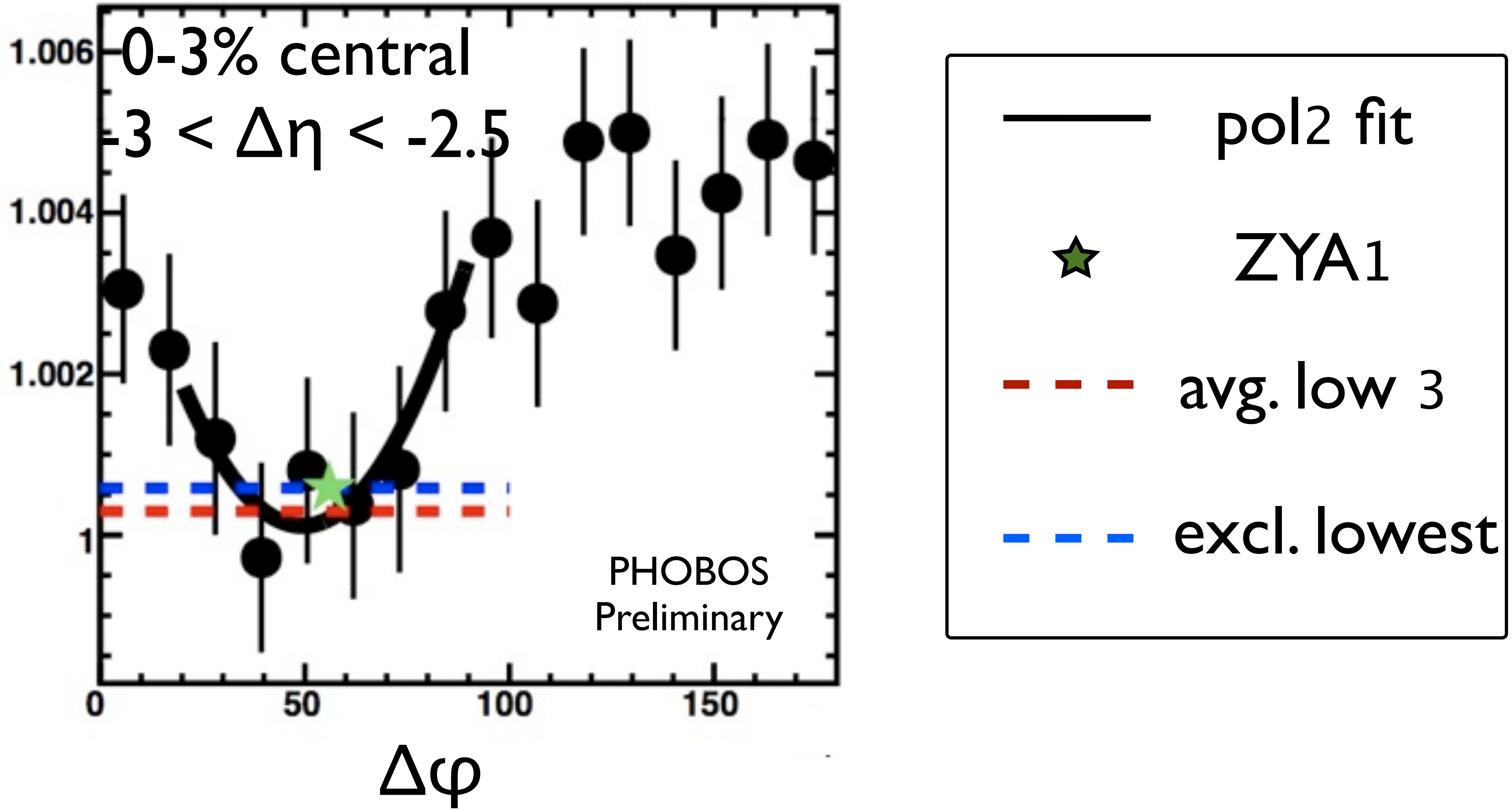
v2 Subtraction Systematics

- The dominant systematic error in this analysis is the uncertainty on the magnitude of $v_2^{trig}\ v_2^{assoc}$
  - ~14% error on $v_2^{trig}\ v_2^{assoc}$ $(\eta=0)$
  - ~20% error on $v_2^{trig}\ v_2^{assoc}$ $(\eta=3)$
  - In the most central collision -- where flow is small compared to the correlation -- the error on $v_2^{trig}\ v_2^{assoc}$ can exceed 50%.



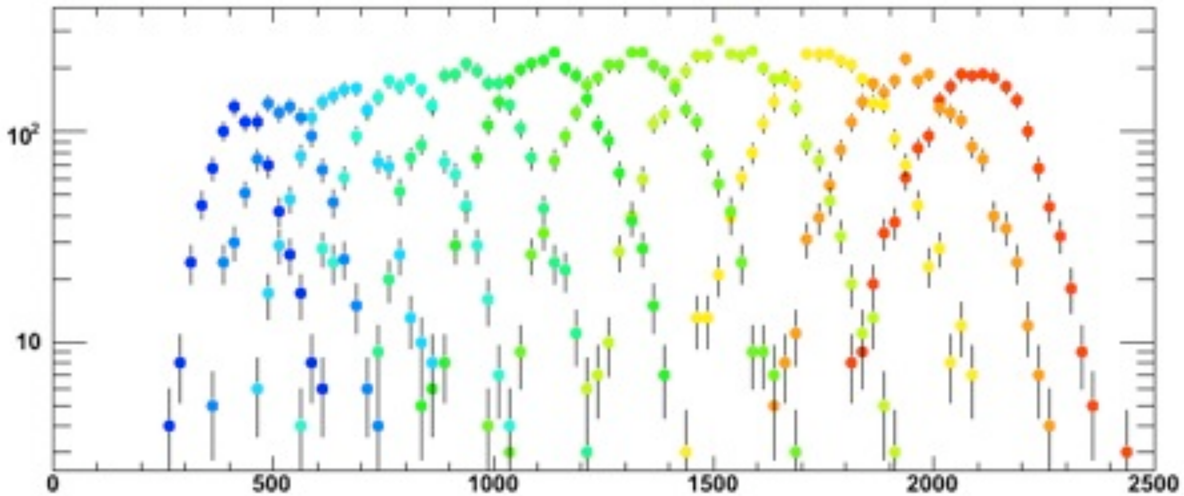


Correlation / Flow

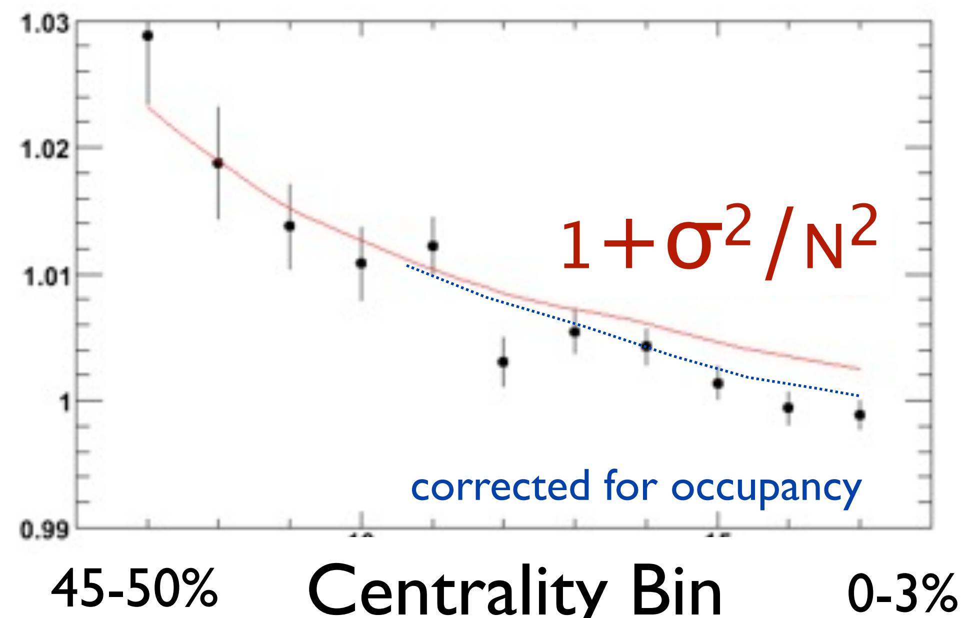


Centrality dependence of ZYAM

Number of octagon hits distribution for different centralities

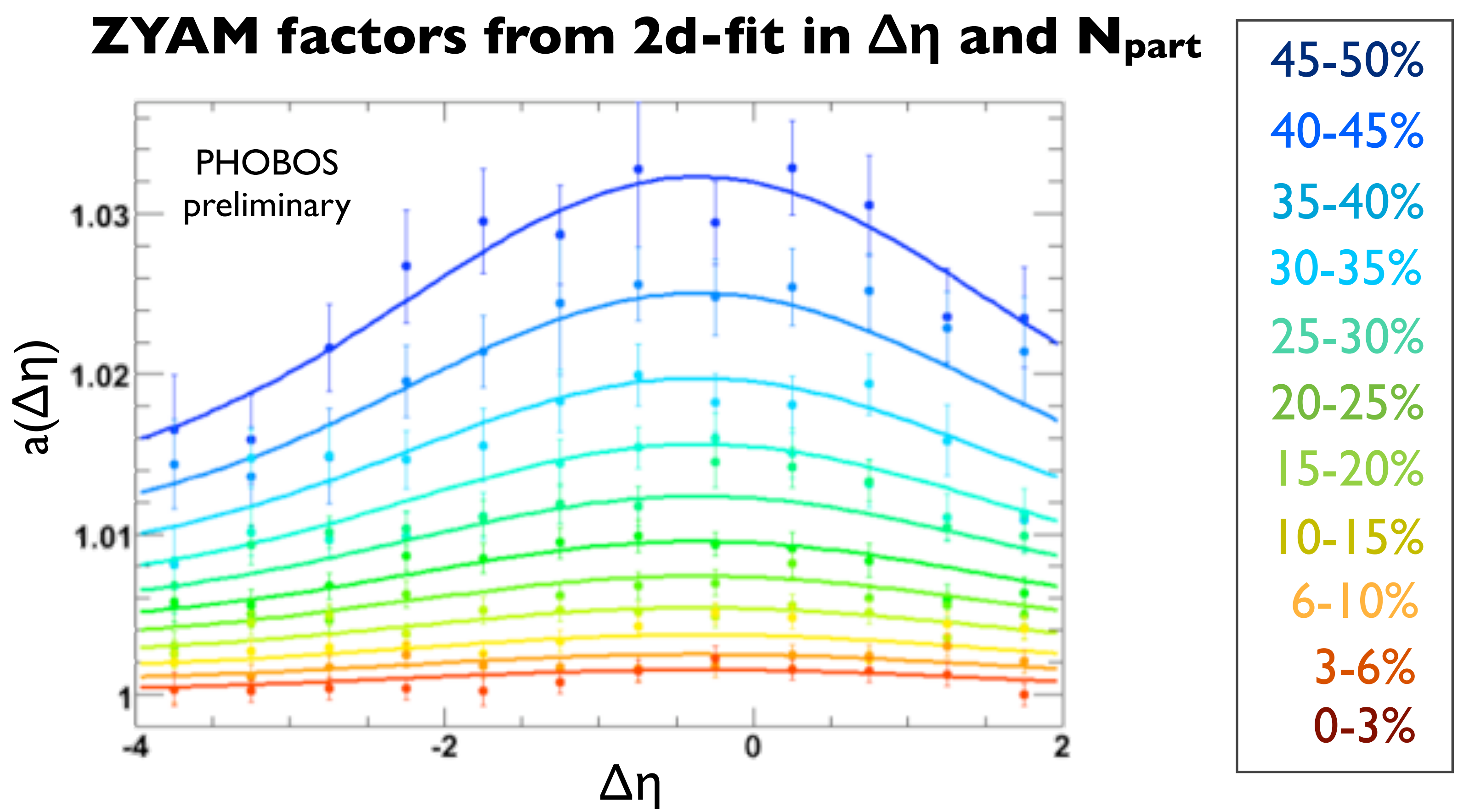


Ratio of octagon hit multiplicities (triggered / untriggered)



σ/N = relative width of centrality bin

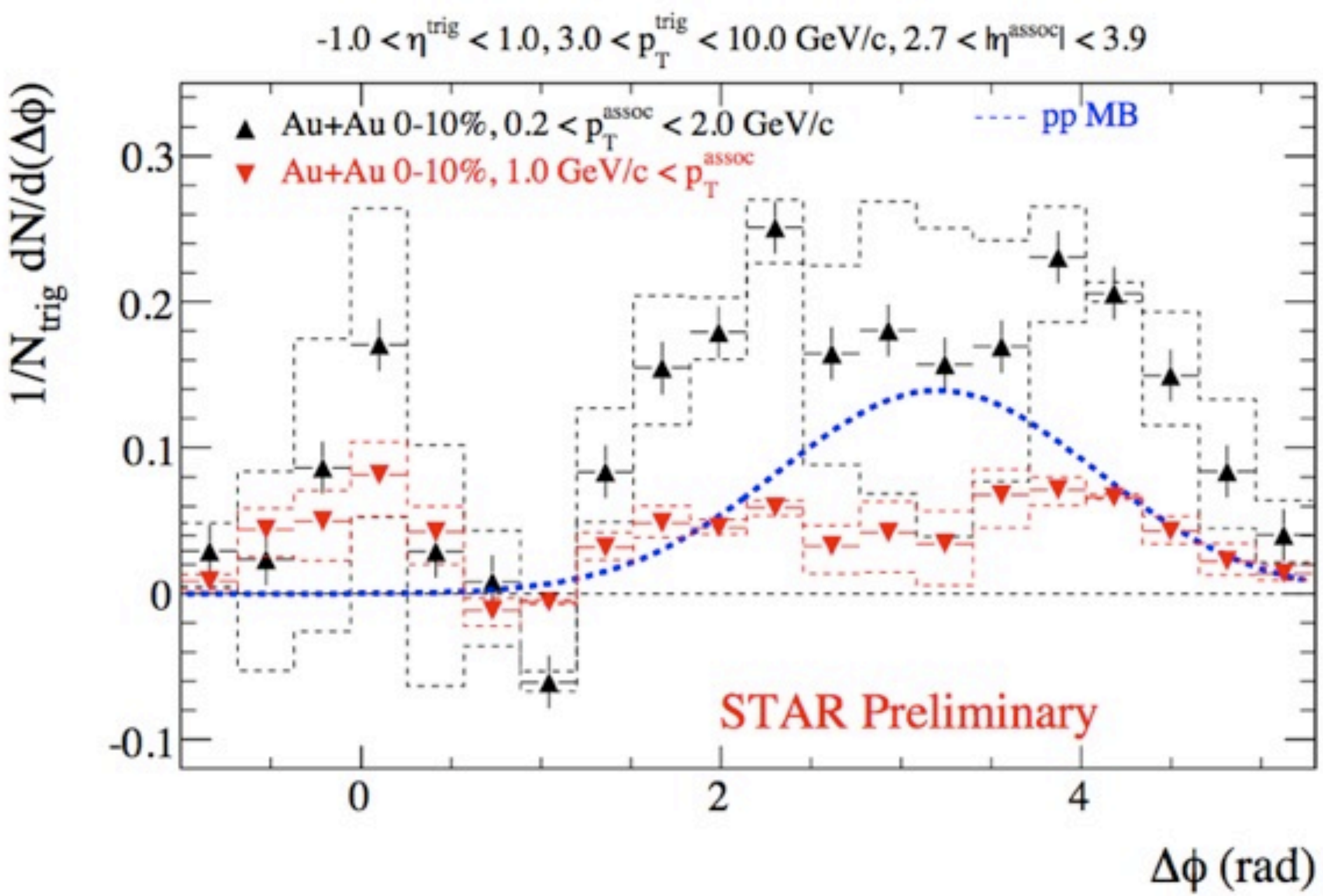
ZYAM implementation (II)



- Constant term: bias of the p_T-triggered signal distribution to higher multiplicity
- Gaussian term: Δη correlation structure underneath v_2-subtracted Δφ correlations. Width/amplitude/N_{part}-dependence same as inclusive correlations

arXiv:0812.1172 (2008)

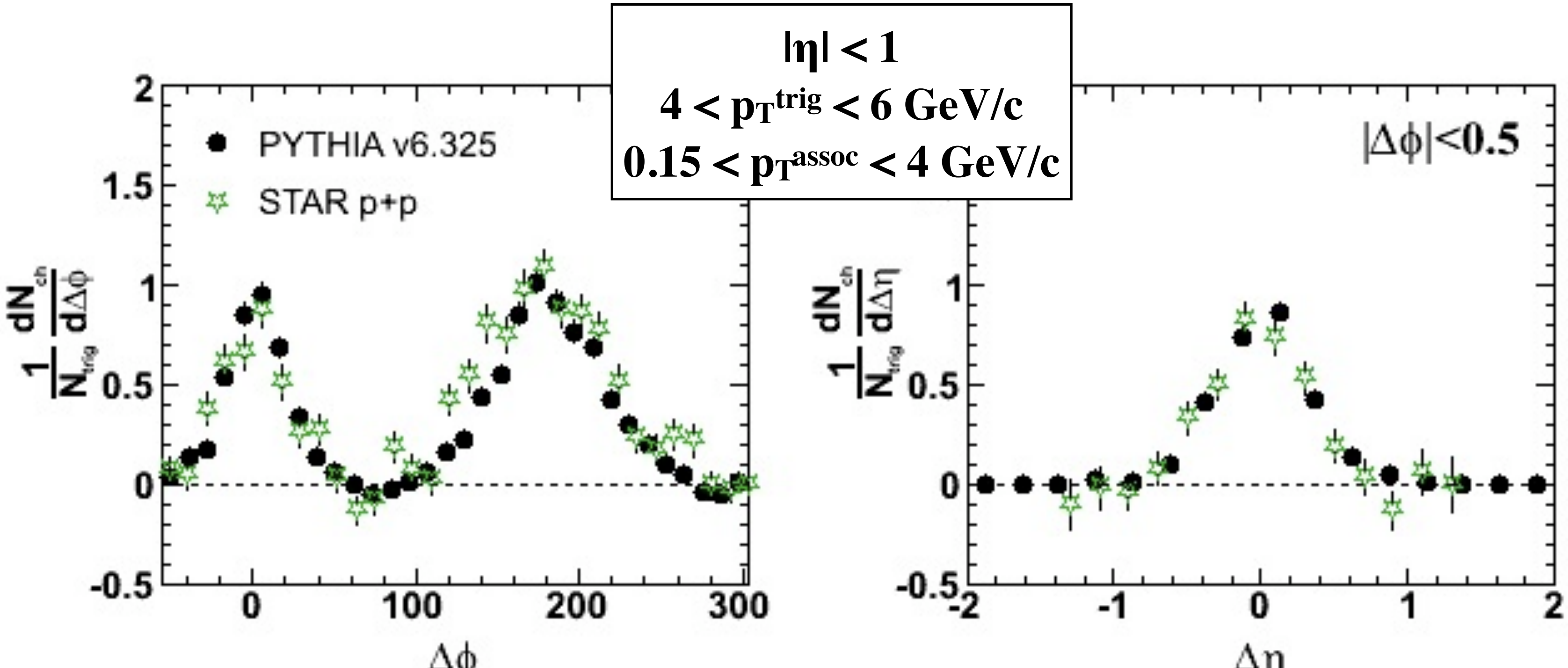
FTPC-TPC Correlation (STAR)



J. Phys. G: Nucl. Part. Phys. **34** (2007) S593–S597

STAR vs. PYTHIA

- PHOBOS is limited by statistics in p+p
- We will compare our Au+Au results to PYTHIA, which reasonably reproduces STAR p+p data



STAR, PRL **95,** 152301 (2005)