Recent STAR Jet and High p_T Results

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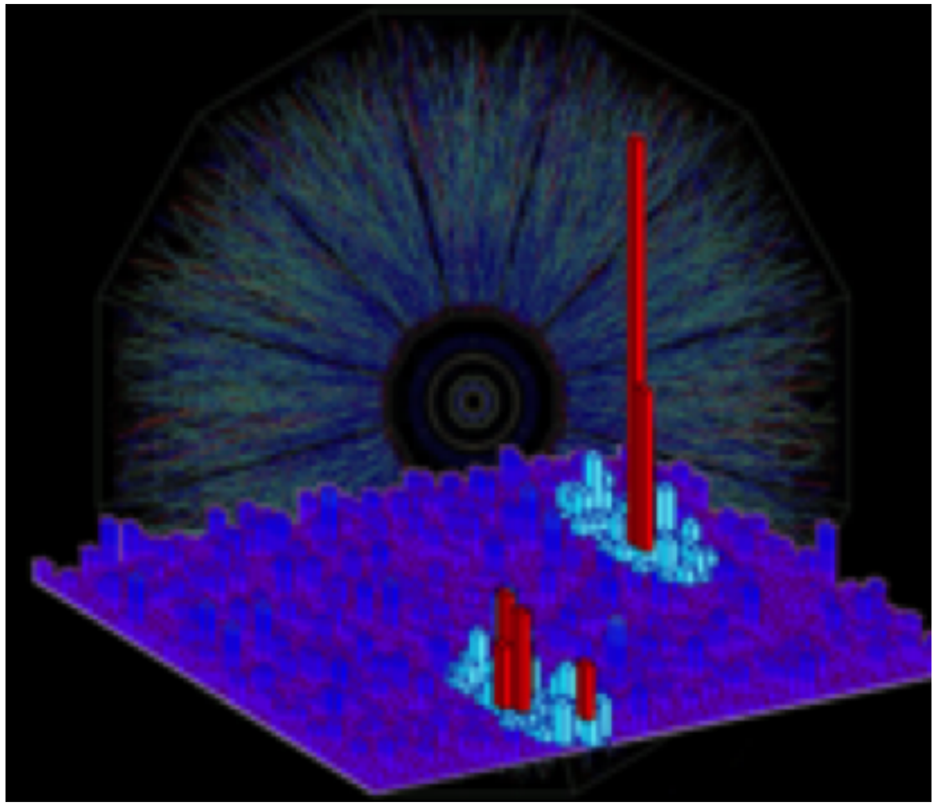
Outline

- Motivation
- Jet geometry selection with trigger bias
- Dihadron with event shape engineering
- Summary

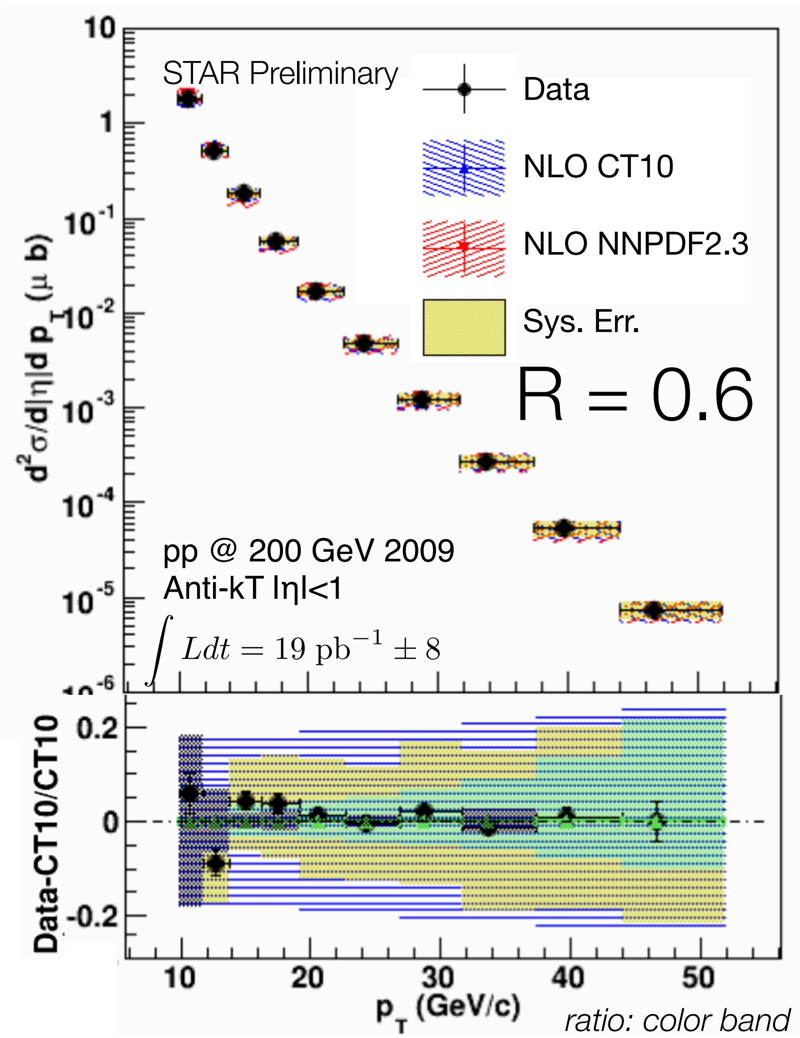


Jets in Vacuum: pp@200 GeV

Jets: reduce complexity of many hadrons to single objects

Inclusive Jet

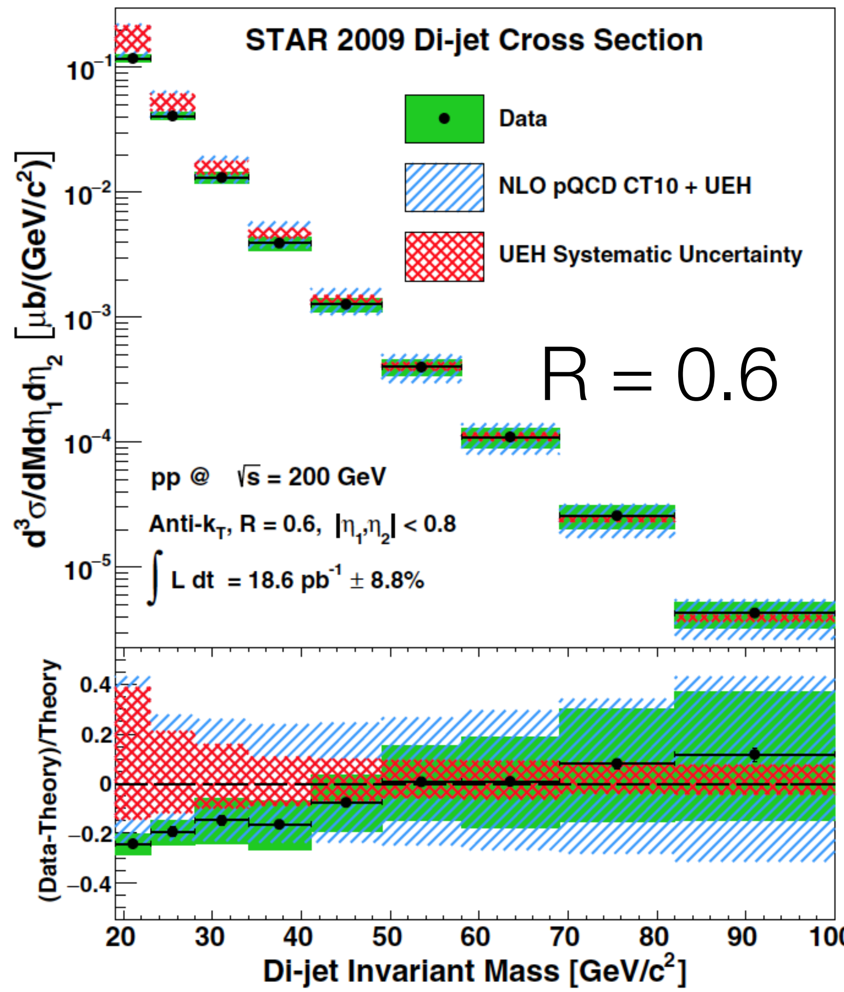
jet cross section



ratio: color band for various sys. err.

Dijet

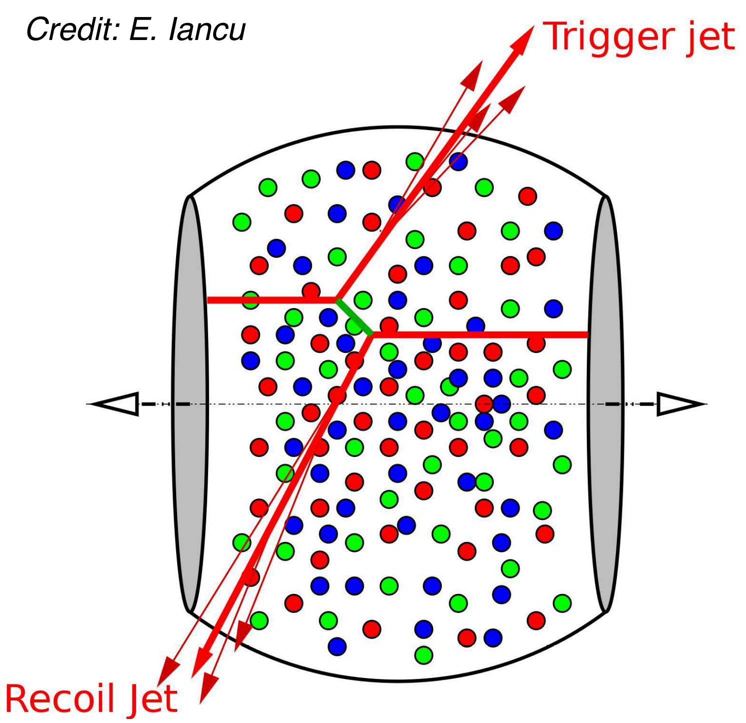
dijet cross section



*STAR, PRD. **95**, 071103(R) 2017*

Well described by NLO pQCD → Jets as high precision tool

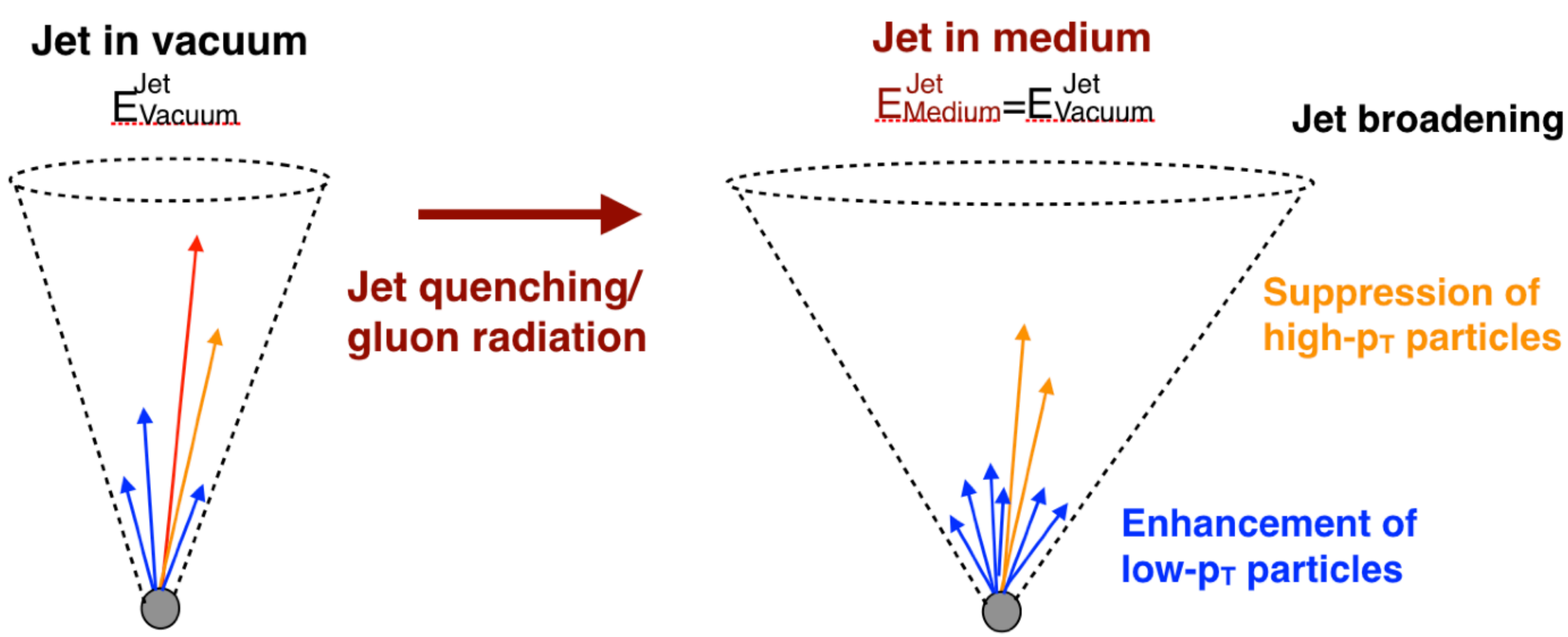
Jets as QGP Probe



partonic energy loss:

- gluon radiation (primary)
- collisional energy loss (small)

—> broadening and softening



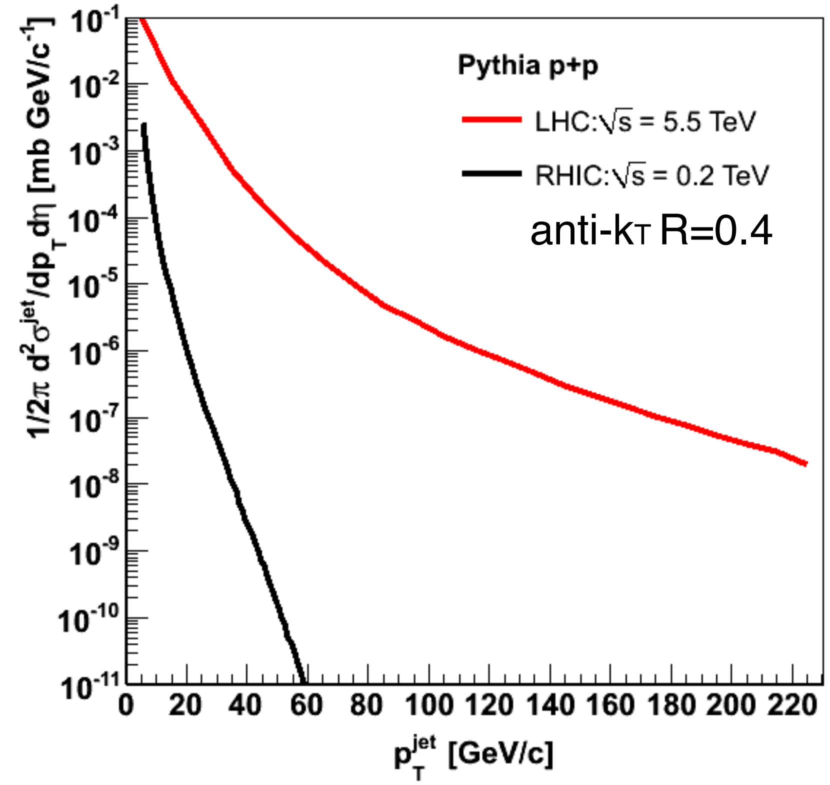
Experimental Knobs on Jet Energy Loss

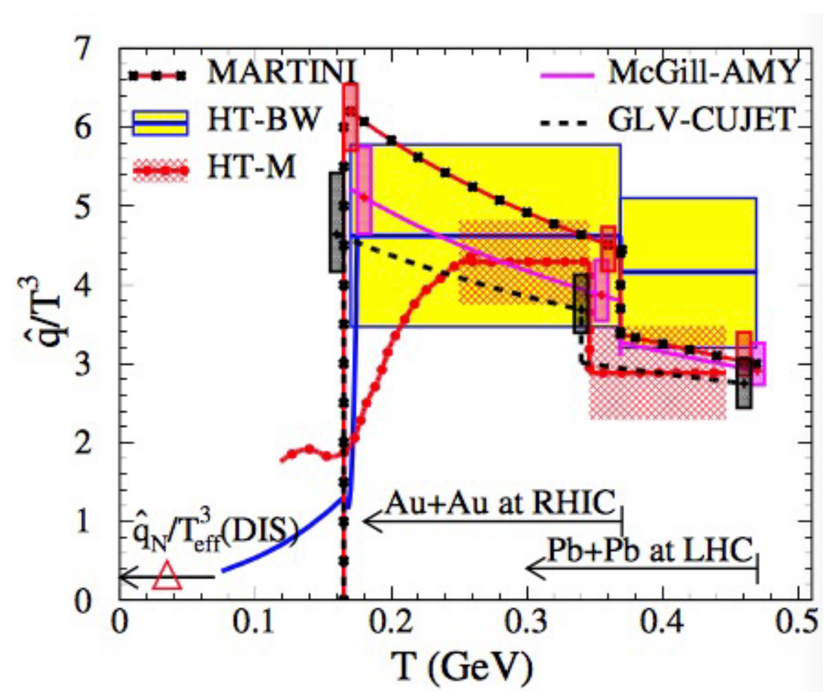
- Collision energies
    - Parton spectra
    - Medium properties

- Jet geometry selections with trigger bias

- Medium event shape engineering

Credit: N. Elsey



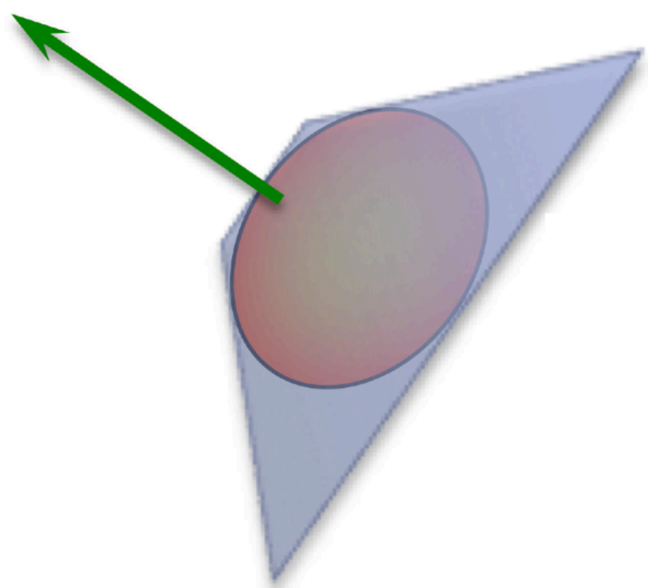


JET: PRC 90 (2014) 014909

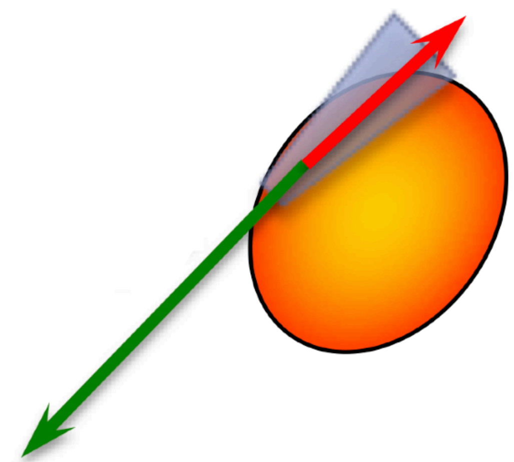
Jet Geometry Selections with Trigger Bias

Hadron and jet triggers —> Surface bias

Leading hadron



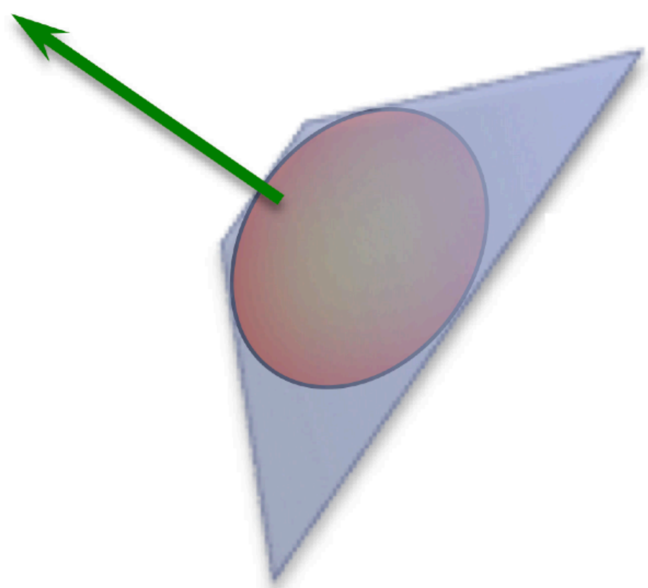
Hard-core dijets



Opportunity for jet vertex and dijet orientation selections

Leading Hadron Recoiled Jets

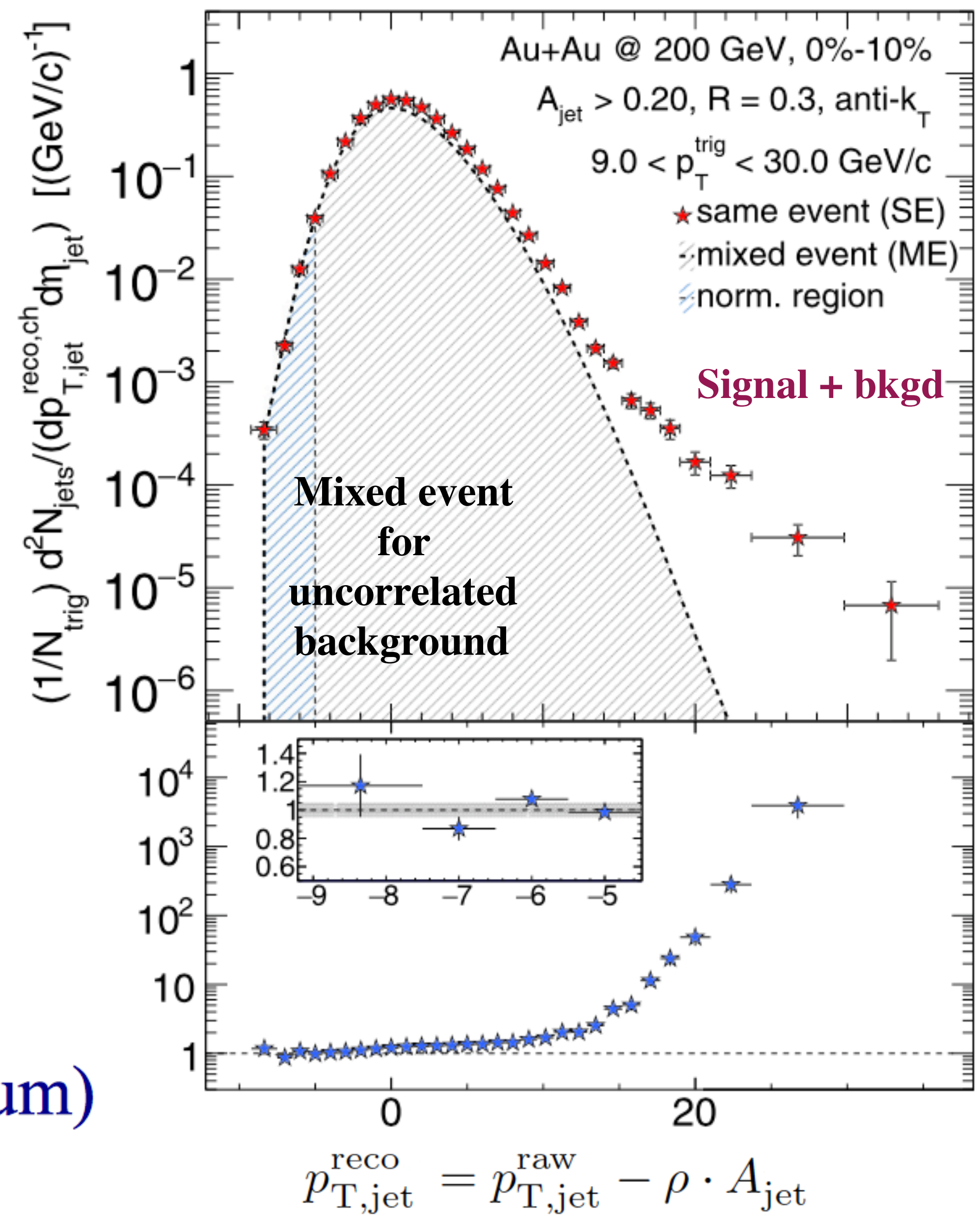
*STAR, PRC **96**, 024905 (2017)*



$$\frac{1}{N^h_{trig}}\frac{dN_{jet}}{dp_{T,jet}} = \frac{1}{\sigma^{AA\to h+X}}\frac{d\sigma^{AA\to h+jet+X}}{dp_{T,jet}}$$

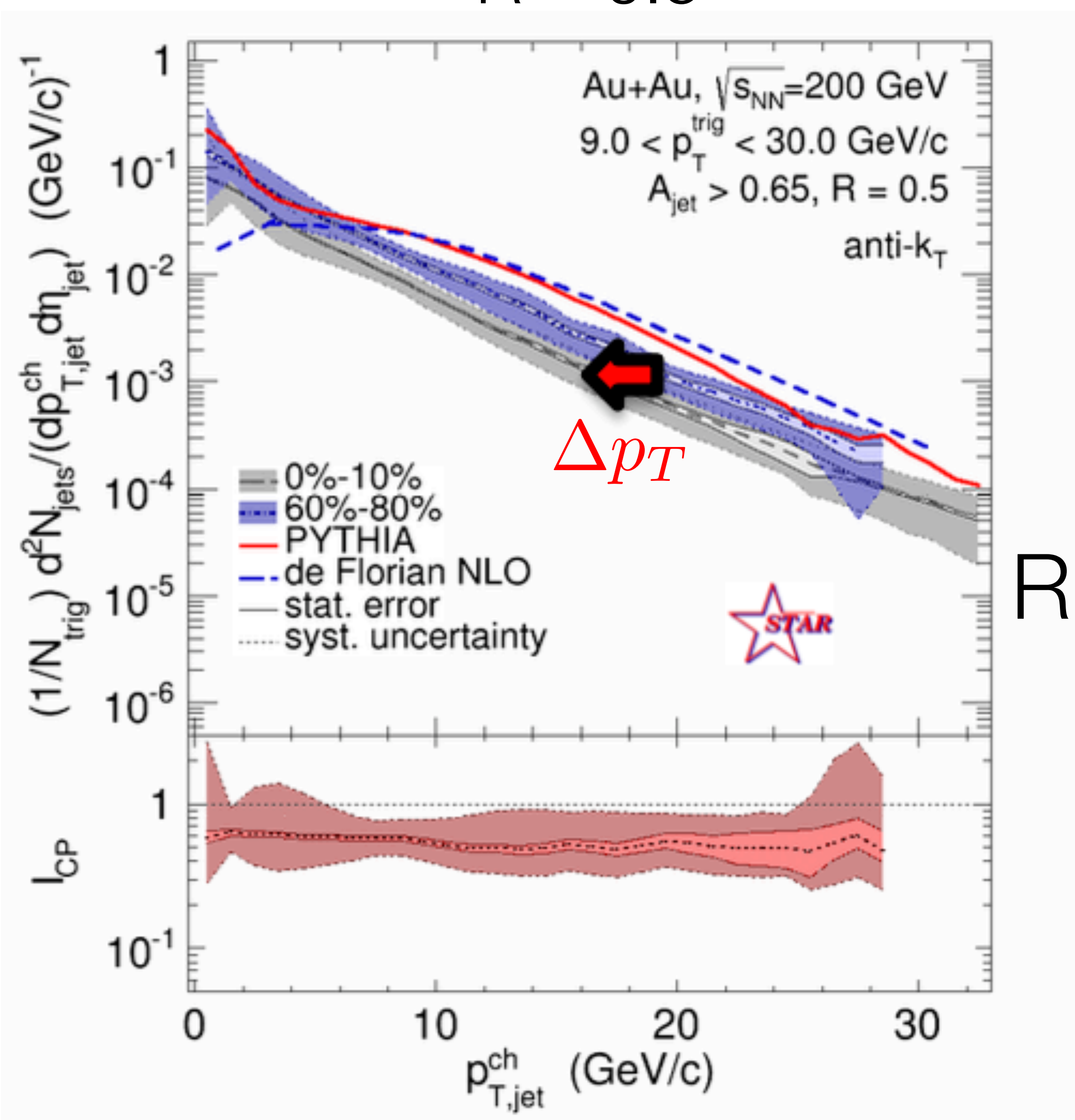
Measurable   Calculable in pQCD (in vacuum)

charged jet
R = 0.3



Energy Shift Out of Cone

charged jet
R = 0.5



STAR, PRC 96, 024905 (2017)

Spectrum shift → energy transport out-of-cone

System	Au+Au $\sqrt{s_{NN}} = 200$ GeV	Pb+Pb $\sqrt{s_{NN}} = 2.76$ TeV
$p^{ch}_{T,jet}$ range (GeV/c)	[10,20]	[60,100]
	p_T-shift of $Y(p^{ch}_{T,jet})$ (GeV/c)	
	peripheral→central	p+p→central
R 0.2	$-4.4 \pm 0.2 \pm 1.2$	
0.3	$-5.0 \pm 0.5 \pm 1.2$	
0.4	$-5.1 \pm 0.5 \pm 1.2$	
0.5	$-2.8 \pm 0.2 \pm 1.5$	-8 ± 2

ALICE, JHEP 09 (2015) 170

R=0.5: smaller shift at RHIC than LHC
→ lower energy loss at RHIC
but larger $\Delta p_T / p_T^{jet}$ at RHIC

Energy Shift Out of Cone

charged jet
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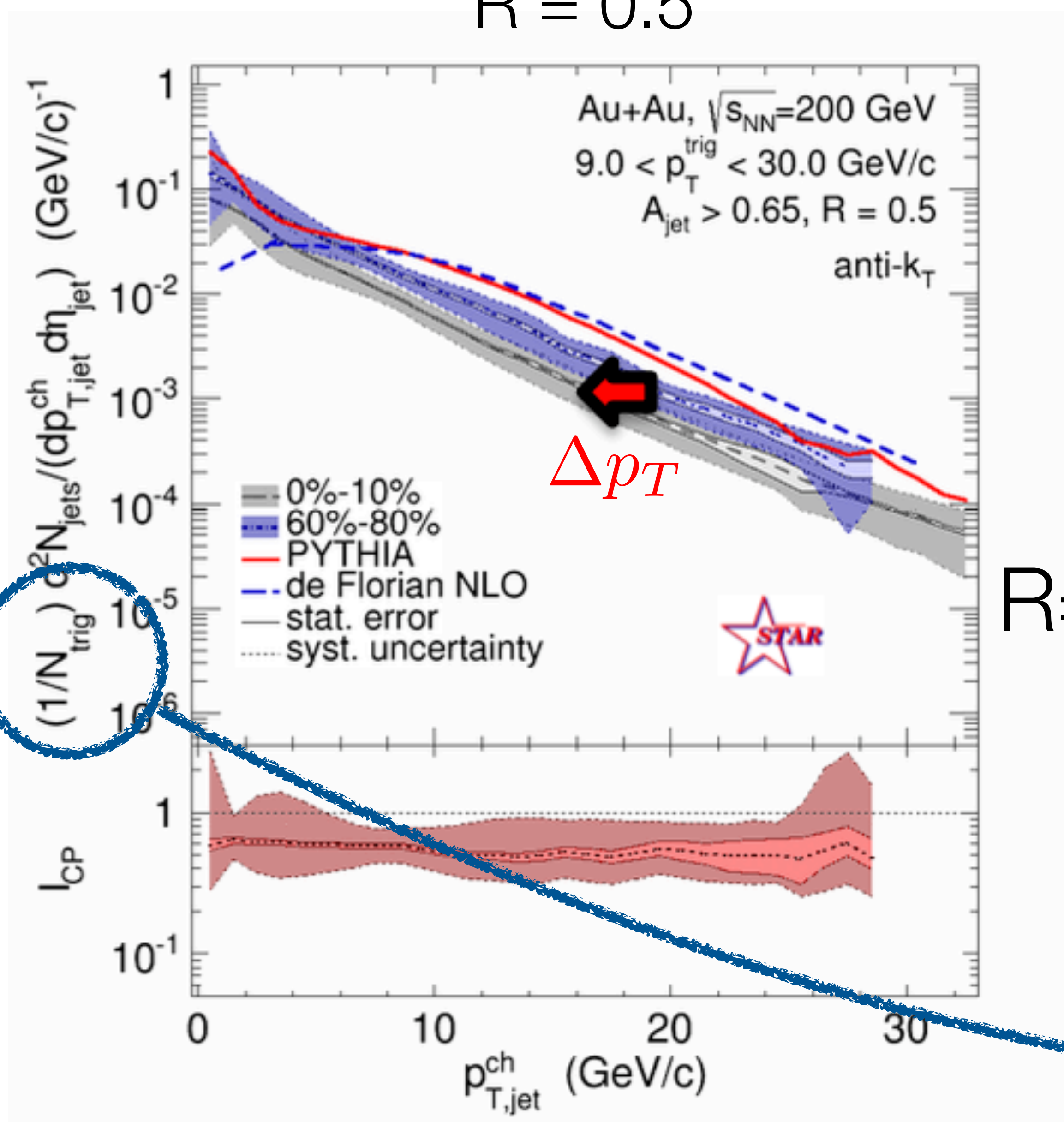

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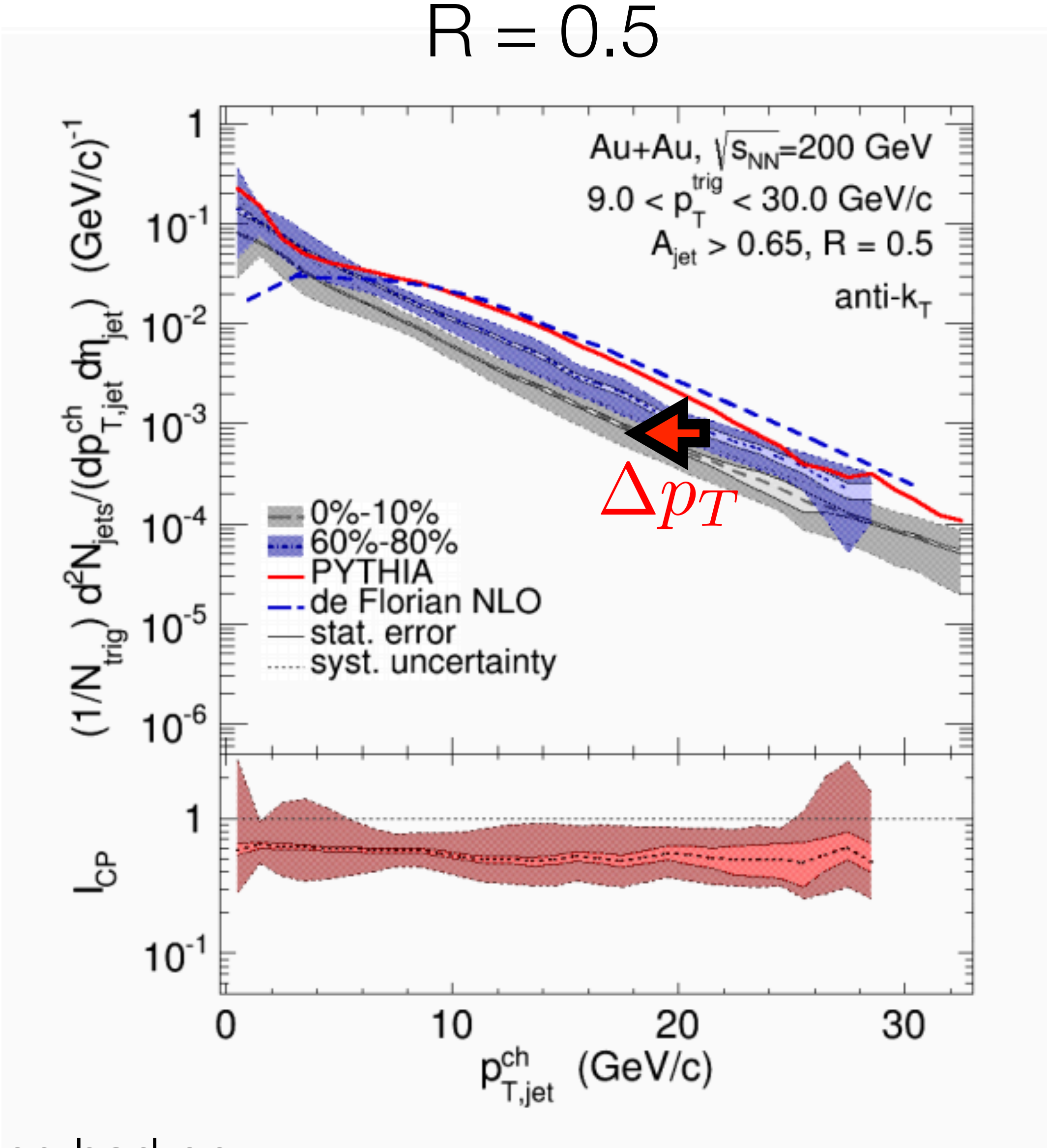
Not a cross section measurement
per trigger instead of per event

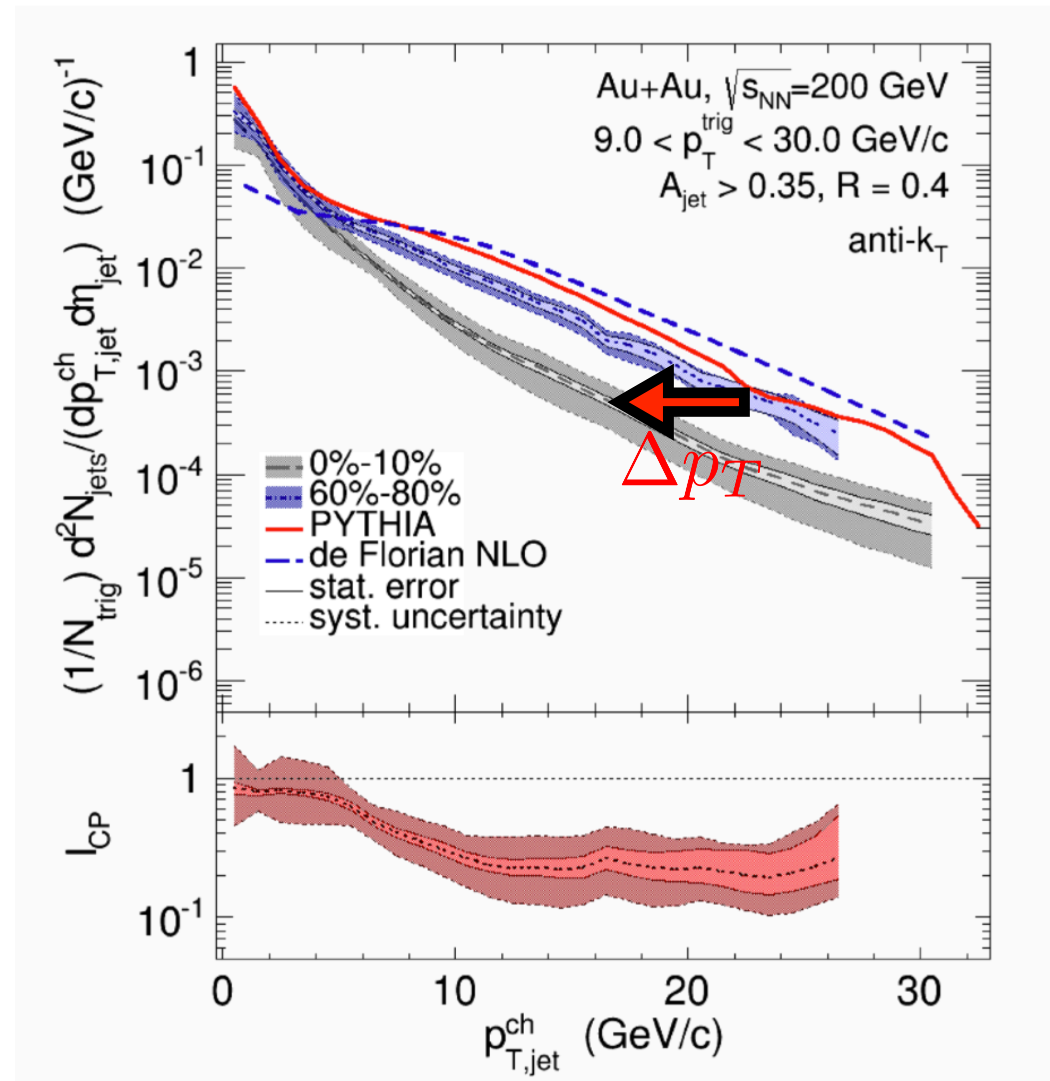
- No N_{coll} needed (from Glauber)
- Minimal sensitivity to cold nuclear matter effect

Jet Broadening

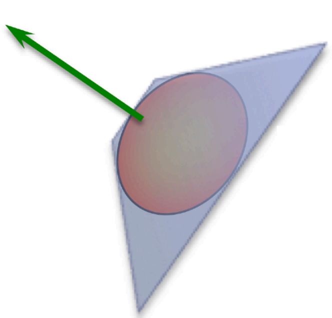
R = 0.5



R = 0.4



Leading hadron



Smaller R, larger energy shift

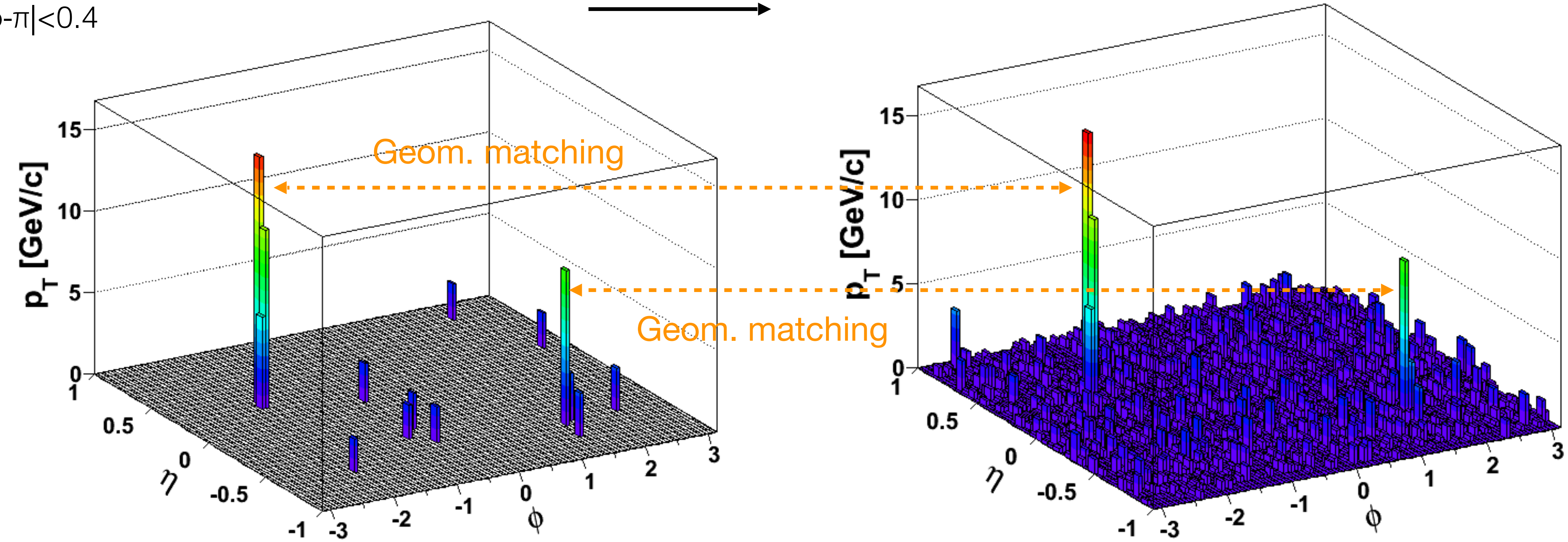
Broadening for R = 0.4

Hard-core Dijets

$p_{T,cut}$=2 GeV/c
p_T^{Lead}>20 GeV/c
$p_T^{SubLead}$>10 GeV/c
$|\Delta\phi-\pi|<0.4$

Rerun jet-finding algorithm anti-k_T for **these dijets**

$p_{T,cut}$=0.2 GeV/c
p_T^{Lead}>20 GeV/c ($p_{T,cut}$=2 GeV/c)
$p_T^{SubLead}$>10 GeV/c ($p_{T,cut}$=2 GeV/c)



Locate dijet with high p_T particle cuts

—> removes almost all background

Geometric matching

—> no combinatoric jets

Reconstruct jets with low p_T particle cuts

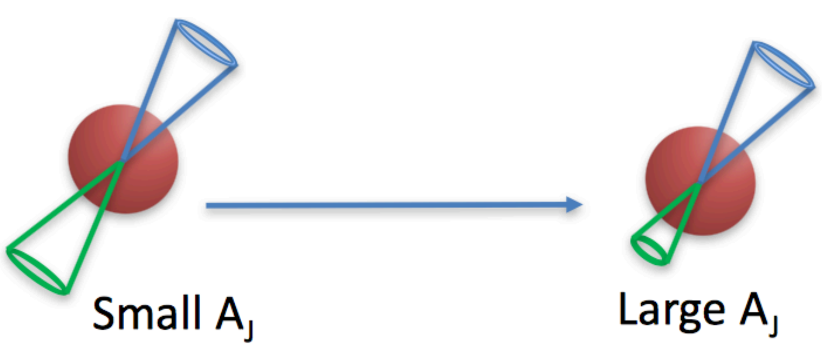
—> recover all constituents

Dijets Asymmetry

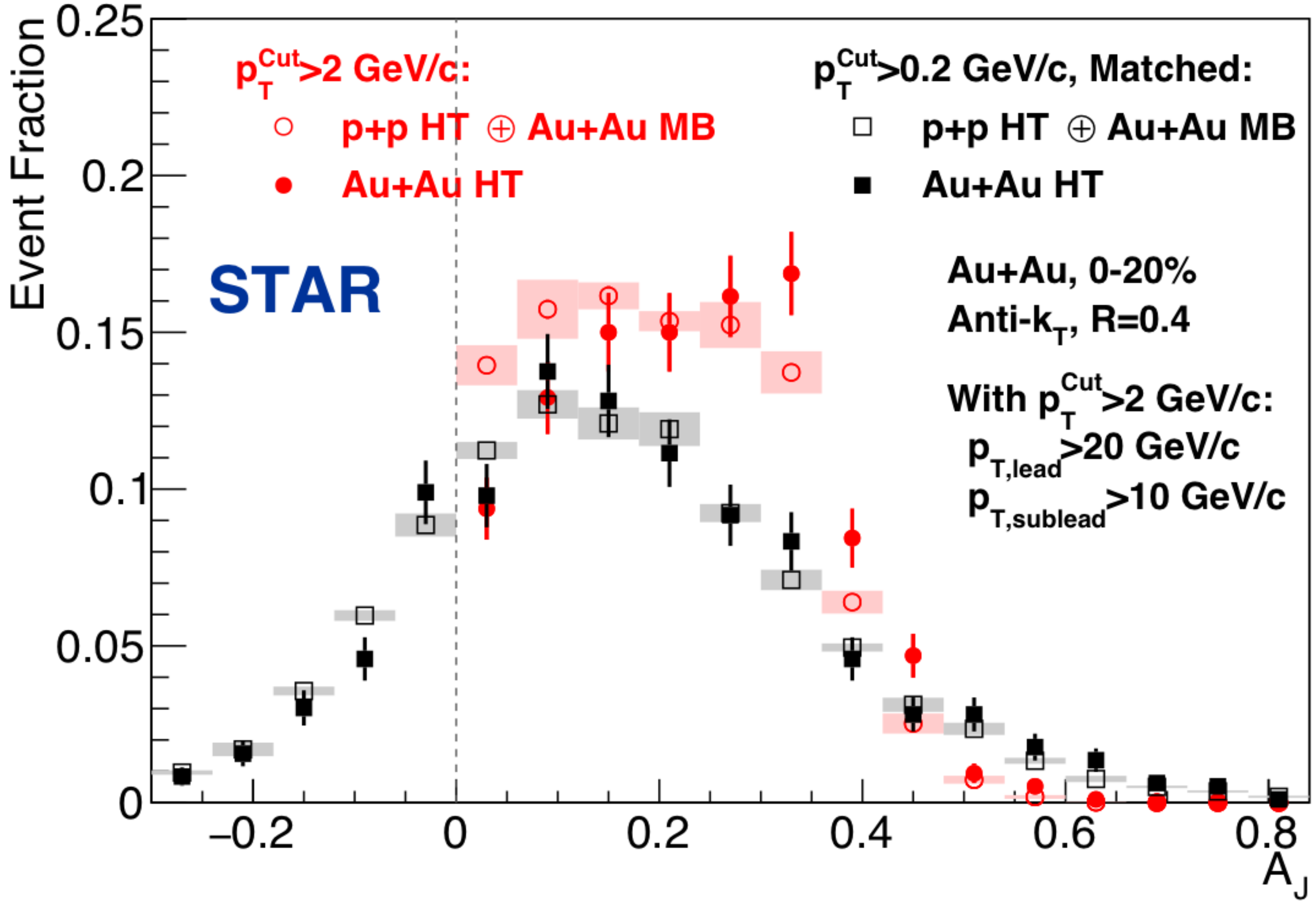
*STAR, PRL **119**, 062301 (2017)*

for **hard core** matched dijets

$$A_J = \frac{p_T^{\mathrm{Lead}} - p_T^{\mathrm{SubLead}}}{p_T^{\mathrm{Lead}} + p_T^{\mathrm{SubLead}}}$$



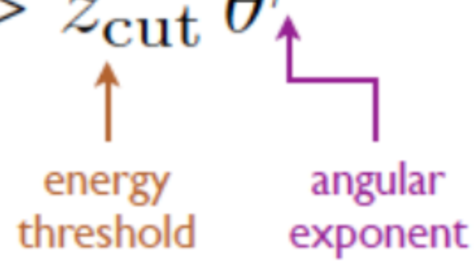
credit: K. Jung

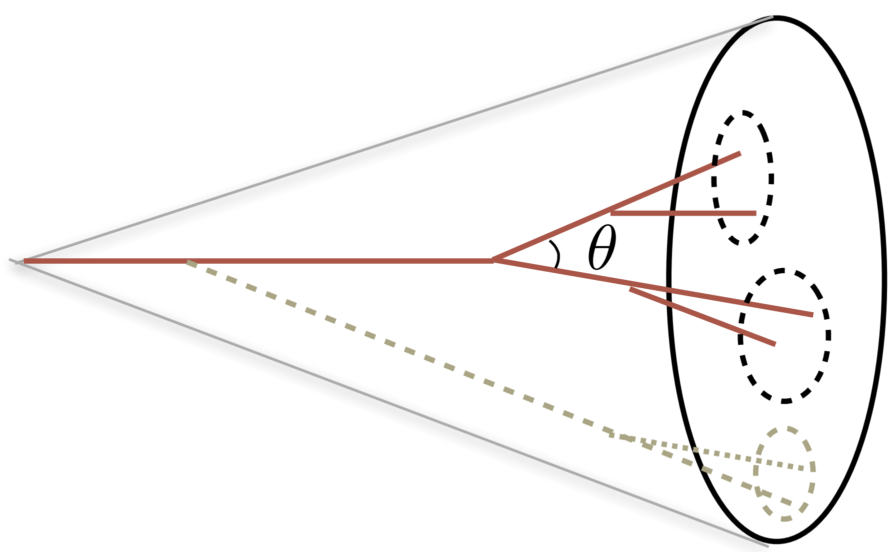


Momentum balance restored to pp baseline for **R = 0.4**, after adding particle < 2GeV/c

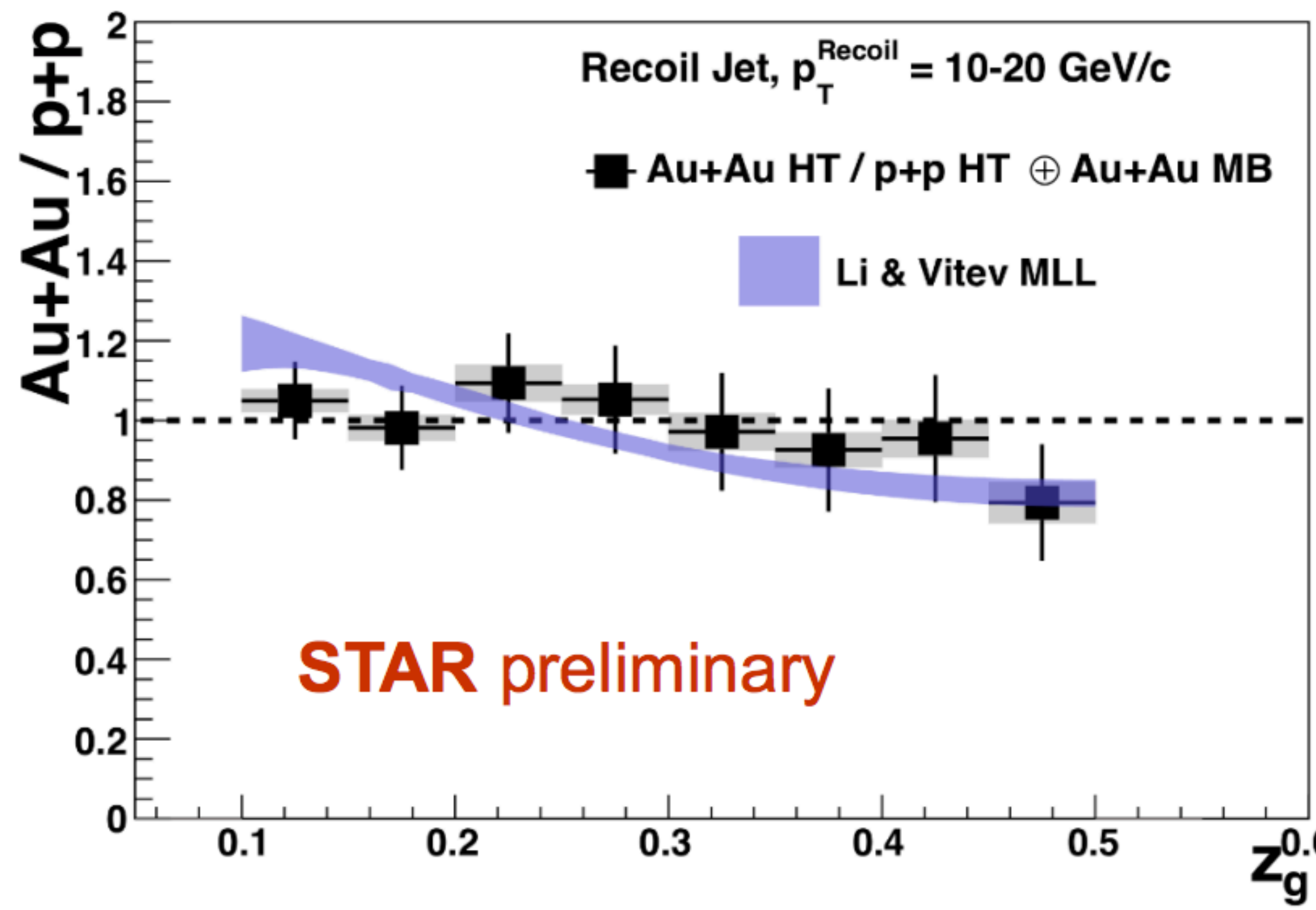
Substructure z_g

$$z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}}\, \theta^{\beta}$$





for **hard core** matched dijets

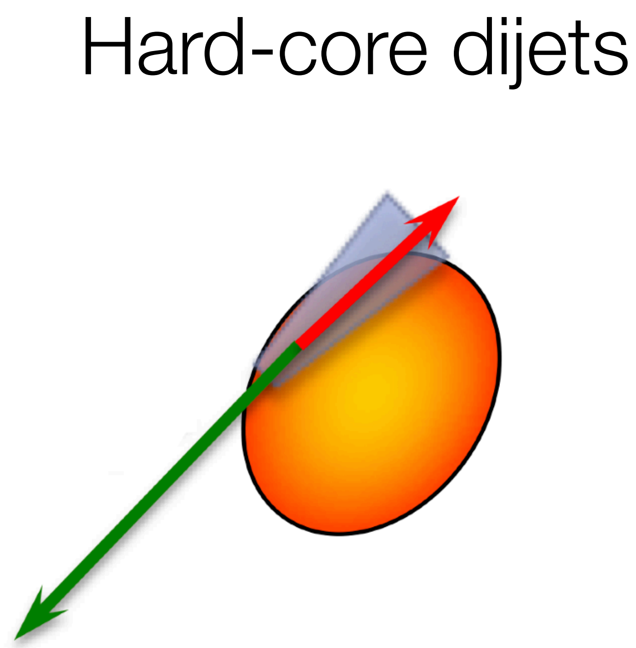


Li & Vitev arXiv: 1801.00008
also see: Chang et al. PLB 781 (2018) 423

No significant splitting modification

How are Hard-core Dijets Modified?

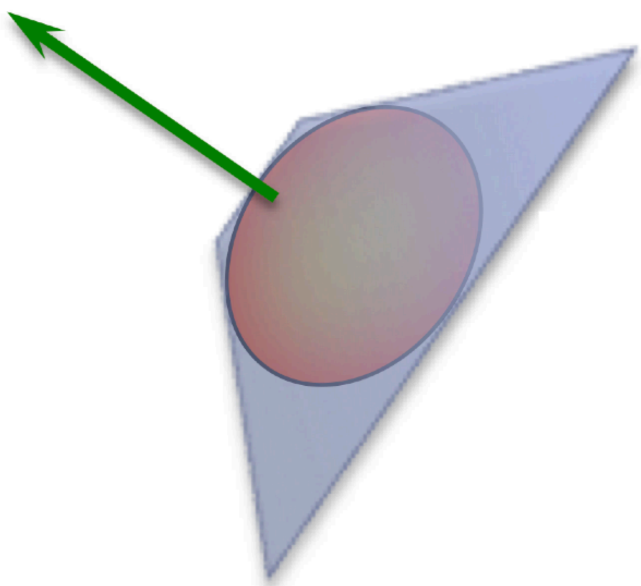
- Softening for $p_T < 2$ GeV/c
- Energy recovered in narrow cone **R=0.4**
- No substructure z_g modification seen



Trigger Bias Effect

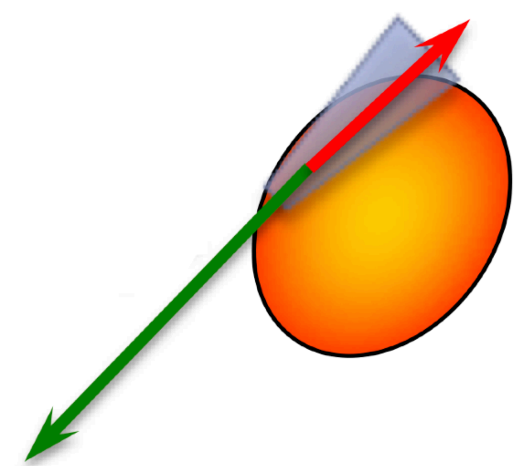
Broadening beyond R = 0.4

Leading hadron



Energy recovered in R = 0.4

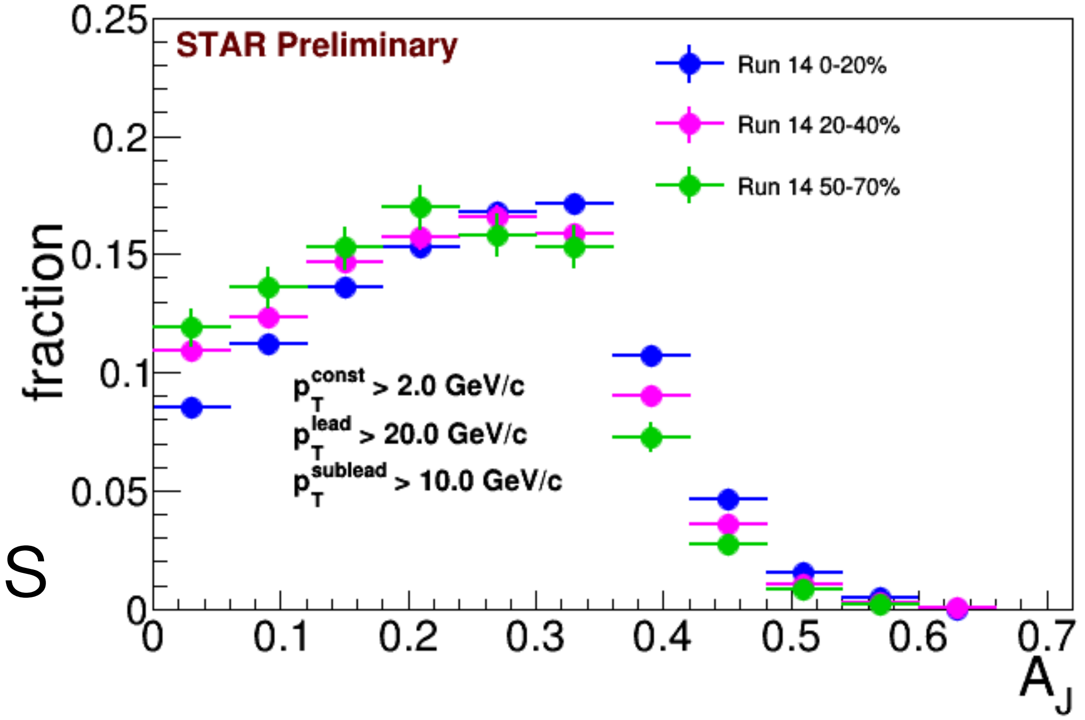
Hard-core dijets



Observed difference can be related to in medium path length/amount of diffusion of medium induced soft gluon radiation (enhancement at fixed $p_T < 2$ GeV/c) in the QGP

Differential Measurements toward Jet Geometry Engineering

STAR Run 14: 20x dijets

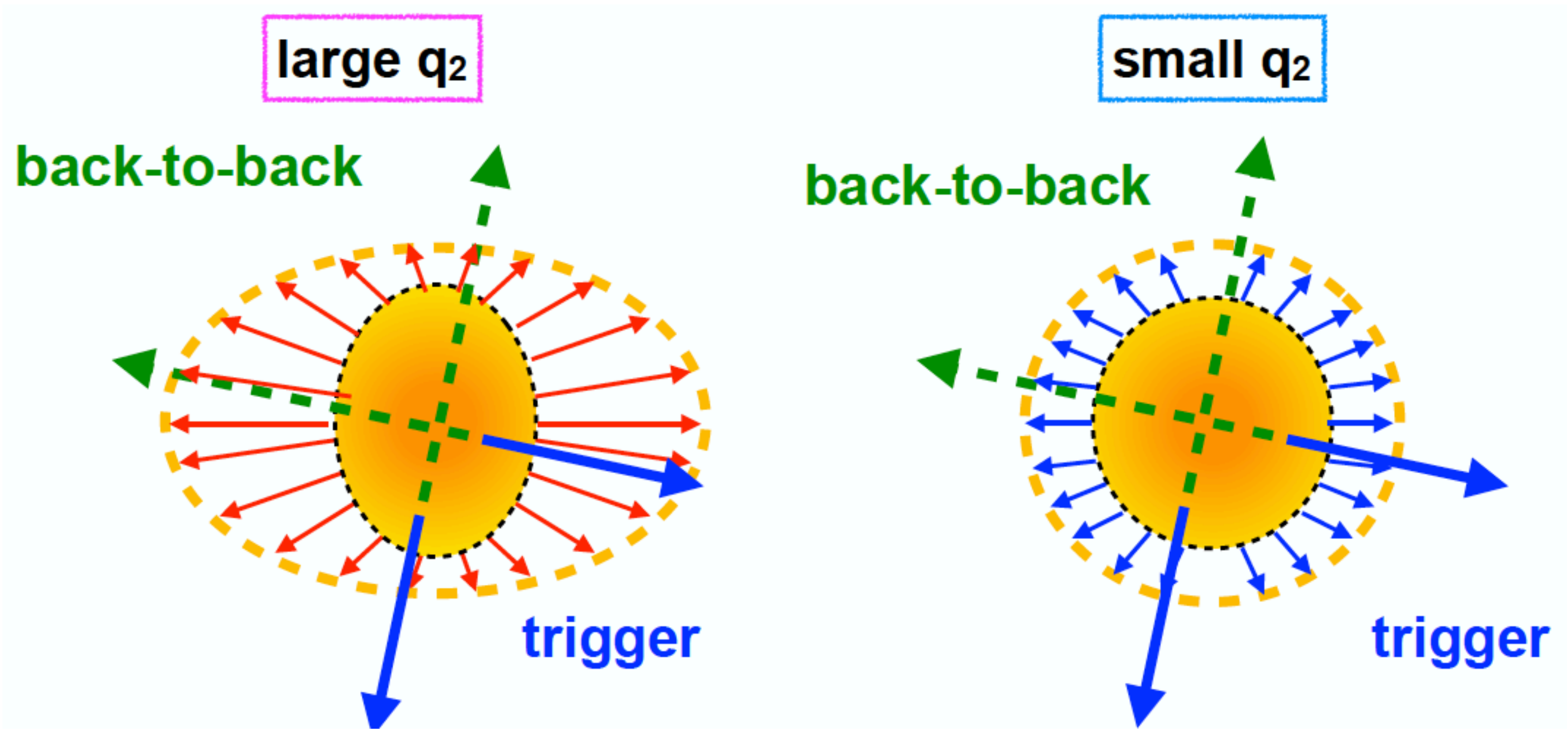


Evolution of A_J:
more balanced in peripheral collisions

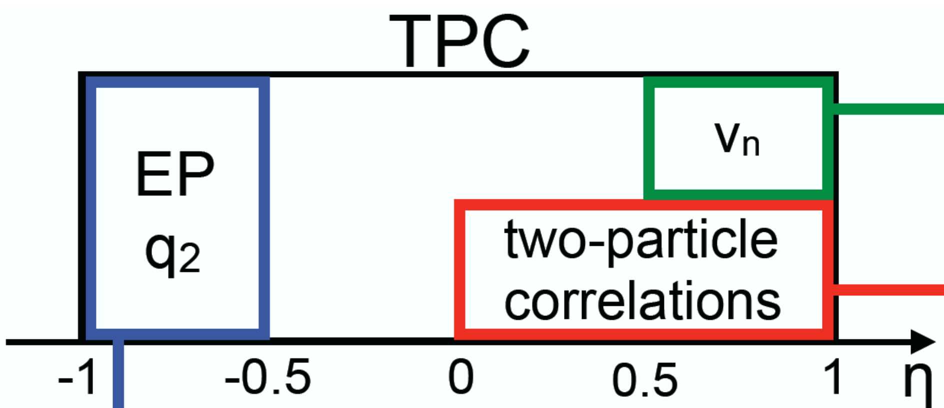
Parameter space scan (R, p_T^{Lead}, p_T^{Sub}, p_T^{Const})
—> "Jet geometry engineering"

Medium Event Shape Engineering (ESE)

- Jet energy loss depends on path length
- Azimuthal anisotropy of the medium: jet angle matters
- Event-by-event fluctuations:
  same centrality ≠ same event shape



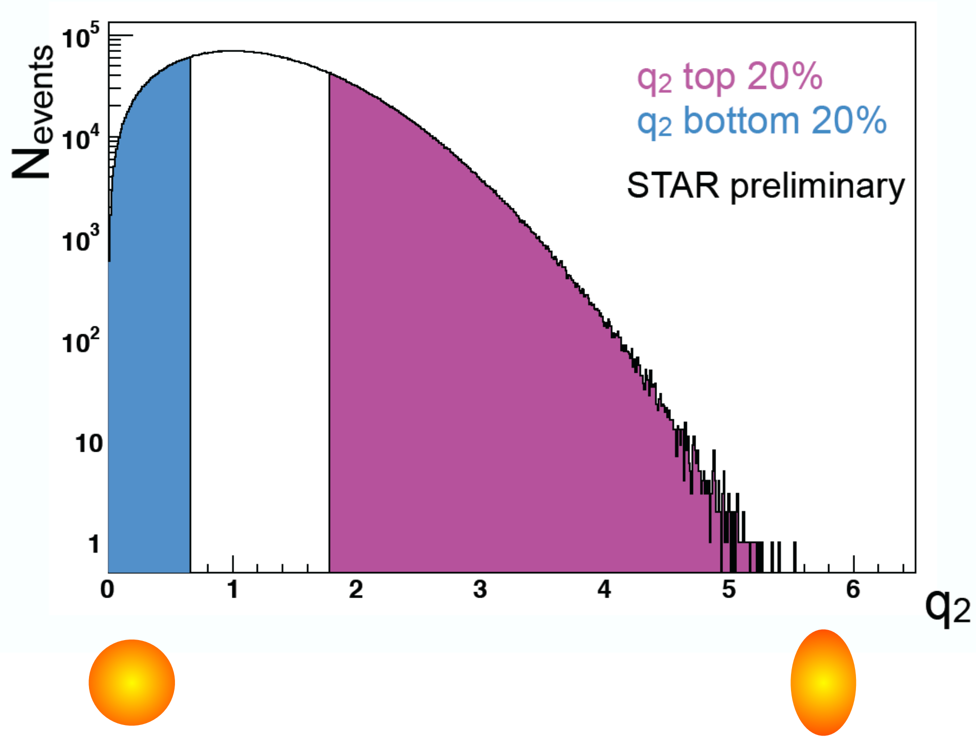
Dihadron Correlations with ESE



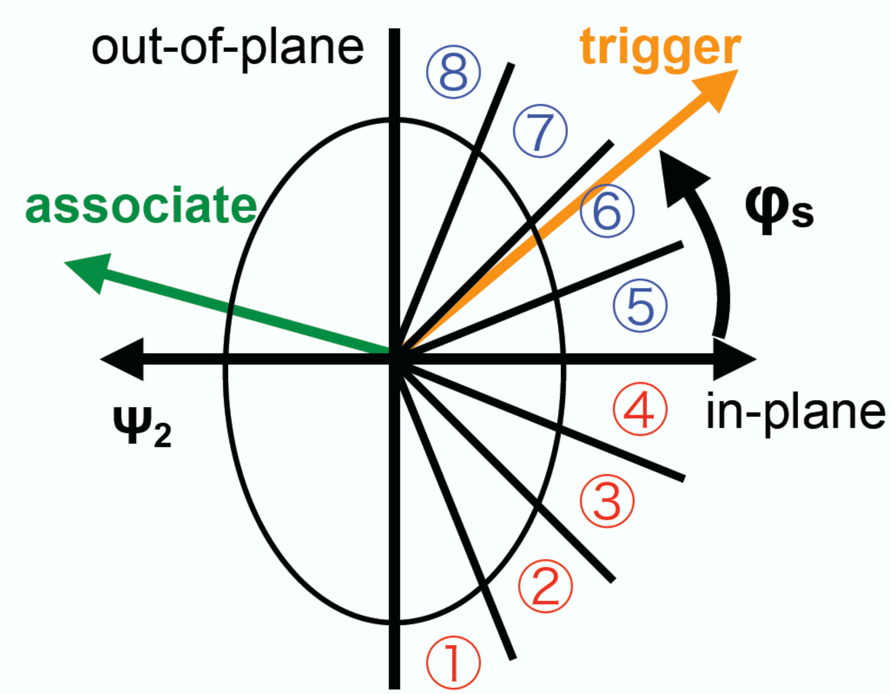
- ✦ **v_n measurement via EP method**
- ✦ **Two-particle correlations**

$$C(\Delta\phi) \propto \frac{N^{real}_{pair}(\Delta\phi)}{N^{mix}_{pair}(\Delta\phi)}$$

- ✦ **Event Plane Ψ_n**
- ✦ **q_2 selection (shape engineering)**
  - top 20% and bottom 20%

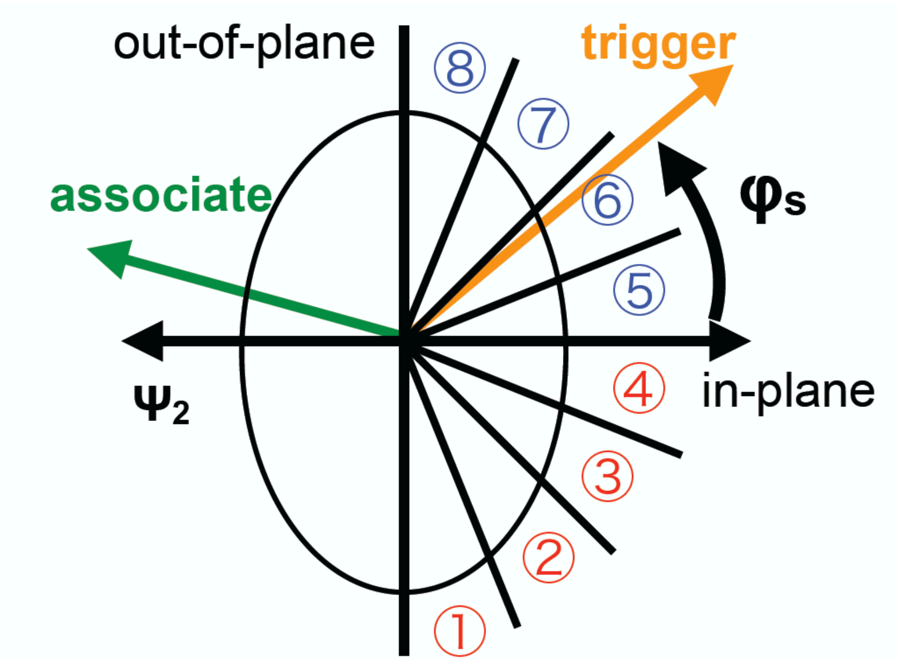


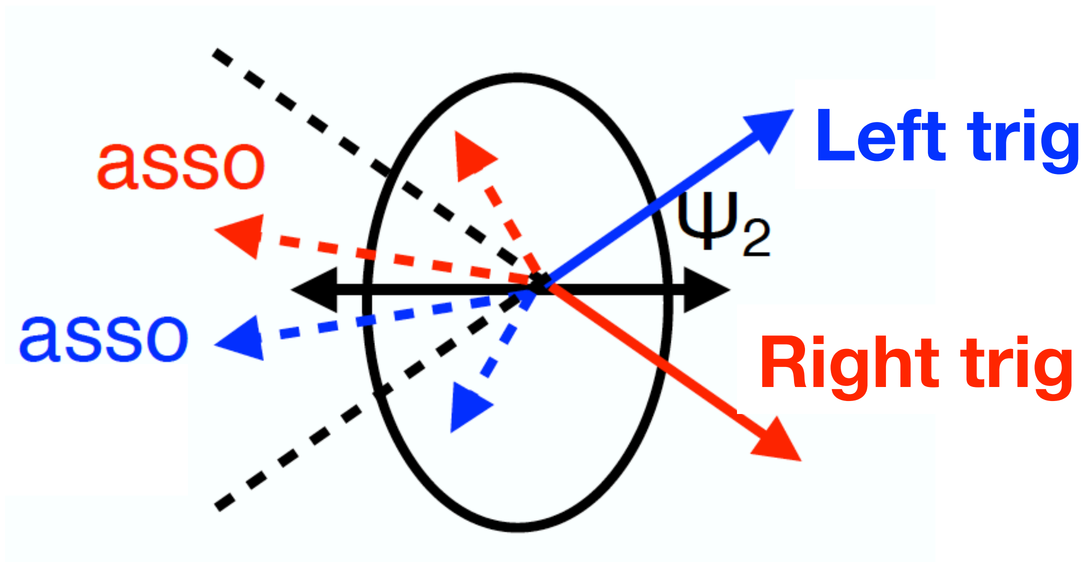
trigger angle selection w.r.t. EP



Left vs Right Trigger

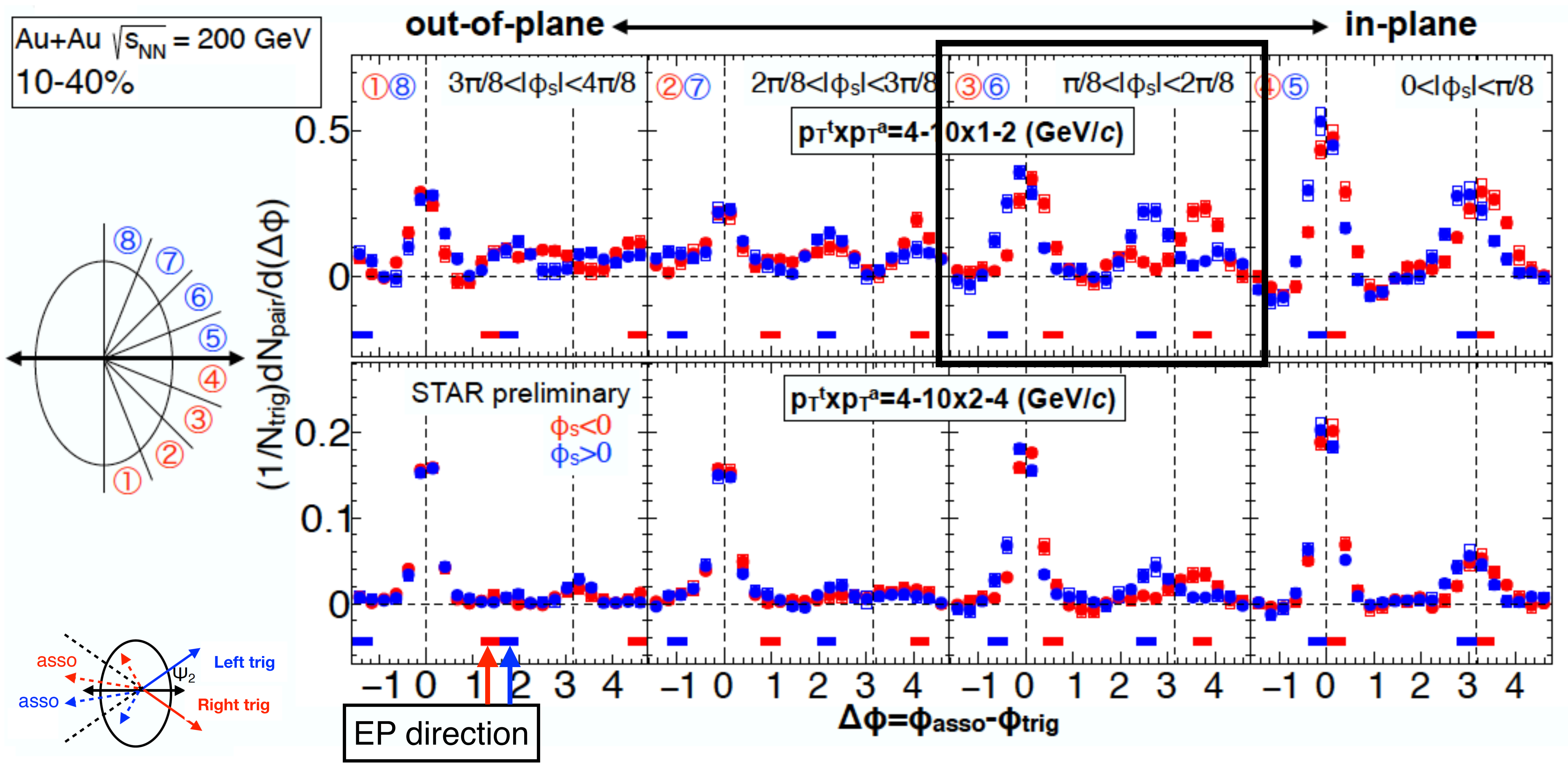
Left/Right mirror symmetric trigger selection w.r.t. EP





Otherwise, information could be averaged out

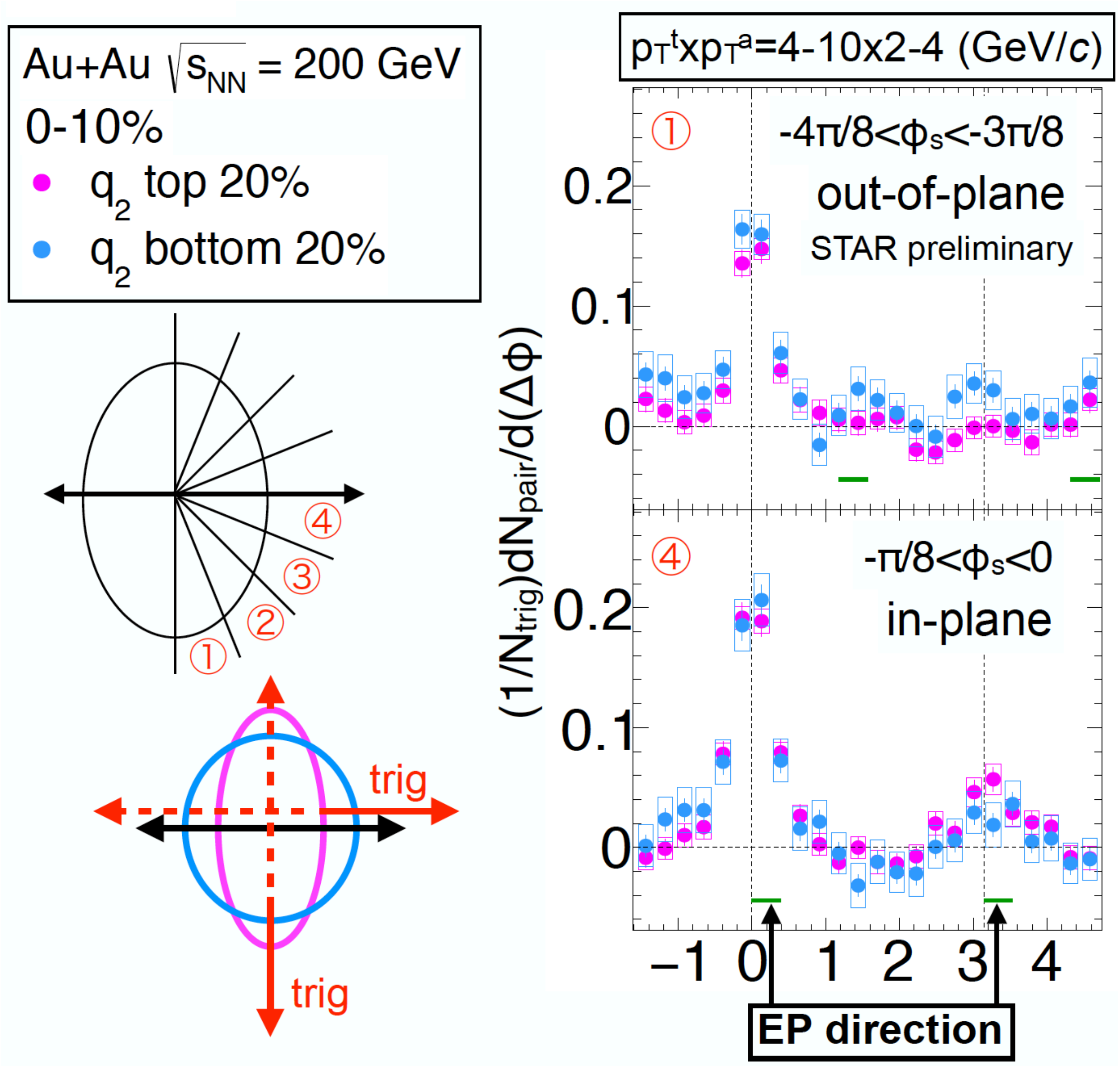
Inclusive Dihadron Correlation



Left/Right separation: asymmetric path length

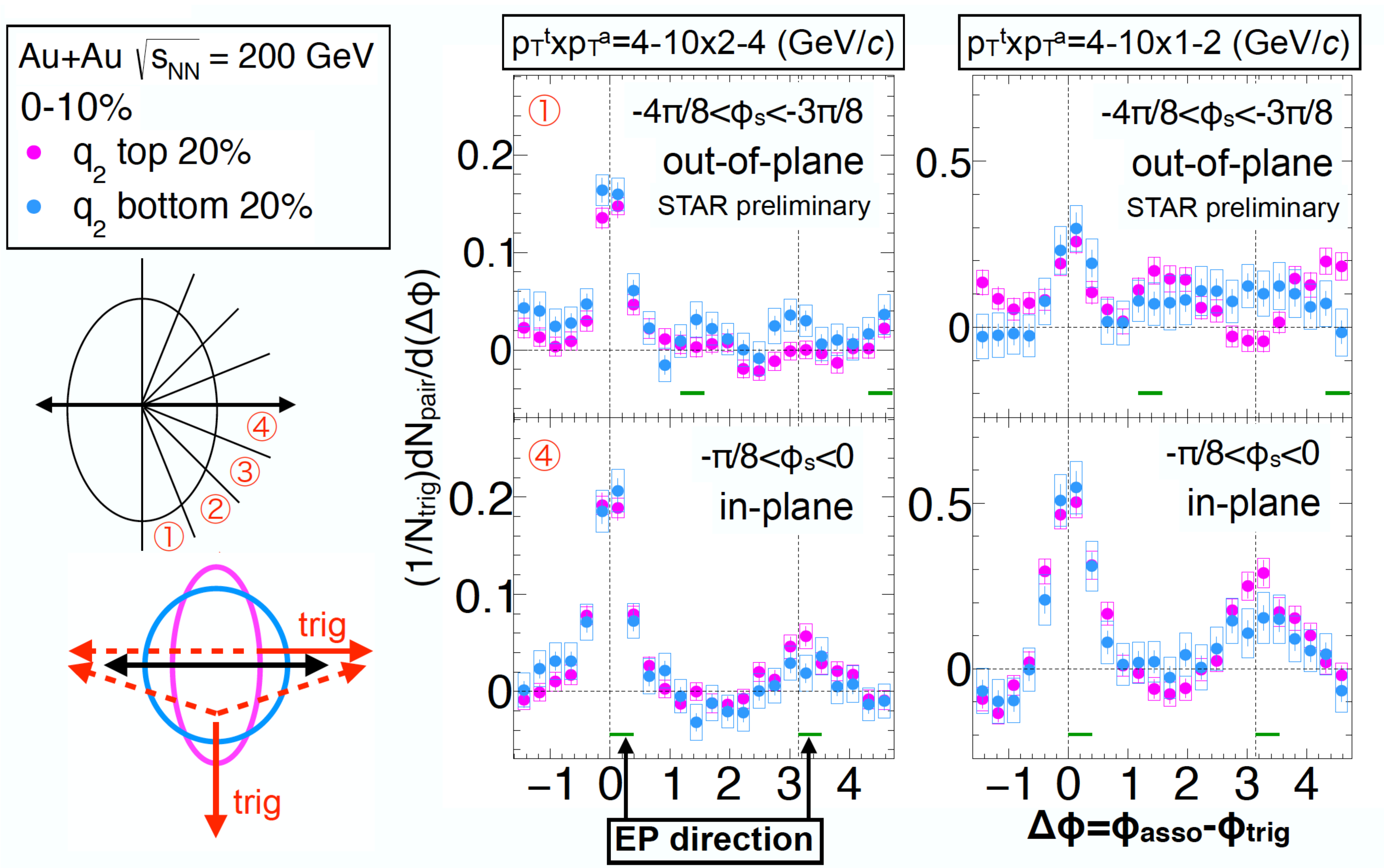
Away-side particles escaping preferentially toward in-plane direction

q-Selected Dihadron Correlation



High-p_T particles penetrate more with short path length

q-Selected Dihadron Correlation

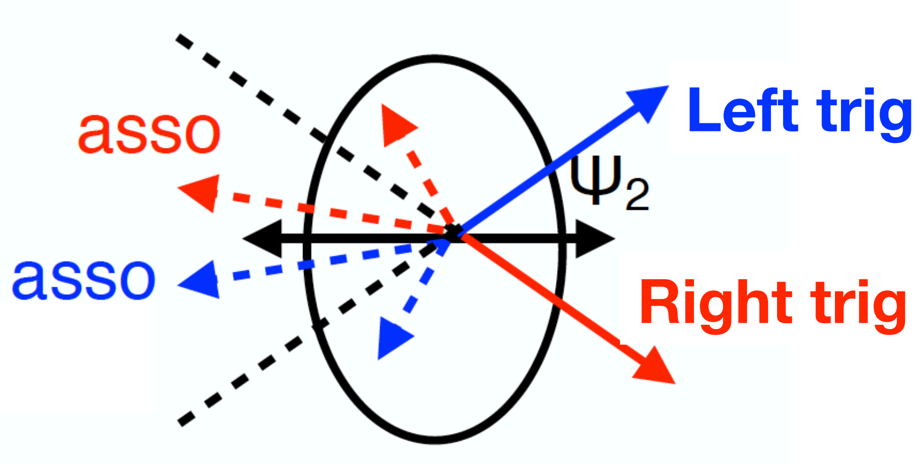


High-p_T particles penetrate more with short path length

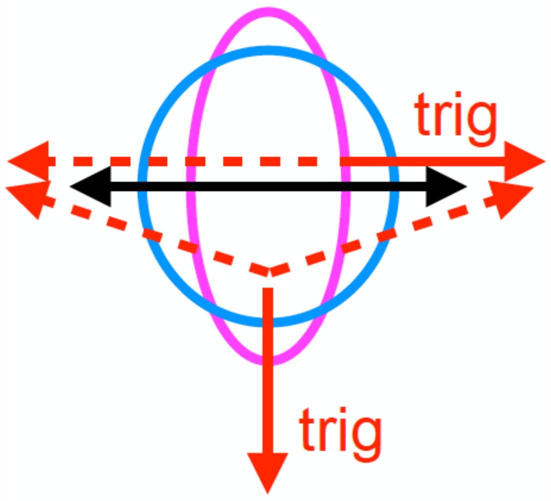
Low-p_T particles pushed toward in-plane with stronger effect for large q_2

Summary for ESE Dihadron

- Left/Right selection of trigger particles reveals path-length dependence of jet penetration

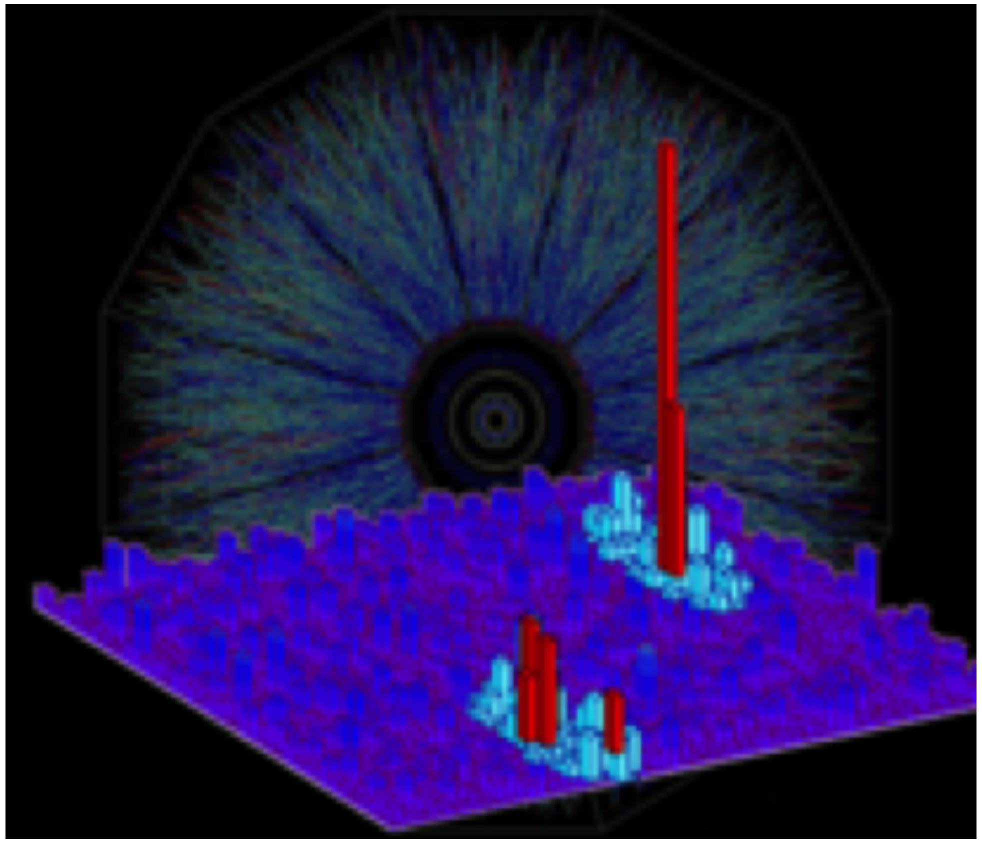


- Event shape engineering with q_2 greatly enhances path-length asymmetry while preserving multiplicity
  Low p_T particles are pushed toward in-plane direction with stronger effect in large q_2 events



- Coupling with expanding medium?

Probing the Jet Modification at RHIC



- pp in very good agreement with theory
  (Di-jets, *PRD 95 (2017) 71103 (R)*)
- Unbiased recoil jets highly suppressed due to medium induced broadening
- Total E_{loss} less than at LHC
  (Hadron-jet correlations, *PRC 96 (2017) 24905)*
- Lost energy re-emerges at low p_T **not** z_T
  (γ-hadron correlations, *PLB 760 (2016) 689)*
- Di-jet energy imbalance largely recovered within R=0.4 when low p_T hadrons included
  (Di-jet A_J, *PRL 119 (2017) 062301* - Editor's suggestion)
- z_g unmodified for hard core jets
  (preliminary release)
- Event shape engineering enhances path length dependence in dihadron correlations
  (preliminary release)
- γ-jet, jet in pA, jet inherent angular scale , flavor jet …
  (-> Hard Probes 2018)

Significantly enhanced understanding of jet modifications at RHIC