Particle Correlations at Variable pT Range at RHIC-STAR

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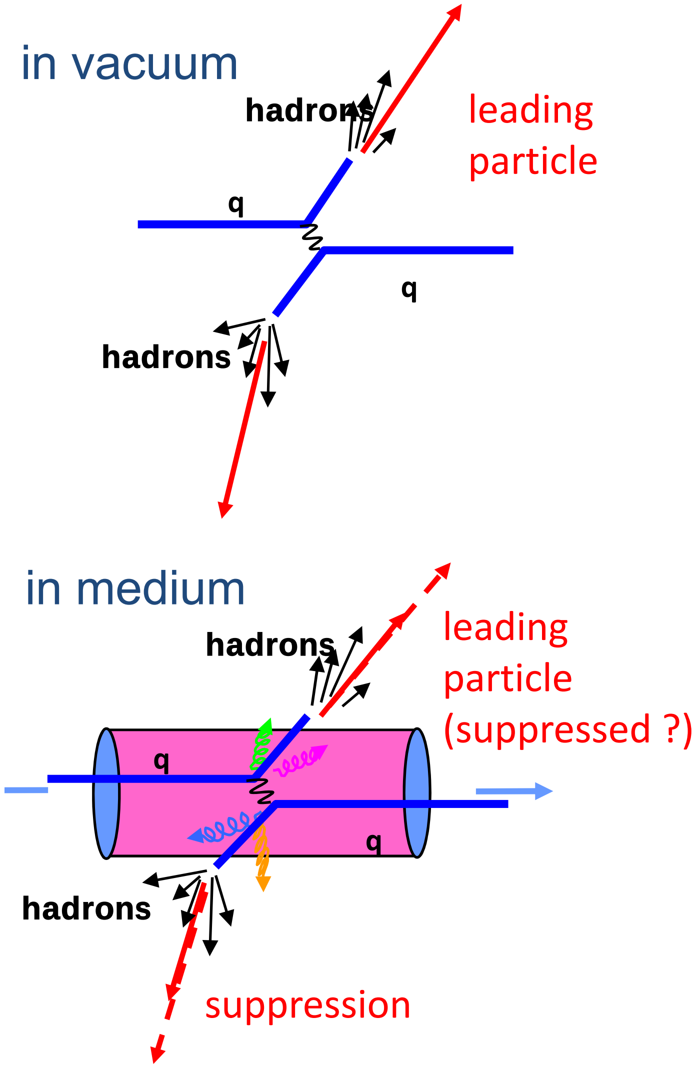
Outline

- Introduction of Correlations at RHIC energy
- Jets study through high-p_T correlation
- Direct photon as the controlling filter
- Initial state study through low-p_T correlation
- Summary and outlook

Why High-p_T?



Theoretically:

▪ Heavy-ion collisions produce QCD matter, dominated by soft partons p ~ T ~ 100-300 MeV

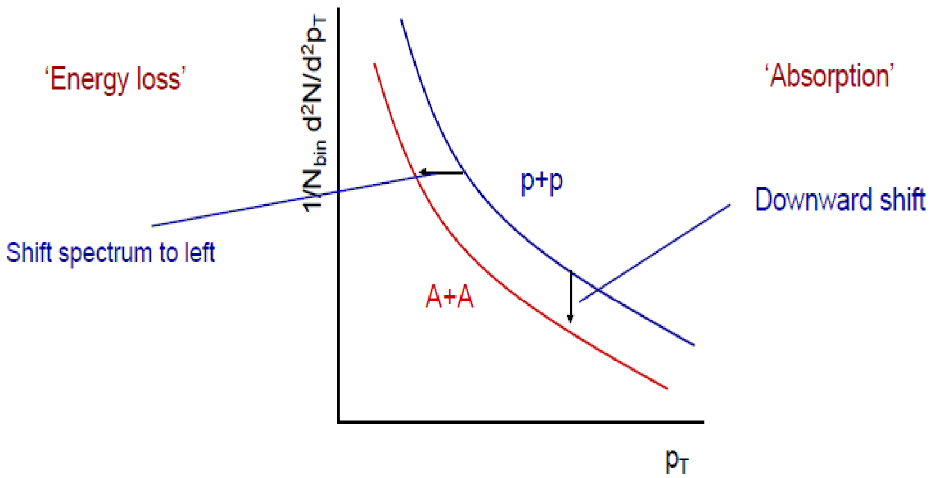
▪ Hard-scattering produce 'quasi-free' partons at the very early stage of collisions, long before the medium forms.

▪ These partons probe the medium through energy loss. Such 'hard probes' are sensitive to medium density and transport properties.

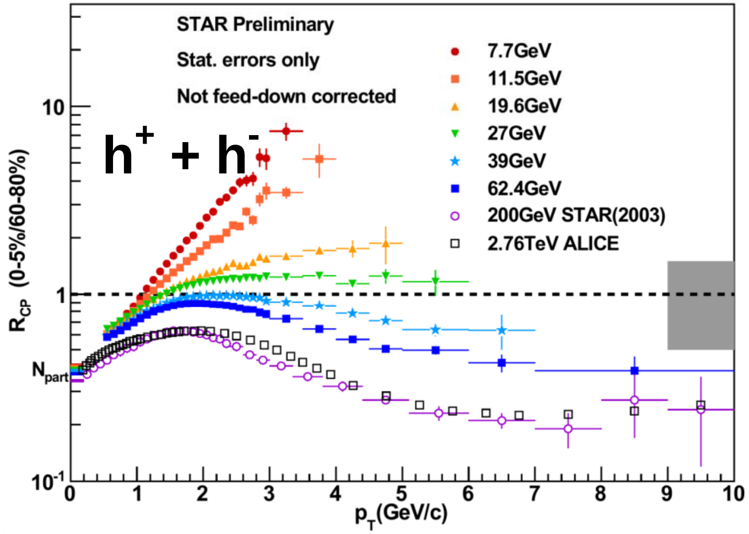
Experimentally:

● The initial state production of such partons are known relatively well from pQCD and p+p collisions results.

Singles and Fragmentation Functions

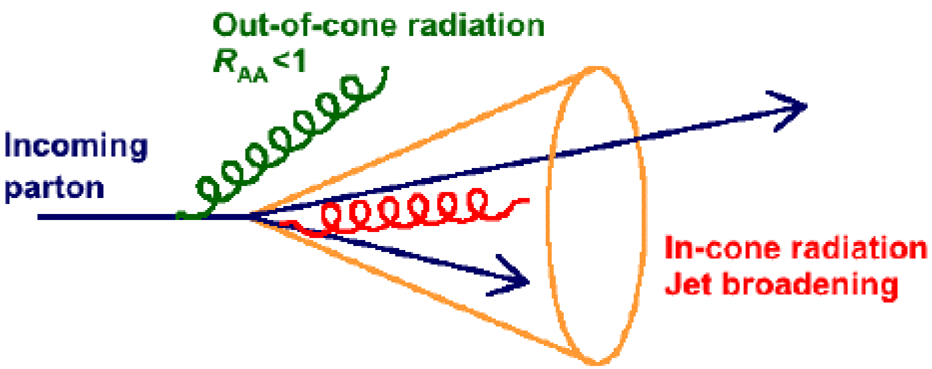


Stephen Horvat and Evan Sangaline, QM2012



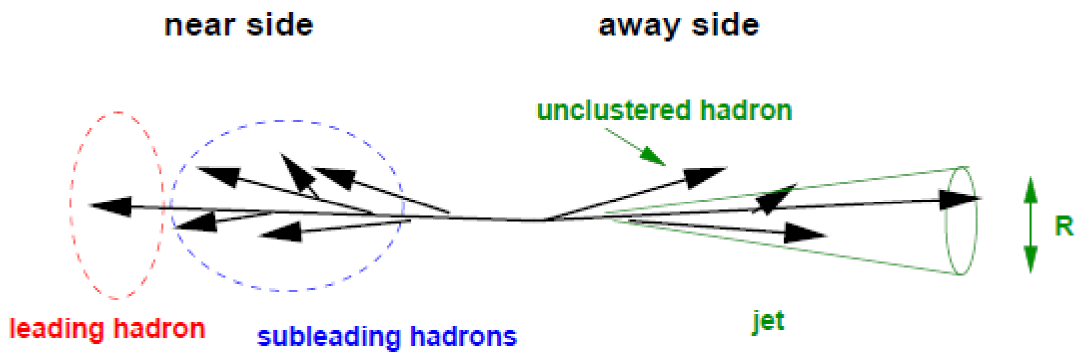
Measured R_{AA} is a ratio of yields at a given p_T

The physical mechanism is energy loss / absorption, shift of yield to lower p_T and yields.



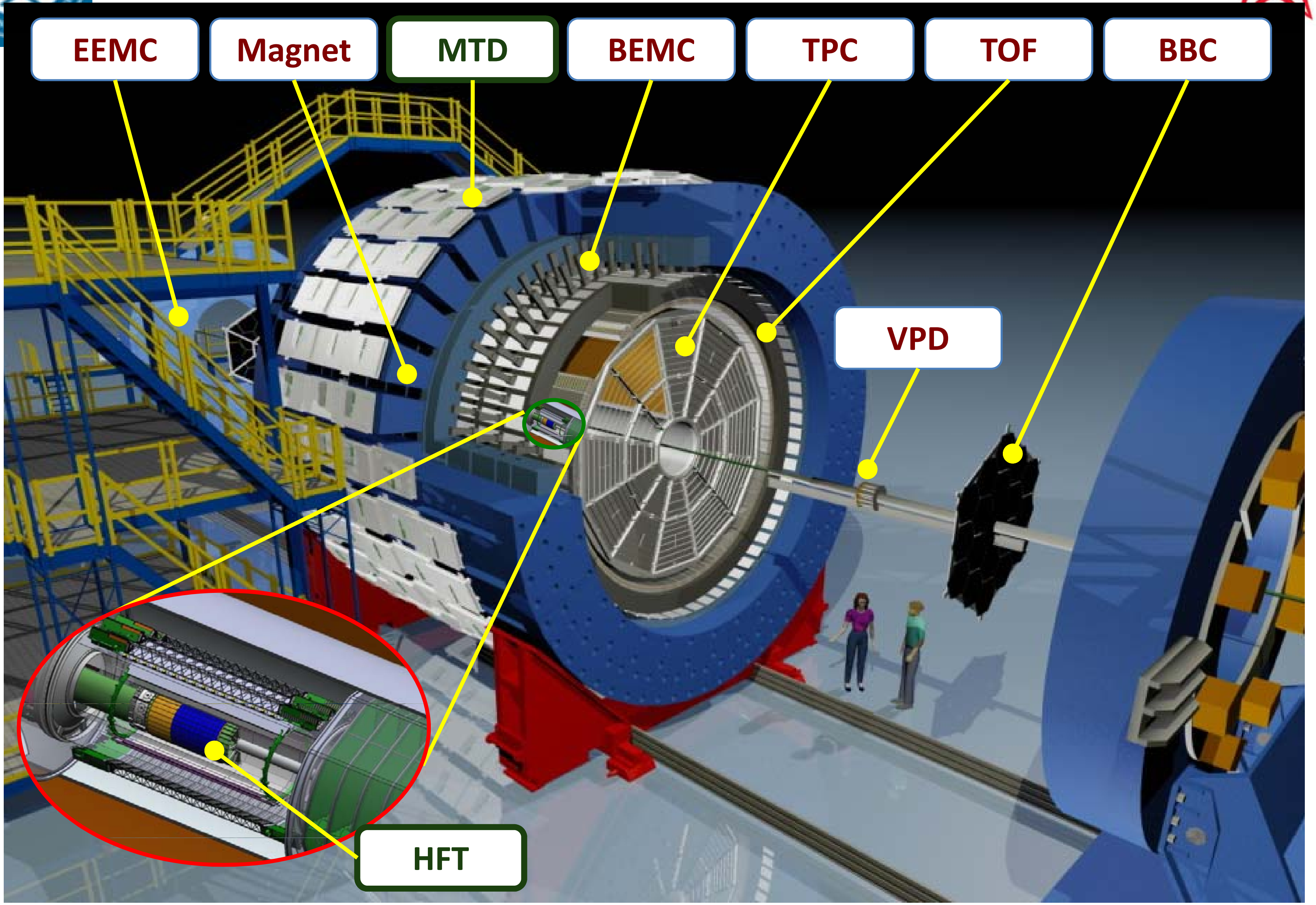
- Energy loss is not single-valued, but of a distribution.
- Perturbative QCD happens at $\tau \sim E/Q^2$
- Medium Modified Fragmentation Function (FF):
  → must take place where the medium acts.

Study Fragmentation Function with correlations



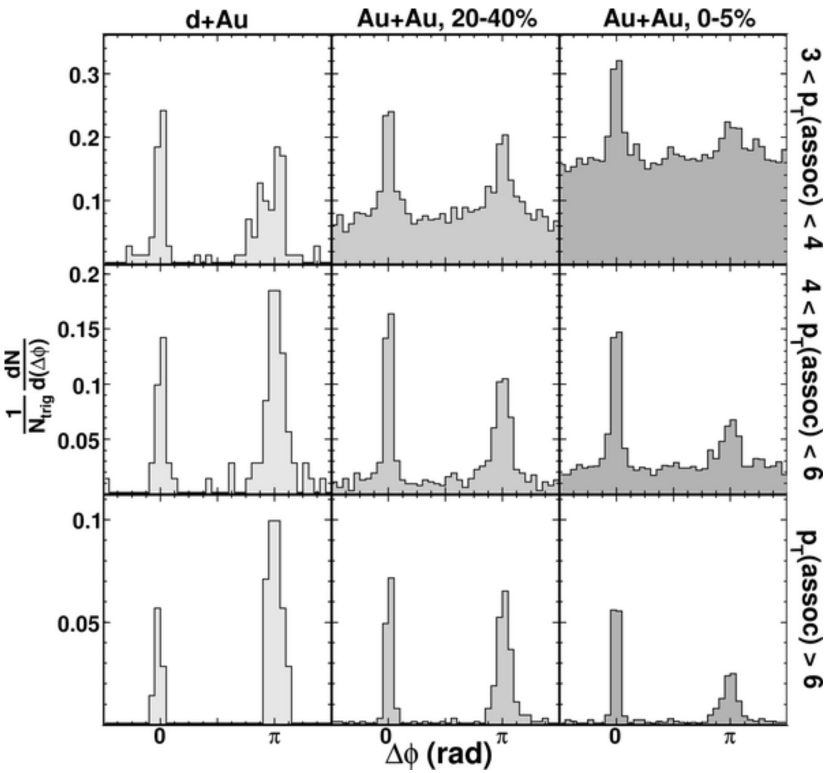
- Basic structure: back to back hard QCD event
- Trigger object: leading hadron, γ, Z^0, clustered jet
  → yield of QCD objects reduced in medium, R_{AA} observables
- Trigger object defines near and away side
  → correlation observables, near and away side I_{AA}, correlation angular width
- Hadron analysis inside a found jet
  → jet observables, jet shape and fragmentation function
- Can all be done dependent on orientation with event plane

STAR Detector System



Away-side peaks in correlation back-to-back jets

Phys. Rev. Lett. 97 (2006) 162301



Facts:

- Correlations are formed with particles at specific kinetic region .
- High-p_T particles are better proxies of jets.

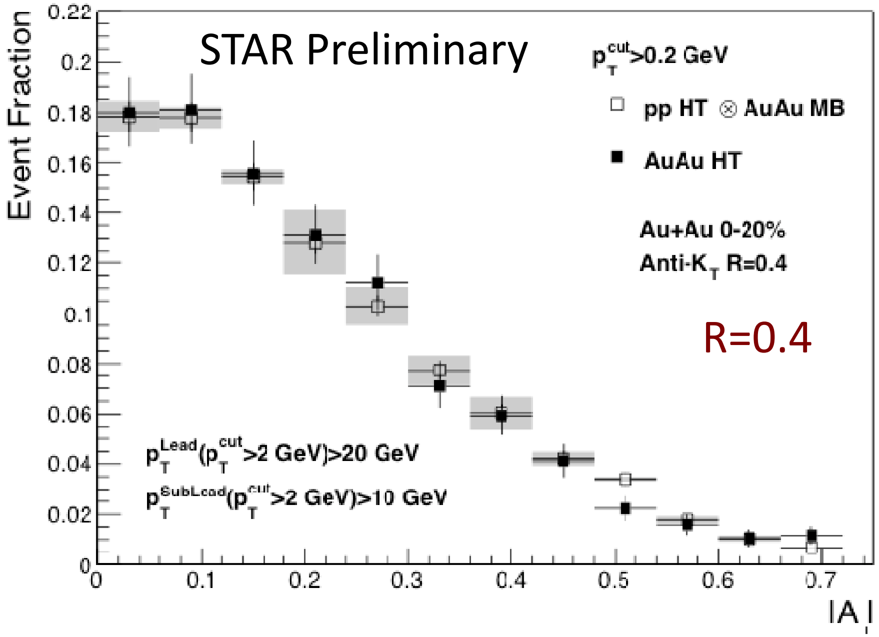
Natural proposal:

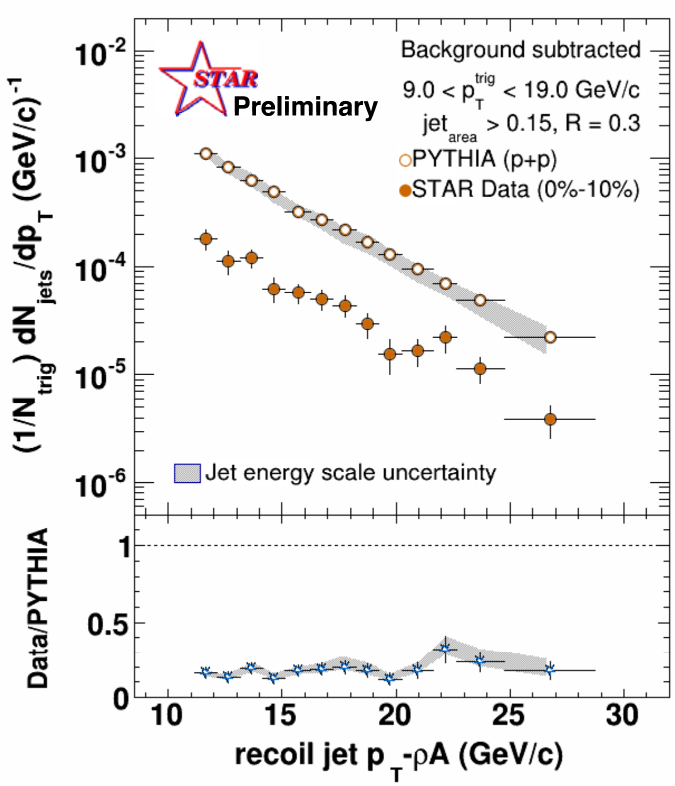
Raise the p_T of **all** particles in correlation to get a higher purity of jets source.

Result:

- The away-side peaks are back with high-p_T trigger and associate.
- The recoil jets are restored, but their rates are much lower.

Di-jets Imbalance A_J Result





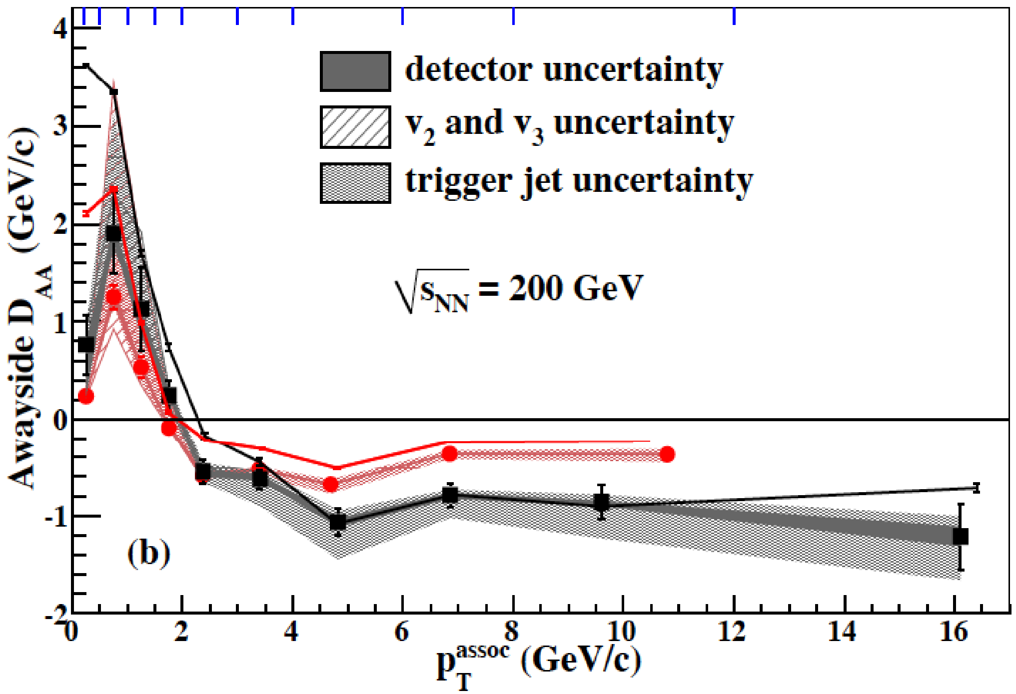
First di-jets imbalance A_J result in Au+Au collisions at RHIC:

1) p_T>0.2GeV/c, **R=0.4**: A_J(AuAu) =A_J(pp) changes in Au+Au collisions are all contained in the cone, unlike the LHC. For **R=0.2**: A_J(AuAu) ≠ A_J(pp), the cone is too small.
2) Recoil jets are suppressed, path length is maximized.
3) Tools for jet analysis are ready at RHIC.

Jet(-axis) correlation

$$D_{AA}(p_T^{assoc}) = Y_{AuAu}(p_T^{assoc}) \cdot \langle p_T^{assoc} \rangle_{AuAu} - Y_{pp}(p_T^{assoc}) \cdot \langle p_T^{assoc} \rangle_{pp}$$

with appropriate background subtraction.



The reconstructed jets are used as triggers, instead of single high-p_T. *Higher acceptance, better background subtraction, more clear jet sample.*

Near-side of jets are consistent between p+p to Au+Au. **Proof of surface-bias.**

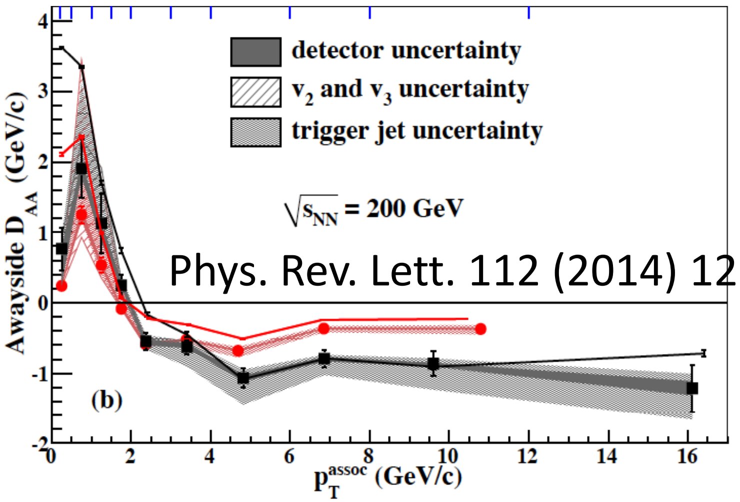
The associated particles on the away-side ($|\Delta\phi-\pi|<\pi/2$) are integrated and compared.

Away-side energy balance: "lost" at high-p_T associated are largely balanced by "gain" at low-p_T end.

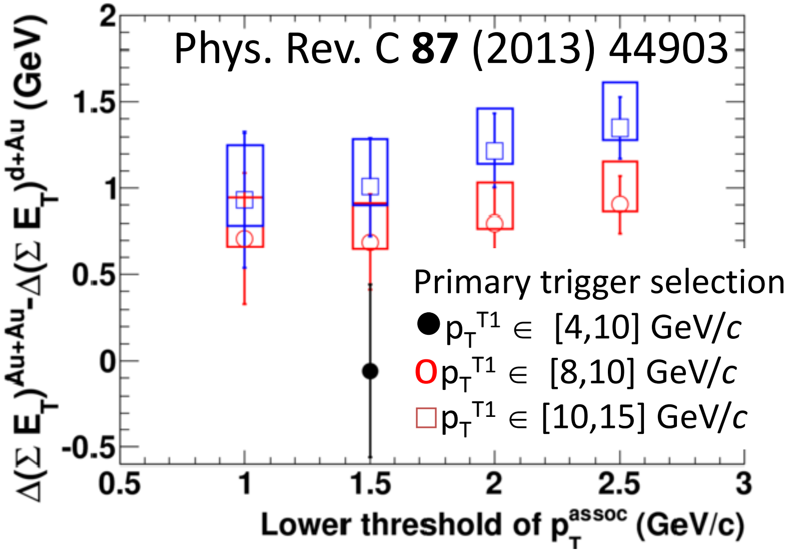
Phys. Rev. Lett. 112 (2014) 122301

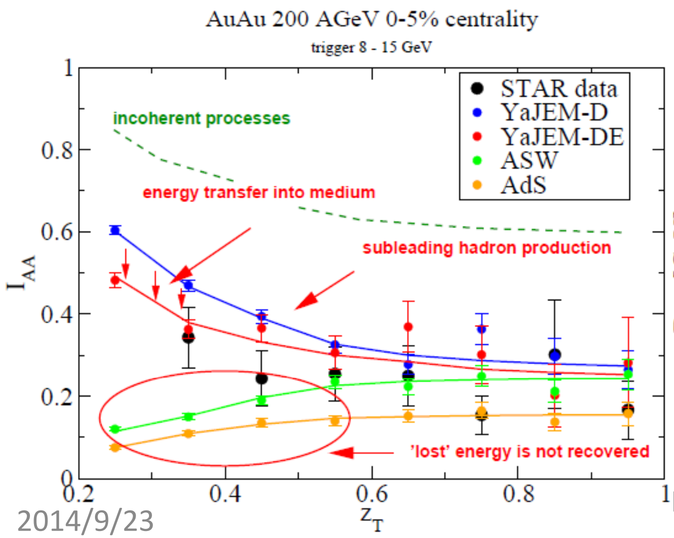
Agreement within others

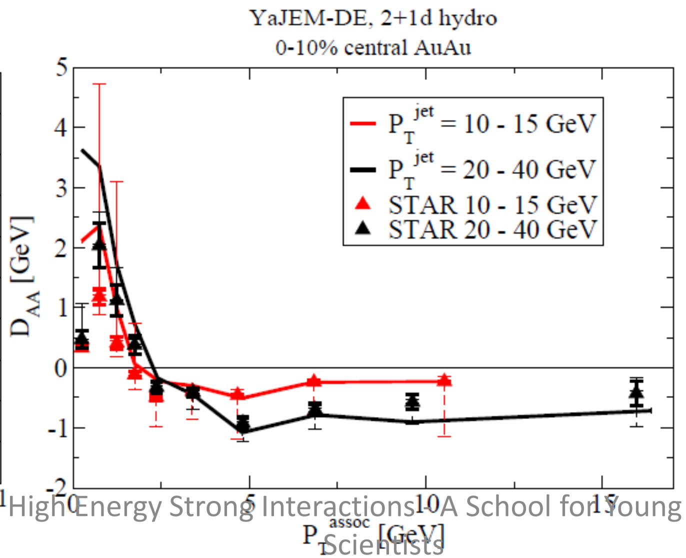
Jet-axis to hadron correlation



Di-trigger (jet proxy) to hadron correlation







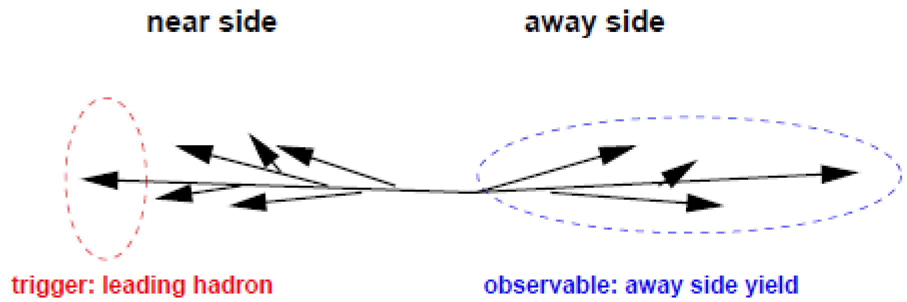
Theorists' work
→T. Renk at QM2014

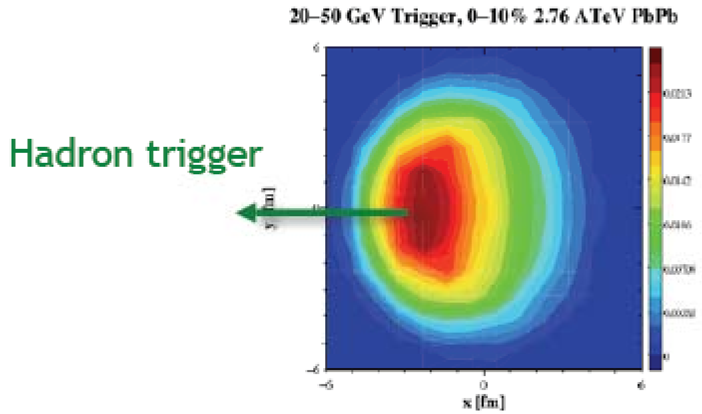
Details still in argument:

- Radiative vs. elastic Eloss
- Path-length dependence
- etc.

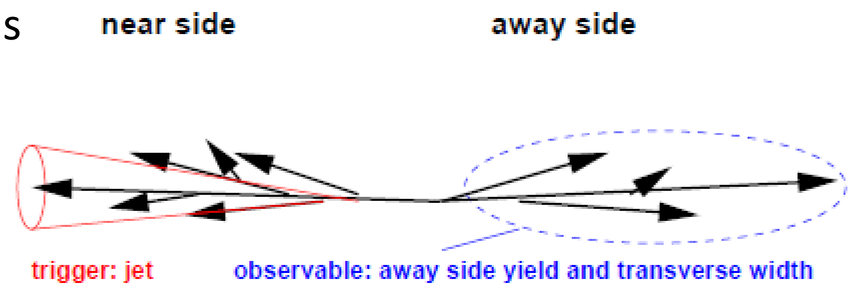
Different observables, different biases

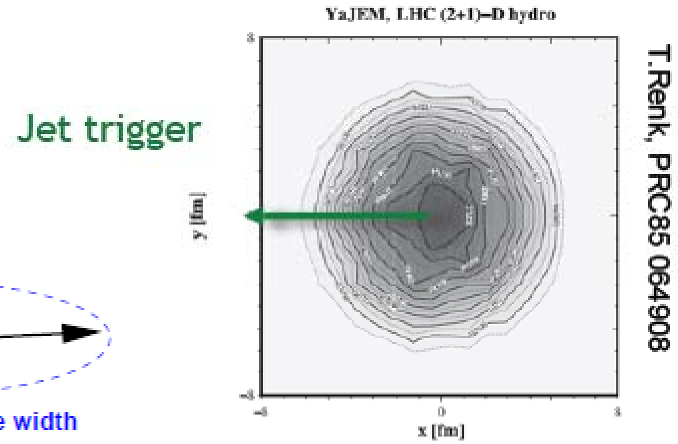
h-h correlations: significant kinematic and parton type bias, low statistics
→ Strong surface bias, maximizes recoil path length





jet-h: reduced bias, higher statistics
→ Less surface bias, partially cancelled by background fluctuations





Other biases such centrality and reaction plane

Direct photon trigger as filter

- 2-particles correlations ($\Delta\phi$):

FF of the recoiling parton from direct γ and π^0

- **Parton initial energy "Compton-Scattering"**
- **Different path length "on average"**
- **Different q/g compositions**

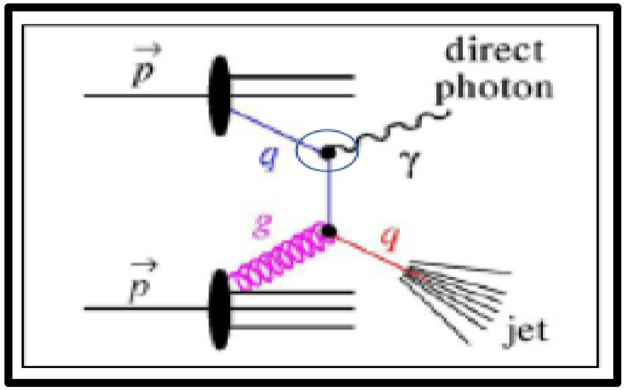
Observable: $I_{AA} = D_{AA}/D_{NN}$

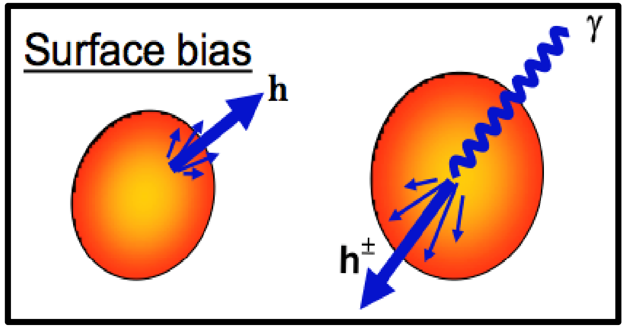
- Reaction plane ($\Delta\phi$):

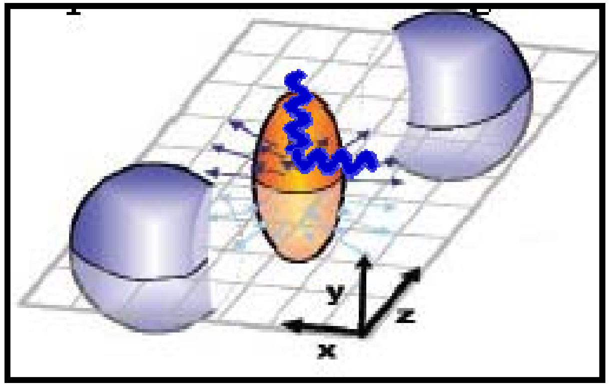
Azimuthal anisotropy of π^0 and γ

- **Path length dependence of ΔE**

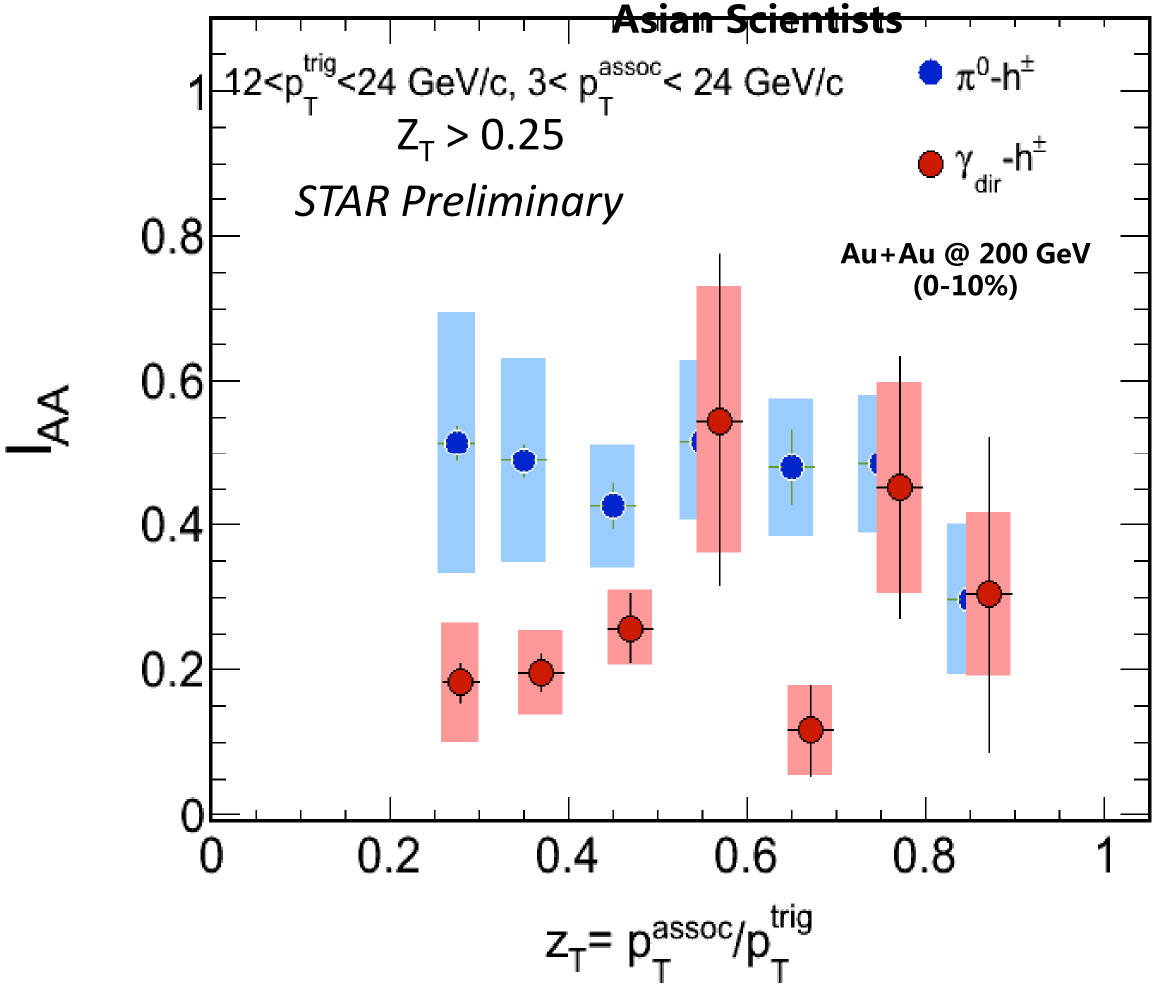
Observable: $v_2\ (p_T) = \langle\cos(2(\phi_{pT} - \psi_{RP}))\rangle$



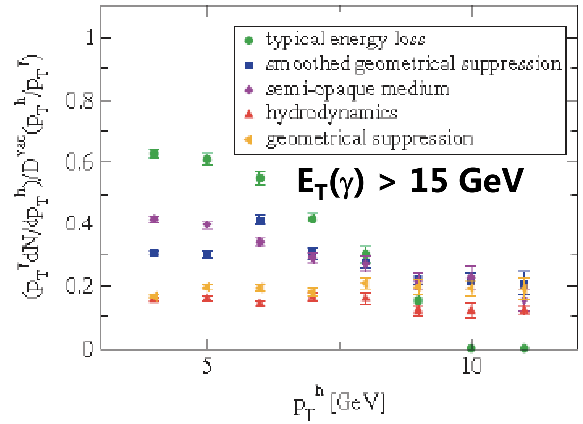




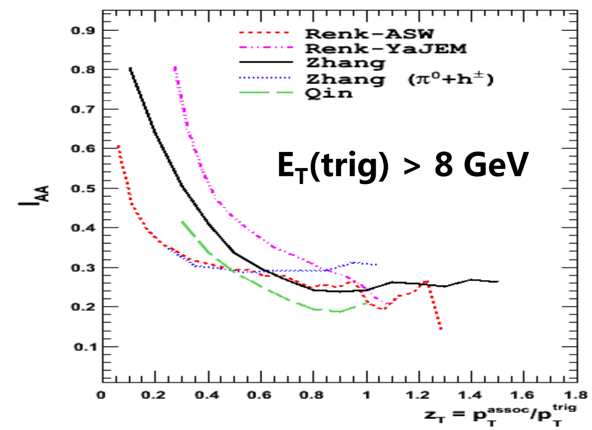
Direct photon correlation -- I_{AA}



Renk, PRC 74 (2006) 034906



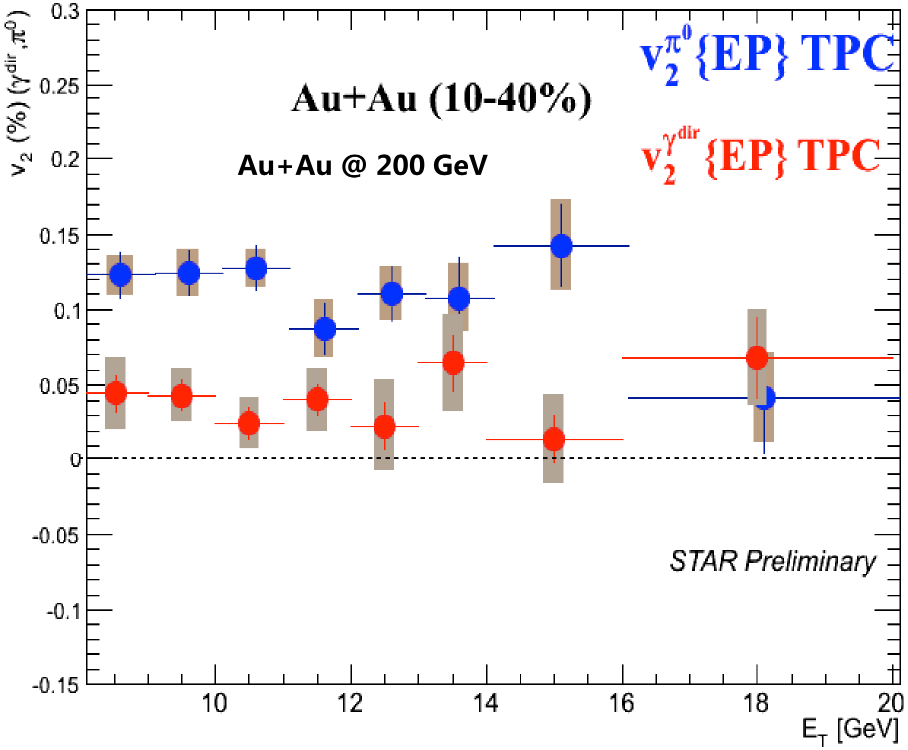
Private Com.



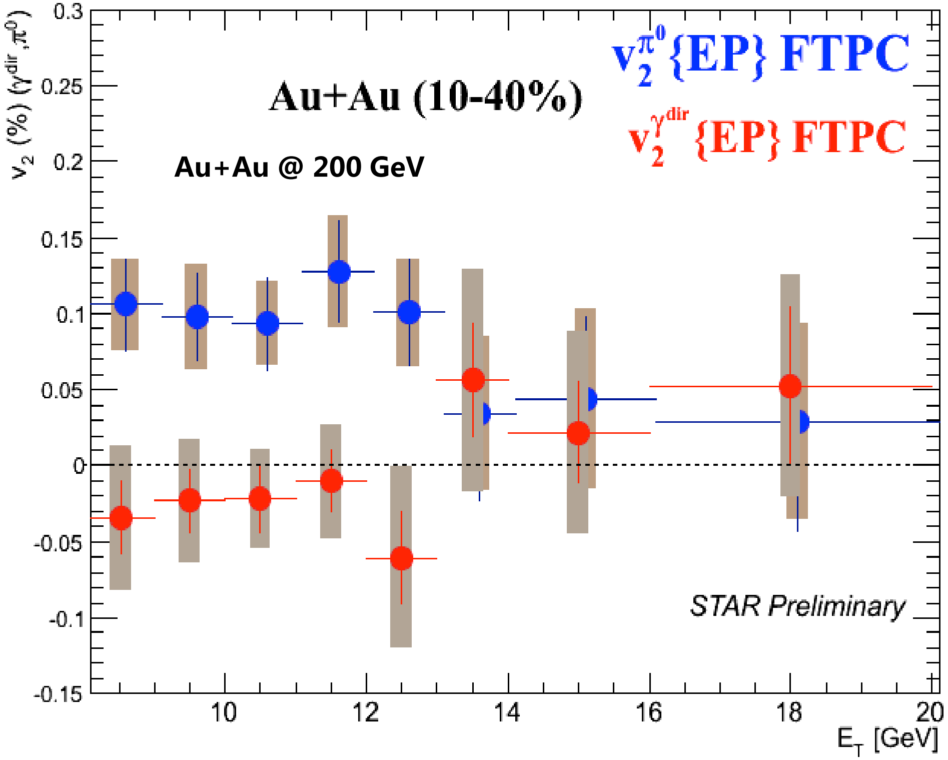
- Both I_{AA} of direct photons and π^0 are flat within current uncertainties in the measured kinematics range

Reaction-plane Correlations: v_2

✓ **BEMC: | η | < 1.0, TPC: | η | < 1.0**



✓ **BEMC: | η | < 1.0, FTPC: 2.5 < | η | < 4.0**



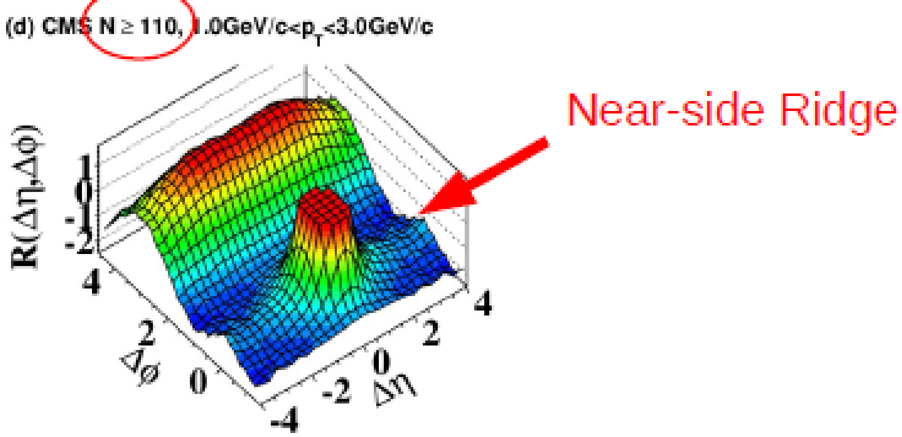
- v_2 of direct photon is consistent with zero within the current systematic errors
- Fragmentation photons have negligible effect on overall v_2 of direct photons

- v_2 of π^0 using the FTPC is apparently due to the path length dependence of energy loss.

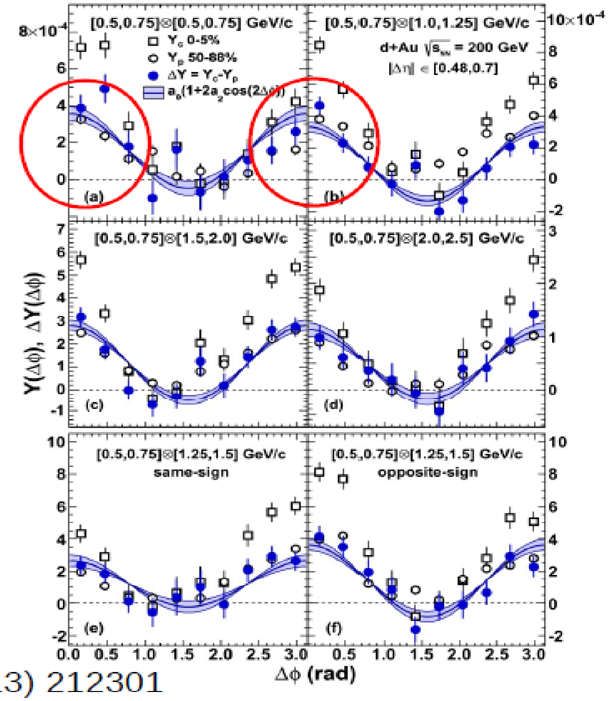
✓ $v_2 < 0$: jet-medium photons
✓ $v_2 = 0$: direct photons
✓ $v_2 > 0$: frag. photons

Evidence of initial state effect?

CMS pp JHEP 09 (2010) 091

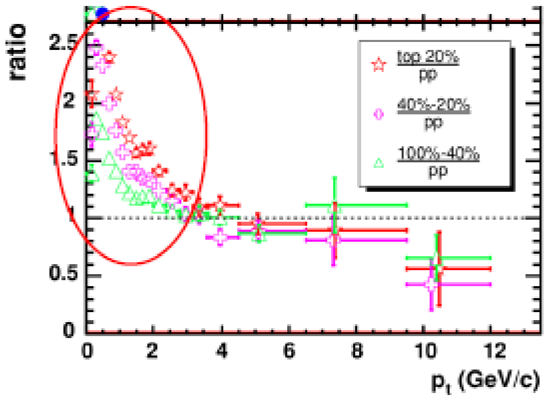


PHENIX d+Au Double Ridge



PRL 111 (2013) 212301

STAR d+Au vs p+p $\langle \sum \cos(2(\varphi_{p_t} - \varphi_i)) \rangle$



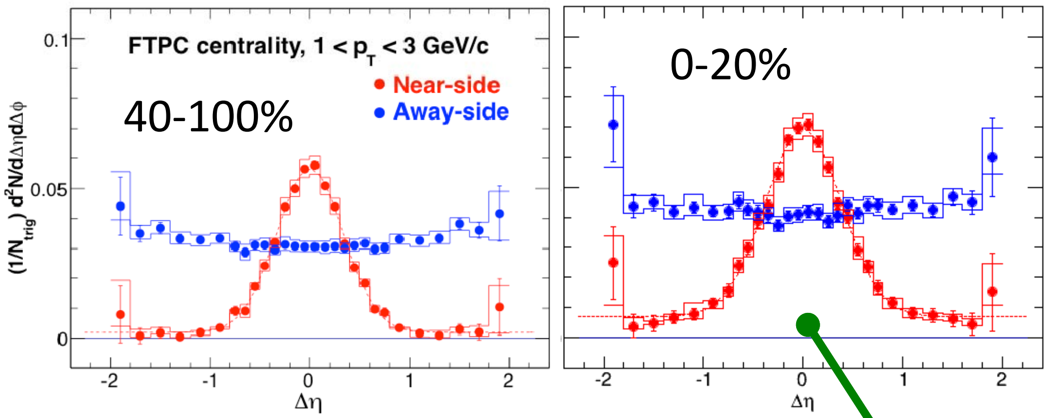
PRC 72 (2005) 014904

Possible physics mechanisms:

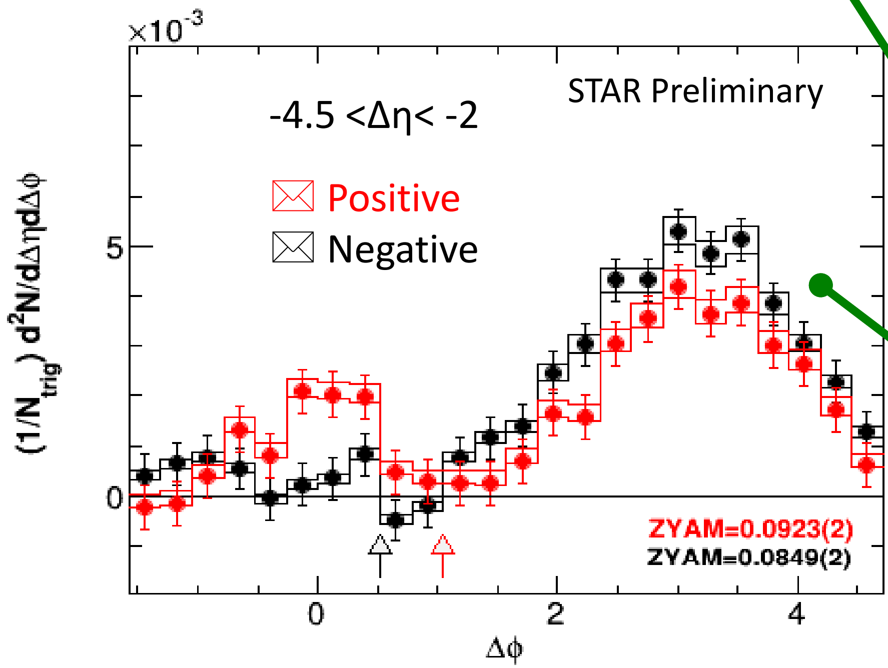
- ✓ Hydro ?
- ✓ CGC ?

Correlations from d+Au Collisions

200 GeV dAu Collisions, STAR Preliminary



Fit Para.	40-100%	0-20%
Width	**0.336(6)**	**0.382(9)**
Area	**0.0459(10)**	**0.0594(18)**
Pedestal	0.0019(4)	0.0070(9)
χ^2/ndf	19/25	19/25



($1 < p_T < 3$GeV/c)

1) Near-side peak: centrality dependent

2) TPC-FTPC correlation, Ridge with $\Delta\eta$~3. Only for positive particles. **Flow effect is not seen in this analysis.**

Summary

- Hard-scattered partons and their evolution are important to probe medium properties.
- Correlations have been an effective tool to study medium-modified fragmentation functions of such partons.
- Different trigger / observables bring different biases, but work as filters of physics OTH.
- Whether the flow-like correlation is due to initial effect is still uncertain.
- Stay tuned for more STAR results!

Backup

A group of R_{AA}