The Need for Surface Bias Studies for Correlation Analyses

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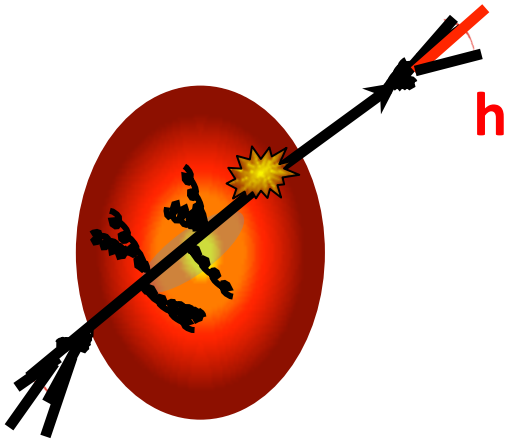
What's in this talk?

- Motivation for studying correlations to study energy loss in the QGP
- Correlations of different types, h-h, jet-h, γ-h are useful in different ways
- Surface bias needs to be understood to disentangle effects between different observables
- Motivate theorist and experimentalists to work together to maximize the information from these correlations

Why Correlations?

- Quantify the transport coefficients of the QGP
  - Measure k_T
- Track lost energy as a function of p_T and angle
- Energy loss depends on the pathlength
  - v_2 for high p_T particles and Jets
- Measurement for all experiments
  - Compare RHIC and LHC

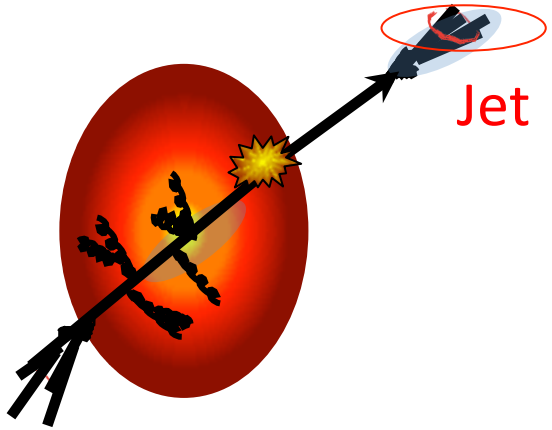
Studying Energy Loss with Correlations



Hadron-hadron

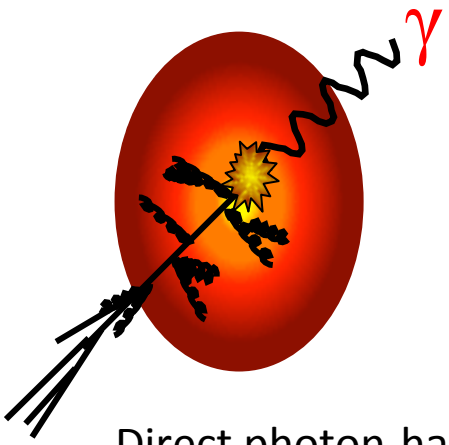
-Surface bias by the trigger

-Broad parton energy distribution



Jet-hadron

-Less surface bias
-Several parameters to vary pathlength
-Better constrains initial parton energy



Direct photon-hadron

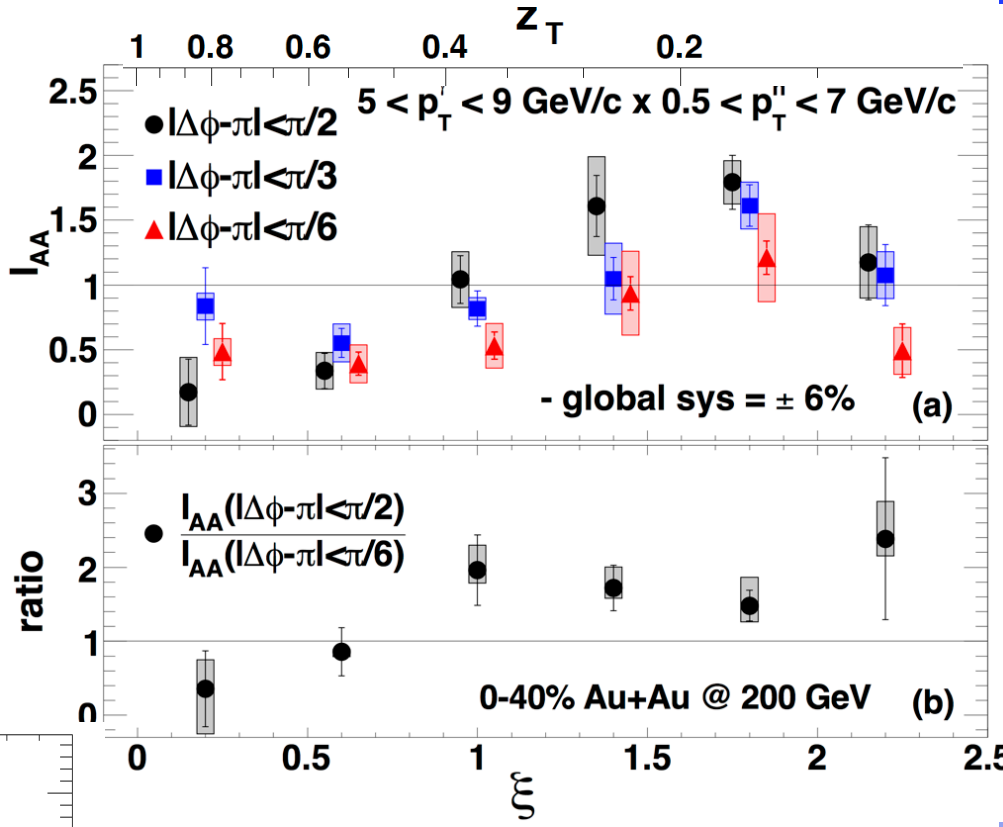
-No surface bias by trigger

-Photon p_T approximates initial parton p_T

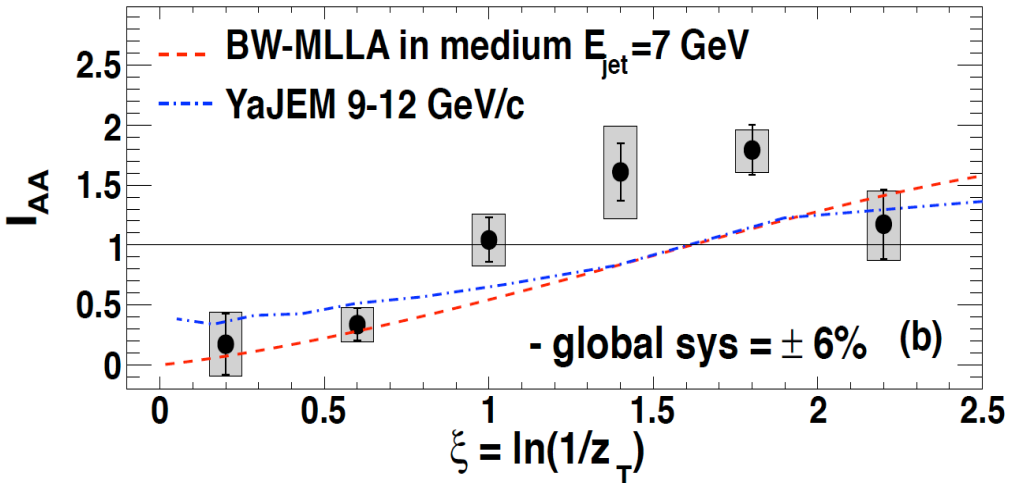
Complementary observables

γ-hadron at RHIC

- Measure per trigger yield on awayside
- I_{AA} quantifies the FF modification
- Suppression at low ξ and enhancement at high ξ
- Enhancement more pronounced for wider angles
- Qualitative agreement with models



Phenix PRL 111, 032301

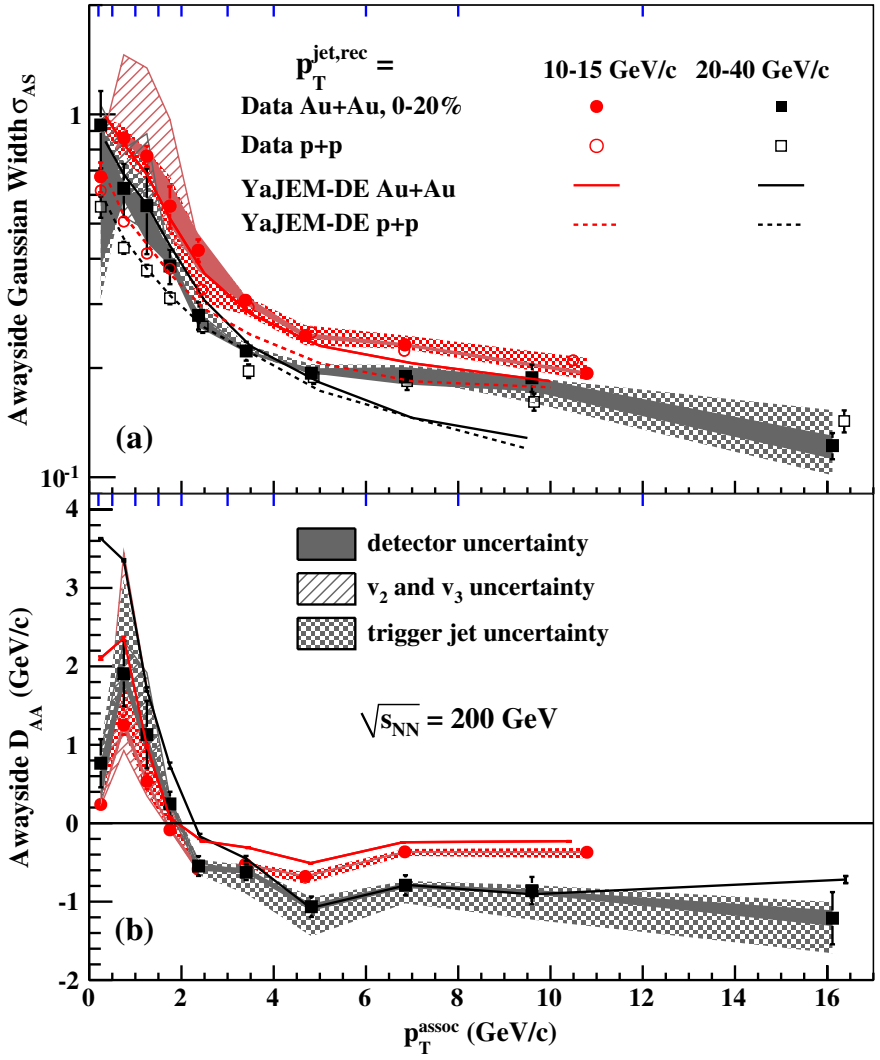


$$I_{AA} = \frac{Y_{AA}}{Y_{pp}} \sim \frac{D_{AA}(z_T)}{D_{pp}(z_T)}$$

$$z = \frac{p_{hadron}}{p_{jet}}$$

Jet-hadrons at RHIC

Jet-hadron Correlations

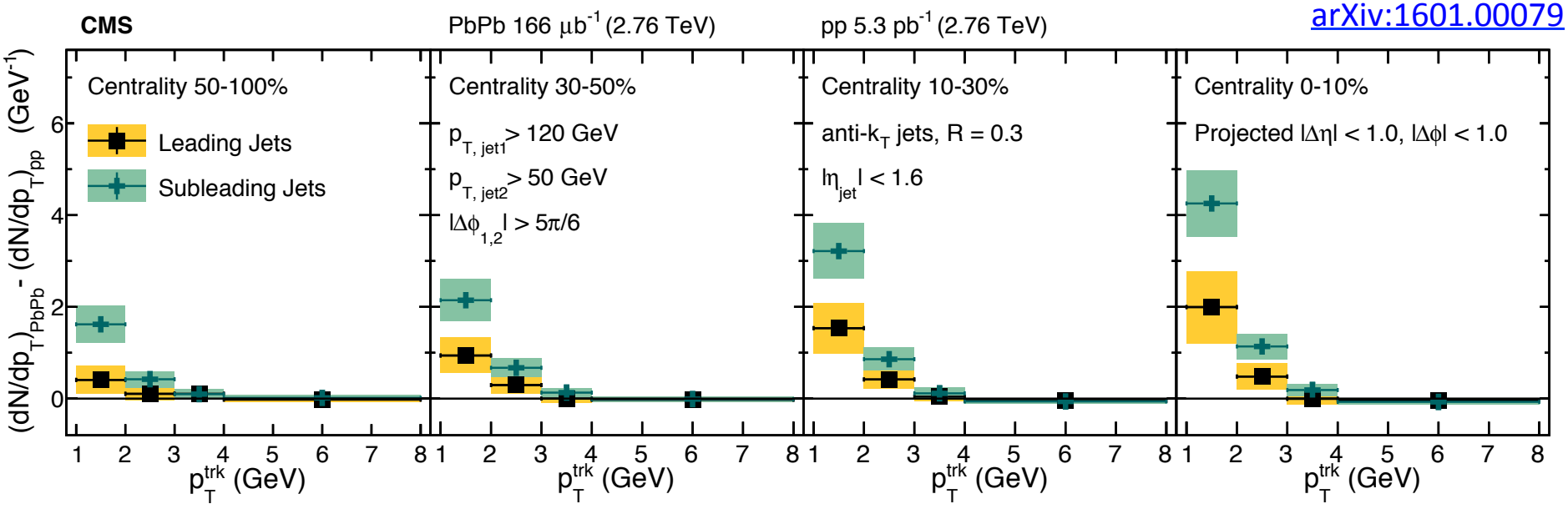


- Surface bias jet with high p_T constituent & study away-side jet
- Enhanced low momentum particle production
- Width appears broader but large uncertainties
- High p_T suppression balanced by low p_T enhancement

$p_T^{jet,rec}$ (GeV/c)	ΣD_{AA} (GeV/c)	Detector uncertainty (GeV/c)	v_2 and v_3 uncertainty (GeV/c)	Jet energy scale uncertainty (GeV/c)
10–15	-0.6 ± 0.2	$^{+0.2}_{-0.2}$	$^{+3.7}_{-0.5}$	$^{+2.3}_{-0.0}$

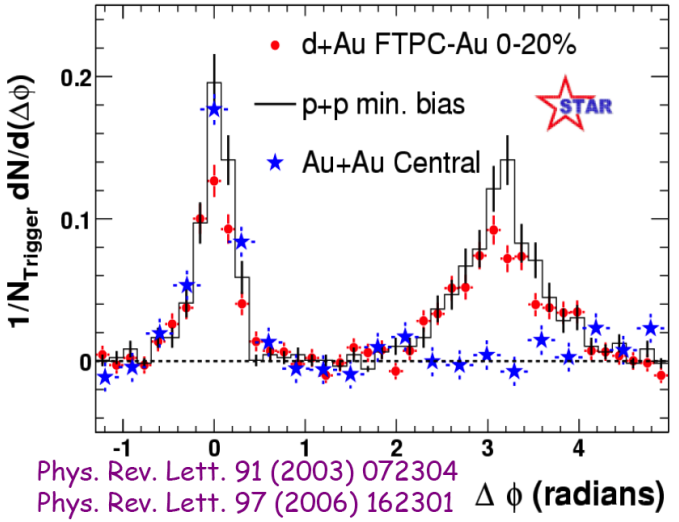
Jet-hadron at LHC

- Jet-track correlations with inclusive jet trigger
- Subtract large Δη to remove flow
- Study nearside for leading and subleading jets
- Stronger modification for subleading jets
- Wider widths observed in both Δφ and Δη



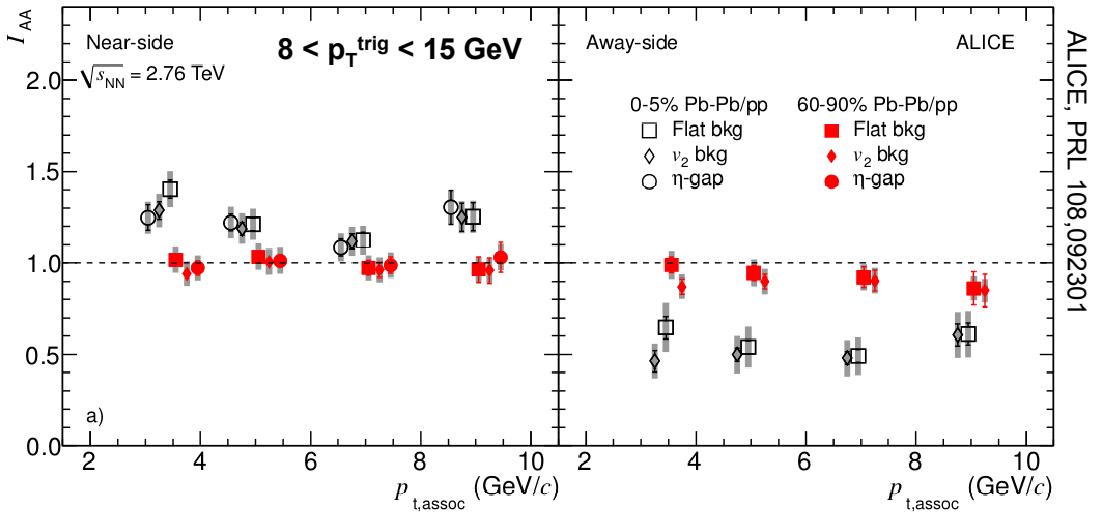
Di-hadrons

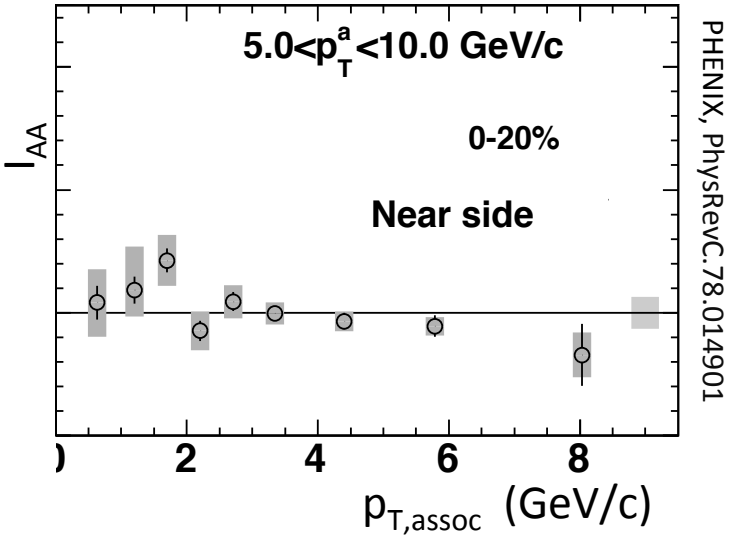
- First evidence of jet quenching in QGP
  - Suppression on the awayside
  - Observed at RHIC & LHC
- Nearside
  - RHIC: I_{AA}=1 → no modification
  - LHC: Enhancement on the nearside



Phys. Rev. Lett. 91 (2003) 072304
Phys. Rev. Lett. 97 (2006) 162301

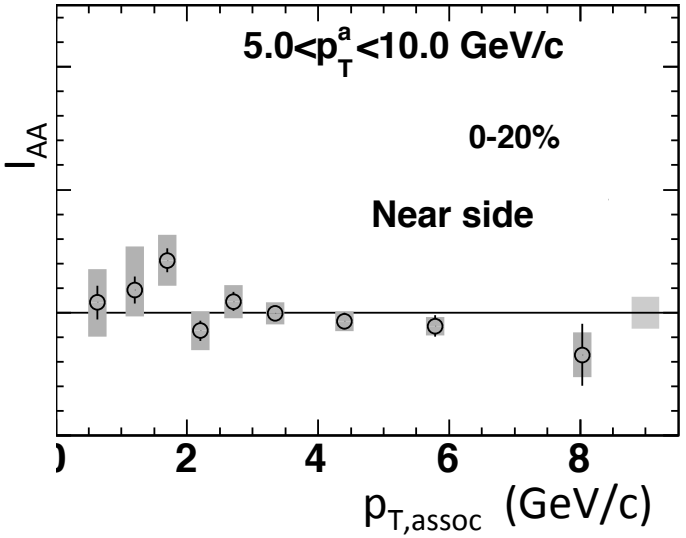
Near side Away side



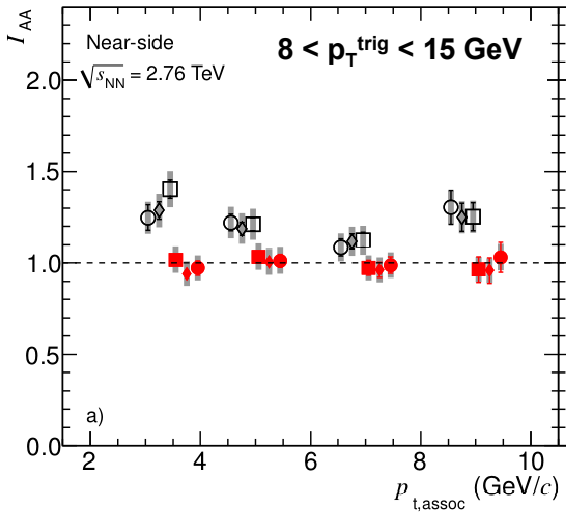


Di-hadrons

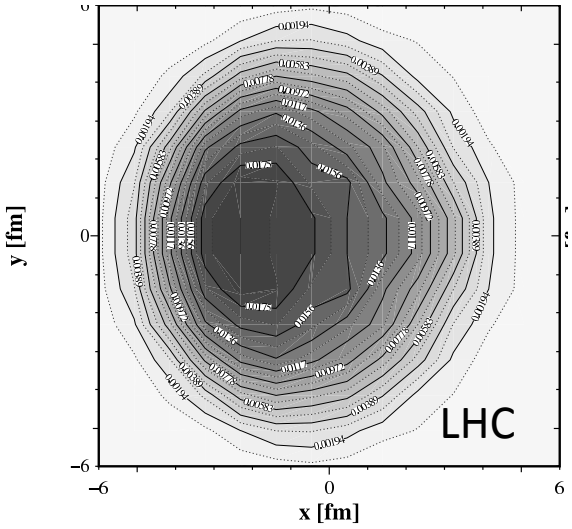
- Nearside
  - RHIC: I_{AA}=1 → no modification
    - Surface biased
  - LHC: Enhancement
    - Modified jet probes a different Q^2 than pp baseline

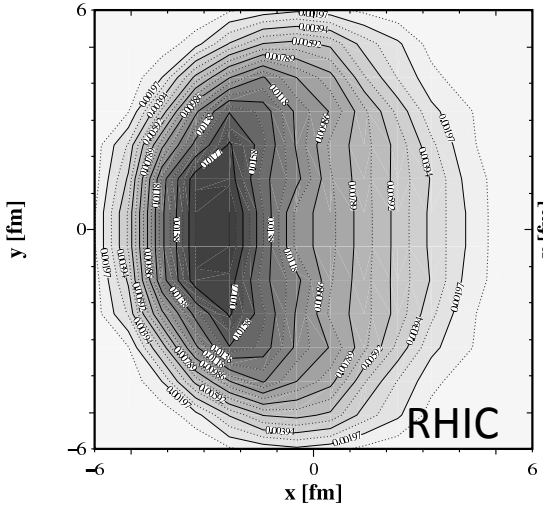


Near side



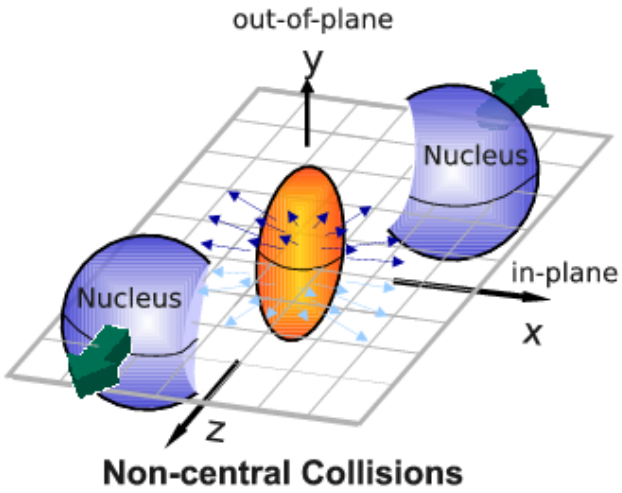
h-h Surface Bias



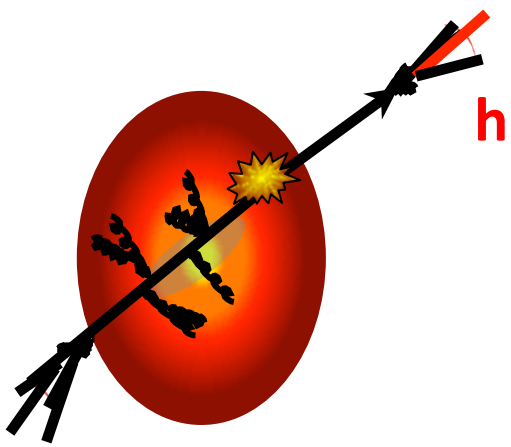


T. Renk, 1212.0646 [hep-ph]

Surface Bias & Path-length

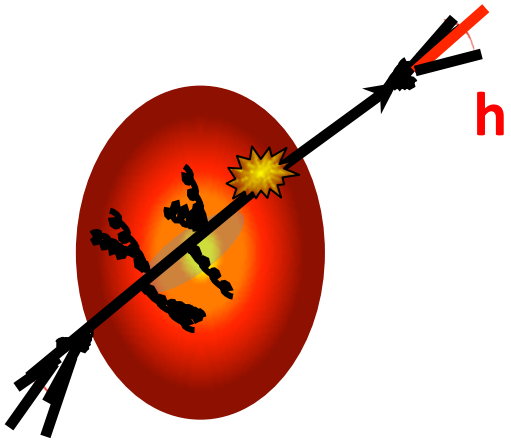


Non-central Collisions

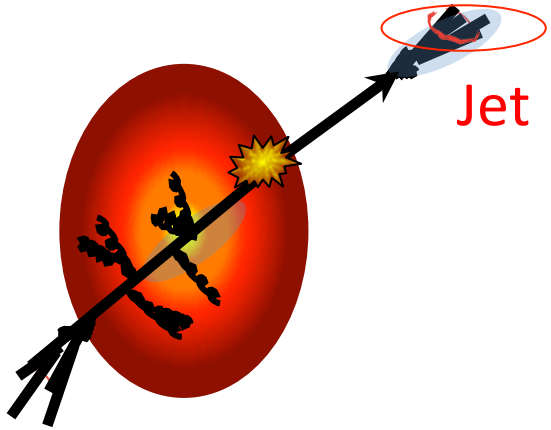


- The energy loss has a path length dependence
- The parton loses more energy the longer it travels through the medium
  - Reaction plane dependence will produce a v_2 signal: Jet v_2
- Surface biased high p_T hadrons
  - A hard scattering near the surface can emit a high momentum parton with little energy loss
- Less surface bias if clustering softer particles into a jet

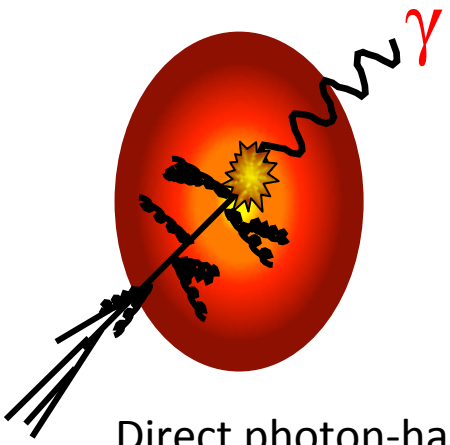
Studying Energy Loss with Correlations



Hadron-hadron

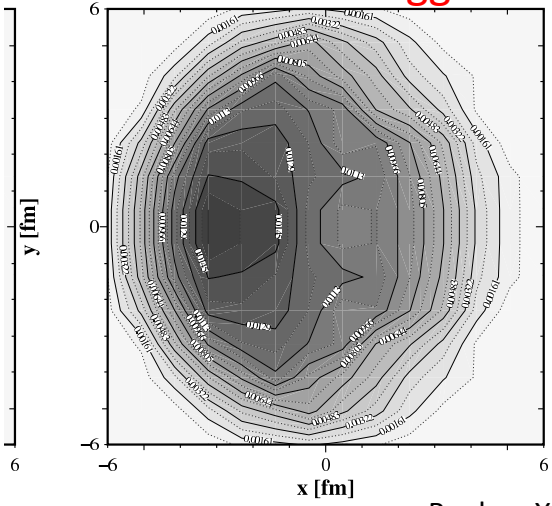


Jet-hadron

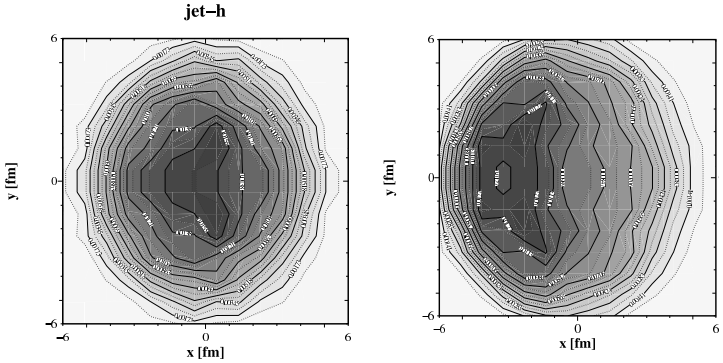


Direct photon-hadron

-Surface bias the trigger



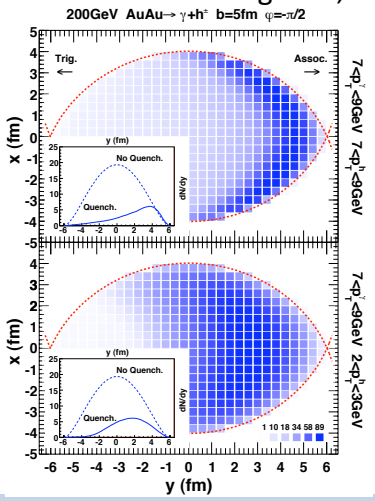
-Less surface bias
-Several parameters to vary pathlength



Renk, arXiv:1210.1330v1

-No surface bias by trigger

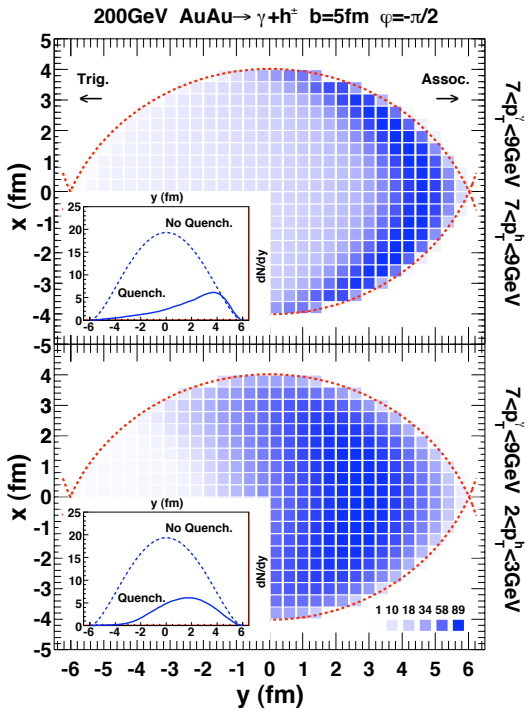
Zhang et al, 0902.4000



Surface Bias Depends on…

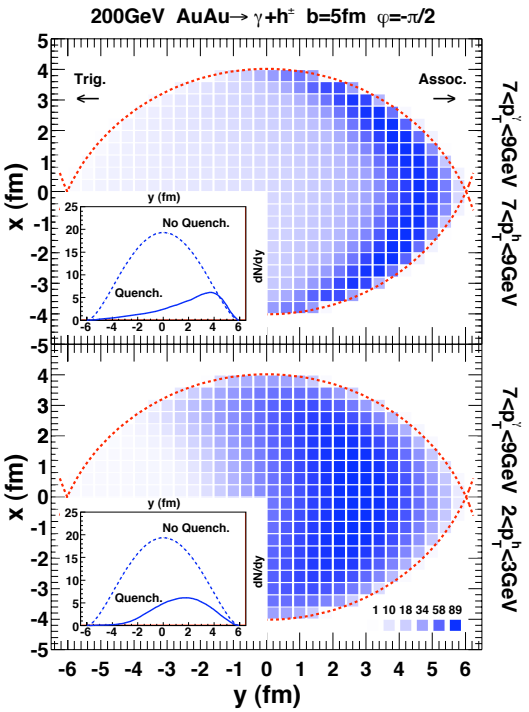
- The trigger (previous slide)
- p_T of associated hadrons

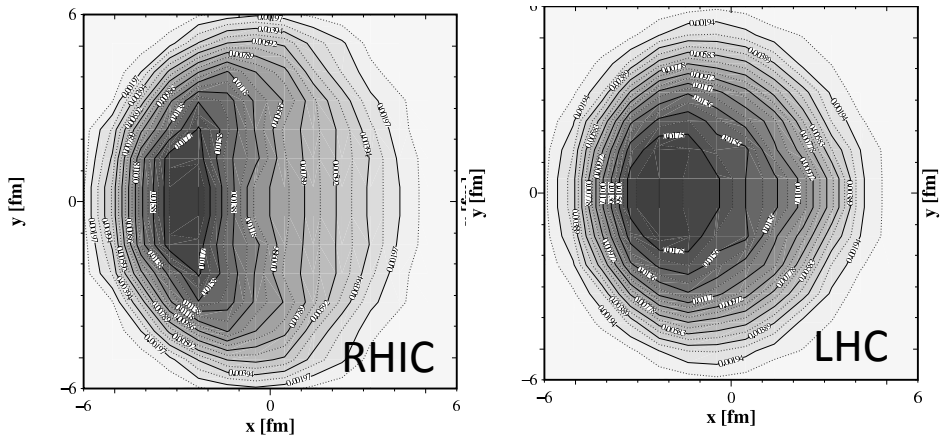
Zhang et al, 0902.4000



Surface Bias Depends on…

- The trigger (previous slide)
- p_T of associated hadrons
- Steepness of hadron spectrum
  - Less surface bias at LHC

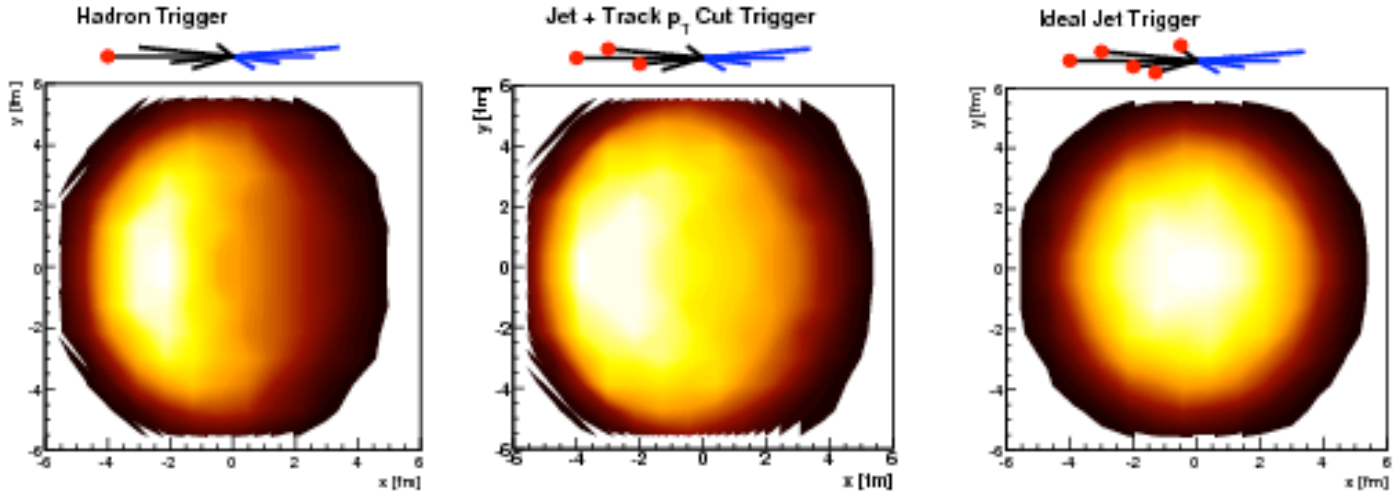




arXiv:1210.1330v1

Surface Bias Depends on…

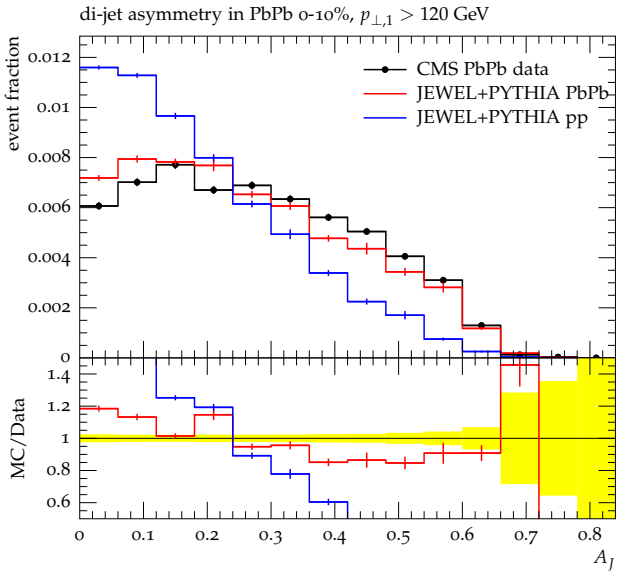
- The trigger (previous slide)
- p_T of associated hadrons
- Steepness of hadron spectrum
  - Less surface bias at LHC
- The observable

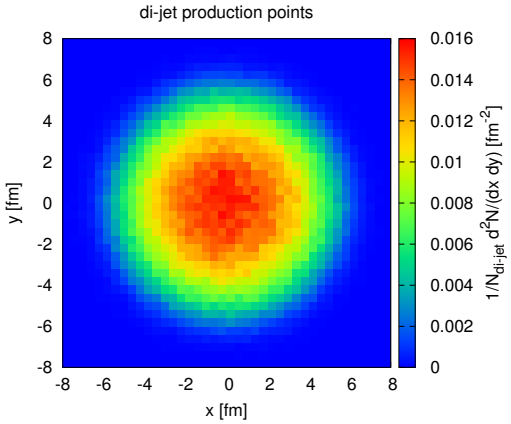


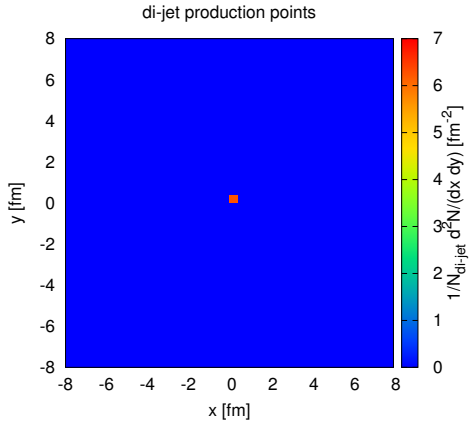
Renk
arXiv:1210.1330v1

Di-Jet Asymmetry at LHC

- Di-jet asymmetry with “ideal” jets
- Recent JEWEL study on di-jet asymmetry
  - Does Asymmetry arise from surface bias?
    - Compare full geometry to central production



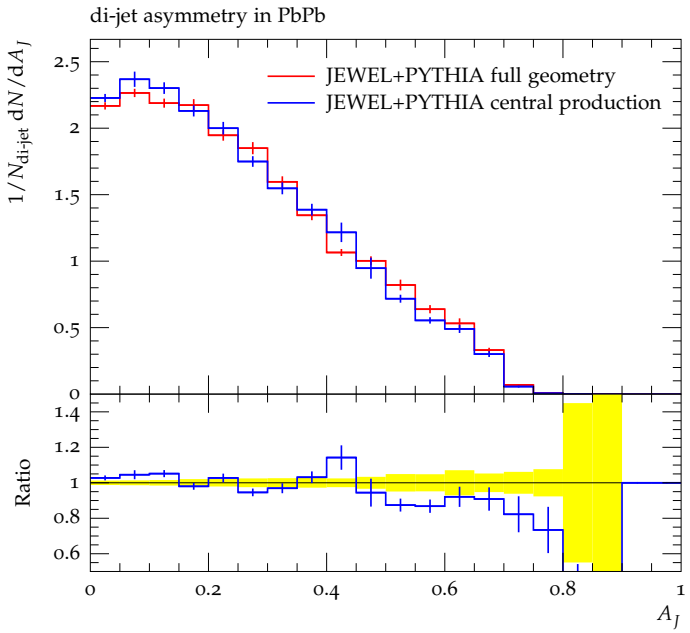


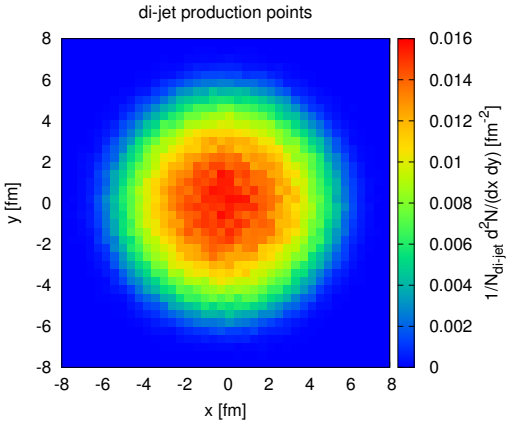


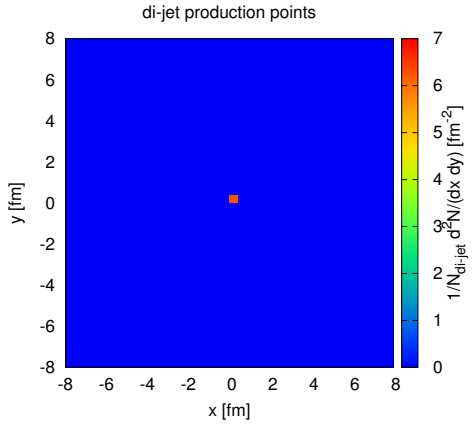
Milhano & Zapp, arxiv:1512.08107

Di-Jet Asymmetry at LHC

- Di-jet asymmetry with “ideal” jets
- Recent JEWEL study on di-jet asymmetry
  - Does Asymmetry arise from surface bias?
    - Compare full geometry to central production
    - Surface bias not a significant effect on Pb-Pb Asymmetry

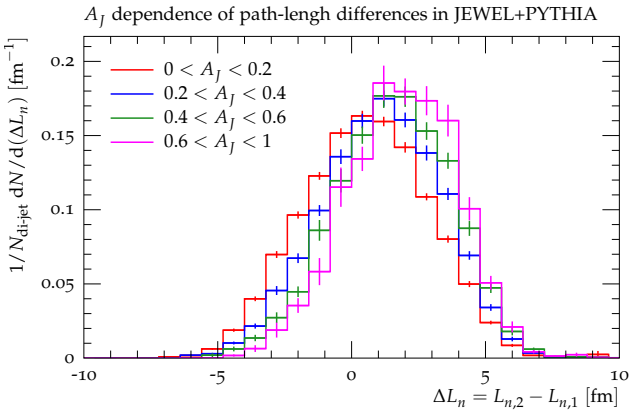






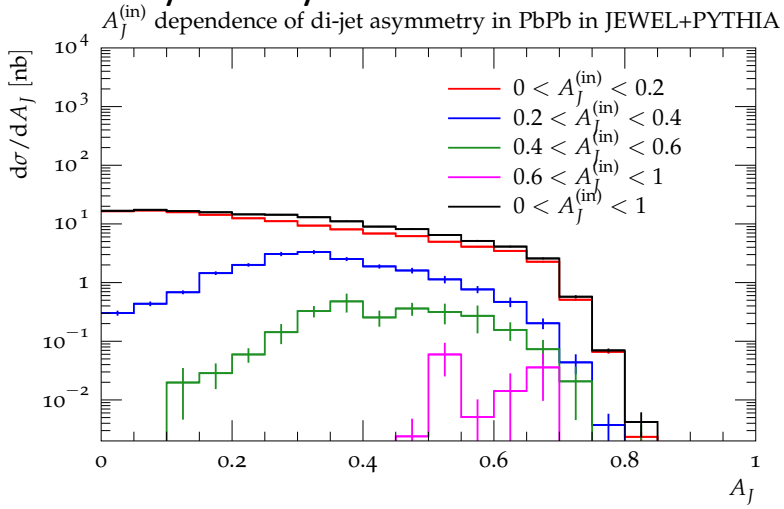
Di-Jet Asymmetry at LHC

- Pathlength effect is not significant
  - Leading jet has a longer pathlength than the subleading jet for 34% of di-jets
- Contributions to Pb+Pb Asymmetry
  - HI dijet asymmetry from fluctuations in vacuum fragmentation
  - Medium fluctuations
  - E loss depends on initial m/p_T ratio

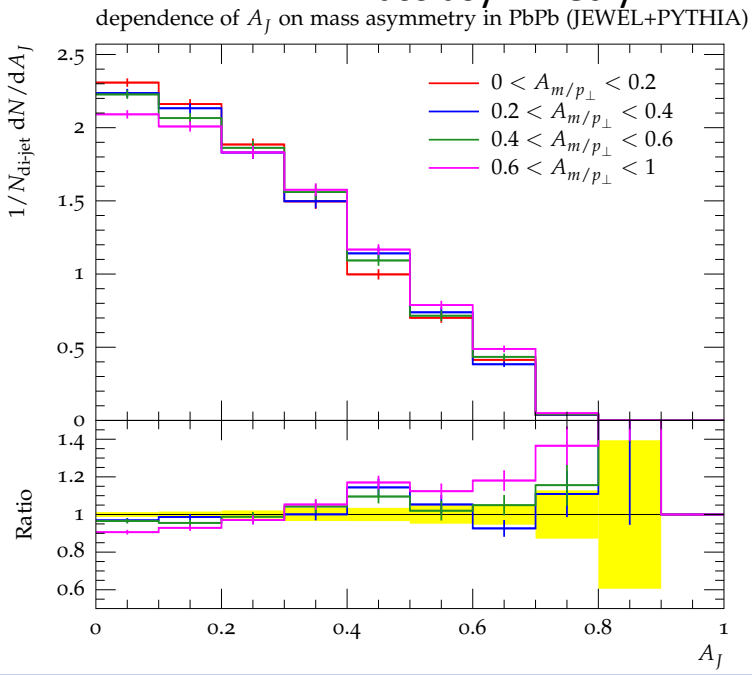


Pathlength difference

Initial asymmetry

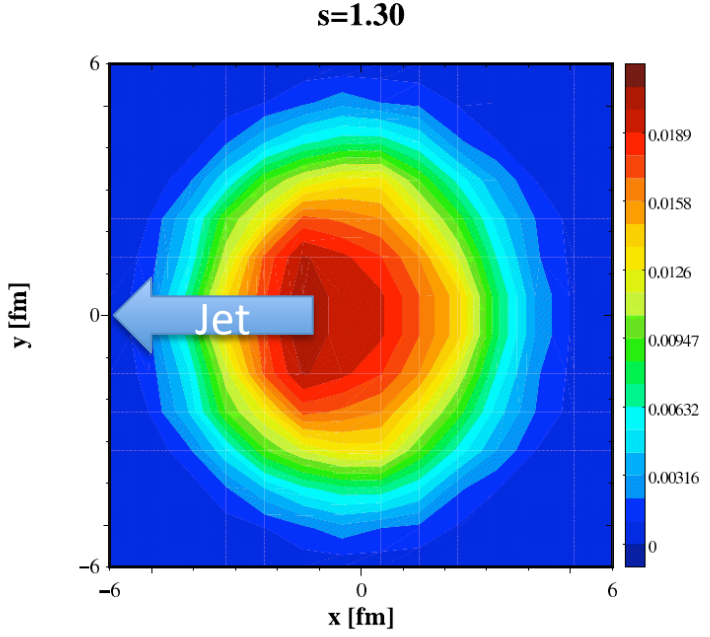


Mass asymmetry

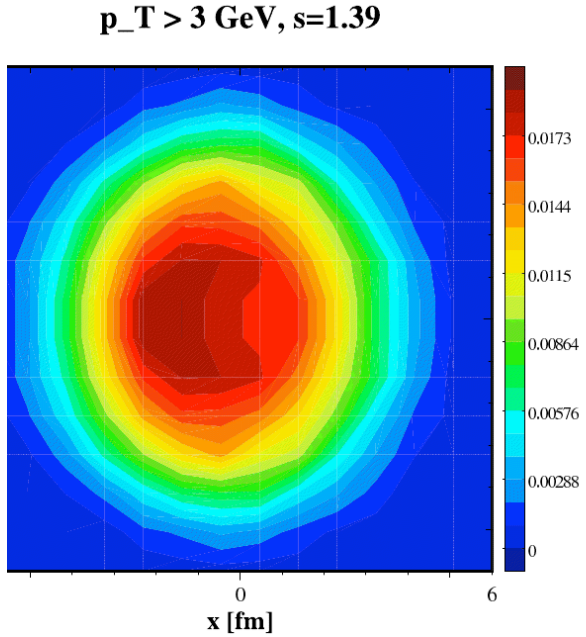


How to bias jets at the LHC

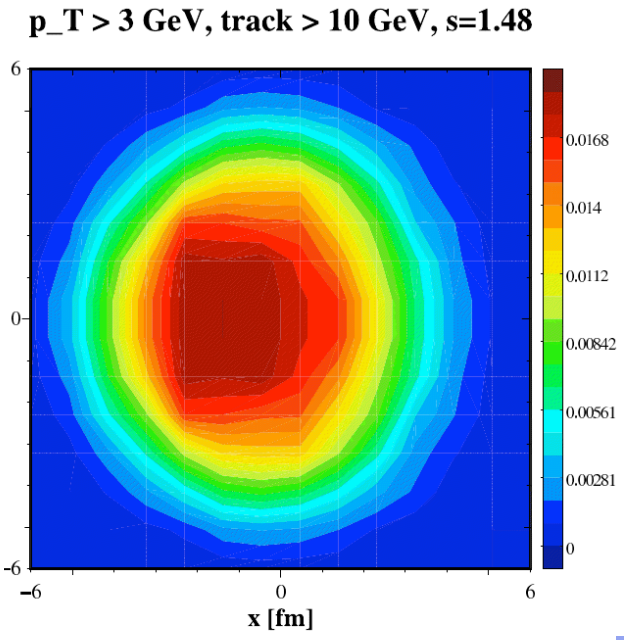
S=LHS/RHS



Constituent cut



Plus leading track requirement



- Density of vertices for 30-60 GeV Jets
- Track cuts enhance surface bias
- Surface biased jets should be comparable to pp jets

YaJEM at LHC T. Renk

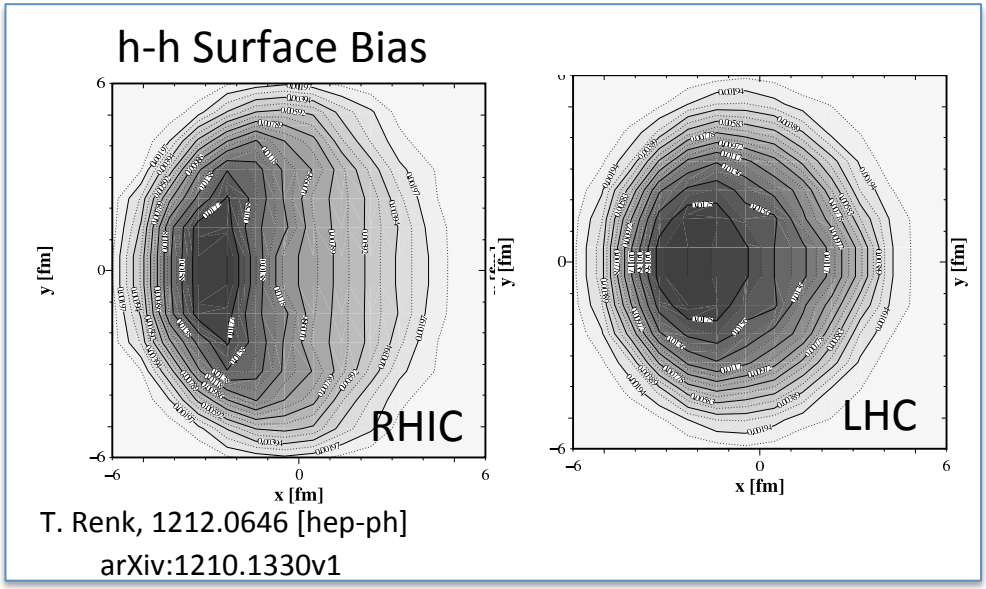
arXiv:1210.1330v1

Jet-Hadron Correlations

- This could be an extremely informative tool in our tool box if we understand the biases correctly
  - More from Kirill Lapidus this afternoon
- Possible at LHC but RHIC is better suited for such tomographic studies
  - Comparison between LHC and RHIC informative

Jets at RHIC vs LHC

- Stronger surface bias at RHIC
- RHIC jets spend more time in the medium
- Di-jet asymmetry for RHIC can differentiate between models
- q-hat as a function of temperature
  - Constrain models with variety of measurements at RHIC & LHC



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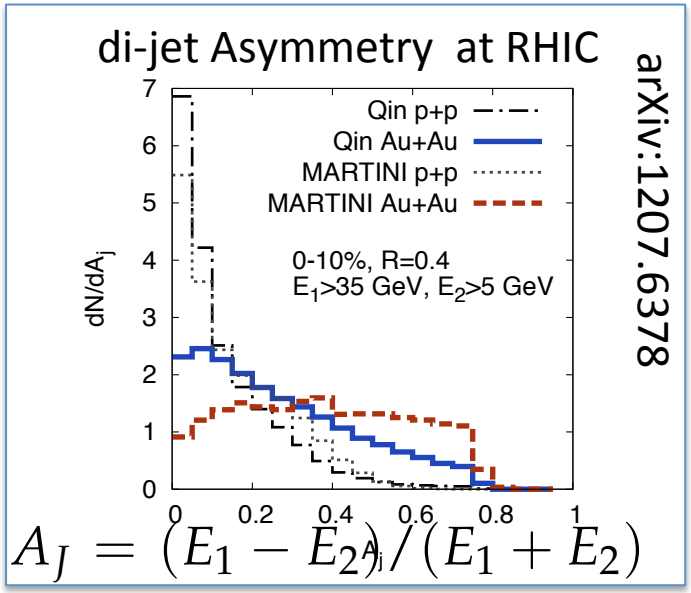
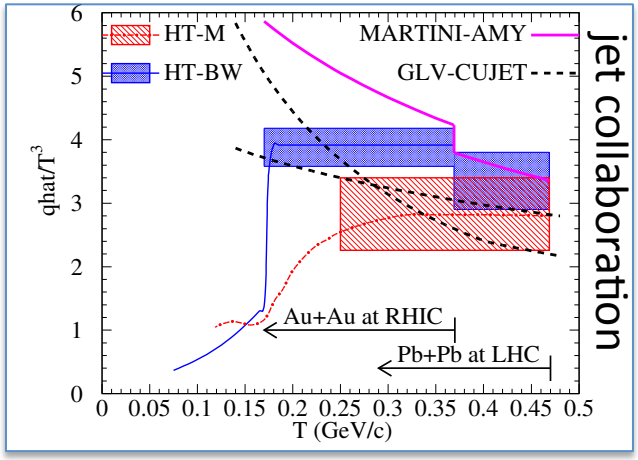
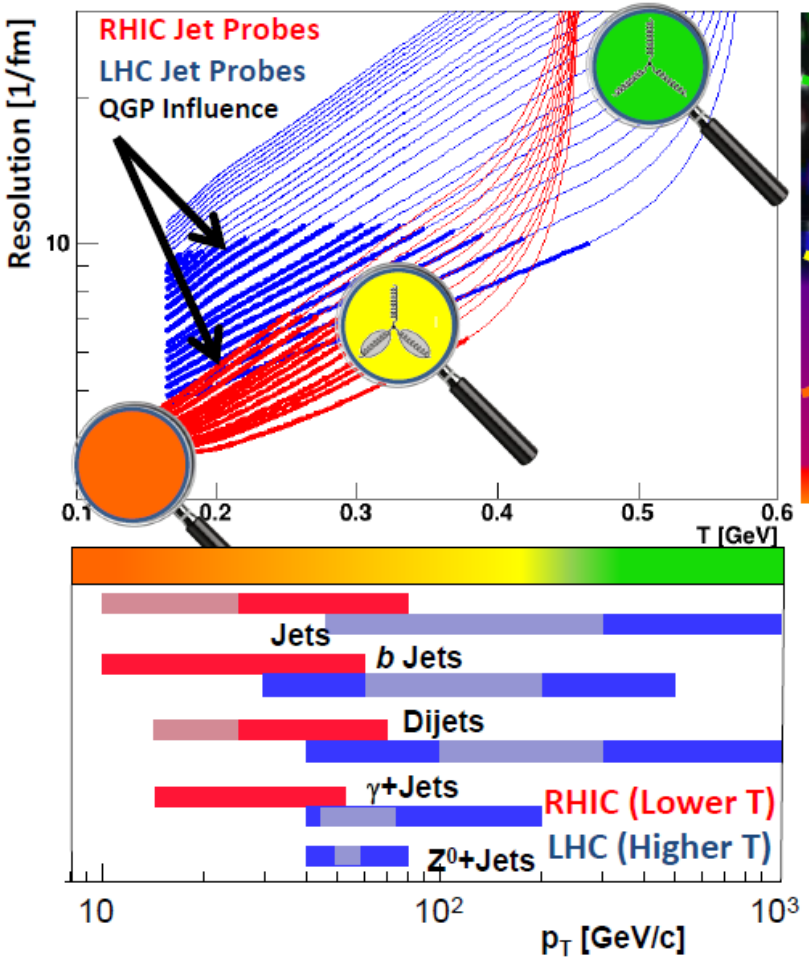
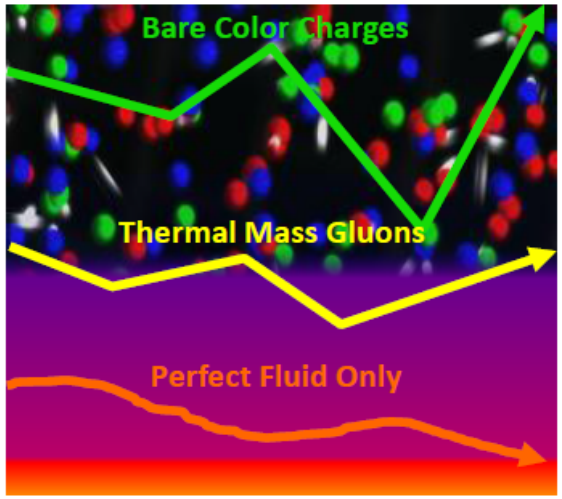




Measurements On the Horizon





- Run 2 LHC data at 5.02 TeV
- Large Au+Au 2014 data set
- sPHENIX
  - High rate jet detector at RHIC
  - ideal for jet tomography

2015 Long Range Plan of Nuclear Science

Summary

- Some predictions for surface biases in hand
  - Need details studies for both LHC and RHIC energies
- More precision correlation data coming soon
- Can the models match all of the correlation data?
  - Quark vs gluon energy loss?
  - Influence of fluctuations?
- Want more guidance from theorists
  - Use theoretical guidance to probe different pathlengths by tuning jet parameters to adjust the depth of the hard scattering inside the medium
  - Predictions for both LHC and RHIC
- Are there additional experimental measurements that could help guide theory?
  - Jet v_2