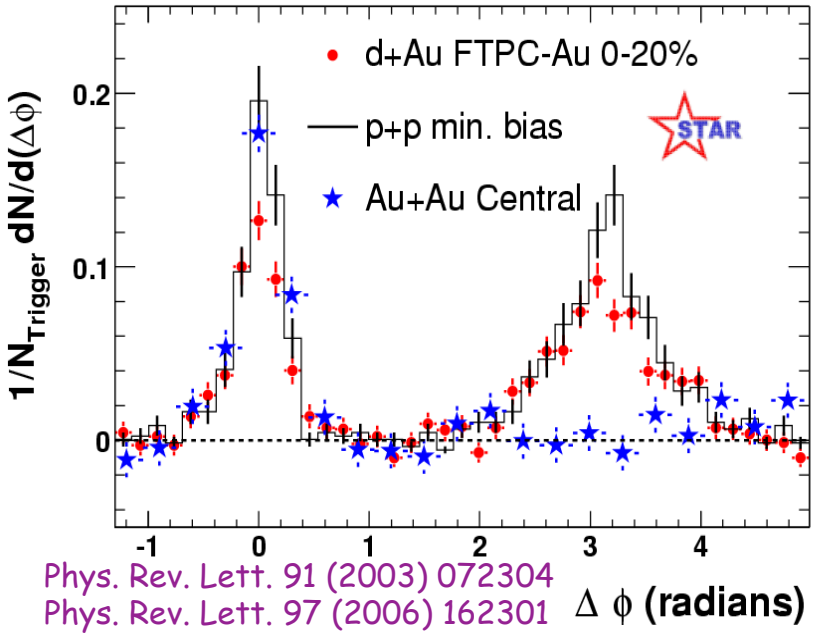
Direct measurement of jets in $\sqrt{s_{NN}}$=200 GeV Heavy Ion Collisions by 

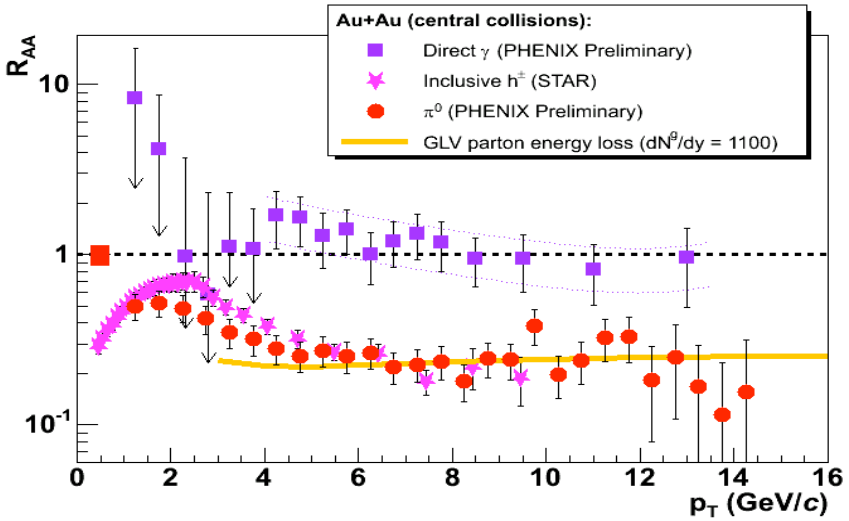
SEViL SALUR for the STAR Collaboration
LAWRENCE BERKELEY NATIONAL LABORATORY

RHIC Famous Results

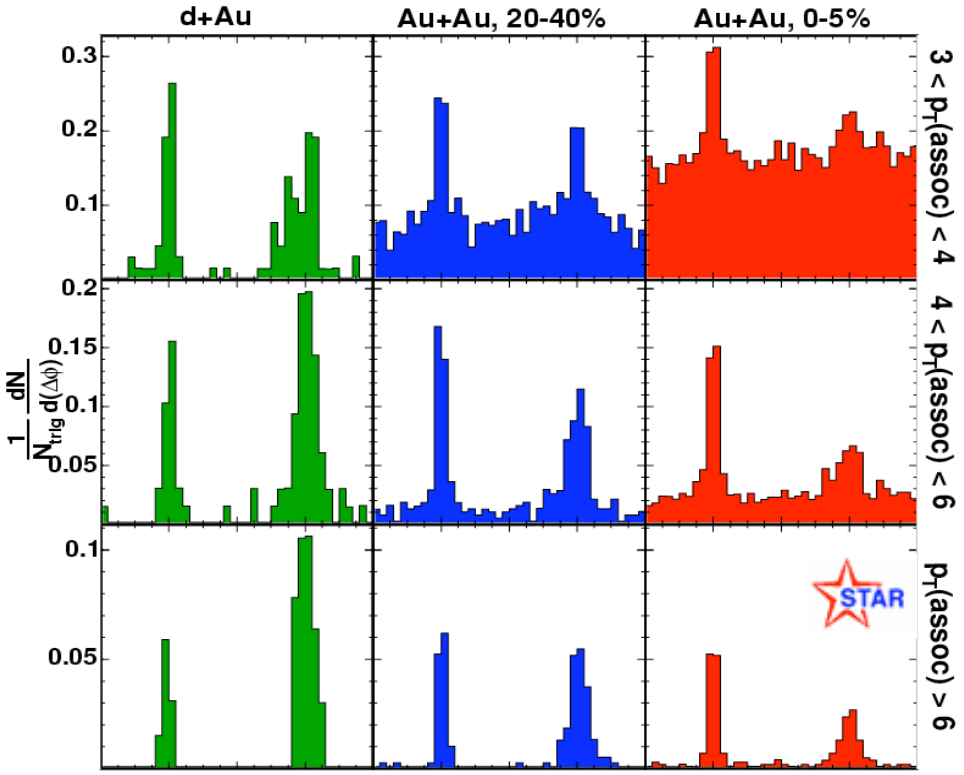


Phys. Rev. Lett. 91 (2003) 072304
Phys. Rev. Lett. 97 (2006) 162301

"Colorful" measurements of High p_T hadron suppression at RHIC observed via di-hadron corelations and R_{AA} and described by pQCD+partonic energy loss.



Phys. Rev. Lett 96 202301 (2006)



Phys.Rev.Lett.97:162301,2006

Why Reconstruct Jets?

Full jet reconstruction gives access to the full spectrum of fragmentation topologies:

- much reduced geometric biases, full exploration of quenching.

- qualitatively new observables: jet shape, fragmentation function, energy flow,...

Goal is Unbiased Jet Reconstruction:

Reconstruct partonic kinematics independent of fragmentation details - quenched or unquenched.

Event Selection and Terminology

Au+Au STAR: 0-10% Central Au+Au $\sqrt{s_{NN}}$=200 GeV selected via charged multiplicity from Year 7 Run.

MB-Trig: Minimum Bias Trigger

HT-Trig: Satisfied Minimum Bias and additional condition that EMC cluster >7.5 GeV

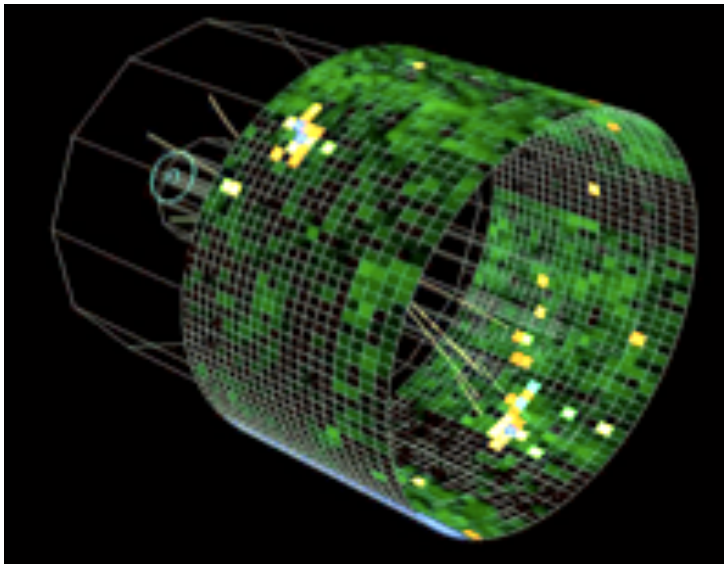
p+p STAR: p+p at $\sqrt{s}$ =200 GeV (Phys. Rev. Lett. 97 (2006) 252001)

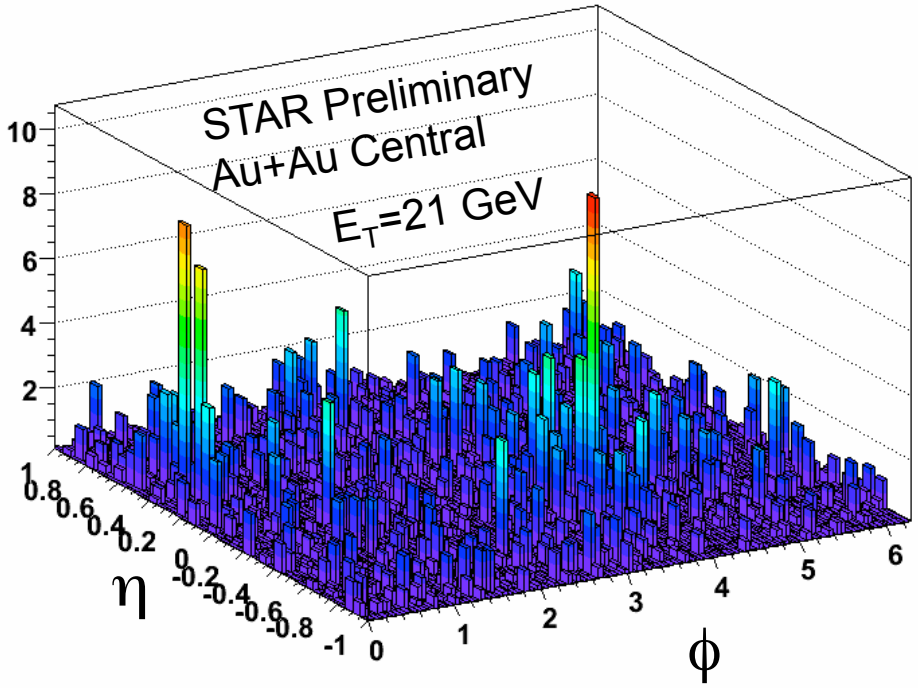
PyTrue: Pythia 8.107 p+p at $\sqrt{s}$ =200 GeV, all particles except neutrinos.

PyDet: Pythia p+p at $\sqrt{s}$ =200 GeV at detector level.

PyEmbed: PyDet, embedded into real Au+Au 0-10% events.

Jet Measurements

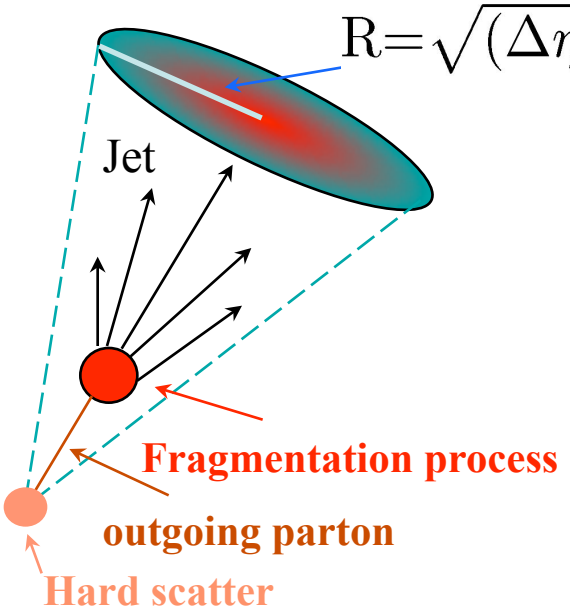




Jets are reconstructed via STAR EMC and TPC.
Correction applied for the hadronic energy in the EMC.

Jet Selection: Take only the highest energy jet per event.

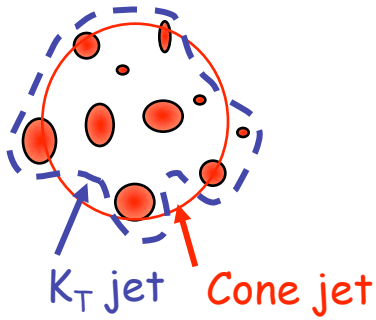
Jet Reconstruction Algorithms:



Cone Algorithm

1. Leading Order High Seed Cone (LOHSC)

2. Mid Point Cone: Merging & Splitting



Sequential recombination

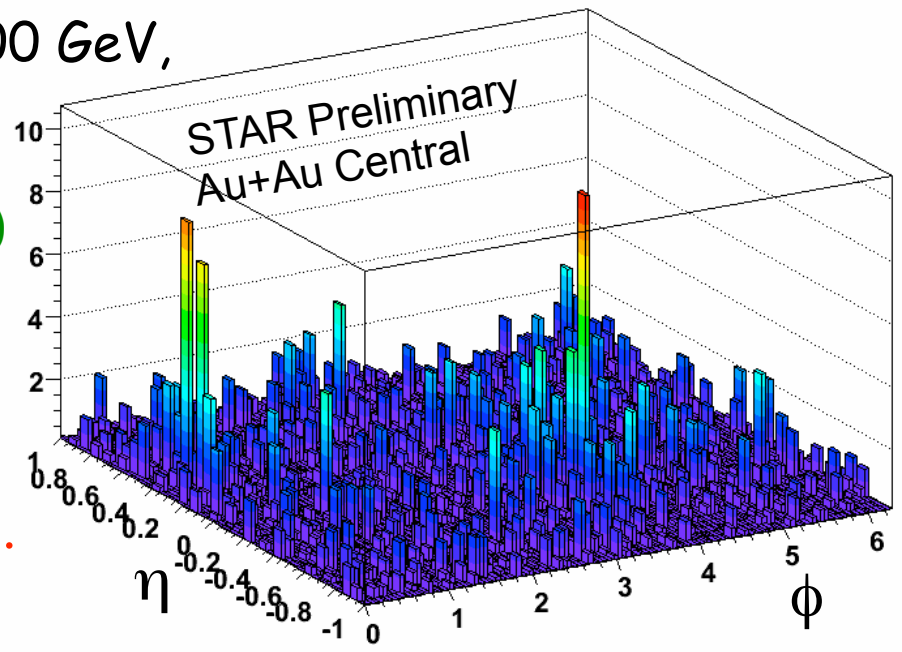
3. KT
4. Cambridge/ Aachen

Explore systematics: Use both Clustering & Cone algorithms.

Correction for Heavy-Ion Background

0-10% Most Central Au+Au at $\sqrt{s_{NN}}$= 200 GeV,

- R=0.4, Bkg Energy ~ 40 GeV
- Unmodified (p+p) jets: ~80% of energy within R~0.3 for 50 GeV jet (CDF/D0 Jets)



- Background Estimates:

Assess backgrounds event by event.

1. **Cone:** Look at $\langle p_T \rangle$ out-of jet cones..
   $A=\pi R^2$

2. **Sequential Recombination**: Estimate the active area of each jet by addition of zero energy particles of known density.

$$p_T \text{ (Jet Measured)} \sim p_T\text{(Parton)} + \rho \times A\text{(Jet)} \pm \sigma\sqrt{A\text{(Jet)}}$$

ρ = Diffuse noise, σ=noise fluctuations

M. Cacciari, G. Salam, G. Soyez 0802.1188 [hep-ph]

Reduction of background fluctuations: p_T cuts, limit R.

Event Characteristics: Jet Area & Fluctuations

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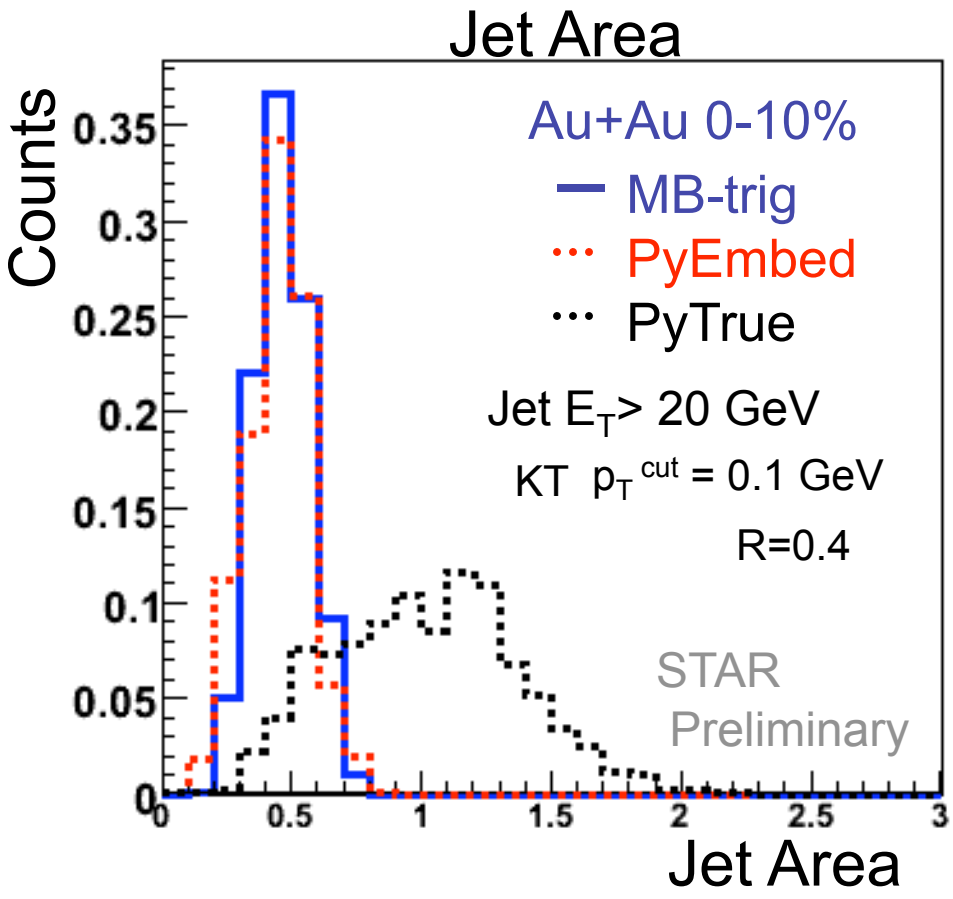
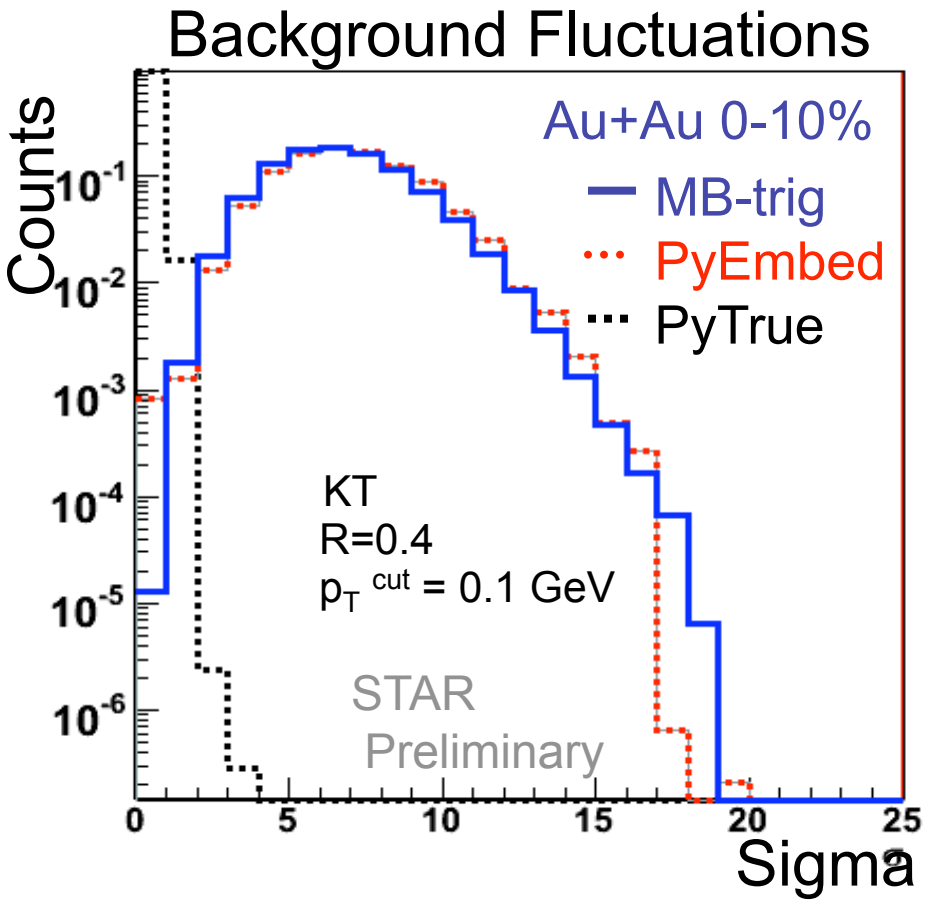
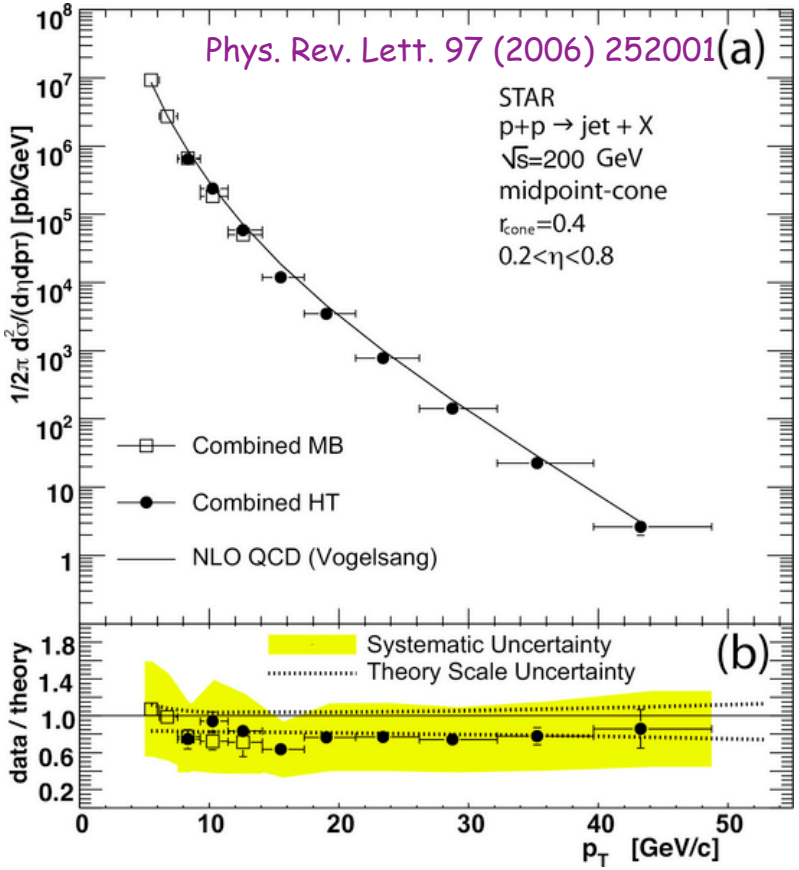




Heavy-ion: Reduction in Jet Area & Increase in fluctuations

Pythia Jets embedded in real Au+Au background events have the same area and fluctuations with that of Jets in real Au+Au data.

Inclusive Jet Measurement at $\sqrt{s}$ =200 GeV p+p collisions



Experimental uncertainty ~50%

Inclusive mid-rapidity jet production in polarized proton collisions at $\sqrt{s}$=200 GeV.

Reconstructed by a mid-point jet cone algorithm with R = 0.4

Agrees also well with NLO p-QCD

Use this result as a reference for Au+Au:

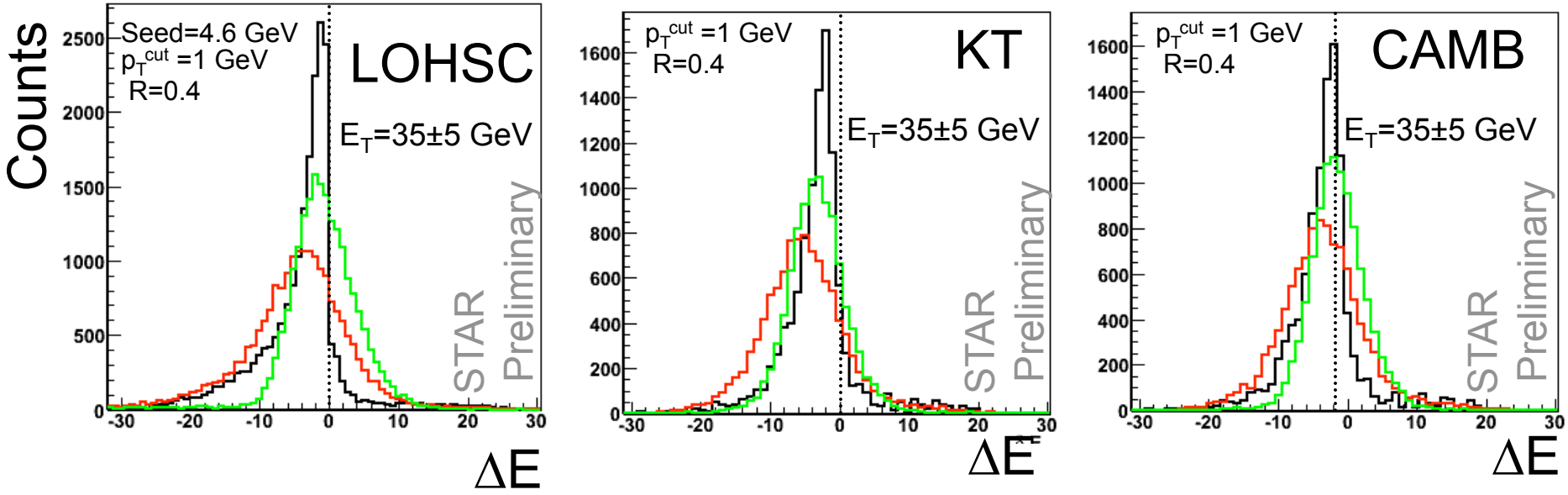
$$\frac{dN^{jet}_{Au+Au}}{dE_T} = T_{AA}\frac{\sigma^{jet}_{p+p}}{dE_T}$$

Unbiased jet reconstruction: Reconstruct partonic kinematics independent of fragmentation details - quenched or unquenched.

If jet reconstruction in Au+Au is unbiased,
N_{binary} scaling relative to p+p will be observed.

Energy Resolution

Event by event comparison of PyTrue vs PyDet vs PyEmbed.



$\Delta E = E^{PyDet} - E^{PyTrue}$

$\Delta E = E^{PyEmbed} - E^{PyTrue}$

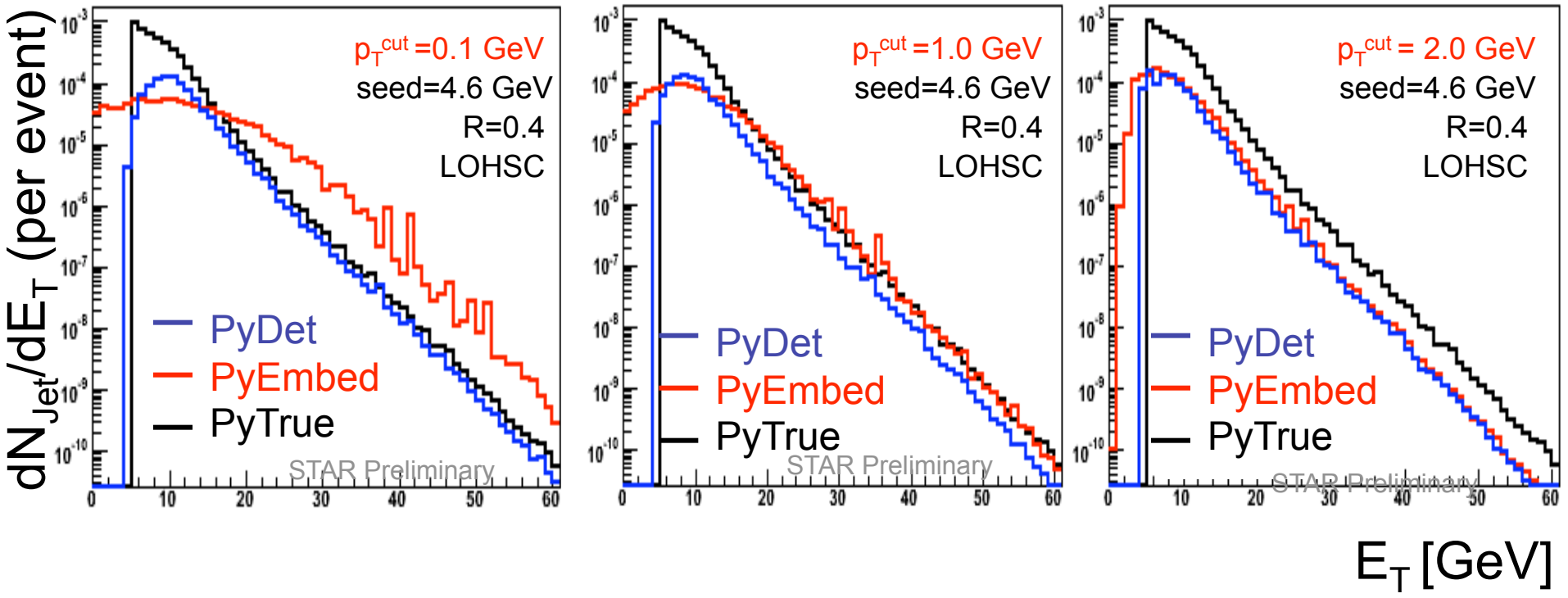
$\Delta E = E^{PyEmbed} - E^{PyDet}$

Shift of median due to un-measured particles (n, K^0_L) and the p_T cut.

Smearing due to background subtraction in Au+Au.

Tail at positive ΔE causes a kick in the spectrum.

Effect of Resolution on Spectrum



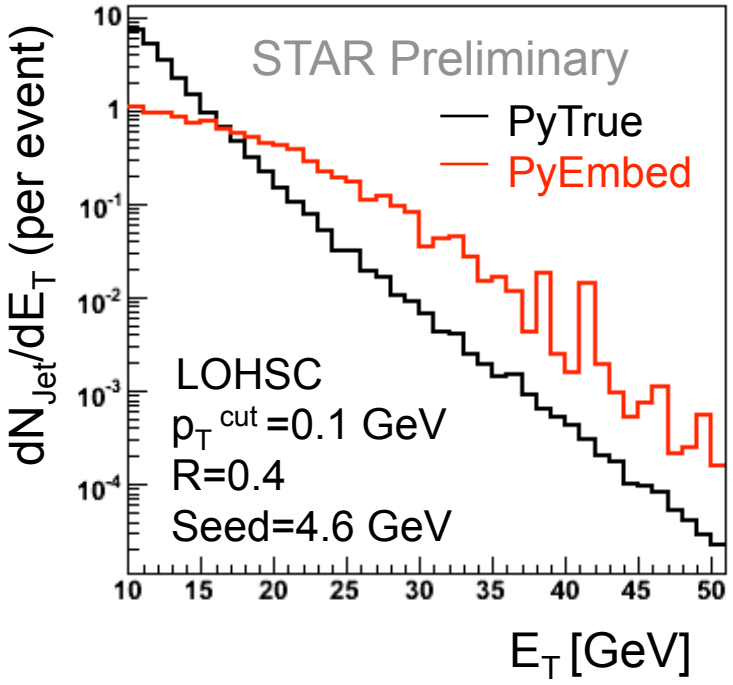
-Increase p_T threshold: Reduce the effect of background fluctuations (jet reconstruction in 0-10% Au+Au is similar in p+p)

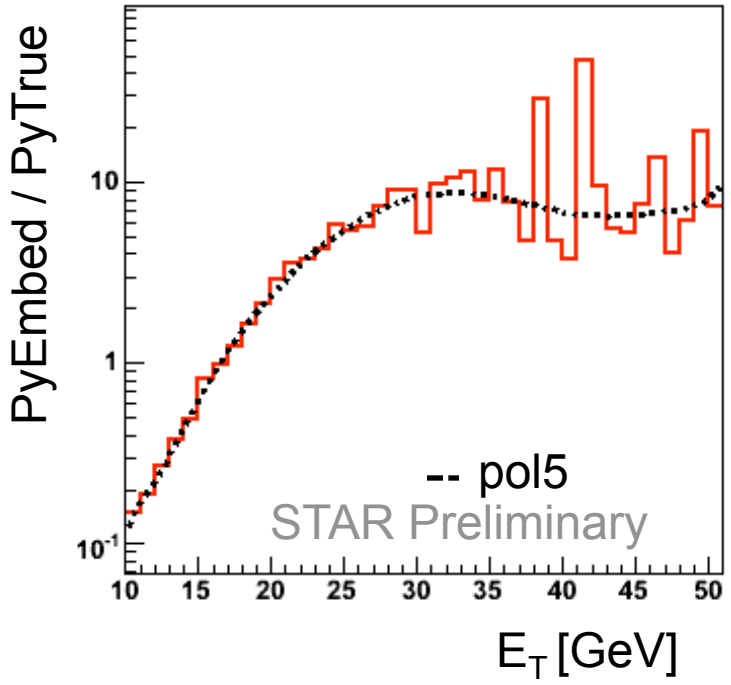
- The p_T cut is expected to produce biases.

Similar effects also observed for KT & Cambridge/Aachen

Resolution and Efficiency & Acceptance Corrections

Resolution effect corrected assuming **Pythia Fragmentation**.
Embed Pythia Jets in 0-10% Central Events with MBtrig.

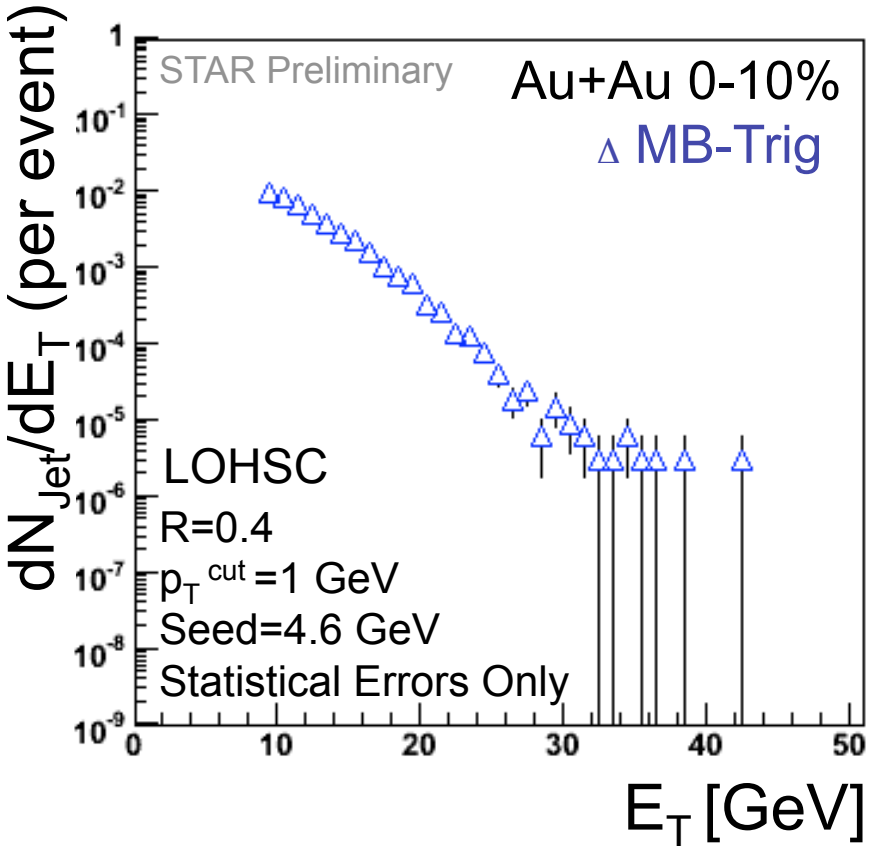




E_T-dependent correction factors			
P_T^{cut}	**LOHSC**	**KT**	**CAMB**
0.1 GeV	0.2-10	1-4	2-6
1 GeV	0.2-1	0.7-1	1-2
2 GeV	0.2-0.3	0.5-1	0.5-1

Use the fit functions from the ratio of PyEmbed to PyTrue to correct for energy resolution, efficiency & acceptance.

Reconstructed Jet Spectra & Corrections:



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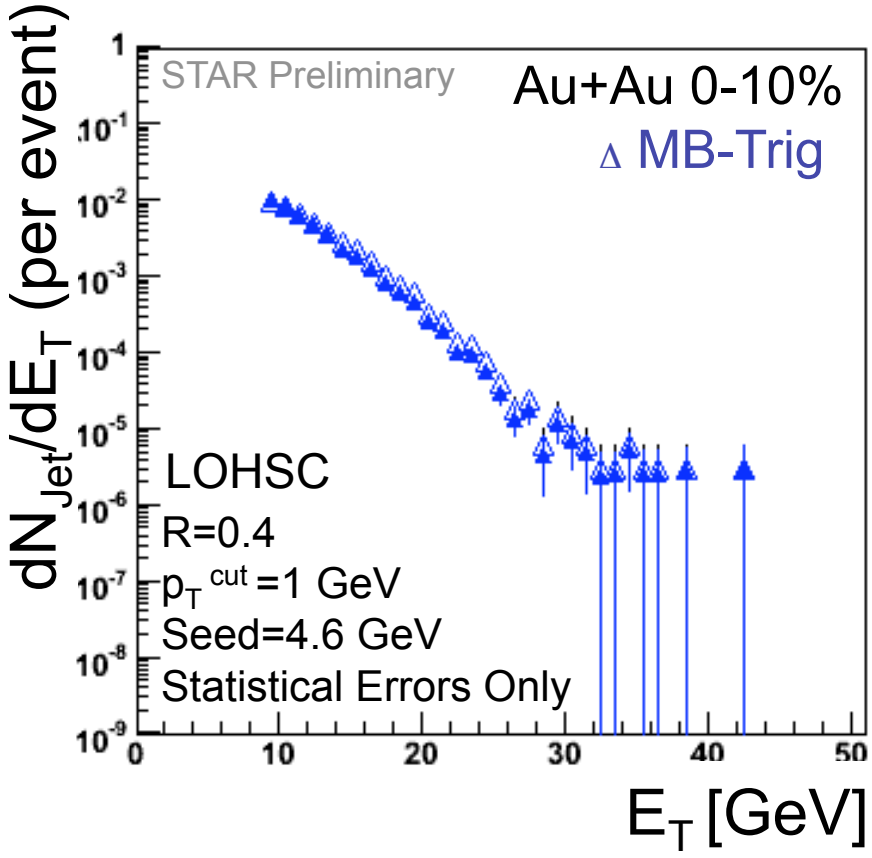

Resolution effect corrected assuming **Pythia Fragmentation**.

p_T^{cut}=1 GeV small correction for resolution, efficiency & acceptance.

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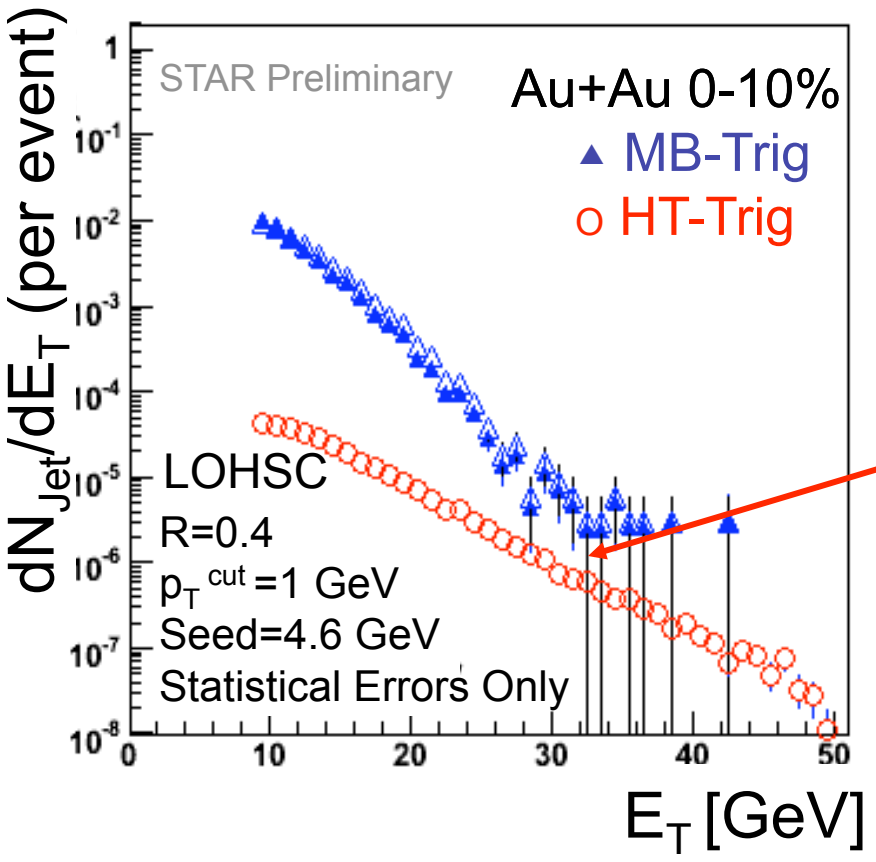

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Large trigger bias persists at least to 30 GeV.

HP 2008 Monday Talk by J. Putschke

Further statistics of MB is needed to assess the bias in HT Trigger. (~20 more MB is recorded)

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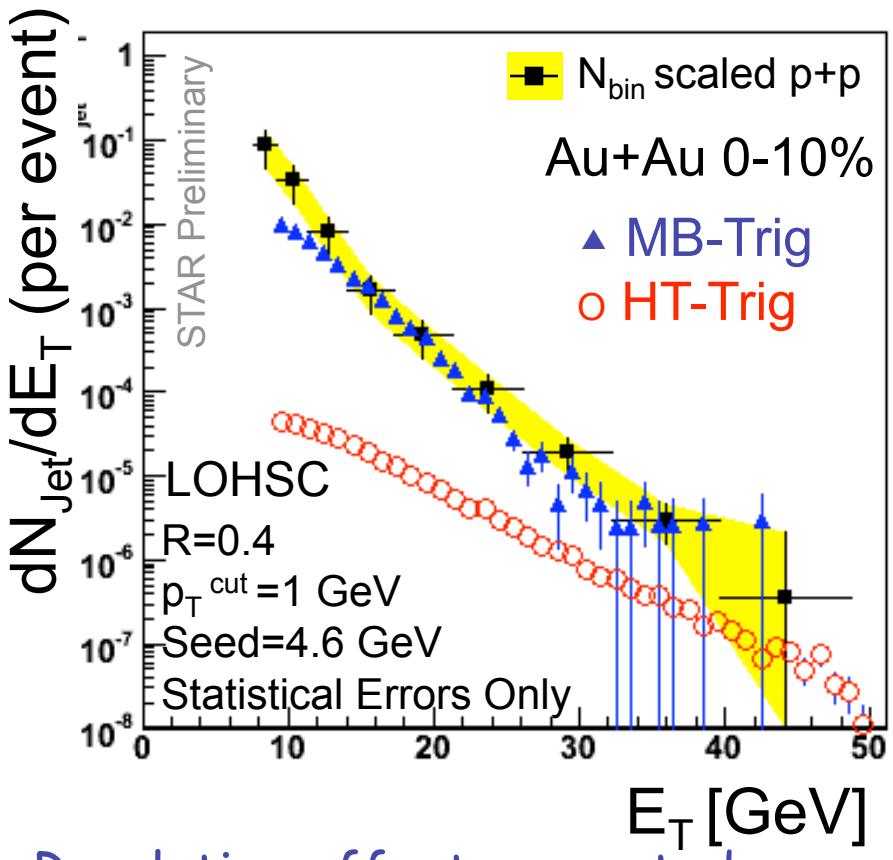

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Further statistics of MB is needed to assess the bias in HT Trigger. (~20 more MB is recorded)

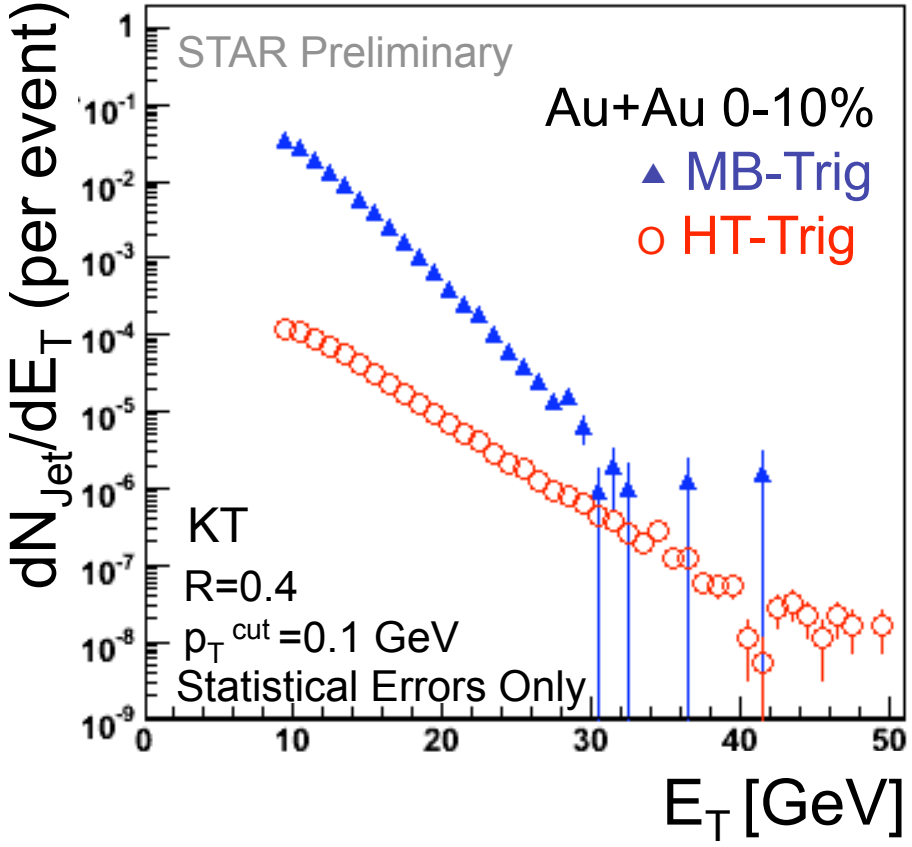
HP 2008 Next Talk by M. Heinz

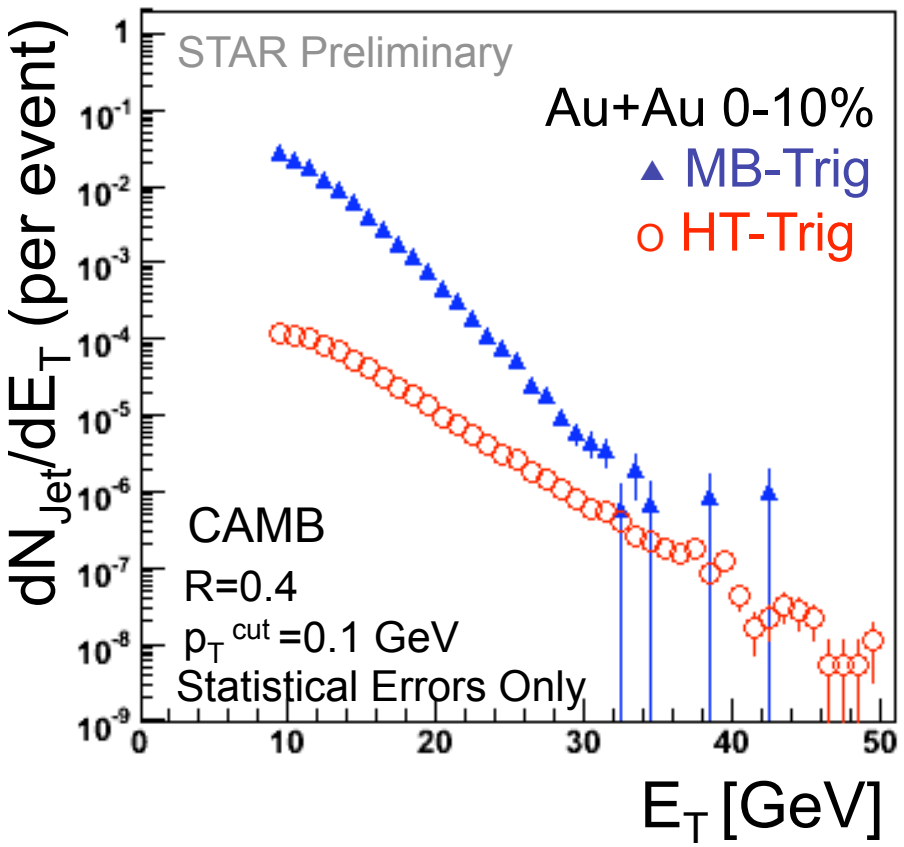
Relative normalization systematic uncertainty: ~50%
Good agreement with N_{bin} Scaled p+p.

What does this mean?

Lets look at other algorithms.

Jets with Sequential Recombination Algorithm





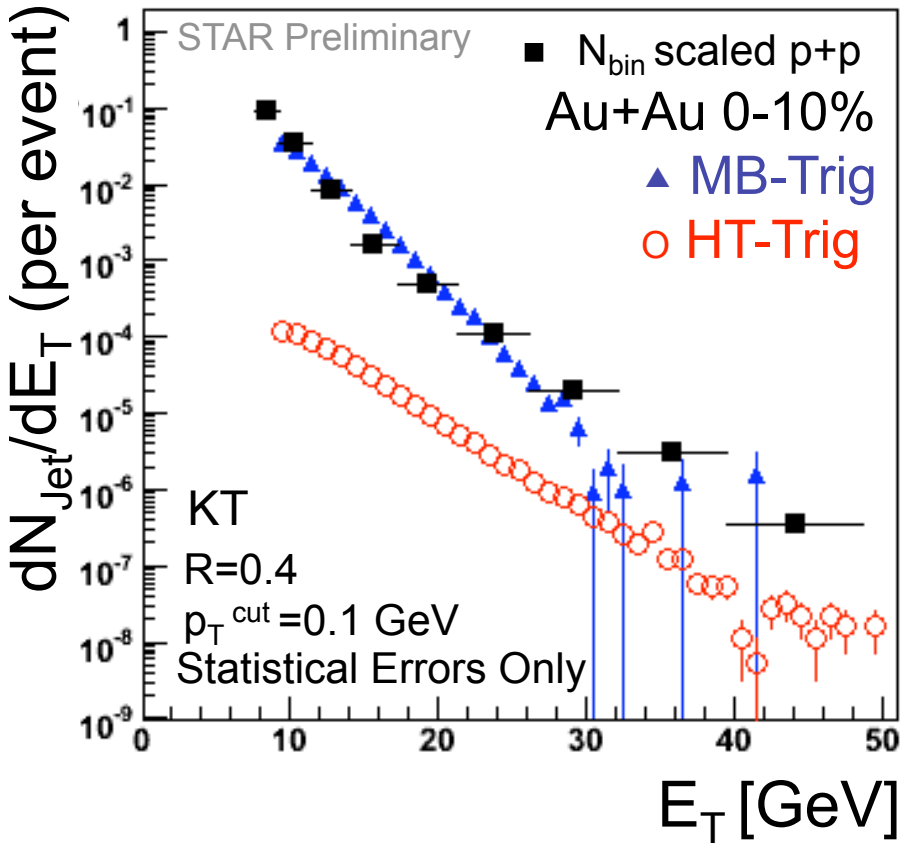
KT & CAMB biases are different wrt. LOHSC due to:

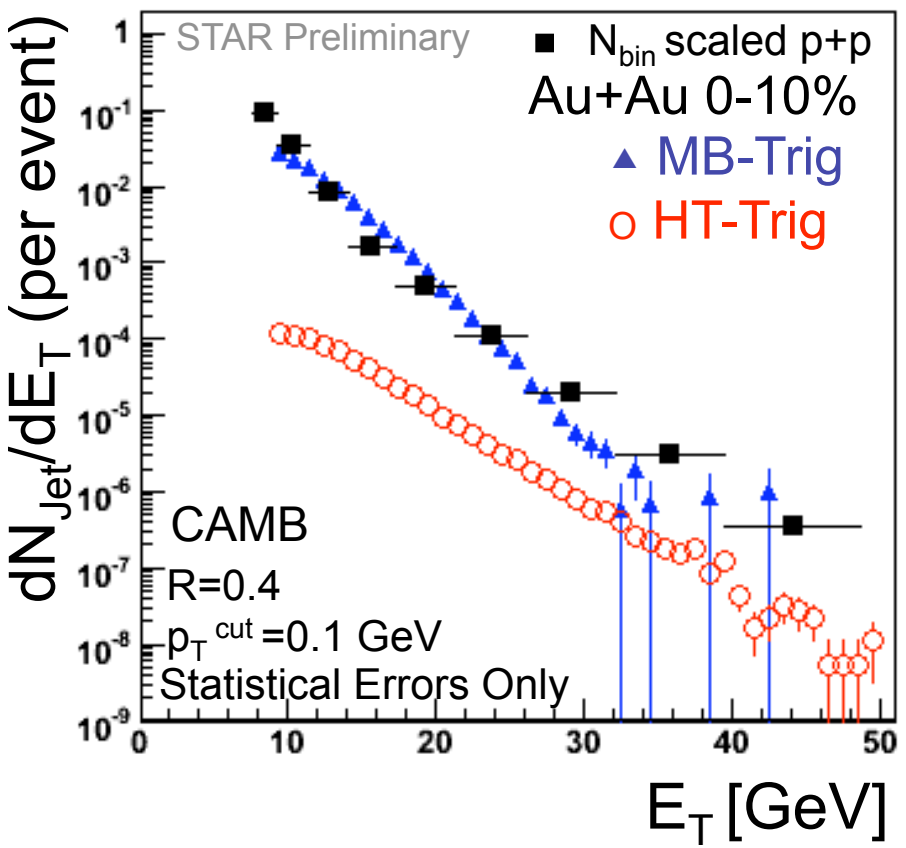
-- background subtraction algorithm

-- no seed

-- low p_T cut

Jets with Sequential Recombination Algorithm





KT & CAMB biases are different wrt. LOHSC due to:

-- background subtraction algorithm

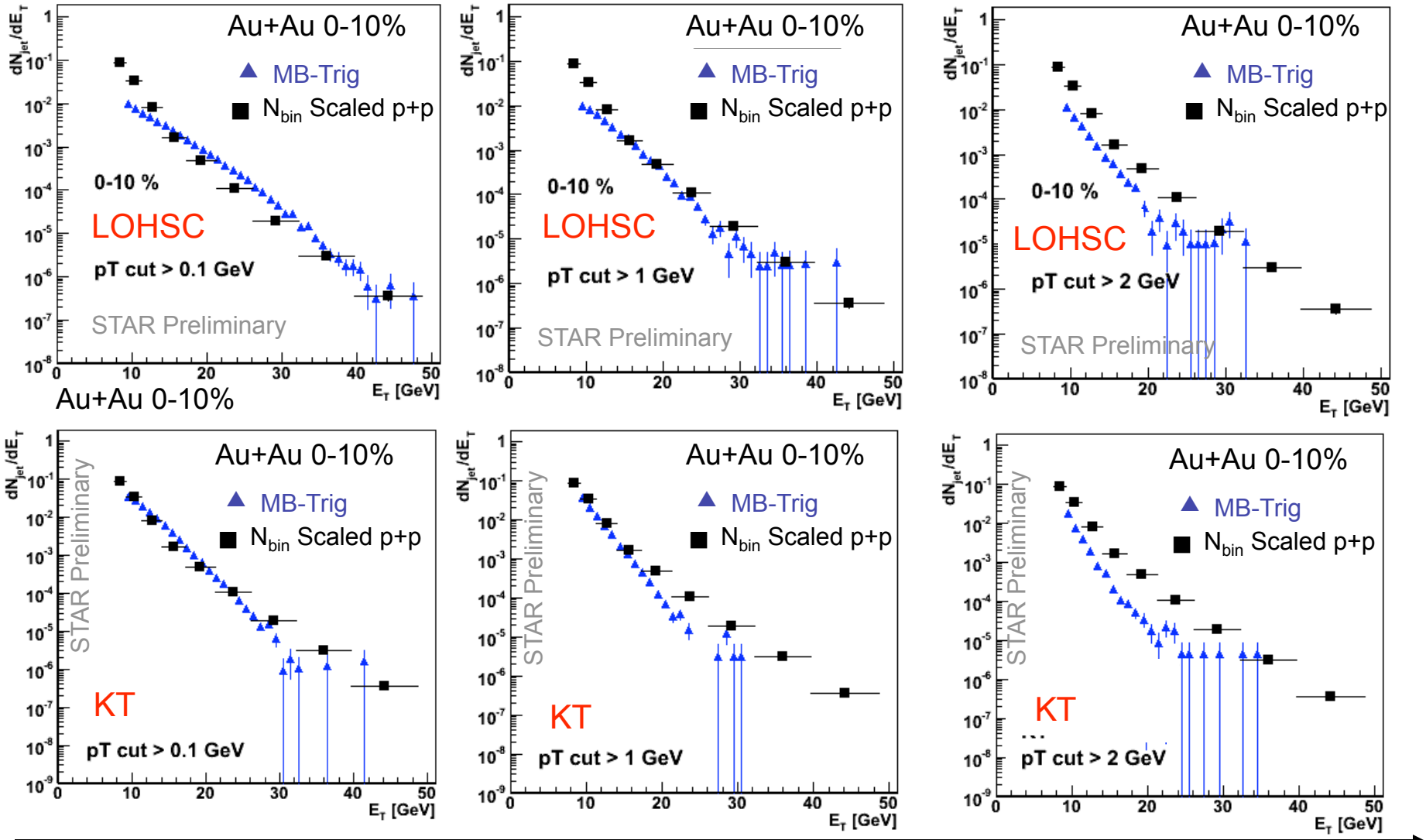
-- no seed

-- low pt cut

Systematic Uncertainity on Normalization: 50%

Good agreement with N_{bin} scaled p+p for unbiased algorithms.

Effect of Variation of p_T Cuts on spectra:



Imprecise subtraction of underlying event?
Do we introduce a bias with p_T-cuts?

P_T Cut

How sensitive are we to fragmentation model in corrections (PYTHIA) ?

Conclusions

- It is possible to reconstruct jets in 0-10% central heavy ion collisions at RHIC collisions. (Current reach is 50 GeV)

- Heavy ion background subtraction is possible, systematics studied via utilizing various algorithms.

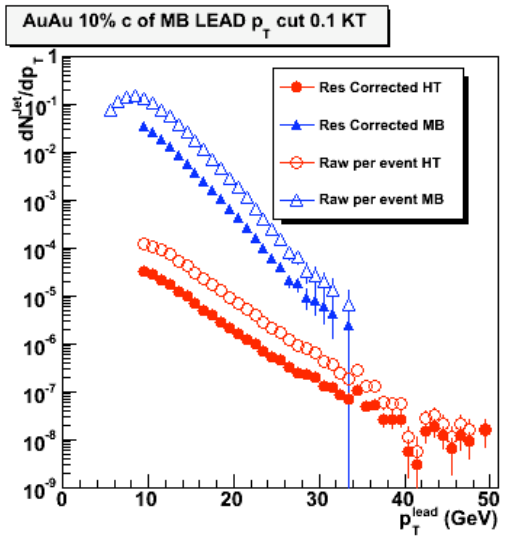
- **N_{bin} scaling (50% Syst Uncert.) observed for least-biased cuts → Unbiased Jet Reconstruction ?**

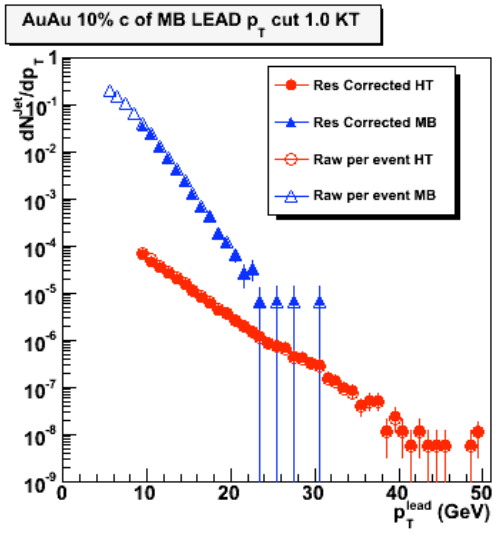
- All the corrections are based on Pythia Fragmentation. Require systematic checks with quenching models.

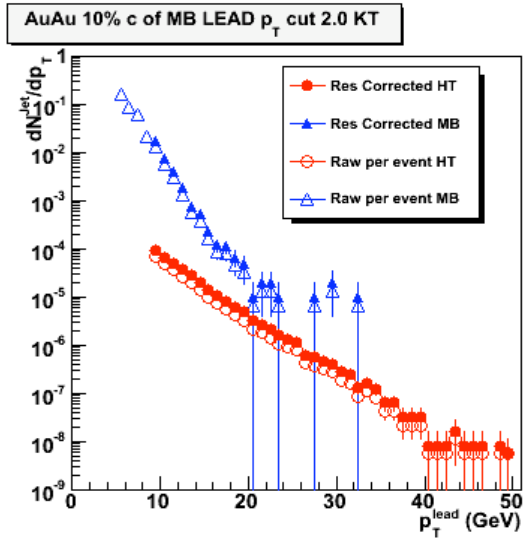
- Biases due to online triggers… Will be addressed with full Min-Bias data set (on tape).

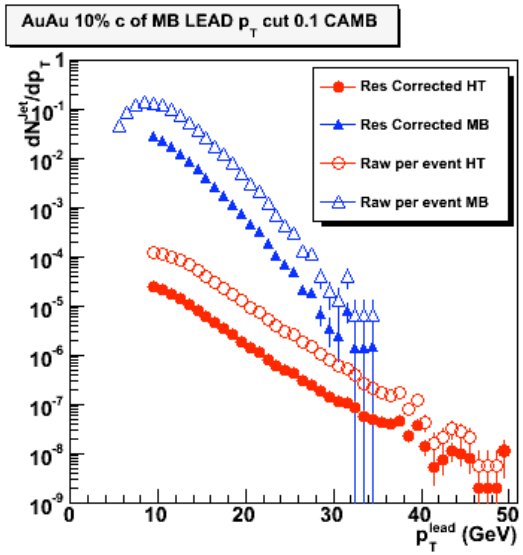
Thanks to all “old” and “new” (Elena Bruna & Mateusz Ploskon)
STAR collaborators.

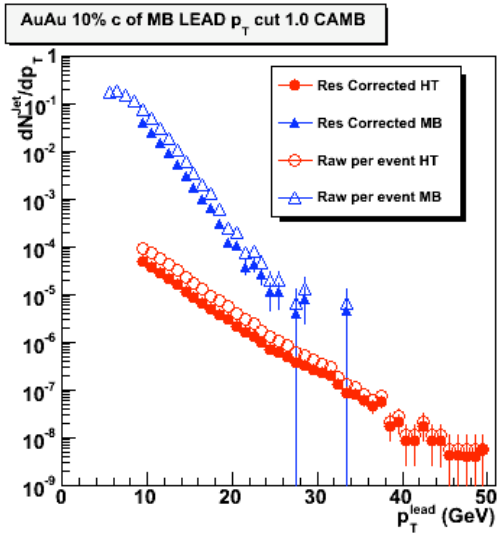
KT and Cambridge

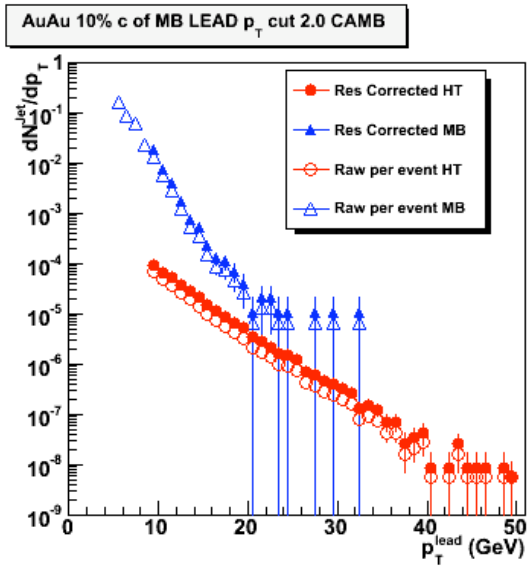












Correction factors: