Exploring Jet Properties in p+p Collisions at 200 GeV with STAR

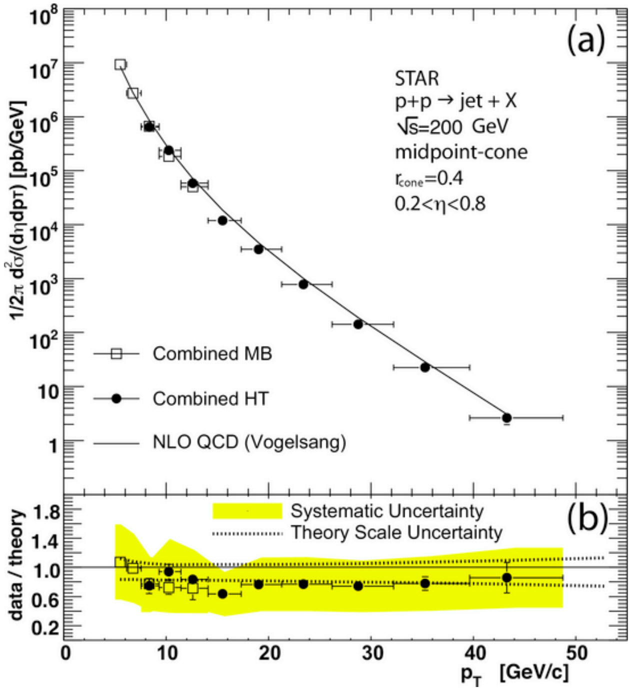
Helen Caines - Yale University - for the STAR Collaboration

Quark Matter 2009
Knoxville,TN, USA
March 30th-April 4th

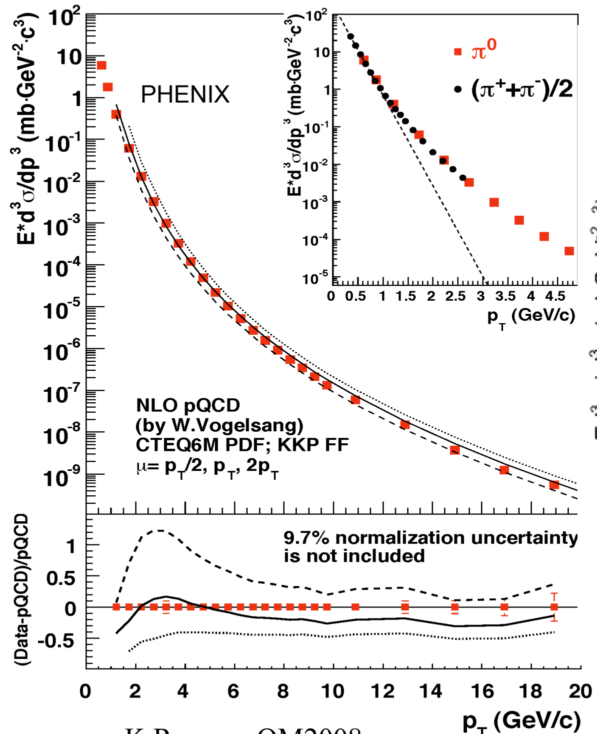
Outline

- What we know already
- Jets and our data set
- z and ξ distributions
- The underlying event
- Summary and outlook

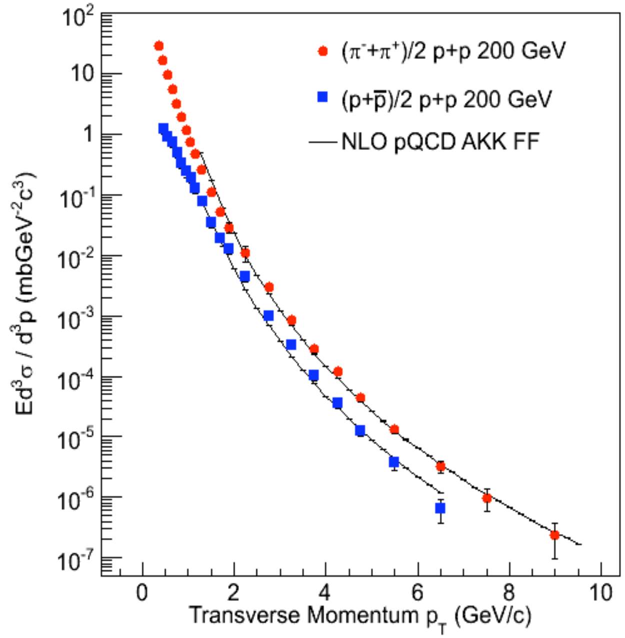
Jets – a calibrated probe



STAR : PRL 97 (2006) 252001



K.Reygers QM2008



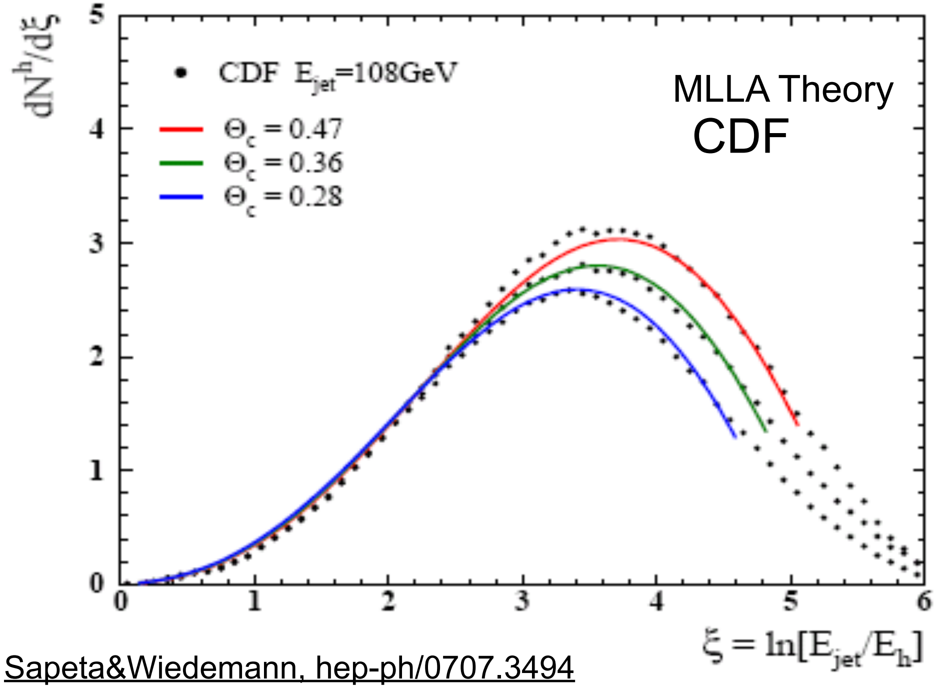
STAR : PLB 637 (2006) 161

S. Albino et al, NPB 725 (2005) 181

- Jet cross-section in p+p is well described in pQCD framework over 7 orders of magnitude.
- Minimum bias particle production in p+p also well modeled.

What about fragmentation?

Fragmentation functions (FF)

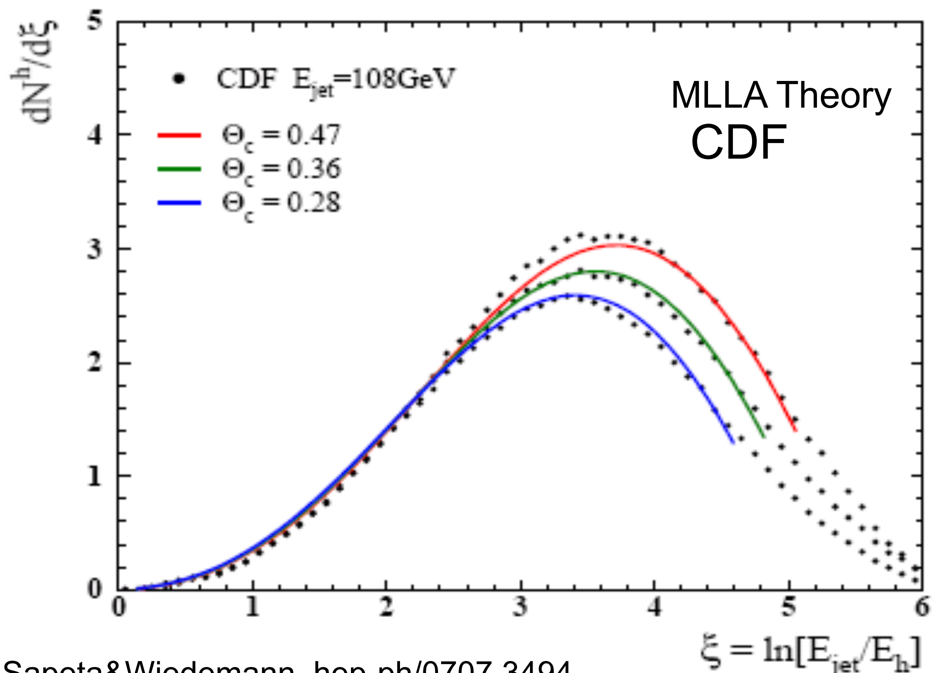


Sapeta&Wiedemann, hep-ph/0707.3494

- No previous comparisons at RHIC energies available.
- Measurements at higher √s agree well with theory.

Test energy scaling of fragmentation functions.

Fragmentation functions (FF)



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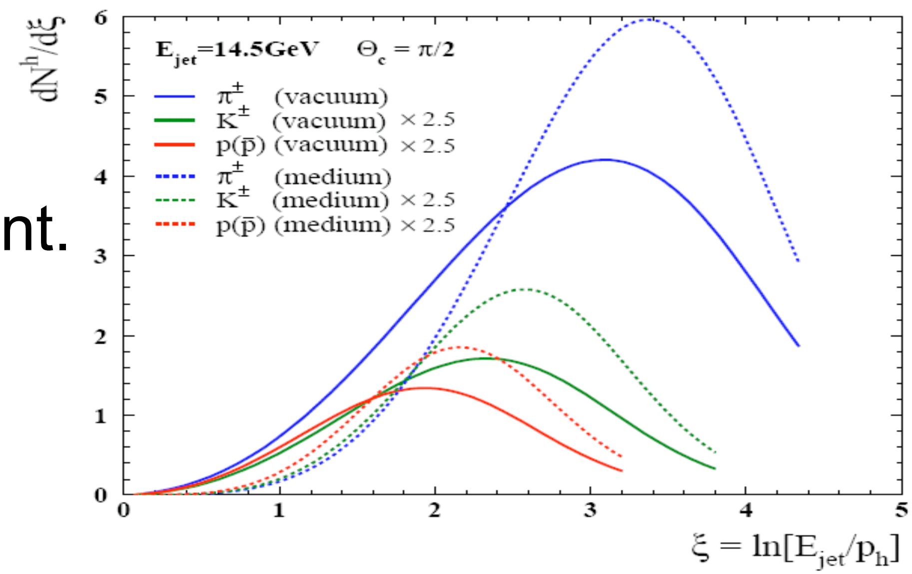
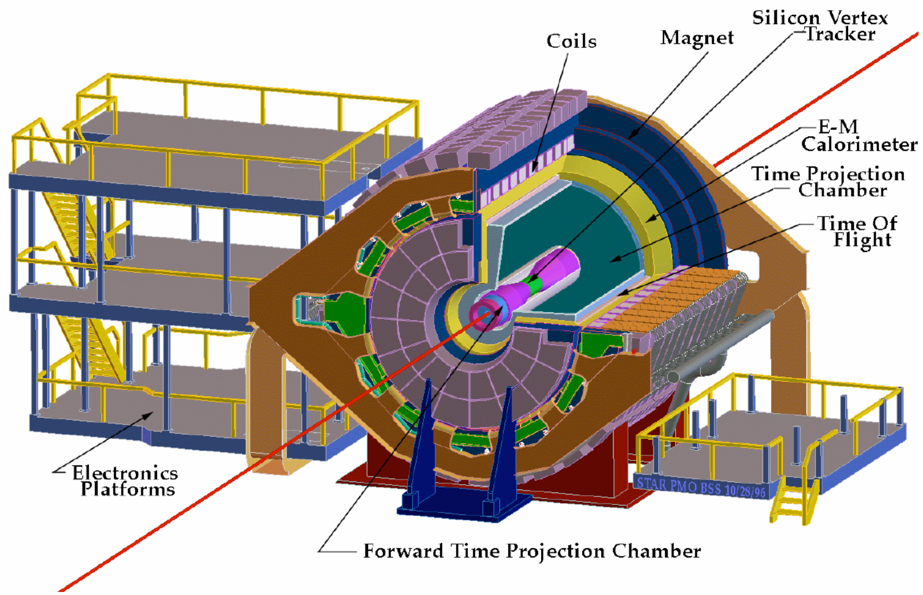
- FF are particle species dependent.

Need to study composition of jets and complete event.



The p+p data set

- TPC tracks to identify charged particles contribution.
- Barrel EMCal for neutral energy contribution.



2006 Run

Sampled luminosity for Jet-Patch triggers:

~8.7 pb^{-1}

(~8 M events)

Jet-Patch Trigger:

BBC coincidence + EMCal Jet-Patch

Jet-Patch:

$E_T > 8$ GeV in

$\Delta\eta \times \Delta\phi = 1x1$

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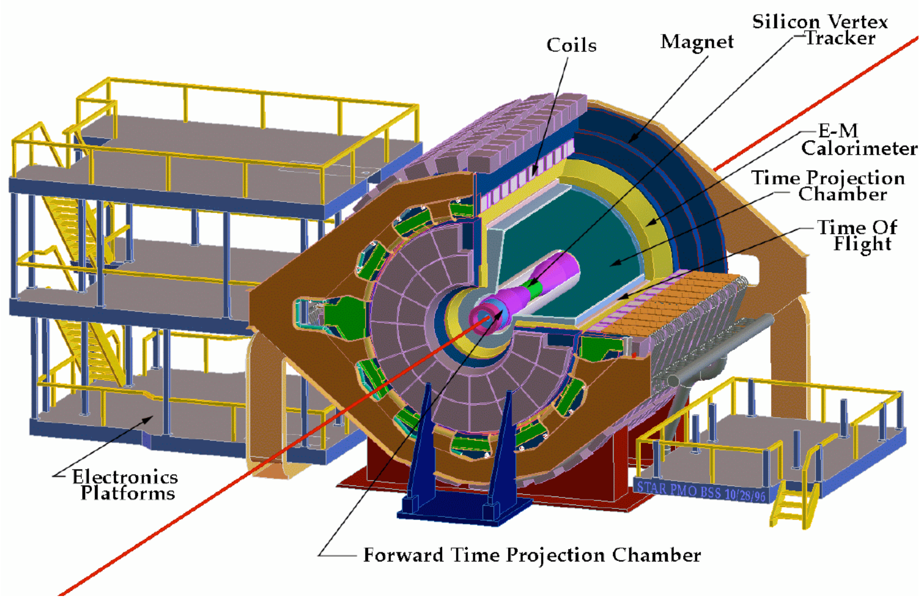

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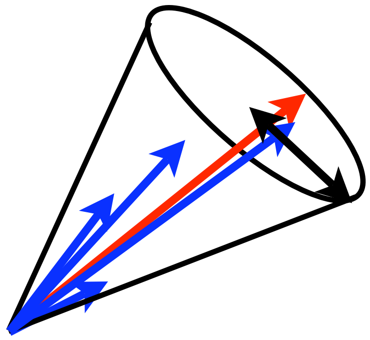
Jet-Patch - NEF FF bias - use non-triggered jet for studies.

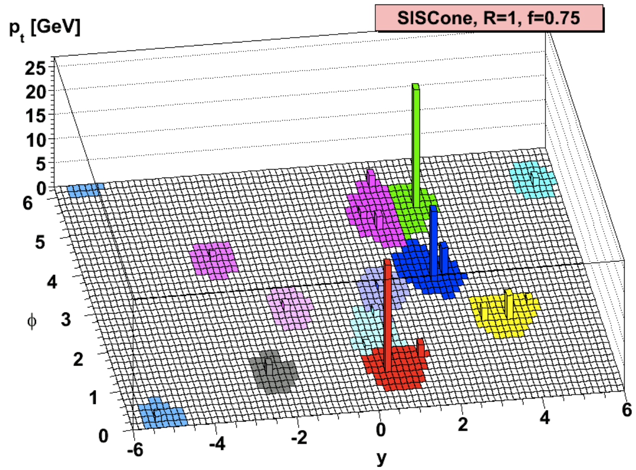
Jet reconstruction - algorithms

Seedless Cone - SISCone



- $R_{cone}=\sqrt{(\Delta\varphi^2+\Delta\eta^2)}$
- all particles used.
- Splitting/Merging destroys cone shape.

Fastjet package - [Cacciari, Soyez, arXiv:0704.0292]



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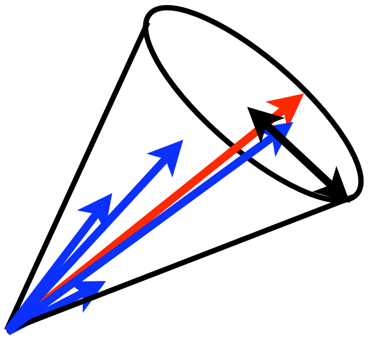

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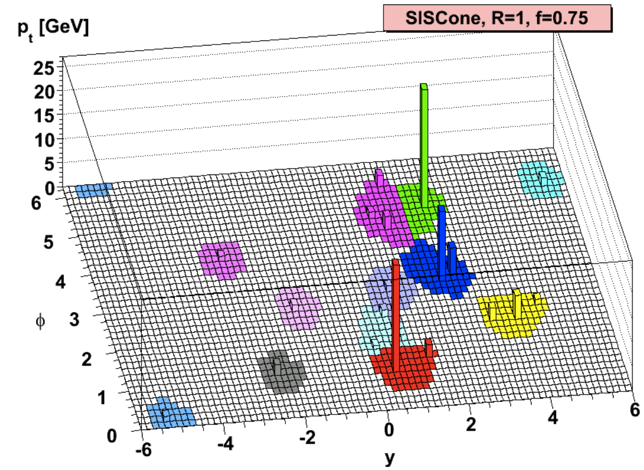


Recombination

k_T

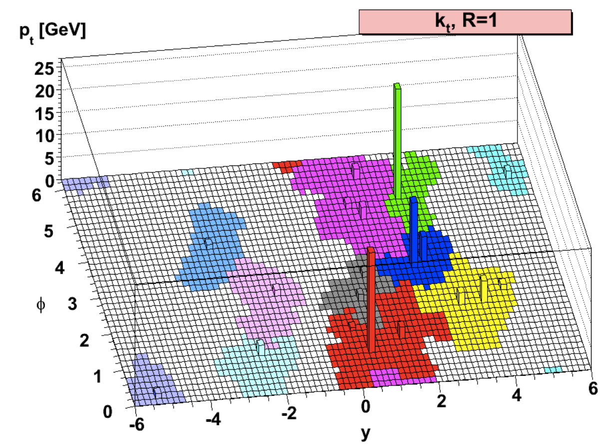
- starts from lowest p_T.
- merges weighted by $1/p_T$

i.e. high p_T is dis-favored.

Anti-k_T

- starts from high p_T.
- merges weighted by p_T

i.e. low p_T is dis-favored.



[Cacciari, Salam, Soyez, arXiv:0802.1189]

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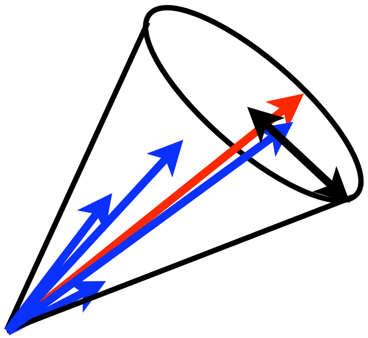

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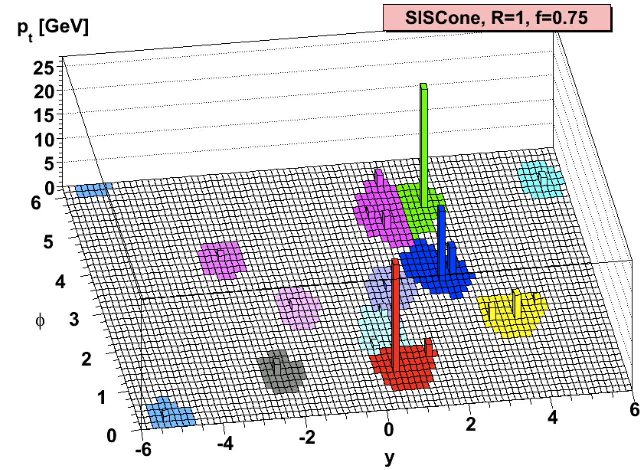

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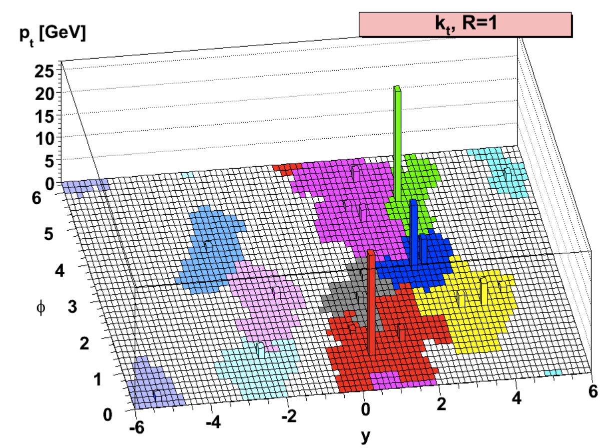
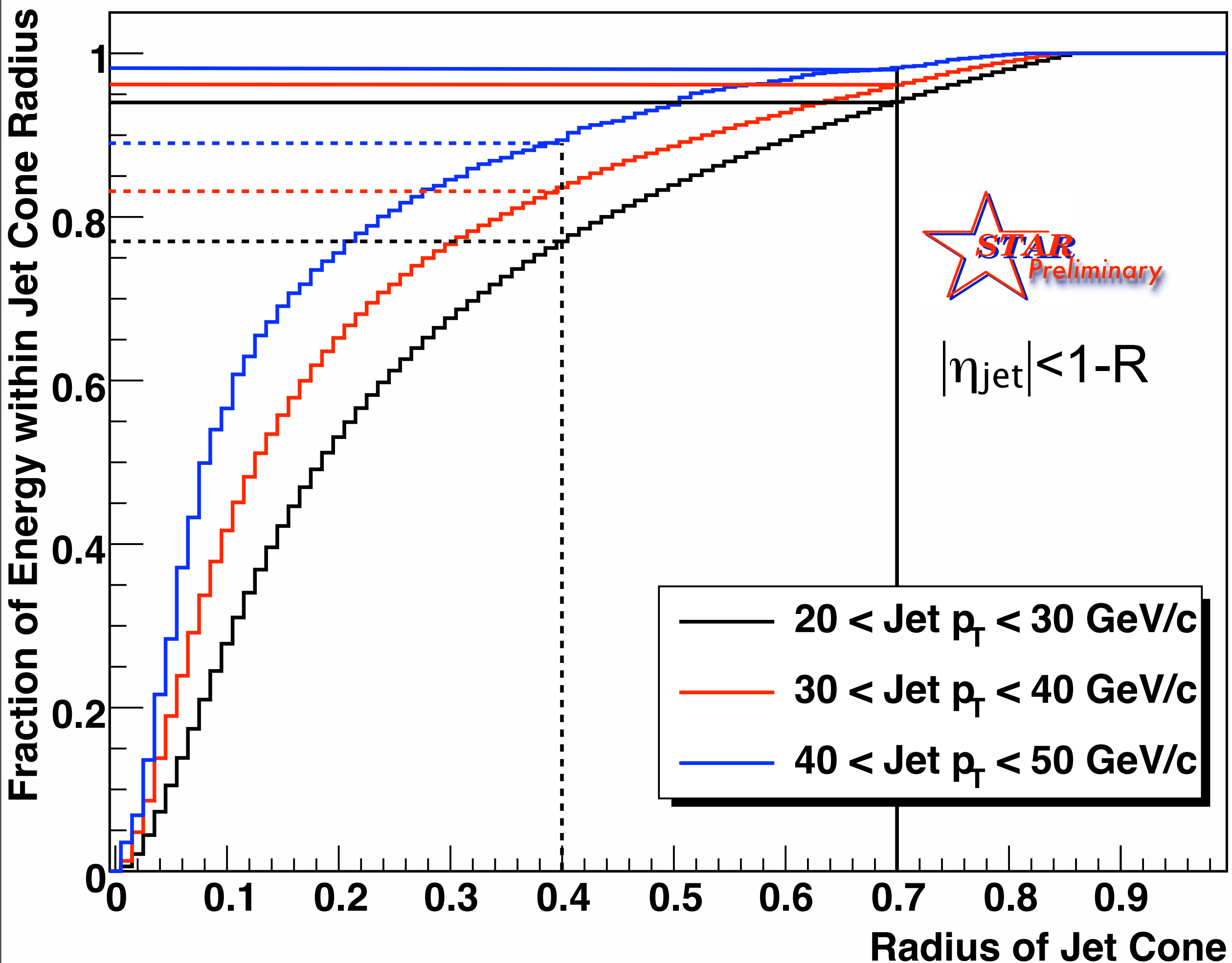


[Cacciari, Salam, Soyez, arXiv:0802.1189]

Compare results to explore systematics.

Jet reconstruction - the resolution parameter



% Energy within resolution parameter R

p_T (GeV/c)	R 0.4	R 0.7
20-30	77%	94%
30-40	83%	96%
40-50	89%	98%

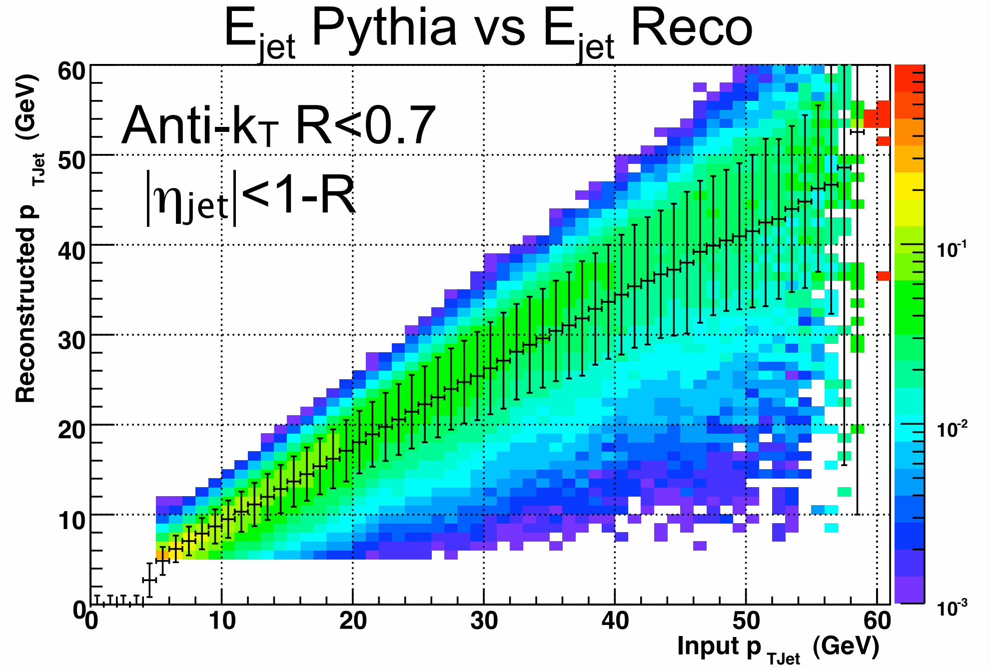
- Consistent with CDF > 80% within R~0.3.
- Larger energy → more focussed jet.

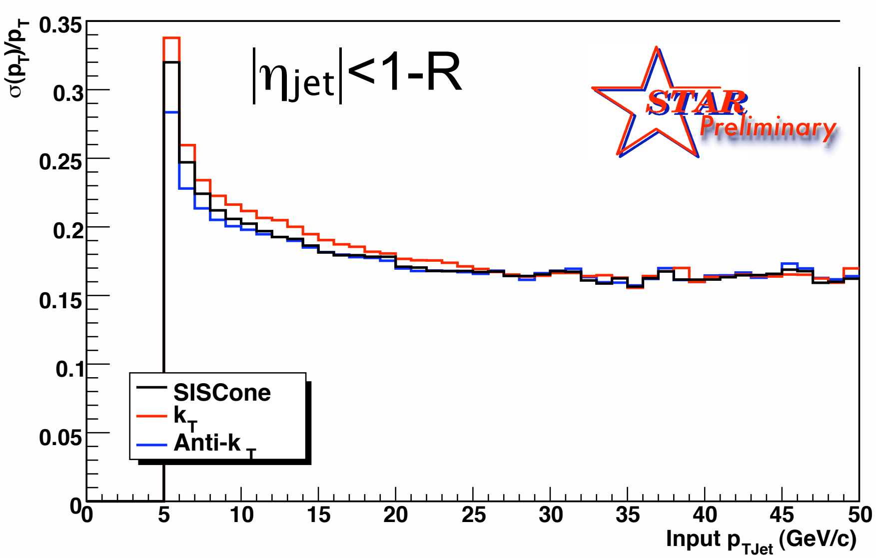
Compare FF using different radii.

Energy resolution - the jet energy scale

Calculated in two way:

- Simulation
  - MC input compared to reconstructed output.





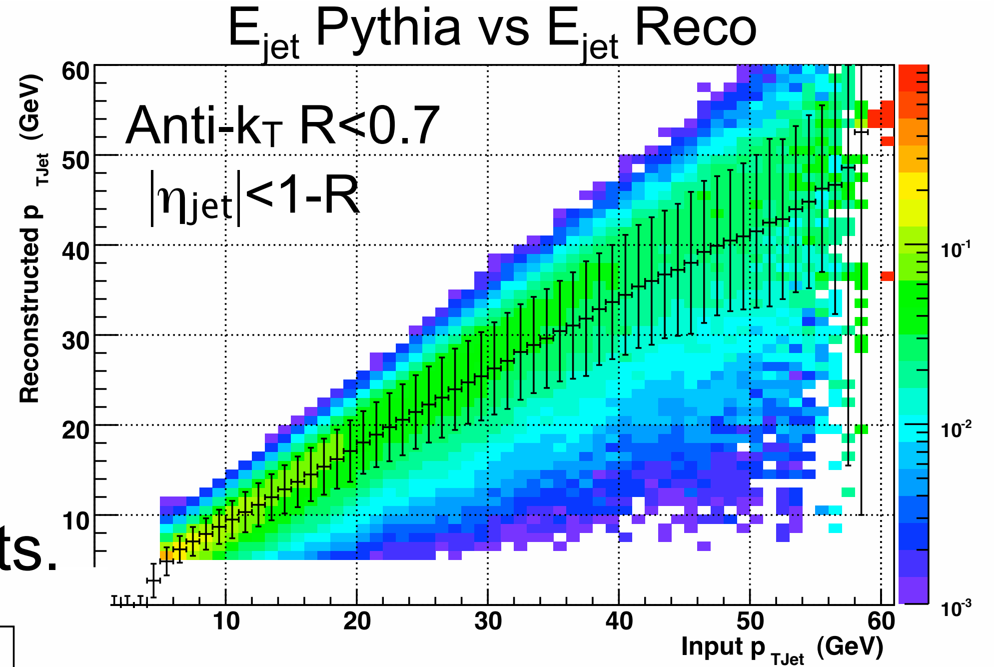
- Offset due to missing energy:
  - Detector efficiencies.
  - Undetected particles (n, K^0_L).

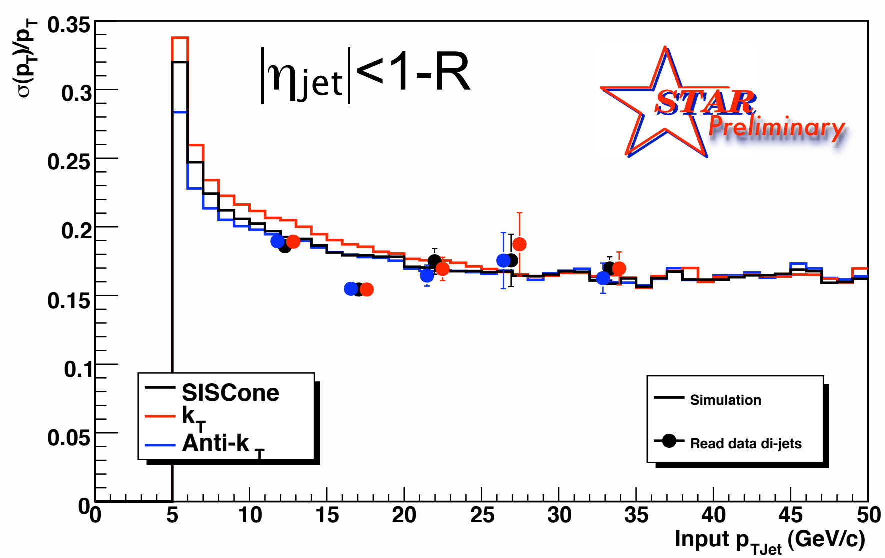
- Resolution ~15-20% for p_{TJet}>15GeV/c.

Energy resolution - the jet energy scale

Calculated in two way:

- Simulation
  - MC input compared to reconstructed output.
- Real data
  - Energy balance of di-jets.





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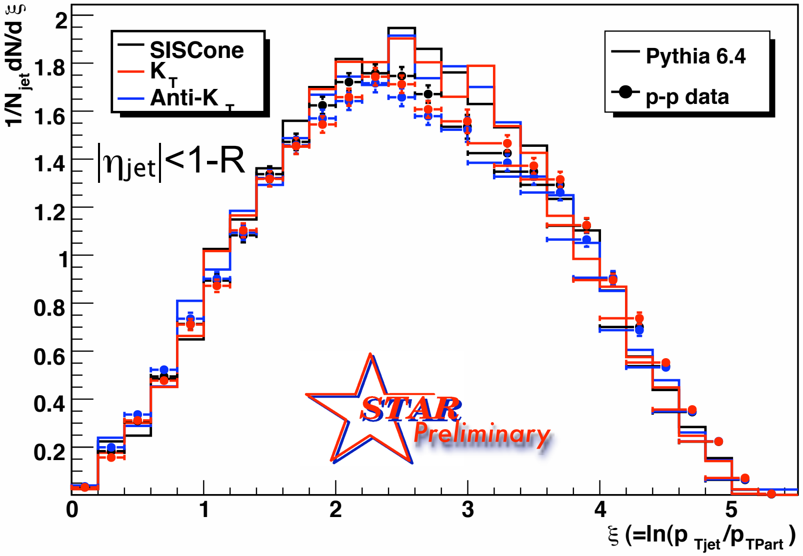
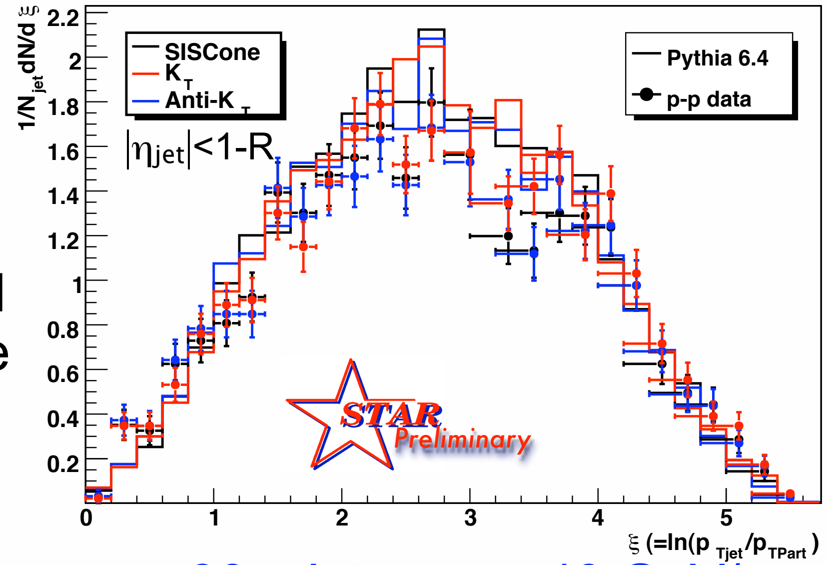
ξ and z distributions for charged hadrons



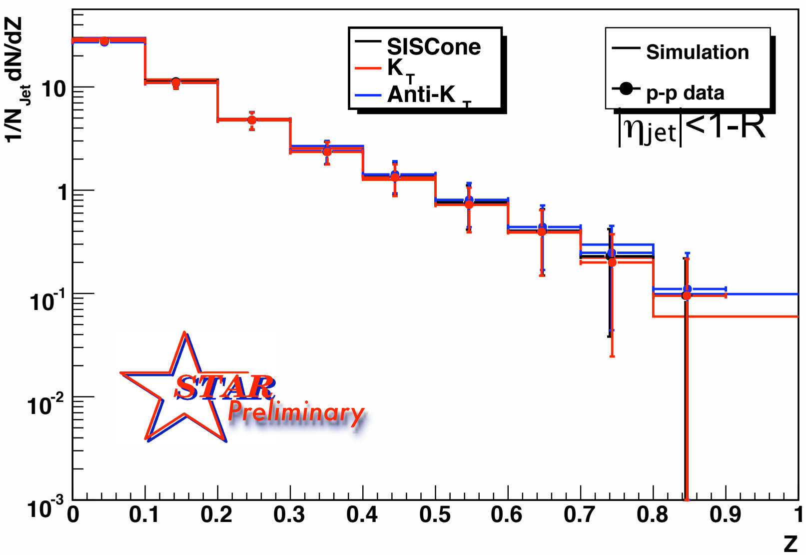
Data not corrected to particle level.



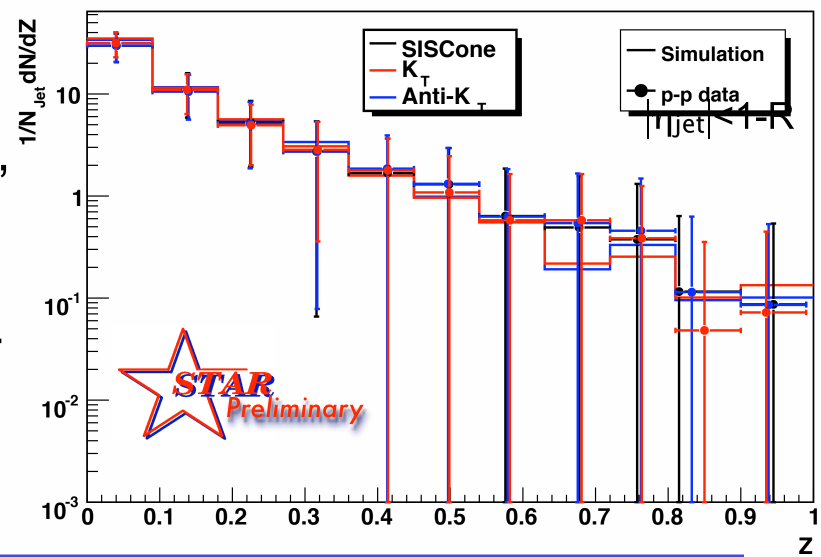
20 <Jet p_{Treco}< 30 GeV/c

R=0.4

30 <Jet p_{Treco}< 40 GeV/c

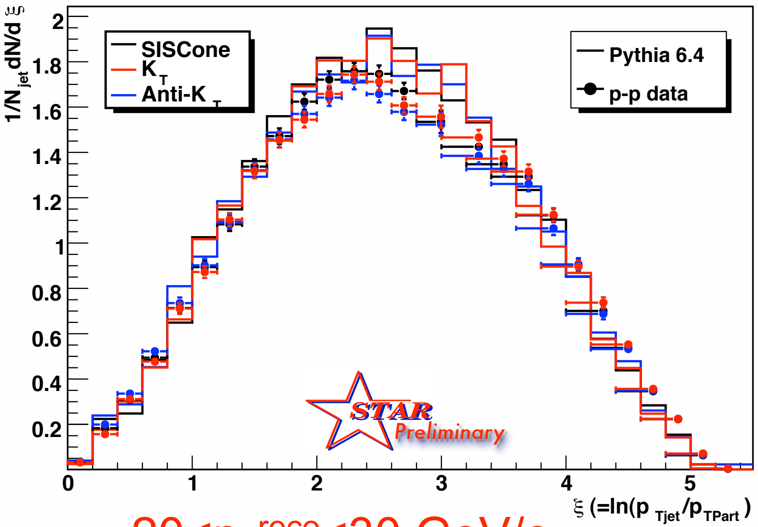


"PYTHIA" = PYTHIA +GEANT

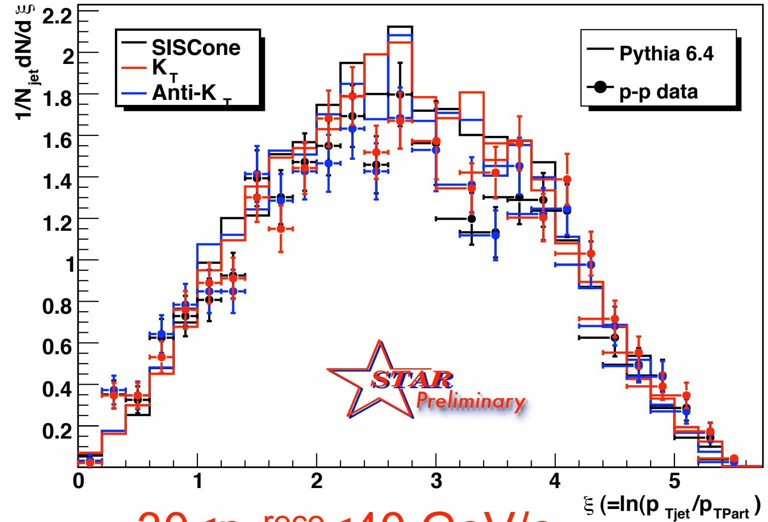


Reasonable agreement between data and PYTHIA+GEANT.

Charged hadrons ξ for different R and jet p_T



$20<p_T^{reco}<30$ GeV/c



$30<p_T^{reco}<40$ GeV/c

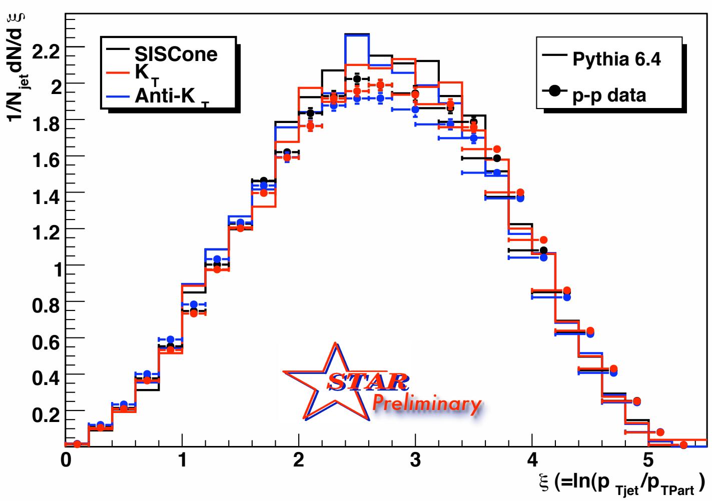
R<0.4

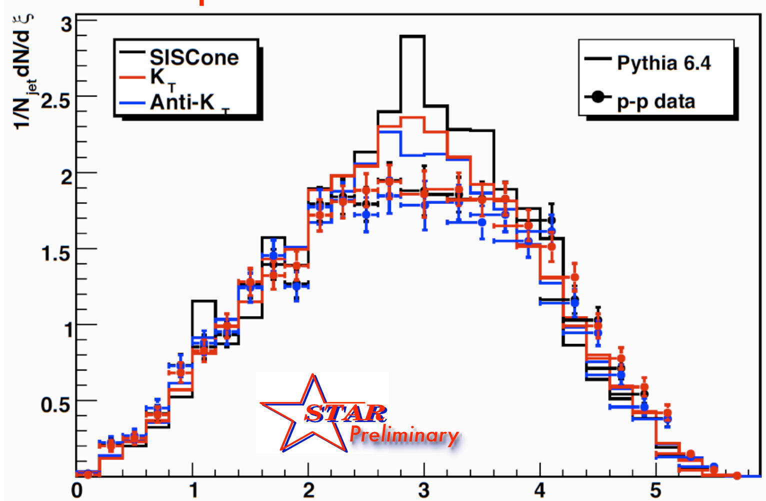
$|\eta_{jet}|<1-R$
$p_{Ttrack} > 0.2$

Data not corrected to particle level.

"PYTHIA" = PYTHIA +GEANT

R<0.7





Agreement similar between PYTHIA and data for both radii.

What about the Underlying Event?

- p-p events are complicated. More than just hard scattering.

- Underlying Event: soft or semi-hard multiple parton interactions, initial & final state radiation, beam-beam remnants

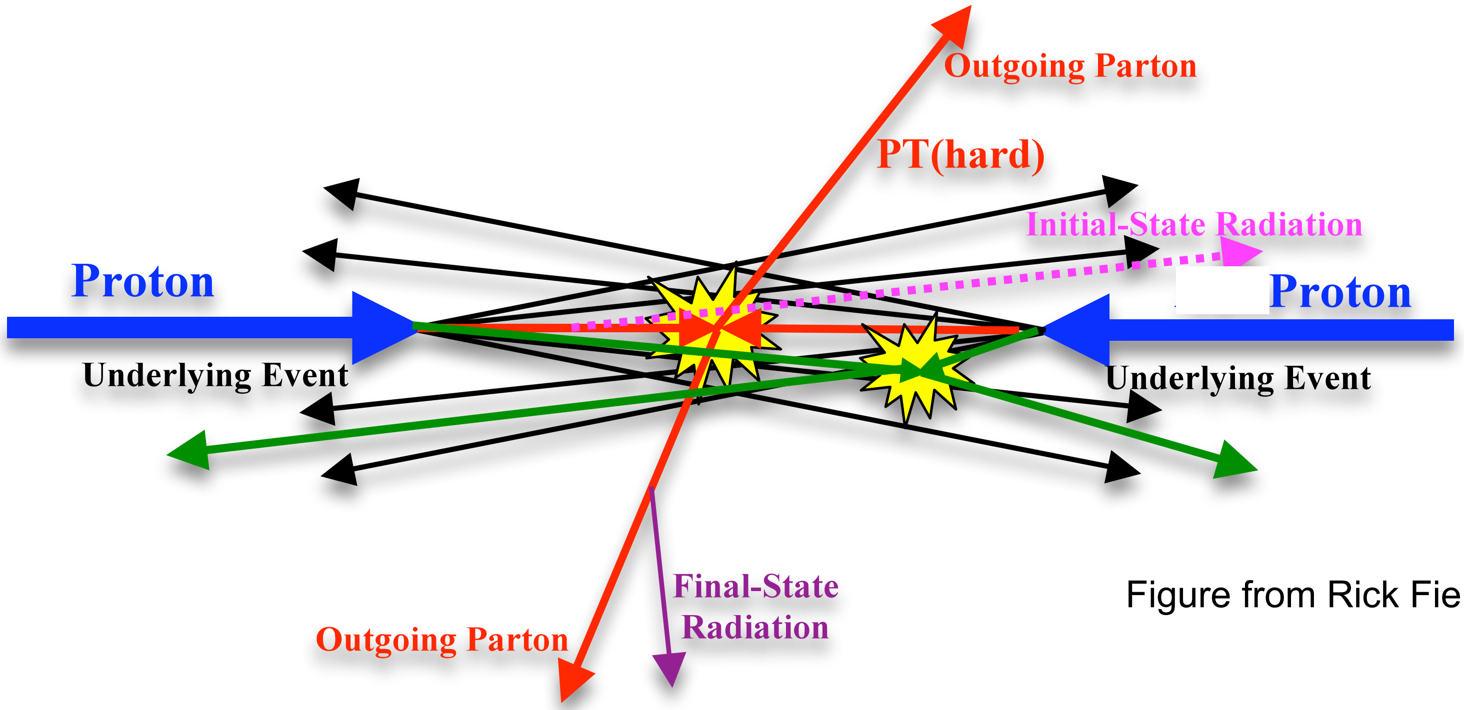
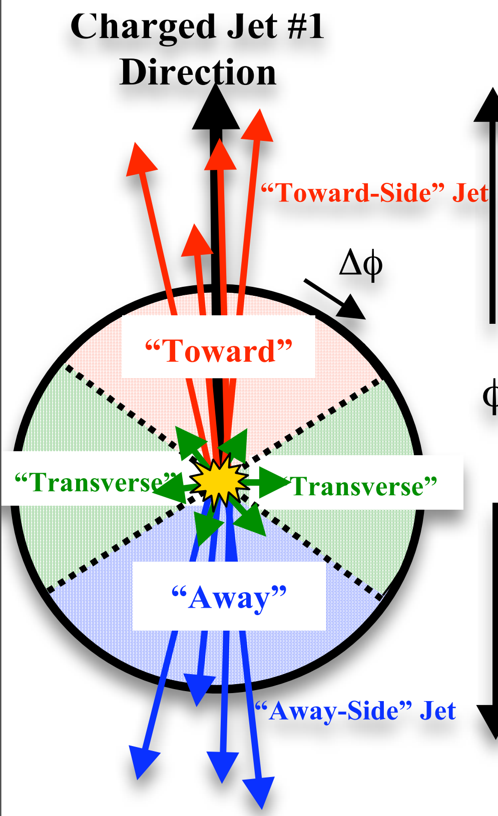
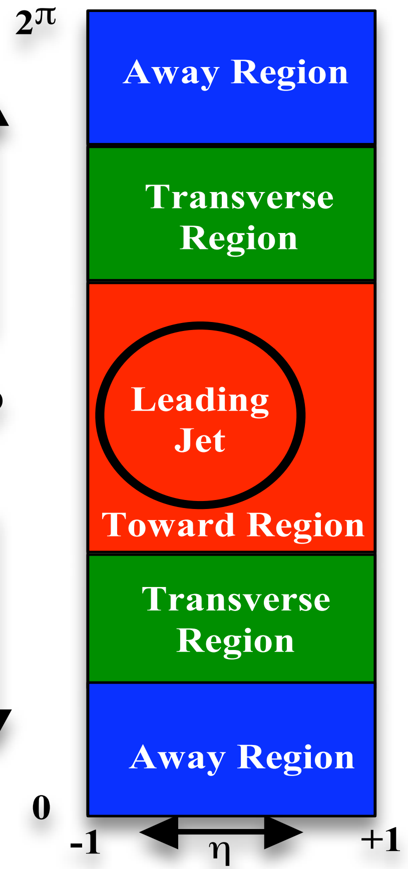


Figure from Rick Field

The Underlying Event is everything BUT the hard scattering

Measuring the Underlying Event





Define:

- |Δϕ| – Angle relative to leading jet
- **"Toward" |Δφ| < 60°**
- **"Away" |Δφ| > 120°.**
- **"Transverse" 60° < |Δφ| < 120°**
  - **TransMax** - Trans. region with highest Σp_T or ΣN_{track}
  - **TransMin** Trans. region with least Σp_T or ΣN_{track}

Underlying Event is the data in the Transverse regions.

Sensitivities of the variables

leading : Most basic jet cut, one jet in our acceptance.

back-to-back : Sub-set of leading jet collection.
Require $|\Delta\phi| > 150$, $p_{TAway}/p_{TLead} > 0.7$
Suppresses hard initial and final state radiation.

TransMin : Sensitive to beam-beam remnants and soft multiple parton interactions.

TransMax : Enhanced probability of containing hard initial and/or final state radiation component.

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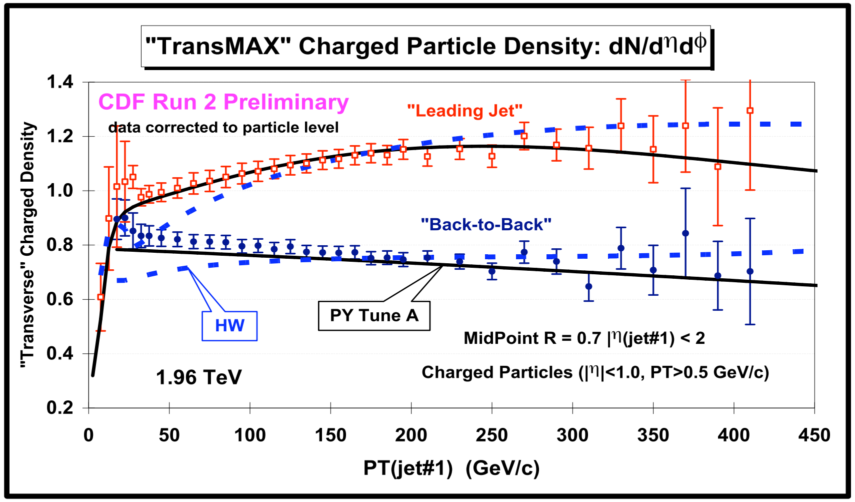
Compare TransMin and TransMax data from leading and back-to-back jet samples →

Information about large angle initial/final state radiation.

TransMin vs TransMax regions of UE



CDF √s=1.96 TeV

- leading TransMax > back-to-back TransMax

Significant initial/final state radiation at large angles.

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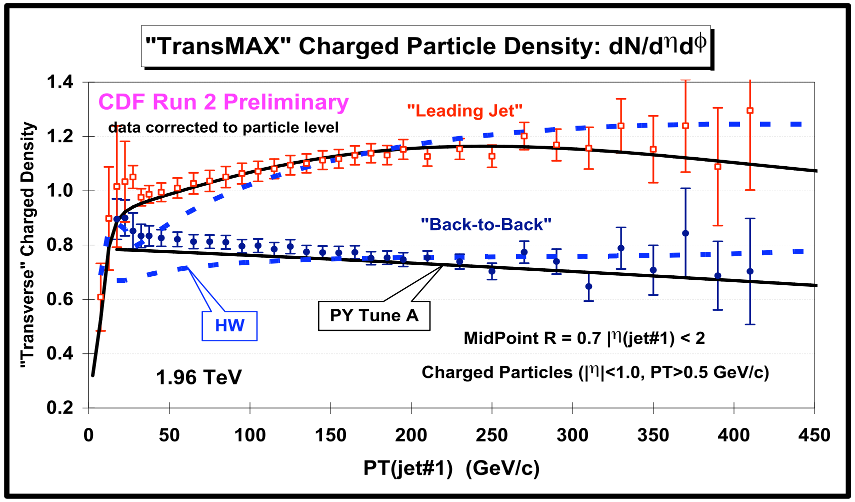
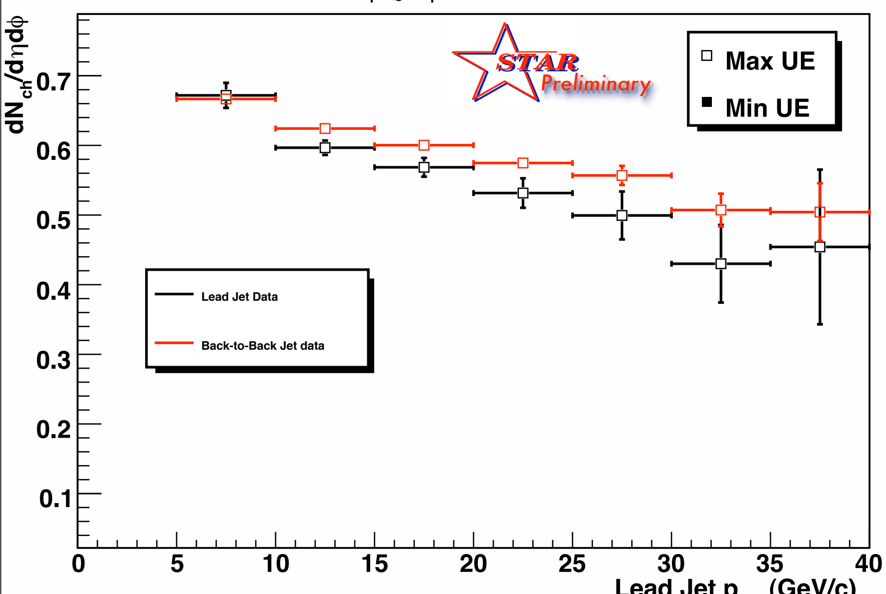


SISCone,R=0.7, $|\eta_{jet}| < 1-R$, $p_{Ttrack} > 0.2$ GeV/c



CDF √s=1.96 TeV

- leading TransMax > back-to-back TransMax

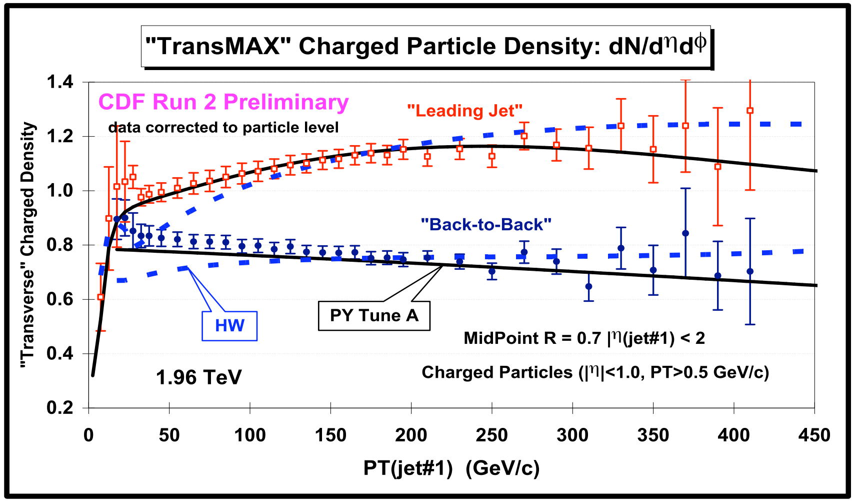
Significant initial/final state radiation at large angles.

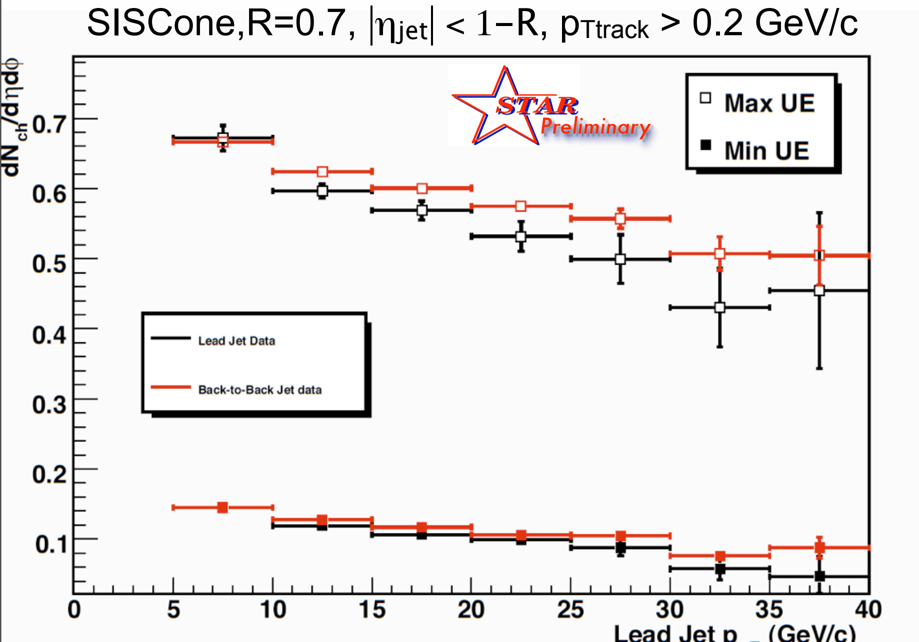
STAR √s=200 GeV

- leading TransMax ~ back-to-back TransMax

Small initial/final state radiation at large angles.

TransMin vs TransMax regions of UE





CDF $\sqrt{s}$=1.96 TeV

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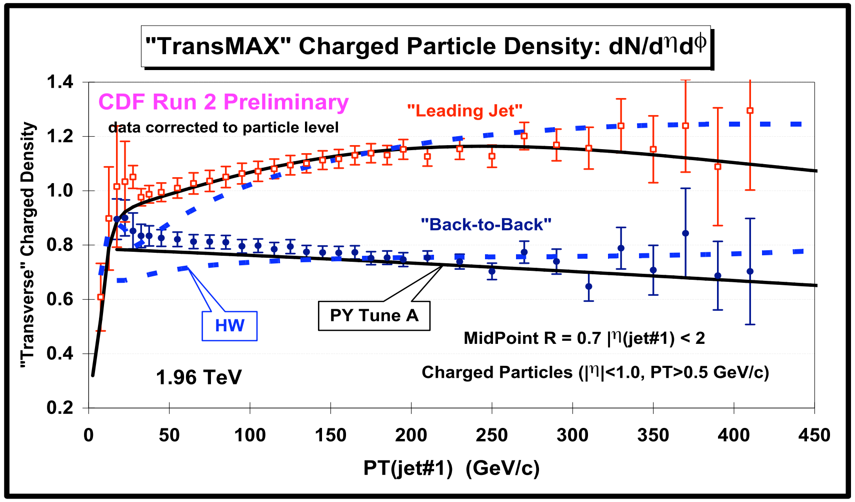

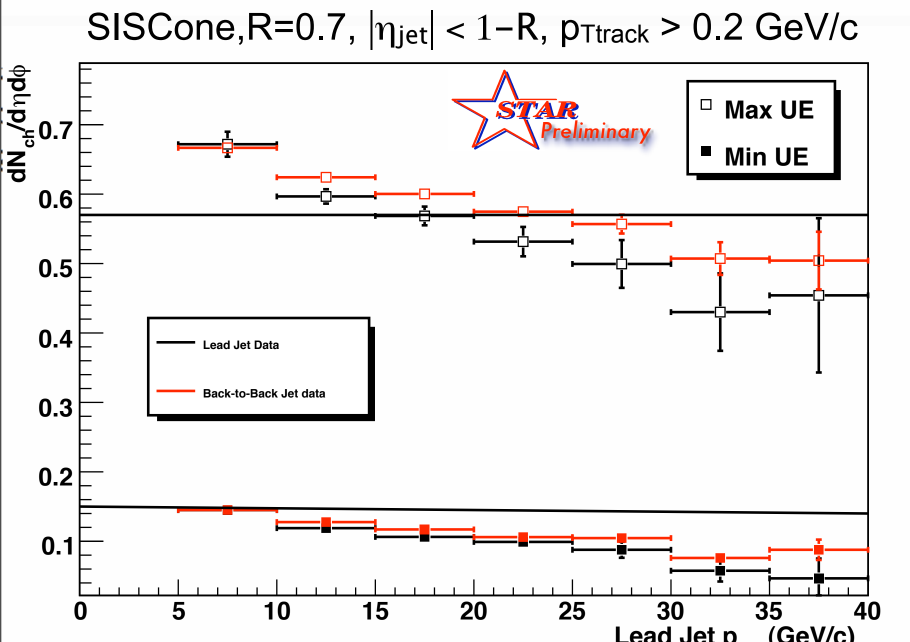

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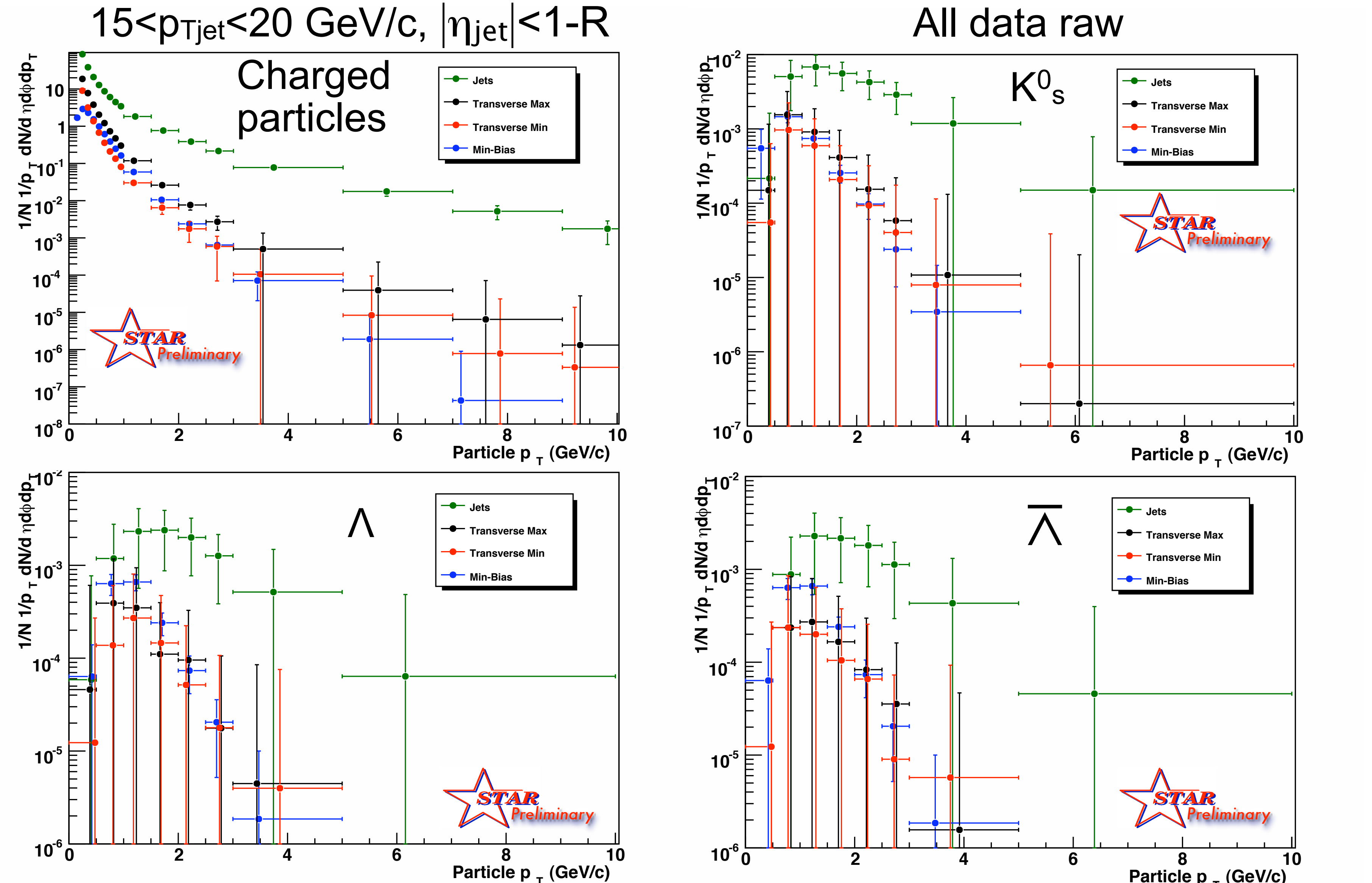
Poisson distribution with average $dN_{ch}/d\eta d\phi = 0.36$

- UE ~independent of jet p_T.

p_T spectra in jet, UE, Min-Bias event



Summary & outlook

- Charged hadron ξ and z distributions at $\sqrt{s}$=200 GeV similar to PYTHIA 6.4.
- Underlying Event largely decoupled from hard scattering.
- Large angle initial/final state radiation is small.
- Particle p_T spectra are significantly softer out of the jet cone compared to in the jet.
- p_T spectra of Underlying Event close to that of Min-Bias triggered events.

<u>Outlook</u>

- Compare more jet-variables (k_T, j_T, etc) to pQCD models.
- Use relativistic rise and newly installed ToF to identify π, K, p.
- Repeat measurements at $\sqrt{s}$=500 GeV.
- Measure PID FF in heavy ion collisions.

See posters: 2-Hadron FF (M. Elnimr), d-Au (J. Kapitan) , UE (HC)