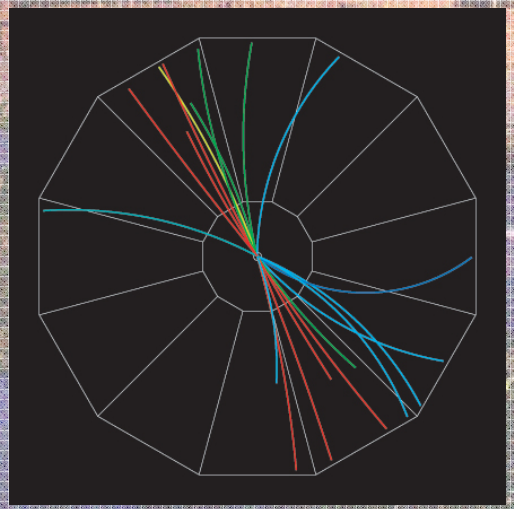
First measurement of the inclusive jet cross section in p+p collisions at E_{CM}=200 GeV

M.L. Miller (MIT)
for the STAR collaboration

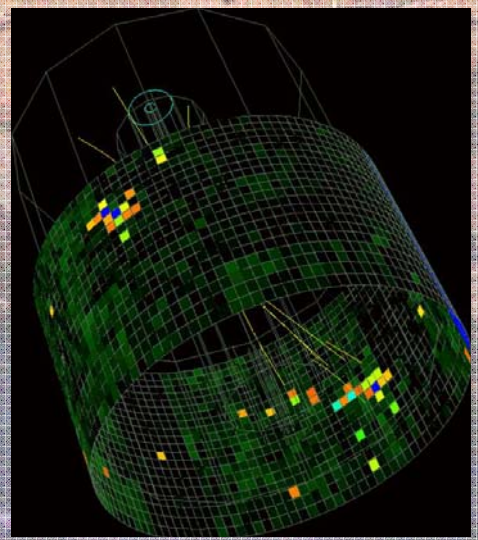


Motivations:

1. Baseline for inclusive jet A_{LL}*
2. Constraining large-x pdf's

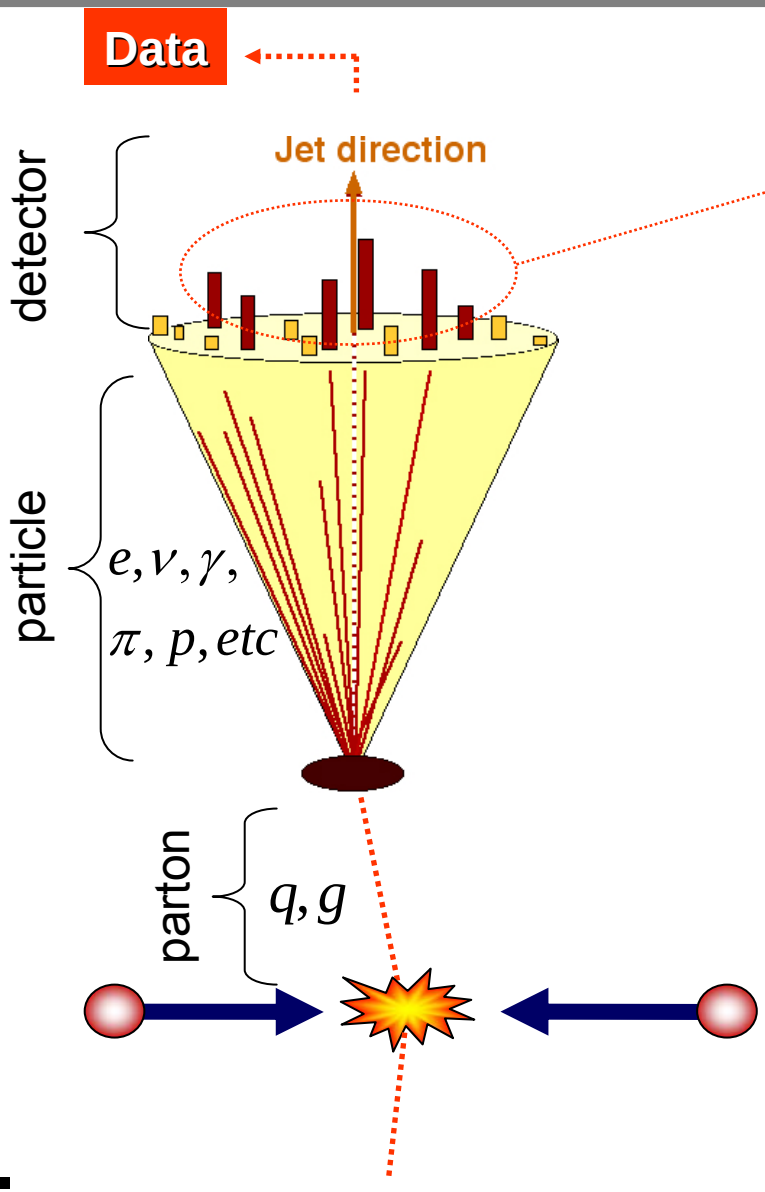
Outline:

1. What do we mean by "jet"?
2. Presentation of work in progress
3. List of short- and long-term tasks towards final results



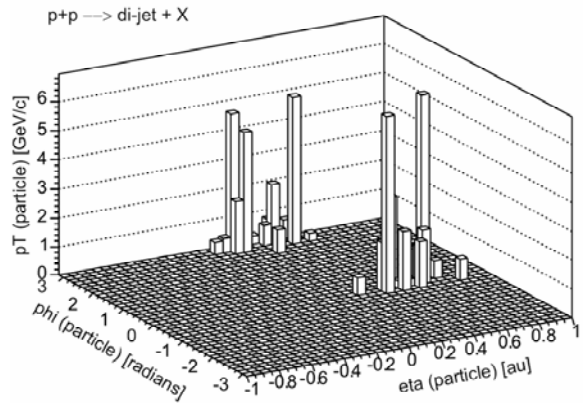
See J. Kiryluk (III.2 Monday)

Clustering and Correction scheme



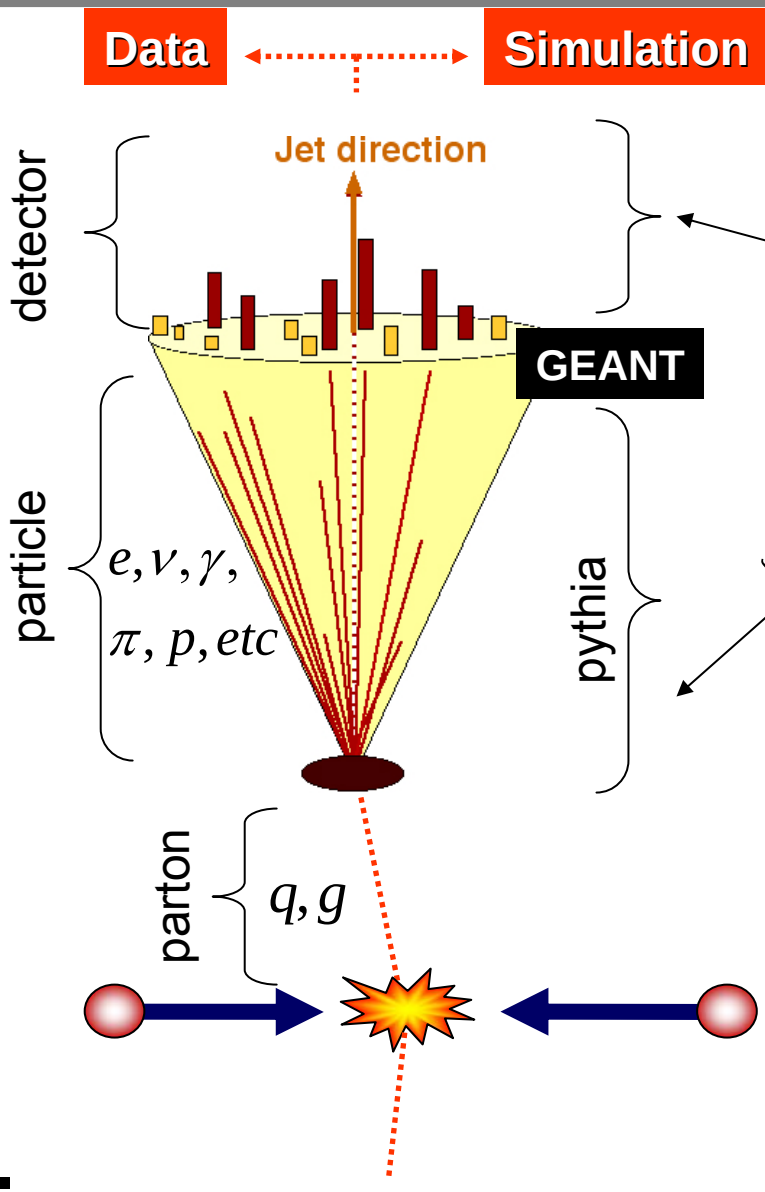
midpoint-cone algorithm*

- Search over "all" possible seeds for stable groupings
- Check midpoints between jet-jet pairs for stable groupings
- Split/merge jets based on $E_{overlap}$
- Add track/tower 4-momenta



*(hep-ex/0005012)

Clustering and Correction scheme



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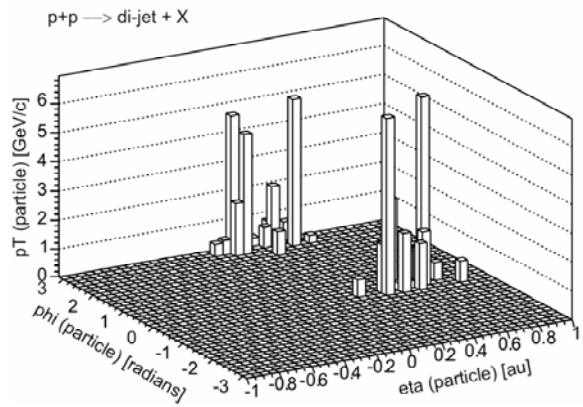


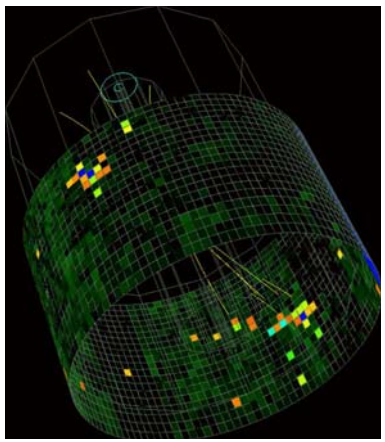
Correction philosophy

- Use Pythia+GEANT to quantify detector response
- Estimate corrections to go from "*detector*" to the "*particle*" level

*(hep-ex/0005012)

2004 *p+p* data set

- Sampled luminosity: ~0.16 pb^{-1}
- 1.4 M High tower (HT) events
- 0.8 M highly pre-scaled minimum bias (MB) events
- → ~220k p_T>5 GeV jets in HT sample before cuts
- Commissioned 1x1 jet patch trigger– main jet trigger in 2005+



TPC

$0<\varphi<2\pi$

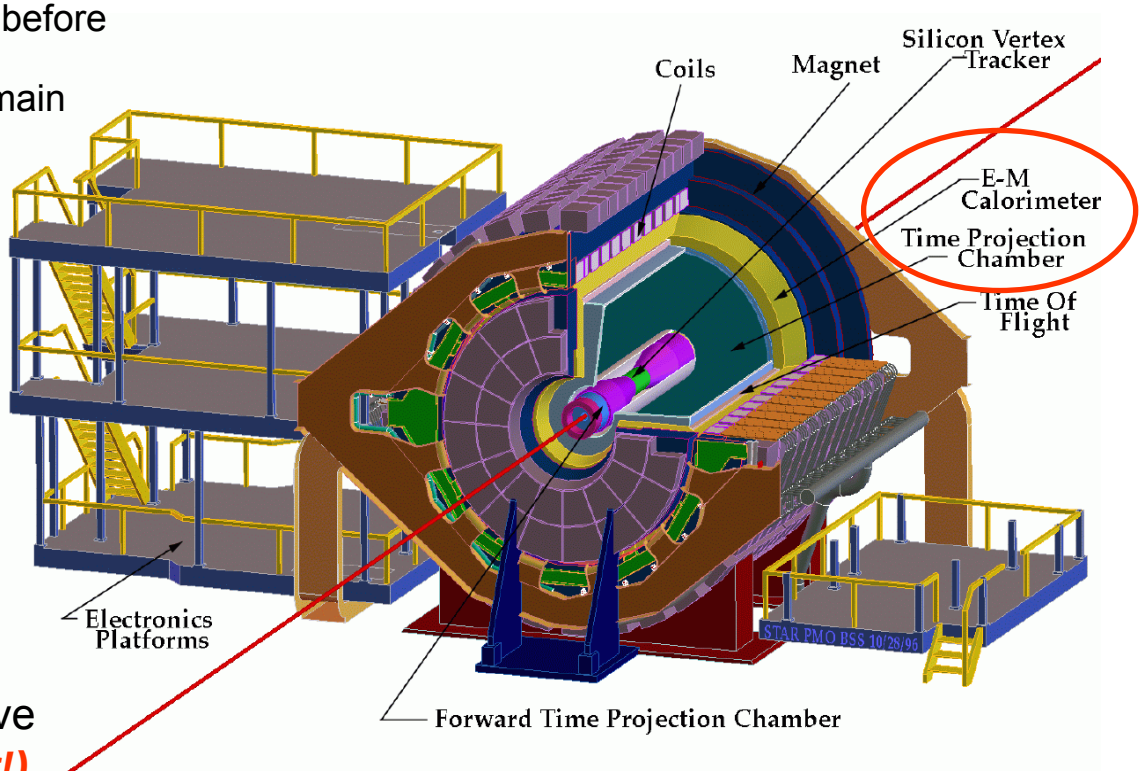
$1<\eta<1$

$\Delta p_T/p_T \sim 1\%$

BEMC

$0<\varphi<2\pi$

$0<\eta<1$



High Tower Trigger

BBC coincidence + one tower above threshold ***(not the best jet trigger!)***

$\varepsilon_{Trig}(\eta=0.0)=1$: $E_{T\text{-}tower}$= 2.5 GeV

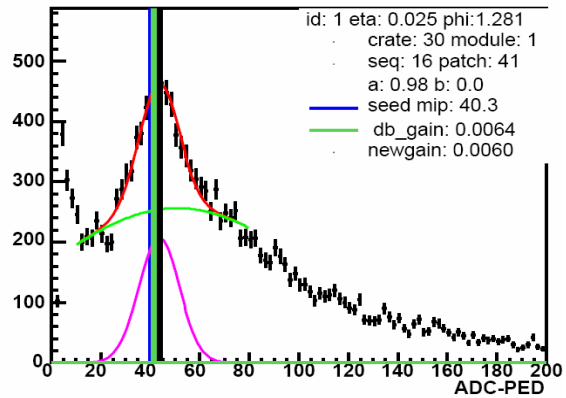
$\varepsilon_{Trig}(\eta=0.8)=1$: $E_{T\text{-}tower}$= 3.3 GeV

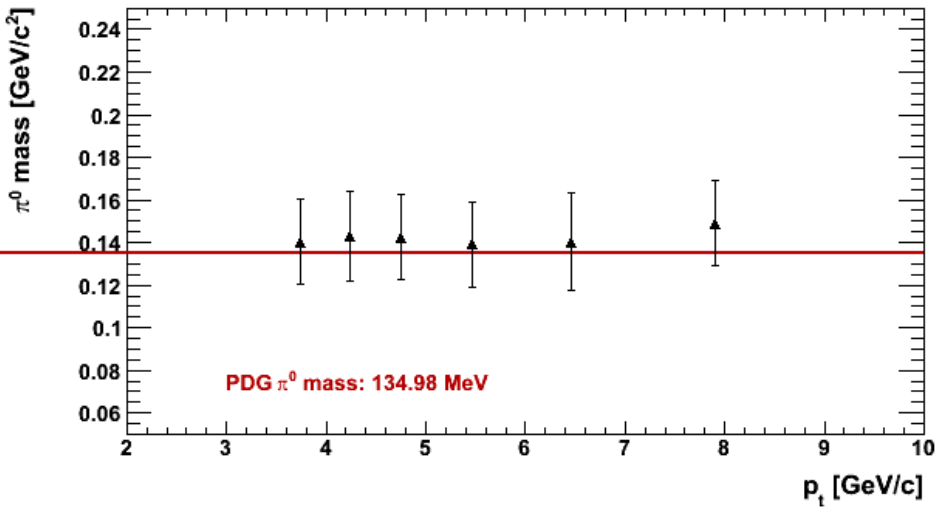
2004 BEMC Calibration

No test-beam calibration
→*in situ* calibration of 2400 channels

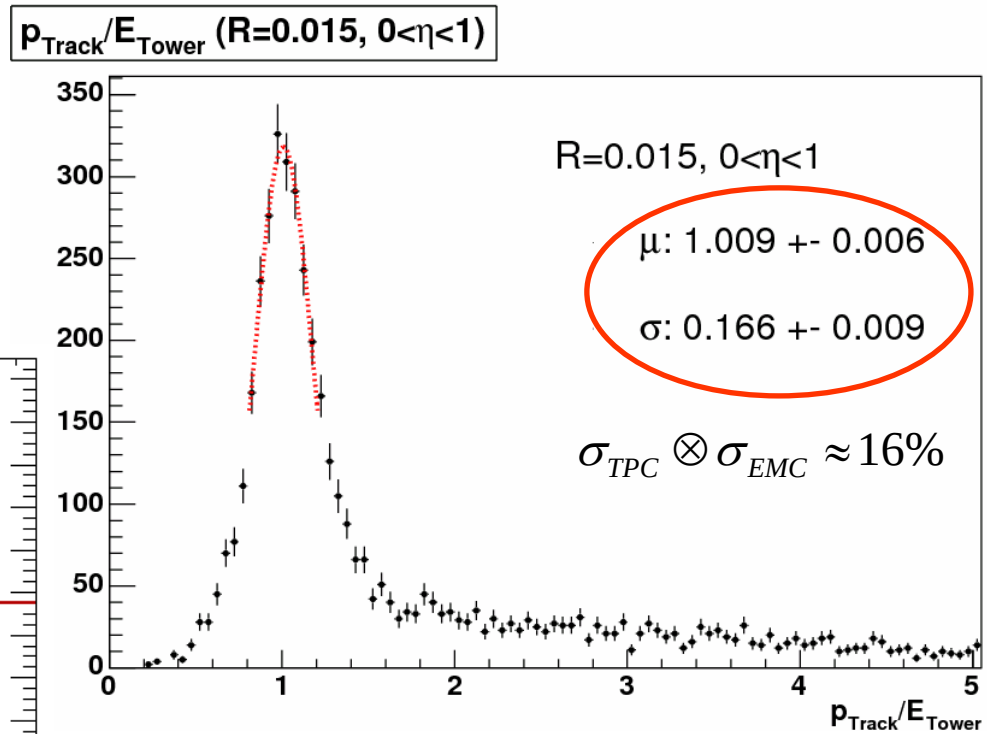
p+p statistics insufficient
→ use Au+Au events from earlier in 2004 run (same HV)

Use TPC tracks
→MIPs: relative gain
→Electrons: energy scale





Set E-scale using 1.8<*p*<8 *GeV/c* electrons



$\sigma_{TPC} \otimes \sigma_{EMC} \approx 16\%$

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

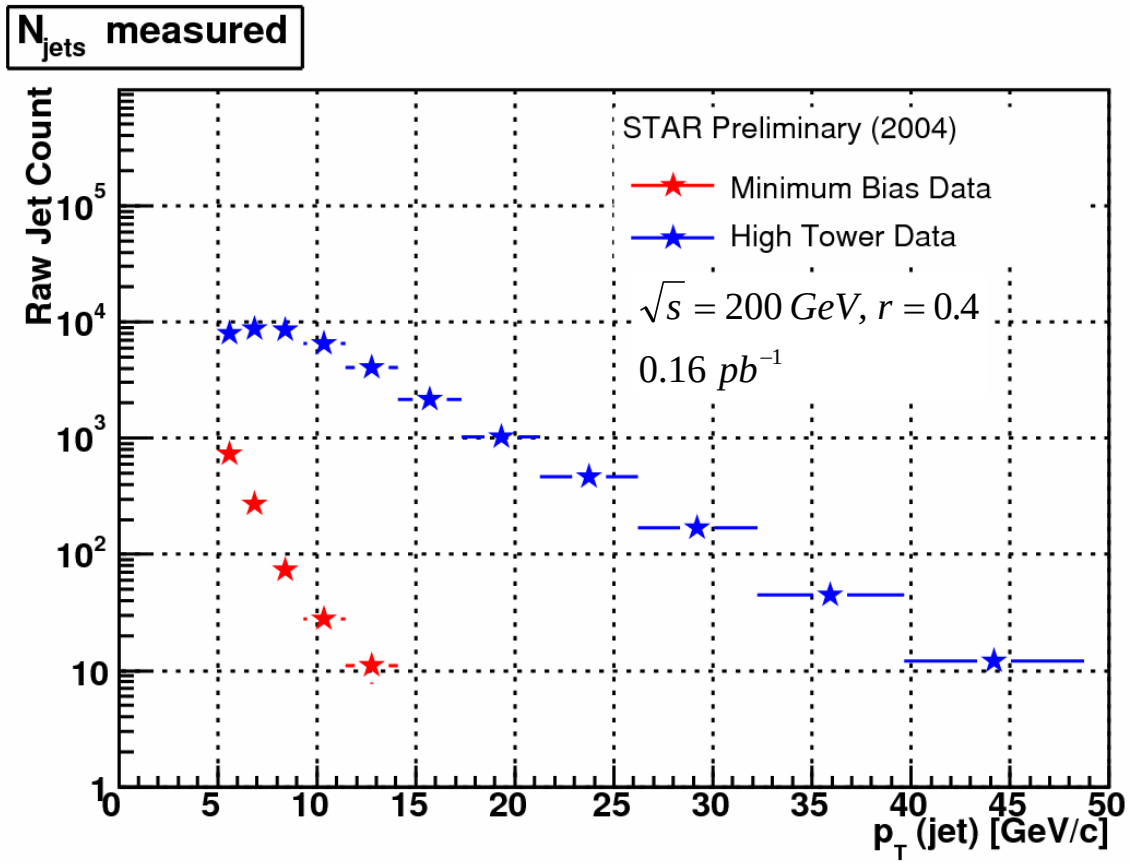
Mike Miller, for the STAR collaboration

Raw Jet Count

Event Selection:
|vertex-z|<60 cm
E_T-*trig*>3.5 GeV/c for HT

Clustering Parameters:
p_T (track/tower) > 0.2 GeV
p_T (seed) = 0.5 GeV
r_{cone} = 0.4
f_{merge} = 0.5

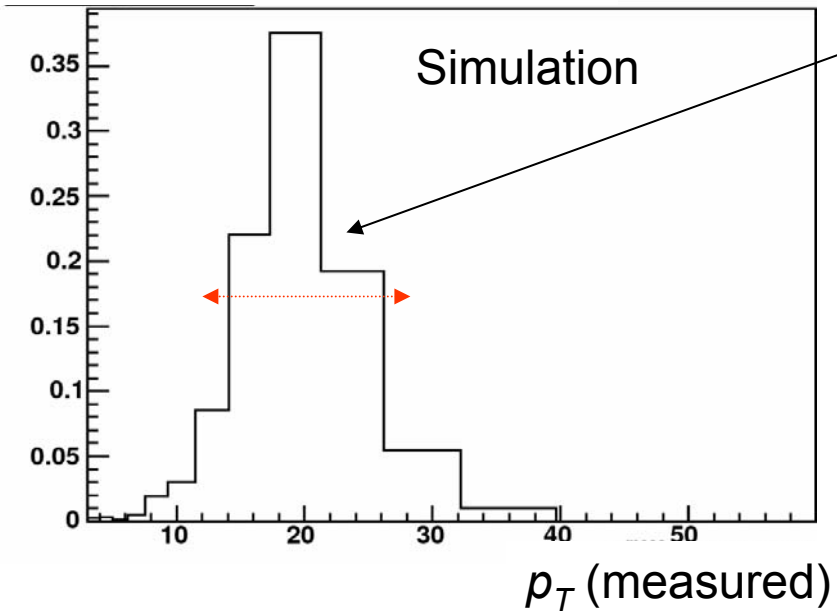
Jet Selection:
0.2< η_{jet} <0.8
Neutral/total <0.9



→ ~55k jets after all cuts

Response Function

17 < p_T(thrown) < 21 GeV/c



$$resolution: \frac{p_T^{true} - p_T^{meas}}{p_T^{true}}$$

Simulation: ~25% ± 5% for $10<p_T<50$ GeV/c

Consistent number derived from (modest) sample of di-jet events

→ Choose bin width = resolution

- Consider detector response (*measured*) to known input (*true*)

"geant jets"

"pythia jets"

reco Bin = thrown bin: →35-40%
reco Bin = thrown ± 1: → ~80%

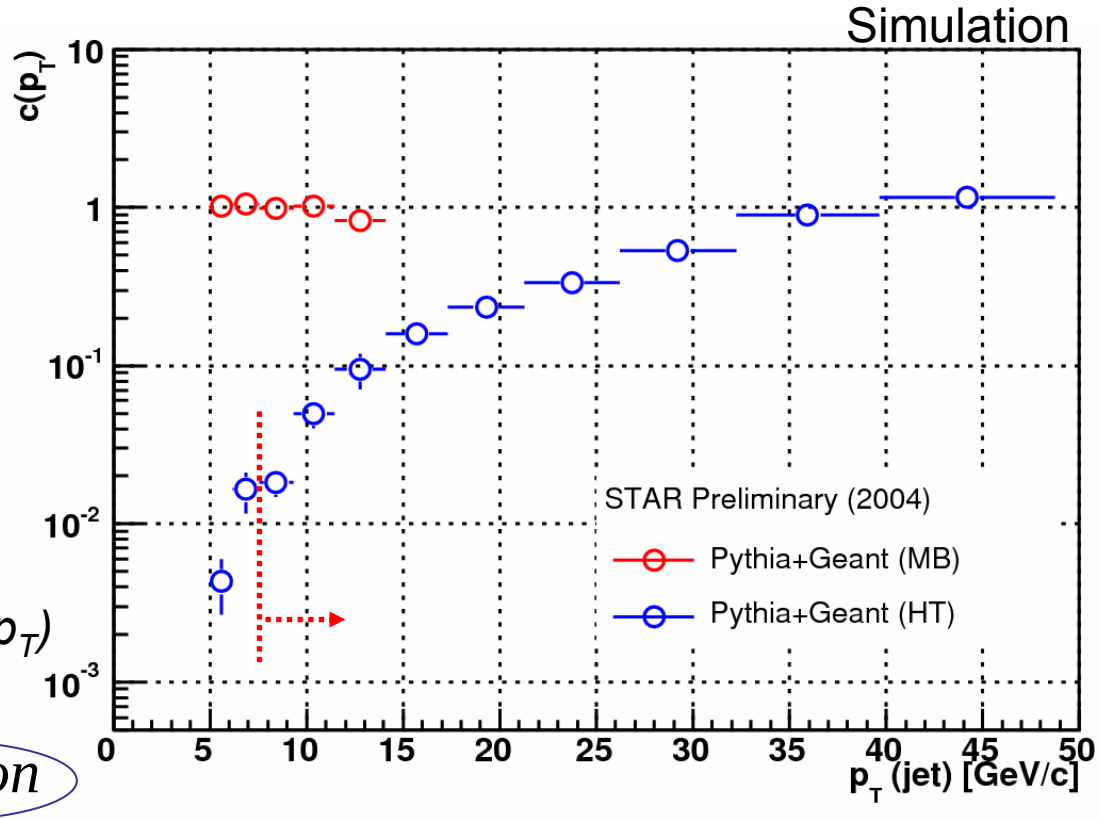
→ Motivates use of bin-by-bin correction factor

Bin-by-bin correction factors

"measured"

$$c(p_T) = \frac{M_{geant}\left(p_T^{geant}\right)}{N_{pythia}\left(p_T^{pythia}\right)}$$

"true"



decreases $c(p_T)$ — increases $c(p_T)$

$$c(p_T): \varepsilon_{trigger} \otimes \varepsilon_{jet} \otimes resolution$$

~0.01 at $p_{T\text{-}jet}$ = 5 GeV
~1 at $p_{T\text{-}jet}$ = 50 GeV

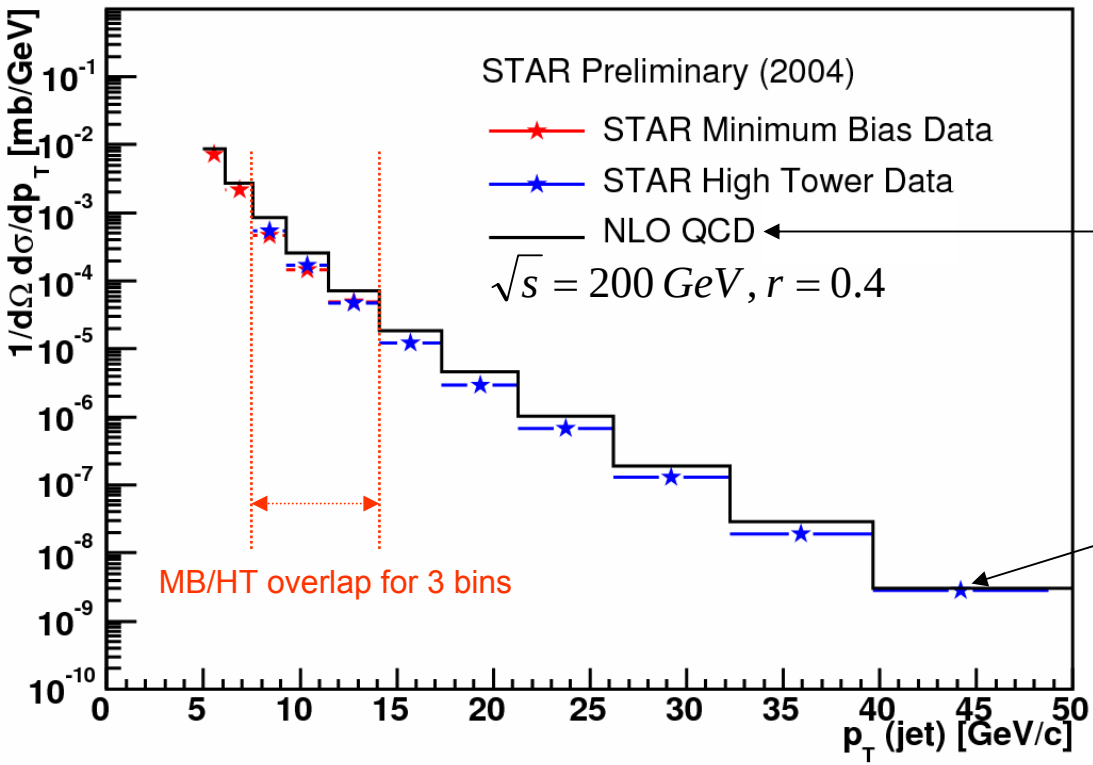
- MB data statistics limited
- More advanced unfolding techniques currently under study

Towards a "corrected" cross section

$$\frac{1}{d\Omega}\frac{d\sigma}{dp_T} = \frac{1}{2\pi \cdot 0.6}\cdot\frac{1}{\Delta p_T}\cdot\frac{1}{\int L\cdot dt}\cdot\frac{1}{c(p_T)}\cdot\frac{dN}{dp_T}$$

$$\frac{1}{\int L\cdot dt} = \frac{\sigma_{BBC}\cdot\varepsilon_{vert}^{MB}}{N_{MB-events}^{accepted}}$$

~60%
Under study



Fortran code from hep-ph/0404057 (Jager et al.)
r_{cone}=0.4
CTEQ 6.1
$\mu_F = \mu_R = p_T$
Agrees with EKS NLO to better than 1%

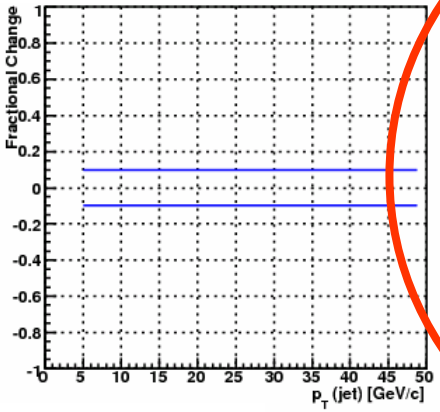
±30% but invisible on this scale

- Only *data*-statistical errors shown
- Systematics and ratios on next slides

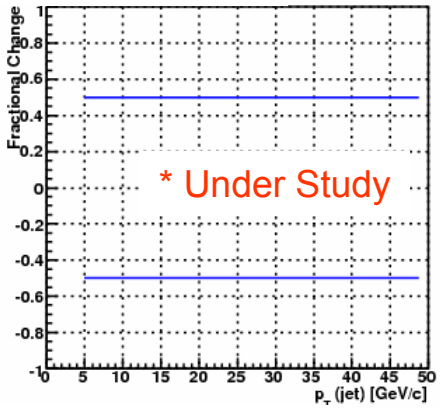
Dominant systematic uncertainty estimates

Fractional Change in x-section

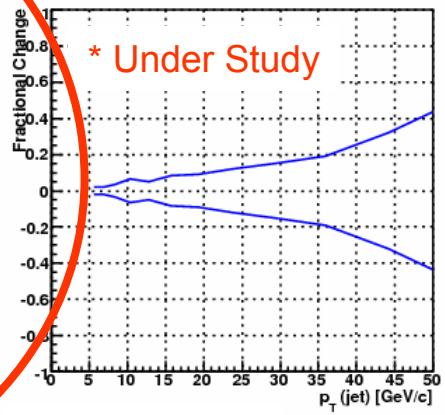
Normalization



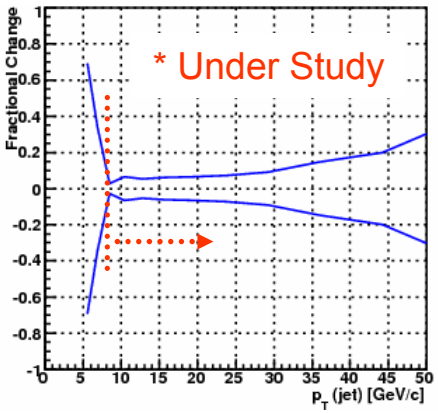
Energy Scale



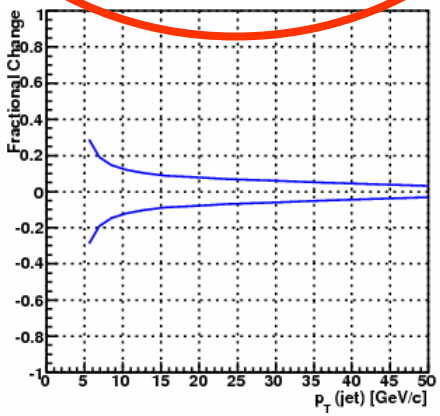
BBC Trigger



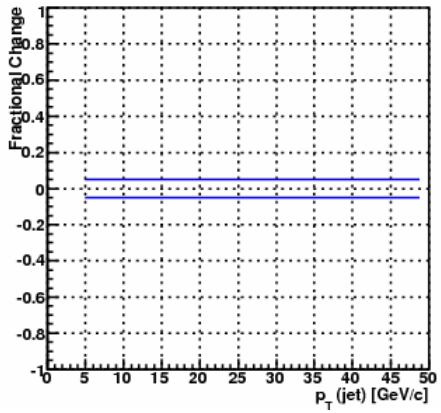
Pythia slope



Statistics of c(pt)

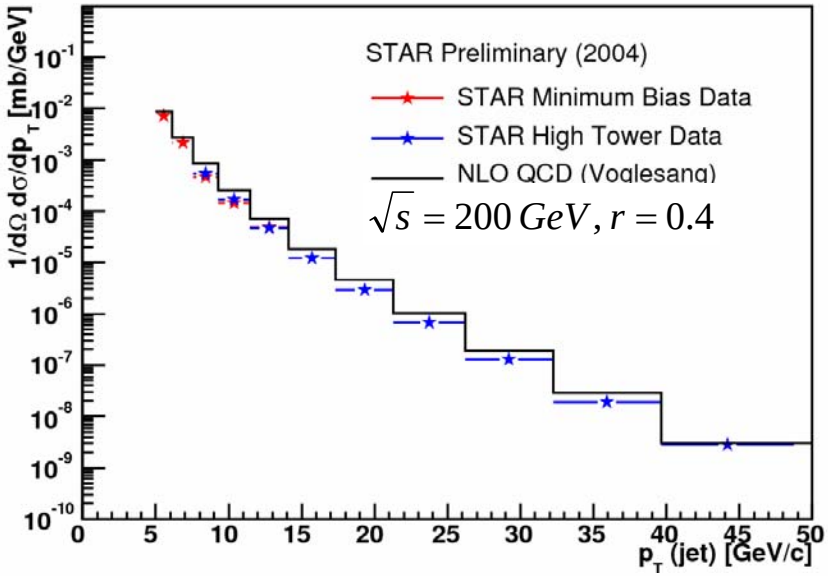


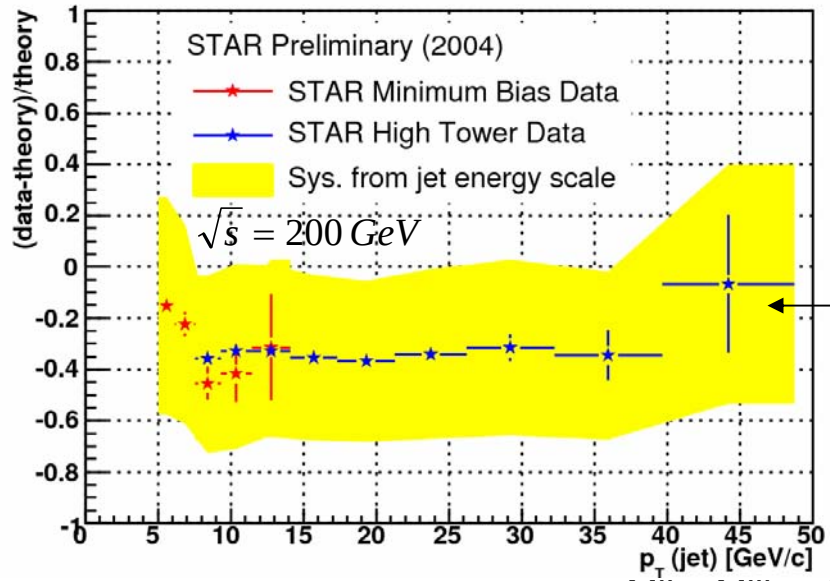
Background



- Dominant uncertainty: 10% change in ECal → ~40% change in yield
- More under long term study (see last slide)

"Corrected" data vs. NLO calculation





Issues that won't go away for 2004:

1. HT trigger: fragmentation bias, slow turn on with p_T-*jet*
2. Jet energy scale (*need integrated luminosity for photon-jet!*)

•50% systematic uncertainty from E-scale shown

•*Agreement (within systematics) over 7 orders of magnitude*

Summary and outlook

- Much work to develop methods and techniques for jet triggering, reconstruction, and analyses
- First look:
  - Significant p_T reach (~50 GeV/c)
  - Agreement within large systematics with NLO calculations
- A few primary issues under study:
  - Refining *in situ* EMC calibrations (AuAu vs. CuCu vs. pp)
  - Overall scale corrections for no-vertex events
  - Improved unfolding methods
  - Fragmentation bias (e.g., Pythia vs. Herwig)
  - NLO clustering scheme
- Goal:
  - Bring 2004 (and 2003) analyses to efficient closure
  - Large 2005 data set produced, thesis analyses underway
- Long term cross section goals
  - Jet shapes, NLO comparisons
  - High stats → possible improvement of large-x pdf's

Backup slides

Uncorrected per-event yield

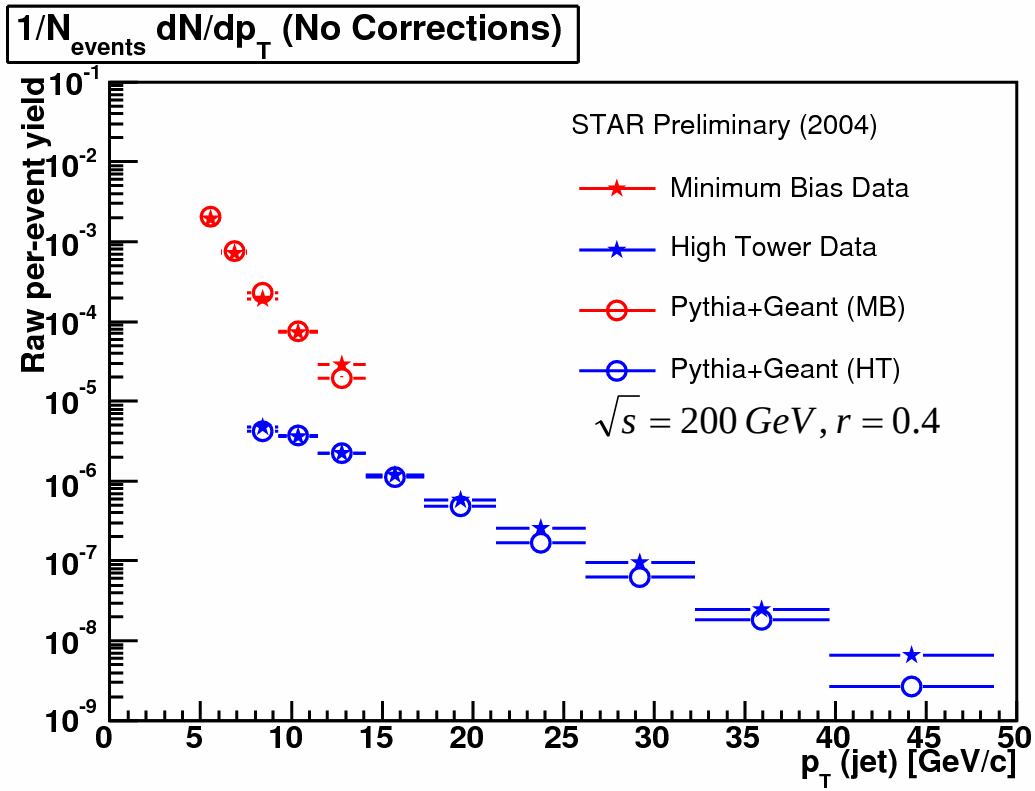
raw per-event yield:

$$\frac{1}{N^{accepted}_{MB\text{-}events}} \cdot \frac{dN}{dp_T}$$

Allows data/MC comparison before luminosity

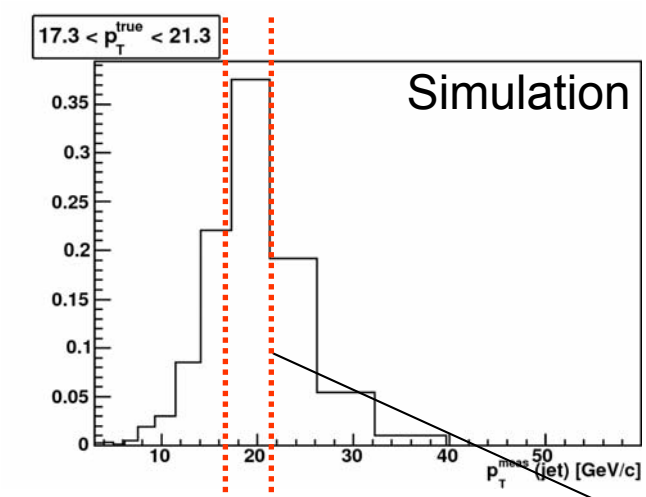
For HT, include trigger pre-scale:

$$\frac{1}{N^{accepted}_{MB\text{-}events}} \rightarrow \frac{1}{N^{accepted}_{MB\text{-}events} \cdot \left\langle ps^{trig}_{MB} \right\rangle}$$



- Reasonable agreement between data/MC
- 10 weighted pythia samples
- Slope difference:
  - Short term: incorporated into sys. uncertainty
  - Long term: iterative re-weighting of MC sample

Response & bin quality factors



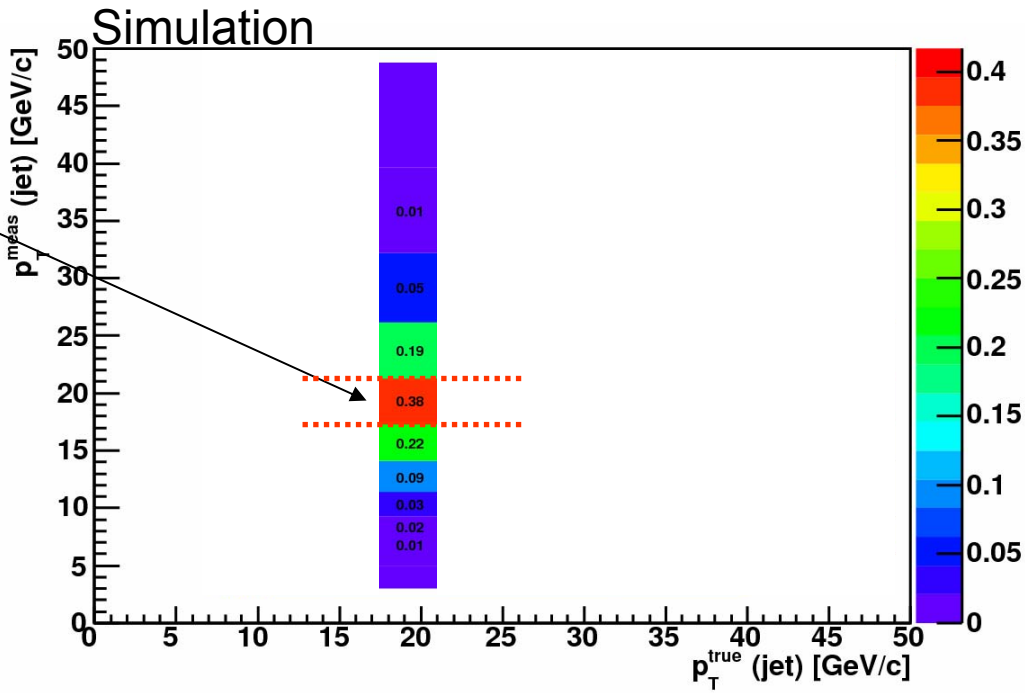
Of all *accepted* jets

$$purity: \frac{N_{measured}}{N_{generated}}$$

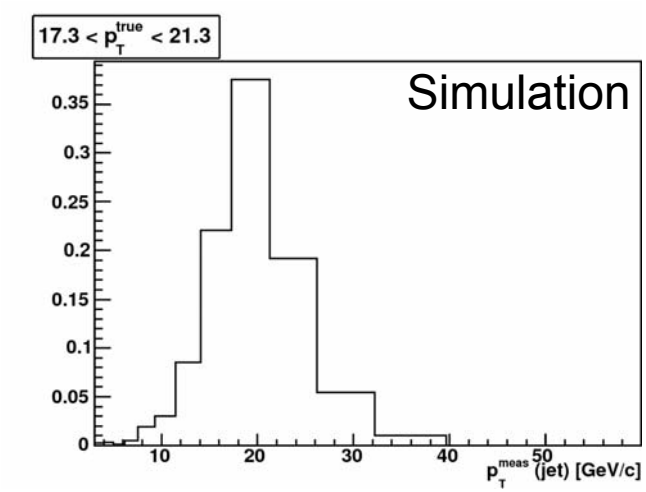
- Consider detector response (*measured*) to known input (*true*)

"geant jets"

"pythia jets"



Response & bin quality factors



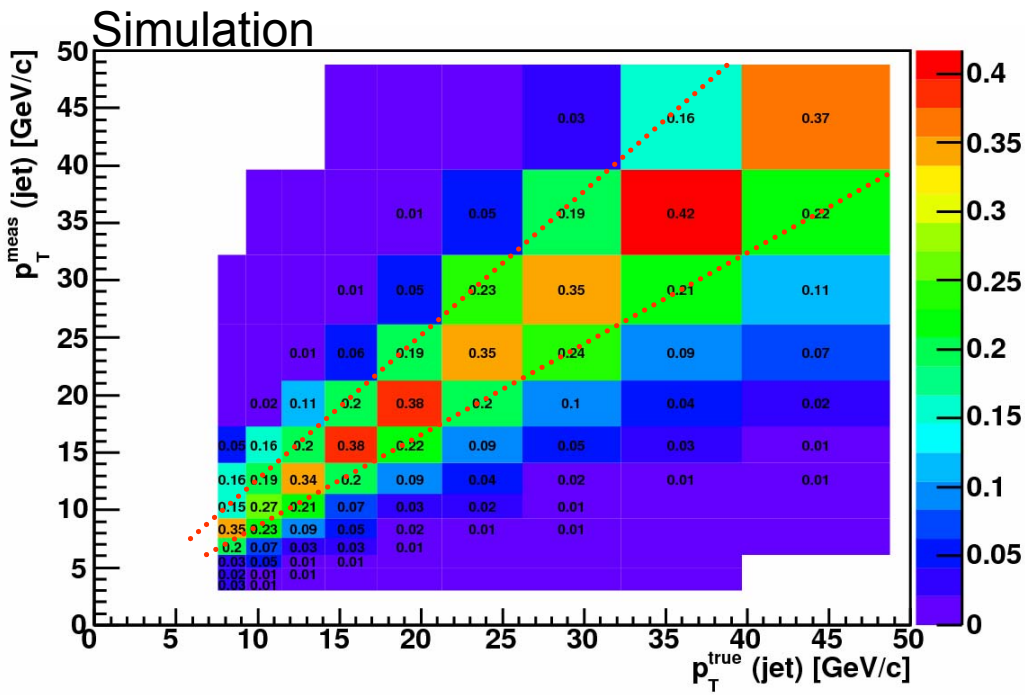
Of all *accepted* jets

$$purity: \frac{N_{measured}}{N_{generated}}$$

- Consider detector response (*measured*) to known input (*true*)

"geant jets" "pythia jets"

- Bins of width 1-sigma → "purity" of ~35% over range on the diagonal.
- Motivates application of bin-by-bin correction factors.

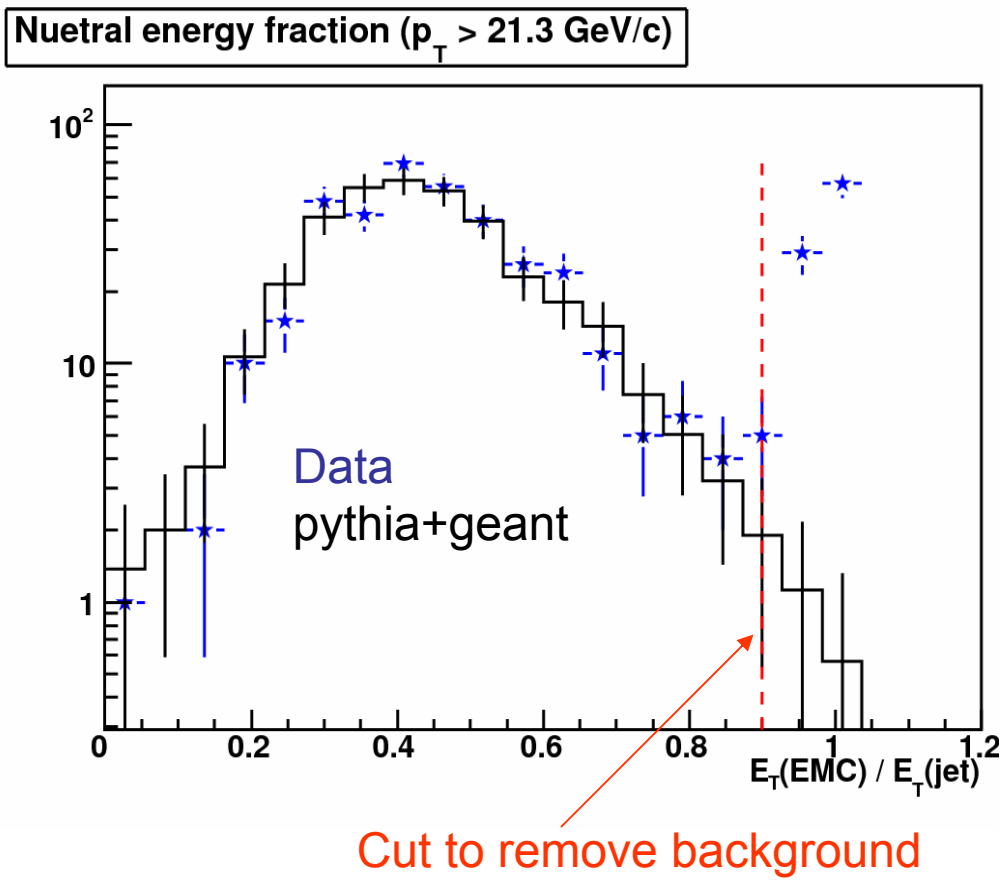


Jet Energy Scale Systematics

Charged Track Momentum	$\Delta p/p$ TPC	1%
Charged Track Inefficiency	10% x 60% jet	6%*
Neutral Tower Energy	$\Delta G_{ain}/G_{ain}$ = 10%	40% in yield
Neutral Energy Inefficiency	$\sum E_T$ from n+$K^0_{L/S}$+η+Ω+ν	6-10%*
MIP Subtraction	10% Correction to Jet E_T	1%
Fiducial Detector Effects	Edges/Dead regions	2%
Jet η calculation	1 tower = $\Delta\eta$=0.05	3%
Background Trigger	Background trigger +MINBIAS event	5% in yield
Background Energy	Jet + underlying Background	0
Underlying Event	Work in Progress	NA
Fragmentation	Comparison to HERWIG ongoing	NA

**** Included in Correction Factor***

Background Removal



neutral energy fraction :

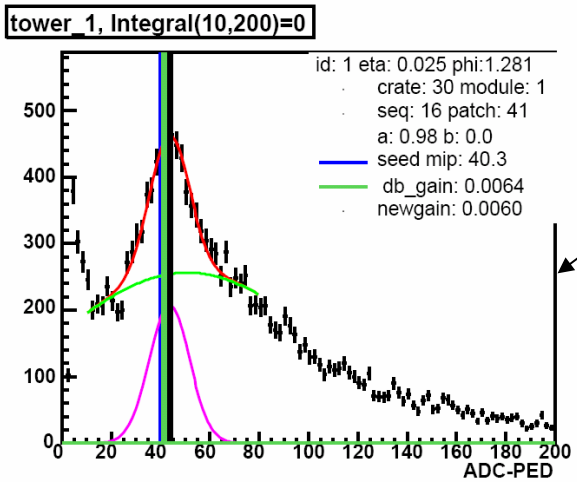
$$f = \frac{\sum E_T^{EMC}}{E_T^{jet}}$$

Systematic uncertainty on yield from background less than ~5%

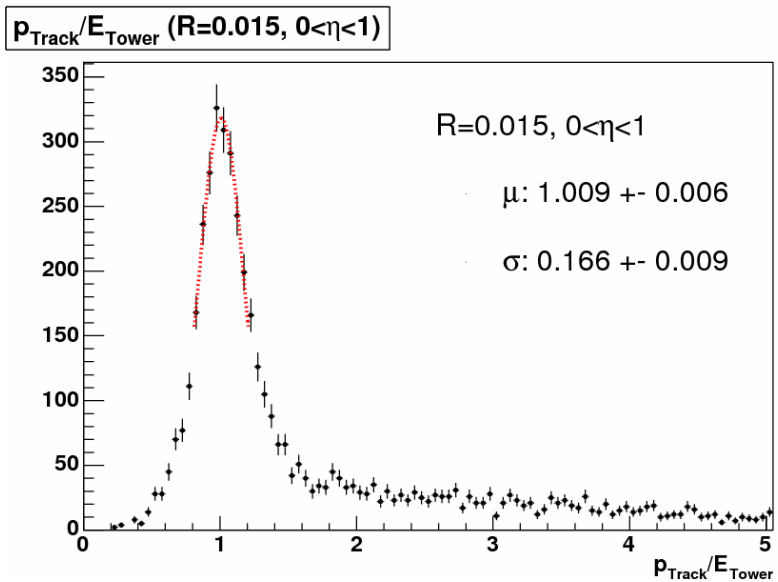
2004 BEMC Calibration

Relative gain:
- tower-by-tower MIP response
- ~250 +- 50 MeV/mip

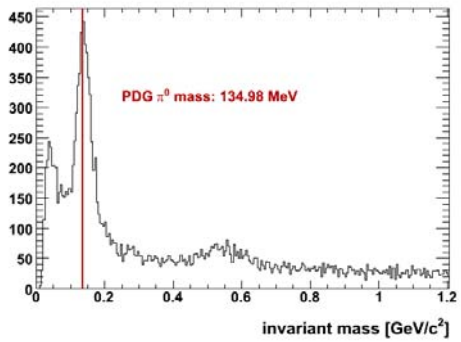
Absolute gain:
- Eta ring TPC-electrons
- $2 < p_{electron} < 6$ GeV/c

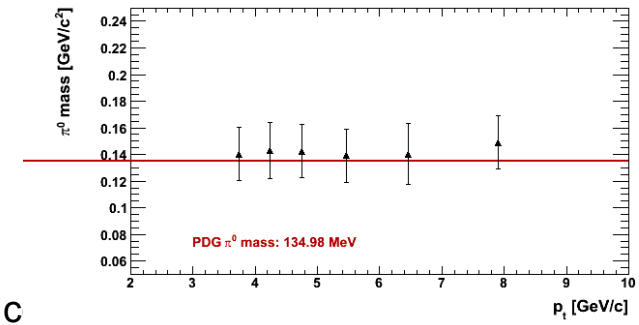


Typical tower response to MIP candidate in 2004 AuAu



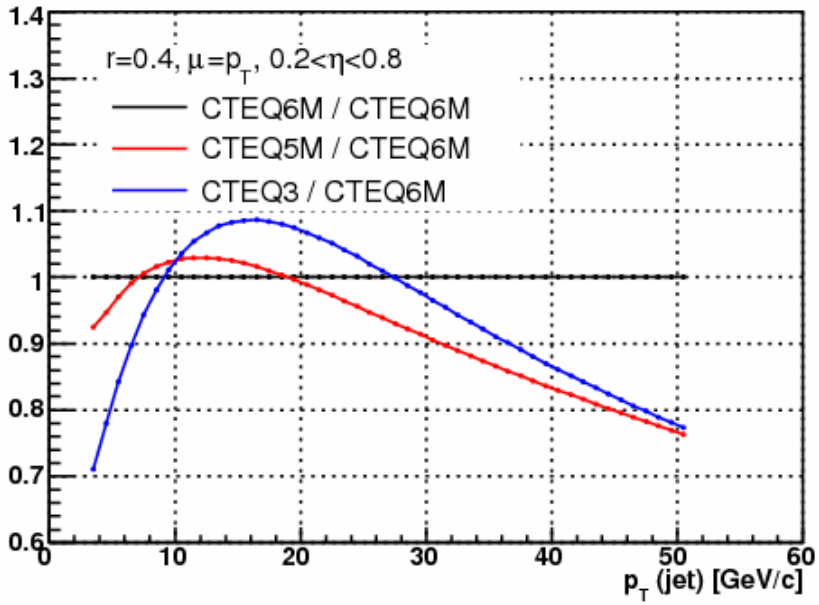
All towers, p_{track} > 1.8 GeV



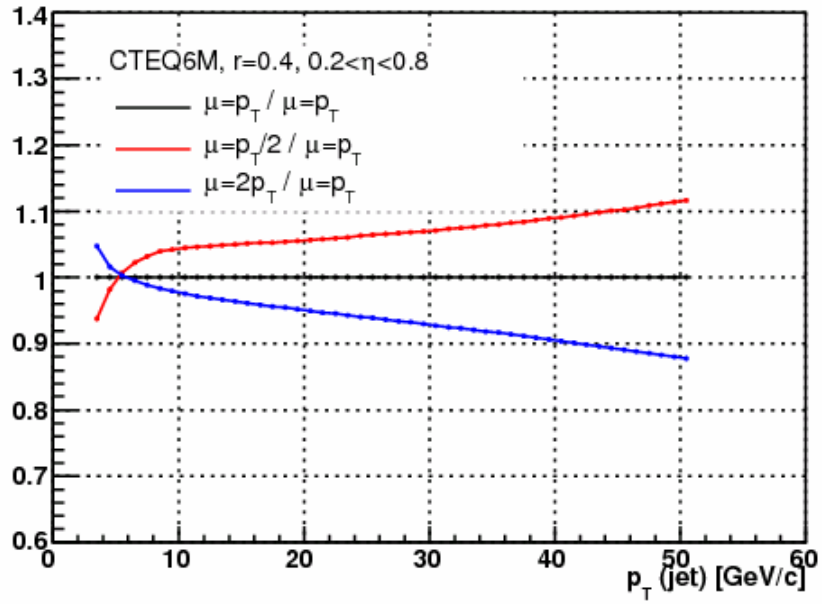


Theory Systematics

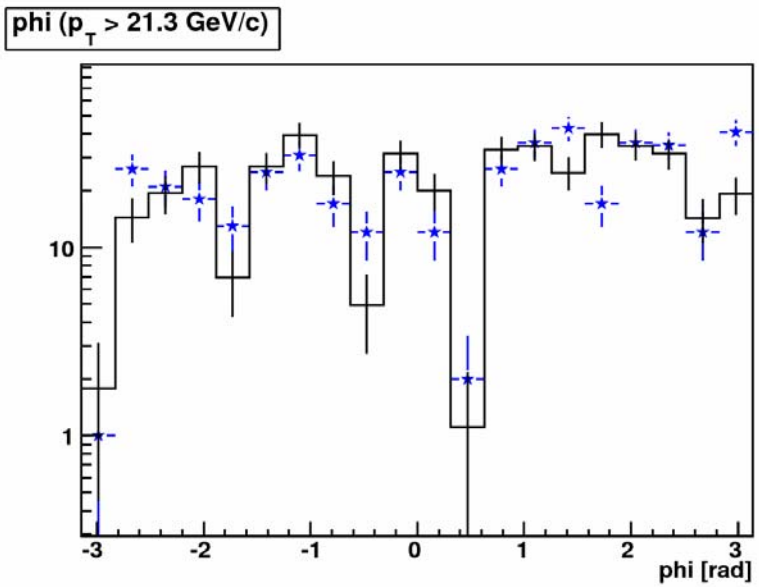
Changing the pdf

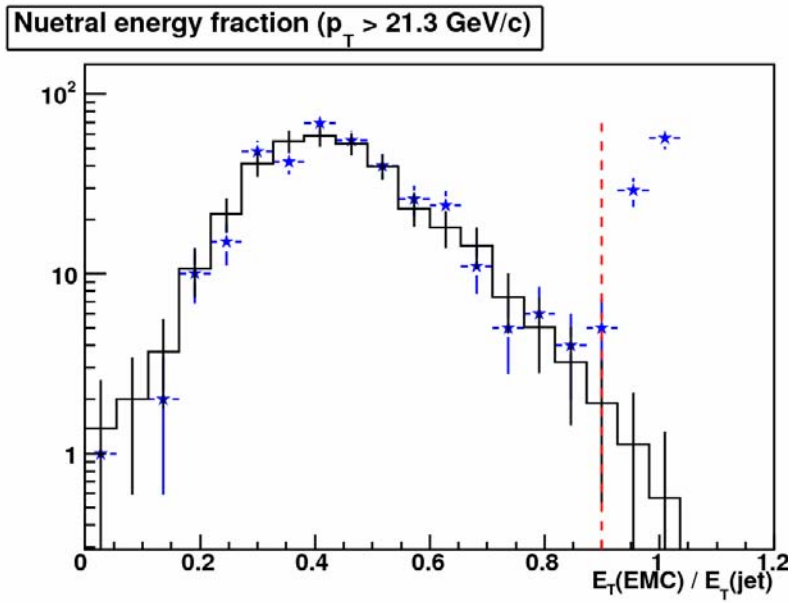


Changing the scale



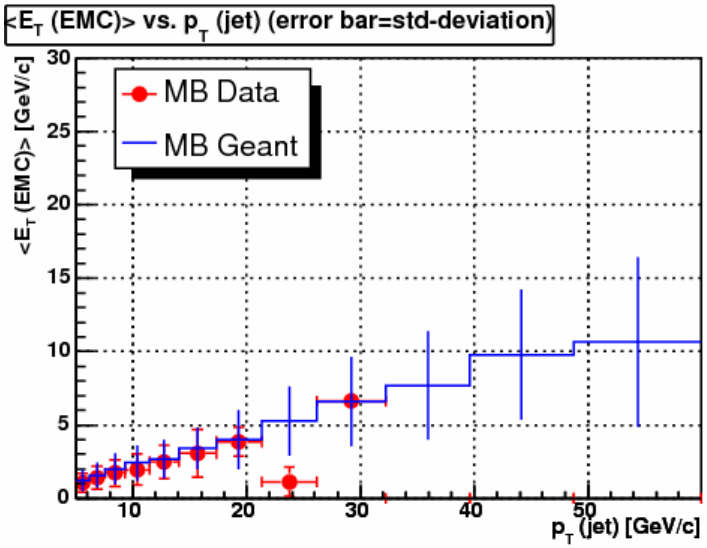
Data vs. MC

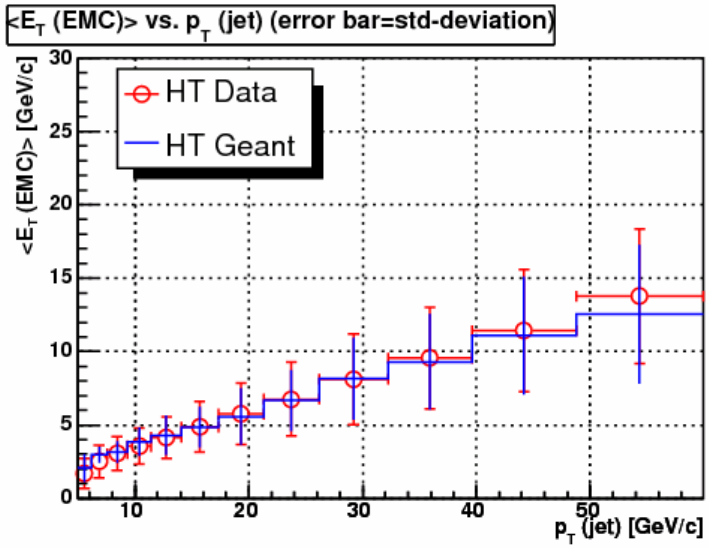


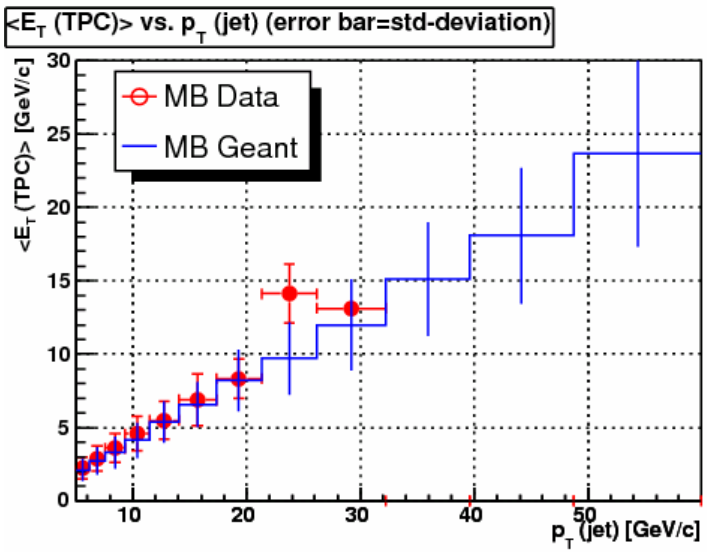


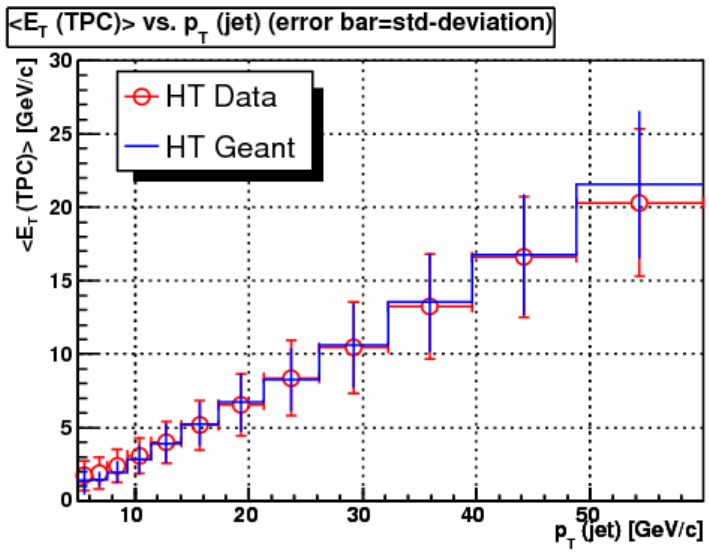
Clear background for ratio>0.9
Data/MC agreement improves at higher pt

Data vs. MC

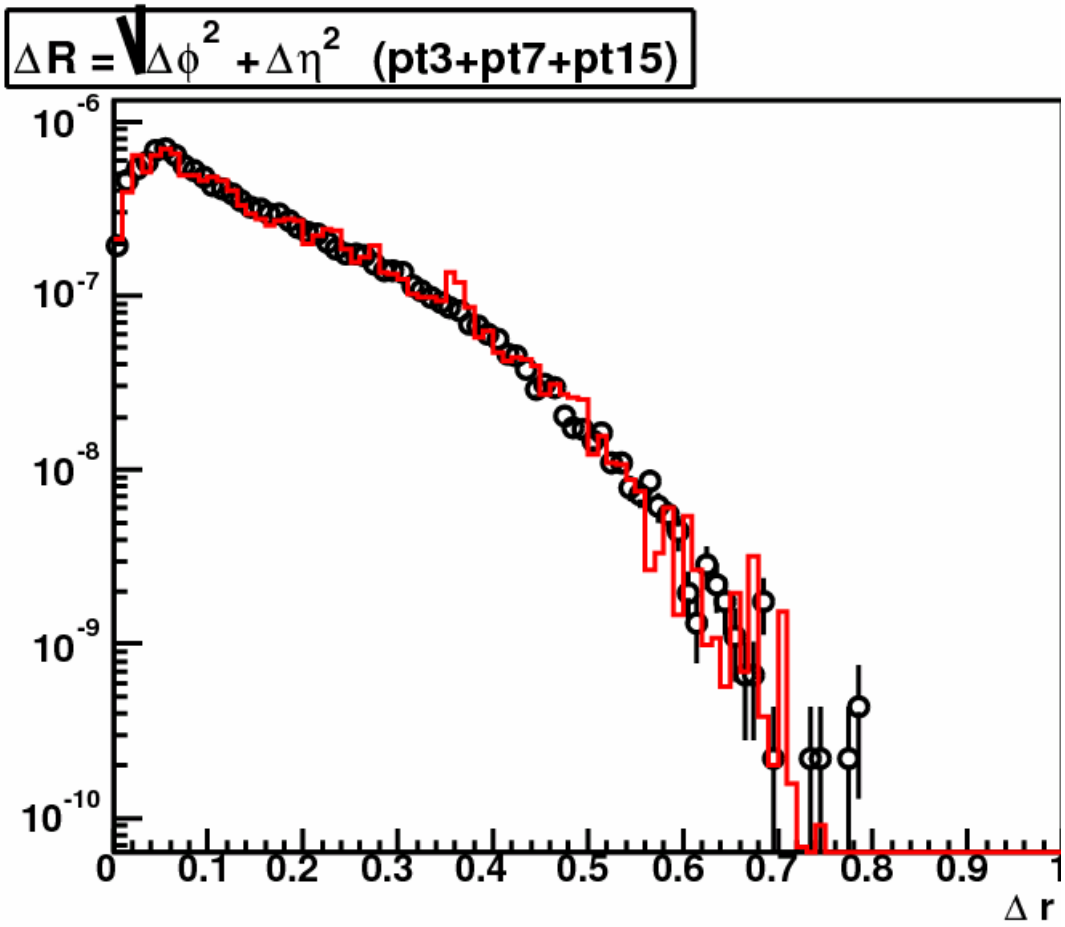

<E_T (EMC)> vs. p_T (jet) (error bar=std-deviation)
MB Data
MB Geant
<E_T (EMC)> [GeV/c]
p_T (jet) [GeV/c]


<E_T (EMC)> vs. p_T (jet) (error bar=std-deviation)
HT Data
HT Geant
<E_T (EMC)> [GeV/c]
p_T (jet) [GeV/c]


<E_T (TPC)> vs. p_T (jet) (error bar=std-deviation)
MB Data
MB Geant
<E_T (TPC)> [GeV/c]
p_T (jet) [GeV/c]


<E_T (TPC)> vs. p_T (jet) (error bar=std-deviation)
HT Data
HT Geant
<E_T (TPC)> [GeV/c]
p_T (jet) [GeV/c]

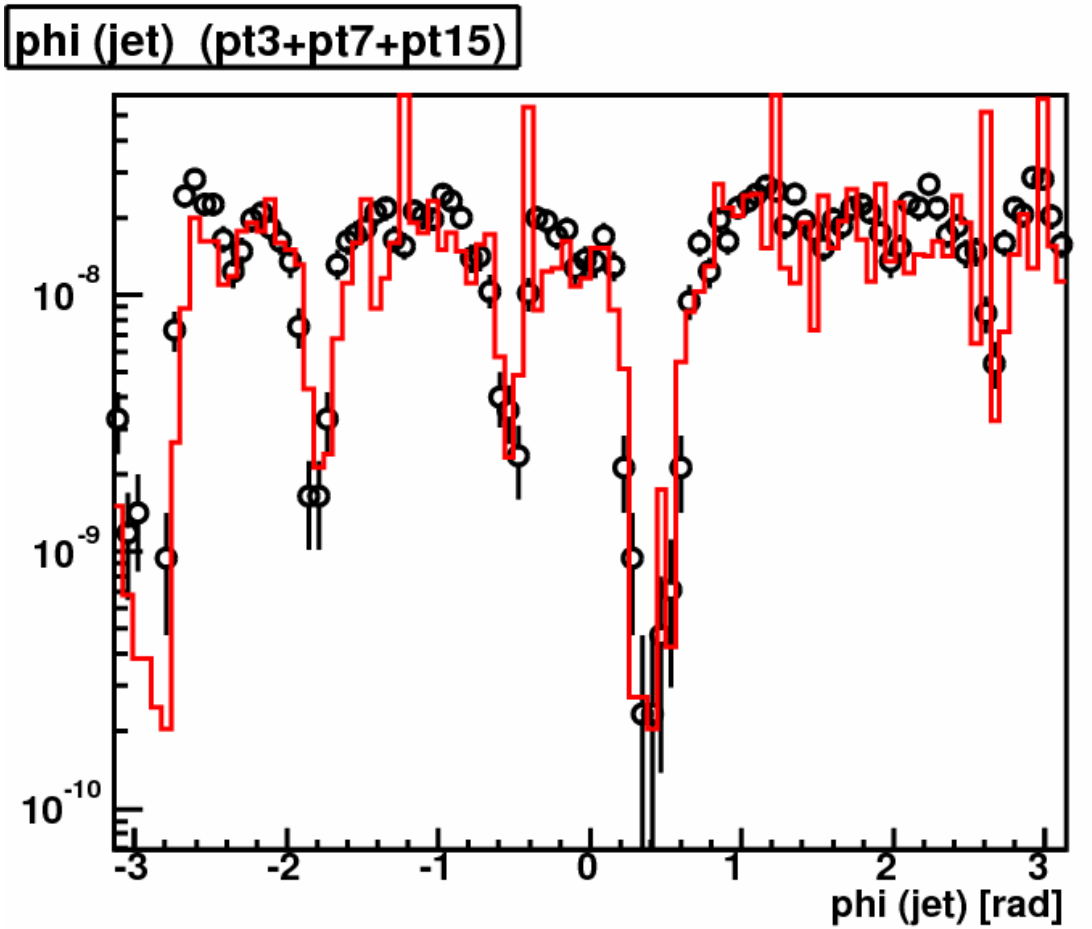
Data vs. MC



Red → pythia + gstar
Black → data
All error bars statistical

High tower trigger
pt (jet) >10 GeV/c

Data vs. MC



Red → pythia + gstar
Black → data
All error bars statistical

High tower trigger
pt (jet) >10 GeV/c

Data vs. MC