Title: Measurement of Azimuthal De-correlations in DiJet Events

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Abstract: TBA

Measurement of the Azimuthal Decorrelation in di-jet events

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PI-ATLAS LHC Day

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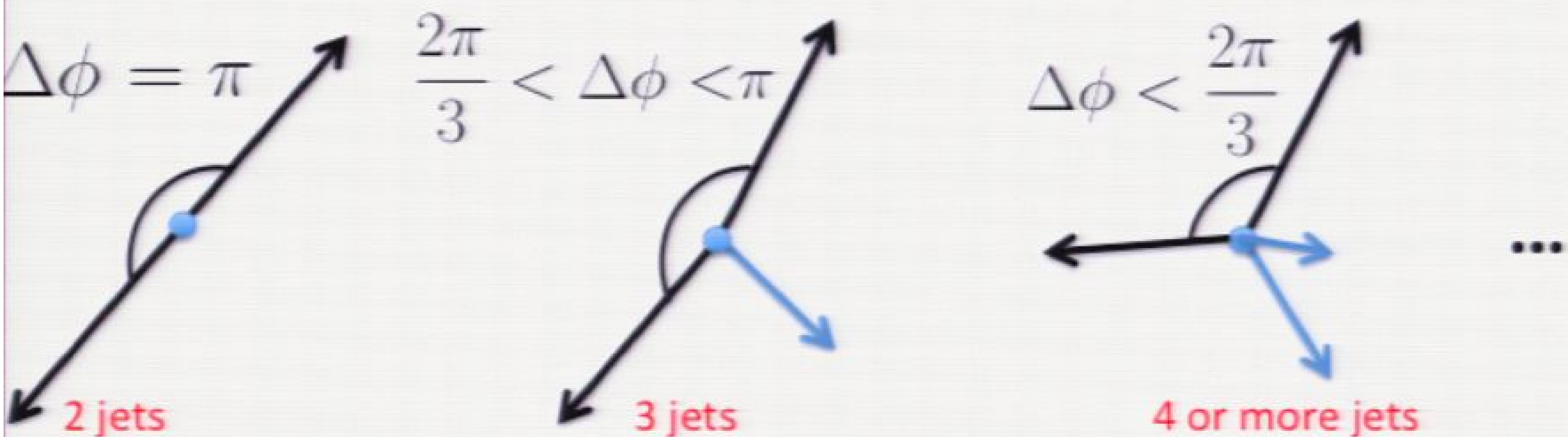
Introduction

$\Delta\phi \equiv$ angle (in transverse plane) between leading 2 jets

- ϕ **is the azimuthal angle**
- **Amount of decorrelation is difference from LO value if** π



- Distribution of $\Delta\phi < \pi$ is necessarily affected by other non-leading jets
- By measuring the azimuthal decorrelation in "dijet" events we can test predictions of higher order pQCD
- We don't have to measure 3rd, 4th ... jets (which is hard to do)
- D0 paper: Phys. Rev. Lett. 94, 221801 (2005)

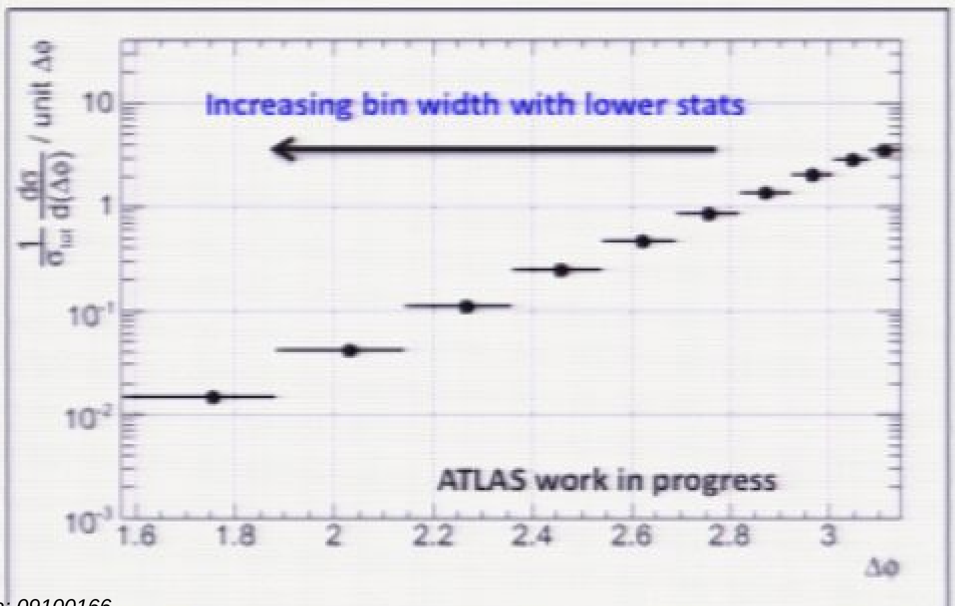
Introduction

- The differential cross section is sensitive to systematics such as trigger efficiencies and uncertainty in integrated luminosity
- We instead choose to scale the differential cross section by inverse of the total cross section integrated over all Δϕ
- We also scale each bin by 1/(bin width) in order to compare distributions with different binning.

$$\frac{d\sigma}{d(\Delta\phi)}$$

$$\frac{1}{\sigma_{tot}}\frac{d\sigma}{d(\Delta\phi)}$$

$$\frac{1}{\sigma_{tot}}\frac{d\sigma}{d(\Delta\phi)} / \ unit\ \Delta\phi$$

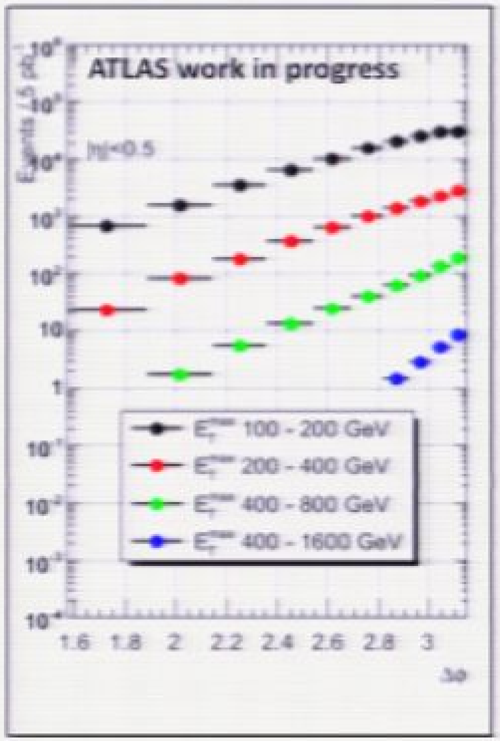


$\pi/2 \longrightarrow \pi$

Final observable

Also make a cuts on η and E_T (see next slide)

Number of events expected in 5 pb^{-1}



Instantaneous luminosity at low luminosity running → $\mathcal{L} = 10^{31}\, cm^{-2}\, s^{-1}$

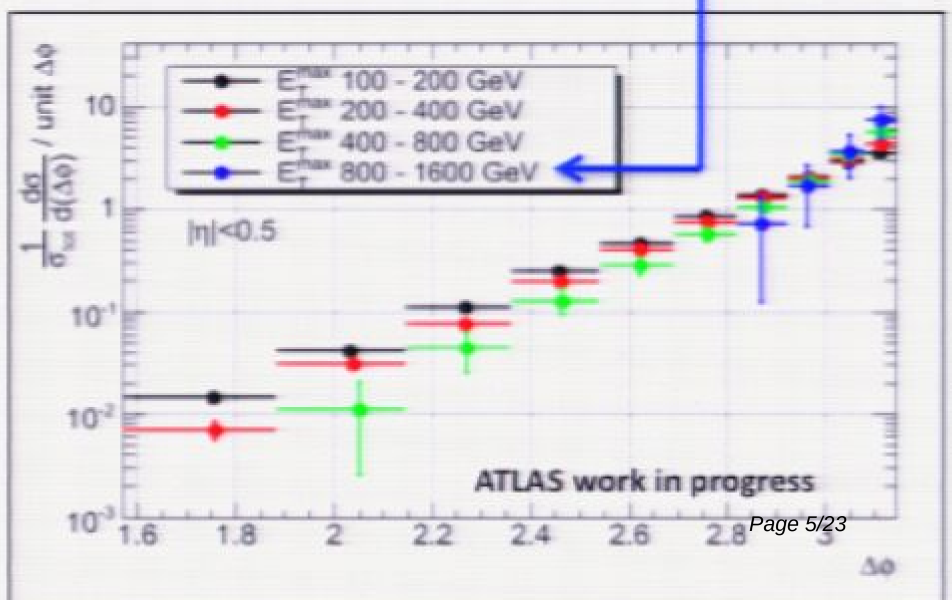
$$= \frac{10^{-5}\, pb^{-1}}{s}$$

Can collect a sufficient data set in very little time → $\Rightarrow 5\, pb^{-1} \approx 14\, hrs$

Not used in the following

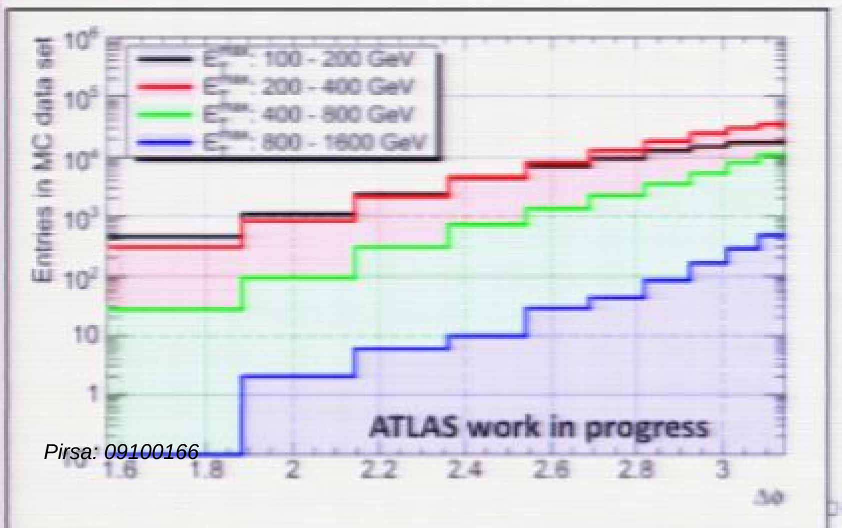
Limit to |η|<0.5

- avoids η dependent corrections
- avoids transitions between sub-detectors
- limits statistics
- need to optimize this cut
- For very early data we will keep it tight



MC Data Set

Leading Jet E_T Range	Number of Partons in ME Calc.	Cross Section
70-140	2	1116548.7 pb
70-140	3	1486726.3 pb
70-140	4	511243.1 pb
70-140	5	162795.3 pb
140-280	2	31872.0 pb
140-280	3	64534.6 pb
140-280	4	50202.6 pb
140-280	5	24146.8 pb
140-280	6	11973.3 pb
>280	2	750.6 pb
>280	3	1920.0 pb
>280	4	2173.4 pb
>280	5	1431.6 pb
>280	6	967.9 pb



- $s=(10\text{ TeV})^2$
- Jet algorithm=AntiKt4 LCtopo jets
- MC generator=Alpgen + Herwig (CTEQ6L1)

Reconstructed Jet: full simulation of the ATLAS detector including electronics

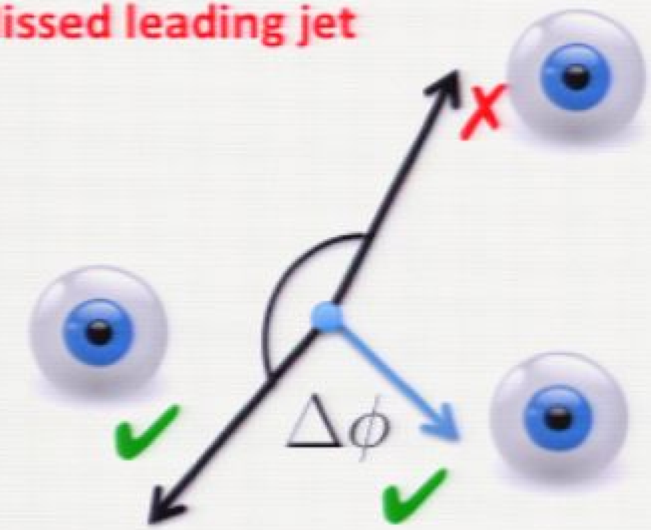
Truth Jet: Jet made from particle just before interacting with the detector

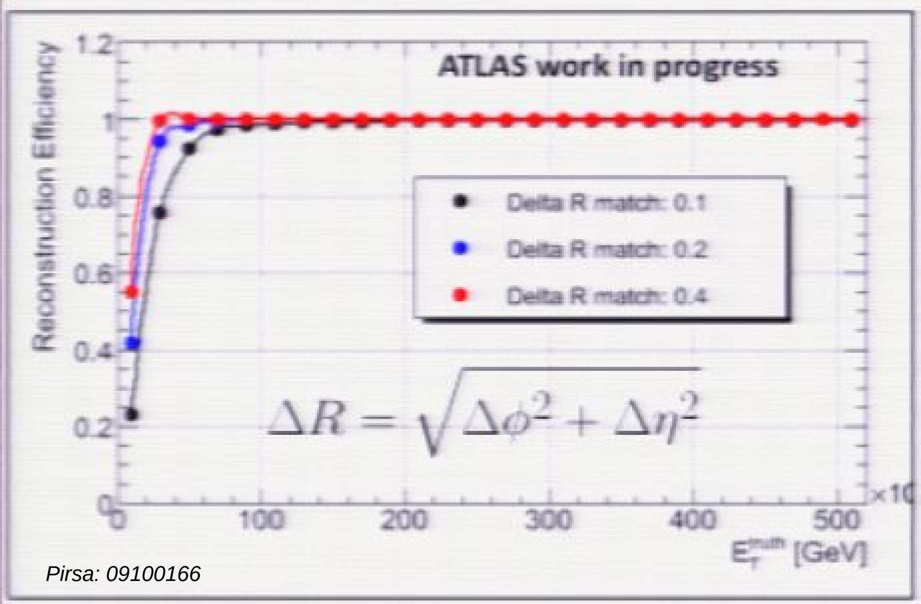
Systematics Studies

- Reconstruction Efficiency
  - Missing leading results in wrong $\Delta\phi$ value
- ϕ angular resolution
  - Steeply rising distribution could result in bin to bin migration
- E_T resolution
  - Can swap 2nd and 3rd jets or push jets out of E_T window
- Absolute Jet Energy Scale
  - Effectively shifts ET thresholds

Reconstruction Efficiency

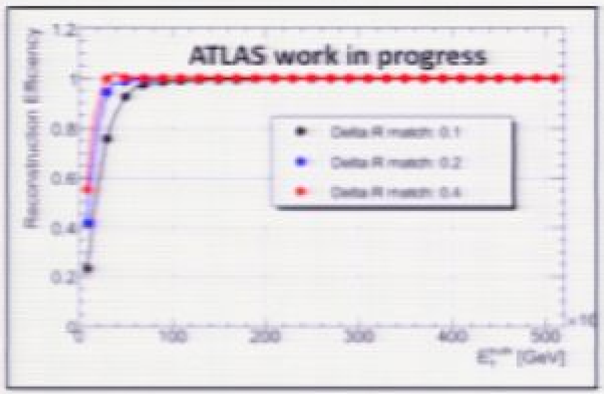
Missed leading jet

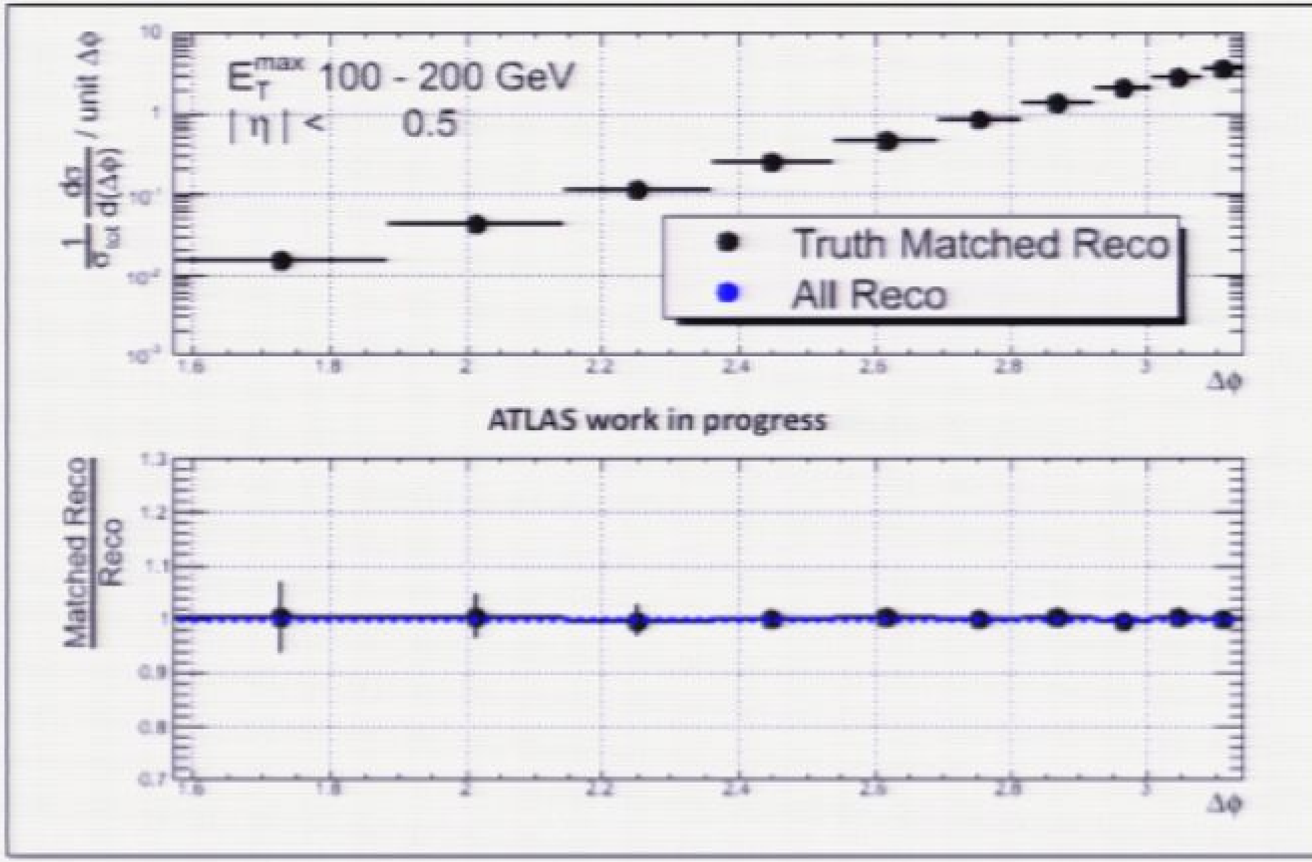




- If one of the leading jets is not reconstructed we measure the wrong $\Delta\phi$
- Here the reconstruction efficiency is measured by matching truth jets to reconstructed jets within ΔR
- Although reconstruction efficiency is high even a few percent in the low $\Delta\phi$ bins can make a big difference
- To measure effect we veto events unless both leading truth are matched to reconstructed jets ($\Delta R<0.1$)

Reconstruction Efficiency

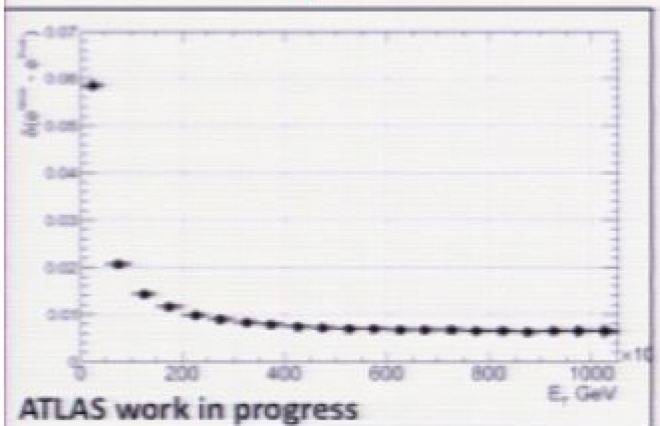




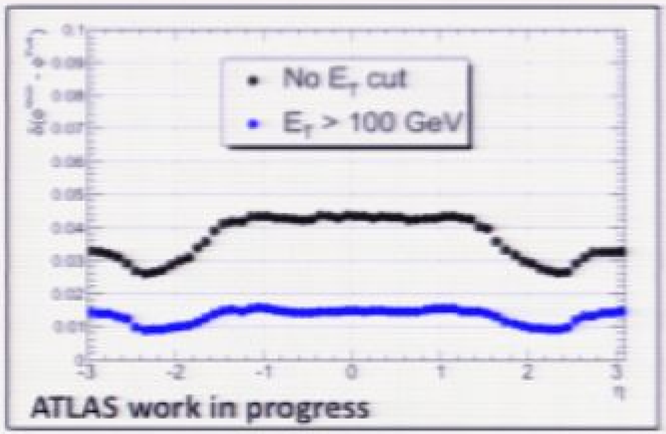
- This effect is not significant according to these MC data

ϕ Angular Resolution

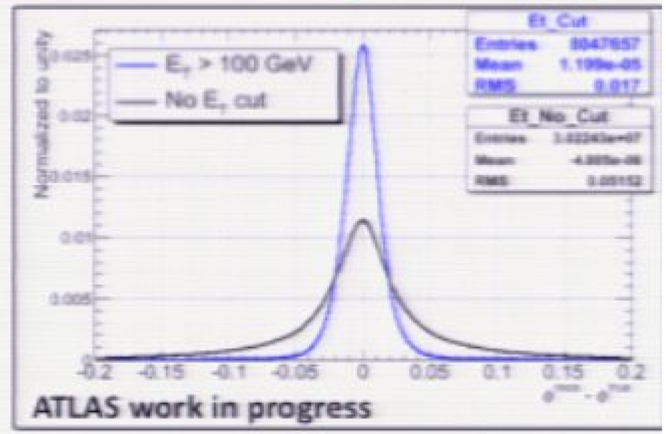
define response as $\phi^{reco} - \phi^{true}$
Resolution $\delta(\phi^{reco} - \phi^{true})$ is defined as the width of response distribution



Above 100 GeV ϕ resolution is approximately flat as function of E_T



With E_T cut, ϕ resolution is flat as function of η



We take the resolution as the width of the response distribution values (**0.017 rad**)

To estimate effect, shift the ϕ value of MC truth jets by a value selected randomly from Gaussian:

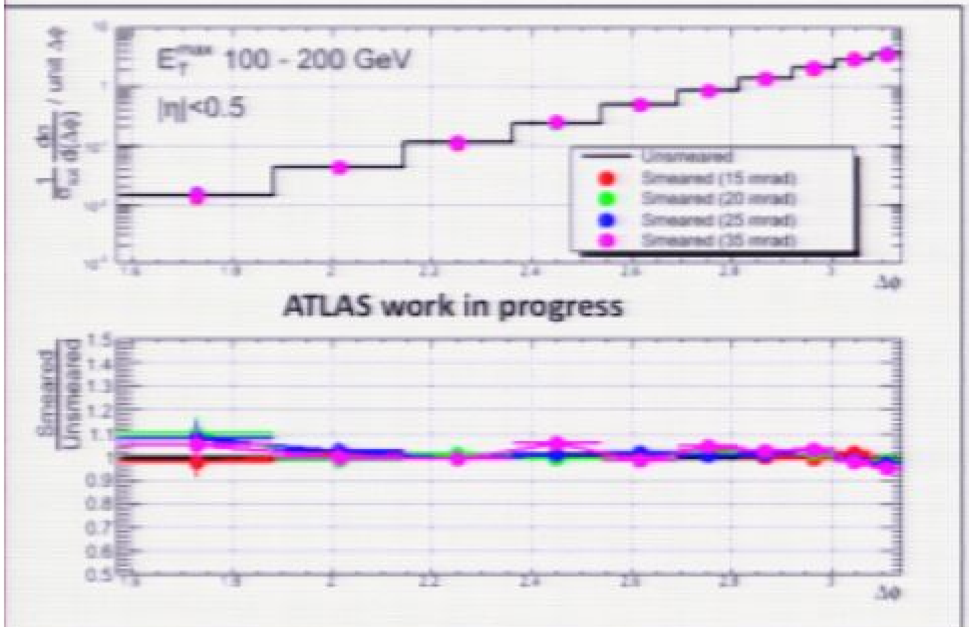
Mean=0

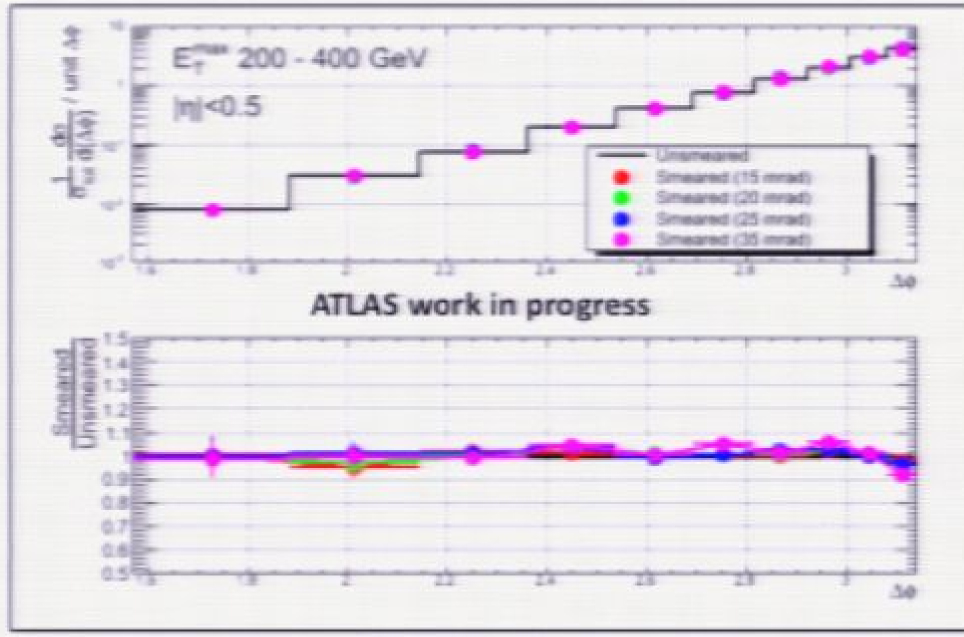
Sigma=**0.015**,0.020,0.025,0.035

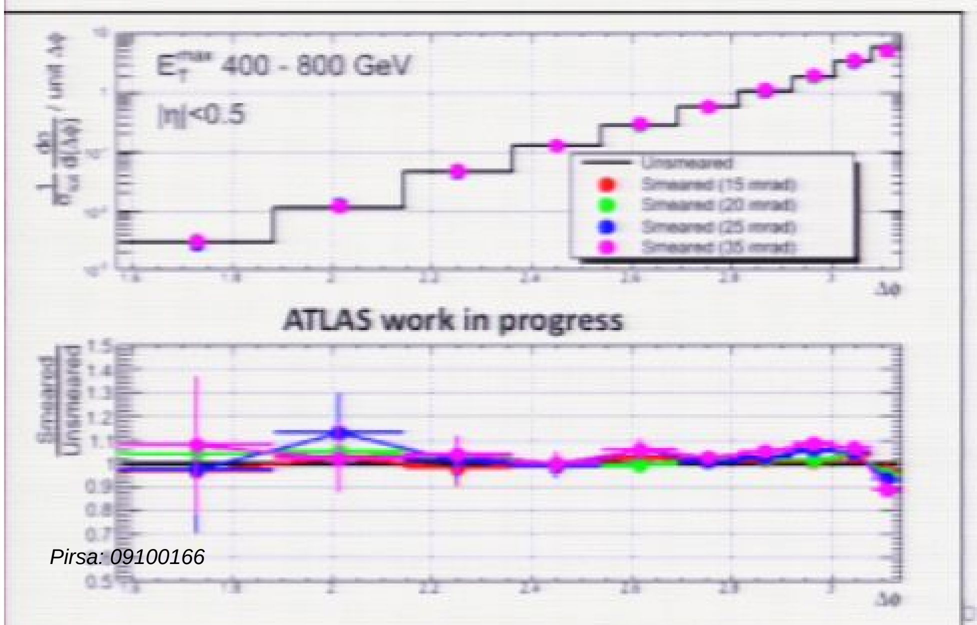
↑

Closest to estimated MC value

ϕ Angular Resolution

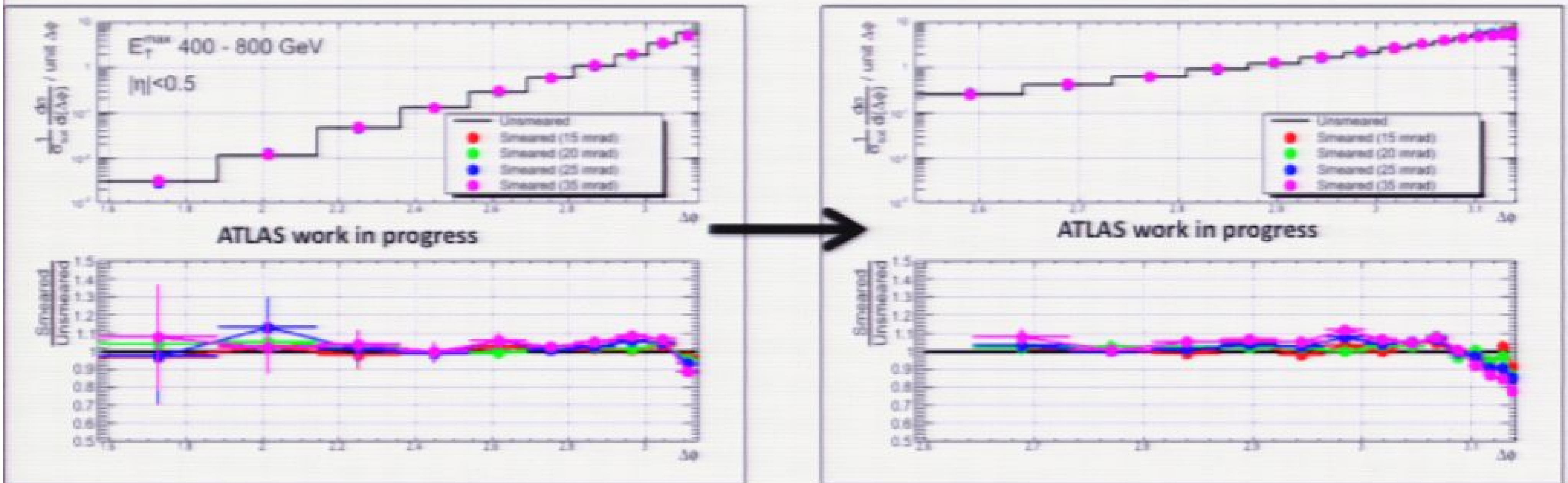






- For most of the distribution we see no systematic shift due to the smearing which would require correction
- At high Δϕ (narrow bin width) there may be some effect (see next slide)

ϕ Angular Resolution



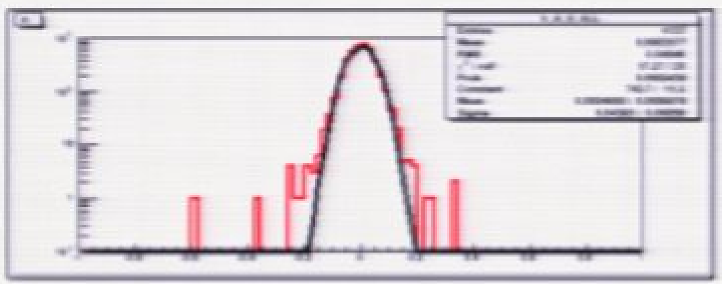
- By doubling the number of bins we see the effect of the finite resolution on narrow bins
- If we require fine binning this effect may need to be corrected
- This type of binning will probably not be necessary

Jet E_T Resolution

Jet Et resolution can be estimated from data using dijet events. Construct variable

$$A \equiv \frac{E_T^1 - E_T^2}{E_T^1 + E_T^2}$$

Histogram A in different Et bins.



It can be shown that the single jet Et resolution can be estimated by

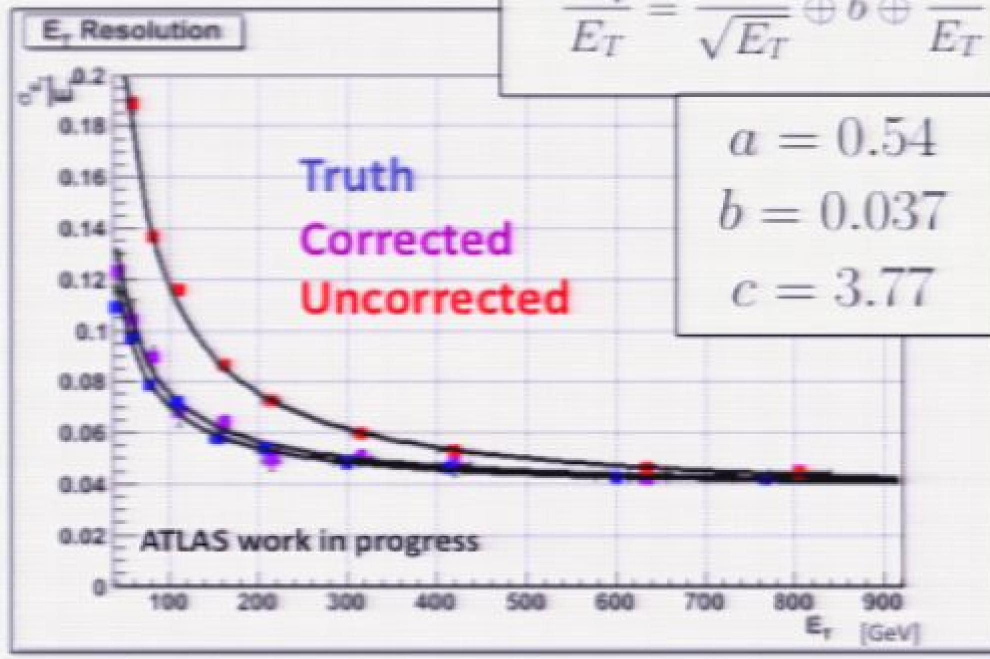
$$\frac{\sigma_{E_T}}{E_T} = \sqrt{2}\sigma_A$$

$$\frac{\sigma_{E_T}}{E_T} = \frac{a}{\sqrt{E_T}} \oplus b \oplus \frac{c}{E_T}$$

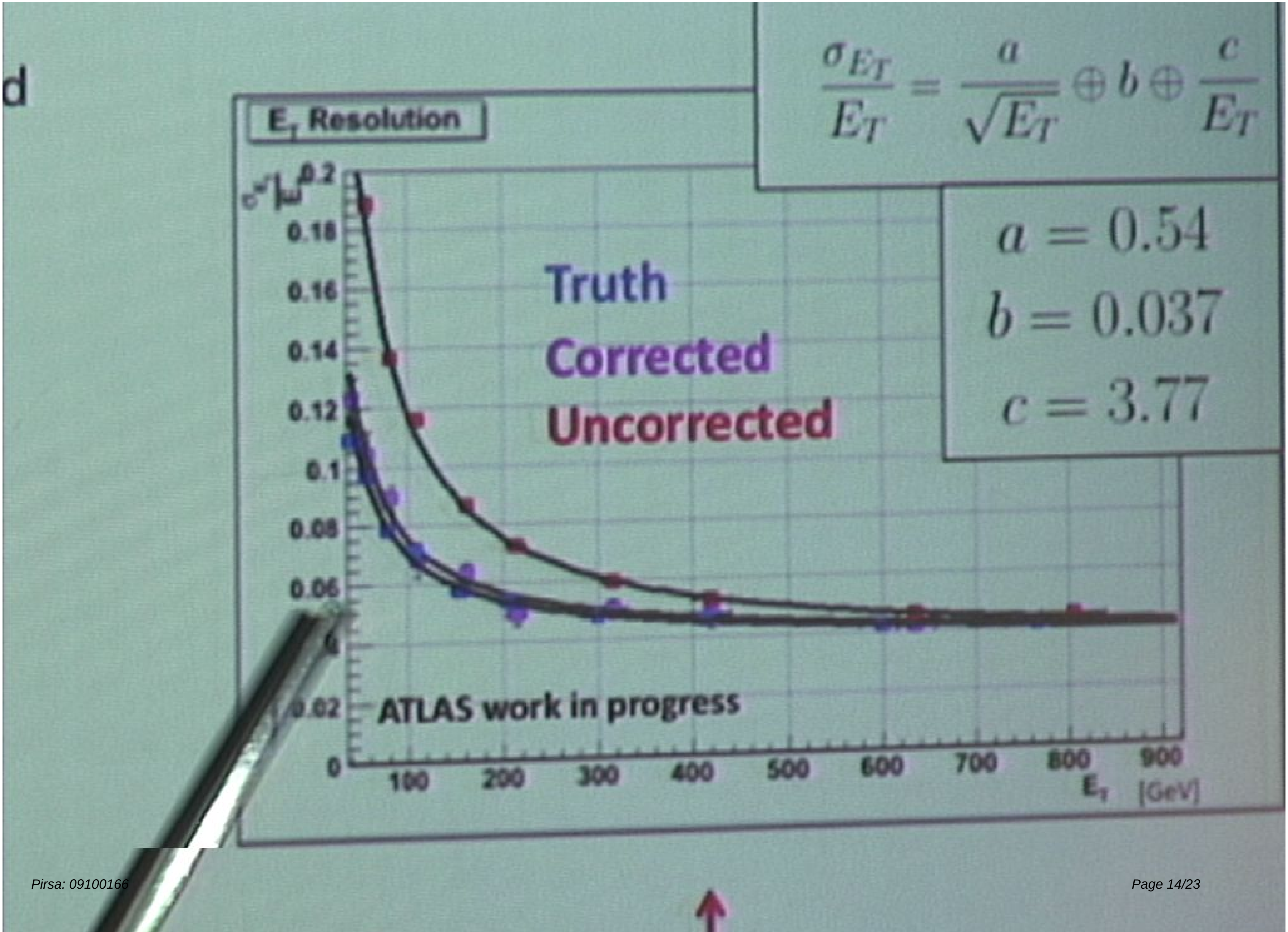
$a = 0.54$

$b = 0.037$

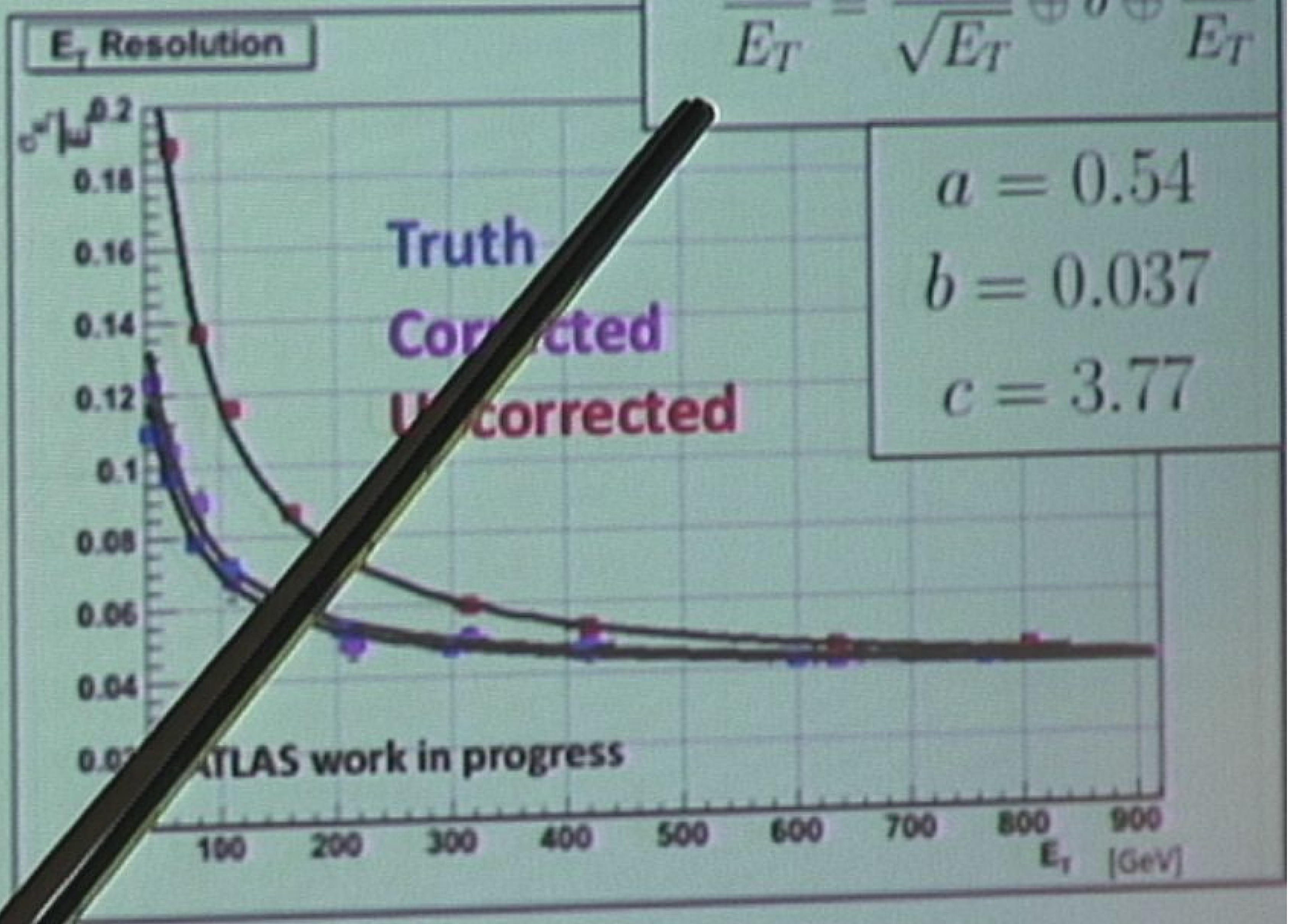
$c = 3.77$



Apply a correction for radiated 3rd jet

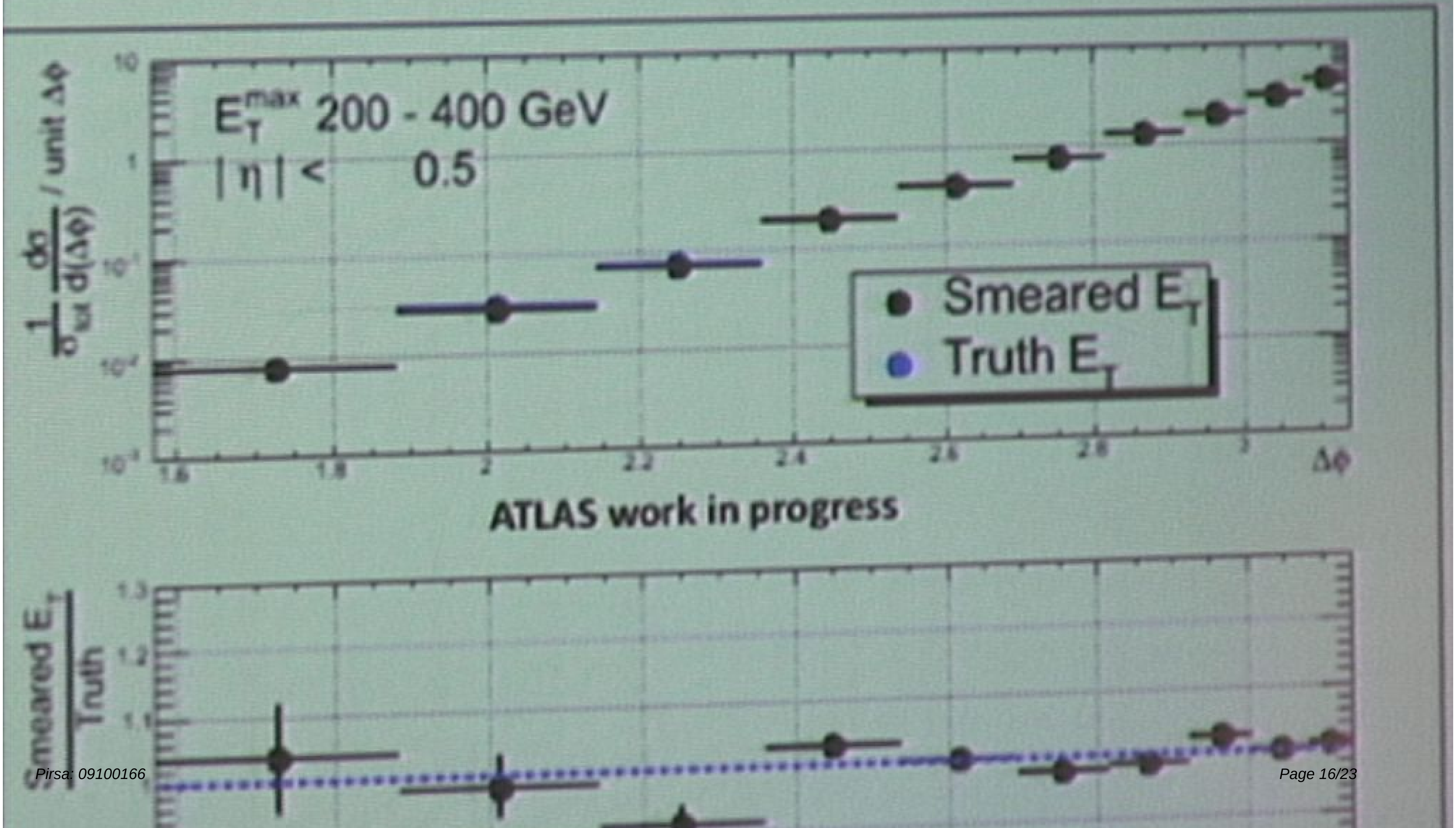

d
E_T Resolution
$$\frac{\sigma_{E_T}}{E_T} = \frac{a}{\sqrt{E_T}} \oplus b \oplus \frac{c}{E_T}$$
$a = 0.54$
$b = 0.037$
$c = 3.77$
Truth
Corrected
Uncorrected
ATLAS work in progress
E_T [GeV]

d



$$\frac{\sigma_{E_T}}{E_T} = \frac{a}{\sqrt{E_T}} \oplus b \oplus \frac{c}{E_T}$$

$$a = 0.54$$
$$b = 0.037$$
$$c = 3.77$$



E_T^max 200 - 400 GeV
|η| < 0.5
Smeared E_T
Truth E_T
Δφ
1.6
1.8
2
2.2
2.4
2.6
2.8
3
ATLAS work in progress
Smeared E_T / Truth
1.3
1.2
1.1

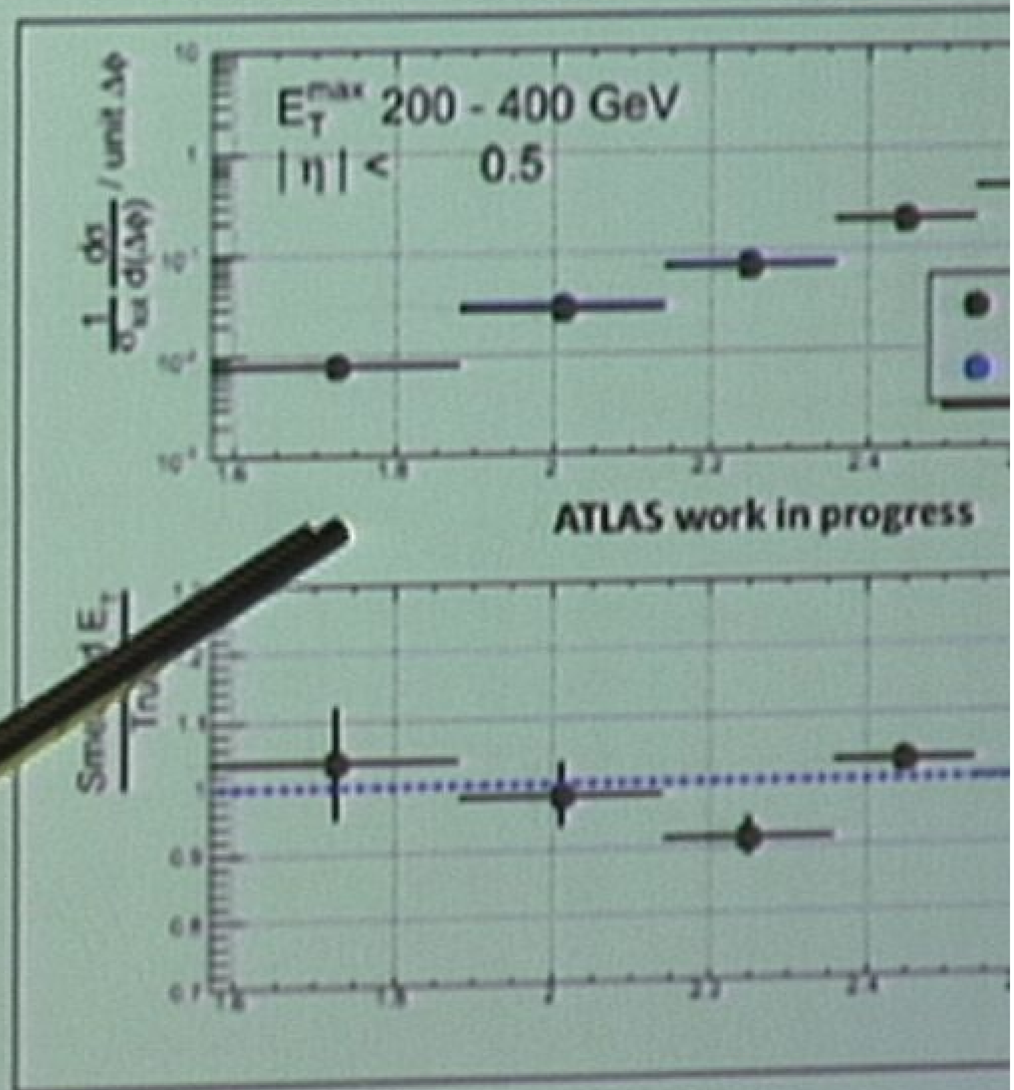
- To isolate effect of Jet Et resolution we smear truth jets according to a Gaussian of width determined by

$$\frac{\sigma_{E_T}}{E_T} = \frac{a}{\sqrt{E_T}} \oplus b \oplus \frac{c}{E_T}$$

$$a = 0.54$$

$$b = 0.037$$

$$c = 3.77$$



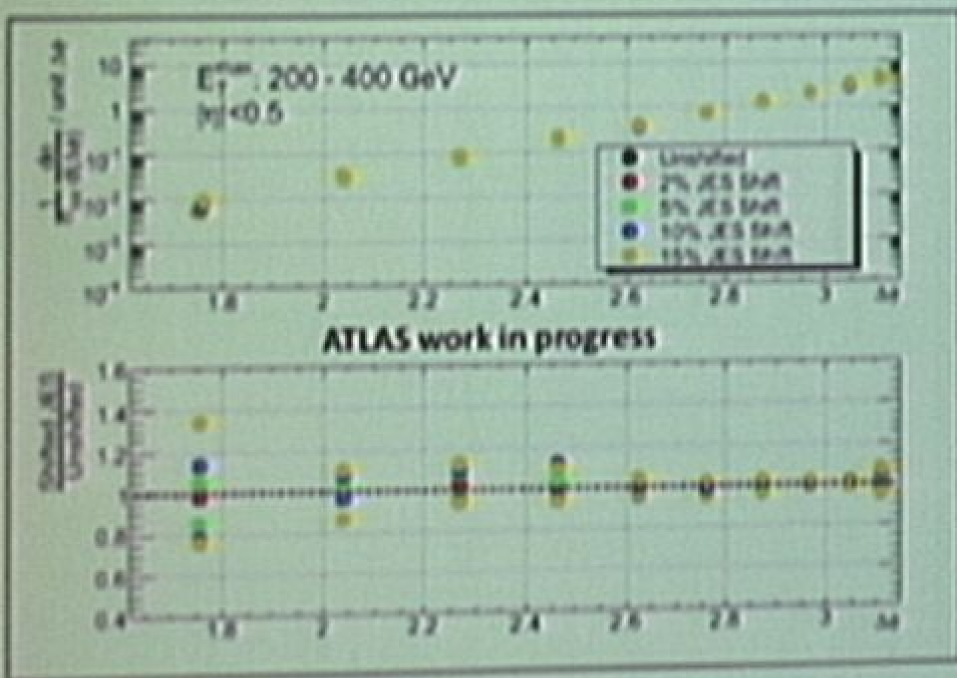
- The eff[...] is <10%

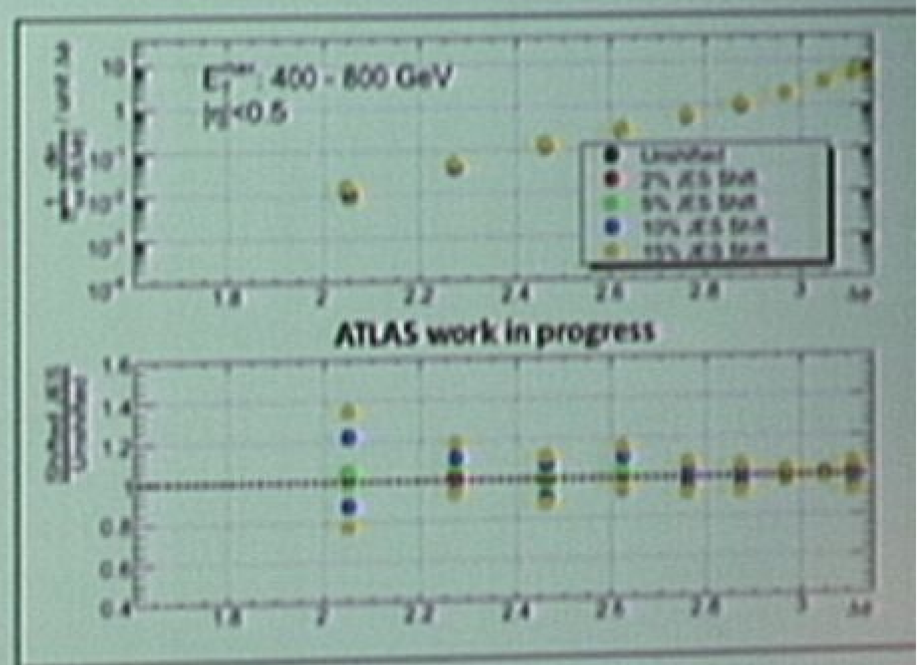
Jet Energy Scale

- **Overall JES shift**
  - Affects only the thresholds
  - Simulate by shifting the thresholds by +/-
    - 2%
    - 5%
    - 10%
    - 15%

    } Next Slide
  - The amount of decorrelation varies with ET, so we expect some effect
- **JES Shift which is function of η**
  - Could have large systematic effect
  - Still need to investigate

Jet Energy Scal





- In medium and high E_T windows the effect is up to 30-40% and low values of $\Delta\phi$
- Low $\Delta\phi$ is region where the the E_T is has largest effect

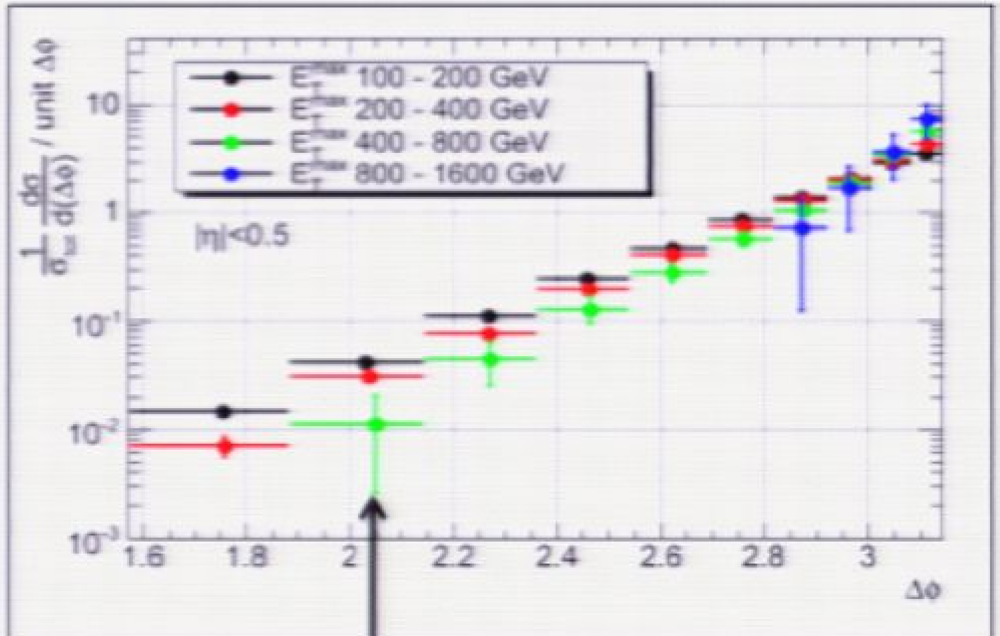
X-position

Steeply falling spectrum requires a calculation of x-position (not just the bin centre)

Weighted mean:

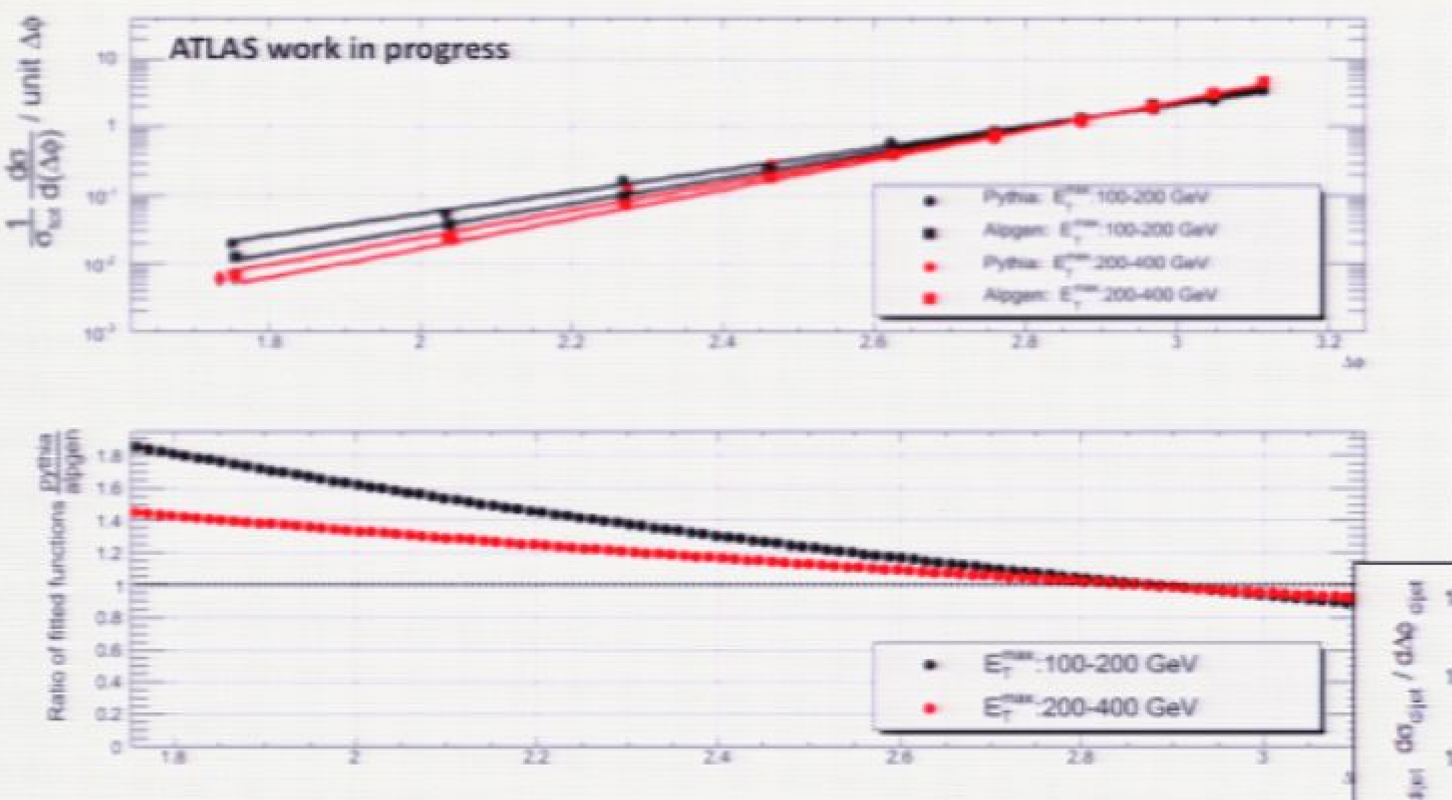
$$< x >= \frac{\sum w_i x_i}{\sum w_i} \ , \ w_i = \frac{\sigma_{dataset}}{N_{dataset}}$$

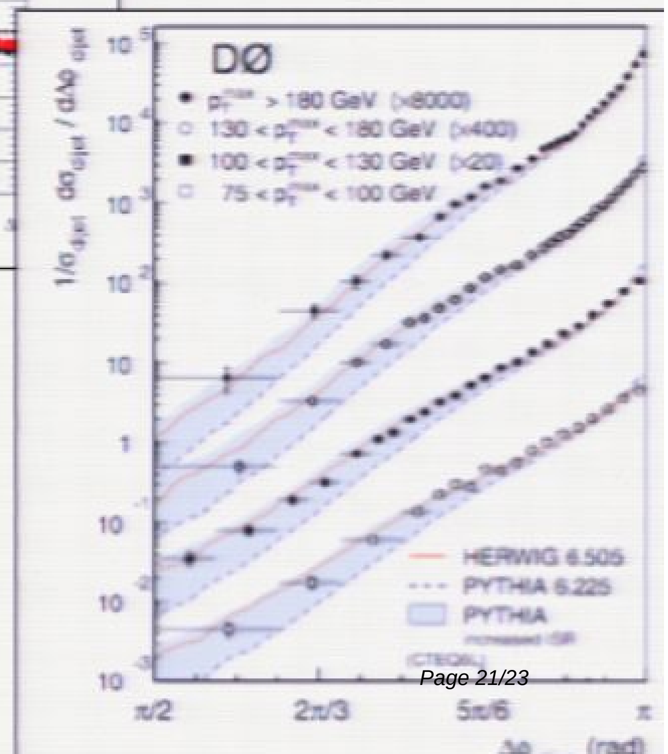
$\sigma_{dataset}$, $N_{dataset}$ are the cross section and number if events from each MC data set.



In some cases the difference is large

Generator Differences





- In order to estimate the difference between pythia and (alpgen + herwig) we fit an exponential to each distribution and take the ratio of the fits
- The difference seems to be substantial in this case
- Other studies have shown even larger discrepancies

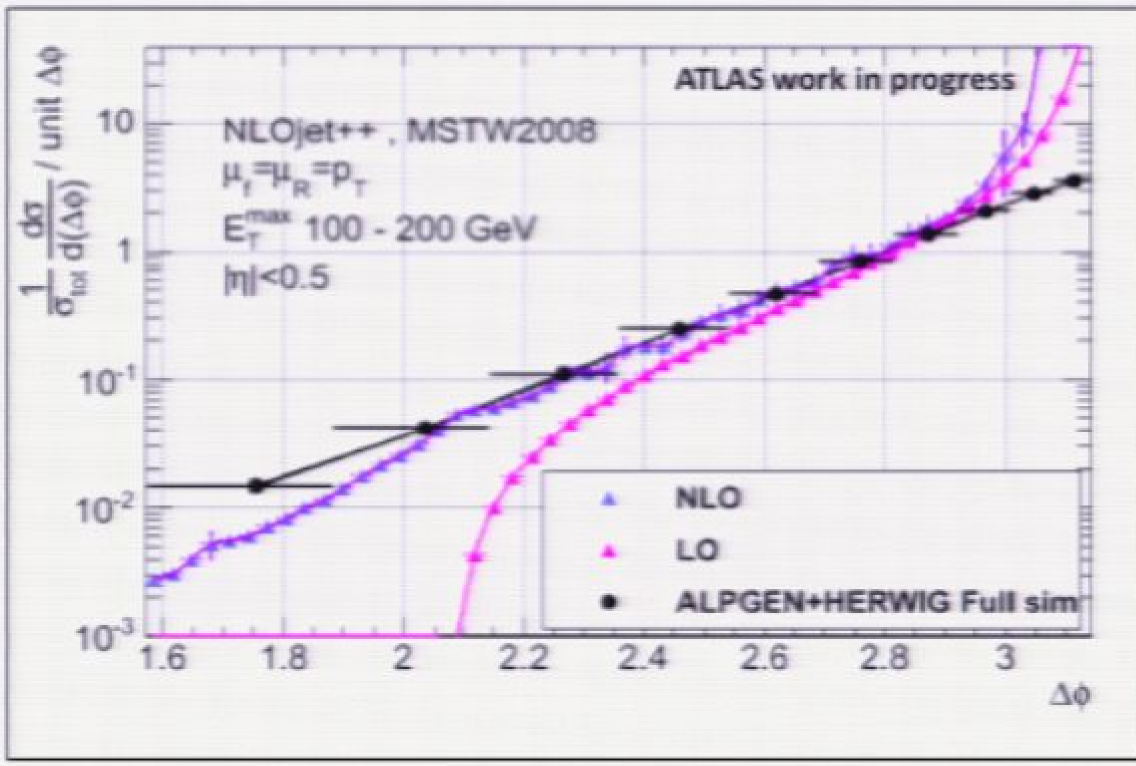
On the way to a theory comparison

NLO

$$\frac{1}{\sigma}\frac{d\sigma}{d(\Delta\phi)} = \frac{(\frac{d\sigma}{d(\Delta\phi)})_{3-jet\ LO} + (\frac{d\sigma}{d(\Delta\phi)})_{3-jet\ NLO}}{\sigma_{2-jet\ LO} + \sigma_{2-jet\ NLO}}$$

LO

$$\frac{1}{\sigma}\frac{d\sigma}{d(\Delta\phi)} = \frac{(\frac{d\sigma}{d(\Delta\phi)})_{3jet\ LO}}{\sigma_{2jet\ LO}}$$



Jets made only with partons. Effect of showering and hadronization is very important. This is just first step.

Conclusions

- The Azimuthal Decorrelation is an observable which should be measurable in very early data
- The |η| range and E_T windows need to be optimized depending on amount and quality of data
- A study of systematic uncertainties showed that at first look systematic uncertainties seem manageable
    1. Reconstruction efficiency (~0%)
    2. Angular resolution (~few %)
    3. Jet Resolution (<5-10%)
    4. Global JES (~30-40% , in worst regions)
- Next steps
    - Modeling JES uncertainty as a function of η
    - Investigating different η regions
    - Obtain accurate distributions from different generators
    - Obtain NLO prediction at the particle jet level