Fluctuations and asymmetric jet events

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CERN, Princeton & LPTHE/CNRS (Paris)
or, according to Indico, "unknown"

based on arXiv:1101.2878
with Matteo Cacciari & Gregory Soyez

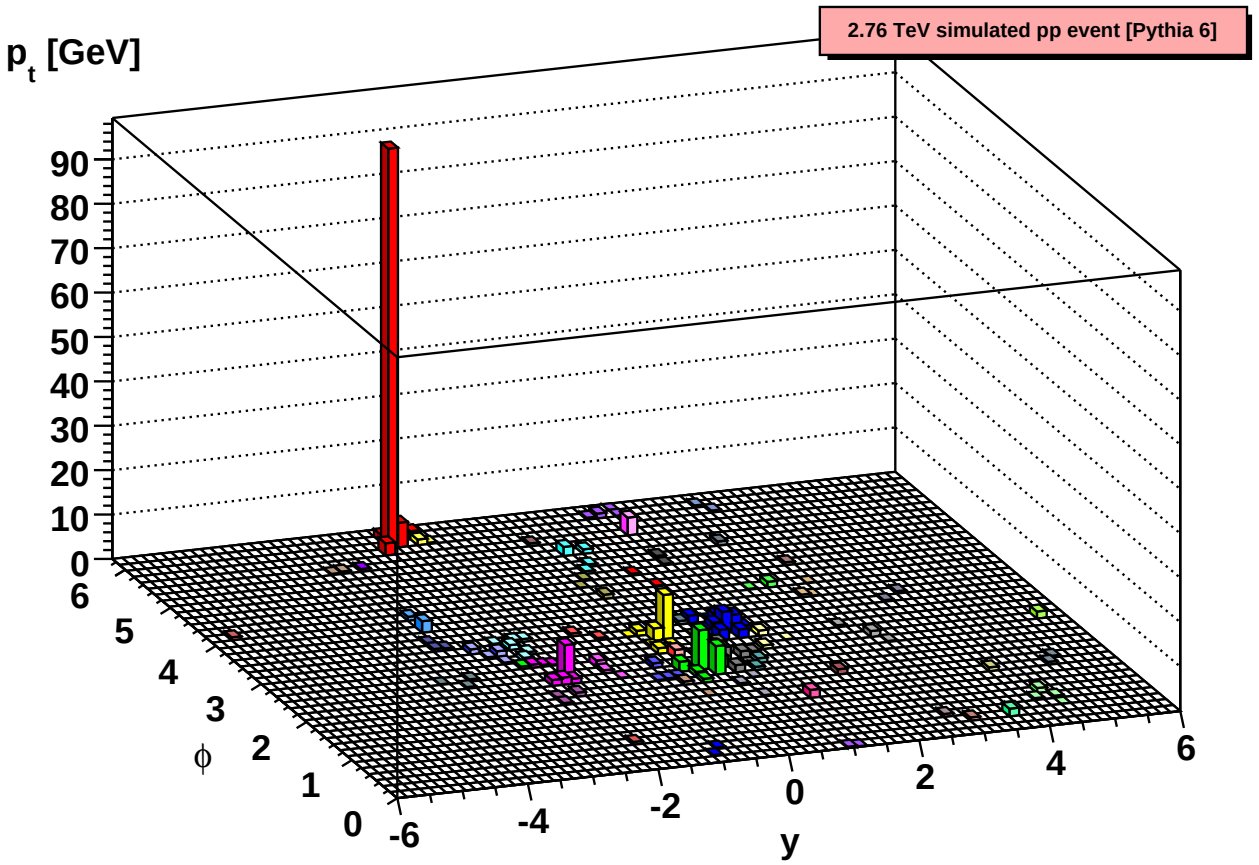
HI at the LHC, a first assessment
LPCC LHC Physics day, 4 March 2011

This talk is somewhere between:

A devil's advocate position

And genuine concern about interpretation of the data

A simulated pp event (Pythia)



Visibly asymmetric jet events occur even in pp collisions.

In discussing full jet quenching, the whole issue is to *quantify* how much more asymmetric they are.

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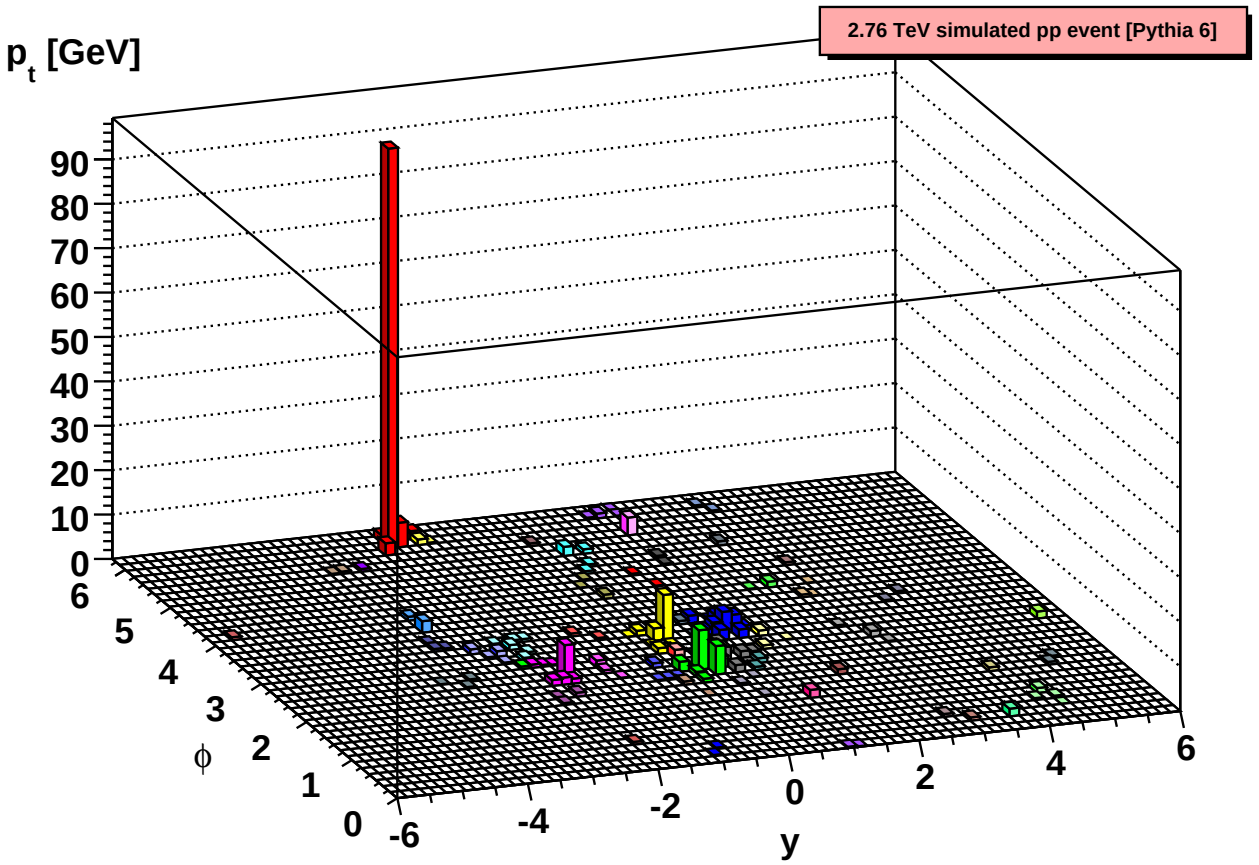

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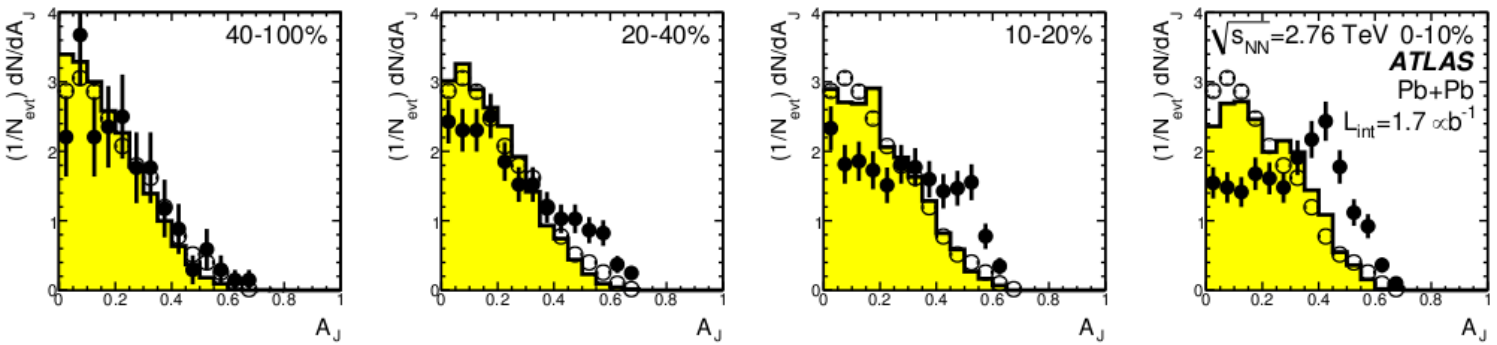
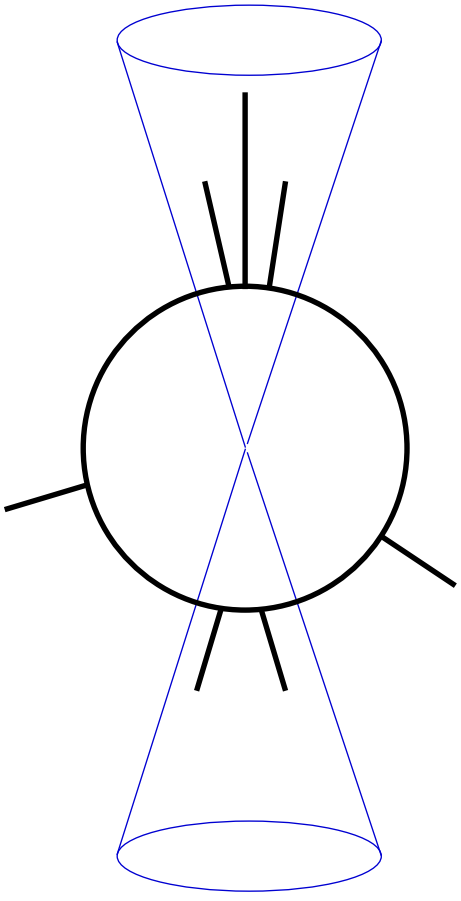


Quenching v. fluctuations

High pt event



QUENCHED JET
THAT HAS LOST ENERGY

Quenching v. fluctuations

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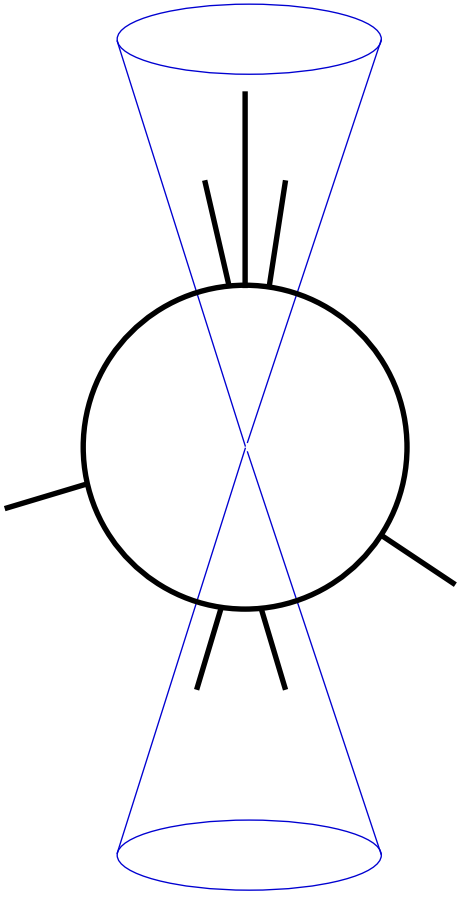

QUENCHED JET
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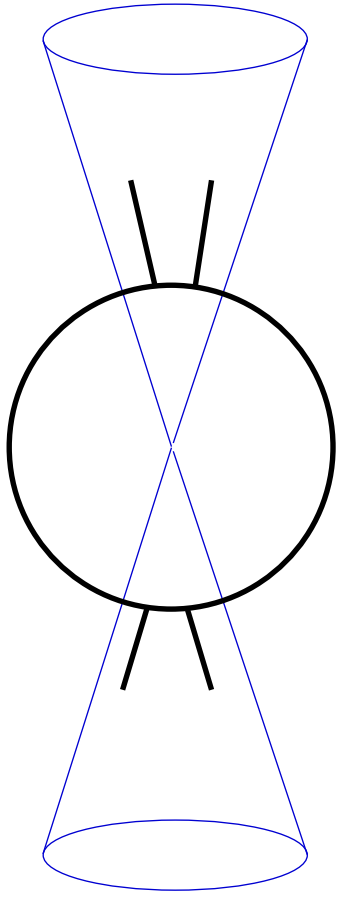
Moderate pt event



NO QUENCHING,

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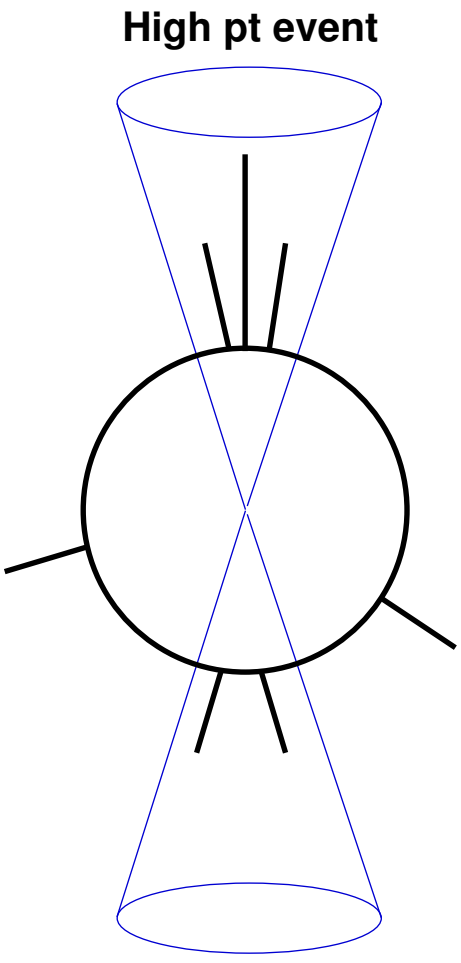

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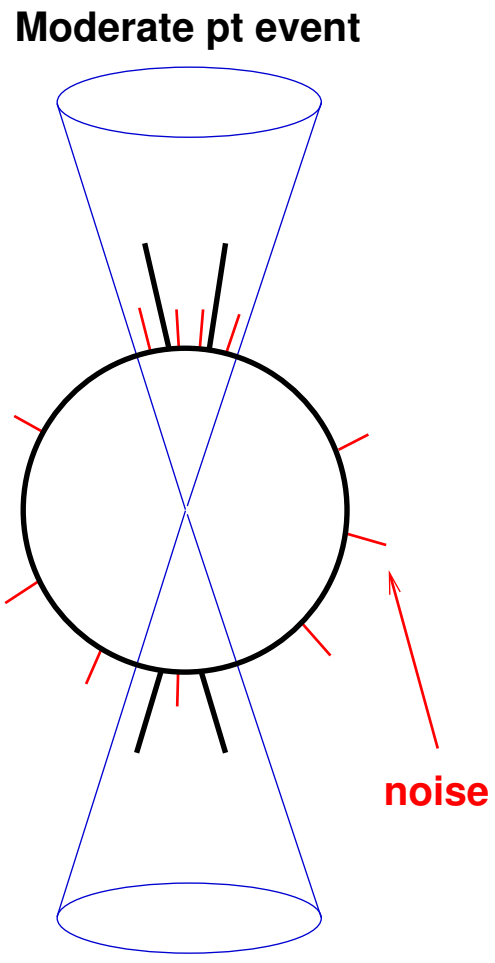
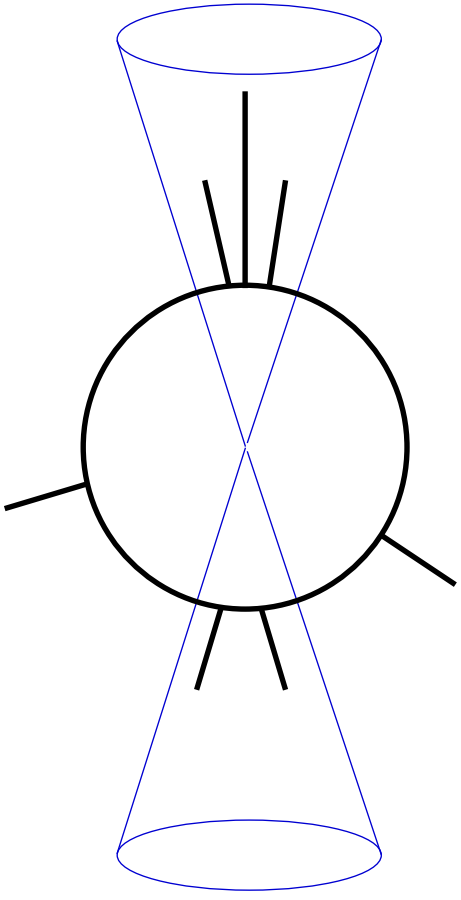


NO QUENCHING,

At LHC, each jet accompanied by $\mathcal{O}\,(100\ \text{GeV})$ of noise.

Quenching v. fluctuations

High pt event



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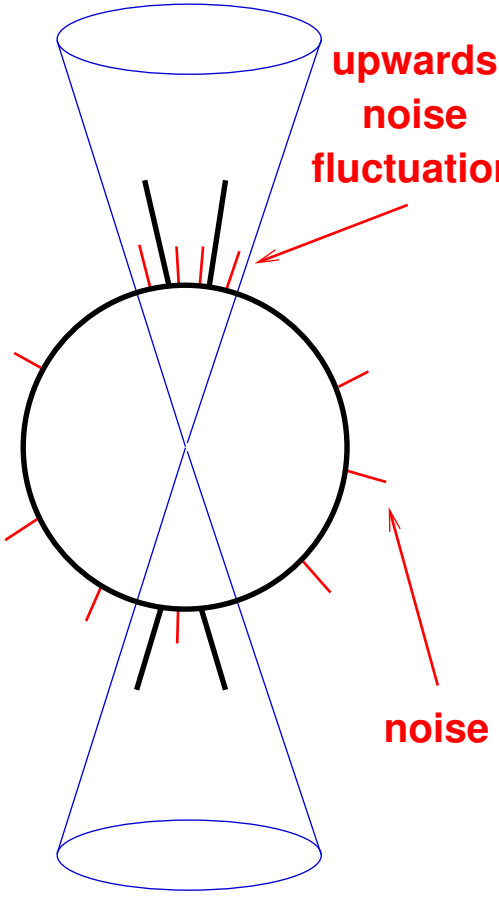

NO QUENCHING,
NOISE–INDUCED
ASYMMETRY

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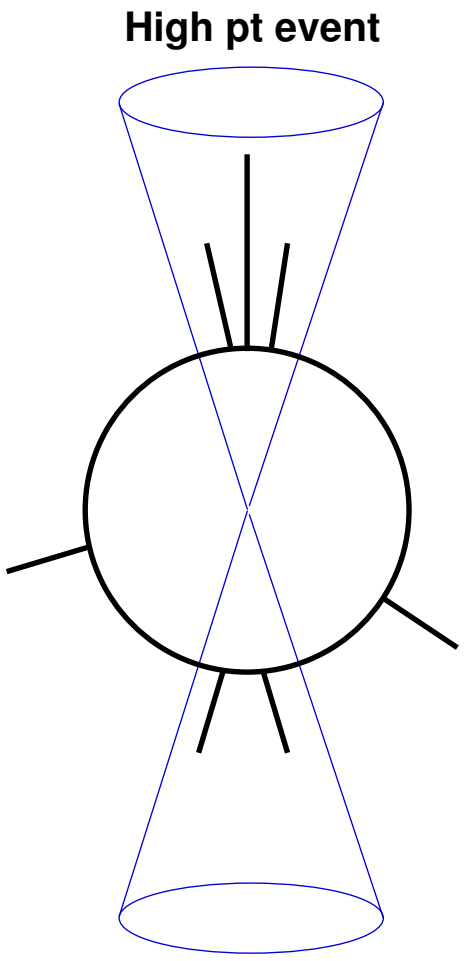
Quenching v. fluctuations



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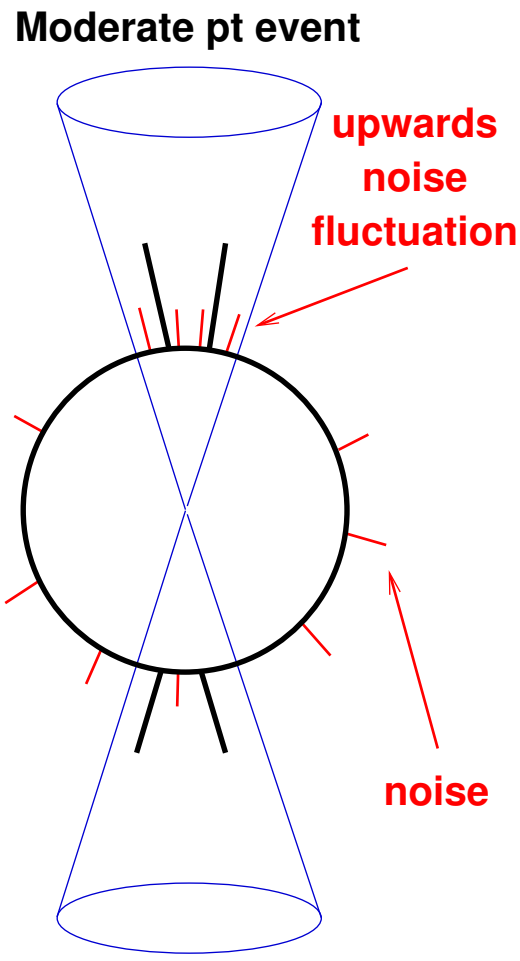

NO QUENCHING,
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ASYMMETRY

At LHC, each jet accompanied by $\mathcal{O}(100\ \text{GeV})$ of noise.

Large, $\mathcal{O}(50\ \text{GeV})$, fluctuations rare.

But moderate-p_t events much more common than high-p_t

Asym. may mix quenching & flucts; quantify latter to learn about former

Two (theorist's) ways of estimating impact of fluctuations

"Toy model"

- Take Pythia *pp* events
- Smear p_t of each jet with a random number with Gaussian distribution

  Accounts for residual noise left over after subtracting background

  Key question is standard deviation of the Gaussian $= \sigma_{\text{jet}}$

  No numbers quoted by experiments. Reasonable values in $10 - 20$ GeV range?

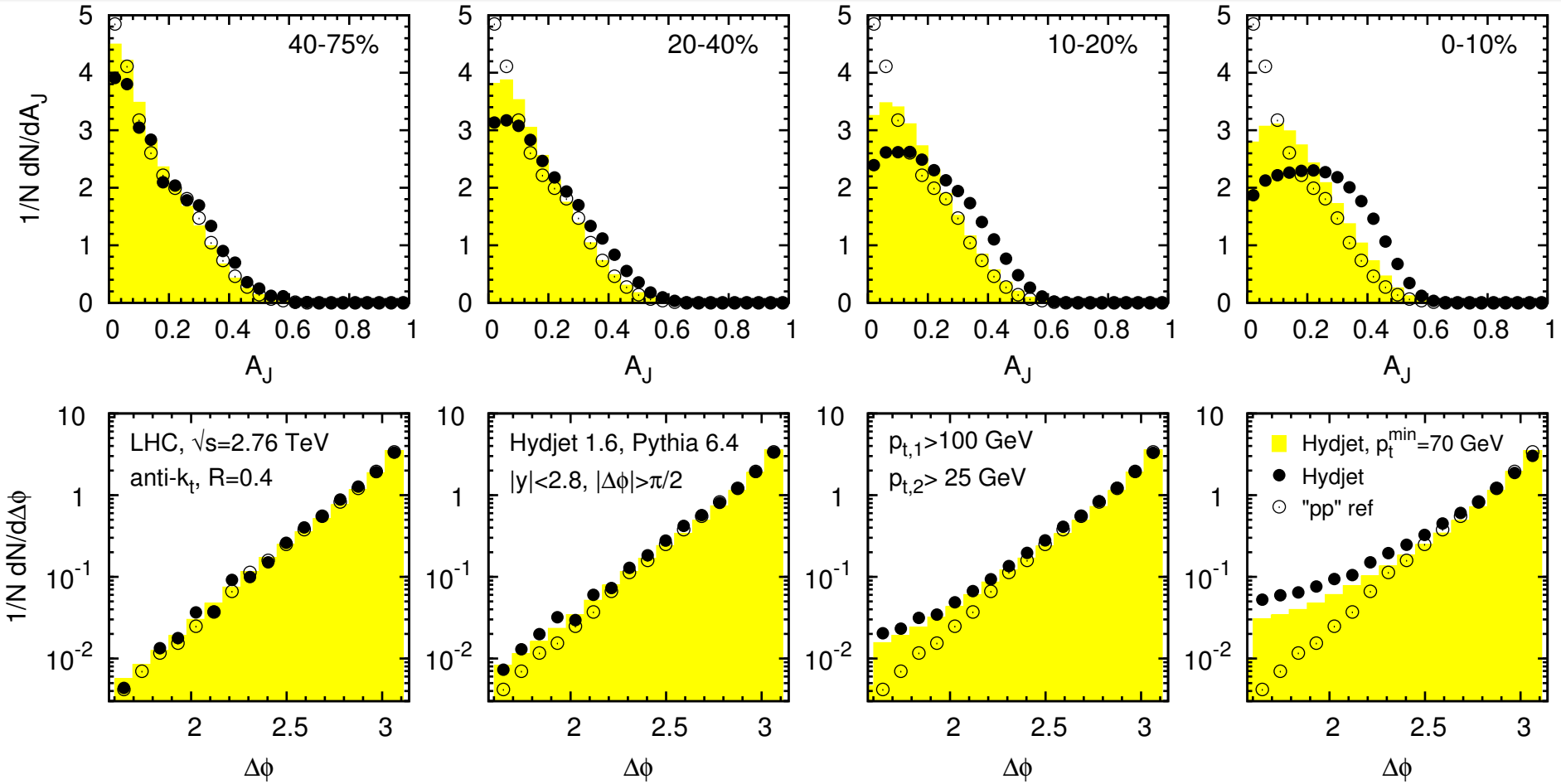
"Simulation"

- Embed Pythia events in Hydjet

  v1.6; quenching turned off; tune that for $0 - 10\%$ centrality gives 210 GeV per unit area ($|\eta| < 2.8$), and $N_{ch} = 1400$ for $|\eta| < 0.5$
- Run a background subtraction procedure similar to ATLAS's

  We used the FastJet area/median procedure

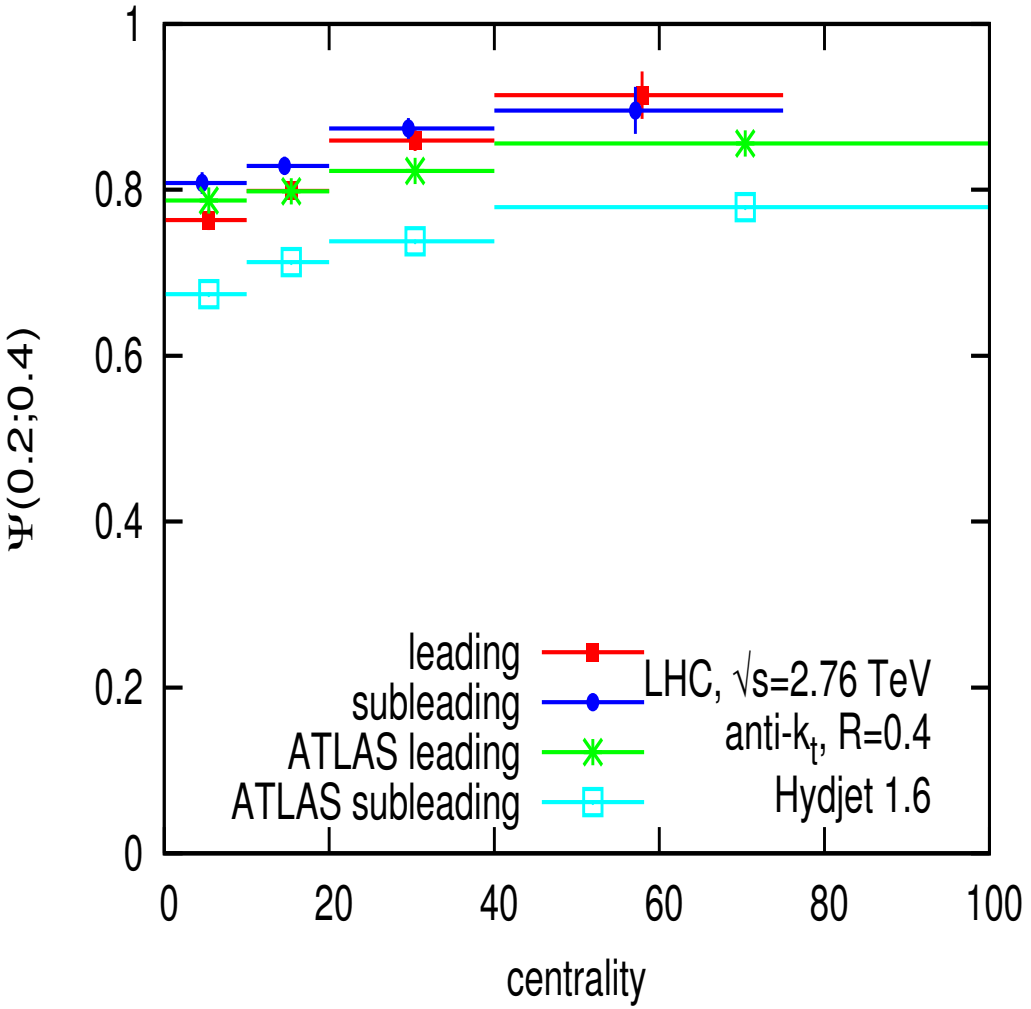
Results from Hydjet embedding (ATLAS cuts)



- Effect of fluctuations appears significant
- It is crucial to include sufficiently low-p_t Pythia events

For the fluctuations present in Hydjet, ATLAS choice of generation cut, 70 GeV, fails to reveal the true impact of fluctuations

ATLAS Control plots



ATLAS has numerous control plots, e.g. $\langle\psi(0.2;0.4)\rangle$ fraction of energy inside core of size 0.2.

Hydjet not fully consistent with ATLAS data; agreement is best for most central events.

Our detector sim. is crude

Centrality dependence (leading jet) weaker in data than in Hydjet.

From this and other control plots: there is probably some quenching, but quantitative use of data is not straightforward

Reliable estimation of fluctuations?

Use of any Monte Carlo model for estimating of fluctuations is potentially risky, unless all aspects of its simulation of background noise are finely characterised.

One alternative (used by STAR, CMS) is embedding of Pythia (or even pp) events into real HI data.

This is probably the most transparent way of estimating impact of fluctuations.

Modulo non-linearities in detector effects

Must not forget to embed spectrum of pp events down to low p_t

Noise removal? Biasing the jets?

CMS embedding of jets into HI events shows only small effect from fluctuations. Does this mean everything is OK? Including for ATLAS?

It's not clear: CMS subtraction of HI background includes a noise-suppression algorithm, which subtracts average + 1 standard-deviation fluctuations from each tower:

$$p_{t,\text{tower}}^{(sub)} = p_{t,\text{tower}} - \langle p_{t,\text{tower}} \rangle_{\text{non-jet towers}} - \sigma_{\text{towers}}$$

Negative towers are then discarded

This roughly **halves the fluctuations.**

halving fluct. $\simeq 90\%$ reduction in their impact

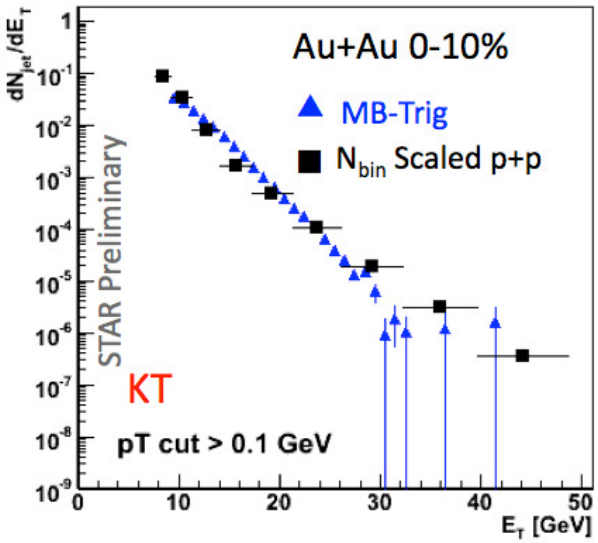
But it is fine tuned to give **overall zero bias for vacuum QCD jets:**

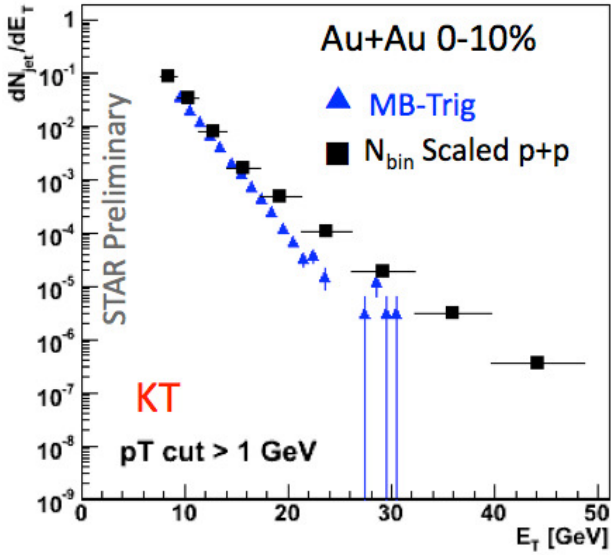
$$p_{t,jet} \simeq p_{t,jet}^{(true)} - (f_{\text{raction of occupied towers in QCD jet}} - 0.08)\sigma_{\text{tower}} n_{\text{tower}}$$

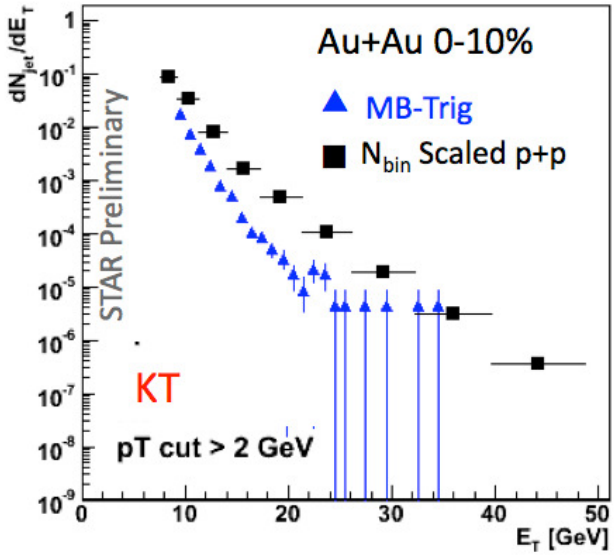
$\sigma_{\text{towers}} n_{\text{tower}} \sim 50 - 100$ GeV; f happens to be ~ 0.1 for QCD jets

But if different for jets in HI $\rightarrow$ **large biases** in reconstruction

STAR jet results showing impact of p_t cut on particles







We believe that HI jets $\neq$ vacuum QCD jets

For HI, in contrast to vacuum QCD, anything that removes $1-2$ GeV particles from the jets (detector limitations; noise suppression) significantly affects the jets

Conclusions

Residual fluctuations after subtracting 100 GeV of noise from a jet are inevitable. Their impact amplified by steeply falling jet spectrum.

What fraction of the "quenching" is actually fluctuations, if any? We had a hard time coming to a clear conclusion.

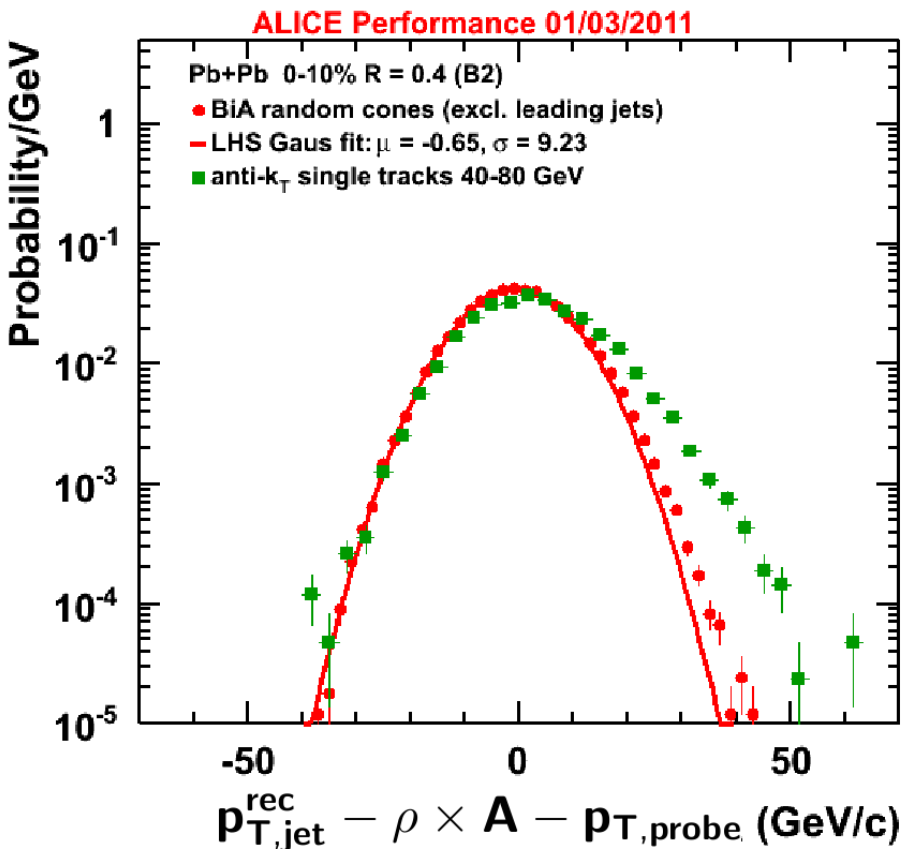
Quantitative use of jet asymmetries will benefit from more detailed evaluation of fluctuations' impact (including systematics)
Ideally their contribution should be unfolded

Noise-suppression techniques also introduce potentially large biases depending on how HI jets differ from vacuum QCD jets

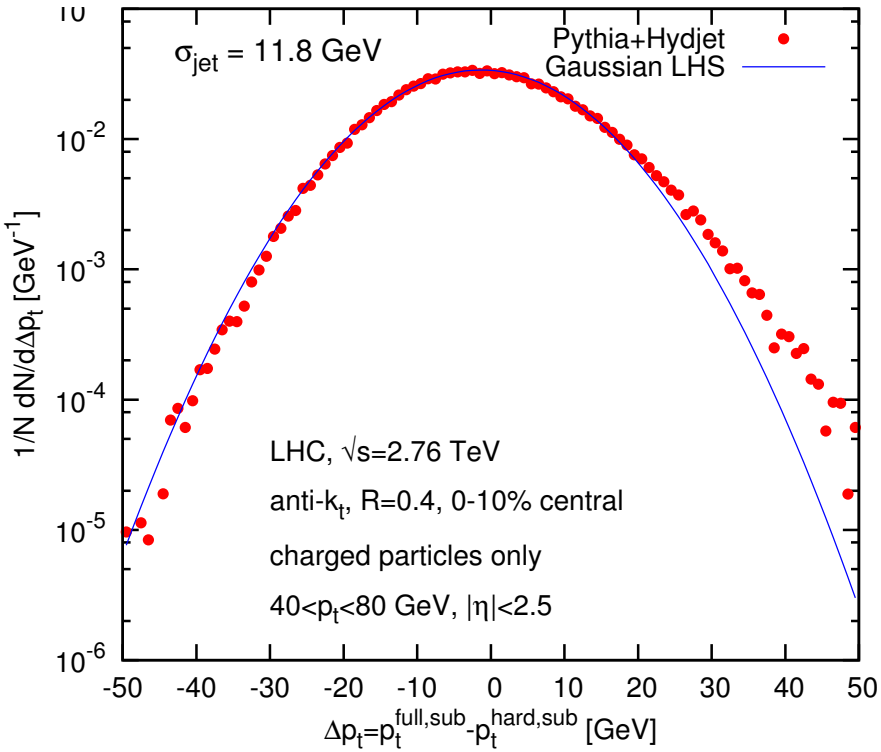
EXTRAS

Stop press. Charged-particle σ_{jet} ALICE v. Hydjet

ALICE: $\sigma_{\text{jet}}^{\text{chg.}} = 9.3$ GeV



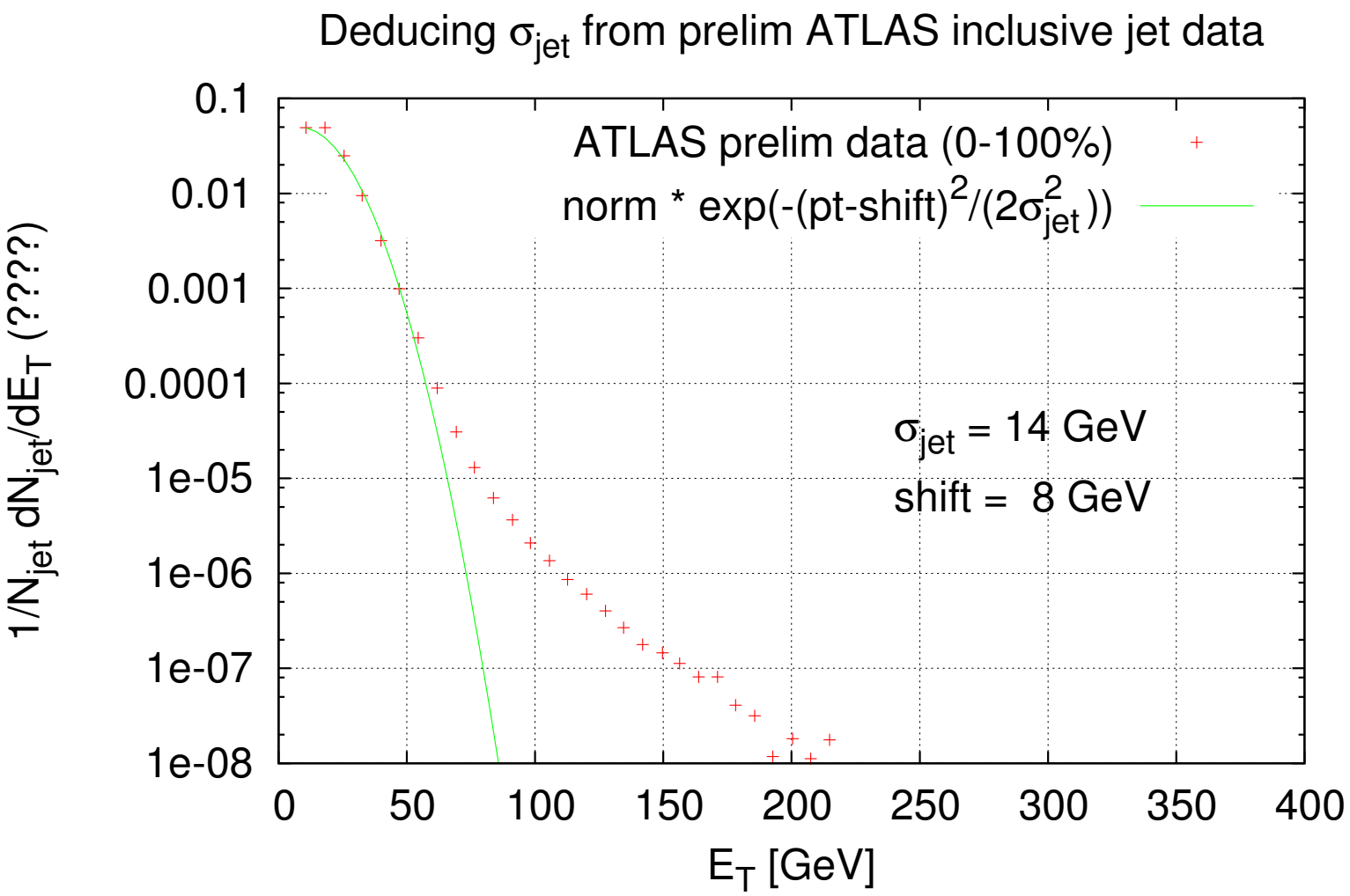
Hydjet: $\sigma_{\text{jet}}^{\text{chg.}} = 11.8$ GeV



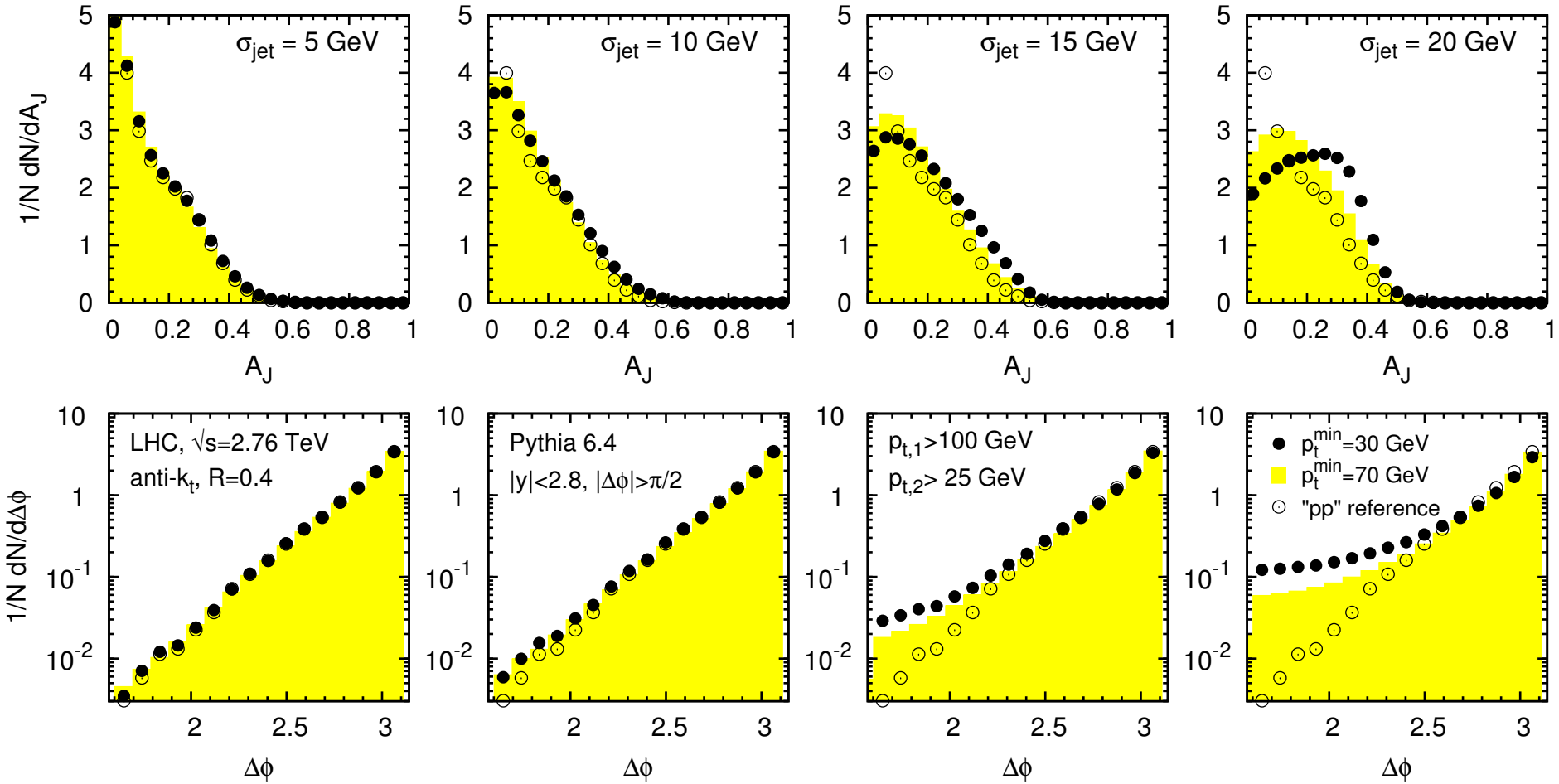
(our unquenched tune of) Hydjet has fluctuations that are 25% larger than data — maybe not too unexpected

Thanks to Gregory for producing plot in the few hours since ALICE showed their results

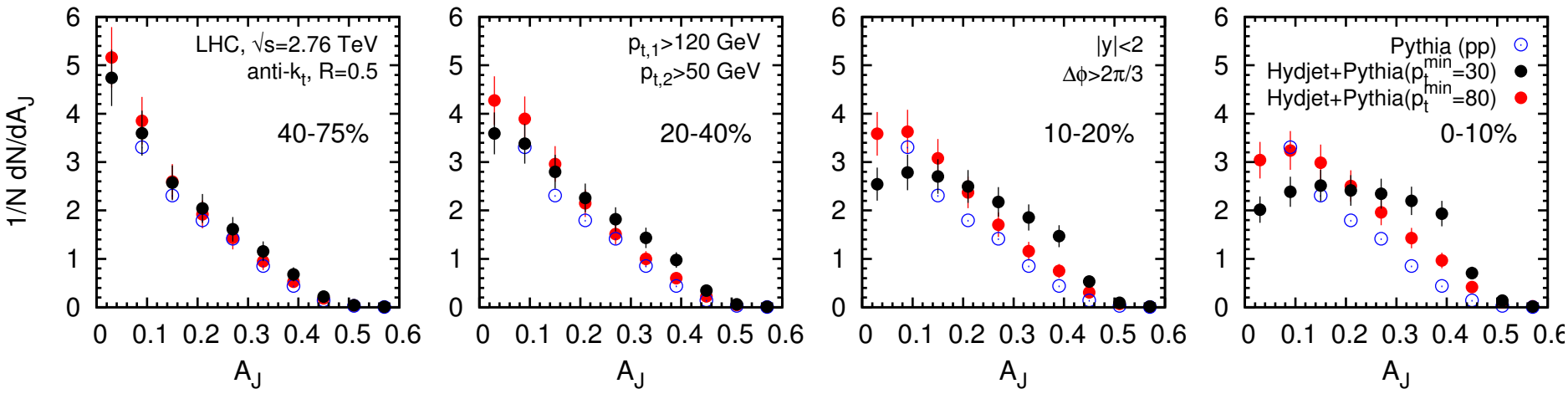
How large are the fluctuations?



Toy model smearing of jet p_t's



CMS cuts; Hydjet (no detector sim.; no noise-suppression)



Spectrum of fluctuations on reconstructed jet p_t (STAR)