New ideas to study radiation between jets and rapidity gaps

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Looking into the gap

Rapidity gap events have been observed already at Hera and the Tevatron

Initial- and final-state radiation plus the underlying event (not to talk about pileup!) can soil the gap

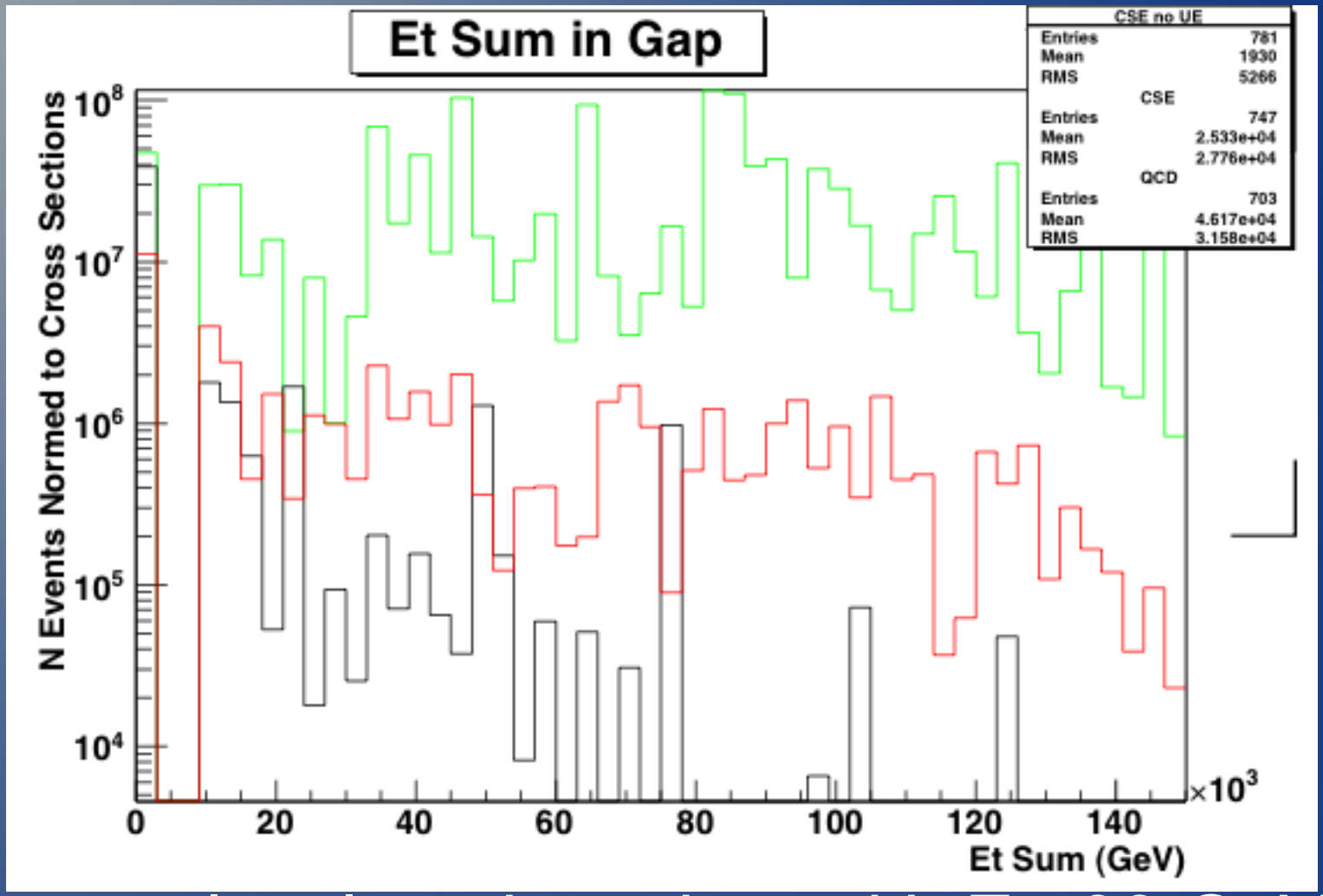
A “clean” gap only observed in a few % of the events (soft survival fraction)

Looking at the tail of a distribution, with small statistics and large model uncertainties.

Not useful to look for VBF-induced rare events (like Higgs) due to low efficiency

There is more colour singlet than just a clean gap!

Gap Et sum at the LHC



Generator-level study on jets with Et>30 GeV $\Delta\eta$>4

Colour singlet, no UE

Colour octet

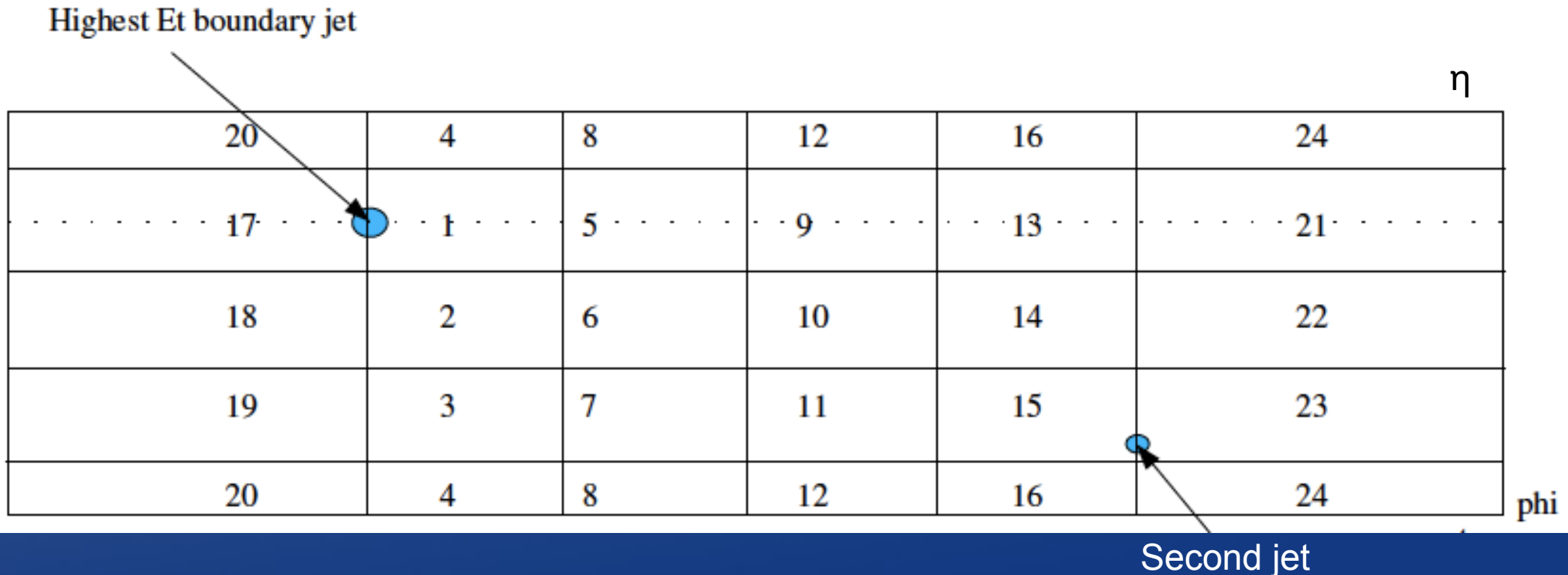
Colour singlet, UE (Jimmy)

Looking into the gap: the gap grid

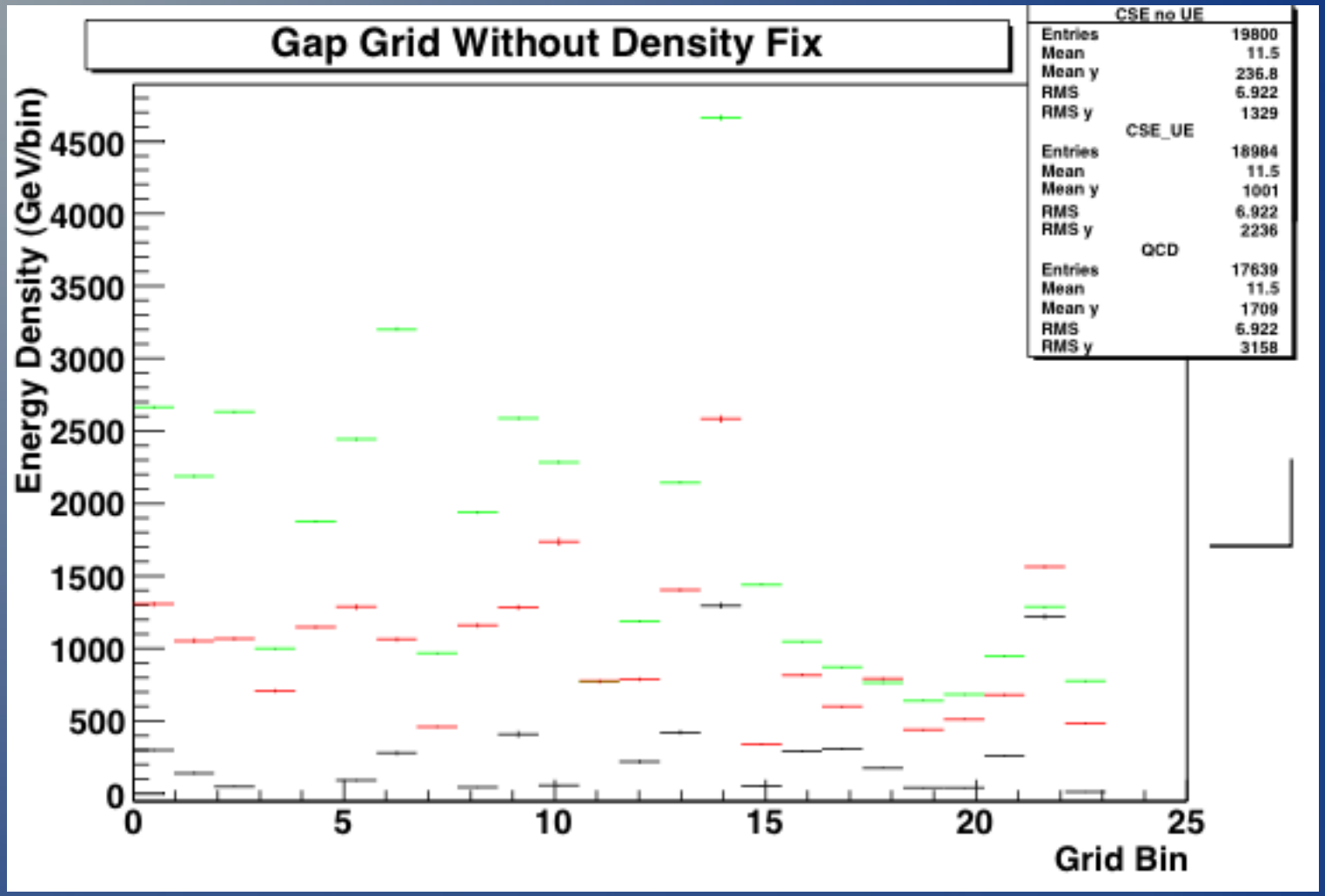
Split gap in equal 4x4 regions in (η,ϕ) of size $(\Delta\eta/4, \pi/2)$ plus 4+4 regions between main jets and beam.

Align ϕ=0 with leading jet, then align other regions according to radiation density (transv. min/max)

Currently including boundary jets, but we checked exclusion as well



Radiation density in various gap regions



Colour singlet, no UE

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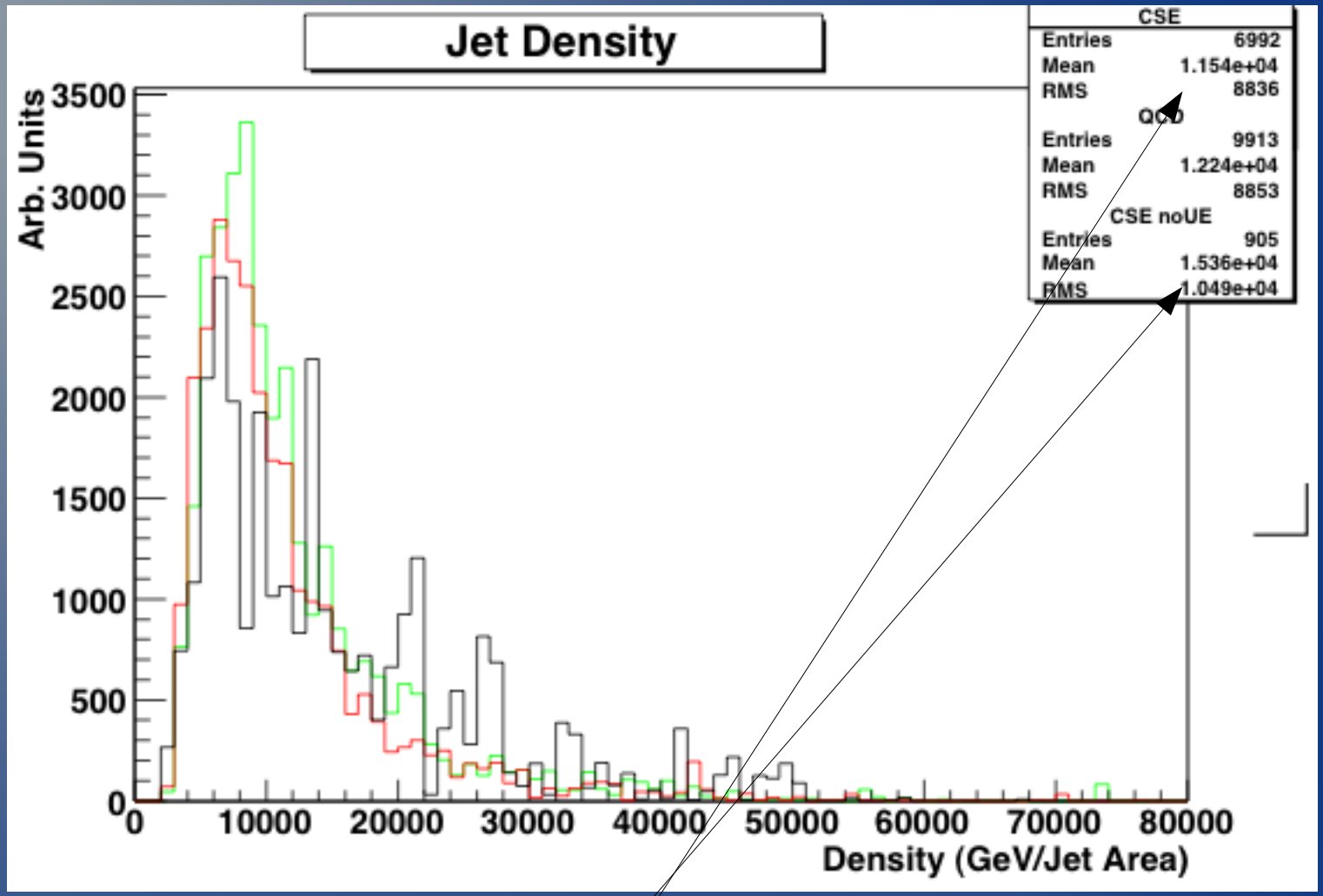
UE corrections: the density method

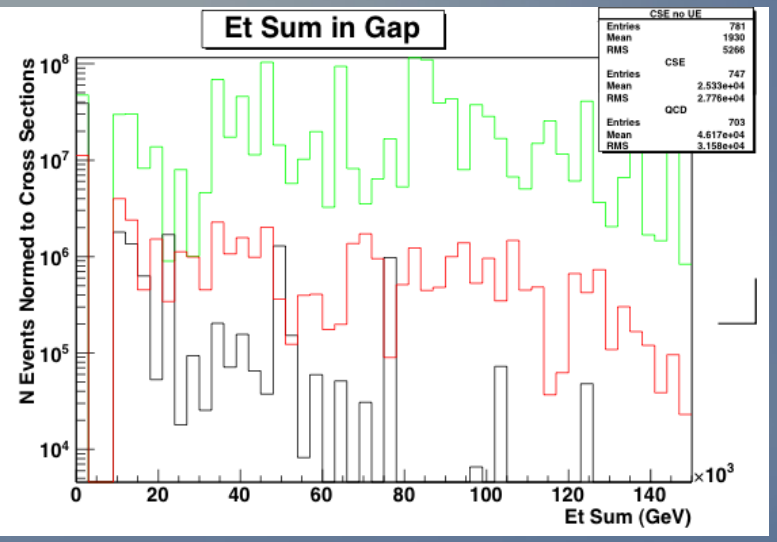


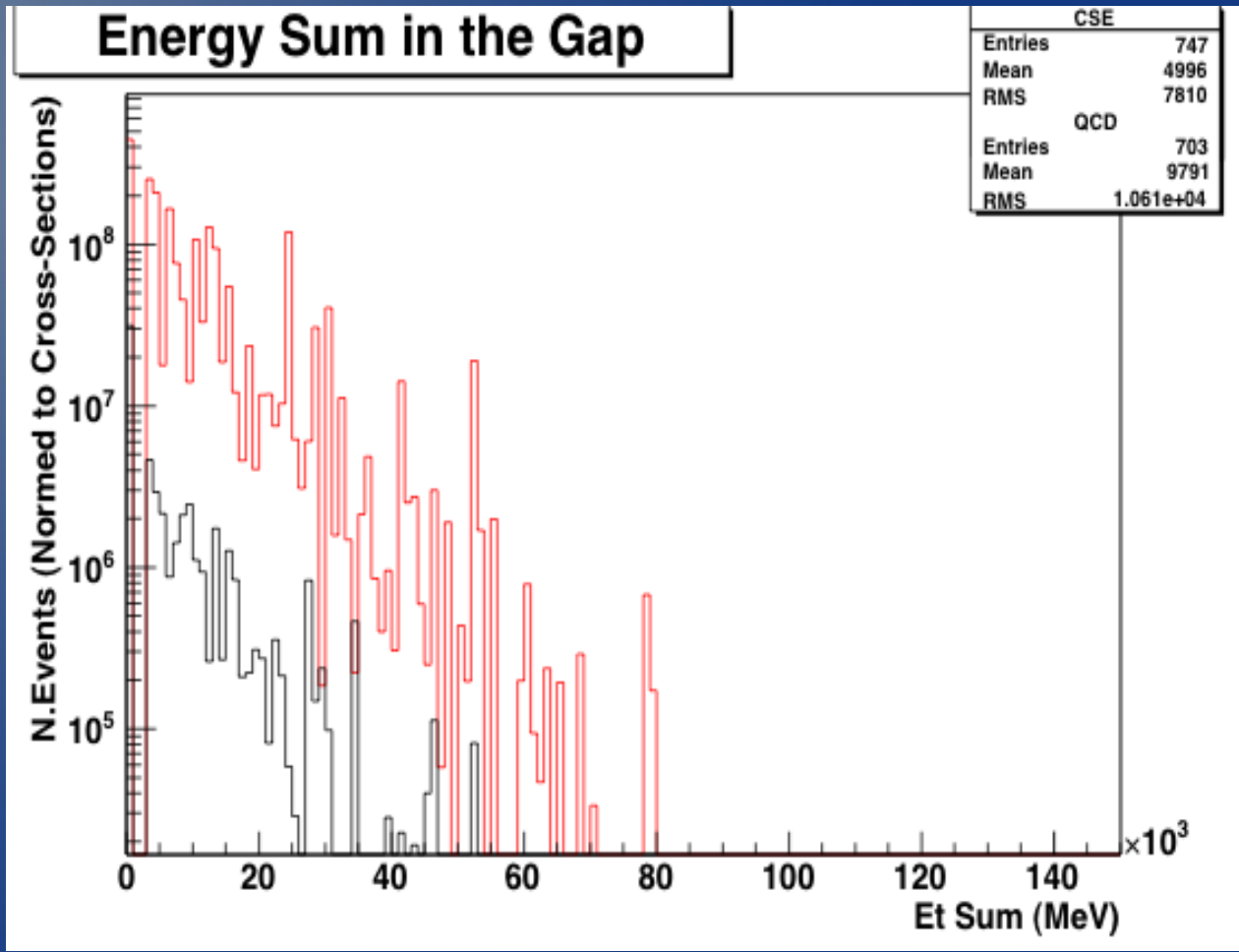
On average, jets from UE have smaller density than those from hard scattering.

Fluctuations make event-by-event UE determination UE mandatory.

Idea (Cacciari and Salam): take the average jet density below a given threshold for each event, and subtract this density from all jets

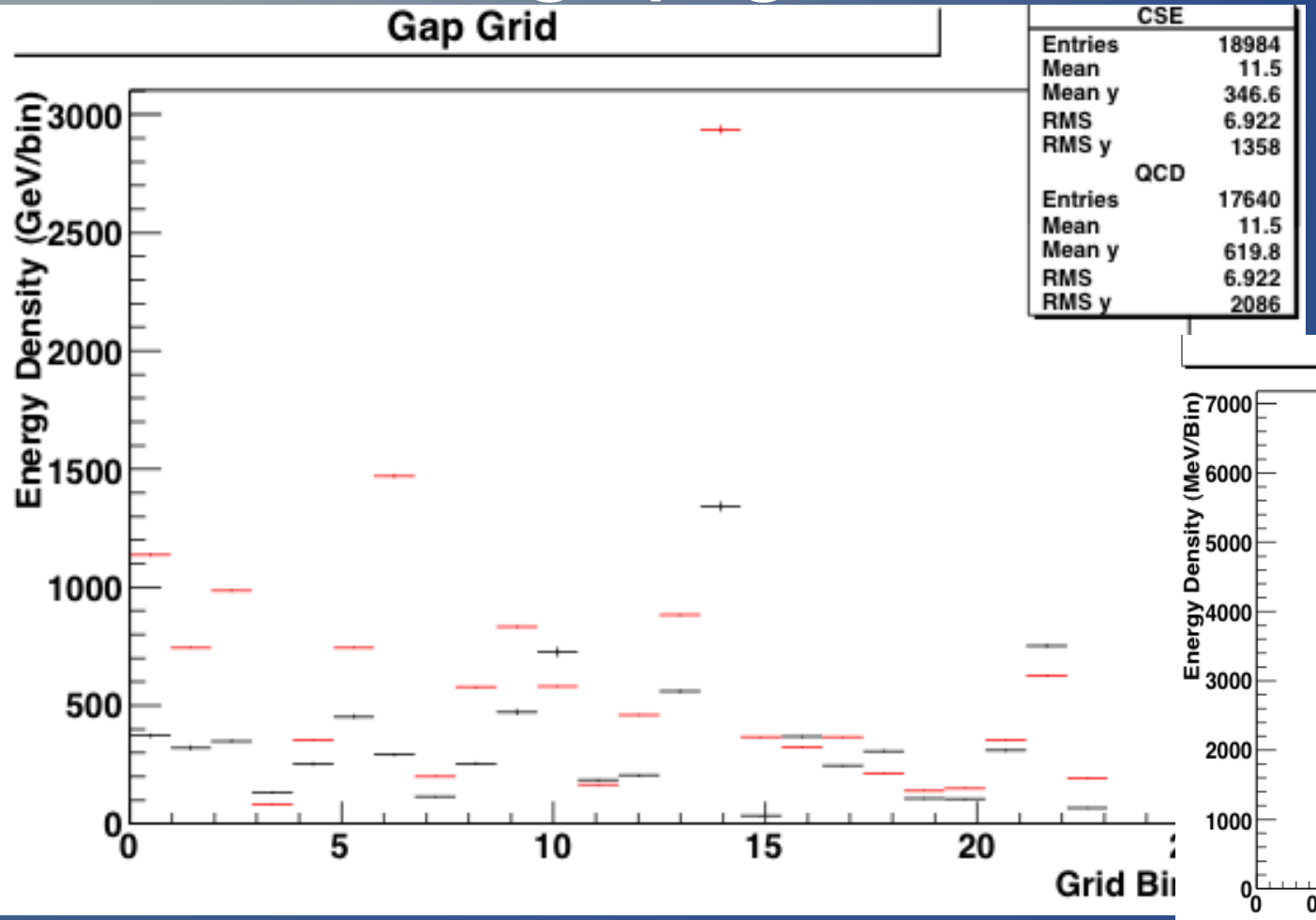
Gap ET sum after correction

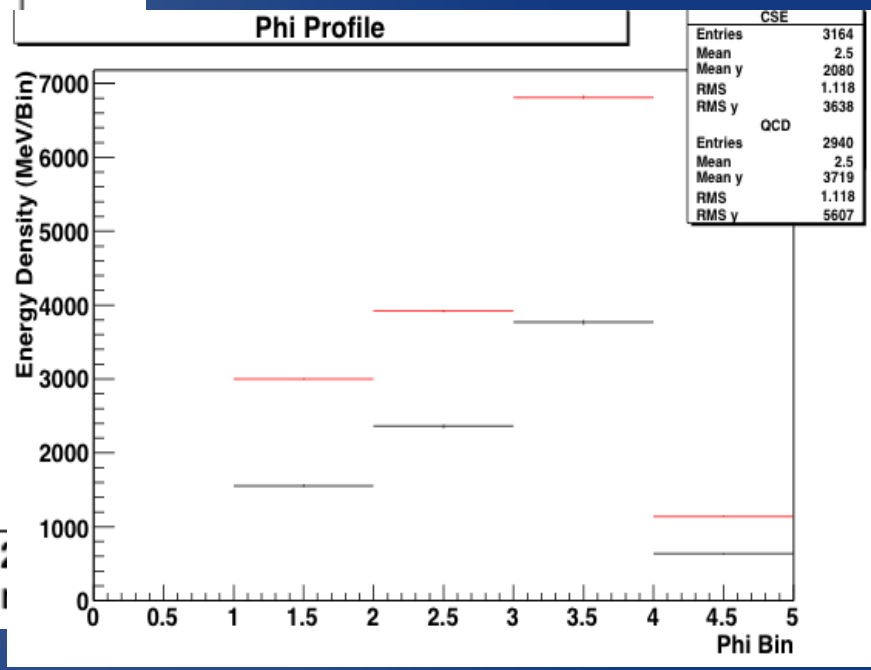




After UE subtraction, also QCD background gaps "cleaned up", but separation power increased

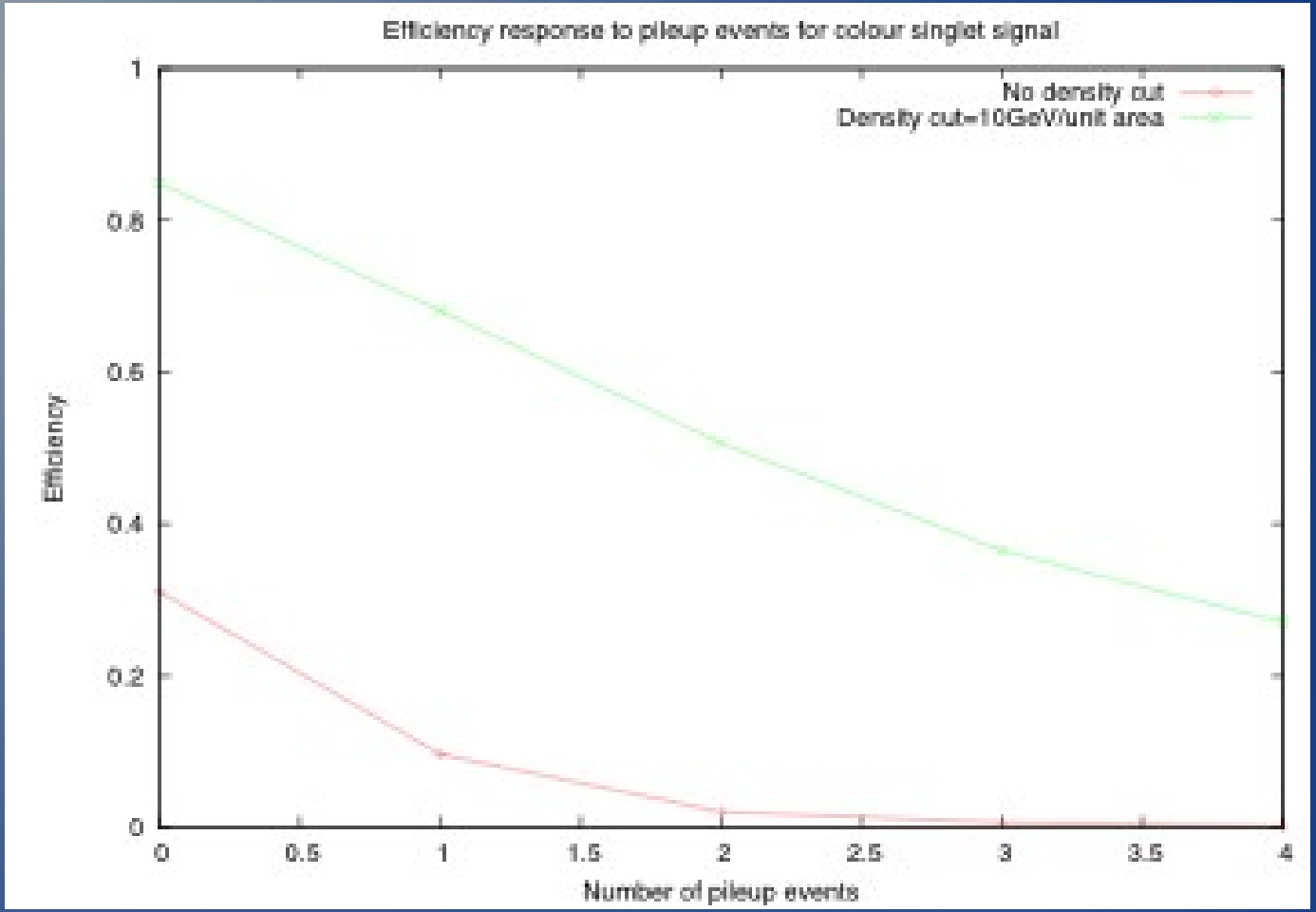
The “gap grid” after correction





A good discrimination power still present, enhanced in some specific regions (like the away regions) rather than others.

Dealing with pileup



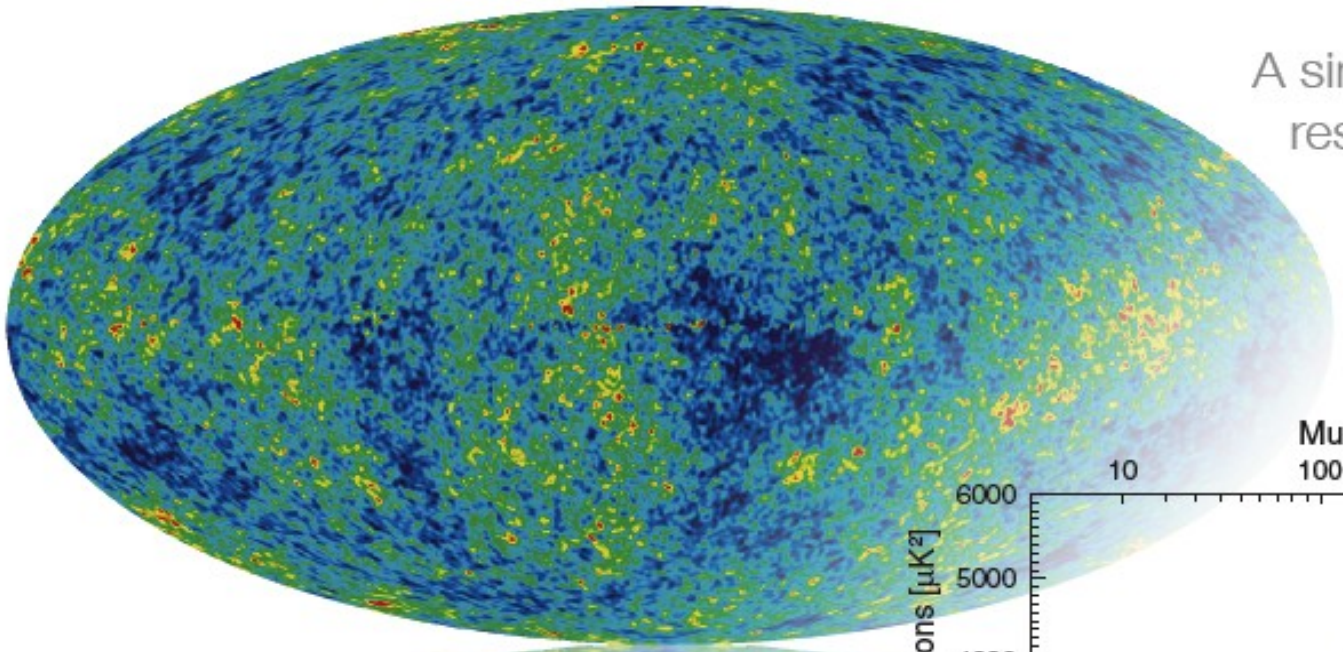
As already said, even the modest pileup expected at the beginning of LHC operations can bring the efficiency to see empty gaps to zero. Area-based correction can restore decent efficiencies

Fourier-transform analysis

QCD analysis of LHC events has features at many different scales:

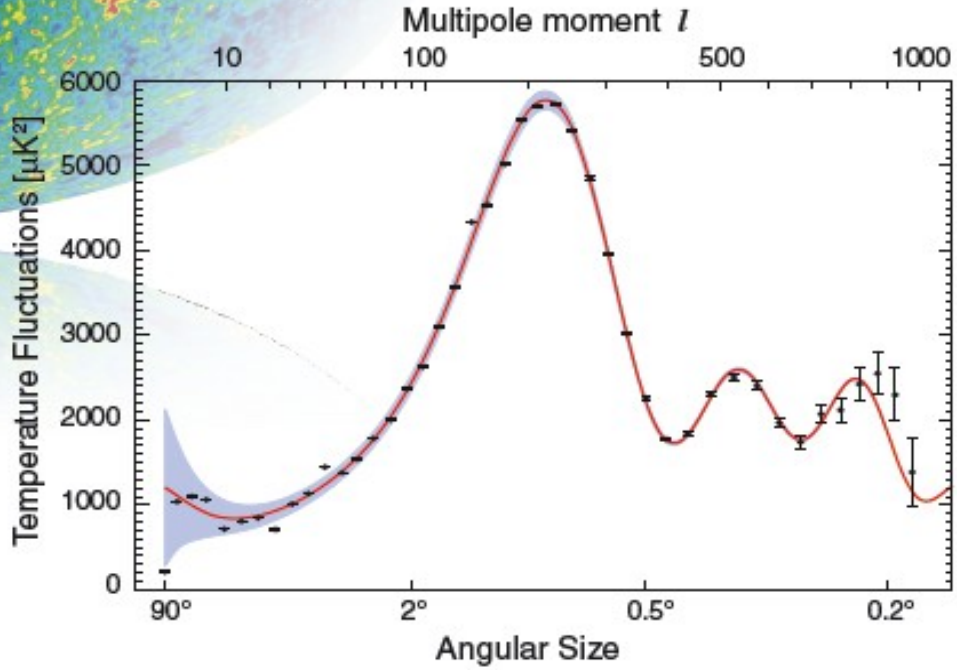
- The Underlying Event (fills the whole detector)
- Inter-jet colour connections (several rapidity units)
- Jets (R ~ 0.5)
- Jetlets and clusters (R ~ 0.1)

This is not the only case in physics a multi-scale process is studied...



A single super-high resolution "event"

$$C_l = \frac{1}{2l+1} \sum_{m=-l}^{l} |C_{lm}|^2$$



CMB decomposed into spherical harmonics

WMAP data

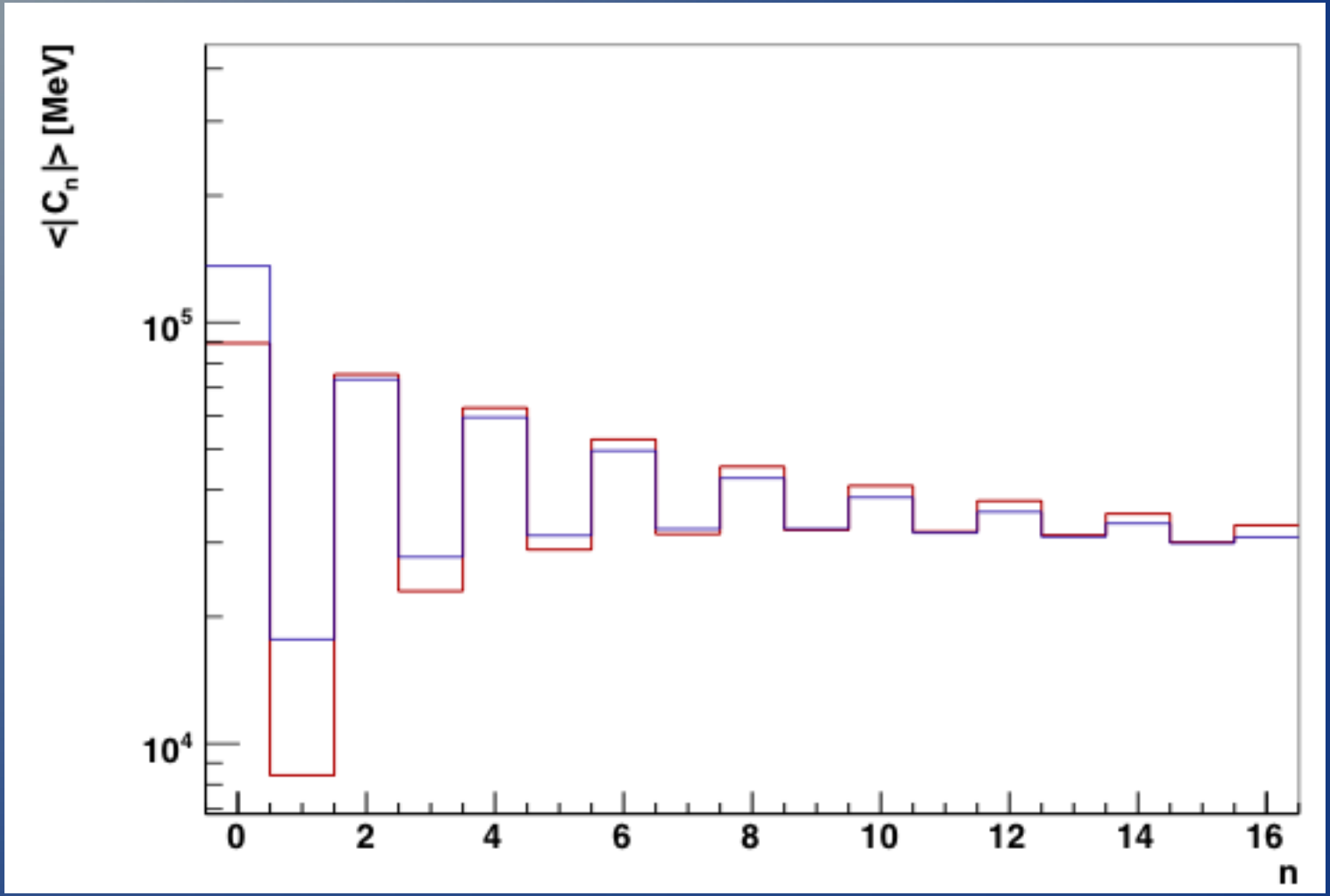
http://map.gsfc.nasa.gov/resources/featured_images_5yr_release.htm

How to use something similar in collider events?

Use cylindrical instead of spherical harmonics
Actually, to start with, we work in 1d, only looking at the ϕ distribution (extension to 2d under way)

Take 32 bins, and put the origin at $\phi = o$
Selection as before (dijets with $\Delta\eta > 4$)
Chose direction to have second jet always at $0 < \phi < \pi$
Study on generator-level Herwig CSE (with and without Jimmy UE) and QCD dijets

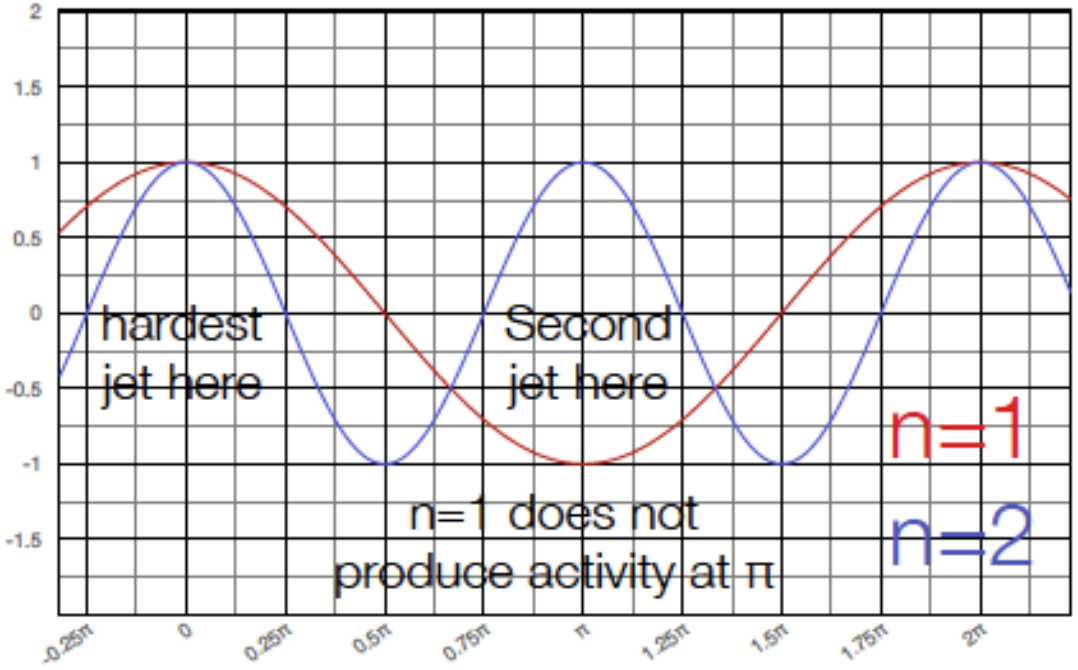
Mean value of coefficient magnitude CSE with and without Underlying Event



As expected, the UE mainly shows up at low coefficients, i.e. at event-wide scales

Suppression of odd coefficients

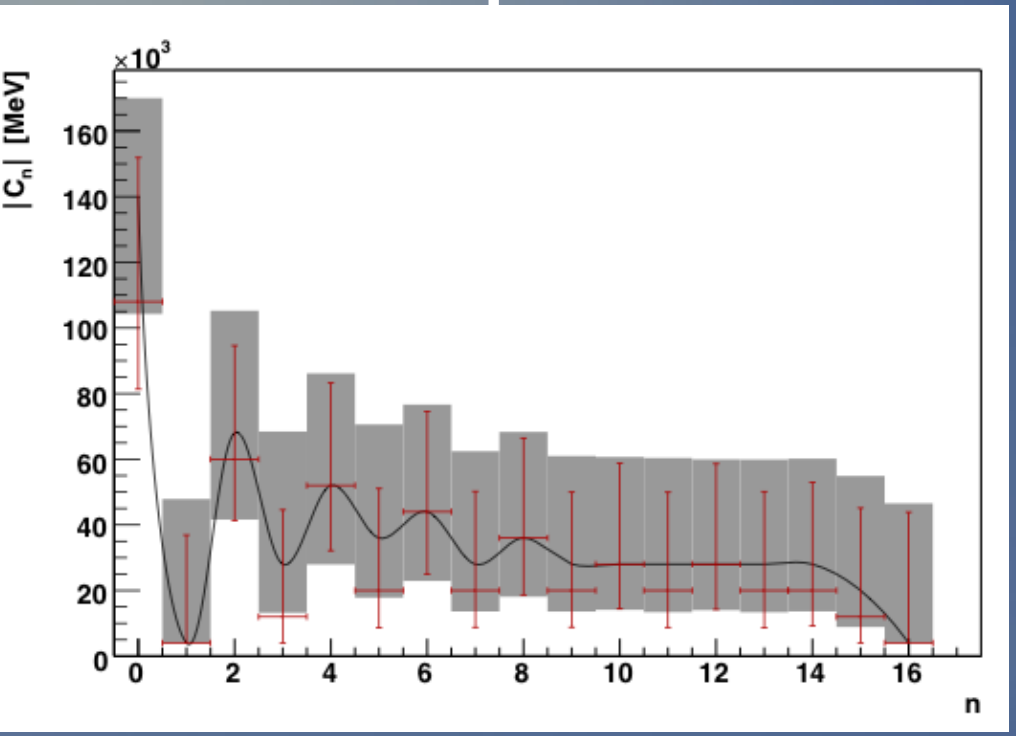
- The n^{th} coefficient corresponds to features of size ~π/n
- The odd coefficients can never have a peak at both 0 and π

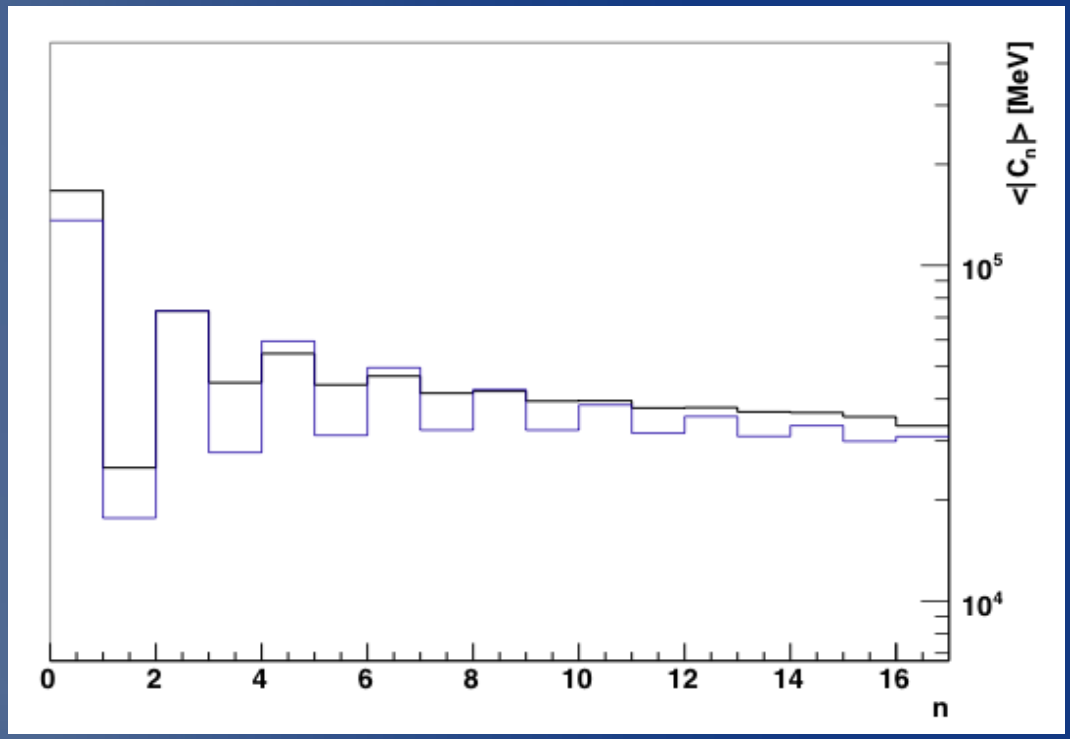


So the small and odd coefficients correspond to features that are large and not di-jet like!

in this case CSE with no underlying event is very di-jet like, so the odd coefficients are suppressed

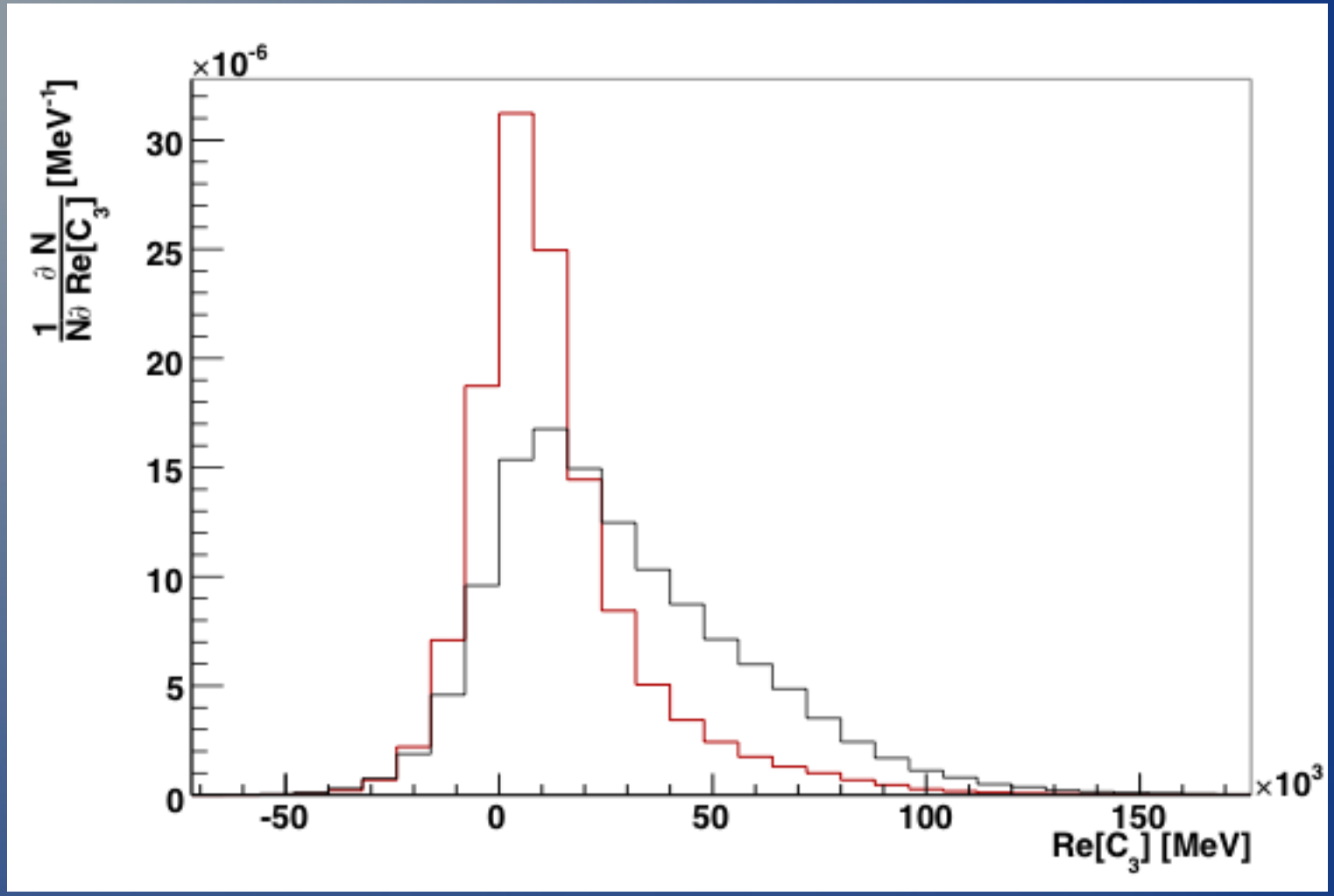
Comparison with Colour Octet





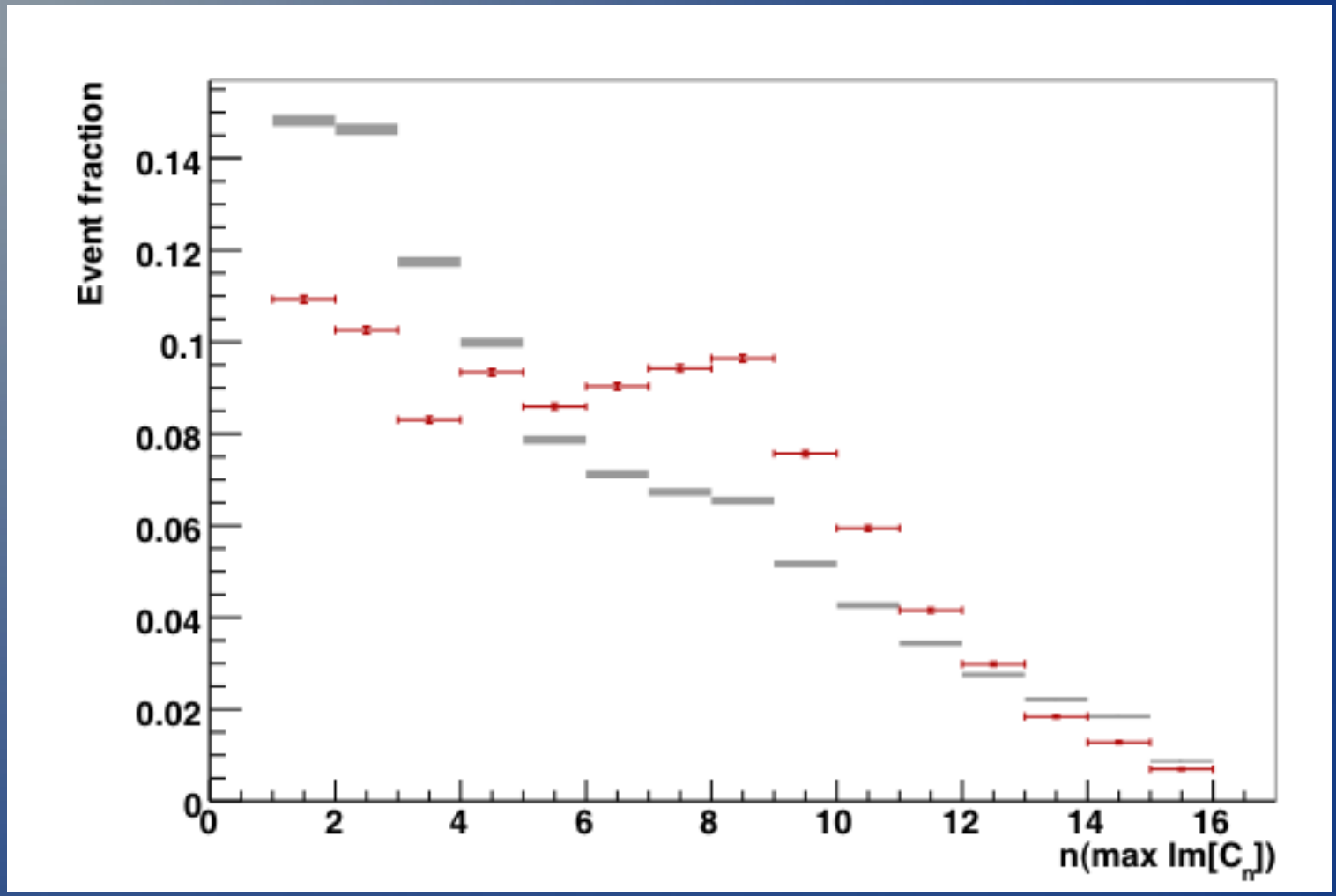
Odd-even coefficient asymmetry almost gone in colour octets (black) due to presence of radiation between jets!

Look at specific coefficients



Coefficients 3 and 5 (typical scale of intra-jet radiation) show the largest difference, so distributions can be fit to templates for different event classes.

Largest coefficient



Bump at ~8 for colour singlets corresponds to jet scale, while lower coefficients show importance of inter-jet radiation (colour octets)

Conclusions

Developing new analysis tools to study QCD at the LHC, in particular separation between singlets and octets, beyond the “clean gap” requirement

Different gap regions show larger sensitivity, and can be more sensitive to different models

Fourier-transform can be a powerful tool to analyse QCD events in hadron collider, allowing to separate different scales in a clean way

1d results only by now, work on 2d going on

Plan to apply all these techniques to the next data in a few months from now.