Physics Validation, 7 April 2004

ATLAS Pixel Test-Beam
First look at
Fluka - Geant4 comparisons

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Outline

- Motivations
- Setup
- Analysis
- G4 Simulation
- Fluka Simulation
- Results
- Some checks
- Conclusions

Motivations

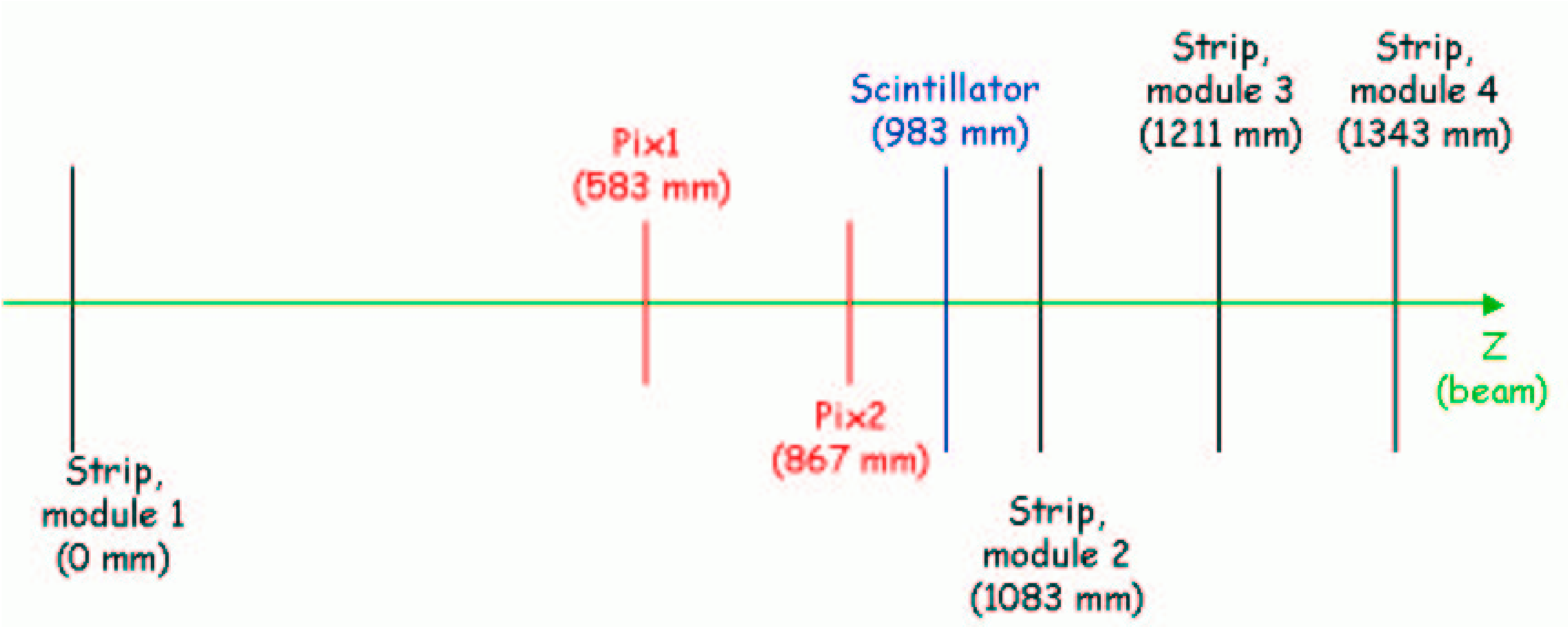
The august 2001 ATLAS Pixel Test-Beam offers an excellent opportunity to test in great detail the final state of hadronic interaction models (multiplicities, angular distributions, topologies).

Tracker test-beams provide a clean, simple and “microscopic” (single-interaction) data for the validation of hadronic physics simulations, that is complementary to the more typical and complex calorimeter test-beams, where the showers are the convolution of many effects (electromagnetic physics, multi-interactions, hadronic cross sections, hadronic final states).

The original analysis was made three years ago by:
Dario Barberis, Mario Cervetto, Bianca Osculati
(Genoa University, INFN).

Setup

- Beam: nominal 180 GeV π^+; real composition: 67 % p, 29 % π^+, 4 % K^+ ,
- Two pixels layers: $50\,\mu m \times 400\,\mu m$ thickness $280\,\mu m$; sensor dimension: $8\,mm \times 7.2\,mm$ (160×18 pixels);
- Telescope: 4 silicon microstrip planes, one upstream and three downstream, double-sided, $50\,\mu m$ pitch;
- Scintillator: trigger energy deposit ≥ 3 mips.


Strip,
module 1
(0 mm)
Pix1
(583 mm)
Pix2
(867 mm)
Scintillator
(983 mm)
Strip,
module 2
(1083 mm)
Strip,
module 3
(1211 mm)
Strip,
module 4
(1343 mm)
Z
(beam)

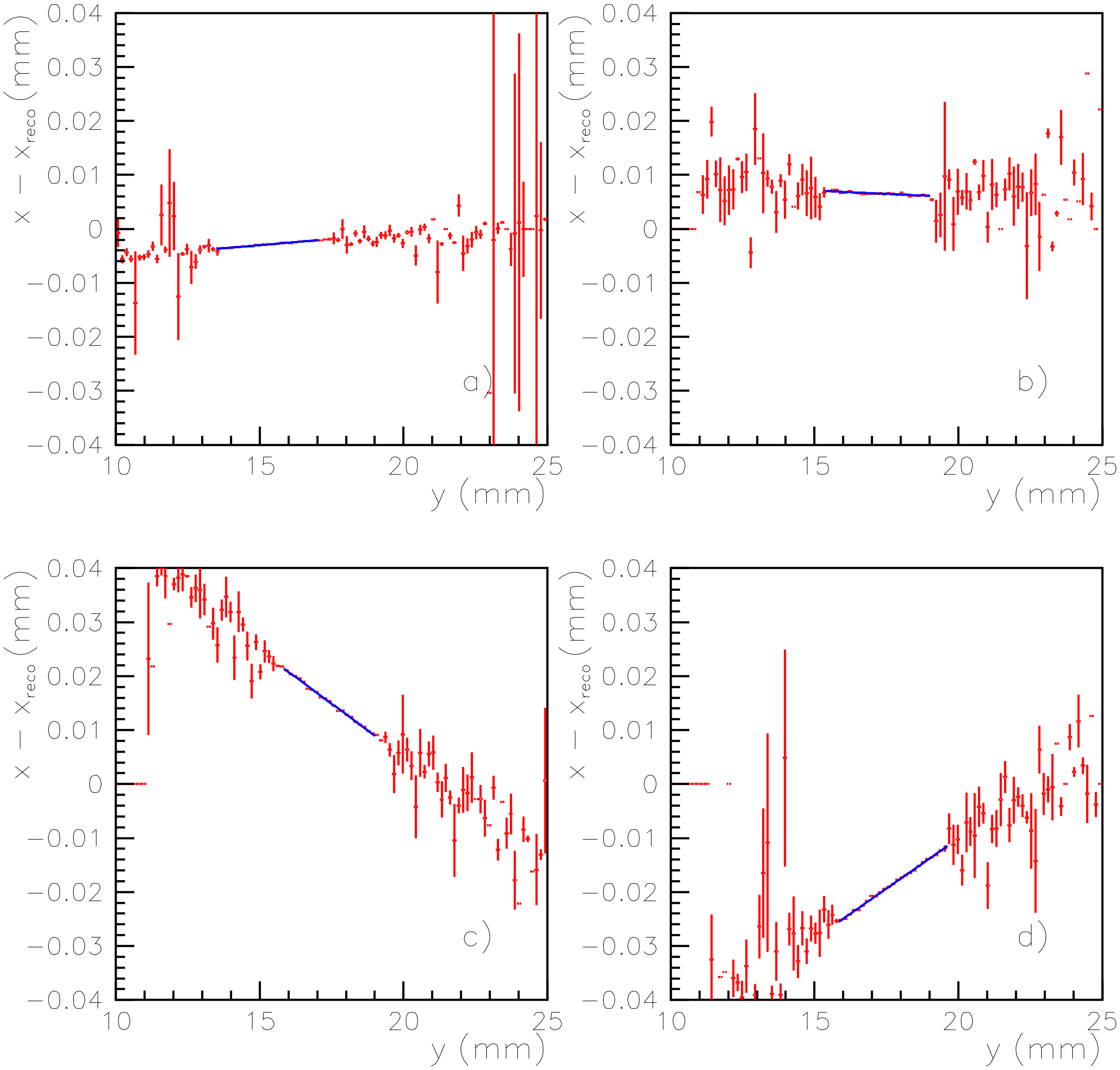
Analysis

- ≥ 3 clusters in each of the three microstrip planes downstream the pixels;
- alignment of the telescope planes;
- calibration of individual pixels (single pixel clusters, pulse injection, radioactive sources);
- track reconstruction in the three microstrip planes downstream of the pixels (straight line fit in xz and yz planes, match in energy);
- interaction point (vertex) reconstruction (weighted mean of all two-by-two track intersections); Pix2 is selected because of the better resolution;
- selection of the interactions in the silicon sensor (closest pixel cluster in transverse plane, $\Delta z < 4\,mm$; $E_{loss}/N_{dig} > 100,000$ electrons).

Then, study of pixel cluster corresponding to the reconstructed vertex coordinate.

Alignement of the Telescope

Small and different rotation angle in each strip plane.



Pixel Detector

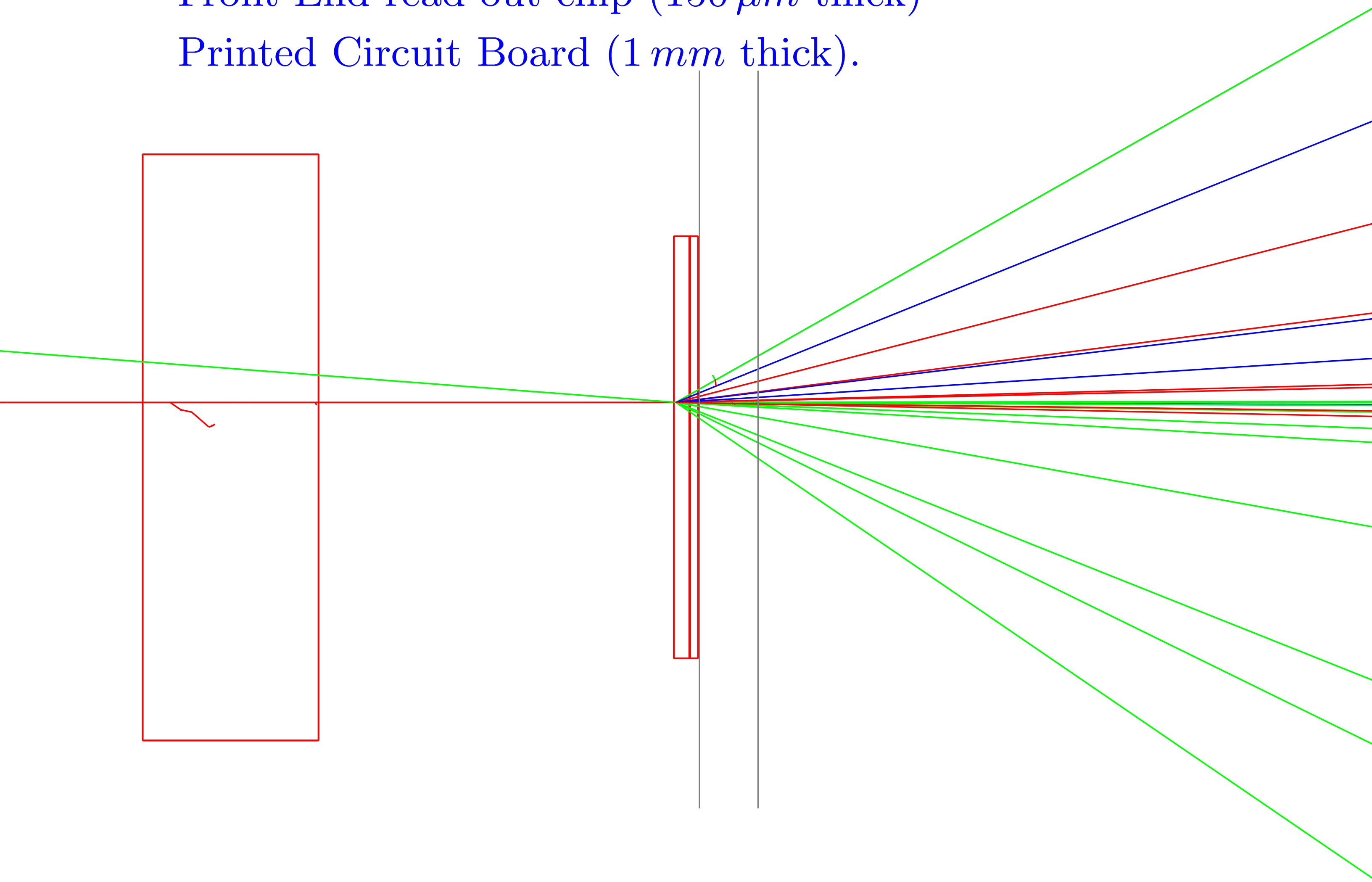
Plastic cover ($3\,mm$ thick)

(air gap for about $6\,mm$)

Silicon sensor ($280\,\mu m$ thick)

Front End read-out chip ($150\,\mu m$ thick)

Printed Circuit Board ($1\,mm$ thick).



Geant4 Simulation

- Geant4 6.01
- Linux RH 7.3, gcc 3.2
- CLHEP 1.8.0.0
- Physics lists: LHEP 3.7, QGSP 2.8, QGSC 2.9
- Range cut: $10\,\mu m$
- Beam divergence, “noise”, cross-talk
- $E_{loss}/N_{dig} > 56,000$ electrons
  (different from real data maybe because of
  non-linearities in the calibration curve)
- 10 million events generated for each Physics List.

Fluka Simulation

- Fluka Fluka2003 (December 2003)
- Linux RH 7.3, gcc 3.2
- Cut: $10\, keV$
  (transportation cut for e^-, e^+, γ; δ-ray threshold; transportation for μ, hadrons, and nuclear fragments is $100\, keV$;
  μ and heavy hadrons bremsstrahlung and pair production thresholds are $300\, keV$).
- FLUGG is used in order to use the same G4 Geometry: this means that the Navigation is done with G4, whereas the Tracking/Stepping and the Physics is done with Fluka.
- Same beam composition and beam divergence as in G4.
- Interface to the C++ digitization: so the same code is used both in G4 and in Fluka.
- Same analysis cut $E_{loss}/N_{dig} > 56,000$ electrons.
- 10 million events generated.

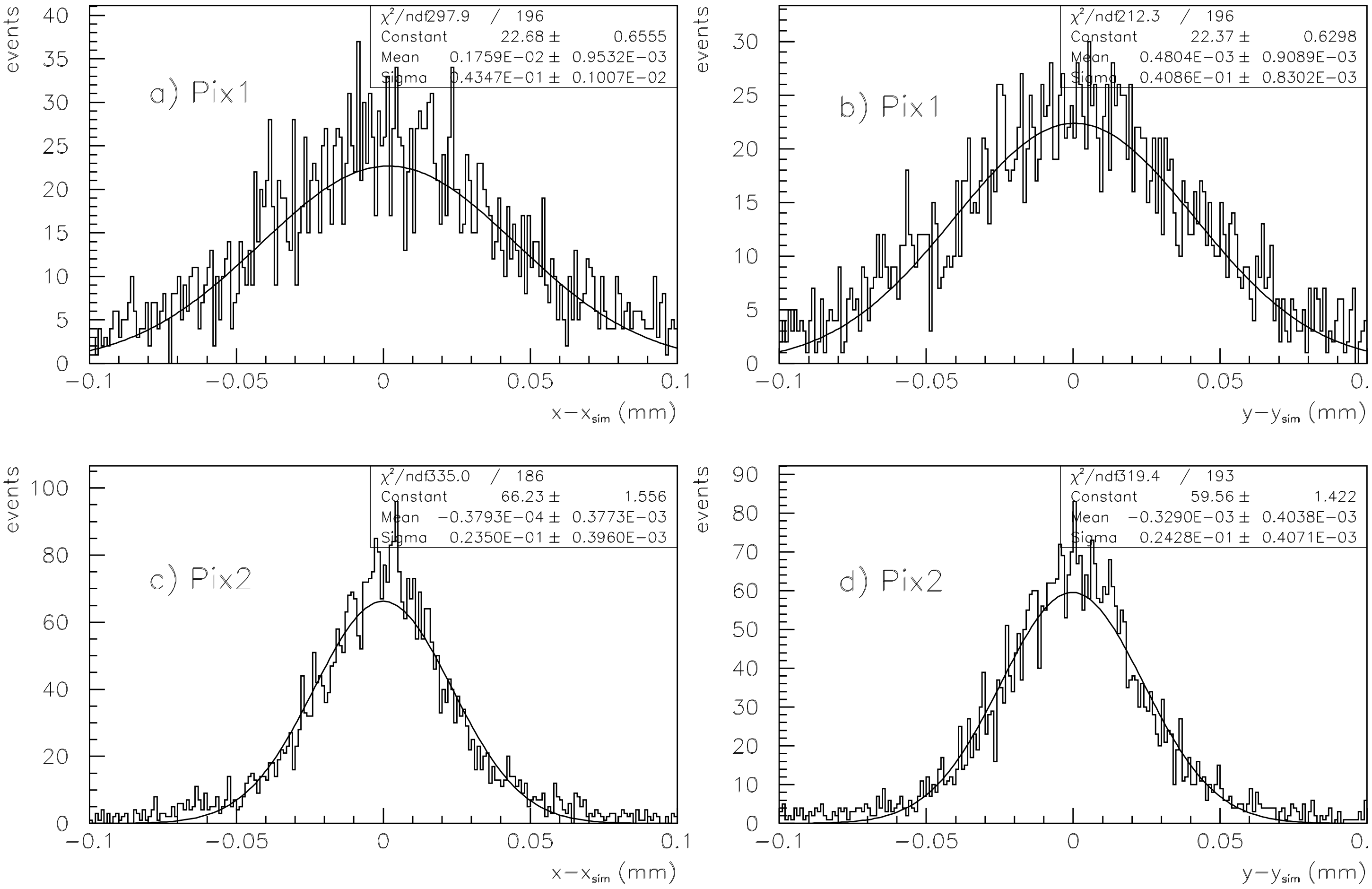
FLUGG

If you have already a Geant4 geometry description of your setup, and you want to try Fluka, the simplest way is to use FLUGG, which is an interface between the transportation and physics of Fluka with the G4 Navigation. FLUGG works well and it is easy to use :

- download the tar ball;
- setup the proper environment variables (FLUGGINSTALL, FLUPRO, G4SYSTEM, CLHEP_BASE_DIR);
- build FLUGG (i.e. gmake);
- create your application: keep only the pure geometrical part of the Geant4 setup (i.e. no sensitive detectors, no hits, no digitization);
- set the name of your application in GNUmakefile, and the name of the geometry class (i.e. MyDetectorConstruction.hh) in the main;
- build your application (i.e. gmake);
- run Fluka a first time for initialization (from which you get the list of materials);
- run Fluka normally.

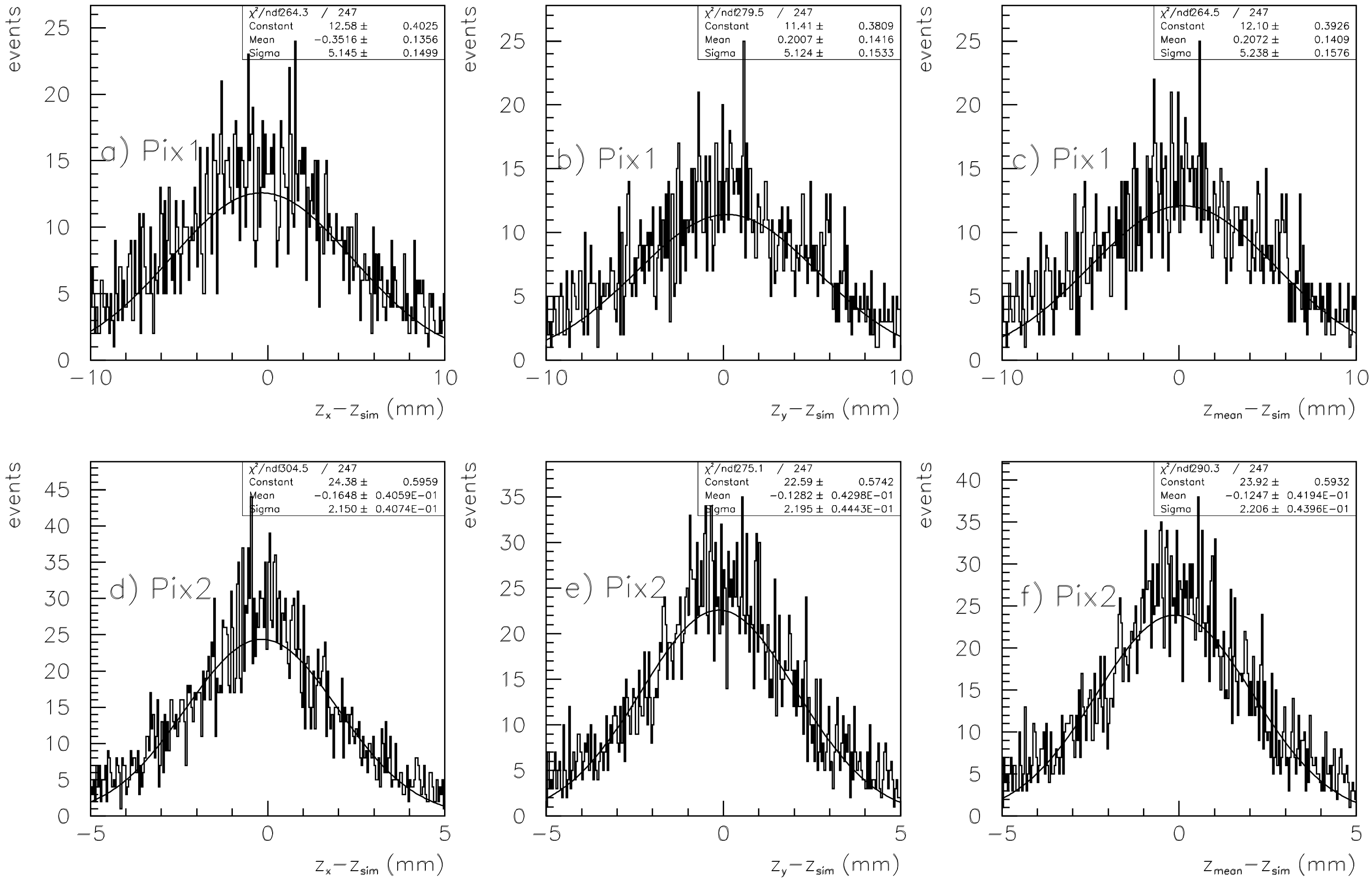
Transverse Vertex Resolution

x y



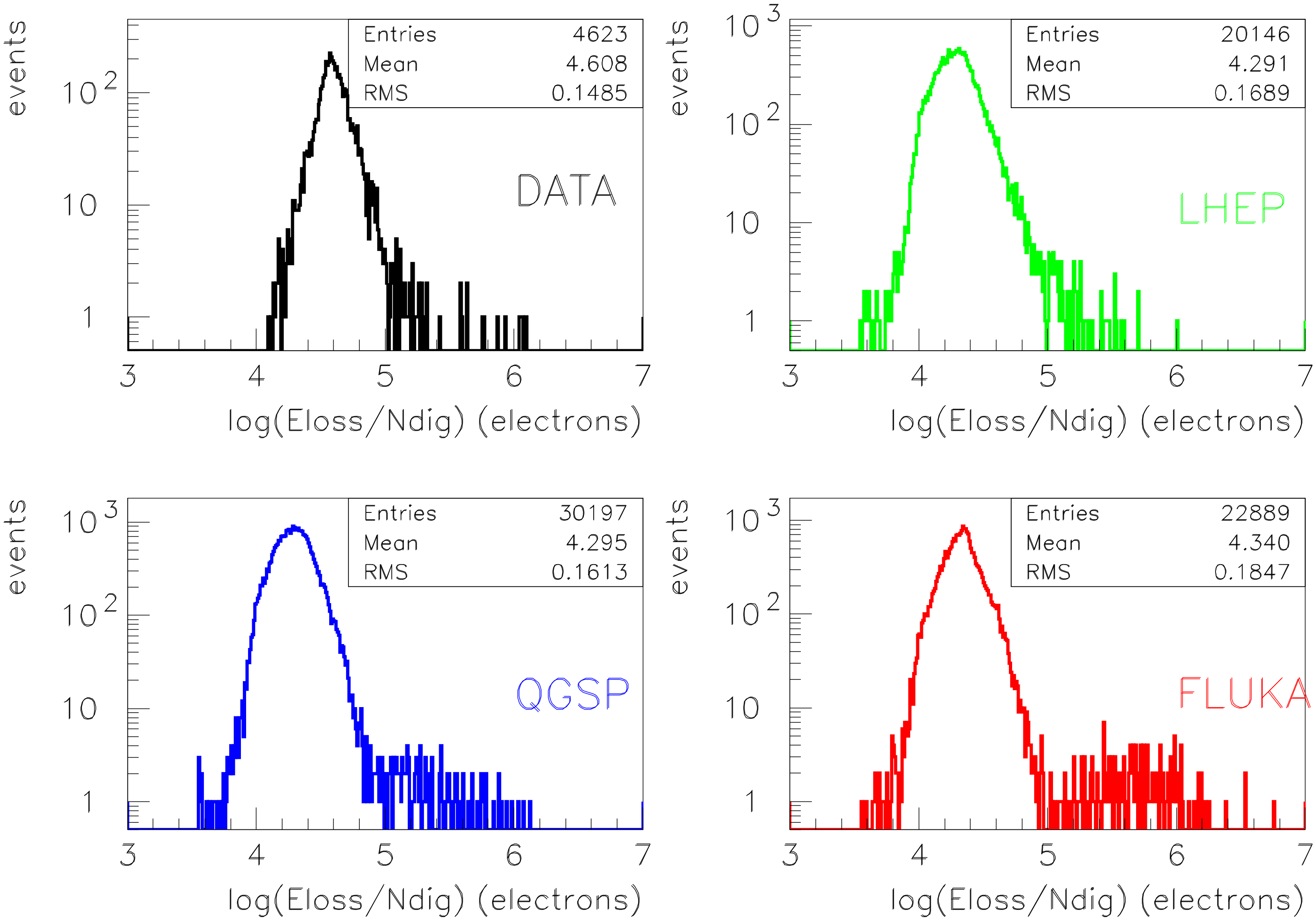
Longitudinal Vertex Resolution

xz yz z_{mean}



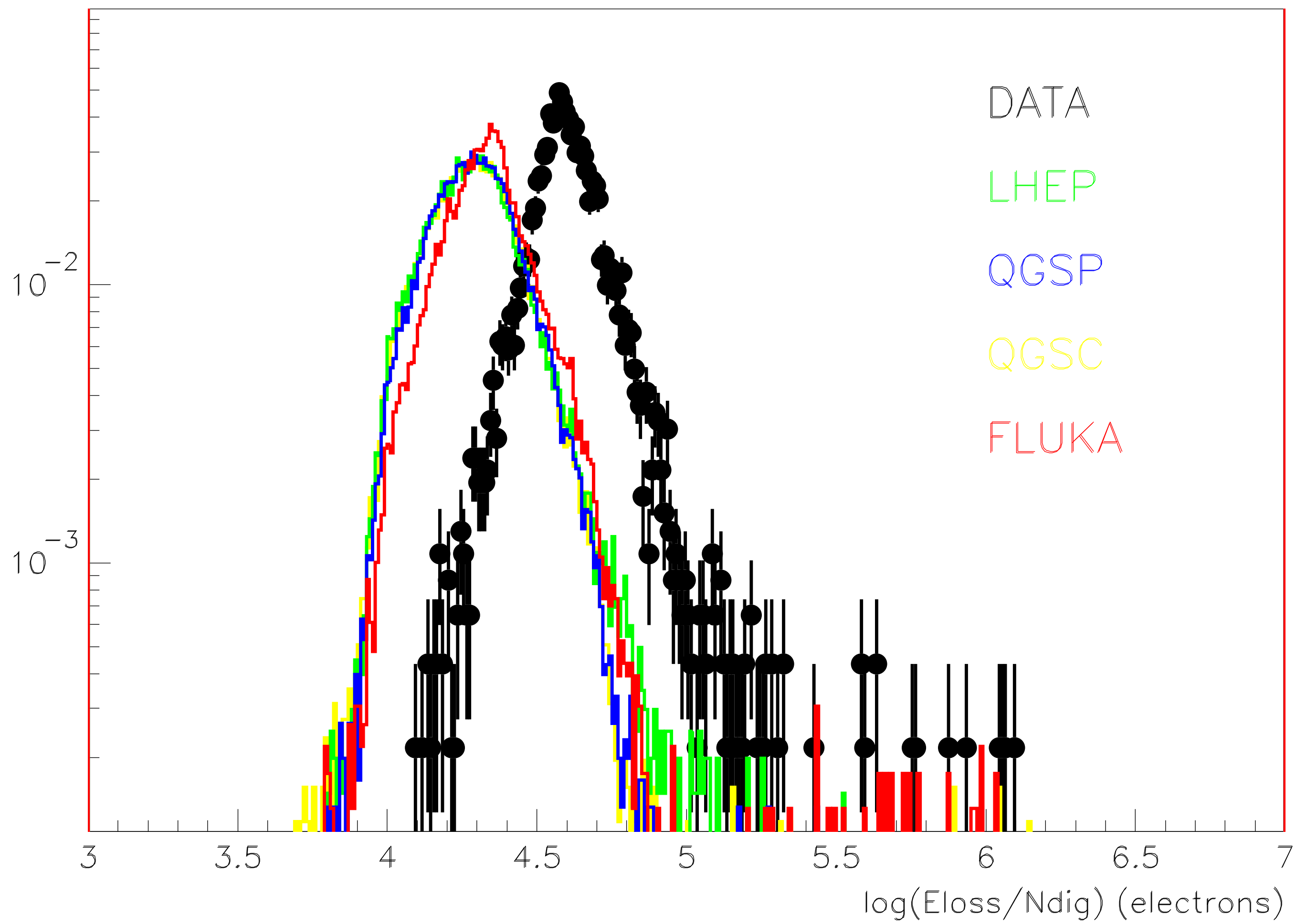
Eloss/Ndig cut

Normalised energy loss for events with interaction vertices reconstructed in the plastic cover, far enough from the sensor ($-15\,mm < zreco - zpix2 < -5\,mm$) to be resolved by our z resolution.



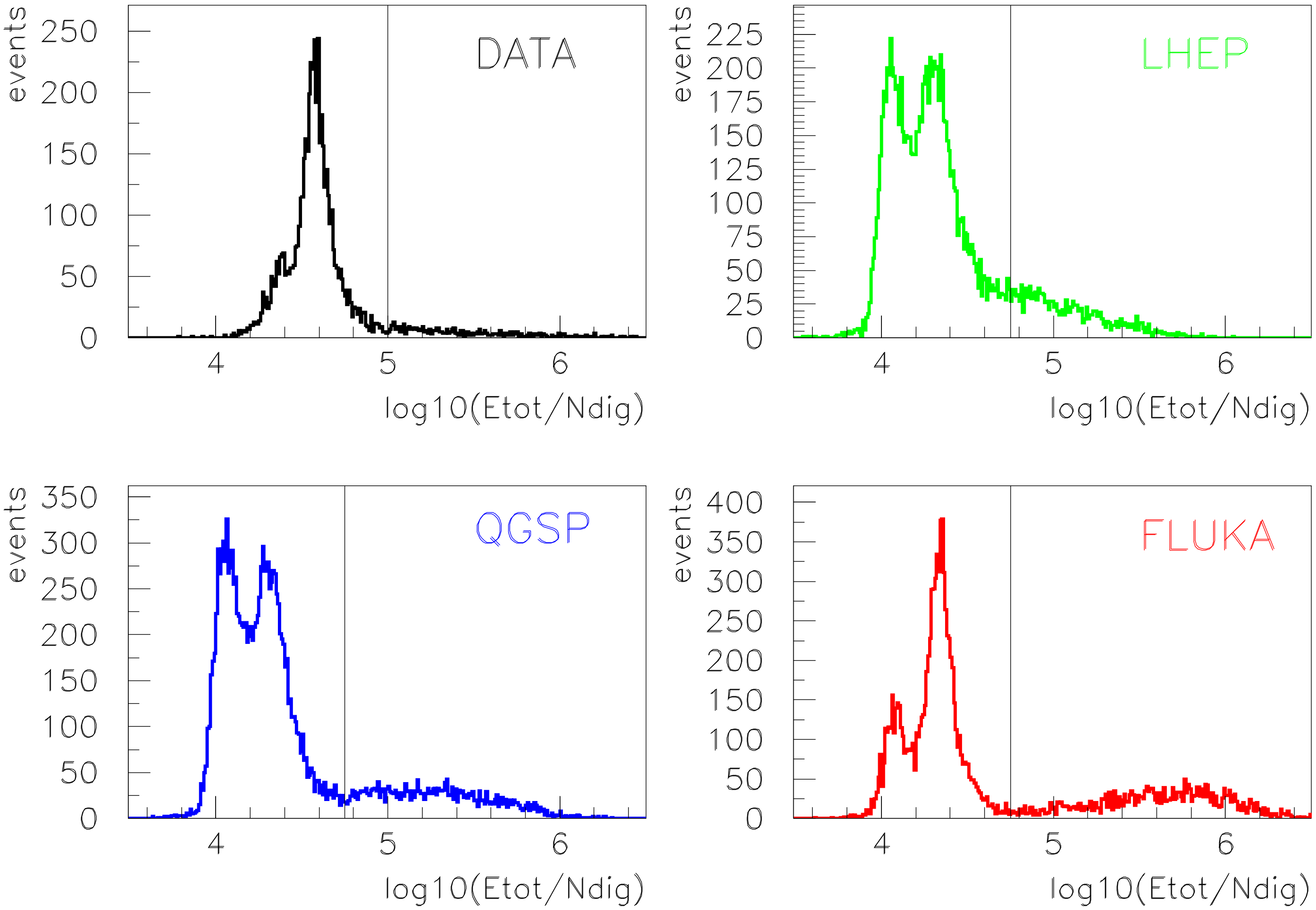
Eloss/Ndig cut

As the previous one, but normalizing to the same number of events.



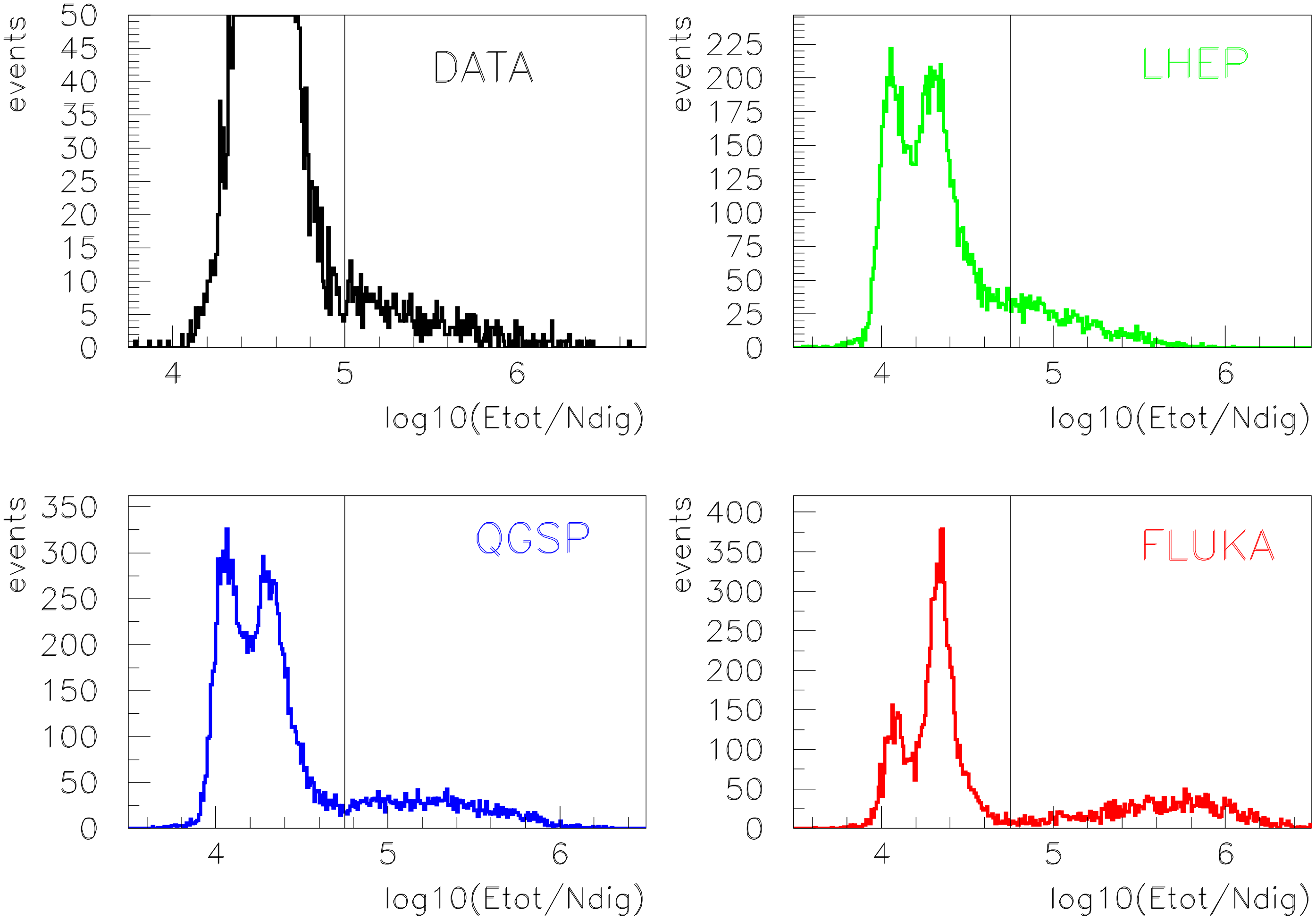
Eloss/Ndig cut (cont.)

Normalised energy loss for events close to the sensor $(-4\,mm < zreco - zpix2 < -4\,mm)$.



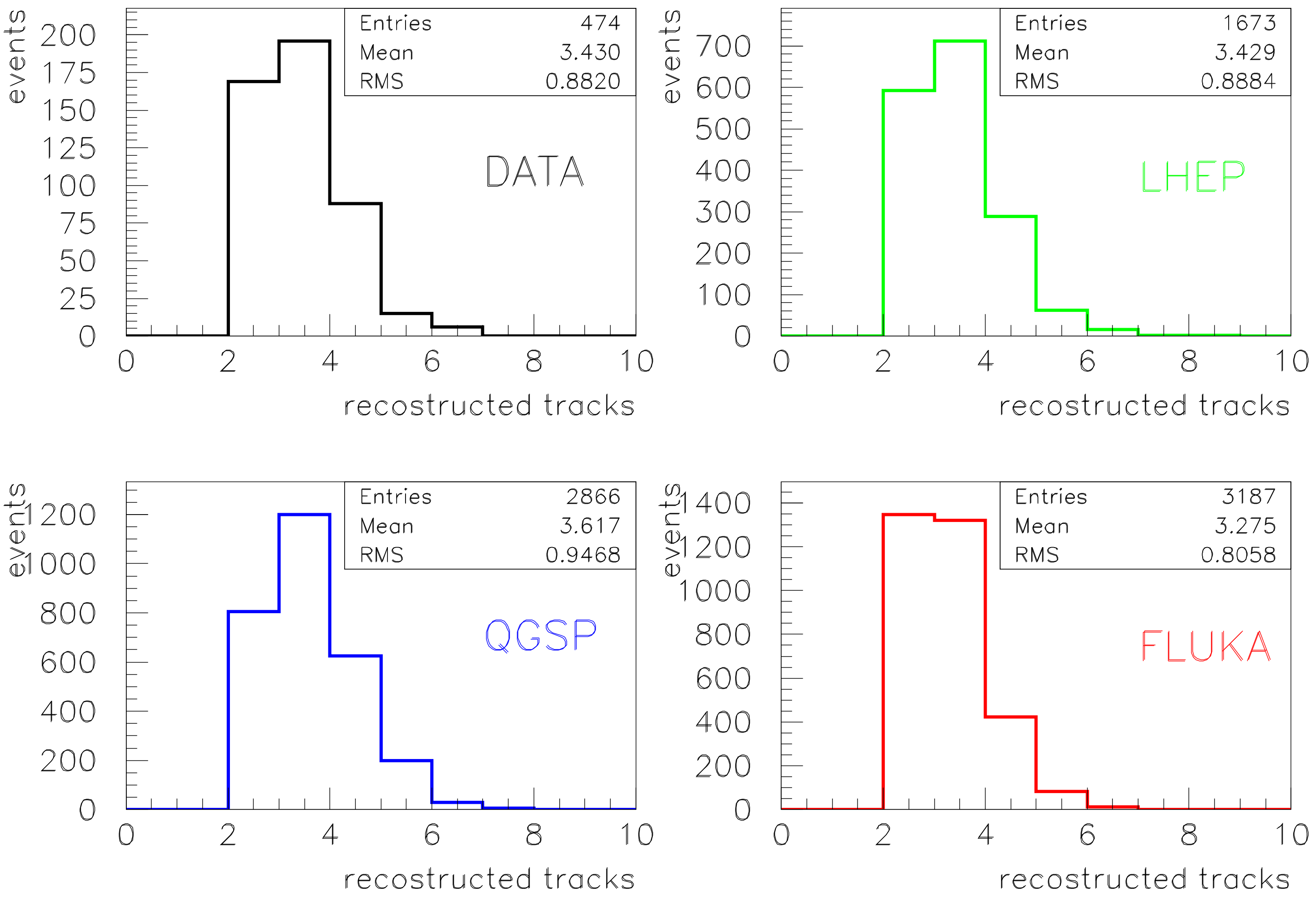
Eloss/Ndig cut (cont.)

As the previous one, but "zooming" on the tail above 5 for the data.

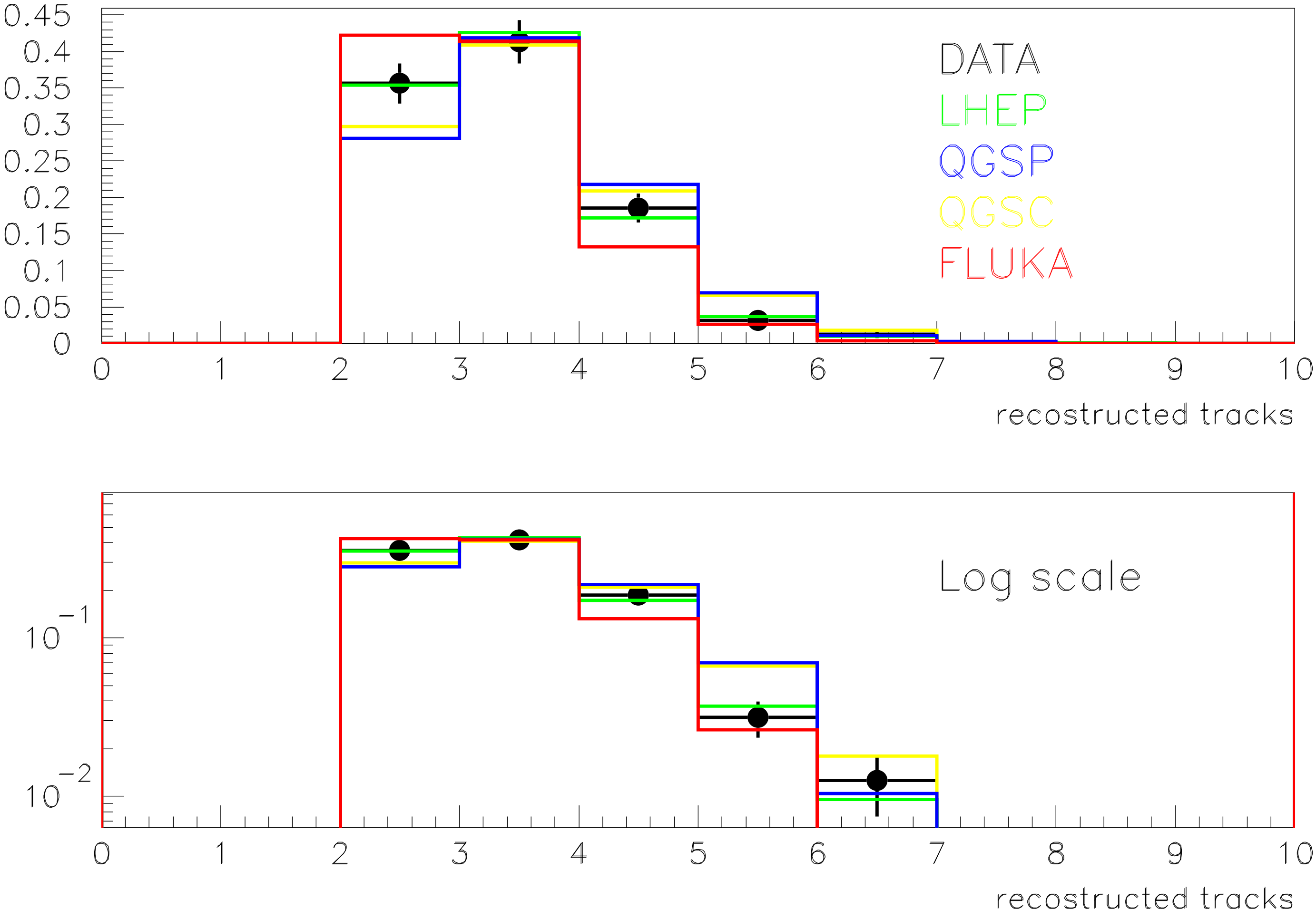


Track multiplicity

Number of reconstructed tracks in the interaction.

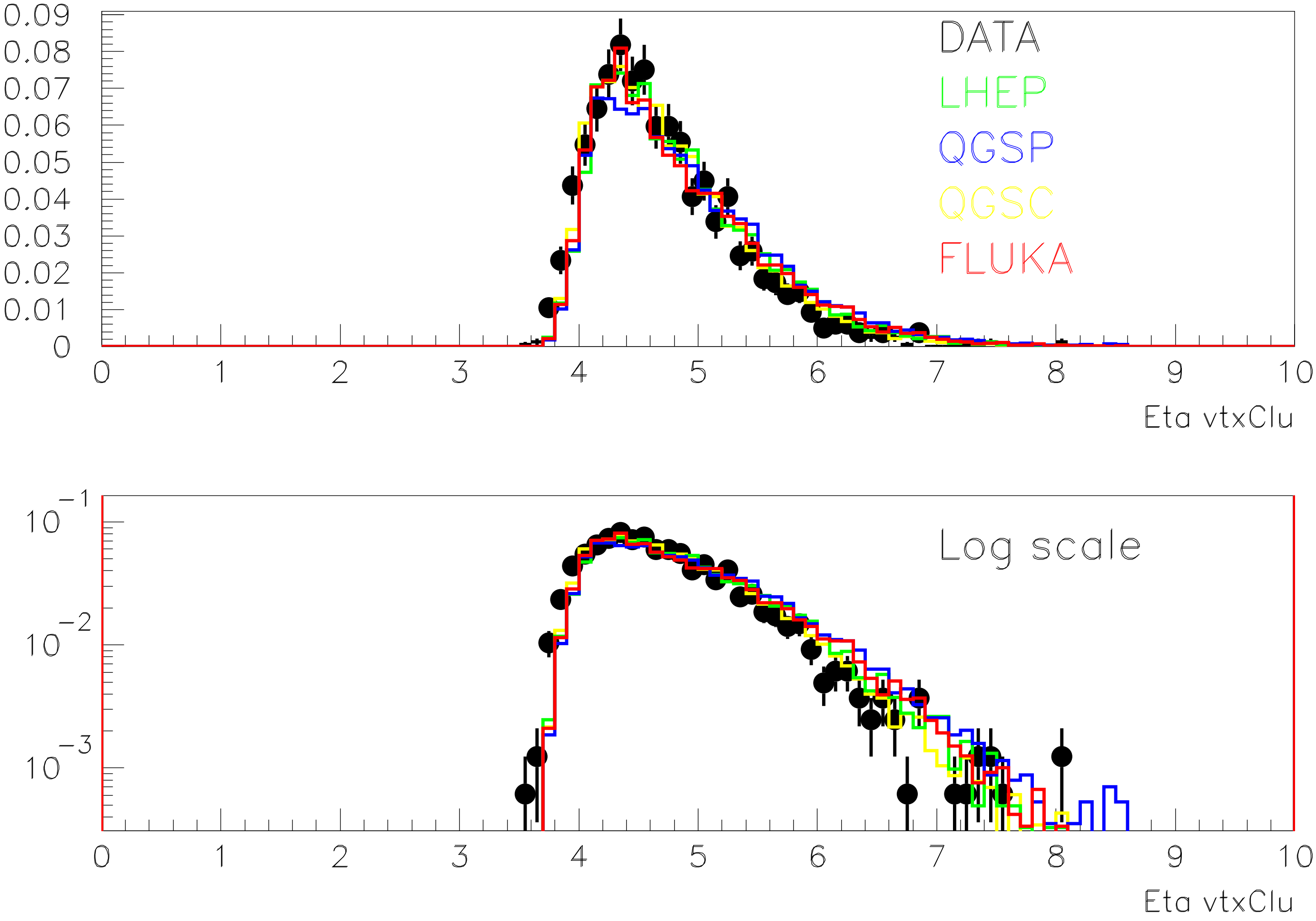


Track multiplicity (cont.)



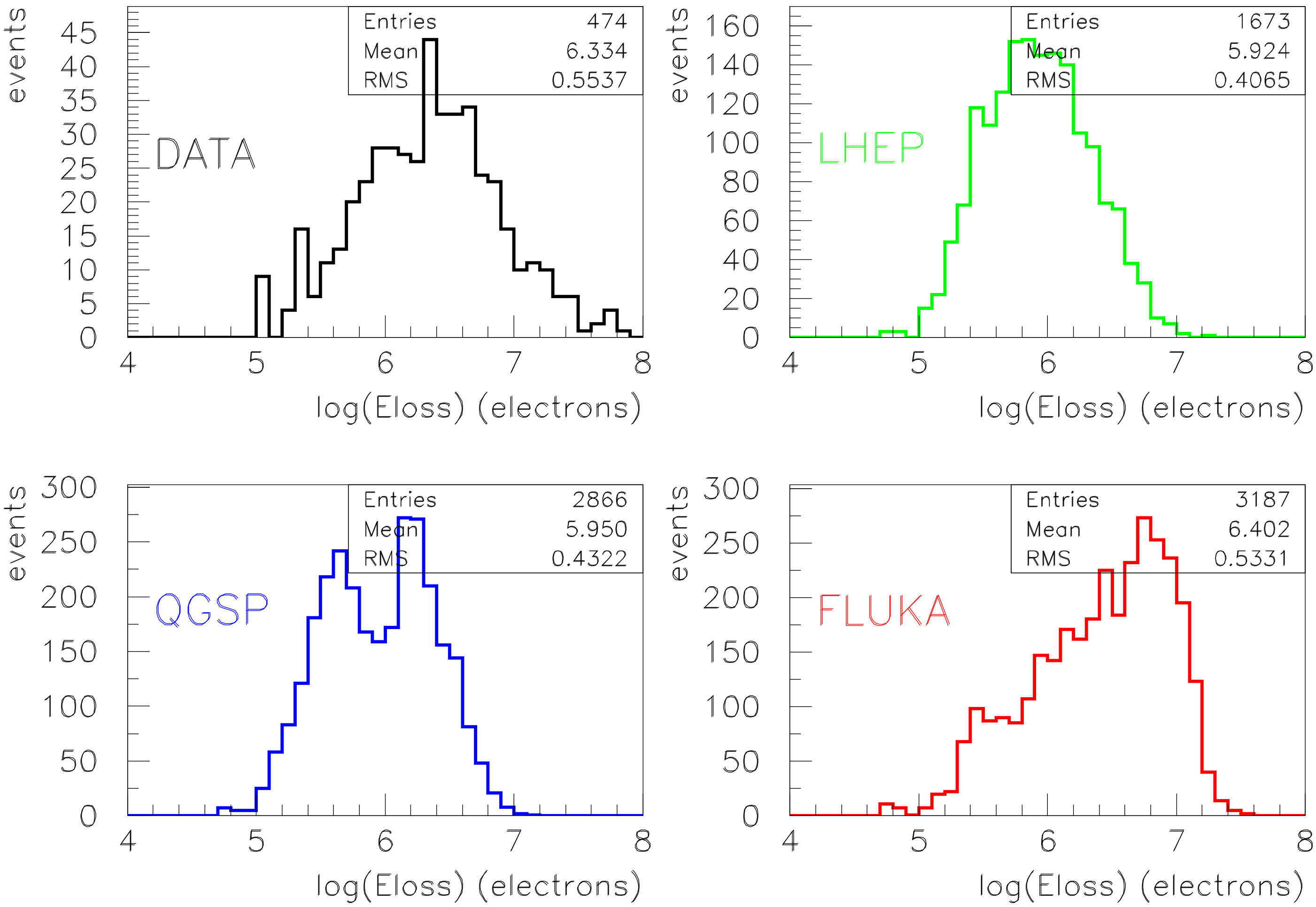
Eta

$\eta = -\ln(|\tan(\frac{\theta}{2})|)$ of the reconstructed tracks.

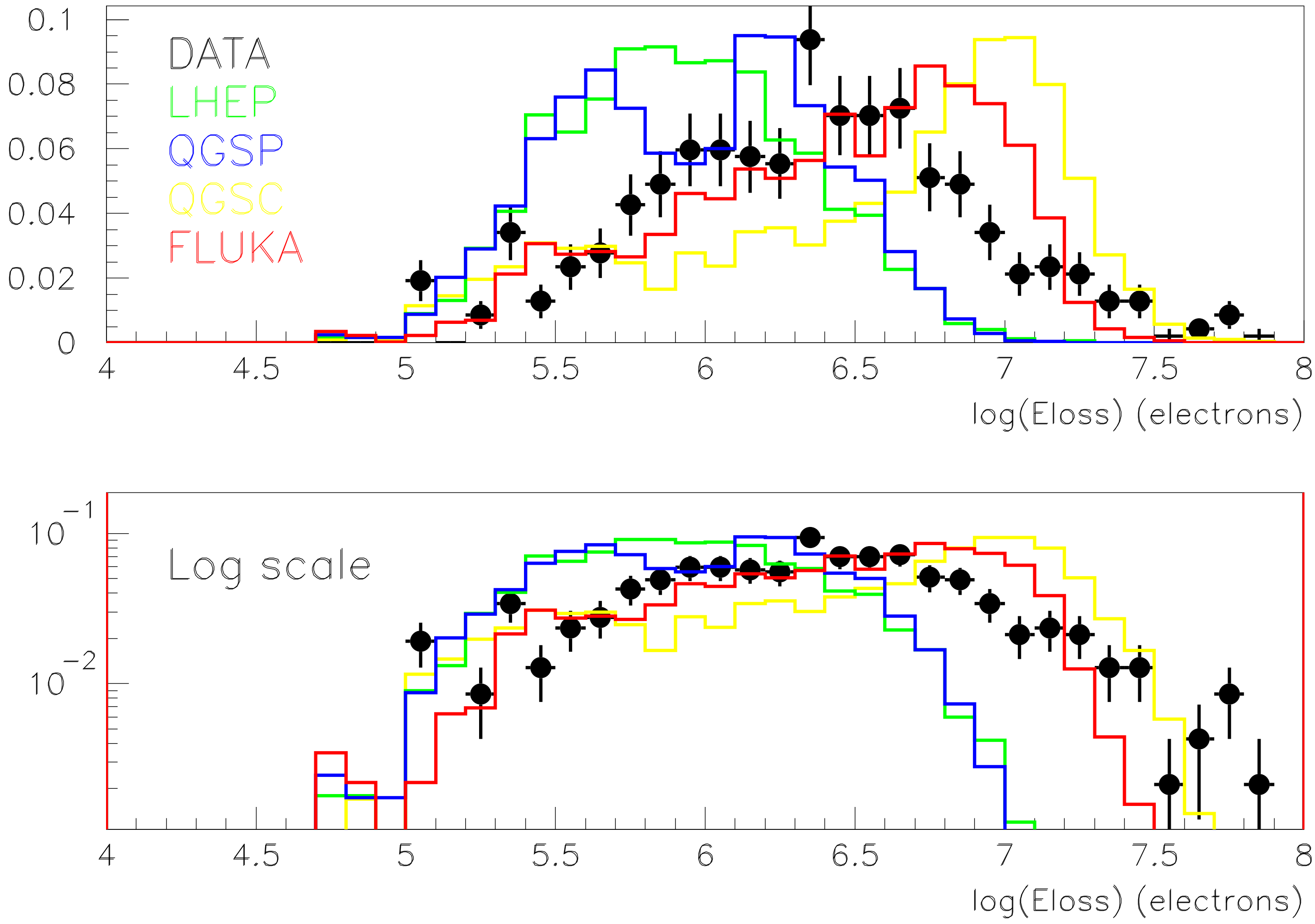


Cluster charge

Log$_{10}$ of the total energy released in the cluster.

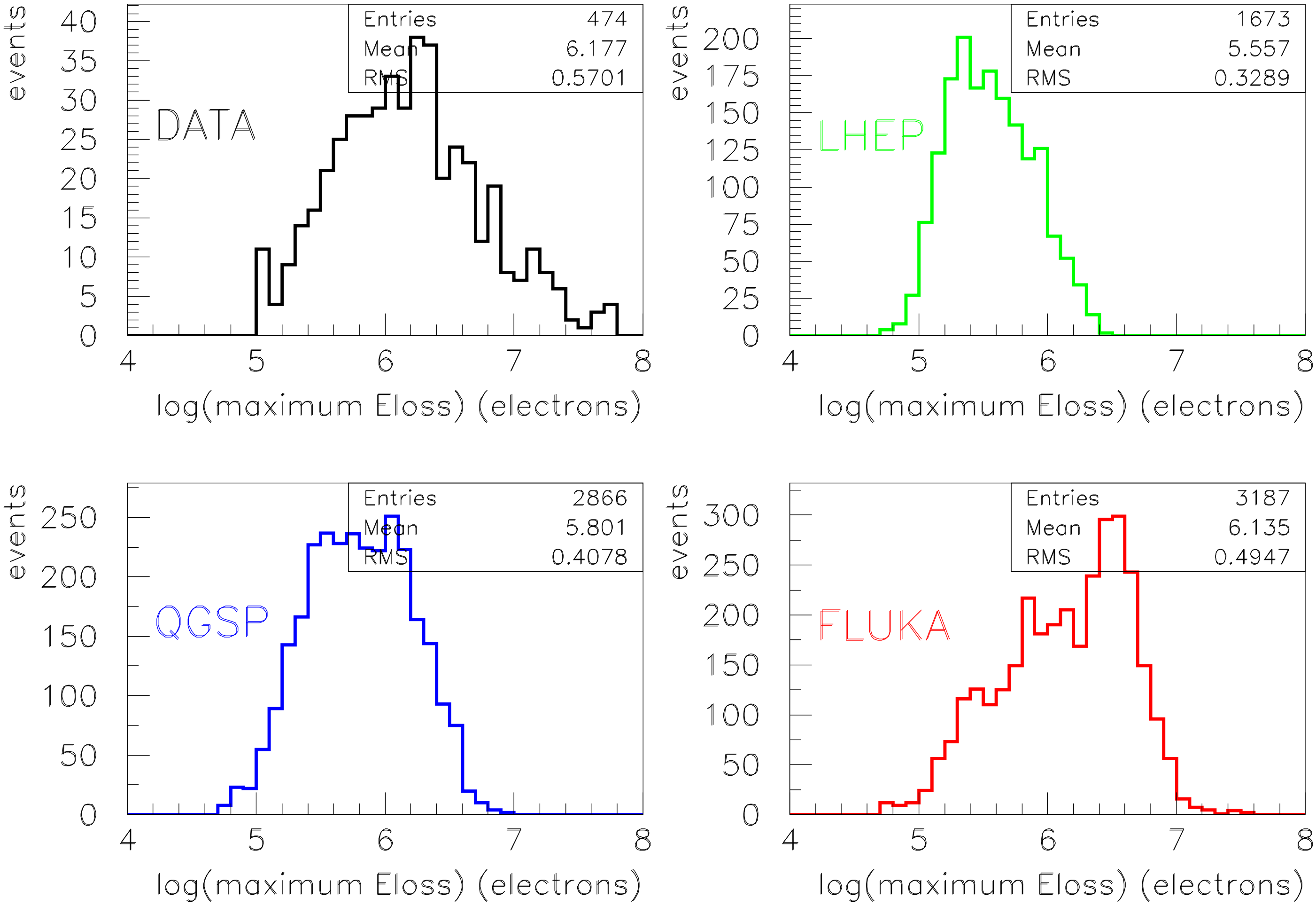


Cluster charge (cont.)

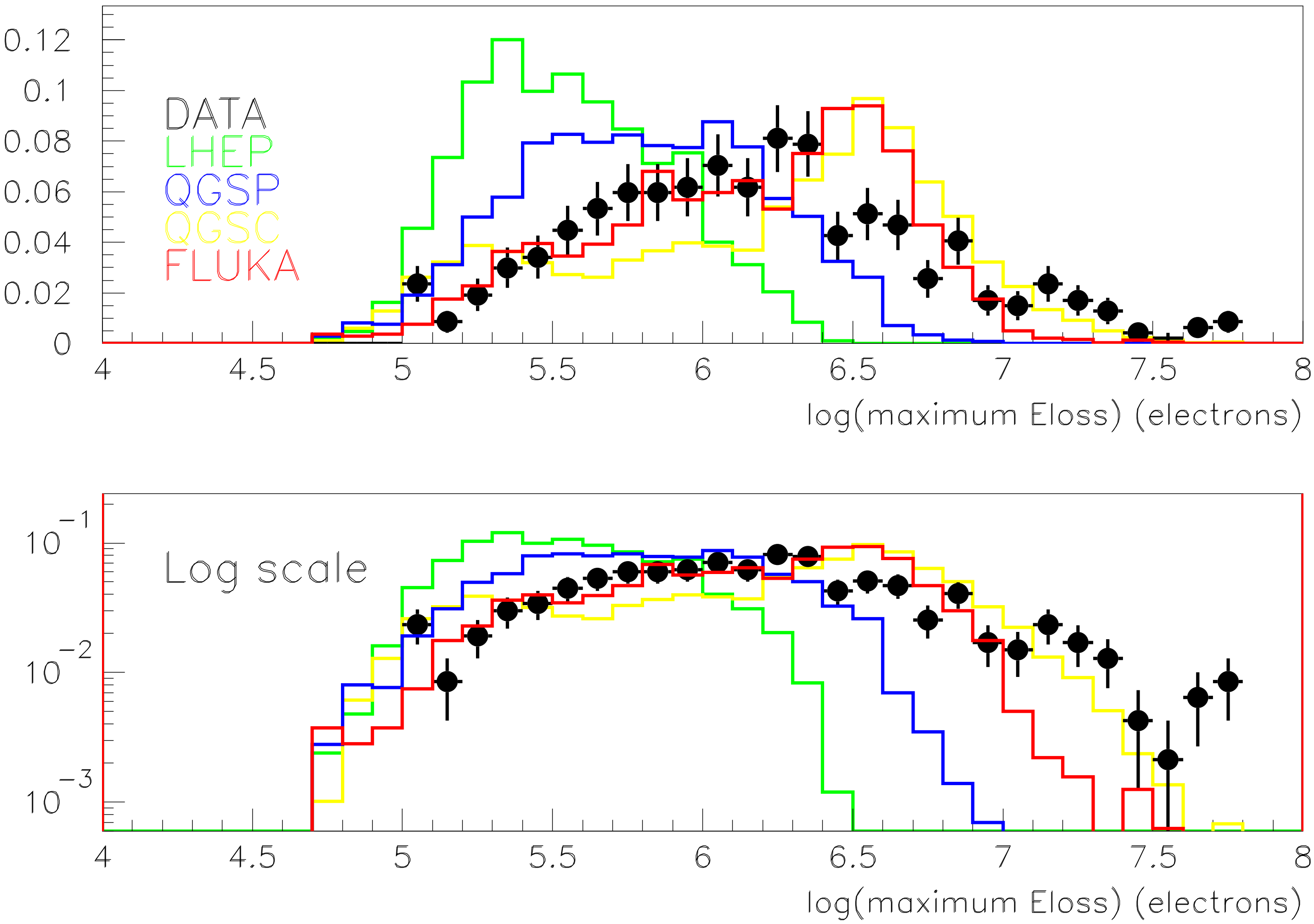


Max pixel charge

Log$_{10}$ of the maximum energy released in a pixel.

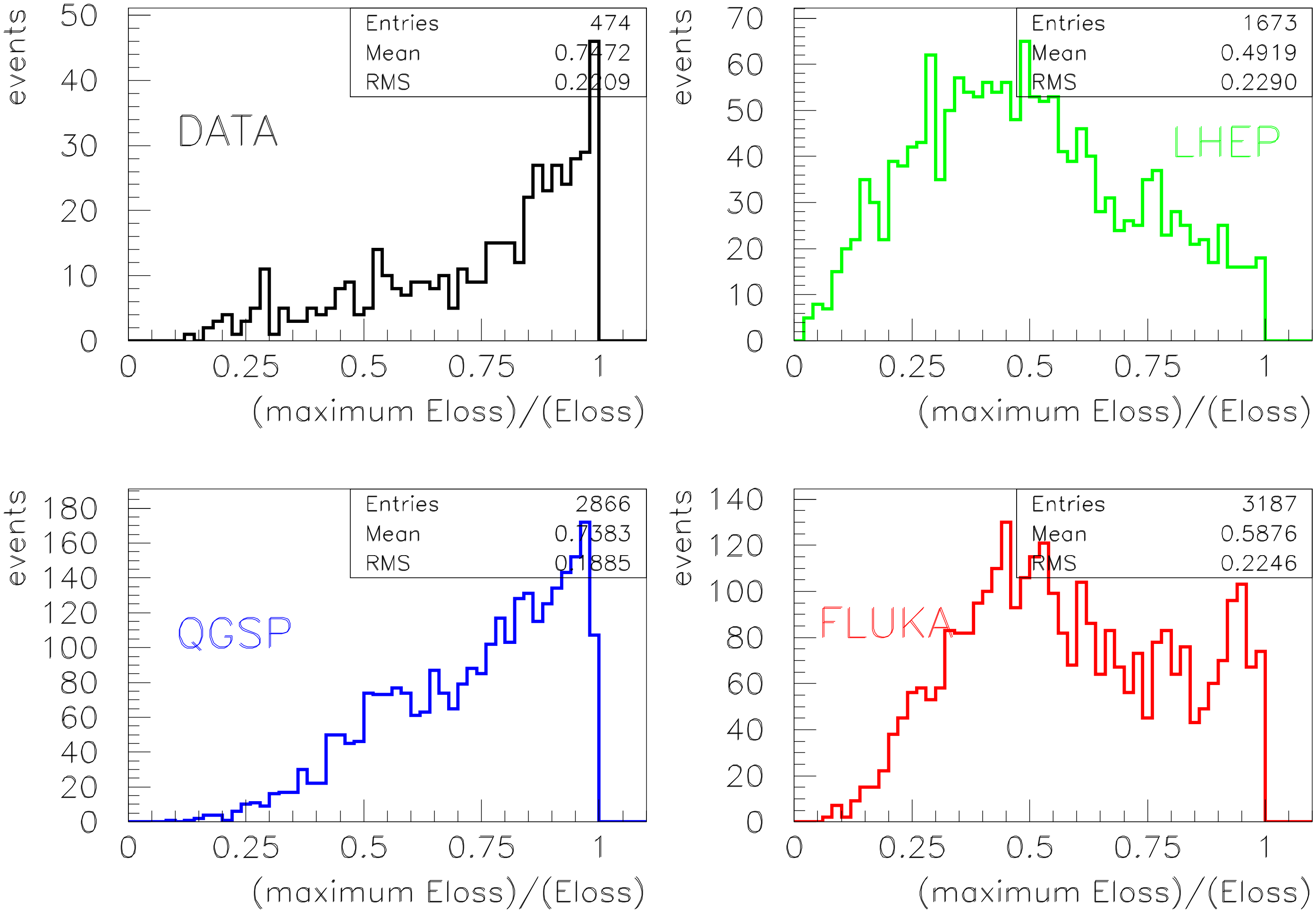


Max pixel charge (cont.)

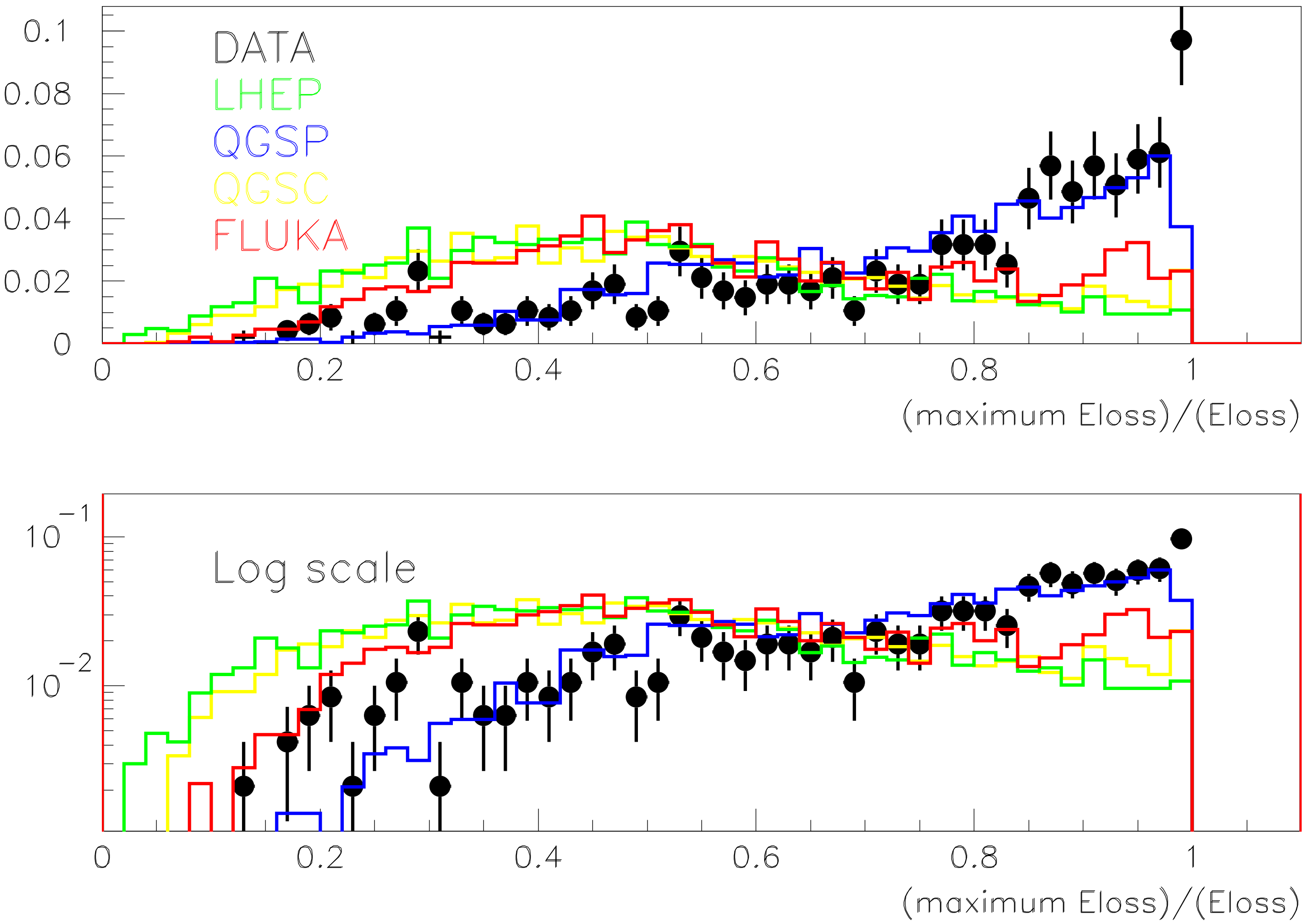


Ratio max pixel charge / total charge

Ratio of the maximum charge released in a single pixel and the total cluster charge.

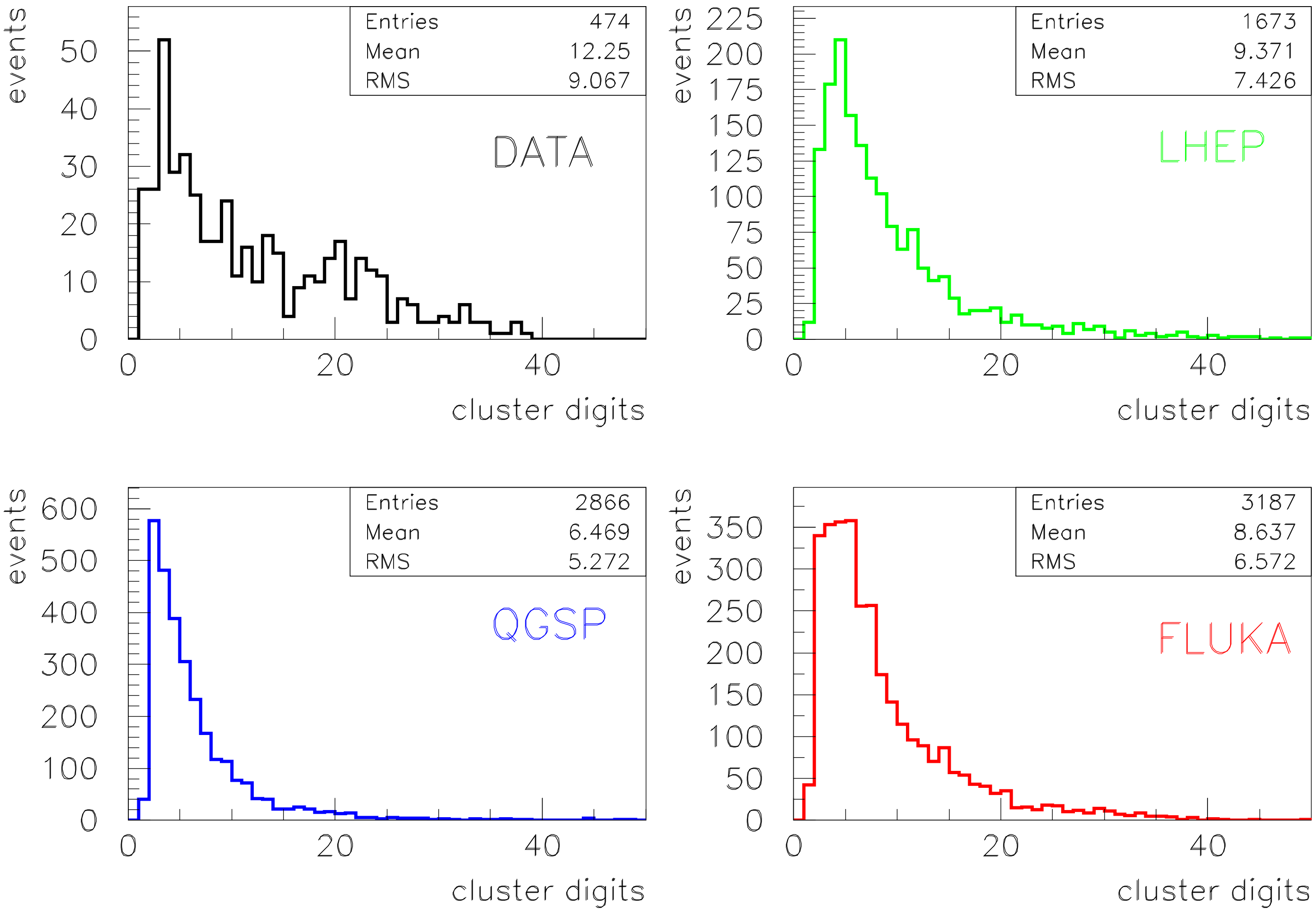


Ratio max pixel charge / total charge (cont.)

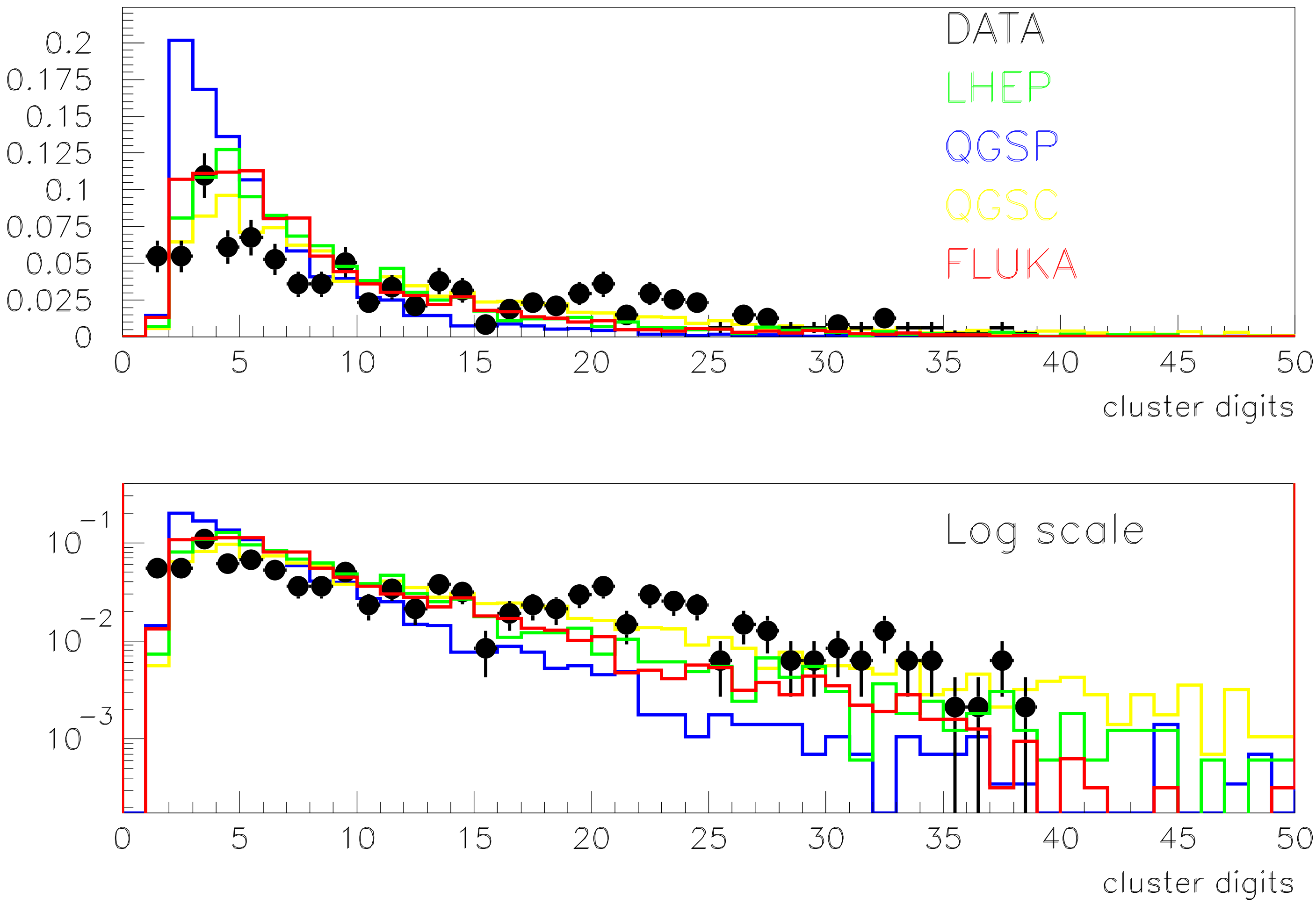


Cluster size

Number of digits (i.e. pixels) in the cluster.

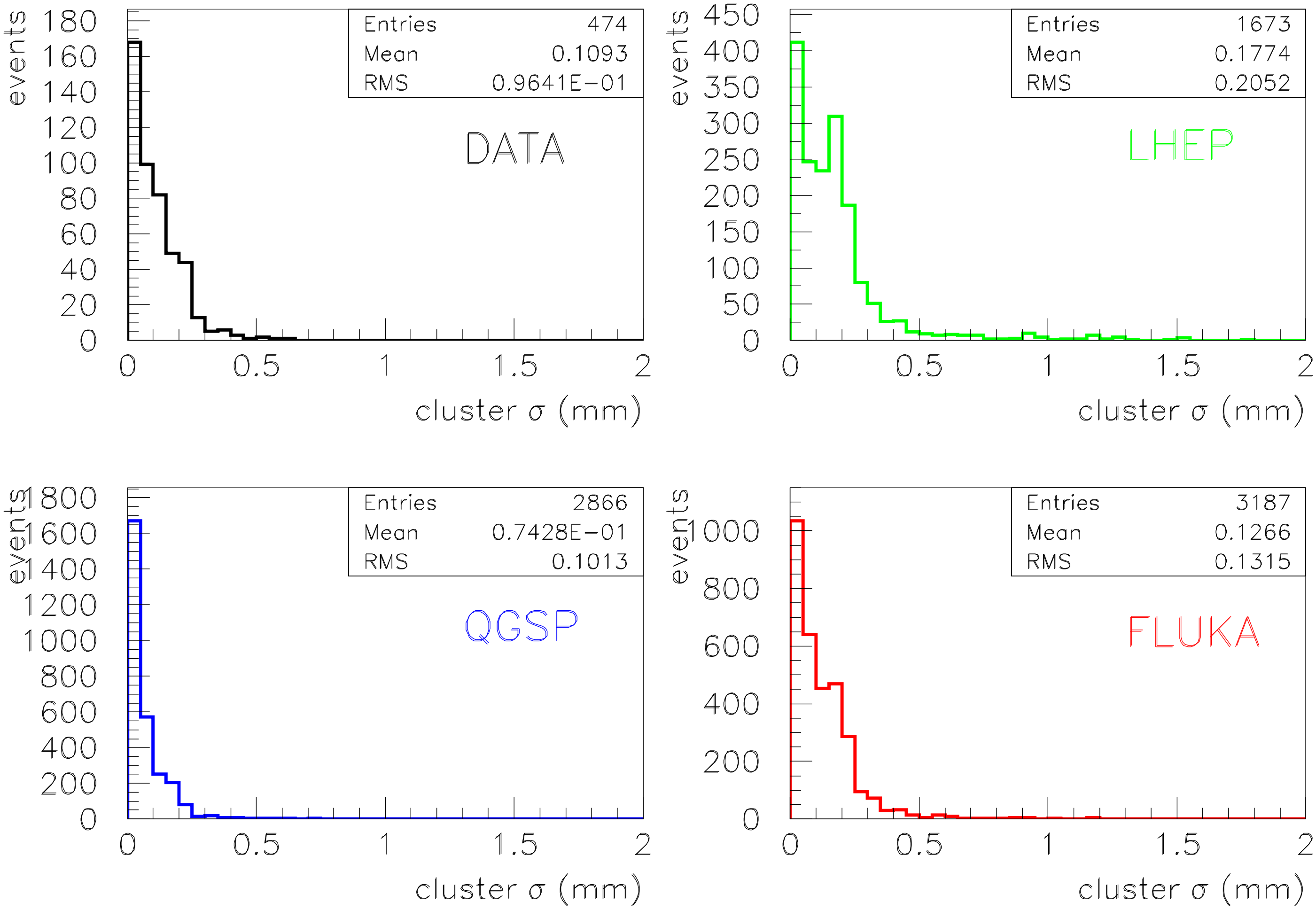


Cluster size

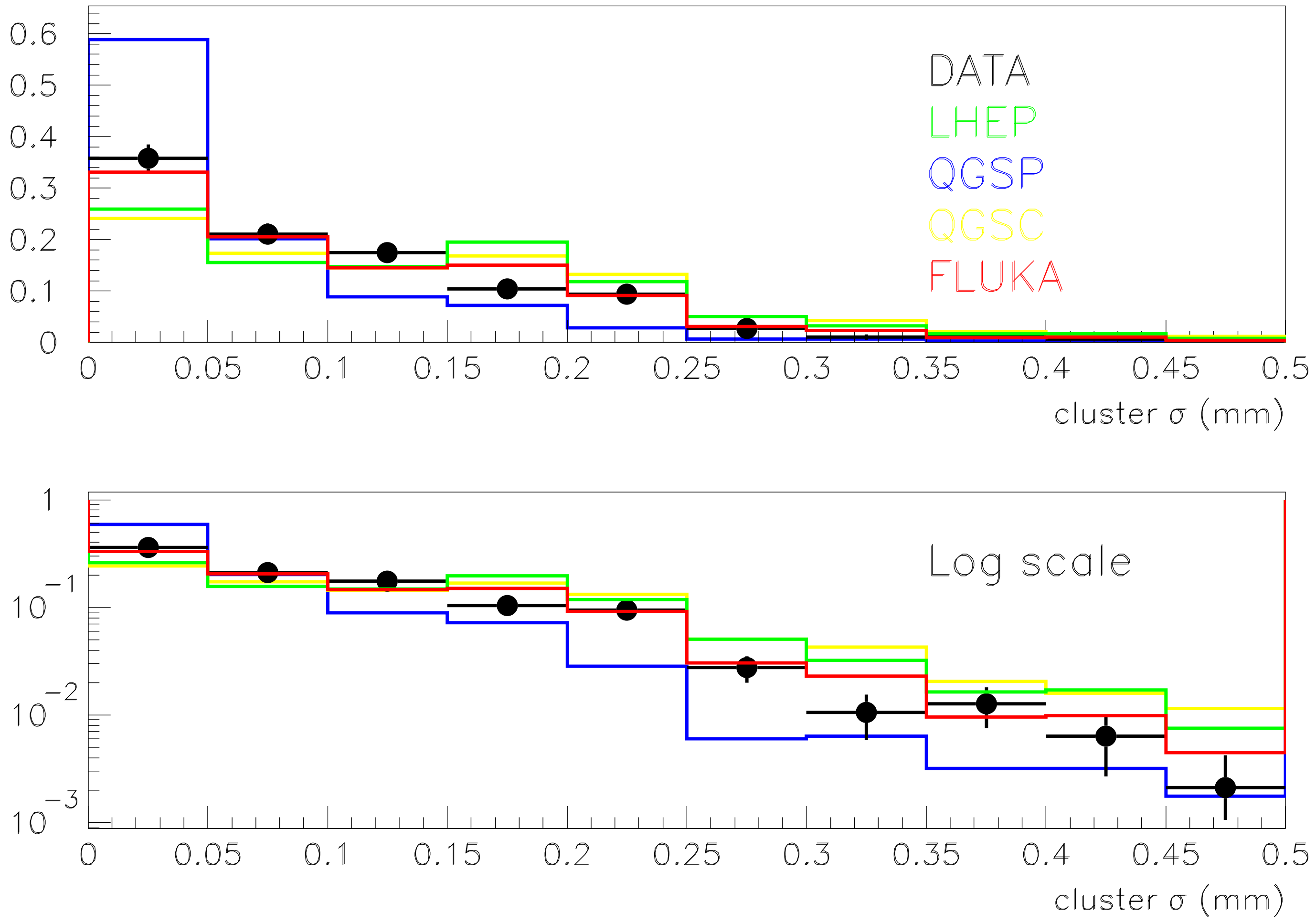


Cluster width

Width of the cluster (mean of the distances of all digits from the cluster barycenter, weighted with the charge of the digits).

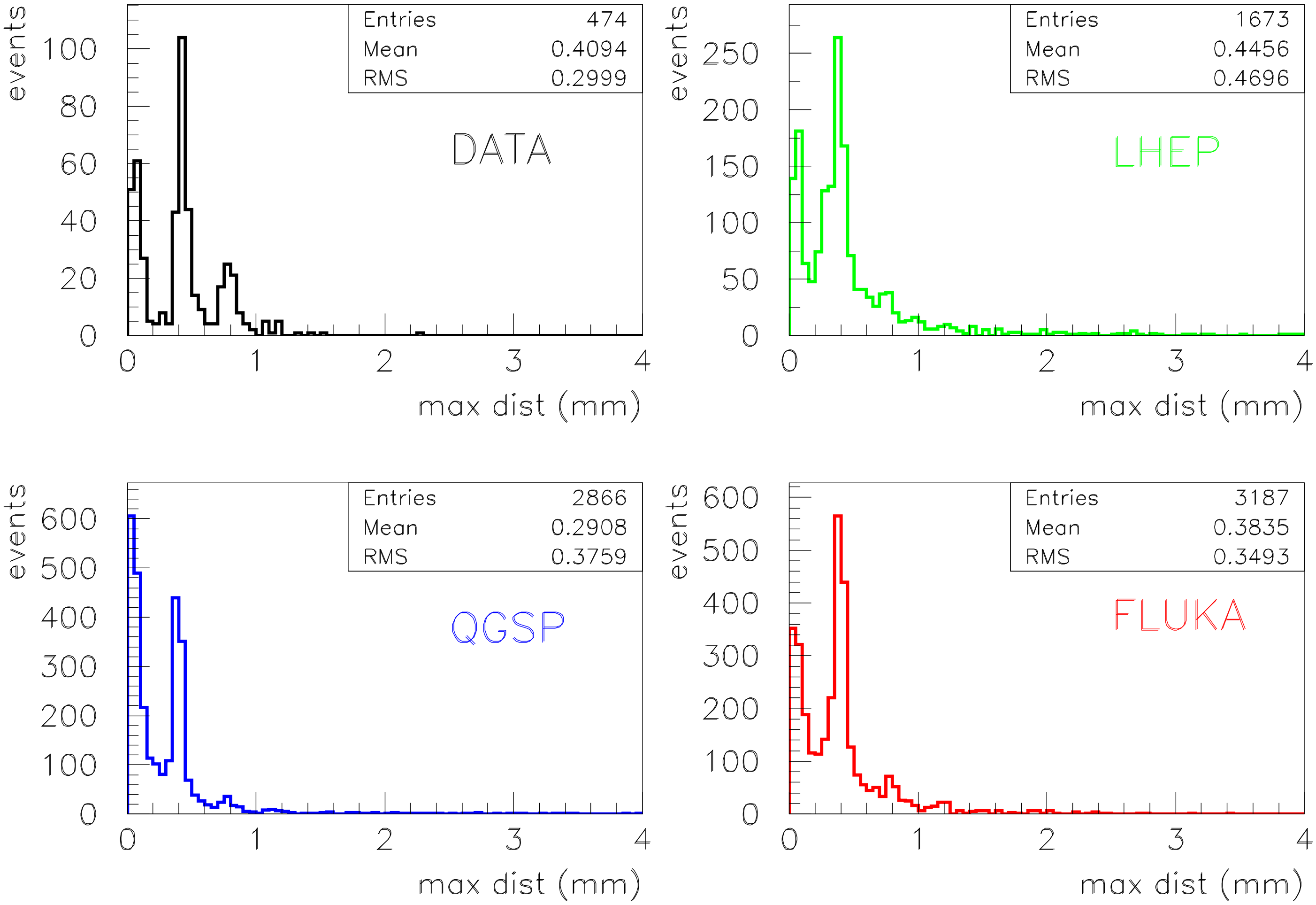


Cluster width (cont.)

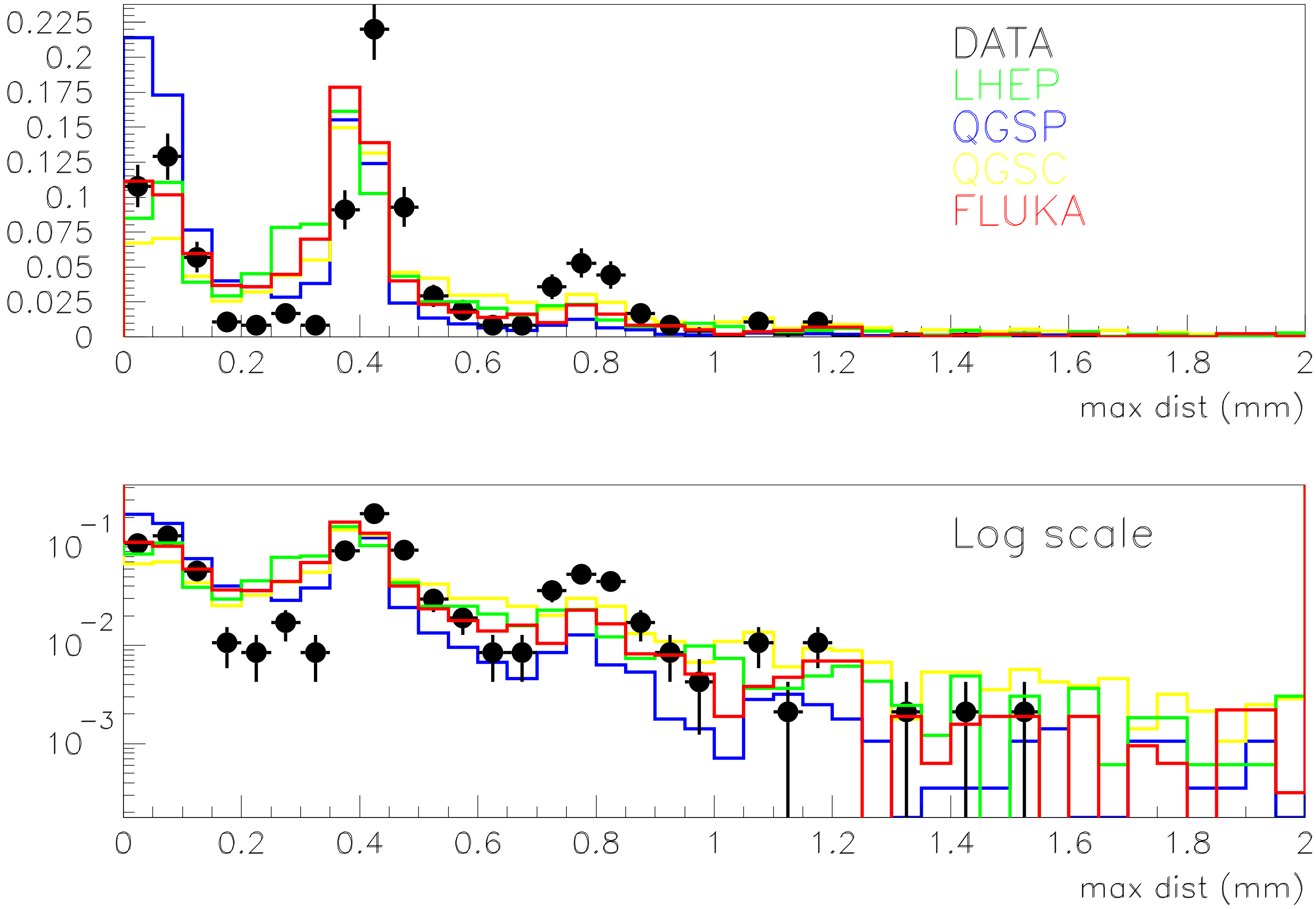


Max distance

Distance of the farthest digit from the cluster barycenter (the peak structure corresponds to the $400\,\mu m$ pixel length).

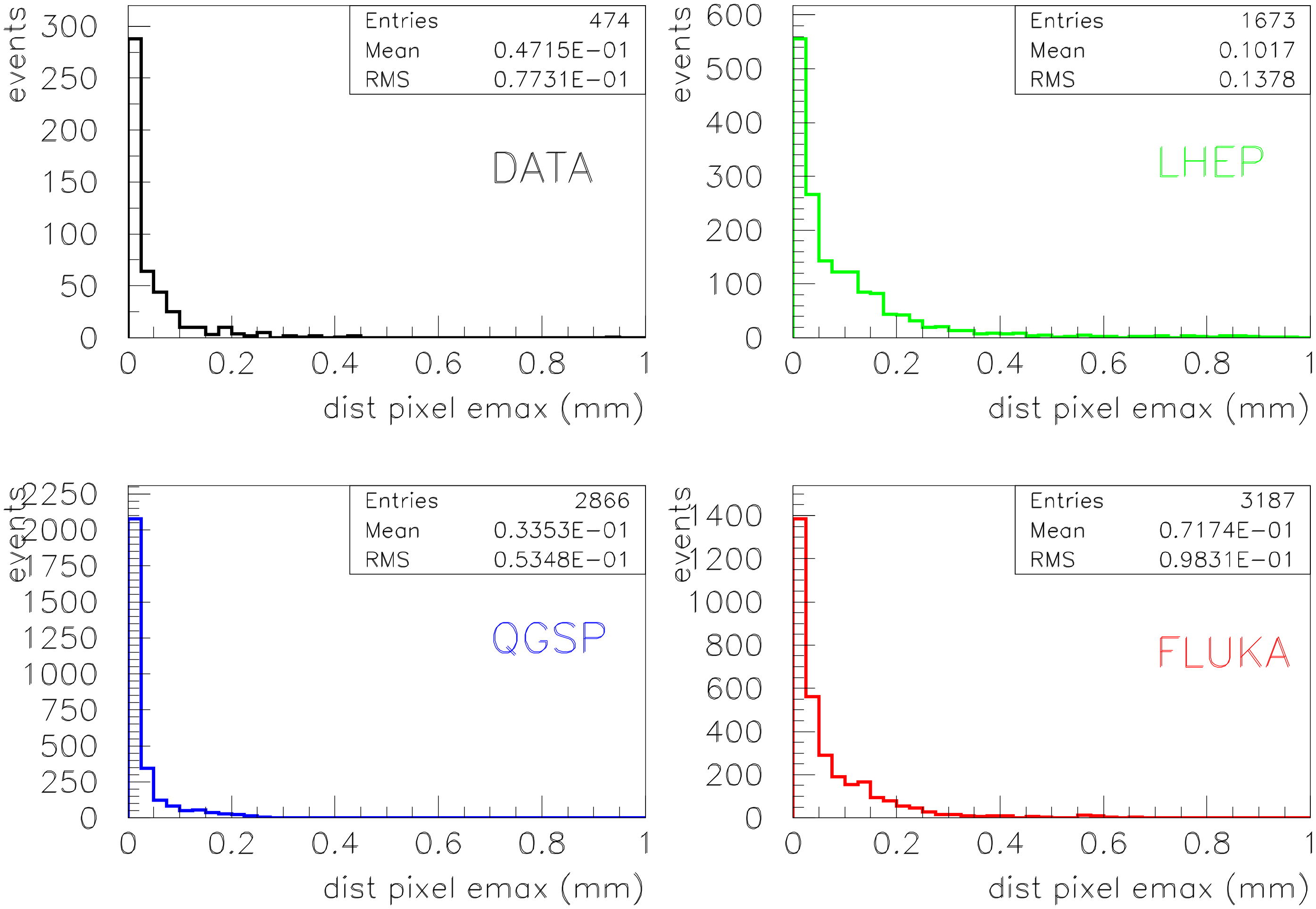


Max distance (cont.)

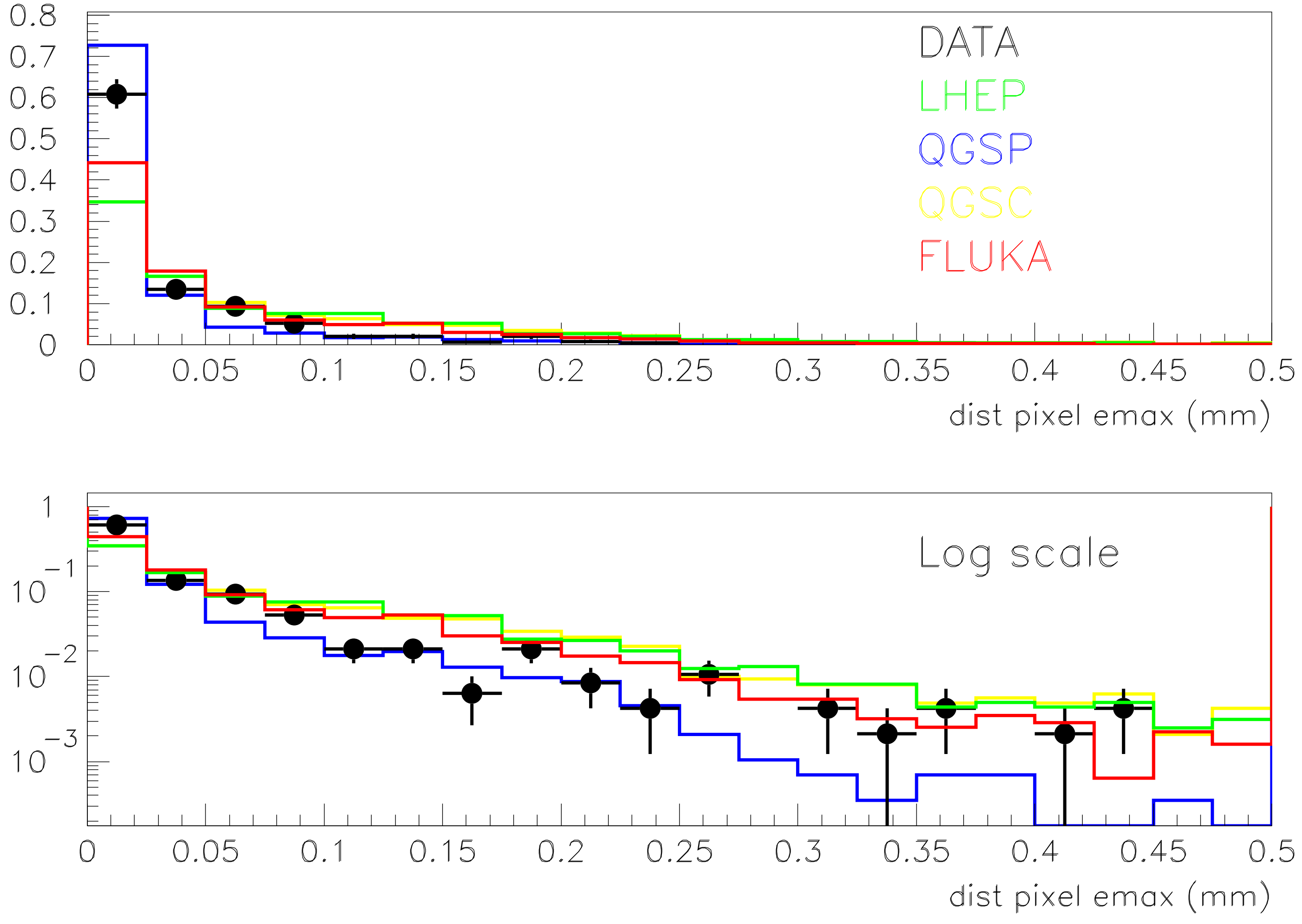


Distance of max pixel charge

Distance of the digit with highest charge from the cluster barycenter.



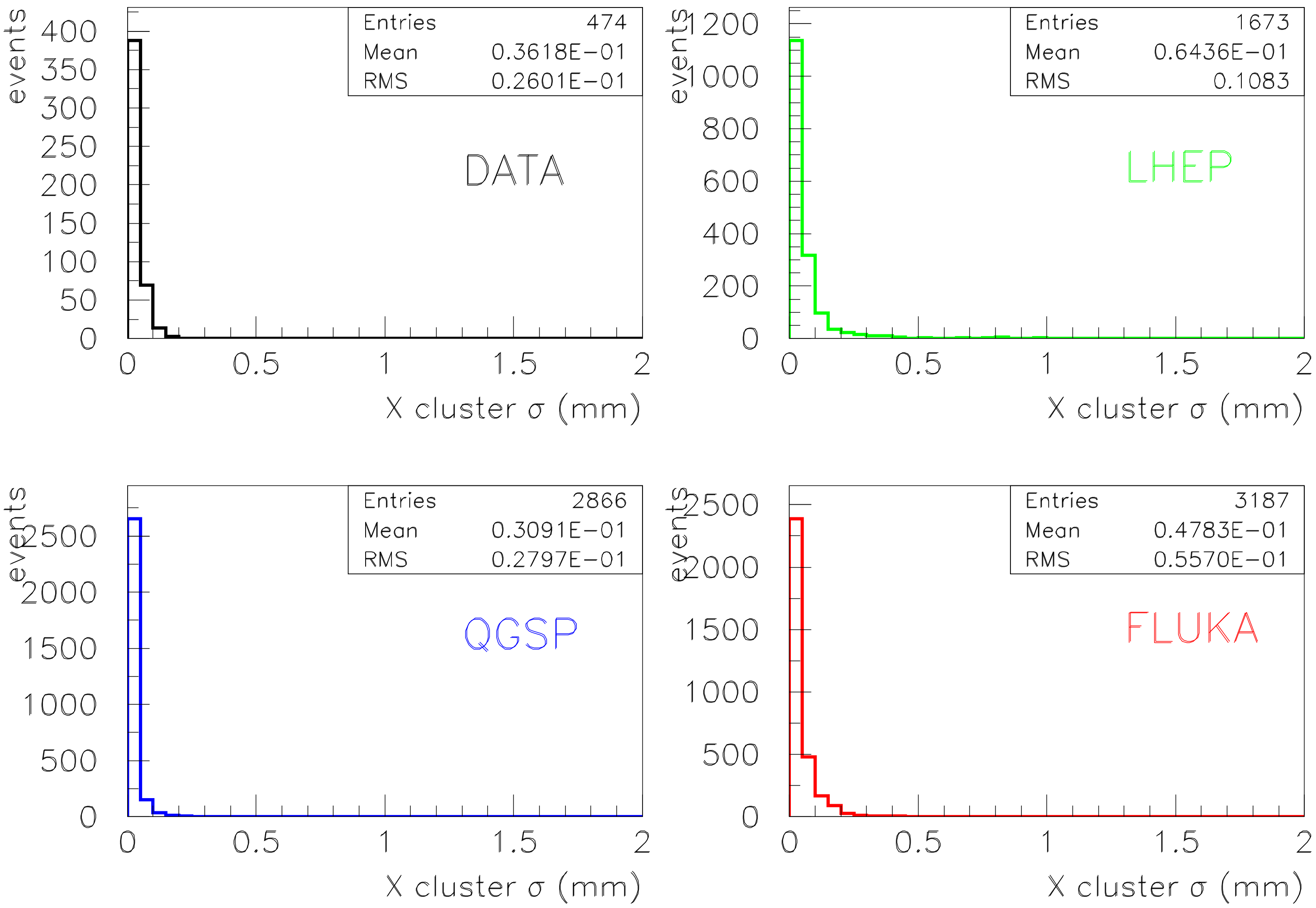
Distance of max pixel charge (cont.)



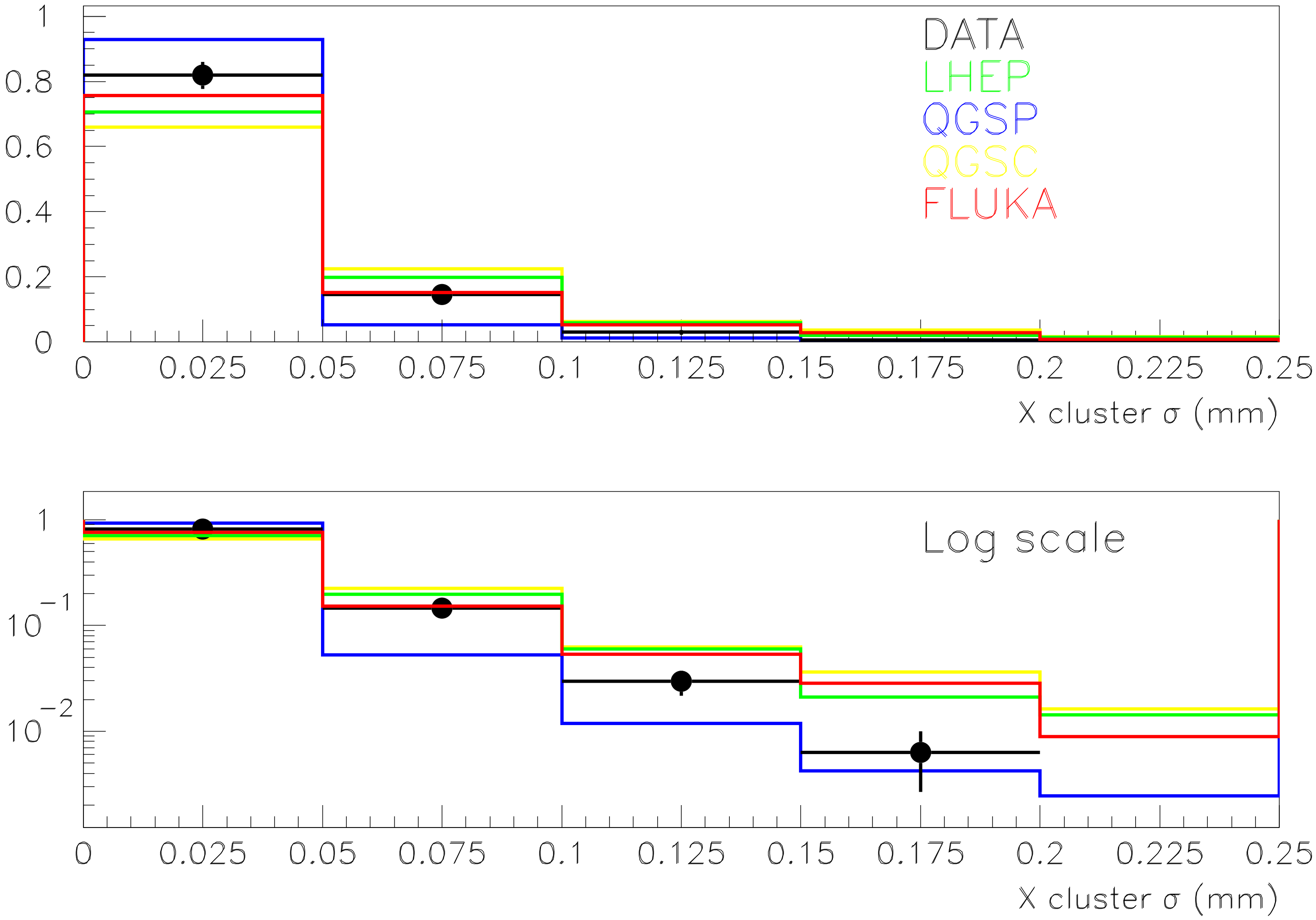
Some checks

- Do the distributions change for small variations of the beam spot ?
- Do the distributions change by reasonable variation of the the noise ?
- Do the distributions change by varying the pixel clustering zero-suppression threshold ?
- Study of the spatial properties of the vertex cluster separately in x and y .
- Look at the other clusters (the ones not associated with the hadronic interaction).
- Look at the correlations.

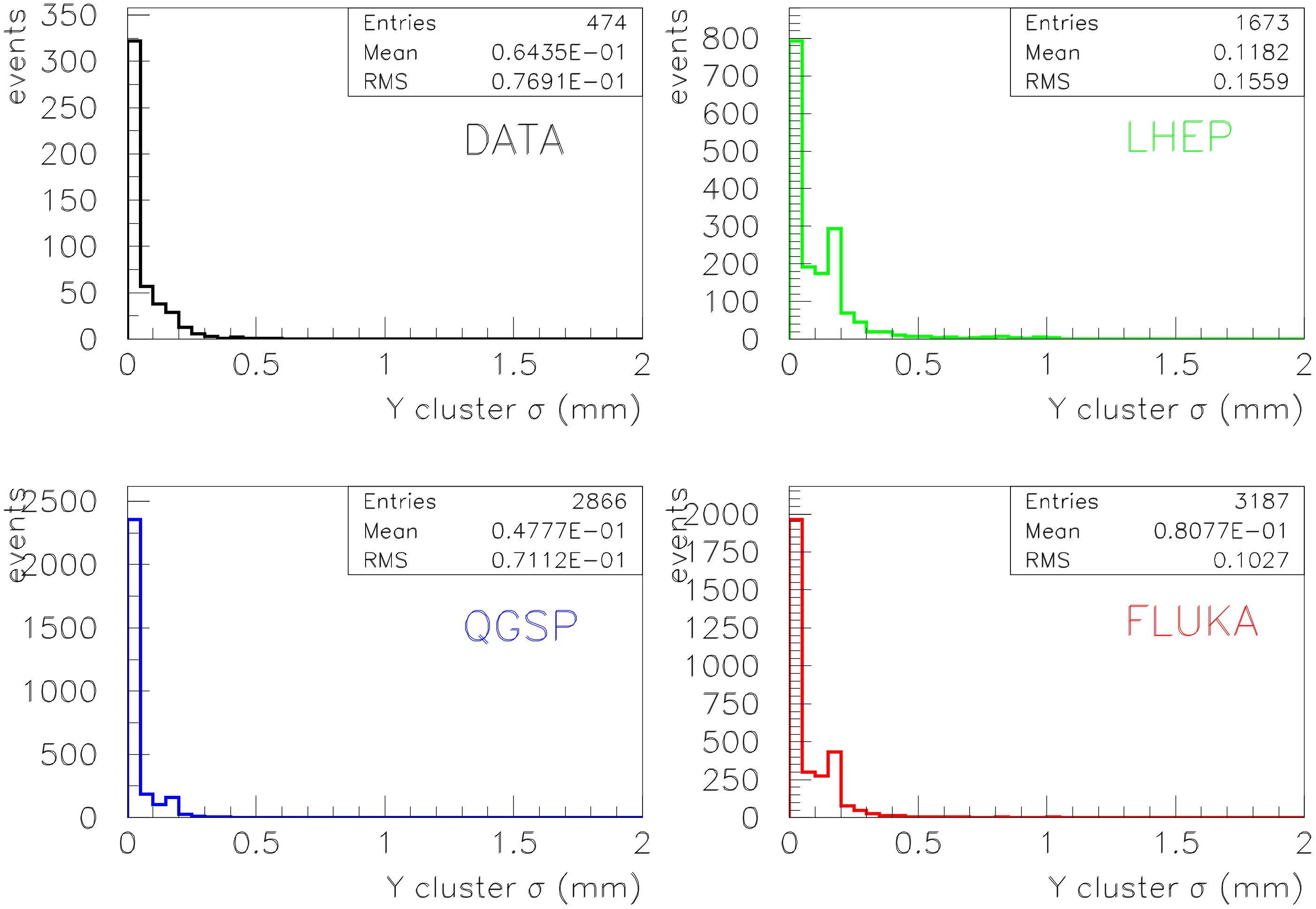
X cluster width



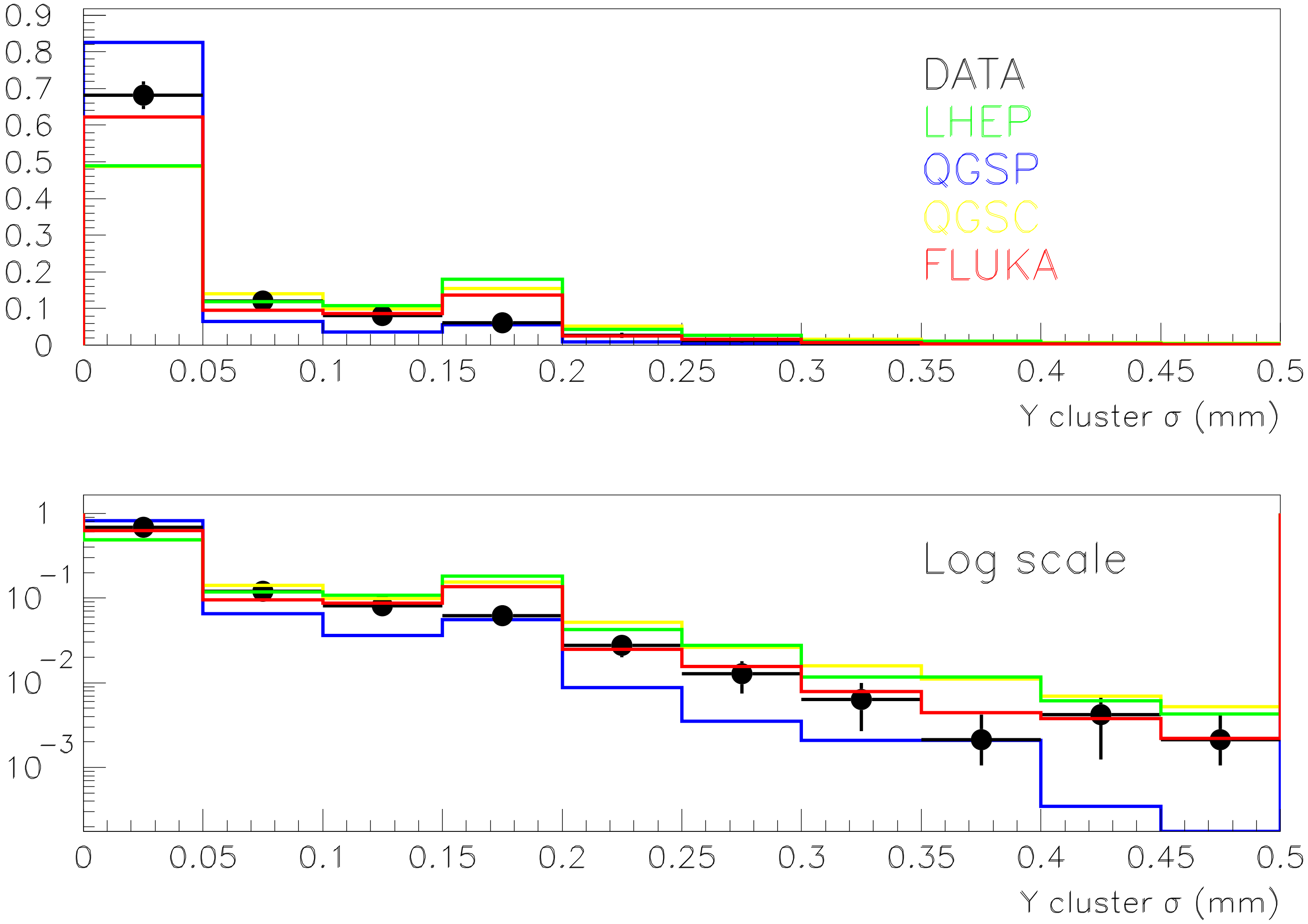
X cluster width (cont.)



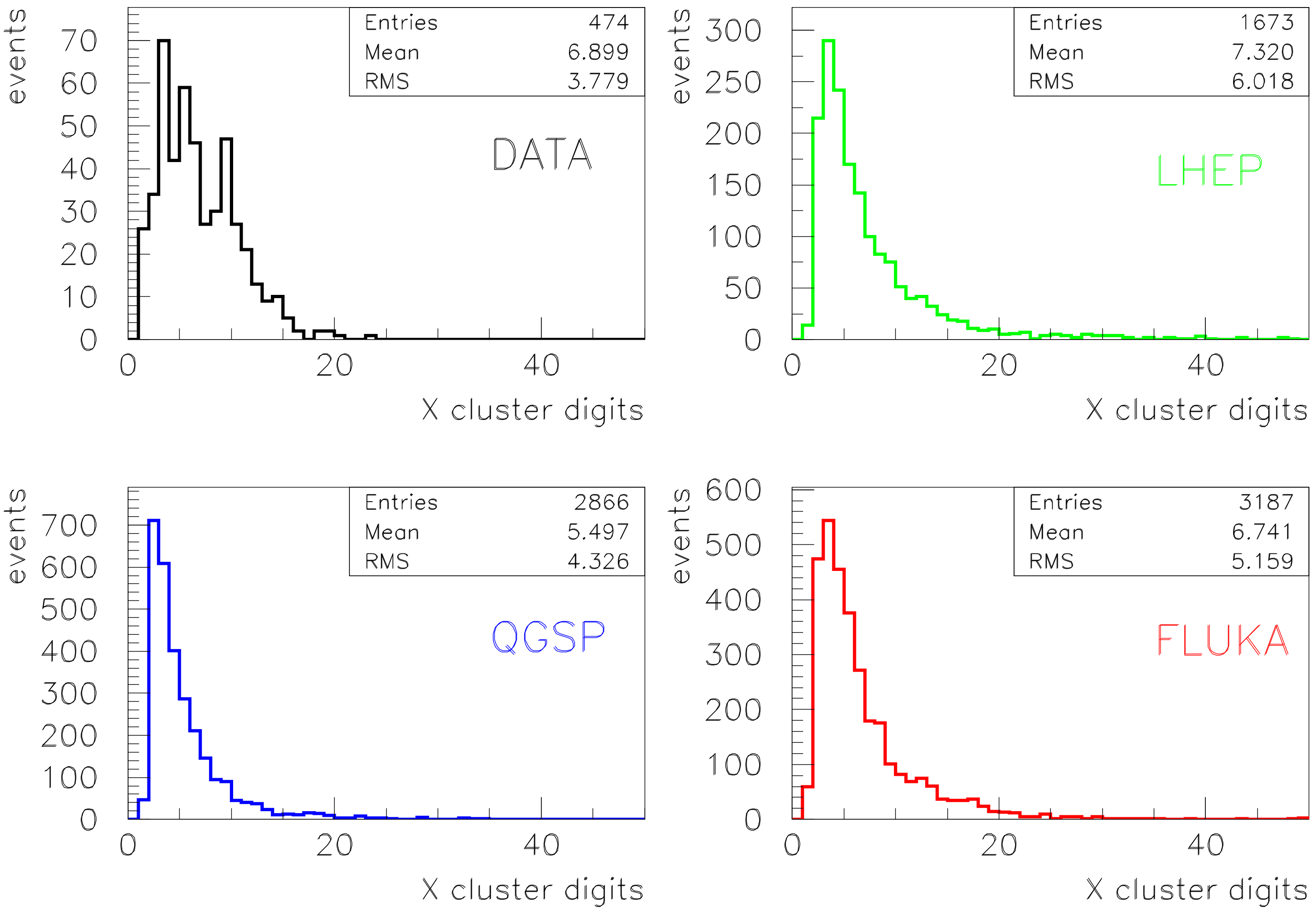
Y cluster width



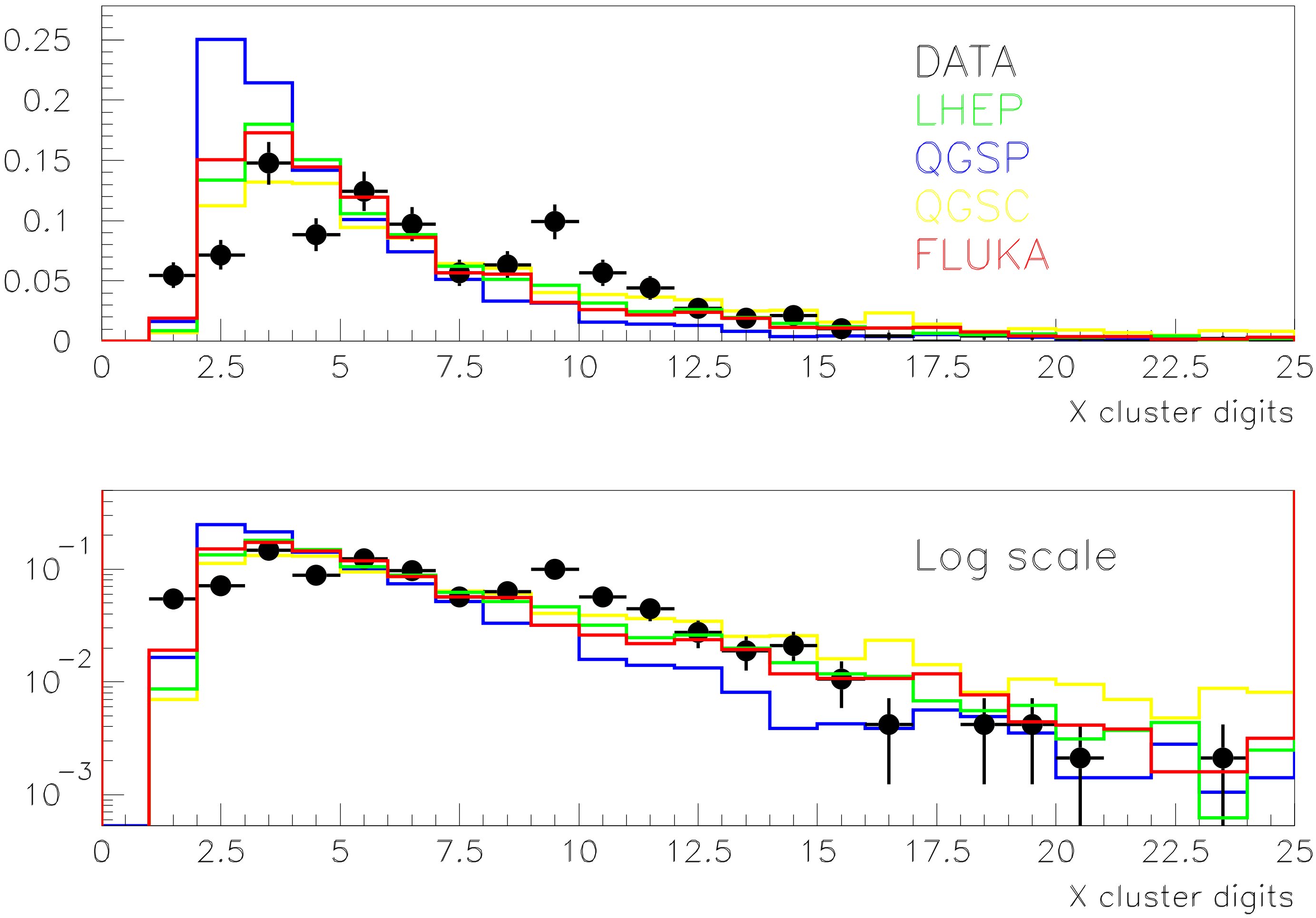
Y cluster width (cont.)



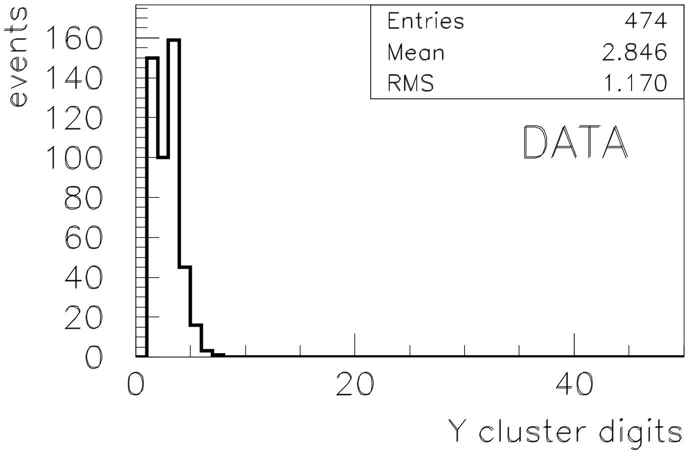
X cluster size

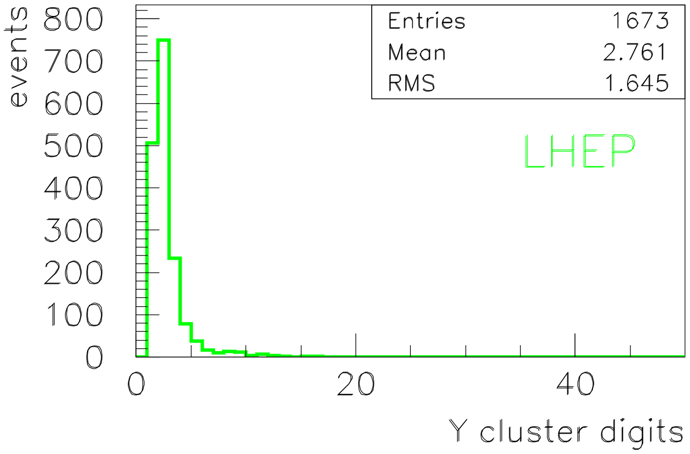


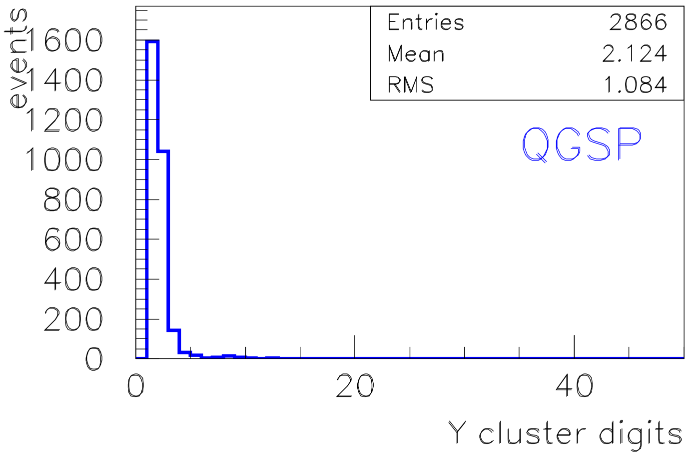
X cluster size (cont.)

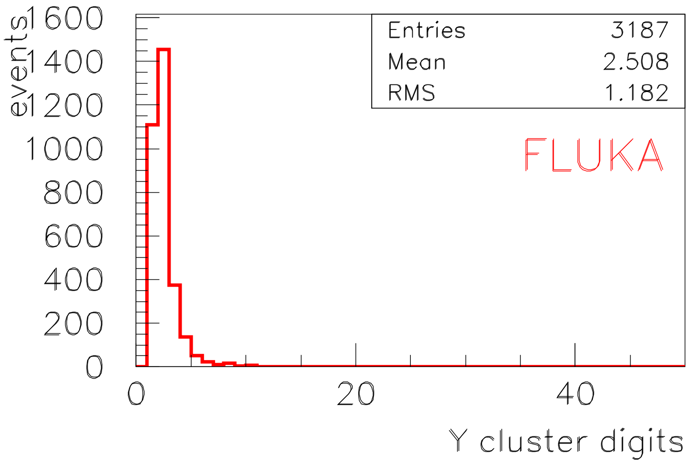


Y cluster size

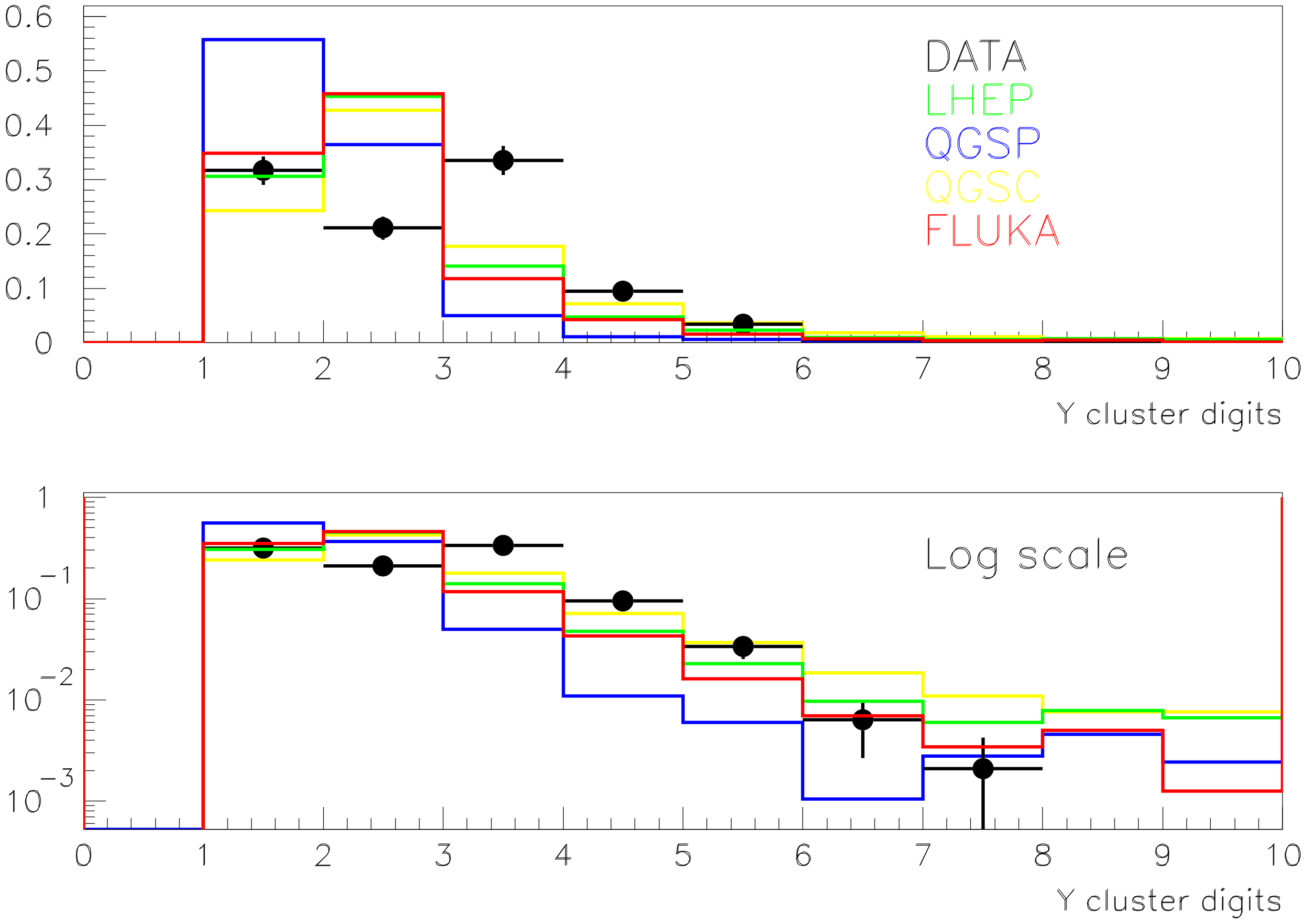




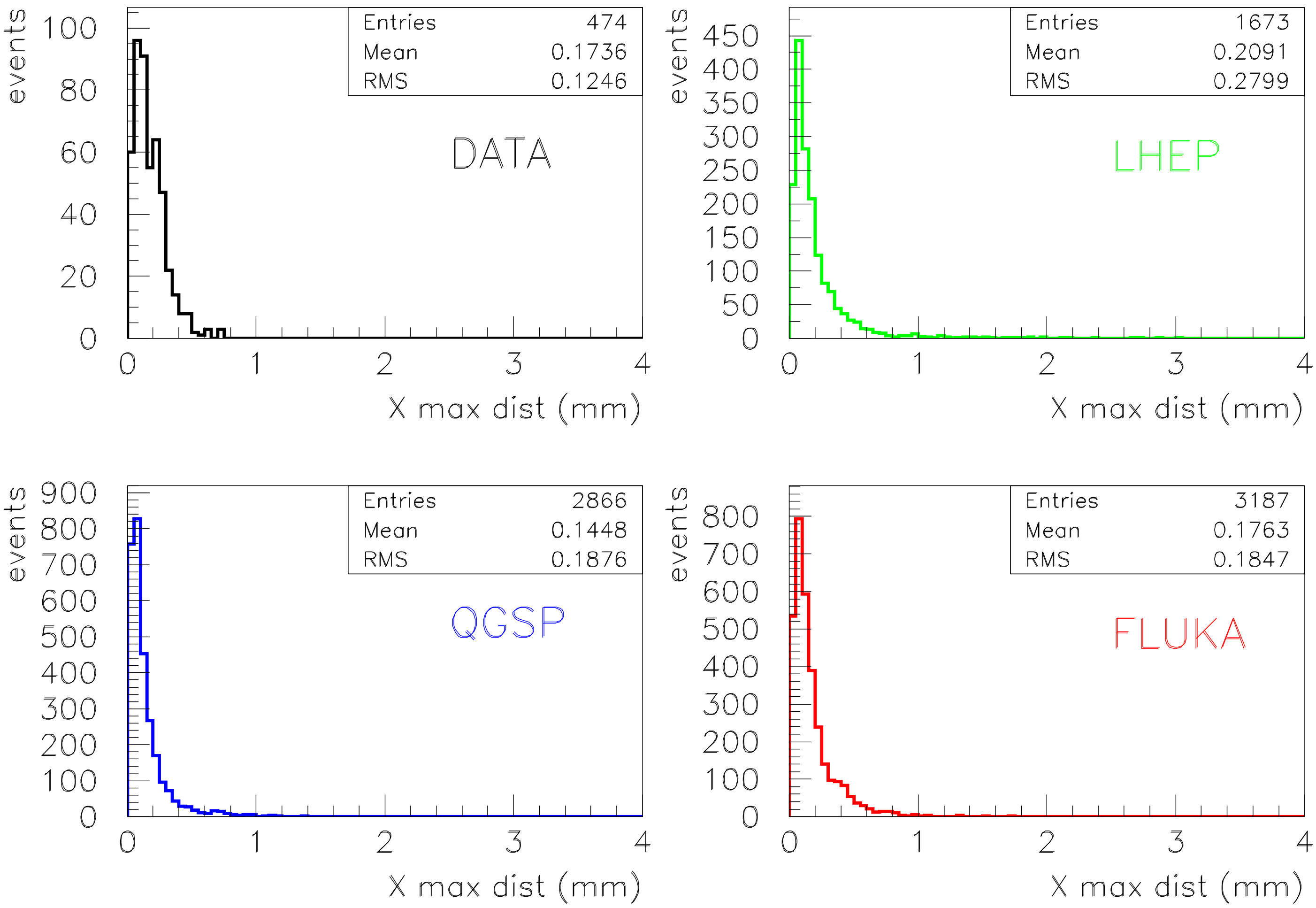




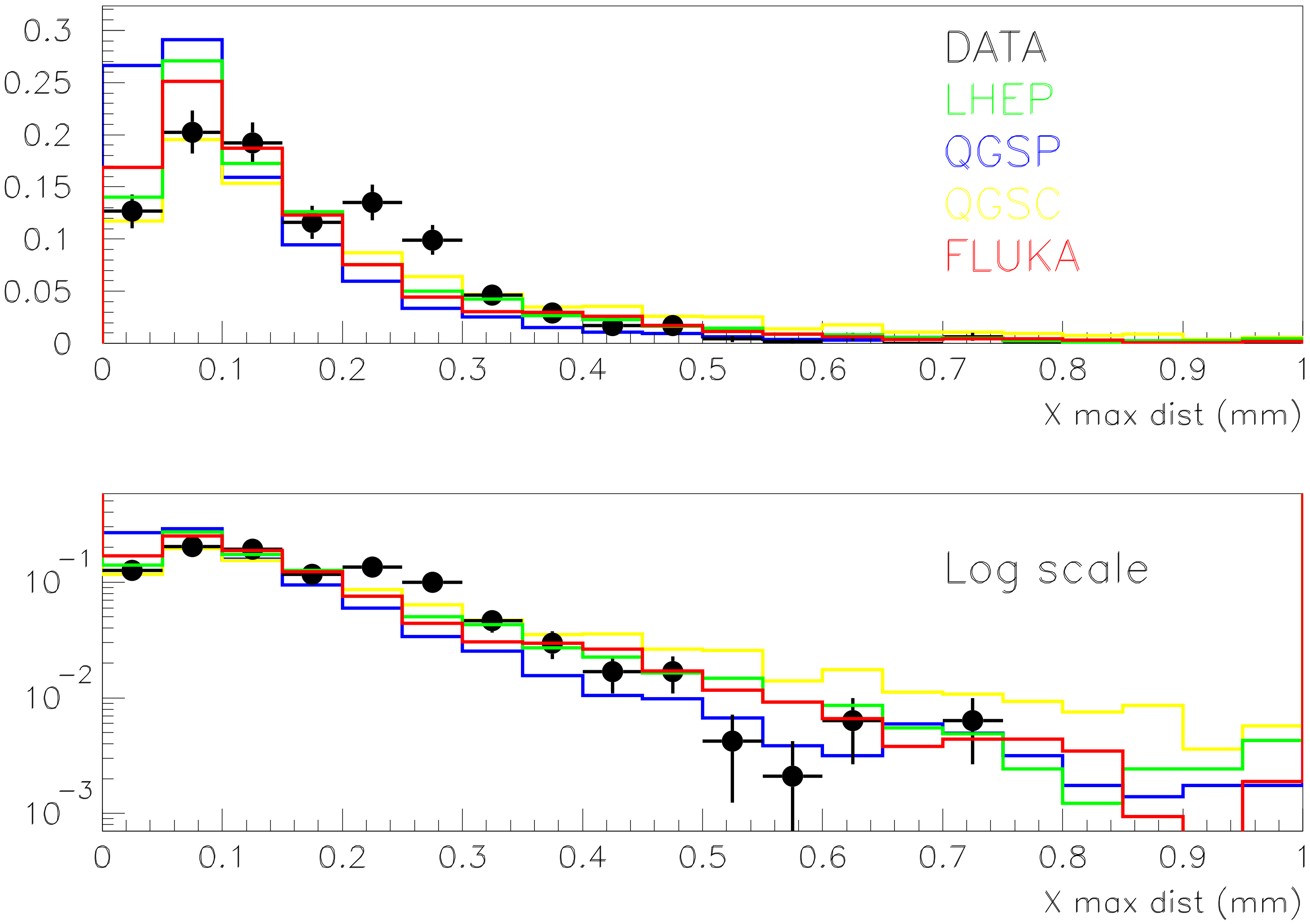
Y cluster size (cont.)



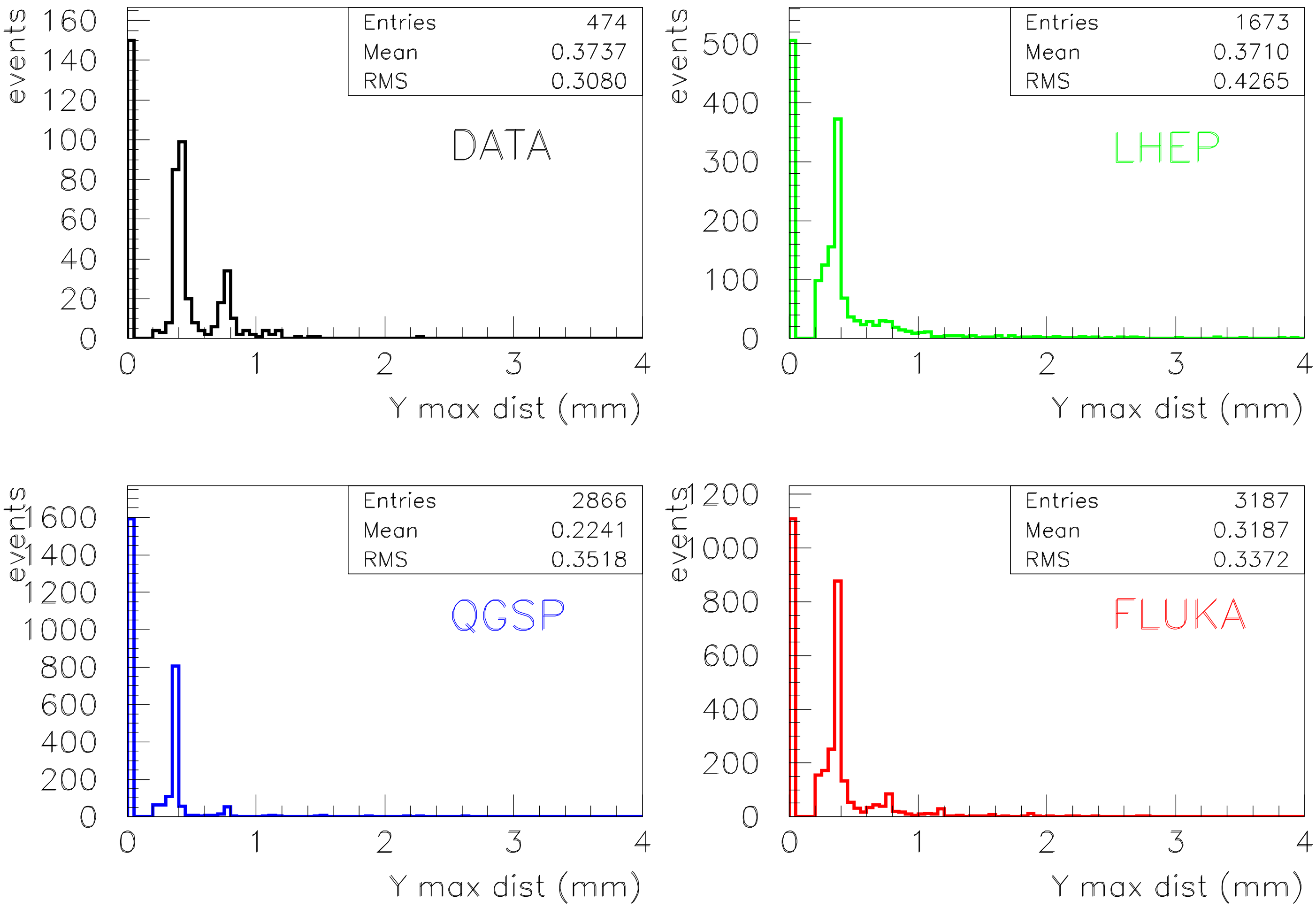
X max distance



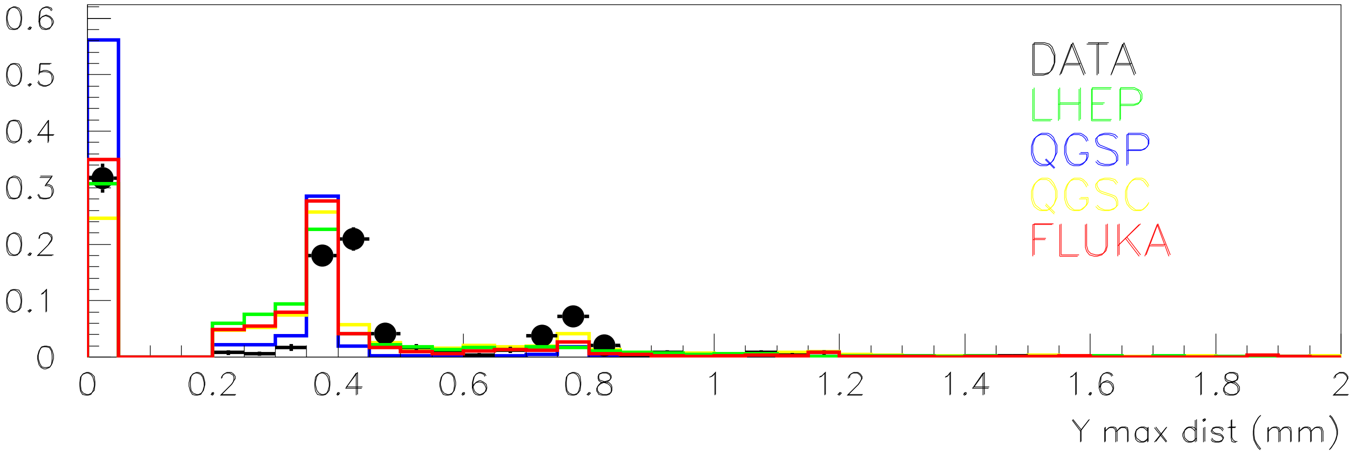
X max distance (cont.)

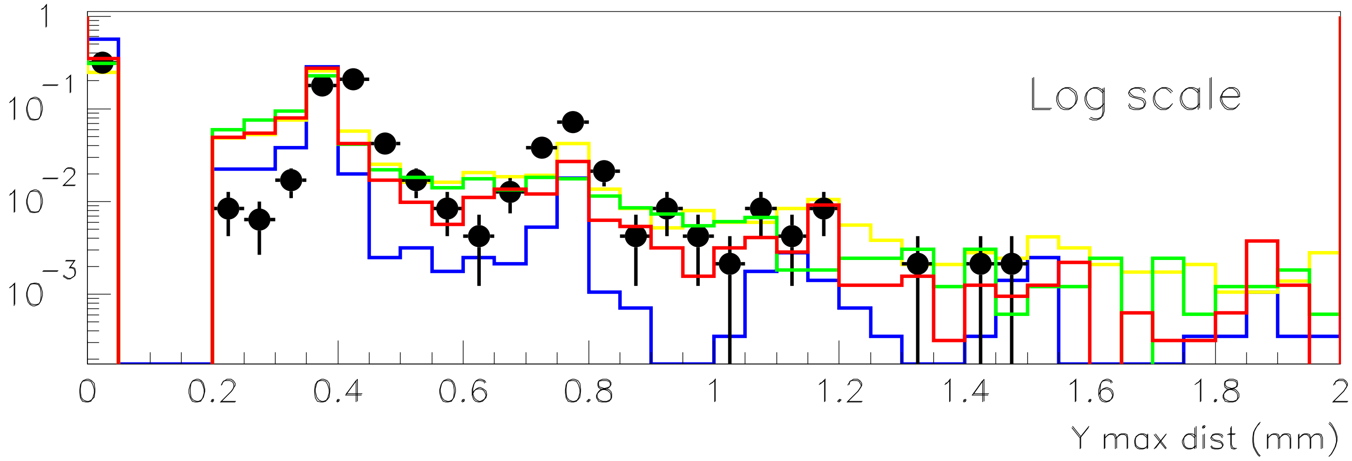


Y max distance

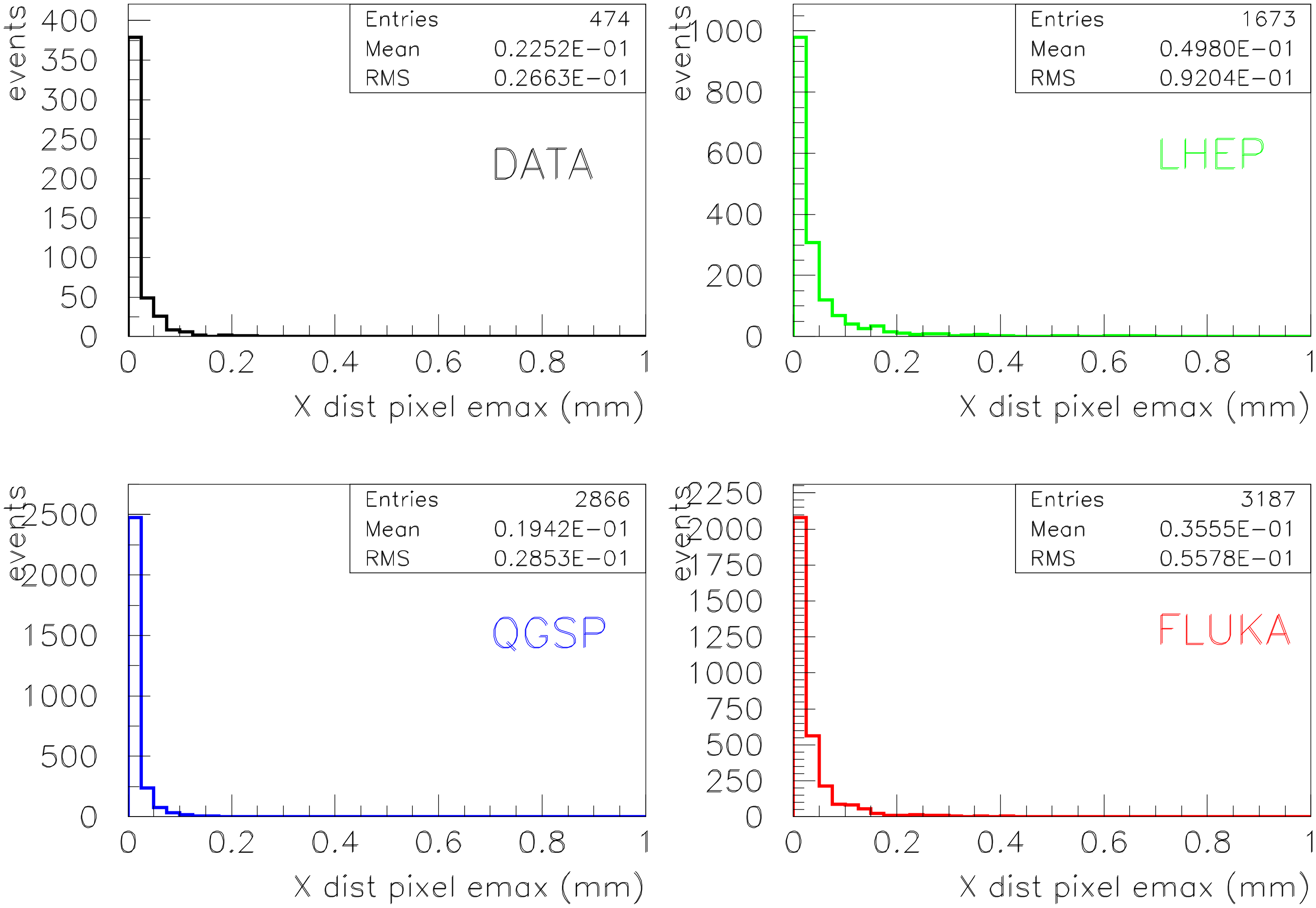


Y max distance (cont.)

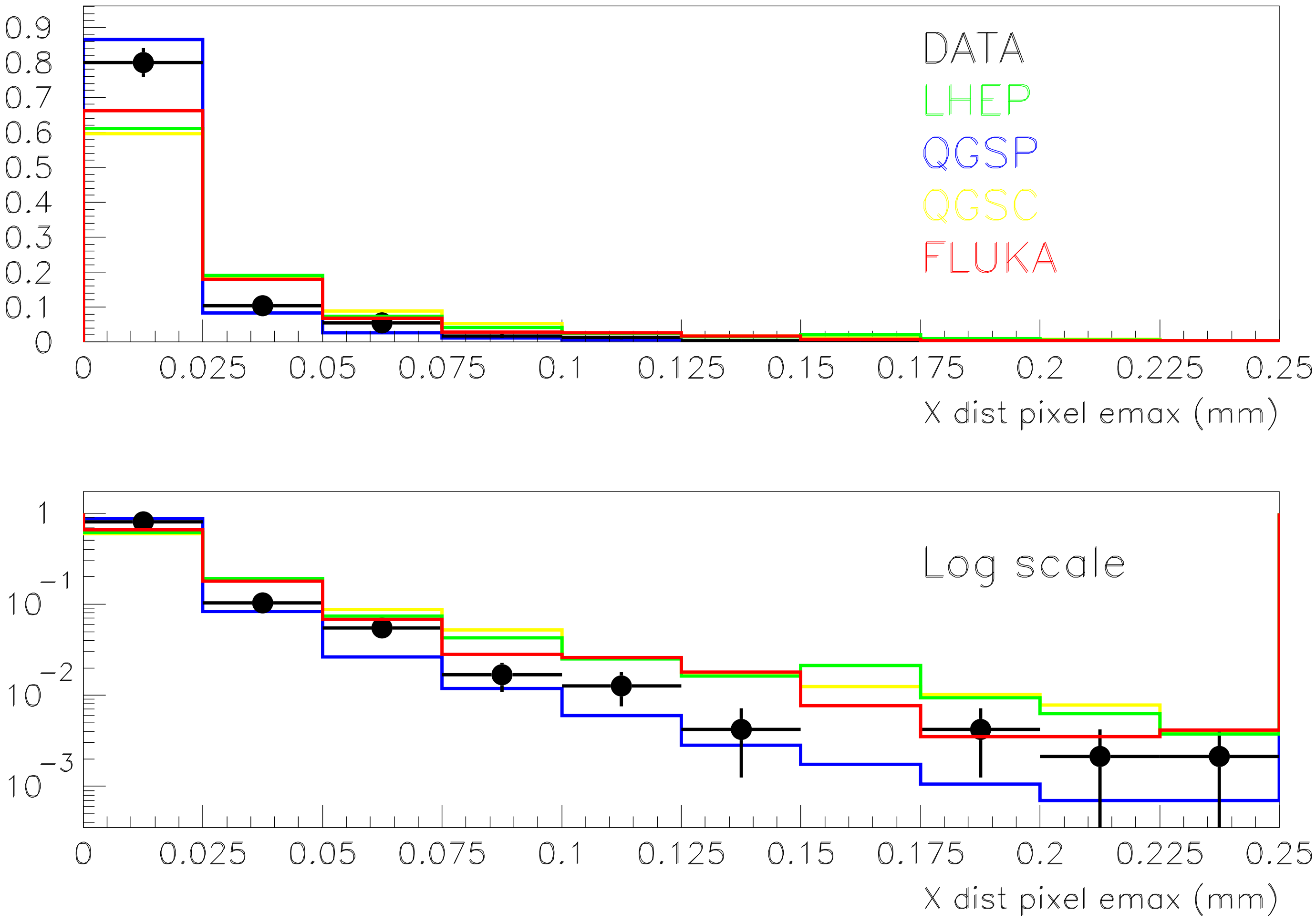




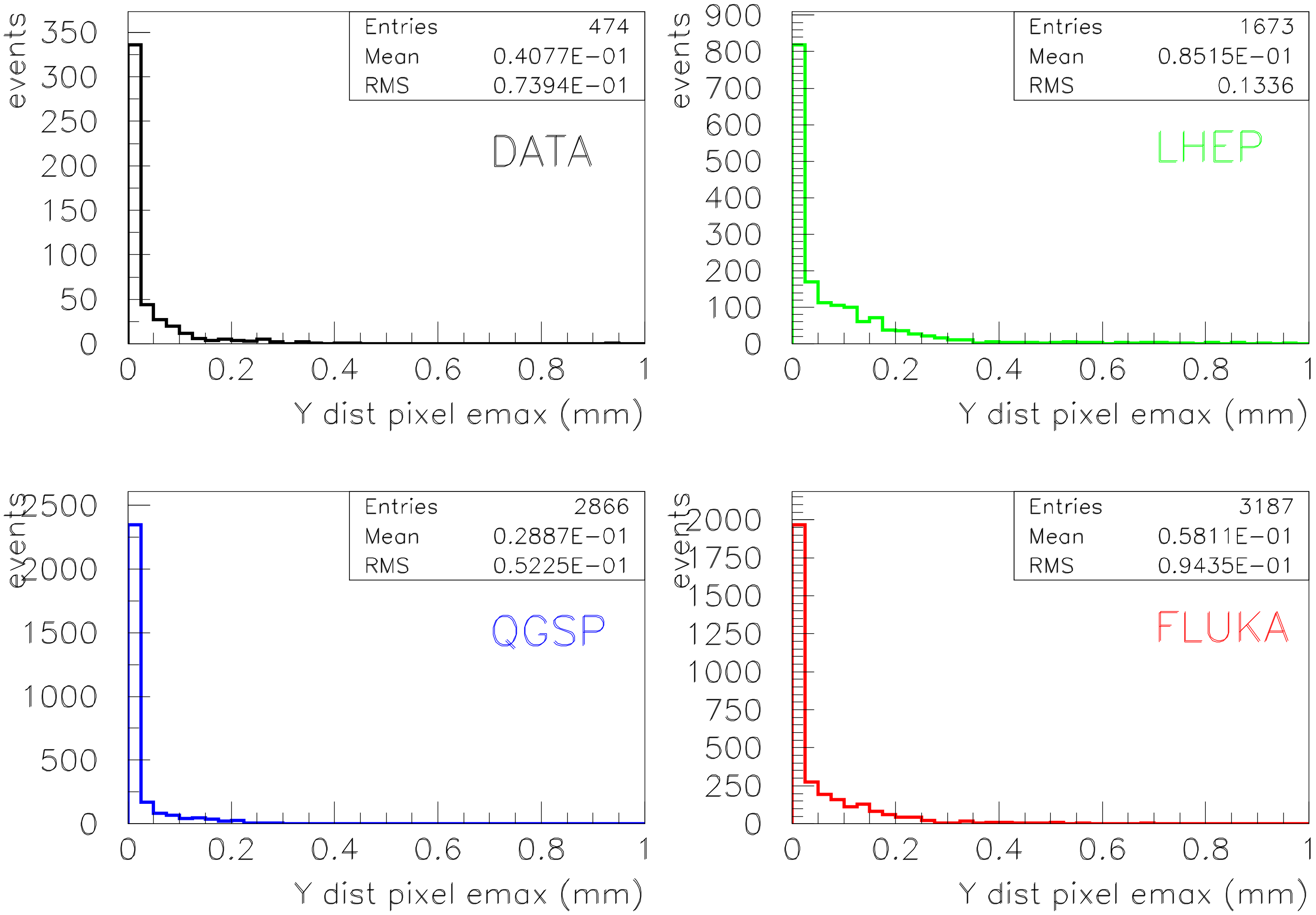
X distance of max pixel charge



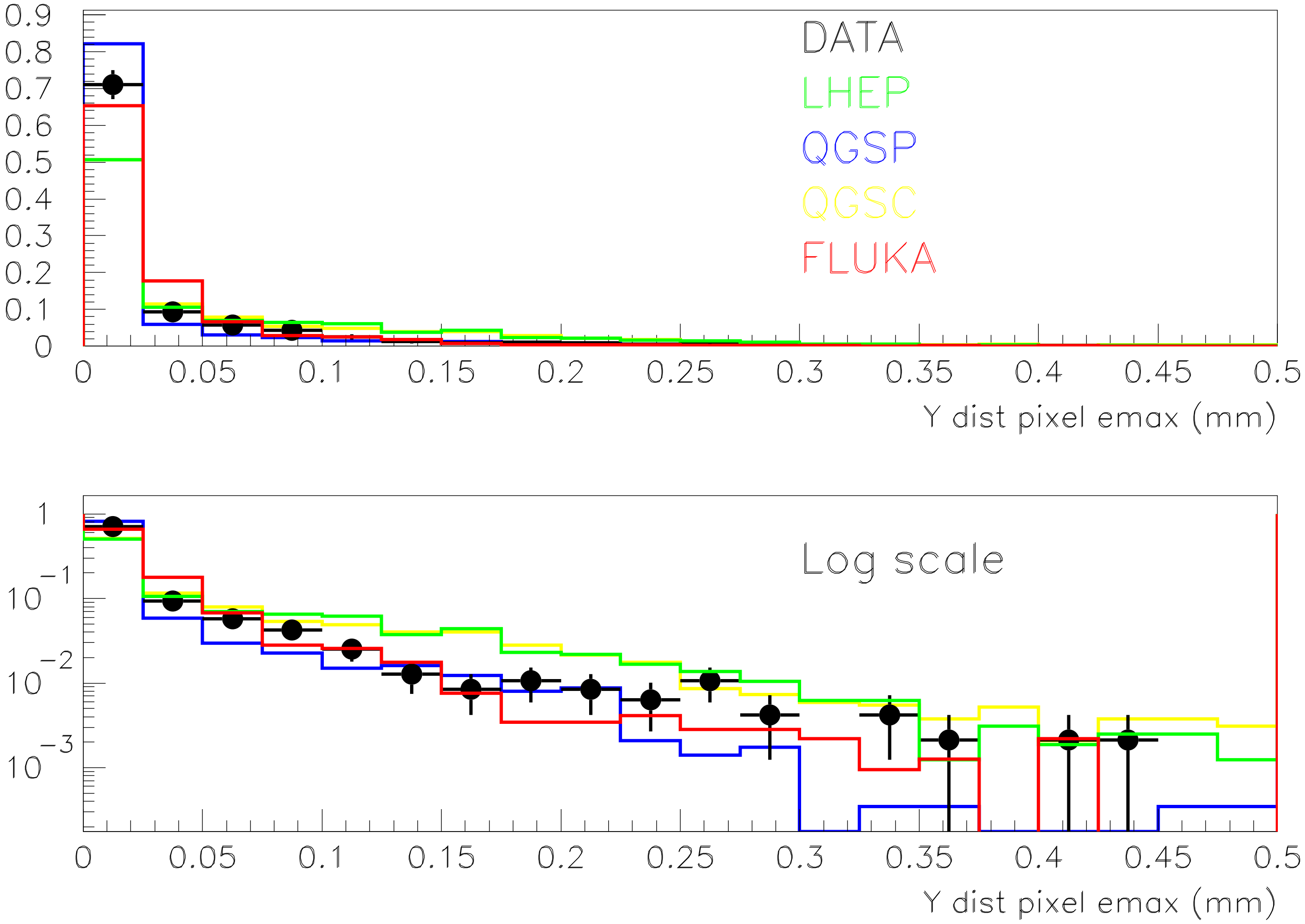
X distance of max pixel charge (cont.)



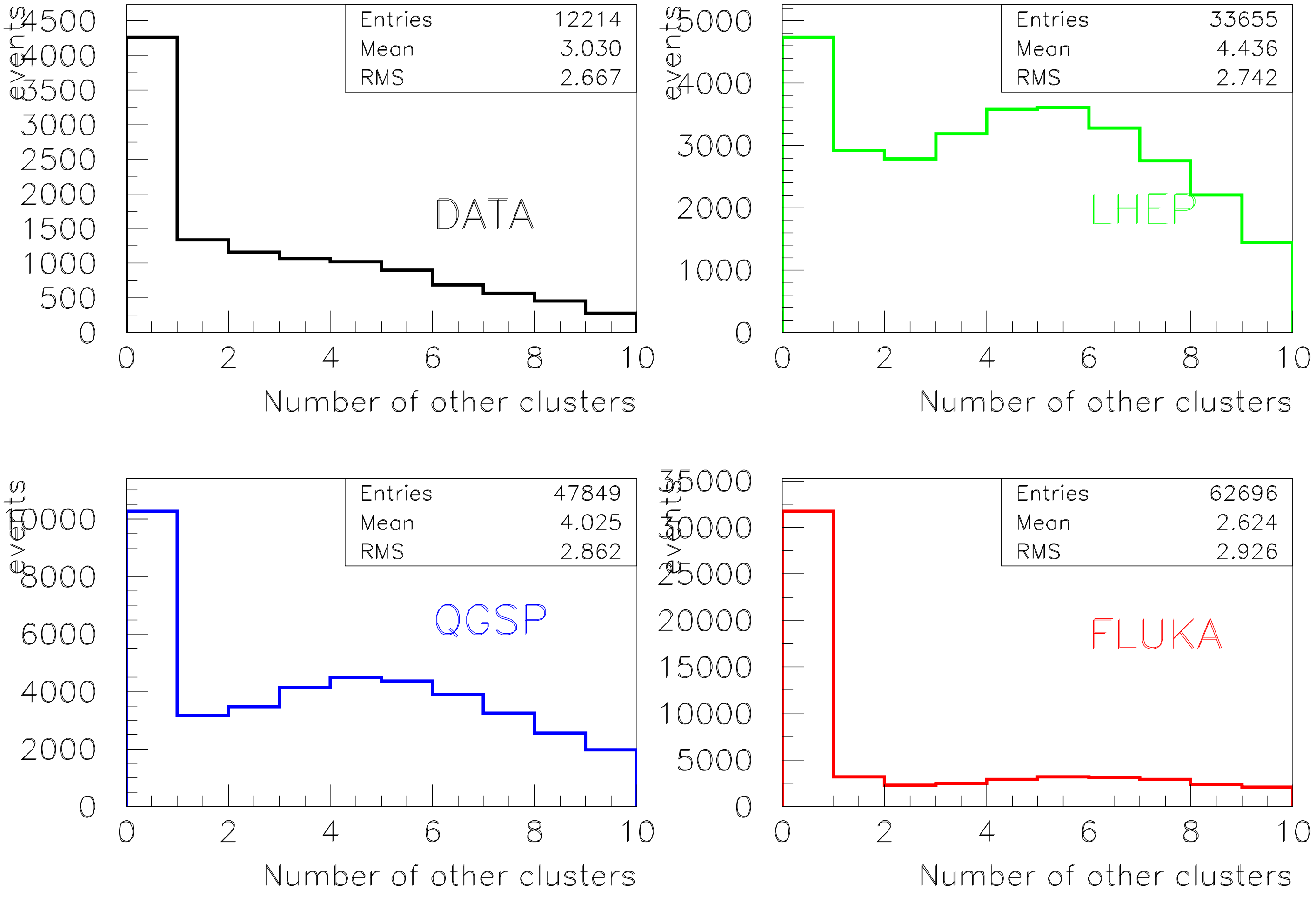
Y distance of max pixel charge



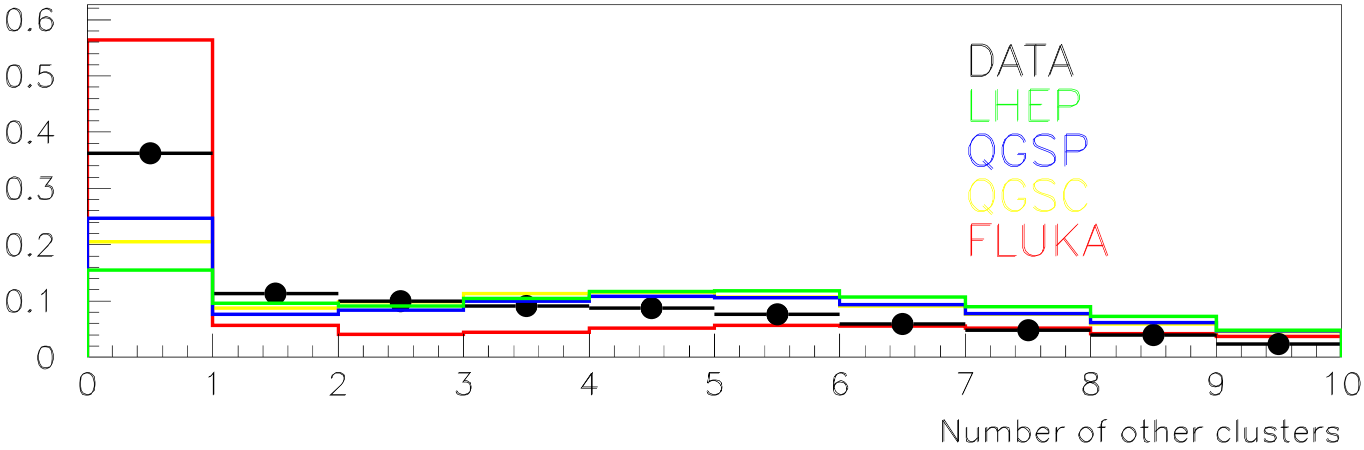
Y distance of max pixel charge (cont.)

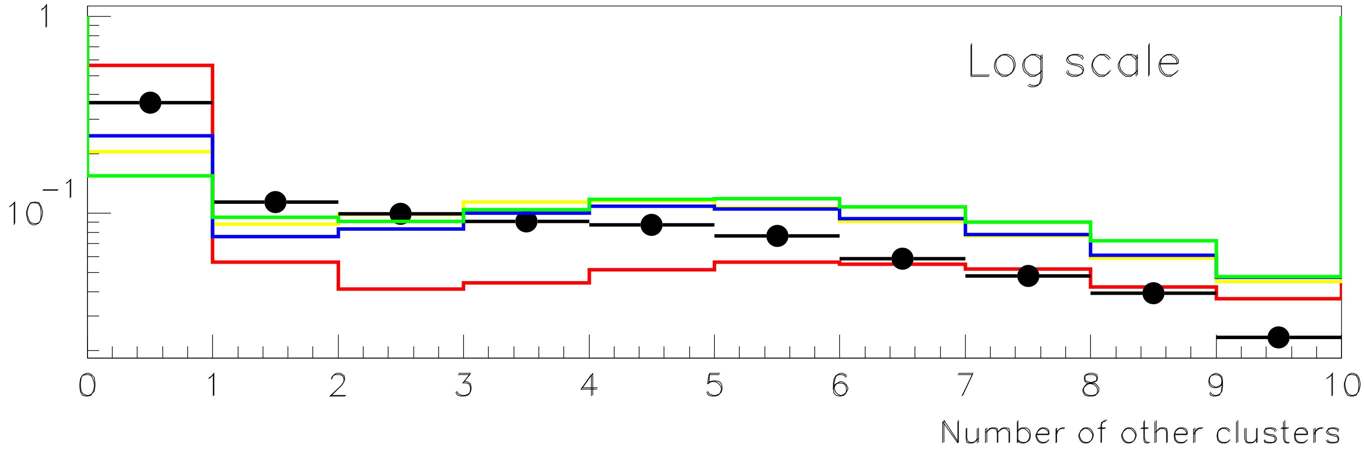


Number of Other Clusters

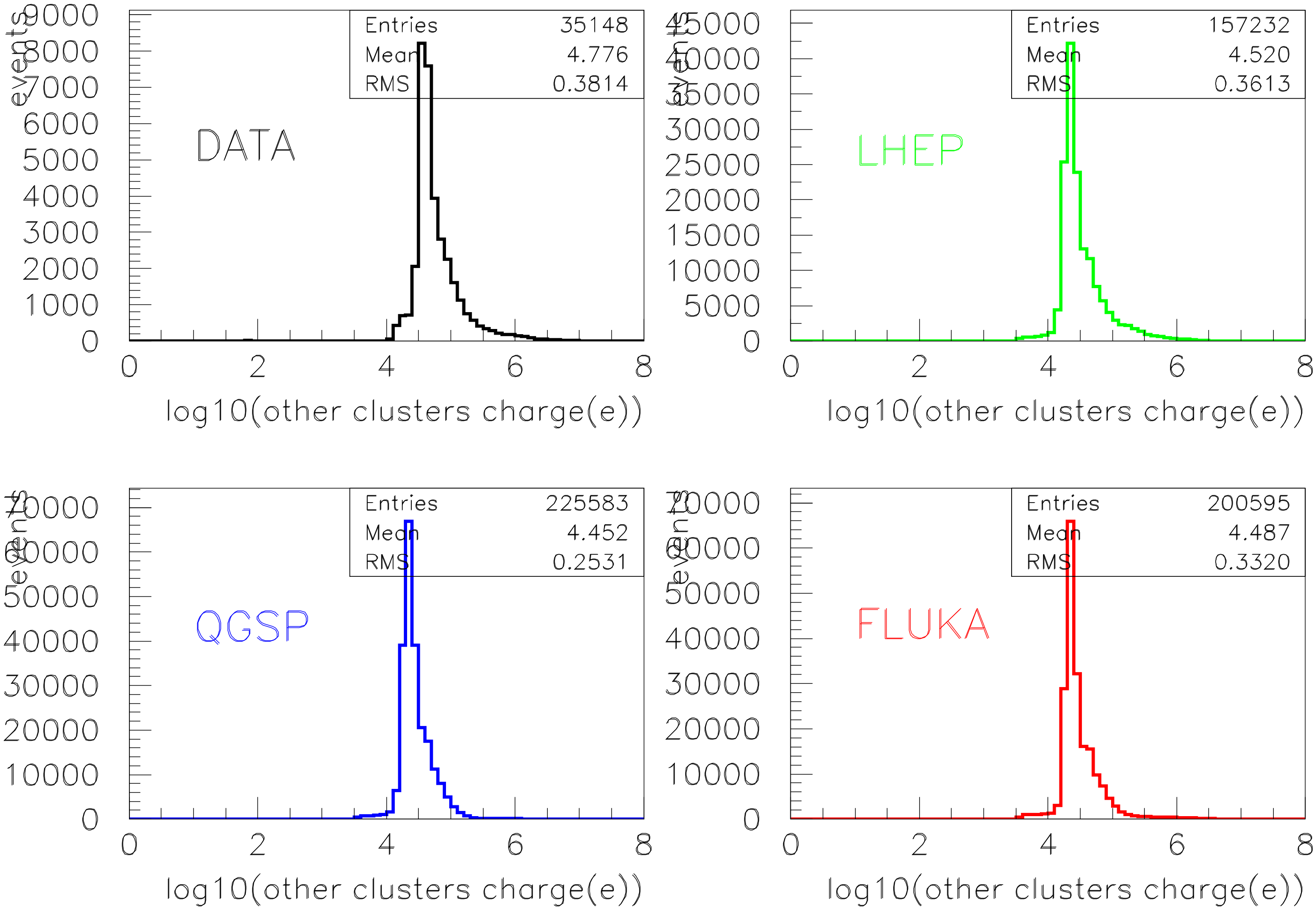


Number of Other Clusters (cont.)

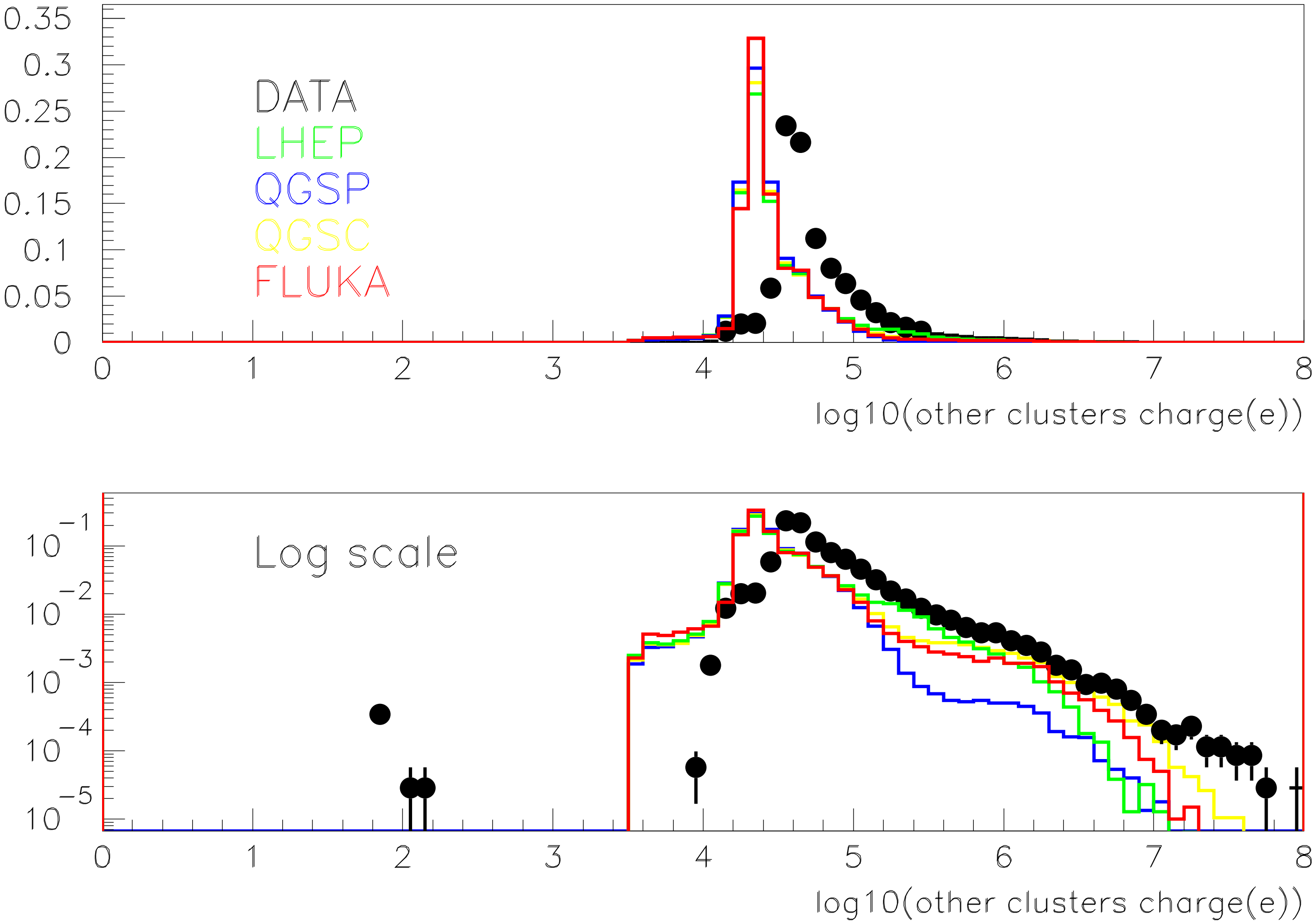




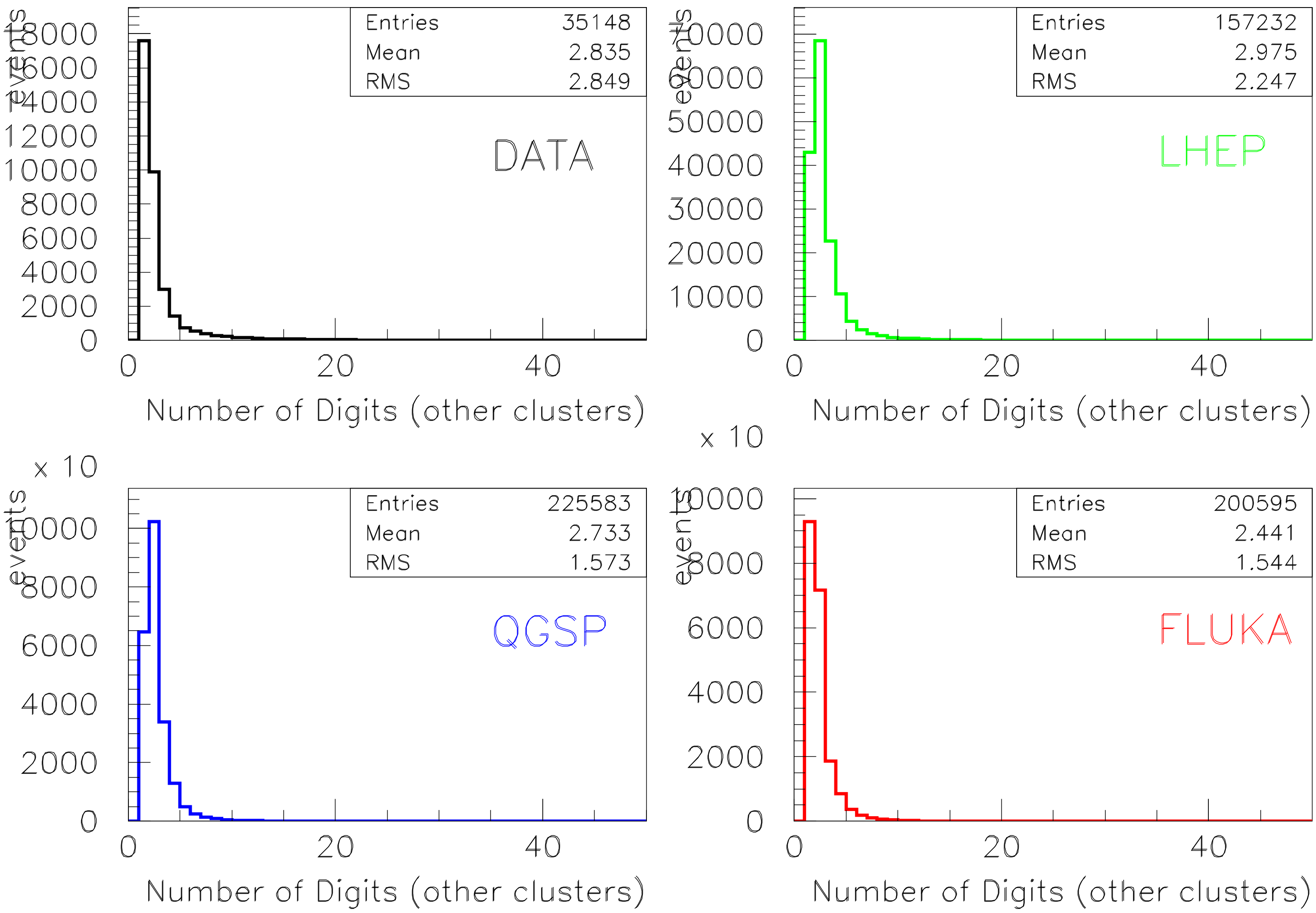
Charge of Other Clusters



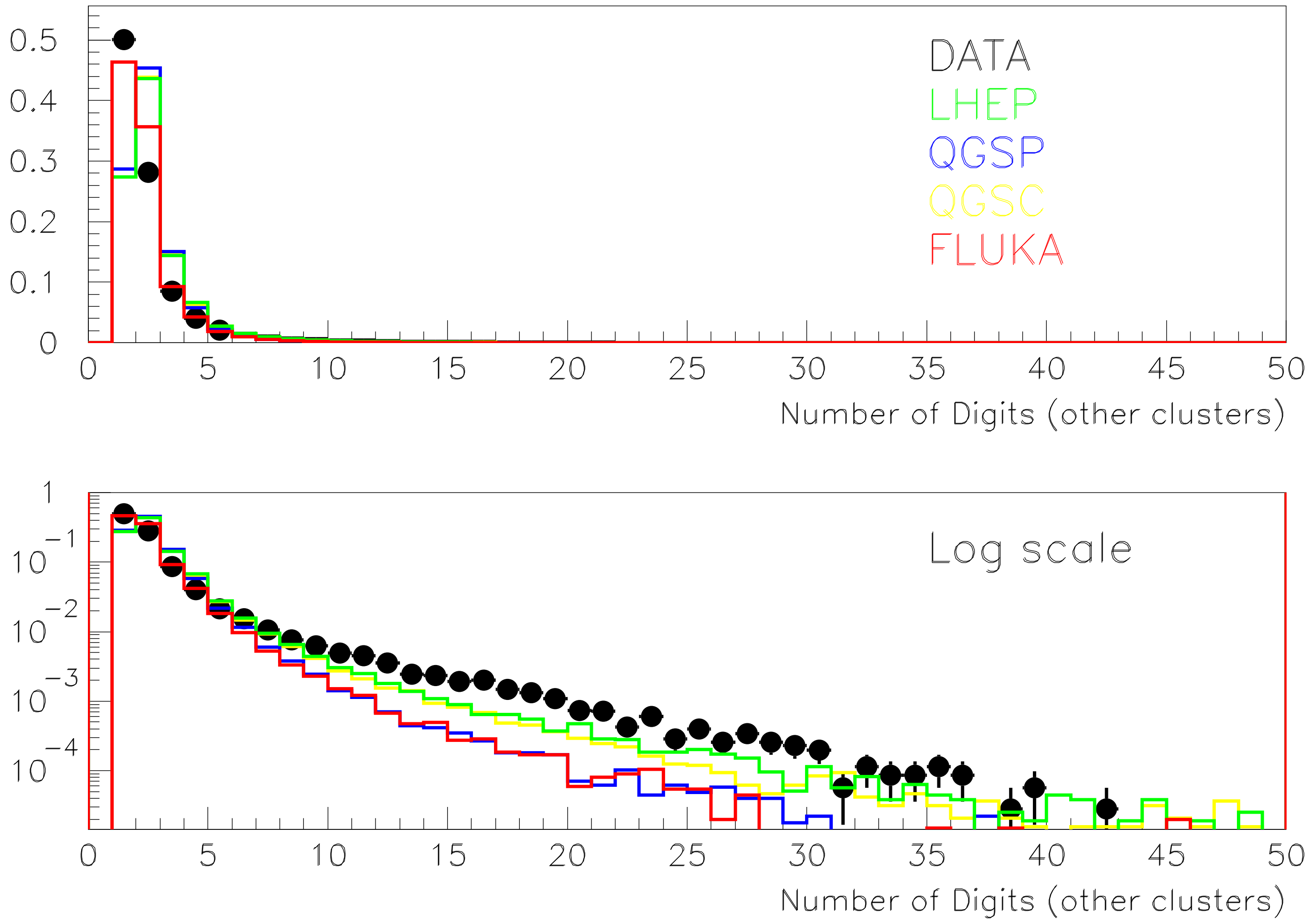
Charge of Other Clusters (cont.)



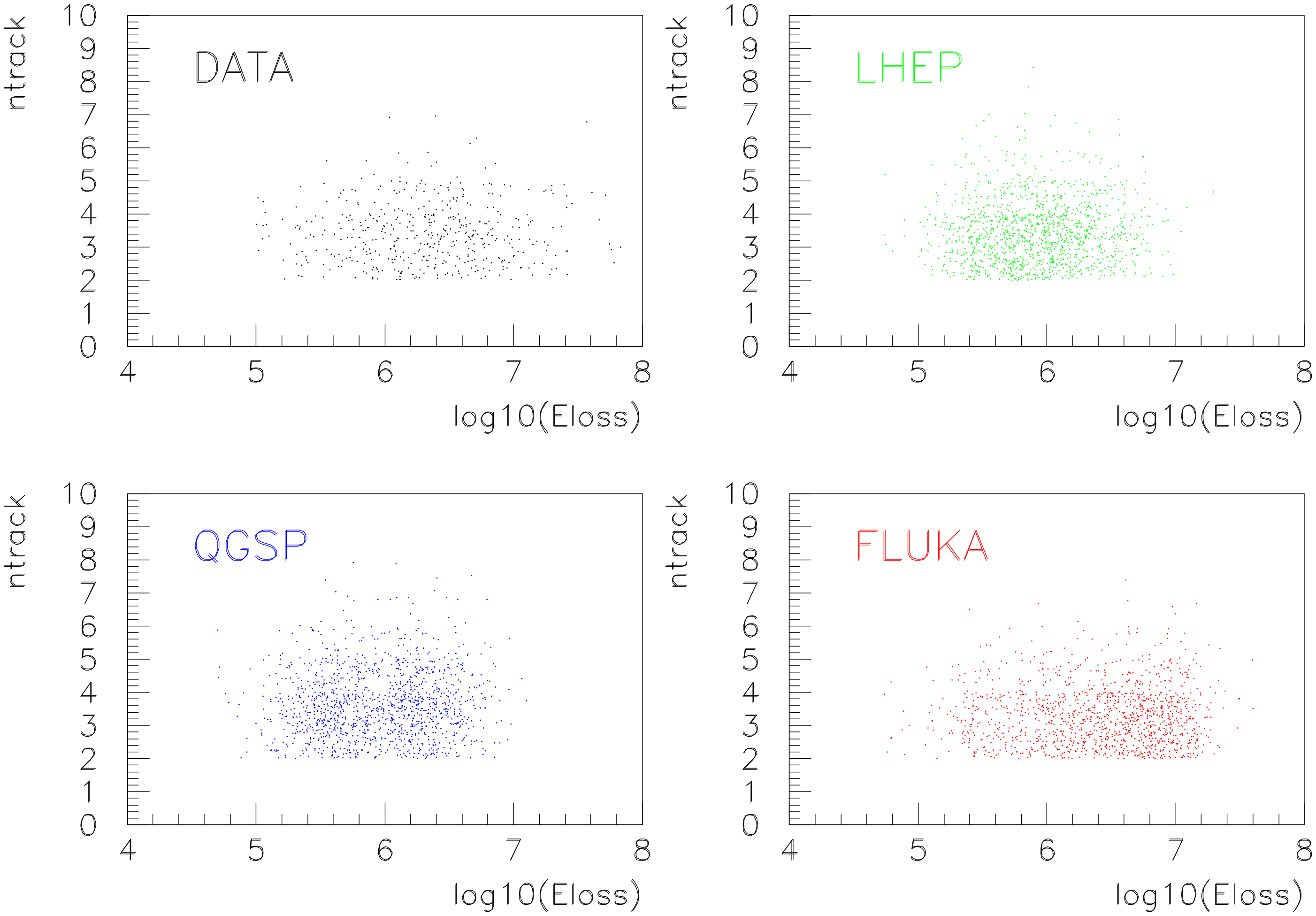
Cluster Size of Other Clusters



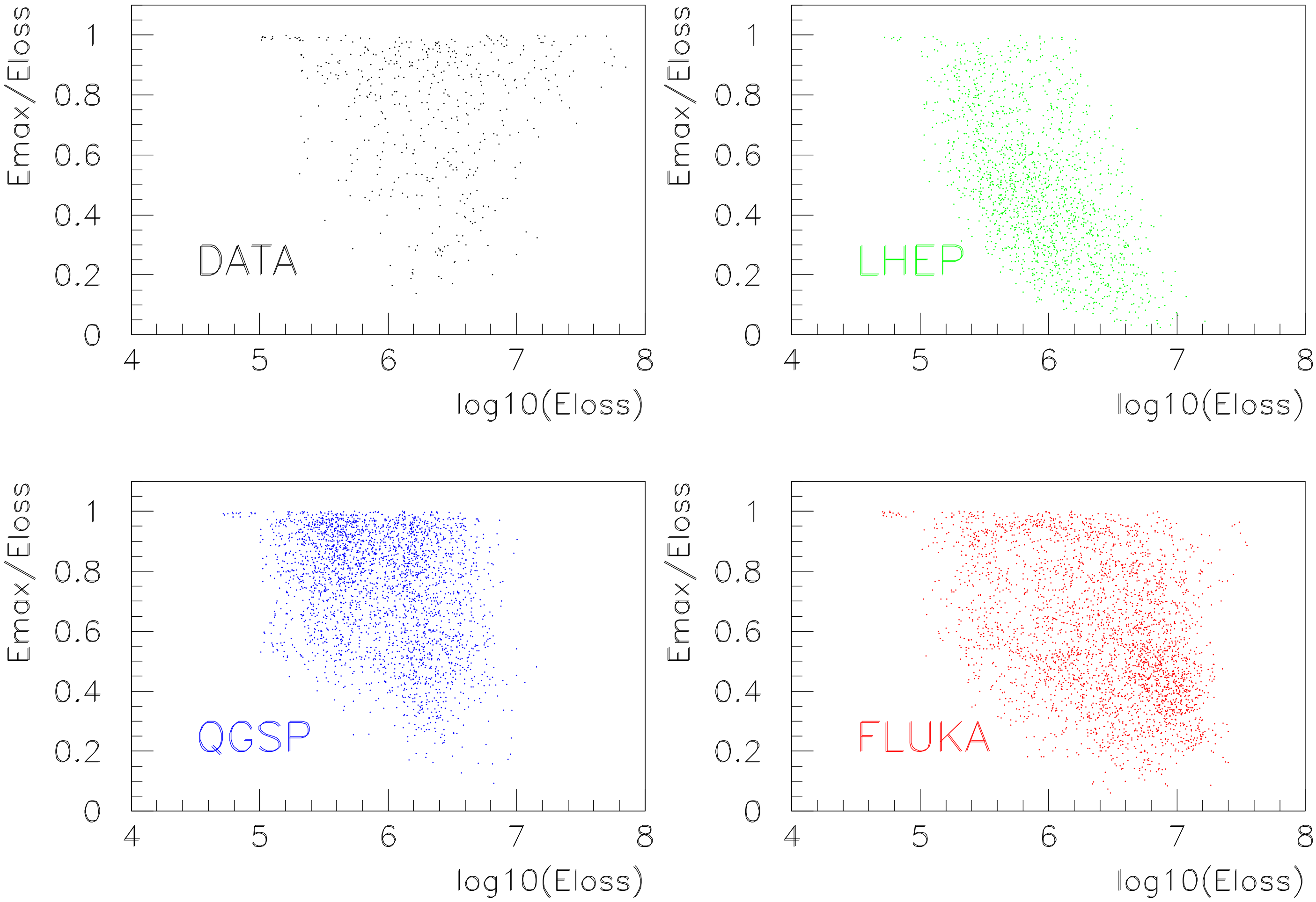
Cluster Size of Other Clusters (cont.)



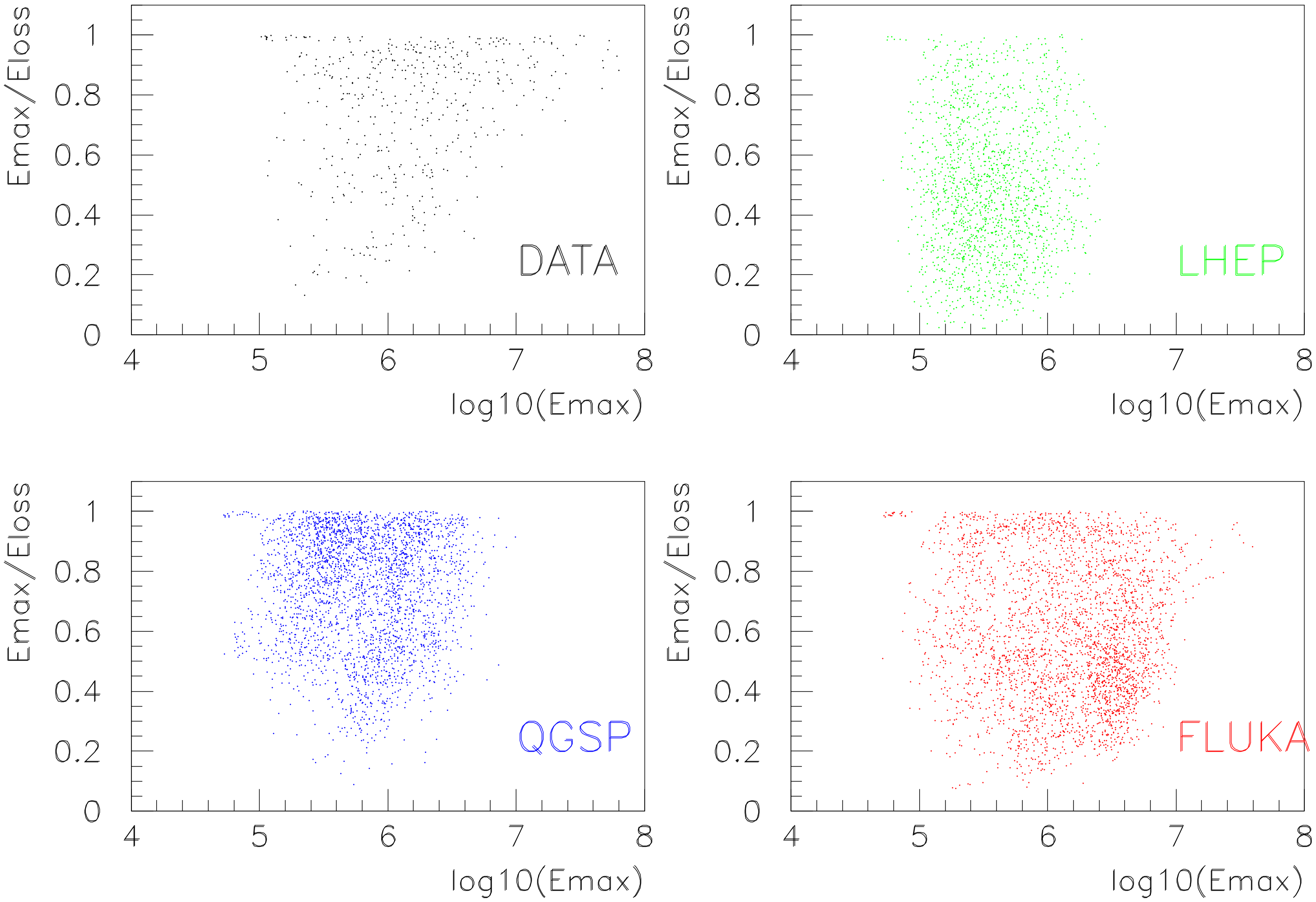
Correlation:
number of track vs $\log_{10}$(cluster charge)



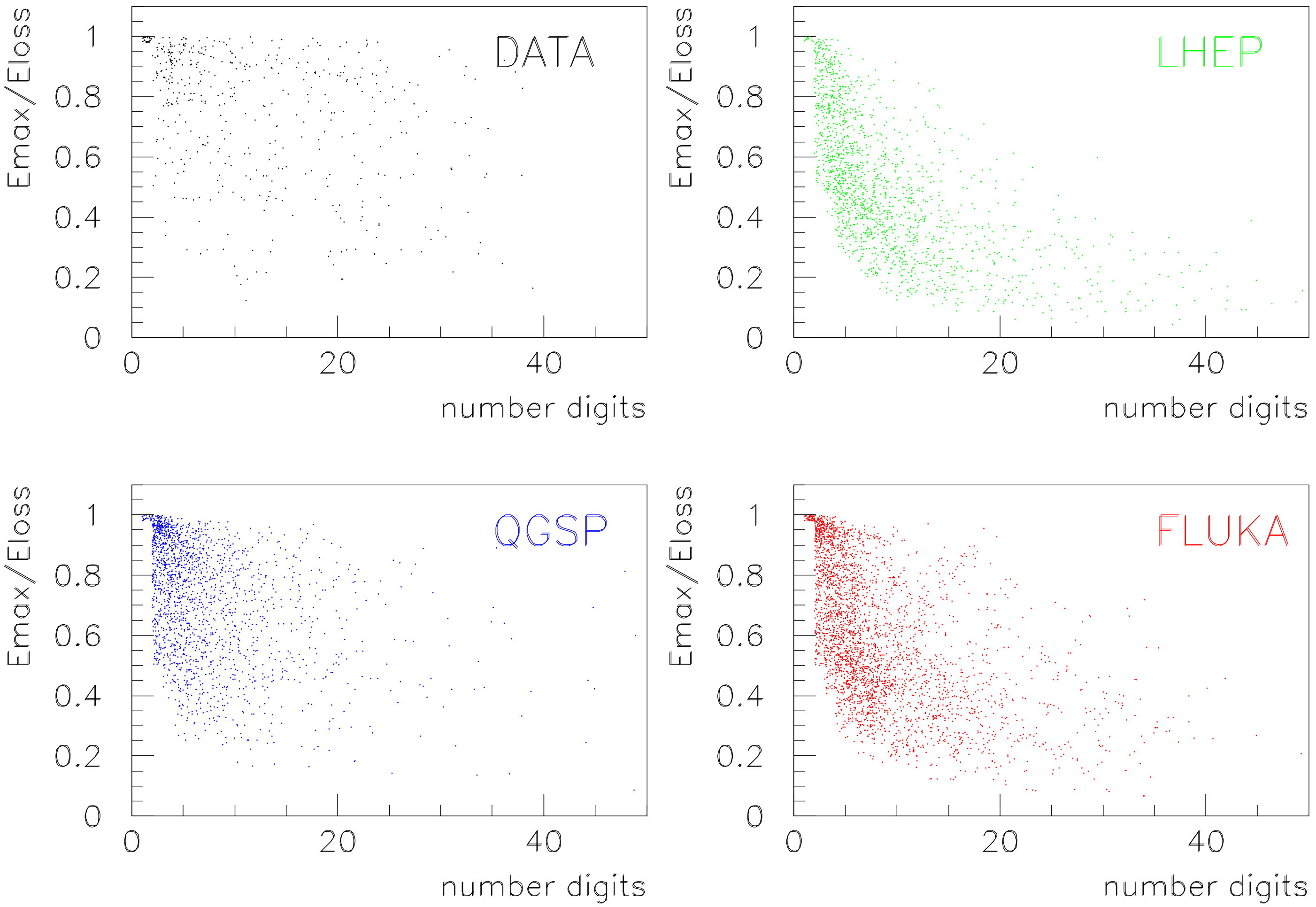
Correlation: ratio of charges vs $\log_{10}$(cluster charge)



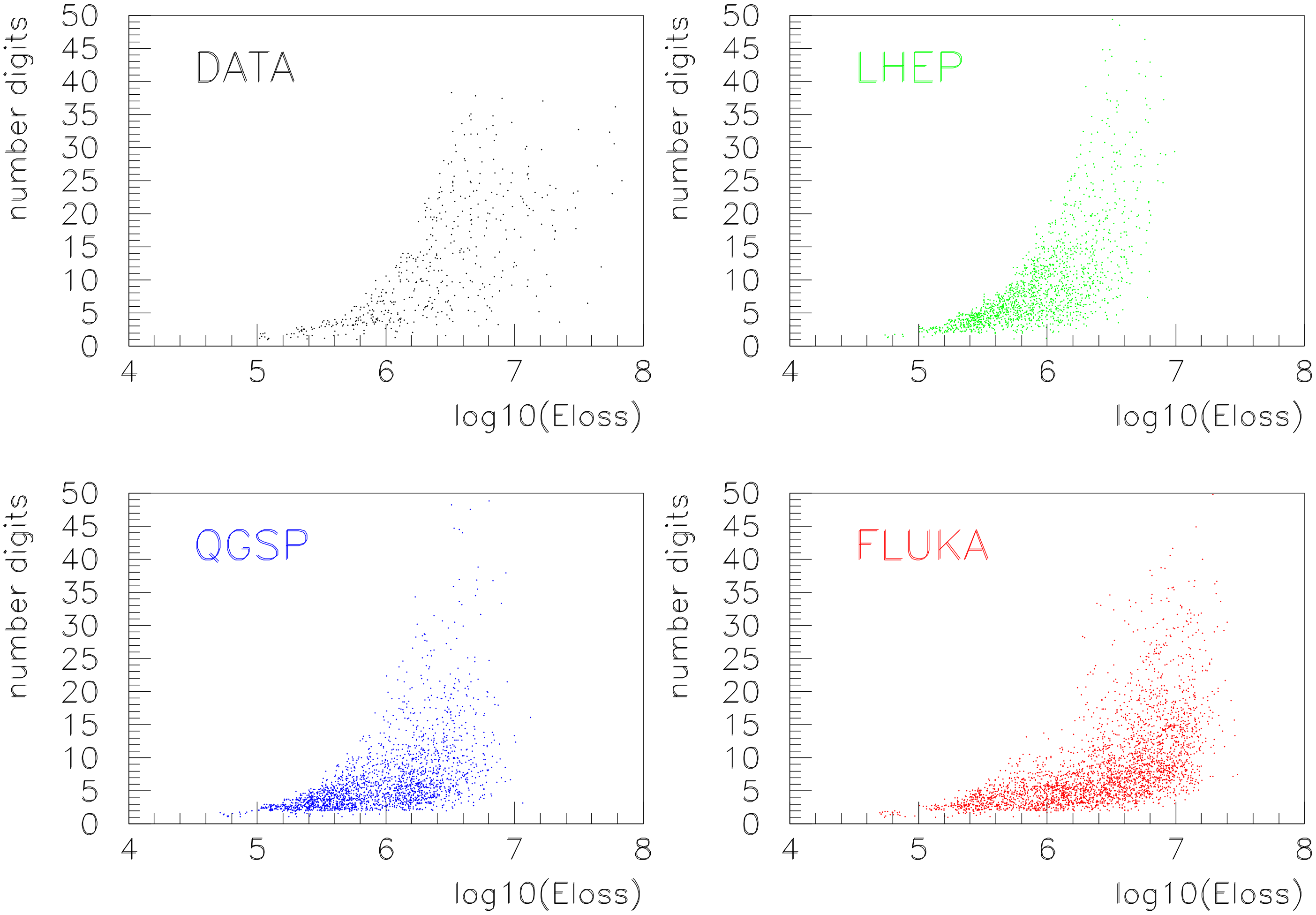
Correlation:
ratio of charges vs $\log_{10}$(max pixel charge)



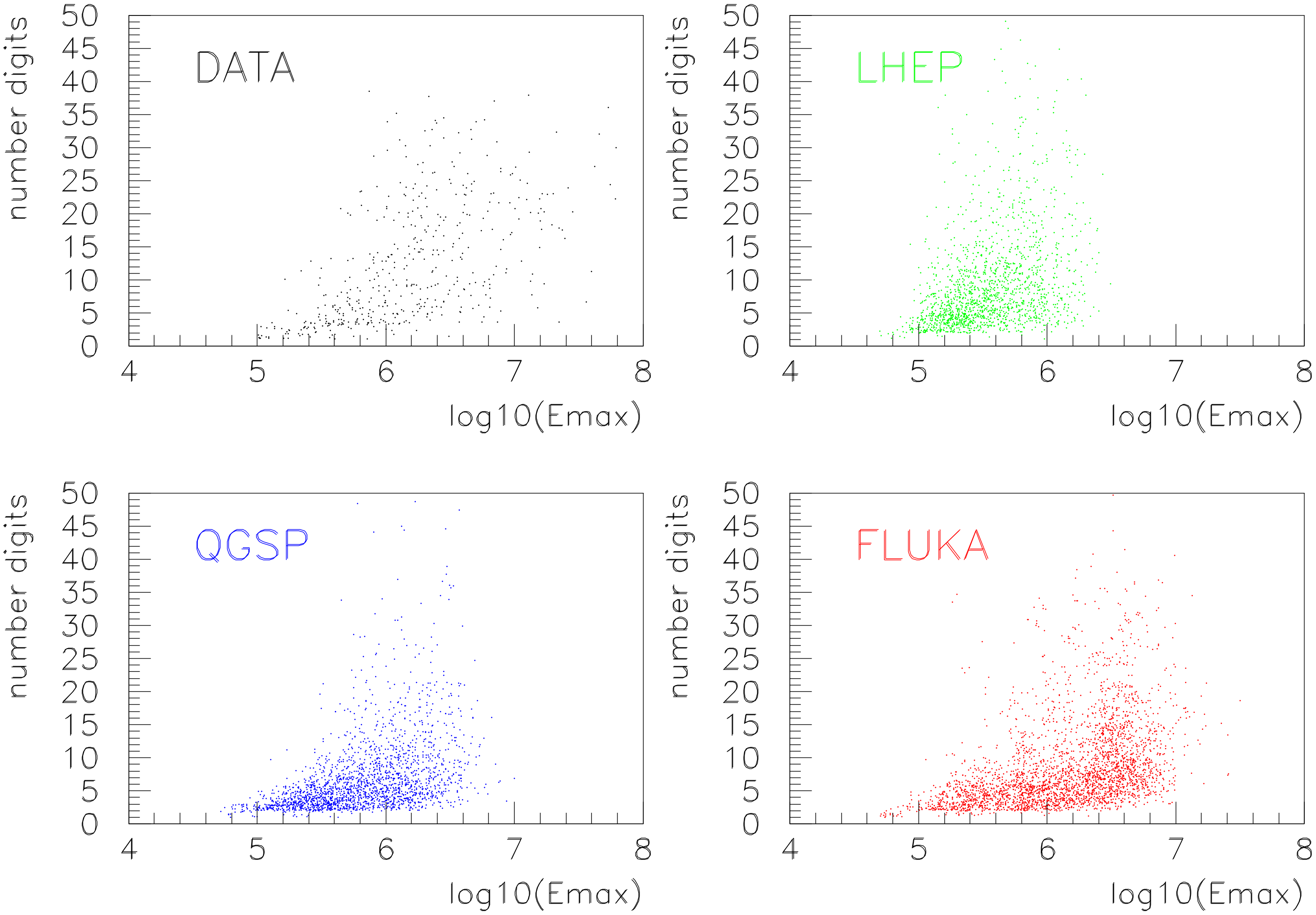
Correlation: ratio of charges vs cluster size



Correlation:
cluster size vs $\log_{10}$(cluster charge)



Correlation:
cluster size vs $\log_{10}$(max pixel charge)



Conclusions

The various cluster distributions are quite stable with respect to many changes. However, the energy calibration , which affects directly only few cluster distributions (Eloss, Emax), is unclear. Other distributions (ntrack, cluster size, farther hit, etc.) should be less affected by this issue.

- Fluka and Geant4 offer a more or less similar description of the ATLAS Pixel test-beam data.
- The overall level of agreement between simulation and data is reasonably good, although not excellent in some observables.
- G4 LHEP describes perfectly the number of reconstructed tracks; G4 QGSP describes well the ratio of max charge over total charge; Fluka describes better the cluster spatial extension.
- G4 QGSC seems to be closer to Fluka than to the other G4 Physics Lists.

Conclusions (cont.)

- There are some features of the data (e.g. a bump in cluster size around 20; the peak around 1 in the ratio of max charge over total charge) which are not reproduced by any model.
- We would like to investigate a bit further the possibility of a contamination, in the real data mainly, of backscattered ionizing hadrons/ions from hadronic interactions in the downstream chip and pixel circuit board.

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