NORTHERN ILLINOIS UNIVERSITY

ECFA DESY Linear Collider Workshop

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Simulation Studies for a Digital Hadron Calorimeter

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- ***Introduction to the DHCal Project***
- ***Simulation Tools and Models***
- ***From Analog to Digital***
- ***Towards an E-Flow Algorithm***
- ***A Proposed Clustering Strategy***
- ***Current Status, Future Plans***

Introduction

- Northern Illinois University (NIU / NICADD)
- University of Texas at Arlington (UTA)
- Argonne National Laboratory (ANL)

October 2001

> ➢ A joint proposal for the development of digital hadron calorimetry technology for the Linear Collider
>
> ➢ NIU investigates a scintillator based design
>
> ➢ UTA investigates a gas based (GEM) design
>
> ➢ ANL investigates an RPC based design
>
> ➢ For hardware project details see talk by J. Repond

Main Goals of the Software Effort

- To assist in the design of a Digital Hadron Calorimeter (DHCAL)

  - Parameter Optimization e.g;
    transverse segmentation,
    cell depth and absorber density, detector depth,
    layer geometry, stack geometry, TRK-EM-HAD matching

- Feasibility and Resolution Reach of an ***Energy Flow*** Strategy

  - Identify energy deposition patterns (clusters) arising from ***individual*** particles
  - Efficient cluster resolution and reconstruction, with central track matching capability under expected Liner Collider (~TeV) conditions
  - Ability to discriminate charged .vs. neutral particle generated clusters

- Develop a solid notion of the Physics Reach (versus cost)

Simulation Tools and Detector Model

Java Analysis Studio

http://jas.freehep.org/

nicadd

The NICADD "sioserver"

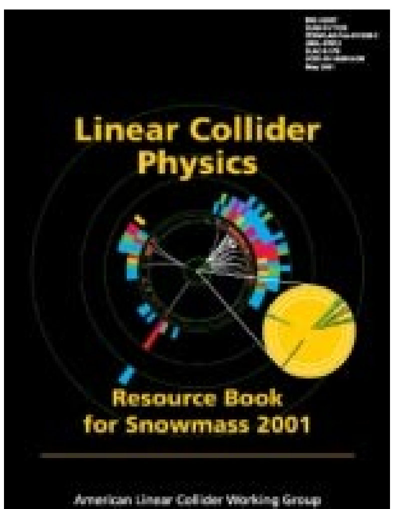
http://nicadd.niu.edu/dhcal/

Linear Collider Detector Simulation Package

http://www-sldnt.slac.stanford.edu/jas/documentation/lcd/

Using the "SD" Detector Model
(Snowmass 2001), as described in;

http://www-sldnt.slac.stanford.edu/snowmass/Welcome.html



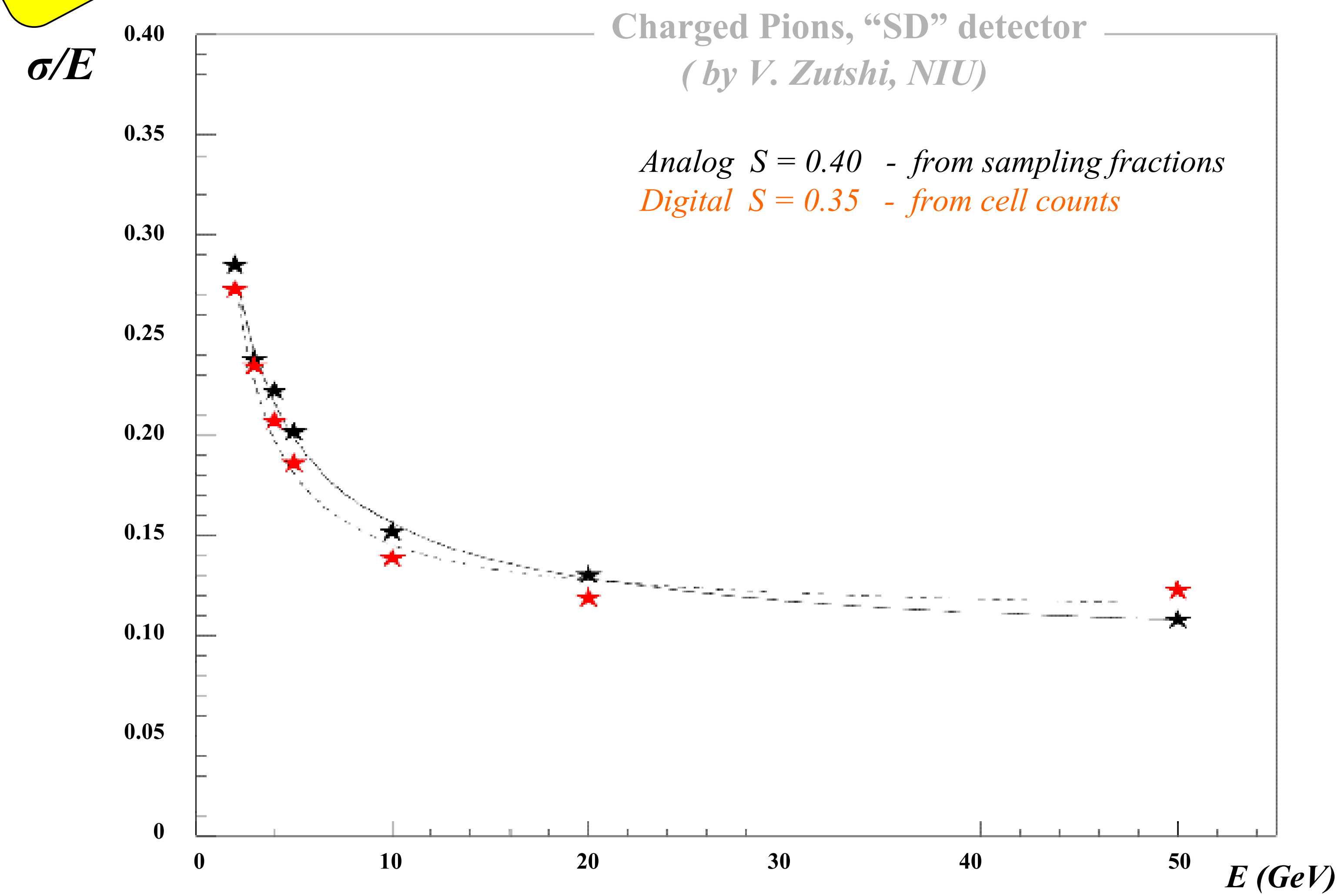
The SD Calorimeter

Projective towers, inside a 5 Tesla B-field

	EM	HAD
Inner Rad	127 cm	154 cm
Outer Rad	142 cm	256 cm
N.of layers	30	34
Z – max	210 cm	312 cm
Segm.(θ x φ)	840 x 1680	600 x 1200
Transv. cell size	0.5 x 0.5 cm	1 x 1 cm
active layer	Si, 0.4 mm	Polyst 1cm
passive layer	W, 2.5mm	S.Steel 2cm
Rad-Int lengths	20 – 0.8	40 – 4

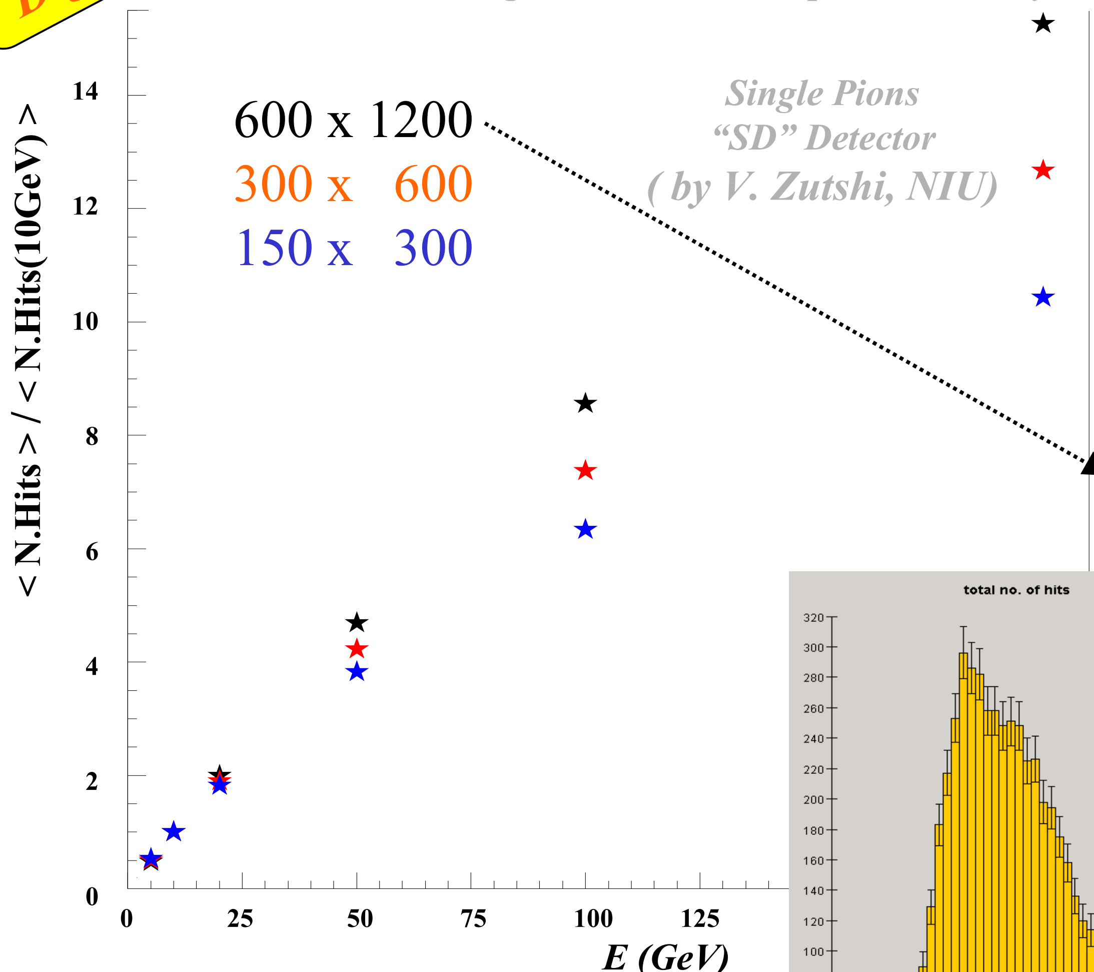
Analog vs Digital

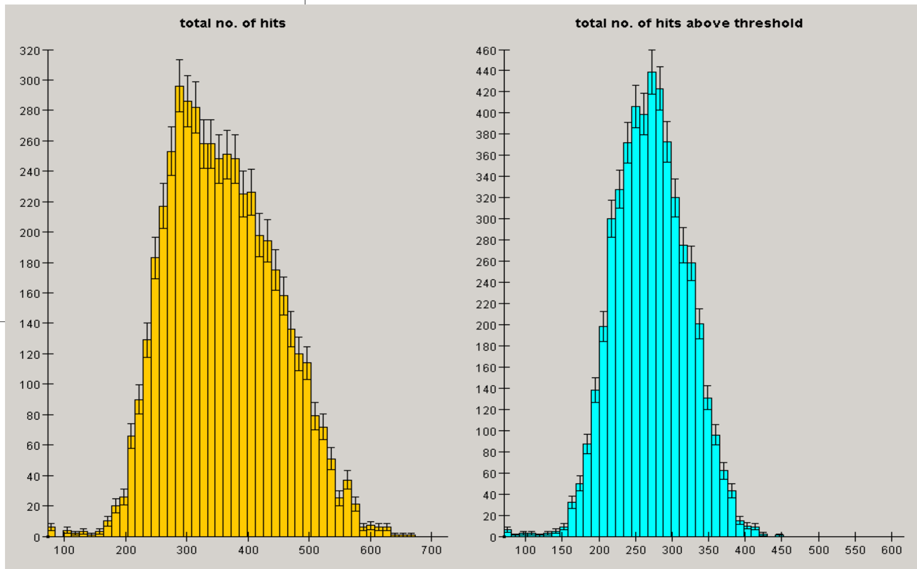
Single Particle Resolution



Segmentation Studies

Analog vs Digital





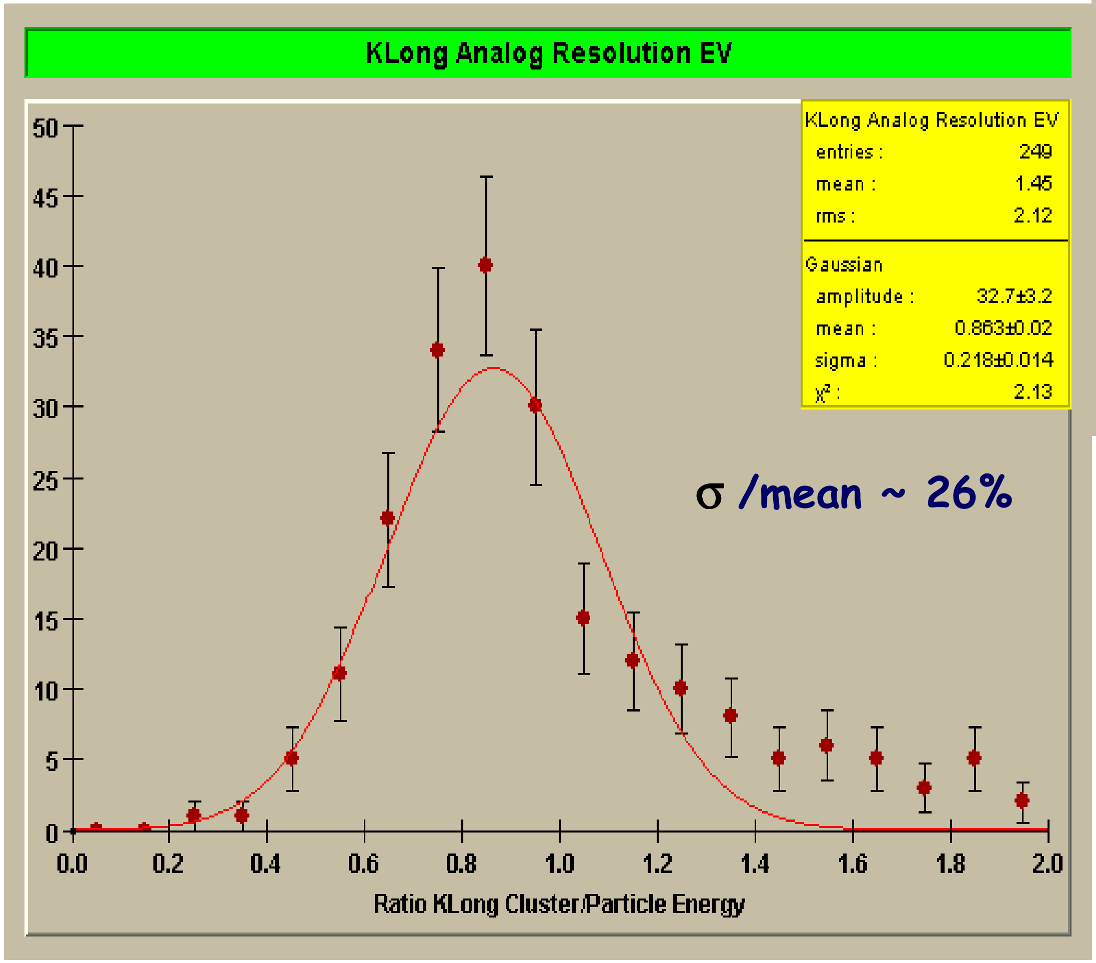
Analog vs Digital Conclusion;

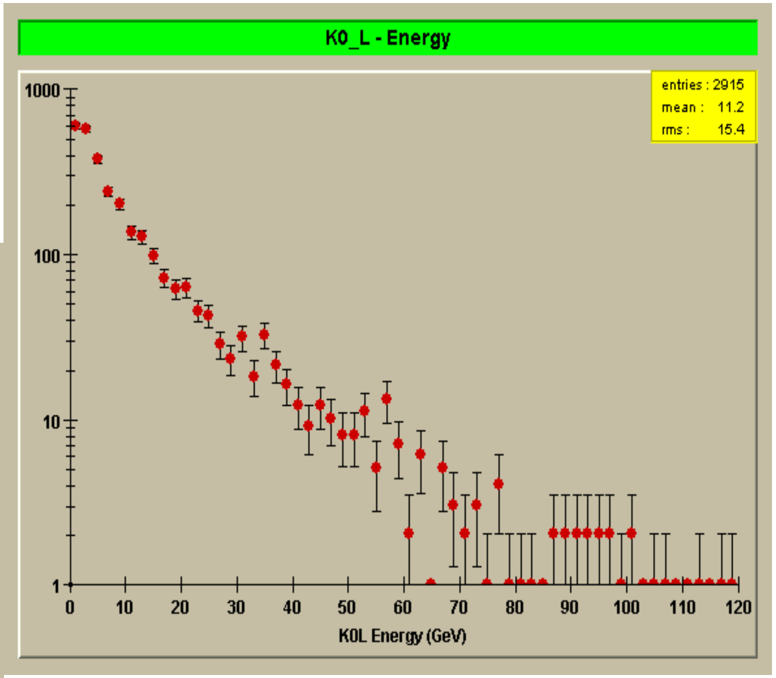
- No apparent penalty in energy resolution
- Obvious gains in spacial resolution (granularity)

Analog vs Digital

K_0^L Analysis
by S.Magill (ANL)

– Analog Readout



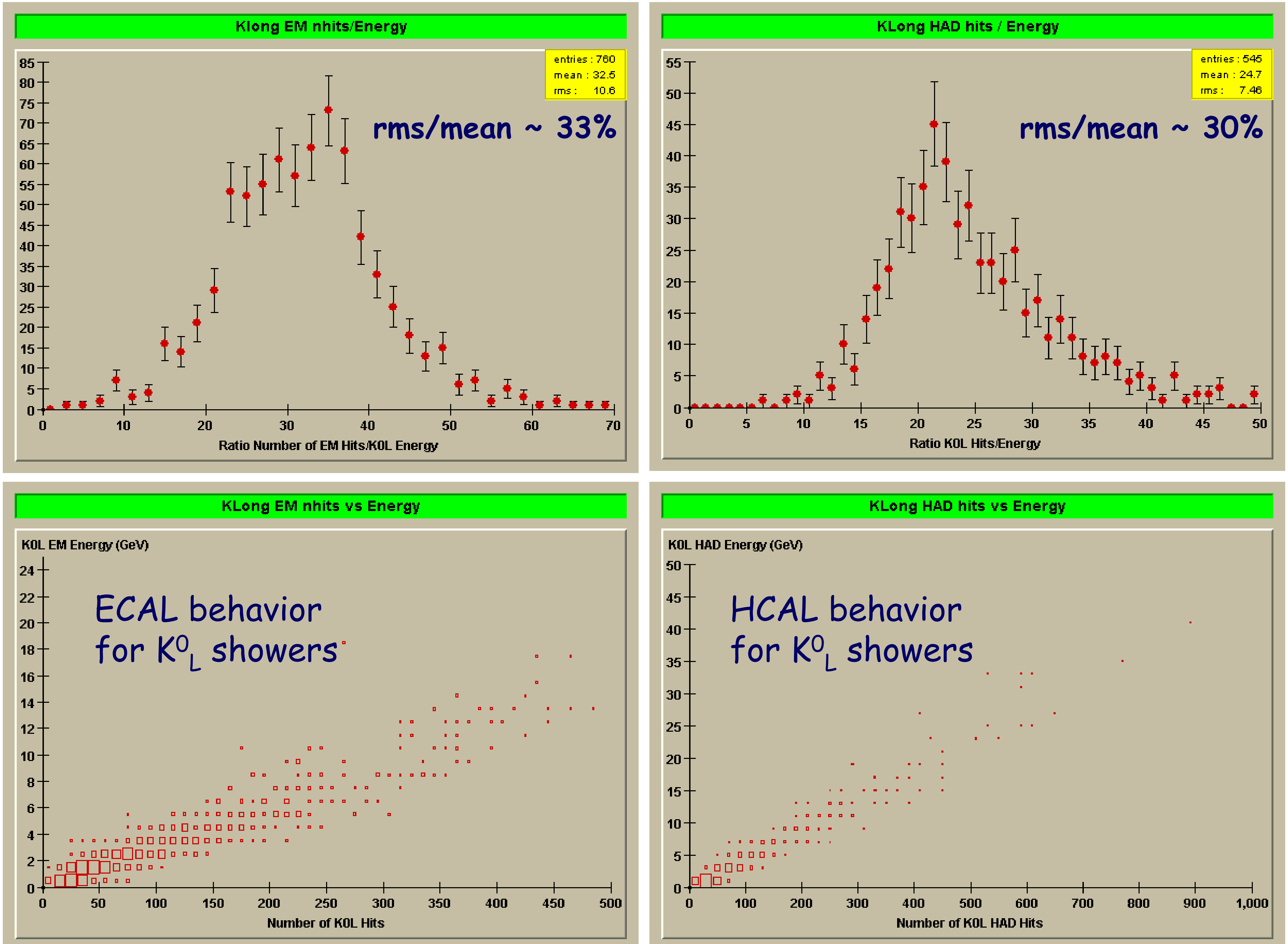


$e^+e^- \rightarrow ZZ$ (500 GeV CM)

Clustering from "MC-truth"

"SD" Detector

Compare to digital ⇒


Klong EM nhits/Energy
entries : 760
mean : 32.5
rms : 10.6
rms/mean ~ 33%
Ratio Number of EM Hits/K0L Energy
KLong HAD hits / Energy
entries : 545
mean : 24.7
rms : 7.46
rms/mean ~ 30%
Ratio K0L Hits/Energy
KLong EM nhits vs Energy
K0L EM Energy (GeV)
ECAL behavior
for K0L showers
Number of K0L Hits
KLong HAD hits vs Energy
K0L HAD Energy (GeV)
HCAL behavior
for K0L showers
Number of K0L HAD Hits

Studies Towards an Energy Flow Algorithm

Two distinct cell-clustering approaches currently being pursued;

(1) A layer by layer search for local maxima (seeds)
Nearest Neighbours cluster building
Longitudinal matching (stacking) of layer clusters

(2) Variable size 3D-Domain(θ, φ, ρ) search for local maxima
Longitudinal matching (stacking) of such cell domains

The plan is to;

- investigate performances independently
- understand strong/weak points
- study a possible synergy between both approaches
  (i.e. collect best aspects into one hybrid method)

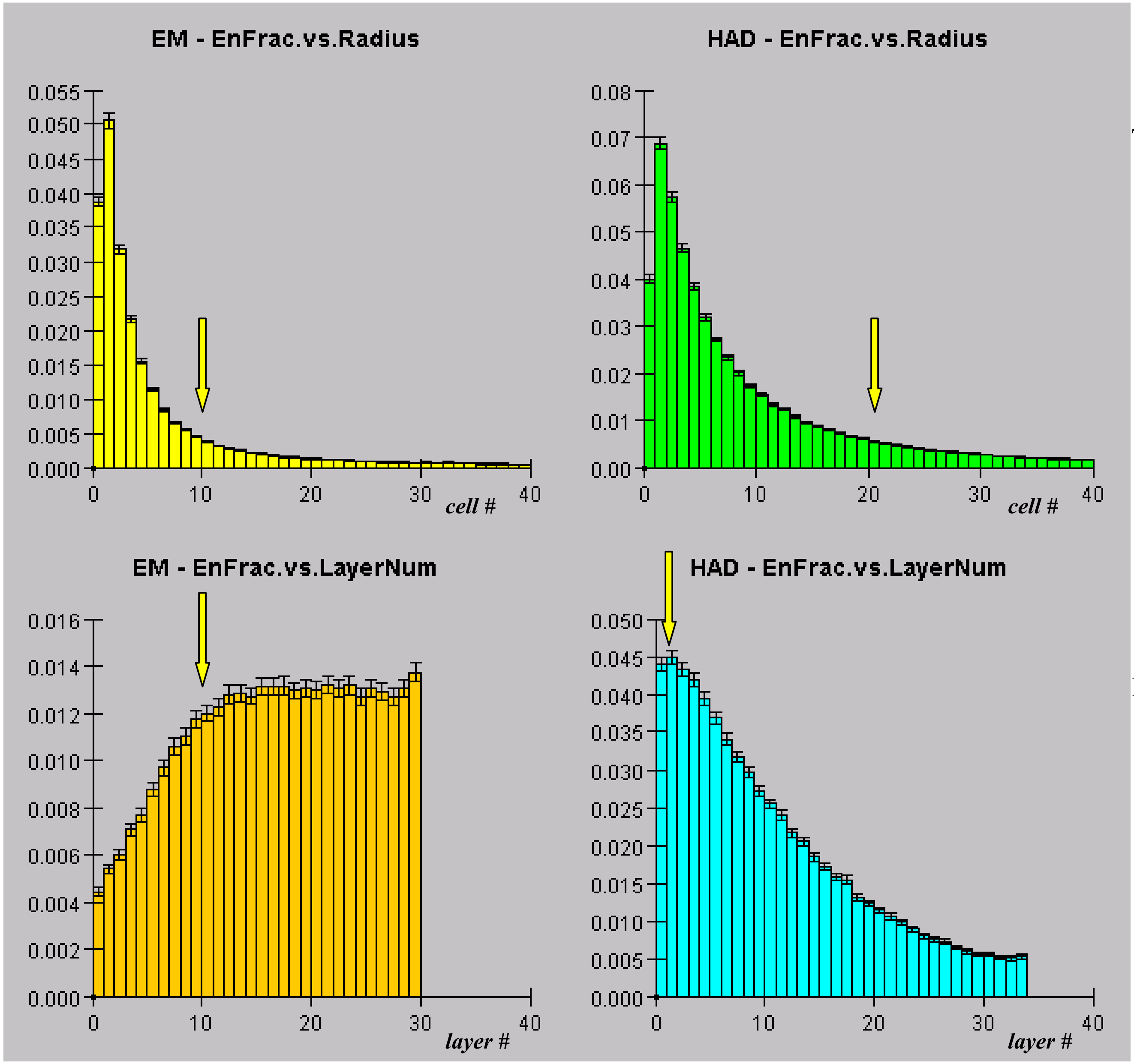
Clustering by Domain Inspection

- A domain is a box ($n_{\theta} \times m_{\varphi} \times l_{\rho}$), all three variable and self adjusting after being given initial values (in plots).
- Searches run in ($n \times m$) with slower-l acting as a test parameter.
- Search produces a set of ($\langle\theta\rangle$,$\langle\varphi\rangle$) centroids for layer matching.
- EM-Cal searches start around shower-max, proceed to edges.
- HAD-Cal searches start around the entry layer.
- Centroids are determined from local maxima (Energy / N.Hits).
- Domain "methods" investigate neighbourhood gradients for the resolution of nearby clusters.

Cluster Energy Profiles for 10 GeV π's

Transverse Profile

Longitudinal Profile



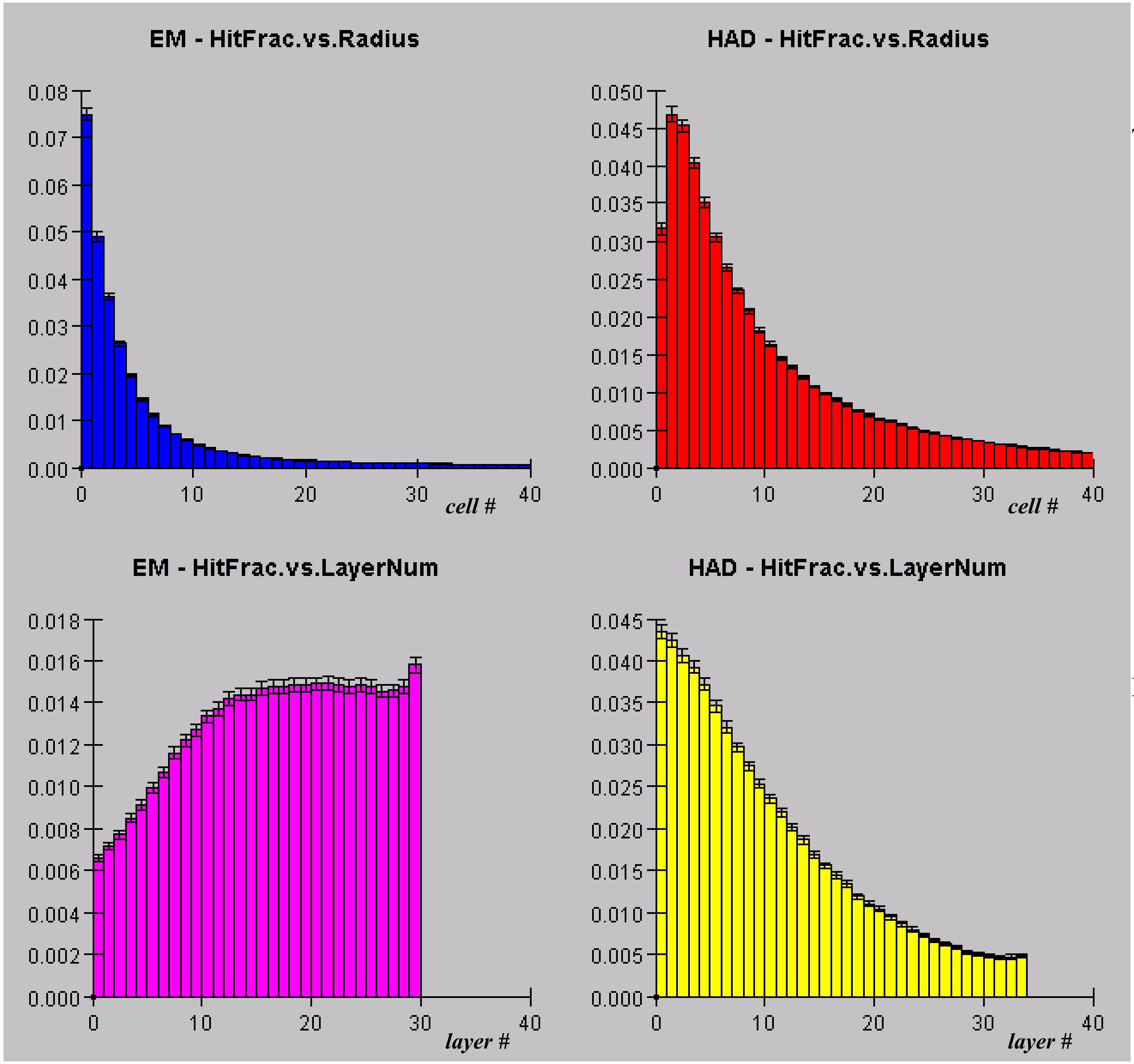
Transverse Profile

Longitudinal Profile

Cluster N.of Hits Profiles for 10 GeV π's

Transverse Profile

Transverse Profile

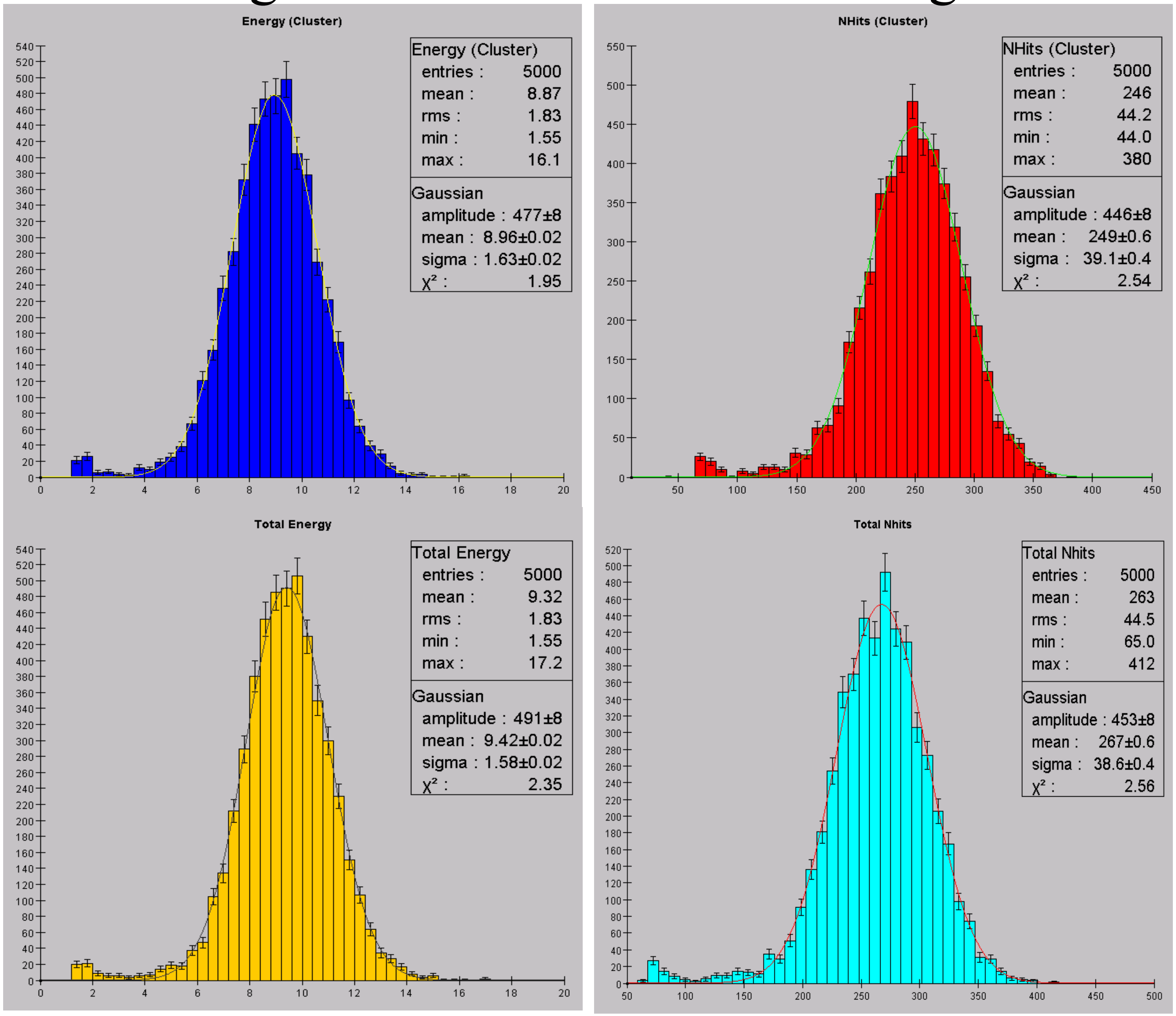


Longitudinal Profile

Longitudinal Profile

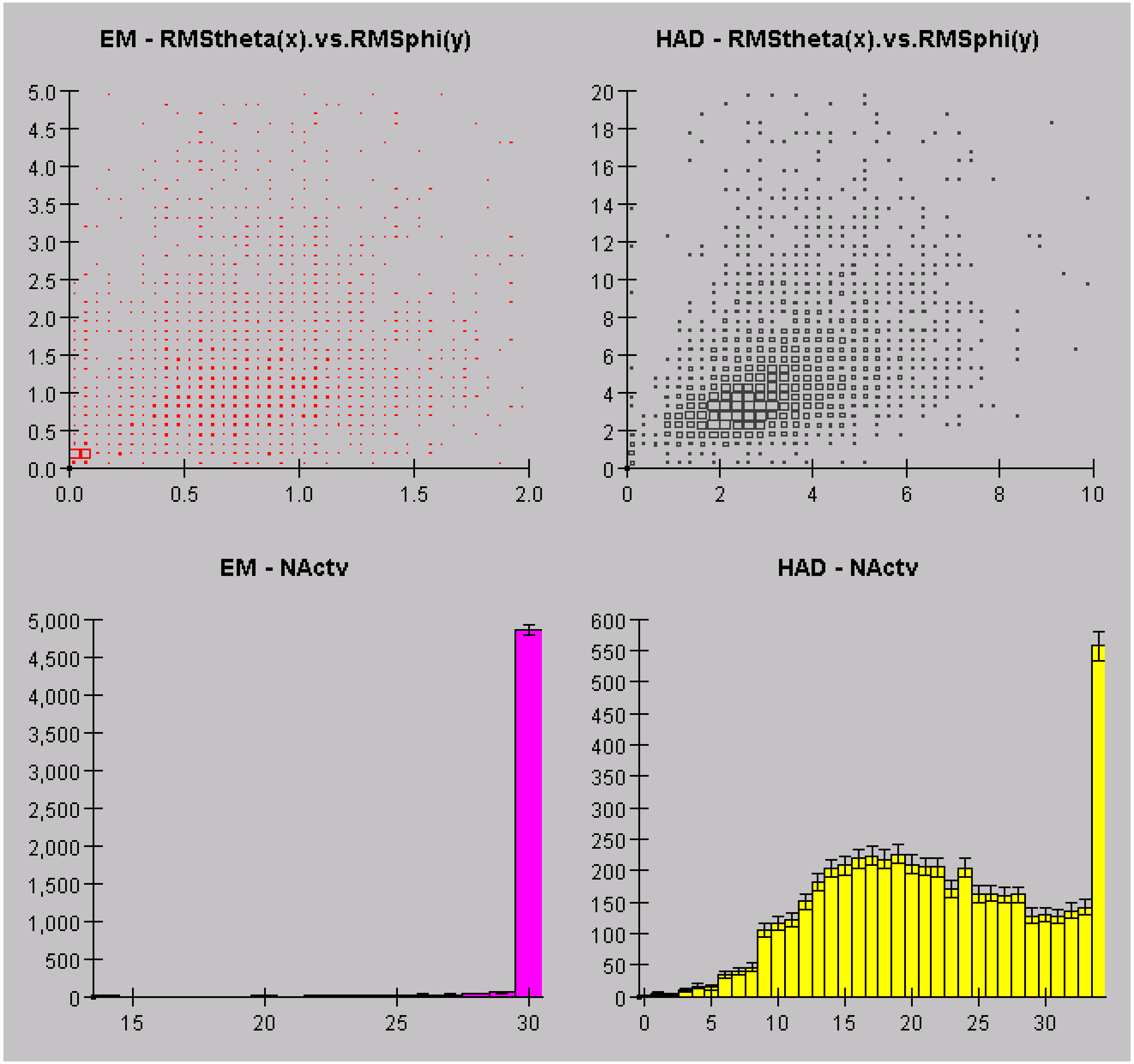
Analog 10 GeV π's Digital

Clustering by Domain Inspection



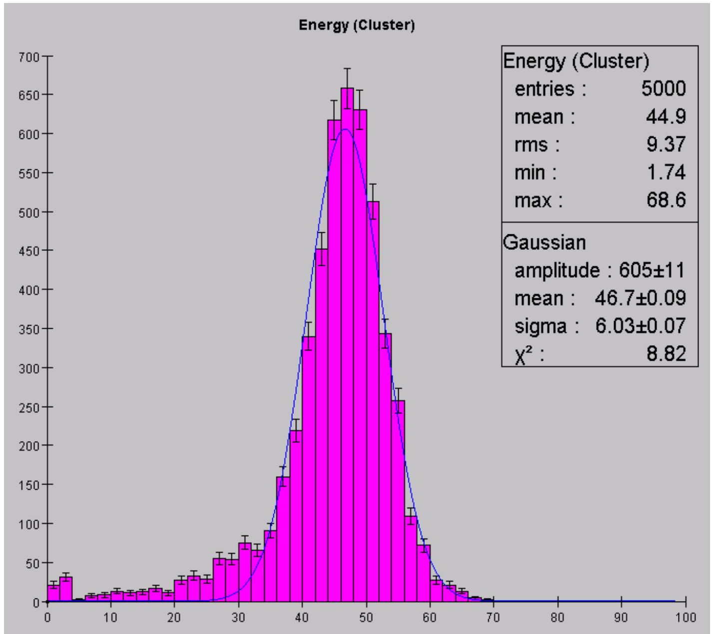
Single Layer Matching Resolution for 10 GeV π's

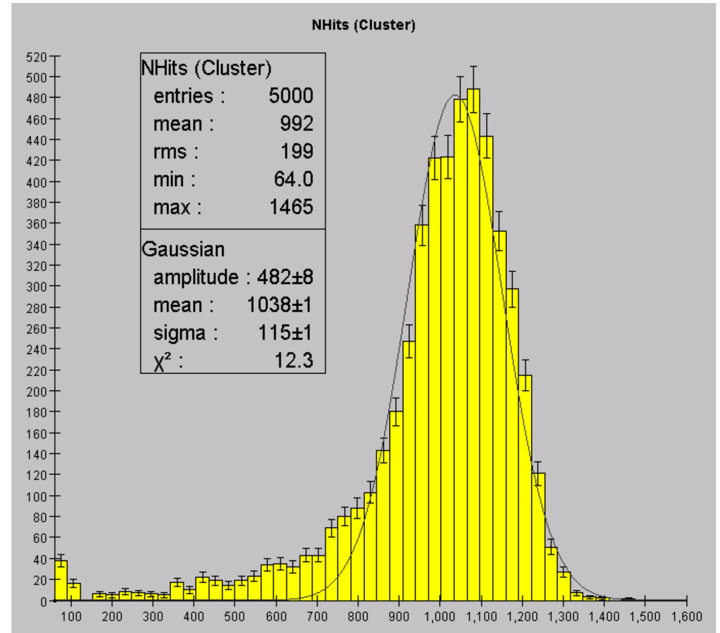
Clustering by Domain Inspection

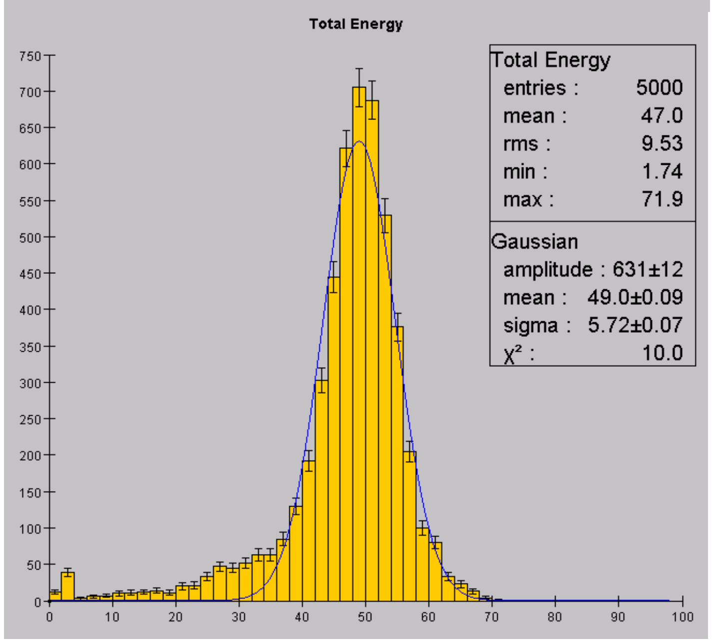


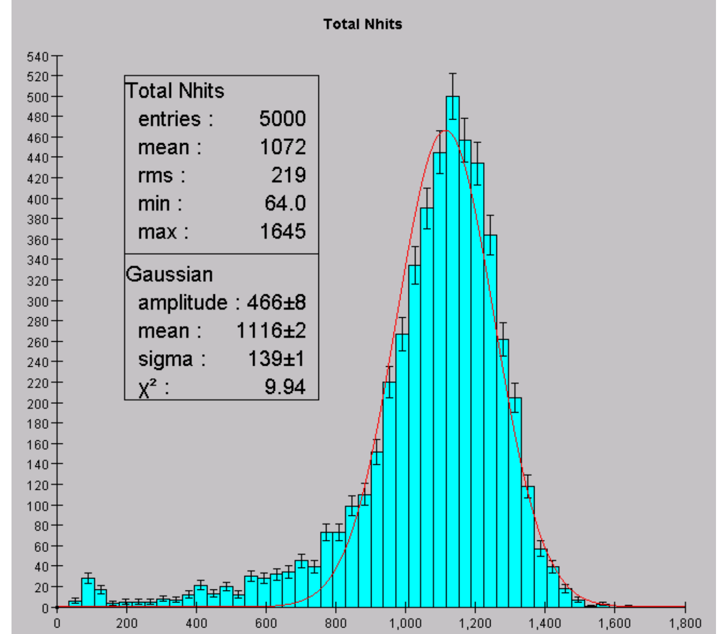
Analog 50 GeV π's Digital

Clustering by Domain Inspection



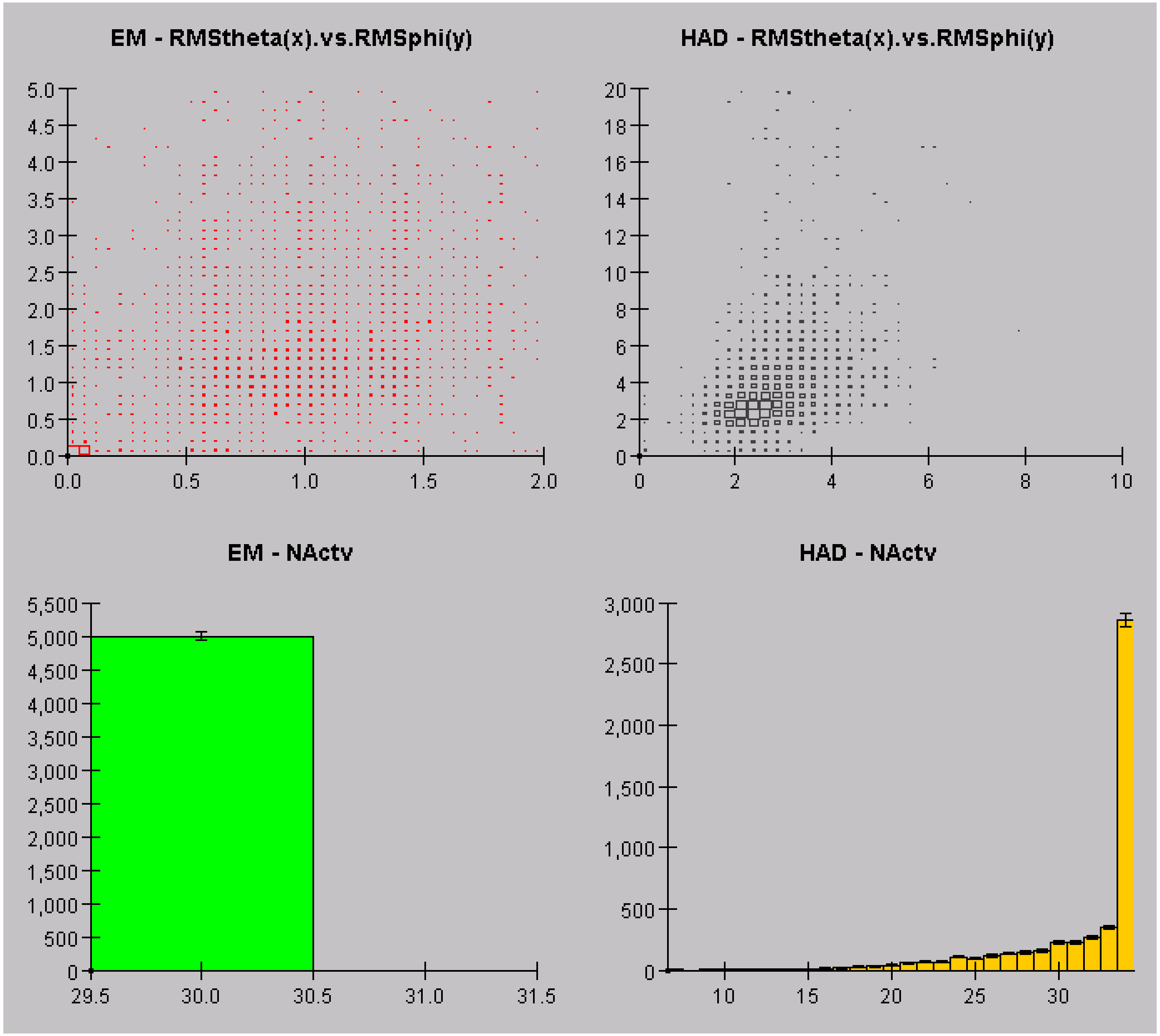






Single Layer Matching Resolution for 50 GeV π's

Clustering by Domain Inspection



Preliminary Tests

- Using mono energetic single tracks
- Internal checks&consistency / debug
- Parameter selection, initial values
- Parameter stability, finding eff.
- Energy resolution, stacking resolution
- Analog .vs. Digital
- Results encouraging (still trivial)

Next Steps

- Space resolution
- Develop domain methods to;
  - determine the transverse bounds of a cluster
  - resolve nearby clusters
  - implement a split-merge strategy
  - generate pattern recognition discriminators (isolation, neighbourhood gradients...)

Example Domain Methods

(Arbitrary units, similar w/ N.hits)

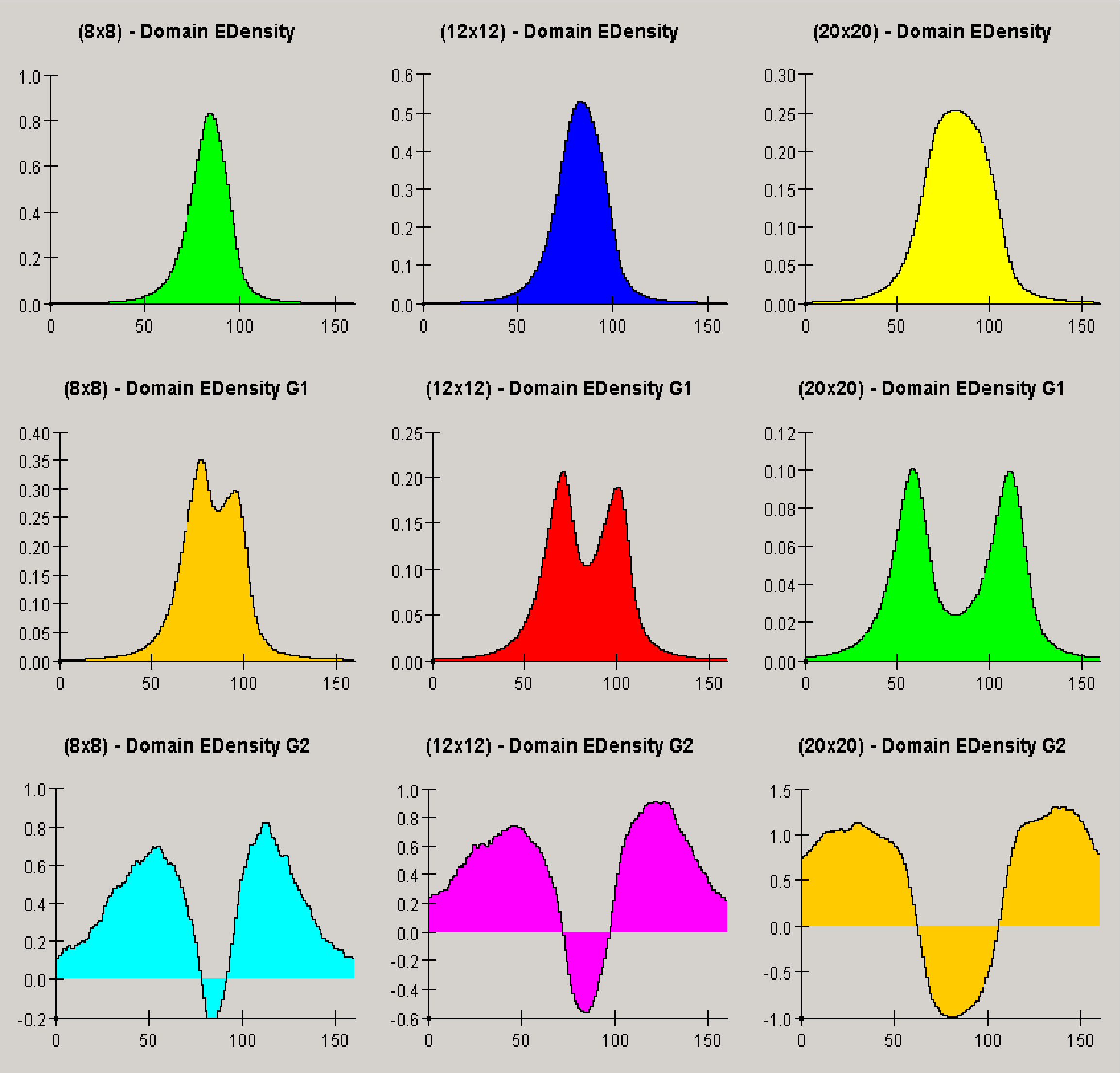
Centroid Determination

Domain Energy
Density

Centroid Isolation

Domain Energy
Density 1st Differential

Domain Energy
Density 2nd Differential



5k. 10GeV π's

Example Domain Methods

(Arbitrary units, similar w/ N.hits)

Centroid Determination

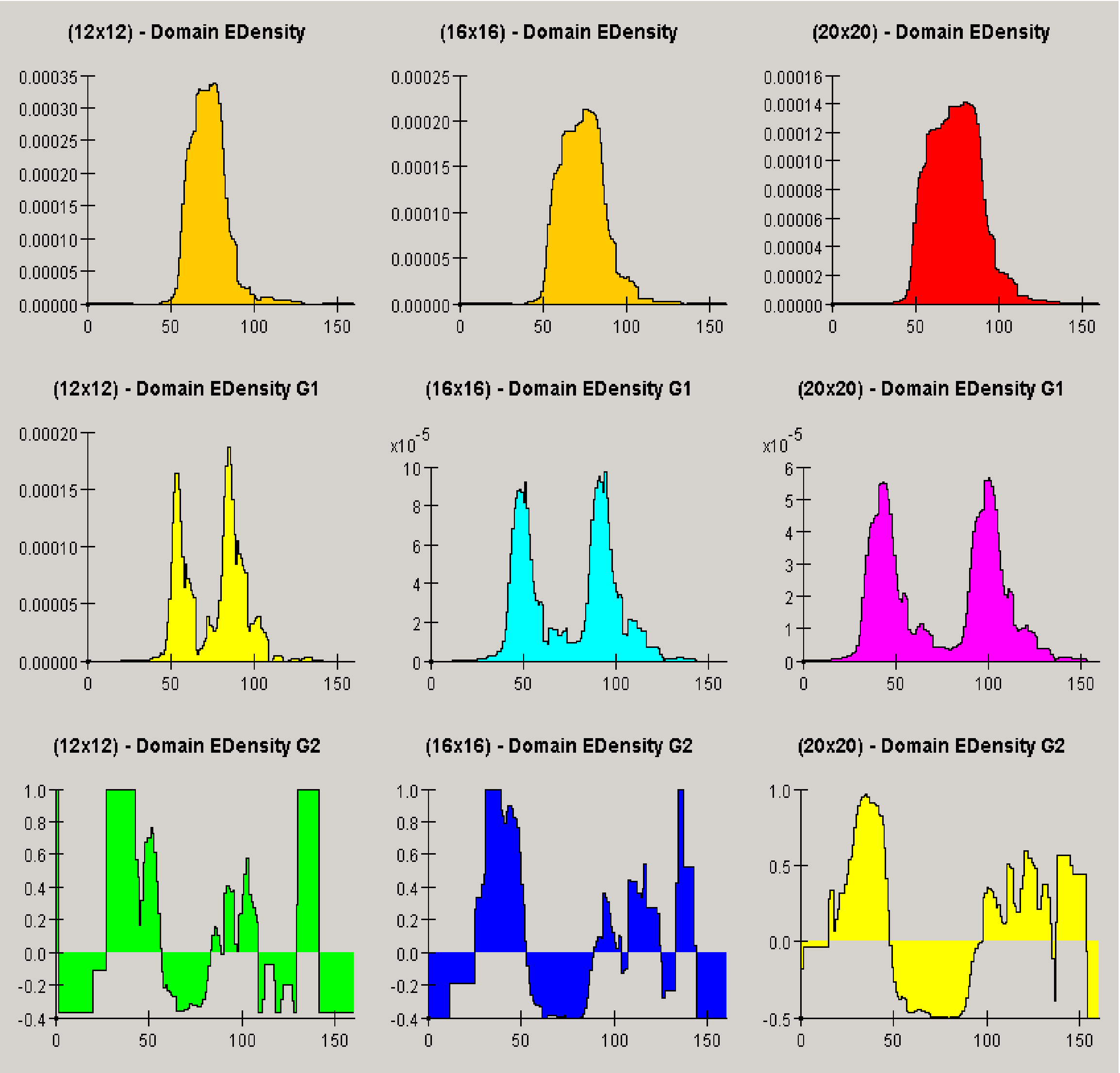
Domain Energy
Density

Centroid Isolation

Domain Energy
Density 1st Differential

Domain Energy
Density 2nd Differential

Single 10GeV π



Example Domain Methods

(Arbitrary units, similar w/ N.hits)

Centroid Determination

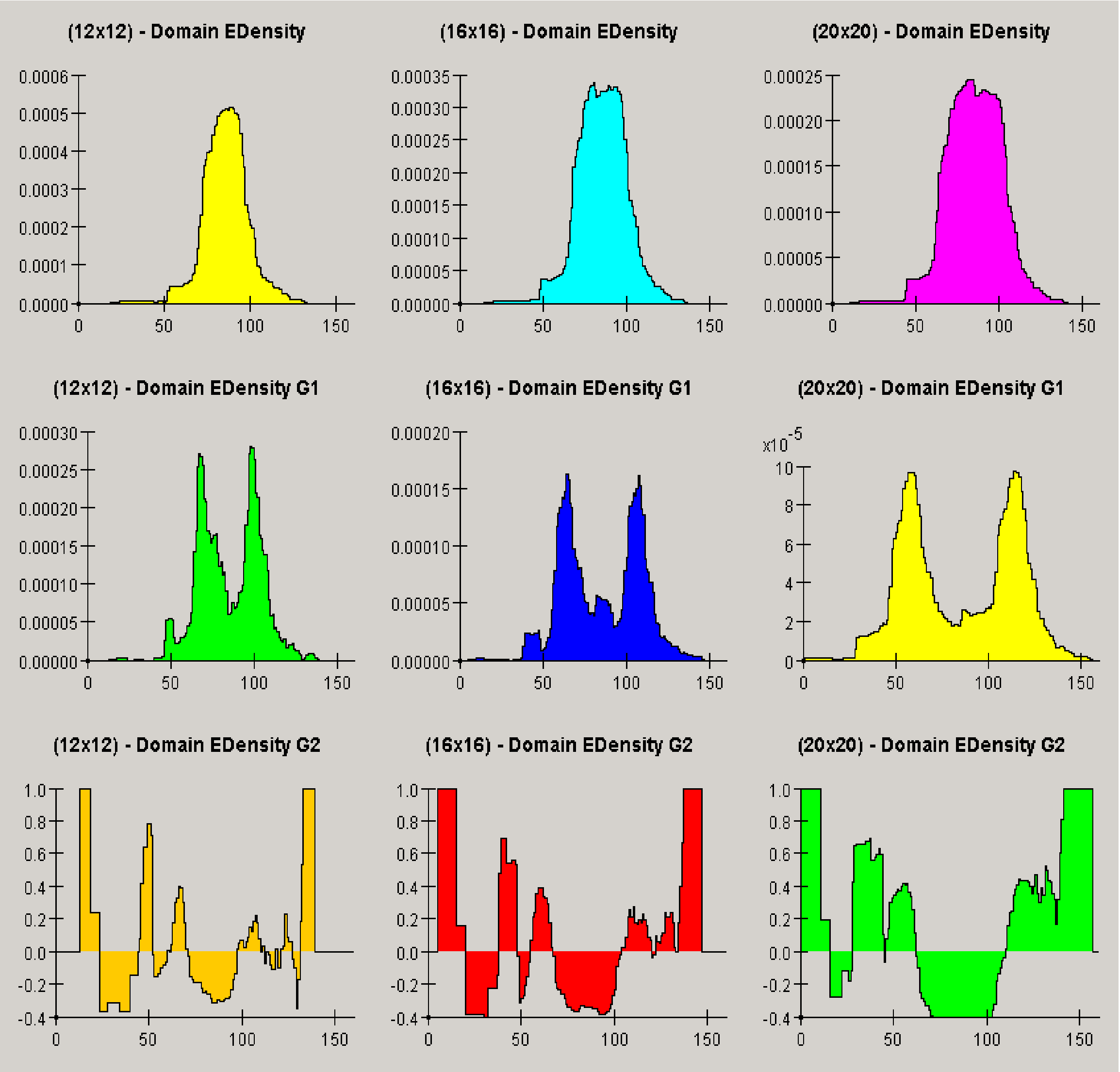
Domain Energy
Density

Centroid Isolation

Domain Energy
Density 1st Differential

Domain Energy
Density 2nd Differential

Single 20GeV π



Summary, Prospects

- Work recently started on two E-Flow driven fronts.
- Now at the preliminary tests and tool development stage.
- Proceed soon to more detailed simulations (*GEANT4*).
- Implement the NIU+UTA+ANL specific prototypes.
- Integrate E-Flow algorithm development into Linear Collider physics studies.
- Pursue a sharing of tools, models and methods with the L.C.Detector community, towards establishing common grounds for detector performance development.