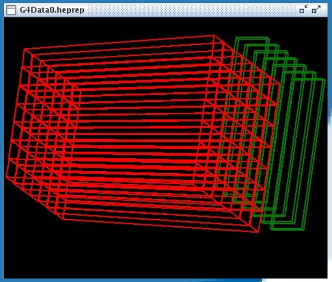


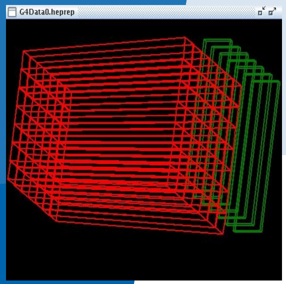
Implementing a dual readout calorimeter in SLIC and testing Geant4 Physics

ALCPG 2009

Hans Wenzel

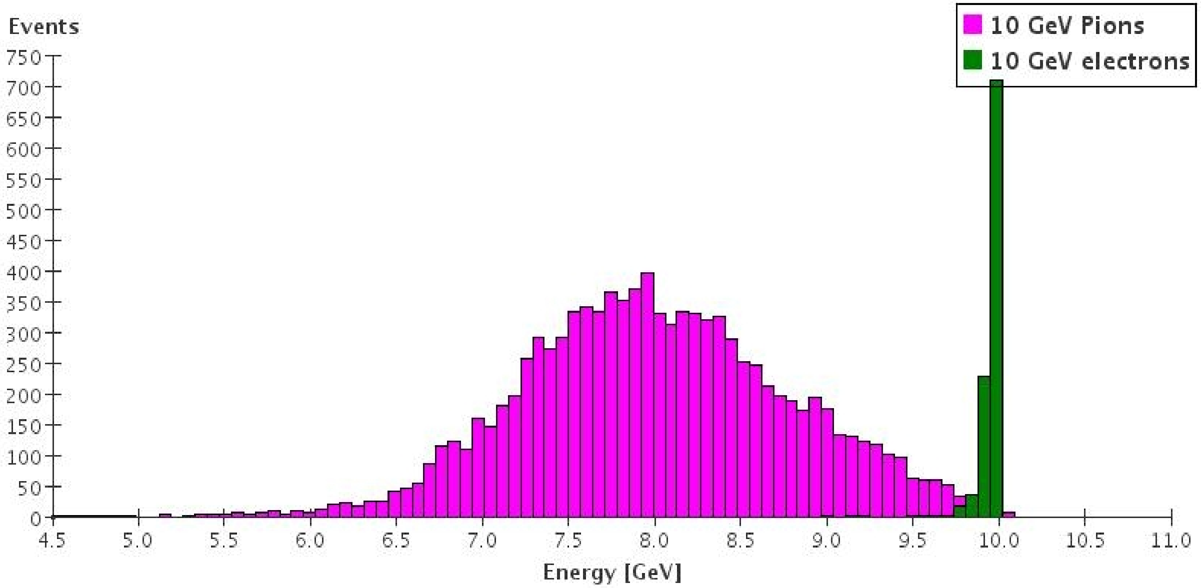
Fermilab

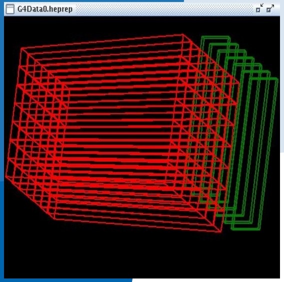
Friday, 2nd October 2009



Outline

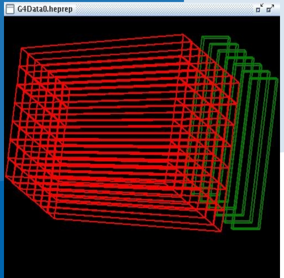
- Enabling dual read out in SLIC and lcsim.
- The ccal02 detector implementation.
- Geant 4: modeling of hadronic physics and optical processes.





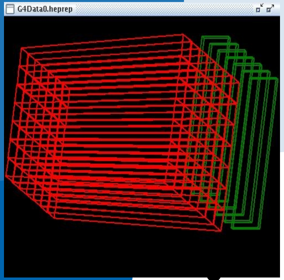
Why SLIC/lcsim?

- Geant 4 based framework for detector simulation.
- XML based detector description:
  - Easy to implement various detector variations: materials, segmentation, optical properties, …
- Variety of physics lists.
- Using SLIC allows us to make use of the entire SID framework: SLIC, lcsim.org (netbeans), WIRED, JAS3, LCIO Event Browser..... → this allows us to study physics performance as part of a complete detector.
- Easy to run SLIC on the grid → Grid scripts : easy to generate large data sets, takes care of names, random seeds etc., http://confluence.slac.stanford.edu/display/ilc/How+do+I+use+the+OSG+Grid
- At the moment we can produce data faster than we can analyze it →automating using lcsim.org



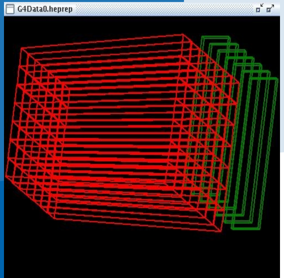
What needed to be done to simulate total absorption dual read out calorimeter in SLIC

- Need to add optical physics (Cerenkov,Scintillation etc.,) → now can be used with any physics list.
- Need to be able to add optical properties to materials in detector description e. g. refraction index/absorption as function of photon energy.
- Sensitive detector needs to be able to produce multiple hit Collection (Energy deposition, Cerenkov) → this is allowed in GEANT 4 but SLIC in its original form only allowed for one Hit collection per sensitive collector.
- Implement special optical calorimeter class:
  - Register energy deposition (Edep hits).
  - deal with optical photons. We don't track optical photons but kill them after the first step and add their energy to the Cerenkov hits.



What can't be done (yet)

- Not the framework for detailed studies of e. g. light yield, spectral response, timing....
- Currently to do that we use GEANT 4 stand alone application. GEANT 4 has all the relevant processes: scintillation, cerenkov, wavelength shifting, dispersion, absorption, reflection ....
- Would be cool to extend SLIC to be able to do this studies:
  - Geometry description needs to be extended to describe additional optical properties e.g. the optical properties of surfaces.
  - Implementation of a photo- detector class.
  - Ability to make our own classes persistent (ROOT).
  - Large amount of optical photons → need to deal with memory issues.

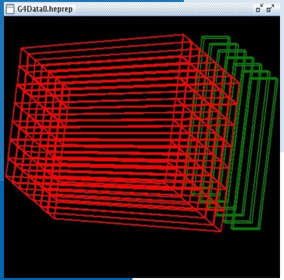


Properties of ccal02

Start with the SID02 description and replace calorimeter with crystal calorimeter consisting of cylindrical layers in the central region and disks in the end caps. All necessary files are in CVS.

				BGO		$PbWO_4$	
Name	Layers	Thickness/Layer	Segmentation	X_0	λ_I	X0	ll
		[cm]	[cm x cm]				
ECAL Barrel	8	3	3 x 3	21.4	1.1	27	1.3
HCAL Barrel	17	6	6 x 6		4.7		5.7
Total Barrel	25				5.8		7
ECAL Endcap	8	3	3 x 3	21.4	1.1		1.3
HCAL Endcap	17	6	6 x 6		4.7		5.7
Total Endcap	25				5.8		7

Material	Density	Radiation length X0	IA length ll
	[g/cm3]	[cm]	[cm]
BGO	7.13	1.12	21.88
PbWO4	8.3	0.9	18
SCG1-C	3.36	4.25	45.6



compact.xml/ccal02.xml

GeomConverter

Lcdd file

Edit by lcdd by hand

Lcdd file with:
- optical properties added (refraction index)
- calorimeter tag replaced with optical_calorimeter where necessary
- proper input for slic (needs optical physics enabled)

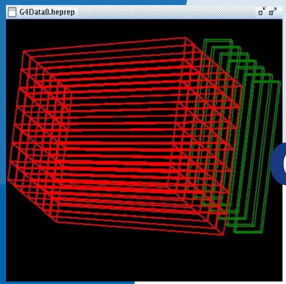
SLIC/Simulation

Analysis/Event Display

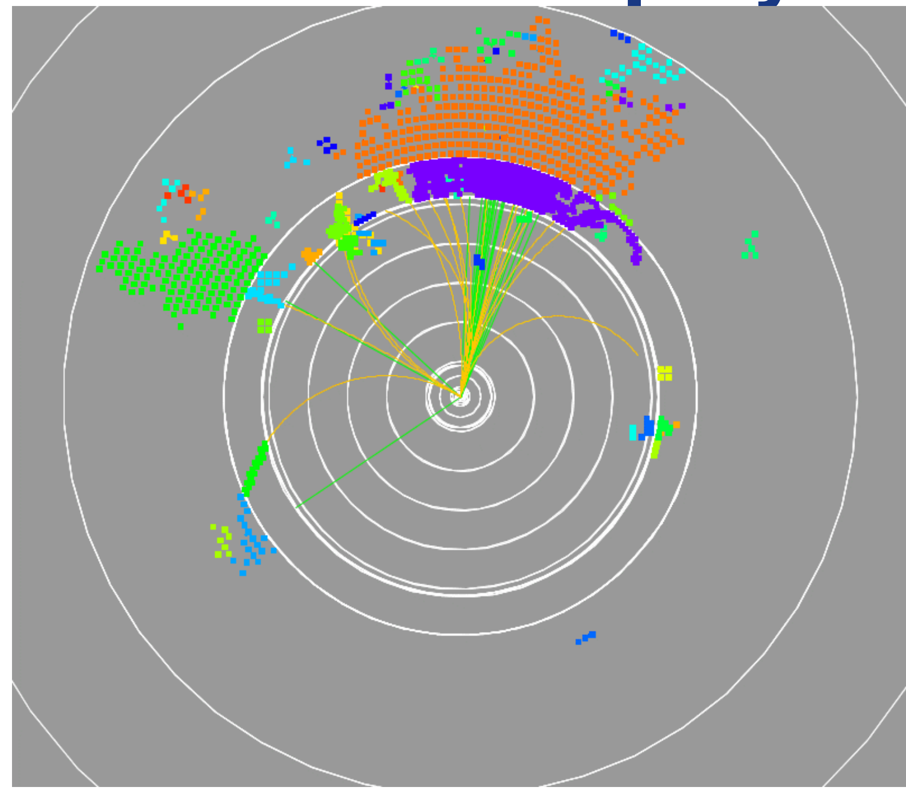
Edit by compact by hand

Compact with Edep_ and Ceren_ calorimeter hit collections

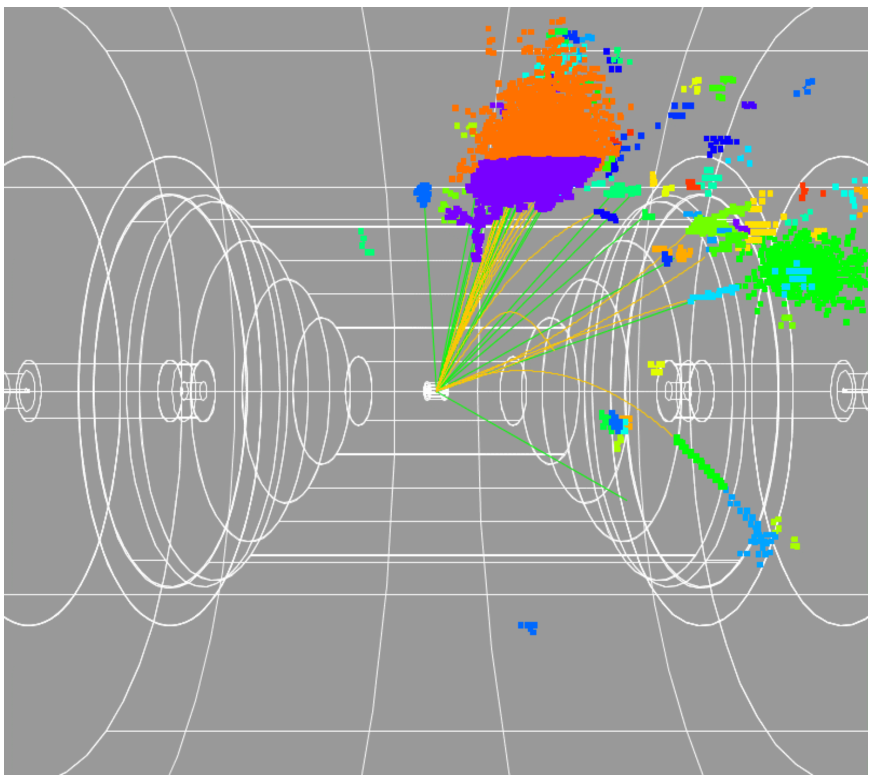
Hans Wenzel



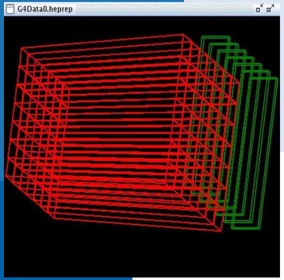
CCAL02 Scintillation response as displayed in the Wired event display



ZZ->qqνν

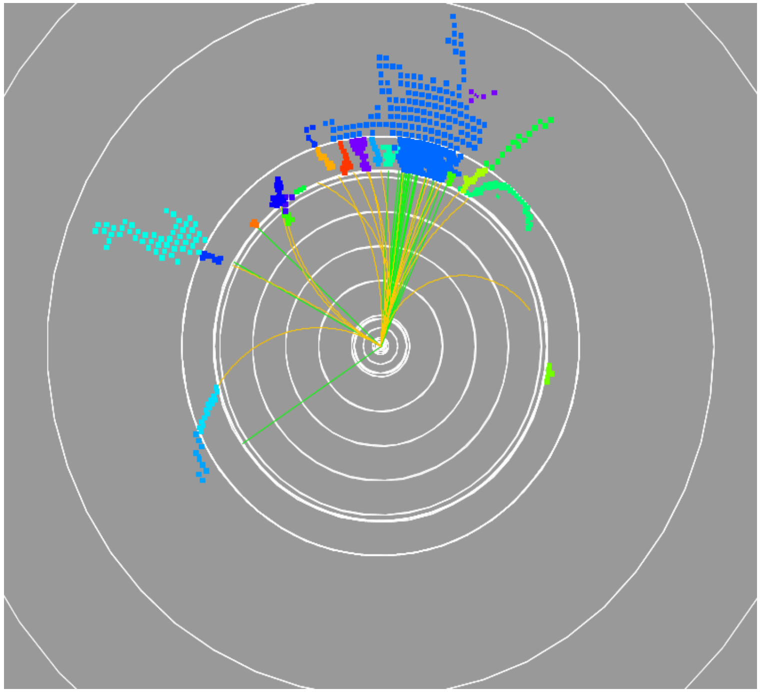


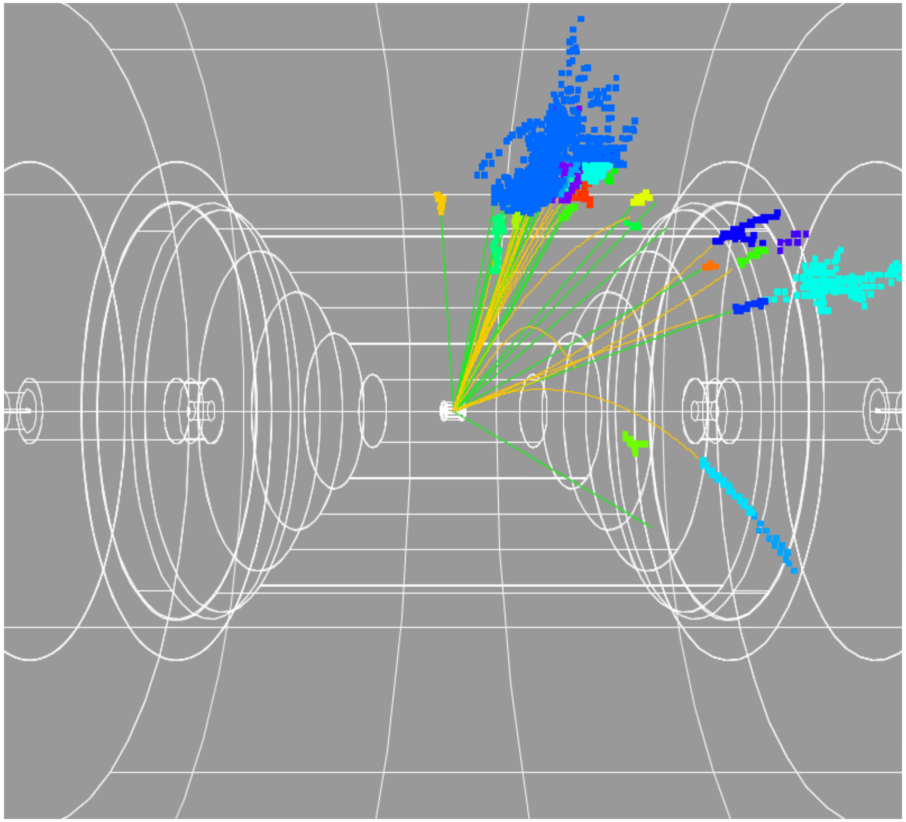
Digisim

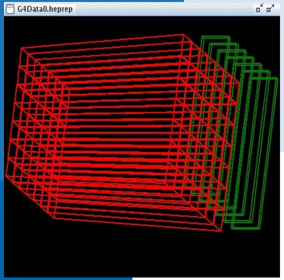


CCAL02 Cerenkov response as displayed in the Wired event display

ZZ->qqνν



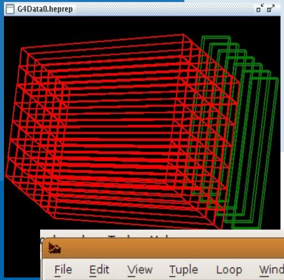




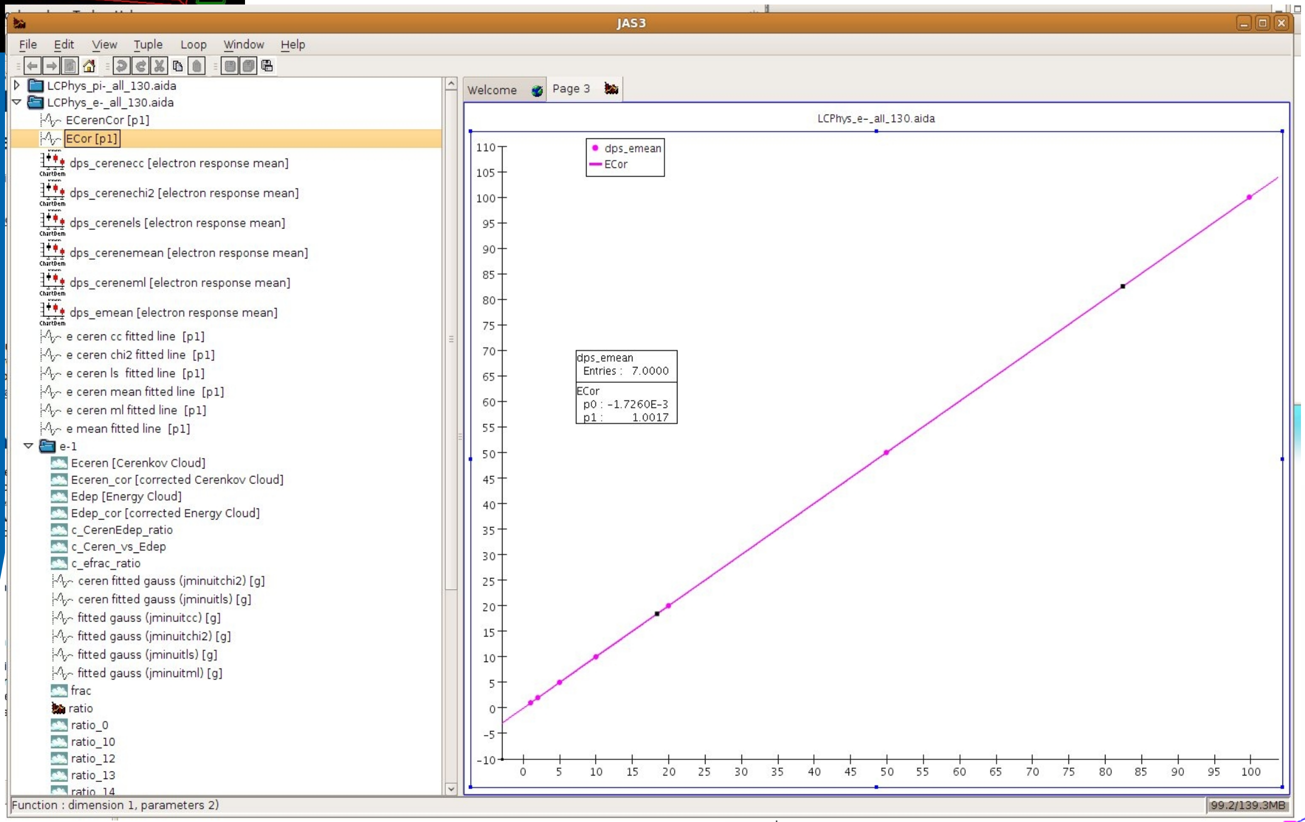
Automate analysis

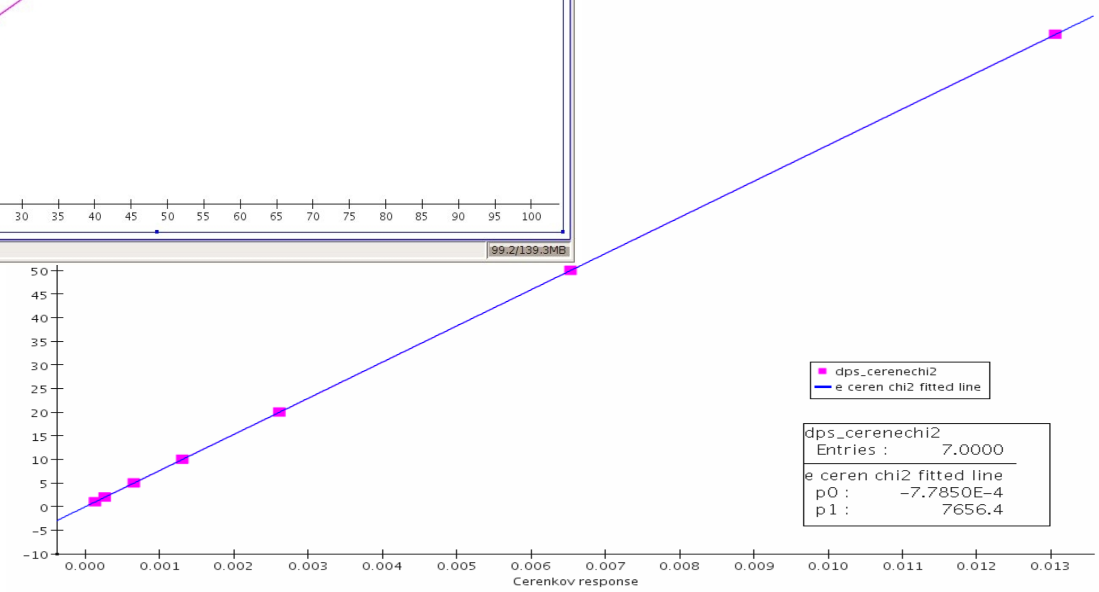
Goal: study many Detector variations, physics list etc. , obtain optimal detector configuration. Use grid to generate data sets, but also need to automate analysis like calculation of energy scale, correction functions and obtain resolution function → three lcsim modules, driven by JobControlManager, output ASCII and .aida.

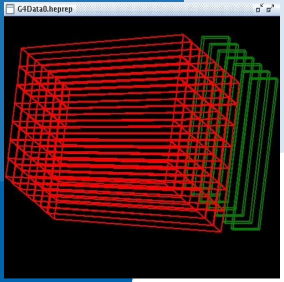
- Ecorrection: expects single electrons, obtains scale for Edep and Cerenkov response.
- DualCorrection: expects single Pions, obtains dual readout corrections combined and for various energies.
- Resolution: obtains resolution as a function of energy.



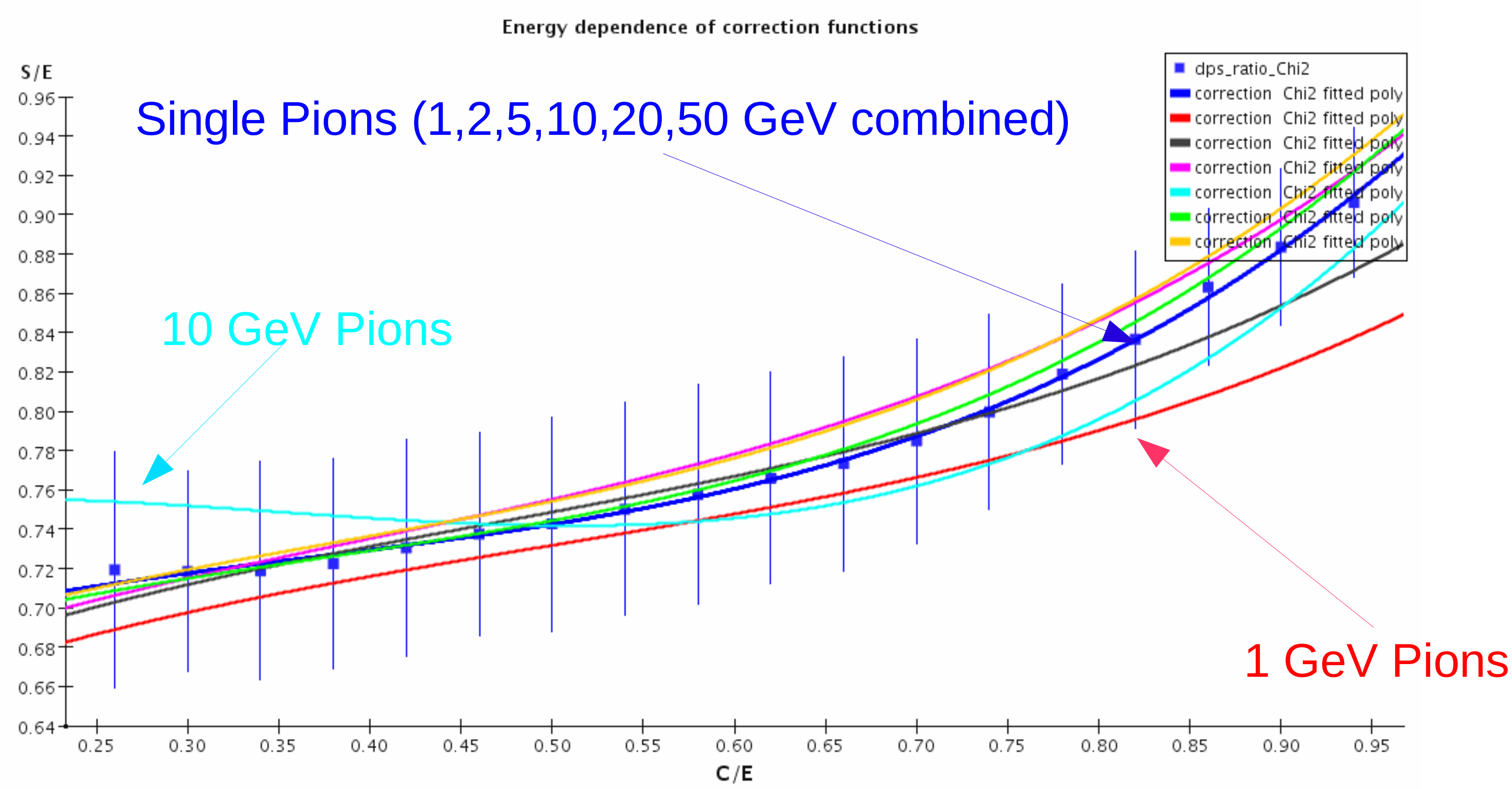
Electron response



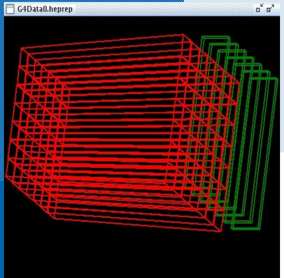




Correction function as function of energy



LCPhys: physics list, ccal02 BGO



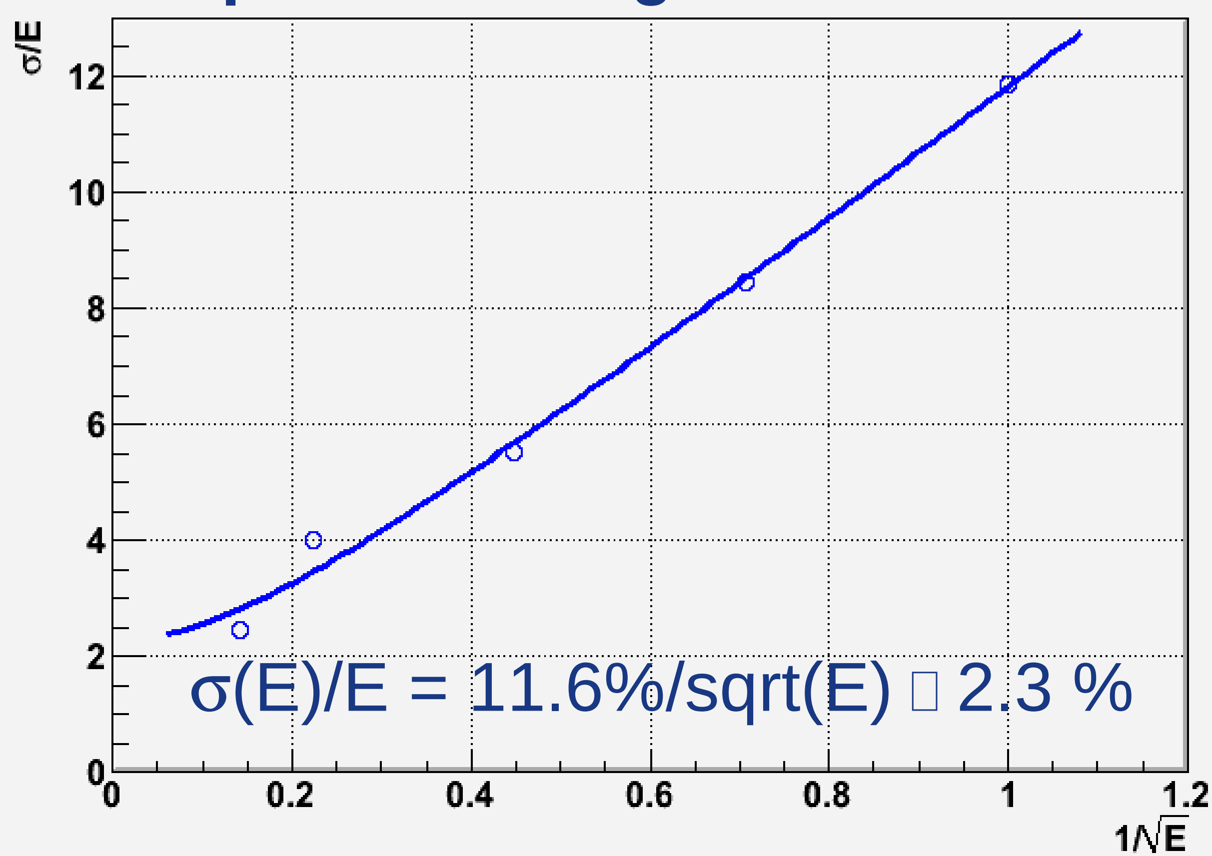
Finally: Resolution function

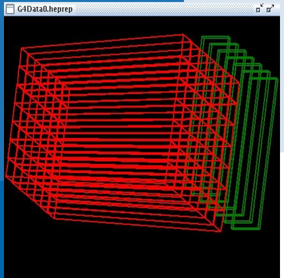
Did it last night!

LCPhys
ccal02 BGO
No threshold
No clustering

Cor. function
(averaged)

Response to single Pi-





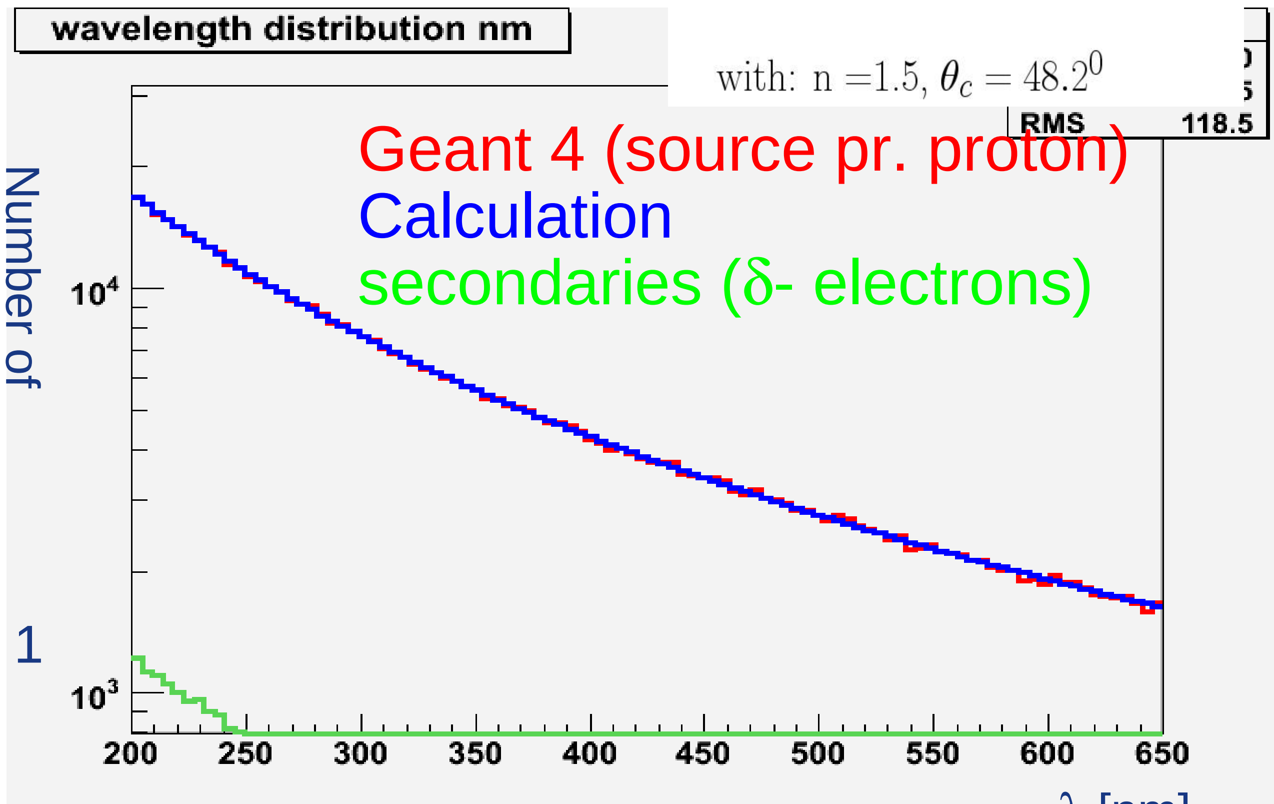
Spectrum of Cerenkov photons

$$n_{photons} = 2\pi\alpha \sin^2\theta_c \cdot \int_{\lambda_2}^{\lambda_1} \frac{1}{\lambda^2} d\lambda$$

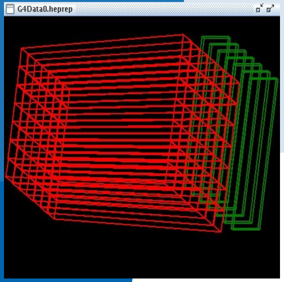
where

$$\cos\theta_c = \frac{1}{\beta n}$$

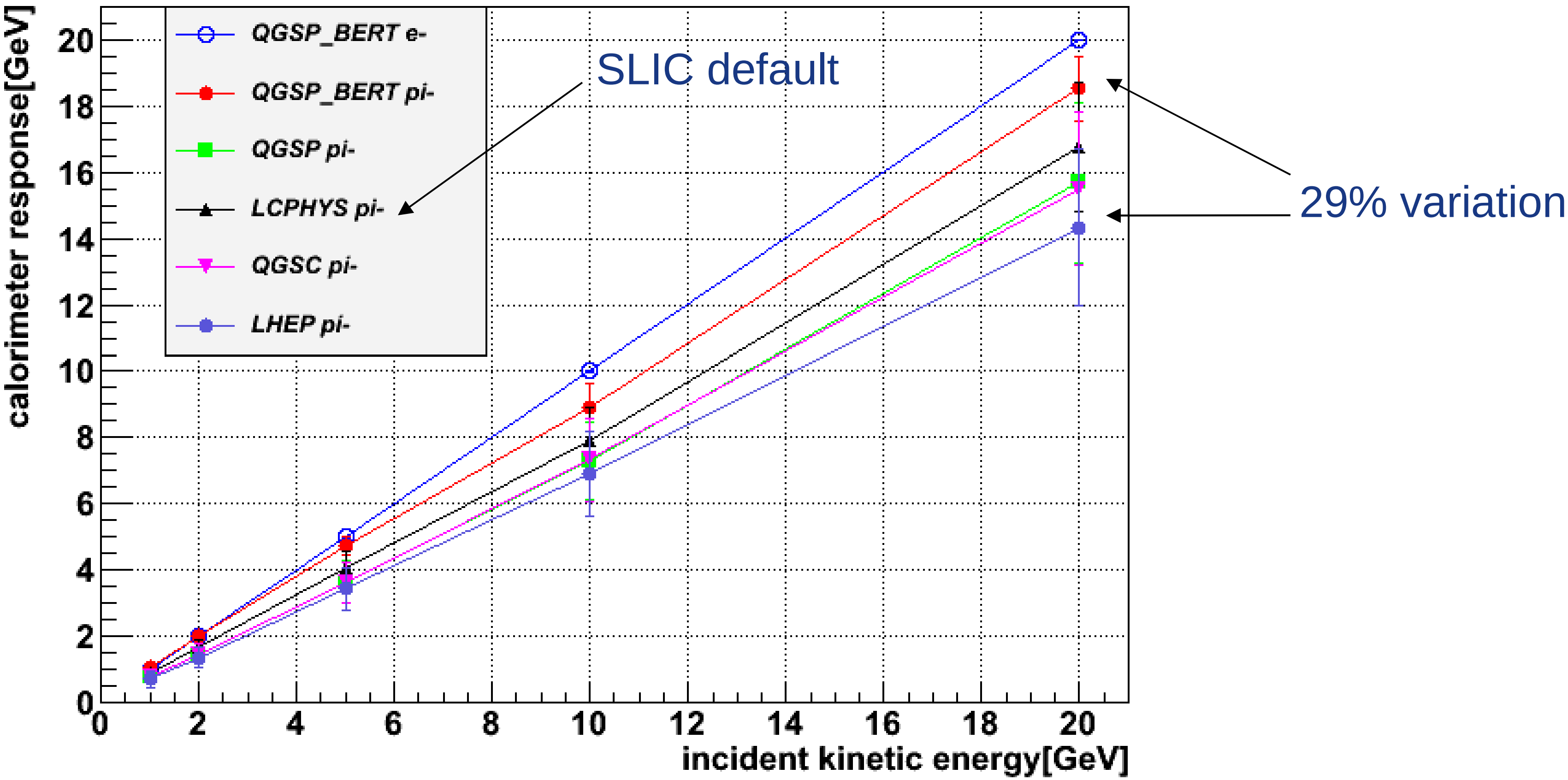
with: n =1.5, $\theta_c = 48.2^0$



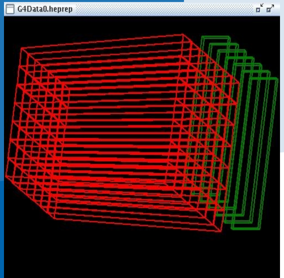
expect ~ 526 photons,
Geant 4 predicts 528+/- 1



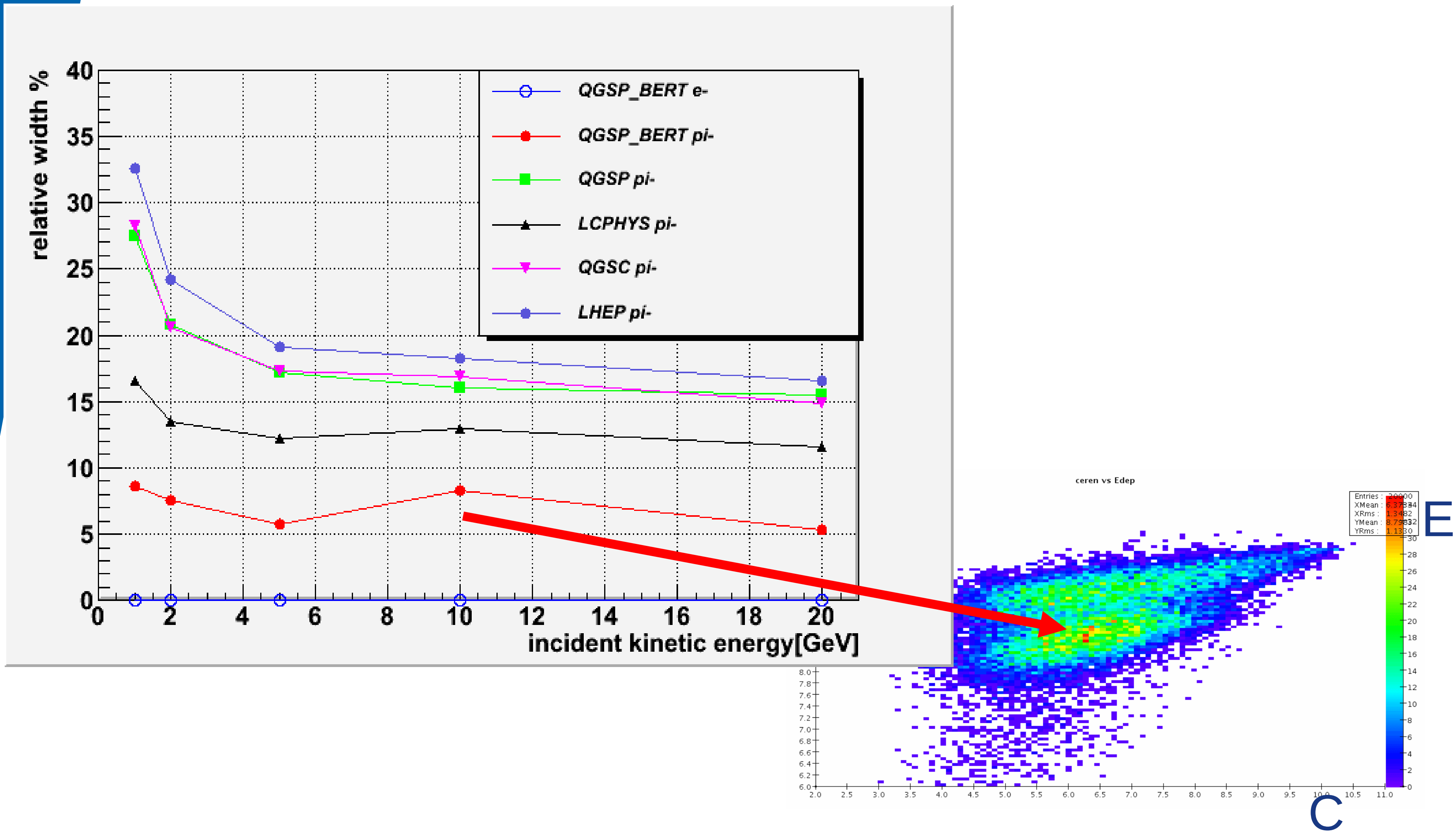
BGO Calorimeter response for different physics models

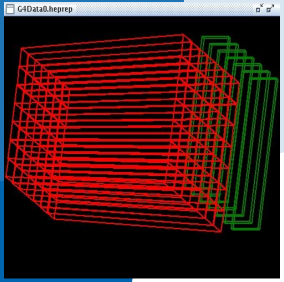


Particles produced within the calorimeter!
No threshold! → all energy deposition are added up

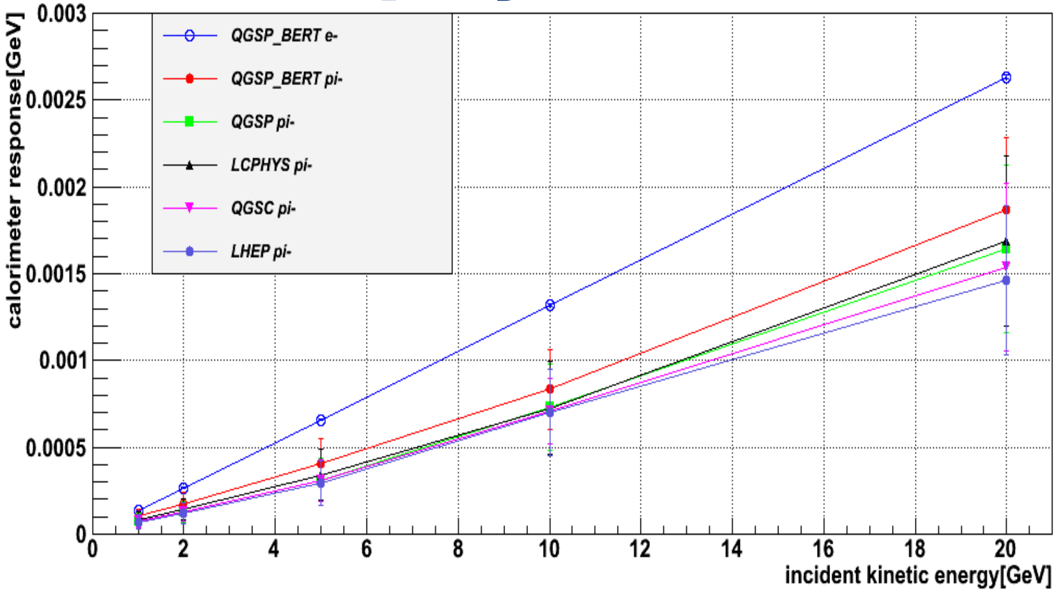


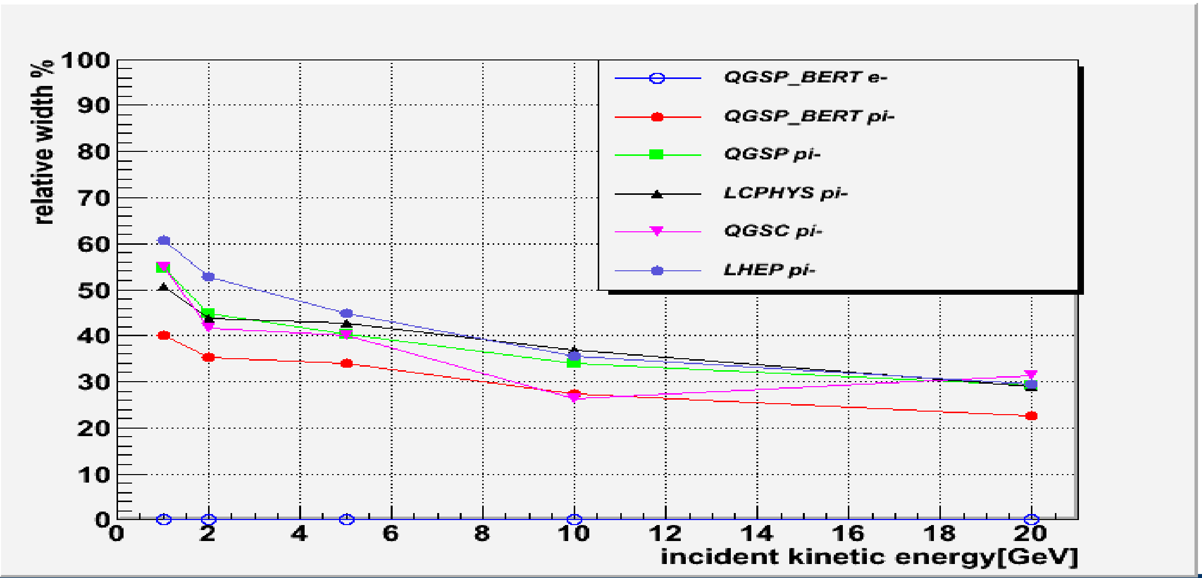
BGO relative width of energy response to charged pions for different physics lists

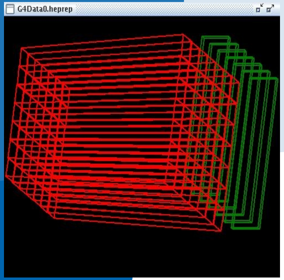




BGO Calorimeter Cerenkov response for different physics models

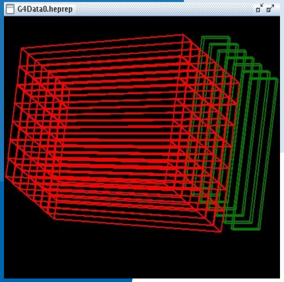




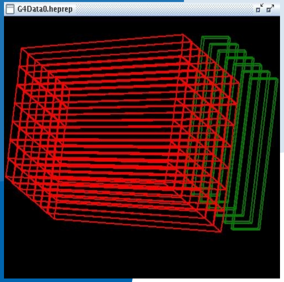


Summary

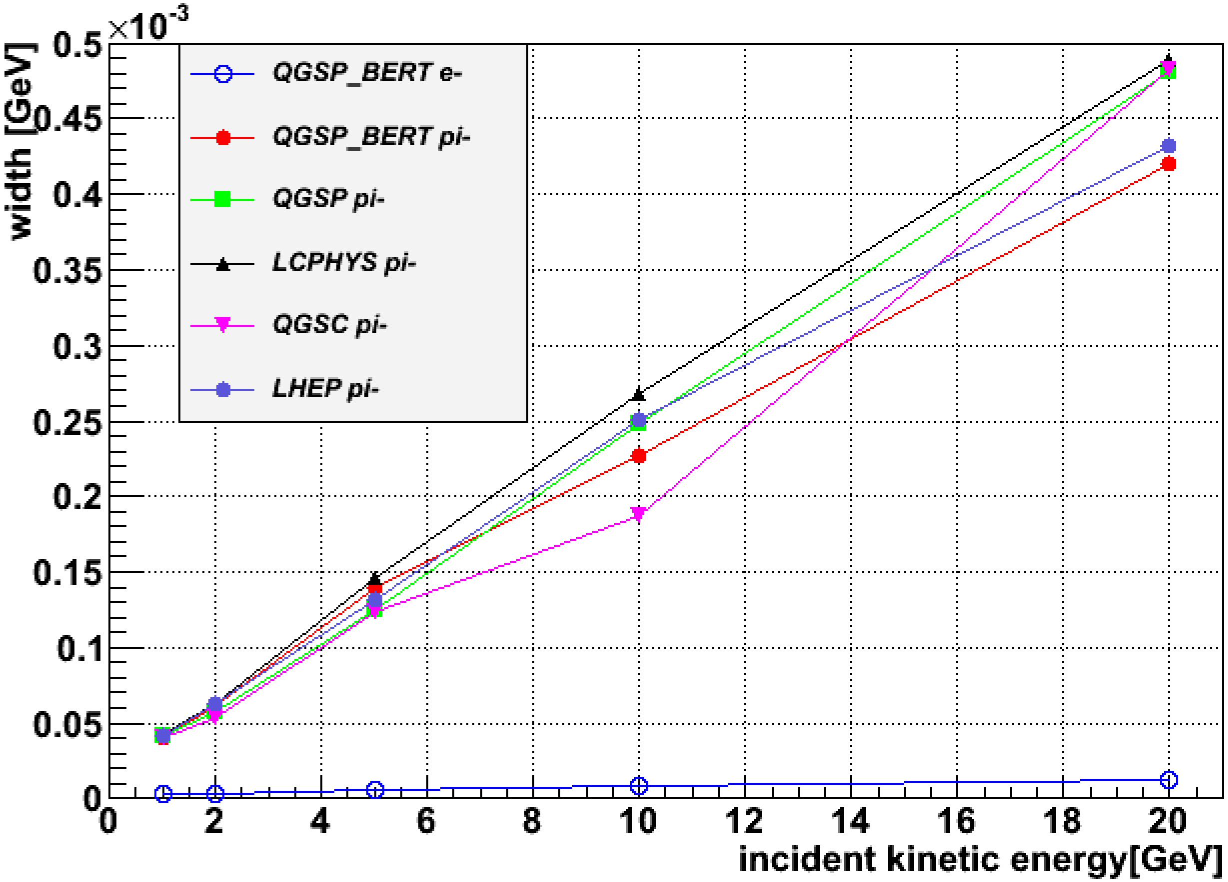
- SLIC has been extended to allow for dual read out. Dual readout is 'completely' integrated in the SID software framework.
- Various detector versions are available (ccal02). Large data sets are available at Fermilab. http://confluence.slac.stanford.edu/display/ilc/SLIC+Dual+Read+out+Tutorial
- GEANT 4: good tool to model optical processes.
- Observe big differences when using different physics lists. Started dialog with the GEANT 4 team and will continue to work with them.

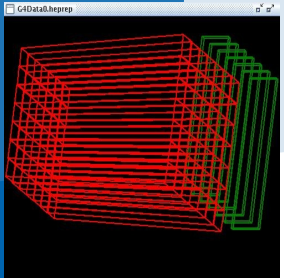


Backup slides

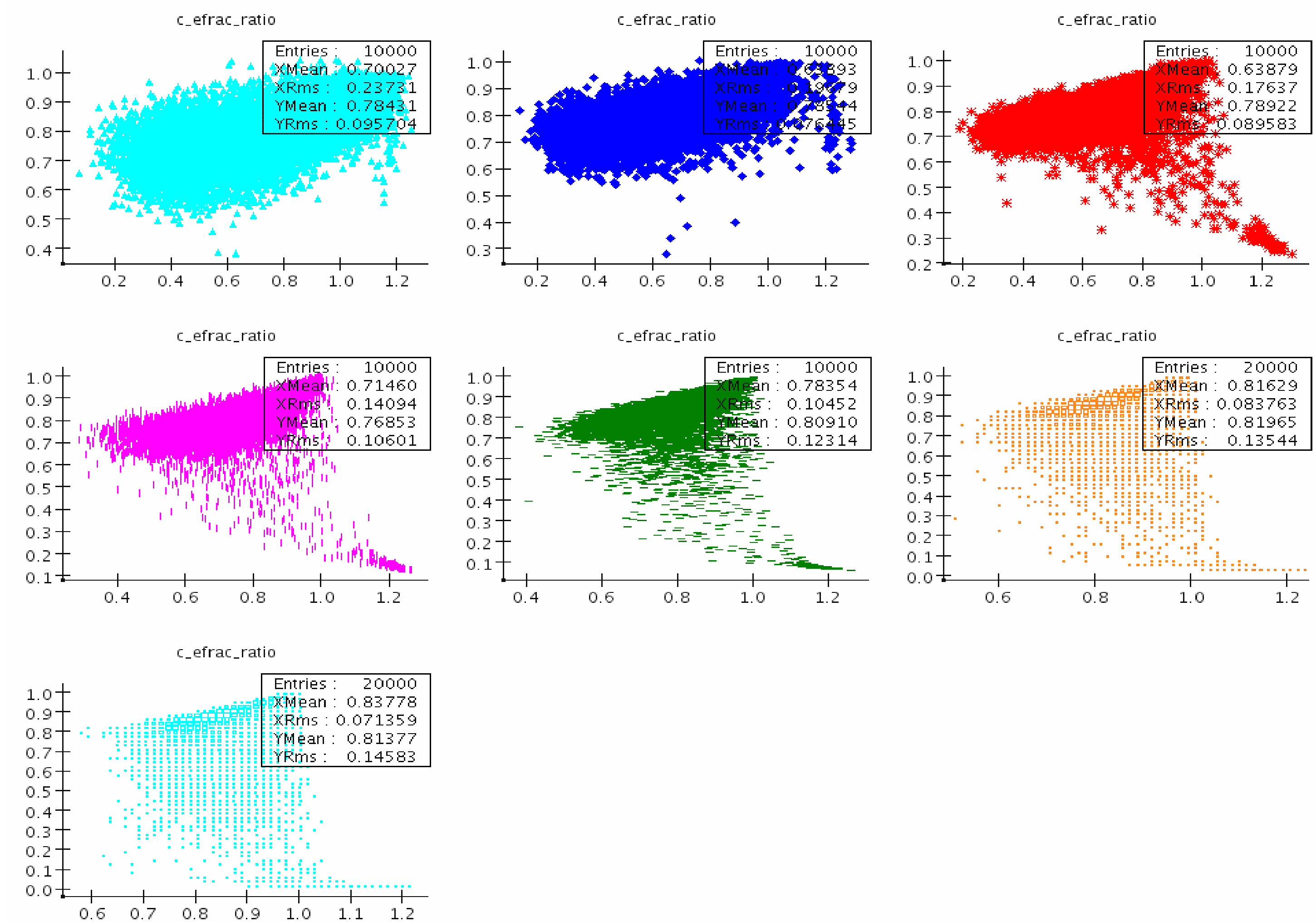


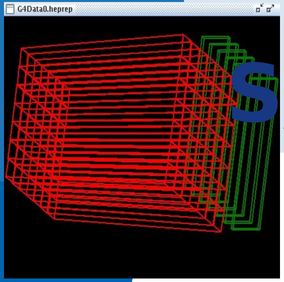
Width of cerenkov distribution



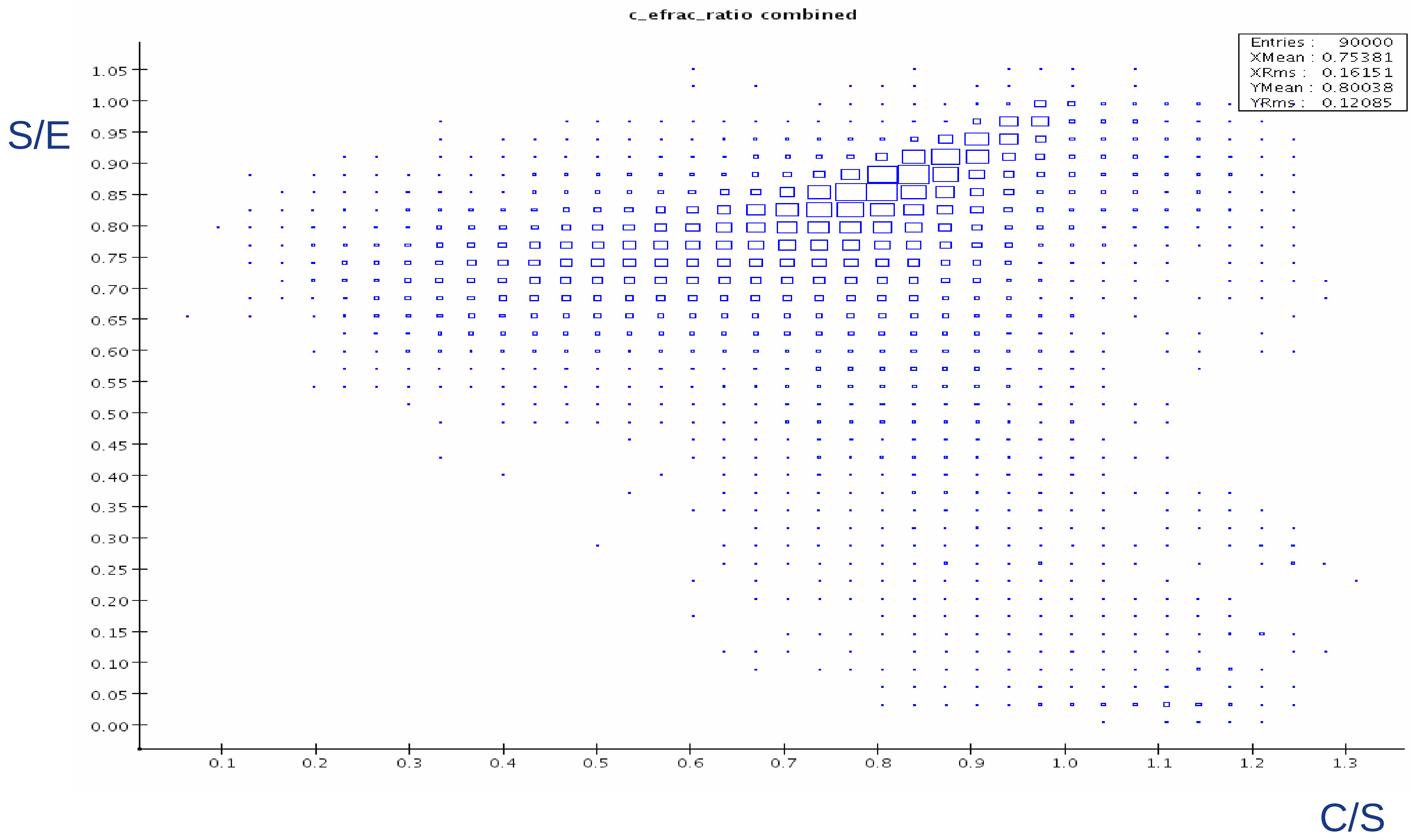


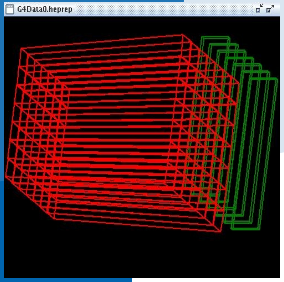
DualCorrection:S/E vs C/S all energies combined



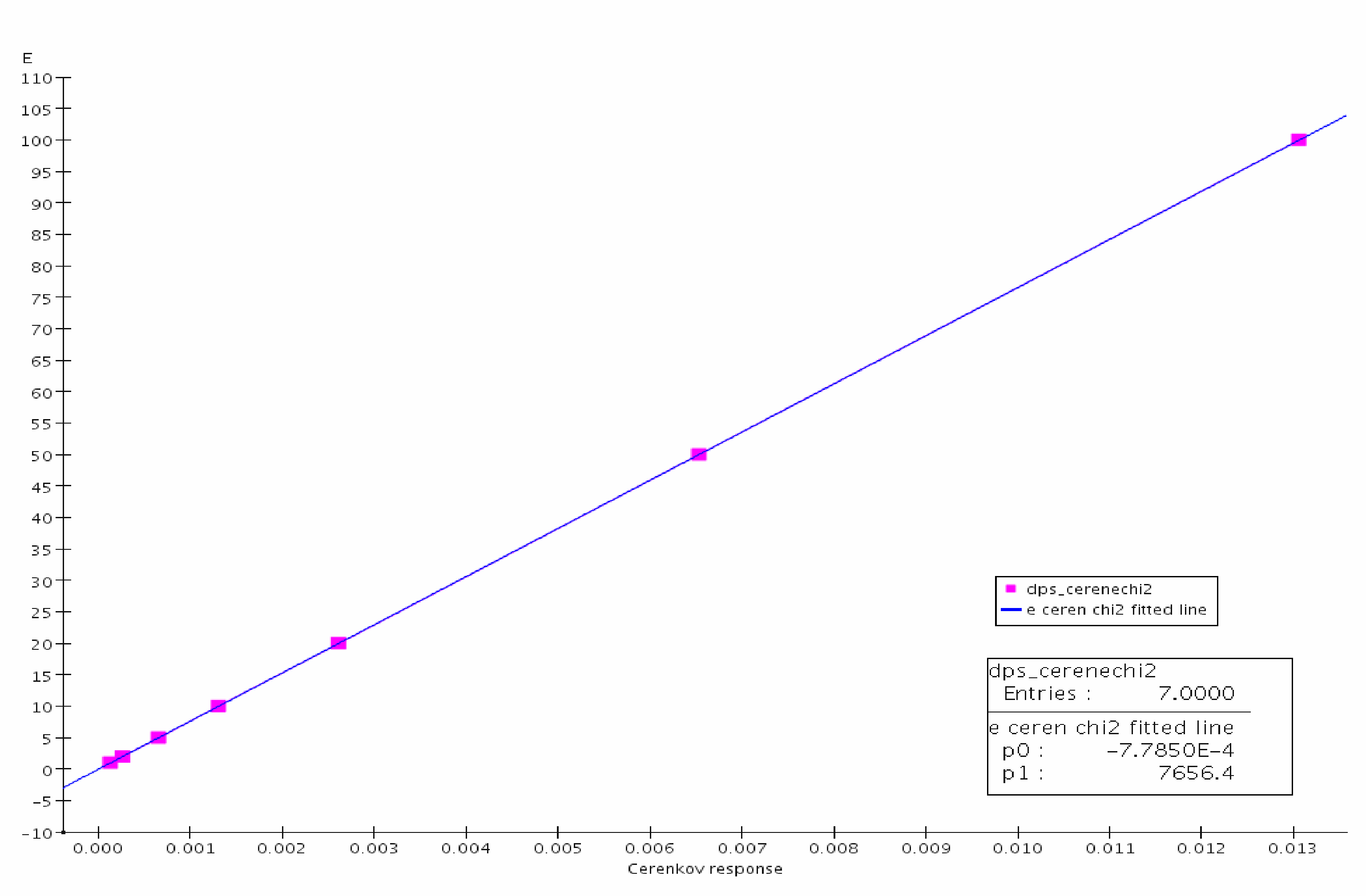


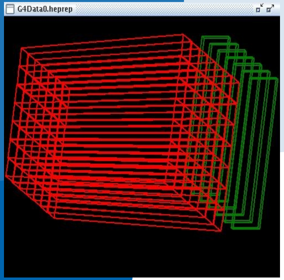
S/E vs C/S all energies combined



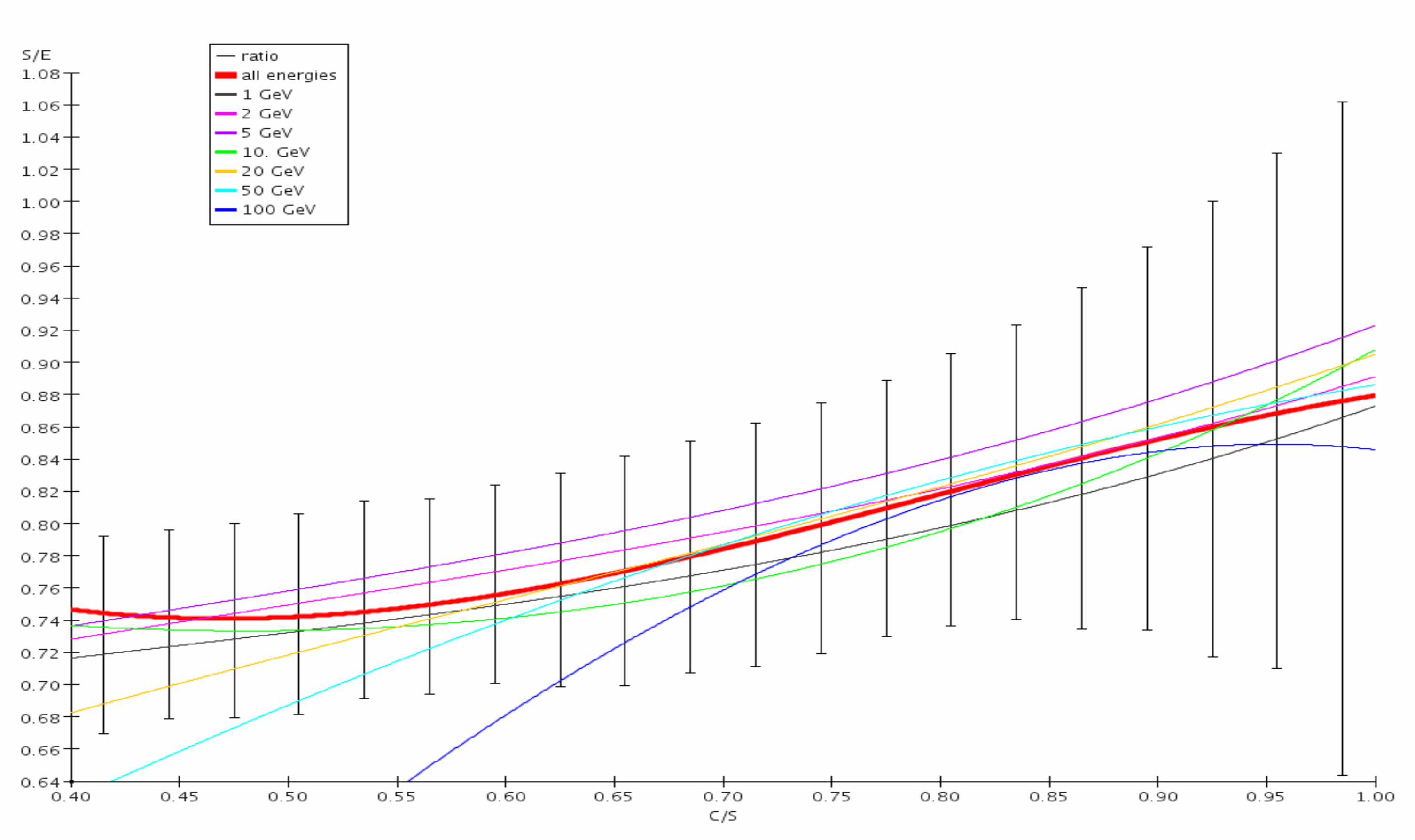


Electron Cerenkov response correction function

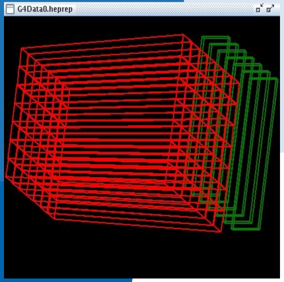




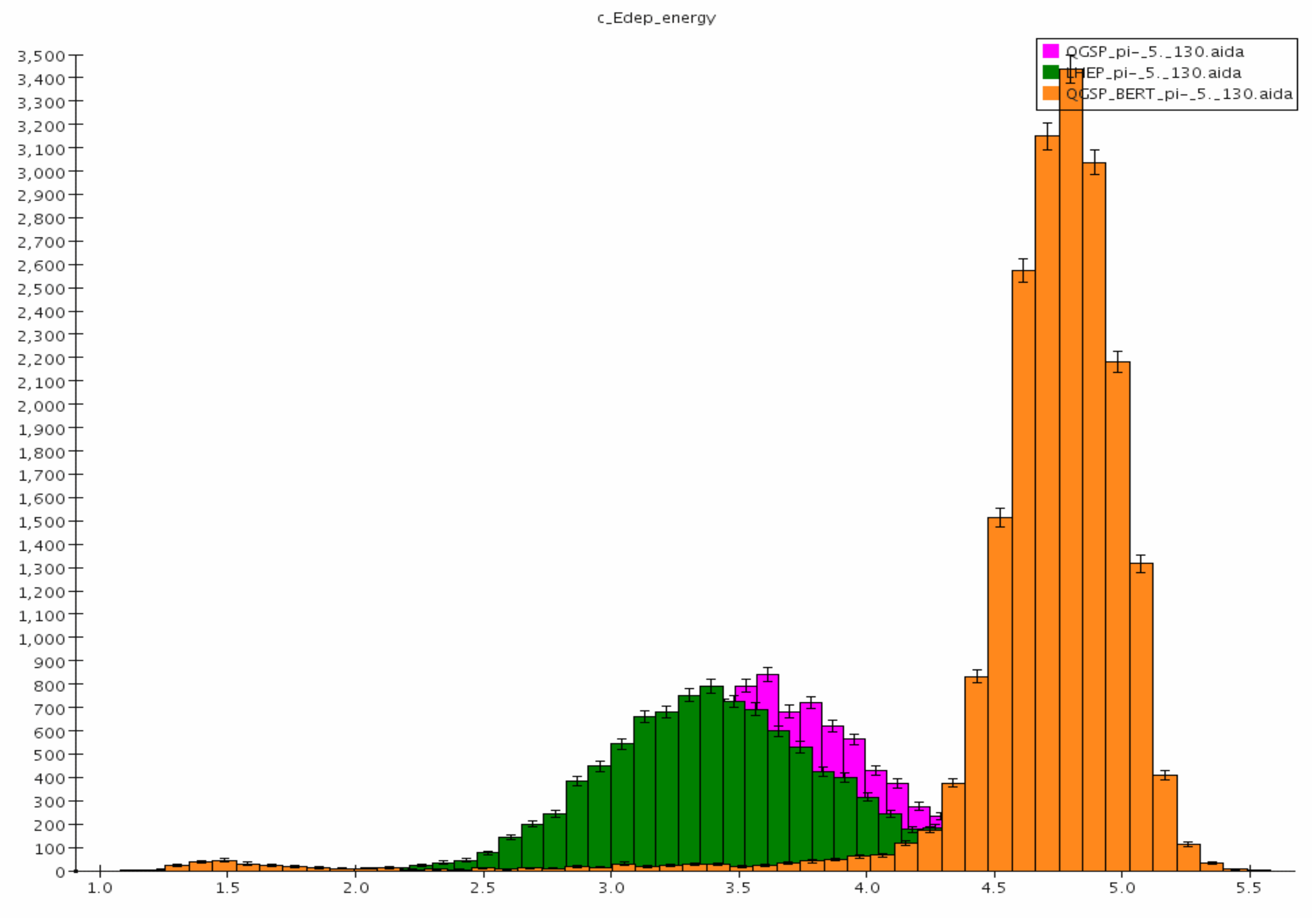
Correction function as function of energy

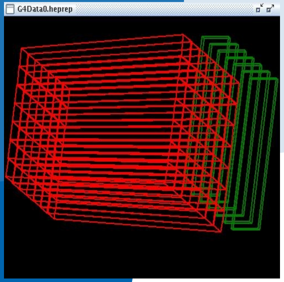


Note: For high energies (50, 100) only the low values in C/S have not been Excluded: resulting in a bad fit.
Non interacting (minimum ionizing) pions not removed

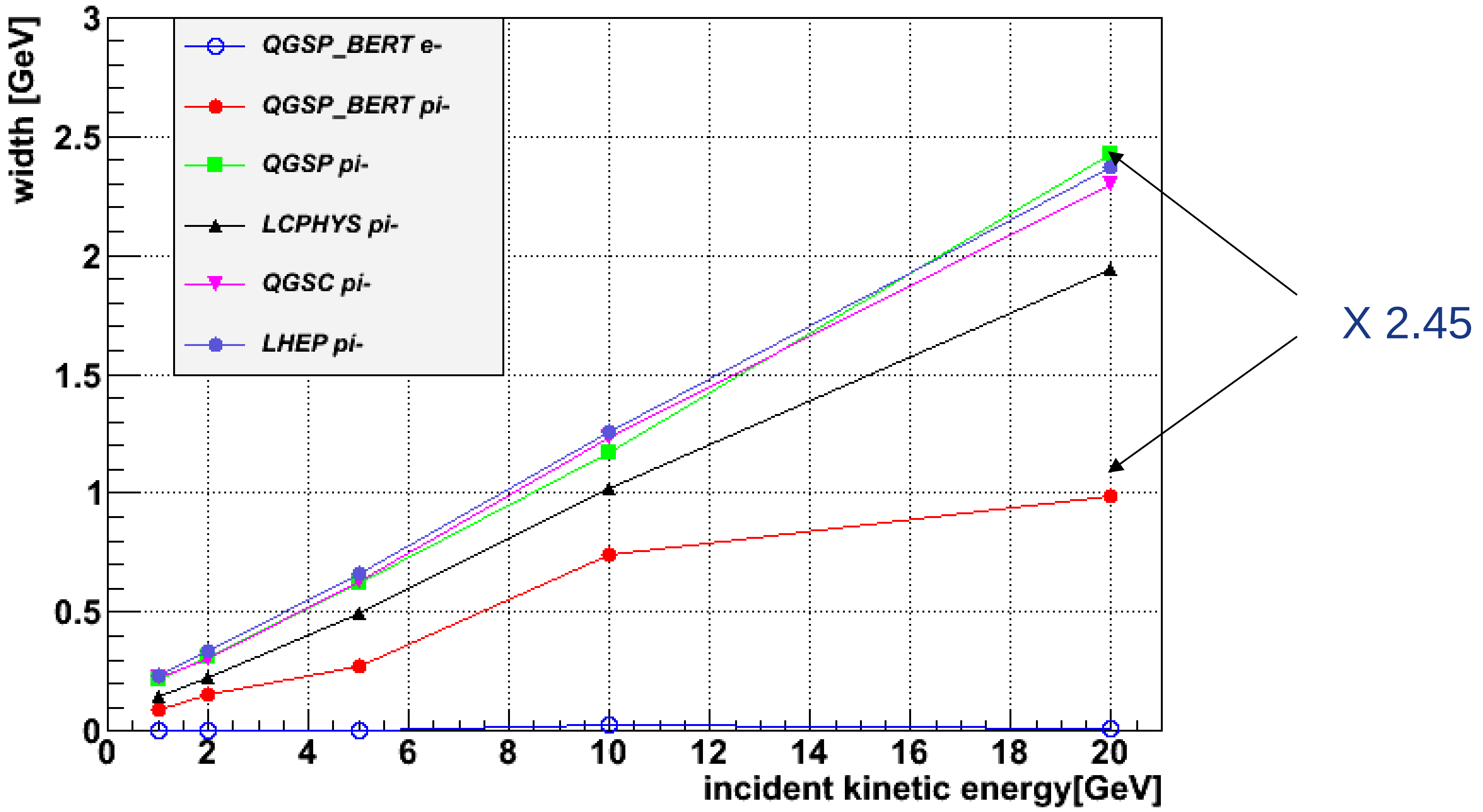


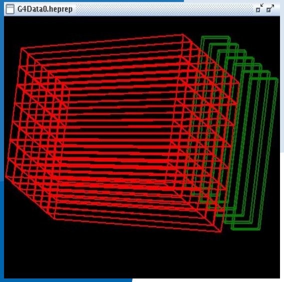
Calorimeter response for different physics models



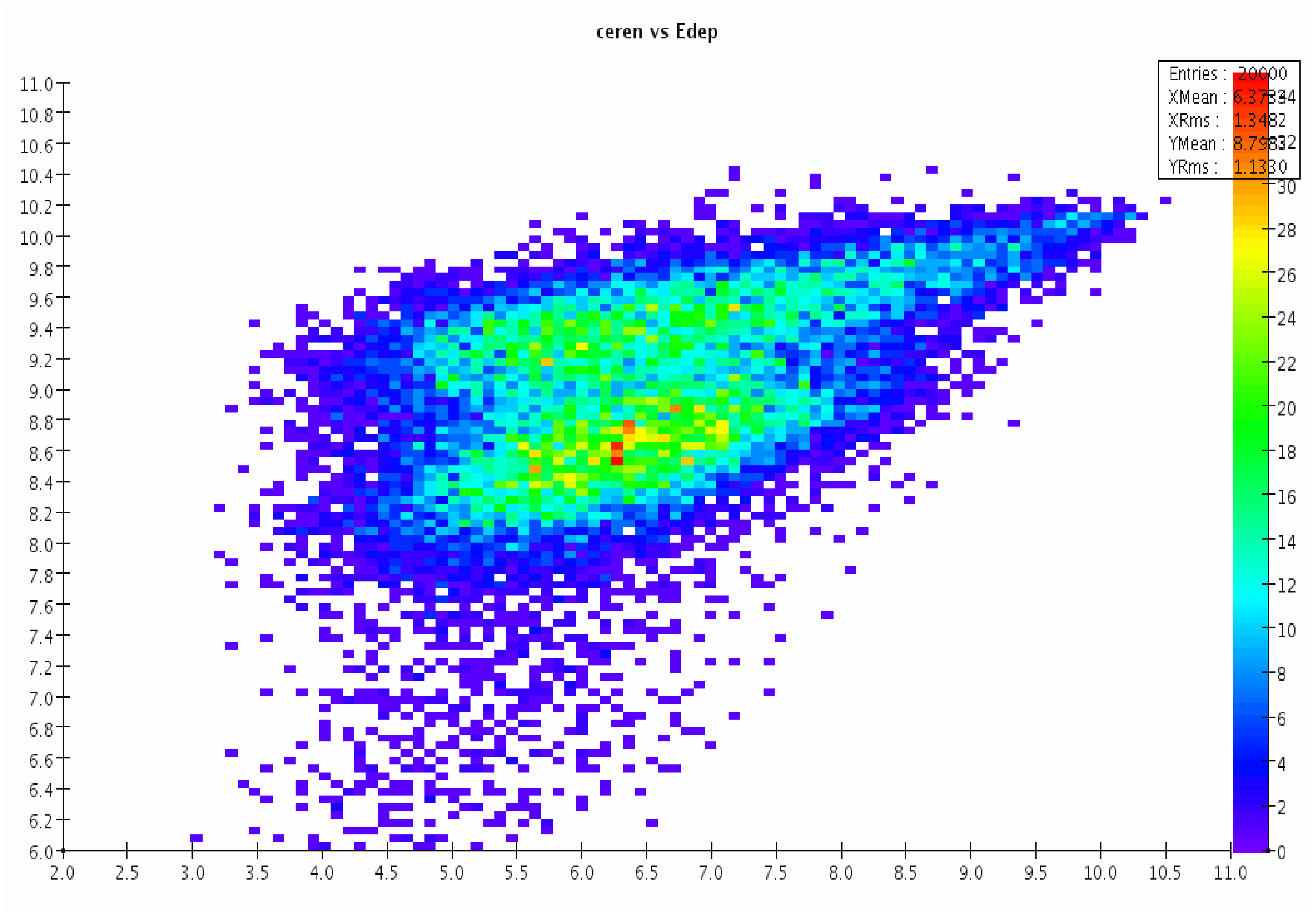


Width of calorimeter response

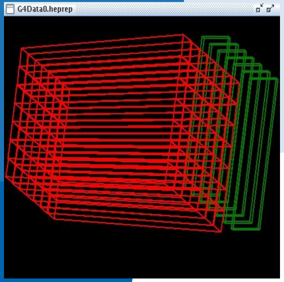




QGSP

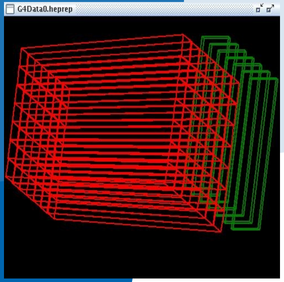


ceren vs Edep
Entries : 20000
XMean : 6.37334
XRms : 1.3482
YMean : 8.79832
YRms : 1.1330

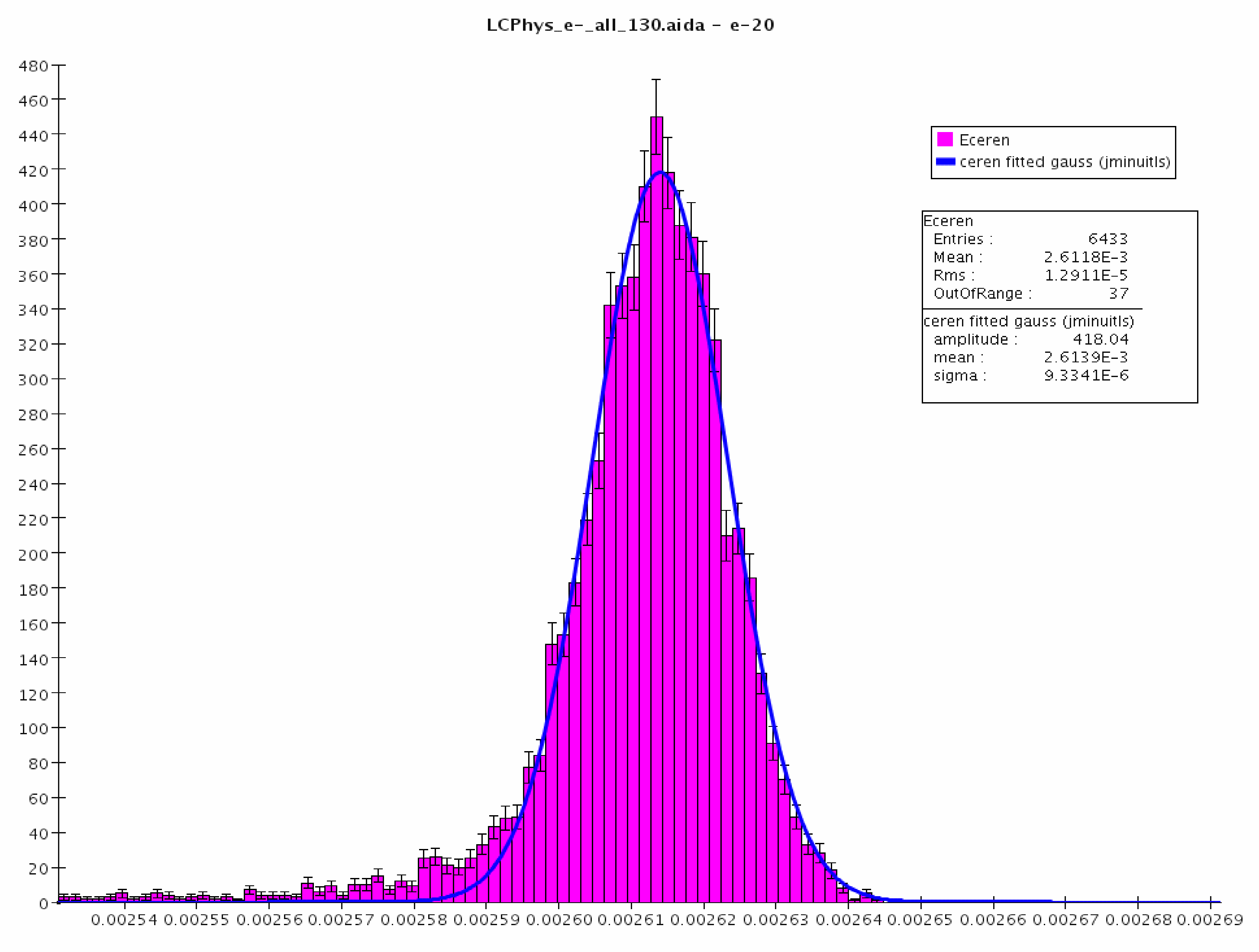


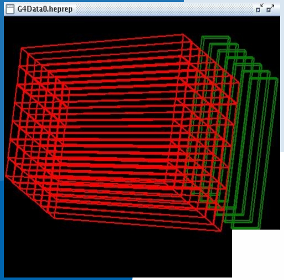
Goals

- Automate calculation of energy scale and correction functions using lcsim.org.
- Learn how to use lcsim effectively.
- Obtain correction functions/resolution curves for different
  - Physics models
  - Detector configurations (n, material....)
  - Incident angles
  - ...
- Make functions available as lcsim module.
- Study energy dependence of correction functions. Can we achieve better resolution with making energy (angular ..) dependent corrections?
- Provide material for ALCPG
- Document everything on: http://confluence.slac.stanford.edu/display/ilc/SLIC+Dual+Read+out+Tutorial

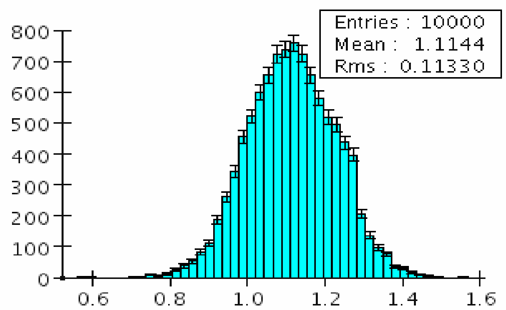


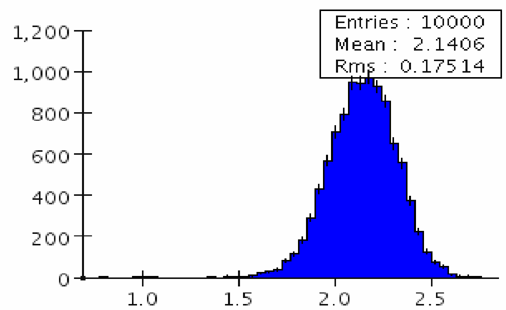
Electron Cerenkov response

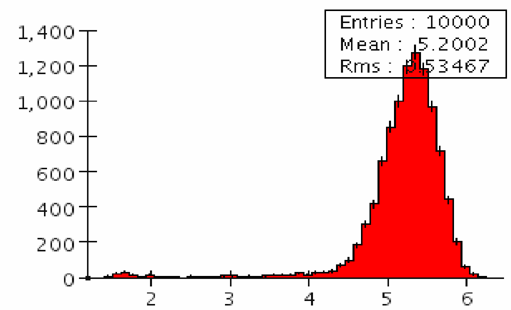


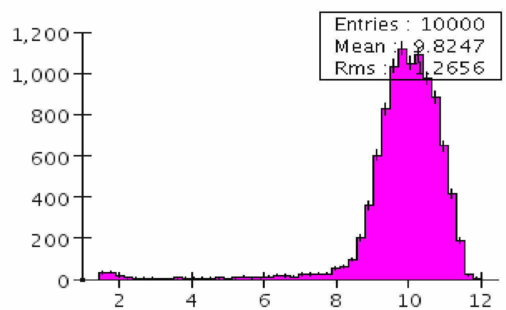


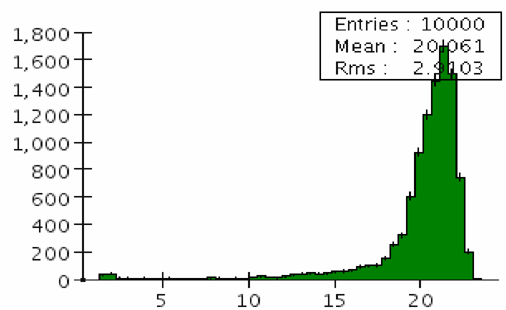
Pion response after dual corrections (all energies combined)

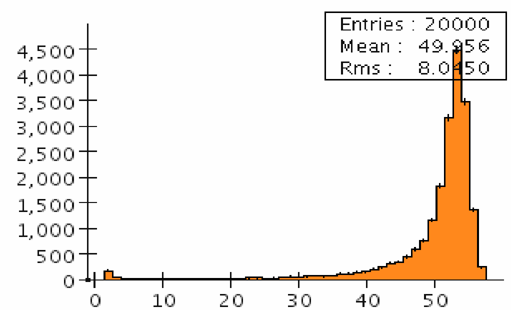


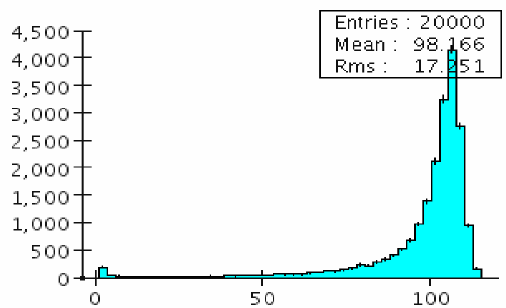


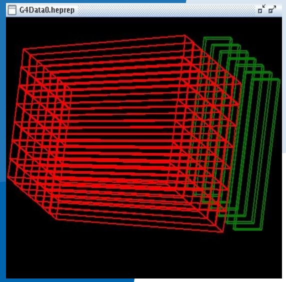












Corrected Cerenkov response