Muon Collider Simulation in org.lcsim: overview, status and plans

- Logistics
- The org.lcsim framework
- The mcd00 detector, time evolution of hadronic showers
- Dual readout calorimeter ccal02
- Additional Tools we developed:
  - DRCalRoot: detailed studies of DR calorimetry
  - DRImageDB: organizing our results
- What's the plan?

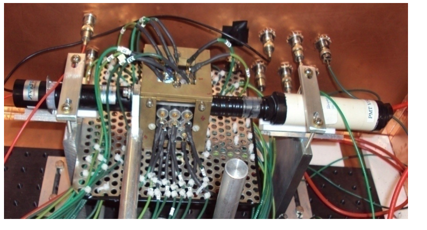
Hans Wenzel

Fermilab

Oct. 19th 2011

Logistics

- Weekly meeting 'every' Friday 10 am in the 8th floor Quarium (this week 1 north)
- Topics:
  - Dual Read out calorimetry: simulation and Event reconstruction.
  - Dual read out calorimetry for future lepton colliders
  - Test Beams: single Crystals → EM calorimeter → soon scintillating glass calorimeter

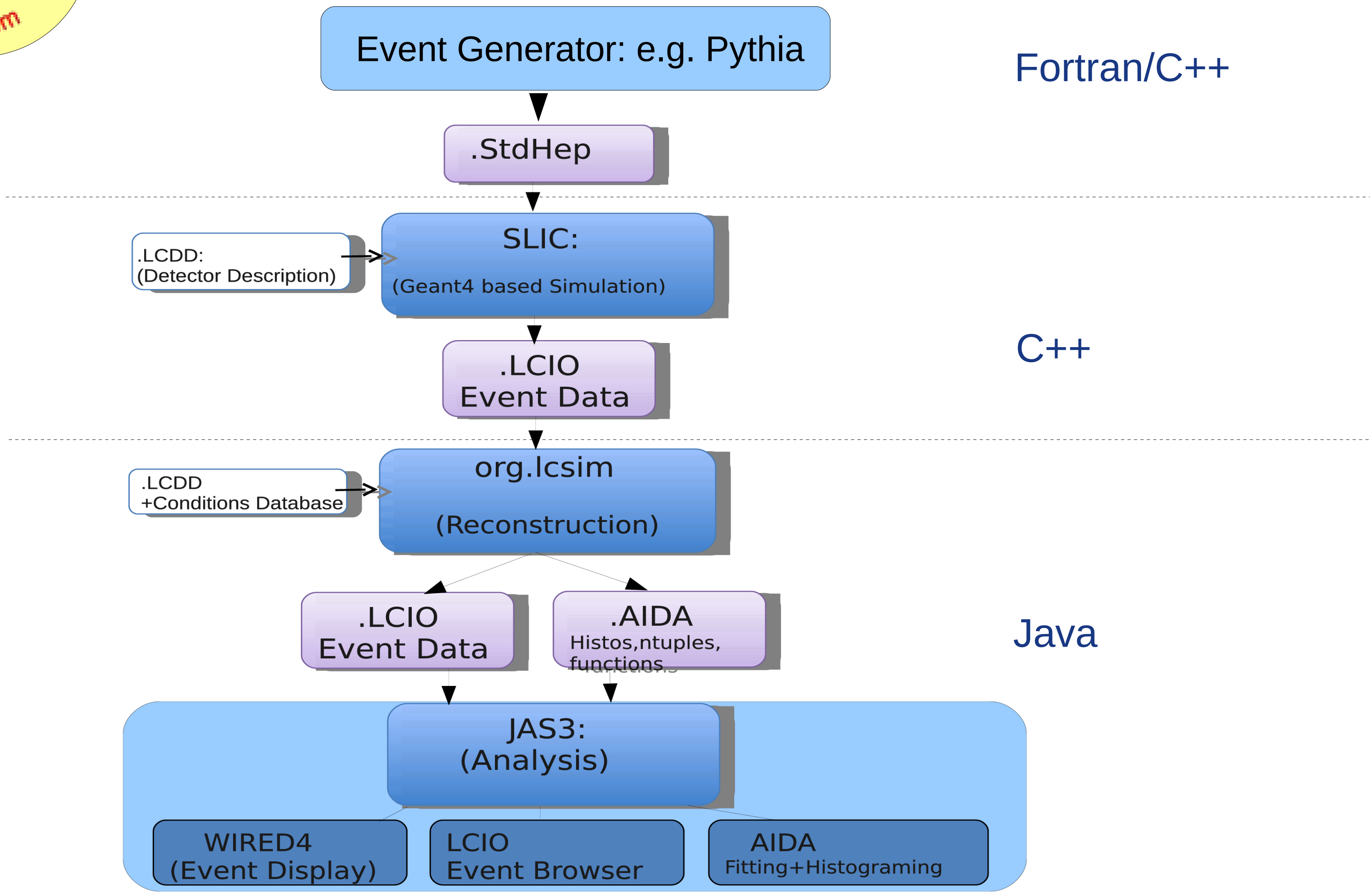


  - Enabling technologies:
    - Photo detectors: SiPM's
    - Dense crystal materials

- If you want to be added to the mailing list send mail to wenzel@fnal.gov
- Agenda page:

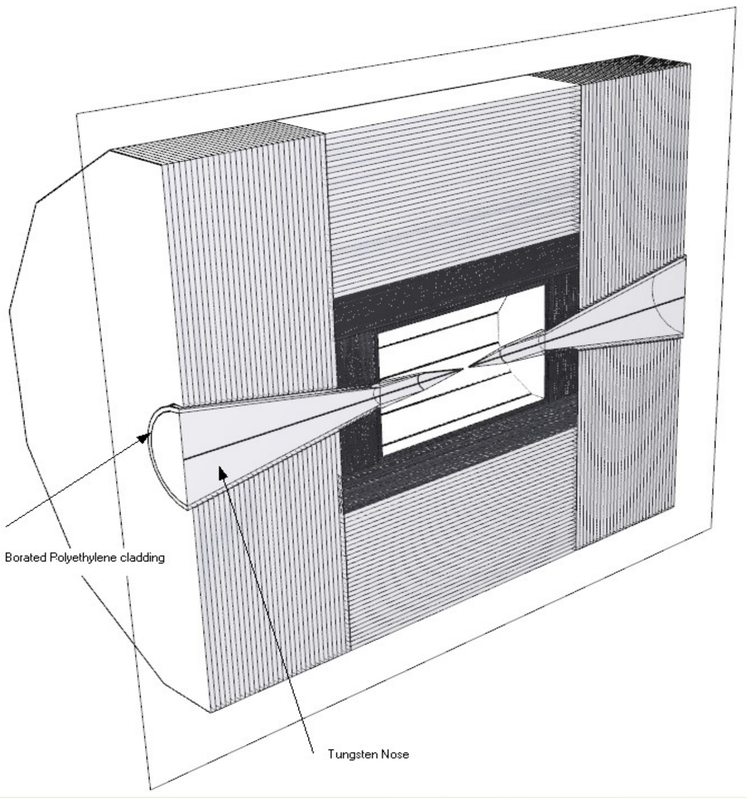
http://ilcagenda.linearcollider.org/categoryDisplay.py?categId=151

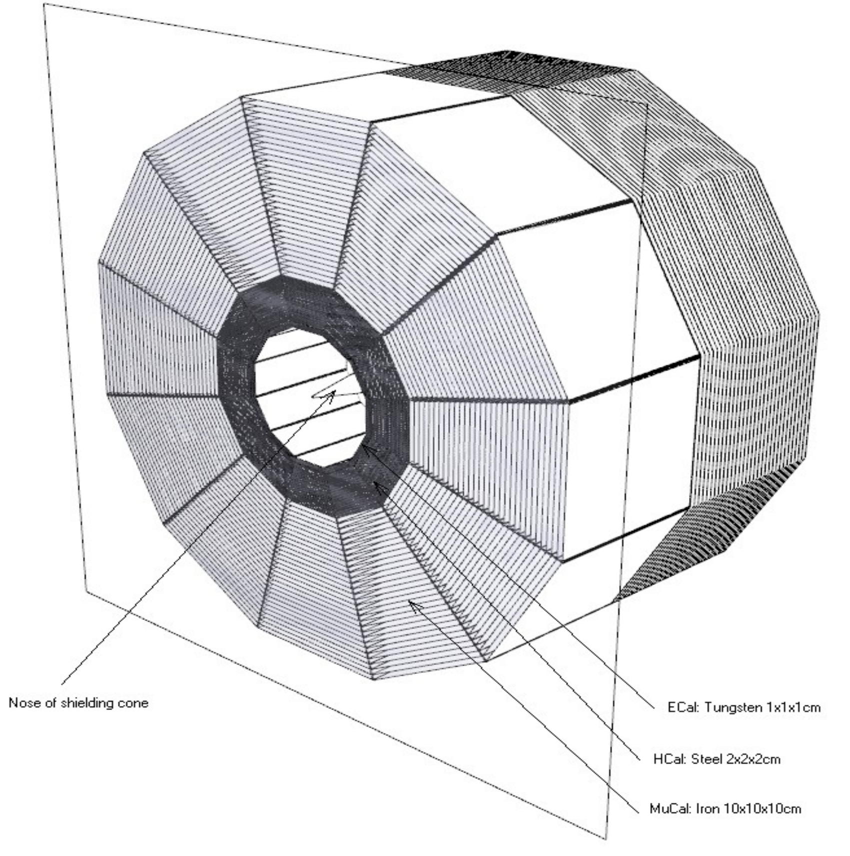
Components of the org.lcsim framework



The mcd00 detector in org.lcsim

Ideal (not realistic) :
- totally active (no sampling)
- total absorption
- 5T solenoidal field but no coil (dead material)





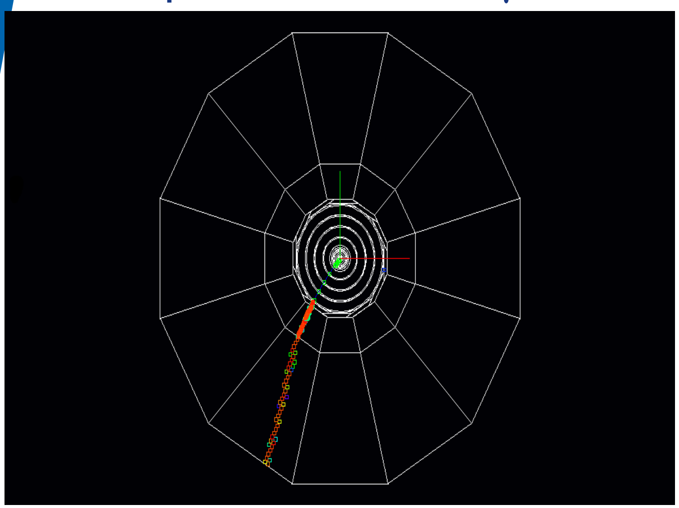
Norman Graf

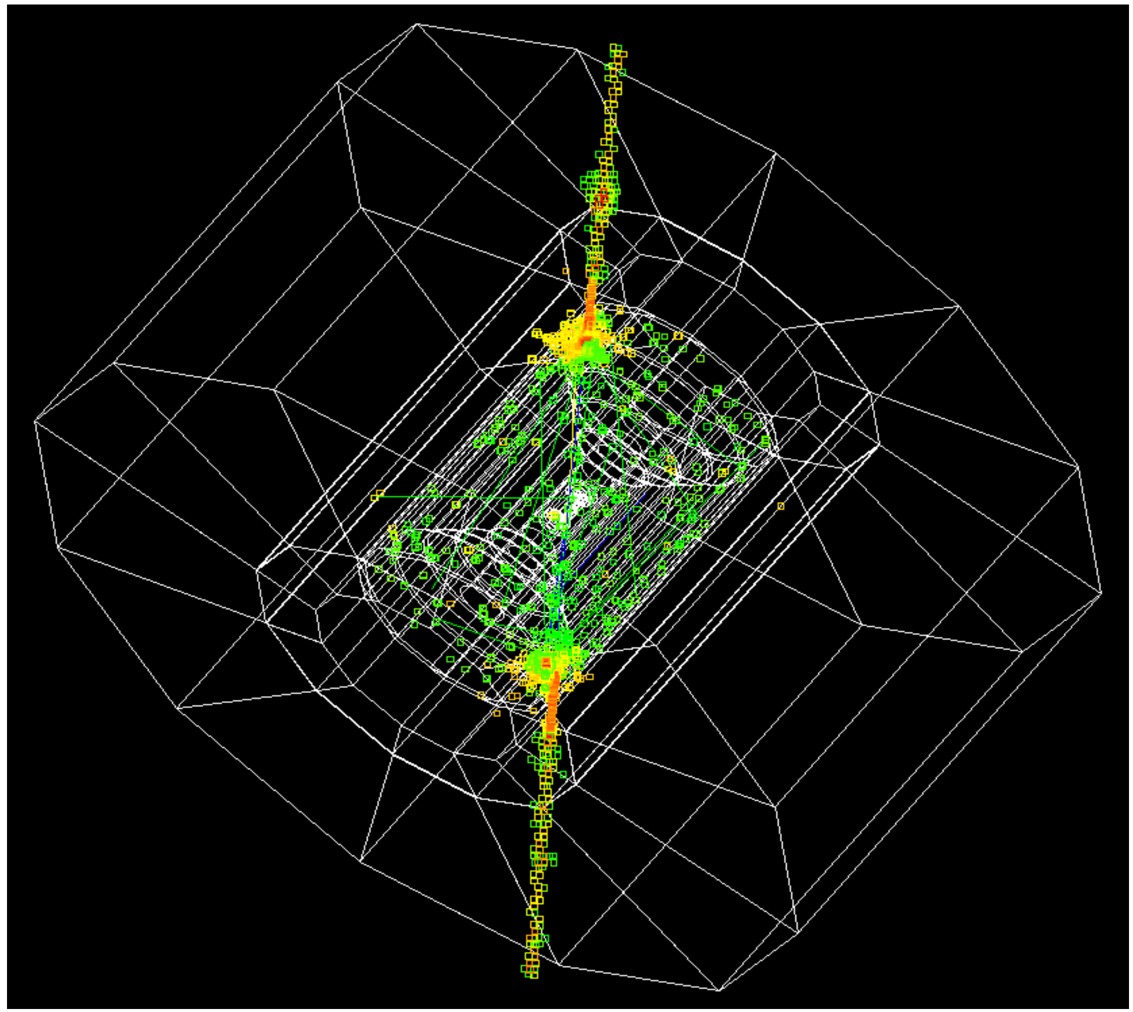
Calorimeter Properties

NUM LAYERS	**EM**	**Hadron**	**Muon**
Material	Tungsten	Steel 235*	Iron
Z	74	---	26
Density {g/cm^3}	19.3	7.87	7.85
Cell size {cm^3}	1	2	10
Detector Depth {cm}	10	80	300
Radiation Length	6.76g/cm^2 0.35 cm	13.9g/cm^2 1.76 cm	13.8g/cm^2 1.76 cm
Nuclear Interaction Length	185 g/cm^2 9.58 cm	132.1 g/cm^2 16.8 cm	131.9 g/cm^2 16.8 cm

Z'(3TeV) → $\mu^+ \mu^-$ in mcd00

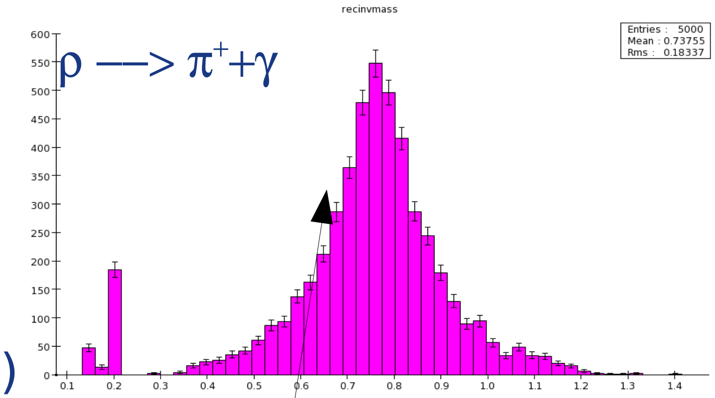
Compare to 10 GeV μ

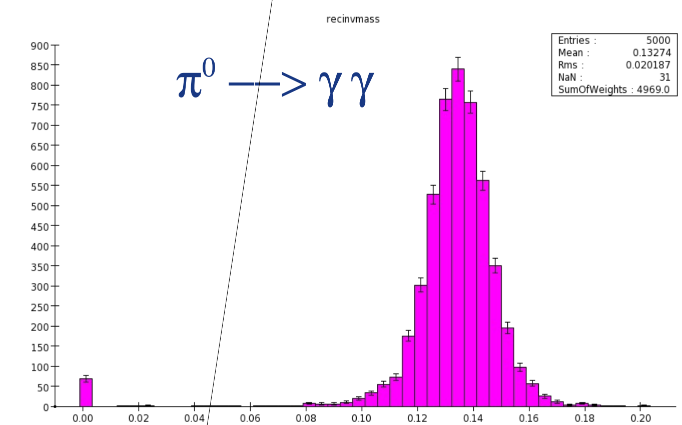




Status

- Entire chain running at Fermilab (together with Alex Conway, (Young Kee's student) and Norman Graf)
  - Event generation (pythia)
  - Simulation (SLIC)
  - Event reconstruction (lcsim.org)
  - Analysis (jas3)
  - Documentation (confluence pages)
- <u>But:</u> Detector description was not complete:
  - Had to create tracker description, steering file for digitization.
- <u>Even bigger BUT:</u> it's buggy simulation hangs for anything more complicated than single event files → scratch mcd00 work on more realistic concept

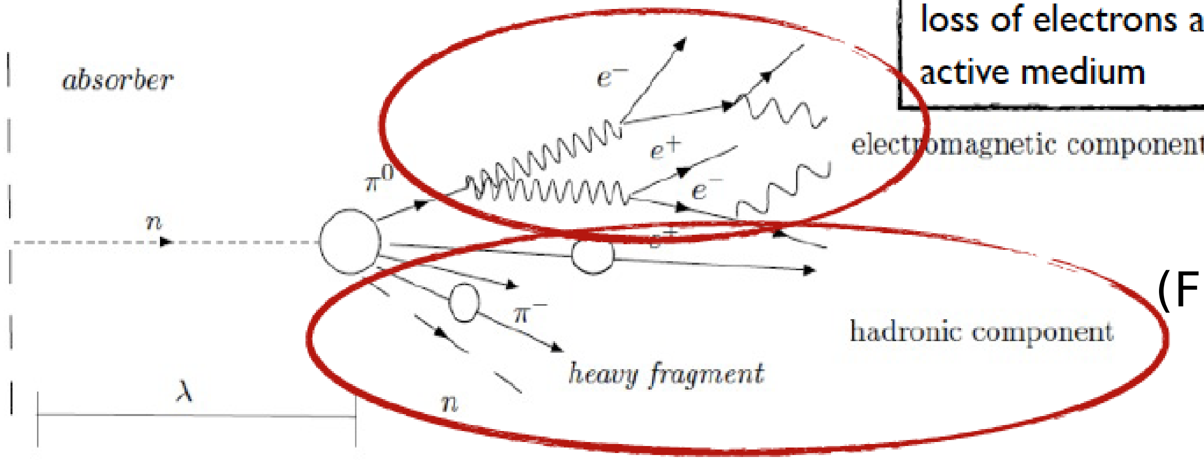




Needs Tracking and calorimetry

Hadron Shower Time Structure

- Hadronic showers have a rich substructure:



instantaneous, detected via energy loss of electrons and positrons in active medium

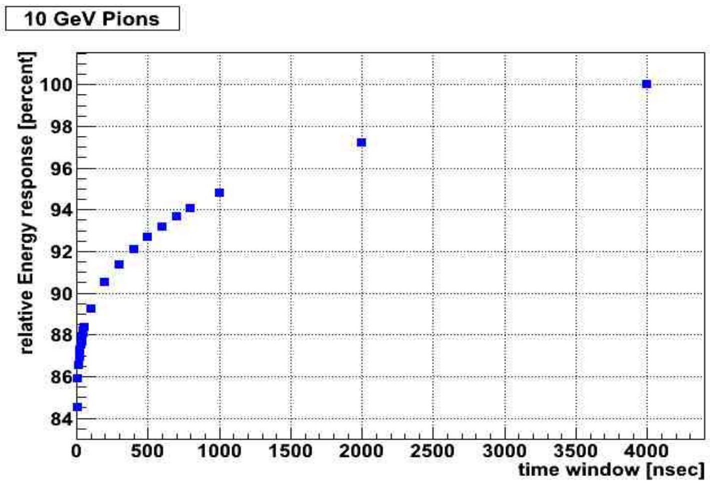
(Frank Simon)

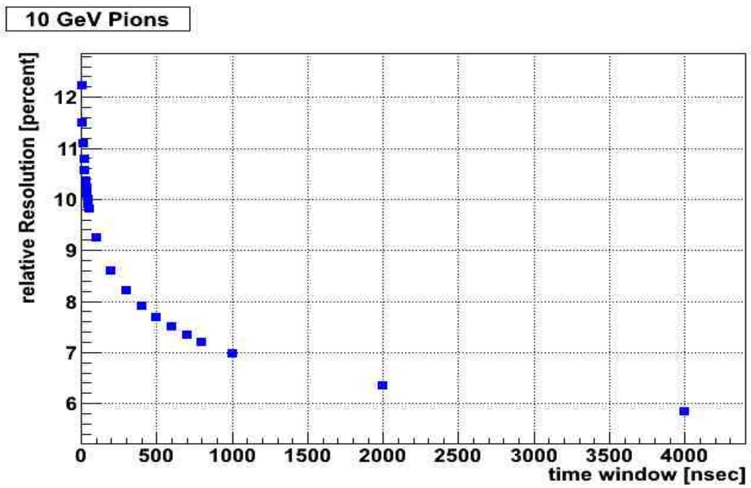
- instantaneous component: charged hadrons detected via energy loss of charged hadrons in active medium
- delayed component: photons and neutrons from nuclear de-excitation, detected via e^+e^- and momentum transfer to protons in hydrogenous active medium

⇨ Importance of delayed component strongly depends on target nucleus

⇨ Sensitivity to time structure depends on the choice of active medium

Time evolution of hadronic showers





But No Dual readout correction! Need to study How much resolution can be recovered by applying Dual read out correction.

Edgar Nandayapa (Summerstudent), Alex Conway (student of Young-Kee Kim)

Energy response and resolution

No clustering:

	Mean energy response (GeV)		RMS (GeV)		RMS/sqrt(E)	
	Electrons	Pions	Electrons	Pions	Electrons	Pions
1000ns	9.95	8.25	0.02	0.58	0.6%	18%
100ns	9.95	7.76	0.03	0.72	1%	23.7%
10ns	9.94	7.48	0.04	0.86	1.3%	27%

Fixed cone clustering

	Mean energy response (GeV)		RMS (GeV)		RMS/sqrt(E)	
	Electrons	Pions	Electrons	Pions	Electrons	Pions
1000ns	9.54	7.90	0.083	0.771	2.6%	24.4%
100ns	9.94	7.57	0.052	0.83	1.6%	26.2%
10ns	9.93	7.34	0.087	0.91	2.8%	28.8%

Alex Conway

Again: We need to study how dual read out correction will help.

A dual read-out calorimeter for the hadron collider

- Fast: photons, SiPm's → make timing possible

- includes both electromagnetic and hadronic parts
 has separate readout of the Cerenkov and scintillation light
→ uses their correlation to obtain superior hadronic energy resolution.

- This HHCAL detector has a total absorption nature
→ energy resolution is not limited by the sampling fluctuations.

- no structural boundary between the ECAL and HCAL
 → no dead material in the middle of hadronic showers.

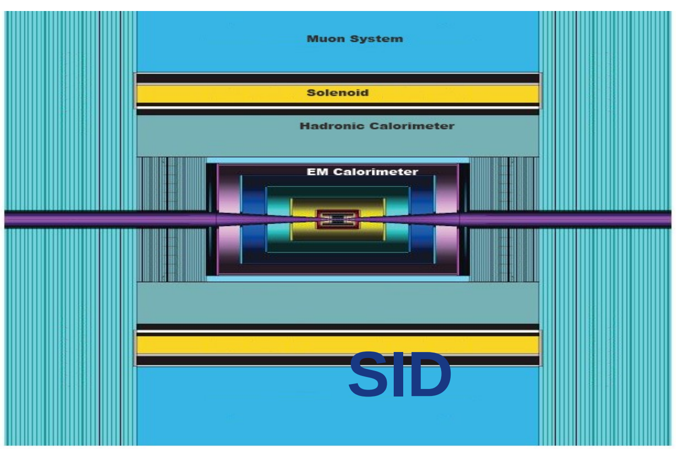
- No differences in response of ecal and hcal.

- Fine segmentation → allows to apply PFA algorithms to further improve (energy/mass) resolution

The CCAL02 detector

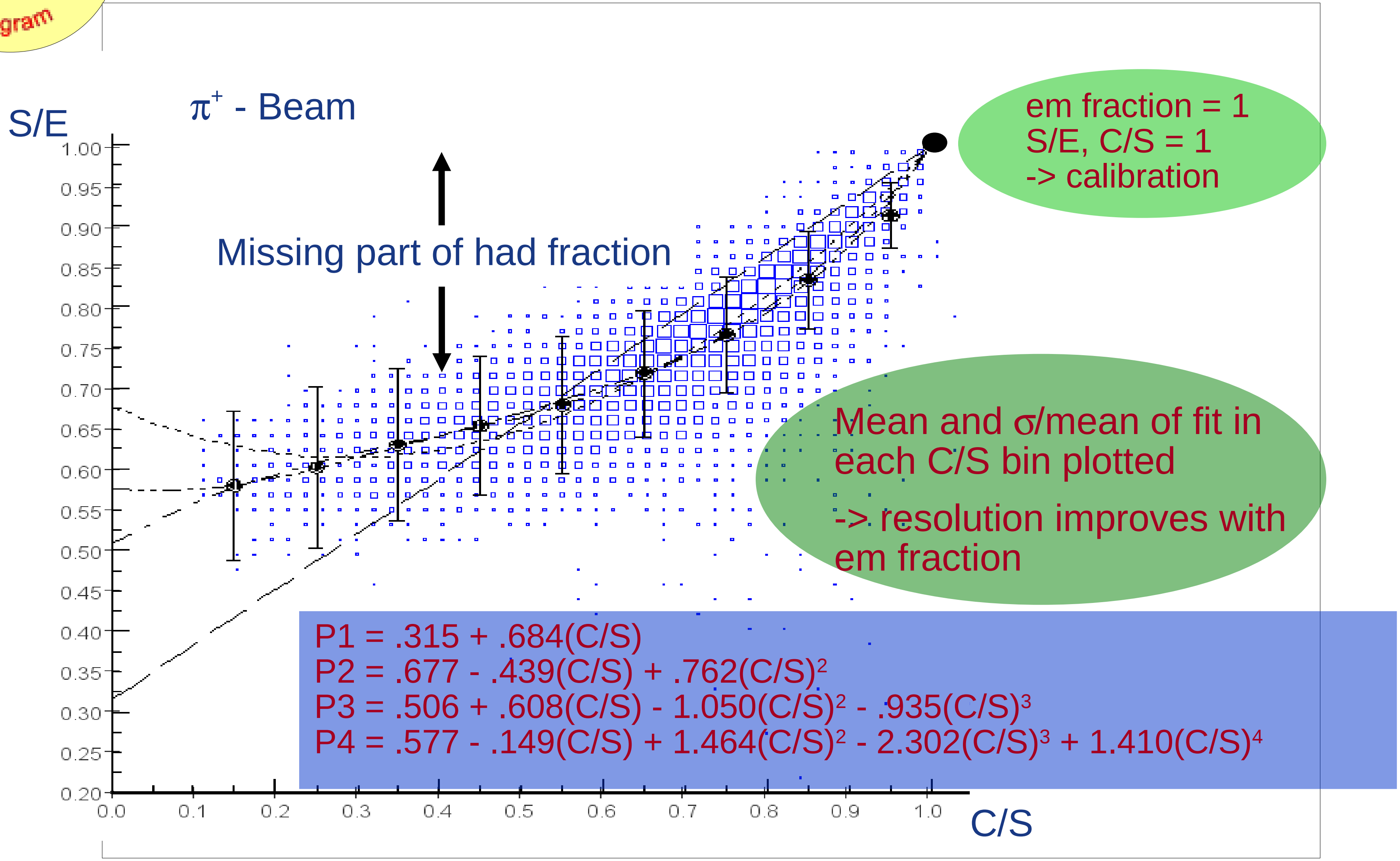
(Crystal Calorimetry version of SID, more realistic than mcd00 but needs to be modified for muon collider environment)

				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	5 x 5		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	5 x 5		4.7		5.7
Total Endcap	25				5.8		7



Material	Density	Rad. len. X0	IA len.
	[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

Polynomial Correction Functions: E=S/Pn



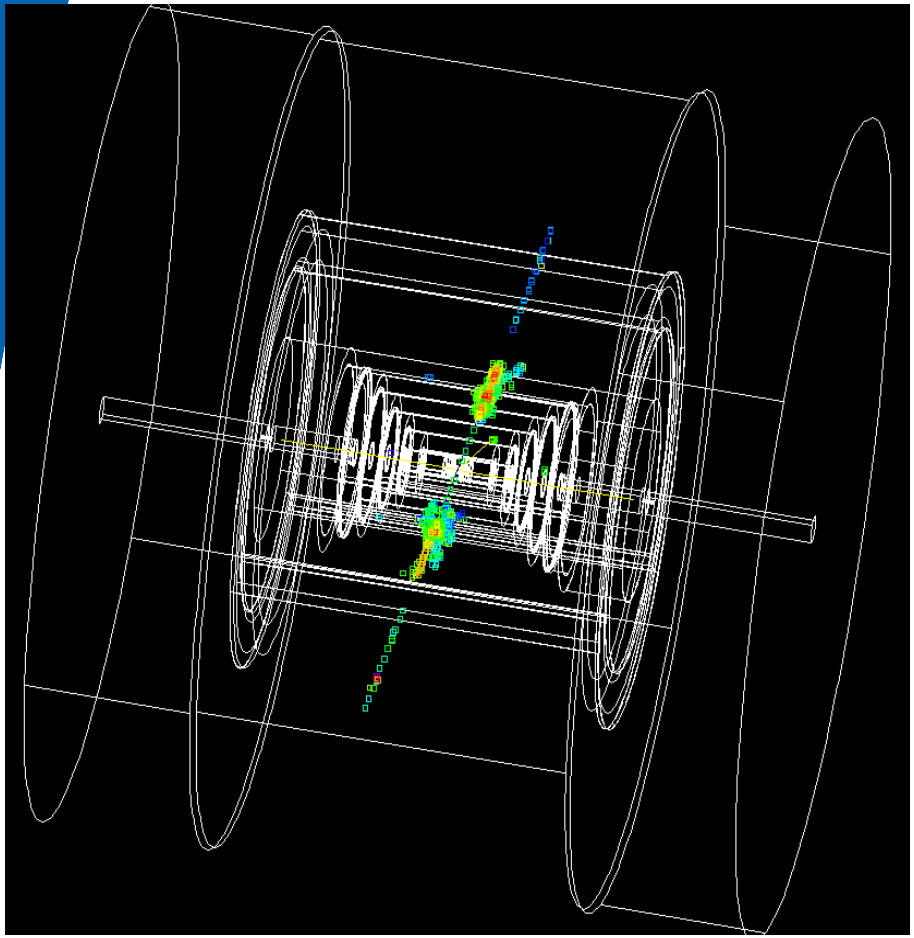
$P1 = .315 + .684(C/S)$

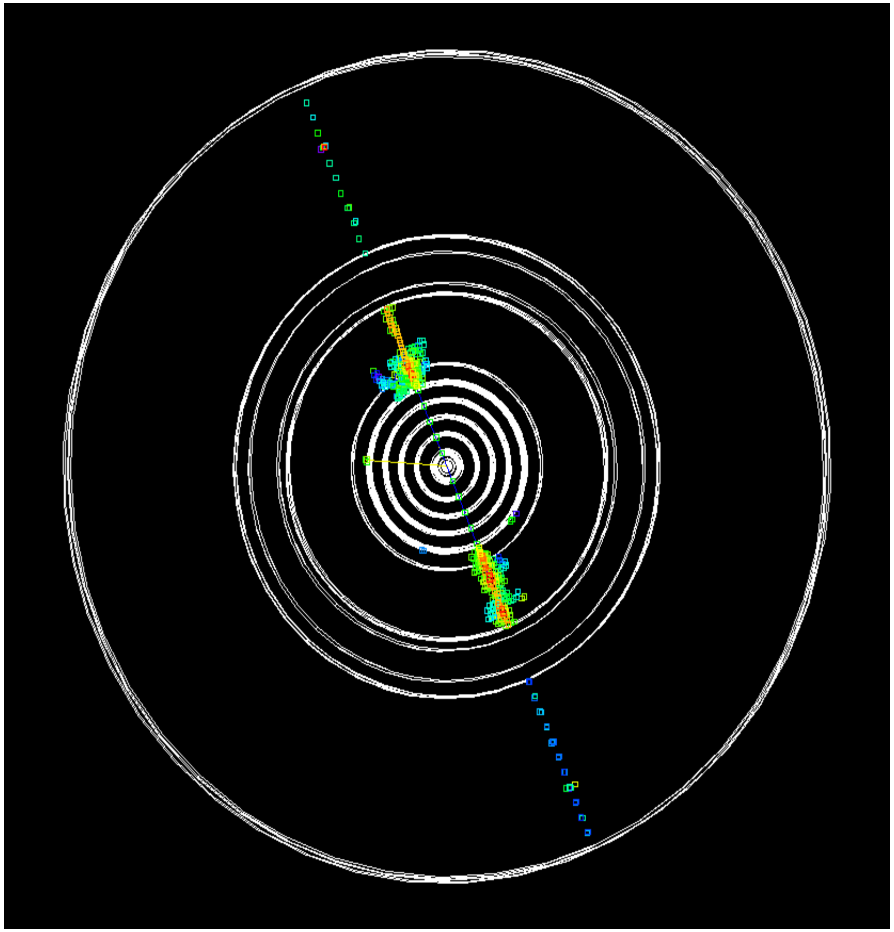
$P2 = .677 - .439(C/S) + .762(C/S)^2$

$P3 = .506 + .608(C/S) - 1.050(C/S)^2 - .935(C/S)^3$

$P4 = .577 - .149(C/S) + 1.464(C/S)^2 - 2.302(C/S)^3 + 1.410(C/S)^4$

Z'(3TeV) → $\mu^+ \ \mu^-$ in ccal02

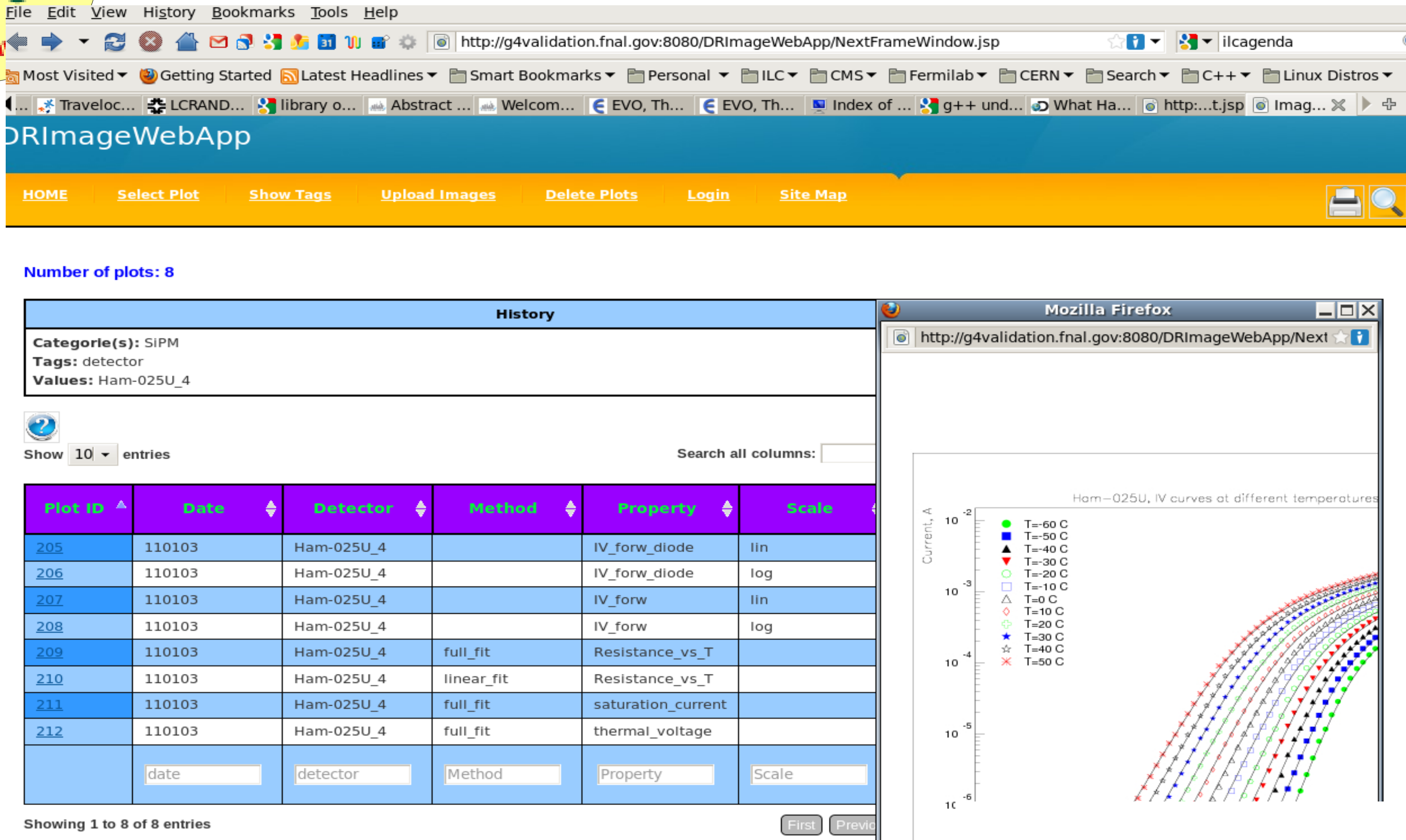




Plan

- Need a working detector model for the muon collider (Work with SLAC). Challenge is to deal with backgrounds while maintaining high precision (can it be done?) → Needs detailed studies.
- Calorimeter:
    - Dual readout (need to study how timing will affect the resolution after dual readout correction is applied)
    - Raja type: (digital sampling calorimeter with traveling time gate, software compensation)
- Tracker:
    - More like LHC than ILC, double or triple layers might be needed to help with pattern recognition. Need fast timing to reject background --> this will all come at a price (material budget)
- Once we have a detector description: debug, biggest challenge will be to deal with the huge backgrounds and getting them into the simulation. (much more challenging than pile up at LHC and that was already difficult)

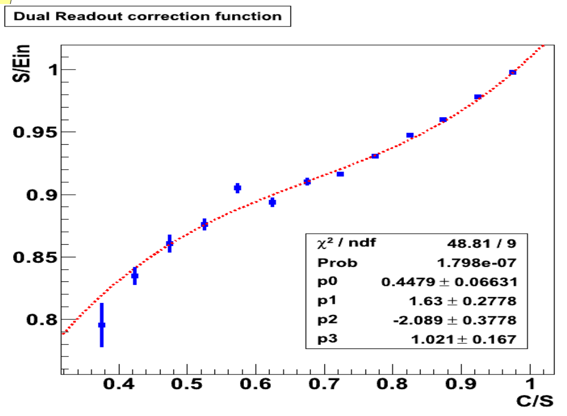
Organizing the data: DRImageDB

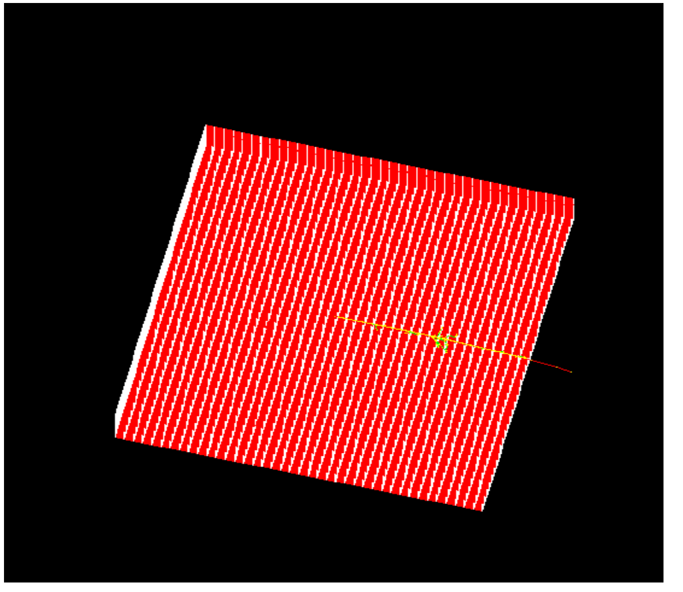


Plot ID	Date	Detector	Method	Property	Scale
205	110103	Ham-025U_4		IV_forw_diode	lin
206	110103	Ham-025U_4		IV_forw_diode	log
207	110103	Ham-025U_4		IV_forw	lin
208	110103	Ham-025U_4		IV_forw	log
209	110103	Ham-025U_4	full_fit	Resistance_vs_T	
210	110103	Ham-025U_4	linear_fit	Resistance_vs_T	
211	110103	Ham-025U_4	full_fit	saturation_current	
212	110103	Ham-025U_4	full_fit	thermal_voltage	

DRCalRoot: Geant 4 standalone application,

allows to do detailed tracing of optical photons.

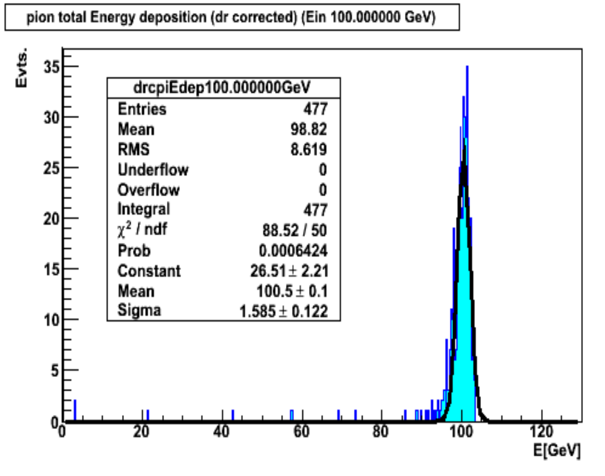




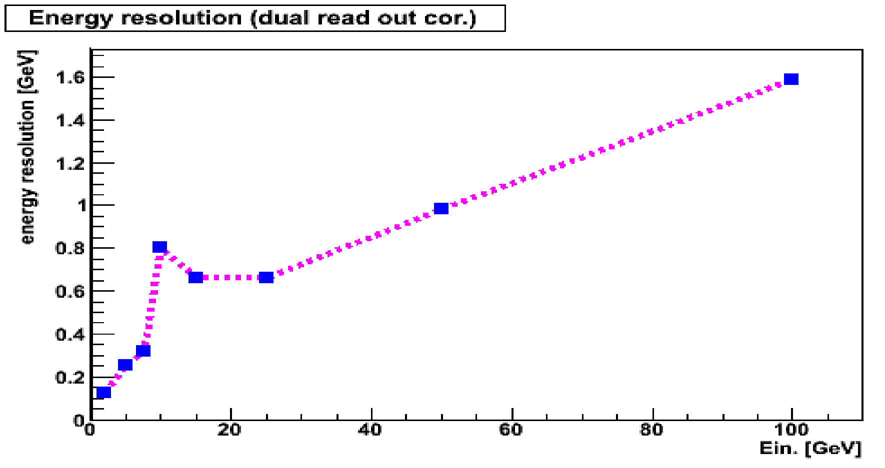
Crystal size in x,y,y: 5 cm
Nr. of cells in x,y,z: 40
Crystal Material : G4_BGO
Crystal Density : 7.13 [g/cm3]
Crystal interaction length: 22.6937 [cm]
Crystal radiation length: 1.11801 [cm]
Crystal total length (z,y,z): 200 [cm]
interaction length (z): 8.81301

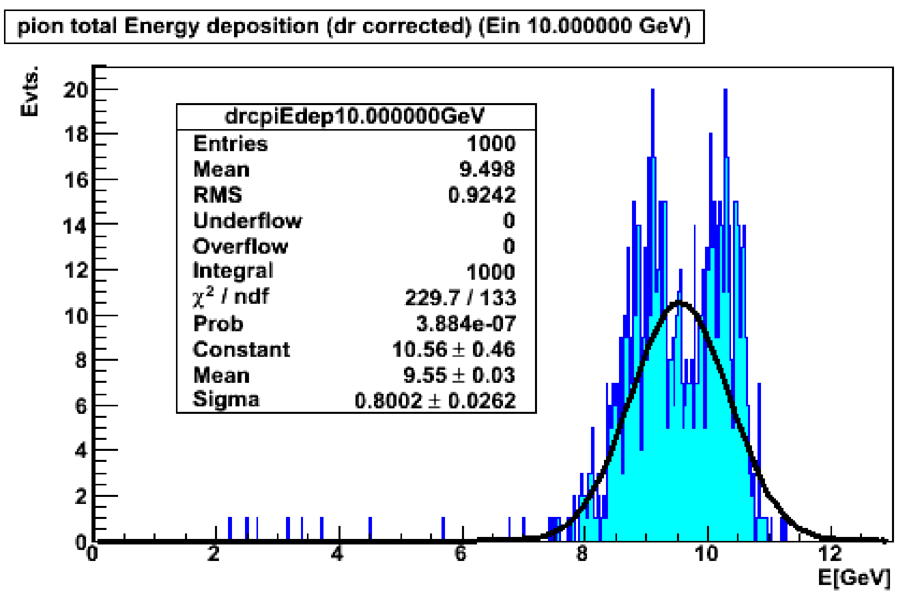
(ignore material of silicon photo dets.
total # of IA length: 0.0524555)

Physics list: (the infamous) QGSP_BERT
No thresholds, no clustering



Hadronic physics in Geant 4





What's the plan?

- Develop a functional and 'realistic' detector description
- add timing information to the calorimeter Hits (done for DRCalRoot)
- Make software generally available (ilcsim2,detsim)
- Provide mechanism to add Background events
- Provide org.lcsim drivers to run the reconstruction and analysis
- collect data cards for physics processes of interest (defined benchmarks) + backgrounds thereof. Provide standard files with generated (stdhep) events.
- documentation to guide physicist through all the steps. Confluence might be a good place for that.