Muon Collider simulation status and plans

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Muon Collider Documentation

Created Confluence page:

https://confluence.slac.stanford.edu/display/MCPDS/Home

Currently:

- Overview
- Event Generation
- Timing studies
- Detector Models
- Available Datasets

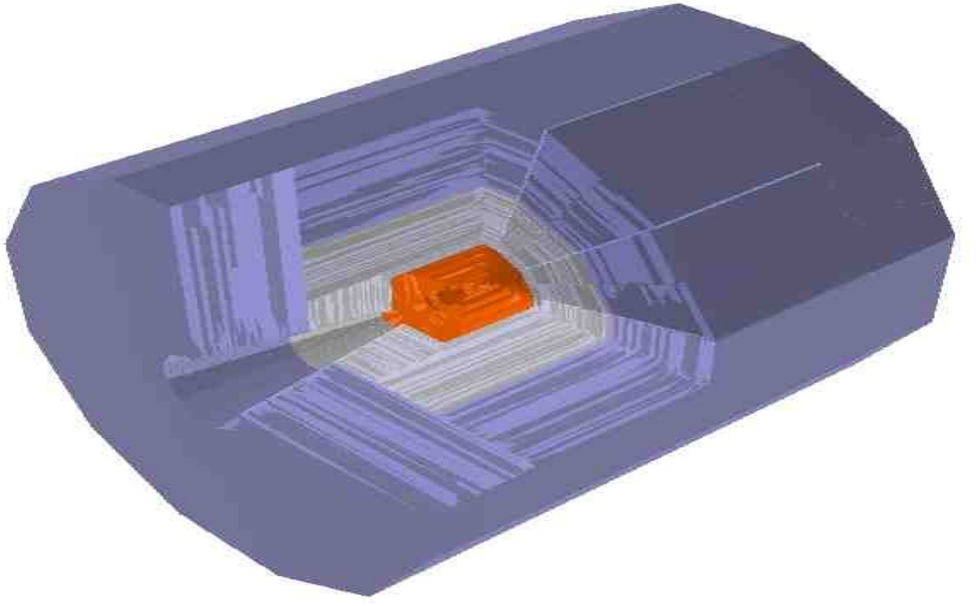
You can sign up here:

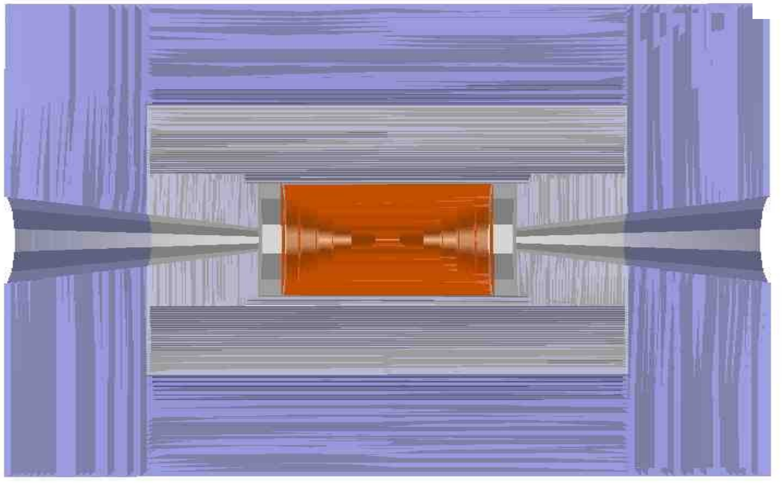
https://jira.slac.stanford.edu/signup/

The mcdrcal00 detector in org.lcsim

5T solenoidal field,
radius=3m

Calorimeter dimensions:
Rmin: 1.25 m
Rmax: 2.96 m
Length: 2x7.4 m





Tracker: SLAC

Calorimeter Properties for Barrel and Endcaps

	EM	Hadron	Muon
Material	BGO (PbF2)	BGO (PbF2)	Iron
Density [g/cm^3]	7.13 (7.77)	7.13 (7.77)	7.85
Cell size [cm^3]	1x1x2	2x2x5	10x10x10
Layers	10	30	22
Detector Depth [cm]	20	150	220
Radiation Length [cm]	1.1 (0.93)	1.1 (0.93)	1.76
Nuclear Interaction Length [cm]	22.7 (22.4)	22.7 (22.4)	16.8
Total Nr of IA length (em+had)	**7.5 (7.6)**		

Caveats

- Tungsten cone commented out-> showers developing in the cone required a lot of CPU --> Need sensitive detector that registers particles that enter but then kills them.
- No Material for coil included
- Jas3 can't display all the calorimeter shapes used for mcdrcal00 (but we can see the hits)
- Not enough iron to return flux of 5T solenoidal field (wanted to keep outer dimensions / MDI)
- Simulation of DR (Cerenkov photons) is very slow due to the use of the Geant 4 G4Cerenkov process. Calculating the number of produced in the optical calorimeter sensitive detector class will speed up the process significantly. Currently the data sets are without optical processes enabled.

Machine Backgrounds

Precision Physics @ muon collider depends on the the ability to get the machine induced BGR. (caused by muon dacay) under control

- Optimize machine parameters, proper shielding, IR, MDI
- Detector design and choice of technology--> detector simulation critical to determine detector parameters and study how it affects physics performance. Dealing with the large bgr is a huge computational problem

Background Sources

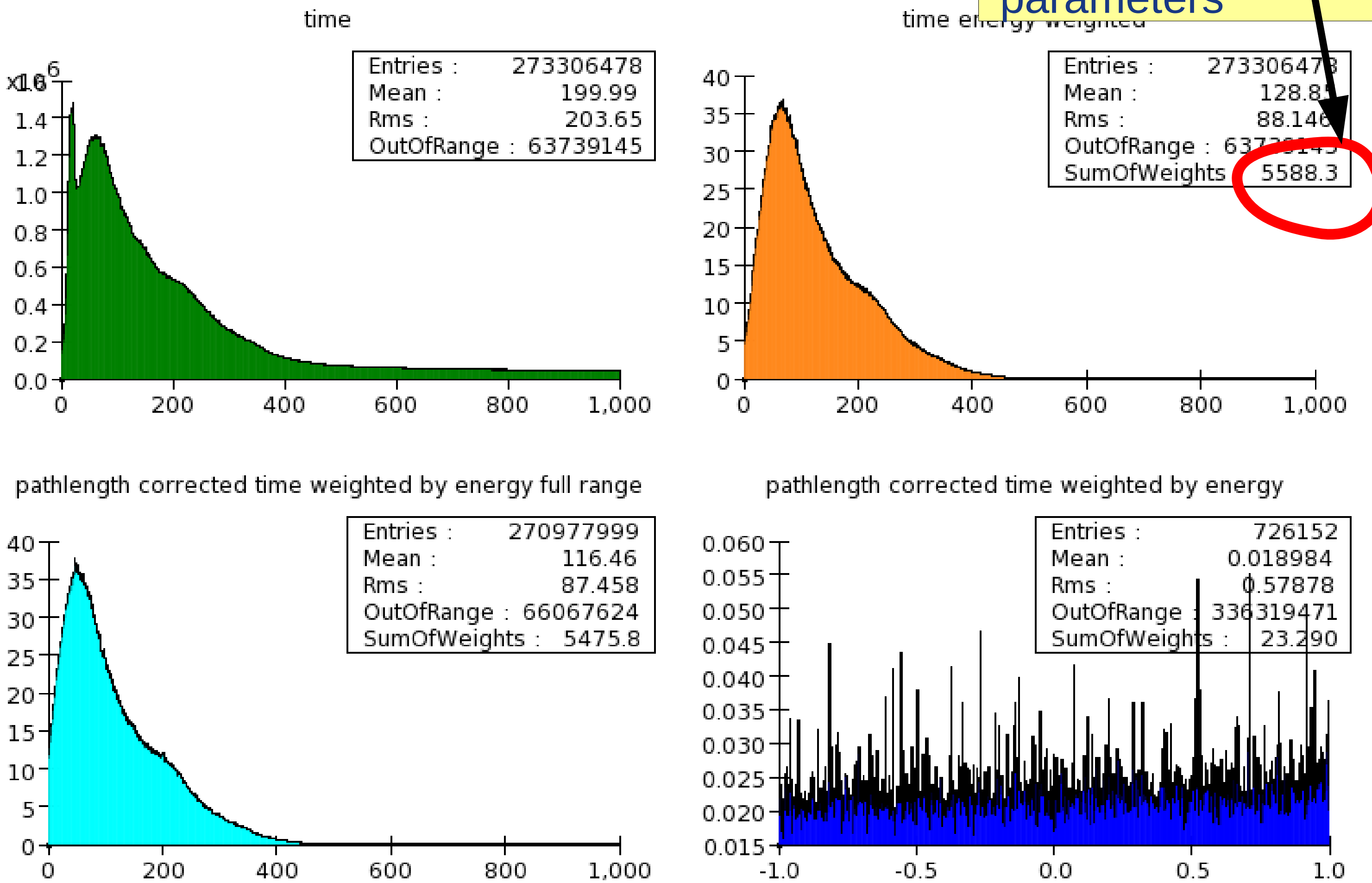
Muon Decay Background:

- Electron Showers from high energy electrons.
- Bremsstrahlung Radiation for decay electrons in magnetic fields.
- Photonuclear Interactions --> Source of hadrons background.
- Bethe-Heitler muon production.

Collider	*μ per bunch*	*Decays/meter*
50 × 50 GeV	4×10^{12}	2.6×10^{7}
250 × 250 GeV	2×10^{12}	2.6×10^{6}
2 × 2 TeV	2×10^{12}	3.2×10^{5}
2.5 × 2.5 TeV LEMC	1.6×10^{11}	2.0×10^{4}

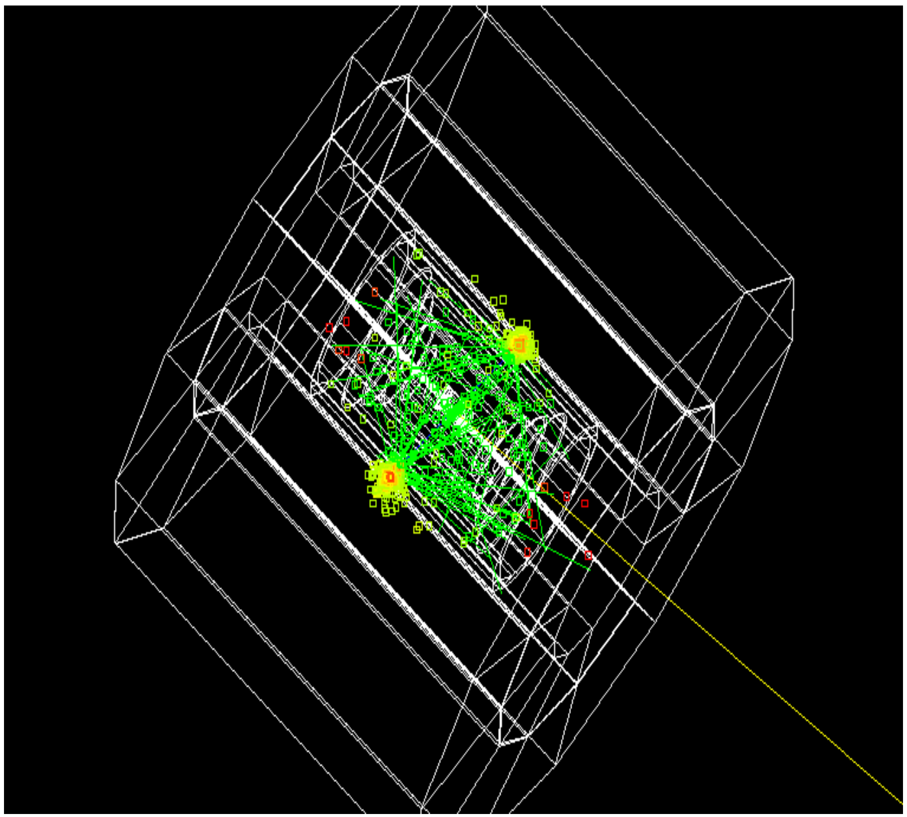
Timing of bgr. Hits in the Calorimeter

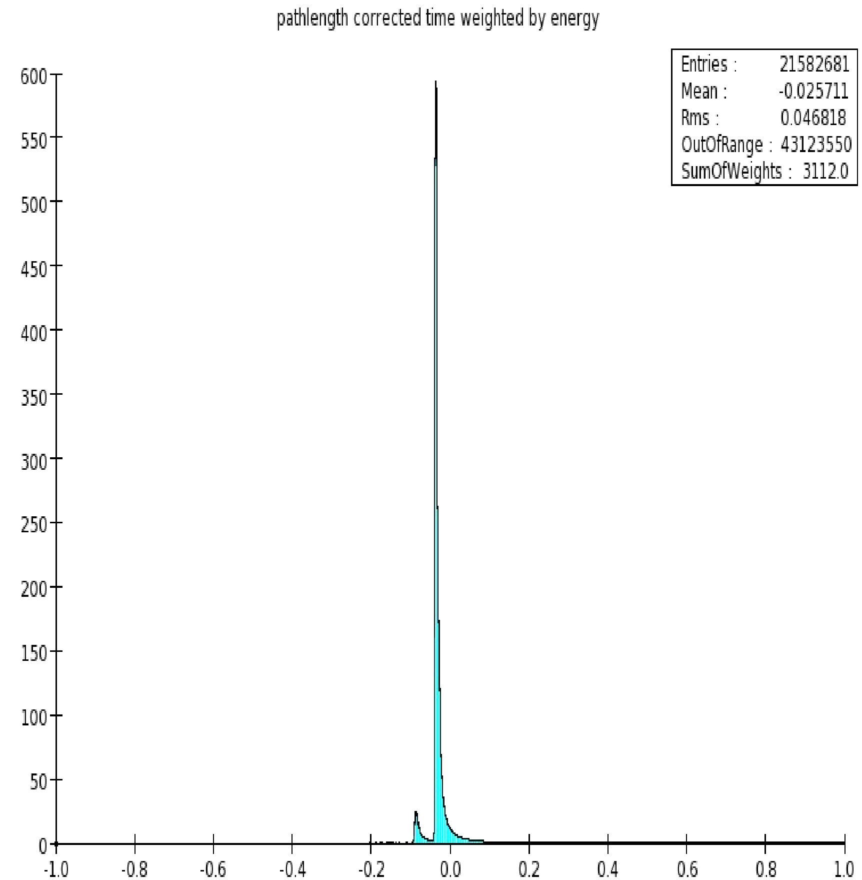
TeV's of energy deposited
In about 500 nsec
Exact amount varies a
lot depending on machine
parameters



~ 4% of 1 bunch crossing, no Bethe Heitler muons

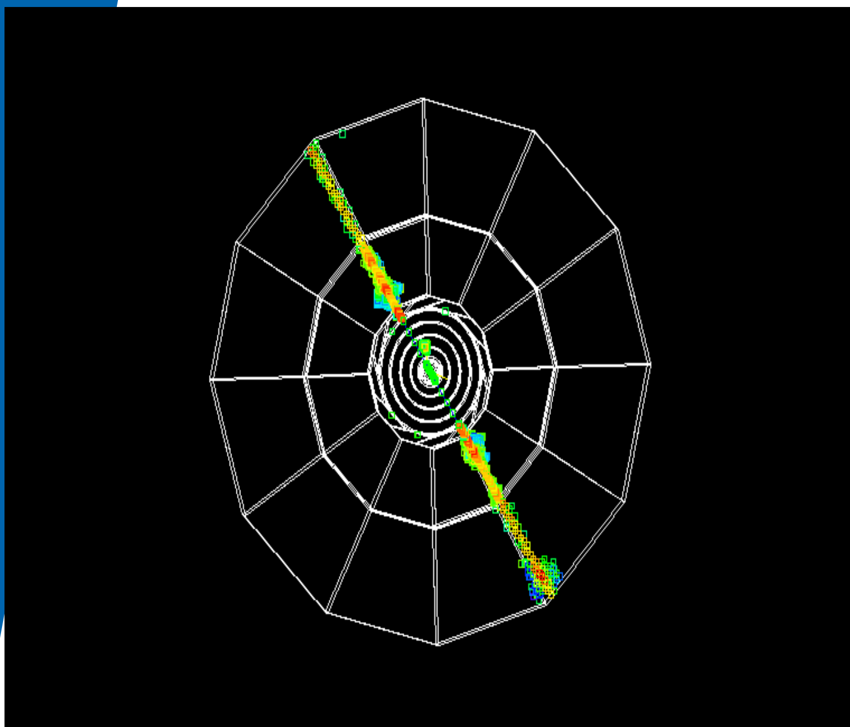
Z'(3TeV) -> e^+e^-

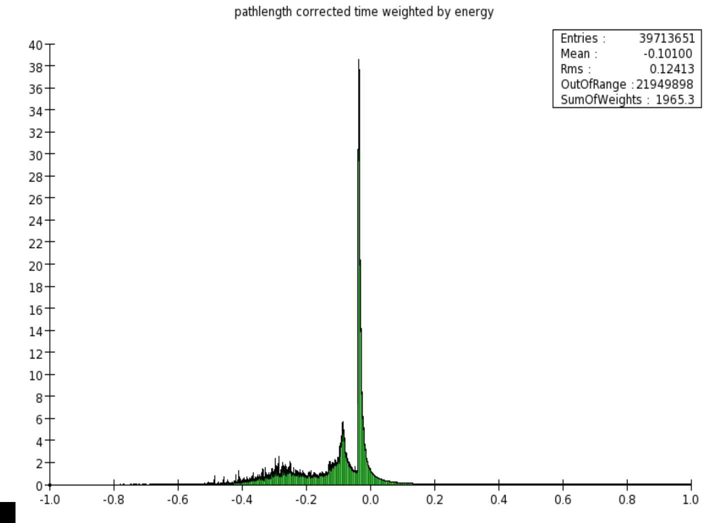


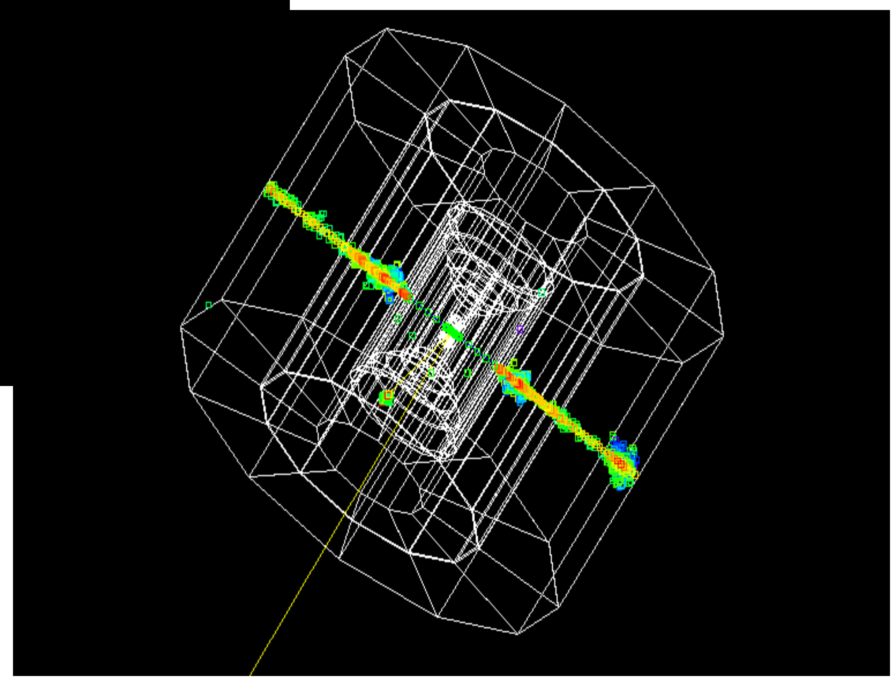


Fight time correct time weighted by energy
Range +/- 1 nsec

Z'(3TeV)->$\mu^+\mu^-$

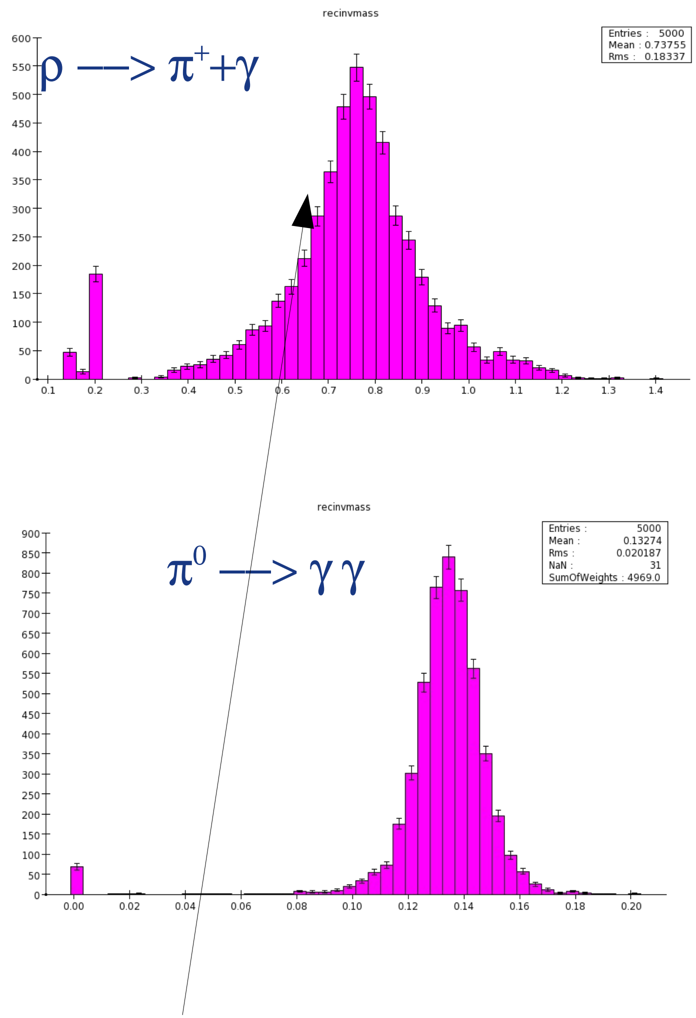



pathlength corrected time weighted by energy
Entries : 39713651
Mean : -0.10100
Rms : 0.12413
OutOfRange : 21949898
SumOfWeights : 1965.3
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0



Analysis chain

- Get entire chain running at Fermilab (together with Alex Conway, YK student and Norman Graf)
  - Event generation (pythia)
  - Simulation (SLIC)
  - Event reconstruction (lcsim.org)
  - Analysis (jas3)
  - Documentation (confluence pages)

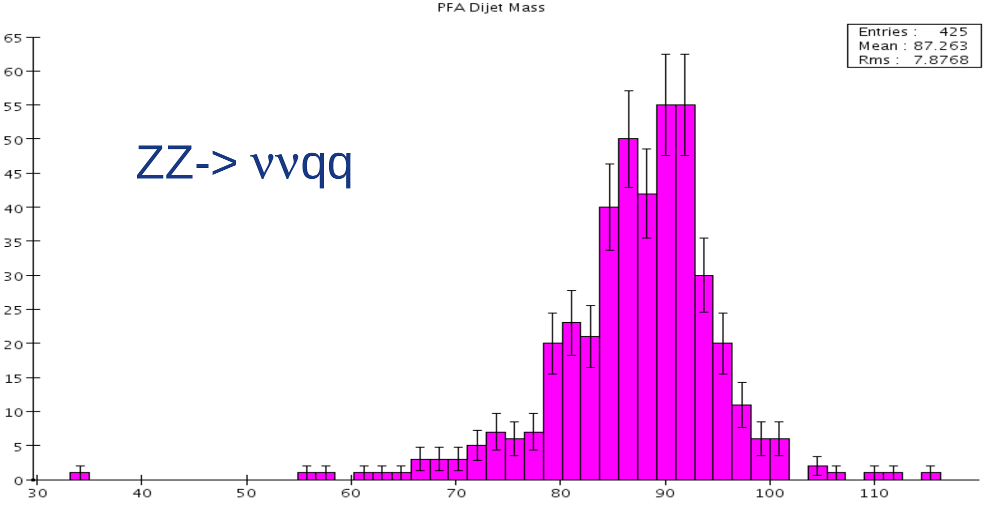


Needs Tracking and calorimetry

Invariant mass reconstruction

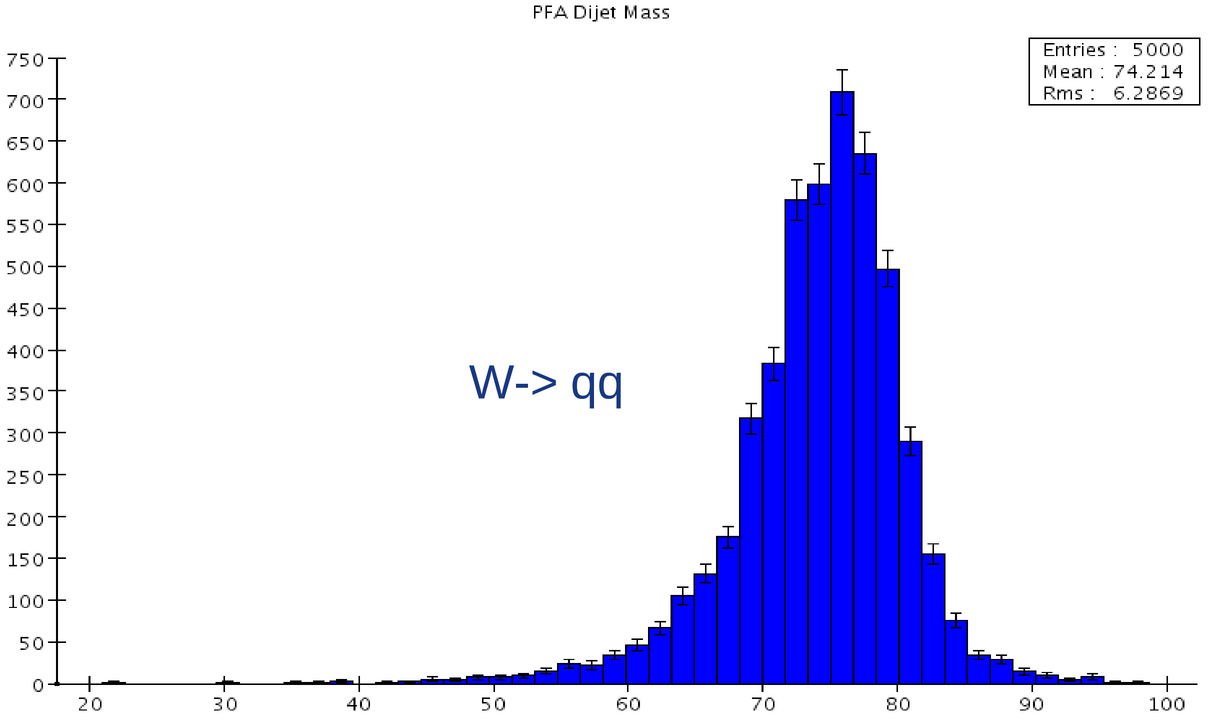
Steve Magill, Alex Conway, Hans Wenzel (ccal02)

Steps are as follows: Find jets--> apply dual readout correction--> correct for magnetic field contribution to invariant mass (global correction) --> use PFA algorithm to assign tracks to calorimeter clusters and use track for invariant mass calculation if match passes stringent requirement (avoid confusion term in PFA)



Invariant mass reconstruction (cont)

Code is in CVS: Steve Magills contrib area name of the driver is: PFADRSelect. (but needs zip file with the correct conditions data)



Getting muc off the ground

- Need dedicated disk area for muon collider data samples, muon collider software (currently SID)

  (may be migrate some of the ilc disk space)

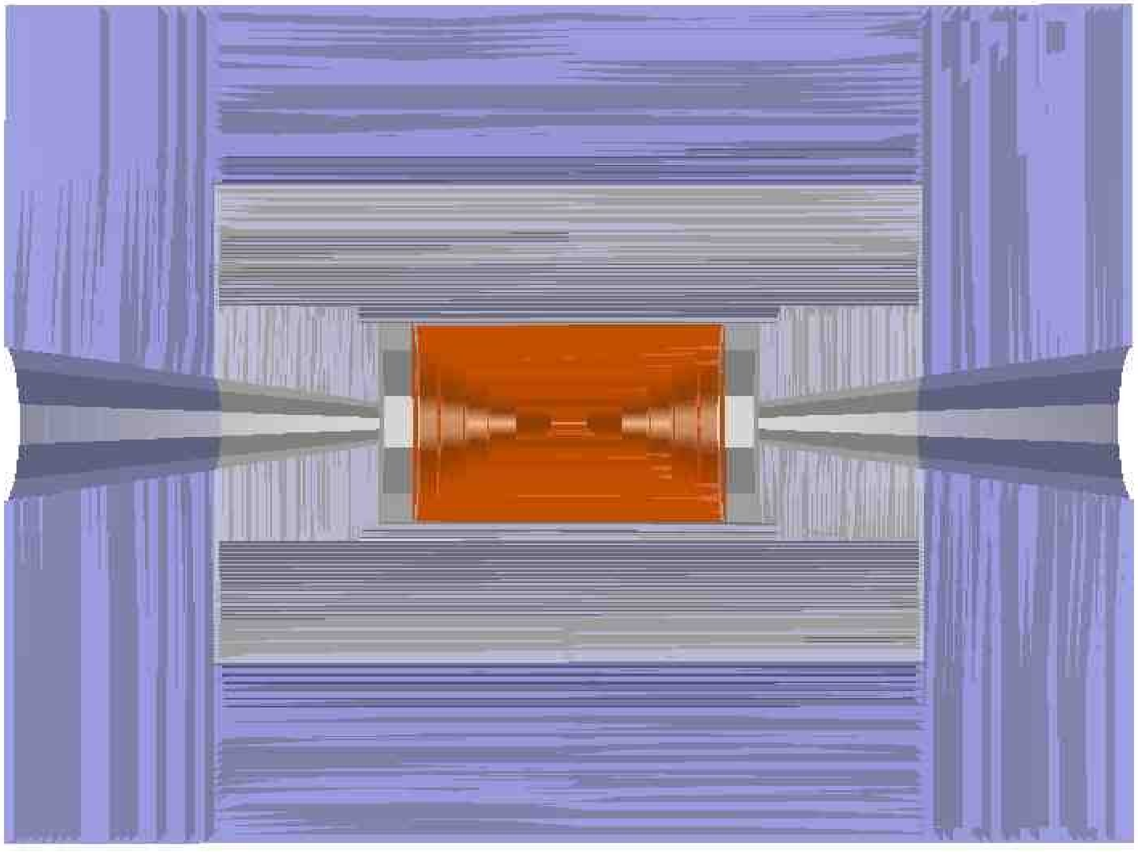
- Need Muon Collider VO for grid submission + dedicated slots on fermigrid

Plan

- Implement sensitive detector that counts the Cerenkov photons.
- Implement sensitive detector for the tungsten cone
- Generate single particle and other data samples.
- We need:
  - a functional and 'realistic' detector description
  - To add timing information to the calorimeter Hits
  - Get Driver to add Background events working
  - org.lcsim drivers to run the reconstruction and analysis
  - collect data cards for physics processes of interest (defined benchmarks) + backgrounds thereof
  - documentation to guide physicist through all the steps. Confluence is a good place for that.

Backup slides

The mcdrcal00 detector in org.lcsim



Plan

- Implement sensitive detector that counts the Cerenkov photons.
- Implement sensitive detector for the tungsten cone
- Generate single particle and other data samples.

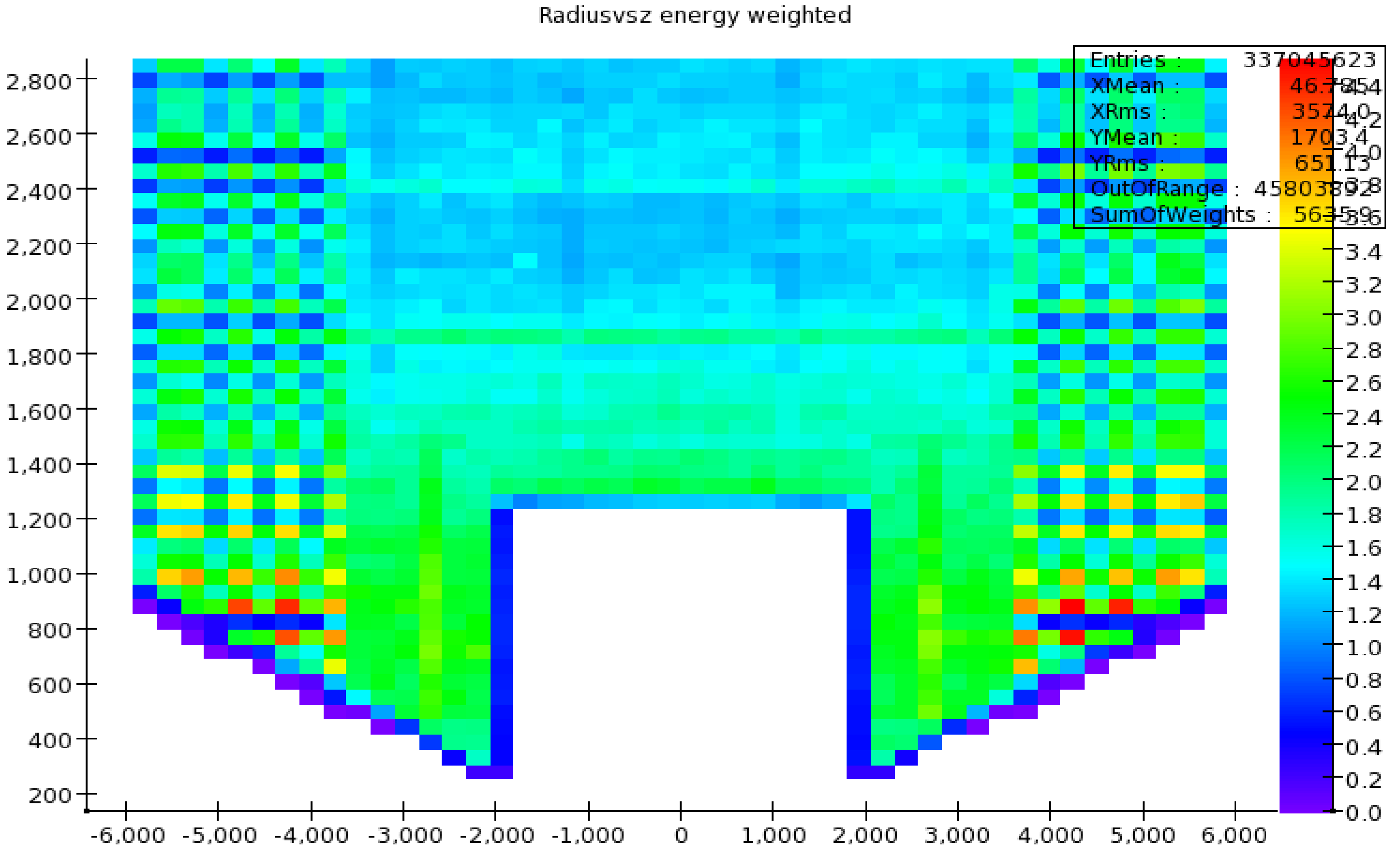
Data samples

Fully simulated events on detsim
(replacement of ilcsim and ilcsim2):

/ilc/sid/wenzel/muoncolliderdata/slcio/bgr

/ilc/sid/wenzel/muoncolliderdata/slcio/signal

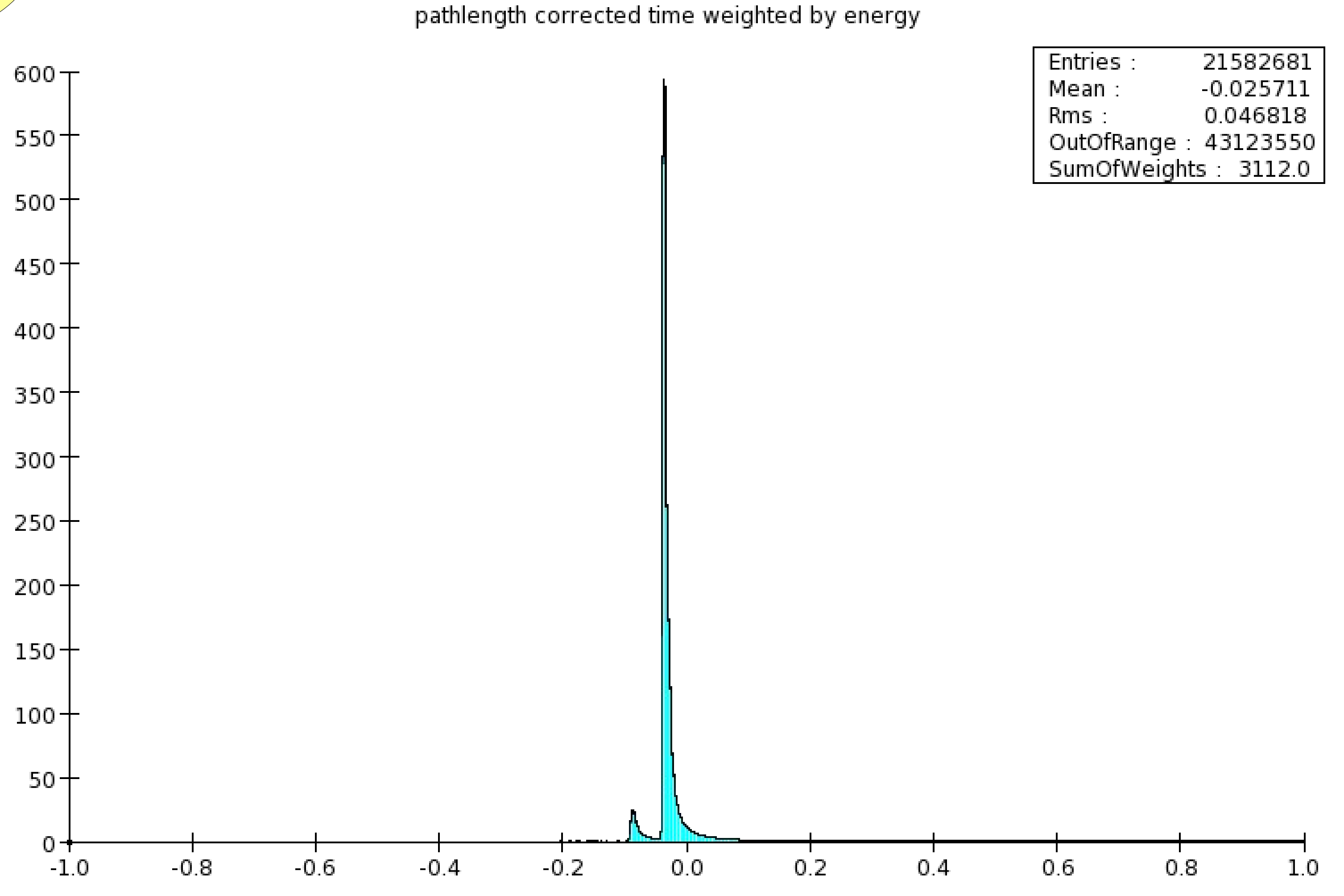
Zp3TeVtoee.slcio
Zptomumu_3TeV_mcdrcal00.slcio

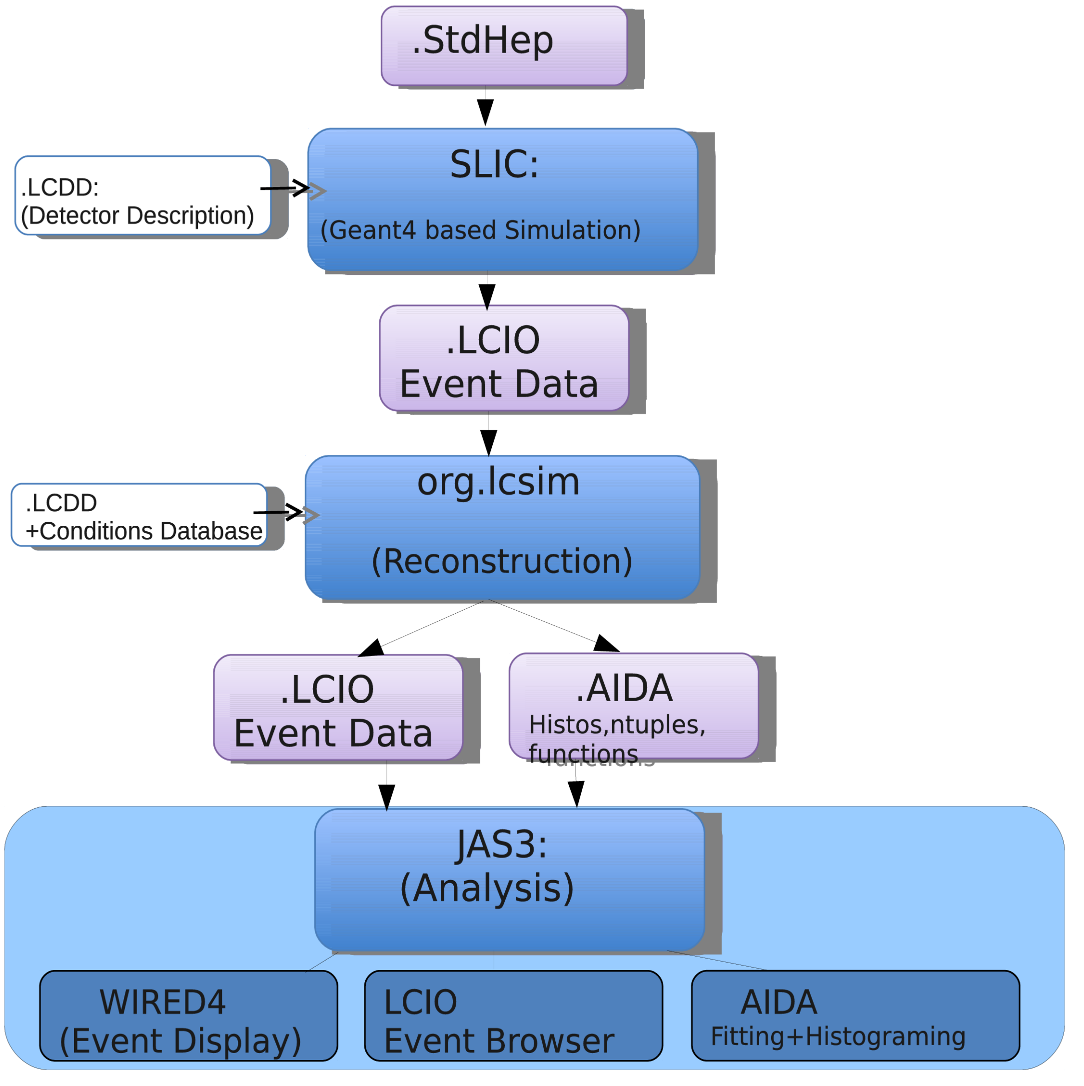

Radiusvsz energy weighted
Entries : 337045623
XMean : 46.7854
XRms : 3574.0
YMean : 1703.4
YRms : 651.13
OutOfRange : 45803892
SumOfWeights : 56359
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-6,000 -5,000 -4,000 -3,000 -2,000 -1,000 0 1,000 2,000 3,000 4,000 5,000 6,000
4.4 4.2 4.0 3.8 3.6 3.4 3.2 3.0 2.8 2.6 2.4 2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0.0

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) --> implement new optical calorimeter
  - 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 it: 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)

Z'-> $e^+ e^-$


pathlength corrected time weighted by energy
Entries : 21582681
Mean : -0.025711
Rms : 0.046818
OutOfRange : 43123550
SumOfWeights : 3112.0
600
550
500
450
400
350
300
250
200
150
100
50
0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0


.StdHep
.LCDD:
(Detector Description)
SLIC:
(Geant4 based Simulation)
.LCIO
Event Data
.LCDD
+Conditions Database
org.lcsim
(Reconstruction)
.LCIO
Event Data
.AIDA
Histos,ntuples,
functions
JAS3:
(Analysis)
WIRED4
(Event Display)
LCIO
Event Browser
AIDA
Fitting+Histograming