Jets and Jet-Jet Mass Reconstruction in a Crystal Calorimeter

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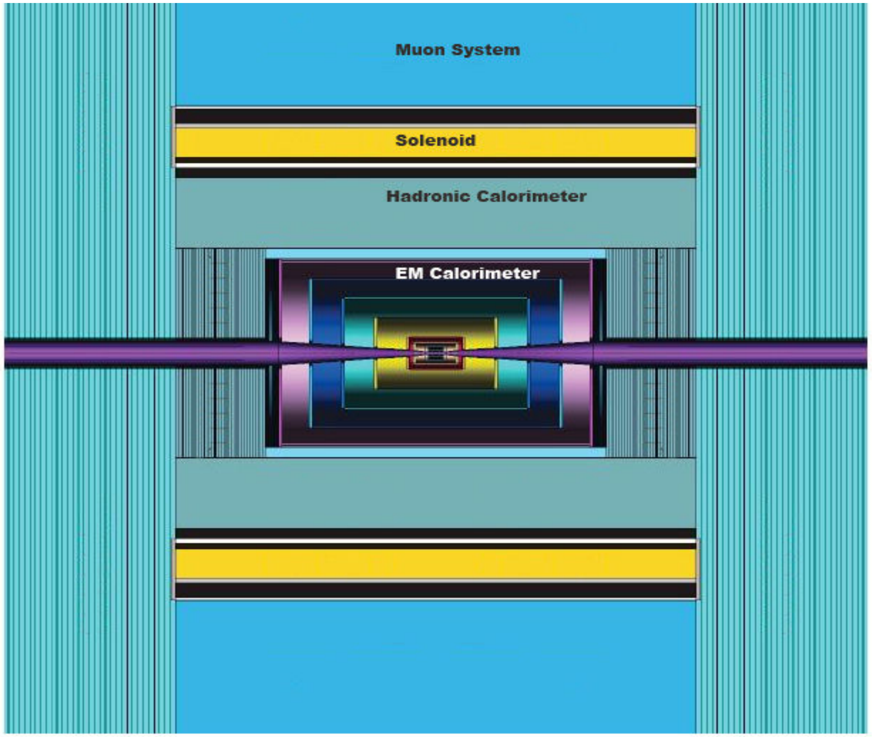
Motivation

- Calorimeters measure energy deposited in the volume of the detector
- Jets (collections of particles) are of interest of physics (but they are ill defined because of the color content)
- Di-jets produced by decays of color singlets (like W/Z) are well defined and they are objects of primary interest
- Crystal calorimeters with dual readout offer a perspective of very high energy resolution, but:
  - How do you reconstruct jets/di-jets?
  - Strong magnetic field bends particles and they land in 'wrong' places in the calorimeter. How does it spoil the di-jet mass resolution

- Summer student project: Nayeli Azucena Rodriguez Briones

Crystal Calorimetry version of SiD



Name	Layers	Thickness/Layer	Segmentation
		[cm]	[cm x cm]
ECAL Barrel	8	3	3 x 3
HCAL Barrel	17	6	6 x 6
Total Barrel	25		
ECAL Endcap	8	3	3 x 3
HCAL Endcap	17	6	6 x 6
Total Endcap	25		

‘Fine’ detector. Simulated and Analyzed

Machinery established to study different segmentations to .study the effects and to optimize the detector design. Very good project for students..

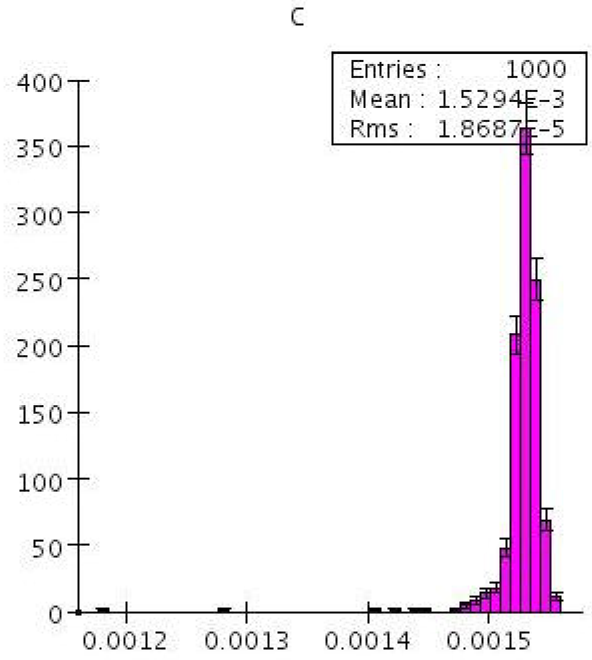
Simulation and Analysis

- Detector simulation within the SLIC environment (optical calorimeter version by Hans Wenzel)
- Large even samples produced on the OSG grid
- Single particles, electrons and pions at various energies simulated to provide the calibration samples
- Single W and single Z (with different energies simulated to stude the di-jet mass resolution
- Analysis carried out within Jas3 framework

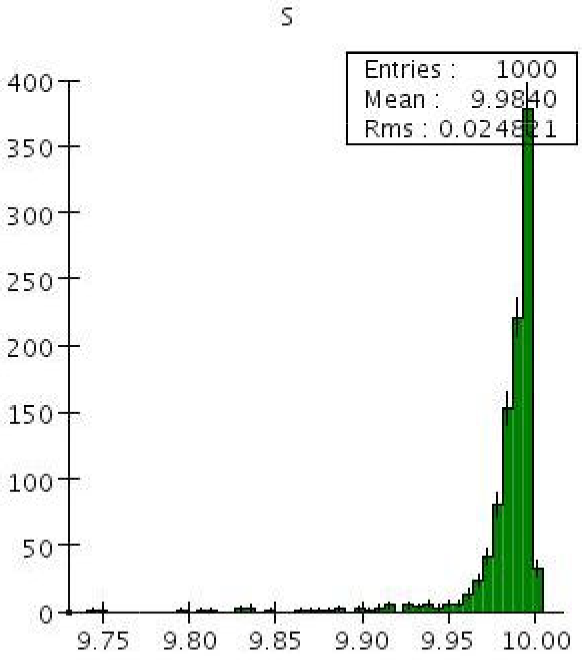
Analysis: Calibration

Establish calibration factors for scintillation and Cherenkov signal using 10 GeV electrons

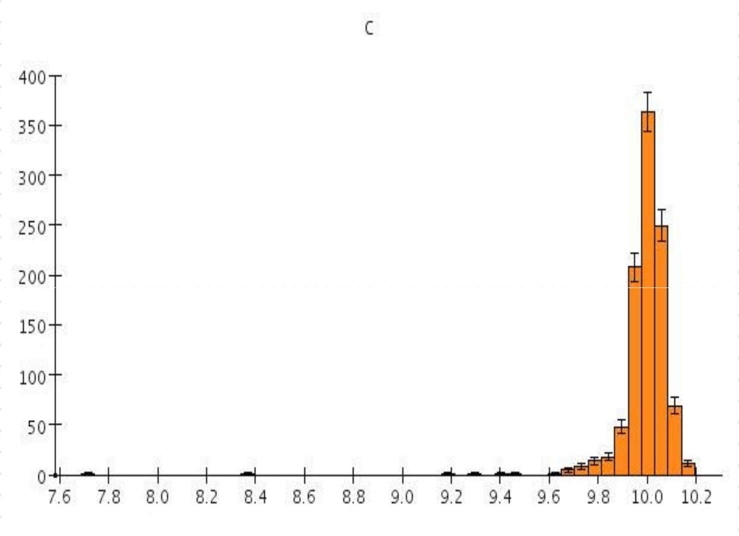
Cherenkov

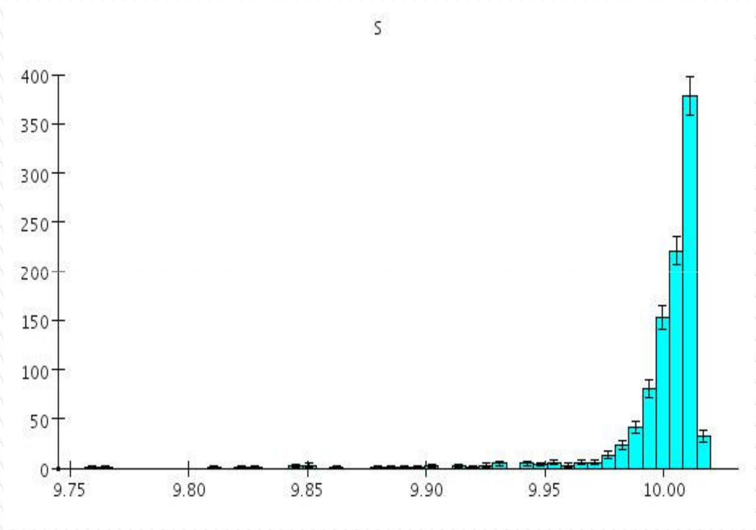


Scintillation



Calibrated Response : 10 GeV electrons



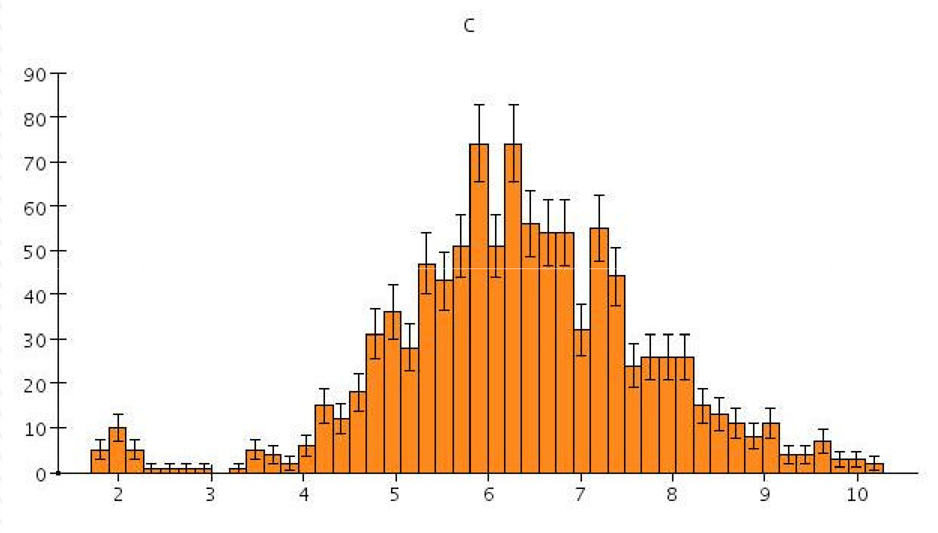


Cherenkov

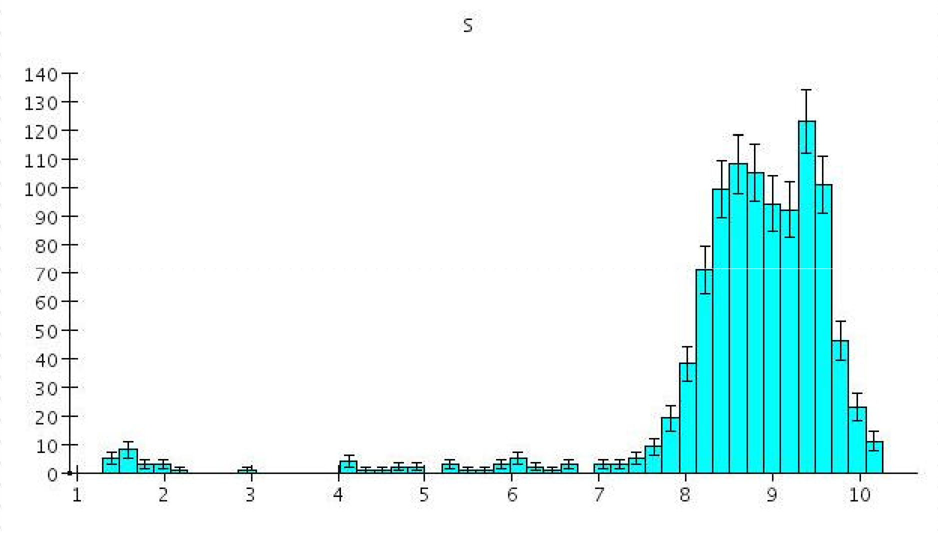
Scintillation

Note the scale: energy resolution is, obviously, superg for electrons

Calibrated Response: 10 GeV Pions

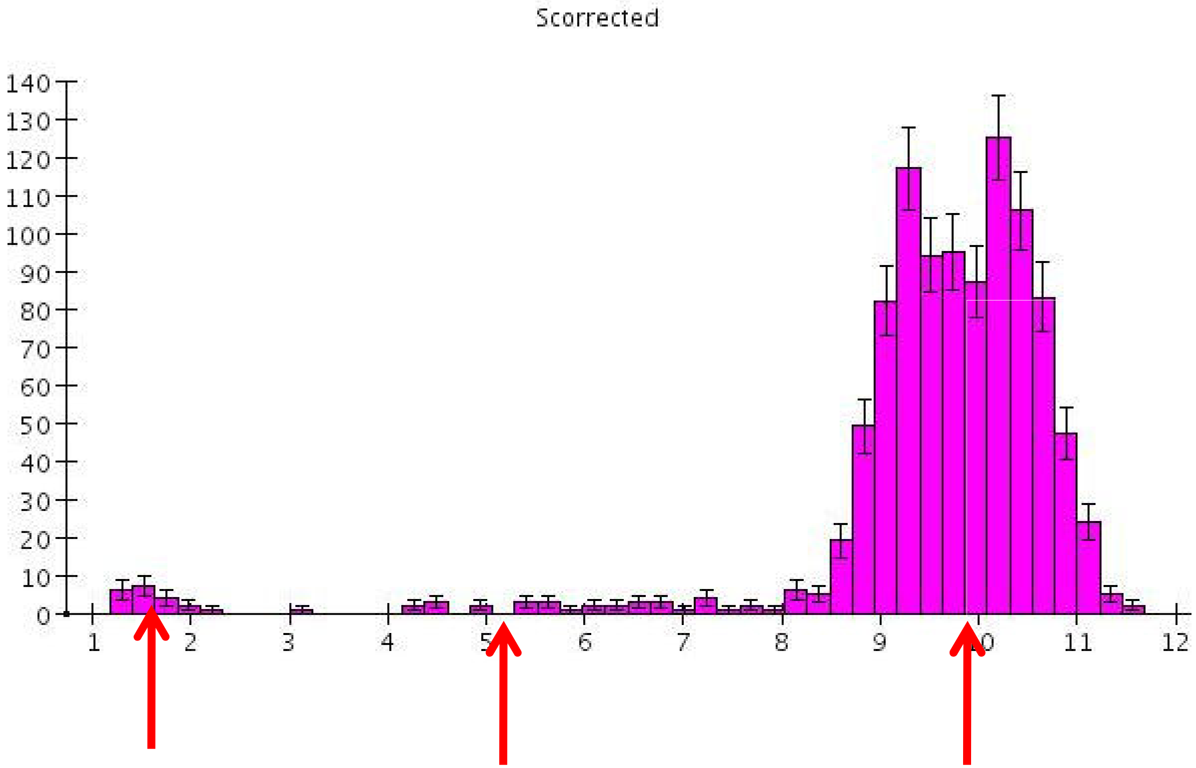


Cherenkov



Scintillation

Dual Readout Correction



Punch through

Leakage

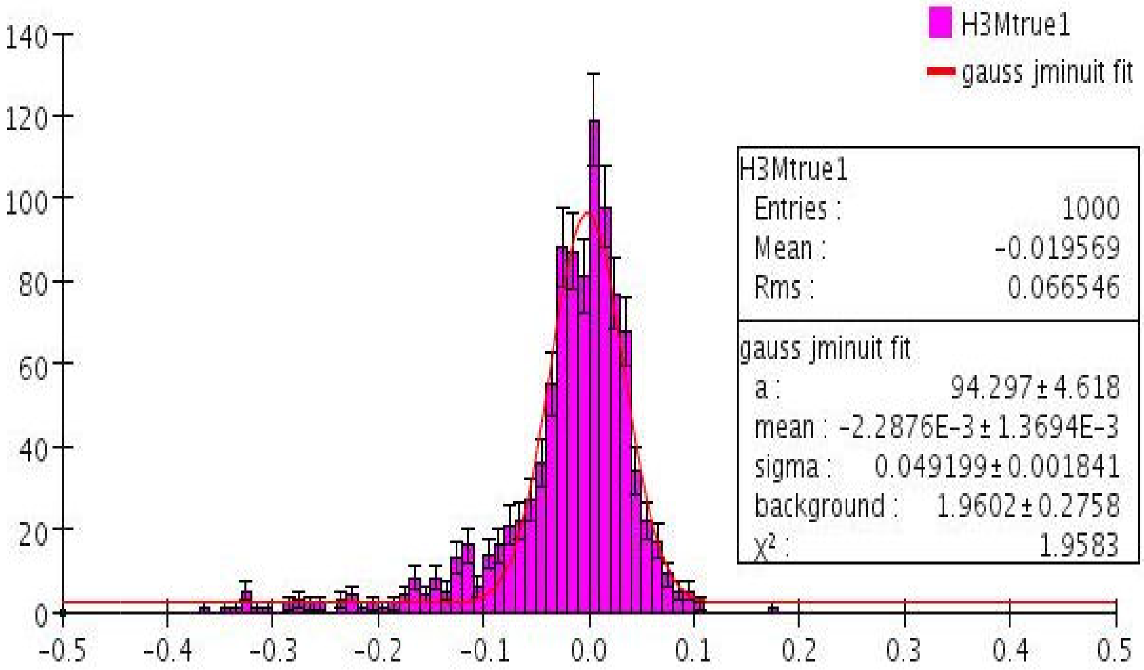
Two physics models (GEANT4)

- Use simple correction (Anna Driutti):

$$E = \frac{S}{0.68 + 0.31C/S}$$

Di-jet Mass Reconstruction

- Single W events, W momentum 0 – 100 GeV
- Treat all cells as massless particles: (E,px,py,pz), with the direction of the momentum vector determined by the cell position (center)
- No B field
- $\Delta M/M \sim 0.049$



H3Mtrue1

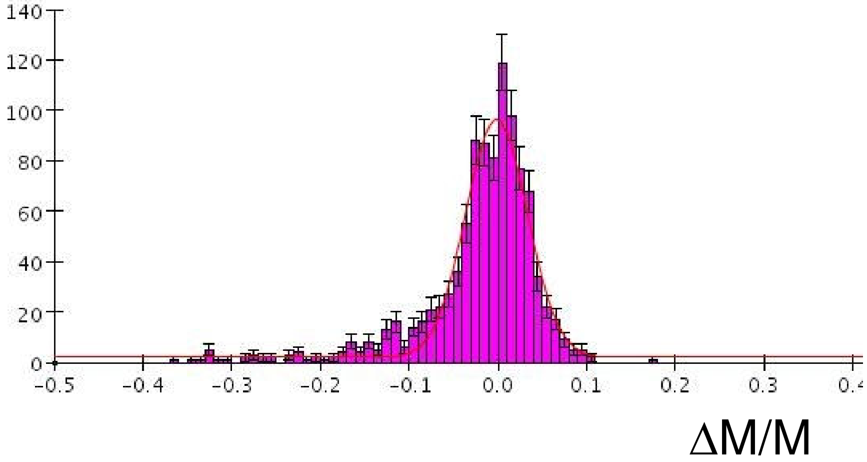
Entries :	1000
Mean :	-0.019569
Rms :	0.066546

gauss jminuit fit

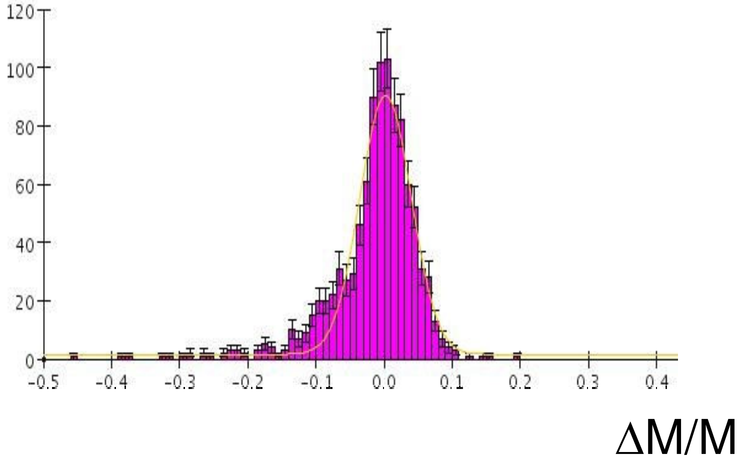
a :	94.297 ± 4.618
mean :	-2.2876E-3 ± 1.3694E-3
sigma :	0.049199 ± 0.001841
background :	1.9602 ± 0.2758
χ^2 :	1.9583

Mass Reconstruction in Magnetic Field

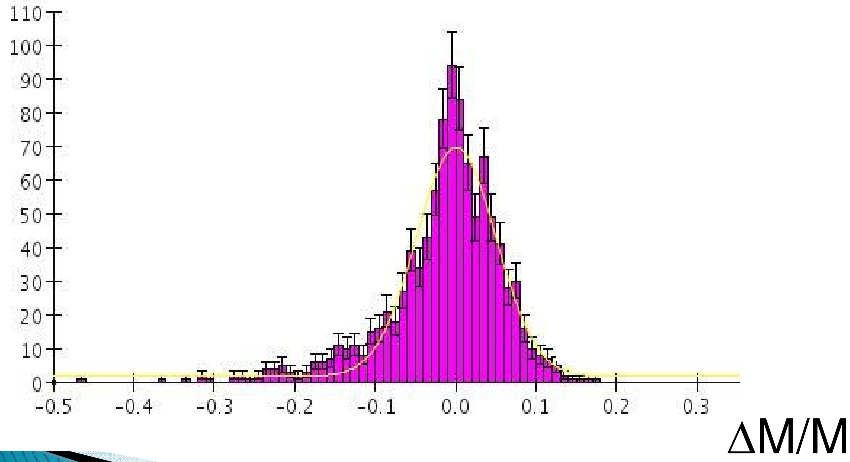
B = 0 T, σ = 0.049



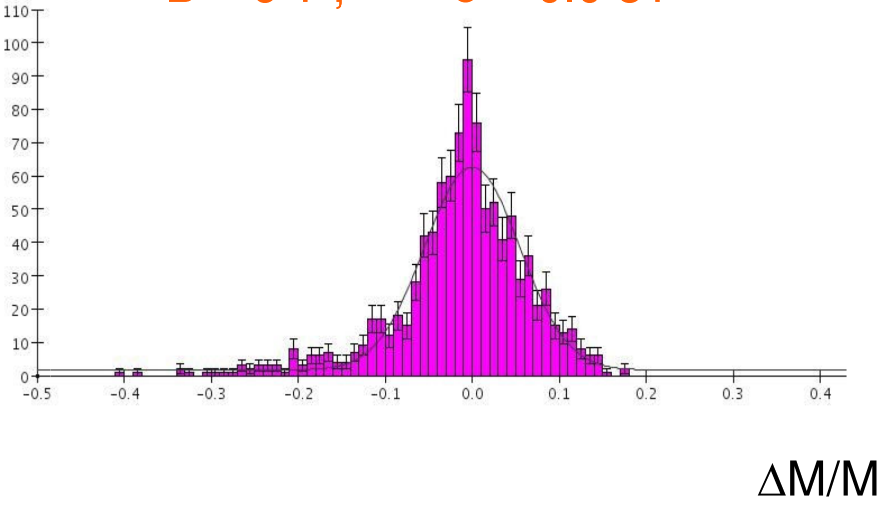
B = 2 T, σ = 0.054



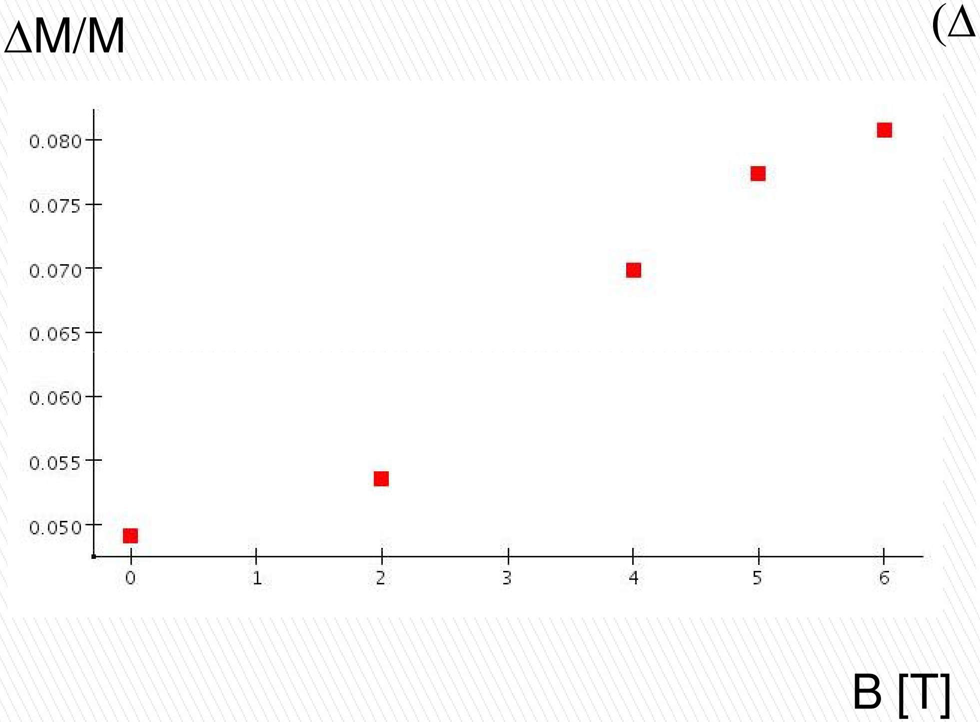
B = 4 T, σ = 0.070



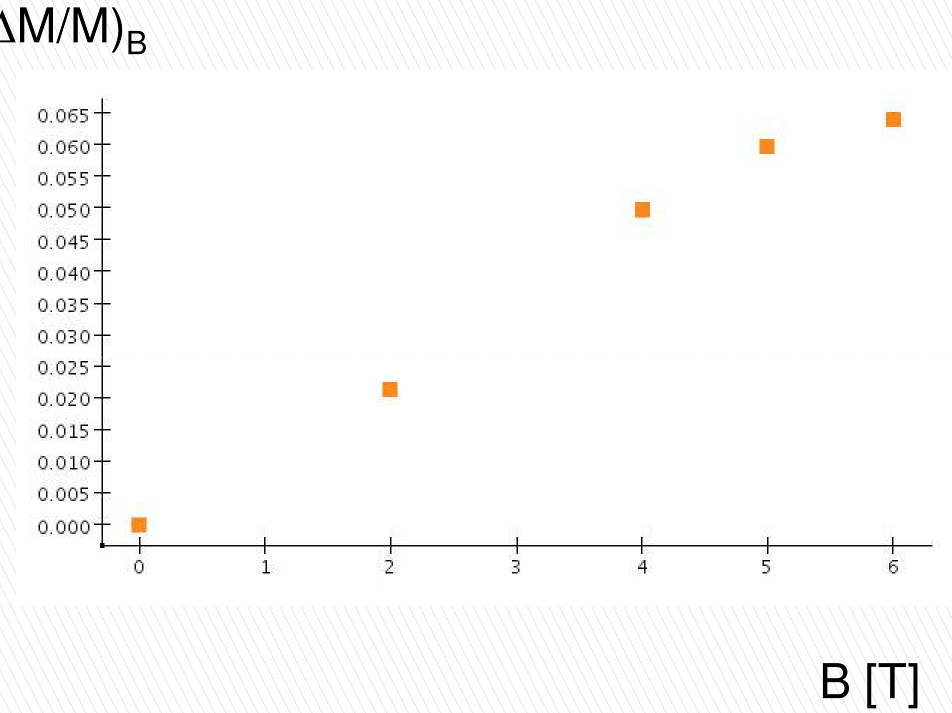
B = 6 T , σ = 0.0 81



Magnetic Field Effect



Mass resolution as a function of B field



Contribution of the magnetic field to the mass resolution

Note: Bending of charged particles in 5T field induces the contribution to resolution larger than the calorimeter itself.

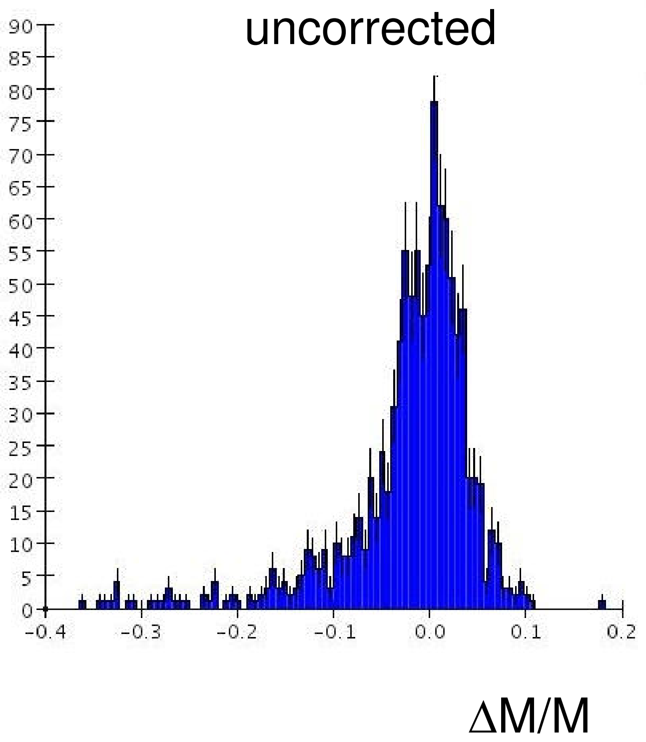
Correcting for the B Field Effect

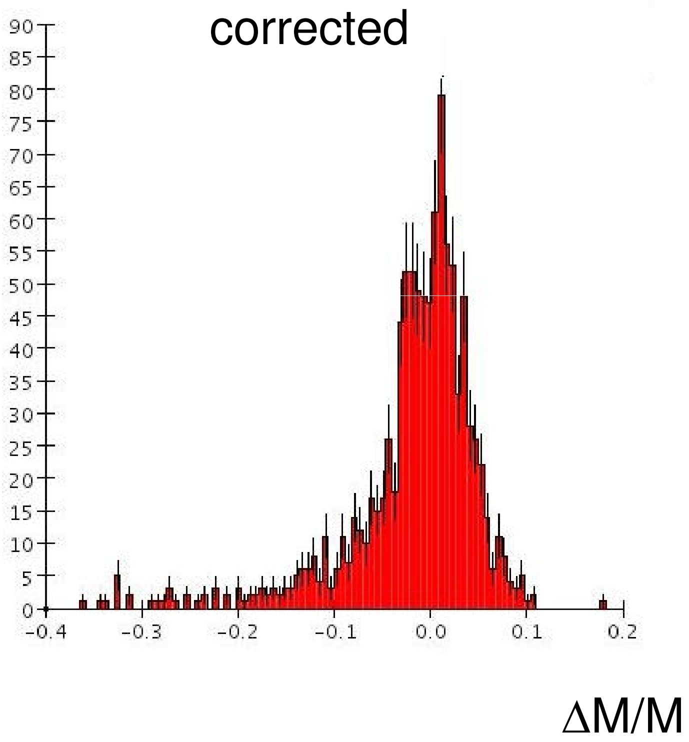
- Magnetic field bends charged particles: the energy depositions are displaced with respect the their ‘true’ directions
- The change of the invariant mass of a system is calculable for each individual event
- $(\Delta M)_B = M_{Ch}(B=0) - M_{Ch}(B)$, where

$$M_{Ch} = \sqrt{\left(\sum E_i\right)^2 - \left(\sum \overrightarrow{p_i}\right)^2}$$

- And the direction of the momentum vector is given by the initial direction (B=0) or the impact point at the calorimeter (B)

Mass Resolution: B=0 (Null correction)



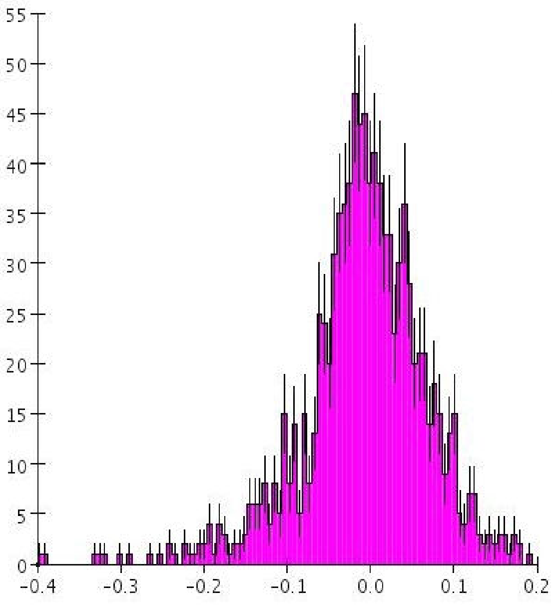


$\sigma = 0.049$

$\sigma = 0.045$

Mass Resolution: B = 6T

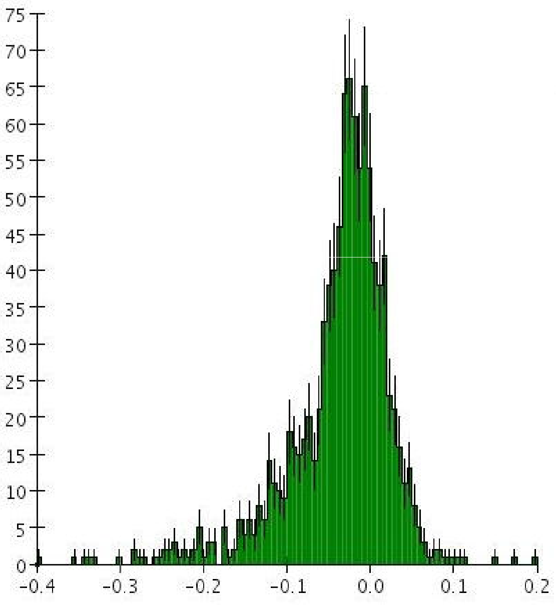
uncorrected



ΔM/M

σ = 0.075

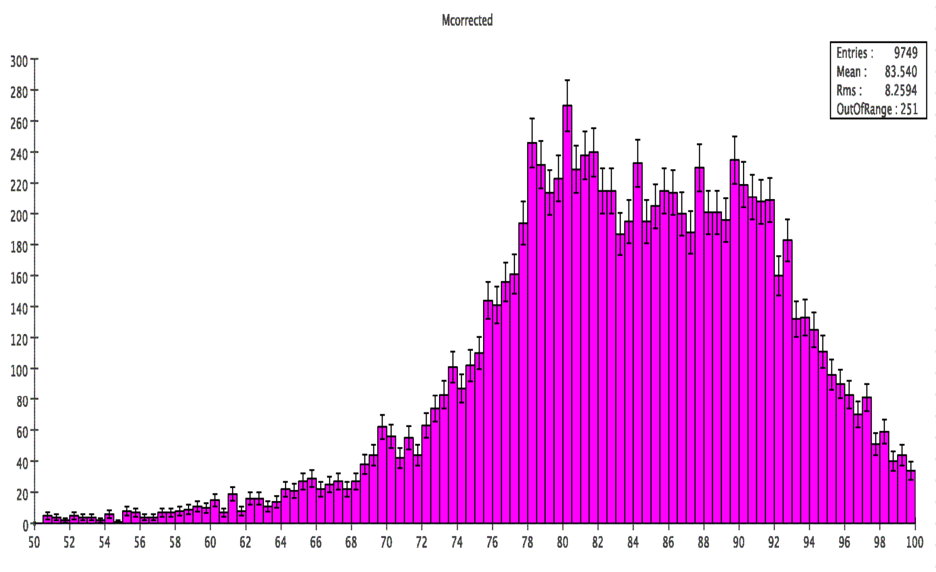
corrected

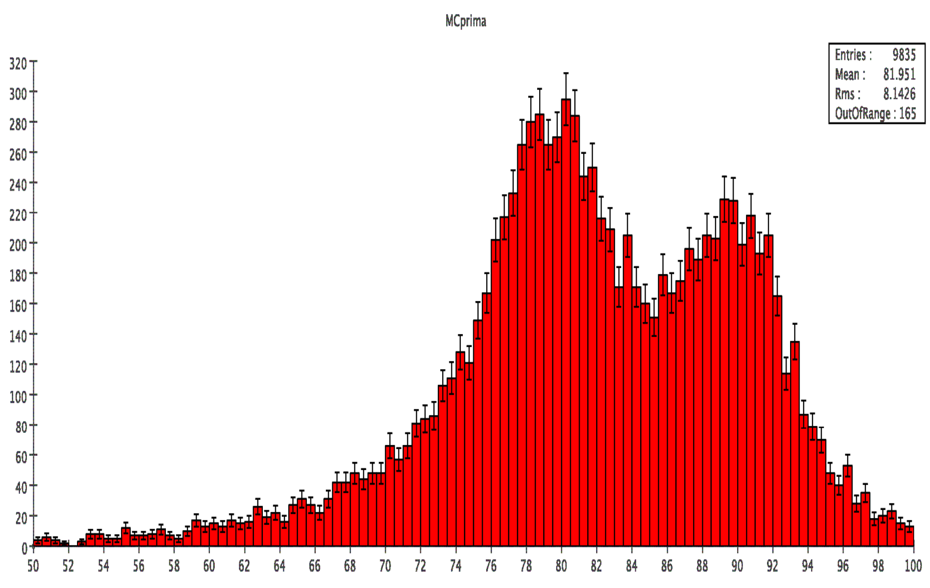


ΔM/M

σ = 0.049

Dijet Mass: W + Z sample, B= 5T





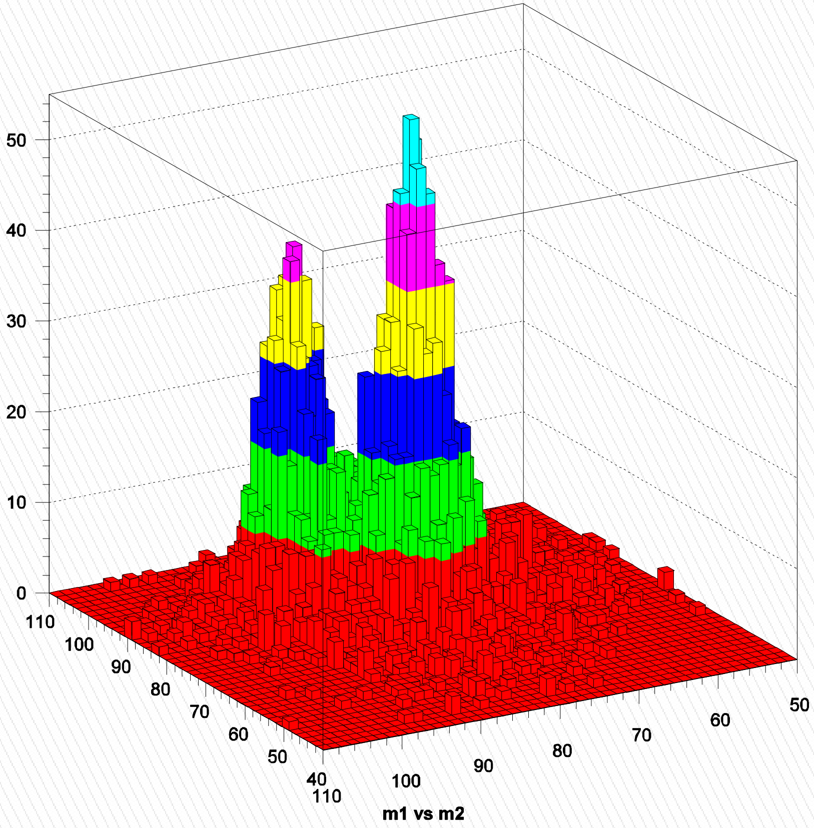
M [GeV]

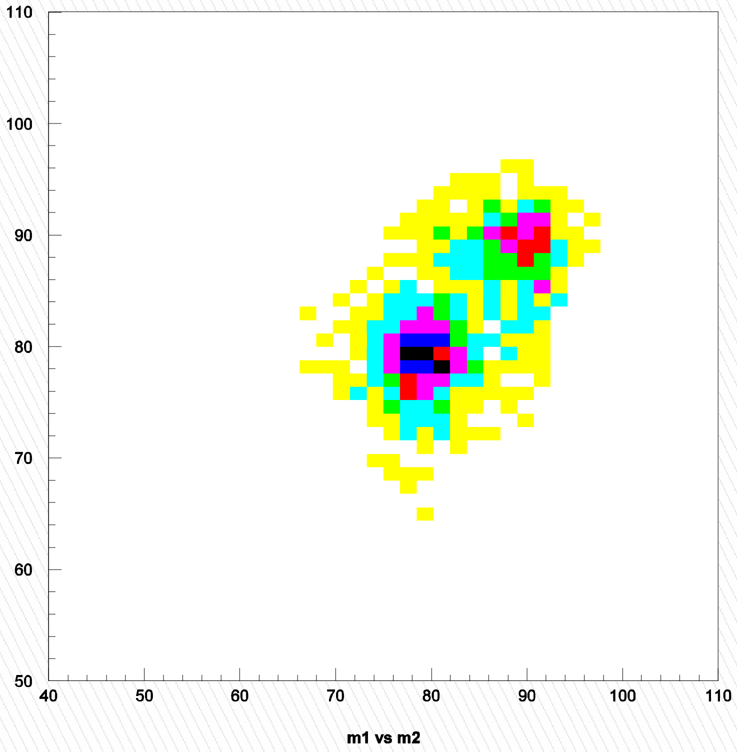
M [GeV]

Uncorrected mass

Corrected mass

WW vs ZZ final states, 5T Field





On the Robustness of the Correction

- Correction for the magnetic field effect is derived from the charged particles (tracking) information
- No correlation of any kind between the tracks and the energy depositions in the calorimeter is used
- Correction is not sensitive to the performance of a tracker:
  - If tracking is inefficient, and some tracks are lost, the correction (additive) is somewhat nderestimated. This is most likely to happen for stiff tracks in a jet core. They contribute nothing to a correction
  - If stiff ghost tracks are ‘invented’ by the pattern recognition failure, they do not produce any contribution to the correction

Conclusion

- Segmented crystal calorimeter offers a powerful tool for precise determination of di-jet masses
- Strong magnetic field induces a sizeable contribution to di-jet mass resolution
- But it is easily correctable using tracking information
- Correction is simple and robust

Note: this was a summer student project. A lot of room for further improvements in in the analysis