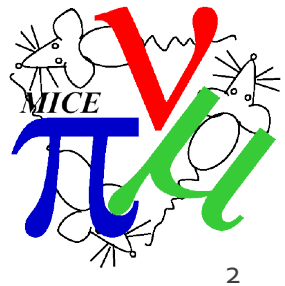
Introduction

- Can we tell the difference between forward polarized and backward polarized muons by their decay electrons energy spectrum in the EMR?
- Looking at:
  - Depolarization of beam - Muon spin changes as it traverses the cooling channel due to presence of electric and magnetic fields and scattering effects
  - Effects of polarization of muon beam on the number of decay electrons seen
- The muon spin vector in the rest frame evolves in electric and magnetic fields according to the Thomas-BMT equation in GEANT 4 : G4EqEMFieldWithSpin :

$$\frac{d\vec{s}}{dz} = -\frac{e}{p_z}\,\vec{\Omega} \times \vec{s}$$

Spin Tracking in MAUS

- Each muon in beam needs a normalized spin three vector (sx, sy, sz) in the muon rest frame – these have been added to the primary and virtual hit definitions
- Spin evolution calculated using GEANT4
- Option added in detector construction to allow spin tracking to be turned on in datacards by adding line "StepperType =SpinTrack"
- Integration tests carried out to ensure that spin is correct i.e that there is some difference between initial and final spin in presence of B field
- Changed the MAUS physics list to use G4DecayWithSpin- added option in datacard to turn polarized muon decays on/off

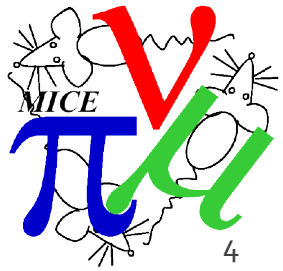


Spin Tracking in MAUS

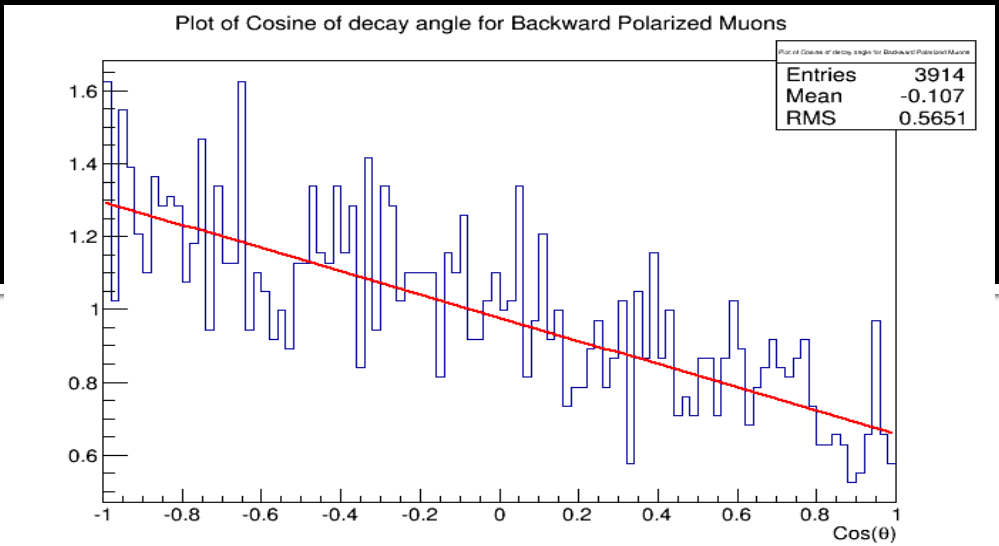
Initial Simulation

Simulating in MICE

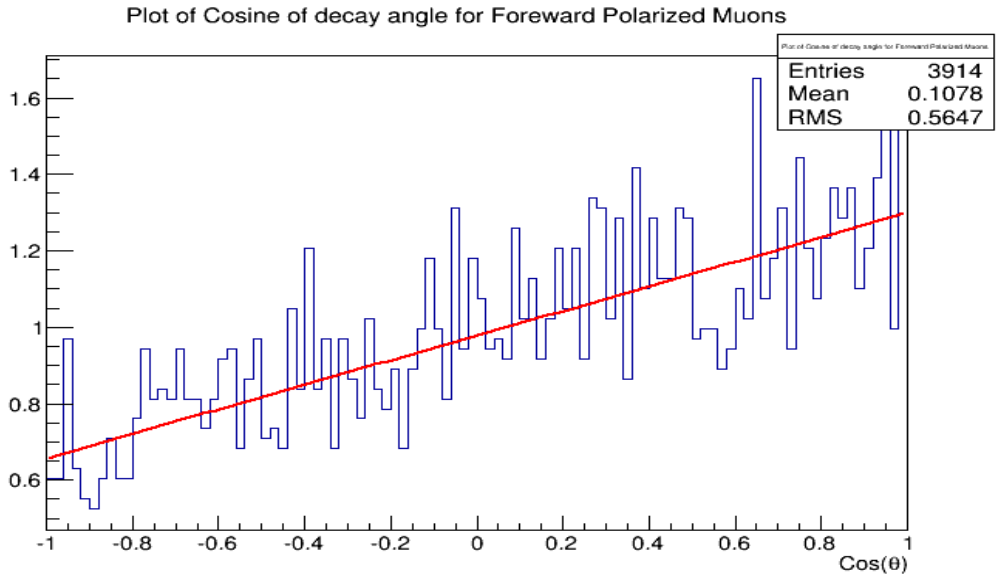
- Initially in very simple geometry but now followed up using EMR geometry file
- Ran MC of beam of muons through SpecialVirtual SensitiveDetector and a simple block of plastic for three cases:
  - "unpolarised beam"
  - "forward polarised beam" (sx, sy, sz) ~ (0, 0, +1)
  - "backward polarised beam" (sx, sy, sz) ~ (0, 0, -1)



Decay Angle

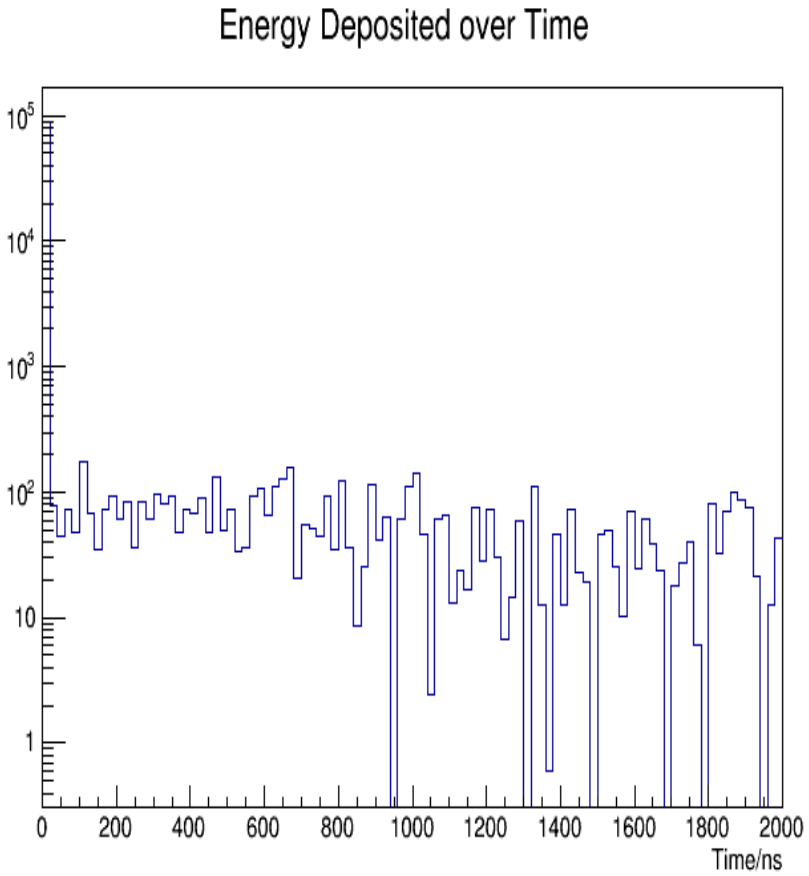


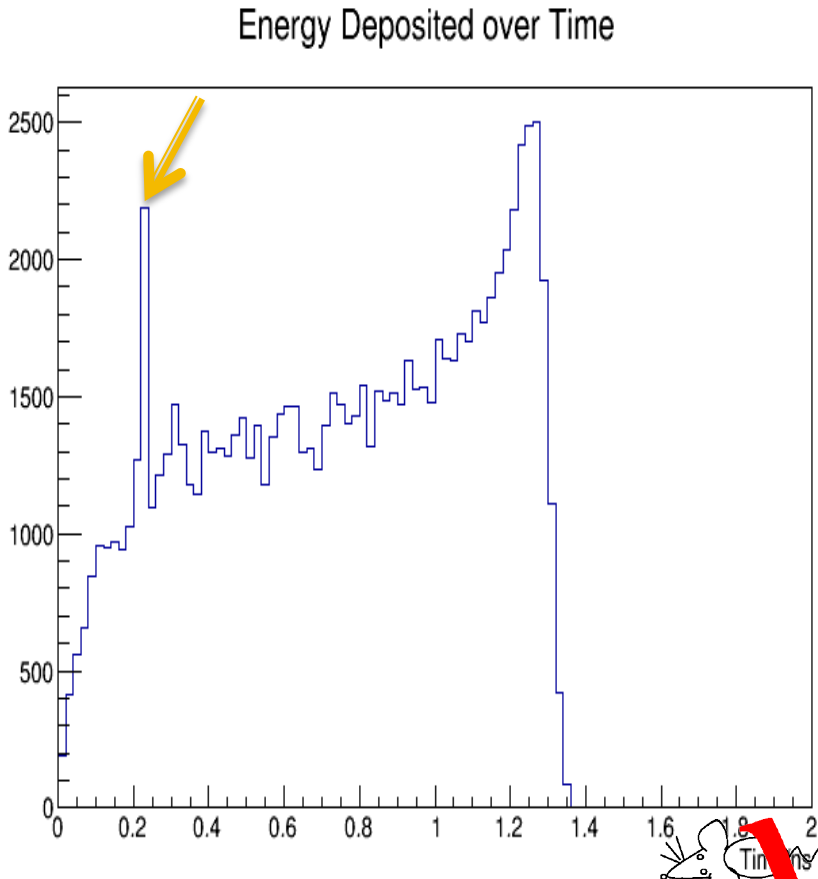
- Intercept = 0.976±0.098, Gradient =+/- 0.31 ± 0.038



$$\frac{d\Gamma}{d\cos\theta} \sim 1 + \frac{1}{3} P_\mu \cos\theta.$$

Energy Deposited





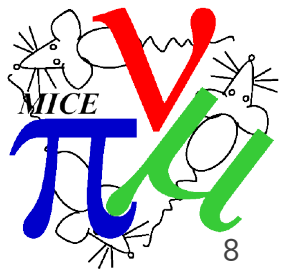
- In order to cut out the primary muons a time cut of >100 ns is imposed

Spin Tracking in MAUS

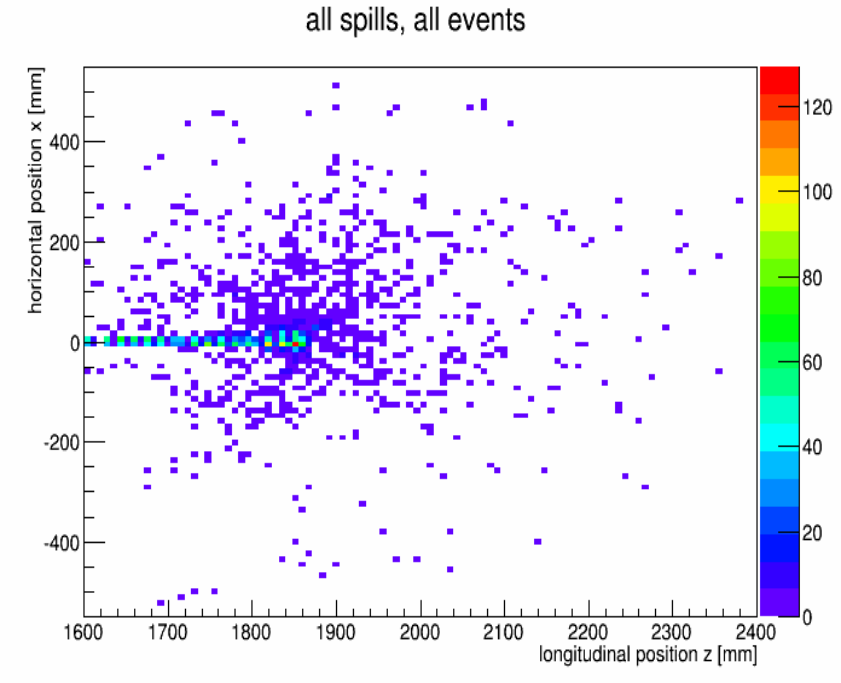
EMR Simulation

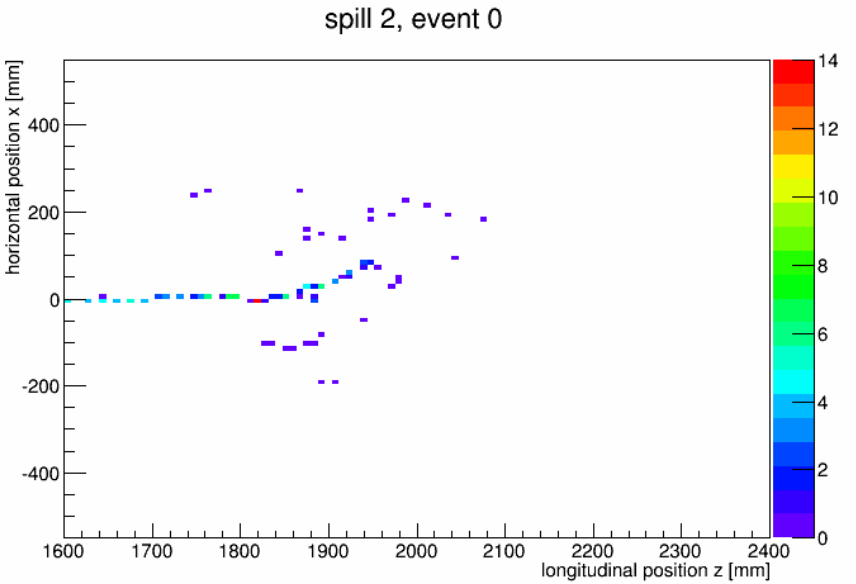
EMR Monte Carlo

- Monte Carlo made within EMR Working Code
- EMR geometry used
- Passed a forward polarized muon beam through geometry
- Spin Tracking "on"
- Polarized muon decays set to "on"



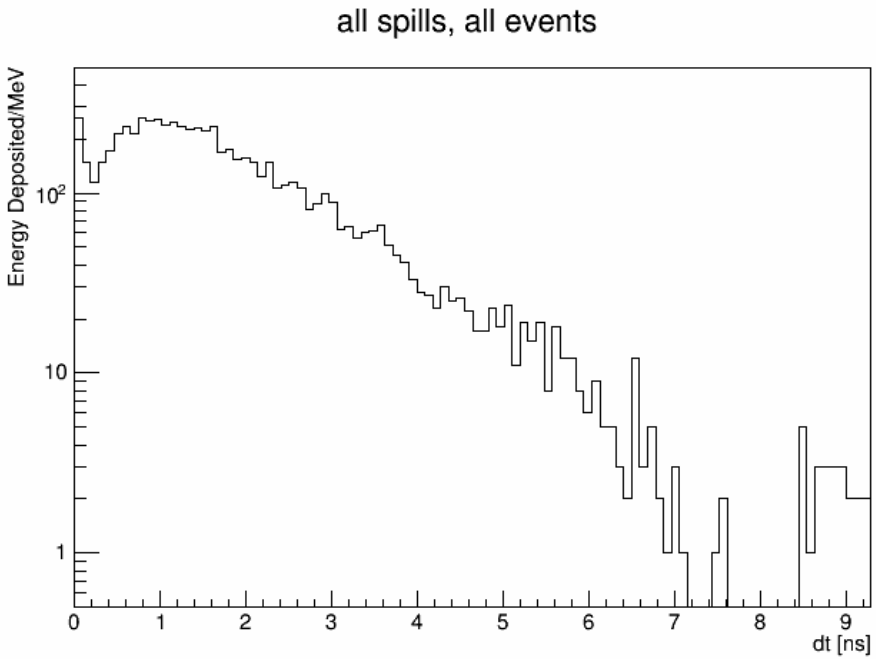
EMR Monte Carlo Tracks

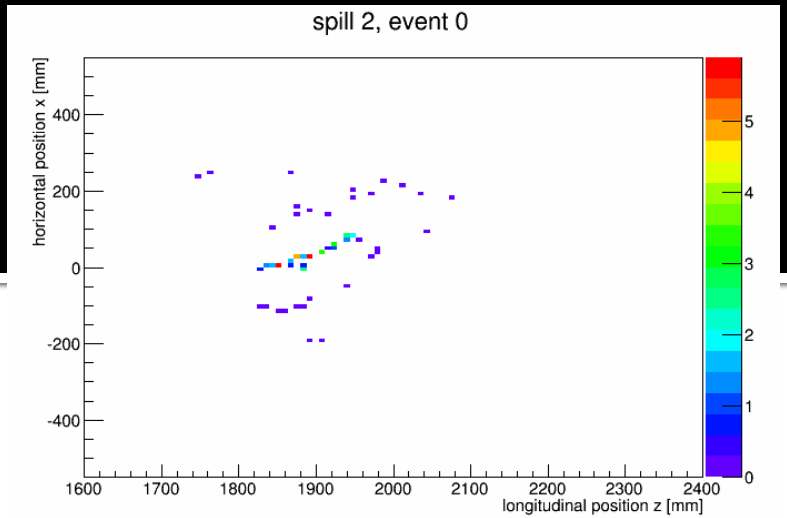


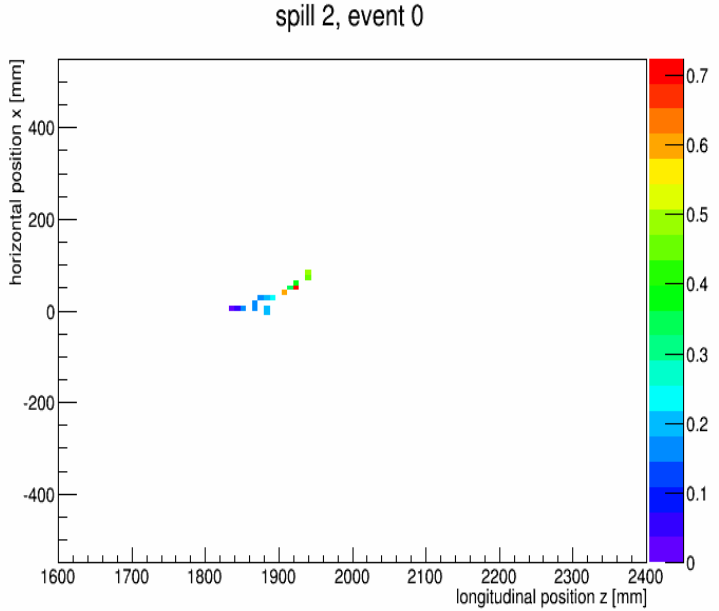


- All tracks weighted by energy deposited in EMR from Monte Carlo
- Single Events can be plotted with muon decay vertex and decay electron track
- 'Noise' also visible

Noise dt cut

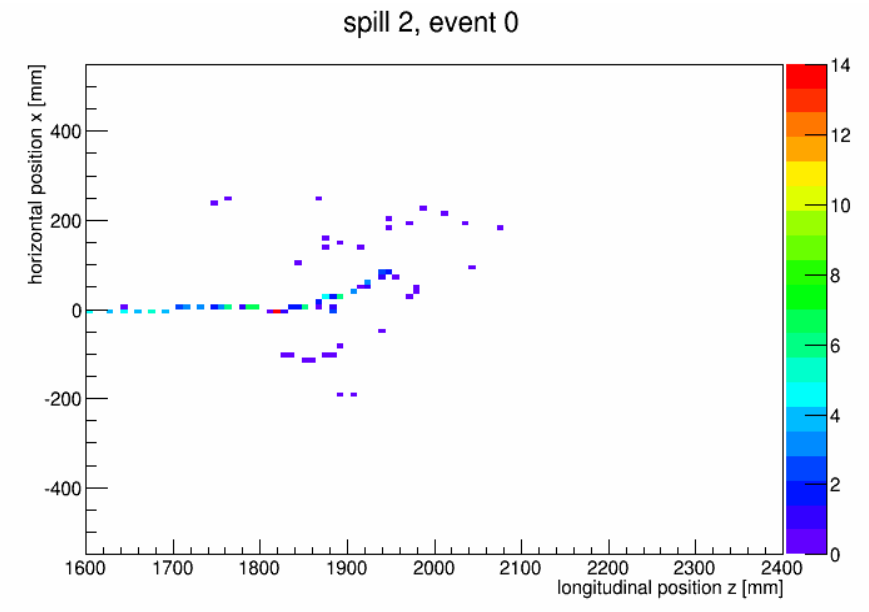


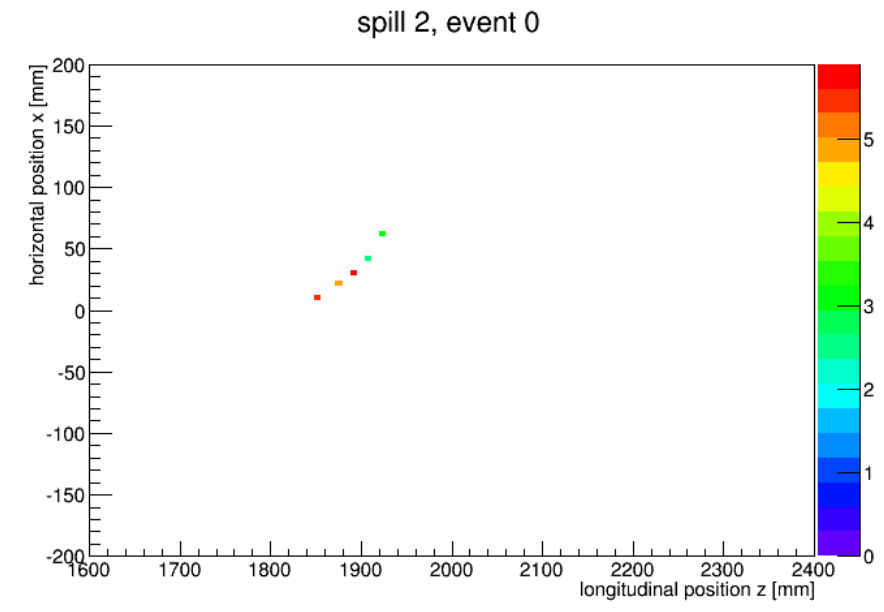




- dt = difference in hit time from the first electron hit observed in that event
- Set dt < 0.5 ns for each event
- Top plot weighted by E dep bottum by dt
- 'Noise' significantly reduced
- Need to know whether EMR resolution will allow for this cut ????

Energy Cut



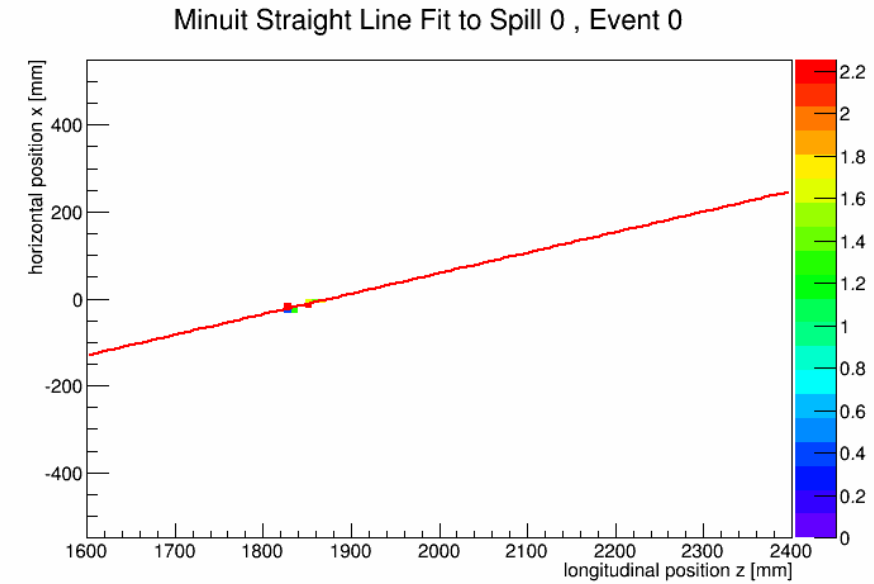


- Look at energy deposited
- Most noise has e_dep < 2.5MeV
- Fit-> not an exact straight line->some Multiple Scattering ?
- Use Minuit to optimise fit

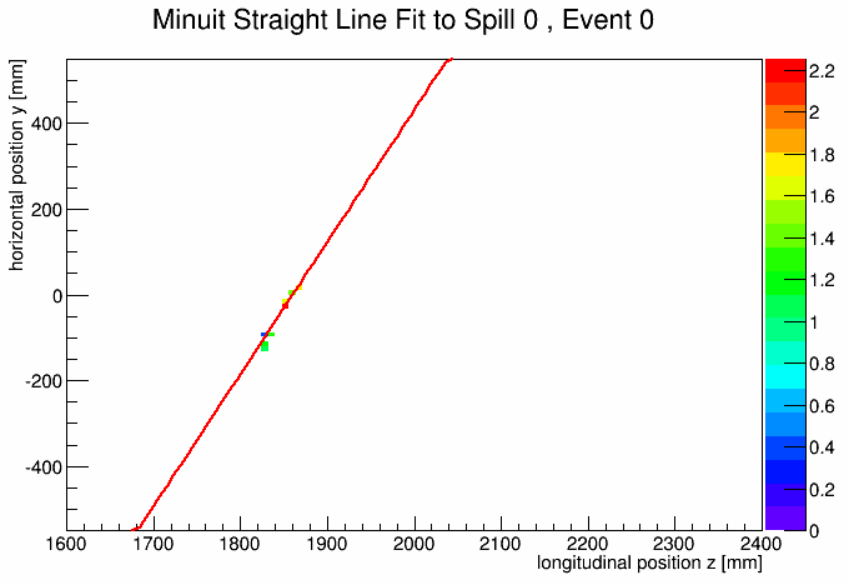
Fitting

TMinuit Cartesian Coord Fit:

X-Z: X = 0.472*Z - 886

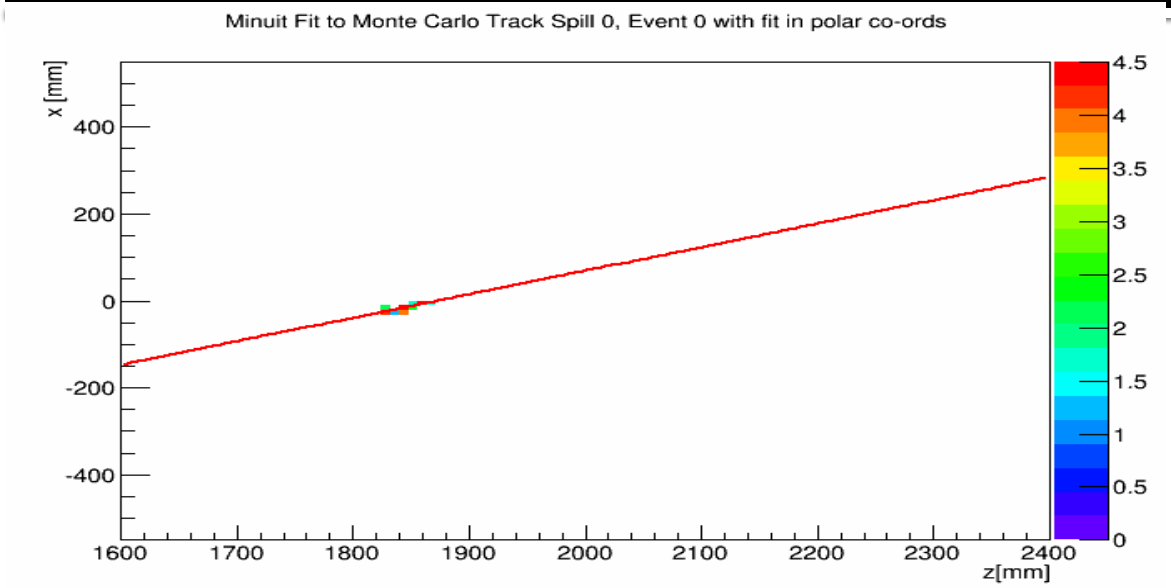


Y-Z: Y =0.308*Z -5727



- Need to optimise using MINUIT
- Used Tminuit case in ROOT
- Try to minimise sum of squared distances from the line
- Gradient = tan(decay angle) however errors when vertical track-> NEED TO PLOT IN POLAR COORDS

Fitting in Polar Co-ordinates



- Cartesian fit just a test
- Better optimization done by minimizing:

$$\sum \theta_0 - \theta_i$$

- 3 parameters: x_0, y_0 and theta_0
- Where:

$$\theta_0 = arctan2(y(x) - y_0, x)$$

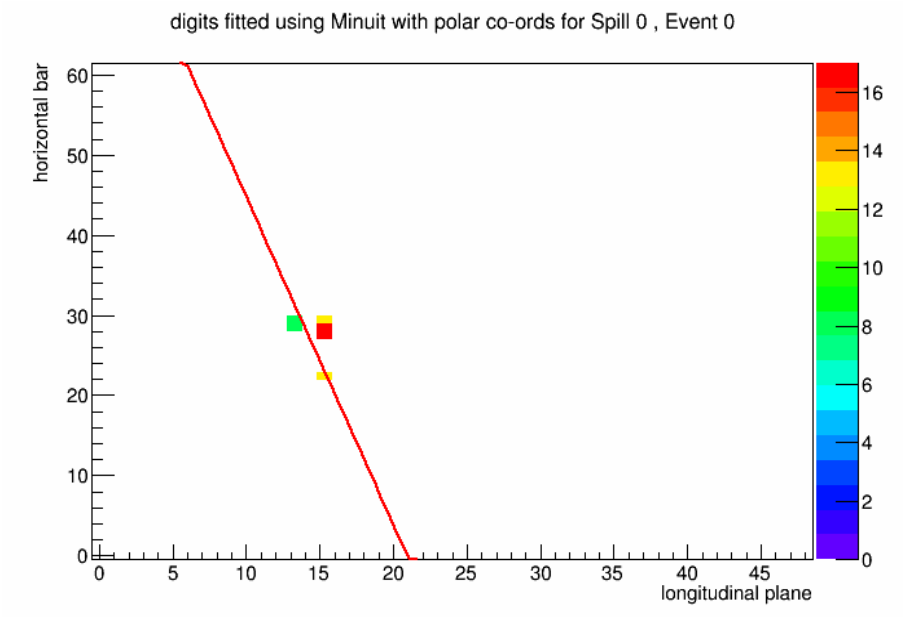
$$\theta_i = arctan2(y_i - y_0, x_i - x_0)$$

- Equation of line :

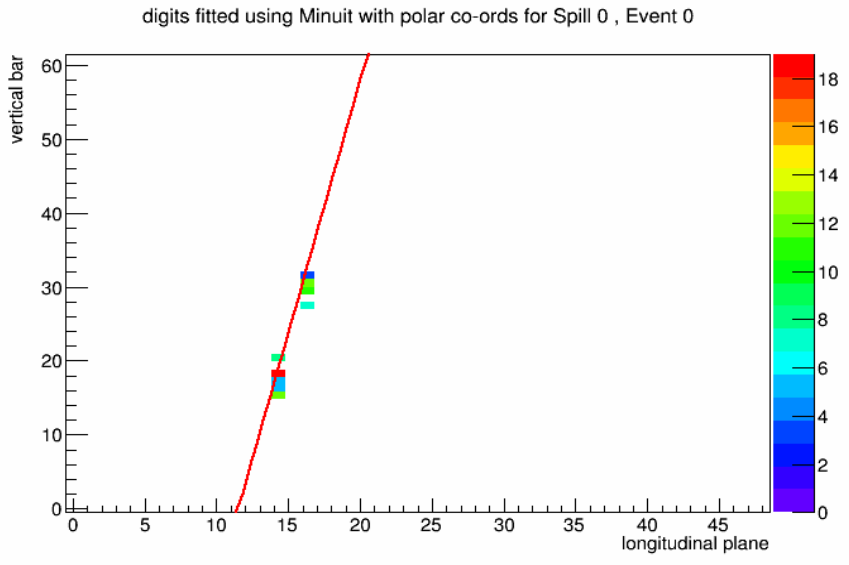
$$y = tan(\theta_0)(x - x_0) + y_0$$

Digitization

X-Z with weight =Time Over Threshold



Y-Z with weight =Time Over Threshold



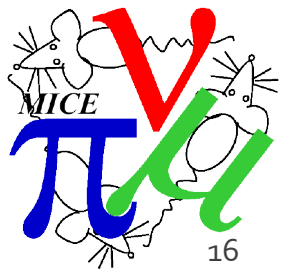
- Process of converting the energy deposited to ADC counts (colours proportional to ADC charge)
- Use bar and plane number instead of distance from start
- Fit parameters limited by efficiency->Needs consideration

Spin Tracking in MAUS

What's Next?

Future Work

- Carry out reconstruction and analysis on EMR Data from 2013
- Look at geometrical effects e.g. how is resolution effected by where muon is in detector and what direction it is travelling in when it decays
- Look at sources of errors e.g. Look at readout effects e.g. cross talk (signal from different bar detected) and mis-cabling
- PID
  - Reject Pions and electrons via TOF2 – TOF0 time cut
  - Look at mis-ID esp. for pions
- MC of real beamline
- Plan to finish work by end Oct. 2014



Thank You for Listening!

Any Questions?