BCAL Timing Distributions

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Simulating Timing Spread

- Produced ROOT tree with *DMCTrajectoryPoint* objects:

```
hd_ana \
    -PPLUGINS=janaroot \
    -PAUTOACTIVATE=DMCTrajectoryPoint \
    -PJANAROOT_MAX_OBJECTS=50000 \
    hdgeant.hddm
```

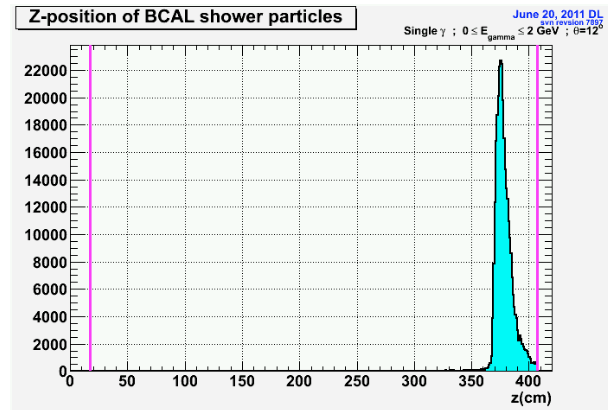
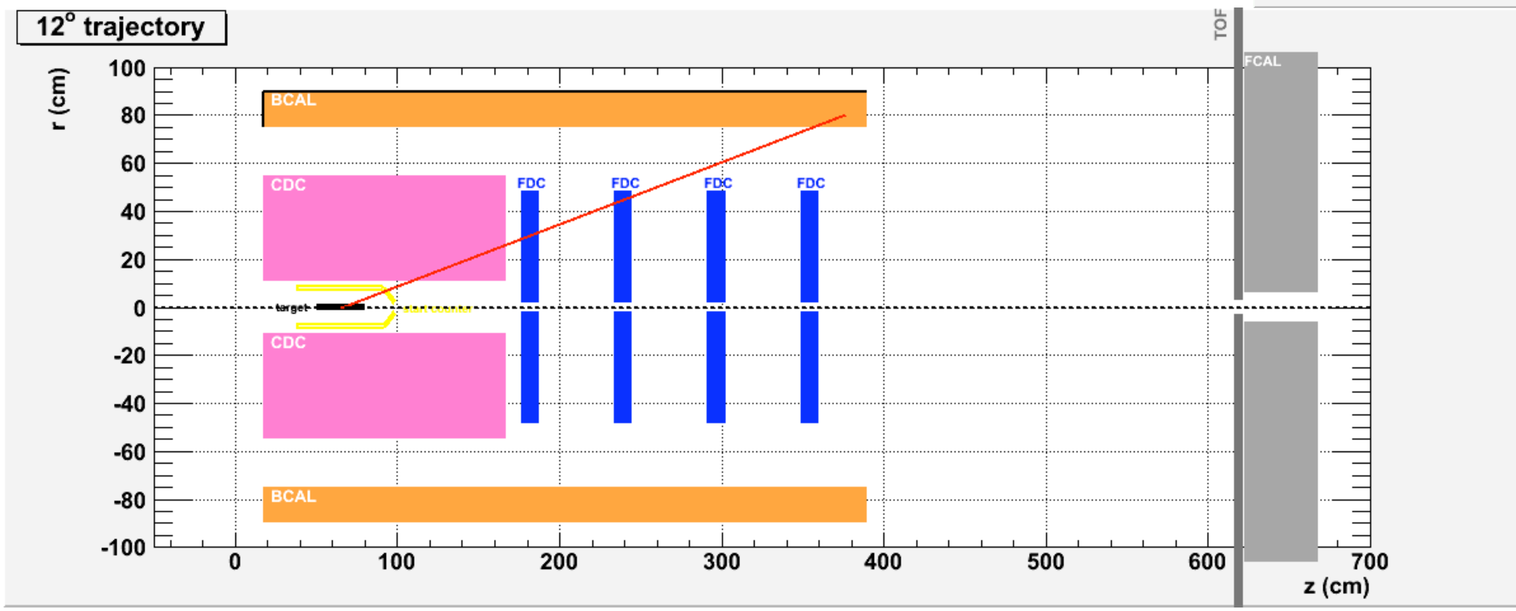


Diagram showing 12º trajectory



DMCTrajectoryPoint objects

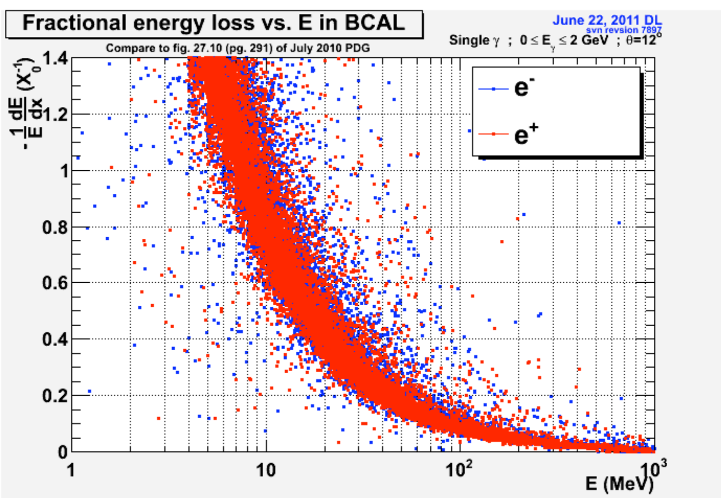
```
float x,y,z,t;
float px,py,pz;
float E, dE;
int primary_track;
int track;
int part;
float radlen;
float step;
int mech;
```

The *DMCTrajectoryPoint* objects contain information from a single call to *gustep* in *hdgeant.*

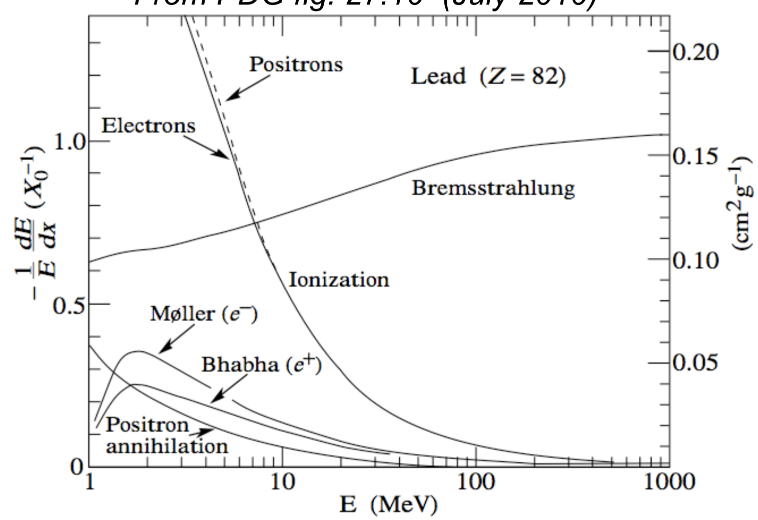
These indicate energy loss mostly due ionization.

Values can be used to indicate energy weighted timing spectrum at photodetectors

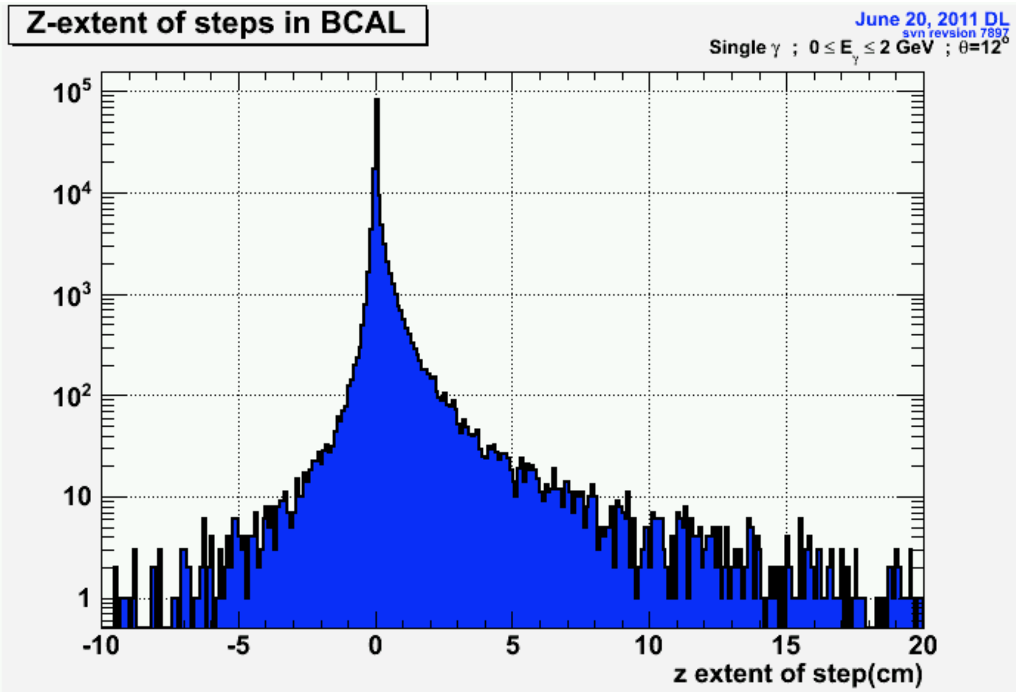
Fractional energy loss in BCAL from DMCTrajectoryPoint



From PDG fig. 27.10 (July 2010)



Distribution of z-projection of steps



Use momentum direction and step size to indicate extent of step in z-direction

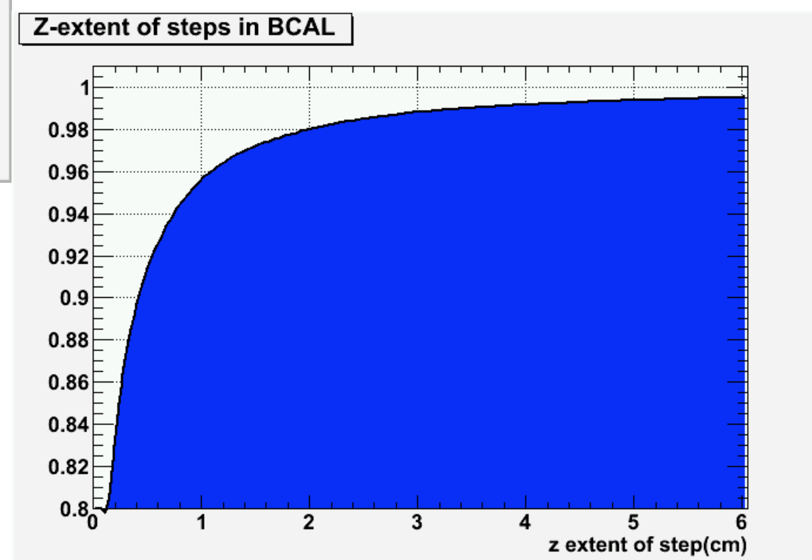
Only steps in BCAL shown

Step size is calculated automatically by GEANT

Some steps are several cm, but majority (98%) are less than 2cm

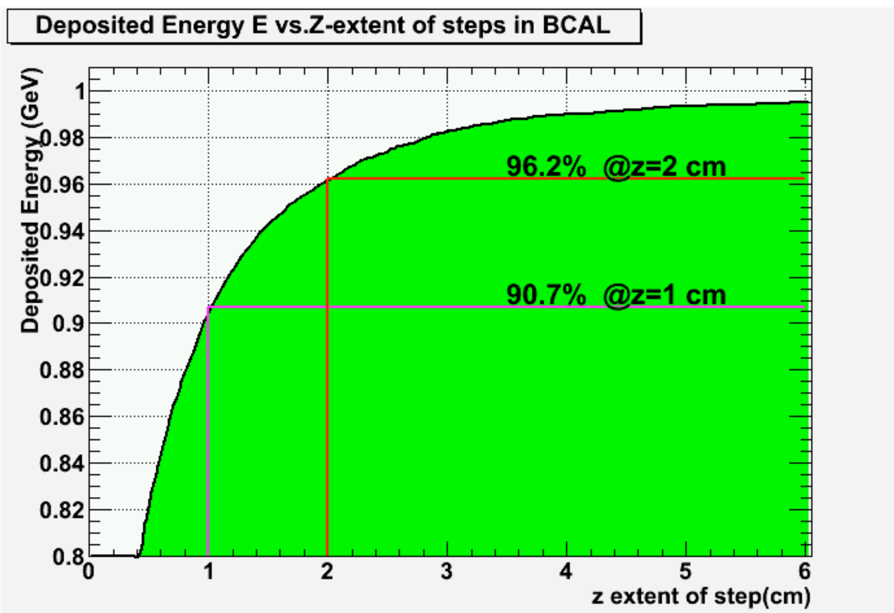
This is due to cell boundaries in geometry definition and 2cm cells (in R)

This will not change from fine to course segmentation since same geometry used for both



Normalized integral of abs(z_extent)

Energy –weighted Distribution of z-projection of steps



Similar to previous, but weighted by energy deposition in step.

More energy loss in larger steps so distribution skewed a little.

Still, >96% of energy is deposited in steps with <2cm projection in z.

This may indicate a reduced step size is not required.

If reduced step size is required in the BCAL, that will take longer to simulate.

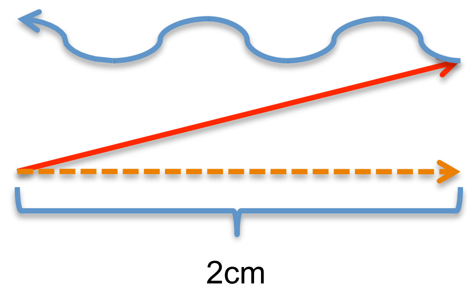
Convolute Pulse shape with energy weighted timing distribution

Effective speed of light in BCAL is 16.75 cm/ns or ~0.5c

A particle traveling 2cm in z at β_z will have a time spread of:

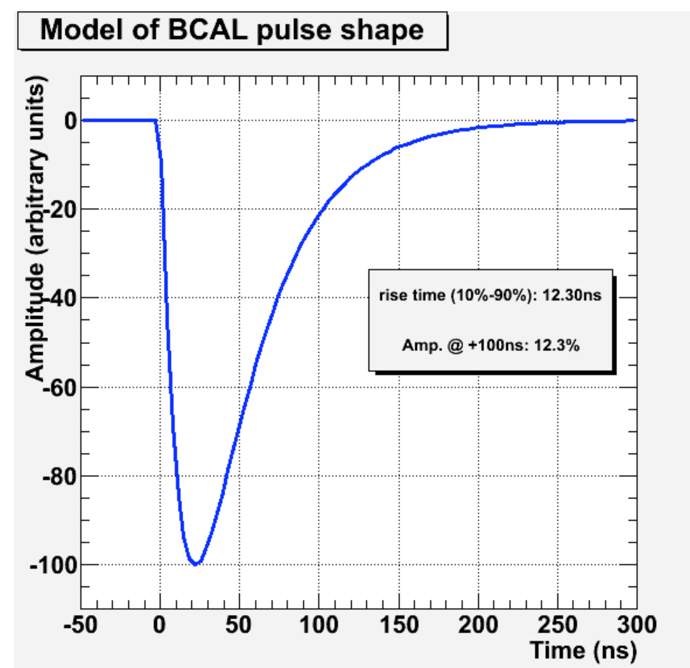
$2cm/\beta_z + 2cm/(0.5c)$ at the upstream SiPM and

$2cm/\beta_z - 2cm/(0.5c)$ at the downstream one



Upstream is worst-case. Assume β_z=c, then spread is:

2cm(1/c + 1/(0.5c)) = 3cm/c = 6cm/(30cm/ns) = 200ps/step



Slower shower particles will lead to larger dispersions in time.

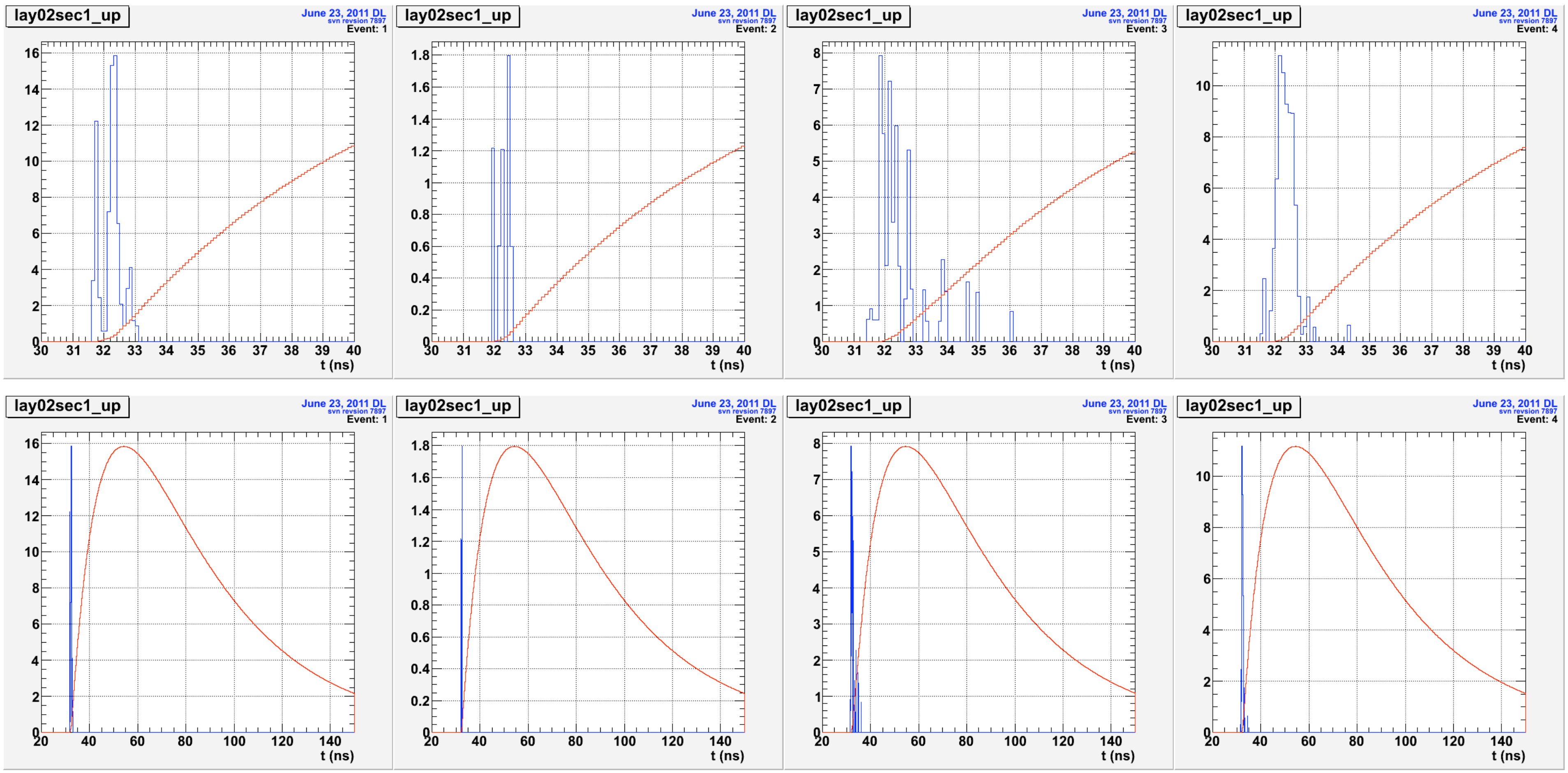
To investigate the effect of signal timing spread, an electronic pulse shape was convoluted with the signal distribution of single events. (*next slide*)

Pulse shape is:

$$f(x) = e^{-x/\alpha}(1 - e^{-x/\beta})$$

Timing distribution of signals arriving at upstream photodetector

- Energy weighted (attenuated) timing distributions for single events, layer 2, sector 1
- Convolution with electronic pulse shape smoothes out variation due to shower spread



Bottom pictures are zoomed out view of top pictures
Maximum of electronic pulse (red) is set to equal that of signal (blue)

Summary

- Single step in GEANT shower simulation has timing spread of order 200ps
- Electronic pulse shape smoothes signal out over much broader range in time which should make it less sensitive to detailed fluctuations in signal timing
- Still need to apply dark hits and threshold to see discriminator timing distributions