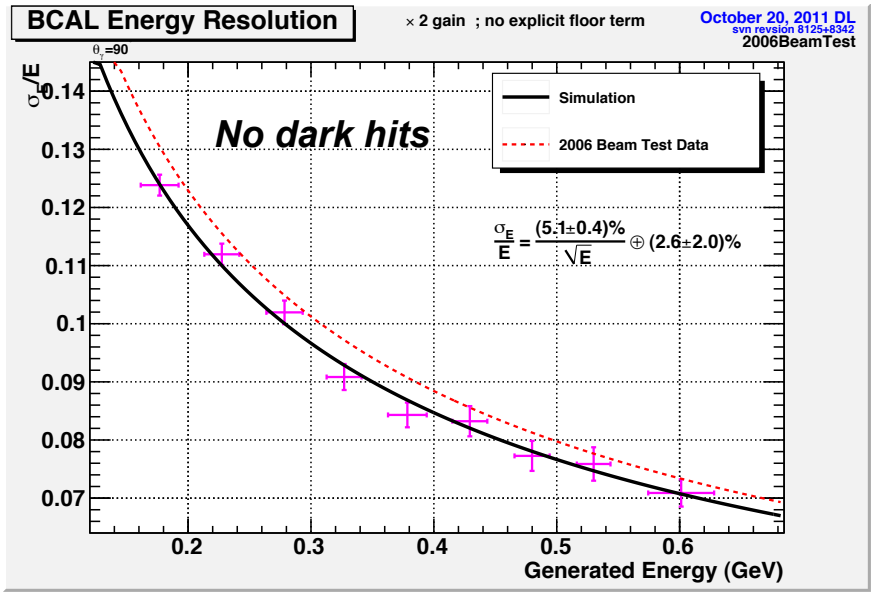
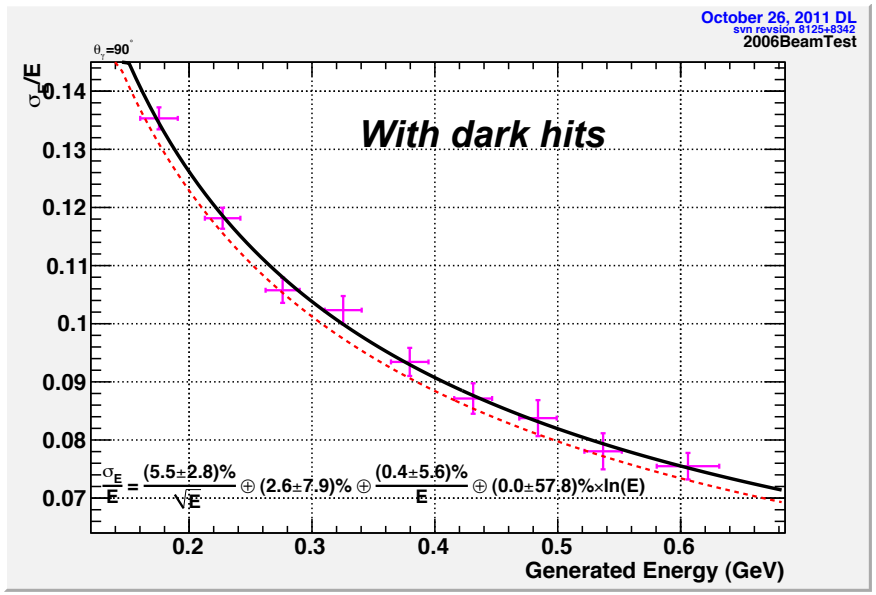
BCAL Resolutions

David Lawrence JLab

Dark Hits Contribution to Energy Resolution

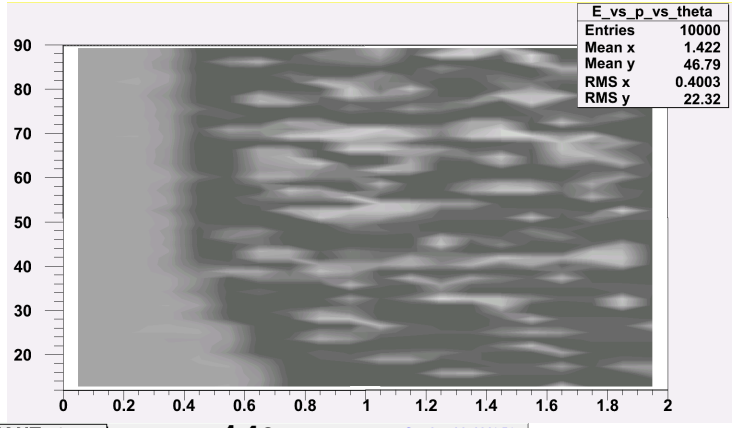
Turning on dark hits for the simulation using the 2006 Beam Test kinematics and geometry *may* yield a slightly worse energy resolution

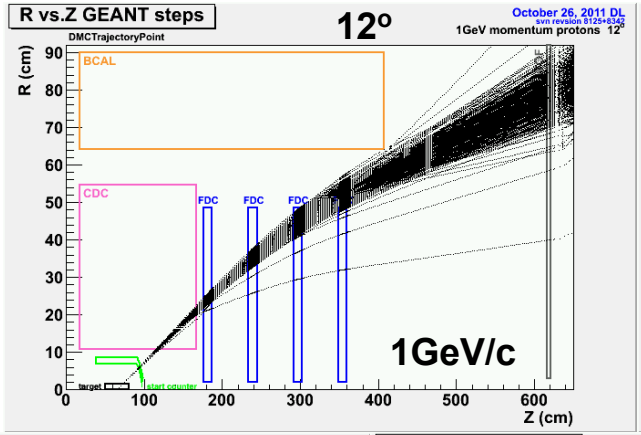


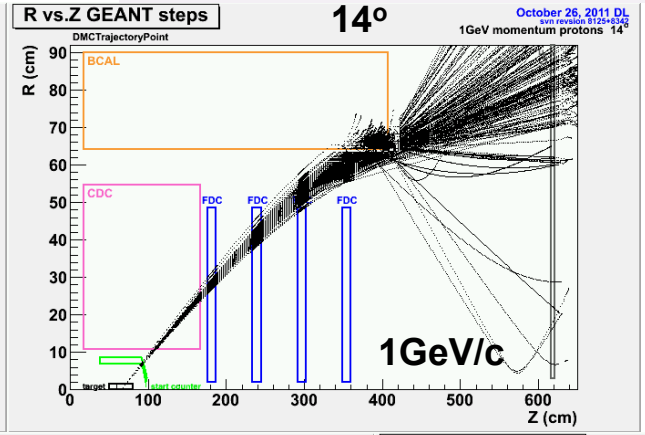


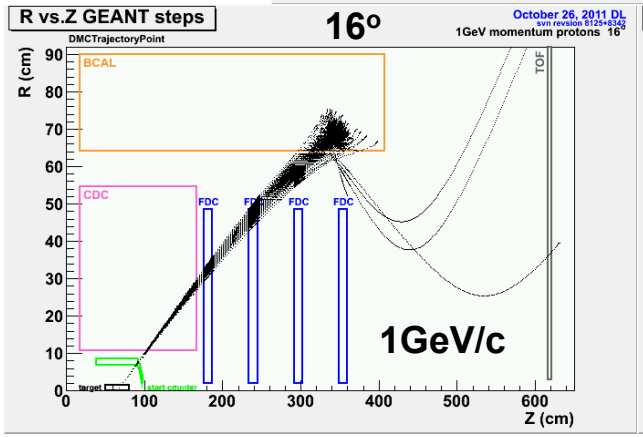
1GeV/c proton trajectories

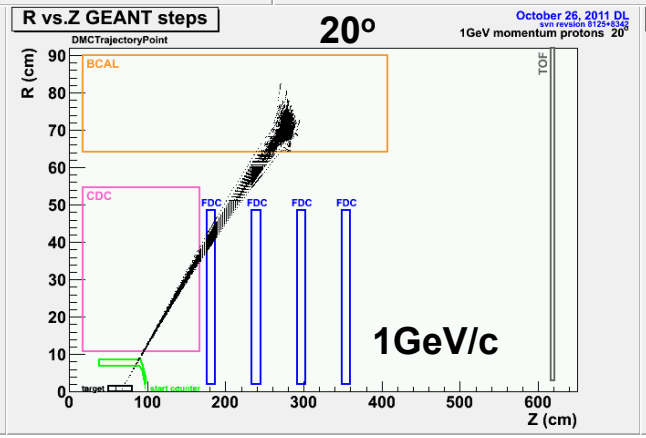
- Map of angle vs. momentum for protons depositing energy in BCAL
- Edge was misleading earlier since it indicates acceptance at 12º, 1GeV/c
- Plots below show proton tracks for 100 events at various angles

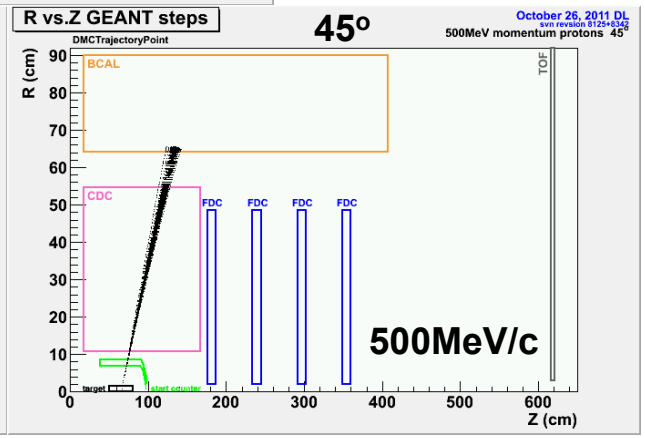




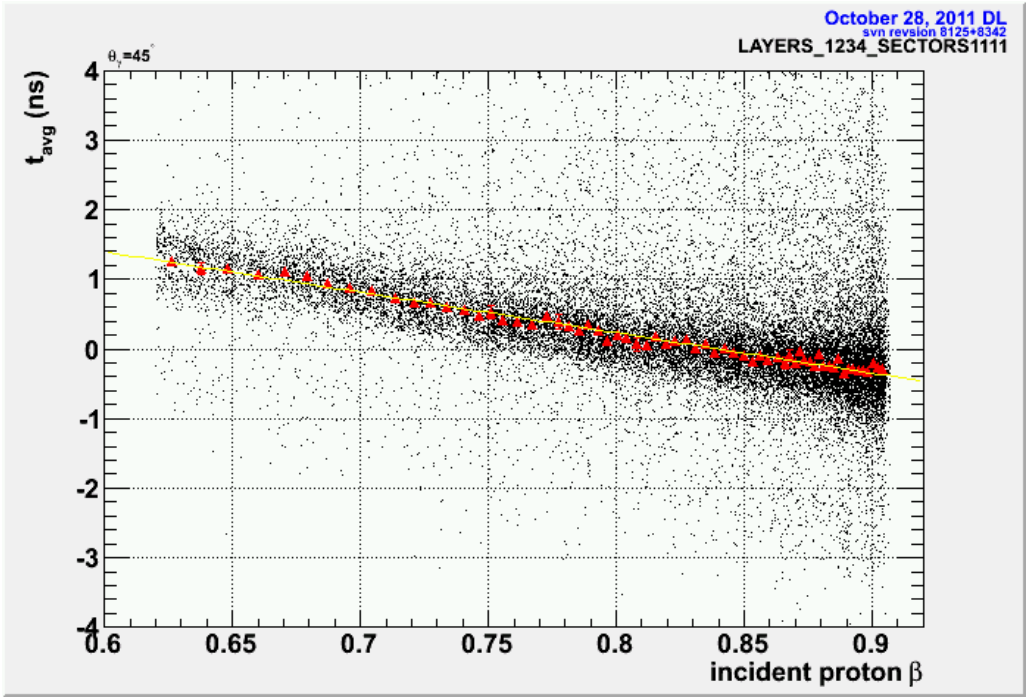








β-dependence of timing



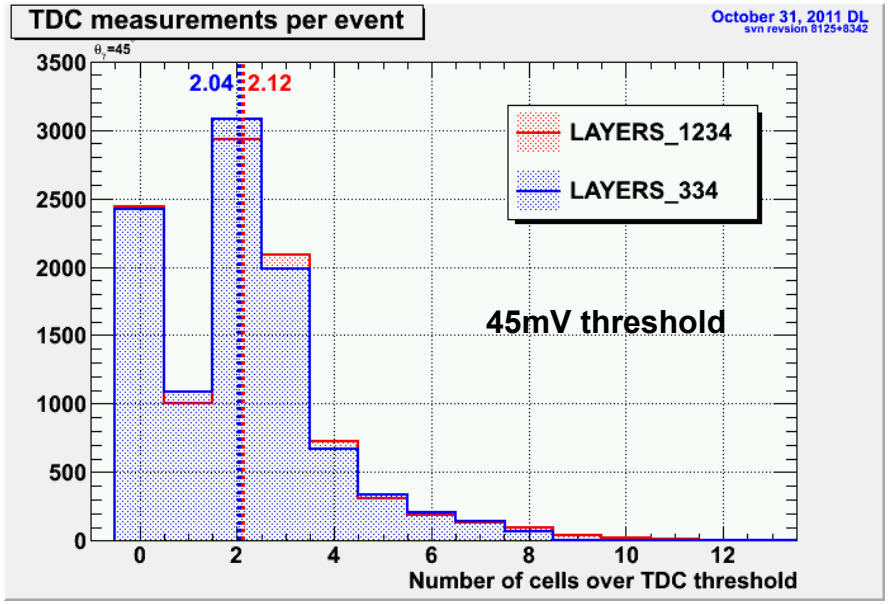
β of the proton will cause a systematic of the time average, but not the time difference

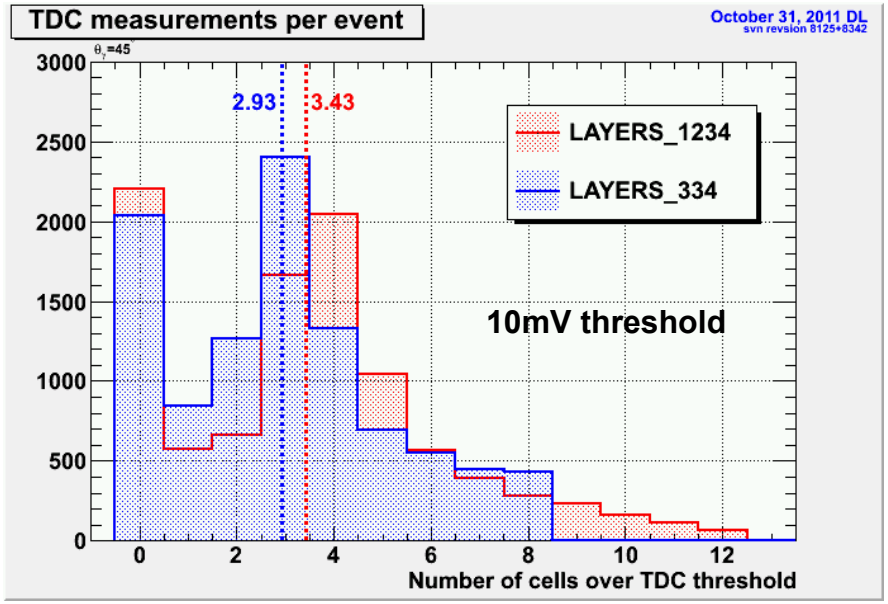
The times must be corrected in the current study to get the correct timing resolution.

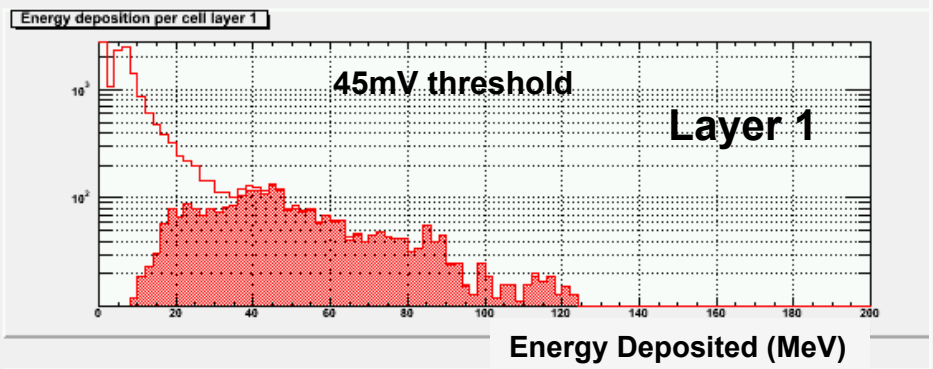
Number of Timing Measurements for protons

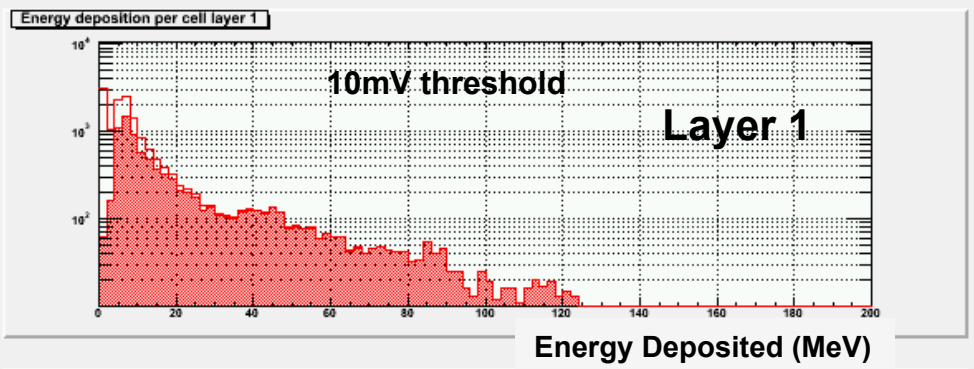
The plots below indicate the number of summed cells with both ends above TDC discriminator threshold

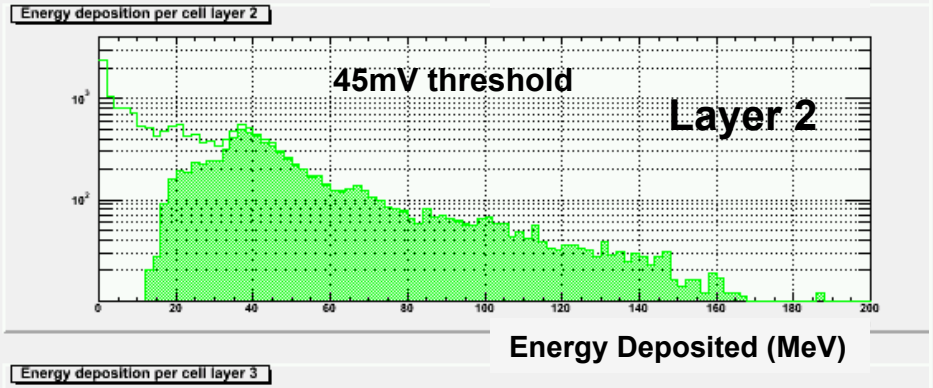
The higher threshold (45mV) causes the first layer of the 1234 scheme not to fire when only ionization losses are present (see next slide)

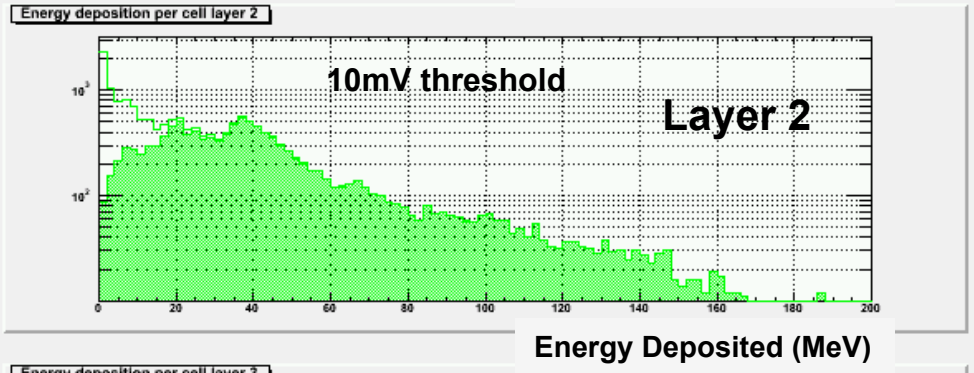


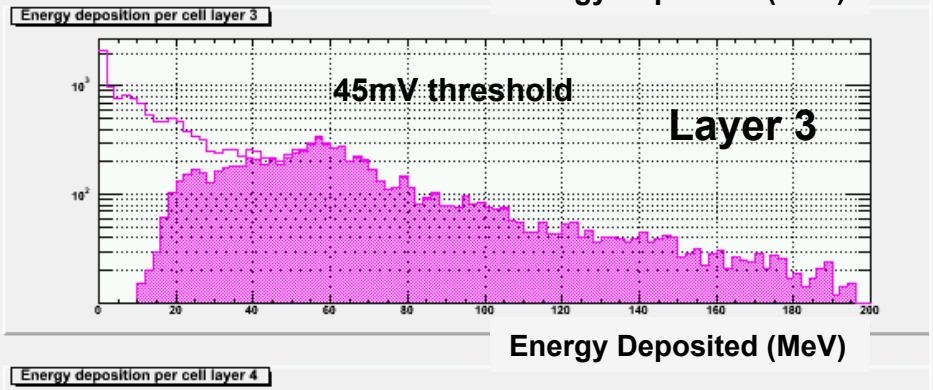


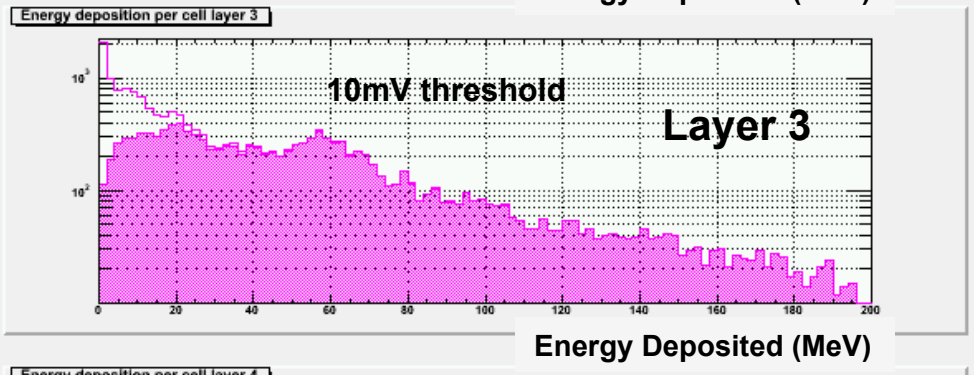

Energy deposition per cell layer 1
45mV threshold
Layer 1
Energy Deposited (MeV)

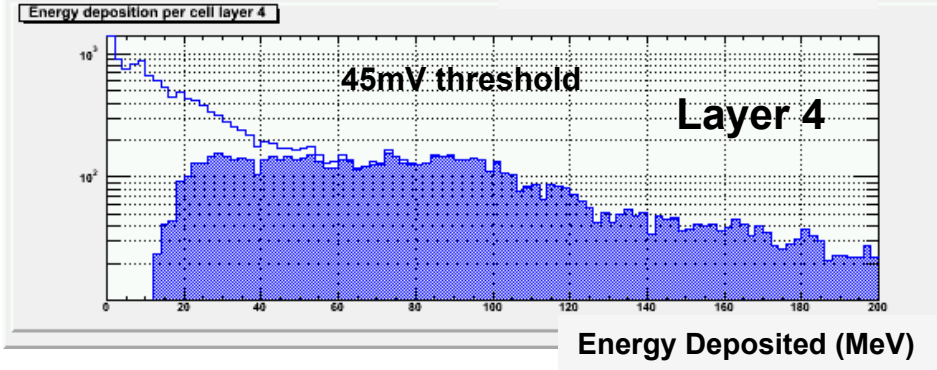

Energy deposition per cell layer 1
10mV threshold
Layer 1
Energy Deposited (MeV)

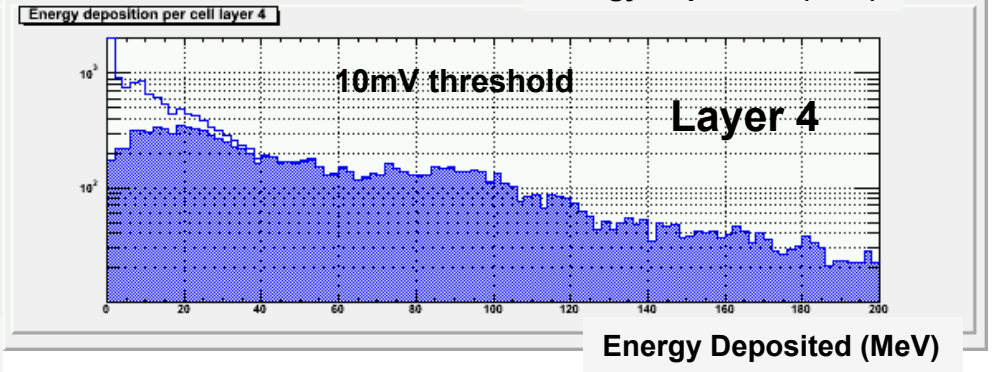

Energy deposition per cell layer 2
45mV threshold
Layer 2
Energy Deposited (MeV)


Energy deposition per cell layer 2
10mV threshold
Layer 2
Energy Deposited (MeV)


Energy deposition per cell layer 3
45mV threshold
Layer 3
Energy Deposited (MeV)

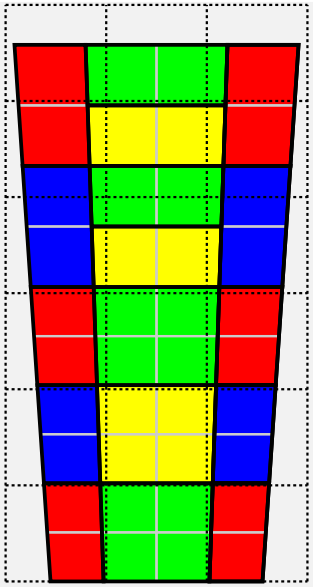

Energy deposition per cell layer 3
10mV threshold
Layer 3
Energy Deposited (MeV)


Energy deposition per cell layer 4
45mV threshold
Layer 4
Energy Deposited (MeV)


Energy deposition per cell layer 4
10mV threshold
Layer 4
Energy Deposited (MeV)

2006 Beam Test Comparison

Matching 2006 Beam Test conditions



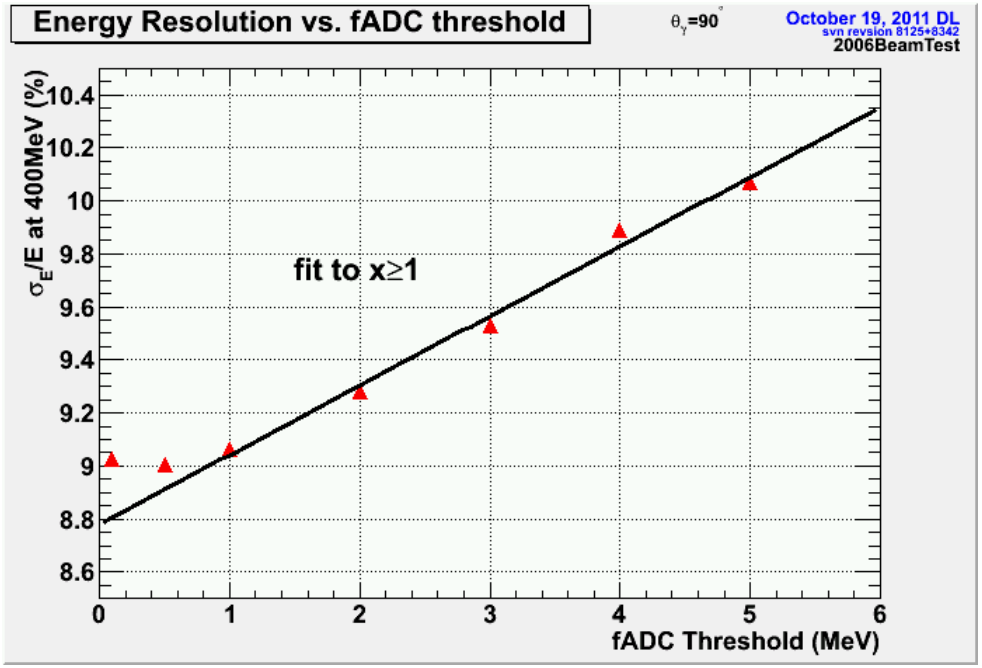
Segmentation to match 2006 Beam Test

Energy: 150MeV – 650MeV
Angle: 90^{o}
Position: center of module

Physical size and shape of prototype module was different from trapezoidal shape of final module design.

Fiber in prototype produced nearly have as much light (75 photons/MeV/side vs. 145 photons/MeV/side)

Threshold Dependence

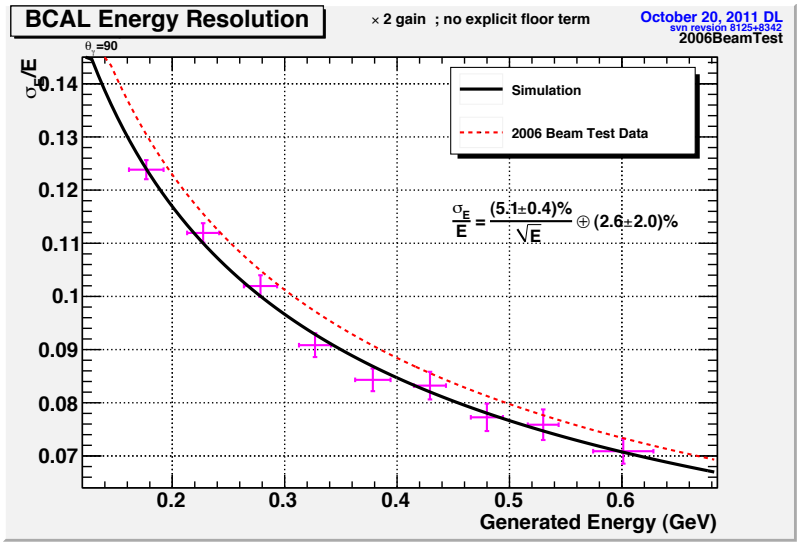


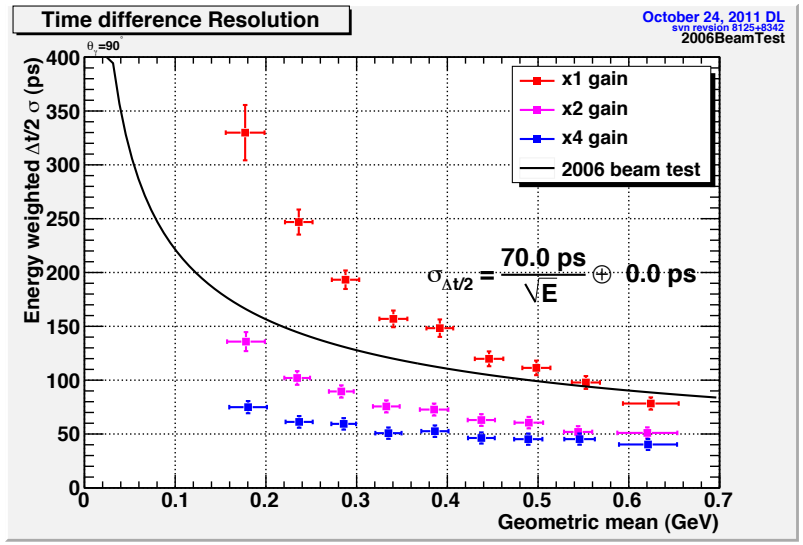
Energy resolution depends on threshold used for single fADC channels

Values plotted are for near end so actual threshold would be 3.7 times greater for doubled ended readout due to attenuation

For energy resolution plots, 1MeV threshold (in units of this plot) are used.

Energy and Timing Resolution Comparison to 2006 Beam Test Results





EM Shower Timing Resolutions

Table 3: Time Average Resolution for $\theta_\gamma = 12°$.

Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(78 ± 7)ps	(58 ± 4)ps	13.9%	18.4%
1234	(81 ± 7)ps	(57 ± 4)ps	11.2%	19.0%
22222	(89 ± 7)ps	(67 ± 5)ps	2.4%	5.1%
244	(89 ± 7)ps	(68 ± 5)ps	1.9%	4.6%
3322	(92 ± 7)ps	(70 ± 5)ps	-0.8%	1.1%
334	(91 ± 7)ps	(71 ± 5)ps	0.0%	0.0%

Table 4: Time Average Resolution for $\theta_\gamma = 16°$.

Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(73 ± 6)ps	(55 ± 4)ps	22.3%	25.7%
1234	(74 ± 6)ps	(56 ± 4)ps	20.9%	23.4%
22222	(89 ± 7)ps	(66 ± 5)ps	5.2%	10.2%
244	(89 ± 7)ps	(66 ± 5)ps	5.0%	10.4%
3322	(90 ± 7)ps	(73 ± 5)ps	3.7%	1.4%
334	(94 ± 7)ps	(74 ± 5)ps	0.0%	0.0%

Table 5: Time Average Resolution for $\theta_\gamma = 20°$.

Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(60 ± 5)ps	(45 ± 3)ps	27.2%	31.0%
1234	(64 ± 5)ps	(48 ± 4)ps	22.0%	26.4%
22222	(69 ± 6)ps	(52 ± 4)ps	16.0%	21.0%
244	(70 ± 6)ps	(53 ± 4)ps	14.8%	19.1%
3322	(81 ± 6)ps	(65 ± 4)ps	1.8%	0.3%
334	(82 ± 6)ps	(66 ± 4)ps	0.0%	0.0%

Table 6: Time difference $(\Delta t/2)$ Resolution for $\theta_\gamma = 12°$.

Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(105 ± 8)ps	(82 ± 5)ps	19.3%	25.5%
1234	(108 ± 8)ps	(83 ± 5)ps	17.2%	24.6%
22222	(124 ± 10)ps	(107 ± 7)ps	4.5%	2.7%
244	(129 ± 10)ps	(108 ± 7)ps	0.8%	1.7%
3322	(130 ± 10)ps	(111 ± 7)ps	0.3%	-1.3%
334	(130 ± 12)ps	(110 ± 8)ps	0.0%	0.0%

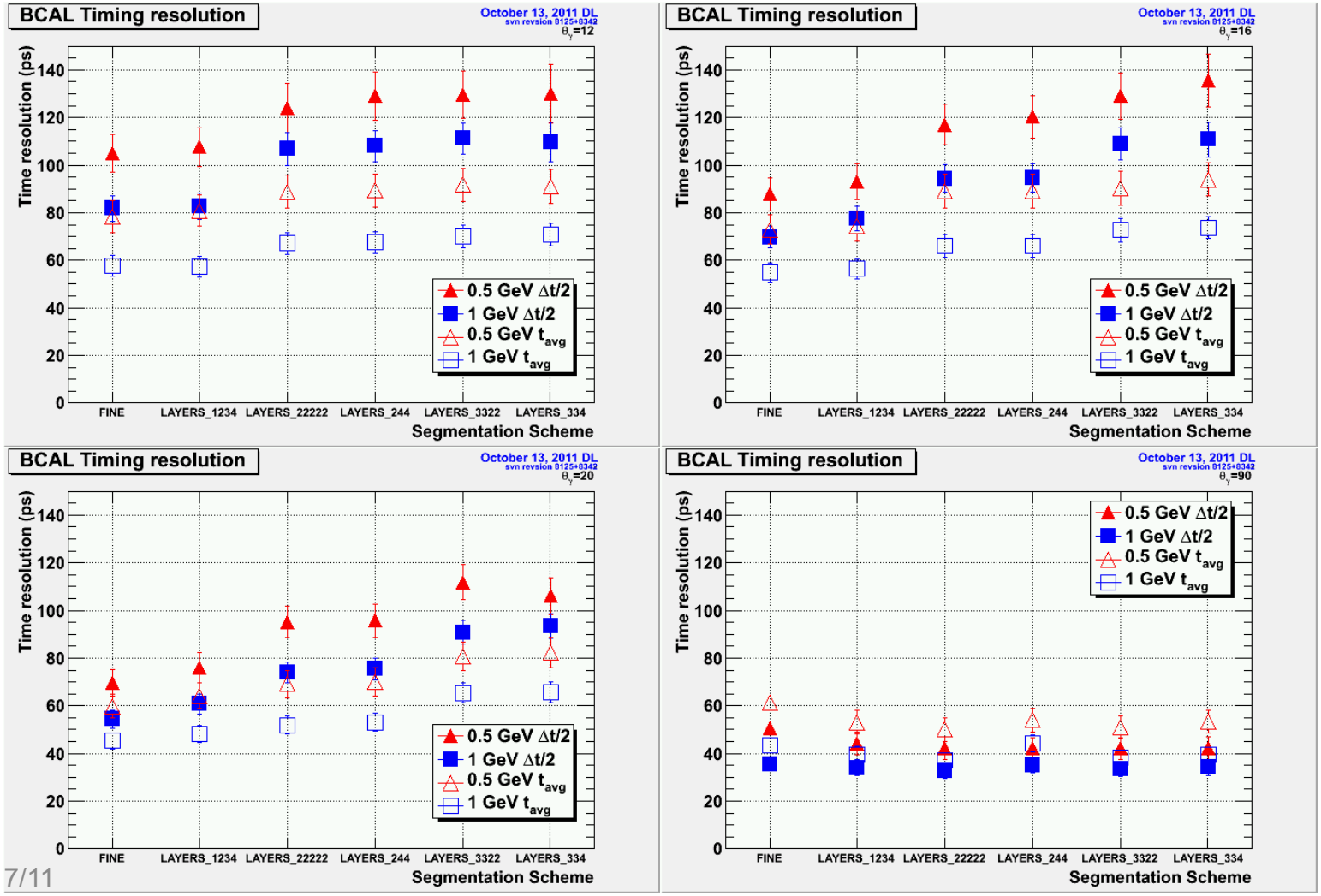
Table 7: Time difference $(\Delta t/2)$ Resolution for $\theta_\gamma = 16°$.

Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(88 ± 7)ps	(70 ± 5)ps	35.2%	37.1%
1234	(93 ± 8)ps	(78 ± 5)ps	31.2%	30.1%
22222	(117 ± 9)ps	(94 ± 6)ps	13.6%	14.9%
244	(120 ± 9)ps	(95 ± 6)ps	11.2%	14.5%
3322	(129 ± 10)ps	(109 ± 7)ps	4.7%	1.7%
334	(135 ± 11)ps	(111 ± 7)ps	-0.0%	0.0%

Table 8: Time difference $(\Delta t/2)$ Resolution for $\theta_\gamma = 20°$.

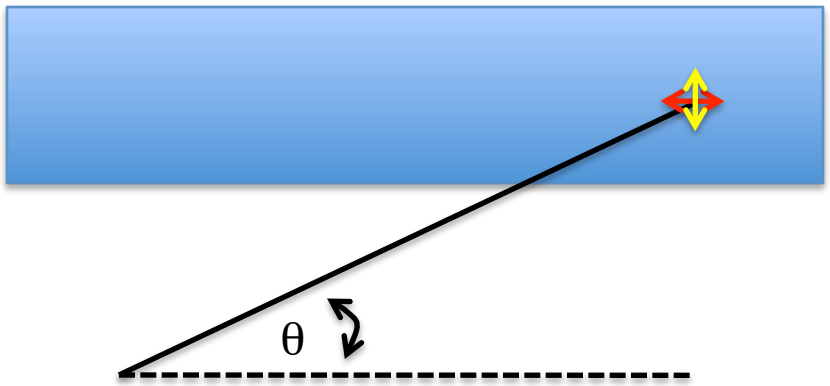
Segmentation Scheme	E=0.5GeV	E=1GeV	% better 0.5GeV	% better 1GeV
FINE	(70 ± 6)ps	(54 ± 4)ps	34.3%	41.7%
1234	(76 ± 6)ps	(61 ± 4)ps	28.3%	34.8%
22222	(95 ± 7)ps	(74 ± 4)ps	10.2%	20.7%
244	(96 ± 7)ps	(75 ± 5)ps	9.8%	19.2%
3322	(112 ± 7)ps	(91 ± 5)ps	-5.6%	2.8%
334	(106 ± 8)ps	(93 ± 5)ps	0.0%	0.0%

Timing resolutions



Backups

Uncertainty in Polar Angle



Uncertainty in r-improves with segmentation

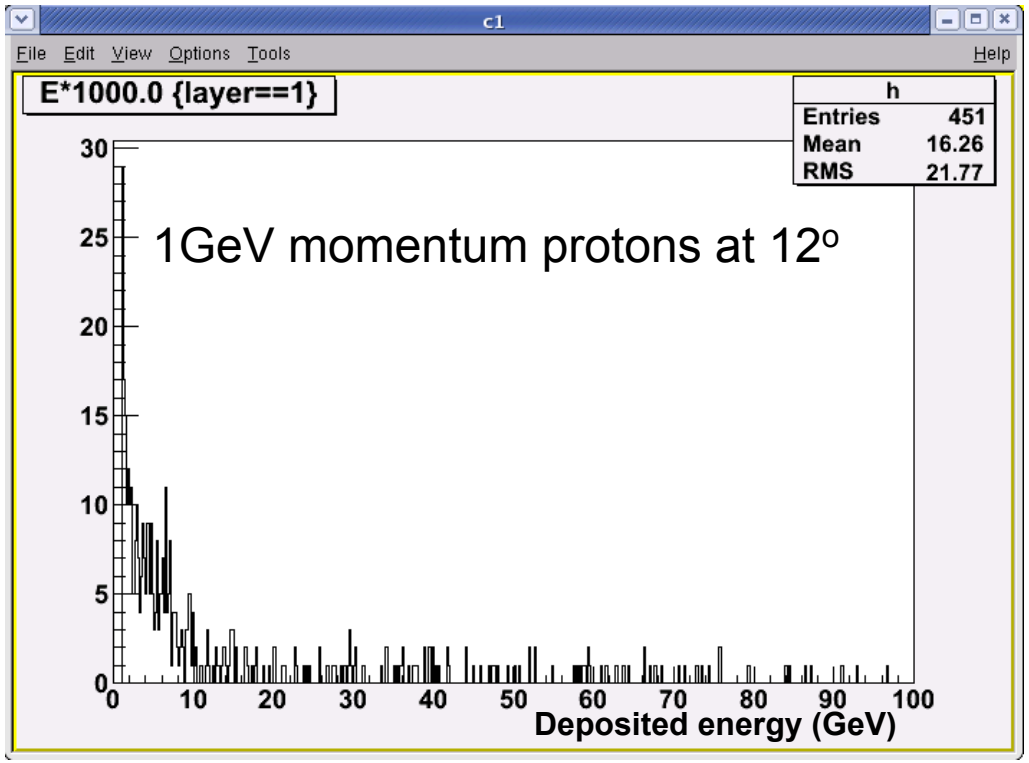
Uncertainty in z-improves with timing

Could expect ~20% improvement in reconstructed polar angle

Protons

Mean energy deposited in 2cm cell:

$$\frac{2MeV}{g/cm^2}\left(\frac{2cm}{21.9cm}\right)(15.50X_o)\left(\frac{7.19g/cm^2}{X_o}\right) = 20MeV$$



At 12°, should be
1/sin(12°) = 4.8 times greater

Threshold: ~30MeV near SiPM

Table 9: Time Average Resolution for $\theta_\gamma = 90^\circ$.

Segmentation Scheme	**E=0.5GeV**	**E=1GeV**	**% better 0.5GeV**	**% better 1GeV**
FINE	(61 ± 2)ps	(43 ± 1)ps	-14.8%	-10.4%
1234	(53 ± 5)ps	(40 ± 3)ps	0.7%	-0.8%
22222	(50 ± 5)ps	(37 ± 3)ps	6.4%	5.9%
244	(54 ± 5)ps	(44 ± 4)ps	-1.0%	-12.2%
3322	(51 ± 5)ps	(38 ± 3)ps	4.4%	2.5%
334	(53 ± 5)ps	(39 ± 3)ps	-0.0%	0.0%

Table 10: Time difference $(\Delta t/2)$ Resolution for $\theta_\gamma = 90^\circ$.

Segmentation Scheme	**E=0.5GeV**	**E=1GeV**	**% better 0.5GeV**	**% better 1GeV**
FINE	(50 ± 2)ps	(36 ± 1)ps	-19.5%	-4.6%
1234	(44 ± 5)ps	(34 ± 3)ps	-4.3%	0.3%
22222	(42 ± 5)ps	(33 ± 3)ps	0.2%	4.5%
244	(42 ± 5)ps	(35 ± 3)ps	0.4%	-3.1%
3322	(42 ± 5)ps	(34 ± 3)ps	0.2%	1.5%
334	(42 ± 5)ps	(34 ± 3)ps	-0.0%	0.0%