

# BCAL Signal Timing Resolutions

Sept. 2, 2011

David Lawrence, JLab

# Photo-detection device time jitter

SiPMs and XP2020 tubes have a similar time jitter per photo-electron:

600ps FWHM or  $\sigma \sim 250$ ps

This effect was included by dividing the energy in every 100ps bin into 1 photo-electron pieces and then shifting each randomly by a time with this  $\sigma$ . The overall effect was small.

*(A trial with a x10 worse jitter was done resulting in slightly less than a factor of 2 worse resolution.)*

## Electrical and optical characteristics (Typ. Ta=25 °C, unless otherwise noted)

Parameter	Symbol	S10362-33			S10931			Unit
		-025C	-050C	-100C	-025P	-050P	-100P	
Fill factor *1	-	30.8	61.5	78.5	30.8	61.5	78.5	%
Spectral response range	$\lambda$	320 to 900			320 to 900			nm
Peak sensitivity wavelength	$\lambda_p$	440			440			nm
Operating voltage range	-	$70 \pm 10$ *2			$70 \pm 10$ *2			V
Dark count *3	-	4	6	8	4	6	8	Mcps
Dark count Max. *3	-	8	10	12	8	10	12	Mcps
Terminal capacitance	Ct	320			320			pF
Time resolution (FWHM) *4	-	500 to 600			500 to 600			ps
Temperature coefficient of reverse voltage	-	56			56			mV/°C
Gain	M	$2.75 \times 10^5$	$7.5 \times 10^5$	$2.4 \times 10^6$	$2.75 \times 10^5$	$7.5 \times 10^5$	$2.4 \times 10^6$	-

\*1: Ratio of the active area of a pixel to the entire area of the pixel

\*2: For the recommended operating voltage of each product, refer to the data attached to each product.

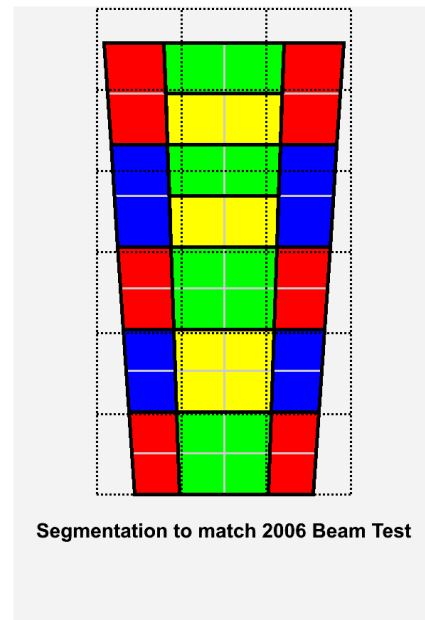
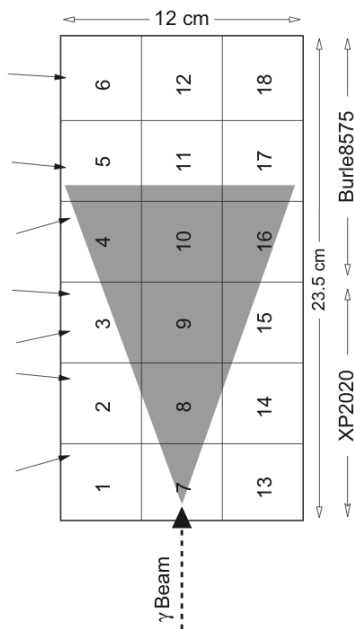
\*3: 0.5 p.e. (threshold level)

\*4: Single photon level

Note: Each value was measured at recommended operating voltage.

The last letter of each type number indicates package materials (C: ceramic, P: SMD).

# Simulation to mimic 2006 Beam Test



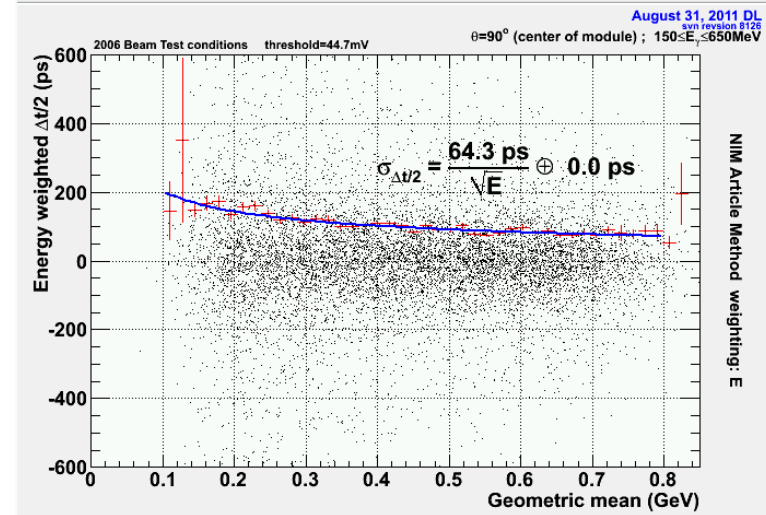
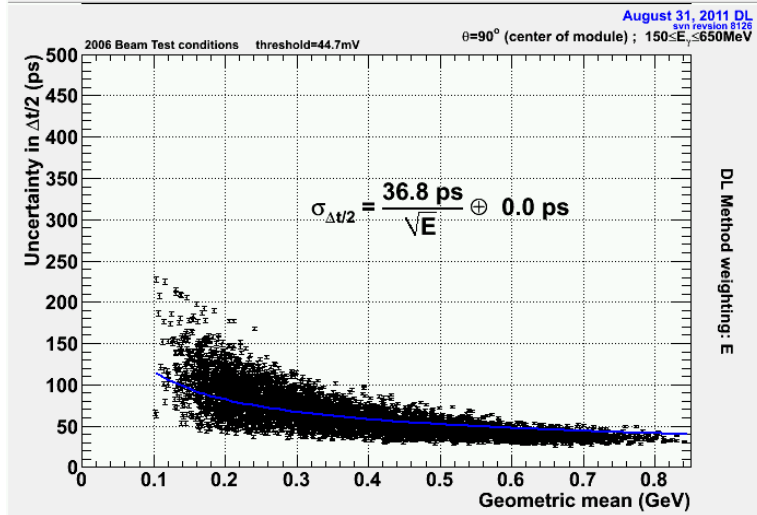
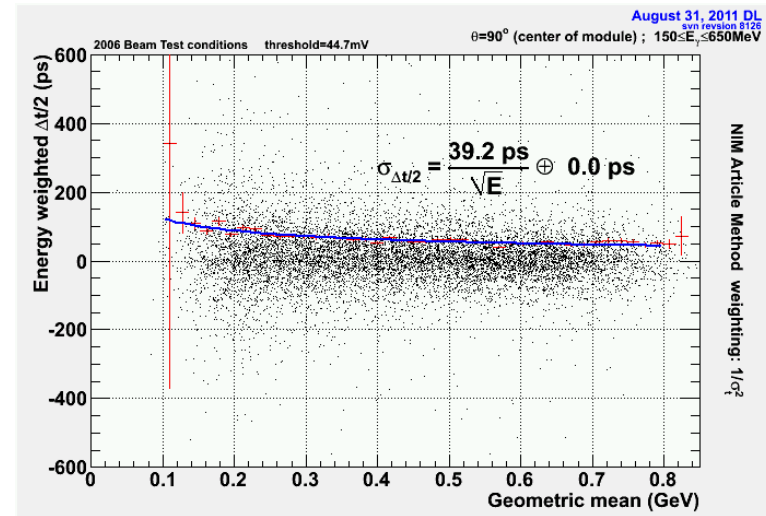
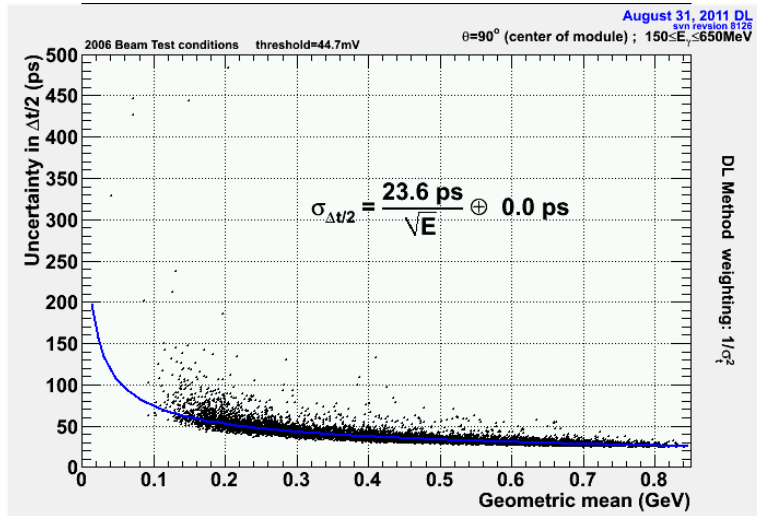
To tie the current M.C. technique into the results of the 2006 beam test, a set of data was produced with photons in the range:

150MeV - 650MeV

At normal incidence to the center of the BCAL module.

A segmentation was chosen that matched that of the 2006 beam test (see plots to the left).

# Comparison to 2006 Beam Test



NIM A596, 327(2008) reported 70ps/sqrt(E)

# Uncertainty dependence on Energy

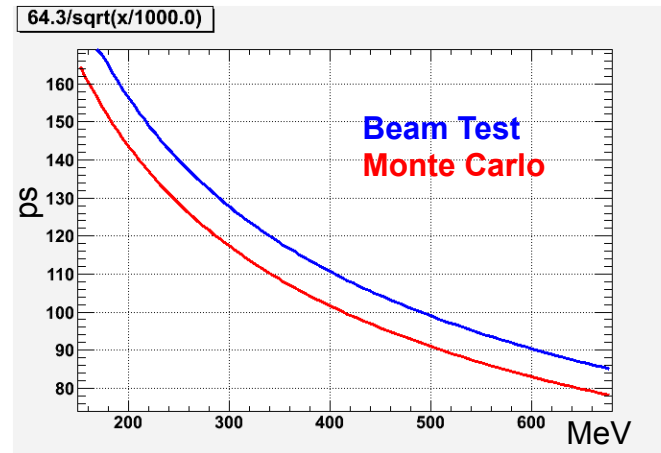
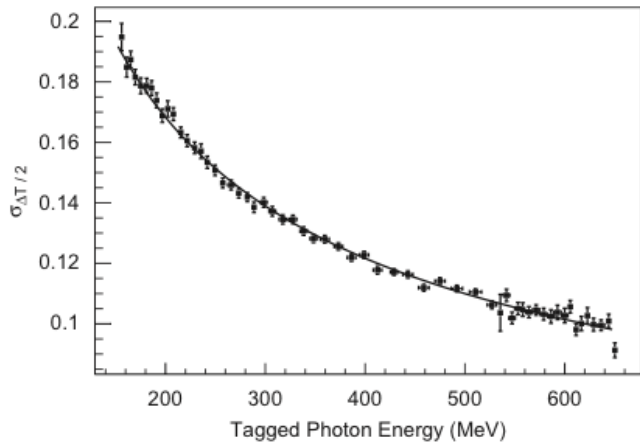
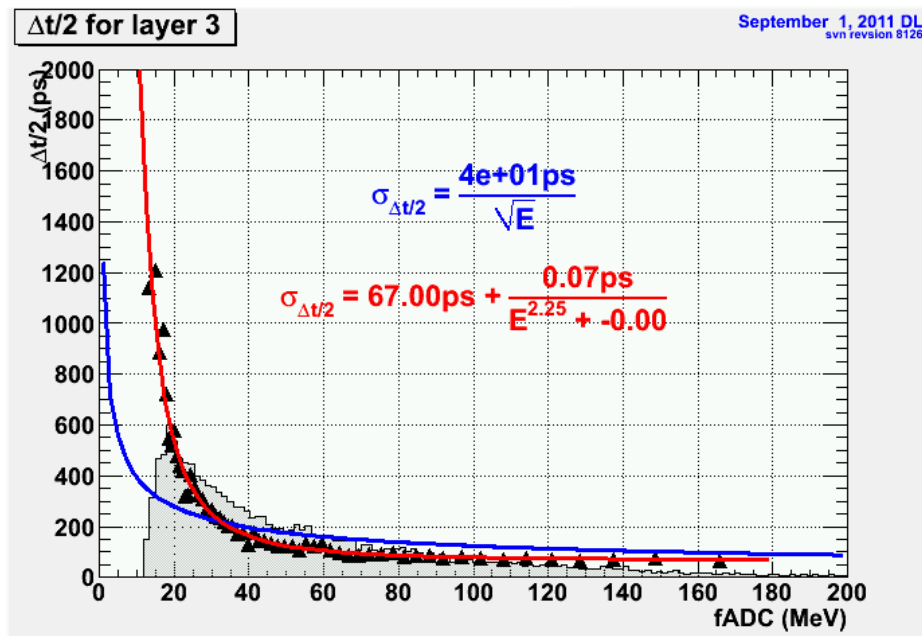


Fig. 15. The time difference resolution, in nanoseconds, for segments 7, 8, 9 and 10 as a function of energy. The fit gives  $\sigma_{\Delta T/2} = 75 \text{ ps}/\sqrt{E(\text{GeV})} \oplus 30 \text{ ps}$ . The fit of Fig. 14 corresponds to the 40th datum from the right (19th from the left) in this figure.



Simulation seems to match well with beam test result. However, better resolutions were achieved by using non-E weighting for cell times

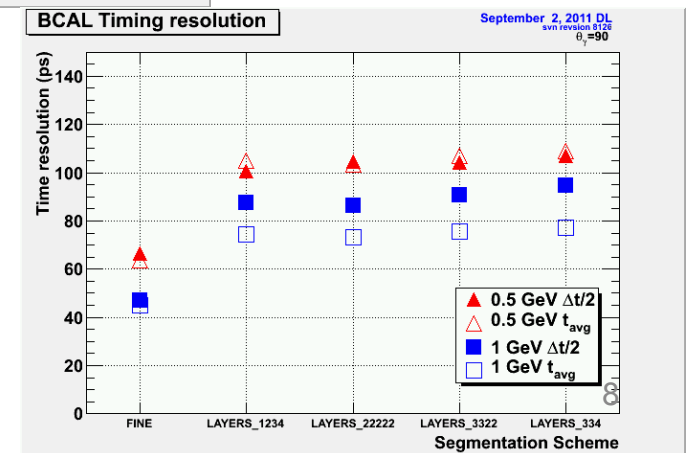
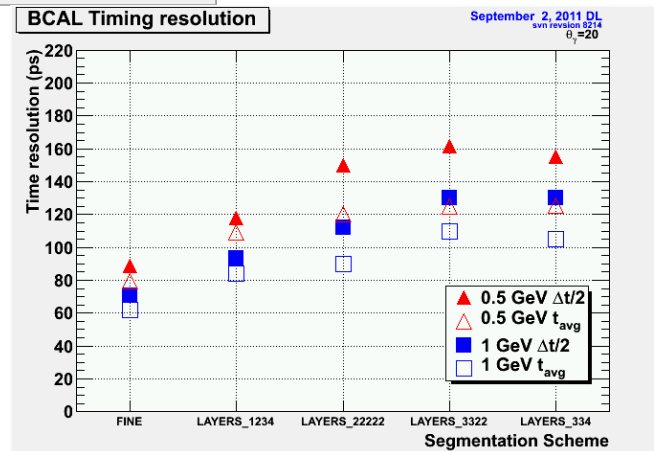
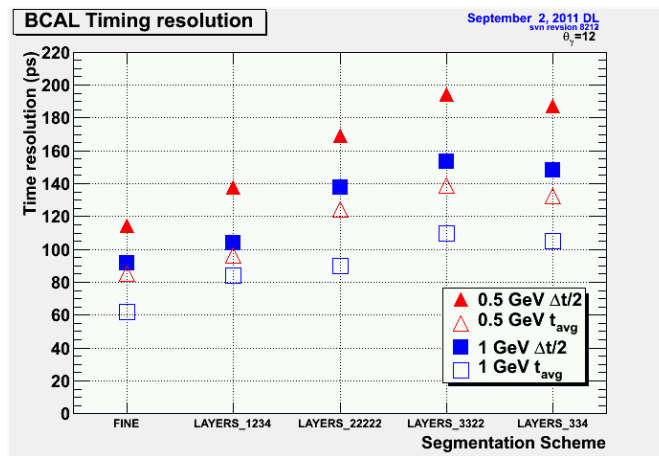
$$\frac{\Delta T}{2} = \frac{1}{2} \frac{\sum_i E_i (T_{N,i} - T_{S,i})}{\sum_i E_i}$$

*NIM article used energy weighted mean*

<b>tavg</b>						
<i>12 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	56.3	30.6	85.30	64.08	35.5%	37.2%
1234	60.9	43.6	96.53	74.90	27.0%	26.6%
22222	75.2	64	124.12	98.75	6.1%	3.2%
322	80.5	79.7	138.97	113.28	-5.2%	-11.0%
334	84	57.9	132.15	102.02	0.0%	0.0%
<i>20 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	50.1	36	79.47	61.69	36.7%	41.1%
1234	69.9	46.4	109.20	83.90	13.0%	19.9%
22222	79.4	42.2	119.96	89.92	4.5%	14.2%
322	60.1	91.5	124.89	109.47	0.6%	-4.5%
334	69.2	78.7	125.58	104.80	0.0%	0.0%
<i>90 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	45	0	63.64	45.00	41.6%	41.6%
1234	74.3	0	105.08	74.30	3.5%	3.5%
22222	73.1	0	103.38	73.10	5.1%	5.1%
322	75.6	0	106.91	75.60	1.8%	1.8%
334	77	0	108.89	77.00	0.0%	0.0%

<b>tdiff</b>						
<i>12 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	68.4	61.4	114.57	91.92	38.8%	38.0%
1234	91	49.6	137.92	103.64	26.4%	30.1%
22222	98.2	96.5	169.11	137.68	9.7%	7.1%
322	119.1	96.9	194.32	153.54	-3.7%	-3.6%
334	114.6	94	187.36	148.22	0.0%	0.0%
<i>20 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	53.8	45.8	88.81	70.65	42.8%	45.6%
1234	71.3	60.7	117.69	93.64	24.1%	28.0%
22222	99.2	52.5	149.79	112.24	3.5%	13.7%
322	96.3	87.4	161.82	130.05	-4.3%	0.0%
334	84.7	98.6	155.15	129.98	0.0%	0.0%
<i>90 degrees</i>						
<b>Segmentation</b>	<b>p0</b>	<b>p1</b>	<b>E=500MeV</b>	<b>E=1GeV</b>	<b>% better 500MeV</b>	<b>% better 1GeV</b>
FINE	47.1	0	66.61	47.10	37.8%	50.2%
1234	49	72.7	100.44	87.67	6.3%	7.3%
22222	58.7	63.4	104.46	86.40	2.5%	8.6%
322	51.1	74.9	104.08	90.67	2.9%	4.1%
334	50.4	80	107.15	94.55	0.0%	0.0%

# Timing resolution





# Summary

- Time jitter effect added to simulation
- Data set and segmentation generated to match (reasonably close) 2006 beam test conditions
  - 64ps/sqrt(E) MC
  - 70ps/sqrt(E) beam test data
- 20-30% improvement in timing resolution seen for “1234” segmentation scheme relative to “334” segmentation scheme