

BigCal Elastics Calibrations

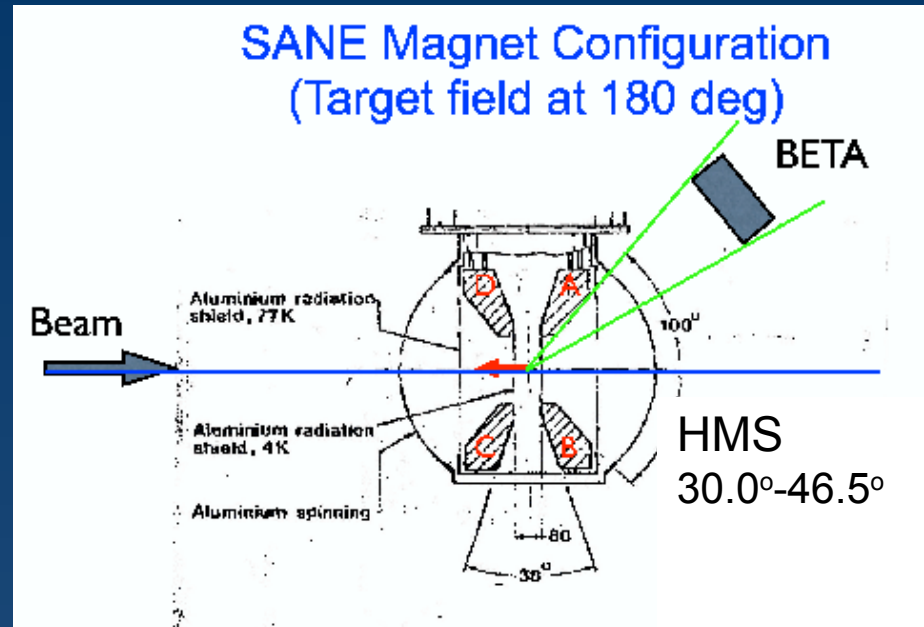
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Overview

- The purpose of the elastic calibrations is to provide an absolute energy calibration of scattered electrons in the calorimeter.
 - Coincidence events with an electron detected in BigCal tagged with a proton in the HMS.
 - Tagged 1.2-1.8 GeV electrons (for 2.40 GeV electron beam).
- Complements the π^0 reconstruction method.
 - Does not depend on $\gamma\gamma$ opening angle reconstruction and resolution.
 - Will also provide invaluable tracking data for BETA's front counters.
- Calibrations will be performed with 5T and 2.5T target fields at 0° , 180° , and with the field off in order to calibrate blocks below, above, and at beam-height.
 - Recent measurements indicate that the BigCal PMT gains will be sensitive to the target field magnitude and orientation, and so gain corrections will be necessary.



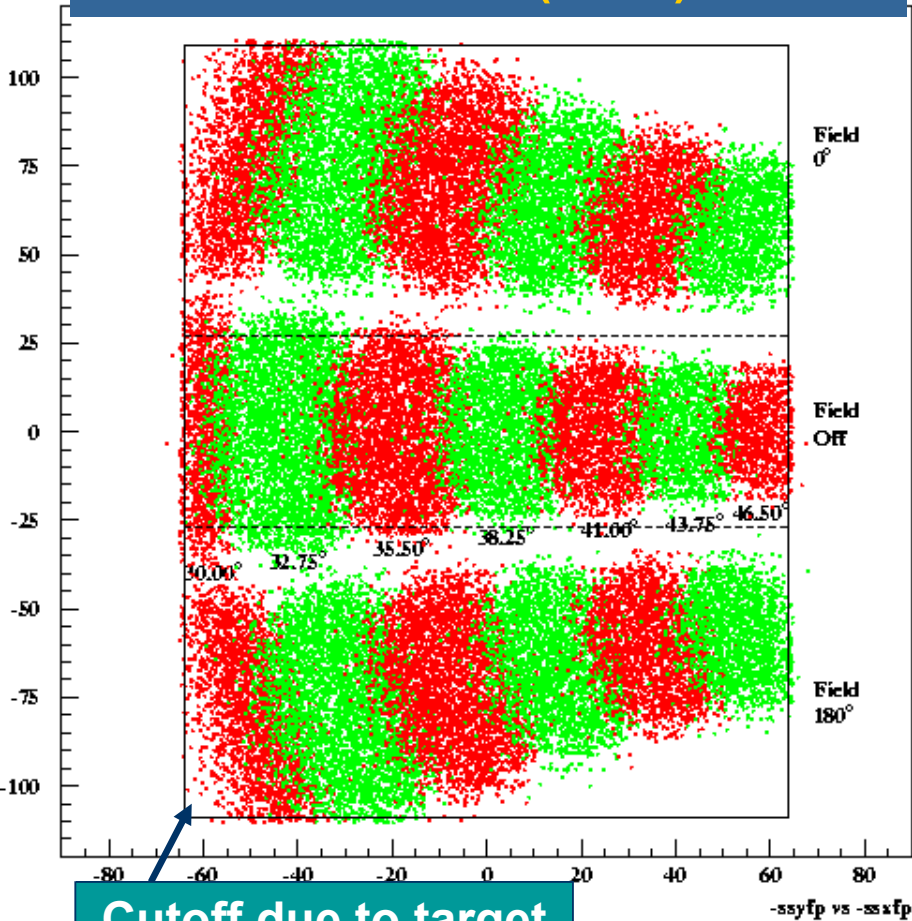
Constraints

- No elastic calibrations can be performed with >4 GeV beam energy.
 - Resulting Q^2 is large, so rate is too low to be useful.
 - Also, the resulting electron energies on the calorimeter would be much higher than for the data, so not as helpful for calibration.
- No elastic calibrations can be performed in the 80° field configuration, since the 2.4 GeV electron beam would be deflected and miss the target.
 - Only 0° , 180° field configurations are possible.
- Can't calibrate all BigCal blocks at once with field on.
 - For the calorimeter at 6m, the field will deflect the 1.5 GeV electrons below the calorimeter, resulting in few coincidences with the HMS.

Simulated BigCal Coverage

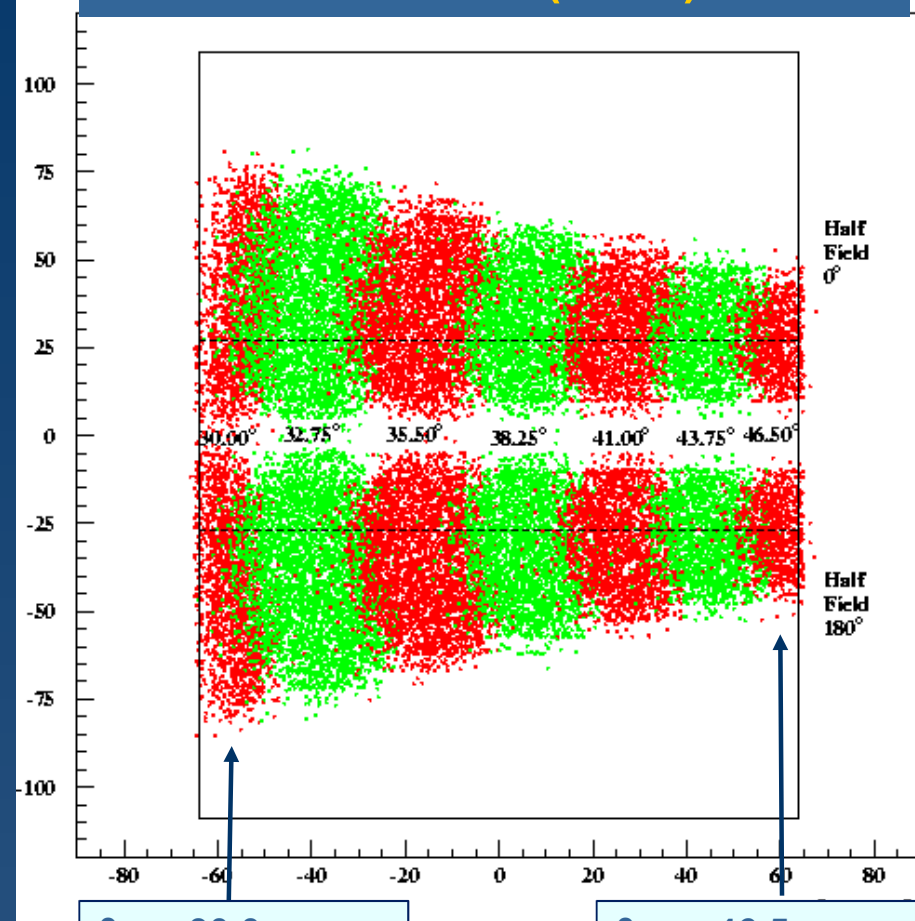
$E_{\text{beam}} = 2.400 \text{ GeV}$, BigCal face at 338cm

Full Field (5.0 T)



Cutoff due to target coil obstruction.

Half Field (2.5 T)



$\theta_{\text{HMS}} = 30.0^\circ$
 $P_{\text{HMS}} = 1.91 \text{ GeV}/c$
 $\theta_{e'} = 50^\circ$
 $P_{e'} = 1.21 \text{ GeV}/c$

$\theta_{\text{HMS}} = 46.5^\circ$
 $P_{\text{HMS}} = 1.23 \text{ GeV}/c$
 $\theta_{e'} = 30^\circ$
 $P_{e'} = 1.79 \text{ GeV}/c$

Elastic Rates per Setting

$E_{\text{beam}} = 2.400 \text{ GeV}$, $1 \mu\text{A}$ - BigCal face at 338cm

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_p (GeV)	θ_p (deg)	Counts/cell/hr				
				0°	180°	Off	$0^\circ\text{-}\frac{1}{2}\text{B}$	$180^\circ\text{-}\frac{1}{2}\text{B}$
1.789	30	1.233	46.50	--	--	1975	1794	1820
1.706	33	1.334	43.75	1327	1297	1436	1416	1382
1.617	36	1.443	41.00	751	759	802	794	779
1.522	39	1.555	38.25	413	407	438	427	424
1.423	43	1.670	35.50	224	225	238	234	234
1.318	47	1.789	32.75	98	103	103	101	103
1.213	50	1.907	30.00	26	27	33	32	30

The rate varies from cell to cell according to $d\sigma/d\theta$.

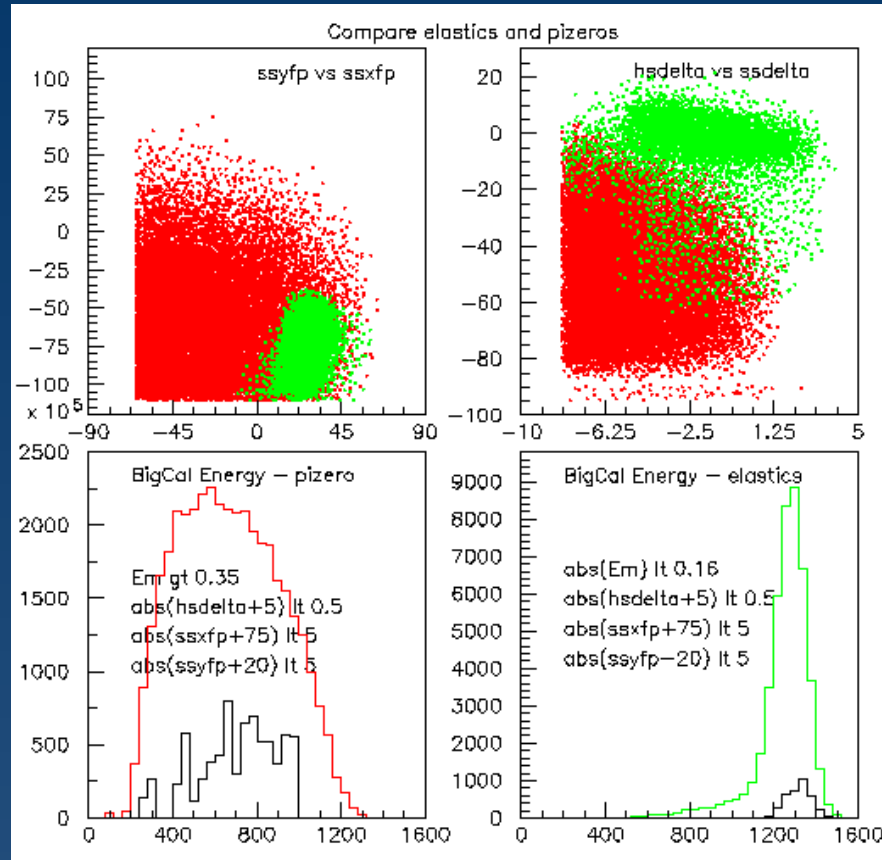
These are the **average rates** assuming **100% data-taking efficiency**.

Run Plan Suggestion

- It will be helpful to switch to 2.400 GeV beam as early as possible in the run.
 - Some of the final detector check-out can proceed in parallel with the elastics calibs, just as long as the BigCal gains are kept stable.
- We also need to reserve some time for BigCal gain adjustments when switching to 80° field.

Can we easily distinguish $p(e,e'p)\pi^0$ from elastics when doing the calibrations?

e-p angular correlation much larger for π^0 events.



E_{BigCal} for π^0 evts. Cut distribution is scaled x100.



ρ_{HMS} vs E_{BigCal} distributions overlap, but easily separated by E_{Missing} cuts.

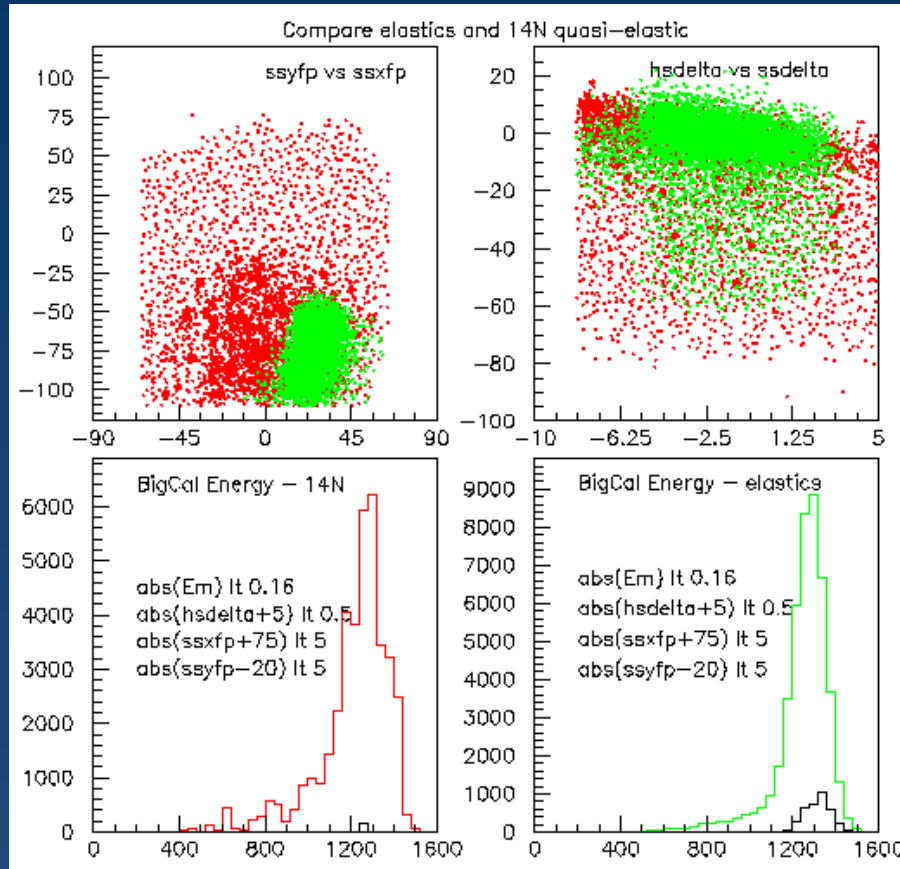


E_{BigCal} for elastics. Cut distribution is scaled x20.

Should be no problem separating the two reactions from Hydrogen. However, Nitrogen Fermi smearing will be a complication. One should be careful when applying kinematic constraints to the π^0 data.

Quasi-elastic $^{14}\text{N}(e,e'p)$

e-p angular correlation larger for ^{14}N events.



ρ_{HMS} vs E_{BigCal} distributions overlap substantially.



E_{BigCal} for $^{14}\text{N}(e,e'p)$. Almost no events survive elastics cuts (scaled x100).



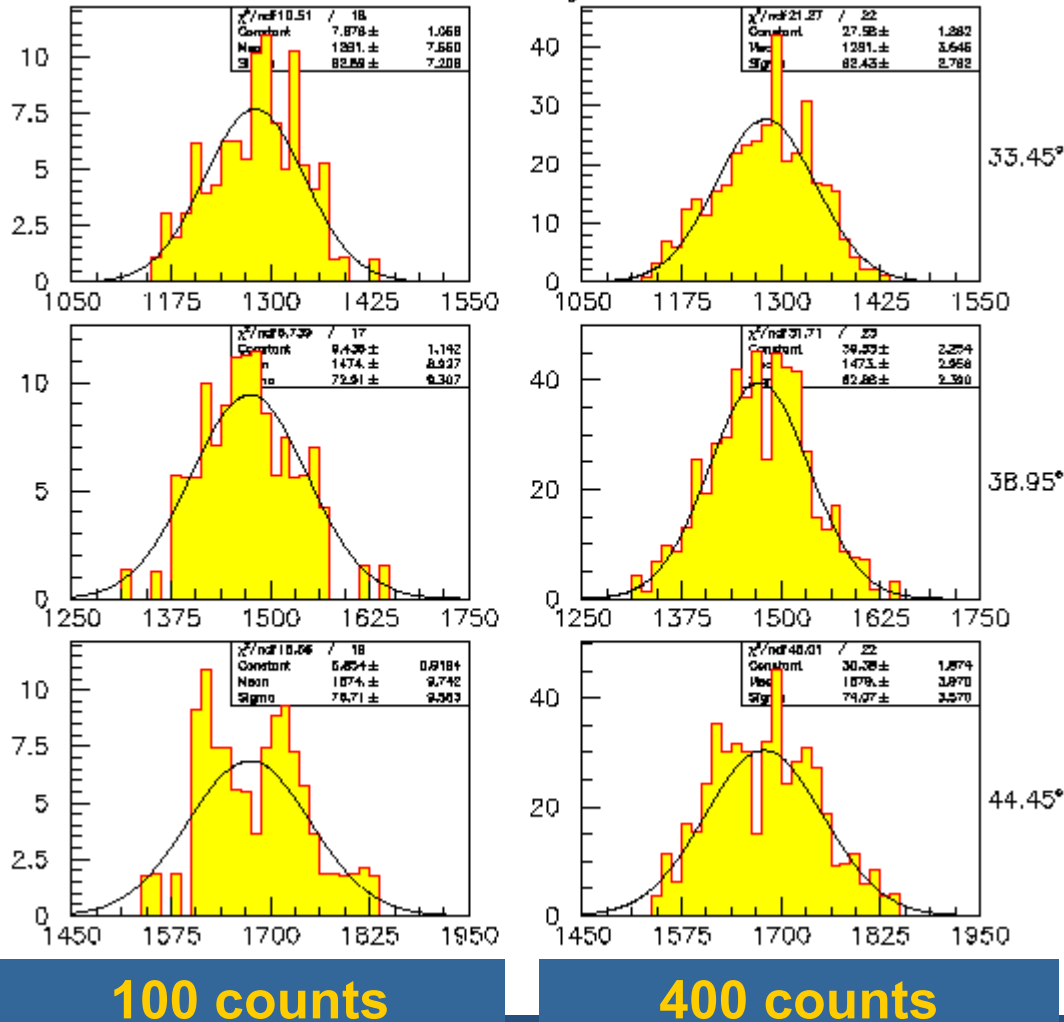
E_{BigCal} for elastics. Cut distribution is scaled x20.



Because ^{14}N quasi-elastics are spread out in both energy and angle, relatively few of them should survive the hydrogen elastics analysis cuts. Their impact on the BigCal elastics calibrations should be small.

100 vs. 400 elastics per cell ?

Elastics in one BigCal block



- No significant improvement in the energy resolution, but no background processes (e.g. Nitrogen) included in the simulation.
- Suggest to take 400 counts/cell for those settings where the rate is the highest, and to reduce the statistics to 100-200 counts/cell elsewhere.

PMT Gain Adjustments

- Recent measurements by Jonathan Mulholland indicate that the BigCal PMT gain could be reduced ~40% by the target field.
 - Out-of-plane PMTs are angled such that less of the field is directed axially along the PMT, and so are likely affected less than the in-plane ones.
- Knowledge of how the B-field affects the PMT gain is necessary not only for the elastic calibrations, but also for the parallel and transverse field production data.
 - PMTs are not sensitive to the field sign, only to its intensity, so it is worthwhile to calibrate with both field directions.

Strategy:

4. Need to know the initial gains in zero-field.
 - Oscar suggests to record the ADC gains for all blocks illuminated with the Gain Monitor light (will take 4-6 hours).
5. The ratio of gains with field ON/OFF can be used to adjust the calibration constants for all PMTs.
 - Is the HV-gain relationship strictly linear? There should be enough data from Gep-3 to know if any non-linear HV corrections are required.

Elastic Run Plan (1)

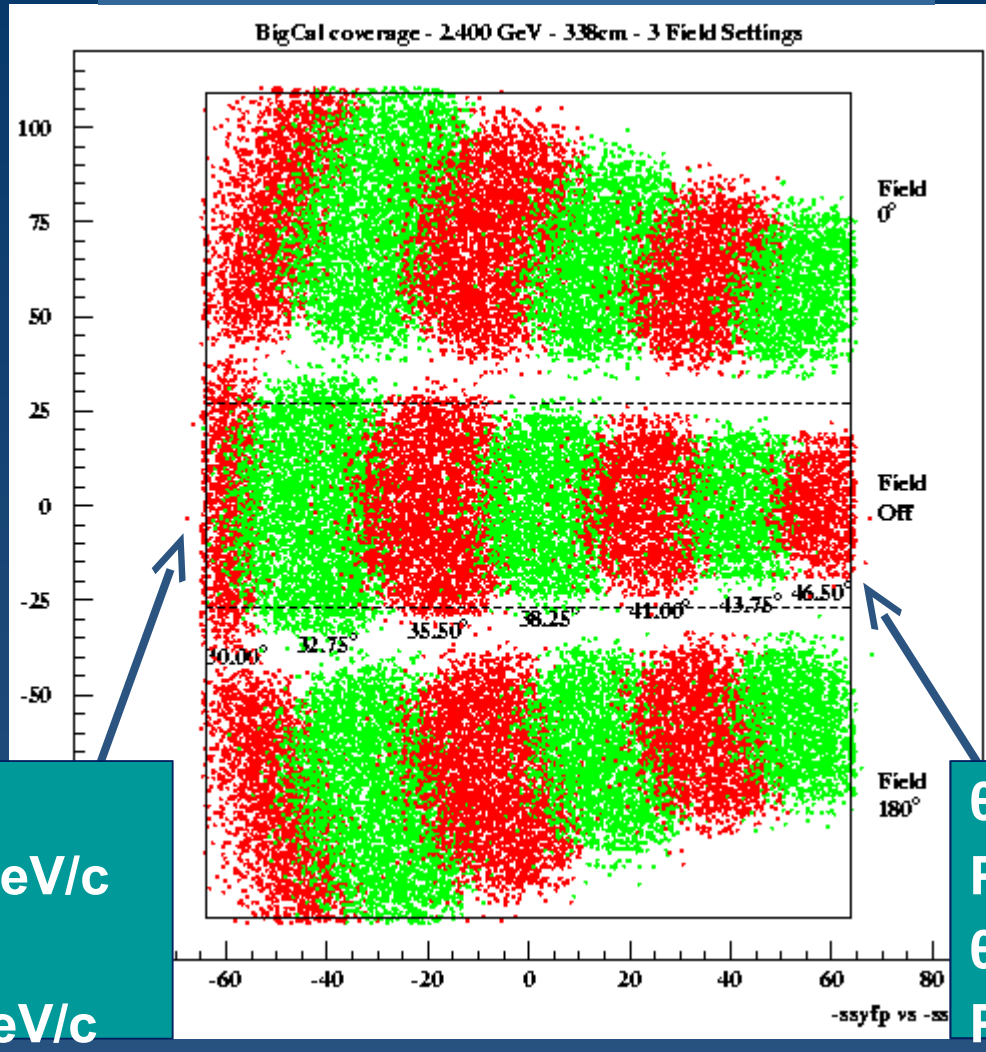
1. Record zero-field ADC gains for all blocks illuminated with the Gain Monitor light (will take 4-6 hours).
2. **Zero-field runs (9hrs @100% efficiency or ~18hrs):**

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_{HMS} (GeV)	θ_{HMS} (deg)	Counts /Cell	Time (hrs)
1.789	30	1.233	46.50	400	0.2
1.706	33	1.334	43.75	400	0.3
1.617	36	1.443	41.00	400	0.5
1.522	39	1.555	38.25	400	0.9
1.423	43	1.670	35.50	400	1.7
1.318	47	1.789	32.75	200	2.0
1.213	50	1.907	30.00	100	3.0

Simulated BigCal Coverage

$E_{\text{beam}} = 2.400 \text{ GeV}$, BigCal face at 338cm

Full Field (5.0 T)



$\theta_{\text{HMS}} = 30.0^\circ$
 $P_{\text{HMS}} = 1.91 \text{ GeV/c}$
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$\theta_{\text{HMS}} = 46.5^\circ$
 $P_{\text{HMS}} = 1.23 \text{ GeV/c}$
 $\theta_{e'} = 30^\circ$
 $P_{e'} = 1.79 \text{ GeV/c}$

Elastic Run Plan (2)

1. Ramp target to 5.1T, 180° orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).
3. **180°-field runs (10hrs @100% efficiency or ~20 hrs):**

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_{HMS} (GeV)	θ_{HMS} (deg)	Counts /Cell	Time (hrs)
1.706	33	1.334	43.75	400	0.3
1.617	36	1.443	41.00	400	0.6
1.522	39	1.555	38.25	400	1.0
1.423	43	1.670	35.50	400	1.8
1.318	47	1.789	32.75	200	2.0
1.213	50	1.907	30.00	100	3.8

Elastic Run Plan (3)

1. Reverse current in target coils: 5.1T 0° orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).
3. **0°-field runs (10hrs @100% efficiency or ~20 hrs):**

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_{HMS} (GeV)	θ_{HMS} (deg)	Counts /Cell	Time (hrs)
1.706	33	1.334	43.75	400	0.3
1.617	36	1.443	41.00	400	0.6
1.522	39	1.555	38.25	400	1.0
1.423	43	1.670	35.50	400	1.8
1.318	47	1.789	32.75	200	2.1
1.213	50	1.907	30.00	100	3.9

Comment re. Half-Field scans

- At this point, about 75% of the BigCal will have been covered by the Off-0°-180° scans.
 - The 0° and 180° half-field scans will bring coverage to ~90%, but still does not provide complete coverage.
- Gain vs. field dependence is not linear, so the half-field calibration might be a useful intermediate point to better understand the gain corrections for overlapping blocks.
 - Axial field for the 80° setting is ~60% of 180° setting.

Suggestion:

- Most of the elastic calibration time should be spent on the Off-0°-180° scan.
- Eliminate the lowest rate $\theta_{\text{HMS}}=30^\circ$ half-field setting and reduce the statistics for a few others.

Elastic Run Plan (4)

1. Reduce current in target coils by half: 2.55T 0° orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).
3. **0°-1/2B runs (3.5hrs @100% efficiency or ~8 hrs):**

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_{HMS} (GeV)	θ_{HMS} (deg)	Counts /Cell	Time (hrs)
1.789	30	1.233	46.50	400	0.25
1.706	33	1.334	43.75	400	0.3
1.617	36	1.443	41.00	400	0.5
1.522	39	1.555	38.25	200	0.5
1.423	43	1.670	35.50	200	0.9
1.318	47	1.789	32.75	100	1.0

Elastic Run Plan (5)

1. Reverse current in target coils: 2.55T 180° orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).
3. **180°-1/2B runs (3.5hrs @100% efficiency or ~7 hrs):**

$E_{e'}$ (GeV)	$\theta_{e'}$ (deg)	P_{HMS} (GeV)	θ_{HMS} (deg)	Counts /Cell	Time (hrs)
1.789	30	1.233	46.50	400	0.25
1.706	33	1.334	43.75	400	0.3
1.617	36	1.443	41.00	400	0.5
1.522	39	1.555	38.25	200	0.5
1.423	43	1.670	35.50	200	0.9
1.318	47	1.789	32.75	100	1.0

Elastic Calibrations Summary

- Our most straightforward absolute energy calibration of scattered electrons in the calorimeter.
 - Complements the $\gamma\gamma \rightarrow \pi^0$ reconstruction method.
- Requires dedicated 2.4 GeV time.

Zero field scan	6 hr BigCal gain measurement + 18hr data (@50% efficiency)
5.0T, 180° field scan	8 hr BigCal gain adjust + 20hr data
5.0T, 0° field scan	8 hr BigCal gain adjust + 20hr data
2.5T, 0° field scan	8 hr BigCal gain adjust + 7hr data
2.5T, 180° field scan	8 hr BigCal gain adjust + 7hr data
TOTAL:	110 hr (4.5 days) @50% efficiency