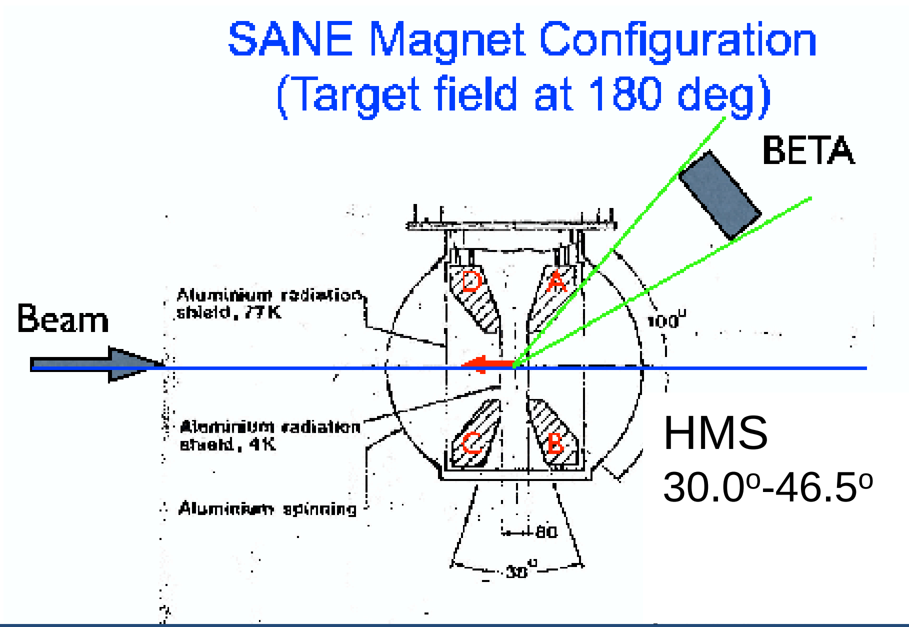
# BigCal Elastics Calibrations

Garth Huber

UNIVERSITY OF REGINA

# 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 $\pi^0$ 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.

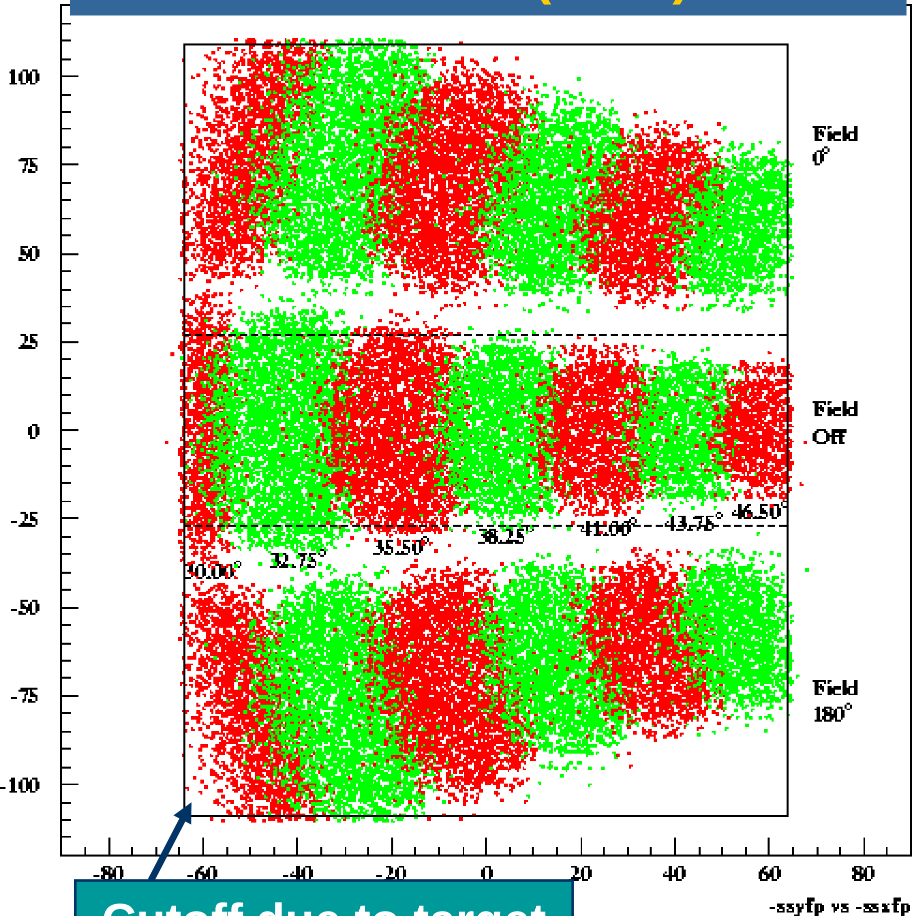
# Constraints

- 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$^o$ field configuration, since the 2.4 GeV electron beam would be deflected and miss the target.
  - Only 0$^o$, 180$^o$ 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

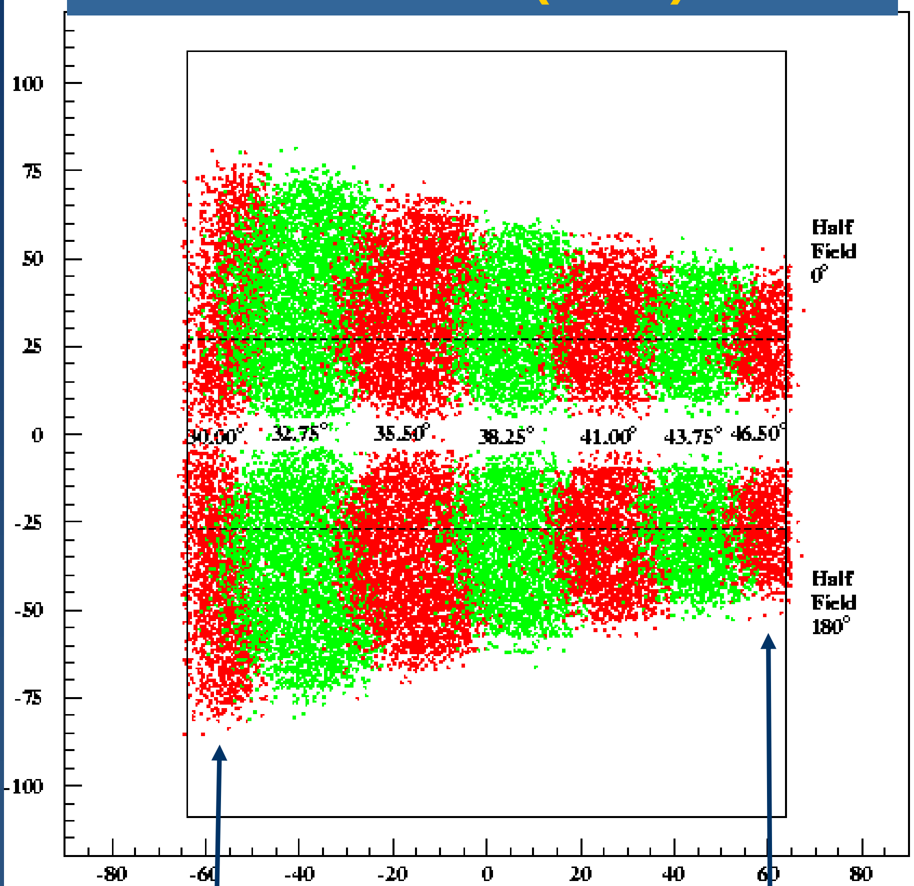
## $E_{beam}$=2.400 GeV, BigCal face at 338cm

### Full Field (5.0 T)




Cutoff due to target coil obstruction.

### Half Field (2.5 T)




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

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

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

# Elastic Rates per Setting

## $E_{beam}$=2.400 GeV, 1μA - BigCal face at 338cm

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_p$ (GeV) | $\theta_p$ (deg) | Counts/cell/hr 0° | 180° | Off | 0°-½B | 180°-½B |
|---|---|---|---|---|---|---|---|---|
| 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**.

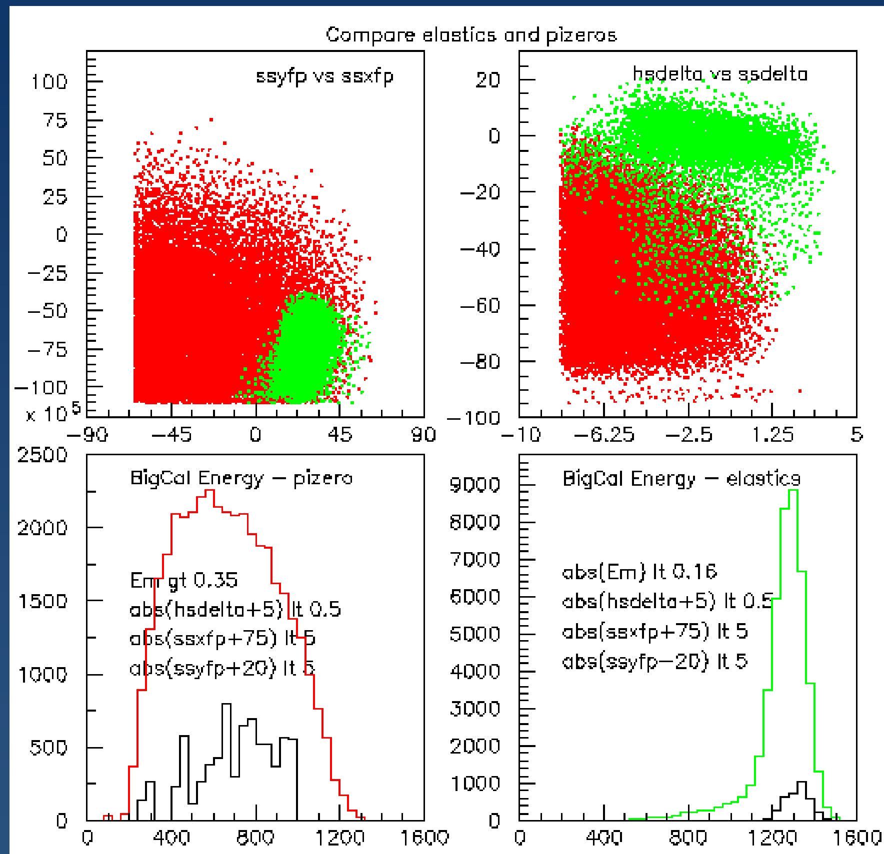
# Run Plan Suggestion

- 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 $80^{o}$ field.

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

e-p angular correlation much larger for $\pi^0$ events.

$E_{BigCal}$ for $\pi^0$ evts. Cut distribution is scaled x100.




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

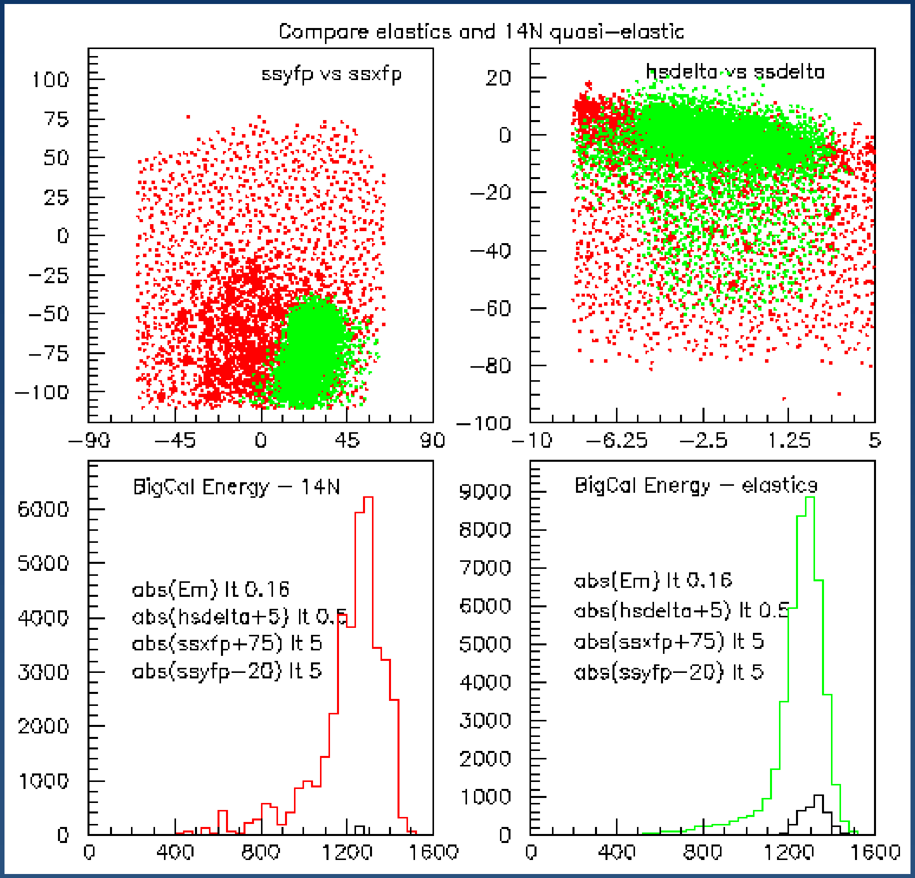
$E_{BigCal}$ for elastics. Cut distribution is scaled x20.

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 $\pi^0$ data.

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

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

$p_{HMS}$ vs $E_{BigCal}$ distributions overlap substantially.

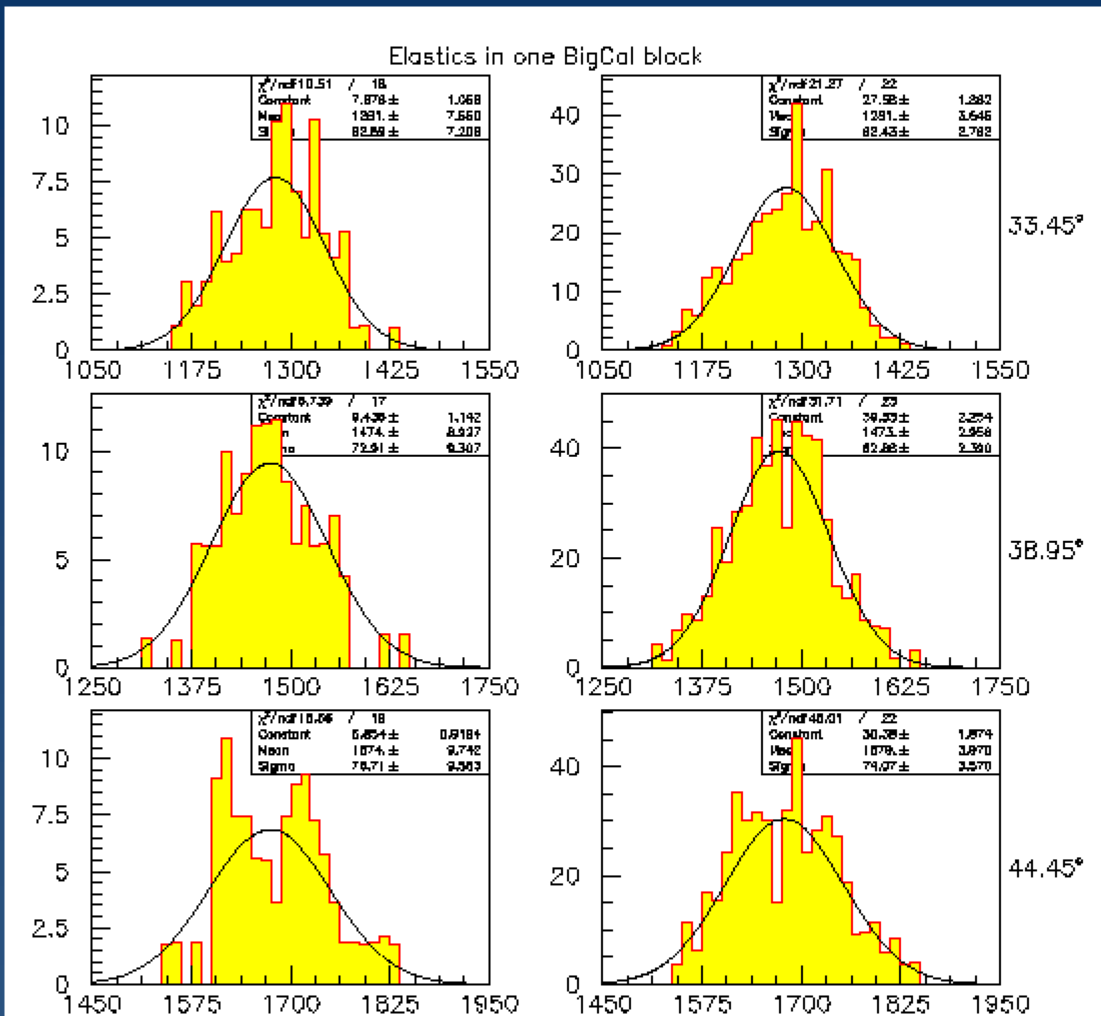



$E_{BigCal}$ for $^{14}N(e,e'p)$. Almost no events survive elastics cuts (scaled x100).

$E_{BigCal}$ 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 ?




100 counts

400 counts

- **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:

1. 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).
2. 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.

# Elastics Run Plan (1)

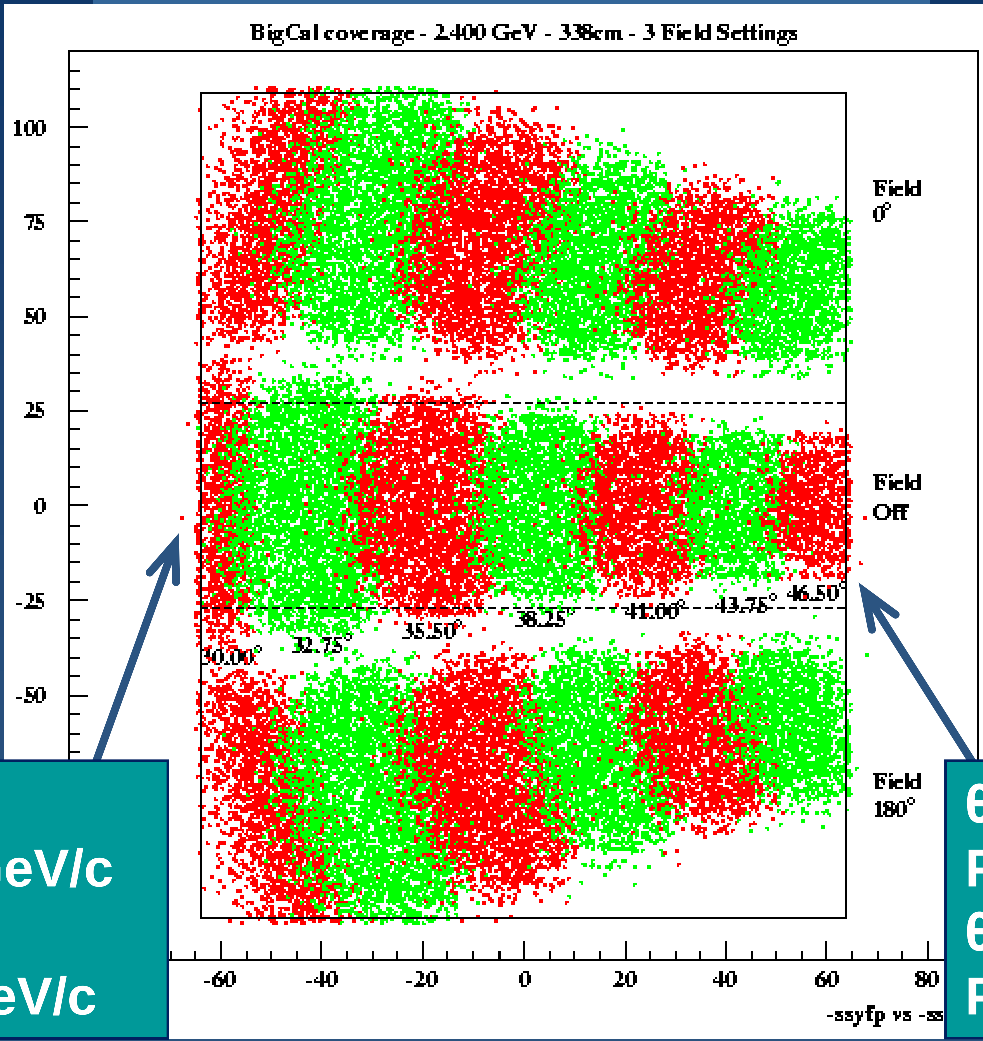
1. Record zero-field ADC gains for all blocks illuminated with the Gain Monitor light (will take 4-6 hours).
2. **Zero-field runs** (9hrs @100% efficiency or ~18hrs):

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_{HMS}$ (GeV) | $\theta_{HMS}$ (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

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

**Full Field (5.0 T)**




$\theta_{HMS}$=30.0°
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$\theta_{HMS}$= 46.5°
$P_{HMS}$= 1.23 GeV/c
$\theta_{e'}$ = 30°
$P_{e'}$ = 1.79 GeV/c

# Elastics Run Plan (2)

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

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_{HMS}$ (GeV) | $\theta_{HMS}$ (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 |

# Elastics Run Plan (3)

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

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_{HMS}$ (GeV) | $\theta_{HMS}$ (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-0º-180º scans.
  - The 0º and 180º 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 80º setting is only ~25% of 180º setting.

**Suggestion:**

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

# Elastics Run Plan (4)

1. Reduce current in target coils by half: 2.55T 0º orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).
3. **0º-½B runs** (3.5hrs @100% efficiency or ~8 hrs):

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_{HMS}$ (GeV) | $\theta_{HMS}$ (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 |

# Elastics Run Plan (5)

1. Reverse current in target coils: 2.55T 180º orientation.
2. Record ADC gains for all blocks illuminated with the Gain Monitor light and make HV adjustments (6-8 hours).

3. **180º-½B runs** (3.5hrs @100% efficiency or ~7 hrs):

| $E_{e'}$ (GeV) | $\theta_{e'}$ (deg) | $P_{HMS}$ (GeV) | $\theta_{HMS}$ (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<br>+ 18hr data<br>(@50% efficiency) |
| **5.0T, 180º field scan** | 8 hr BigCal gain adjust + 20hr data |
| **5.0T, 0º field scan** | 8 hr BigCal gain adjust + 20hr data |
| **2.5T, 0º field scan** | 8 hr BigCal gain adjust + 7hr data |
| **2.5T, 180º field scan** | 8 hr BigCal gain adjust + 7hr data |
| **TOTAL:** | **110 hr (4.5 days) @50% efficiency** |