清華大學
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Luminosity and Helicity Analysis

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Luminosity Analysis

Luminosity Run List

Target	RunNo	ps4	Pre-scale	Current (μA)	Duration (min)	Events	Events*ps (k)
LH2	1514	0	1	5	10	1023966	1024
	1515	2	3	10	10	912408	2736
	1516	3	5	15	10	751598	3758
	1517	4	9	25	15	811950	7308
LD2	1518	7	65	40	15	521346	33884
	1519	6	33	25	10	485796	16031
	1520	6	33	18	10	289841	9563
	1521	5	17	10	10	328346	5581
	1522	4	9	5	10	345025	3105
Carbon	1523	4	9	35	10	180135	1621
	1524	3	5	35	10	156607	783
	1525	3	5	40	10	187356	937
	1526	3	5	25	10	144809	724
	1528	2	3	15	10	153366	460
	1530	0	1	5	15	190627	190

- KinC_x50_2
- HMS 12.493°
- SHMS 36.88°
- NPS 20.58°
- Calo HV off
- Sweep magnet off
- EDTM 100Hz

Luminosity Analysis

Overview

- Fill all the BCM4A scaler current readouts into a 1-D histogram → Gaussian Fitting → Get I and σ
- Use $I - 3\sigma$ μA cut to calculate the charge for each run
- Apply the same beam-on-time cut when selecting El-REAL events

Scaler Yield

$$\frac{\text{scaler\_htrig4} - \text{scaler\_edtm}}{\text{charge}}$$

Cuts for scaler counting:

- Beam current cut

Non-tracking Yield

$$\frac{\#\text{ of events} \times \text{ps-factor}}{\text{charge} \times \text{LT}}$$

Cuts for event selection:

- Beam current cut
- Non-edtm
- npeSum>2
- 0.6<etotnorm<1.5

Tracking Yield

$$\frac{\#\text{ of events} \times \text{ps-factor}}{\text{charge} \times \text{LT} \times \text{track\_eff}}$$

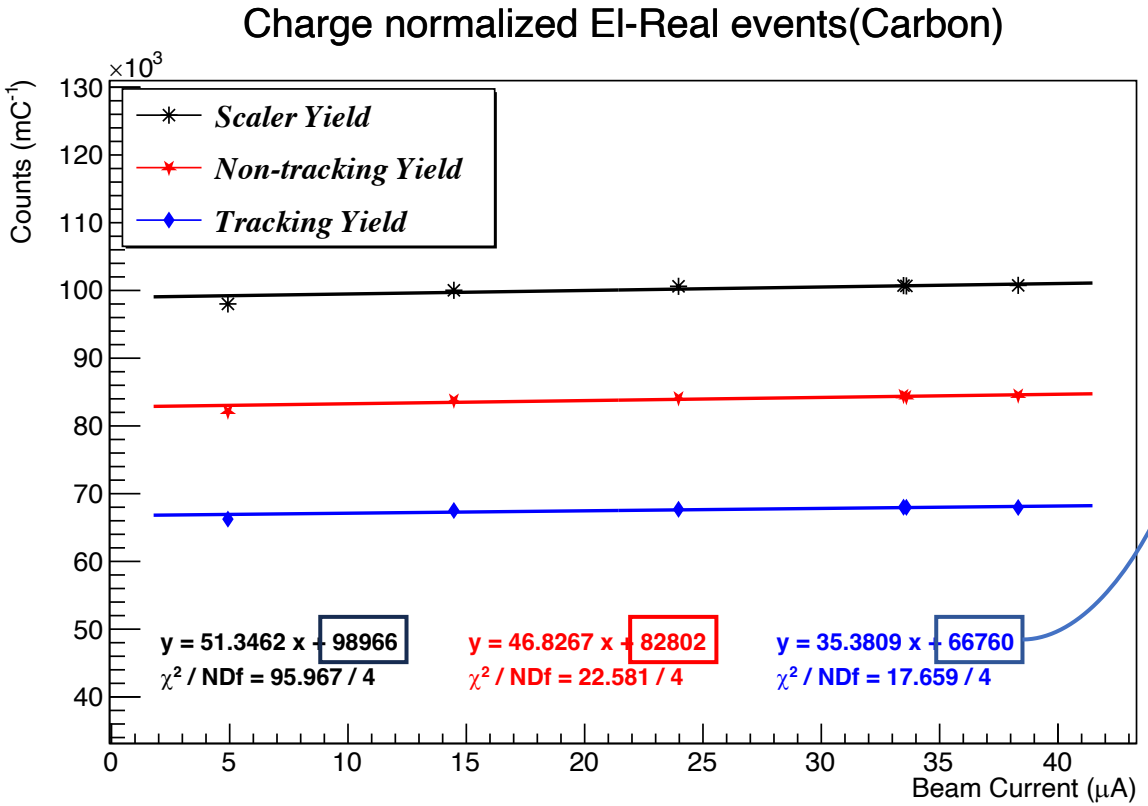
Cuts for event selection:

- Beam current cut
- Non-edtm
- npeSum>2
- 0.6<etotnorm<1.5
- $|\text{gtr\_dp}| \leq 10$
- $|\text{vtx\_z}| \leq 4$
- vtx_ok and gtr_ok

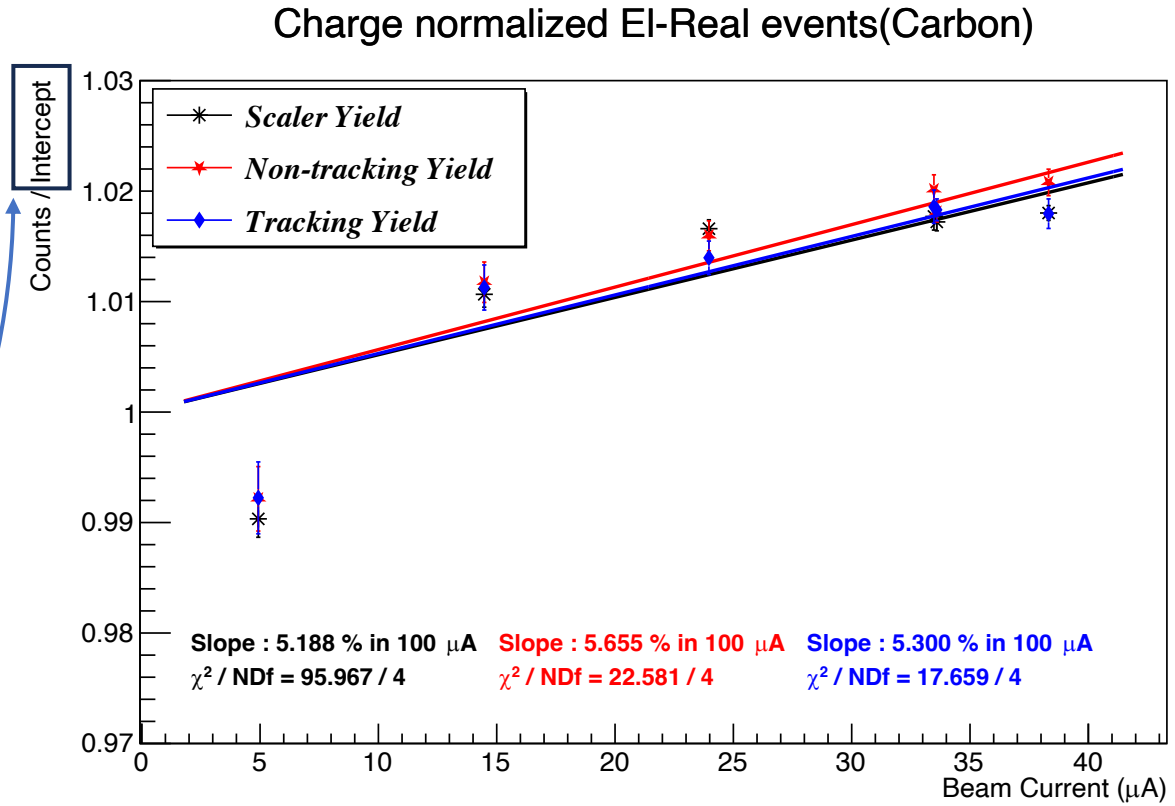
$$\text{LT} = \frac{\#\text{ of events}}{\text{scaler\_htrig4} - \text{scaler\_edtm}} \times \text{ps factor}$$

Luminosity Analysis

Linear Fitting (Carbon for example)



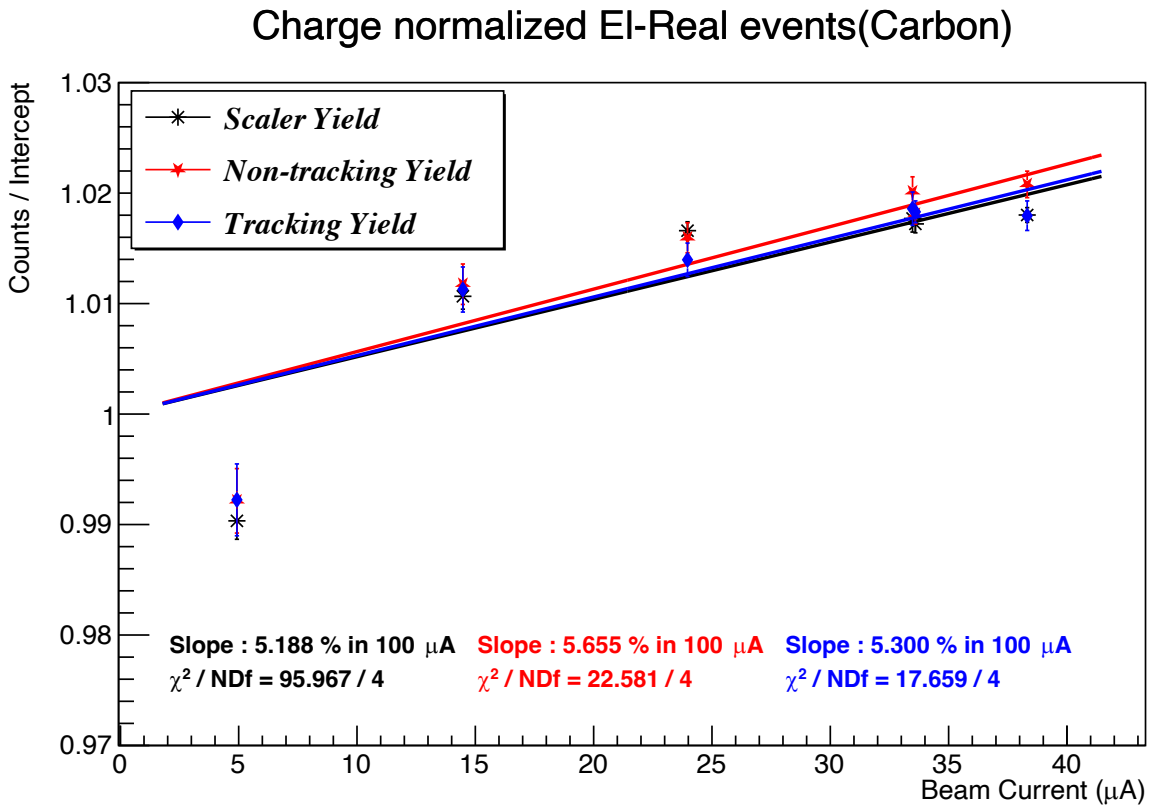
First Fitting



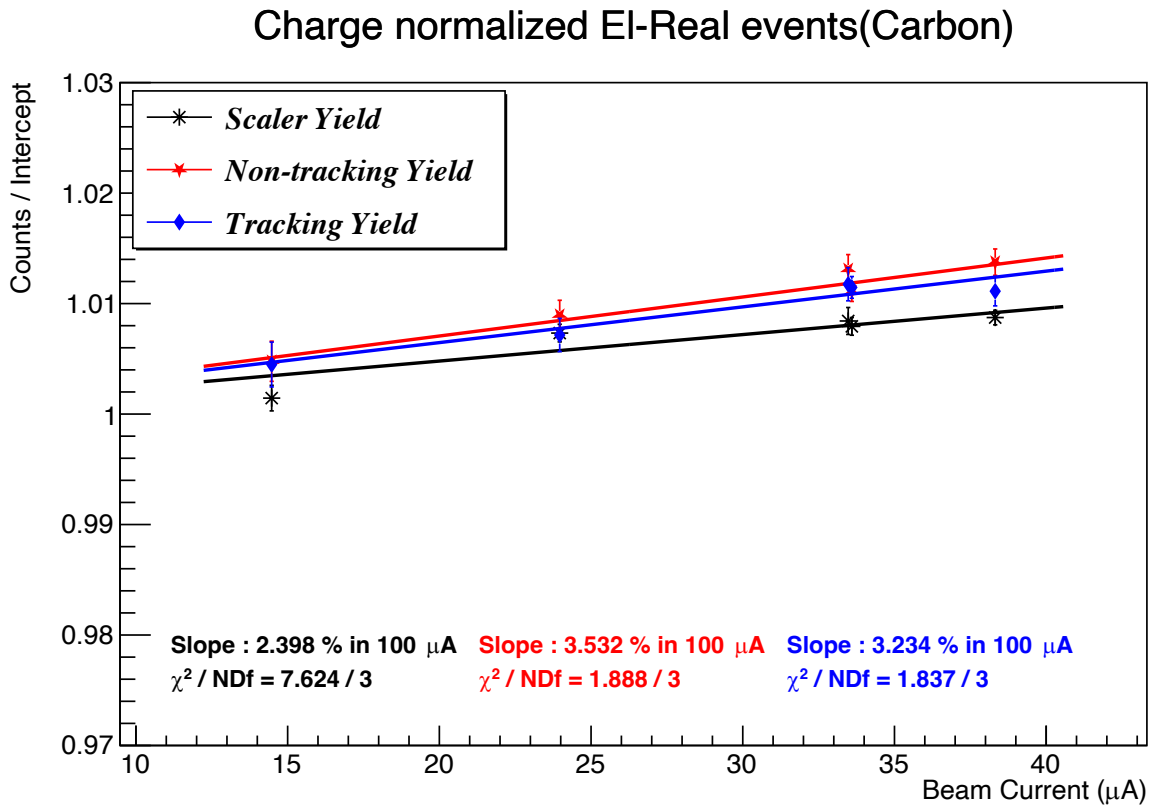
Second Fitting

Luminosity Analysis

Carbon



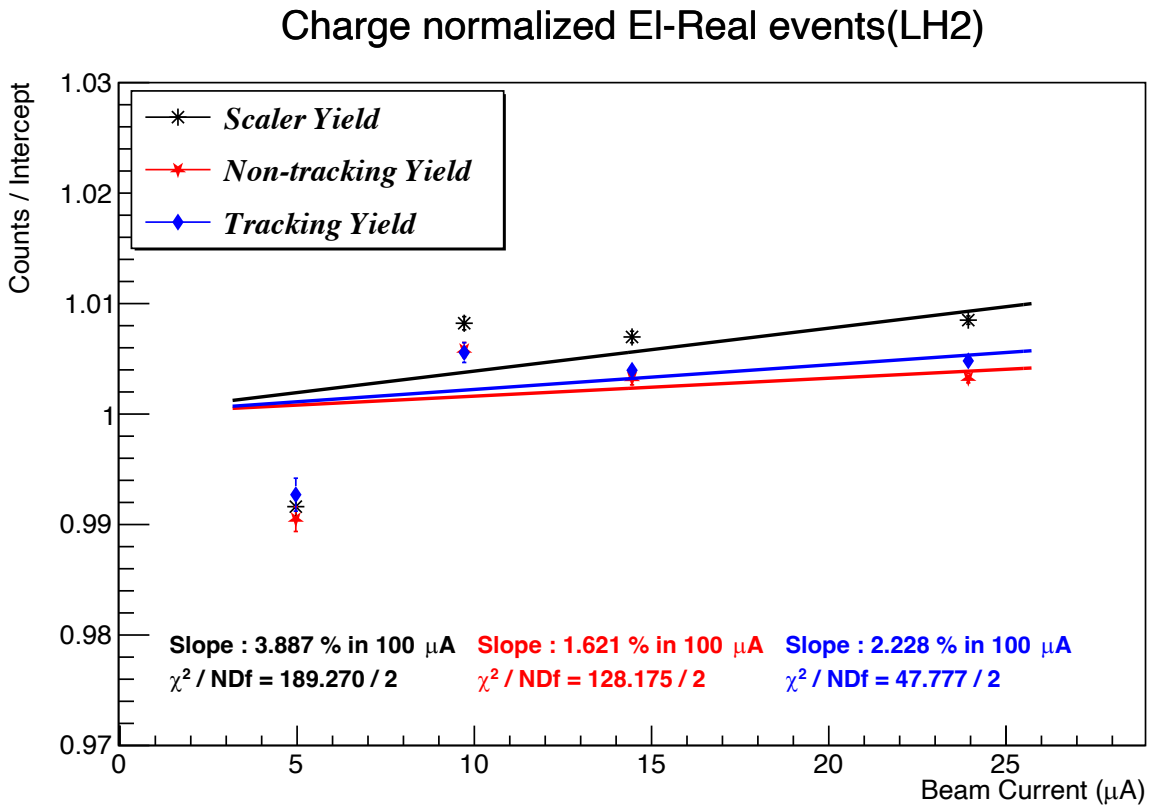
With 5 μA run



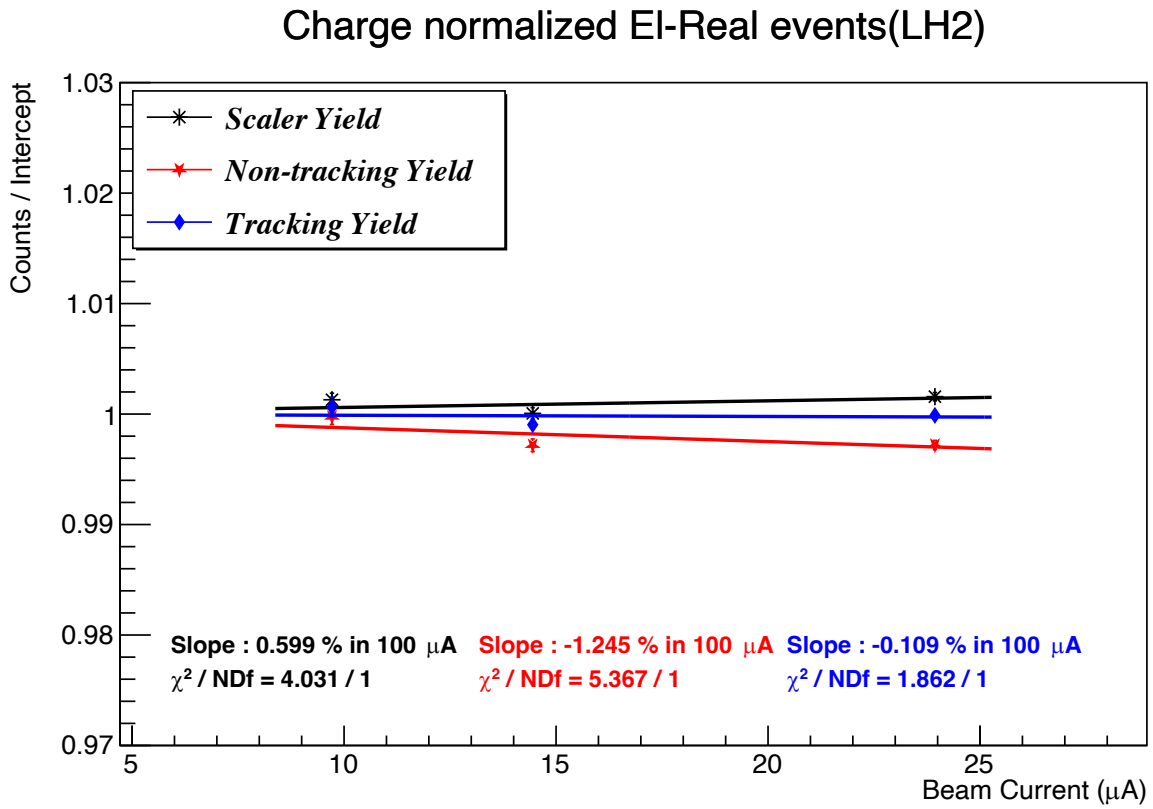
Without 5 μA run

Luminosity Analysis

LH2



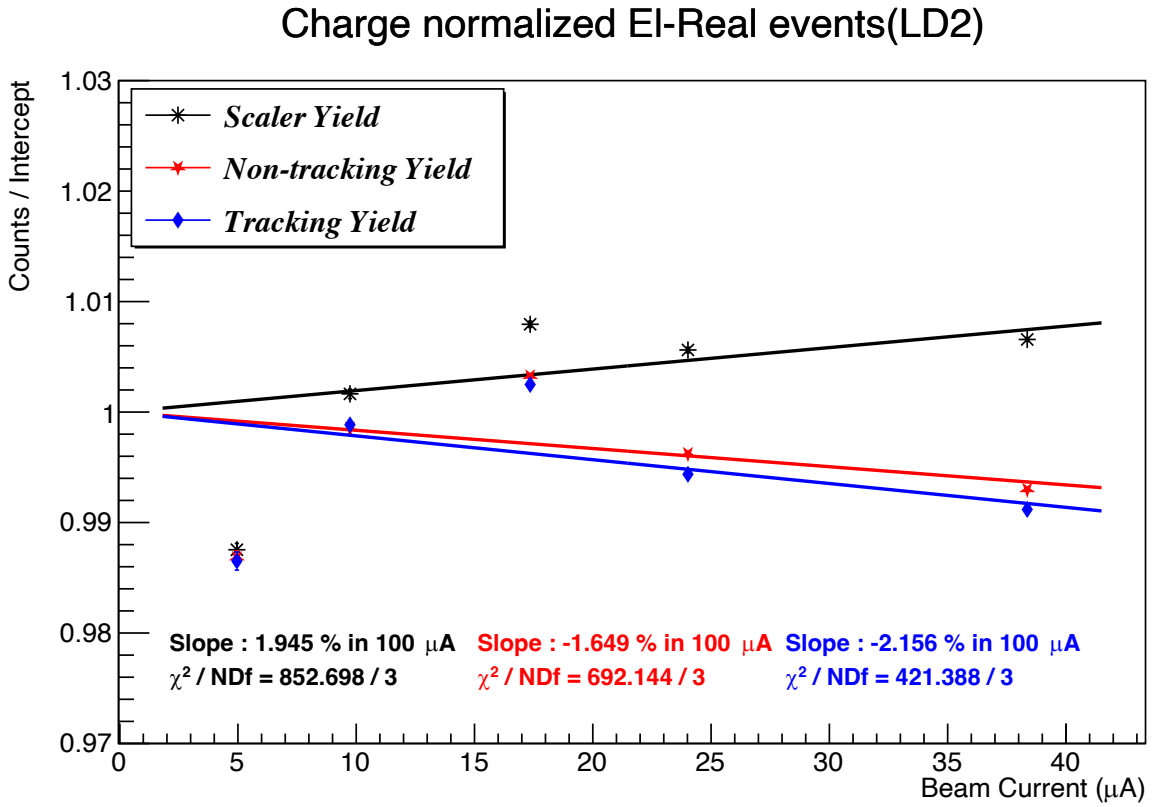
With 5 μA run



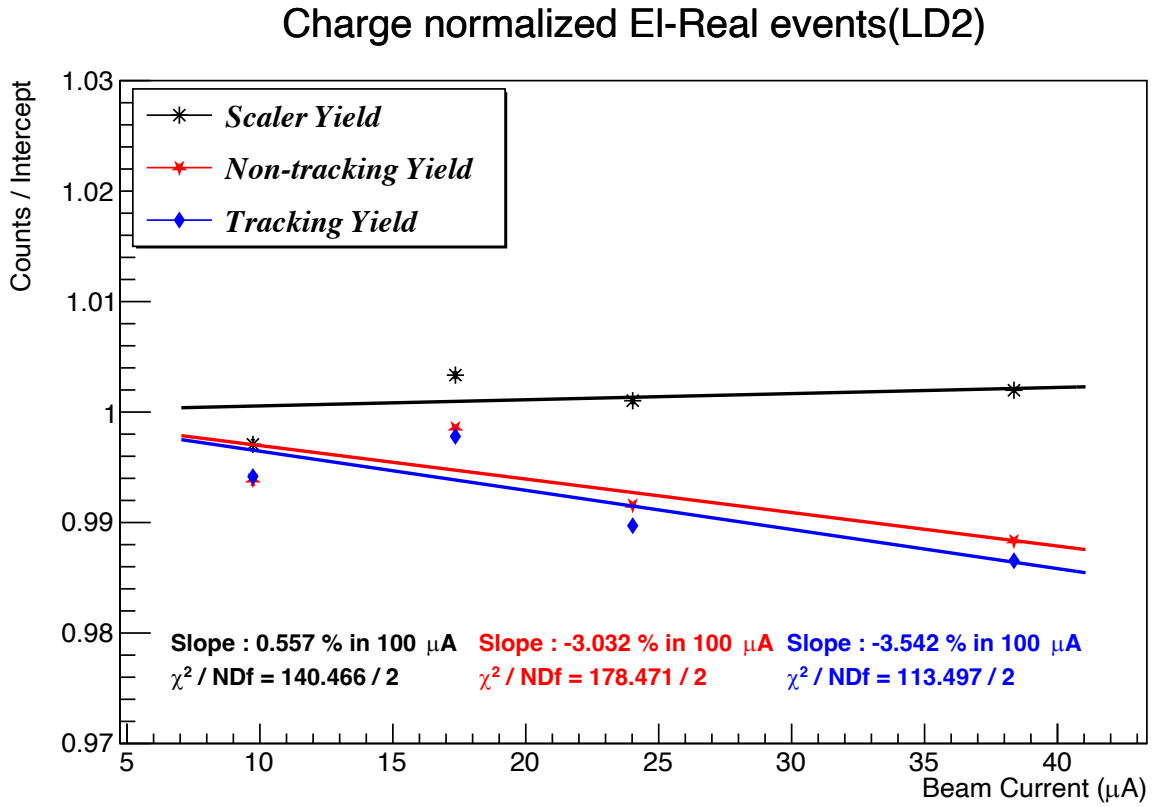
Without 5 μA run

Luminosity Analysis

LD2



With 5 μA run



Without 5 μA run

Luminosity Analysis

Slope Table

	With 5 μA run			Without 5 μA run		
% in 100μA	Scaler	Non-Tracking	Tracking	Scaler	Non-Tracking	Tracking
Carbon	5.188	5.655	5.300	2.398	3.532	3.234
LH2	3.887	1.621	2.228	0.599	-1.245	-0.109
LD2	1.945	-1.649	-2.156	0.557	-3.032	-3.542

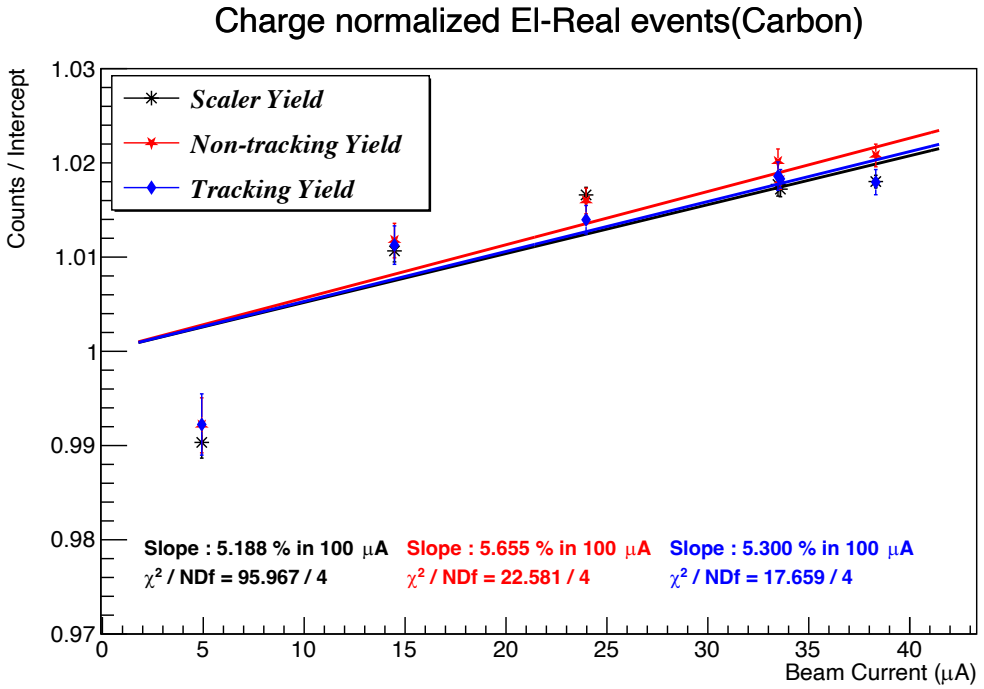
Luminosity Analysis

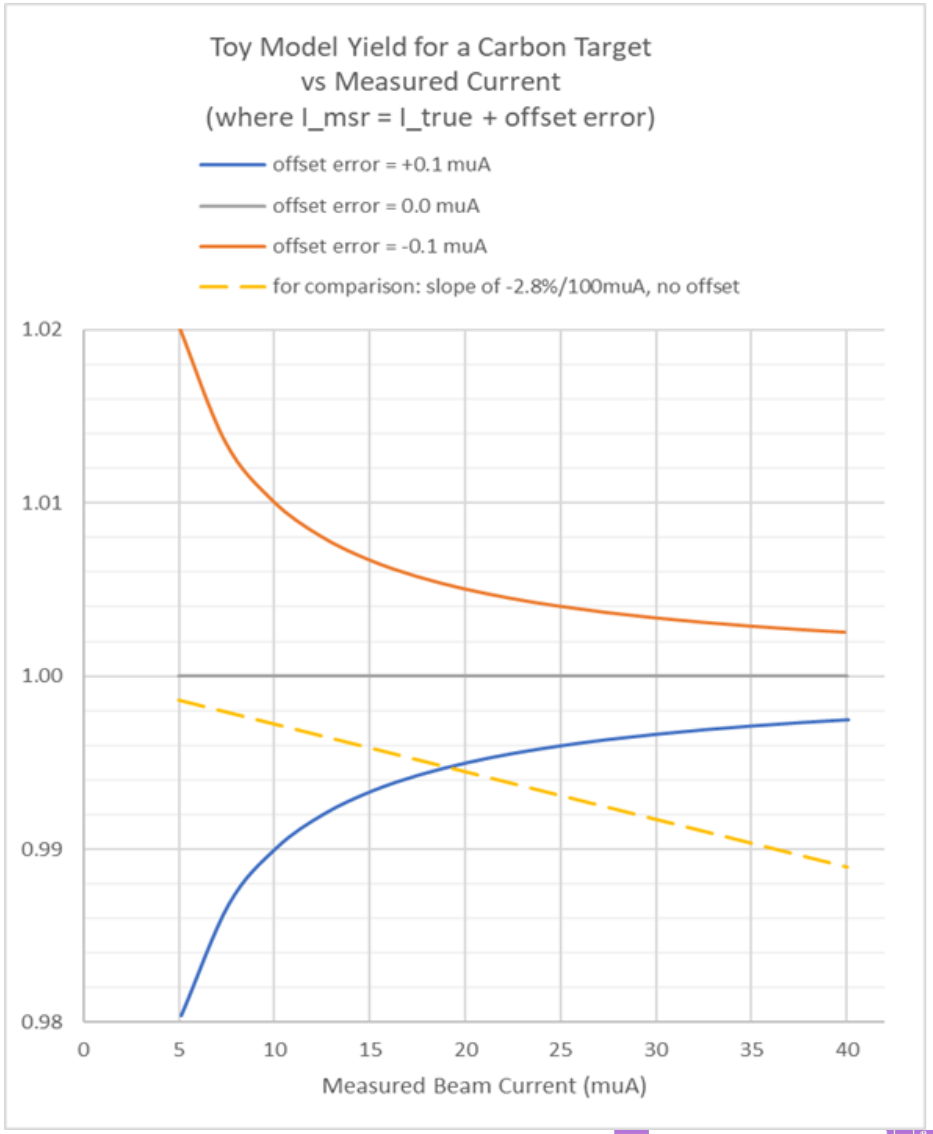
BCM offset optimization

The formula to calculate the BCM4A current:

$$I_{BCM4A} = \frac{\left(scaler_{diff} \div Time_{diff}\right) - \boxed{(-1605)}}{\boxed{9570}}$$

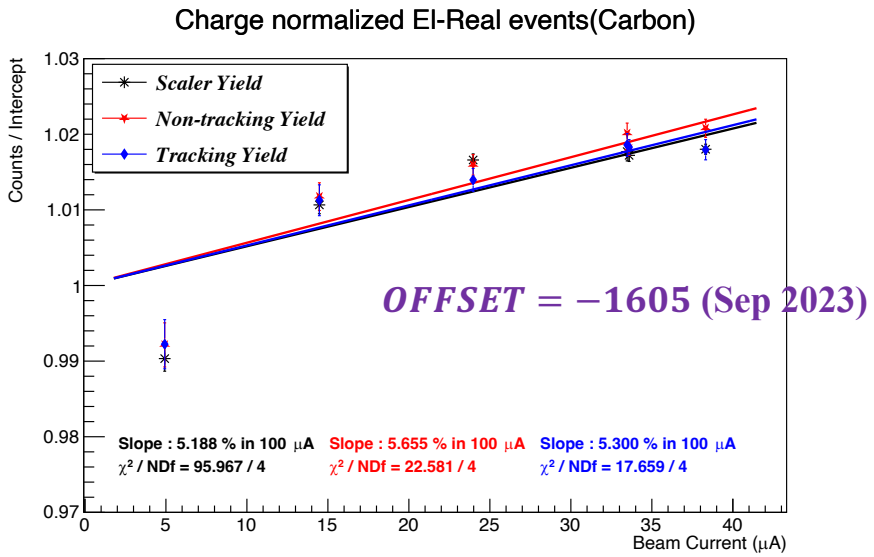
$OFFSET$ $GAIN$

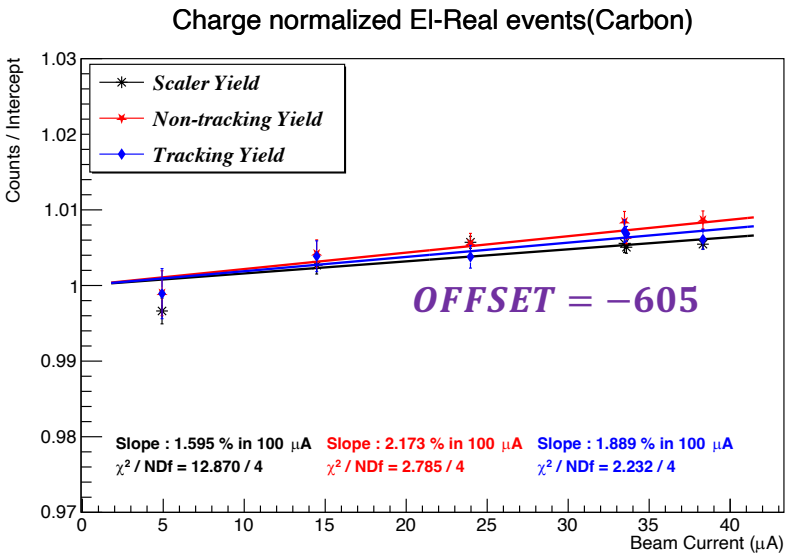


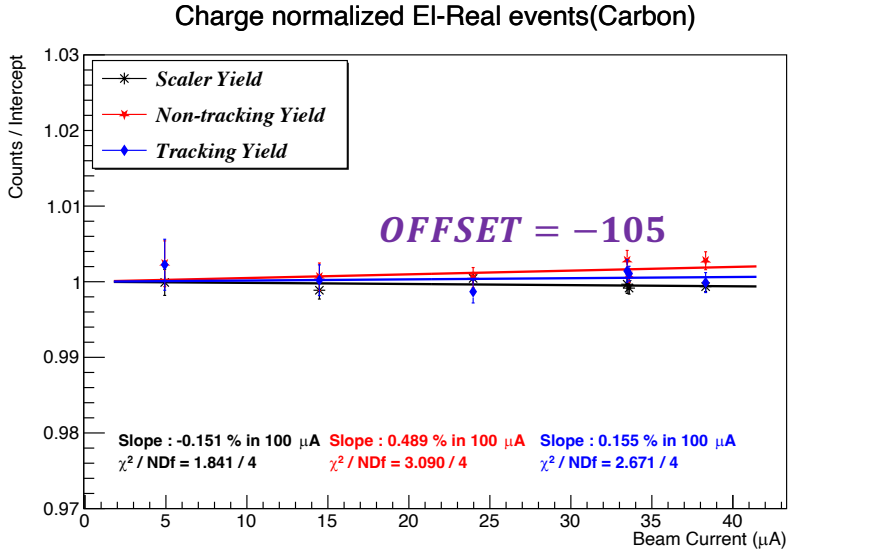


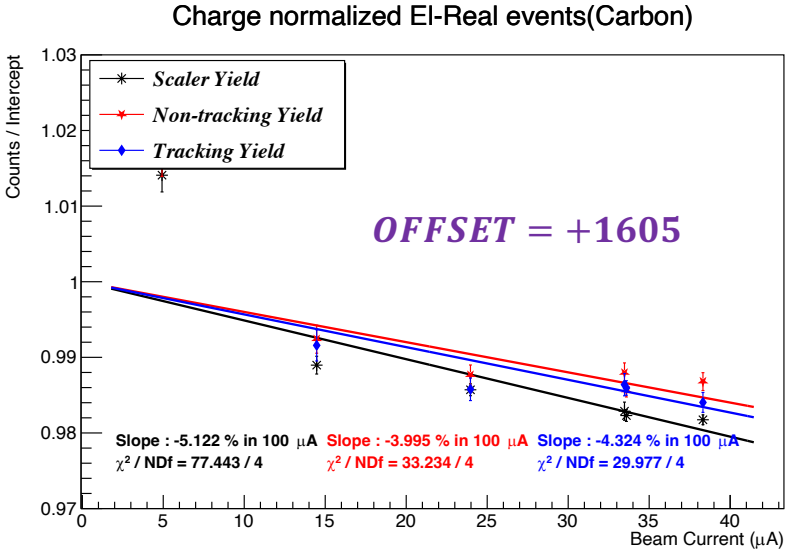
Luminosity Analysis

BCM4A offset optimization



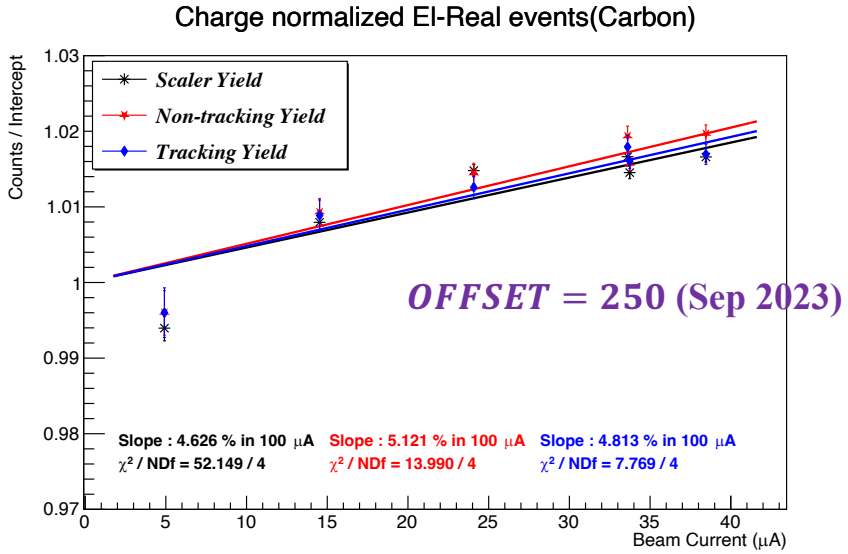


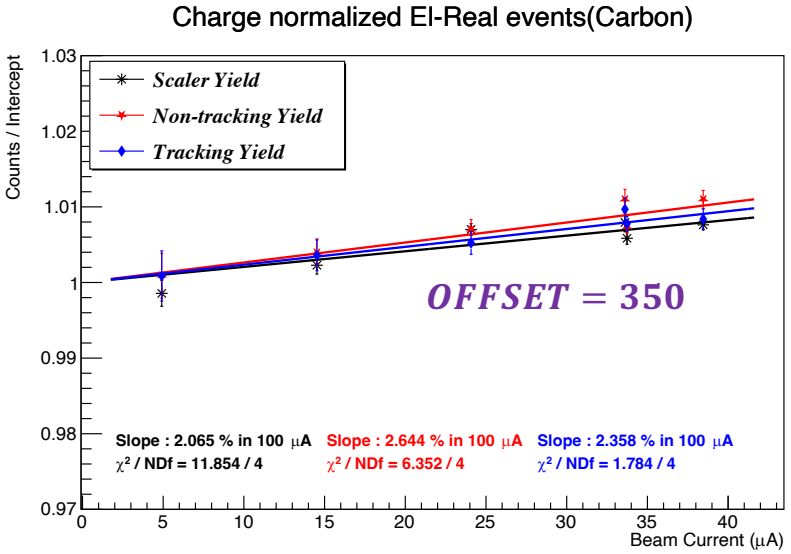


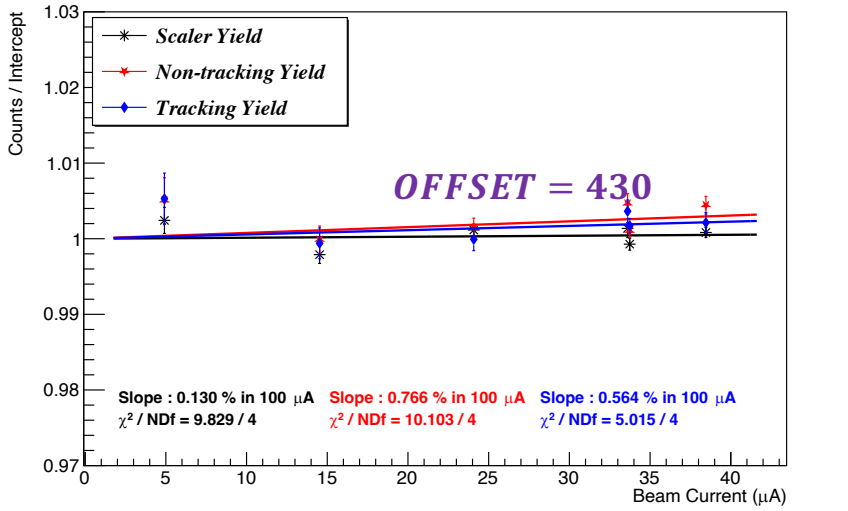


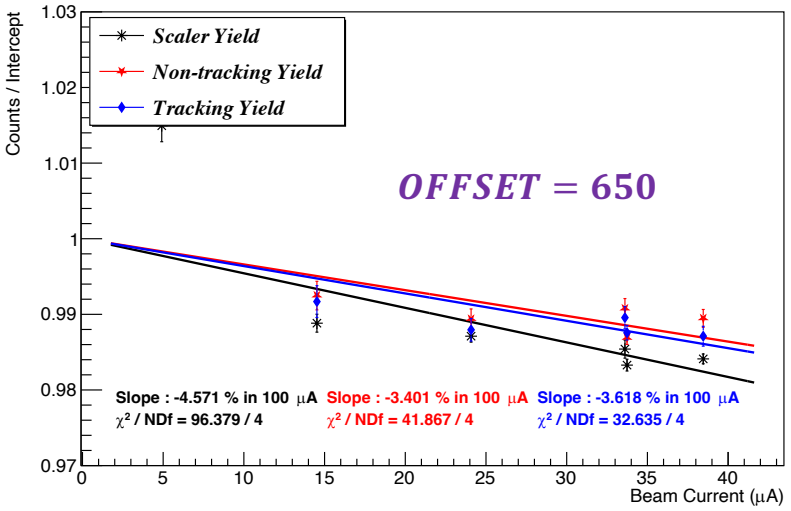
Luminosity Analysis

BCM4C offset optimization



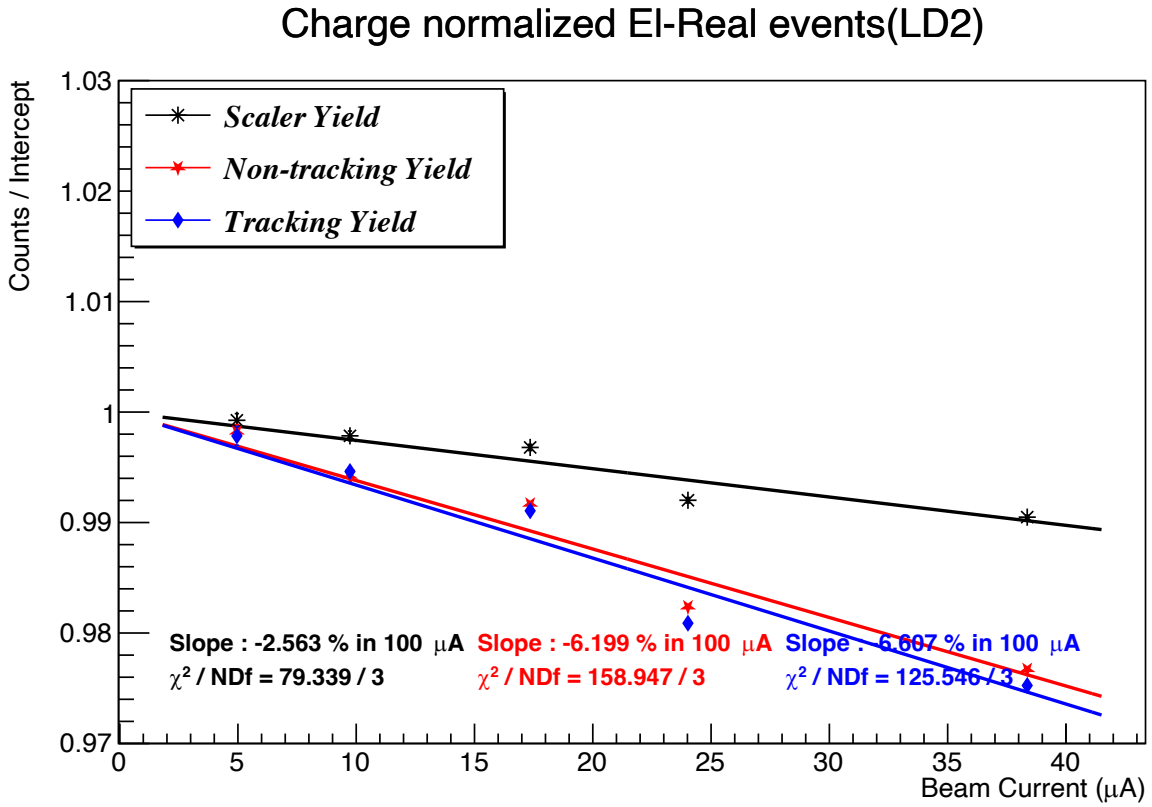




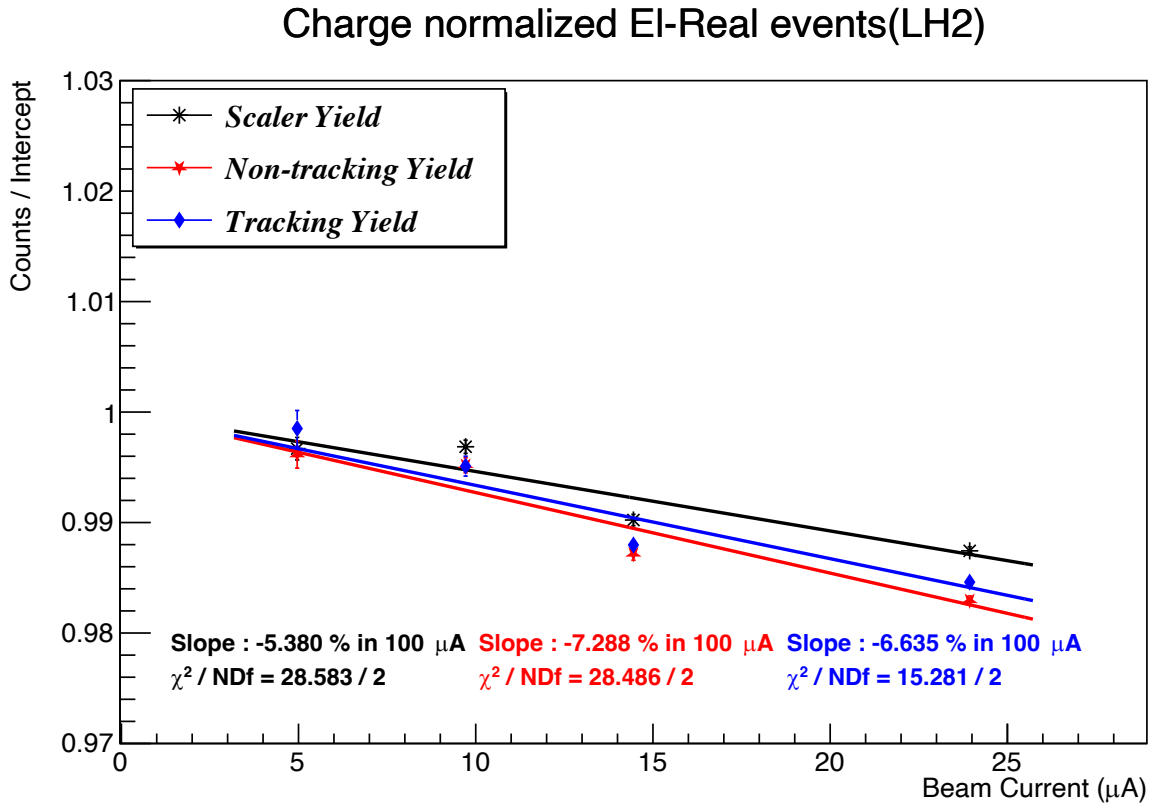


Luminosity Analysis

Yield with new BCM4A offset (−105)



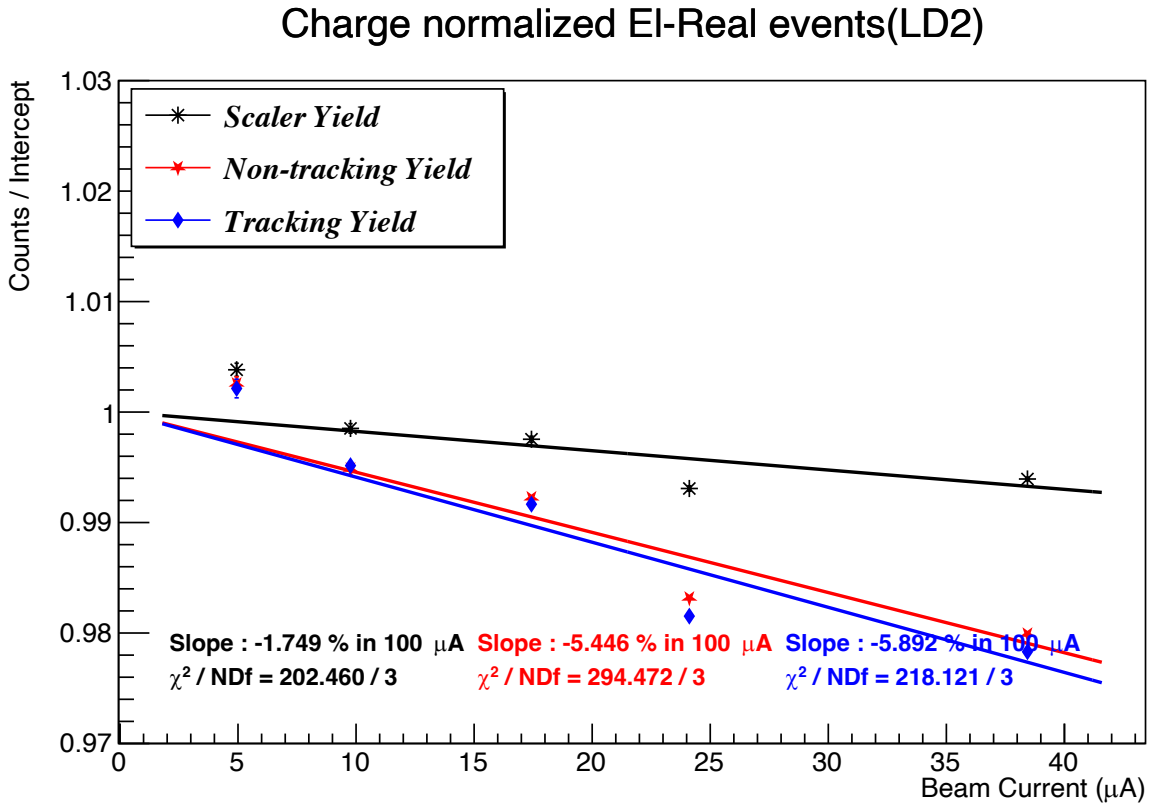
LD2



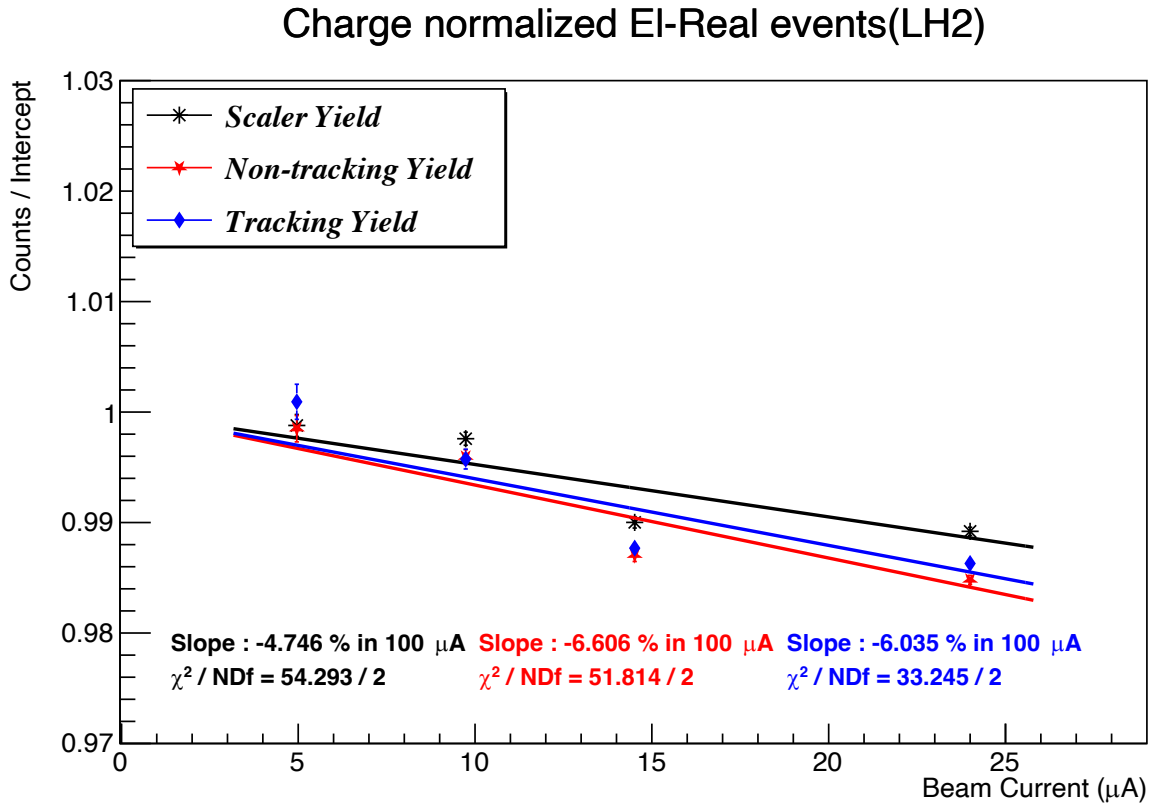
LH2

Luminosity Analysis

Yield with new BCM4C offset (430)



LD2



LH2

Luminosity Analysis Summary

What I have done:

1. Analyzed the luminosity runs at the beginning of the experiment (calculated charge and scalers carefully myself)
2. Applied the pre-scale factors and got the scaler/non-tracking/tracking yield for Carbon, LH2 and LD2
3. Optimized the BCM calibration offsets and make the Carbon yield flat

What needs to be done:

1. Analyze the luminosity runs at the end of the experiment
2. Use correct BCM offsets and get the slope for LH2 and LD2
3. According to Richard Trotta's email and slides, what we should do next:
   - Make sure the TDC cuts are correct (Avnish and I will work on this next)
   - Use "H_cal_etottracknorm" rather than "H_cal_etotnorm" for the tracking yield
   - For the HMS cuts, need to apply tighter cuts: npeSum>6
   - For the LT correction, Richard used EDTM LT but I used trigger LT, which one is better?
   - Why scaler yield is higher than the tracking and non-tracking yield?

$$\mathrm{LT} = \frac{\#\ \text{of events}}{\mathrm{scaler\_htrig4} - \mathrm{scaler\_edtm}} \times \text{ps factor}$$

Helicity Analysis

π^0 helicity dependent cross-section

- π^0 cross section:

$$\frac{d\sigma_\nu}{d\Omega_f dE_f d\Omega} = \frac{d\sigma_T}{d\Omega} + \epsilon\frac{d\sigma_L}{d\Omega} + \sqrt{2\epsilon(1+\epsilon)}\frac{d\sigma_{LT}\cos\phi}{d\Omega} + \epsilon\frac{d\sigma_{TT}}{d\Omega}\cos 2\phi + h\sqrt{2\epsilon(1-\epsilon)}\frac{d\sigma_{LT'}}{d\Omega}\sin\phi$$

helicity dependent part

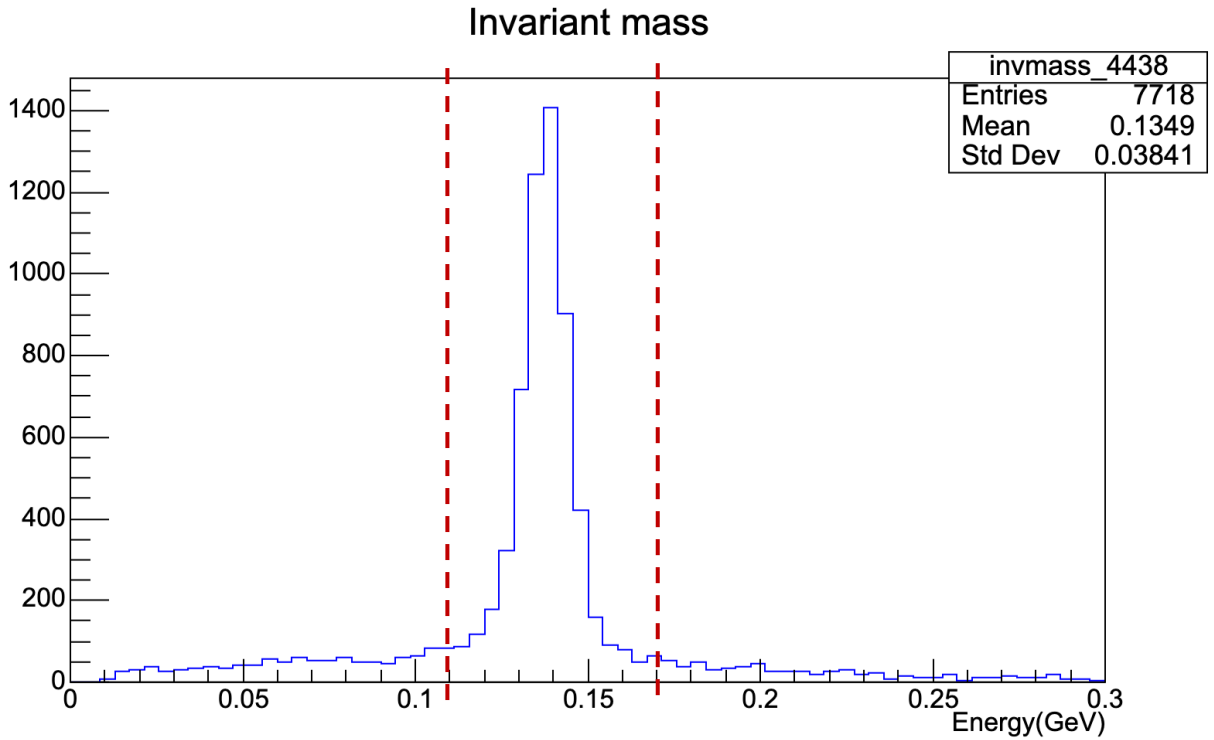
- $\pi^0\ Asymmetry = \frac{N_+ - N_-}{N_+ + N_-}$ Only helicity dependent part remains

Cuts applied:

- π^0 invariant mass$\in [0.11, 0.17]$
- No missing mass cut

Half-wave Plate Status:

IN	OUT	IN
4033-4063	4064-4428	4437-4517
21 runs	250 runs	36 runs

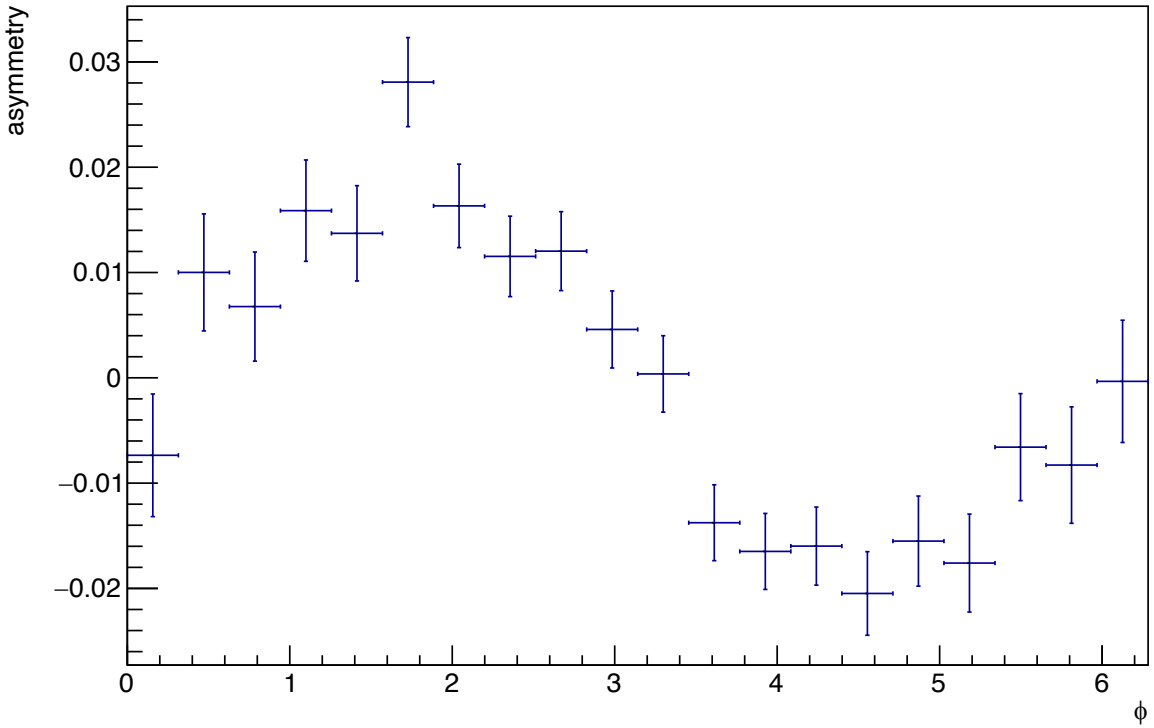


Helicity Analysis

π^0 asymmetry

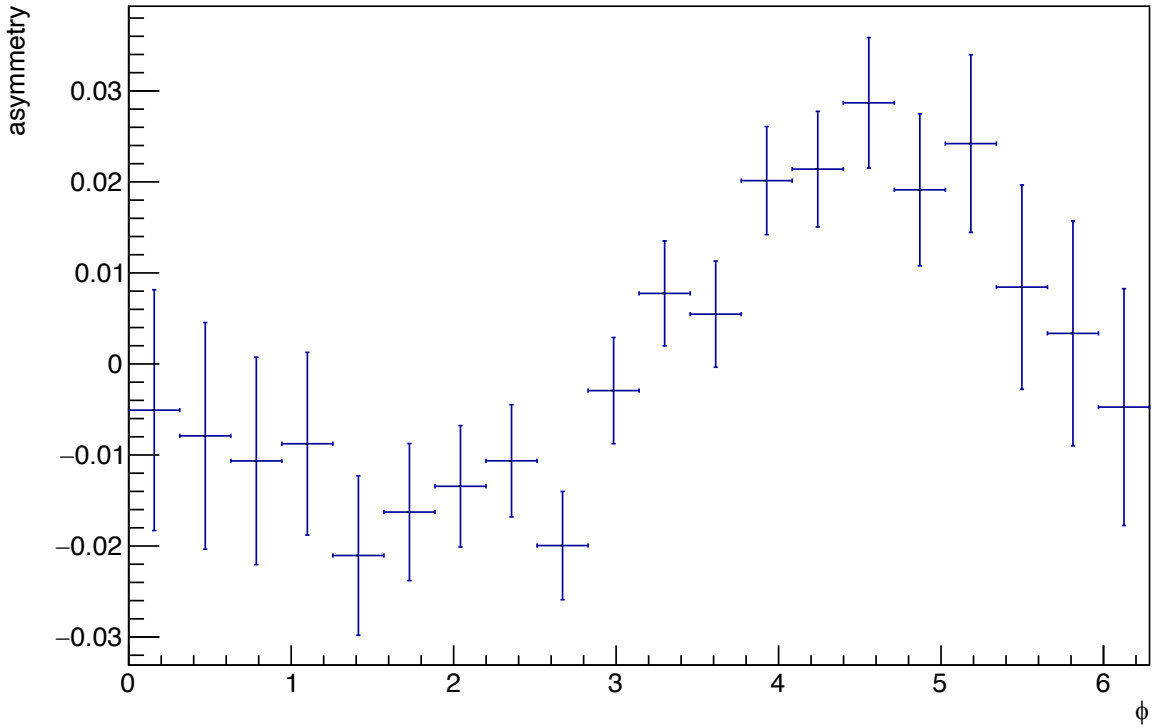
- $\pi^0\ Asymmetry = \frac{N_+ - N_-}{N_+ + N_-}$ Uncertainty: $\Delta A = \sqrt{1-A^2}\frac{\Delta N}{N} = \sqrt{1-A^2}\frac{1}{\sqrt{N}}$

π^0 asymmetry



OUT 4064-4428 250 runs
~ 1.1 million events

π^0 asymmetry

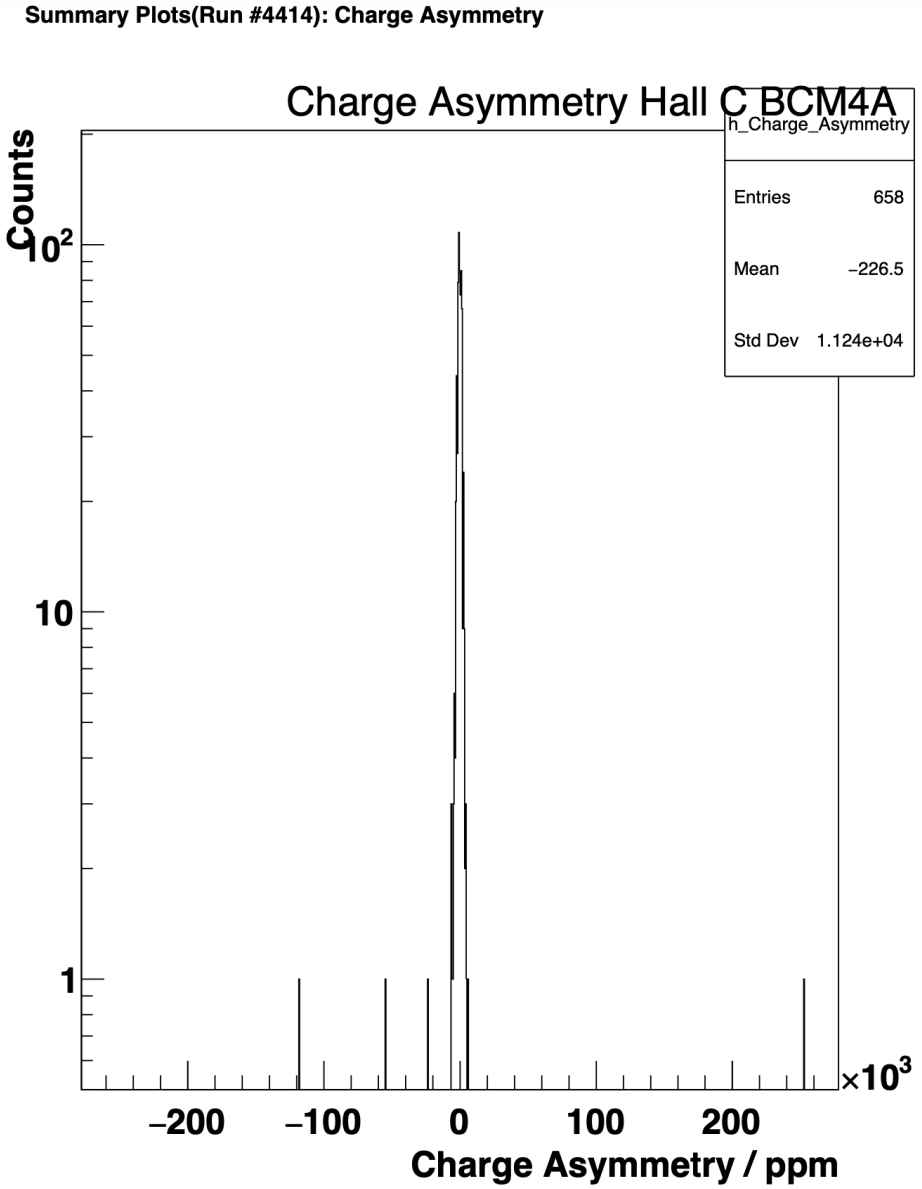


IN 4033-4063 4437-4517 57 runs
~ 0.35 million events

Helicity Analysis

Charge asymmetry

- There is a plot for charge asymmetry in the online GUI
- We ran the script for the first 50k events when taking data
- For most of the runs, the charge asymmetry is close to 0



THANKS!

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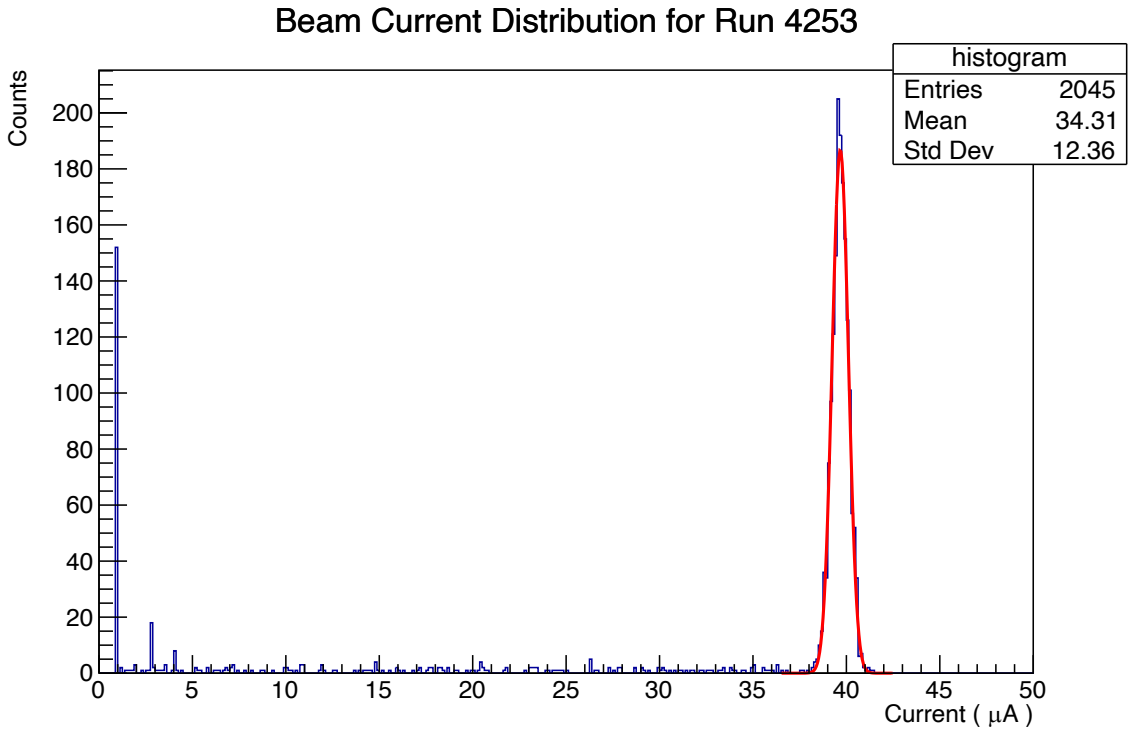
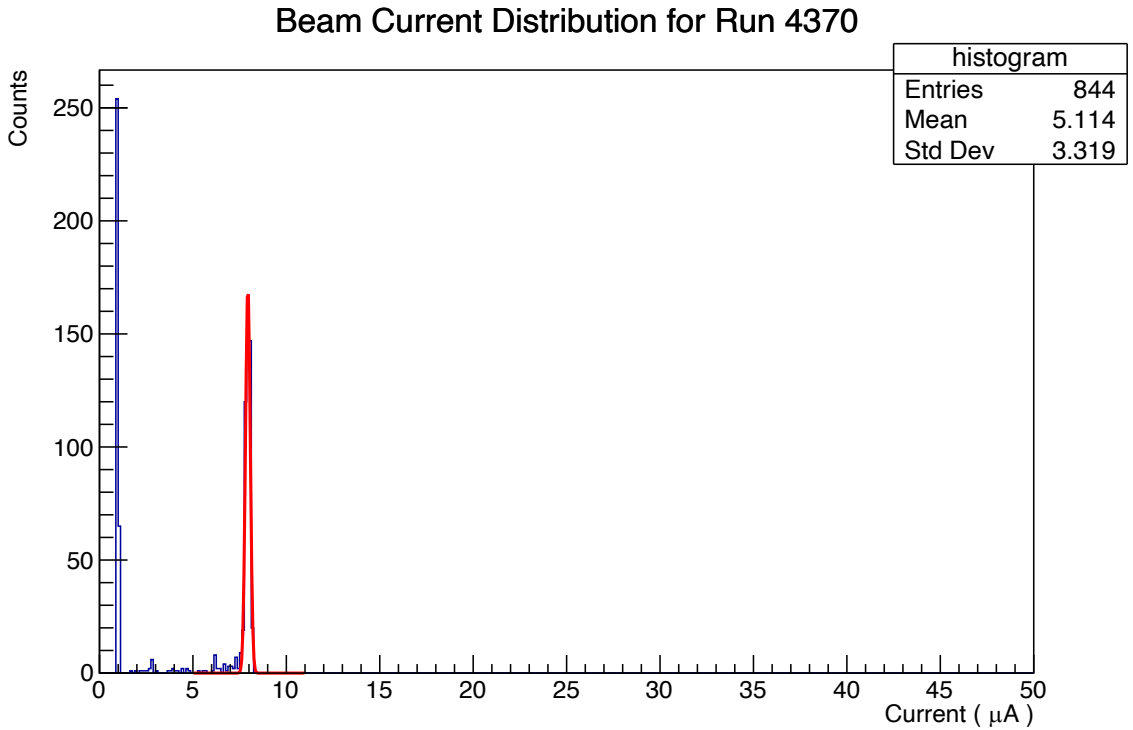
Appendix

Beam Current Calculation

- Gaussian Fitting



Run 4253

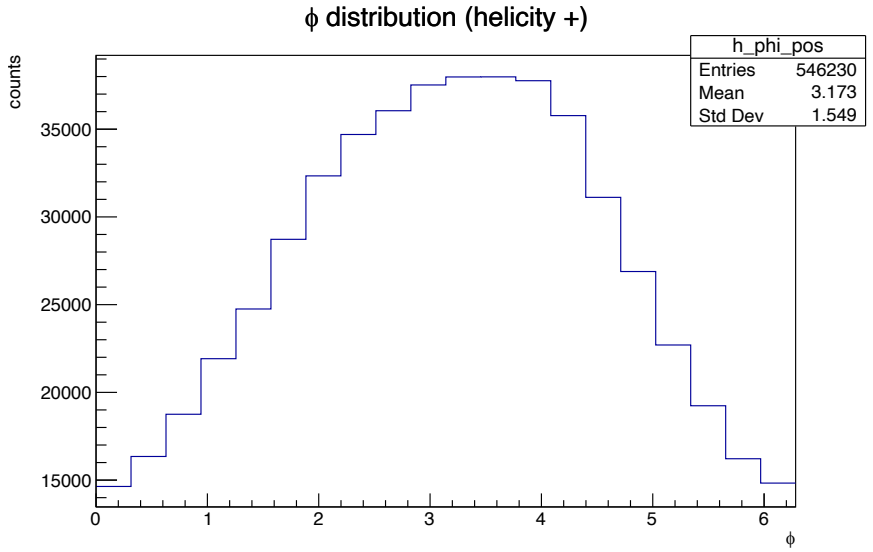


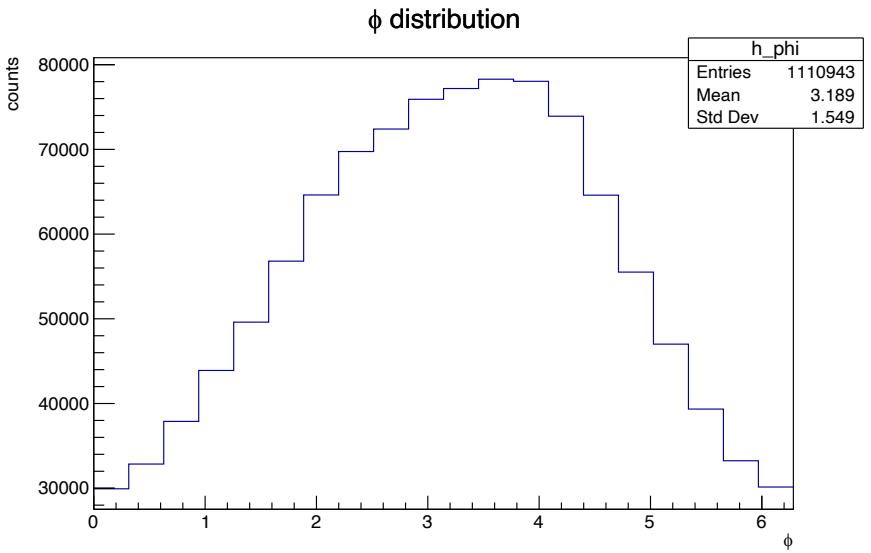
Run 4370

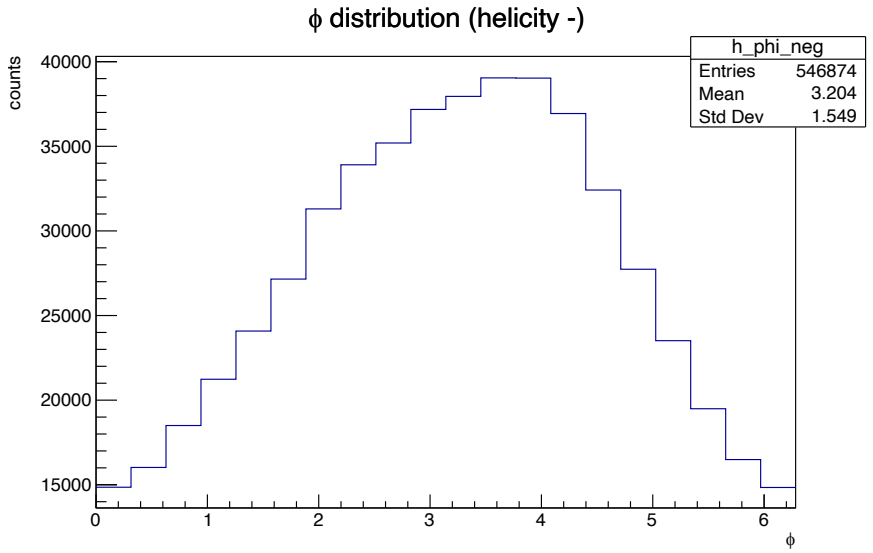
Appendix

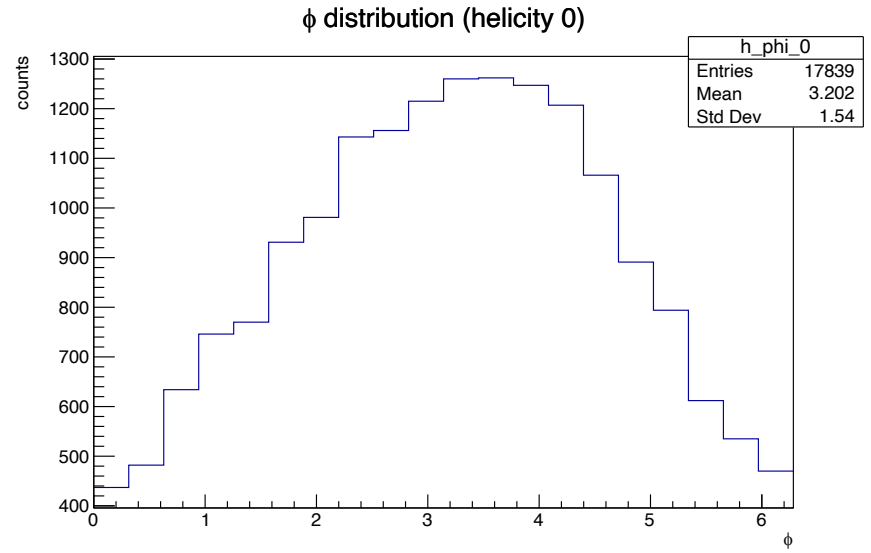
π^0 asymmetry

OUT 4064-4428 250 runs





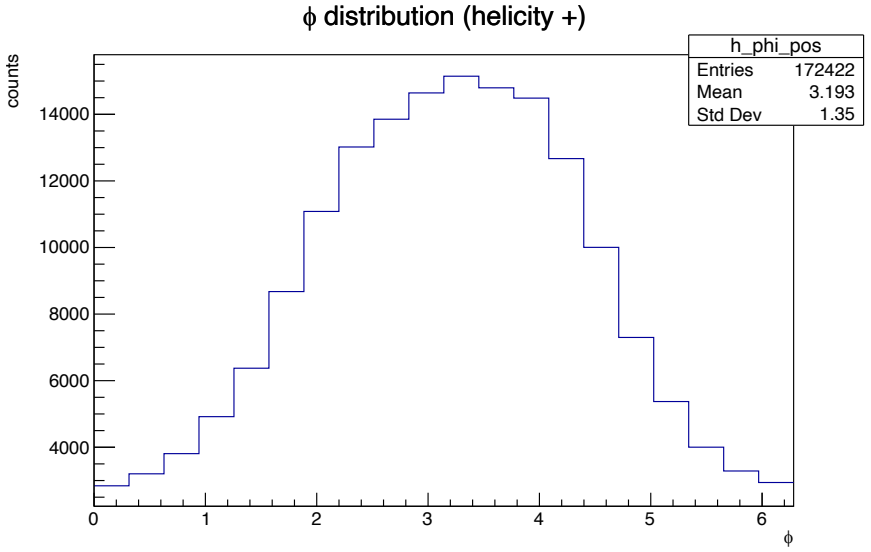


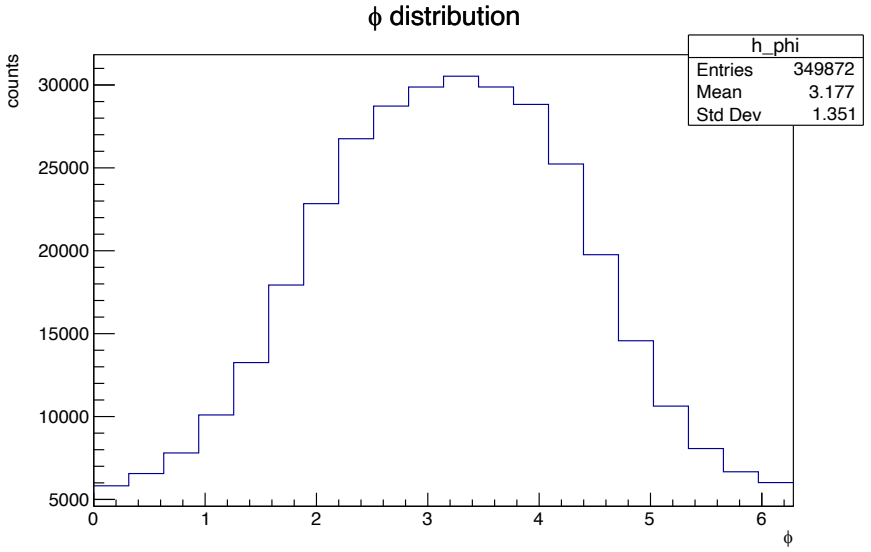


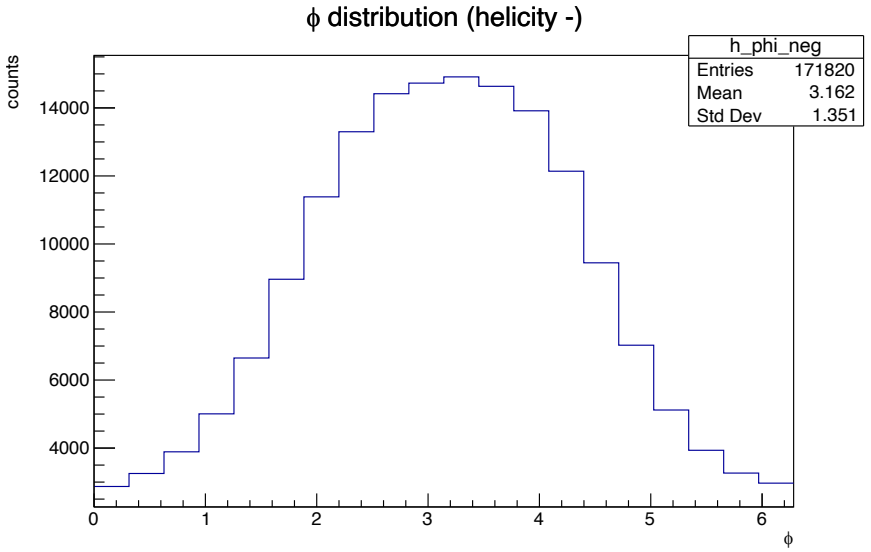
Appendix

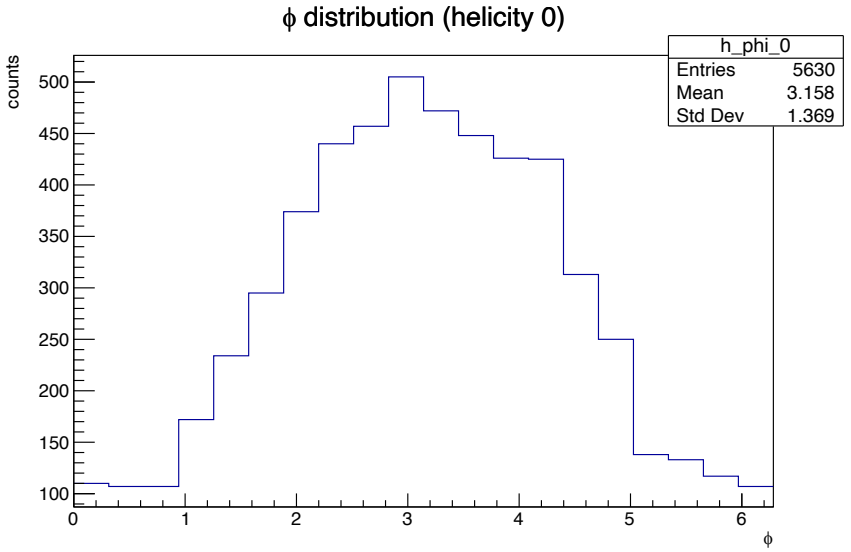
π^0 asymmetry

IN 4033-4063 4437-4517 57 runs









Appendix

π^0 asymmetry

➢ $\Delta A = \sqrt{1-A^2}\frac{\Delta N}{N} = \sqrt{1-A^2}\frac{1}{\sqrt{N}}$

$$A = \frac{N_+ - N_-}{N_+ + N_-}$$
$$N = N_+ + N_-, \quad N_+ = \frac{1}{2}N(1+A), \quad N_- = \frac{1}{2}N(1-A)$$
$$\Delta N = \sqrt{N} = \sqrt{N_+ + N_-}$$
$$\Delta N_+ = \sqrt{\frac{1}{2}(1+A)N} = \sqrt{\frac{1}{2}(1+A)}\Delta N$$
$$\Delta N_- = \sqrt{\frac{1}{2}(1-A)N} = \sqrt{\frac{1}{2}(1-A)}\Delta N$$

$$\frac{\partial A}{\partial N_+} = \frac{2N-}{(N_+ + N-)^2} = \frac{N(1-A)}{N^2} = \frac{1}{N}(1-A)$$
$$\frac{\partial A}{\partial N_-} = \frac{-2N+}{(N_+ + N-)^2} = -\frac{1}{N}(1+A)$$

$$\begin{aligned}\Delta A^2 &= \left(\frac{\partial A}{\partial N_+}\Delta N_+\right)^2 + \left(\frac{\partial A}{\partial N_-}\Delta N_-\right)^2 \\ &= \left[\frac{1}{N}(1-A)\sqrt{\frac{1}{2}(1+A)}\Delta N\right]^2 + \left[-\frac{1}{N}(1+A)\sqrt{\frac{1}{2}(1-A)}\Delta N\right]^2 \\ &= \left(\frac{\Delta N}{N}\right)^2\left[\frac{1}{2}(1-A)^2(1+A) + \frac{1}{2}(1+A)^2(1-A)\right] \\ &= \frac{1}{2}\left(\frac{\Delta N}{N}\right)^2(1-A^2)(1-A+1+A) \\ &= \left(\frac{\Delta N}{N}\right)^2(1-A^2)\end{aligned}$$

$$\Delta A = \sqrt{1-A^2}\frac{\Delta N}{N} = \sqrt{1-A^2}\frac{1}{\sqrt{N}}$$