Luminosity analysis

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Jefferson Lab

Luminosity runs

■ **Luminosity Run List (Sep 30, 2023 – Oct 01,2023)**

Target	RunNo	ps4	Pre-scale	Current (μA)	Duration (min)	Events	h3/4 rate (kHz)
LH2	1514	0	1	5	10	1023966	2.429
	1515	2	3	10	10	912408	4.966
	1516	3	5	15	10	751598	7.137
	1517	4	9	25	15	811950	11.509
LD2	1518	7	65	40	15	521346	48.681
	1519	6	33	25	10	485796	30.510
	1520	6	33	18	10	289841	22.035
	1521	5	17	10	10	328346	12.158
	1522	4	9	5	10	345025	6.152
Carbon	1523	4	9	35	10	180135	4.044
	1524	3	5	35	10	156607	3.893
	1525	3	5	40	10	187356	4.563
	1526	3	5	25	10	144809	2.831
	1528	2	3	15	10	153366	1.513
	1530	0	1	5	15	190627	0.560

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

■ **Luminosity Run List (May 13, 2024)**

Target	RunNo	ps4	Pre-scale	Current (μA)	Duration (min)	Events
Carbon	6845	0	1	5	10	130446
	6846	0	1	20	10	484576
	6847	0	1	15	10	323955
	6848	0	1	10	10	210257
	6849	0	1	3	14	83328
LH2	6850	0	1	5	10	170876
	6851	0	1	20	11	558105
	6852	0	1	15	10	440747
	6853	0	1	10	10	315654
	6854	0	1	3	10	118057

- ❑ KinC_x50_0
- ❑ EDTM 40Hz
- ❑ SHMS 36.88°

Carbon runs:

- ❑ HMS 21.05°

LH2 runs:

- ❑ HMS 25.94°

■ **Luminosity Run List (May 19, 2024)**

Target	RunNo	ps4	Pre-scale	Current (μA)	Duration (min)	Events
Carbon	7003	0	1	40	6	212049
	7004	0	1	30	8	207087
	7005	0	1	20	12	208227
	7006	0	1	10	22	217021
	7007	0	1	5	32	203780

- ❑ KinC_x60_3
- ❑ EDTM 40Hz
- ❑ SHMS 36.443°
- ❑ HMS 16.477°

Tables taken from Yaopeng.

Livetime Definitions (current cut: peak+-1uA)

1. Total EDTM Livetime

- **Definition**:

$$\text{Total EDTM Livetime} = \frac{\text{EDTM triggers accepted}}{\text{Total EDTM scalers}}$$

- **EDTM triggers accepted**:
  `T_hms_hEDTM_tdcTimeRaw[0] != 0`
- **Total EDTM scalers**:
  Accumulated in **TSH** tree
- **Note**:
  No current cut applied

2. Computer Livetime All (TSH)

- **Definition**:

$$\text{Computer LT (TSH)} = \frac{\text{Accepted triggers (scalers)}}{\text{Total hTRIG4 triggers (scalers)}}$$

- **Accepted triggers**:
  `H.hL1ACCP.scaler`
- **Condition**:
  Current cut applied

3. Computer Livetime All (TDC)

- **Definition**:

$$\text{Computer LT (TDC)} = \frac{\text{Accepted hTRIG4 (TDC)}}{\text{Total hTRIG4 (scalers)}} \times \text{beam\_on\_percent}$$

- **Accepted hTRIG4**:
  `T_hms_hTRIG4_tdcTimeRaw[0] != 0`
- **beam_on_percent**:

$$\frac{\text{trig\_accp\_total\_current\_cut}}{\text{trig\_accp\_no\_cut}} \quad \text{(from scalers)}$$

4. Computer Livetime Physics (TDC)

- **Definition**:

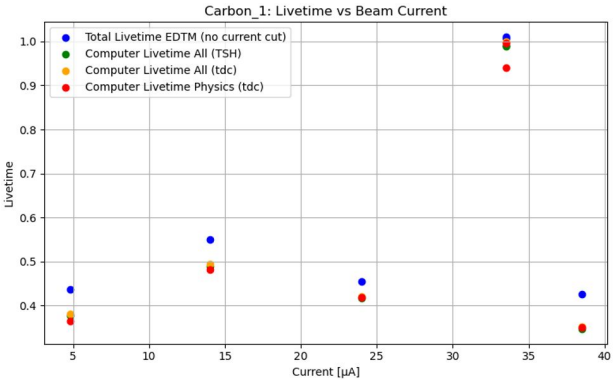
$$\text{Physics LT (TDC)} = \frac{\text{Accepted physics triggers (TDC)}}{\text{scaler\_hTRIG4\_total} - \text{scaler\_edtm\_total}} \times \text{beam\_on\_percent}$$

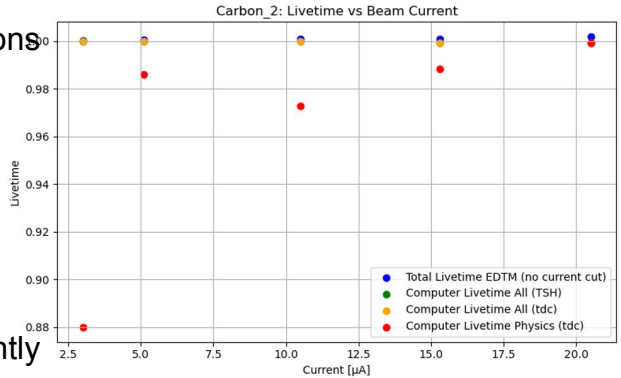
- **Accepted physics triggers**:
  `T_hms_hTRIG4_tdcTimeRaw[0] != 0` and `T_hms_hEDTM_tdcTimeRaw[0] == 0`

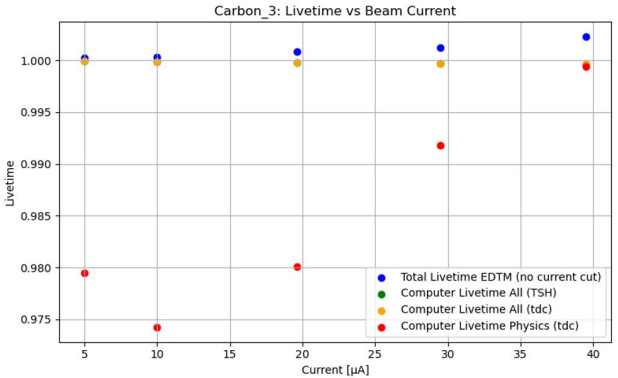
Carbon runs

EDTM Livetime > 1 in some runs → indicates logical inconsistency:

- More accepted than generated EDTM pulses — not physically possible.
- **Potential issues:**
  - Hardware/electronics limitations
  - DAQ **prescaling** errors?
- **Carbon 1**: Most extreme deviation
- **Carbon 2 & 3**:
  EDTM > 1
  Other livetimes < 1
  Physics livetime fluctuates significantly







LH2 and LD2 runs

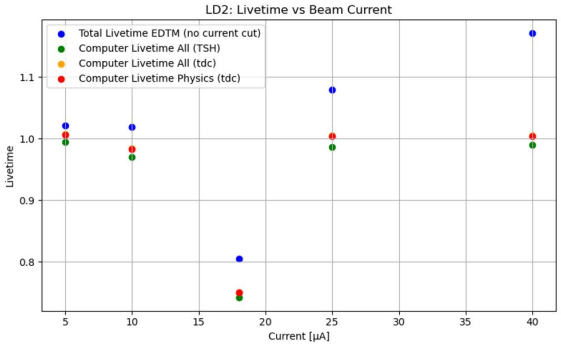
LH1_1: Livetime **increases with current** contrary to expectations

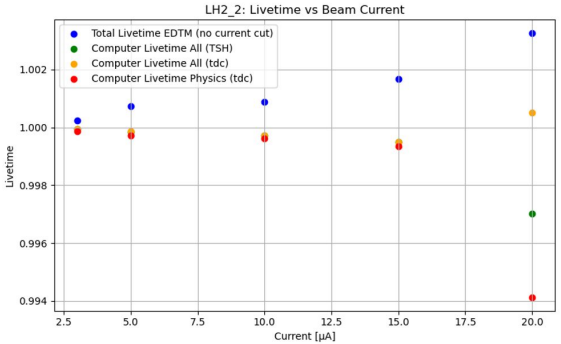
LH2_2:

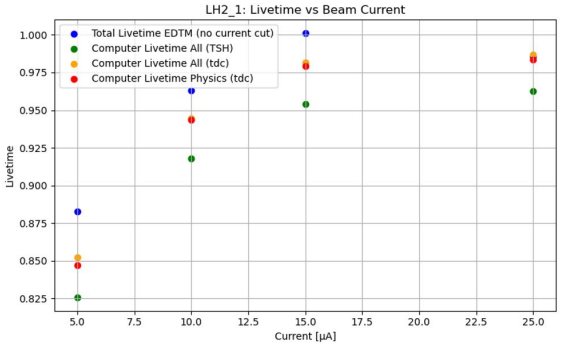
- EDTM > 1
- Most other livetimes approach 1 as current → 0

LD2:

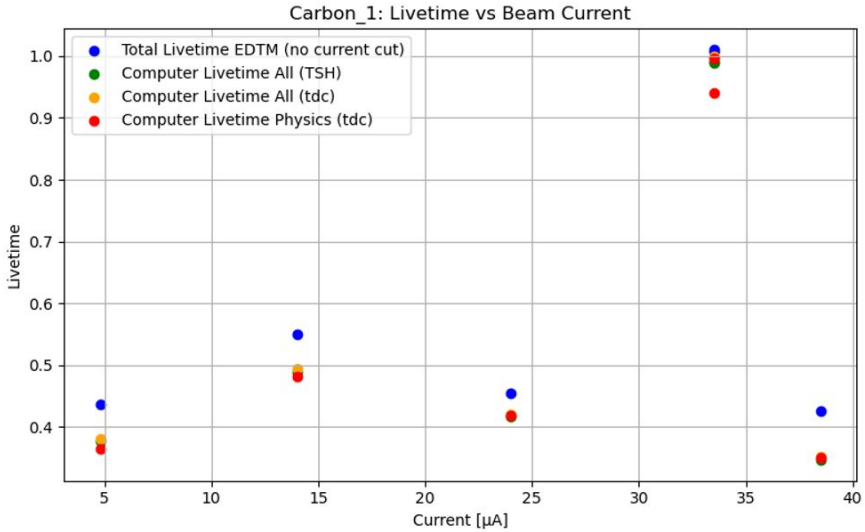
- EDTM > 1; other livetimes also exceed 1
- **Abrupt dip** around ~18 μA
- Possibly due to **sudden rate spike**; extrapolates to ~1 at zero current

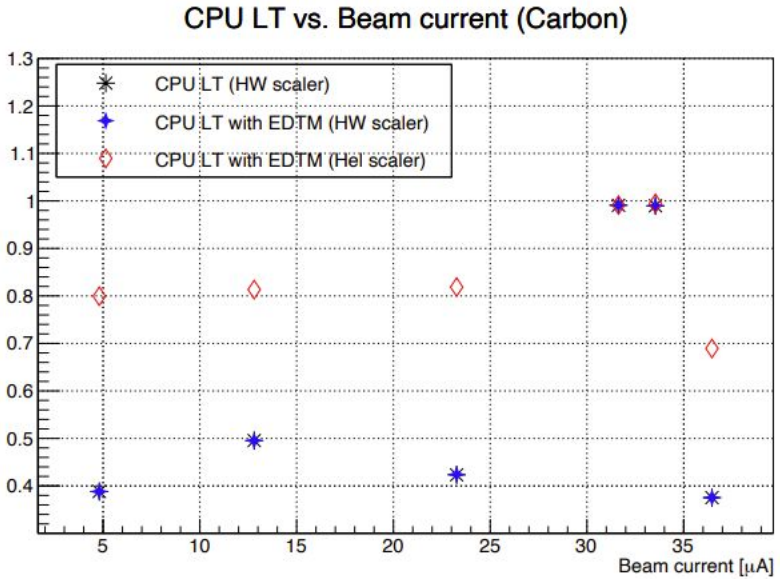






Comparison: Carbon 1

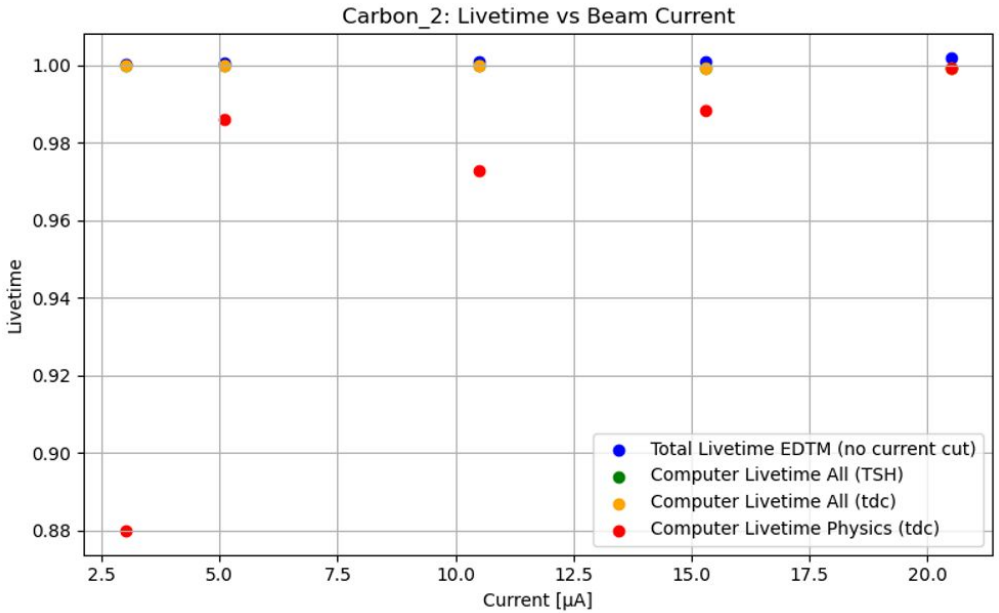


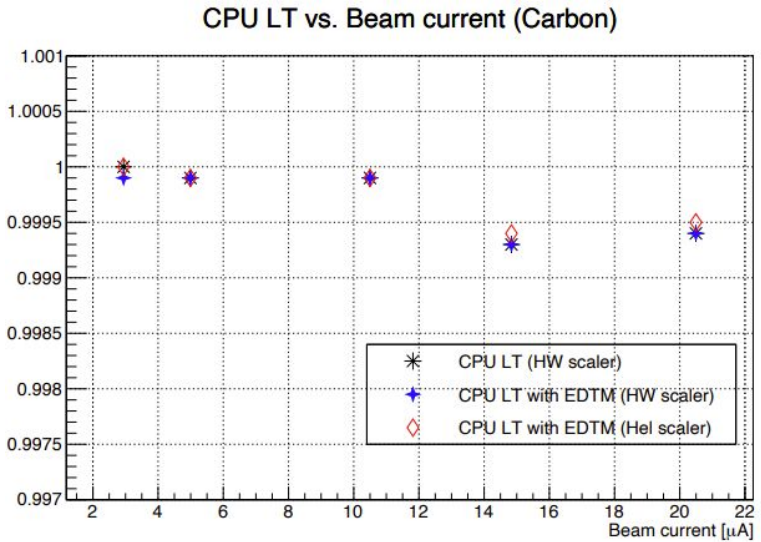


Computer Livetime Physics (tdc) ⟺ CPU LT (HW scaler);
Computer Livetime All (tdc) ⟺ CPU LT with EDTM (HW scaler)

Ref: Yaopeng

Comparison: Carbon 2

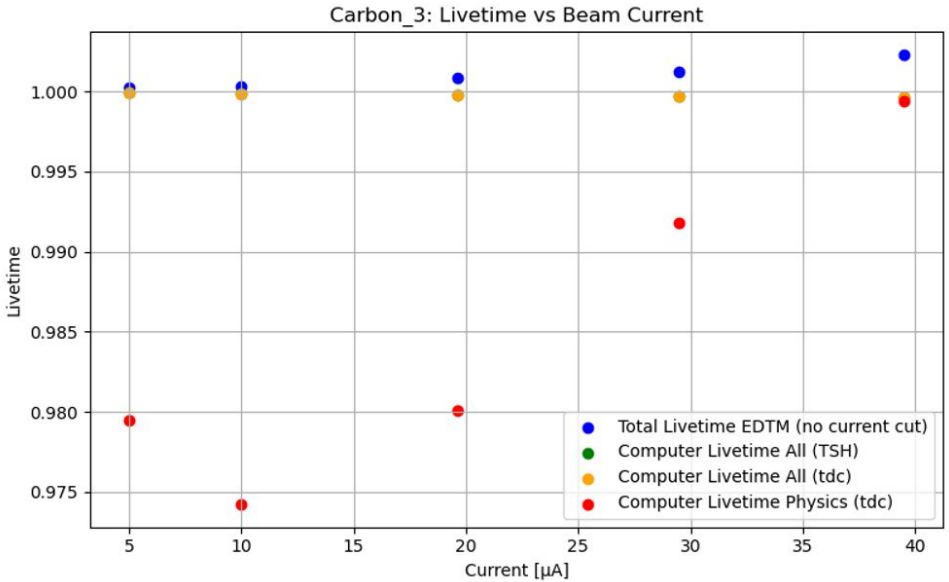


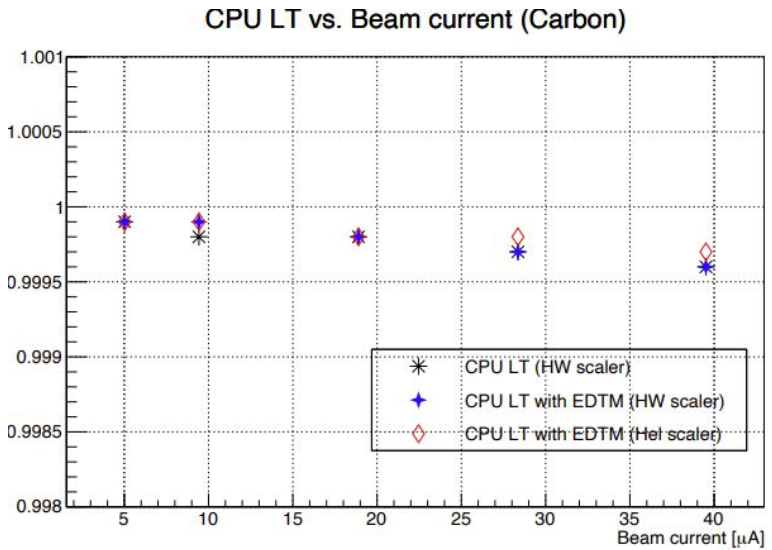


Ref: Yaopeng

Computer Livetime Physics (tdc) ⟺ CPU LT (HW scaler)
Computer Livetime All (tdc) ⟺ CPU LT with EDTM (HW scaler)

Comparison: Carbon 3





Ref: Yaopeng

Computer Livetime Physics (tdc) ⟺ CPU LT (HW scaler)
Computer Livetime All (tdc) ⟺ CPU LT with EDTM (HW scaler)

Investigation into Low Livetime in Luminosity Scans

run	beam_on_percent_edtm	beam_on_percent_trig_accp	TLT_livetime_edtm	CLTA_livetime_tsh	CLTA_livetime_tdc	CLTP_livetime_tdc
1524	0.282147	0.830967	1.006677	0.990288	0.999073	0.940895
1525	0.831179	0.850799	0.426136	0.34609	0.351903	0.349728
1526	0.942738	0.96411	0.455052	0.416527	0.420666	0.418816
1528	0.704111	0.870983	0.549617	0.489407	0.494703	0.481882
1530	0.860732	0.91566	0.436322	0.377493	0.381609	0.364245
6845	0.91214	0.97055	1.000651	0.999891	0.999898	0.986157

DAQ Issues Identified (Log Entry 4190122)

- **Runs 1526–1532**: npsvme3 failed to communicate with CODA
- CODA required multiple restarts
- **Runs 1526–1534**: Missing END_OF_RUN entries in logbook
  → Strong indicator that DAQ was not functioning properly

Anomaly in Run 1525

- Run 1525 has low livetime **despite** a valid END_OF_RUN entry
- **Green highlight**: large difference between
  - `beam_on_percent_edtm`
  - `beam_on_percent_trig_accp`
- This discrepancy is **unique** to Run 1524 onward

- **Red** = runs with low livetimes
- **Green** = notable beam-on discrepancy

$$\textbf{Beam On \%} = \frac{\text{Accepted Triggers (with current cut)}}{\text{Accepted Triggers (no cut)}}$$

Change in ps_factor and Potential Misconfiguration

- **ps_factor changed in Run 1524**
- Known CODA issue: ps_factor changes may not save correctly
- Likely caused problematic DAQ configuration
- May explain both beam-on mismatch and DAQ failures

Carbon	1523	4	9	35	10	180135	4.044
	1524	3	5	35	10	156607	3.893
	1525	3	5	40	10	187356	4.563
	1526	3	5	25	10	144809	2.831
	1528	2	3	15	10	153366	1.513
	1530	0	1	5	15	190627	0.560

Summary of livetimes

- ps_factor change in Run 1524 correlates with beam-on tracking anomaly
- Runs 1525–1530 show unusually low livetimes
- Runs 1526–1534 lack proper END_OF_RUN entries
- CODA likely failed to read or record data correctly during this period
- Decide on the usability of the first luminosity scan.
- Need to decide which livetime to use.

Yield Definitions

Accepted Trigger:

- `T_hms_hTRIG4_tdcTimeRaw[0] != 0`

Untracked Yield Criteria:

- `TRIG4` fired
- `H_cer_npeSum[0] > 2`
- `|H_cal_etotnorm[0] - 1| < 0.4`
  → Counted as **untracked event**

Tracked Yield Criteria (All above + tracking cuts):

- `|H_gtr_dp[0]| < 10`
- `|H_gtr_th[0]| < 0.09`, `|H_gtr_ph[0]| < 0.055`
- `H_gtr_ok[0] == 1`, `H_react_ok[0] == 1`
  → Counted as **tracked event**

- **Scaler Yield**:

$$\frac{\text{Accumulated } hTRIG4 - \text{Accumulated EDTM}}{\text{Accumulated Charge}}$$

- **Untracked Yield**:

$$\frac{\text{Accepted Untracked TRIG4} \times \text{Beam On \%} \times \text{PS Factor}}{\text{Accumulated Charge} \times \text{Livetime}}$$

- **Tracked Yield**:

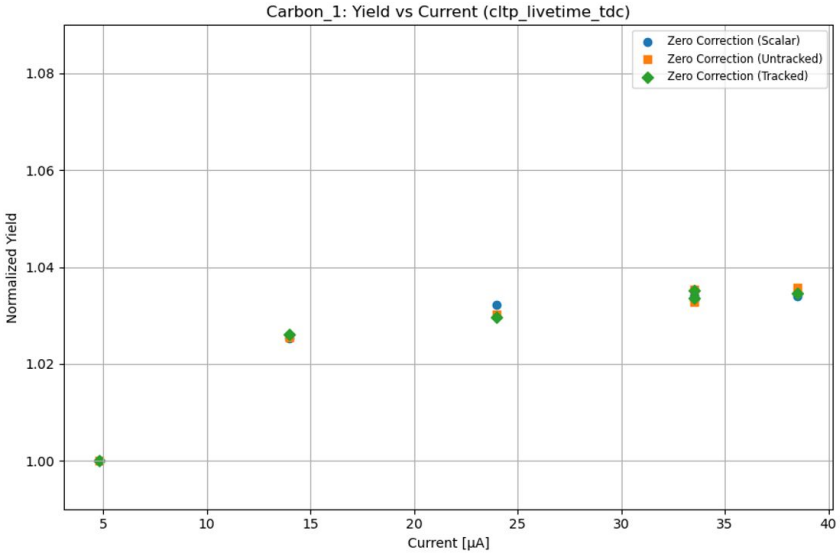
$$\frac{\text{Accepted Tracked TRIG4} \times \text{Beam On \%} \times \text{PS Factor}}{\text{Accumulated Charge} \times \text{Livetime}}$$

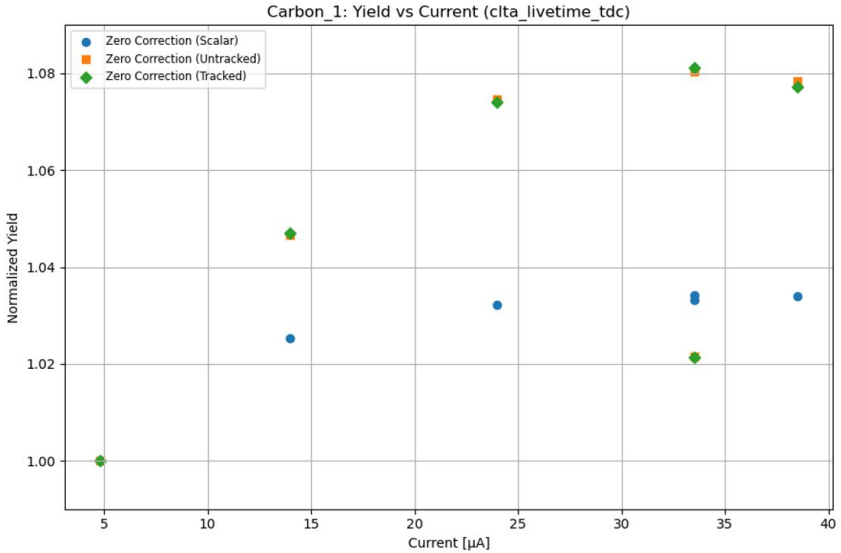
- Used to map scaler-based livetime (TSH tree) to event-level triggers (T tree), since there's no direct one-to-one mapping.

$$\textbf{Beam On \%} = \frac{\text{Accepted Triggers (with current cut)}}{\text{Accepted Triggers (no cut)}}$$

- Triggers counted from: `H.hL1ACCP.scaler`

Carbon Yields: Carbon 1

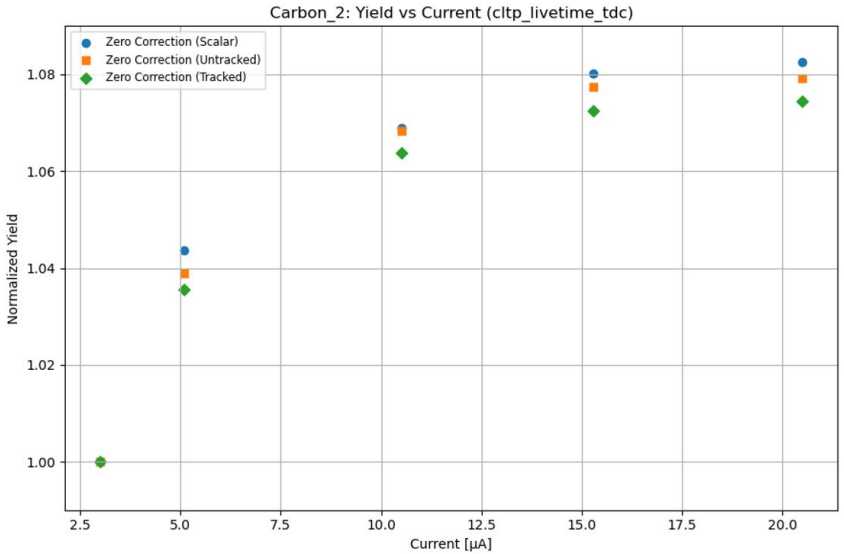


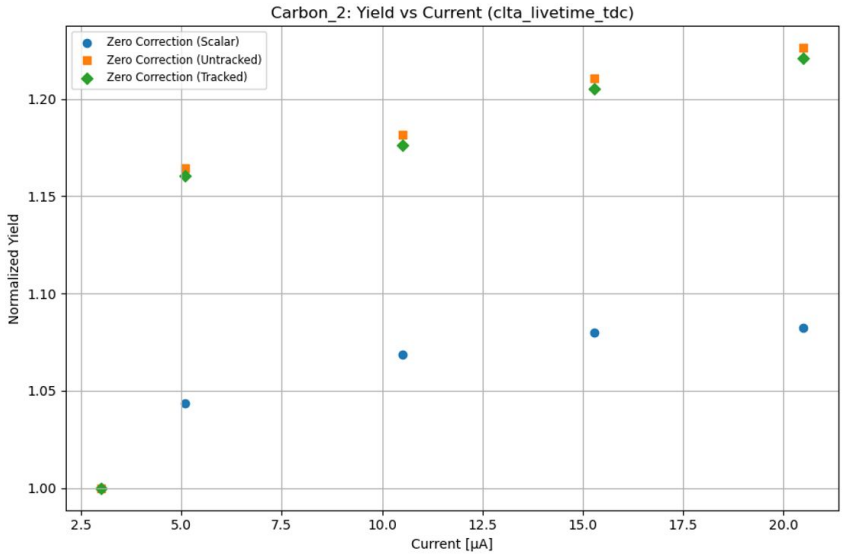


- **Tracked and untracked yields**, calculated using **computer livetime (physics triggers only)**, **match** the **scaler-based yields** trend. This consistency **supports Yaopeng's findings**.

- However, when using **computer livetime (all triggers = physics + EDTM)**, the **tracked and untracked yields** show **deviations up to ~20%** from scaler-based yields.

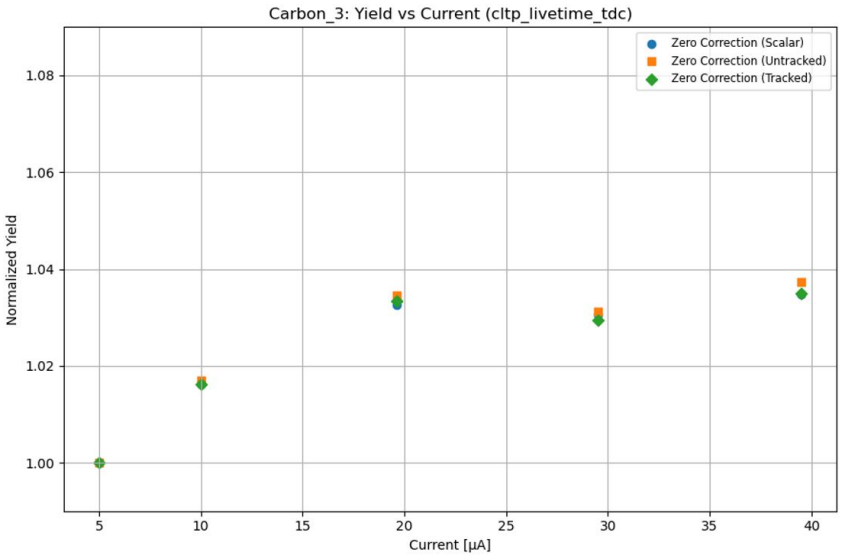
Carbon Yields: Carbon 2

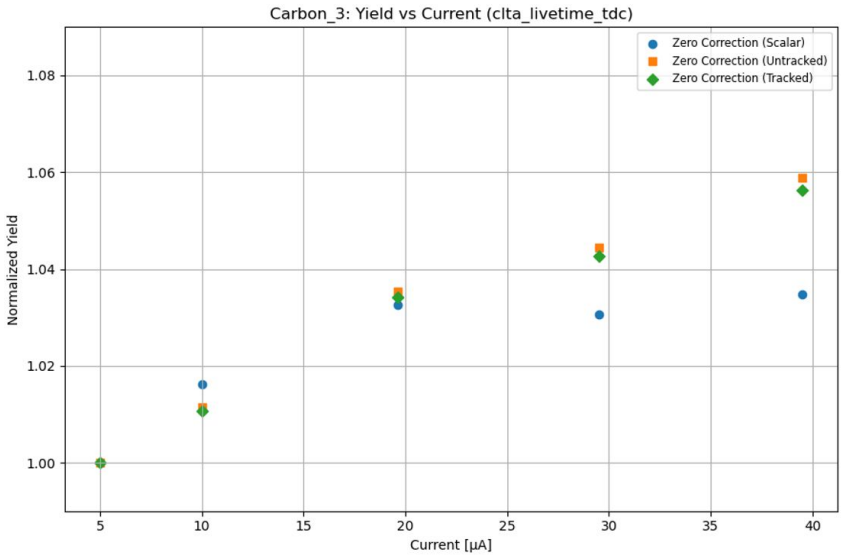




- Need to decide on the more reliable between the two livetimes.

Carbon Yields: Carbon 3





- Need to decide on the more reliable between the two livetimes.

Flattening the Carbon runs

Observed an *“anti-boiling”* trend — an increase in Carbon’s charge-normalized yield with increasing beam current.

Initialize: Load TSH tree to access scaler info from ROOT files.

Select Current Window: Filter events within peak ± 1.0 μA (adjustable).

Filter Events: Exclude events outside current window for all scaler sums.

Accumulate Scalers: Use 2 s intervals (via 1 MHz clock) to sum accepted scalers.

Apply Correction:

- Compute:
  `corrected_current = BCM4A_current + correction`
- Use to calculate corrected total charge.

Optimize Correction:

- Tune correction to minimize deviation from unity in Carbon yields.
- Cost function:
  $\text{cost} = \sum(\text{normalized\_yields}_i - 1)^2$

Apply to LH2/LD2: Use optimal Carbon correction for final yield normalization.

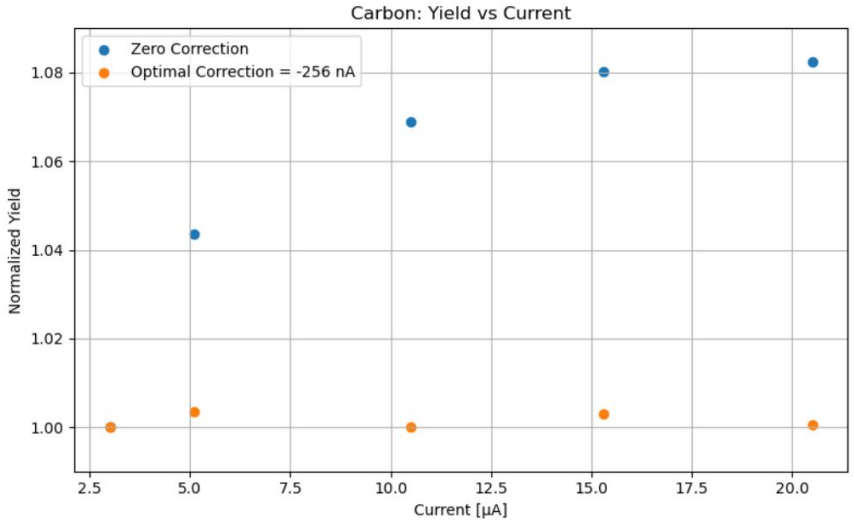
Correction methods

To correct this effect, I implemented two approaches:

1. **Global Correction**
    - Based on the method used in the **KaonLT** experiment.
    - Applies a fixed offset to the **BCM4A current** (in Amperes).
    - KaonLT used a global shift of **33 nA**.
2. **Rate-Dependent Correction**
    - Accounts for **Unser monitor noise**, modeled as at least **2 μA /√Hz**.
    - Correction applied dynamically based on beam rate.
    - Unit: **A√Hz**

Global correction

- Applies a **fixed offset** (in Amperes) to `BCM4A_current`, regardless of run conditions:
  `corrected_current = BCM4A_current + correction`
- **Optimized corrections** for Carbon run periods:
- Results align with Yaopeng's estimate of **~200 nA**.

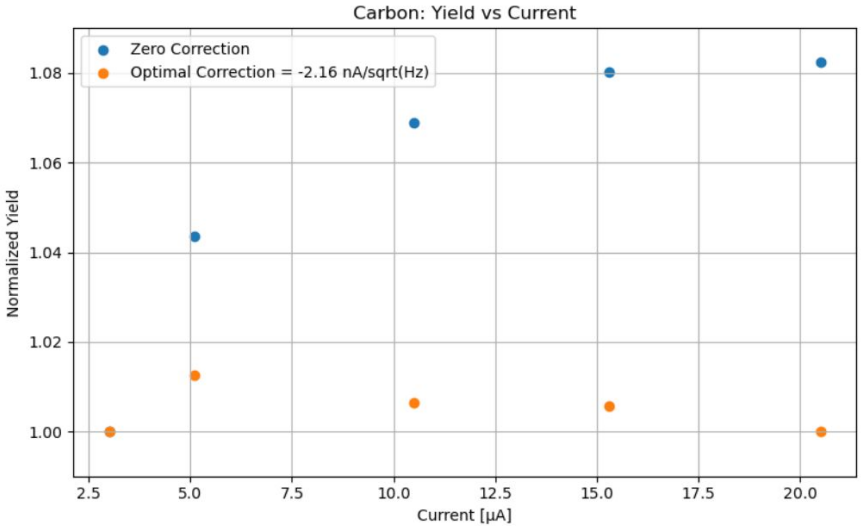


Run Period	Optimal Correction
Carbon 1 (1523 – 1530)	−185 nA
Carbon 2 (6845 – 6849)	−256 nA
Carbon 3 (7003 – 7007)	−203 nA

Table: Correction values based on the scaler yields.

Rate dependent method

- Correction varies with **BCM scaler rate**, computed every **2 s interval**.
- Formula:
  `corrected_current = BCM4A_current + correction × √(BCM_rate)`
- **Correction unit**: A/√Hz



Runs	Optimal_correction
Carbon 1 (1523 - 1530)	-1.16 nA/$\sqrt{\text{Hz}}$
Carbon 2 (6845 - 6849)	-2.16 nA/$\sqrt{\text{Hz}}$
Carbon 3 (7003 - 7007)	-1.17 nA/$\sqrt{\text{Hz}}$

Table: Correction values based on the scaler yields.

Summary

- Four definitions of livetimes were studied.
- Two definitions called “Computer livetime All (tdc)” and “Computer livetime Physics (tdc)” bear confidence. (refer slide 4)
- Livetimes as calculated by Yaopeng are in disagreement for some runs which ask for further investigation into the detailed implementation of livetimes as compared to this study.
- First luminosity scan might be bugged due to the crashed CODA.
- Scaler, untracked, and tracked normalised yields were calculated and compared using two different livetime definitions as mentioned above.
- A difference in the two yields is shown by the two methods.
- Need to decide on which livetime to use for the analysis.
- Two correction methods for flattening the Carbon runs are checked.

Thank you for listening :D

Extras

Livetime definitions

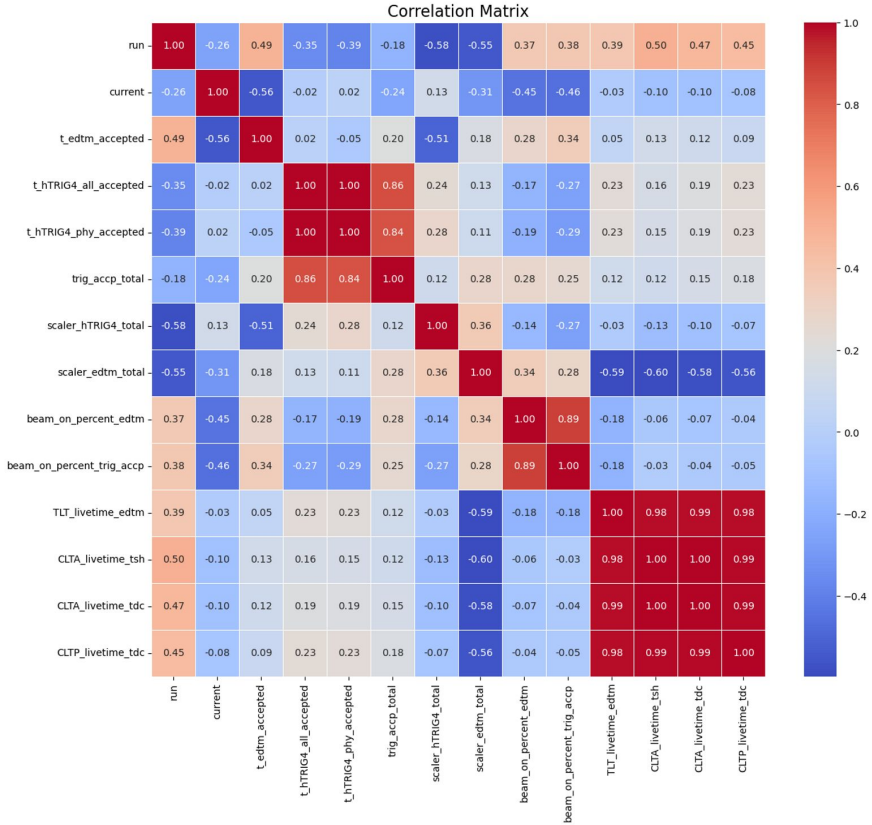
Total EDTM livetime = (EDTM triggers accepted)/(Total EDTM scalers); EDTM triggers accepted: T_hms_hEDTM_tdcTimeRaw[0] != 0; Total EDTM scalers: Total edtm scalers accumulated in TSH tree; No current cut

Computer Livetime All (TSH) = (accepted triggers accumulated in scalers)/(total hTRIG4 triggers accumulated in scalers); Current Cut; accepted triggers: H.hL1ACCP.scaler

Computer Livetime All (tdc) = ((accepted hTRIG4 triggers from tdcTimeRaw)/(total hTRIG4 triggers accumulated in scalers))*beam_on_percent; accepted hTRIG4: T_hms_hTRIG4_tdcTimeRaw[0] != 0; beam_on_percent = (trig_accp_total_current_cut/trig_accp_no_cut) from scaler

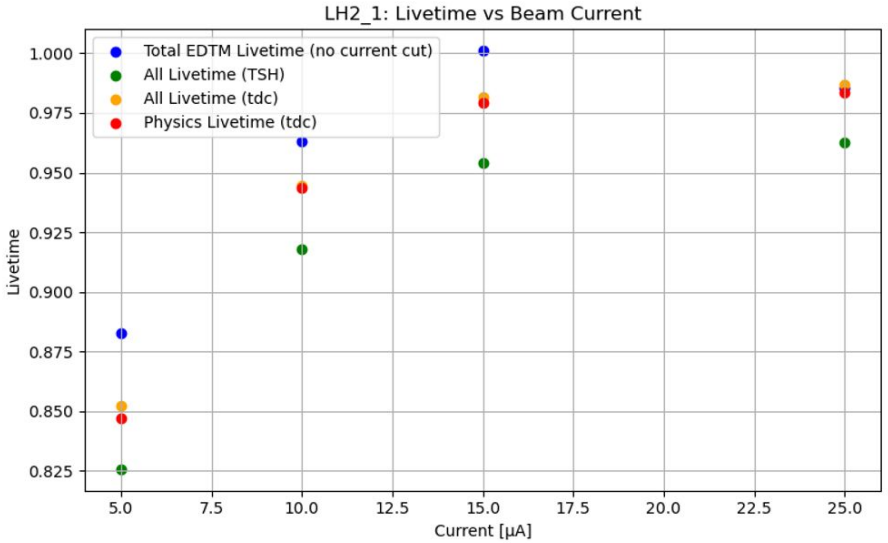
Computer Livetime Physics (tdc) = (accepted physics triggers from tdcRawTime)/(scaler_hTRIG4_total - scaler_edtm_total)*beam_on_percent; accepted physics triggers: T_hms_hTRIG4_tdcTimeRaw[0] !=0 and T_hms_hEDTM_tdcTimeRaw[0] == 0:

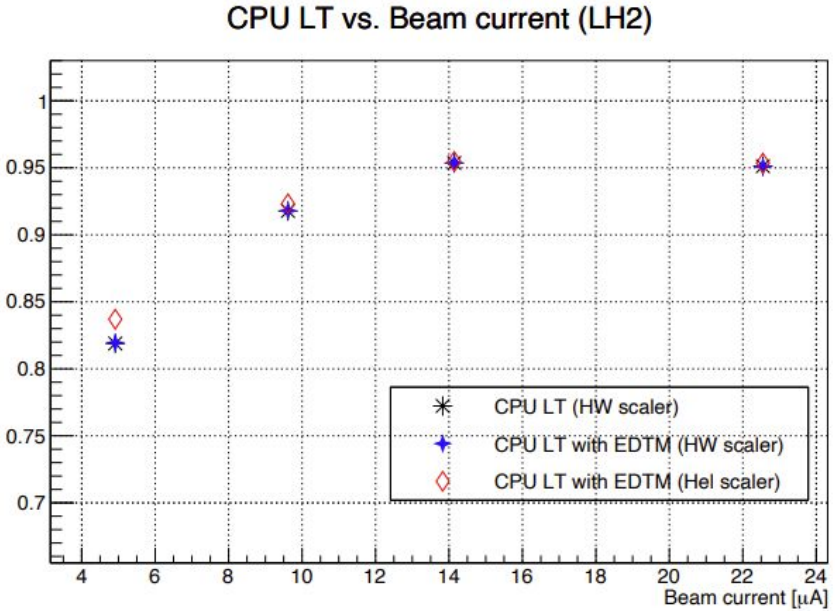
Correlations



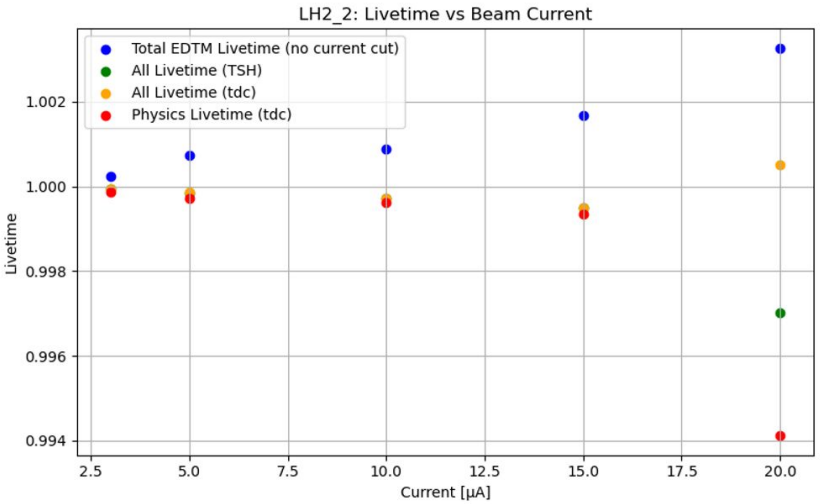
No correlation found between the variables.

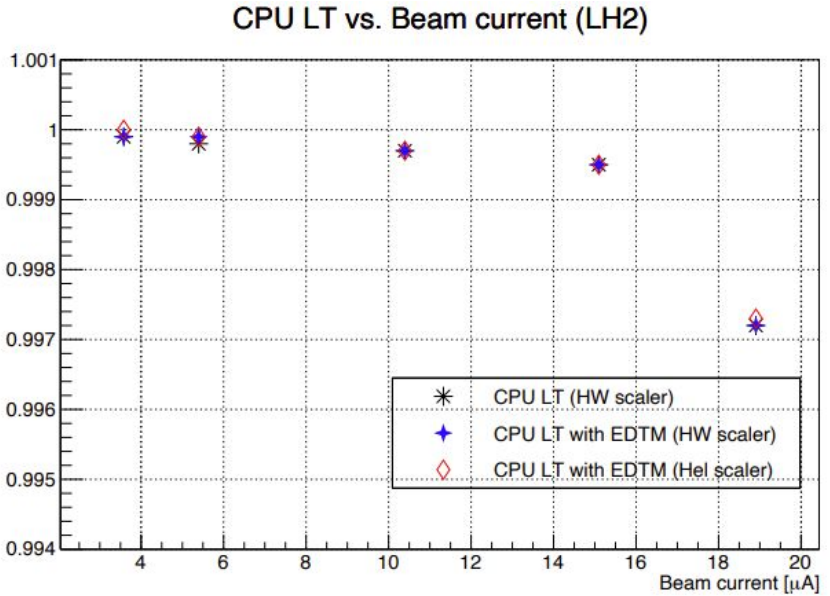
Comparison: LH2_1 livetimes



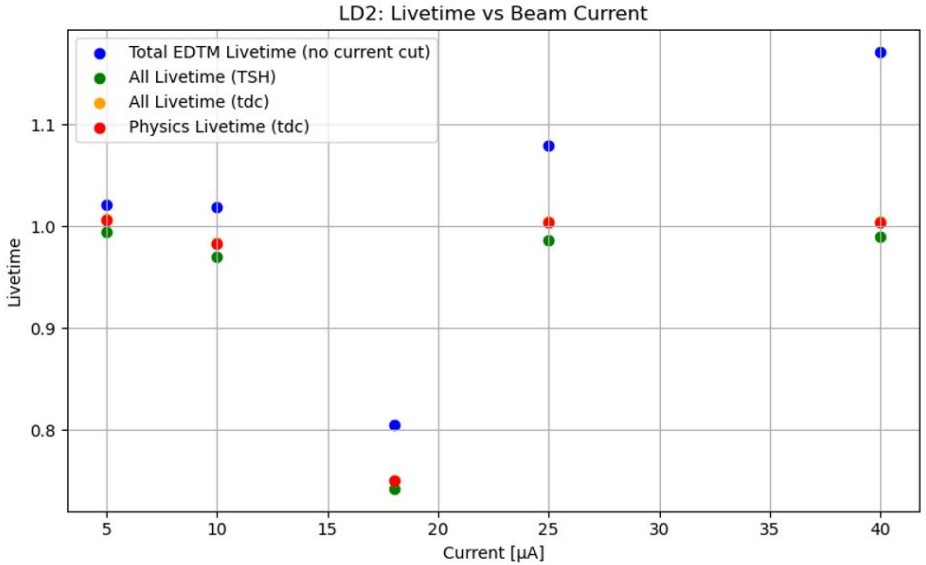


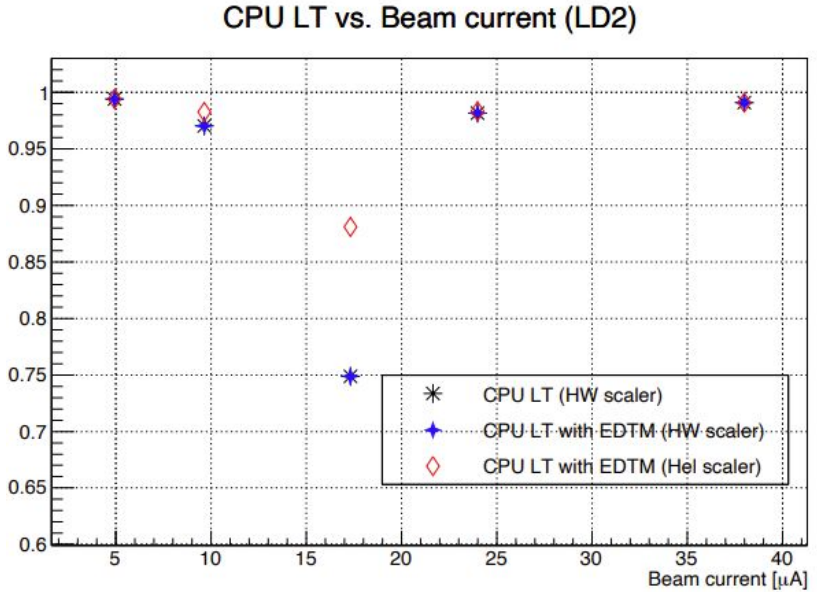
Comparison: LH2_2 livetimes



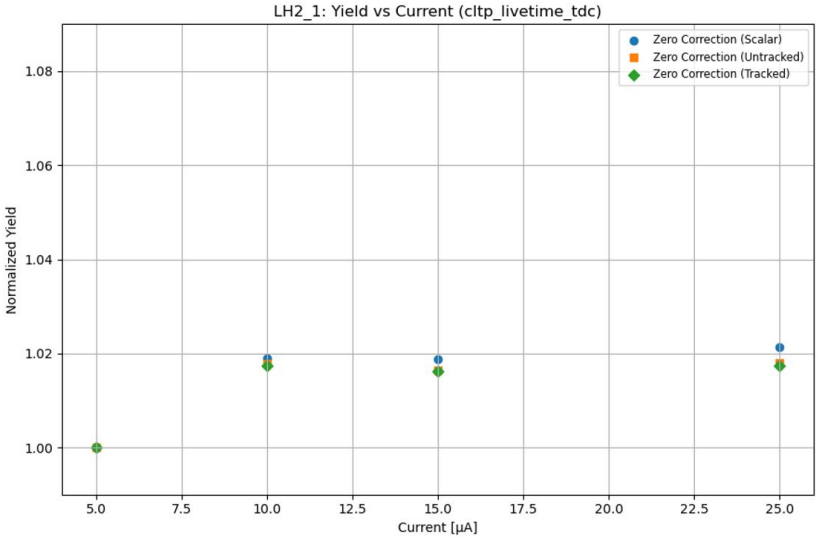


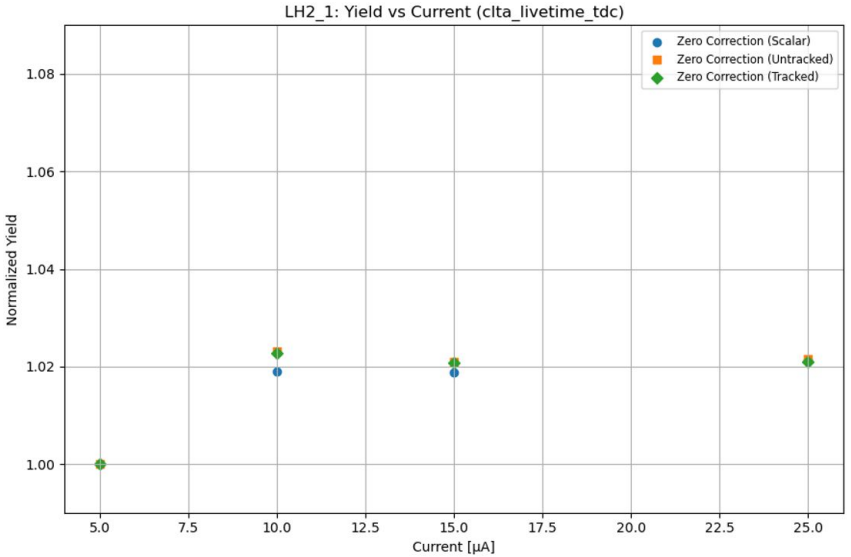
Comparison: LD2 livetimes



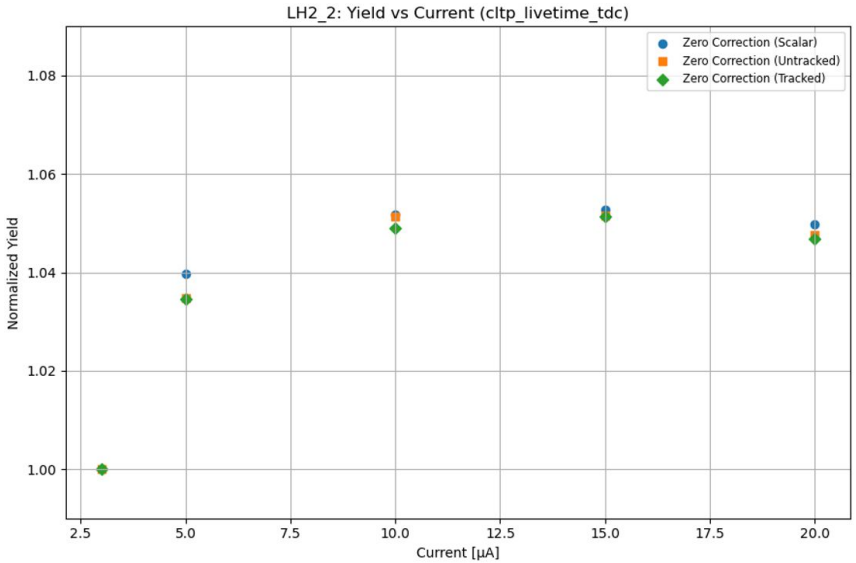


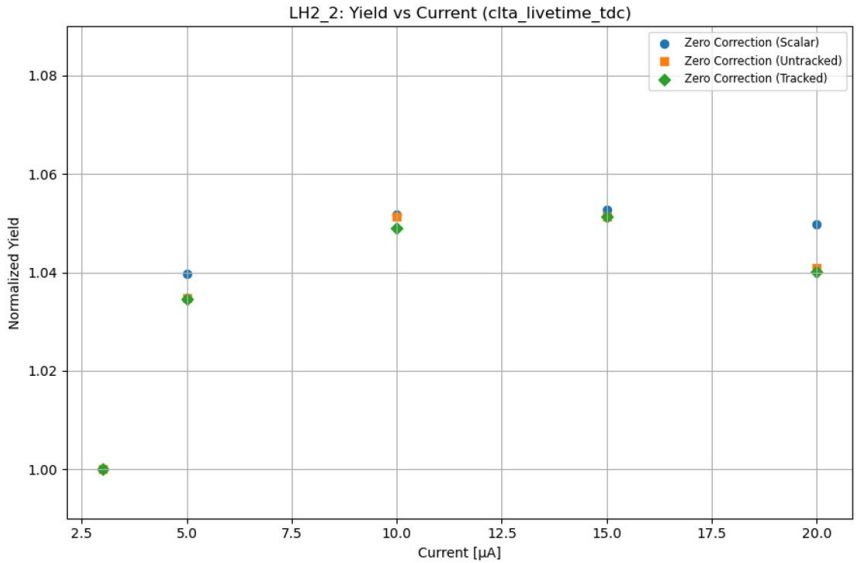
LH2 Yields


LH2_1: Yield vs Current (cltp_livetime_tdc)
Zero Correction (Scalar)
Zero Correction (Untracked)
Zero Correction (Tracked)
Normalized Yield
1.08
1.06
1.04
1.02
1.00
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
Current [μA]

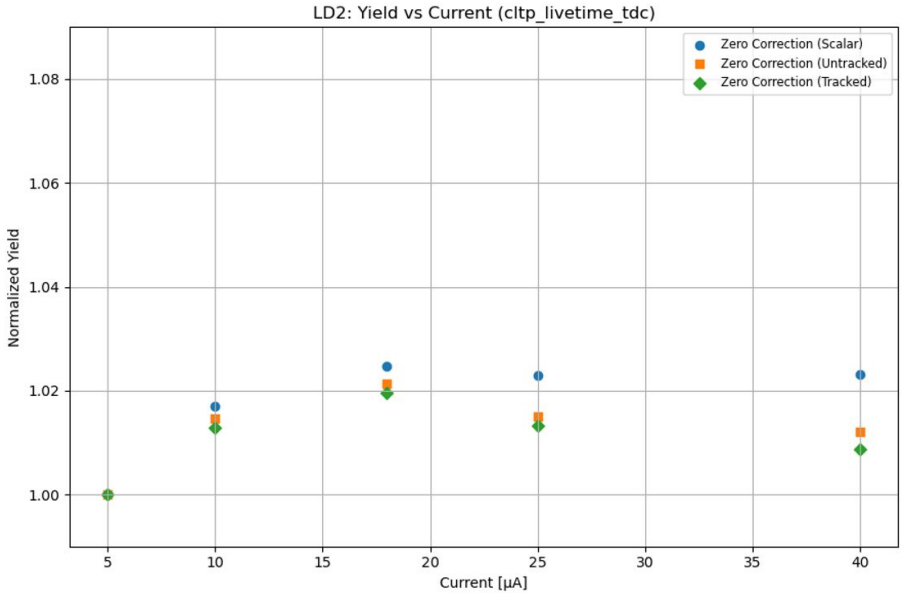

LH2_1: Yield vs Current (clta_livetime_tdc)
Zero Correction (Scalar)
Zero Correction (Untracked)
Zero Correction (Tracked)
Normalized Yield
1.08
1.06
1.04
1.02
1.00
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
Current [μA]

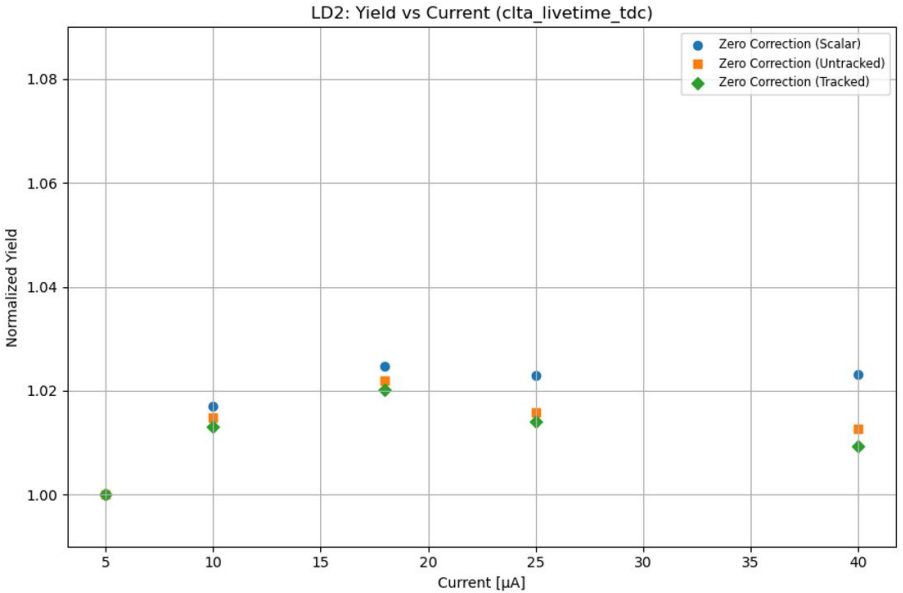
LH2 Yields (2nd scan)



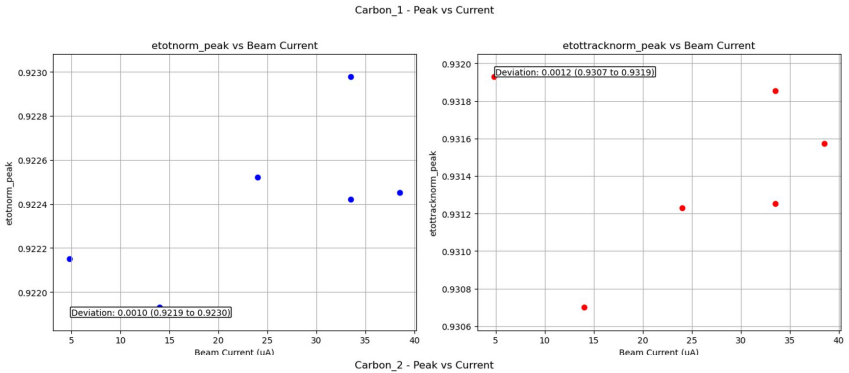


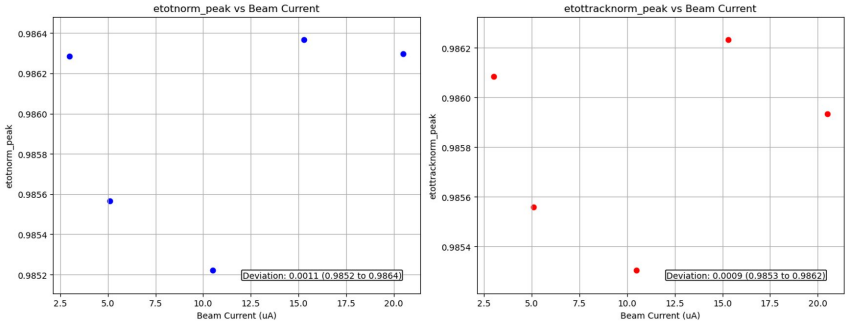
LD2 Yields


LD2: Yield vs Current (cltp_livetime_tdc)
Zero Correction (Scalar)
Zero Correction (Untracked)
Zero Correction (Tracked)
Normalized Yield
1.08
1.06
1.04
1.02
1.00
5
10
15
20
25
30
35
40
Current [μA]


LD2: Yield vs Current (clta_livetime_tdc)
Zero Correction (Scalar)
Zero Correction (Untracked)
Zero Correction (Tracked)
Normalized Yield
1.08
1.06
1.04
1.02
1.00
5
10
15
20
25
30
35
40
Current [μA]

E/P peaks against current (carbon runs)

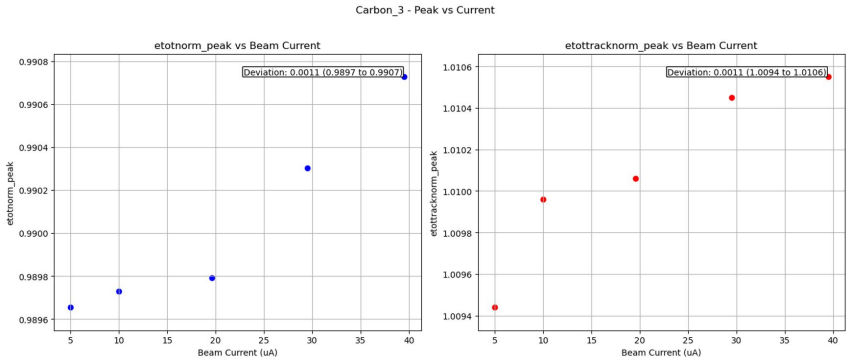




Reasoning:
A **positive shift** could push more pions above the **etotnorm > 0.7** cut, possibly **inflating yields**.

Carbon runs show a **~0.11% shift** in peak position.
→ Envelope estimates indicate **negligible impact** on yield.

For **LD2 and LH2**, a more detailed study could help, but currently deemed **non-critical** after further discussion.



E/P peaks against current (LH2 and LD2 runs)