Luminosity Analysis of PionLT/KaonLT

2024 NPS Collaboration Meeting

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Introduction to Luminosity Scans

- Physical measurements are independent of luminosity therefore luminosity scans provide…
  - A means to understand the accuracy of the efficiencies
  - Correct for any rate dependencies
  - Correct for any target boiling that may occur at higher currents

- DIS measurements are taken as a function of current on a target (LH2, LD2, Carbon) and efficiency corrected yields are analyzed.
- Data is collected at set kinematic conditions while altering beam currents for both the cryotarget (e.g., LH2) and Carbon-12
  - Carbon-12 is used as a reference point because of its high boiling point (4098 K), which far exceeds any heat the beam can create
- By looking at the relative yield, the yield of each current normalized by the lowest, the trend of the yields versus current should be flat.
- For Carbon-12, this comparable yield should be constant for all currents, so any deviation indicates systematic effects.

Luminosity Analysis Procedure

- Steady beam is crucial!
- Since the carbon density should not change with current/rate…
  - Any deviation of the yield from unity is indicative of a rate dependence in an efficiency that needs to be addressed.
- Once carbon is understood one can move onto cryotarget
  - Any deviation of the yield from unity is indicative of possible target boiling that will need to be corrected
- Carbon analysis first then repeat for cryotarget
  - Scaler Yields
    - Current cuts, scaler check
  - Non-track Yields
    - PID cuts, TLT check
  - Track Yields
    - Tracked cuts, track efficiency check

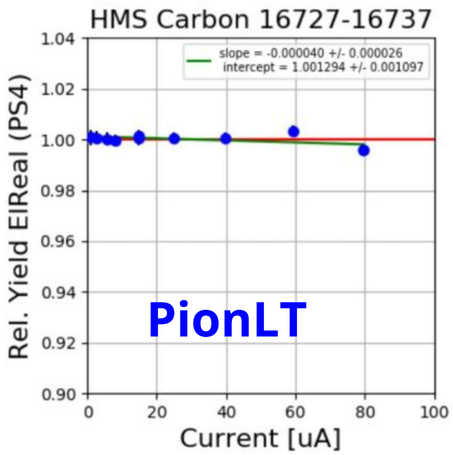
Scaler Yield Calculation

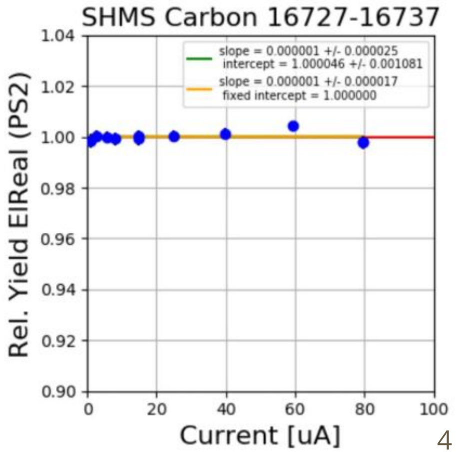
PionLT Analysis by Nathan Heinrich and Zach Sullivan

$$N_{scaler} = \Sigma(trigscaler) - EDTM_{scaler}$$

$$Y_{scaler} = \frac{N_{scaler}}{Q_{tot}}$$

$$Q_{tot} = (H.BCM.scaler.charge)$$

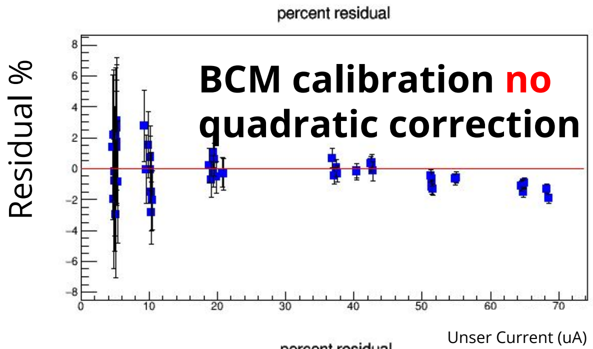


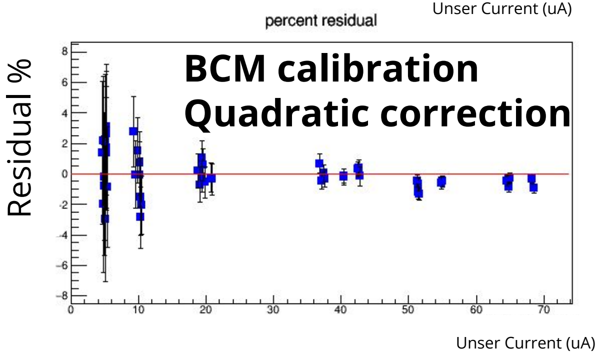


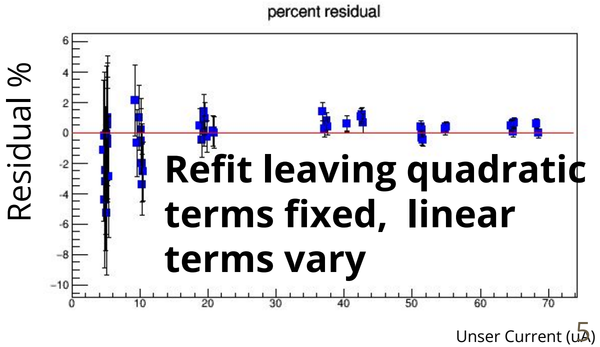
Total Charge Preparation

- Before calculating total charge
  - Proper BCM calibrations
    - For KaonLT, Dave Mack provided these
    - For PionLT, Nathan Heinrich has some good updates (see on KaonLT Redmine)
  - Determine current threshold cut
    - At the scaler recount level,
      |bcm_scaler-set_current| < thres_current
- Increment over all scaler counts to reproduce scalers
  - UTIL_KAONLT example
  - Recalculate charge with proper beam-on-time
  - Sufficient current cut such that…
    - Remove ramp up and trips

Next Quarterly Analysis Meeting topic??







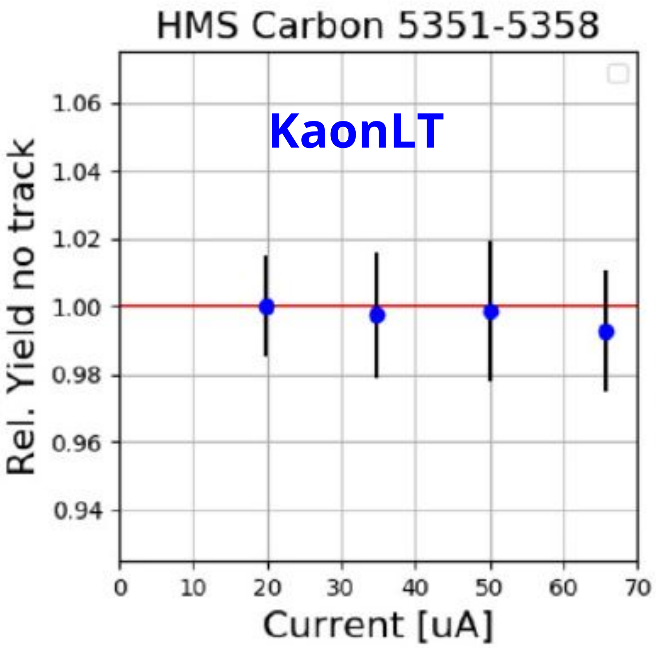
No Track Yield Calculation

$$EDTM_{LT} = \frac{numOfNonzeroTDChits}{numOfScalerCounts}$$

Total elastic events

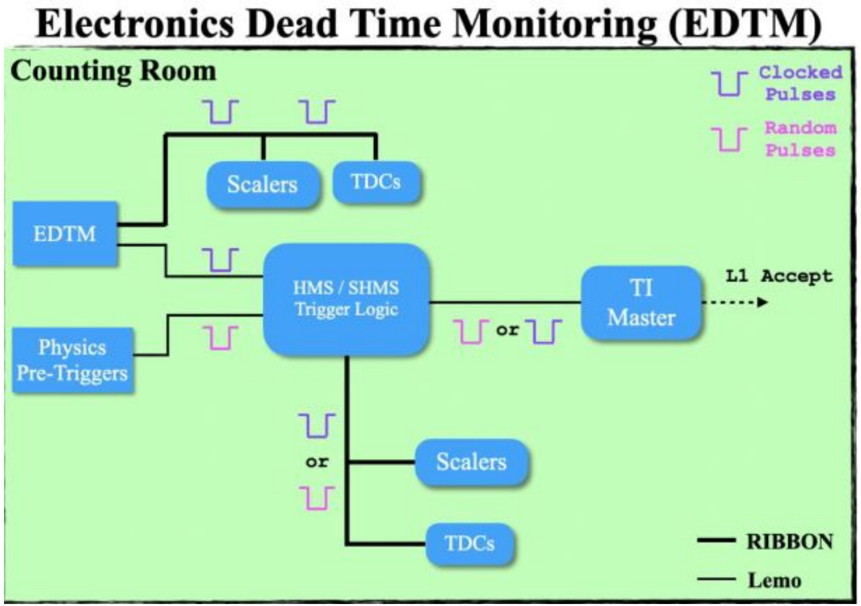
$$\text{Yield} = \frac{N}{Q_{tot}\epsilon_{tot}}$$

$$Q_{tot} = (H.BCM.scaler.charge)$$



Electronic Dead Time Monitor (EDTM)

- Clocked, known pulses to measure sources of deadtime
- EDTM pulses pass through all trigger logic
  - Still must meet prescale condition
- Received EDTM events experience both CPU and Electronic deadtime
  - Electronic deadtime expected to be small, but some variance is expected between triggers (single vs coin)



Schematic by Carlos Yero

EDTM Calculation

This equation does not account for prescaling

- Ratio of L1ACCP EDTM pseudo-trigger and the EDTM scaler that determine the total dead time
- Since the EDTM scaler is saved before the pseudo-trigger reaches the TM
  - The L1ACCP EDTM pseudo-trigger is prescaled while the EDTM scaler is not!
- This necessitates a correction due to the simultaneous EDTM pulse across all triggers, recording only one event per pulse.

$$\epsilon_{prodTLT} = \frac{EDTM_{accept}}{EDTM_{sent}}$$

↓

$$\epsilon_{\#TLT} = \frac{EDTM^{\#}_{accept}}{C_{\#} \cdot EDTM_{sent}}$$

$$C^1 = \frac{1}{PSF^1} - \frac{1}{PSF^1 * PSF^3} - \frac{1}{PSF^1 * PSF^6}$$

Example: Correction factor for prescaled ¾ run with one active trigger

EDTM Report

Lumi Cuts

Very tight cuts to assure the cleanest particle samples

- tdcTimeRaw cuts on pTrigs and EDTM
- Evttype cuts (HMS Evttype==2, SHMS Evttype==1 or 3)
- abs(current-setcurrent) < 2.5

"+" SHMS (pion)

- P_hgcer_npeSum > 1.5
- P_aero_npeSum > 1.5
- P_cal_etotnorm < 0.9

"+" SHMS (proton)

- P_hgcer_npeSum < 1.5
- P_aero_npeSum < 1.5
- P_cal_etotnorm > 0.0

"-" SHMS (electron)

- P_hgcer_npeSum > 0.5
- P_aero_npeSum > 2.0
- P_cal_etotnorm > 0.8

HMS (electron)

- H_cer_npeSum > 6.0
- H_cal_etotnorm > 0.6

Track Yield Calculation

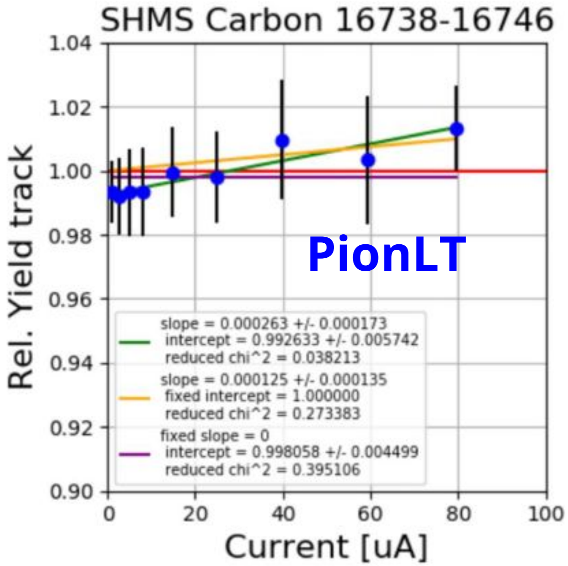
$$EDTM_{LT} = \frac{numOfNonzeroTDChits}{numOfScalerCounts}$$

$$track = \frac{\Sigma track_{nontrack}}{\Sigma track_{ntrack}}$$

Total elastic events

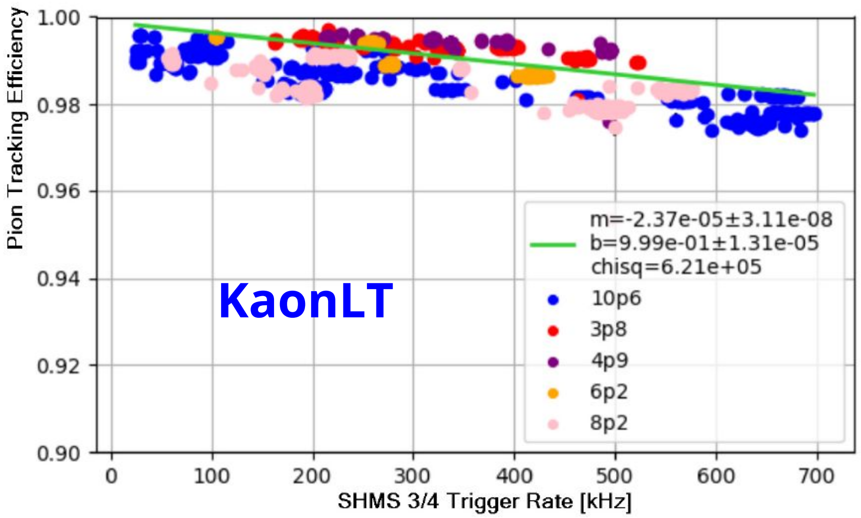
$$\text{Yield} = \frac{N}{Q_{tot}\epsilon_{tot}}$$

$$Q_{tot} = (H.BCM.scaler.charge)$$



Methods of golden tracks

1. χ^2 fit, simply the smallest χ^2 is chosen
2. SCIN method
   - Select best track through HMS by seeing which track is closest to S2Y or if none then S2X
   - If there are still multiple tracks select track with smallest χ^2
3. Prune method
   - First loop over the following…
     - xp, yp, ytar, delta, shower energy, ToF, β, # of DoF of track, χ^2, # of PMT hits on track (within time cut), χ^2 of β, focal plane time relative to nominal time, a hit in S2Y and S2X
   - Reject all tracks which have a greater value than these quantities
   - If there are still multiple tracks select track with smallest χ^2



$$\epsilon_{k(e)track} = \frac{N_{\text{did,track}}}{N_{\text{should,track}}}$$

$$\delta\epsilon_{k(e)track} = \sqrt{\frac{(N_{\text{should,track}} * N_{\text{did,track}}) - (N_{\text{did,track}} * N_{\text{did,track}})}{(N_{\text{should,track}})^3}}$$

Track Lumi Cuts

- tdcTimeRaw cuts on pTrigs and EDTM
- Evttype cuts (HMS Evttype==2, SHMS Evttype==1 or 3)
- abs(current-setcurrent) < 2.5
- (P)H_goodscinhits == 1
- abs(P_gtr_beta-1) > 0.3

“+” SHMS (pion)

- P_hgcer_npeSum > 1.5
- P_aero_npeSum > 1.5
- P_cal_etottracknorm < 0.9

“+” SHMS (proton)

- P_hgcer_npeSum < 1.5
- P_aero_npeSum < 1.5
- P_cal_etottracknorm > 0.0

“-” SHMS (electron)

- P_hgcer_npeSum > 0.5
- P_aero_npeSum > 2.0
- P_cal_etottracknorm > 0.8

HMS (electron)

- H_cer_npeSum > 6.0
- H_cal_etottracknorm > 0.6

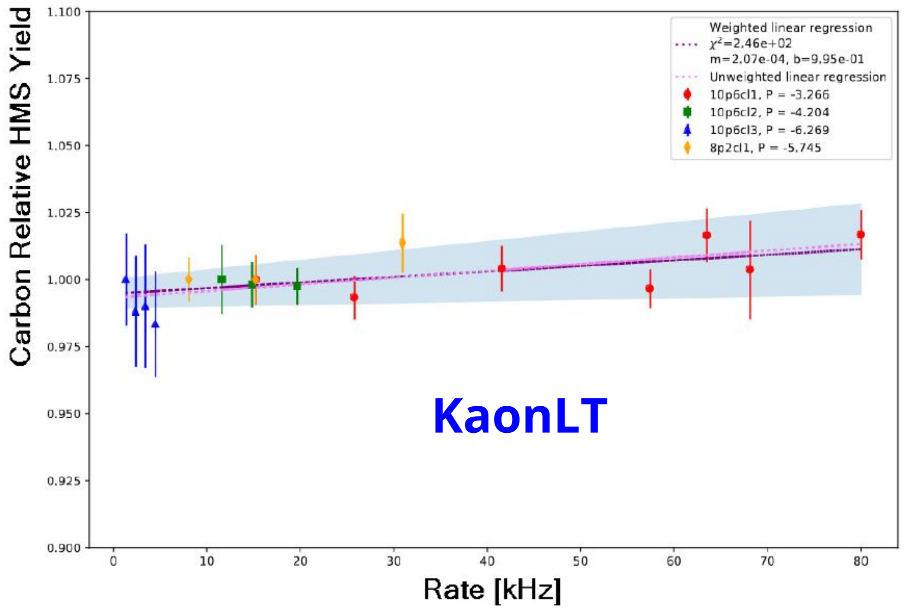
KaonLT Challenges (I)

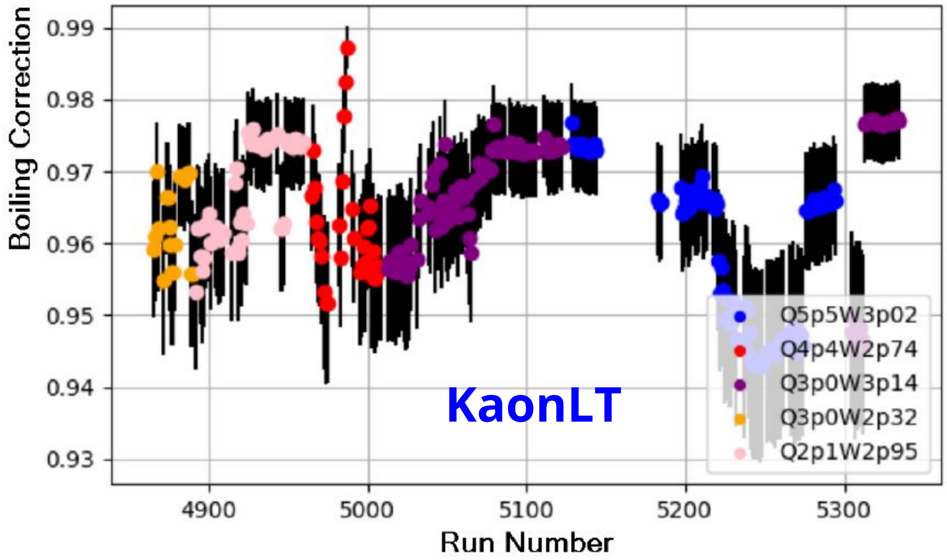
- KaonLT was a 12 GeV commissioning experiment
    - **No EDTM GUI**, clock had to be set manually
        - EDTM clock sometimes set too high for a given scaler rate and thus would drown out physics events
    - Poor beam on time, due to overall poor beam quality when the luminosity studies were performed
    - Data was taken with the prescaled single triggers set in both arms
        - Lost TLT could not be disentangled from the coupled EDTM events in both single triggers
    - Much of the SHMS luminosity data was taken at positive polarity

KaonLT Challenges (II)

Carbon: +0.169 ± 4:3%
LH2: -7.900 ± 1.829%.

- To give confidence in the Carbon-12 yield results
  - The luminosity data for all settings were combined and fit with a weighted linear regression using least squares and weighted by the uncertainty





Summary and Conclusion

- Luminosity scans provide…
  - A means to understand the accuracy of the efficiencies
  - Correct for any rate dependencies
  - Correct for any target boiling that may occur at higher currents
- For Carbon-12, this comparable yield should be constant for all currents, so any deviation indicates systematic effects.
- Carbon analysis first then repeat for cryotarget
  - Scaler Yields
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  - Non-track Yields
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  - Track Yields
    - Tracked cuts, track efficiency check
- Current cuts, EDTM, tracking efficiency, and PID cuts each need in depth analysis at the above stages

Extra