Precise measurement of photomultiplier tube non-linearity for the MOLLER experiment

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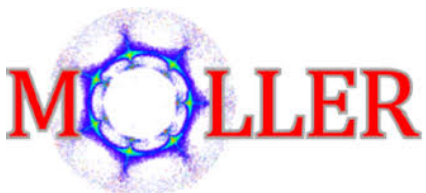
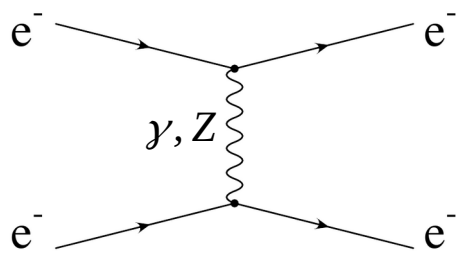


MOLLER Experiment Goal:

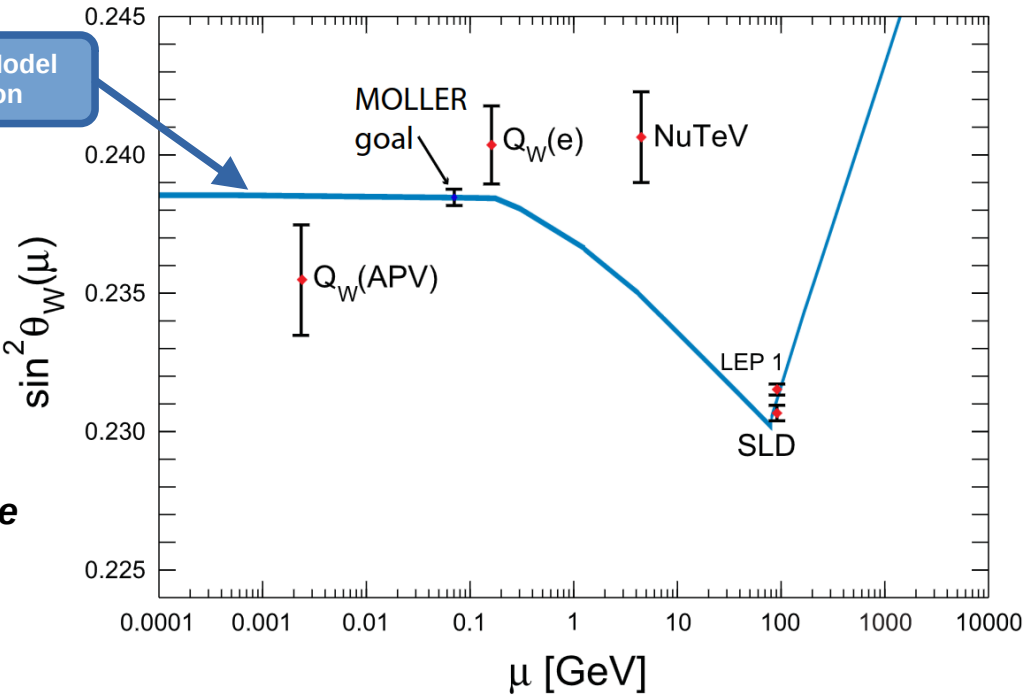
- Precise measurement for the ***weak-mixing angle*** at low momentum transfer using the parity violating asymmetry (A_{PV}) in polarized electron-electron (møller) scattering.



$$A_{PV} = \left[\frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}\right] = mE\,\frac{G_F}{\sqrt{2}\,\pi\alpha}\,\frac{4\sin^2\theta}{(3+\cos^2\theta)^2}\,(1-4\sin^2\theta_W)$$

weak-mixing angle

Overall fractional accuracy: 2.4%



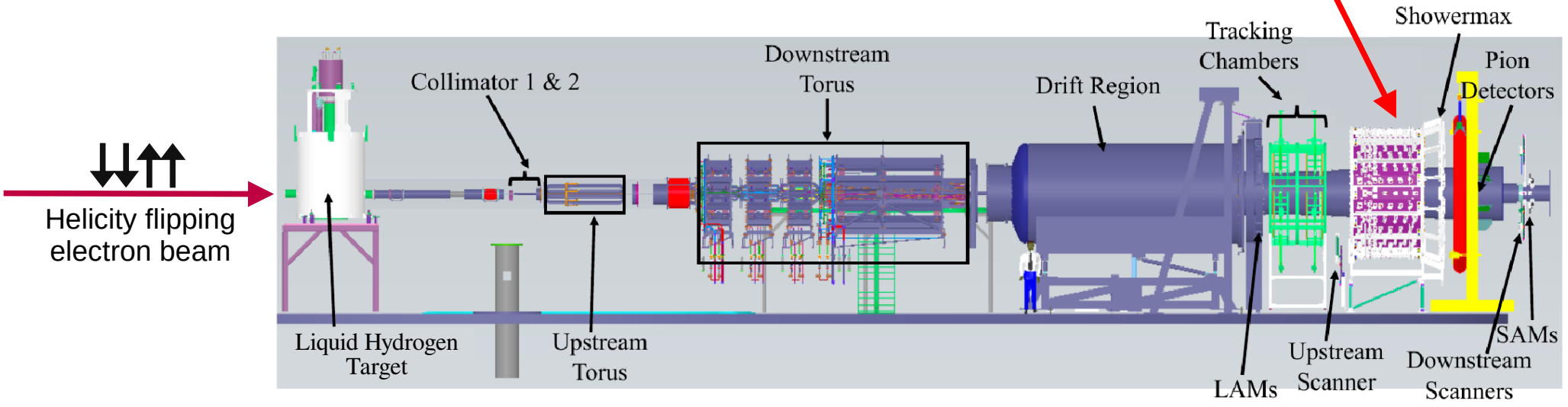
J. Benesch et al.[2014]

MOLLER Beam-line

- Being built at JALB
- Operational in 2025
- 11GeV Continuous Electron Beam

Main electron detector

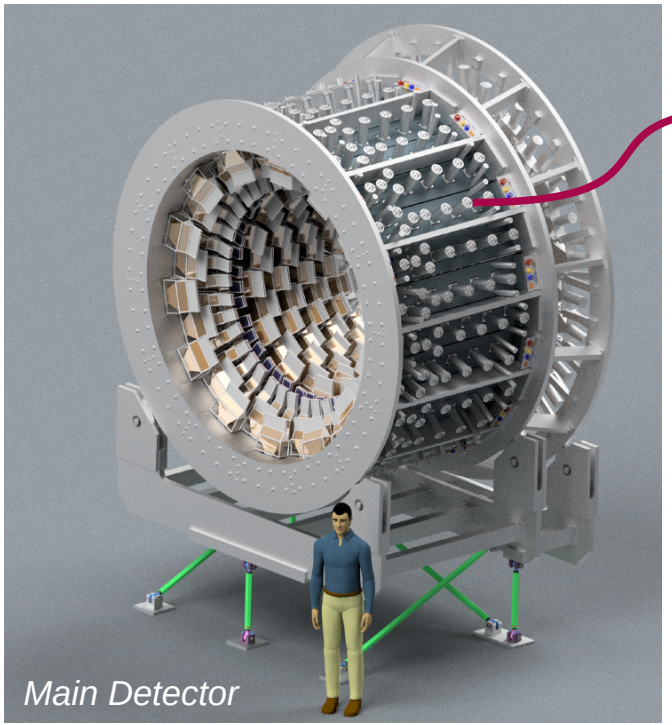
$$A_{PV} = \left[\frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}\right]$$

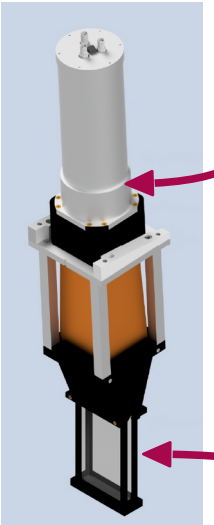


Main detector: - Being built by the team at the University of Manitoba
- 224 detector modules

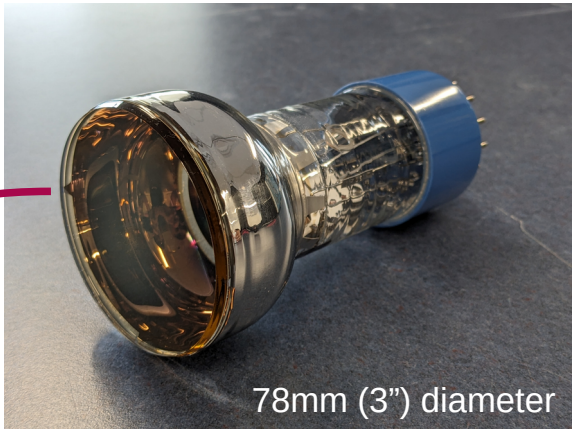
The MOLLER TDR [2022]

Main electron detector



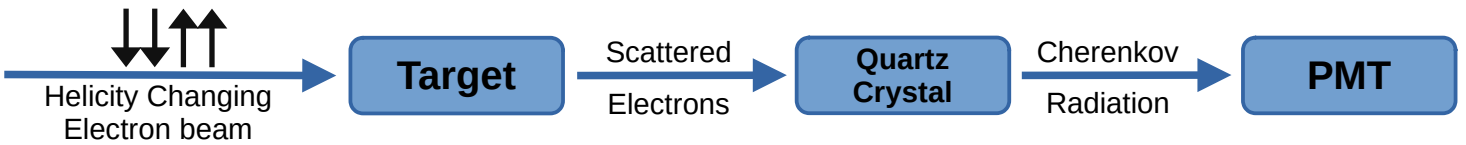


Detector module



Photomultiplier Tube

Quartz Crystal

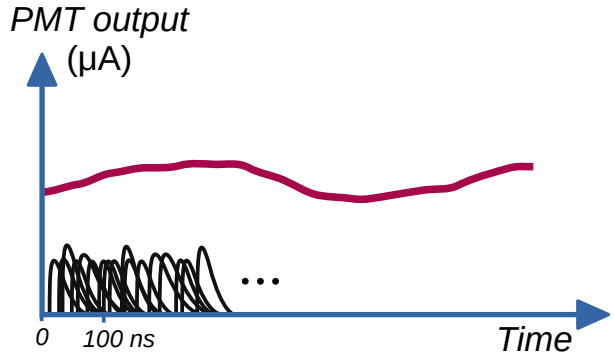


The MOLLER TDR [2022]

Non linearity overview

- High beam rate of MOLLER → Cannot resolve individual electrons
- Integrating mode measurement → Requires highly linear detectors

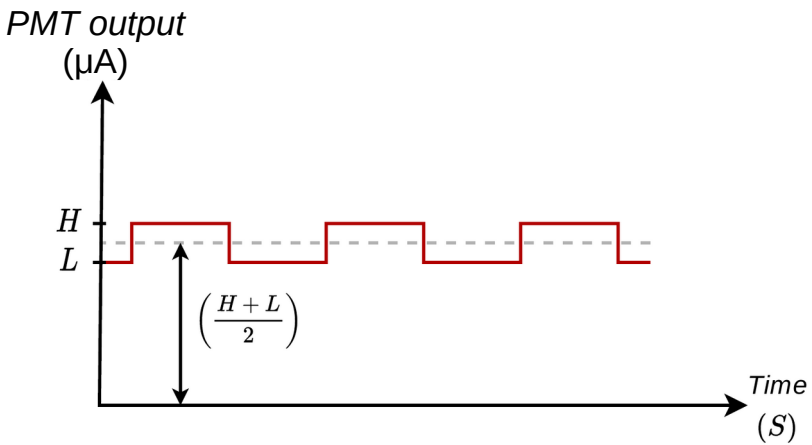
PMT non-linearity ≤ 0.5±0.1%



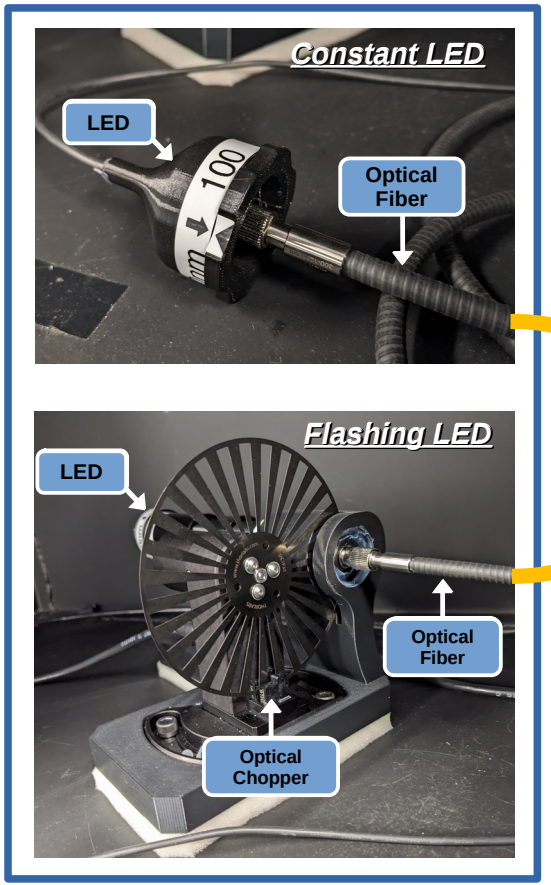
- Asymmetry signal was replicated using two LEDs.
  - LED 1: Bright constant → represents helicity independent signal
  - LED 2: Dim flashing → represents the parity violation

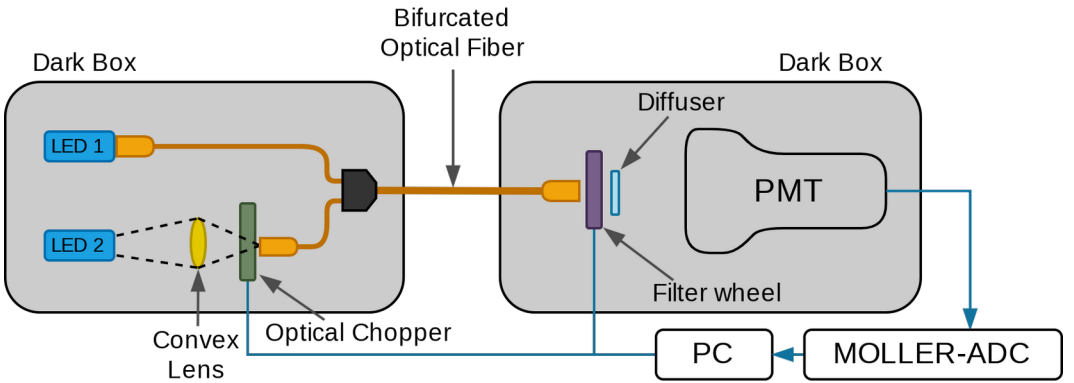
LED Asymmetry: $A_{LED} = \left(\frac{H-L}{H+L}\right)$

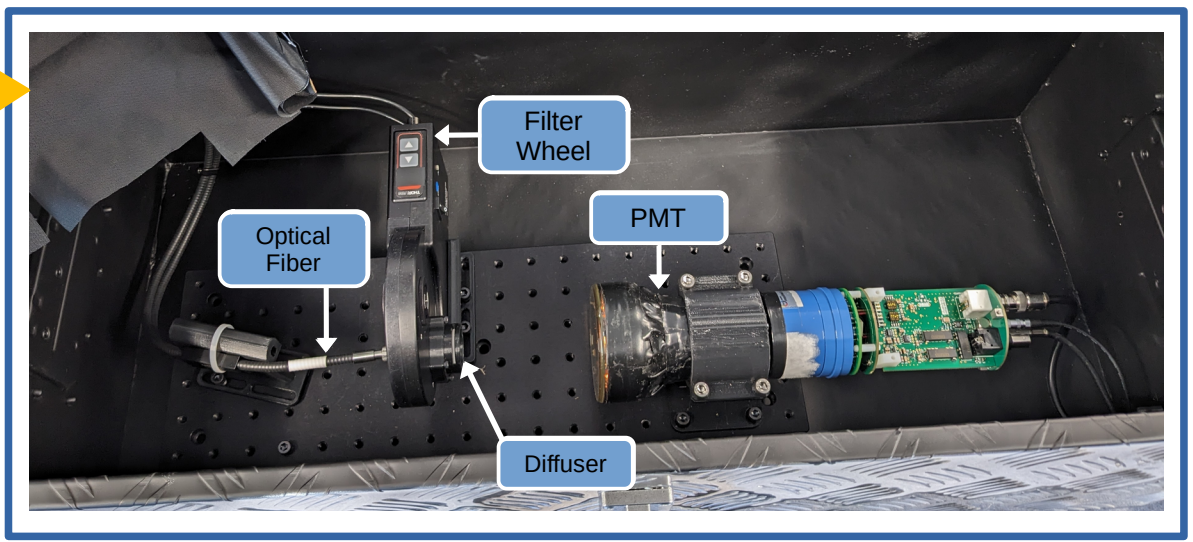
$A_{PV} = \left[\frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}\right]$



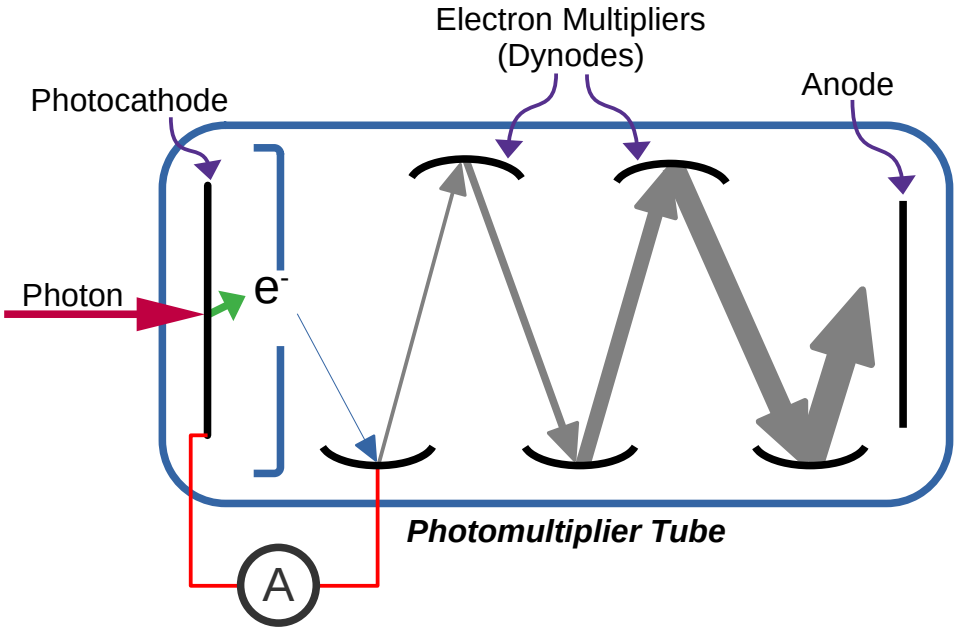
Bench-top Setup

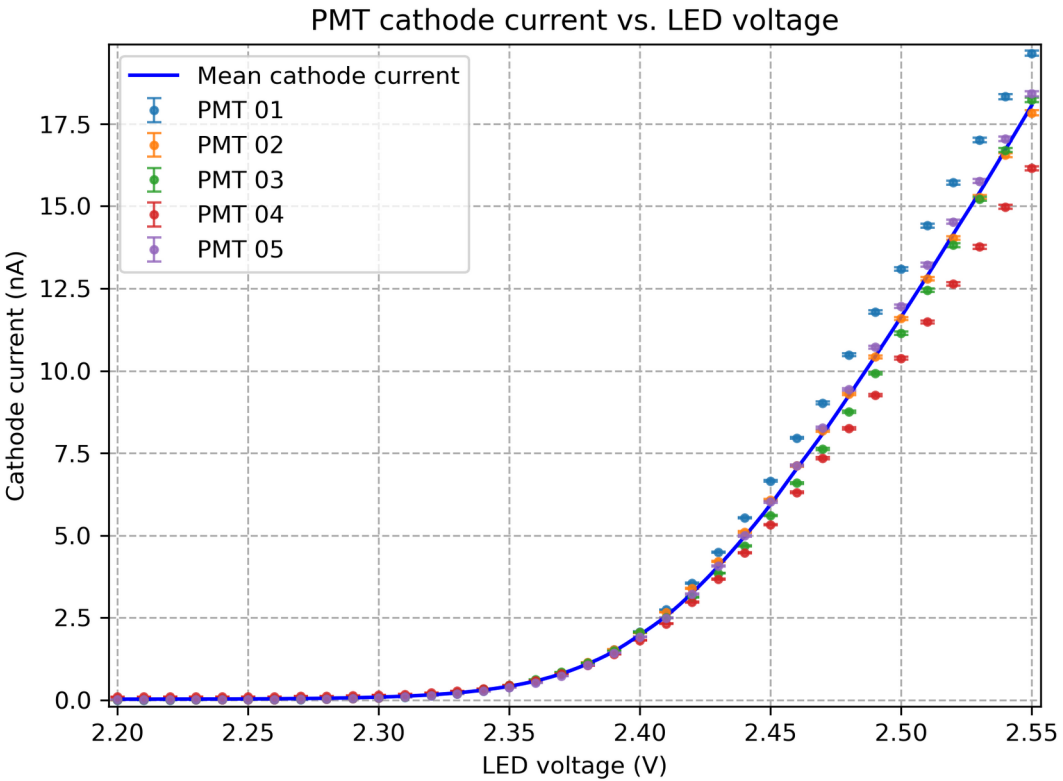






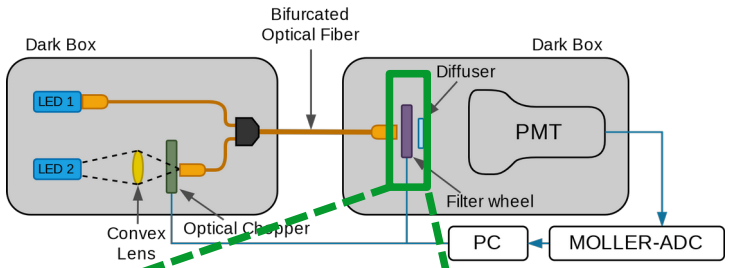
Choosing LED brightness



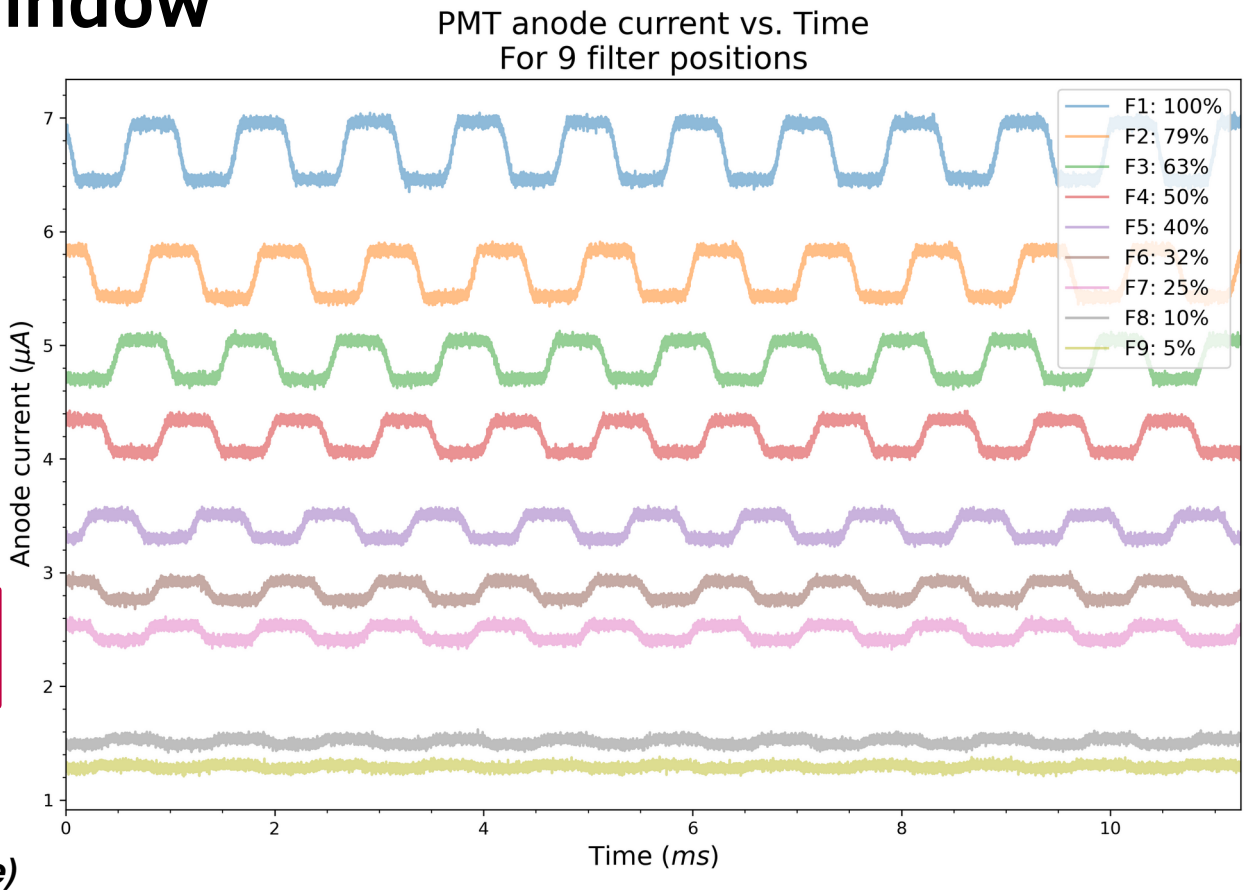


- Cathode current → LED brightness
- Typical cathode current during MOLLER: < 20 nA

Sample Acquisition Window



$$A_{LED} = \left(\frac{H - L}{H + L} \right)$$



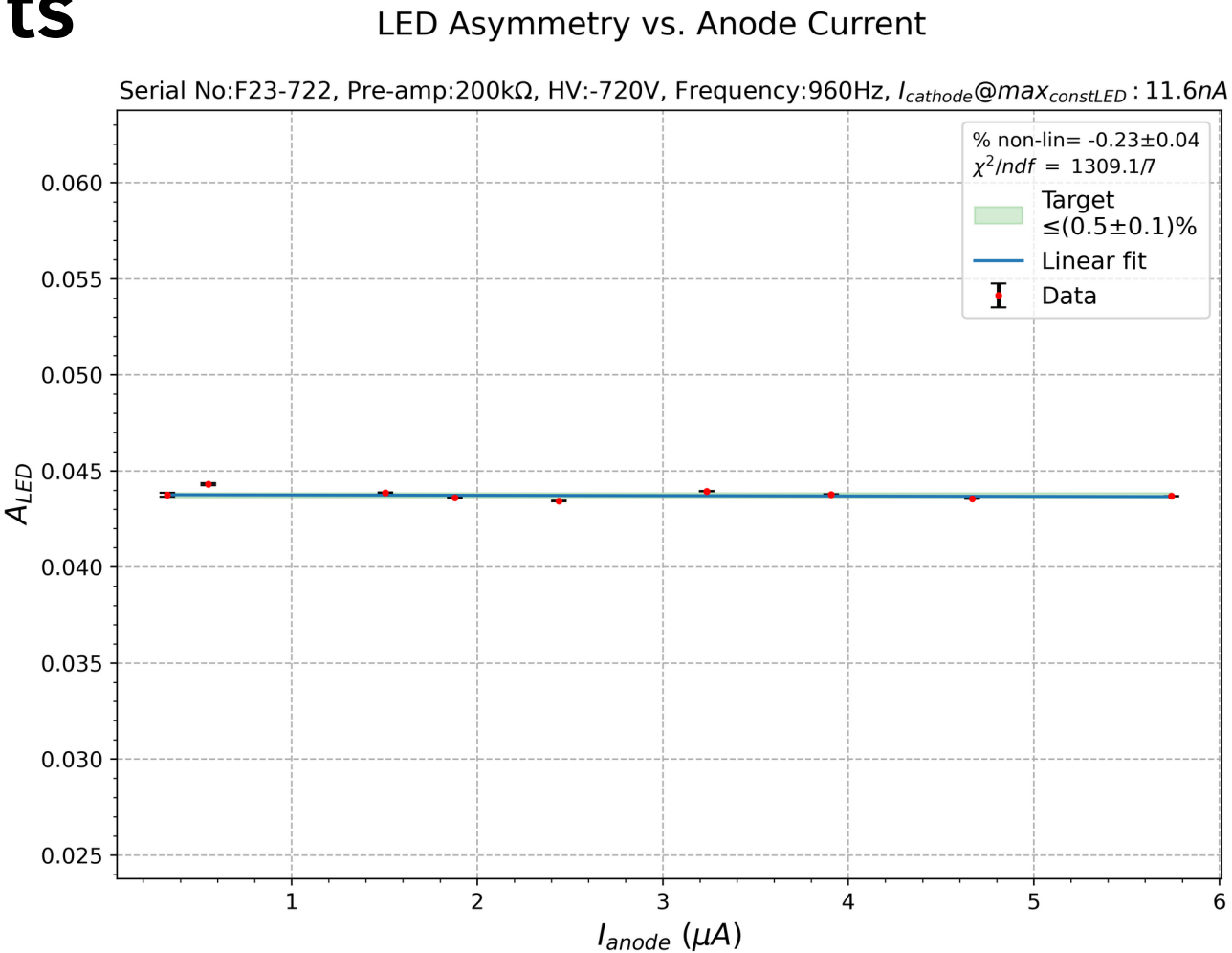
- Chopper frequency: 960 *Hz*
  - ***(Same as Moller helicity reversal rate)***

Only a portion of the full run is plotted

Preliminary results

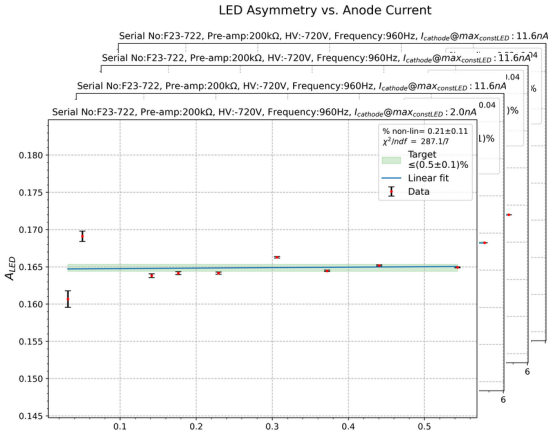
Non- linearity: **0.23±0.04%**

Target: **0.5±0.1%**



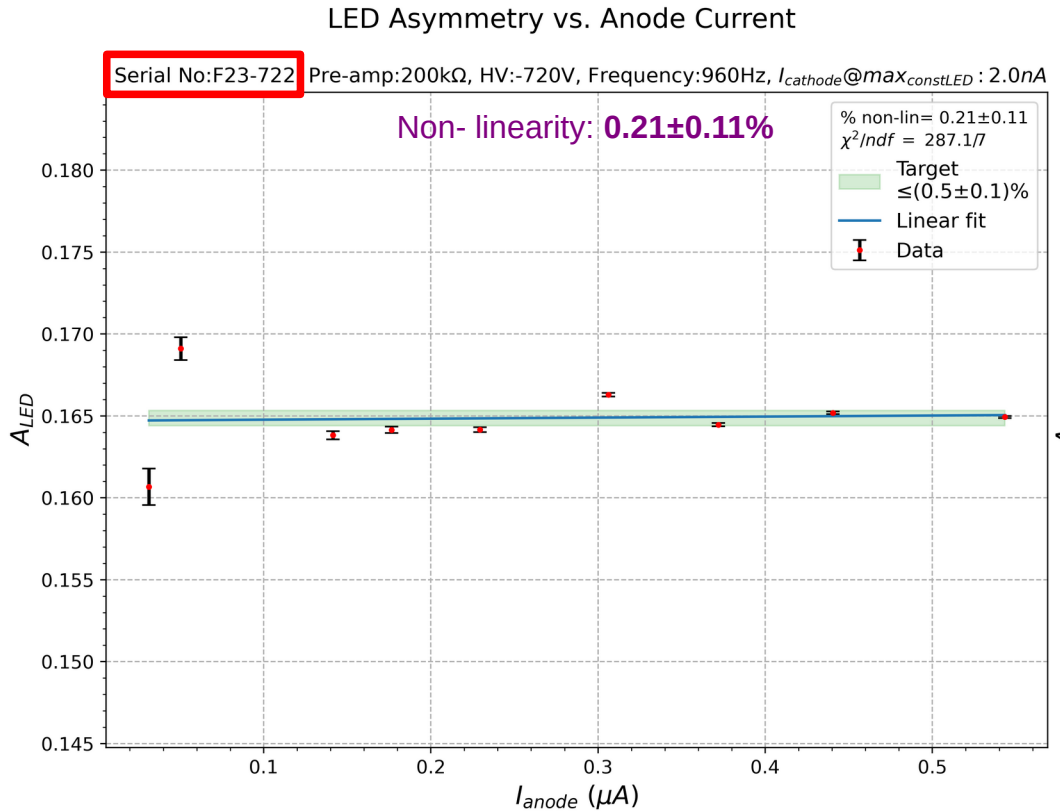
Conclusion and Future plan

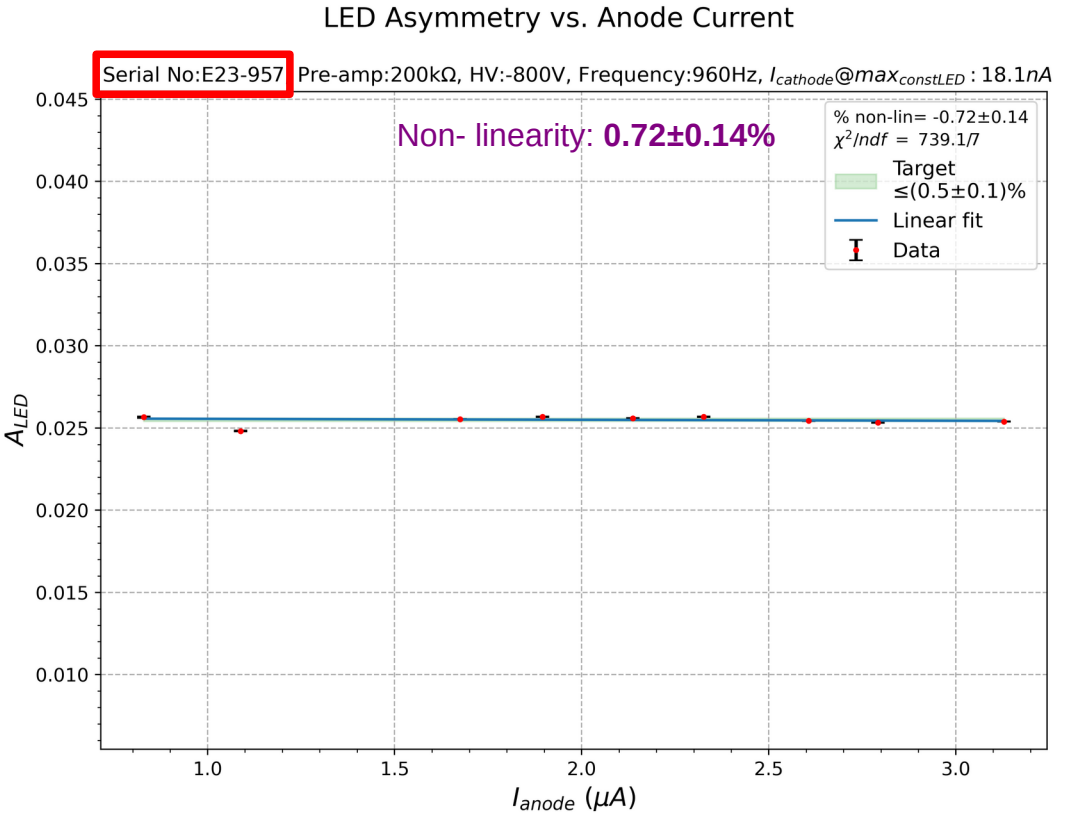
- Promising preliminary results
- Apparatus is ready for non-linearity measurements
- Testing the rest of the PMTs
- Automated data taking process
- Install the tested PMTs in the main detector at JLab



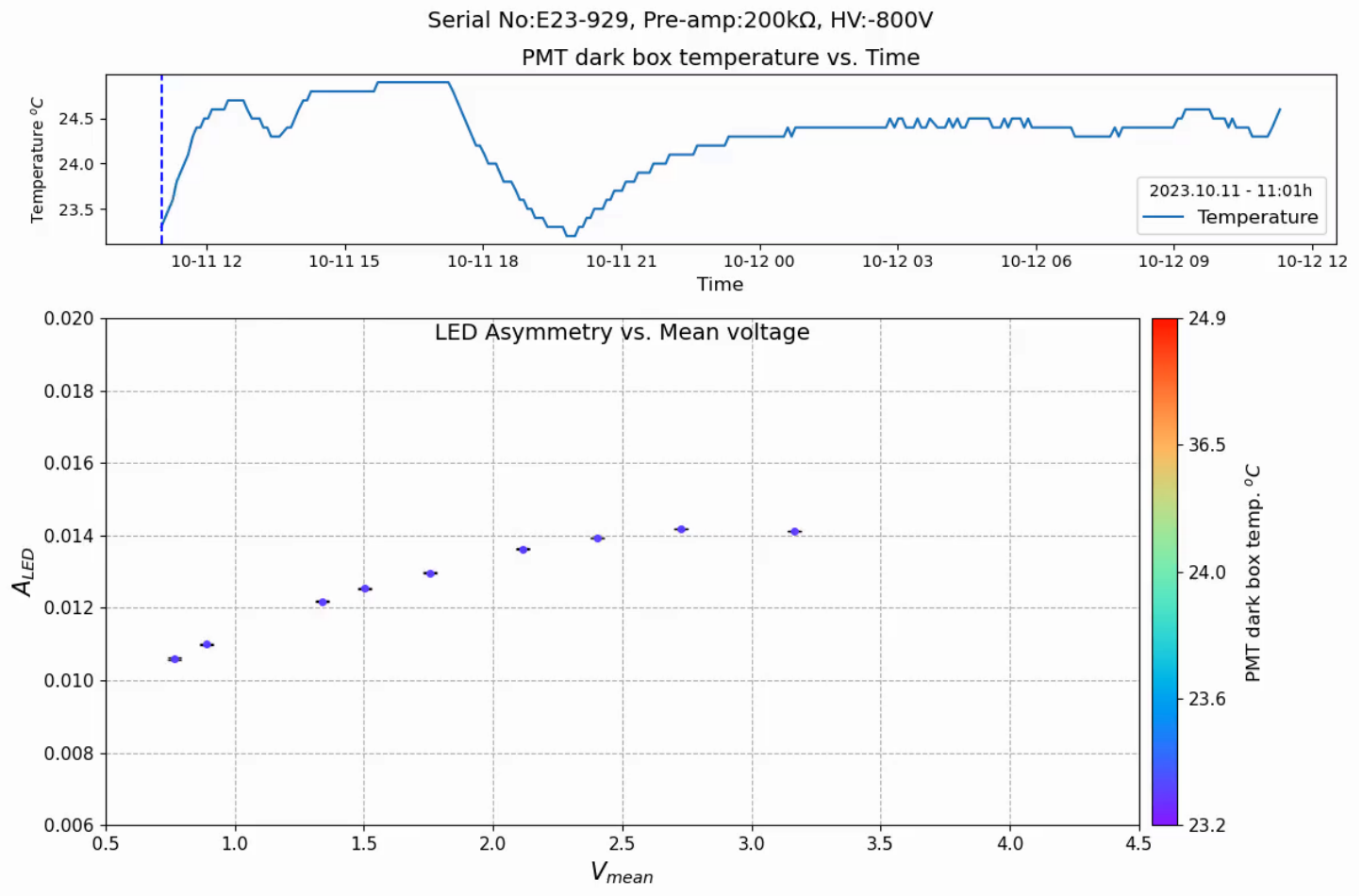
Extra Slides

Extra: More non linearity results





Extra: Apparatus stability



Extra: Data analysis