Clatterbridge 24th – 25th November 2016 ADC Data Analysis

Anastasia Basharina-Freshville

(University College London)

Summary of Measurements Made

- Optical module setup used:
  - 2” Hamamatsu R13089-100-11 PMT with negative HV UCL soldered base
  - 3 cm x 3 cm x 5 cm cuboid ENVINET standard scintillator
  - Coupled with BC-630 Saint Gobain silicone optical gel (refractive index = 1.465) http://www.crystals.saint-gobain.com/uploadedFiles/SG-Crystals/Documents/Organic%20Product%20Accessories%20Data%20Sheet.pdf

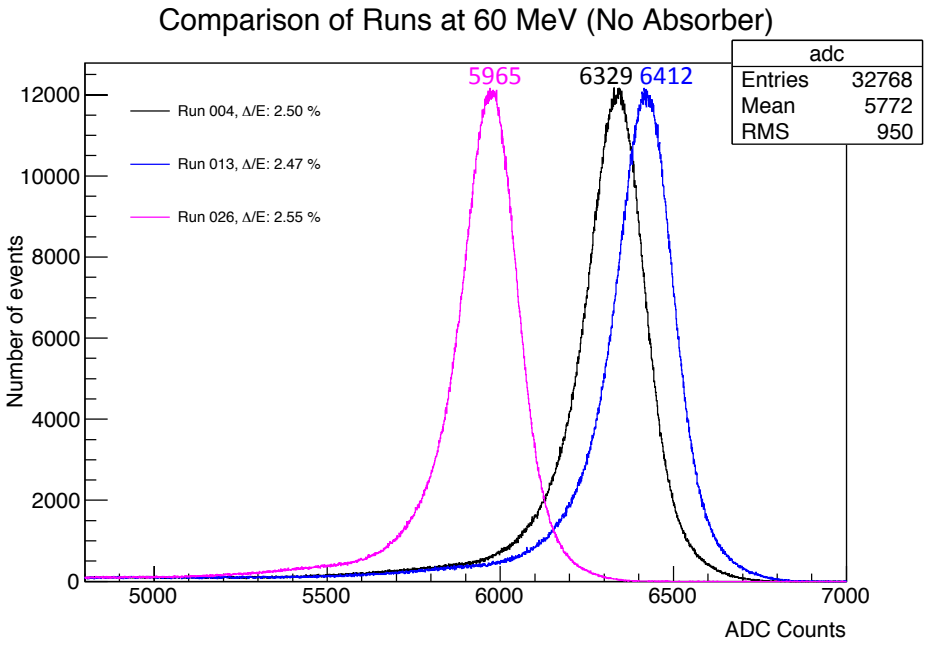
- Thursday the 24th August 2016:
  - All measurements carried out at -900 V
  - Measurements of beam operating at different rates (30 kHz – 400 kHz)
  - Monitoring of correlation between the rate measured on the oscilloscope and the displayed scattering foil current
  - Waveform data collected with the LeCroy oscilloscope in order to more accurately measure rates
  - Waveform data collected with the digitiser and the LeCroy oscilloscope simultaneously using a 50 Ω LEMO splitter and barrels
  - Peak current estimate at -900 V (for an amplitude of 447 mV and a width of ~16 ns, for a threshold of -100 mV):
    11.2 mA

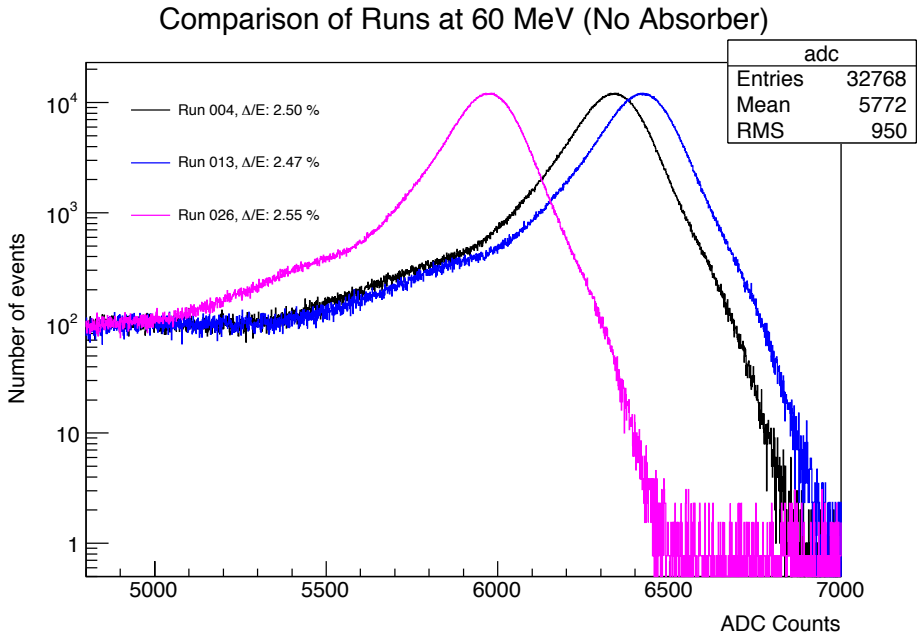
Summary of Measurements Made

- Wednesday the 3rd August 2016:
  - All measurements carried out at -900 V
  - Energy-range calibration scan with the Clatterbridge calibration wheel carried out at low rates starting at 50 kHz for a gate of 150 ns
  - Measurements with two PMMA plate thicknesses corresponding to those of the wheel to establish whether we go through one or more of the wheel segments with the beam

Energy Resolution and Reproducibility of Measuremets: 60 MeV Beam

- 1.98 mm Ø collimator
- Energy resolution: ~2.5 %





Time difference between runs:

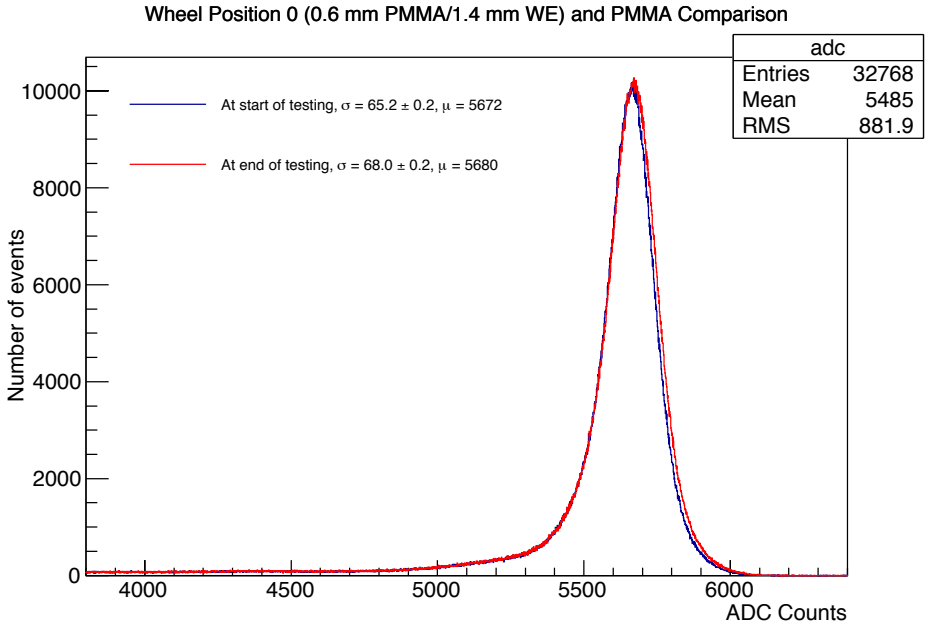
004: 12.27

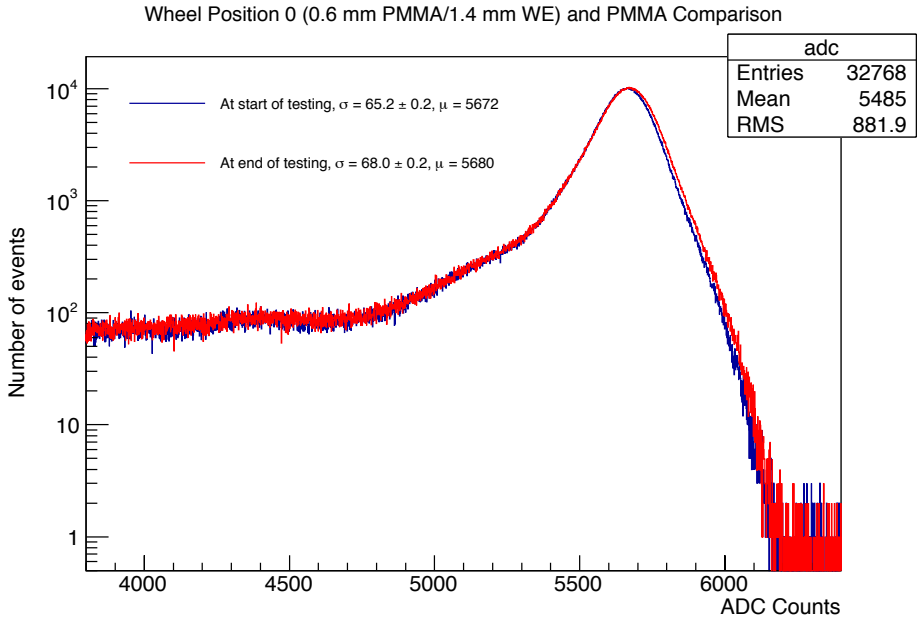
013: 14.17

026: 15.38

Reproducibility of Measurements: Wheel Position 0

- 1.98 mm Ø collimator
- Wheel position 0 (1.4 mm water equivalent, 1.2 mm PMMA)
- Energy resolution: 2.7 – 2.8 %





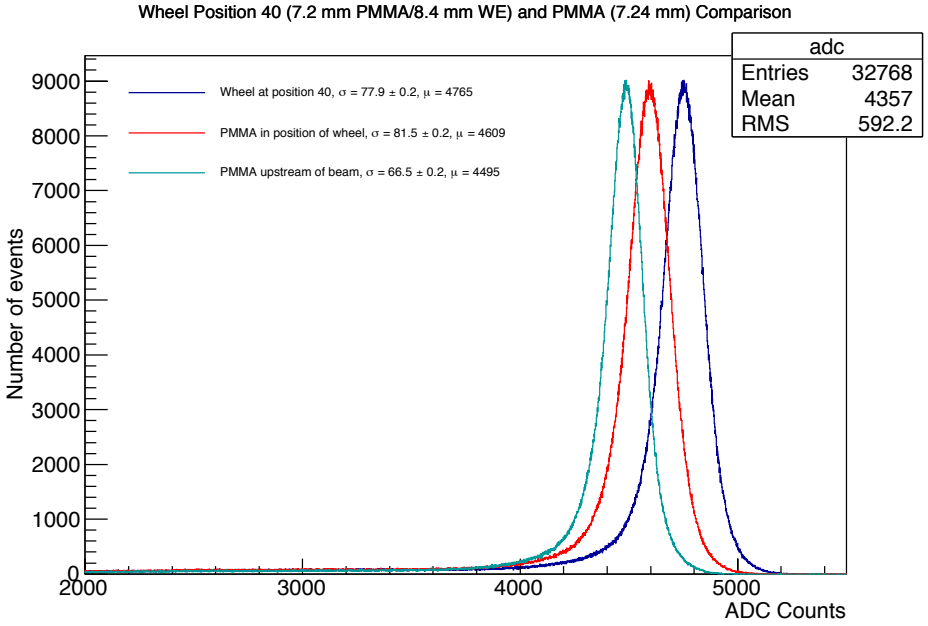
Time difference between runs:

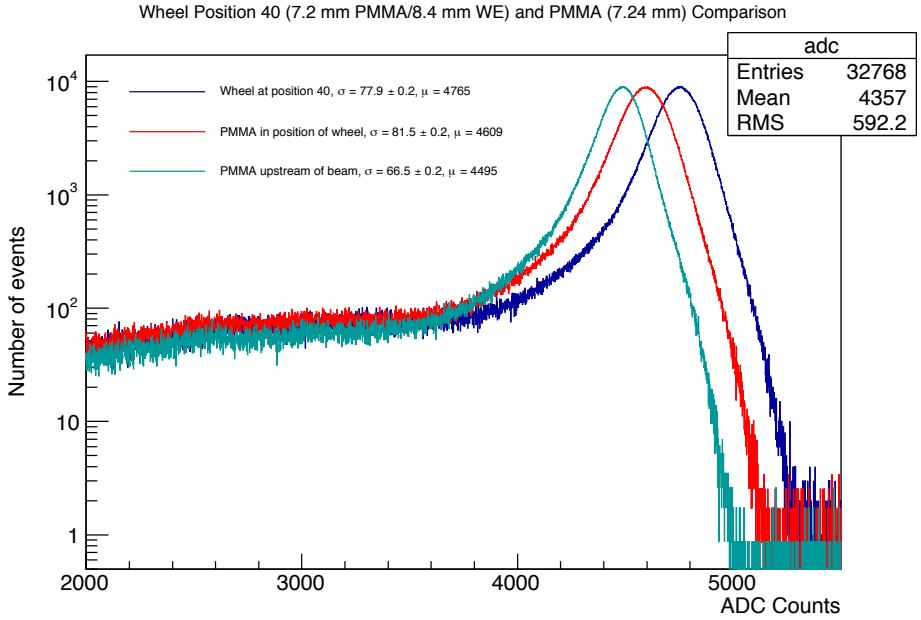
001: 09.58

030: 11.27

Comparison of Wheel Position 40 and PMMA

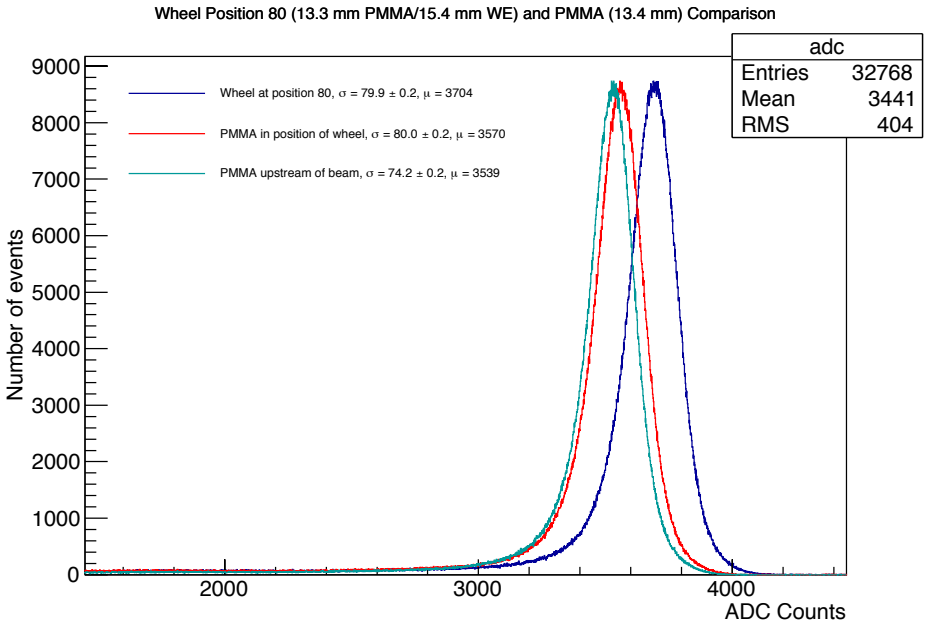
- 1.98 mm Ø collimator
- Wheel position 40 (7.2 mm PMMA), PMMA plate used: 7.24 mm
- Energy resolution: 2.5 – 3.5 %

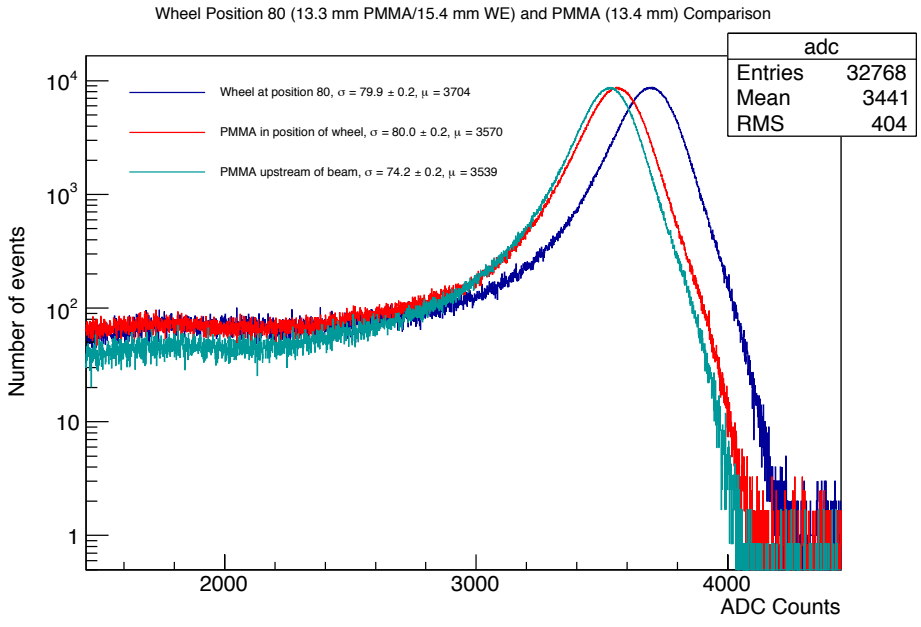




Comparison of Wheel Position 80 and PMMA

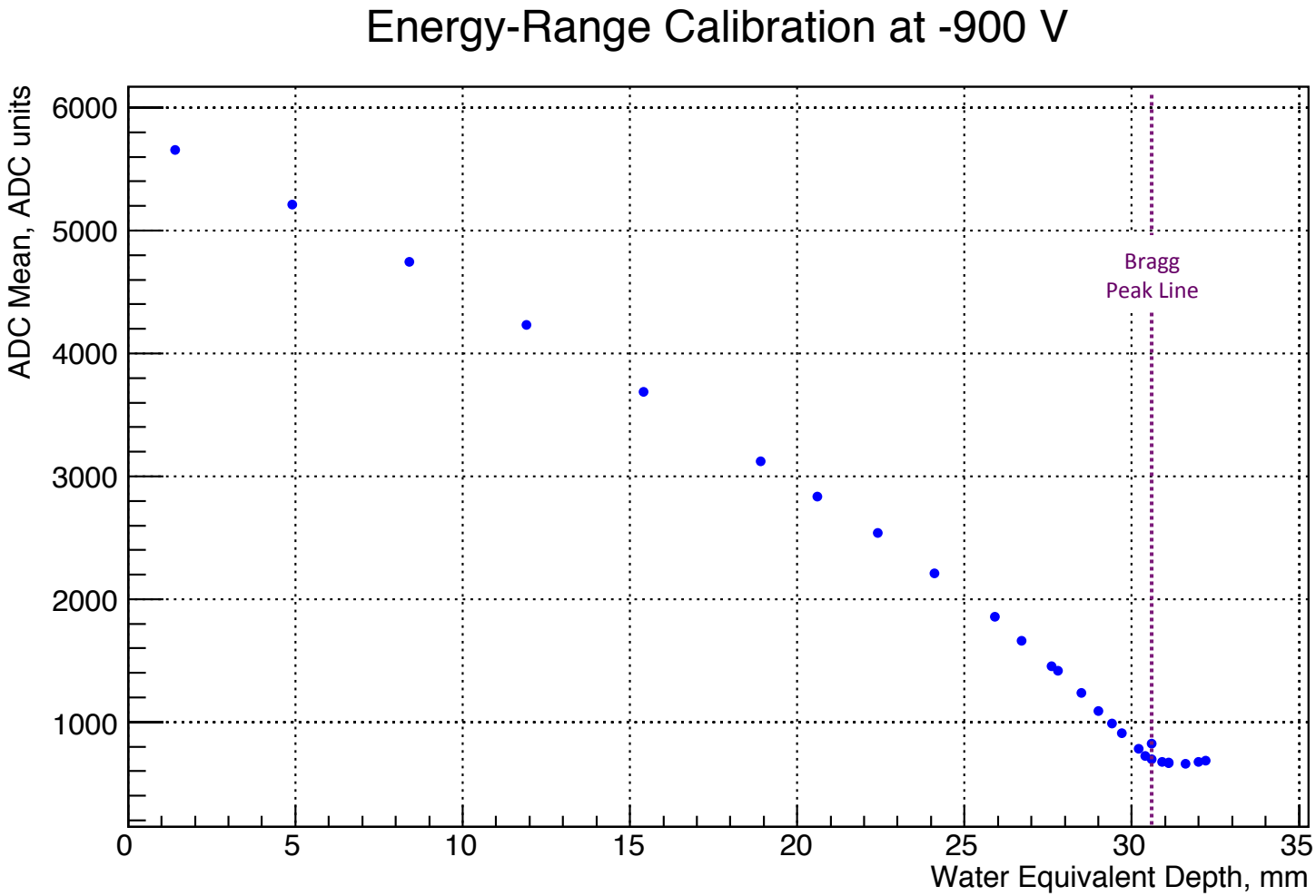
- 1.98 mm Ø collimator
- Wheel position 80 (13.3 mm PMMA), PMMA plate used: 13.4 mm
- Energy resolution: 4.9 – 5.3 %





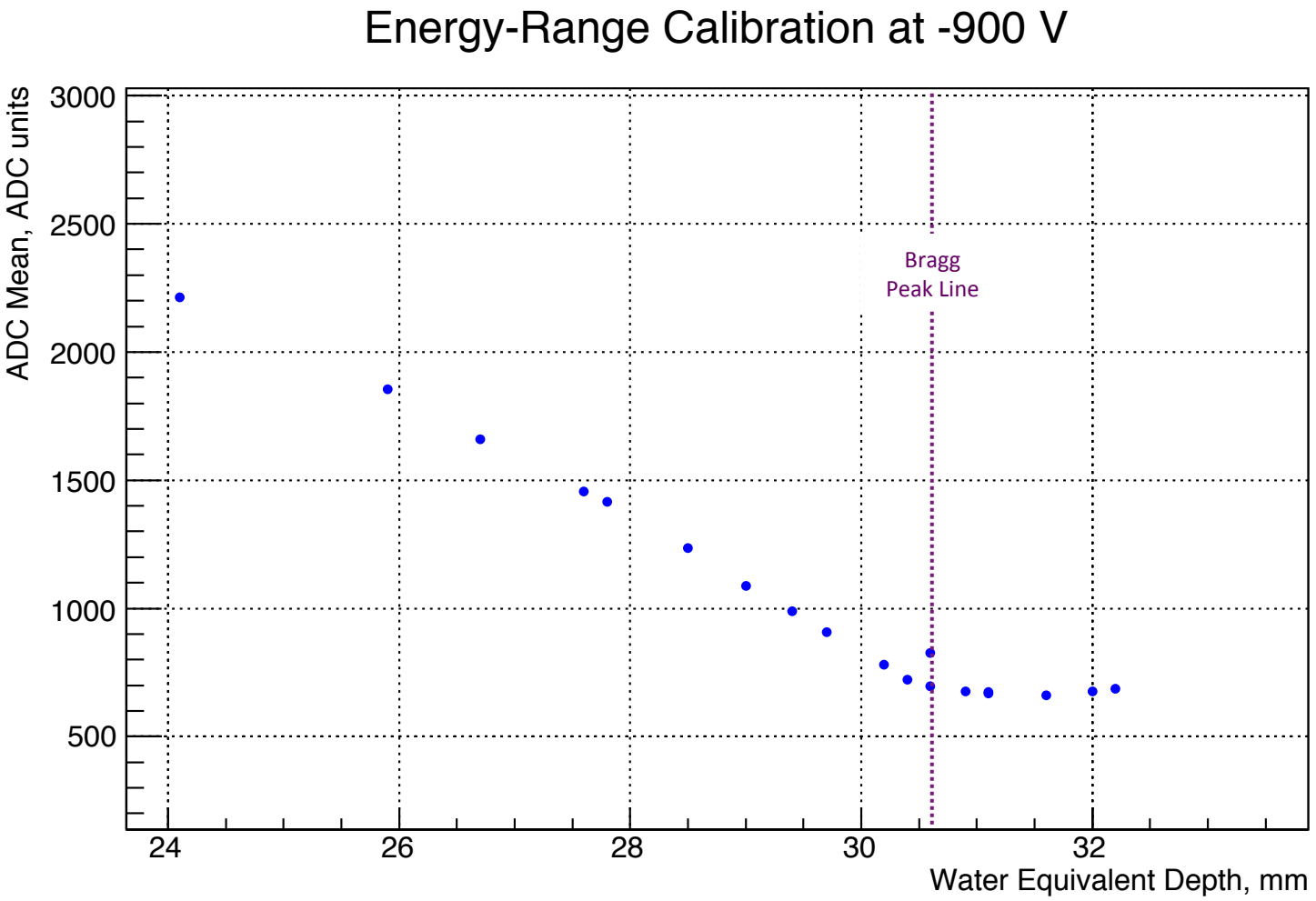
- σ is similar for measurements with the wheel and the PMMA plates
  - We can conclude that we are therefore only going through one wheel segment.

Energy-Range Calibration

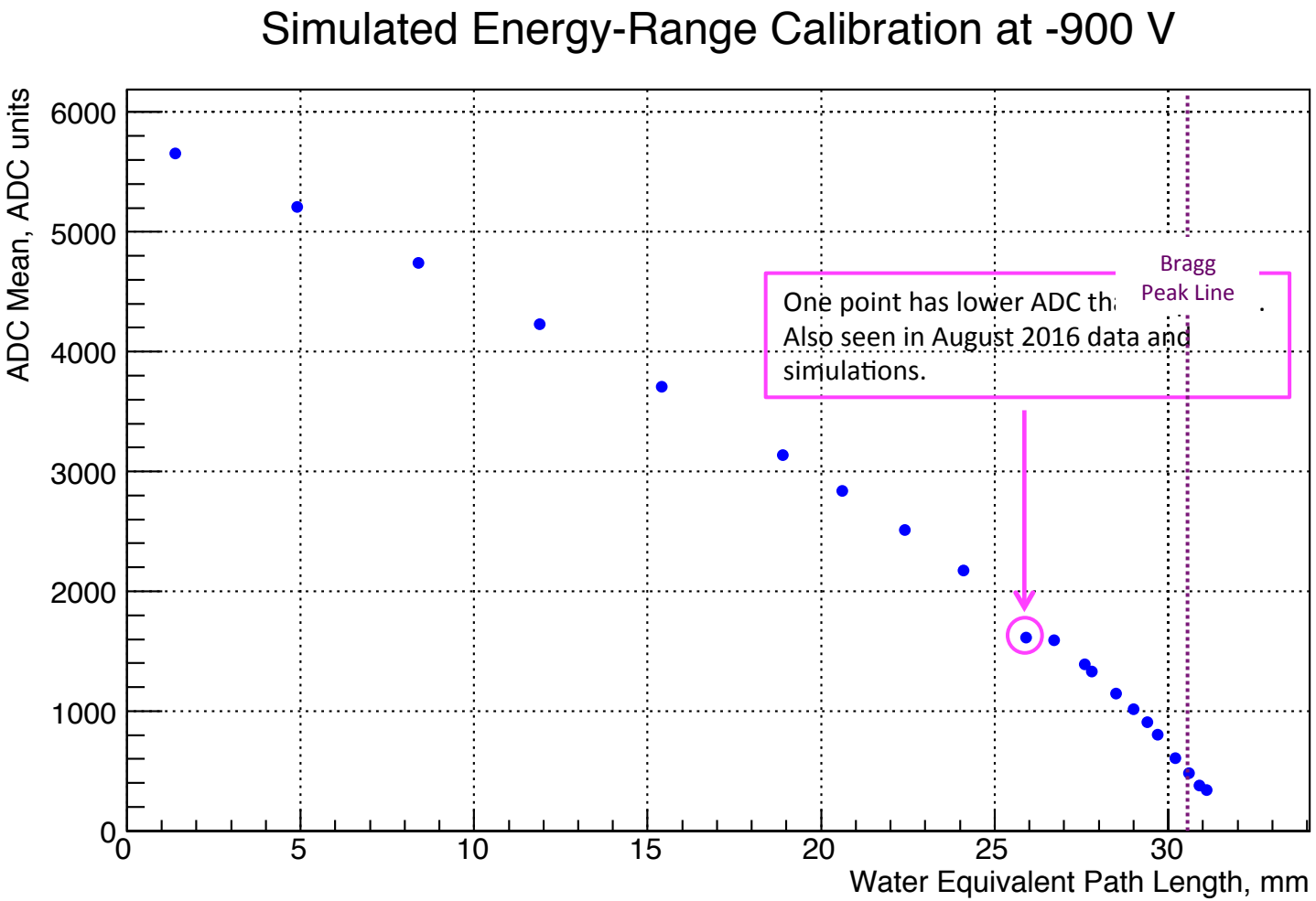


- Measurements at higher water equivalent depth do not produce a spectrum that can be fit with the Lan-Gaus convolution
- μ measured using a simple Gaussian around the peak for all points for consistency
- Note: The μ returned by Lan-Gaus and by the simple Gaussian fits are usually within ± 10 ADC counts of each other
- A more sensible looking calibration than August 2016 data?

Energy-Range Calibration (Zoom Around Bragg Peak Points)

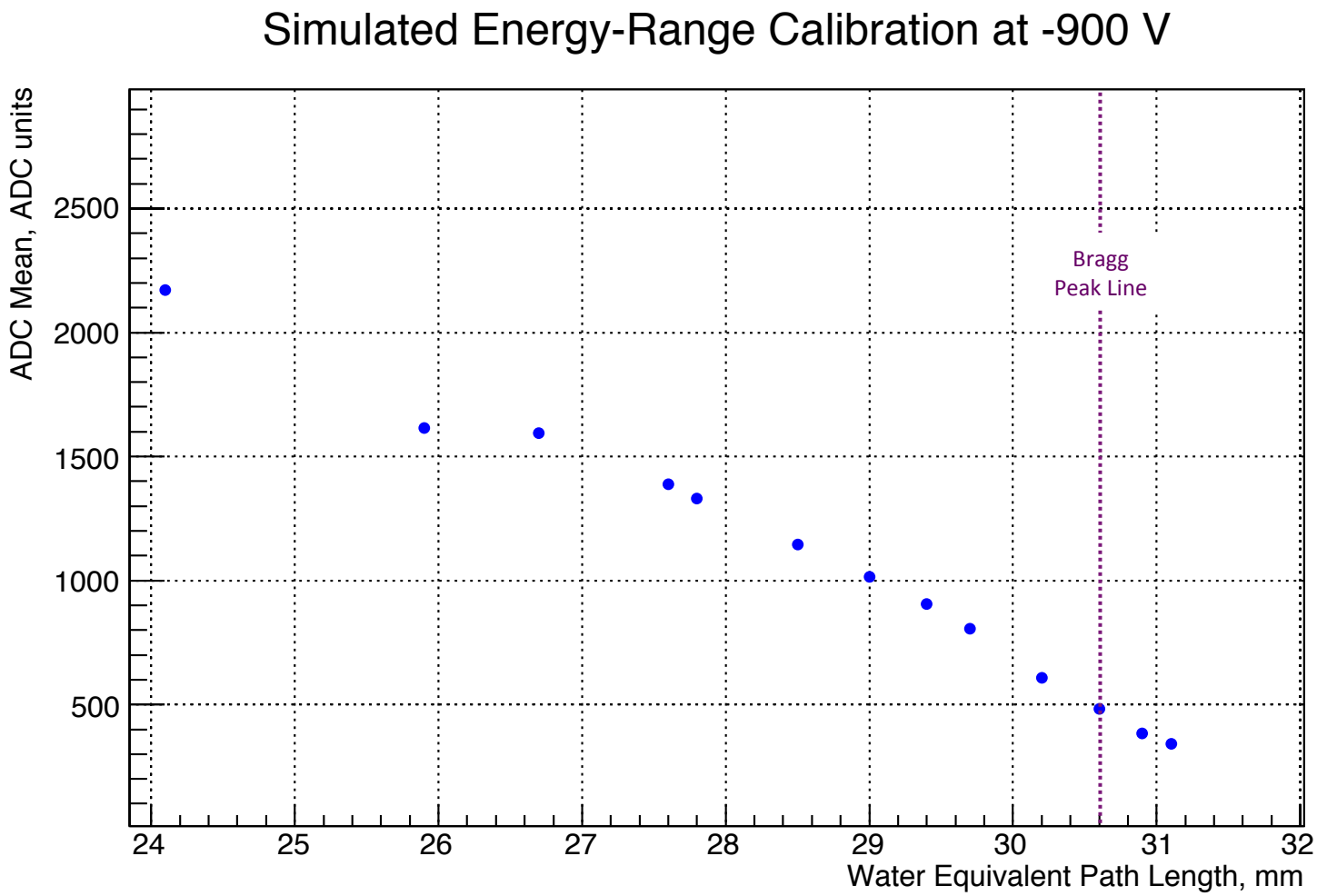


Energy-Range Calibration from Simulations

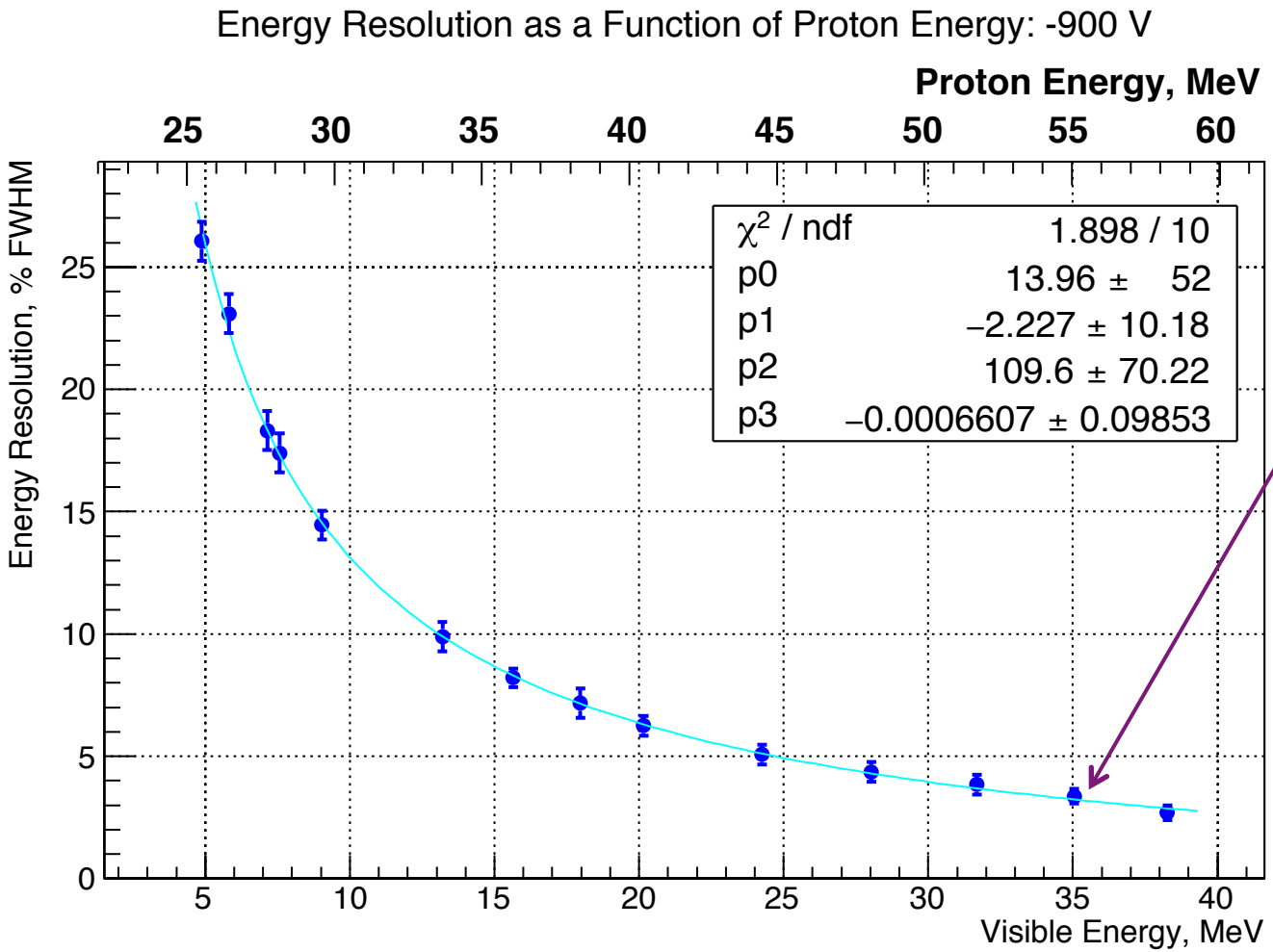


- Simulations carried out in GEANT v10.0.2 (SL 5)
- No beam line, scintillation turned off
- MeV to ADC calibration taken from MeV vs ADC plots on Slide 14 (data taken during this test beam)

Energy-Range Calibration from Simulations (Zoom Around Bragg Peak Points)



Energy Resolution as a Function of Energy (FWHM)

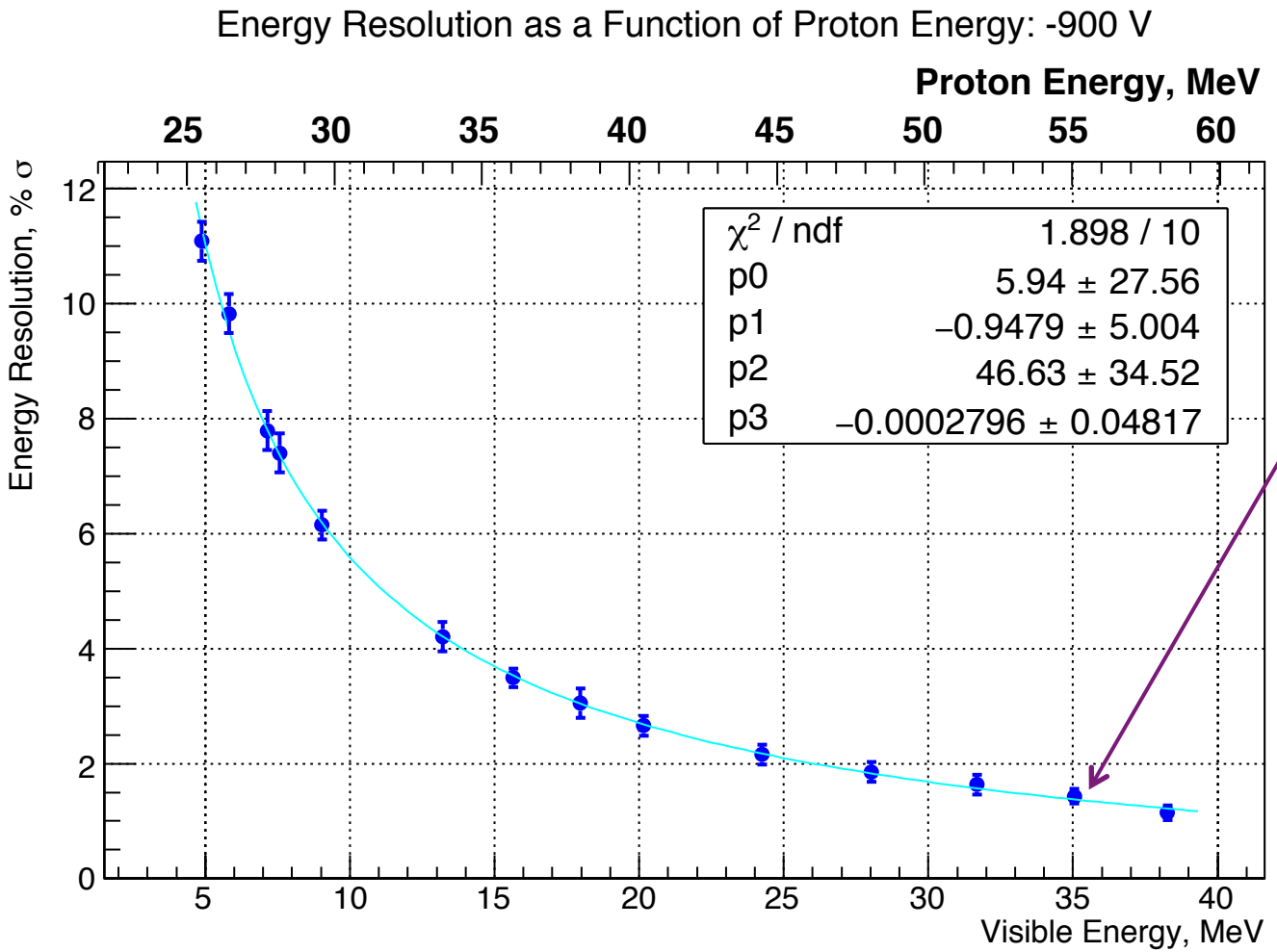


$$y = p0 + \frac{p1}{\sqrt{x}} + \frac{p2}{x} + p3 \cdot x$$

NOTE:

- Systematic errors still need to be estimated for this data set
- "Guesstimate" for now just for the fit, with ± 1% for the lowest energy points
- A great χ^2/NDF even with incorrect errors

Energy Resolution as a Function of Energy (σ)



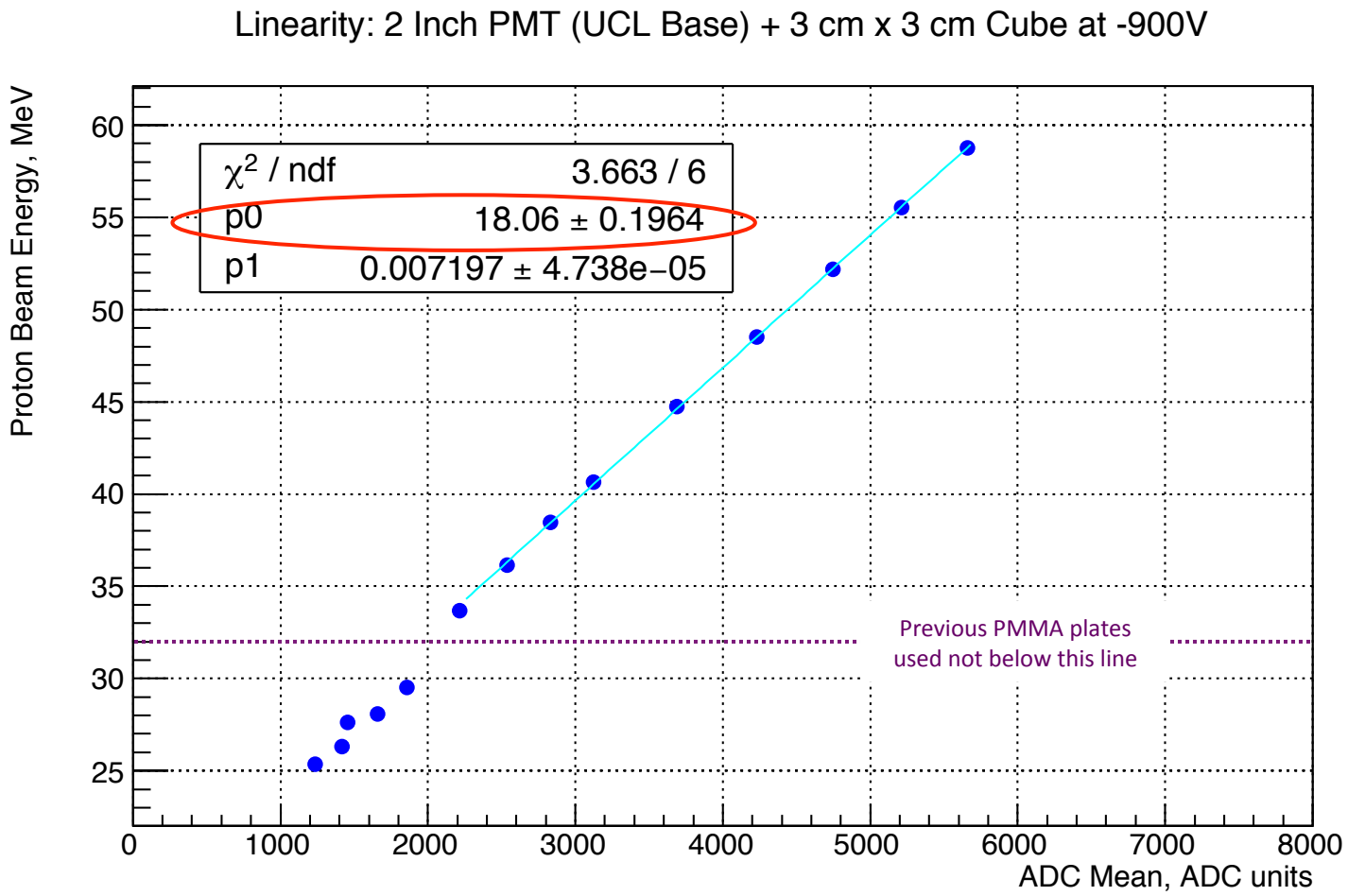
$$y = p0 + \frac{p1}{\sqrt{x}} + \frac{p2}{x} + p3 \cdot x$$

NOTE:

- Systematic errors still need to be estimated for this data set
- "Guesstimate" for now just for the fit, with ± 1% for the lowest energy points
- A great χ^2/NDF even with incorrect errors

Linearity/Energy Scan: -900 V

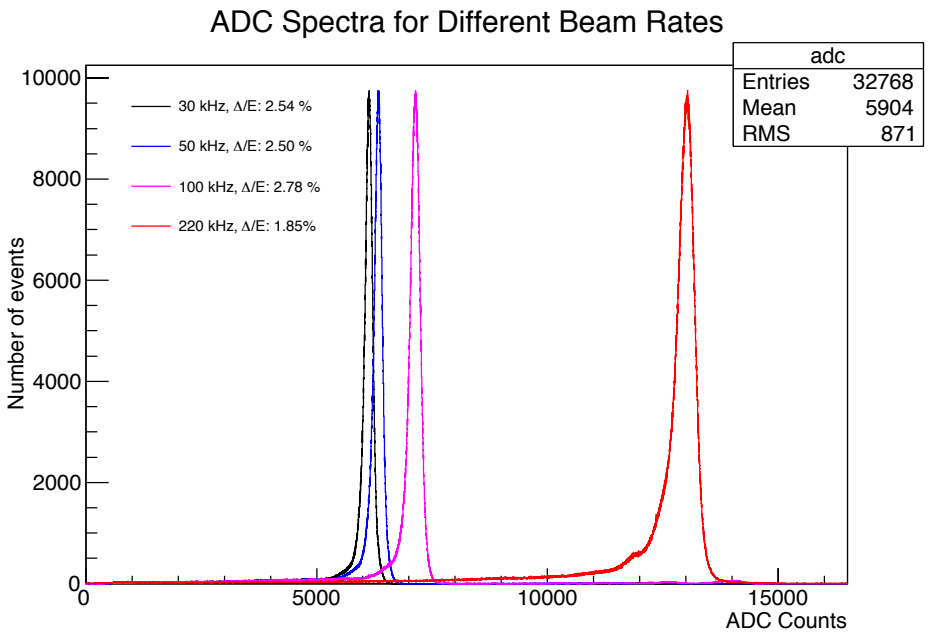
- 1st degree polynomial fit over range shown on plot

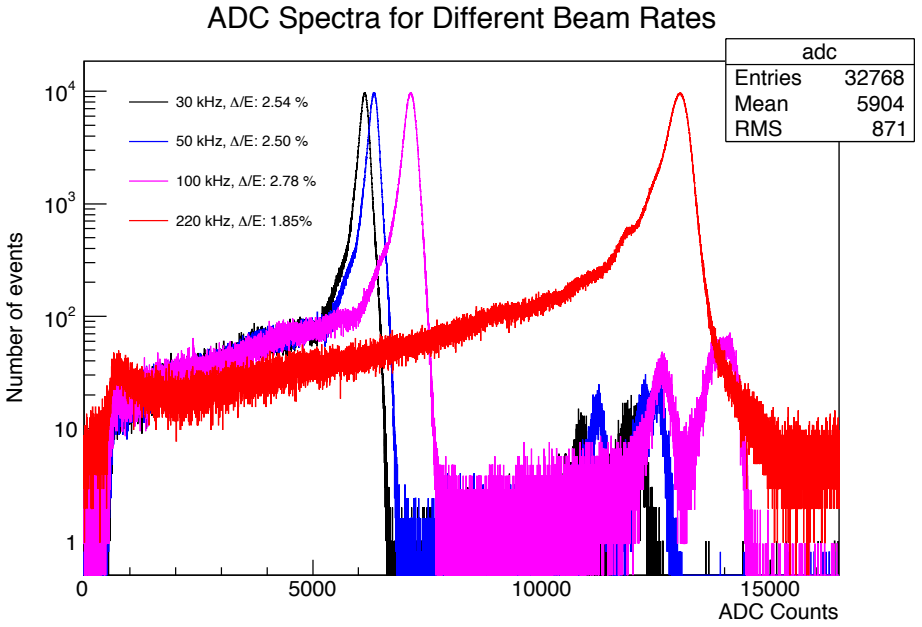


- p0 gives an estimate of quenching in the scintillator (cf 20.49 MeV from simulations for EJ PVT scintillator):
  - 18.06
- Previously, the lowest proton beam energy we tested to was ~ 32 MeV
- Harder to fit the mean at lower energies due to lower statistics
- But even at lower energies we still look to be linear

Rate Tests

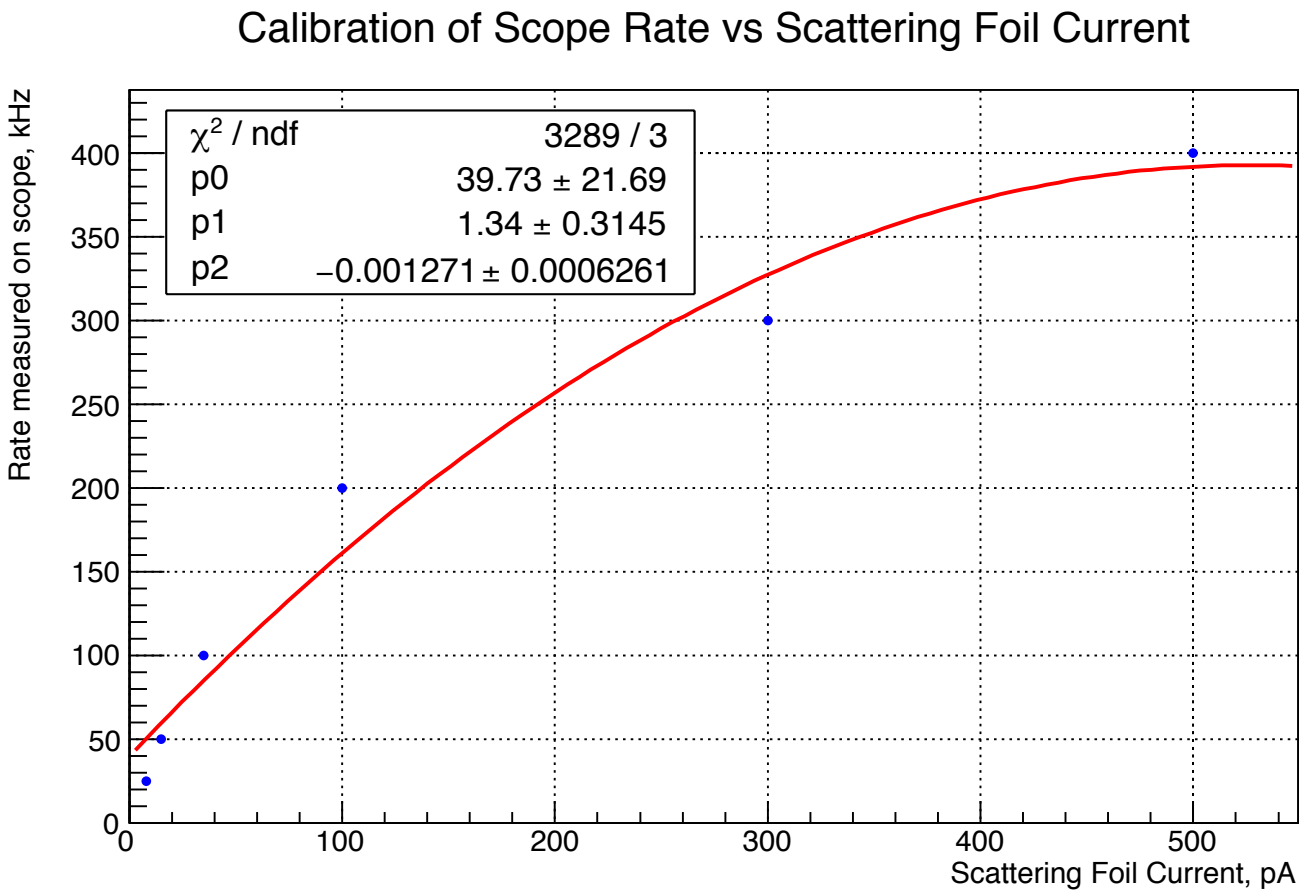
- 1.98 mm Ø collimator





- As rate increases, ADC mean increases and energy resolution appears to improve.
- The ADC mean increasing is the opposite trend to the data we collected in August 2016 with the Hamamatsu active divider base!

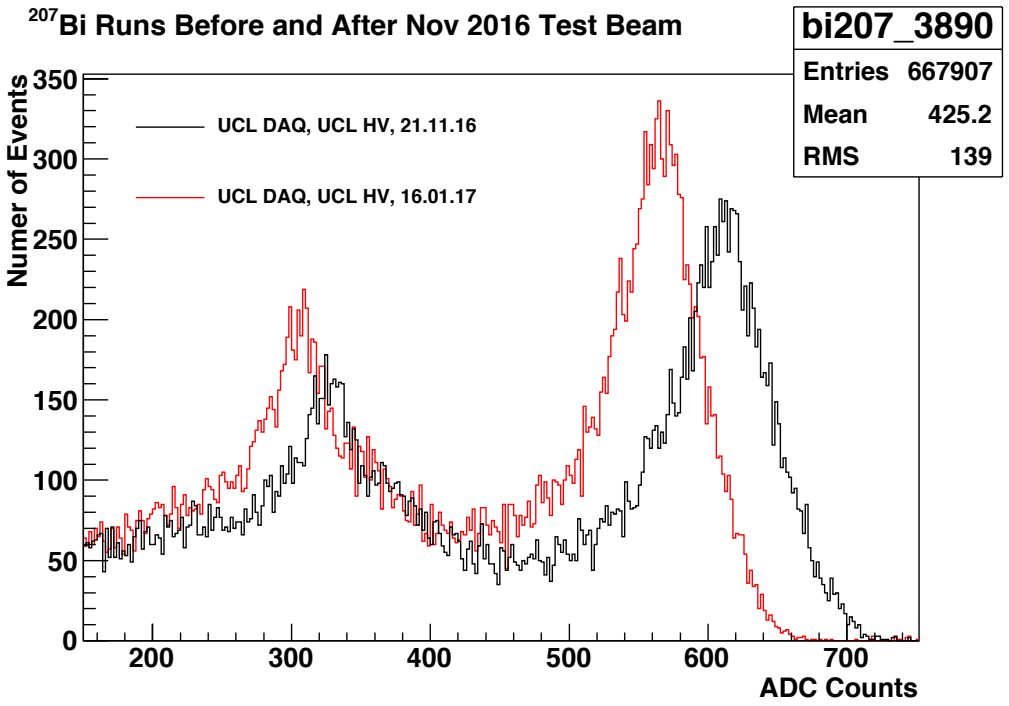
Scope Rate – Scattering Foil Current Calibration



- The plot currently shows scope rate measured at Clatterbridge using the "duration" function
- For complete accuracy we need to analyse scope waveform data to get accurate rates
- Once we have an accurate measurement of this calibration we should be able to rely on the scattering foil current for rate measurements

Radiation Damage Assessment

- ^{207}Bi tests carried out at -1700 V:
  - before test beam: 21/11/2016
  - after test beam: to be done
- Total radiation dose received by 2” OM (not yet accounting for collimators etc.): 428.4 monitor units (0.9 Gy/monitor unit) in 367 minutes of running.
- Scaling for 1.98 mm collimator diameter from a 17 mm beam diameter and converting to Gy: 1.5 Gy



- This scintillator has now received a total of 4.2 Gy (August 2016) + 1.5 Gy (November 2016): **5.7 Gy**

Date	HV Supply	DAQ	ΔE/E (%)
21/11/16	UCL	UCL	9.02 ± 0.22
Clatterbridge Test Beam: 24-25/11/16			
16/01/16	UCL	UCL	7.98 ± 0.15

- No noticeable worsening in resulting energy resolution.