NSSC 8
NUCLEAR SCIENCE and SECURITY CONSORTIUM

Nuclear Science and Security Consortium

September Workshop and Advisory Board Meeting

Proton Light Yield Measurements in Organic Scintillators

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Radiation Detection and Instrumentation

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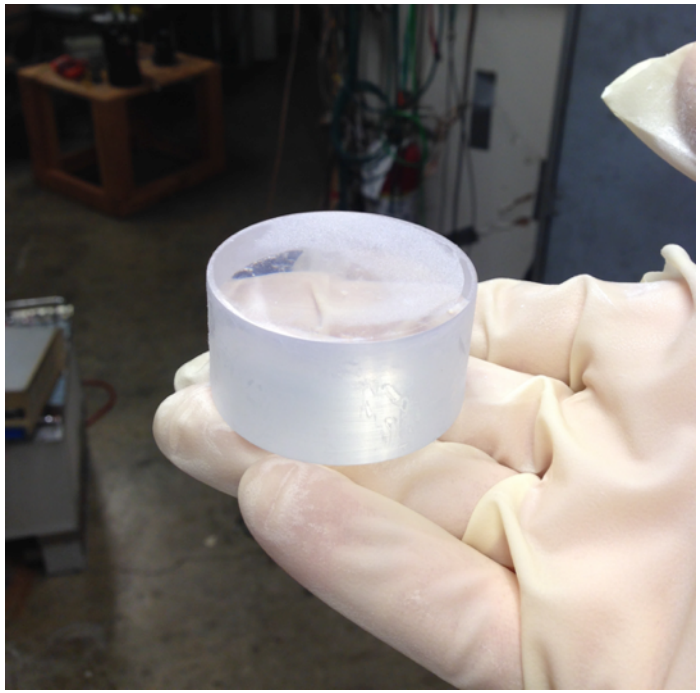
Organic Scintillators

A **scintillator** is a material that emits light when excited by ionizing radiation.



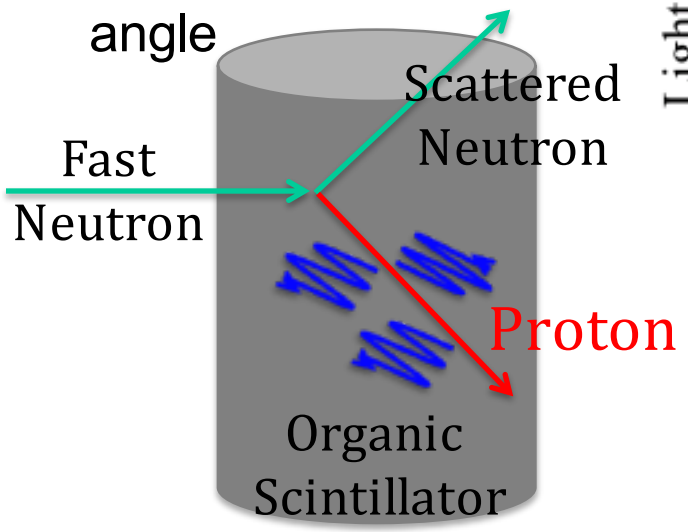
Applications:
- fast neutron imaging
- neutron spectroscopy
- source localization
- basic physics experiments

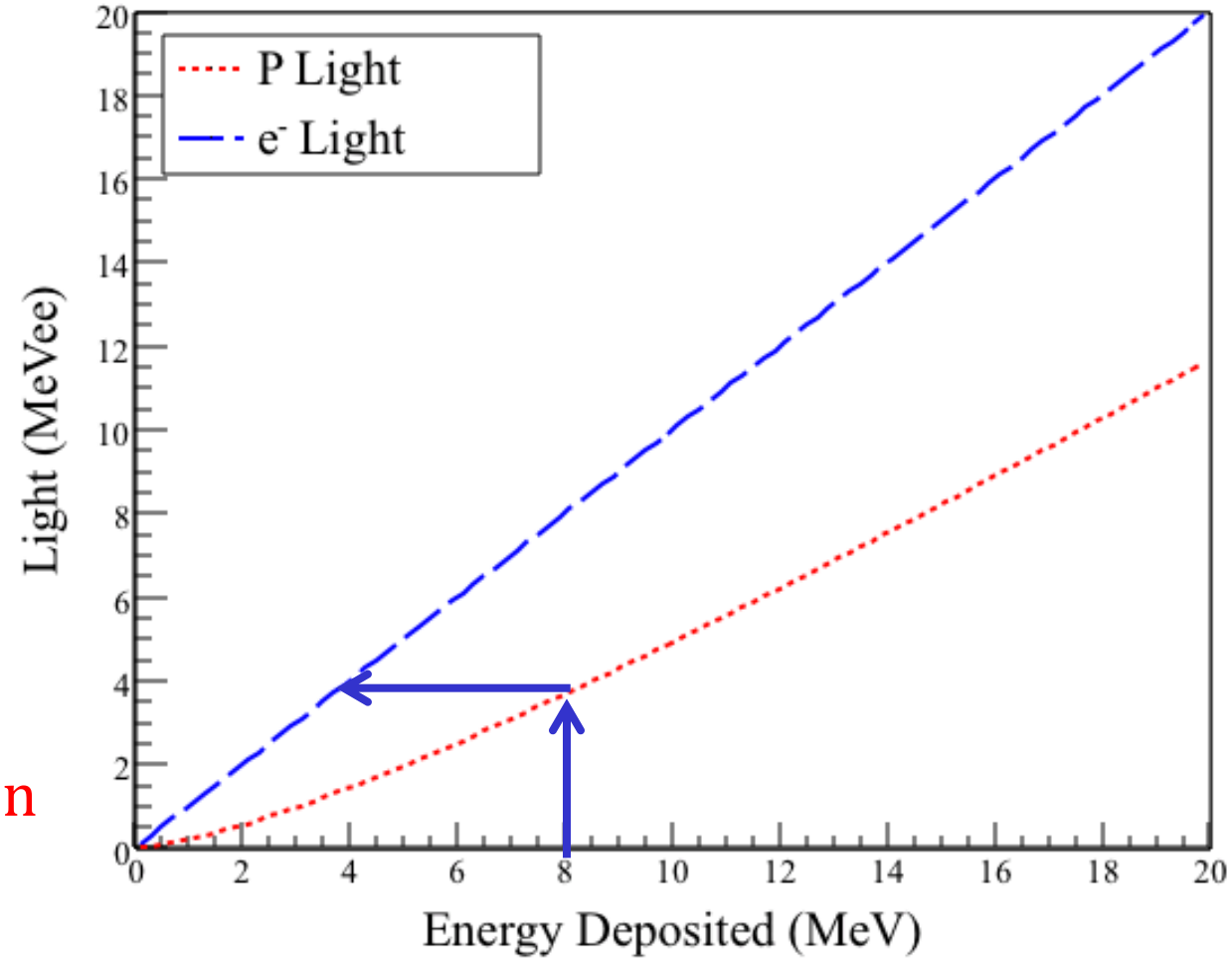
Important to understand the relationship between the energy deposited by the ionizing particle and the light emitted.

Proton Light Yield – Note on Units

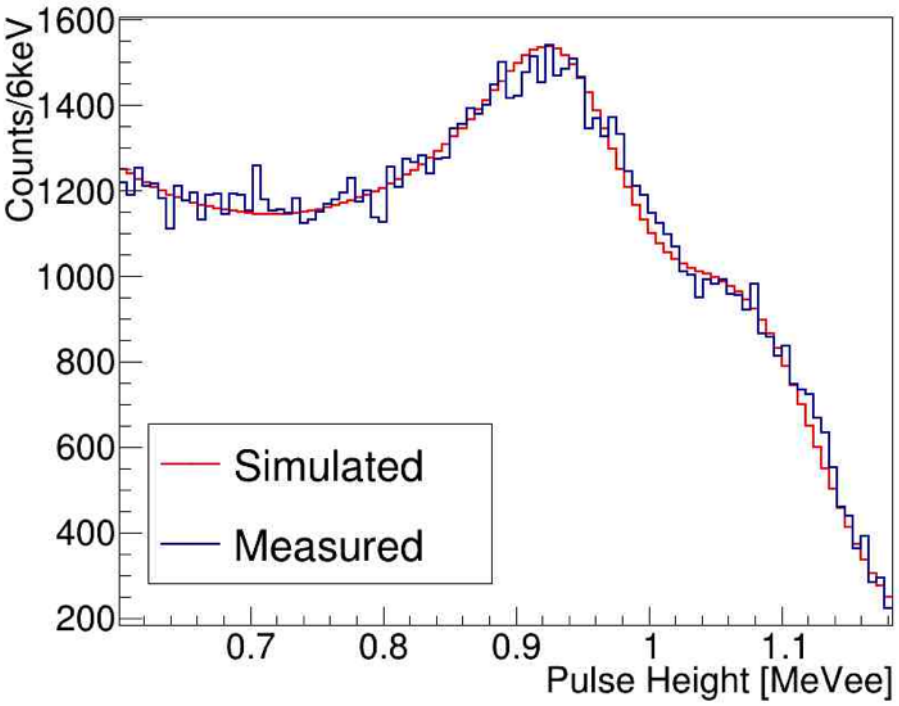
Primary light generating mechanism is n-p scattering

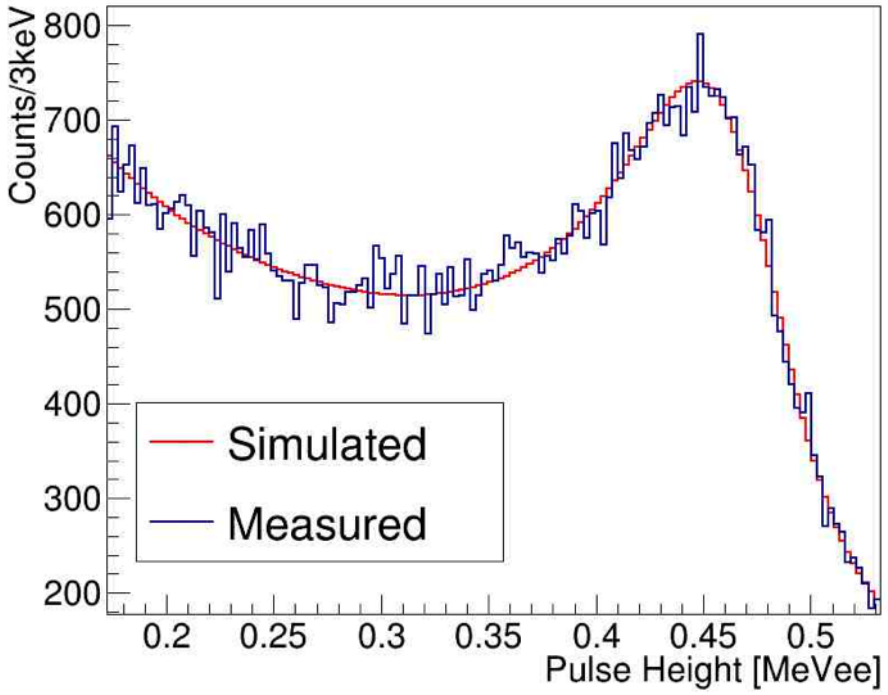
➔ Energy transferred to the proton is a function of the neutron scattering angle





MeVee Calibration





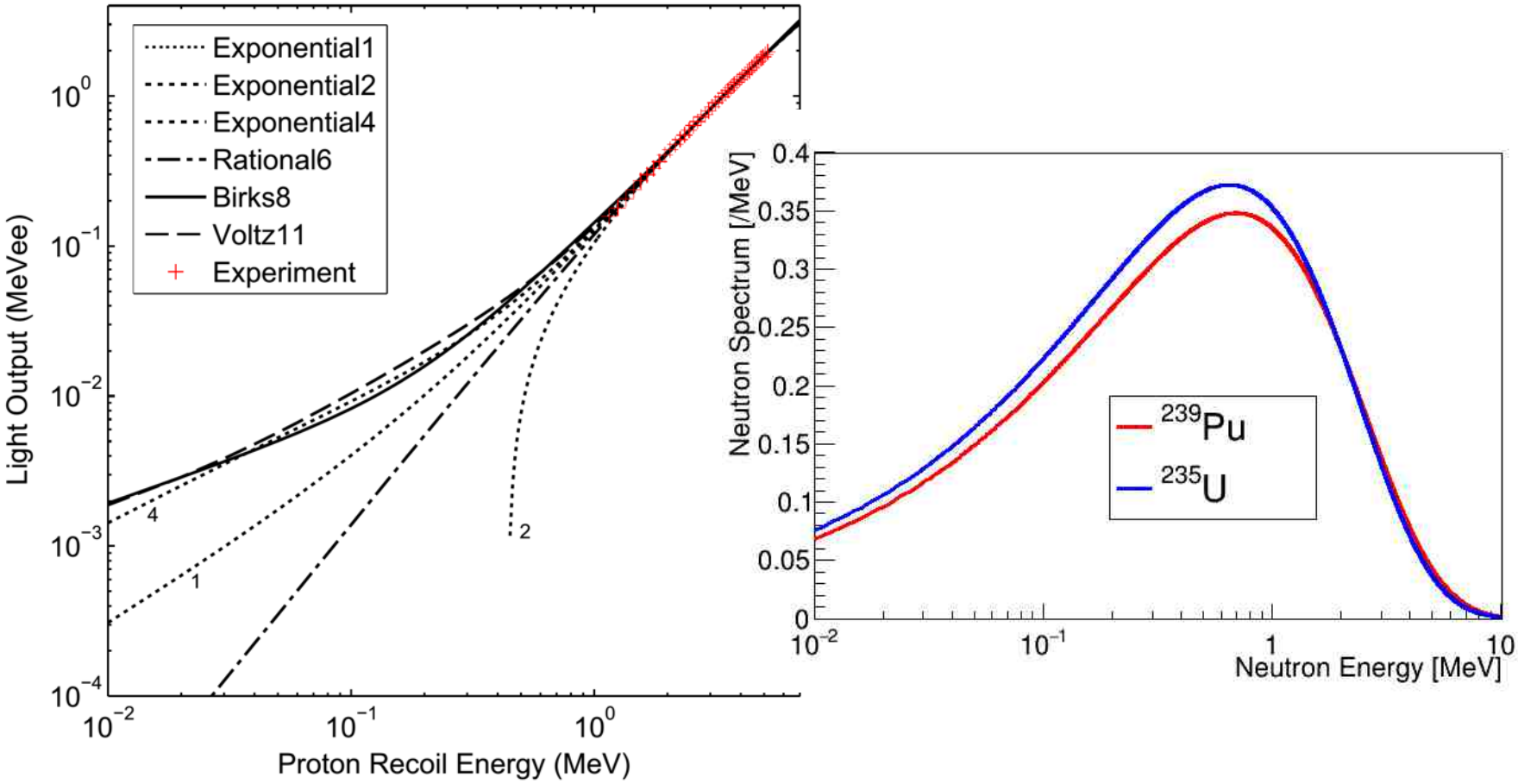
^{60}Co

Eγ = 1.17,1.33 MeV

^{137}Cs

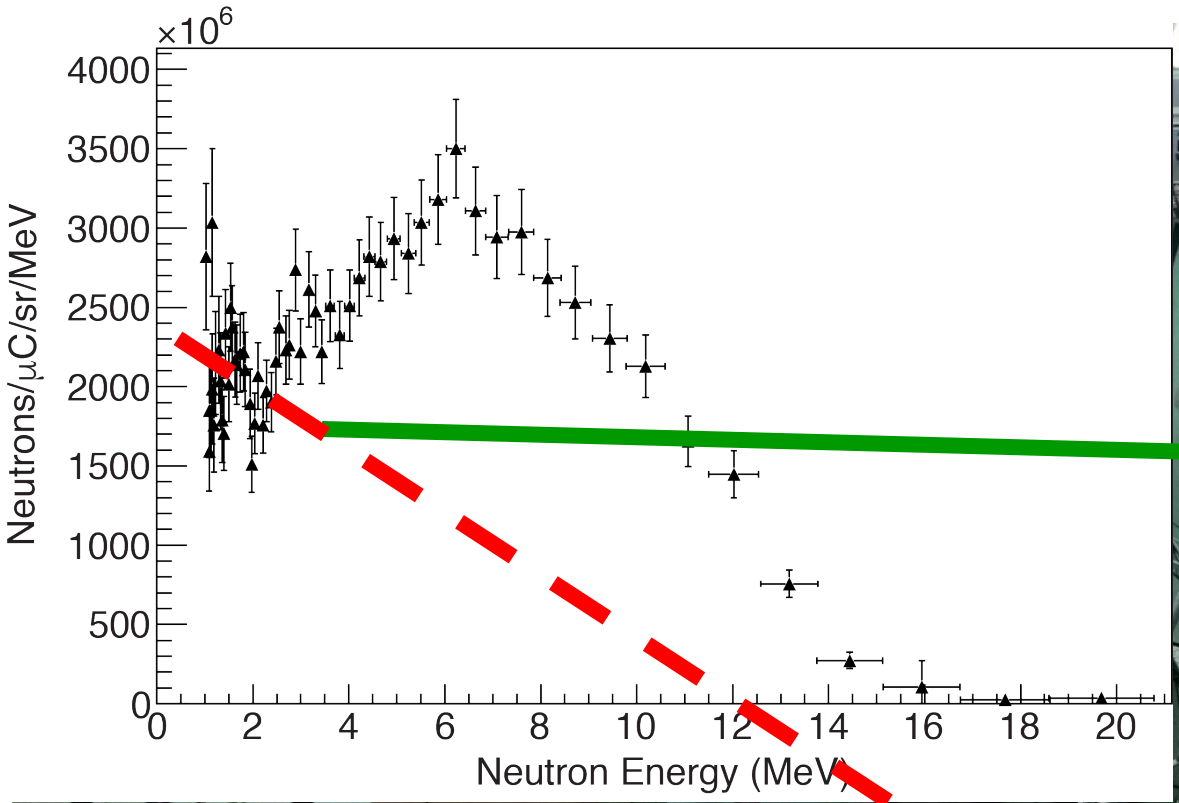
Eγ = 662 keV

Low Energy Light Yield



M.A. Norsworthy et al, NIM A 842 (2017).

Scintillator Characterization Capability at LBNL

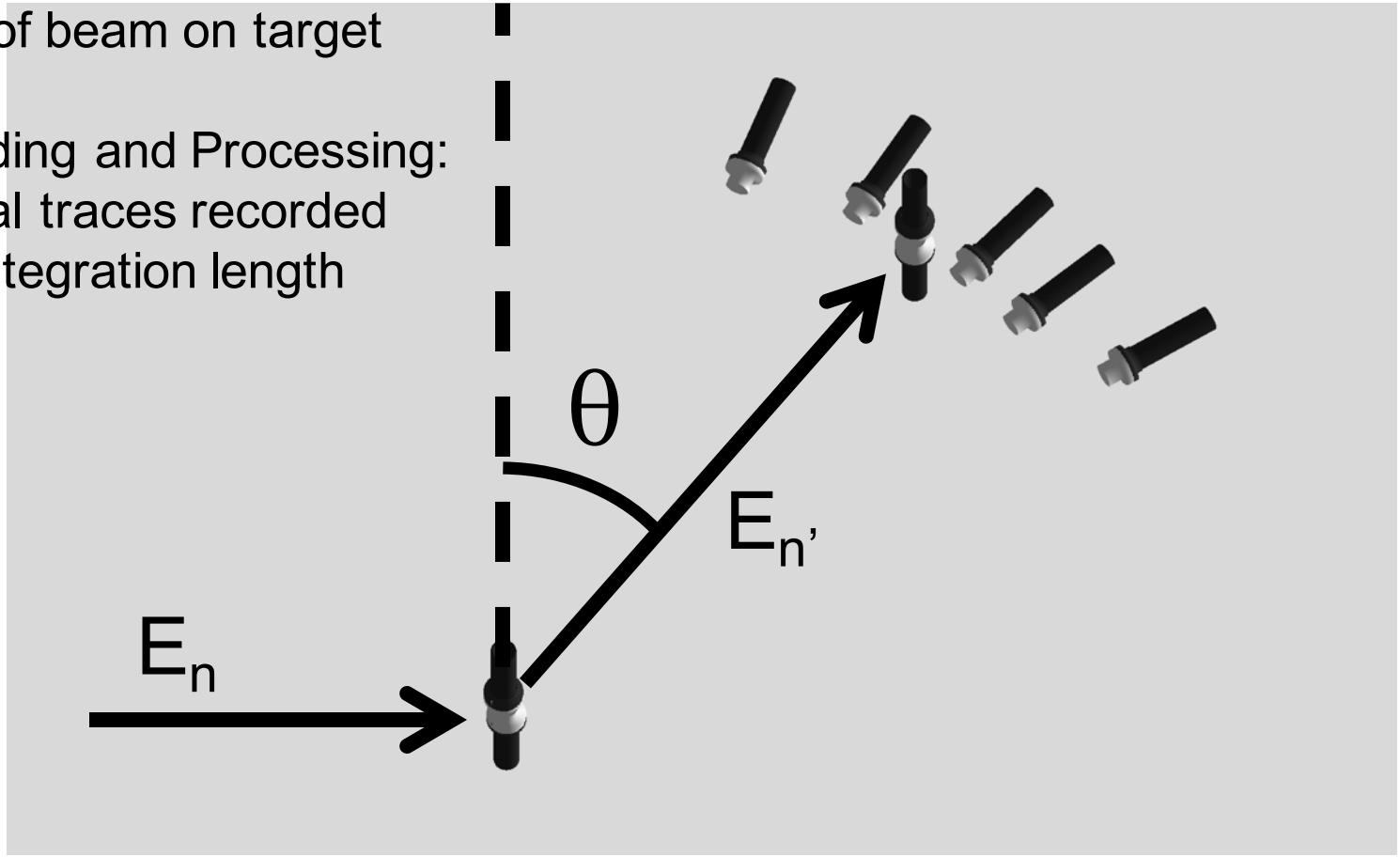


K. P. Harrig *et al.*, submitted to NIM A

EJ309 Measurement

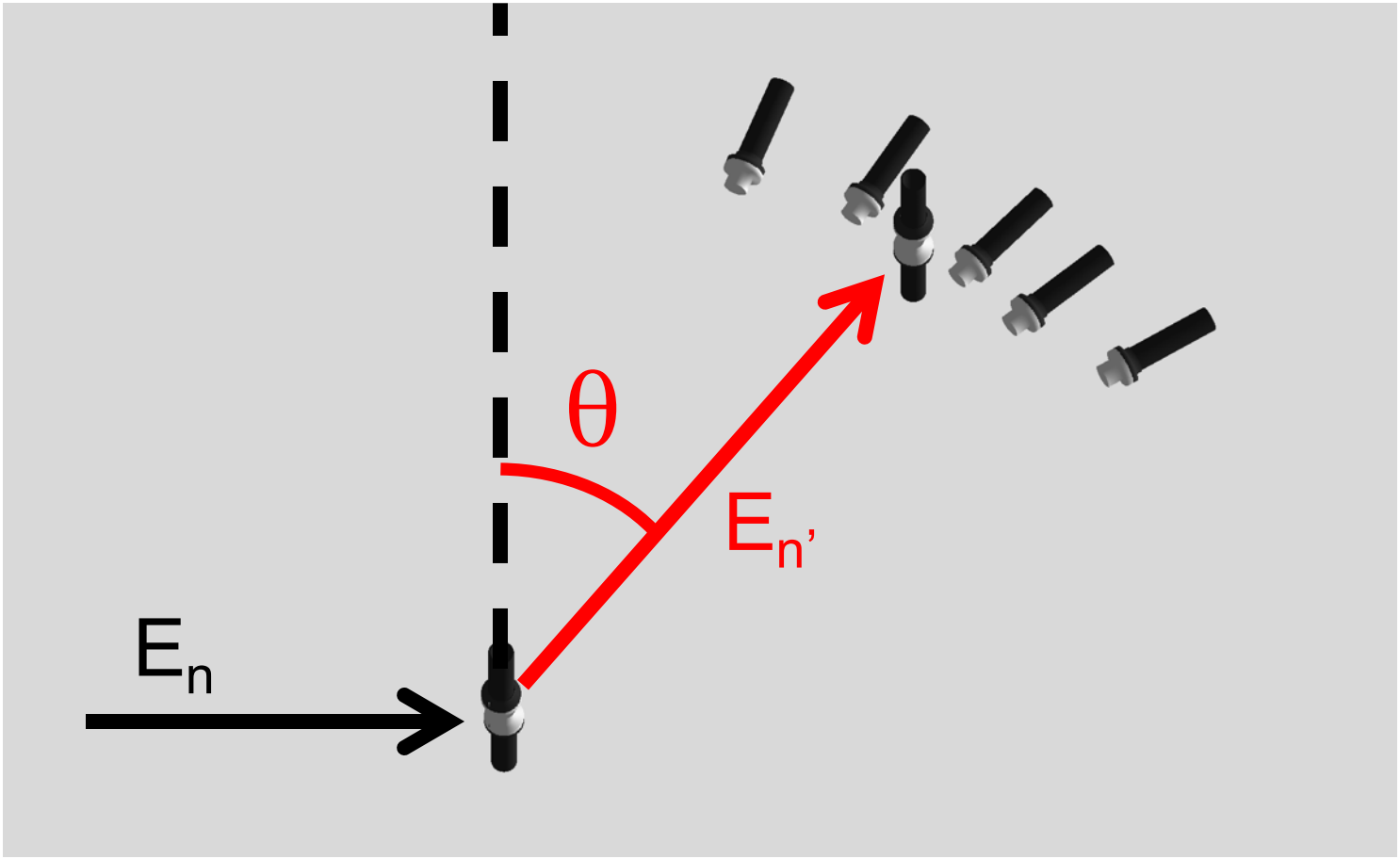
- 16 MeV deuterons on Ta breakup target
- Coincidence between Target, Scatter and Cyclotron RF
- 7 Hours of beam on target

Data Recording and Processing:
- Full digital traces recorded
- 300 ns integration length



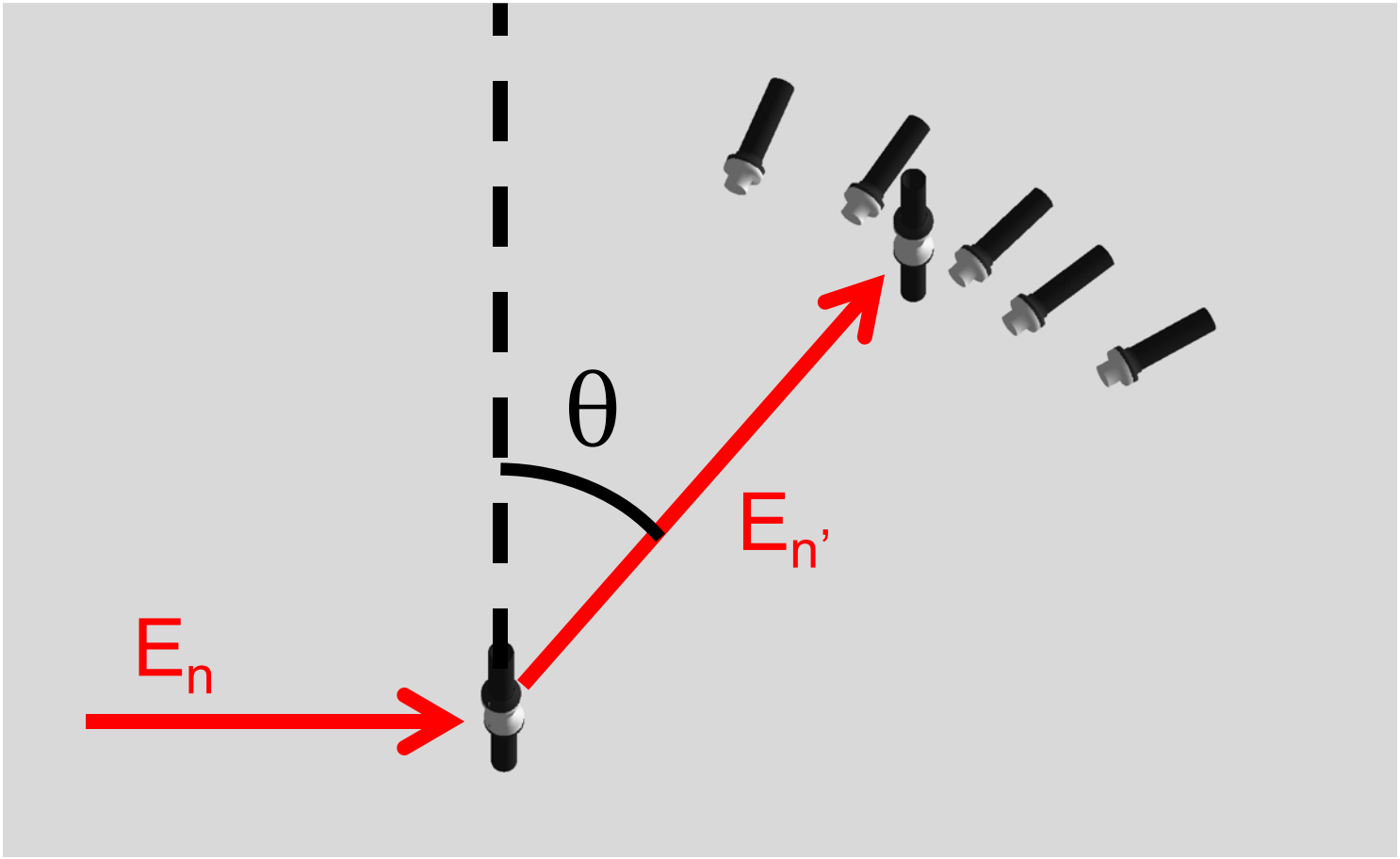
Overconstrained System

Angle + Outgoing Time of Flight



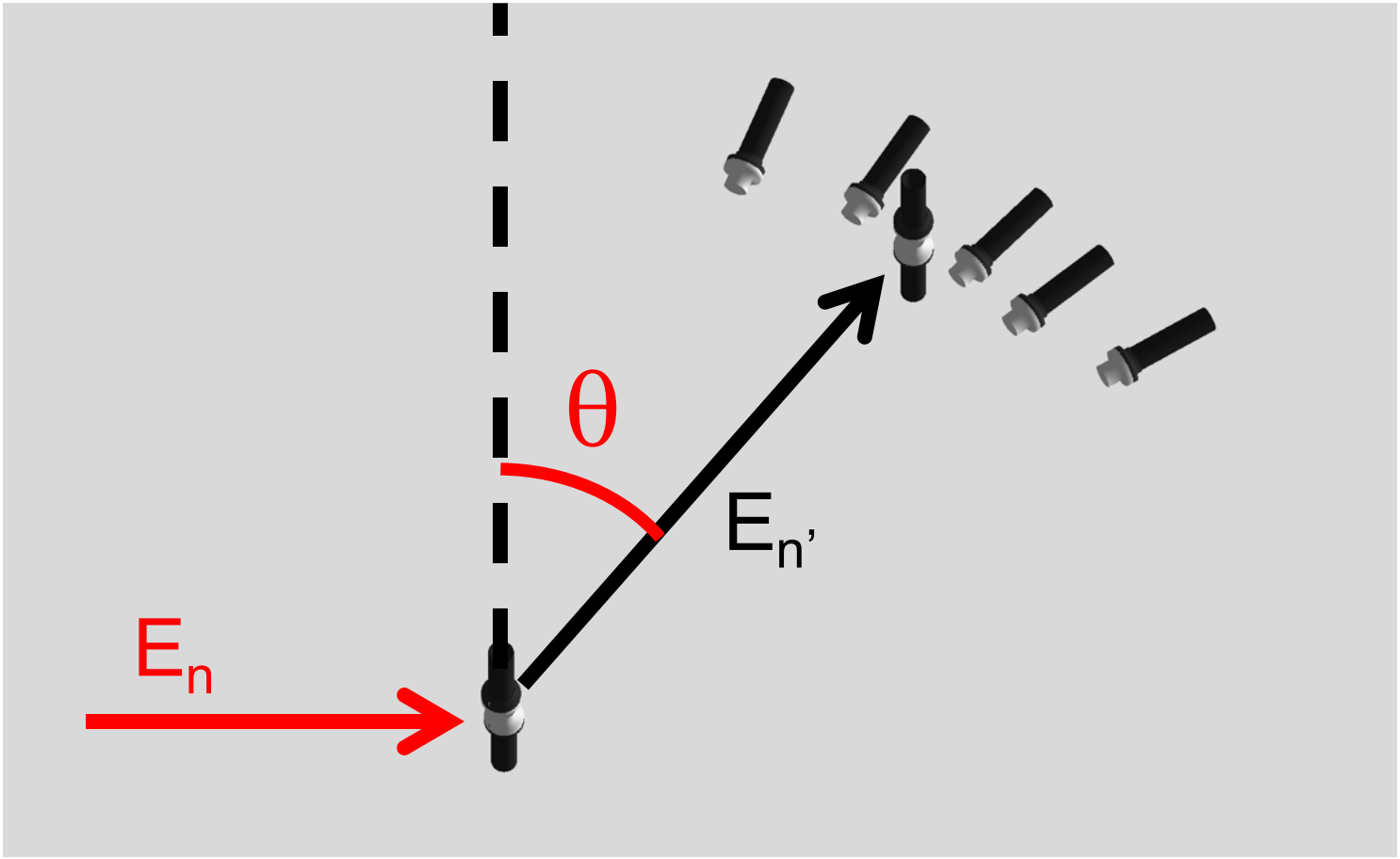
Overconstrained System

Incoming + Outgoing Time of Flight

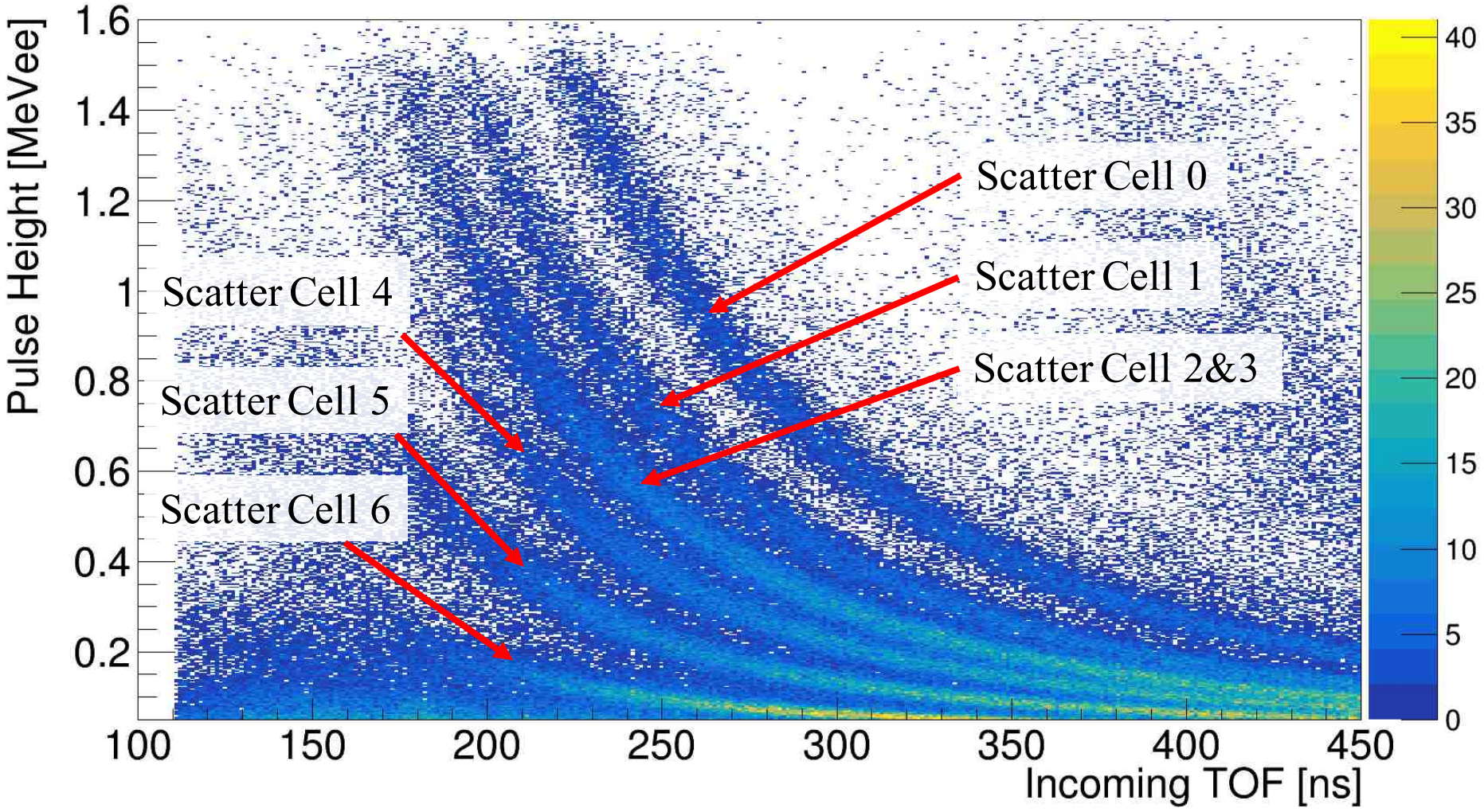


Overconstrained System

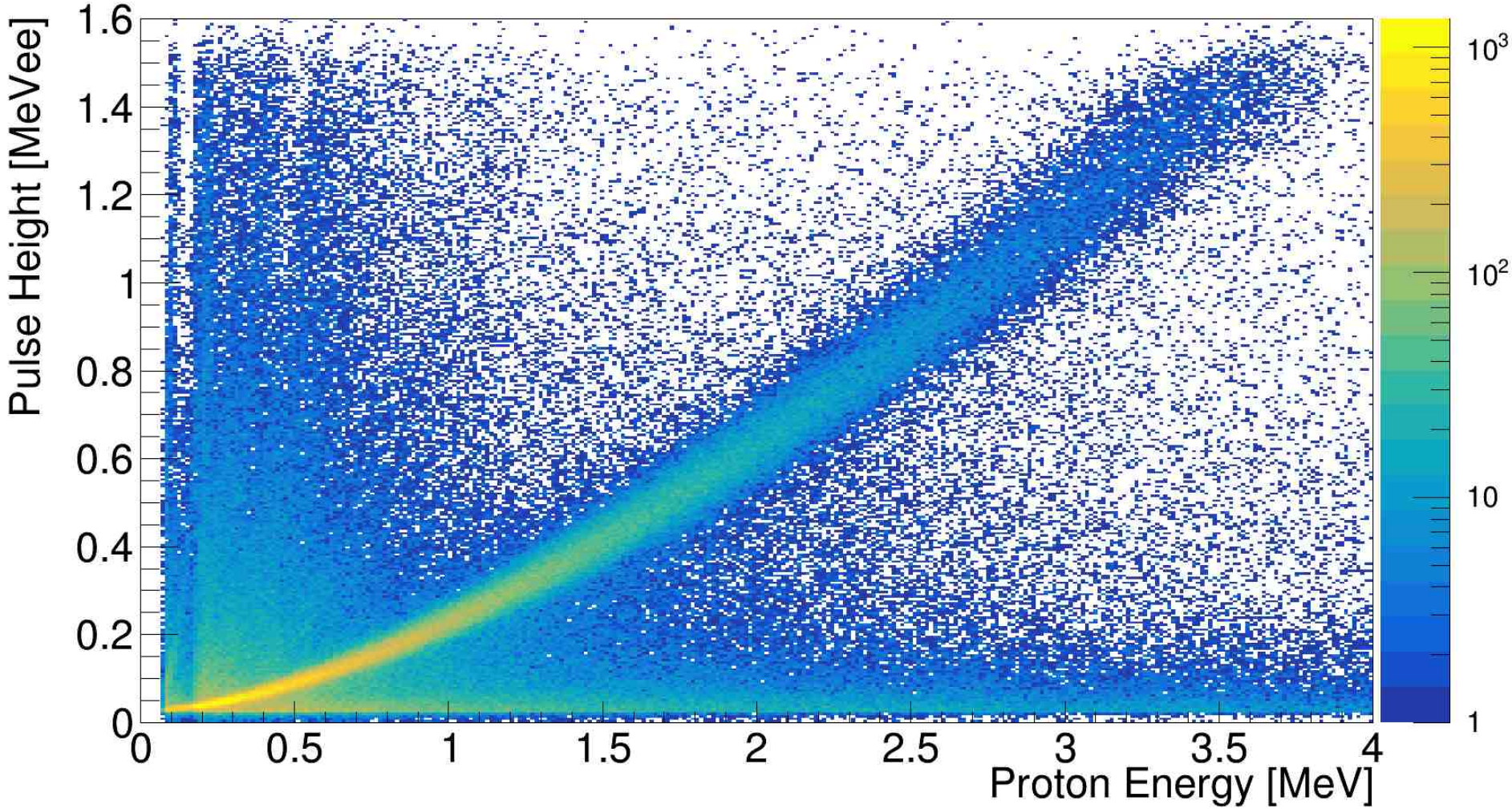
Angle + Incoming Time of Flight



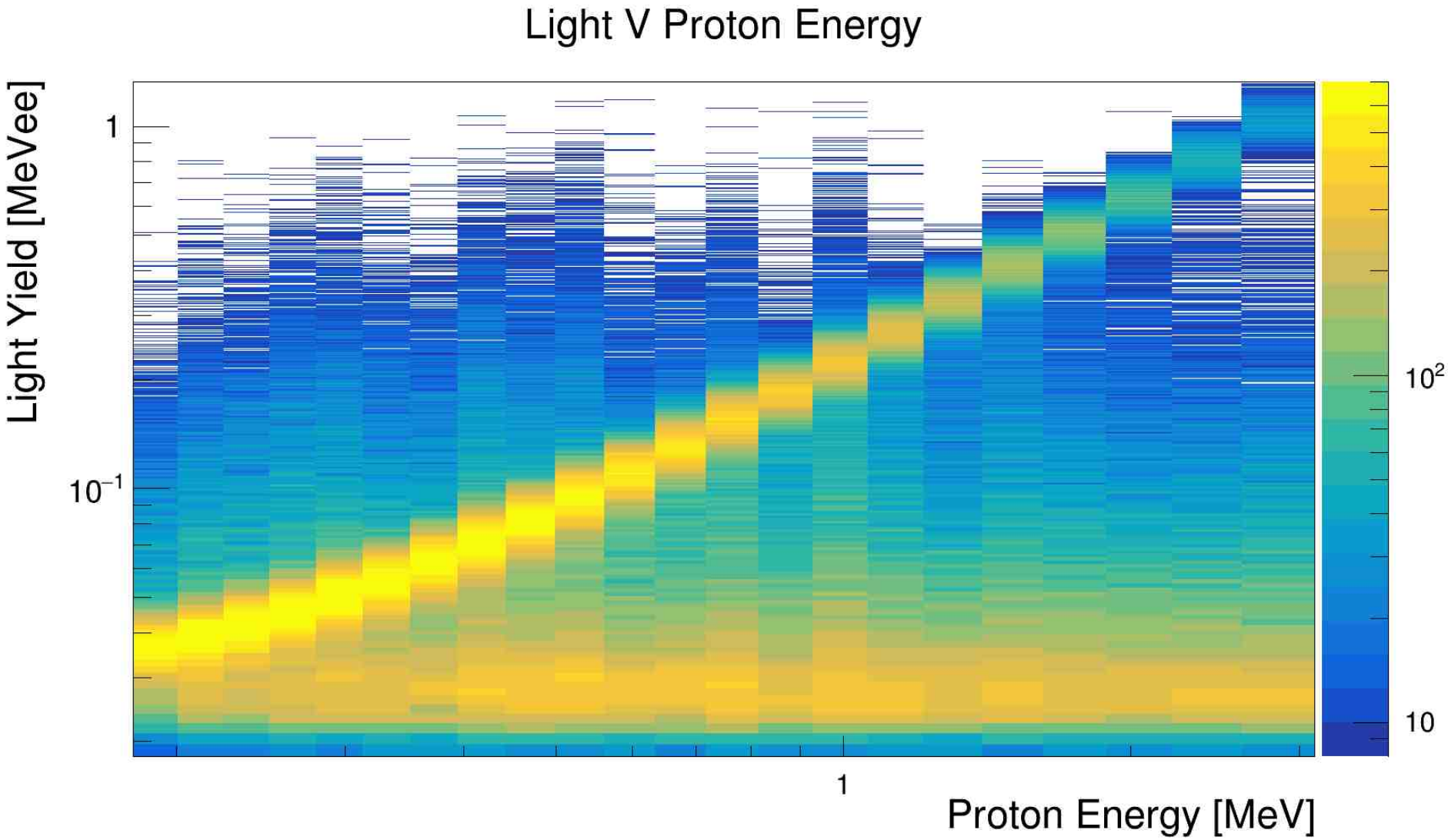
Light Yield vs Incoming TOF



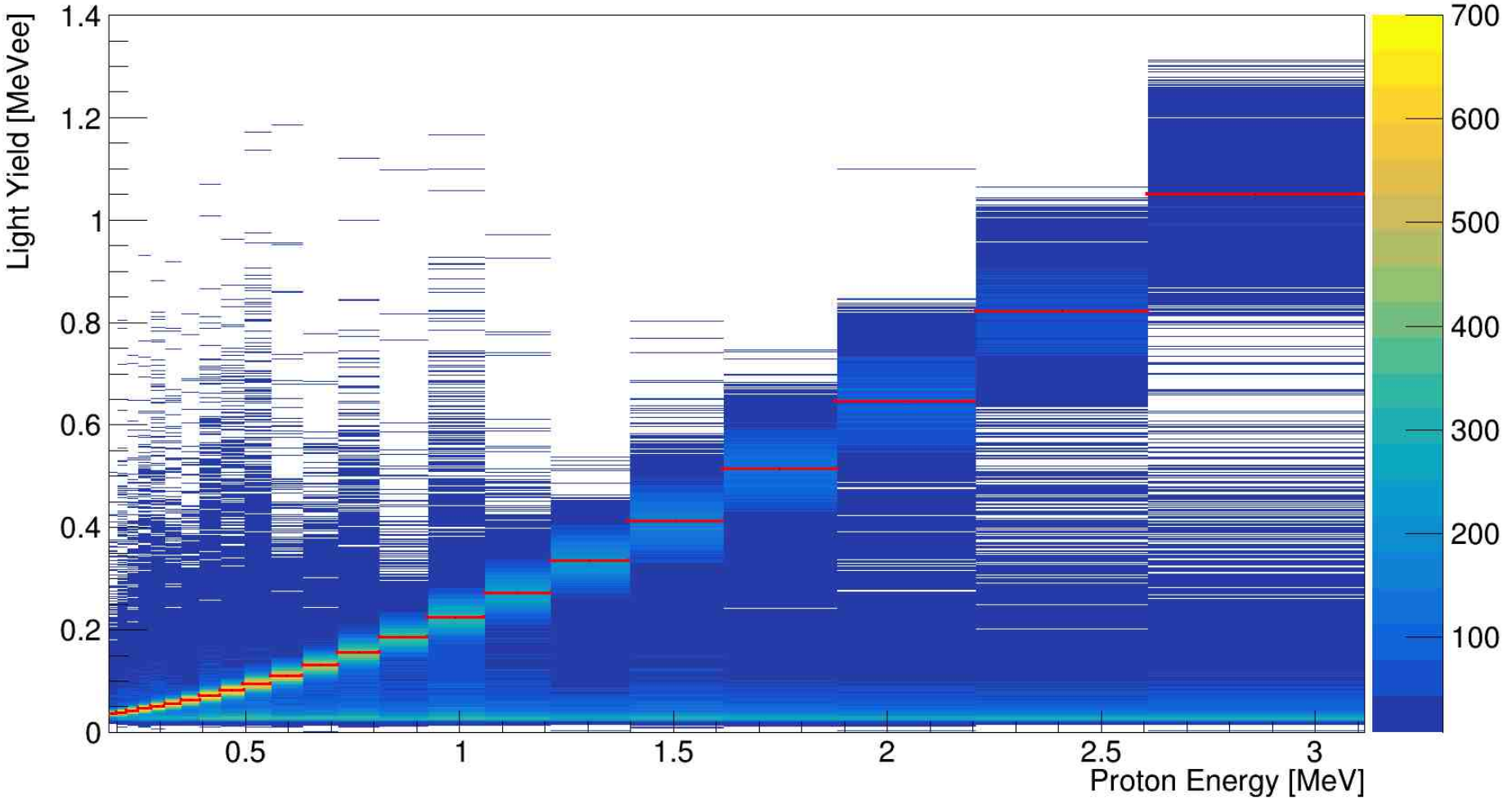
Proton Light Yield



Proton Energy Resolution

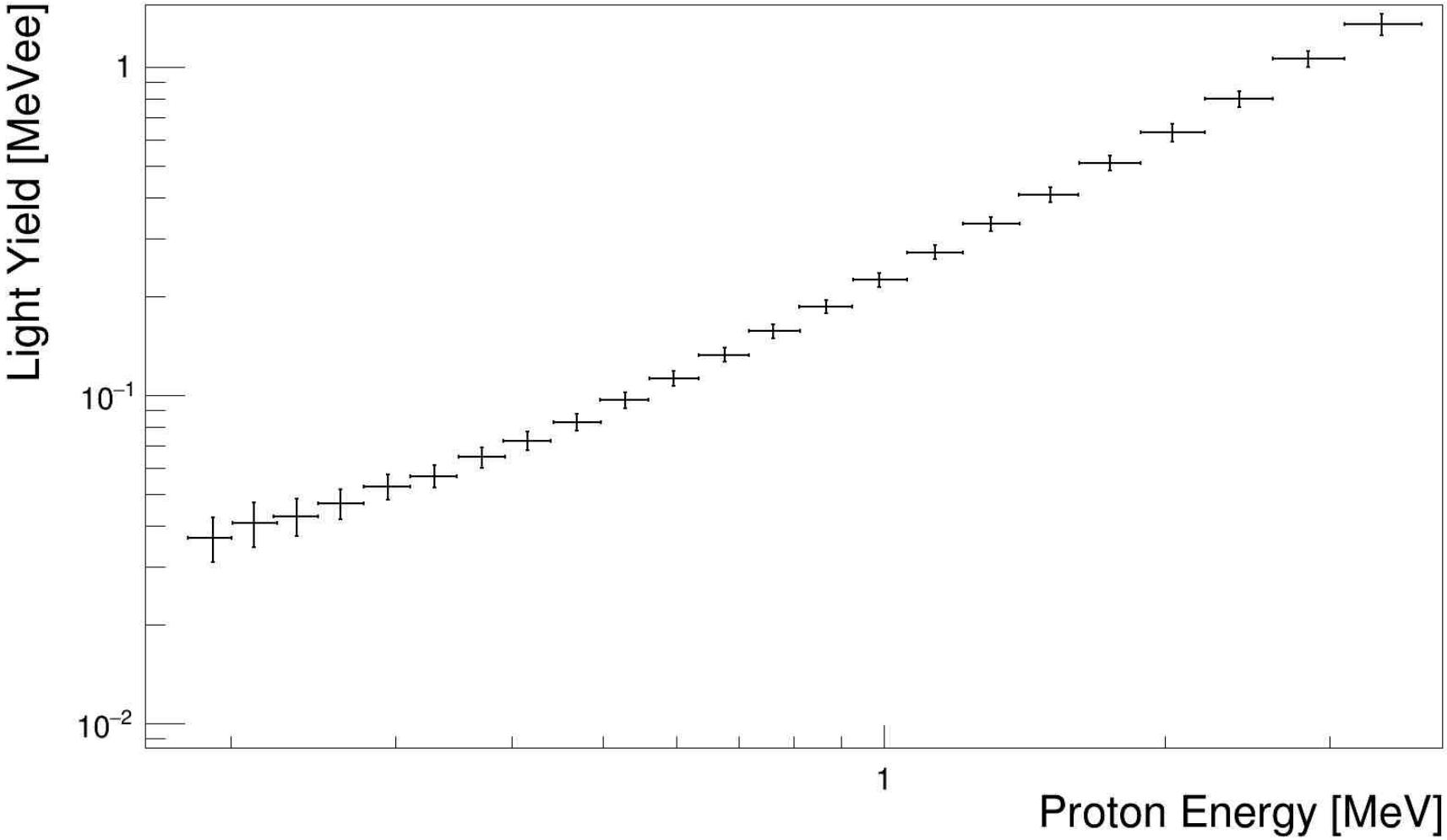


Light Yield Centroid Determination

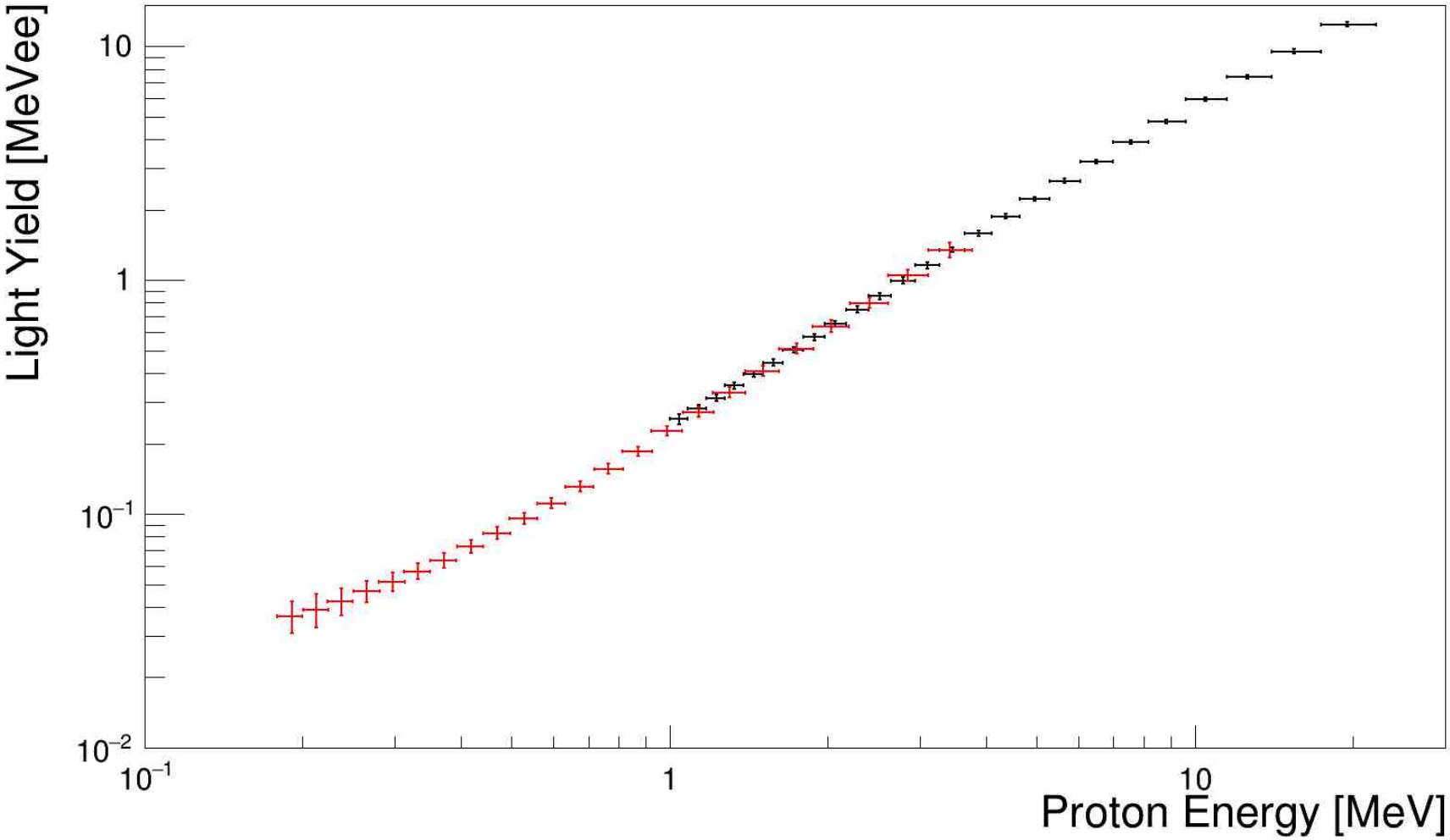


Systematic Error Analysis

EJ309



Comparison with other EJ309 measurement



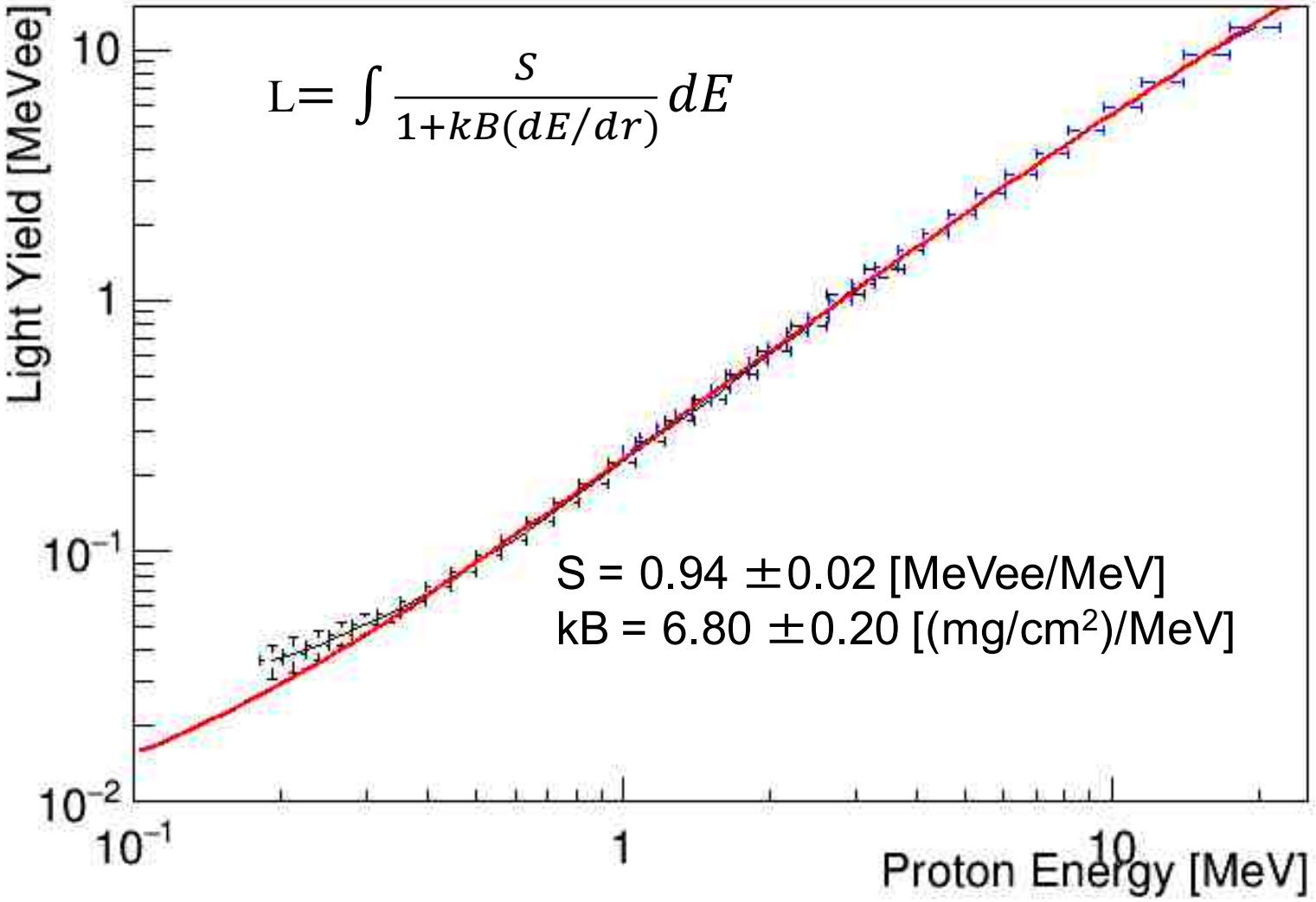
Physics Models

Birks Light Yield [1]: $\frac{dL}{dr} = \frac{S\,(dE/dr)}{1 + kB(dE/dr)}$

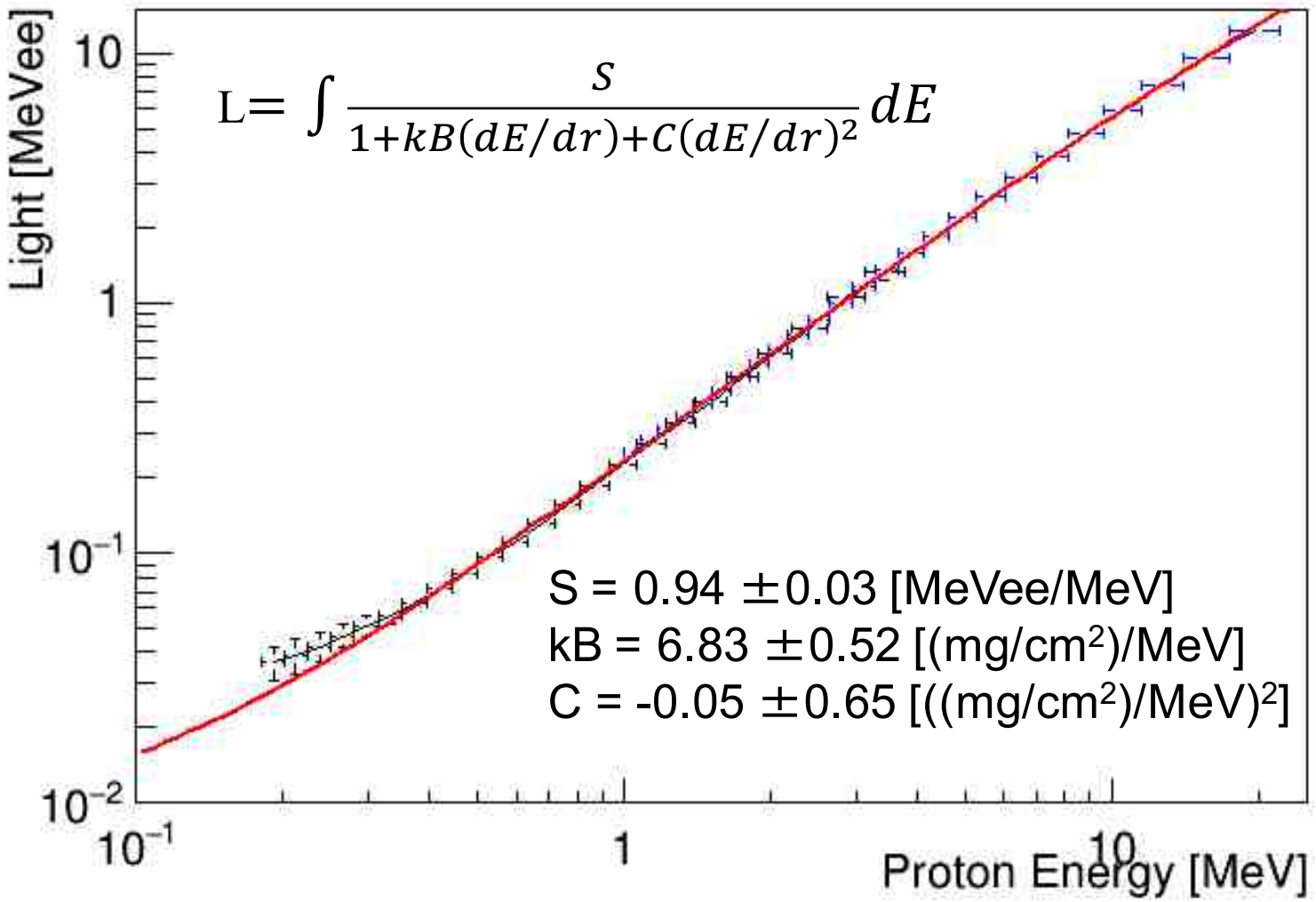
L = Scintillation intensity
S = Light emission efficiency
kB = Quenching parameter

[1] J.B. Birks, Proc. Phys. Soc. A **64** 874, (1951).

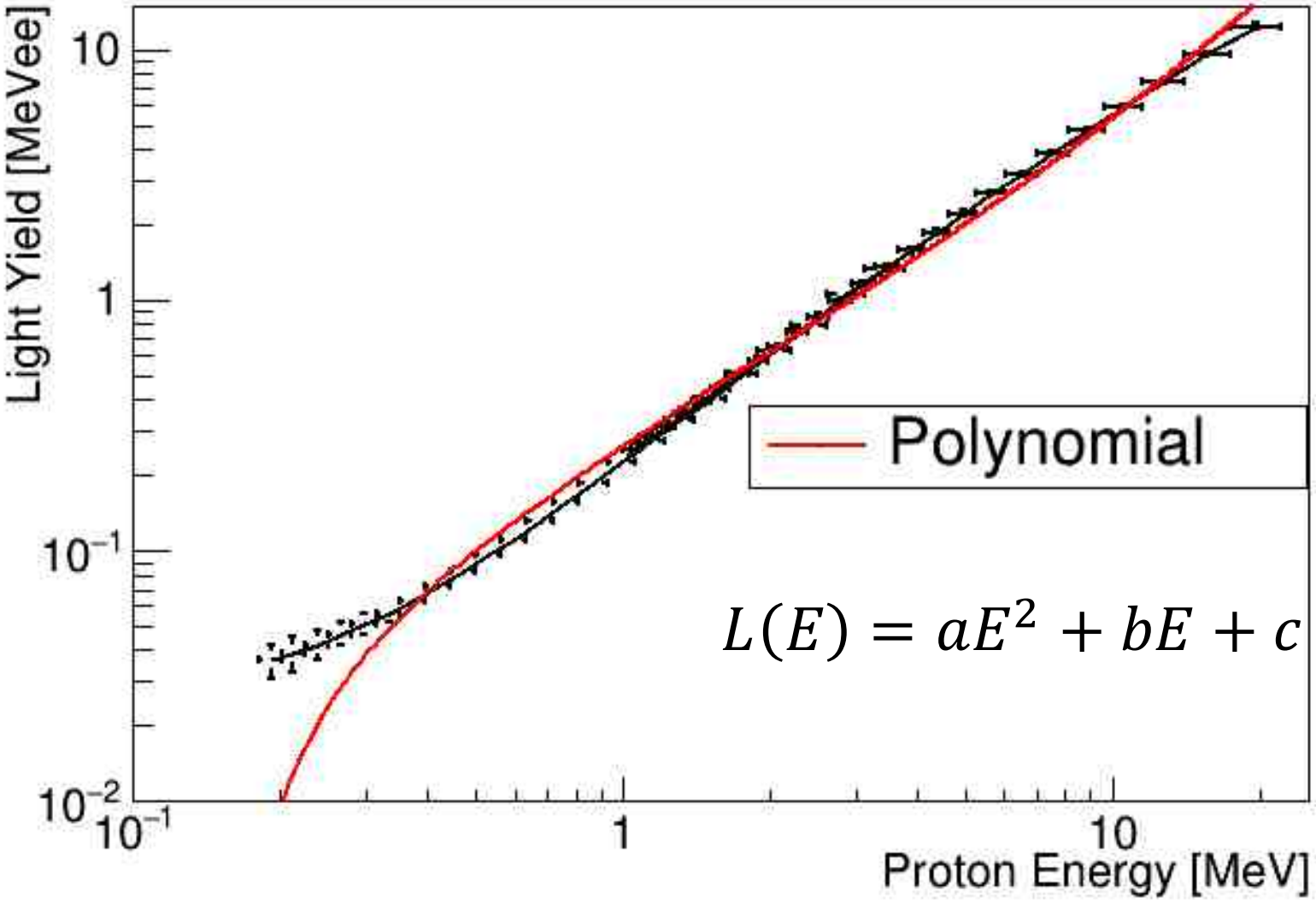
Birks' fit


$L = \int \frac{S}{1+kB(dE/dr)} dE$
S = 0.94 ±0.02 [MeVee/MeV]
kB = 6.80 ±0.20 [(mg/cm²)/MeV]
Light Yield [MeVee]
Proton Energy [MeV]
10
1
10^{-1}
10^{-2}
10^{-1}
1
10

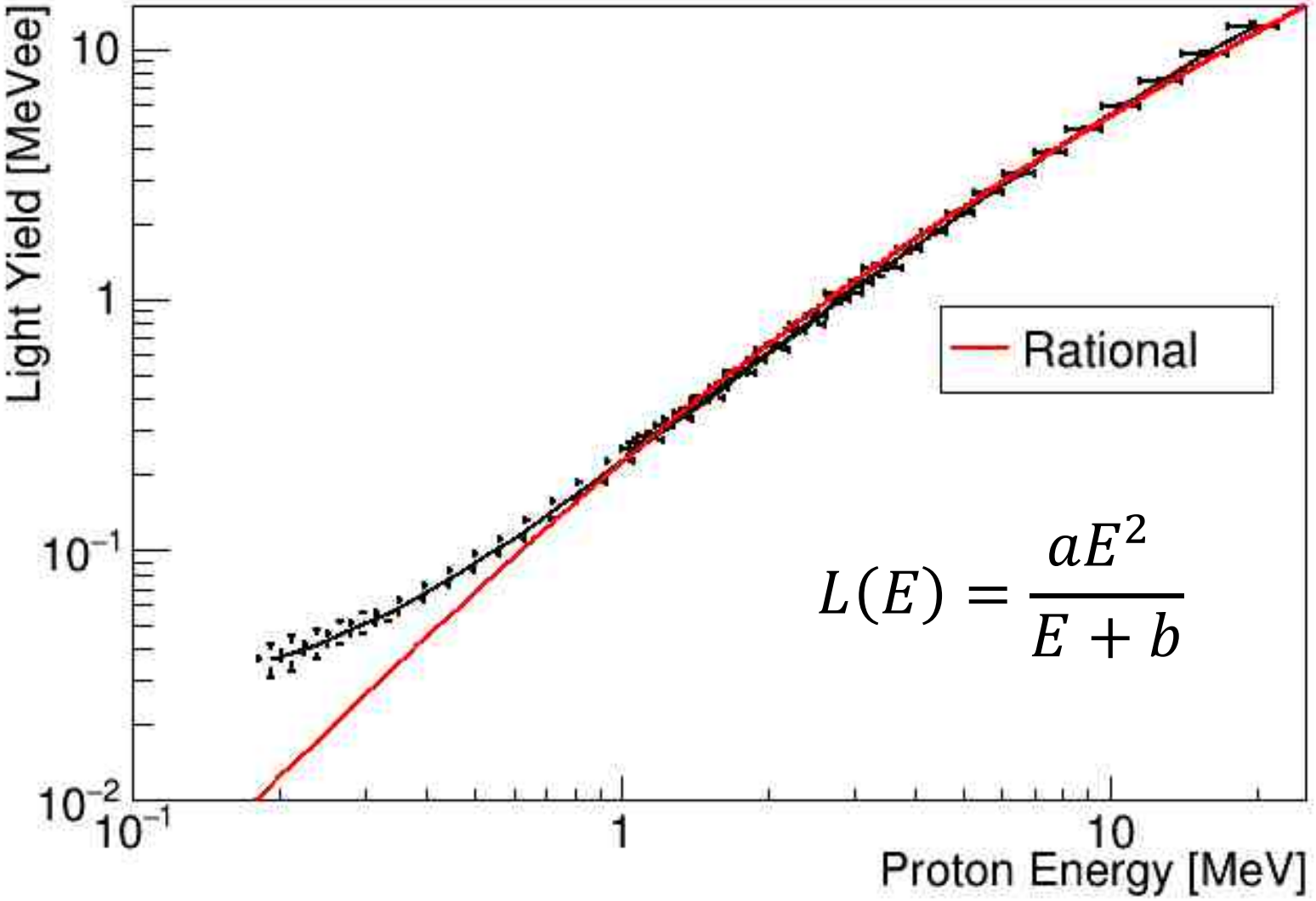
Chou's fit


$L = \int \frac{S}{1+kB(dE/dr)+C(dE/dr)^2} dE$
S = 0.94 ±0.03 [MeVee/MeV]
kB = 6.83 ±0.52 [(mg/cm²)/MeV]
C = -0.05 ±0.65 [((mg/cm²)/MeV)²]
Light [MeVee]
Proton Energy [MeV]
10
1
10^{-1}
10^{-2}
10^{-1}
1
10

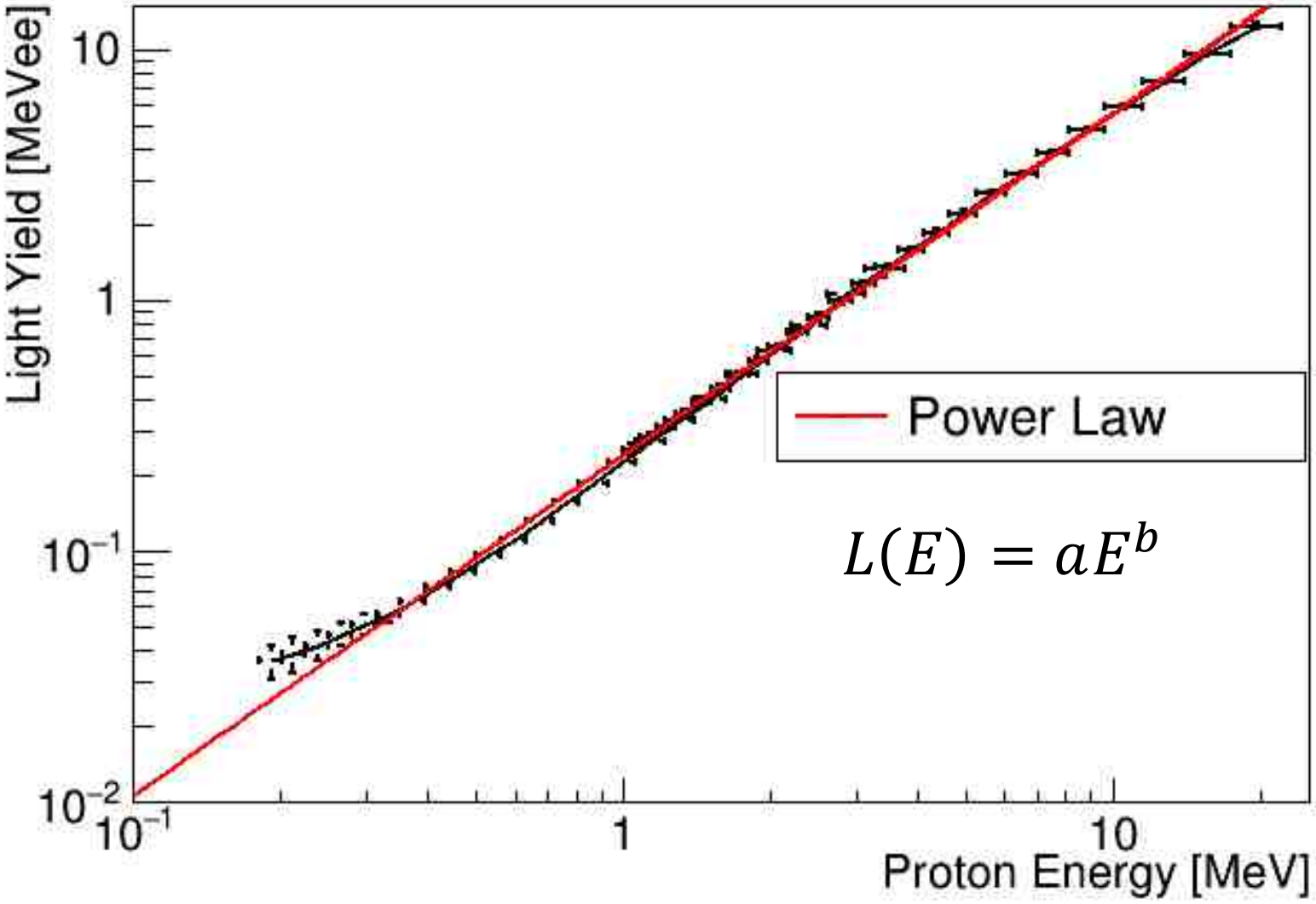
Other Functional Forms



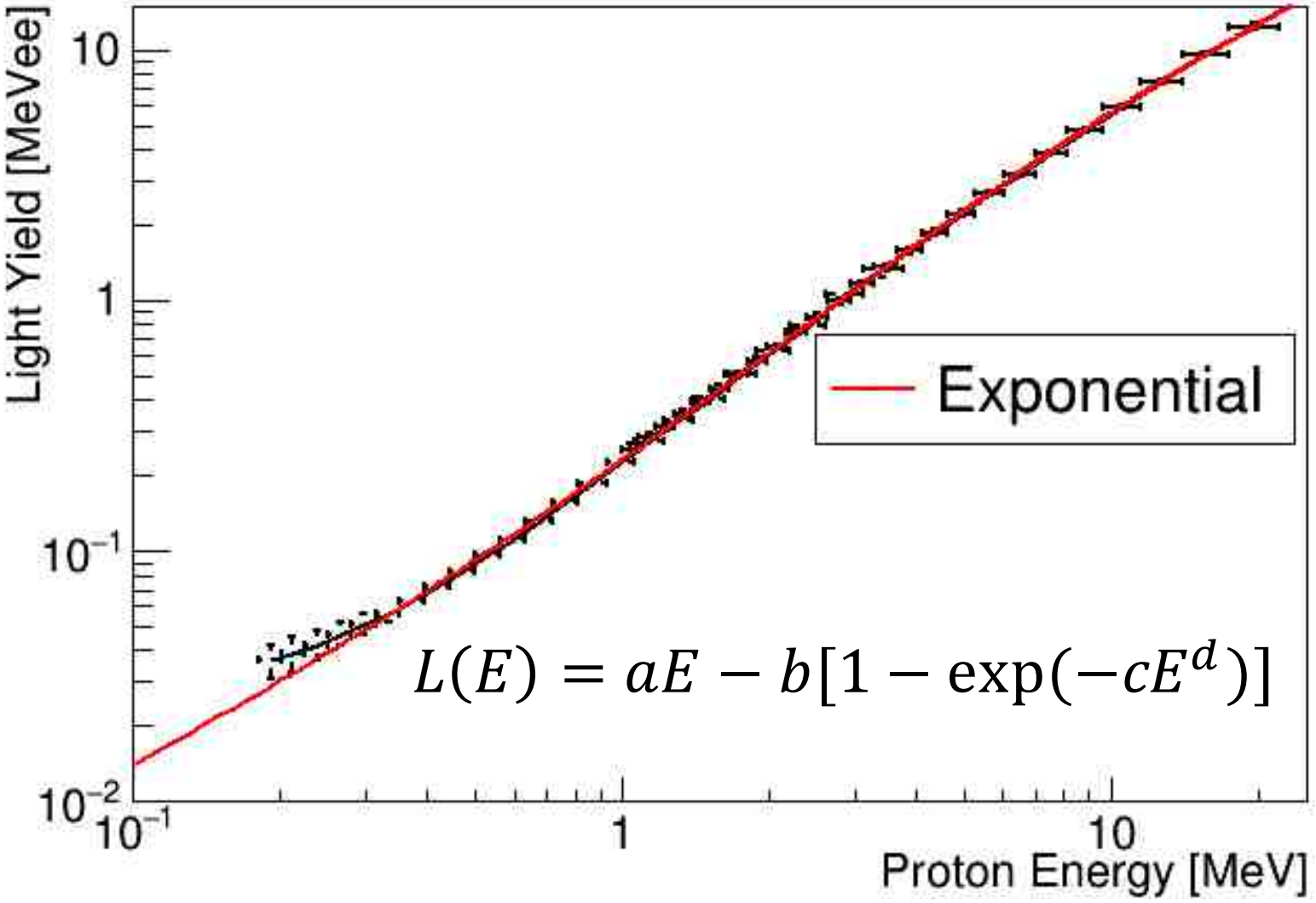
Other Functional Forms



Other Functional Forms



Other Functional Forms



Summary & Future Work

- Experimental method + Software to characterize scintillators at the 88-Inch cyclotron at LBNL

Acknowledgments

- Bethany Goldblum, Josh Brown, Keegan Harrig, Matthew Harasty, Alexander Blank
- Patrick Feng , David Reyna, Erik Brubaker, Peter Marleau
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