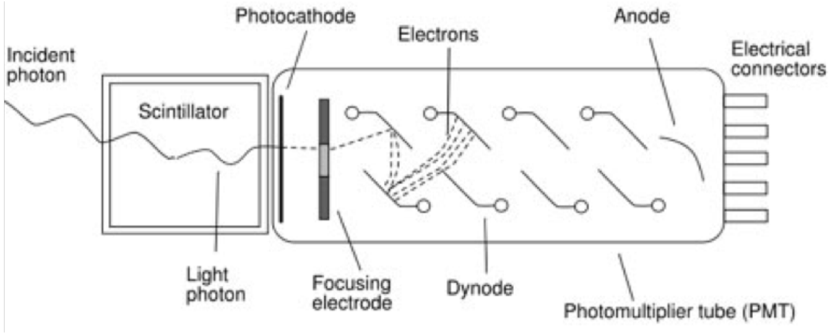
Measurement of proton quenching factors in p-terphenyl

Miriam Matney, Rice University
Advisors: Dr. Greg Christian, Dr. Cody Parker

Detector principles

A molecule, excited by an incident particle, de-excites and releases light that can be converted into an electrical signal with a photomultiplier tube (PMT)



Scintillator and PMT schematic (1)

The solid organic scintillator used in this project, **p-terphenyl**, is bright (27,000 photons/MeVee), has a fast decay time, and has excellent pulse-shape discrimination (PSD)

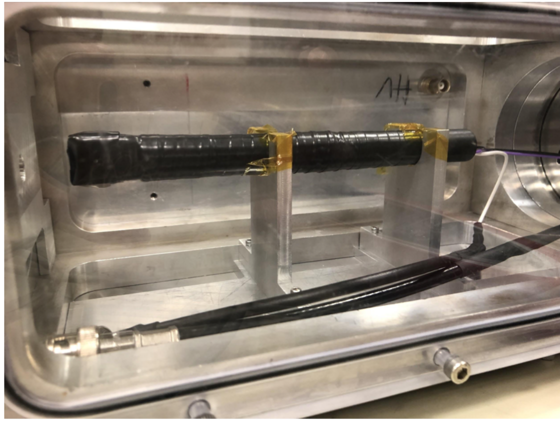
- Good properties for neutron detection

Quenching factors

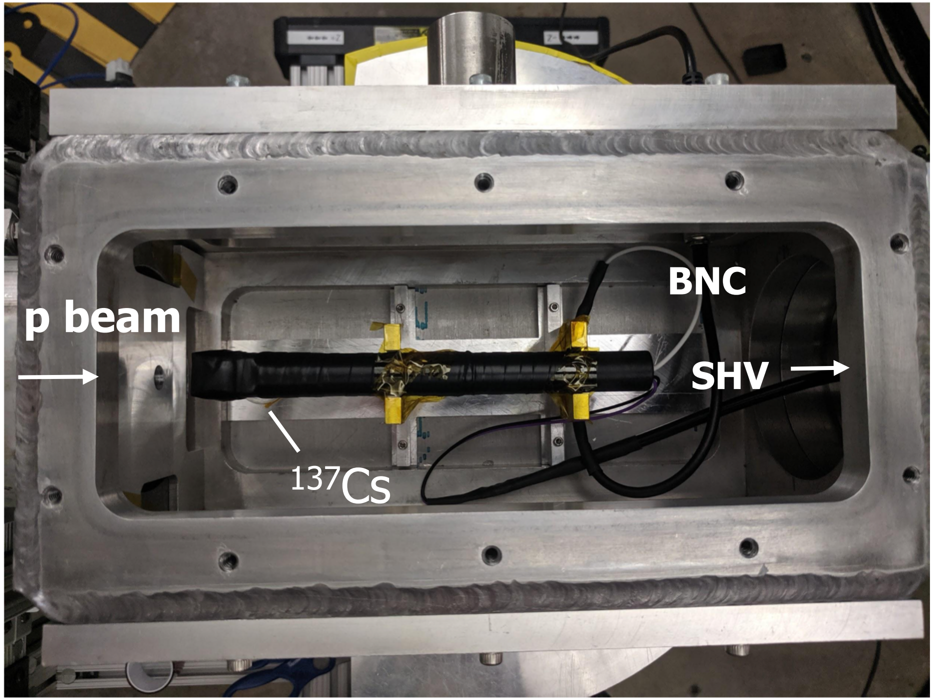
- **Quenching:** molecular de-excitation inside scintillator that does not result in the production of light
  - Results in a measured energy in the scintillator that is lower than the incident energy
- Relevant for neutrons, protons and heavier particles that cause nuclear excitation in the scintillator that is then transferred to the molecule
- The relationship between incident particle energy and measured particle energy is the **quenching function**
- This project used a proton beam from the K150 cyclotron
  - Energies ranging from 3.42 MeV to 15.02 MeV

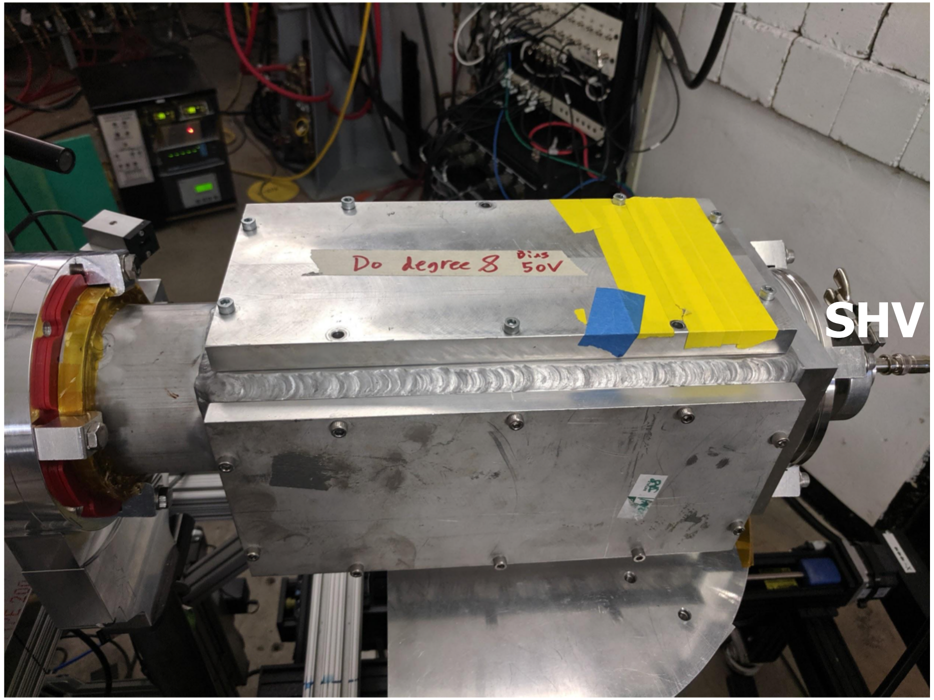
Detector construction

- 15x15x25 mm^3 p-Terphenyl crystal
- Wrapped in Teflon; Mylar window on front face
  - Thickness is known for simple energy loss calculation with SRIM
- Attached to PMT with optical grease and wrapped in more Teflon
- Connected to base by wrapping in electrical tape for security and light-tightness



Setup on the K150 SEE-line

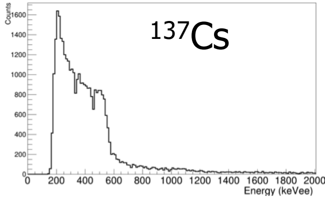




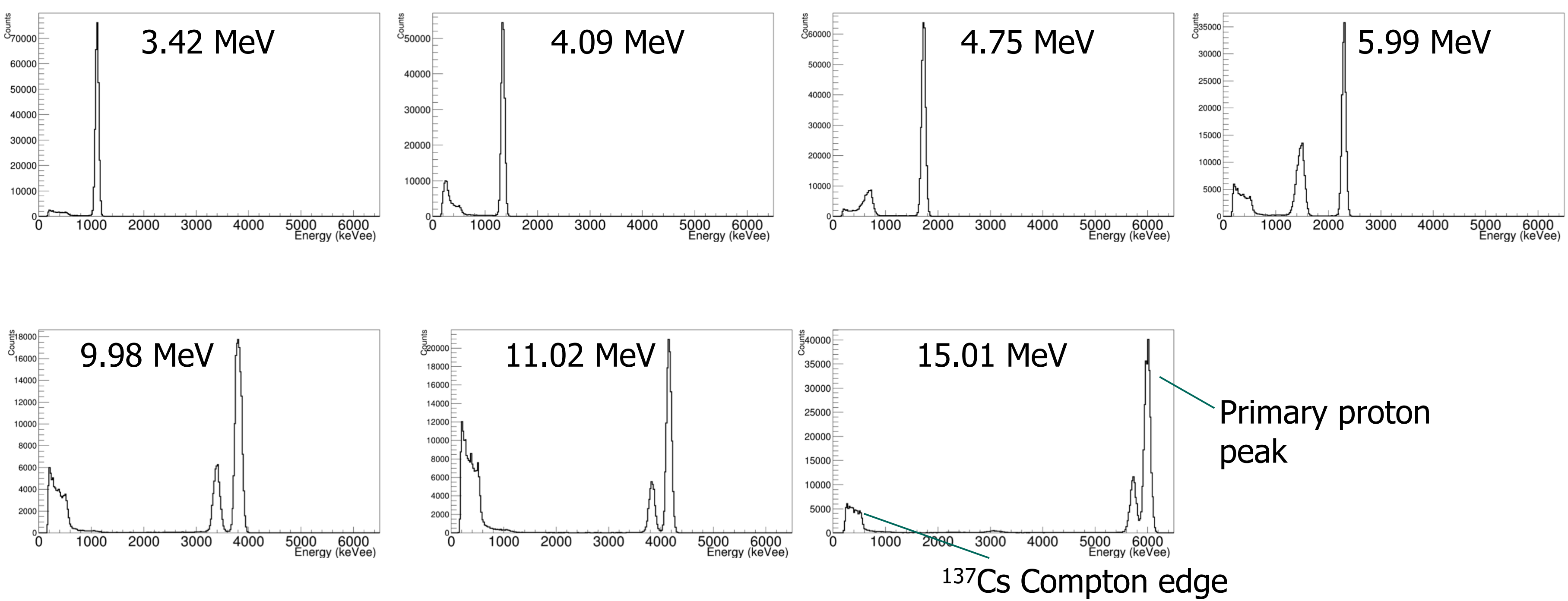
Beam time procedure

- Pump down to 8×10^{-7} torr vacuum with ^{137}Cs source inside chamber
- Take two ^{137}Cs calibrations at different gain settings
- Adjust beam flux as needed to avoid oversaturation
- Take two runs at each coarse gain, aiming for >3E05 counts
- Repeat ^{137}Cs calibrations each day and with each proton energy change
- Took ^{207}Bi calibration under vacuum when data collection was finished and ^{137}Cs was removed

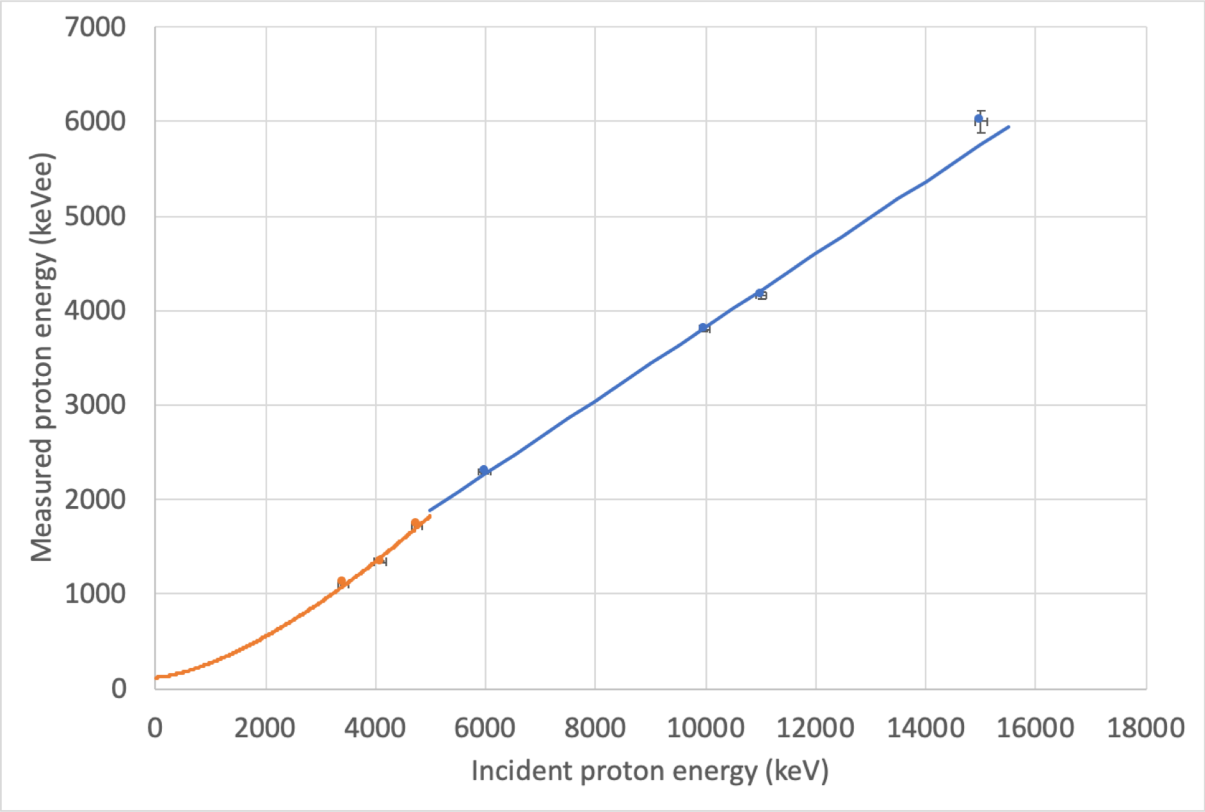
Proton spectra



The ^{137}Cs calibration source remained in the chamber during proton data collection



Quenching relation



Uncertainty in beam energy is ±0.1 MeV. Error in measured proton energy is due to the channel-to-energy relation determined from the calibration sources.

E_r < 5 MeV:

$E_e = (4.85 \times 10^{-3} \pm 5.3 \times 10^{-4}) E_r^{3/2} + (121 \pm 137)$

E_r > 5 MeV:

$E_e = (0.387 \pm 0.011) E_r - (39.5 \pm 97.8)$

- $E^{3/2}$ relation for <5 MeV protons as expected from literature (2)

Future directions

- Inspect waveforms from proton data and compare PSD for protons and photons (from ^{137}Cs)
- Investigate possible phosphorescence that may have occurred at higher proton energies

References

(1) Stanford University Scintillator Materials webpage
(2) Glenn F. Knoll, *Radiation Detection and Measurement*, 4th ed.