Proton light yield of water-based liquid scintillator

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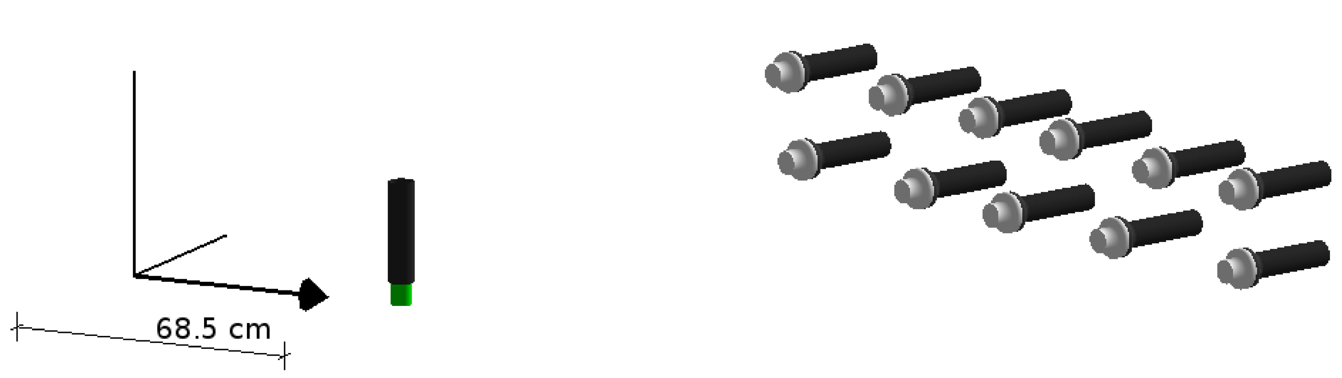
Introduction and Motivation

- Upcoming NE-1 detector will be sensitive to inverse beta-decay events from reactor antineutrinos (prompt positron + delayed neutron capture)
- Water-based liquid scintillator (WbLS) emerging as a candidate target material
- Fast neutrons scatter off protons (prompt) and capture (delayed) as a background
- Characterization of proton light yield is imperative to reliably classify such events

Technical Approach

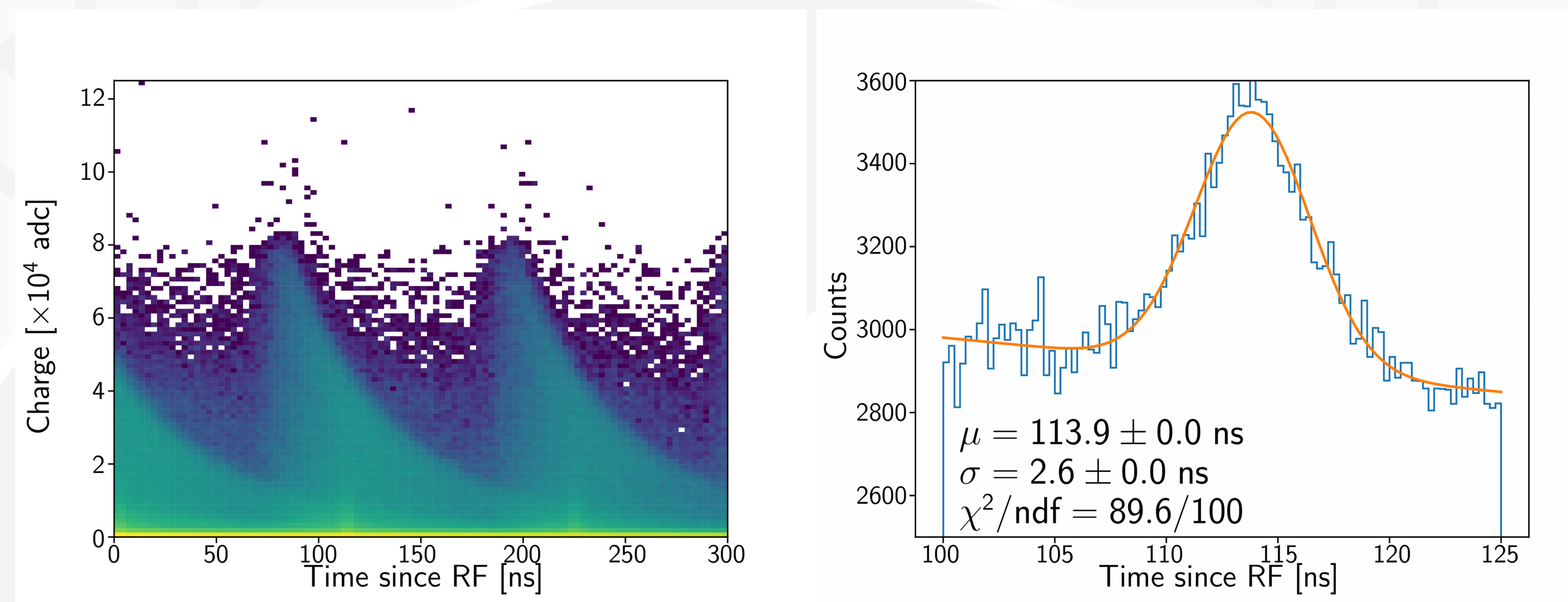
- Broad-spectrum neutron beam produced via 33 MeV deuteron breakup on Be target at 88-Inch Cyclotron at LBNL
- Neutrons undergo n-p elastic scattering in target and are scattered into 11 auxiliary detectors
- Double time-of-flight methodology results in relatively pure sample of proton recoils
- Calibration of light output using Compton edge of known sources



Mission Relevance

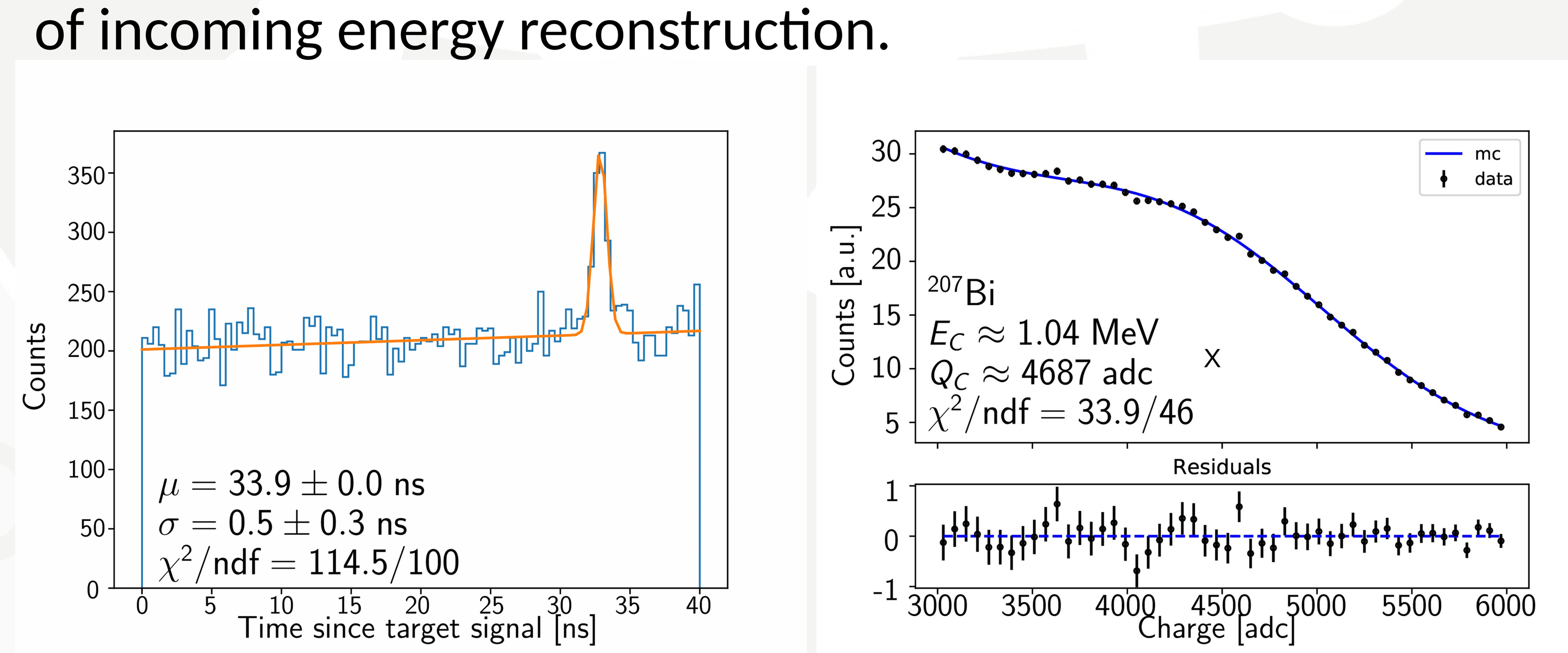
- Facilitating new capabilities for nuclear reactor discovery and exclusion at large stand-off
- Supports monitoring and verification of reactor operations for proliferation detection

Results



Left: Charge collected in photomultiplier tube (PMT) vs time since beam pulse. The triangular populations consist of n-p scattering events, and the low-charge, isochronic populations of Compton scatters of beam-correlated gammas.

Right: Gaussian fit to low-charge event time profile, which calibrates gross delay between measured and physical time differences, and contributes to determining the the resolution of incoming energy reconstruction.



Left: Gaussian fit to post-scatter time-of-flight profile, which calibrates inter-cell time differences, and contributes to determining the resolution of outgoing energy reconstruction.

Right: Example light calibration using Compton edge of 1-MeV bismuth line. The response model consists of a linear charge response, Gaussian smearing, and power-law background form

Expected Impact

- Improved suppression of fast-neutron backgrounds in WbLS-filled NE-1 detector
- Capability to measure flavor-inclusive supernova neutrino energy spectrum

MTV Impact

- Professional development through usage of 88-Inch Cyclotron at LBNL
- Collaboration with nuclear engineers at UCB/LBNL, as well as Nuclear Science & Security Consortium members
- Supporting innovative detection technologies for potential use in NE-1 detector

Conclusion

- Proton recoils from n-p scattering have been detected in 5% WbLS
- Calibration of light levels performed using known radioactive sources
- Further enables WbLS as a candidate target material to be deployed in the upcoming NE-1 detector

Next Steps

- Measure and correct for non-linearity of PMT response
- Future measurements of 1% and 10% WbLS, as well as isotopically loaded samples, using e.g. gadolinium

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