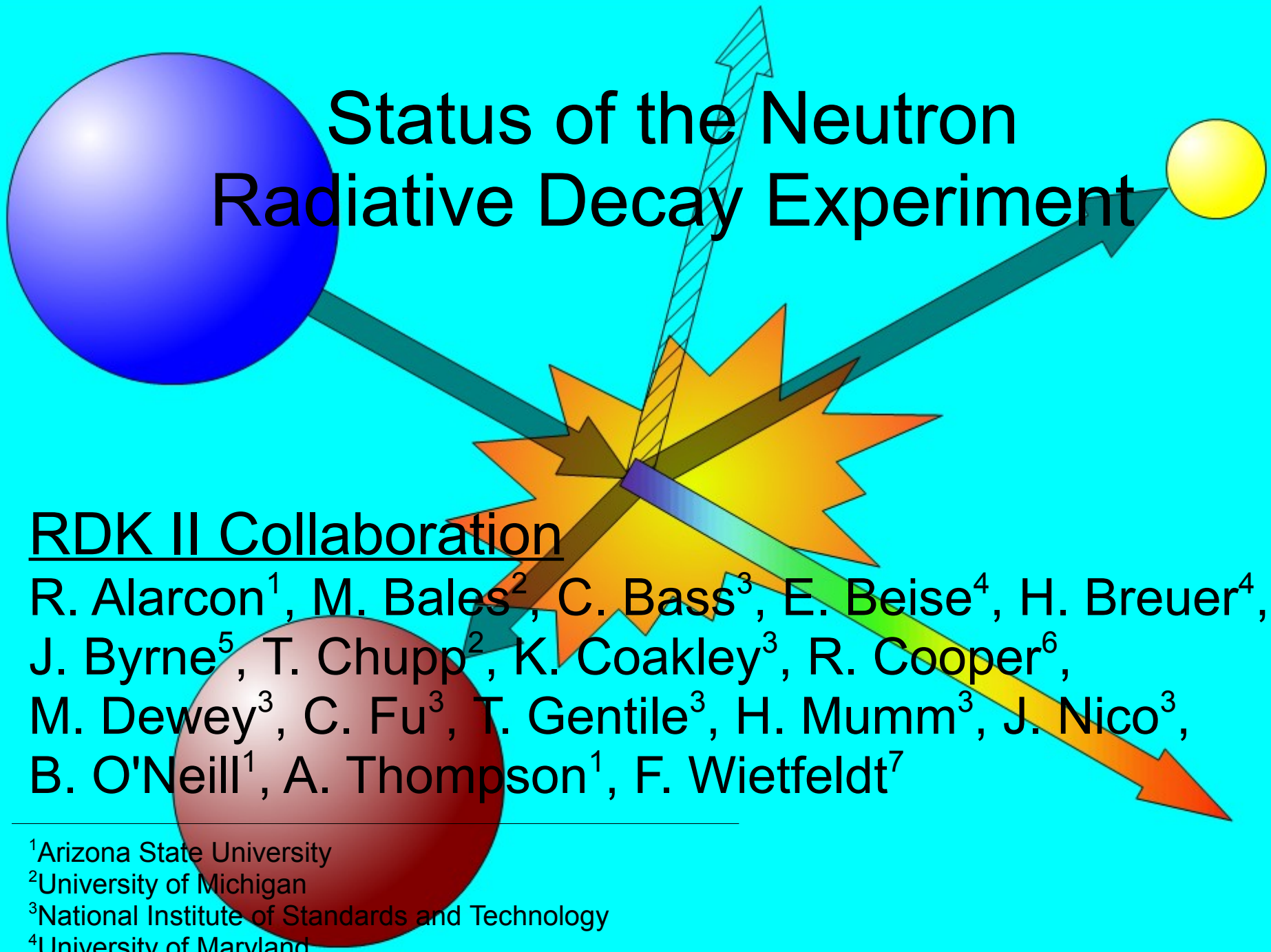
# Status of the Neutron Radiative Decay Experiment




## RDK II Collaboration

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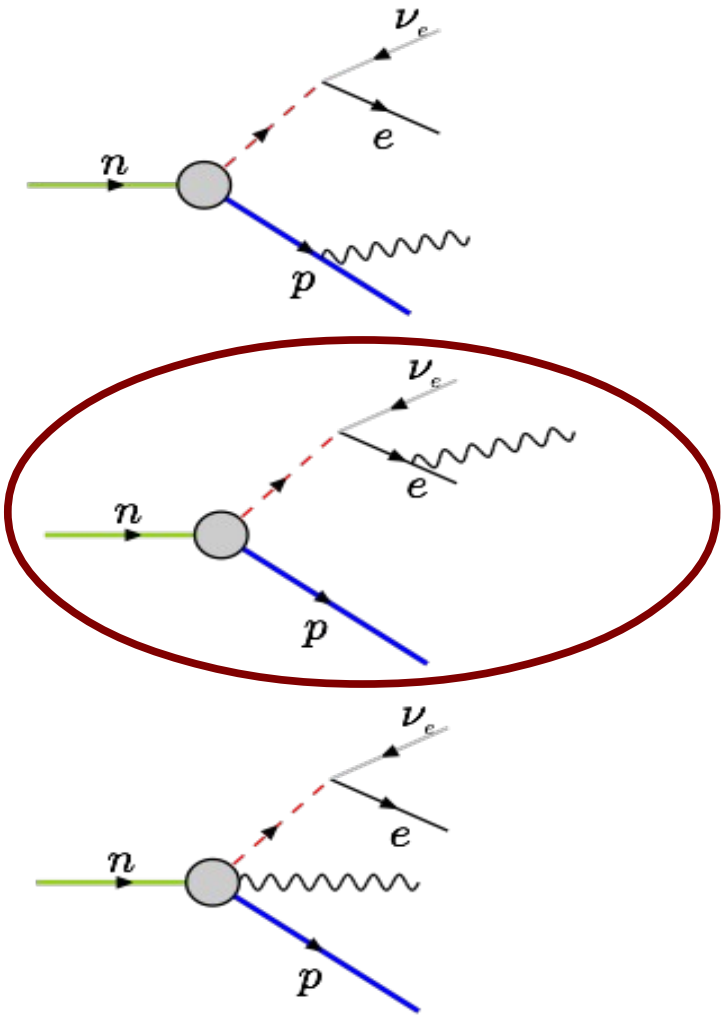
[3]National Institute of Standards and Technology
[4]University of Maryland
[5]University of Sussex
[6]Indiana University
[7]Tulane University

# Radiative Decay Measurement

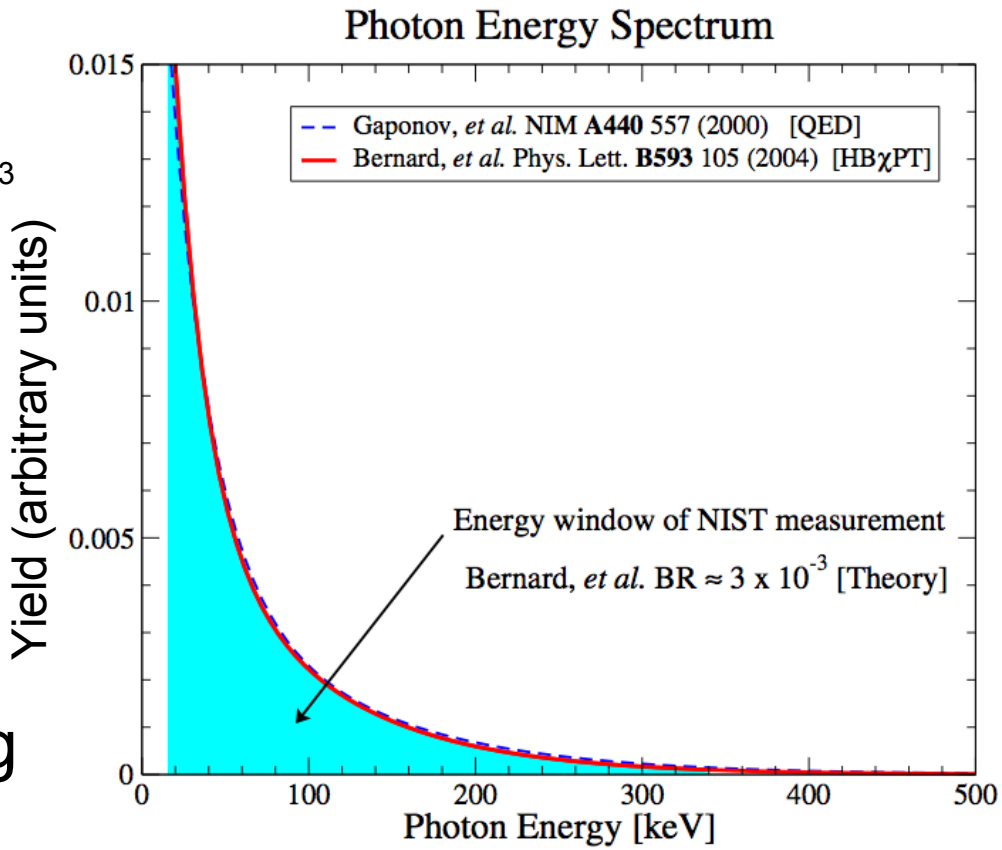
$n \rightarrow p^{+} + e^{-} + \bar{\nu}_e + \gamma + 782\text{keV}$

- Measure neutron radiative decay branching ratio and energy sprectrum to 1% uncertainty
  - 10% uncertainty in RKD I
- Test QED neutron radiative corrections
- Challenges
  - Long lifetime $\tau_n$=(881.5±1.5)s
  - Small branching ratio
  - Large $\gamma$ background



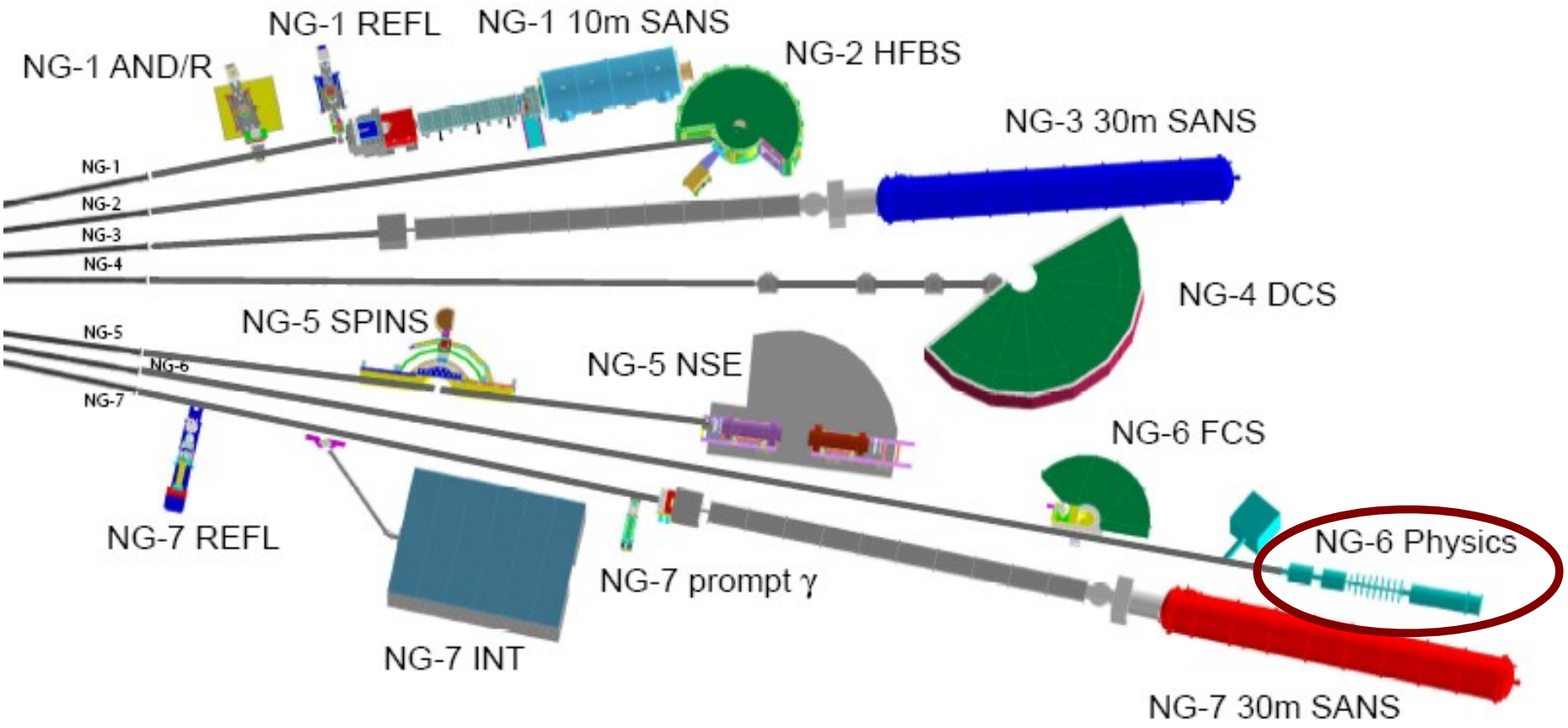
# Motivation

- RDK I[1,2]
  - (3.09±0.30[syst.]±0.11[stat.])×$10^{-3}$
- RDK II
  - Goal 1% uncertainty
- Beyond 0.5%
  - Non-leading order terms
    - Proton bremsstrahlung
    - Recoil corrections
  - Polarization (*n*, $\gamma$, etc.)
  - Gardner & $He^3$

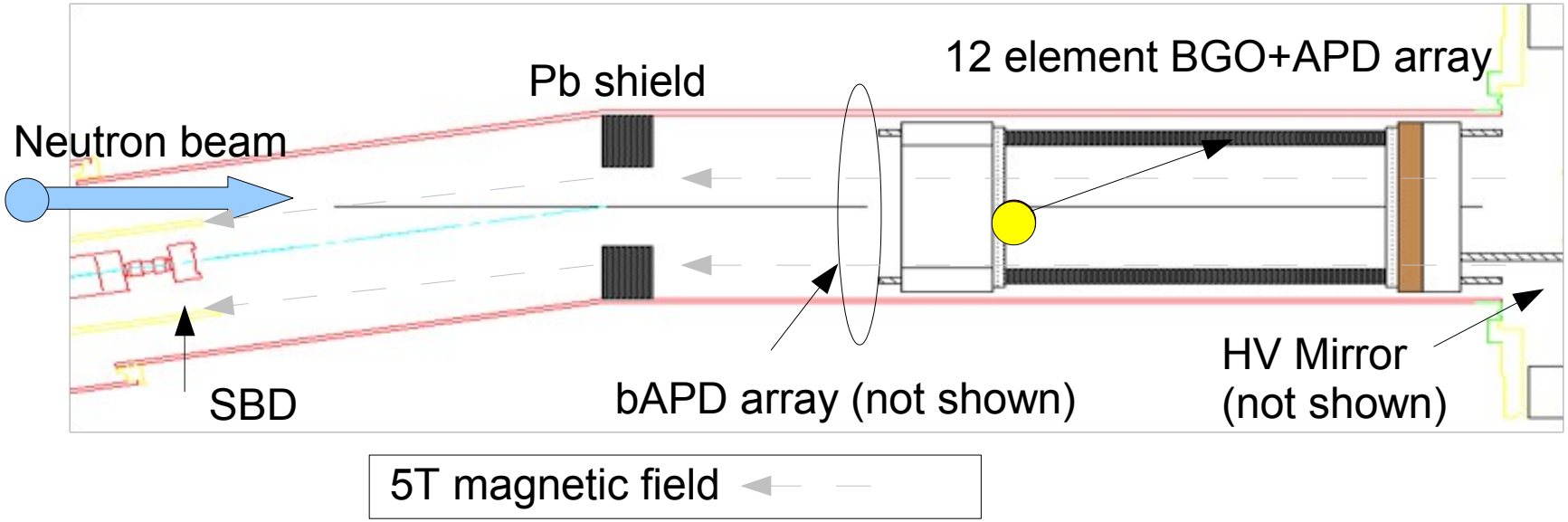



[1]Cooper, R. *et al.* PRC 81, 035503 (2010)
[2]Nico, J. S. *et al*. *Nature* 444, 1059–1062 (2006)
[3]arXiv:1101.1128v1

# NIST Beam Line



# Experimental Setup

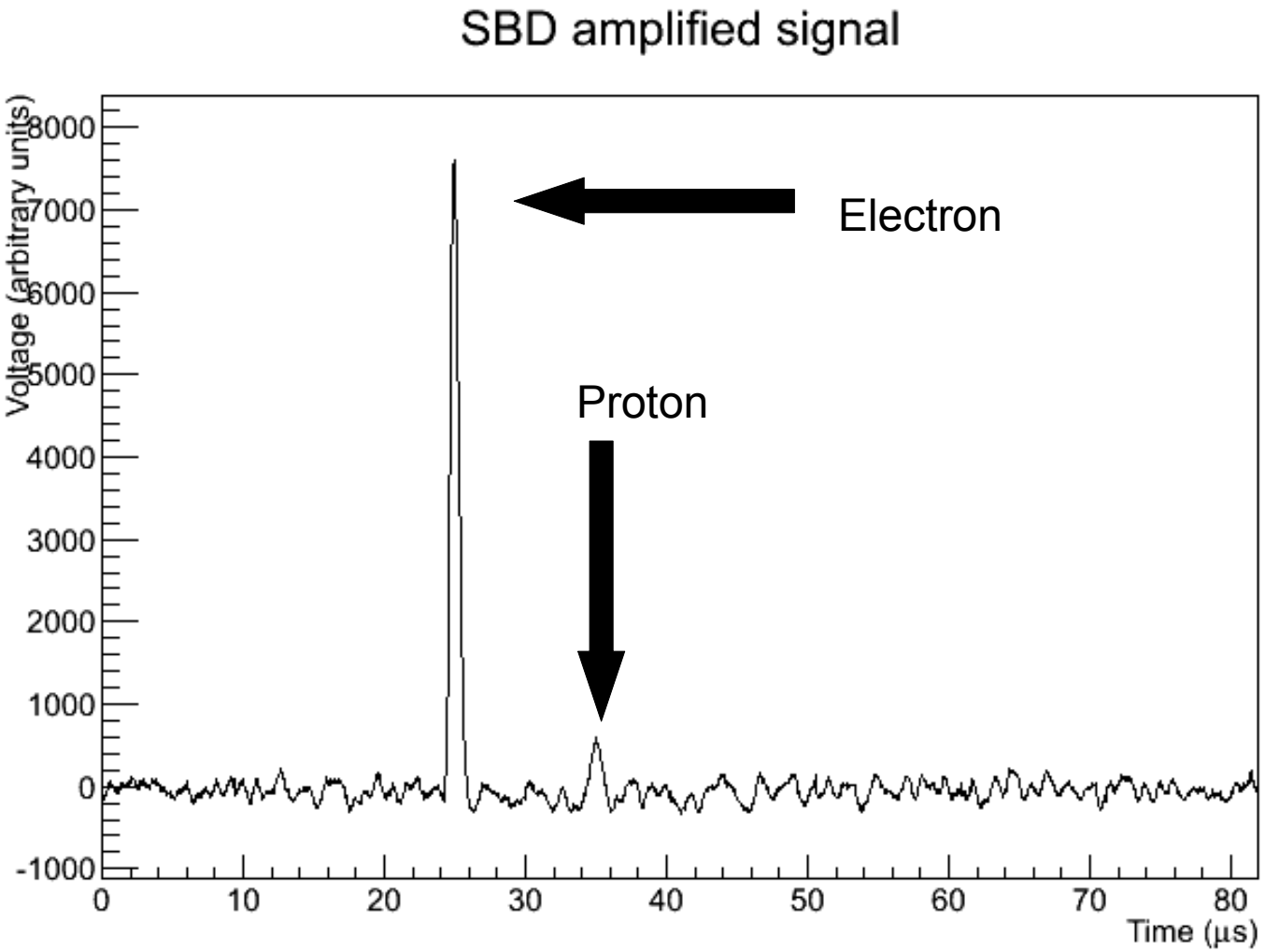



- Neutrons decay along beam
- Protons and electrons are confined in cyclotron orbits by magnetic field and guided into silicon detector
- Electrostatic mirror turns around “wrong-way” protons
- Protons are accelerated into the silicon detector
- Waveform base data acquisition

# Electron-Proton Detector

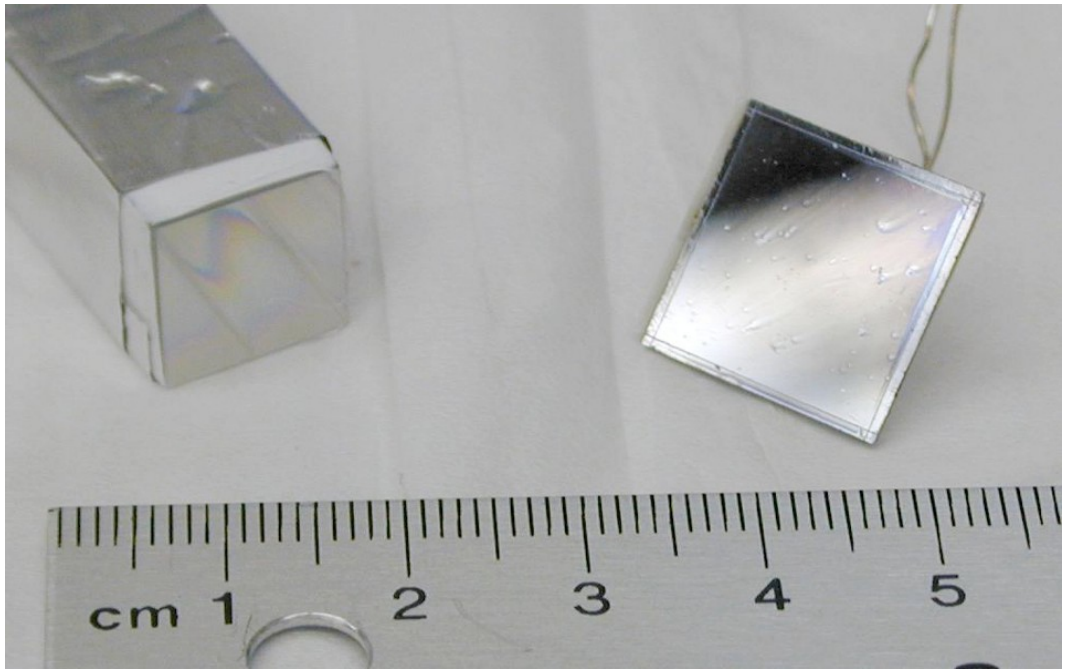
- Surface Barrier Detector (SBD)
  - 1-1.5mm thick
  - 600mm$^2$ area
  - At -25kV bias

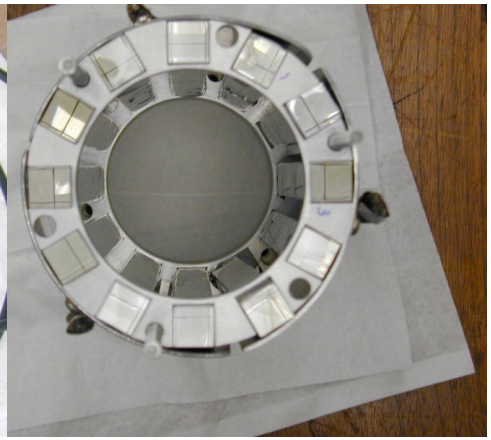
# Electron-Proton Detector



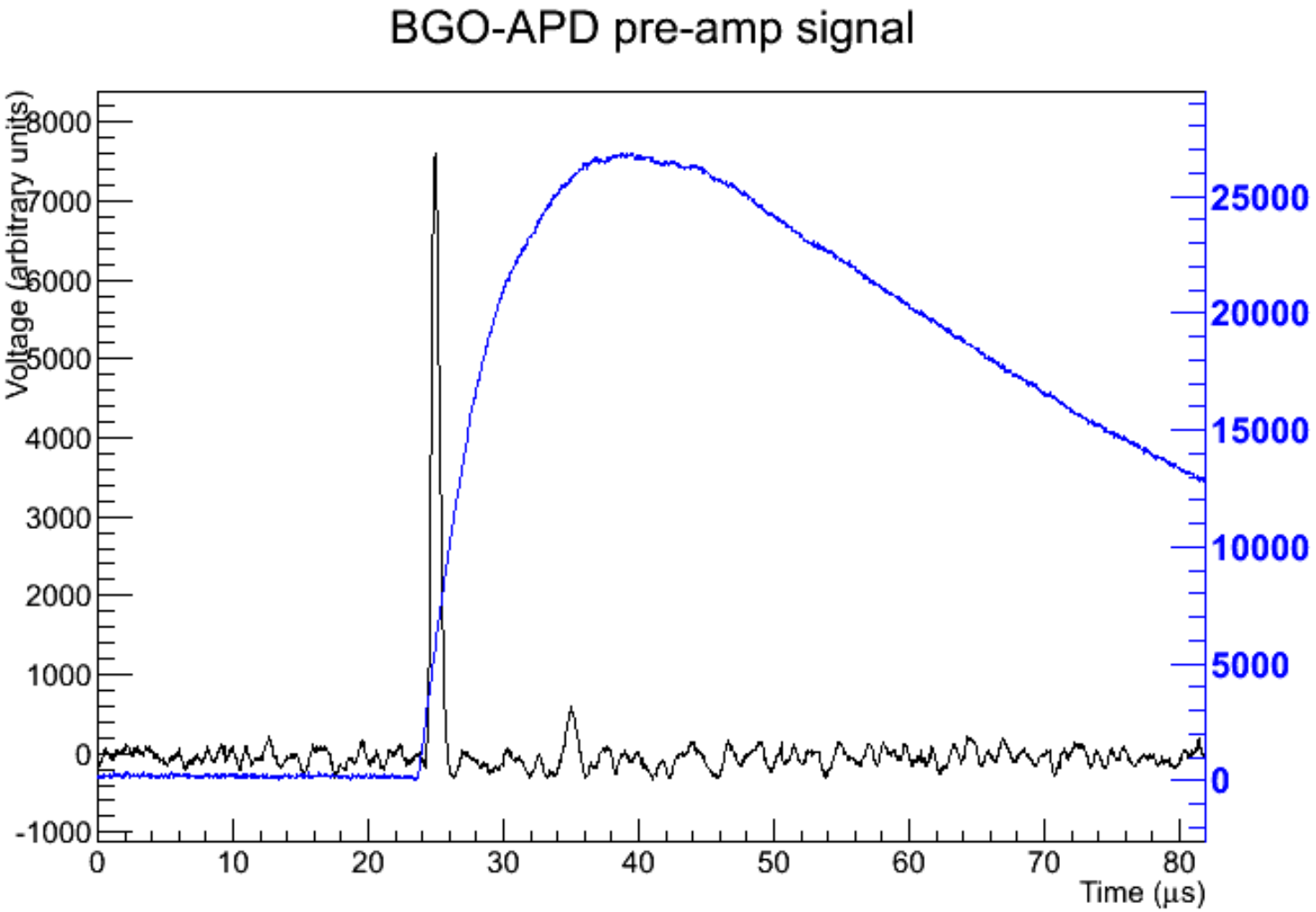
# Scintillator Detector

- Bismuth germanate (BGO) scintillator crystals coupled to avalanche photo-diodes (APD)
  - 12 Detectors
  - 200x12x12mm$^3$ BGOs
  - 14x14mm$^2$ APDs
  - ~5keV – endpoint



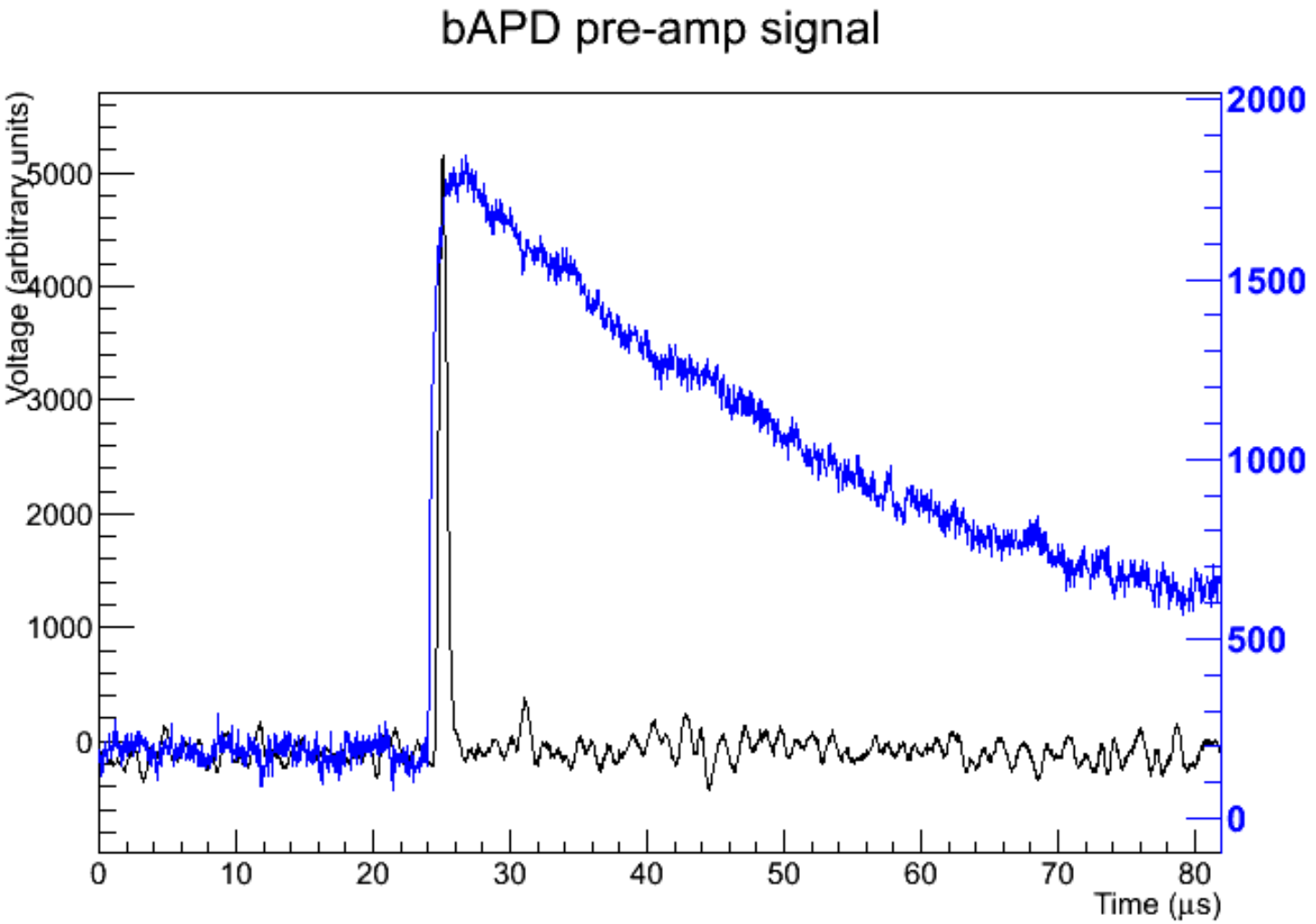
# Scintillator Detector



# Direct Detector

- Large area bare (non scintillating) avalanche photo-diode (bAPD) to extend low energy range
  - 3 detectors
  - 28x28mm$^2$
  - ~500eV – ~20keV

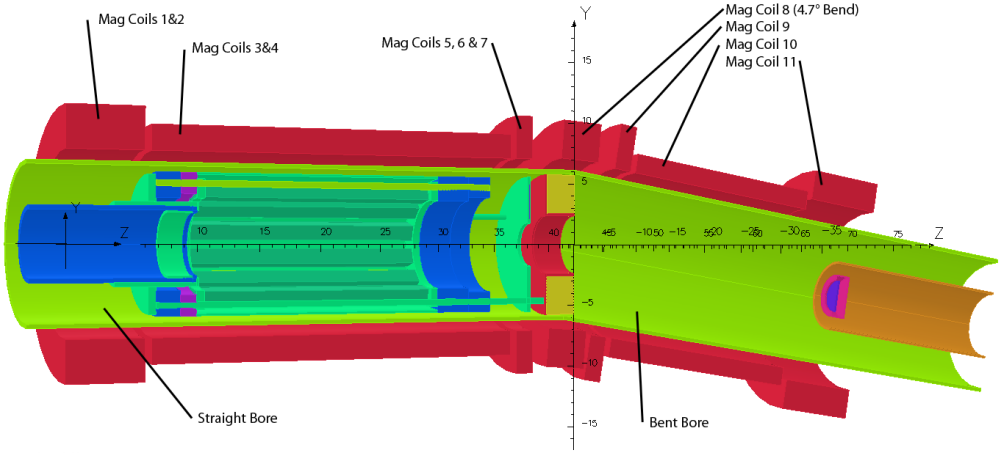
# Direct Detector

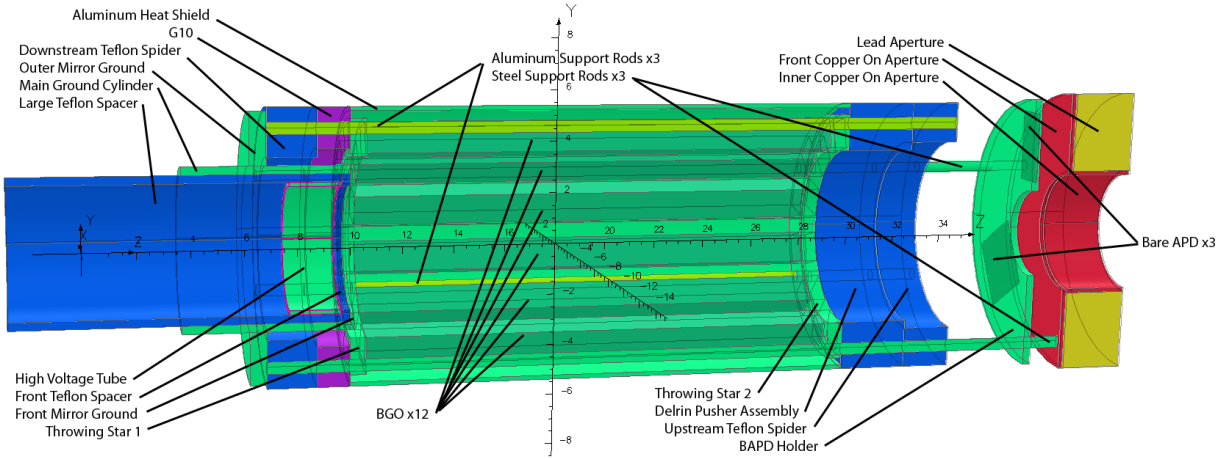


# Simulation

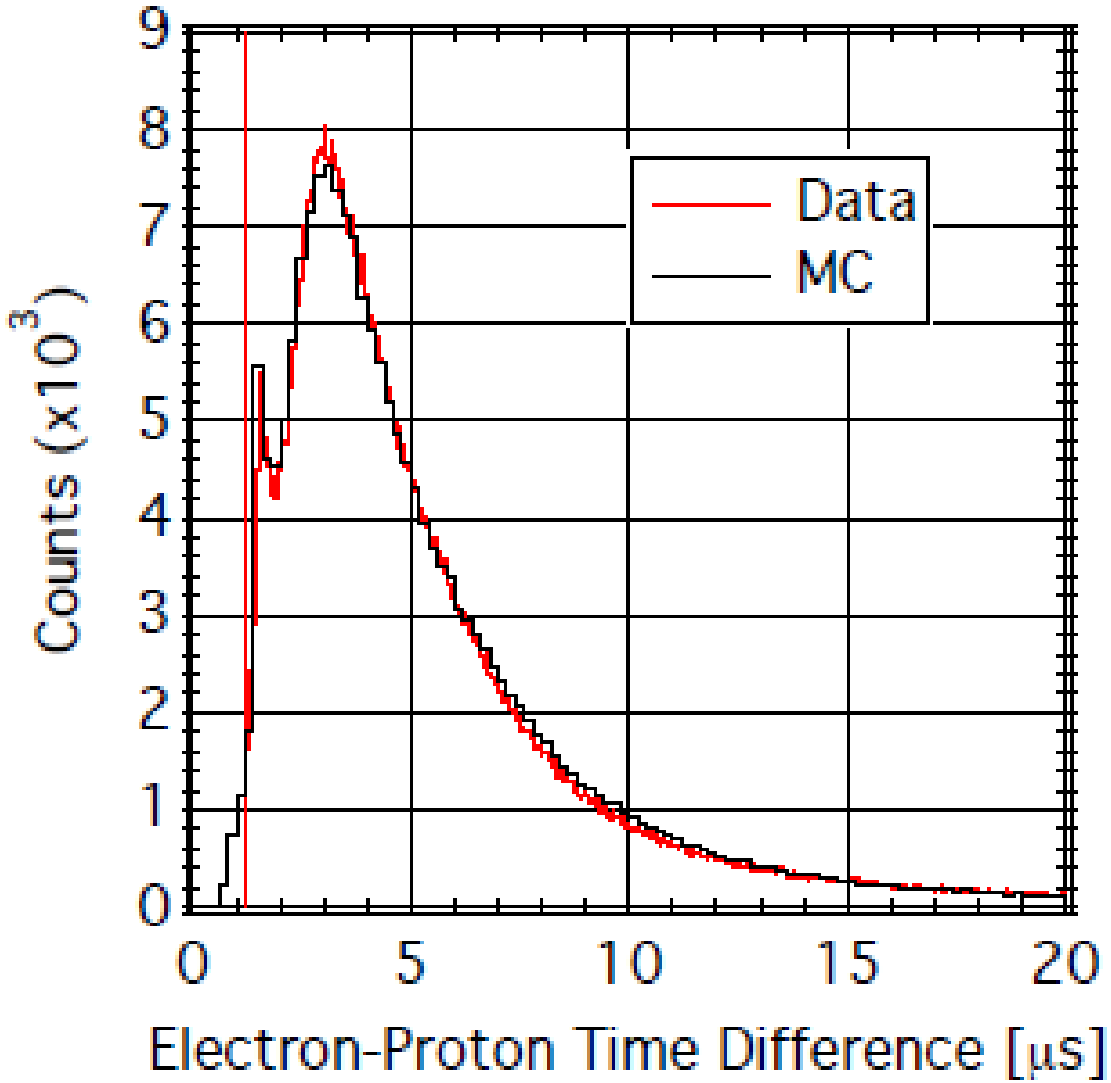
Critical to extracting results:

- Monte Carlo
  - Geant4
  - MCMP
- EM Field
  - Biot-Savart
  - TOSCA



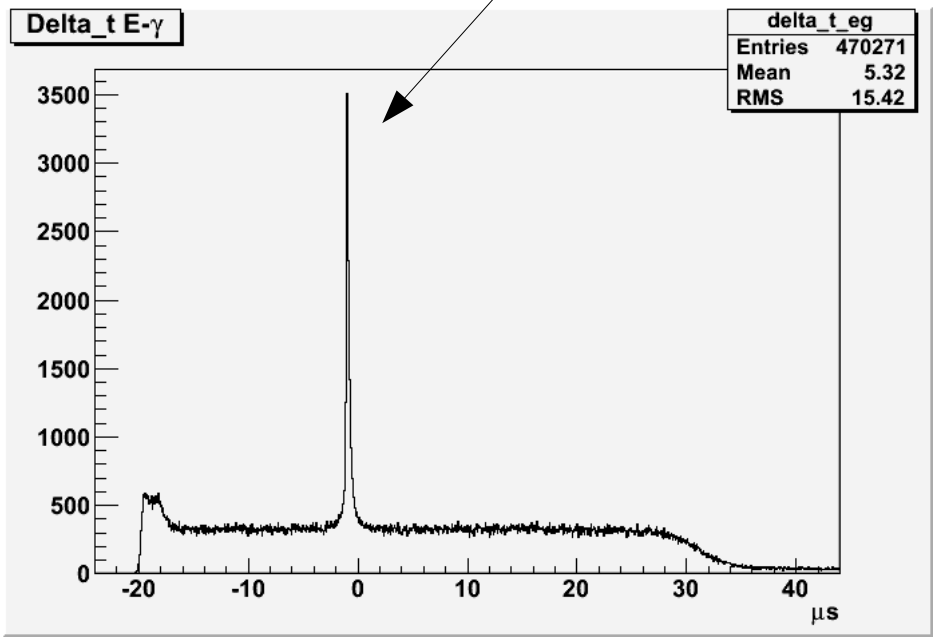



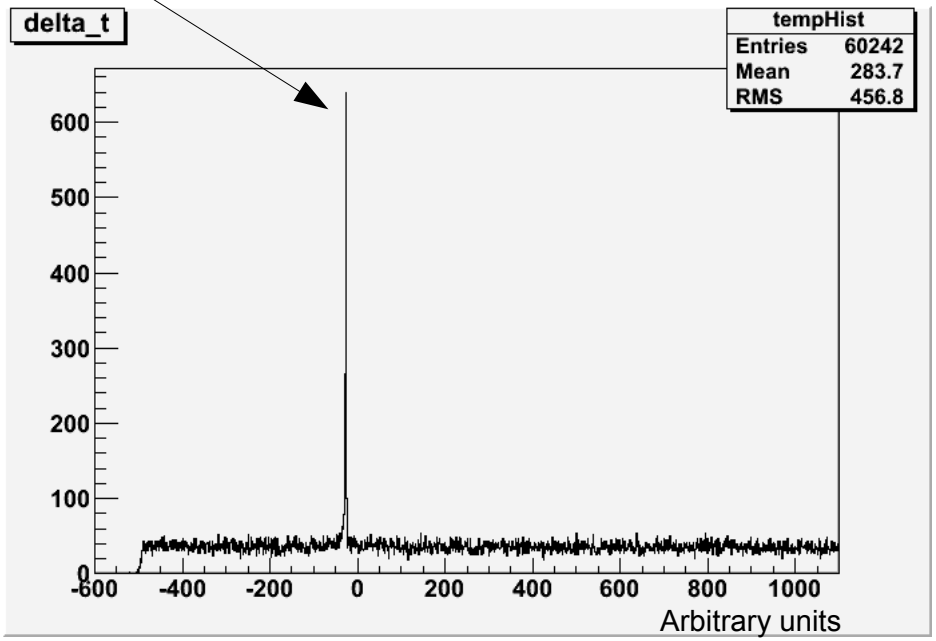
# Electron-Proton ToF



# Status of RDK II Analysis

Radiative decay peak



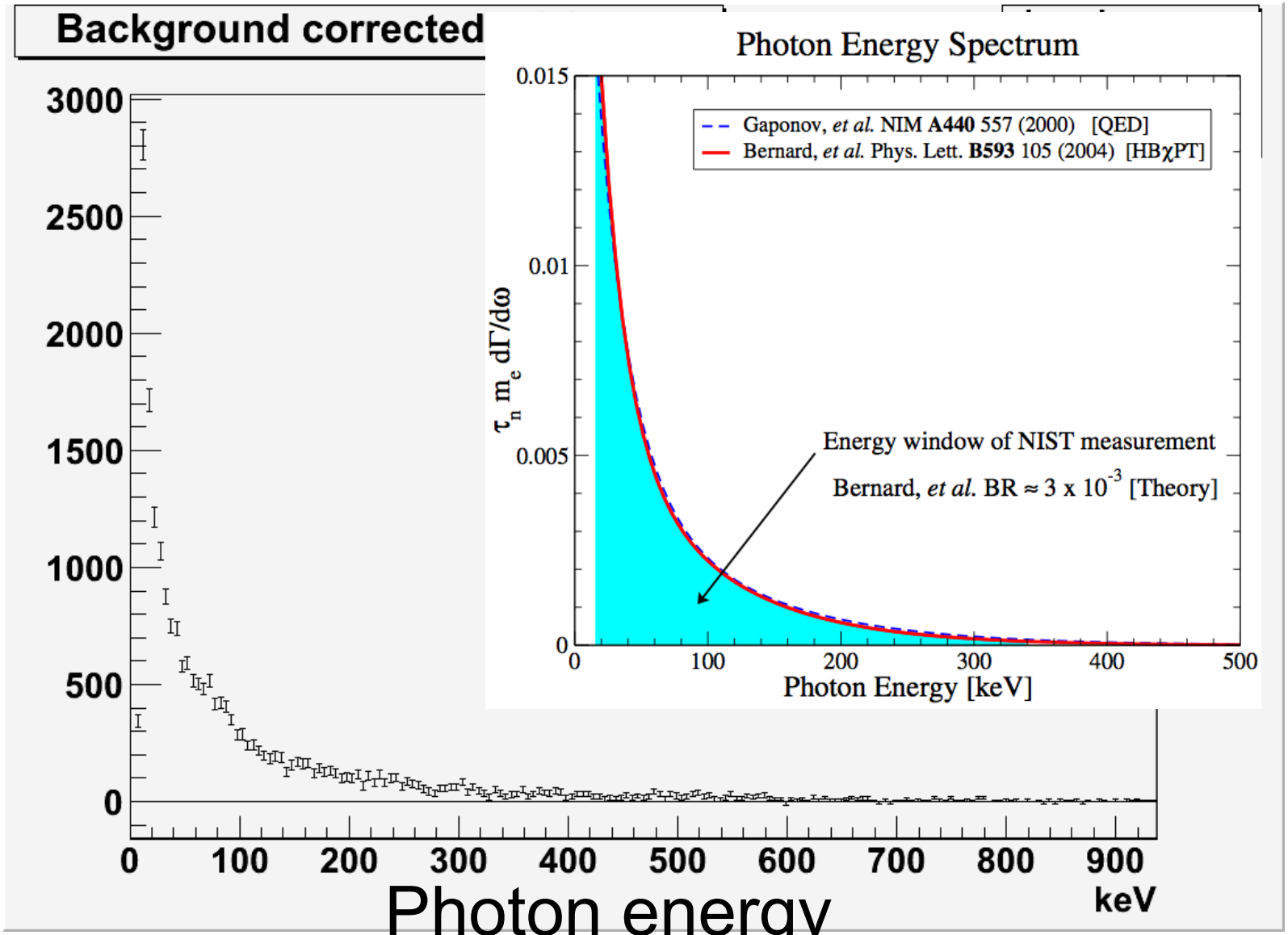

Yield

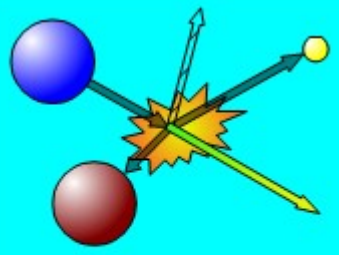
BGO-APD

bAPD

Photon timing

# Status of RDK II Analysis





# Conclusion

- Achieved ~0.5% statistics on branching ratio
- Expanded energy range below 1keV and up to the endpoint (approx 780keV)
- Work continues on systematic errors
  - Analysis of Calibrations
    - Detector response, temperature dependence, non-linearity
  - Monte Carlo
- Goal of ~1% total uncertainty on branching ratio and energy spectrum
- Future work pending results of anaysis