Design of Gamma Ray Detectors and Associated Readout Electronics for a ^{92}Rb Time Reversal Experiment

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Outline

- CPT theorem and connection to baryon asymmetry
- Description of atom trap
- Design of gamma ray detector and acquisition electronics
- Presentation of preliminary results (analysis ongoing)

C, P, and T violation

- Charge symmetry obeyed by gravity, electromagnetism, and strong force, but violated by weak force
- Parity symmetry also violated by weak interaction
- Combined CP violation observed in 1964 in K^0 decay → 1980 Nobel Prize (Cronin and Fitch)
- However, CP violation combined with T violation is a symmetry → they are equivalent

CPT theorem

- This is formally expressed in the CPT theorem – conjugating all charges, flipping parity, and reversing time results in a symmetric system
- Only known combination of C, P, and T which is symmetric
- Theorem widely believed to be true but never proven

CP violation → baryon asymmetry

- Sakharov (1967): three conditions to create asymmetry of matter over antimatter
- One of these is CP violation in the early universe
  - The other two are baryon number B violation (unobserved) and interactions outside of thermal equilibrium
- Current amount of CP violation in Standard Model is too small by 10^{10} – need to find more sources

TRINAT experiment approach

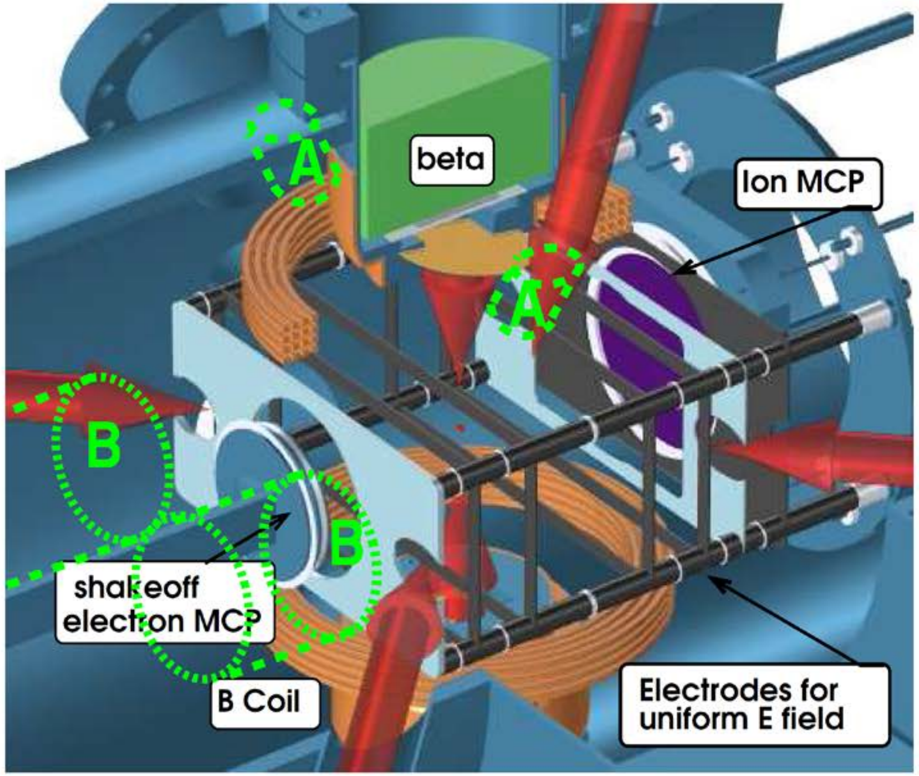
- TRINAT experiment looks for CP violation in radiative β^- decay (now ^{92}Rb, next ^{38m}K)
- Look at triple product of products (excluding antineutrino):

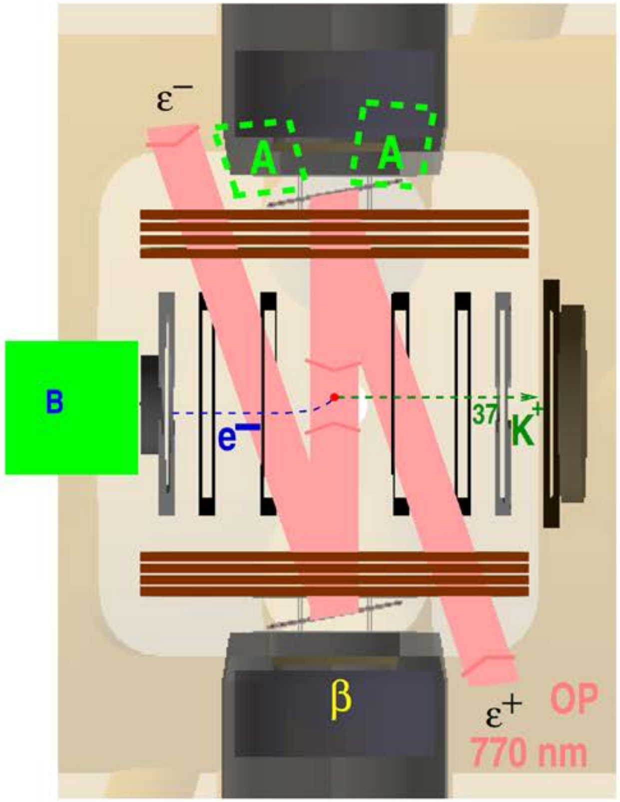
$$p_{recoil} \cdot (p_\beta \times p_\gamma)$$

- Time reversal: $t \rightarrow -t \Rightarrow p \rightarrow -p$
- Thus, under time reversal,

$$p_{recoil} \cdot (p_\beta \times p_\gamma) \xrightarrow{t \rightarrow -t} -p_{recoil} \cdot (p_\beta \times p_\gamma)$$

TRINAT atom trap

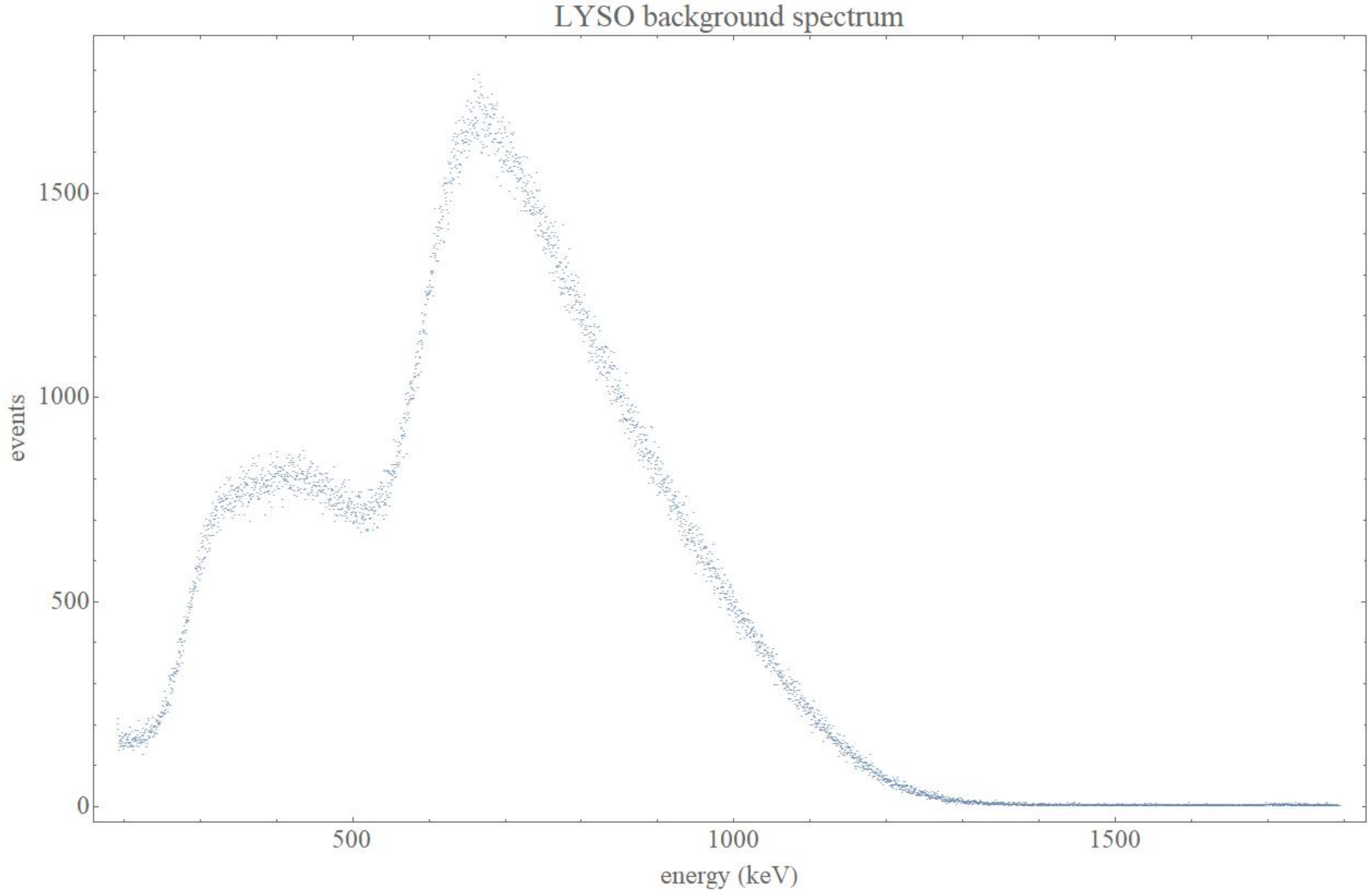




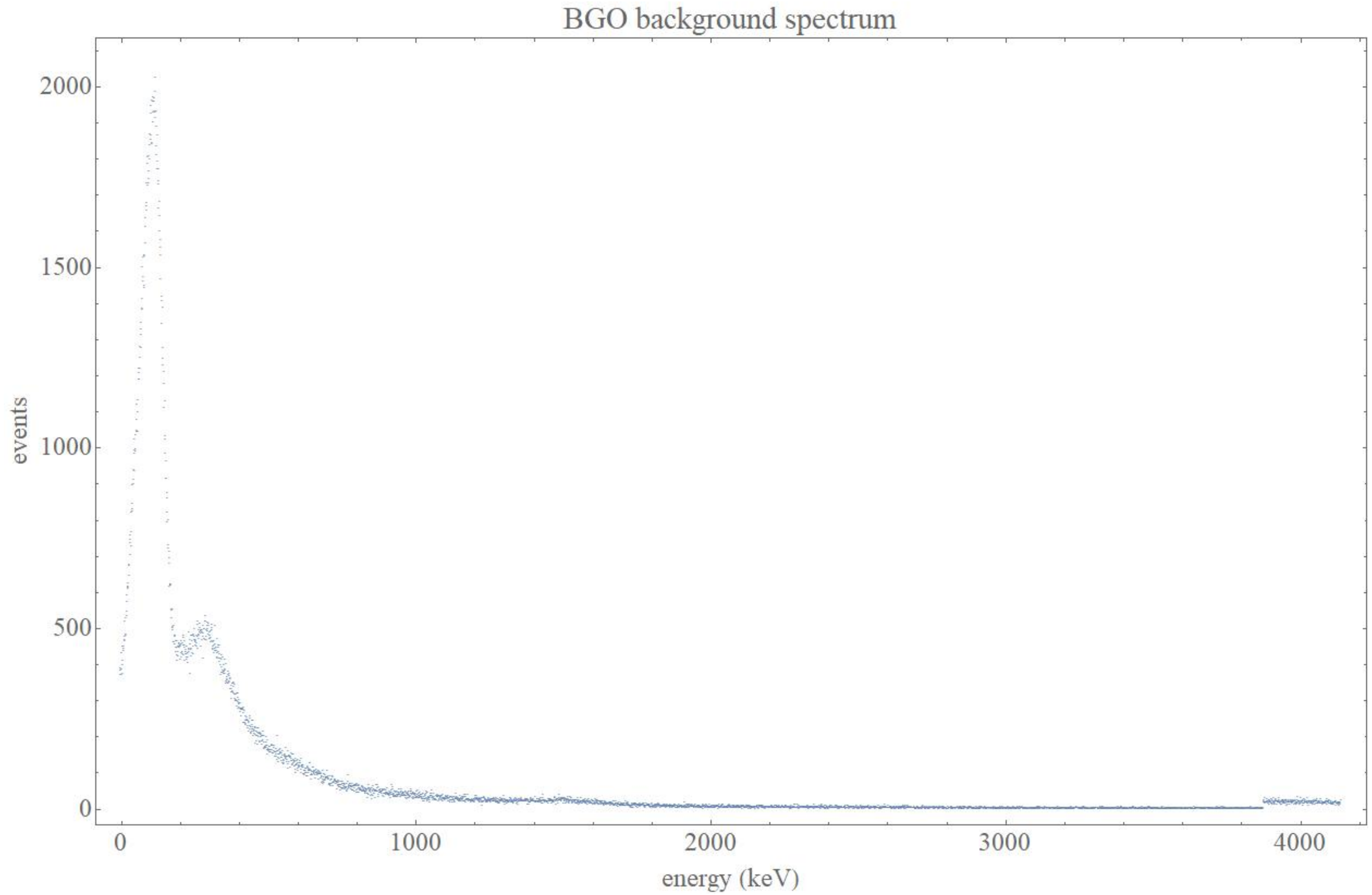
Outline of γ detector

- Scintillating material on top of a silicon photomultiplier (SiPM)
- SiPM outputs must be summed and sent to acquisition electronics
- Acquisition must be able to ignore electronic noise while still accepting most real events

Scintillating material - LYSO



Scintillating material - BGO



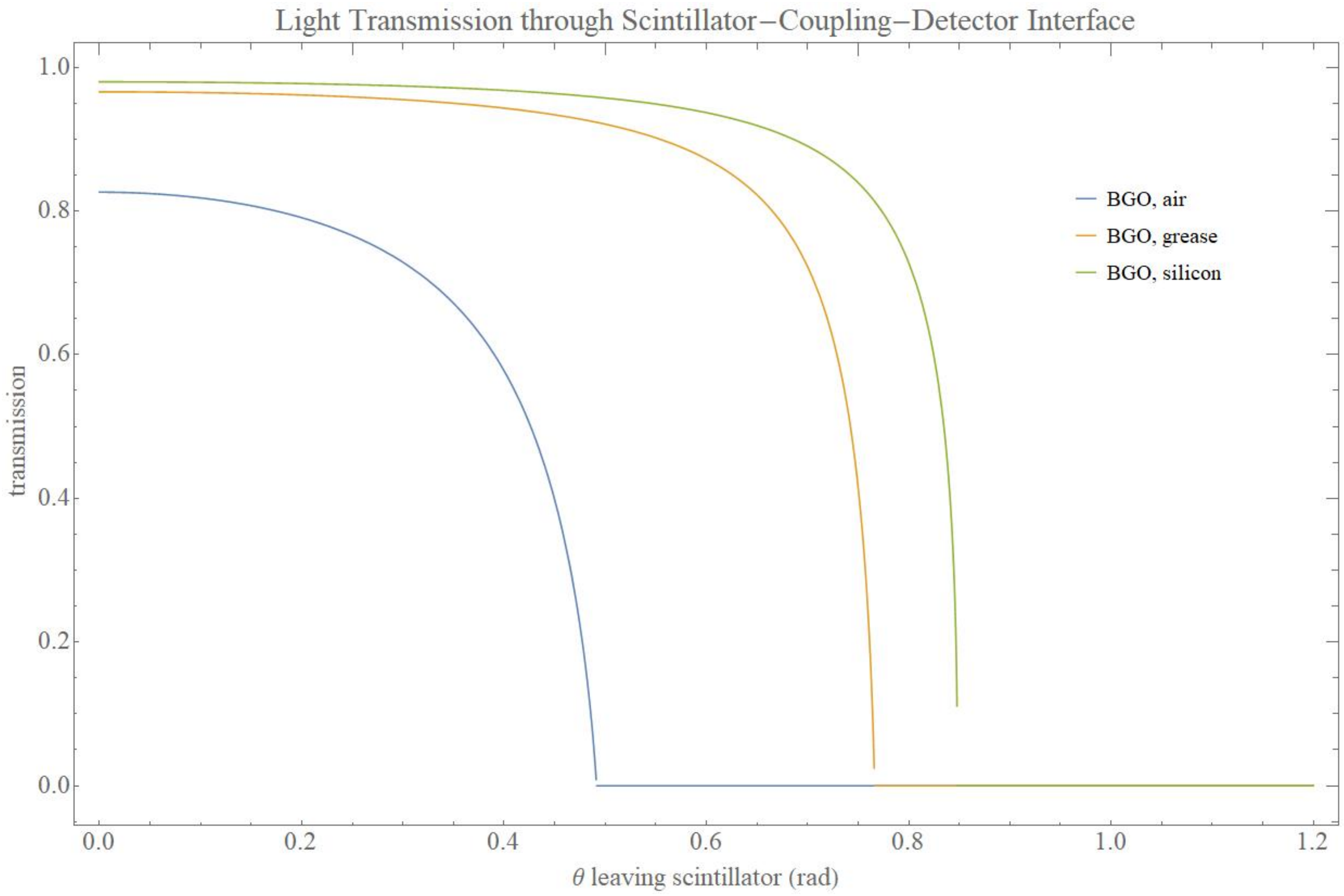
BGO crystal

- 2"x2" diameter crystal and SiPM contained in an optical tube
- Two layers of Teflon + a plastic cap between trap and crystal
- Sides of crystal coated with dielectric mirror film – trying to keep scintillation light in crystal

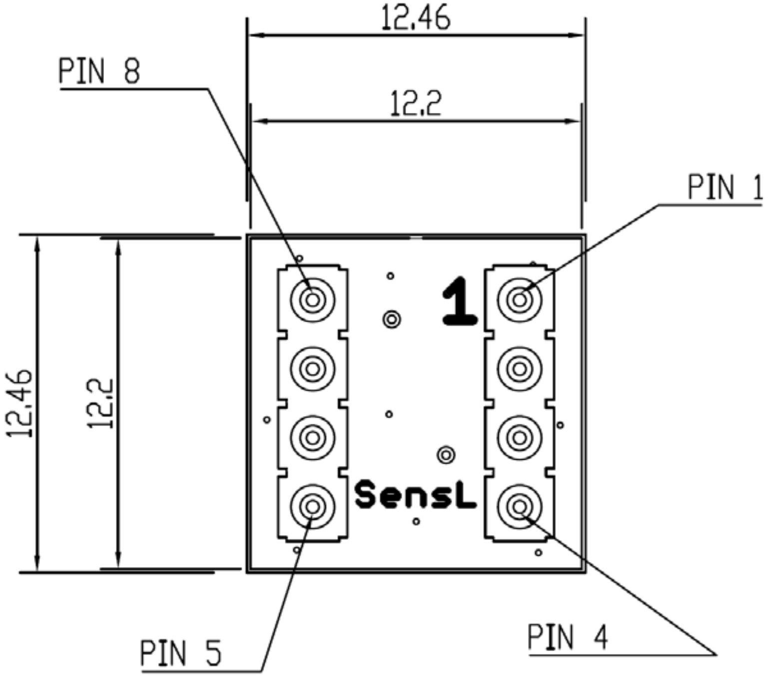
BGO-SiPM coupling

- Face of crystal toward SiPM coated in titanium dioxide
- Silicon gel between BGO and SiPM

Effects of silicon gel

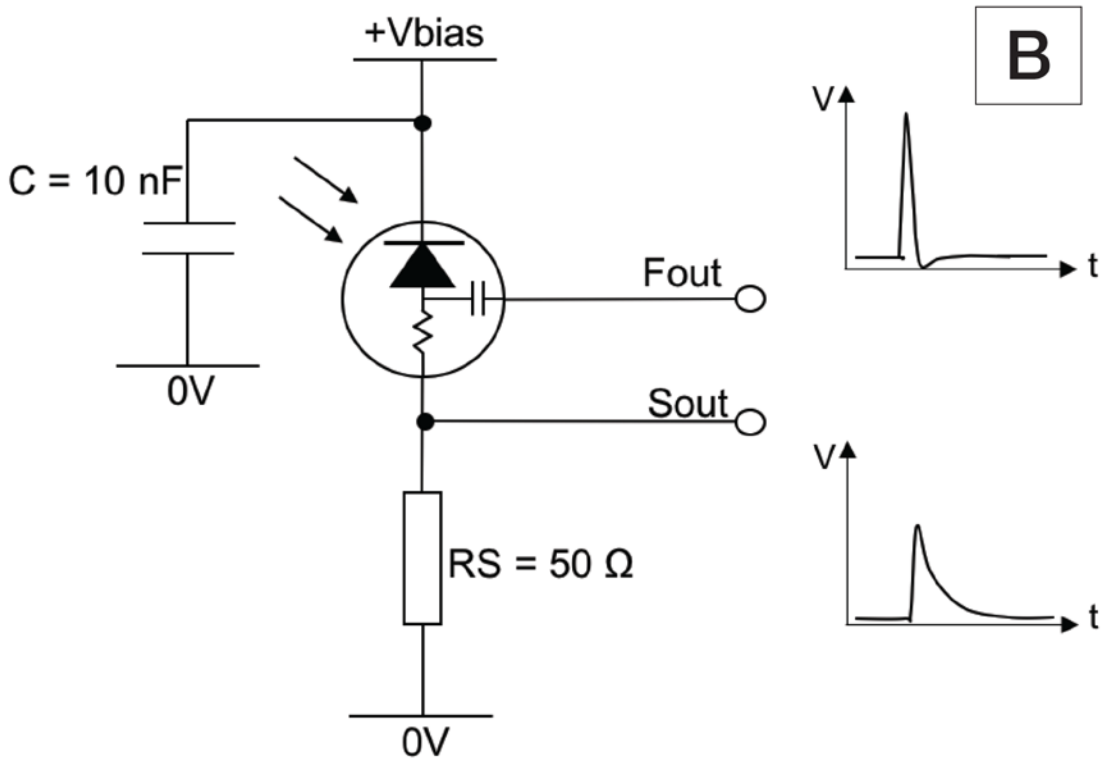


SiPM - wiring



Bottom View

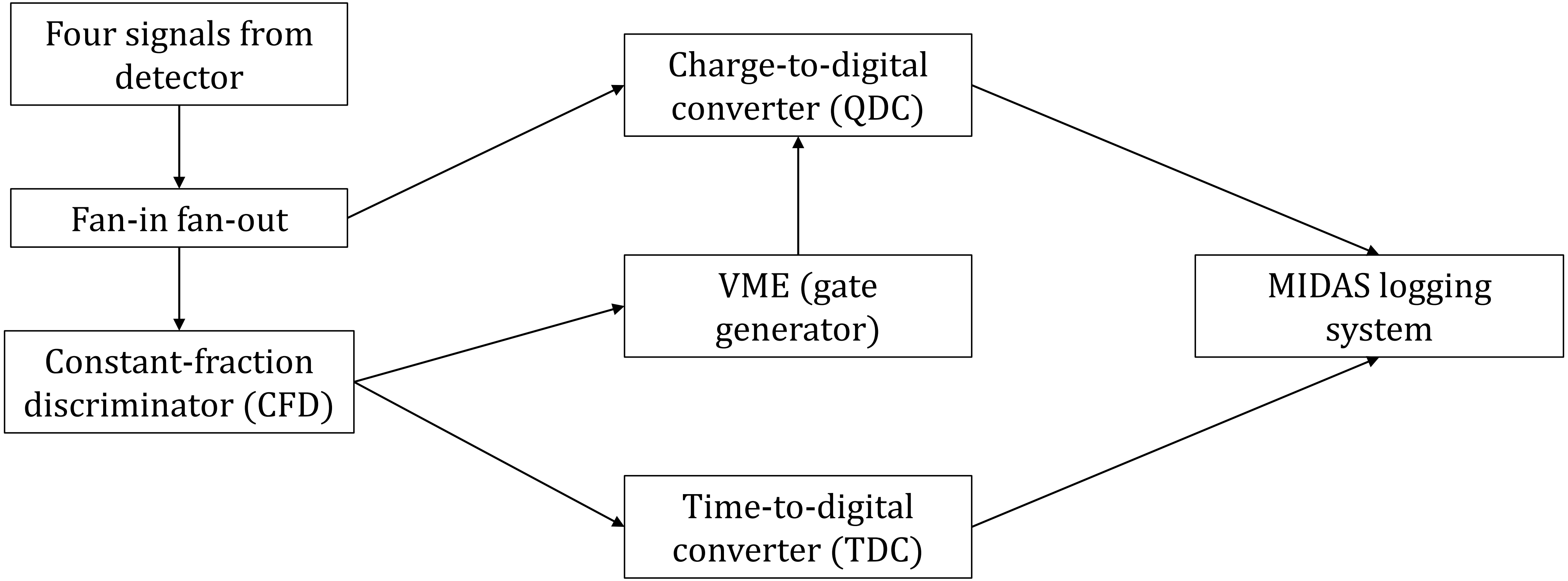
SiPM - wiring



SiPM - wiring

- Four anodes (S_{out}) connected to each other
- Four of the red wires each carry the sum of four anodes – fifth provides bias voltage

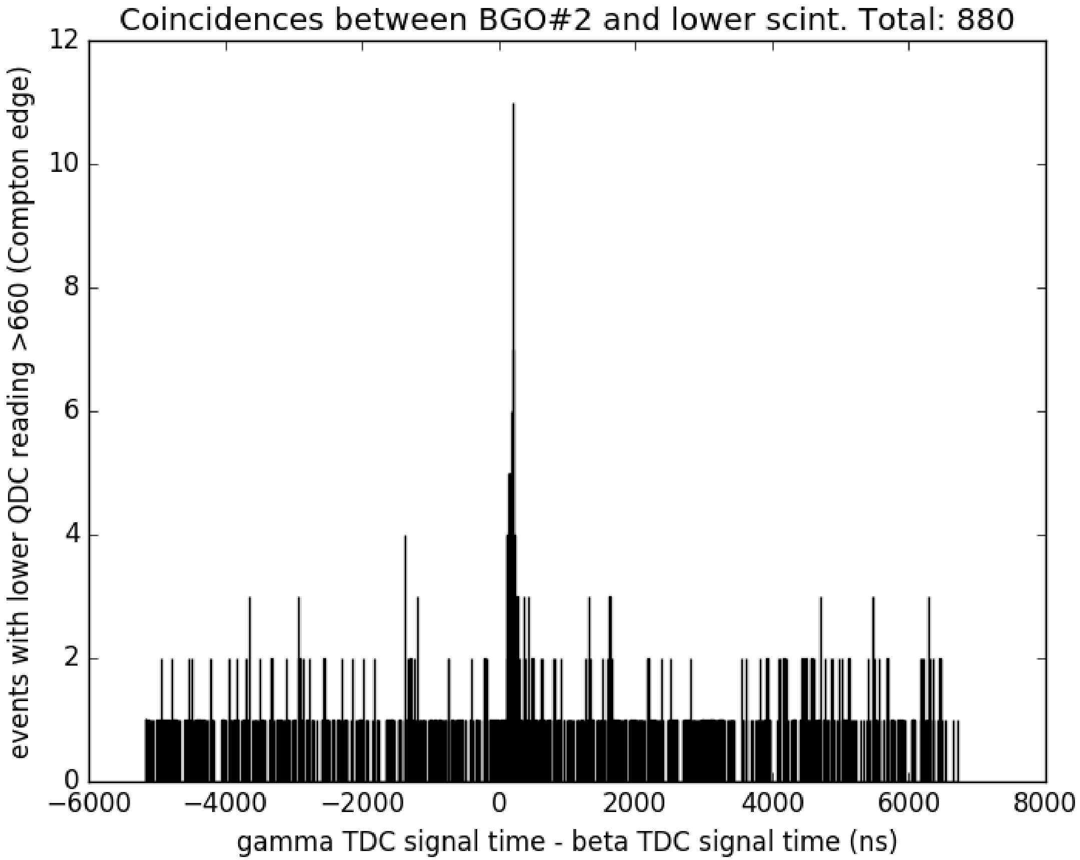
Data acquisition



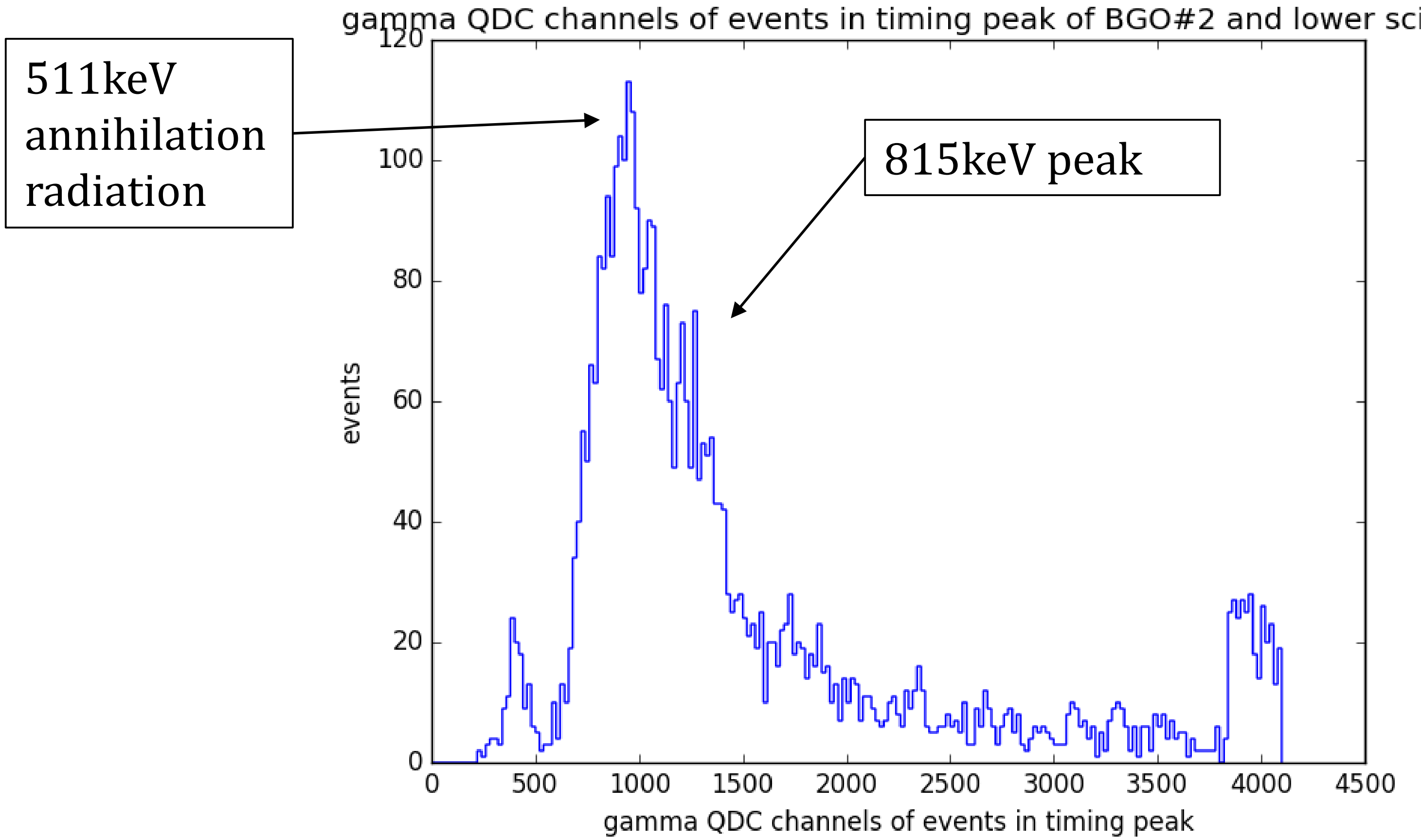
Data analysis concerns

- Need to ignore noise – γ emitted in only 3% of ^{92}Rb decays
- Low-energy noise is significant – bremsstrahlung (“braking radiation”) from betas crashing into the Teflon in front of the BGO
- Filtered out most such noise by setting a beta threshold

Beta-gamma timing

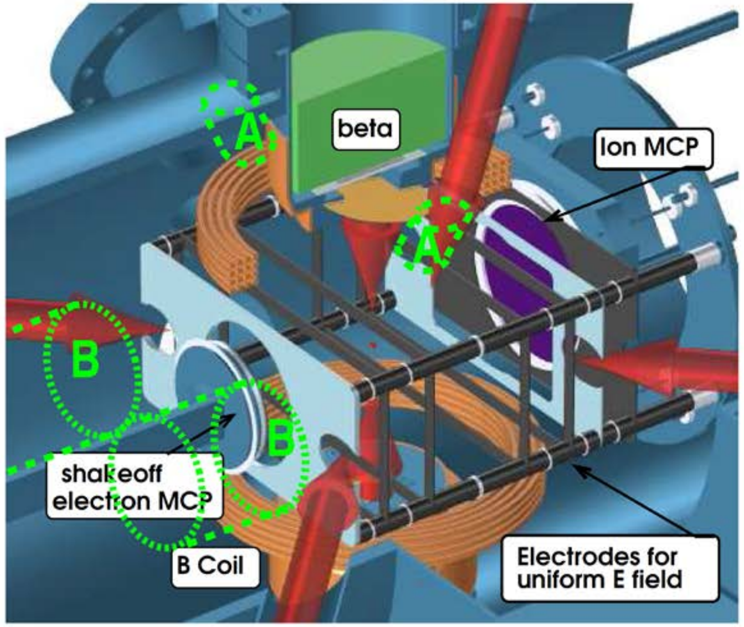


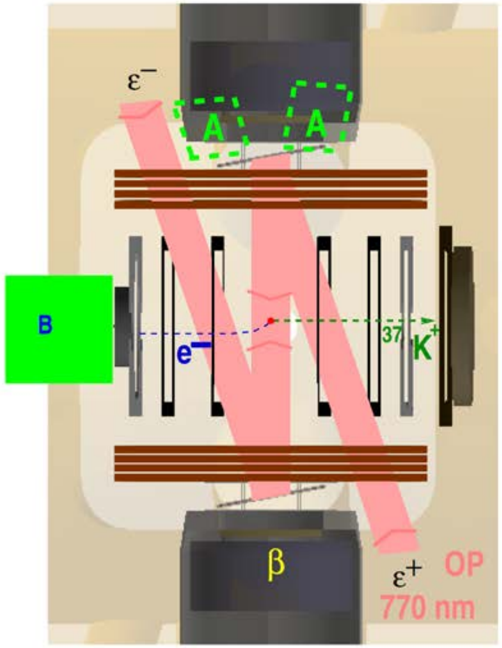
Gamma energies in timing peak



Analysis – next steps

- Take 815keV events and plot gamma-ion coincidences
- Each charge state of the ion should have two distinct peaks
- Different shapes and sizes of the two peaks may point toward CP violation





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Questions?