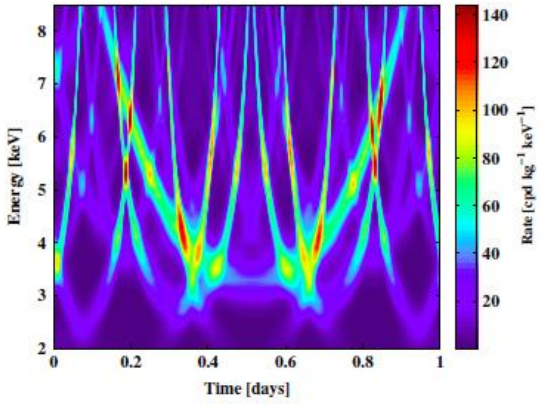
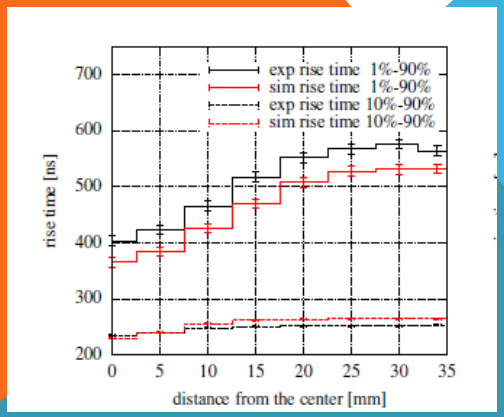


AXION DETECTION WITH GERMANIUM DETECTORS

HANNAH LETOURNEAU



OVERVIEW

Image Credit: MAJORANA Collaboration

Point-Contact Enriched-Ge Crystal

MAJORANA Demonstrator

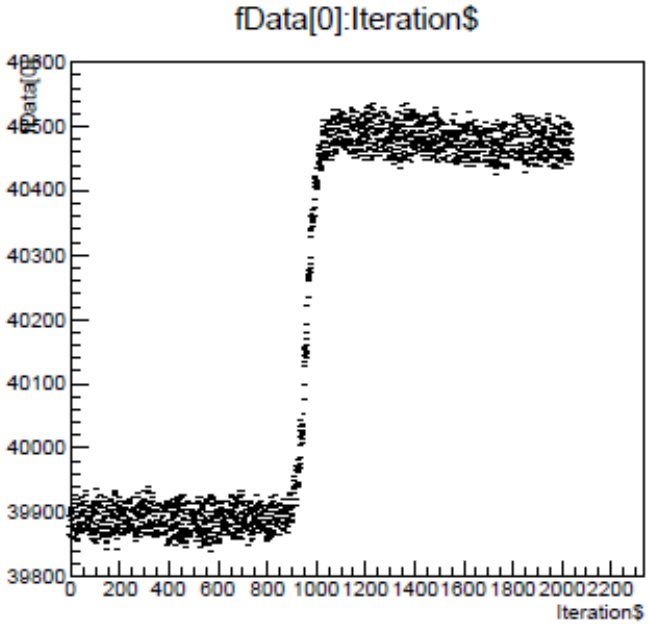
- Motivation
  - Neutrinoless double beta decay
  - Search for axions
- Design

Germanium detectors

- Semiconductor detectors
- Germanium data collection process

Detector characteristics I measured

- Leakage current
- Detector Capacitance
- Crystal axis orientation



NEUTRINOLESS DOUBLE BETA DECAY

Emission of 2 electrons from Ge-76 with no neutrinos

- Lepton number

Neutrino Mass

Majorana mass term

- Particle is its own antiparticle
- Grand Unification Theory
- Matter-Antimatter Symmetry

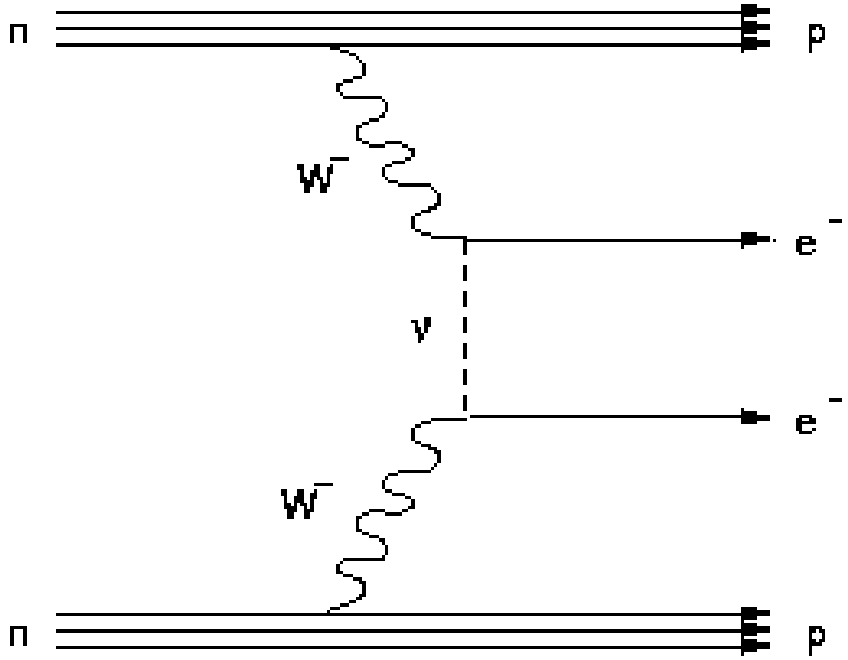


Image Credit: UCL NEMO Group, http://www.hep.ucl.ac.uk/nemo/

DESIGN

- Located 4850’ underground at Sanford
- 40-kg of Ge detectors, 30-kg enriched to 86% Ge-76
- 2 independent cryostats made of ultra-clean, electroformed Cu
- Background goal: 3 counts in the 0νββ peak region of interest in a one tonne-year exposure
- Compact Pb and Cu shield + muon veto

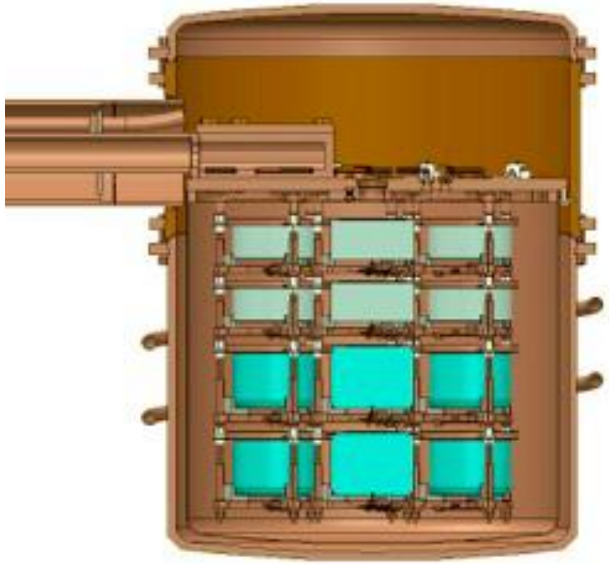
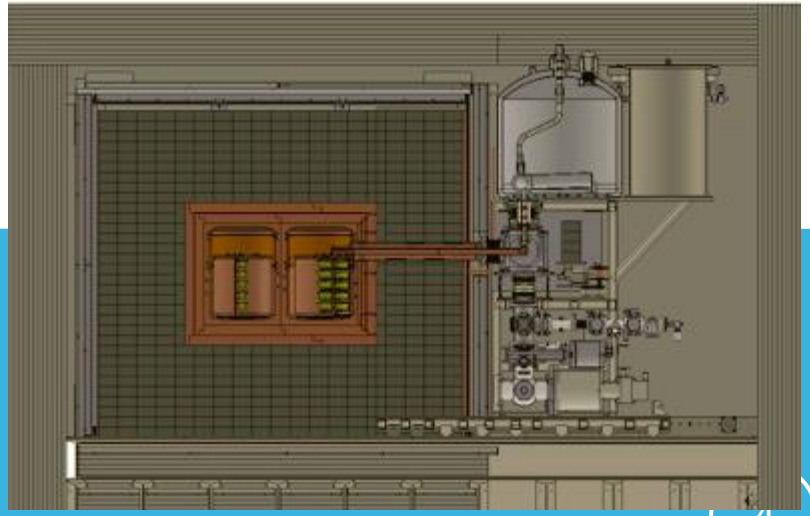


Image Credits: Jason Detwiler



AXIONS AND GERMANIUM

Proposed particle to solve strong CP problem

Potential source of photons in Ge

Sun as point source

Crystal axis relationship

- Bragg scatter on crystal
- Energy deposition depends on plane because of electric field
- allows elimination of most background

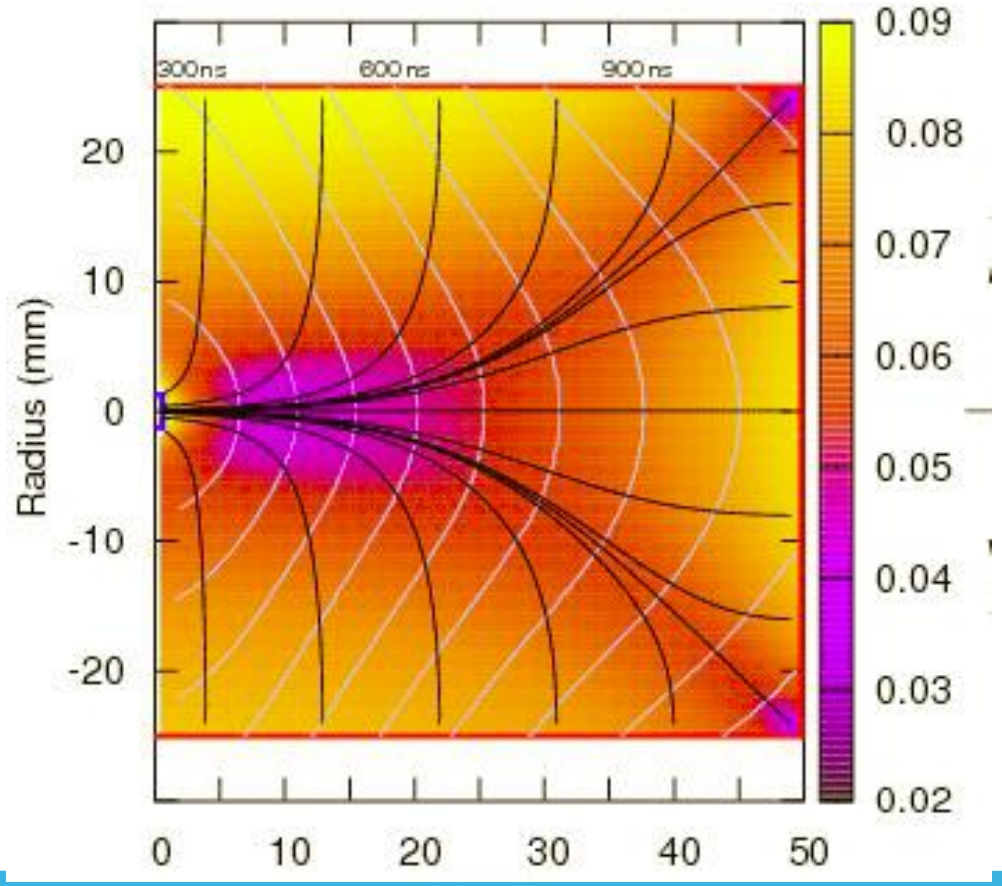


Image Credit: Jason Detwiler

AXION DETECTION

Graph shows energy ranges that are excluded by the time of the day
Traditional method: collimated low energy radiation source
Our problems:

- thick cryostat
- 114 crystals
- Room gammas
- Noise

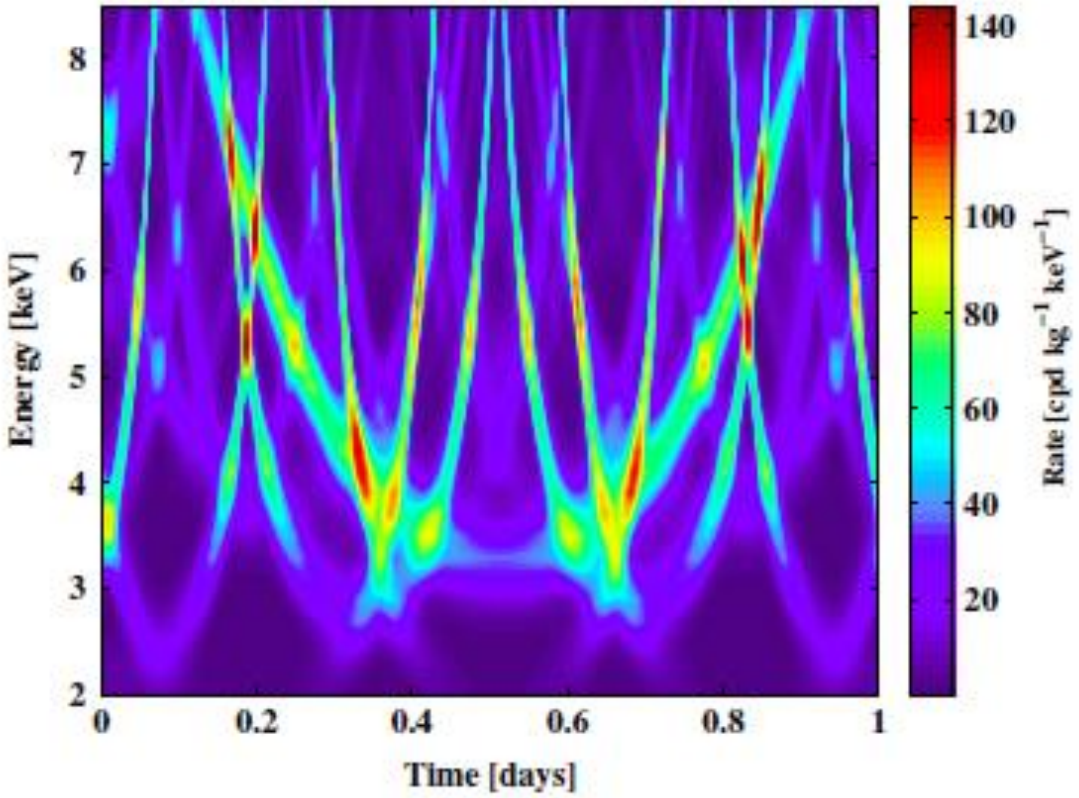


Image Credit: "Search for Axions with the CDMS Experiment." *Physical Review Letters* 103 (2009).

SEMICONDUCTOR DETECTORS

Crystal with too many/too few electrons

Incident radiation creates a hole by ionizing an electron from the valence band to the conduction one

Holes and electrons move randomly

Current flows if biased

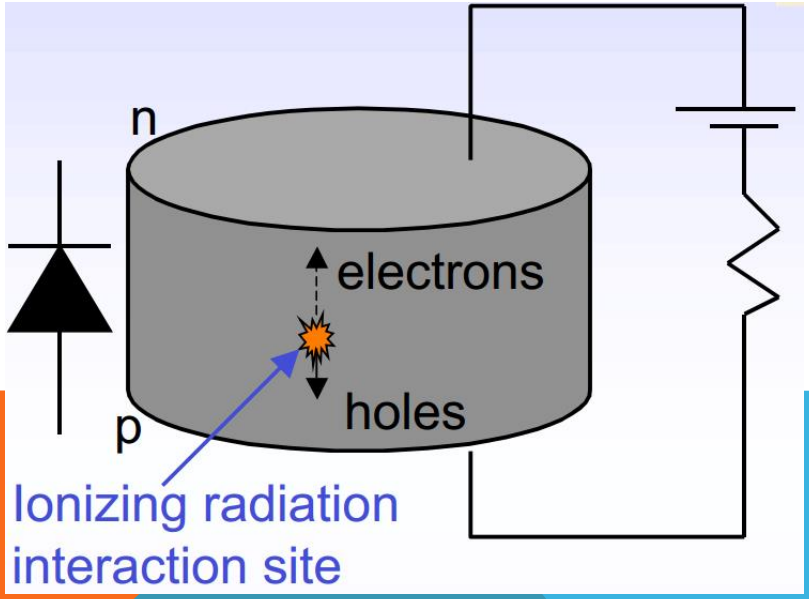
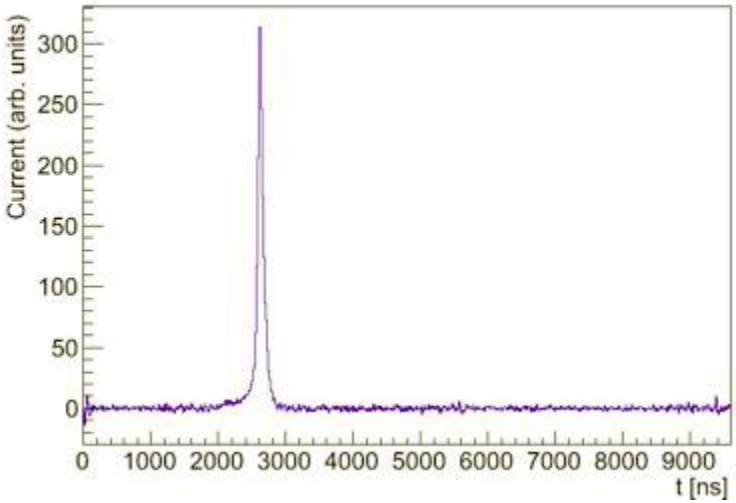
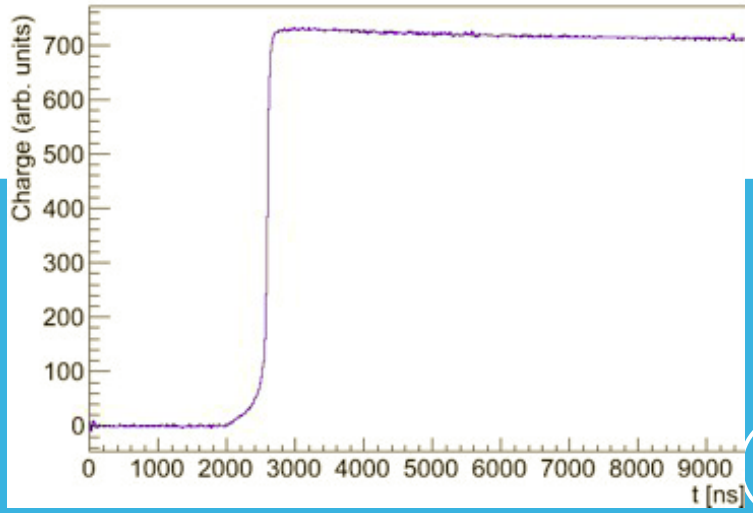


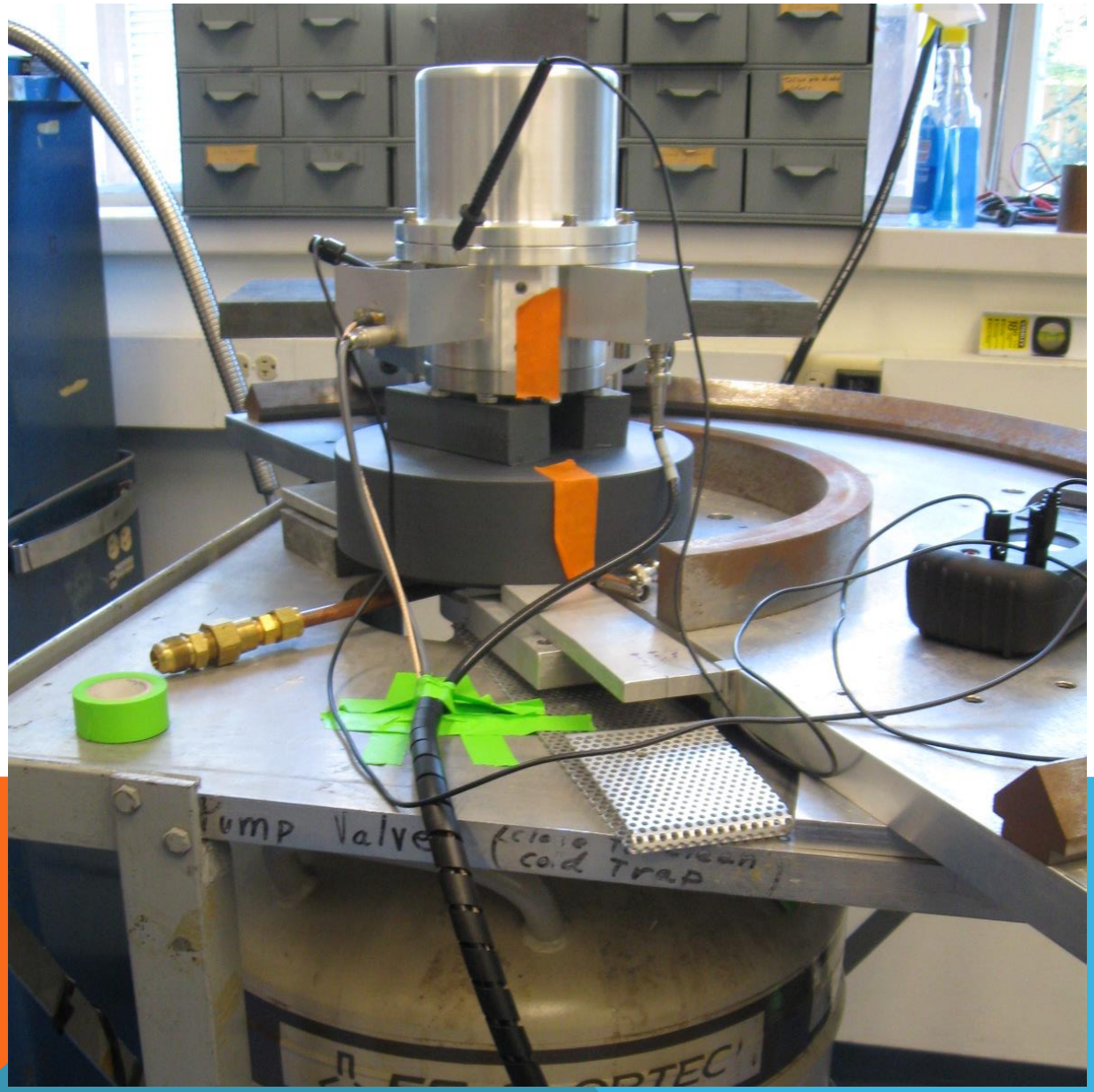
Image Credit: Reyco Henning, UNC Chapel Hill

Image Credits: Jason Detwiler





GERMANIUM DETECTORS



Point contact detector
~80K operating temperature
1500 V needed for bias

DATA COLLECTION AND PROCESSING

Probes detect the current

Preamplifier gives a good signal to noise ratio

Data card converts from analog to digital; trapezoidal filter

ORCA, Root

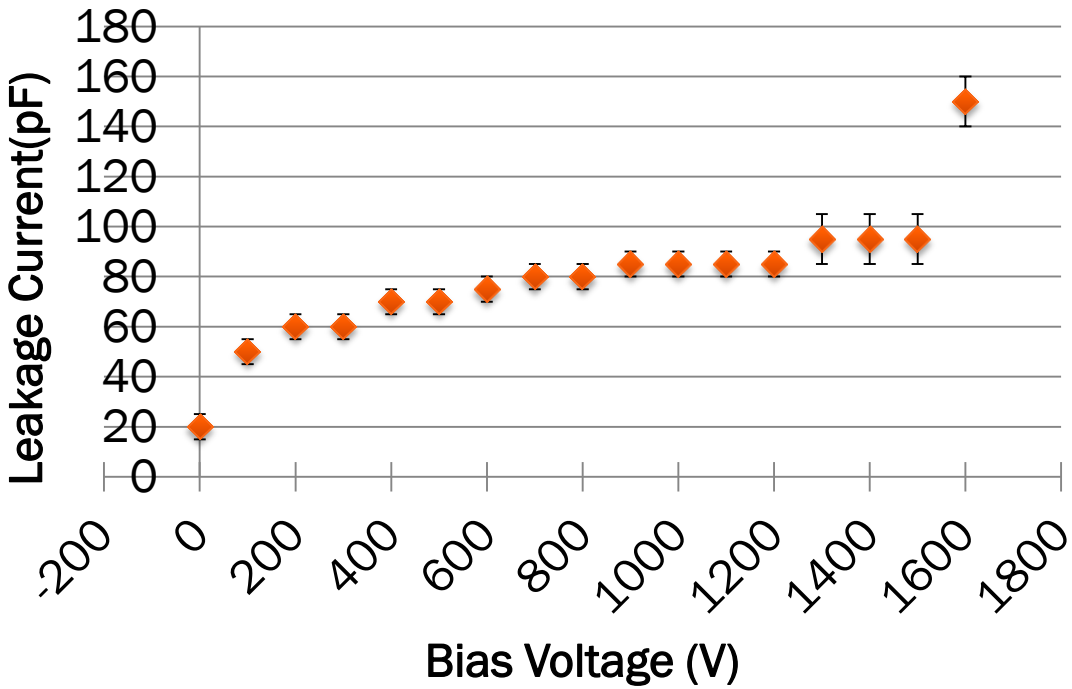
LEAKAGE CURRENT

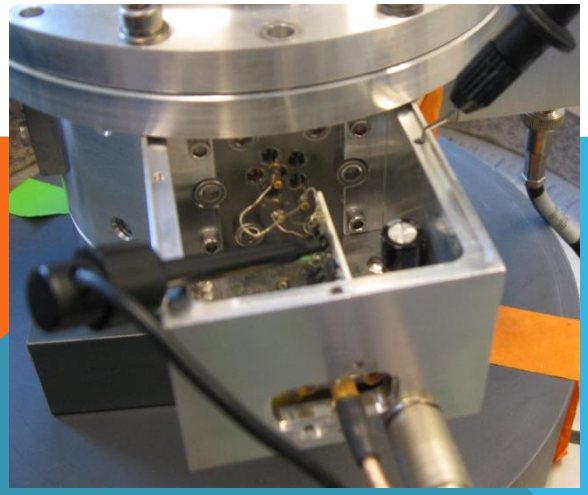
Free electrons flowing around detector

Health of detector; noise; operating conditions

Procedure:

- Turn voltage up, from 0V to 1.5 kV by 100 V increments
- Measure current with circuit on preamp after it has settled
- 1mV=1pA





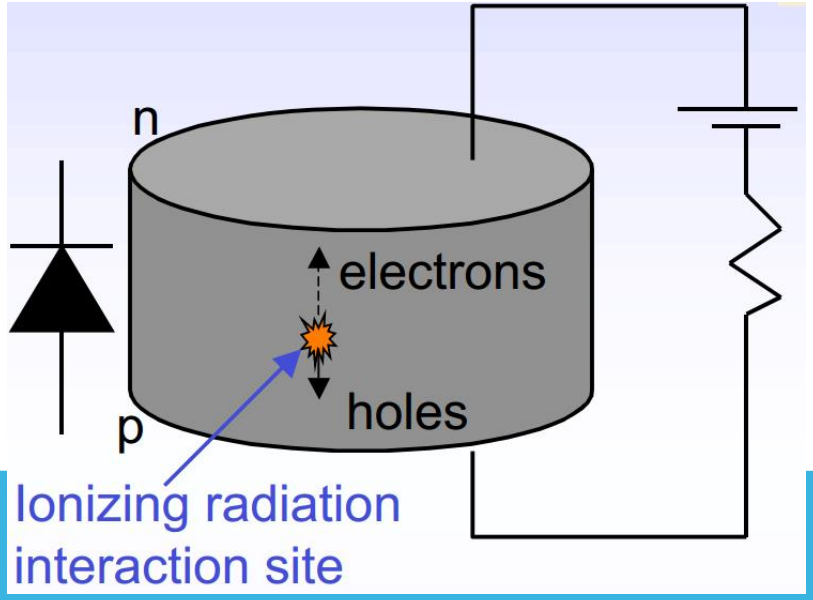
DETECTOR CAPACITANCE

Indication of where it operates as a radiation detector

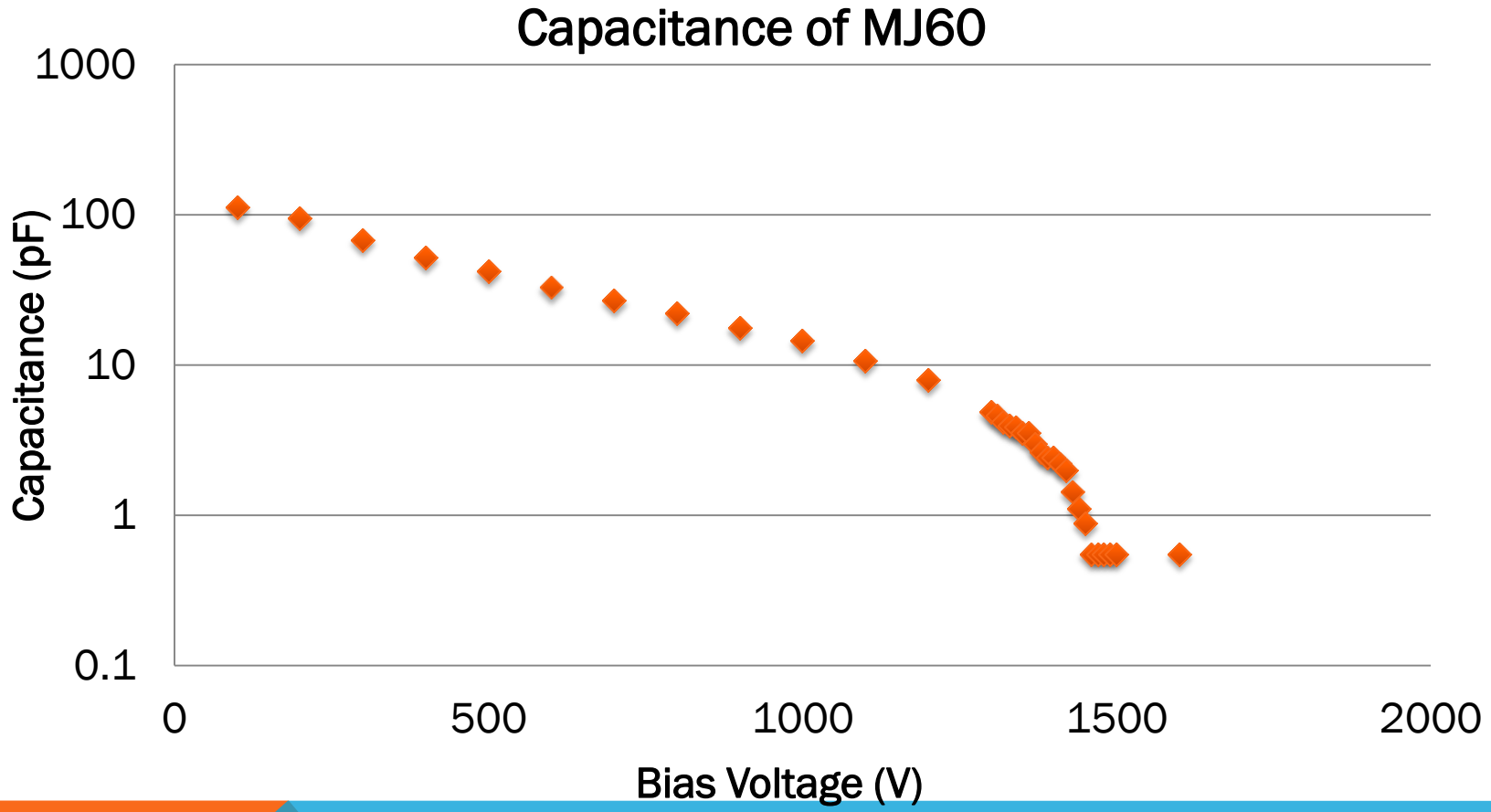
Procedure:

- Bias detector
- Square wave pulser (100 mV) into HV input
- Lower voltage in steps of 100 V, except near depletion (1400 V)
- Measure amplitude of pulses
- $Cd = \frac{Cf * V1}{Vp * \frac{5.62}{5.62+45.3}}$
  - Cf=.17 pF
  - V1=voltage on oscilloscope
  - Voltage divider: detector resistors
  - Vp=voltage in; 100 mV

Image Credit: Reyco Henning, UNC Chapel Hill



DETECTOR CAPACITANCE



Capacitance at 1400 V=2.5 pF

CRYSTAL AXIS ORIENTATION

Property of Crystal

Affects energy deposition and signal propag similarly

- Fastest along faces of crystal
- Slowest in the middle of the faces
- Smooth transition
- Sin wave with 90 degree periodicity

Traditional Method vs. Ours:

- Point vs. plane
- Low vs. high energy

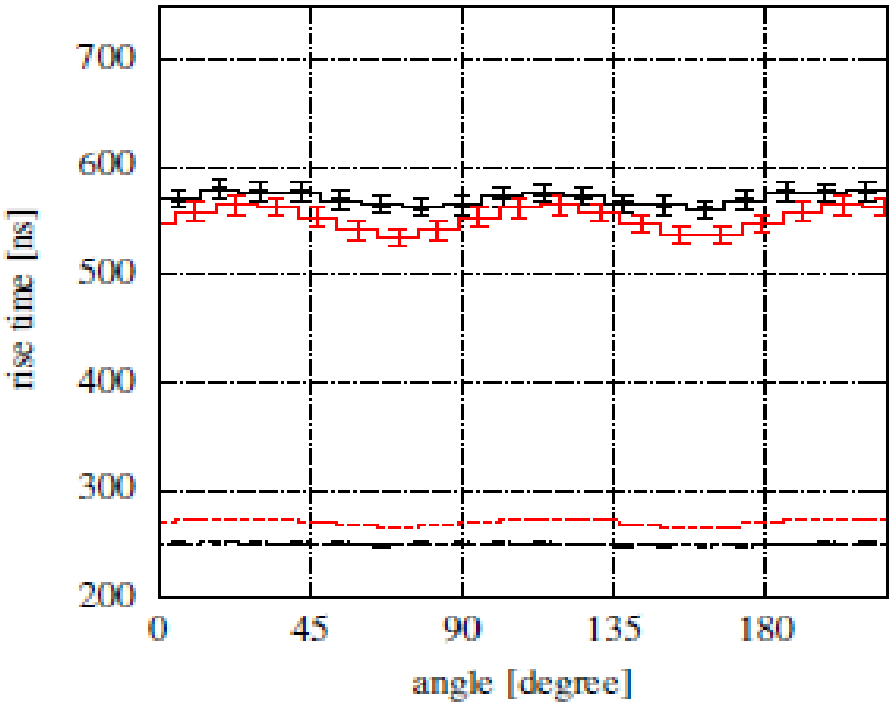


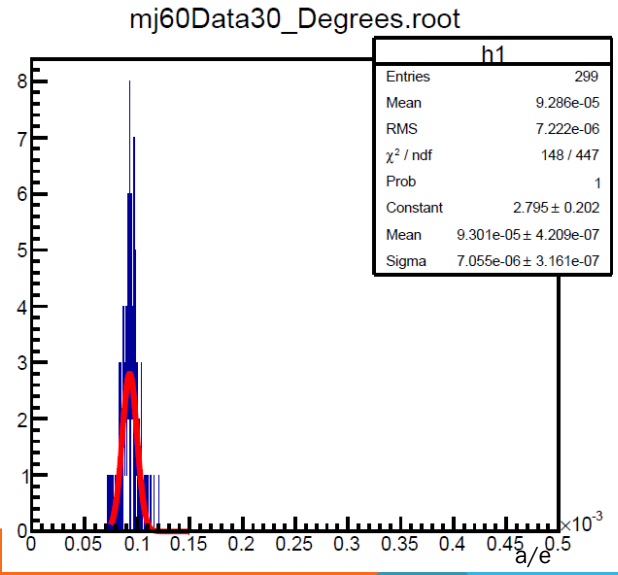
Image Credit: "Signal modeling of high-purity Ge detectors with a small read-out electrode and application to neutrinoless double beta decay search in Ge-76." *Journal of Instrumentation* 6 (2011)

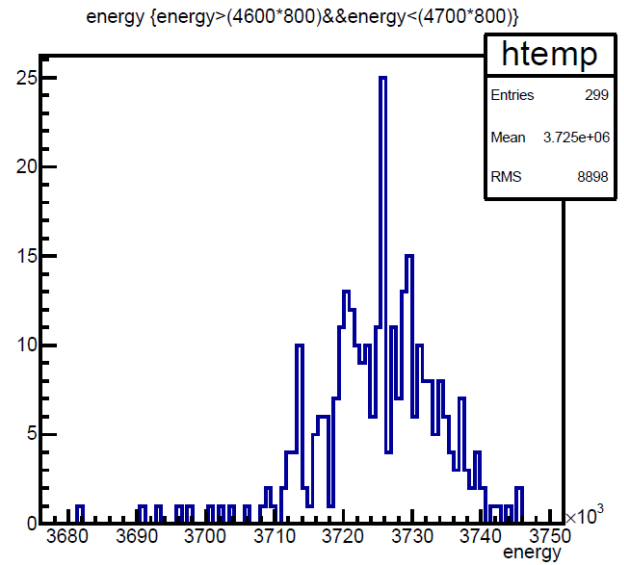
CRYSTAL AXIS ORIENTATION PROCEDURE

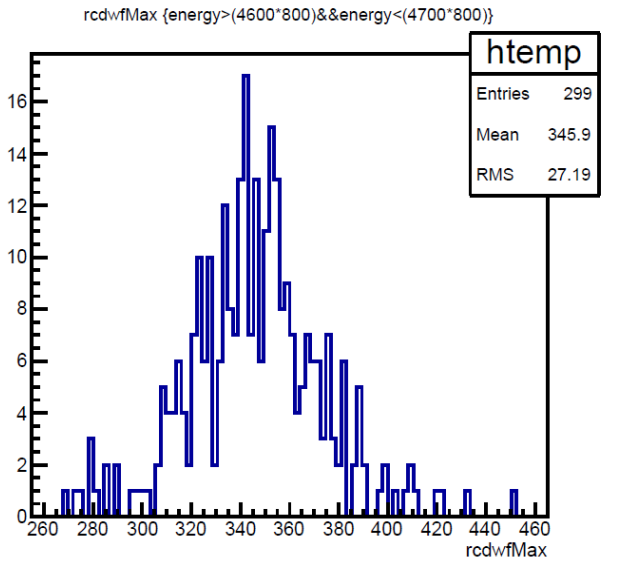
Scan around detector at increments of 5-10 degrees with collimated radioactive source

Rise time

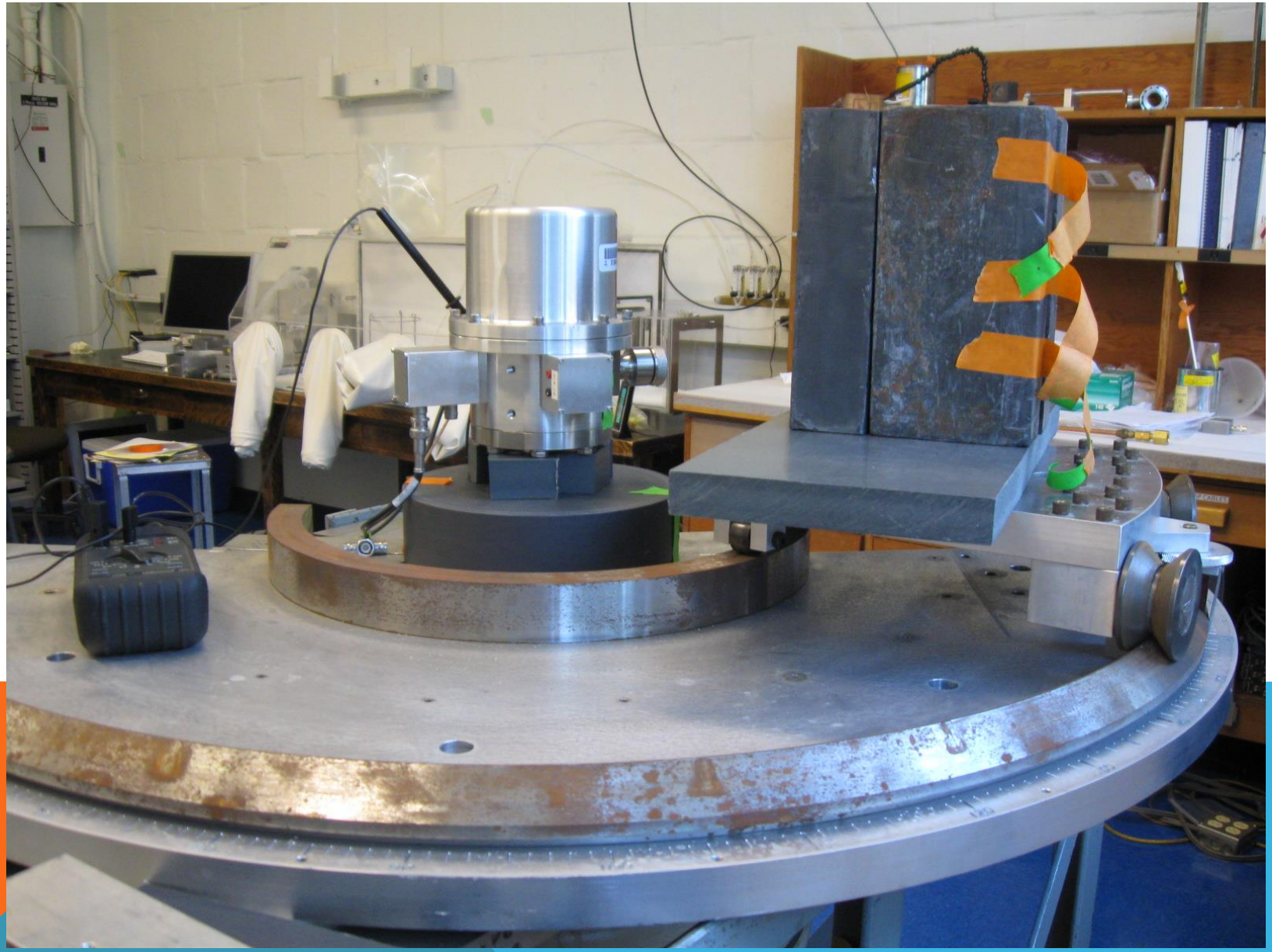
Calculate amplitude/energy of pulses in the energy range



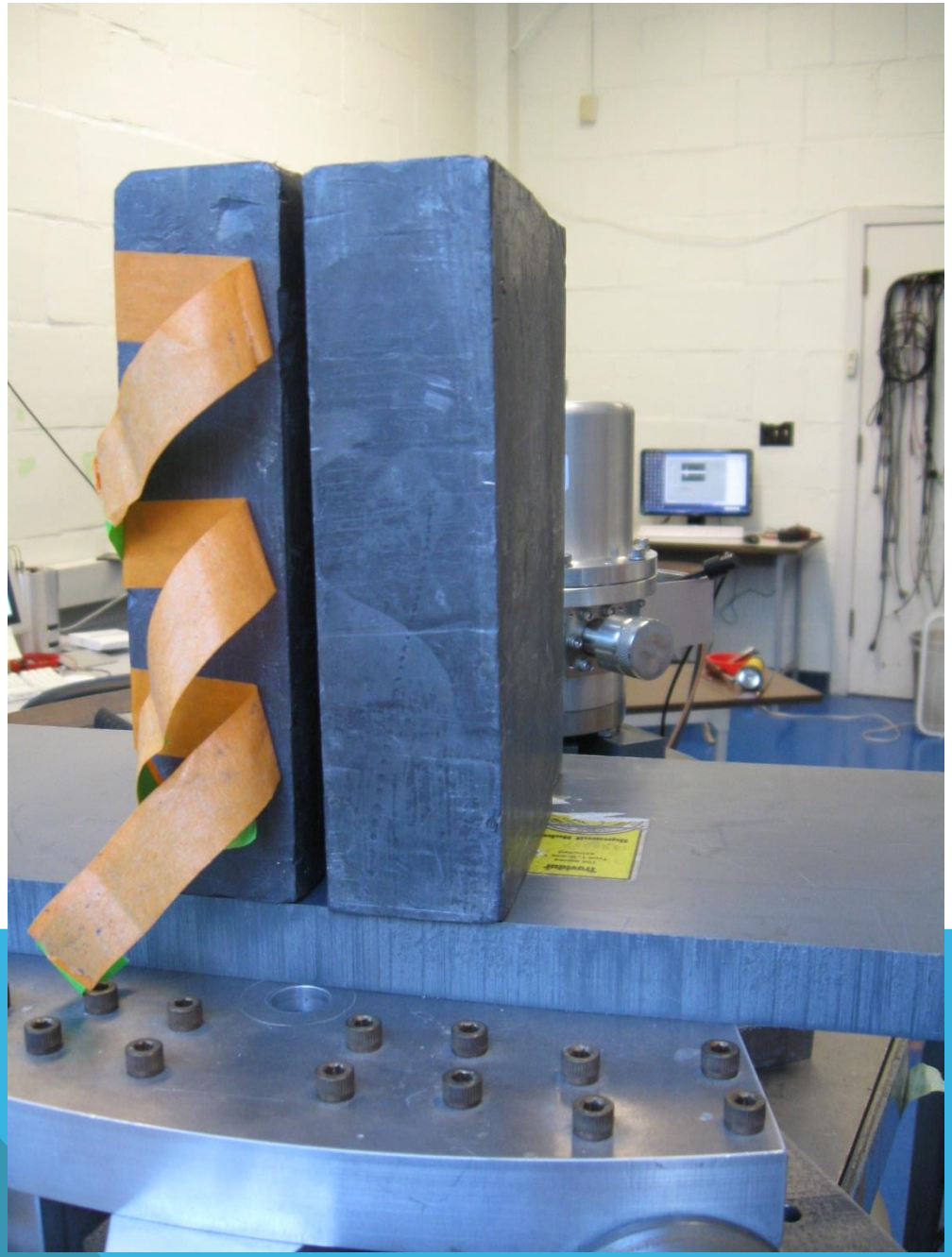




APPARATUS



COLLIMATOR



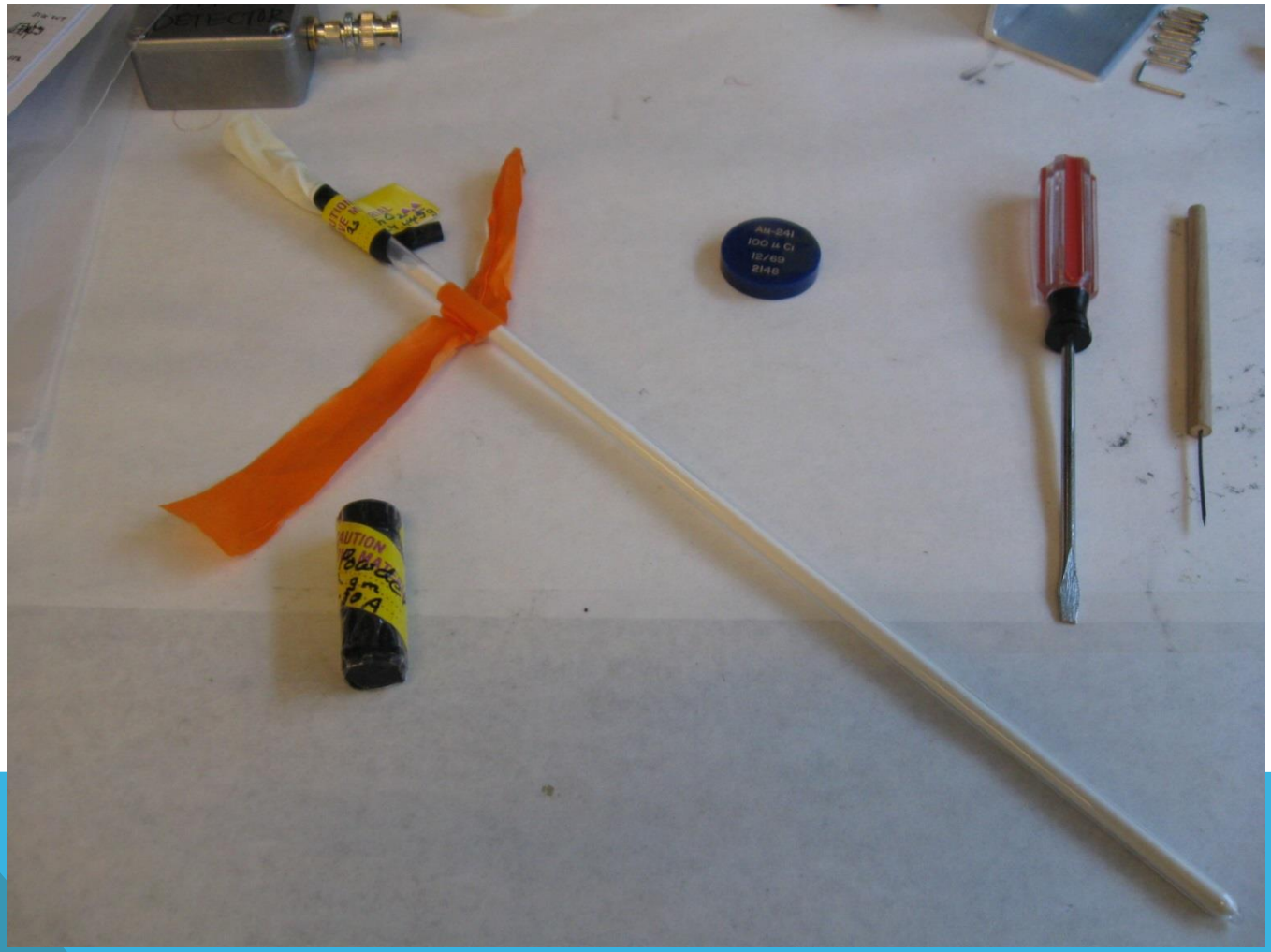
RADIOACTIVE SOURCES

Americium 241

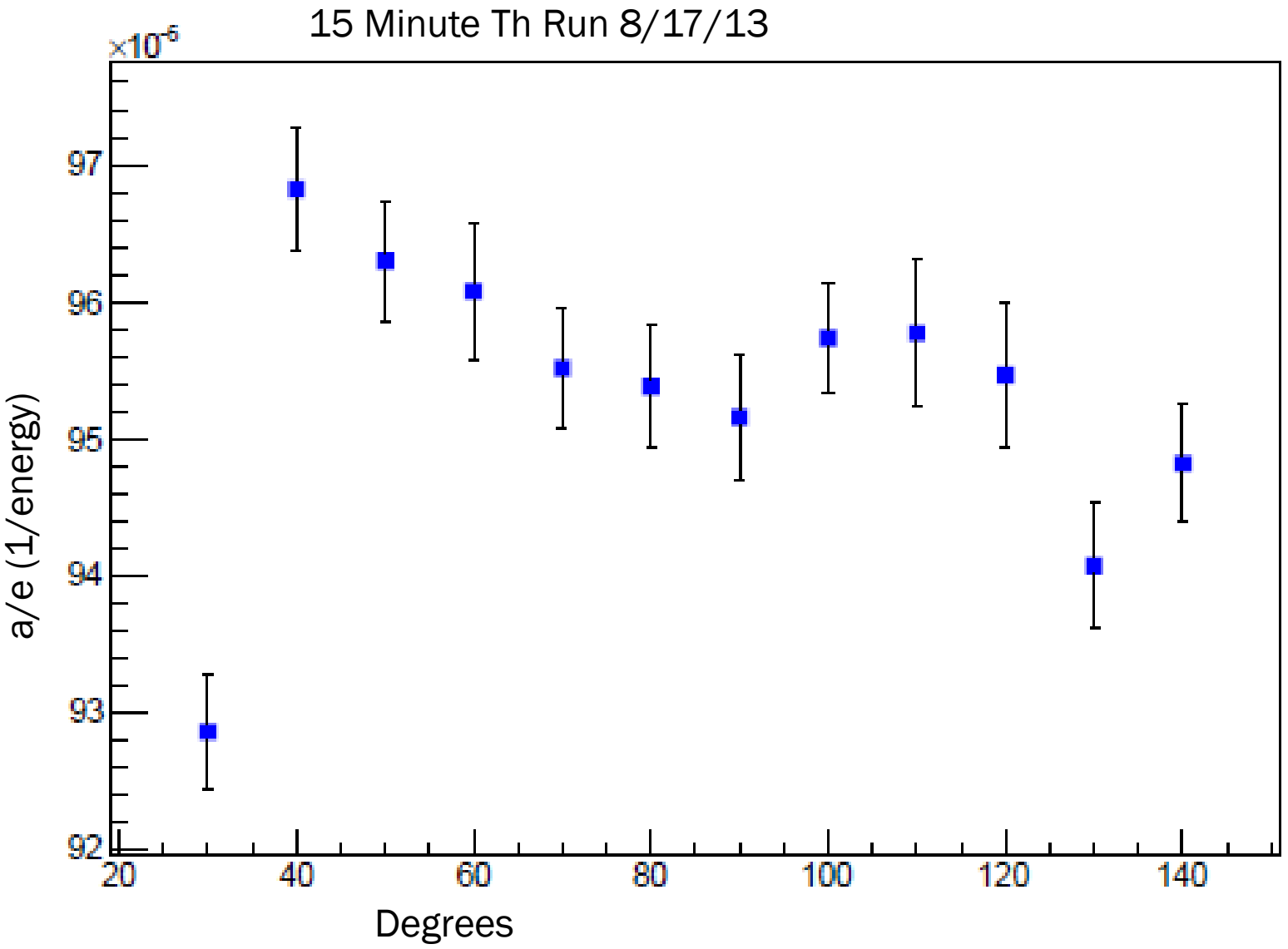
- 60 keV peak
- “Button source”

Thorium 232

- Thallium 208
- 2615 keV peak
- Density; height

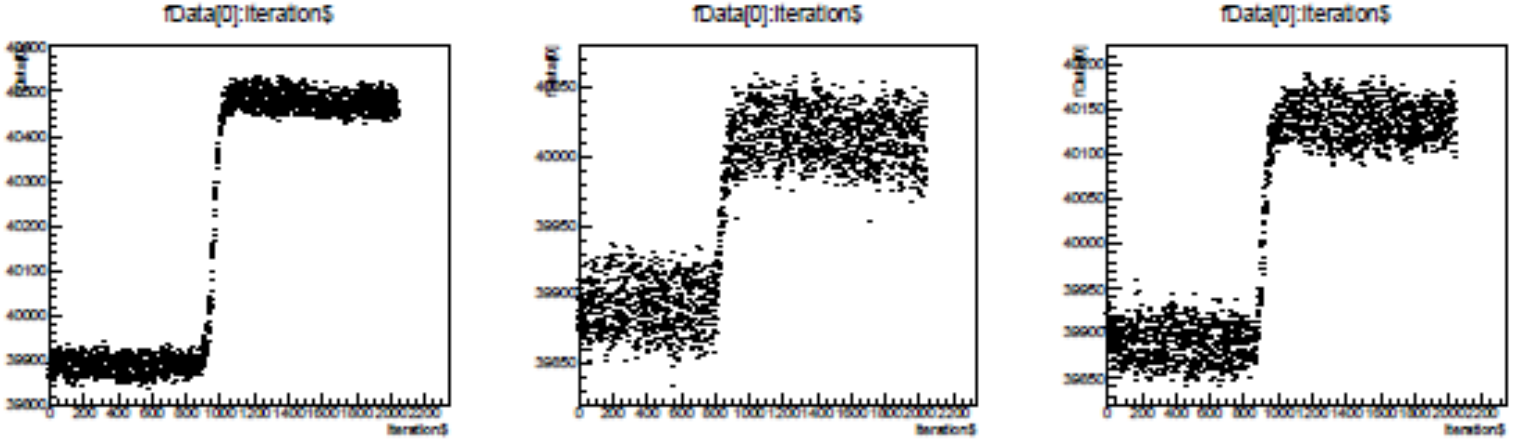


RESULTS

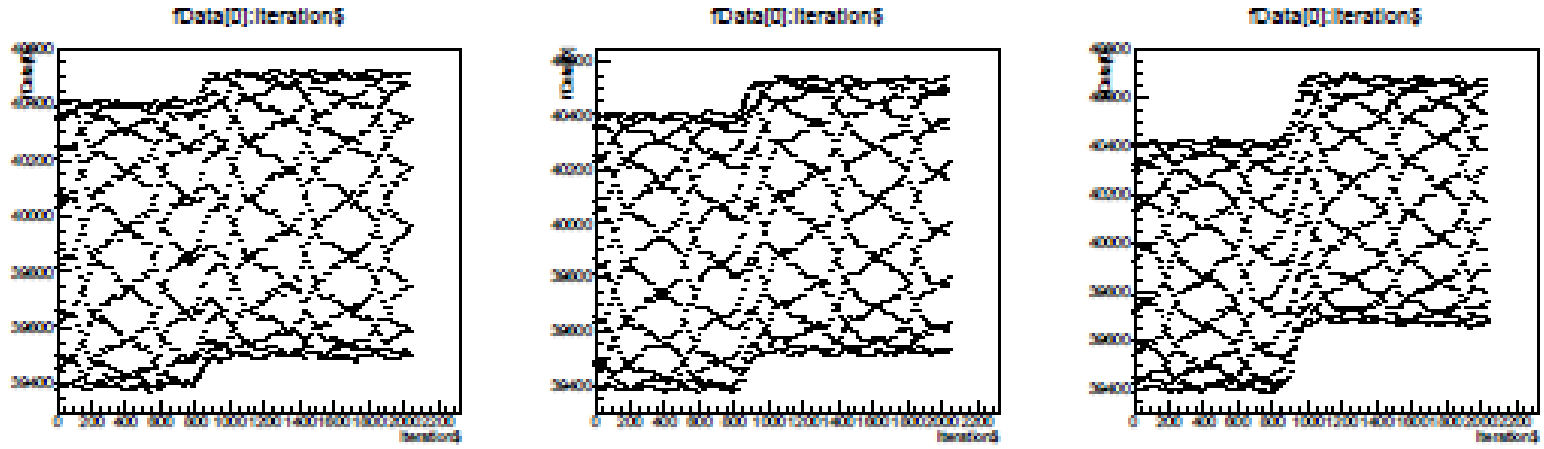

15 Minute Th Run 8/17/13
×10⁻⁶
97
96
95
94
93
92
a/e (1/energy)
20
40
60
80
100
120
140
Degrees

NOISY WAVEFORMS

From best Th run



From worst Th run



NOISE

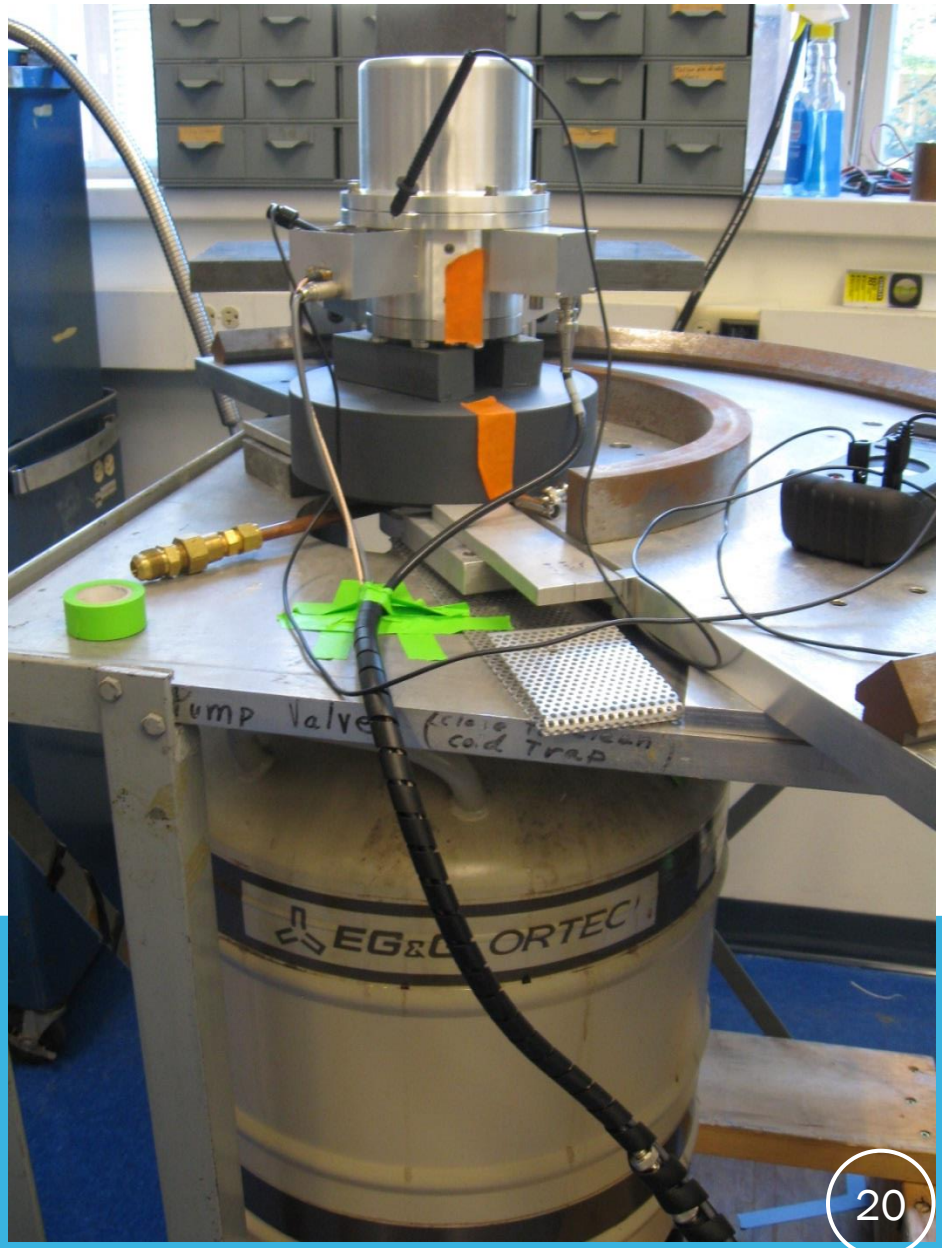
Radioactive sources

- Thorium vs. Americium
- Attenuation coefficient of Th

Preamp noise

- Fixed by multimeter
- Possibly from high leakage current

Spiral wrapped cables—Ground loops



CONCLUSIONS

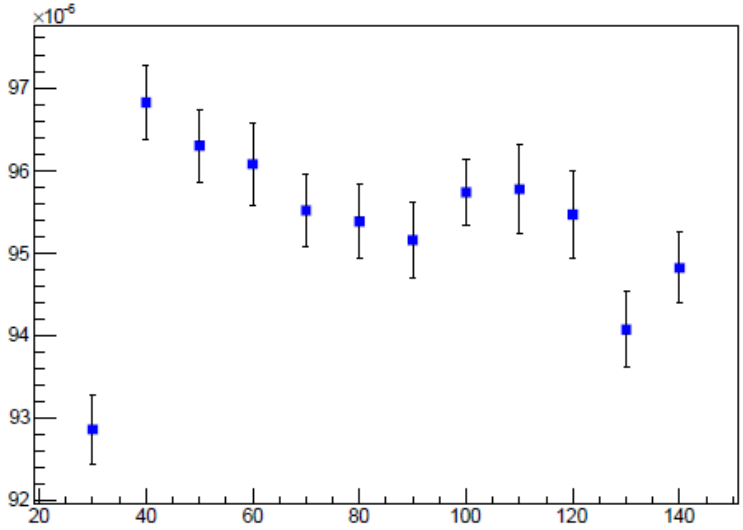
Noise is dominating signal

Positive Results

- Built a system that is capable of the measurement, with the exception of noise

Next steps

- Fix preamp
- Advanced filtering
- Superpulse
- Higher statistics



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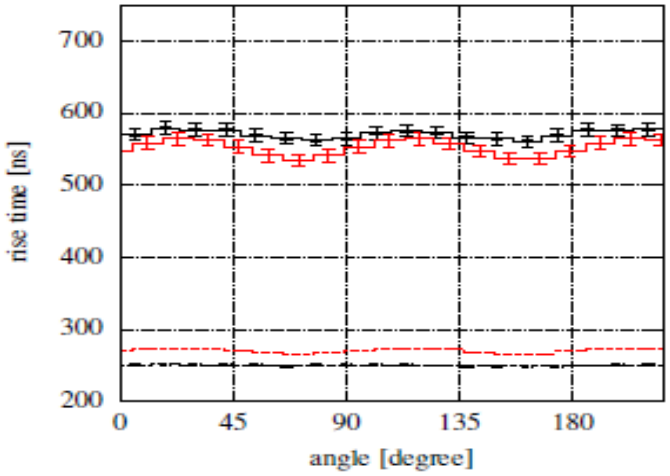

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