

# Progress in Diamond Sensor Development for Use in LENR Experiments

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for Nuclear Renaissance  
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# Schedule

- Recap of results presented at ICCF 17
- Developments in 2012-2013
  - Procedures
  - Experimental setup
  - Detection methods
- Results
- Conclusions
- Future work

# Recap – Motivation

- If LENR phenomena are in fact nuclear, it is reasonable to expect nuclear products from their interactions
  - Excess heat, neutrons, transmutation into unstable nuclei
- Predominant in-situ neutron detector is CR-39
  - Integrating detector provides no rate data
  - Time delay between experiment and results
  - Resolution and threshold energy depend on etching and counting processes

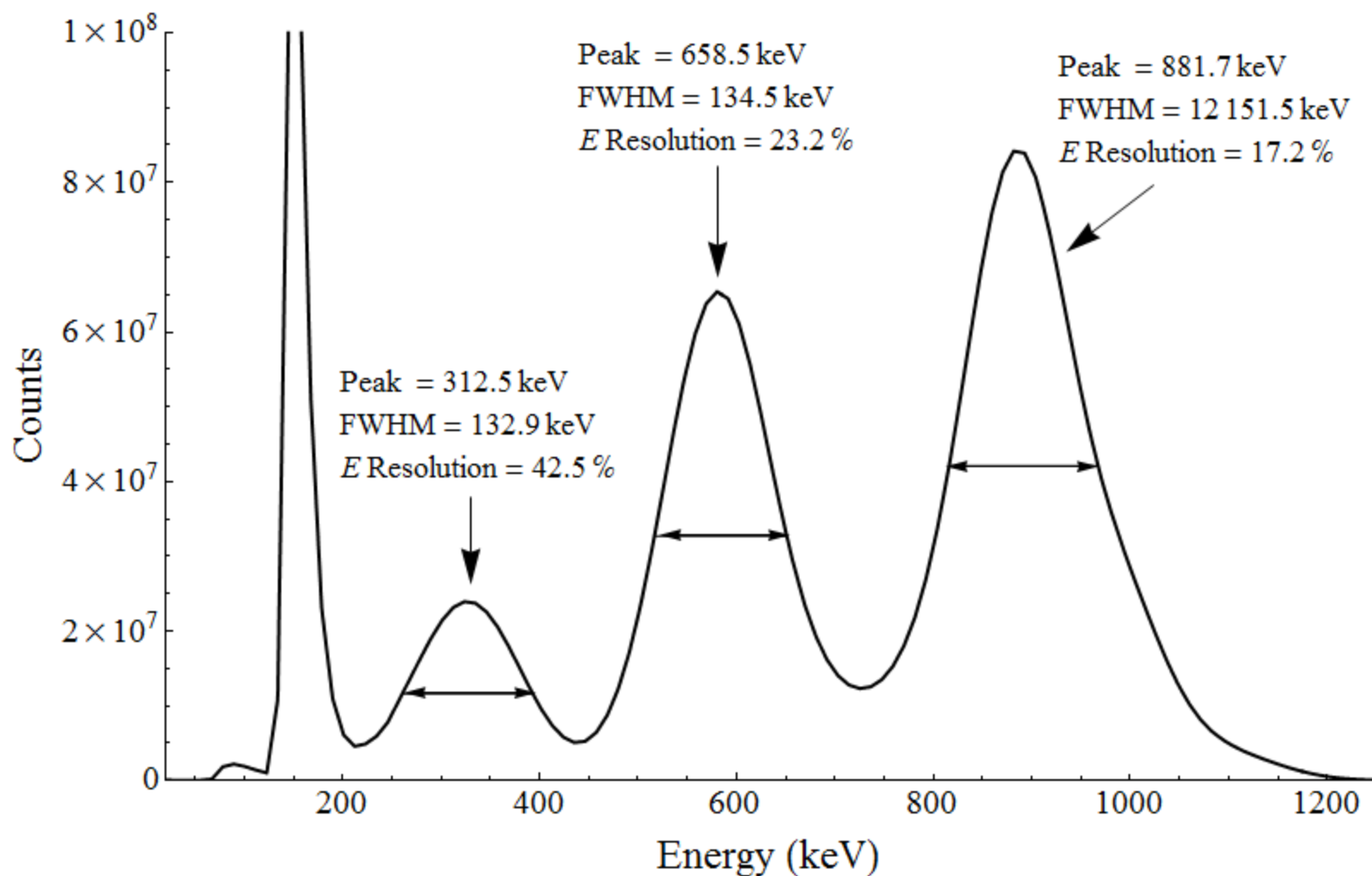
# Recap – Motivation

- Useful to switch to diamond
- Real-time detector
  - 50 ps pulse rise-time
- Good energy resolution
  - $R=2.35 N^{-1/2}$ 
    - R: resolution; N: # electrons produced
  - For 5.5 MeV alpha particle,  $N \sim 4.2E5$
  - Minimum resolution ends up being .365%, 0.3 – 3% in literature
- Low noise
  - 5.47 eV bandgap
  - Insensitive to temperature and stray light
- Chemically inert, can be used in-situ cf. standoff detection modalities
- No easy intrinsic particle discrimination

# Recap – ICCF 17

- Preliminary results last year
  - DLC/Pd (10nm/100nm)
  - DLC/Au/Pd (10/100/100nm)
  - Long detector prep time
- Trials using three gases
  - H<sub>2</sub> – contact peeled off
  - He – contact peeled off
  - D<sub>2</sub> – strange peaks
  - Need better deposition mechanisms
- MCNP results
  - Based on MCNP models, whatever caused the signal appears to not be monoenergetic
  - No narrow full energy peaks in observed spectra

# Recap – Results



# Interim Work

- More trials
  - Increase sample size
  - Look for reproducibility
- Using different materials
  - Improve contact robustness
  - Reduce fabrication time
- Single run, no interruptions
- Include SEM

# Procedures

- Clean
- Coat
- Calibrate
- Experiment



# Procedures – Clean

- 3x3x0.5mm single crystal diamond plate
- Prepare diamonds for deposition
- Alternate acid/base washes
  - Remove metal layers
  - Oxygen terminate the surface
- Interim washing with DI
- Final rinse
  - Acetone
  - Methanol
  - DI H<sub>2</sub>O

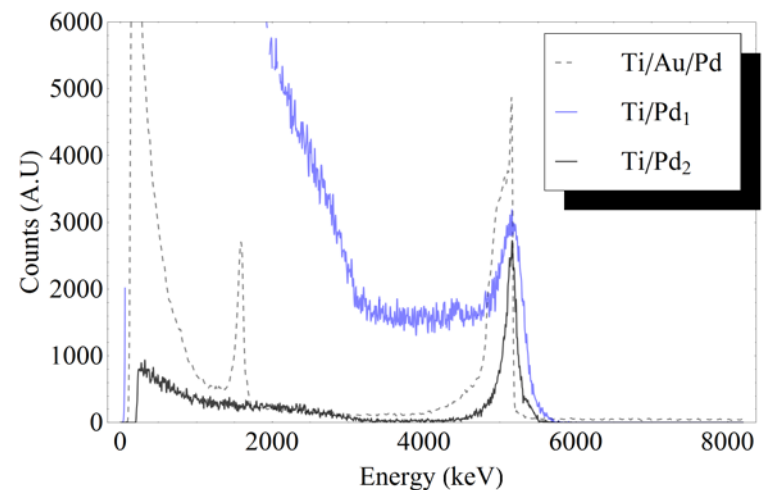
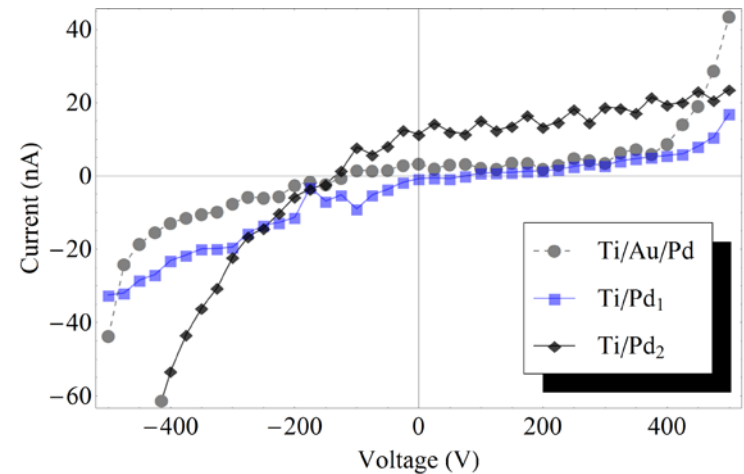
# Procedures – Coat

- Electrode materials
  - Ti/Au/Pd
  - Ti/Pd
- Processes
  - Argon plasma sputtering
    - 600 eV
  - Thermal evaporation

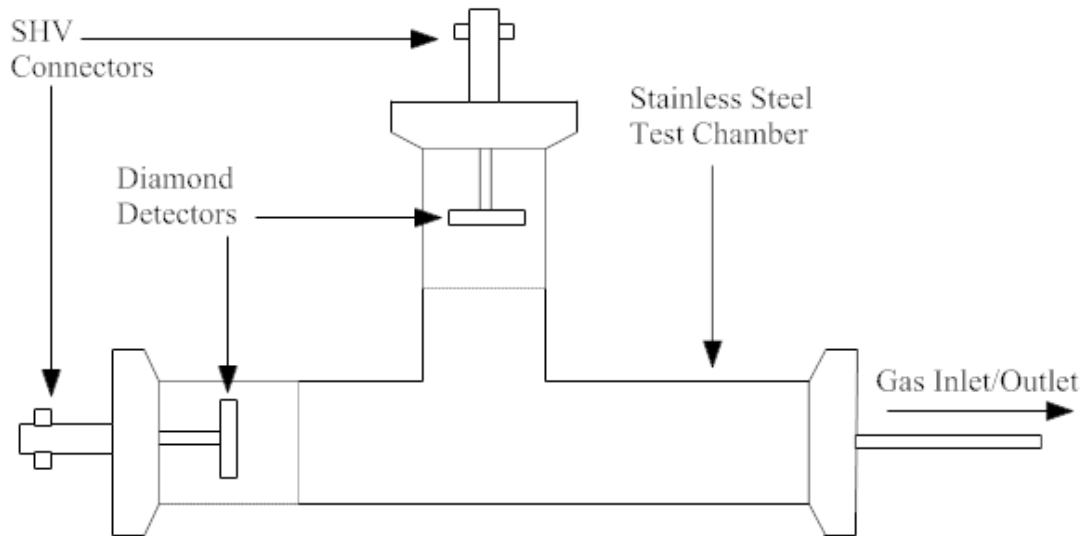
Sensor #	Ti (nm)	Au (nm)	Pd (nm)
1	50	50	100
2	50	-	150
3	50	-	130

# Procedures – Calibrate

- I-V test
  - Linear between 0-300 V
  - 200 V yields 100% CCE
- Pu-239 calibration
  - First sensor failed calibration check – not used
  - Others showed
  - 2<sup>nd</sup> sensor used low-activity source for calibration
  - 2.4% resolution at 5.2 MeV



# Procedures – Experiment

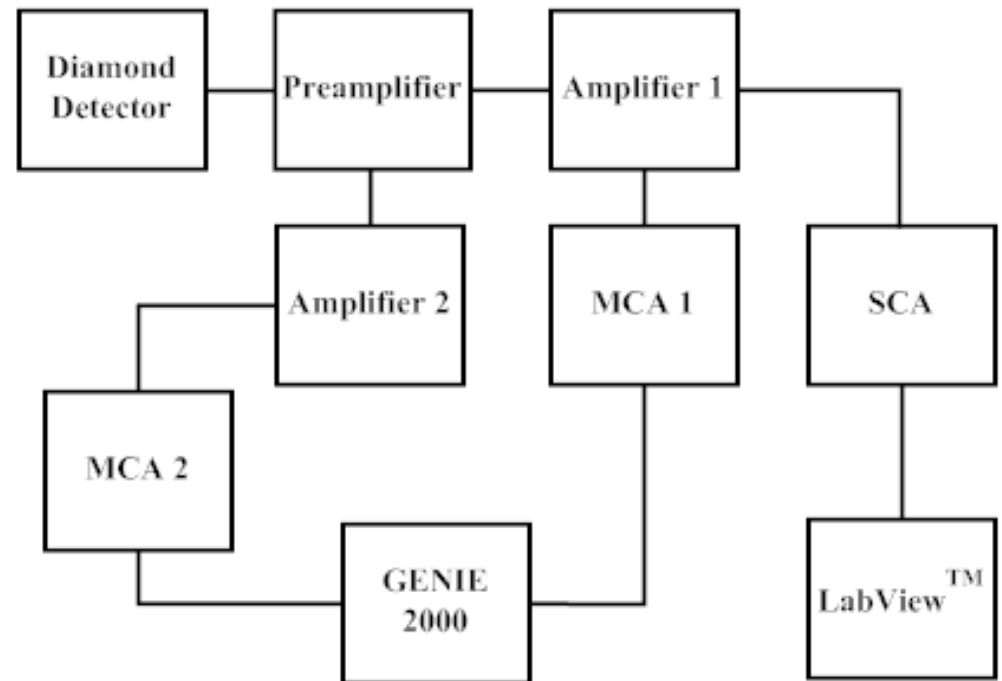


- Connected diamond sensor to SHV connectors
- Closed chamber
- Placed in 3" thick lead cave
- Evacuated with diaphragm pump
- Load chamber with  $D_2$  gas to pressure of 691 kPa; measured using MKS 722 Baratron Absolute Capacitance Manometer

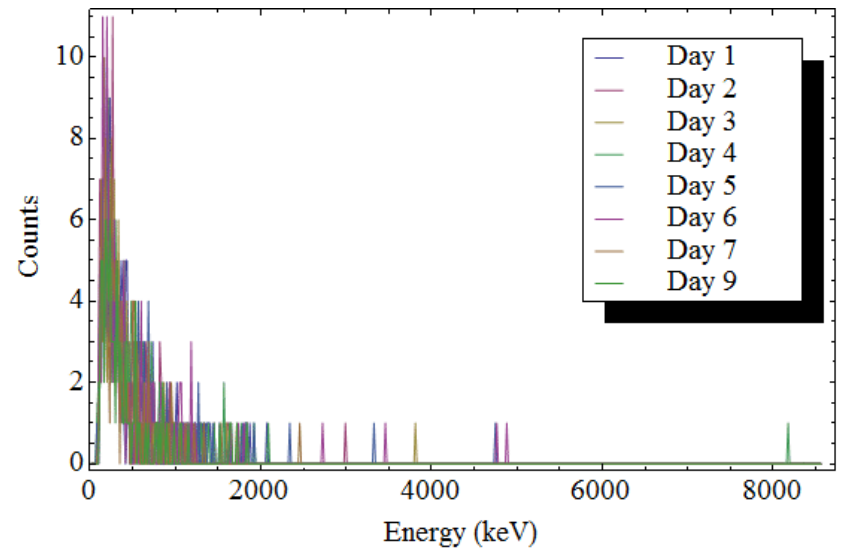
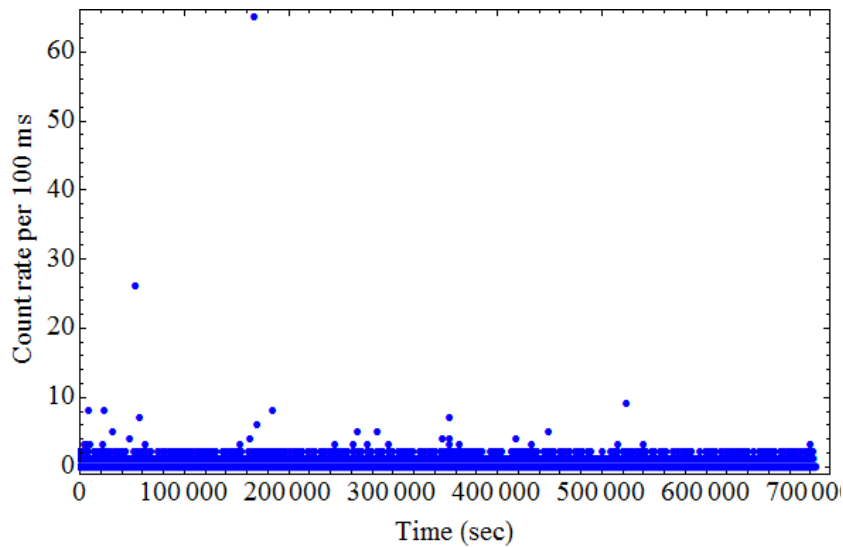


# Detection Setup

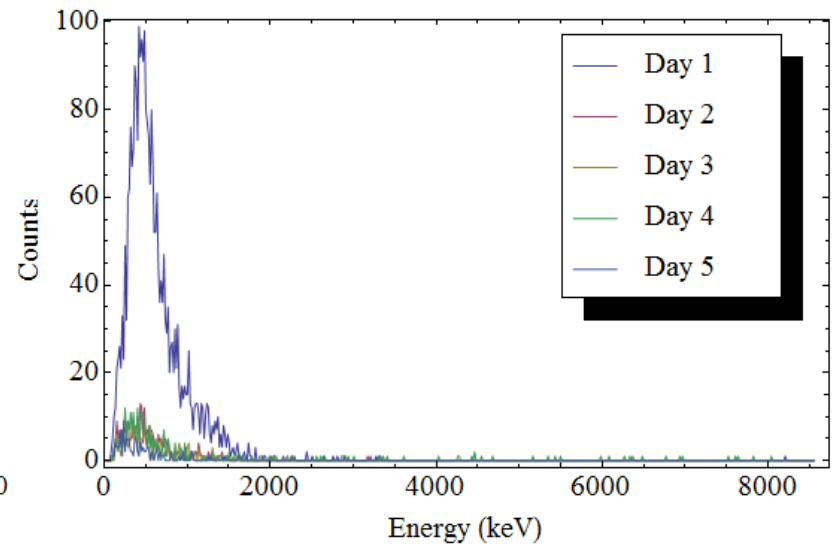
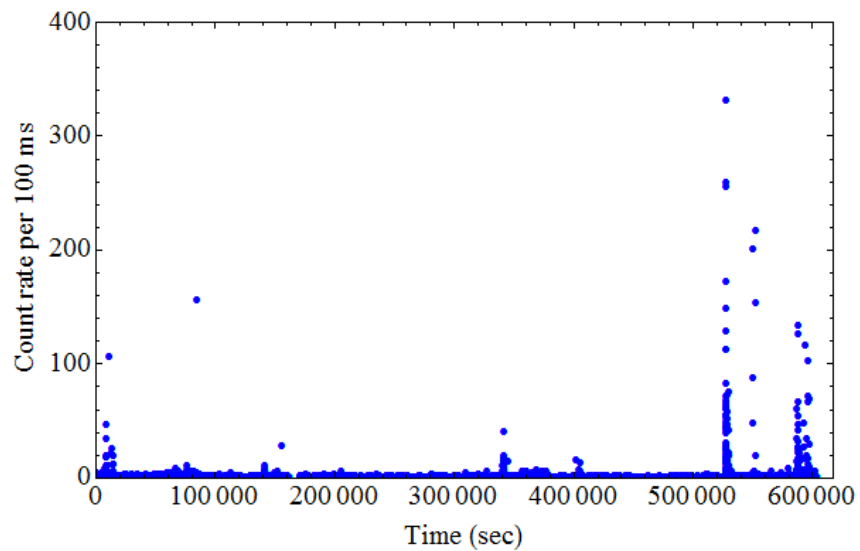
- Energy spectroscopy
  - No high energy signal was previously observed
  - Only used low energy amplification
  - Plotted with GENIE2000
- Count rate
  - SCA fed into LabVIEW™ counter



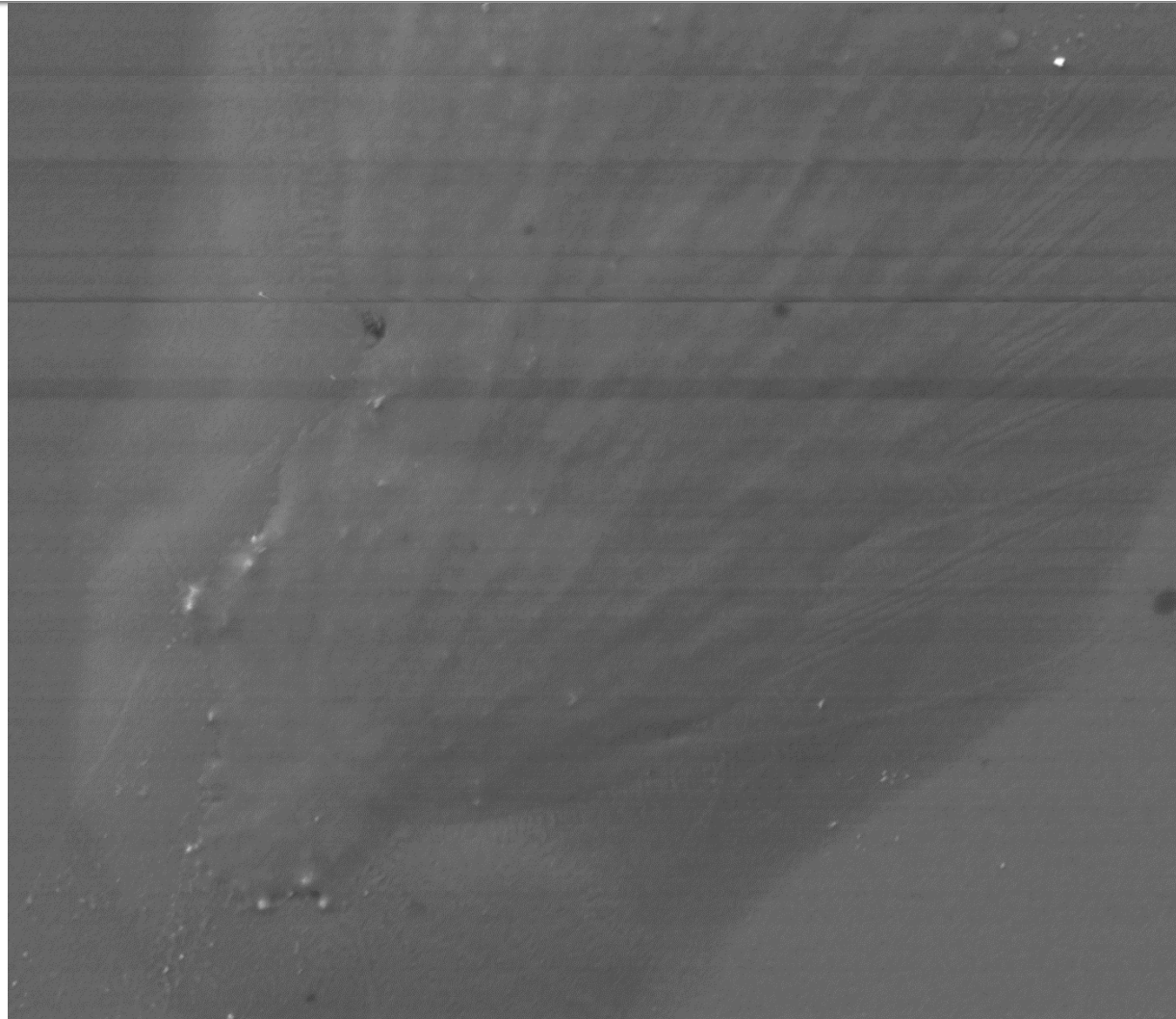
# Results – Sensor 2, Load 1



# Results – Sensor 2, Load 2



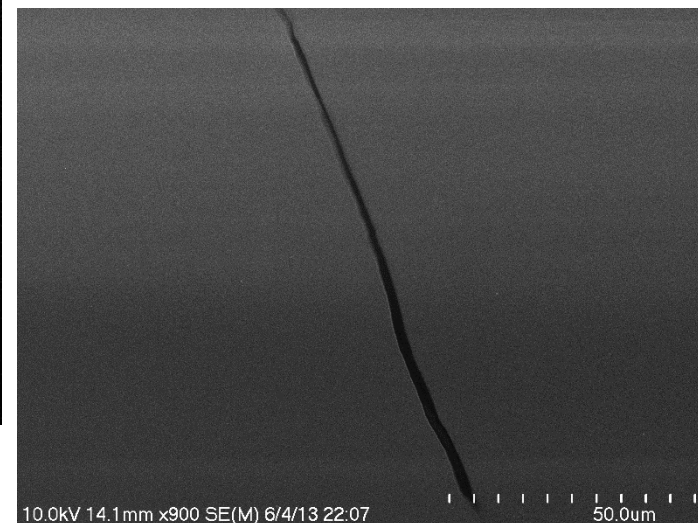
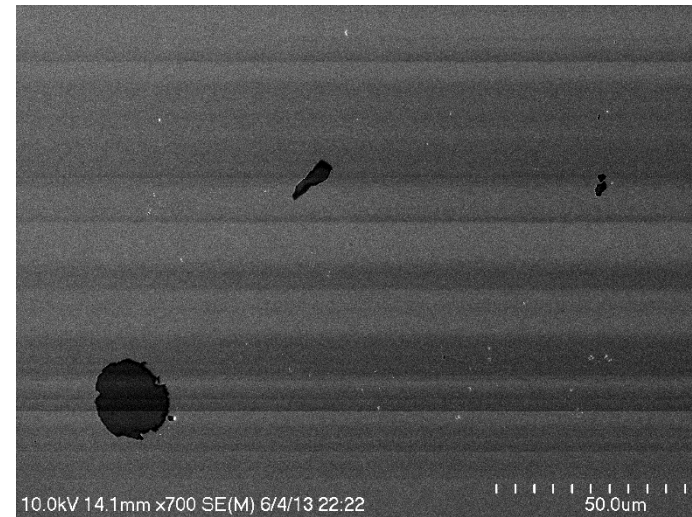
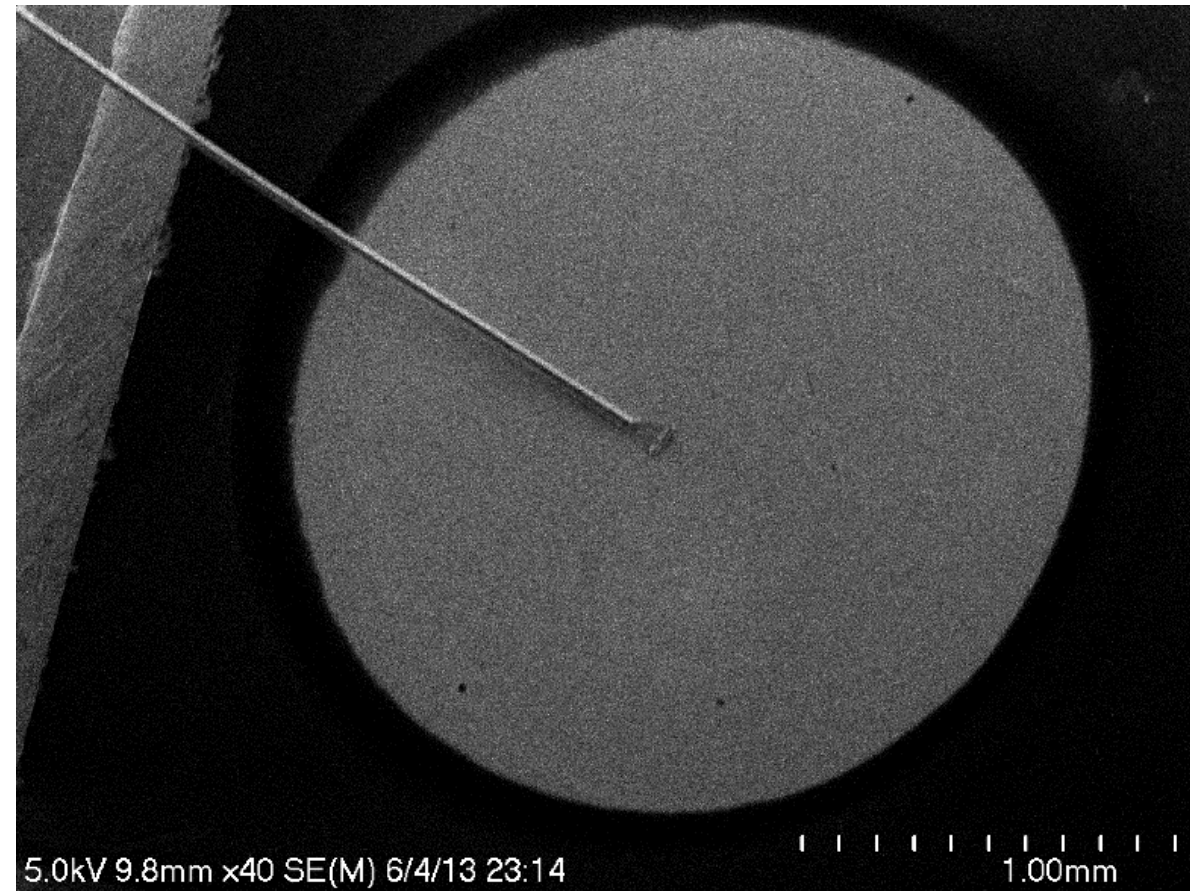
# Results – Sensor 2, Load 2



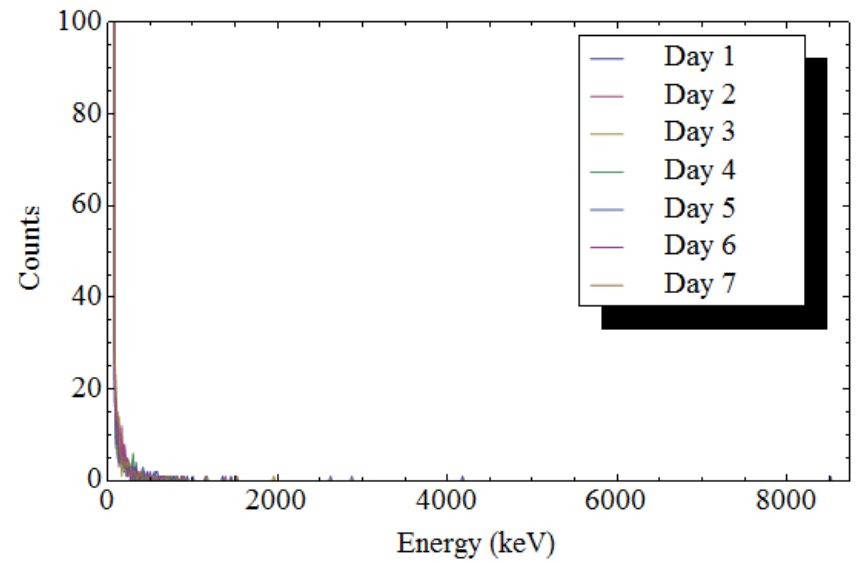
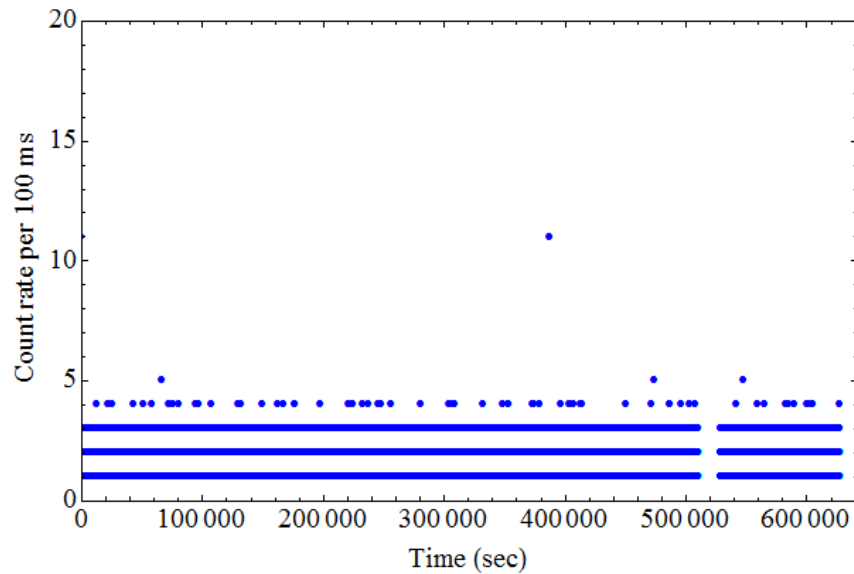
mag	HV	WD	mode	det	5/3/2013	10 μm
4 589 x	10.00 kV	9.9 mm	SE	ETD	1:11:26 PM	BSE#3



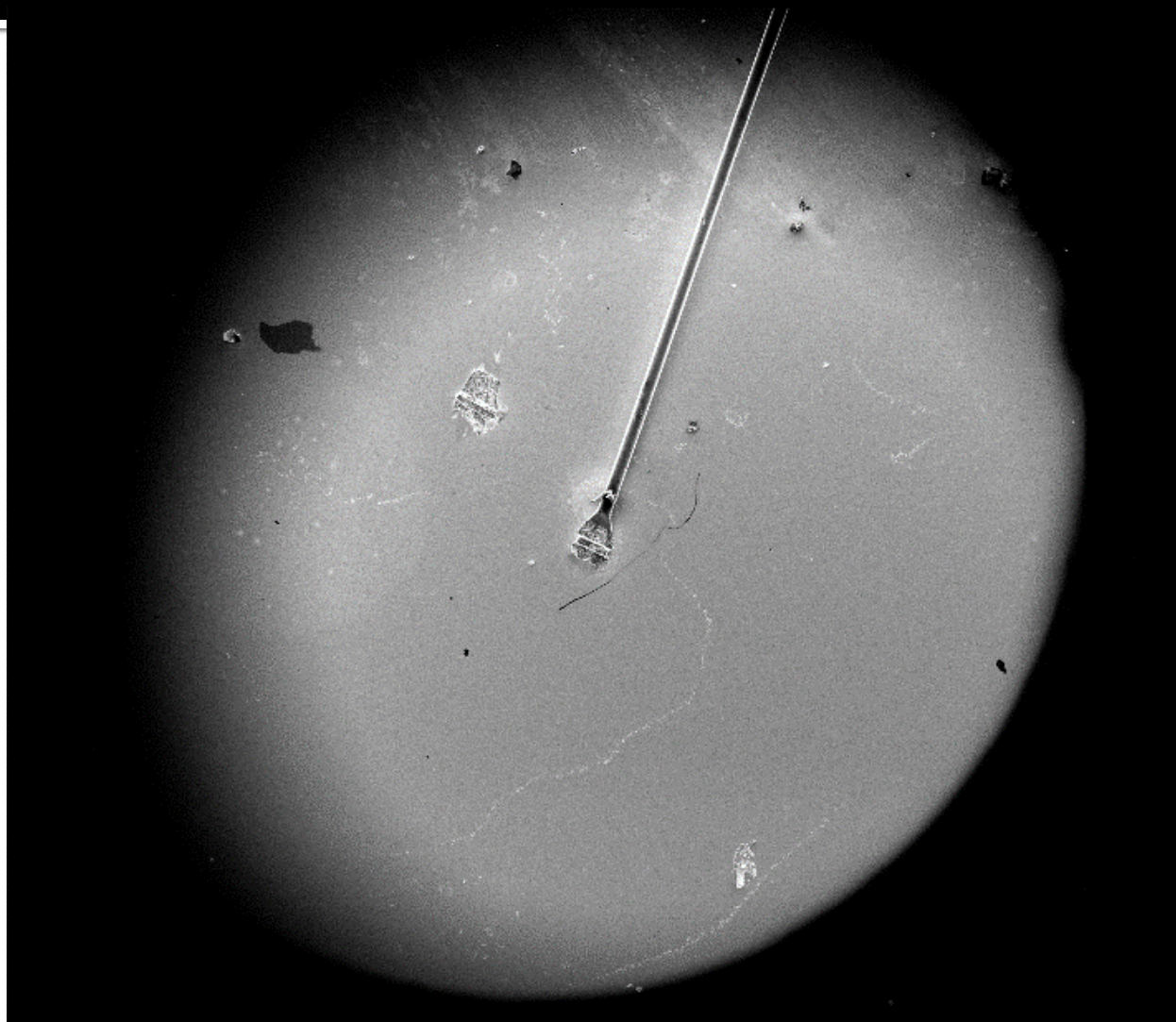
# Results – Sensor 3, Load 1



# Results – Sensor 3, Load 1



# Results – Sensor 3, Load 1



mag	#	HV	WD	mode	det	6/17/2013
61	x	10.00	kV 8.8	mm SE	ETD	10:06:14 AM

500  $\mu$ m

# Conclusions

- Counts only indicate that charge is being produced
  - Response is inconsistent with monoenergetic particles
  - Not yet reproducible
  - Current results inconsistent with ICCF 17 results
- Possible causes
  - Small-scale delamination of films due to gas loading
  - Interactions between films
  - LENR events
- We have a fast and consistent fabrication method to produce robust sensors
- So what do we need to do in the future?

# Future Work

- Even more trials
  - Consistent production method on a faster turnaround than initial diamonds
  - Improve chances of reproducibility
- Make additional control measurements
  - Number of controls so far is small; results are inconsistent.
- Prepare two sensors simultaneously
  - Expose one to inactive gases (H,He)
  - Expose other to deuterium
  - Ideally both experiments are isolated and run simultaneously
  - Distance between ideal and actual is measured in cost

# Future Work

- Account for interactions at Ti-Pd interface
  - Separate Ti & Pd, swap with Au *or*
  - Determine lattice characteristics after loading
- Once we establish reproducibility conditions
  - Analyze all reaction and energy release mechanisms to correlate with measured spectra

# Acknowledgements

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- Dr. Shubhra Gangopadhyay and Cherian Joseph Mathai
- Dr. Eric Lukosi

# Questions?

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