Non-Linearities in STJs and Their MCA Readout

or

How Good is Your Energy Calibration?

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Calibration accuracy of spectra is ultimately limited by:

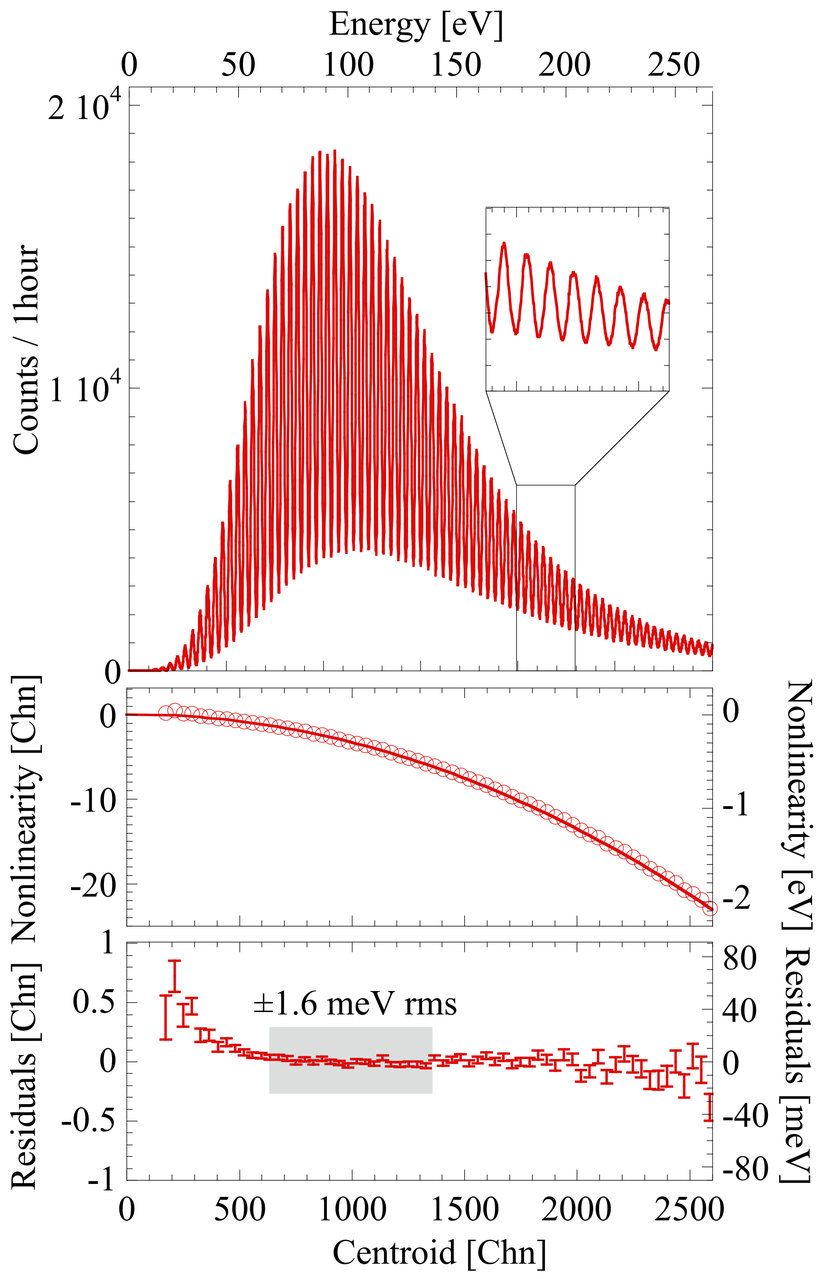
1) Accuracy of calibration energies
2) Predictability of detector response function
3) Linearity of MCA readout

Pulsed lasers are great for detector and MCA characterization:

1) Accurately measurable single photon energy
2) Large number of peaks corresponding to n-photon absorption
3) Exactly equidistant peak energies
4) Negligible linewidth
5) Tunable laser intensity to change energy range

STJ Calibration with Pulsed Nd:YVO4 laser:

1) Single photon energy 3.49865 ± 0.00015 eV
2) 5000 counts/s



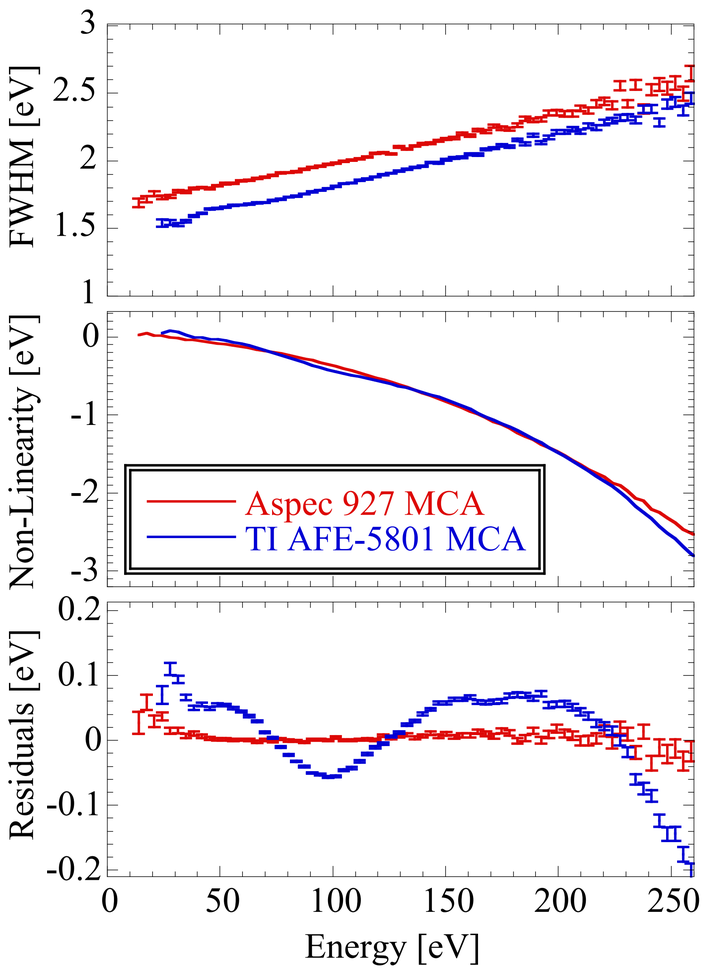
Results:

1) Statistical Error <1 meV in 1 hour (*top*)
   – STJ peak shape is Gaussian
2) STJ response exactly quadratic (*middle*)
   – MCA non-linear for first 600 channels
3) Calibration accuracy ~1 meV (*bottom*)
   – Limited by error of photon energy

Same STJ Detector, Preamp and Signals, Different Shaper and MCA:

Ta-Al-AlOx-Al-Ta STJ from STAR Cryo, custom XIA / LLNL preamp

1) Analog Ortec 627 shaper, Ortec Aspec 927 MCA (red)
2) Texas Instruments AFE5801 digitizer, trapezoidal filtering (blue)



Results:

1) TI digitizer has lower noise (*top*)
   – Shaper input noise can contribute
2) Similar non-linearity (*middle*)
   – Quadratic term dominated by STJ
3) Ortec MCA is more linear (*bottom*)
   – Sliding scale linearization matters
   – MCA non-linearity changes slowly
   – High gain reduces effect of MCA

Conclusions:

1) Pulsed lasers enable calibration accuracy of ~1 meV
   – 1 part in 10^5 for energies up to several 100 eV
2) Higher-order non-linearities can be corrected
   – *If* the detector response is exactly quadratic

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