Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

EPI-Lo Technology Development

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Outline

- EPI-Lo Technology Developments to TRL6
- Performance requirements and derivation
- Energy System Development
  - Fidelity of Test Article
  - Test and Analysis Results
- Sensor / Timing System Development
  - Fidelity of Test Article
  - Test and Analysis Results
- TOF-D/CFD-D ASIC Development
  - Fidelity of Test Article
  - Test and Analysis Results
- Transition to Flight

EPI-Lo Technology Developments to TRL6

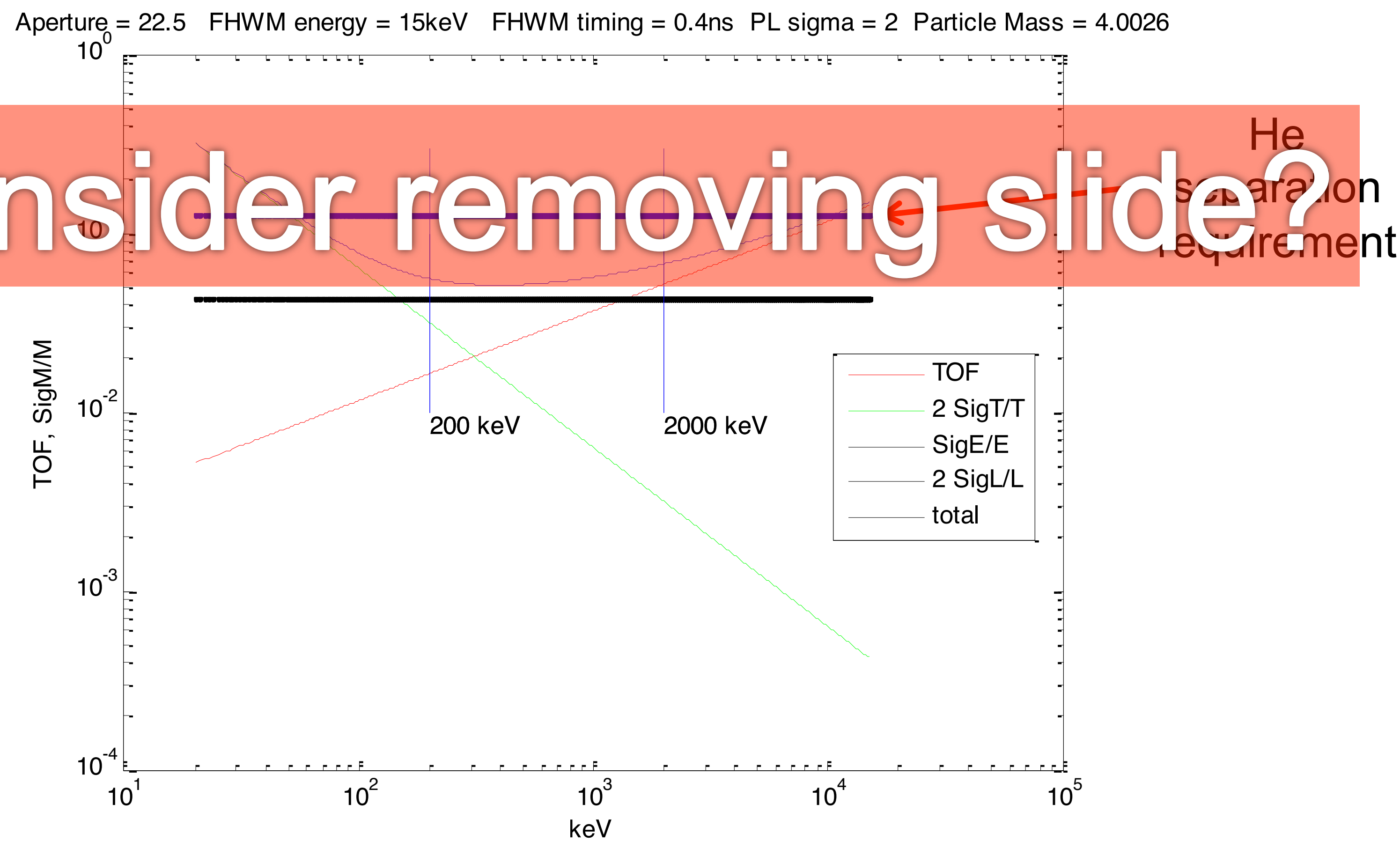
- Species composition driven by two systems, energy system and timing system
- Energy and TOF performance to meet 3He / 4He separation
  - Validate one anode covering two quadrants has adequate timing performance
  - Validate SSD has adequate energy performance
  - **3He, 4He: 0.5 FWHM AMU for incoming energies between ≤0.2 MeV and ≥2.0MeV**
- TOF-D and CFD-D ASIC development

EPI-Lo Performance Modeling

- Two independent models used
  - Monte-Carlo
    - Inputs are timing noise, SSD noise, and path length variation
    - Inputs can by any distribution (not limited to Gaussian)
  - Analytical
    - Inputs are timing noise, SSD noise, and path length variation
    - All inputs are Gaussian
  - The two models have been compared and shown to give identical results
  - Does not include foil losses (not significant for 200keV He)
- **Modeling shows 400pS FWHM, 15keV FWHM performance comfortably meets requirements**

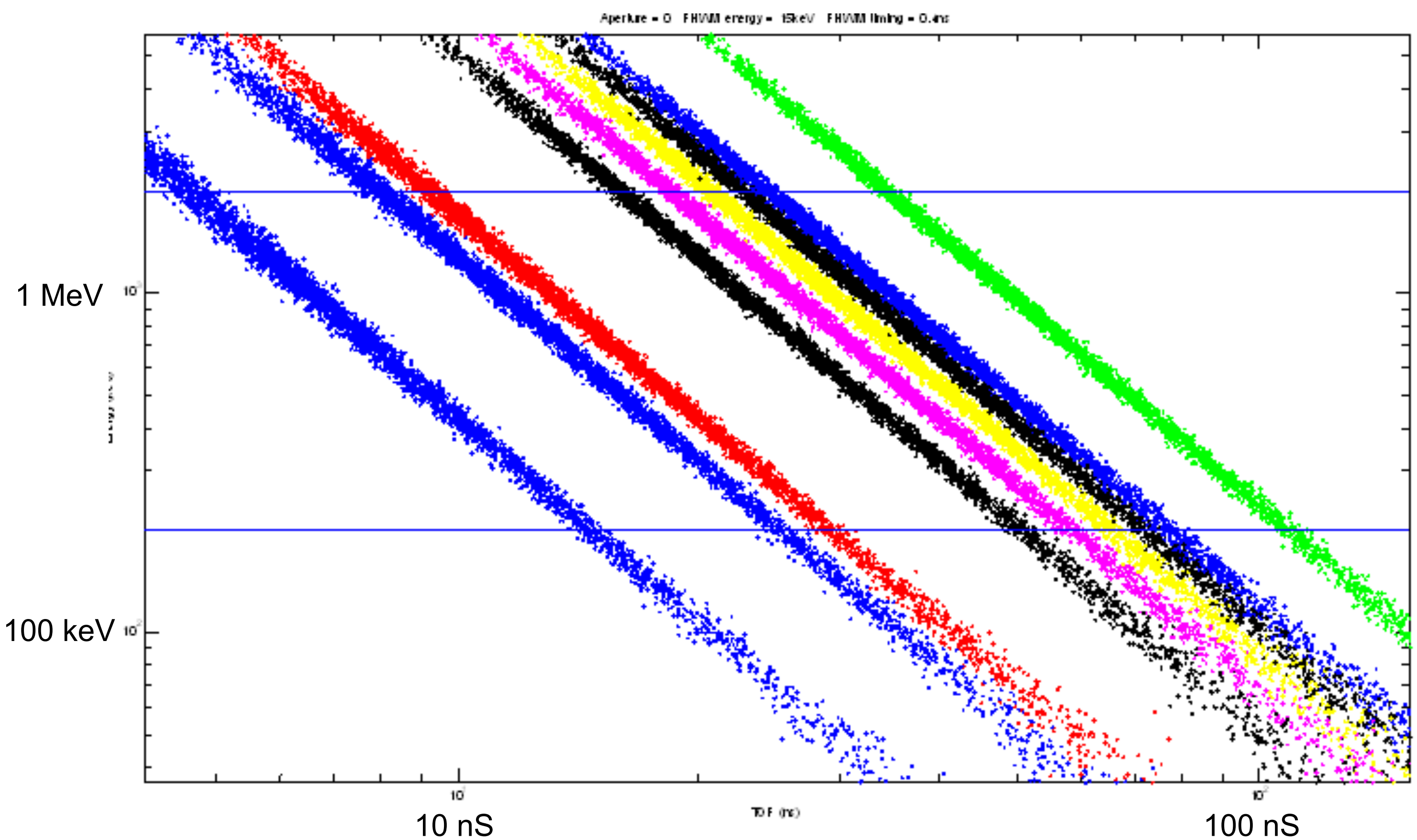
22.5 degree aperture

- Mass is calculated by $m = 2E\left(\frac{\tau}{L}\right)^2$
- Therefore uncertainty is mass measurement is $\left(\frac{\sigma_m}{m}\right)^2 = \left(\frac{\sigma_E}{E}\right)^2 + \left(2\frac{\sigma_\tau}{\tau}\right)^2 + \left(2\frac{\sigma_L}{L}\right)^2$



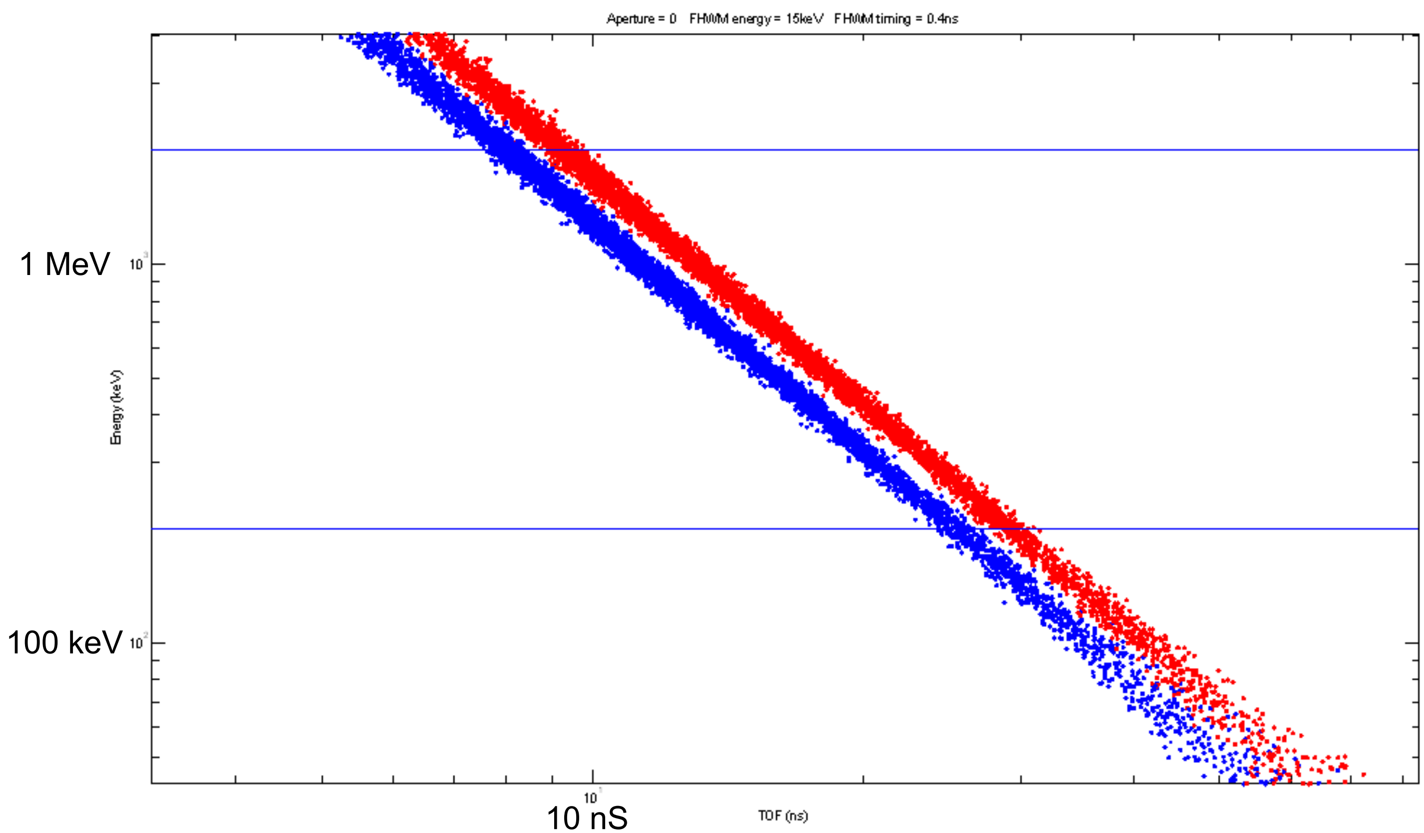
Track Simulations

- Monte-carlo model for all species with 400pS FWHM timing and 15keV FWHM energy resolutions



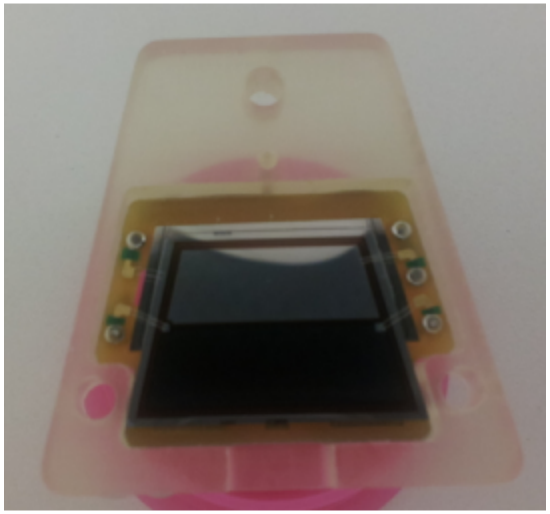
He3/He4 separation

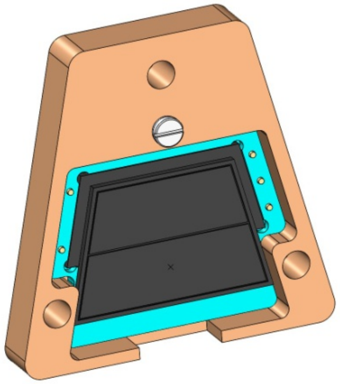
- Monte-carlo model shows separation of He3/He4 over 200 keV to 2 MeV with 400nS FWHM timing and 15keV FWHM energy resolutions

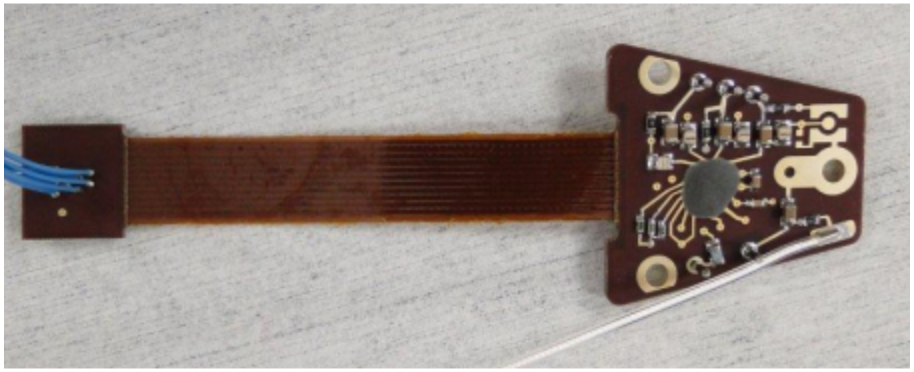


Energy System Development

- Solid State Detector is fabricated and mounted to carrier board
- Energy board is fabricated and populated
- All components nearly identical to flight – no design changes expected



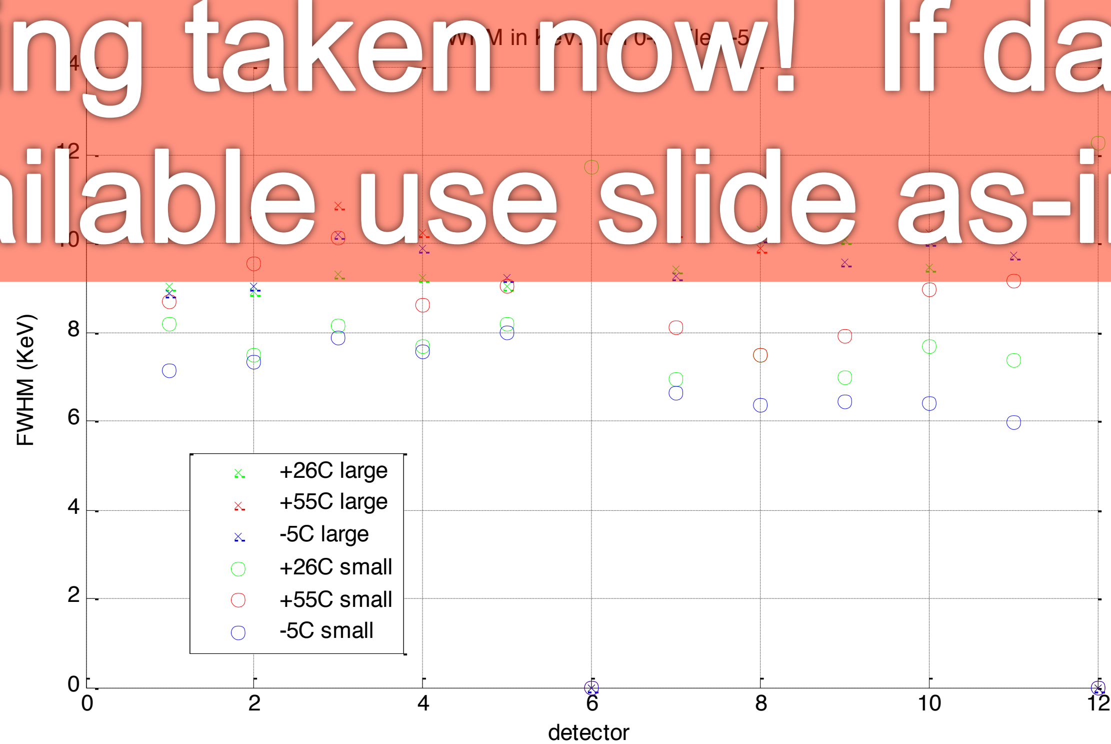




RBSPICE DATA with 60keV X-ray source FWHM in keV

- SSD performance base-lined on RBSPICE instrument tested with 60keV Xray
- Performance is ~11keV FWHM

Data being taken now! If data no
Available use slide as-in



Timing performance: Timing Budget

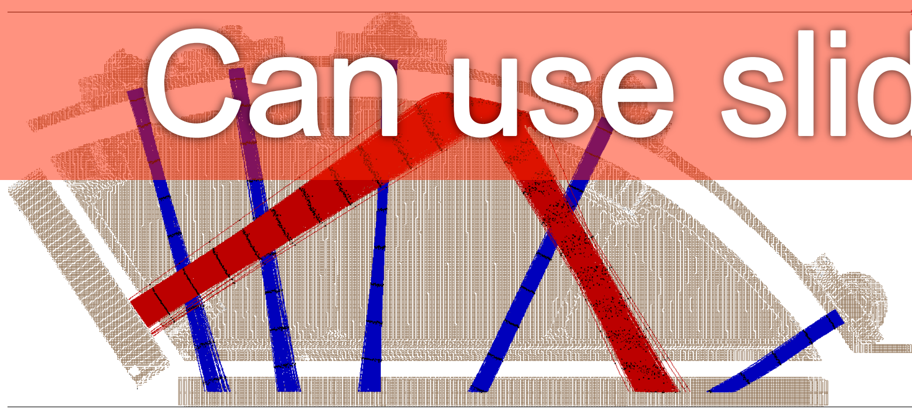
- Electron Dispersion: 200pS
- TOF-D ASIC: 200pS
- CFD-D: 200pS
- Total: 350pS (requirement is 400pS)

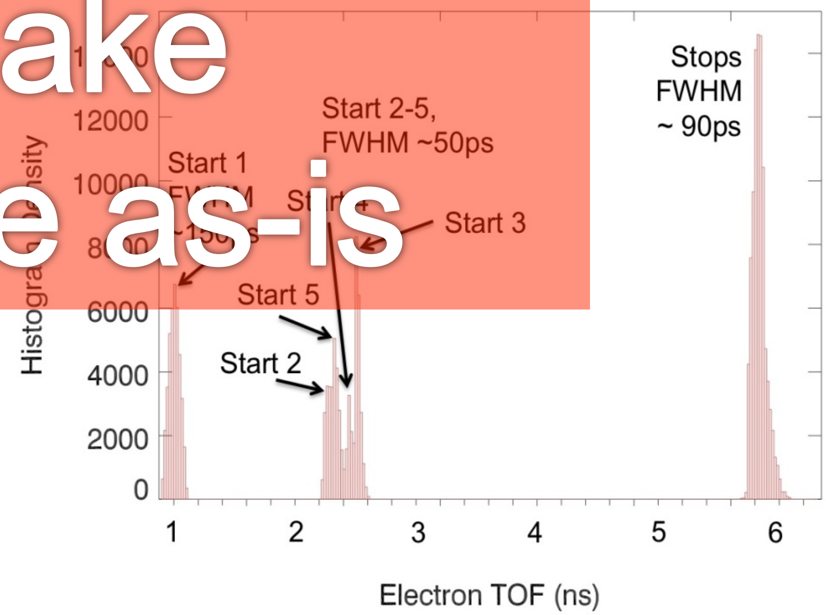
Timing budget – secondary electron dispersion simulatoins

- 250 ps Time Markers
- Electron dispersion is less than 200pS

Updates expected from Joe Westlake

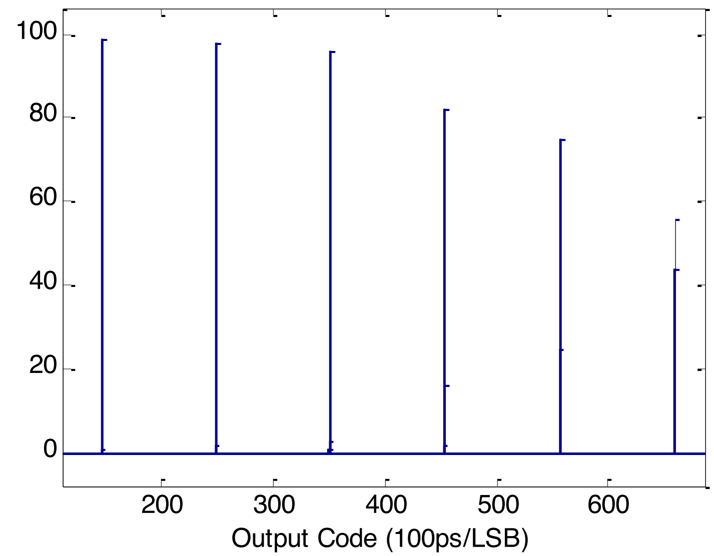
Can use slide as-is

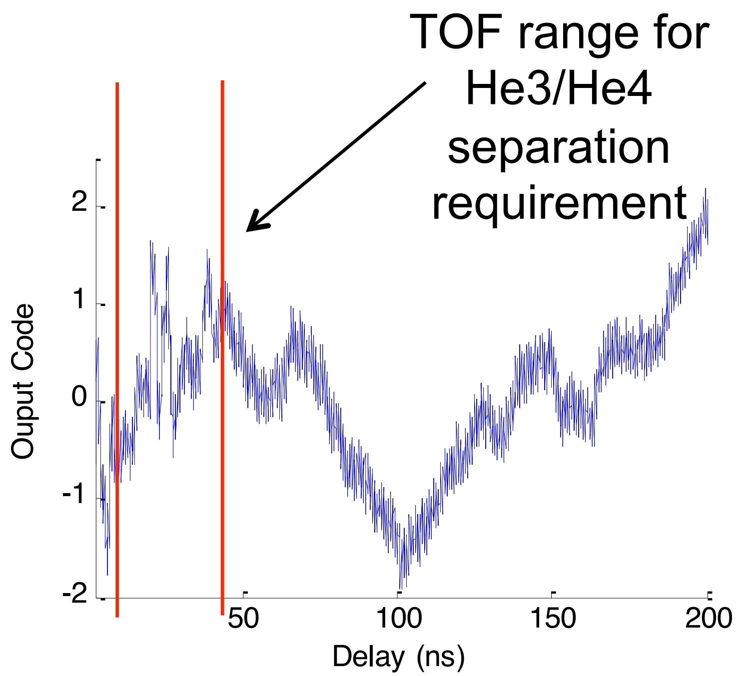


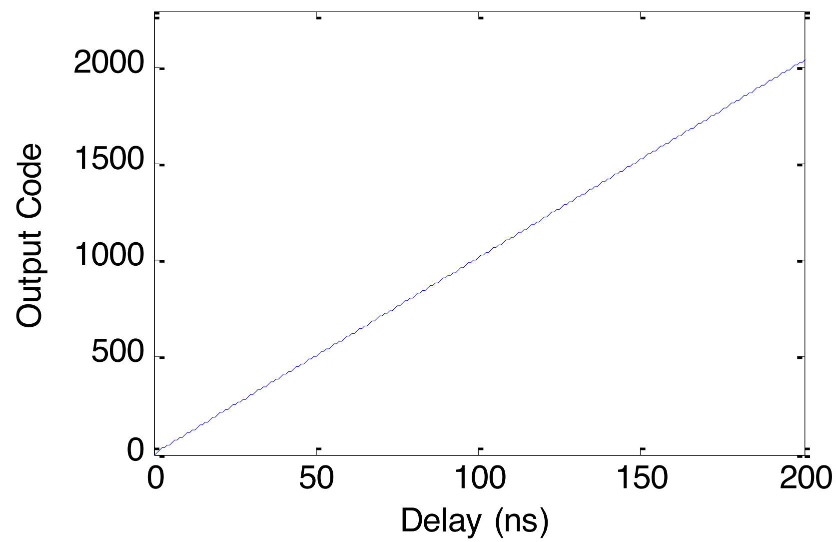


TOF-D Test Results

- TOF-D performance meets requirement
- INL variations compensated for with look-up-tables
  - Same LUTs used to normalize path length for different apertures
- Jitter is less than 1 LSB FWHM

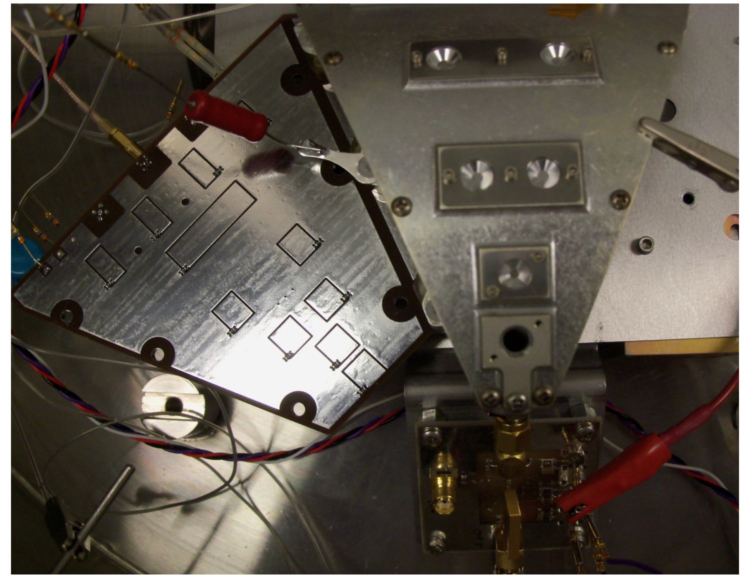


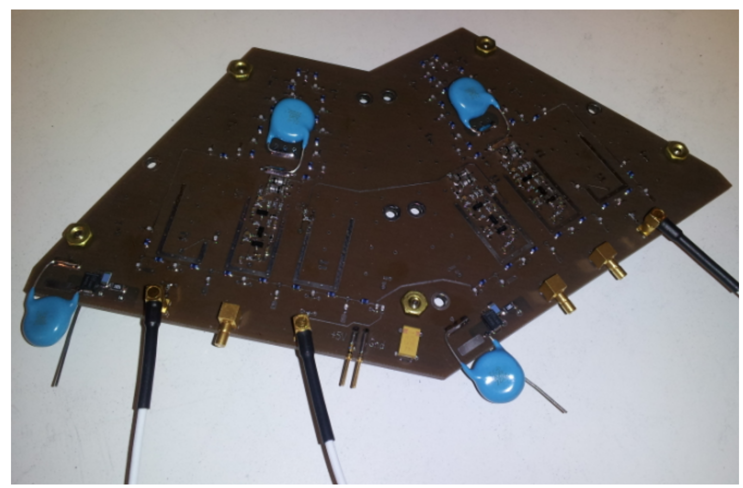




Prototype Quadrant Sensor Testing

- Timing performance testing completed on prototype sensor
- End-to-end test includes variations due to electron dispersion, anode board performance, and CFD-D V0 performance
  - Does not include TOF-D ASIC
- Prototype anode board is close to flight configuration
  - HV isolation in imbedded capacitance
  - Start delay line covers two sensors
  - Does not mechanically fit flight design
- Prototype sensor is similar to flight sensor – key sensor geometries are the same





Prototype Quadrant Sensor Testing

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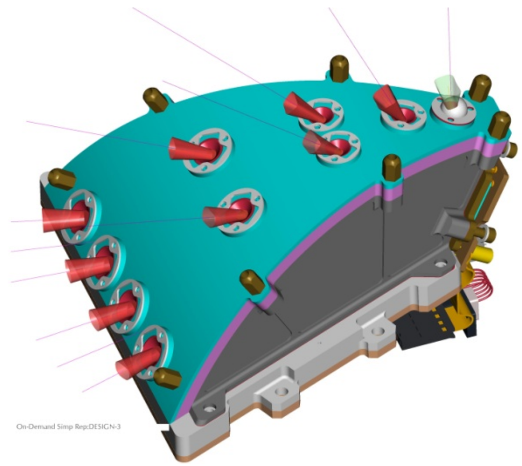
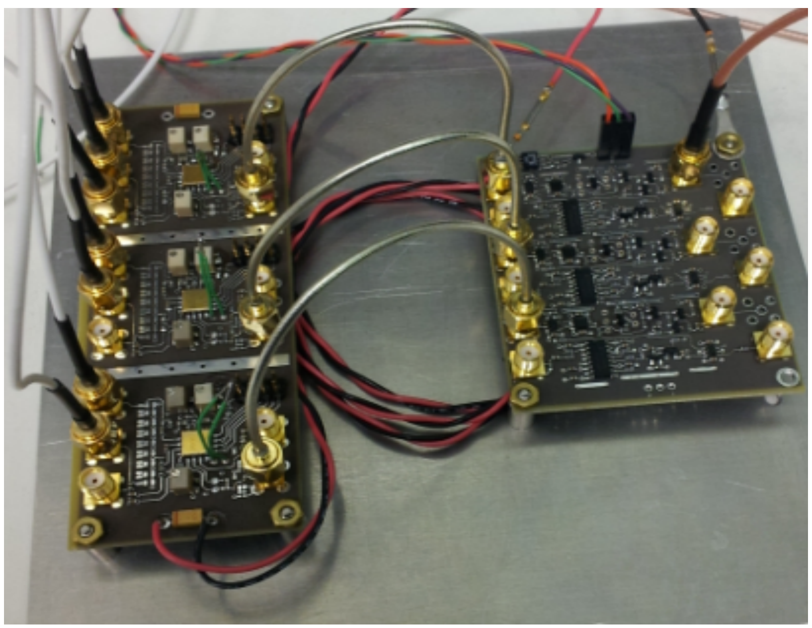
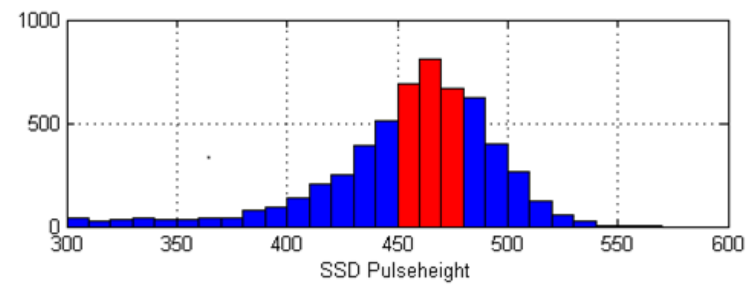
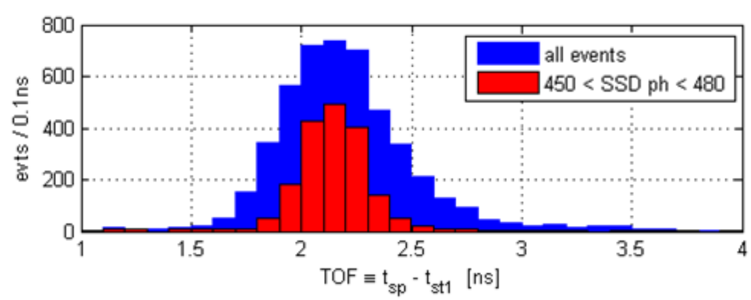
- Initial results show about 300pS FWHM timing performance (CFD-D and Electron optics contributions), which meets our requirements. The next version of the CFD-D has lower jitter at low thresholds and reduced walk, which we expect will improve performance.



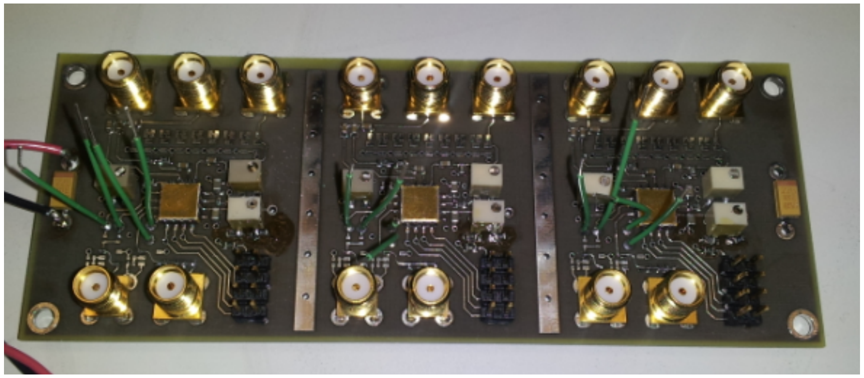


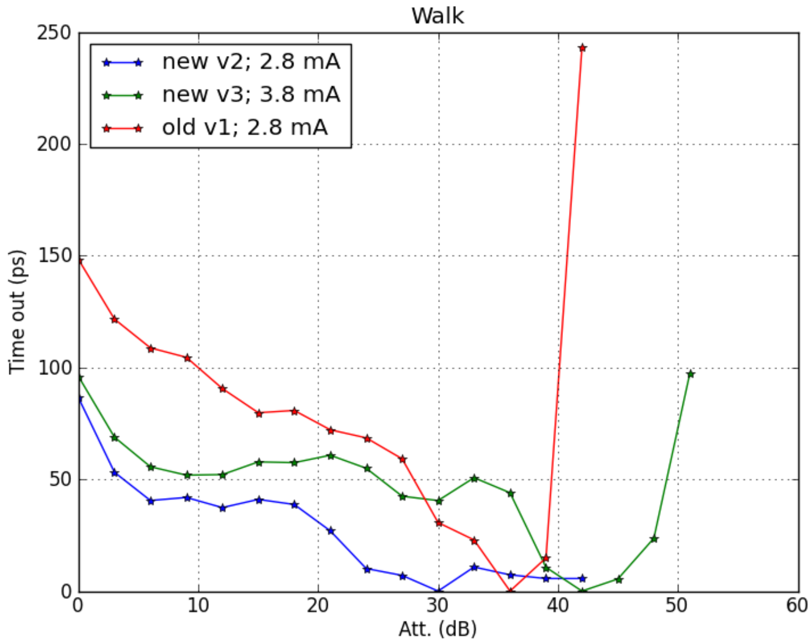


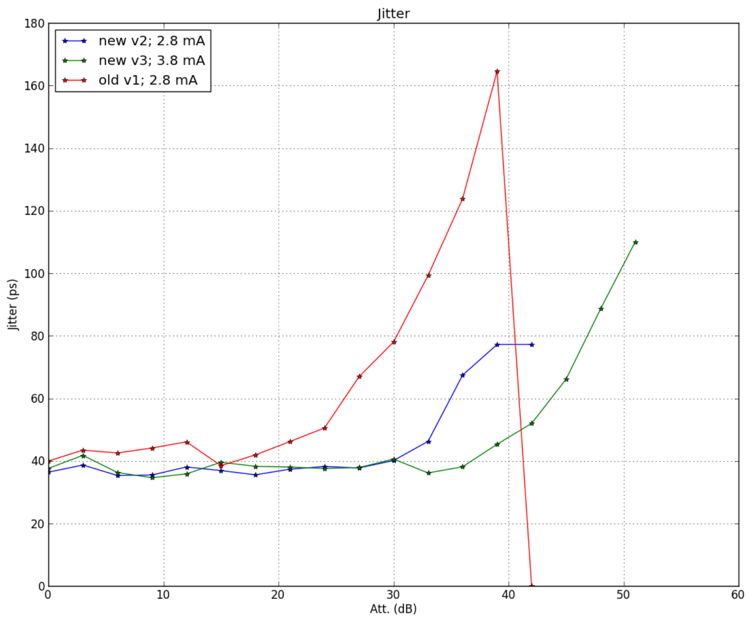


CFD-D test results

- CFD-D extensively tested
- Tests performed using CFD-D test board
- CFD-D V3 has improved performance

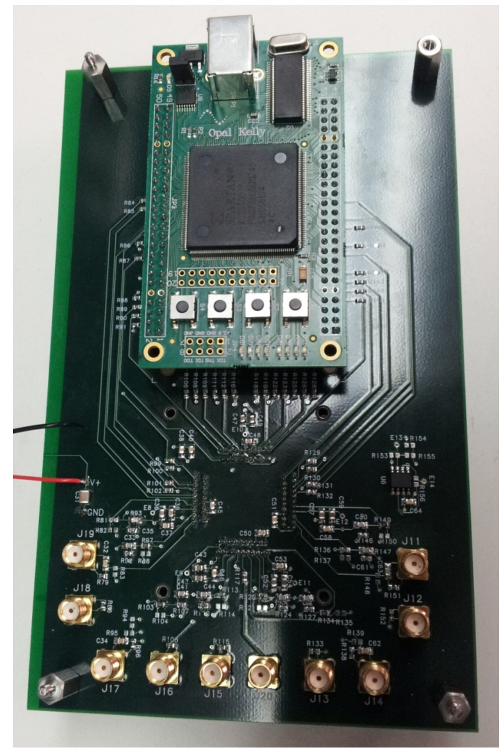






Technical Development: ASIC Progress

- First version of TOF-D chip fabricated and tested
  - Temperature testing from -40°C TO 70°C
  - Supply tested from 3.0V to 3.6V
  - Functionality verified over 10ps to 2ns LSB
  - Successfully completed SEE testing at Texas A&M
  - Completed total dose testing
- Second version of TOF-D chip and first version of CFD-D chip fabricated and tested
- Flight Fabrication - Third version of TOF-D chip and second version of CFD-D chip fabricated and tested
  - Temperature testing from -40°C TO 70°C
  - Supply tested from 3.0V to 3.6V
  - TOF-D functionality verified over 10ps to 2ns LSB
- Working with vendor for final qualification of both ASICs



Transition to Flight

- TOF-D, CFD-D ASICs
  - Complete qualification with external test house
  - Complete radiation testing on flight parts (prototype parts passed all radiation testing)
- Sensor Development
  - Build and test EM sensor
  - Integrate sensor with SSD
- SSD
  - EM design complete
  - Finish testing EM SSD
  - Flight design will be identical

Notes

- These will be removed from the final presentation

- Talked to Don
  - We are officially moving ahead with 0.4nS FWHM, 15keV FWHM. All model simulations are based on these performance numbers
  - Helium not much affected at 200keV by foil losses
  - Something on efficiency??? Not sure why this made it into SwRI's spreadsheet for TRL6 activities, but I think Ken has results on this

EPI-Lo Wedge Development		
Test type	Test location	Notes
Efficiency Measurement of detector system	JHU/APL	Complete
Fabrication/testing of quadrant electronics	JHU/APL	Complete
Integration of dectector wedges to quadrant anode	JHU/APL	Complete
Demonstration of low TOF dispersion	JHU/APL	Complete
Performance demonstration of separation of 3He 4He	JHU/APL	Complete
		TRL6 achieved

EPI_Lo TOF ASIC Development		
Test type	Test location	Notes
Prototype ASIC		Complete
Fabrication and Test	JHU/APL	Complete
Temperature testing	JHU/APL	Complete
Supply Voltage variation test	JHU/APL	Complete
TOF functionality 10ps to 2 ns	JHU/APL	Complete
Radiation Testing	Texas A&M	Complete
Flight ASIC		Test of Flight ASICs for TRL6 success
Fabrication and Test	JHU/APL	
Temperature testing	JHU/APL	
Supply Voltage variation test	JHU/APL	
TOF functionality 10ps to 2 ns	JHU/APL	
Radiation Testing	Texas A&M	

EPI-Lo performance Model

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4.3 Mass resolution

Equation (1) showed how mass is calculated from the measured solid state detector signal, E, time of flight, τ, and particle path length, L:

$$m = 2E\left(\frac{\tau}{L}\right)^2$$

The uncertainty in the mass measurement is then given by:

$$\left(\frac{\sigma_m}{m}\right)^2 = \left(\frac{\sigma_E}{E}\right)^2 + \left(2\frac{\sigma_\tau}{\tau}\right)^2 + \left(2\frac{\sigma_L}{L}\right)^2$$

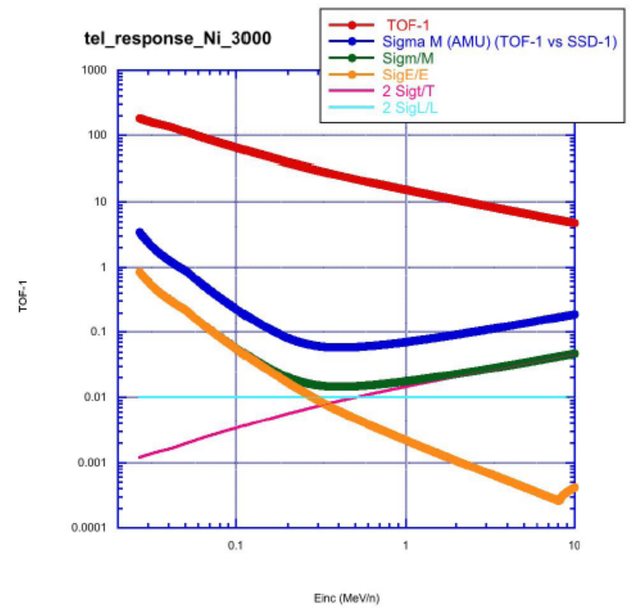
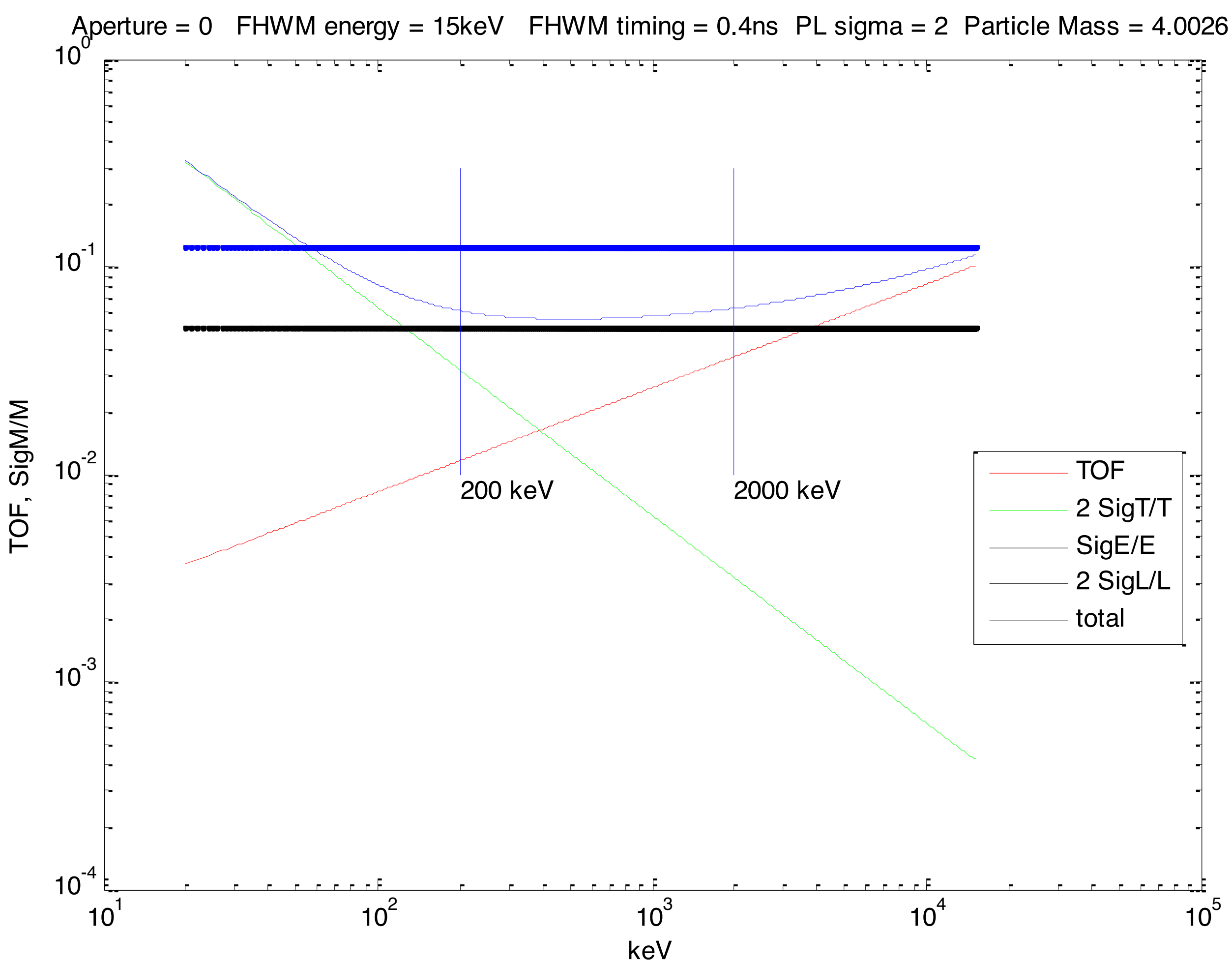
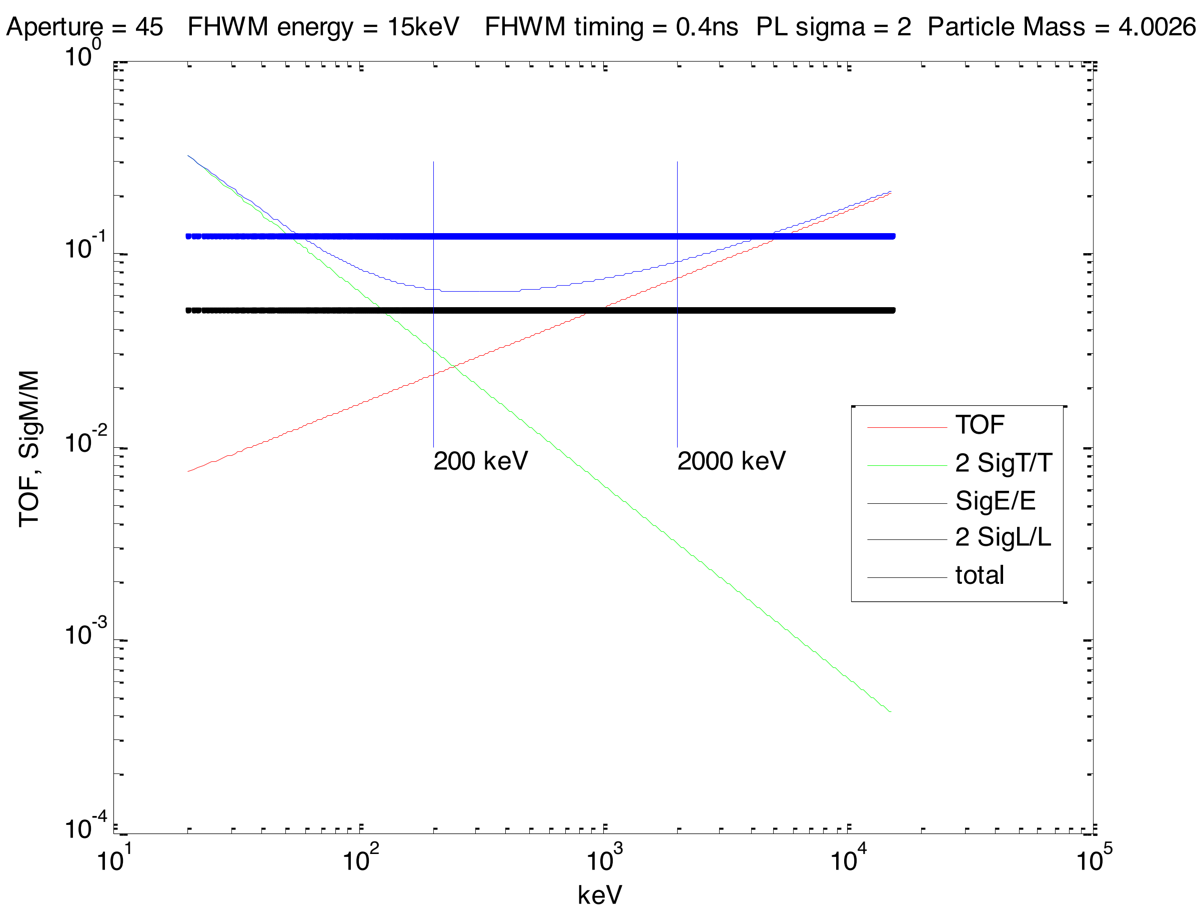


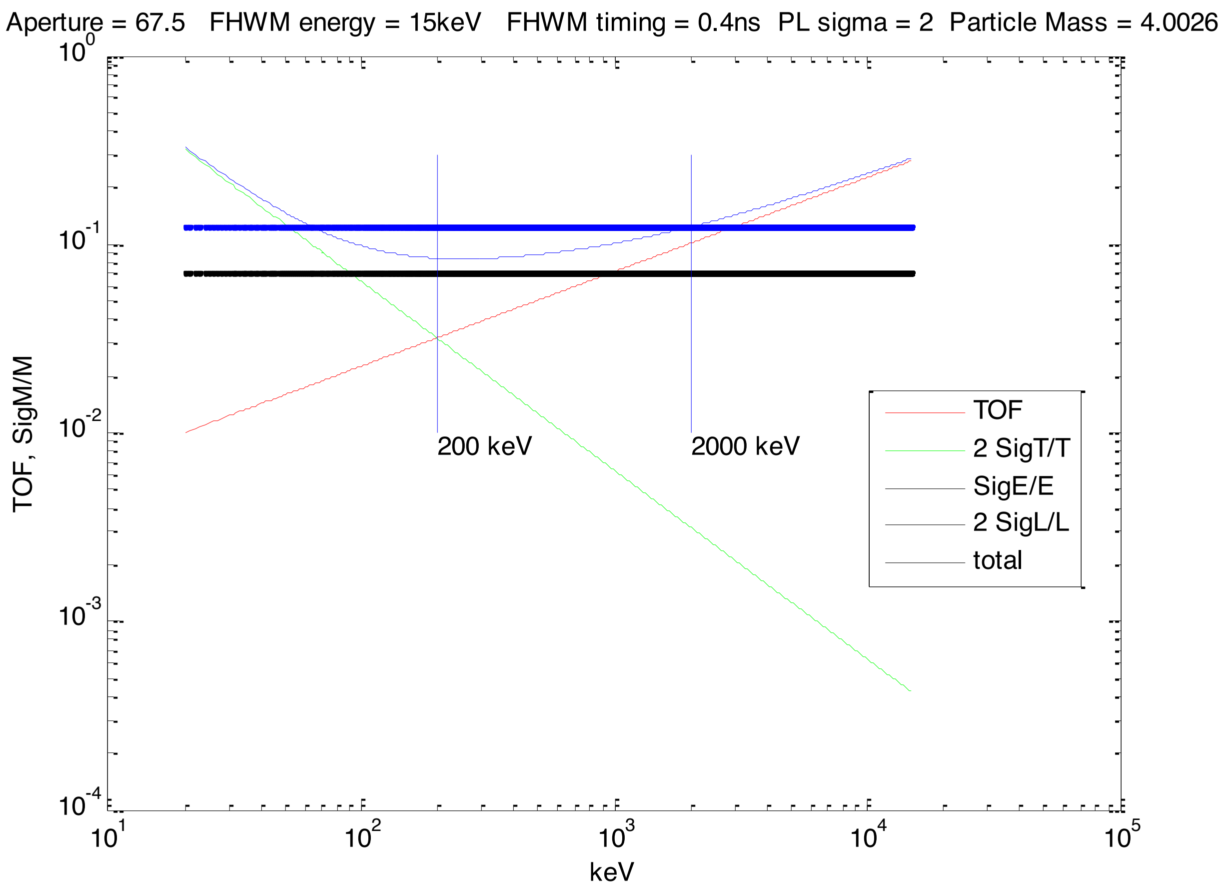
Figure 21 -- Mass resolution contributions for [4]He in SIS, assuming 20 keV FWHM SSD noise, and TOF dispersion $\sigma = 0.11$ ns. *(ref file: tel_response_He.qpc 7/24/2012)*



Aperture = 0   FHWM energy = 15keV   FHWM timing = 0.4ns   PL sigma = 2 Particle Mass = 4.0026
TOF, SigM/M
keV
200 keV
2000 keV
TOF
2 SigT/T
SigE/E
2 SigL/L
total



Aperture = 45   FHWM energy = 15keV   FHWM timing = 0.4ns   PL sigma = 2   Particle Mass = 4.0026
TOF, SigM/M
keV
200 keV
2000 keV
TOF
2 SigT/T
SigE/E
2 SigL/L
total



Aperture = 67.5 FHWM energy = 15keV FHWM timing = 0.4ns PL sigma = 2 Particle Mass = 4.0026
TOF, SigM/M
keV
200 keV
2000 keV
TOF
2 SigT/T
SigE/E
2 SigL/L
total