Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

EARLY DRAFT

Preliminary Design Review

05 – 06 NOV 2013

EPI-Lo Technology Development

Reid Gurnee

Outline

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

Update to matc
presentation

EPI-Lo Technology Developments to TRL6

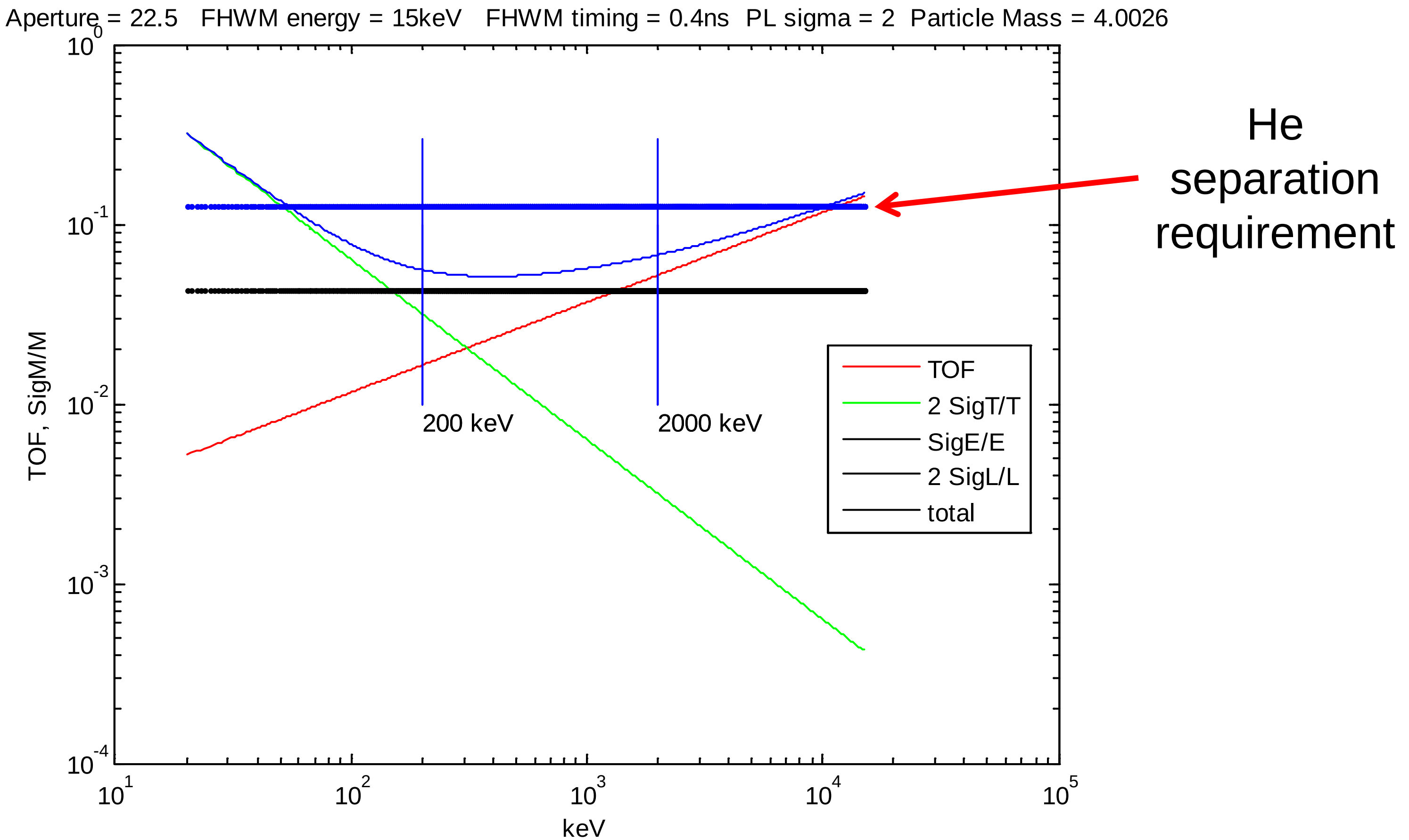
- Energy and TOF performance to meet 3He / 4He separation
  - Validate one anode covering two quadrants has adequate timing performance
  - Validate SSD has adequate energy performance
  - **3He, 4He: 0.5 FWHM AMU**
    for incoming energies between ≤0.2 MeV and ≥2.0MeV
- TOF and CFD ASIC development

EPI-Lo Performance Modeling

- Species composition driven by two systems, energy system and timing system
- 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 similar results
  - Does not include foil losses (not significant for 200keV He)
- **Modeling shows 400nS FWHM, 15keV FWHM performance comfortably meets requirements**

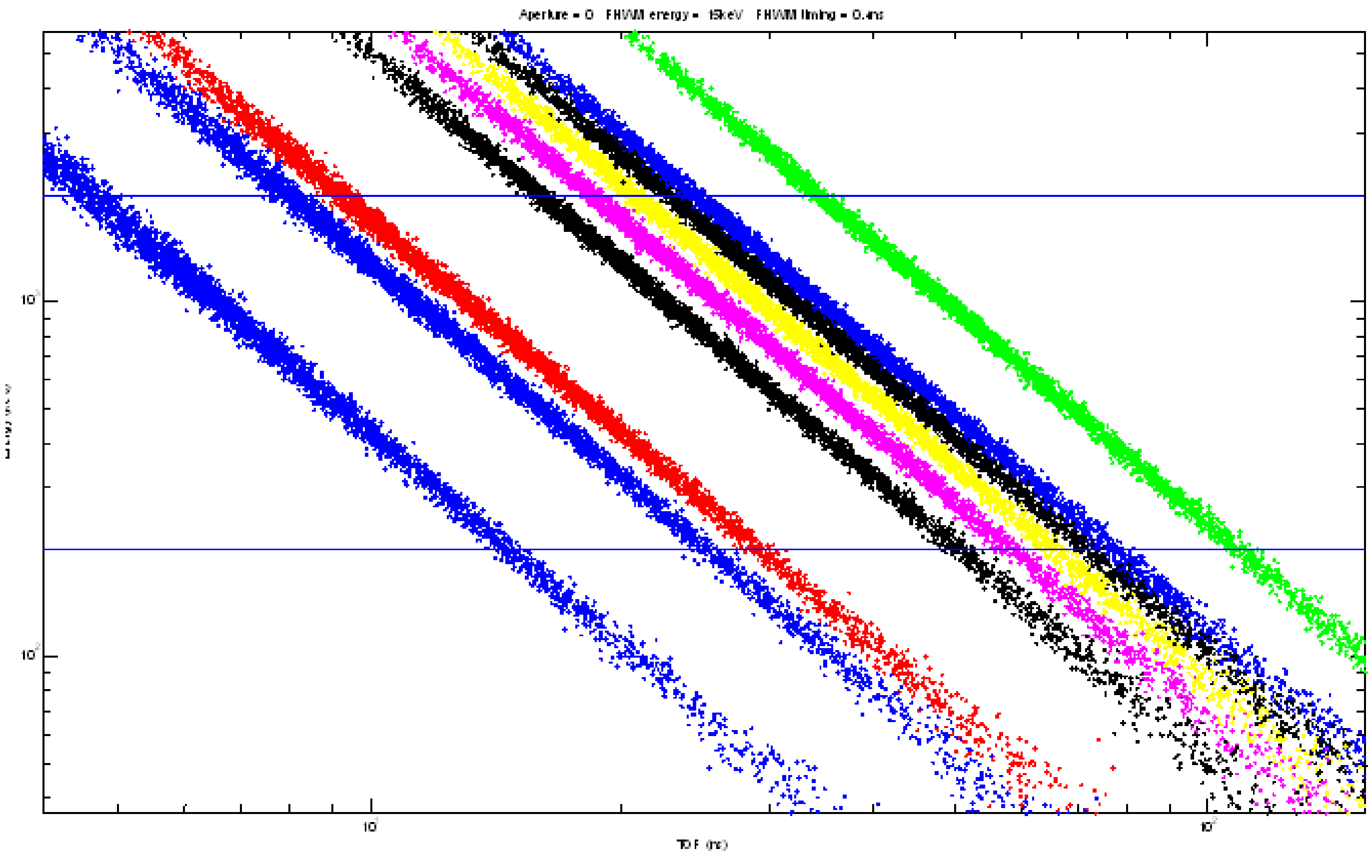
22.5 degree aperture

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



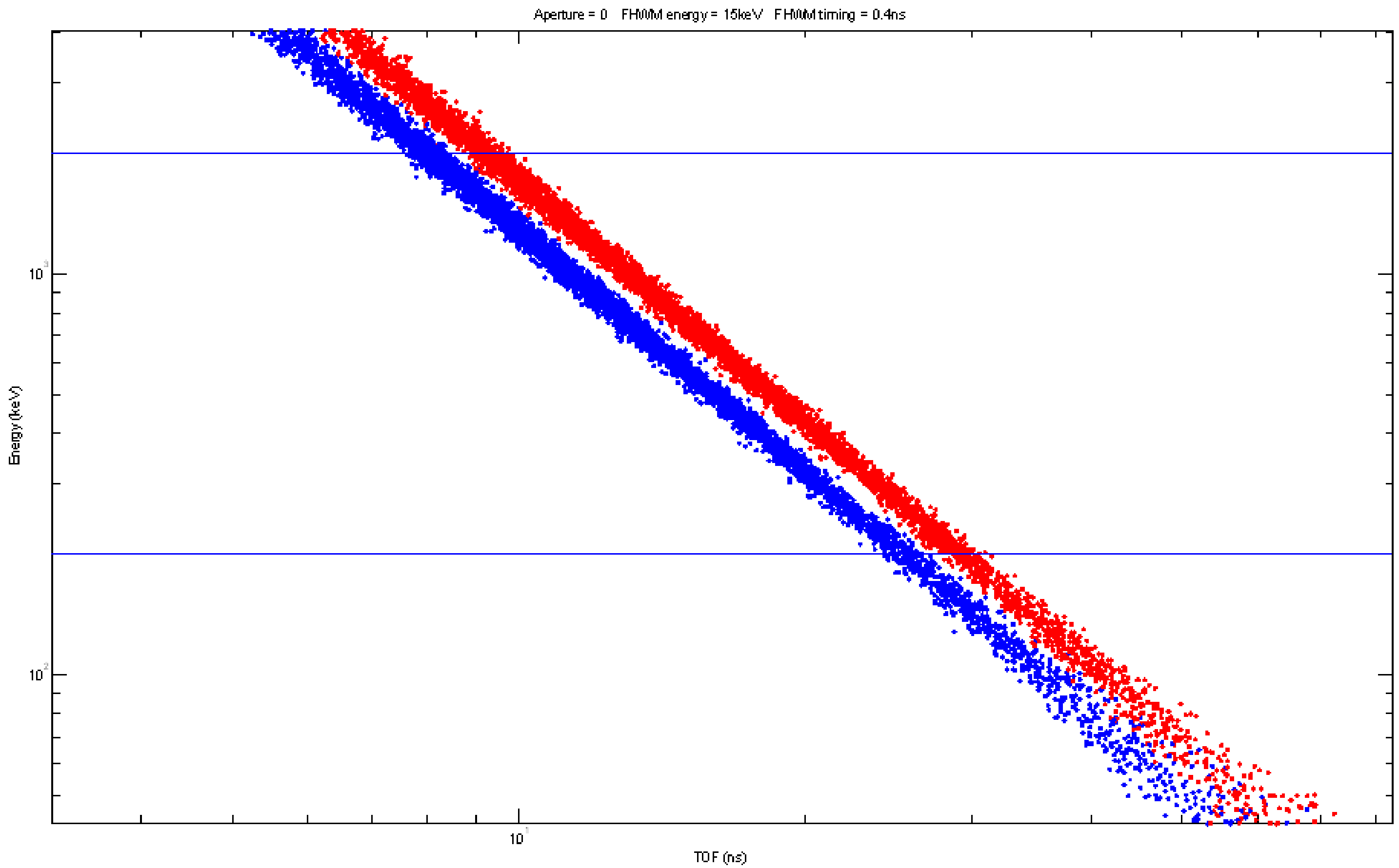
Track Simulations

- Monte-carlo model for all species



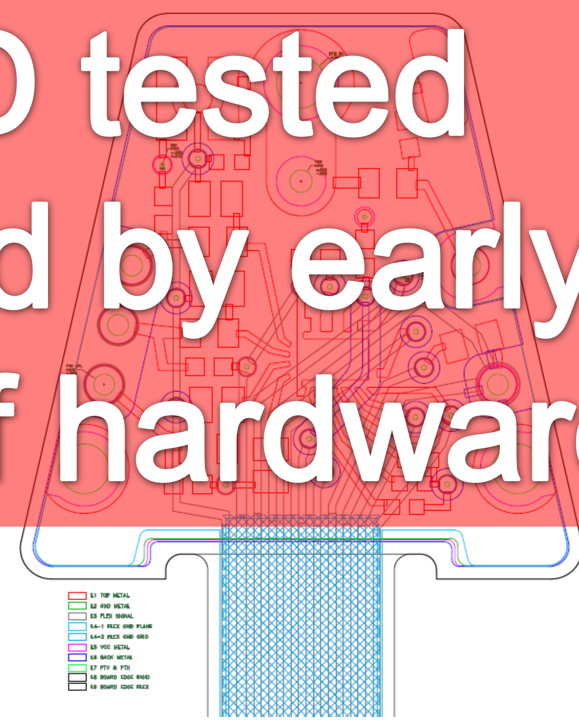
He3/He4 separation

- Monte-carlo model shows separation of He3/He4 over 200 keV to 2 MeV



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

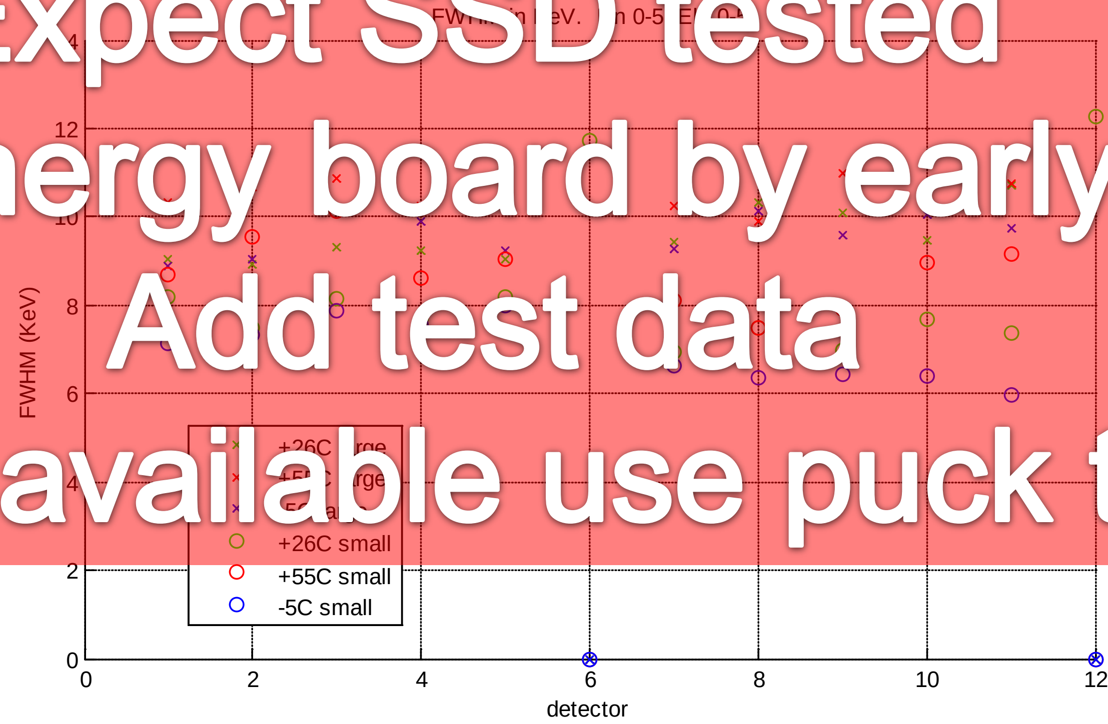


Expect SSD tested
with energy board by early Oc
Add photos of hardware

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

Expect SSD tested
with energy board by early Oct
Add test data
f data not available use puck test c



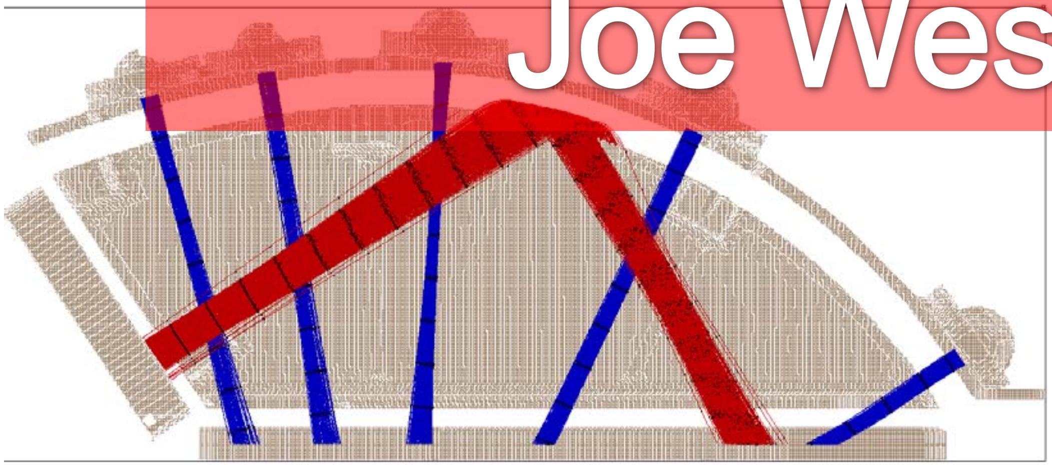
Timing performance: Timing Budget

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

Timing budget – secondary electron dispersion simulatoins

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

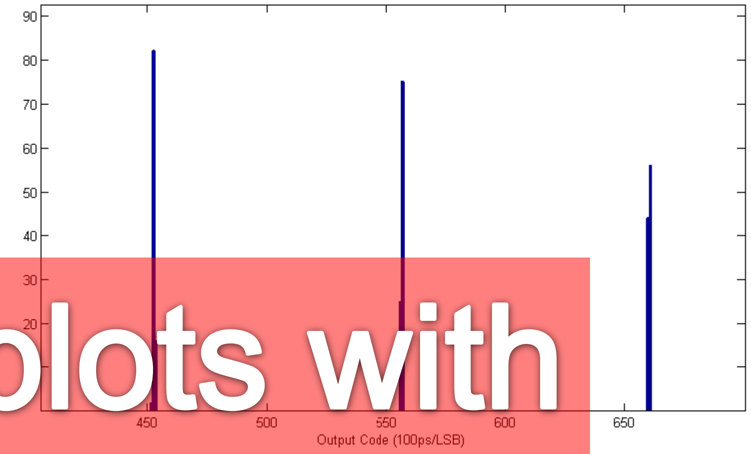
Updates expected from Joe Westlake

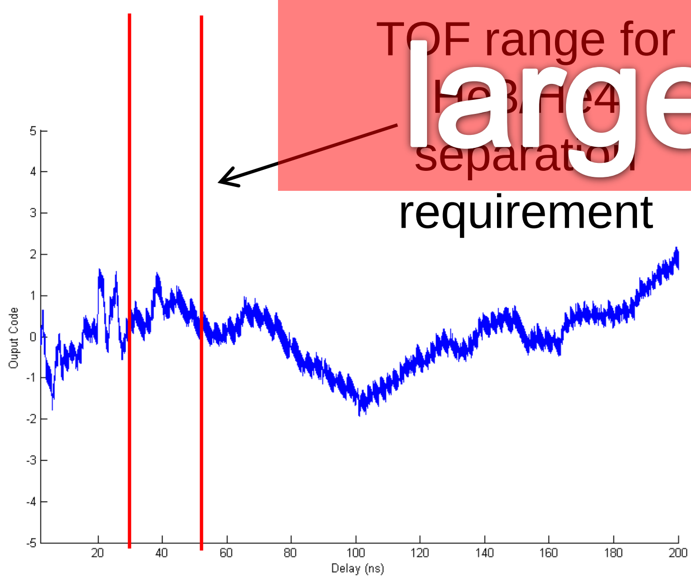


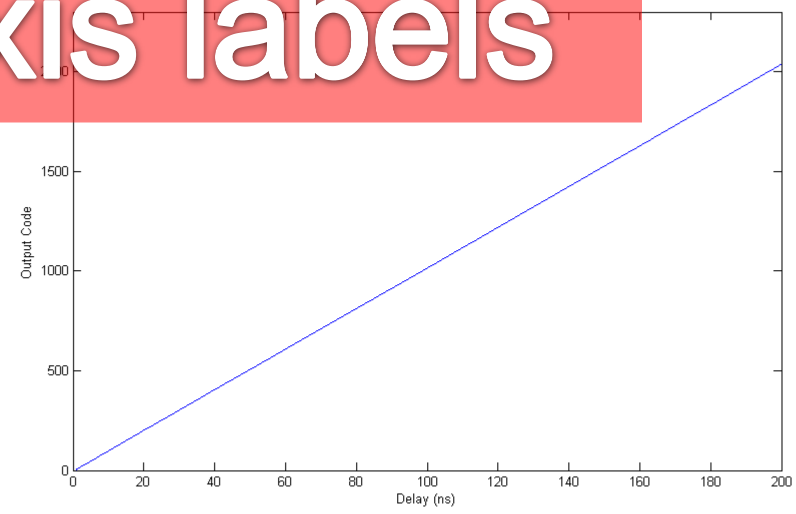
TOF-D Test Results

- 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

Generate plots with larger axis labels

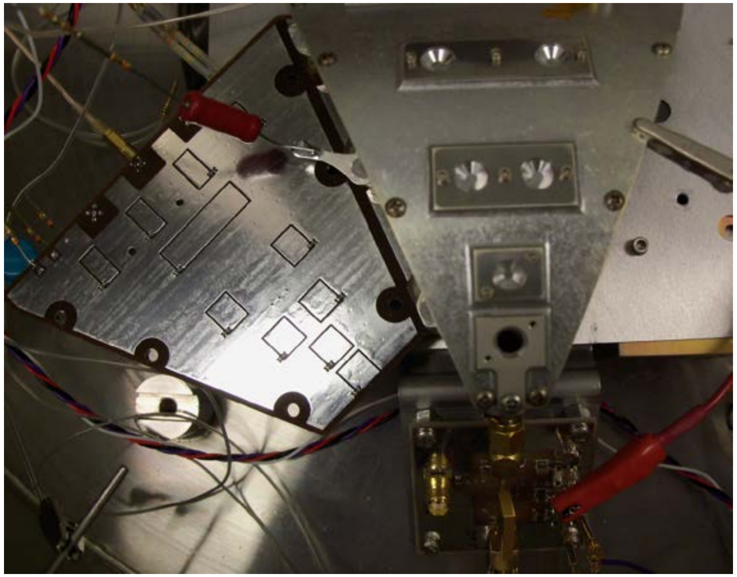


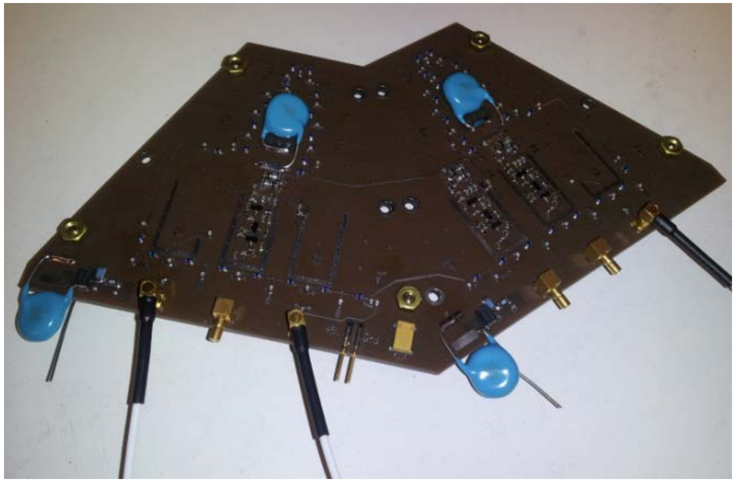




Prototype Quadrant Sensor Testing

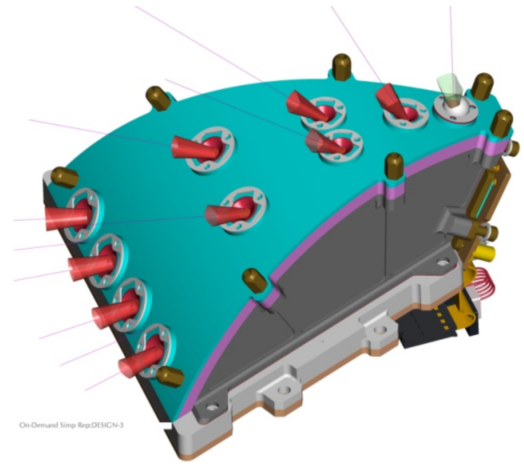
- Timing performance testing completed on prototype sensor
- End-to-end test includes variations due to electron dispersion, anode board performance, and CFDD V0 performance
  - Does not include TOFD ASIC
- Prototype anode board is close to flight configuration
  - HV isolation in imbedded capacitance
  - 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

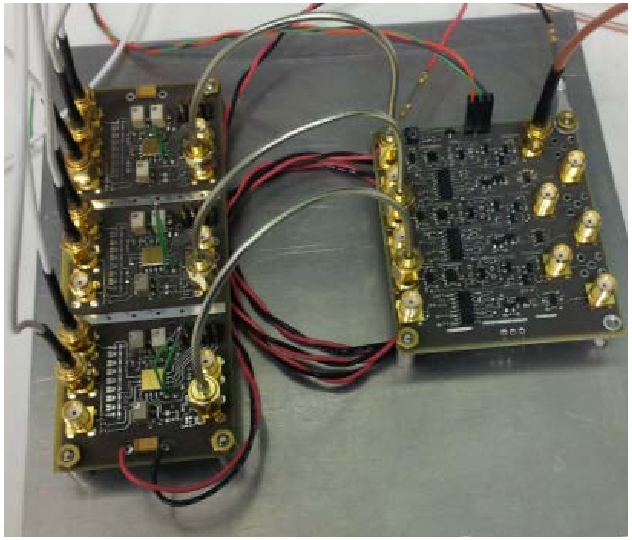


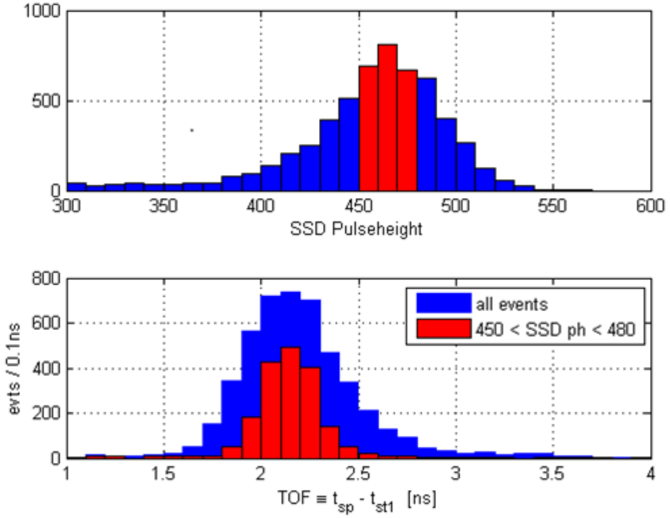


Prototype Quadrant Sensor Testing

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

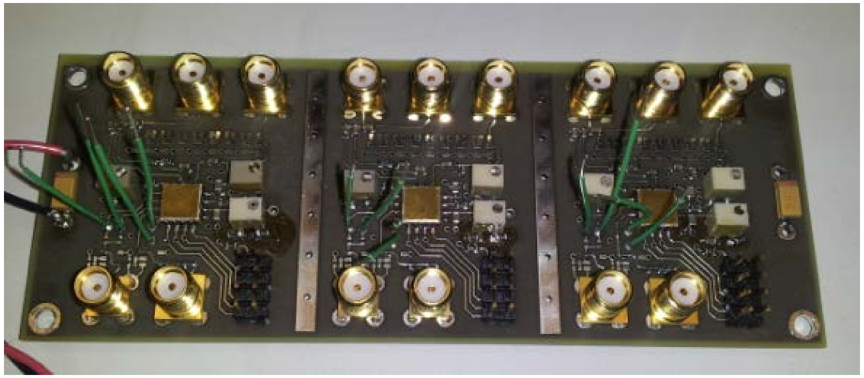


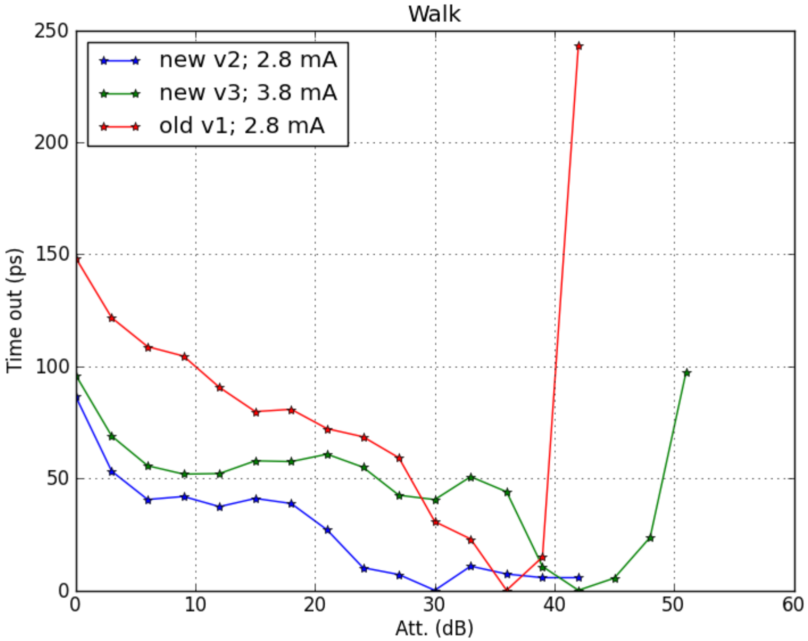


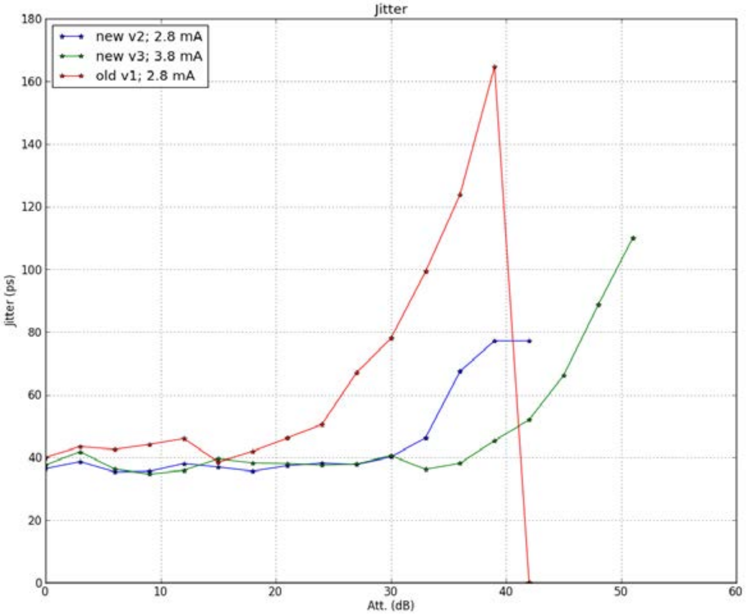


CFDD test results

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







Technical Development:
ASIC Progress

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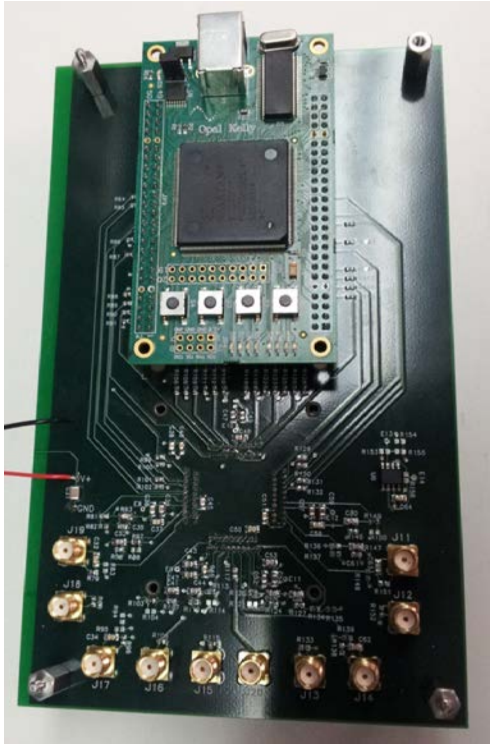
- First version of TOF chip fabricated and tested
  - Temperature testing from -40°C TO 70°C
  - Supply tested from 3.0V to 3.6V
  - Functionality verified over 10ps to 2ns LSB
  - Successfully completed SEE testing at Texas A&M
  - Completed total dose testing
- Second version of TOF chip and first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



Transition to Flight

- TOF, CFD ASICs
  - Complete qualification with external test house
  - 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
  - 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.

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

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:

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

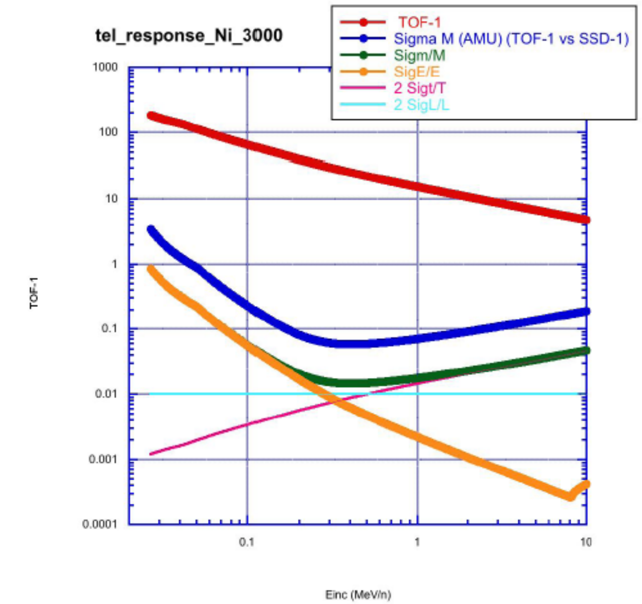
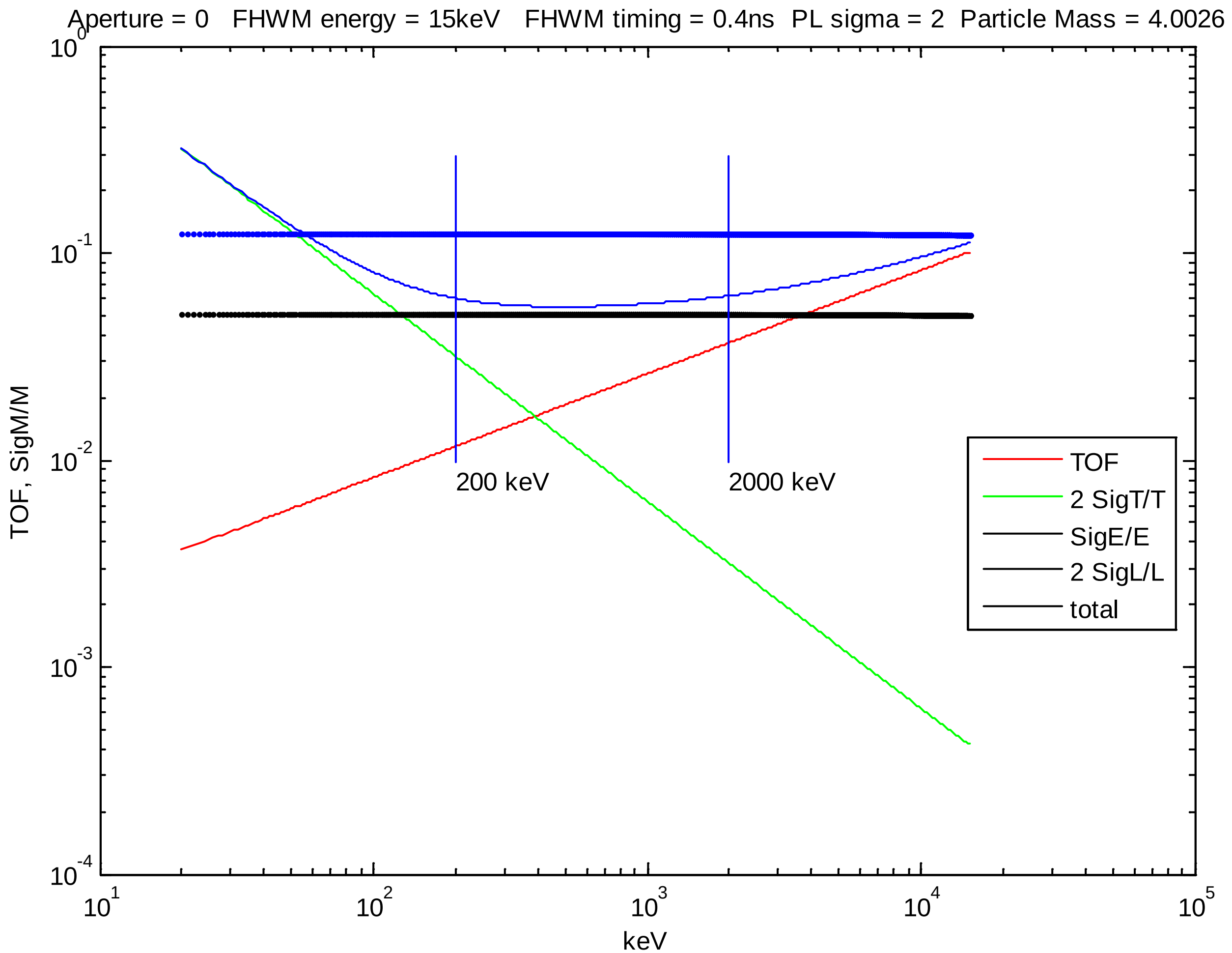
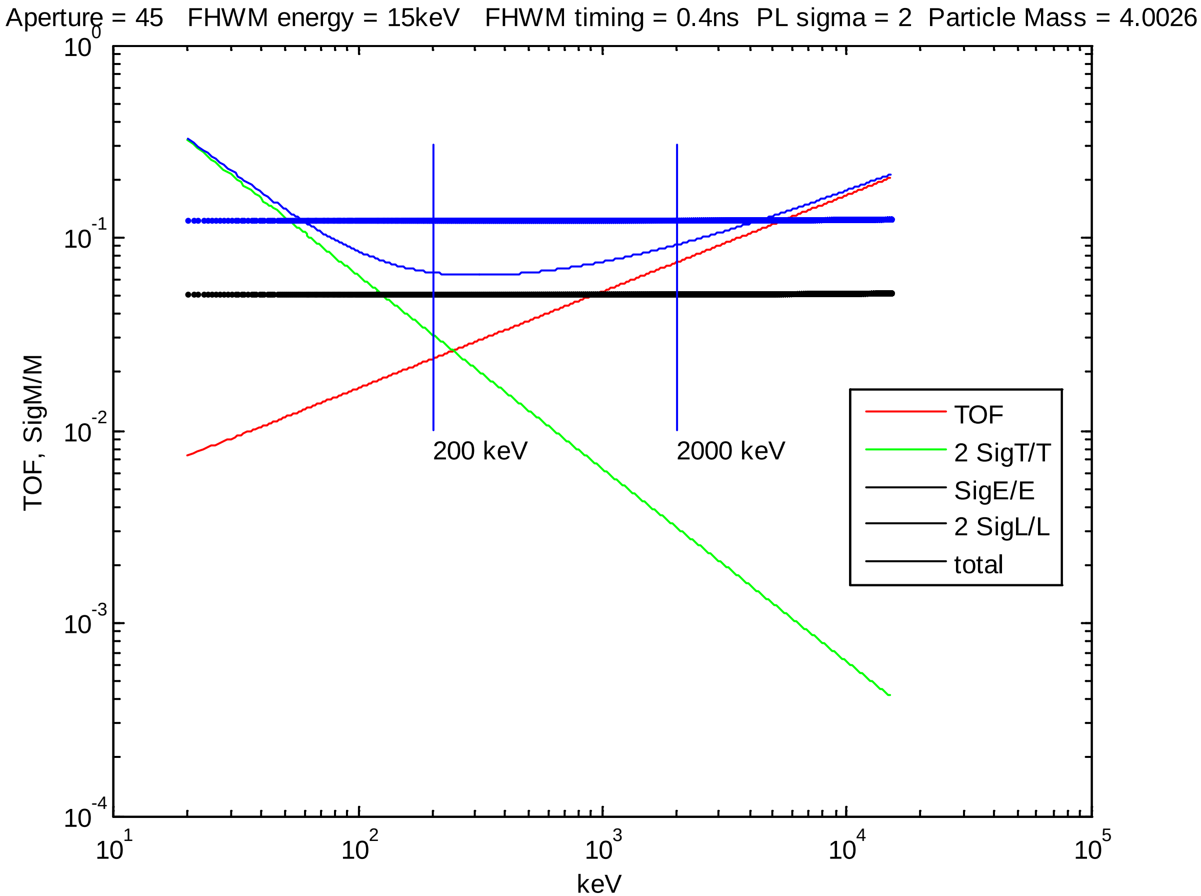


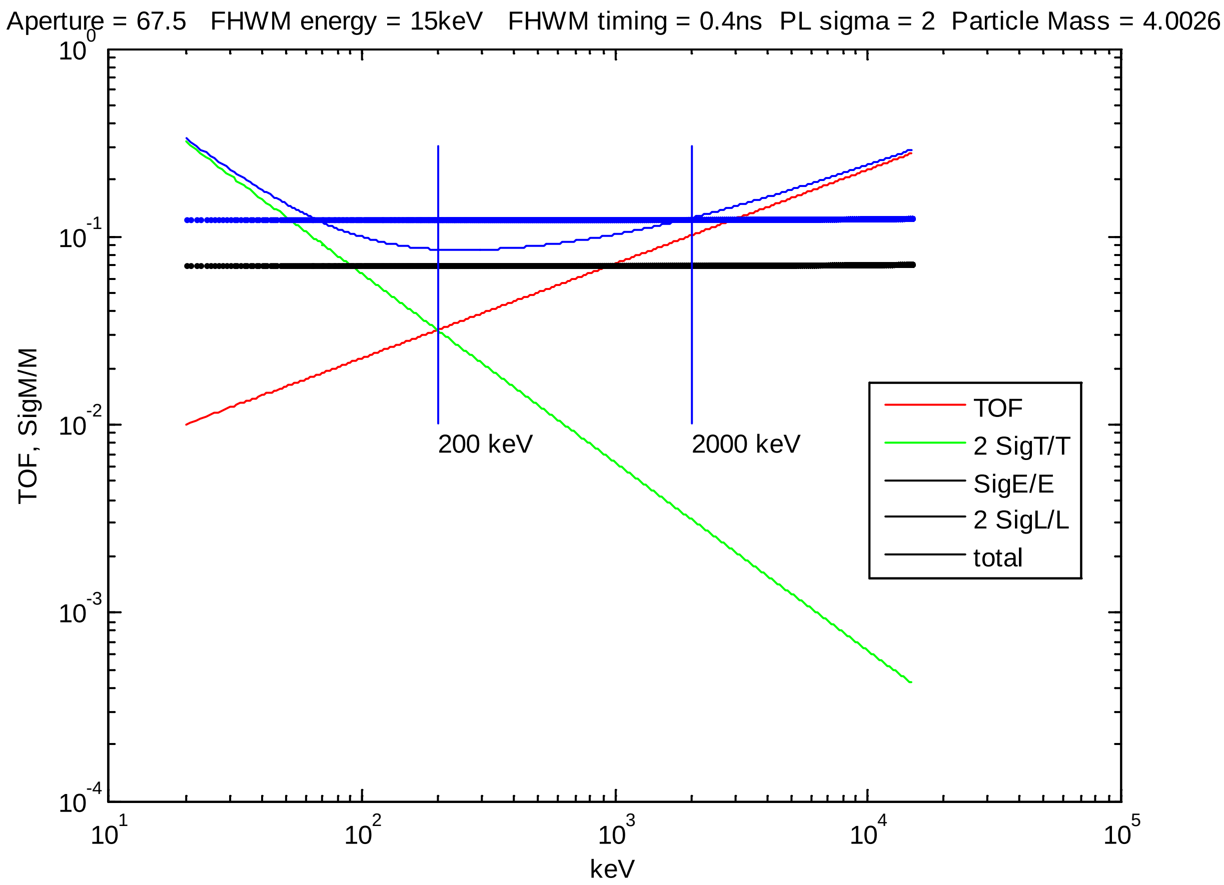
Figure 21 -- Mass resolution contributions for [4]He in SIS, assuming 20 keV FWHM SSD noise, and TOF dispersion $\sigma = 0.11$ ns. *(ref file: tel_response_He.qpc 7/24/2012)*



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