Solid State Detectors and Instrumentation

Davin Larson

2008-04-23

- Outline:
  - Energy loss in Matter
  - Energetic Particle Detectors
  - Instrument Design

- Outline:
  - Energy loss in Matter
    - Photons
    - Charged Particles
      - Ions
      - Electrons
  - Energetic Particle Detectors
  - Instrument Design

Energy loss in Matter

- The manner in which energetic particles interact with matter depends upon their mass and energy.
  - Photons - have “infinite range”- Their interaction is “all-or-nothing” They do not slow down but instead “disappear”, typically through 1 of 3 interactions:
    - Photoelectric effect (Low energy: E<~50 keV
    - Compton Scattering (50 keV ~< E < 1 MeV)
    - Pair production (E >2 x 511 keV).
  - Particles with non-zero mass (Electrons and Ions) will slow down as they pass through matter.

Energy Loss in Matter – Particles with mass

- Charged particles primarily interact with the electrons in a material. Typically the energetic particle suffers numerous, distant collisions with a Fermi sea of electrons losing a small amount of energy with each interaction (much like a plasma!).
- The interaction is typically strongest when the velocity of the energetic particle is approximately the same as the Fermi speed.
- Energetic neutral atoms are quickly ionized soon after entering the solid.
- Neutrons are a different matter altogether

- The stopping power for heavy particles is given by the Bethe-Bloch formula (1932):

$$-\frac{dE}{dx}=\frac{4\pi N_A z^2 e^4}{m_e c^2 \beta^2} B$$

Where:

$$B=\frac{Z\rho}{A}\left[\ln\left\{\frac{2m_e c^2\beta^2}{I(1-\beta^2)}\right\}-\beta^2-\frac{C}{Z}-\frac{\Delta}{2}\right]$$

Rate of energy loss is ~ inversely proportional to energy, and proportional to z, (the effective charge)

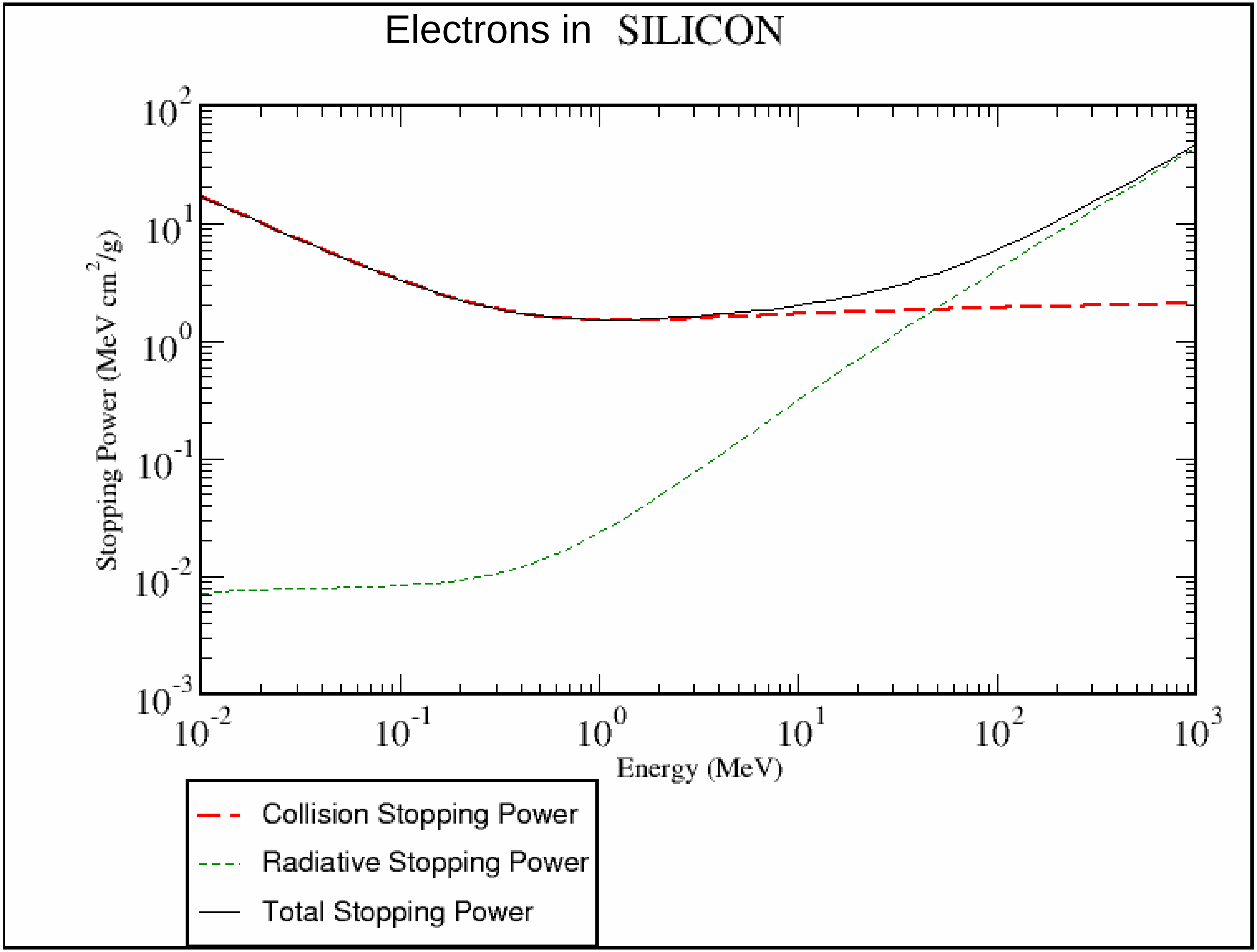
- The range is given by:

$$R = \int_{Estart}^{0} \left(\frac{dE}{dx} \right)^{-1} dE$$

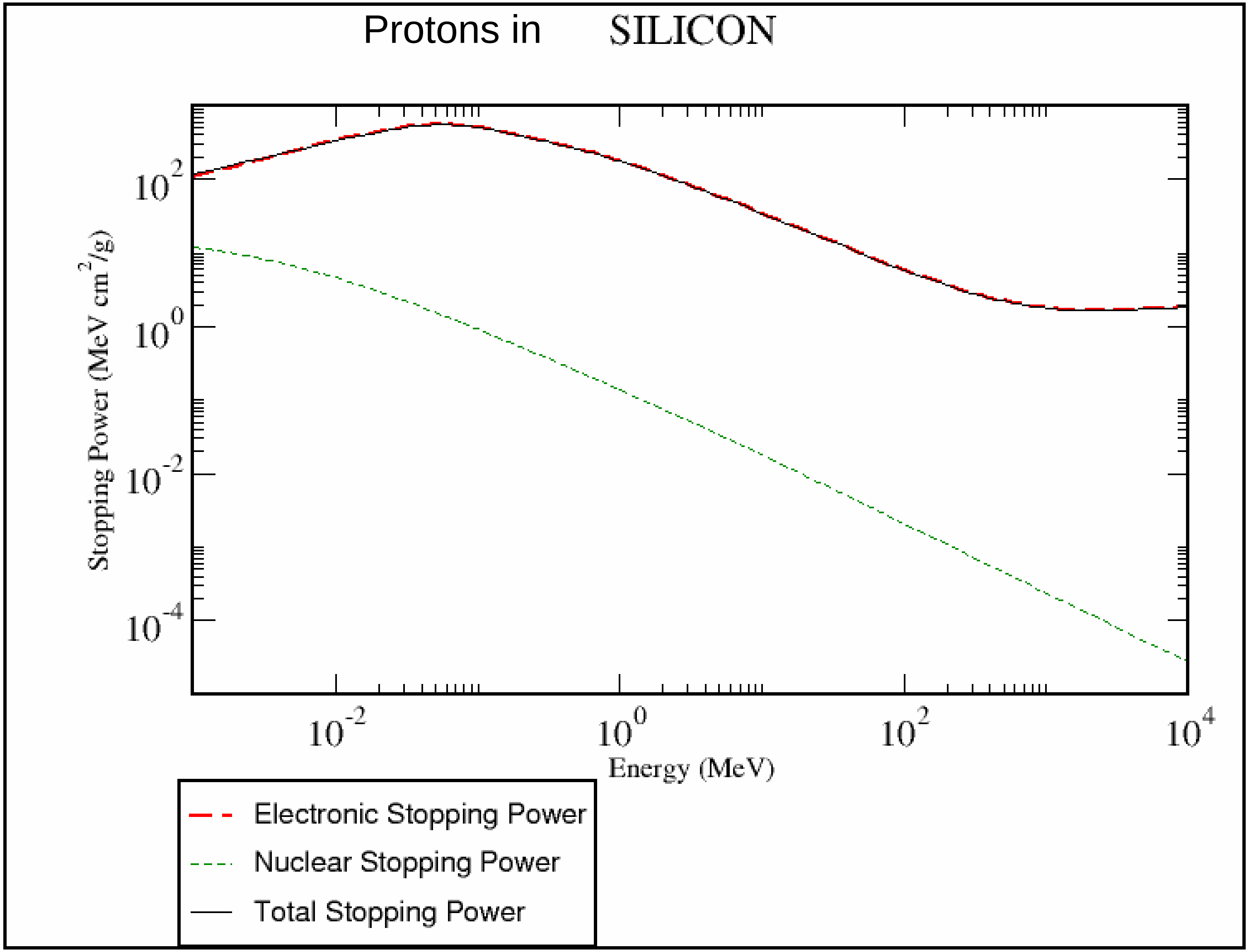
This formula is only useful for ions for reasons we will soon see.

- Some Useful Software tools for determining /simulating the passage of particles through Matter
  - NIST – stopping power and range
    - Estar - electrons
    - Pstar - protons
    - Astar - alphas
  - CASINO – Electron propagation
  - SRIM – Ion Propagation
  - GEANT –Does everything!

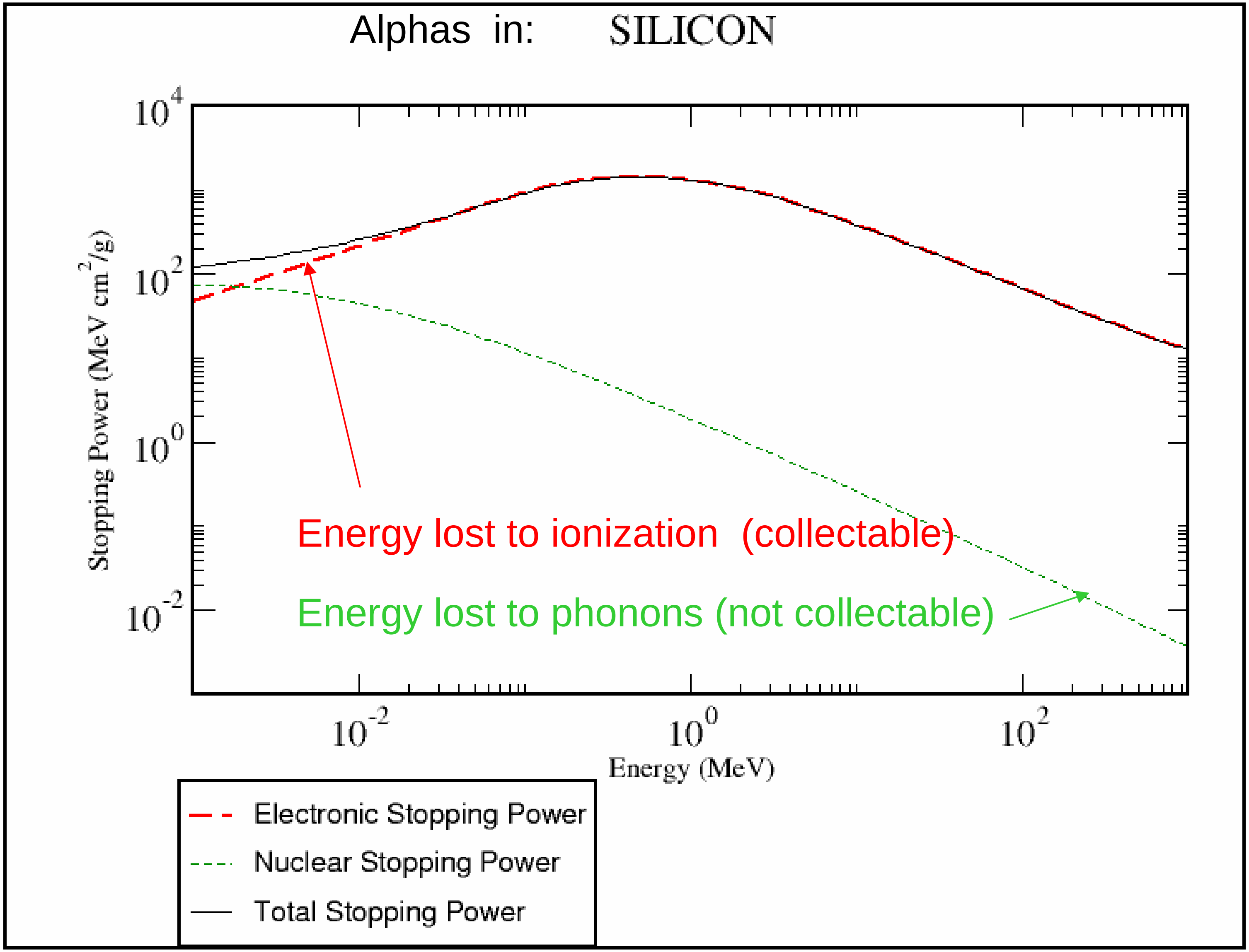
Energy Loss in Matter -Electrons



Energy Loss in Matter- Protons



Energy Loss in Matter - Alphas



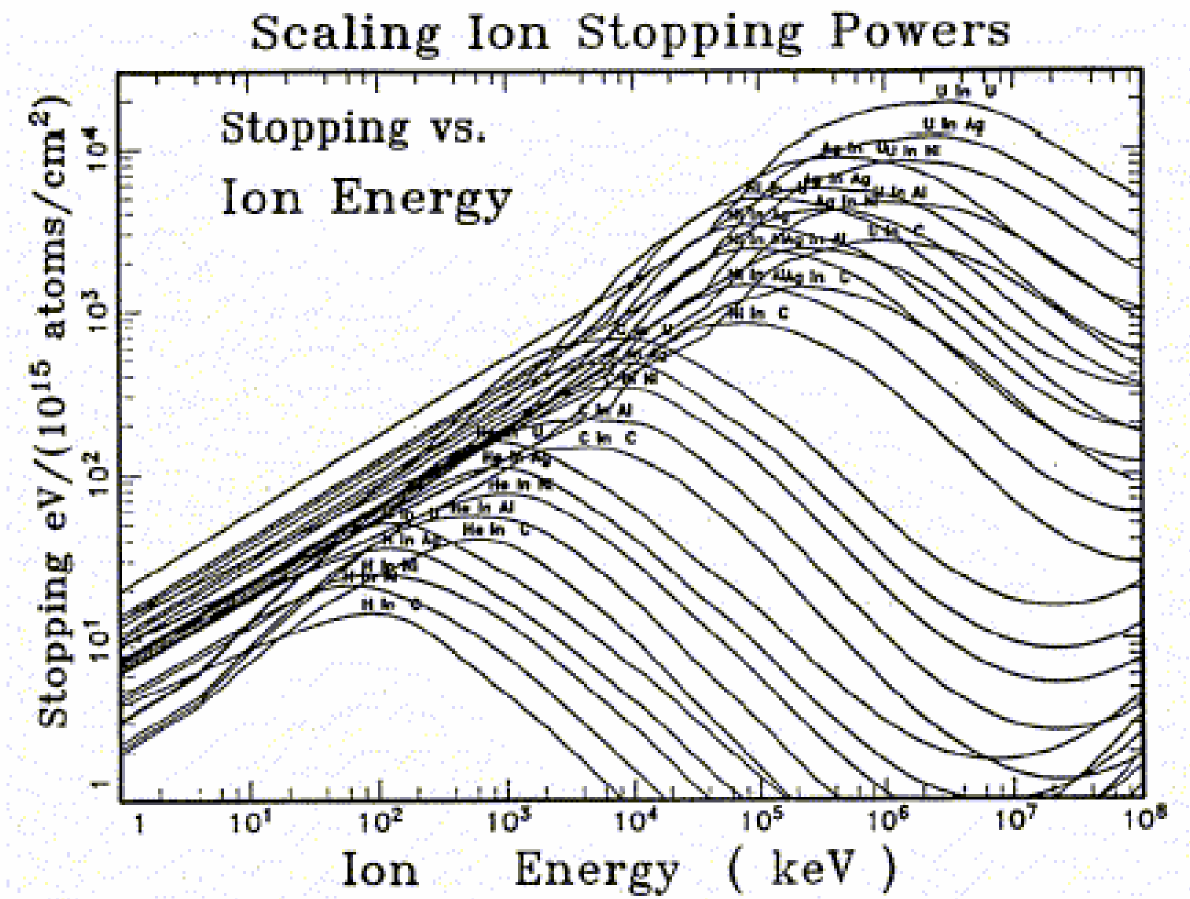


Figure 1- 1 The Stopping of Ions in Various Solids
This figure shows the stopping power of ions from H to U in various elemental targets from C to U. The stopping is in units of eV/(10^{15} atoms/cm^2), which is approximately the energy loss per monolayer of a solid. The ion energies extend over eight orders of magnitude, which covers most scientific applications. The data in this figure will be used later in this chapter to illustrate advances in stopping theory.

- Electrons and Ions behave differently due to the different mass ratio:
- The primary interaction of all energetic particles is with the sea of electrons.
- Ions interact with a series of distant collisions. Each interaction results in a small energy loss and very little angular scattering. – They travel in nearly straight lines as they slow down. The dispersion is small. (Imagine a fast bowling ball thrown into a sea of slow moving ping pong balls.)
- Electrons can lose a large fraction of their energy and undergo large angle scattering with each interaction (Imagine a high speed ping pong ball thrown into the same sea)

- When an electron hits an atom it can undergo a very large angle deflection, often scattering it back out of the material.
- Bremstrahlung (breaking) radiation is produced when electrons undergo extreme accelerations. X-rays are easily generated when energetic electrons strike high Z materials. (a good reason to avoid high Z materials on exposed surfaces)

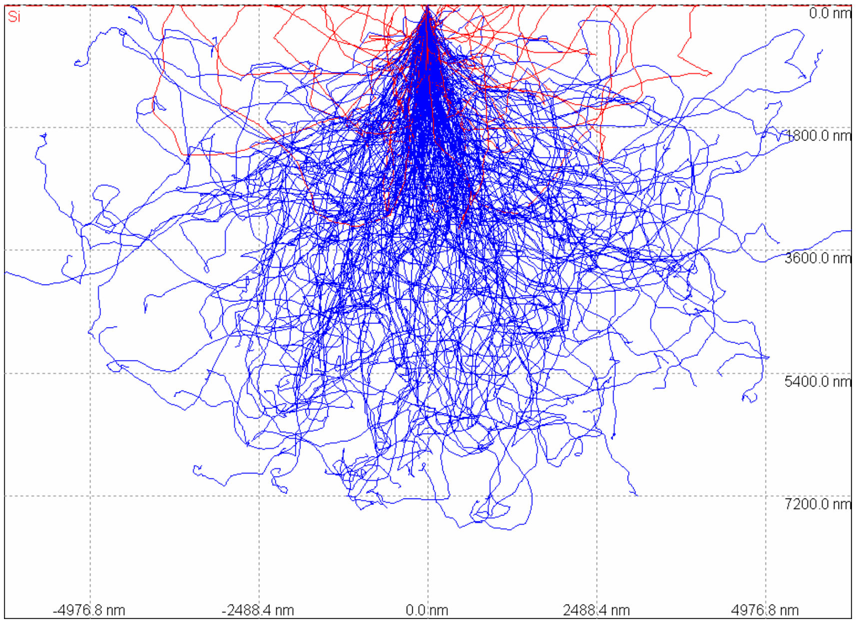
Solid State Detector – Simulation tools

- CASINO - " monte CArlo SImulation of electroN trajectory in sOlids ".
  - A very useful simple tool that simulates electron propagation within solids
  - Developed for electron microscopy
  - http://www.gel.usherbrooke.ca/casino/index.html

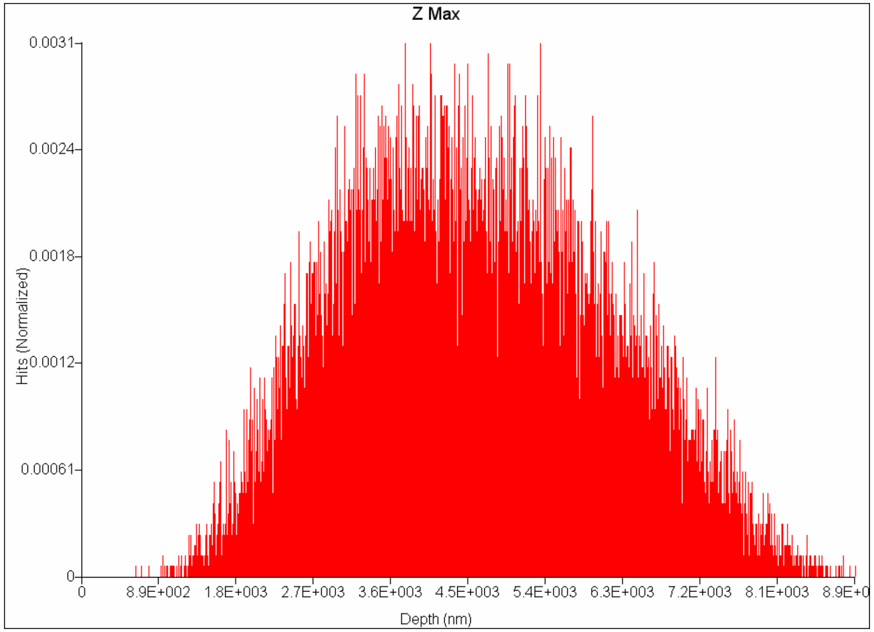
This program is a Monte Carlo simulation of electron trajectory in solid specially designed for low beam interaction in a bulk and thin foil. This complex single scattering Monte Carlo program is specifically designed for low energy beam interaction and can be used to generate many of the recorded signals (X-rays and backscattered electrons) in a scanning electron microscope. This program can also be efficiently used for all of the accelerated voltage found on a field emission scanning electron microscope(0.1

to 30 KeV)

- Simulation of 30 keV electrons in Silicon



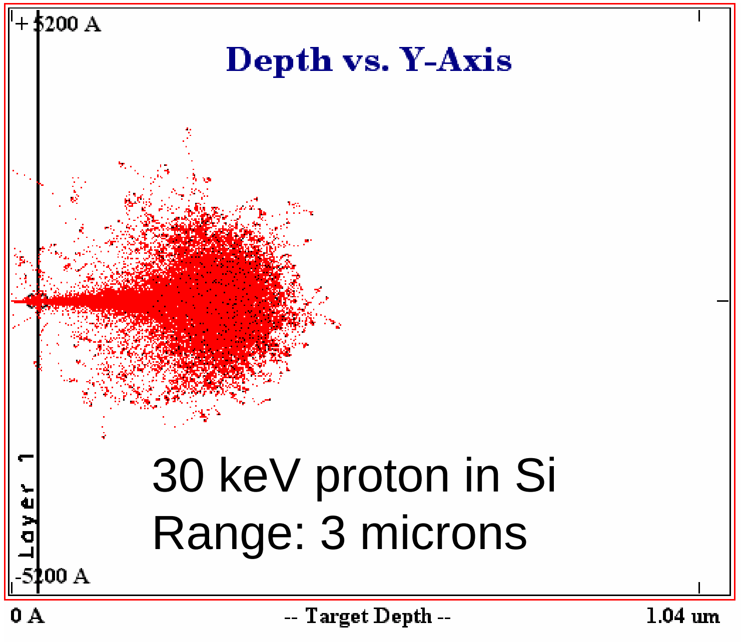
Electron Trajectories
(16 % backscattered in red)



Distribution of Maximum Z value.
Mean: 45 microns

Ion simulation software

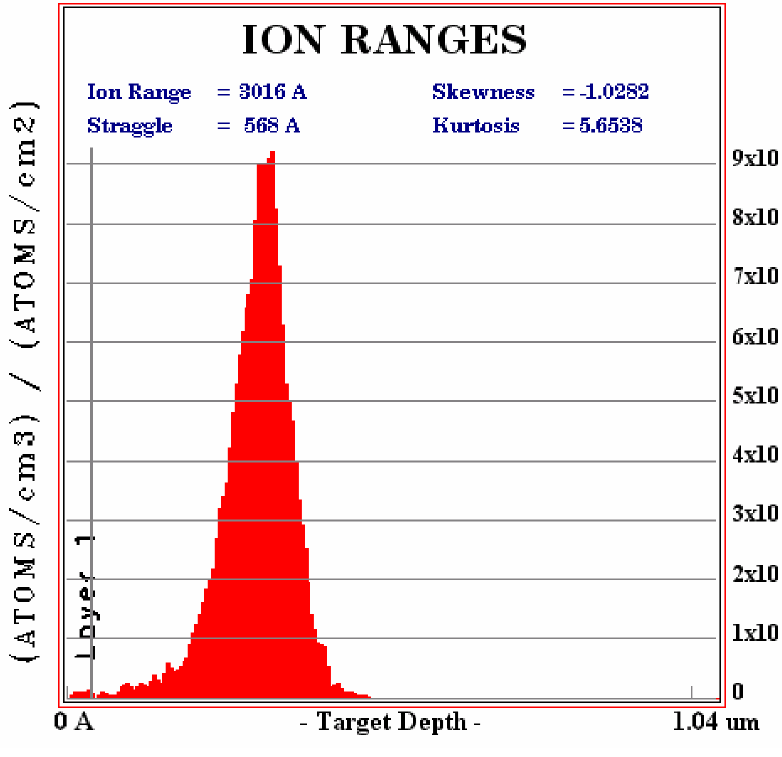
- SRIM/TRIM “Stopping and Range in Matter”
- Only for ions
- Download from: http://www.srim.org/
- Simple to use.

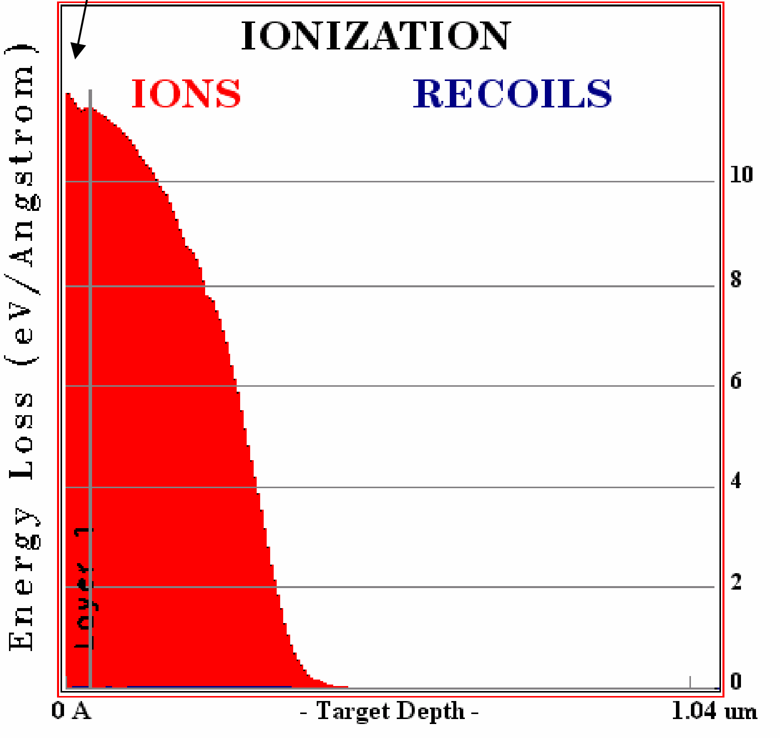


TRIM Simulation - 30 keV

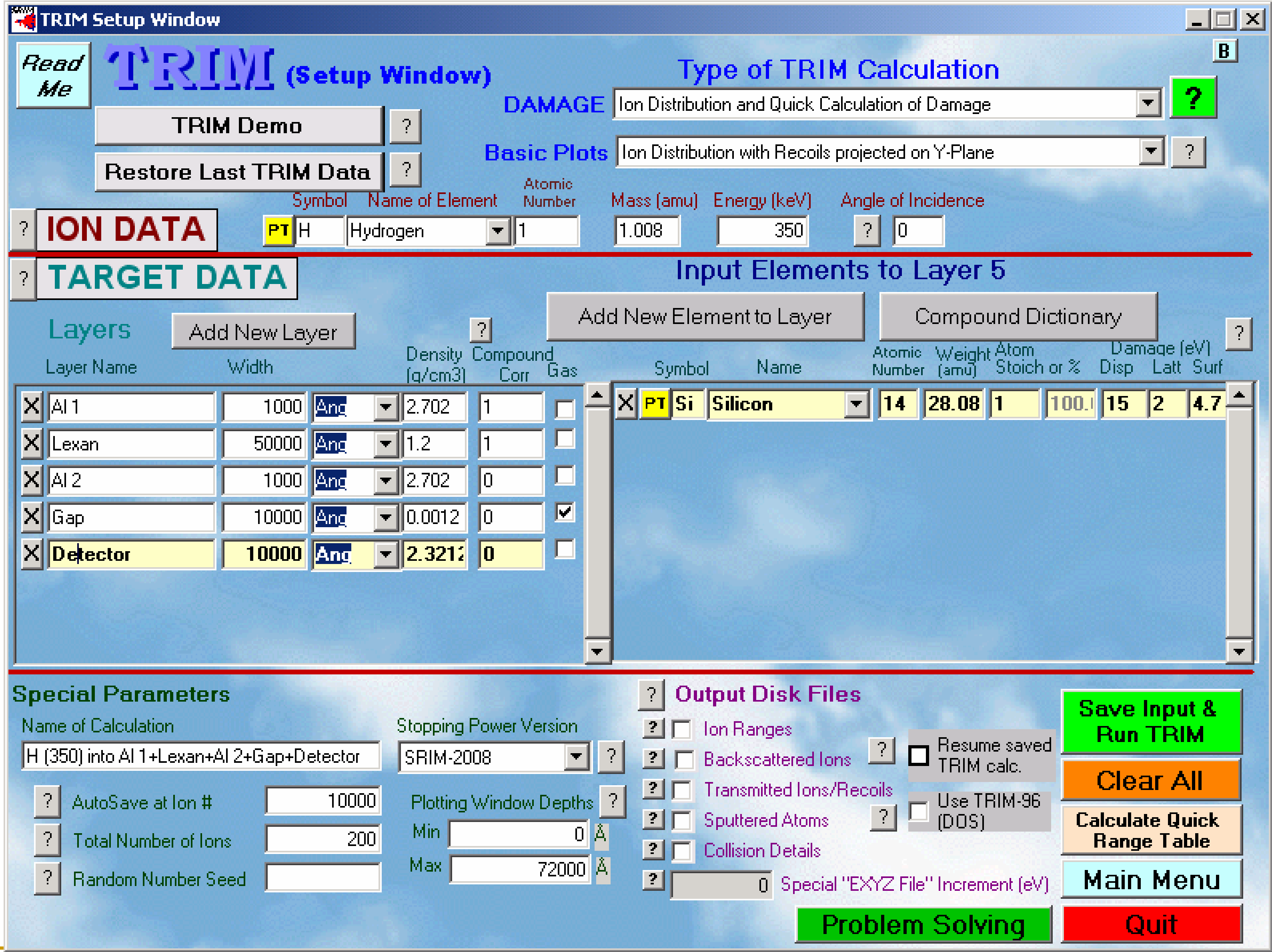
- Simulation results for 30 keV ions in Silicon detector

Ionization energy not collected in 400 Angstrom Dead layer



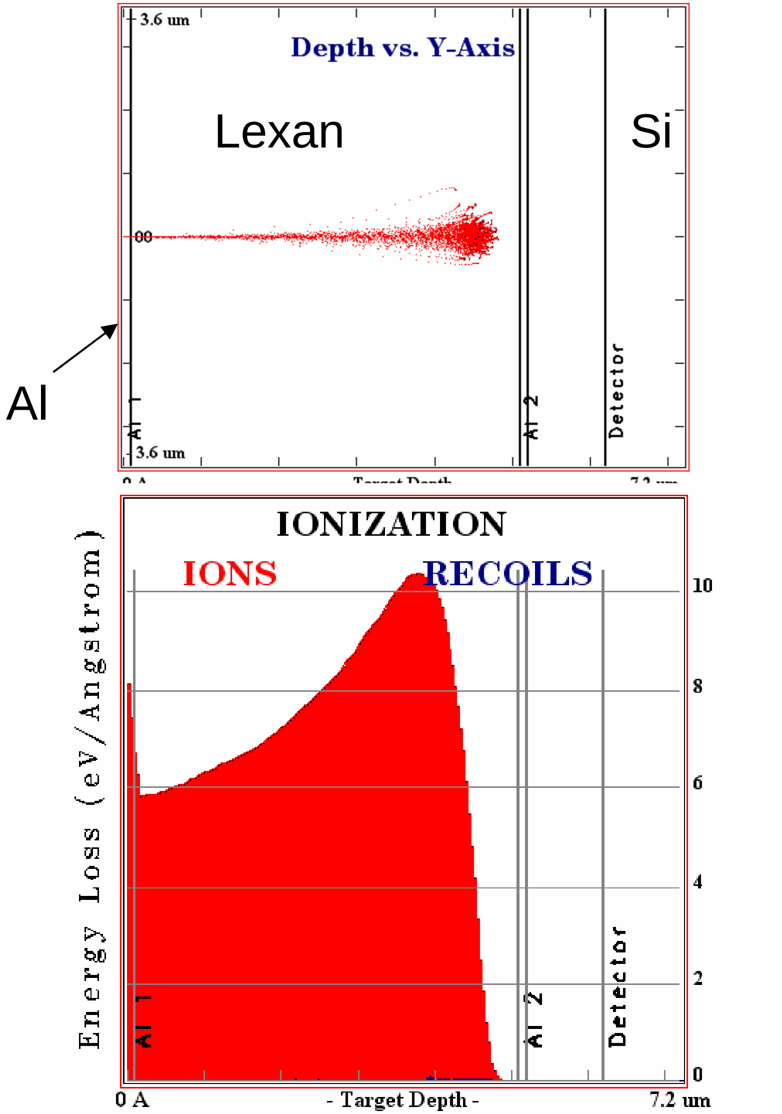


TRIM/ SRIM ion simulation

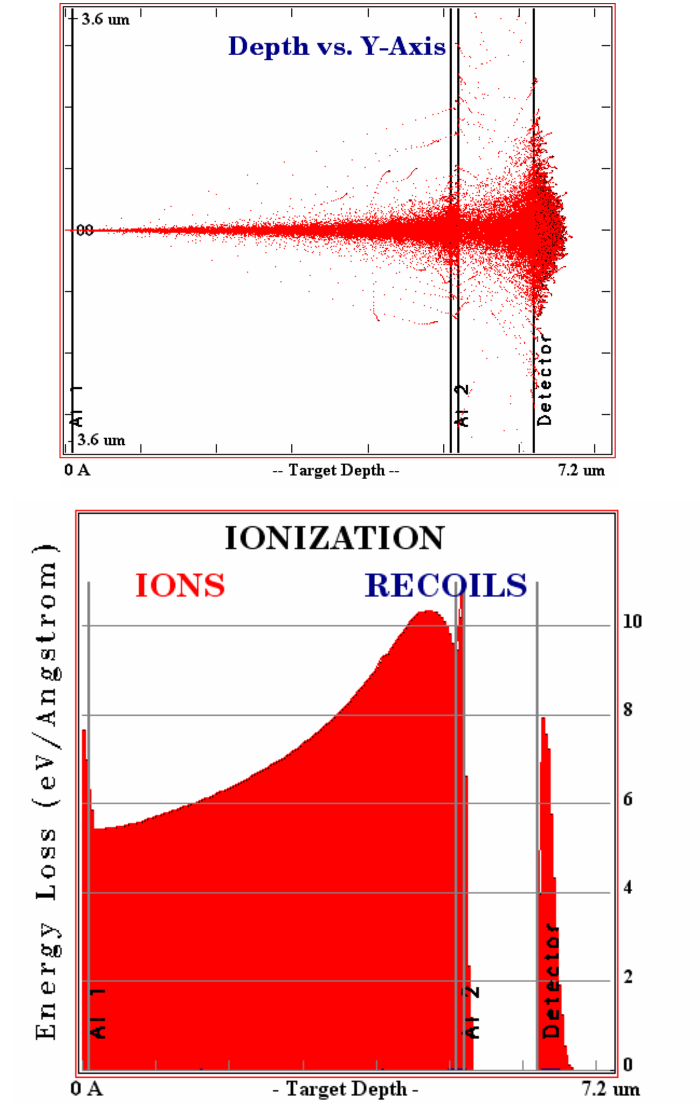


CASINO Simulation

350 keV protons

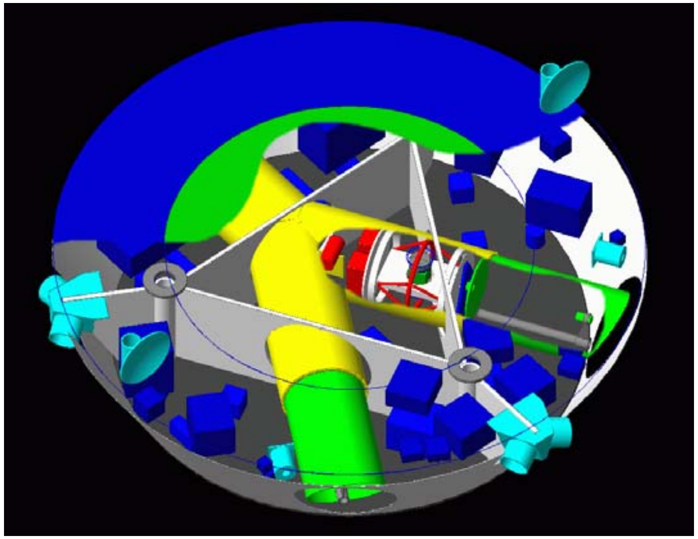


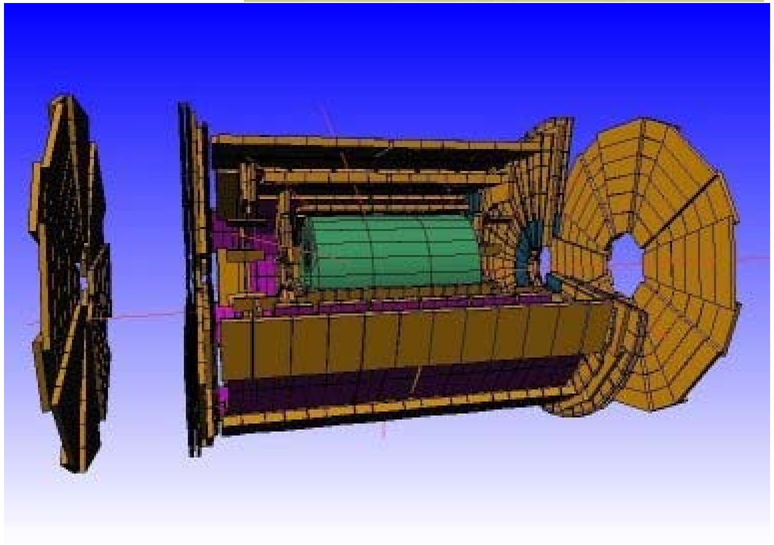
400 keV protons



Energetic particle simulation tools

- GEANT4 – **GEometry ANd Tracking**
  - The ultimate simulation tool
  - Developed at CERN for high energy particle accelerators and detectors
  - Allows complex 3D geometries
  - Simulates all particles (electrons/ion/photons) and recursively tracks all daughter products.
  - Fairly difficult to use.
  - May not be accurate at low energy (<10 keV) ?
  - Now available on WINDOWS/XP!
  - More info at: http://geant4.web.cern.ch/geant4/





- Energy loss in Matter
- Energetic Particle Detectors:
  - Solid State Detectors
    - Silicon Solid State Detectors
      - PIPS
      - Surface Barrier
    - Lithium Drifted Silicon
    - High Purity Germanium
  - Light producing detectors
    - Scintillators
      - Organic
      - Inorganic
    - Cherenkov Radiators
  - New Technologies
    - Avalanche Photodiodes
    - CCD Readout
    - Delta-doped
- Instrument Design, Test and Calibration Instruments

- Solid State Detectors (SSDs) not only detect individual particles, they can be used to measure particle energy with good energy resolution.
- Typically only good for E>20 keV
- Recent improvements push the limit to ~2 keV

Silicon Diode Detectors

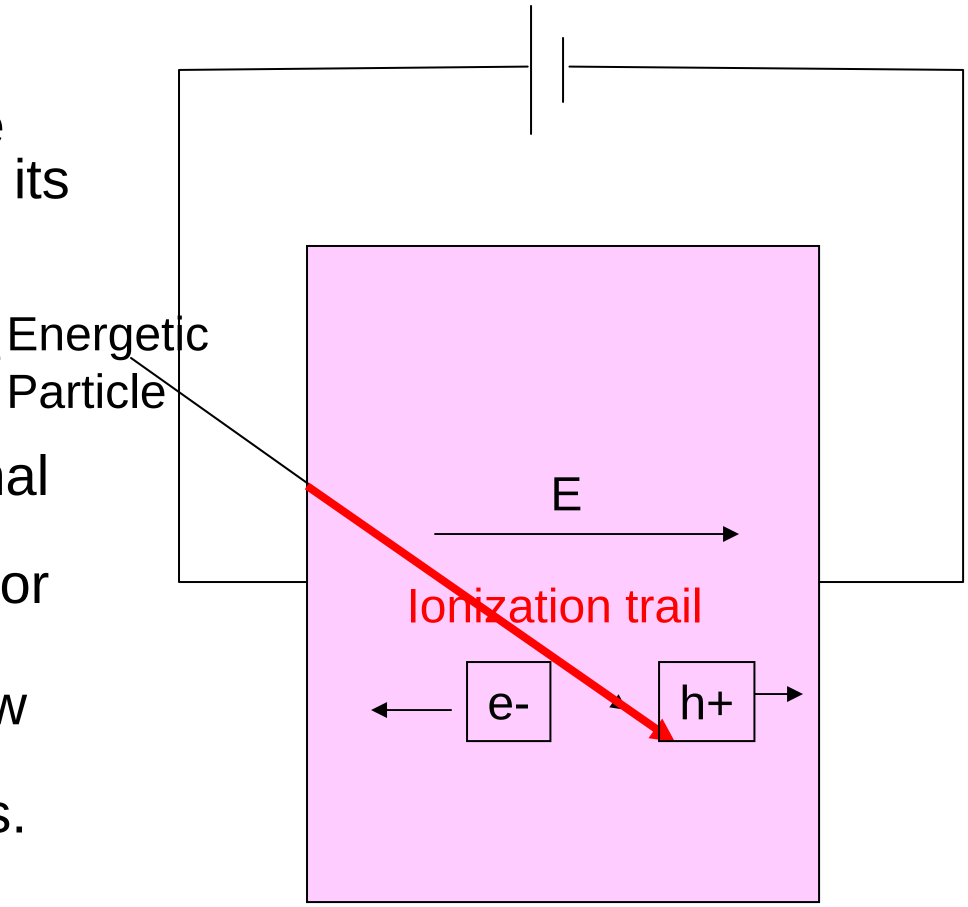
- Two varieties of Silicon Diode Detectors
  - Implanted Ion (i.e. Canberra PIPS)
    - Produced by implanting p-type material into an n-type silicon substrate
    - Easy to produce pixelated surfaces
    - Very rugged
  - Surface Barrier
    - Chemical process to create diode surface
    - Easily damaged, sensitive to solvents
    - Not too common anymore
- Typically both varieties are run fully depleted (electric field extending throughout bulk of material)
- Maximum thickness is ~1000 microns – defines max energy particle that can be stopped within the detector
- Particles can be incident on either side of detector

Other Detectors Continued…

- Lithium Drifted Silicon
  - Requires (?) LN2 storage for stability
  - Can be made in thicknesses up to 1 cm to stop very energetic ions (~100 meV)
  - Reduced energy resolution for ion studies
- HP (High Purity) Germanium
  - Expensive!
  - Large Z high stopping power
  - Very large form factor are possible
  - Generally used for x-rays, gamma-rays
- CdZnTd (Cad Zinc Telluride)
  - High Z
  - Cheaper than Ge

Solid State Detectors – Principle of operation

- With the application of a (large enough) reverse bias voltage an electric field is established throughout the silicon.
- An energetic charged particle will leave an ionization trail in its wake.
- The electron hole pairs will separate and drift to opposite sides.
- The total charge is proportional to the electronic energy deposited. (3.61 eV per pair for Silicon).
- The signal contains only a few thousand electrons thus requiring sensitive electronics.
- The trick is to collect and measure this small signal.



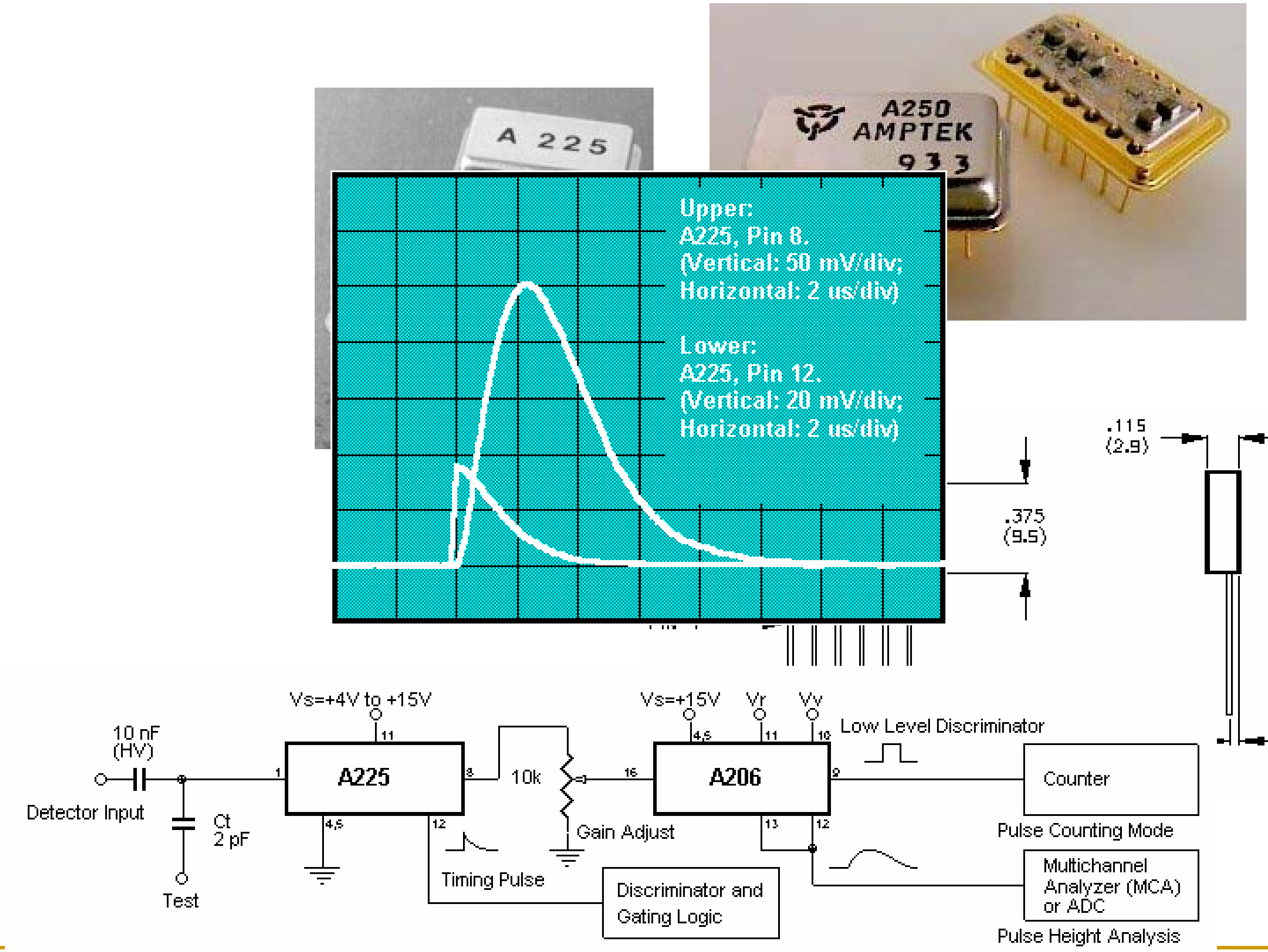
Other detector types

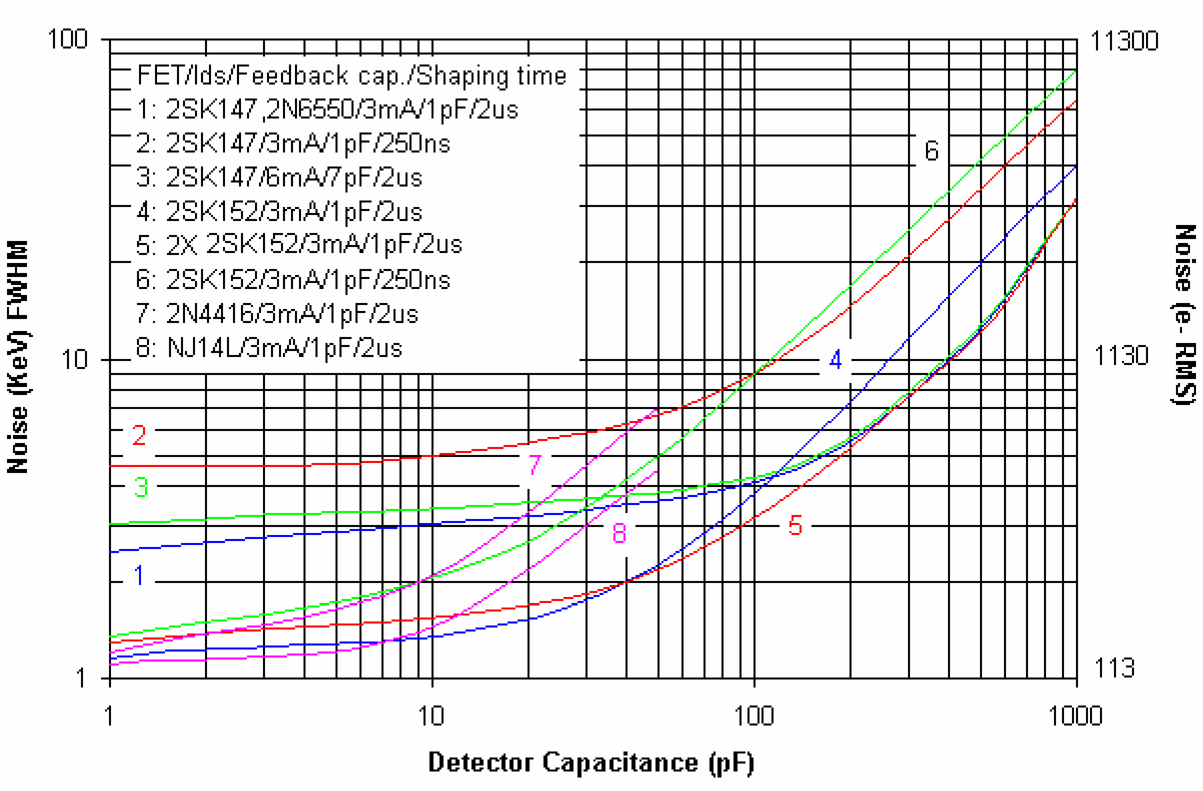
- Scintillators
  - Emit light when charged particle traverses the material.
  - Light output is approximately linear with deposited energy
  - Light is typically collected with a photomultiplier
  - Easily shaped to accommodate instrument requirements
  - Relatively poor energy resolution
  - Often used as active shielding (veto device) or as final stop for very energetic particles (cosmic rays)
  - Two Classes:
    - Inorganic (Ionic crystals, ie. NaI is very common)
      - High stopping power (high Z)
    - Organic (plastics)
      - Generally have low stopping power
      - Very fast (good for coincidence events)
- Cherenkov Detectors
  - Utilizes Cherenkov radiation emitted when a particle travels faster than speed of light in that medium (extremely relativistic particles only)

Instrument Design

- Energy loss in Matter
- Energetic Particle Detectors:
- Instrument Design
  - Issues to be aware of:
  - Choice of shaping time/
    - Pulse Height Defect
    - Dead Layers
    - Radiation Damage
    - Light Sensitivity
    - Paralyzibility of charge sensitive amplifiers
    - Pulse Pileup
    - Electronic Noise Limitation
    - Cooling / Temperature sensitivity
    - Micro-acoustic sensitivity
    - Magnetic cleanliness

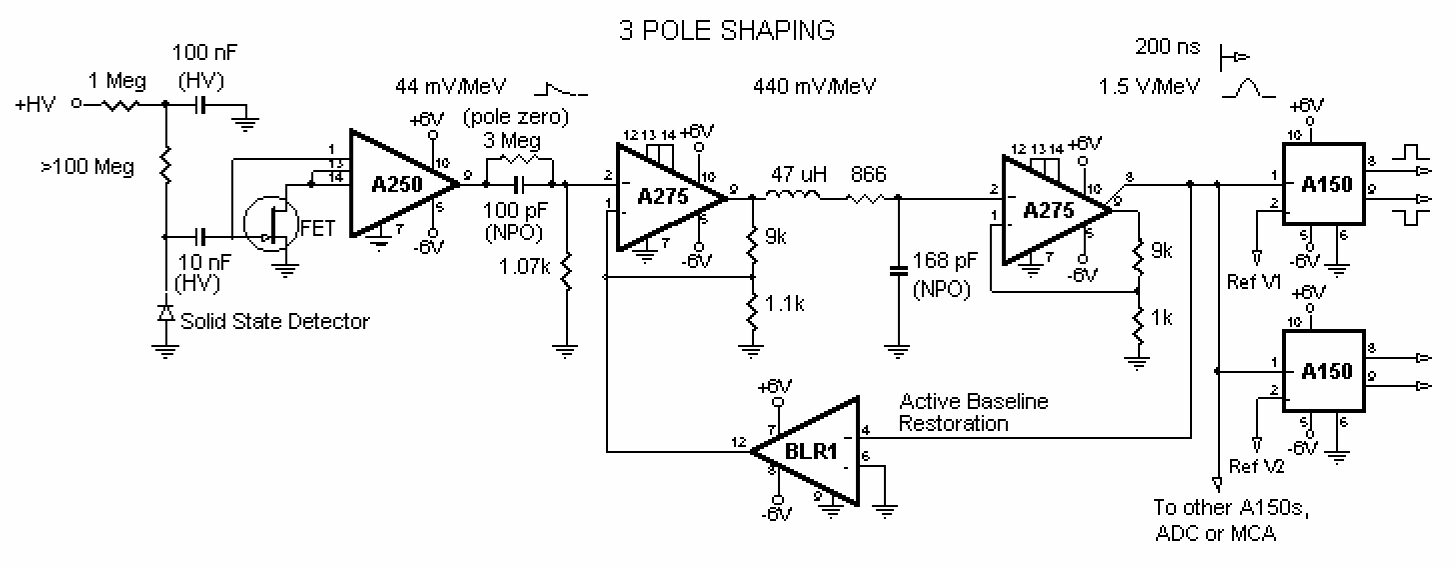
The AMPTEK preamplifier



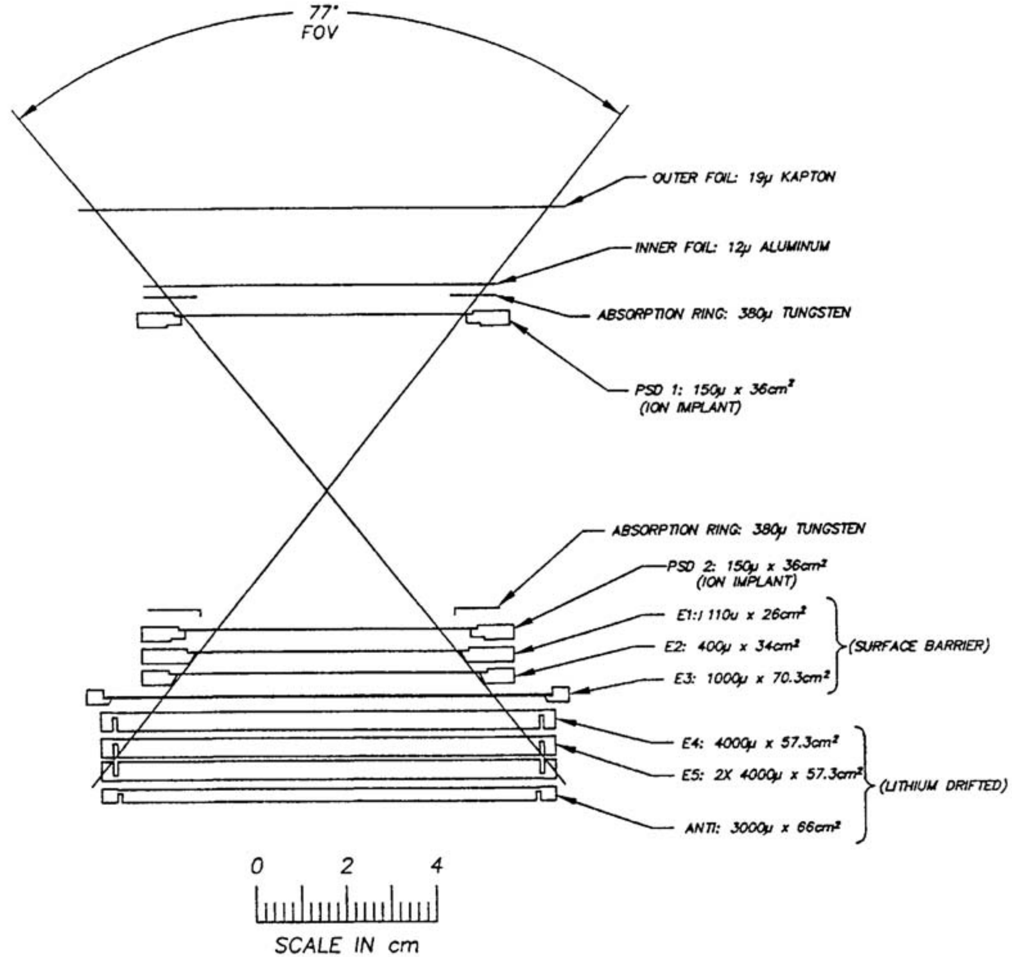


FET/Ids/Feedback cap./Shaping time
1: 2SK147,2N6550/3mA/1pF/2us
2: 2SK147/3mA/1pF/250ns
3: 2SK147/6mA/7pF/2us
4: 2SK152/3mA/1pF/2us
5: 2X 2SK152/3mA/1pF/2us
6: 2SK152/3mA/1pF/250ns
7: 2N4416/3mA/1pF/2us
8: NJ14L/3mA/1pF/2us
Noise (KeV) FWHM
Noise (e- RMS)
Detector Capacitance (pF)
100
10
1
11300
1130
113
1
10
100
1000

Instrument Electronics



Solid State Telescope examples –WIND EPACT



Cross section of the EPACT isotope telescope on Wind. The first two detectors are two-dimensional position sensitive strip detectors (PSD1, PSD2). They are required so that path-length corrections may be made for the angle of incidence and for non-uniformities in detector thickness. Tungsten rings are used to mask off circular areas for each PSD. There are 6 solid-state detectors increasing in thickness with depth in the stack in order to minimize Landau fluctuations. From von Rosenvinge et al. [1995].

Solid State Telescope examples – WIND SST

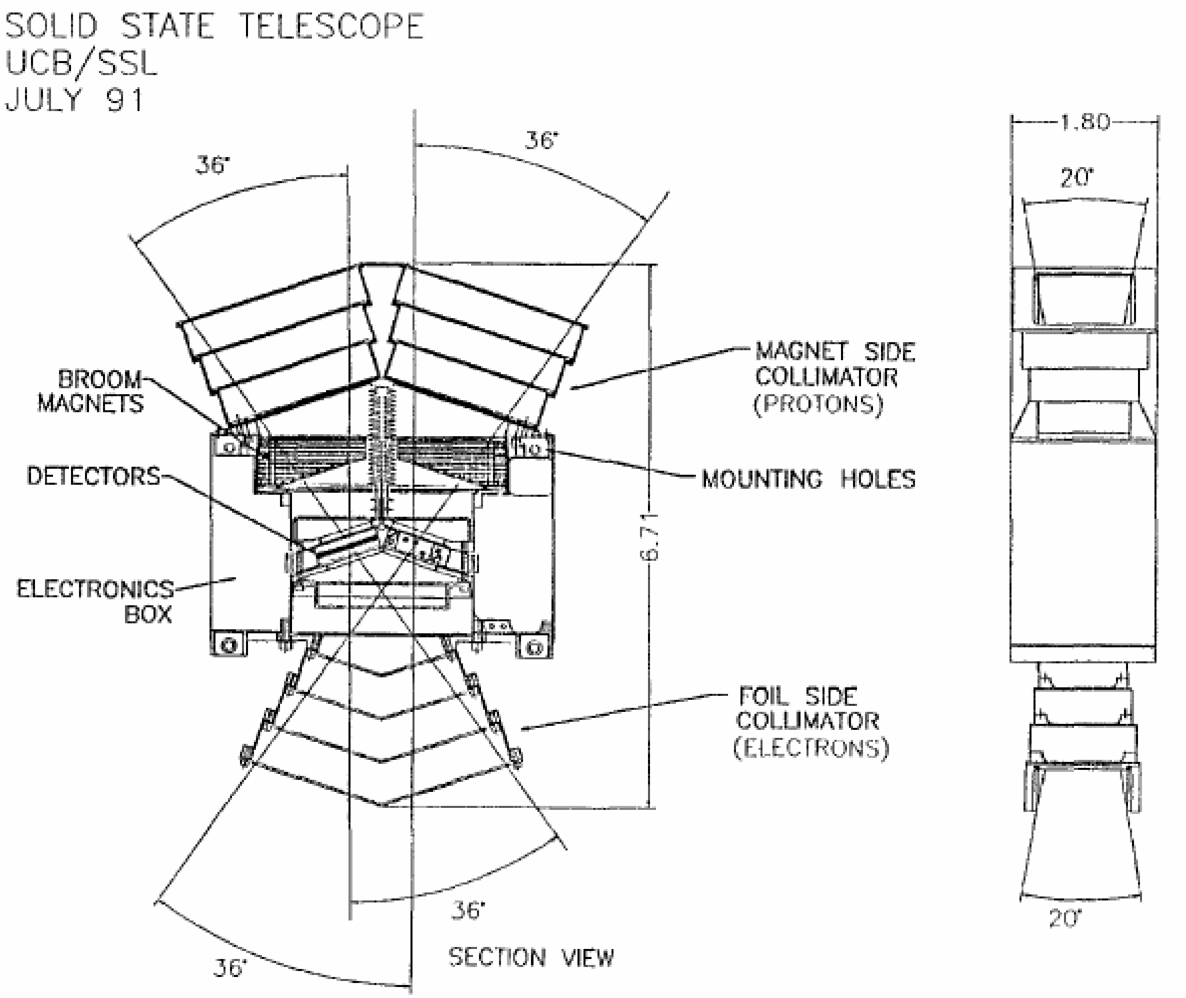
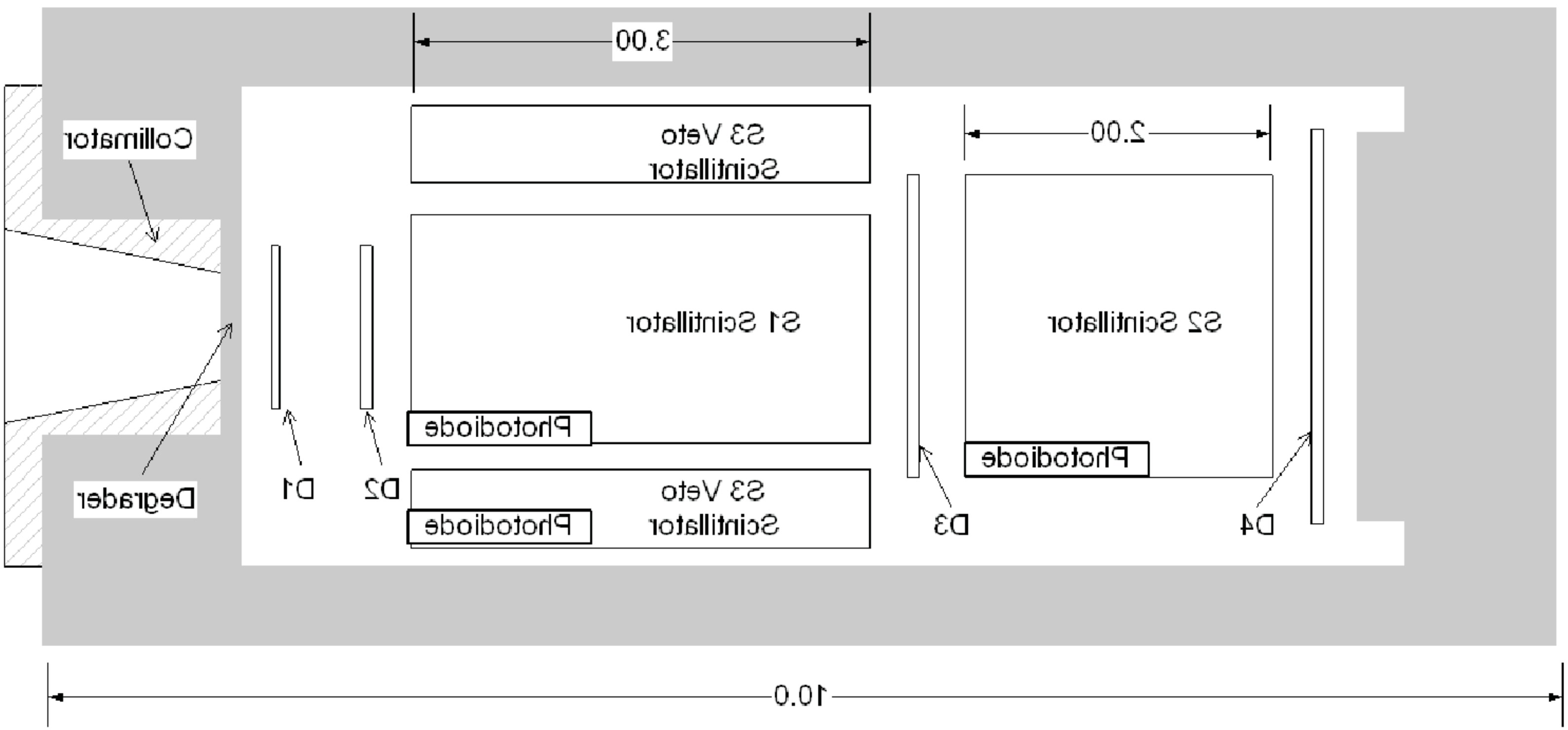
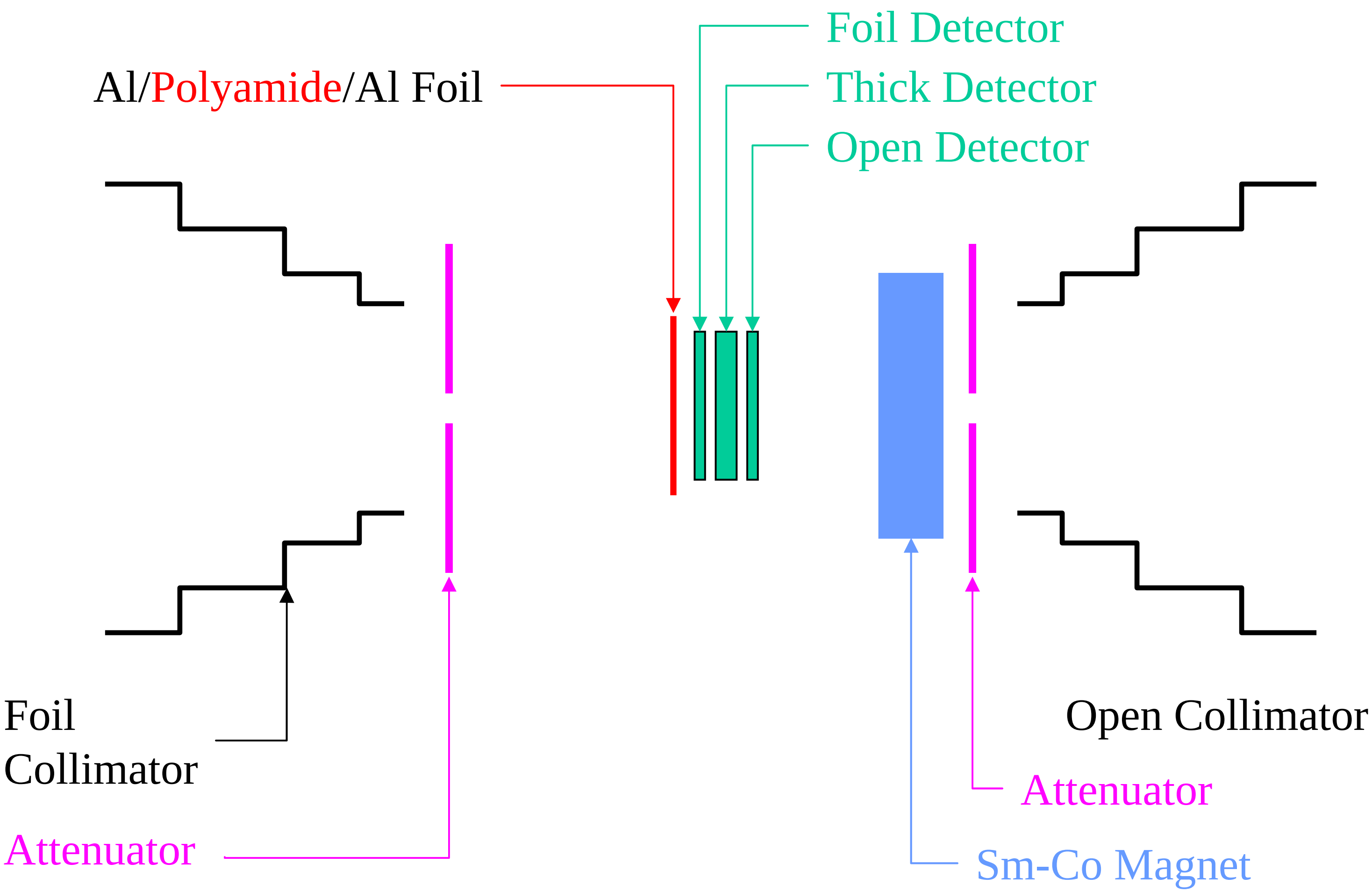


Fig. 9. An array of two double-ended telescopes is shown in a section view. Particles entering the two upper collimators pass through a sweep magnet while those entering the lower collimator pass through a thin lexan foil.

- Proposed Instrument that combines SSDs, active shielding, and scintillators. Used to detect particles >400 MeV

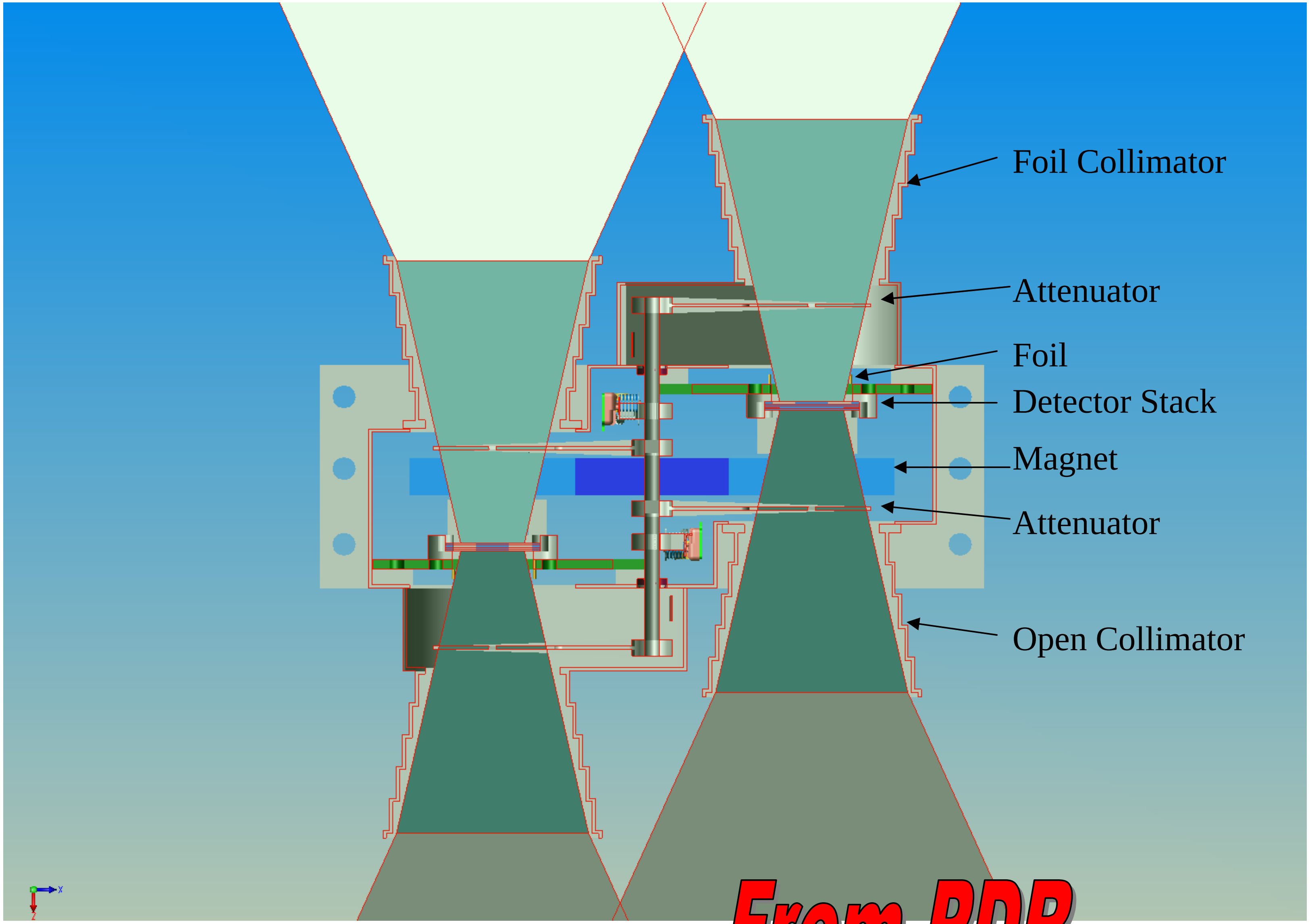


Sensor Unit Schematic

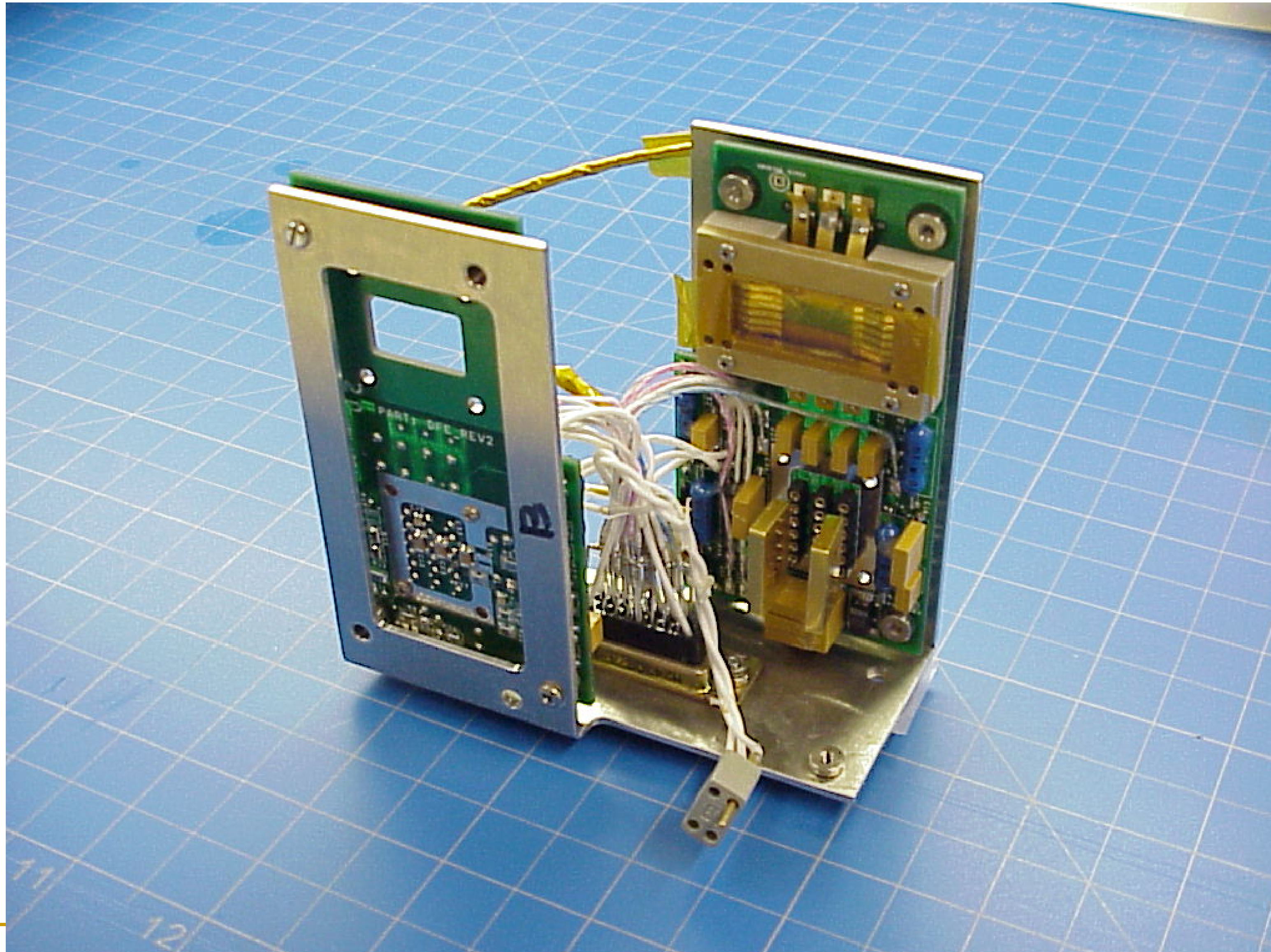


From PDR

Sensor Cross Section



From PDR


PART# DFE_REV2

Overview

- Solid State Telescope (SST)
  - Requirements and Specifications
  - Block Diagram
  - Mechanical Design
    - Detectors
    - Collimation
    - Magnets
    - Attenuator (aka shutter, door)
    - Detector placement / FOV issues
    - Mass estimates
  - Electrical Design
    - DFE – (Detector Front End)
    - DAP – (Data acquisition and Processing)
    - Power Estimates
  - Testing and Calibration
  - Schedule
  - Issues

Science Requirements

- SST-1: The SST shall perform measurements of the tailward-moving current disruption boundary speed using the finite gyroradius technique (4.1.1.2, 4.1.1.5).
- SST-2: The SST shall measure the time-of-arrival of superthermal ions and electrons of different energies emanating from the reconnection region to determine the Rx onset time (4.1.1.3, 4.1.1.5).
- SST-3: The SST shall compute the partial energy moments due to the superthermal ions and electrons in the magnetotail plasma sheet (4.1.1.3, 4.1.1.6, 4.1.1.7, 4.1.1.9, 4.1.1.10).
- SST-4: The SST shall obtain measurements of ion and electron distribution functi[illegible]sec required) (4.1.1.2, 4.1.1.3).
- SST-5: The SST shall measure energetic electron fluxes as close to Earth as 6RE geocentric, at all local times. (Radiation belt science-tertiary objective – achieved by nominal design).
- SST-6: The SST shall measure energetic ions in the solar wind, at the magnetopause and in the magnetosheath (Dayside science – secondary objective – achieved by nominal design).

Example Requirements

Performance Requirements

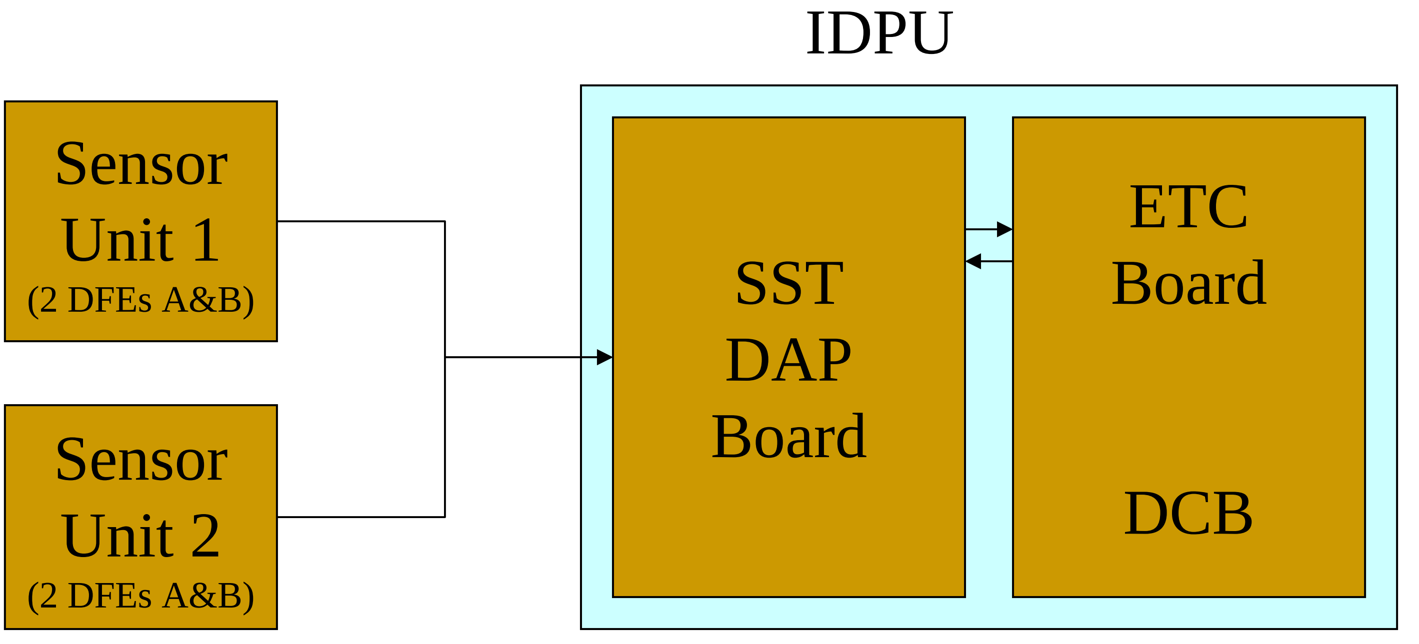
- SST-7: The SST shall measure energetic particles over an energy range of 30-300keV for ions and 30-100keV for electrons found in the magnetotail plasma sheet (SST-1, SST-2).
- SST-8: The SST energy sampling resolution, dE/E, shall be better than 30% for ions and electrons (SST-1, SST-2).
- SST-9: The SST shall be capable of measuring differential energy flux in the range from: 10^2 to 5x10^6 for ions; 10^3-10^7 for electrons (keV/cm2-s –st- keV) whilst providing adequate counts within a 10 second interval. (exact values TBD) (SST-1, SST-2)
- SST-10: The SST shall measure over 90^o in elevation with a minimum resolution of 45^o (SST-1, SST-2, SST-3, SST-4).
- SST-11: The SST shall [illegible] ...lution of 45^o (SST-1, SST-2, SST-3, [illegible]
- SST-12: The SST shall supply the high energy partial

Example Requirements

Overview

- Solid State Telescopes:
  - Measure Energetic Electrons and Ions
  - Energy Range:
    - H+: 25 keV to 6 MeV (possible ~2 MeV)
    - Electrons 25 keV to ~800 keV
  - Angular Coverage:
    - Theta
      - 4 look directions (+55, +25, -25, -55)
      - Resolution: ~ 30 deg FWHM
    - Phi
      - 32 sectors
      - Resolution: ~20 deg FWHM
  - Geometric Factor: ~0.1 cm2-ster (~1/3 of WIND)
  - Pinhole Attenuator: Cuts geometric factor by 64

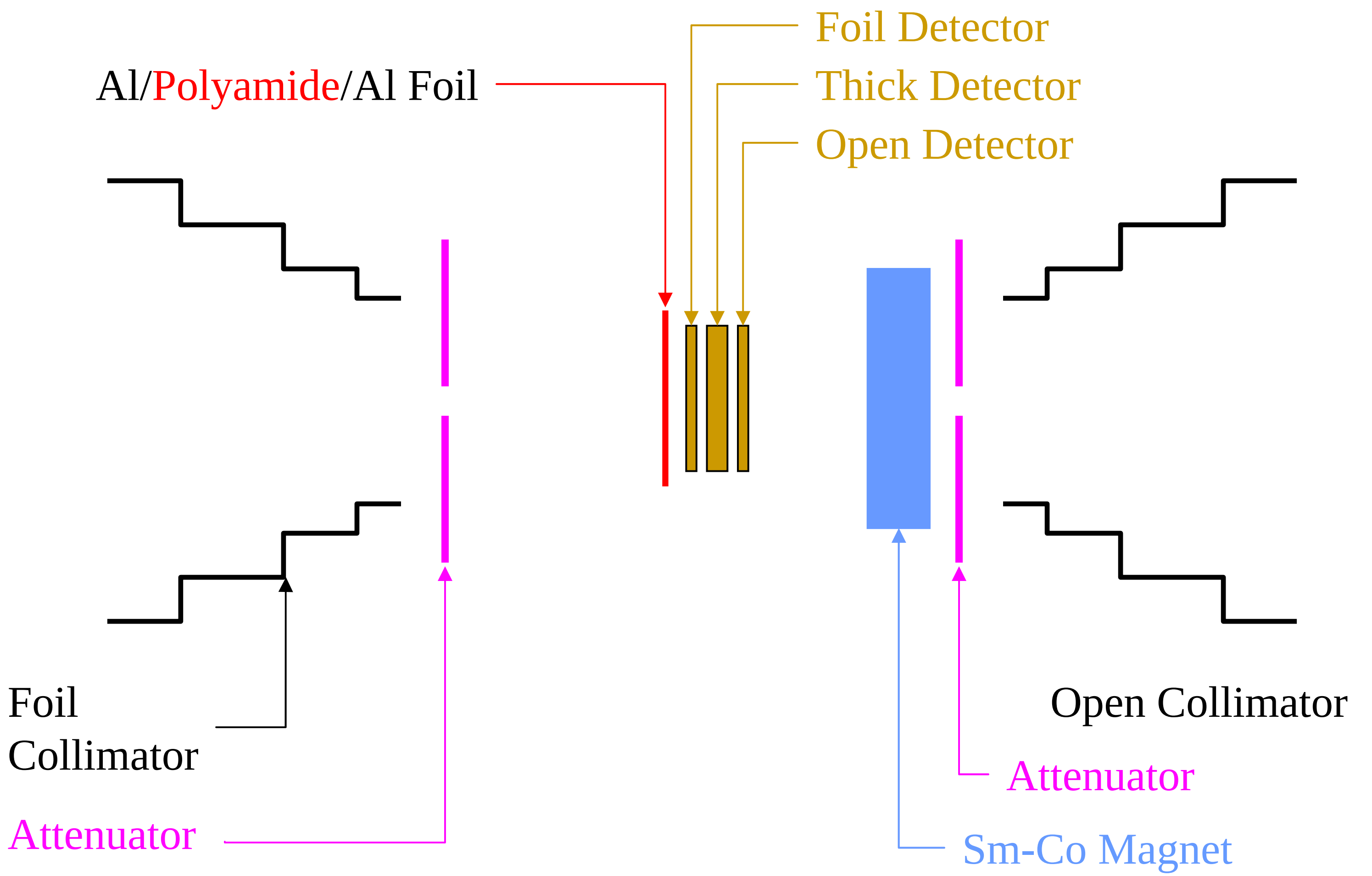
Block Diagram



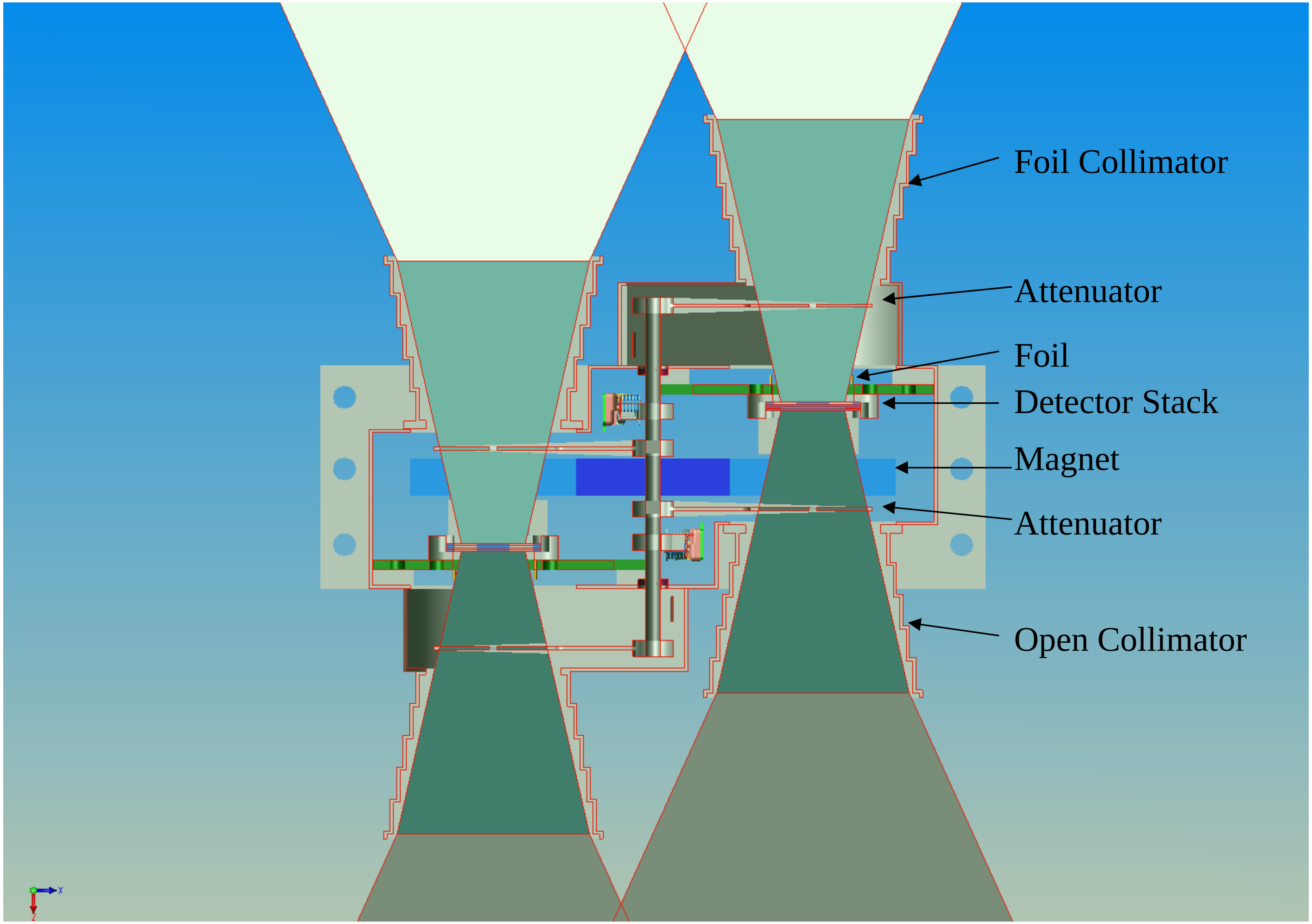
Sensor Units

- Each sensor unit is a:
  - Dual-double ended solid state telescope
  - Each double ended telescope (1/2 sensor) has:
    - Triplet stack of silicon solid state detectors
    - Foil (on one side)
      - Filters out ions <~350 keV
      - Leaves electron flux nearly unchanged
    - Magnet / Open side
      - Filters out electrons <400 keV
      - Leaves ion flux nearly unchanged
    - Mechanical Pinhole attenuator
      - Reduces count rate during periods of high flux
      - Reduces radiation damage (caused by low energy ions) during periods of high flux
    - Collimators
    - Preamplifier / shaping electronics

Sensor Unit Schematic



Sensor Cross Section



Design Details

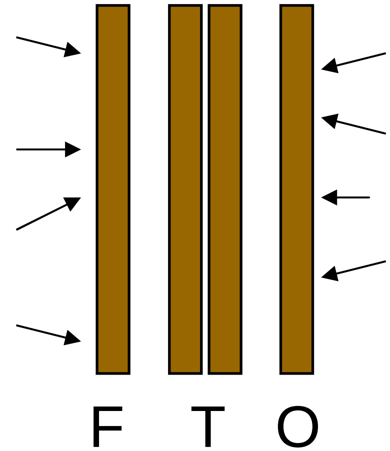
Thomas Moreau

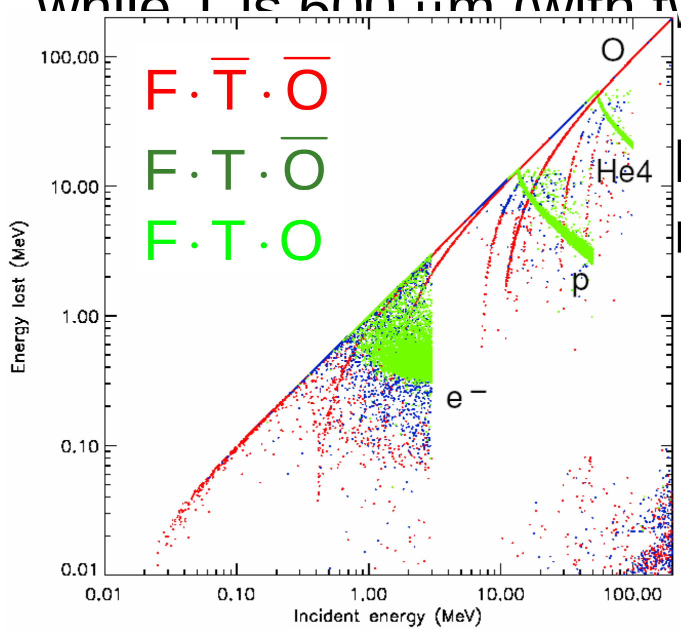
Sensor Considerations

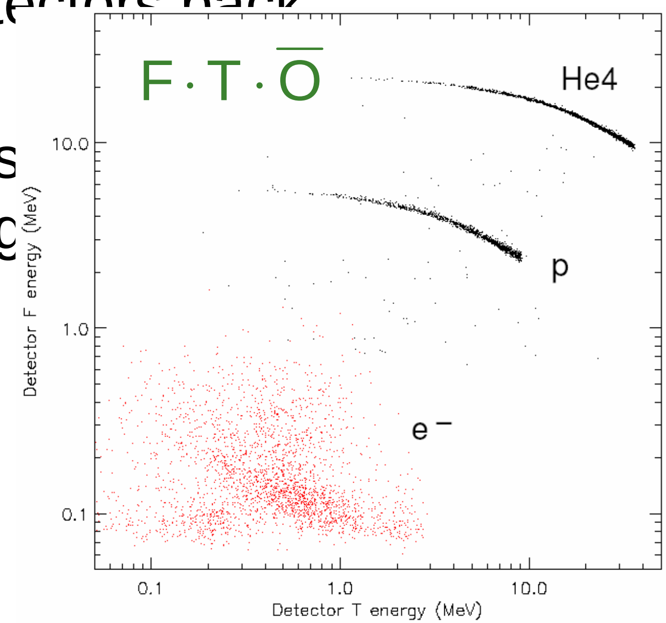
- Detector system
  - Measure electrons and protons > 20 keV
- Geometrical analysis
  - Collimator aperture
  - Solid state detector size
  - Thin foil
    - Stop protons < 350 keV
  - Magnet system
    - Deflect electrons < 400 keV
    - Not to disturb particle trajectories out of the magnet gap
    - Low stray magnetic field at the position of the magnetometers
  - Attenuator System

Detector System

- Detectors stacked in "Triplet" sequence:
  - Foil (F) | Thick (T) | Open (O)
  - Area used 1.32 × 0.7 cm^2
  - Front detectors F and O are 300 μm thick while T is 600 μm (with two detectors back
- h a sys
  nce loc

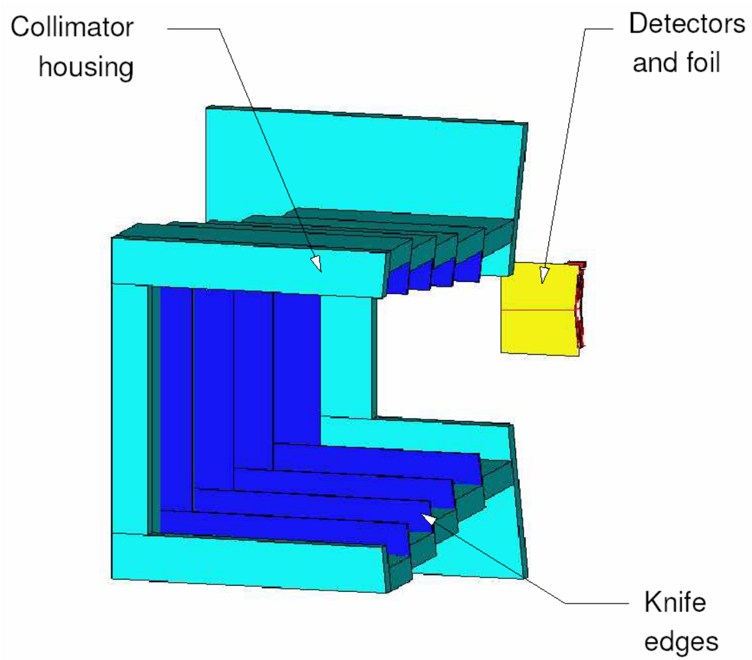






Collimator System

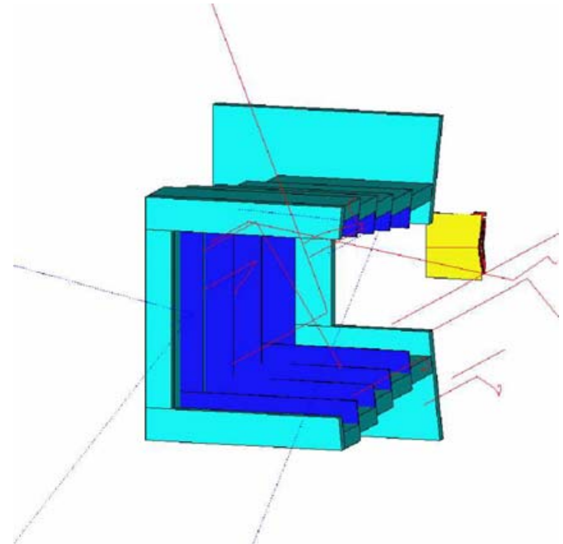
- 3D numerical model (GEANT3) of the collimator with detectors/foil

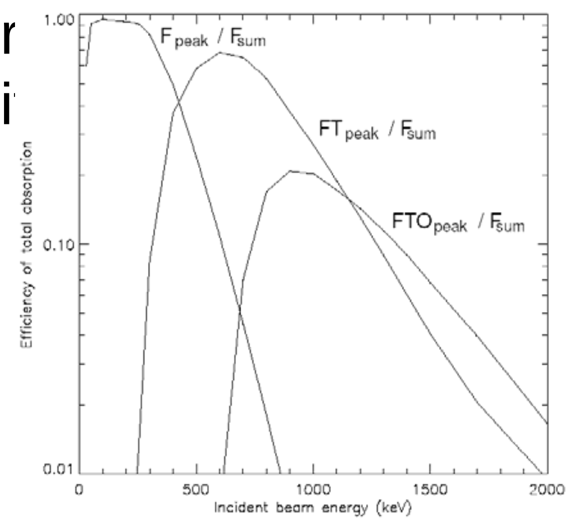


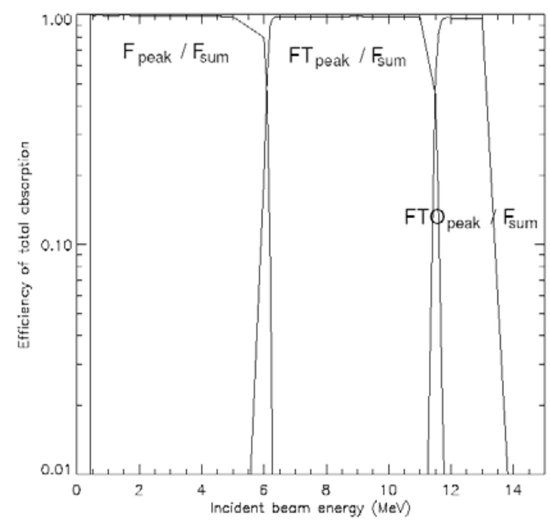
- Collimator baffle offers 42° × 23° rectangular full field-of-view
- Be-Co knife-edges intercept out-of-beam low-energy particles and reduce scattered light
- Aluminum housing shielding (0.5 mm) stops normally incident protons < 8 MeV and electrons < 400 keV
- Al/Polyimide/Al (*LUXÉL*) three layer foil (~1500Å/4μm/1500Å) absorbs protons < 350 keV

Telescope Response

- Monte-Carlo simulation
  - 3D ray tracings are performed: a clean electron-proton separation is obtained
  - Particles' angular distributions are determined ($27^\circ \times 14^\circ$ FWHM)
  - Efficiency plots of the electron-
    pr
    di

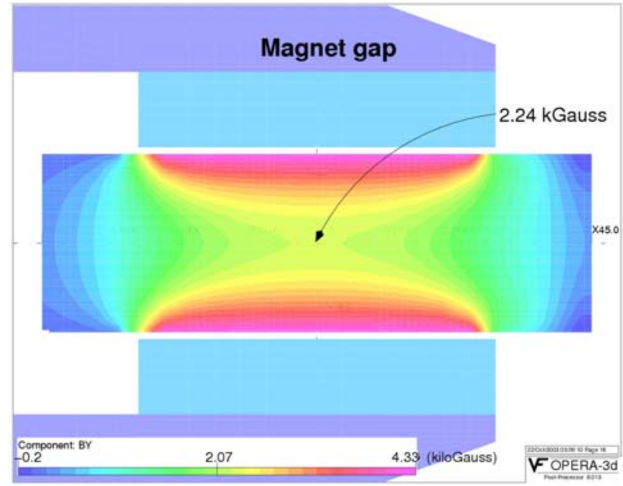


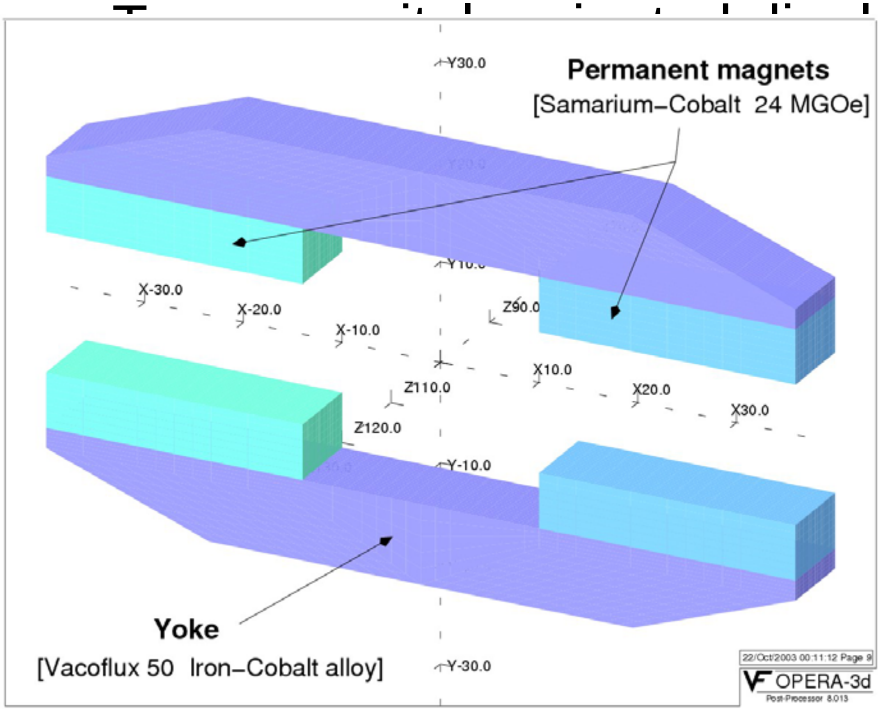


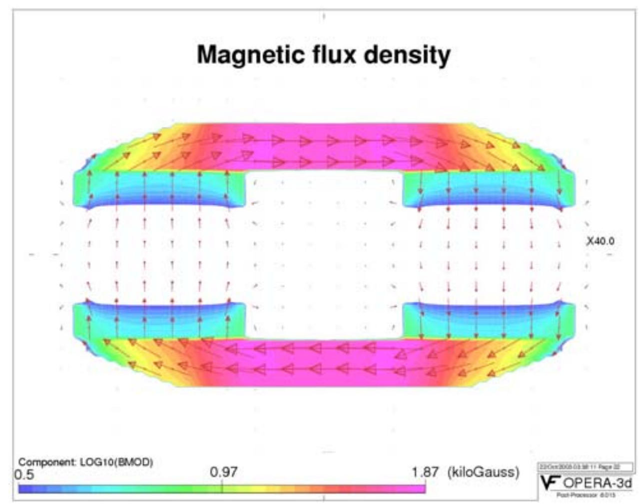


Magnet System

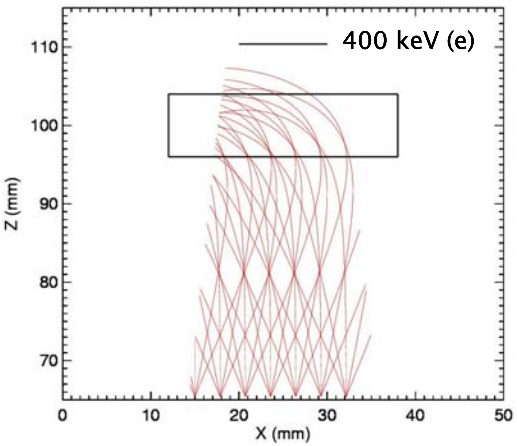
- Magnetic circuit design
  - 4 permanent magnets (*Dexter Magnetic Technologies*) + 2 yokes (*Vacuumschmelze, Germany*)

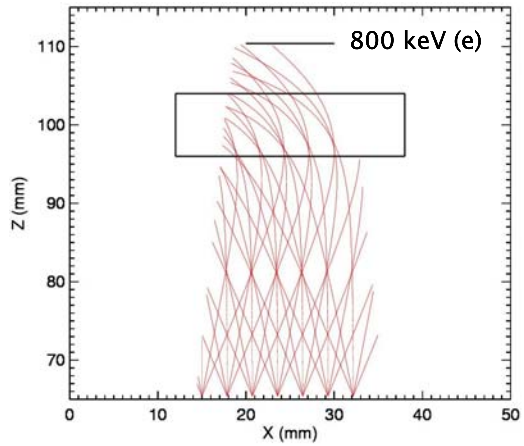


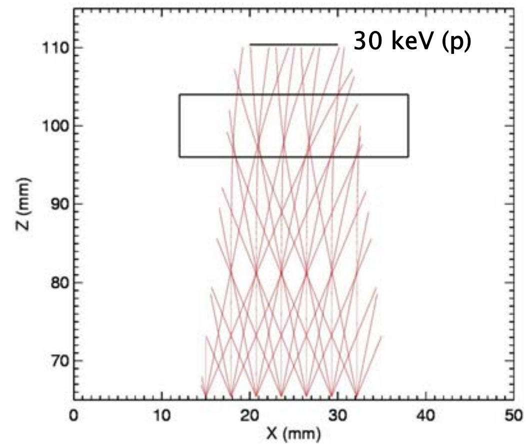


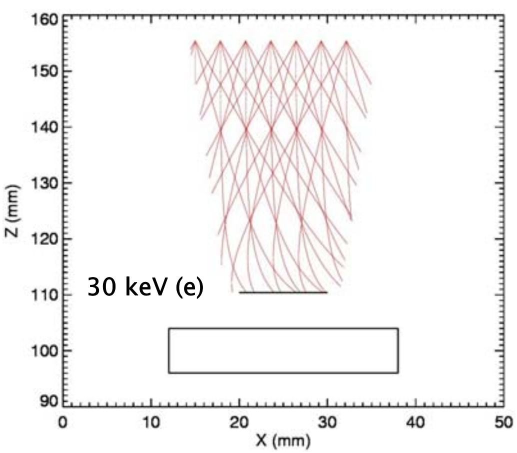


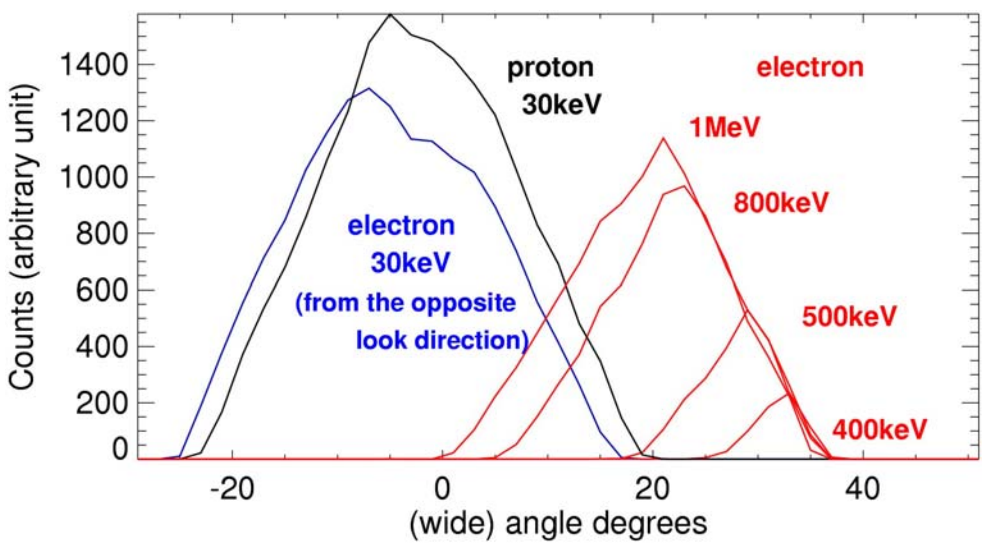
- Particle tracing





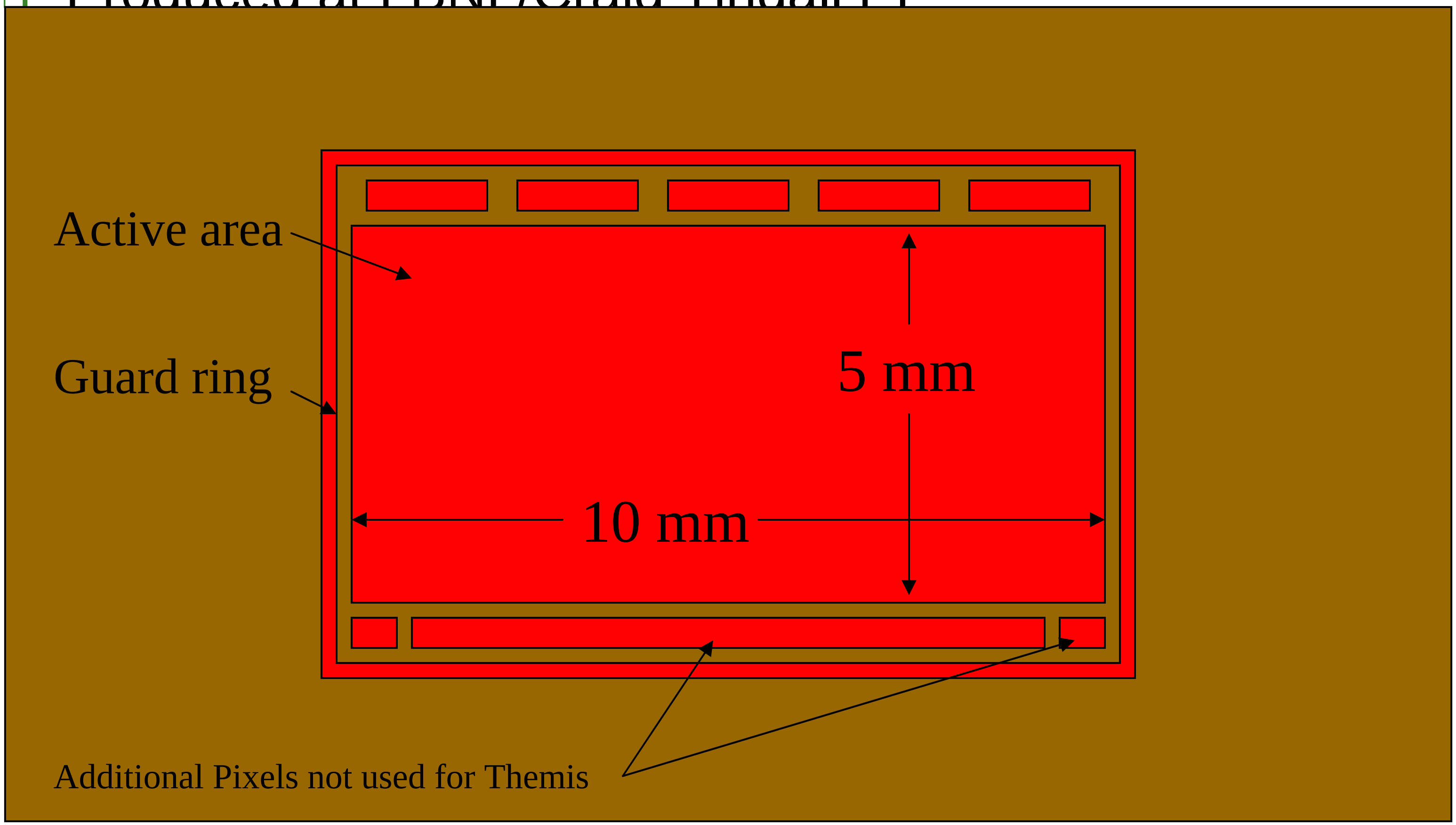




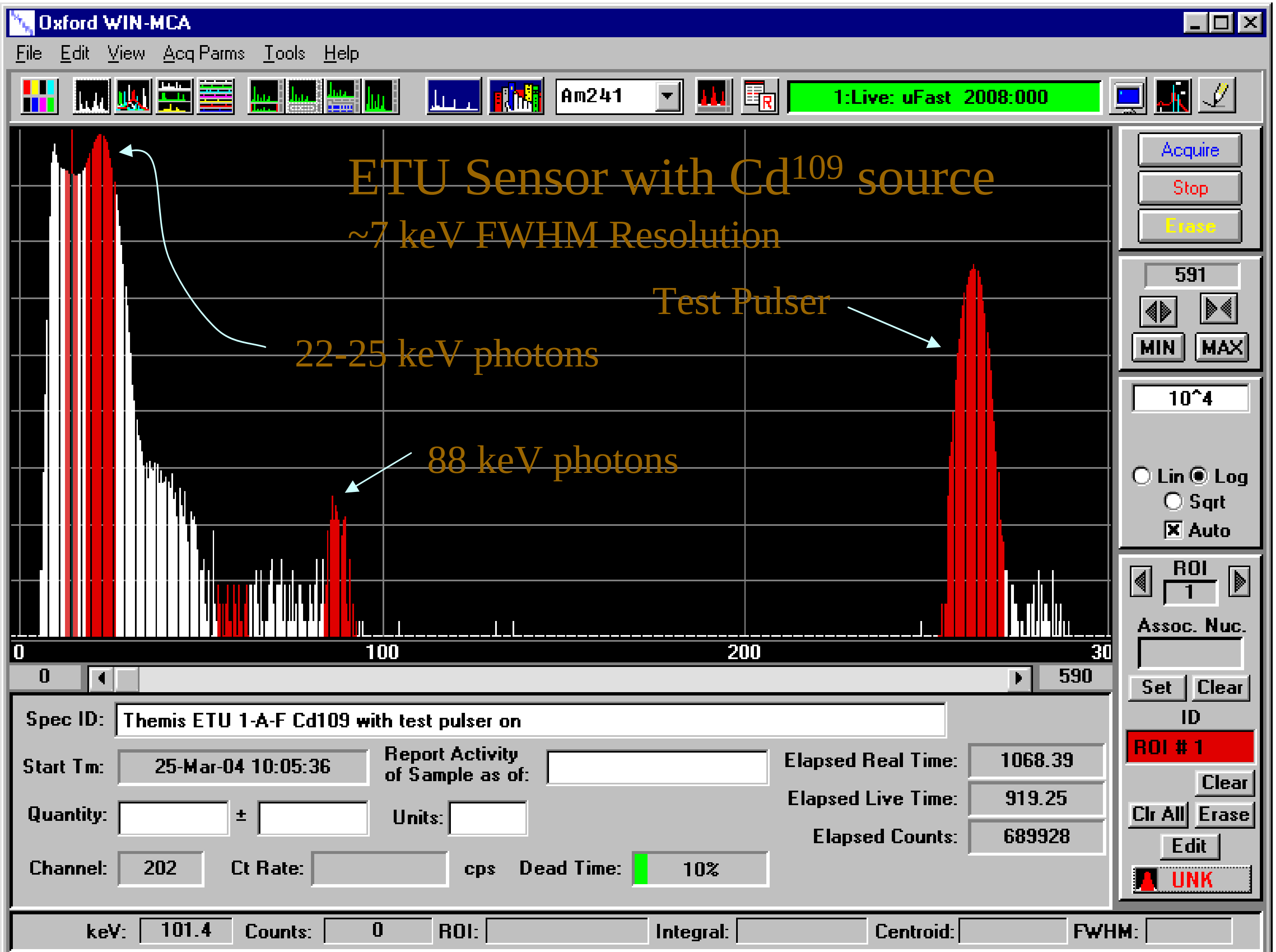


Detector Pixelation

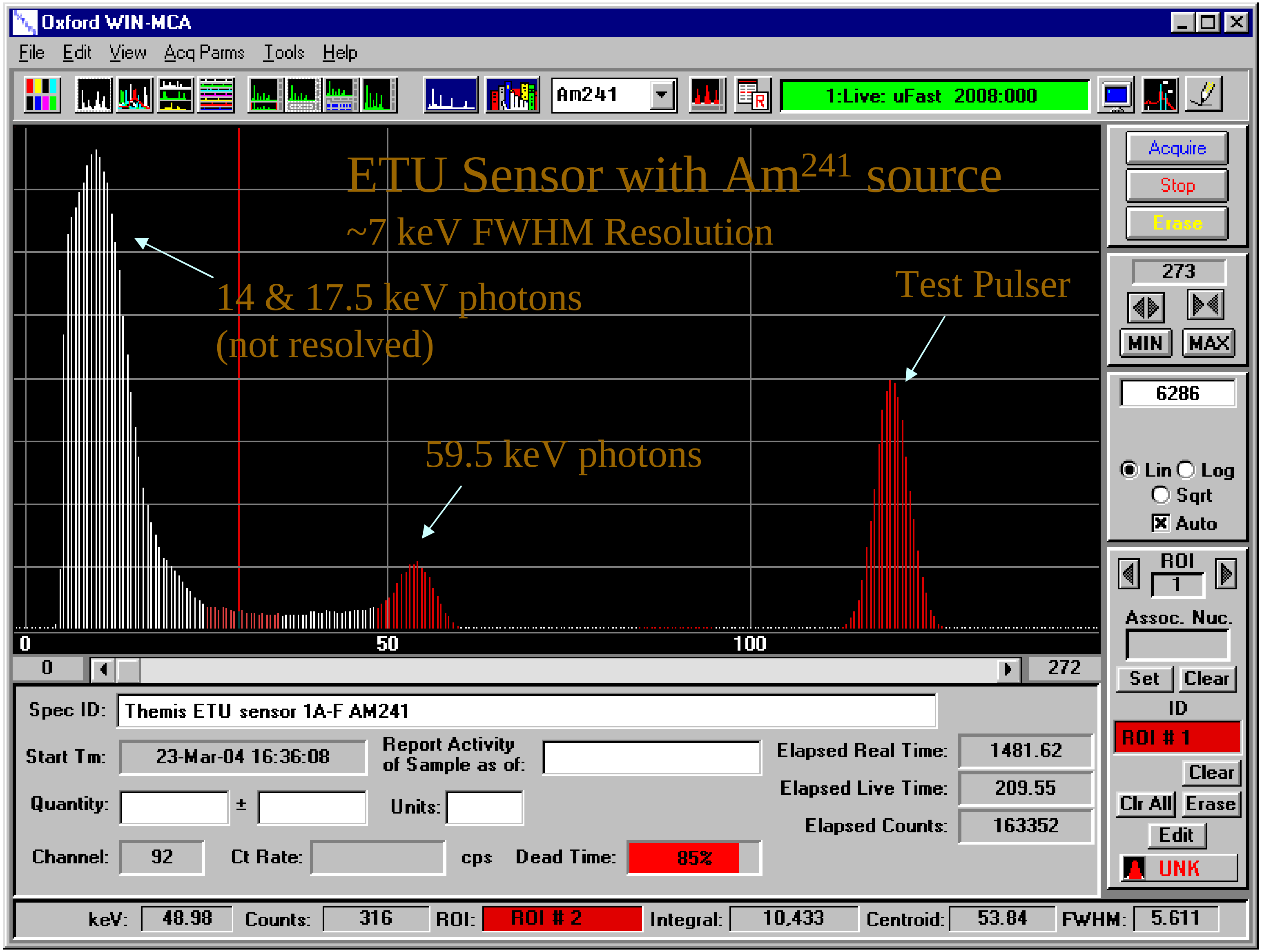
- Detectors similar to STEREO/STE
  - Produced at LBNL/Craig Tindall PI



ETU Sensor Testing



ETU Sensor Testing



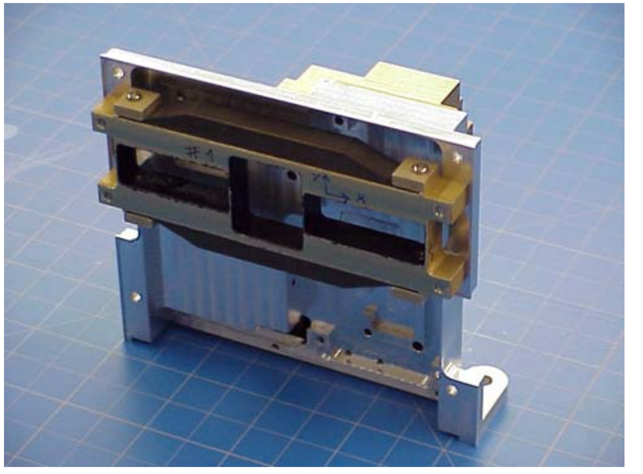
SST MECHANICAL

Robert K. Lee

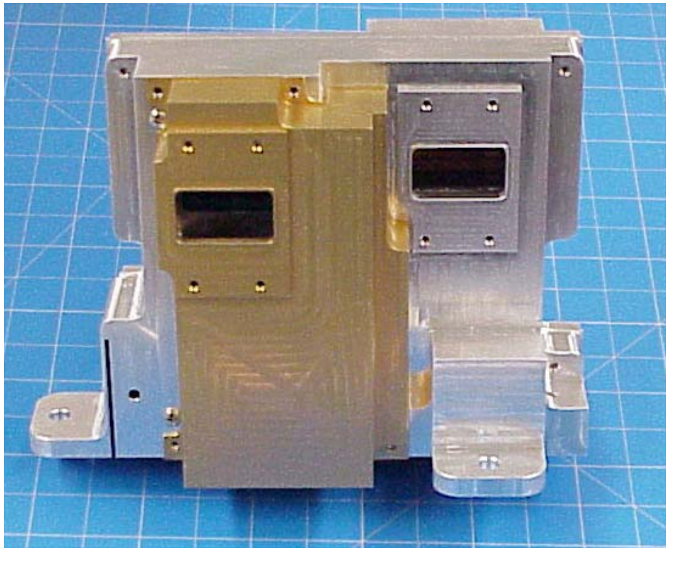
SST Mechanical Design

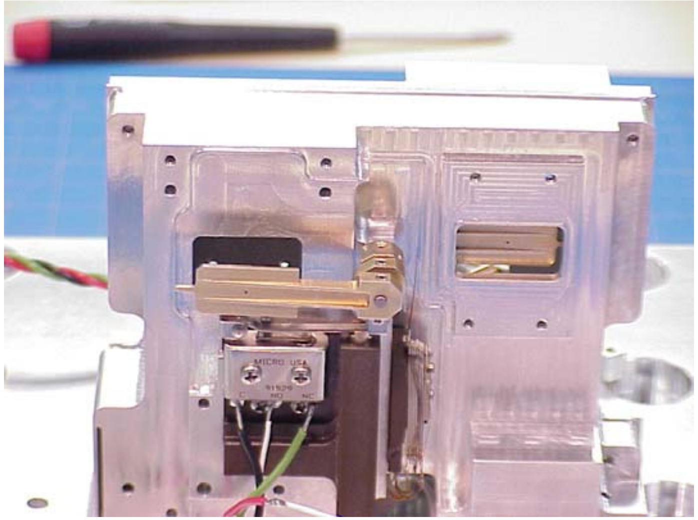
- Solid State Telescope (SST)
  - Mechanical Requirements
  - Mechanical Design
    - SST Sensor Unit Buildup
    - Sensor Unit Mounting Using Kinematic Flexures
    - Attenuator Actuation
    - Attenuator Control
  - Analysis Results
    - Attenuator Mechanism
    - Modal Analysis
    - Quasi-Static Acceleration
  - Attenuator Mechanism Cycling Test
  - Electronics and Cabling
  - Mass Summary

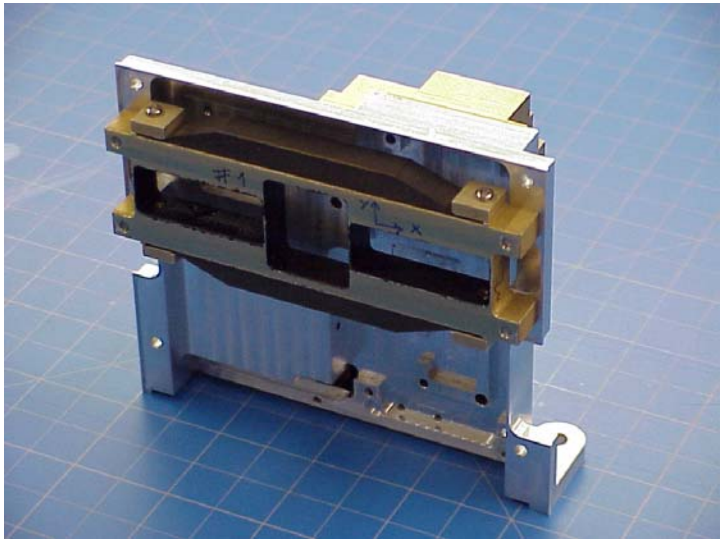
SST Mechanical Design

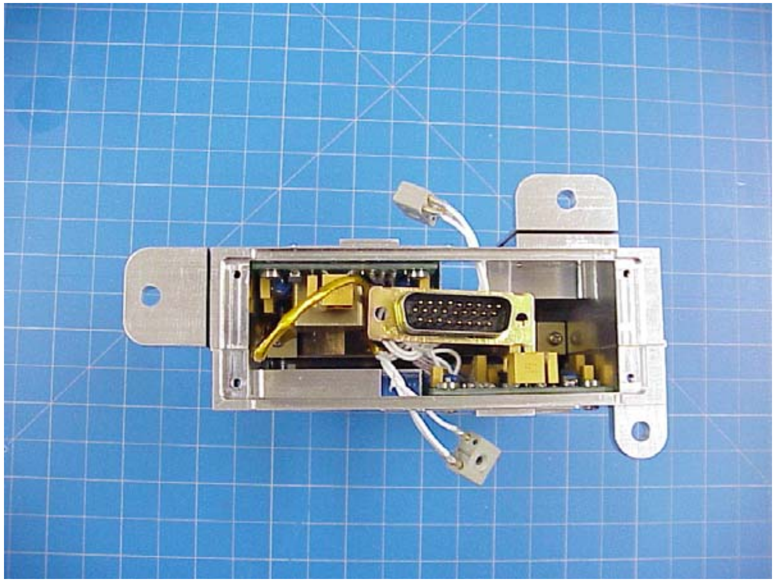


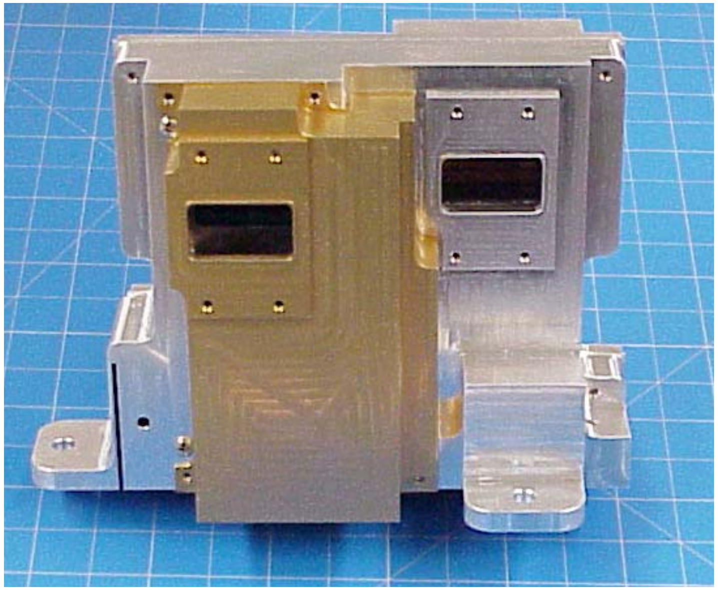
- SST Sensor Unit Buildup
  - DFE Board Subassembly
  - Magnet-Yoke Subassembly
  - Attenuator-Actuator Subassembly
  - Collimators
  - Support Structure
  - Bi-Directional FOV
- Sensor Unit Mounting Using Kinematic Flexures
- Attenuator Actuation
  - Linear Actuators
  - Position Switches
- Attenuator Control
- Electronics and Cabling
  - DAP Board
  - Harness
- Mass Summary

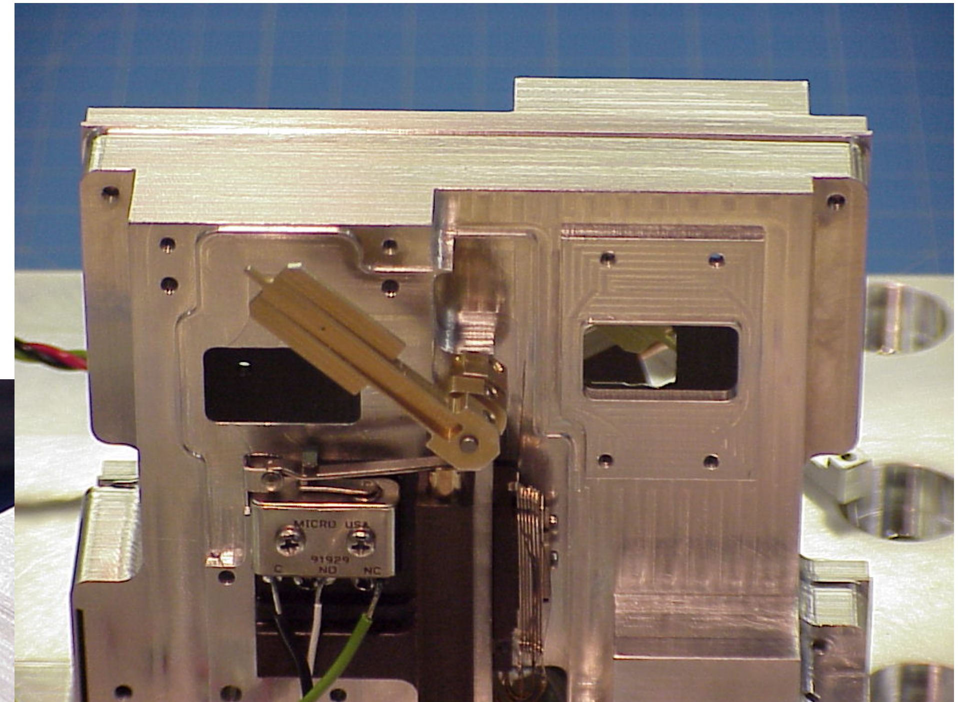


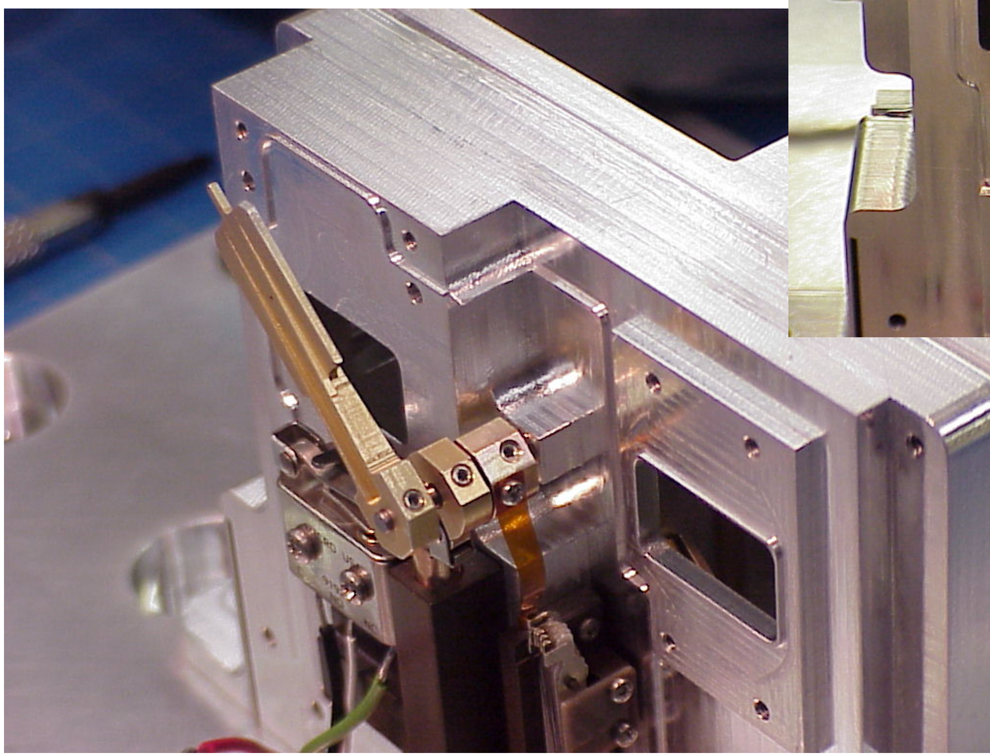




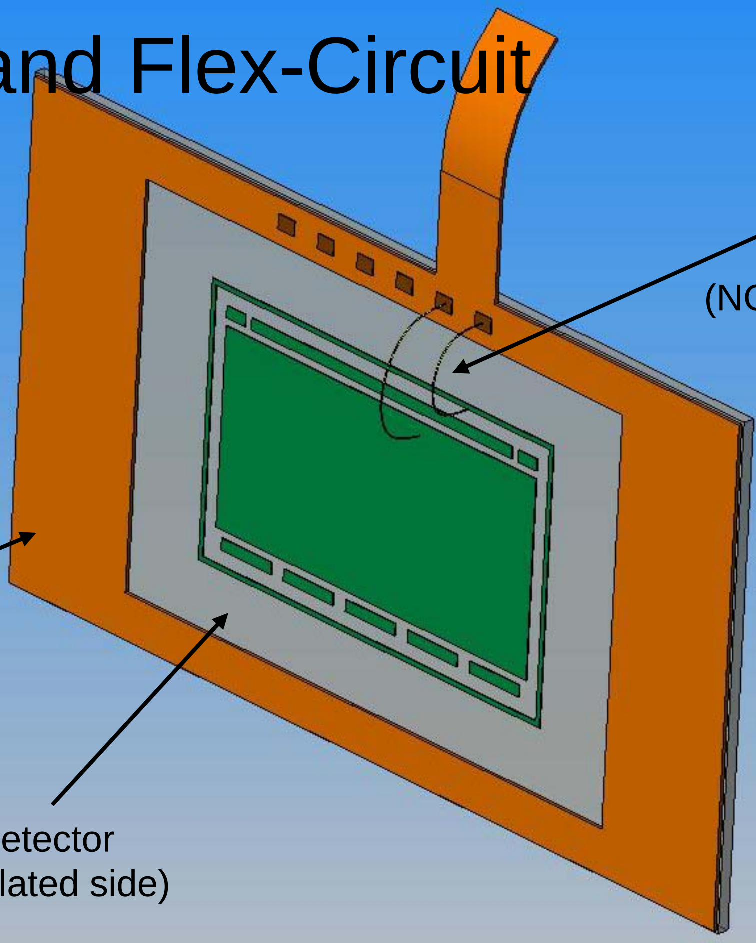





MICRO USA
91929
C NO NC

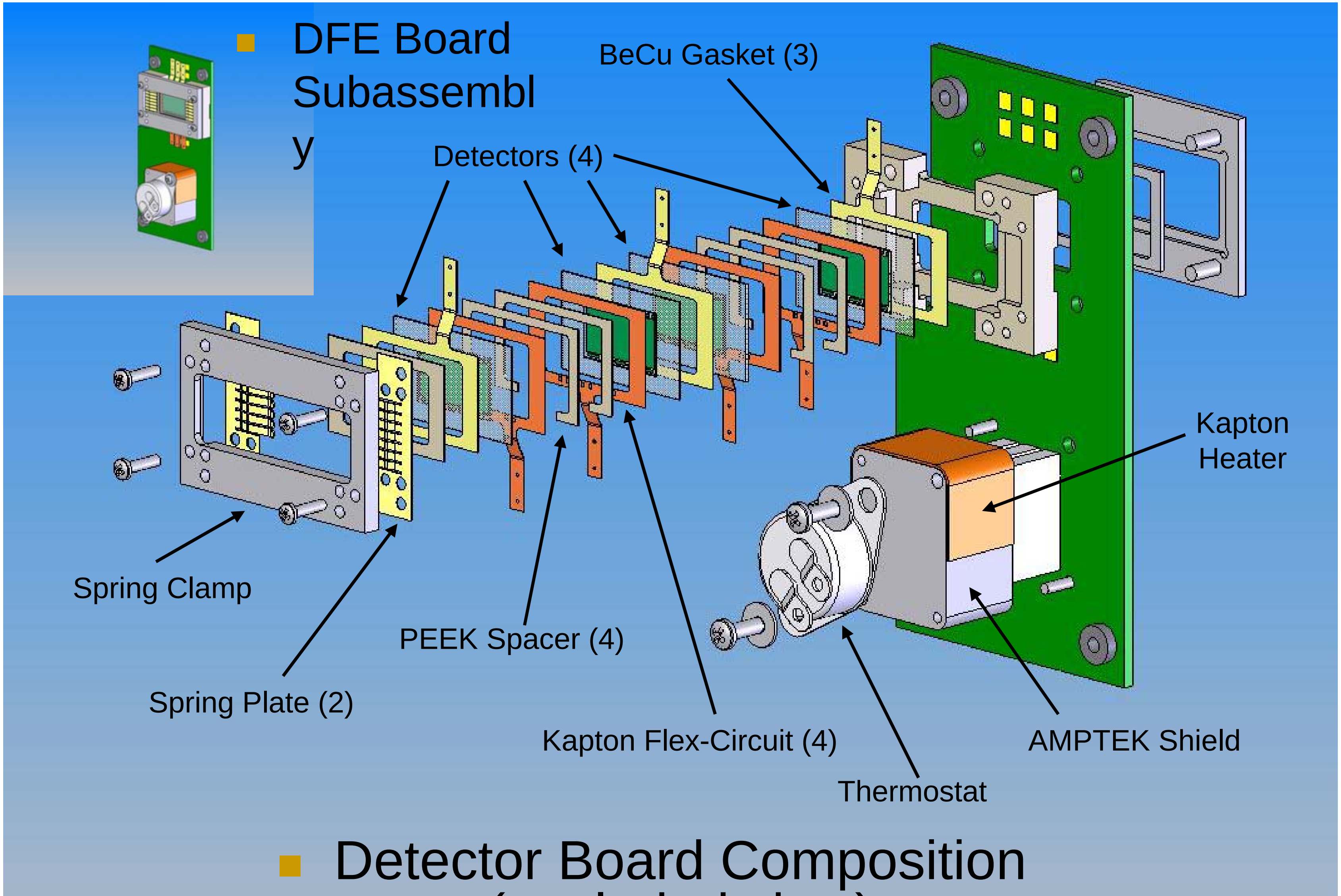


- Typical Electrical Connection Between Detector and Flex-Circuit



SST Mechanical Design

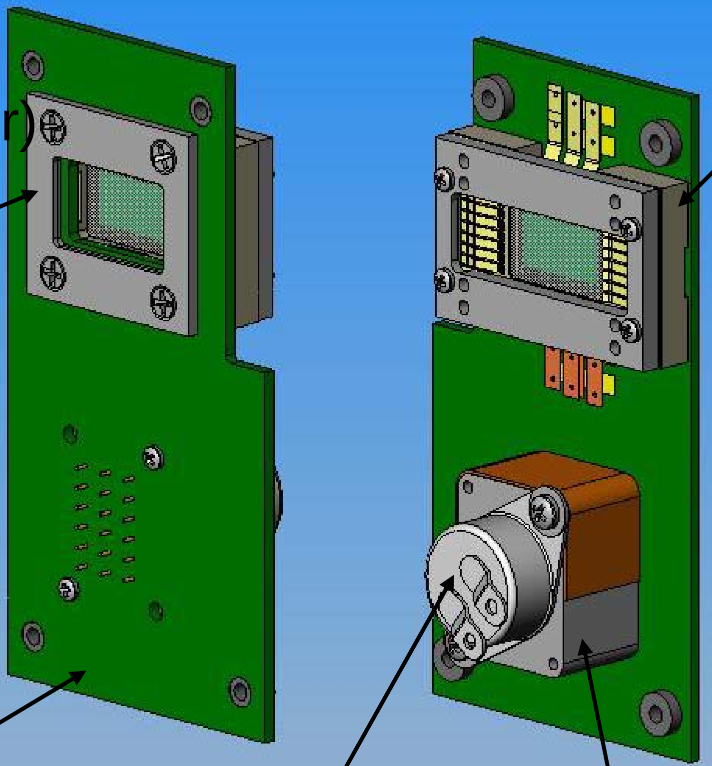
- DFE Board Subassembl y



- Detector Board Composition (exploded view)

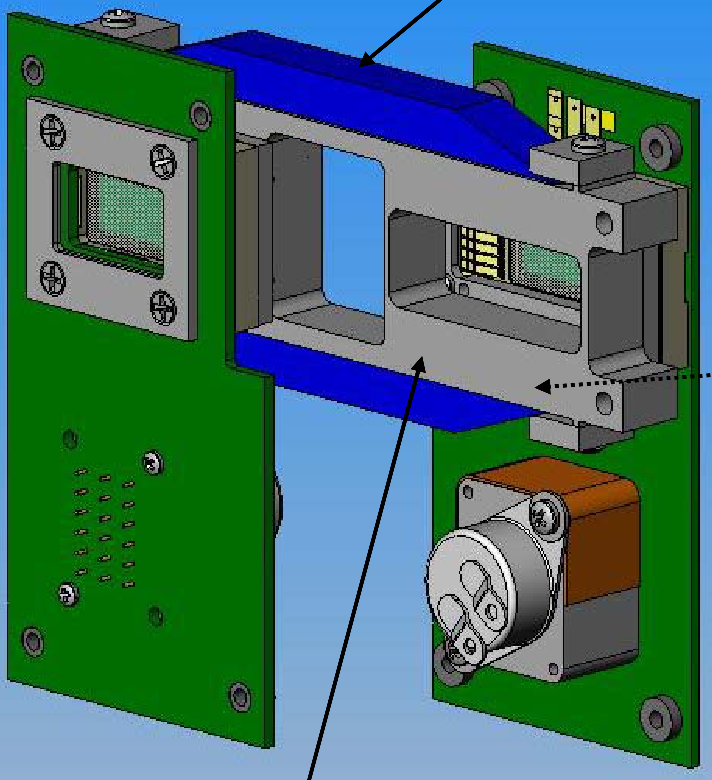
SST Mechanical Design

- DFE Board Subassembly Relative Positions
- (2 per sensor)



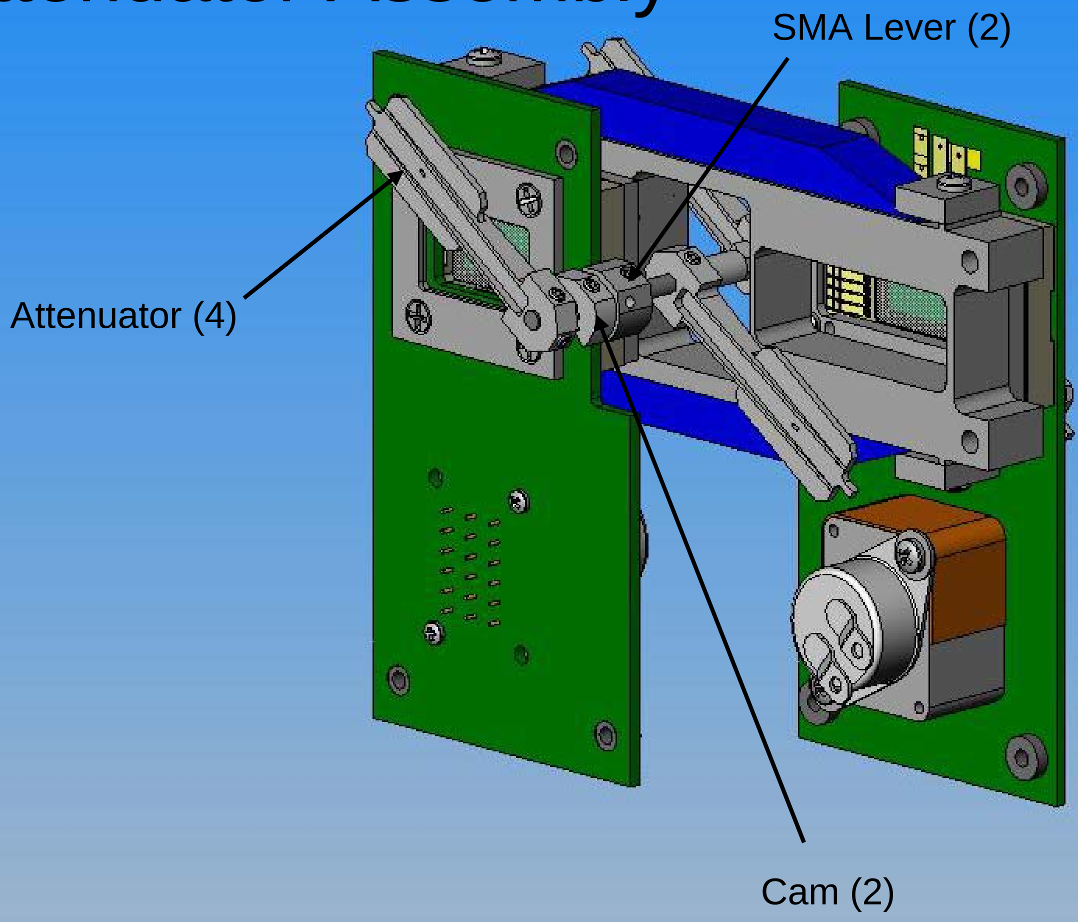
SST Mechanical Design

- Magnet-Yoke Assembly

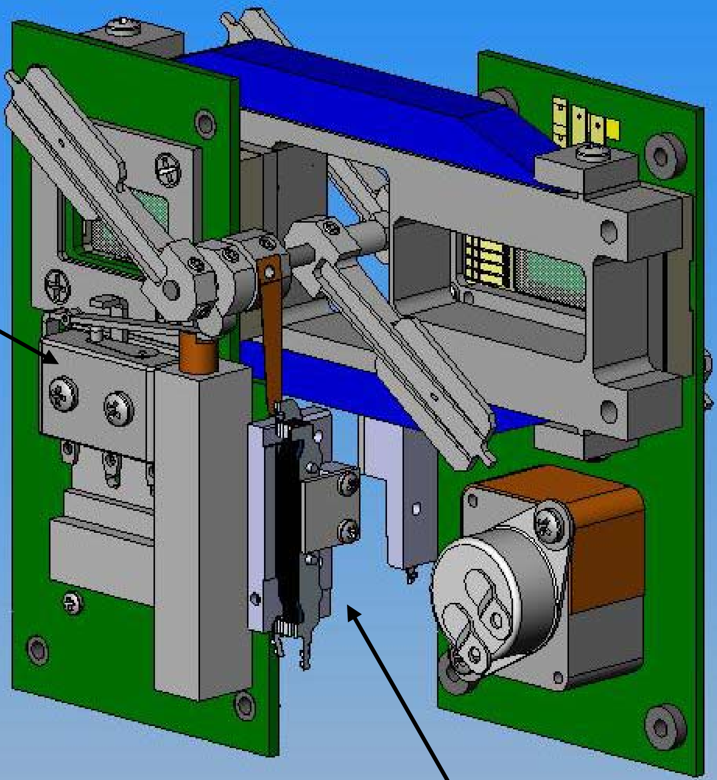


SST Mechanical Design

- Attenuator Assembly

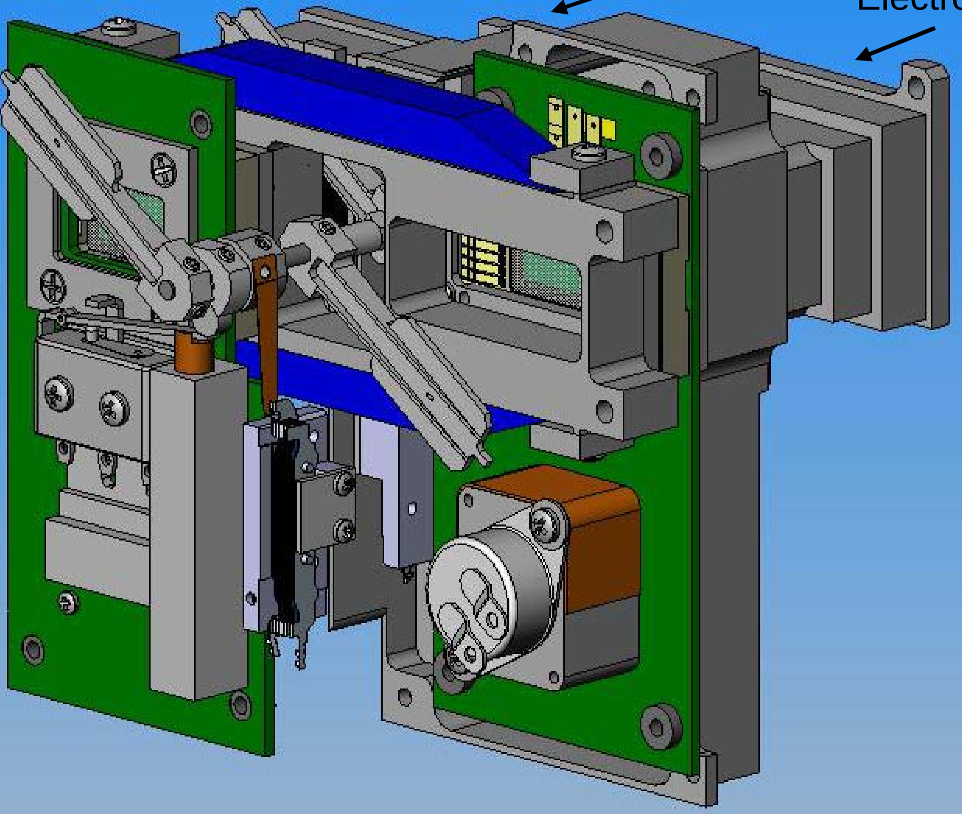


- Actuators and Position Switches



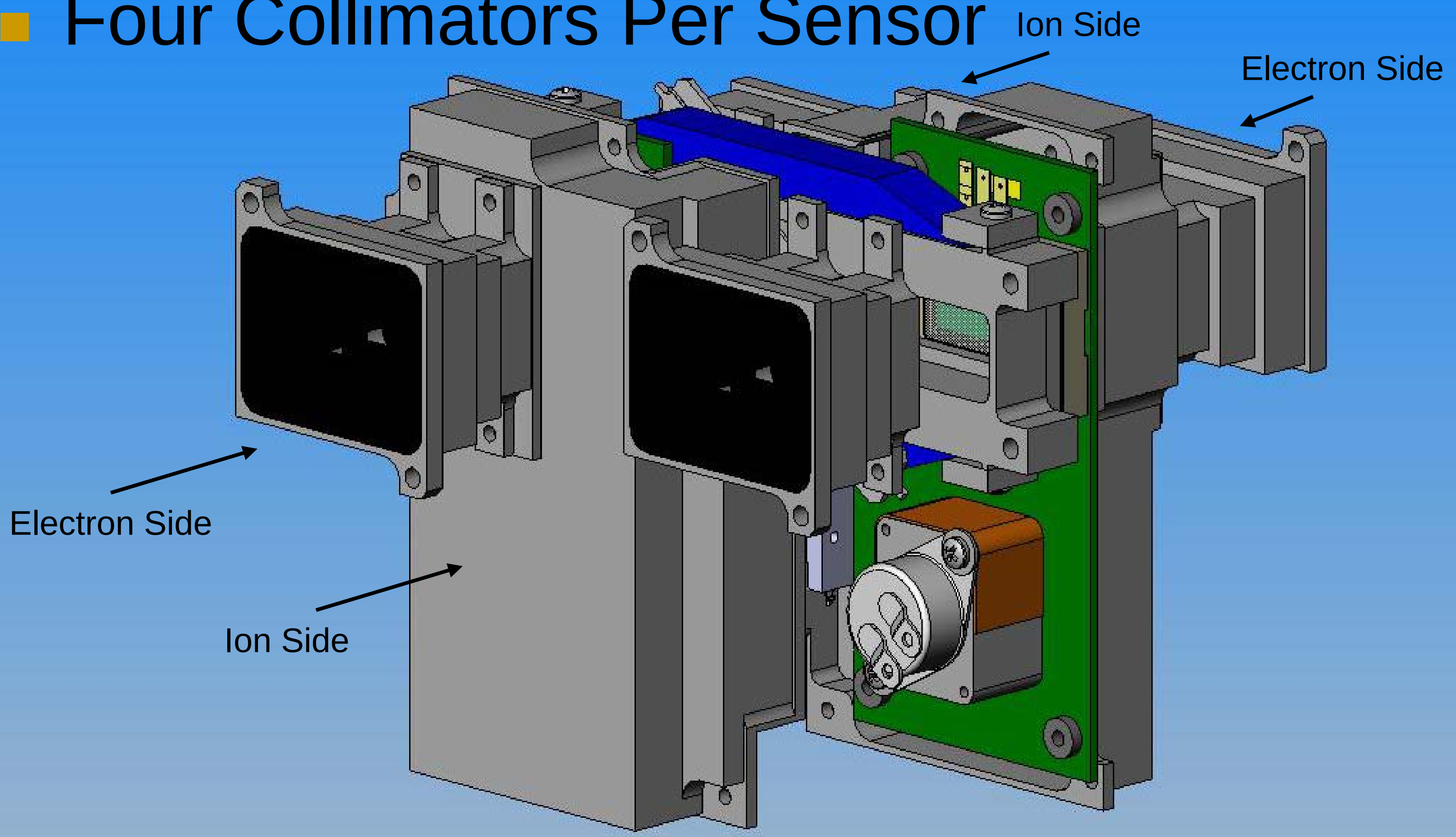
SST Mechanical Design

- Two Collimators Per Side



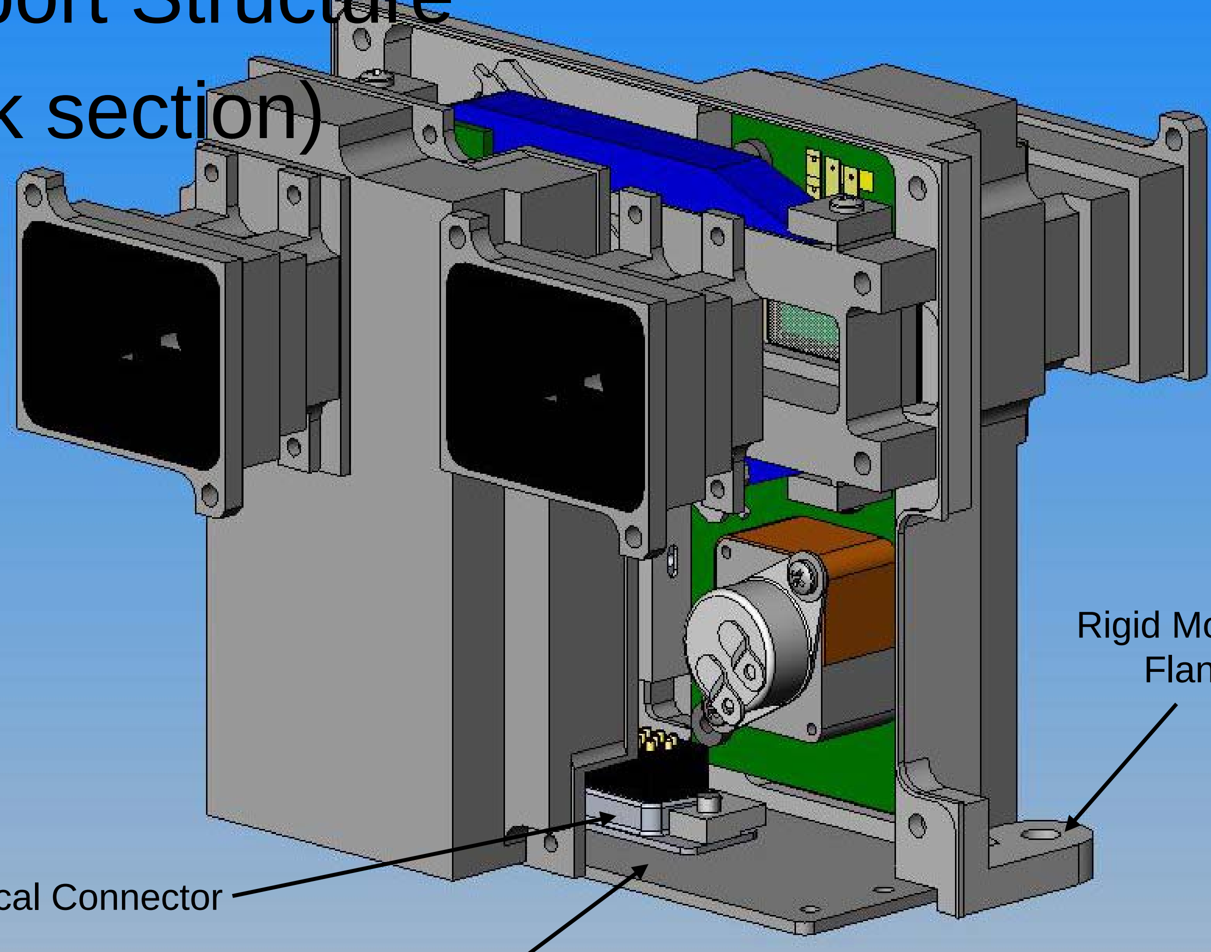
SST Mechanical Design

- Four Collimators Per Sensor



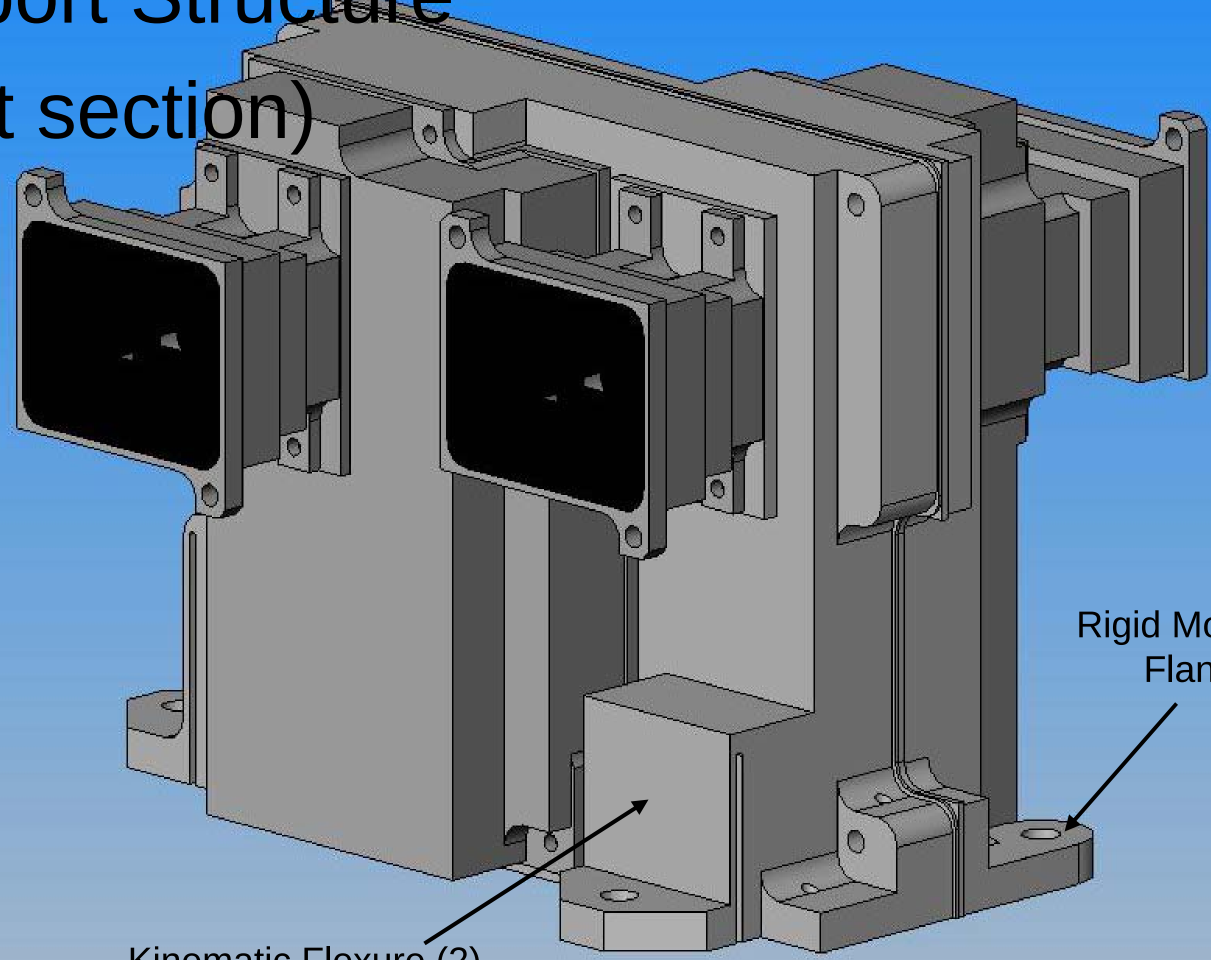
SST Mechanical Design

- Support Structure
- (back section)



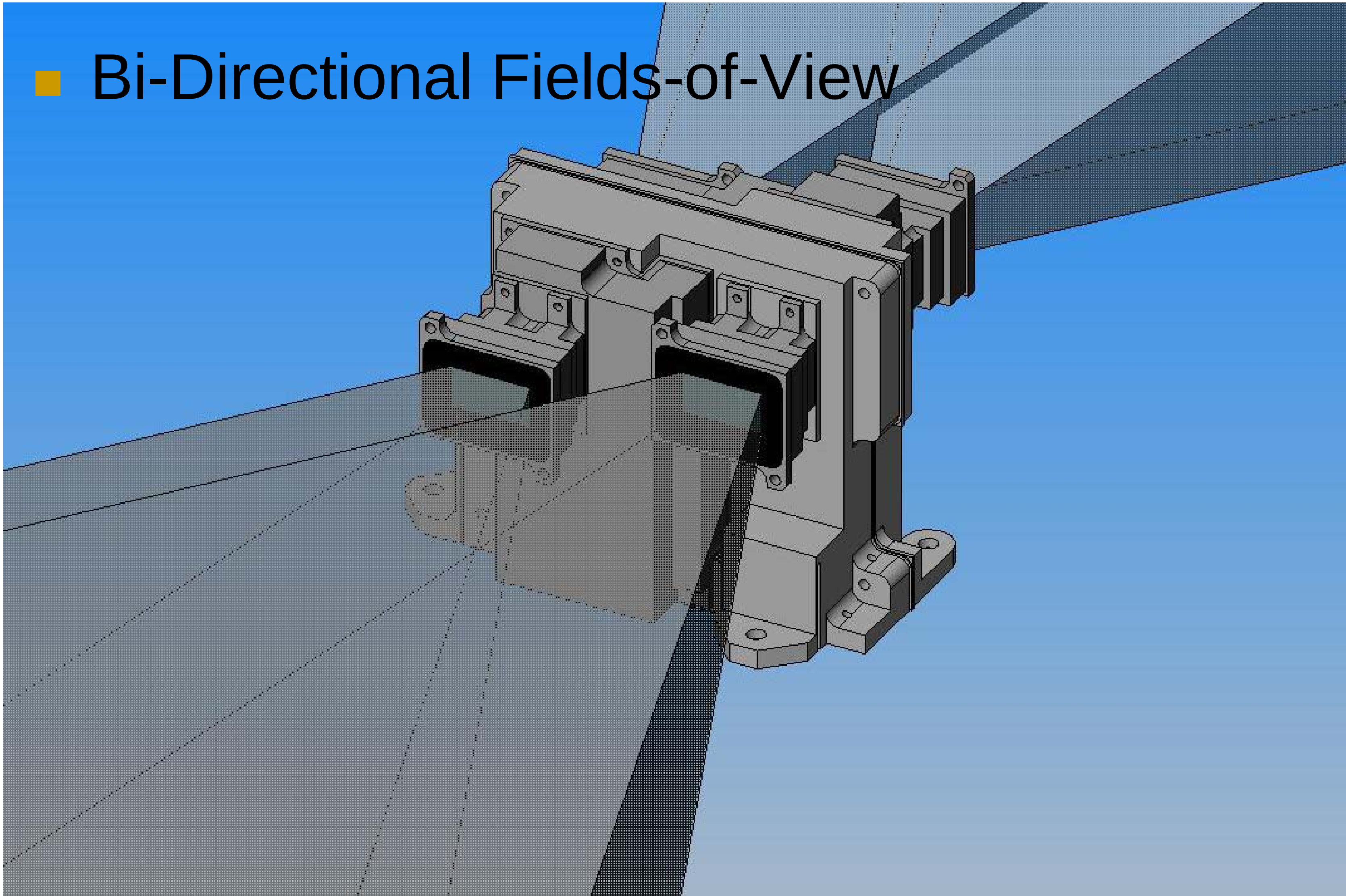
SST Mechanical Design

- Support Structure
- (front section)



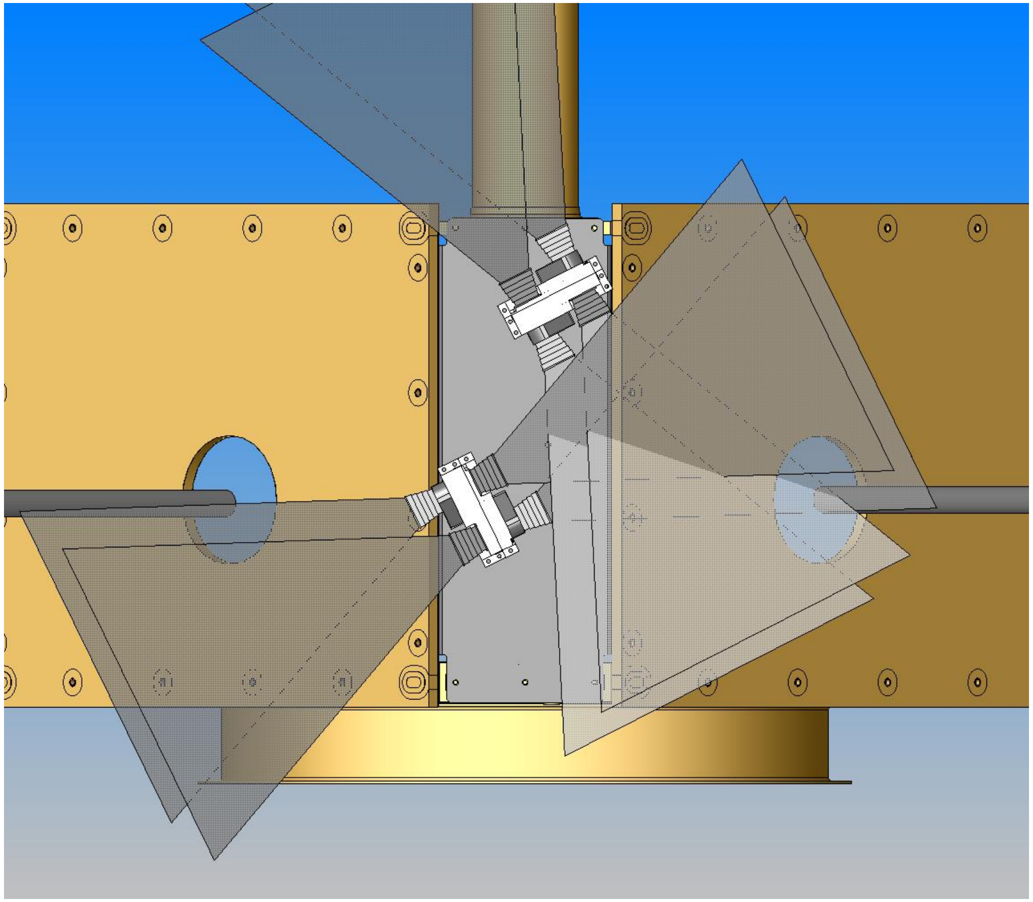
SST Mechanical Design

- Bi-Directional Fields-of-View

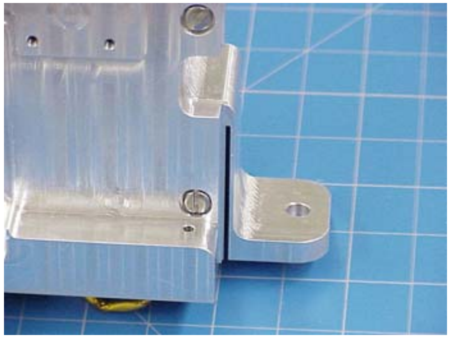


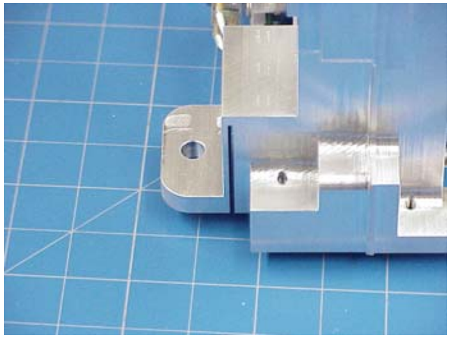
SST Mechanical Design

- Sensor Orientation Relative to Spacecraft Bus

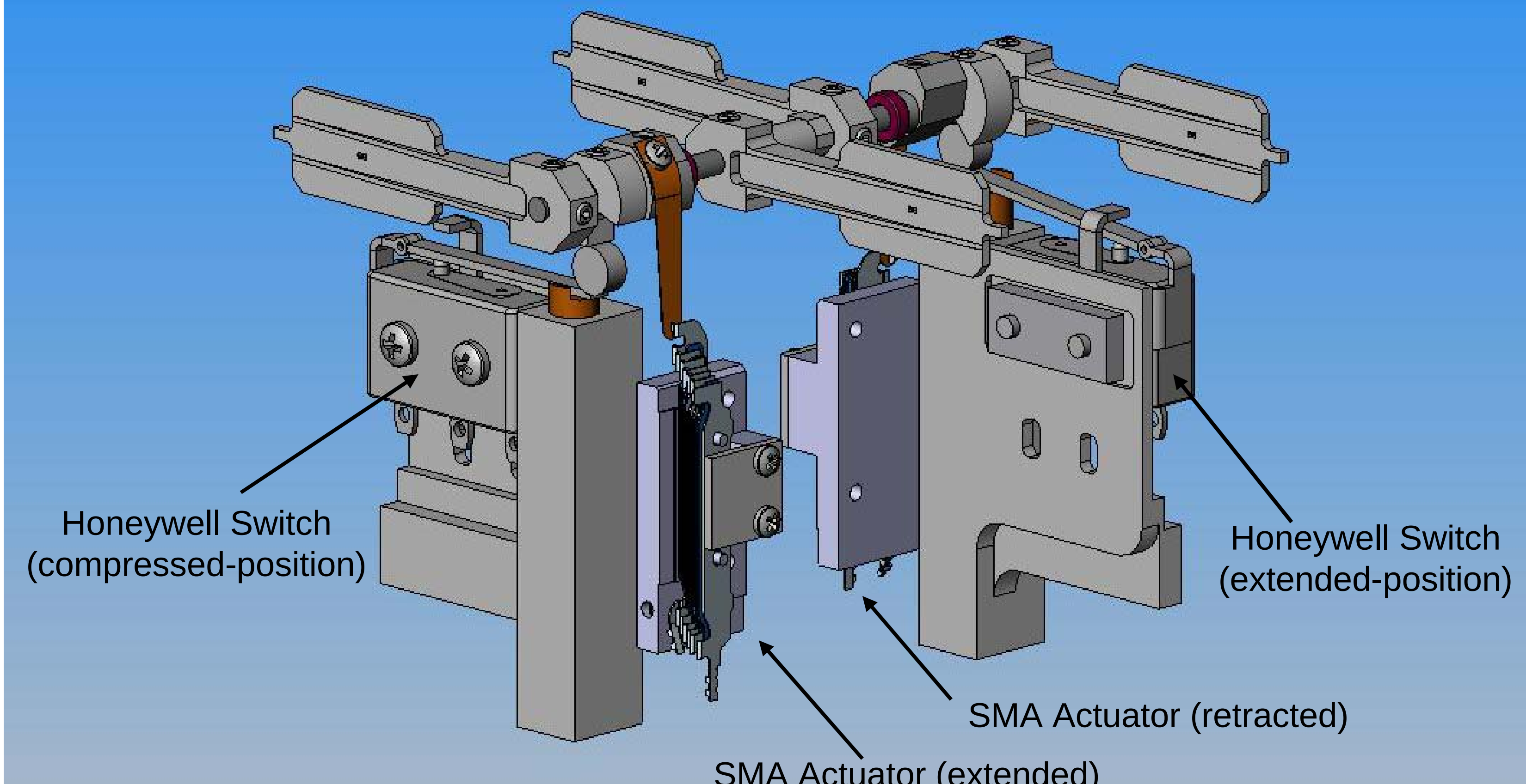


- Sensor Unit Mounting Using Kinematic Flexures
  - Each sensor mounted to spacecraft panel at three points
    - One rigid mounting flange
    - Two mounting flanges with kinematic flexures
  - Allows relative motion due to CTE differences between sensor structure and spacecraft panel
    - Predicted expansion differential along instrument axes with 120 ºC temperature gradient:
      - X-Axis: 0.006” (0.15 mm)
      - Y-Axis: 0.013” (0.33 mm)
  - Flexure dimensions sized to keep maximum bending stresses below 6061-T6 yield strength
    - Factor of Safety (F.S.) > 1.4 per NASA-STD-5001



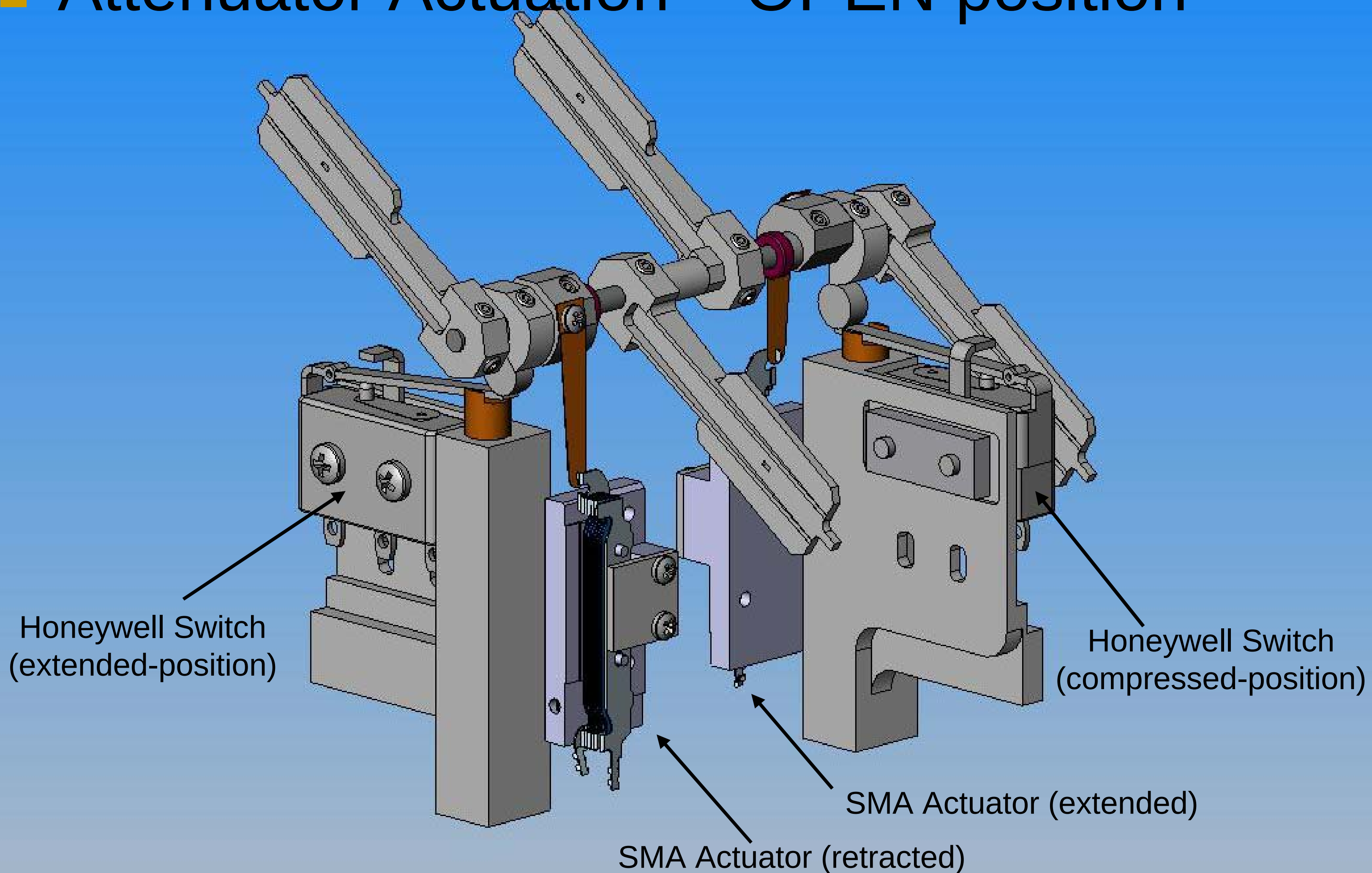


- Attenuator Actuation – CLOSED position

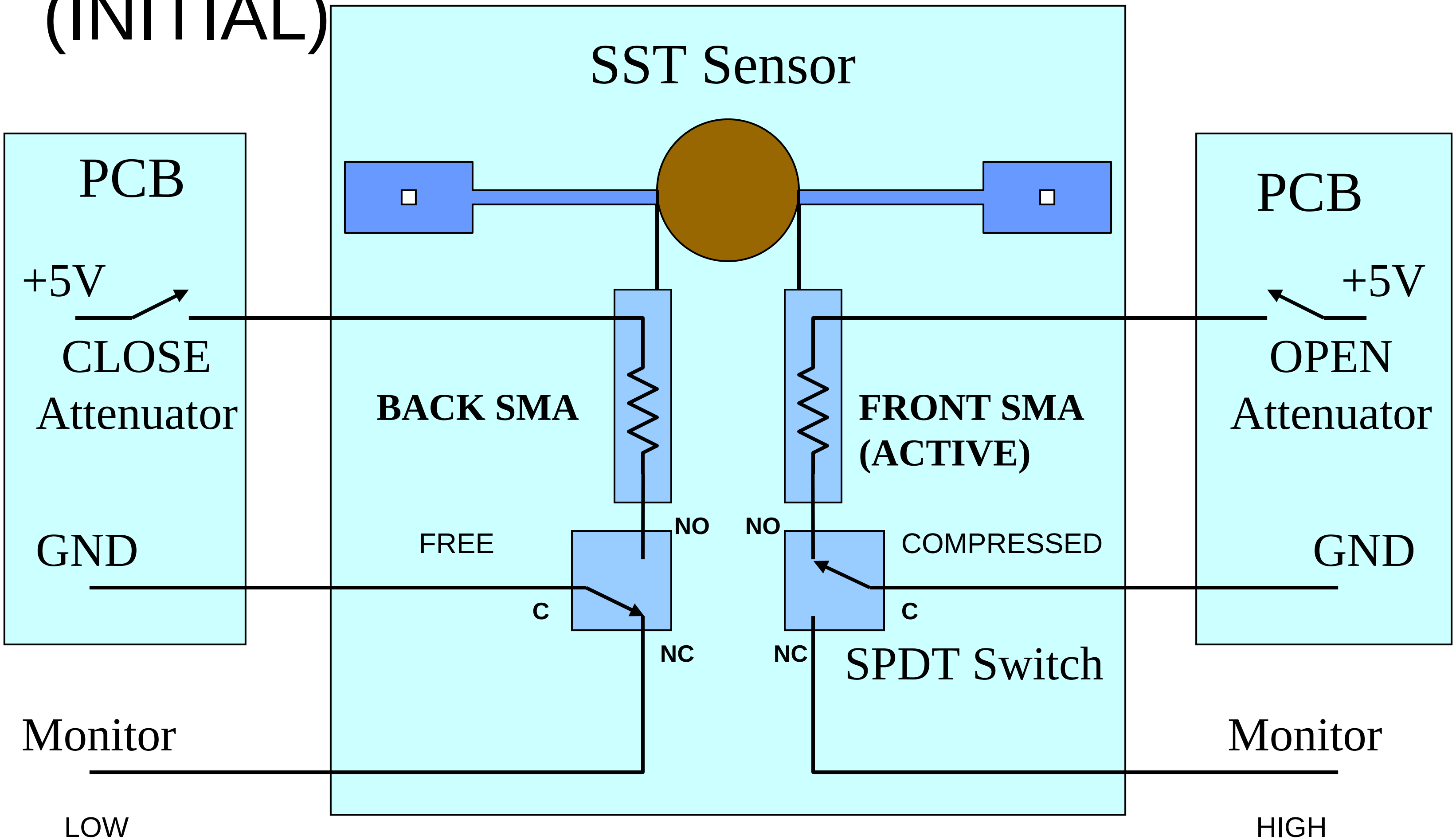


SST Mechanical Design

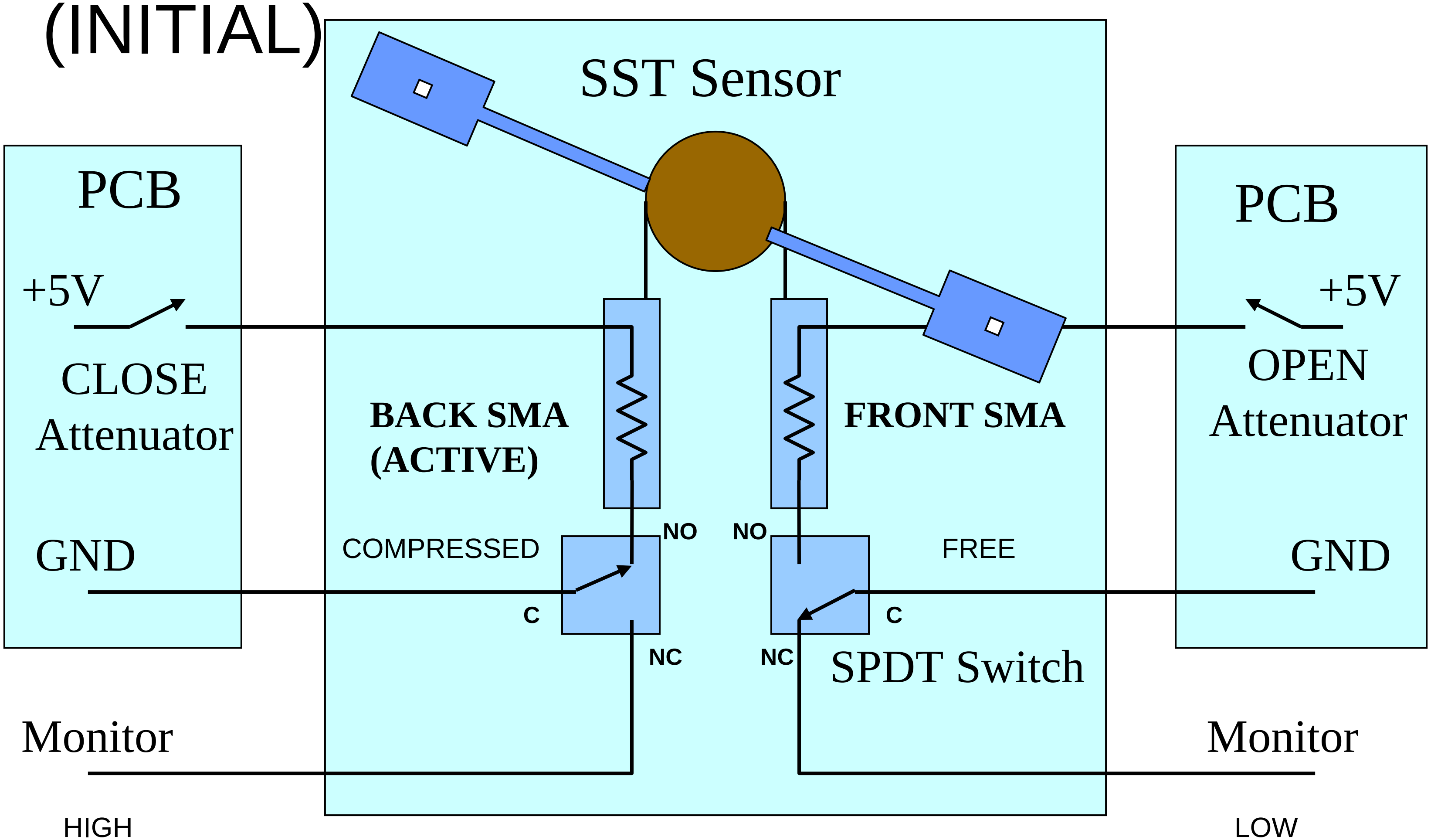
- Attenuator Actuation – OPEN position



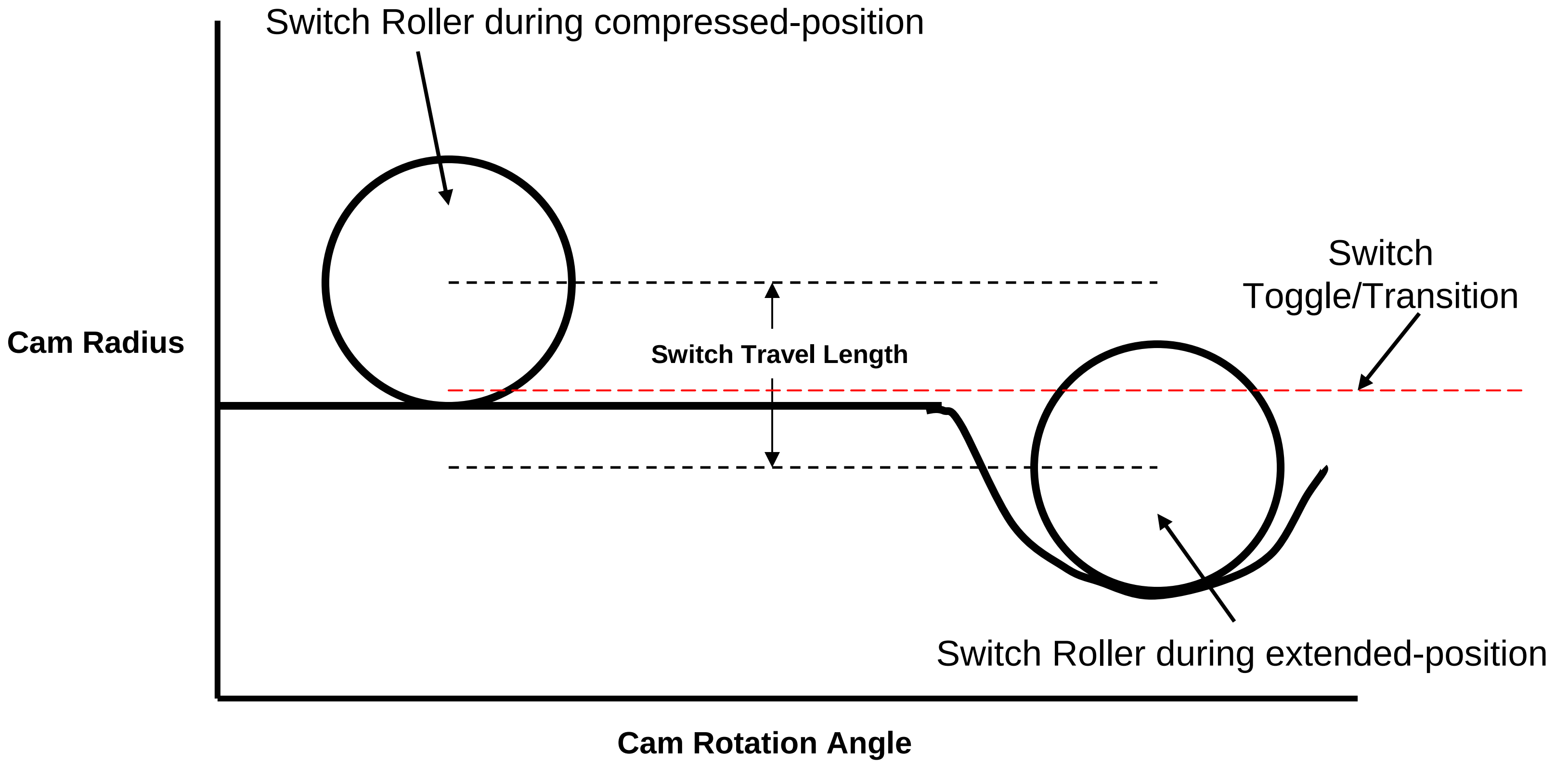
- Attenuator Control – CLOSED to OPEN (INITIAL)



- Attenuator Control – OPEN to CLOSED (INITIAL)

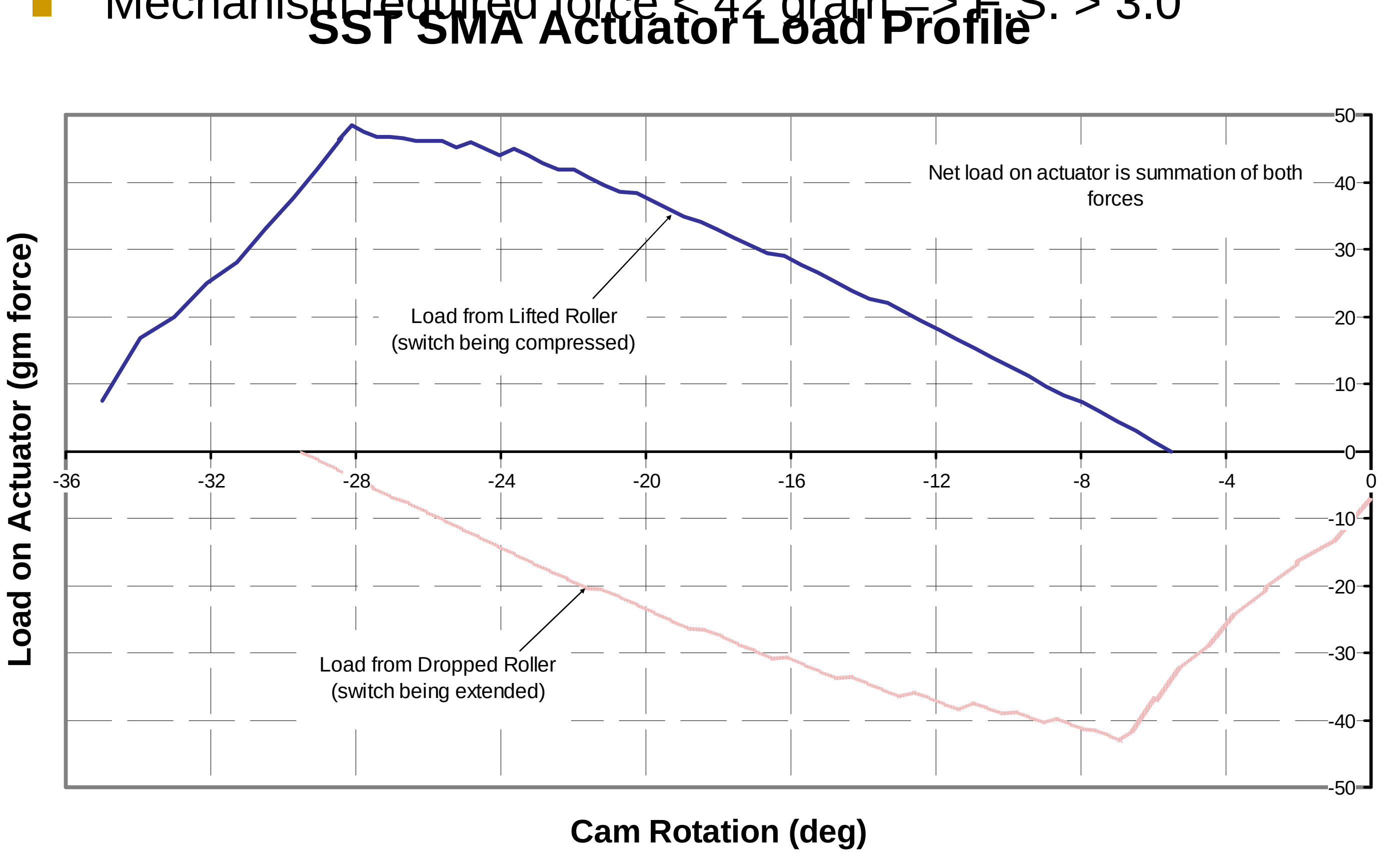


- Attenuator Control – Switch Activation

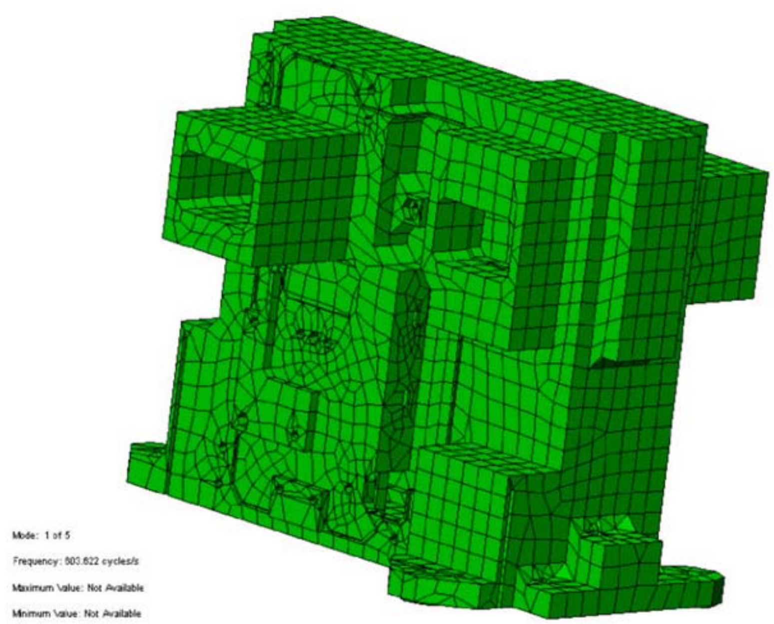


Note: Sketch NOT drawn to scale

- Analysis Results - Attenuator Mechanism
  - SMA pull-force of 125 grams
    - Mechanism required force < 42 gram => F.S. > 3.0



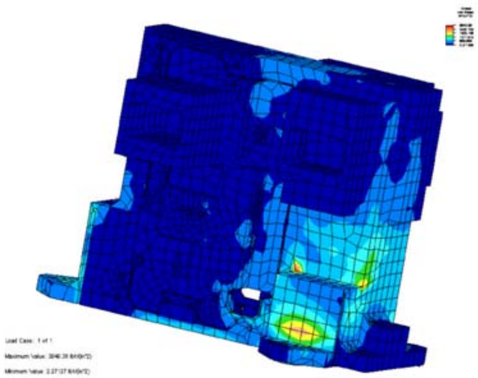
- Analysis Results - Modal Analysis
  - ALGOR FEMPRO Version 13.30
    - First Mode @ 600 Hz
    - Second Mode @ 1200 Hz
    - Third Mode @ 1550 Hz
  - Modal f um levels



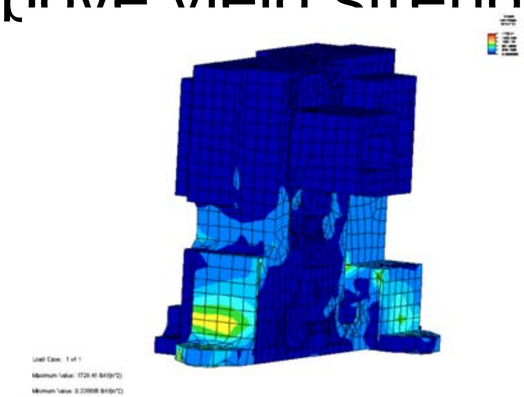
Finite element model with mass simulators

- Analysis Results – Quasi-Static Acceleration
  - ALGOR FEMPRO Version 13.30
  - 40g load along each instrument axis
    - X-axis maximum stress: 3040 psi
    - Y-axis maximum stress: 1730 psi
    - Z-axis maximum stress: 1440 psi
  - F.S. > 1.4 above yield strength for 6061-T6

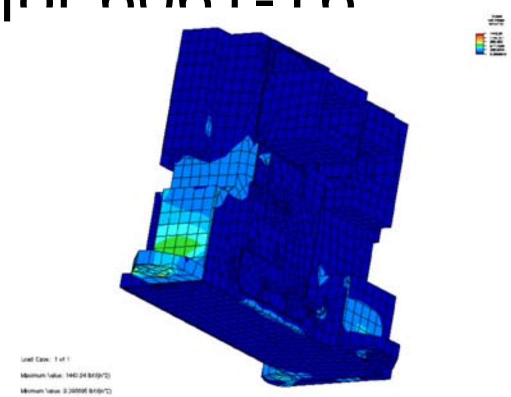
X Axis Load



Y-Axis Load

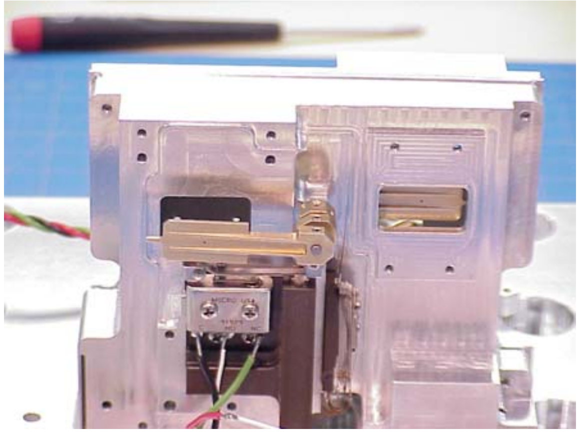


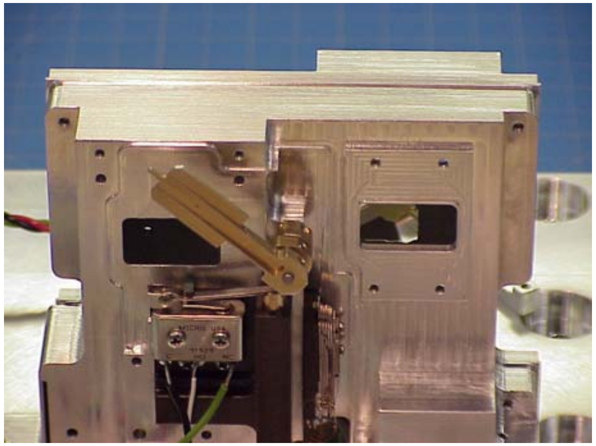
Z-Axis Load



SST Mechanical Design

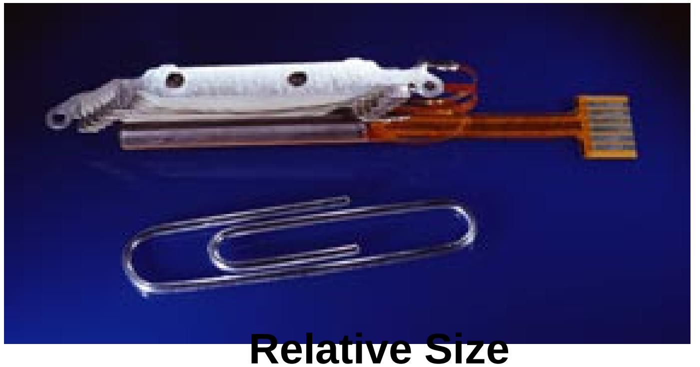
- Attenuator Mechanism Cycling Test
- Run over 40,000 cycles
- Pivot shaft (303 Stainless) showed significant abrasion damage on contact surfaces with sapphire bearings
  - Subsequent shafts to be treated as follows:
    - Titanium Nitride (TiN) coating to increase hardness
    - Tungsten Disulfide (WS_2) coating for dry film lubrication
- Required SMA stroke reduced from 3.5 mm to 3 mm for additional operating margin (maximum stroke: 4 mm)
- Mechanism test will be performed again with modified components on ETU (late April 2004) with minimum target of 150,000 cycles
  - Target values based on 10 times expected number of actuations on-orbit
  - Cycle counting will not be necessary for flight components





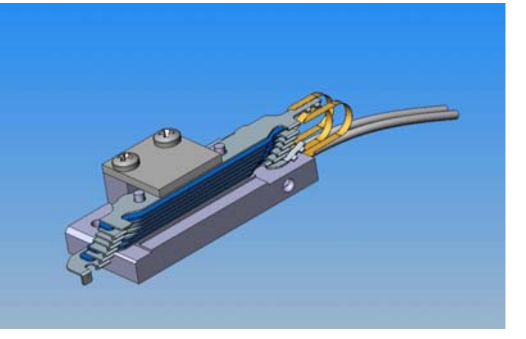
SST Mechanical Design

- Linear Actuators
  - Shaped Memory Alloy (SMA) actuator
  - Single direction 125 gram pull-force
    - Required force < 42 gram => F.S. > 3.0
  - Operating temp range: -70°C to +75°C

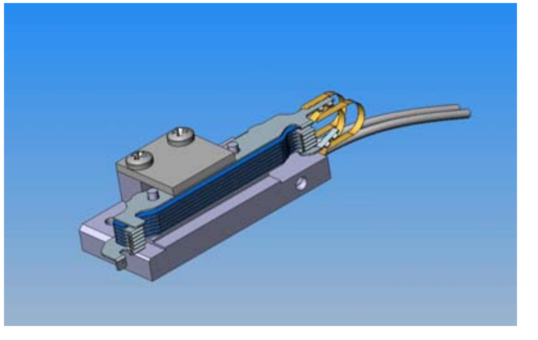


Relative Size
(commercial model shown)

Extended Position

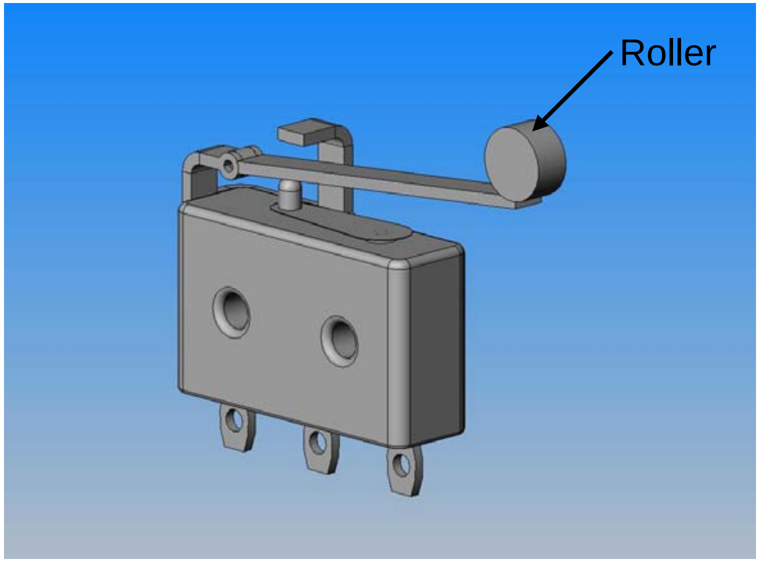


Retracted Position

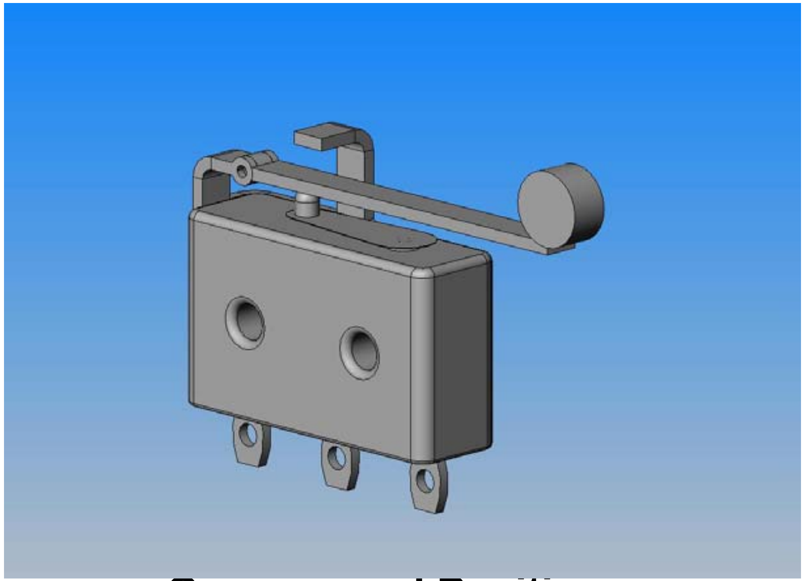


SST Mechanical Design

- Position Switches
  - Honeywell miniature hermetically sealed switches
  - Single-Pole-Double-Throw (SPDT)
  - Operating temperature range: -65°C to +121°C
  - Exceeds MIL-S-8805 shock and vibration requirements



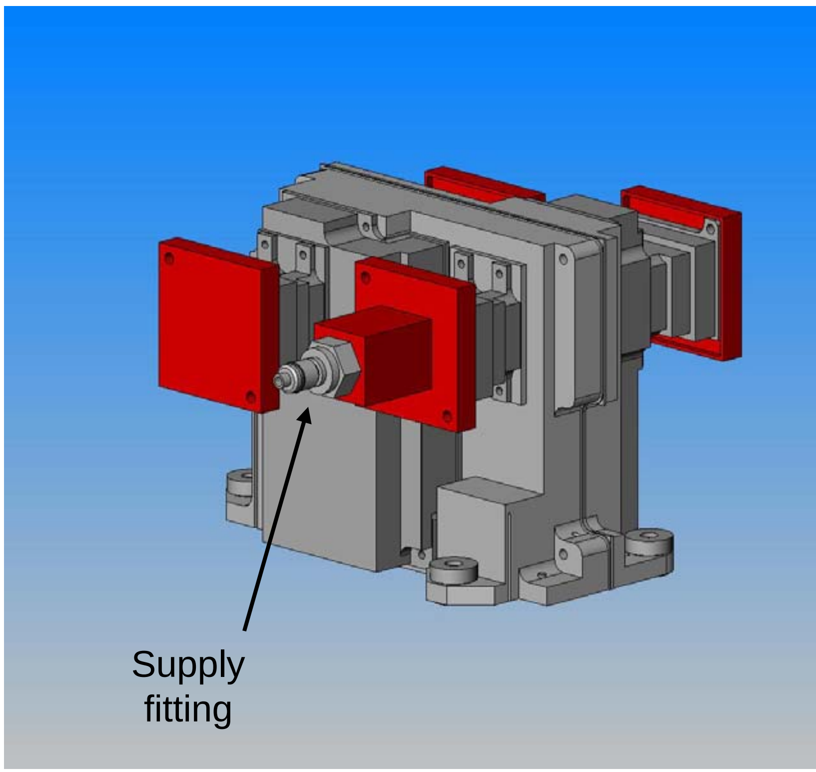
Extended Position

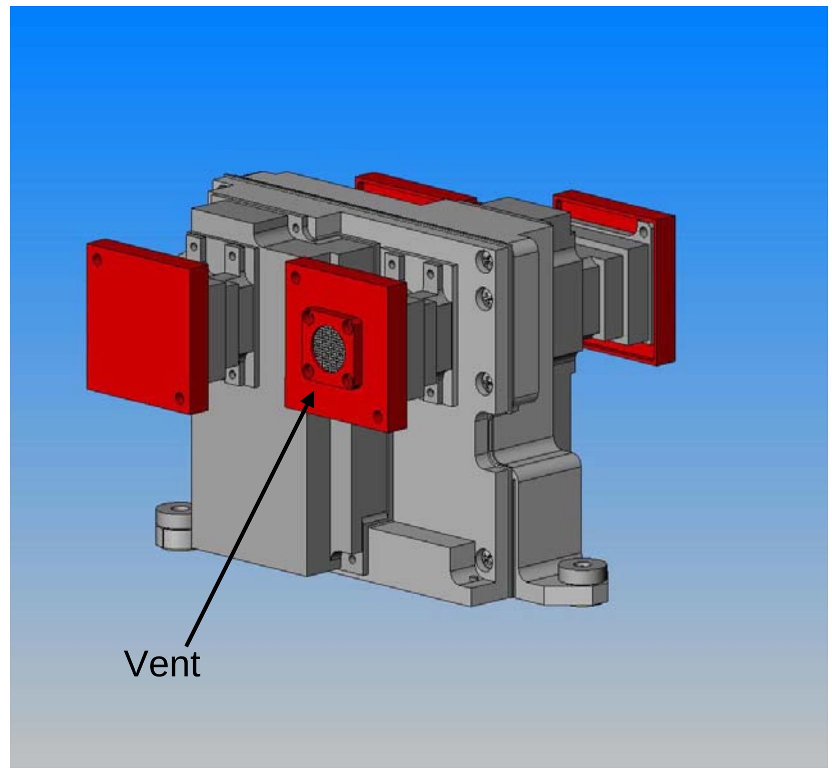


Compressed Position

SST Mechanical Design

- Nitrogen Purge Connection
  - Nitrogen line is connected to SST purge fitting during pre-flight operations to purge instrument interior
  - Gas supplied at 5 psig





SST Mechanical Design

- Electronics and Cabling
  - DAP Board
    - Located within IDPU
    - Type 6U card
    - Radiation shielded with 5mm of aluminum
    - Will be discussed in further detail in IDPU section
  - Harness (per sensor)
    - Approximate length of 1.6m x 64 gm/m
    - Composition:
      - 13 x 36 AWG coaxial cables - 6 Signals, 6 Test, 1 Bias voltage
      - 3 x 28 AWG wire   - 2 Door monitors, 1 Temperature
      - 3 x 24 AWG (TT) - Door Open/Close power
      - 2 x 26 AWG (TP) - Heater supply
      - 3 x 26 AWG (TT) - Preamp Power
    - 26 pin HD Cannon at each end

SST Mass Summary

Mass Summary:

Sensor: 586 gm

Cable: 122 gm

Total x2= 1416 gm

Reasons for increased mass:

Bigger magnets: ~+50 gm

Inaccurate estimates: +50 gm

Parts not included: ~+170 gm

Note: First estimates were based on unreasonably low estimates of the WIND SSTs

SST Mass Estimates					Item Mass [g]	Items/unit	Mass [g]		# units	Total Mass [g]		%	%
Sensors													
Magnets					9.6	4	38.4					6.6	
Yoke					33.2	2	66.4					11.3	
Magnet and Yoke Cage					16.7	1	16.7					2.8	
Retainer plates and fasteners					1.4	4	5.7					1.0	
Sub total Magnet Assembly								**127.2**					**21.7**
Housing 20 mil (front and back)					107.1	1	107.1					18.3	
Bottom closeout 62.5 mil					14.3	1	14.3					2.4	
Collimators (with baffles)					14.4	4	57.7					9.8	
Attenuator cover					18.6	2	37.2					6.3	
Thermal Spacer					0.3	6	1.9					0.3	
Baseplate Washer					1.6	3	4.9					0.8	
Housing fasteners					0.8	16	12.2					2.1	
Sub total Housing								**235.3**					**40.1**
Attenuator (axle/4 paddles/2 cams, 2 levers,2 bearings, 8 se					10.6	1	10.6					1.8	
HM Switch Assembly (mounting plate, spring, nut plate, plur					9.8	2	19.6					3.3	
HM Switch (w/ aux lever)					5.8	2	11.7					2.0	
SMA actuator (nanomuscle, T-bone, nut plate and screws)					4.6	2	9.2					1.6	
1/2 Winchester w/o wire					1.7	2	3.3					0.6	
Sub total Attenuator								**54.4**					**9.3**
Connector (26 pin DD w/ nut plate)					9.2	1	9.2					1.6	
Internal wires					15.0	1	15.0					2.6	
DFE board (unloaded)					10.3	2	20.6					3.5	
DFE EEE parts					5.7	2	11.4					1.9	
Amptek 225FB					2.3	6	14.0					2.4	
Amptek Shield Cover (3mm Cu)					22.0	2	44.0					7.5	
Detectors					0.0	8	0.0					0.0	
Detector Stack					10.0	2	20.0					3.4	
Polyamide Foil & Holder					1.9	2	3.7					0.6	
Thermostat					7.8	2	15.6					2.7	
Heater Patch					2.2	2	4.3					0.7	
1/2 Winchester w/o wire					1.7	2	3.3					0.6	
screws and pem nuts					1.1	8	8.5					1.4	
Sub total DFE assembly								**169.6**					**28.9**
Sensor Total:							**586.5**	**586.5**	**2**	**1172.9**		**100.0**	**100.0**
Cables:													
Custom (see below)	64.7	gm/m	1.6	m	103.6	1	103.6						
Connectors (26 pin DD)					9.0	2	18.0						
Cable Total:							**121.6**		**2**	**243.1**			
								Non IDPU mass:		**1416.0**	**gm**		
IDPU electronics													
DAP Board (unloaded)	0.39	gm/cm1	368.0	cm1	142.0	1	142.0						
DAP board components	0.39	gm/cm2	368.0	cm2	142.0	1	142.0						
shield board	0.10	gm/cm2	368.0	cm2	36.8	1	36.8						
Shielding penalty			69.3	cm3			187.2						
IDPU Total:							**508.0**		**1**	**508.0**			
Total:										**1924.0**	**gm**		

- Unit Level Test Requirements
  - Attenuator Mechanism Cycling
    - ETU target of 150,000 cycles (10x expected on-orbit maximum value)
  - Vibration
    - Per THEMIS Instrument Payload Environmental Verification Plan and Test Specification THM-SYS-005B
      - Sine burst, random, sine sweep
    - Updated test levels to be provided by Swales in place of GEVS
  - Thermal-Vacuum
    - Per THEMIS Instrument Payload Environmental Verification Plan and Test Specification THM-SYS-005B
    - Sensor alone
    - 8 Cycles

- THEMIS Environmental Test Matrix

HARDWARE			MECHANICAL												ELECTRICAL					THERMAL							CONTAMINATION				OTHER				
COMPONENT (ITEM)	QUANTITY	SUPPLIER	ALIGNMENT	MODAL SURVEY	STATIC LOAD	RANDOM VIBRATION	SINE VIBRATION	ACOUSTIC	PROOF TEST	CLAMP BAND SHOCK	VENTING/PRESSURE PROFILE	MASS PROPERTIES	MECH FUNCTION	LIFE TEST	INTERFACE VERIFICATION	CONDUCTED EMISSIONS	CONDUCTED SUSCEPTIBILITY	RADIATED EMISSIONS	RADIATED SUSCEPTIBILITY	THERMAL VACUUM (# CYCLES)	THERMAL BALANCE	THERMAL AIR (# CYCLES)	THERMAL LIMITS (OPERATING, DEPLOY)	THERMAL PREDICTS	THERMAL TEST LIMITS (QUAL) LIMITS +/-10C VAC; +/-15C AIR	THERMAL TEST LIMITS (ACC) PREDICTS +/-10C VAC; +/-15C AIR	ESC AND GROUNDING	DC MAGNETICS	AC MAGNETICS	BAKEOUT	RADIATION	OPERATING HOURS	FAILURE FREE HOURS	WORST-CASE ANALYSIS	COMMENTS
Instrument Payload	6	UCB													T9	T10	T10	T10	T10	6			-30 to +45		-40 to +50	-40 to +55			M3	T14		1000	100		
SST Sensor	2	UCB		T1	A2	T4	T5				A7	M1	T7		T9					2			-65 to +40	-52 to +13	-75 to +50	-65 to +30	T11	M2			A	100		A	

notes:

T1 0.25g sweep from 5 Hz to 2000 Hz
A2 Analysis to show margin on Yield at 2.0 x limit load; and Ultimate at 2.6 x limit load
T3 Test conducted at 1.25 x limit load
T4 ETU tested to Qual; F1 tested to Protoflight; F2-F6 tested to Acceptance. Levels from coupled loads analysis
T5 ETU tested to Qual; F1 tested to Protoflight; F2-F6 tested to Acceptance (sine profile in thm-sys-005)
T6 ETU tested with SC shock test
A7 Analysis to show margin at 2 x maximum pressure differential (launch ascent profile in thm-sys-005)
M1 Mass, CG and MOIs measured
T7 At least 10 x number of actuations during the mission life, unless mechanism is on Limited Life Items List
T8 SPB Motor to go through Life Test - operation after 6 months (TBR)
T9 Safe-to-Mate and compliance to ICD prior to Integration
T10 Per MIL-STD-461C (levels in thm-sys-005)
T11 Grounding checked for each component prior to integration
M2 DC Magnetics measured prior to Instrument Payload integration
M3 AC Magnetics measured in mag facility at Probe Level
T12 Total Dose and SEE Testing at part level if necessary
T13 60C for 48 hours prior to TV w/ integrated payload
T14 Contamination Verification w/ TQCM during Instrument Payload Thermal Vac

- Solid State Telescope
- Thermal

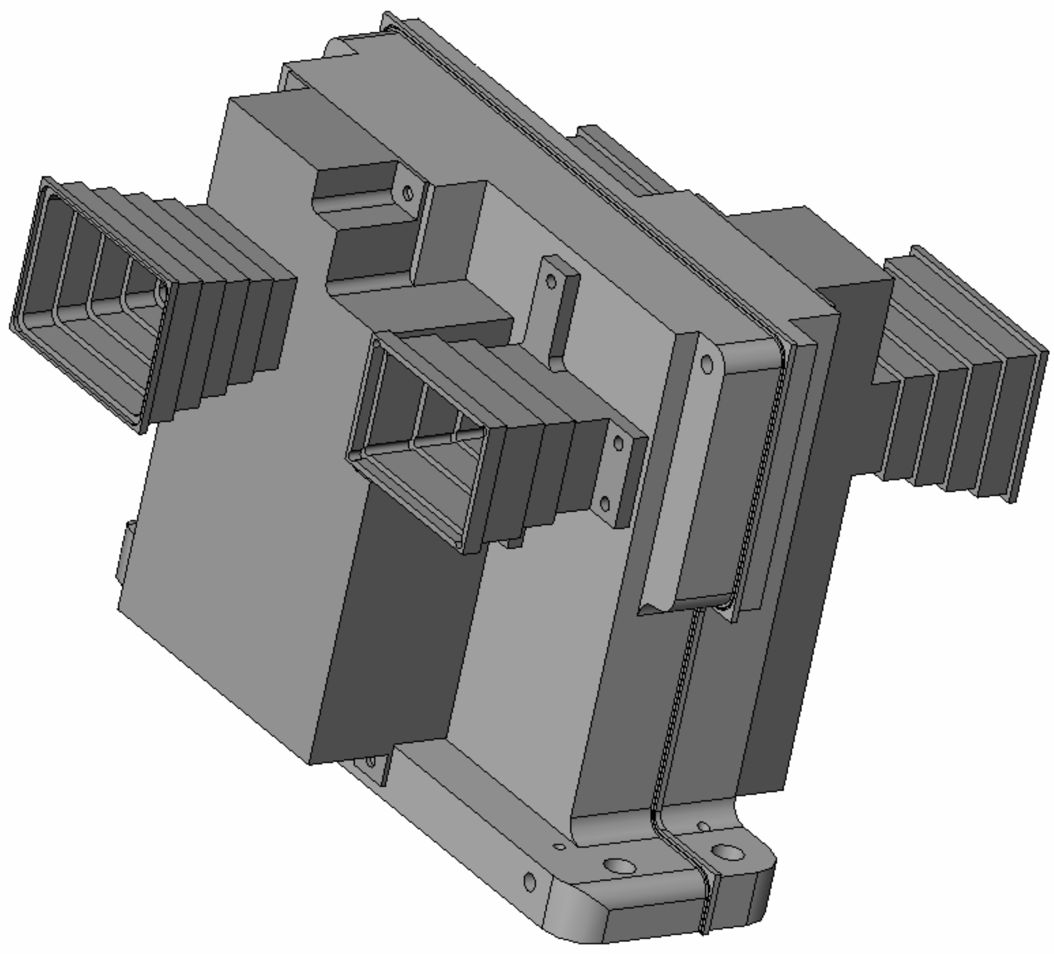
- Christopher Smith
- Thermal Engineer
- csmith@ssl.berkeley.edu
- 510-642-2461

SST

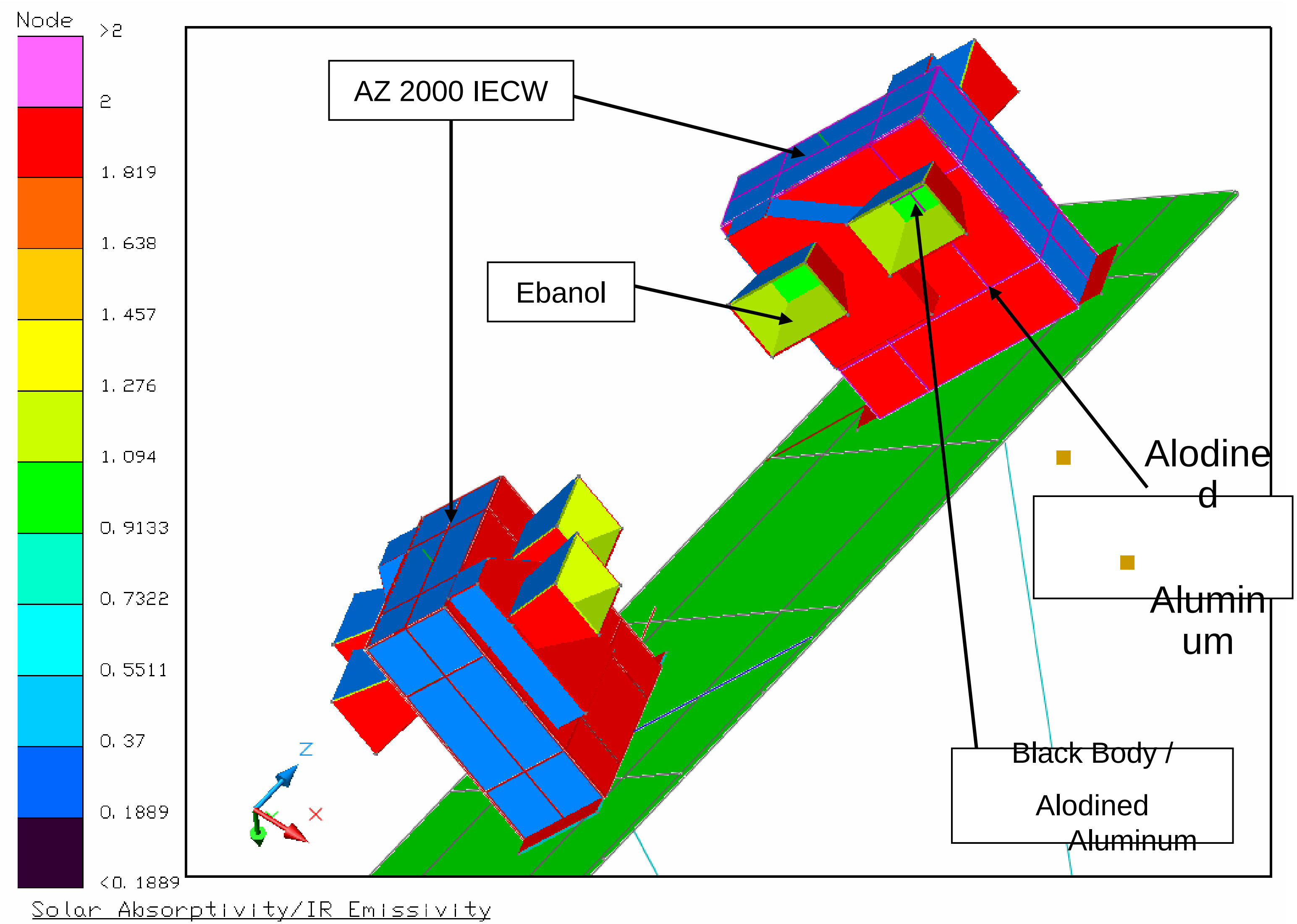
- Mounts directly to the corner panel on three 1/8 inch isolators

- Has four open apertures that are sometimes obscured by attenuators

- Must operate at 10 Deg C or less



SST Geometry Model



SST Model Inputs

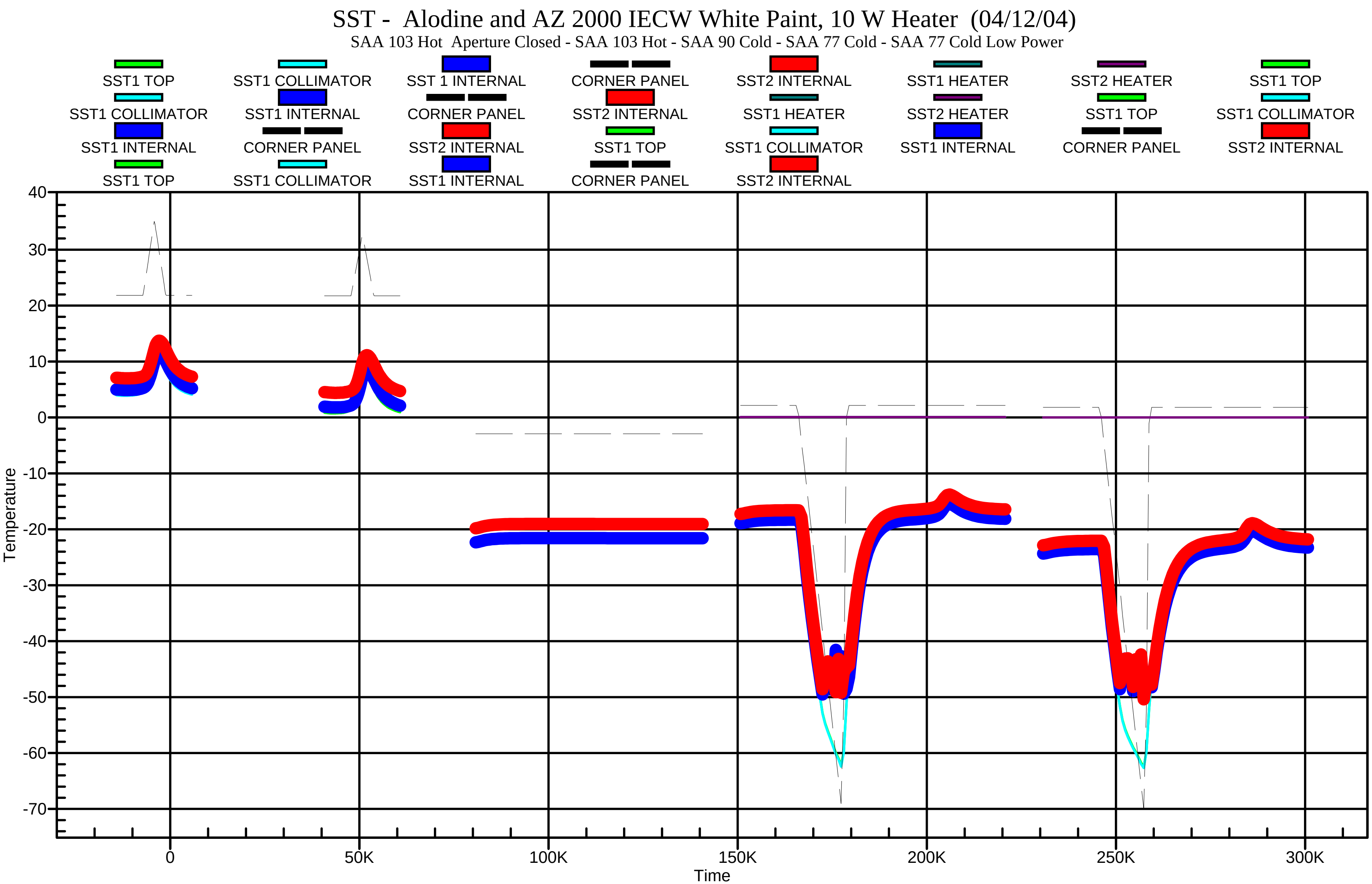
- Optical materials
  - Ebanol
  - AZ 2000 IECW White Paint
  - Alodined Aluminum
- Thermophysical materials
  - Aluminum, 6061
  - ULTEM
- Heaters
  - Two 5 watt heaters per sensor head controlled by redundant thermostats
  - Set points –50 and -42
- Conductors
  - 3 ULTEM isolators to corner panel, 0.0078 < G < .0133 W/C each
- Power Dissipation
  - 0.125 W Watts Nominal per Sensor

SST Case Sets

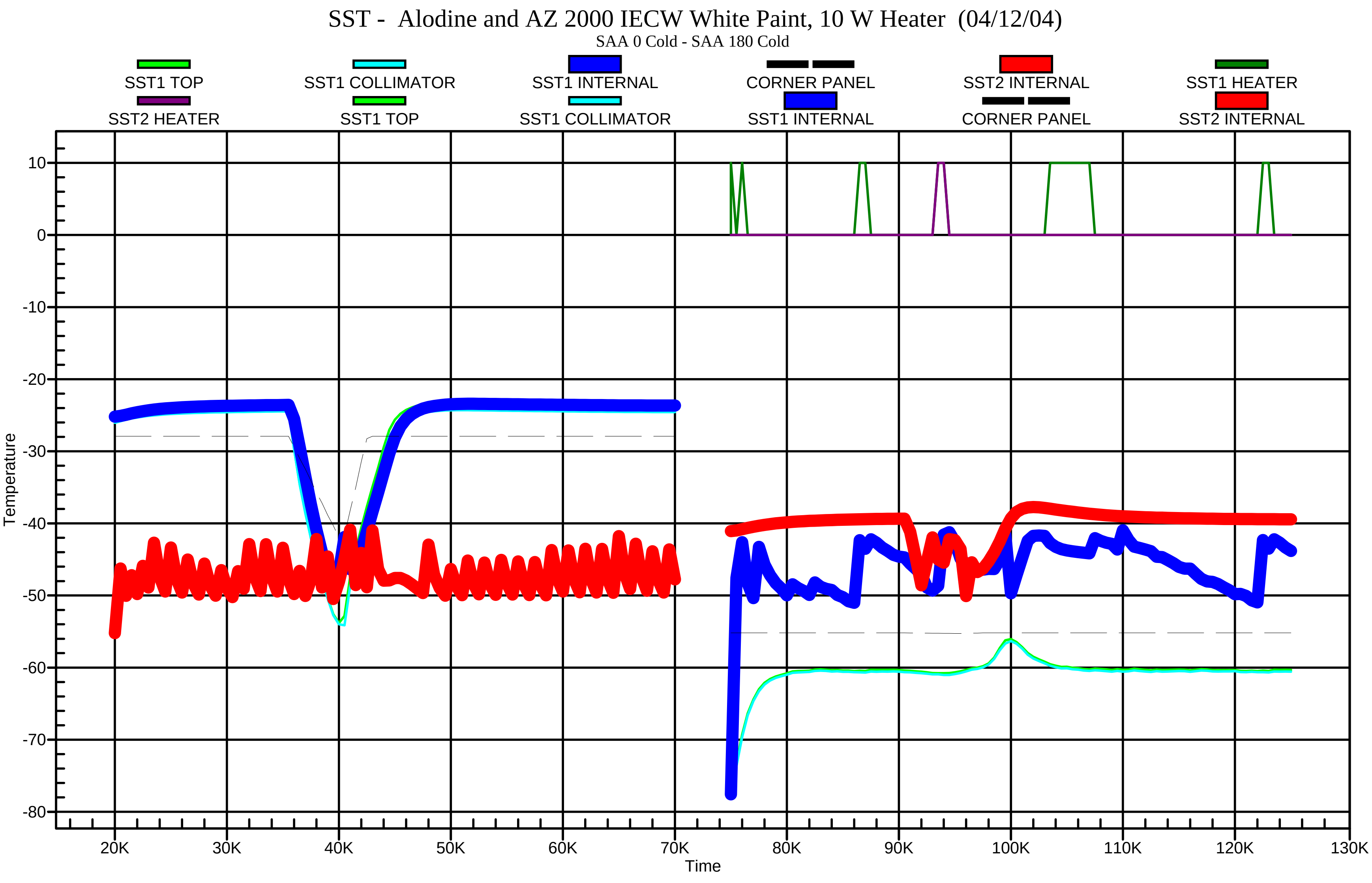
SST

UCB Case Set	Optical Properties	Blanket	Solar Aspect Angle	Solar Flux	Earth IR	Earth Albedo	Power Dissipation	Conductors	Eclipse Length	Orbit	Swales Bondary Condition
Coldest	BOL	N/A	77	1287	209	0.16	0.2295	High	180	P1	SAA 77 Cold Low Power
Cold	BOL	N/A	77	1287	209	0.16	0.2295	High	180	P1	SAA 77 Cold
Nominal	BOL	N/A	90	1356	235	0.255	0.27	Nominal	180	P1	SAA 90 Cold
Hot	EOL	N/A	103	1425	261	0.35	0.3105	Low	0	P4	SAA 103 Hot
Top To Sun Cold	BOL	N/A	0	1287	209	0.16	0	High	180	P1	SAA 0 Hot
Bottom To Sun Cold	BOL	N/A	180	1287	209	0.16	0	High	180	P1	SAA 180 Hot

SST – Nominal Plots



SST – Top and Bottom to Sun Plots



SST Results Table

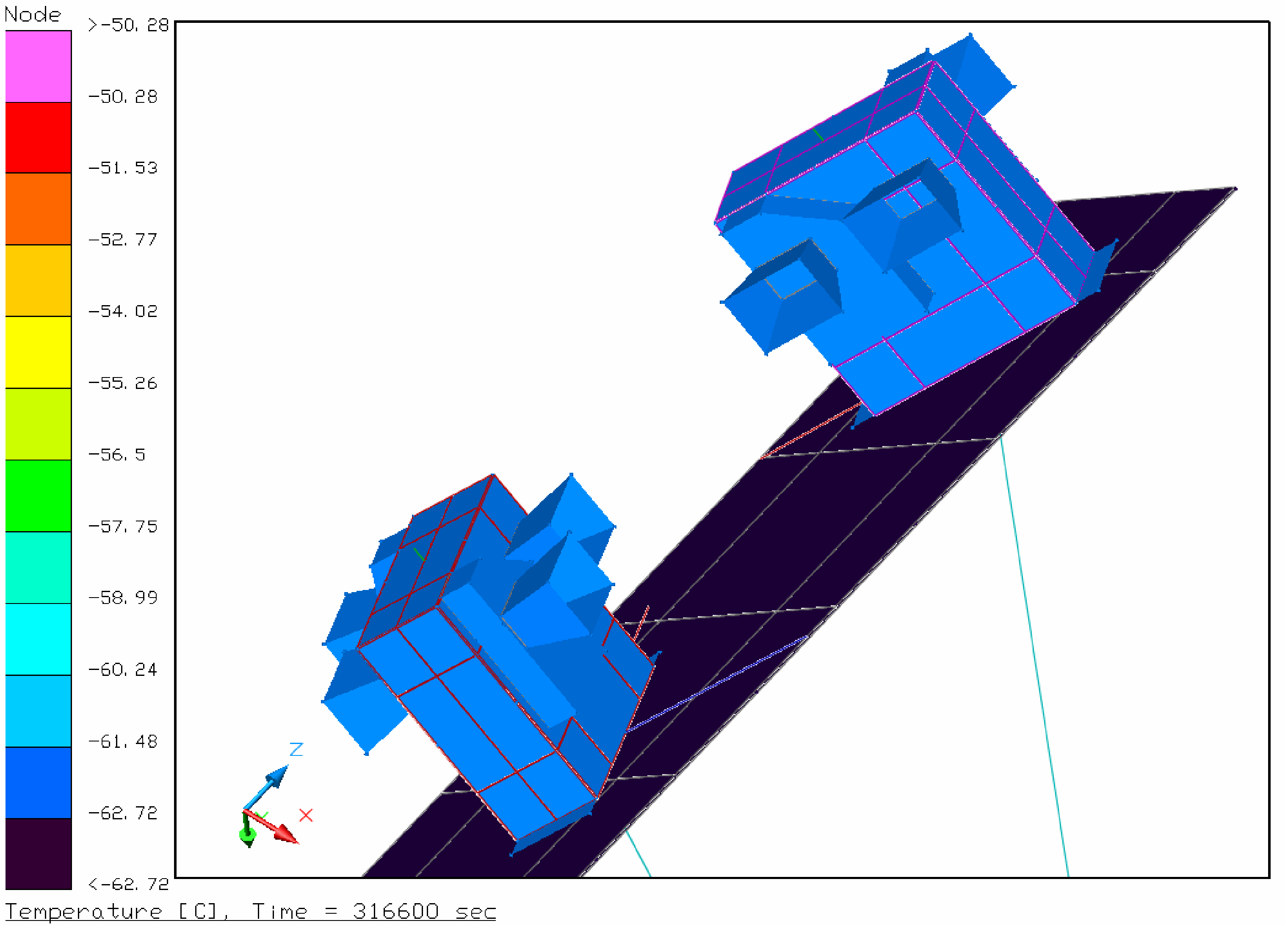
SOLID STATE TELESCOPE

	SST1/SST2 INTERNAL			SST TOP		
	MIN	AVE	MAX	MIN	AVE	MAX
Cold - Low Power	-50.4	-27.4	-18.9	-62.5	-29.5	-20.3
Cold	-49.5	-22.6	-13.8	-62.2	-25.1	-16.0
Nominal	-22.3	-20.4	-19.0	-23.1	-22.4	-22.4
Hot	1.8	5.0	11.1	0.7	2.7	7.9
Hot Aperture Closed	2.2	5.3	11.3	1.1	3.0	8.2
Top To Sun Cold	-55.2	-37.0	-23.4	-53.8	-26.6	-23.1
Bottom To Sun Cold	-51.0	-43.0	-37.7	-66.4	-60.2	-56.0

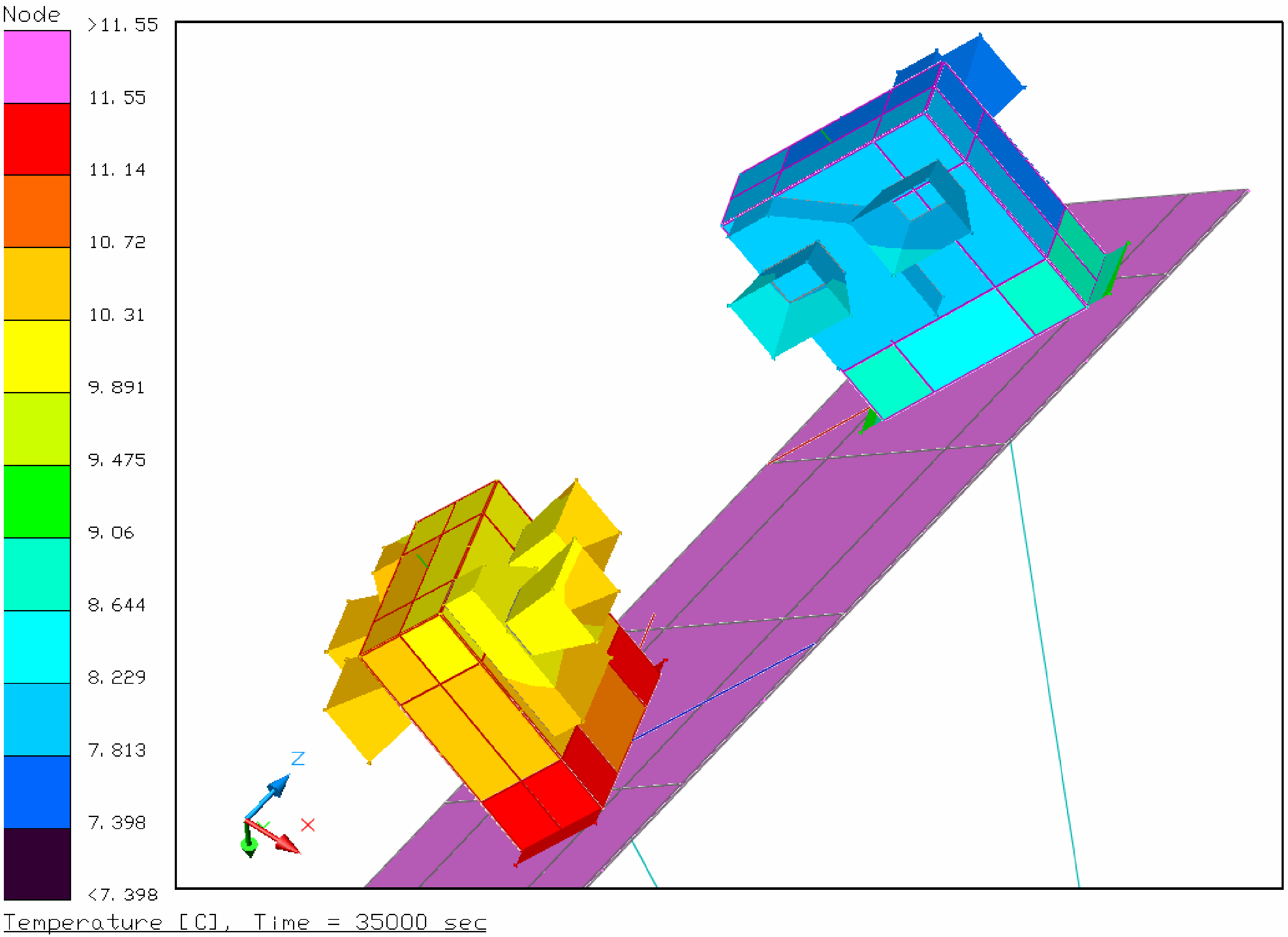
	MIN	LIMIT	MARGIN	MIN	LIMIT	MARGIN
Science Operation	-27.4	-55	27.6	-29.5	-80.0	50.5
Eclipse Operation	-55.2	-65	9.8	-62.5	-80.0	17.5
Survival	-55.2	-65	9.8	-66.4	-80.0	13.6

	MAX	LIMIT	MARGIN	MAX	LIMIT	MARGIN
Science Operation	5.0	40	35.0	2.7	65.0	62.3
Eclipse Operation	11.3	40	28.7	8.2	65.0	56.8
Survival	11.3	65	53.7	8.2	65.0	56.8

SST – Coldest Heat Map



SST Hottest Heat Map



Tests and Calibration

Thomas Moreau

Tests Magnet System

- 2 magnet assemblies assembled for prototype
- Spot-checks of measured magnetic field versus those obtained from the analytical calculations are done: small discrepancy due to the misalignment of vector magnetization and the non-uniformity of magnetization
- The discrepancy of magnetic properties between 4 magnets of each assembly is minimized
- Magnetic induction in the center of the gap is measured ~2.23 kG (in agreement with 2.24 kG of the model)
- Mapping of the magnetic field strength at SSL and additional measurements at IGPP/UCLA

- Need to characterize the sensor response in terms of:
  - Species (electron, proton, oxygen and helium ions)
  - Energy:- *determine the detection threshold for a particular channel*
    - *determine the energy thresholds for the coincidence counting rate channels*
    - *to provide the look-up tables*
  - Angle: - *determine the off-axis response (including information on the response to scattered particles)*
  - Dead time

Calibration Set Up

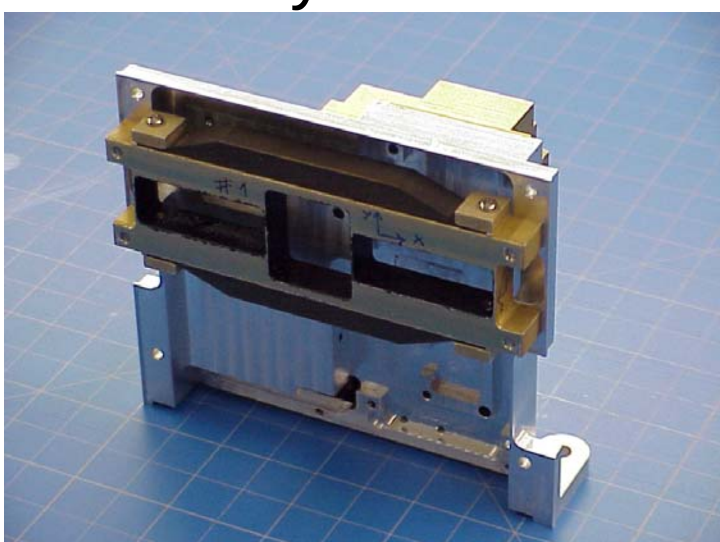
- Initial calibrations at SSL, Ba-133, Bi-207, Cd-109 and Cs-137 conversion electron sources will be used to determine channel energies over the range 62 keV to 1060 keV

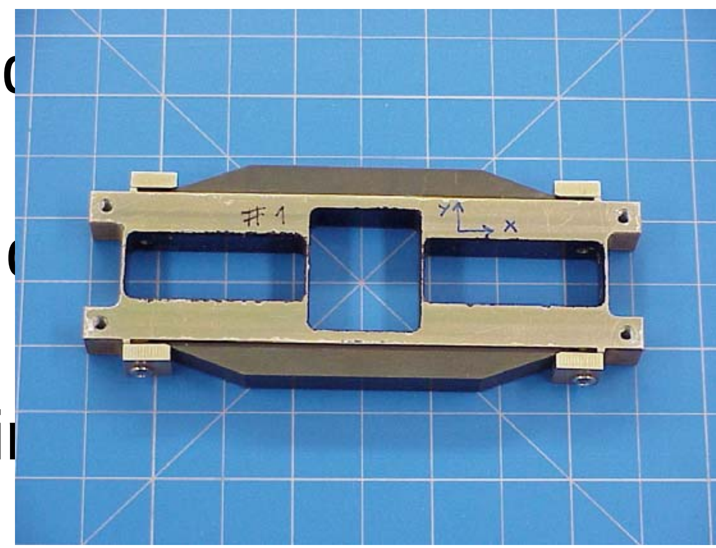
- Low-energy (up to 50 keV) and detection efficiency calibration for both electrons and protons will be done at the new SSL acceleration facility

- Additional energy and detection efficiency

Magnetics Testing

- Magnet Cage assembly #1
- Measured Py for 19 magnets (All values were very close)
- Selected 4 magnets for assembly #1
- Measured dipole and quadrapole moments of assembly
- ual c
- and c l
- of i

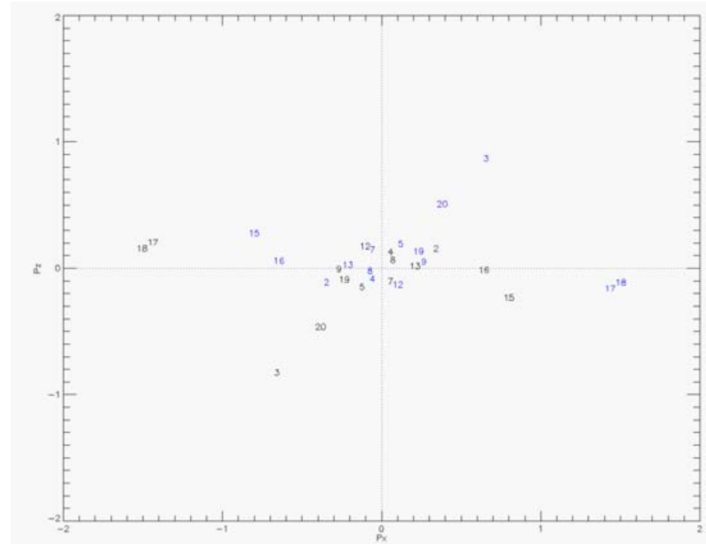


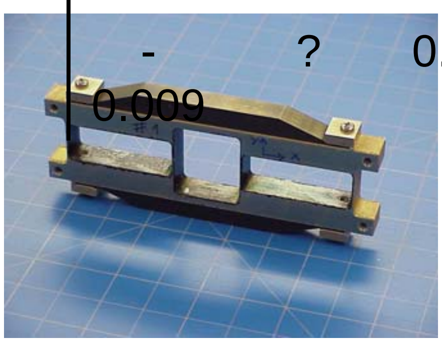


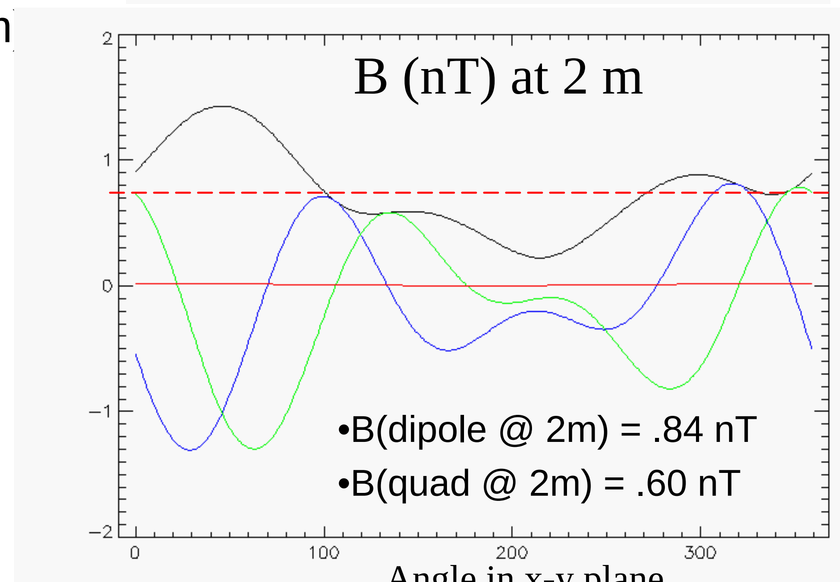
Magnetics Testing

- Magnet Cage assembly #2
- Measured Px, Py & Pz for 15 magnets
- Selected 4 magnets for assembly #2
- Measured dipole and quadrapole moments of assembly #2
- Still Found significant residual dipole moment:
  - P=[-0.244, -0.343, -0.012] nT-(2m)
  - Q=

0.034	0.389	0.009
-0.389	0.018	?
-0.009	?	0.016

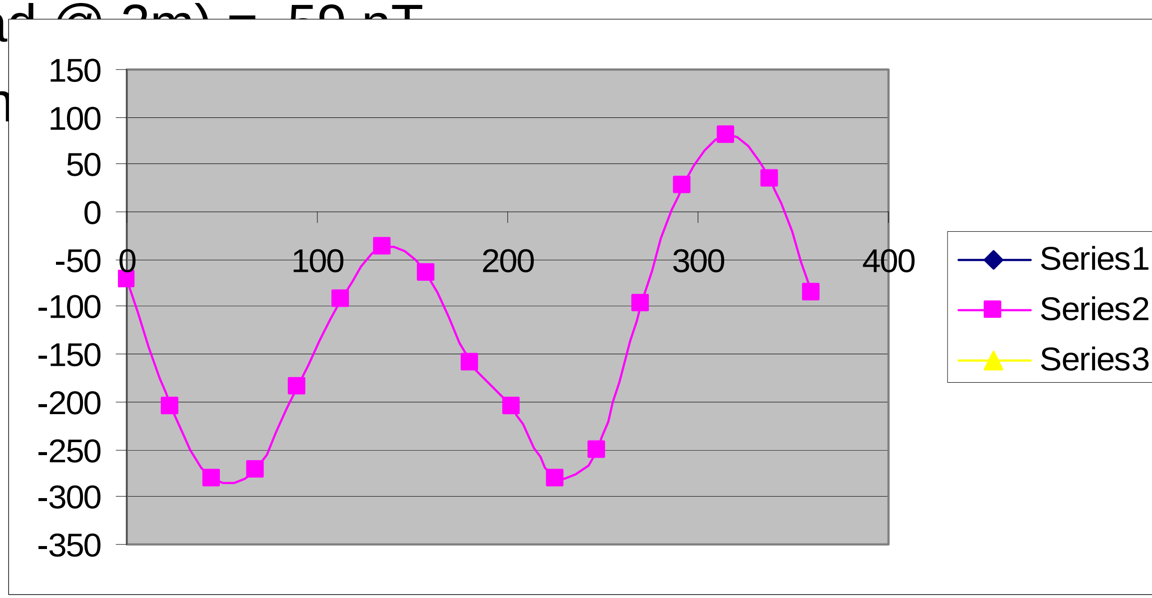




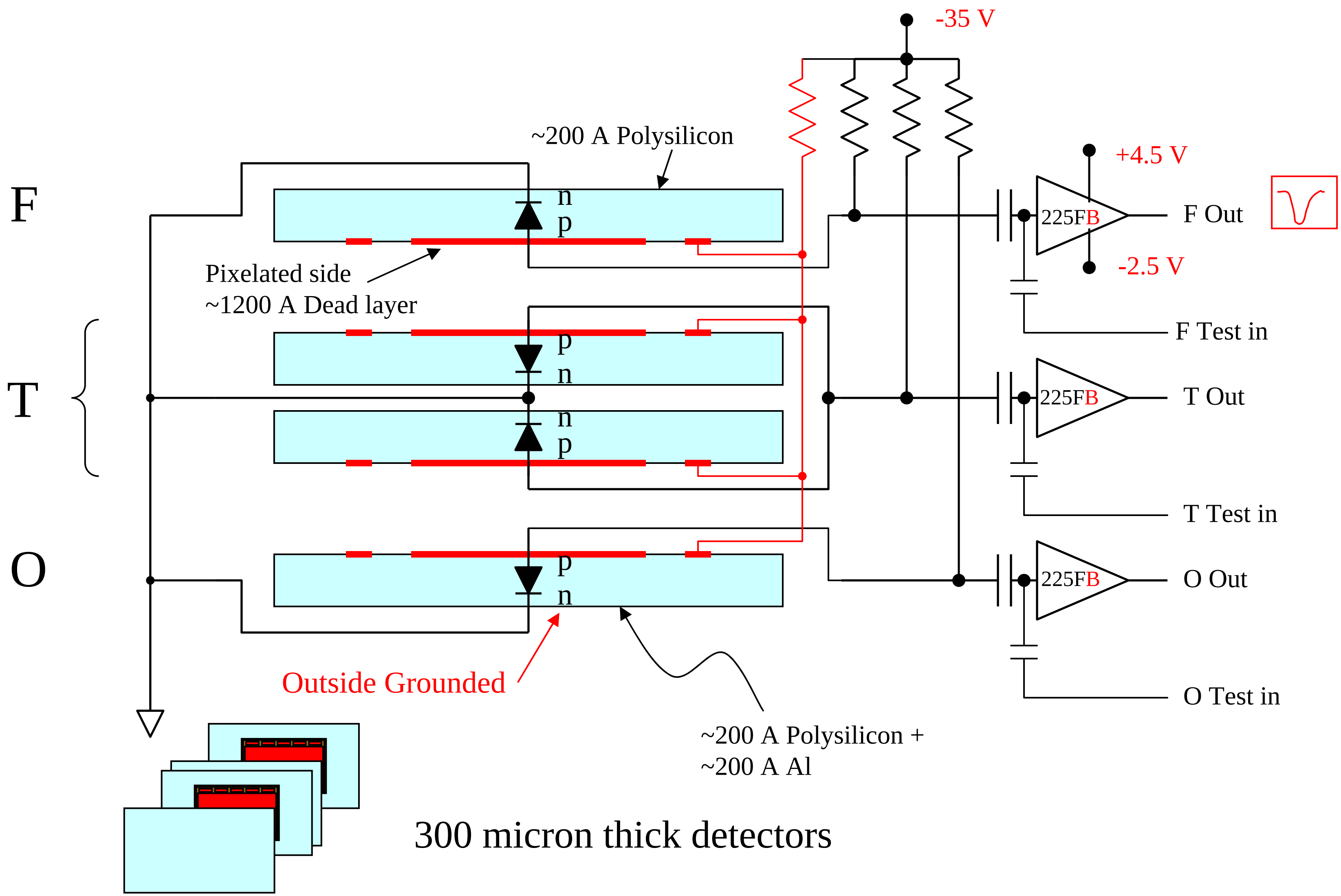


Magnetics Testing

- Sent Magnet Cage assembly #2 to UCLA for testing
- Results are virtually the same
- Contribution of dipole and quadrapole fields are similar at 2 m:
  - B(dipole @ 2m) = .88 nT
  - B(qua
- The sum … 75 nT @ 2m)

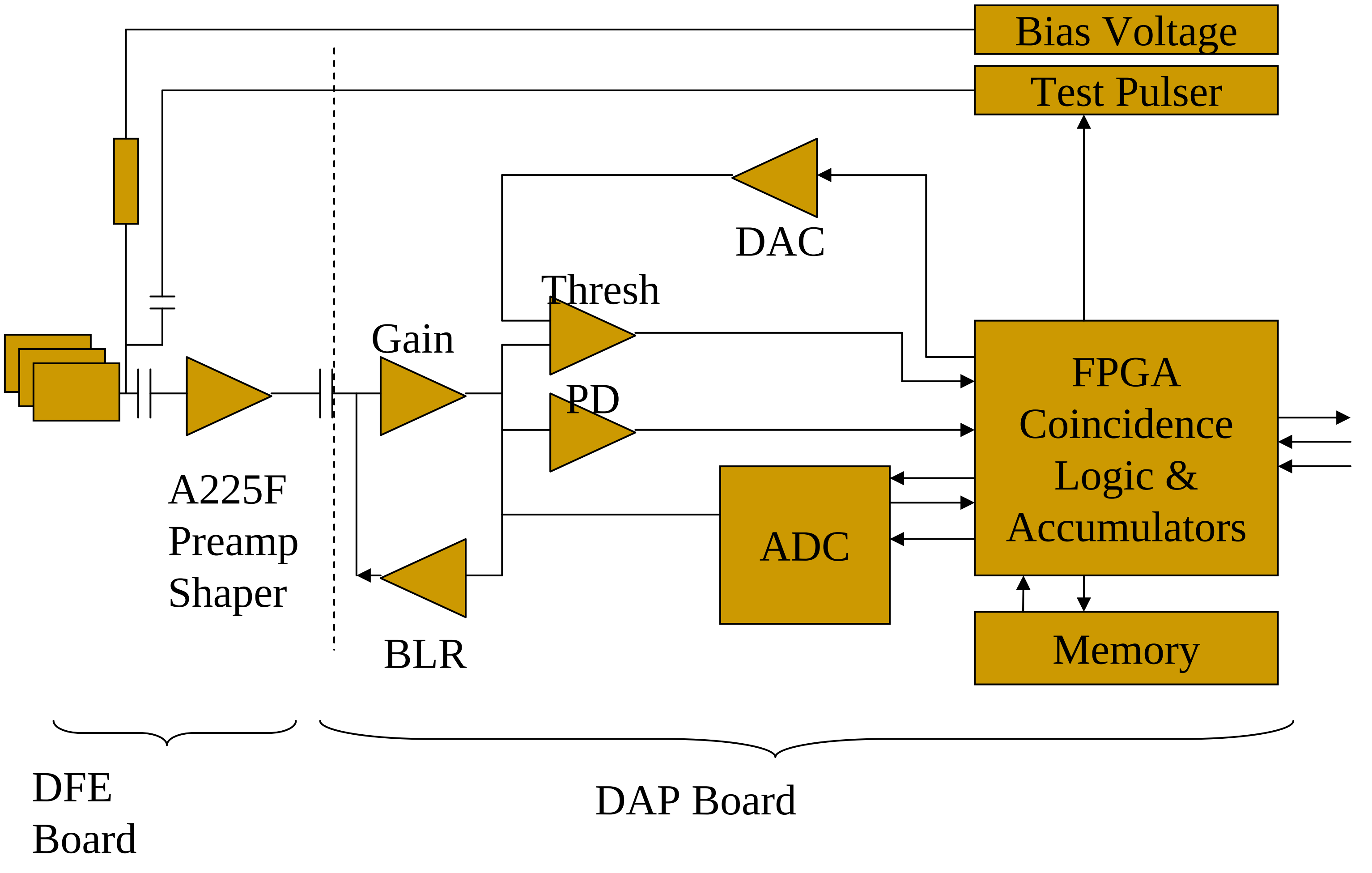


- Electrical Systems



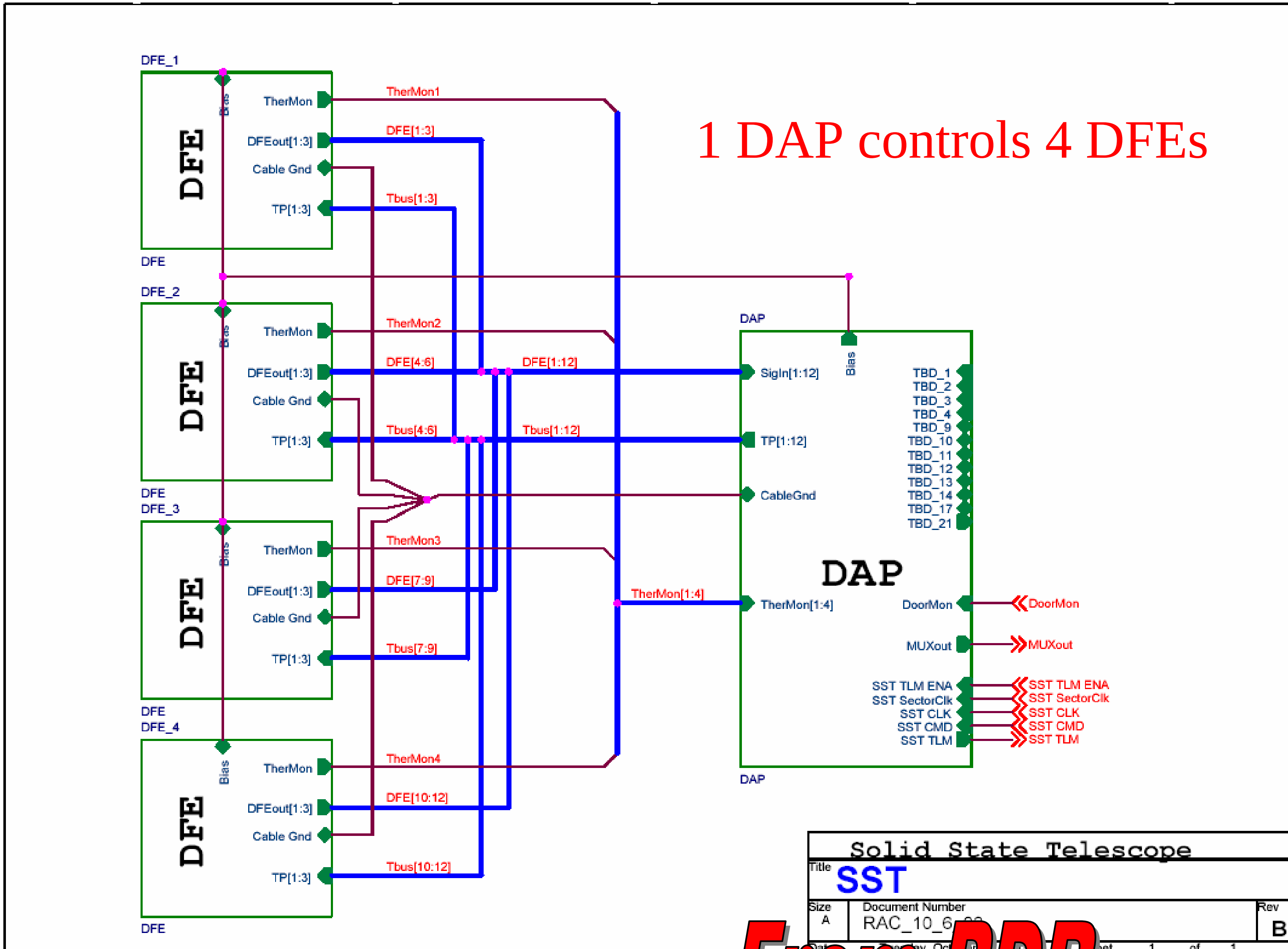
300 micron thick detectors

- Signal chain: 1 of 12 channels shown



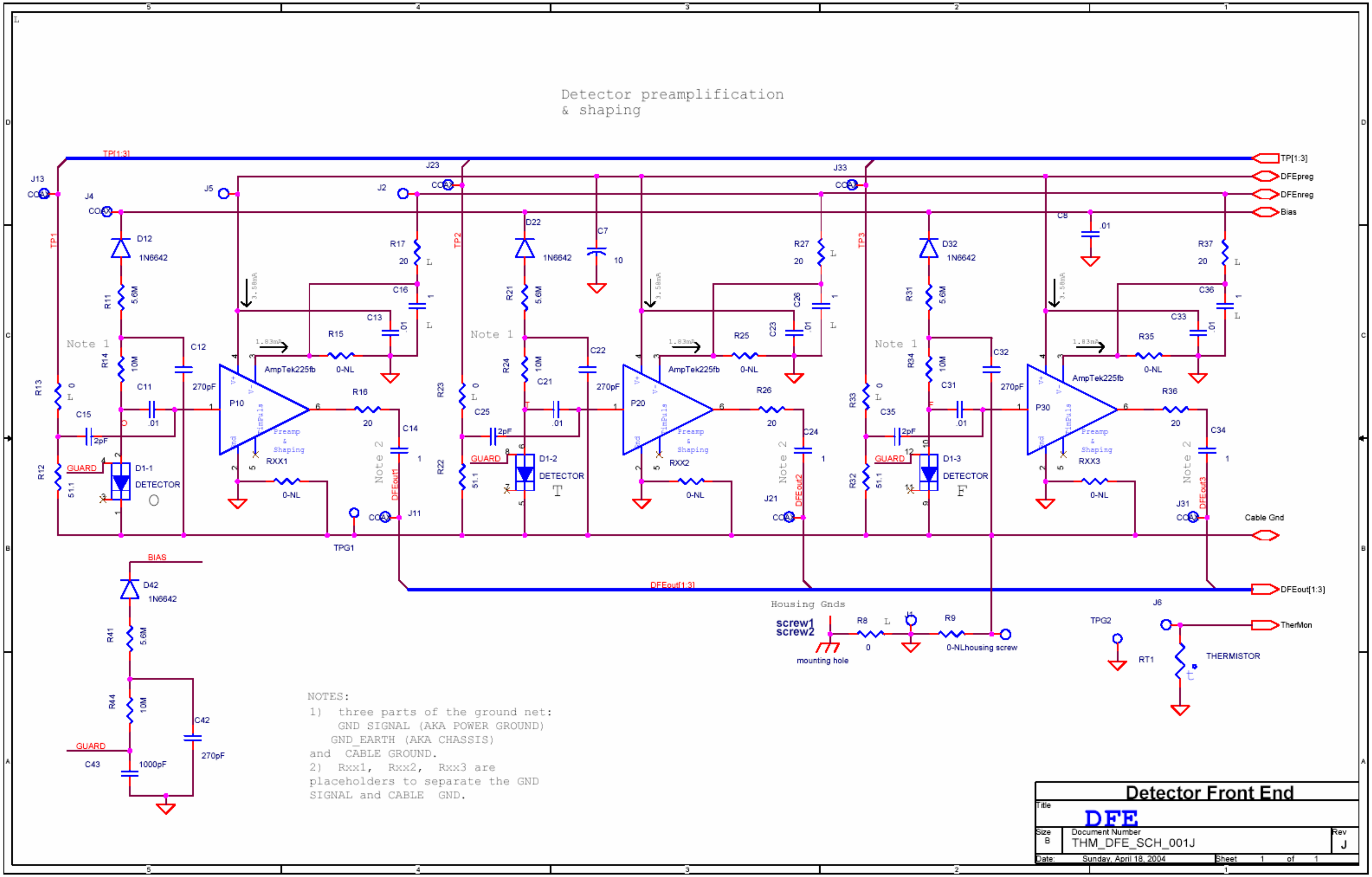
SST Schematic

1 DAP controls 4 DFEs



From PDR

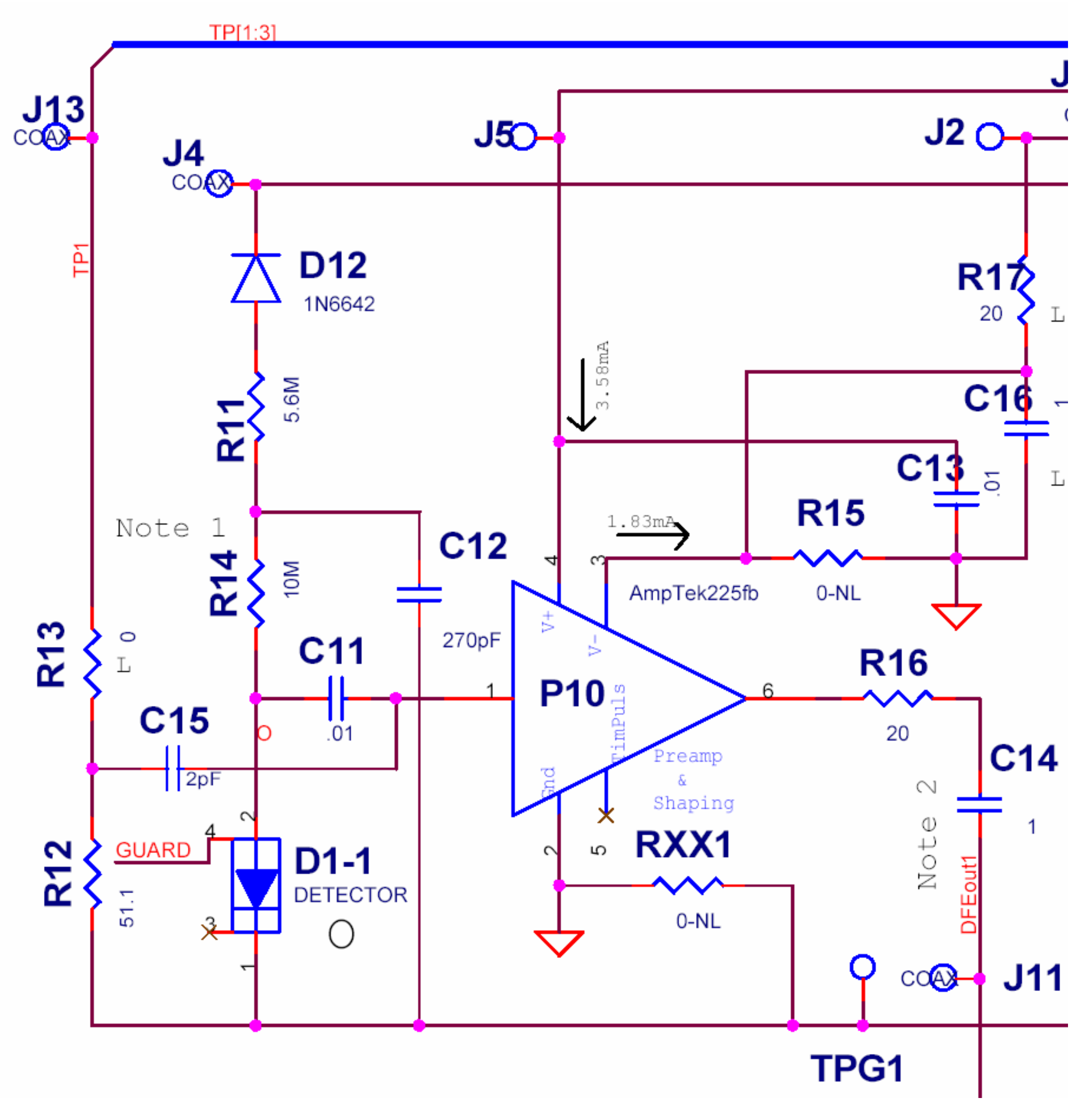
DFE Schematic



DFE Schematics

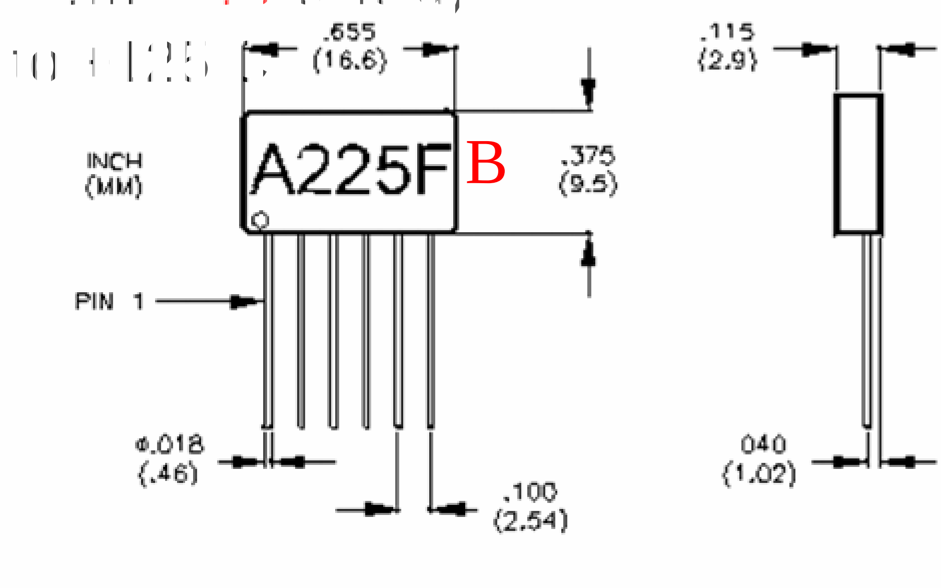
Detector Front End Schematic

–Single Channel



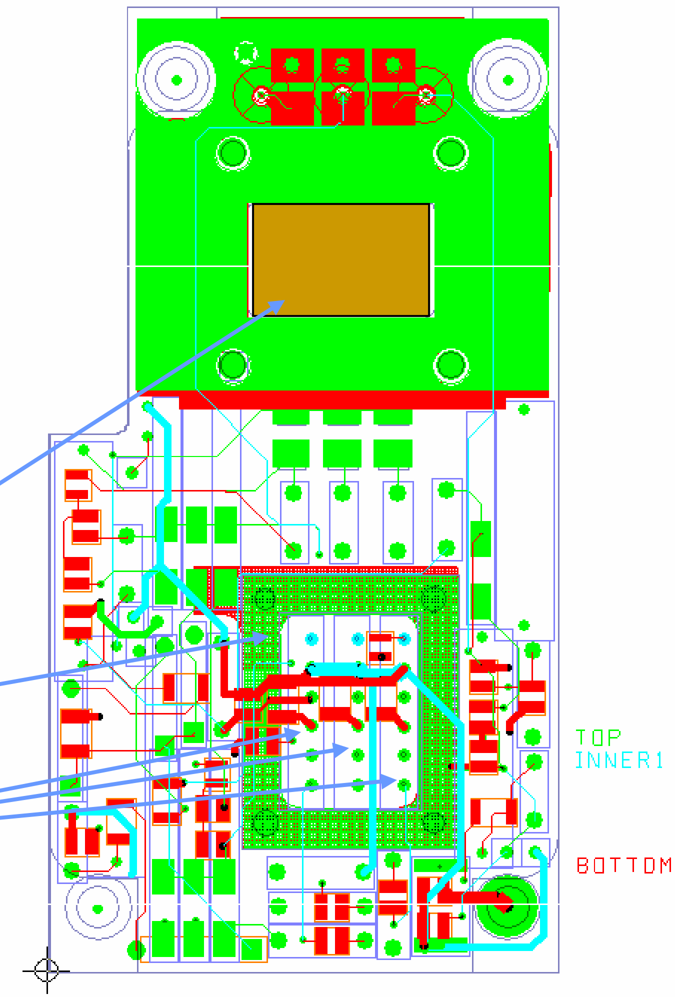
Preamps/Shaping

- Using Amptek 225FB (6pin sip Hybrid - special request)
- Characteristics:
  - ~6 keV electronic noise (with 1.5 cm^2 detector)
  - ~2.5 uS shaping time (time to peak)
  - ~26 mW (Increases with negative supply voltage)
  - 100 Krad (still needs ~3mm Cu shield)
  - Operating range: -55



DFE Layout

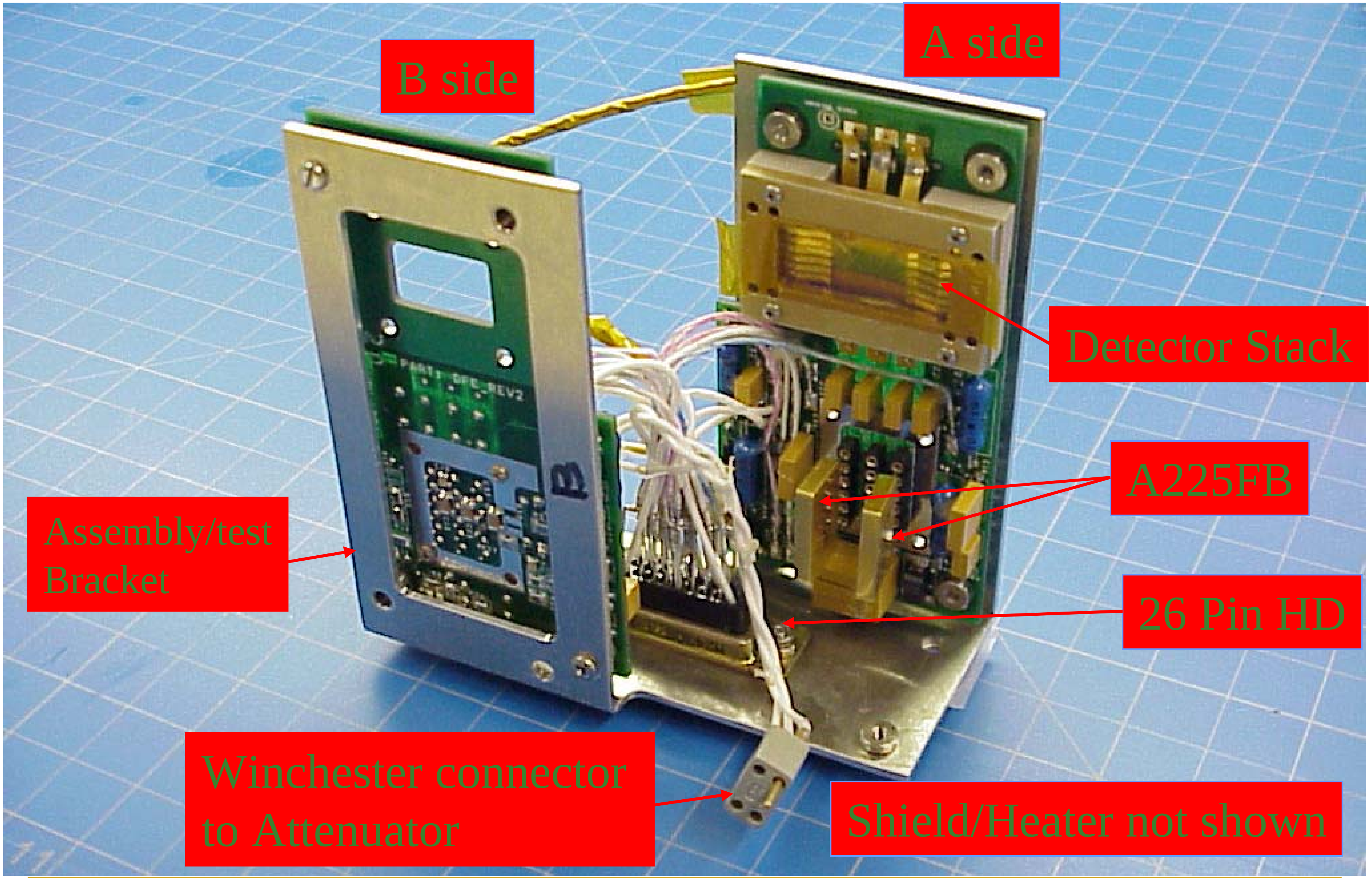
- ETU board layout (version 2).
  - A225FBs have 3.5 mm Cu radiation shielding
  - Caps/Resistors have ~0.5mm Al shielding
  - Detectors located near Preamps
  - Flexible, rugged design



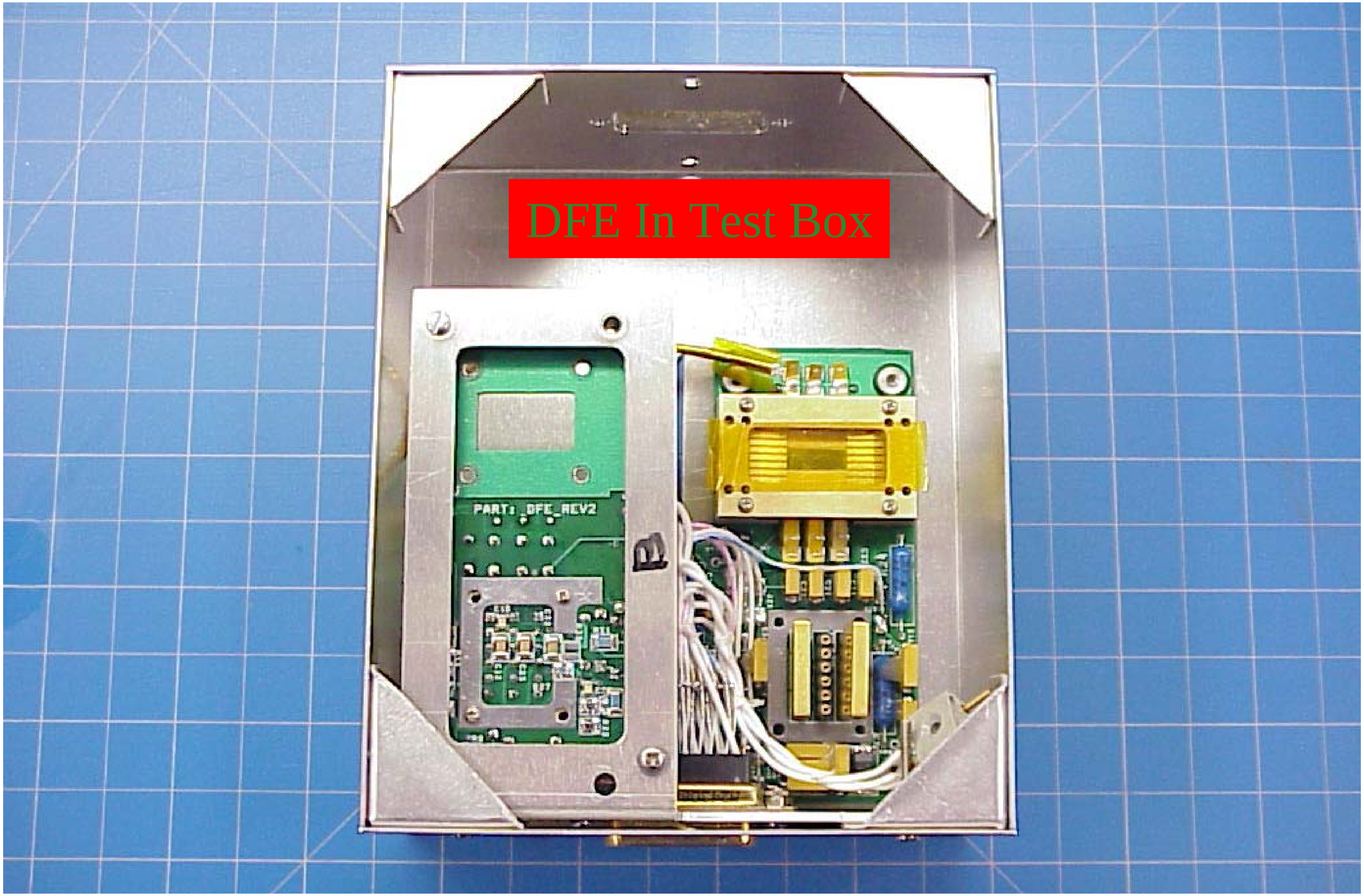
- Dual supply allows negative output pulses

End of Presentation

ETU DFE Assembly

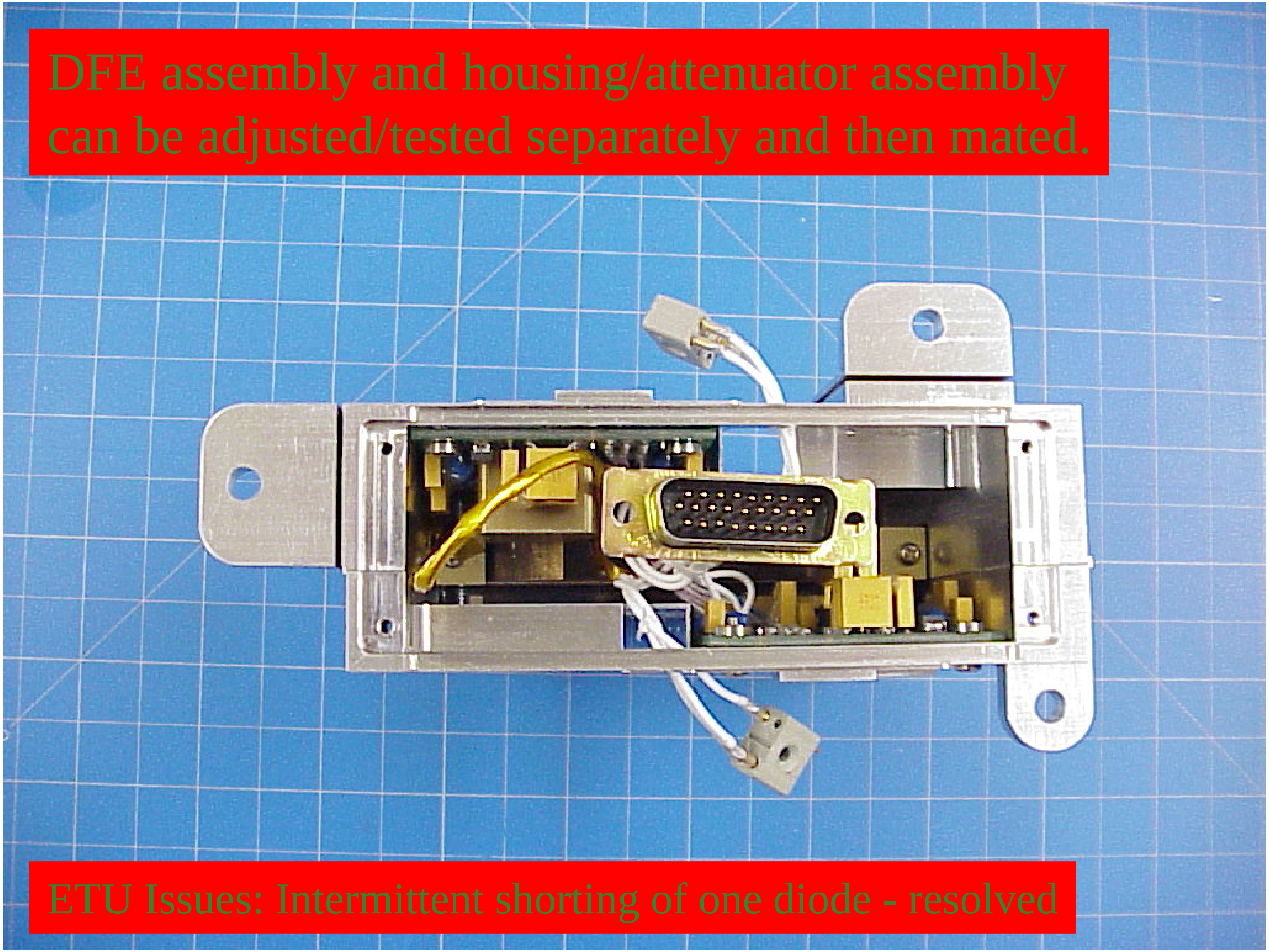


ETU DFE Assembly



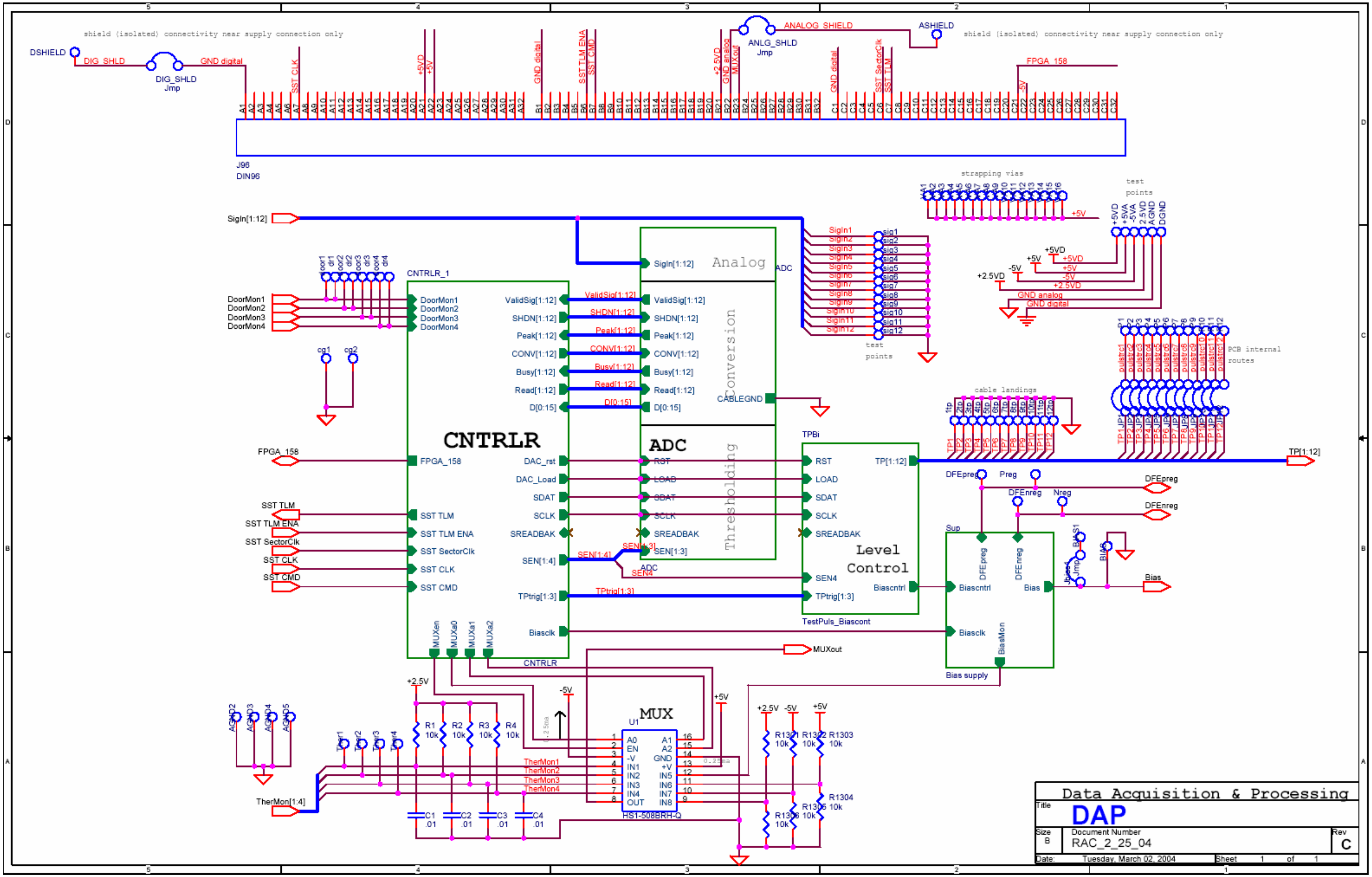
DFE/Mechanical Mating

DFE assembly and housing/attenuator assembly can be adjusted/tested separately and then mated.

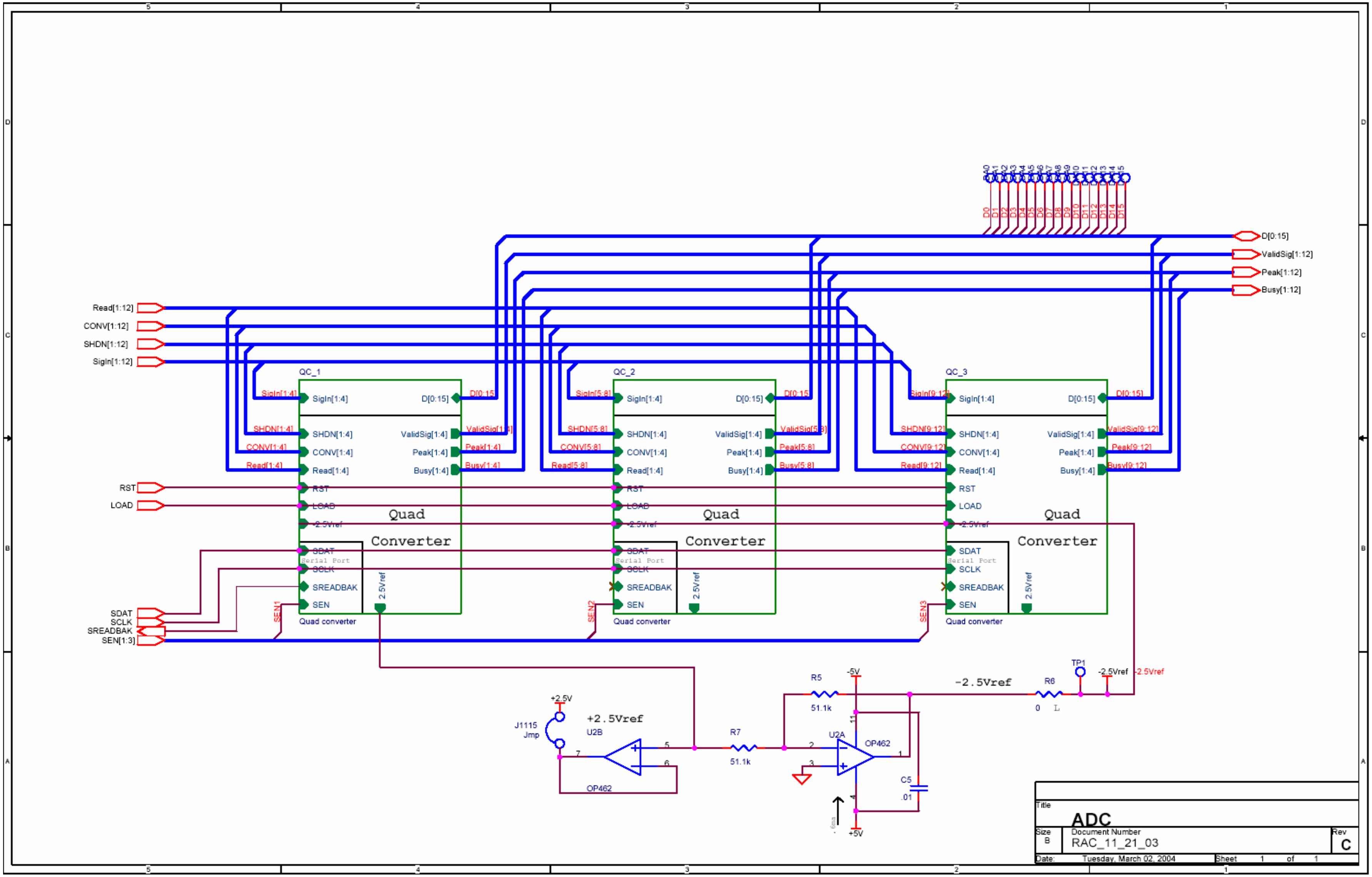


ETU Issues: Intermittent shorting of one diode - resolved

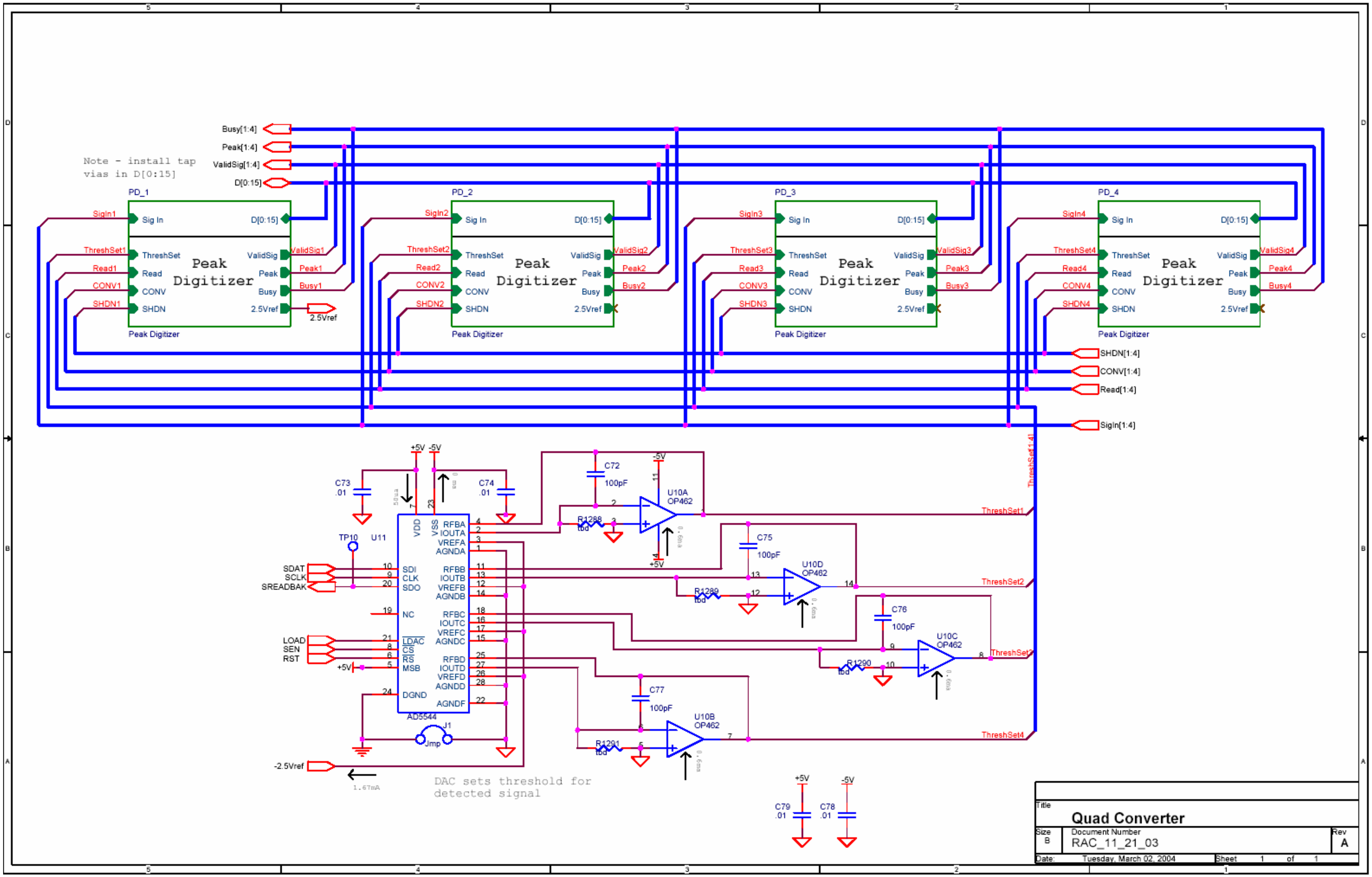
DAP Schematic



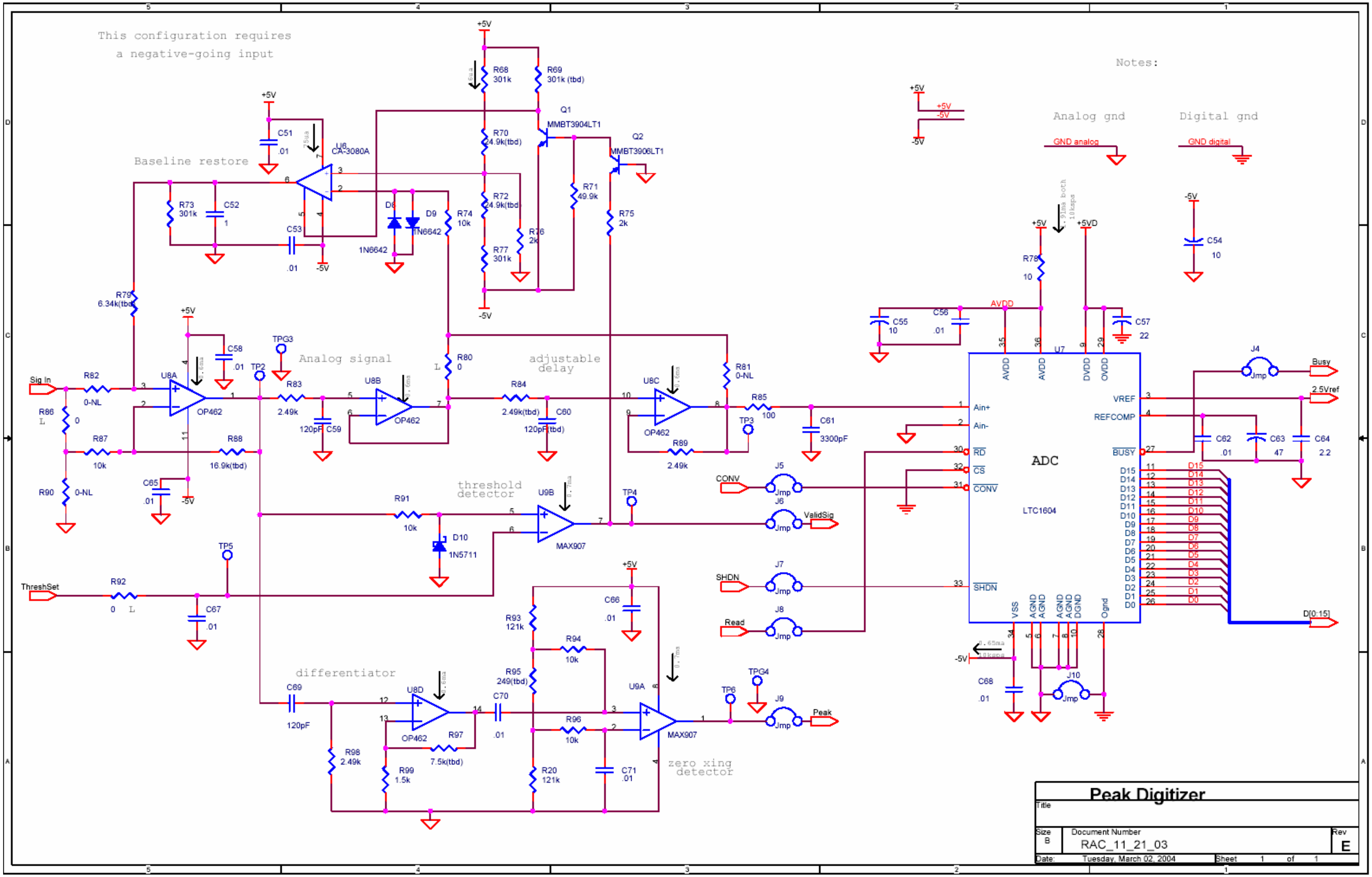
ADC Schematic



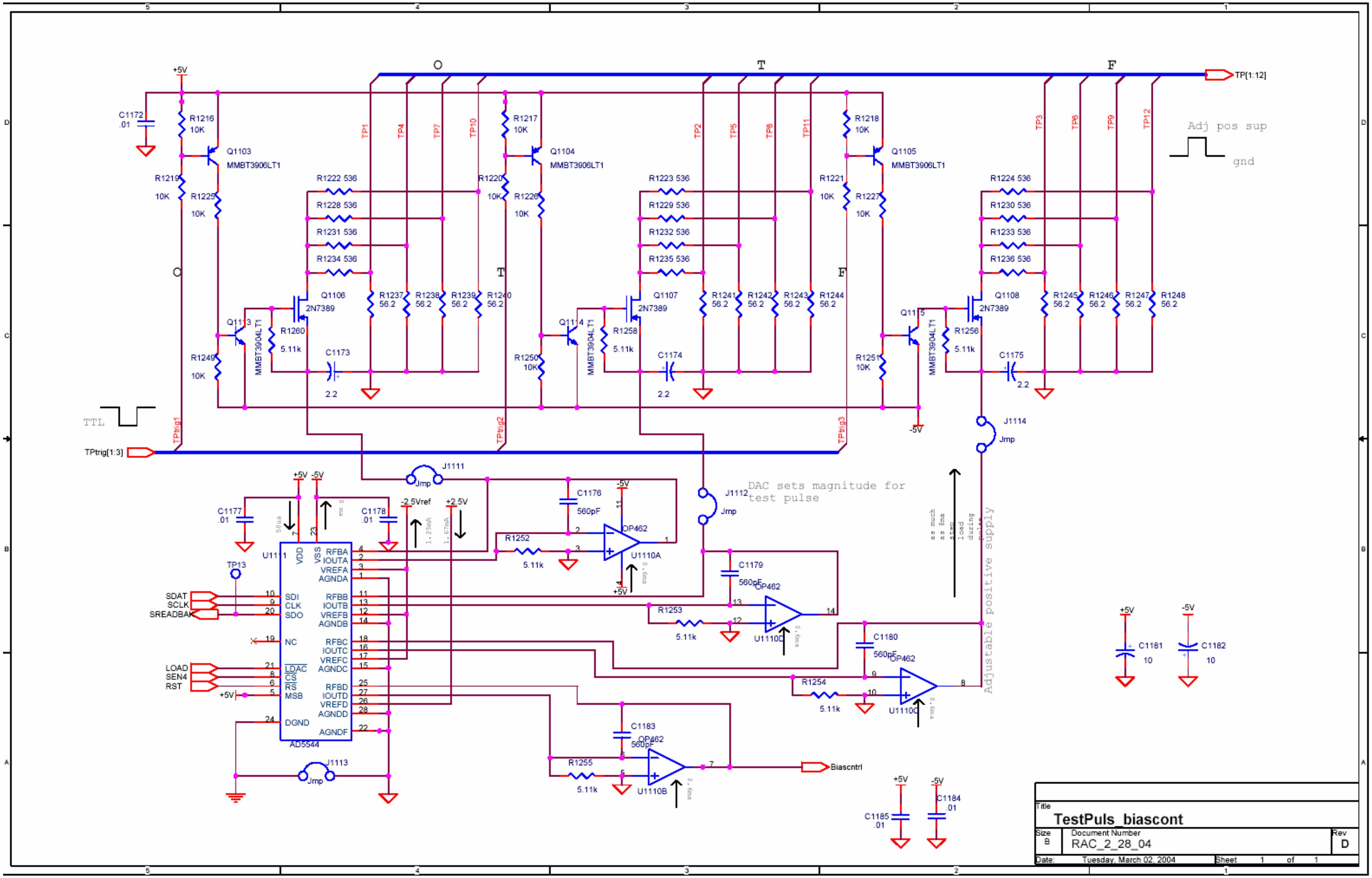
Quad Converter Schematic



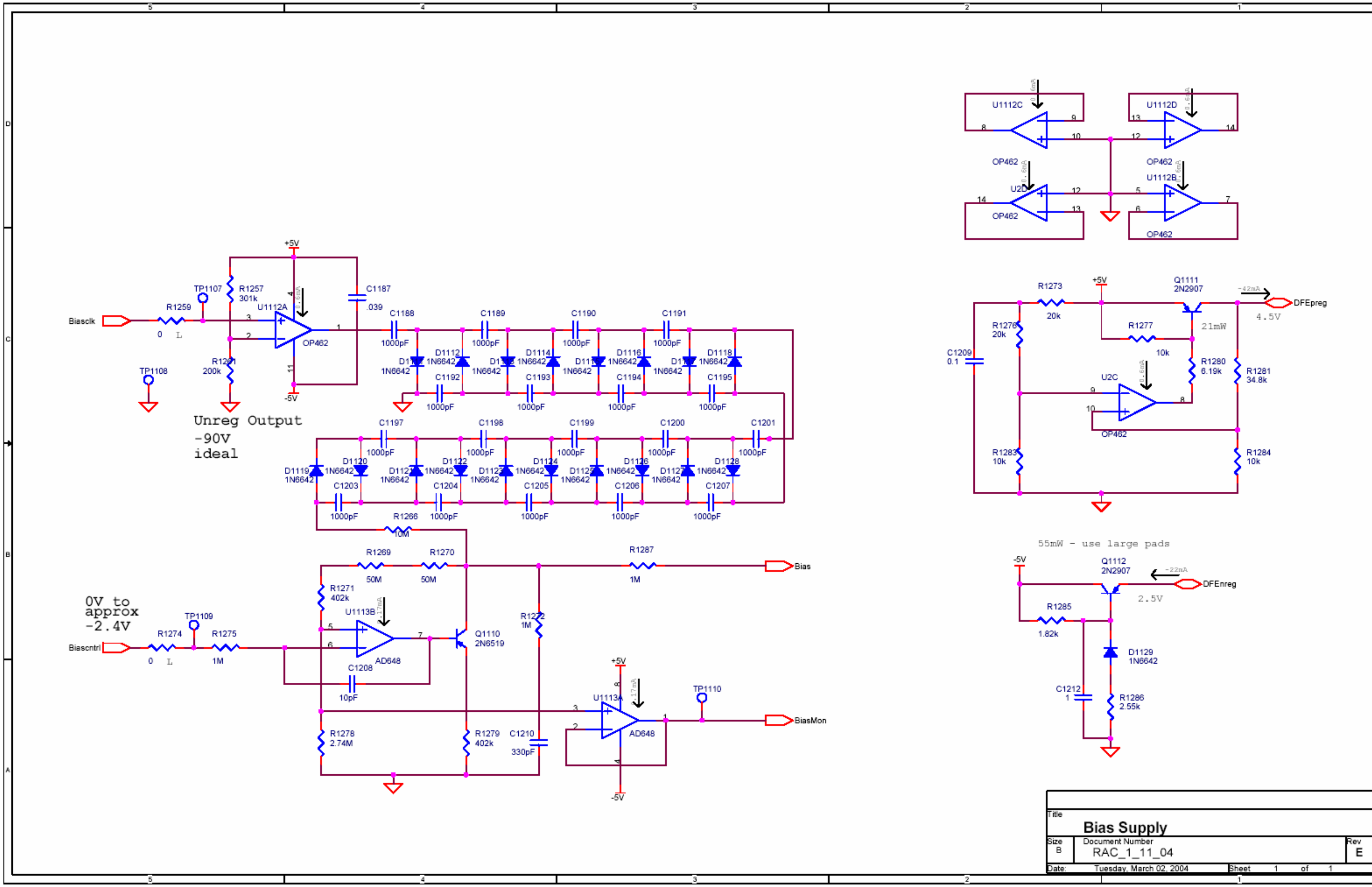
Peak Digitizer Schematic



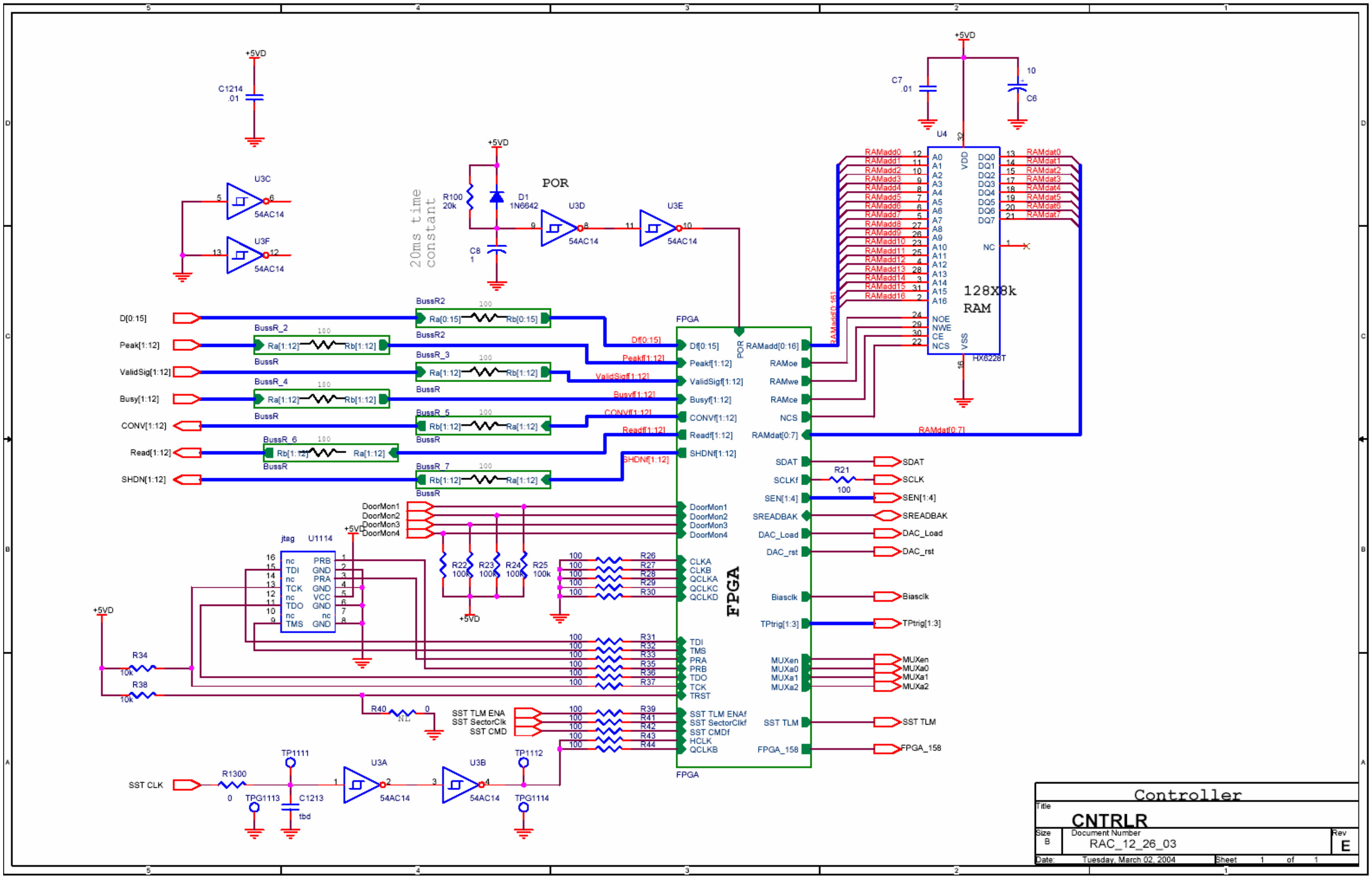
Test Pulse Schematic



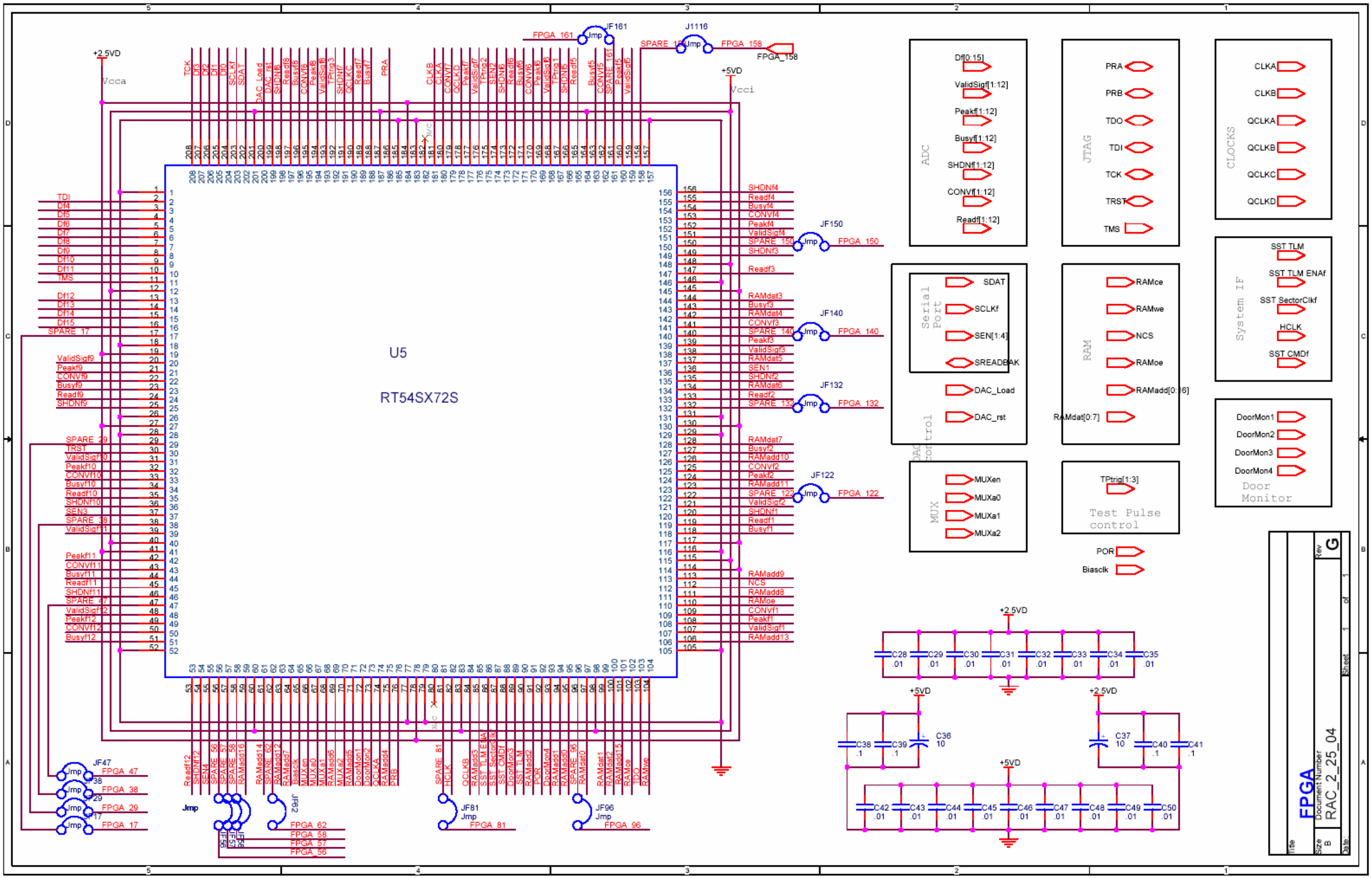
Bias Supply Schematic



Controller Schematic



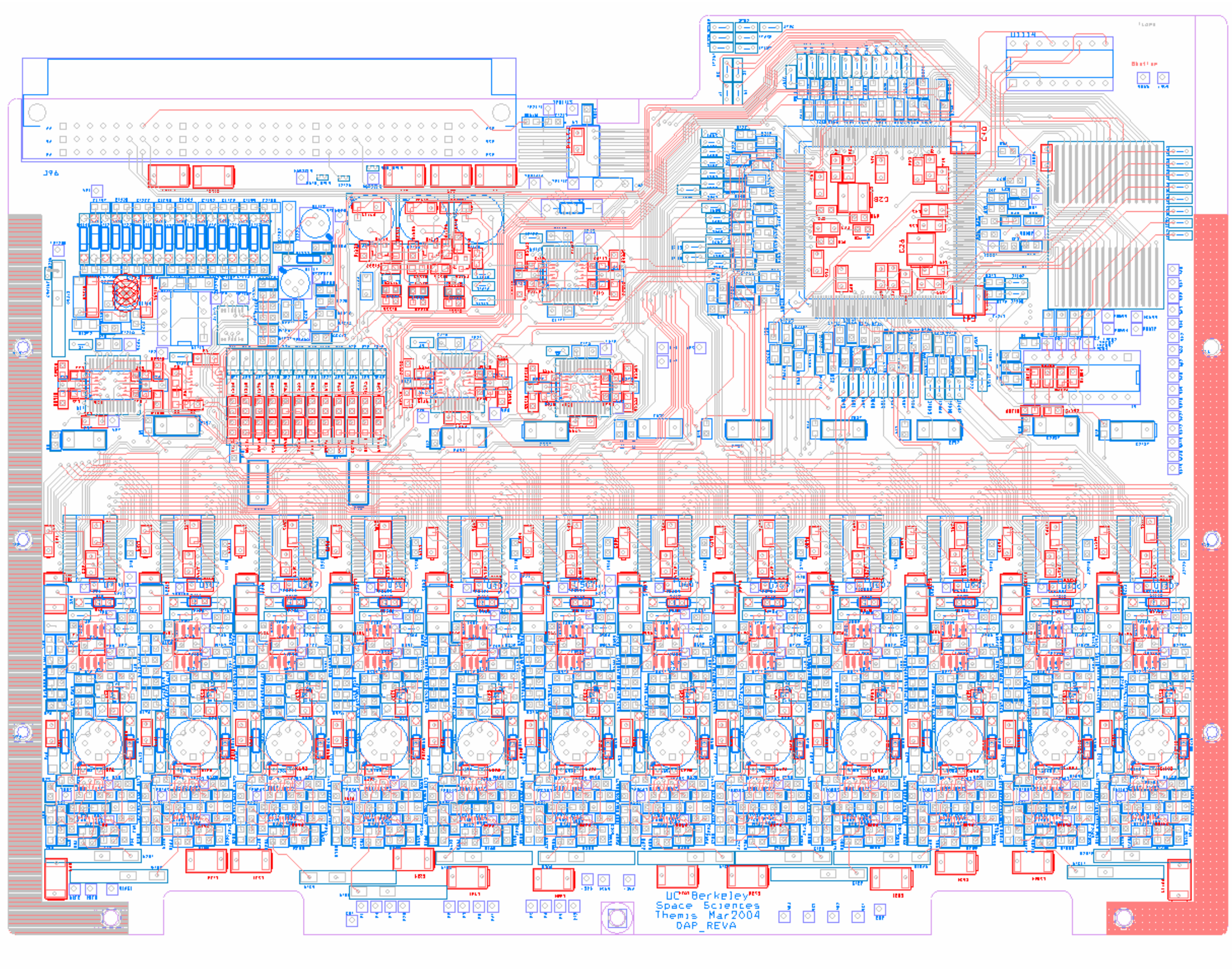
FPGA Schematic



DAP Layout

Layout:

- Started:
  ~2004-01-05
- Finished:
  ~2004-03-24
- Partially loaded Board Received:
  2004-04-05
- Actel Installed:
  2004-04-12
- Testing:
  Still in progress-
- Issues:
  - ~~Peak detect chatter~~
  - ~~Channel cross talk~~
  - FPGA lockup
  - Erratic FPGA current



Power Estimates

SST Power Estimates			Current					
		2.5	5	5	5			
		+2.5V D (mA)	+5V D (mA)	-5V A (mA)	+5V A (mA)		Power mW	
DFE electronics								
A225FB	(assumes 2.5 volt negative ref)			1.800	3.450		26.25	
x	**12**			**21.600**	***41.400***		**315.00**	
IDPU electronics								
ADC channels								
OP462				2.200	2.200		22.00	
CA3080A				0.075	0.075		0.75	
MAX907					1.400		7.00	
LTC1604			0.955	0.650	0.955		12.80	
Gate transistors					0.016		0.08	
subtotal			*0.955*	*2.925*	*4.646*		*42.63*	
ADC subtotal x	**12**		**11.460**	**35.100**	***55.752***		**511.56**	
Threshold (quad)								
AD5544				0.000	0.050		0.25	
OP462				2.200	2.200		22.00	
subtotal				*2.200*	*2.250*		*22.25*	
TH subtotal x	**3**		**0.000**	**6.600**	***6.750***		**66.75**	
LT1217				**1.000**	**1.000**		**10.00**	
Test Pulse & Bias control								
AD5544			0.000	0.000	0.050		0.25	
OP462			0.000	2.200	2.200		22.00	
TP&BC subtotal			**0.000**	**2.200**	**2.250**		**22.25**	
Bias Voltage circuit								
AD648				**0.680**	**0.680**		**6.80**	
POR			**0.200**				**1.00**	
FPGA (actel)		**0.000**	**48.000**				**240.00**	
SRAM (128K)			**0.000**				**0.00**	
							1173.36	
Total		**0.000**	**59.660**	**67.180**	**107.832**		**1173.36**	**mW**

Estimated Power Consumption: ~1200 mW

FPGA Requirements

- Usinge Actel RT54SX72S (modeled on STEREO/STE)
  - Controls 12 ADCs
    - Monitor / Count threshold events
    - Monitor peak detect signal
    - Produce convert strobe
    - Coincidence detection
    - Readout ADC (energy)
  - Psuedo-logrithmic energy binning
    - ADC measurement used as address of LUT to increment accumulators (LUTs and accumulators stored in SRAM)
  - Data Readout (controlled by ETC board)
  - Command Data Interface (CDI), (load tables)
  - Test Pulser control

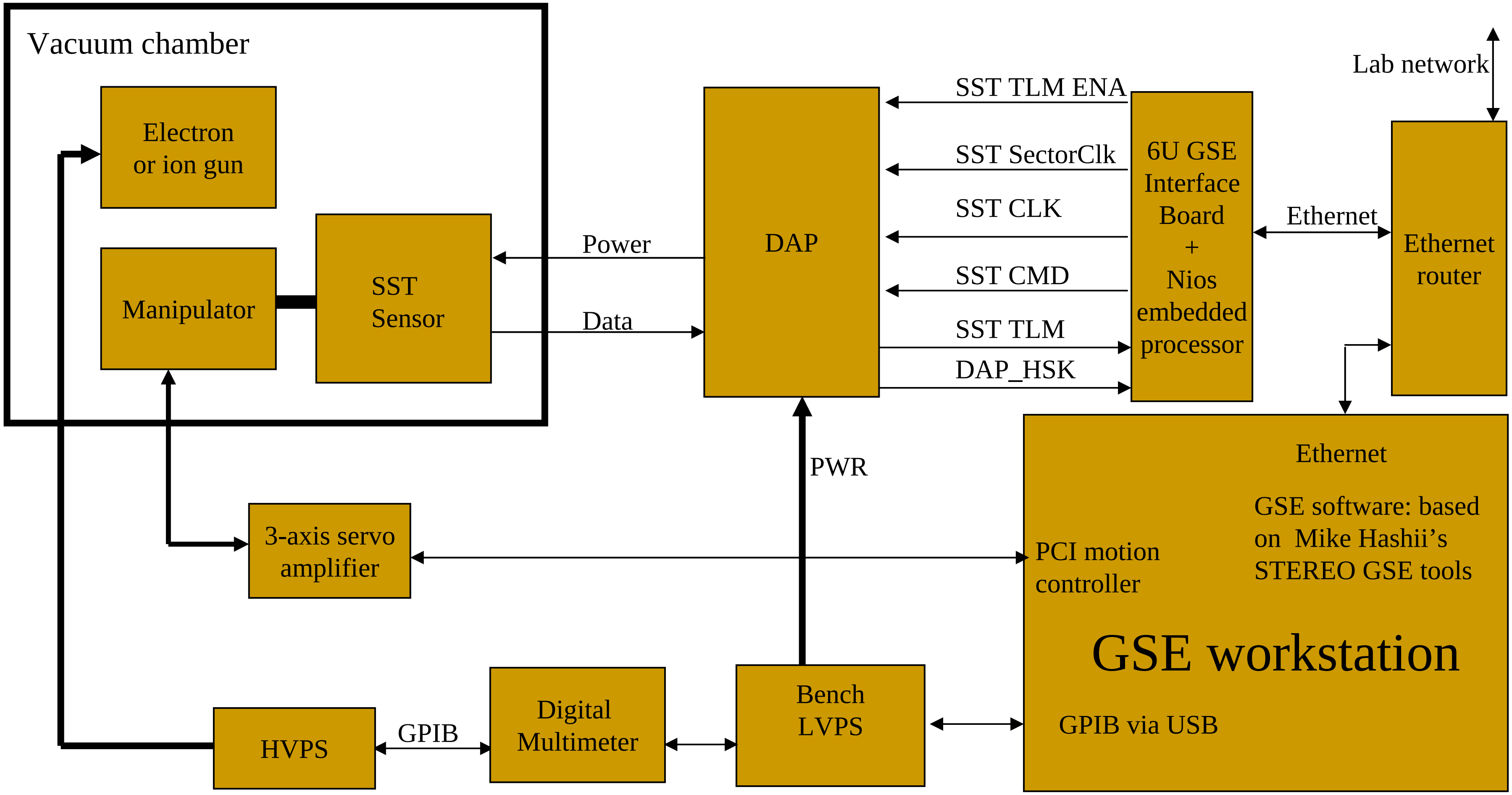
From PDR

ACTEL Development

- Designed by Jianxin Chen – Baja Technologies
- First installed 2004-04-12 (one week ago)
- Functionality:
  - Controls 12 ADCs
    - Monitor / Count threshold events - Working
    - Monitor peak detect signal - Working
    - Produce convert strobe - Working
    - Coincidence detection - ????
    - Readout ADC (energy) - ????
  - Psuedo-logrithmic energy binning
    - ADC measurement used as address of LUT to increment accumulators (LUTs and accumulators stored in SRAM) - ????
  - Data Readout (controlled by ETC board) - ????
  - Command Data Interface (CDI) (loads tables) -working ??
  - Test Pulser control - ????

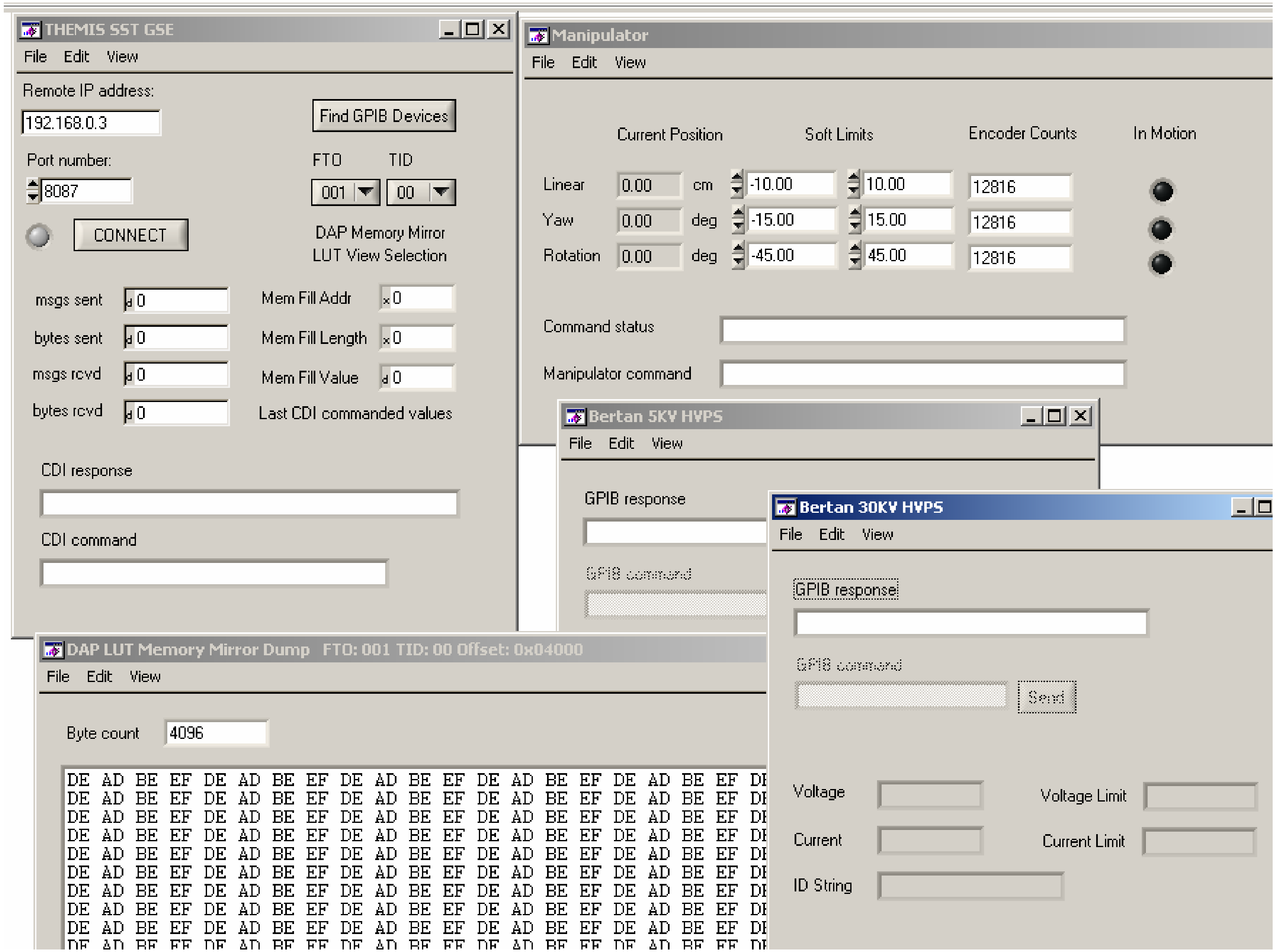
SST GSE
Jim Lewis

SST/DAP GSE Block Diagram

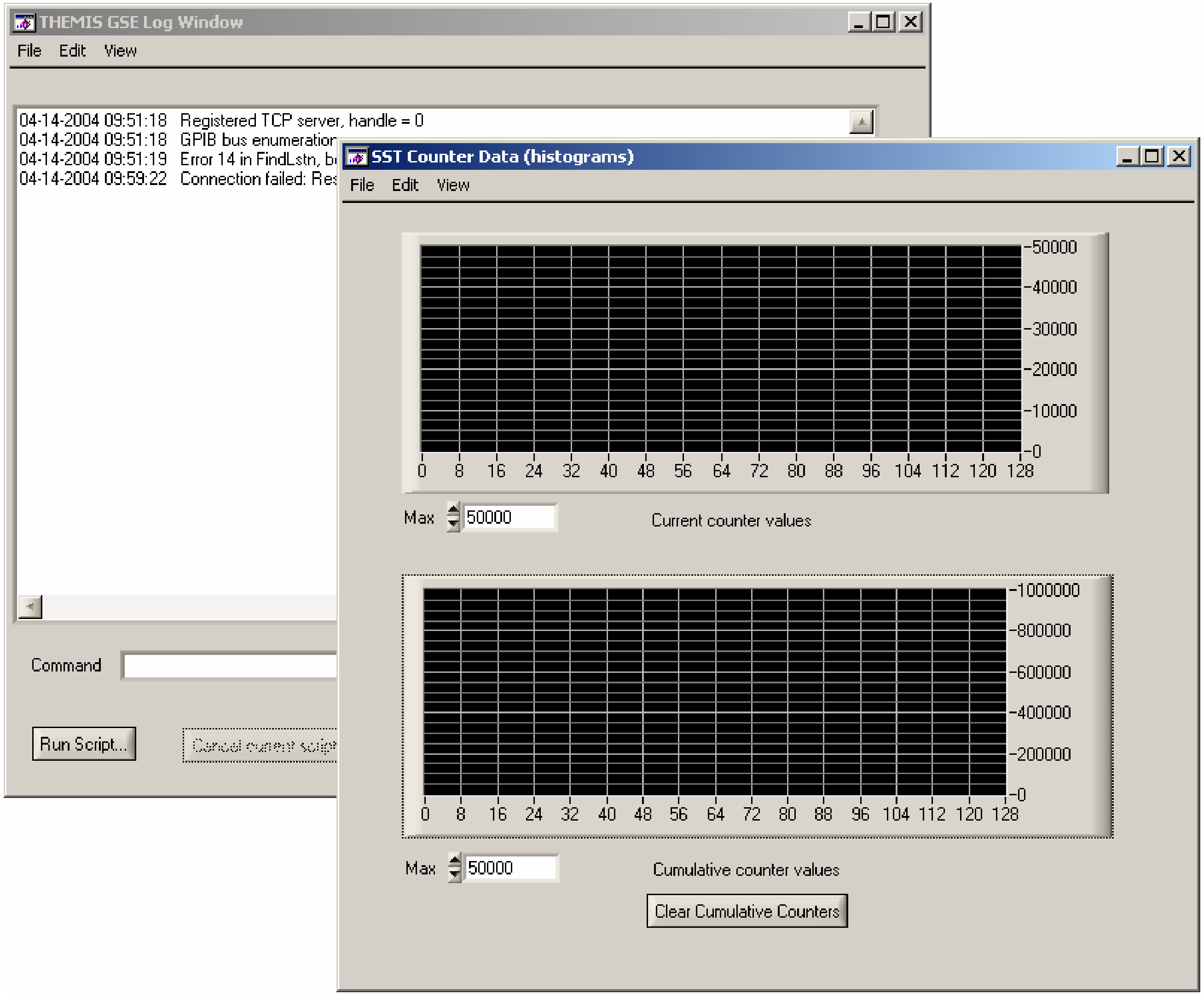


- Capabilities:
  - Scripted or interactive entry of CDI, GPIB, and manipulator commands
  - Simulates ETC board to command DAP and acquire telemetry
  - Real-time display of counter histograms, raw hex telemetry dumps, analog housekeeping values, manipulator status
  - Monitoring of CDI commands to mirror DAP memory operations and validate correct DAP FPGA operation
  - Telemetry and log messages archived to disk for later examination and processing
  - Device control
    - GPIB programmable LV and HV power supplies, digital multimeter
    - Internal PCI motion controller, external servo amp and motor

GSE Screen Shots



GSE Screen Shots



Testing and Calibration

- GSE Devolopment
- Vacuum Chamber Refurb
- Ion Gun (Peabody Scientific)

From PDR

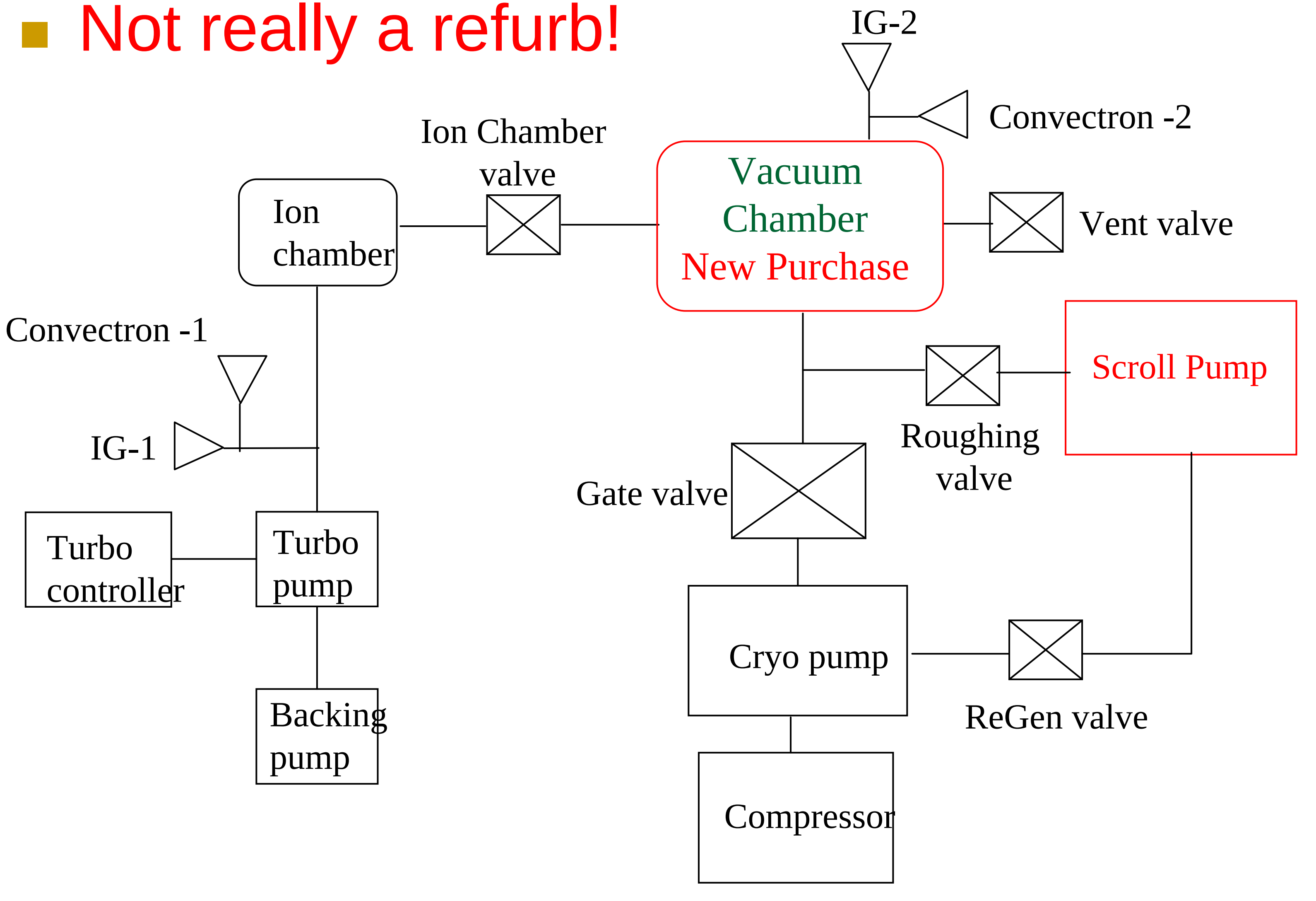
Contamination Control

- Standard cleanliness procedures will be followed
- The sensor units will have a dry Nitrogen purge system and red tagged covers (removed at last possible opportunity)
- Nitrogen purge can be removed for transport (<24? hours) with sensor in sealed containers.
- Red tape to cover apertures during spin balance
- Sensor contamination from fairing during launch – still open issue

From PDR

Vacuum Chamber Refurb

- Not really a refurb!



Vacuum Chamber refurb

9/11/2003					
item	description	vendor	p/n	price($)	note
1	Cryo Pump	CTI	8160001sys	14200.00	Cryo-Torr 8 / 8200 Compressor System, complete
2	Cryo temp indicator	CTI	8043459G001	1372.00	Cryo head temp monitor
3	chamber gate valve	MDC	304005-05	2825.00	8" port, 1-1/2" rough port, ANSI ASA6 flanges
4	gate valve hardware	MDC	190177	74.00	hex head bolts for ASA6 flange
5	Turbo-V 301 Navigator	Varian	9698828	7280.25	complete system w/ controller, N2 250 L/s, 120VAC, ISO NW100
6	turbo air cooling kit	Varian	9699299	297.60	very convenient
7	turbo inlet screen	Varian	9699302	76.60	
8	SH-100 Scroll pump	Varian	SH01001UNIV	2450.00	backing pump for turbo, 120VAC, 60Hz, oil-free
9	exhaust silencer	Varian	SH0100EXSLR	83.00	
10	scroll pump power cord	Varian	656458203	free	15A/125VAC, 6' length
11	adapter nipple	MDC	832008	225.00	ISO NW100 to ISO NW80 reducer
12	reducing cross	MDC	825043	290.00	ISO NW80 to NW40 KF
13	Ion Chamber valve	MDC	306005	1500.00	4" port manual swing gate valve, ISO NW100 flange
14	roughing valve	MDC	312029	340.00	2-3/4" CCF, metal seal bonnet, manual
15	vent valve	Varian	9515085	325.00	Rt angle valve, NW16 KF, manual
16	regen valve	MDC	310073	245.00	NW25 KF, metal seal bonnet, manual
17	vacuum gauge controller	Granville-Phillips	307502-C10-T1	2095.00	307, dual IG/rough gauge capability, IEEE 488
18	ion chamber rough gauge	Granville-Phillips	275316	180.00	Convectron gauge(1), range atm to 8e-4 Torr, NW40 KF
19	chamber rough gauge	Granville-Phillips	275316	180.00	Convectron gauge(2), range atm to 8e-4 Torr, NW40 KF
20	ion chamber ion gauge	Granville-Phillips	27453	470.00	BA Nude IG(1), all metal case, NW40 KF
21	chamber ion gauge	Granville-Phillips	27453	470.00	BA Nude IG(2), all metal case, NW40 KF
22	rough gauge cables	Granville-Phillips	303040-10	90.00	Dual Convectron cable, 10'
23	ion gauge cable	Granville-Phillips	307046-CR	140.00	BA IG cable
24	ion gauge cable	Granville-Phillips	307046-CR	140.00	BA IG cable
25	misc.plumbing			2000.00	fittings, rough lines, switches, etc.
26	cleaning chamber	Pullbrite(510 659-9770)		750.00	soak, scrub, and electropolish
27	half nipple	Varian	INH1000400	100.00	ISO NW100 weldable to chamber
28	in house fab	SSL shop		1325.00	25 hr @ $53.00/ hr
			Total	39523.45	

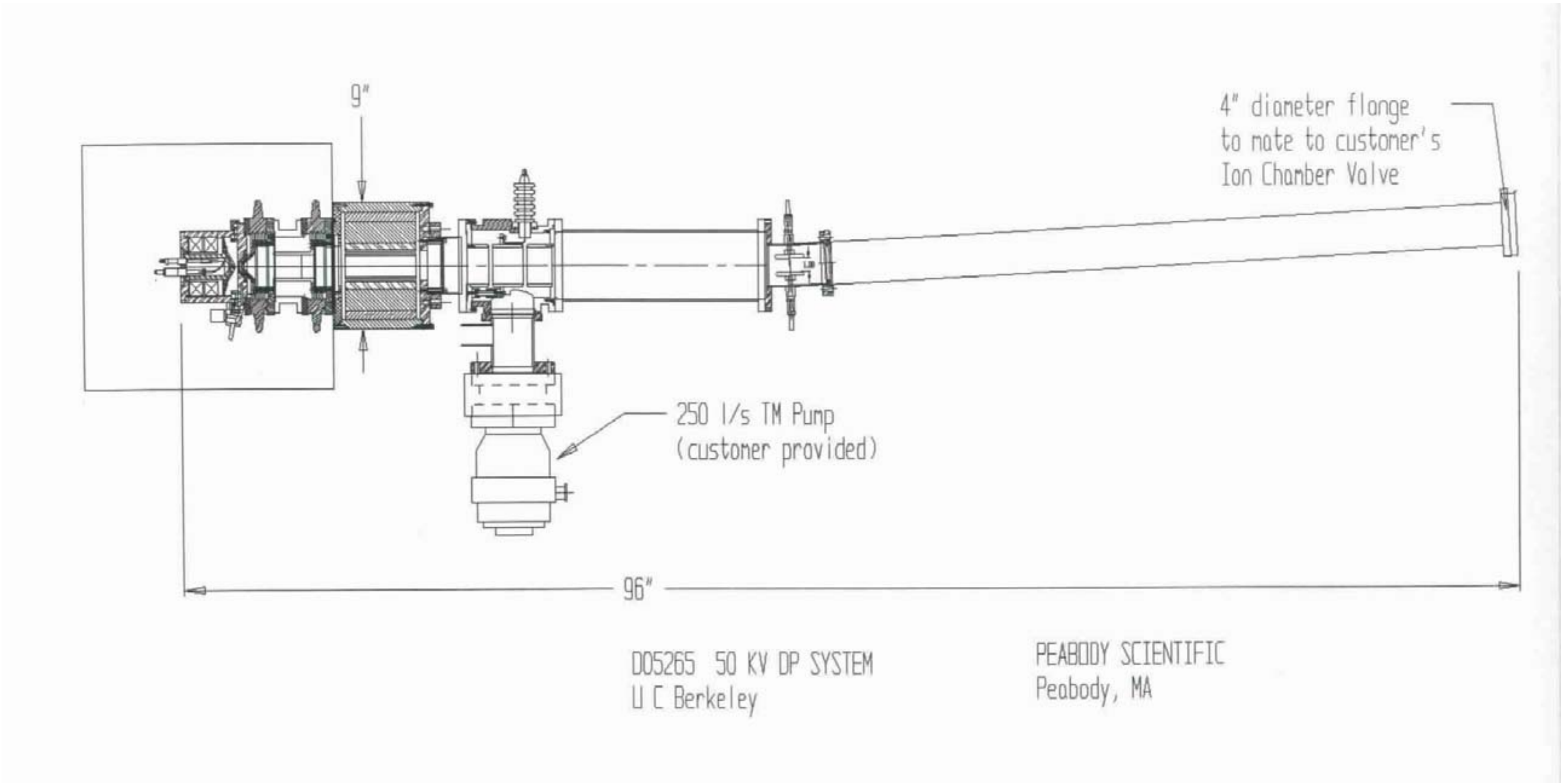
From PDR

Ion Gun Specifications

10/6/2003			
	List of Specs		
	1	energy range	1KeV to 50 KeV
	2	energy width	0.5% over full range or 50eV, whichever is greater
	3	energy stability	1% over full range for 20 minutes
	4	particle flux	1000 to 100000 particles/s/cm^2
	5	beam cross section	4 cm diameter
	6	beam flux stability	<2% for 20 minutes
	7	beam flux variation	<20% over cross section
	8	species	H^+, He^+, Ne^+, O^+, N^+, Ar^+, (Kr^+)
	9	mass resolution	distinguish above species
	10	system footprint	not to exceed 9' x 4' (preference, not required)
	11	power requirement	120VAC
	12	cooling requirements	preferably air, but H_2O OK
	13	lead time	4 to 5 month
	14	vacuum system req	ability to interface to 250 l/s turbo pumping system

From PDR

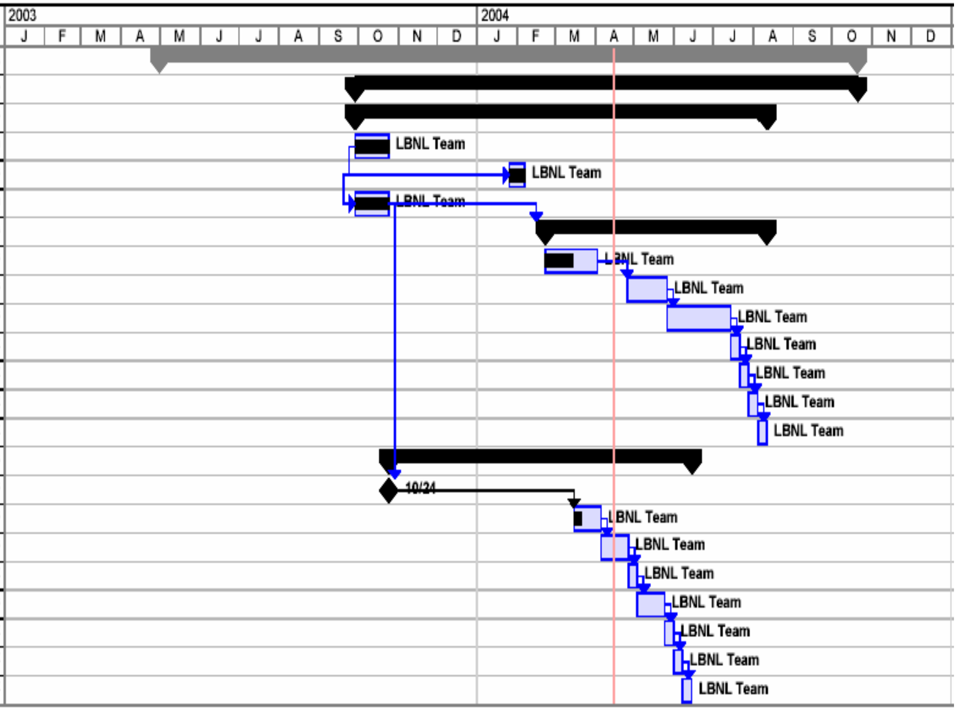
Ion Gun Schematic



From PDR

Detector Schedule

ID		Task Name	Start	Finish	Duration
0		THEMIS SST	Thu 5/1/03	Wed 10/20/04	385 days
83		**SST FLT**	**Mon 9/29/03**	**Wed 10/20/04**	**278 days**
84		**SST FLT DETECTOR FAB**	**Mon 9/29/03**	**Wed 8/11/04**	**228 days**
85		SST FLT Det Photo Mask Design	Mon 9/29/03	Fri 10/24/03	1 mon
86		SST FLT Det Photo Masks Prcmt	Mon 1/26/04	Fri 2/6/04	2 wks
87		SST FLT Fab Batch I Det Getter Layer	Mon 9/29/03	Fri 10/24/03	1 mon
88		**SST FLT Fab Rework Batch II Det Getter Layer**	**Mon 2/23/04**	**Wed 8/11/04**	**123 days**
89		SST FLT Fab Batch II Det Getter Layer (25)	Mon 2/23/04	Fri 4/2/04	6 wks
90		SST FLT Implantation Batch II (25)	Mon 4/26/04	Wed 5/26/04	4.6 wks
91		SST FLT Bk Side Repolishing Batch II (25)	Thu 5/27/04	Wed 7/14/04	7 wks
92		SST FLT Mounting Batch II (25)	Thu 7/15/04	Wed 7/21/04	1 wk
93		SST FLT Detector Batch II Dice	Thu 7/22/04	Wed 7/28/04	1 wk
94		SST FLT Detector Batch II Test	Thu 7/29/04	Wed 8/4/04	1 wk
95		SST FLT Detector Batch II Mounting	Thu 8/5/04	Wed 8/11/04	1 wk
96		**SST FLT Fab Rework Batch III Det Getter Layer**	**Fri 10/24/03**	**Mon 6/14/04**	**166 days**
97		SST FLT Fab Batch III Det Getter Layer (13)	Fri 10/24/03	Fri 10/24/03	0 days
98		SST FLT Implantation Batch III (13)	Tue 3/16/04	Mon 4/5/04	3 wks
99		SST FLT Bk Side Polishing Batch III (13)	Tue 4/6/04	Mon 4/26/04	3 wks
100		SST FLT Mounting Batch III (13)	Tue 4/27/04	Mon 5/3/04	1 wk
101		SST FLT Detector Batch III Test (13)	Tue 5/4/04	Mon 5/24/04	3 wks
102		SST FLT Detector Batch III Dice	Tue 5/25/04	Mon 5/31/04	1 wk
103		SST FLT Detector Batch III Test	Tue 6/1/04	Mon 6/7/04	1 wk
104		SST FLT Detector Batch III Mounting	Tue 6/8/04	Mon 6/14/04	1 wk



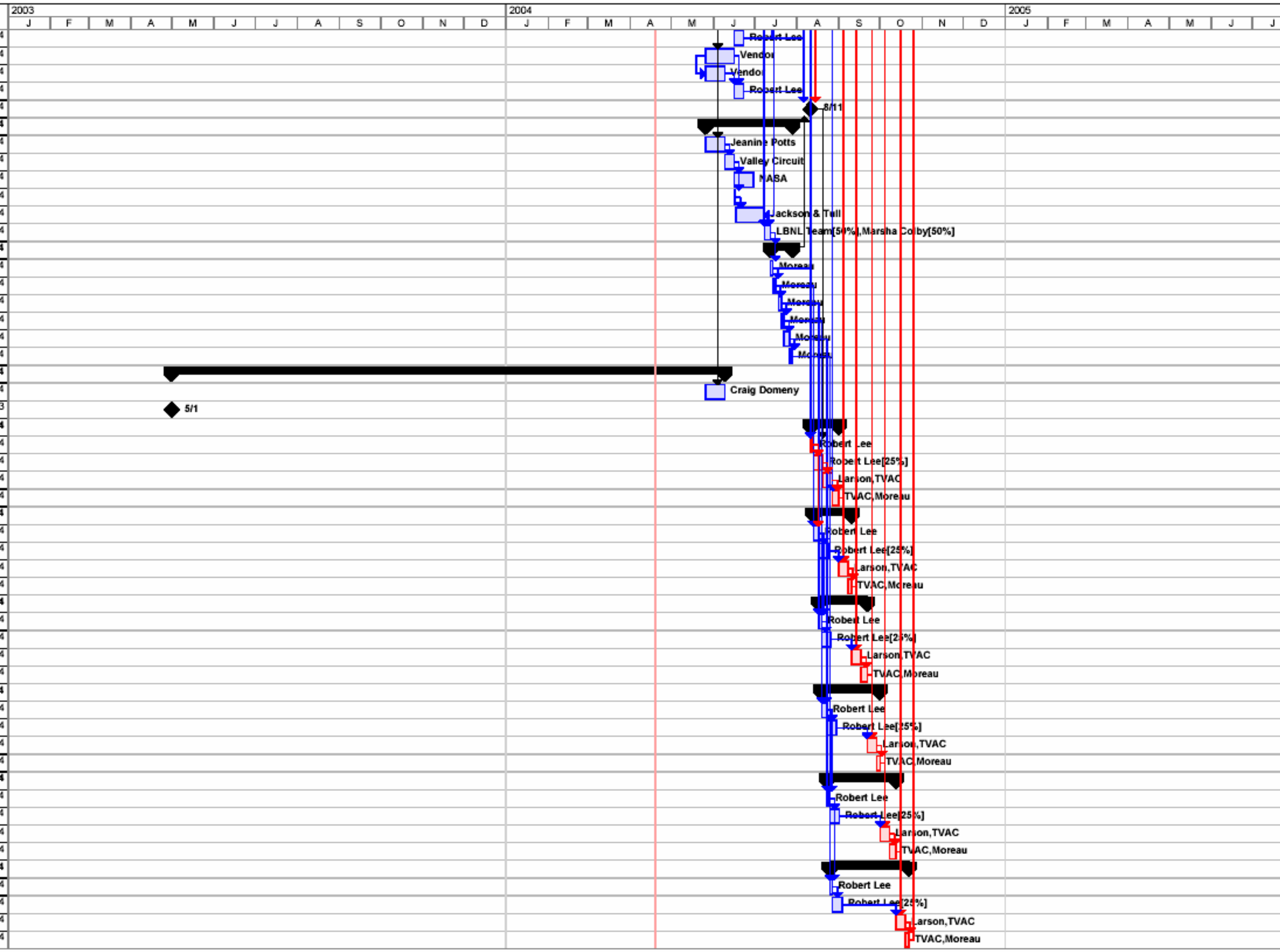
Schedule

ID		Task Name	Finish
56	✓	SST DFE ETU PWB Fab	Tue 10/14/03
57	✓	SST DFE ETU Assy	Tue 10/21/03
58	✓	SST DFE ETU Prelim Te	Tue 11/4/03
59	✓	SST DFE ETU Layout Re	Fri 2/27/04
60	✓	SST DFE ETU PWB Fab	Wed 3/3/04
61	✓	SST DFE ETU Parts Kit II	Wed 3/3/04
62	✓	SST DFE ETU Assy II	Wed 3/10/04
63	✓	SST DFE ETU Final Test	Wed 3/17/04
64		**SST ETU Sensor Testing**	**Wed 5/12/04**
65	✓	SST ETU Sensor DFE Fit	Thu 3/25/04
66		SST ETU Vibration Level	Wed 4/21/04
67		SST ETU Sensor Vibe Pr	Fri 4/30/04
68		SST ETU Functional Test	Wed 5/5/04
69		SST ETU Sensor Therma	Wed 5/12/04
70		SST ETU DAP Board (IDPU)	Thu 5/1/03
71		SST ETU Mated Test	Wed 5/26/04
72		SST ETU Complete	Wed 5/26/04
73		**SST GSE**	**Fri 4/30/04**
74	✓	SST GSE FPGA	Fri 2/27/04
75	✓	SST GSE SW	Fri 2/13/04
76	✓	SST Manipulator Refurbishing	Fri 1/30/04
77		SST Manipulator Motor Replaceme	Fri 3/12/04
78	✓	Vacuum Chamber Refurb	Tue 3/9/04
79		Vacuum Chamber Replacement	Tue 4/20/04
80		Ion Gun Procurement	Fri 4/30/04
81		**SST FLT**	**Fri 10/22/04**
82		**SST FLT DETECTOR FAB**	**Wed 8/11/04**
83	✓	SST FLT Det Photo Mask Des	Fri 10/24/03
84	✓	SST FLT Det Photo Masks Pr	Fri 2/6/04
85	✓	SST FLT Fab Batch I Det Gett	Fri 10/24/03
86		**SST FLT Fab Rework Batch**	**Wed 8/11/04**
87	✓	SST FLT Fab Batch II De	Fri 4/2/04
88		SST FLT Implantation Ba	Wed 5/26/04
89		SST FLT Bk Side Repolis	Wed 7/14/04
90		SST FLT Mounting Batch	Wed 7/21/04
91		SST FLT Detector Batch	Wed 7/28/04
92		SST FLT Detector Batch	Wed 8/4/04
93		SST FLT Detector Batch	Wed 8/11/04
94		**SST FLT Fab Rework Batch**	**Mon 6/14/04**
95	✓	SST FLT Fab Batch III De	Fri 10/24/03
96	✓	SST FLT Implantation Ba	Mon 4/5/04
97		SST FLT Bk Side Polishir	Mon 4/26/04
98		SST FLT Mounting Batch	Mon 5/3/04
99		SST FLT Detector Batch	Mon 5/24/04
100		SST FLT Detector Batch	Mon 5/31/04
101		SST FLT Detector Batch	Mon 6/7/04
102		SST FLT Detector Batch	Mon 6/14/04
103		**SST FLT Mech Fabrication**	**Wed 8/11/04**
104		SST FLT Mechanical Redesig	Wed 6/2/04
105		SST FLT Attenuator Compone	Wed 6/30/04
106		SST FLT Attenuator Assy	Wed 7/14/04
107		SST FLT Attenuator Cycling T	Wed 8/11/04
108		SST FLT Magnet & Yoke Mac	Wed 6/23/04
109		SST FLT Magnet Cage Machi	Wed 6/16/04
110		SST FLT Magnet Cage Assy &	Wed 7/14/04
111		SST FLT Structure Componen	Wed 6/16/04

10:20 AM Mon 4/19/04 Page 2 thm_sst.mpp

Schedule

ID		Task Name	Finish
112		SST FLT Structure Assy	Wed 6/23/04
113		SST FLT Collimator Machining	Wed 6/16/04
114		SST FLT Collimator Baffles Et	Wed 6/9/04
115		SST FLT Collimator Assy	Wed 6/23/04
116		SST FLT Mech Fab Complete	Wed 8/11/04
117		**DET FLT Fab, Assy Test**	**Wed 7/28/04**
118		DFE FLT Layout Mods	Wed 6/9/04
119		DFE FLT PWB Fab	Wed 6/16/04
120		DFE FLT Coupons	Wed 6/30/04
121		DFE FLT Kit	Thu 6/17/04
122		DFE Assy F1-F6	Thu 7/8/04
123		DFE /DET Mating	Mon 7/12/04
124		**DFE/DET Test F1-F6**	**Wed 7/28/04**
125		DFE/DET Test F1	Wed 7/14/04
126		DFE/DET Test F2	Fri 7/16/04
127		DFE/DET Test F3	Tue 7/20/04
128		DFE/DET Test F4	Thu 7/22/04
129		DFE/DET Test F5	Mon 7/26/04
130		DFE/DET Test F6	Wed 7/28/04
131		**DAP FLT Fab,Assy,Test (2)**	**Wed 6/9/04**
132		DAP FLT Layout Mods	Wed 6/9/04
133		DAP F1-F6 Ready	Thu 5/1/03
134		**SST F1**	**Tue 8/31/04**
135		SST Assy F1	Fri 8/13/04
136		SST Vibration F1	Fri 8/20/04
137		SST Vac Test F1	Fri 8/27/04
138		SST Calib F1	Tue 8/31/04
139		**SST F2**	**Fri 9/10/04**
140		SST Assy F2	Tue 8/17/04
141		SST Vibration F2	Tue 8/24/04
142		SST Vac Test F2	Tue 9/7/04
143		SST Calib F2	Fri 9/10/04
144		**SST F3**	**Tue 9/21/04**
145		SST Assy F3	Thu 8/19/04
146		SST Vibration F3	Thu 8/26/04
147		SST Vac Test F3	Fri 9/17/04
148		SST Calib F3	Tue 9/21/04
149		**SST F4**	**Fri 10/1/04**
150		SST Assy F4	Mon 8/23/04
151		SST Vibration F4	Mon 8/30/04
152		SST Vac Test F4	Tue 9/28/04
153		SST Calib F4	Fri 10/1/04
154		**SST F5**	**Tue 10/12/04**
155		SST Assy F5	Wed 8/25/04
156		SST Vibration F2	Wed 9/1/04
157		SST Vac Test F5	Fri 10/8/04
158		SST Calib F5	Tue 10/12/04
159		**SST F6**	**Fri 10/22/04**
160		SST Assy F6	Fri 8/27/04
161		SST Vibration F2	Fri 9/3/04
162		SST Vac Test F6	Tue 10/19/04
163		SST Calib F6	Fri 10/22/04



10:20 AM Mon 4/19/04 Page 3 thm_sst.mpp