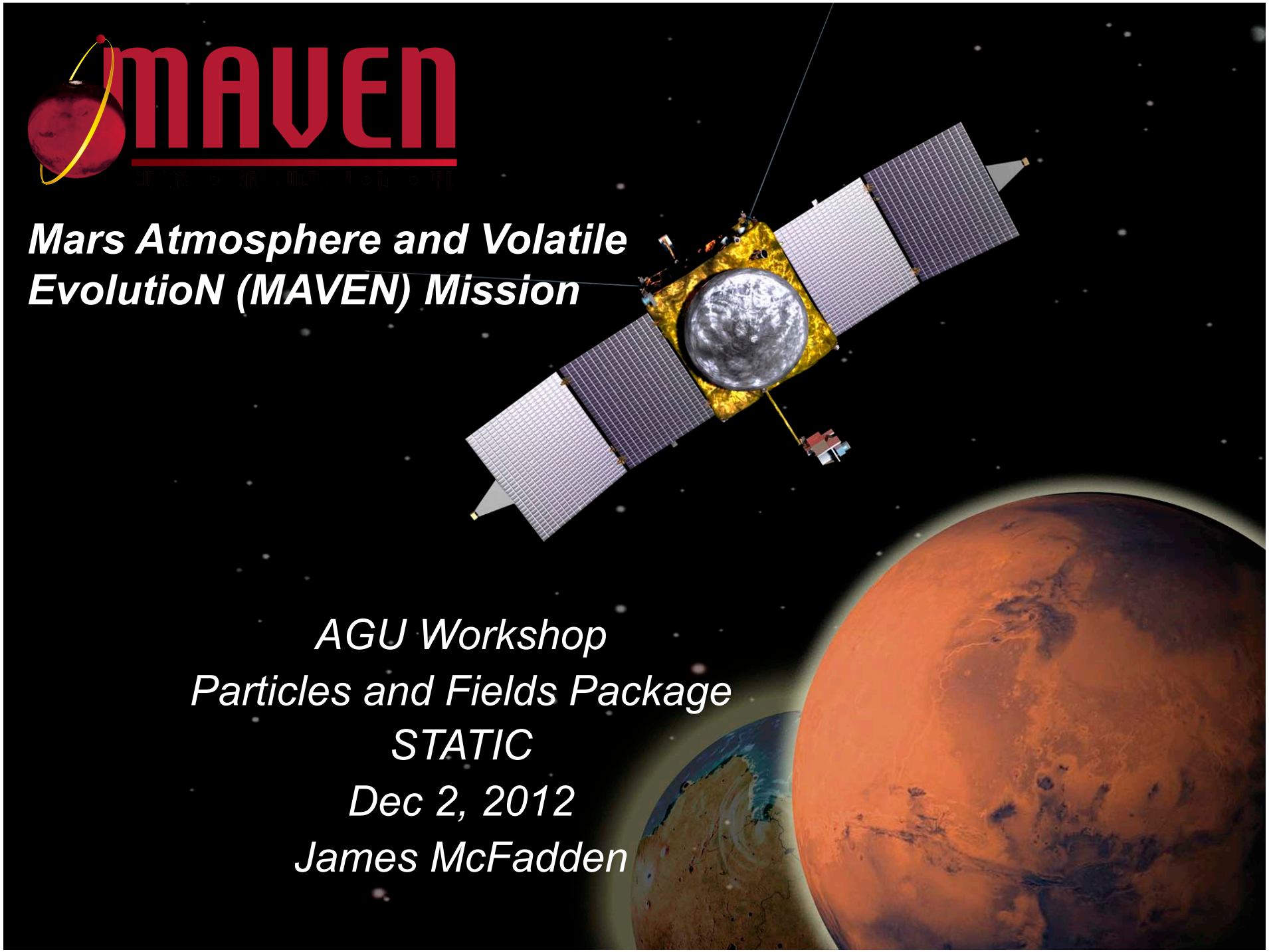
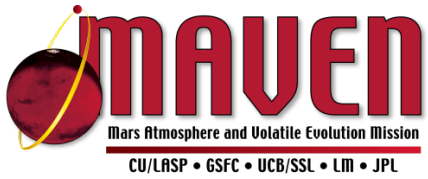

MAVEN
Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission
AGU Workshop
Particles and Fields Package
STATIC
Dec 2, 2012
James McFadden

STATIC Team



STATIC (Supra Thermal And Thermal Ion Composition)

Or (Significant Troubles Ahead, Take Immense Caution)
Or (Start of Thermovac Activities Thrown Into Confusion)
Or (Slipped Timetables Annoy That Irate Curtis)

Instrument Lead: James McFadden

Electrical: Robert Abiad, Ken Hatch, Dorothy Gordon, Chris Tiu, Peter Berg, Selda Heavner

Mechanical: Greg Dalton, Greg Johnson, Paul Turin, Chris Smith

Testing: Onno Kortmann, Mario Markwordt

Summary of Science Requirements

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

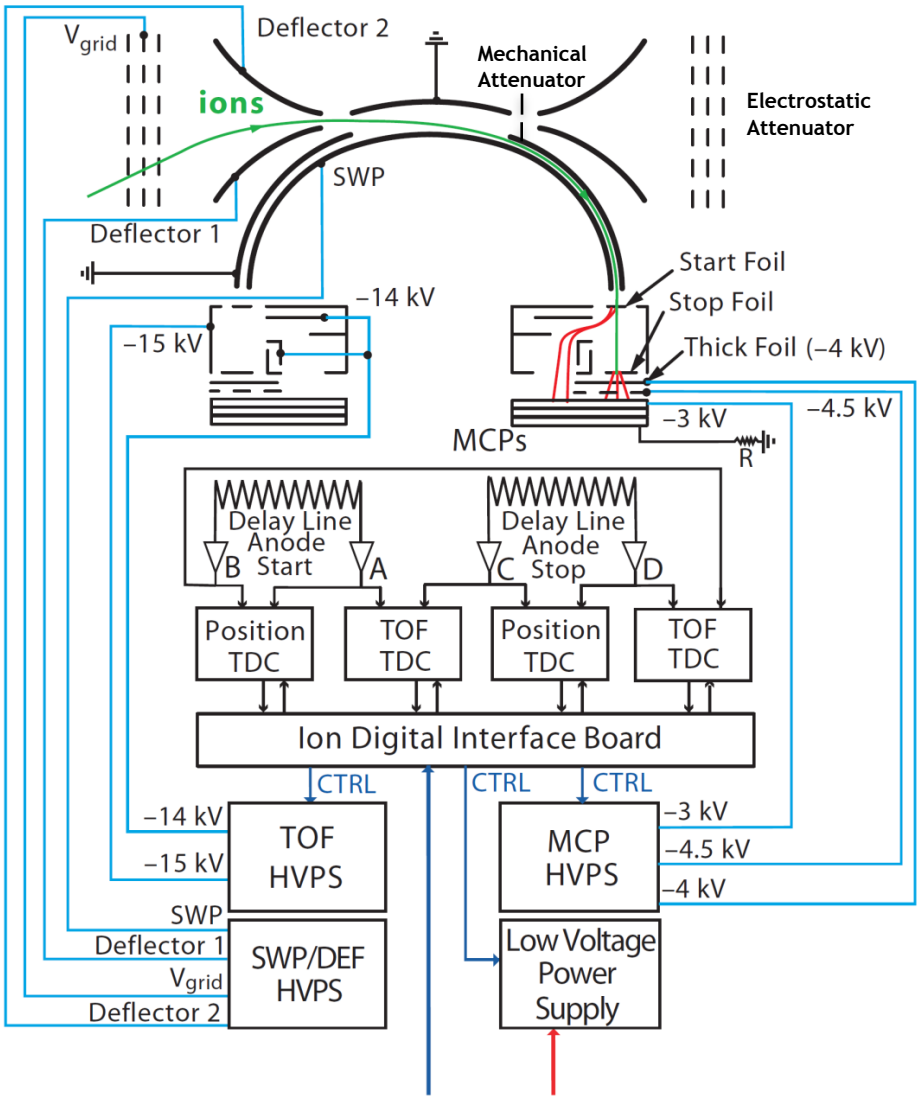
STATIC Science Objectives and Requirements

Thermal Ionospheric Ions (0.1-10 eV)
- >1 eV due to RAM velocity (~4 km/s), peak flux at ~2-3 eV
- densities of 10^5/cm^3 require both attenuators
- densities of 10^3-10^4/cm^3 require single attenuator
- resolve 3D angle distribution requires ~10-20 deg sensor resolution
- resolve parallel temperature down to ~0.1 eV requires ~1 eV

Suprathermal Ion Tail – Conics (5-100 eV)
- >5 eV ions with escape velocity
- expected fluxes similar to Earth's aurora
- as RAM ions drop below ~10^2/cm^3, switch off attenuators

Pick-up Ions (100 – 20,000 eV)
- tenuous flux may require long integrations
- flux generally maximum perpendicular to solar wind **V** and **B**
- optimal measurements may require rotation of APP
- instrument should not saturate in magnetosheath

STATIC Block Diagram



Starting from the top:

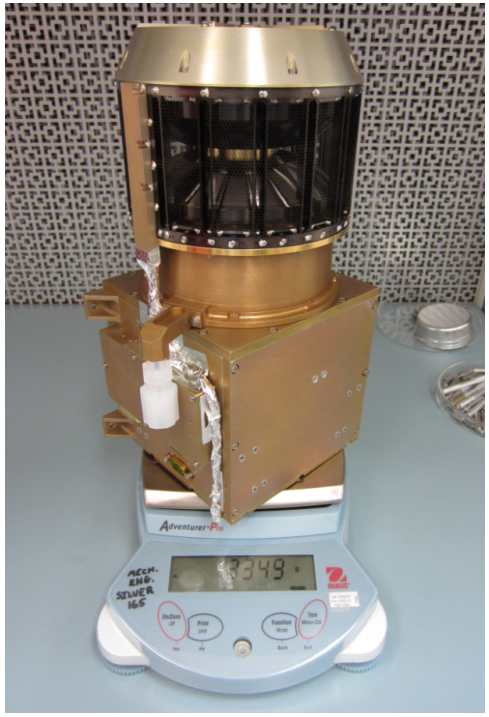
1) Ions are energy selected by the analyzer
2) Ions post accelerated by 15 kV
3) Ions penetrate Start foil producing e-
4) Start electrons accelerated and deflected to the MCP producing signal in Start anodes
5) Ions traverse 2 cm and penetrate Stop foils producing e-
6) Stop e-, accelerated by ~10 kV, penetrate thick foil (-4-5 kV), strike MCP producing signal in Stop anodes
7) Protons penetrating Stop foil are captured by thick foil before reflecting
8) Heavy ions may reflect before thick foil, due to energy losses in foils, but have high efficiency for foil e- production
9) Separate delay line anodes for Start and Stop signal allows both position and time coincidence for rejection of noise.
10) Digital interface board decodes and stores event before transfer to PFDPU
11) 4 sec cycle time 64E x 16 Deflections

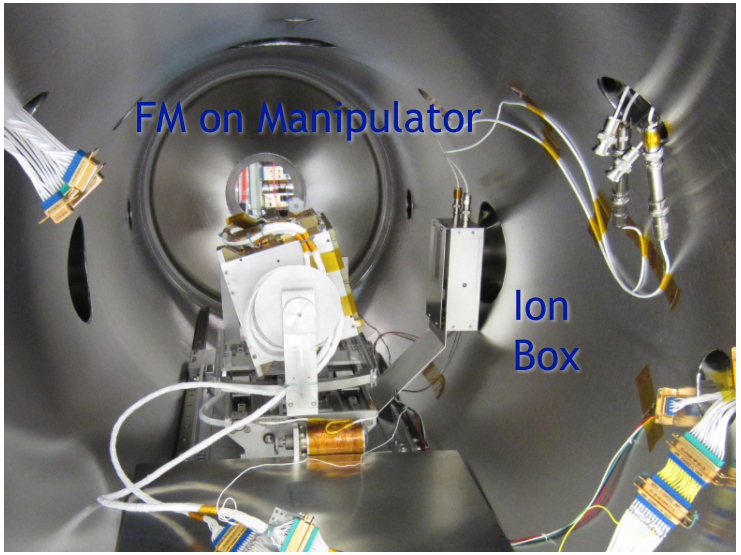
PF Level 3 Requirements

REQUIREMENT	STATIC DESIGN
PF55: STATIC shall measure energy fluxes from **10^7 to 10^{10}** eV/cm2-sec-ster-eV with 20 second resolution	**Compliance.** STATIC includes 2 attenuators that extend the dynamic range to **10^{12}** eV/cm^2-s-ster-eV
PF56: STATIC shall measure energy fluxes from **10^4 to 10^8** eV/cm2-sec-ster-eV with 30 minute resolution	**Compliance.** STATIC is designed to handle isotropic fluxes up to **10^8** eV/cm^2-s-ster-eV with the attenuators off w/o significant dead time . At flux levels of **10^4** eV/cm2-sec-ster-eV, STATIC will register 15 counts in a single energy-angle channel with 30 minute integration.
PF57: STATIC shall measure ions from at least **1-44** amu	**Compliance.** STATIC mass range will extend to at least **70** amu.
PF58: STATIC shall have mass resolution **m/dm of at least 2**	**Compliance.** STATIC prototype testing indicates **m/dm of ~4** at O_2+, and higher resolution at lower masses.
PF59: STATIC shall measure ions from **1 to 10,000eV**	**Compliance.** STATIC analyzer energy constant and HV specification allow measurements up to **30 keV**. STATIC sweep HV supply is designed to measure and correct for OPamp offsets and drifts to provide accurate low energy measurements to **1 eV.**
PF60: STATIC shall have energy resolution dE/E of at least **30%**	**Compliance.** STATIC's energy analyzer has an intrinsic energy resolution dE/E of **~15%.**
PF61: STATIC shall have angular resolution of at least **30 degrees**	**Compliance.** STATIC's angular resolution is **22.5 degrees** in azimuth (anode resolution) and **~6 degrees** elevation (varies w/ deflection).
PF62: STATIC shall have a FOV at least **60 degrees by 180 degrees**	**Compliance.** STATIC's FOV is **90 degrees by 360 degrees,** minus losses do to s/c obstruction (<90) in the 360 deg FOV.
PF63: STATIC shall have time resolution of **20 seconds** or better for Flux range 1	**Compliance.** STATIC's time resolution is **4 seconds**.
PF64: STATIC shall have time resolution of **30 minutes** or better for Flux range 2	**Compliance.** STATIC's time resolution is 4 seconds, but uses **~2 minute** averaging times for tenuous pickup ions.

STATIC Calibration

- Full calibrations of flight unit were completed prior to and after environmental testing.

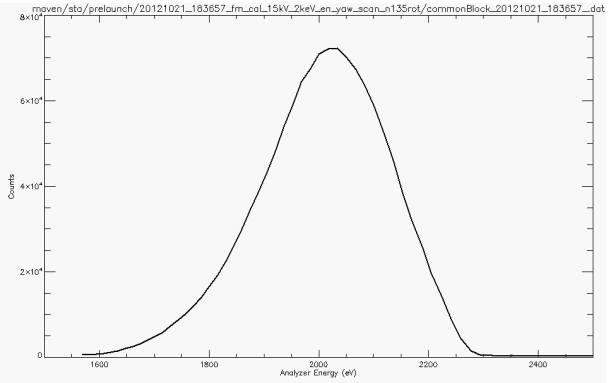




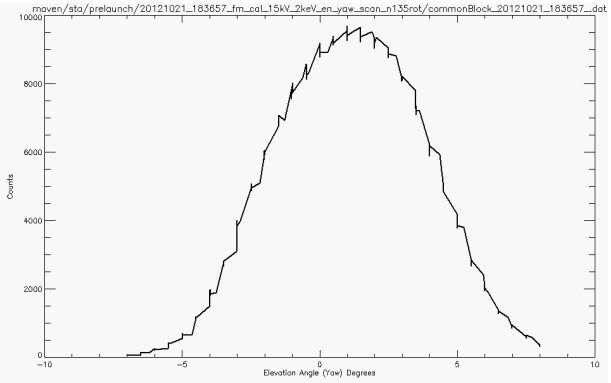
STATIC Calibration (PF 60,61)

Sensor Energy-Angle resolution tested with 2000 eV ion beam, no Attenuator.

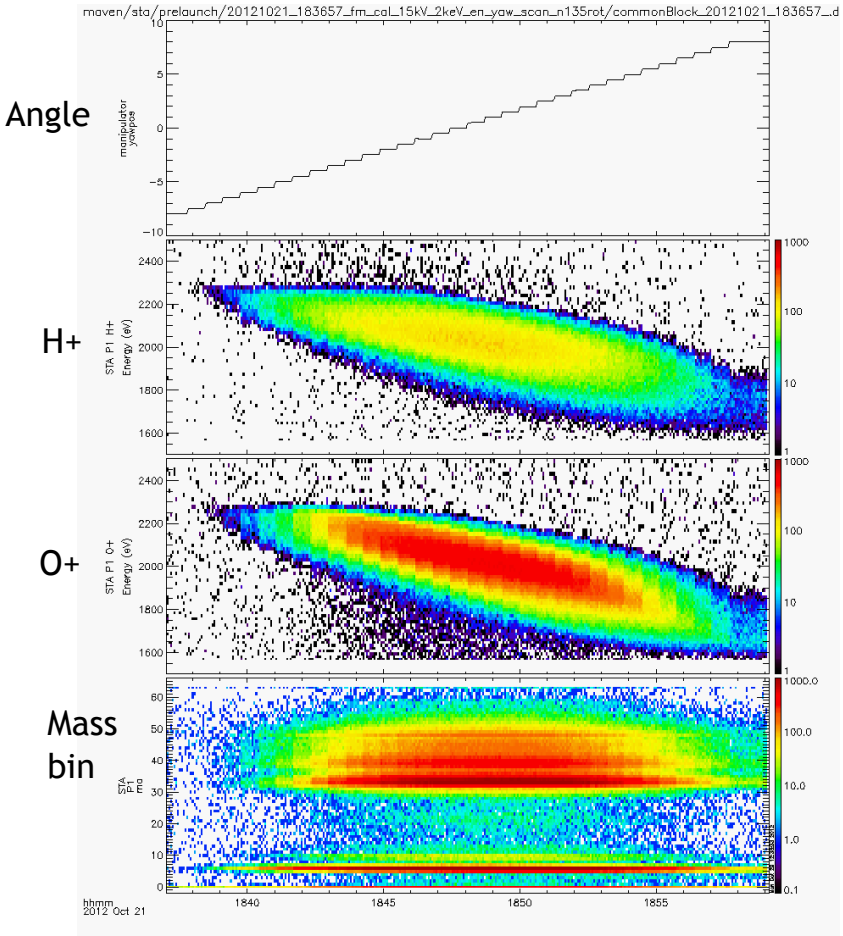
Sensor Energy and Angle resolution as expected. Ion gun beam broadens angular response slightly. ~1º offset in beam center consistent with alignment error. H+ and H_2O+ have identical response.



Energy Resolution: ~13.5% (Sim ~13%)



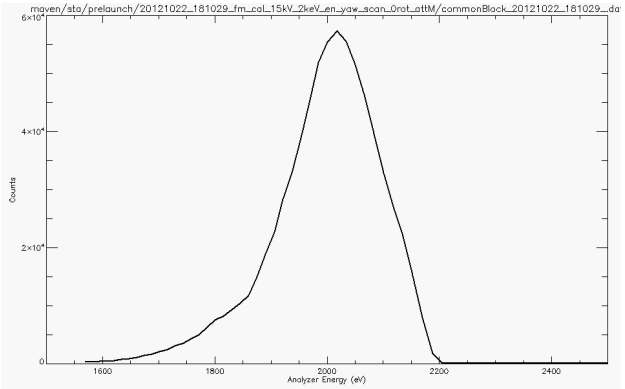
Angle Resolution: ~8º (Sim ~7º)



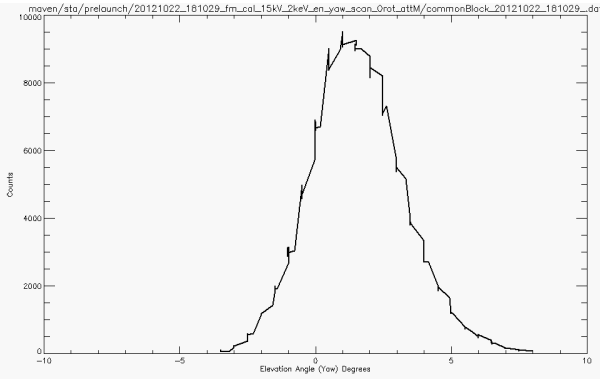
STATIC Calibration (PF 60,61)

Sensor Energy-Angle resolution tested with 2000 eV ion beam, with Mech Attenuator.

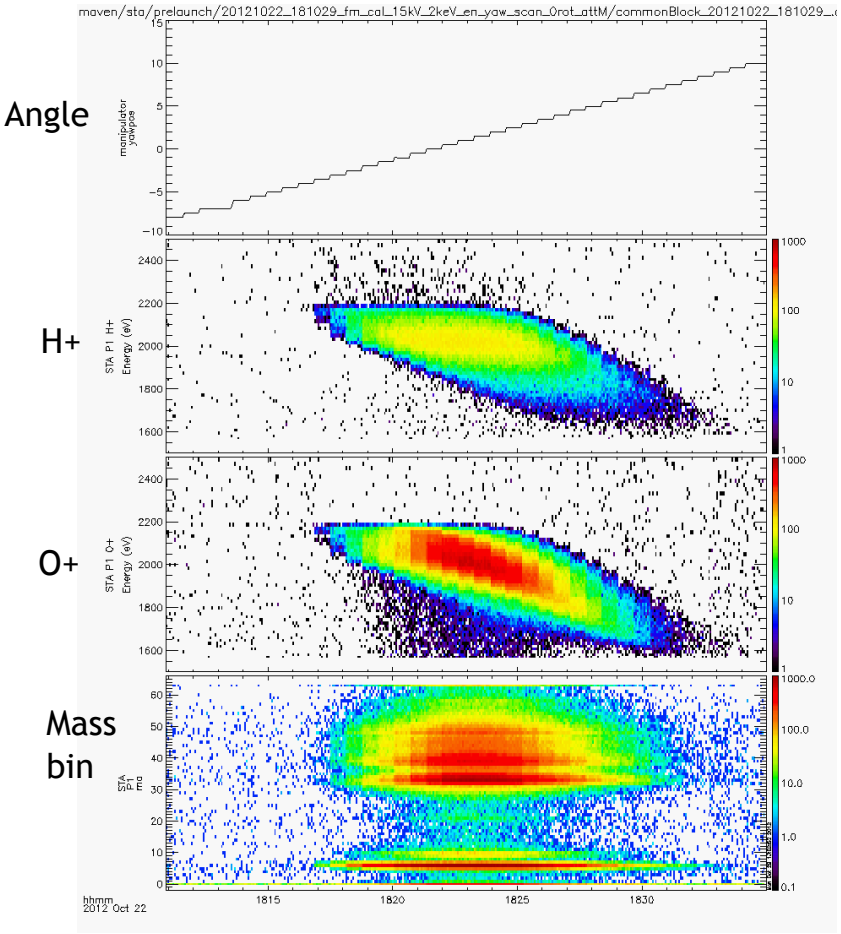
Sensor Energy and Angle resolution with Mech Attenuator as expected. Same ~1º offset in beam center. Energy and Angle response narrower as expected. H+ and H_2O+ have identical response.



Energy Resolution: ~9%



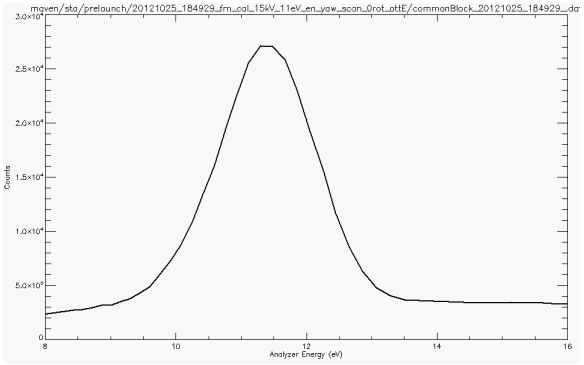
Angle Resolution: ~4º



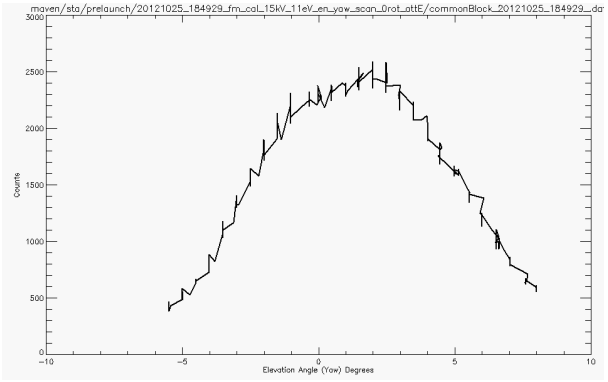
STATIC Calibration (PF 60,61)

Sensor Energy-Angle resolution with 11.5 eV ion beam, with Electrostatic Attenuator.

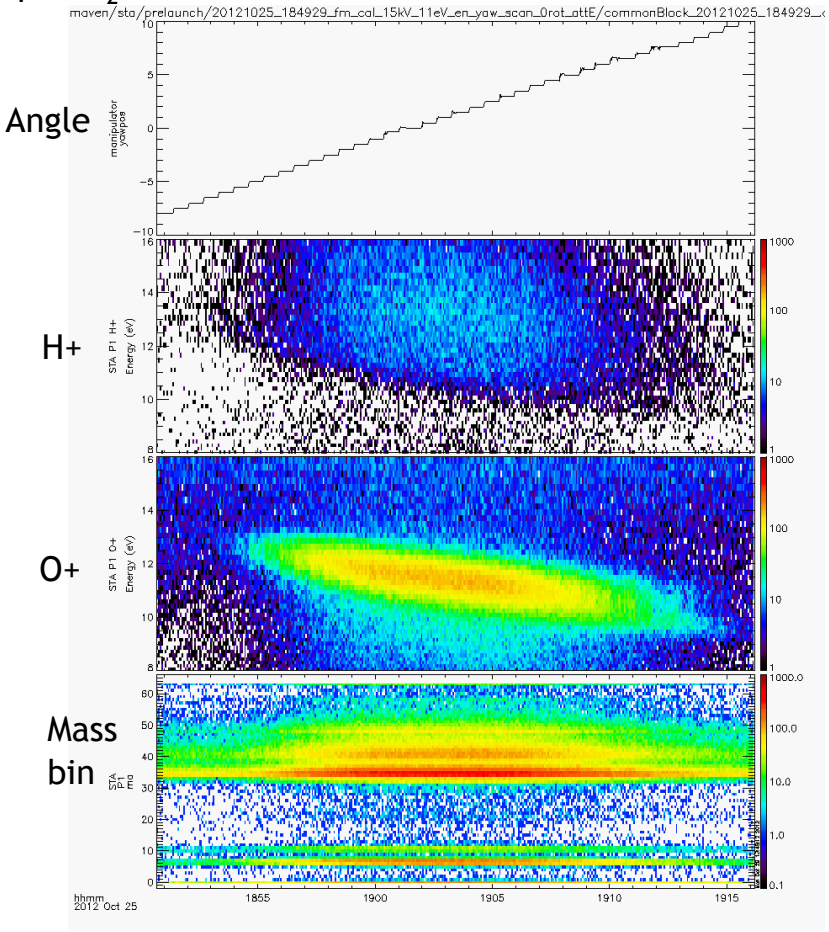
Sensor Energy and Angle resolution with E-static Attenuator as expected. Same ~1º offset in beam center.
O+ Energy and Angle response as expected for 1 eV beam – $(0.135)^2 + (1/11.5)^2)^{1/2} = 16\%$
H+ response is broad due to dissociation energy upon H_2O ionization.



Energy Resolution H_2O+ : ~17%



Angle Resolution: ~8º



STATIC Calibration (PF 62)

360º FOV, No Attenuators

Sensor meets requirement (PF62) for 360º FOV in detection plane without attenuators

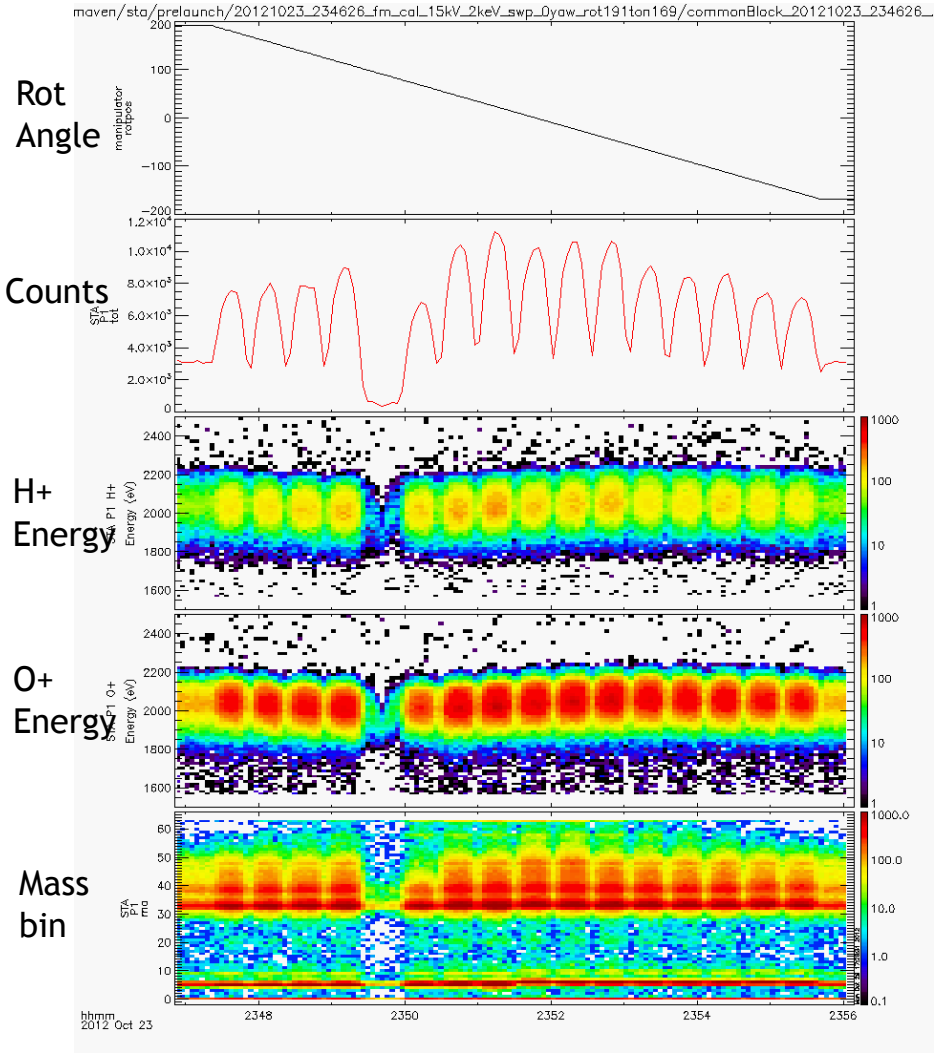
Ion gun energy fixed 2000 eV

Sensor sweeping energy 1500 to 2500 eV.

Sensor rotated 360º about symmetry axis.

Sensor deflectors are off.

Minima between peaks are due to modulation by aperture posts, coupled with a narrow energy parallel beam.



STATIC Calibration (PF 62,55,56)

360^{o} FOV with
Mechanical Attenuator

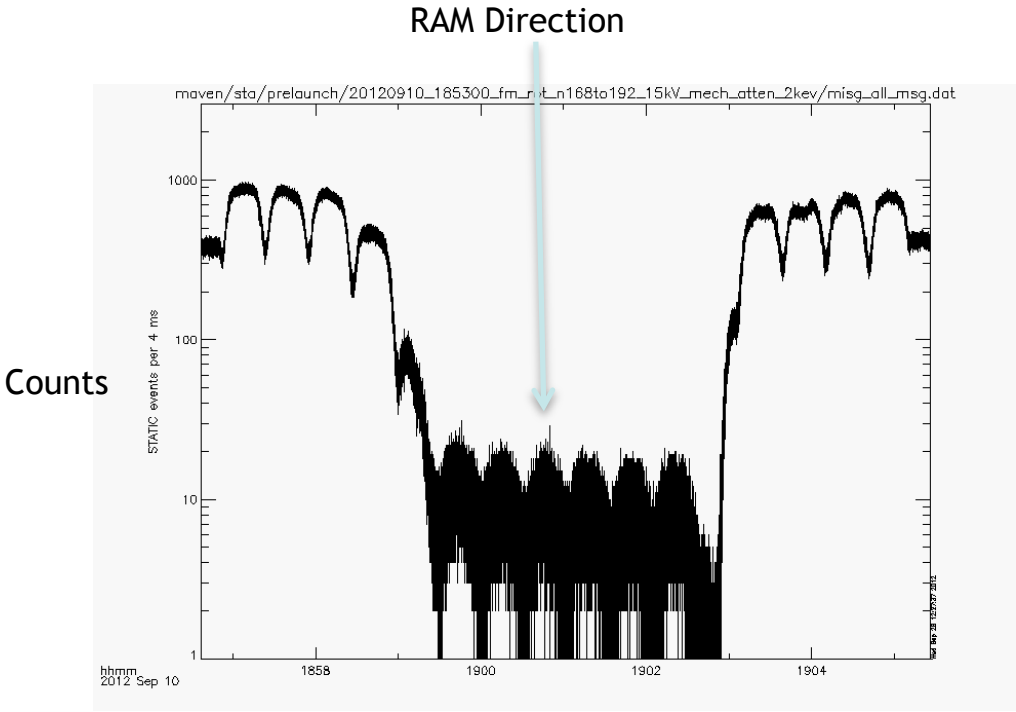
Sensor meets requirement (PF62) for 360^{o} FOV in detection plane.

Attenuator provides factor of 100 reduction in flux over +/-60^{o} centered on the RAM direction.

Ion gun energy fixed 2000 eV

Sensor rotated 360^{o} about symmetry axis.

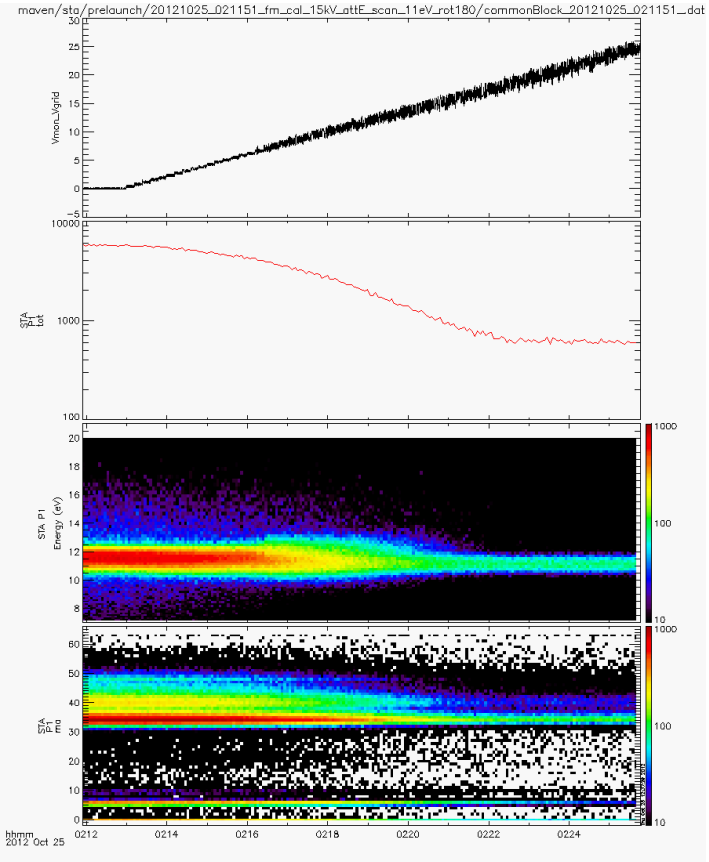
Sensor deflectors are off.



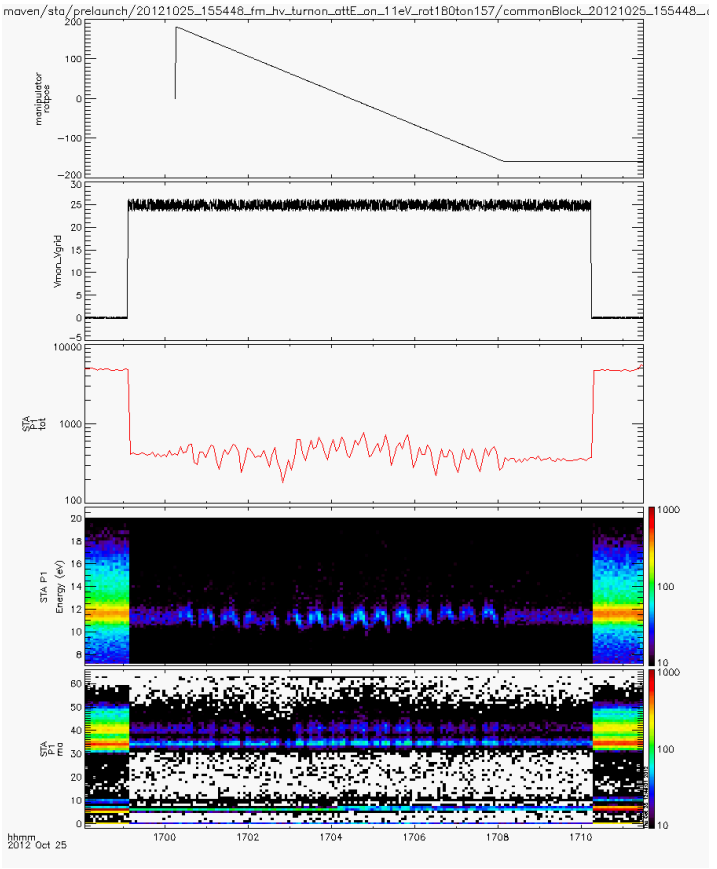
STATIC Calibration (PF 55)

Dynamic Flux Range – Electrostatic Attenuator (x 0.1)

Sensor sweeping energy: 7 to 20 eV
Gun 11.5 eV beam
Vgrid swept from 0 to 25 V
Cutoff at Vgrid~18V



Sensor sweeping energy: 7 to 20 eV
Gun 11.5 eV beam
Vgrid swept from 25 V
Sensor rotated across all anodes



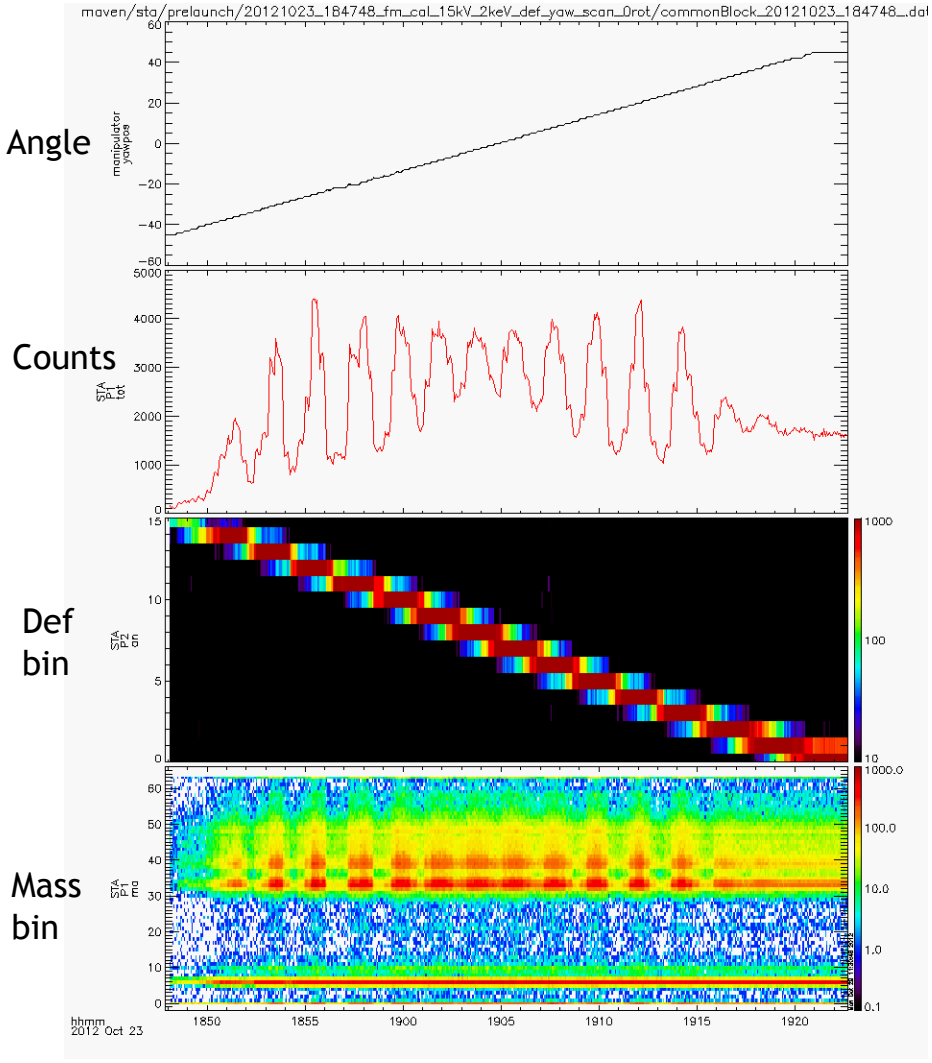
STATIC Calibration (PF 62)

Sensor exceeds requirement (PF62) for FOV extending 60º out of detection plane. Actual FOV extends 90º (+/-45º) out of plane.

Ion gun energy fixed 2000 eV
Sensor energy fixed 2000 eV
Sensor rotated +/-45 deg out of plane.

Sensor deflectors are stepped through 16 deflector angles: -45,-39,…,-3,3,9,…39,45

Minima between peaks are due to energy-angle response with a fixed energy beam and discrete deflection steps.



STATIC Calibration (PF 59)

Sensor exceeds requirement (PF59) for energy range. Capable of ~30keV by design. HV tested to 30 keV. Beam tested to 4 keV.

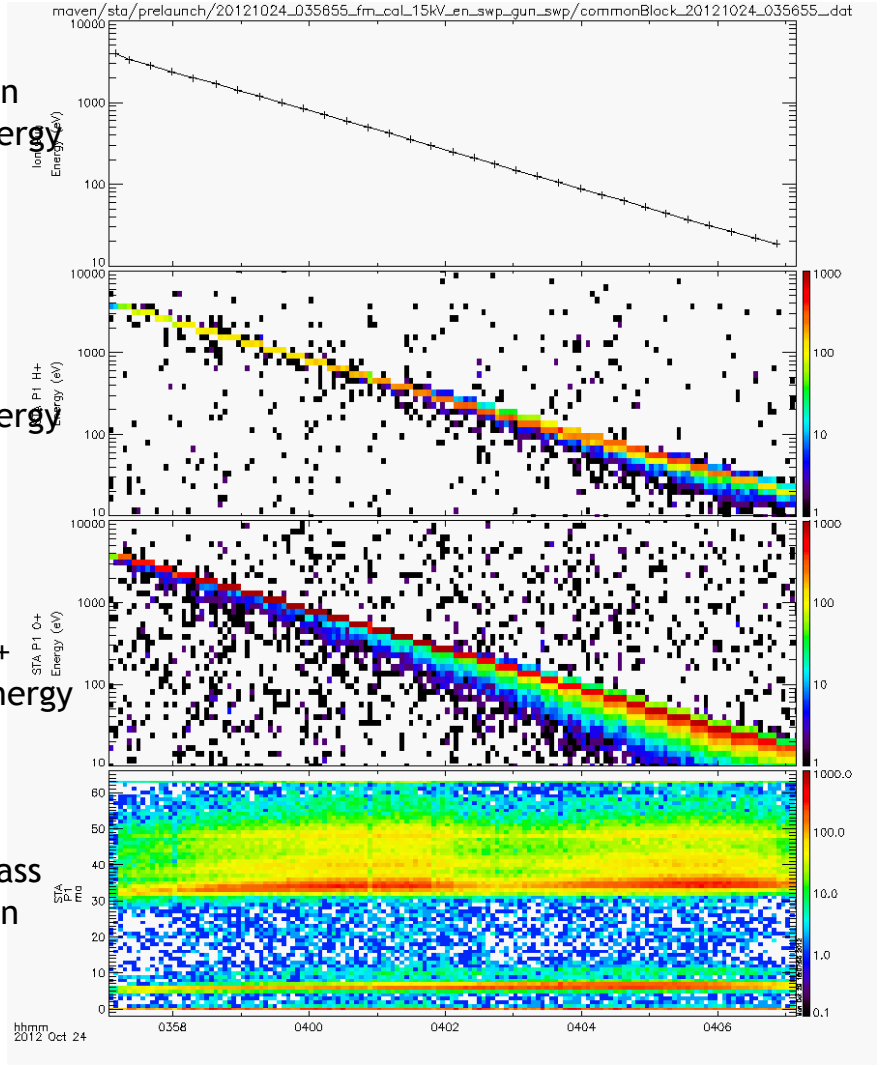
Ion gun stepped from 4 keV to 20 eV with fixed beam direction

Sensor in pickup ion sweep mode sweep 30 keV to 0.5 eV.

Low energy shift of O+/H+ are due to gun issues.

Low energy measurements require special gun configuration seen in next slide.

Energy Range 4000 to 20 eV



STATIC Calibration (PF 59)

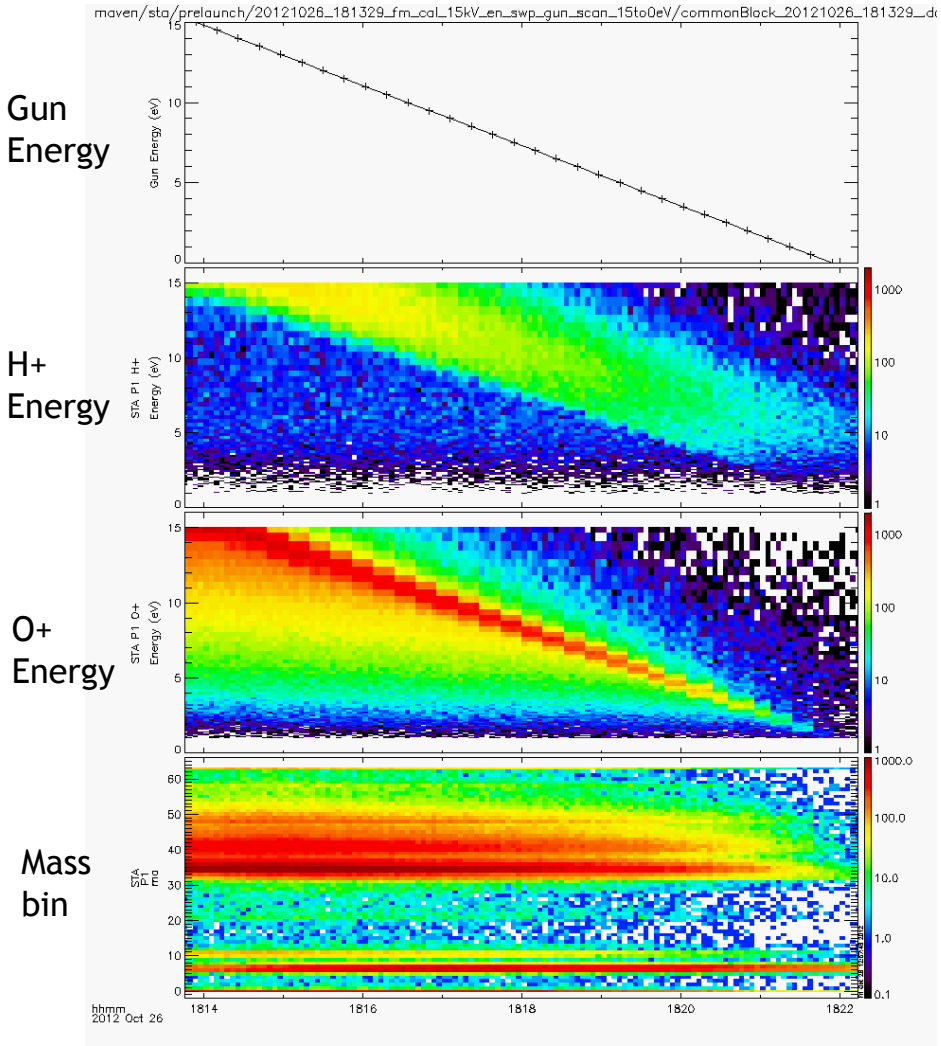
Sensor meets requirement (PF59) for low energy (1eV) range. Testing at low energy shows sensor resolves cold O+ and reveals response of ion gun.

Ion gun stepped from 15 to 0 eV.
Ions ~0.5 eV higher in energy due to ionization chamber bias.

Sensor in low energy sweep mode 15 eV to 0.5 eV.

Filament Gun ionizes residual gas in chamber, primarily water.
Ionization chamber has 1 V bias gradient to eject ions.
H+ is produced from H_2O dissociation.
Dissociation energy (~5eV) goes to H+ due to conservation of momentum.
Water peak (H_2O+, HO+, O+) is narrow.
Low energy water tail due to scattering and ions produced outside the ionization chamber.

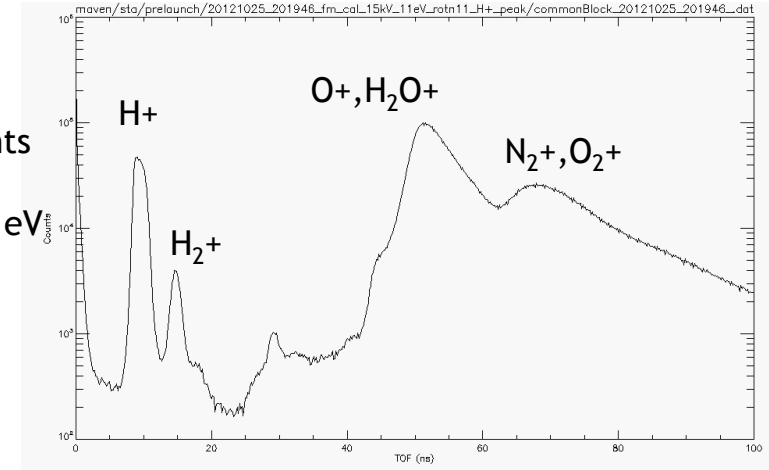
Energy Range 15 to 0.5 eV



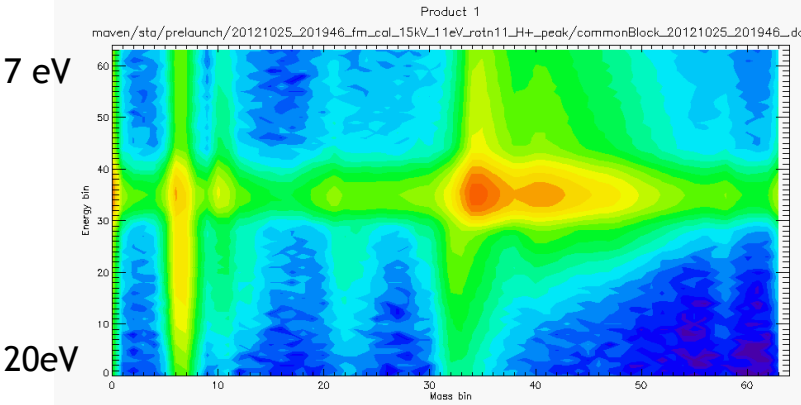
STATIC Calibration (PF 57,58)

STATIC Mass resolution (M/dM >2) and Mass range at least 1-44 AMU

Counts At 11.5 eV



Time of Flight (ns)

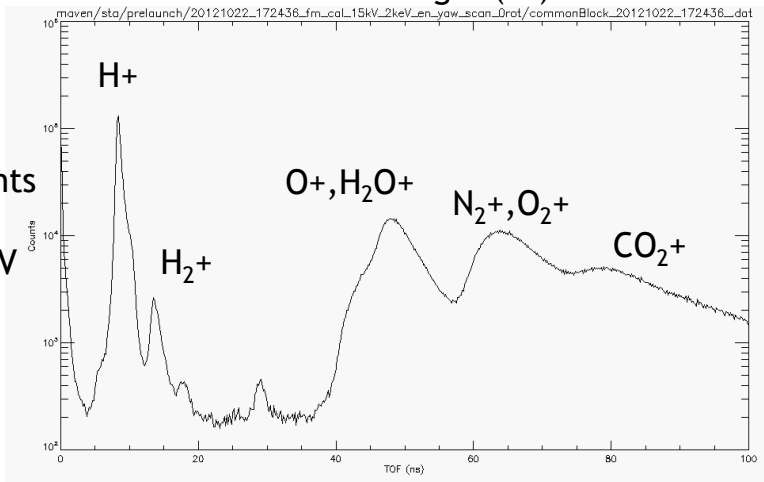


7 eV

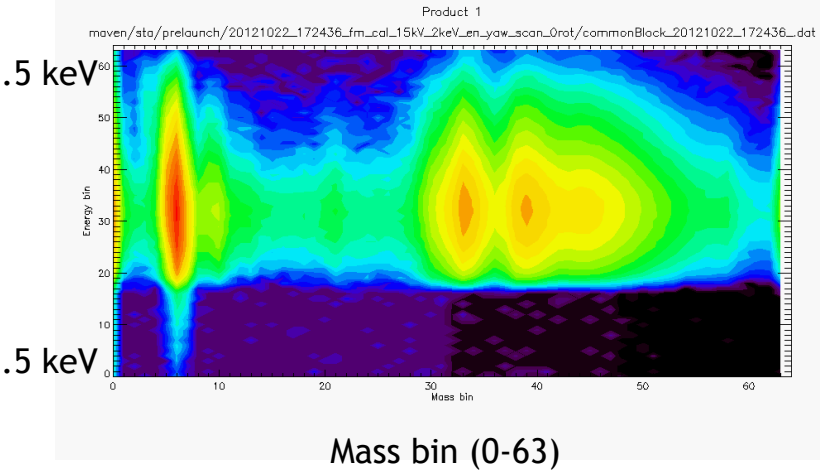
20eV

Mass bin (0-63)

Counts At 2 keV



Time of Flight (ns)



1.5 keV

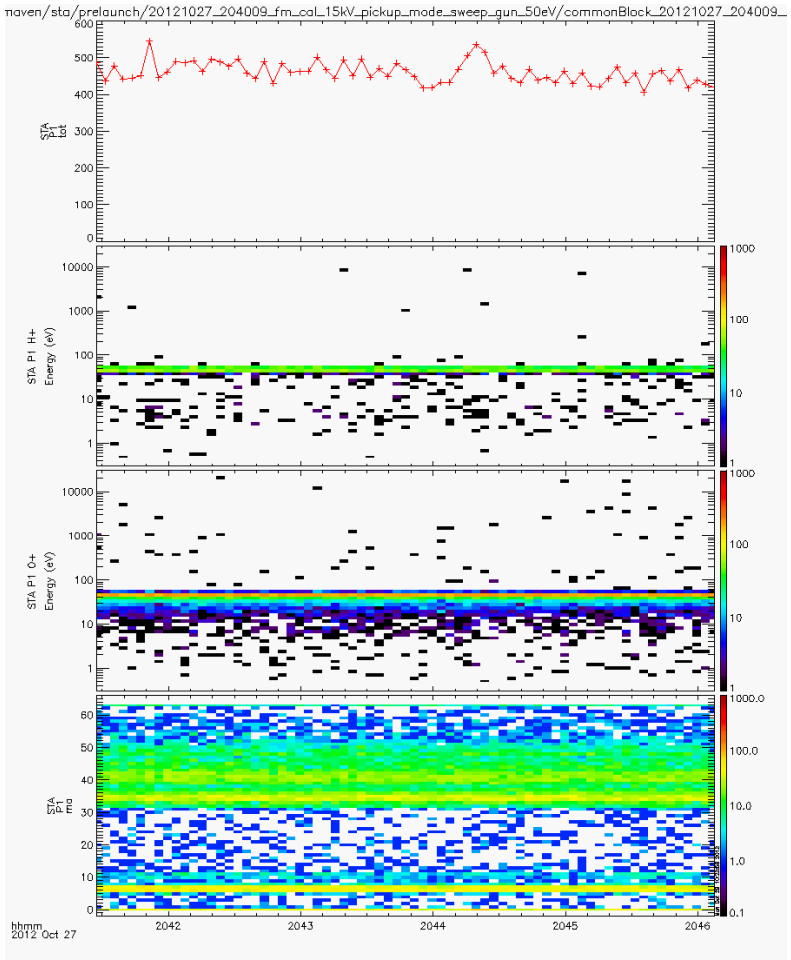
2.5 keV

Mass bin (0-63)

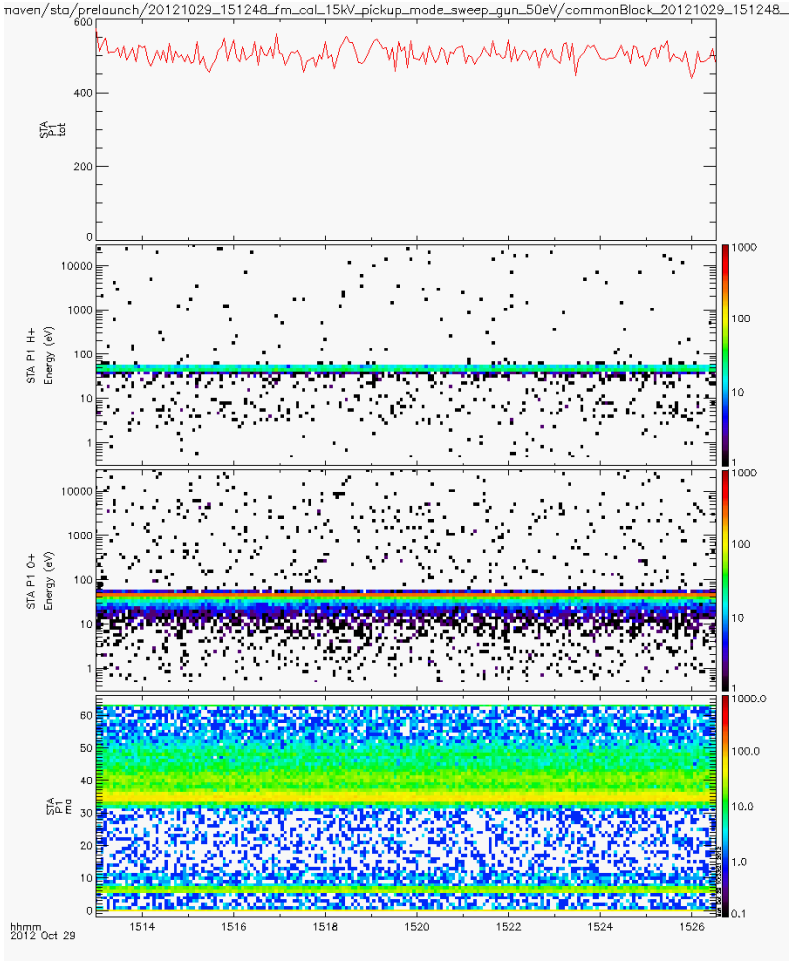
STATIC Calibration

Pickup Mode, 50 eV beam – 42 hr test, nominal operations

Before



After



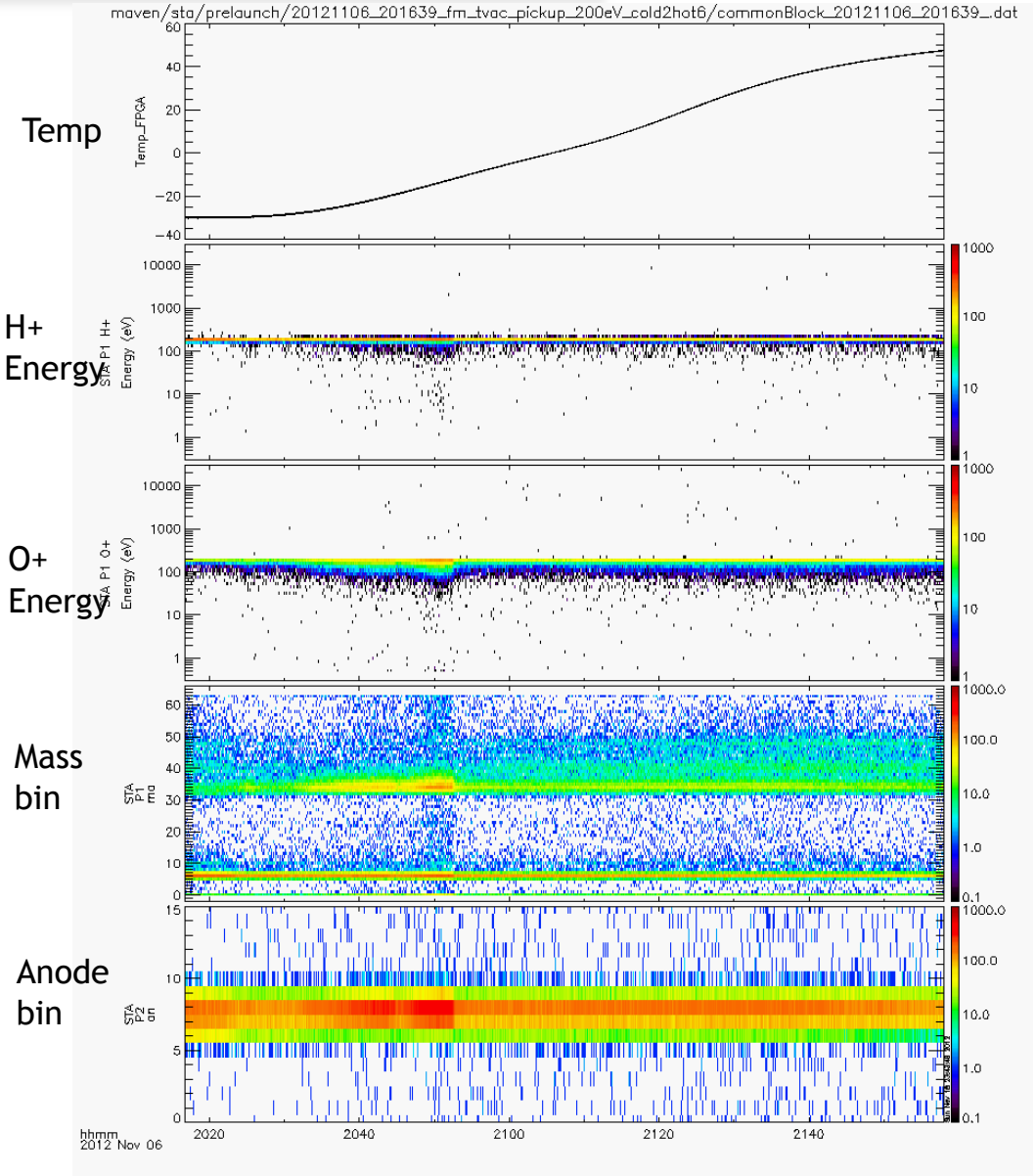
STATIC TV Operations with Ion Gun

Plot of STATIC during a transition from Cold Cycle 5 to Hot Cycle 6.

STATIC was in pickup mode, sweeping energy from 1 eV to 30 keV.

The ion gun was operated continuously at 200 eV during this transition to demonstrate no drift in instrument energy with temp.

As chamber temperature rose, flux increased with temperature. At 20:52, filament current was reduced to prevent electronics saturation.



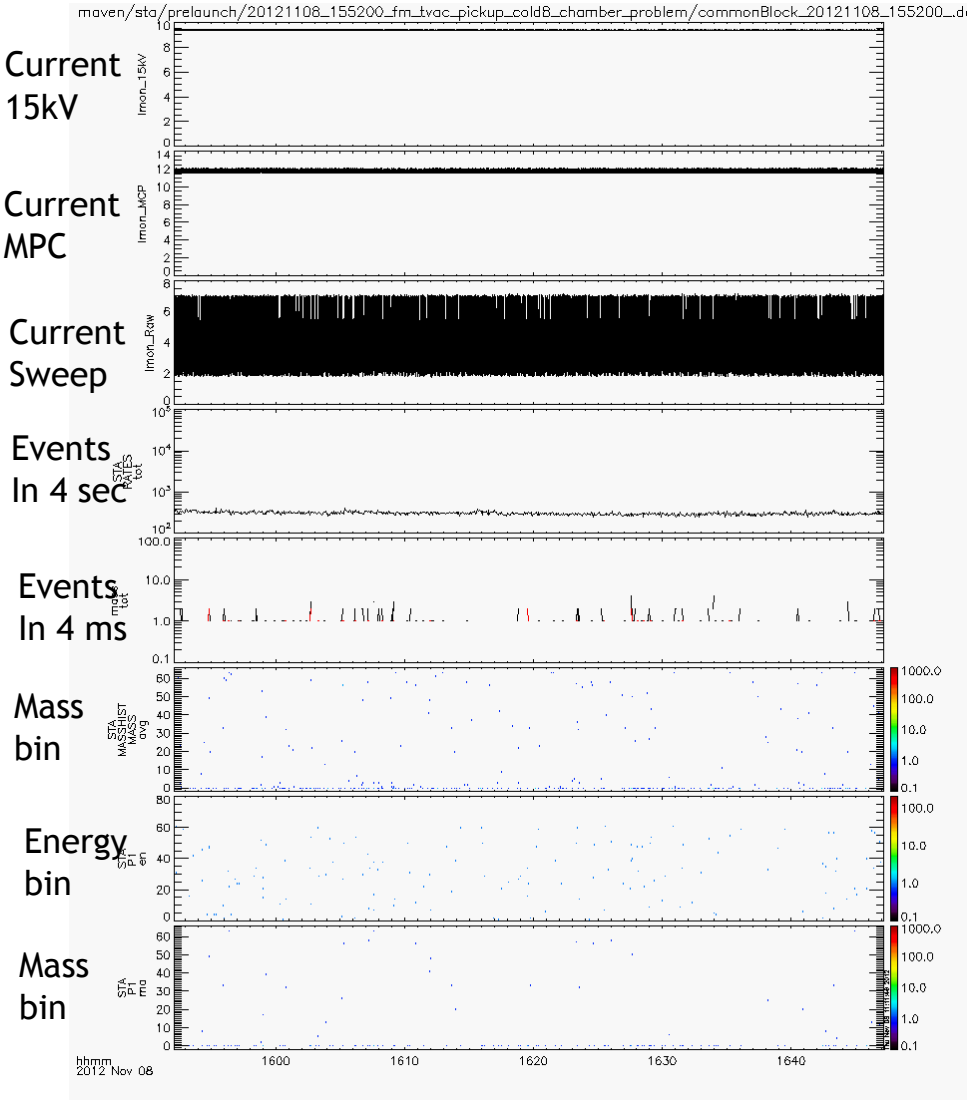
STATIC Background at end of TV

50 min plot of STATIC data after continuous operation during the last thermal cycle.

Plots (top to bottom) are 15kV supply current, MCP current, Sweep HV current (variations expected for sweeping energy), event rate in 4 sec, event rates in 4 ms accumulations.

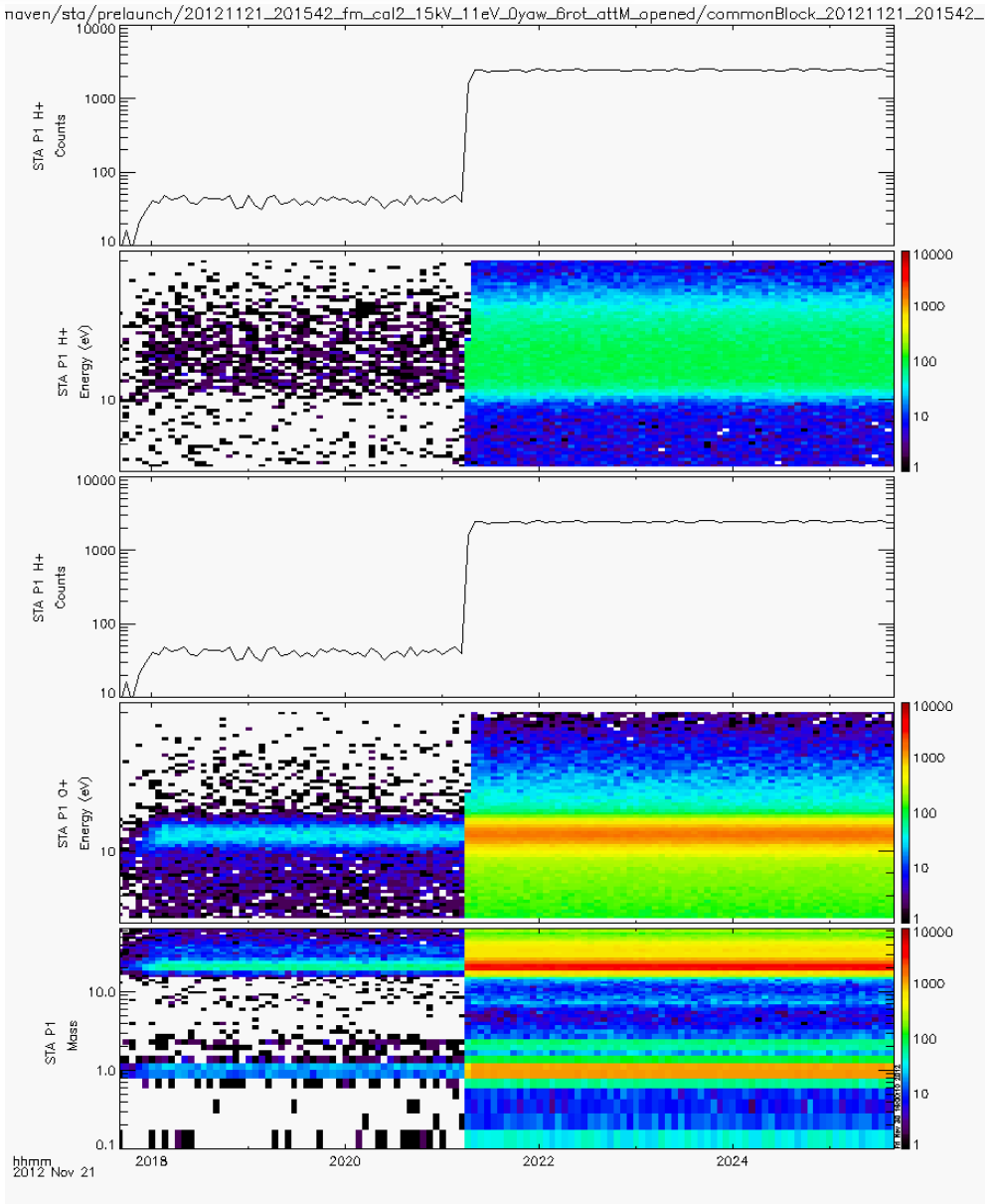
Lower 3 panels show events not rejected by coincidence (<<1/s)

Background event rates (~100 Hz) – about that expected for cosmic ray events and radioactive decay in an MCP with active area ~50 cm^2.



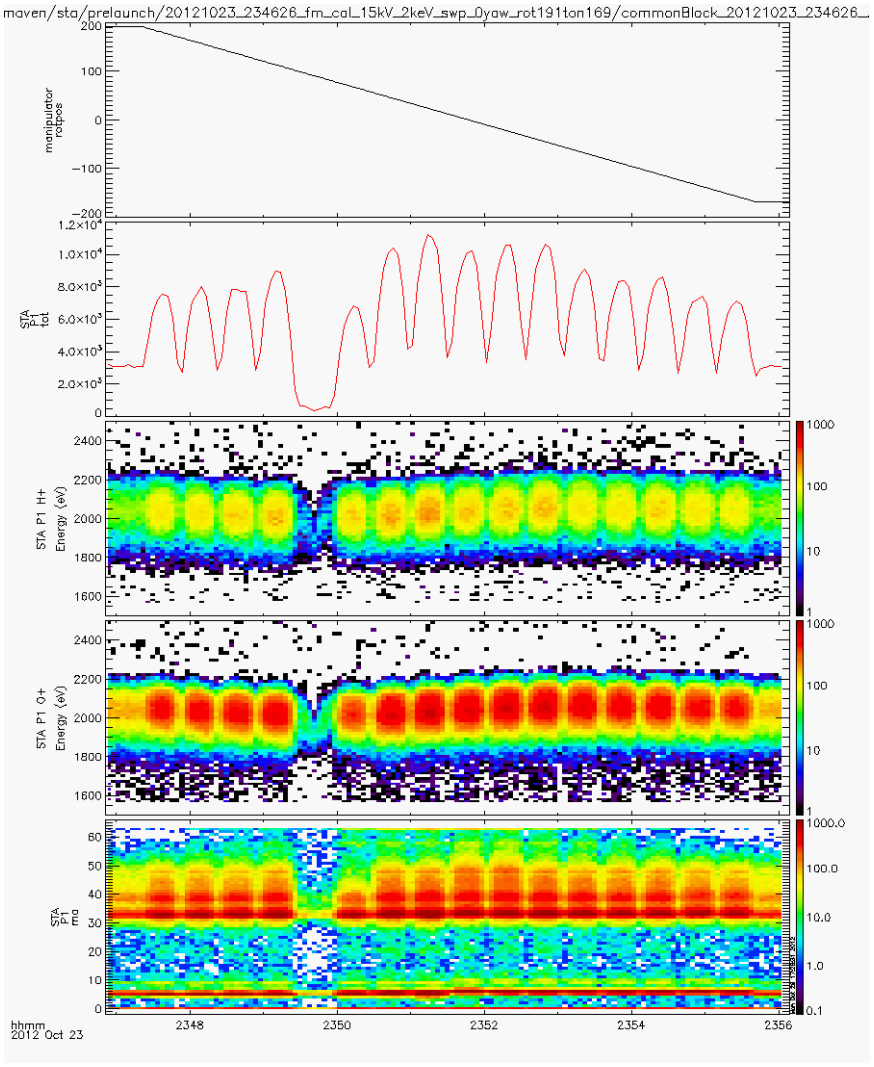
STATIC Mech Atten 11 eV

Turning on the Mechanical Attenuator

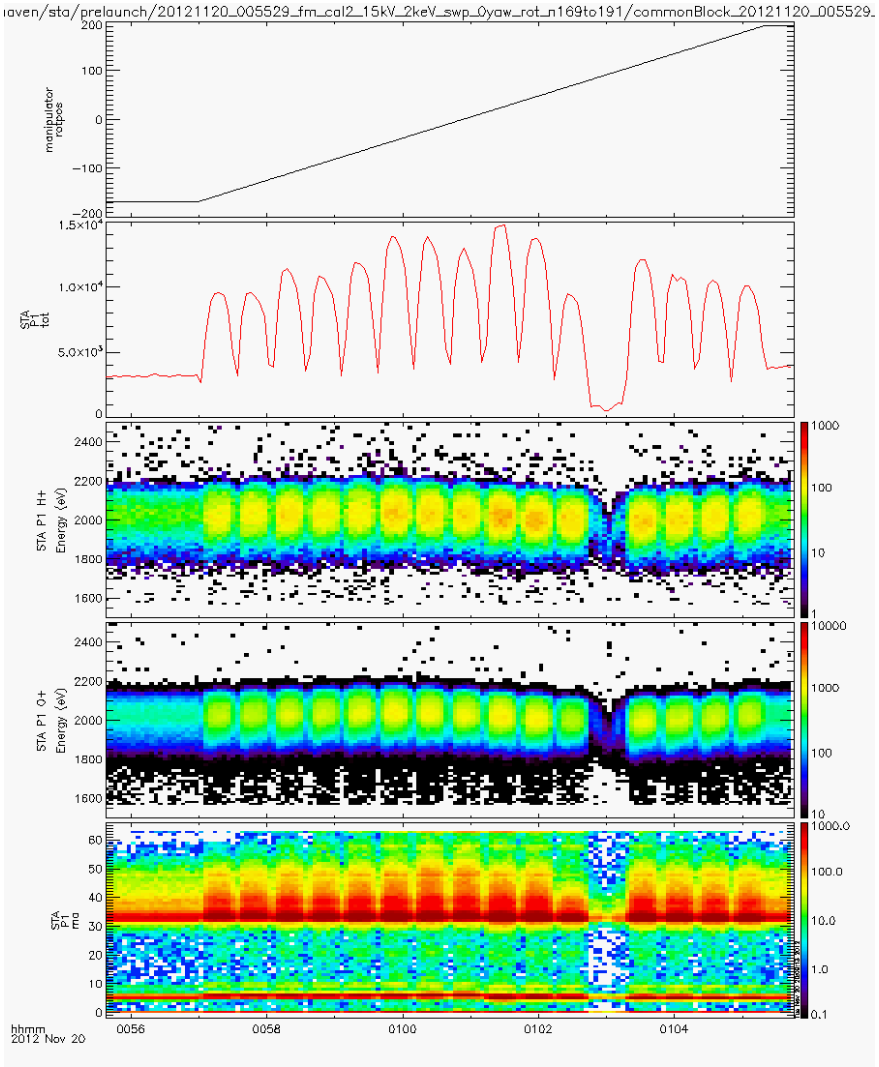


Rot Scan Pre/Post Environmental

Pre- Environmental

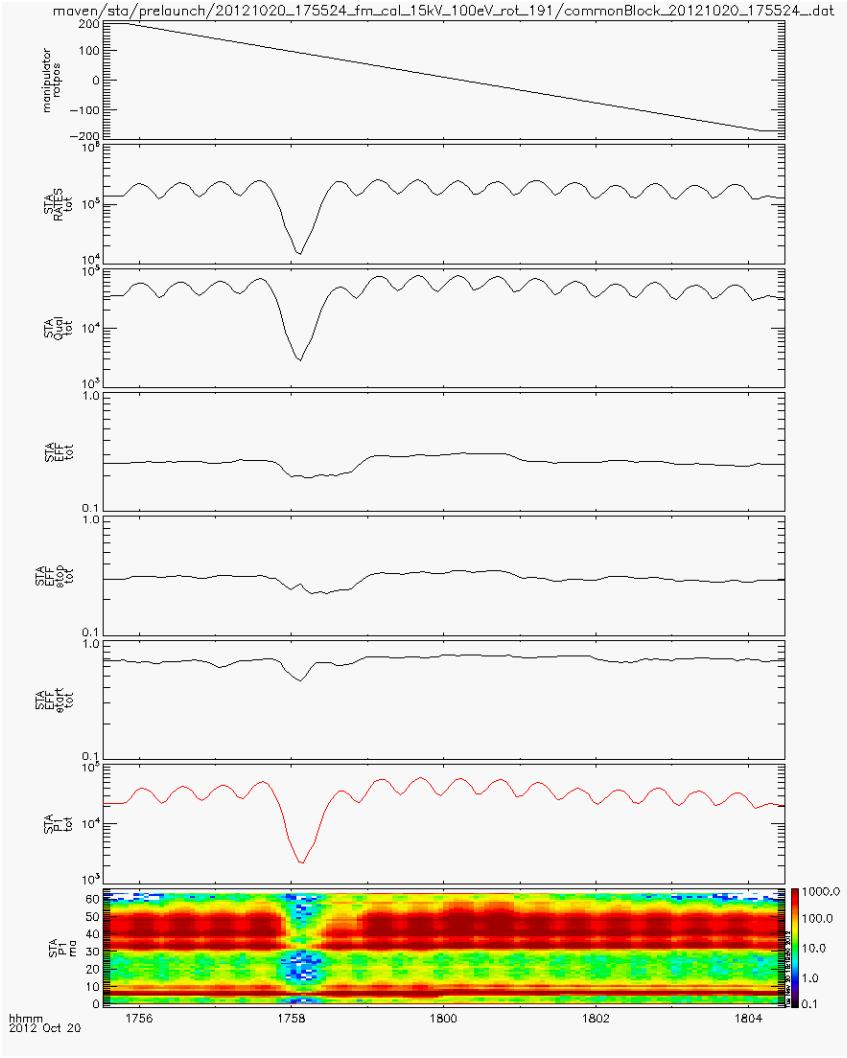


Post- Environmental

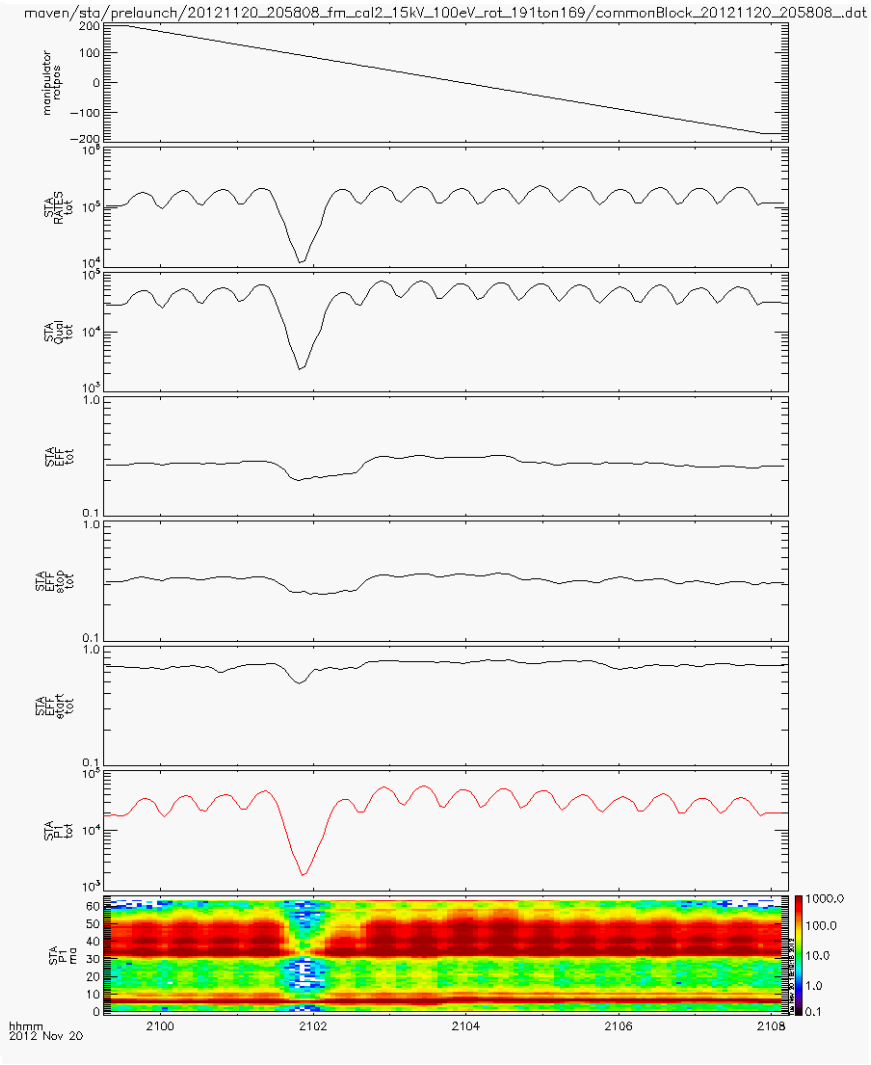


Rot Scan Pre/Post Environmental

Pre- Environmental



Post- Environmental



STATIC Calibration Results

- 16 angle sectors: ~50% variation in sensitivity-efficiency with look direction.
- ~2% variation in energy with look direction
- Detection efficiency for fully qualified events ~25%.
- Ghost Peaks appear to be minimal based on low energy measurements.
- Background event rates ~100 Hz – negligible fully qualified
- Coincident protons will be main source of background
- TBD: Work out the efficiency versus mass: expect a proton efficiency about 25% that of higher mass ions

STATIC Data Messages

STATIC Messages to PFDPU every 4 s		kbit/s *
P1 - 64M x 64E		8.
P2 - 16D x 64E		2.
P3 - 16A x 4D x 16E		2.
P4A - 8D x 32E x 32M	(ram mode)	16.
P4B - 16A x 4D x 16E x 16M	(conic mode)	16.
P4C - 16A x 4D x 32E x 8M	(pickup mode)	33.
P4D - 16A x 32E x 8M	(scan mode)	8.
Raw Event messages 32 x 48bits / 4 ms		384.
Rate messages 12 x 16bits / 4ms		24.
Mass Histogram 1024M		2.

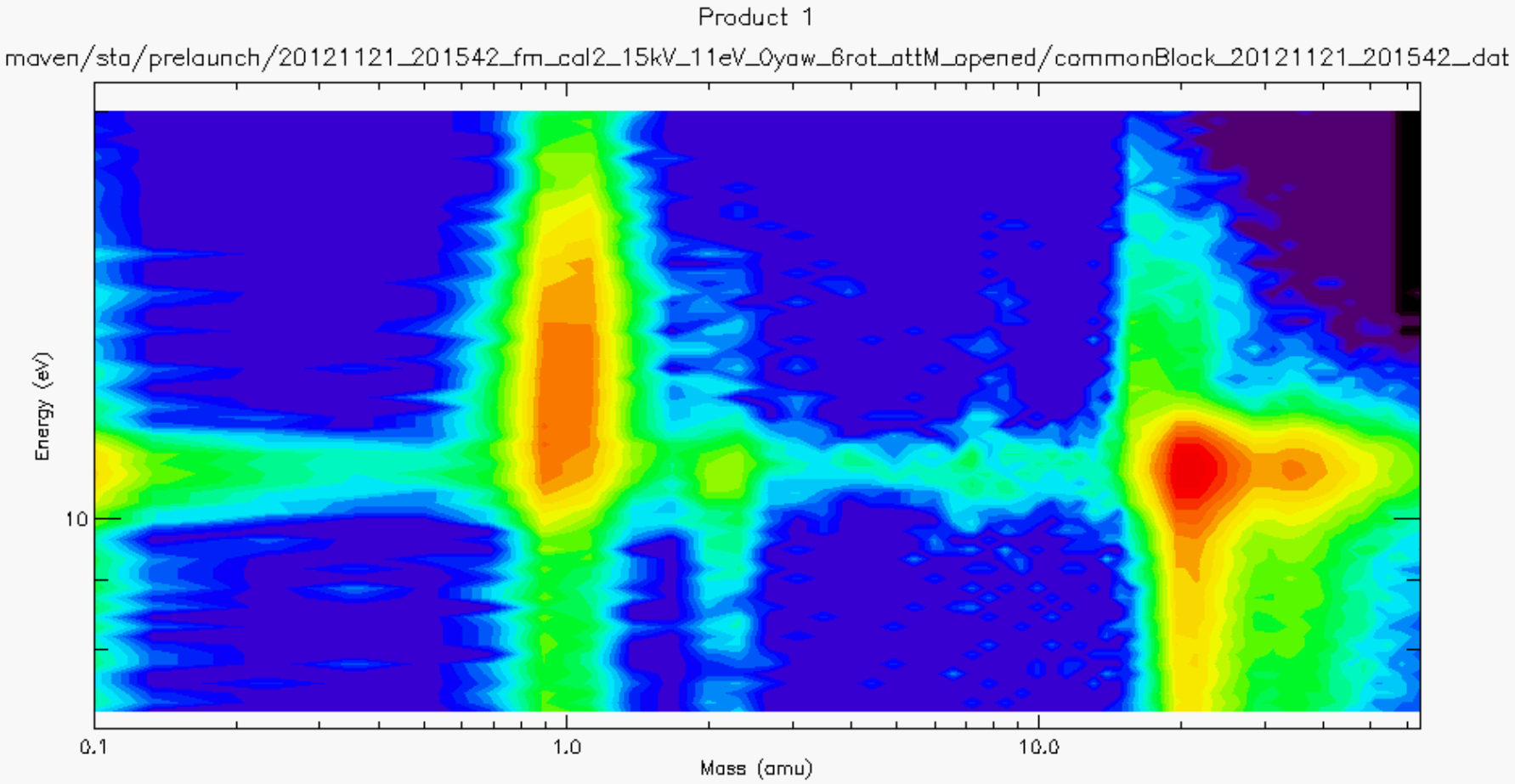
*Assumes 19->8 bit compression for everything but Raw Events

Average data volume needs to be reduced to ~2 kbit/s

STATIC Data Products

APID	Measurement	Resolution	Mode	Message
C0	64E x 2M	4s(8s)	All (Pickup)	P1 - 64M x 64E
C2	32E x 32M	8s(128s)	Ram/Conic (Pickup)	P1
C4	4E x 64M	4s (32s)	Ram/Conic (Pickup)	P1
C8	32E x 16D	8s	Ram/Conic	P2 - 16D x 64E
CA	16E x 4D x 16A	8s	Ram/Conic	P3 - 16A x 4D x 16E
D4	4D x 16A x 2M	8s	Pickup	P4C
CC/CD	32E x 8D x 32M	64s	Ram	P4A - same
CE/CF	16E x 4D x 16A x 16M	128s	Conic	P4B - same
D0/D1	32E x 4D x 16A x 8M	256s	Pickup	P4C - same
D2/D3	32E x 16A x 8M	16s	Scan	P4D - same
C6	32E x 64M	128s	Scan	P1
D8	12R	4s	All	Rates
D9	12R x 64E	64s	All	Rates
DA	1R	64ms	All	Rates
DB	1024M	64-512s	All	Mass Histogram

STATIC – Mass Calibrations



STATIC Resources

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

Power

- No HV
  - Cold: 89 mA
  - Hot: 94 mA
- HV on, non-sweeping
  - Cold: 118 mA
  - Hot: 137 mA
- HV on, sweeping
  - Cold Peak: ~150 mA
  - Hot peak: ~165 mA

Mass

- 3.349 kg as measured mass
  - NTE is 3.31 kg
  - ~50 g addition of board braces as a result of PFR-115 *SWIA Frequency Shift*