ALTEA – shield:
an ESA sponsored USLab radiation survey

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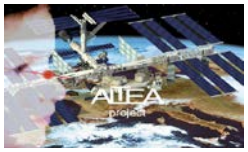
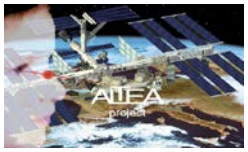
University of Rome "Tor Vergata"



Content

- Importance in measuring radiation in the ISS … again
- ALTEA, very few words
- Our survey: times and locations
- Results (averages, time dynamics, spectra):
    - Different selection criteria
    - Different locations
    - Different axis
    - SPEs
- Future
    - LIDAL
    - LORE



Radiation in *(deep)* space

- Radiation in deep space is due to:
  - Galactic, **GCR** (*modulated by solar activity)*
  - Solar Particle Events, **SPE** *(more frequent at solar maximum, random in nature)*

GCR:

high-energy protons
heavy ions (HZE's)

SPE

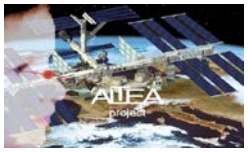
mostly lower energy protons *(can be mitigated with Radiation Shelters)*

→ ***secondary*** (produced in shielding)
neutrons, protons, heavy ions

In LEO
+ Earth magnetic field
+ SAA contribution

Study radiation environment in ISS is needed to
- provide needed infos to assess risks in the ISS
- provide database for models / CADs validation

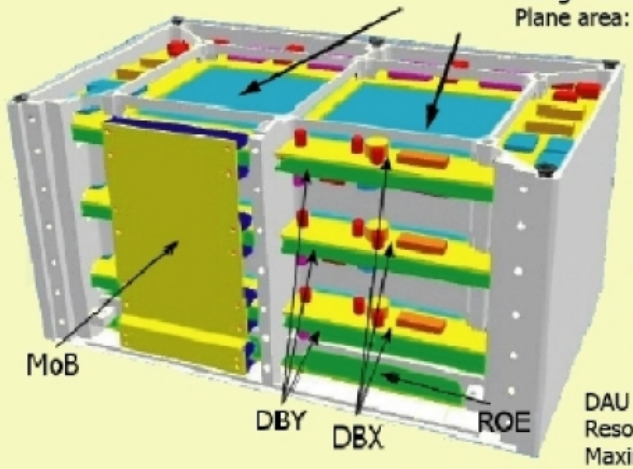
NOTE: A large amount of data is now available and validation should start ASAP.



ALTEA characteristics

SDU: Silicon Detector Unit

DETECTORS: 6 double strip silicon layers arranged alternately-along X and Y directions
Plane area: 2 x (8x8) cm^2

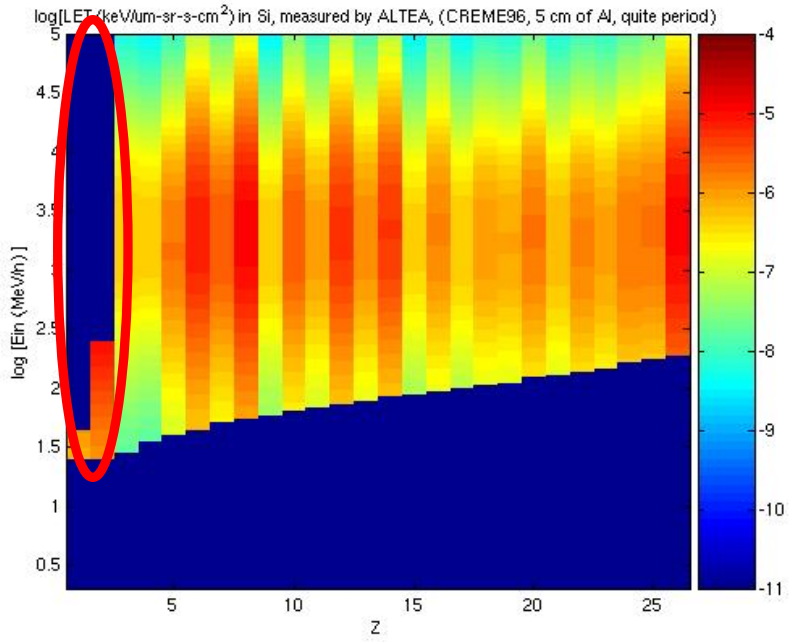


Thickness: 380 µm
Distance X-Y planes: 3.75 cm
Maximum error of angular reconstruction: 1.8°
Geometric Factor (bidirectional): 200 cm^2 sr

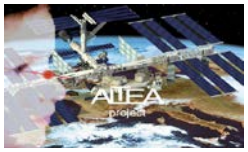
PERFORMANCES:
Threshold: 5 -33 MIP
Saturation: 2400 MIP
(1 MIP=109 KeV/plane)
ADC: 12 bit

DAU SOFTWARE PARAMETERS:
Resolution: 0.64 MIP/ADC ch
Maximum Acquisition Rate: 700 Hz
Autotrigger (logic OR or logic AND of X planes, software switchable)

i) 3D – trajectories
ii) multiple measurements
iii) nuclear discrimination
iv) LET spectra
(3 keV/µm < LET_{Si} < 800 keV/µm)
v) Real Time



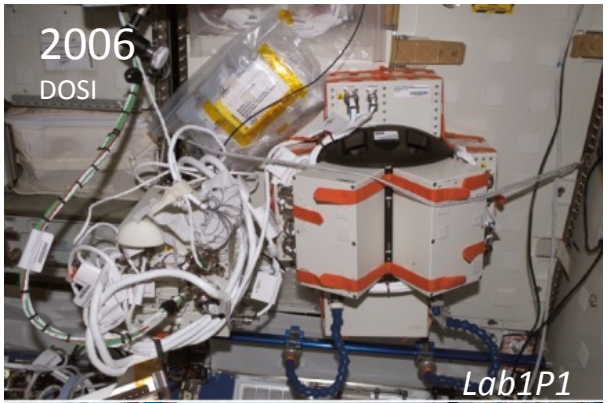
GCR as detected by the ALTEA system:
- Low energy ions stop in the detector
- High energy low Z ions (H and He) do not trigger the detector

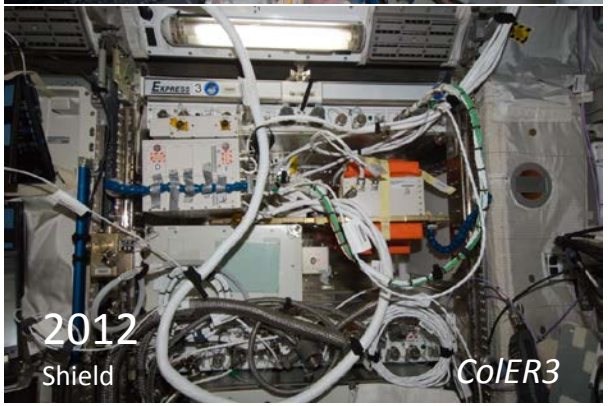


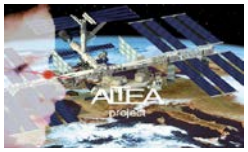
ALTEA runs

≈ 7 years of space ≈ 3.6 years of measurements

year	*location*	*experiment*
2006	Lab1P1	ALTEA-DOSI (ASI)
2007	Lab1P2	ALTEA-DOSI (ASI)
2009	Lab1P1	ALTEA-DOSI (ASI-NASA)
2010	Lab1O2	ALTEA-DOSI (ASI-NASA)
2010	Lab1S1	ALTEA-shield/survey pos 1 (ESA)
2010	Lab1O2	ALTEA-shield/survey pos 2 (ESA)
2011	Lab1P4	ALTEA-shield/survey pos 3 (ESA)
2011	Lab1S6	ALTEA-shield/survey pos 4 (ESA)
2012	Lab1S6	ALTEA (ASI-NASA)
2012	ColER3	ALTEA-shield/shield (ESA)



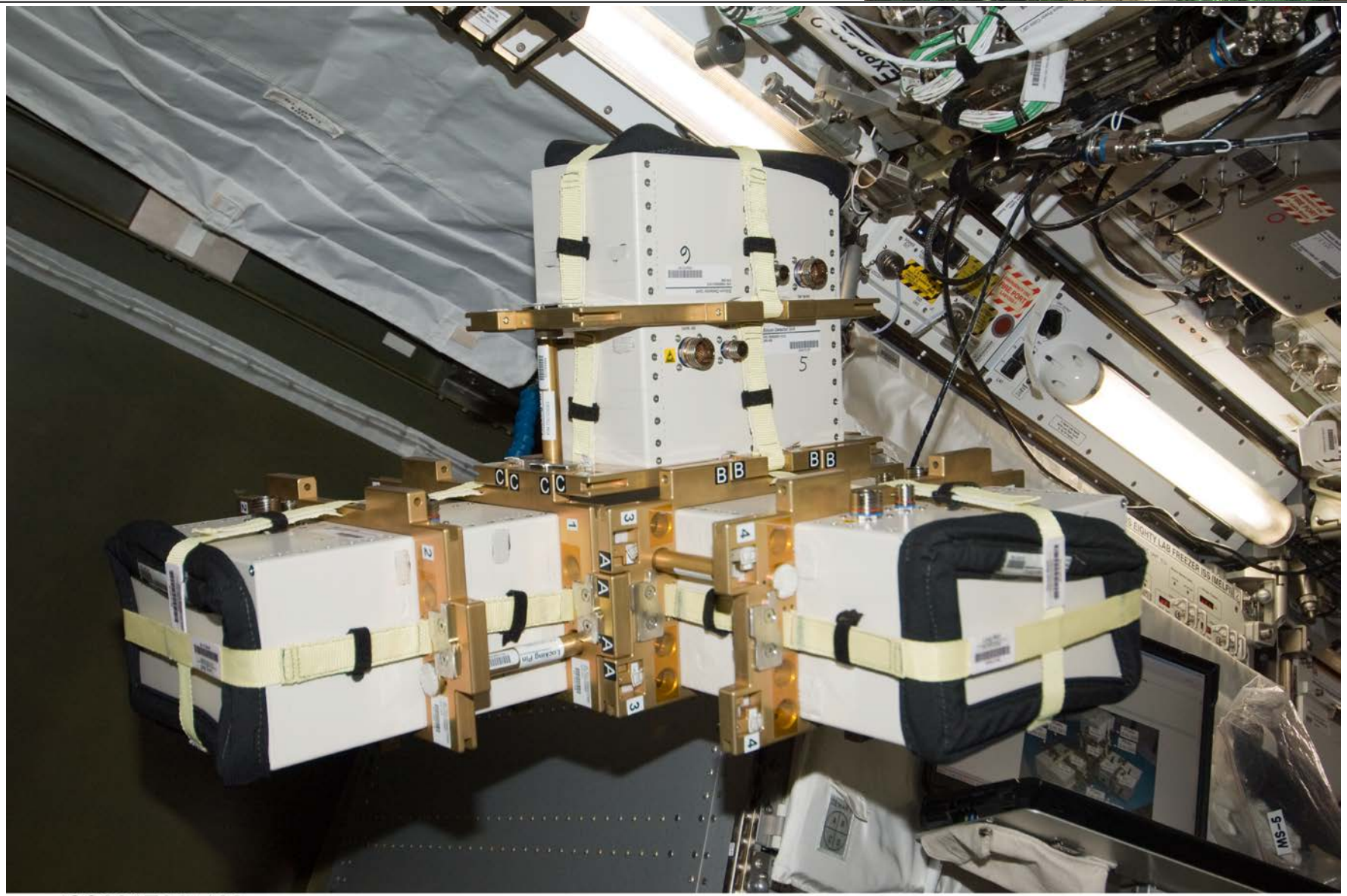




Survey: time and positions

Year	Date	Total Duration (days)	Position Name	Position
2010	09/20 – 10/04	14	P1	Lab1S1
2010	10/15 – 11/30	40	P2	Lab1O2
2011	04/24 – 07/22	90	P3	Lab1P4
2011/2012	07/23/2011 – 06/07/2012	263	P4	Lab1S6
2012	06/08 – 11/15	151	P5	Columbus ER 3

ALTEA X Y Z configuration



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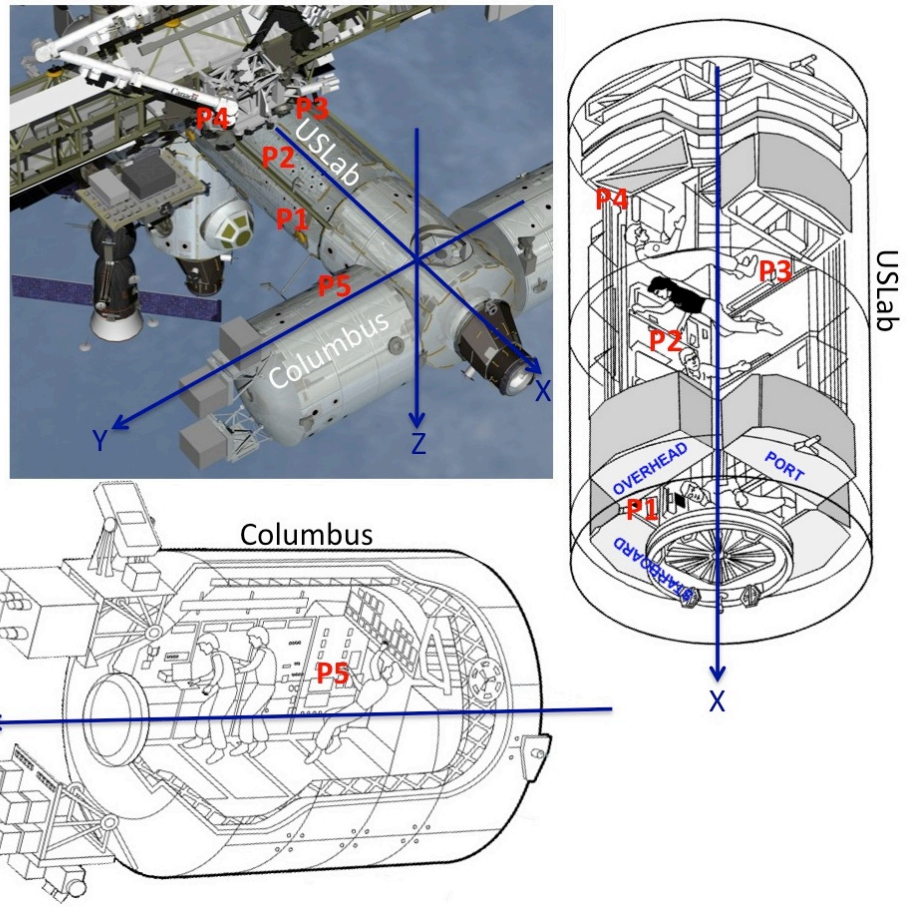
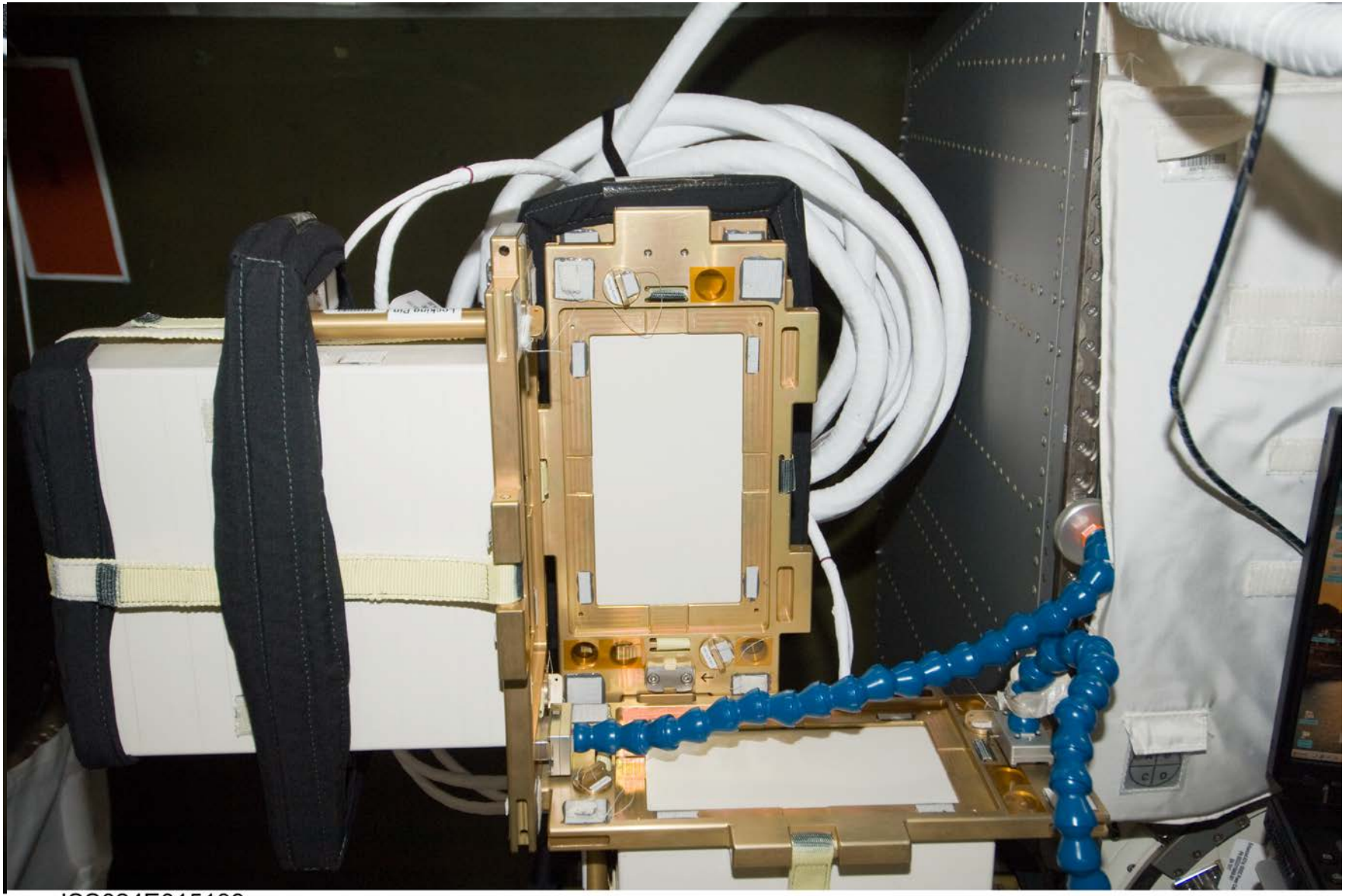
Survey: positions



Survey: position 1

09-20-2010
10-04-2010



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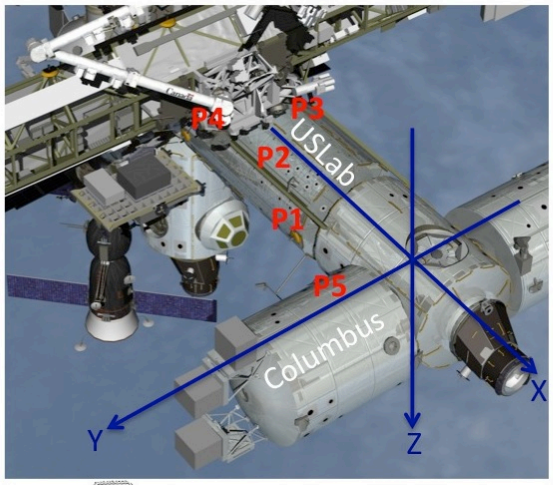
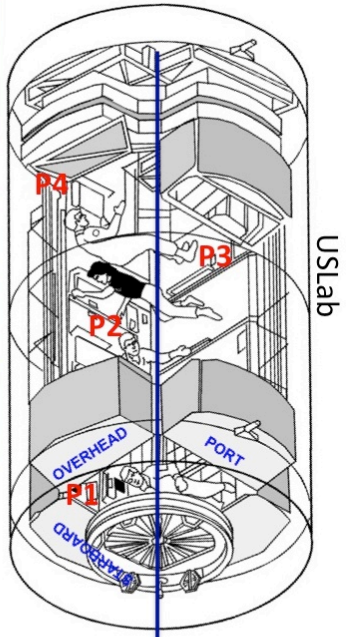
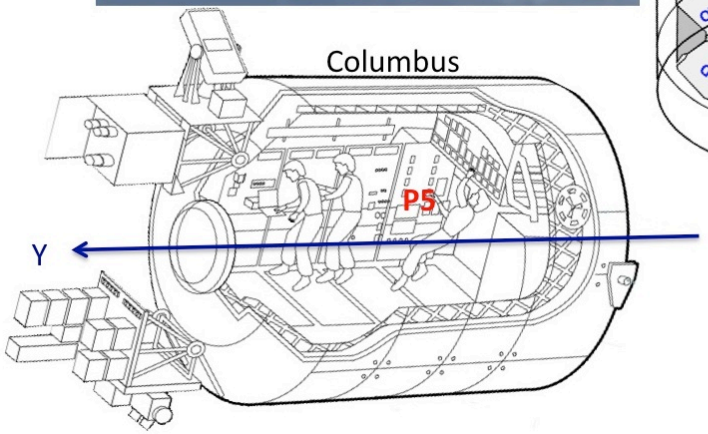
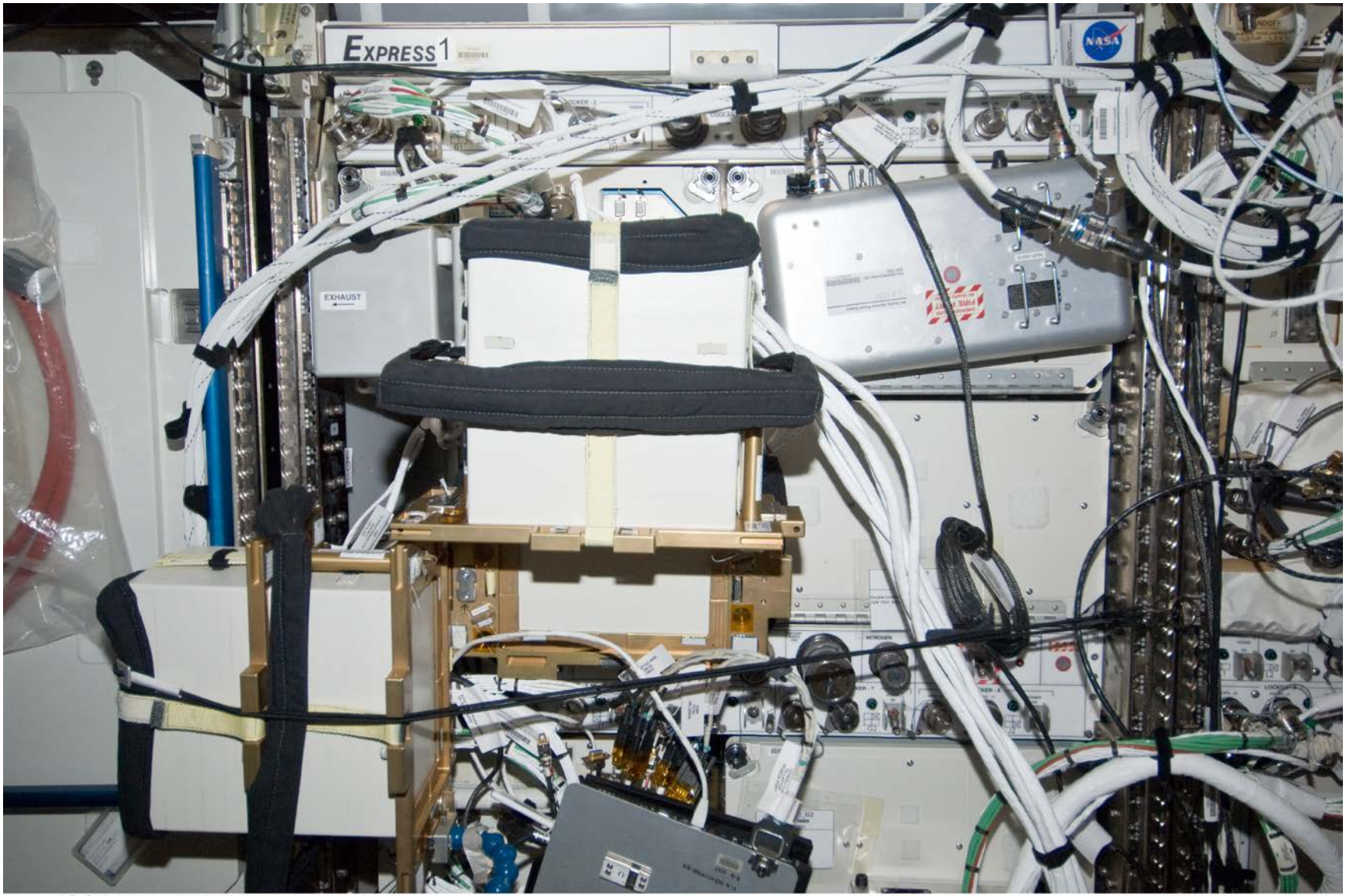






Survey: position 2

10-15-2010
11-30-2010



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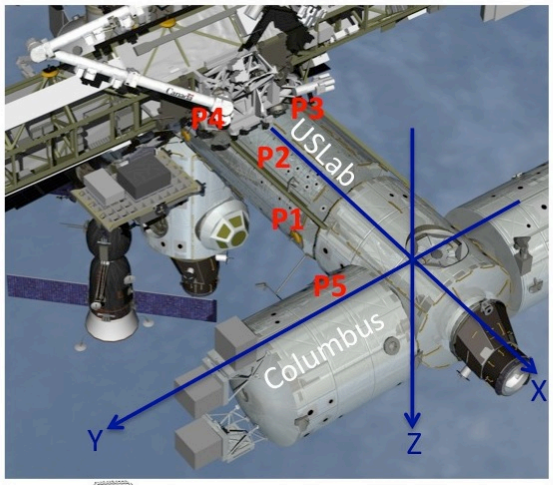
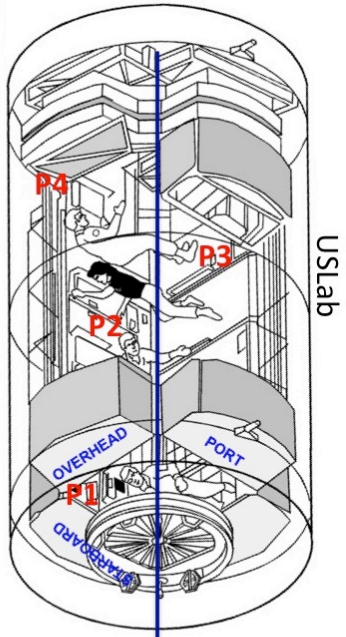
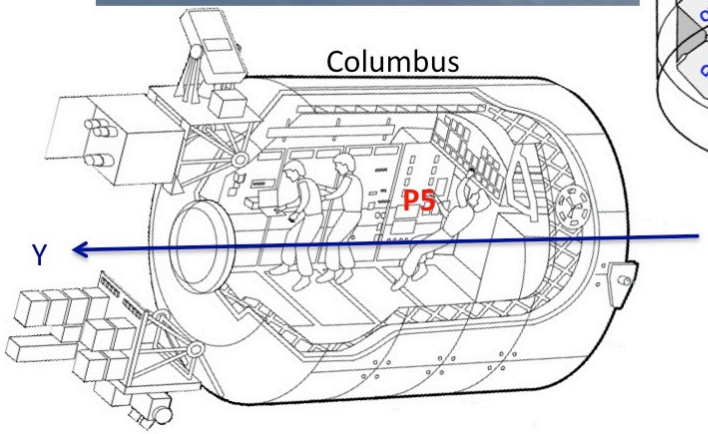
Survey: positions

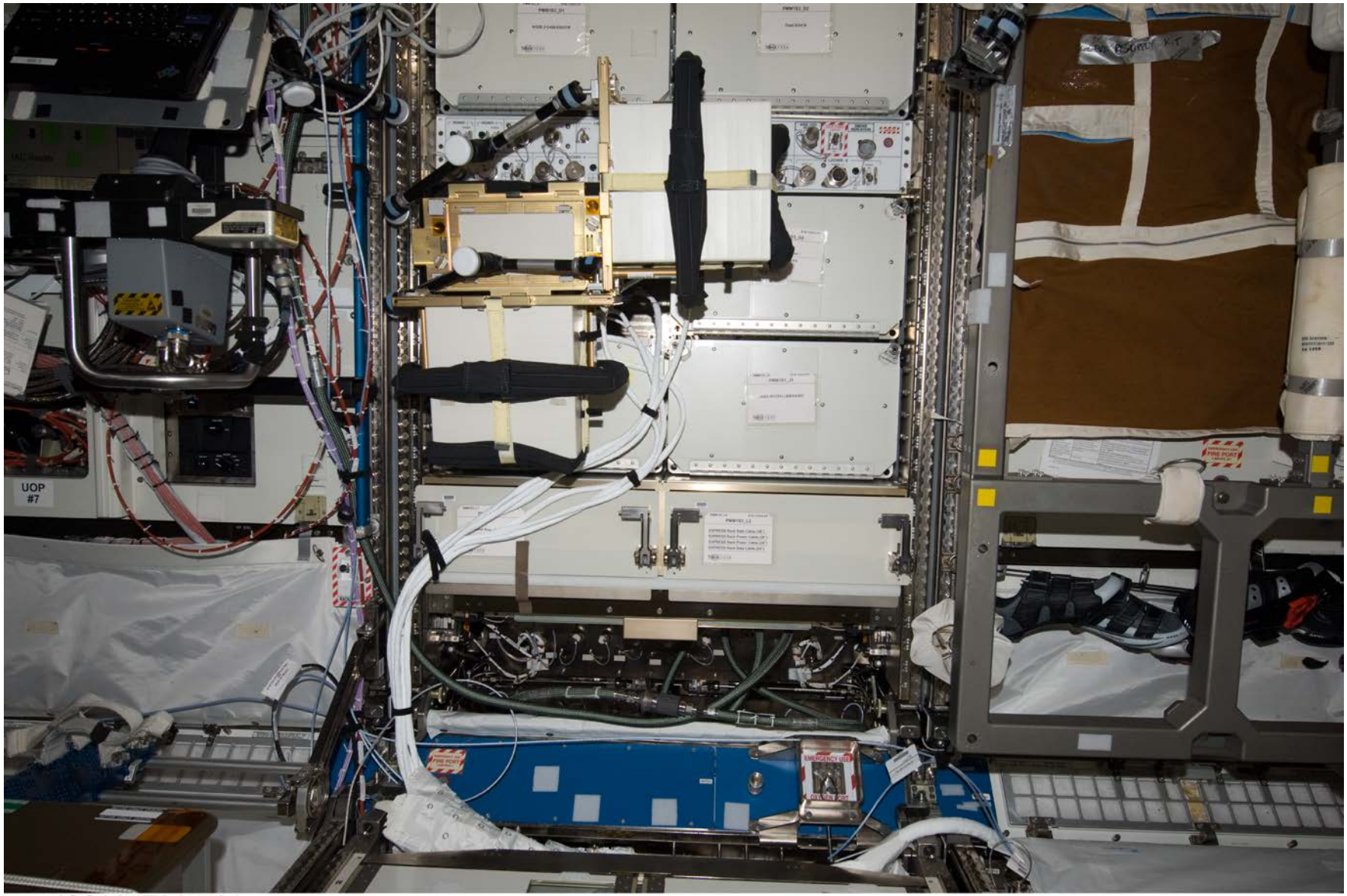






Survey: position 3

04-24-2011
07-22-2011



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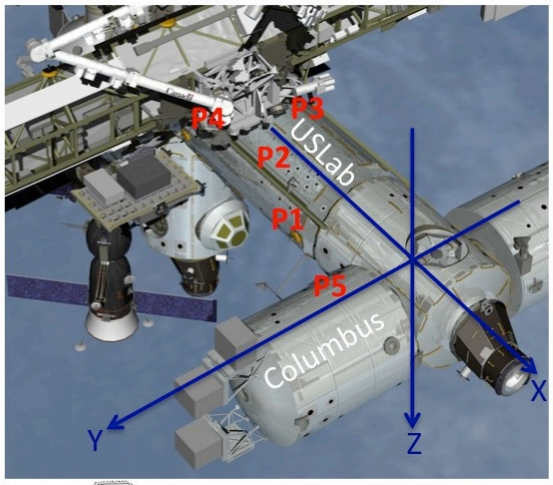
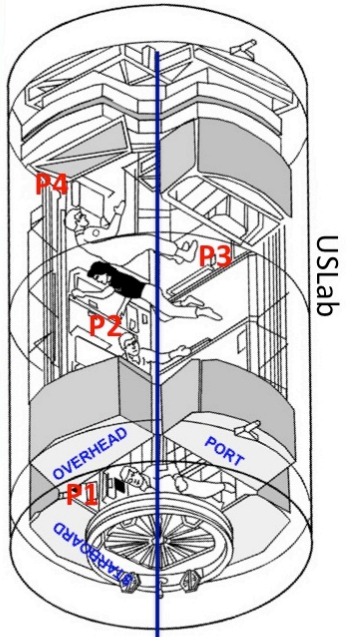
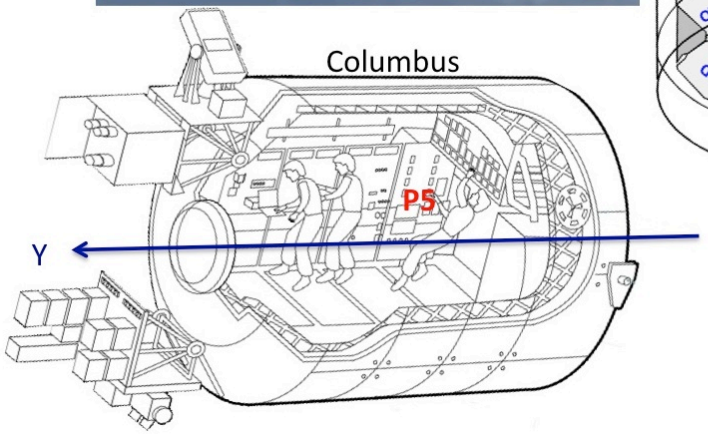
Survey: positions



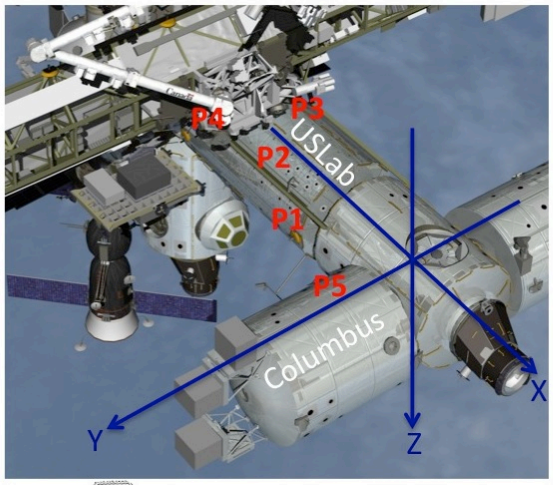


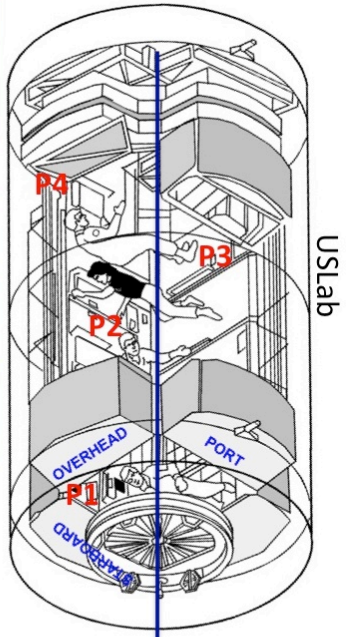


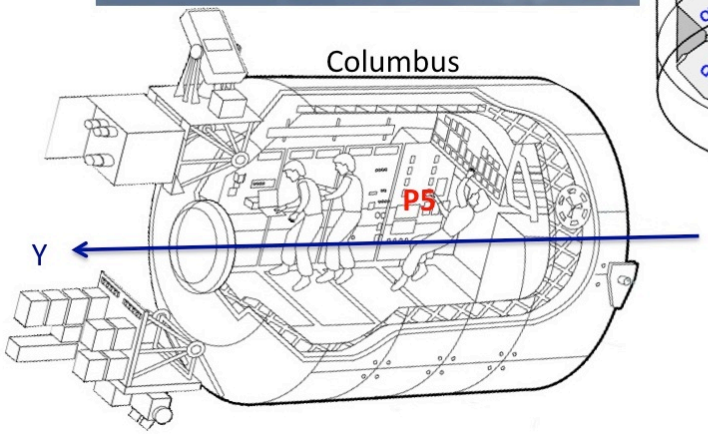
Survey: position 4

07-23-2011
06-07-2012

Survey: positions

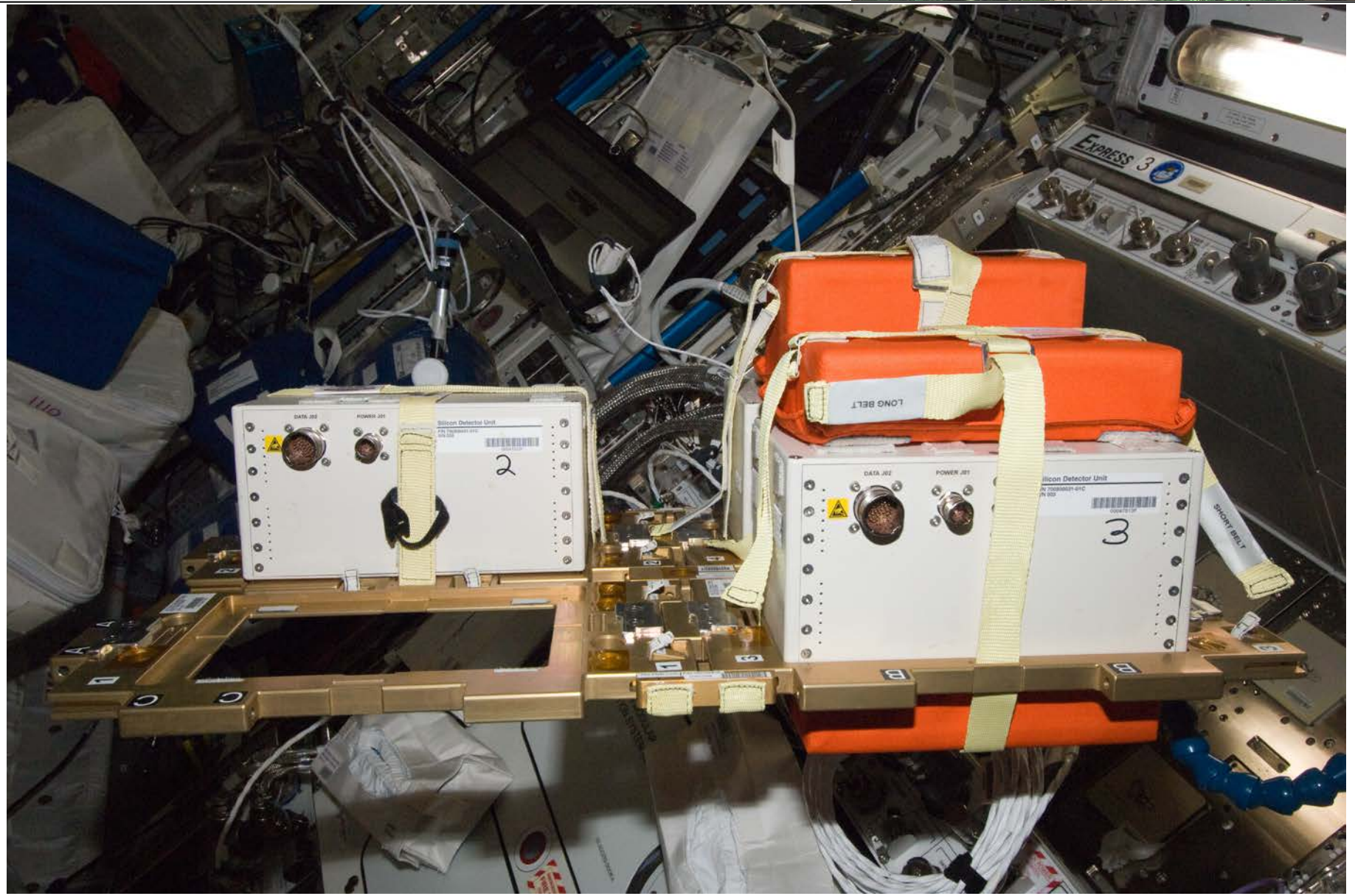


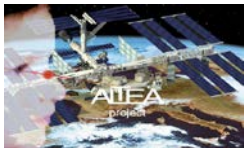




Survey: position 5

06-08-2012
11-15-2012





Pre analysis

Pedestals subtractions

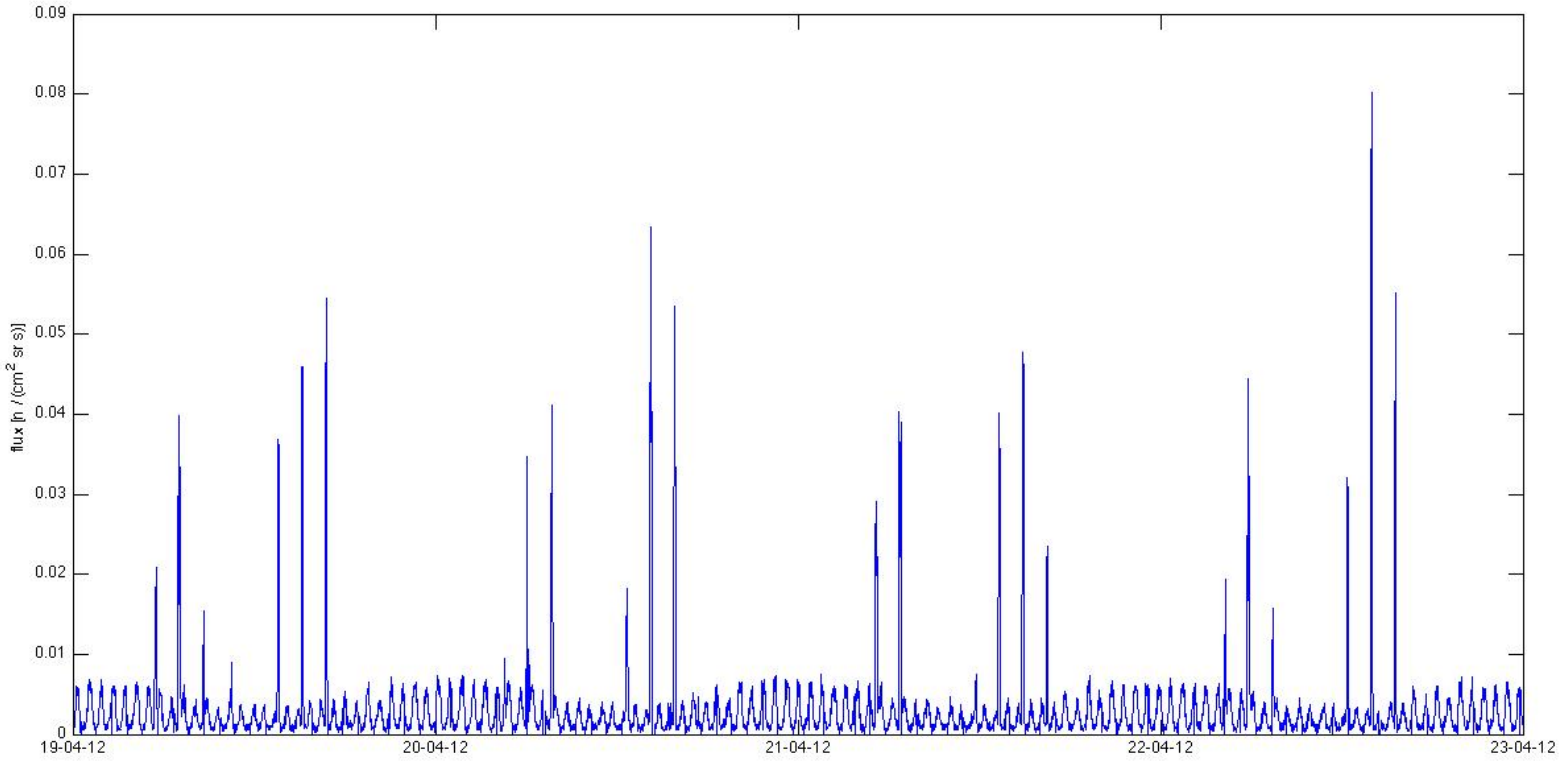
Normal incidence

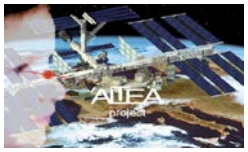
Single tracks

Region selections *(* → *High Latitude as best replica of deep space)*

Selections: eliminate SAA 1

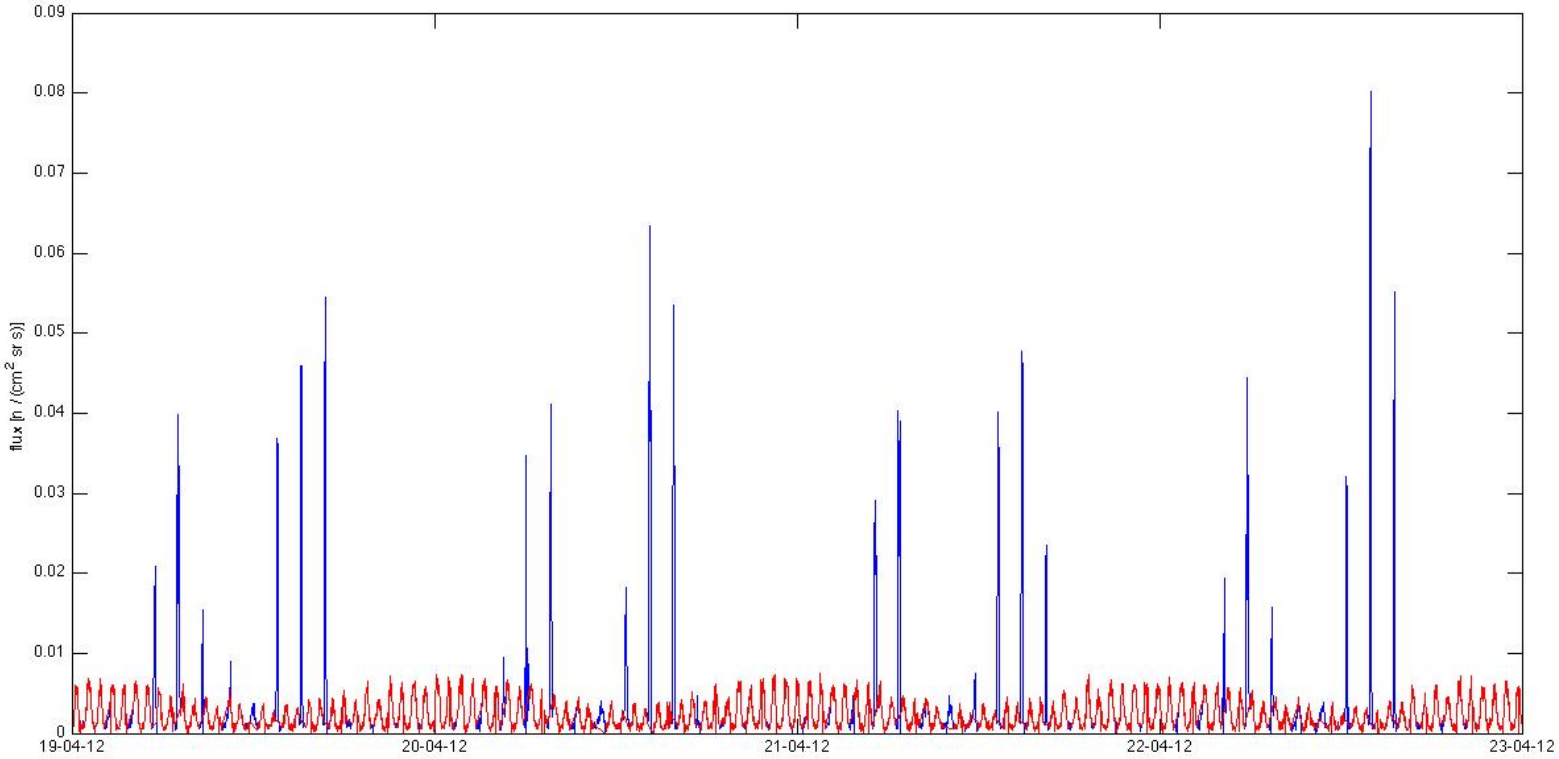
One point per minute, SDU2





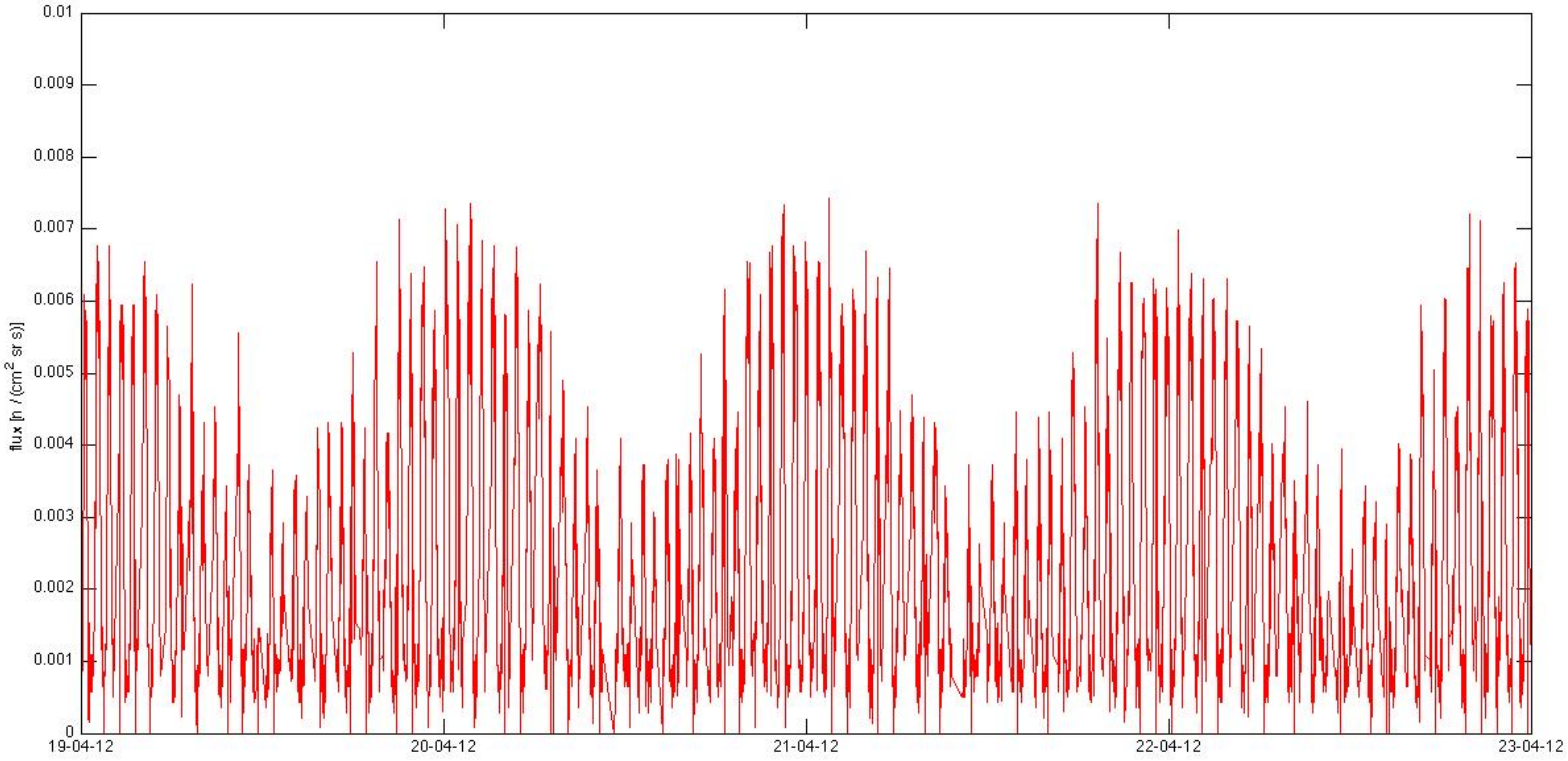
Selections: eliminate SAA 2

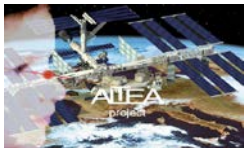
One point per minute, SDU2



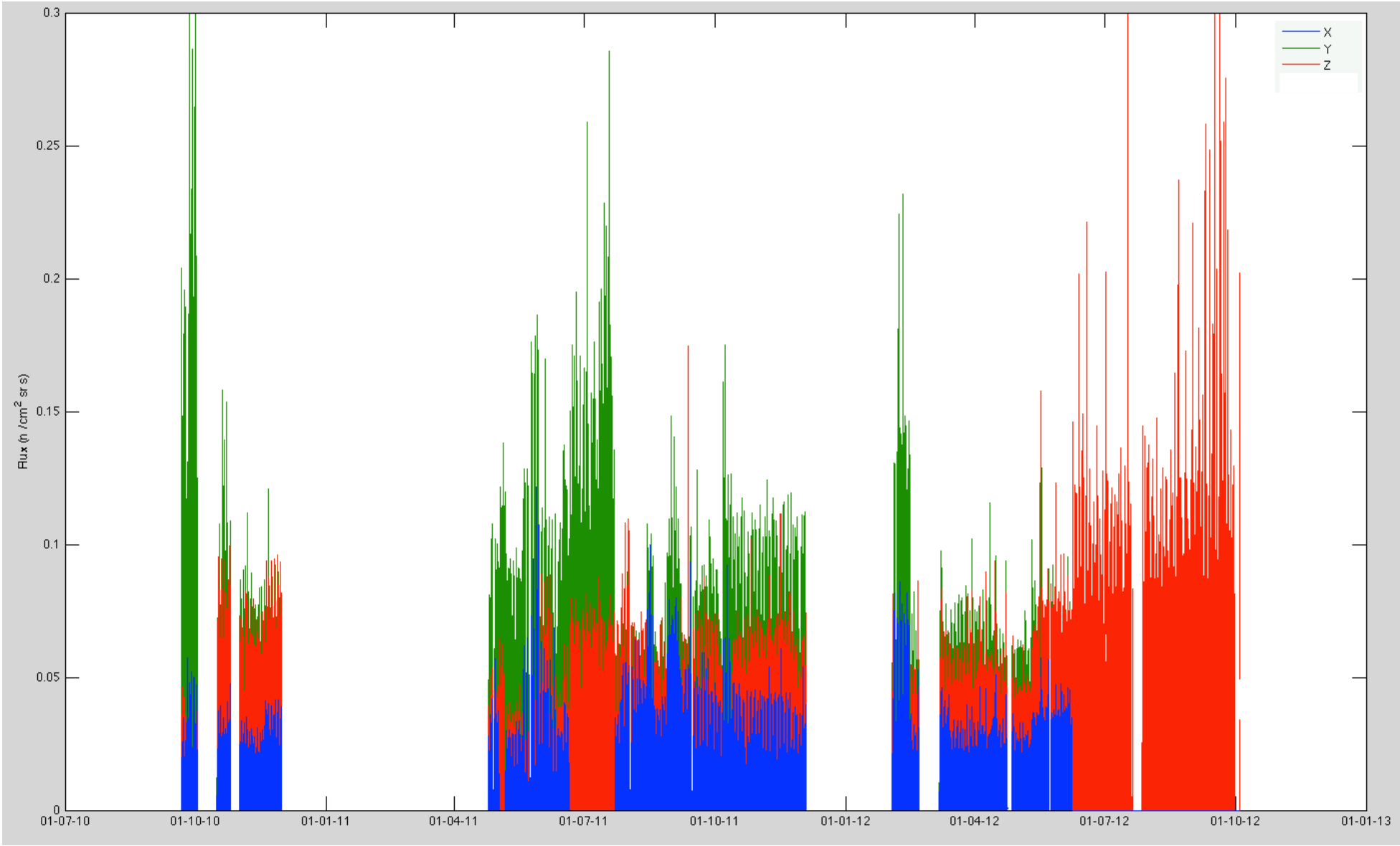
Selections: eliminate SAA 3

One point per minute, SDU2

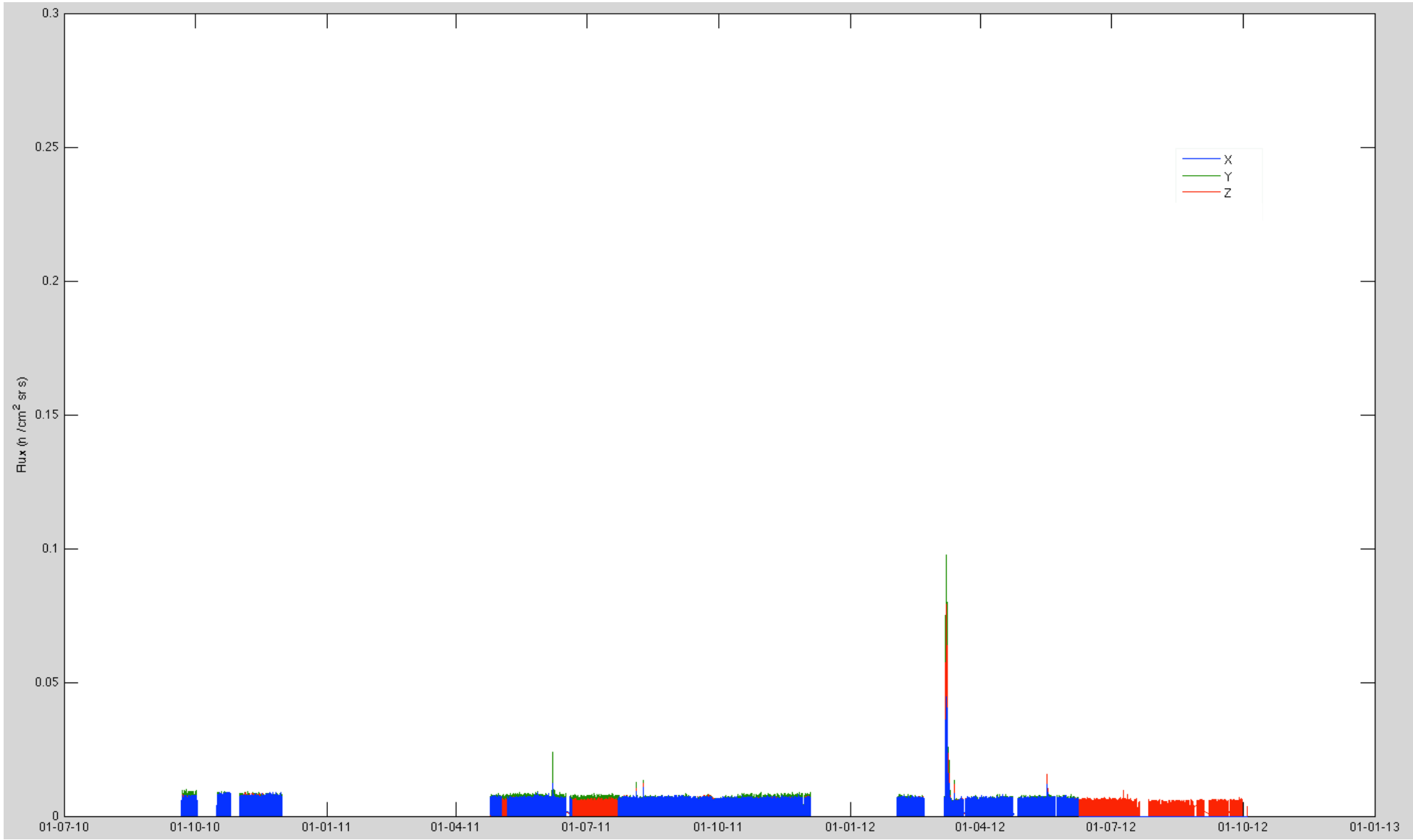




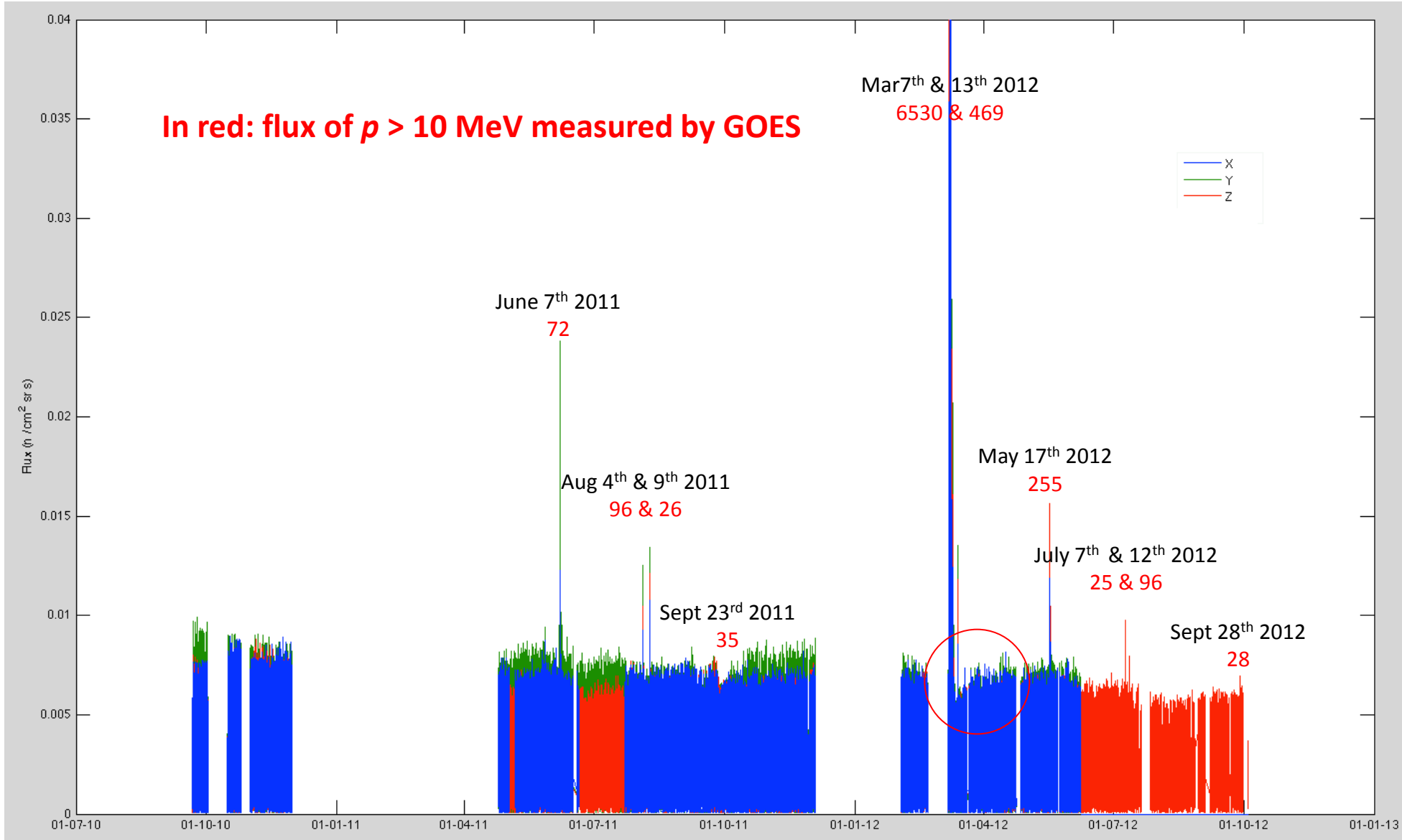
Flux XYZ: all data

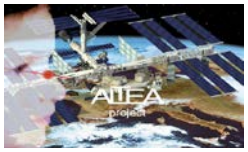


Flux XYZ: data without SAA



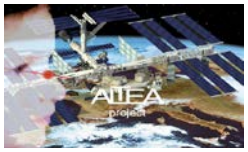
data without SAA: SPEs et al



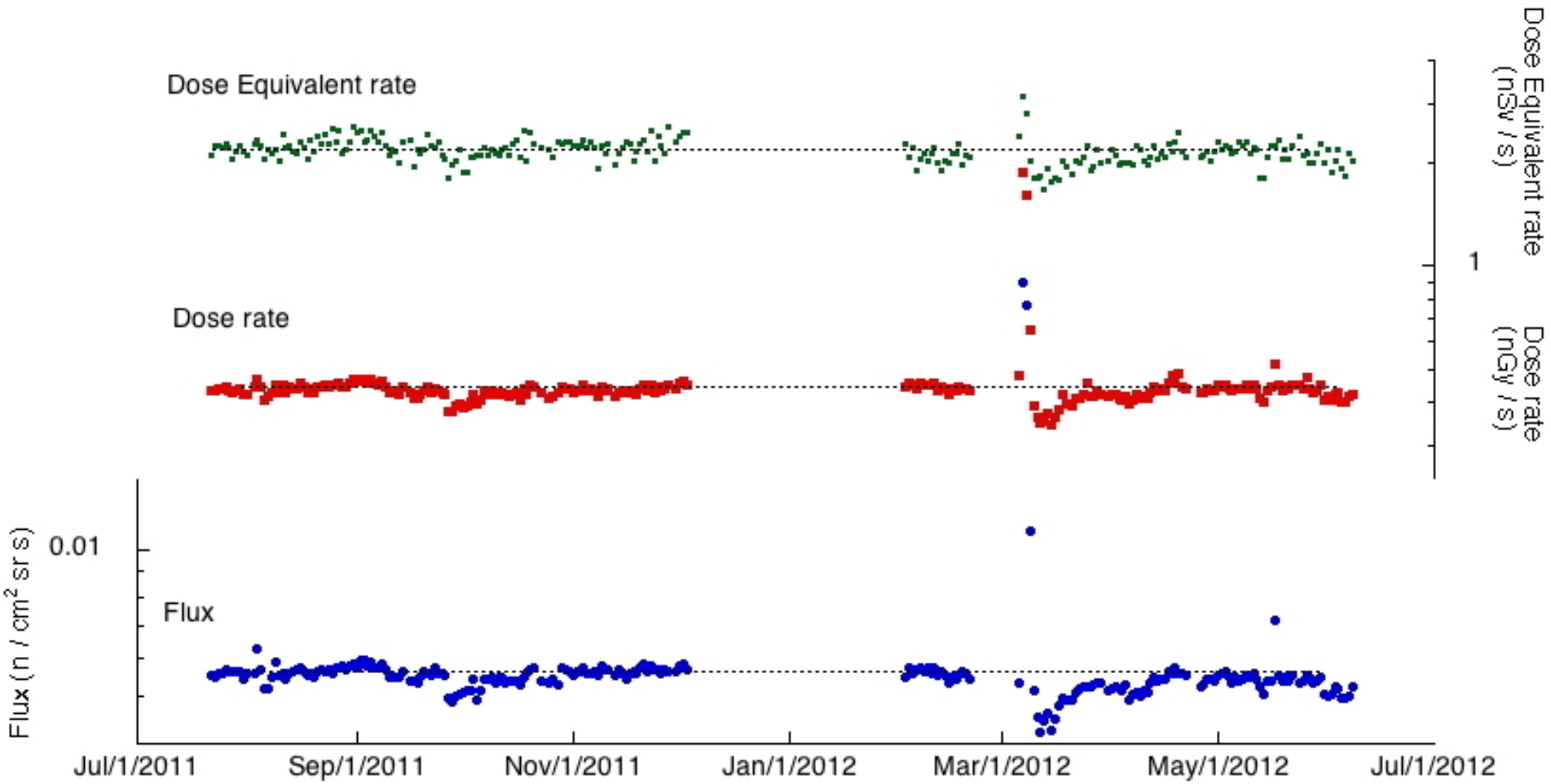


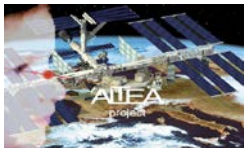
SPEs from GOES

PARTICLE EVENT				ASSOCIATED CME, FLARE, AND ACTIVE REGION				
Start (Day/UT)	Maximum (Day/UT)	Proton Flux (pfu @ >10 MeV)	Year	CME	Maximum (Day/UT)	Importance (X ray/Opt)	Location	NOAA SEC Region No.
			2010					
Aug 14/1230	Aug 14/1245	14		West /14 1730	Aug 14/1005	C4/0F	N17W52	11099
			2011					
Mar 08/0105	Mar 08/0800	50		NW /07 2000	Mar 08/2012	M3/Sf	N24W59	11164
Mar 21/1950	Mar 22/0135	14		NW /21 0236	(farside)			11169
Jun 07/0820	Jun 07/1820	72		Halo /07 0803	Jun 07/0641	M2/2N	S21W64	11226
Aug 04/0635	Aug 05/2150	96		Halo /04 0412	Aug 04/0357	M9/2B	N15W49	11261
Aug 09/0845	Aug 09/1210	26		Halo /09 0812	Aug 09/0805	X6/2B	N17W83	11263
Sep 23/2255	Sep 26/1155	35		Halo (asymmetric) /22 1048	Sep 22/1101	X1/2N	N11E74	11302
Nov 26/1125	Nov 27/0125	80		Halo /26 0712	Nov 26/0710	C1/long duration	N08W49	11353
			2012					
Jan 23/0530	Jan 24/1530	6310		Halo /23 0400	Jan 23/0359	M8/long duration	N28W36	11402
Jan 27/1905	Jan 28/0205	796		Halo /27 1827	Jan 27/1837	X1/long duration	N27W71	11402
Mar 07/0510	Mar 08/1115	6530		Halo /07 0036	Mar 07/0024	X5/3B	N17E15	11429
Mar 13/1810	Mar 13/2045	469		Halo /13 1736	Mar 13/1741	M7	N18W62	11429
May 17/0210	May 17/0430	255		Partial Halo /17 0148	May 17/0147	M5	N12W89	11476
May 27/0535	May 27/1045	14		Halo (asymmetric)/27 2112	(Farside)			11428
Jun 16/1955	Jun 16/2020	14		Halo (asymmetric)/14 1430	Jun 14/1435	M1	S17E14	11504
Jul 07/0400	Jul 07/0745	25		Halo (asymmetric)/06 2312	Jul 06/2308	X1	S18W50	11515
Jul 12/1835	Jul 12/2225	96		Halo (asymmetric)/12 < 1710	Jul 12/1649	X1	S16W09	11520
Jul 17/1715	Jul 18/0600	136		Partial Halo/17 1348	Jul 17/1715	M1	S17W75	11520
Jul 23/1545	Jul 23/2145	12		Partial Halo (asymm.)/23 0236	(Farside)			11520
Sep 01/1335	Sep 02/0850	59		Full Halo/31 2012	31/2043	C8	S06E20	None
Sep 28/0300	Sep 28/0445	28		Full Halo/28 0018	27/2357	C3	N08W41	11577



The march 2012 SPE (<XYZ>)

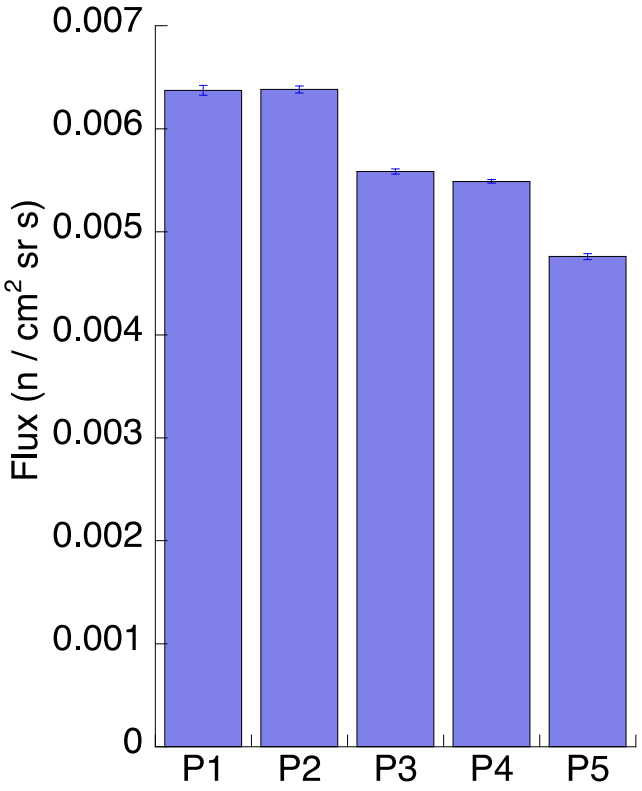


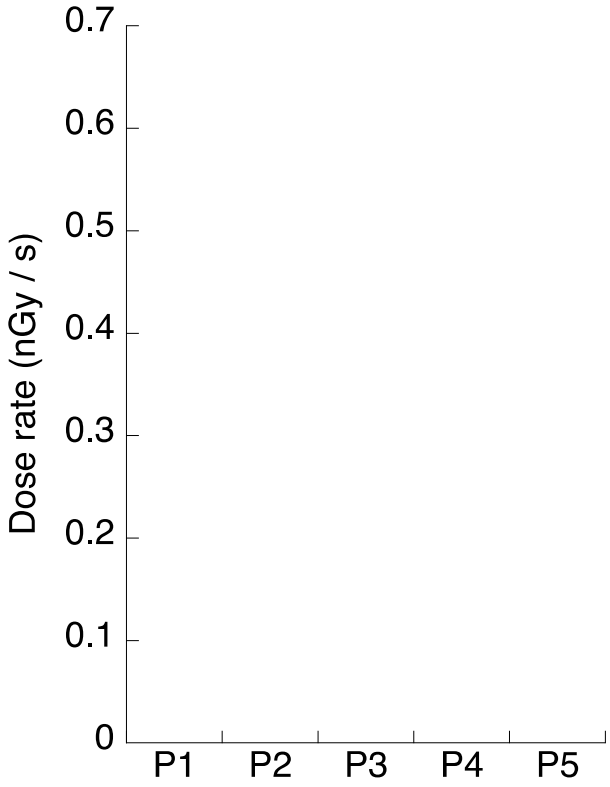


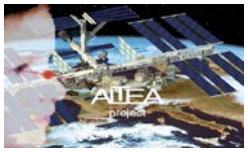
Averaged results

Results: averages per position

High Latitude

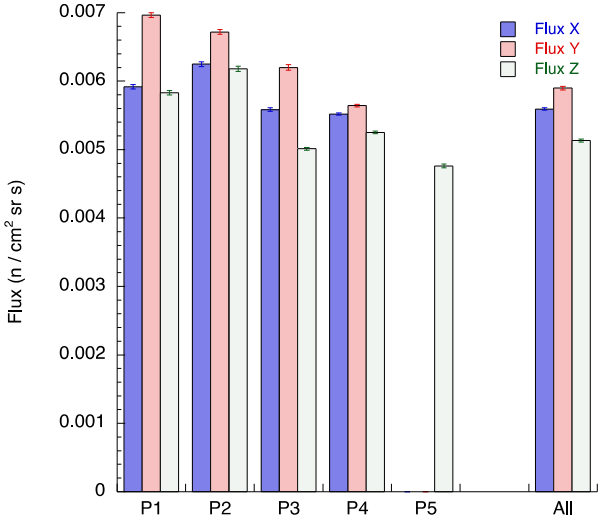


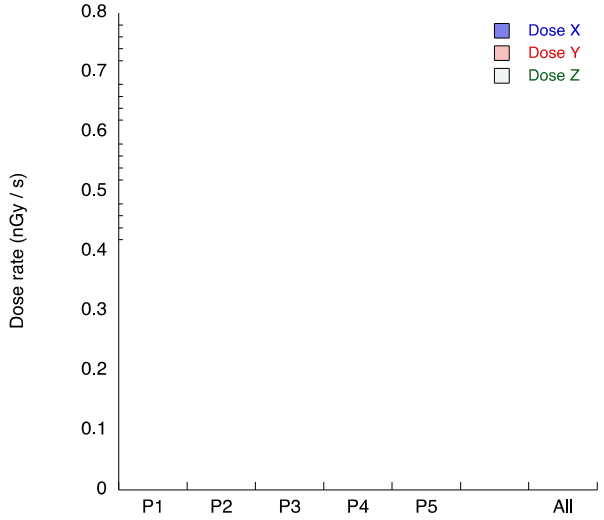


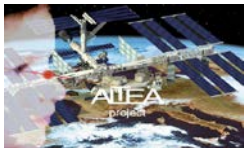


Results: average per pos./direct.

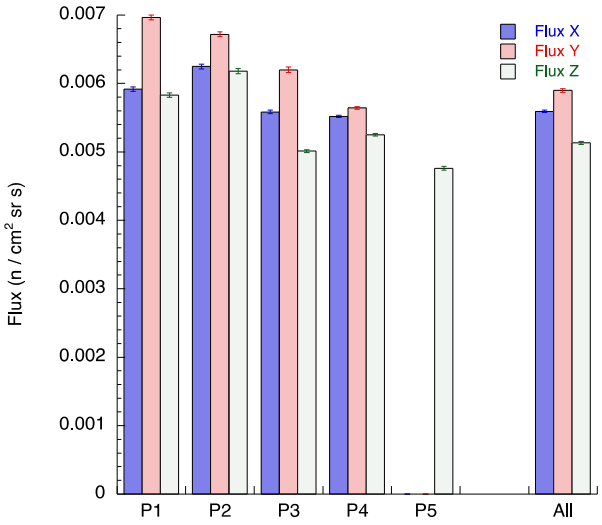
High Latitude

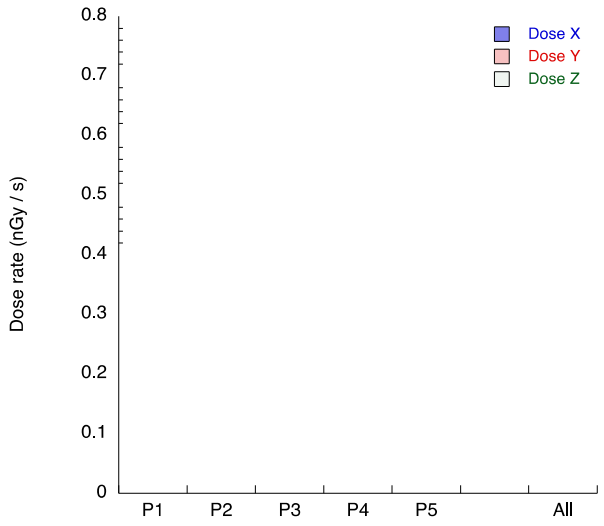


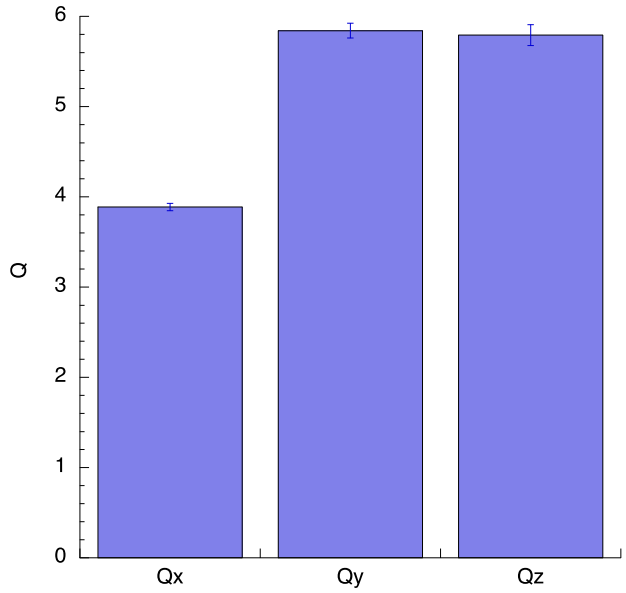


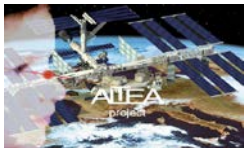


The averaged quality factor Q

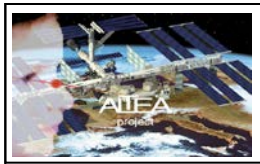








Daily results



Flux vs time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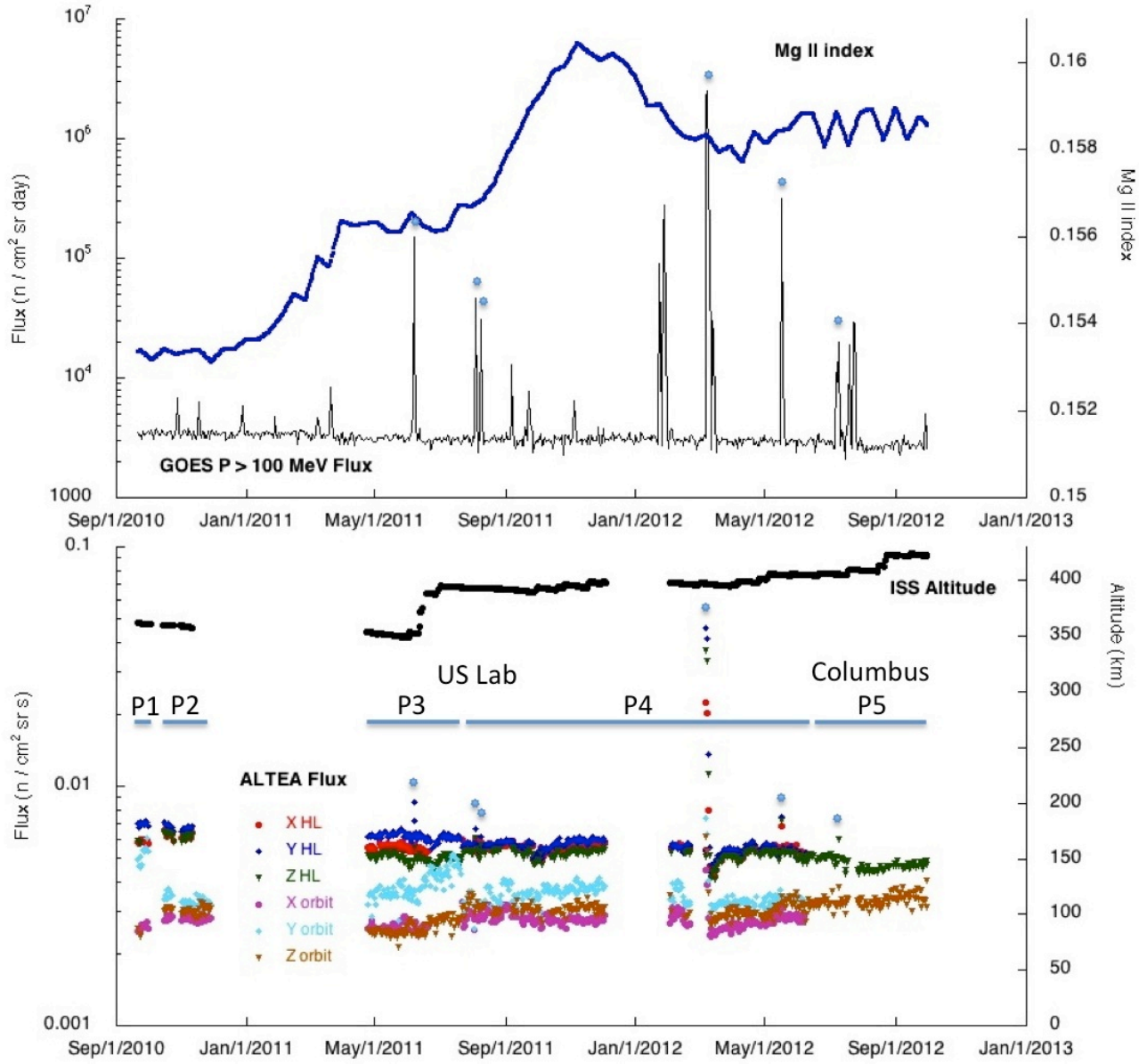
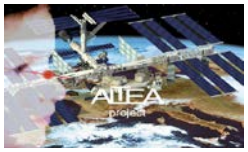
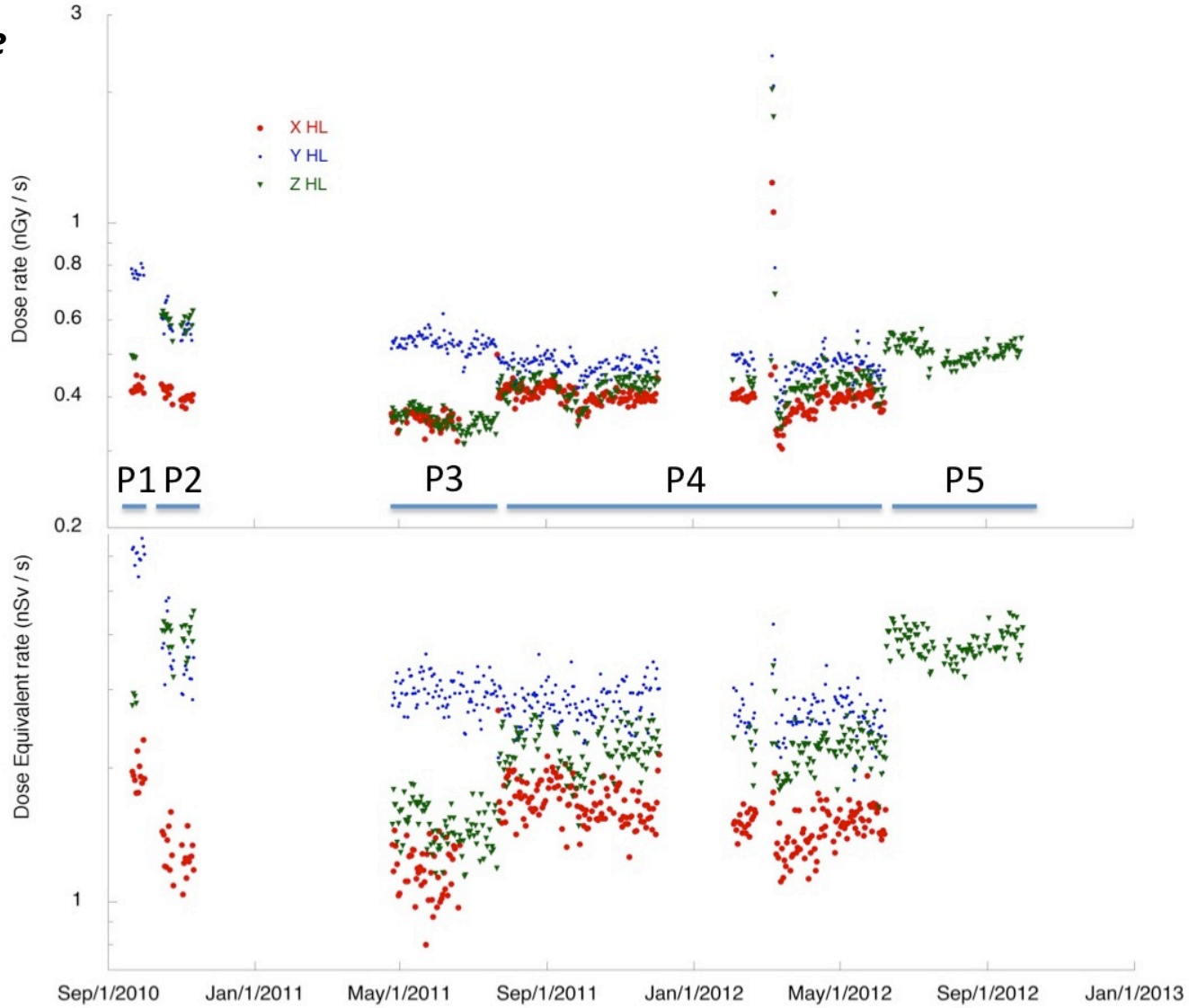
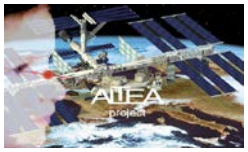

Mg II index
GOES P > 100 MeV Flux
Flux (n / cm² sr day)
Mg II index
Sep/1/2010
Jan/1/2011
May/1/2011
Sep/1/2011
Jan/1/2012
May/1/2012
Sep/1/2012
Jan/1/2013
ISS Altitude
US Lab
Columbus
P1 P2
P3
P4
P5
ALTEA Flux
X HL
Y HL
Z HL
X orbit
Y orbit
Z orbit
Flux (n / cm² sr s)
Altitude (km)



Dose & Dose Eq rates vs time

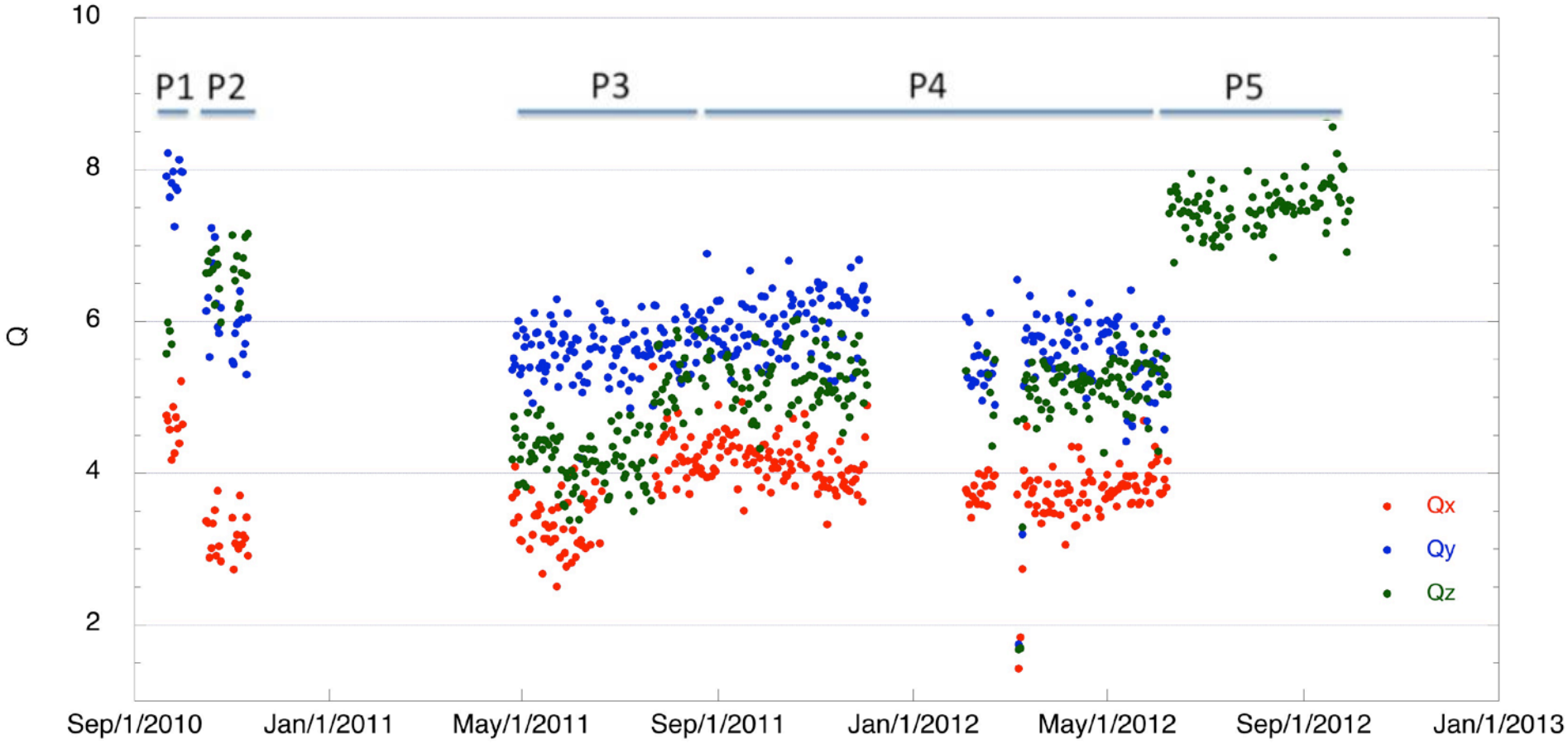
High Latitude

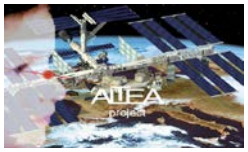




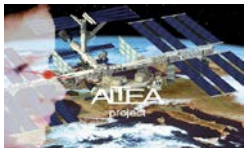
Q vs time

High Latitude

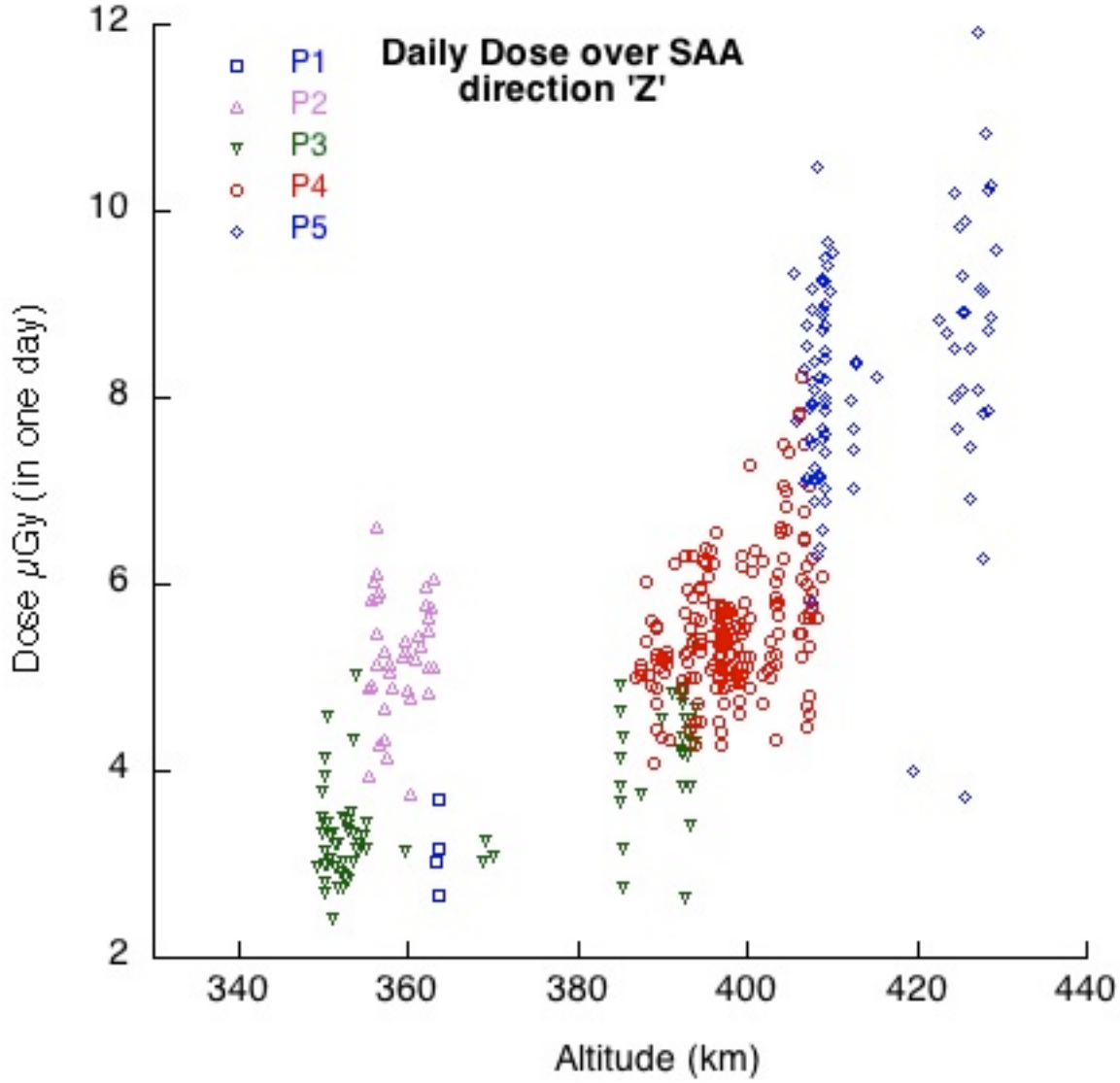


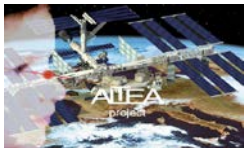


SAA variability, pos. & alt.



SAA variability, pos. vs alt.




ALTEA
project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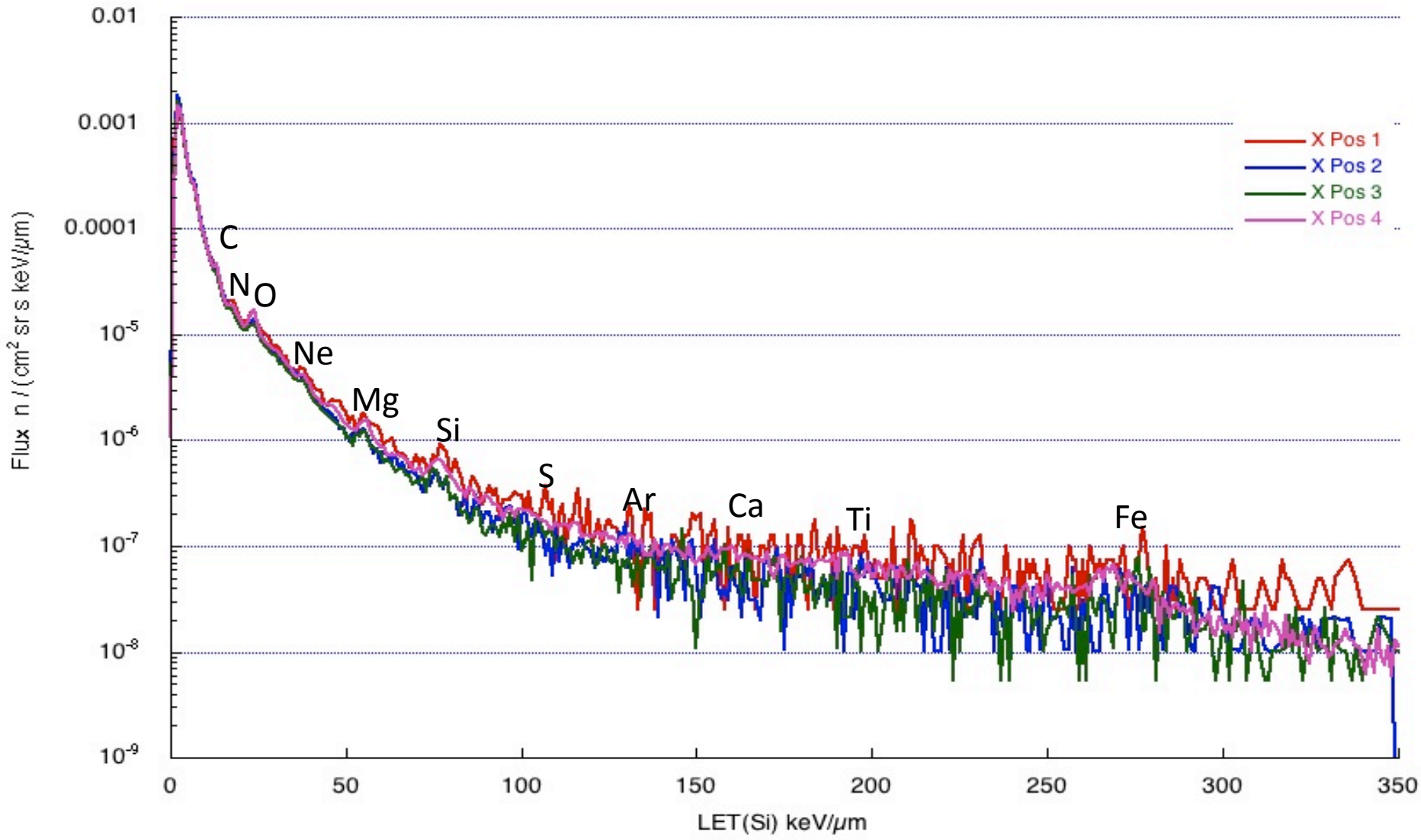
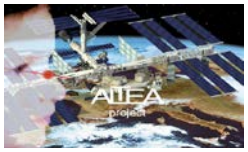
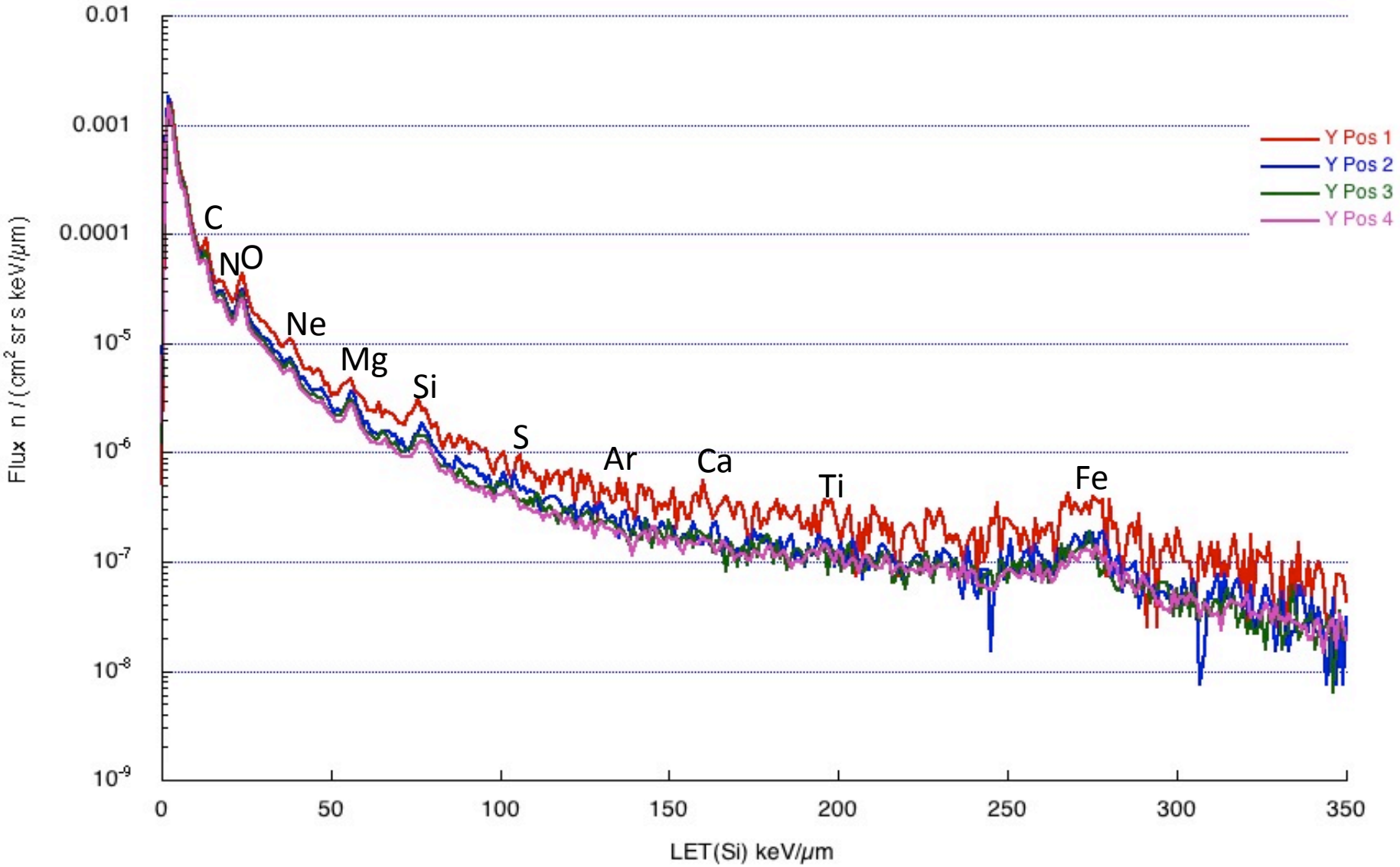
Spectra

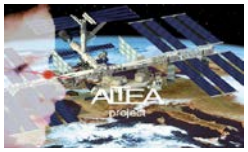
Spectrum X direction



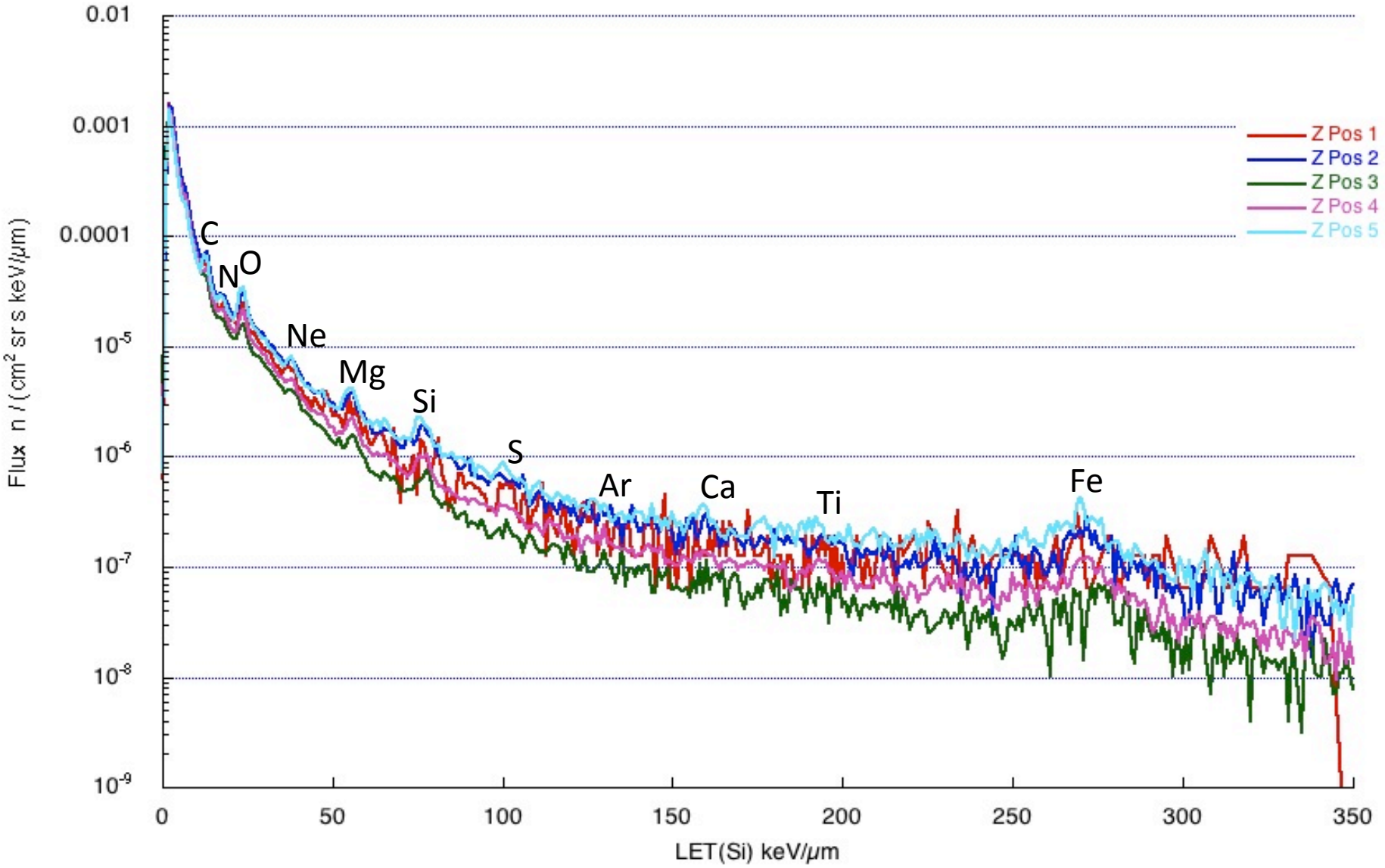


Spectrum Y direction

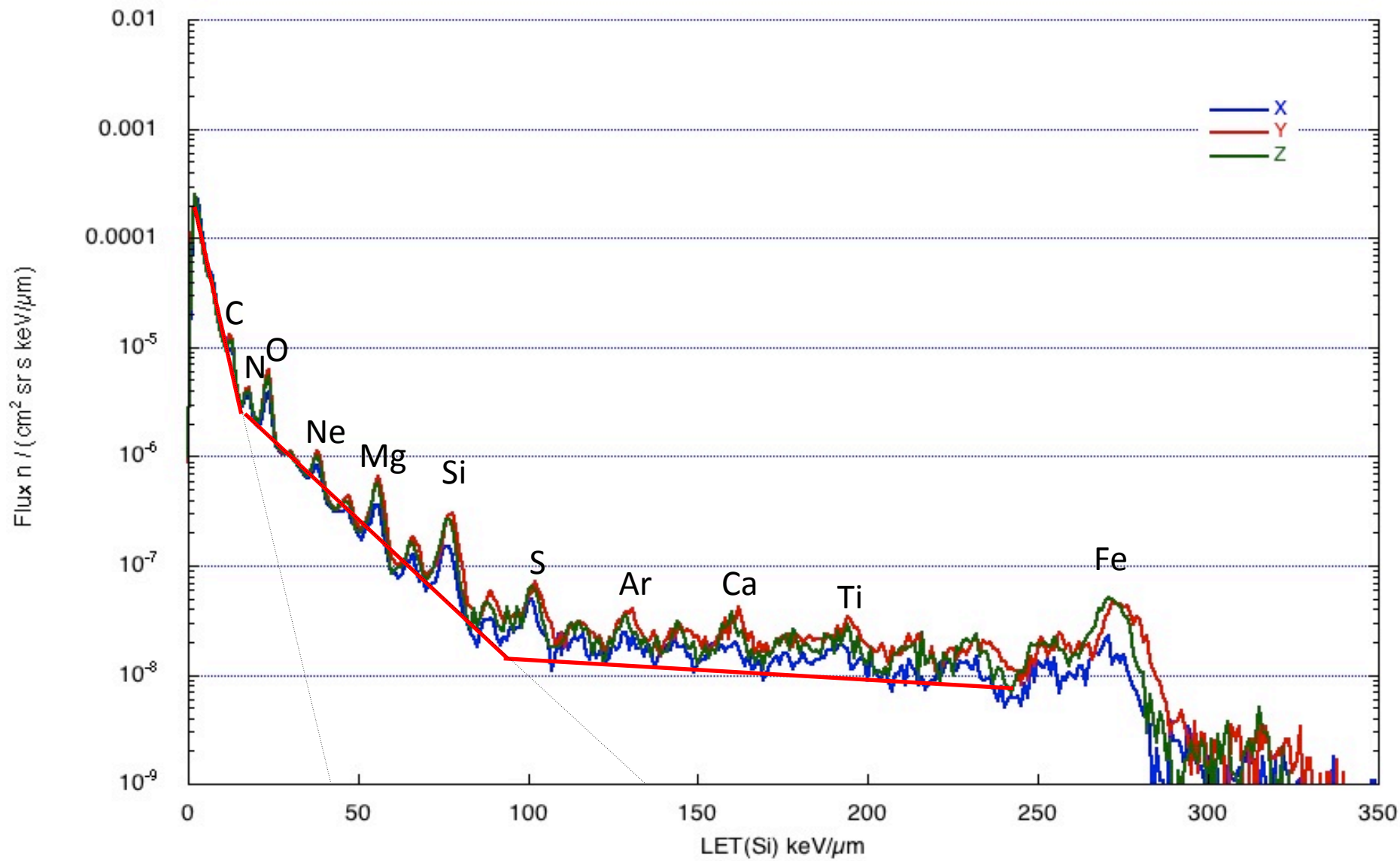


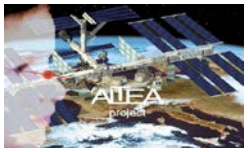


Spectrum Z direction

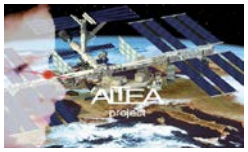


Spectrum Low Latitude XYZ





Future



LIDAL

Light Ion Detector for ALTEA: LIDAL *(selected by ASI)*

Rationale:
1)expand ALTEA energy acceptance window to include all H and He
2)provide a direct measure of ions kinetic energy

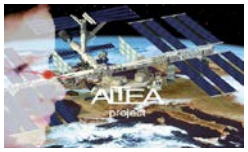
Plan:
Build a system based on fast scintillator detectors to be used as ToF and as trigger for ALTEA

- Two Detector Units (DUs) to be positioned at the end of a Silicon Telescope (ST: 1 or more SDUs)
- Each DU made of thin plastic scintillators (full ST field of view covered)
- Scintillators will be segmented in the two orthogonal directions (provide first position/tracking)
- Scintillators read by Silicon Photomultiplier (SiPM)
- Resolution aimed to be better then 100 ps

-ToF measurements provide energy determination
-Signal from DUs can be used as ALTEA trigger

***STATUS**: favorable reviewing from ASI, waits for financing (probably next year). Upload NET 2016*

On the ISS NET 2016



LORE = µALTEA

Light Observatory for Radiation Environment: LORE

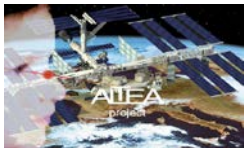
• Results from ALTEA can be used for testing configurations and software for a miniaturized device

A step towards miniaturization & modularity.

• Miniaturizing decreases performances and the compromise could come from **modularity**: a combination of these µdetectors would improve performances if/when needed

• Physics measurements (Energy loss, Z Ein) **separated** from risk oriented calculations (to be performed in firmware)

Study for best sensor material as well as optimized firmware



Conclusions

• Throughout 3D study of the radiation environment in the ISS – USLab (+Columbus ER3) 2010-2012 using the ALTEA detector system.

• Aimed at the understanding of the radiation environment in the ISS, and at building a database useful for deep space model validations,

• Using the selection capability of the system the ISS is indeed the best available replica for deep space radiation measurements.

• Data from several SPEs requires further analyses to understand the proper solar parameter set to to be linked at the SPE effect in a spacecraft.

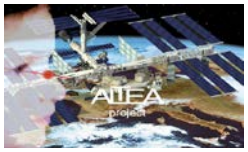
• The radiation flux is shown to be roughly similar across the different positions/directions

• The radiation quality features a larger variability, mostly due to the shielding distribution along the three ISS axis.

• The Dose Equivalent, and the quality factor Q well describe this variability.

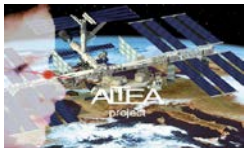
• The amount of variability (reaching a factor 3) suggests careful considerations when designing spacecrafts and planning countermeasures for long manned missions in deep space.

• The presence of the radiation from the SAA strongly modifies the measured radiation pattern, with time dynamics that appears difficult to predict. Care must therefore be taken when interpreting integrated results.



A final comment

NOTE: A large amount of data is now available and validation of models and CADs should start ASAP.



ALTEA: the international team

Dept. di Physics, Univ. of Rome "Tor Vergata" and INFN Sect. Roma2 , Roma
Dept of Physics, Univ. of Pavia, Pavia
Dept of Physics, Univ. of Milan, Milan
DISM-Univ. of Genoa, Genoa
L.N.F. - INFN, Frascati (Rome)
CERN - INFN
Dept. of Physics,Univ. e Sect. INFN of Trieste, Perugia, Firenze
Dept. of Sc. and Chemical Tec., Univ. of Rome "Tor Vergata"
Dept. of STB - Univ. of L'Aquila, L'Aquila
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Royal Institute of Technology, Stockholm, Sweden
Chalmers University of Technology, Sweden

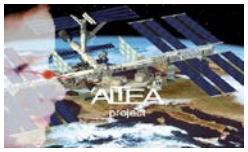
Institute for BioMedical Problems, Moscow, Russia.
Russian Space Corporation "Energia" by name Korolev, Korolev, Moscow region, Russia
Moscow State Engineering Physics Institute, Moscow, Russia

JAERI, Japan

Johnson Space Center, NASA, Houston TX, USA
Goddard Space Flight Center, NASA, USA
Brookhaven National Laboratory, NY, USA
Lawrence Berkeley National Laboratory, CA, USA
Loma Linda University, CA, USA
Cole Eye institute, The Cleveland Clinic, Cleveland, OH, USA
Wyle Laboratories, TX, USA
Eril Research, CA, USA

+ others joining in

Thanks to ESA, ASI, NASA and ISS crews!



Thank you for your attention