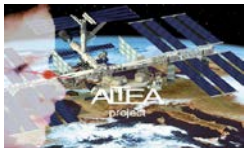
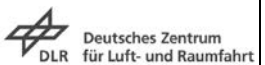


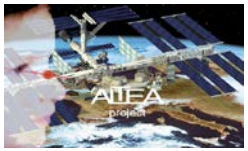
Comparing active detectors: ALTEA and DosTel

L. Narici[1,2], T. Berger[2], S. Burmeister[3], M. Casolino[1], L. Di Fino[1], P. Picozza[1], D. Matthiä[2], Guenther Reitz[2]

1 Department of Physics, University of Rome Tor Vergata & INFN – Roma2
2 Institute of Aerospace Medicine, German Aerospace Center, DLR, Cologne, Germany
3 Institute of Experimental and Applied Physics, Christian Albrechts Universität zu Kiel, CAU, Kiel, Germany

University of Rome
Tor Vergata

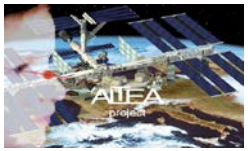




Content

- Objective
- The two Detectors
- Handling the Detectors' characteristics
- ALTEA re – calibration
- The datamatrix
- Results:
    - Dose and fluxes (GCR, high L)
    - SPEs
    - SAA passages

- *Search Book*



Objectives of this study

Present a procedure to put results from different active detectors in a single datamatrix

- this talk will focus on **ALTEA** and **DOSTEL**

in particular:
- acquisition of a detailed knowledge of the hardware and of the detection strategies
- definition of the needed information that must be provided to make full use of the datasets
- development of software needed to take care of the different detection strategies

➔ Exploit the combined ALTEA and DOSTEL measurements

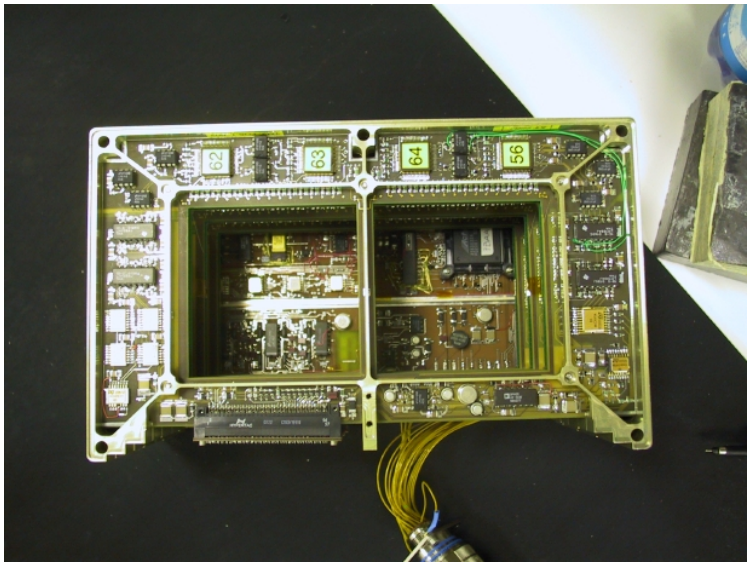
➔ Suggest how to proceed in the harmonization effort for active detectors

The effort to provide knowledge of
what / where / when
active radiation measurements for human exploration have been taken
will also be mentioned

Hardware description: ALTEA

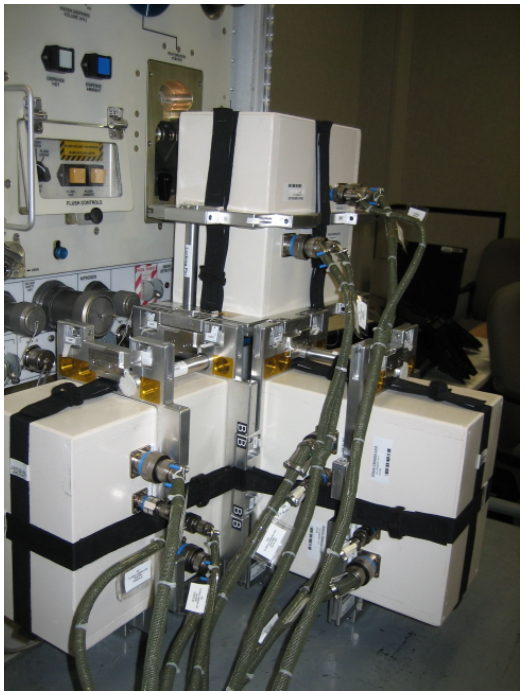
The ALTEA system is a set of **6** silicon striped active telescopes
Each telescope (Silicon Detector Unit or SDU) features 6 sensitive silicon planes, each striped in alternate directions 'X' and 'Y'. Each plane is 16 x 8 x 0.038 cm^3. The distance between the first and the fifth planes is 7 cm. Geometrical factor is 230 $(cm^2\ s\ sr)^{-1}$.

Each SDU is auto – triggered by ions passing through at least 5 planes
The read out electronics is set in such way ions are measured if they release
3 keV/µm ≤ LET(Si) ≤ 700 keV/µm (the lower cut leaves out most protons and He ions)



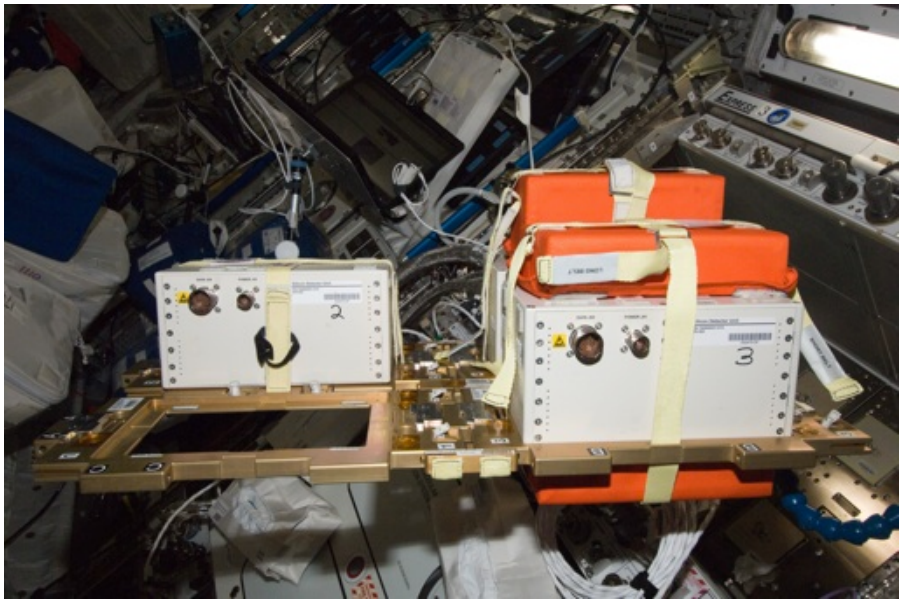
Open ALTEA SDU before mounting the silicon planes

ALTEA Ground model in the X Y Z configuration during astronauts training in JSC - NASA



ALTEA: ALTEA shield/survey & shield/shield

ALTEA before deployment in the USLab



ALTEA before deployment in Columbus

ALTEA has been measuring radiation in the ISS from 2006 to 2012
(for a total of more then 3 y)

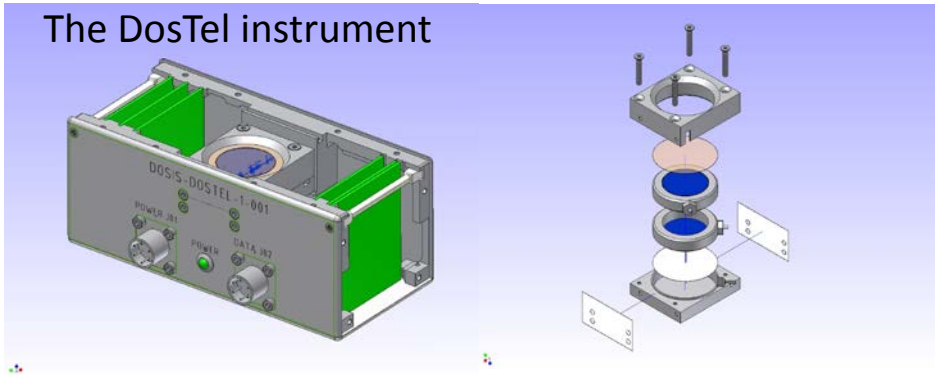
In this talk we will focus on the last 2 years of operation (ESA sponsored ALTEA-shield)

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 – 09/30	114	P5	Columbus ER 3

Hardware description: DOSTEL

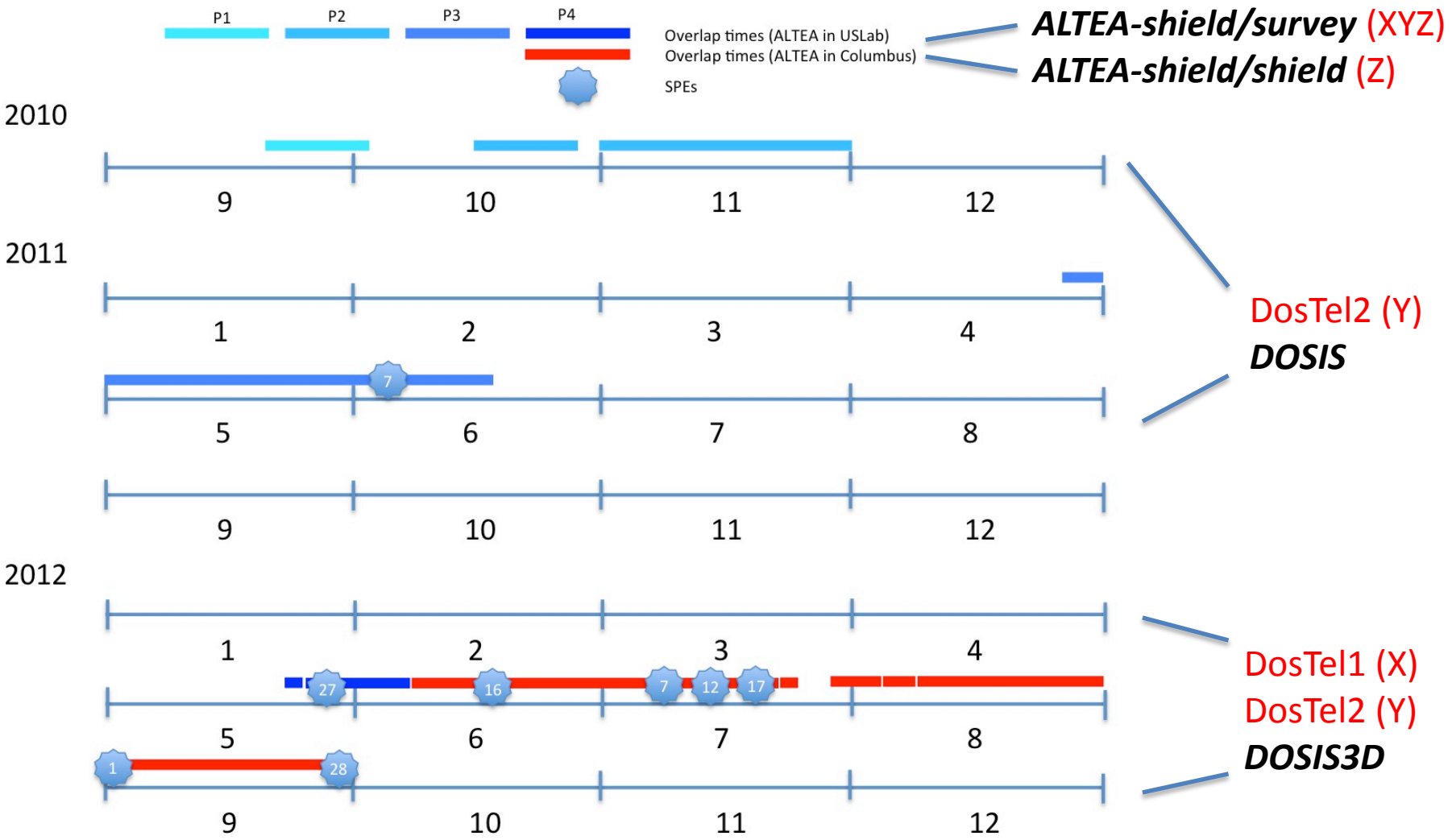
The DOSTEL system has been already described and is part of the DOSIS and DOSIS3D projects. It consists of 2 silicon active detectors (DOSTEL1 and DOSTEL2), looking in two perpendicular directions (X and Y) featuring 2 sensitive silicon round planes, each of 3 cm in diameter and 0.0354 cm thickness. The distance between two planes is 1.5 cm. Geometrical factor (for the single plane) is $2\pi A = 44$ cm^2 sr.
The read out electronics is designed to cover the LET range *0.08 keV/µm ≤ LET(Si) ≤ 440 keV/µm*.

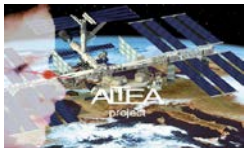
DOSIS main box
(2 DosTel + DPDU)
Beneath the EPM rack in Columbus



Blow out view of the telescope

Site and times of measurements (overlaps)





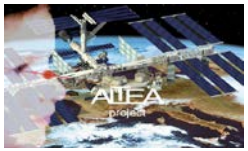
Site and times of measurements (overlaps)

n	*From*	*To*	*ALTEA Site*	*Full days*	*For each Site*
1	20-Sep-2010 18:58:00	02-Oct-2010 03:25:00	P1	11	11
2	15-Oct-2010 17:32:00	25-Oct-2010 11:14:00	P2	09	
3	31-Oct-2010 12:33:00	30-Nov-2010 09:48:00	P2	29	38
4	24-Apr-2011 15:12:00	17-Jun-2011 14:54:46	P3	53	53
5	21-May-2012 11:28:54	23-May-2012 00:08:00	P4	01	
6	24-May-2012 00:00:00	08-Jun-2012 07:00:00	P4	14	15
7	08-Jun-2012 12:05:00	19-Jul-2012 04:07:00	P5	40	
8	20-Jul-2012 12:19:00	20-Jul-2012 18:11:00	P5	00	
9	27-Jul-2012 08:05:00	04-Aug-2012 03:58:00	P5	08	
10	04-Aug-2012 14:30:00	08-Aug-2012 23:59:00	P5	03	
11	09-Aug-2012 18:08:00	30-Sep-2012 14:35:00	P5	51	102

Tot: 219 full days

- Unfortunately no measurements at the same time / site / direction

- A test quite period chosen to be between Aug 10th 2012 and Aug 31st 2012:
  - No prominent solar activity
  - Both detectors in Columbus



Handling the detector properties

Major differences between the two systems:

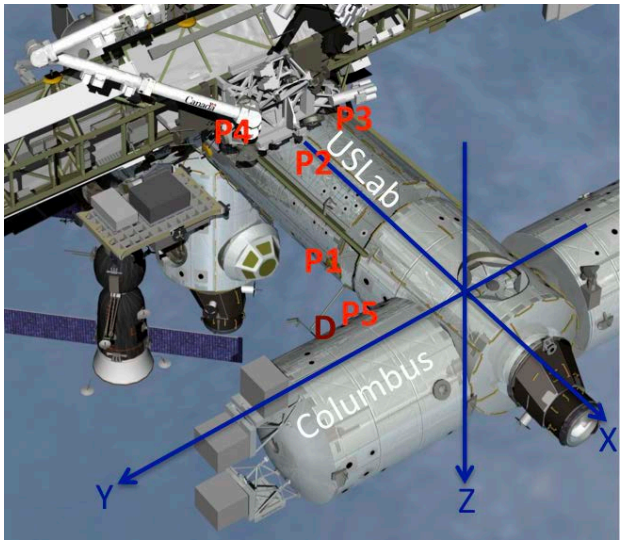
• dose are calculated straightforwardly for DOSTEL as ΔE / M while ALTEA, being a telescope, must first estimate the source of the measured radiation and therefore calculate the dose

• ALTEA has the ability of tracking each ion, via the striped silicon planes, so, for example, it can select single traces (rejecting showers and or unwanted noise) while for DOSTEL we can only calculate a mean path-length if using the telescope feature and can minimize the contribution of noise with a electronic acceptance threshold.

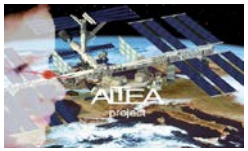
• The telescope auto – triggering features of ALTEA leaves out most of H and He ions, and also lighter secondary particles (such as e, π) that are instead measured by DOSTEL.

ALTEA: dose rate (L > 3, i.e. High Latitude, HL)

Many features can be appreciated in these ‘raw’ dose results



To compare results with those obtained with different instruments the ALTEA characteristics must be taken into account



Handling the detector characteristics

ALTEA calibration

• the dose rate *D* in ALTEA is calculated taking into account the geometrical issues via the geometrical factor *GF*:

$$D = \frac{4\pi}{h\rho GF}\sum_{k=1}^{N_0} E_k$$

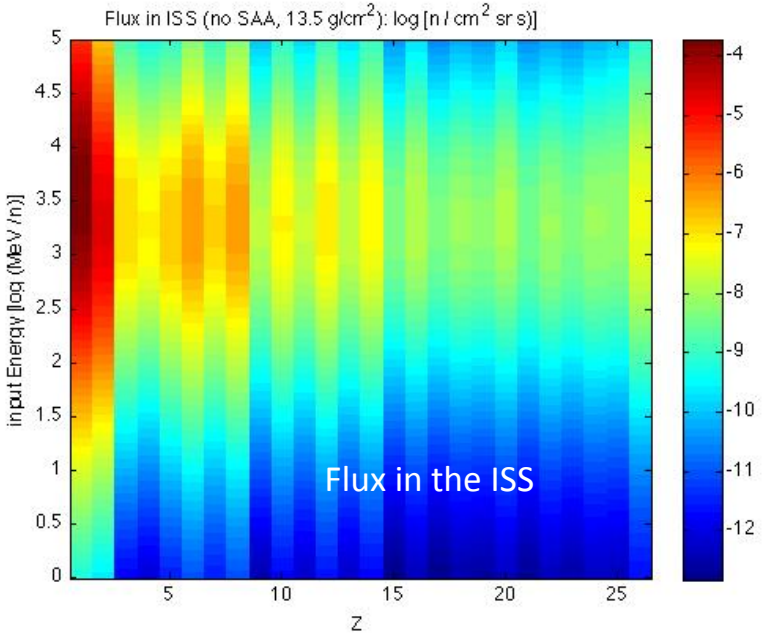
(*h* is the silicon thickness, ρ the water density, *D* is the dose rate, E_k the energy measured due to the k_{th} ion, and the sum is taken over the measured N_0 ions in the unit of time)

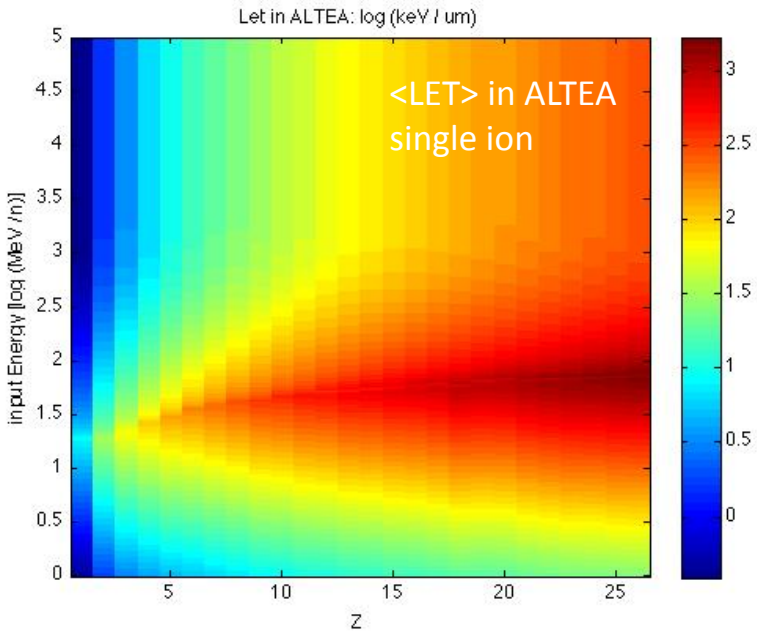
• trigger issues are taken into account by

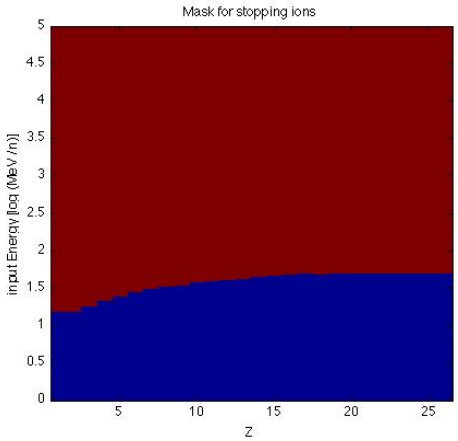
providing a simulated spectra in the ISS, based on CREME (and on the DLR model)
providing a simulation of the ALTEA SDU, based on PHITS
calculating in each L shell the percentage of the total radiation missed by ALTEA.

→ calculating calibration coefficients (function of L) for the flux and dose rate.
calibrating the time data using the previous coefficients.

Handling the detector characteristics 2

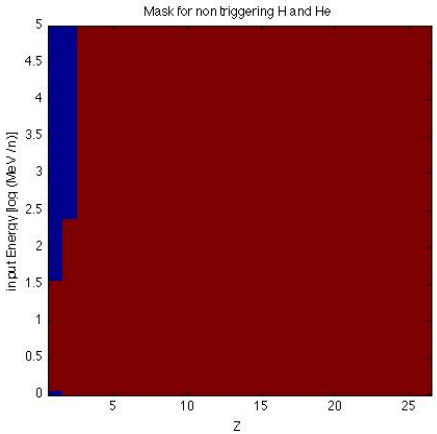






Blue: NO

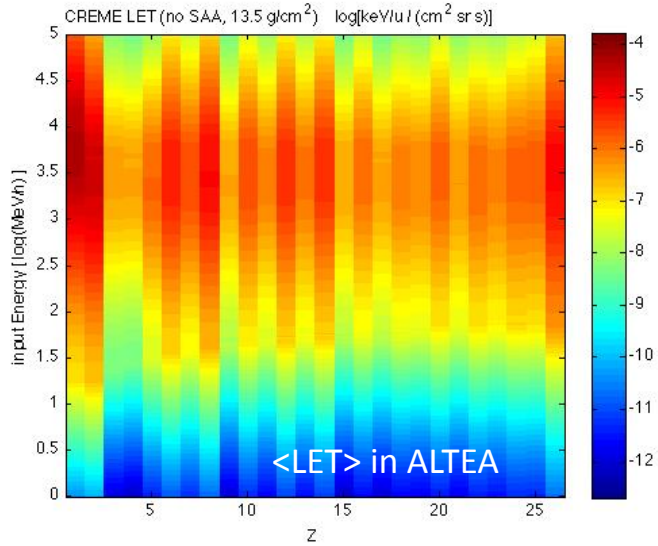
Brown: YES

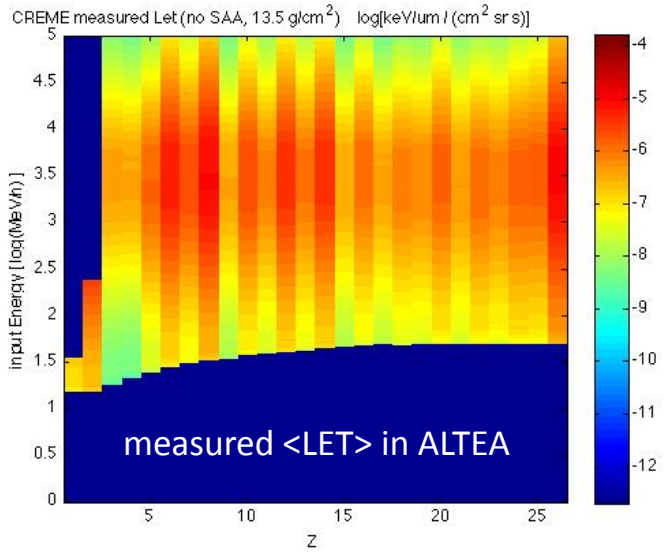


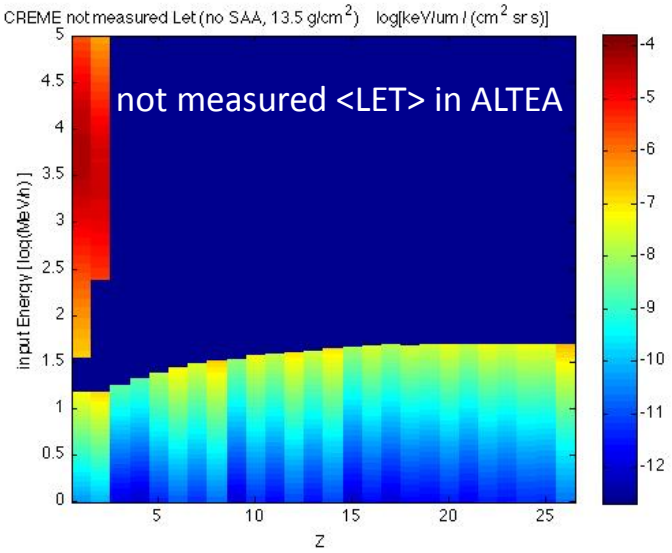
Telescope triggering

Minimum released Energy

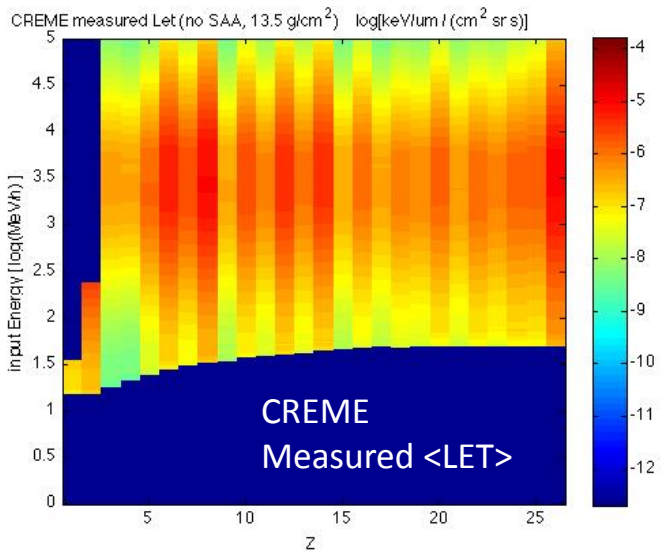
Handling the detector characteristics 3

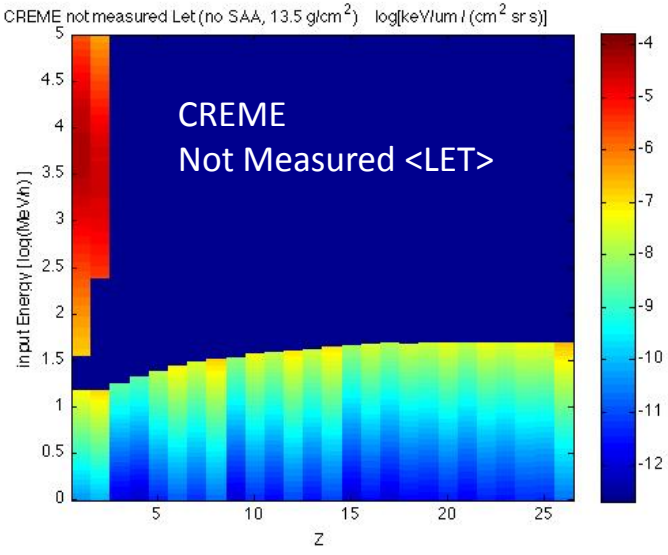


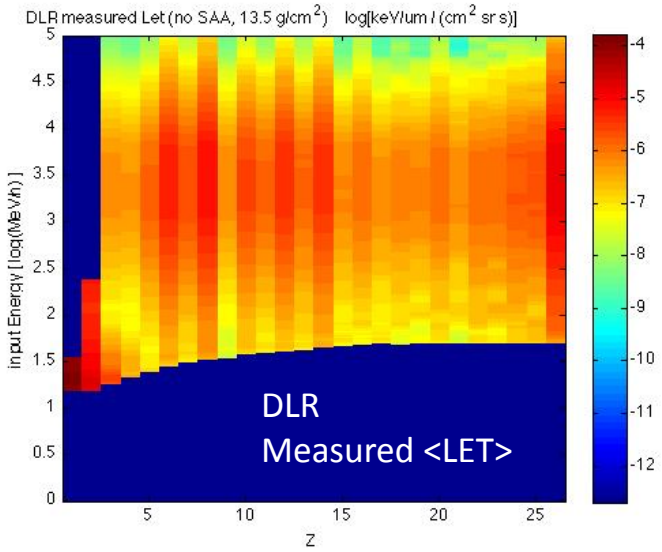


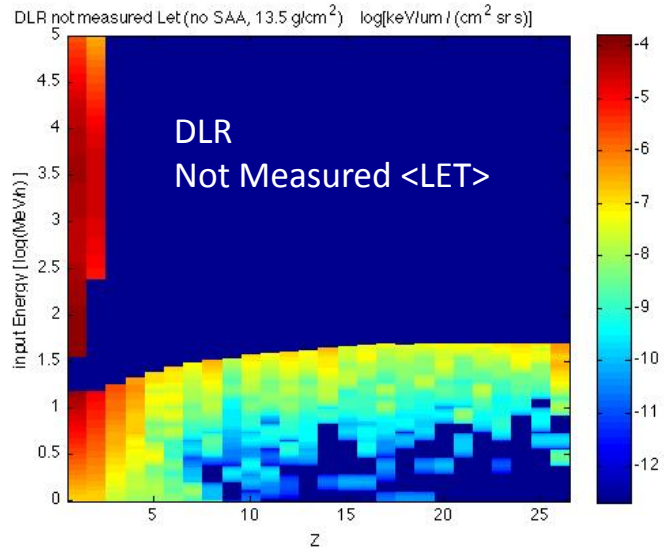


Handling the detector characteristics 4









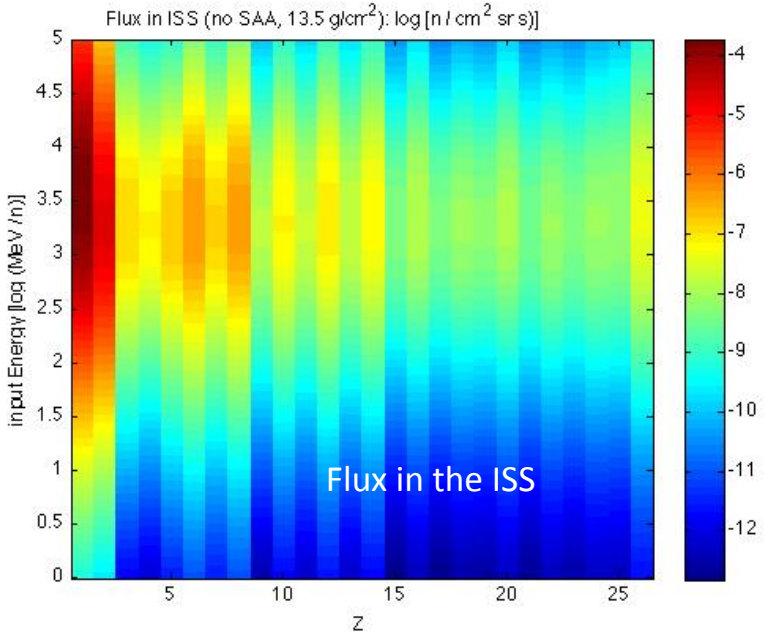
Mean values over Z

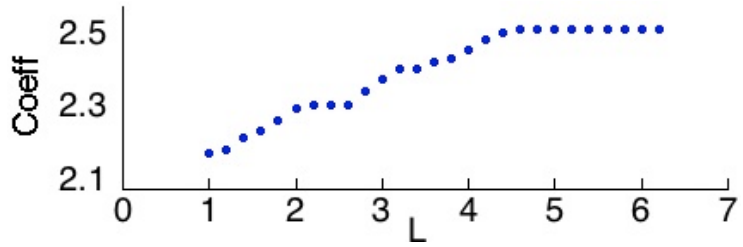
CREME	DLR
1 / 2.3	1 / 2.7

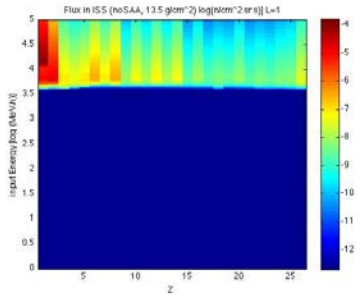
The following results use the CREME simulation. Similar work is in progress with DLR model

Handling the detector characteristics 5

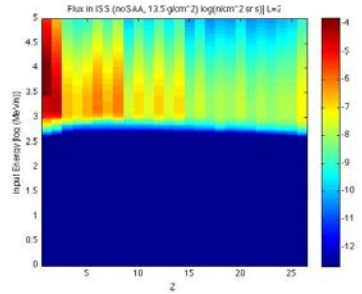
Constructing the L – dependent calibration coefficient



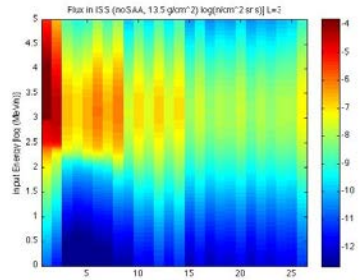




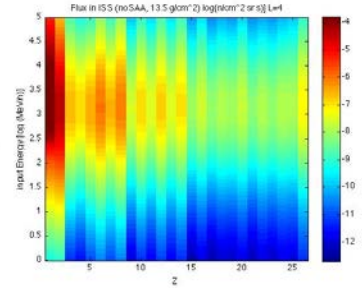
L = 1.0 ± 0.1



L = 2.0 ± 0.1



L = 3.0 ± 0.1



L = 4.0 ± 0.1

Handling the detector characteristics 6

DOSTEL calibration

• DOSTEL counting rate should be divided by the *GF* to obtain the flux (which is independent by the detector and assumes isotropy).

• The amount of energy released by showers (most likely due to the impact of radiation on close by hardware) in DosTel is considered and cannot be discriminated.

• Above a pre-set electronic threshold all signals are considered particles (noise is assumed negligible).

Common datamatrix

A common datamatrix allows to exploit together the calibrated data coming from the two detectors:

- data should be linked to the same time points: an interpolation is used (linear interpolation)

➔ we used a 1 min – step time vector.

- a number of ancillary data is merged in the same dataset:

➔ altitude
B
L *(McIlwain's coordinate)*
Latitude
Longitude

Datamatrix Columns

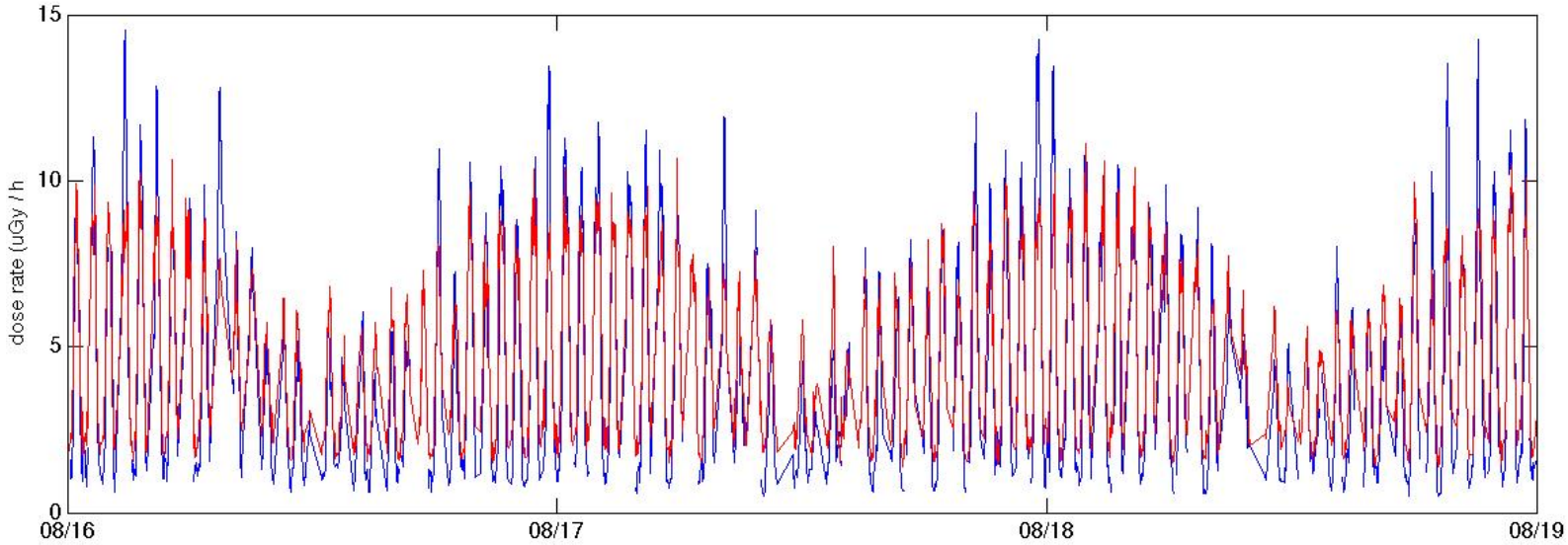
Common:
- minute
- Altitude
- Magnetic field
- L coefficient
- Latitude
- Longitude
- GOES …

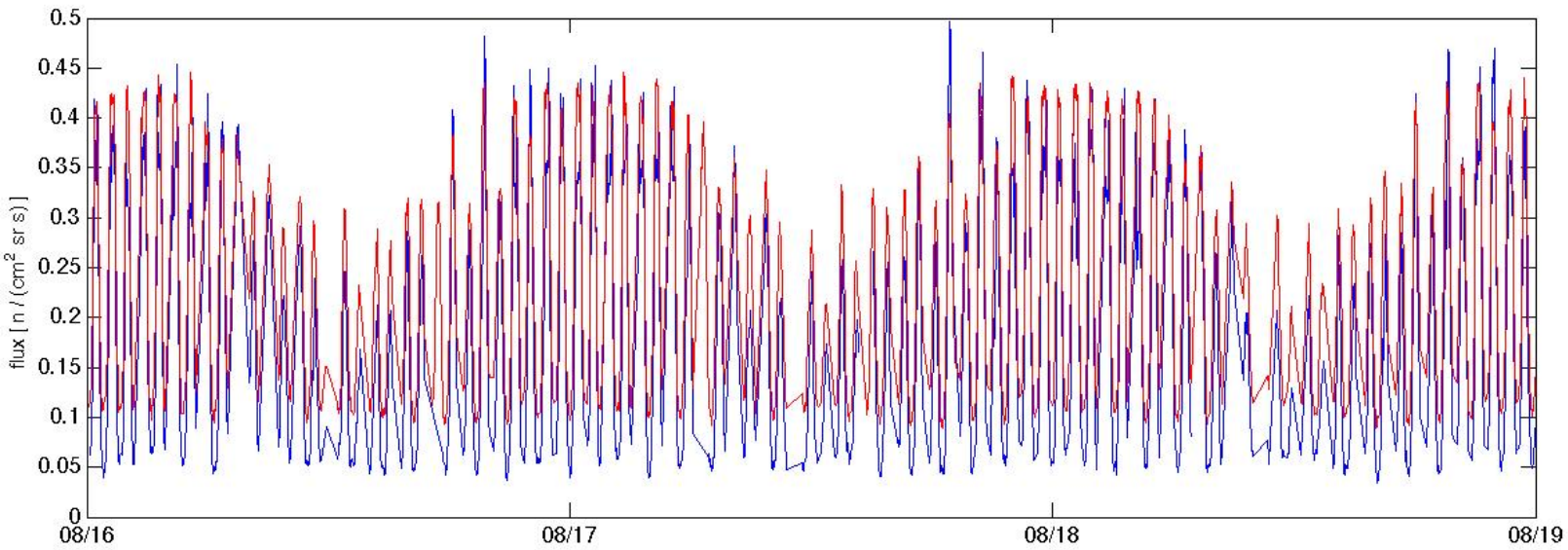
For each Detector:
- Flux (3D + ave)
- LET (3D + ave)
- Dose (3D + ave)
- Dose Equiv. (3D + ave)

- complementary data (such as from GOES) should be, if possible, merged in the dataset

***NOTE**: in the following results only GCR data are shown, the SAA contribution is taken out: GCR radiation at high L (low rigidity cut off) measured in LEO is mimicking deep space radiation*

3 days in the test period





Dose rate

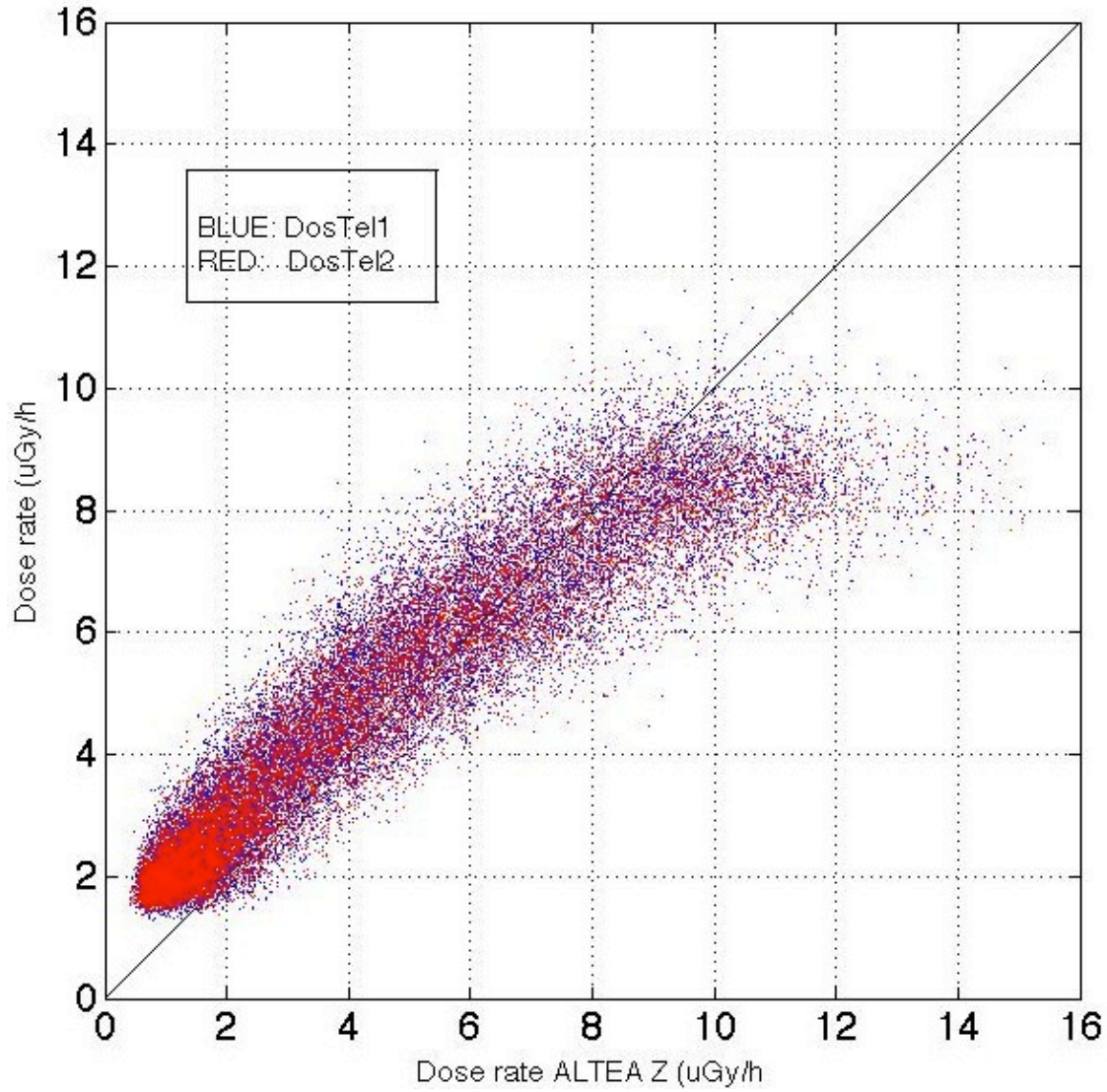
RED: DosTel2

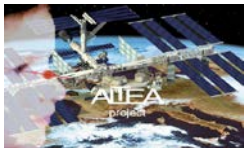
BLUE: ALTEA

Flux

Comparison during test period

Aug 10th 2012 to Aug 31st 2012 – quiet sun (GCR)





Lessons … to be learned

The agreement between ALTEA and DOSTEL data, after calibration, is remarkable.

➔ The most evident discrepancy is shown at low values of L:
(low L – high rigidity cut off – low latitude – low counting rates)

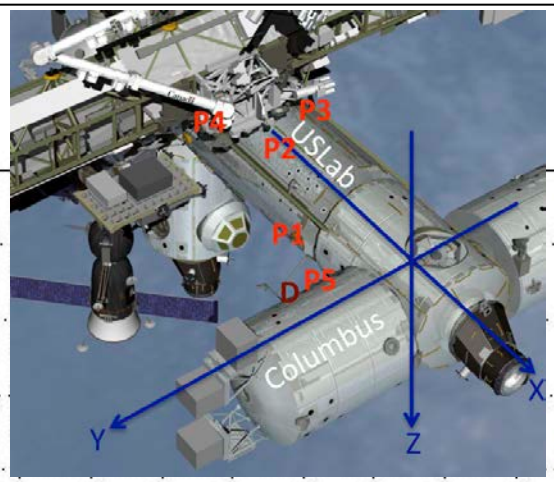
Possible causes (under investigation):

- Model used in the calibration to be improved (1st candidate: CREME transport function) ?
- Missing particles by ALTEA, non taken into account by the calibration (namely secondary e, π, …) ?
- Multiple hits (showers) detected by DOSTEL (these are selected out by ALTEA) ?
- ….

This disagreement, however, is not crucial for our aim today, concerning mostly high L values

Comparison (dose) over the full period (L > 3)

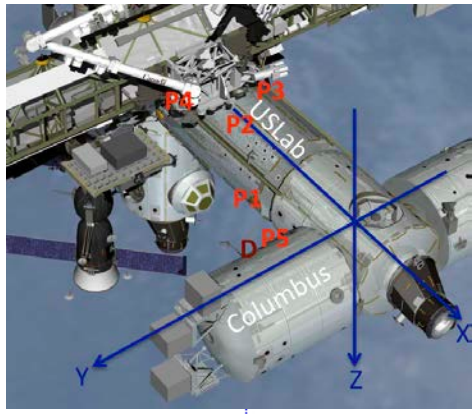
(low rigidity cut off: L>3)

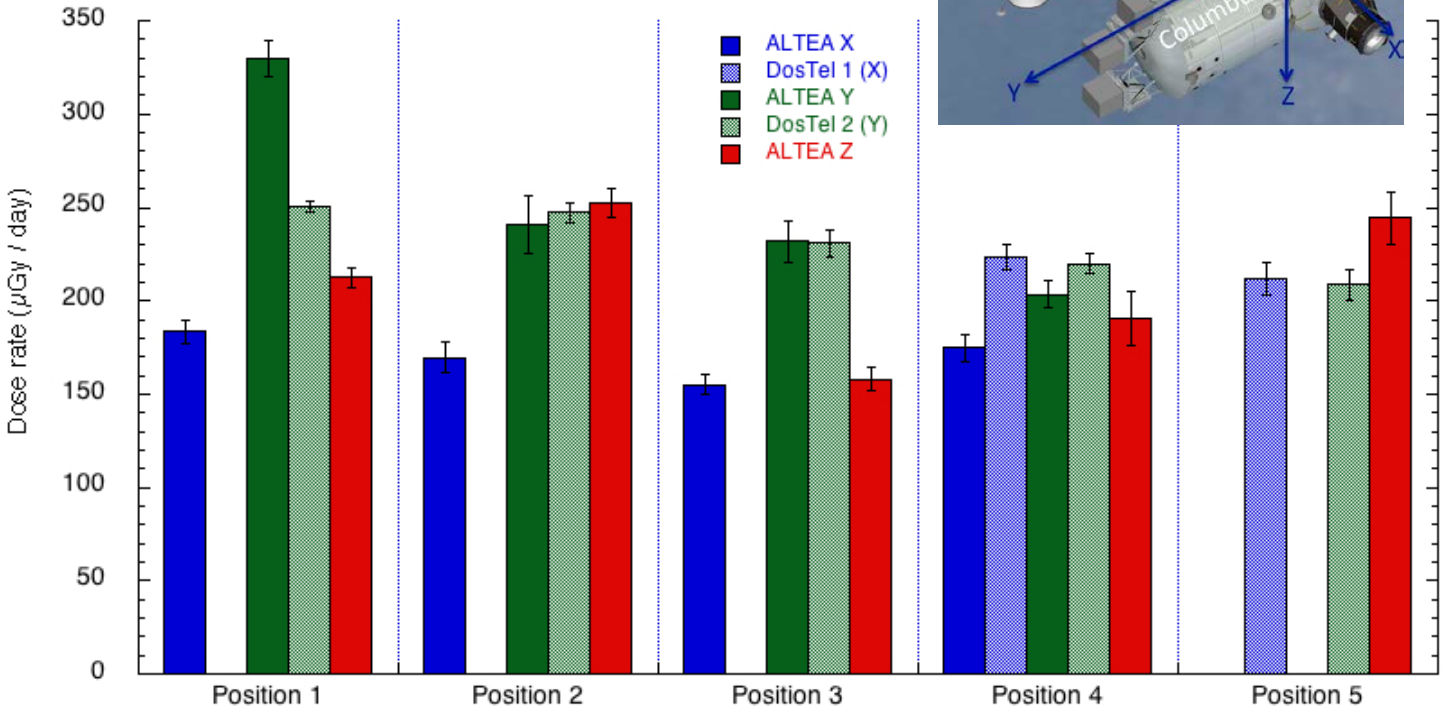


Note: P1 – P5 are the 5 measurement sites for ALTEA

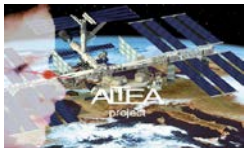
Doses in GCR (low rigidity cut off: L>3)

GCR(L>3)



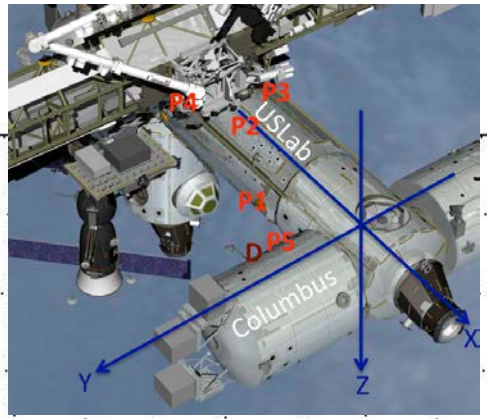


Note: P1 – P5 are the 5 measurement sites for ALTEA



Comparison (flux) over the full period (L > 3)

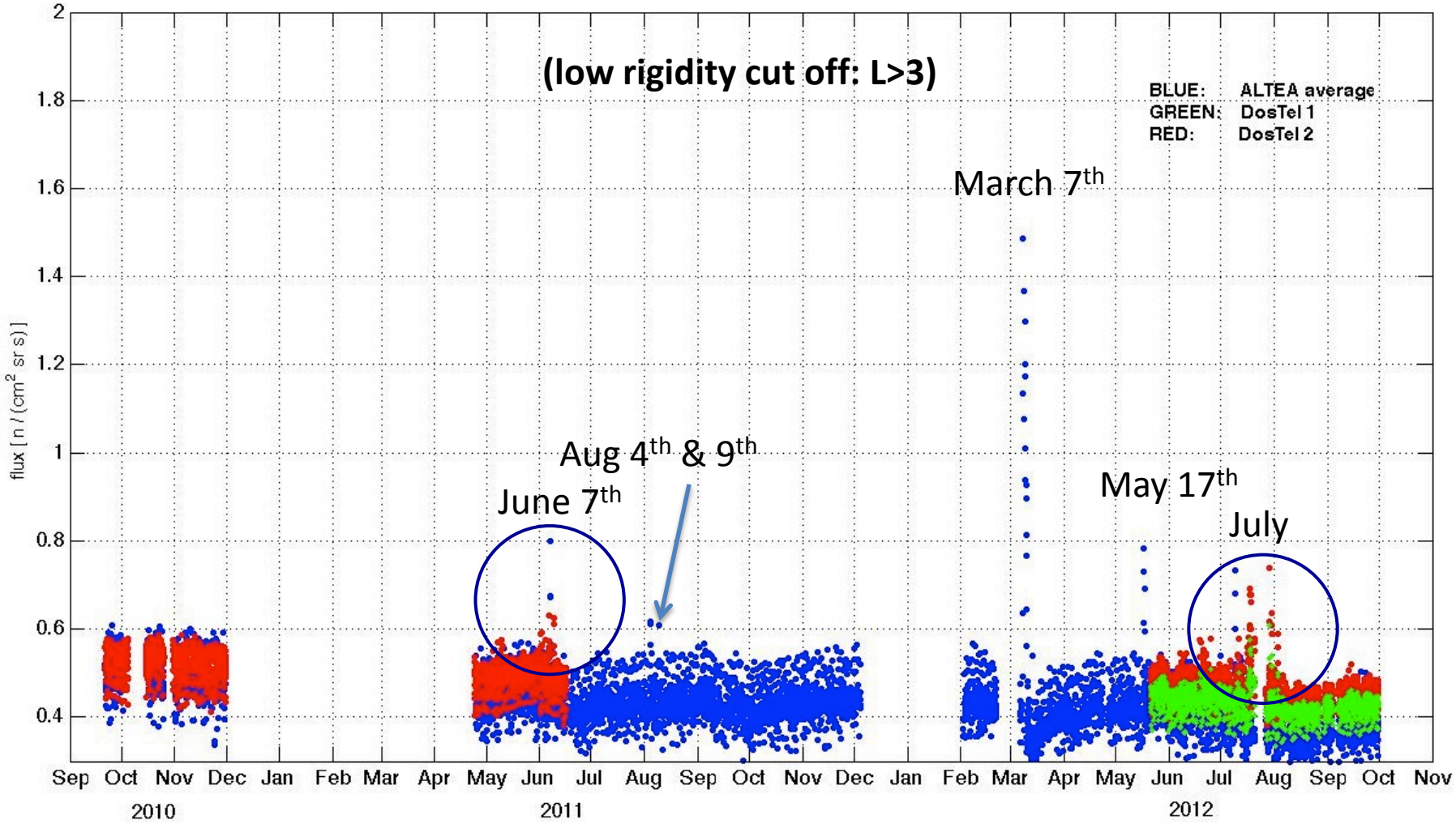
(low rigidity cut off: L>3)



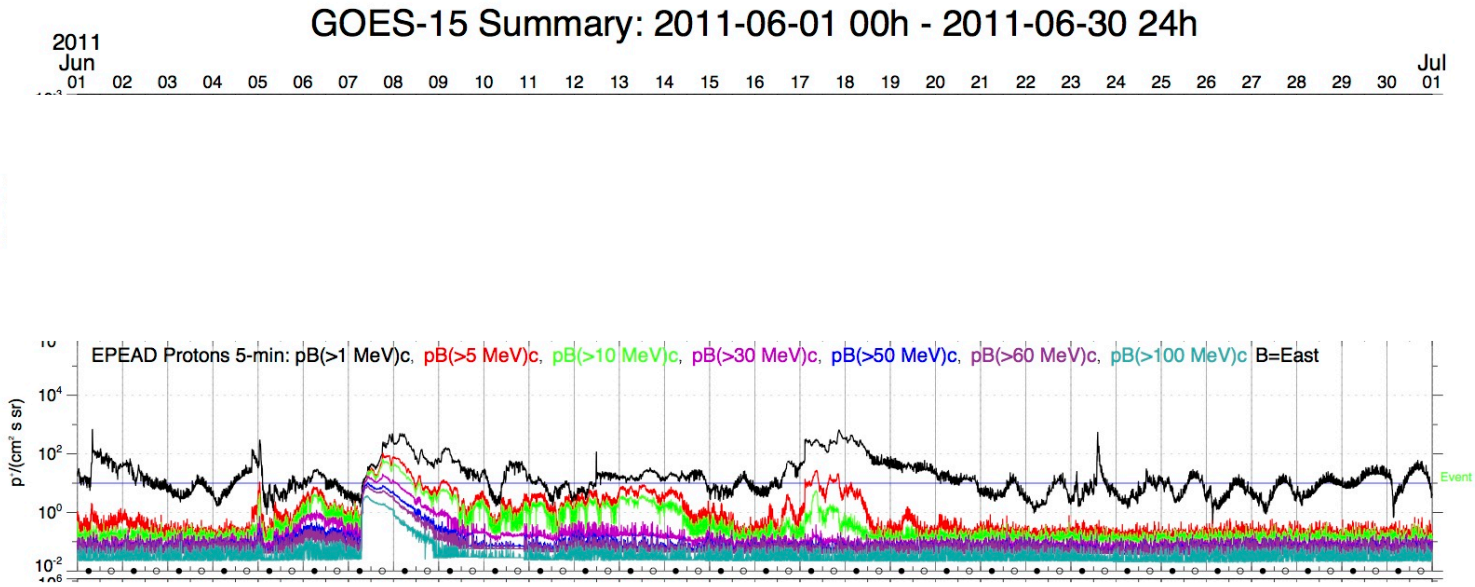
Note: P1 – P5 are the 5 measurement sites for ALTEA

Work in progress: search for SPEs

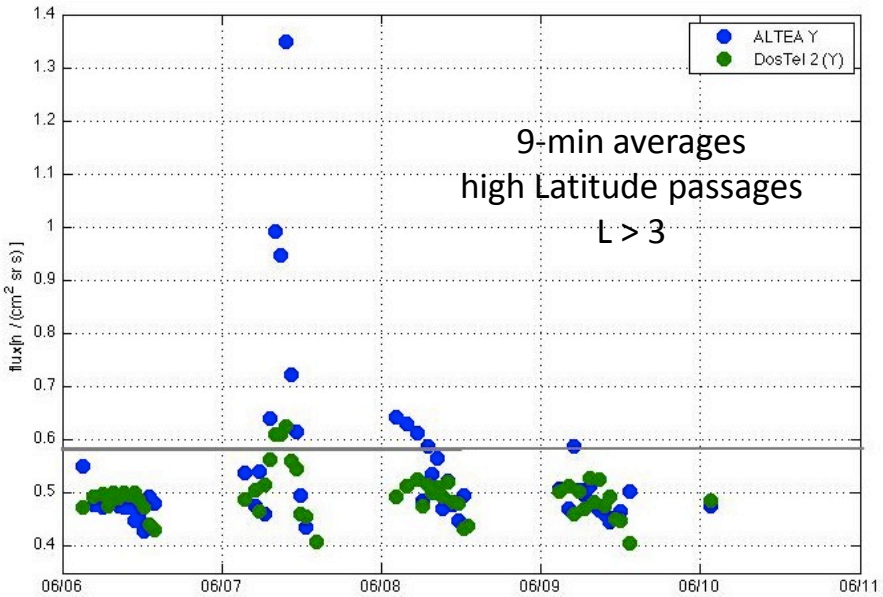
Note: each data point represents the 9-min average during high Latitude passages with L > 3



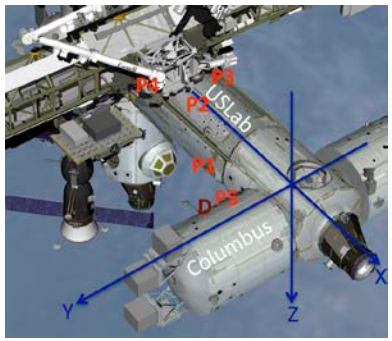
GOES Summary June 2011

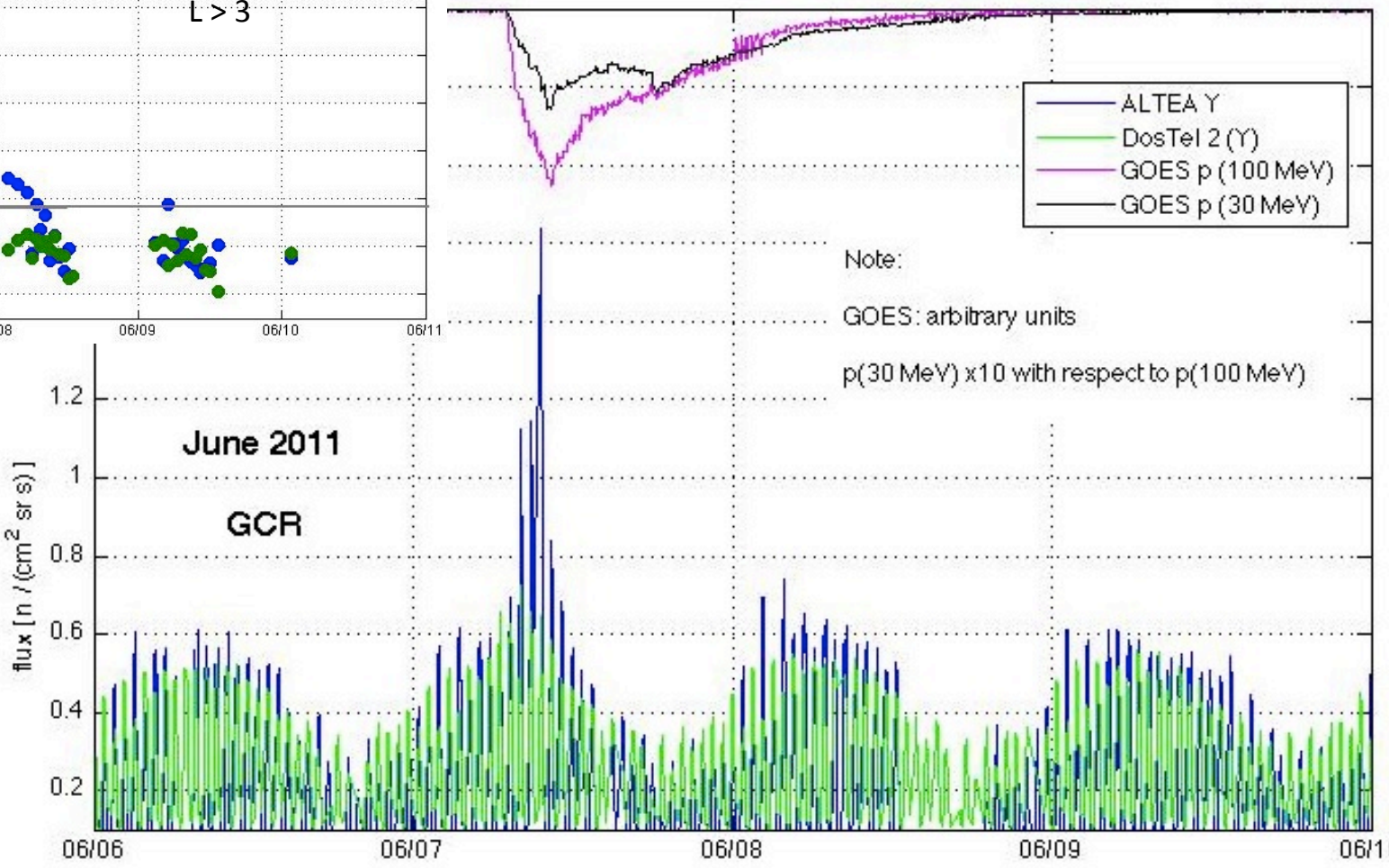


Solar Particle Event in June 2011

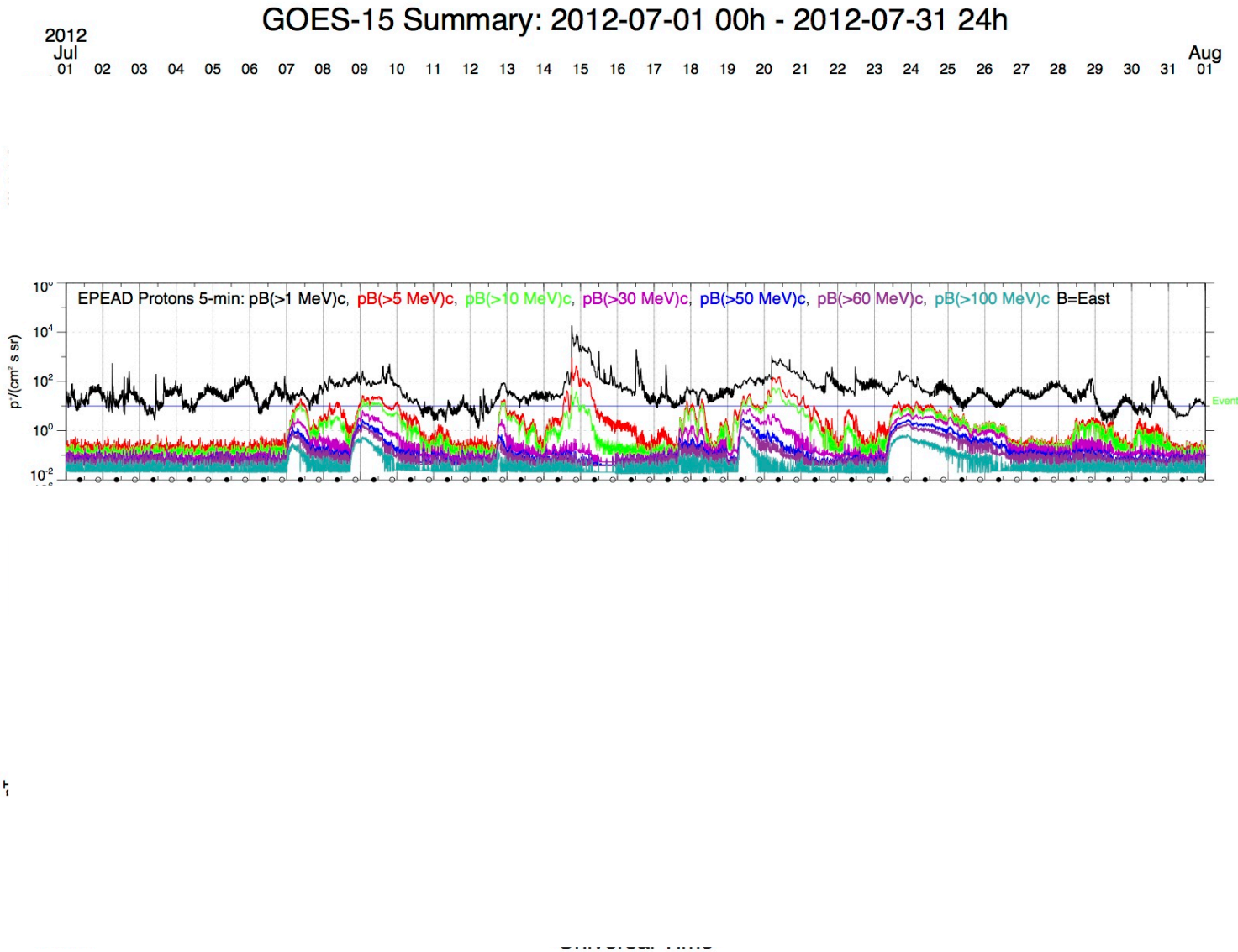


ALTEA in P3

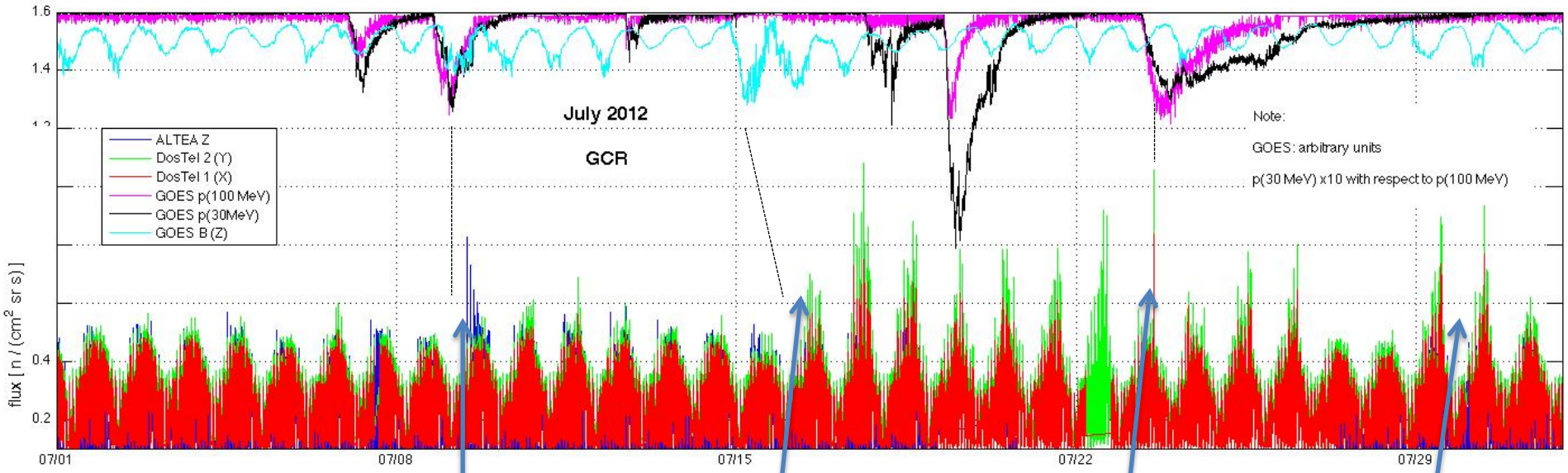




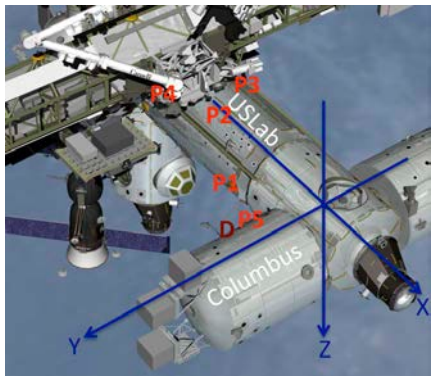
GOES Summary July 2012



Solar Events in July 2012



ALTEA in P5 (**only Z**)



ALTEA measures SPE when gets in high L regions
No DosTel response

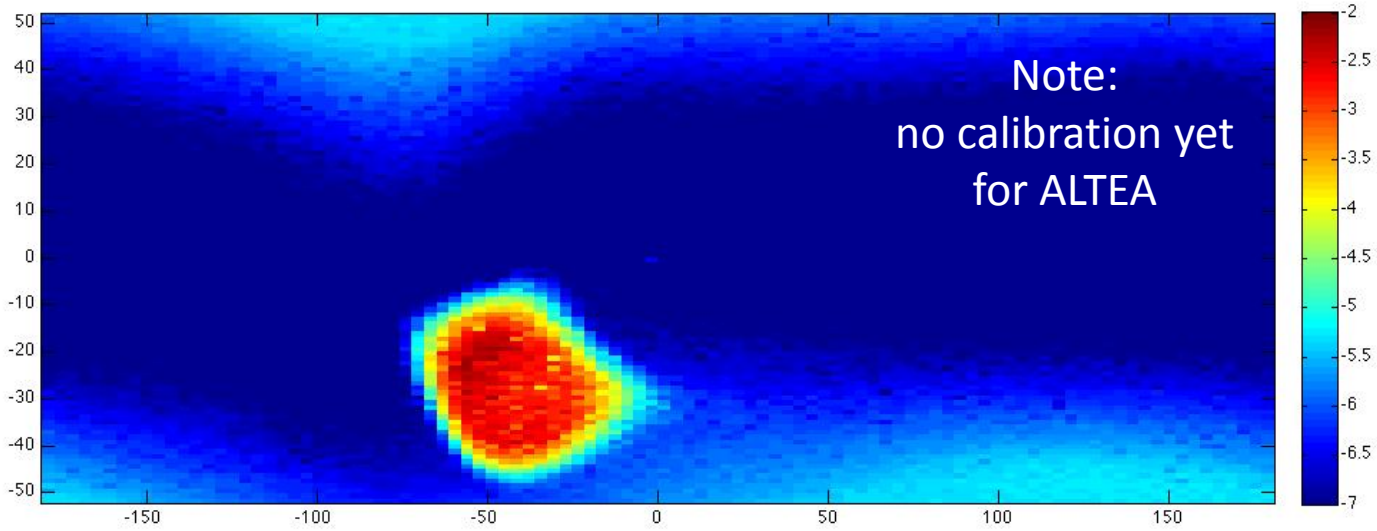
DosTel measures magnetic Z event (?)
No ALTEA response
(note: ALTEA measures 'Z' particles)

A single orbit
DosTel response to SPE
ALTEA was off

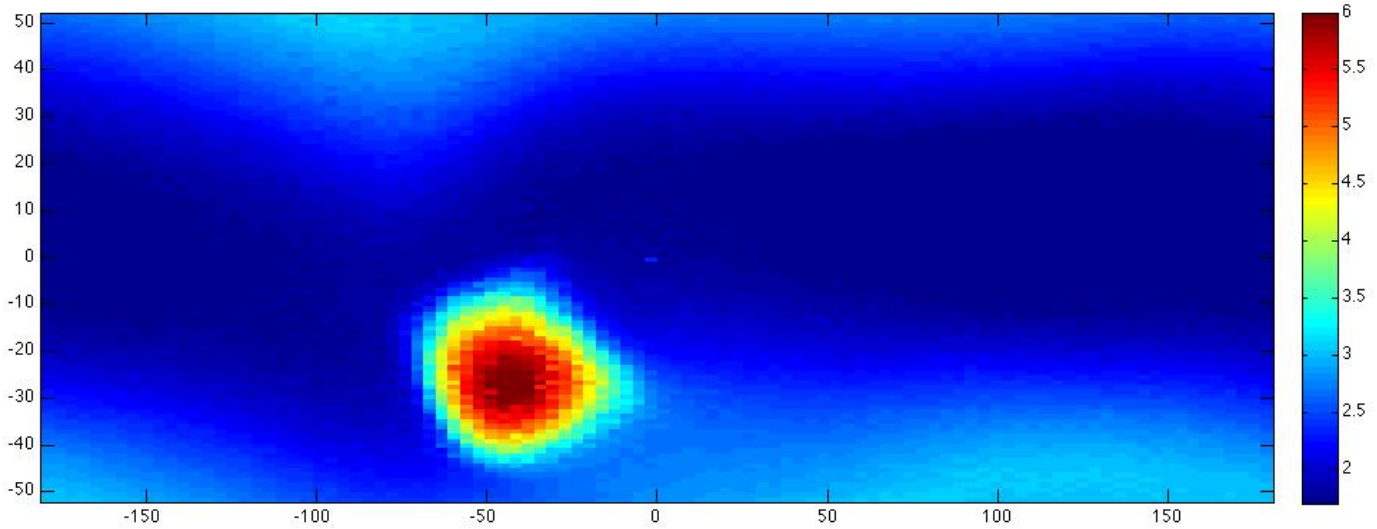
?

Work in progress: SAA 1

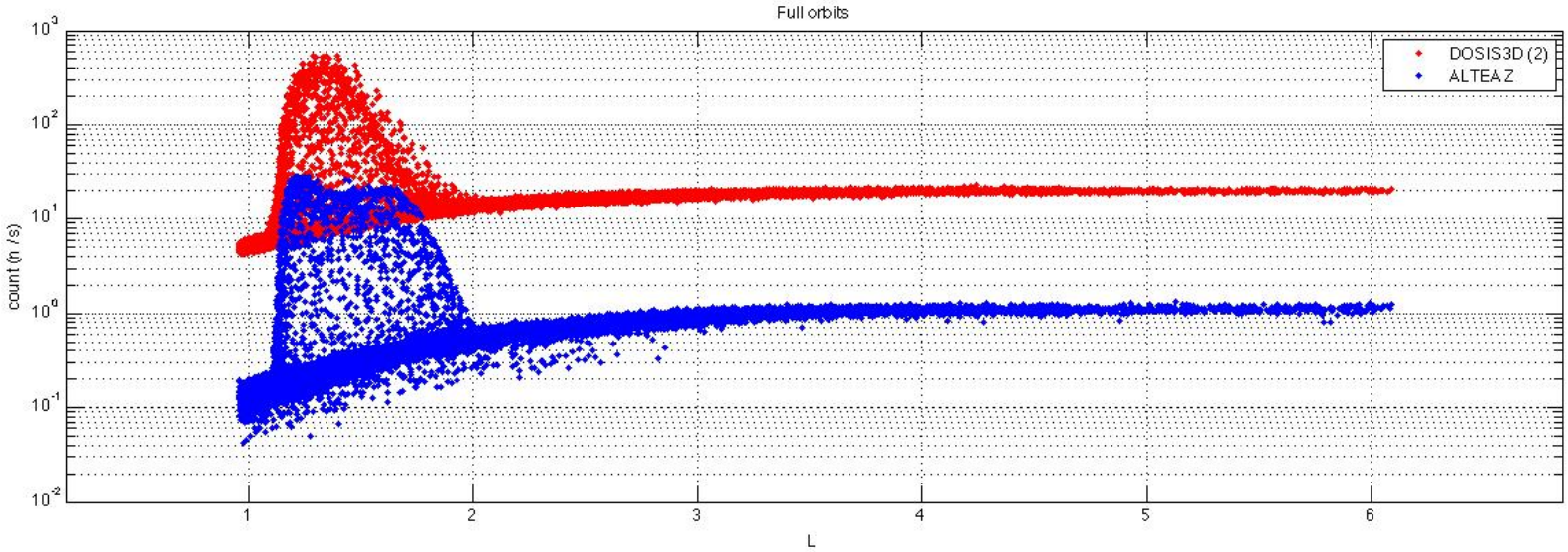
ALTEA, flux

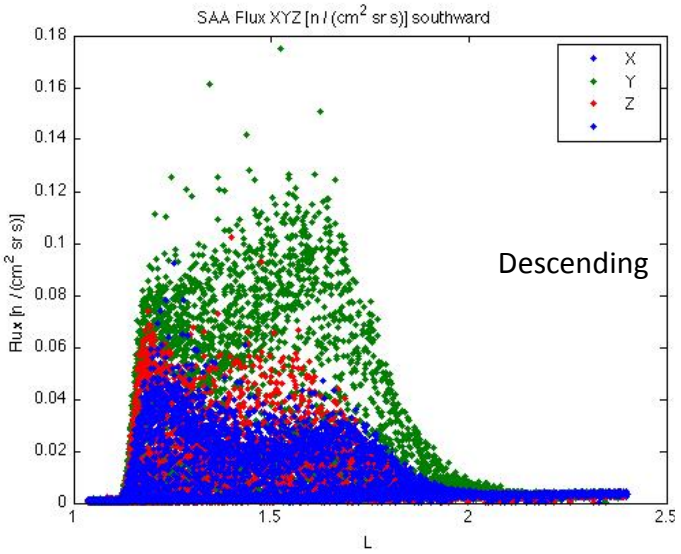


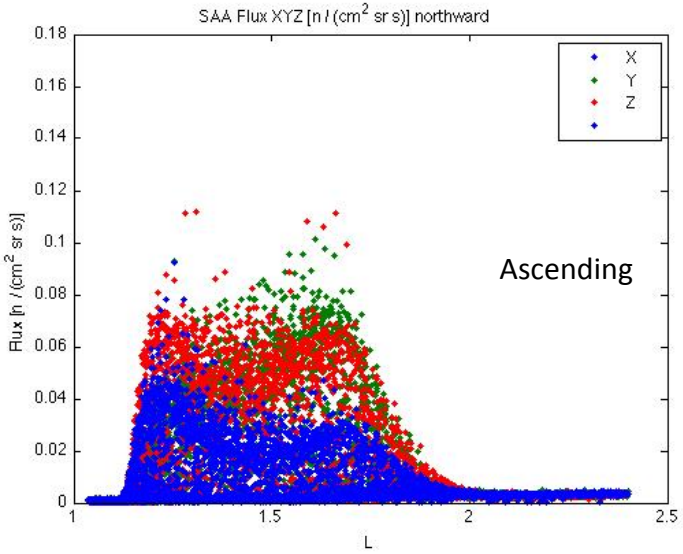
DosTel, count rate



Work in progress: SAA 2



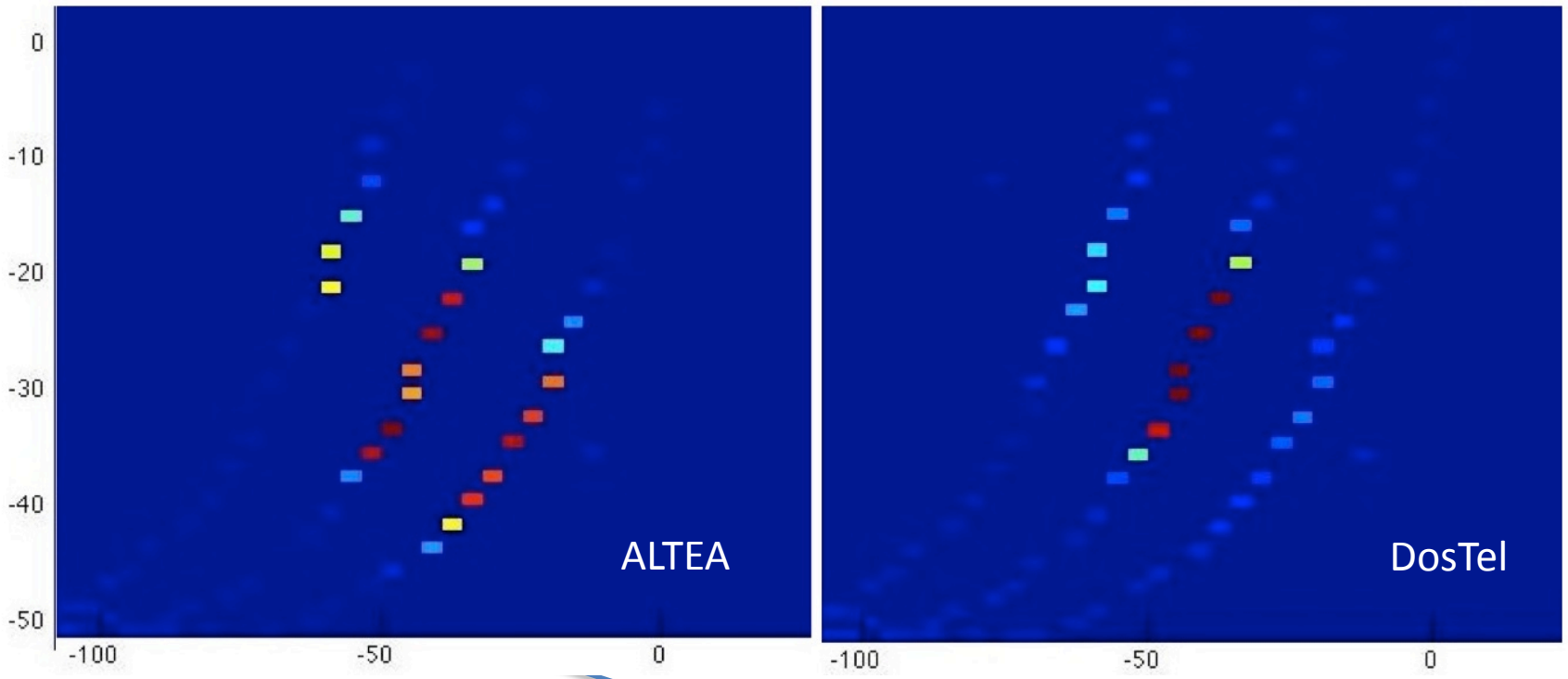




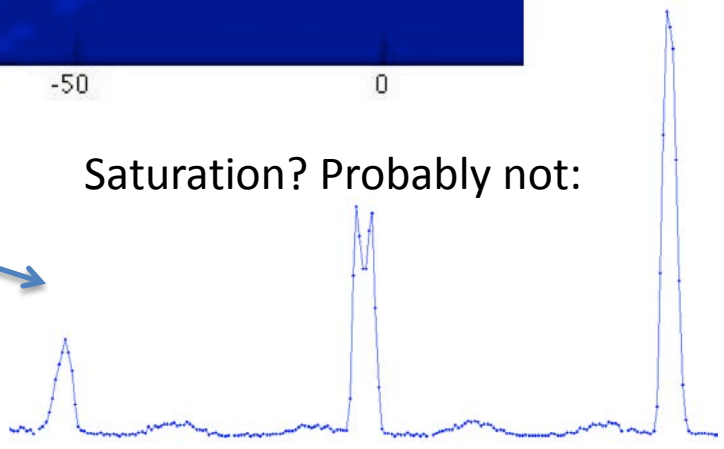
Note the double peak from ALTEA

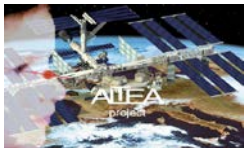
Work in progress: SAA 3

A triple passage measured by ALTEA (z) and DosTel (y)



Saturation? Probably not:





Work in progress: Search Book 1

ISS

Modulus	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
USLab	Liulin-E094																
USLab	ALTEA																
Columbus	*R3DE*																
Columbus	DOSTEL-1																
Columbus	DOSTEL-2																
Columbus	ALTEA																
Russ Seg	Liulin-ISS																
Pirs	Liulin-5																
Zvezda	R-16																
Zvezda	DB-8																
Zvezda	*R3DR*																
MRM1	Liulin-5																

LEO Satellites

Satellite	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Foton-M2	R3D-B2																
Foton-M3	Liulin-Phot																
Foton-M3	R3D-B3																
Foton-M4	RD3-B3																
Bion-M1	RD3-B3																
Resurs-DK1	PAMELA																

Moon Satellites

Satellite	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Chandrayaan	RADOM																
LRO	CRaTER																

Mars Satellites

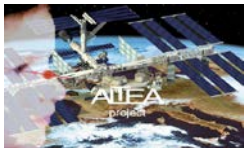
Satellite	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Odyssey	MARIE																

Mars cruise

System	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Curiosity	MSL-RAD																

Mars surface

System	*detector*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Curiosity	MSL-RAD																



Work in progress: Search Book 2

2009

ISS

Modulus	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
USLab	Liulin-E094												
USLab	ALTEA						1 ---	---	---				
Columbus	*R3DE*									3			
Columbus	DOSTEL-1							18					
Columbus	DOSTEL-2							18					
Columbus	ALTEA												
Russ Seg	Liulin-ISS												
Pirs	Liulin-5		17 ---	---			---	---	25 ---			10-20 ---	
Zvezda	R-16												
Zvezda	DB-8												
Zvezda	*R3DR*			31									
MRM1	Liulin-5												

LEO Satellites

Satellite	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Foton-M2	R3D-B2												
Foton-M3	Liulin-Phot												
Foton-M3	R3D-B3												
Foton-M4	RD3-B3												
Bion-M1	RD3-B3												
Resurs-DK1	PAMELA									30			

Moon Satellites

Satellite	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Chandrayaan	RADOM									29			
LRO	CRaTER									15			

Mars Satellites

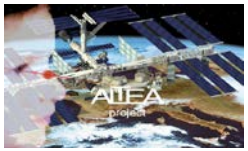
Satellite	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Odyssey	MARIE												

Mars Cruise

System	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Curiosity	MSL-RAD												

Mars Surface

System	*detector*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Curiosity	MSL-RAD												



Work in progress: Search Book 3

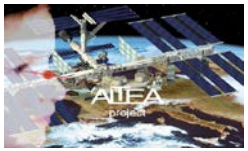
DETECTOR NAME	**ALTEA**
Sensor Material	**Silicon**
Detector kind	**Telescope**
Sensor shape and number (if telescope)	**Rectangular**, **6**
Sensor Dimensions	16 cm x 8 cm, thickness = **380 µm**
Distances between consecutive sensors (if telescope)	**3.75 mm, 33.75 mm, 3.75 mm, 33.75 mm, 3.75 mm**
Geometrical factor	GF(telescope 1-5) = **230 cm² sr**
LET acceptance	**3 kev/µm ≤ LET(Si) ≤ 700 keV/µm**
Energy Deposition Range	
Maximum rate	**700 s^{-1}**

NOTES

The detector system is made of 6 identical telescopes

The 6 telescopes can be deployed in different configurations

Power unit and digital acquisition unit are in a separate enclosure

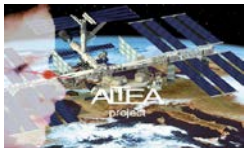


Summary and take home messages

- A step by step procedure to merge measurements has been suggested
- Indications about the information needed to go along with the dataset has been provided

(Note: the original dataset should always be provided too)

- The importance of the ancillary data (Alt, Lon, Lat, L, B) has been underlined
- The importance of complementary data (GOES …) has been showed
- Measurements must be merged with knowledge of detailed shielding (CAD of the ISS + information about mass movements)
- Need to perform whenever possible coupled measurements with different devices (same time / site / direction) to have a precise off line comparison and cross correlation
- With all these, survey of the ISS is possible with multiple instruments
- Interesting inputs for the study of the influence of Solar Events in a Spacecraft have been provided, several issues still open
- SAA studies just began, not understood double peak in ALTEA.
- Search Book for active detectors in progress, *please send in infos*. Passive … ?



Thank you for your attention