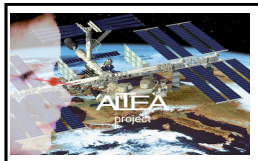

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Noordwijk, The Netherlands

Università di Roma Tor Vergata

ALTEA Measurements on radiation shielding efficacy of Kevlar, compared to Polyethylene performances, in the International Space Station

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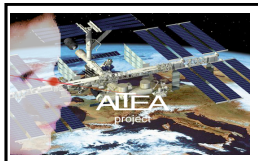
1 Department of Physics, University of Rome Tor Vergata, Rome, Italy
2 INFN Roma II, Rome, Italy



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  - Integrated
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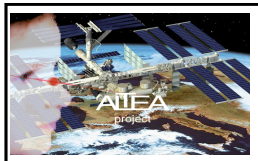
  - SPE
  - Fragmentation
- Conclusions

LIDAL

- Rationale
- Improvements over ALTEA
- Hardware and Logic
- Conclusions



Rationale

Passive radiation shielding is essential for human space exploration

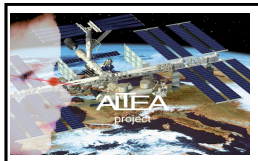
'Multi-purposes' materials will have an important role in building space habitats

Materials are tested with simulations, than on ground and finally undergo final space testing

The ISS is the optimal existing platform to perform these space measurements being the closest replica of deep space radiation we have available (especially at high latitudes)

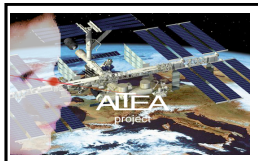
Tests should address the effectiveness of materials with respect to the radiation quality parameters

*This **ESA – sponsored ALTEA-shield** project is aimed at testing the effectiveness of shielding materials using the ALTEA detector in the ISS: POLYETHYLENE, highly hydrogenated, well known material is compared with KEVLAR, a 'multi-purpose' material that has shown promising radiation shielding capabilities plus a number of highly considered features (such as resistance to impacts).*



ISS measurements issues

- Radiation field modulation(s): need to use active detectors.
- Nuclear identification and detector efficiency.
- Angle of view of the telescope.
- Need to have concurrent baseline measurements.
- Unknown amount of ISS shielding and of its changes.



Strategy

The active ALTEA detector system provides capabilities allowing for a full space assessment of material shielding efficacy, including a probabilistic nuclear identification capability[1]. ALTEA, however, features an incomplete protons / helium coverage.

The modularity of the ALTEA system allows for the first time to measure the attenuation provided by the shielding in space referring to a concurrently acquired 'baseline'

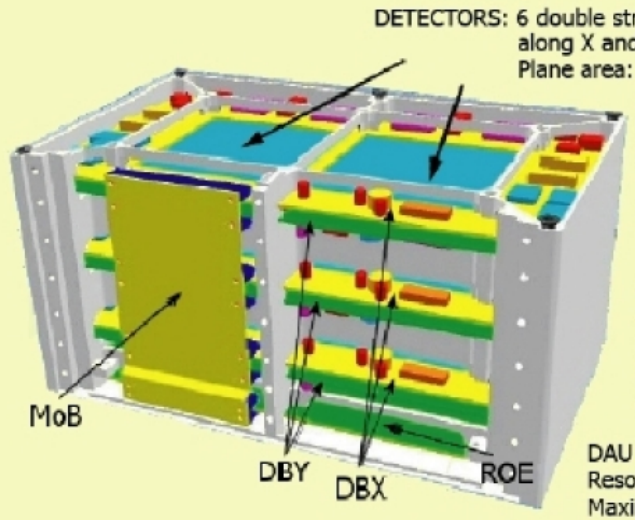
ALTEA allows for selecting specific orbital tracts[2] so to use only the best data to mimic deep space radiation.

Three of the six ALTEA detectors are used in a flat assembly (same view): one as reference (with no shielding) and the other two bilaterally covered by two different thicknesses of the same material (5 g/cm^2 and 10 g/cm^2)

1 Di Fino et al Adv. Space Res. 50:408-414 (2012)
2 Zaconte et al. Adv. Space Res. 46:797-799 (2010)

The detector characteristics[1]

SDU: Silicon Detector Unit

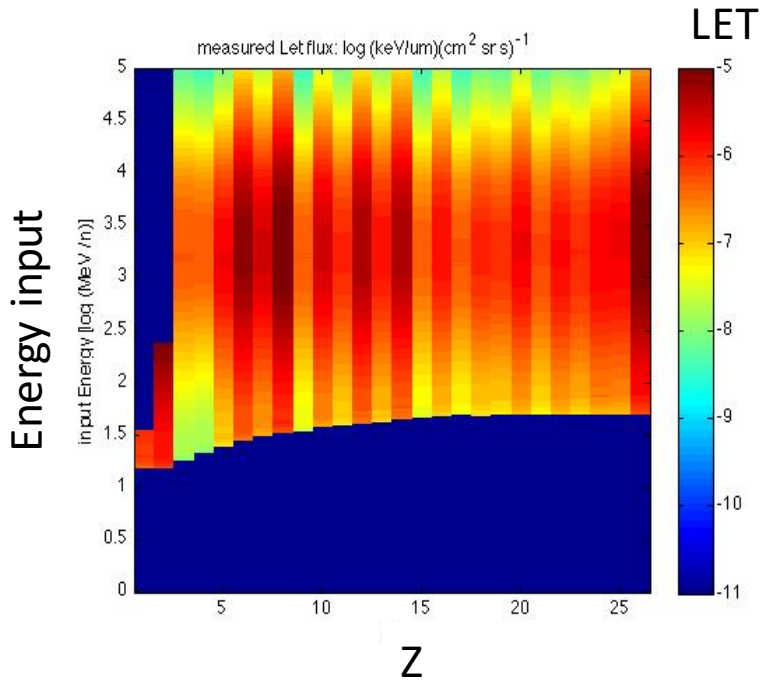


DETECTORS: 6 double strip silicon layers arranged alternately-along X and Y directions
Plane area: 2 x (8x8) cm^2
Thickness: 380 µm
Distance X-Y planes: 3.75 cm
Maximum error of angular reconstruction: 1.8°
Geometric Factor (bidirectional): **230** cm^2 sr

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)

Measured by ALTEA

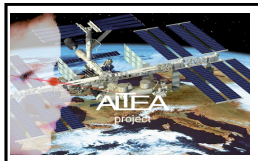


With the used parameters:

3 keV/µm < **LET(Si)** < 800 keV/µm

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

1 Zaconte et al. Nucl. Instrum. and Meth. B 266:2070-2078 (2008).



Running times

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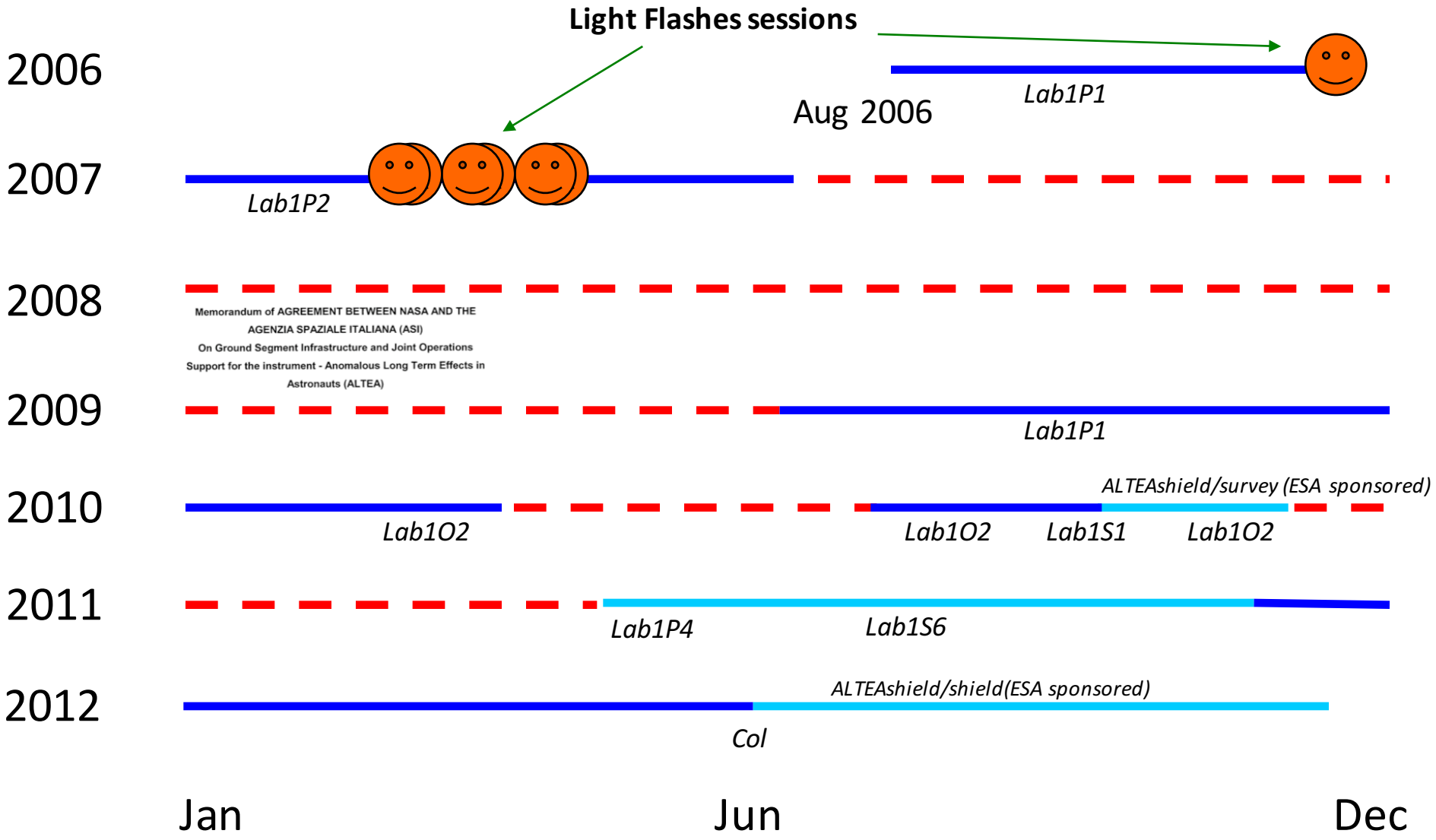
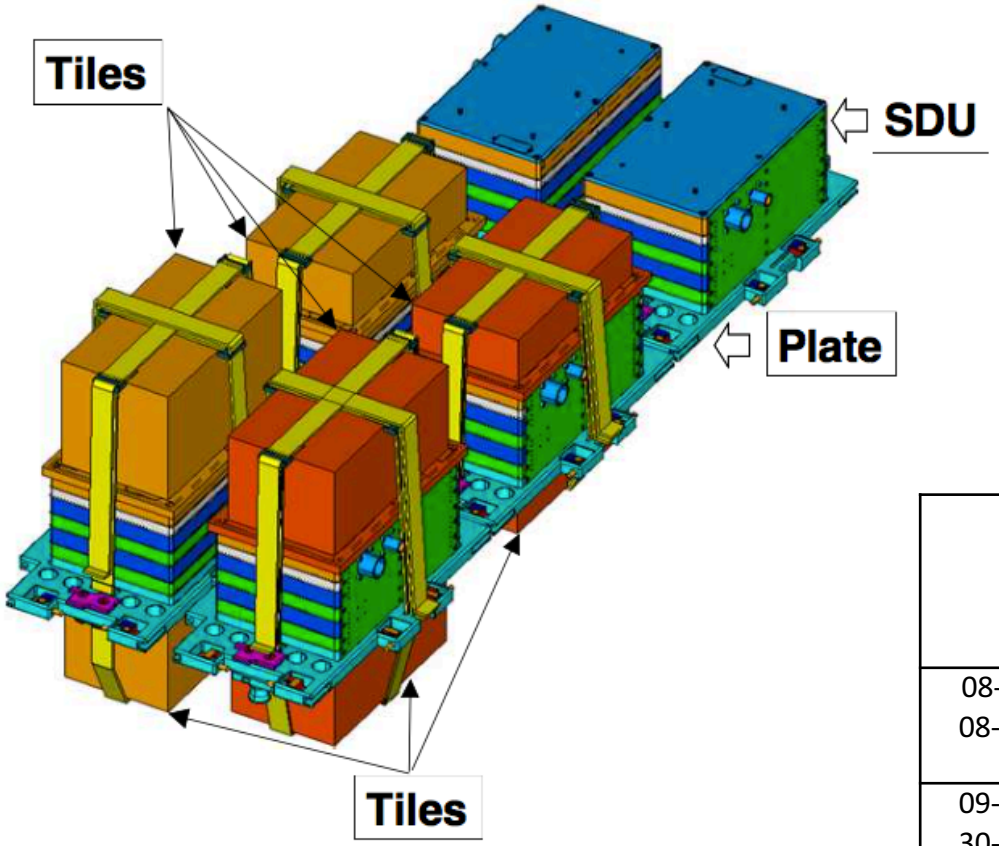
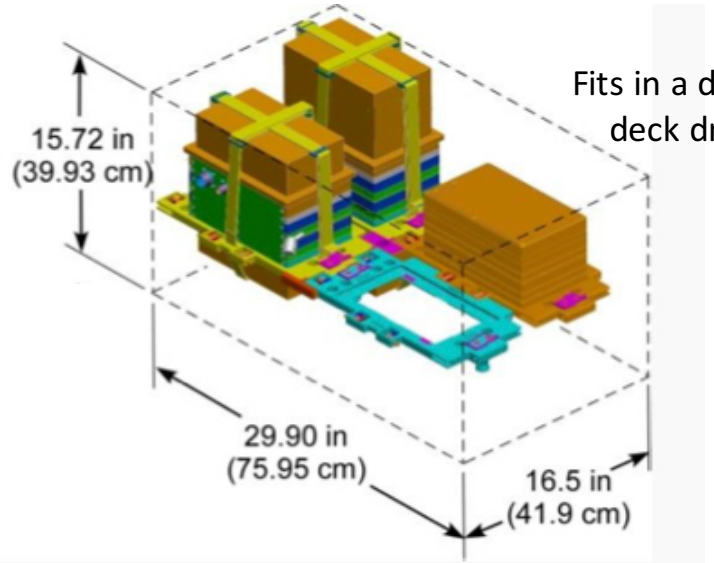


Detector system configurations

Original idea



Adopted solution



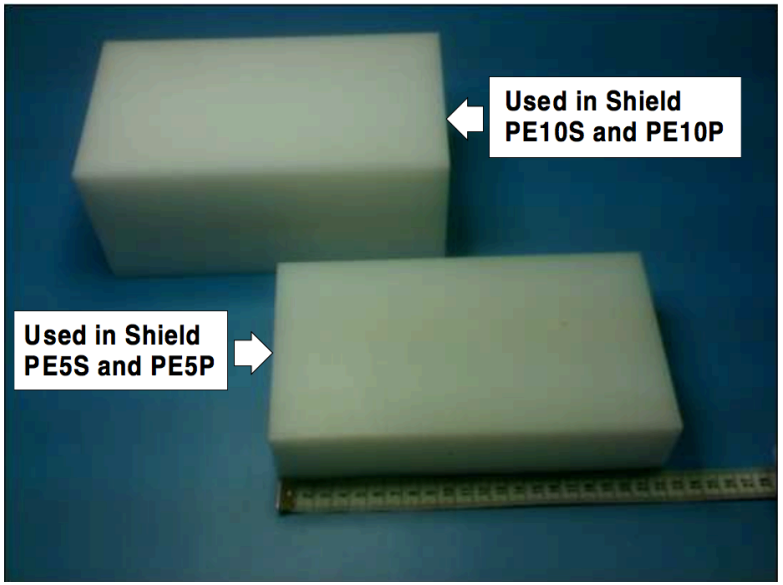
Fits in a double deck drawer

Date	Material	Total Duration (days)	Position
08-Jun-2012 00:00 08-Aug-2012 23:59	Polyethylene	62	ER3 Columbus
09-Aug-2012 18:09 30-Sep-2012 14:22	Kevlar	52	ER3 Columbus

Tested materials: POLYETHYLENE

The selected PE is from Ensinger manufacturer (TECAFINE PE5)

Polyethylene density is **0.96 g/cm^3**



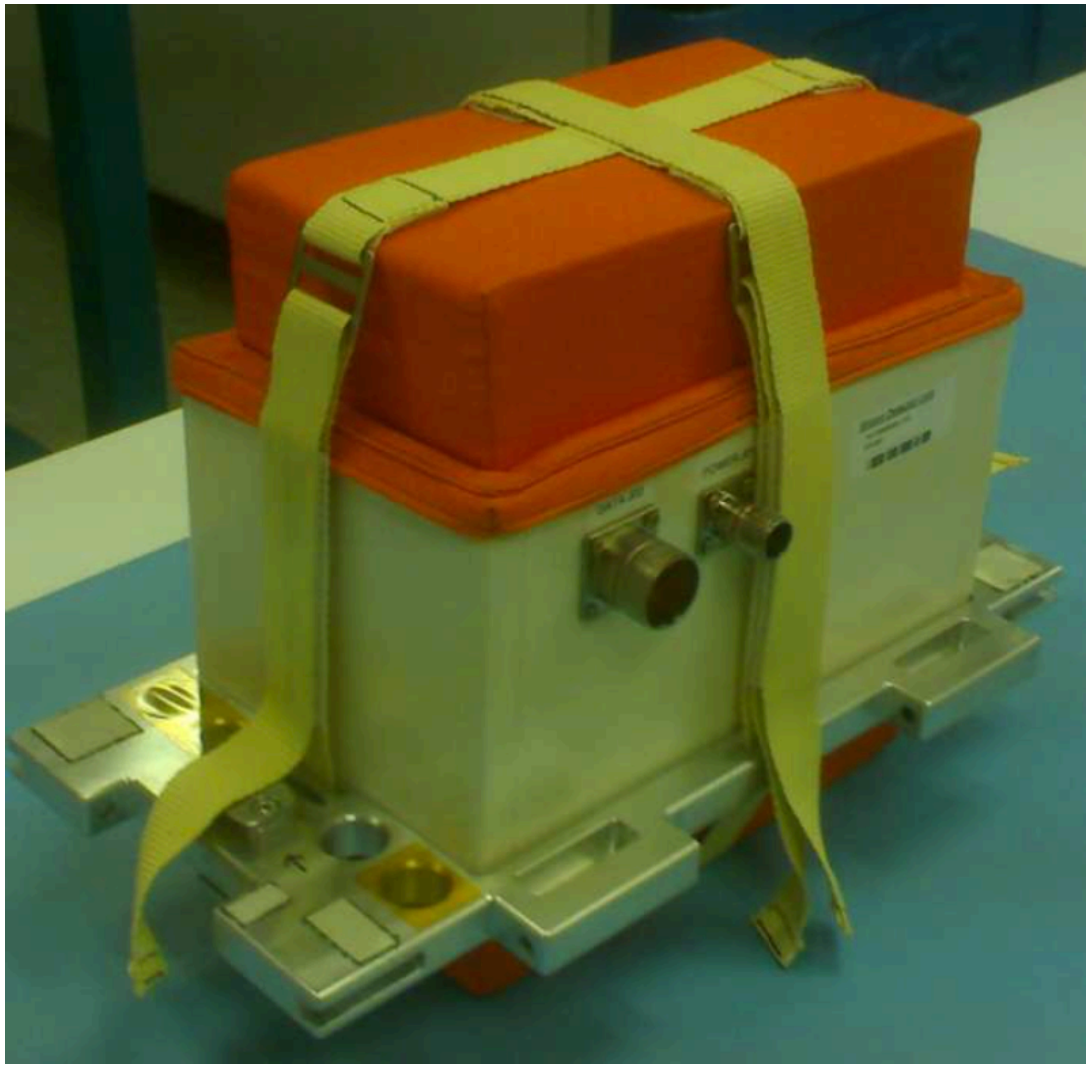
Tested materials: KEVLAR

The selected fabric is Kevlar@29 Style 745 Resistant Fabric (Du Pont).

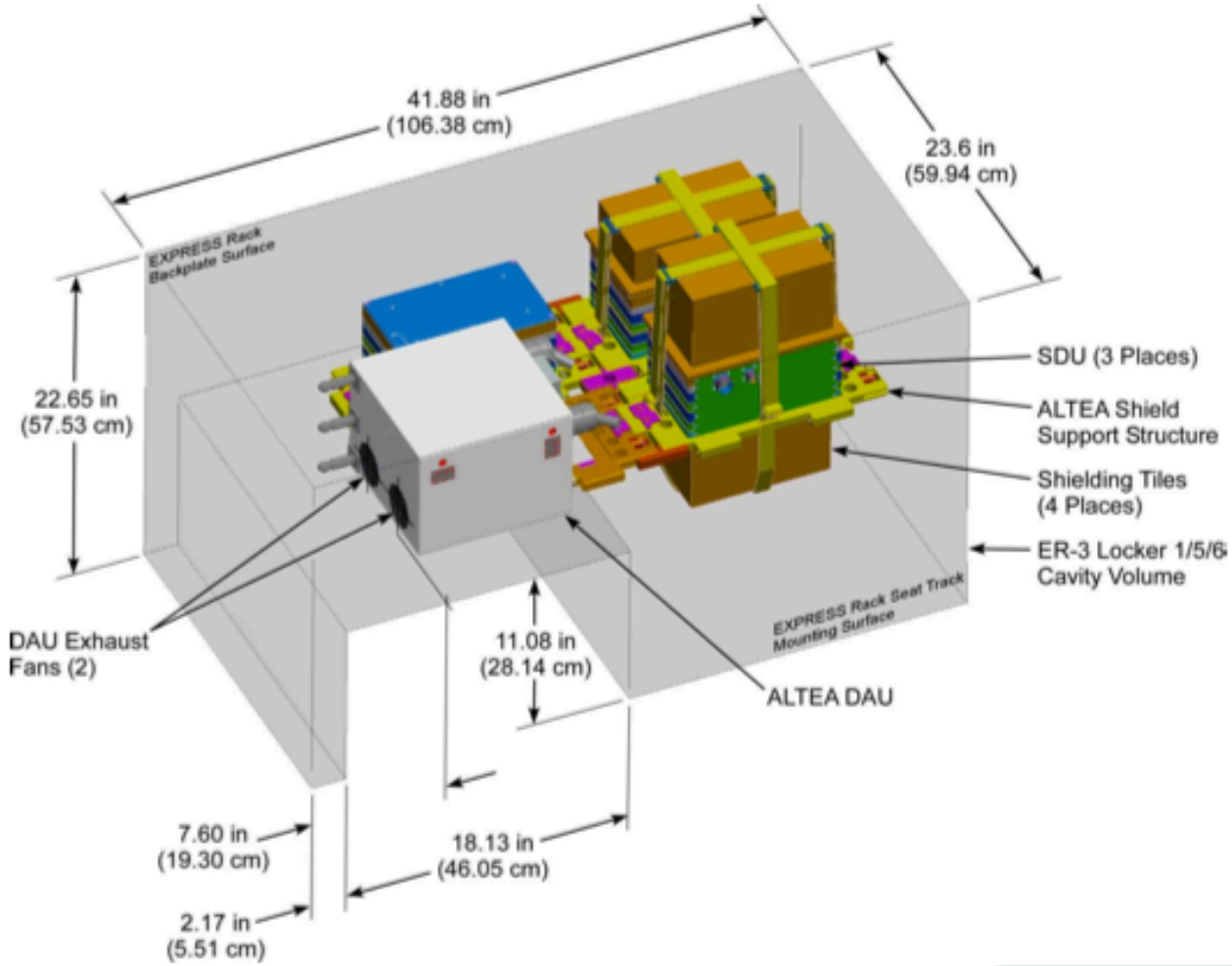
Kevlar density is **1.4 g/cm^3** *("equivalent density" about a factor two lower)*

Shield (g/cm^2)	Material	Thickness (cm)
5	PE	5
	Kevlar	6.5
10	PE	10
	Kevlar	13

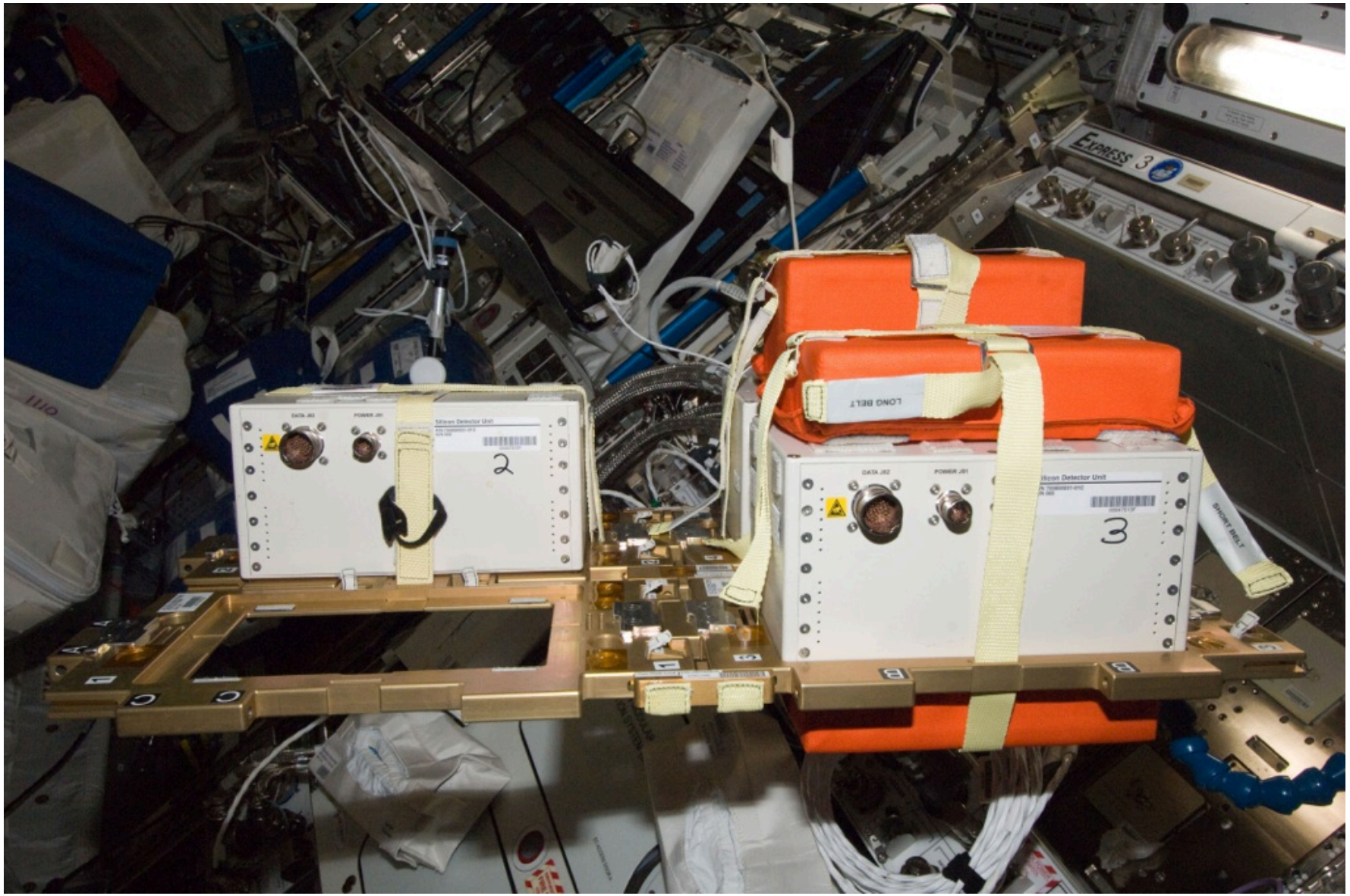
Tiles support



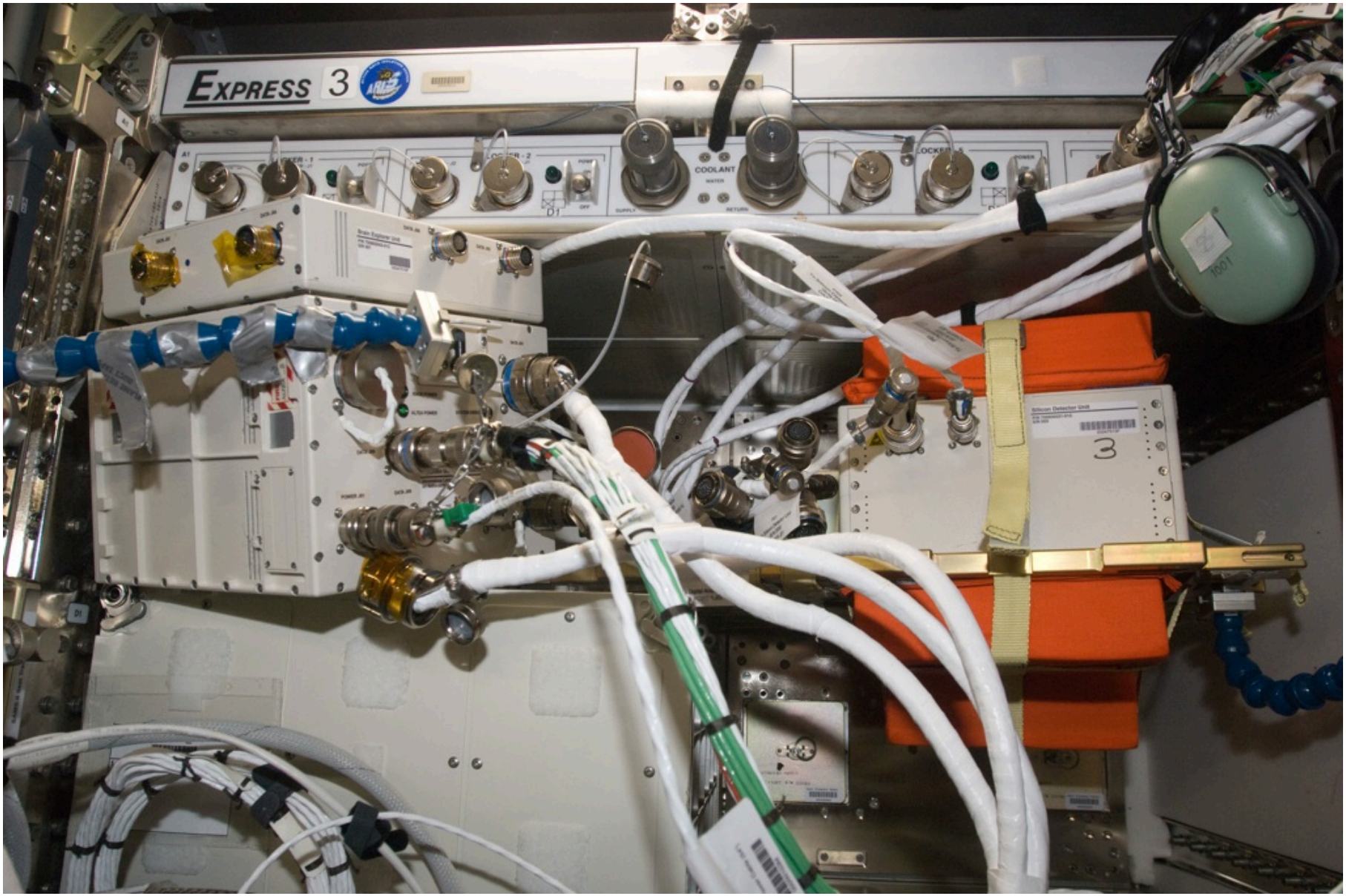
ALTEA in Columbus ER3



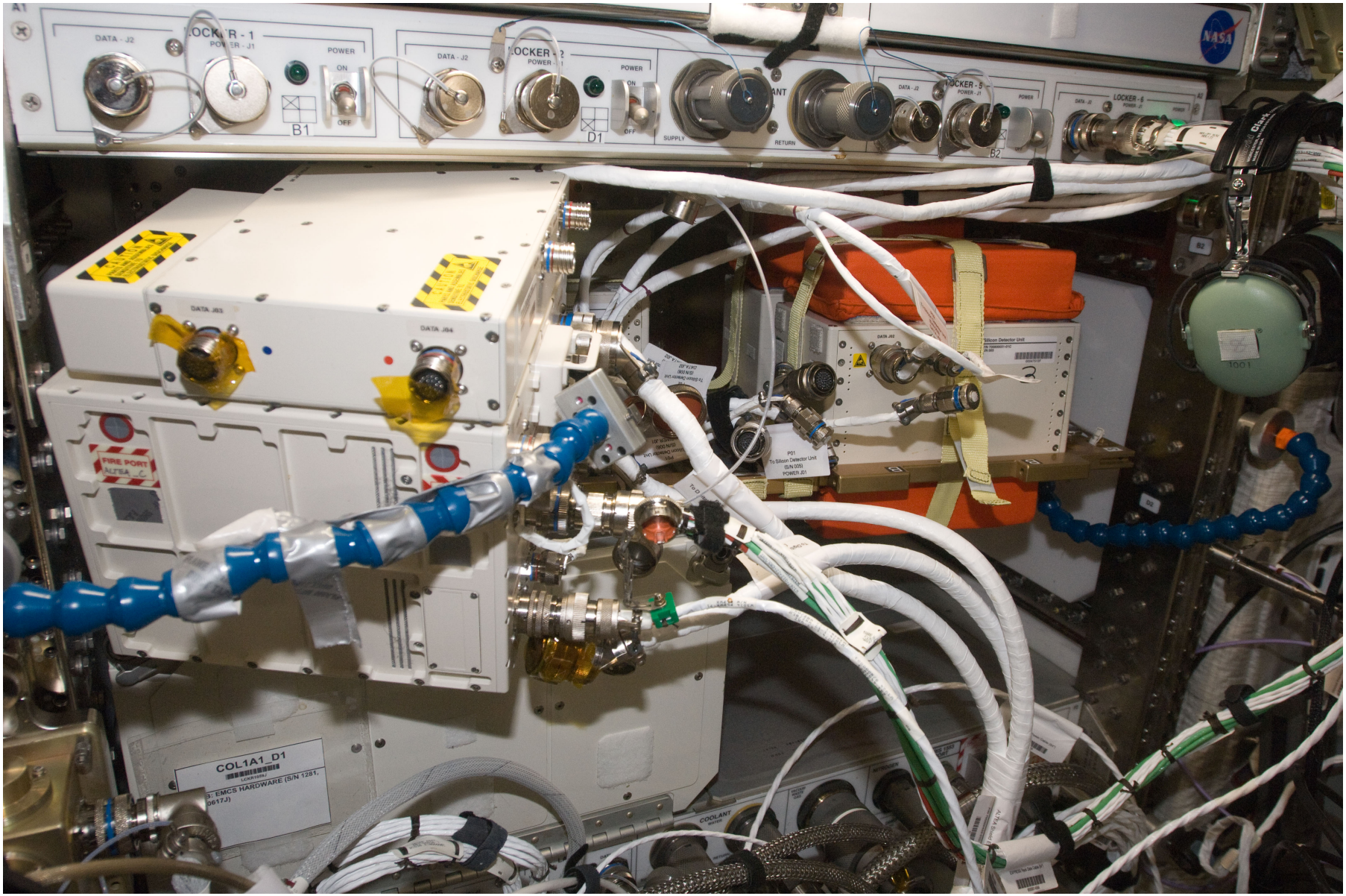
ALTEA in Columbus ER3



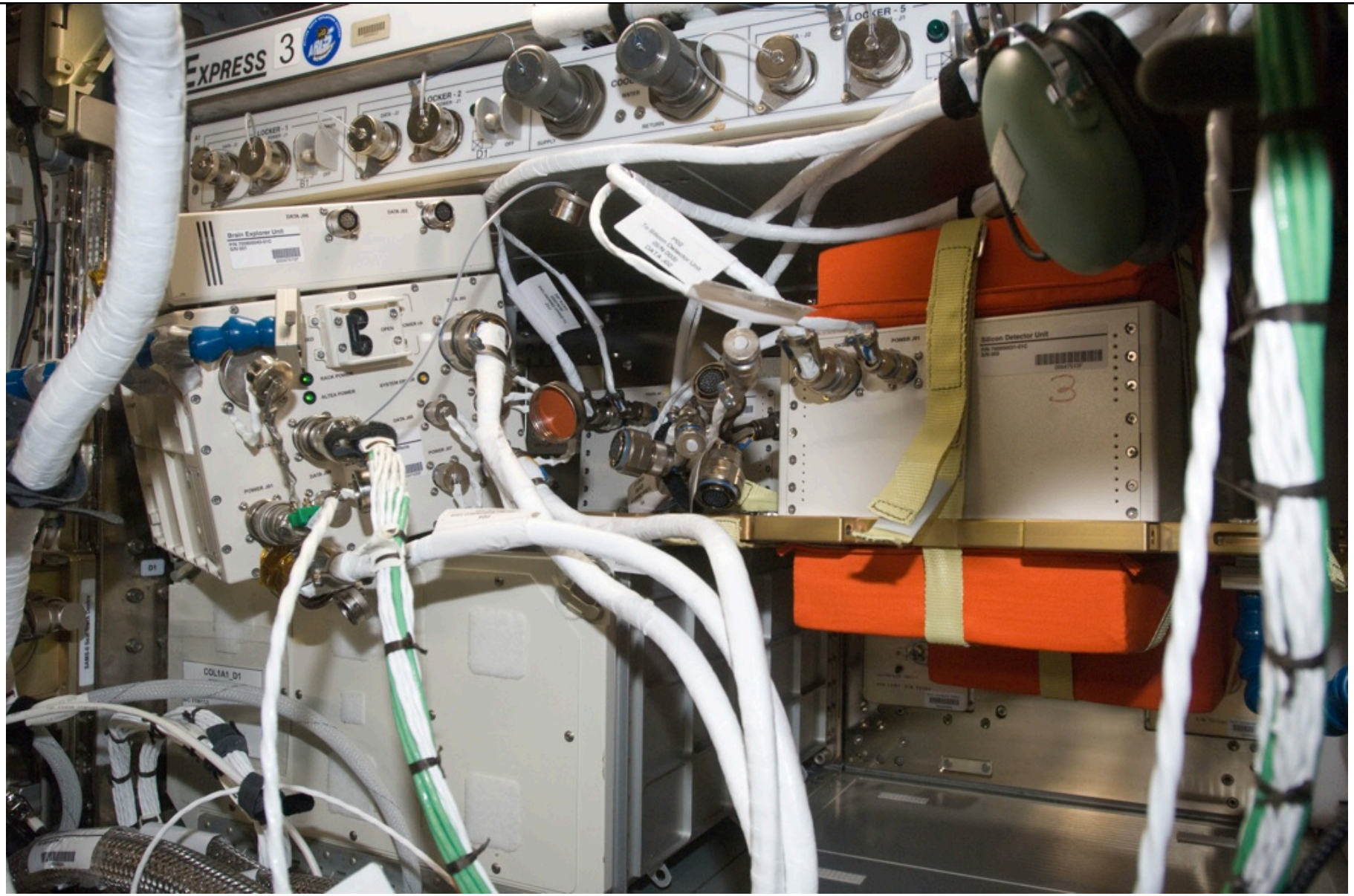
ALTEA in Columbus ER3



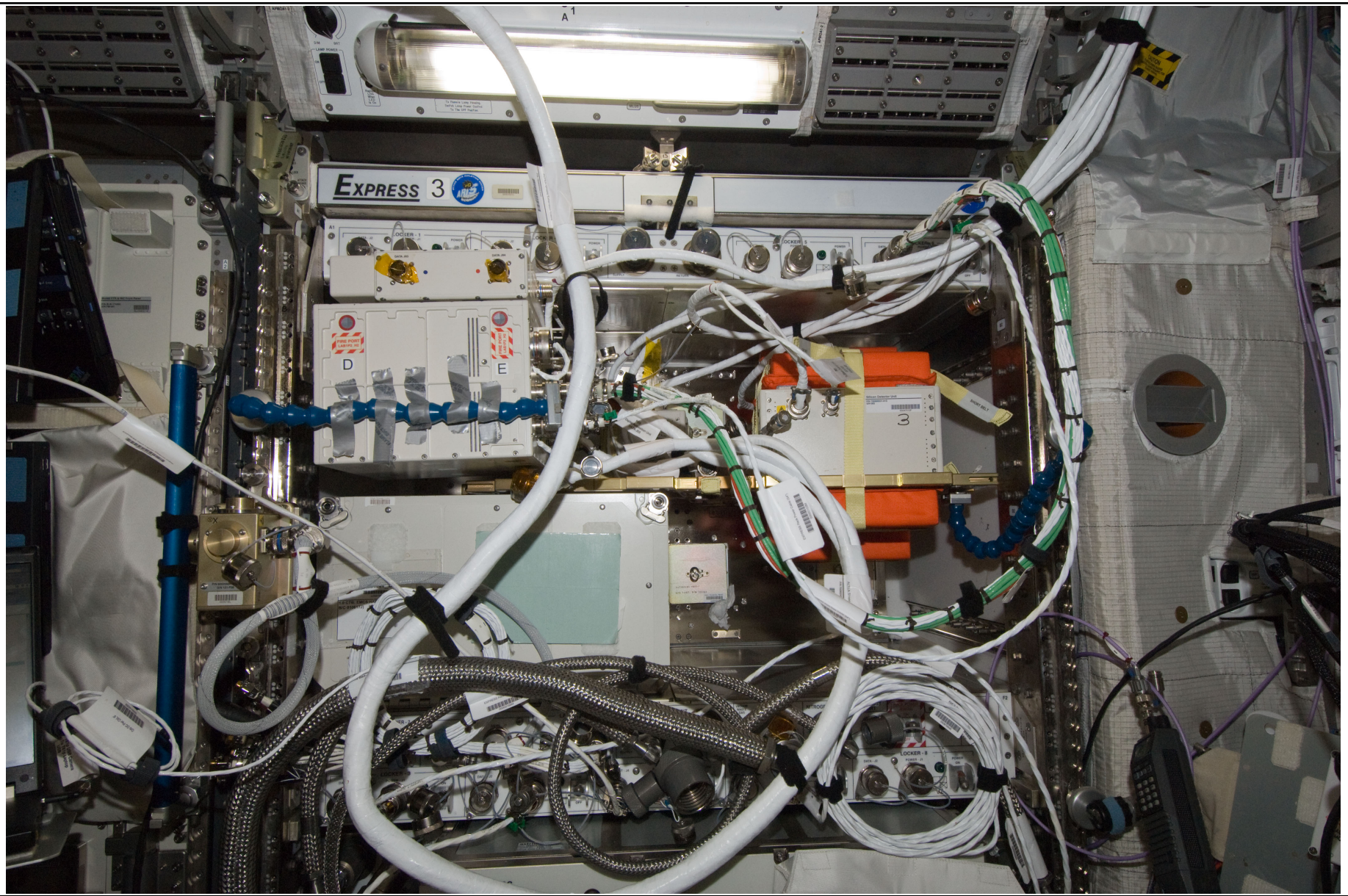
ALTEA in Columbus ER3



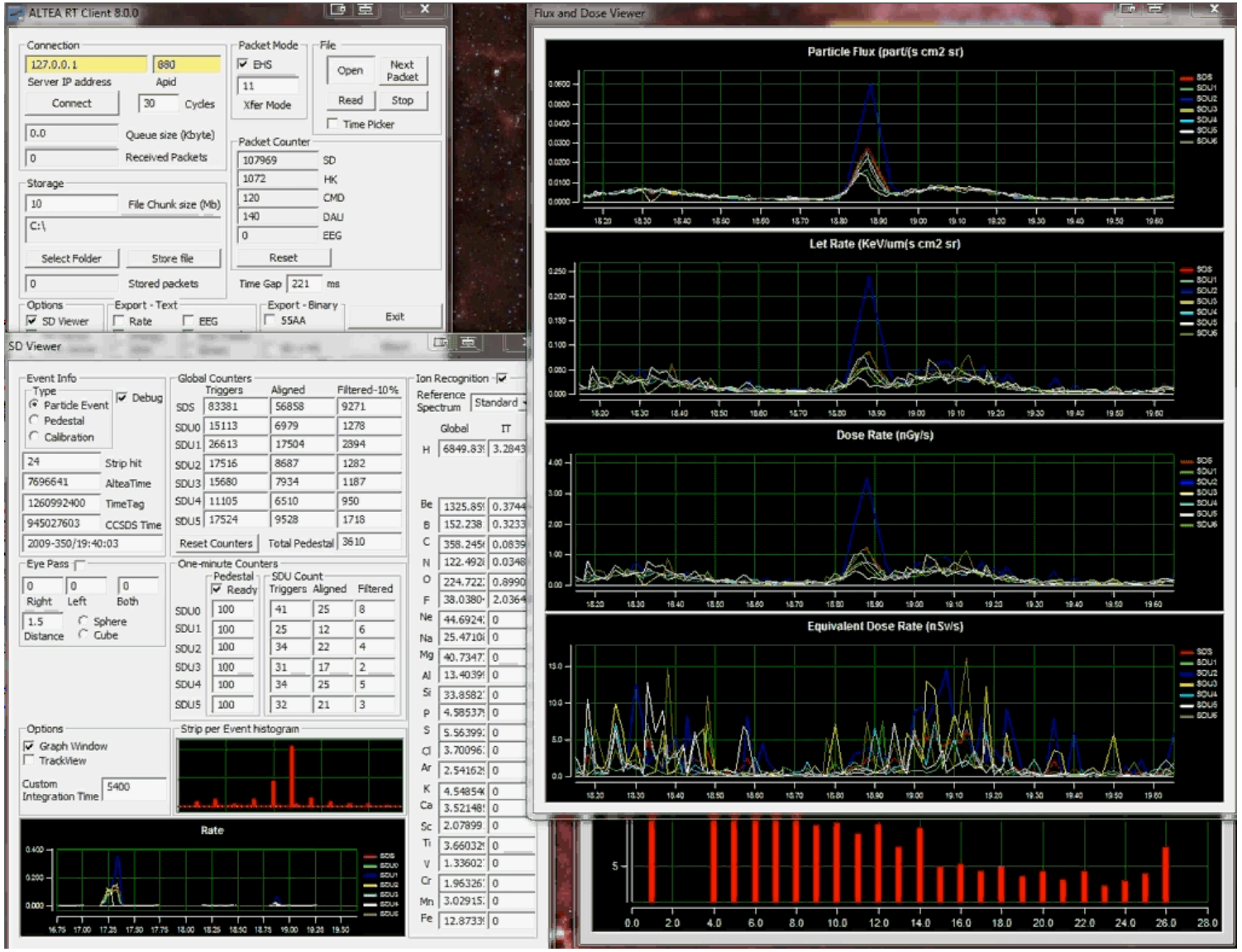
ALTEA in Columbus ER3



ALTEA in Columbus ER3



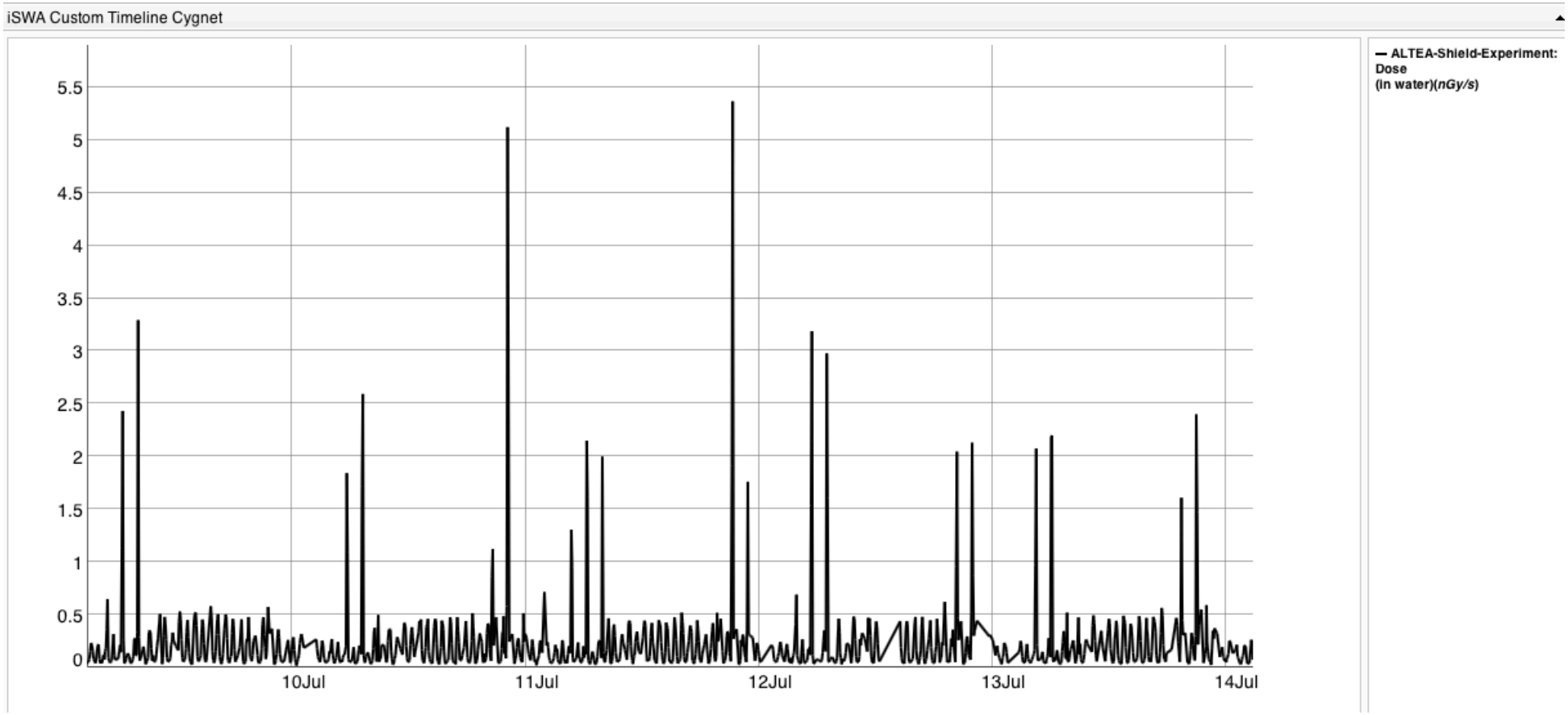
Real time in Rome DFURTV - UHB



Di Fino et al. Adv. Space Res. 1710-1715 (2006)

Real time in NASA – GSFC [iSWA – web]

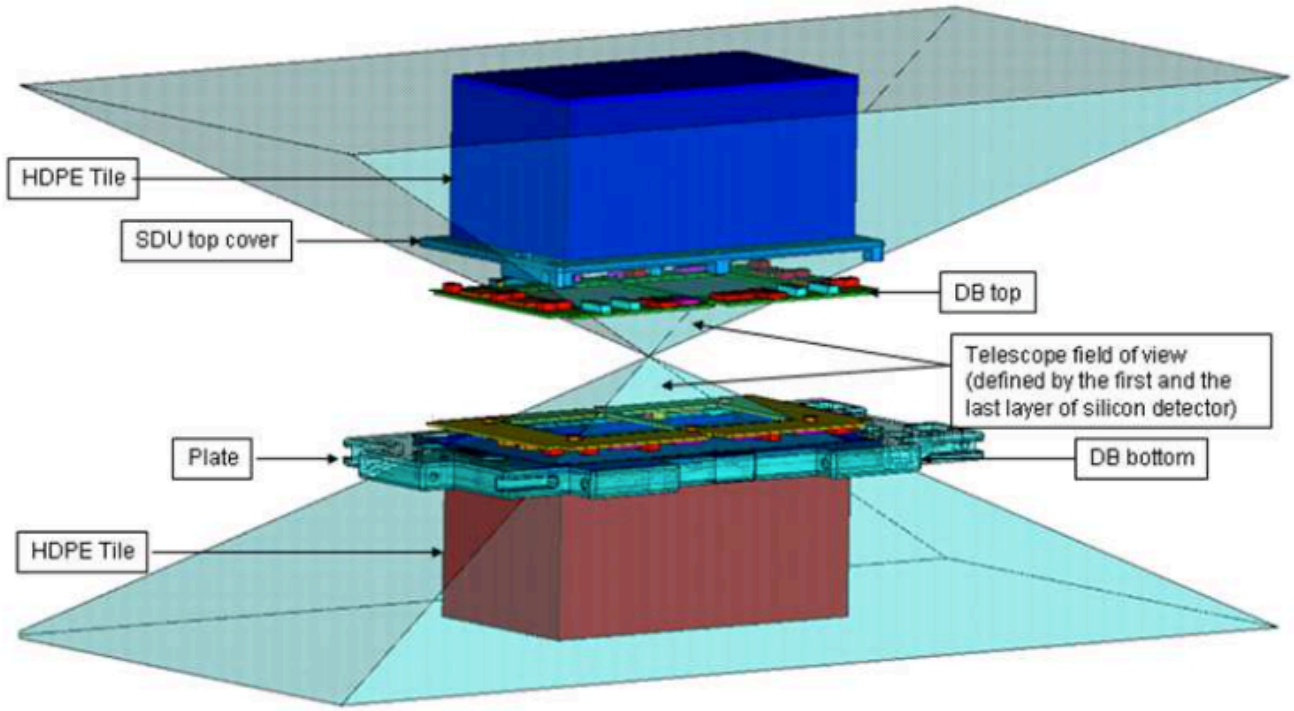
Data Sharing Agreement Between **ESA**'s ALTEA-shield experiment and **ASI**'s ALTEA experiment wit **NASA GSFC** Space Weather Laboratory



PUBLIC:

http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/index.jsp?i_1=388&l_1=4&t_1=27&w_1=1239&h_1=614&s_1=0

Field of view and angular selections



Selected angle of view

Integrated results:

$\Theta = \pm 0.11$ rad $= \pm 6.3°$

$\Delta h \leq 0.5\%$

GF = 9.5 cm^2 sr

Spectra

$\Theta = \pm 0.2$ rad $= \pm 11°$

$\Delta h \leq 2\%$

GF = 31 cm^2 sr

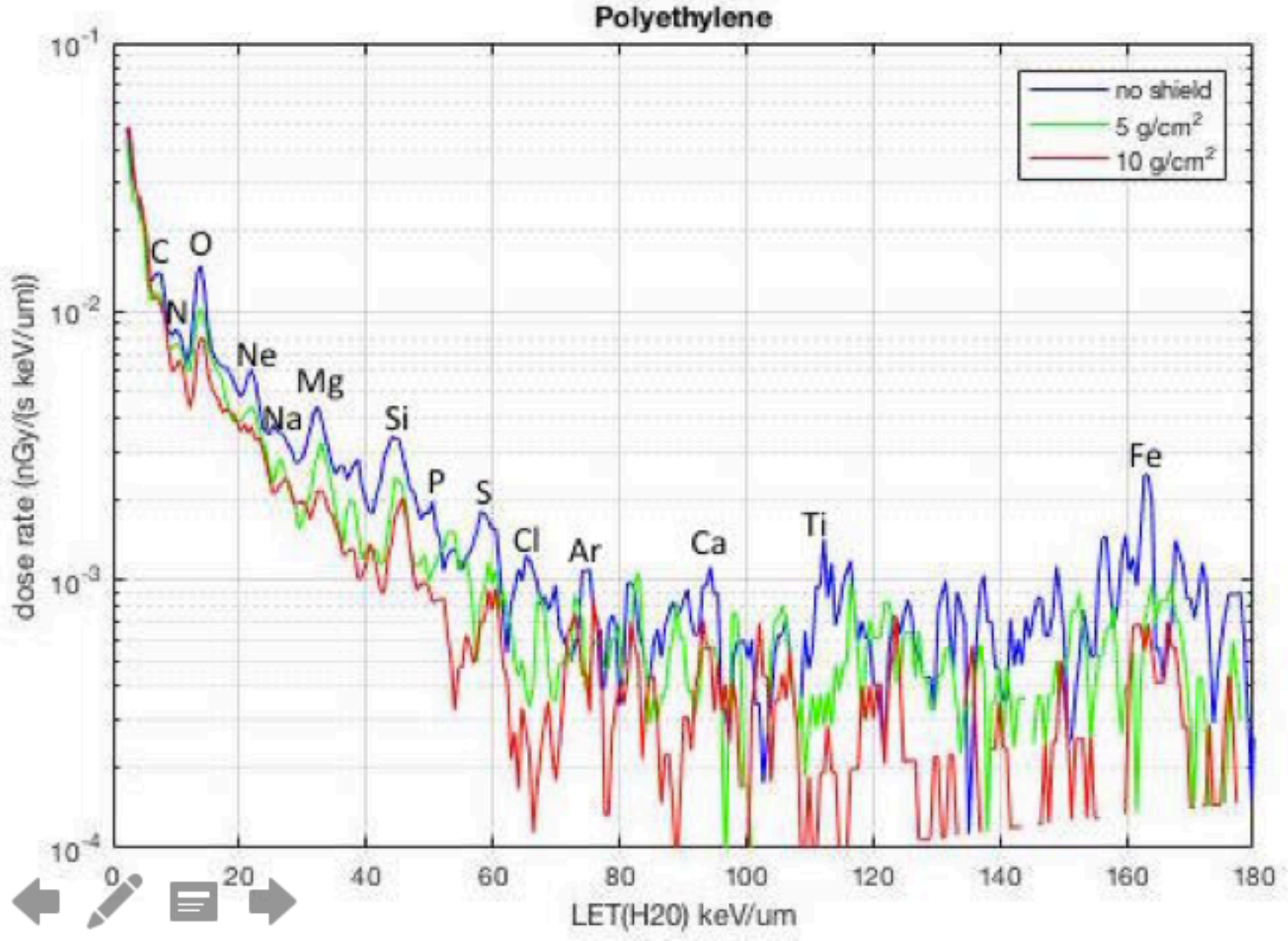
For the 10 g/cm^2 tiles:

≈ 10 % of POLY

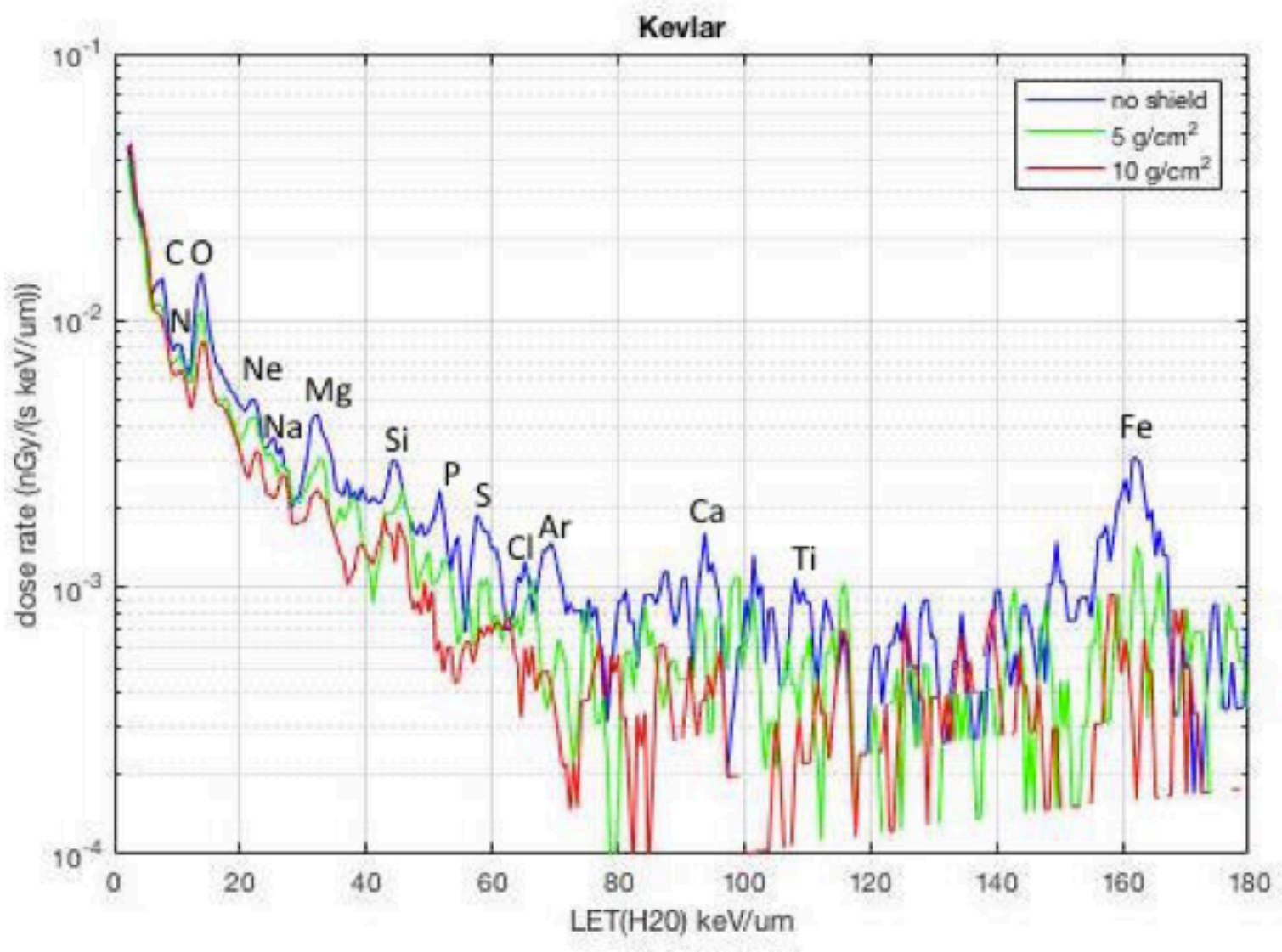
≈ 20% of KEVLAR

Travel partly outside the tiles

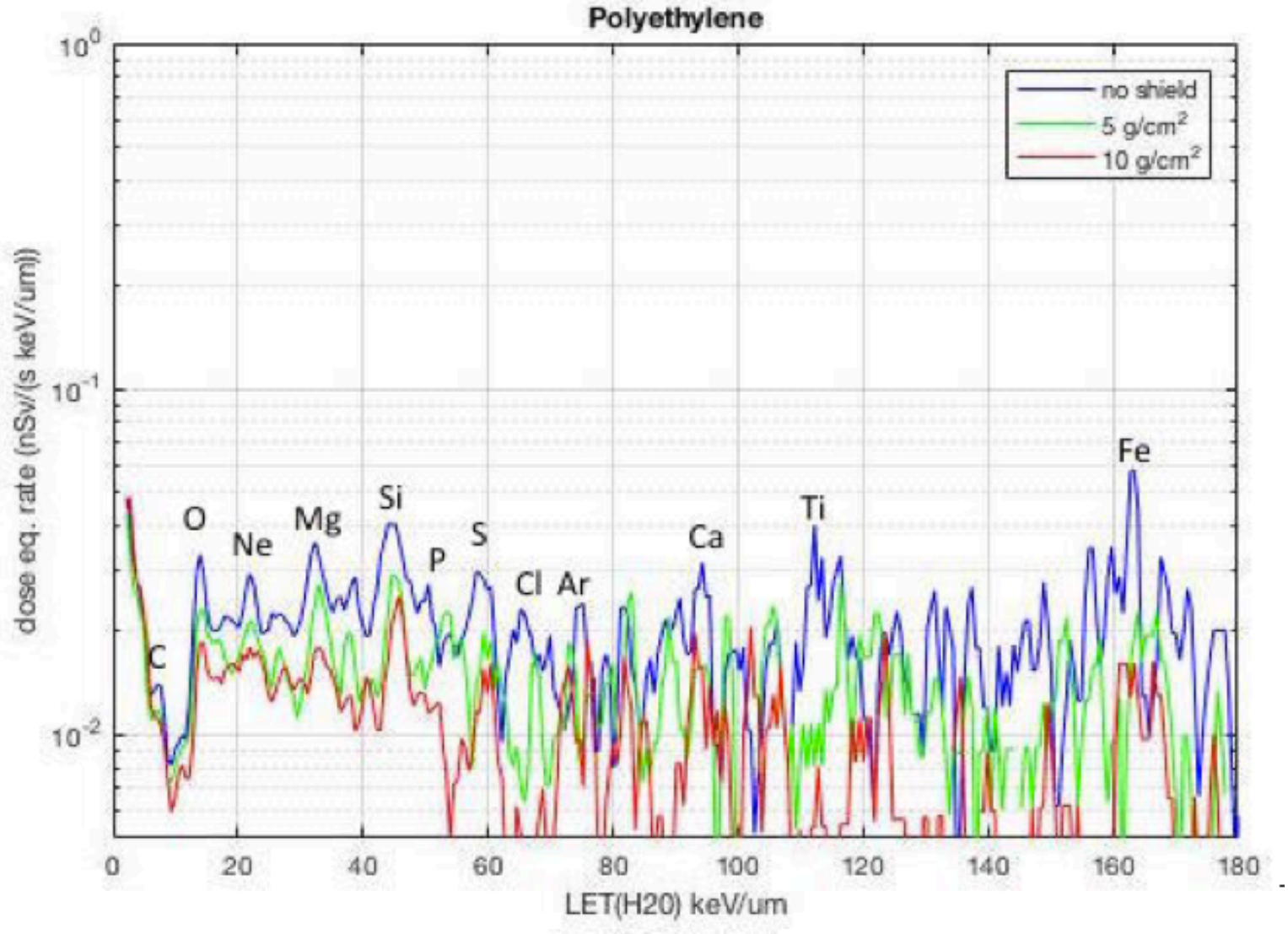
Results: Spectra, dose rate polyethylene



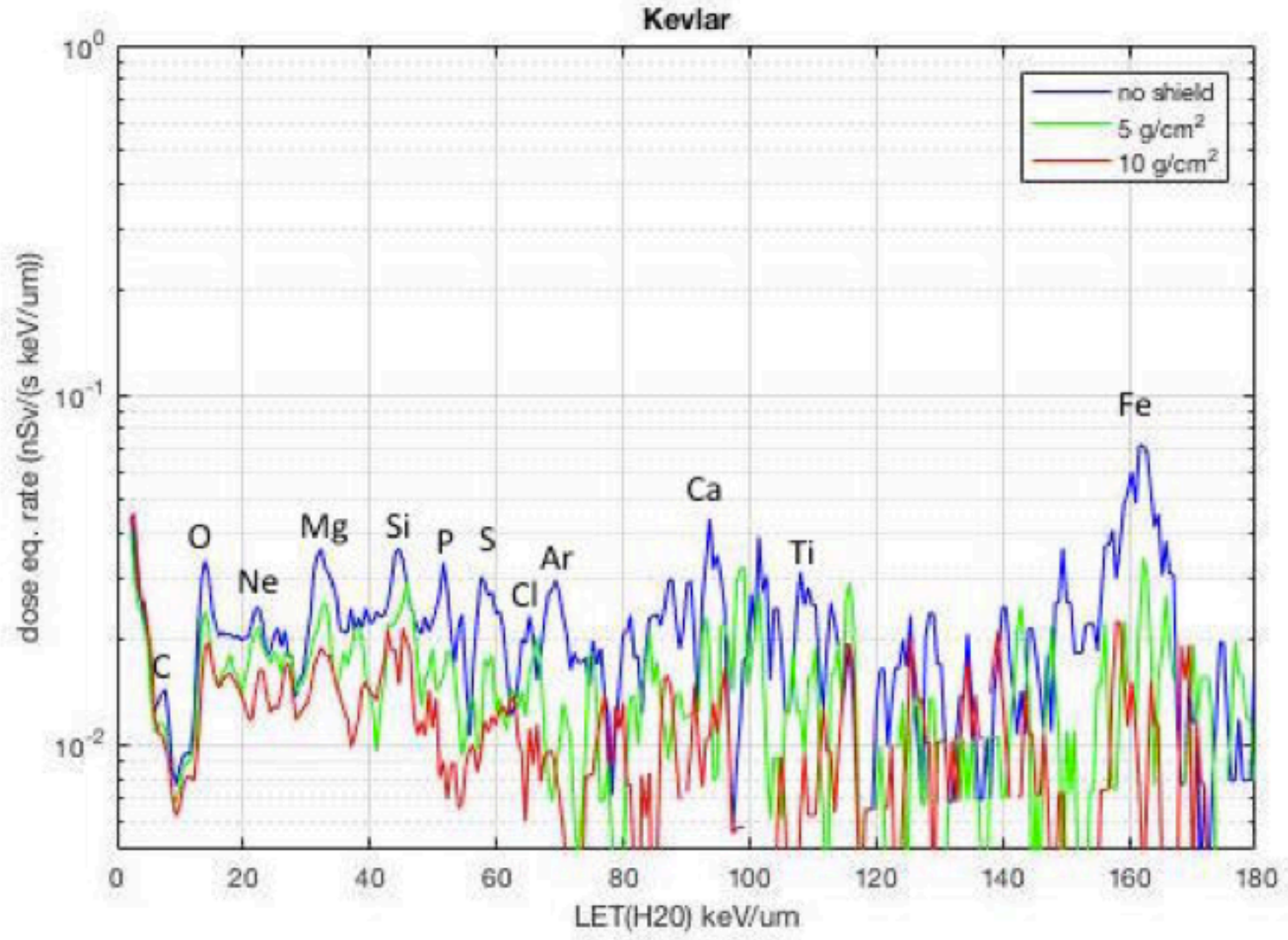
Results: Spectra, dose rate Kevlar



Results: Spectra, dose equivalent polyethylene

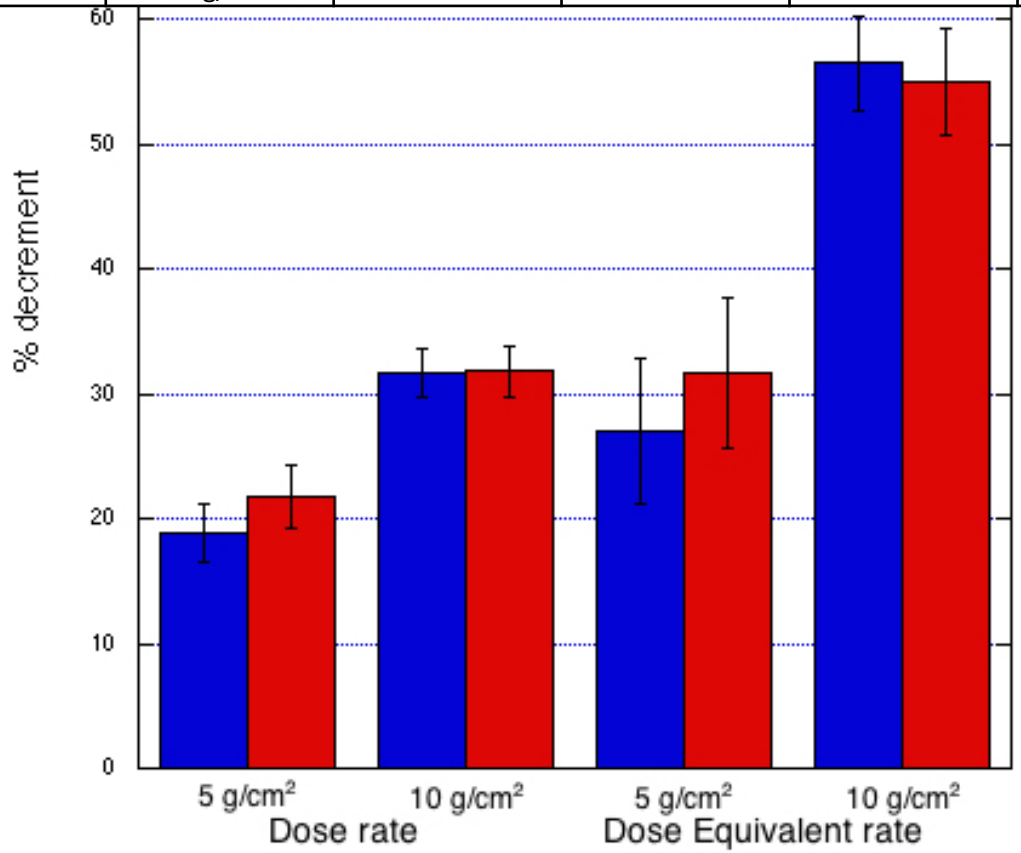


Results: Spectra, dose equivalent Kevlar

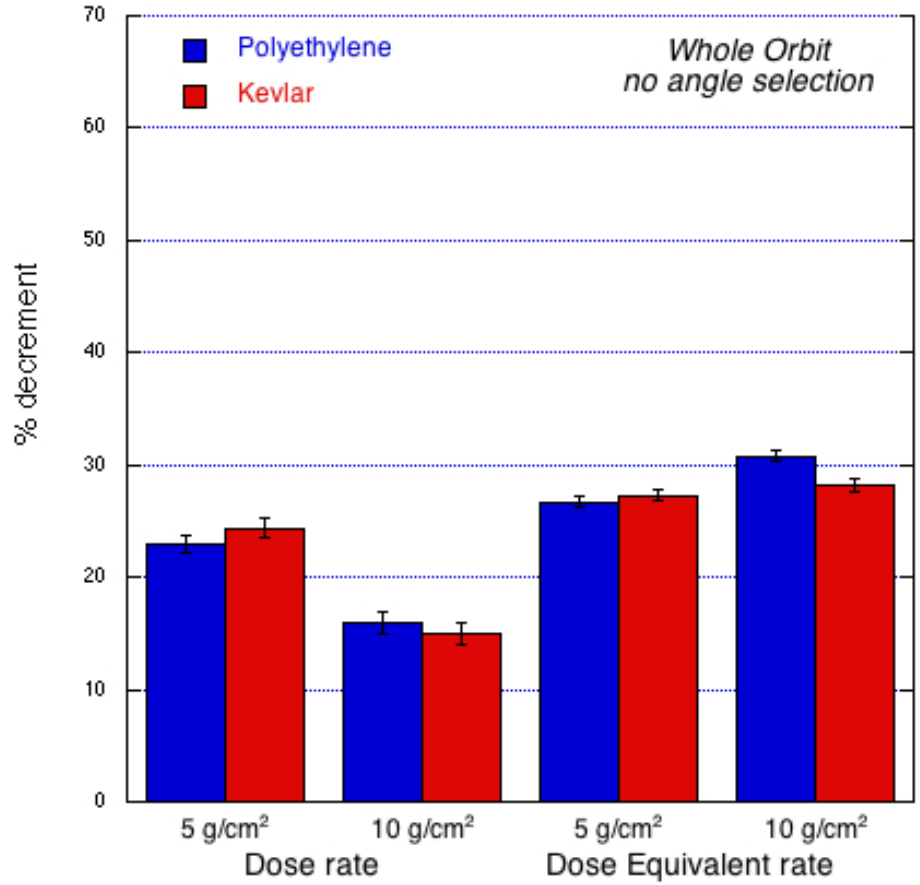


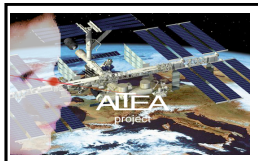
Results: integrated

		High Latitude		Whole orbit	
		Polyethylene	Kevlar	Polyethylene	Kevlar
Dose rate	5 g/cm^2	19 ± 2	22 ± 3	19 ± 1	21 ± 1
	10 g/cm^2	32 ± 2	32 ± 2	28 ± 1	27 ± 1
Dose equivalent rate	5 g/cm^2	27 ± 6	32 ± 6	26 ± 3	32 ± 3
	10 g/cm^2	57 ± 4	55 ± 4	53 ± 2	48 ± 2



Results: integrated *(with no or larger angular selection)*



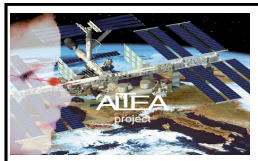


Results: comparisons with literature

Dose rate (percent decrease)					
Paper	Kevlar			Polyethylene	
	5 g/cm^2	10 g/cm^2		5 g/cm^2	10 g/cm^2
Zeitlin et al 2006				21*	37*
Guetersloh et al 2006				18#	31#
				<26$	<51$
Lobascio et al 2008	15^	29^		18^	36^
Pugliese et al 2010	---	---			
This work (*HL*)	**22**	**32**		**19**	**32**
This work (whole orbit)	**21**	**27**		**19**	**28**
Dose Equivalent rate (percent decrease)					
Guetersloh et al 2006				<31.6$	<63.2$
This work (*HL*)	**32**	**55**		**27**	**57**
This work (whole orbit)	**32**	**48**		**26**	**53**

* 1GeV/n Fe-ions
# 1GeV/n O-ions
$ many ion species and energy considered, these values are the maximal, extrapolated from the value at 2.83 g/cm2, assuming linear relationship.
^ 1 GeV/n Fe-ions, extrapolated from values for unit areal density, assuming linear relationship

Guetersloh et al. Nucl. Instrum. and Meth. B 252:319–332 (2006)
Zeitlin et al. Nucl. Instrum. and Meth. B 252:308–318 (2006)
Lobascio et al. Health Phys. 94:242–247 (2008)
Pugliese et al. Radiat Environ Biophys 49:359–363 (2010)



Conclusions / comments

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Very similar effectiveness of Polyethylene and Kevlar, reaching a reduction of about 30% in Dose and 50% in Dose Equivalent (10 g/cm^2)

Kevlar appears to be performing as Polyethylene

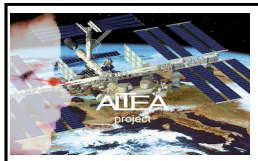
Concurrent baselining needed due to radiation field dynamics and shielding changes

Statistics maybe an issue if angular selection must be performed

High latitude passages mimic deep space, however differences with whole orbit might not be significant.

Shielding (even at 5 g/cm^2) appears to null SPE effects (within ALTEA sensitivity)

Fragmentation analysis (just started) might lead to interesting results.



The LIDAL rationale

Light Ion Detector for ALTEA: LIDAL

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

The LIDAL project:
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: three 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)
- Time resolution aimed to be better then 100 ps

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ITALIA

Back to the ALTEA acceptance

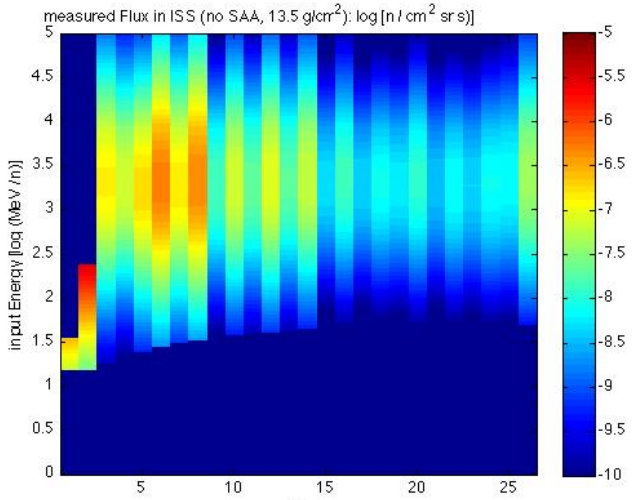
CREME model (GCR) inside the ISS + PHITS model of ALTEA

Z	***%measured***
1	0.024 %
2	3.2 %
>2	>99 %
All	1.3 %

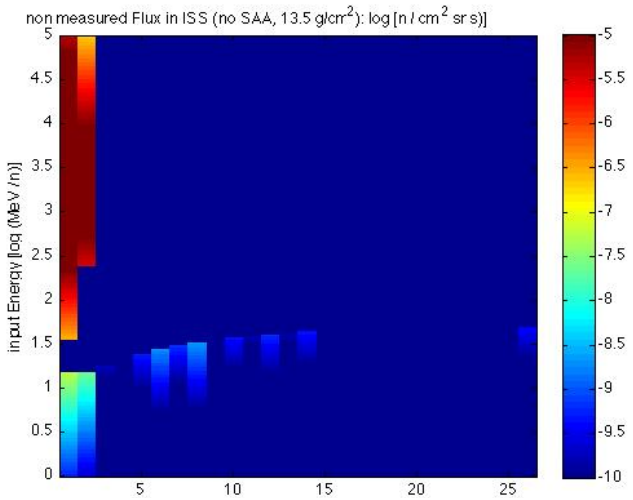
Z	***%measured***
1	0.29 %
2	8.7 %
>2	>99 %
All	41 %

Flux

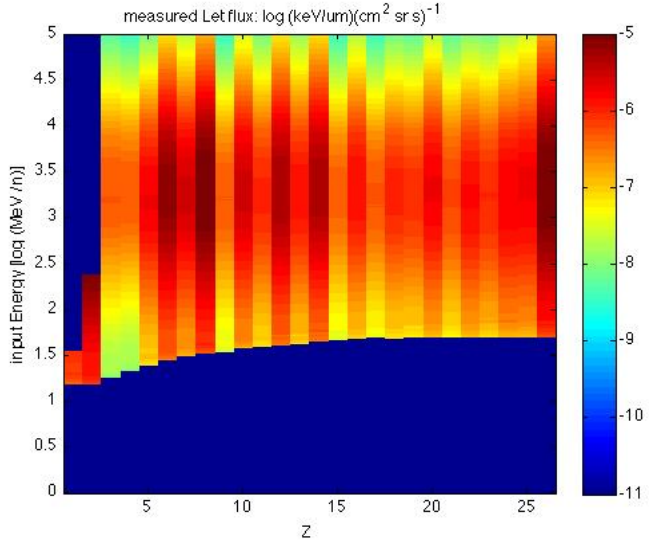
Measured by ALTEA

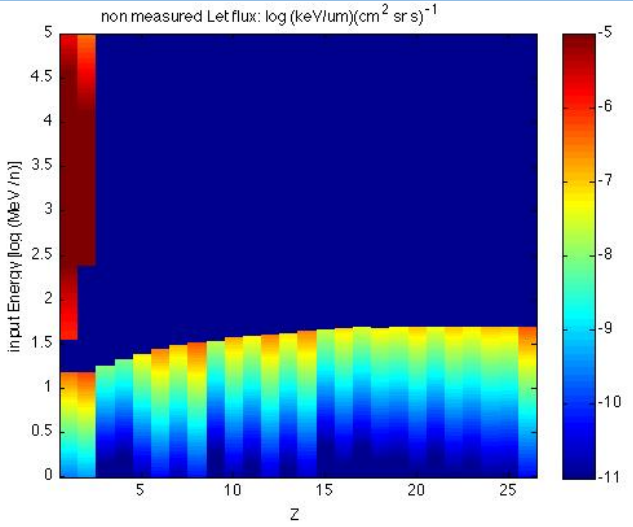


Not measured by ALTEA

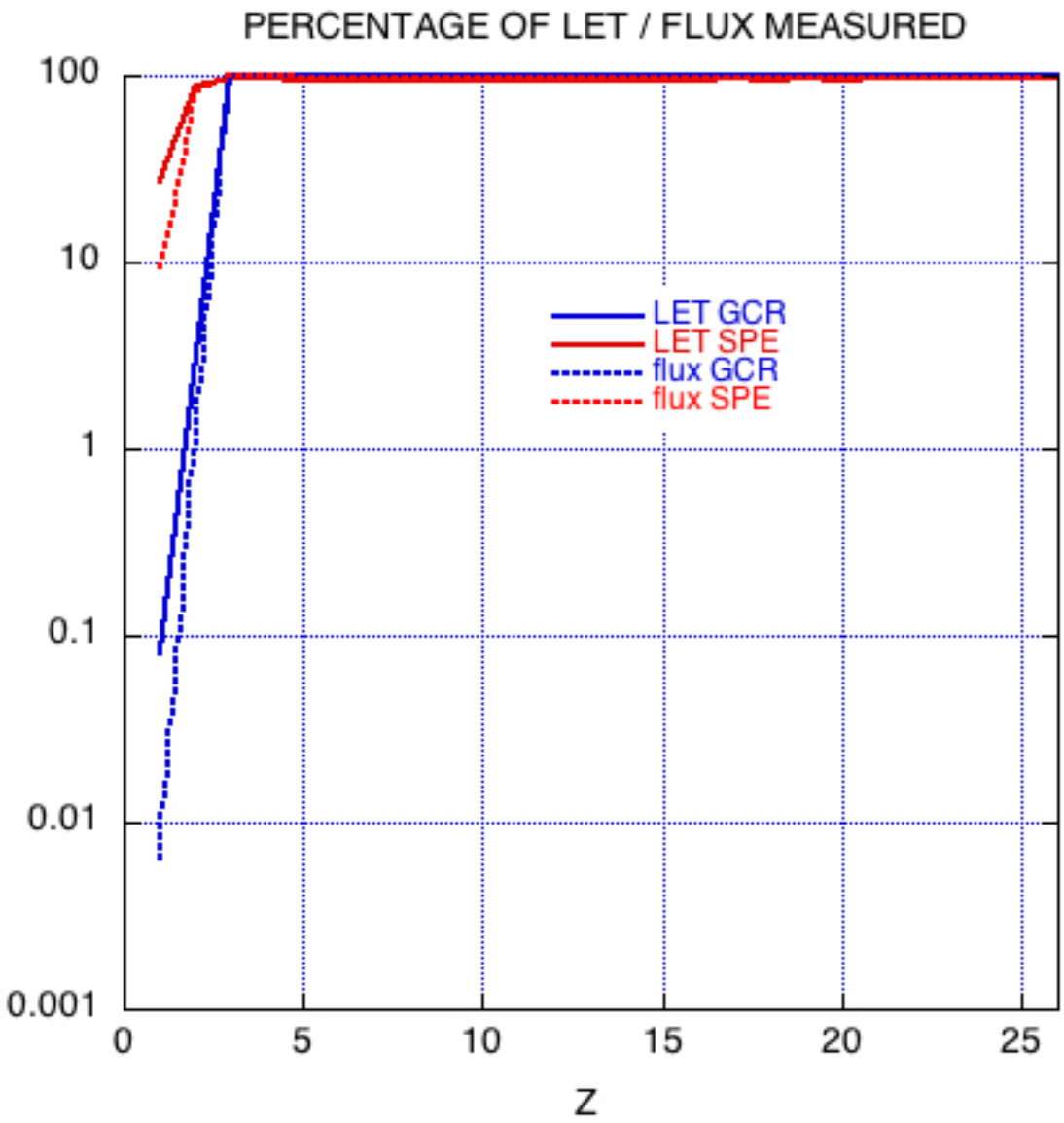


LET



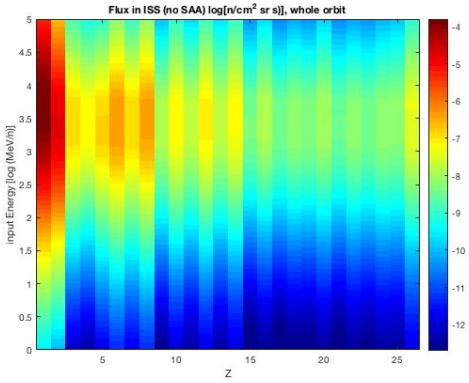


Back to the ALTEA acceptance 2



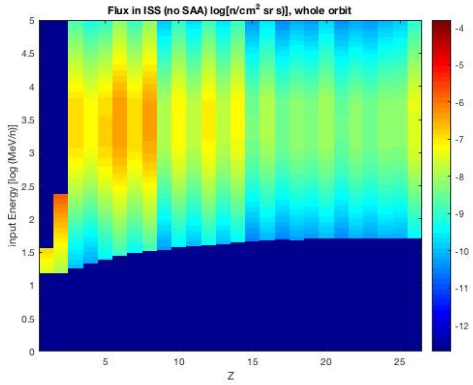
LIDAL improvements

Simulated GCR flux in ISS



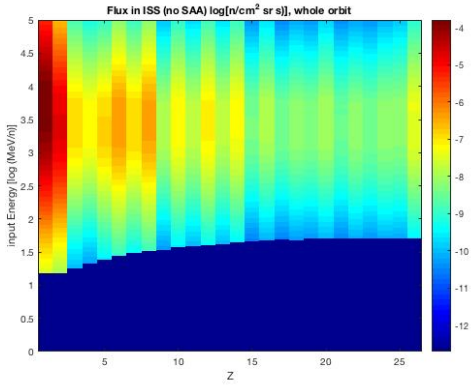
ALTEA

1 % of the flux and 41 % of the Dose.

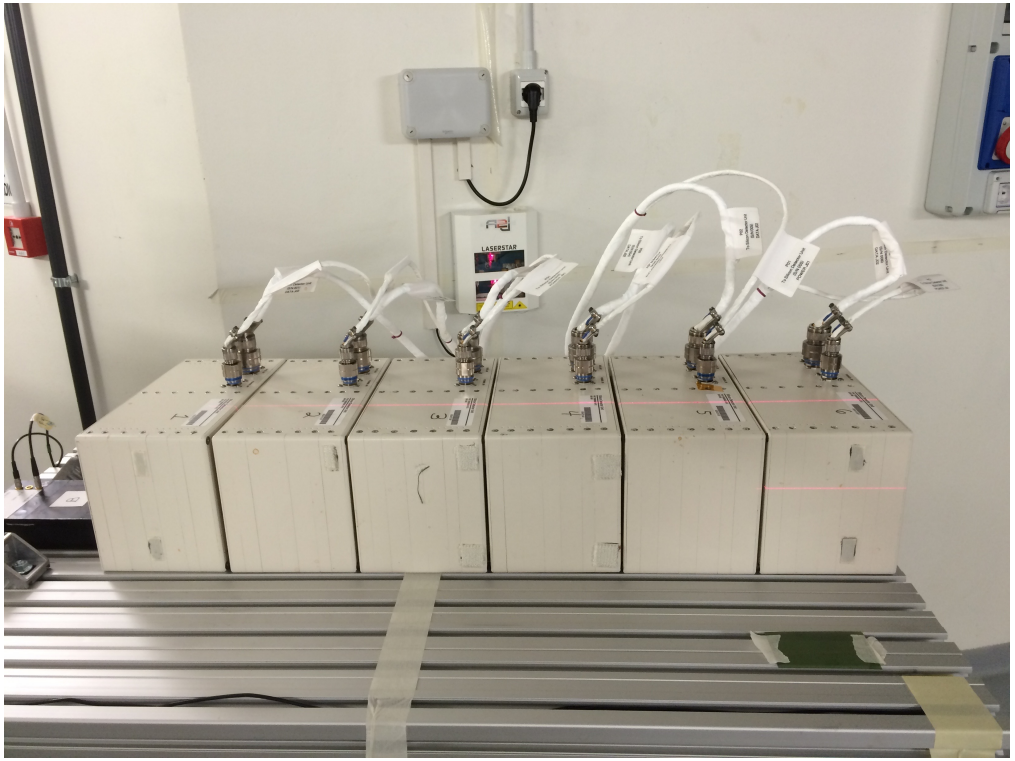


ALTEA – LIDAL

≈100 % of the flux and ≈100 % of the Dose.



Test on proton beam



The statistical identification and the LIDAL improvement

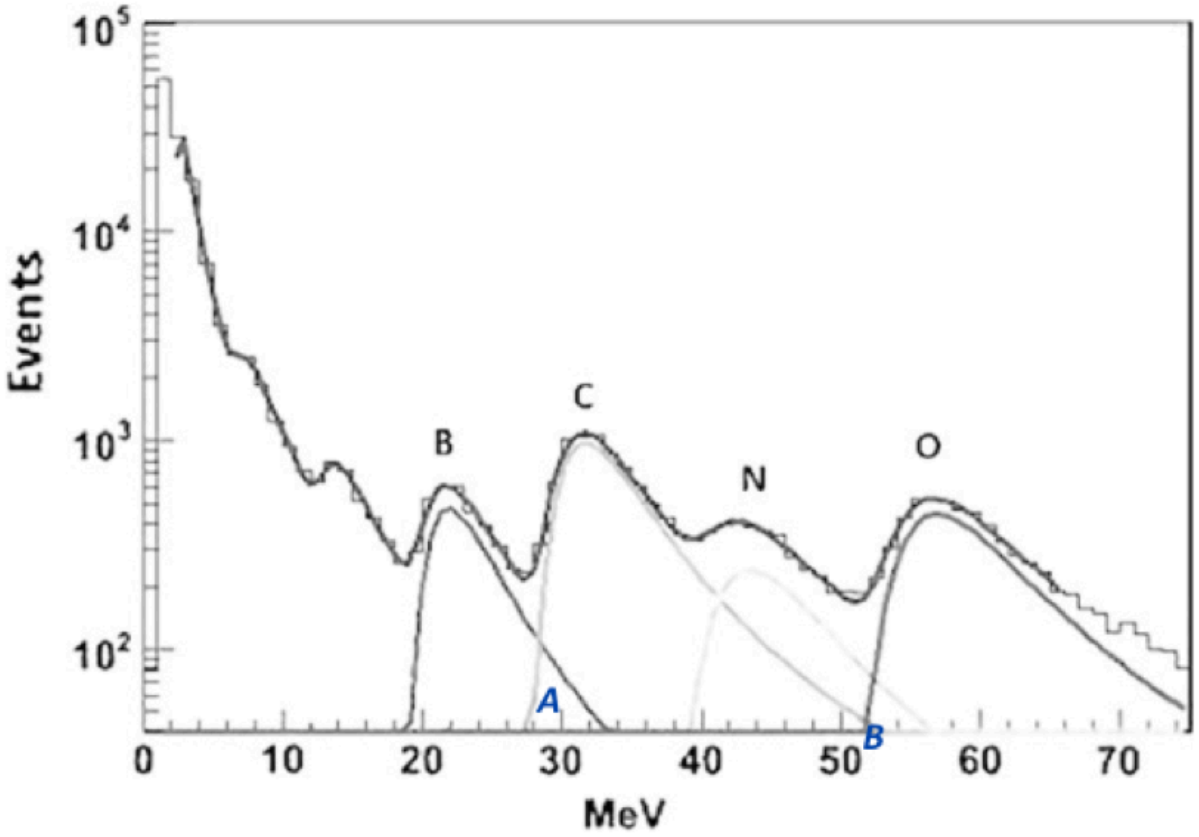


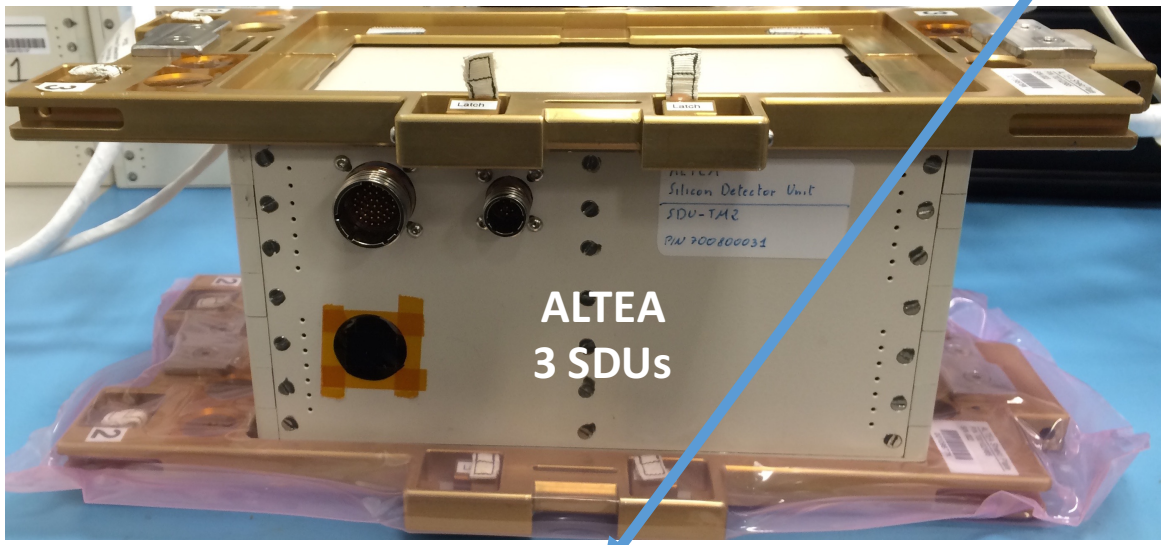
Figure 5A portion of the energy loss spectrum, simulated over the whole Silicon length (≈ 2 mm), fitted with a sum of Landau curves. Without even considering Z ≤ 4 tails in region A can be found Boron or Carbon ions, while, for example, in B, Carbon, Nitrogen or Oxygen ions. The relative population amount can be used to provide a probability for each ion (see Di Fino et al 2012).

The independent measurements of the ion velocity gives information to resolve ions in A and B

Di Fino et al Adv. Space Res. 50:408-414 (2012)

LIDAL hardware

+ 2 sets of scintillators
On the two sides of the SDU stack

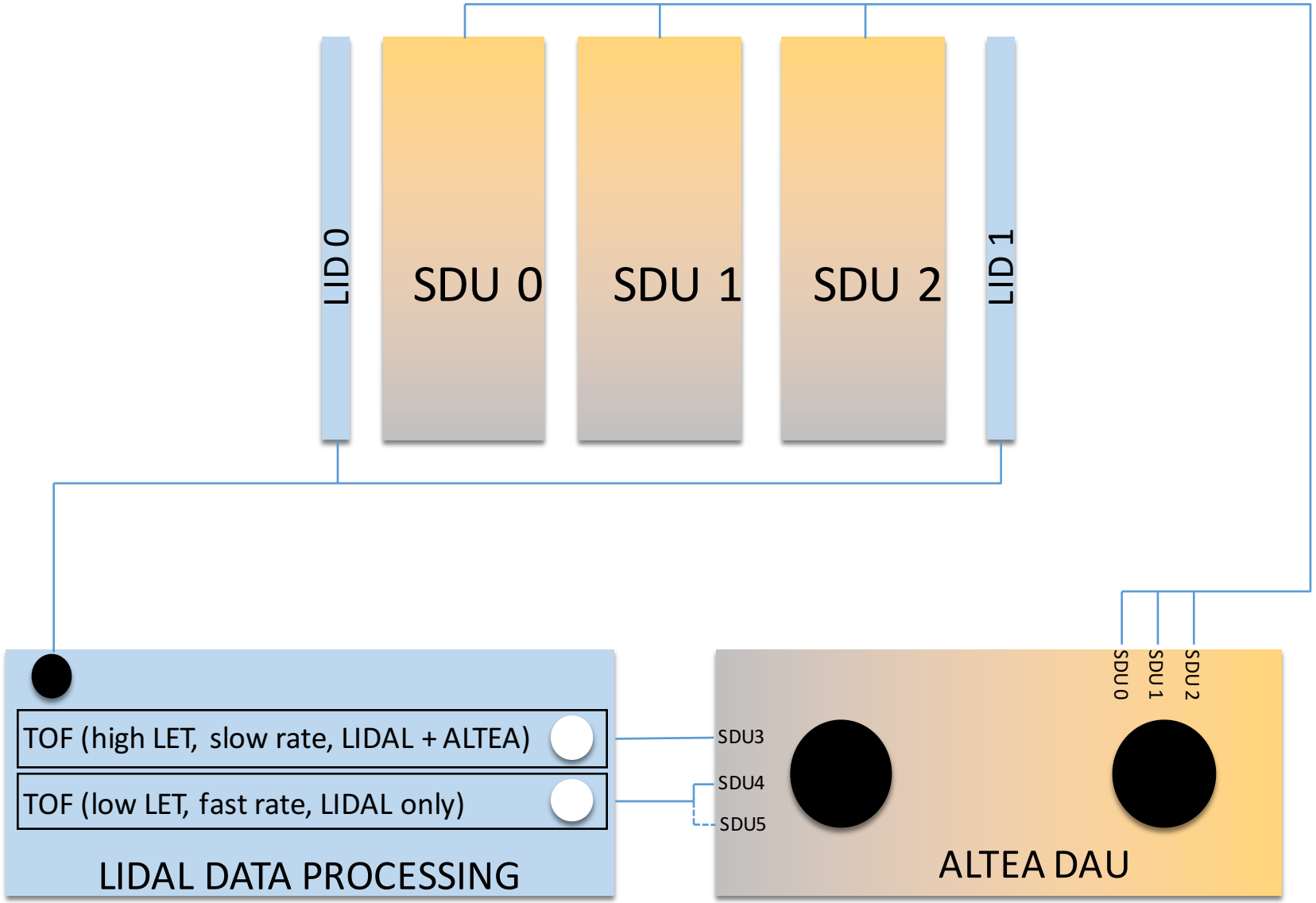


LIDAL are two sets of scintillators to be coupled to ALTEA to provide sensitivity to protons and Time of Flight capability

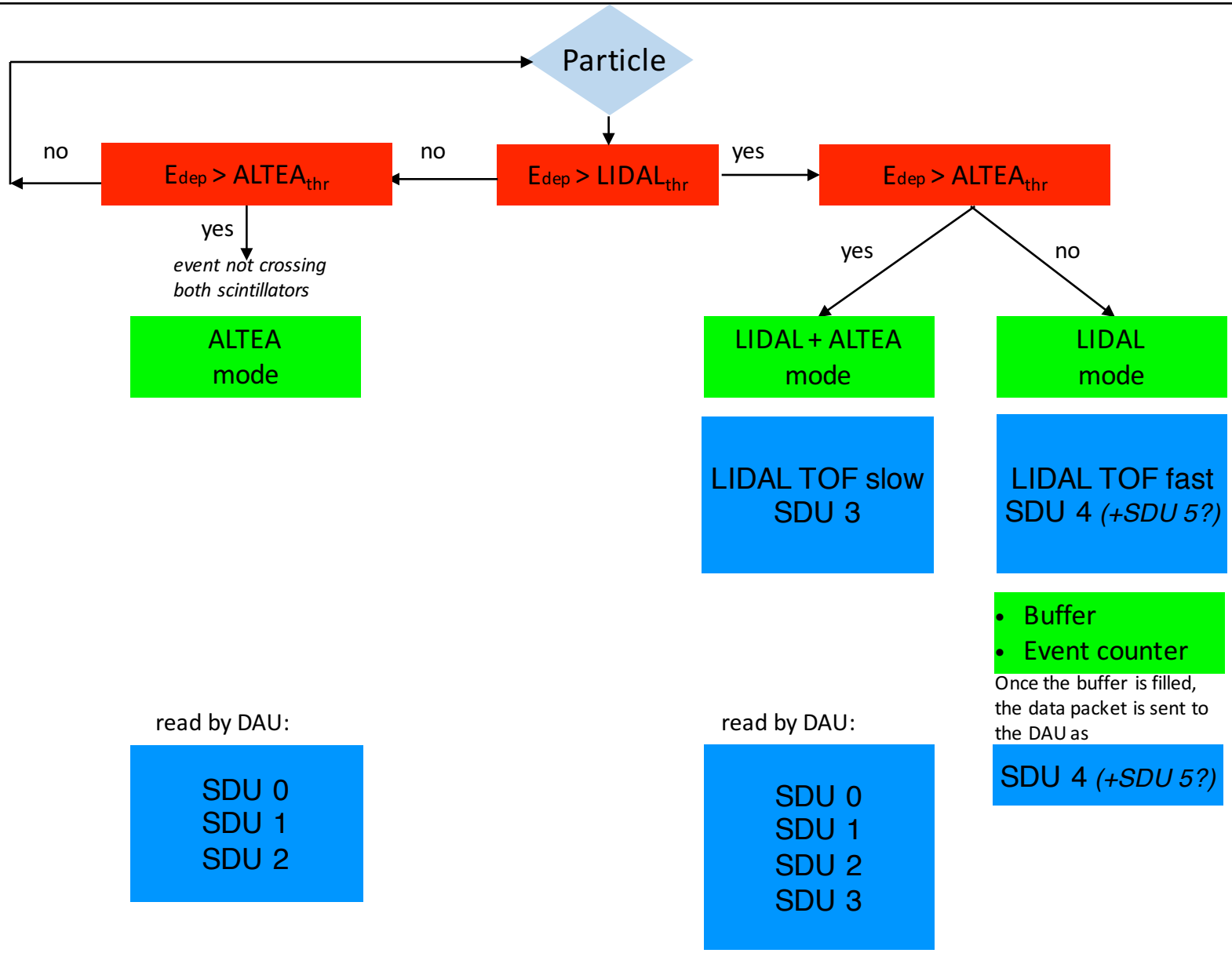
Flight hardware:

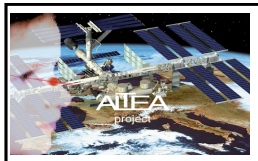
- Two detector units (approx. 240 mm x 120 mm x 60 TBC) + one control unit.
- Each detector unit includes segmented scintillators coupled to photomultipliers (compact and low powered).
- The two units will be mounted at the two sides of 3 of the ALTEA Silicon Detector Unit(s).
- The TOF system high performances guarantees a time resolution $\approx 10^2$ ps.

LIDAL logic


LID 0
SDU 0
SDU 1
SDU 2
LID 1
TOF (high LET, slow rate, LIDAL + ALTEA)
TOF (low LET, fast rate, LIDAL only)
LIDAL DATA PROCESSING
SDU3
SDU4
SDU5
SDU 0
SDU 1
SDU 2
ALTEA DAU

LIDAL logic


Particle
no
E_{dep} > $ALTEA_{thr}$
no
E_{dep} > $LIDAL_{thr}$
yes
E_{dep} > $ALTEA_{thr}$
yes
event not crossing both scintillators
yes
no
ALTEA mode
LIDAL + ALTEA mode
LIDAL mode
LIDAL TOF slow SDU 3
LIDAL TOF fast SDU 4 (+SDU 5?)
• Buffer
• Event counter
Once the buffer is filled, the data packet is sent to the DAU as
SDU 4 (+SDU 5?)
read by DAU:
SDU 0
SDU 1
SDU 2
read by DAU:
SDU 0
SDU 1
SDU 2
SDU 3

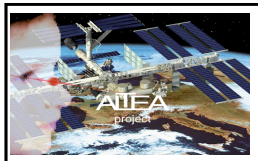


Conclusion

LIDAL will provide the sensitivity to most (≈ 100%) of the relevant ions

Time of Flight will allow for a direct and independent measurement of velocity and therefore will strongly improve nuclear identification

LIDAL contract has been just signed.



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Thank you for your attention!