Lightweight Observatory for Radiation Environment (LORE)

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esa space radiation & plasma environment monitoring ws
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INFN

Rationale

- In most recent human exploration roadmaps the issue of personal active dosimetry is strongly stressed.

Most recently in the EU THESEUS roadmap* it can be read:

… Access to an active real-time personal dosimeter will allow the user to monitor his/her radiation exposure and seek out preferable regions to reduce their radiation risk…

…

Proposed investigations and recommendations:

…

- *New small active detector systems need to be developed delivering optimised information of the radiation field parameters.*

…

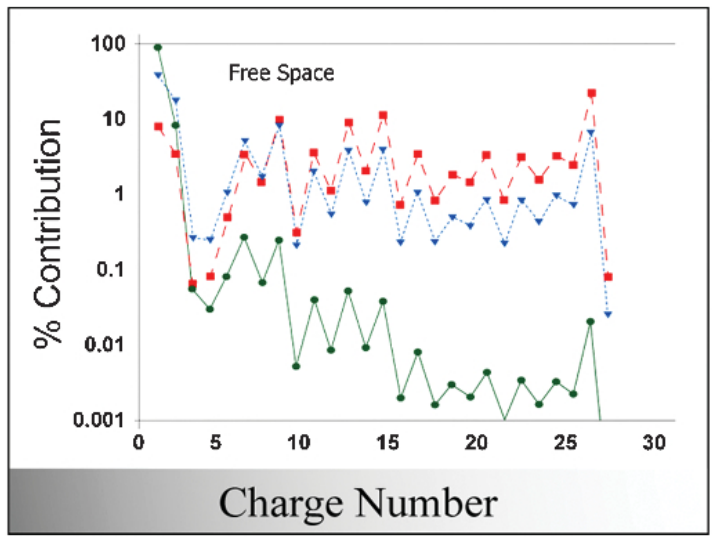
** THESEUS – seventh Framework Programme – Cluster 3: Space Radiation*

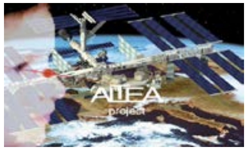
Rationale 2

- In CFI – ESA 2010:

The ISS can provide a perfect testing ground for new improved information systems for the crew, which will increase their autonomy and decrease their dependency on ground support. Envisioned systems will provide intelligent data management and displays to aid the crew in making correct critical decisions as well as reduce the amount of less critical data the crew is exposed to

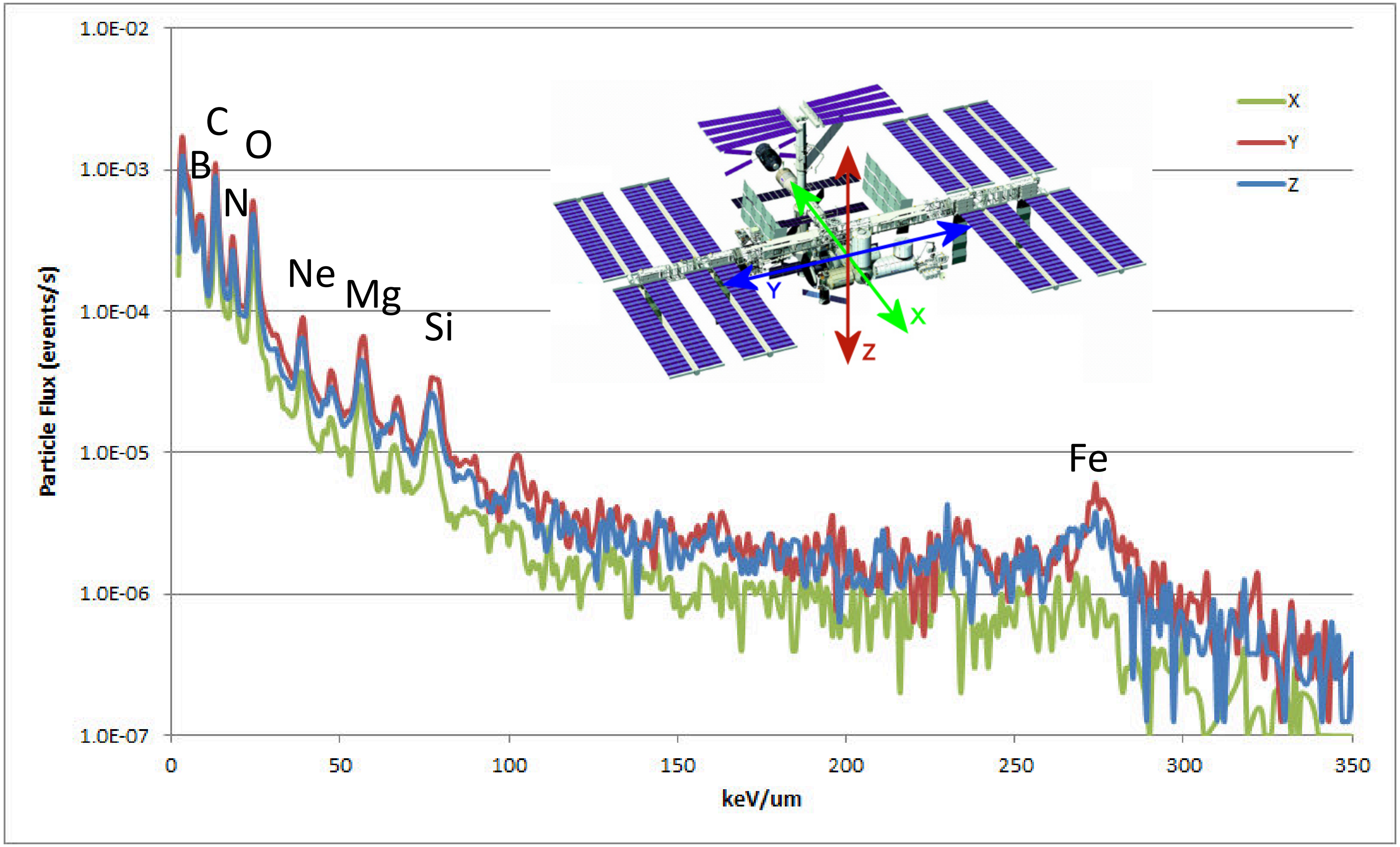
- Details of radiation environment (*radiation quality*) are needed:





Background 1

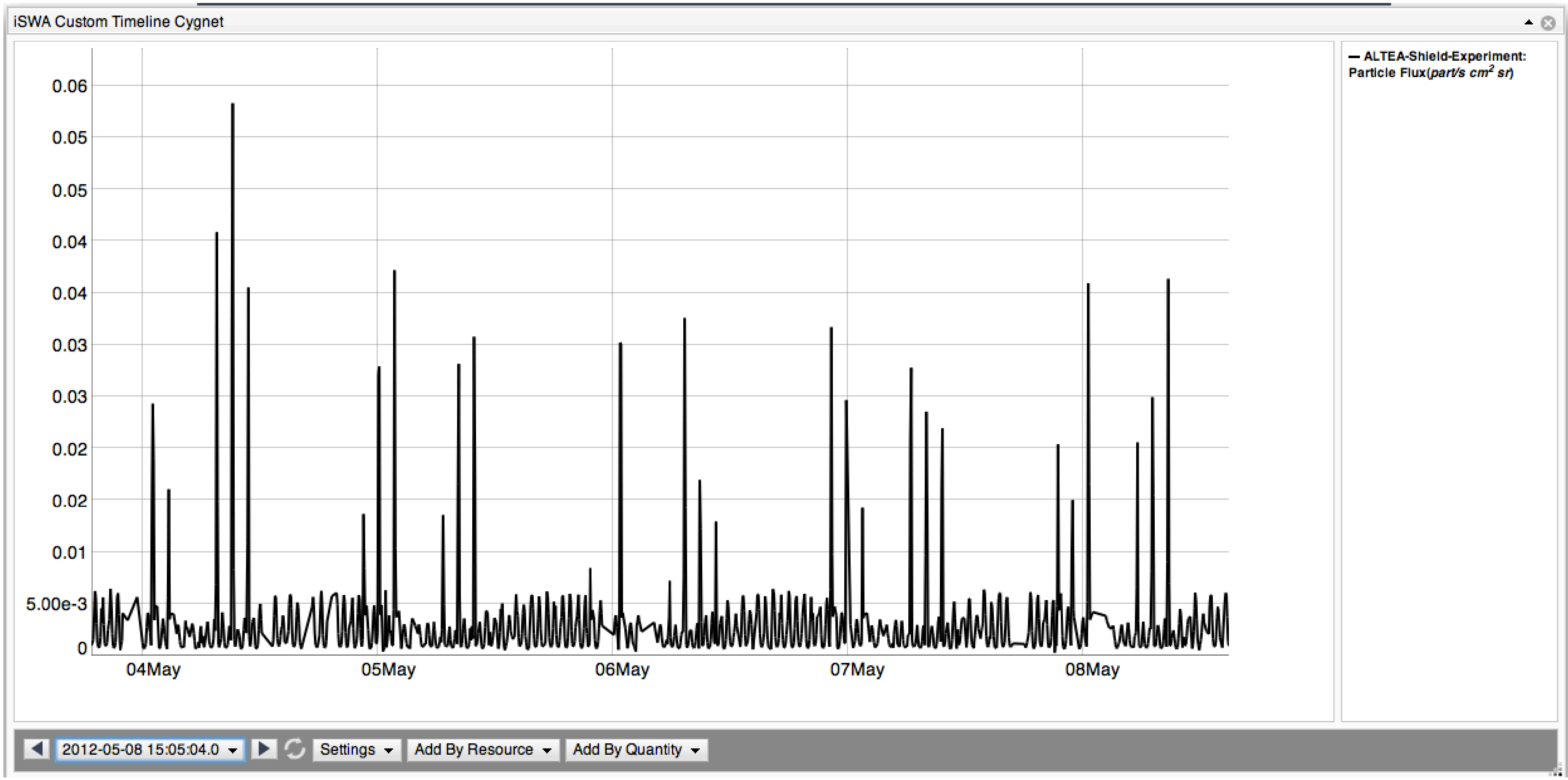
With ALTEA we can measure spectra like this

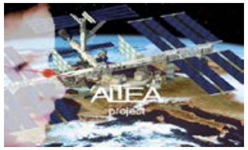


ALTEA-shield/survey
200 d (up to May 5th 2012)
no energy cuts

Background 2

And we can work on data in real time:



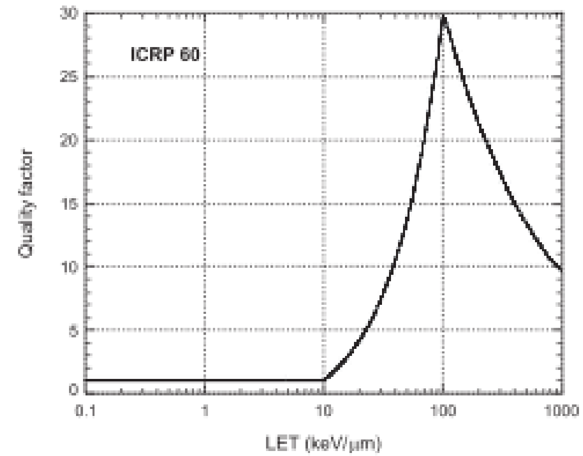


Background 3

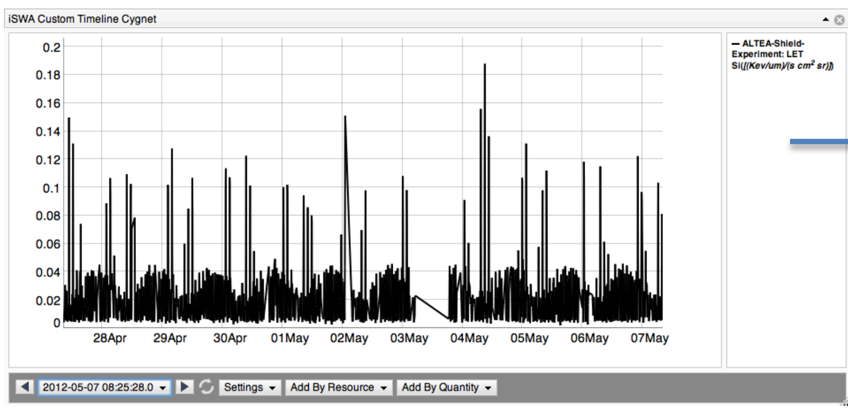
A first analysis of that Data can give
Dose Equivalent in Real Time

Using (**I**nternational **C**ommission on **R**adiological **P**rotection, ICRP-60, 1991)*

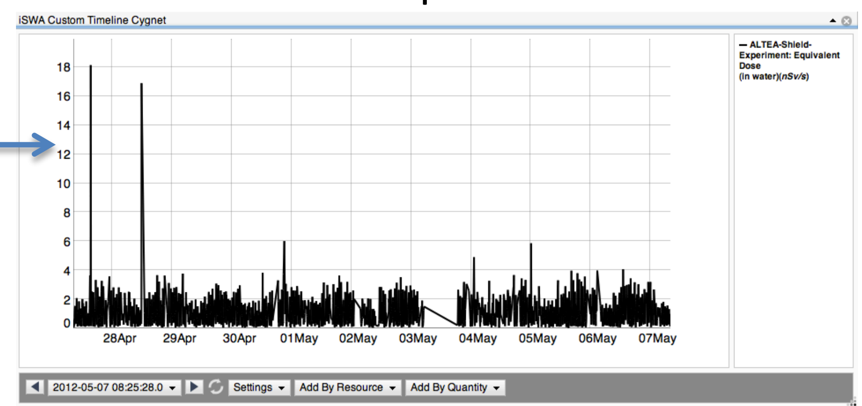
$$H_T = \frac{1}{m}\int_m dm \int Q(L)F_T(L)LdL$$



From LET



to Dose Equivalent



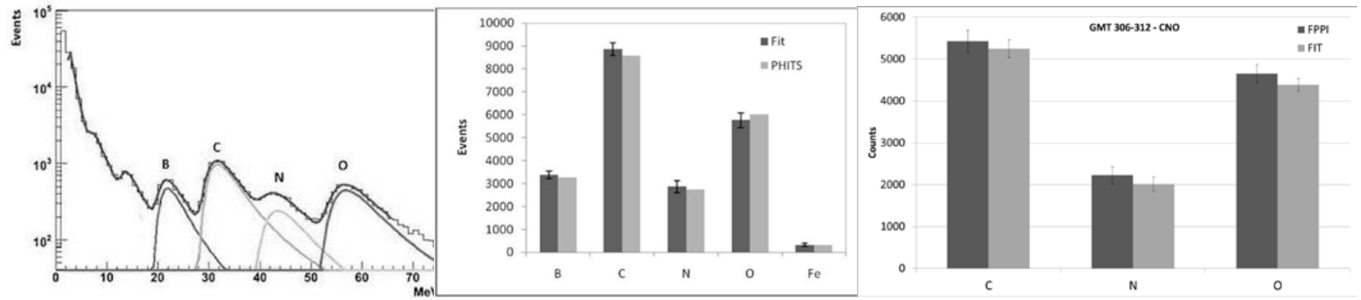
.. we can further estimate the important parameters for the radiation quality .....

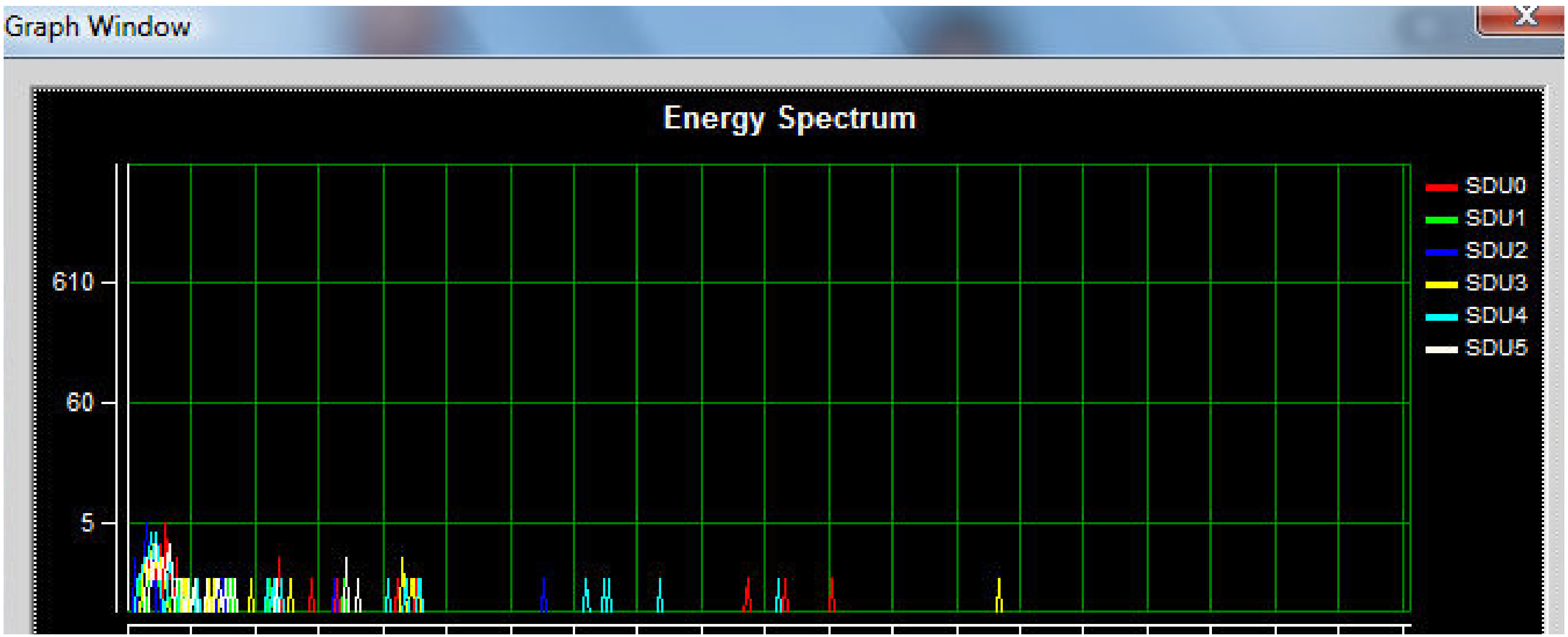
** Durante e Cucinotta Rev. Mod. Phys. 2011*

Background 4

Fast Probabilistic Particle Identification algorithm

… under improvement





Di Fino et al 2012 Adv. Space Res. In press

Background 5

So ALTEA has most of the ingredients to fulfill the tasks we mentioned before:

*New **small active** detector systems need to be developed delivering **optimised information of the radiation field parameters***

ALTEA already features:

- sensitivity to charged radiation *(missing most of the H, and part of the He)*
- real time detection
- real time software for a first analysis up to Dose equivalent
- large device and large angular coverage
- nuclear discrimination capability

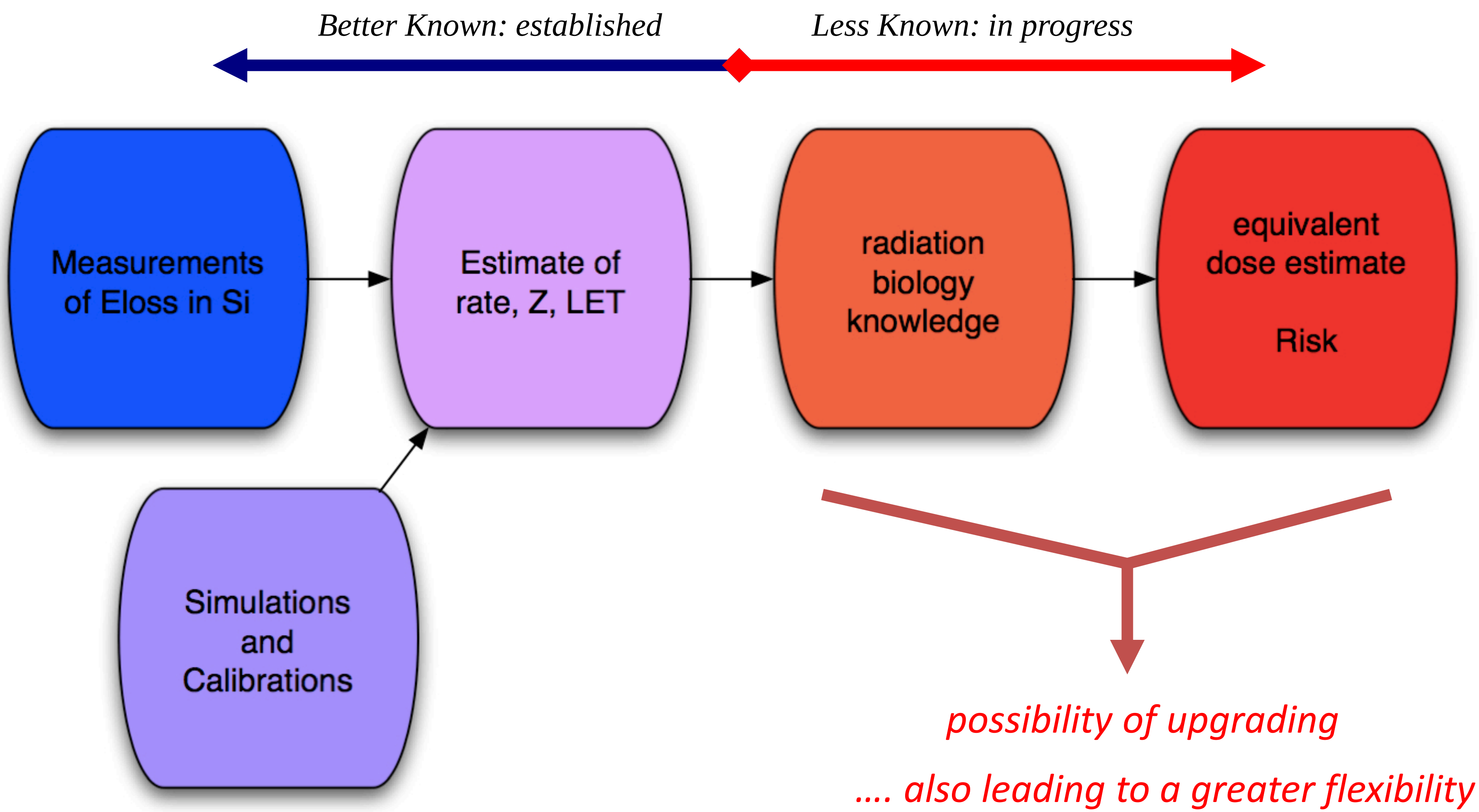
→ it can provide *all* information to assess risk from a *radiation quality* point of view

*We should therefore "squeeze" ALTEA into a **small** package, (not only ....)*

LORE: the logic

separate what is "established" from what is "in progress":

start with measuring Z/E_{in} and LET, then transform to risk



possibility of upgrading

…. also leading to a greater flexibility

LORE new ideas

The **new** ideas behind this devices are:

- provide information of **radiation quality** (about E_{in}, Z, rate) even in a small volume
- using a combination of sensing systems to optimize the performance /volume ratio

Developing new hardware

Can be tested on ALTEA first

- use ad hoc firmware (+ look up tables) to:

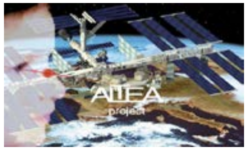
  i) perform **real time analysis** of the physical readings

  ii) transform **physical readings into risk** (discriminating readings/alarms for different organs)

  iii) produce alarms if / when needed

  iv) define / modify the **minimum set of critical data** to be shown to the astronauts

- allow for an **easy upgrading** of the firmware to follow improvements of the radiation biology understanding



LORE: a flexible Risk-Meter

Transform **physical readings into risk** can be first achieved with successive steps

- LET-based model for risk determination
- new risk model based on detailed radiation analysis (β, Z, rate, organs)

LORE *would become a* ***Personal Risk-Meter***

The whole procedure will be first independently tested on ALTEA

ALTEA *would become an* ***Area Risk-Meter****

** with some shortcomings .. but we are working to eliminate them*

LORE and AMORE

• This Risk Meter will be also a needed instrument to facilitate the migration from Earth Control Centers to the Crew in space **of the decisional processes about radiation** (both in routine and in emergency) *{needed during the far interplanetary voyages}* :

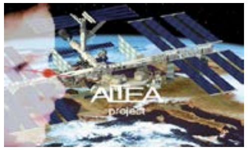
AMORE (Autonomous Monitoring Of Radiation Environment (ESA CFI 2010)

LORE ⟷ AMORE

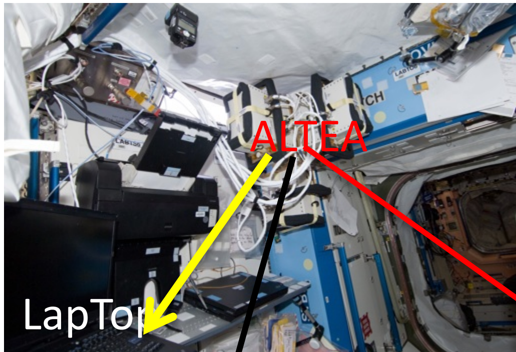
• The information **set** provided directly at the crew by the LORE detector should be the ***minimum set of critical radiation data*** needed to take all the related decisions.

To define this set a close collaboration with *operation- and medical-offices* will be set up.

All preliminary work can be done on real time ALTEA data on ground and then tested in orbit, before implementing it in LORE.

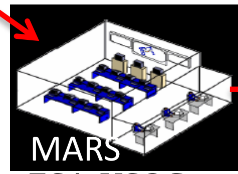


Data routing and need for additional re-routing

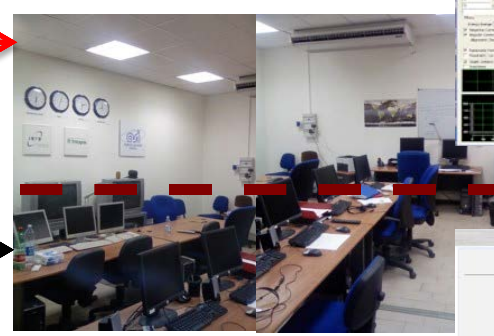


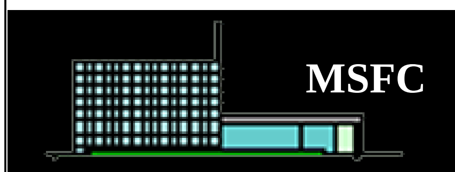
All Scrambled data

REAL TIME



ESA-USOC



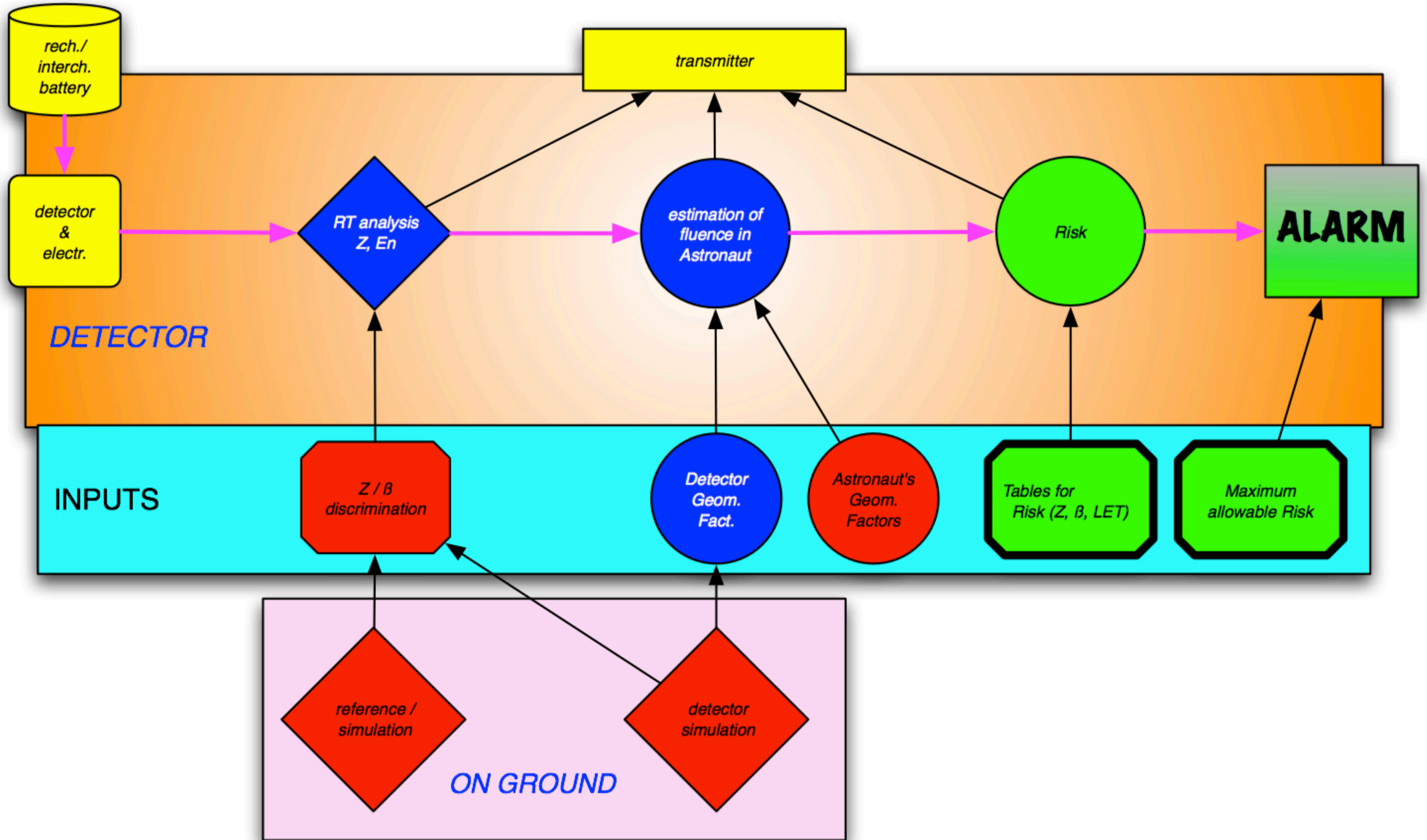


All sequential data

Paylod Operations Integration Center

QUASI REAL TIME
(≈ 5 - 24 h)

LORE: software and risk estimate flow chart



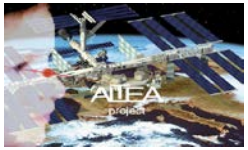
LORE: the physics 1

We propose to utilize as sensors two types of detector layers:

• the first based on **square scintillating fibers** (from .2 to 3 mm , 4% cladding material) ordered in a plain layer, read out by an array of SiPM (SFL).

• The SiPM signal is acquired by an integrated multichannel preamplifier, containing a charge signal sample and hold plus the multiplex and an array of comparators with variable threshold to generate the trigger signals.

• The second is a **single element crystal/silicon** read out via an hybrid electronic element giving the charge measurement in semi-logarithmic way (multiple step gain) and a high threshold trigger signal (SiL). The necessity of hybrid solution is due to the very high dynamic range necessary.



LORE: the physics 2

The characteristics of the two layers allow very powerful particle identification:

• The **scintillating layers** accomplish the goal of **trace position acquisition** even in case of a minimum ionizing particle thanks to the high gain of SiPM sensitive to single photon charge (this allows a very simple preamp electronics). Also the triggering properties are very effective. The disadvantages are the limited dynamic range of both scintillating material and SiPM.

• The **crystal/silicon** has an extremely **large dynamic range** and moreover is simpler to implement thin surface deposition layer to protect (passivate) the surface from the environment and to cut the light. This is a major concern due to the minimum energy particles to be detected (below 10 MeV/n). The disadvantages are the sensitivity to interference noise at low charge release (require a high integration time preamplifier) avoided in the SFL by the avalanche gain of the SiPM.

The minimum number of layers necessary are **four SFL and four SiL**. The four SFL give two X Y measurement necessary for the angle correction. The eight layer give the charge measurement in the various range of energy and the trigger signals for the DAQ logic. The overall thickness of four minimum layers is of the order of 2 mm.

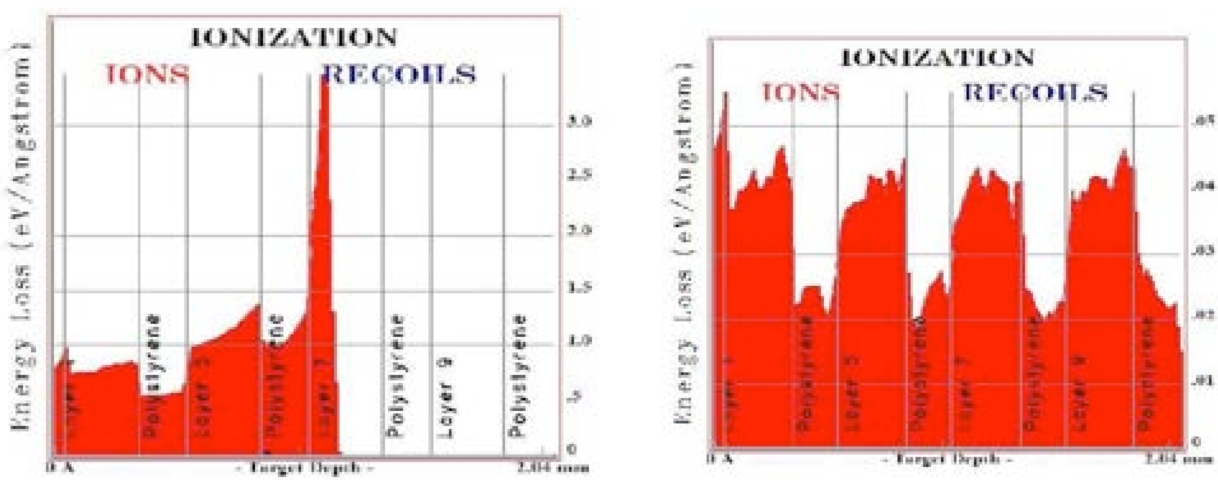
LORE: the physics 3

The following range of energy are to be measured:

1 Minimum Particle energy range. The charged particle stops internally to the SiL detector (Bragg) with the largest charge released. Minor errors due the saturation of the SFL. Triggers from SiL.

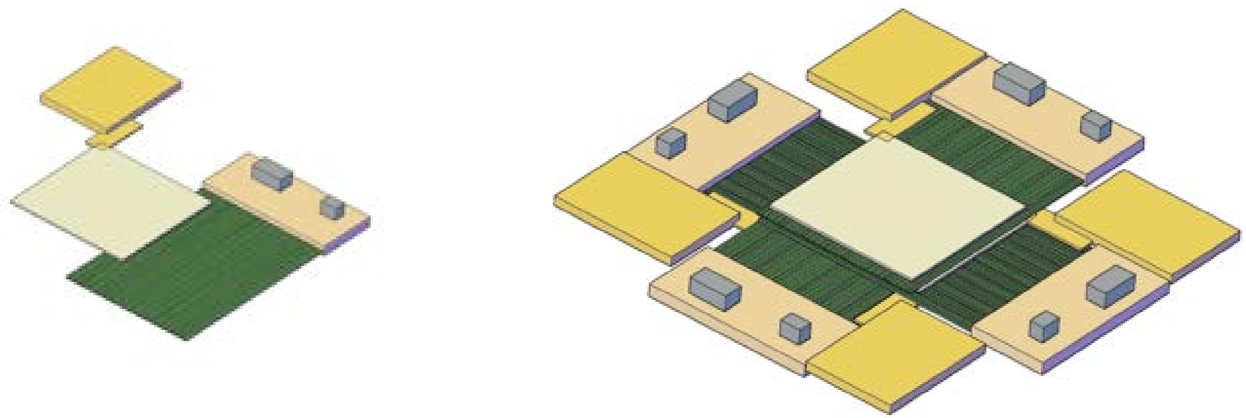
2 Intermediate Particle energy range. The particle is far from the minimum but crosses all the layers. Four charge measurement in SiL and position and trigger from SFL.

3 Minimum ionizing particles. Till ≈ Carbon the SFL give accurate measurement, over the Carbon the SiL shall measure the charge release. The SFL give the trigger.



Energy released in the device by a minimum energy particle (left) and minimum ionizing particle (right), Z = 1

LORE: the physics 4



Possible simple drawing of two layers (SiL + SFL) and SiPM and of a complete 8 layer apparatus (4+4)

Available technology

- The technology of SiPM with the collaboration of IRST in Trieste
- The SiPM preamplifier chip and silicon preamplifier from INFN
- The silicon and fiber technology from INFN

LORE features, summary

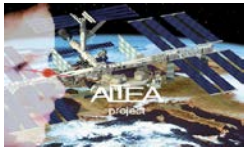
The device will therefore feature:

- small size (≈ cigarette box)
- detection from H to Fe { n? γ?}
- **“up-to-date” dosimetry** (e.g. **discriminability in Z/E_{in}** and LET)
- translation of physical parameters into risk: ***RISK-Meter***
- correct information needed to increase **crew autonomy**
- **“upgradable”**
- monitoring radiation/dose in Real Time
- dose - alarms
- WiFi

And will be of use

- in the ISS
- in future space vessels
- in the Moon and Mars Bases
- during EVA
- in *several instances on ground*

- develop a complete phase A
for the sensing elements of LORE,
for the integration with the firmware,
for power and transmission (WiFi) systems



ALTEA the international team

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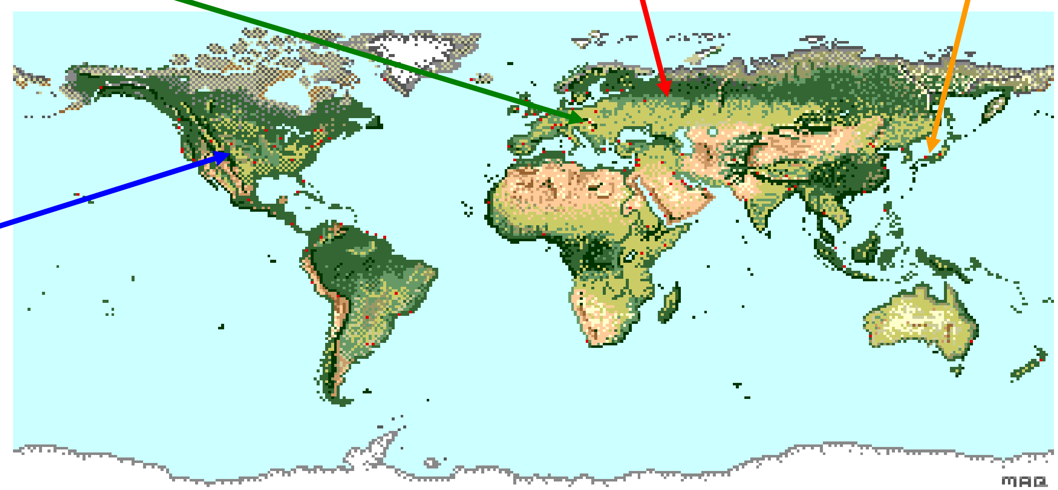
Eril Research, CA, USA



+ others joining in

Thank you for your attention