TOR VERGATA
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Dipartimento di Fisica

HSERLAB
Human Space Exploration Radiation LAB

# MAM: Modeling Aided Measurements

a new vision for evaluation of the radiation environment in a space habitat

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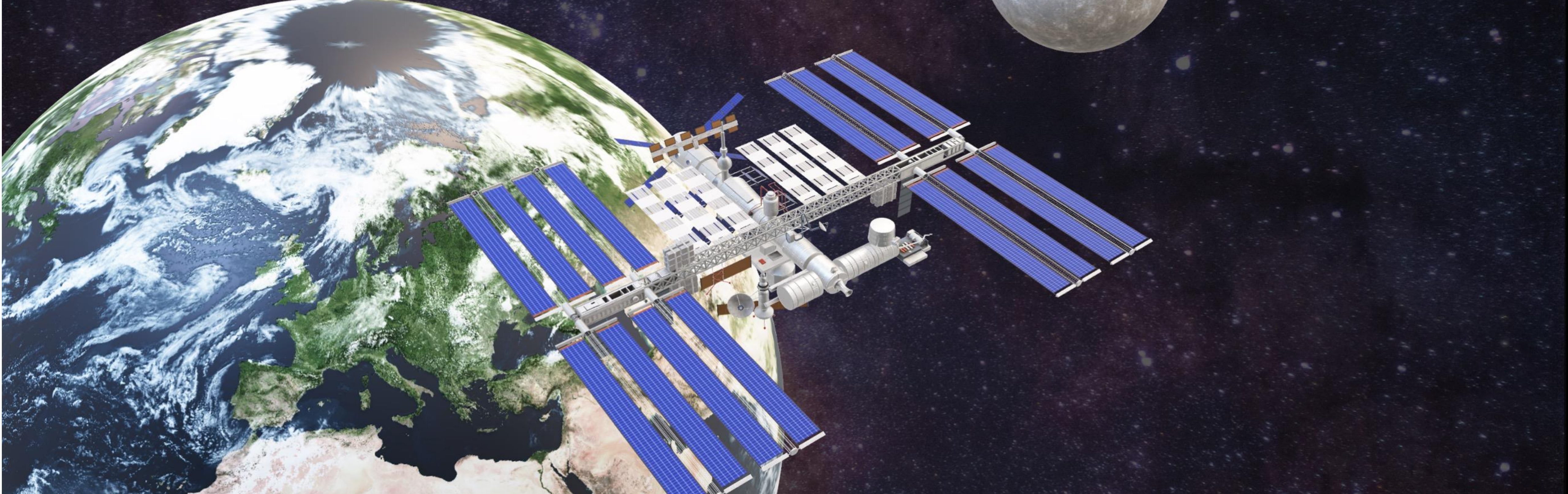


# RATIONALE



*This is 'just' an idea presented here to discuss its feasibility and usefulness*

We have seen that

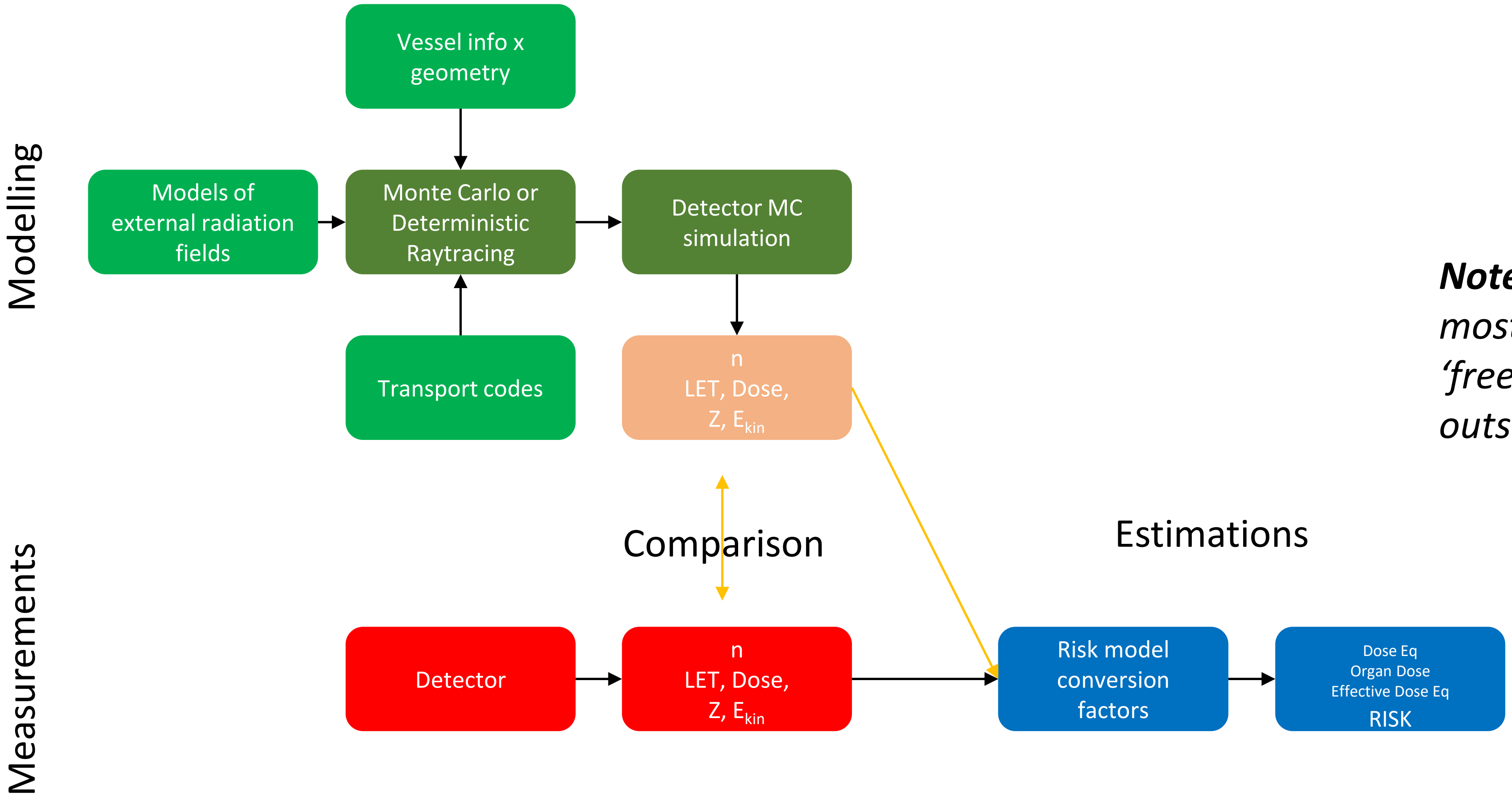
- We do NOT have detailed knowledge of the radiation in a vessel (ISS):
  - radiation values in the same modulus can differ by factors (2 – 4…6)
  - a relatively small number of measurement sites can be provided

→ Use modeling to support extrapolations of the measurements, eventually in real time

# MEASUREMENTS and MODELLING



One of the reasons to measure ISS radiation environment: validate models!
We sometime do it, but we do not exploit it in a space habitat.




***Note**: this comparison is most often provided for 'free space' or also outside the vessel in LEO*

# ACCURACY/DIFFERENCES OF THE MEASUREMENTS



In general the measurements are quite accurate

- The accuracy is most often pretty high (statistics … ≈ few %)

- Measurements are reported often in a complete way (instrument, position, time … etc) but also referred in simpler ways (e.g. 'radiation in Columbus' …)

- Differences in radiation measurements in the same modulus are well known, and ascribed to local shielding, far away directional shielding, detectors fields of view and energy windows

- These differences can easily cause discrepancies in radiation measurements up to a factor 2 (up to a factor 6 in some cases)

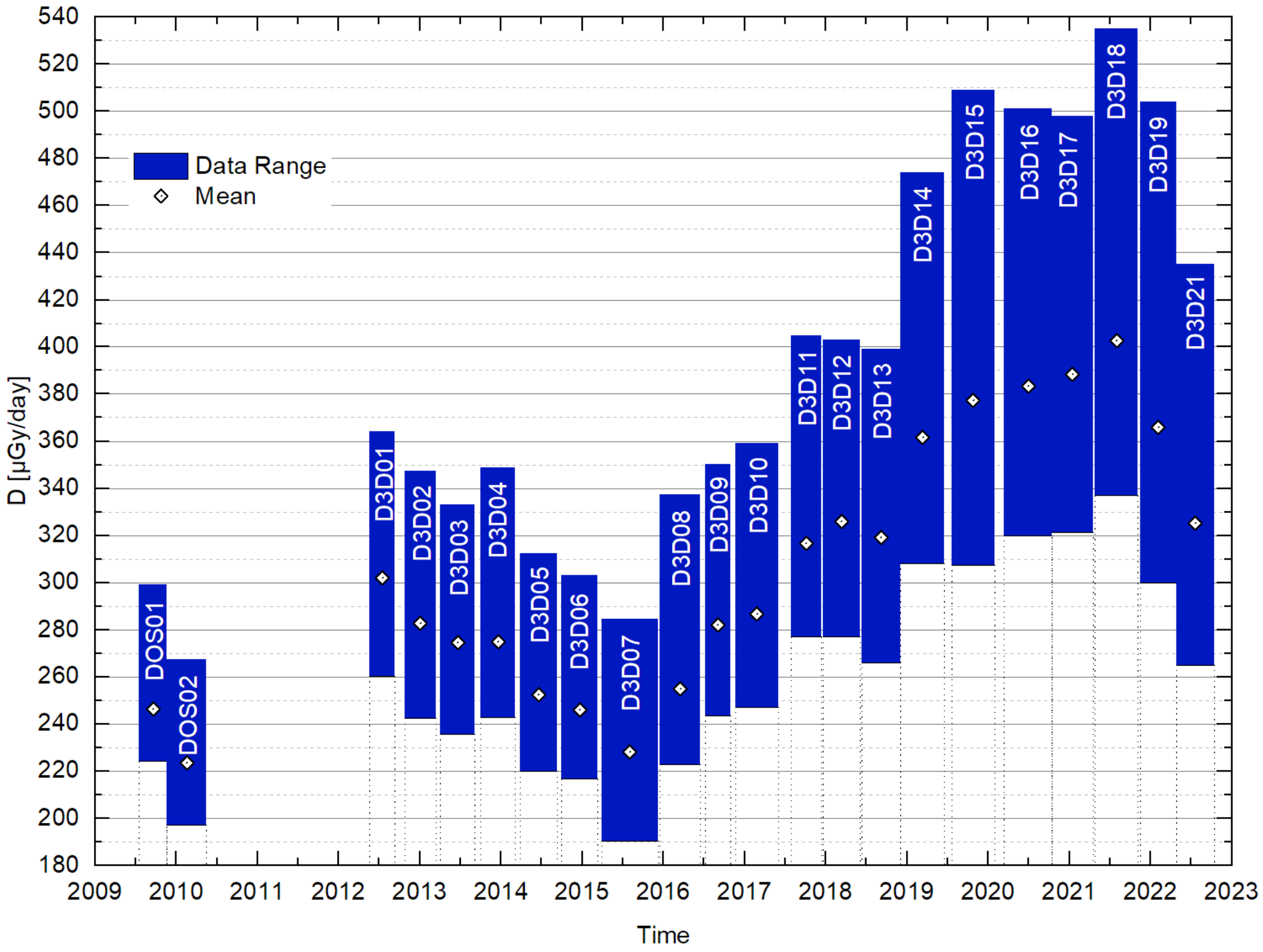
- Beside the uncertainty in the detailed knowledge of the radiation in the ISS this may affect also radiation-linked Bio/Physio experiments, as well as full usability of models in a space habitat

- This MAM idea is to solve/mitigate this problem exploiting all the information we have about radiation in the ISS

Let’s give a look at those differences

# DIFFERENCES IN THE SAME MODULUS



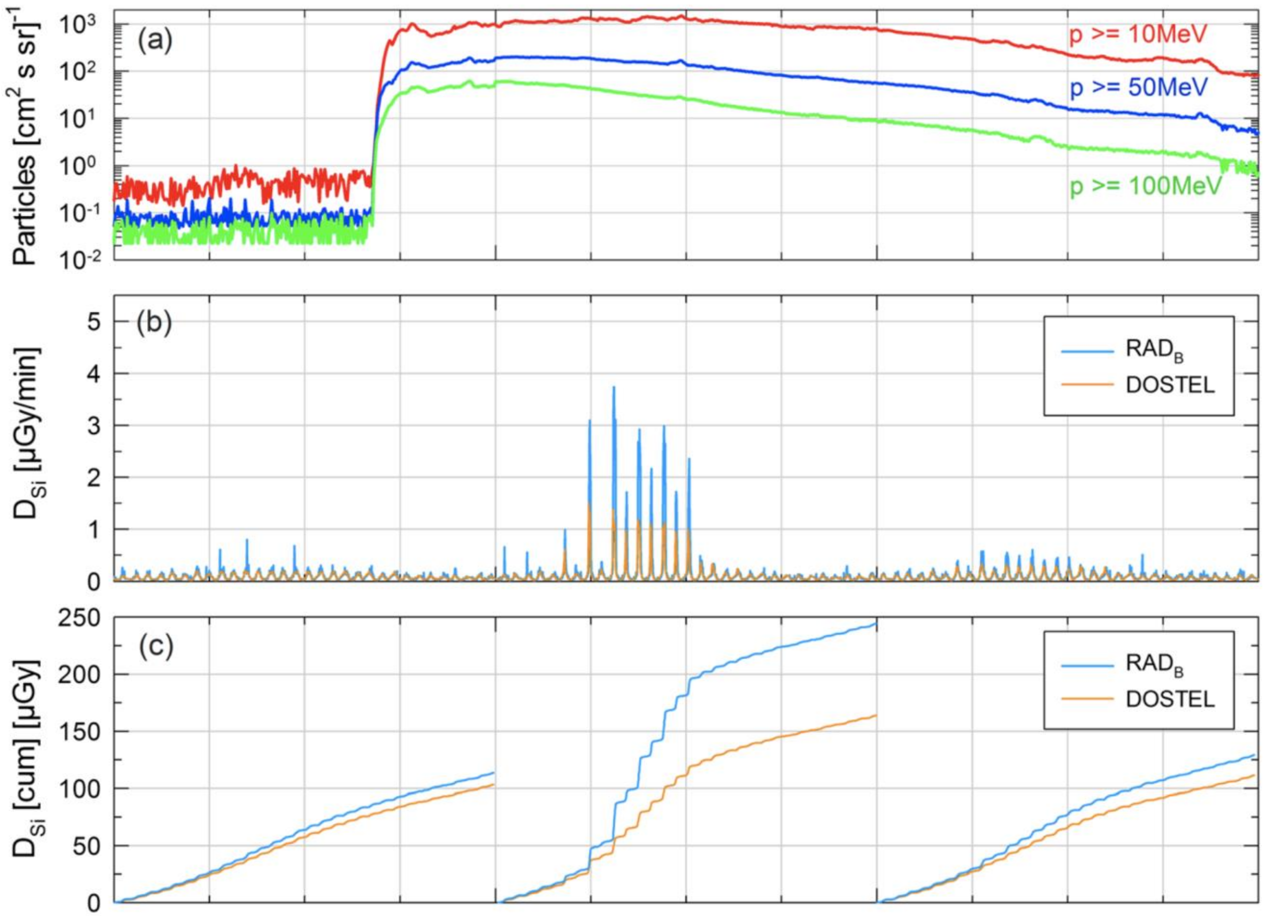



DOSIS3D

# DIFFERENCES IN THE SAME MODULUS



- The SPE of September 11 2017 seen by 2 detectors in Columbus




September 10

**ISS-$RAD_B$ : 113.6 μGy/d**
**D3D D-2: 103.7μGy/d**

September 11

**ISS-$RAD_B$ : 244.3 μGy/d**
**D3D D-2: 163.8 μGy/d**

September 12

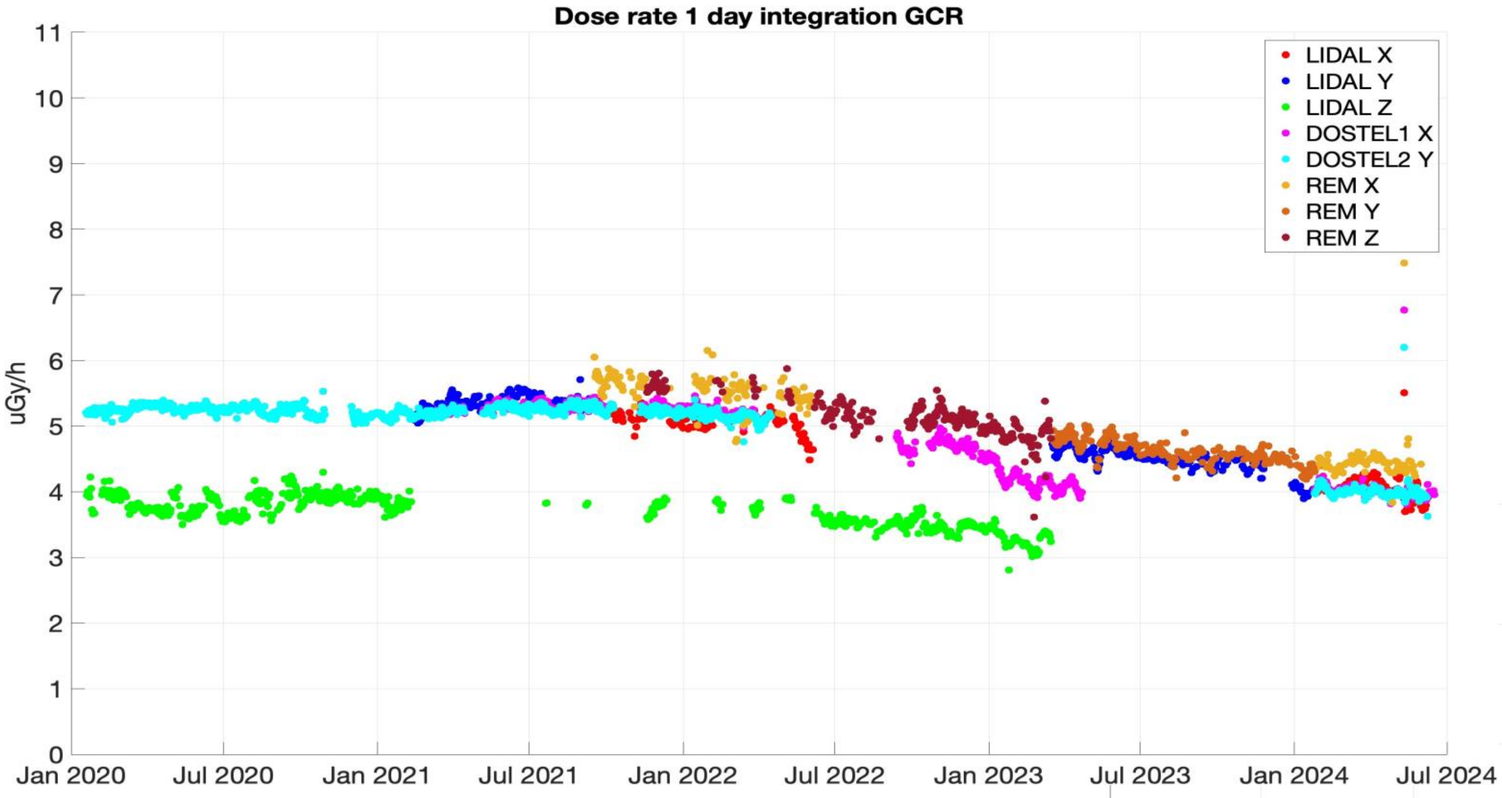
**ISS-$RAD_B$ : 129.1 μGy/d**
**D3D D-2: 111.4 μGy/d**

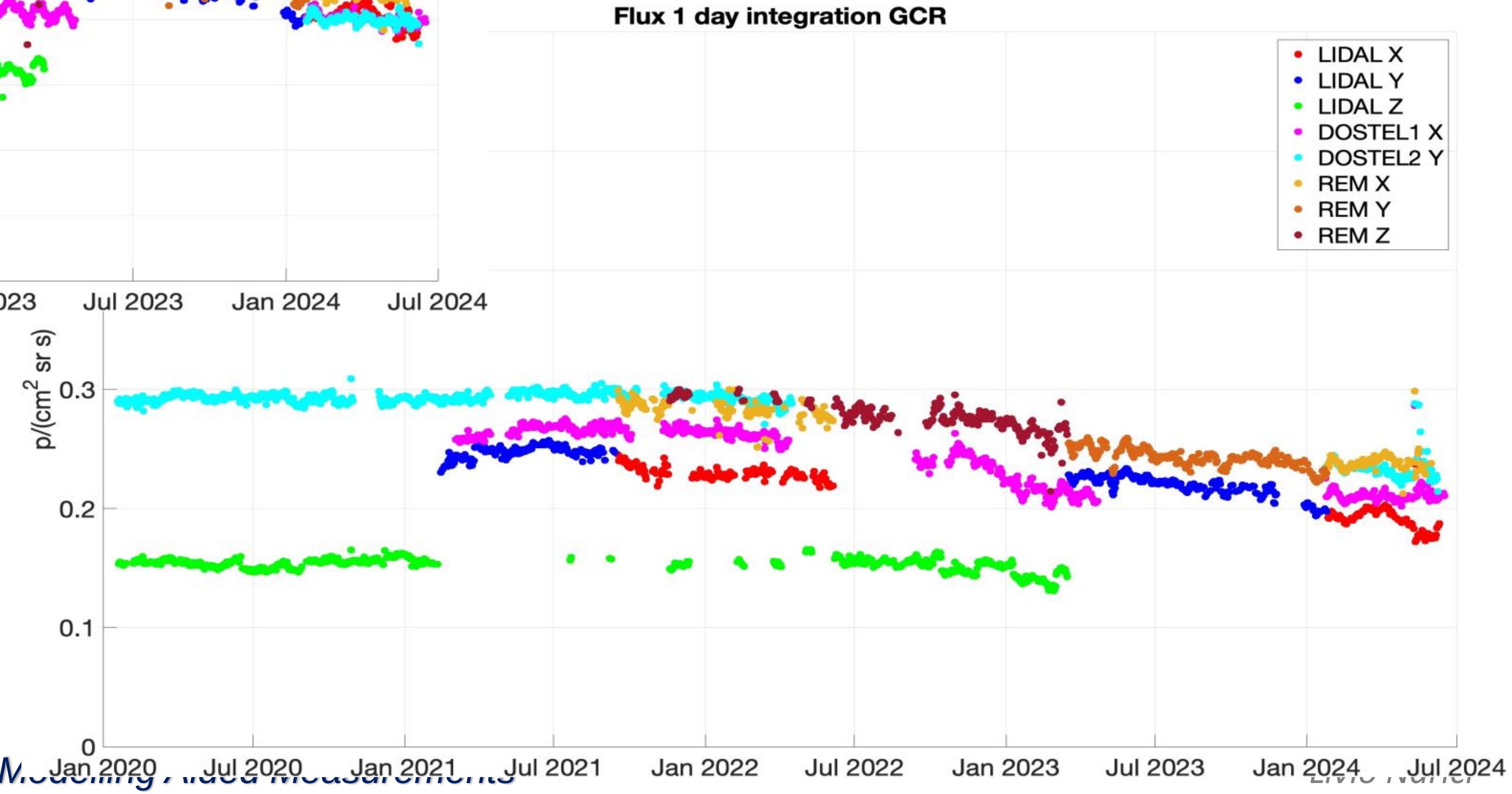
A factor ≈ 2 difference explained by local shielding differences

*Berger et al Space Wea. 2018*

# DIFFERENCES IN THE SAME MODULUS





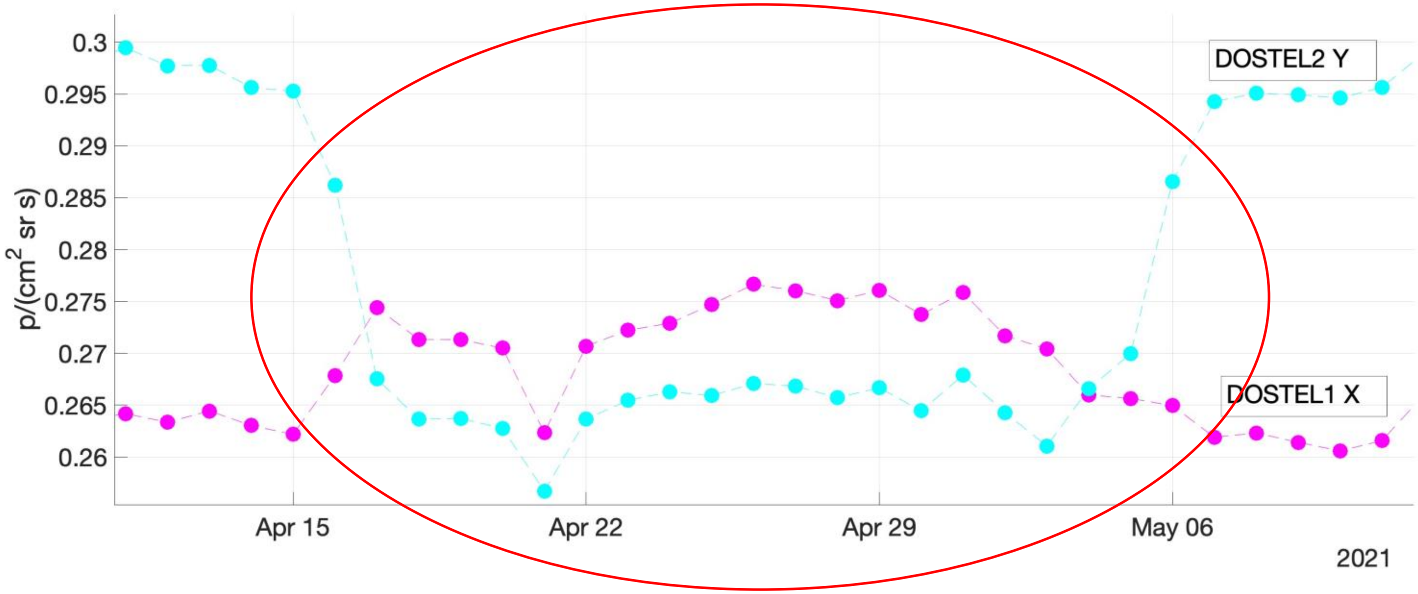



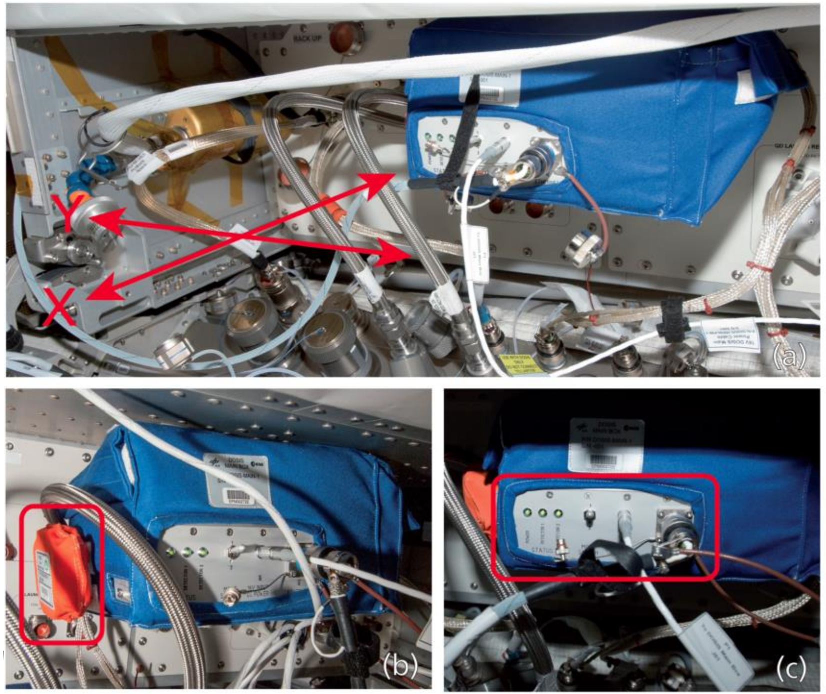

The DORELI studies provide further evidences of these known differences

# DIFFERENCES IN THE SAME MODULUS



- Some data you will not see in the DORELI results




In spring 2021, for about a week, DOSTEL 1 & 2 were hold just by the cables: floating!

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# DIFFERENCES IN THE SAME MODULUS

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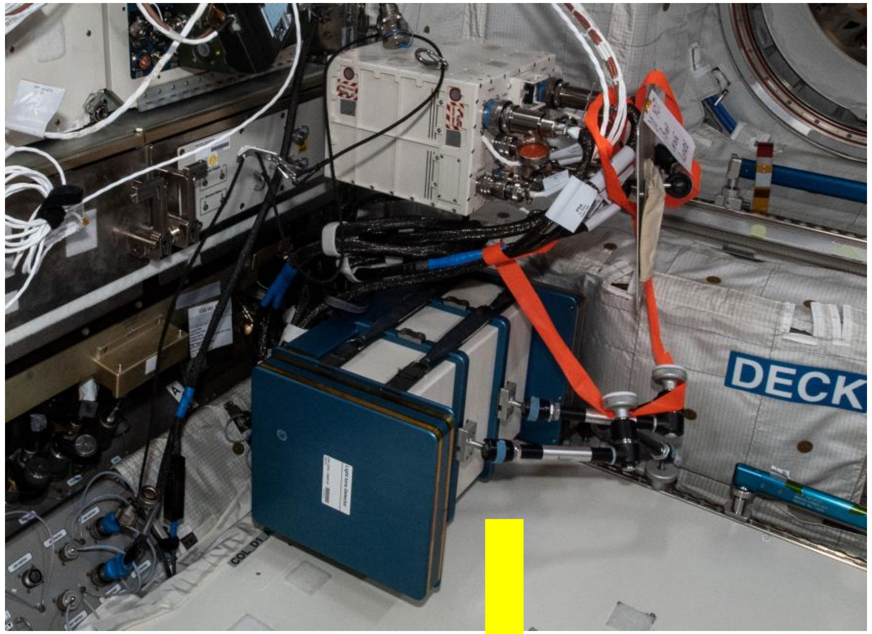
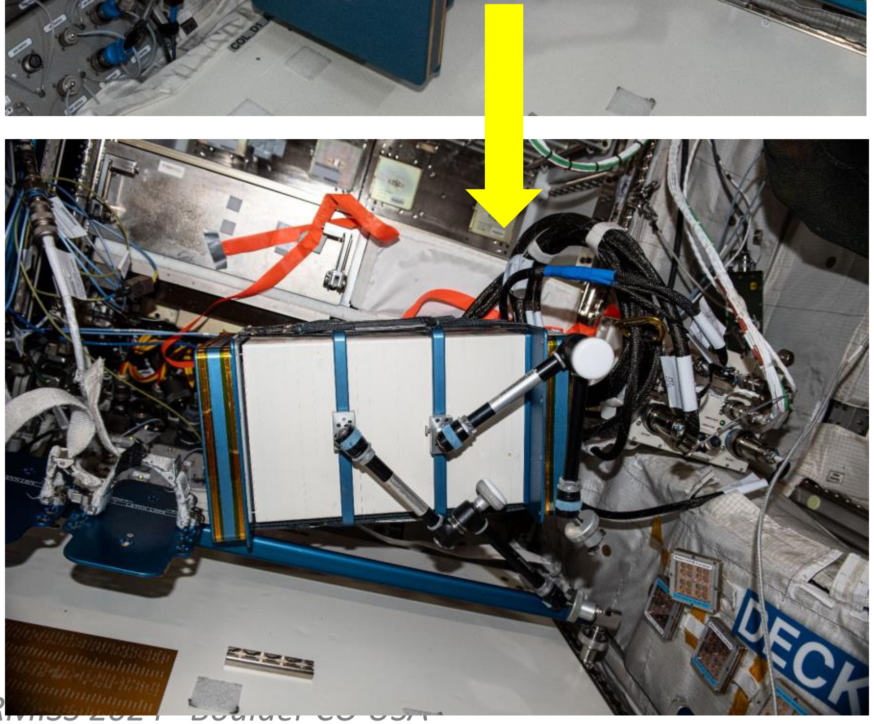
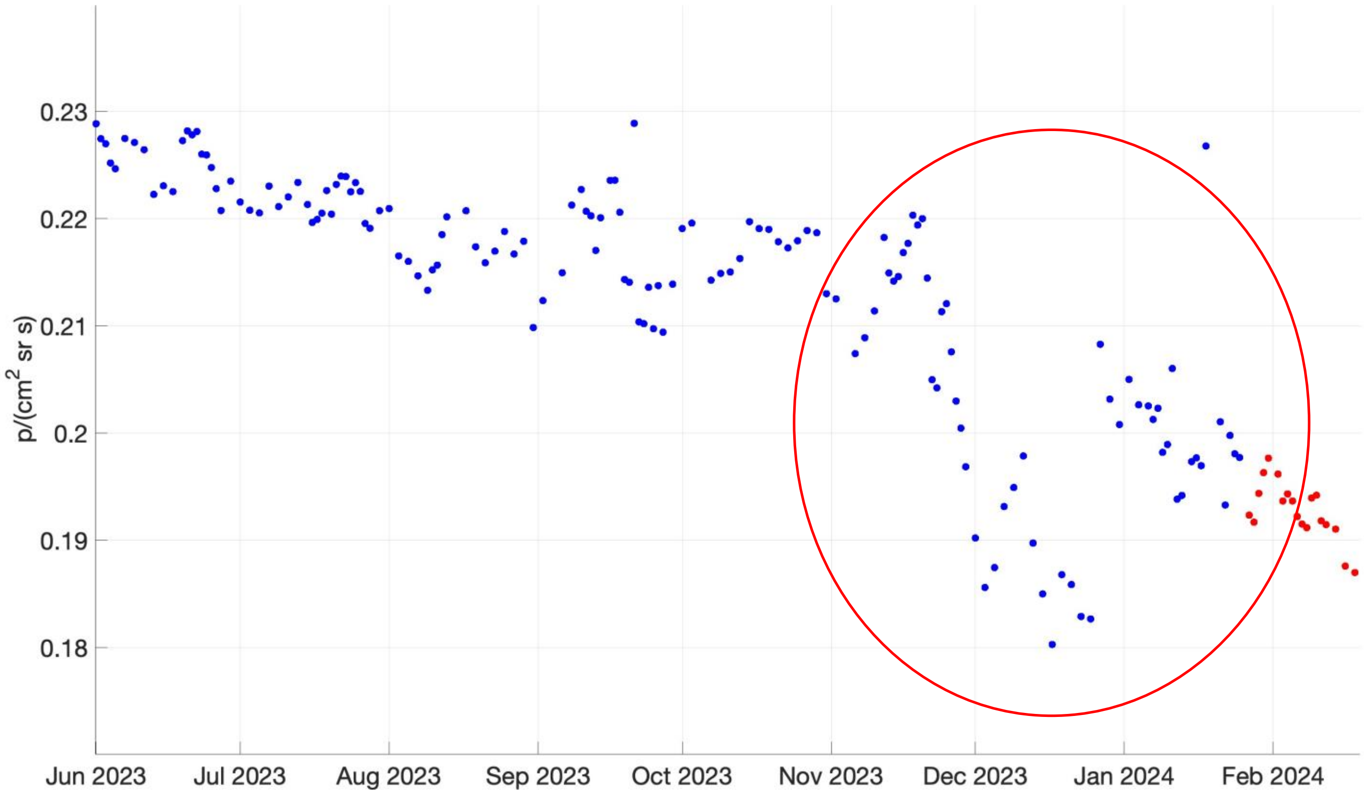


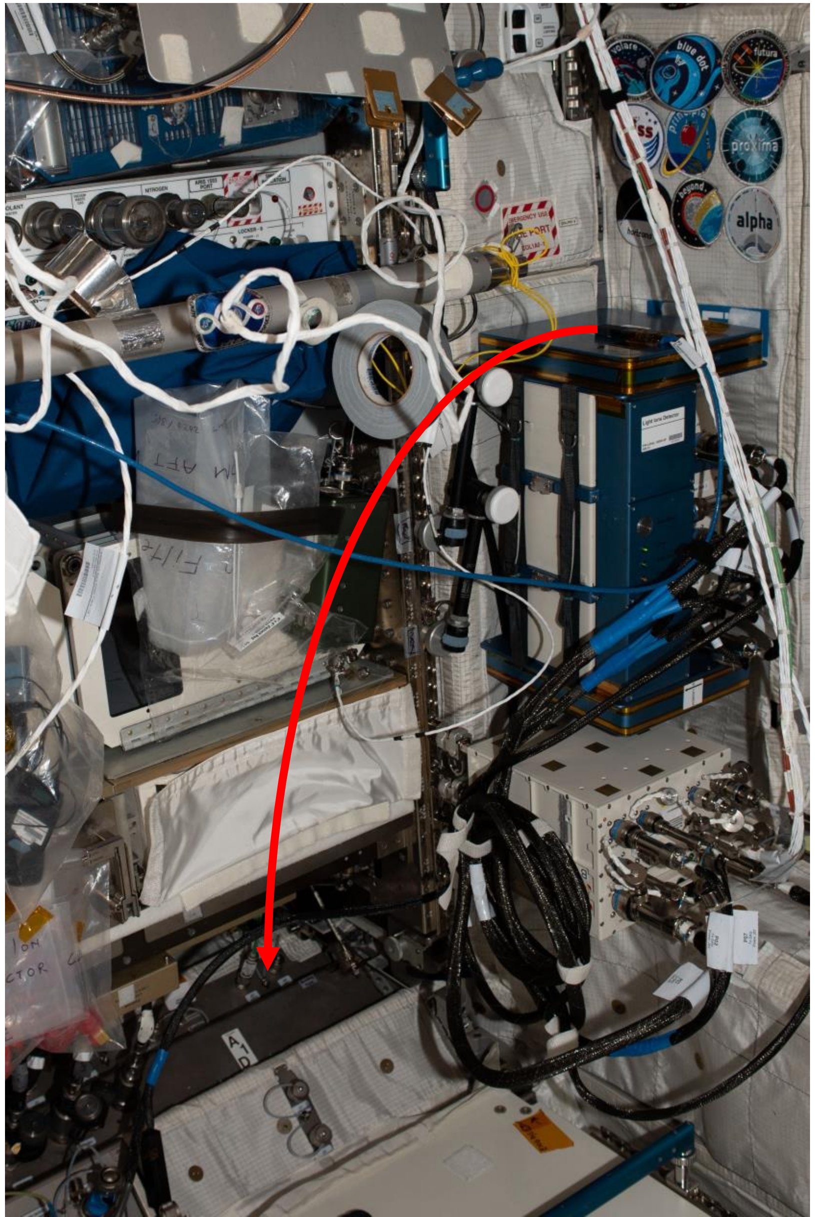




At the end of 2023 LIDAL went through a similar problem

# DIFFERENCES IN THE SAME MODULUS



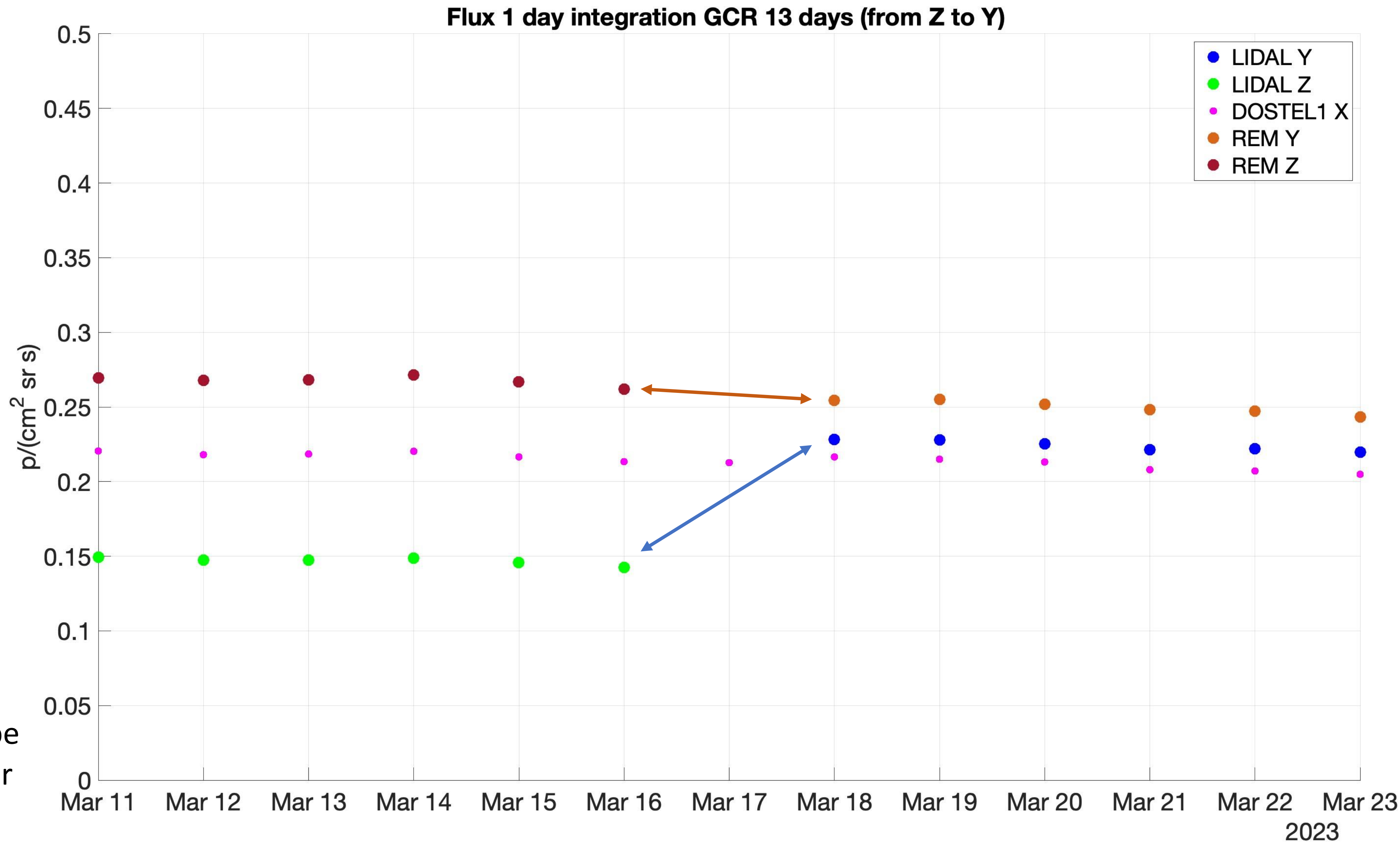
In the movement Z – Y REM not only rotate, but also translates of about 0.7  m



# DIFFERENCES IN THE SAME MODULUS



Going from Z to Y
Looking at GCR
For REM: no difference
For LIDAL: jump




Note:
LIDAL: narrow FoV telescope
REM: → ‘*spherical*’ detector

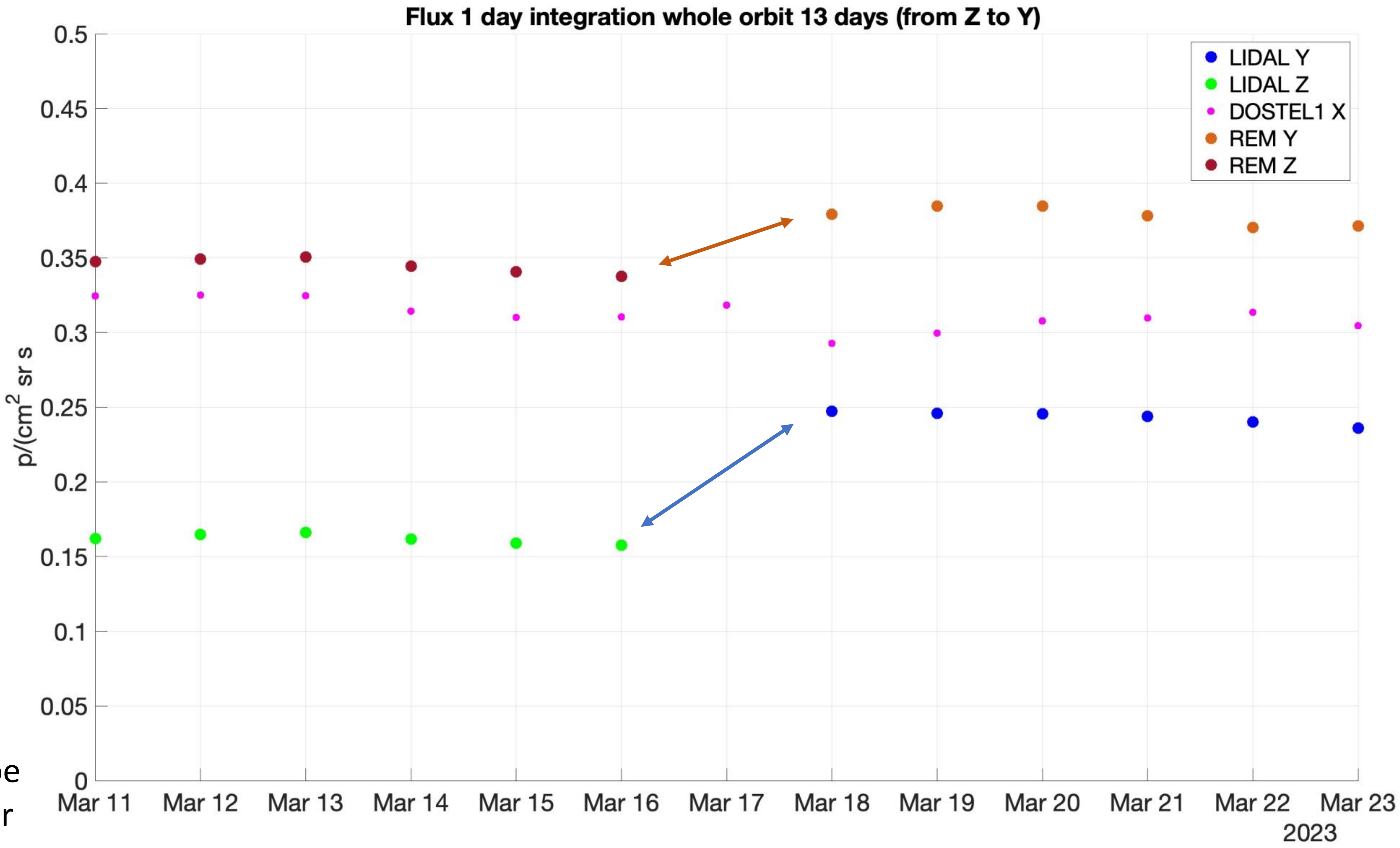
# DIFFERENCES IN THE SAME MODULUS



Going from Z to Y
Looking at whole orbit (including SAA)
For REM: jump
For LIDAL: jump

→ Local shielding

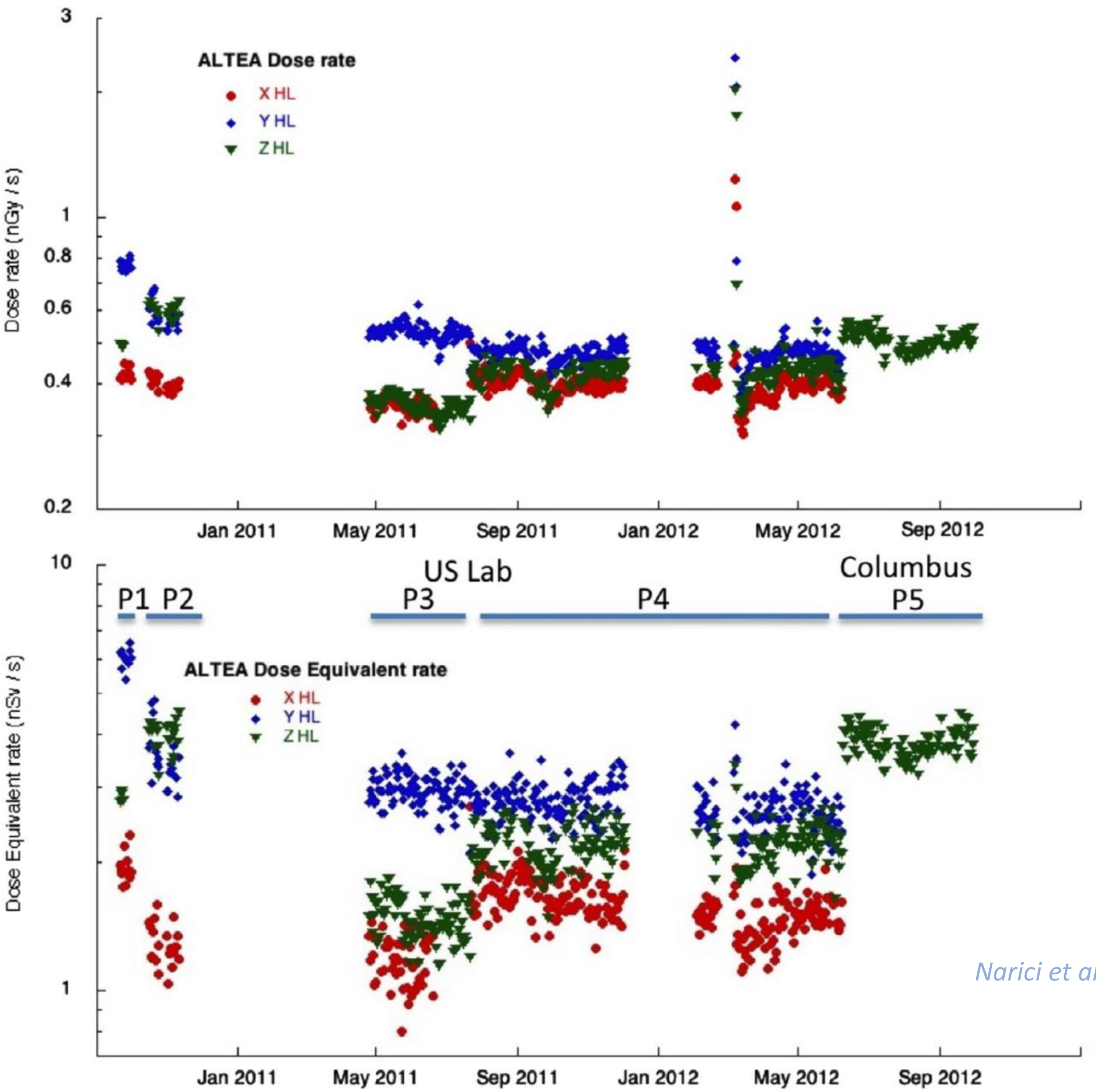
Note:
LIDAL: narrow FoV telescope
REM: → '*spherical*' detector



# DIFFERENCES IN THE SAME MODULUS



ALTEA telescopic 3D system shows the quite different shielding along the three ISS directions




*Narici et al JSWSC 2015*

What can we do about it? (if we should do something … )

# SUMMARIZING AND GOING FURTHER



1 we have a quite good knowledge of the radiation in the measurement sites and times (very small uncertainties, with a specific instrument)
2 we do NOT have good knowledge of the radiation environment of a randomly chosen site/time in any modulus (say within ≈ ± 20-200%)

Q1: do we care? Or … who cares?

3 we have (many) models able to provide radiation evaluations inside a spacecraft, when used together with geometry (CAD), Monte Carlo, ray tracing …

4 There are a few validations with measurements in an habitat → the validations have the same limitations as the measurement: in that site, time, with that instrument

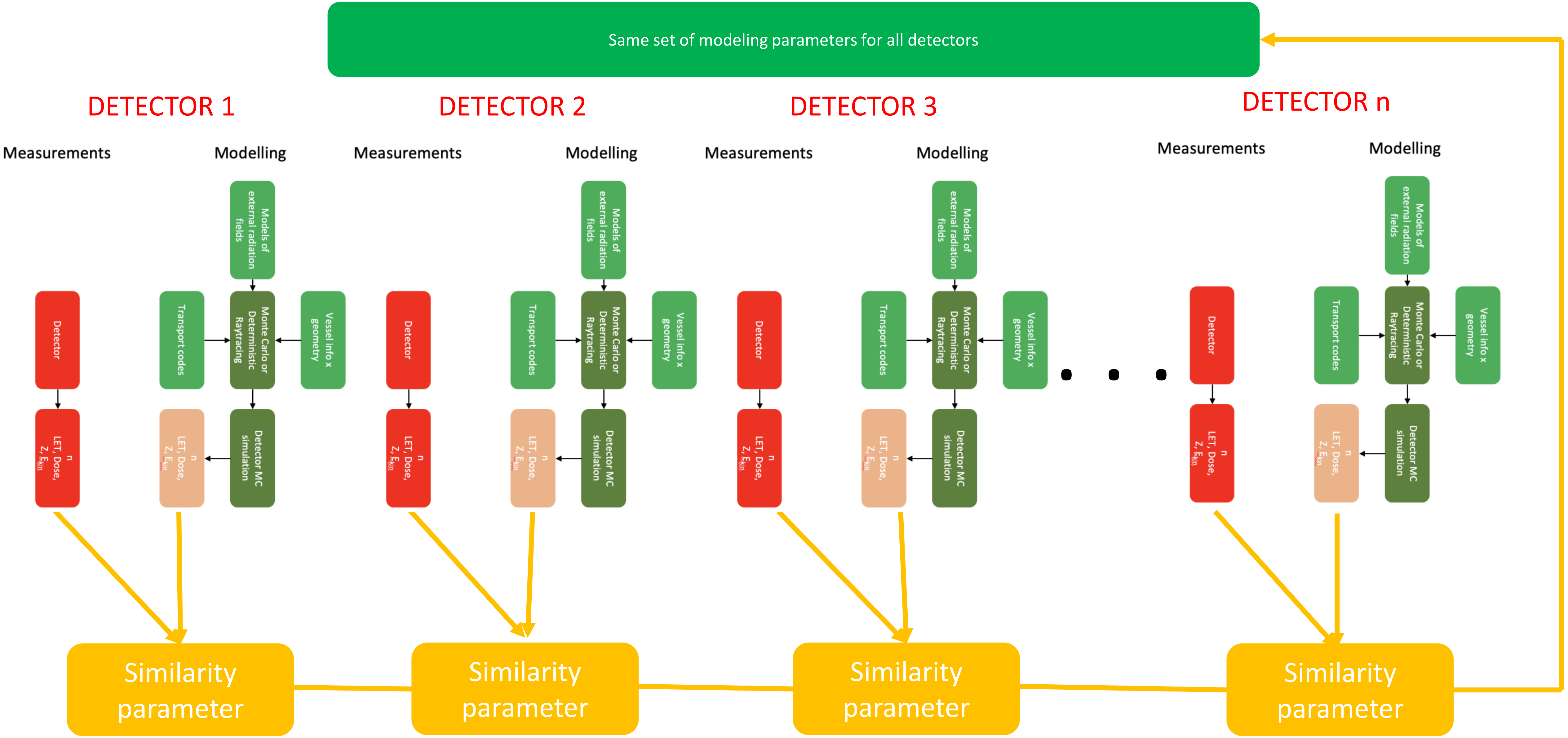
Q2: do we care? Or … who cares?

→ We should exploit both worlds, measurements and modeling, performing 1, 2 and 4 <u>for many detectors sites/times</u>, <u>using the same models and models parameters.</u> The combination of measurements and modelling surely provides many added values!

→ 'Virtual Detector'

# MAM: ALL MEASUREMENTS + MODELING

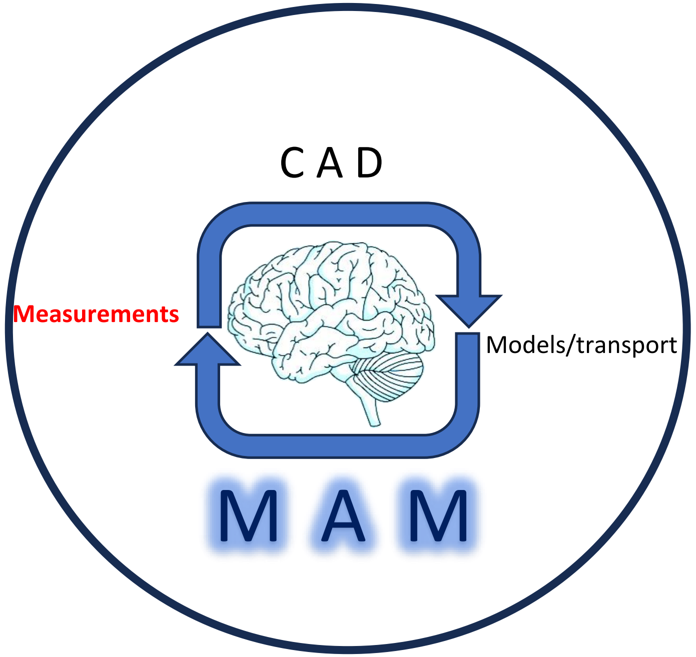




# MAM: ALL MEASUREMENTS + MODELING



MAM could be performed in real time in a vessel, in an eventually all-connected-detector-system




- As many **measurements** points as possible (of any variable)
- Geometry of the habitat (**CAD: Computer Aided Design**) (in time)
- Models of the **sources and transport**

**MEASUREMENTS**
**+**
**GEOMETRY (CAD)**
**+**
**MODELS**

***Modelling Aided Measurements***

knowledge of the radiation field
At any point
At any time
… possibly in real time

→ ***'Virtual Detector' (1)***

# MAM PROJECT APPROACH ON THE ISS



**Feasibility**

1) Select 3-4 detectors in the ISS
2) Provide complete information from those detectors (data in a defined period + metadata)
3) Use models + geometry to provide field estimations at the same sites & times
4) Compare measurements results and models estimation, calculate similarities
5) Perform optimization of the models to maximize overall similarities
6) Use 1 detector less, repeat (1-5), evaluate the model results at the site of the not used detector
7) Study the found discrepancies, if needed go back and improve

**Full project**

8) Increase the number of detectors to N
9) Repeat (2-7) [using in (6 to 7) m detector less, m<<N]
10) Increase the number of detectors to all the available
11) Repeat (9)

**Go real time**

12) Optimize the algorithms in (3-5) to work in real time using AI techniques
13) Test the optimized algorithms on (10)

**Go in space**

14) Select on ISS detectors who could provide real time outputs
15) Test on the ISS

# USE of RadLab



Of course RadLab can be the backbone tool for all this, providing handy data and metadata to perform all points on ground (points 1-13).

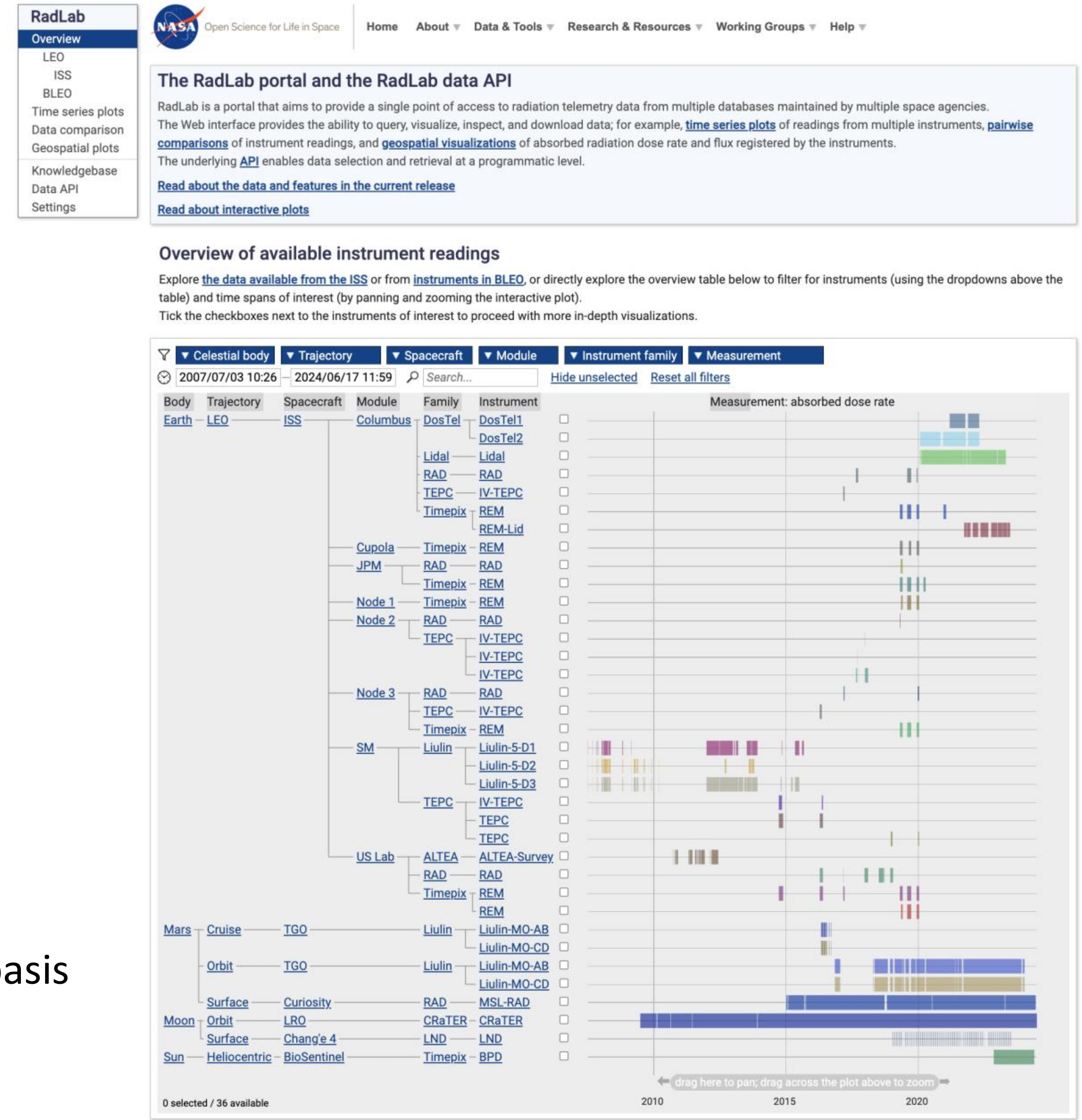
*2 major points to be faced and solved:*

1) Single coordinate reference system for ISS geometry & for all detectors (detectors' coordinates should be added to the RadLab metadata)
2) All detectors must be 'Monte Carlo simulated'

*First step:*

• **'Modelers' have to feed their estimations (point 3) into RadLab as new 'measurements'**

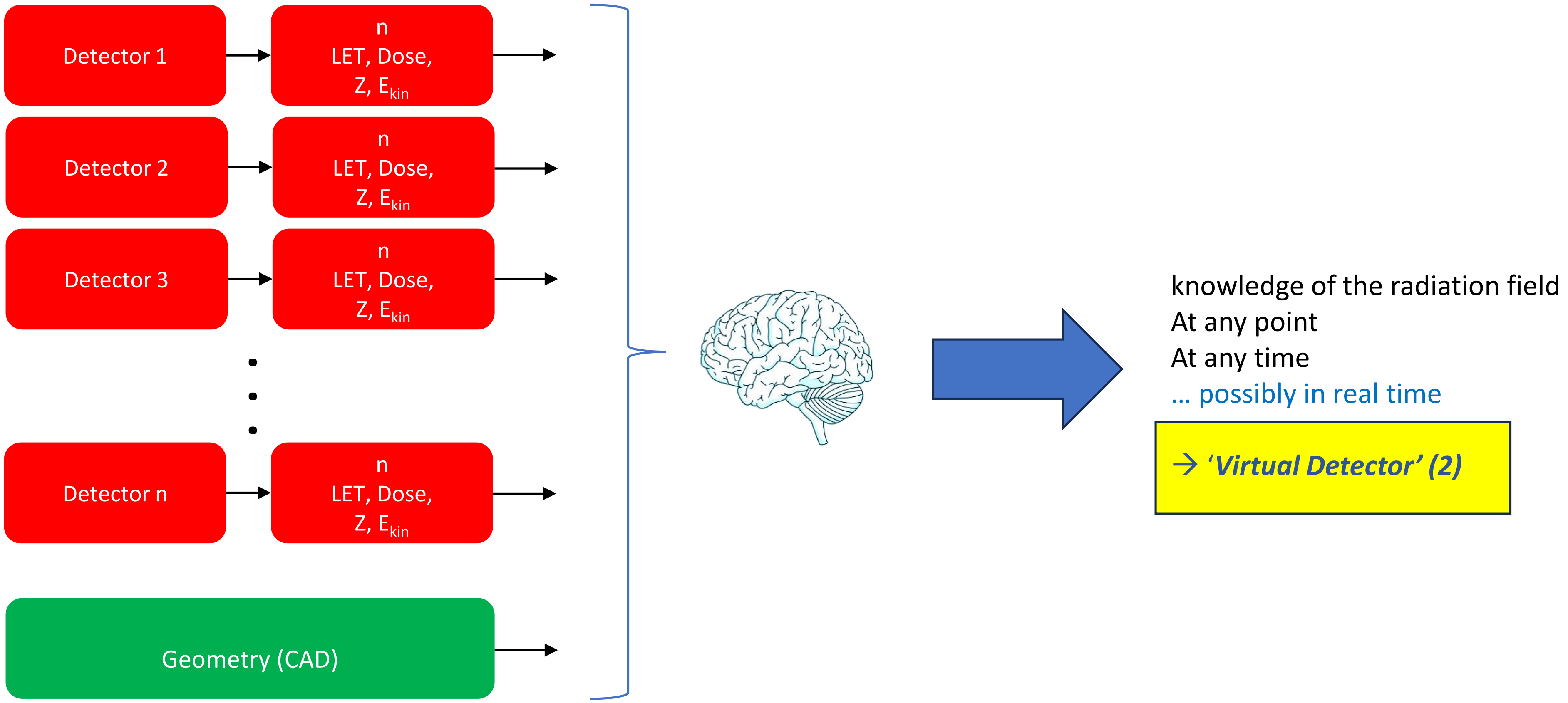
NOTE: what is done for the ISS could be done for all vessels and basis



# MAM to AIM (Artificial Intelligence aided Measurements)



- A further step, a maybe a possible, far fetched, 'Virtual Detector (2)' realization:




→ 'Virtual Detector (1)' must provide training & validating data

# Thank you for your attention