Data exploitation of new Galileo environmental monitoring units

ESA Contract No. 4000119253/17/NL/LF/hh

I. Sandberg (SPARC)

GALEM team

- **SPARC**: I. Sandberg, G. Provatas , S. A-Giamini, A. Tsigkanos, C. Papadimitriou
- **University of Surrey**: K. Ryden, A. Hands
- **DH Consultancy**: D. Heynderickx

ESA: D. Rodgers, H. Evans

Kick-Off: February 2017
Expected project closure: April 2019

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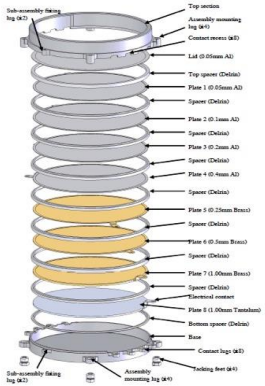
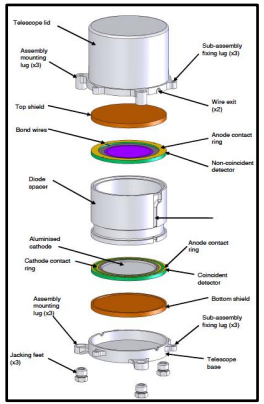
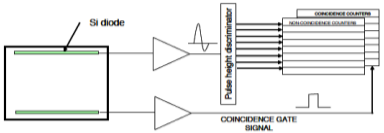
Environmental monitoring unit

- Designed for use in the Galileo orbit
- Built by RUAG, Switzerland
- Design based on the heritage of the SURF, CREDO and Merlin developed by QinetiQ UK.
- Size: 72 H x 182 W x 242 L mm^3

- SURF: current collecting plates
  - Ee= 0.1-10 MeV
- Proton Telescopes
  - Ep=20-100 MeV
- Heavy Ion Telescope
- RADFETS (4)







Main Objectives

- Calibration of EMU sensors
- Derivation of EMU charging currents/fluxes/doses
- Galileosats/EMU database (ODI)
- EMU data service
- Validation of radiation environment models
- Update MOBE-DIC model

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Galileosats

In the Galileo constellation, two EMUs are currently flying in two different orbital planes.

- FOC FM07 (Galileosat 15, Antonianna), launched on 17/11/2016
- FOC FM15 (Galileosat 19, Nicole), launched on 12/12/2017

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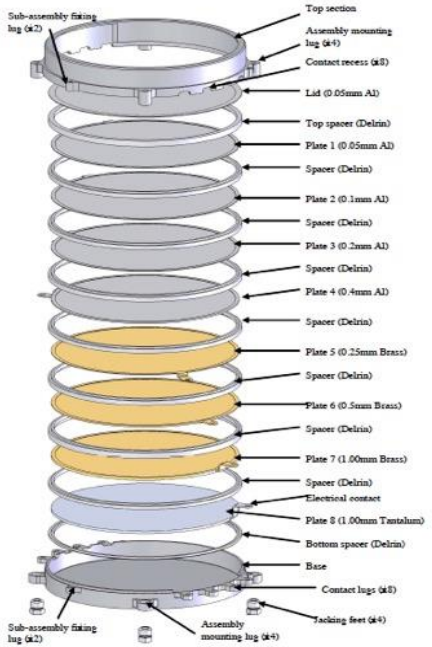
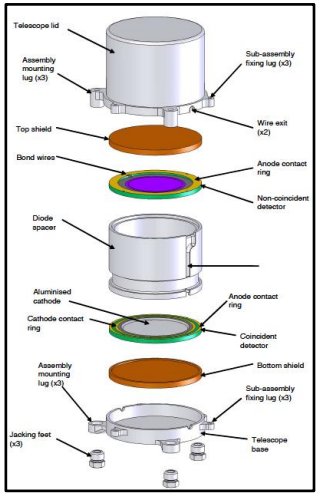
EMU/SURF: status

- SURF data: healthy
- Proton contamination: Not at all!
- Signal: appears in **all** plates
- SURF_H data in the first plates: may saturate
- SURF_L data are used only for these cases
- Time- & temperature- dependent bias/bgr: removed
- SURF charging currents: calculated
- SURF electron fluxes: derived



EMU/PT: status

- 7 PTs: healthy
- 1 PT: low signal
- e-contamination (pile-up effect!)
- PT/BT effective energies and scaling factors derived
- Cross-calibration - September 2018 SPE: successful!



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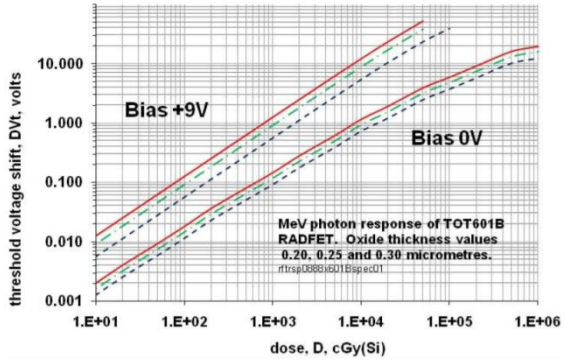
EMU/RADFET: status

- RADFET data: healthy & consistent with EMU fluxes
- Temperature effects: removed
- Doses: calculated
- Results: consistent with EMU-derived proton & electron fluxes



Data Sheet, REM Oxford Ltd

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User and S/W Requirements

- Needed to ensure that "…the functionality of the data provision software meets the needs of the customer in terms of utility, presentation and ease of exploitation."
- The "customer" is ESA (others would require ESA permission)
- UR broken into seven elements:
  - Provision and Storage (Galileo security restrictions)
  - Functions and Outputs (user-friendly!)
  - Data Gaps and Errors (transparency of processes)
  - Formats and Compatibility (e.g. SPENVIS compatibility)
  - Updates and Maintenance (hopefully EMU data will accrue for a long time)
  - Operating Environment (Windows, Linux)
  - Accessibility (more Galileo security restrictions!)

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Data processing and service provision

- Spacecraft data are stored in an ODI (see presentation Wednesday afternoon) database: science, housekeeping, status and state configuration files.
- In accordance with access security policy, data are delivered on encrypted disk and the ODI database runs on an isolated server.
- The database is mirrored at ESA/ESTEC using the ODI ingestion and processing scripts.
- Creation of a level 2 dataset (calibrated fluxes and currents) is handled by applying calibration algorithms using ODI and IDL scripts.
- ESA can repeat the processing step above using the consortium software uploaded in an SVN code repository.

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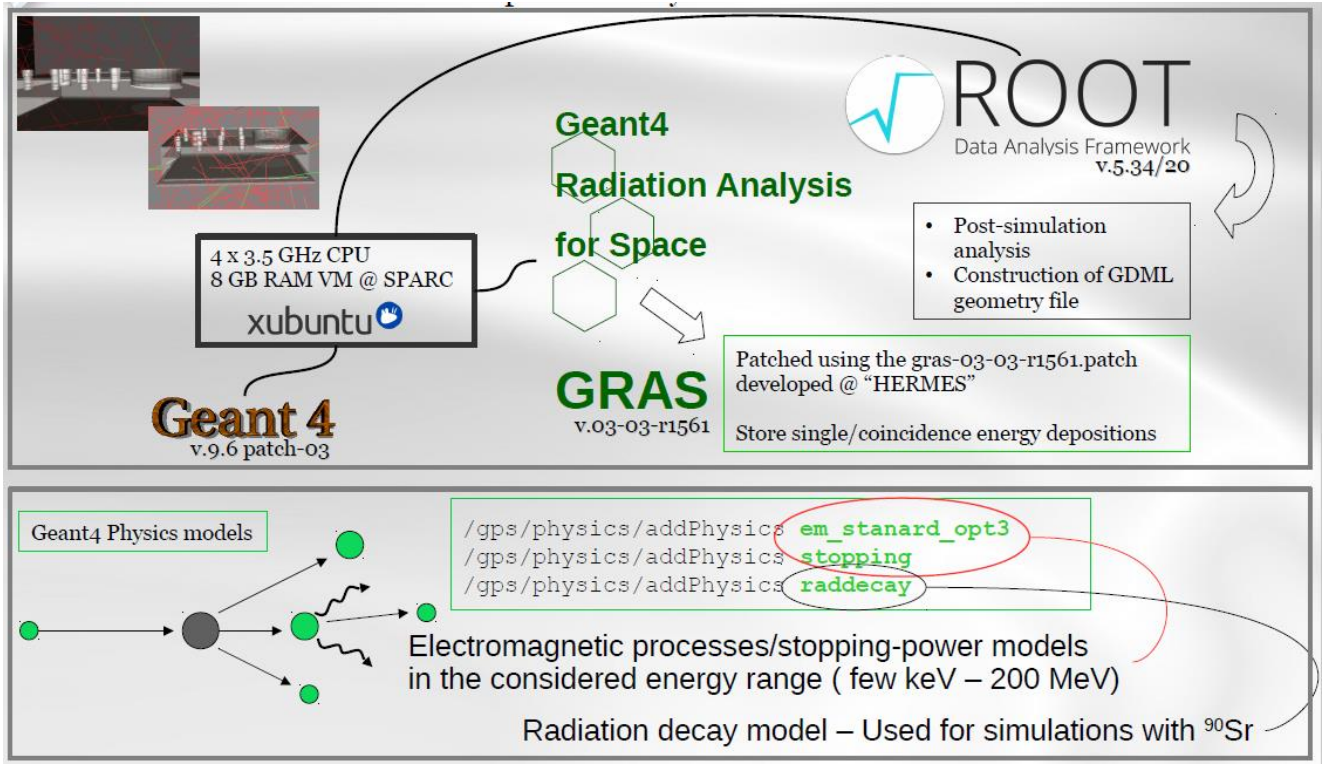
Data processing and service provision

- Version control is maintained for updates in processing routine: new ODI datasets are created when calibration routines are updated.
- Outside access can be provided to processed data using ODI tools and REST service. This will depend on the security restrictions.

Calibration



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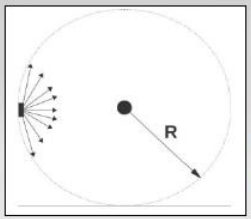
Calibration

Geant4 Particle Source

```
############################
#Source d e f i n i t i o n#
############################
/gps/particle proton
#/gps/particle e-
/gps/pos/type Surface
/gps/pos/shape Sphere
/gps/pos/centre 0. 0. 0. cm
/gps/pos/radius 17.65 cm
/gps/ang/type cos
/gps/ene/type Mono
```



e- and p fluxes

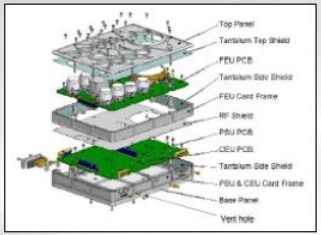
Spherical source

Cosine law
Omnidirectional

Mono-energetic fluxes of e- and protons of energies 0.1-10 MeV and 1-200 MeV

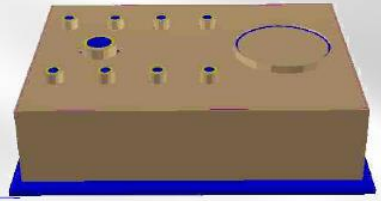
Linear/Logarithmic energy binning (40-100 bins)

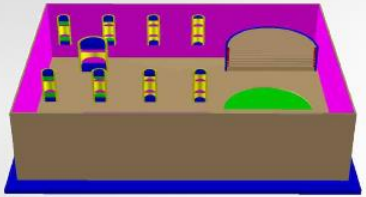
The 3D Model file



Prepared with the ROOT geometry package: Chassis, Ta Shield, Al Shield, Card Frames, Radiation Sensors etc.

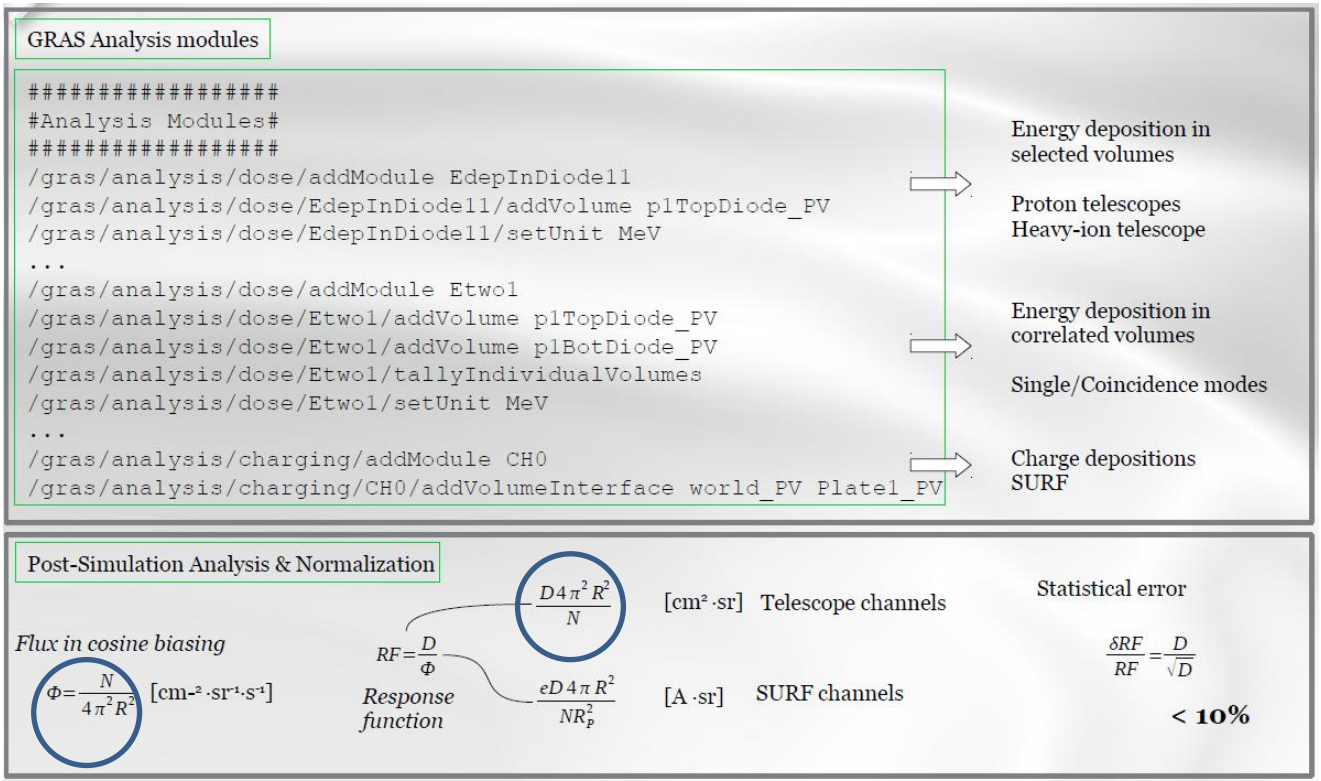
Extracted to GDML format for use in GRAS



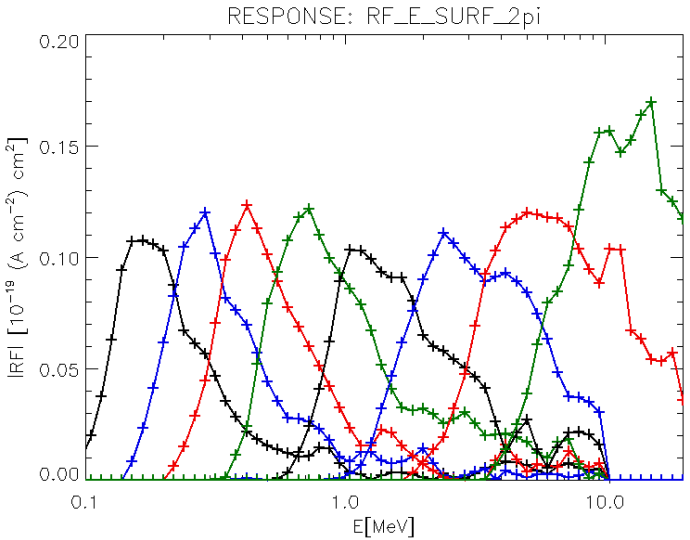


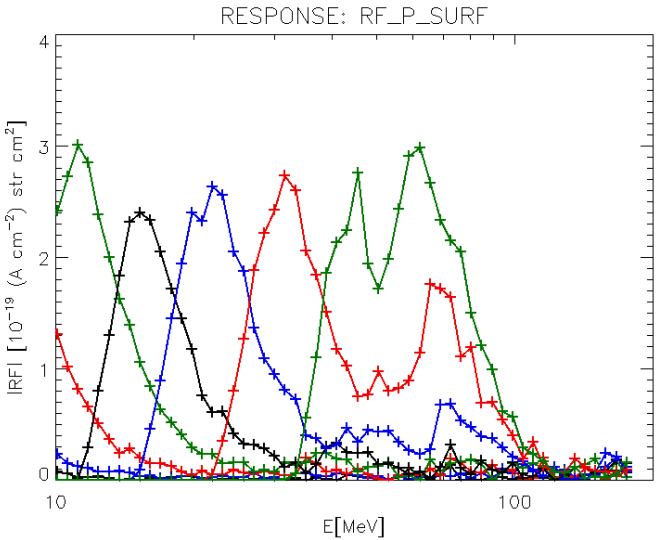
Characteristics (shielding, diode thickness/distance) from available documents + KR

Calibration



Response functions





Note: NO contamination during September

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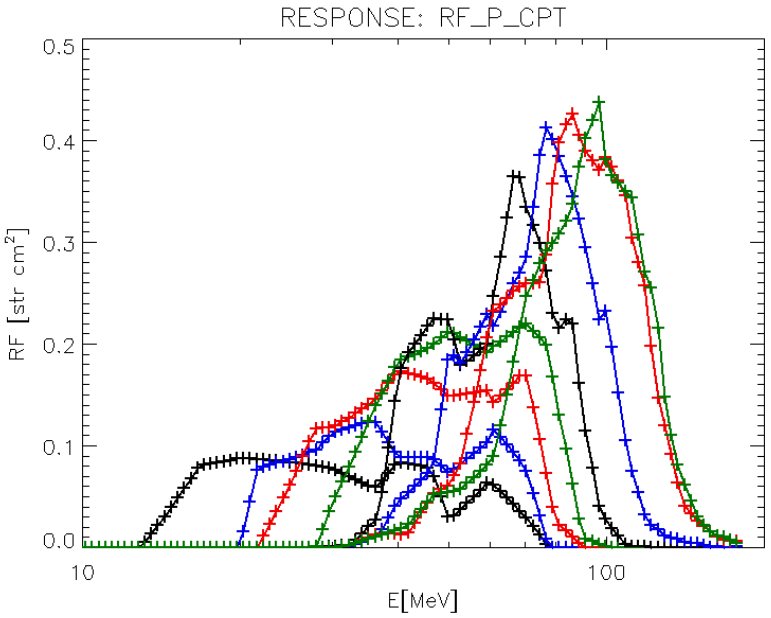
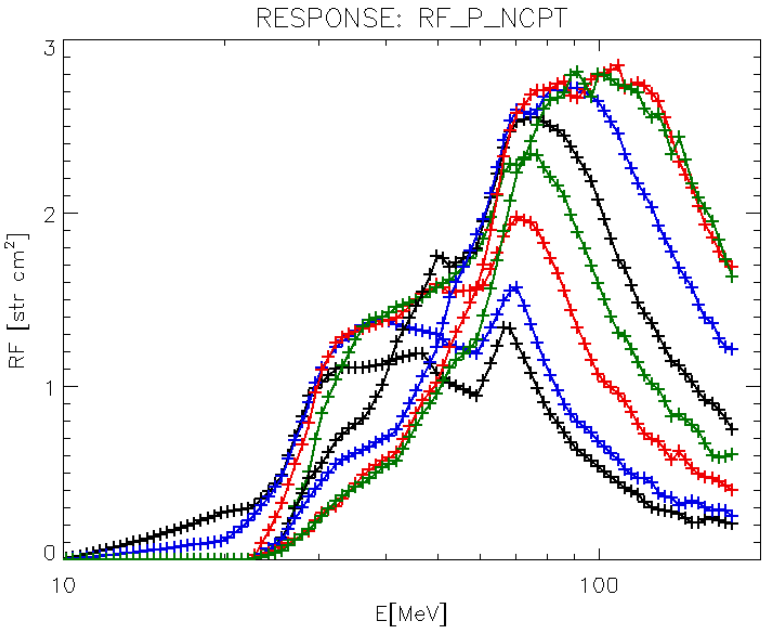
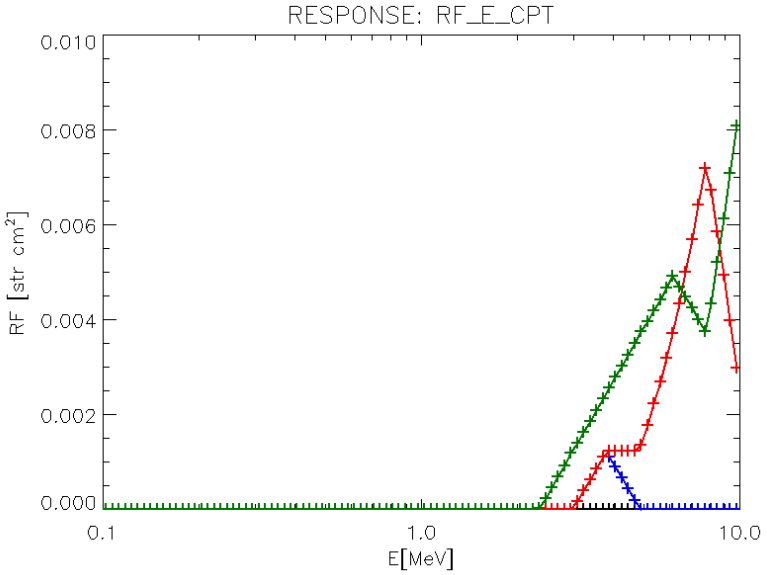
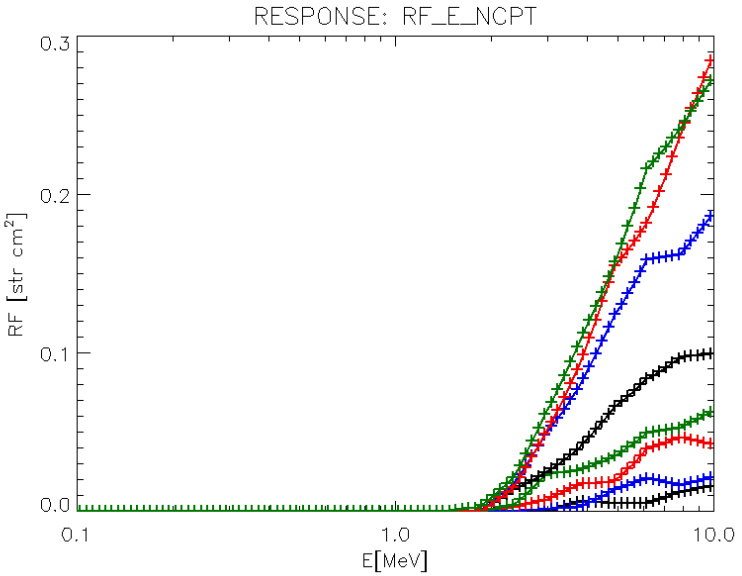
PT: proton response





PT: electron response





Data Unfolding

$$V = V_{offset} + A \int_{E_{min}}^{E_{max}} f(E) RF(E) dE$$

$$C_i = \sum_{q=p,e} C_{i,q} = \sum_{q=p,e} \left[\int_0^{\infty} f_q(E) RF_{i,q}(E) dE \right]$$

- Bow tie analysis
- Correlative unfolding method

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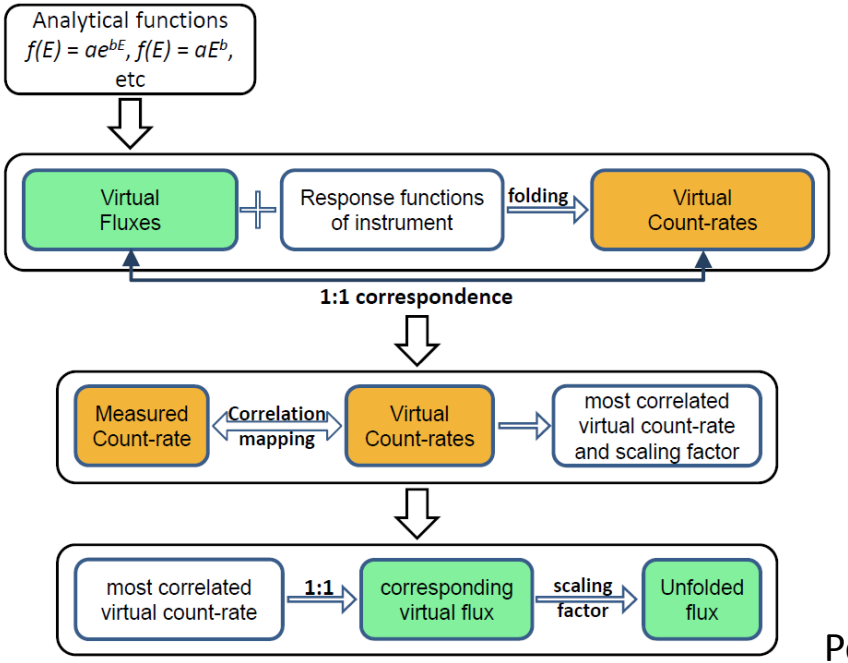
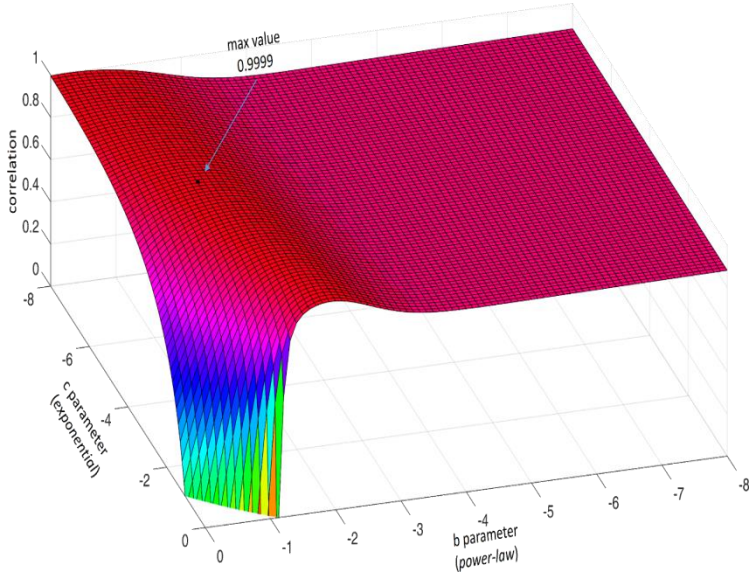
CORUM

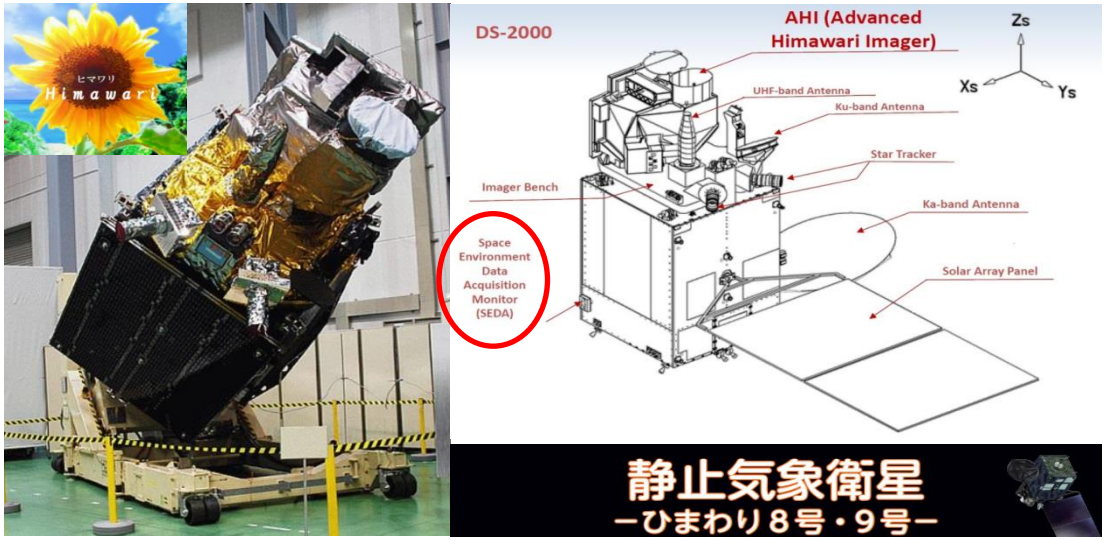




Pearson correlation metric is used for mapping data to virtual data Analytical function: $f(E) = aE^{b}e^{(cE)}$

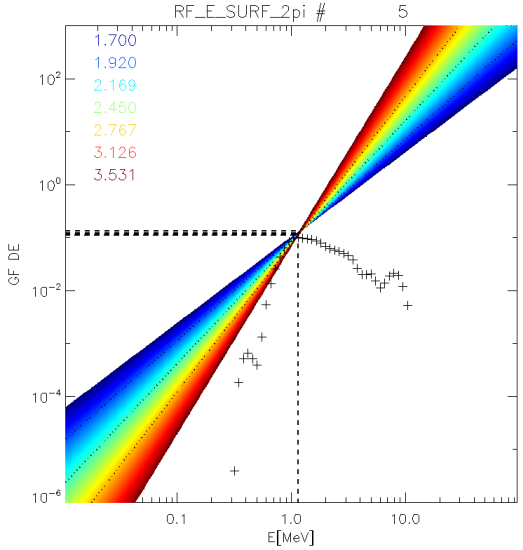
Note: *CORUM was recently integrated with genetic code for optimization of data reconstruction. Paper by S.A-Giamini et al is under preparation.*

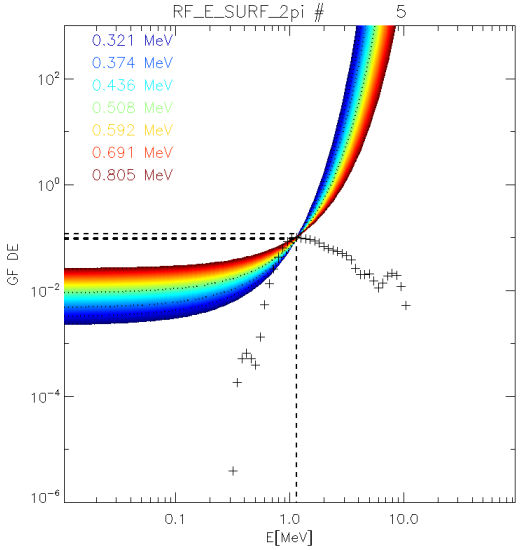
SEDA on board Himawari-8 (GEO)

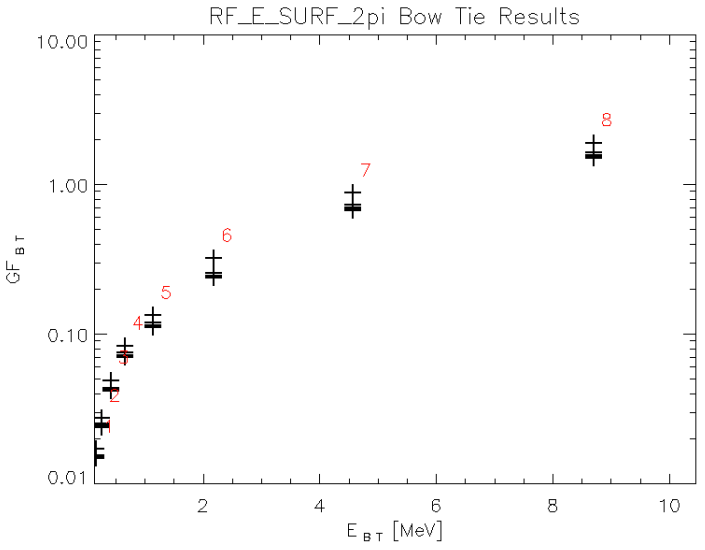


SEDA fluxes & raw data **provided by Dr. T. Nagatsuma**
Space Weather and Environment Informatics Laboratory, NICT, Japan

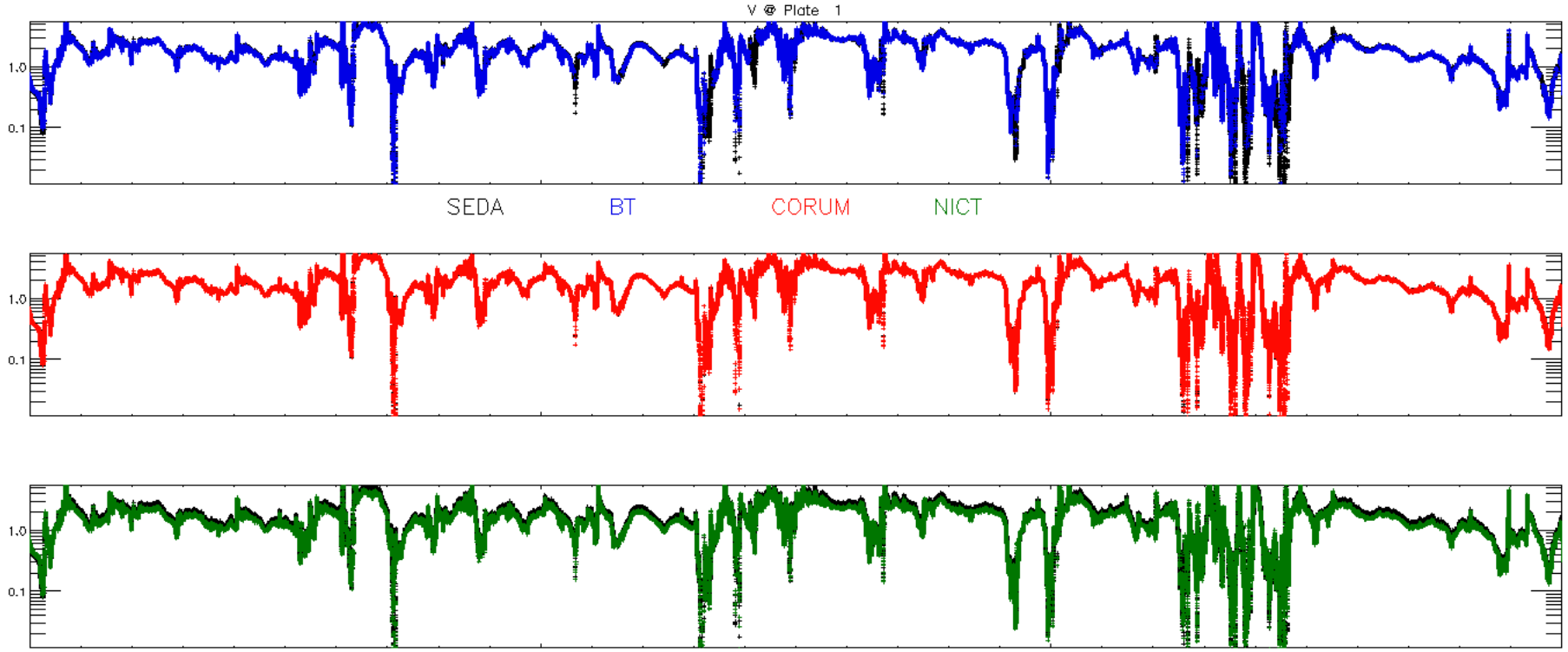
SURF: BT results







SEDA/SURF reconstruction



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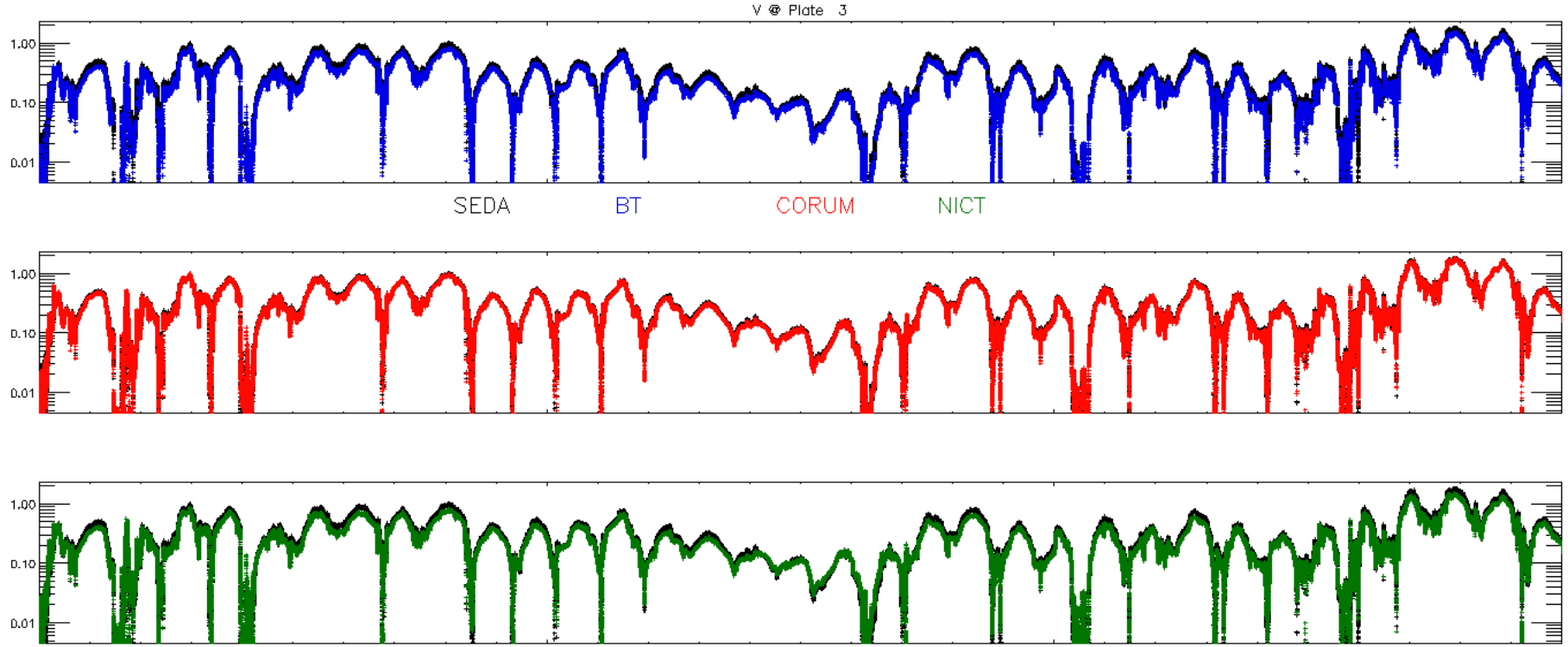
SEDA/SURF reconstruction



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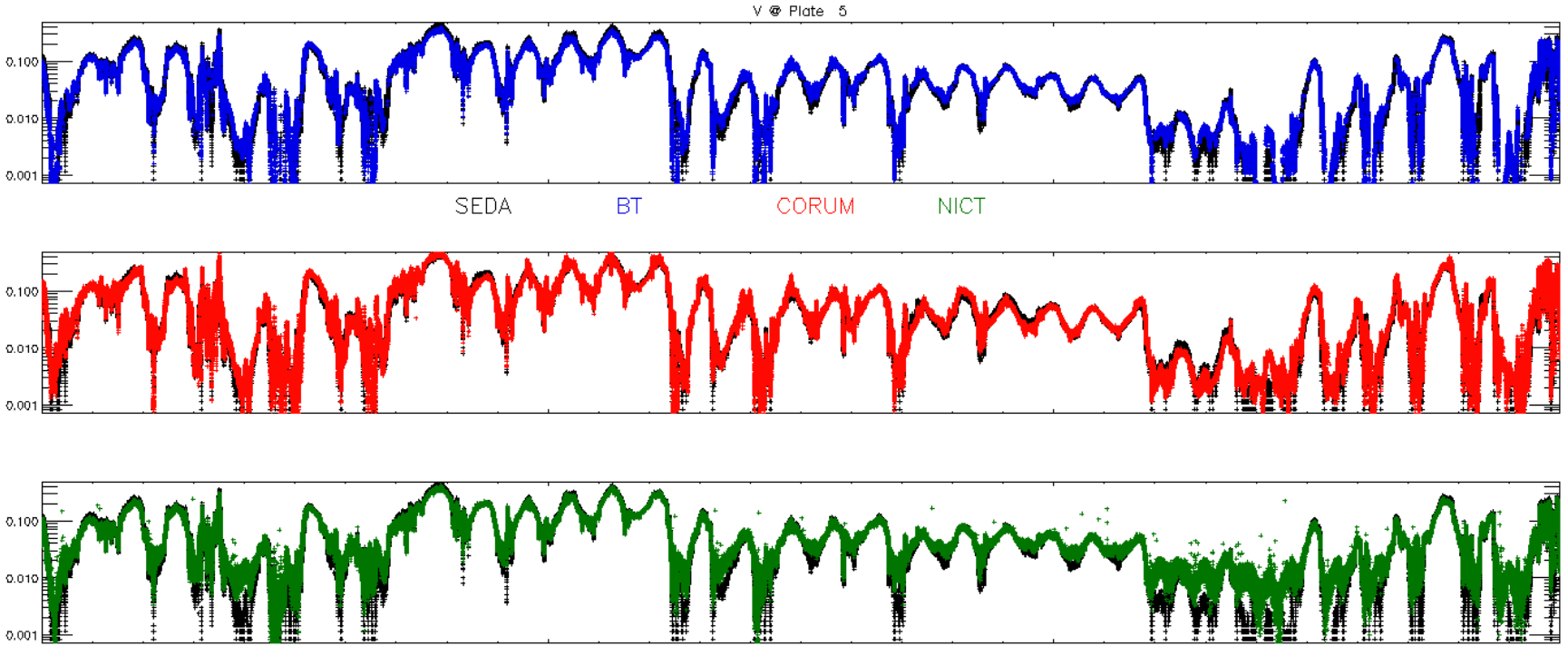
SEDA/SURF reconstruction



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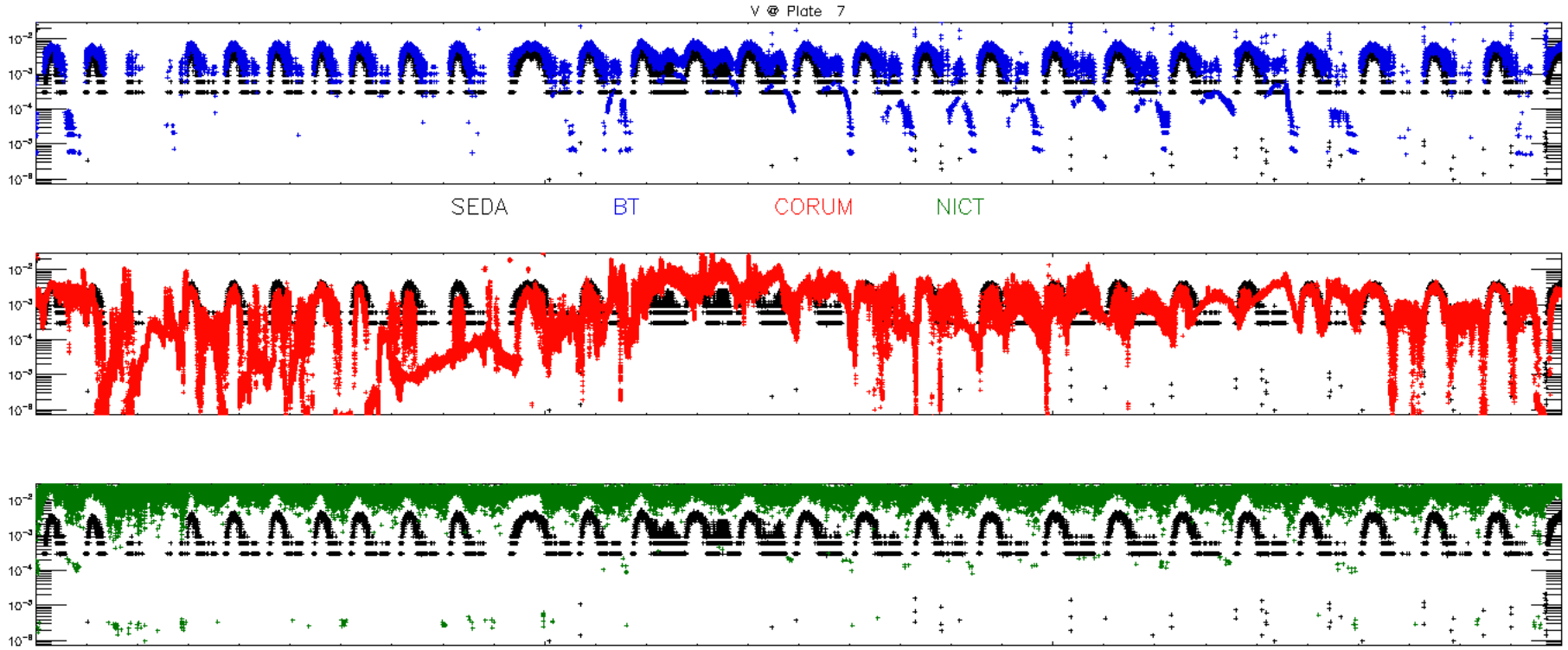
SEDA/SURF reconstruction



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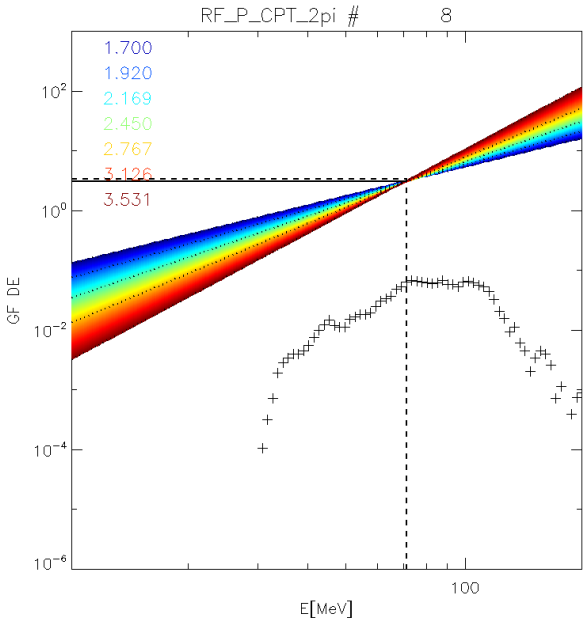
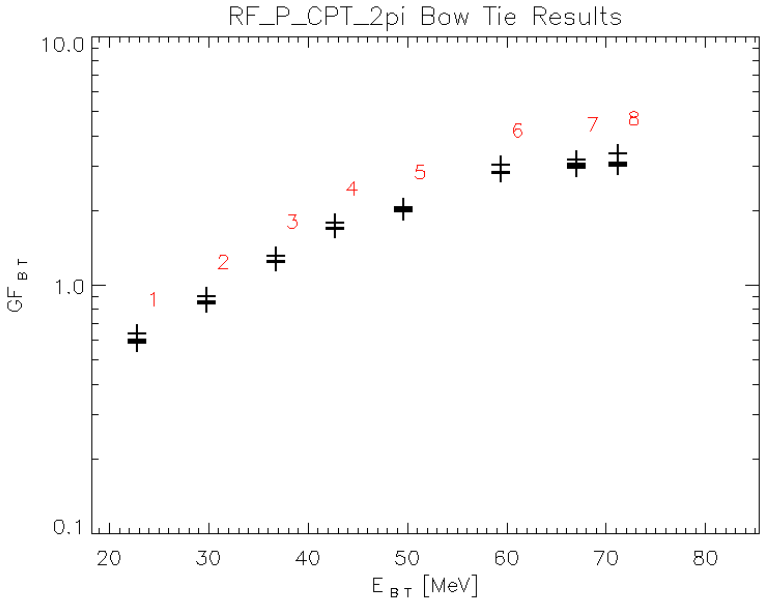
PT: BT-analysis

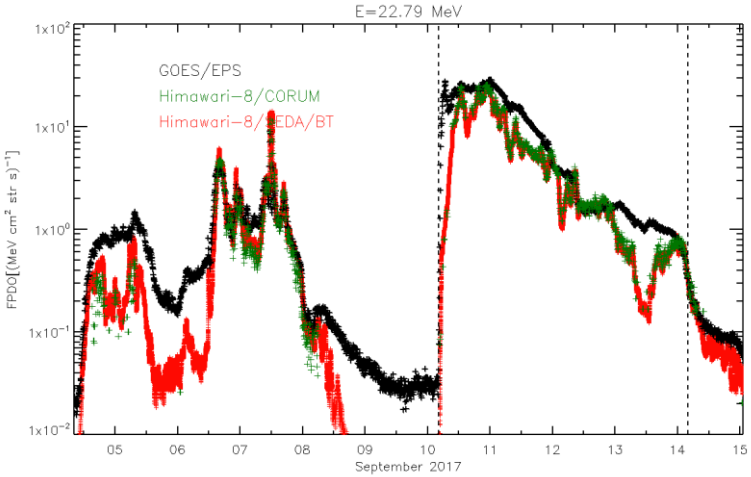


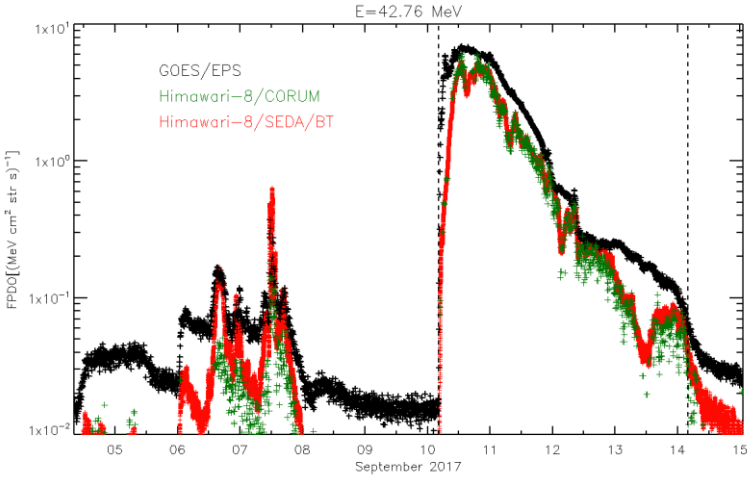


Note 1: *Validation of SPARC BT algorithm products is in progress*

Note 2: *NCPT BT analysis: similar results larger uncertainties. iBT more proper!*

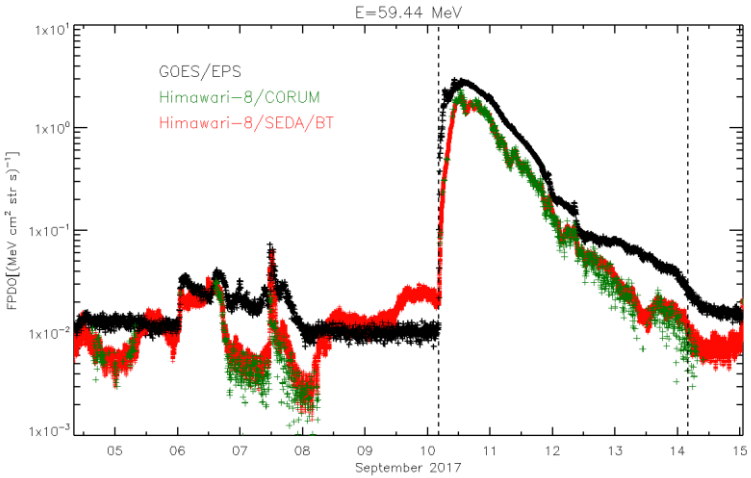
SEDA/FPDO vs RDS2.0

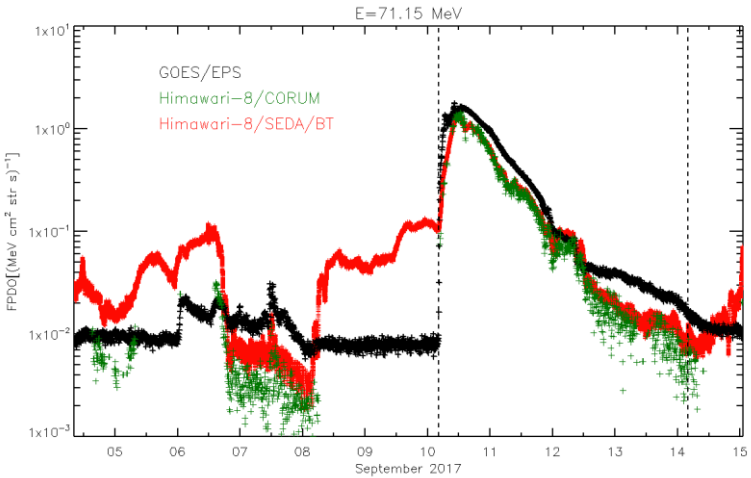




Note: EMU/PT/FPDO present much better agreement with GOES/EPS

SEDA/FPDO vs RDS2.0





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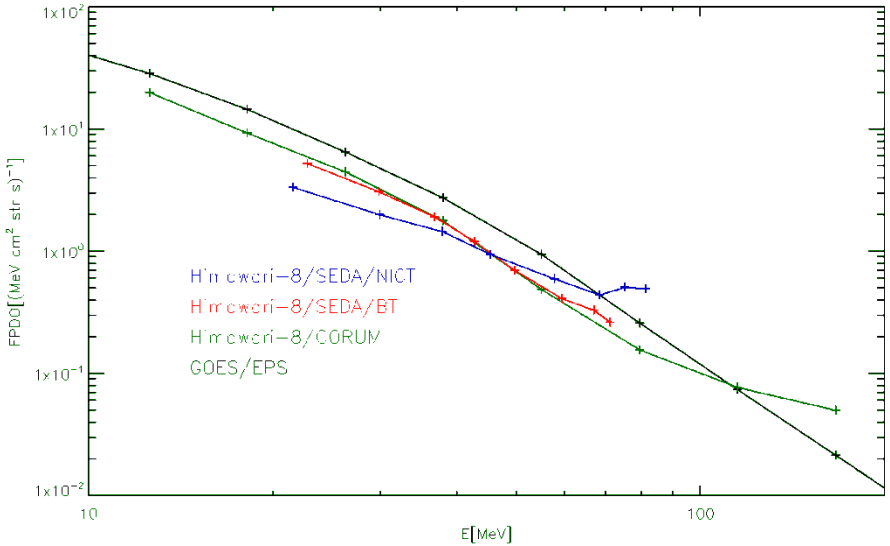

- GALEM - derived scaling factors/ effective energies improve drastically SEDA proton flux spectra

Conclusions

- Galileosat15/EMU data: analyzed
- EMU sensors: calibrated
- Doses & Electron/proton fluxes: derived
- S/W & EMU ODI database: v.1 ready
- Cross-calibrations: tbd
- Heavy Ion Telescope : tbd
- Validation of environment models : tbd
- Update of MOBE-DIC model : tbd


RADECS 2018 PROCEEDINGS

Data Exploitation of New Galileo Environmental Monitoring Units: Initial results

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Acknowledgments: T. Nagatsuma, NICT, Japan

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