Characterization and physical origin of particles on Planck HFI

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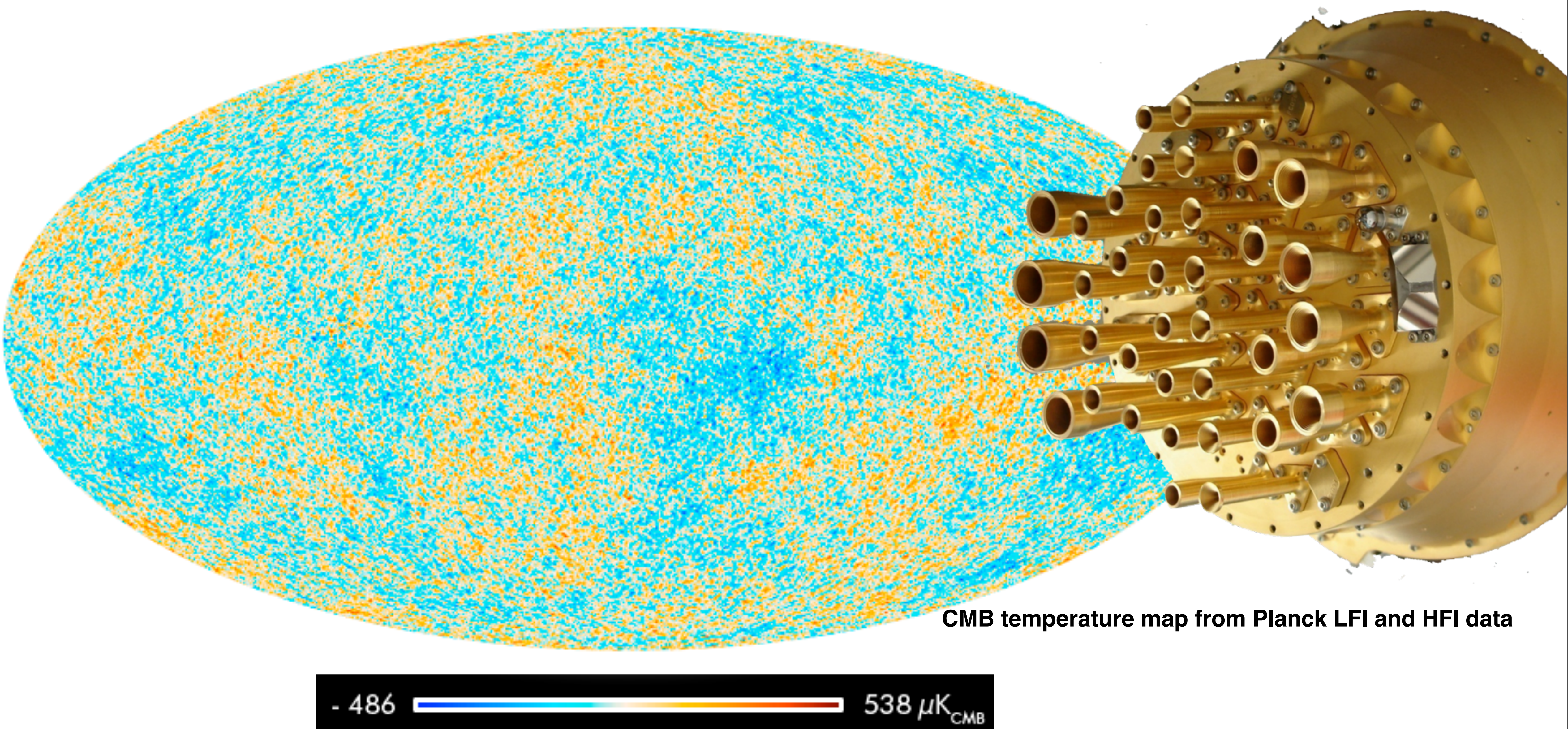
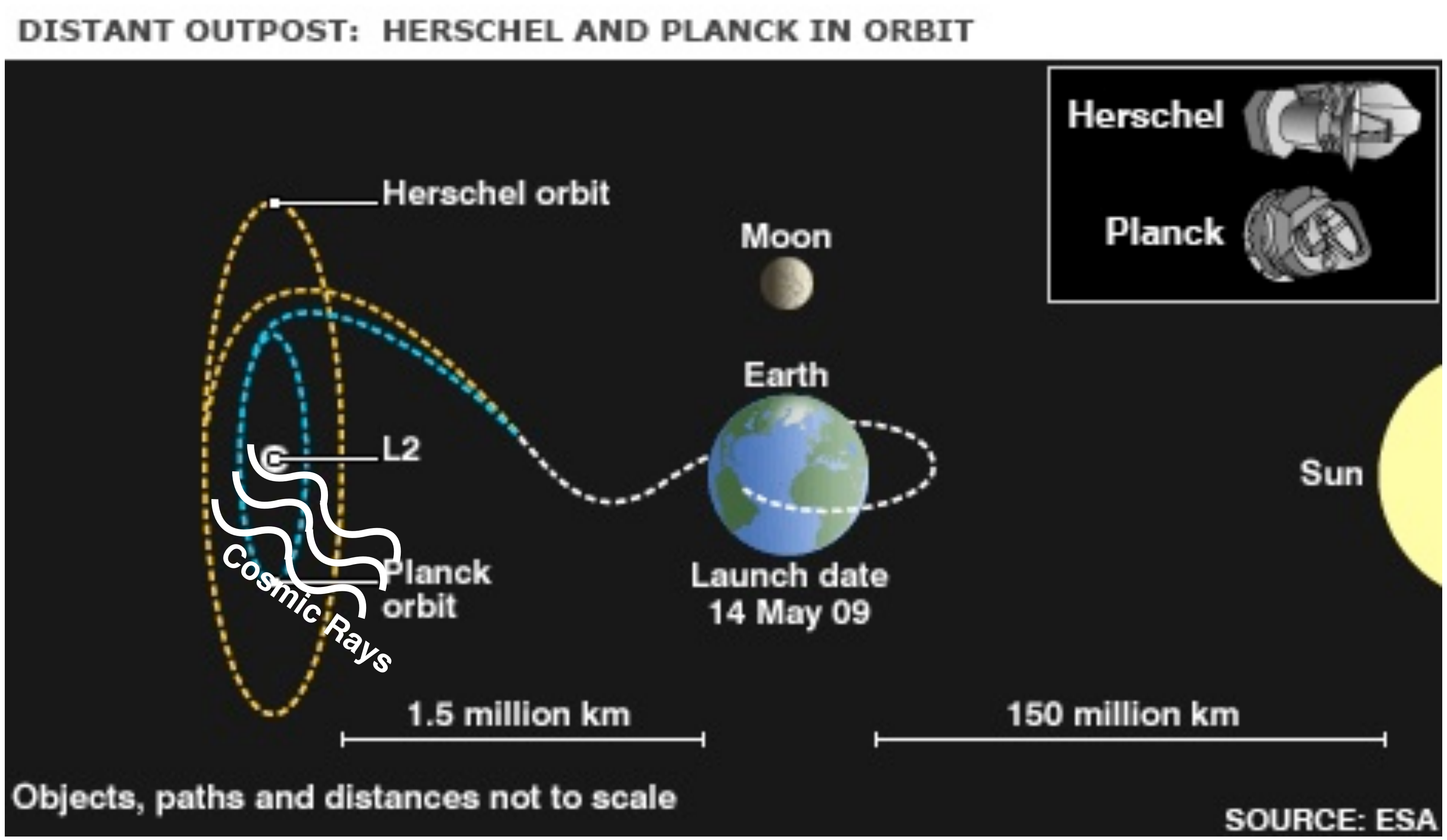


CMB temperature map from Planck LFI and HFI data

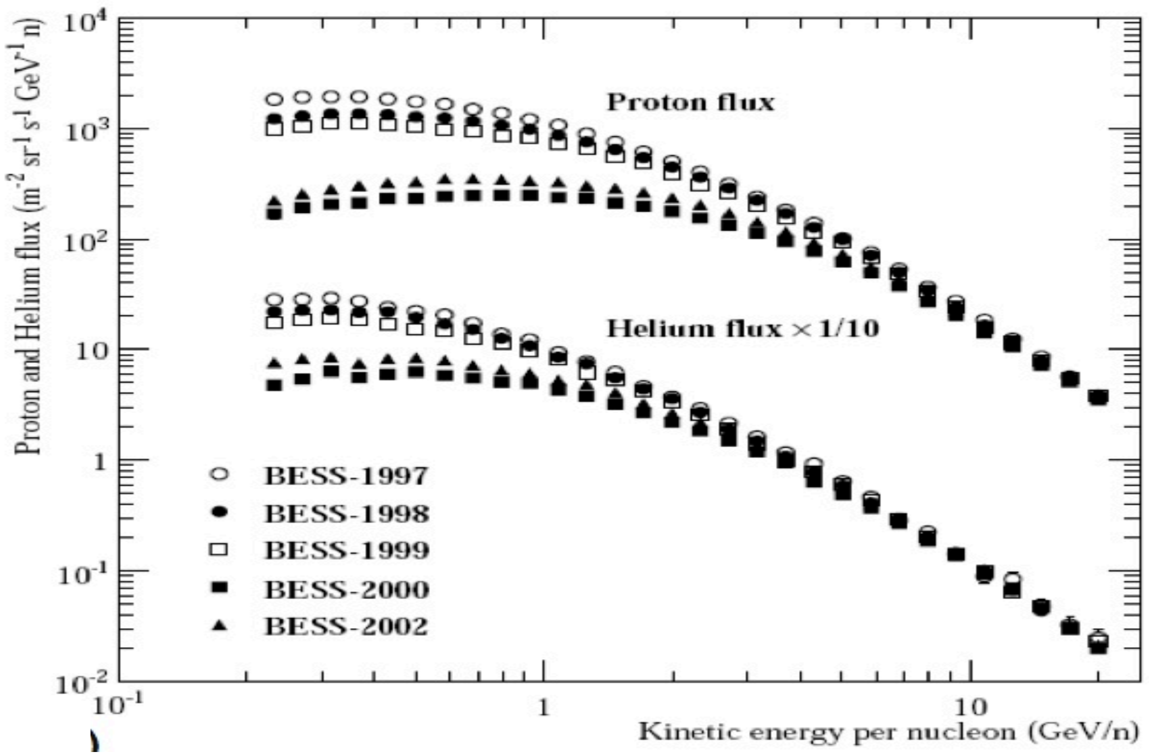
Overview

- Cosmic Rays at second Lagrangian point.
- Impact of cosmic rays on HFI Data.
- Origin of the HFI glitches : Ground Measurements.



Galactic Cosmic Rays & Solar Activity

Proton and Helium fluxes at the top of the atmosphere from 1997 through 2002.



3-4 10^3 particles $m^{-2}sr^{-1}s^{-1}MeV^{-1}$ peaks at 300MeV

Galactic Cosmic Rays:

Protons : ~ 89 %

He Ions: ~ 10 %,

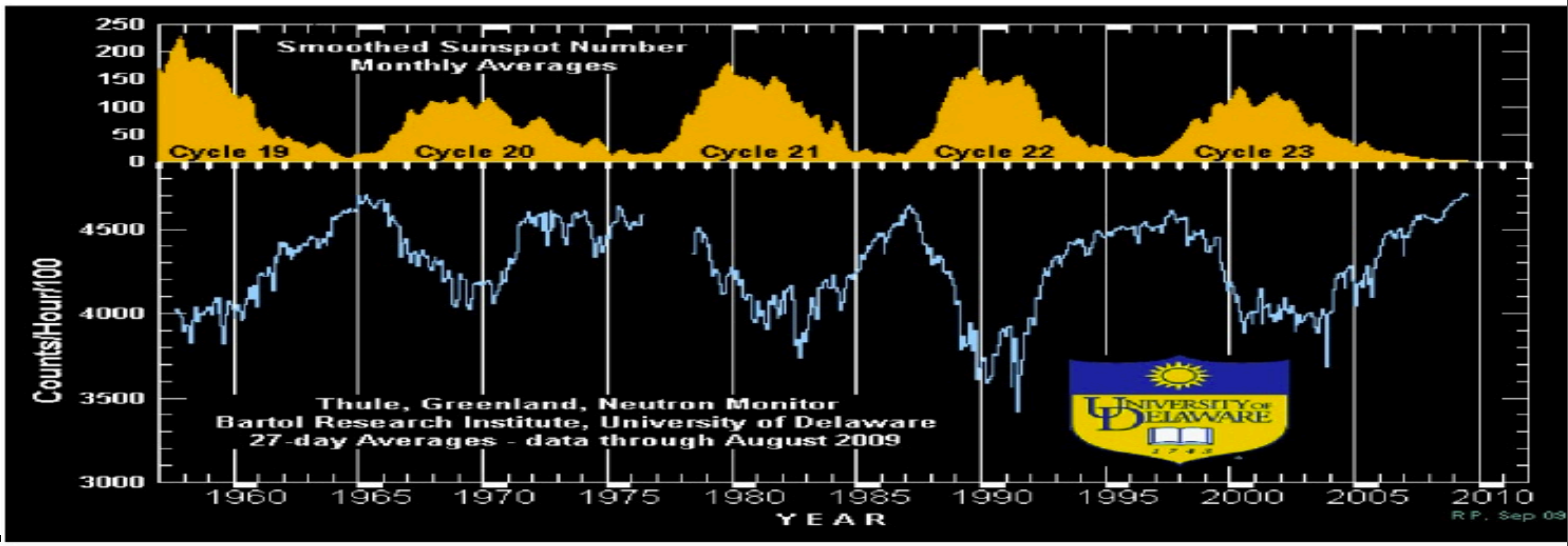
Heavier elements: ~ 1 %

Electrons : < 1 %

Solar Activity

The GCRs are modulated by the solar wind, which decelerates and partially shields the inner solar system from lower energy galactic CRs.

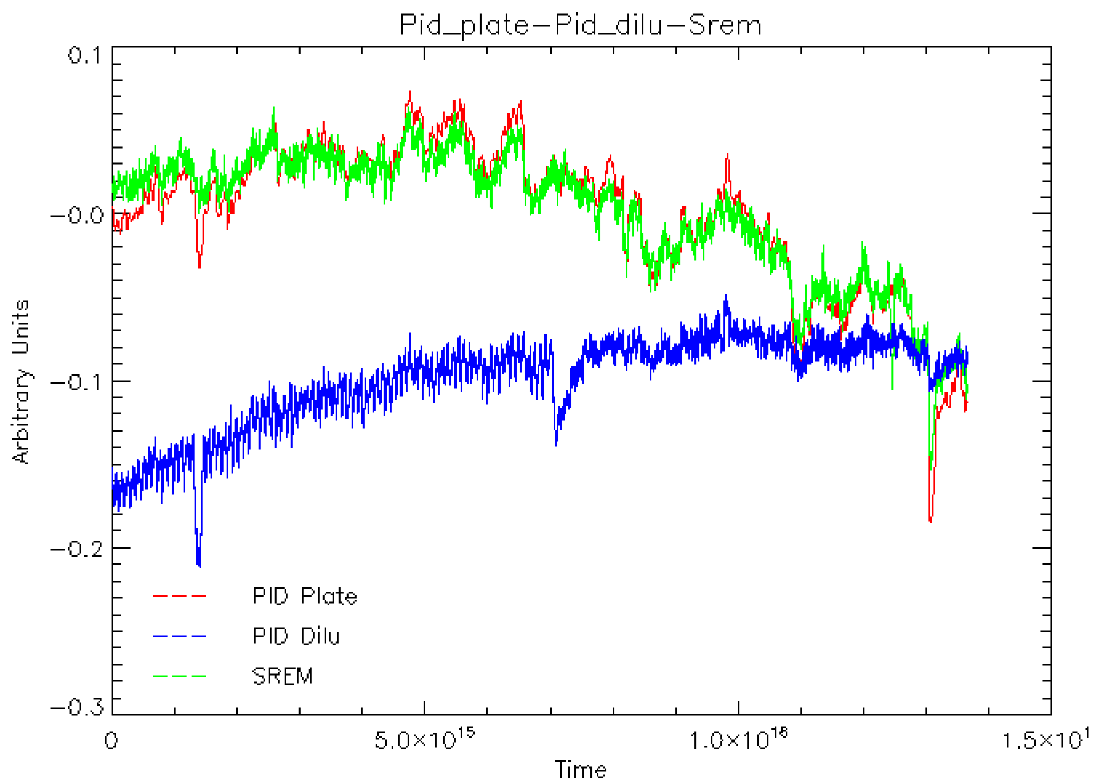
Thule Greenland Neutron Monitor (Delaware University)

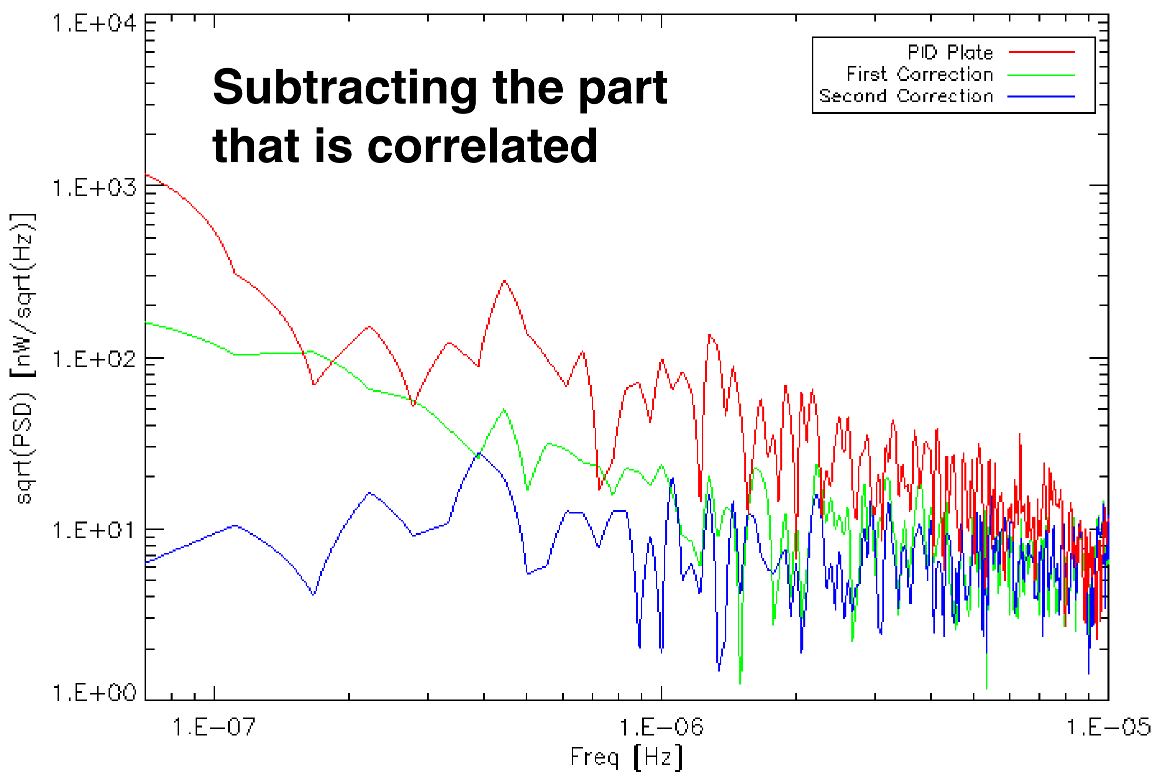


Indirect Effects (Planck coll. - 2011)

- **Solar modulation effect: ~10nW load on 100mk stage due to the cosmic rays of total ~ 300nW**

We observed a very good correlation between the signal of the Standard Radiation Environment Monitor (SREM) and the signal of the active regulation of the temperature of the bolometer plate.

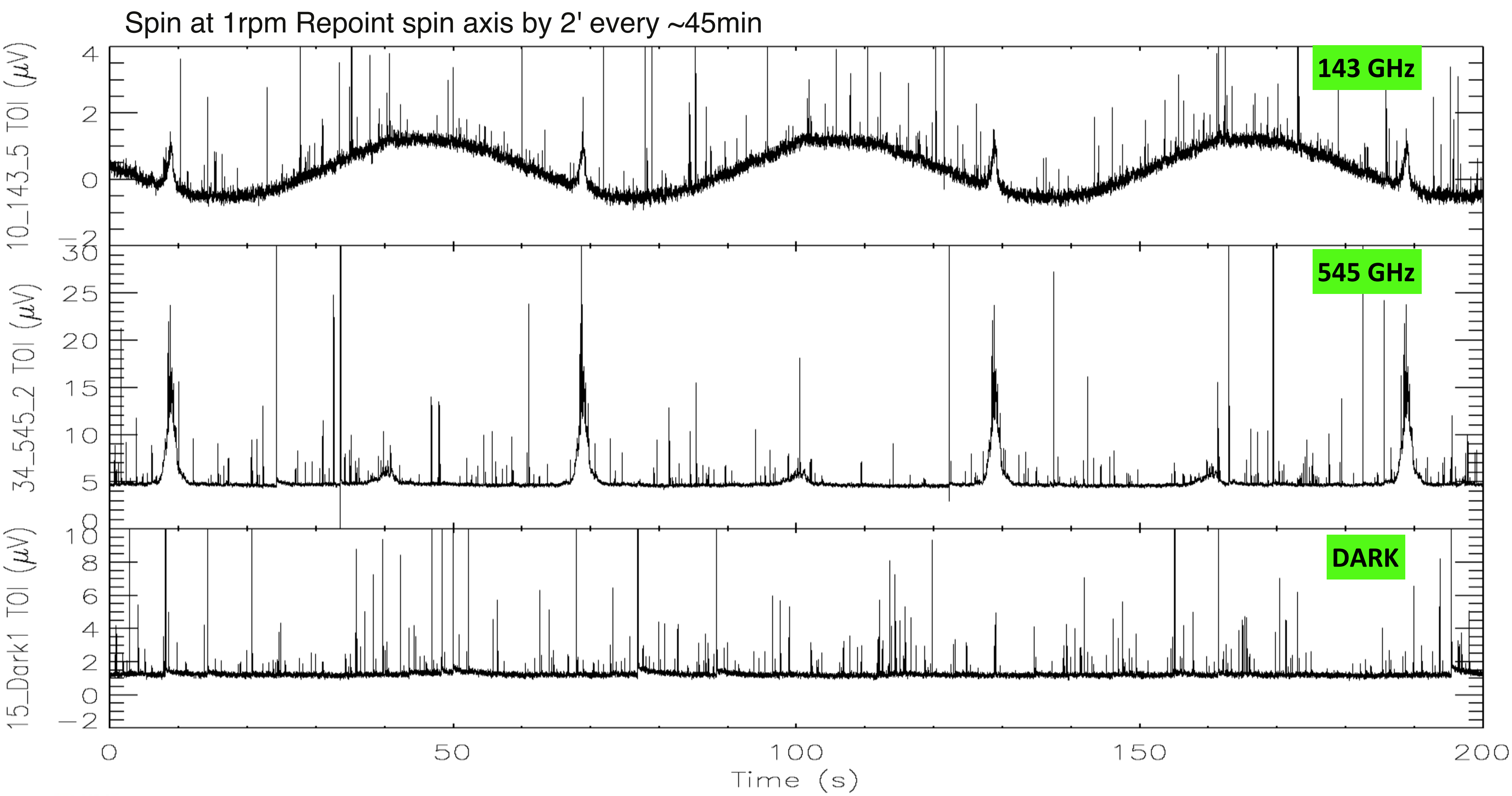




- **HCE/Elephants : simultaneous glitches detected in many bolometers increasing the plate temperature up to several microK (for furthers informations please visit Miniussi's poster).**

Effects on bolometers

The measured in-flight glitch-rate was 20 times larger than expected from the coupling between the absorber and the CRs flux (producing 15% not useable data).

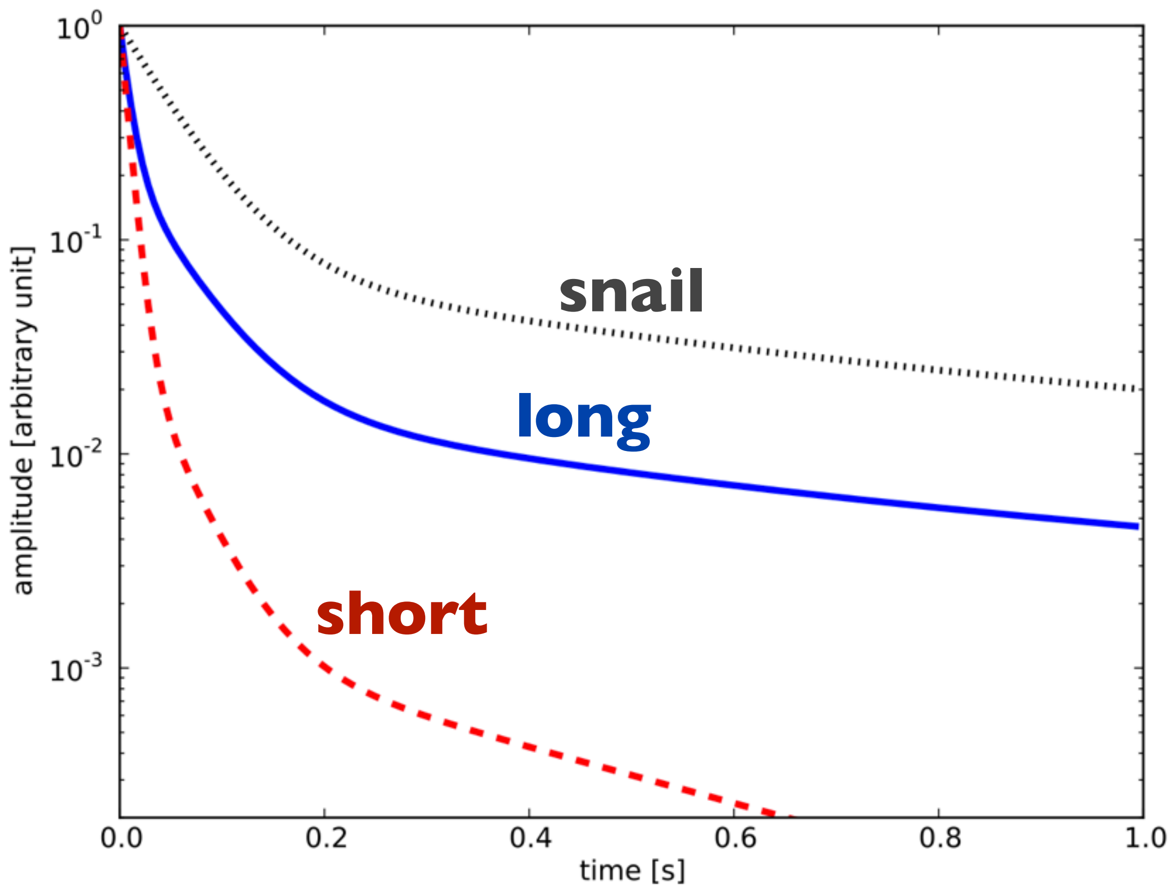


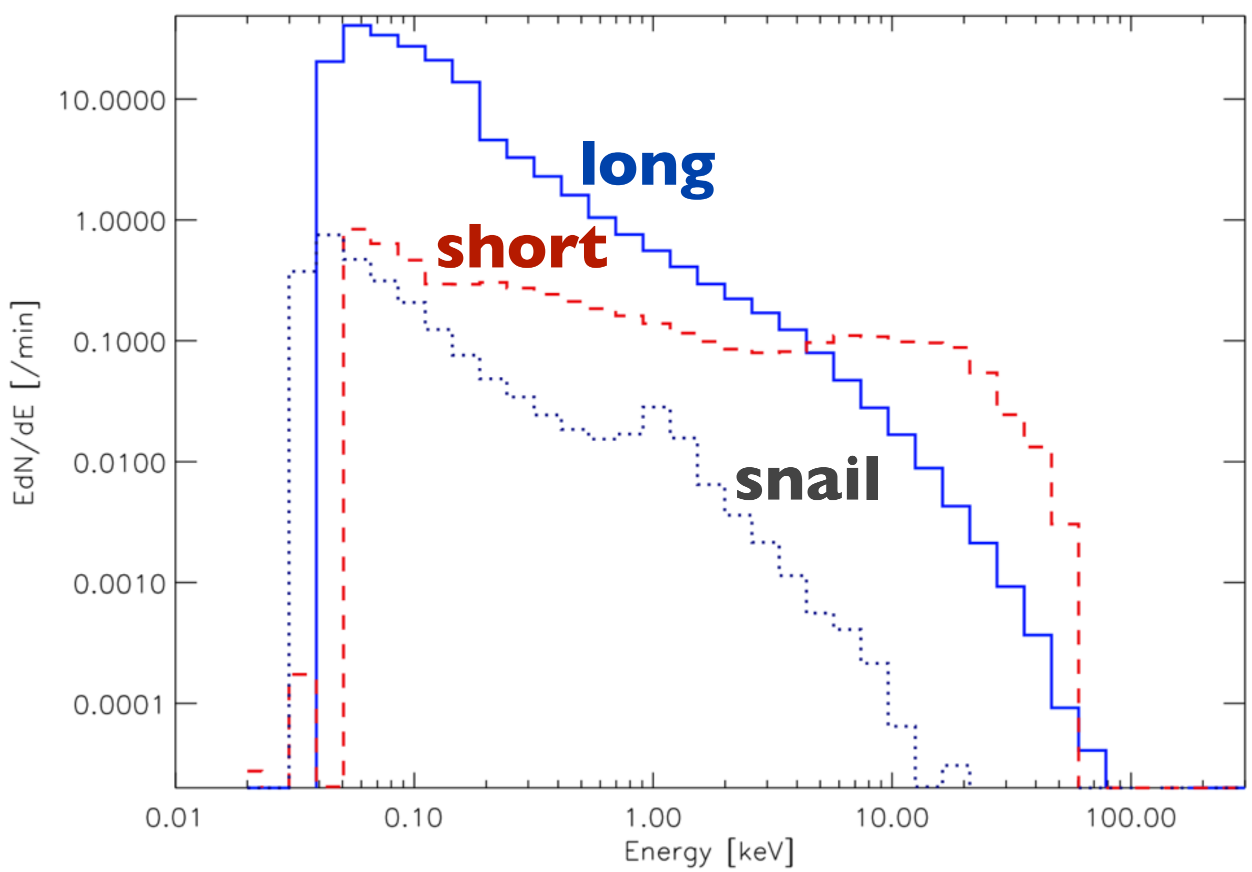
HFI In-Flight Glitches - Shape, Spectrum

Short Glitches :
Rate : 4 glitch/mm^2/min
Shape: Fast decay but low amplitude tail showing intermediate to long time constants of ~ 40 ms, 100 ms, 2s.
Distribution : double structure, power law fit in the range of small energies, bump in the range of high energies.

Long Glitches :
Rate : 1/cm2/sec
Shape : Time constants: ~ 10ms + 10% 60ms + 1% 2s decays (Seen in coincidence in PSB-a and PSB-b 50%-60%).
Distribution : power law index (ind= 1.3)

Slow/Snail Glitches :
Shape : Time constants: ~ 10ms + 10% 60ms + 1% 2s decays.
Distribution : Same as the long glitches.





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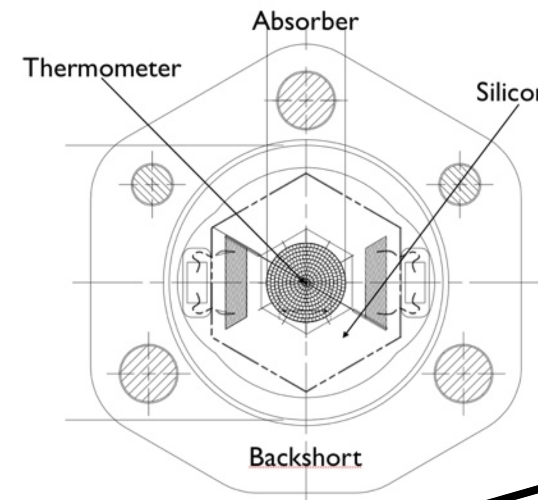
Ground Tests: (AC et al in preparation)

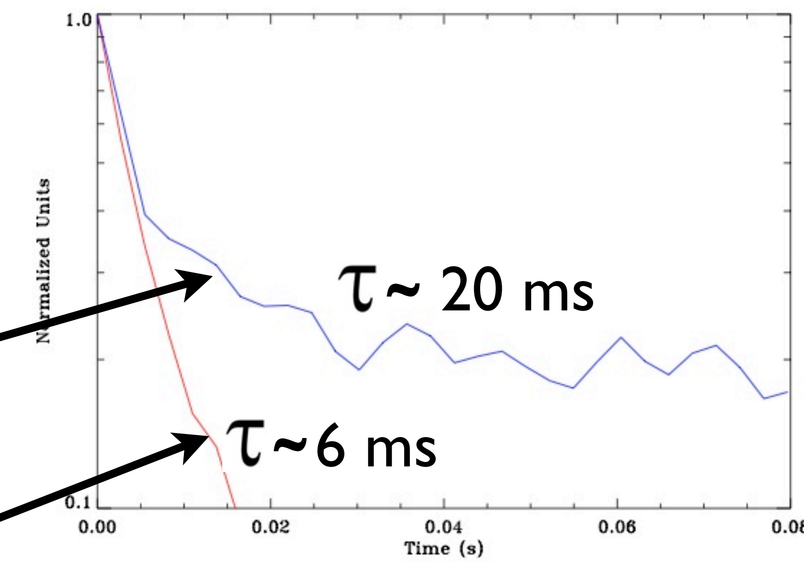
For an improved understanding of the origins of the glitches seen in HFI flight data, we performed several ground-based tests on HFI spare bolometers between the late 2010 and spring 2013. The aim of the tests is to have a more complete view of the physical origin of the different families of glitches.

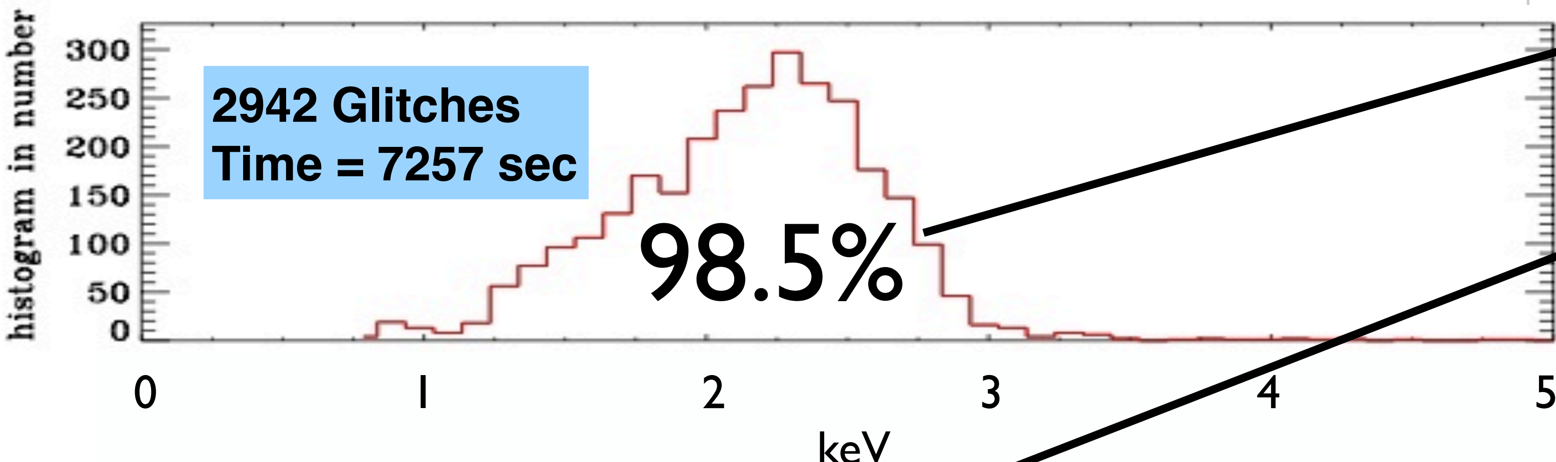
HFI Spiderweb Bolometer

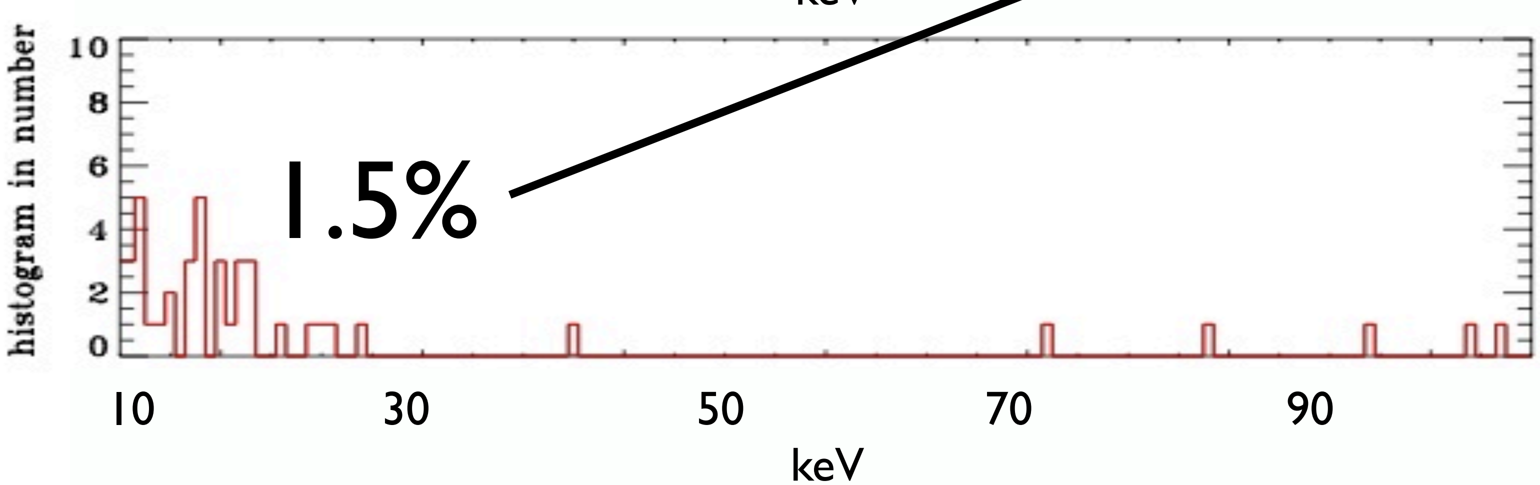


TANDEM Test (@IPN-Univ. Paris Sud)

- Protons at 23MeV.
- 3 HFI spare spiderweb bolometers.
- Same Read-Out electronics than HFI.







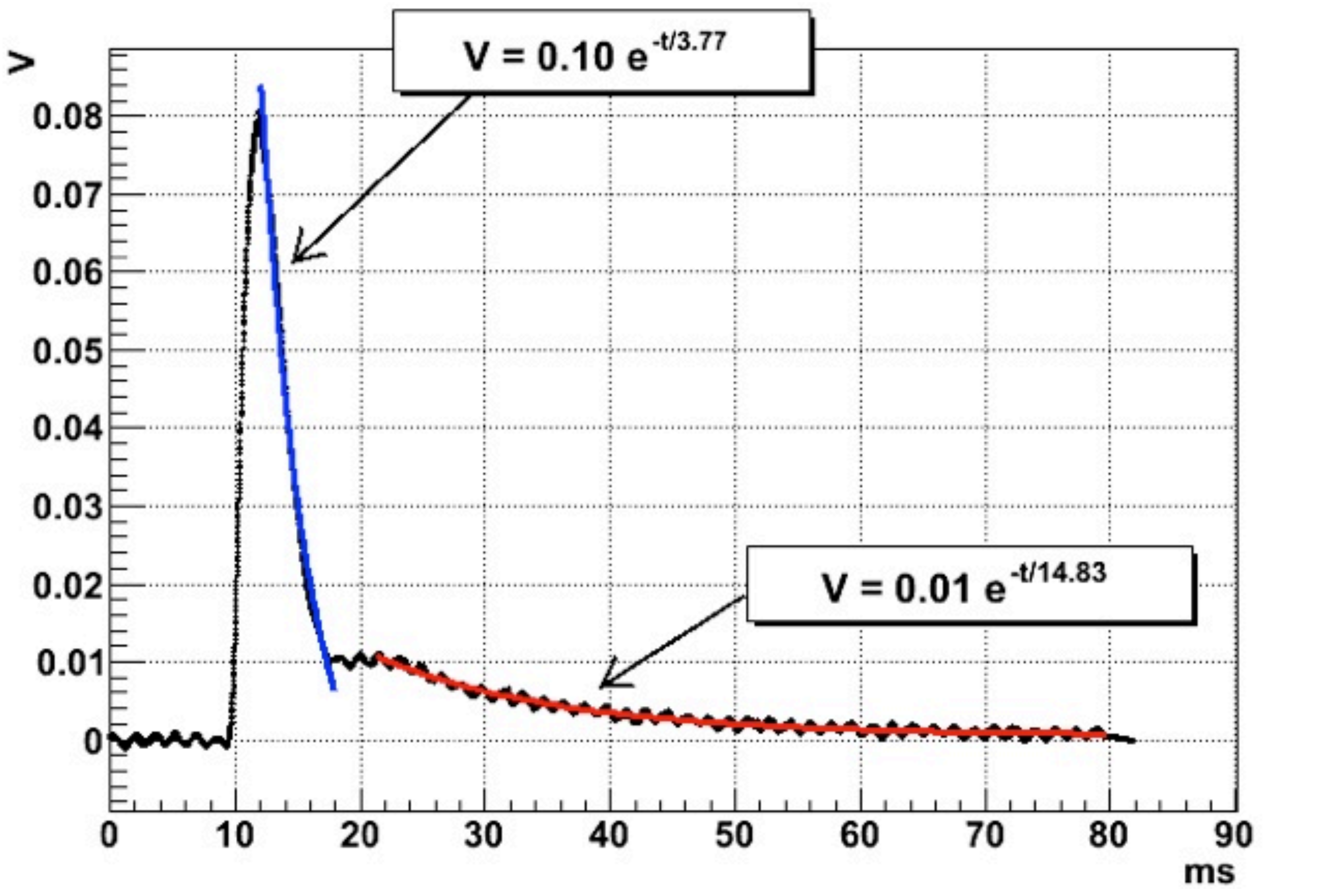
- The bolometer with gold shield shows the same results as the one without the shield.
- We are able to isolate long glitches and short glitches without introducing any delta-electrons production process.
- The two families of glitches show the same rate ratio and the same time constants as observed in HFI data in-flight.
- Slow/Snail glitches were not observed as we did not use PSB bolometers during the test.

Hypothesis: protons on sil. die: derived attenuation factor is equal to 650

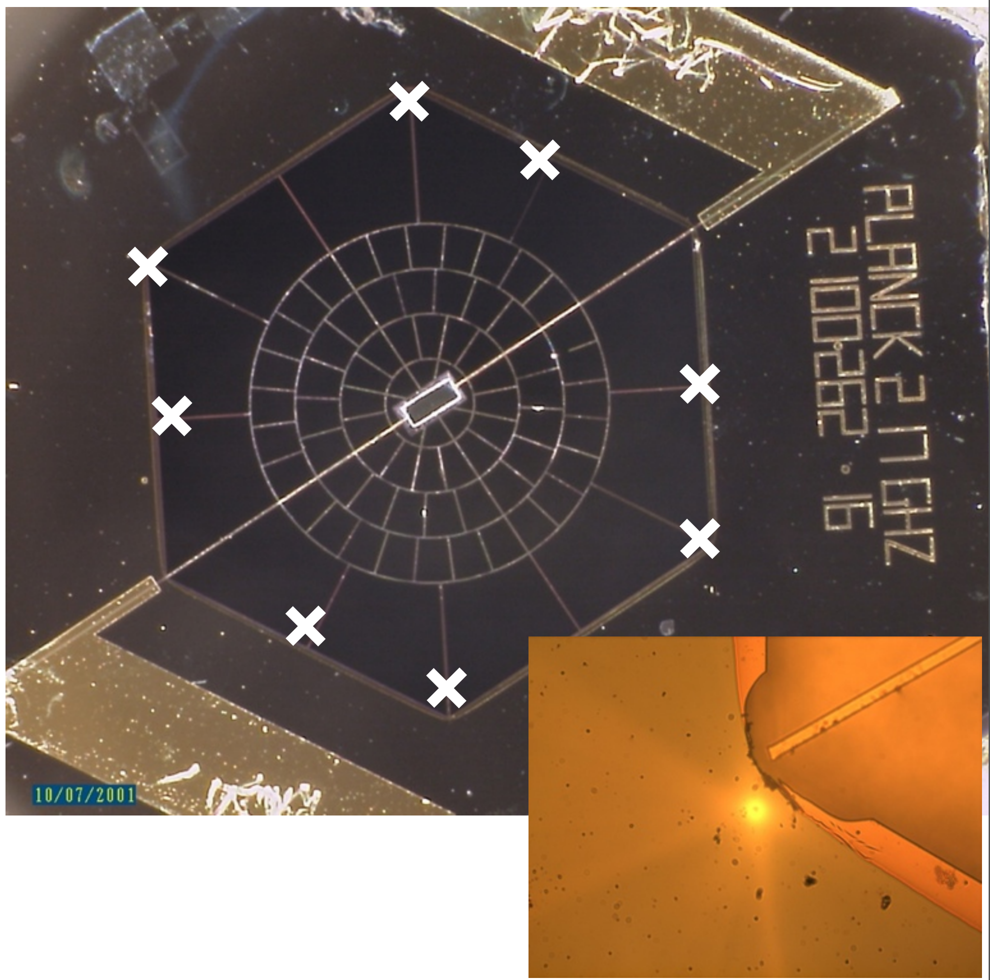
Physical Interpretation

Silicon Die Tests

- 241Am and Cu Sources - Alpha particles at 5.4-5.9MeV.
- 2 HFI spare SWB
- HFI AC Read-Out and DC electronics.



Modified Bolo Test

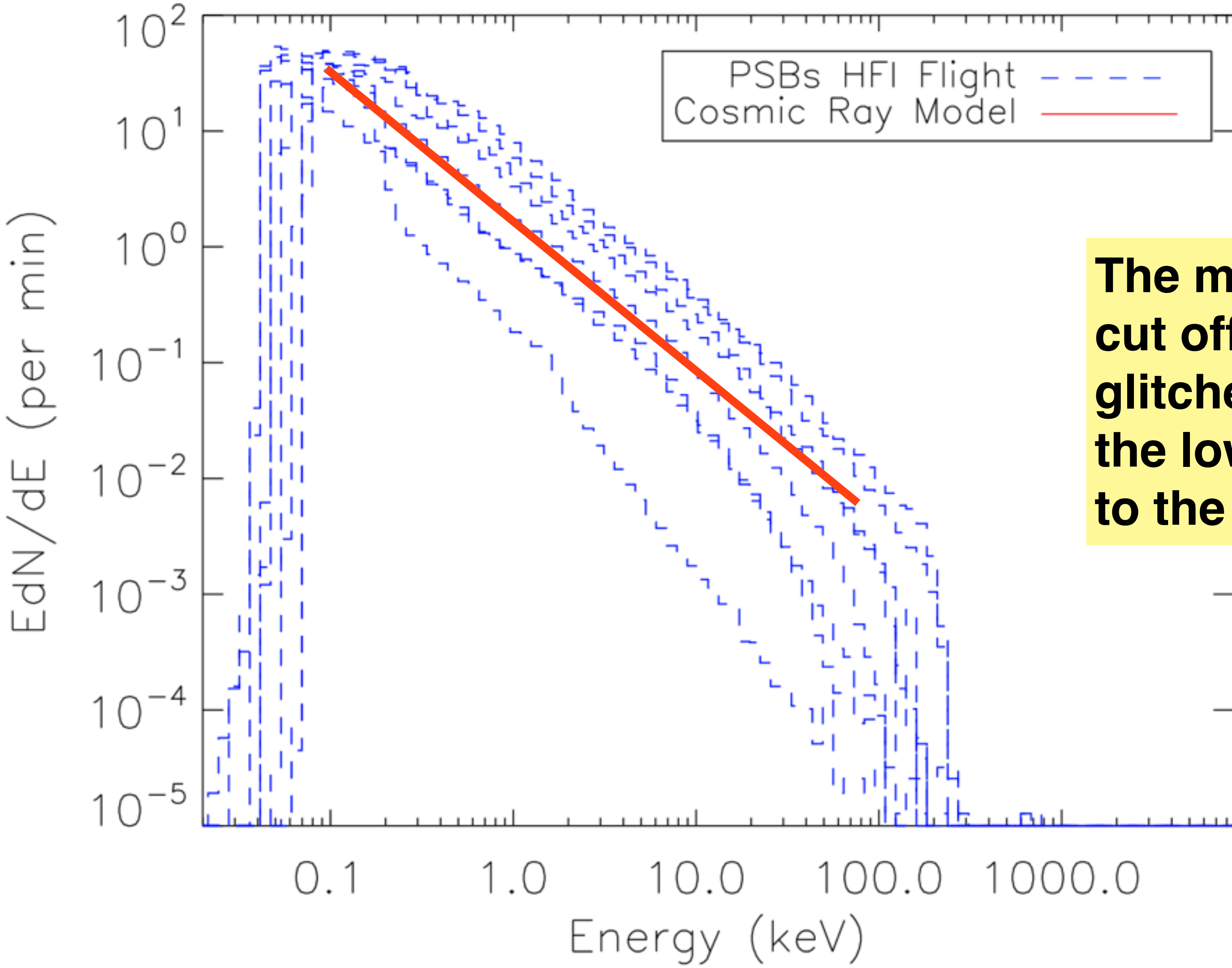


	Amp_{fast} [%]	τ_{fast} [ms]	τ_{slow} [ms]
Bolo Not Modified	46 ± 2.1	4.0 ± 0.8	20.0 ± 1.9
Bolo Modified	37 ± 2.6	3.6 ± 0.9	18.9 ± 1.9

The faster time constant can be explained by ballistic phonons heat conduction. The longer time constant of tens of milliseconds represents the heat diffusion between the silicon die and the NTD thermometers.

Long Glitches Model

Toy model considering the impact of CRs at the second Lagrange point with the silicon die



The model shows the cut off of the long glitches distribution of the low signal is close to the noise level.

Energy spectrum of some typical HFI in-flight bolometers (blue dashed lines) together with the predictions (red line)

Conclusion

• Glitch shapes are not simple single pole exponential decays and fall into a three families.

• The glitch shape for each family has been characterized empirically in flight data and removed from the detector time streams. The spectrum of the count rate/unit energy as a function is computed for each family and a correspondence to where on the detector the particle hit is made.

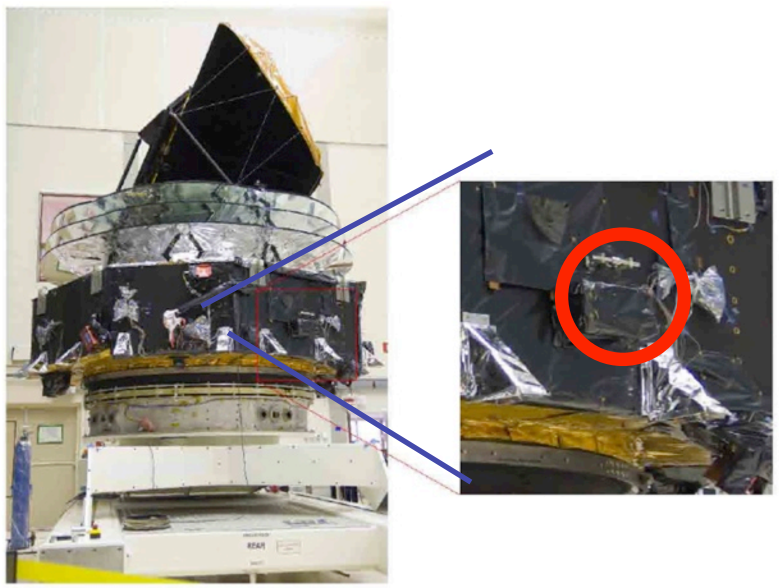
• Most of the detected glitches are from particles incident on the Silicon die frame supporting the micro-machined bolometric detectors.

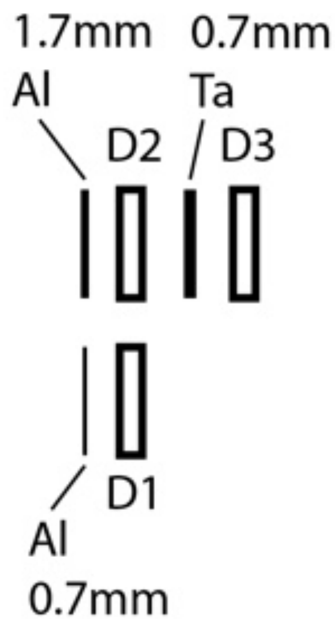
• The influence of CRs for future generation arrays for space must be taken into account from the very first phases of the design in parallel with all the other characteristics like NEP and time response. In particular, beam testing should be planned to study irradiation on whole array of detectors (pixels, substrate and housing).

The Standard Radiation Environment Monitor

(Mohammadzadeh et al. 2003)

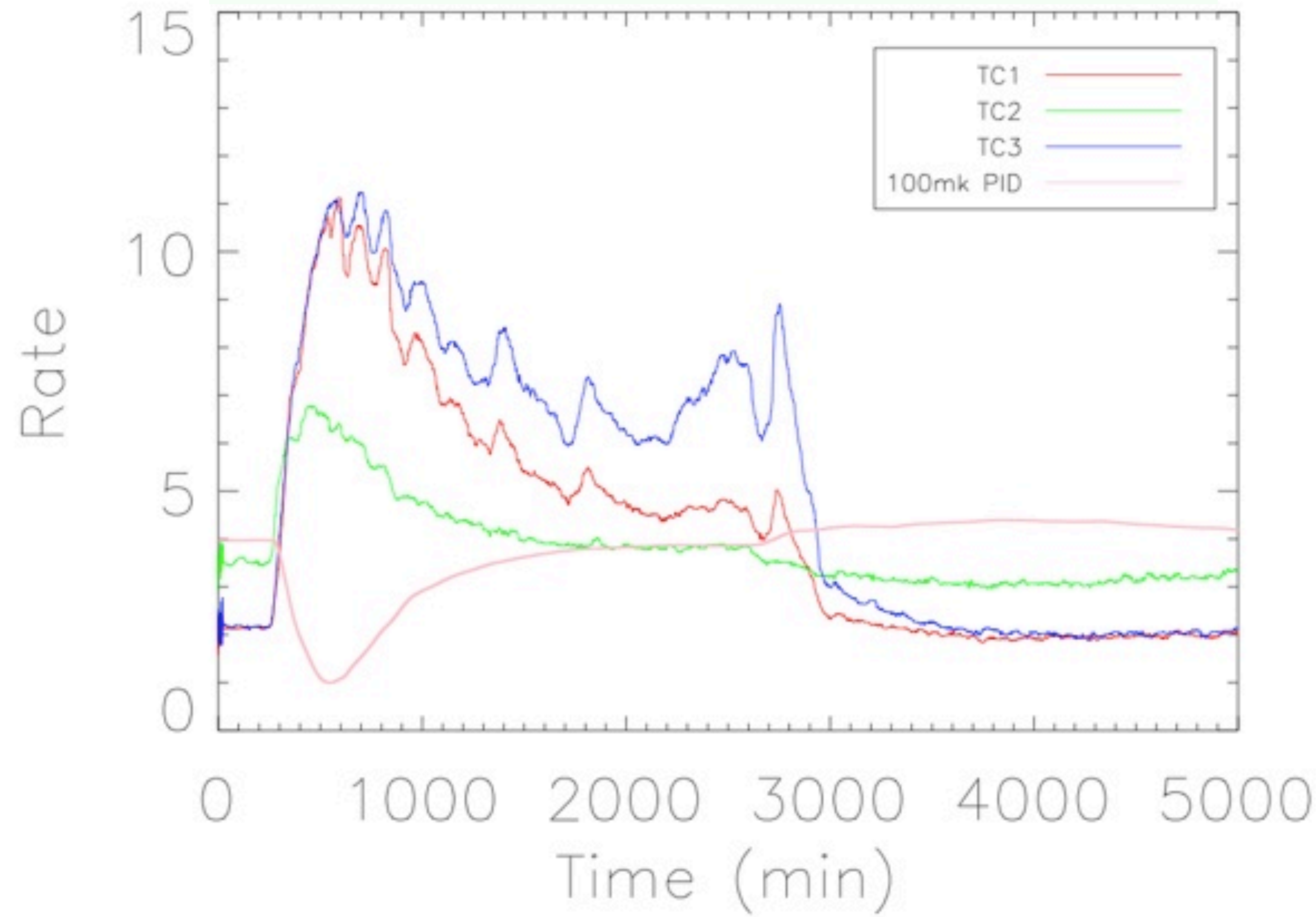
SREM consists of three detectors (D1,D2,D3) in two detectors heads configurations





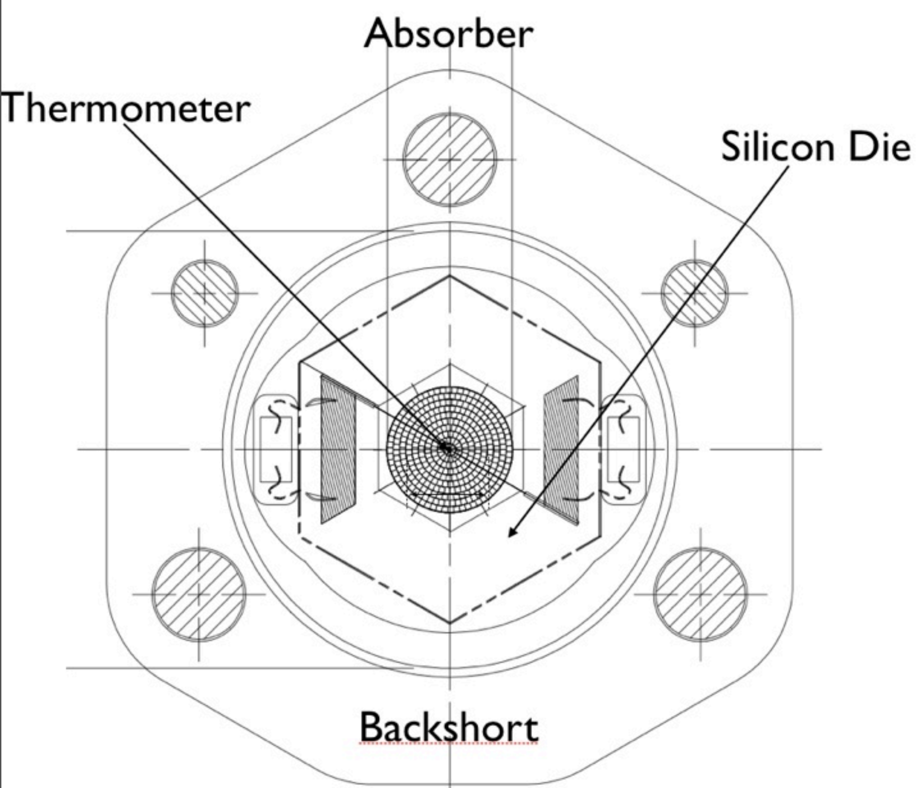
- TC1 (D1) measures protons in a range of energy between 20 MeV and Inf.
- TC2 (D2) measures protons in a range of energy between 39 MeV and Inf.
- TC3 (D3) measures electrons in a range of energy between 0.5 MeV and Inf and protons.

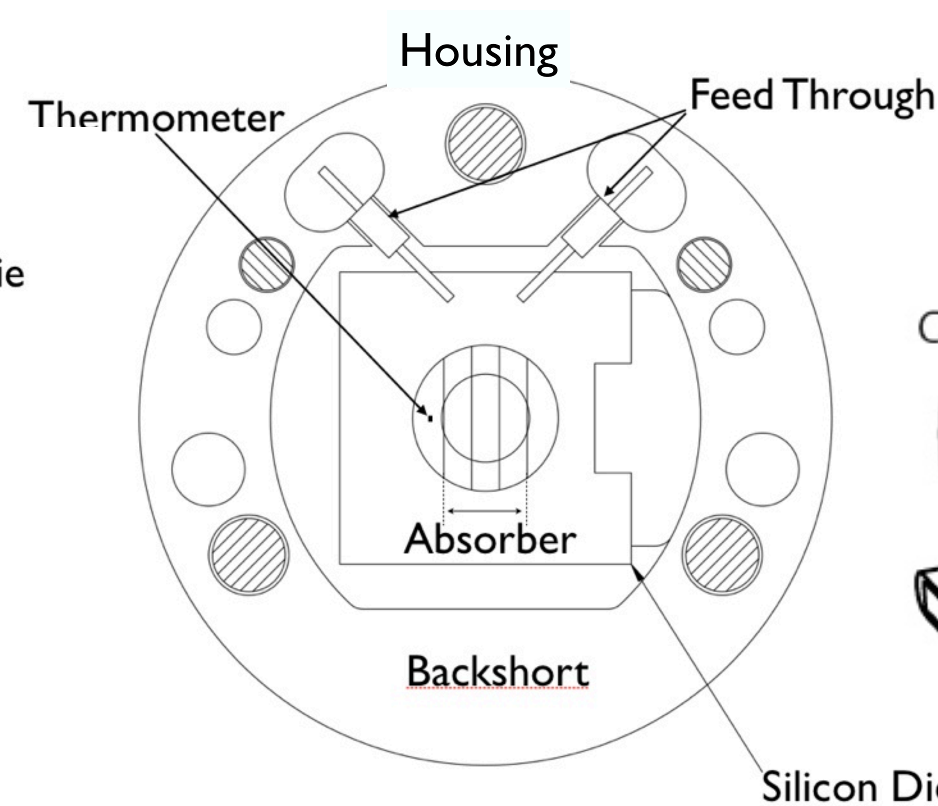
TC1-TC2-TC3 signals during the solar flares and the 100mk stage PID (in arbitrary units)

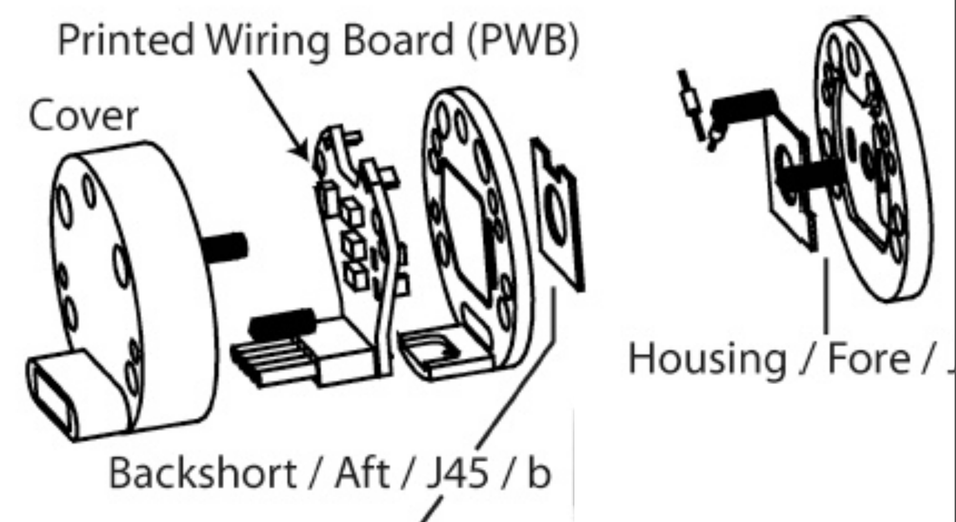


Low energy protons (below 40Mev) and high energy electrons are not able to penetrate the satellite up to the 100mK stage.

HFI Bolometers (Holmes et al. - 2008)







Thermometer (Ge) :
20x100x300 micron
Surface : 3 10^4 micron^2

Grid :
Diameter = 4 mm
2.4 - 6.4 micron wide
Thickness Si3N4= 1 micron
Surface :3.9 10^4 - 4.6 10^5 micron^2
Au - 12 nm

Silicon Die :
Thickness = 360 micron
Surface 0.4-0.8 cm^2