PROTON INDUCED ACTIVATION

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Determination of activation

- Why?

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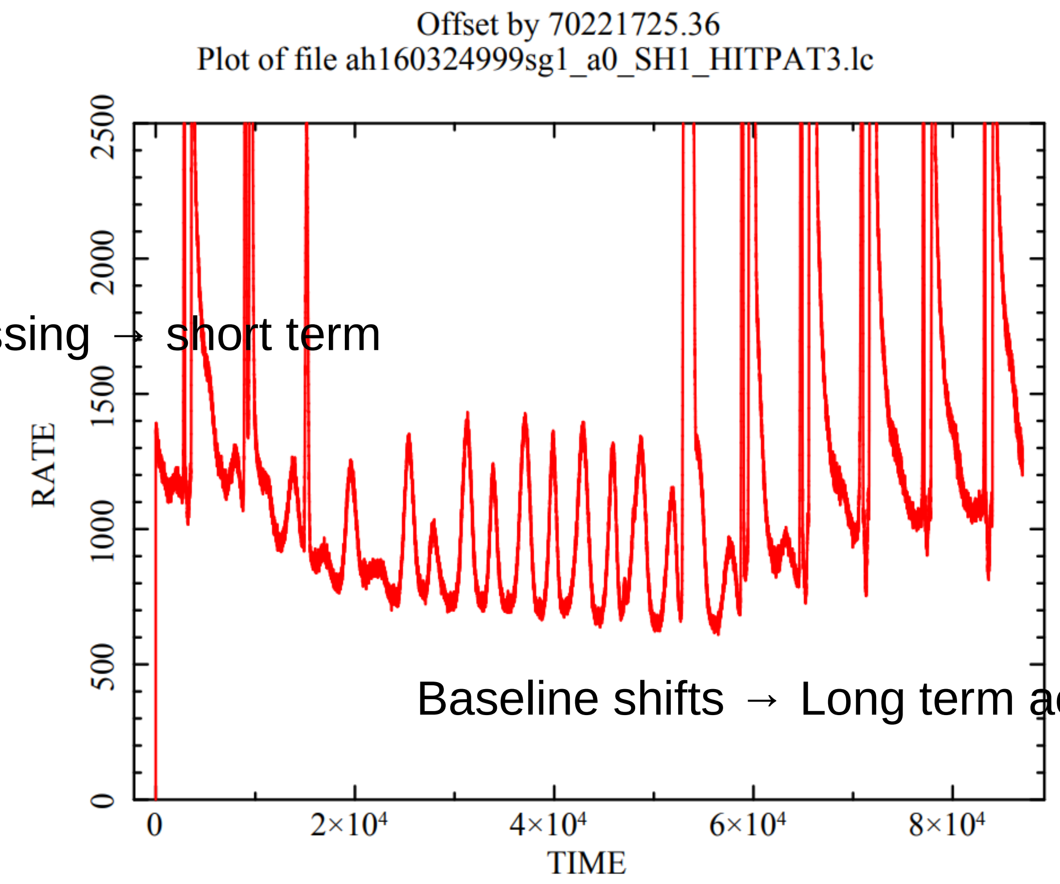
- Why?
- An example from Hitomi



SAA passing → short term

Baseline shifts → Long term activation

How can we do it fast?

- Direct Monte-Carlo takes a lot of time (especially when we want precise results)

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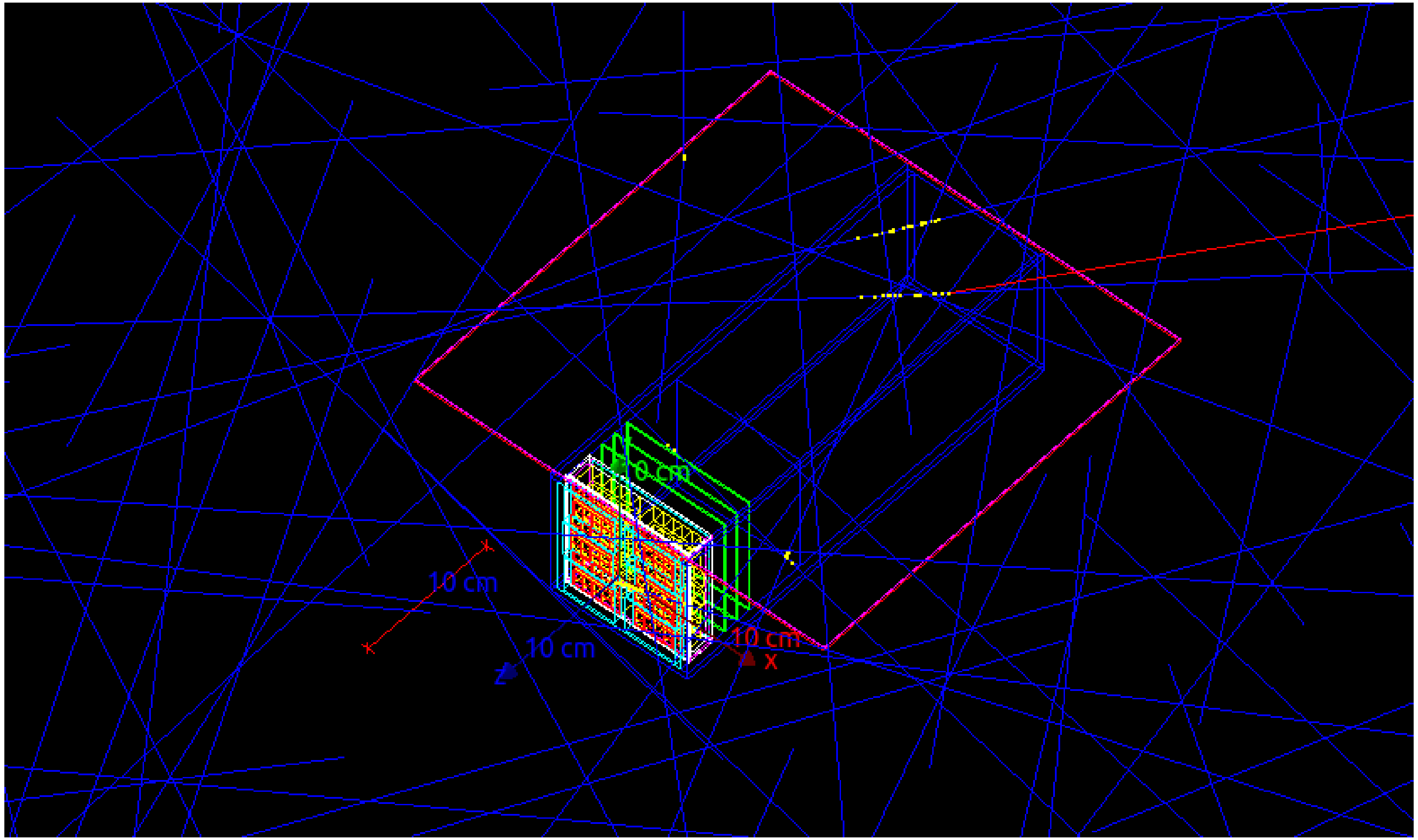
- Direct Monte-Carlo takes a lot of time (especially when we want precise results)
- Solution: Decouple radioactive isotope production and their decays
- Three steps:
    1. Simulate the irradiation of a short interval and determine the produced isotopes
    2. Determine what isotopes are abundant after a certain time (analytical)
    3. Run second simulation with the isotopes produced

Step 1 -- Isotope production



Step 1 results

- List of produced isotopes and their production rate
- Treated independently in all volumes and energies!
- For example for 100 MeV inside scintillator 6 most abundant:

Name	Normed production to 100 000 cm^{-2} fluence
O15	67699
Ga68	68917
Ga67	71839
Tb154	74031
Tb155	88155
Tb153	89373

Step 2 – Solving the Bateman eq.

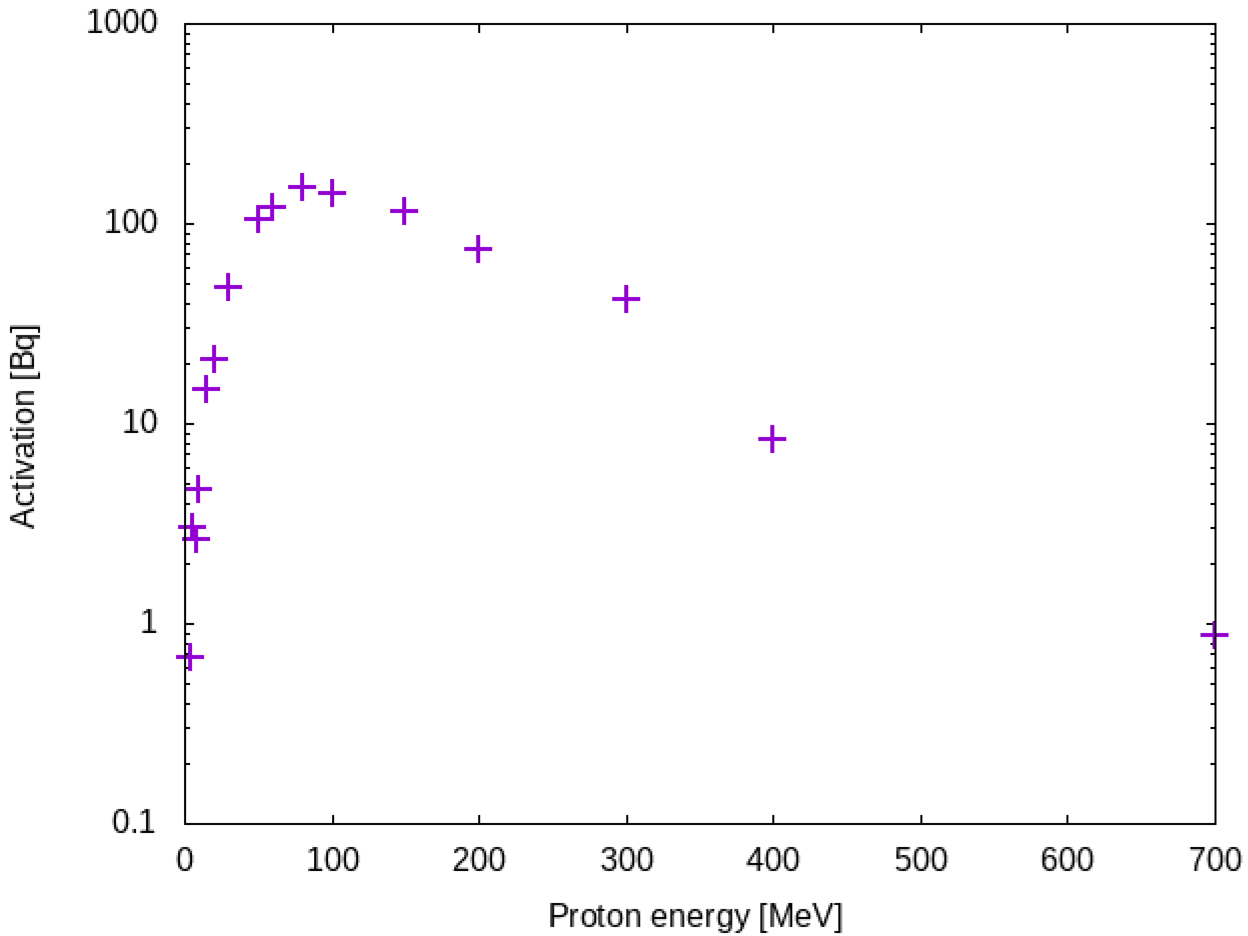
- Building up decay chains for isotopes identified in step 1
- Solving the Bateman-eq to get activation:
  - For each volume
  - For each energy
  - For each timeslice
- Summing up the activation for different irradiation timeslice and energy

Step 2 – Results

- Lot of decay chains for high energy → e.g. 700 MeV 1 844 382 decay chains
- Also long decay chains:

  e.g. Hf156 Yb152 Tm152[482.320] Tm152 Er152[1715.400] Er152 Ho152[179.400] Ho152 Dy152[3500.000] Dy152 Tb152[256.930] Tb152 Gd152[2880.670] Gd152 Sm148 Nd144
- **800 Bq of activity, half of it is in the scintillator**
- After half year in orbit with inclination of 40°
- AP9 90% CL input spectrum → "Worst case scenario"

Step 2 – Results



The contribution of different energy bands of primary protons to the activation of the satellite. The fluence used for this followed the fluence in an orbit with inclination of 40°.

Step 2 – Results

- 100 MeV scintillator

Activity [Bq]

Ga68 3.2

Tb153 2.8

Tb155 2.7

Ga67 2.6

Tb154 2.3

- 20 MeV scintillator

Activity [Bq]

Ge69 0.56

Ge71 0.18

Tb155 0.14

N13 0.071

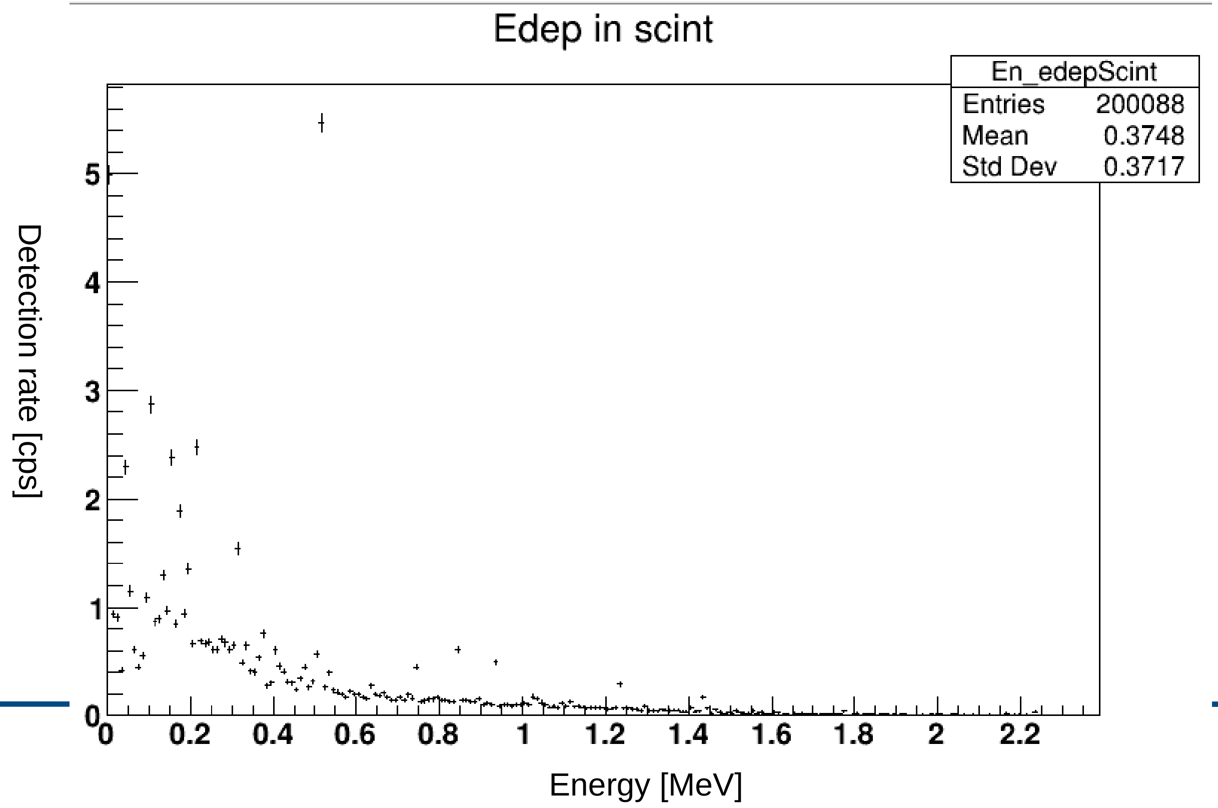
Tb156 0.046

Step 3 – Detector response

- Place most active isotopes for each volume in its regarding volume and record deposited energy inside the detectors (SDD and scintillators)
- Possible to decouple the activation of each volume!
- Crate simulated spectrum that is what we would actually measure from activation!
- For each volume the 5 most active isotopes chosen and places inside the respective volume (30 volumes)

Step 3 – The final result

- After half year in orbit with inclination of 40°
- AP9 90% CL input spectrum → “Worst case scenario”
- 60 cps background from activation



Next steps

- Run the same simulation for different orbits → Activation in polar orbits?
- Validate simulation with GAGG activation measurements
- Check short term activation