PXD HV “Trips” Issues
By Over-Voltage-Protection
&
The relation to (neutron) doses “on top of Belle”

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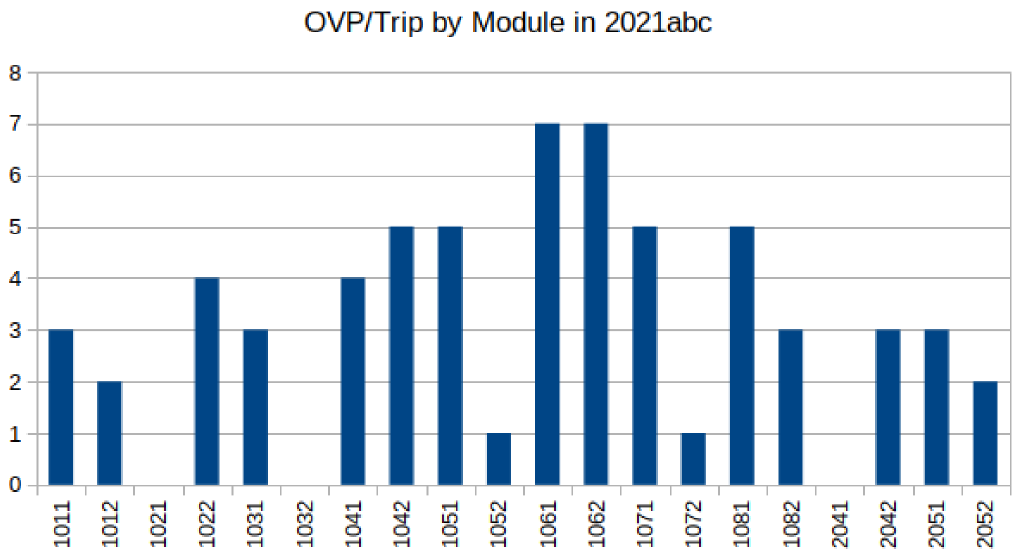
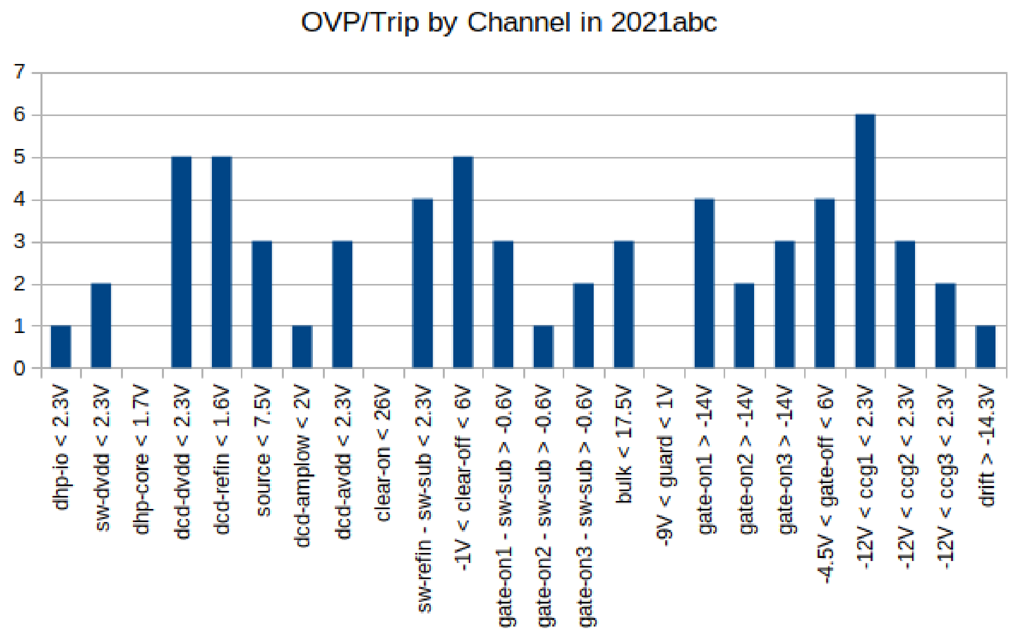
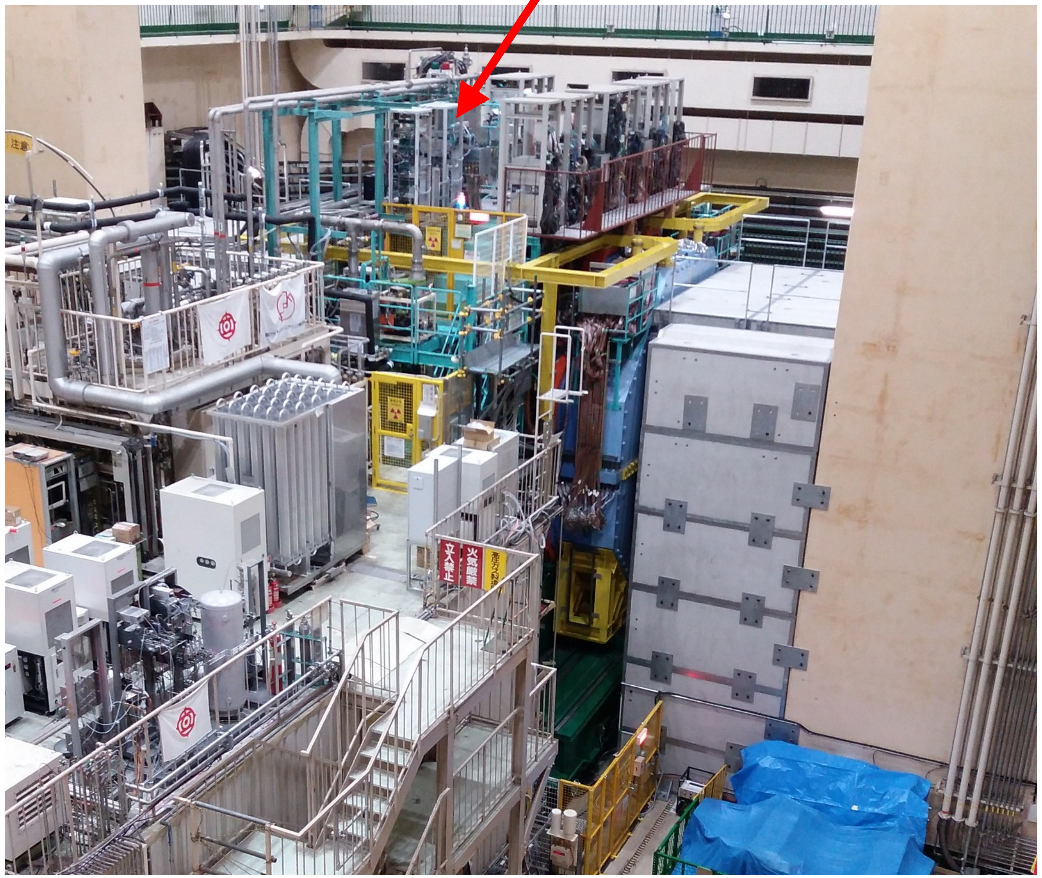
Reminder PXD PSU "HV Trips"

- PXD "HV Trip" rate increased in spring 2021, rate ~0.5-1 per day
  - Issued by the Over-Voltage-Protection board, which pretects sensor and ASICs from over voltage or wrong polarity between voltages to the PXD sensor (and ASICs); altogether 24 relations between voltages
  - Hard-wired, faster than monitoring, but we can see which channel/condition triggered
- Observation: (within statistics) evenly distributed over most PSU units and monitored conditions → cannot be explained by issues/SEU on the detector modules/ASICs themselves
    - We could rule out many possible reasons (rack, crate, MCU firmware, software, …)
    - Rate went up when we increased beam currents/lumi in 2021?
  - PXD Power supplies are located on top of Belle → Hint to SEU in PSU?





PSU Racks – Location

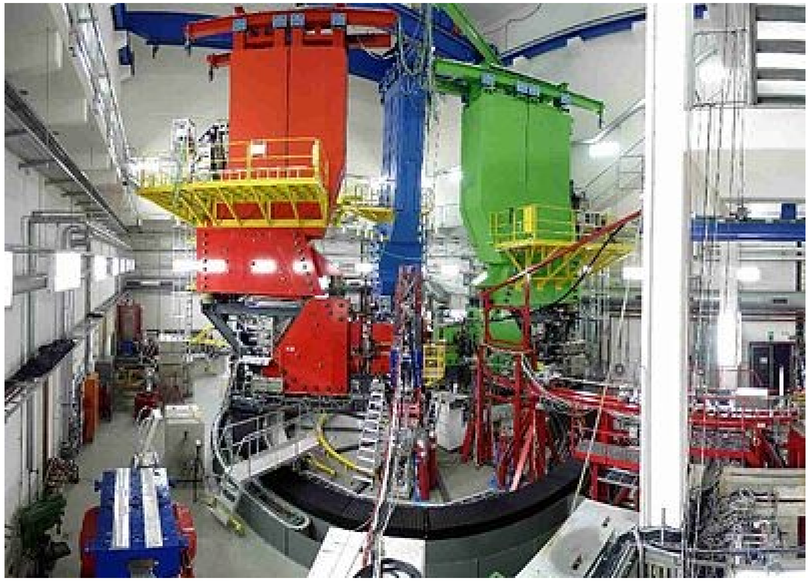


Sry, didn't find nicer pictures

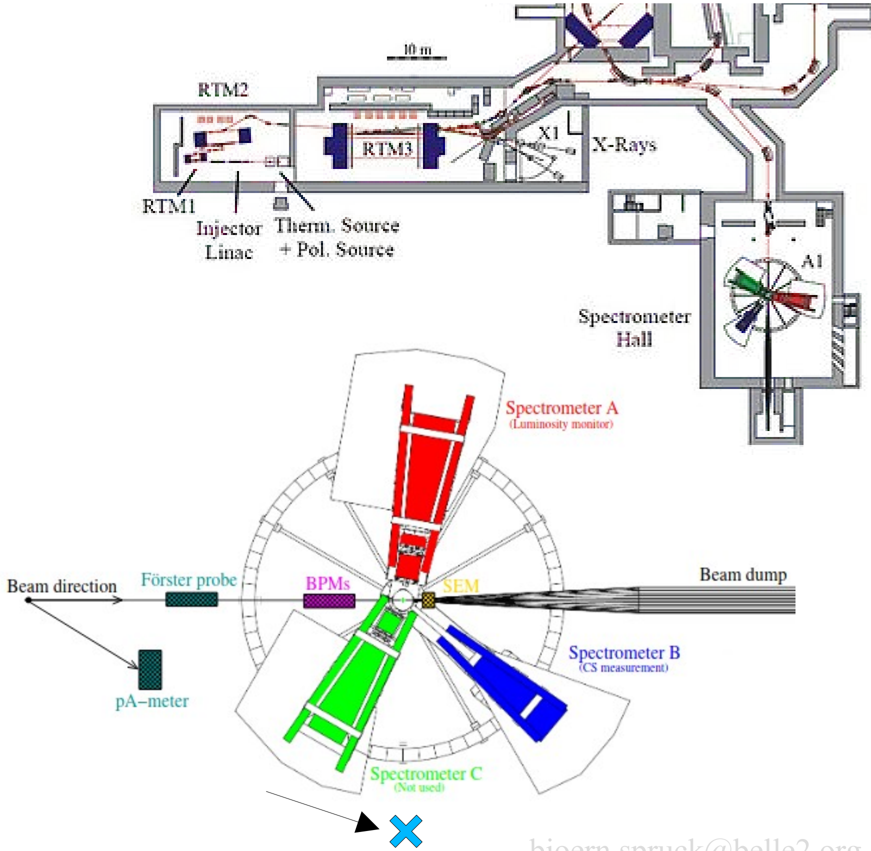
- But let me clearly state:
  - We did not expect SEU in electronic equipment at this position at that rate!
  - Does not fit with observations of other equipment at same position!

Verification – Irradiation Test at MAMI

- Goal: Check if we can issue KEK-like OVP/Trips by irradiating a PS Unit
  - Only PSU, **no module**
- Parasitic experiment, we just take advantage of the radiation levels in the MAMI A1 spectrometer hall
  - Scattering 15uA of 882 MeV e- beam on Ca target

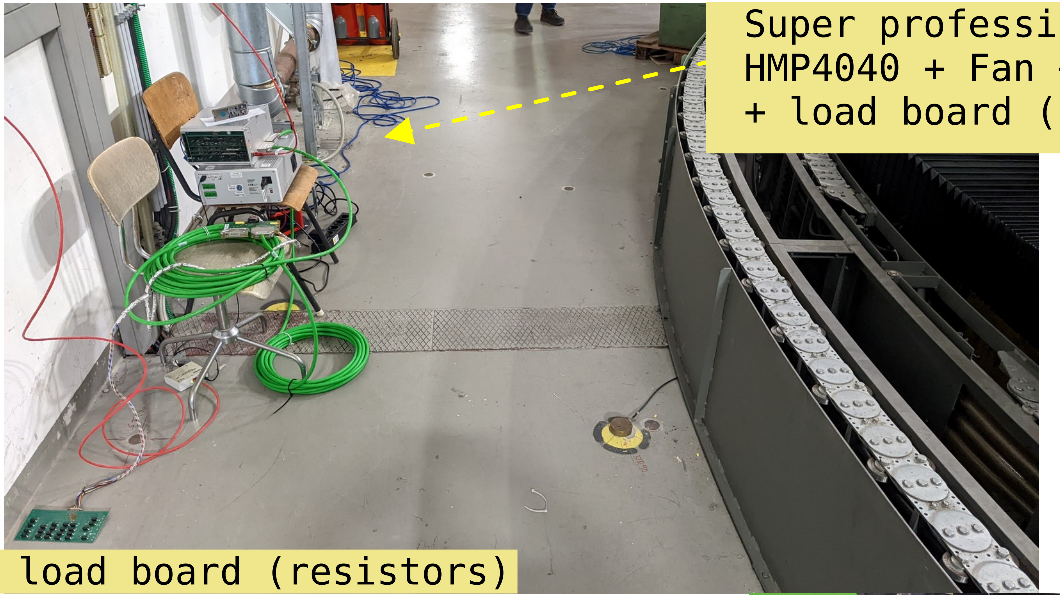


- Challenges:
  - We do not know the precise radiation levels nor radiation types on top of Belle nor in the A1 hall. Are they comparable?
  - We observed 0.5 trips/day with 20 PSU at KEK, need 100-1000 times the radiation to see some useful statistics
  - Radiation level depends on angle and distance to target
  - We started with a simple see/no see experiment, quantify in a second round



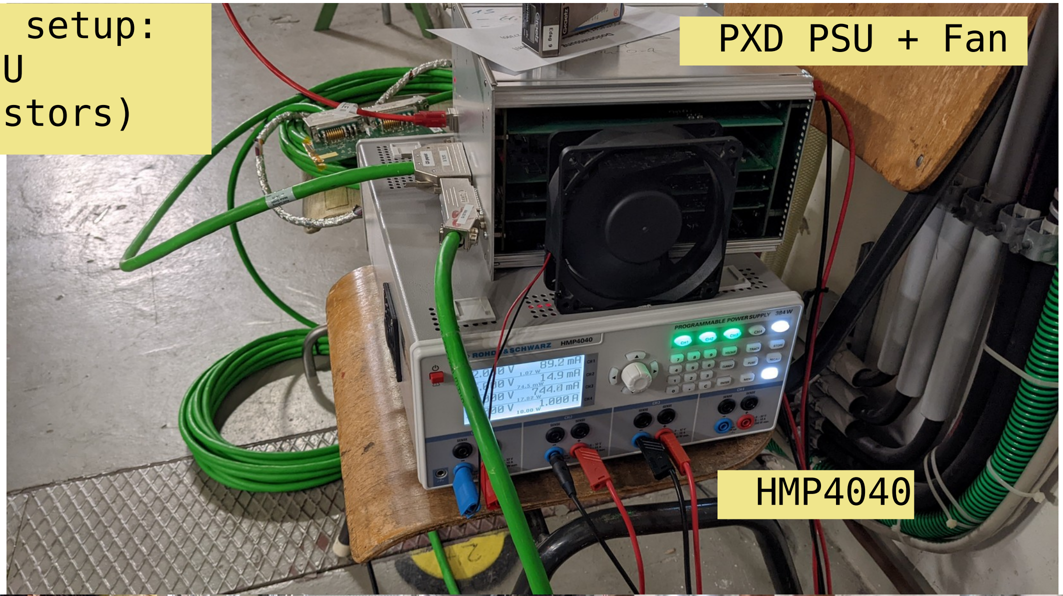
  - Done in a rush: idea mid January, first test beginning of February, second campaign until end of March

Setup



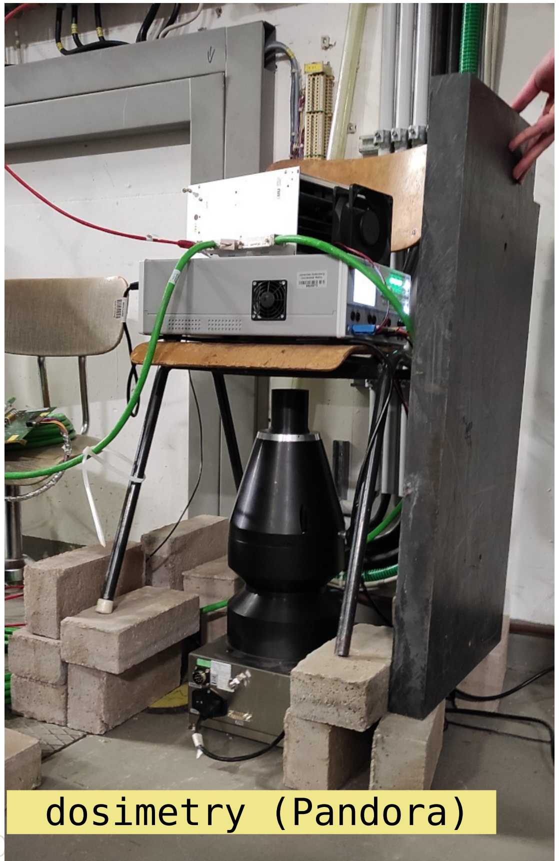
Super professional setup:
HMP4040 + Fan + PSU
+ load board (resistors)

load board (resistors)



PXD PSU + Fan

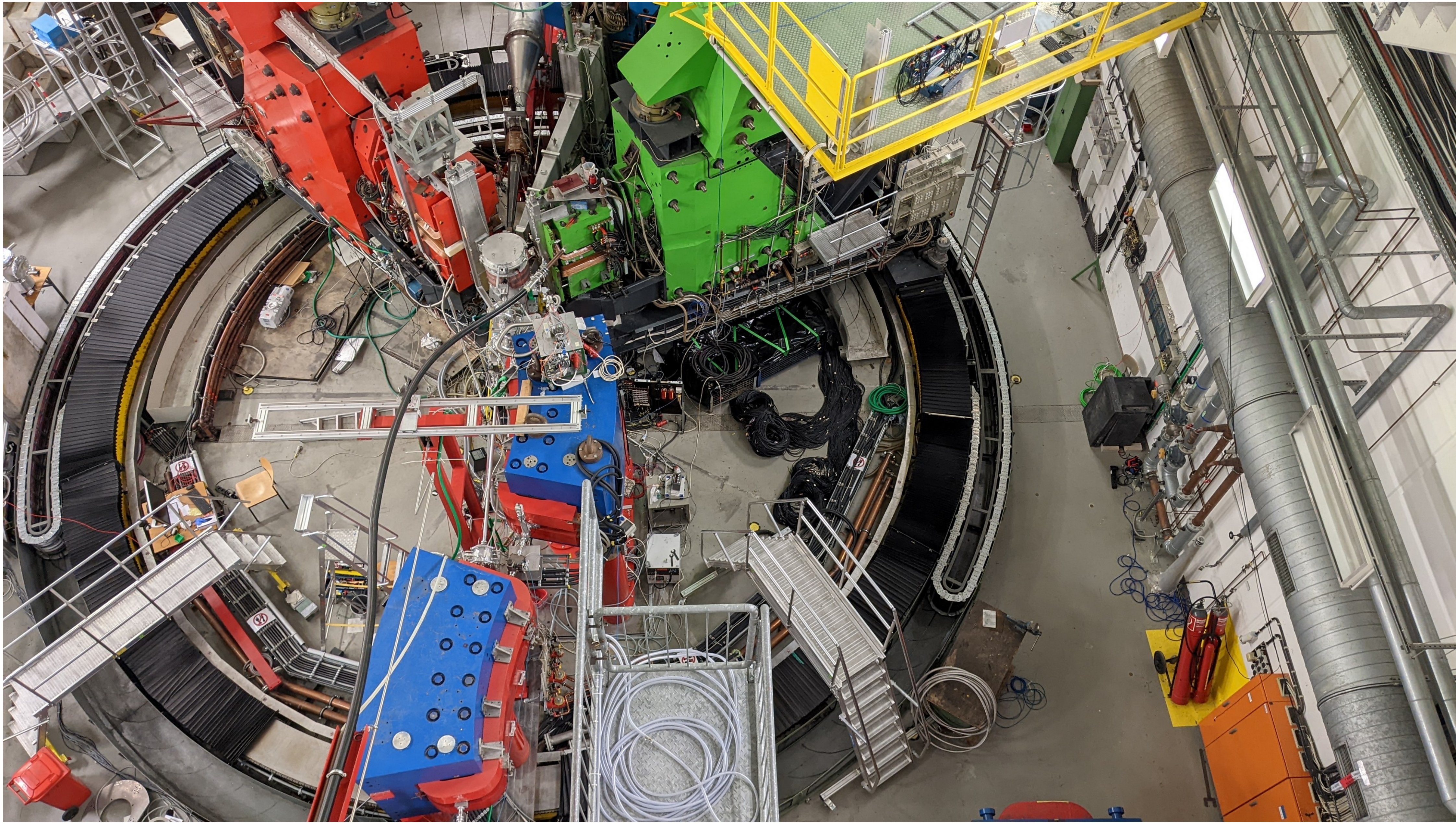
HMP4040



dosimetry (Pandora)

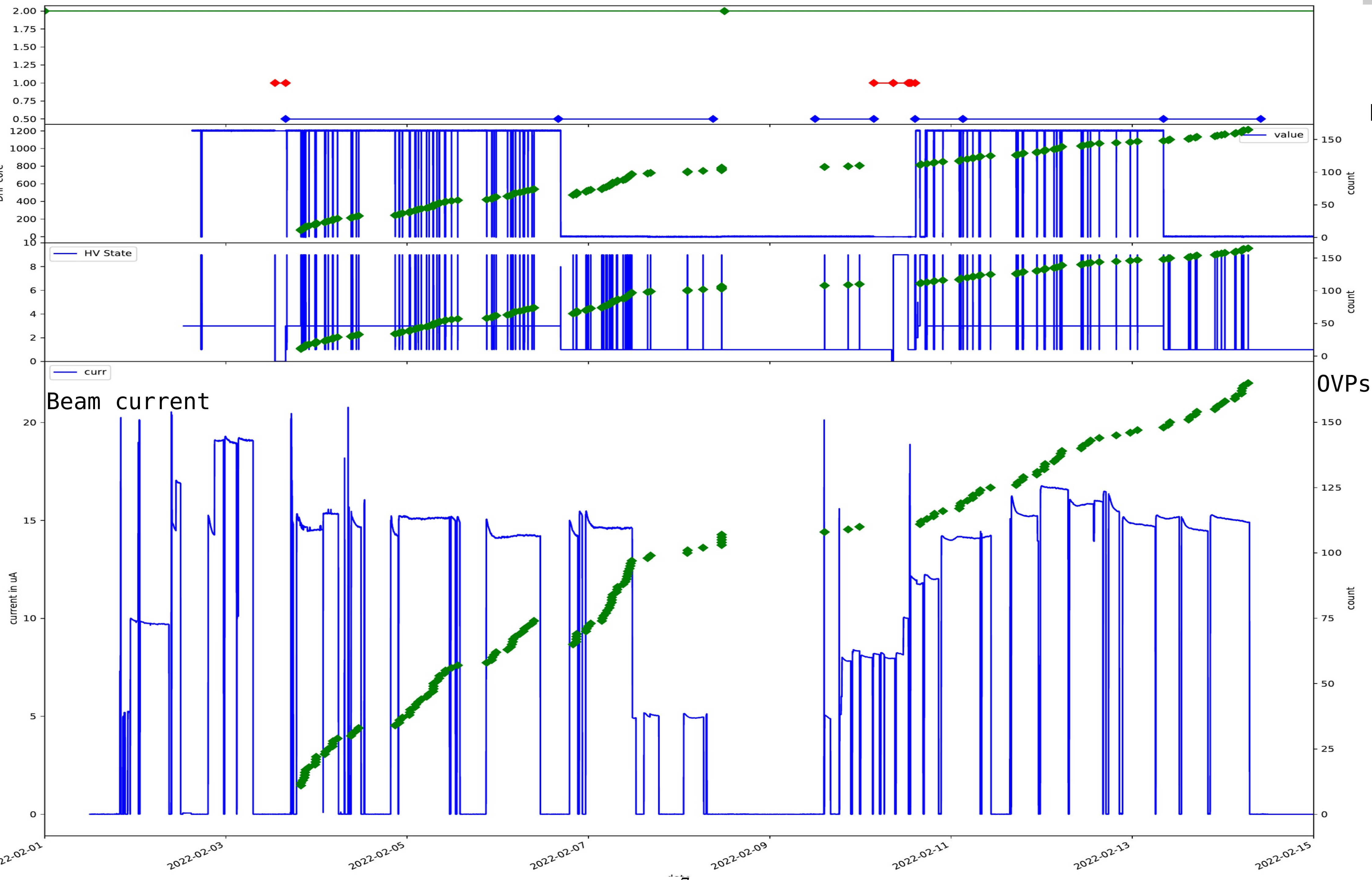
Adding PE housing n*5cm (with ??% Boron)
and proper dosimetry (Pandora)

Setup

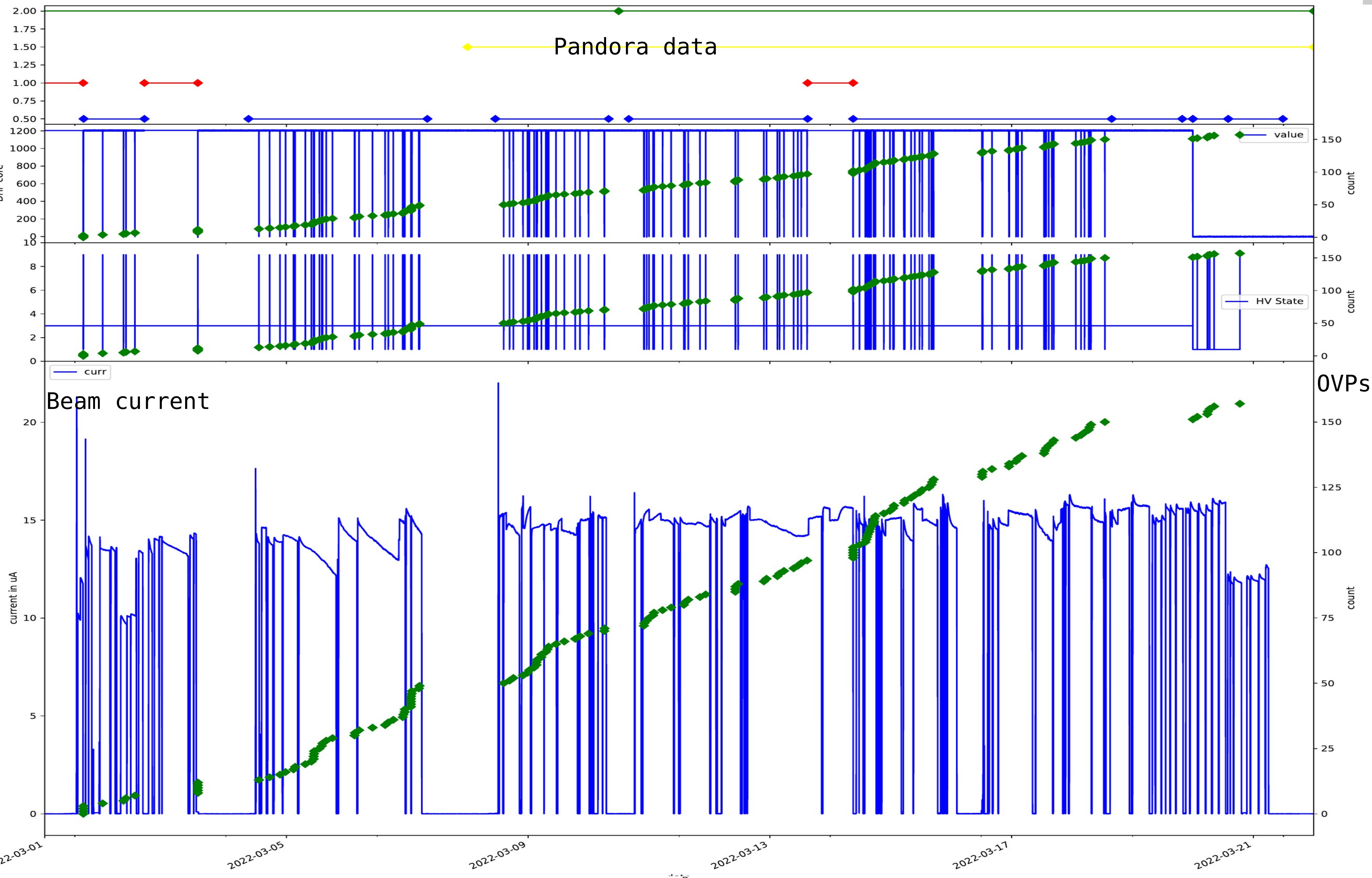


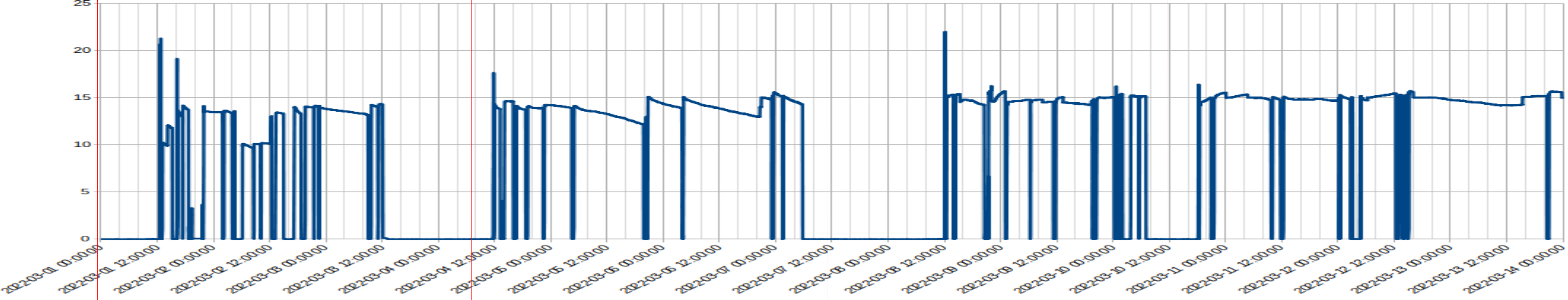
Crew: Jannes Schmitz, Matthias Hoek, Felix Keil: setting up, organizing, monitoring etc
And thanks to DESY for Pandora and Arthur Bolz for the Laptop ;)

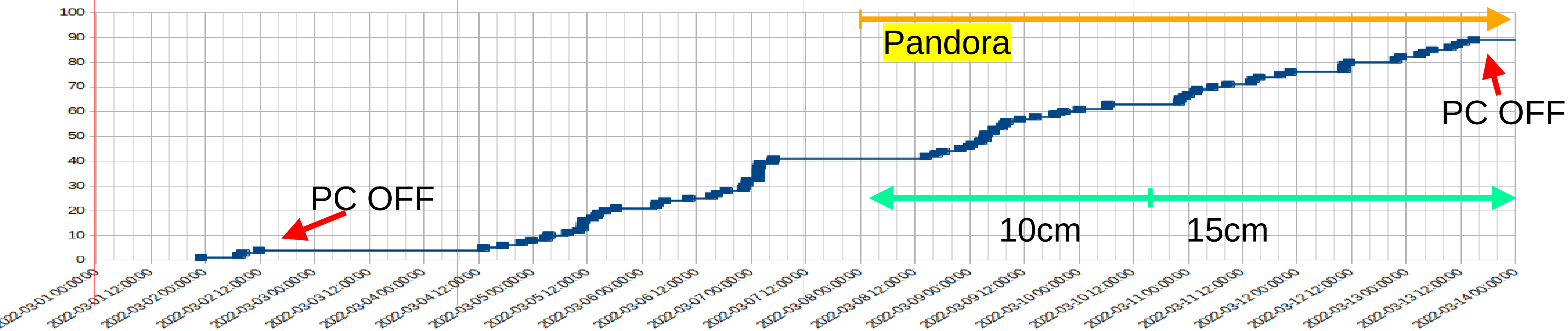
MAMI, Overview February



MAMI, Overview March



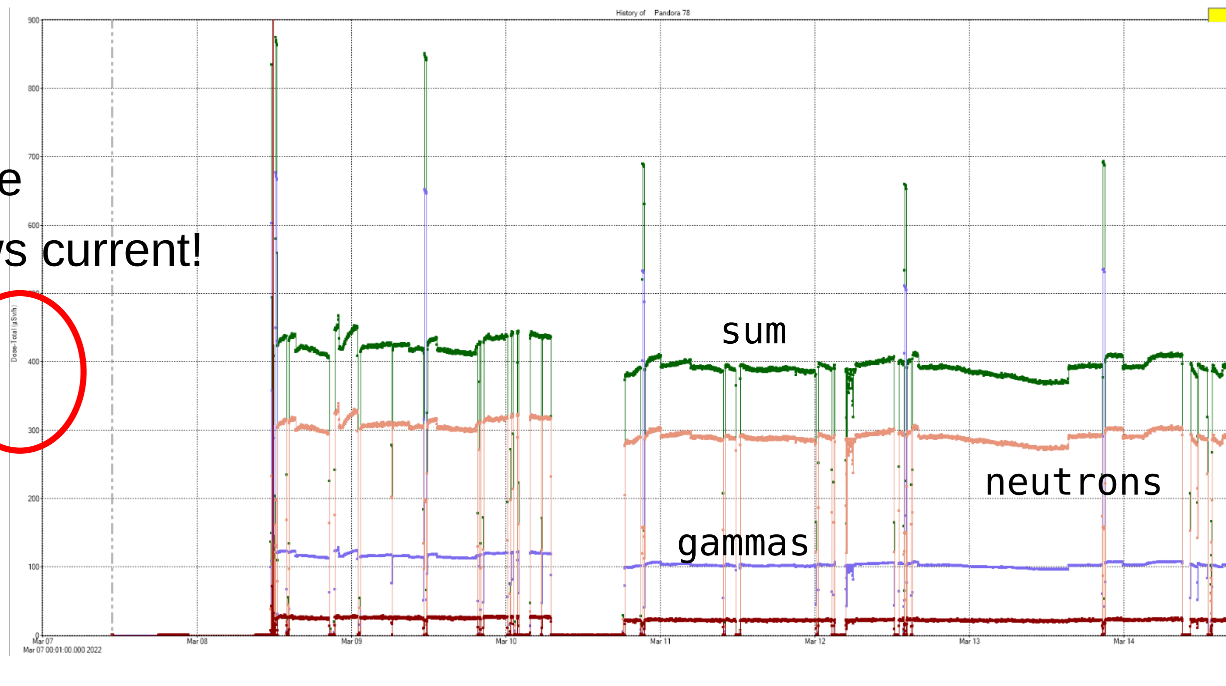




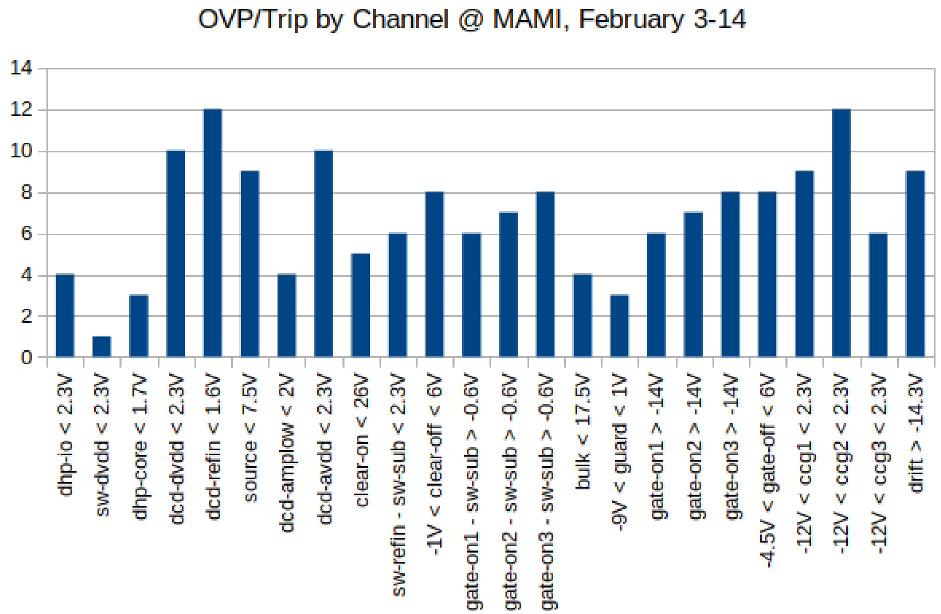
Linear Scale

Dose follows current!

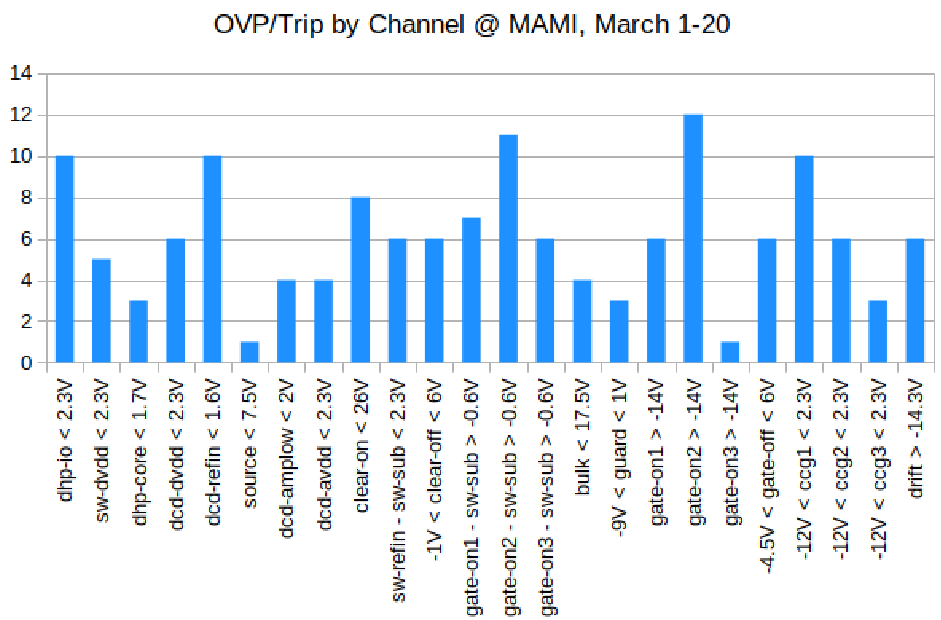
400 uSv/h
Compare to KEK
1 uSv/h

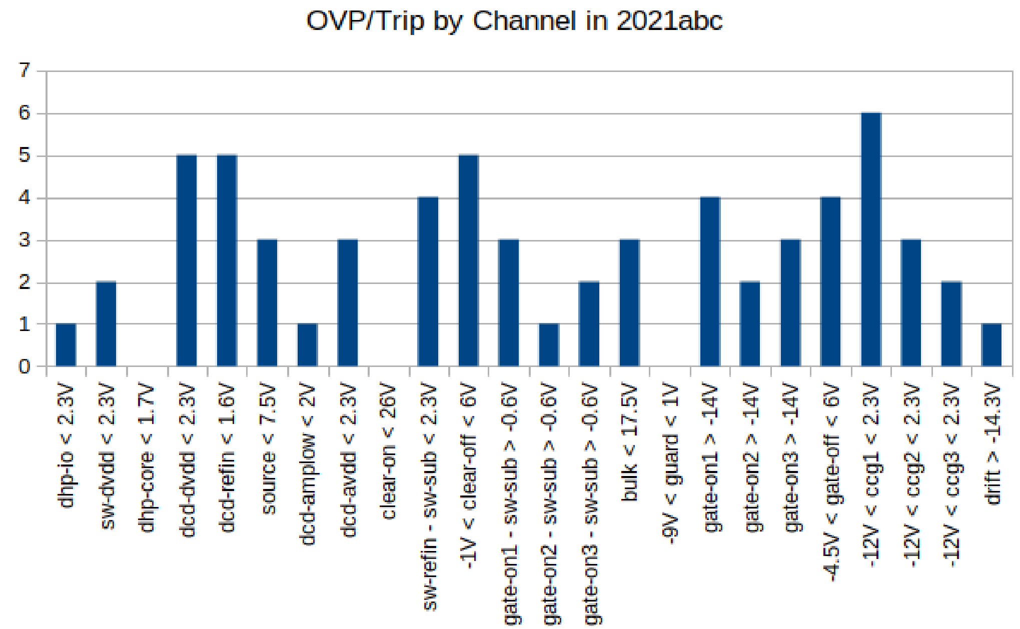


By Channel



- All Channel affected
- Uniform within statistics fluctuation
- OVPs happen in PEAK, STANDBY, OFF and in masked channels

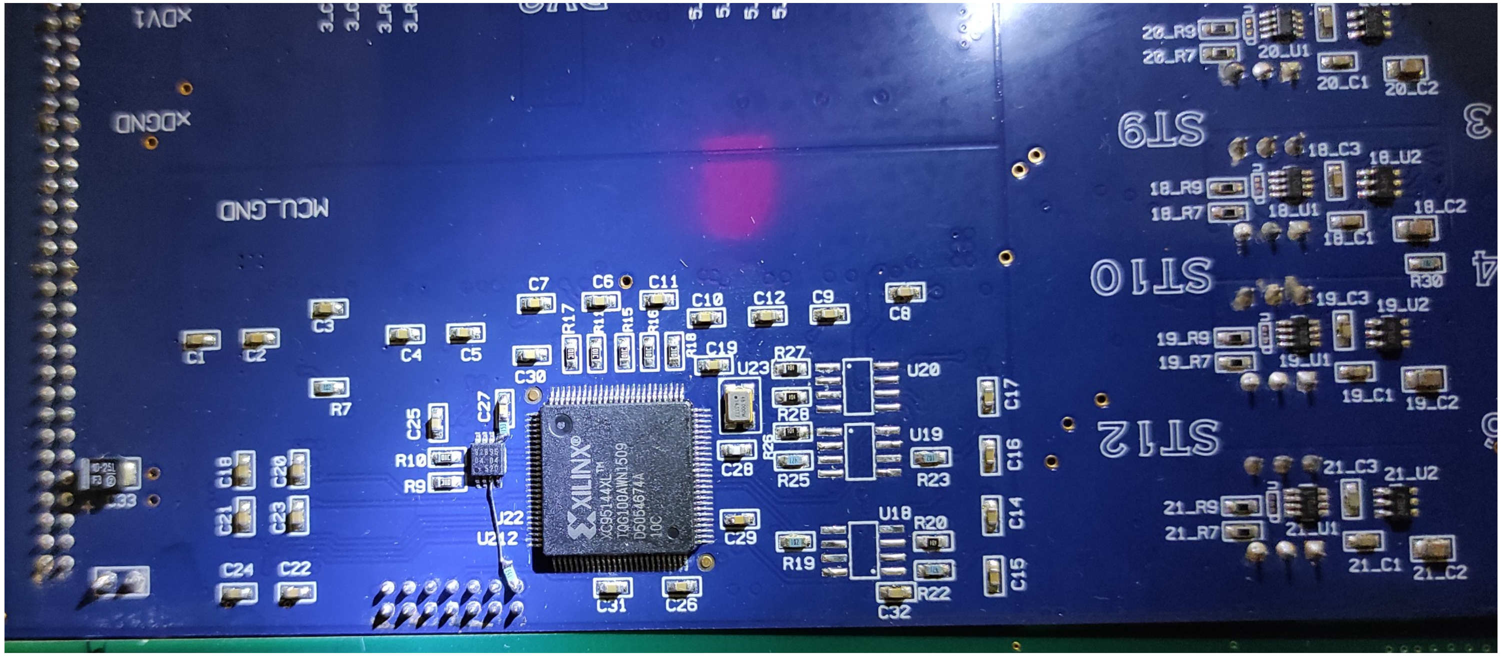




Outcome

- We observed >300 radiation induced OVPs within several weeks
  - → it is proven that it is coming from radiation (even so not its kind)
  - Evenly distributed over channels, similar to KEK
- OVPs happen even if the voltage regulators are off (by now also seen at KEK)
  - → points to radiation sensitive component on the OVP detection board (the CPLD???)

Why CPLD?

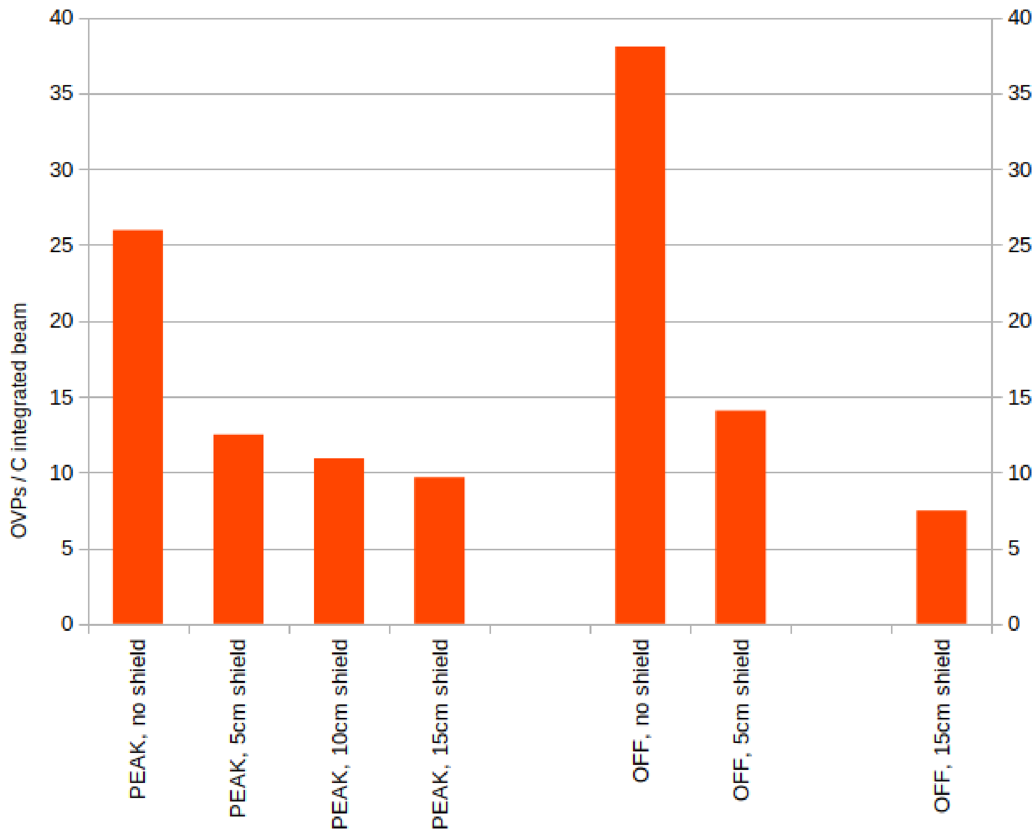


- All channels are affected → common component for all channels
- CPLD issues the direct emergency off signal and the monitoring for i2c
- (there are two CPLDs, but only one handles the emergency off)
- Radiation sensitivity? No data available (but nobody asked Xilinx directly yet)

Effect of Shielding

- 5cm of PE reduced the rate by 50% (estimate, we had no proper dose measurement here and had to normalize to beam currents under different conditions)
  - Adding more PE (10cm, 15cm) did not yield much additional effect

- Limits:
  - Normalization to beam currents difficult, as radiation is depending on experimental conditions on top of current (beam on target?)
    - → effect of PE was hard to quantify without proper dose measurement (we only had it for 10cm and 15cm)
    - Scattering of neutrons? 10/15cm only towards target, not to the sides (5cm).
  - Boron content of PE not known

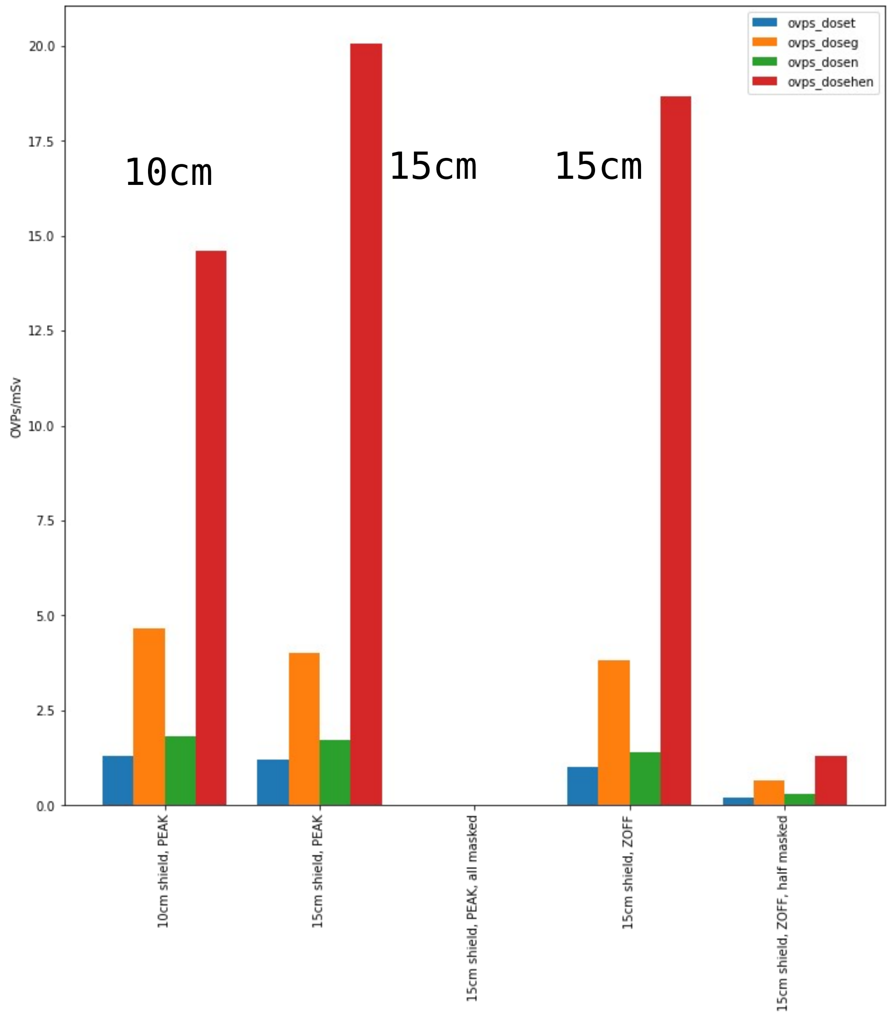


Doses / OVPs in Test @Mainz

- ~ 1 OVP/mSv total dose
- ~ 1.3 OVP/mSv neutron dose
- ~ 4 OVP/mSv gamma dose

- Attention for comparison:
  - Placement of sensors
  - Incident angle to radiation source
  - Different radiation sensors!

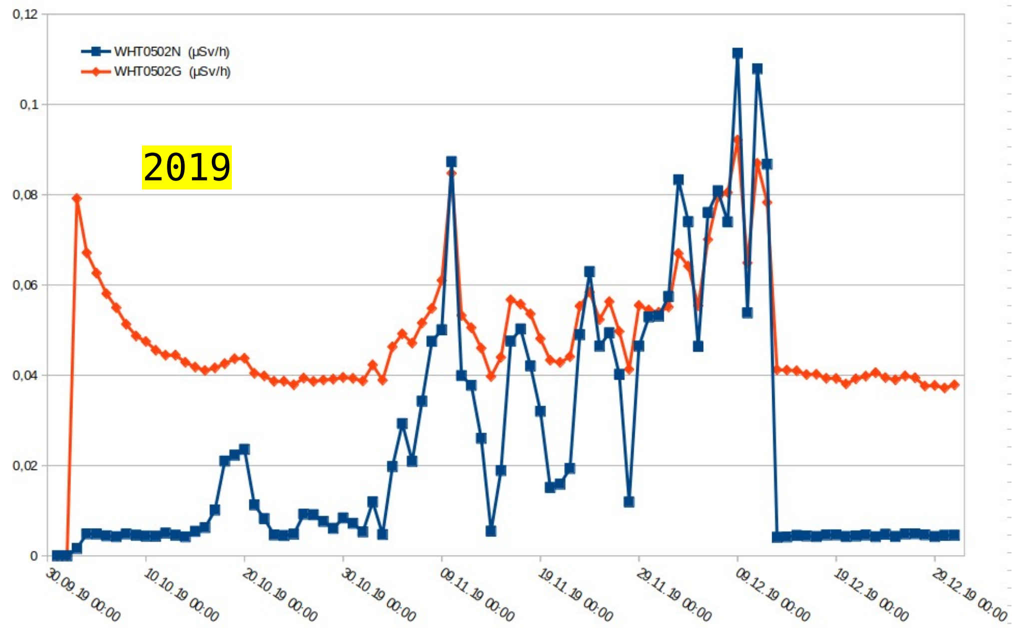
- Remarks:
  - In the first estimate without shielding, we saw 5 OVP/mSv ionizing dose (very basic dose measurement)
  - Fluctuations: our first preliminary result was ~ 2 OVP/mSv neutrons



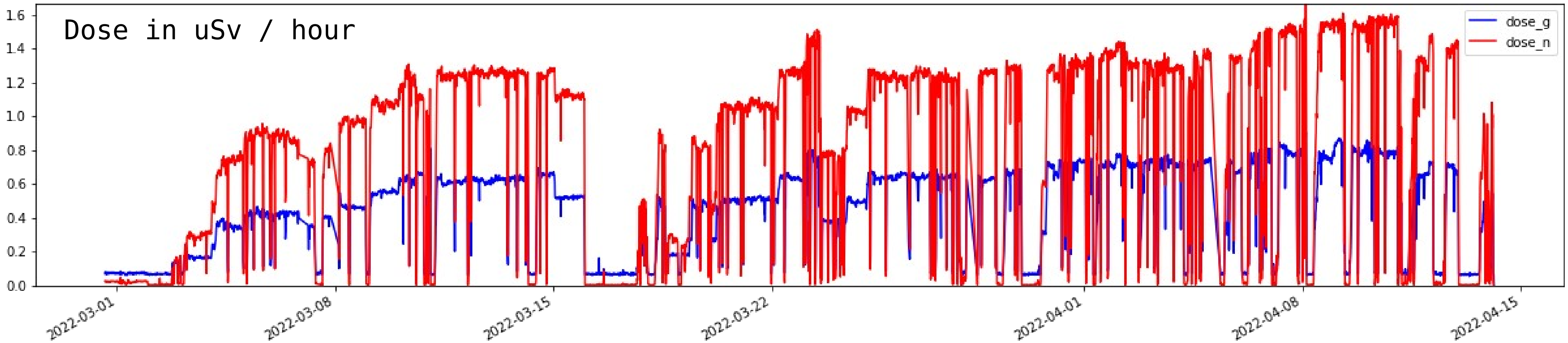
Dose is measured inside PE housing next to the PSU, thus numbers for 10cm and 15cm should be “identical”

At KEK

- A time series of gamma/neutron measurement *near* top of Belle was measure in late **2019**. Not very useful for comparison because of lower currents and different position. Order of magnitude: ~0.1 mSv/hour for gamma and neutron

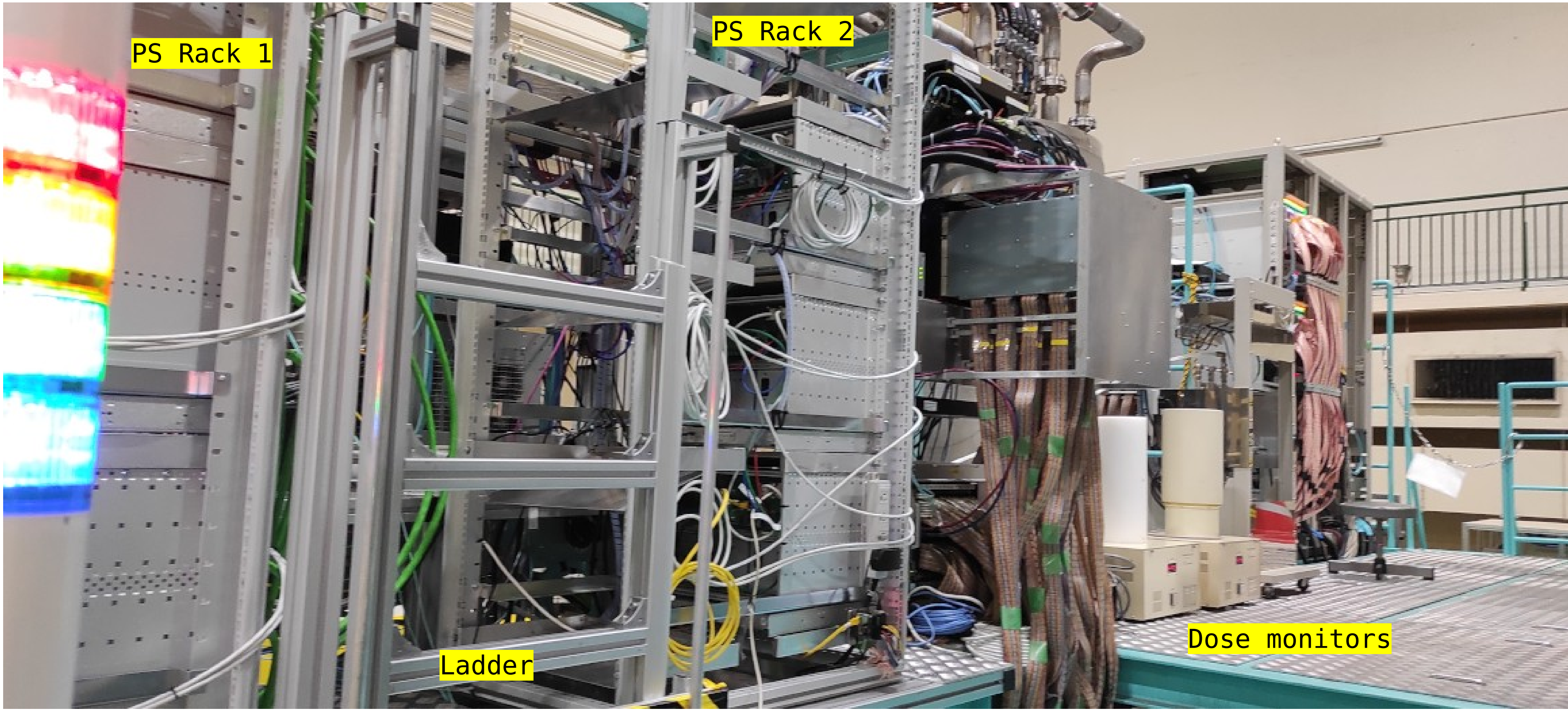


- Now: counters near PSU rack since start of 2022
  - (you may notice some short periods w/o valid data)



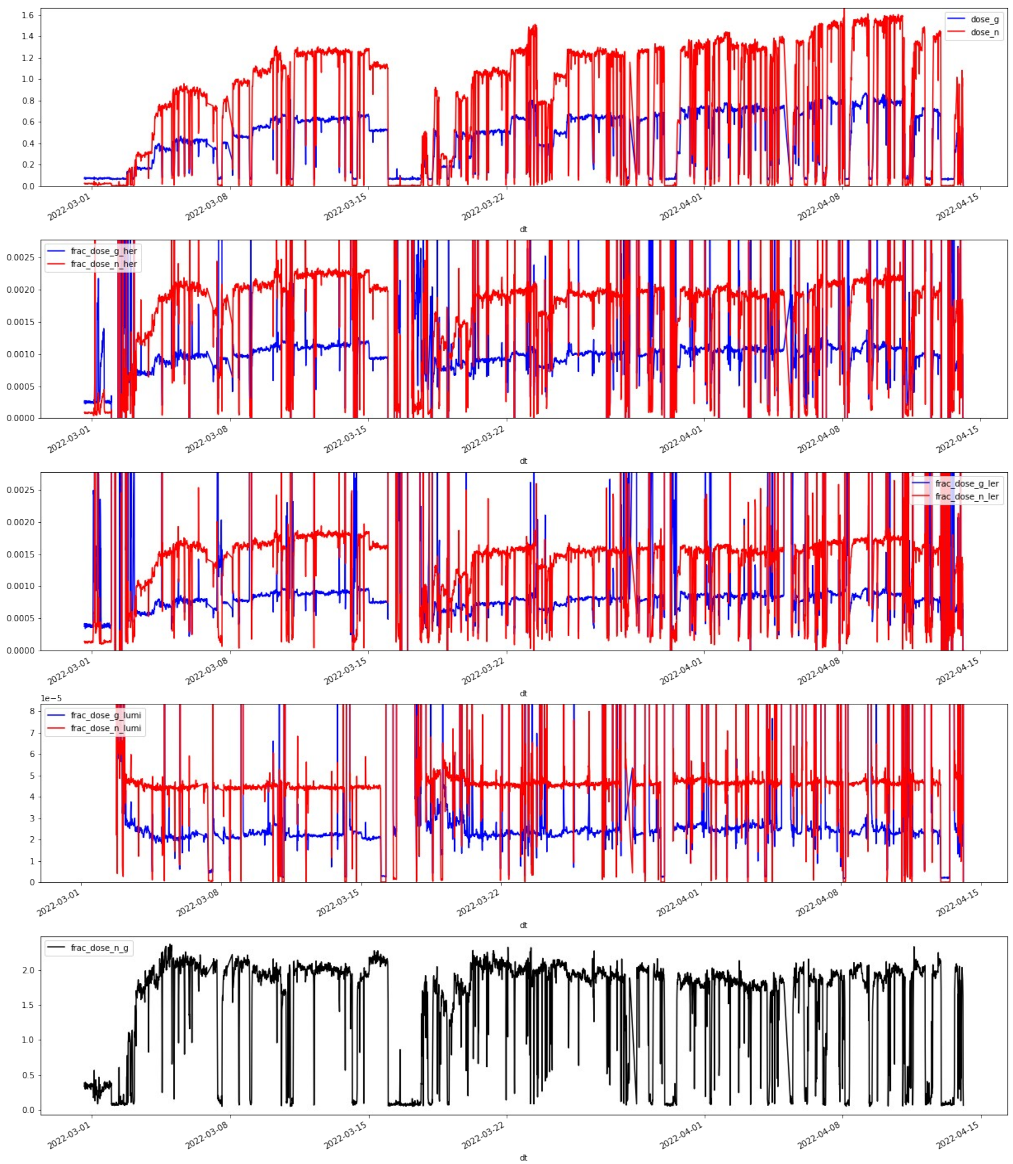
Location

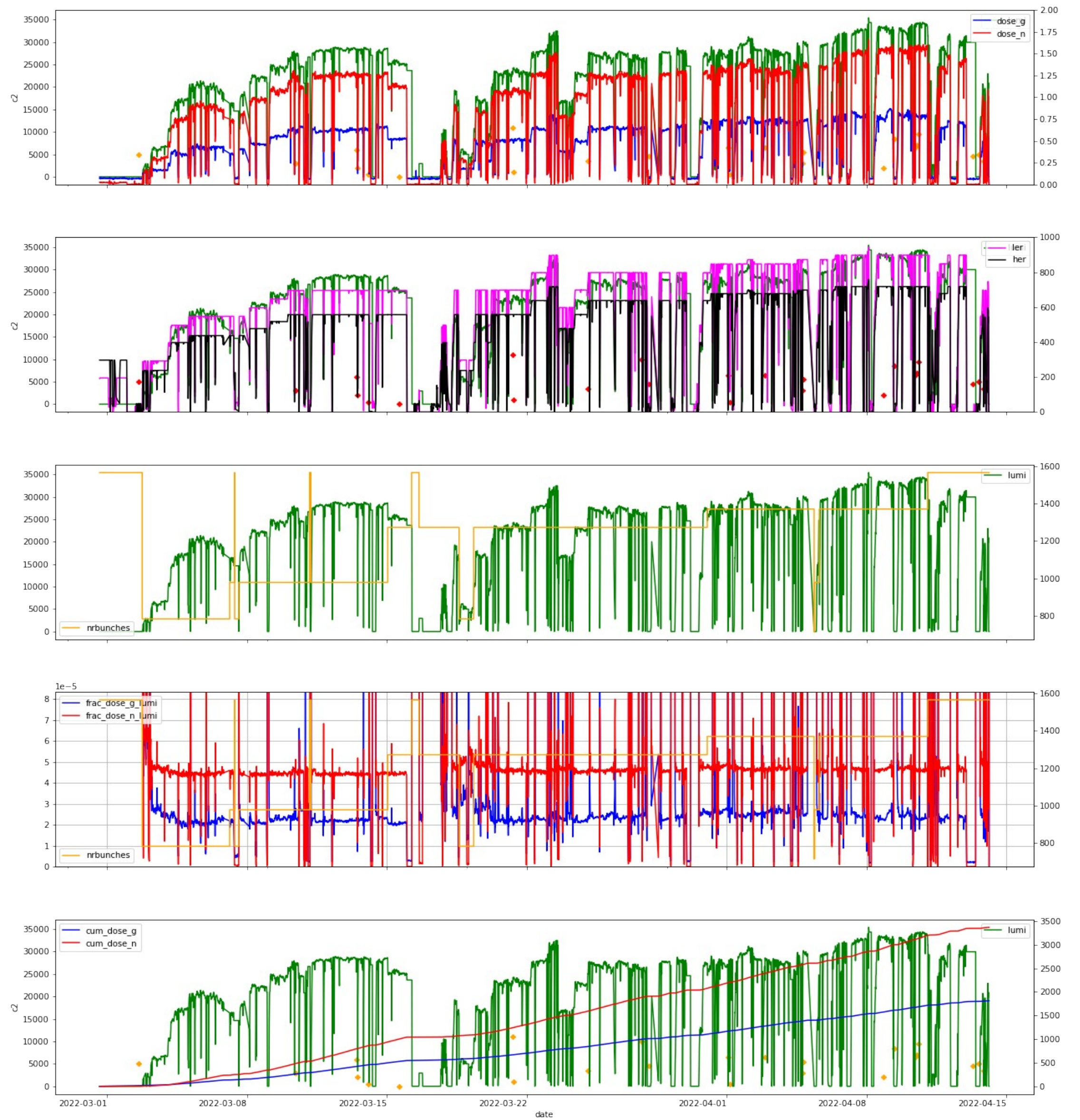
- 2-4m away from PS rack
  - (view from staircase)



Doses and OVPs

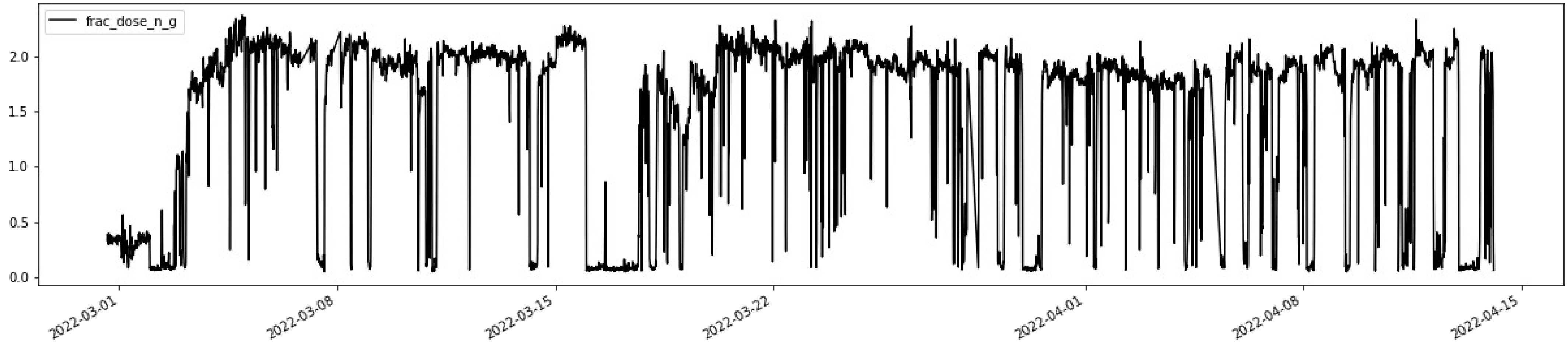
- Doses at KEK measured “near” PS rack.
- Dependencies on currents, lumi, … ?





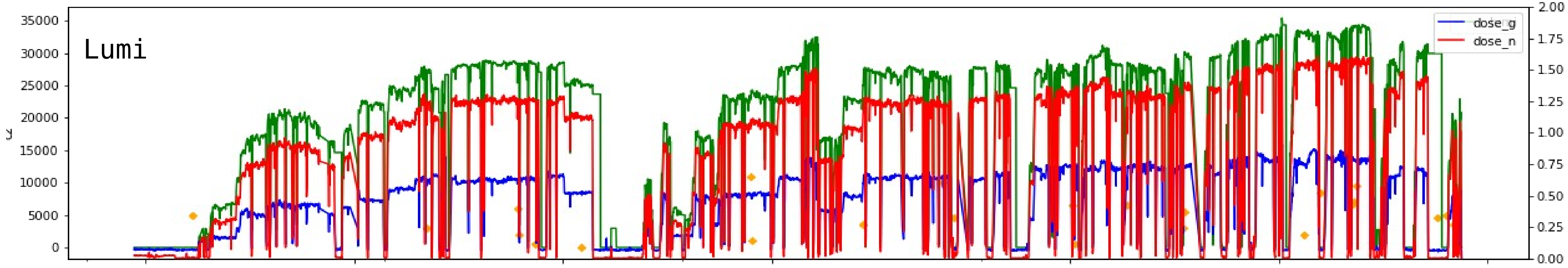
Trends

Fraction neutron/gamma



Neutron and gamma dose do not behave completely the same way.

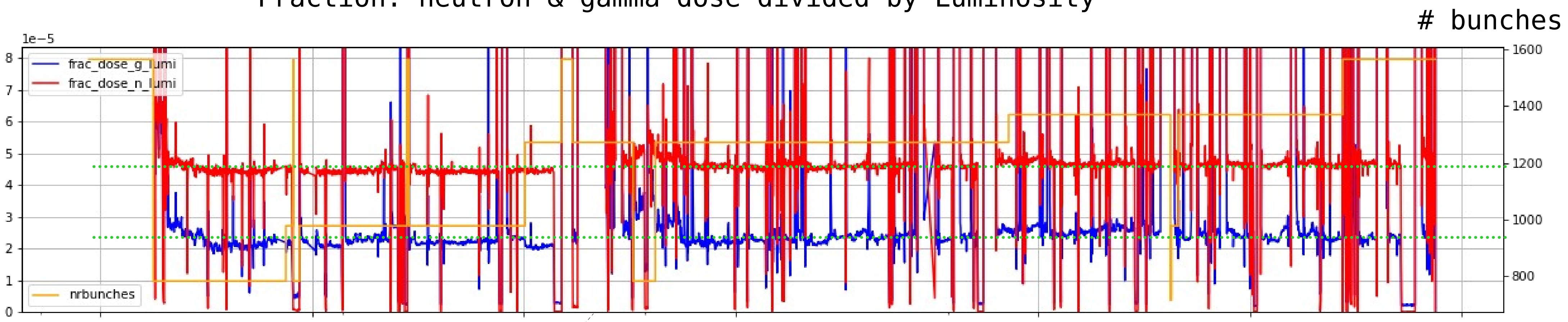
Luminosity & neutron, gamma dose trend

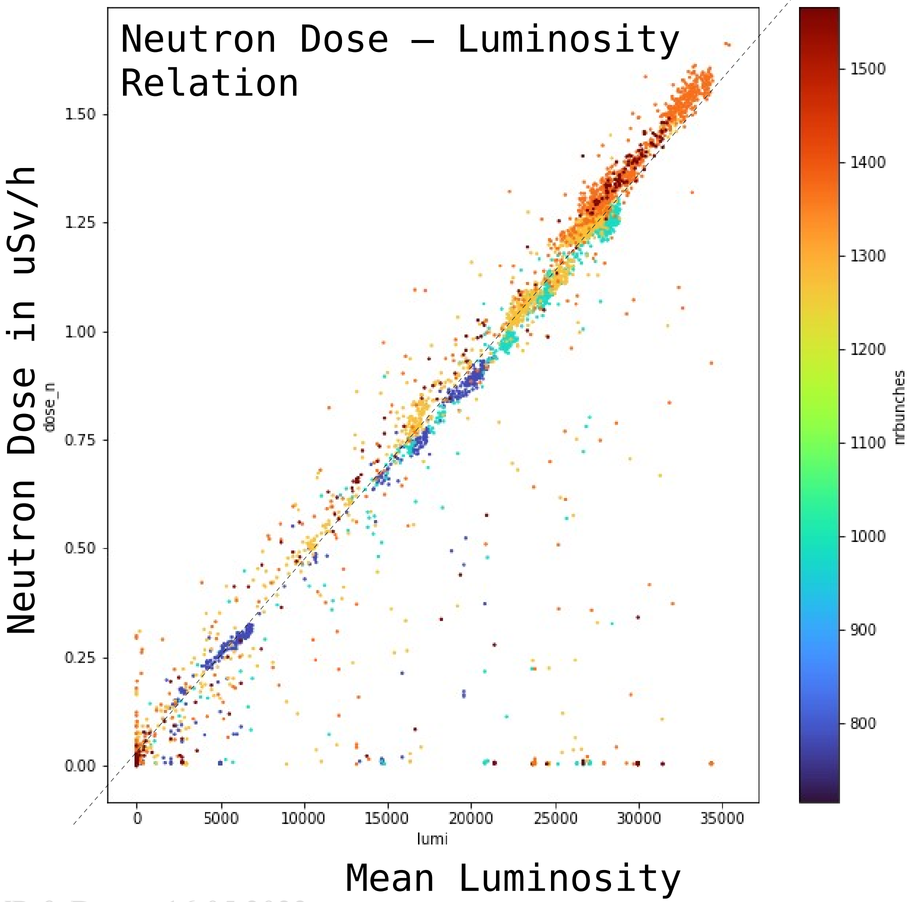


→ Neutron and gamma dose follow the Luminosity closely!

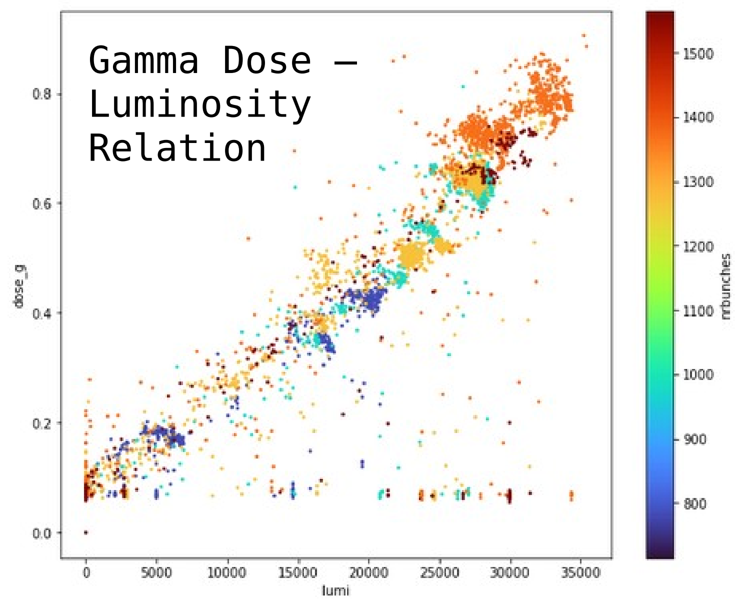
Trends

Fraction: neutron & gamma dose divided by Luminosity



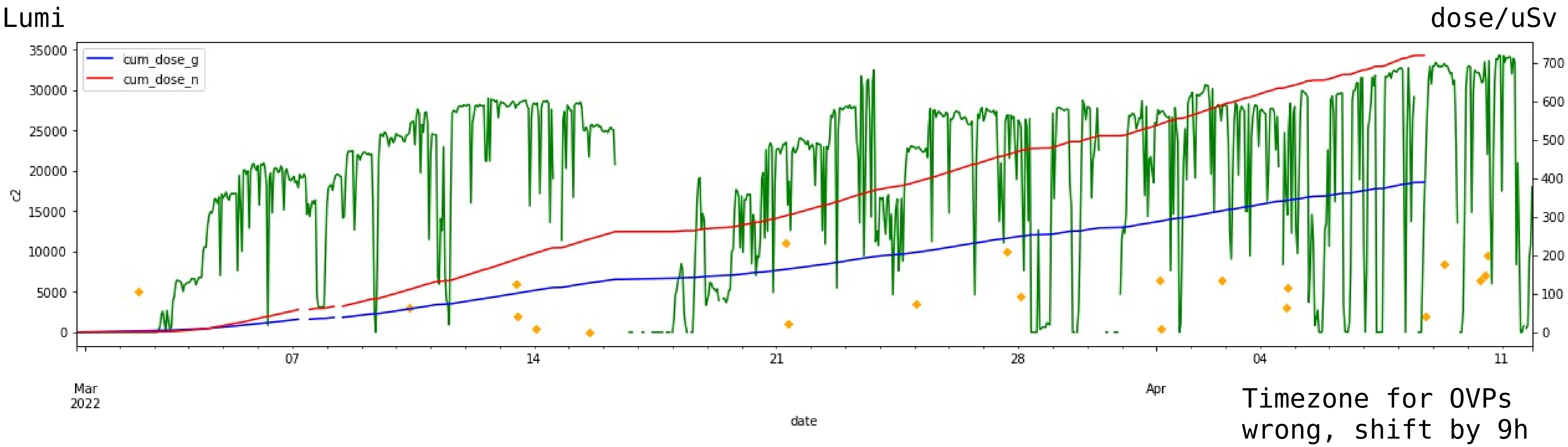


- Clear linear behavior for neutron dose, but some additional influence not clear yet



Doses / OVPs at KEK

- Gamma and Neutron counter near our PS rack
- → relate doses with OVPs



- ~1uSv/h neutron dose → integrated up since beginning of March
- → ~700 uSv neutrons, 400 uSv gammas
- → 14 OVPs
- → ~20 OVPs / 1mSv neutron dose (in 20 PSUs)
- → ~1 OVP / 1mSv neutron dose per PS Unit
  → ~1.8 OVP / 1mSv gamma dose per PS Unit

Rough numbers!

Summary

- We can relate PXD PS "Trips" to SEU in the OVP board
  - One component must be extremely sensitive to radiation (CPLD?)
  - Estimates OVP/dose in Mainz and KEK match
  - Assume SEU by neutrons

- n-Doses at KEK (near PXD PS Rack) seems to scale with Luminosity
  - → would be bad if it stays like this! Currently 0.5-1 OVP/day.
- Shielding may be possible, but reduction estimated to ~50%
  - May need some modification in PS electronics

- Question: Where are the neutrons coming from?

KEK:

- ~1 OVP / mSv neutron dose per PS Unit
- ~1.8 OVP / mSv gamma dose per PS Unit

Mainz:

- ~ 1 OVP / mSv total dose
- ~ 1.3 OVP / mSv neutron dose
- ~ 4 OVP / mSv gamma doses

KEK

KEK: Here's some specifications of this sensor.
- Gammas are measured by Clear Pulse CMB10, whose energy range is 50keV ~ 3MeV.
- Neutrons are measured by Reuter-Strokes 1-inch He-3 detector. Neutron spectrum are calibrated using AmBe checking source and adjusted to detect <10MeV neutrons.

Mainz (Pandora)

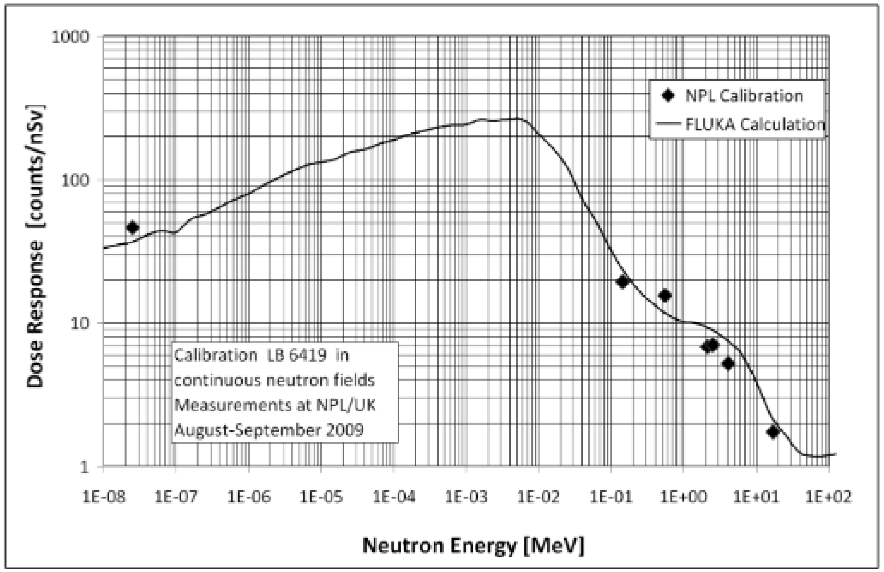


Figure 4: Neutron Dose Response

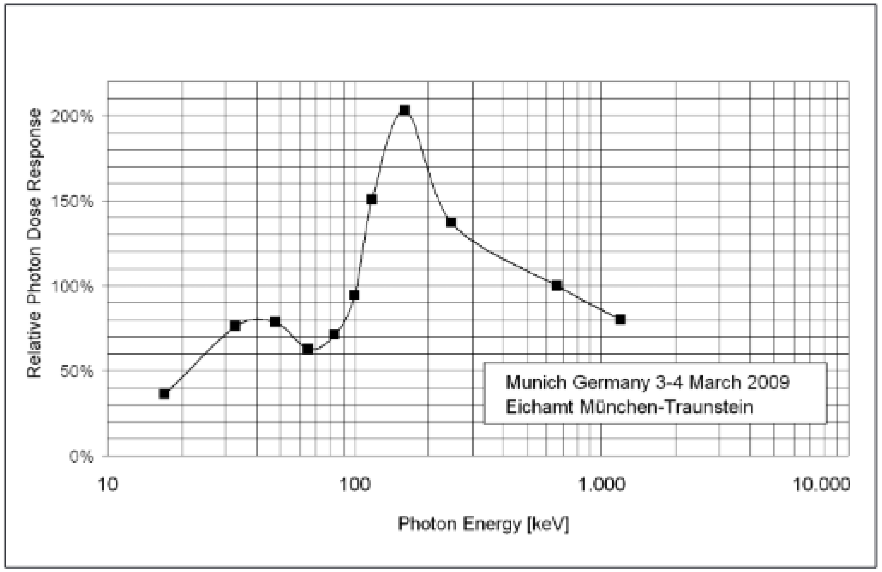


Figure 5: Photon Dose Response