Hypoxic cold irradiation tests of HGCAL plastic scintillators at GIF++

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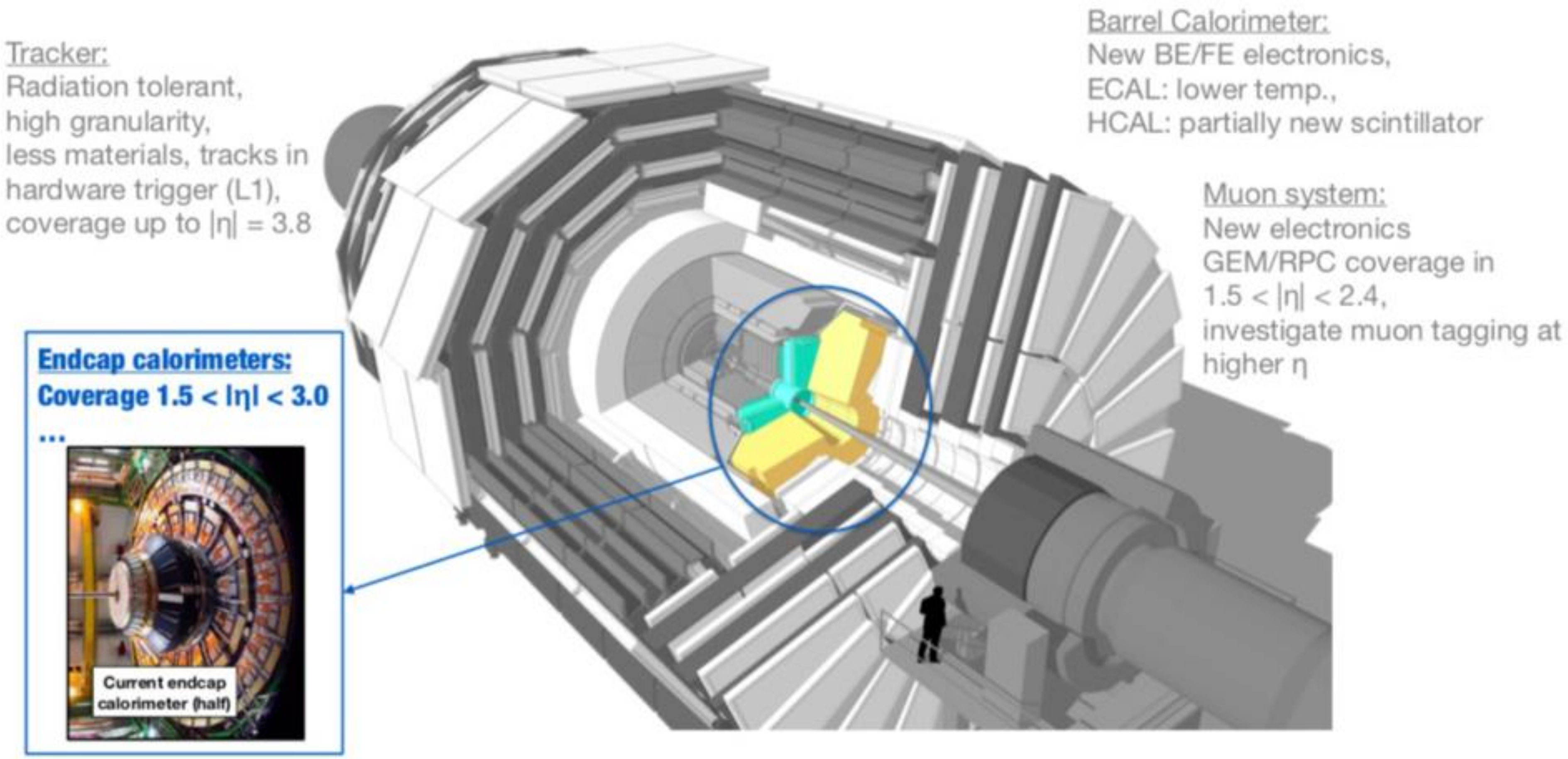
CMS Upgrade for HL-LHC

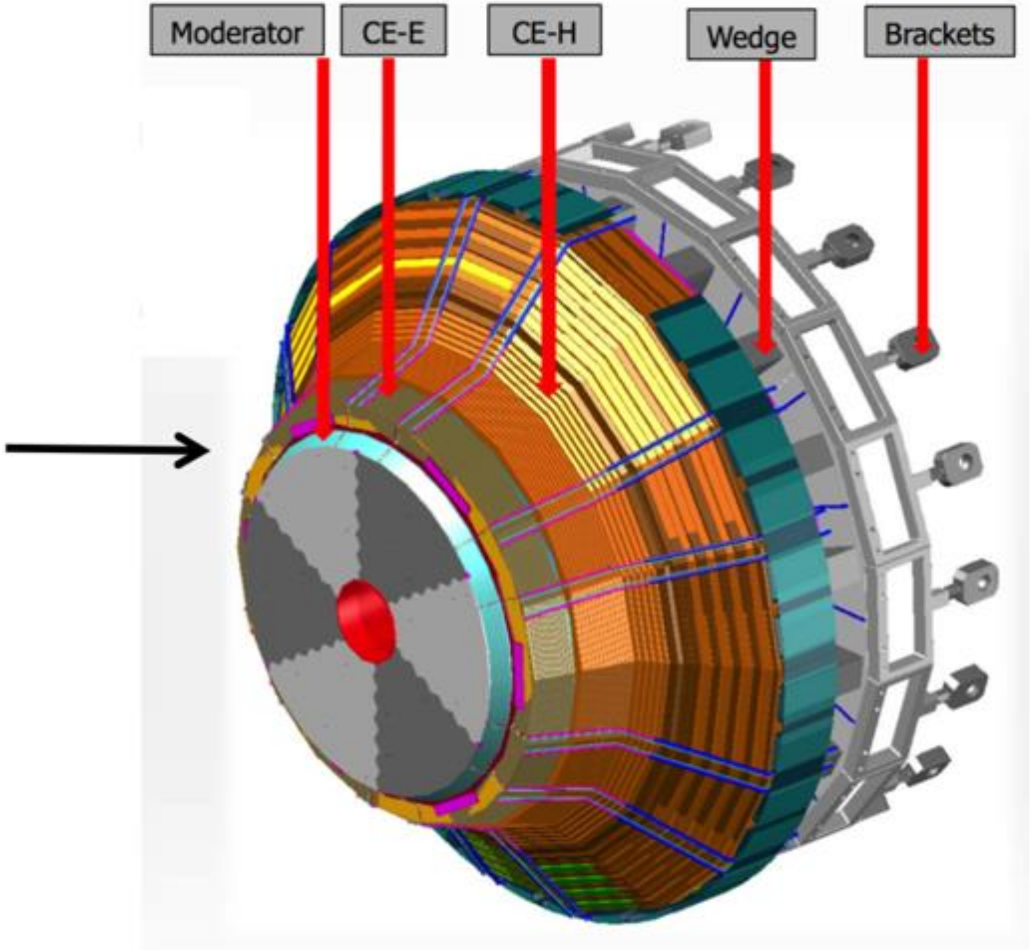
- The High Granularity Calorimeter (HGCAL) is to replacing existing CMS endcap pre-shower, electromagnetic and hadronic calorimeter, none of which would remain performant at the HL- LHC.



Overall mechanical design of HGCAL heavily constrained by present endcap calorimeters

Present CMS endcap calorimeters

HGCAL design

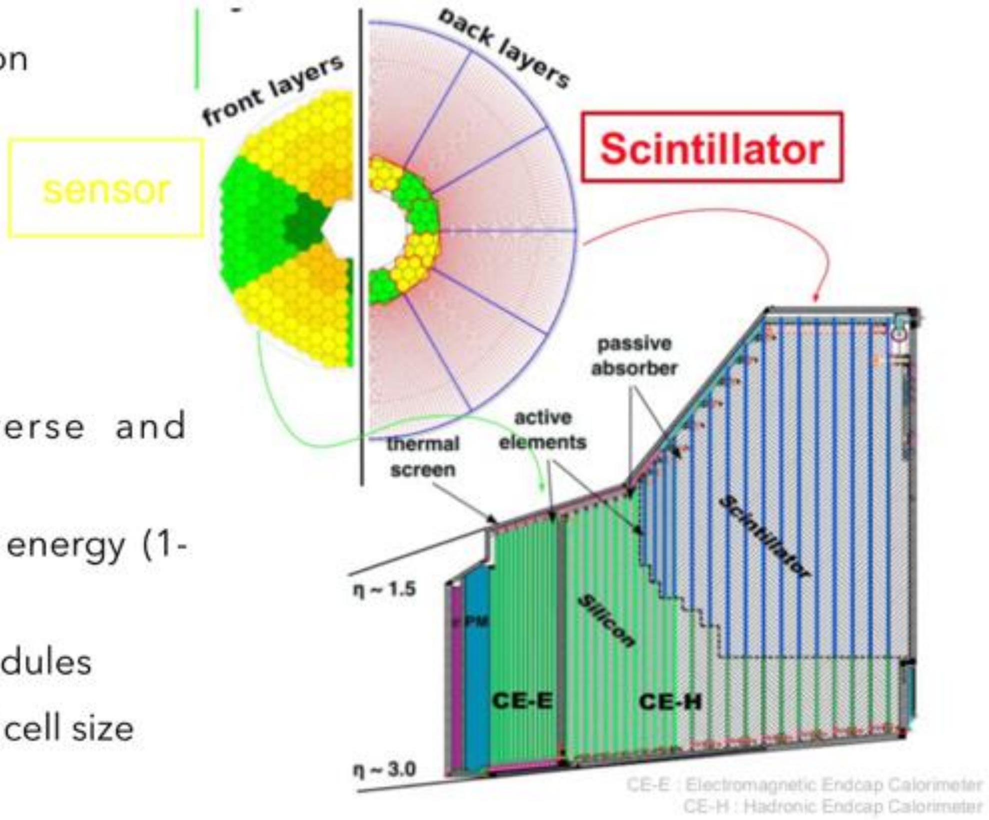


Concept: **remove** complete endcap calo. system and **replace** with HGCAL

CMS internal nomenclature: Calorimeter Endcap (CE), divided into CE-E and CE-H

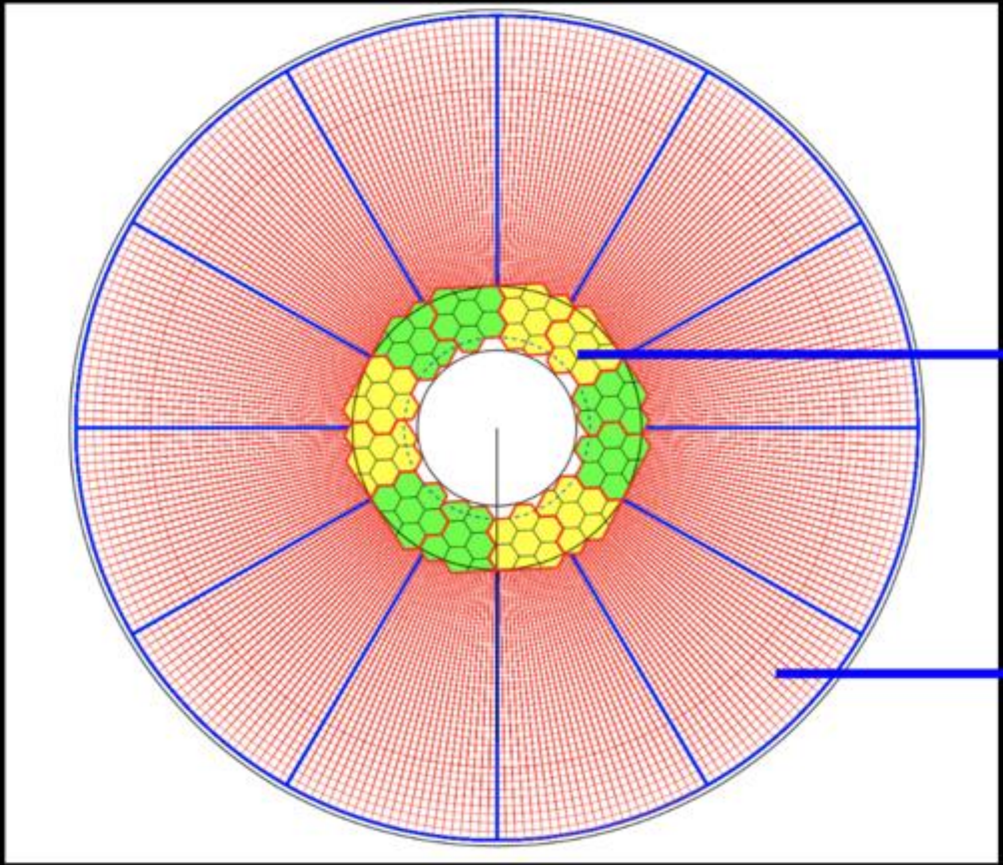
CMS High Granularity Calorimeter (HGCAL)

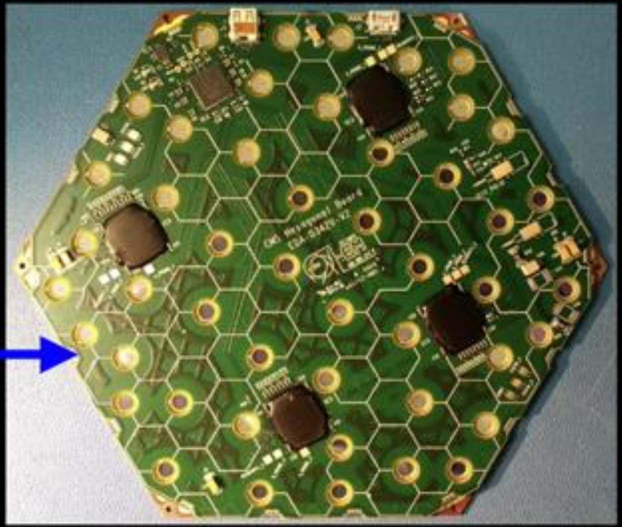
- Sampling calorimeter for CMS Phase 2
- **Active elements:** silicon sensors and silicon photomultiplier tubes (SiPM)
- **Key parameters**
  - Acceptance of 1.5 < |eta| < 3.0
  - Full system maintained at -30 °C
  - Features unprecedented transverse and longitudinal segmentation
  - Fine granularity (cell size 1-30 cm^2), energy (1-10k MIP range)
  - ~640 m^2 silicon sensors in ~31000 modules
  - ~6.1M silicon channels, 0.5 or 1.1 cm^2 cell size
  - ~370m^2 of scintillators
  - ~240k scintillator channels



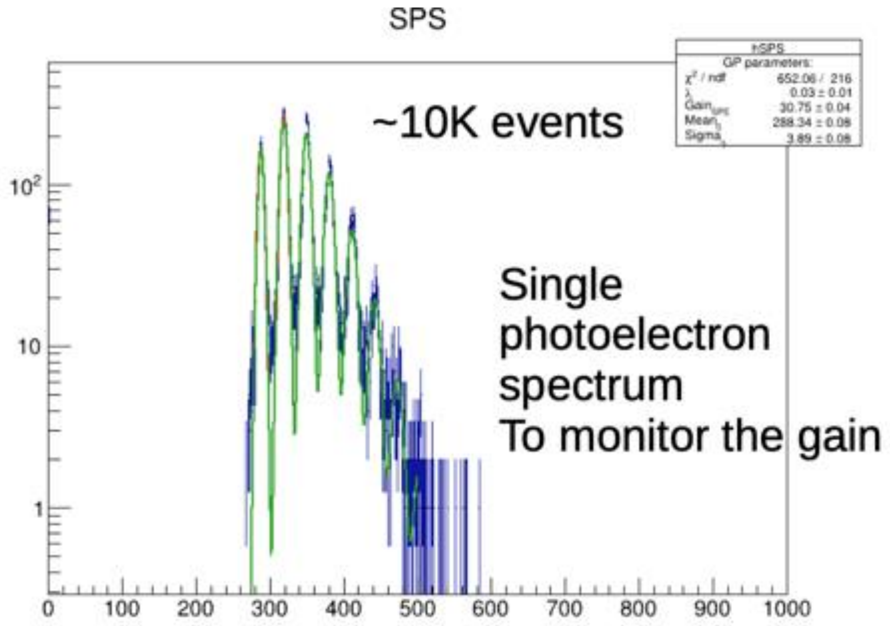
Sensor layout in the scintillator section

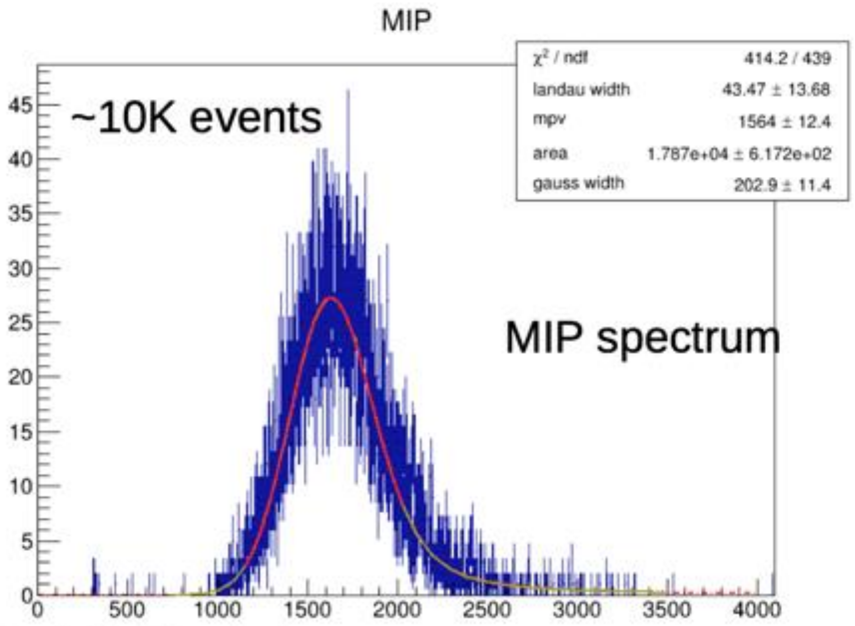
- Hadronic section features silicon sensors and SiPM-on-tile readout sensors





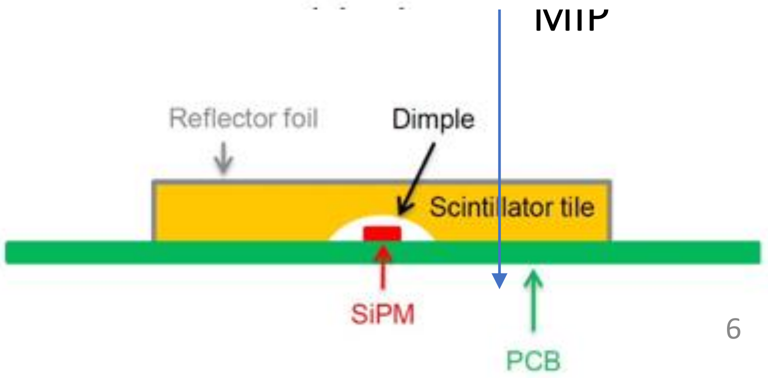
SiPM_on_tile: SPS spectrum and MIP signal



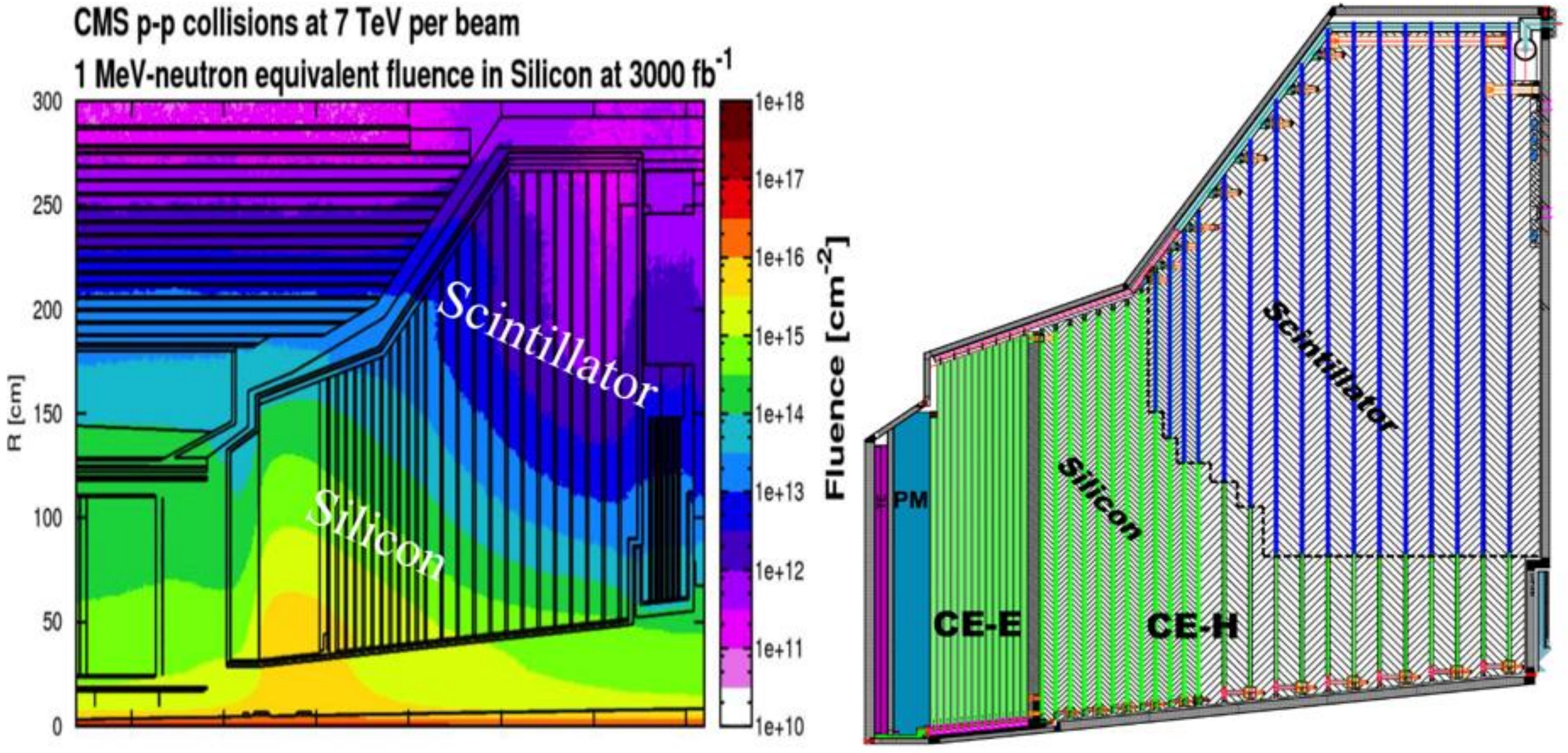


- Combination of this 2 plots allows to express the light yield of the tile in **NUMBER OF FIRED CELLs**

MIP should be visible during all HGCAL lifetime



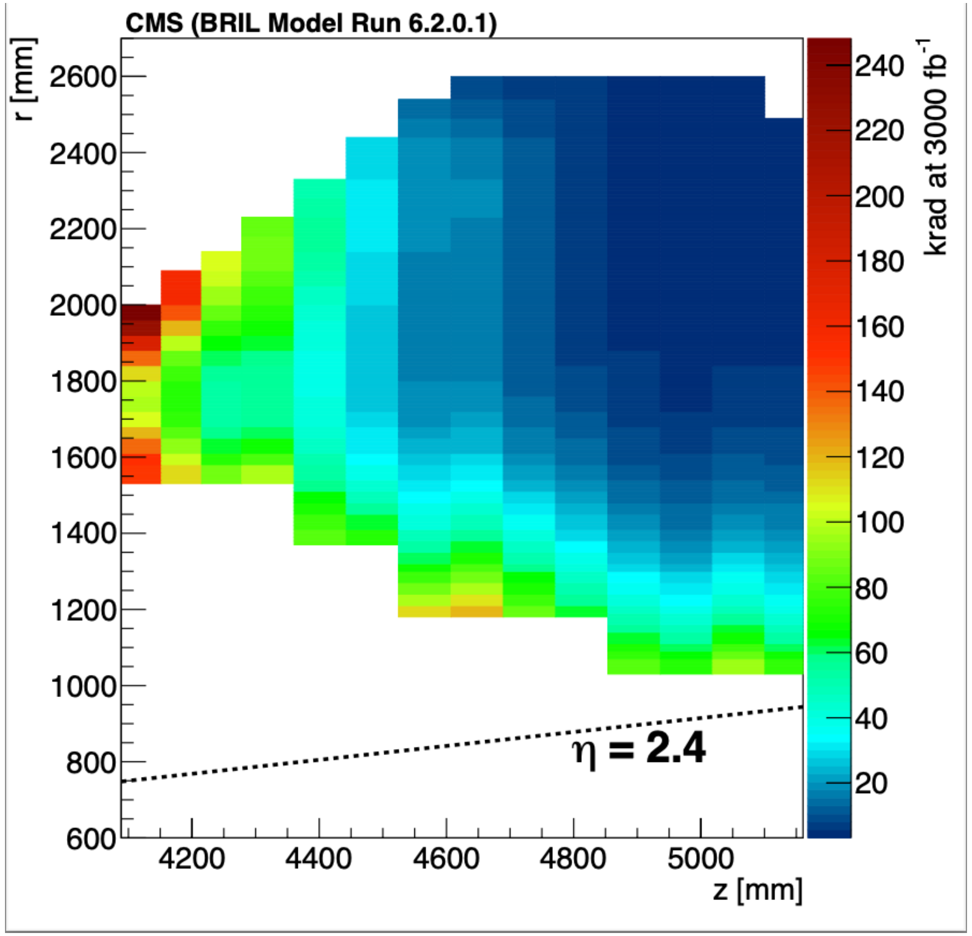
Regions of silicon or silicon + scintillator/SiPM governed by radiation field



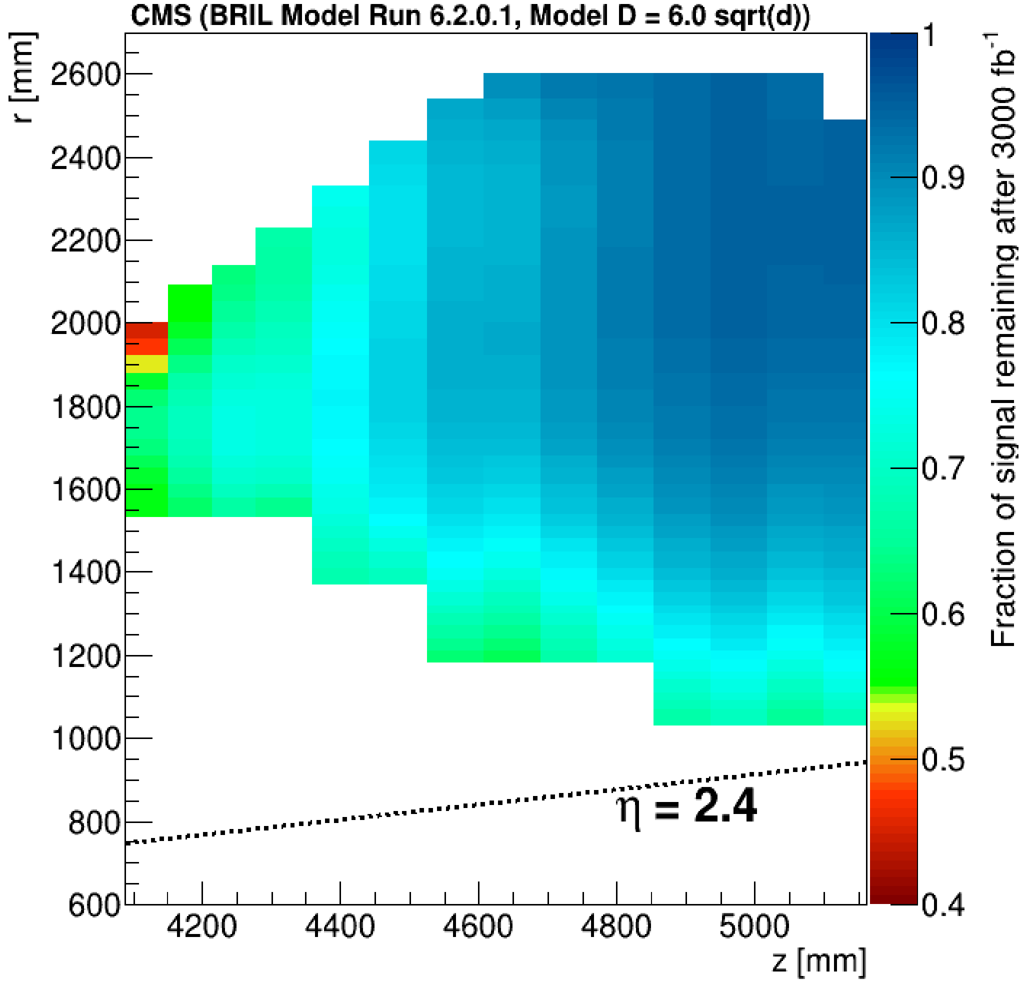
Fluence in HGCAL spans **5 orders of magnitude**
Silicon in high-radiation regions; scint+SiPM in lower-radiation regions

Prediction for the light loss due to scintillator ageing

Total absorbed dose

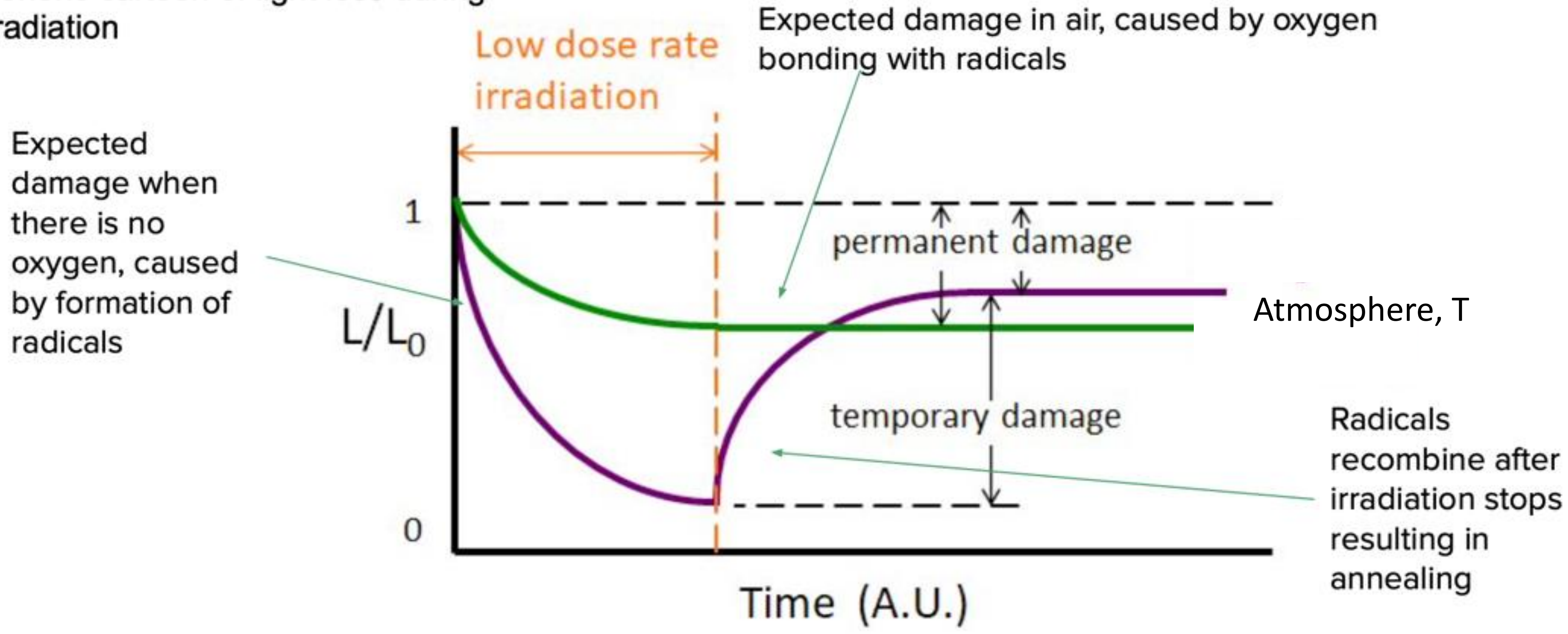


Expected permanent and temporary damage with annealing for 10 years of HGCAL operation



“Temporary” versus “permanent” damage

Generic cartoon of light loss during irradiation



We should check and see if we closer to the green or purple in our actual running conditions. While HCAL is close to the green, what if we are close to the purple?

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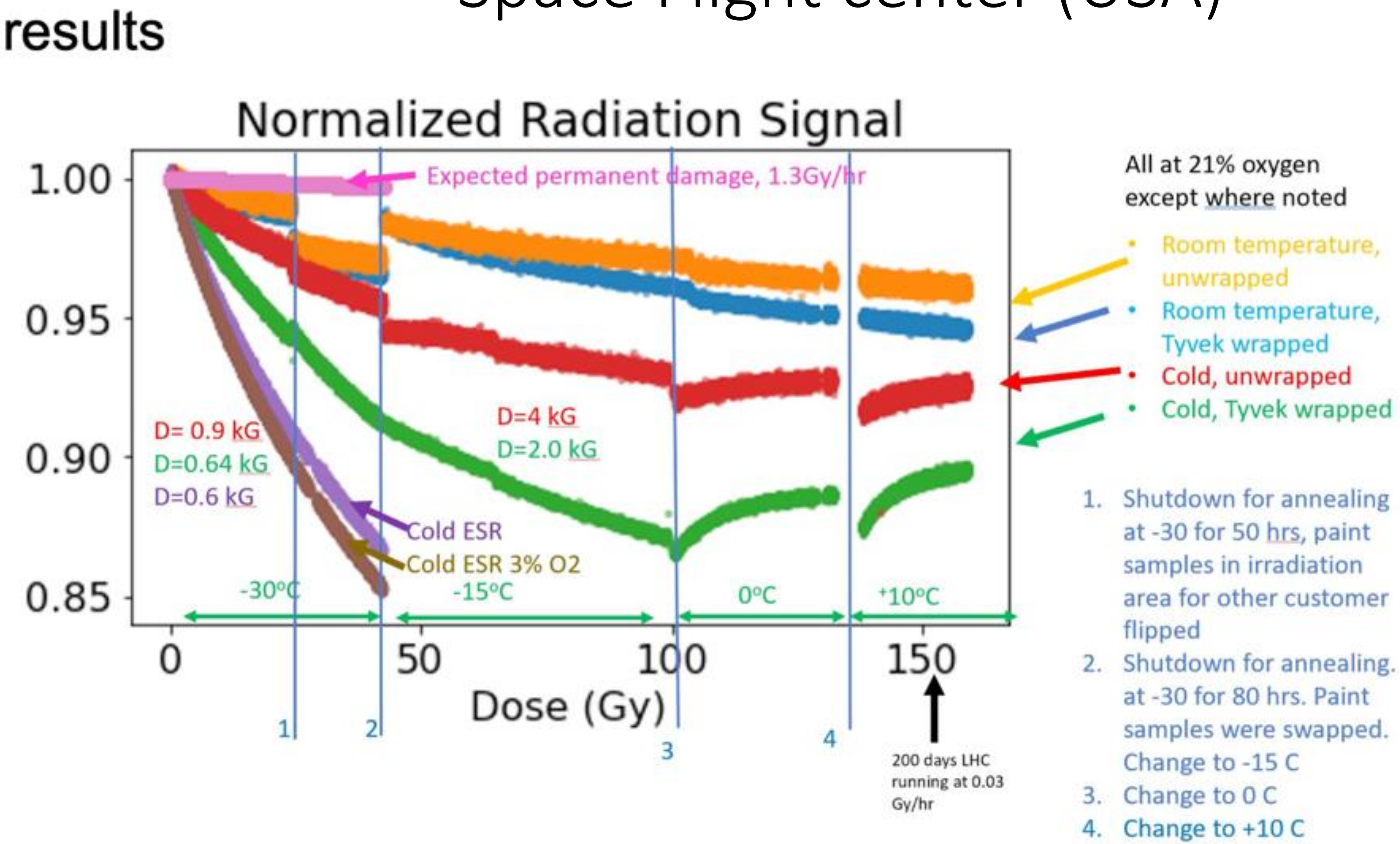
A lot of studies performed by UMD group at Goddard Space Flight center (USA)



Still many open questions. Answers are crucial for the HGCAL desigh

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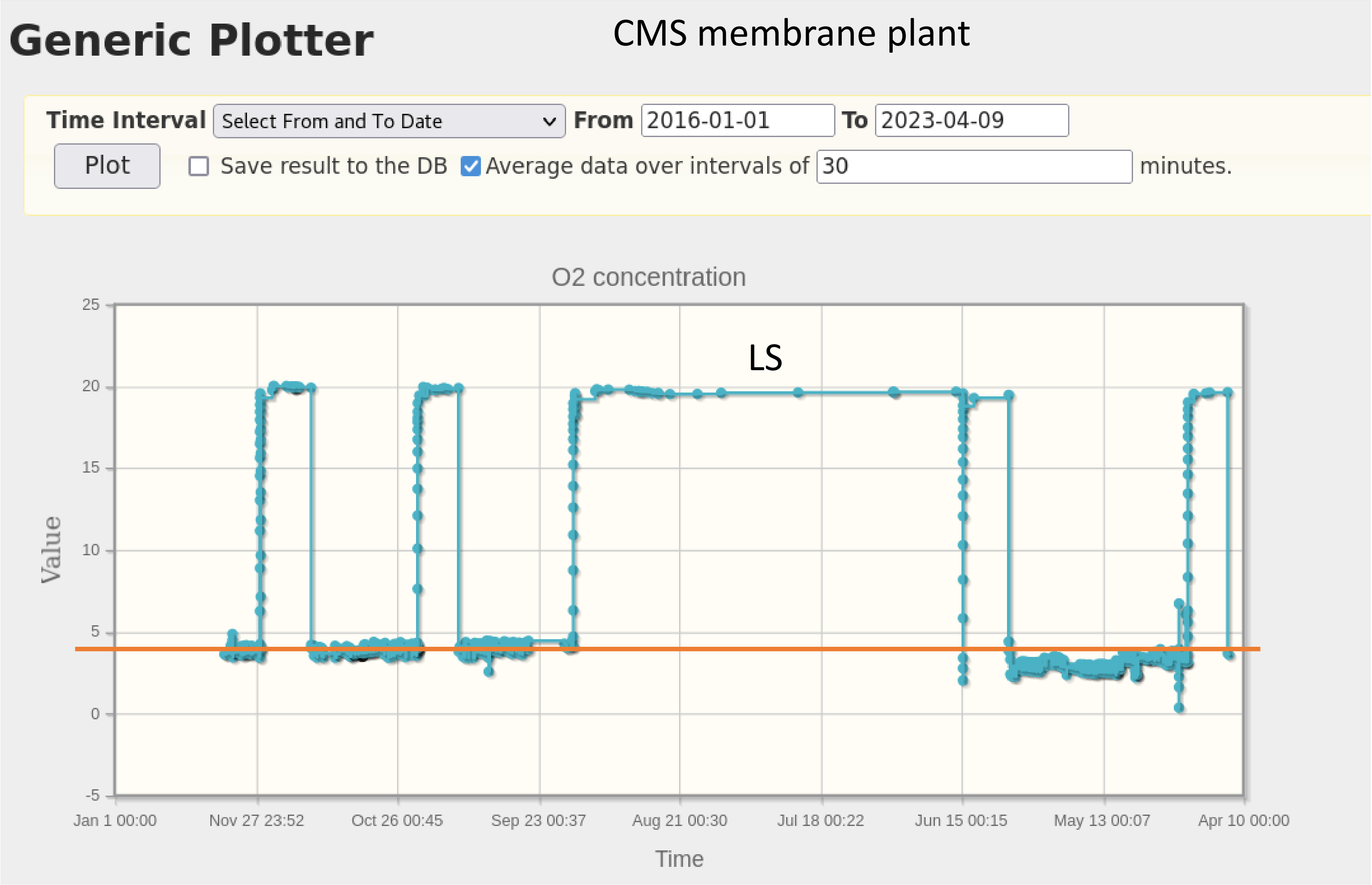
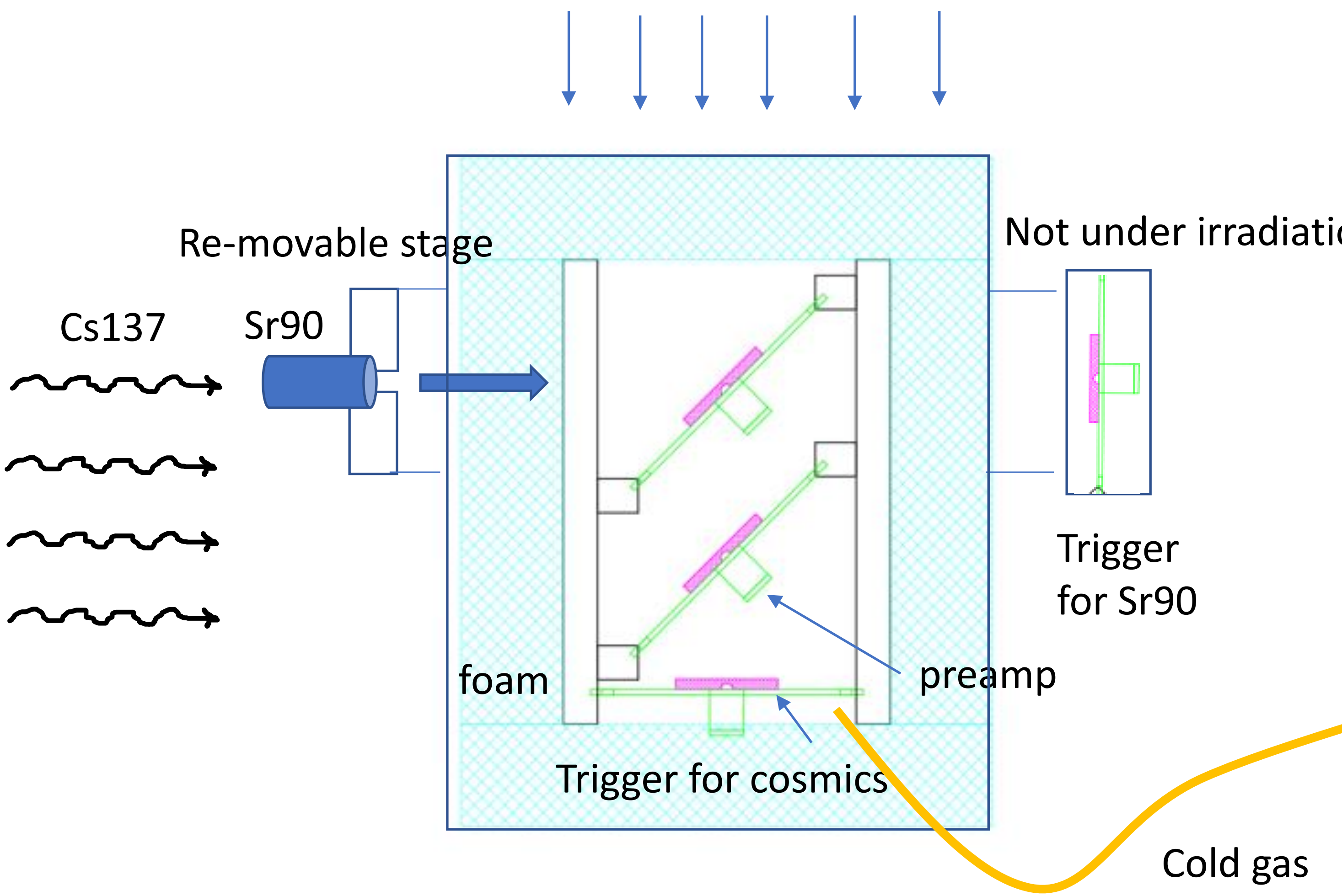
Tasks for GIF++ HGCAL tiles study:

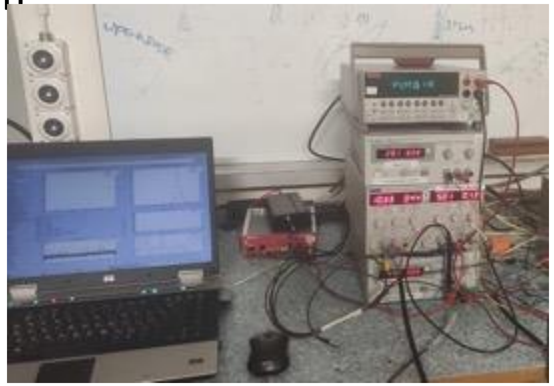
- Long term irradiation (months) with dose rate D~0.2-0.5 Gy/h up to ~50 Gy at T=-30C and dry hypoxic atmosphere – GIF++
- Long term annealing (months) at T=-5C with dry air (some lab at CERN, Point5, testbeam?)
- Long term monitoring system for HGCAL SiPM-on-tile (years?) at conditions of HGCAL operation (T=-30C, dose rate D ~0.15 Gy/h, dry hypoxic atmosphere) GIF++

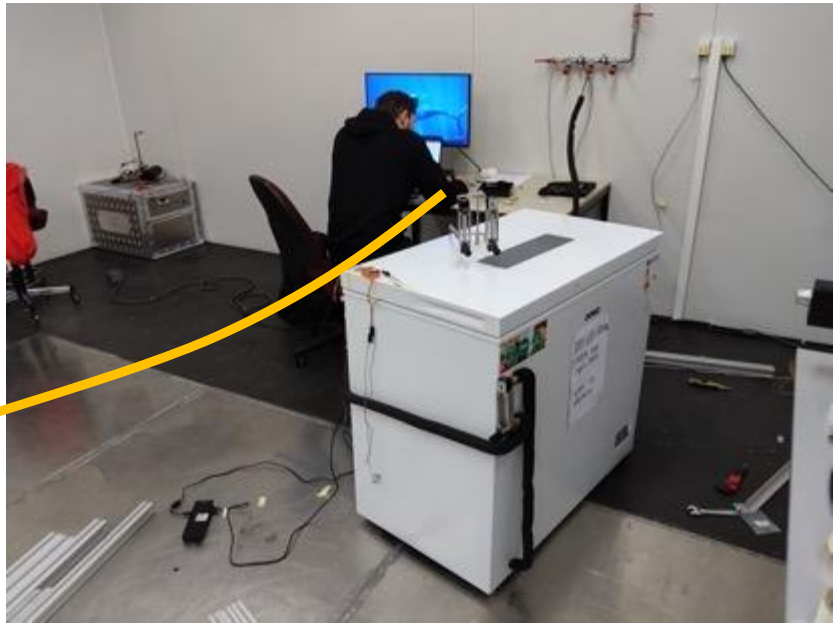


Outline of the setup for irradiation at GIF++

Draft drawing, not final system





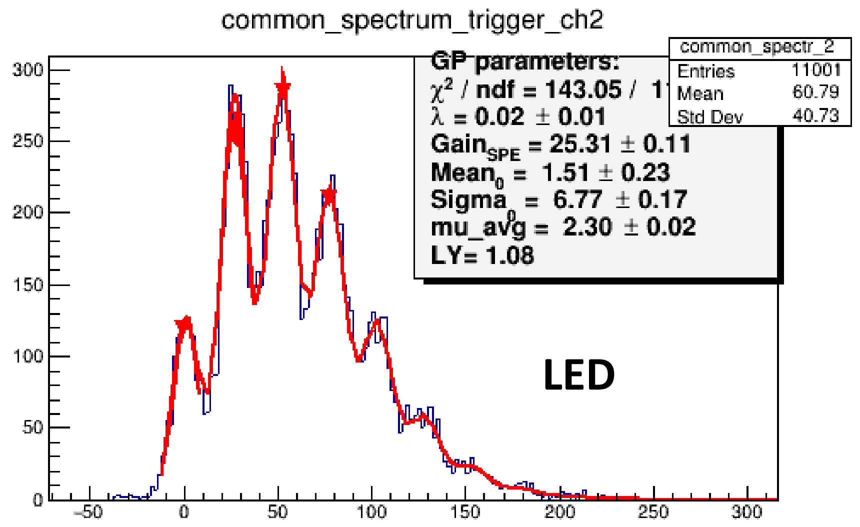


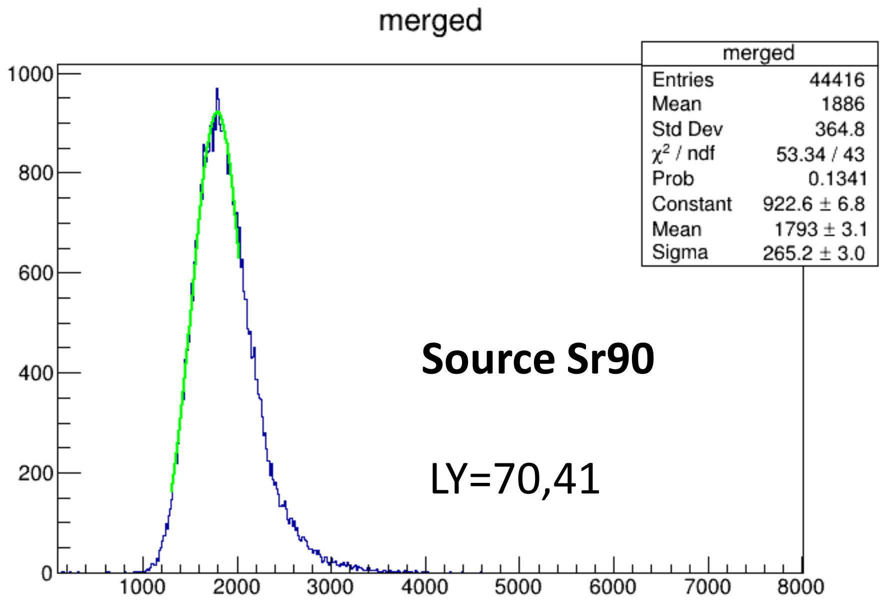
Cooling system

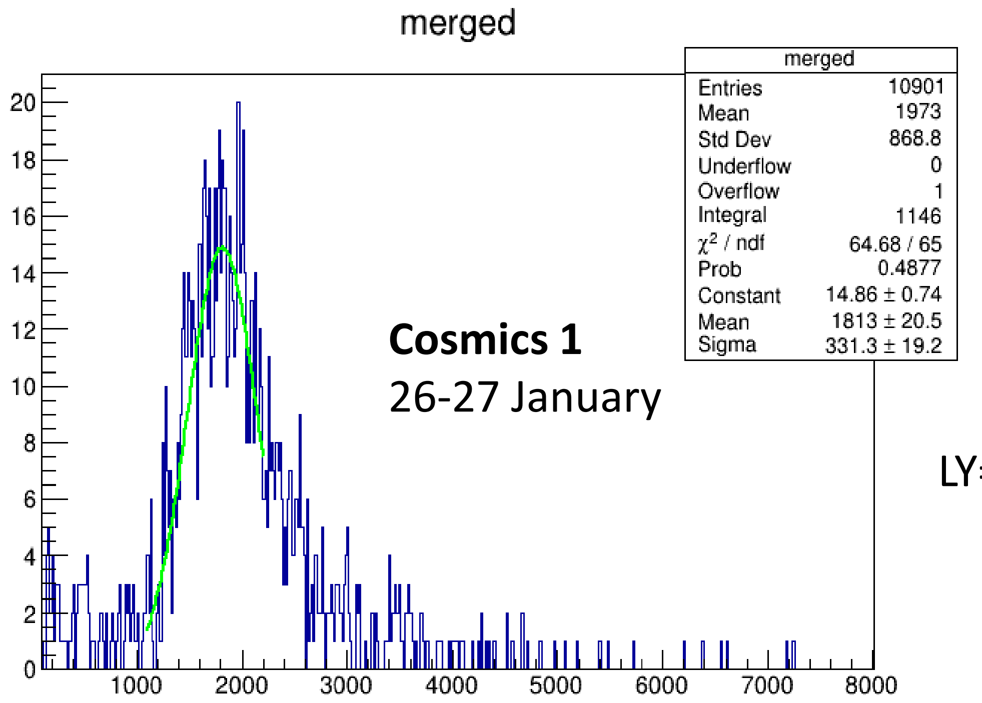
- Dose rate ~0.15Gy/hour (max 0.5Gy/h)

Regular access to GIF++ every Wednesday

DAQ for GIF++ test

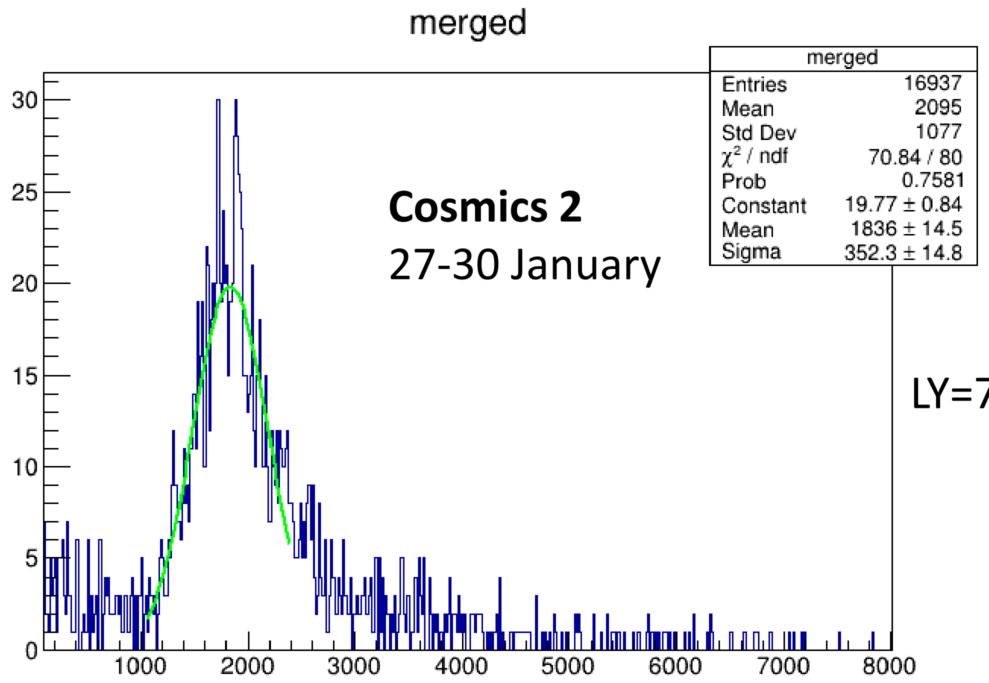






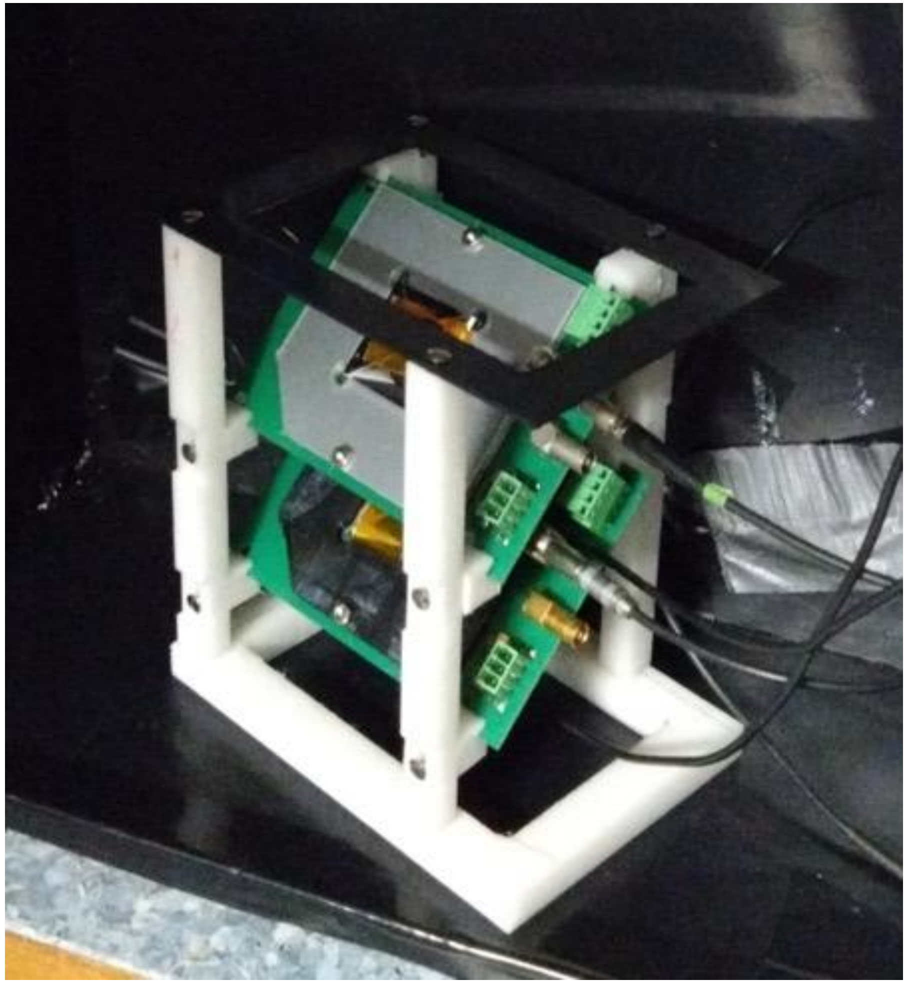
LY=71,19

Trigger
8x8mm2



LY=72,1

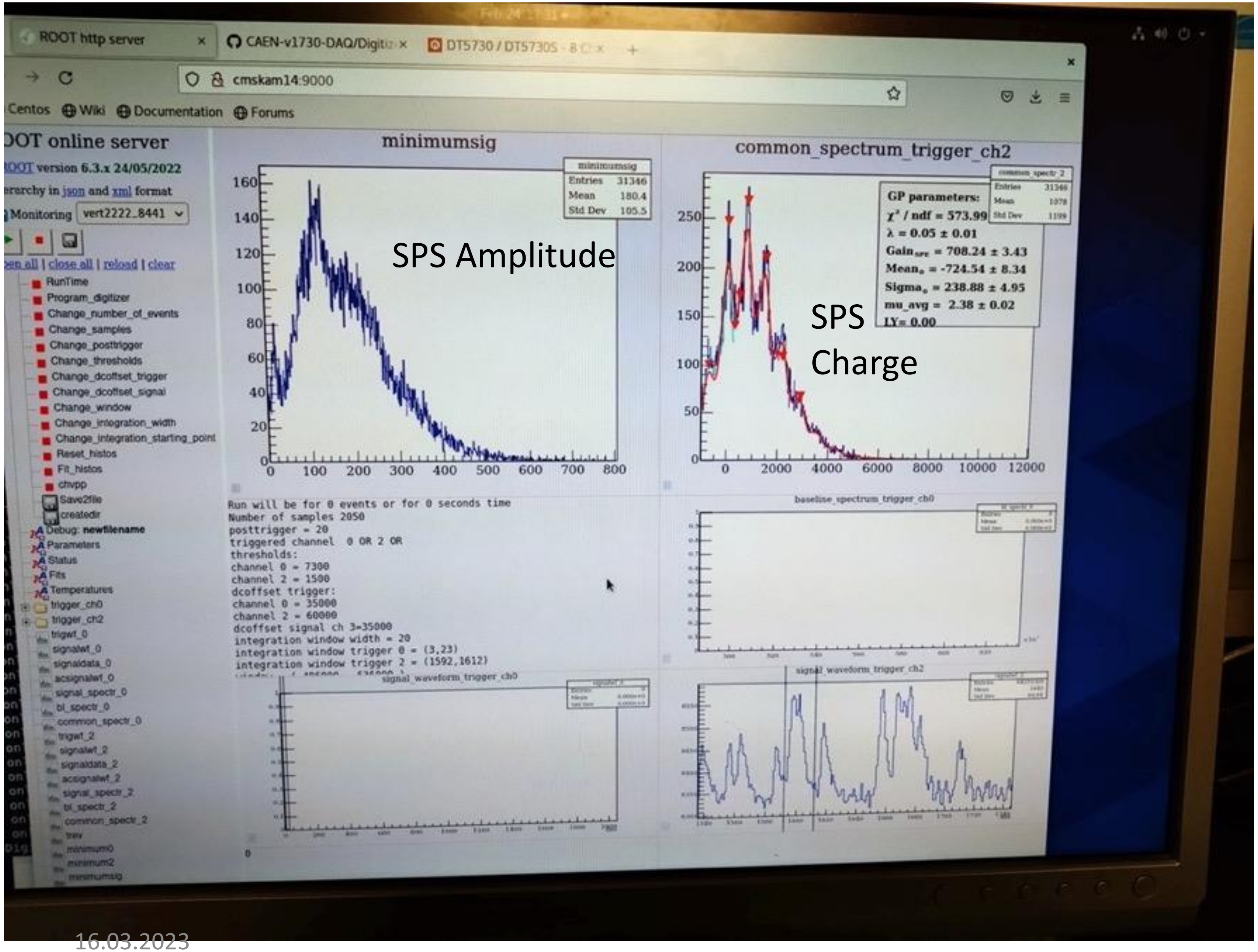
Starting point for the closest 2 weeks: Small prototype feasibility tests at GIF++ with room temperature and dose rate D~0.2-0.3 Gy/h 1 week

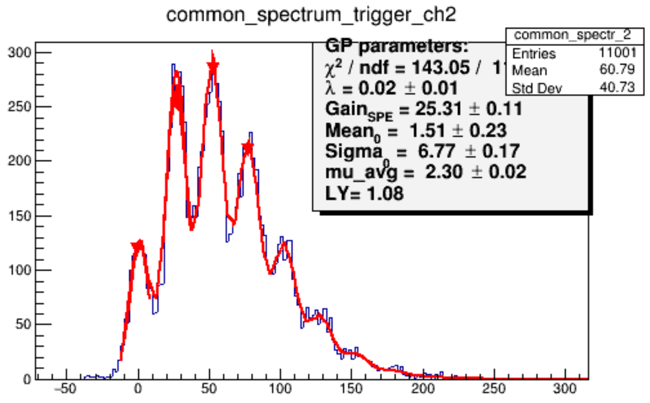


- Preamps under Cs137 irradiation
- SiPM SPE spectra from LED with presence of Cs137
- SiPM+tile cosmics signal with presence of Cs137
- Dosimetry at place of installation – who and how?

Setup is superlight: PCB, plastic, foam.
EM and humidity shielding : 200 um copper

Preliminary tests in the lab





The Cs137 background was simulated by illumination of the SiPM with continuous light.

With background current I=1.7 uA, we can effectively resolve the peaks in single photoelectron spectrum

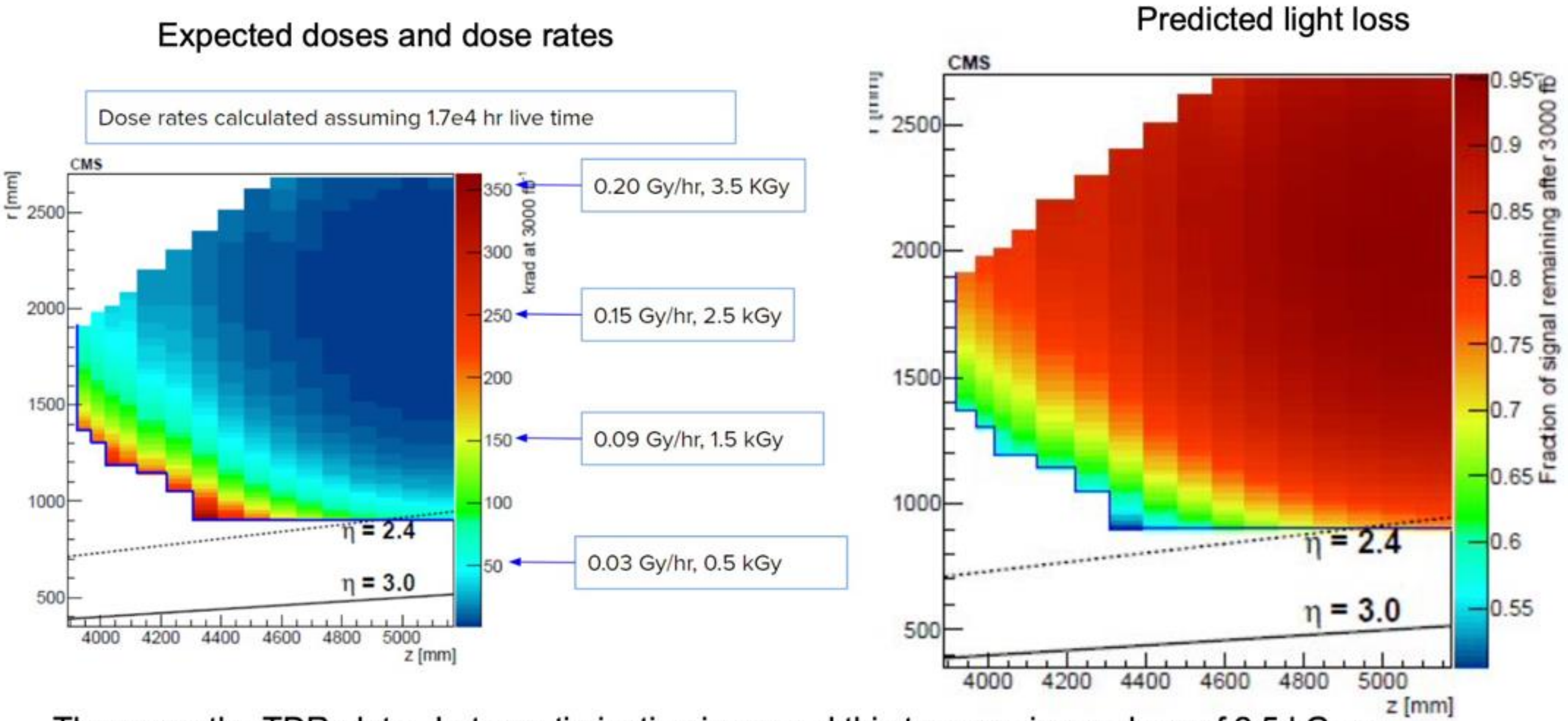
Overvoltage=4V
SPS resolution with LED

HGCAL GIF++ program challenges:

- Long term tests at cold environment
  - 100% continuity
  - Gas mixture (hypoxic dry air).
- Multiuser ussies at GIF++
  - Dose rate variation at GIF++ (different attenuations)
  - Dose rate might be changed due to the other users requests or source maintenance work. How should we proceed? To accumulate different dose rates or to find a shadow place to wait with -30C without irradiation?
- Sr90 during gamma irradiation?

backup

TDR predictions of light loss



These are the TDR plots. Later optimization improved this to a maximum dose of 2.5 kGy, a maximum damage of 20%, and maximum dose rate of 0.15 Gy/hr

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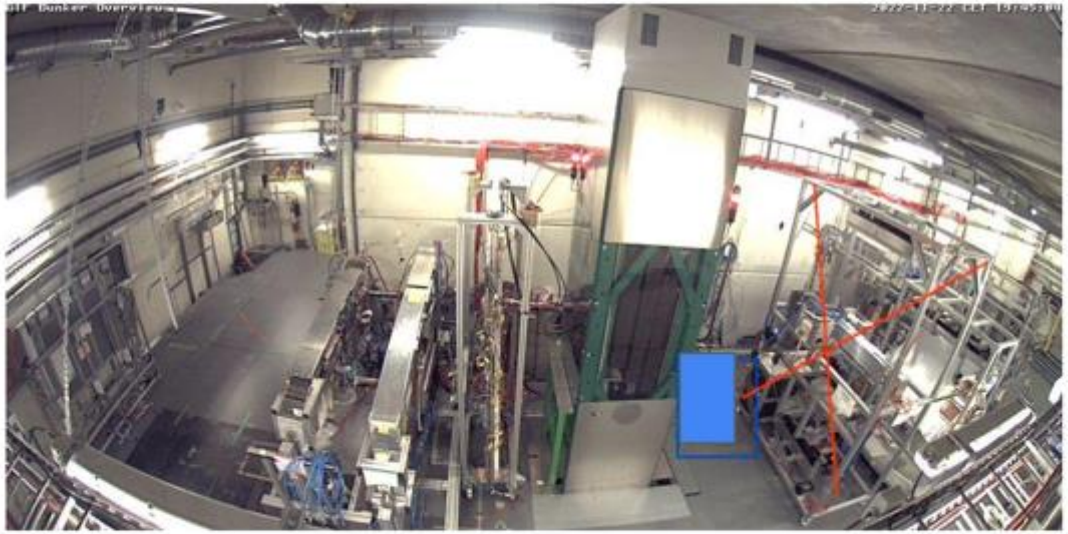
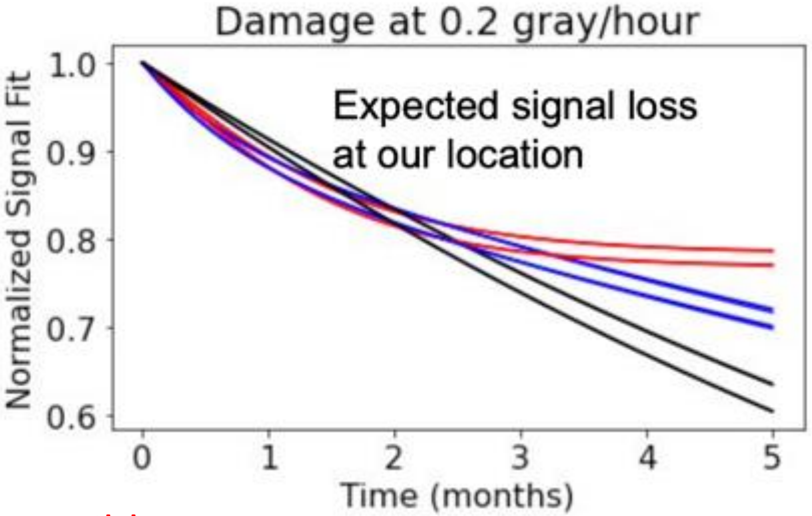
GIF++: a possible plan





Not possible

- We would be in the blue box. The hardware with the red X would be removed. Irradiator shown in green near blue box.
- Would run at about 0.2 Gy/hr (may vary over the sample)
- Would be out of beam, but cannot irradiate when beam is on (7-9 weeks/year)
- Need to buy a freezer
- Would need European help to keep experiment going

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