

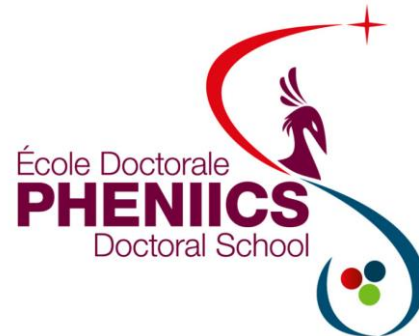
Development of high resolution and radiation hard electromagnetic calorimeter for the DVCS experiment

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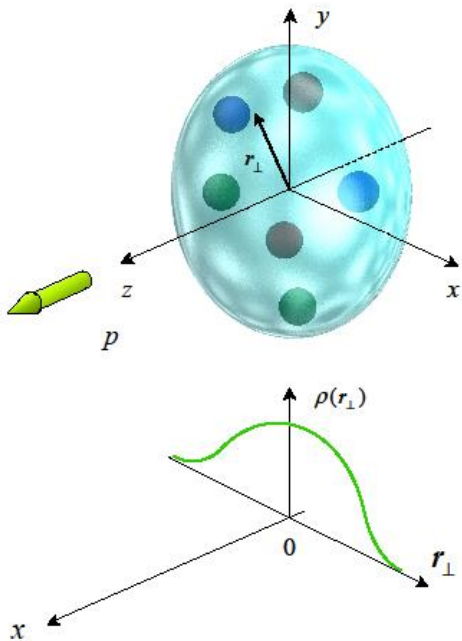
In collaboration with

- Catholic University of America, USA
 - PbWO_4 light yield & transmittance measurement cross-check
- Justus Liebig University Giessen, Germany (many works have been done)
 - PbWO_4 light yield & transmittance measurement cross-check
 - PbWO_4 radiation hardness measurement cross-check
 - Optical bleaching method

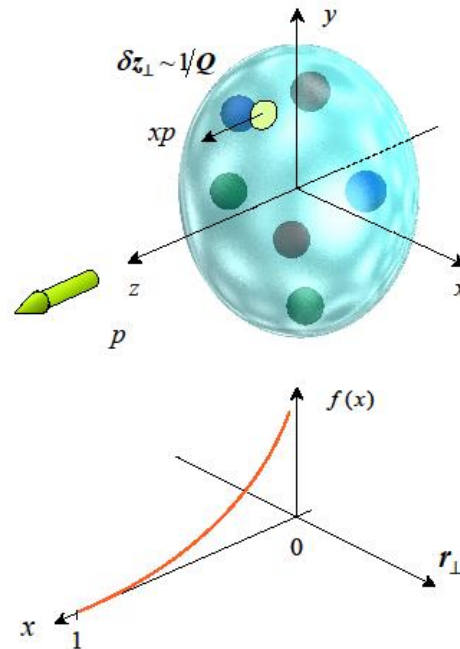
Outline

- Deeply Virtual Compton Scattering(DVCS) for GPDs measurements
- Neutral Particle Spectrometer(NPS) for DVCS experiments in Hall C
- NPS simulations and crystal optical properties measurement
 - Energy resolution simulation
 - Radiation hardness measurements
 - Crystal optical properties recovery tests

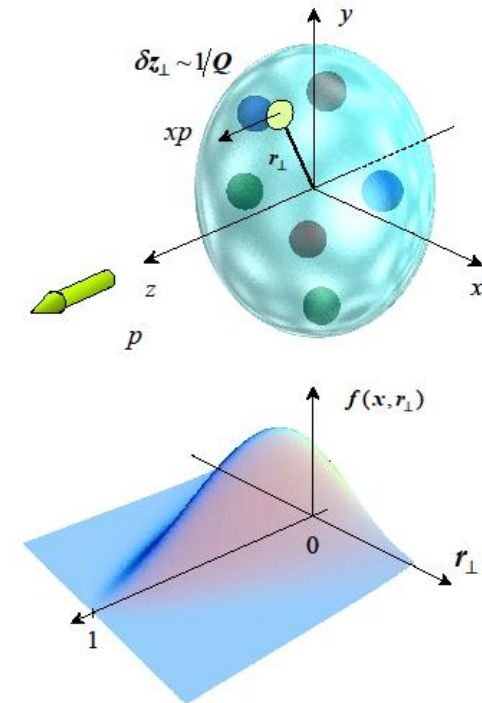
Generalized Parton Distributions



Form Factors:
via elastic scattering
 -charge & magnetization
 spatial distribution

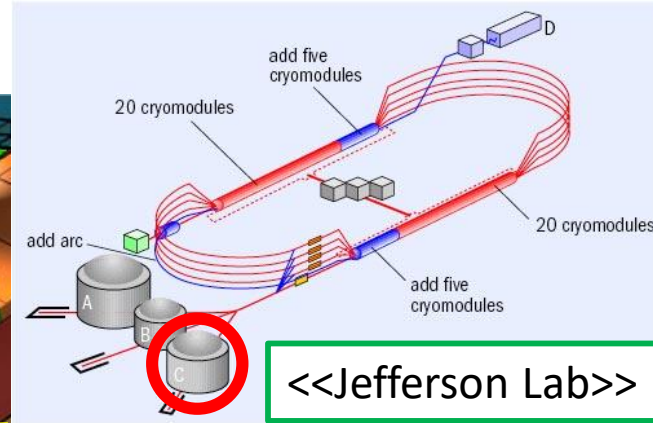
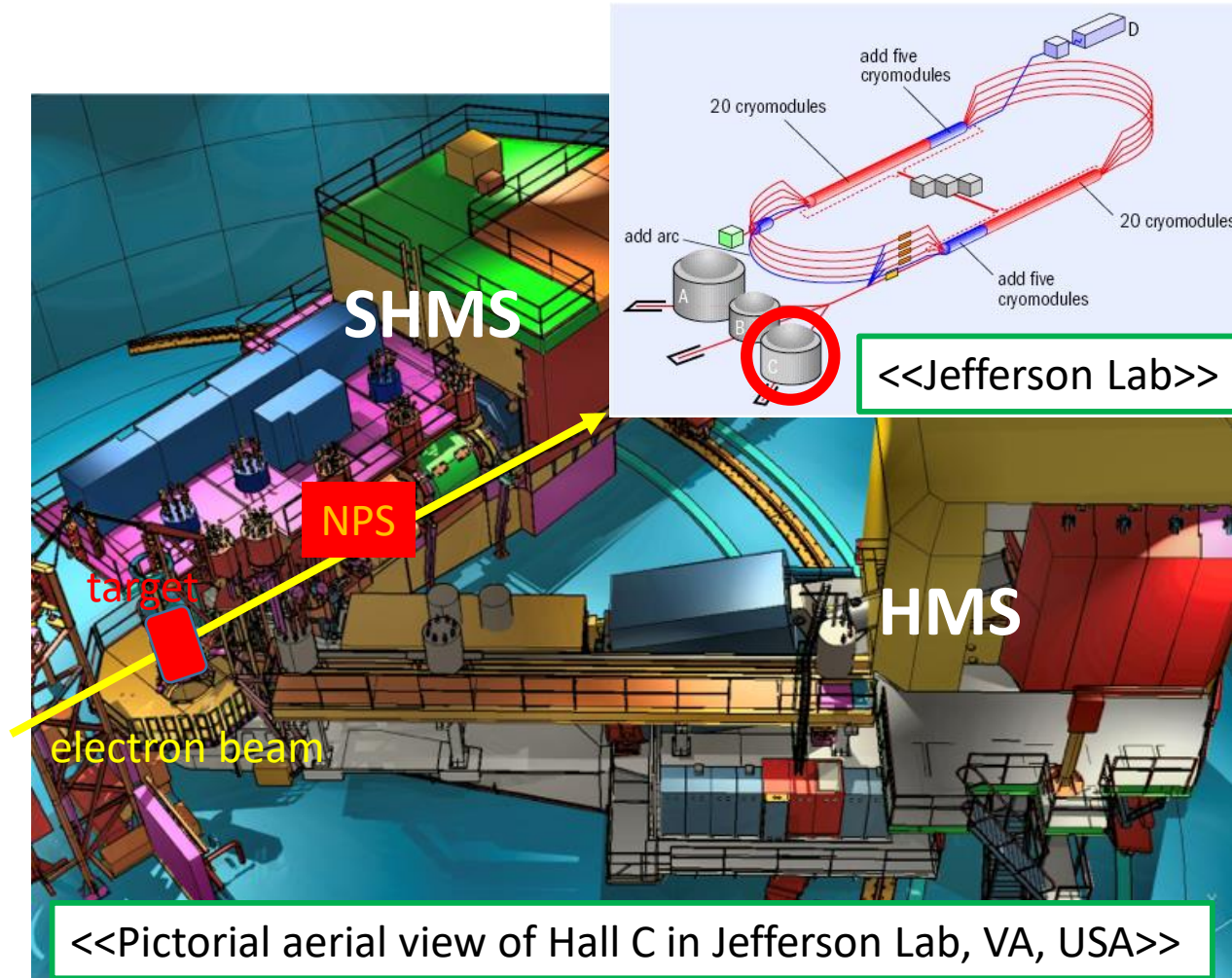


Parton distribution:
via deep inelastic scattering
 -Longitudinal momentum
 & helicity distribution of partons



Generalized Parton Distributions:
via exclusive reactions [eg. DVCS]
 -Transverse position distribution
 and longitudinal momentum of partons

Neutron Particle Spectrometer(NPS) in Hall C



$$e p \rightarrow e' p' \gamma$$

$$\gamma^* p \rightarrow p' \gamma \quad \text{(Exclusive process)}$$

To detect neutral particles (γ , π_0),
NPS will be installed on to the SHMS
SHMS will be used as a cantilever

HMS detects scattered electrons
NPS detects neutral particles

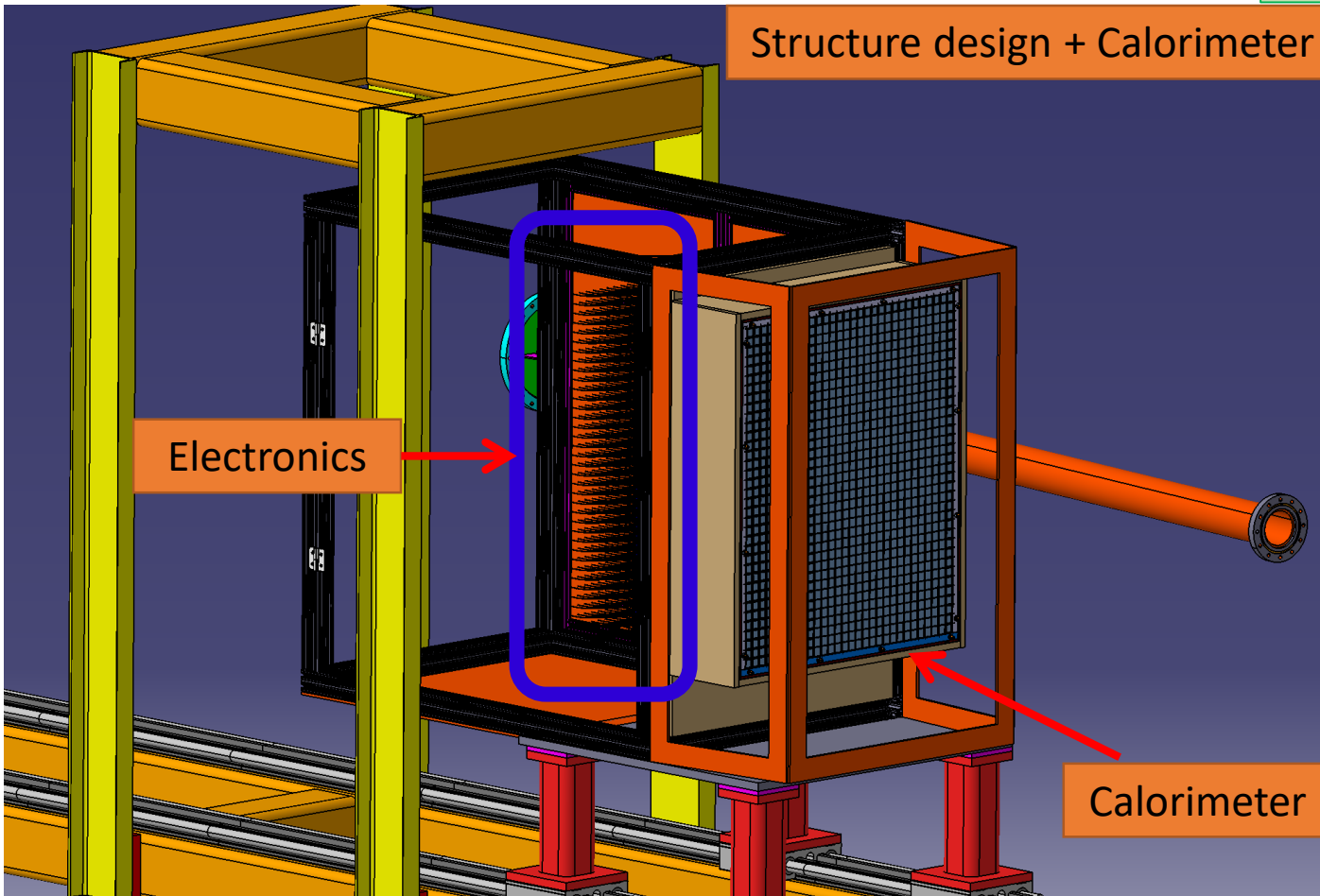
HMS : High Momentum Spectrometer
SHMS : Super High Momentum Spectrometer

Continuous 11 GeV electron beam

Neutron Particle Spectrometer(NPS) in Hall C

<<picture : Emmanuel Rindel>>

Highest luminosity($\sim 10^{38} \text{cm}^{-2} \text{s}^{-1}$) of DVCS ever before

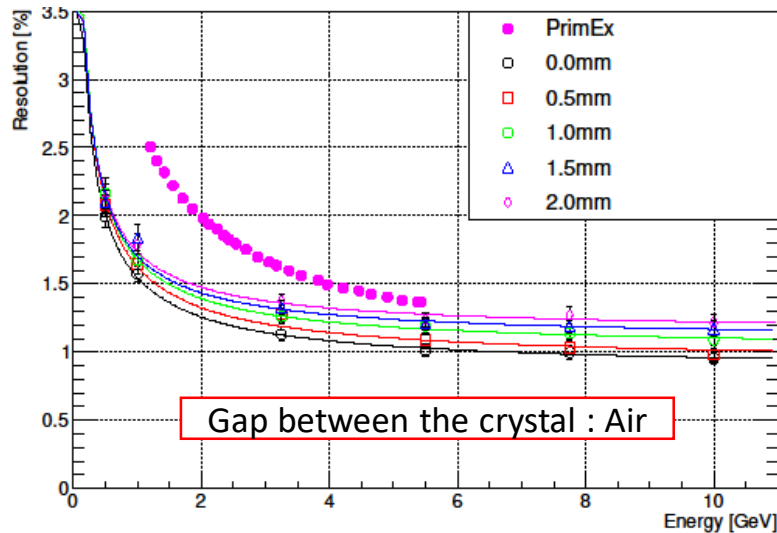
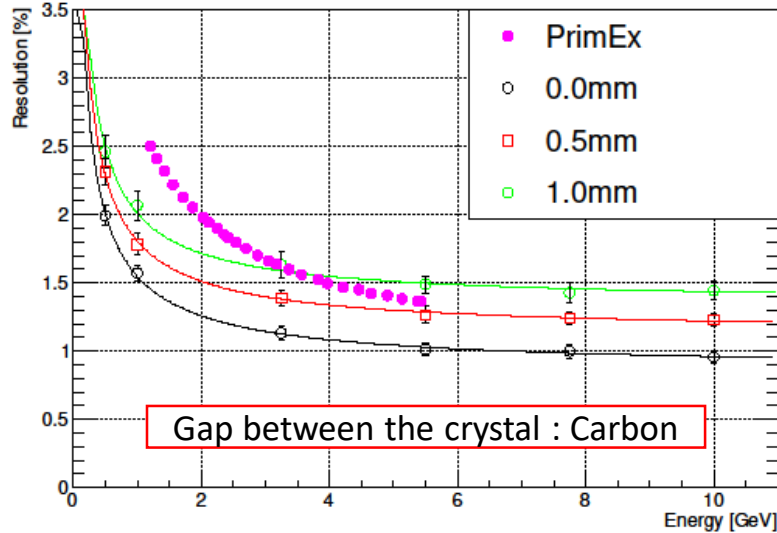


- 1080 (30X36) PbWO_4 blocks
each crystals : $2 \times 2 \times 20 \text{ cm}^3$, $\sim 670 \text{ gram}$
- PbWO_4 as a scintillator :

-Radiation hard
-140~200 photons/MeV
-Widely used in high energy physics as a calorimeter

Electronics : PMT, LED, and optical fiber

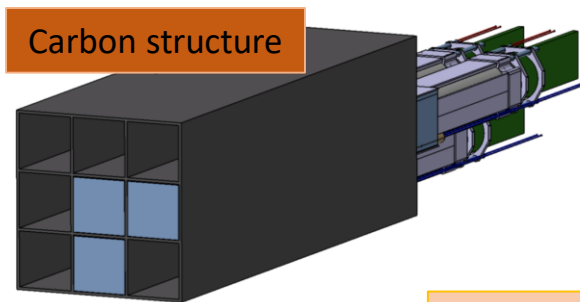
NPS Energy Resolution Simulation



$$\frac{\sigma}{E} = A \oplus \frac{B}{\sqrt{E}} \oplus \frac{C}{E}$$

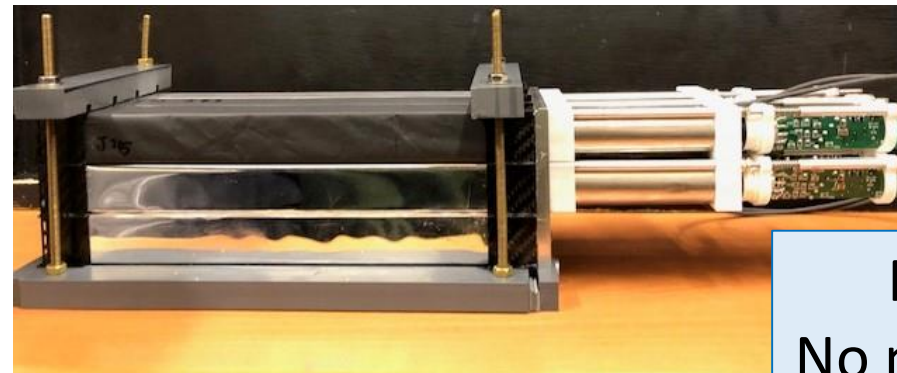
• Purpose :

- NPS is made of 1080 crystals (30X36, stacked)
- Need structures for uniform arrays → Better energy resolution
- More structure between crystals → Worse energy resolution



<<picture : Julien Bettane>>

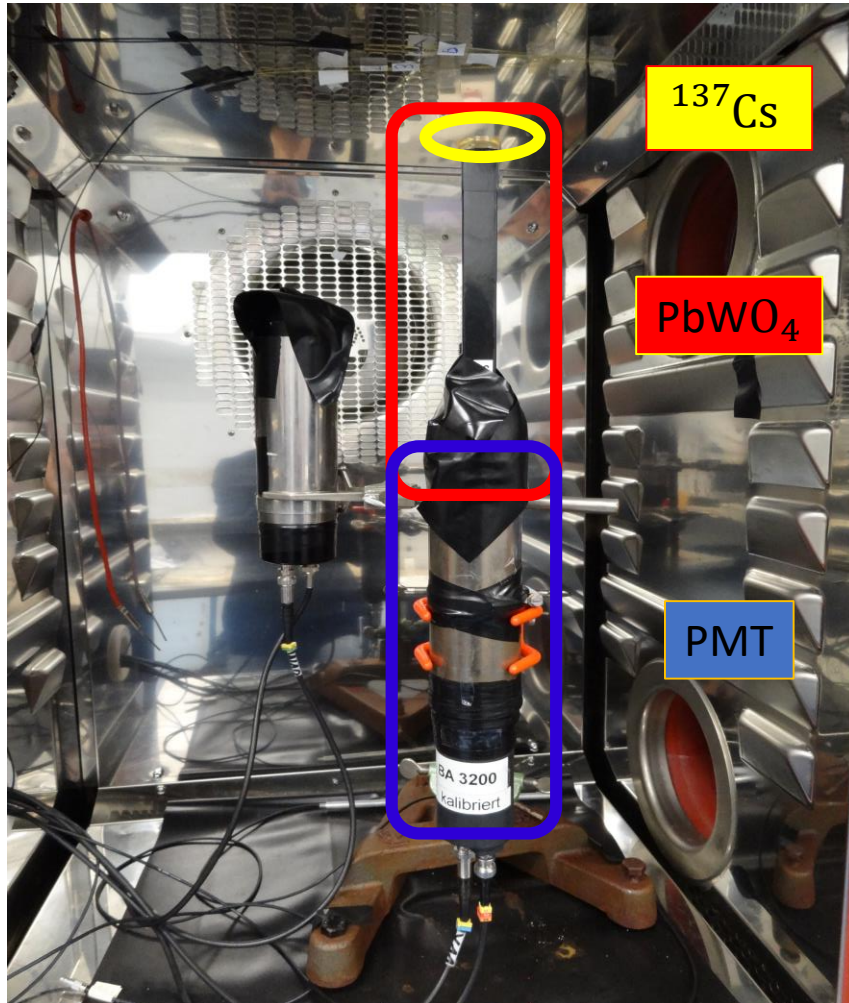
→ Check the dependency of the energy resolution of the NPS on the distance between the crystals(gap)



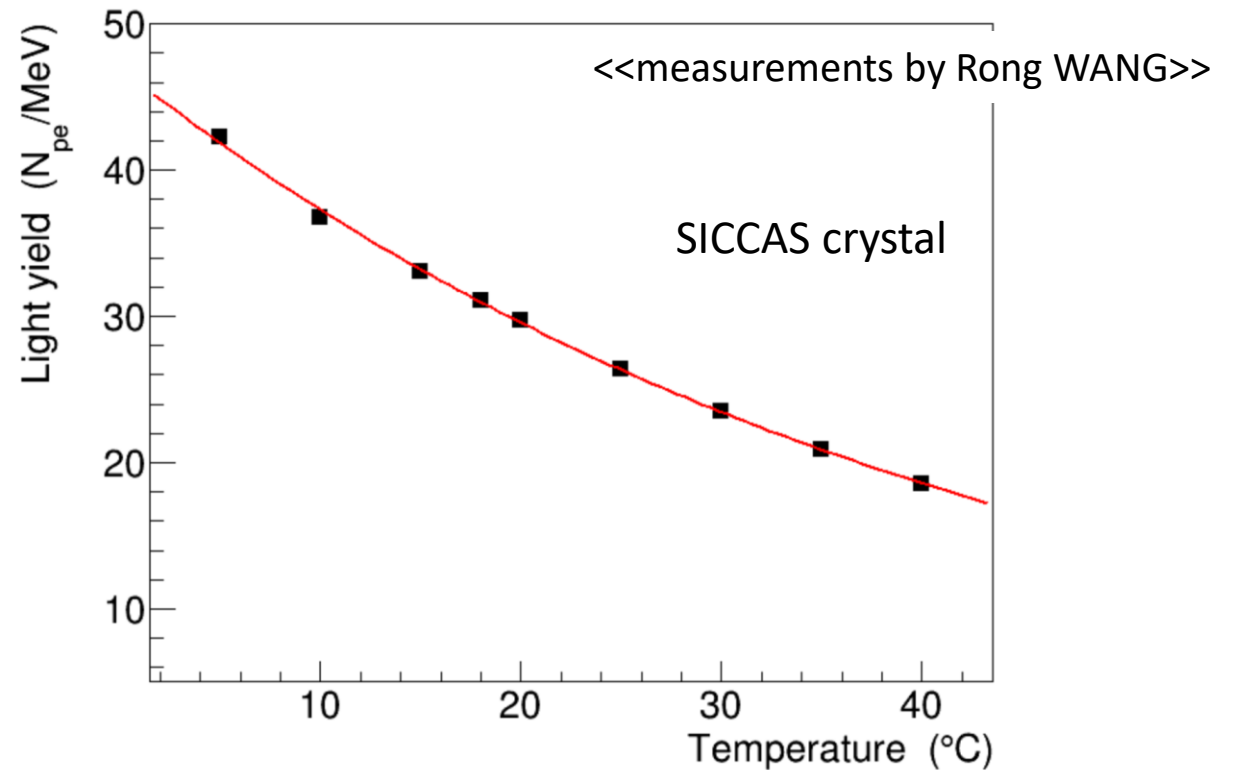
Recent NPS prototype :
No material in the middle part

<<PrimEx also used PbWO_4 crystals for the calorimeter>>

PbWO₄ light yield's temperature dependence



<<Light yield measurement in temperature controlled box>>



The light yield has temperature dependence.
→ The temperature of the calorimeter will be fixed at 18°C

PbWO₄ Irradiation Test

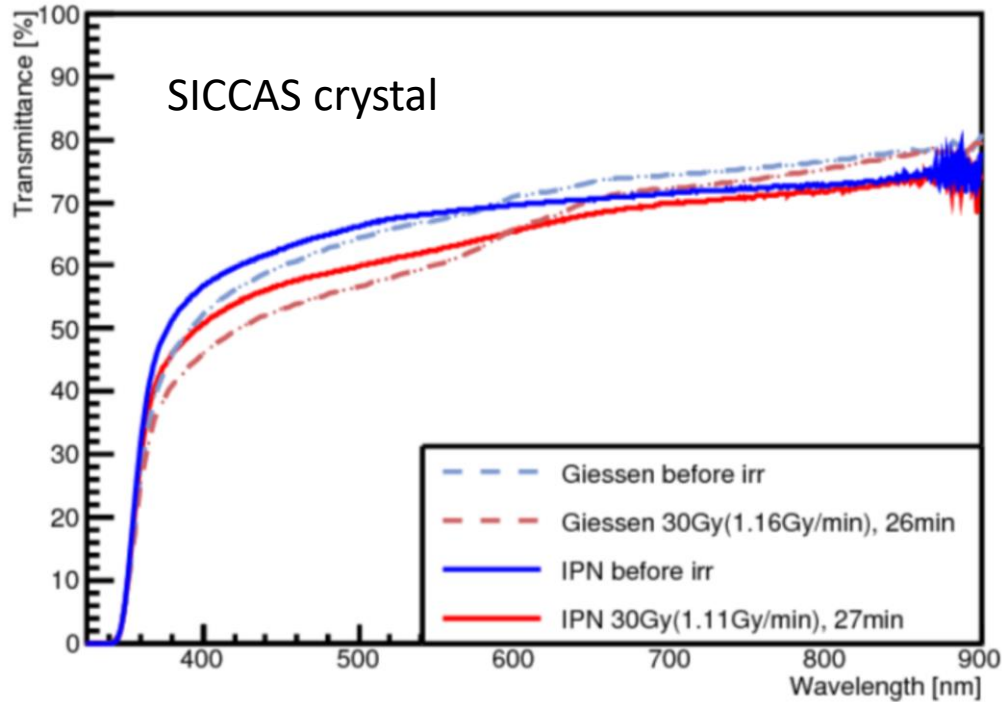


- Radiation hardness measurement
 - Check crystal performance in high radiation environment
 - Optical bleaching
 - Method to recover the optical properties of the crystals after the irradiation damage
- 222TBq ⁶⁰Co source
 - Vary the distance from the source to change the dose rate
 - Can simultaneously irradiate 9 crystals

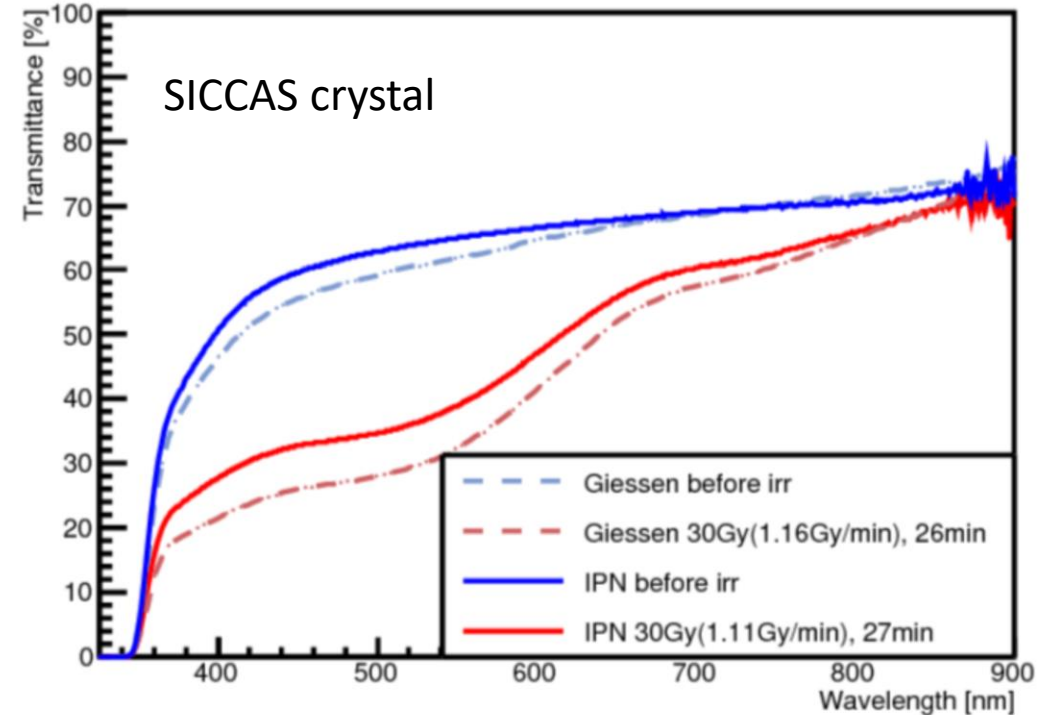
PbWO₄ Irradiation Test

Light transmittance measurement

J43



J23



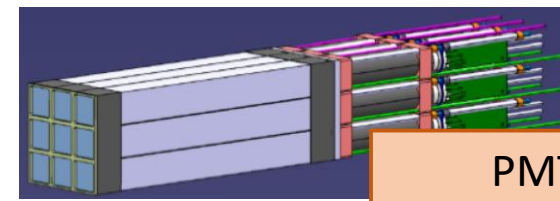
Picture : ~20Gy/min ~4hrs with ⁶⁰Co
at Laboratoire de Chimie Physique

The radiation damage differs for every crystal

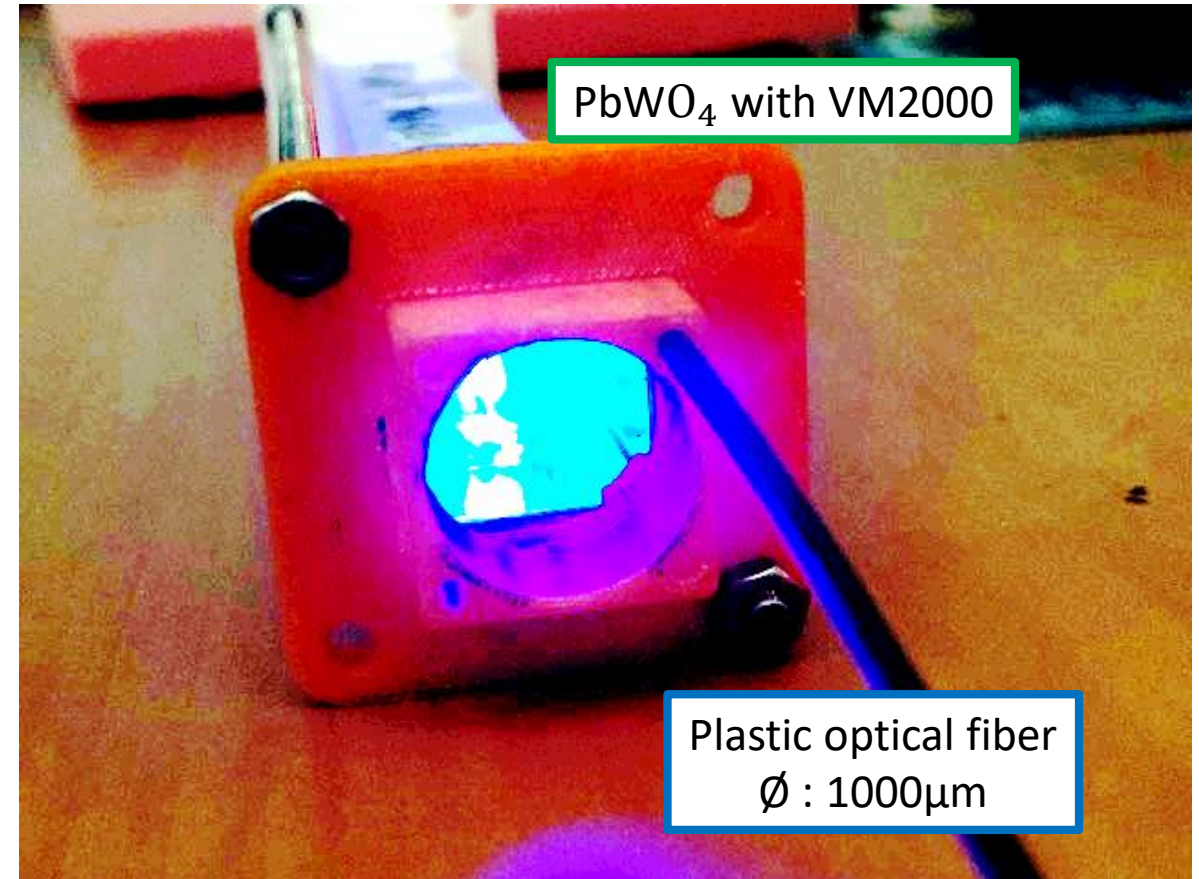
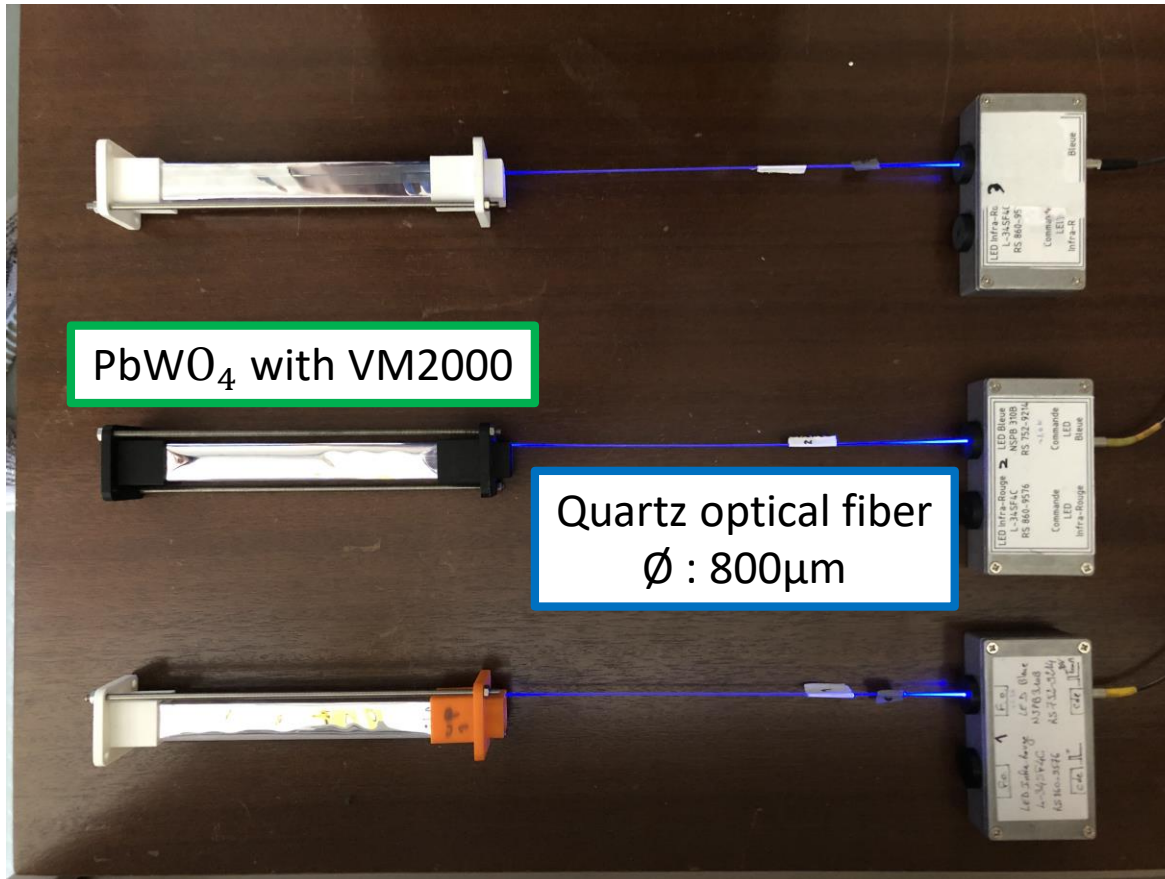
PbWO₄ Radiation Damage Recovery

- Ionizing radiation creates color centers
 - By electron traps or point structure defects
- Relaxation of color centers
 - Thermo-activation
 - Injection of specific energy
 - Blue light : PMT sensitive
 - Infrared light : PMT insensitive → possibility of curing during data taking

PbWO₄ Optical Bleaching

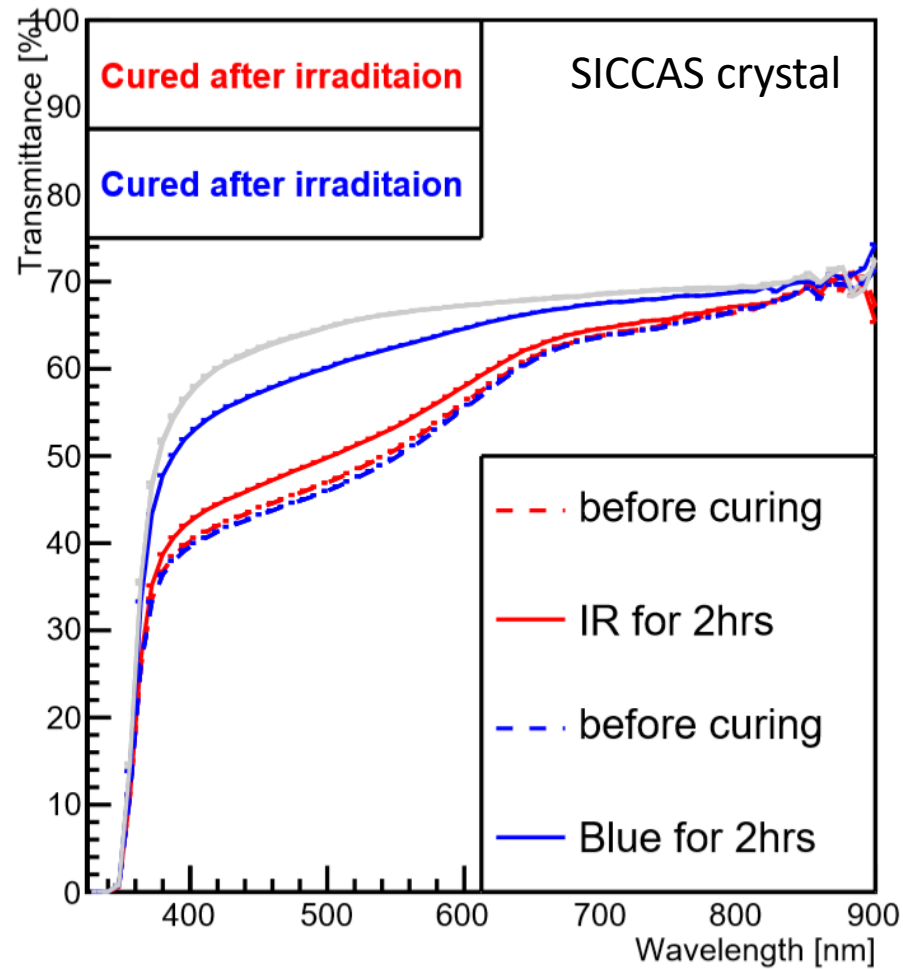


PMTs, LEDs, optical fibers
on the back side of the calorimeter



<<Crystal curing using blue light with optical fiber attached to the crystal>>

PbWO₄ Optical Bleaching



- The crystal was irradiated with 30Gy of dose
- Applied two types of light illumination recovery

- Infrared(IR) light with optical fiber for 2hrs
- Blue light with optical fiber for 2hrs

→ Blue light works better in recovering the transmittance.

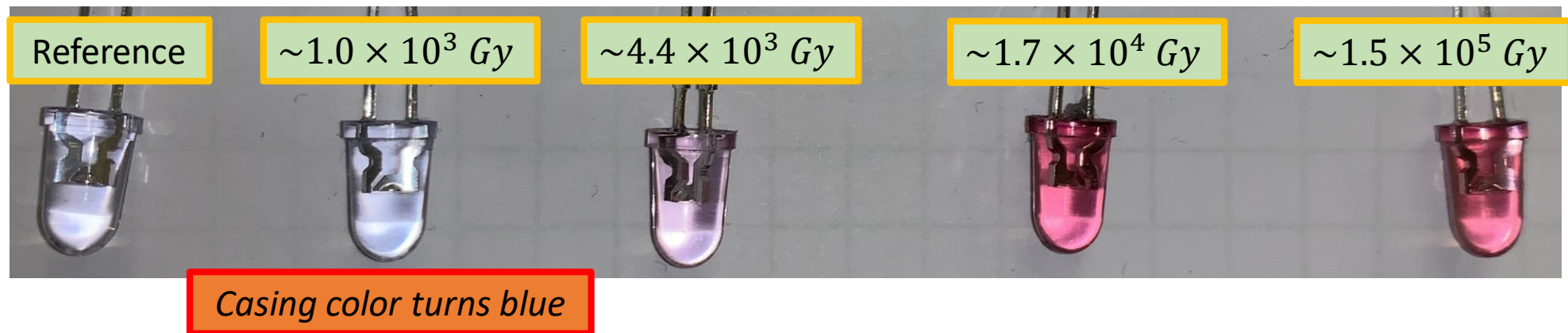
→ Blue light for the crystal optical property damage recovery system of NPS

Optical Bleaching

Quartz (\varnothing : 1000 μ m & 800 μ m) and plastic (\varnothing : 1000 μ m) optical fiber have no difference in the amount of recovery for 2hrs of curing after 30Gy of irradiation.

LED and Optical Fiber irradiation test

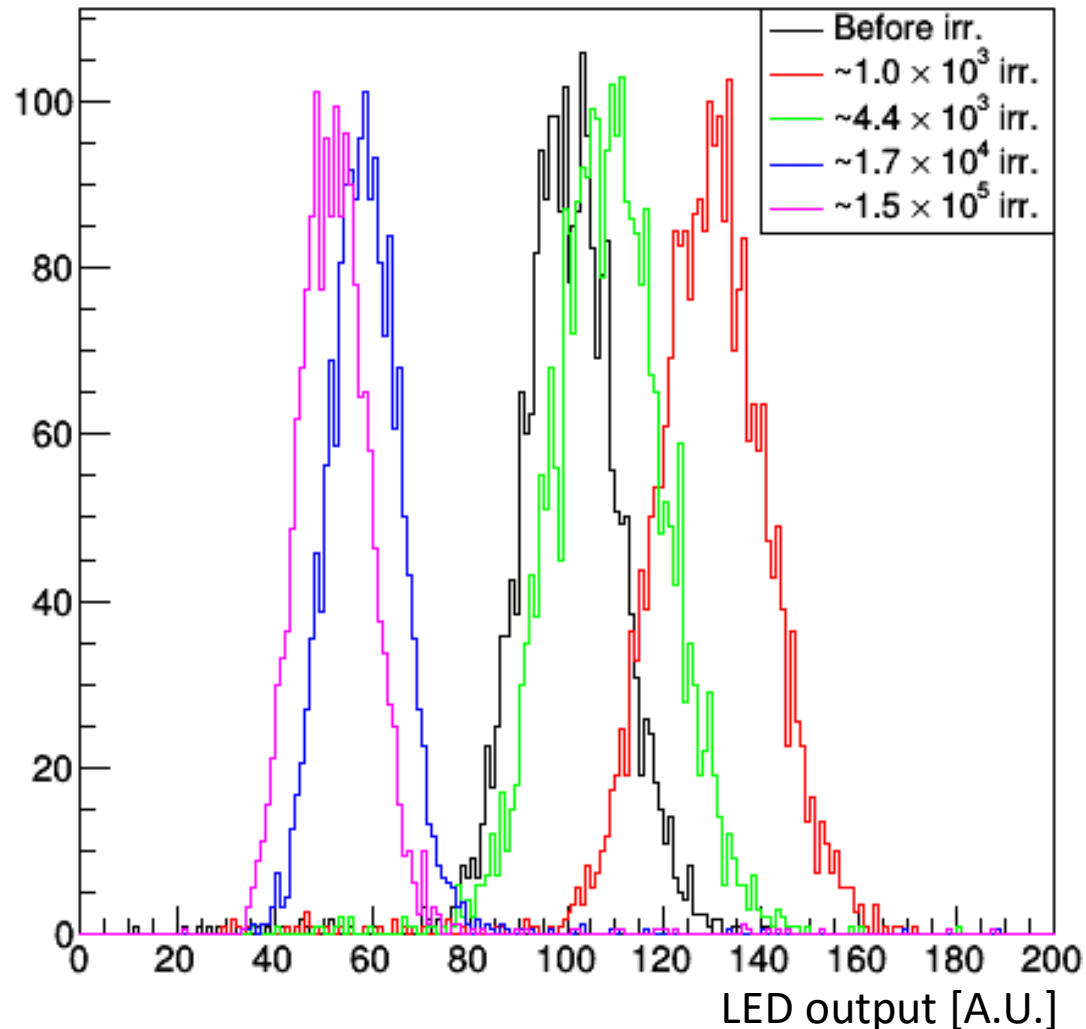
- LED and quartz optical fiber will also be used as a calibration tool for the calorimeter
 - Tests these equipments' radiation hardness



- Quartz optical fiber is radiation hard up to $\sim 1.5 \times 10^5 \text{ Gy}$
- LED is not radiation hard
 - The LED's casing color changes after $\sim 1.0 \times 10^3 \text{ Gy}$

Expected dose in the experiment : $< 300 \text{ Gy}$

LED and Optical Fiber irradiation test



- The LED's plastic casing changes its color due to irradiation.
- Its light output changes. However, **increases** first and then **decreases**.

Expected dose in the experiment : < 300 Gy

➔ Further LED irradiation tests are planned with less radiation dose

Summary

- DVCS access to the GPDs
- NPS is needed in Hall C in order to perform the DVCS experiment
- NPS energy resolution calculation with Geant4
 - Detector structure : 0.5mm carbon material only in the front and the back side, 2cm each of the crystals
- Optical bleaching method for maintaining calorimeter's energy and position resolution
 - Blue light curing (optical bleaching) via quartz optical fiber to be used for the NPS

Time Line of the NPS

- Detector construction at the end of 2019
- Delivery of NPS to Jefferson Lab at the beginning of 2020
- NPS tests at Jefferson Lab in 2020
- DVCS experiment expected in 2021