NPS Calorimeter

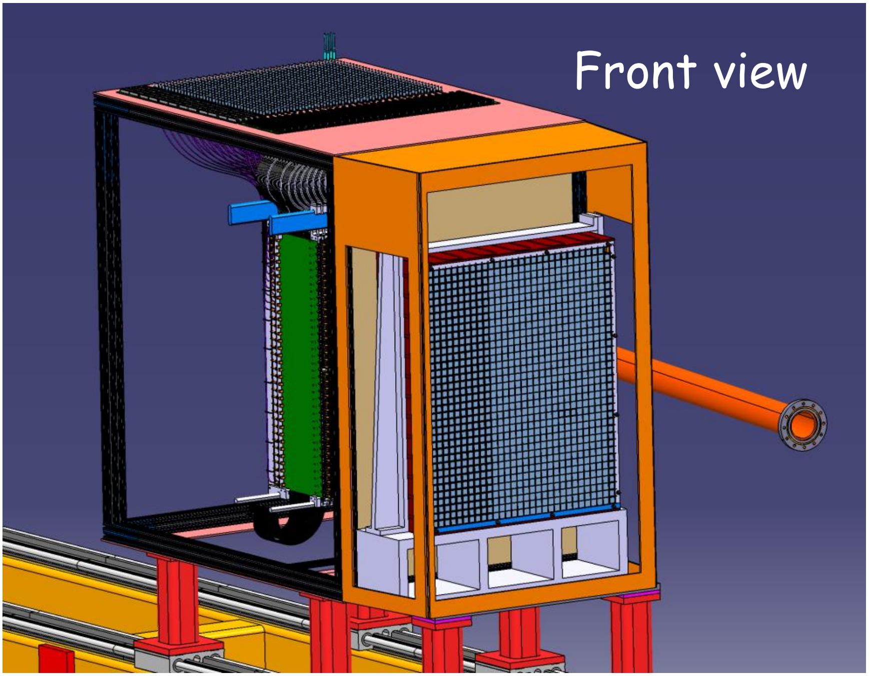
ERR, May 15 (2019)

Carlos Munoz Camacho, IPN-Orsay
for the NPS Collaboration

IPN-Orsay NPS group:

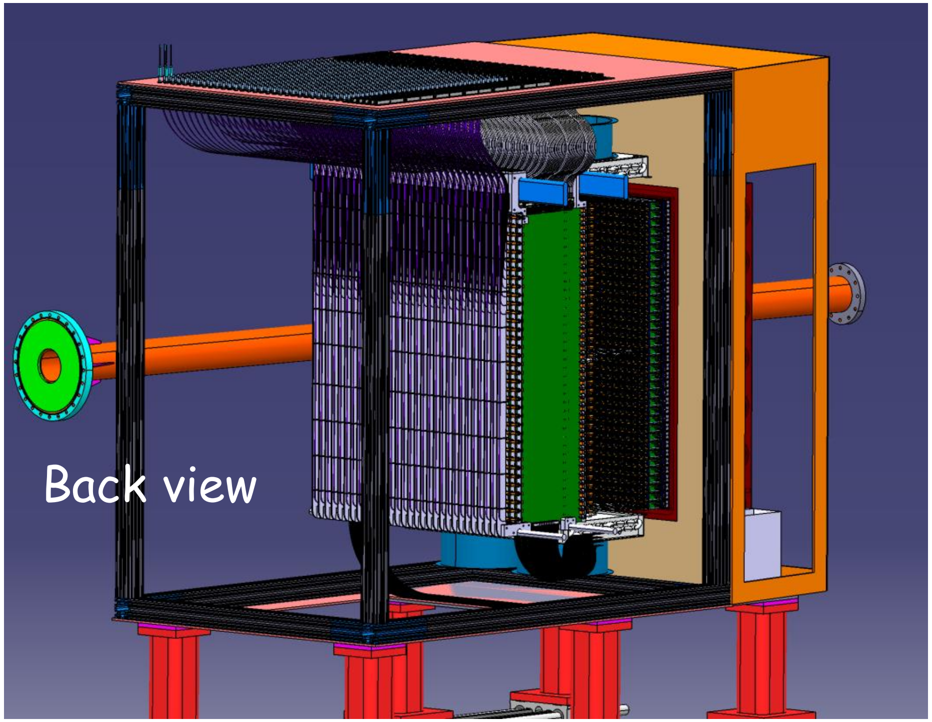
- E. Rindel, T. Nguyen Trung, G. Hull, J. Bettane
- C. Domingues, M. Imre, B. Mathon, L. Seminor, L. Vatrinet, B. Geoffroy
- H. S. Ko, C. Munoz

Overview: conceptual design



- 30x36 (1080) $PbWO_4$ crystals ($2x2x20$ cm^3) JLAB, CUA
- Hamamatsu R4125 PMTs JLAB, YEREVAN
- Custom-made active bases OHIO, YEREVAN

Survey & alignment requirements: ~1mm



Calorimeter frame: ORSAY

- Crystals placed in a 0.5 mm-thick carbon frame to ensure good positioning
- PMTs accessible from the back side to allow maintenance
- Calibration and radiation curing with blue LED light though quartz optical fiber

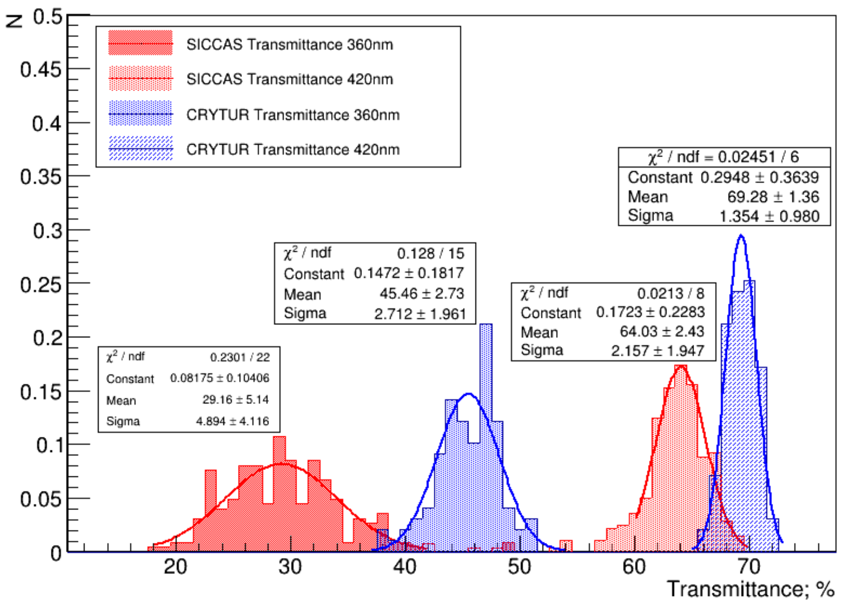
Design 100% completed

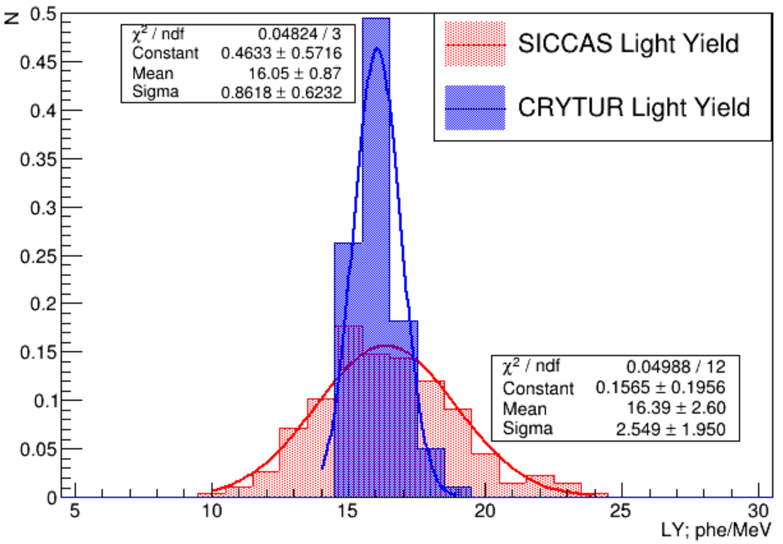
Crystals status

Vendor	Samples	Delivered
SICCAS	460	FY 2017
CRYTUR	100	FY 2018

Experimental investigation	CRYTUR	SICCAS
Visual inspections including 5mW green laser	100%	100%
Dimension measurements	100%	100%
Transmittance measurements	100%	100%
Light yield measurements	100%	70%
Radiation resistance, sample of 10 pieces	to be done	done
Beam tests (additional)	to be discussed	done; data analysis ongoing
Chemical and surface analysis few samples (optional)	done	done

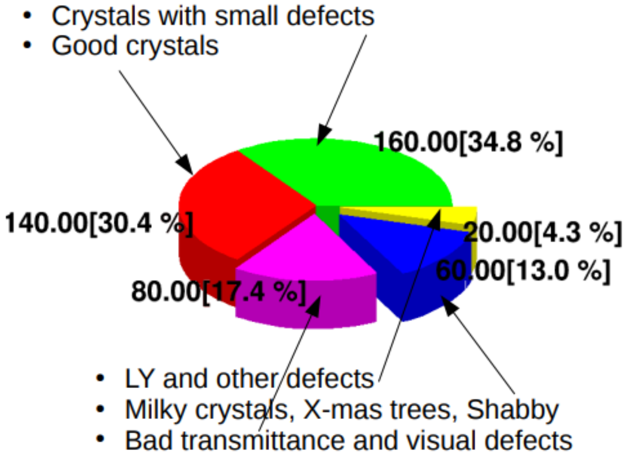
Quality analysis:





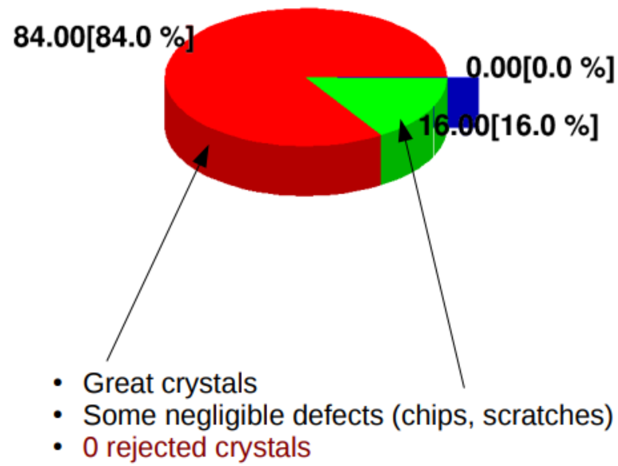
Crystals status

SICCAS



160 rejected crystals

CRYTUR



Crystal procurement:

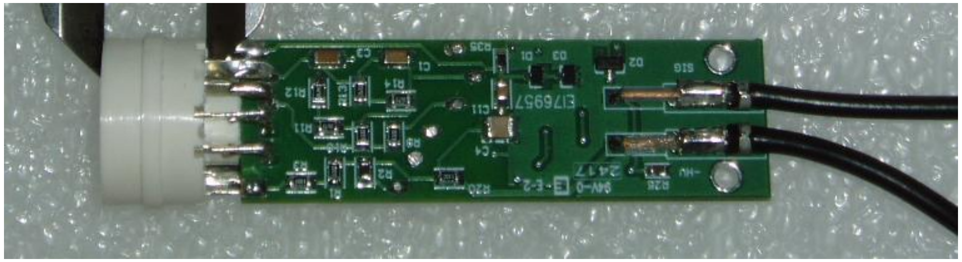
SICCAS:
460 (2017-18) onsite

CRYTUR:
100 (2018) onsite
250 (ordered 2019)
300 (ordered 2019 - replacing an order to SICCAS)
=======
650

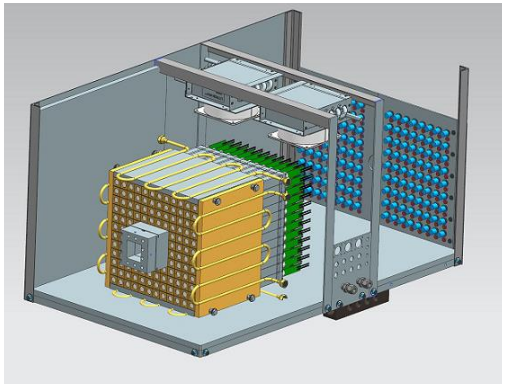
All crystals will be onsite by Summer 2020

PMT and voltage dividers

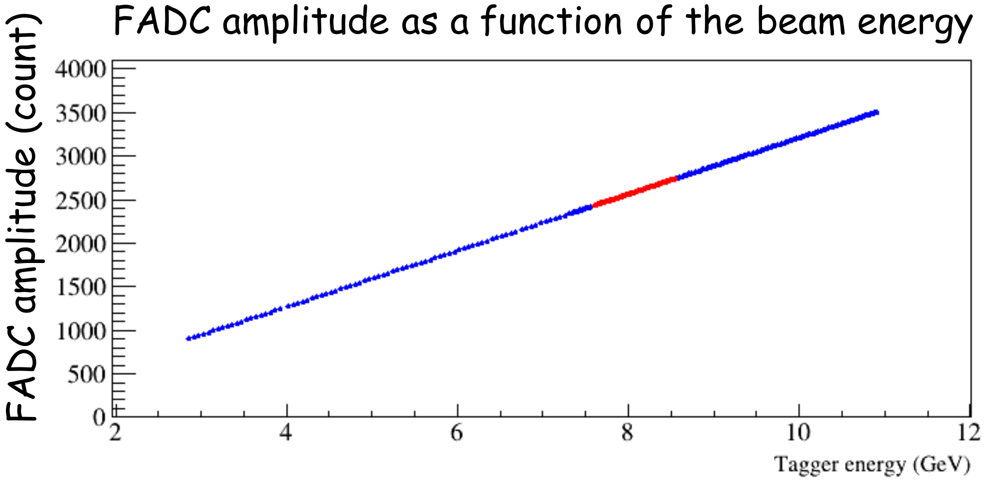
- PMT (Hamamatsu R4125):
  340 onsite, 1000 more ordered (delivery by Summer 2019)
- Voltage dividers:
  80% of them (865) assembled. Completion expected by Summer 2019



Array of 12x12 $PbWO_4$ crystals

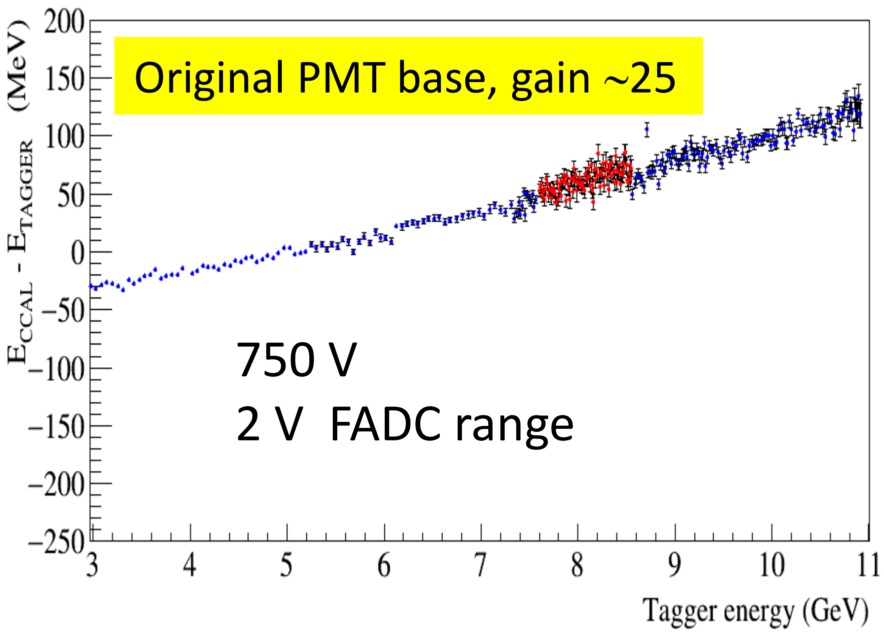


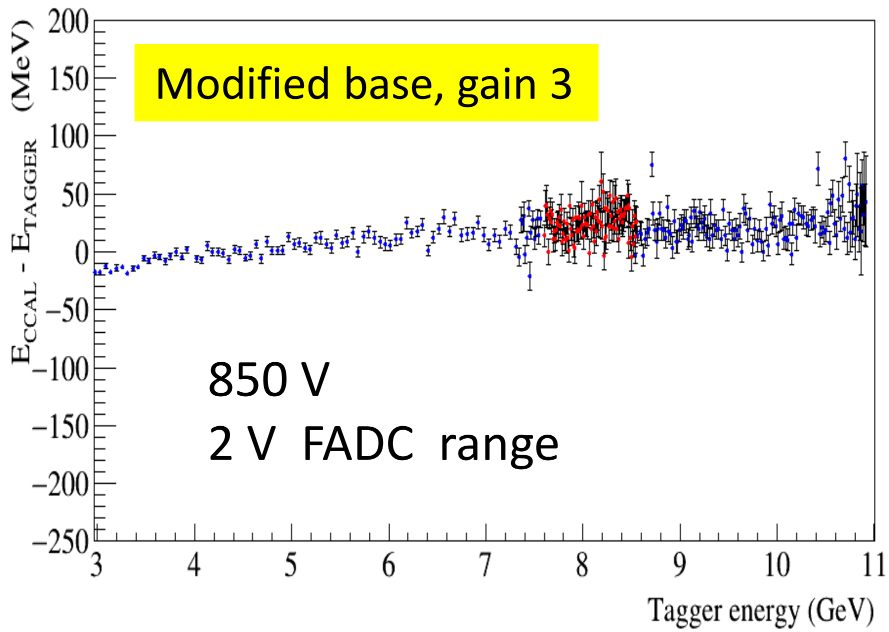
Voltage dividers tested in the Hall D ComCal prototype:



10 GeV :	3200 FADC channels
FADC range:	2 V (maximum range)
Typical HV:	700 – 750 V

Linearity of the FADC peak amplitude





- Some non-linearities on the level of 2 – 3 % were observed for the original PMT base

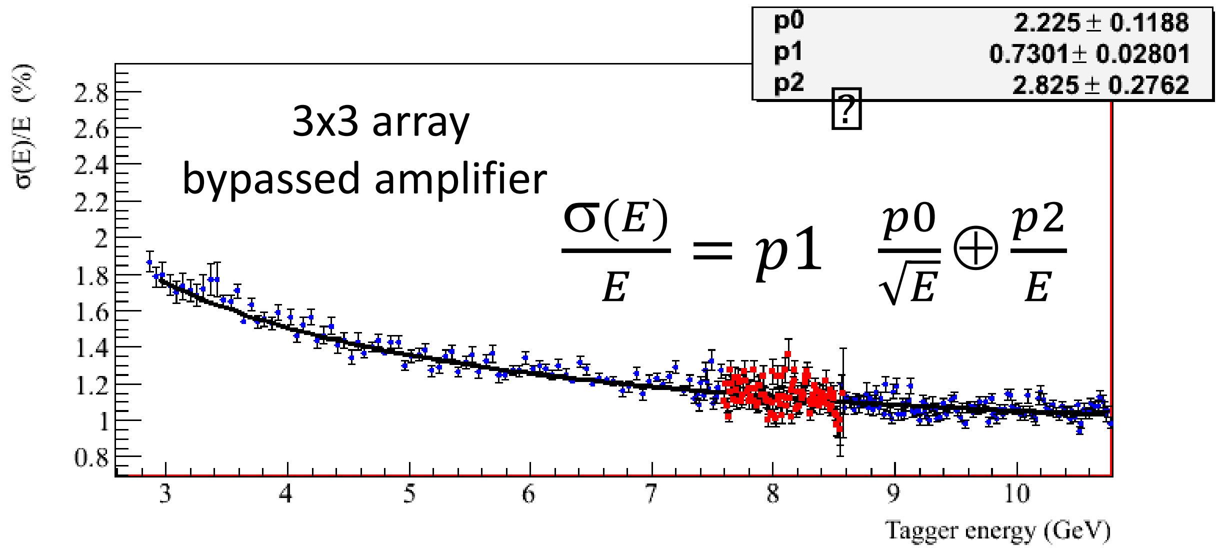
  (PMT was operated at relatively small HV, recommended HV is about 1 kV)

- The linearity can be improved by reducing the amplifier gain and increasing HV: change of 1 resistor in the base needed

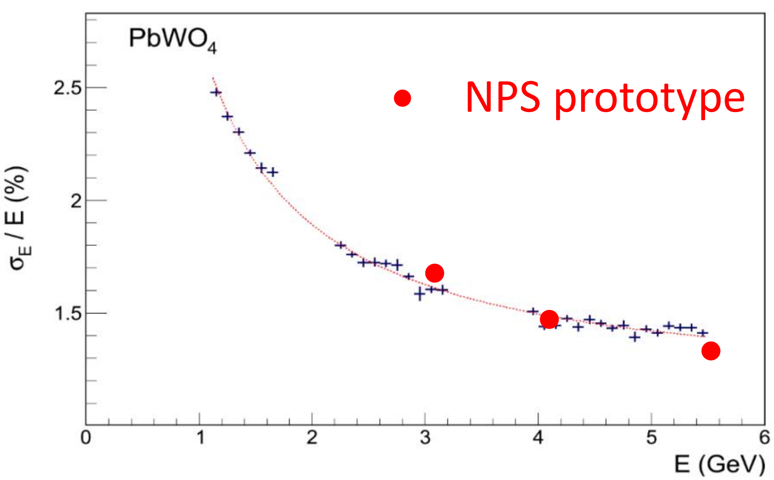
- Anode current will be evaluated and gain adjusted as needed

Energy resolution of prototype

NPS Prototype



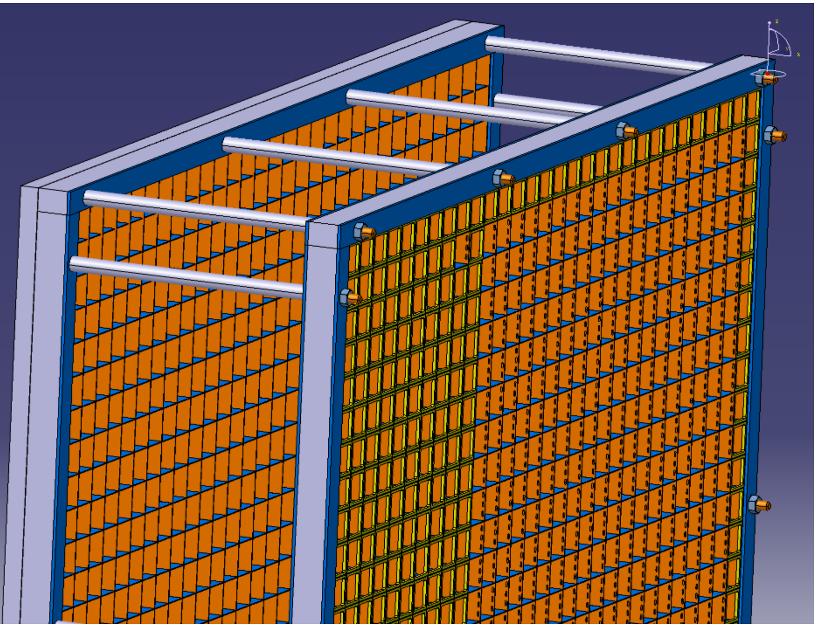
HyCal



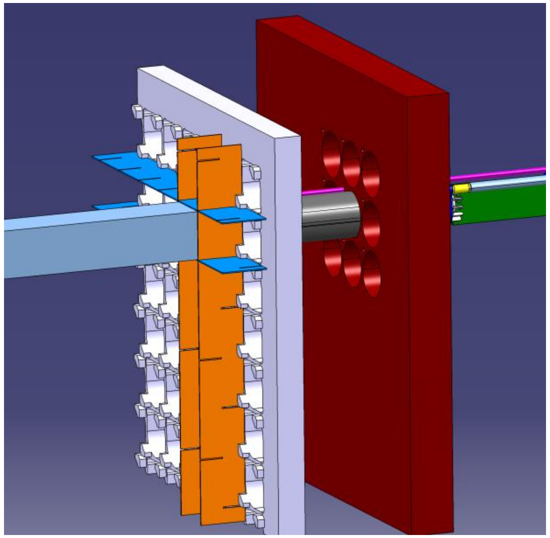
- Relatively good energy resolution.
- Consistent with Hall B HyCal, constructed with SICCAS crystals

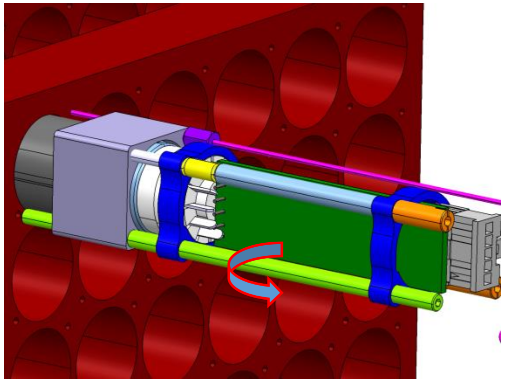
More details can be found in GlueX-doc-3590, GlueX-doc-3998, V. Berdnikov, A.Somov, J. Crafts

Calorimeter carbon frame

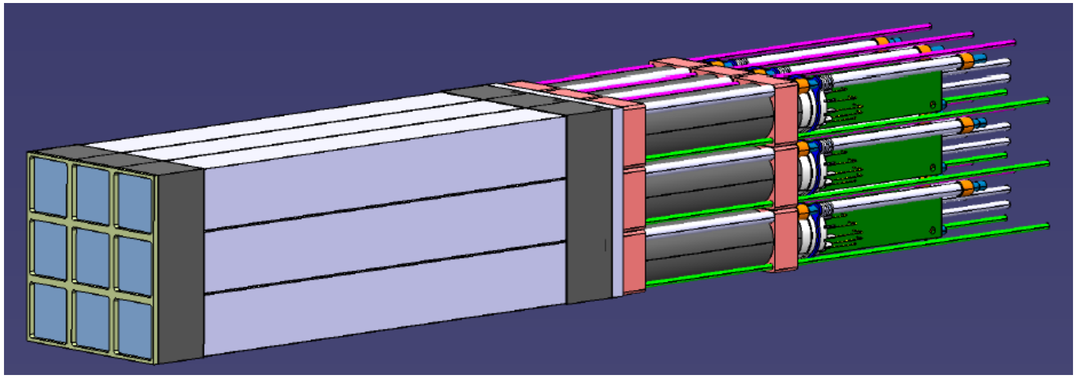


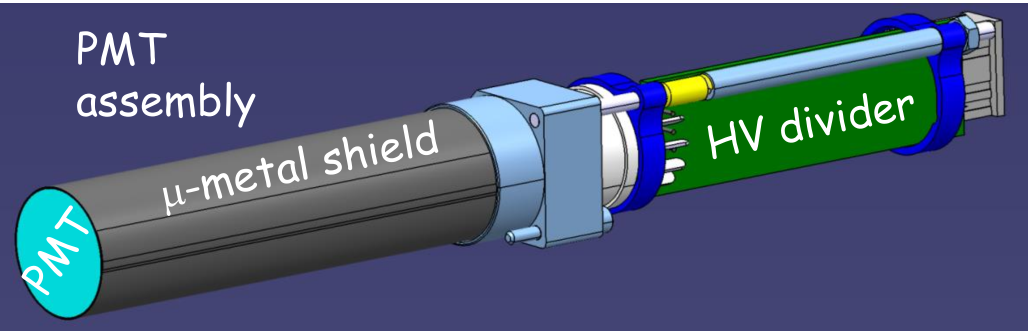
2-cm of C (0.5 mm thick) at the front and back of the crystals





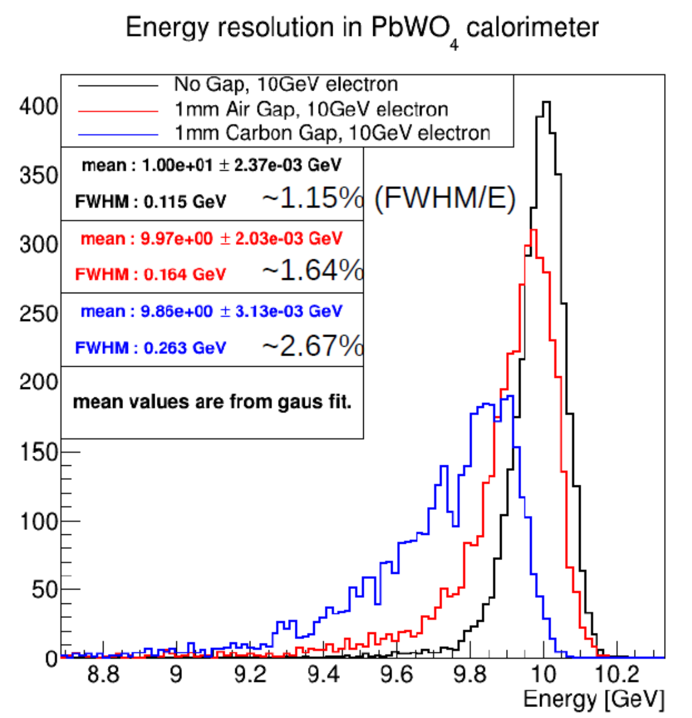
Easy disassembly of PMT block with one long single captive screw

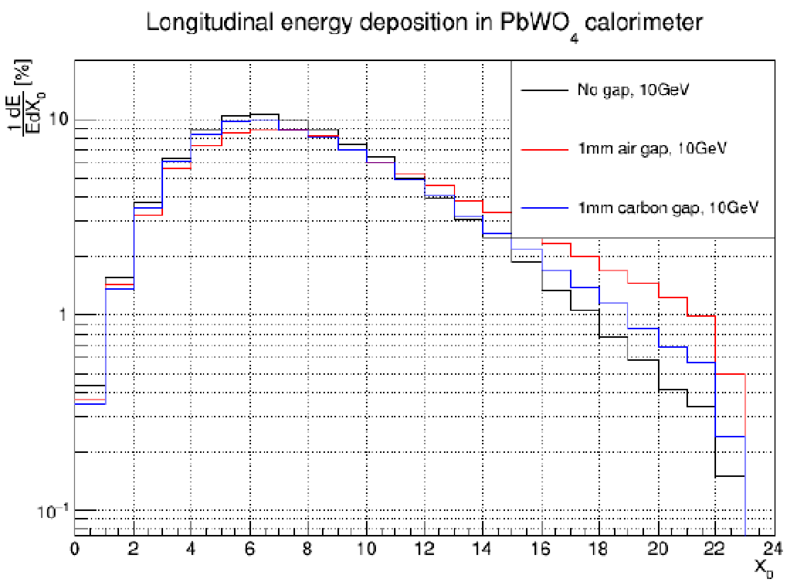


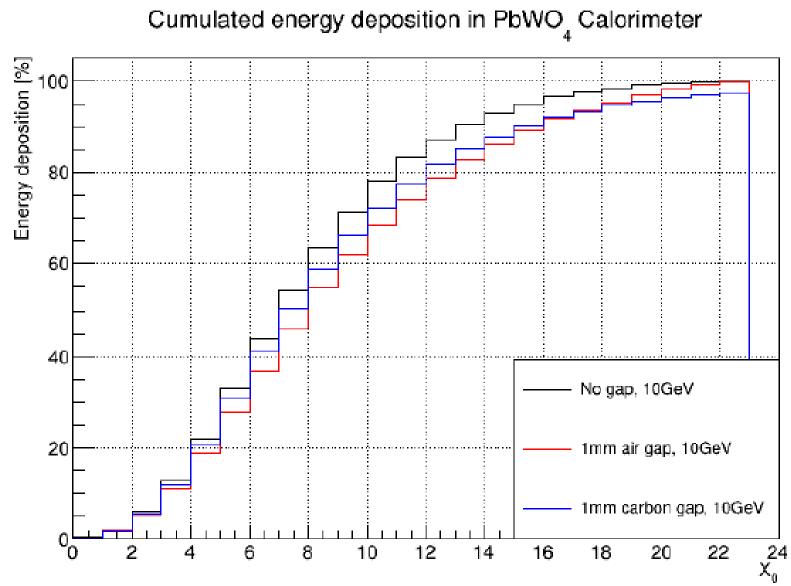


Carbon frame: impact on energy resolution & efficiency

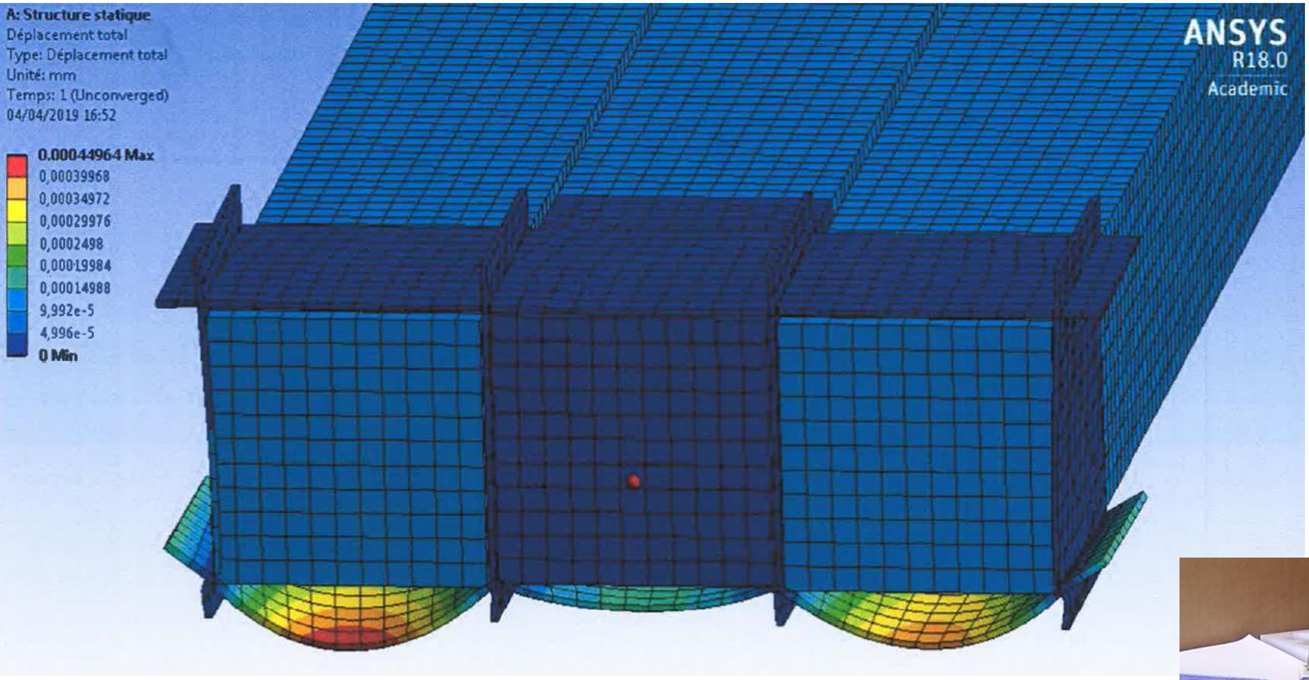
- 1.2% (ideal case) to 1.6% at 10 GeV with 1mm of air between crystals
- More than 97% of energy collected after 22 X_0







Carbon frame: mechanical simulations and tests



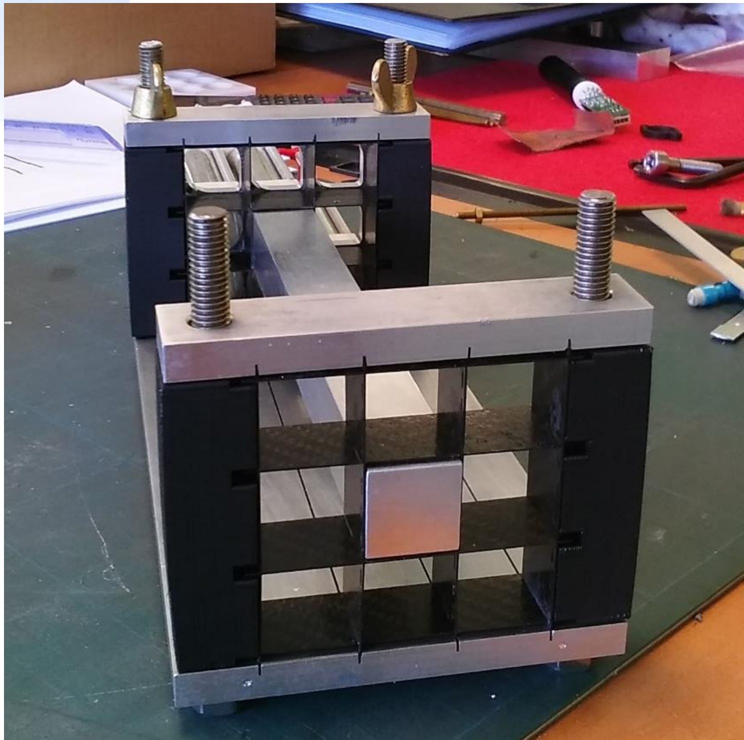
Simulations:

Effect of 1 crystal in each cell

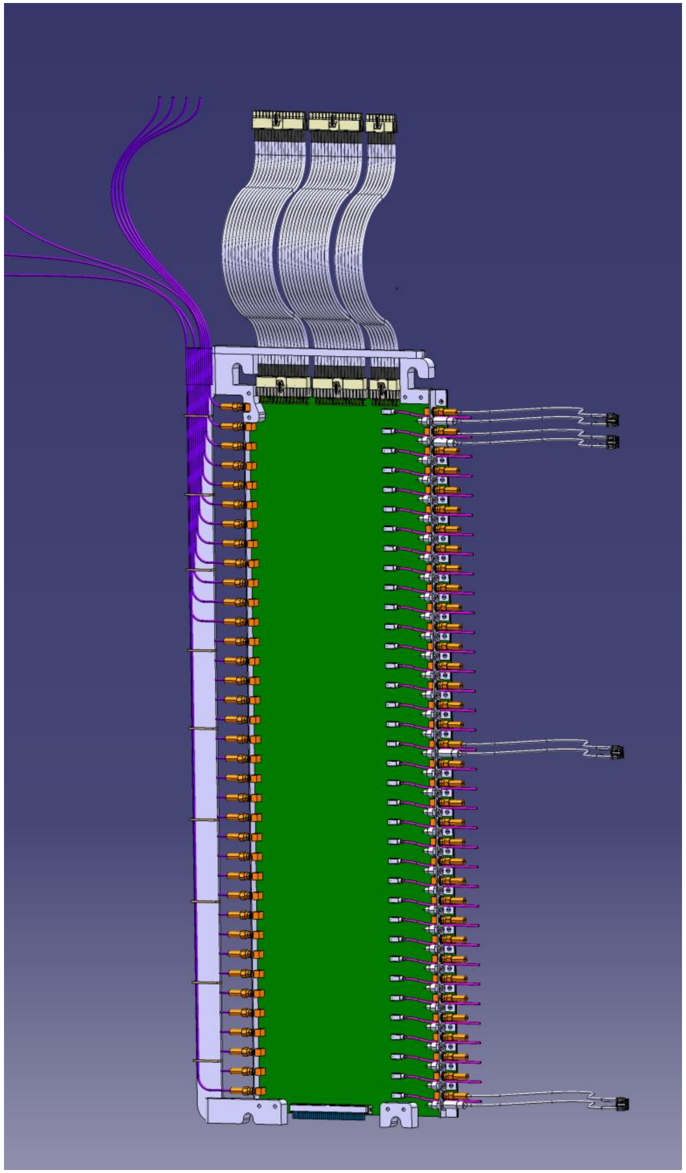
- Less than 0.2 μm deformation at the center
- 0.4 μm deformation on external layer

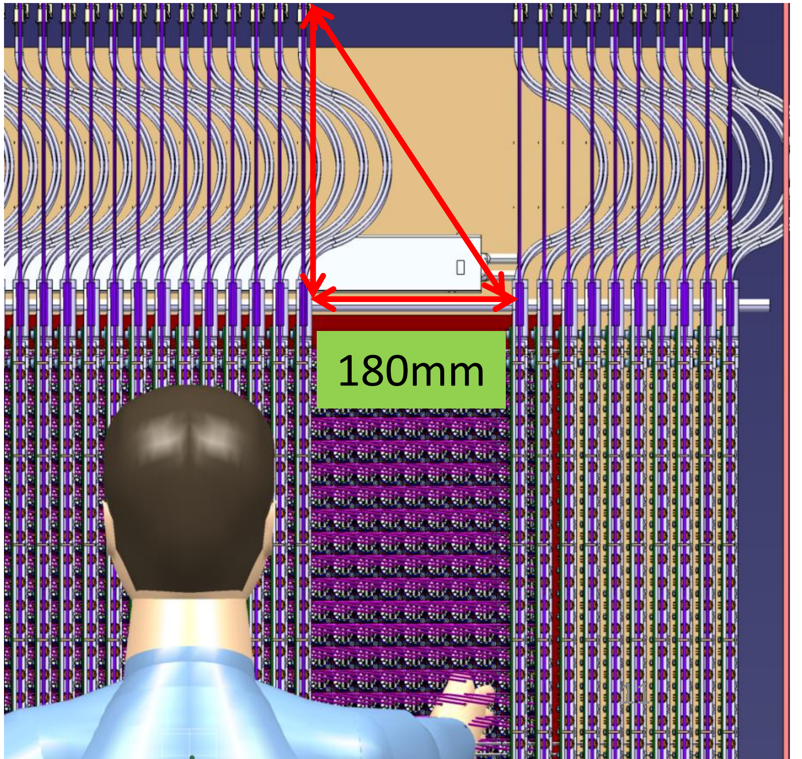
Very resistant structure

Real tests on the bench ongoing:

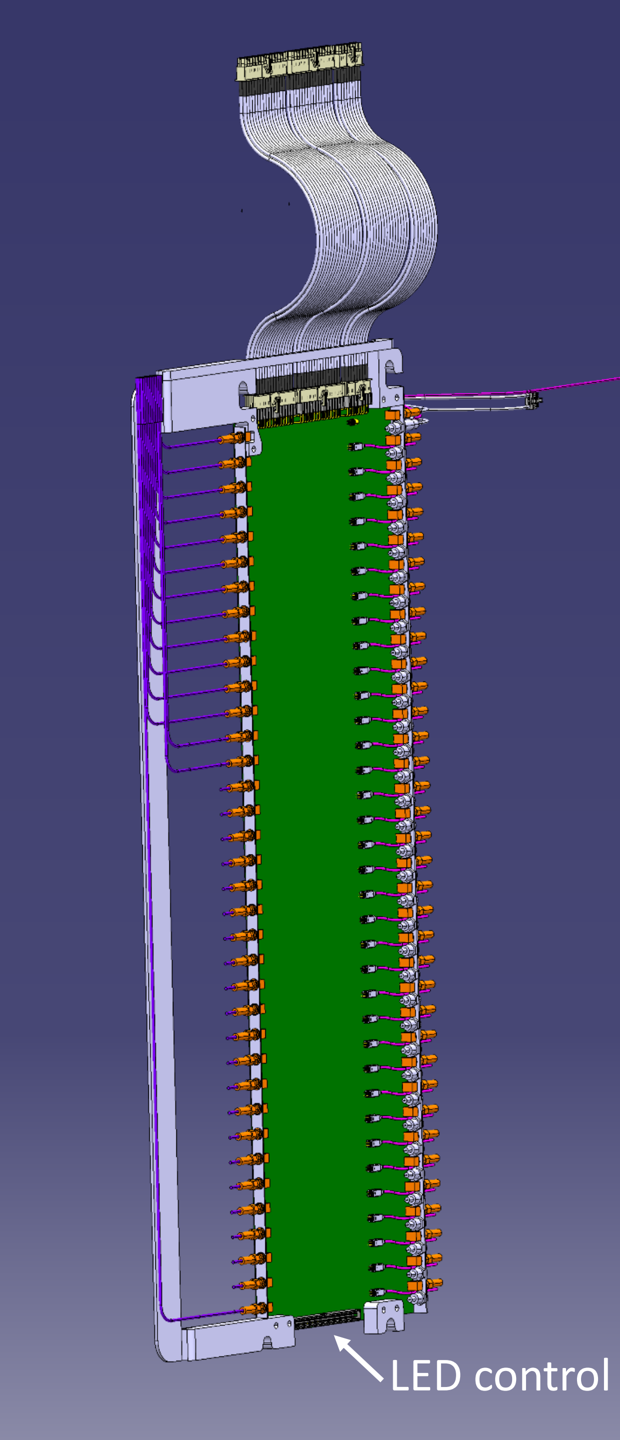


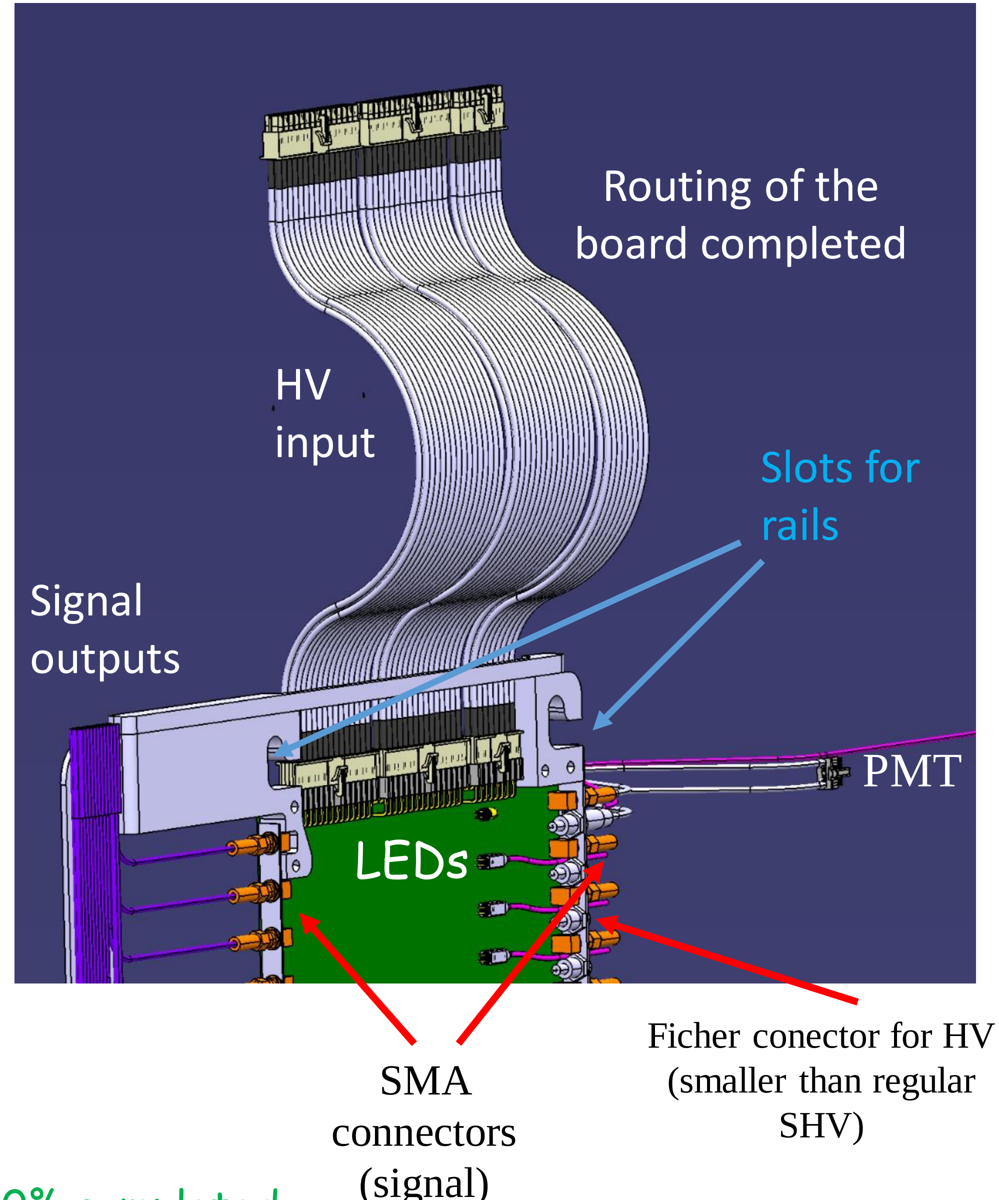
Cables and fibers





PCB design (HV, signal, LED)





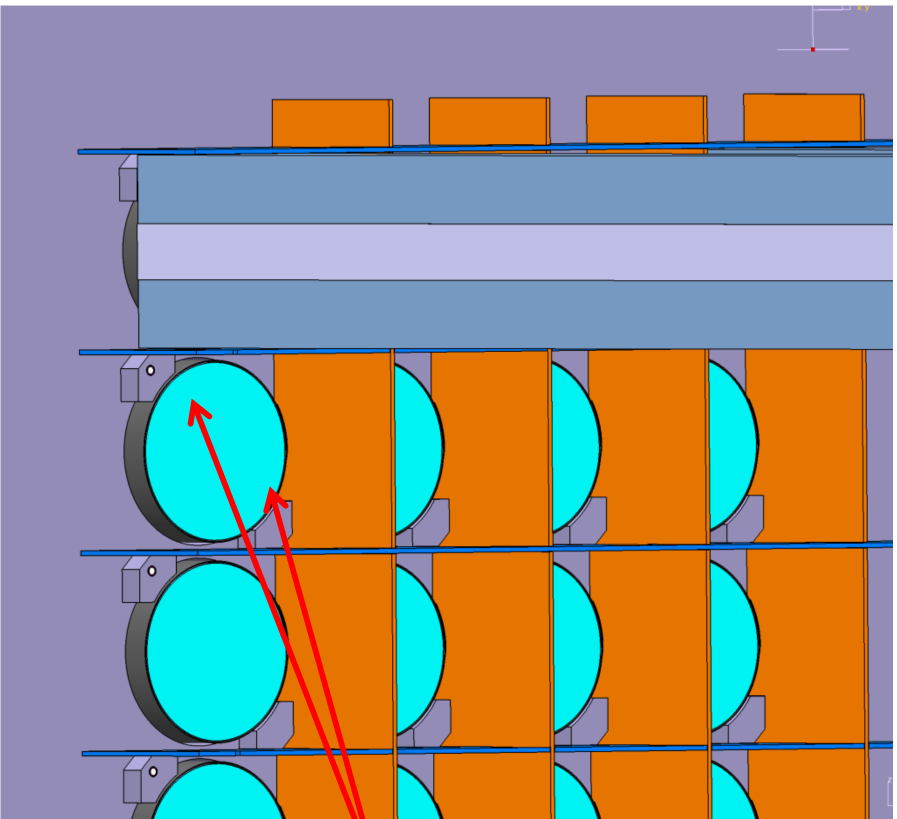
Design 100% completed
1st board being manufactured (delivery by end of May)

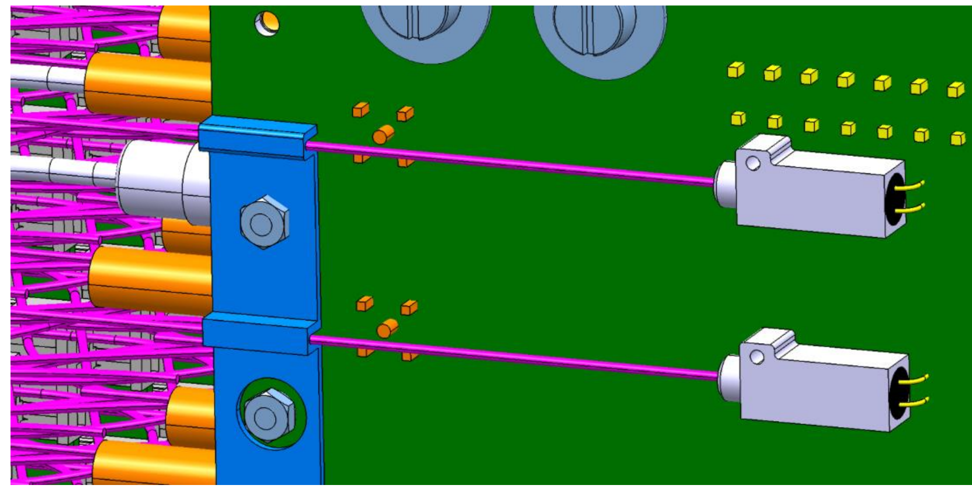
Calibration and curing

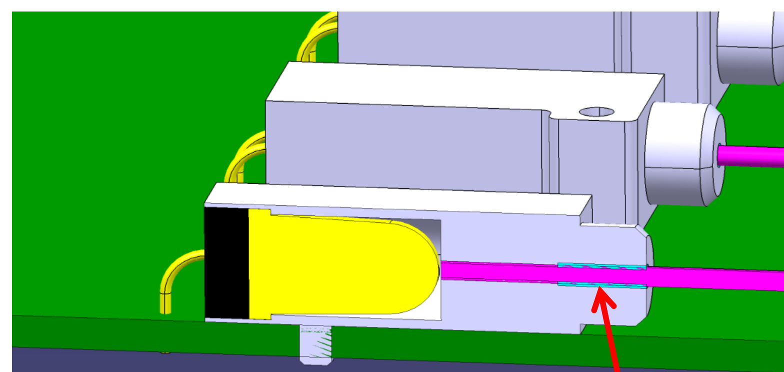
TO DO:
LED control board (JLAB)

1 blue LED per channel (onto the PCB board)

- Pulsed mode for calibration
- Continuous mode for curing
- Light through 800 μm diameter silicate fiber (radiation hard)



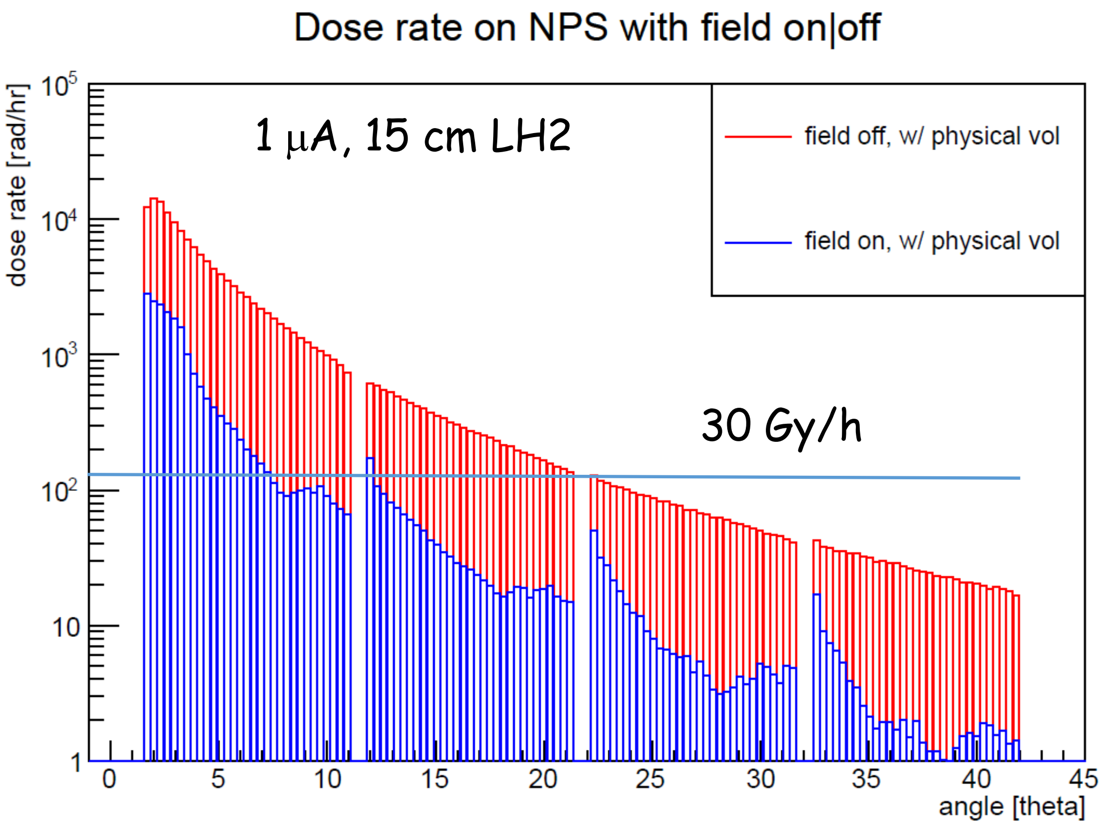




grease

glue

Radiation environment



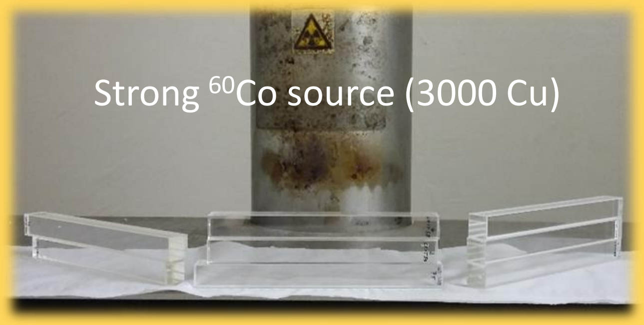
Curing expected to be needed every few days or few weeks, depending on the kinematics setting

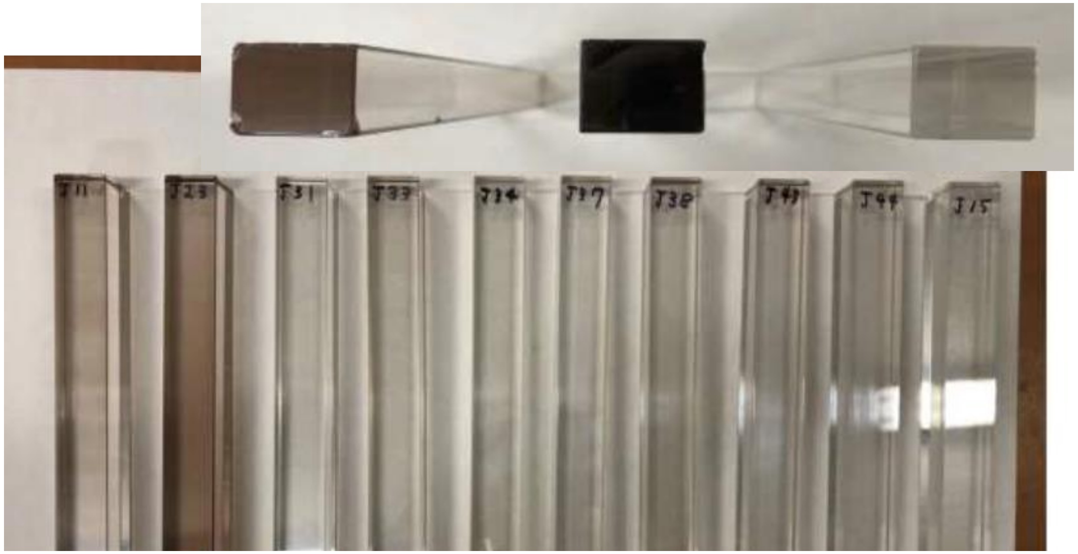
Irradiation and curing tests made with 30 Gy at 1Gy/min rate

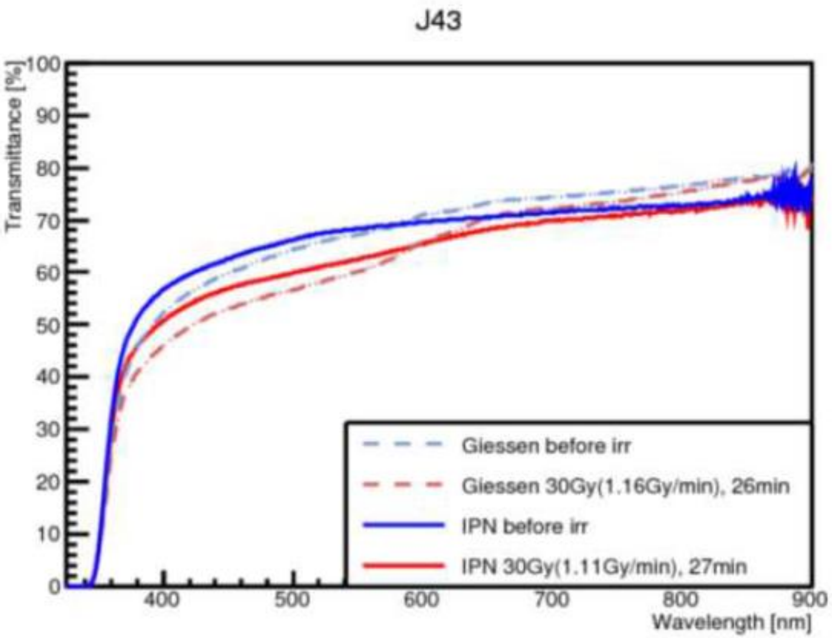
Geant4 simulation, cross-checked with RadCon estimates

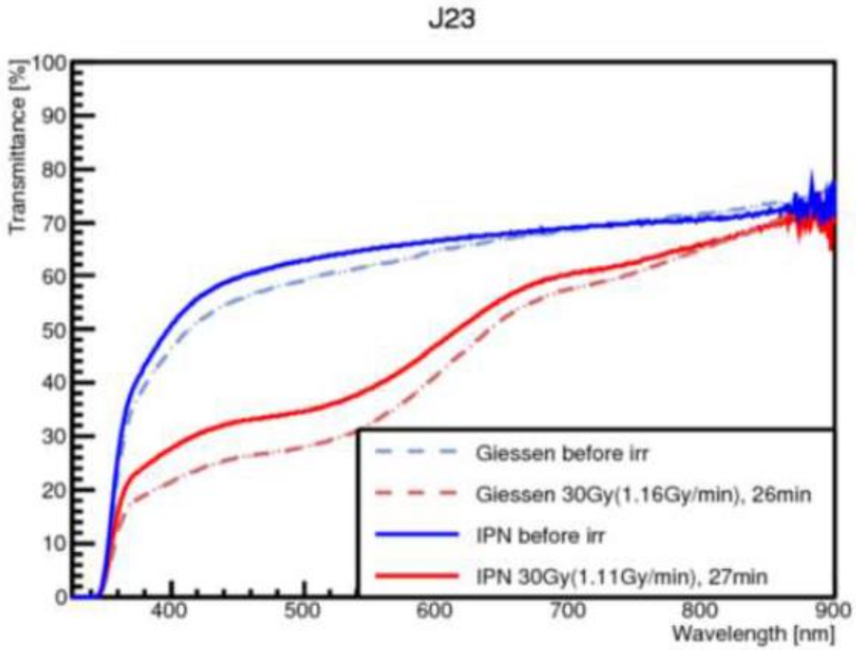
Irradiation and curing tests

Radiation hardness measurements

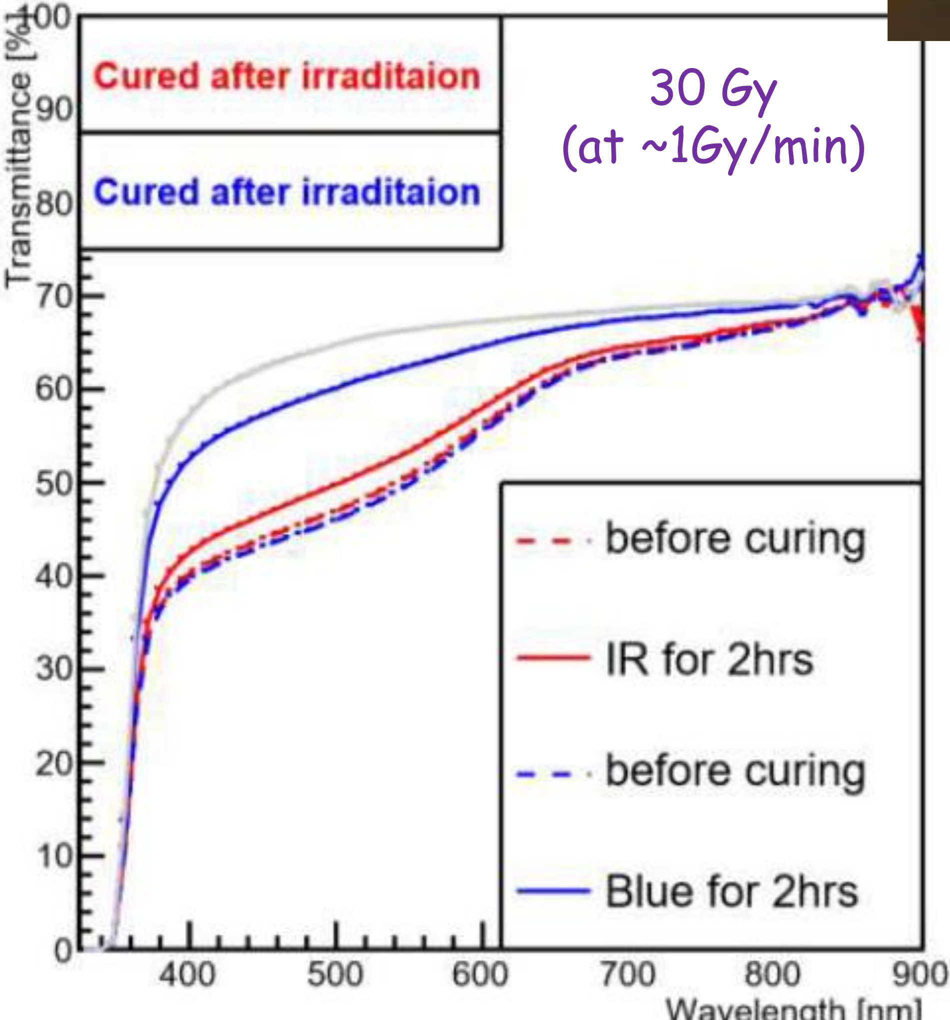








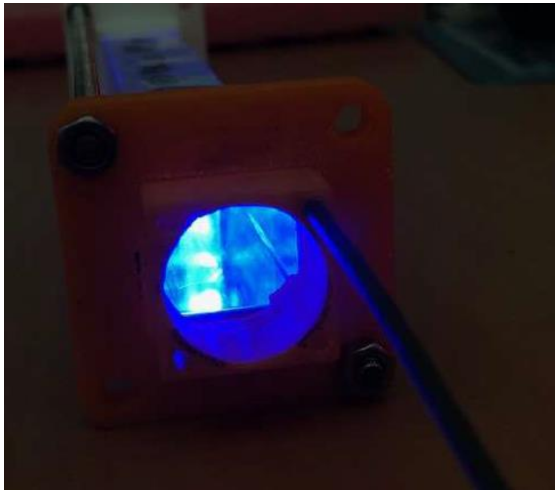
Irradiation and curing tests



30 Gy
(at ~1Gy/min)

Radiation damage recovered with a few hours of blue light curing

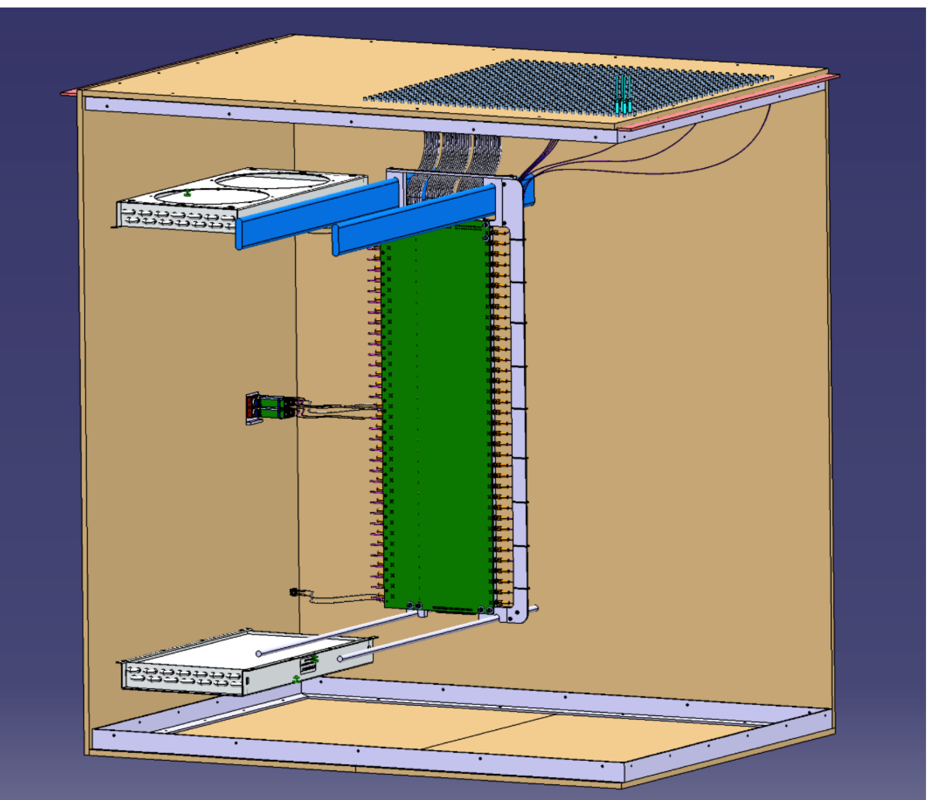
Blue LED optical bleaching



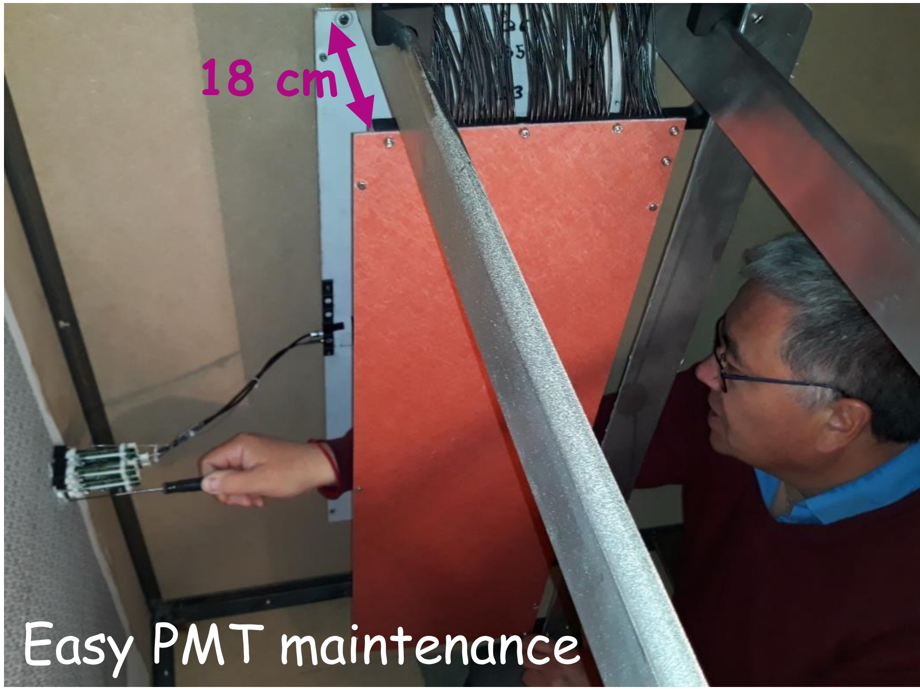
Full scale mock-up of NPS frame

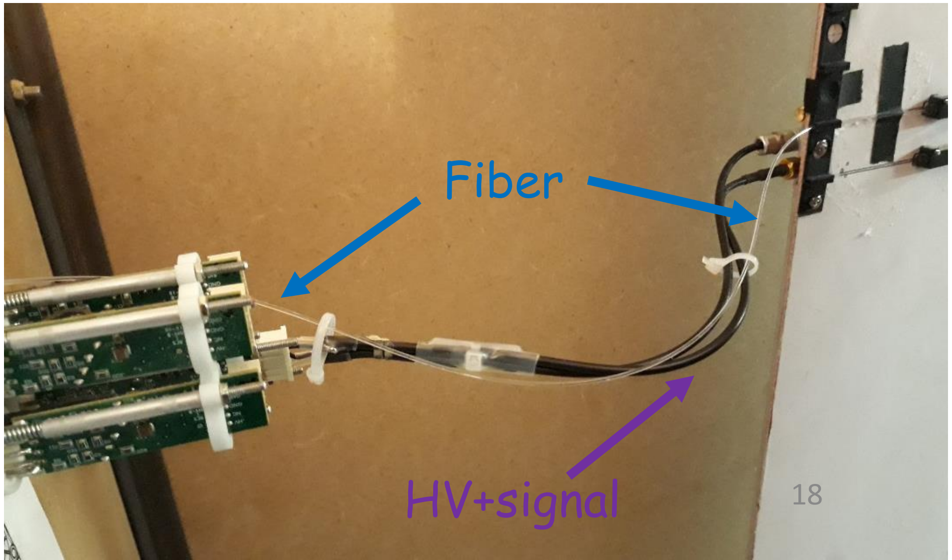
Cable lengths defined:

- 32 cm PMT->PCB (HV+signal)
- Signal PCB-> top of box: 0.5-1.5 m

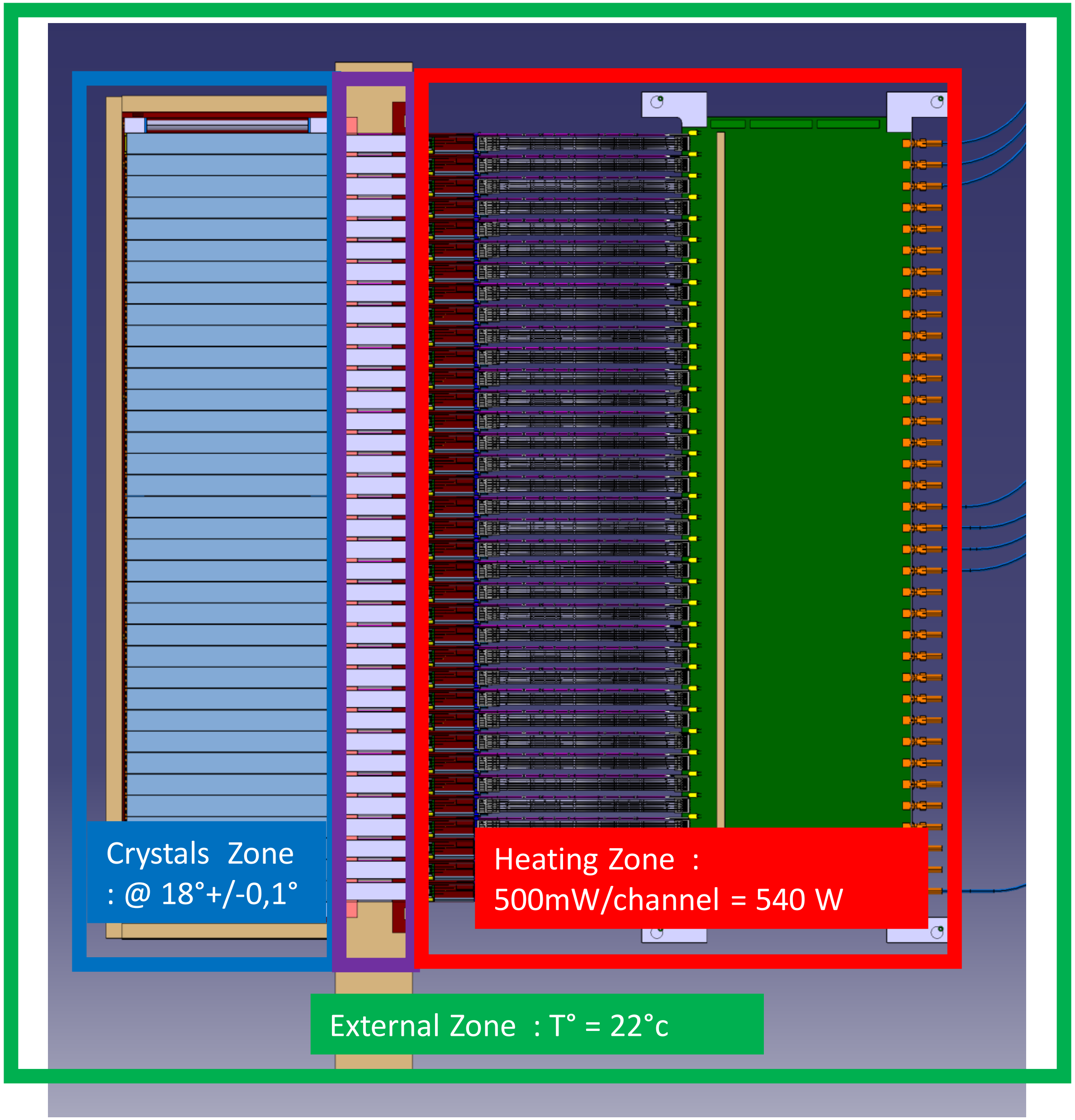


Full scale mock-up of NPS frame

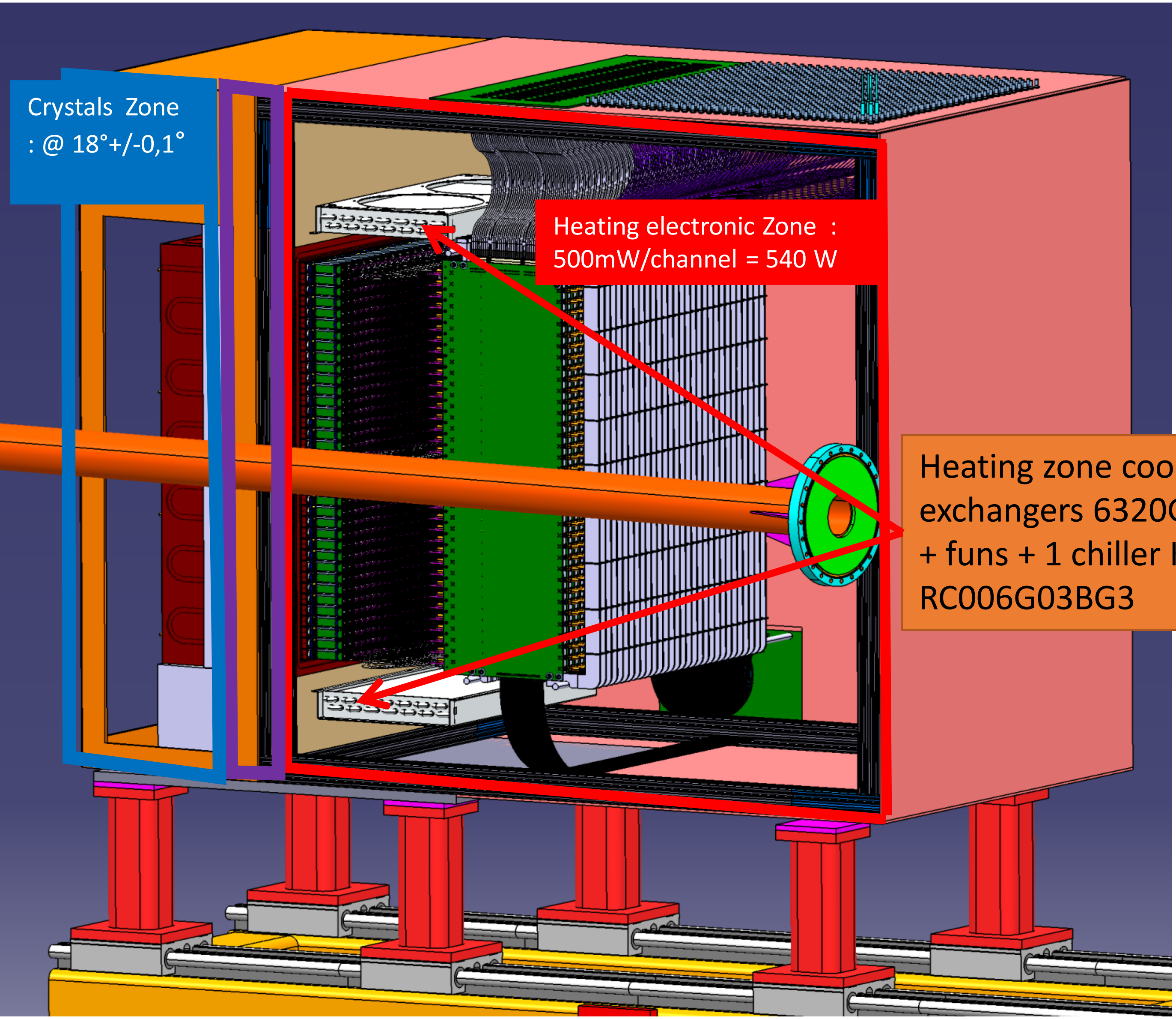




Temperature zones



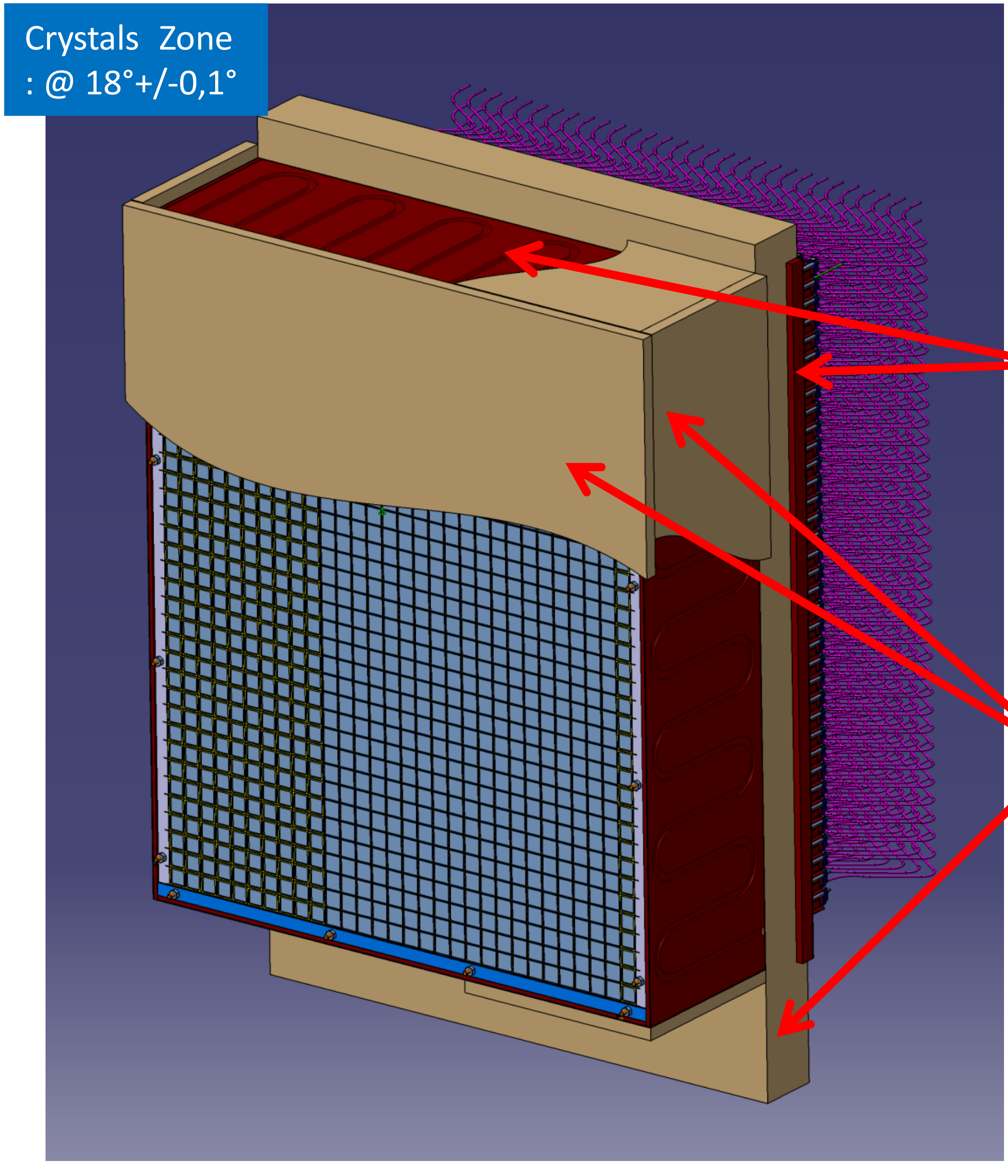
Temperature control: back side



Heat exchangers & chiller procured

- Same manufacturer than the ones used for HyCal
- Higher heat load specification

Temperature control: crystals



4 copper plates around + 1 intermediate copper plate + 1 other chiller (cooling separated from backward zone)

Foam : thermal insulator

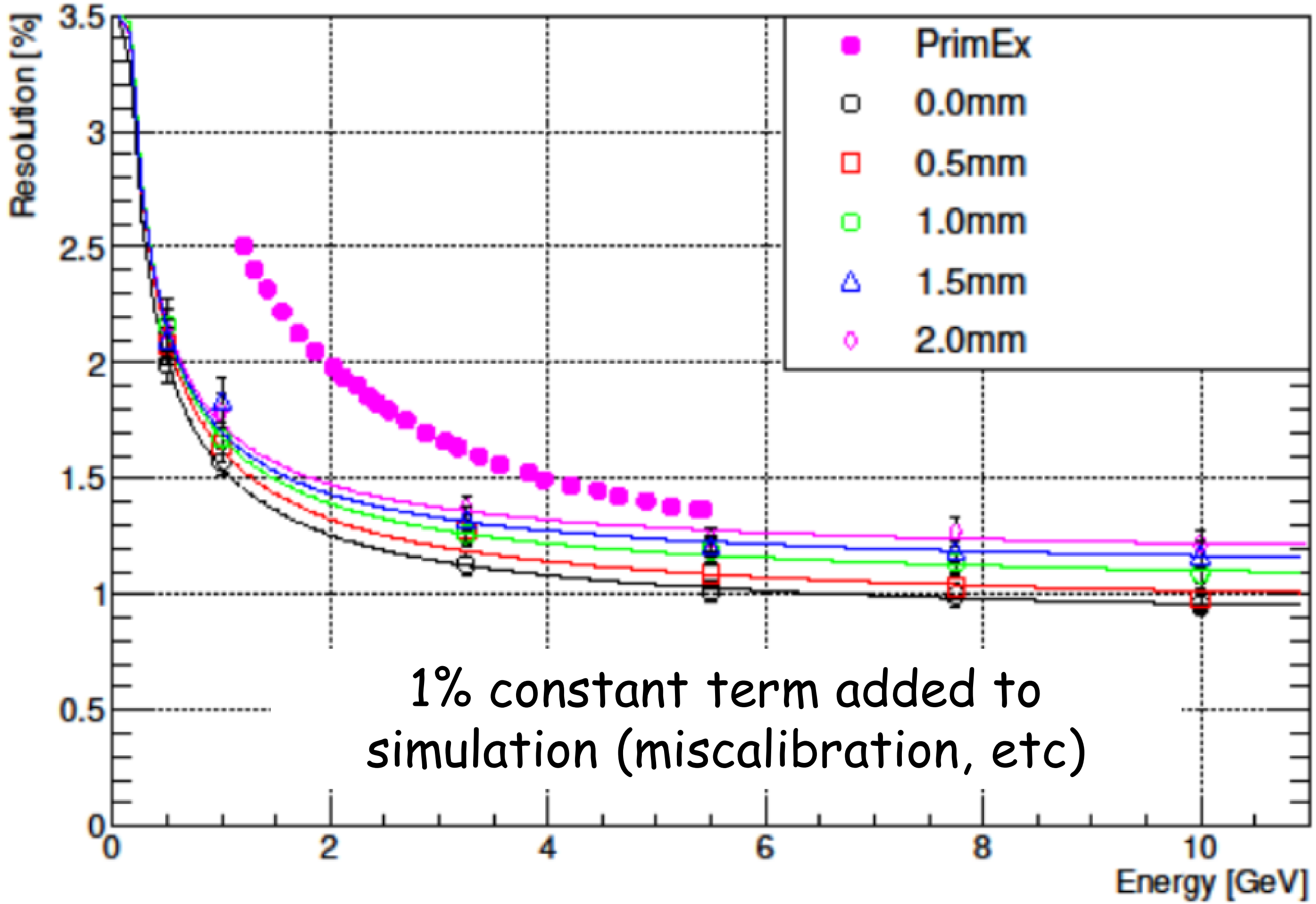
Summary

- ✓ NPS calorimeter construction in progress:
  - All crystals and PMT/bases will be onsite by Summer 2020
  - Calorimeter frame components will be shipped (from Orsay) early 2020
  - Assembly (+tests) at JLab can start from September 2020

- ✓ No show-stoppers anticipated

Back-up

Gap between the crystal : Air

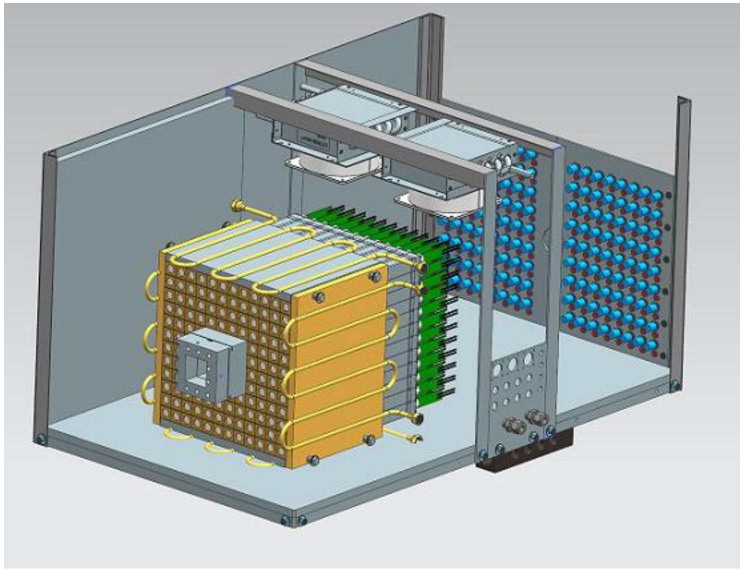


Beam Test of the Calorimeter Prototype

Installed in the experimental Hall D. Used to detect Compton events in the PrimEx D experiment

- successfully operated during PrimEx D production run in the Spring of 2019

- Array of 12x12 $PbWO_4$ crystals
- Beam hole: 2 x 2 crystals
- Tungsten absorber covers the inner most layer (taken from HyCal)
- Water cooling (minimum 5° C), nitrogen purge
- LED-based gain monitoring system
- Positioned on X-Y movable platform

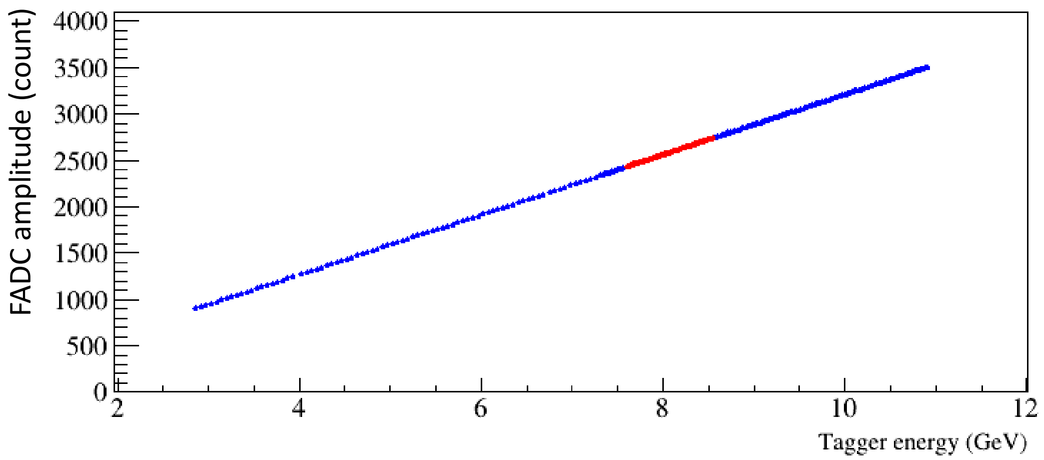


Calibration

- Move each calorimeter module to the photon beam
  - Calibration runs at small luminosity (rate in the module 30 kHz at 30 MeV threshold)

- Use beam energy provided by the Hall D tagger counters to equalize gains

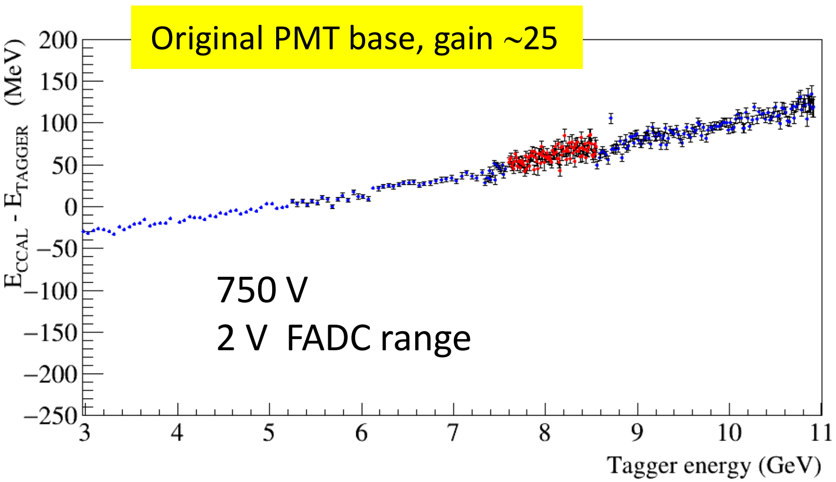
FADC amplitude as a function of the beam energy

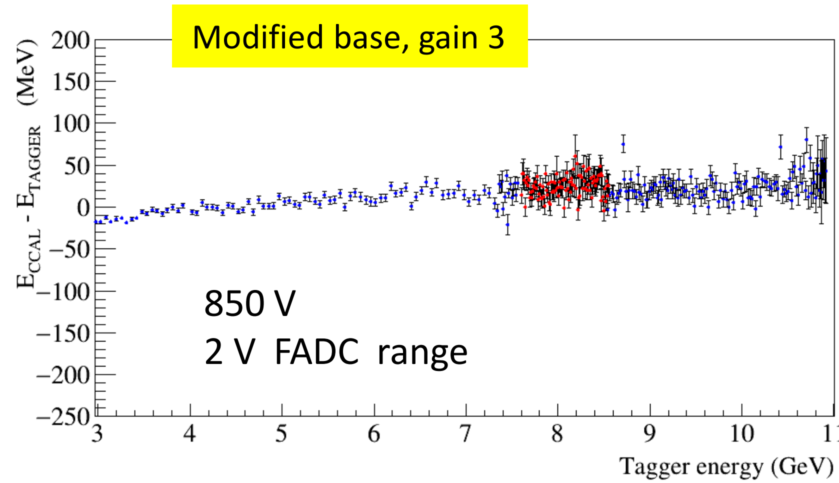


10 GeV :	3200 FADC channels
FADC range:	2 V (maximum range)
Typical HV:	700 – 750 V

Linearity

Linearity of the FADC peak amplitude





- Some non-linearities on the level of 2 – 3 % in the calorimeter response were observed for the original PMT base for both the peak amplitude and pulse integral

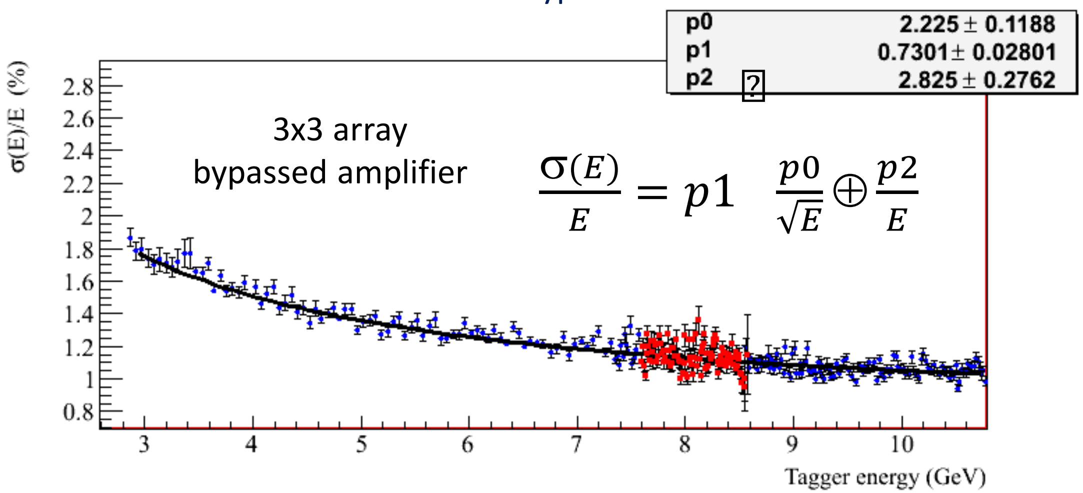
  - PMT was operated at relatively small HV, recommended HV is about 1 kV

- The linearity can be improved by reducing the amplifier gain and increasing HV. Some tuning of the PMT base may be required

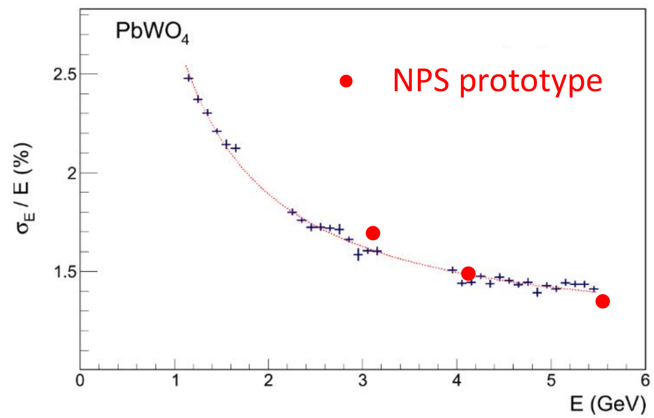
Energy Resolution

This plot will be updated

NPS Prototype



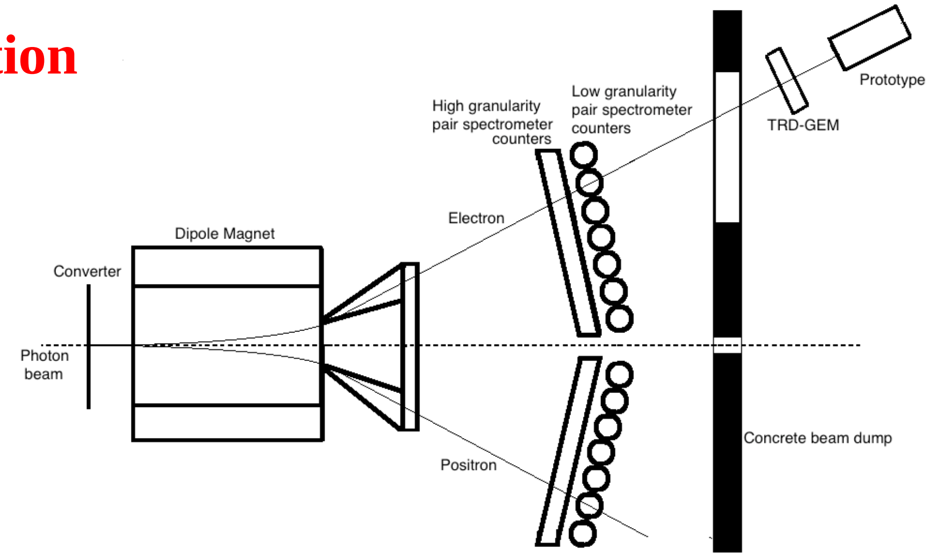
HyCal (Hall B)

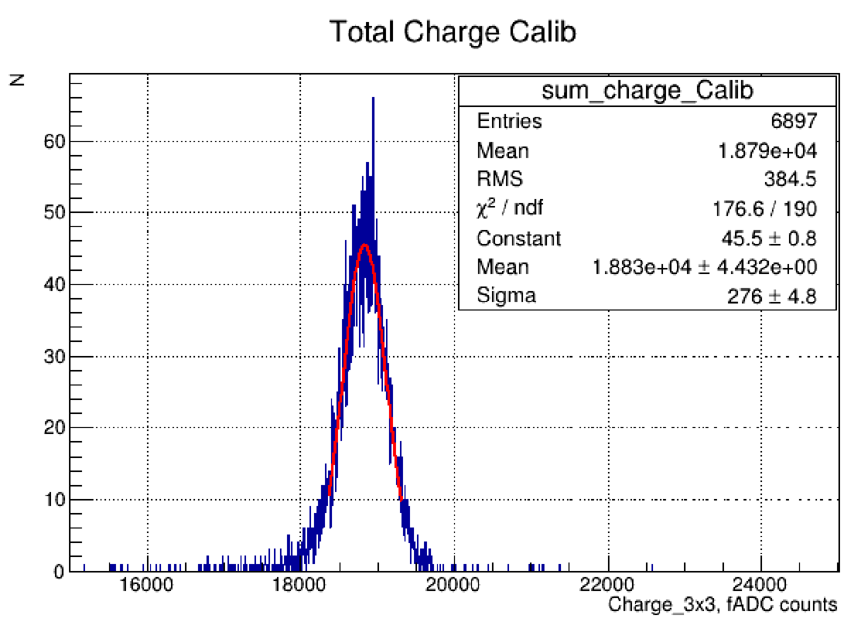


Relatively good energy resolution, which is consistent with the resolution of the Hall B HyCal calorimeter (which was constructed using SICCAS crystals)

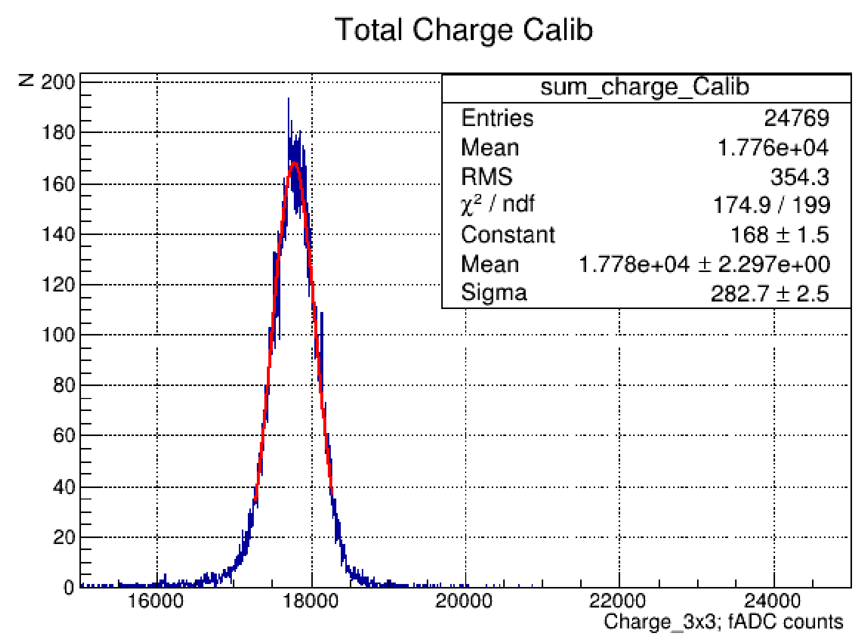
More details can be found in
GlueX-doc-3590, GlueX-doc-3998, V. Berdnikov, A.Somov, J. Crafts

Energy Resolution





3x3 SICCAS crystals



3x3 CRYTUR crystals