KLOE to SAND Progress Report

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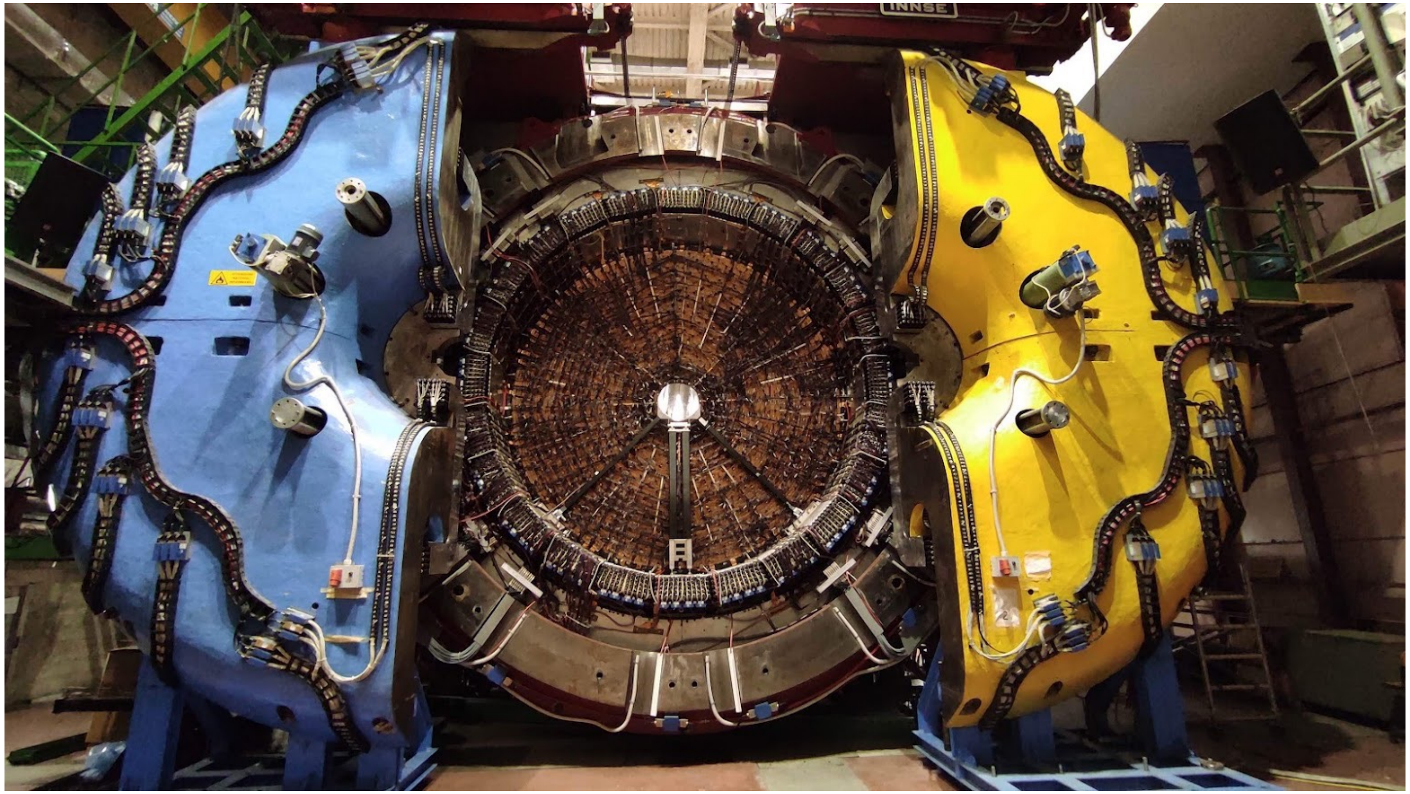
and INFN-Roma, Italy

on behalf of the SAND-ECAL and SAND-Magnet WGs



DUNE Collaboration Meeting – CERN – 23 January 2024

The SAND-ECAL working group

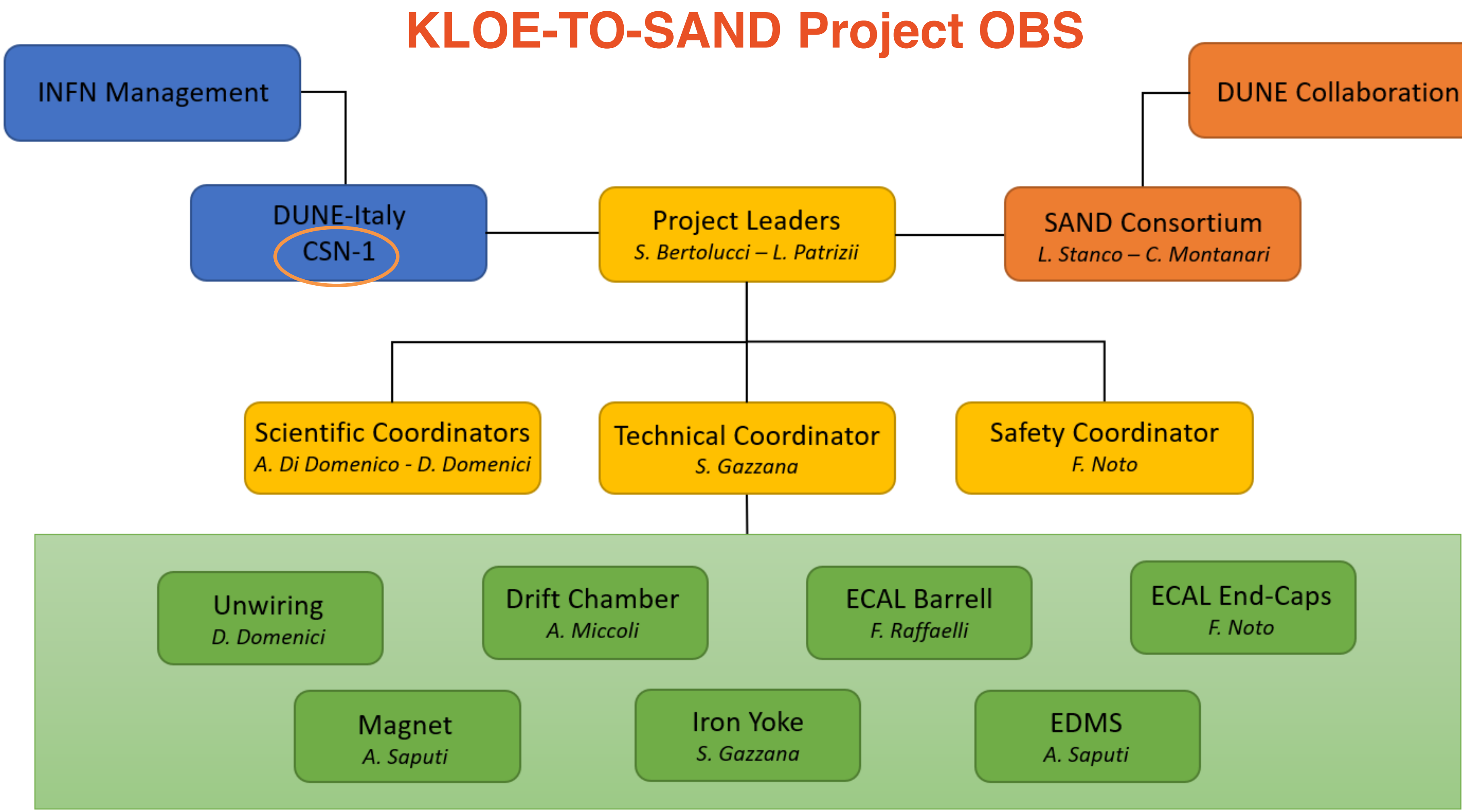
- Activities related to the extraction of the electromagnetic calorimeter (ECAL) from KLOE detector, ECAL refurbishment, transportation to FNAL, installation and commissioning at the DUNE ND cavern.
- In general, the activities at LNF of the whole KLOE-to-SAND project are followed and discussed inside the ECAL WG, including the SAND/MAGNET WG activities due to the high correlation of operation and planning of the two WGs.

- WG chairs: A. Di Domenico, D. Domenici

- Dedicated mailing list DUNE-ND-SAND-ECAL@LISTSERV.FNAL.GOV
- Regular weekly meeting every Monday 2:15 PM (CET) – 7:15 AM (CT)

- Material presented and discussed during WG meeting available on Indico:
  https://agenda.infn.it/category/1684/ (from 7-FEB to 26-APR-2022)
  https://indico.fnal.gov/category/1413/ (since 2-MAY-2022)

KLOE-to-SAND: dismounting of KLOE



KLOE-to-SAND activities at LNF

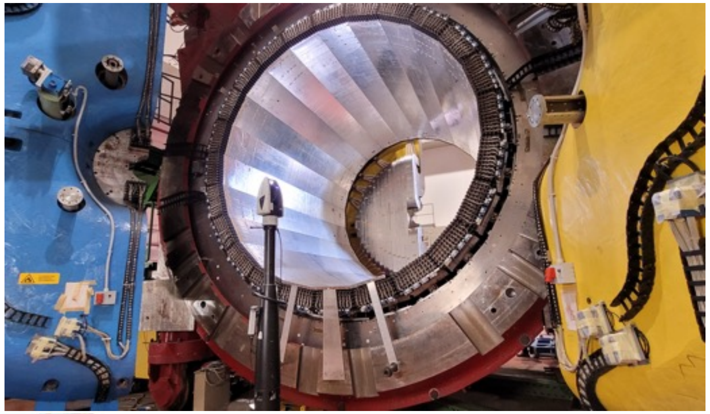
Plan of operations:

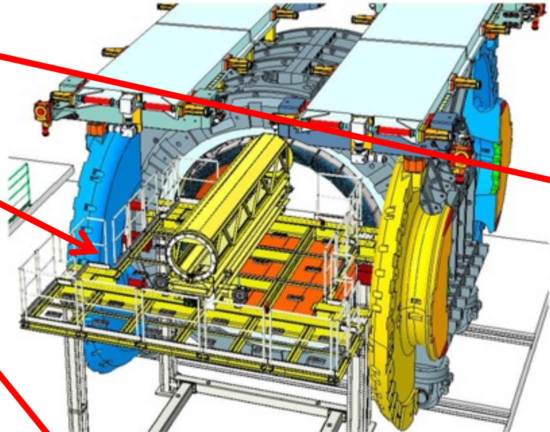
✓ Removal of all cables and the FEE+HV racks
✓ Extraction of the Drift Chamber

Calorimeter

✓ Laser tracker survey before ECAL dismounting

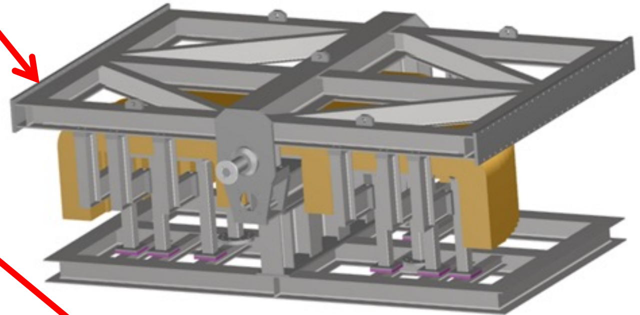
- Extraction of Barrel (24 modules)
  - original insertion/extraction machine completely refurbished and operational
  - platform construction is being completed
- Dismounting of EndCaps
  - original insertion/extraction/rotation machine is being refurbished and modified
- Operational test of ECAL modules
- Studies for the ECAL working point & FEE





Magnet and Yoke

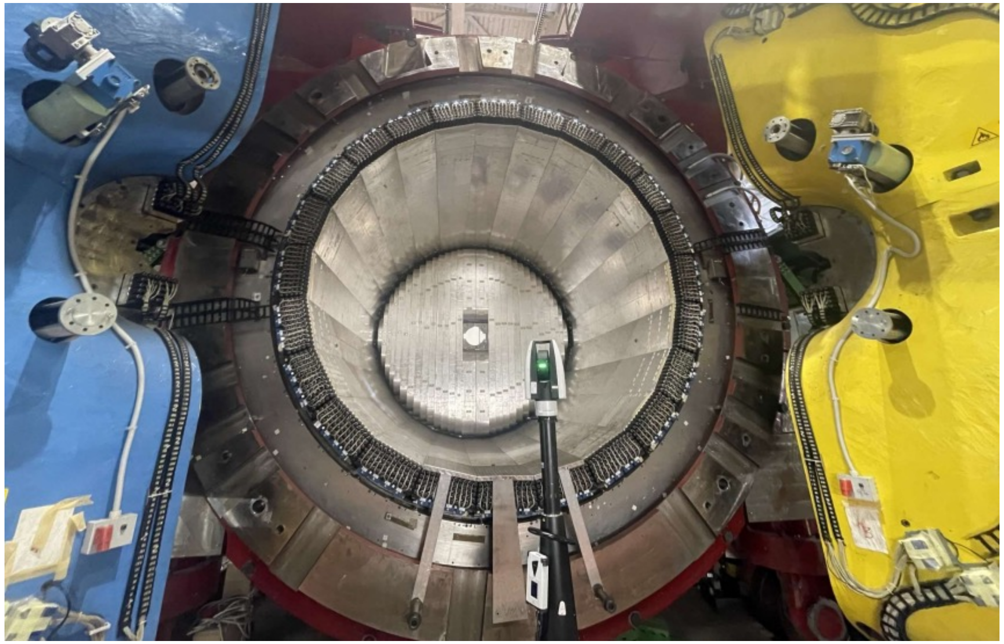
- Installation of new Power Supply
  - new Power supply is being purchased (CAENels)
  - Power Electronics is being revamped (OCEM)
  - Control system and full support for magnet test/ dismount/remount by ANSALDO ASG
- Cooling of coil
- Operational test of magnet
  - in preparation
- Extraction of coil
- Dismounting of Iron Yoke



Packaging & Shipping at Fermilab

ECAL geometry survey

Survey performed by a specialized company: HEXAGON METROLOGY GEATOP Metrology & Survey



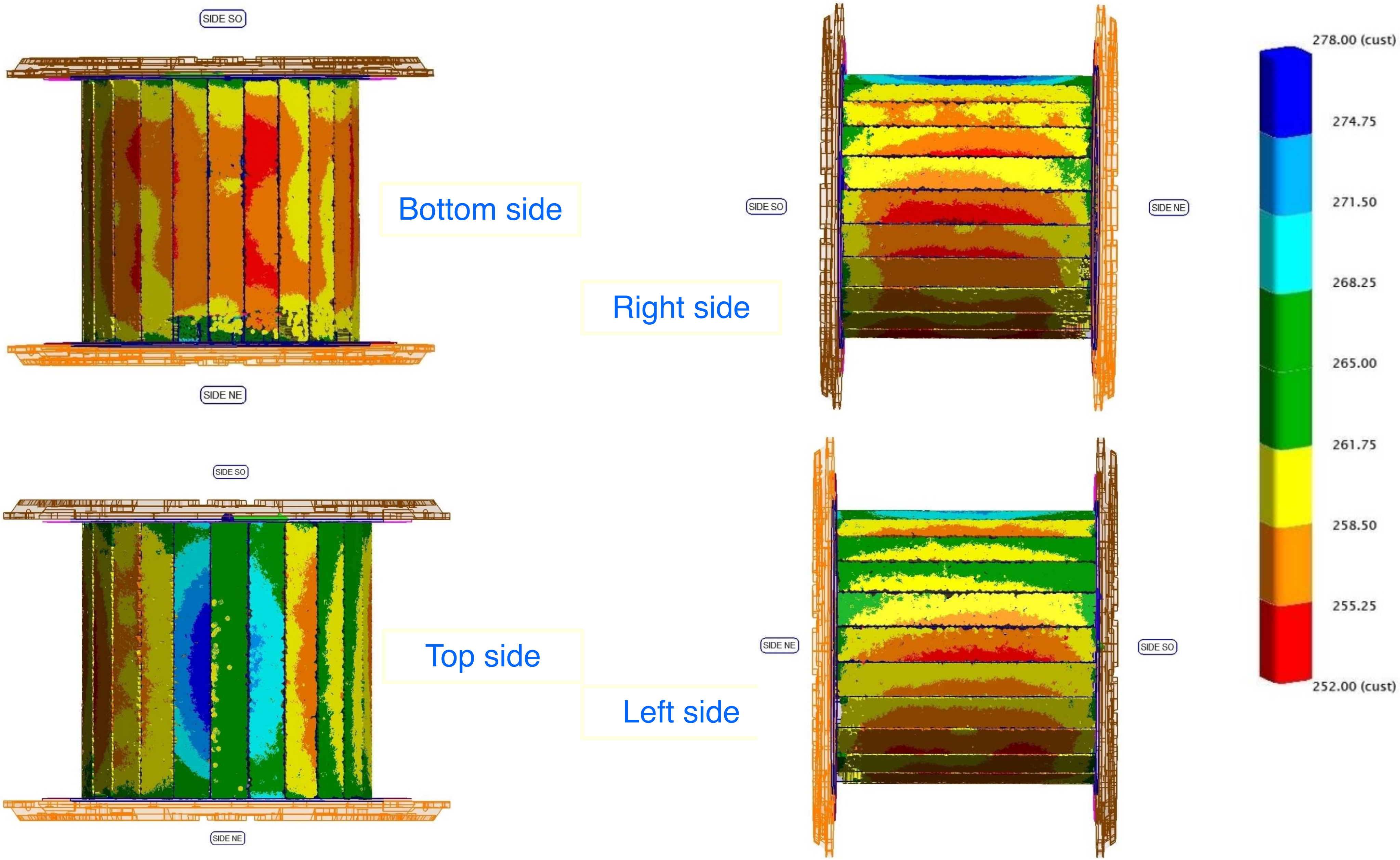
Measured distance between:

Cloud of points (10x10 mm^2 pitch matrix) measured on the ECAL internal surface

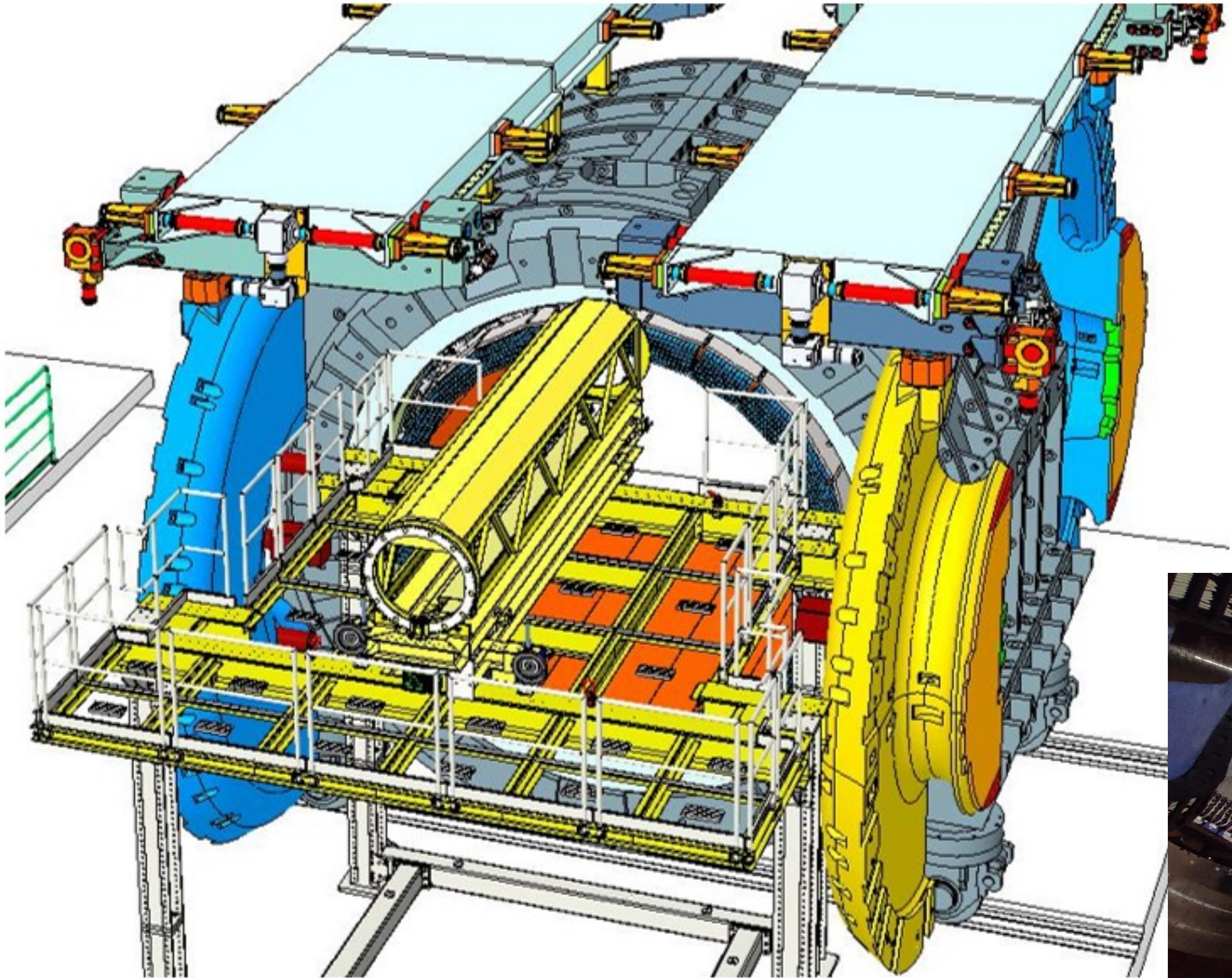
Bottom plane reconstructed by accessible points on the Aluminum backplane at both module ends

Nominal value should be 230 mm (Pb+SciFi height)+ 25 mm Al plate thickness = 255 mm

ECAL geometry survey

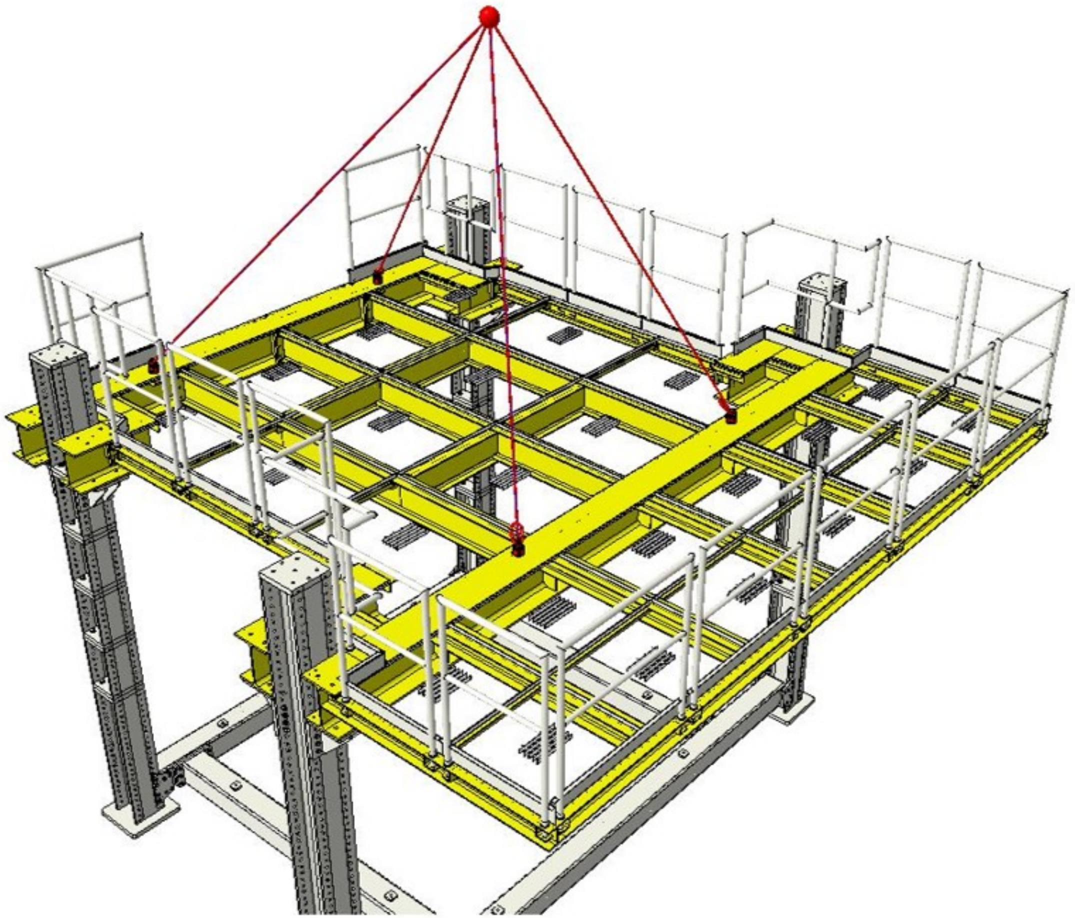


Extraction of barrel modules: movable platform



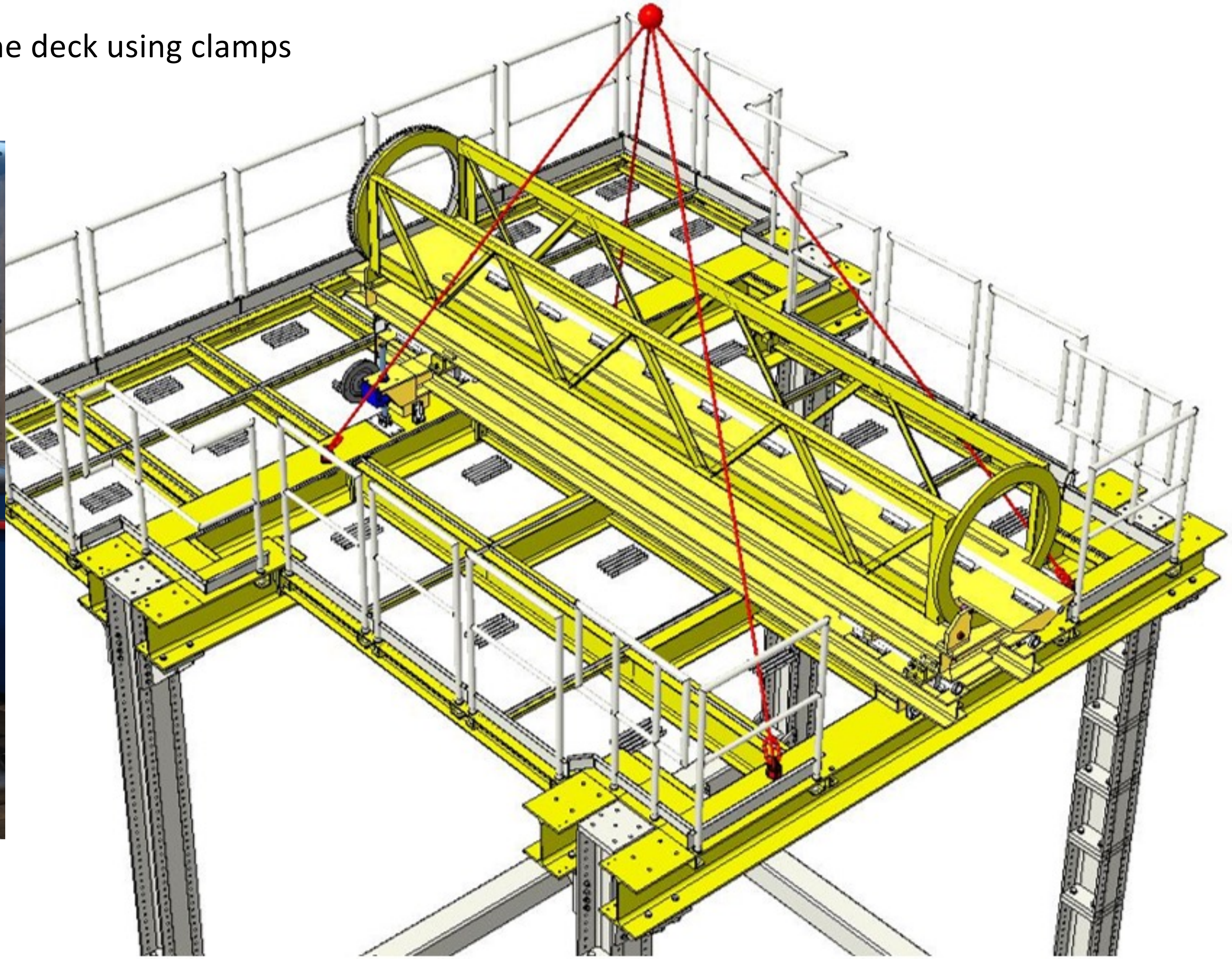
Extraction tool fully revamped, tested, and ready

Extraction of barrel modules: movable platform



Extraction of barrel modules: movable platform

The extraction tooling is restrained to the deck using clamps



Extraction of barrel modules: movable platform

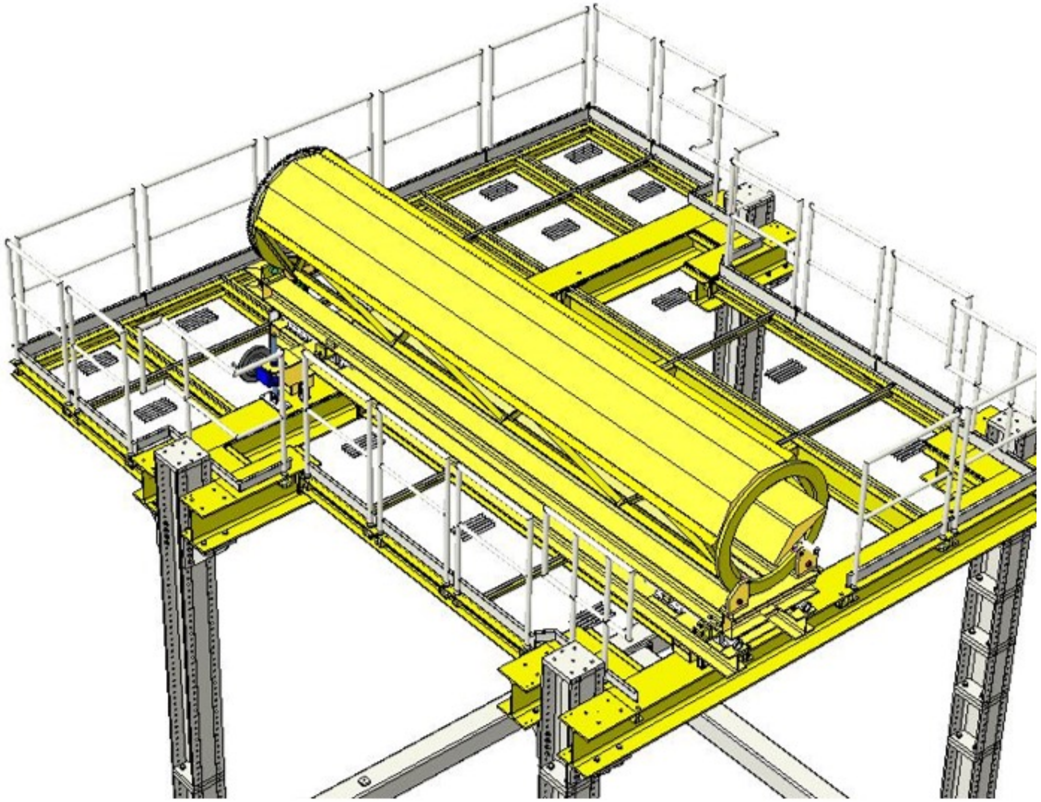


Figure 11 Removal of module 5.

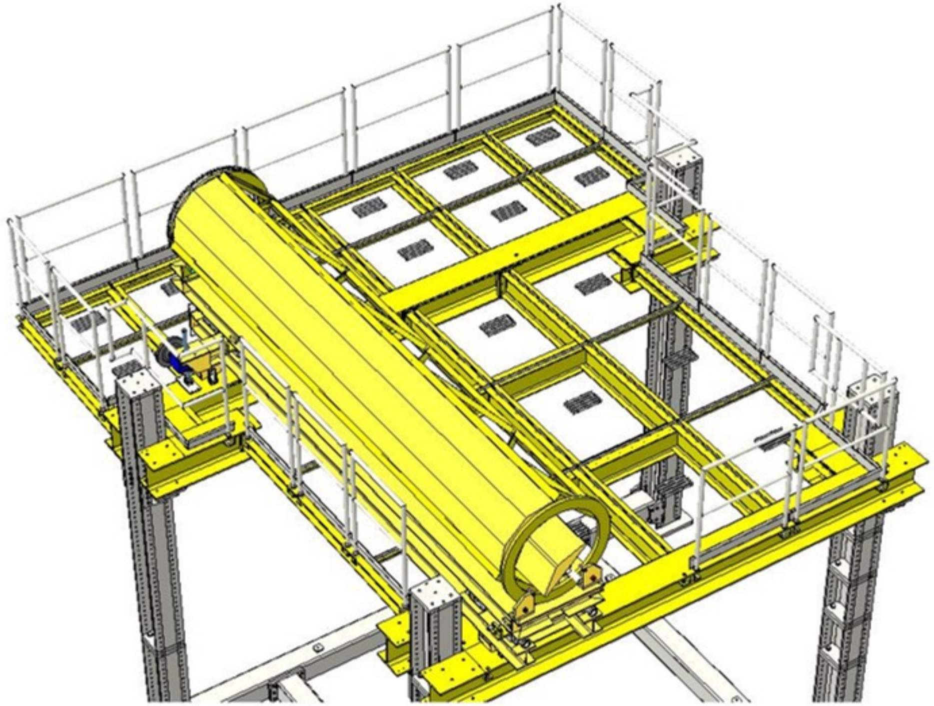


Figure 12 Removal of calorimeter module 4.

Extraction of barrel modules: movable platform

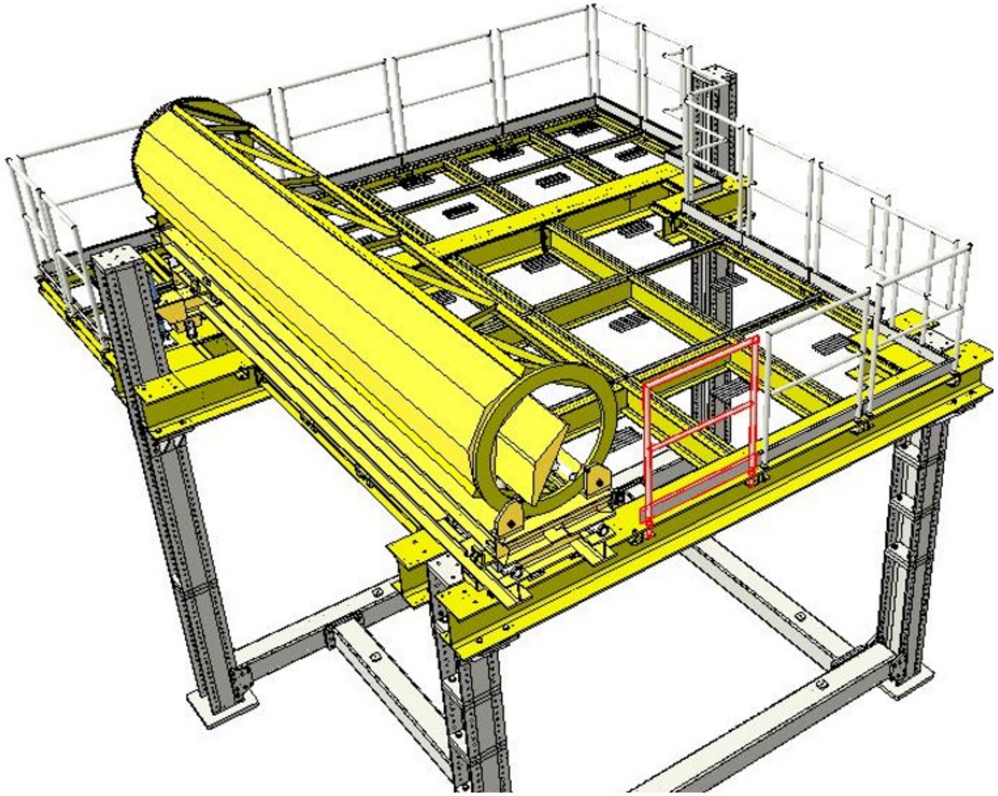


Figure 14 Removal of calorimeter module 3.

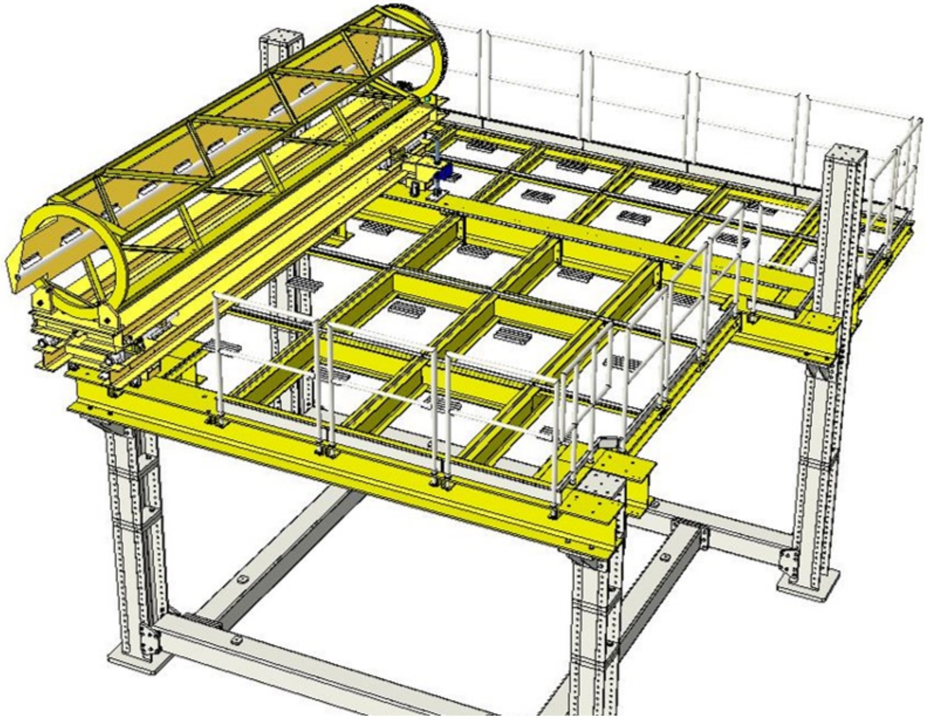


Figure 15 Removal of calorimeter module 2.

Extraction of barrel modules: movable platform

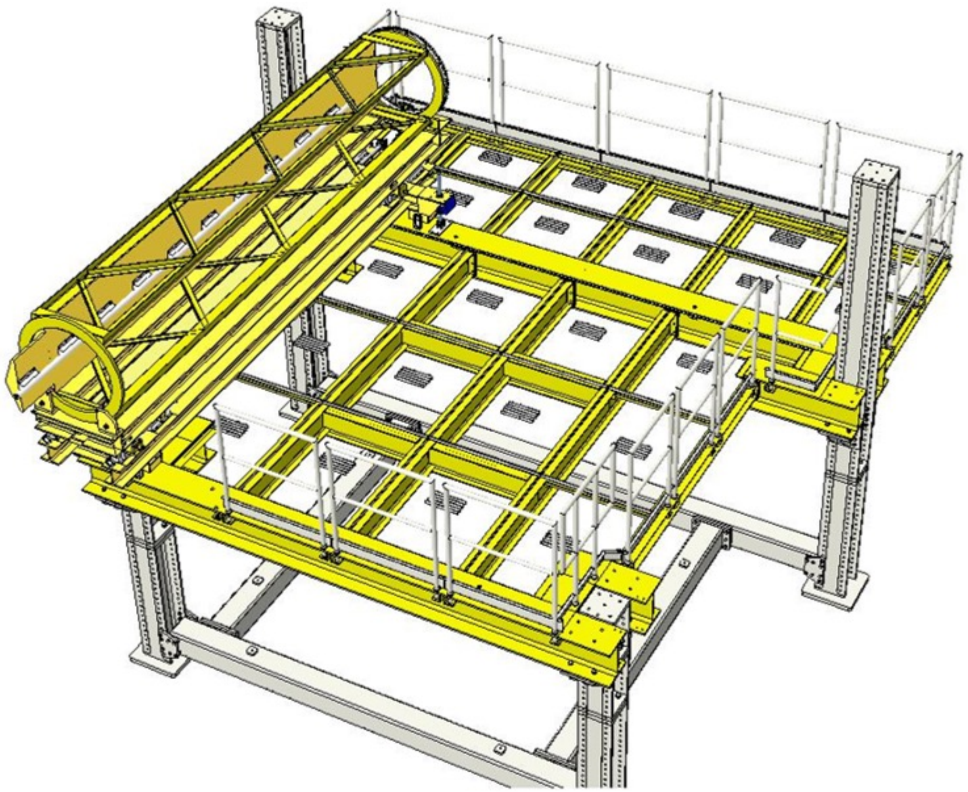


Figure 16 Removal of calorimeter module 1 at level 2458 mm.

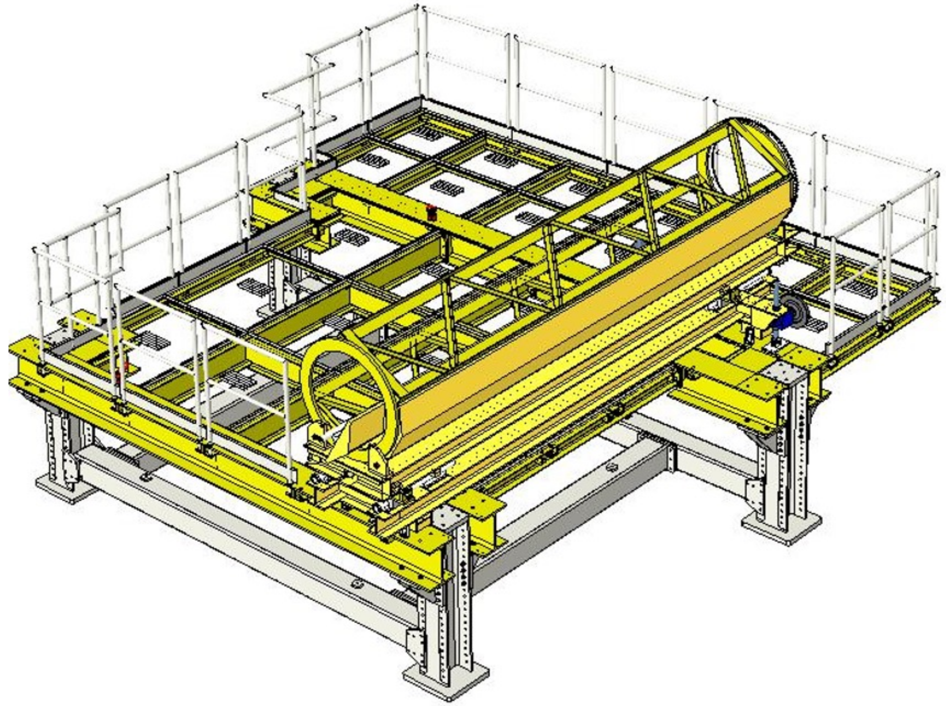


Figure 17 Removal of module 15 at level 1468 mm.

Extraction of barrel modules: movable platform

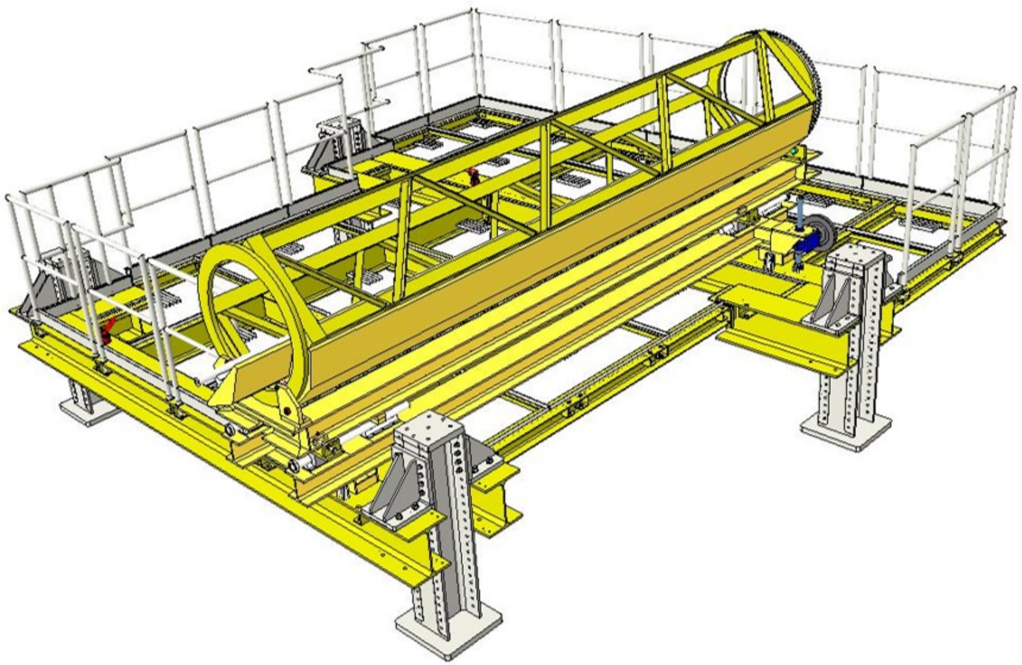
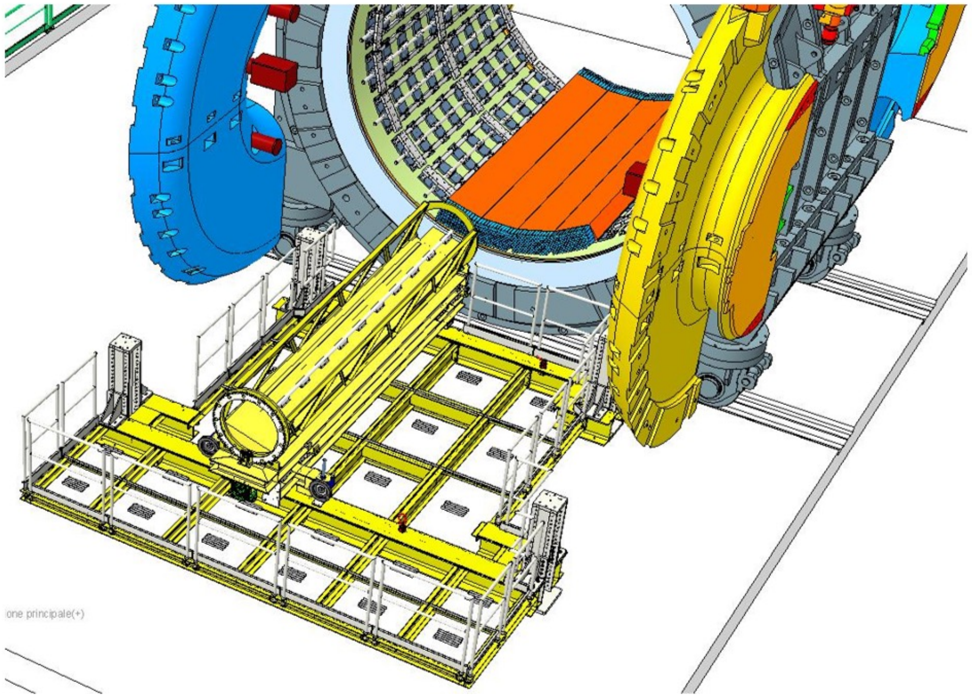


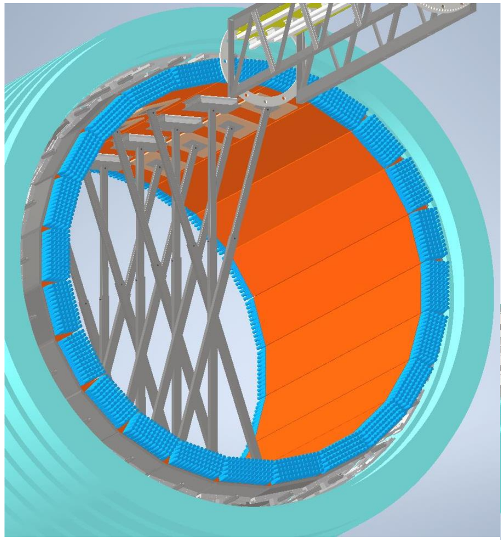
Figure 18 Setup to extract module16 at level 1038 mm.

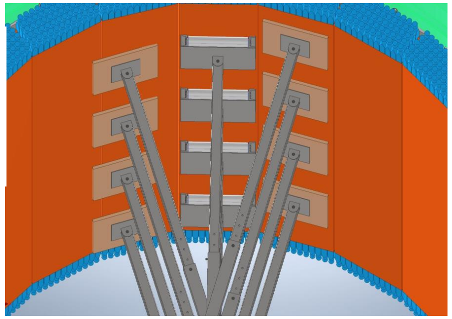


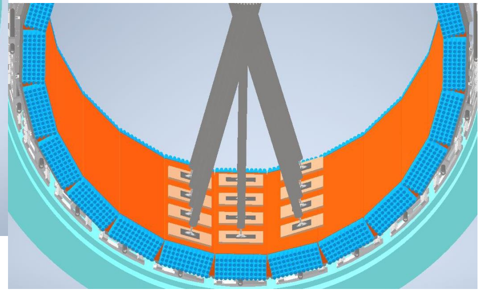
Extraction of barrel modules: movable platform

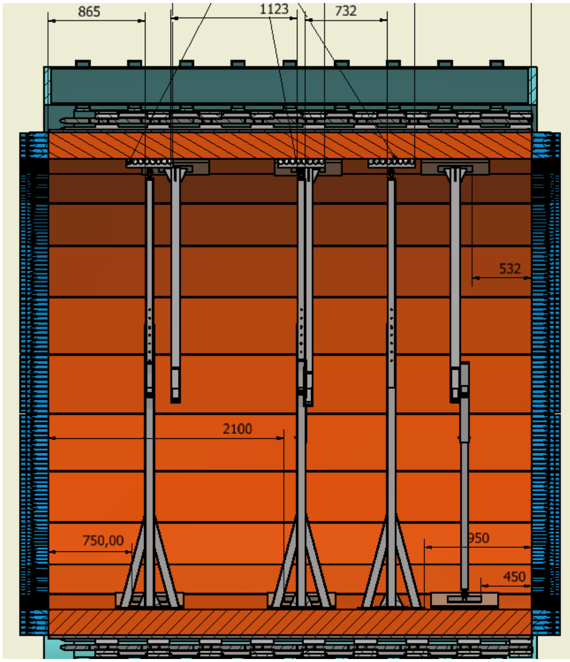
All platform pieces have been built (soldering, milling, cleaning, painting etc.. completed) by Fantini Sud company (Anagni).
Final tests and safety certifications are being completed.
Delivery and installation at LNF in the next 1-2 weeks.

Extraction of barrel modules: rollers and pillars





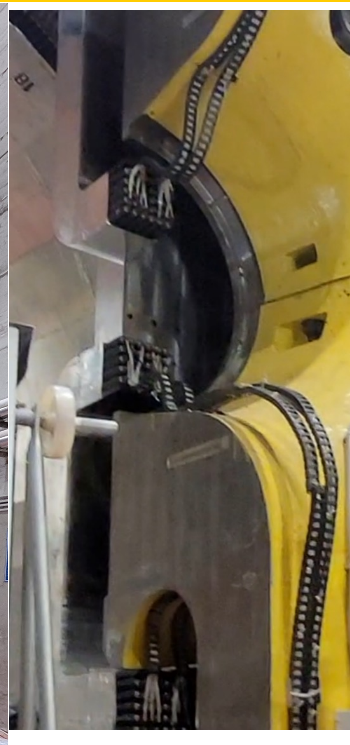




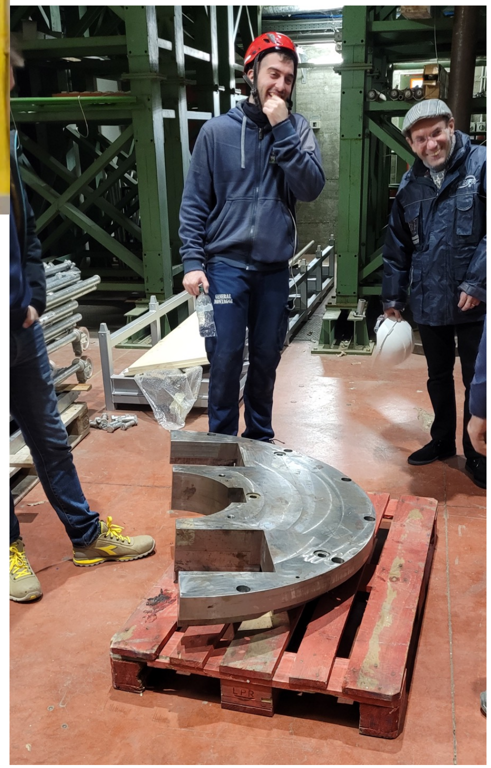
12 rollers mounted on pillars will be placed as a redundant safety support for the extraction of the upper 3 modules.
All pieces built and delivered at LNF, are being tested and mounted in KLOE.

F. Raffaelli – INFN Pisa

Extraction of barrel modules: preparation of End-Caps

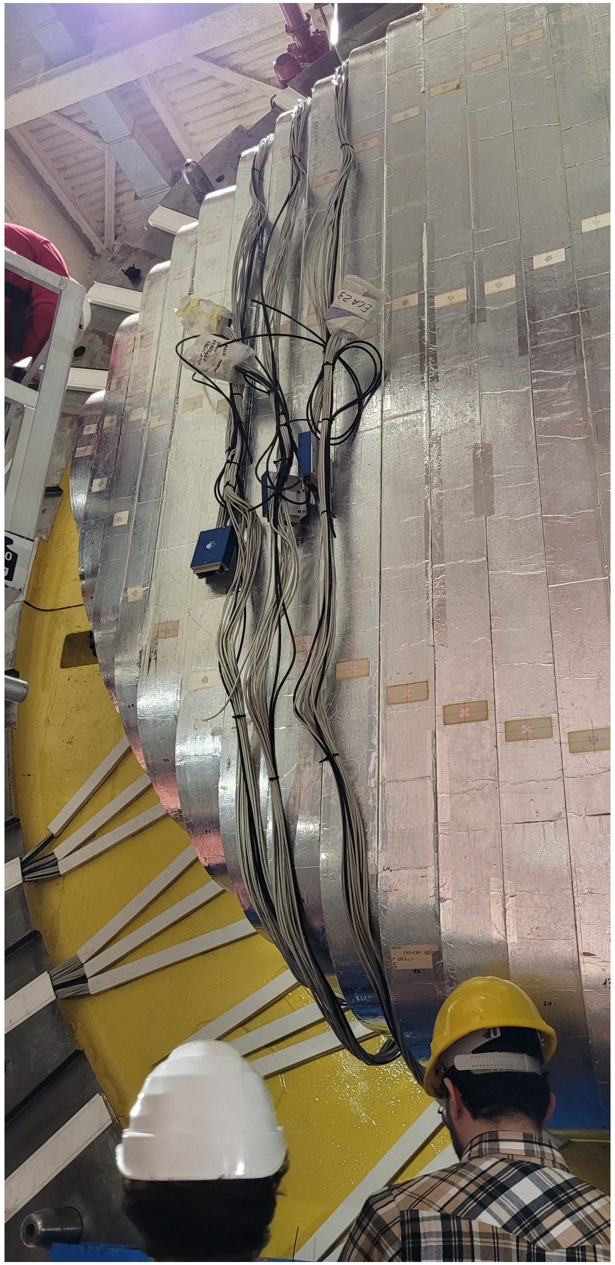


dismounting the iron half plates



Extraction of barrel modules: preparation of End-Caps

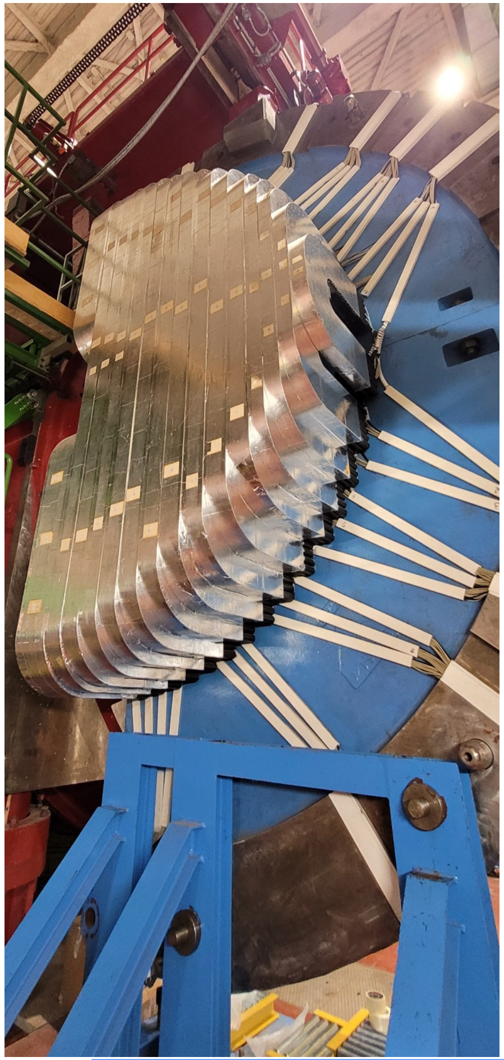
Extraction of barrel modules: preparation of End-Caps



Extraction of barrel modules: preparation of End-Caps

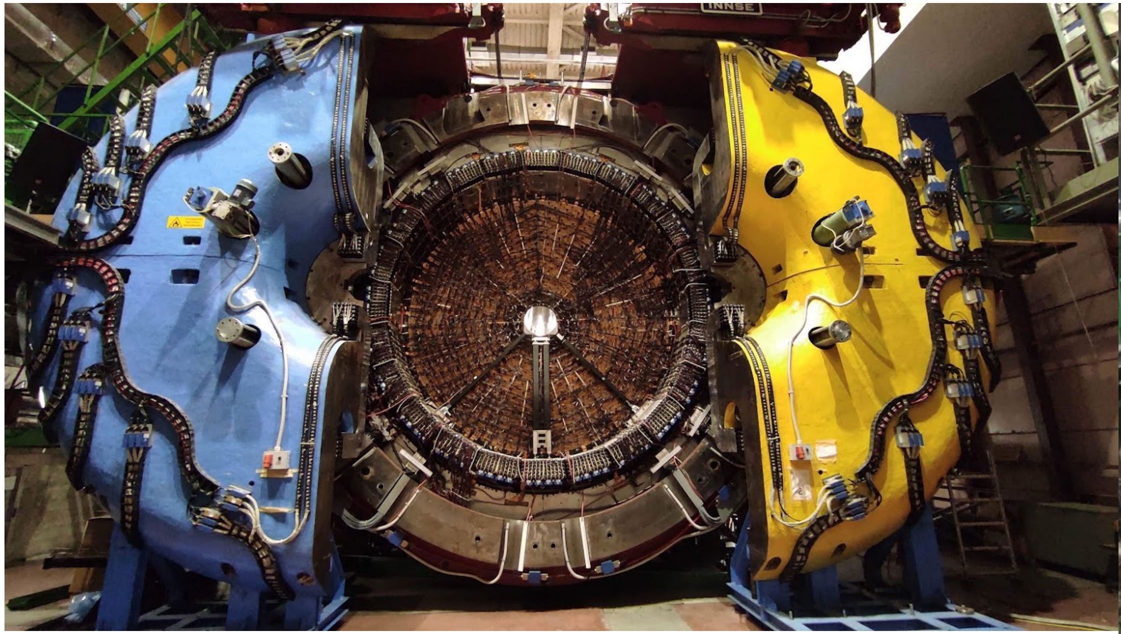
cleaning the End-Cap iron yoke surface and positioning the cables integral with ECAL modules

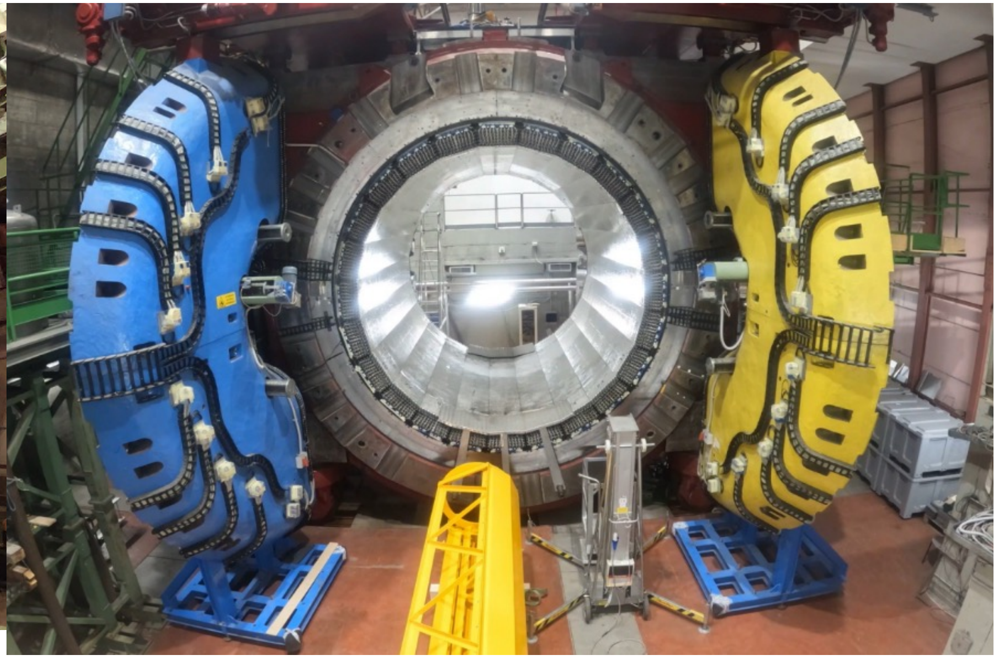
before

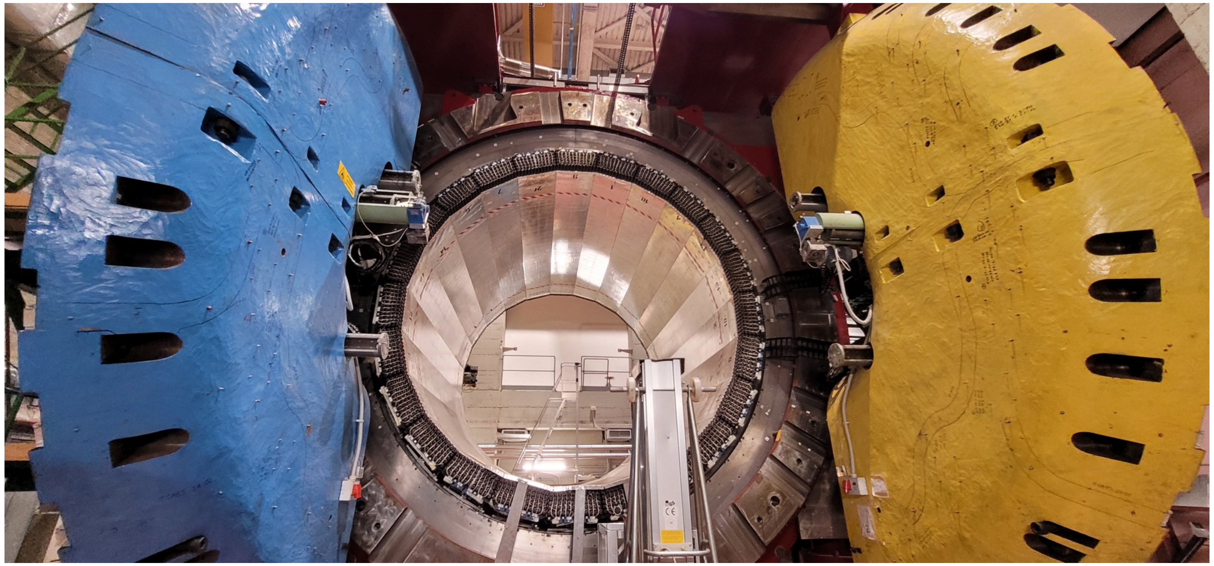


after

Extraction of barrel modules: preparation of End-Caps







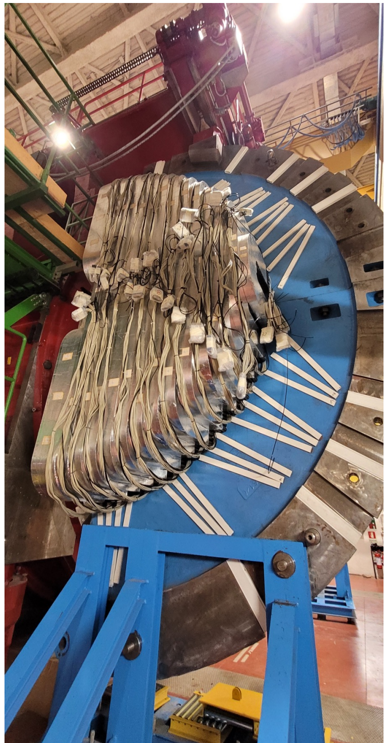
Thanks to LNF technical support and additional technicians from INFN Bologna, Lecce, Pisa, Roma

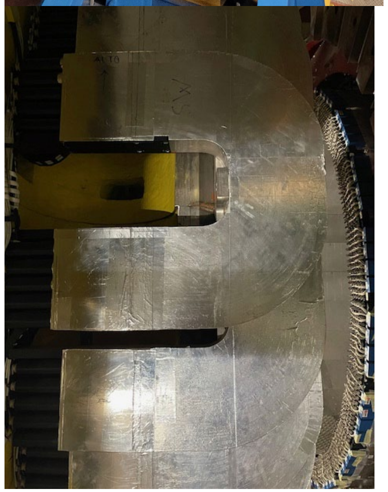
Dismounting of End-cap modules

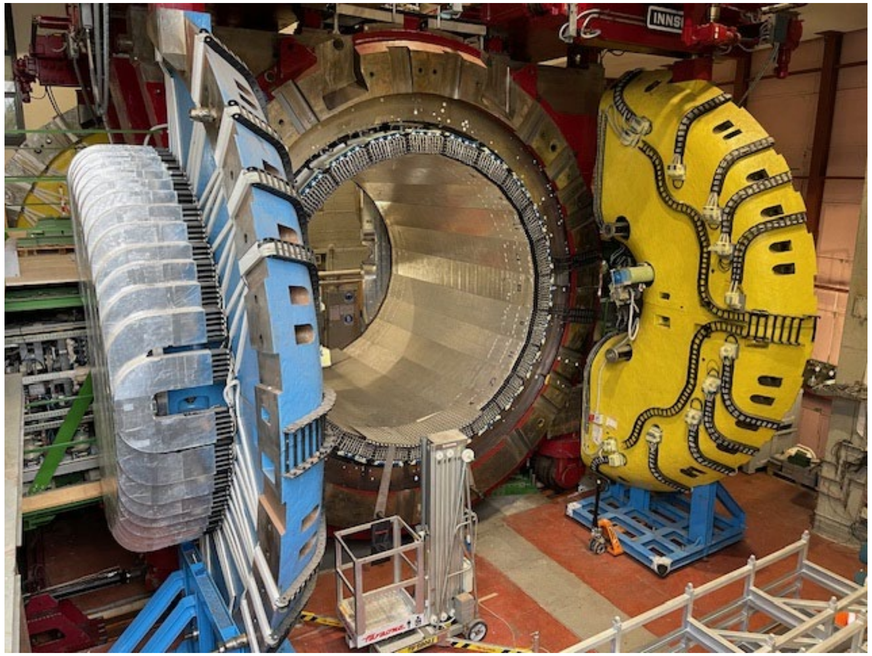
Tools are being revamped (non-destructive structural analysis done), some parts replaced.

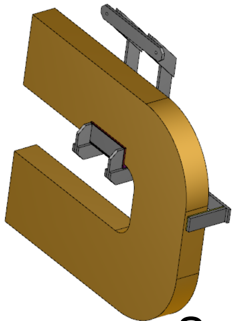
F. Noto – INFN LNS

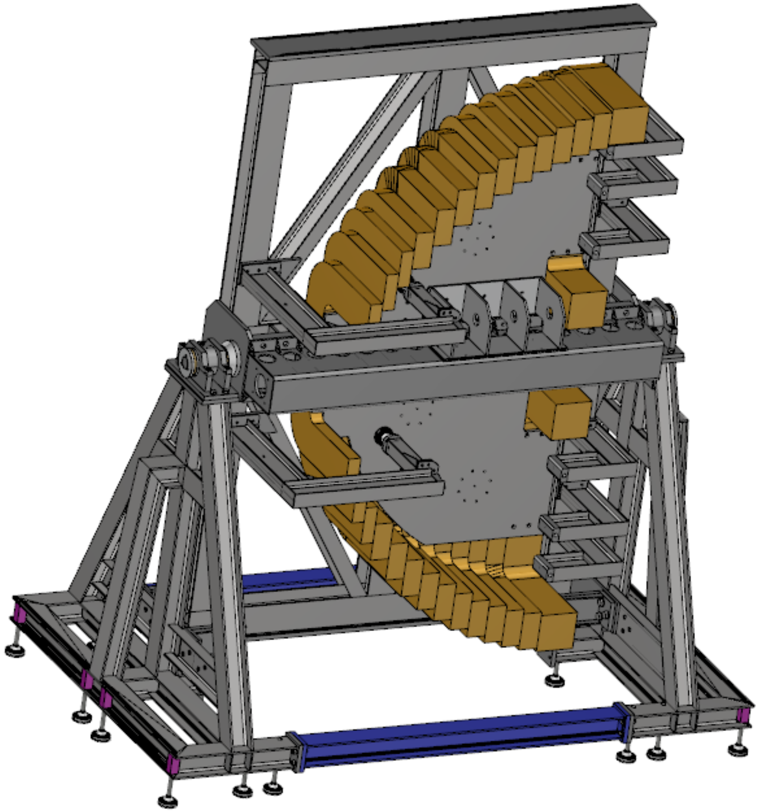
Dismounting of End-cap modules









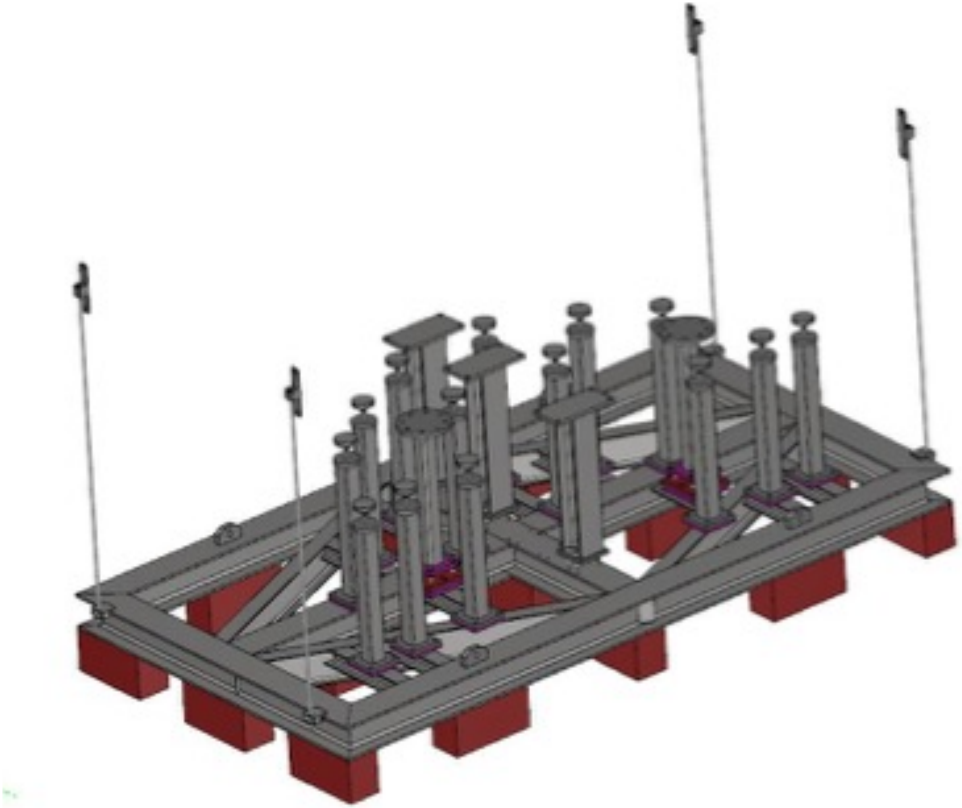


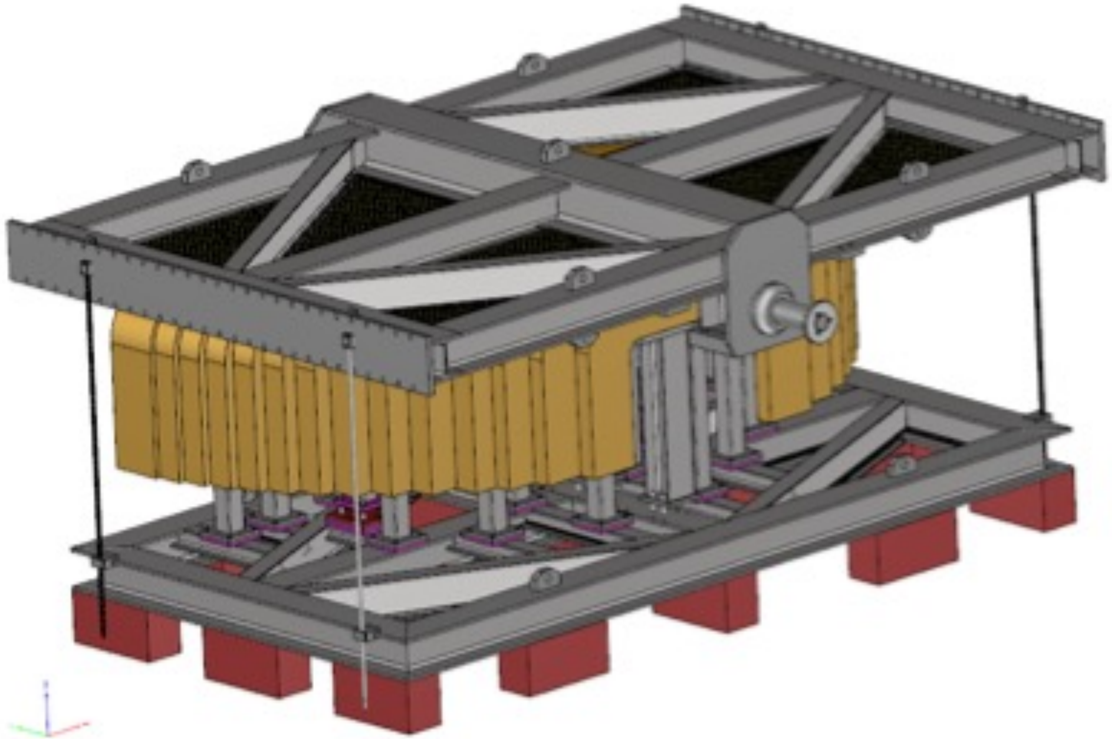
Design of supports for handling and transportation of each half End-cap completed

Special tool for dismounting
the smallest module built and ready.

F. Noto – INFN LNS

Dismounting of End-cap modules





Design of supports for handling and transportation of each half End-cap completed

Order done, construction started.

Dismounting End-Cap modules foreseen by April-May 2024

F. Noto – INFN LNS

ECAL module refurbishment and test

- After dismounting operation, the special protective adesive tape of all barrel modules has to be replaced
- light tightness to be checked
- test basic performance with cosmics rays
- test FEE prototypes

a new area assigned at LNF for ECAL barrel is being prepared:

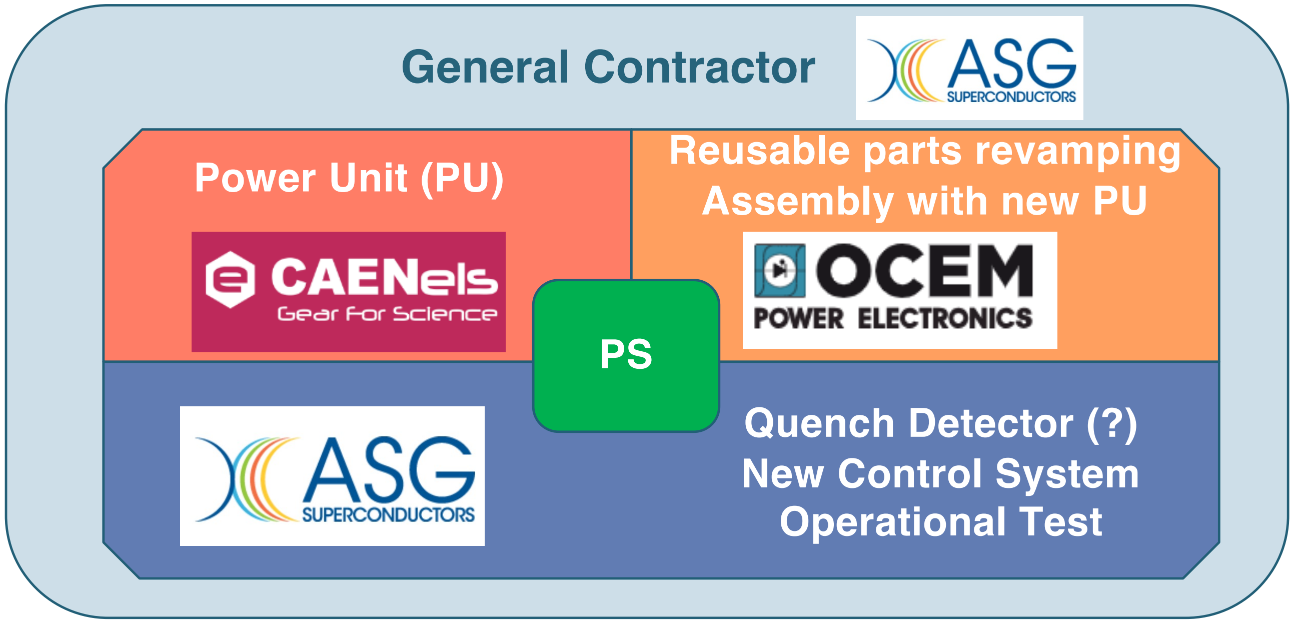
n.5 A8030P boards 48 ch. 3 kV/1 mA
n.1 SY4527B mainframe
n. 1 A2551 board 8 V / 12 A (to be purchsed)

Contribution (shifts) from ad-hoc trained technicians and physicists

MAGNET New Power Supply Procurement

A new Power Supply (PS) is needed, with the same performances of the old one

to save procurement time, avoiding long EU calls for tenders, we are setting the procurement with 3 partners



Possibly still usable:
busbars, contactors, dump resistor, transformers

Obsolete and/or aged components to be replaced:
transistors banks, cooling pipe, water loss, elctrolitic capacitors, electronic boards

Estimated PS delivery time 6 months
Possible delivery of PS in second half of 2024

Possible PS+Magnet Test
End od 2024

MAGNET New Power Supply Procurement

CAENels
Gear For Science

Power Unit on blanket order INFN-CAEN

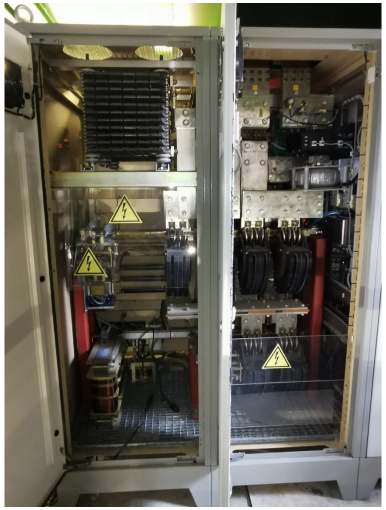
8 TDK-Lambda Genesys+ (375A, 20V) in parallel with CAEN-REGUL8OR regulation unit customized with our interlock interface (all USA standard compliant)

Quench Detector	Dump resistor Filter	Bus bars Contactors	Power Unit Free wheels diodes

OCEM
POWER ELECTRONICS

Old PS dismounted from Kloe platform and delivered to OCEM for inspections of components possibly saved

OCEM could also provide its own PU but would not be part of a blanket order.
We asked a PU quotation for a comparison with CAENels

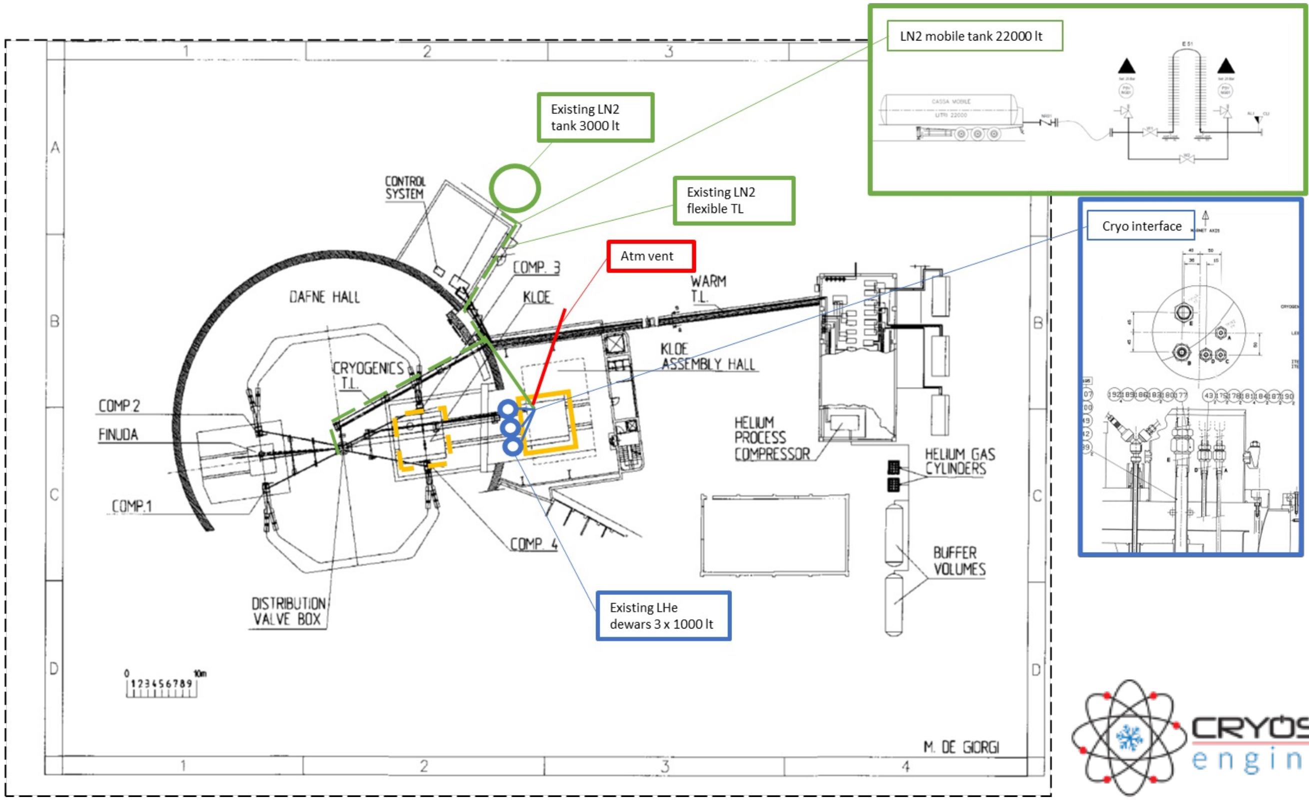


KLOE PS Dump resistor and contactors

KLOE PS delivered to OCEM

MAGNET Renovation and Test

Before dismounting and shipping (but after new PS installation) an operational test of the magnet is foreseen to test integration of all parts (PS, Quench Detector, Control System, Software Interface)



Coil cool-down

36kl LN_2 + 6kl LHe from mobile tanks
No need for DAFNE cryo plant
Noncomplex cryo interface
HW suitable to repeat test in US

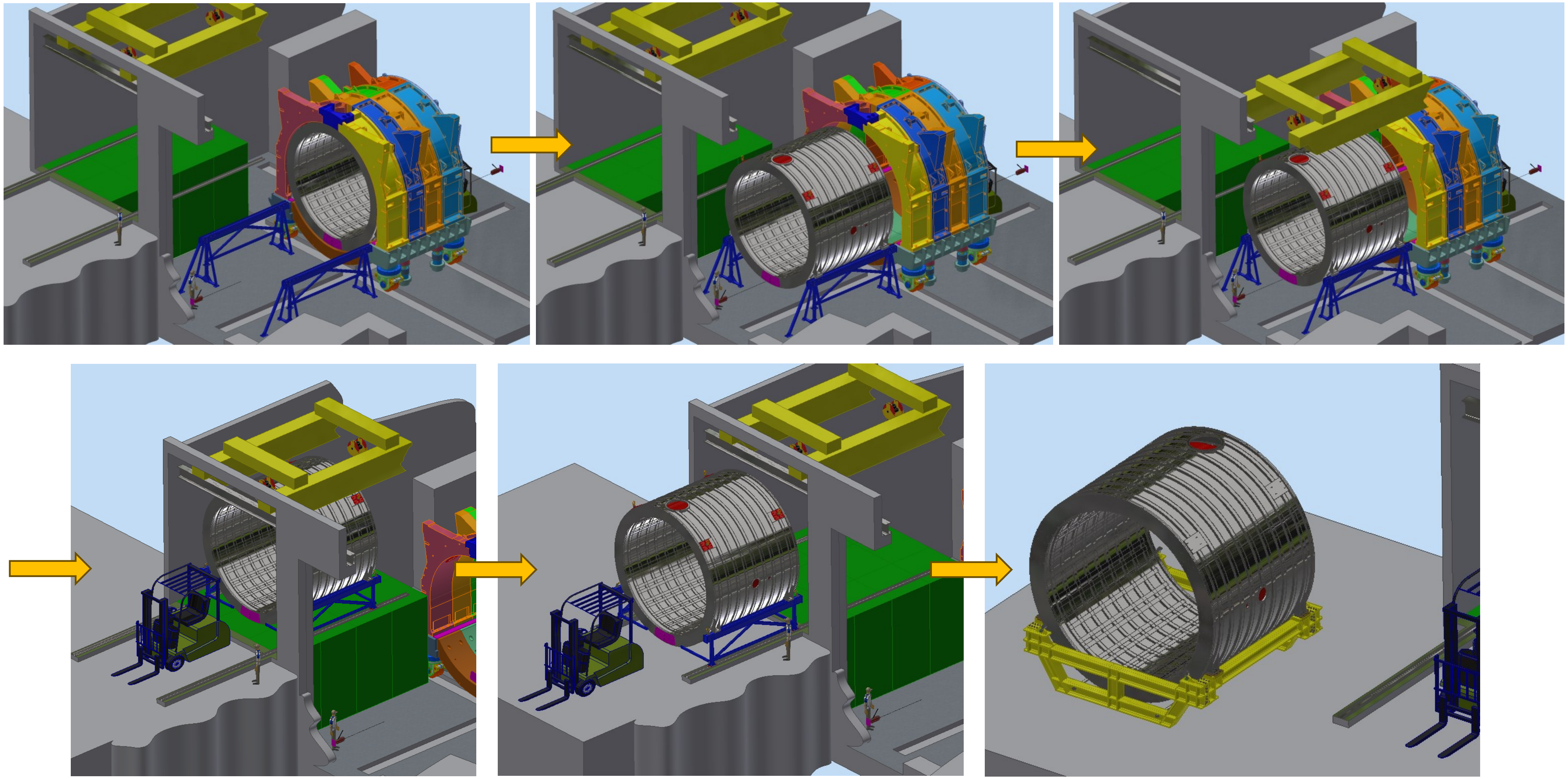
Procurement

New cryo interface provided by Cryosystem Engineering (order placed with 2023 funds)

Cryo liquids provided by AirLiquid
LN_2 funded in 2023
LHe funded SJ in 2024

Coil extraction and transportation

Magnet extraction procedure

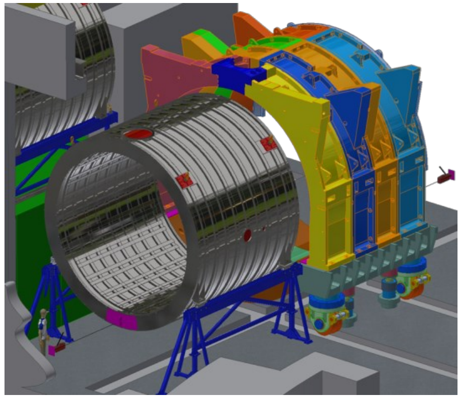


A. Saputi – INFN LNS

Coil extraction and transportation

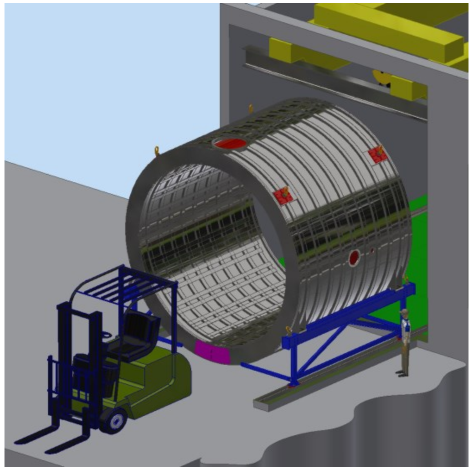
Main services, structures and tools for extraction

Crane = 22 t + 22 t

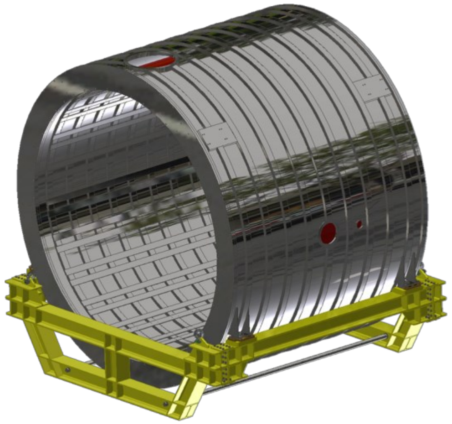


Extraction/Insertion Tool

Loading Dock



Trolley System



Cradle

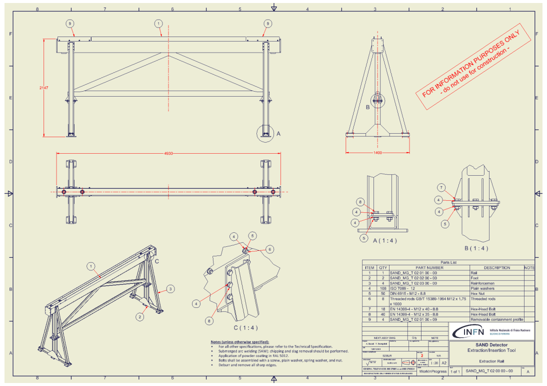
Lugs

The existing loading dock will be refurbished and enlarged on purpose

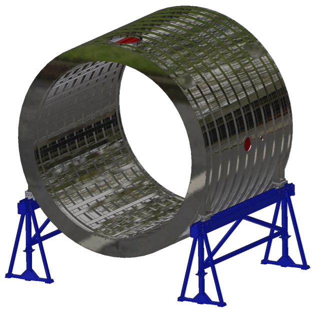
A. Saputi – INFN LNS

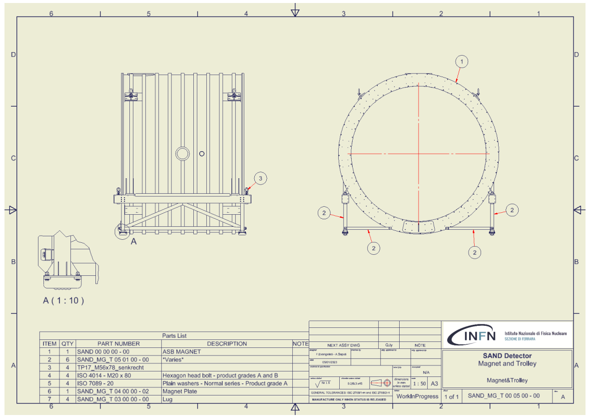
Coil extraction and transportation

Main services, structures and tools for extraction



- All workshop drawings are ready
- Technical specification is ready





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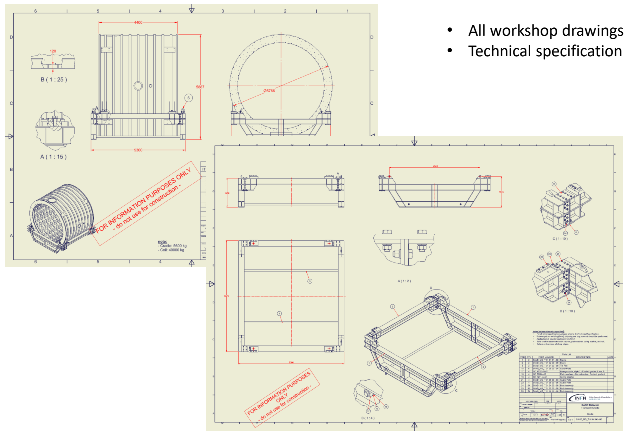

- All workshop drawings are ready
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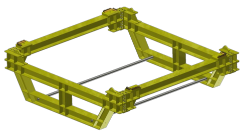
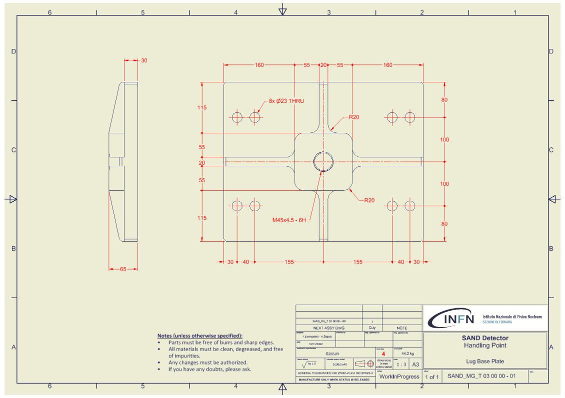
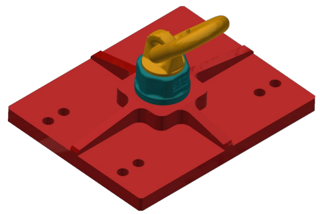
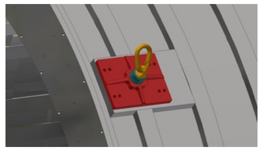




- All workshop drawings are ready
- Technical specification is ready
- Holes centre spacing to be checked





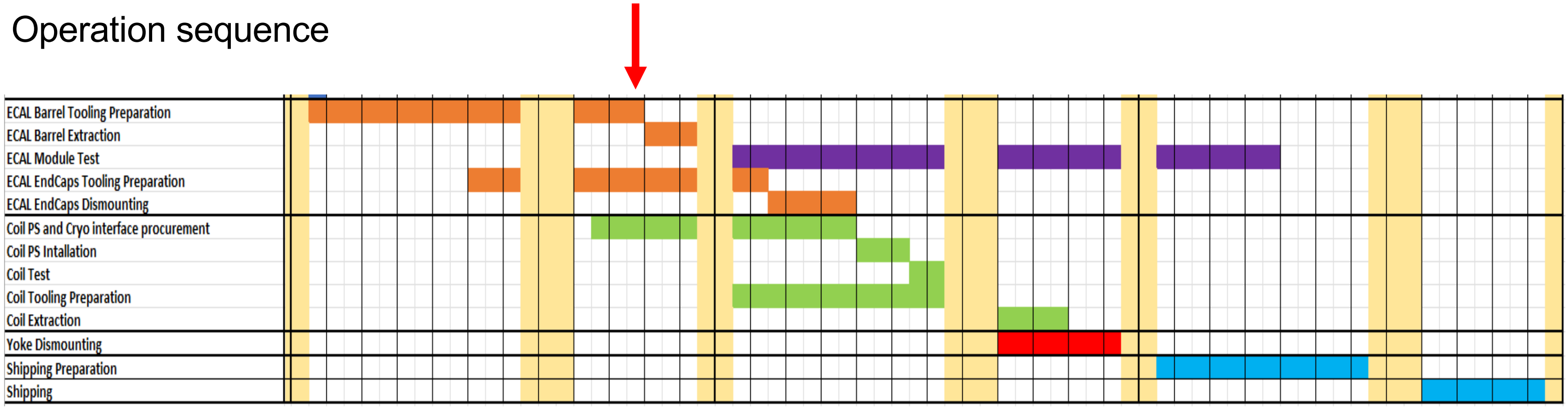
Reverse engineering of vessel
Design of all handling and transportation tools completed.
Call for offers started.
Certification EU and US compliant

A. Saputi – INFN LNS

KLOE-to-SAND: time schedule

we are here

Operation sequence



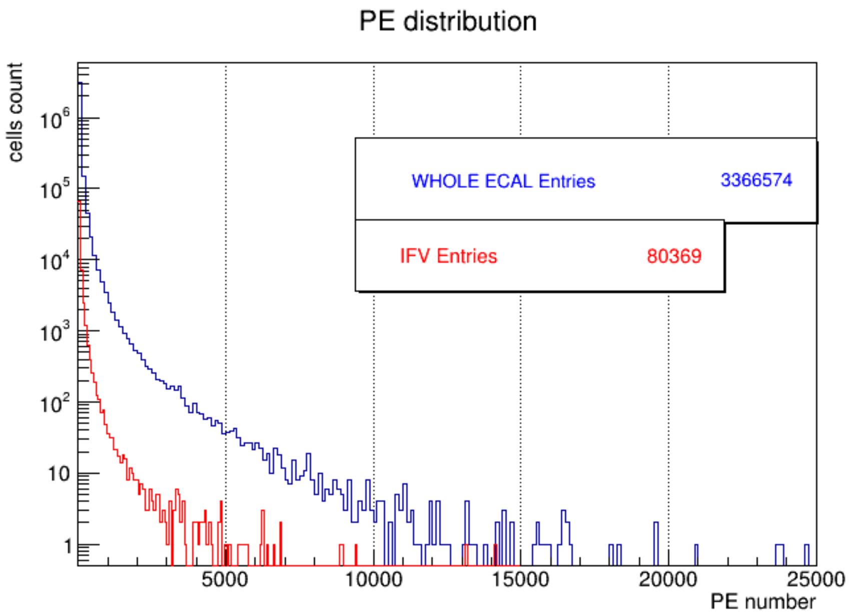
1 month

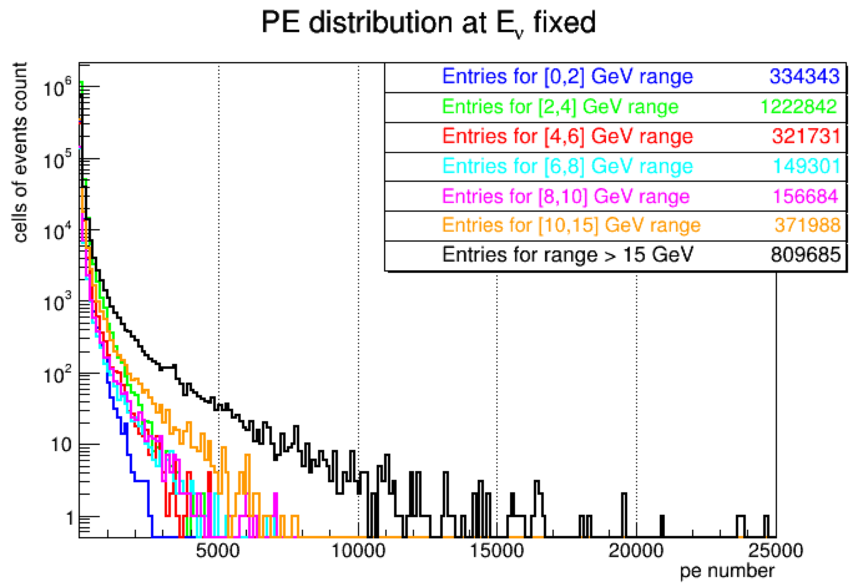
ND-hall availability: 2028

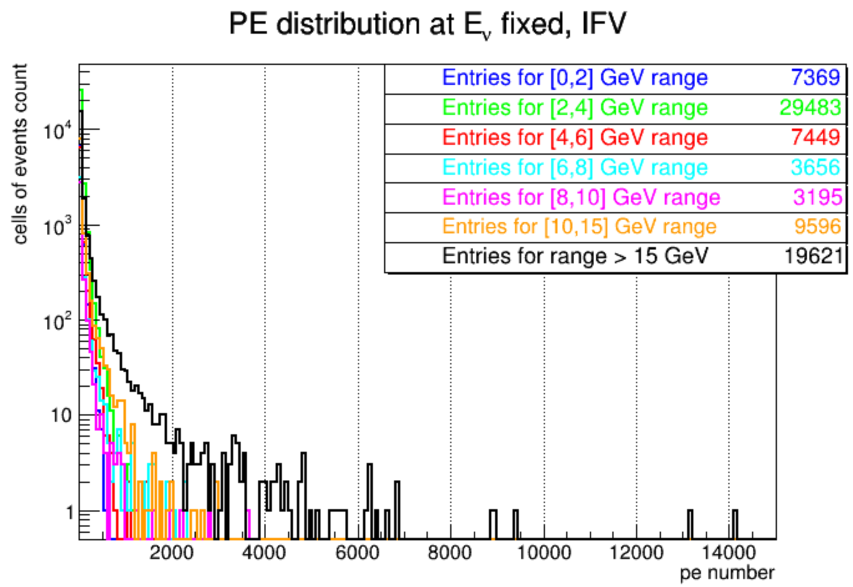
Studies for the optimization of the ECAL working point and FEE

A. Di Domenico, V. Di Silvestre, P. Gauzzi, D. Truncali - INFN-RM1
A. Balla - INFN-LNF

Np.e. distributions





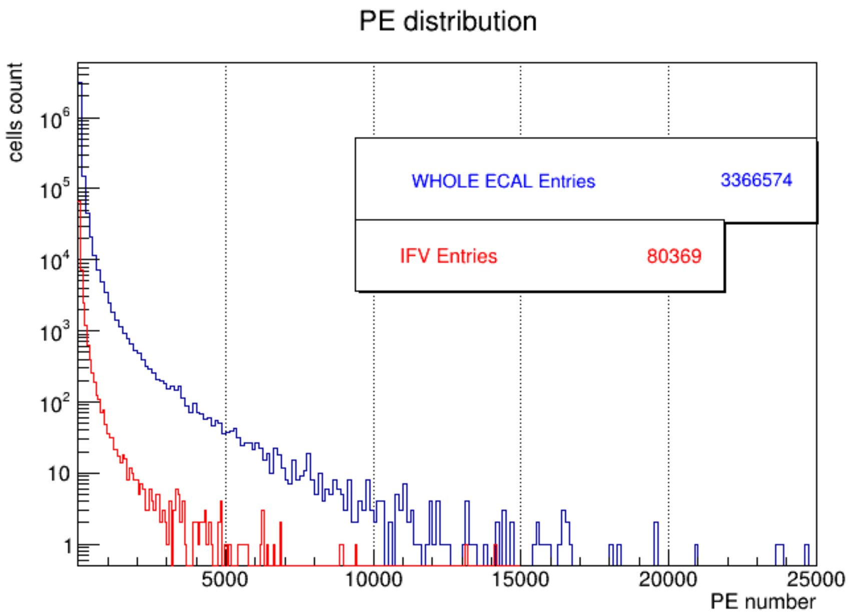


E_ν range = [0,10] GeV	
Events number	101,696
Events cells number	2,184,901

Fraction of events with at least one cell above PE threshold	[%]
1000 PE threshold	2.58
2000 PE threshold	0.49
3000 PE threshold	0.13
4000 PE threshold	$3.64 \cdot 10^{-2}$

Fraction of hit cells above PE threshold	[%]
1000 PE threshold	0.19
2000 PE threshold	$3.03 \cdot 10^{-2}$
3000 PE threshold	$7.19 \cdot 10^{-3}$
4000 PE threshold	$2.11 \cdot 10^{-3}$

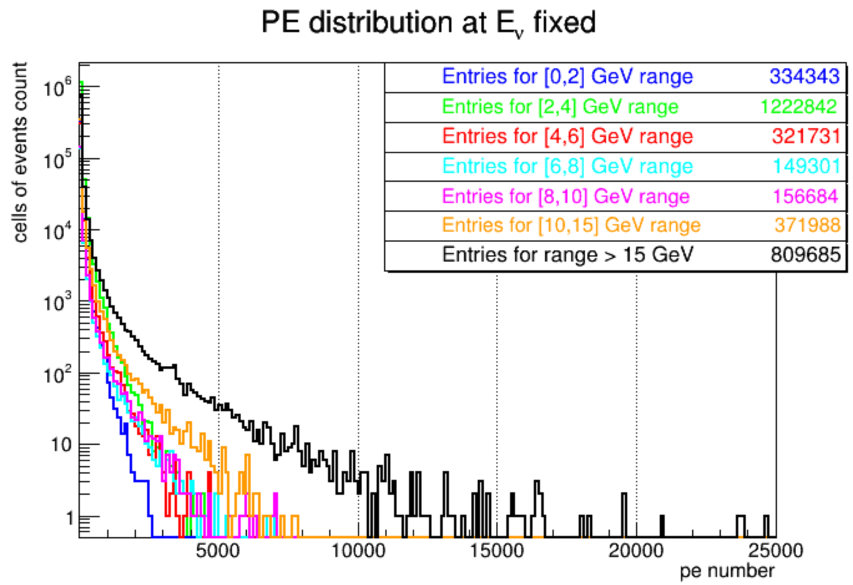
Np.e. distributions

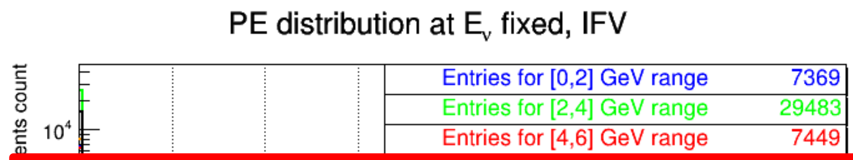


E_ν range = [0,10] GeV	
Events number	101,696
Events cells number	2,184,901

Fraction of events with at least one cell above PE threshold	[%]
1000 PE threshold	2.58
2000 PE threshold	0.49
3000 PE threshold	0.13
4000 PE threshold	$3.64 \cdot 10^{-2}$

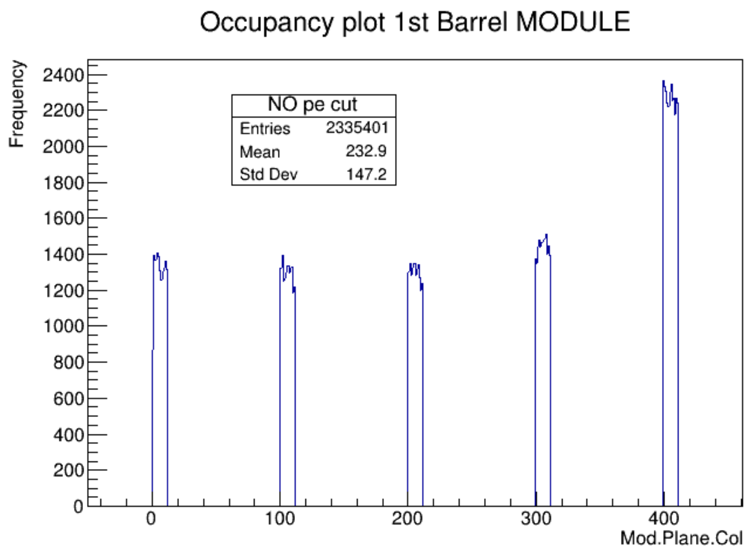
Fraction of hit cells above PE threshold	[%]
1000 PE threshold	0.19
2000 PE threshold	$3.03 \cdot 10^{-2}$
3000 PE threshold	$7.19 \cdot 10^{-3}$
4000 PE threshold	$2.11 \cdot 10^{-3}$



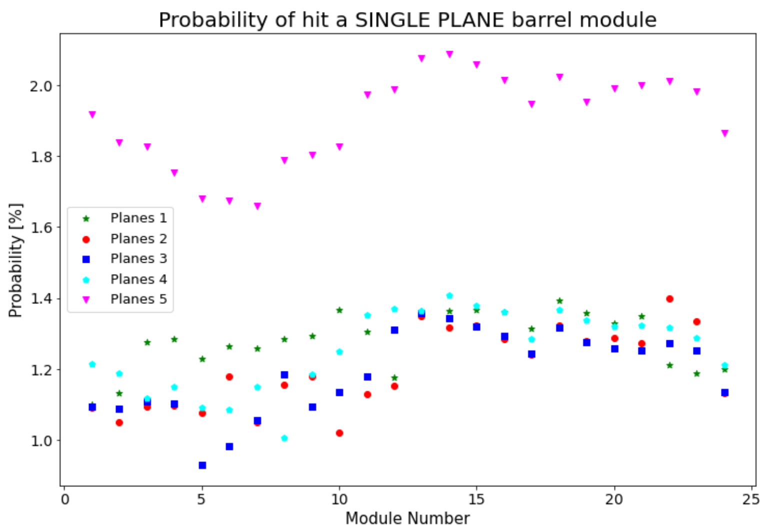


- Neutrino energy range of interest for oscillation analyses is [0,10] GeV
- In this range the MAXIMUM Np.e. that has to be treated by FEE can be safely set between 1000 and 2000
  => see next slides for the choice of the FEE dynamic range

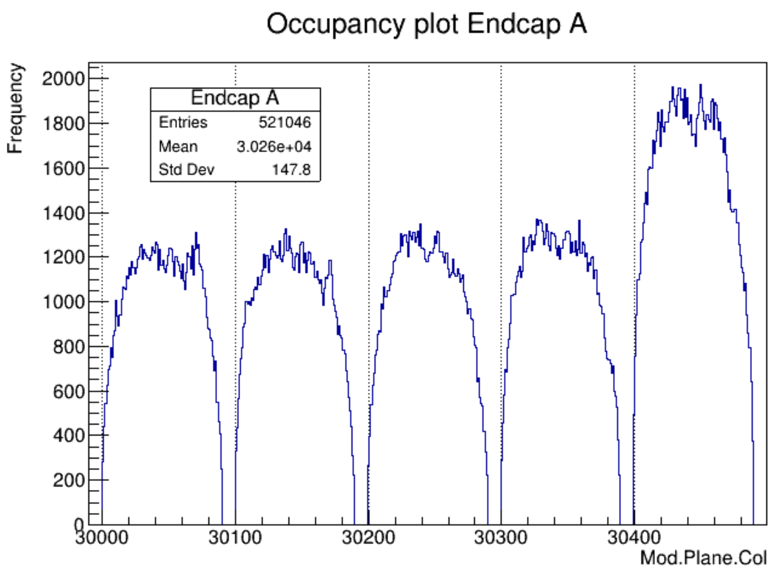
Cell occupancy plots and hit probability



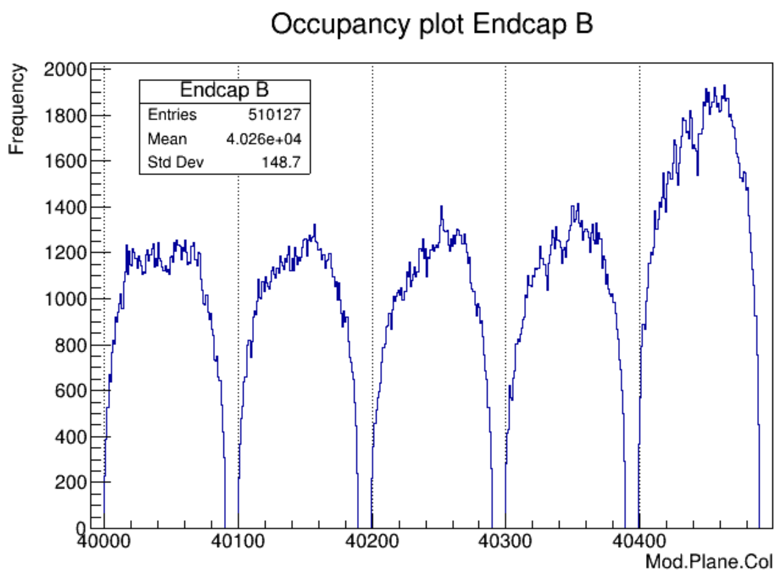
Barrel



Ecap A



Ecap B



Average probability that a cell is fired/hit in a neutrino interaction event:

P_{barrel} = 1.37%
P_{ecapA} = 0.88%
P_{ecapB} = 0.86%

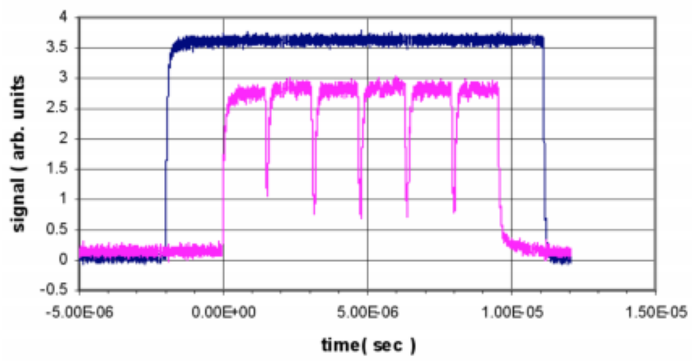
P_{cell} = 1.16%

Beam, spill structure, and event rates in SAND

Beam power 1.2 MW
7.5×10^{13} protons extracted every 1.2 s at 120 GeV
1.1×10^{21} pot/year

Spill time structure

- 9.6 μs per spill
- 6 batches, 84 bunches/batch
- 2 empty bunches
- 1 bunch: Gaus(σ = 1.5 ns)
- Δt bunches = 19 ns



Event rates expected in SAND
~ 84 interactions/spill
$\lesssim$1 interaction/spill in the SAND fiducial volume

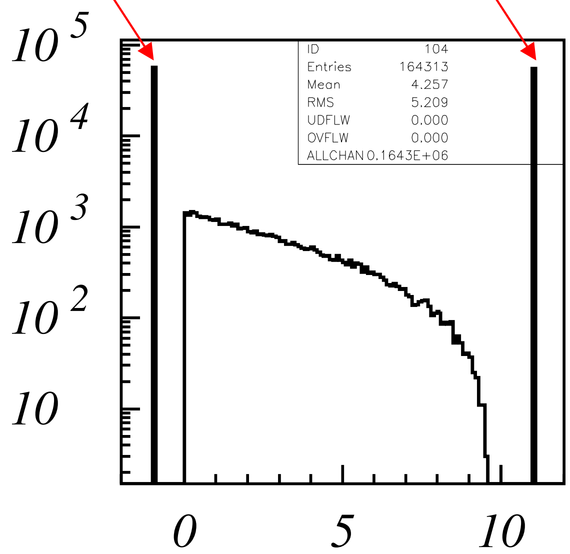
(negligible rock muons and cavern background assumed)

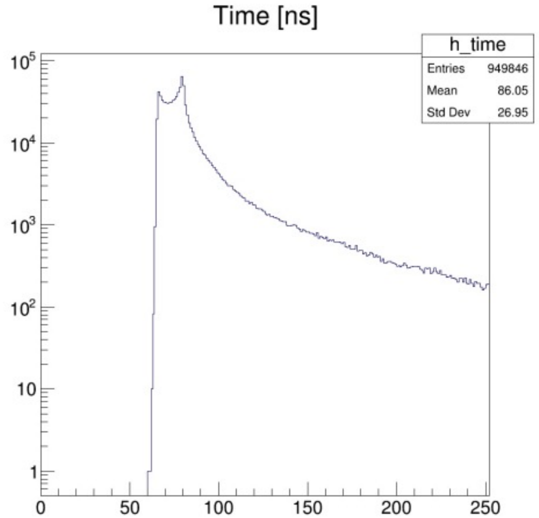
Pile-up probability

The beam time structure is reconstructed to simulate the time of the neutrino interaction event and calculate the pile-up probability that, given a PMT signal, a second signal arrives within a fixed time window (TW) after the first signal.

The times of N interactions per spill (in average **N=84**) are extracted uniformly between 0 and 9.6 μs. The time difference between two consecutive interactions is calculated for all spills, following an exponential distribution with $\tau_{spill} \simeq$ 114 ns. From this, the distribution of time differences for a single cell with a probability to be hit of P_{cell} = 1.16% is evaluated, and then the pile-up probabilities for different time windows are also evaluated, TW = 50, 100, 150, 200 ns.

spills with 0 hit 1 hit





Time propagation/smearing of hits in a single neutrino interaction event.

	before smearing			after smearing		
P_{CELL} [%]	**1.16**	**1.5**	**2.0**	**1.16**	**1.5**	**2.0**
Time window [ns]						
50	0.67	0.90	1.28	0.64	0.86	1.36
100	1.33	1.81	2.52	1.32	1.71	2.56
150	1.95	2.71	3.72	1.91	2.60	3.78
200	2.59	3.58	4.87	2.52	3.48	4.93

Pile-up probability

The beam time structure is reconstructed to simulate the time of the neutrino interaction event and calculate the pile-up probability that, given a PMT signal, a second signal arrives within a fixed time window (TW) after the first signal.

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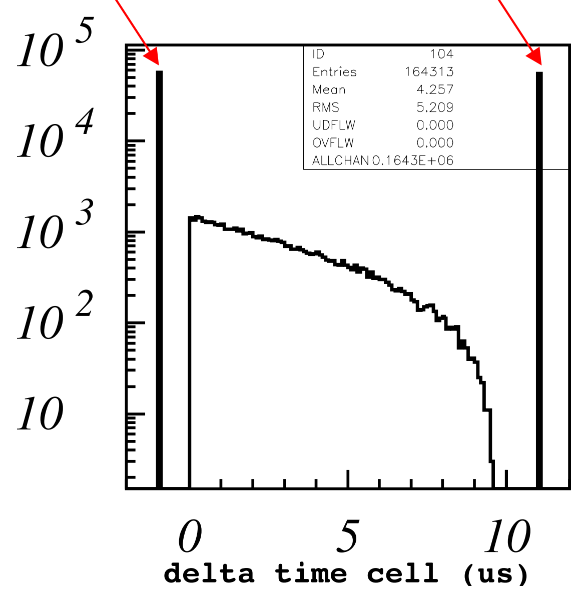

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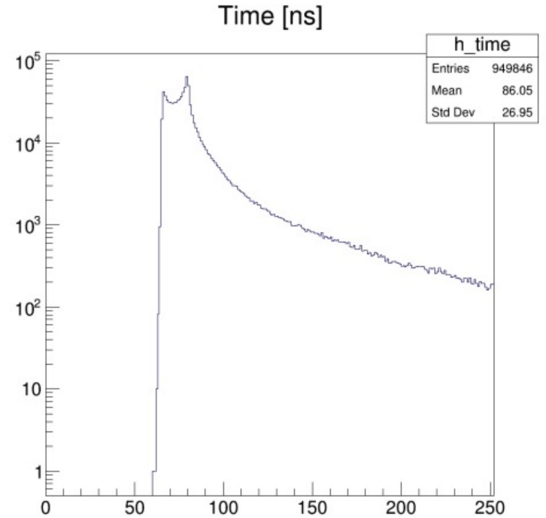


Time propagation/smearing of hits in a single neutrino interaction event.

PMT signal and discriminator threshold in KLOE

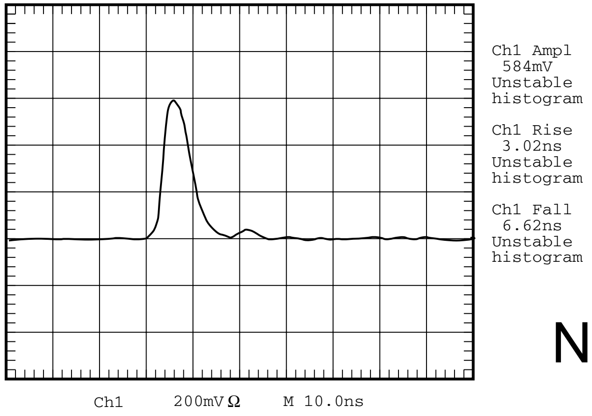
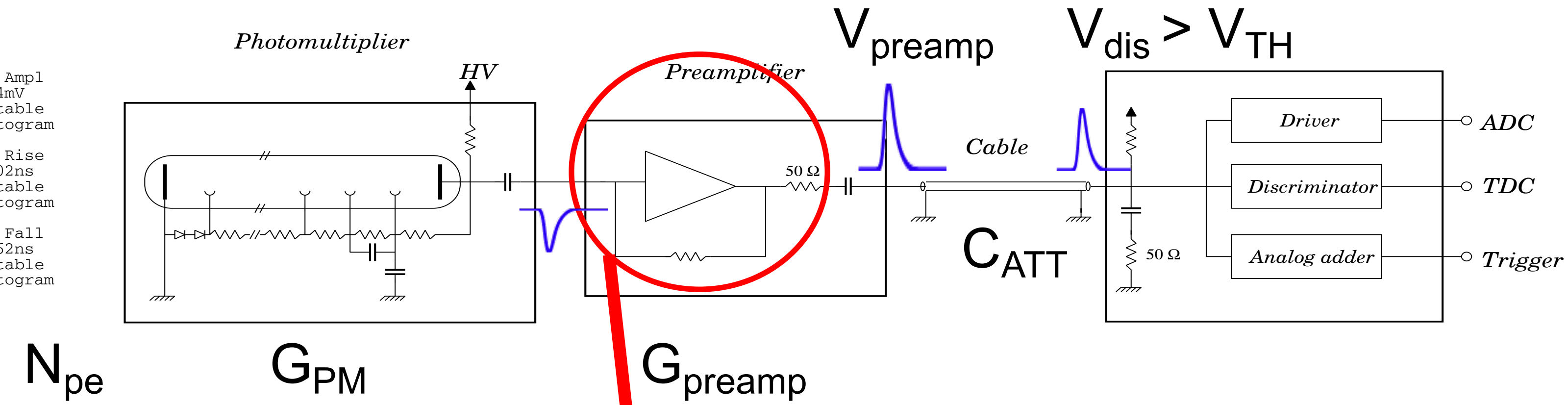
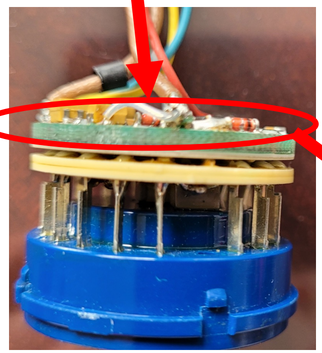


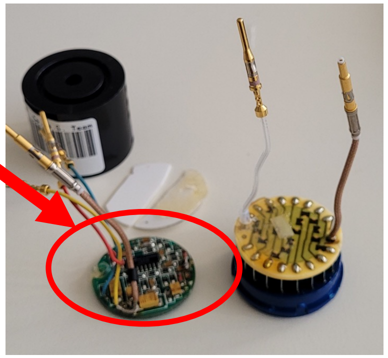
Figure 4: Typical signal from the PM base.



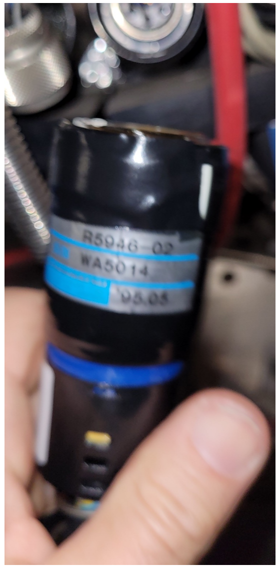
Constraints:

- minimum discriminator threshold 4-5 mV
- maximum HV for PMs divider is 2300 V
  typical HV 1700-1800 => G~1-3 x 10^6
- preamplifier linear (within 0.2%) for signals
  up to 4.7 V (gain preamp ~ 2.5)
  => 1.74 V at discriminator level after
  12-15 m long cables and termination





thanks to A. Balla and P. Ciambrone



Test of preamp saturation

with preamplifier

saturation over 3.2 V

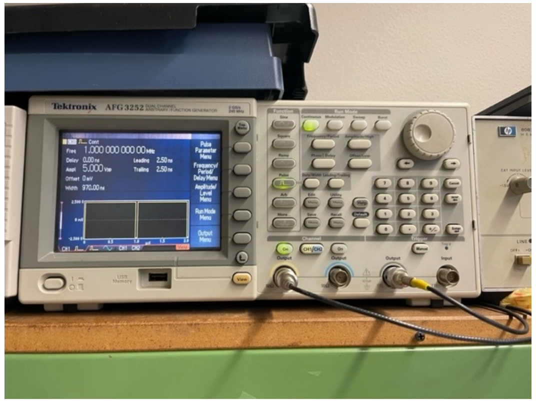
In this specific case (negligible cable length) we expect:
$V_{dis}(max) = V_{preamp}(max) \bullet\ 0.5\ = 2.35$ V

Assuming to increase $V_{preamp}(max)$ by 15% while keeping linearity at an acceptable level, e.g. 1% (feasible - see next slide), we get:

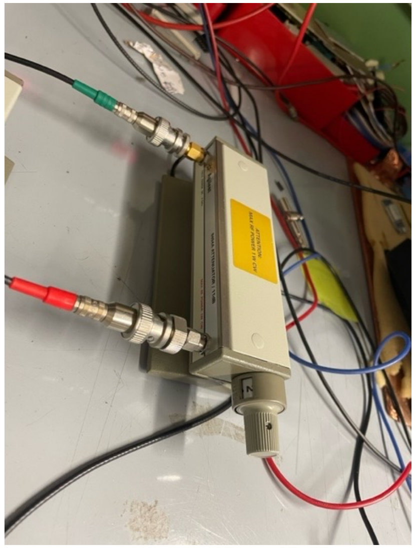
$V_{preamp}(max\ ) = 5.4$ V
$V_{dis}(max) = V_{preamp}(max) \bullet\ 0.5\ = 2.7$ V

Preamp linearity test (1) using pulse generator

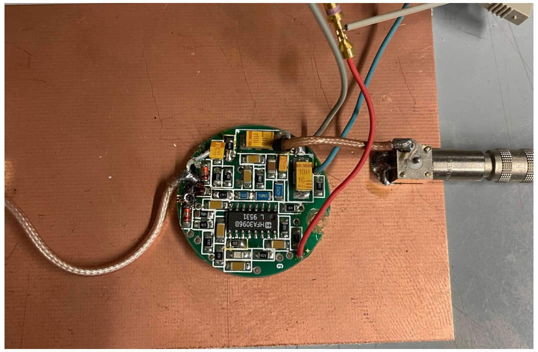
Test set-up



Signal amplitude varied with calibrated attenuators (pulse width ~ 30 ns)

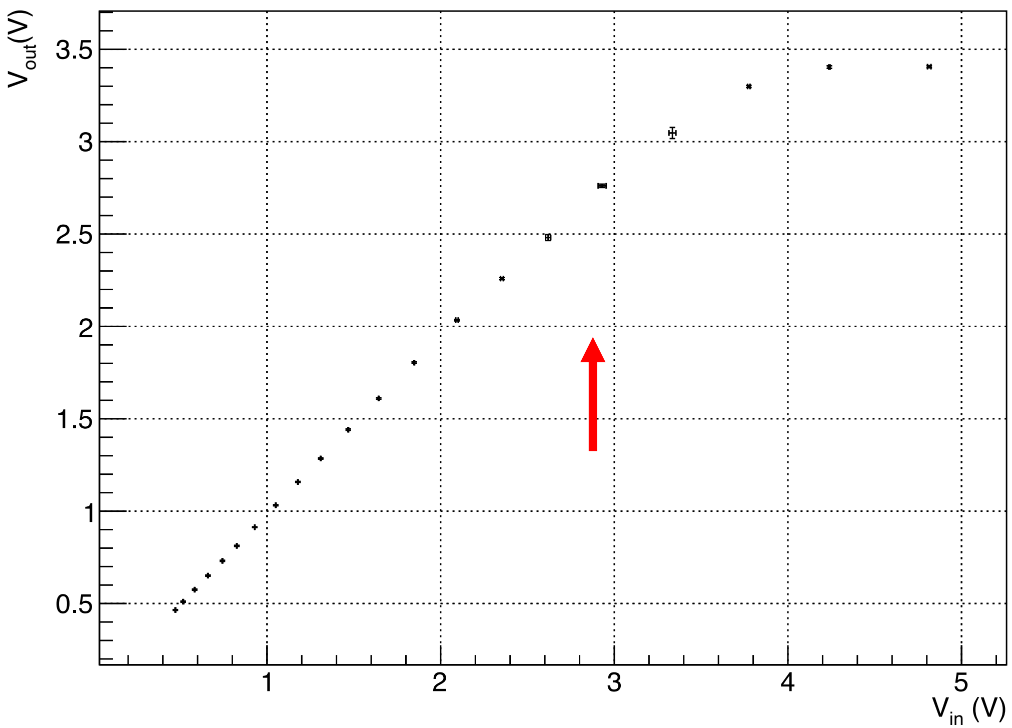


Signal at a modified test input: preamp gain ~1

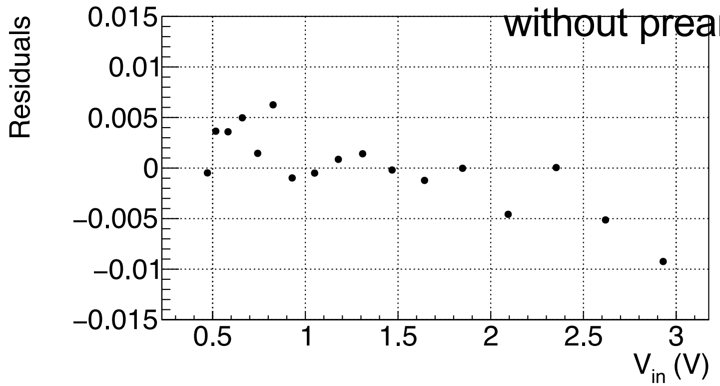


Preamp linearity test (1): linear and saturation regimes

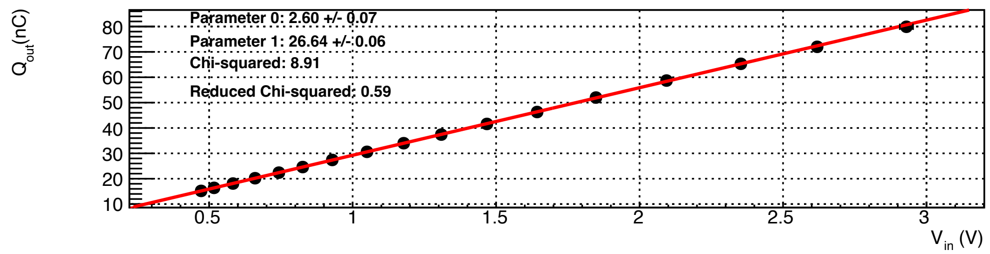
Linearity test



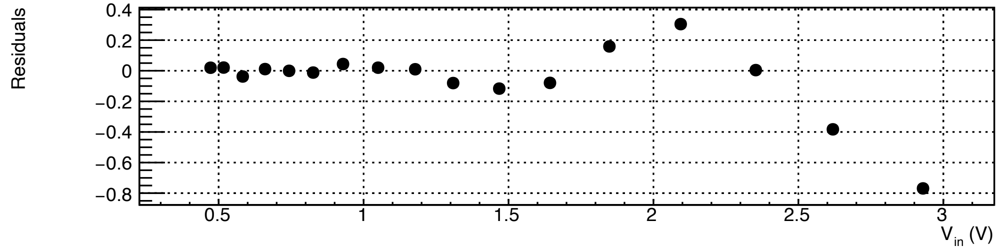
Residuals (subtracted system response without preamp)



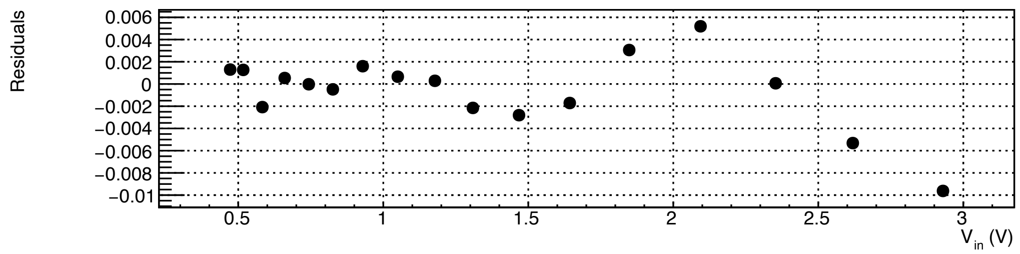
Linear fit



Non normalized residuals



Residuals



Choice of the dynamic range

Assuming:

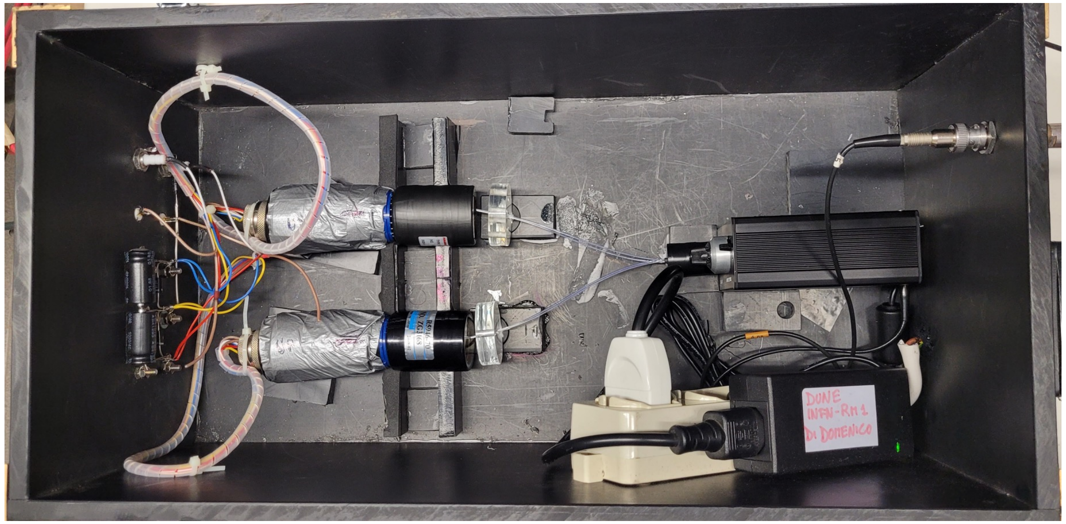
- to increase $V_{preamp}(max)$ by 15% => $V_{preamp}(max) = 5.4$ V
- $(N_{pe}\, G_{PM})(max) = 95 \cdot 10^7$
- $V_{dis}(max) = V_{preamp}(max) \cdot 0.5 \cdot C_{ATT} =$ 2.0 V (12m long cable attenuation: $C_{ATT} = 0.74$)
- to have a very low noise environment as in KLOE => lowering (halving) the minimum discriminator/digitizer threshold to $V_{TH}=$ 2.5 mV

G_{PM} $(\times 10^5)$	G_{tot} $(\times 10^6)$	$N_{pe}(\max)$	signal amplitude (mV/pe)	$N_{pe}(\min)$ $V_{TH} = 2.5$ mV	MeV at module center
4.8	1.2	~ 2000	1.0	~ 3	3.0
6.4	1.6	~ 1500	1.3	~ 2	2.0
9.5	2.4	~ 1000	2.0	~ 1	1.0

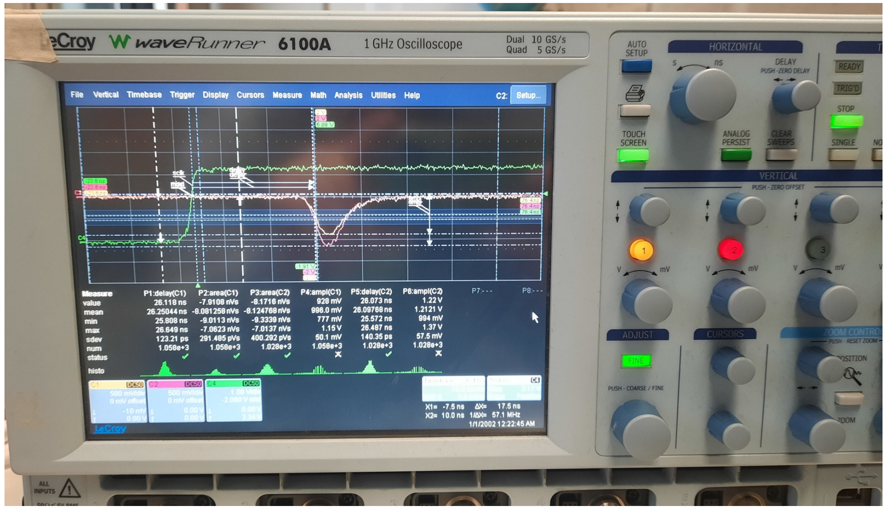
- Different dynamic ranges can be implemented changing G_{PM} => the final choice should be a compromise between an affordable level of events with energy saturated cells, depending on $N_{pe}(max)$, and an acceptable neutron detection efficiency, depending on $N_{pe}(min)$.

Preamp linearity test (2) with PMT system test

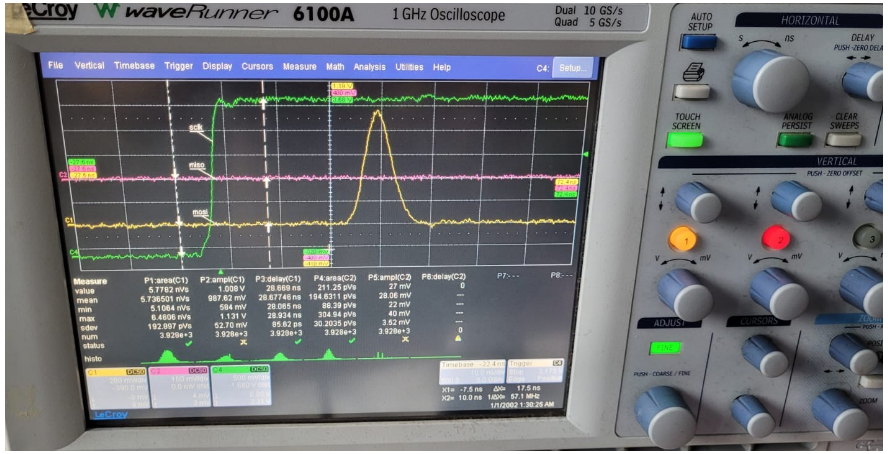
PMT system test at LNF with
- CAEN LED driver SP5601 (wavelength ~ 400 nm) with fine tunable LED intensity
- scint. fiber splitter
- two PMTs (for relative QE meas.)



no preamplifier

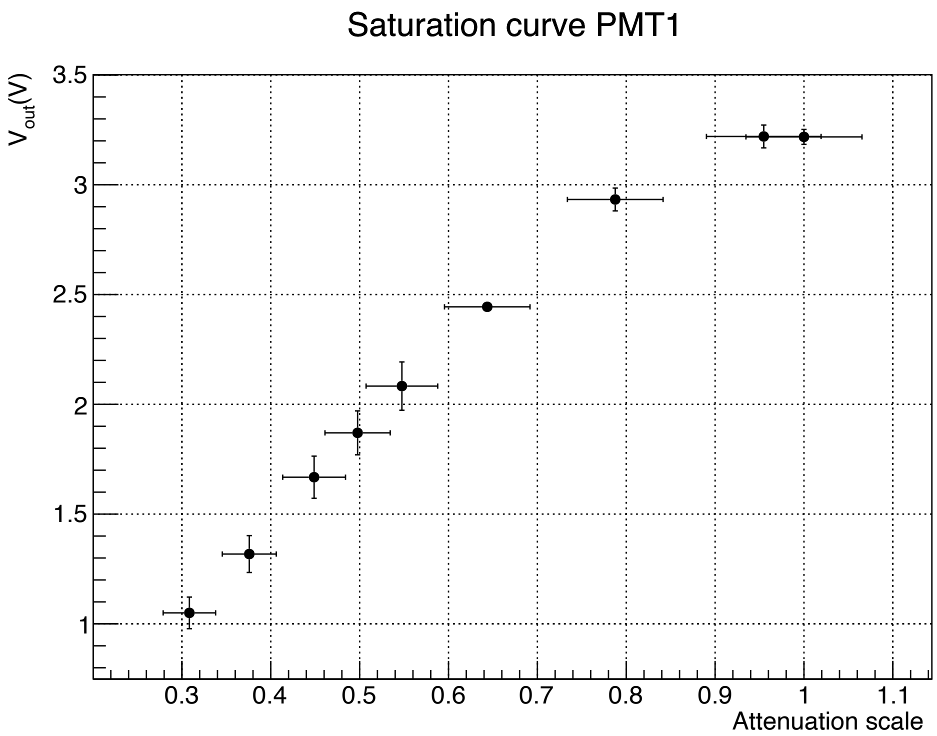


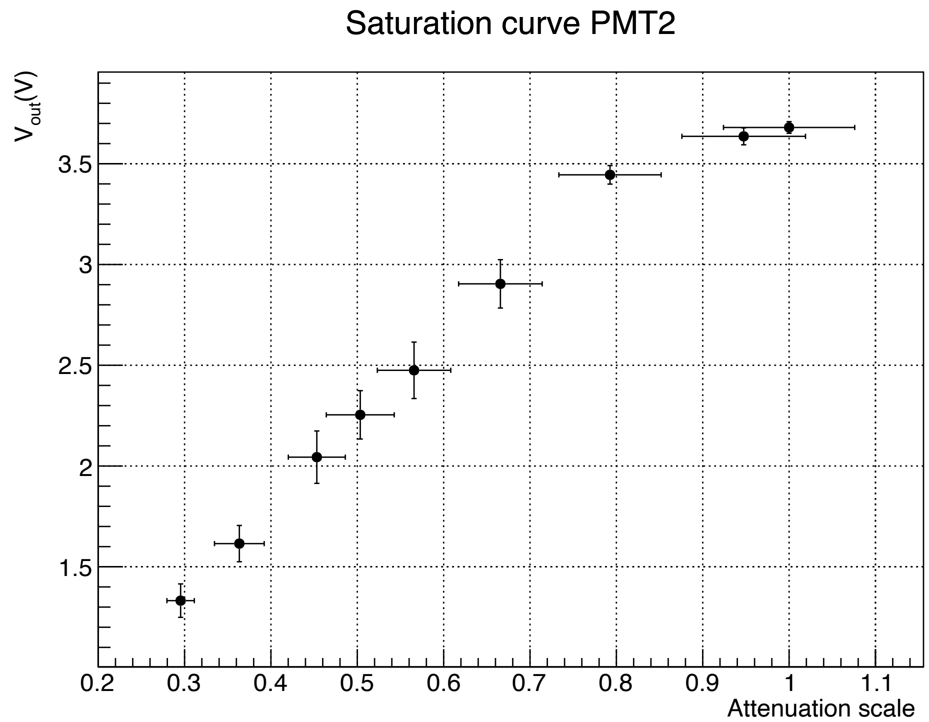
with preamplifier

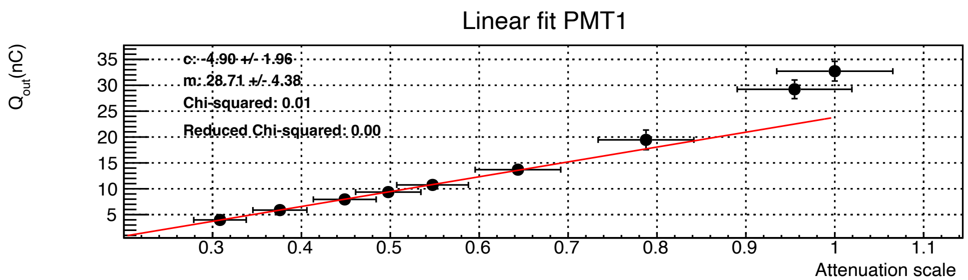


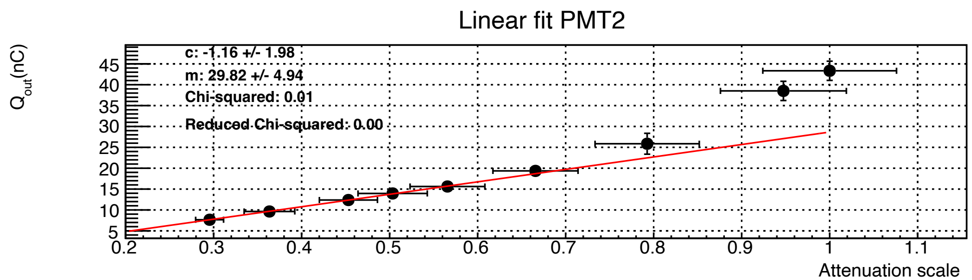
Preamp linearity test (2): results (i)

LED driver attenuation scale checked and calibrated with PMT response in linear region









Preamp linearity test (2): results (ii)

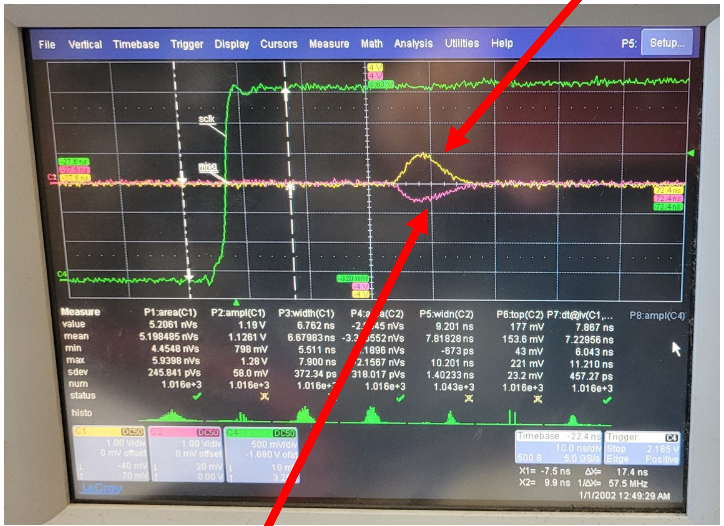
PMT2 HV=1700 V

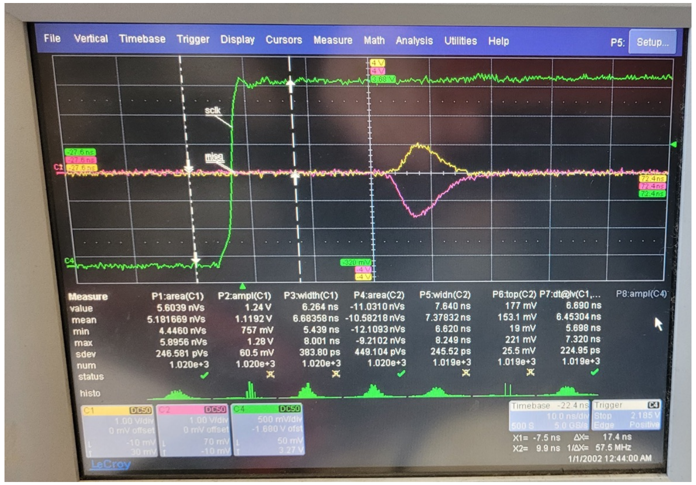
REF PMT1

HV=1900 V

fixed LED intensity (full)

HV=2100 V





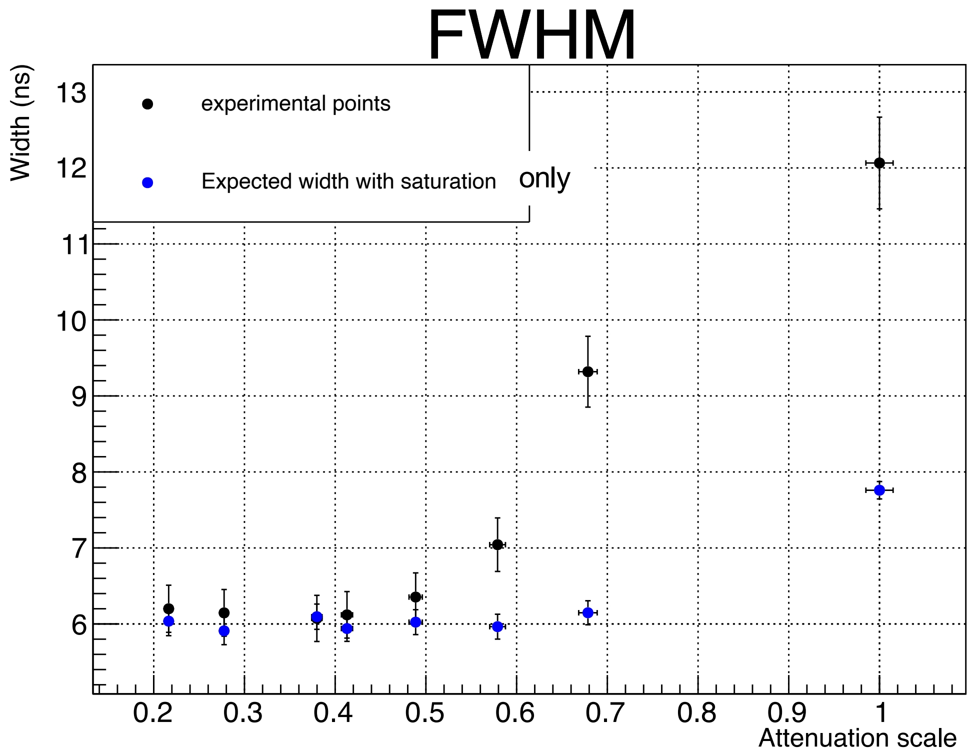
no preamp PMT2

with preamp PMT2

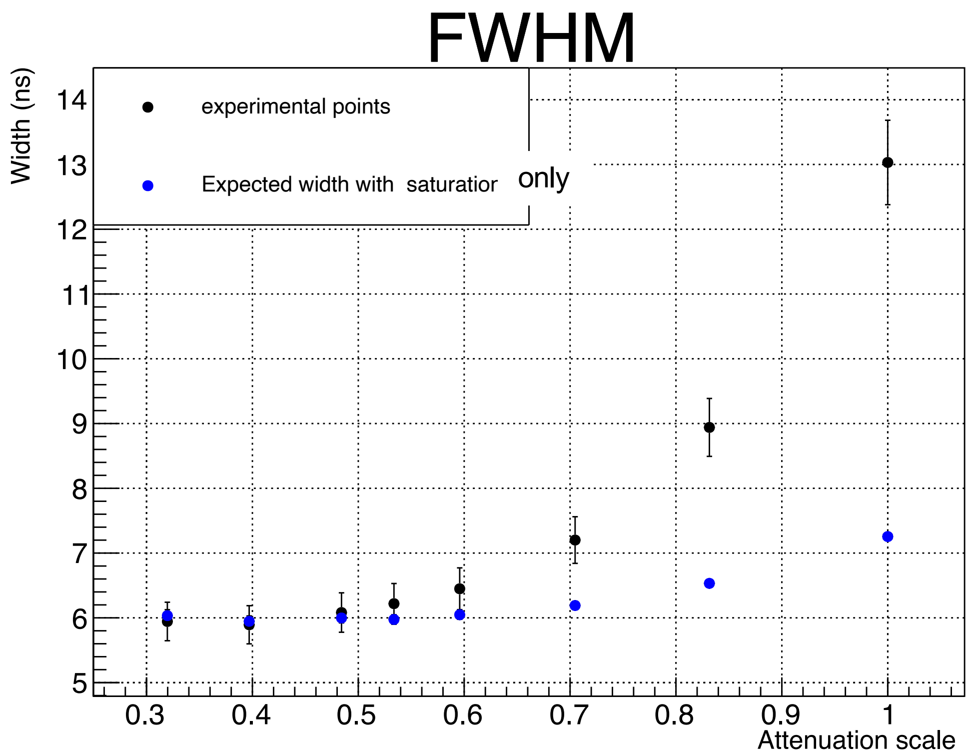
preamp recovery time from saturation depends on input amplitude signal

Preamp linearity test (2): results (iii)

PMT1



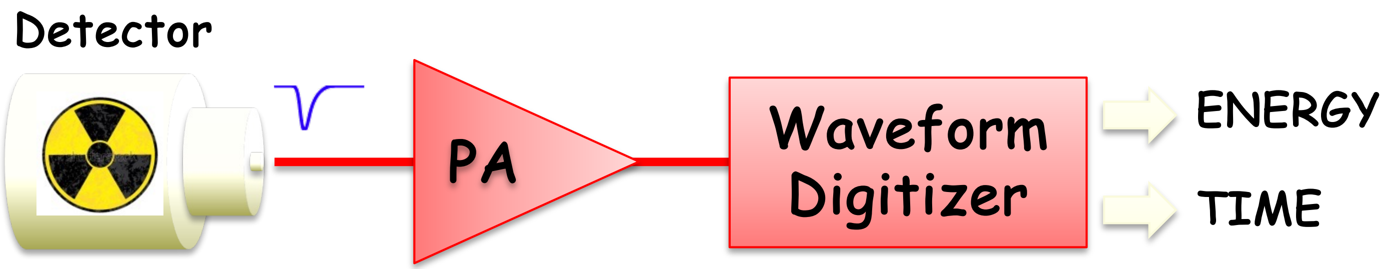
PMT2



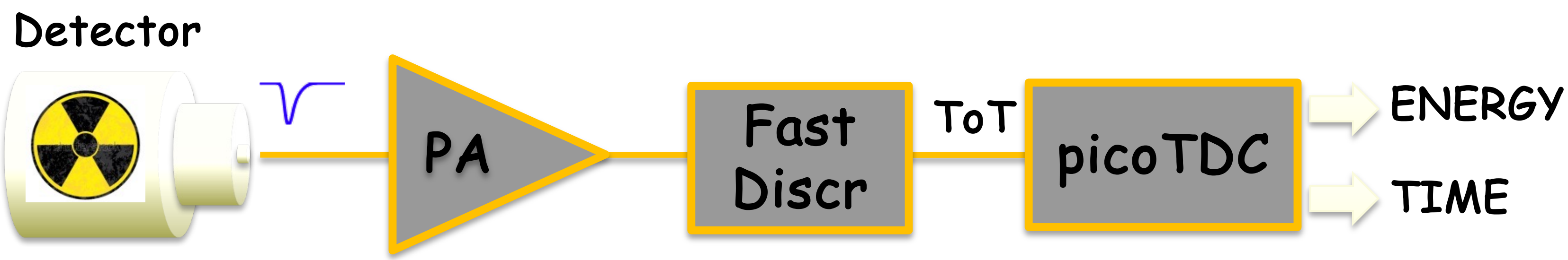
- The time baseline is distorted during saturation. The recovery time from saturation to linear regime depends on the input signal amplitude.
- The input information is not fully lost during the saturation regime. The "over-linearity" of the integrated charge or the signal width increase vs the input signal amplitude could be exploited to characterize signals beyond the preamp saturation regime.

Choice of FEE for SAND/ECAL

Three possible read-out schemes:

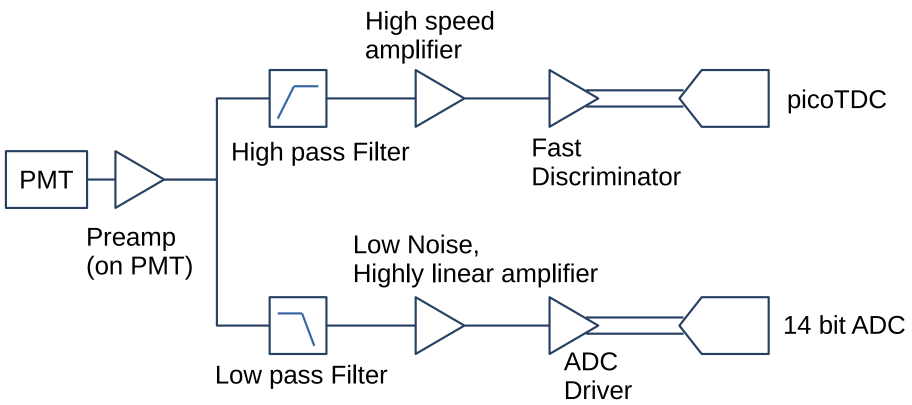


Highest Flexibility
=>
Fsampl ~ 1 GS/s =>High Cost or
Fsampl ~ 125-250 MS/s
+ signal shaper



Less Flexibility
=> energy by ToT
with 2 or more thresholds
not to worsen energy resol.
Time walk correction
needed

a more conventional approach
proposed by N. Tosi – INFN BO



ENERGY

less Flexibility

TIME

Note: some stages may be folded into a single active component

CAEN:

collaboration for a commercial (partly customized) solution keeping KLOE energy and time performance

Conclusions

Advances in all KLOE-to-SAND activities:
- movable platform for the barrel modules extraction is being built; ~ready to be installed.
- design of mechanical tools for the End-cap dismounting ready; construction started.
- design for the dismounting of the magnet coil ready; call for offer.
- the magnet test is being prepared; agreement with contractors is being finalized.

Studies for the optimization of the working point of the SAND calorimeter read-out electronics have been performed.
The dynamic range and pile-up of the signals have been studied with MC.
PMT preamplifiers have been tested for linearity and are well compatible with needed dynamic range and proposed FEE solutions, with the additional advantage of a lower gain and HV level, beneficial for PMTs lifetime.
The features of preamp saturation could be exploited to partially recover input signal information during saturation regime.

Possible solutions for the FEE that could constitute a good compromise between cost and performance are being investigated in collaboration with CAEN.
(Very recent and preliminary results obtained by CAEN on ToT with picoTDC and walk correction appear promising.)
In general, any solution must be integrated in the SAND DAQ scheme, with possible synergies with other detector electronics.