KLOE-to-SAND and ECAL + Magnet WG status report

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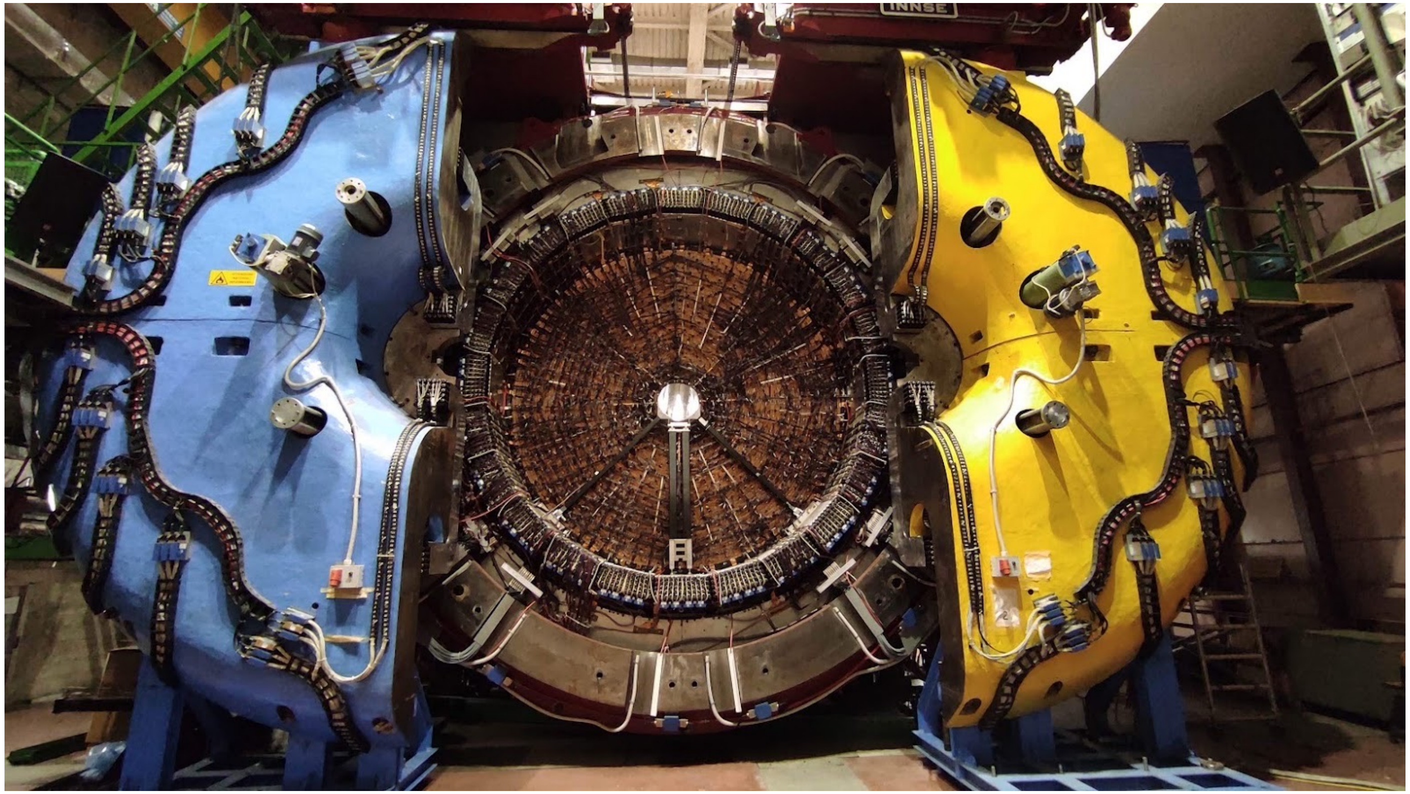


SAND General/Technical Meeting – 14th November 2023

The SAND-ECAL working group

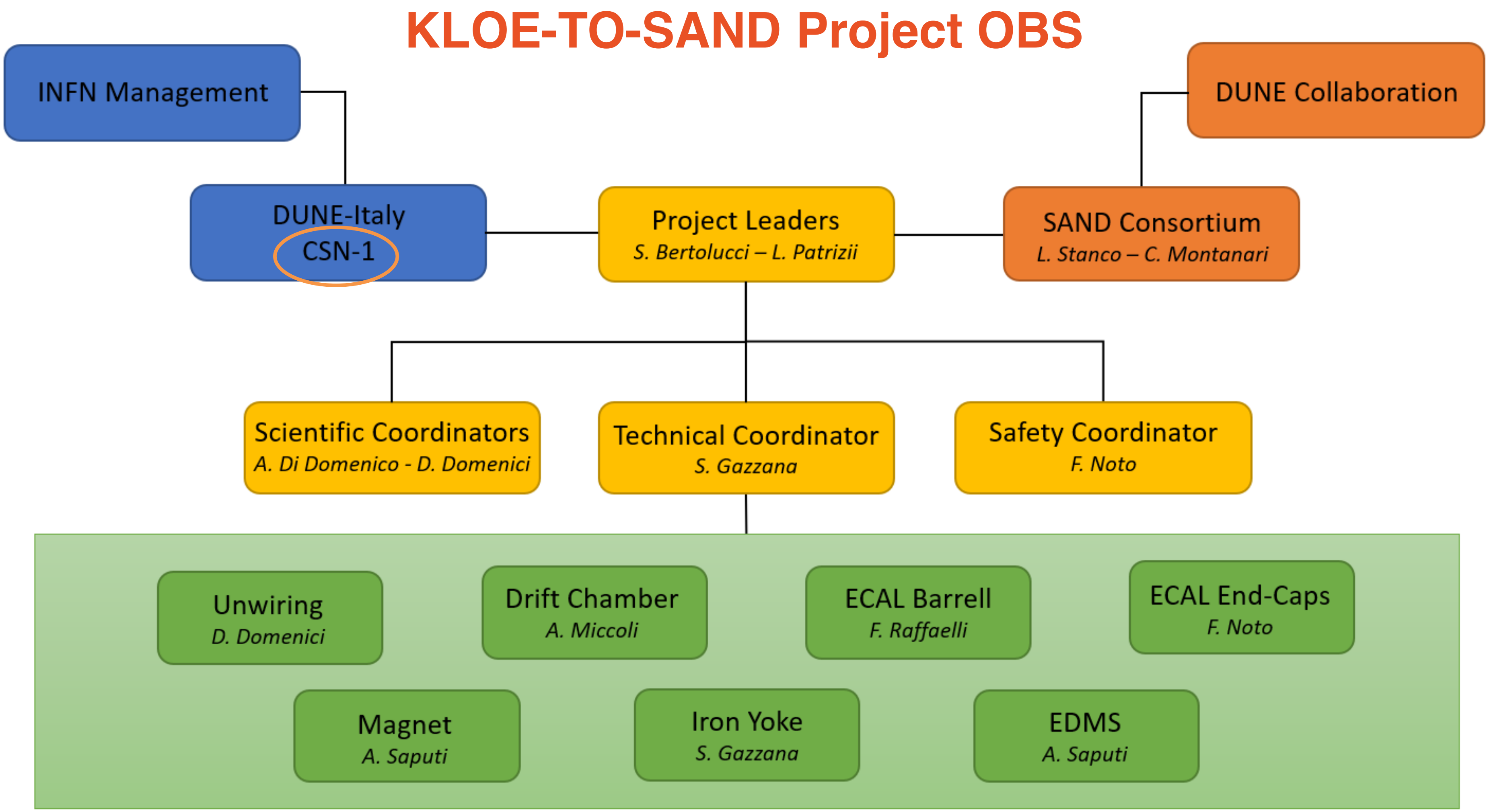
- Activities related to the extraction of the electromagnetic calorimeter (ECAL) from KLOE detector, ECAL refurbishment, transportation to FNAL, installation and commissioning at the DUNE ND cavern.
- In general, the activities at LNF of the whole KLOE-to-SAND project are followed and discussed inside 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

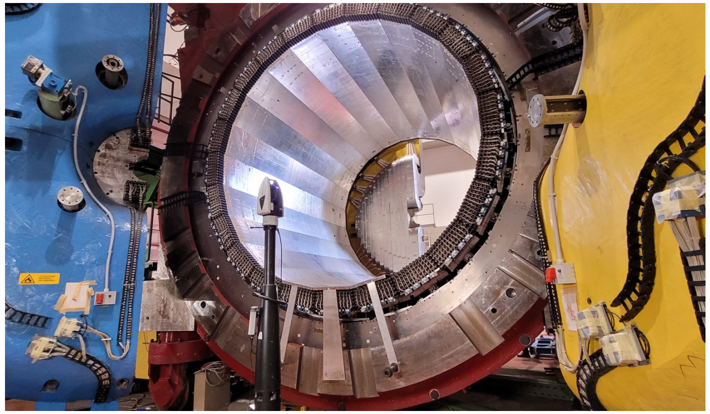
<u>Plan of operations:</u>

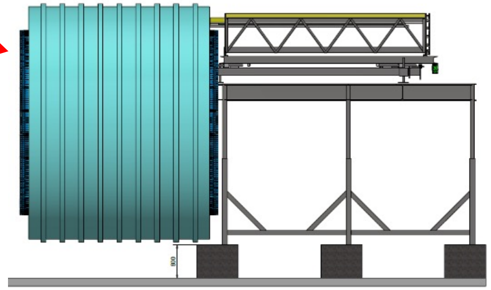
✓ Removal of all cables and the FEE+HV racks

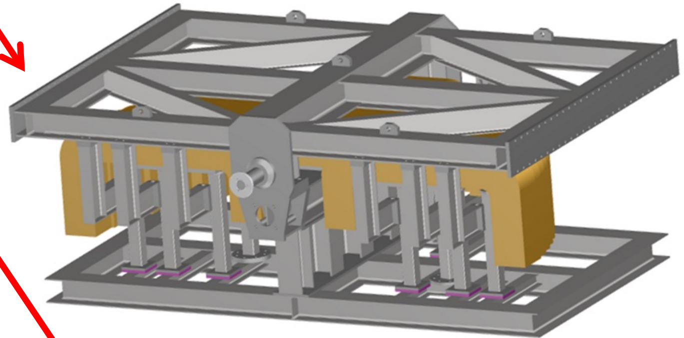
✓ Extraction of the Drift Chamber

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

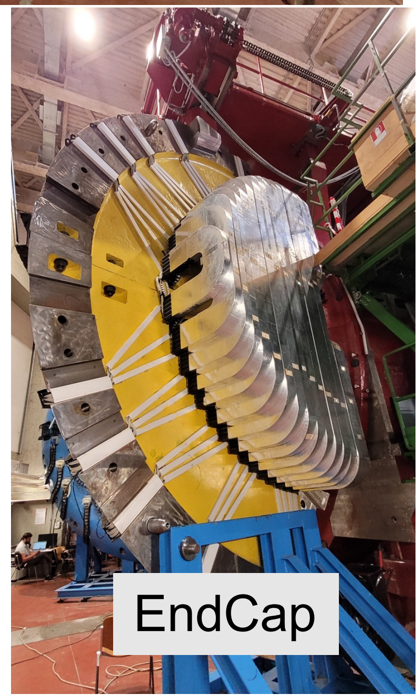






Magnet and Yoke

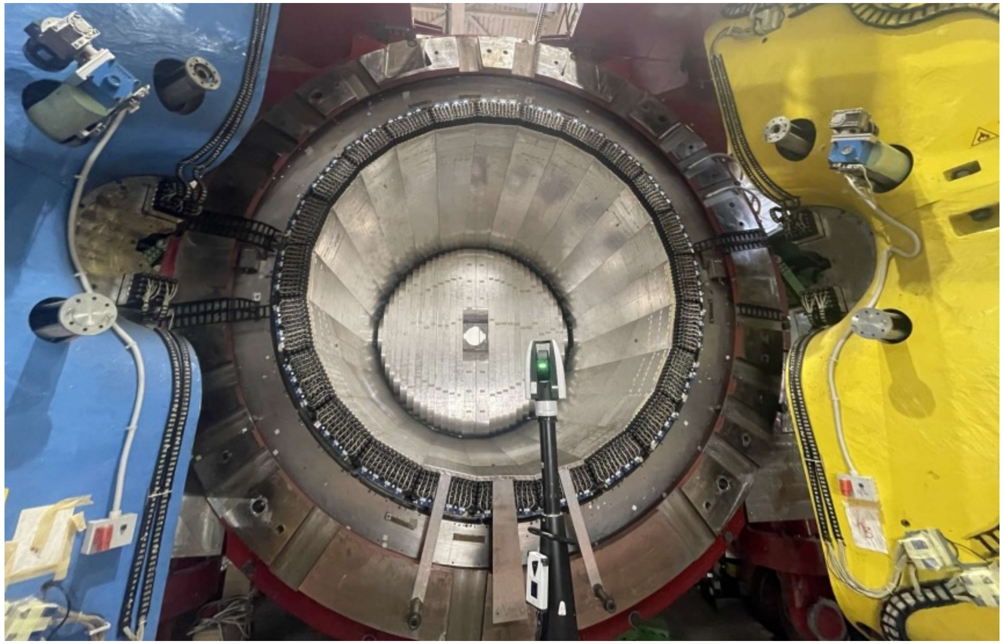
- Installation of new Power Supply
  - new Power supply is being purchased (CAENels)
  - Power Electronics is being revamped (OCEM)
  - Control system and full support for magnet test/ dismount/remount by ANSALDO ASG
- Cooling of coil
- Operational test of magnet
  - in preparation
- Extraction of Magnet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

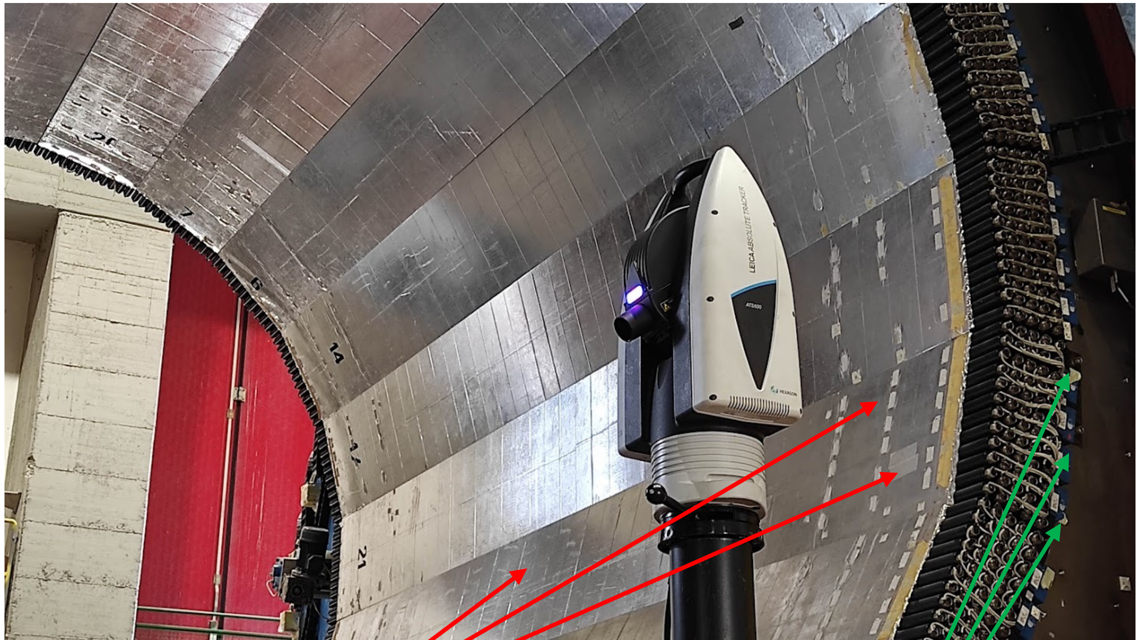


Packaging & Shipping at Fermilab

ECAL geometry survey

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





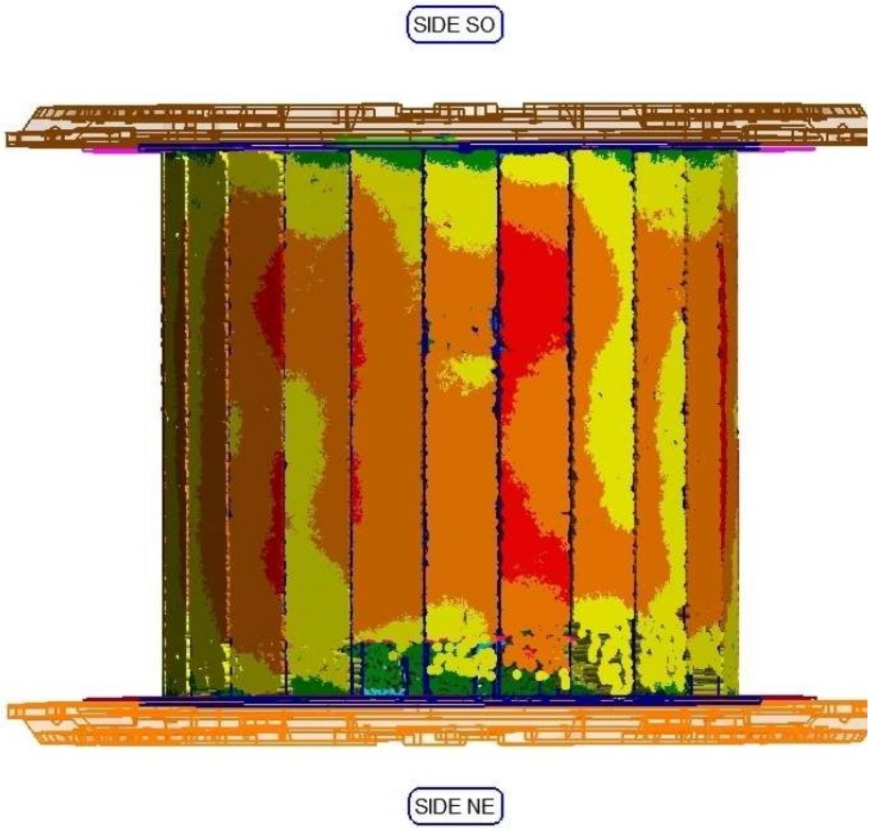
Measured distance between:

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

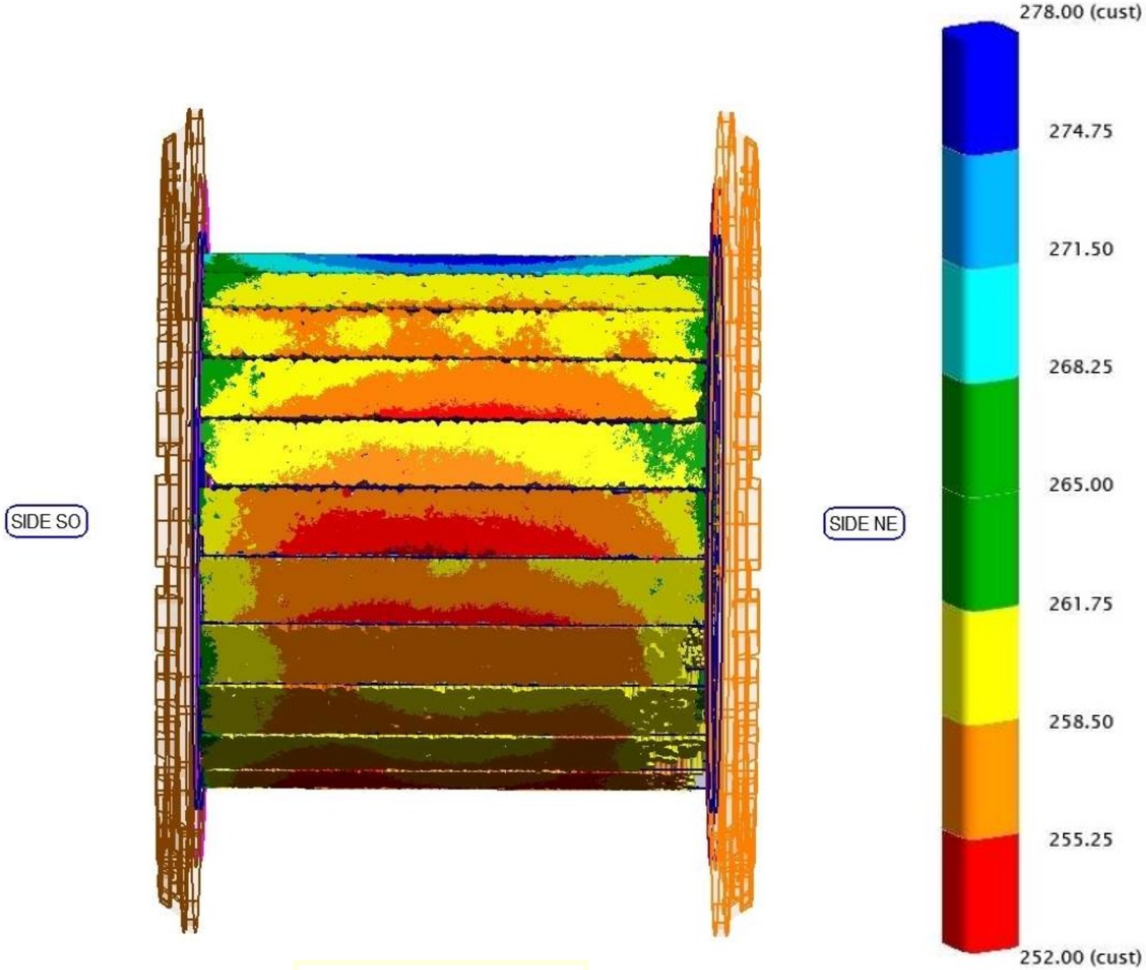
Bottom plane reconstructed by accessible points on the Aluminum backplane at both module ends

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

ECAL geometry survey

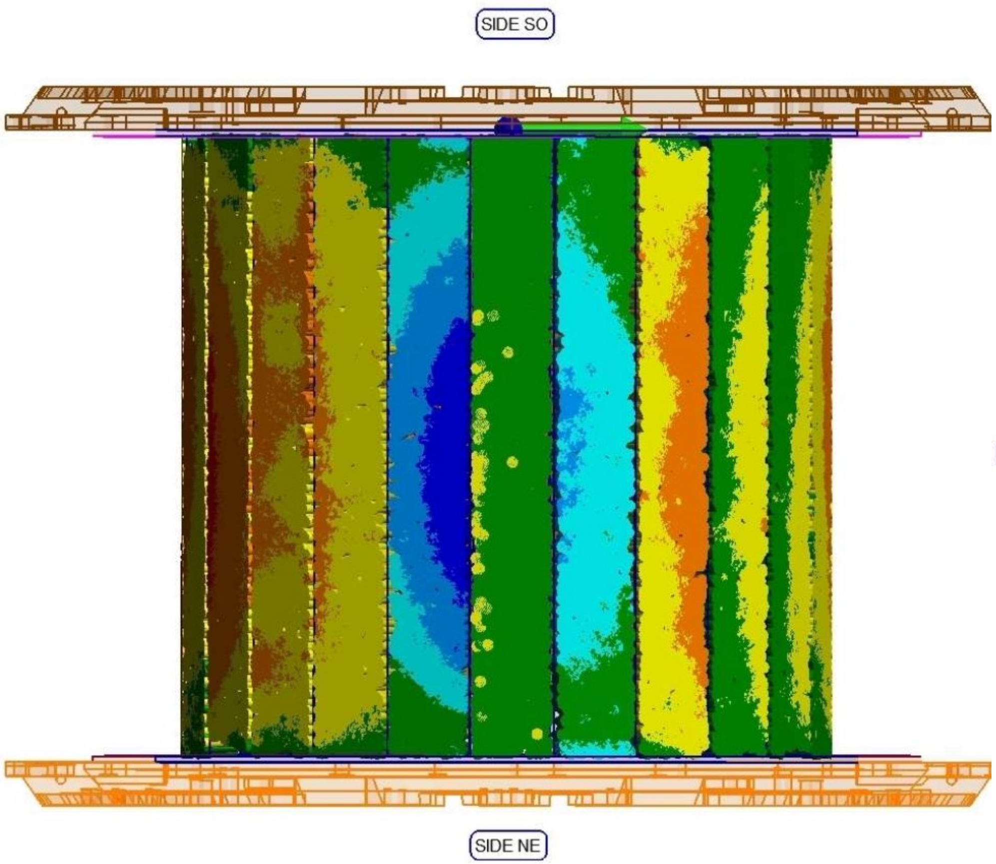


Bottom side

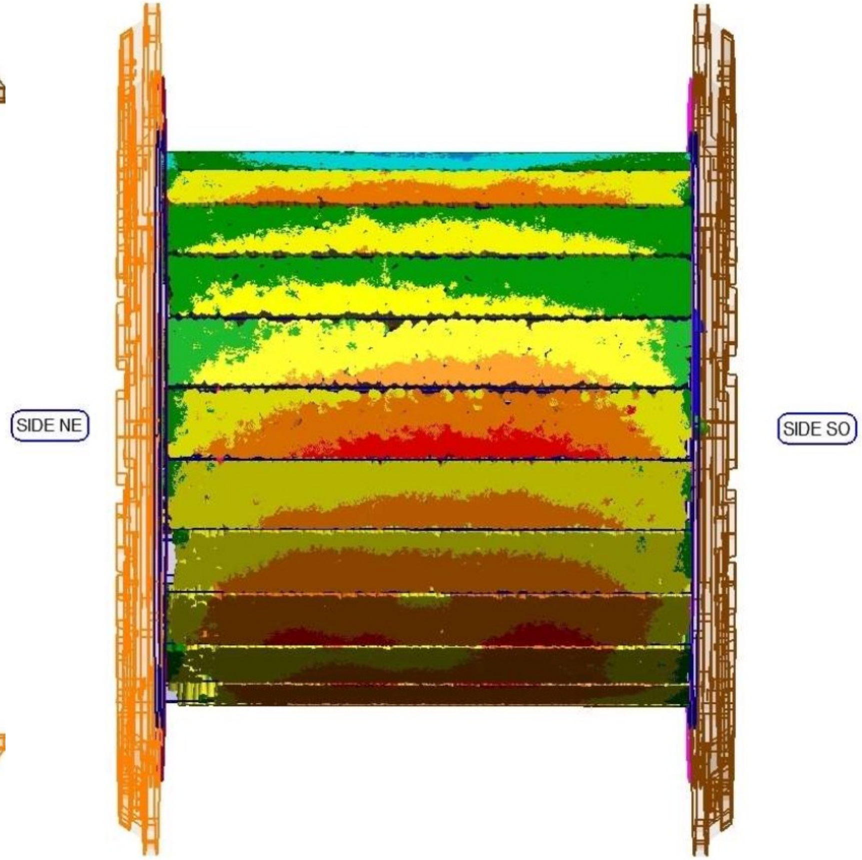


Right side

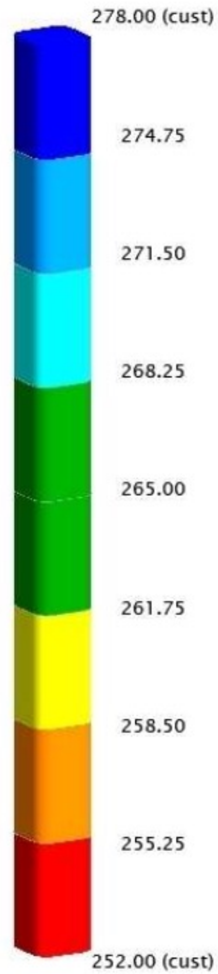
ECAL geometry survey



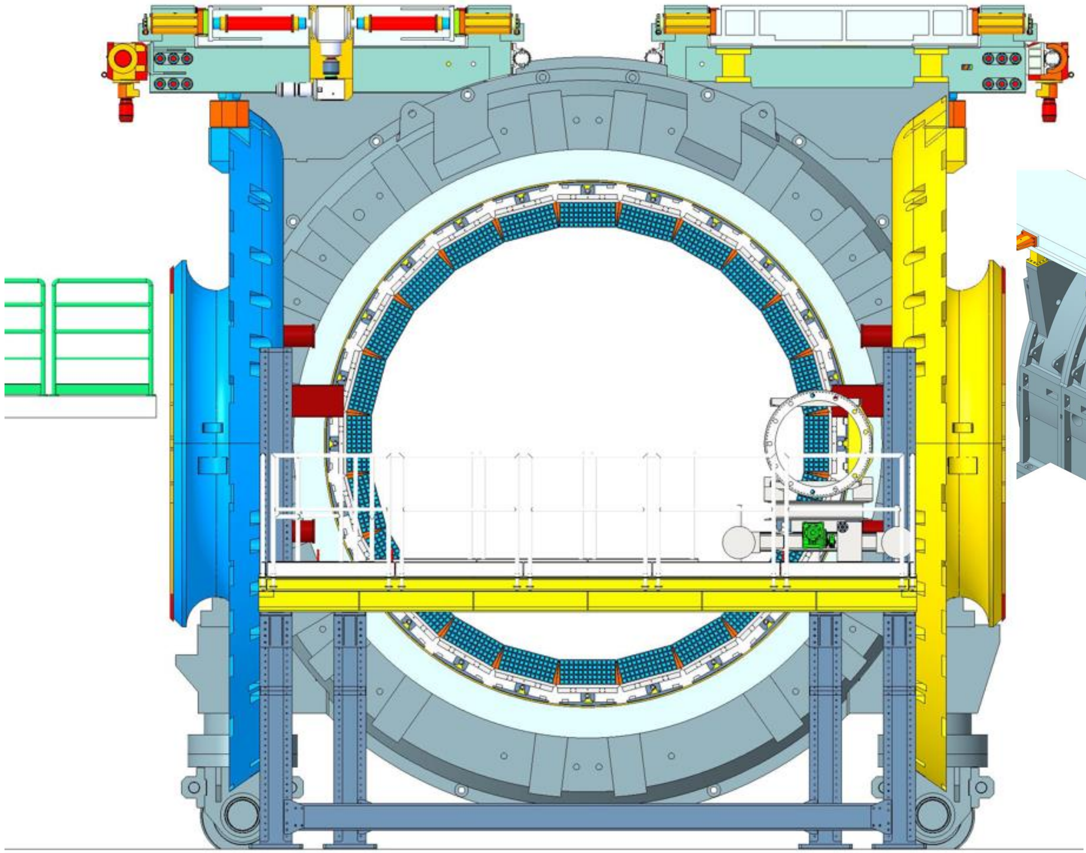
Top side

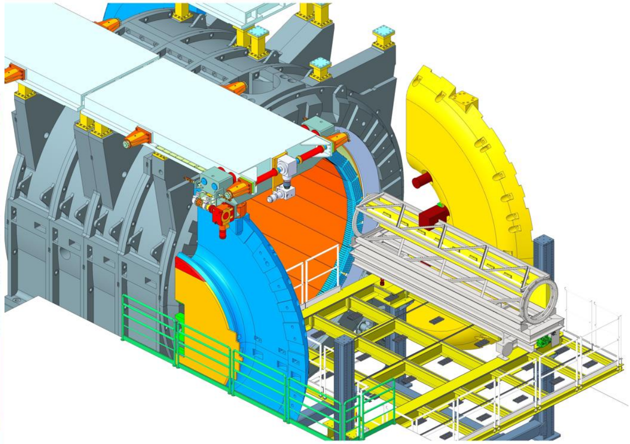


Left side



Extraction of barrel modules: movable platform

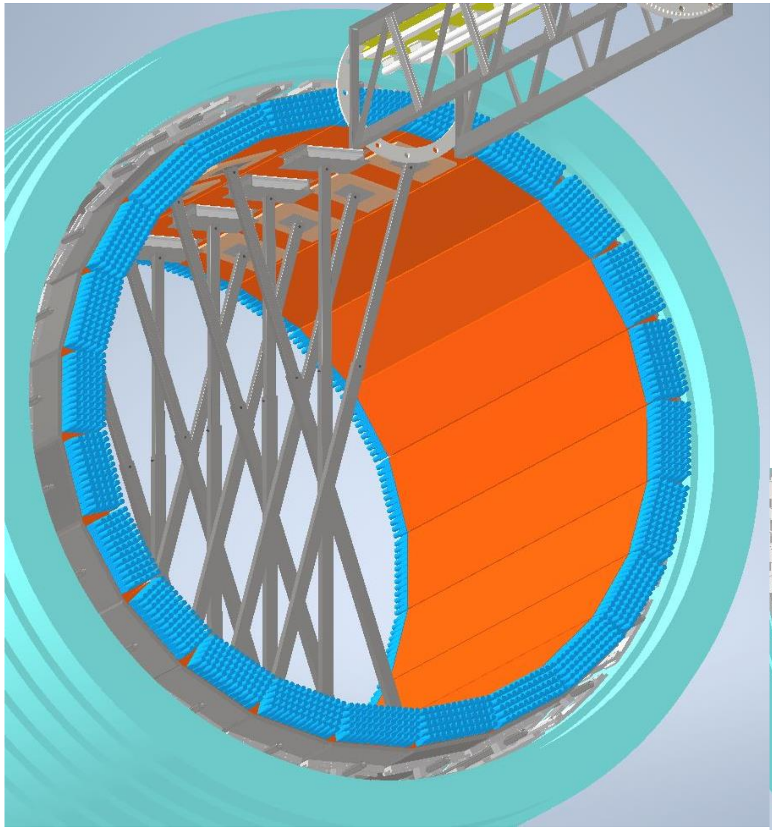




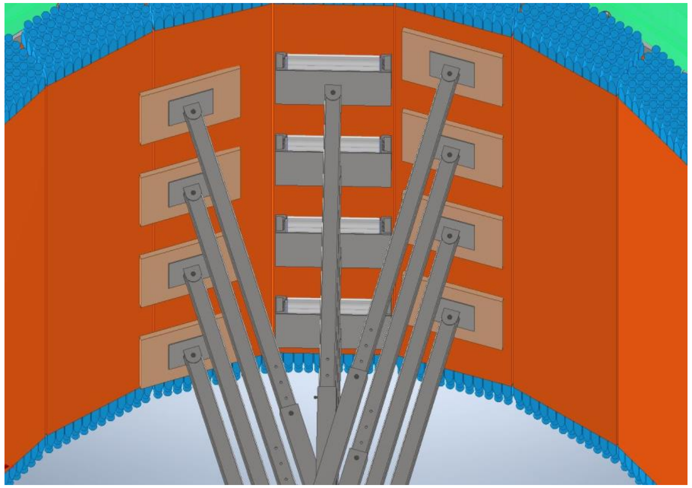
Extraction tool fully revamped and ready

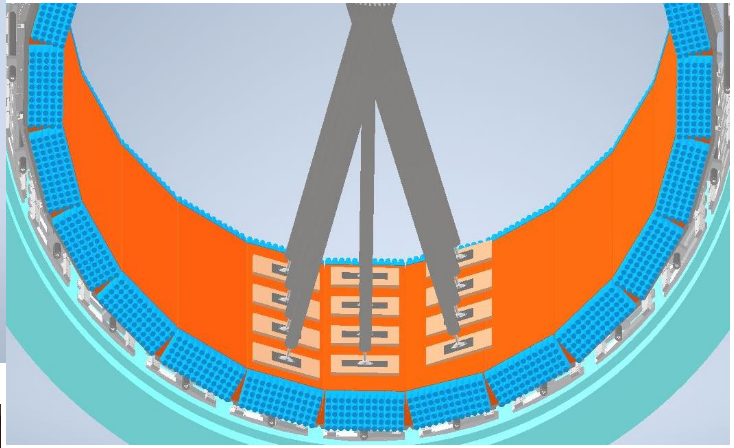
F. Raffaelli – INFN Pisa

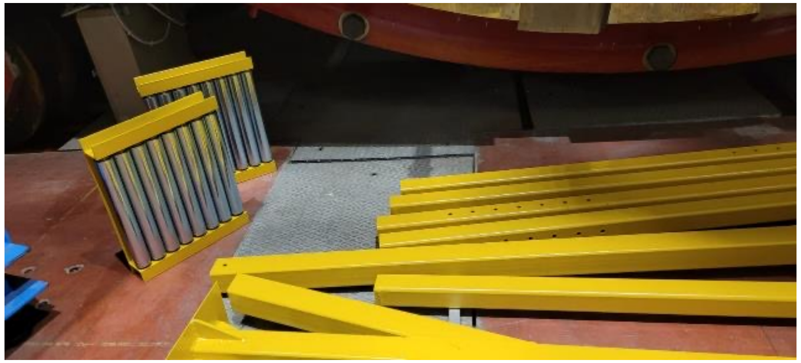
Extraction of barrel modules: rollers and pillars



Support are necessary before extracting modules.



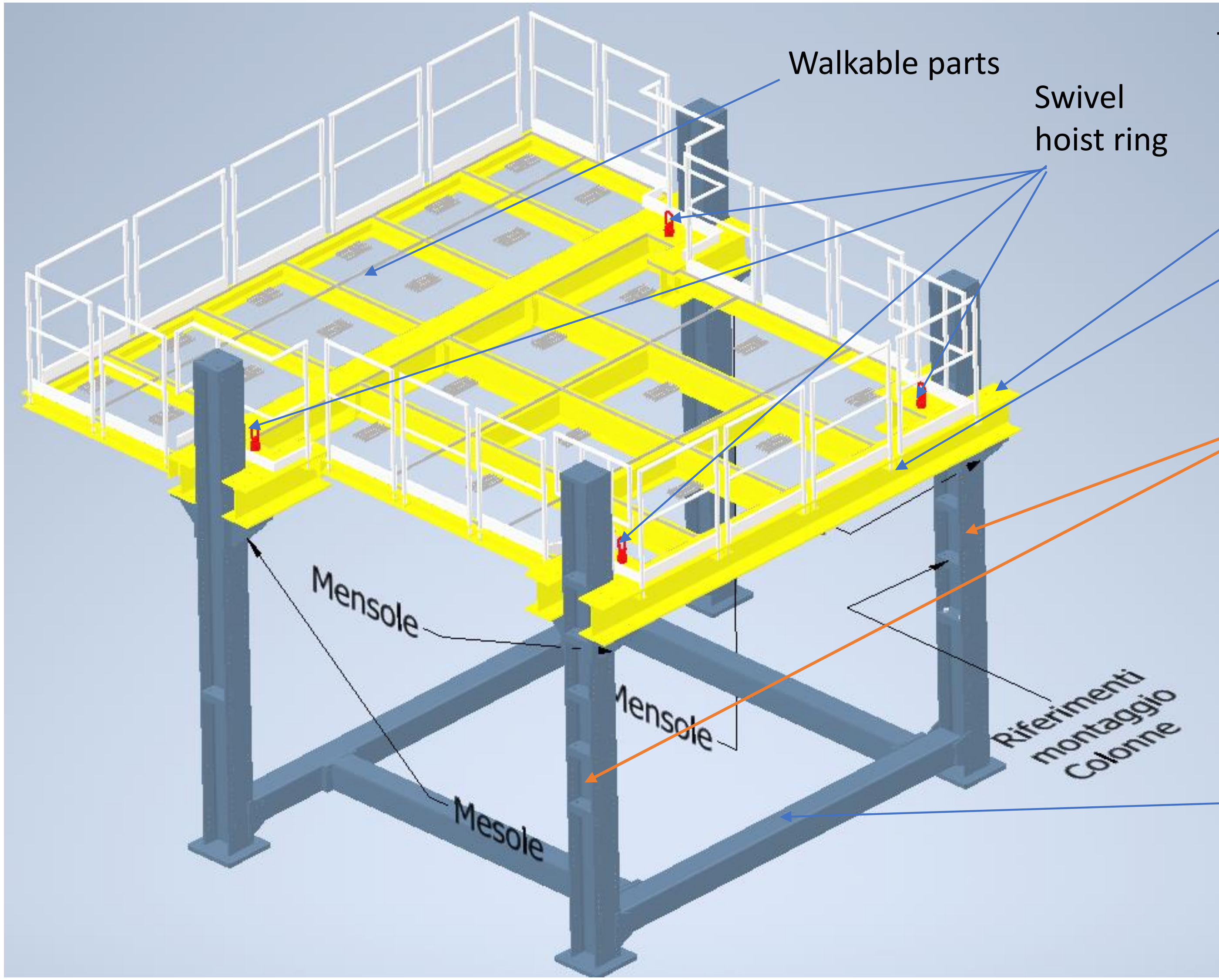




12 rollers mounted on pillars will be placed as a redundant safety support for the extraction of the upper 3 modules.
Built and ready to be mounted in KLOE hall.

F. Raffaelli – INFN Pisa

Extraction of barrel modules: movable platform



Walkable parts

Swivel hoist ring

The top part is made in three main parts

Part that supports the extraction tooling and the calorimeter modules

The two columns closest to the Calorimeter are composed by several pieces that can be removed during the modules dismount.

The lower structure is made in seven main parts: the four vertical columns; the four connecting beams.

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Extraction of barrel modules: movable platform

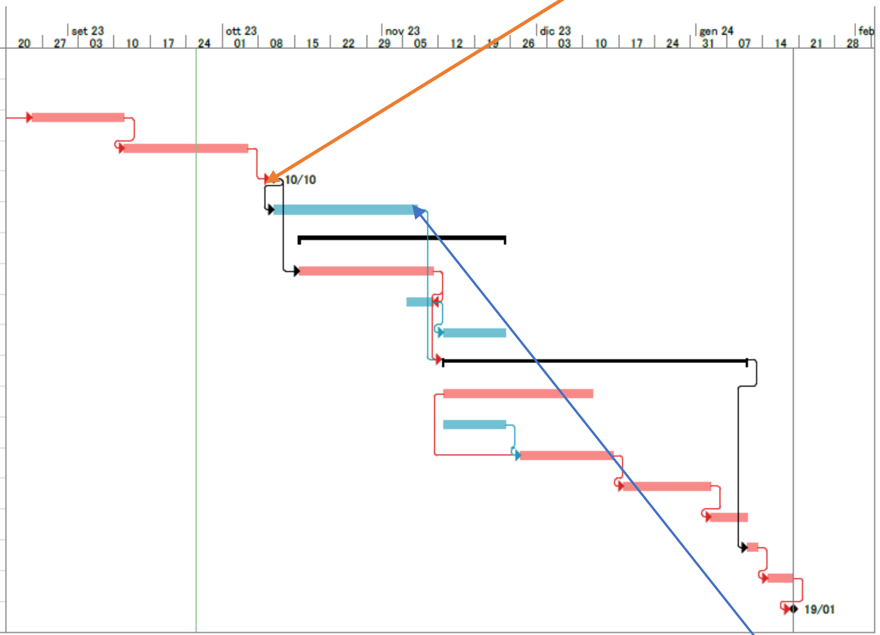
INFN approved the platform design the 17 October
We receive the drawing the 11 of October

39365-WBS

Piattaforma Smontaggio KLOE
Work Breakdown Structure

Fantini Sud Spa

ID	Nome attività	MILES	Durata	Inizio	Fine
1	Apertura Commessa	M1	0 giorni	ven 21/07/23	ven 21/07/23
2	KOM e rilievi nella sala di KLOE		2 giorni	mar 25/07/23	mer 26/07/23
3	Elaborazione del Progetto Concettuale		12 giorni	ven 25/08/23	lun 11/09/23
4	Definizione del Progetto d'Assieme		18 giorni	mar 12/09/23	gio 05/10/23
5	Approvazione del Progetto d'Assieme	M2	0 giorni	mar 10/10/23	mar 10/10/23
6	Approvvigionamento dei materiali		20 giorni	mer 11/10/23	mar 07/11/23
7	Progettazione di dettaglio		30 giorni	lun 16/10/23	ven 24/11/23
8	Elaborazione dei disegni di dettaglio		20 giorni	lun 16/10/23	ven 10/11/23
9	Analisi di rischio		5 giorni	lun 06/11/23	ven 10/11/23
10	Documentazione e manuali		10 giorni	lun 13/11/23	ven 24/11/23
11	Produzione		36 giorni	lun 13/11/23	mer 10/01/24
12	Lavorazioni di carpenteria		20 giorni	lun 13/11/23	lun 11/12/23
13	Programmazione CAM		10 giorni	lun 13/11/23	ven 24/11/23
14	Lavorazioni di MUT		13 giorni	mar 28/11/23	ven 15/12/23
15	Trattamenti superficiali		7 giorni	lun 18/12/23	mer 03/01/24
16	Premontaggio		5 giorni	gio 04/01/24	mer 10/01/24
17	Collaudo in fabbrica (FAT)	M3	2 giorni	gio 11/01/24	ven 12/01/24
18	Smontaggio, imballaggio e trasporto		5 giorni	lun 15/01/24	ven 19/01/24
19	Consegna a Frascati		0 giorni	ven 19/01/24	ven 19/01/24

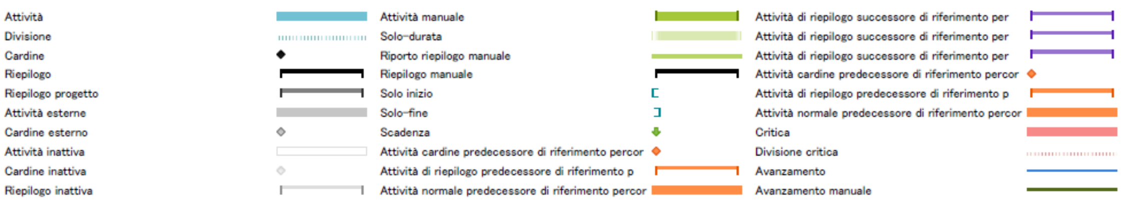


The order for material was placed on Tuesday 31 October.

Drawings for the execution of the platform will be ready in the next few days.

Expected delivery of Materials (21-27 November)

Progetto: msproj11
Data: mar 26/09/23



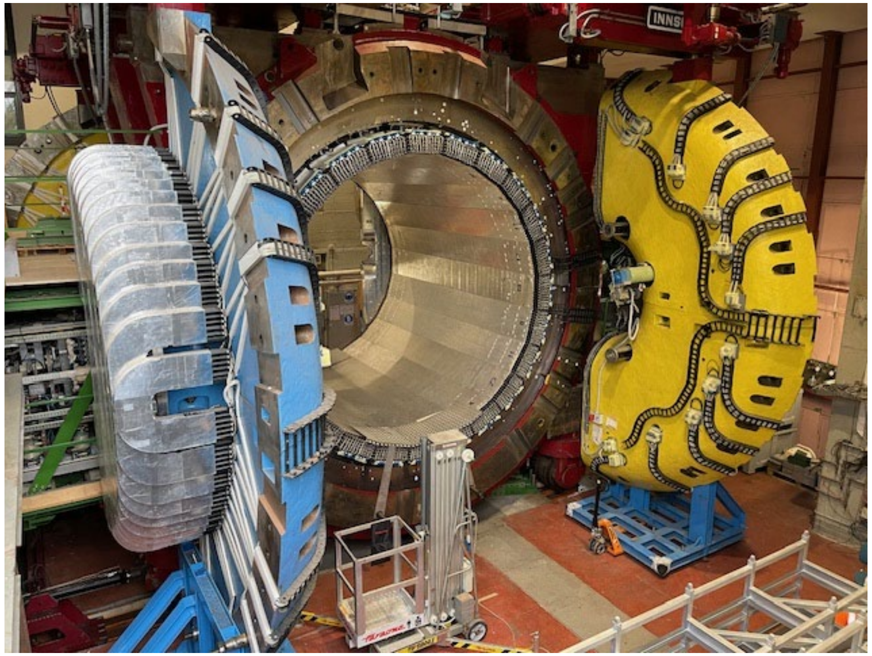
F. Raffaelli – INFN Pisa

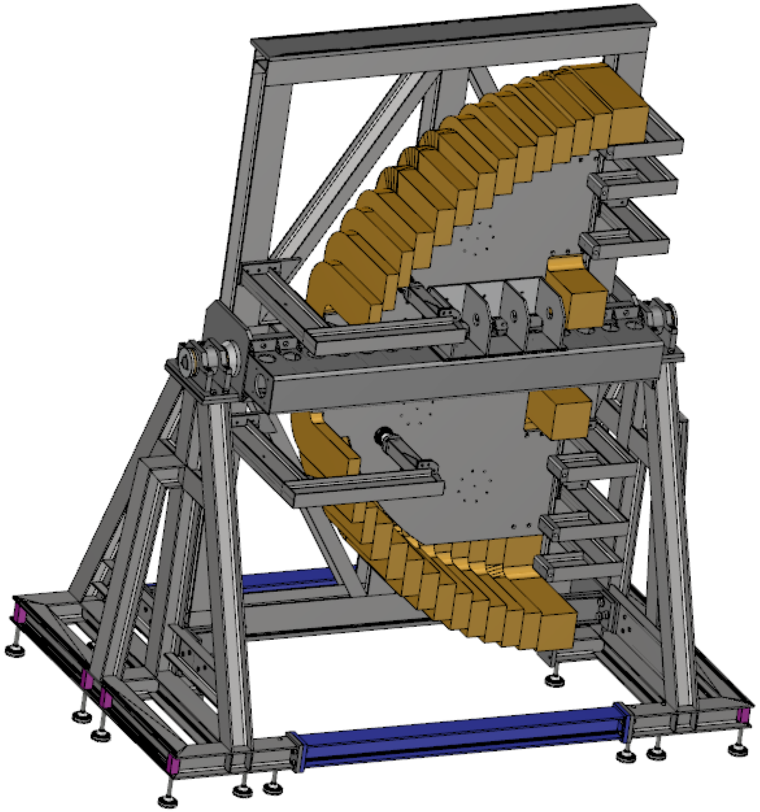
Dismounting of End-cap modules

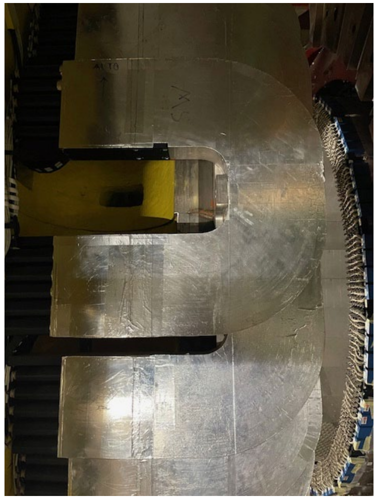
Tools are being revamped (non-destructive structural analysis done), some parts replaced.

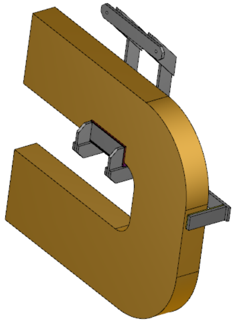
F. Noto – INFN LNS

Dismounting of End-cap modules





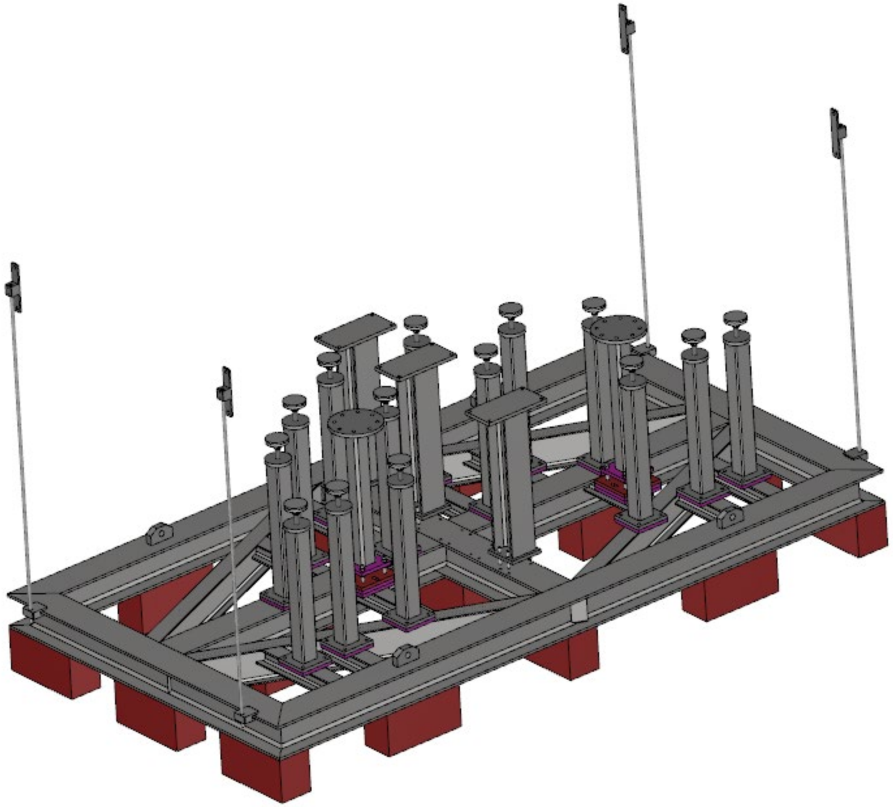


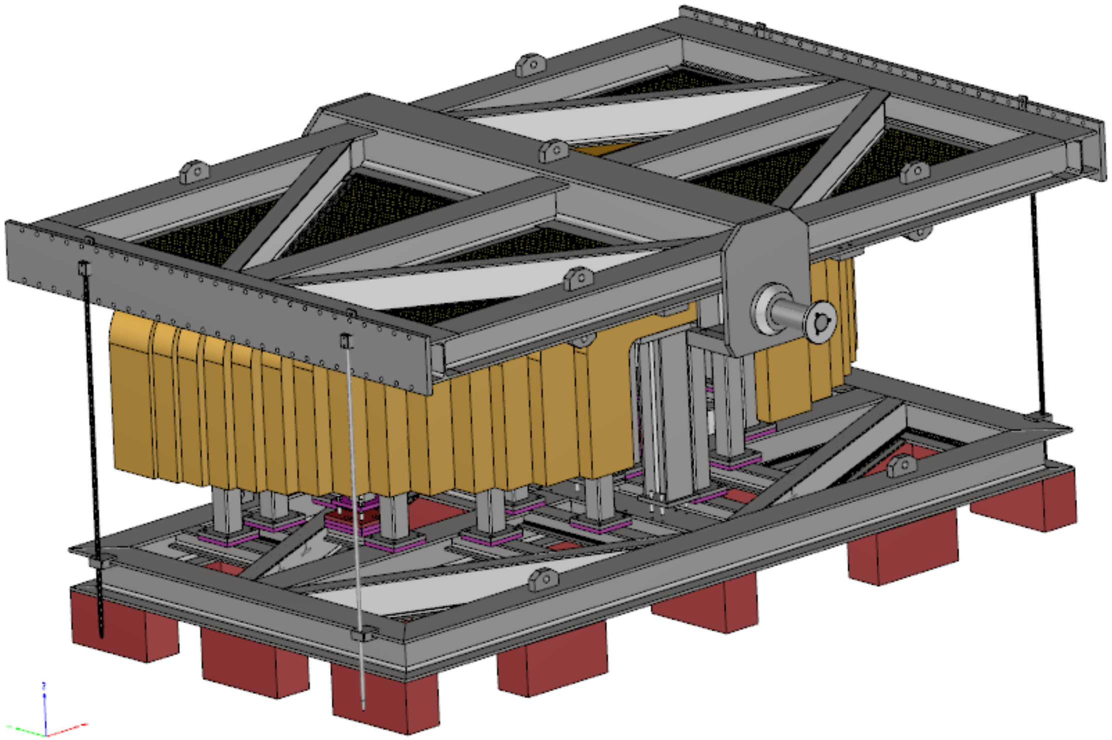


Design of supports for handling and transportation of each half End-cap completed

F. Noto – INFN LNS

Dismounting of End-cap modules





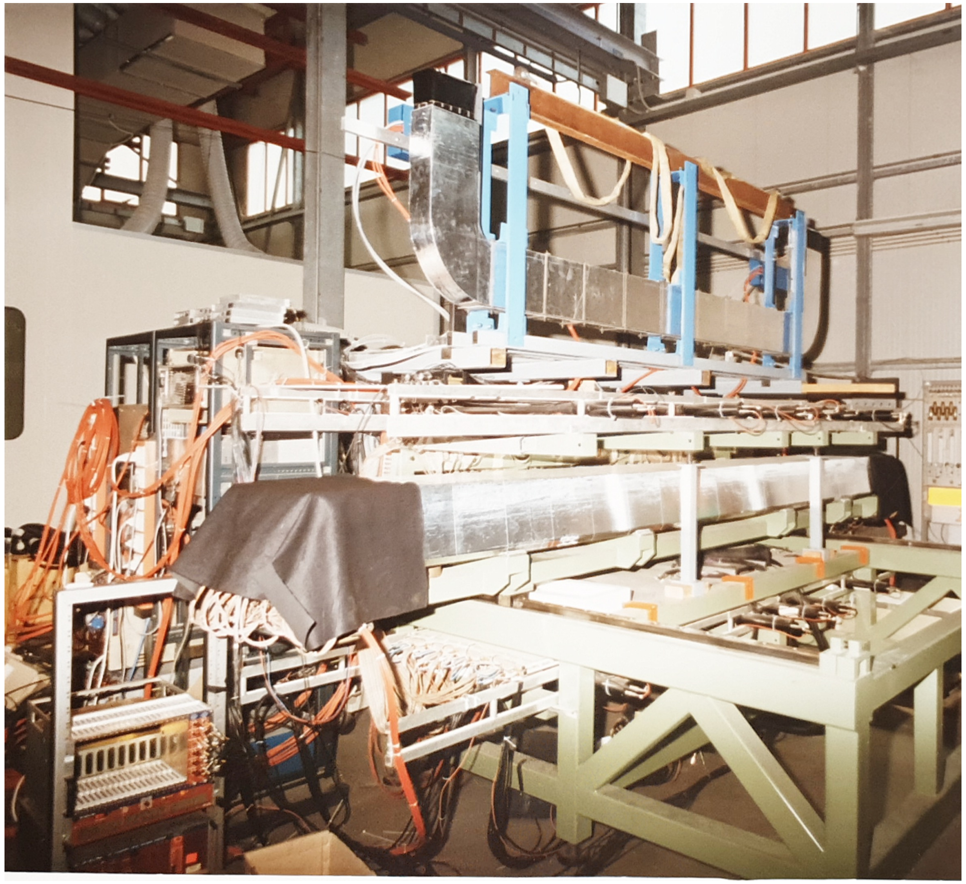
Design of supports for handling and transportation of each half End-cap completed

Tools ready and start dismounting End-Cap modules foreseen by mid-April 2024

F. Noto – INFN LNS

ECAL module refurbishment and test

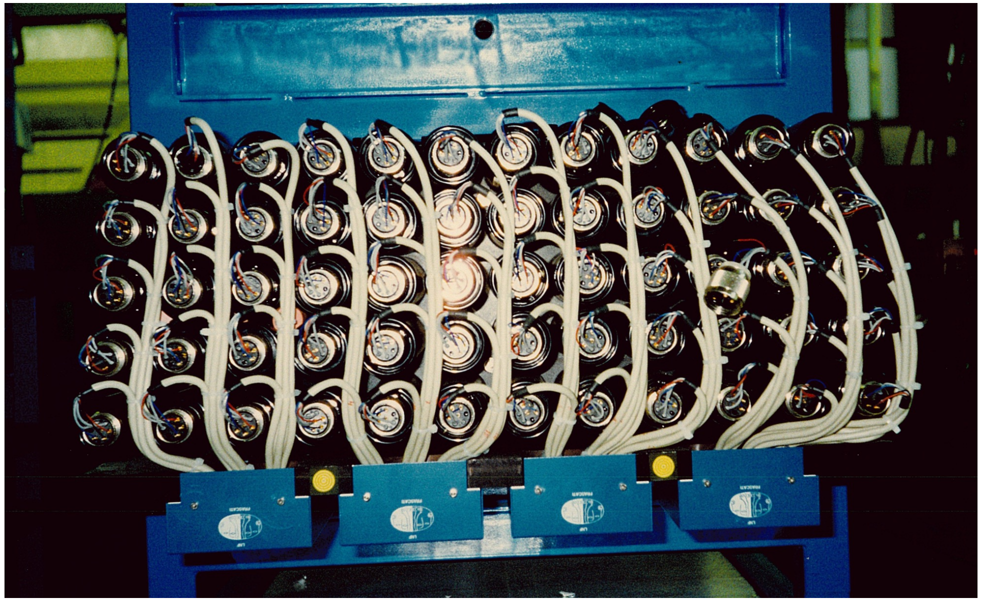
- After dismounting operation, the special protective adesive tape of all barrel modules has to be replaced
- light tightness to be checked
- test basic performance with cosmics rays
- test FEE prototypes



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

ECAL module refurbishment and test



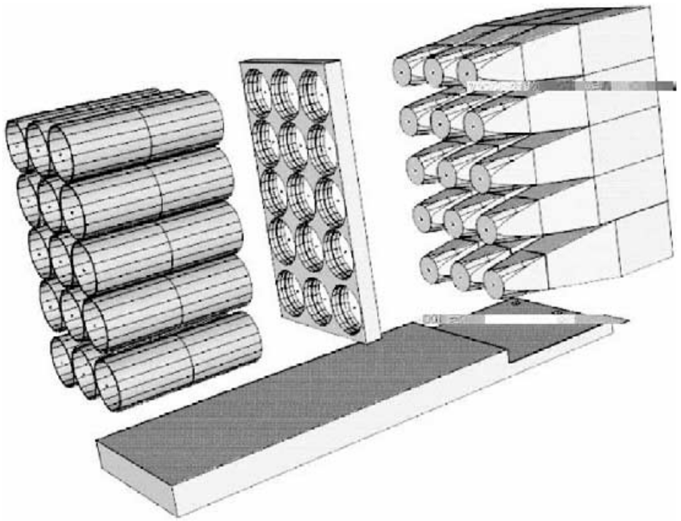
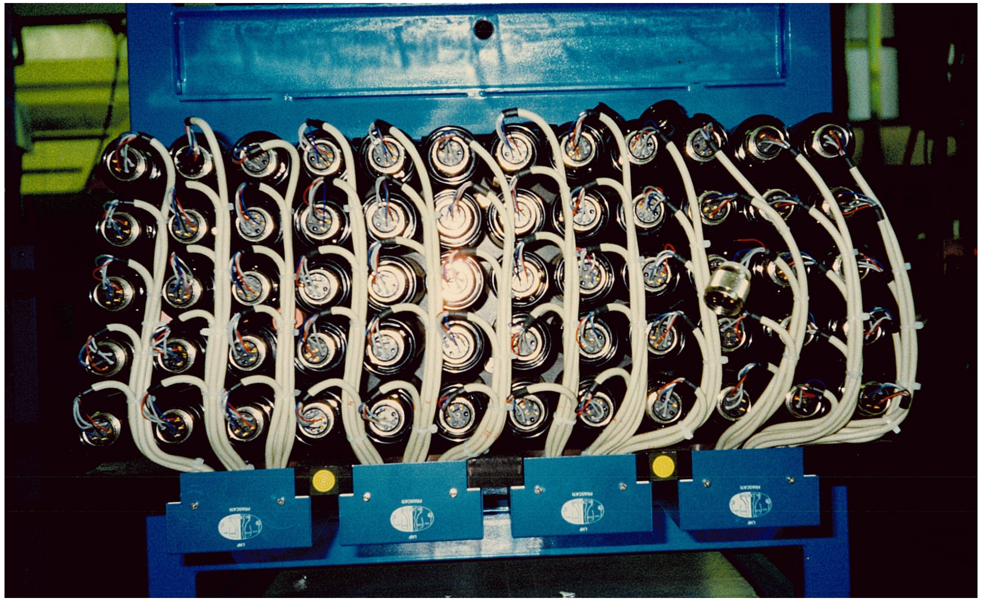
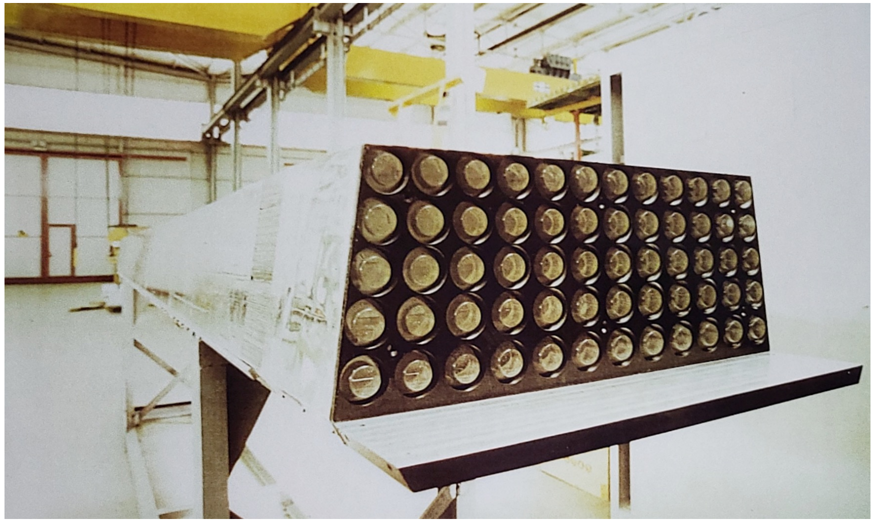


Fig. 4. Exploded view of the PM box.

ECAL module refurbishment and test

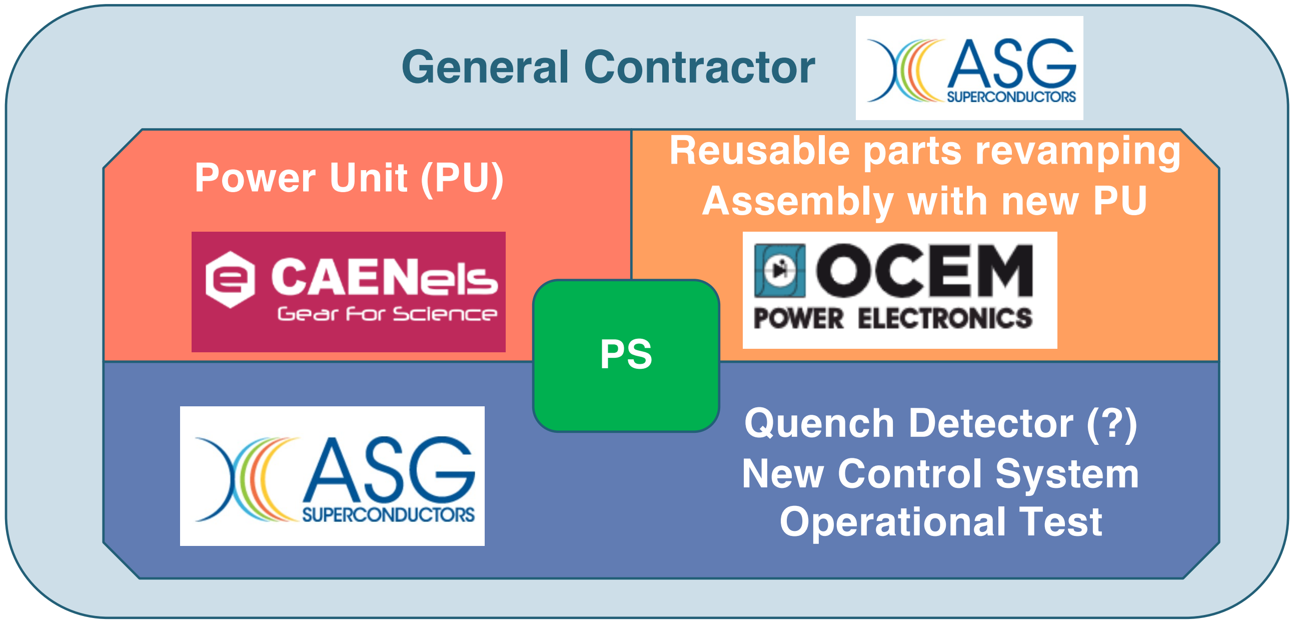




MAGNET New Power Supply Procurement

We want a new Power Supply (PS) keeping 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

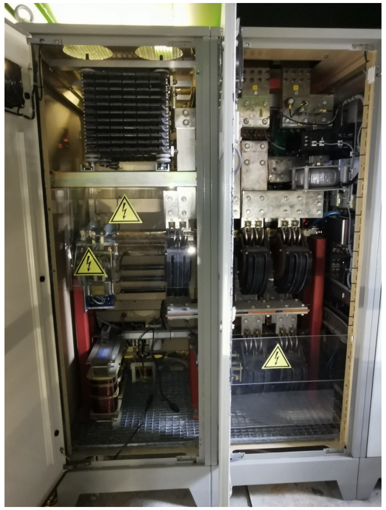
8 TDK-Lambda Genesys+ (375A, 20V) in parallel with CAEN-REGUL8OR regulation unit customized with our interlock interface (all USA standard compliant)

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

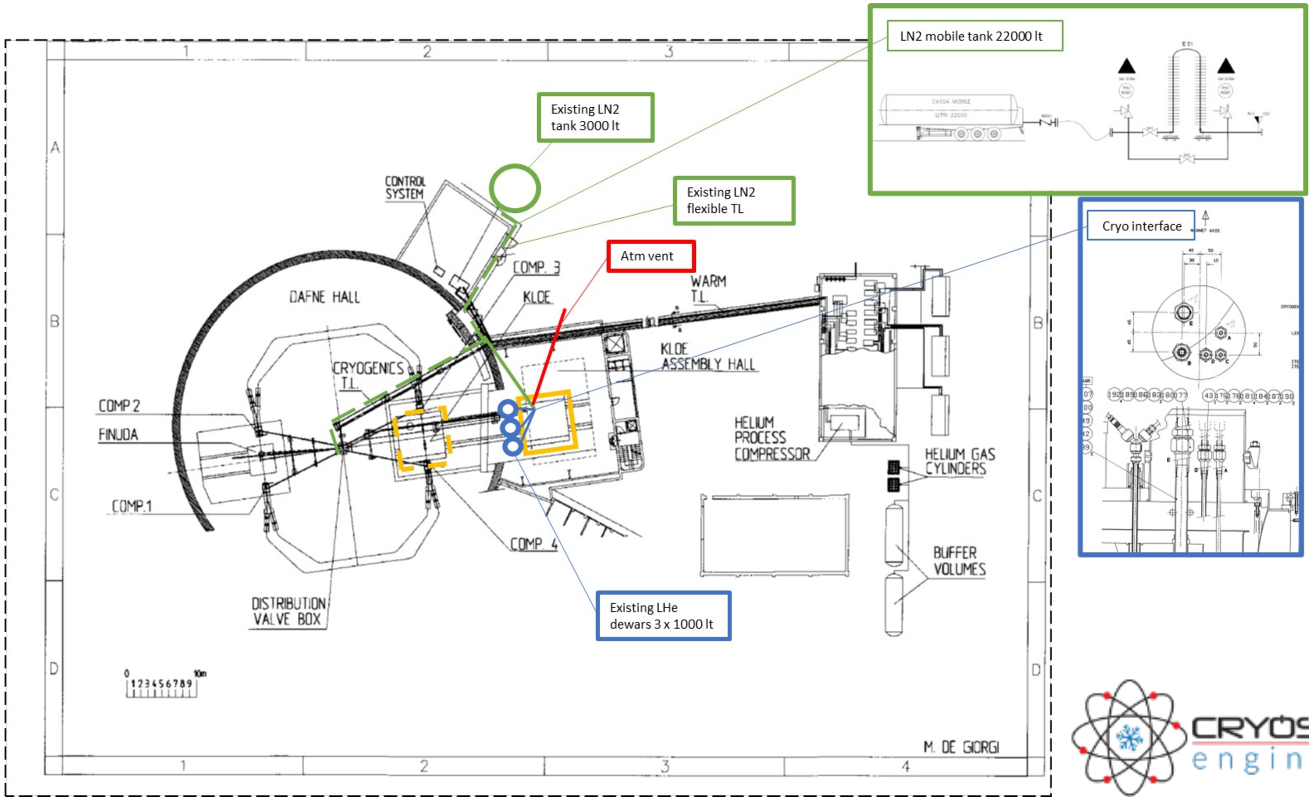


KLOE PS Dump resistor and contactors

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

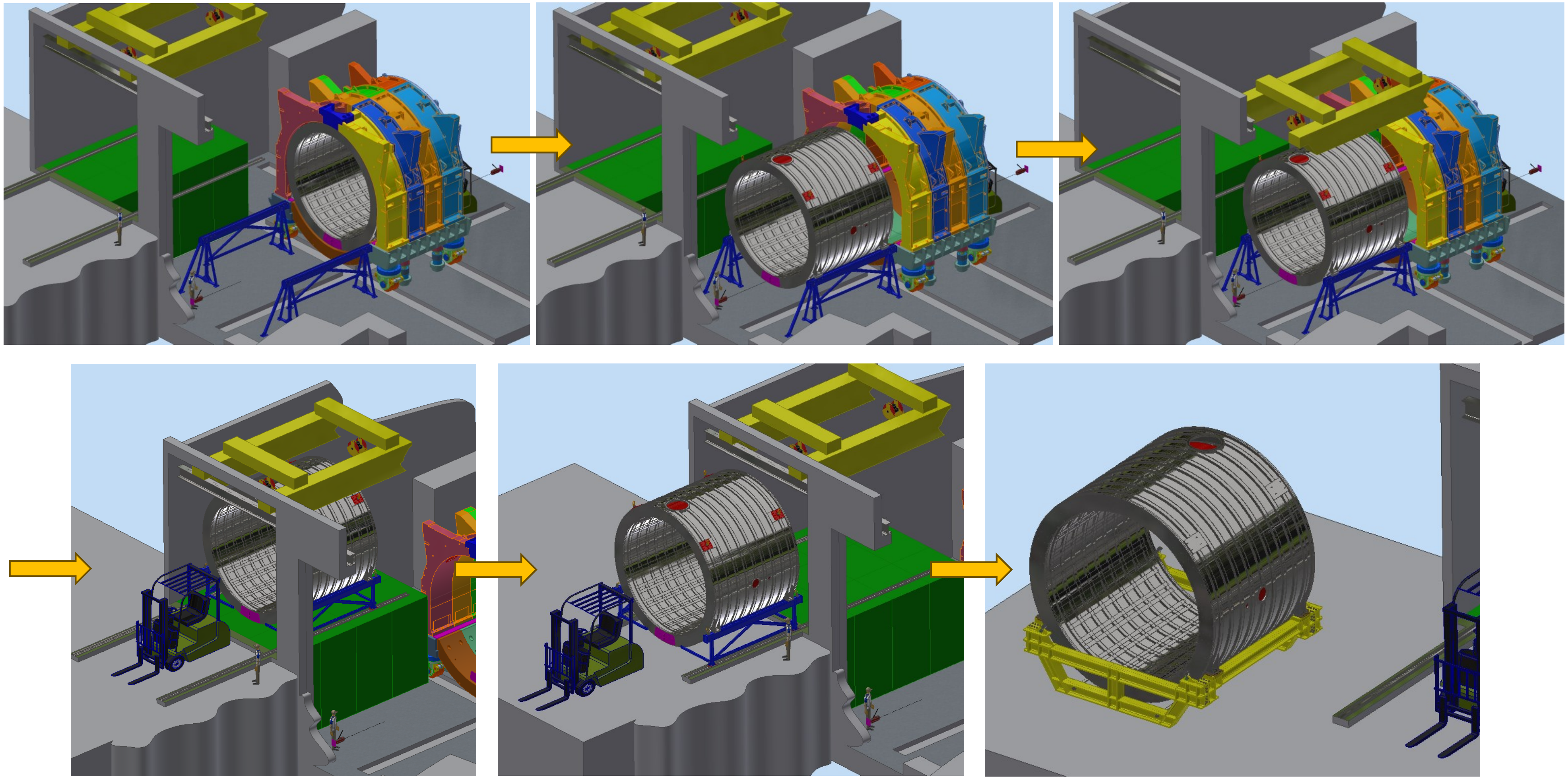
Procurement

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

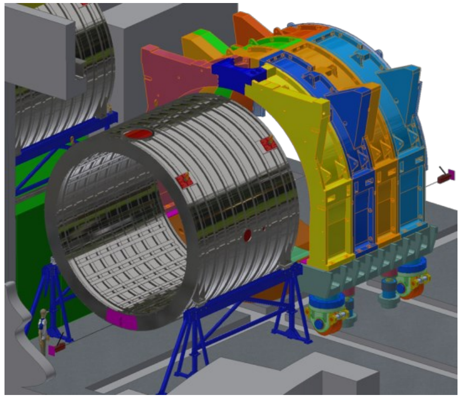


A. Saputi – INFN LNS

Coil extraction and transportation

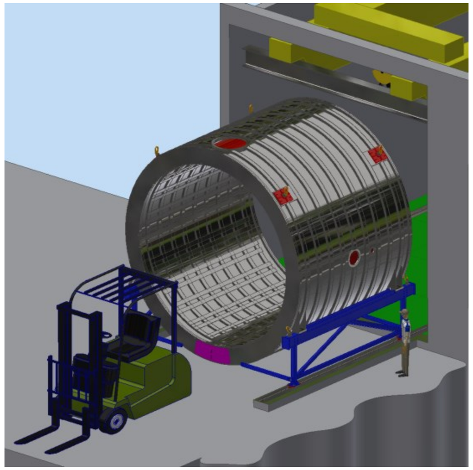
Main services, structures and tools for extraction

Crane = 22 t + 22 t

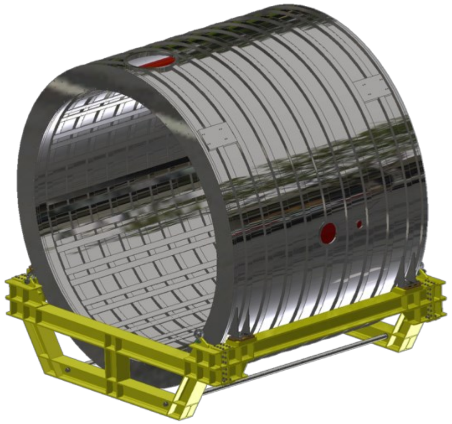


Extraction/Insertion Tool

Loading Dock



Trolley System



Cradle

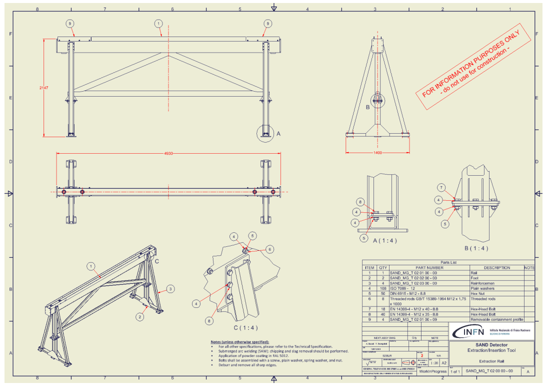
Lugs

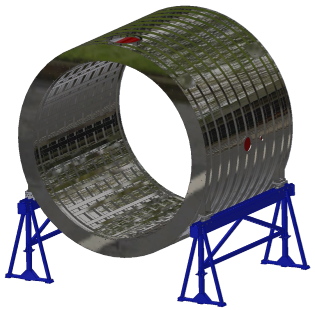
The existing loading dock will be refurbished and enlarged on purpose

A. Saputi – INFN LNS

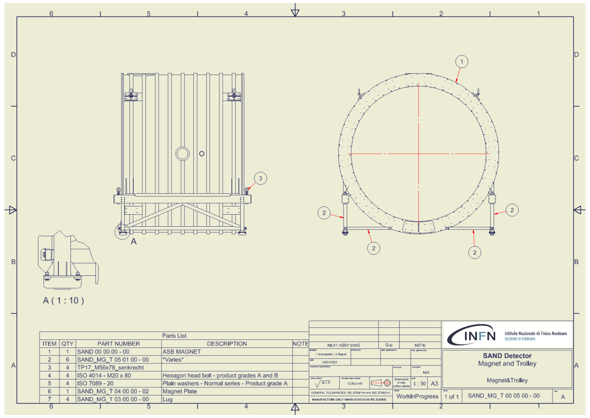
Coil extraction and transportation

Main services, structures and tools for extraction





- All workshop drawings are ready
- Technical specification is ready



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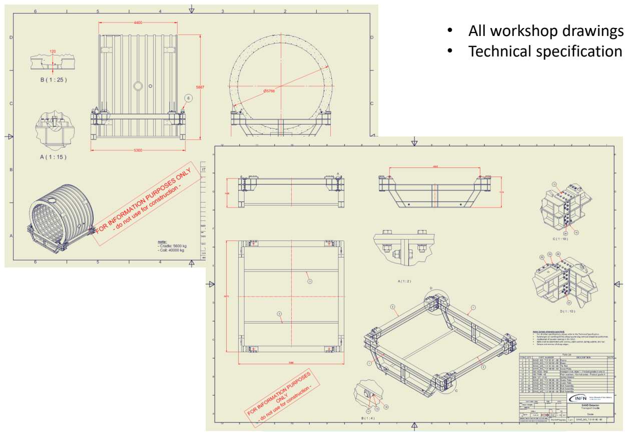

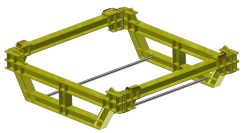

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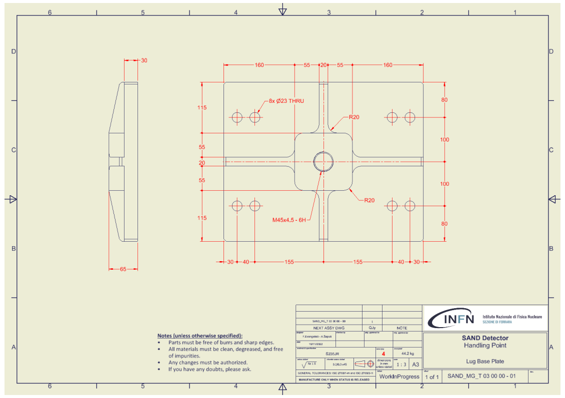
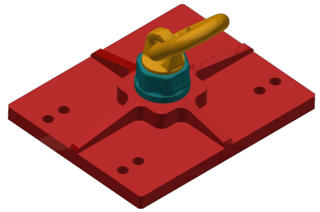
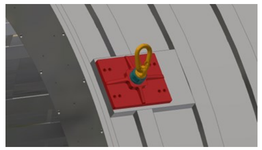


- All workshop drawings are ready
- Technical specification is ready
- Holes centre spacing to be checked

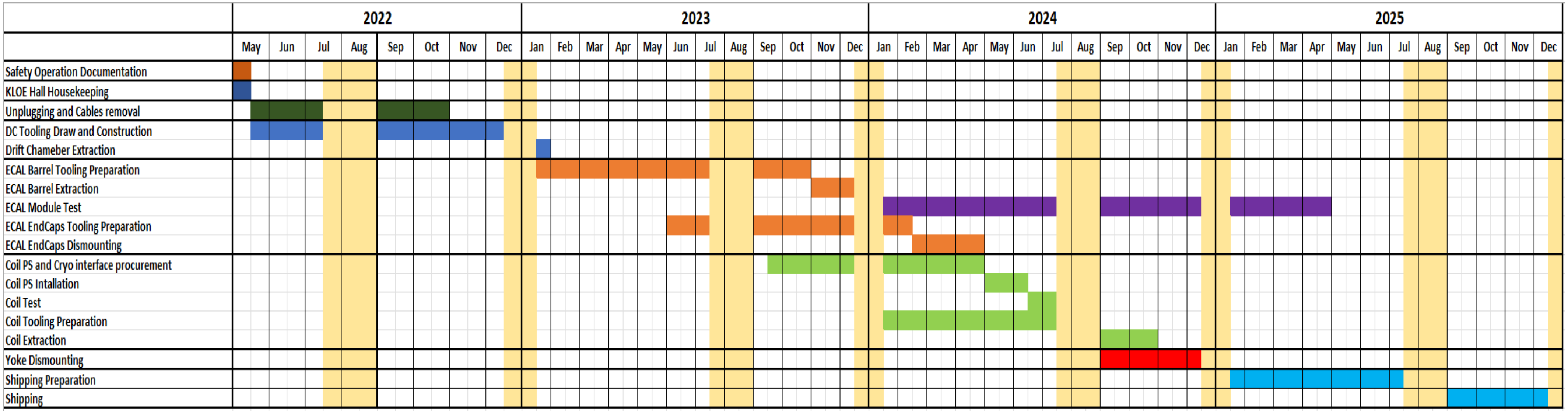




Reverse engineering of vessel
Design and construction of handling and transportation tools
Certification EU and US compliant

A. Saputi – INFN LNS

KLOE-to-SAND: time schedule

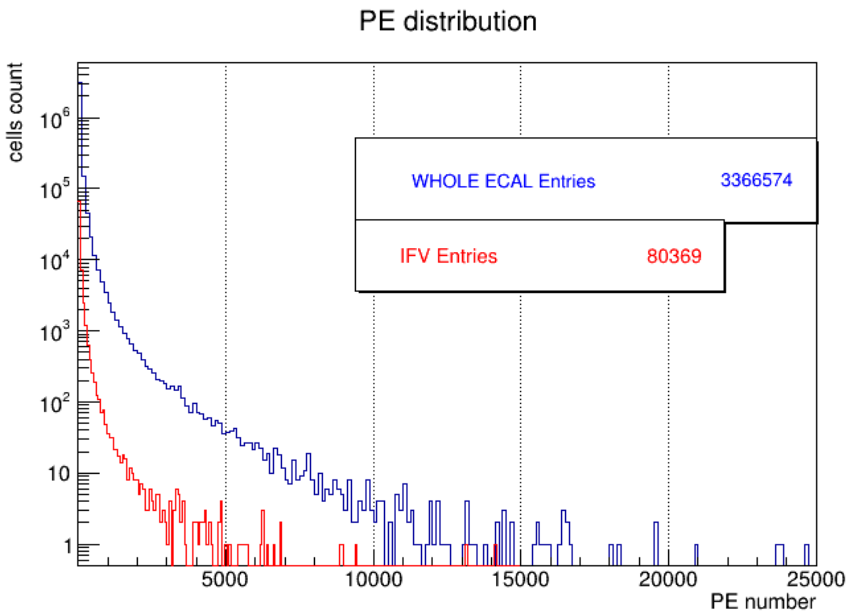


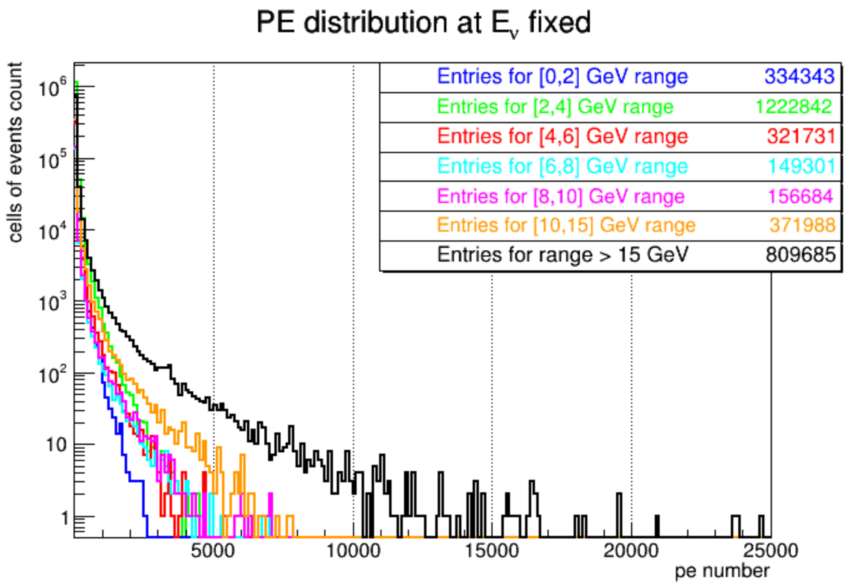
ND-hall availability: 2028

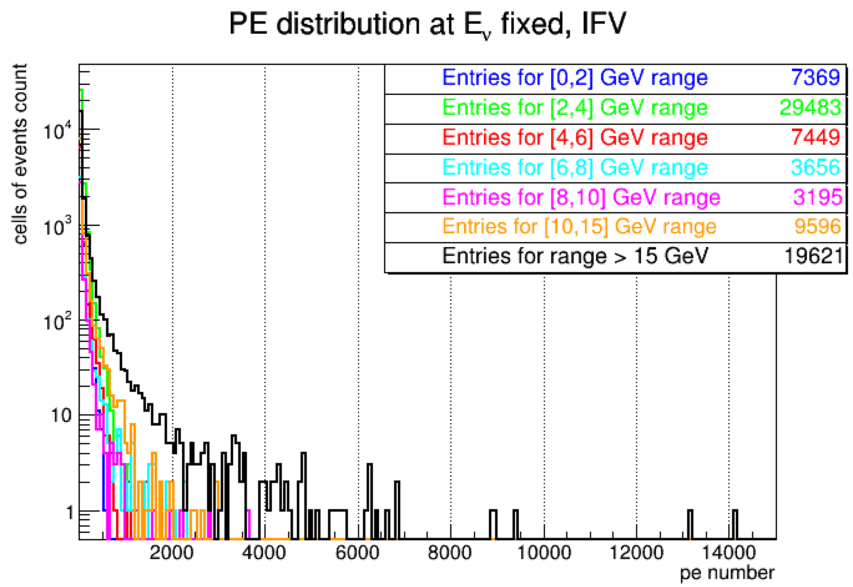
Studies for the optimization of the ECAL working point and FEE

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

Np.e. distributions





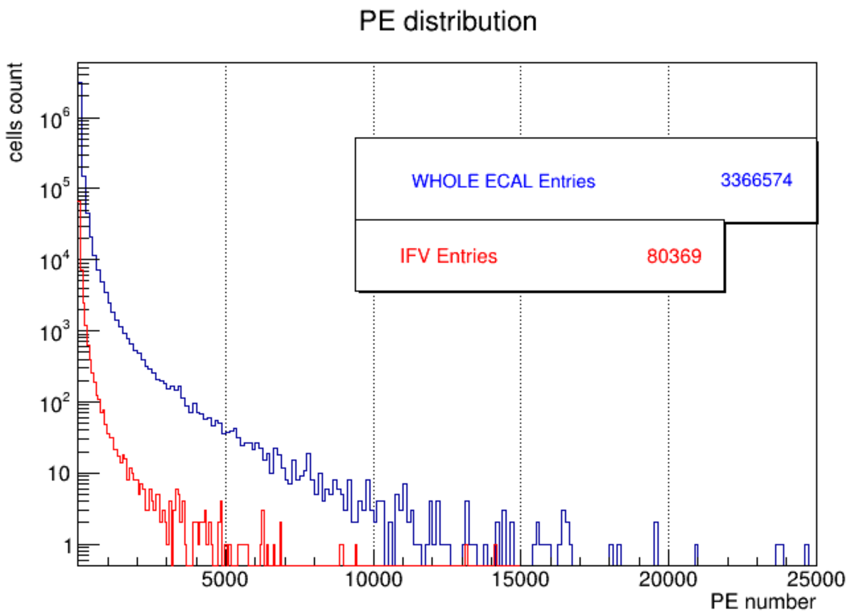


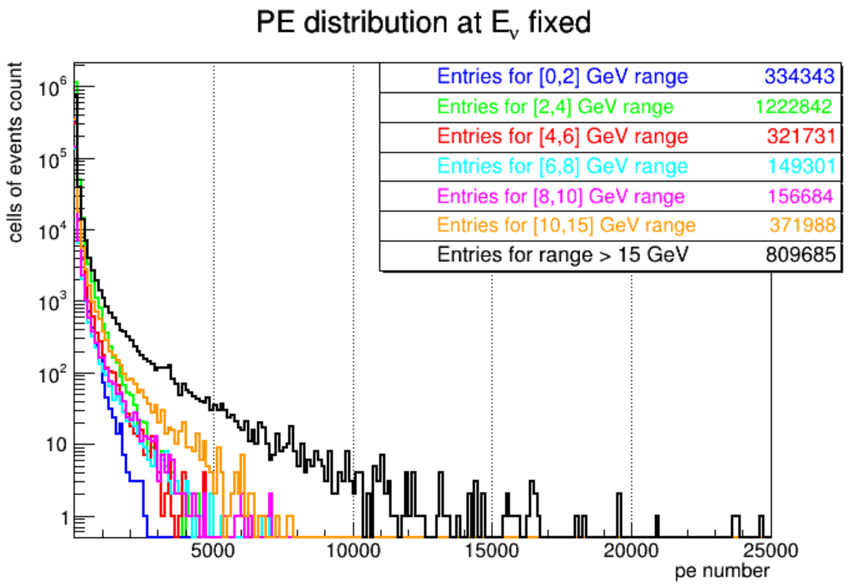
E_ν range = [0,10] GeV	
Events number	101,696
Events cells number	2,184,901

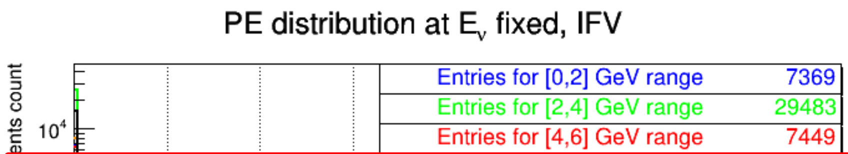
Fraction of events with at least one cell above PE threshold	[%]
1000 PE threshold	2.58
2000 PE threshold	0.49
3000 PE threshold	0.13
4000 PE threshold	$3.64 \cdot 10^{-2}$

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







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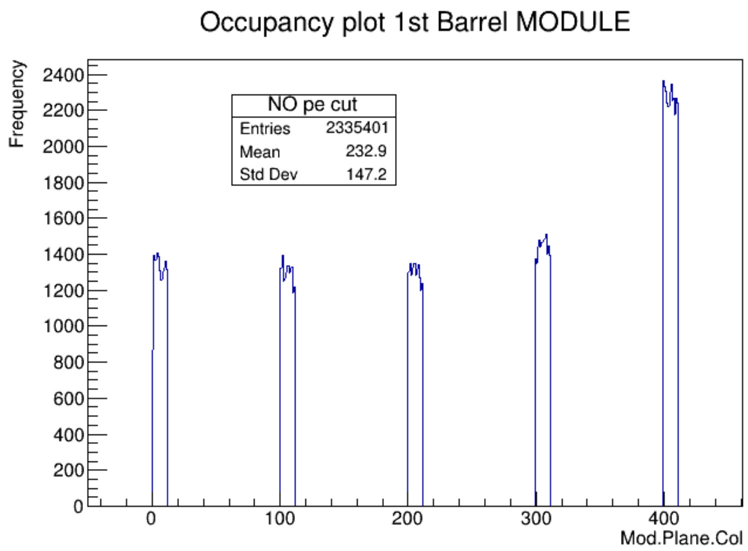
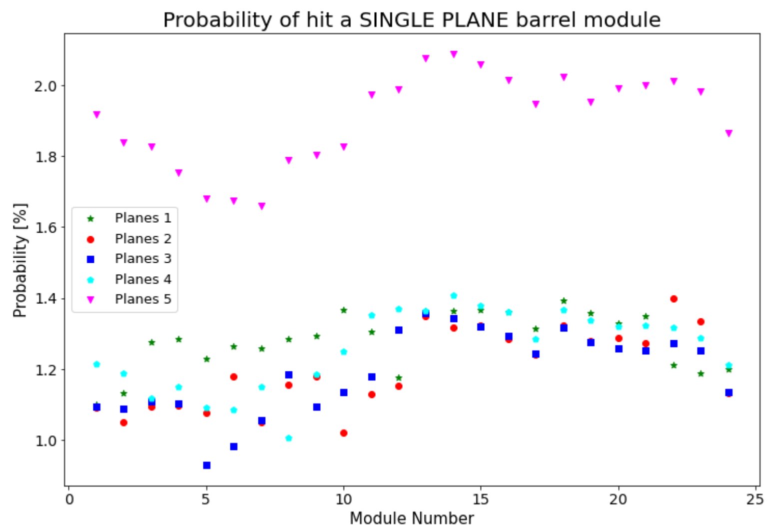
4000 PE threshold	$2.11 \cdot 10^{-3}$

- 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

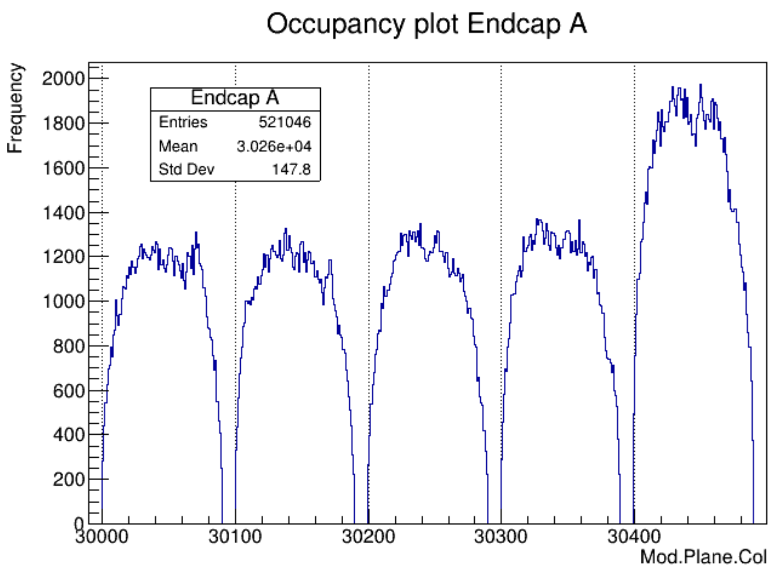
Cell occupancy plots and hit probability



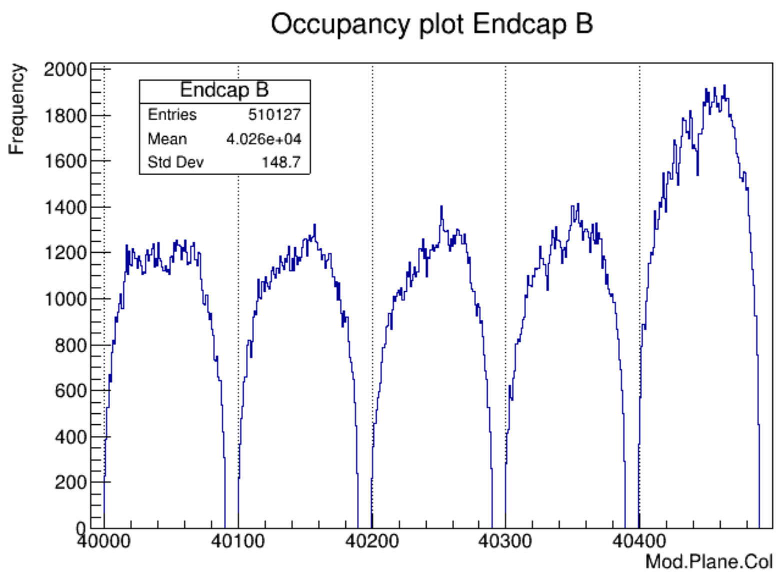
Barrel



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%

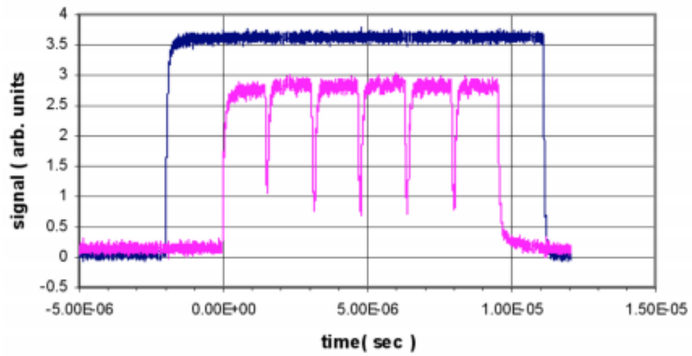
P_{cell} = 1.16%

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



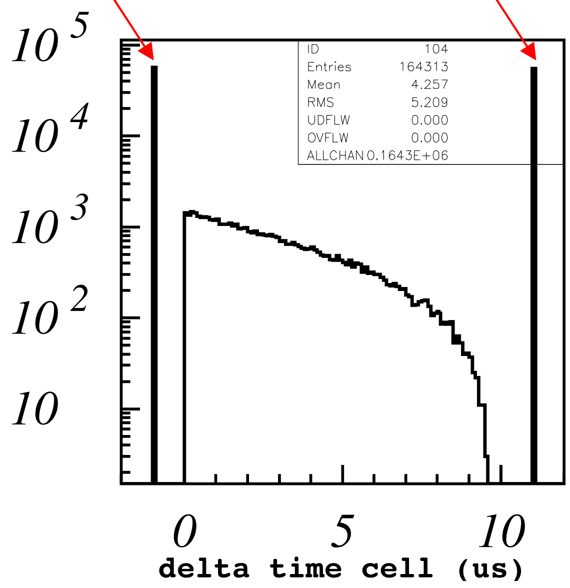
Event rates expected in SAND
~ 84 interactions/spill
$\lesssim$1 interaction/spill in the SAND fiducial volume

(negligible rock muons and cavern background assumed)

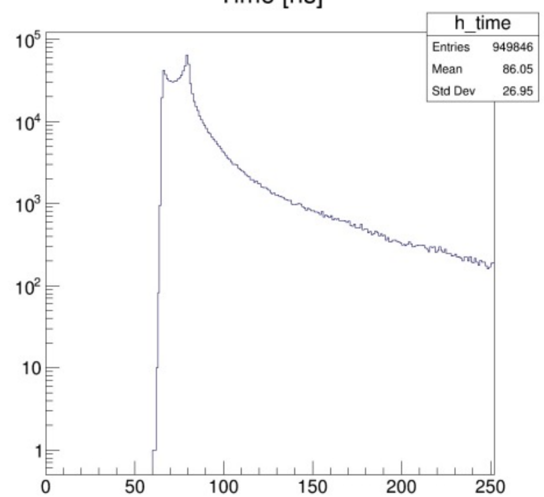
Pile-up probability

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.



	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



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

Pile-up probability

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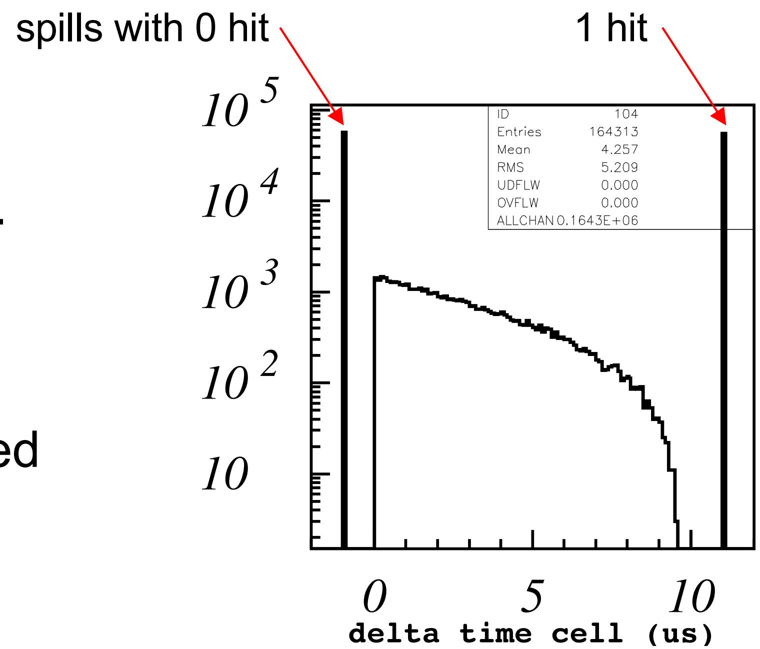

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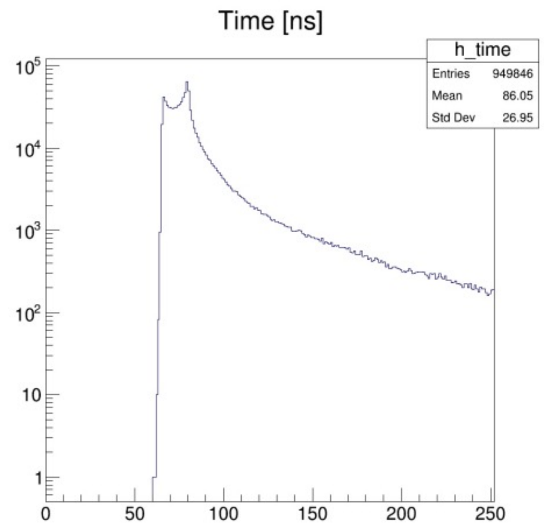


Time propagation/smearing of hits in a single neutrino interaction event.

PMT signal and discriminator threshold in KLOE

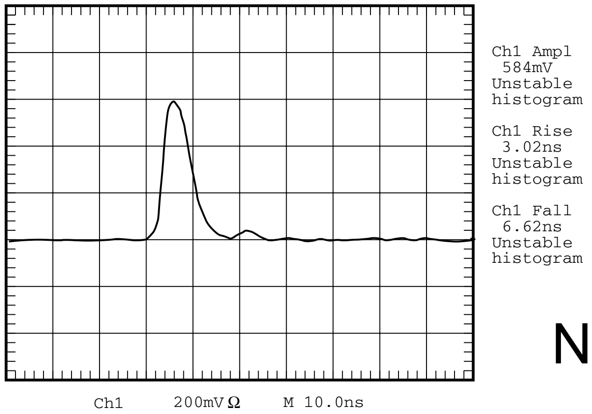
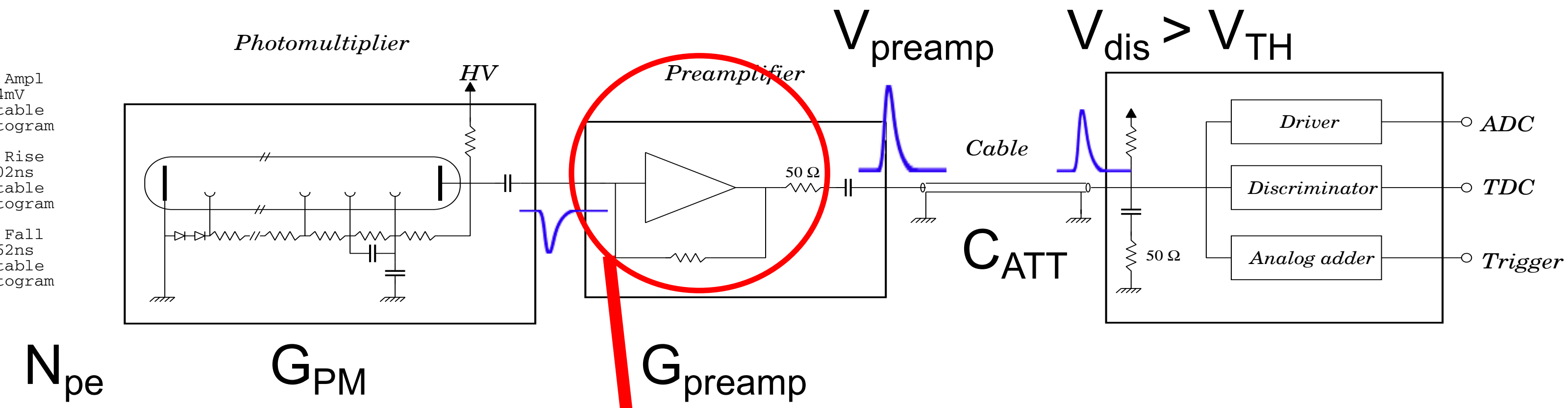
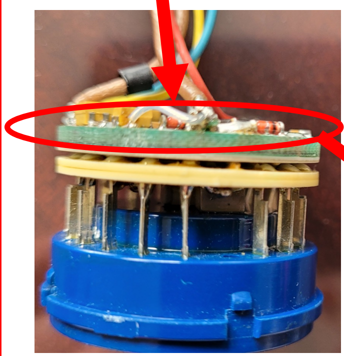


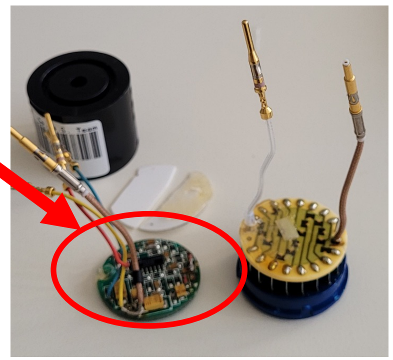
Figure 4: Typical signal from the PM base.

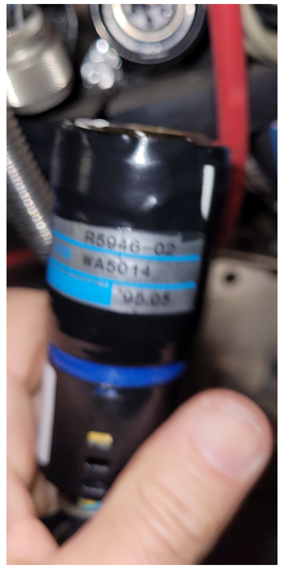


Constraints:

- 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

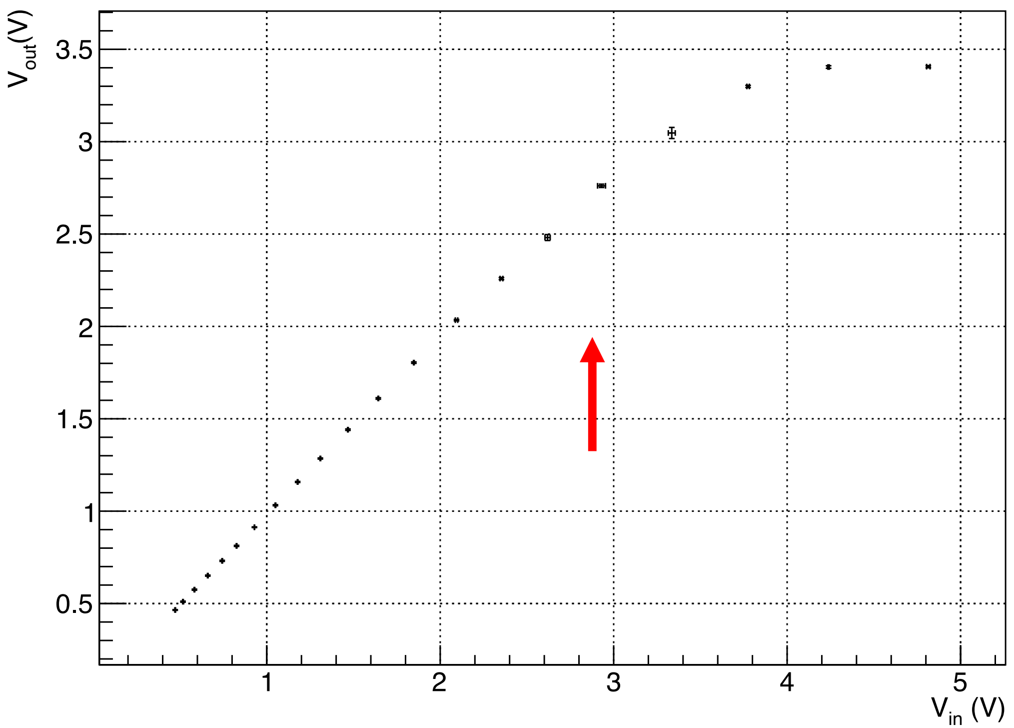
In this specific case (negligible cable length) we expect:
$V_{dis}(max) = V_{preamp}(max) \bullet\ 0.5\ = 2.35$ V

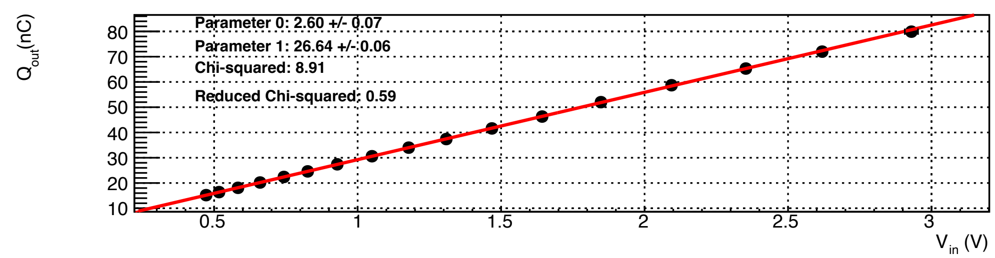
Assuming to increase $V_{preamp}(max)$ by 15% while keeping linearity at an acceptable level, e.g. 1% (feasible - see next slide), we get:

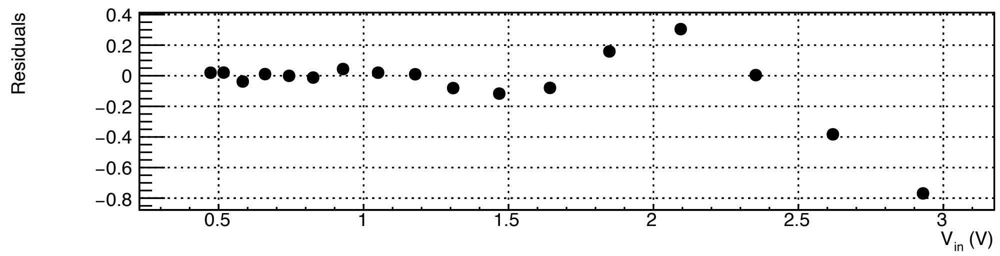
$V_{preamp}(max\ ) = 5.4$ V
$V_{dis}(max) = V_{preamp}(max) \bullet\ 0.5\ = 2.7$ V

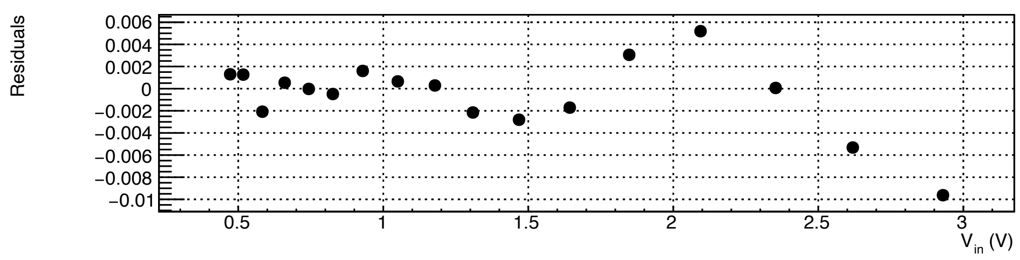
Preamp linearity test and saturation threshold

Linearity test

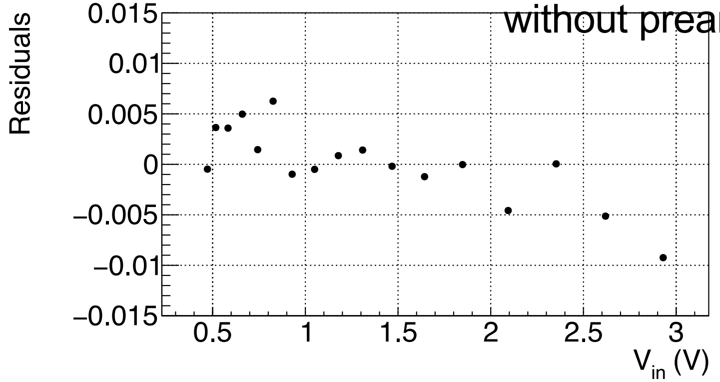








Residuals (subtracted system response without preamp)



Choice of the dynamic range

Assuming:

- to increase V_{preamp}(max) by 15% => V_{preamp}(max) = 5.4 V
- $(N_{pe}\,G_{PM})(\max) = 95\cdot10^7$
- V_{dis}(max) = V_{preamp}(max) • 0.5 • 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

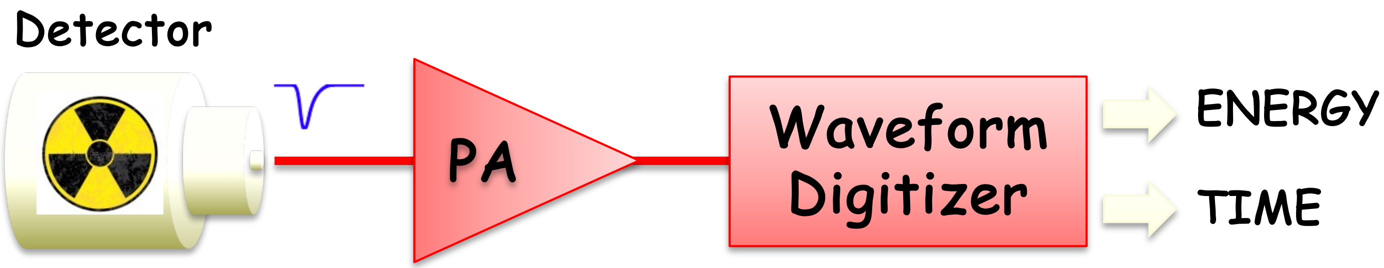
- Different dynamic ranges can be implemented changing G_{PM} => the final choice should be a compromise between an affordable level of events with energy saturated cells, depending on N_{pe}(max), and an acceptable neutron detection efficiency, depending on N_{pe}(min).

Choice of FEE for SAND/ECAL

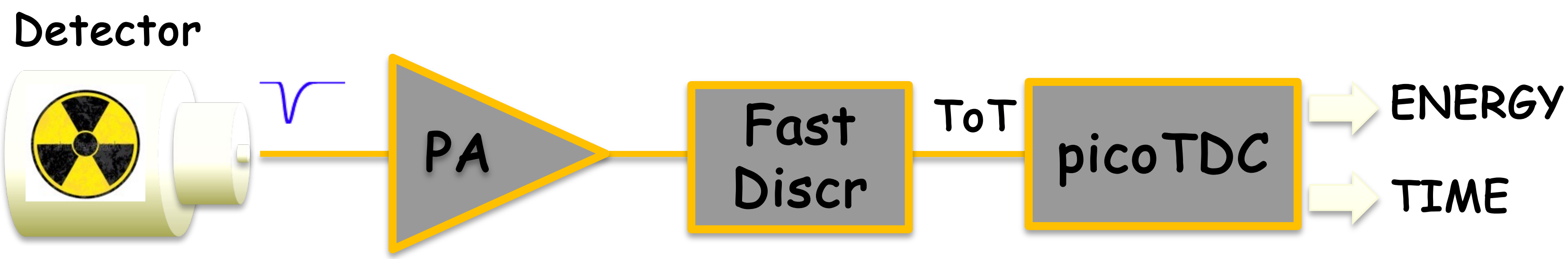
Constraints on signal dynamic range

see previous slides

Two possible read-out schemes:



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



No Flexibility
=>medium cost
energy by ToT
with 2 or more
thresholds not to
worsen energy resol.

CAEN:

possible ready-to-use solution maintaining KLOE energy and time performance

Choice of FEE for SAND/ECAL

Digitizer solution:
$V_{signal}(max) = 2$ V
$V_{signal}(min) = O(0.1)$ mV
=> no problems to set V_{TH} and $V_{signal}(max)$ to match $V_{dis}(max)$

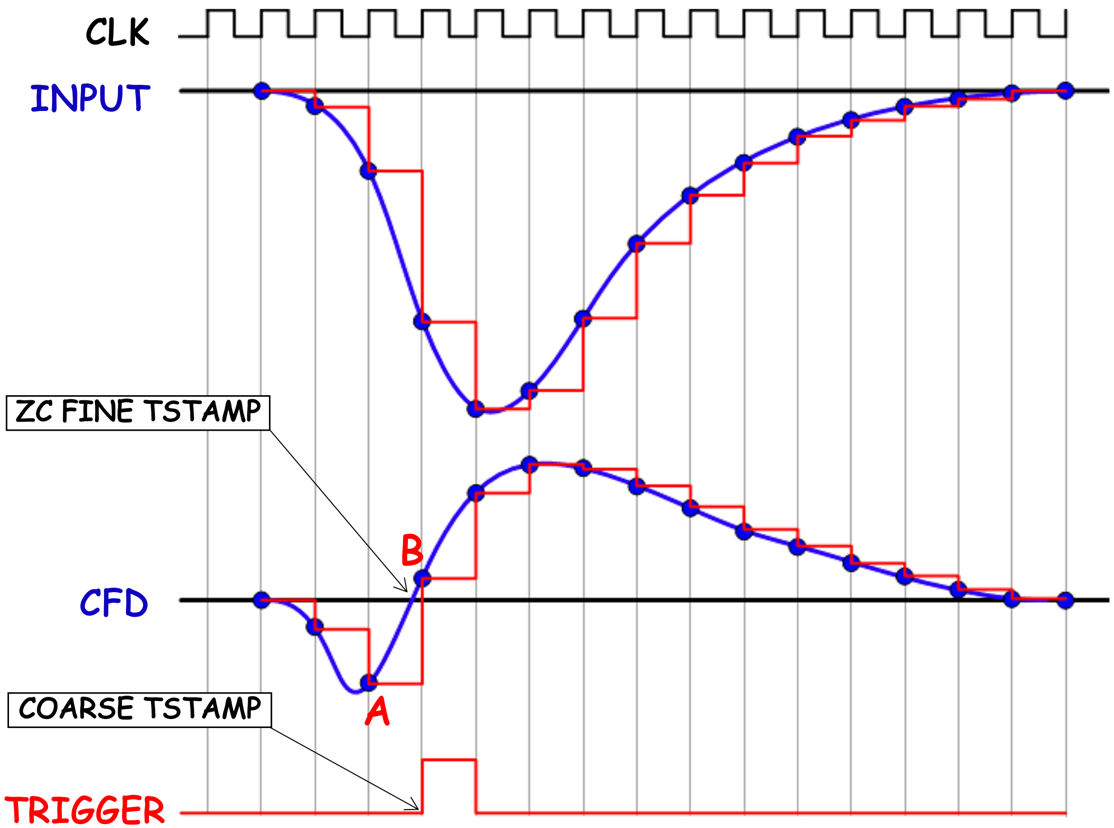
Best choice, high cost:
1 GS/s digitizer => 1 ns: 4-5 time measurements on the rising edge of the 14 ns base signal to preserve time resolution

Alternative lower cost choice:
Using a lower cost digitizer, 125 or 250 MS/s => 8 or 4 ns, requires a shaper to stretch the signal.
In principle this solution does not worsen the time resolution, but requires to keep the pile-up under control, as confirmed by MC (or to detect it from the signal shape).

A 500 MS/s digitizer (14 bit) => 2 ns might not need to stretch the signal (use of ad-hoc correction algorithms and calibration for measuring the time) => under test at CAEN.

Digital CFD with interpolation

CAEN Tools for Discovery



Preliminary tests with FERS by CAEN

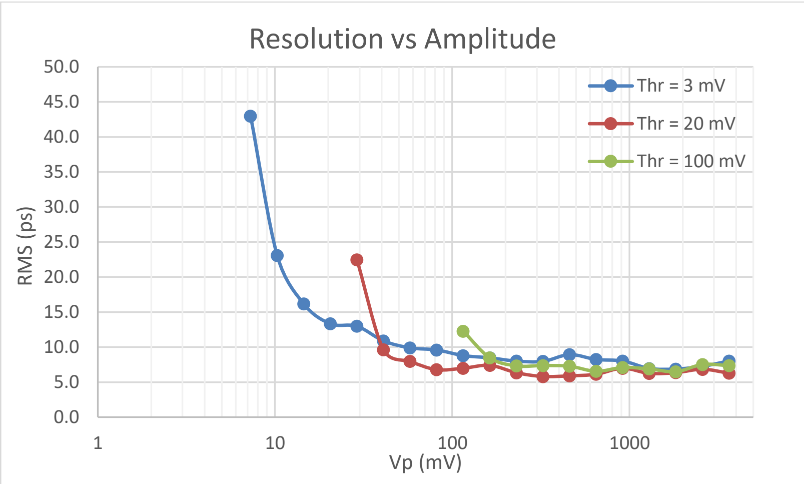


Fig. 2.2: Timing Resolution vs Pulse Amplitude

FERS A5203
(pico TDC)

fast input signal:
FWHM = 1.6 ns,
Rise = 1.1 ns,
Fall = 1 ns

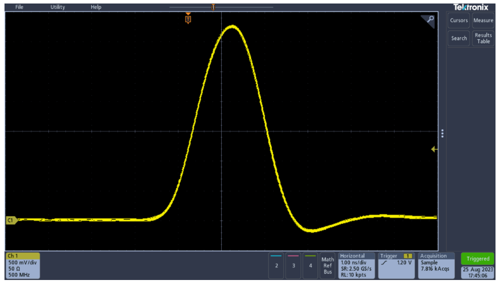


Fig. 2.1: Fast pulse from Agilent 81110A (width=1.5 ns; rise=fall=0.8 ns)

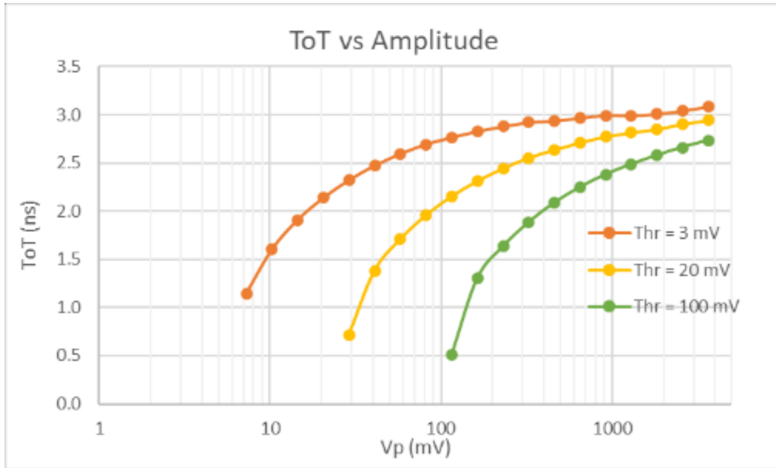


Fig. 2.3: ToT vs Amplitude

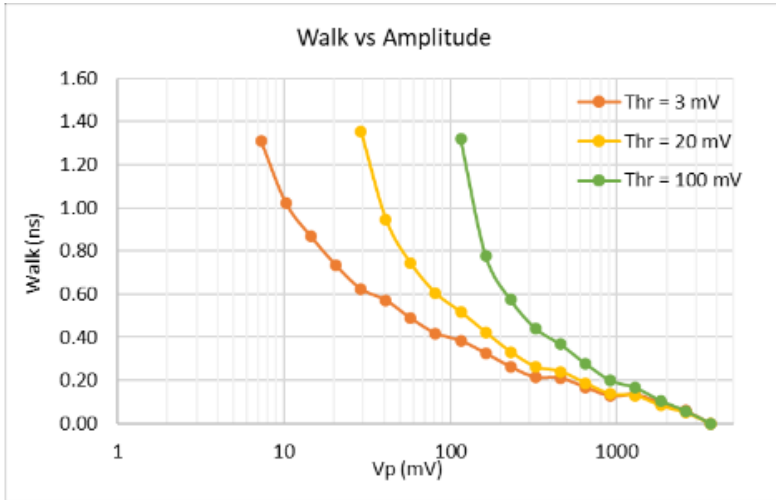


Fig. 2.4: Walk vs Amplitude

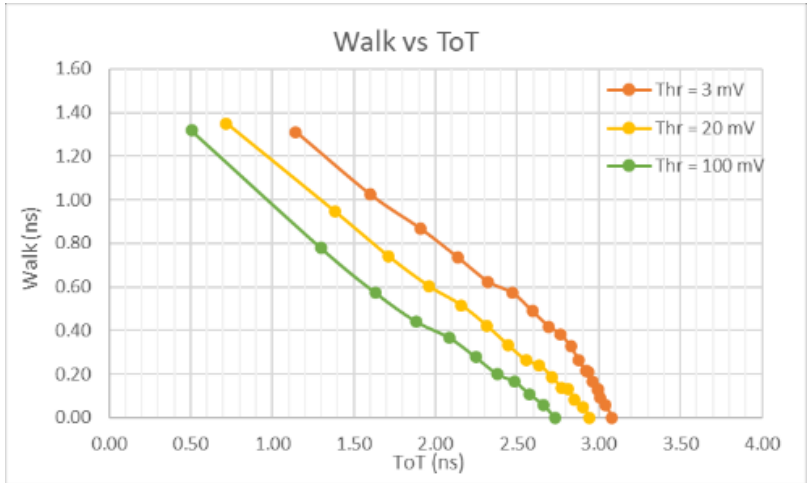
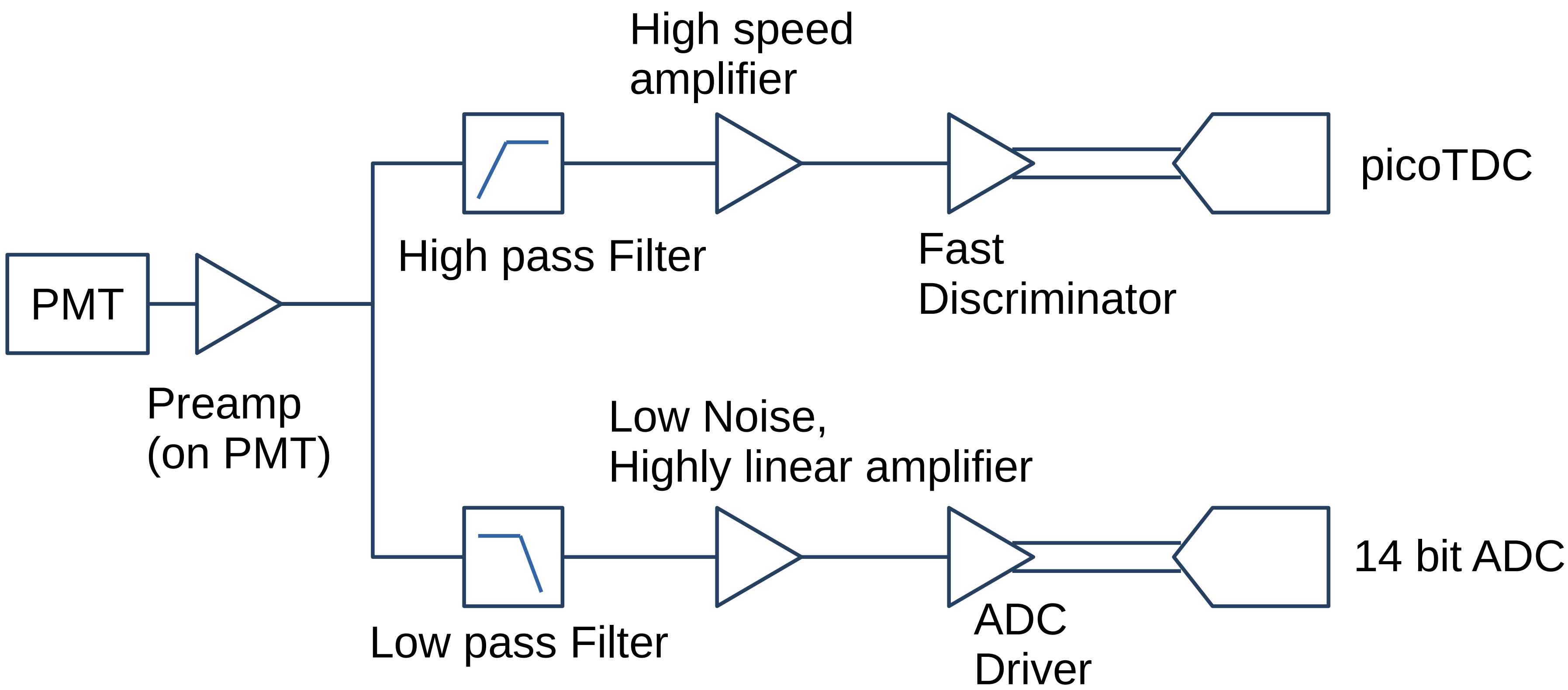


Fig. 2.5: Walk vs ToT

Test done by CAEN:
amplitude and walk reconstructed with ToT

Choice of FEE for SAND/ECAL

a more conventional approach splitting the signal:



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

N. Tosi – INFN BO

Conclusions

Advances in all KLOE-to-SAND activities:
- movable platform for the barrel modules extraction is being built
- design of mechanical tools for the End-cap dismounting ready
- design for the dismounting of the magnet coil ~ready
- the magnet test is being prepared

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 tested for linearity and well compatible with needed dynamic range and proposed FEE solutions, with the additional advantage of a lower gain and HV level, beneficial for their lifetime.

Possible solutions for the FEE that could constitute a good compromise between cost and performance are being investigated in collaboration with CAEN.