



Slow Control for DUNE Double Phase Far Detector

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Define Slow Control system and goals.

Requirements for a Control System and Instrumentation.

An example of Slow Control: WA105 Detectors and progress.

How to scale it to DUNE Far Detector.

New Challenges.

Conclusions.

Monitor – and control where possible:

- temperature,
- pressure,
- impurities in gas phase and in liquid phase with purity monitors,
- deformation of materials in cold,
- status of the Tank and of the Insulation Space,
- High Voltage system (Electron gain stage and Drift Field),
- thermodynamic condition of LAr.

Slow Control:

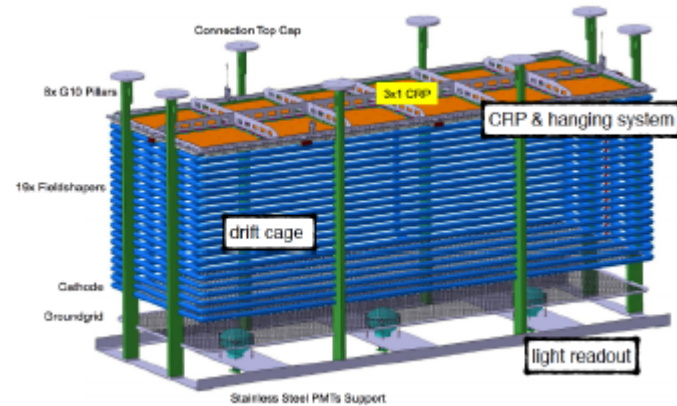
Global system to measure all these quantities helpful for data reconstruction and provide interface for operators to monitor status of the Detector:

- operate it safely
- guarantee data quality over long period of time
- can embed the Calibration system!

In terms of physics, we want to measure:

- the **electric field map**, which could be distorted by the
 1. **space charge** induced by large number of cosmic rays passing the detector constantly
 2. hardware construction — shrinking, misalignment, etc.
- electron **drift velocity**
- electron **lateral and transversal diffusion**
- electron **lifetime**, electron recombination, important factors in calculating de/dx for particle identification.
- **fiducial volume** of the detector to verify how big volume of the detector is responding properly for physics measurement.

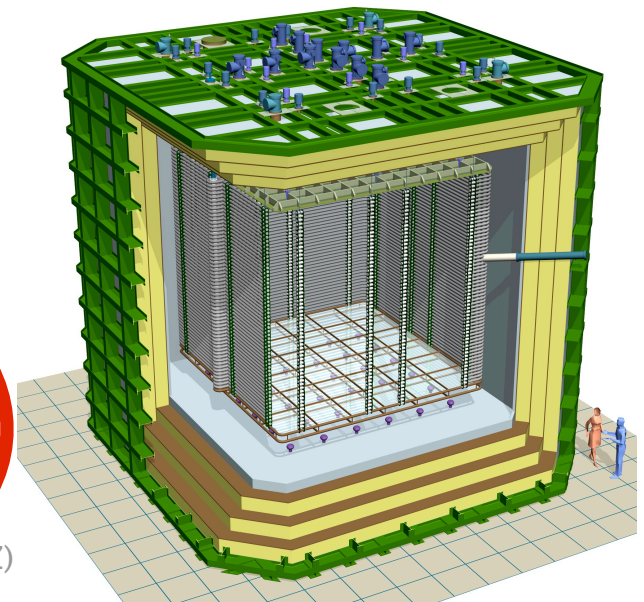
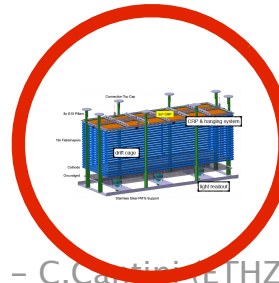
These items affect event reconstruction!

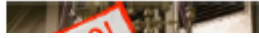


Learning new things step by step !

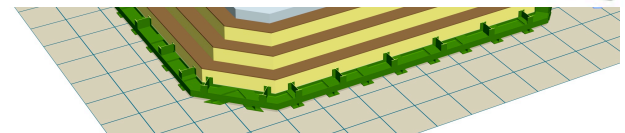
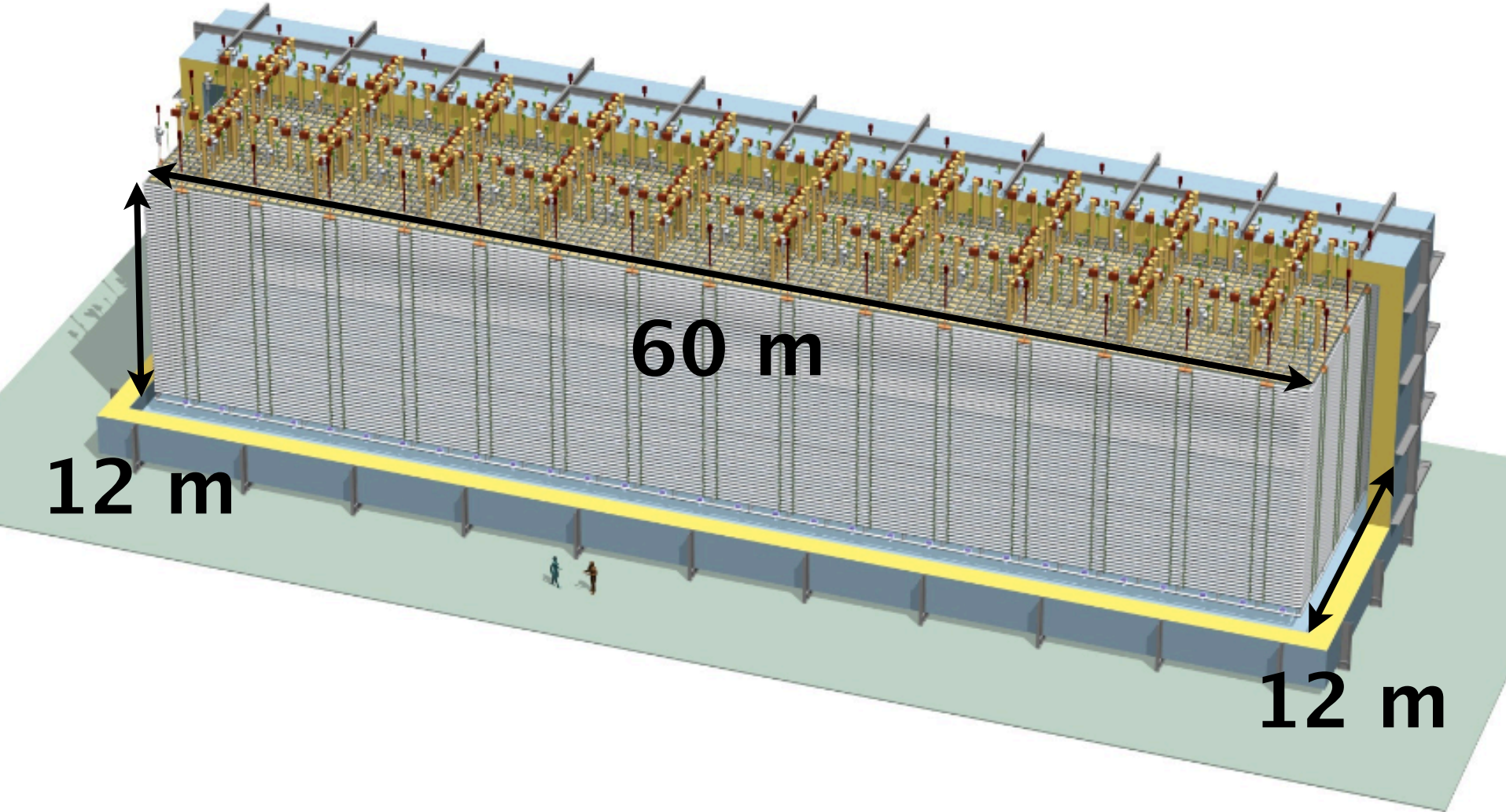
- Continuous R&D on 3L, 250L detectors
- Physics Run ArDM experiment
- Commissioning of 3x1x1 Detector
- Design of 6x6x6 Detector

6x6x6 m³
VS
3x1x1 m³





Connection Top Cap



Phased approach

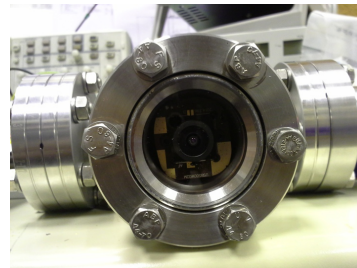
Cold test of 50x50 cm² LEM

In the last months we started here at CERN a **testing campaign on each subsystem** of the Slow Control for 311 Detector system addressed to:

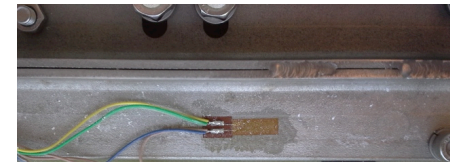
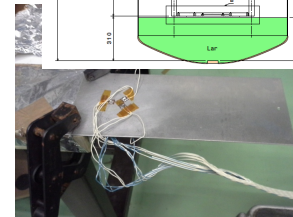
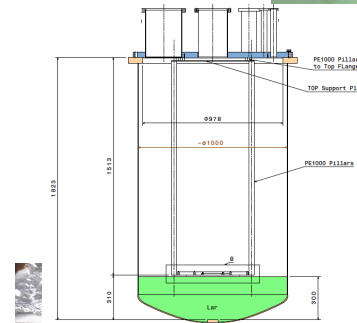
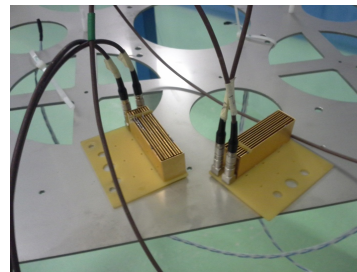
1. validate the measuring techniques and calibration of sensors
2. extract useful information for the design of the **6x6x6 m³ Detector** – chimneys, feedthrough, hanging structure of Charge Readout Plane
3. test the slow control architecture



Calibration of Pt sensors
Calibration of Level Meters



Cryo Cam

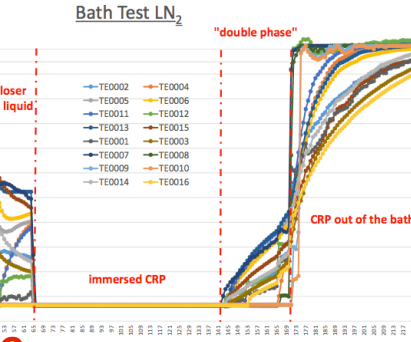
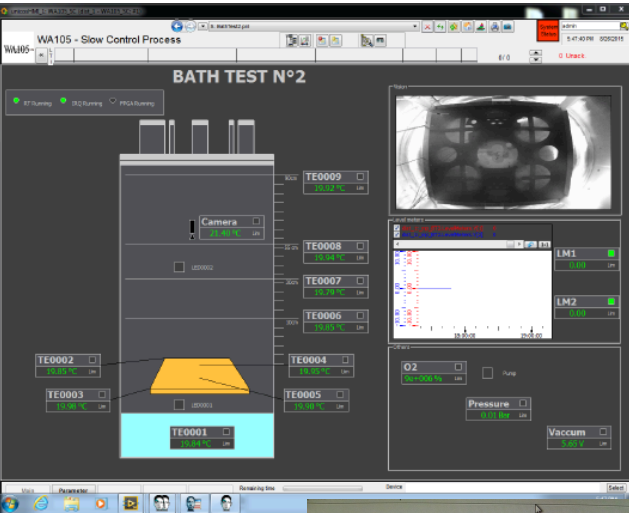


Test Strain Gauge

Phased approach

**Cold test of
3x1 m² CRP**

**Temperature monitoring
Photogrammetric measure**



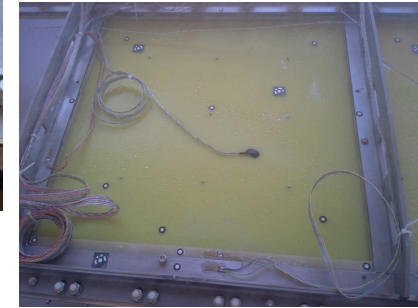
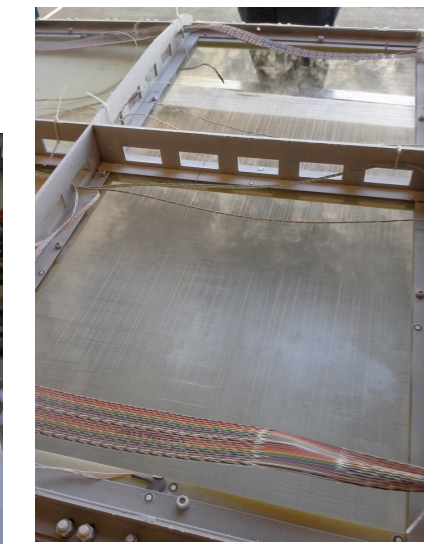
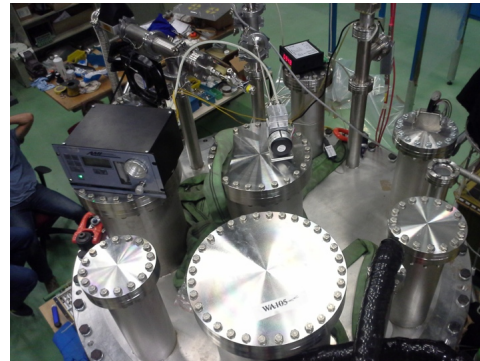
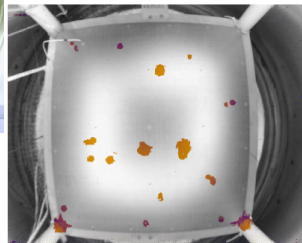
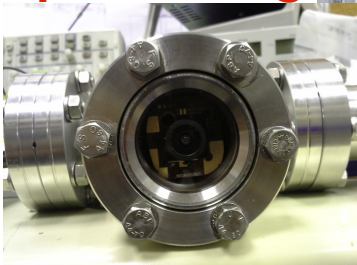
PVSS implemented!

PH/DT
G.Maire
N.Bourgeois
Y.Rigaut
S.Ravat

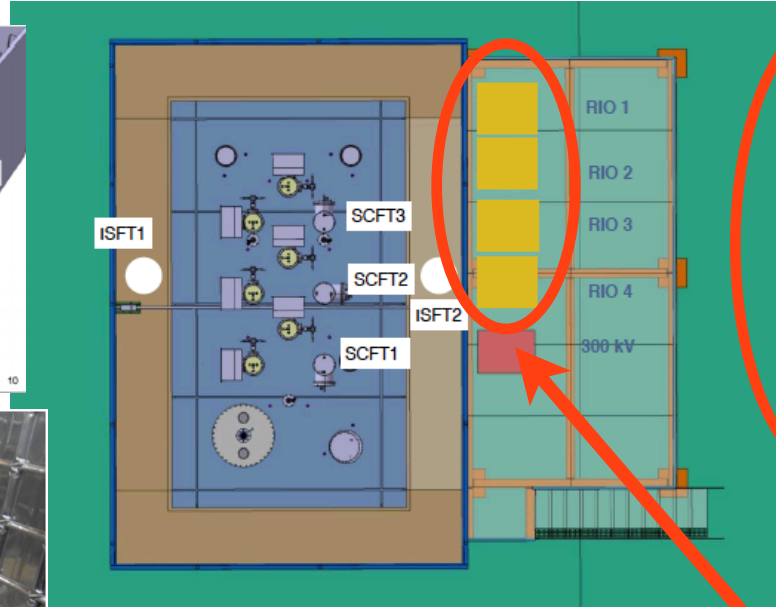
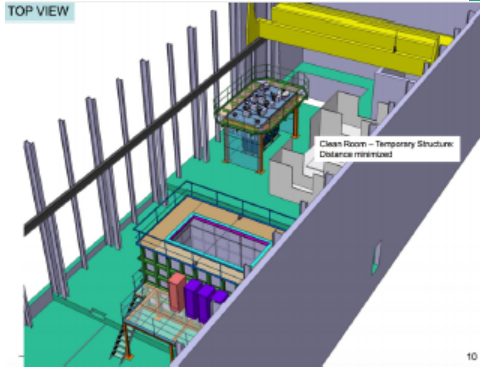
**Cold test of
50x50 cm² LEM**

Monitor Purity over long time

**Image
processing**



Building 182 CERN



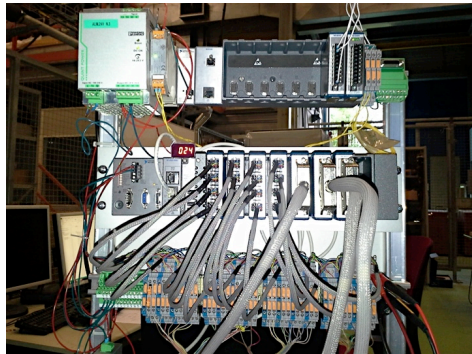
- DCS (High Voltage and Low Voltage monitoring)
- PCS (Control and Level sensors IN/OUT)
- DSS
- Electrical Distribution
- communication
- LAMP
- Cryo 1
- Cryo 2
- Cryo 3

Far racks.
Most of material been purchased and is been assembled

PH/DT CERN
G.Maire,
N.Bourgeois,
Y.Rigaut
EN/HDO CERN
F.Duval

Ready!

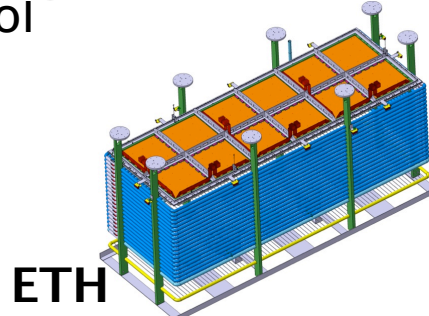
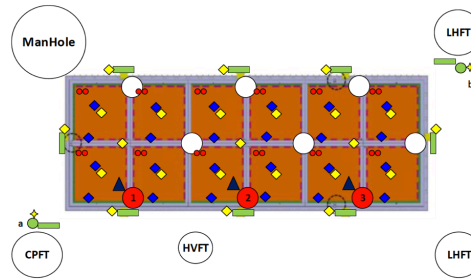
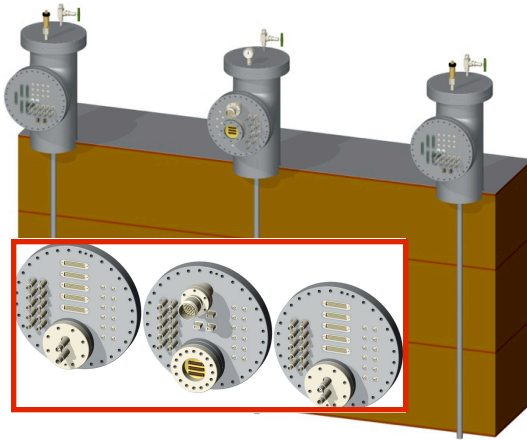
Remote IO based on **National Instruments acquisition cards**
Racks on platform, interface for sensors – **minimize** number of cables to far racks.



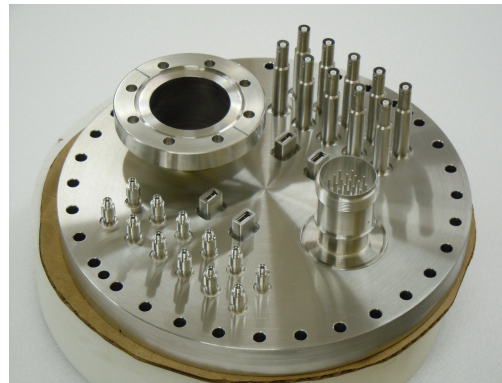
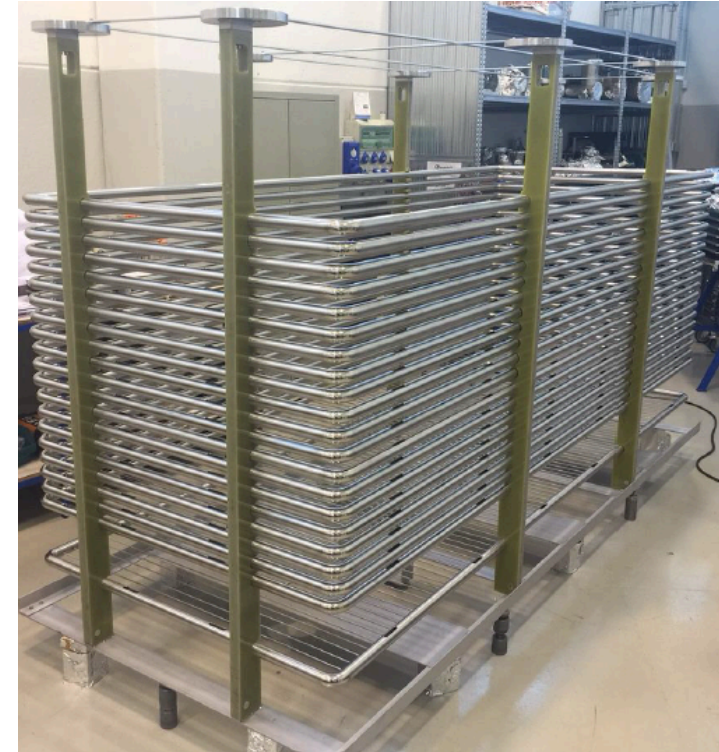
WA105

3x1x1 Detector:

- Number of sensors intentionally redundant.
- Custom made Slow Control flanges with weldable connectors.



ETH
F.Sergiapietri



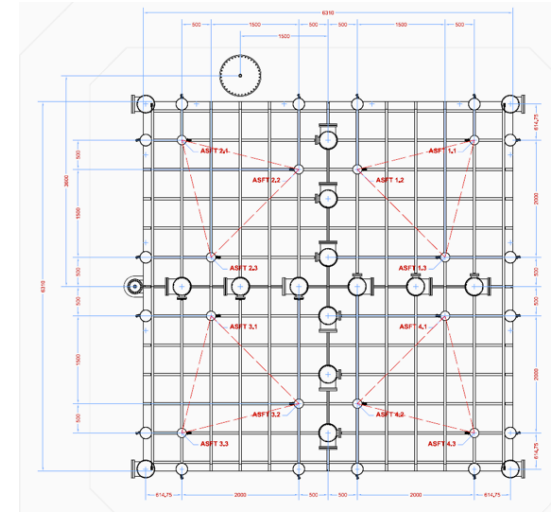
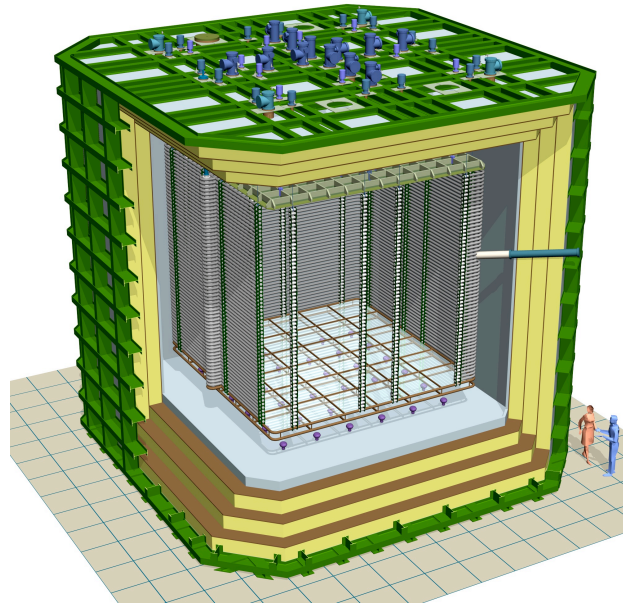
The design of SC/Calib system influences the design of the vessel and TPC! R&D on flanges!

The Double Phase prototypes

6x6x6 Detector:

- Number of sensors **drastically reduced** – after testing activities on 3x1x1.
- **1 Slow Control FeedThrough per each 3x3 m² foreseen**
- **4 Slow Control FTs**
- **12 Signal FTs**

WA105

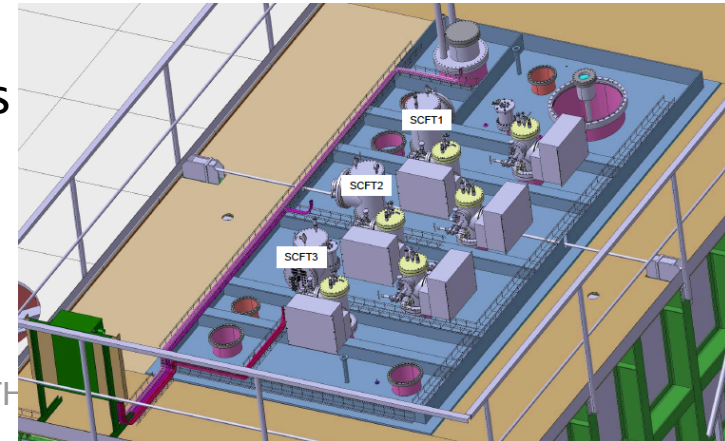


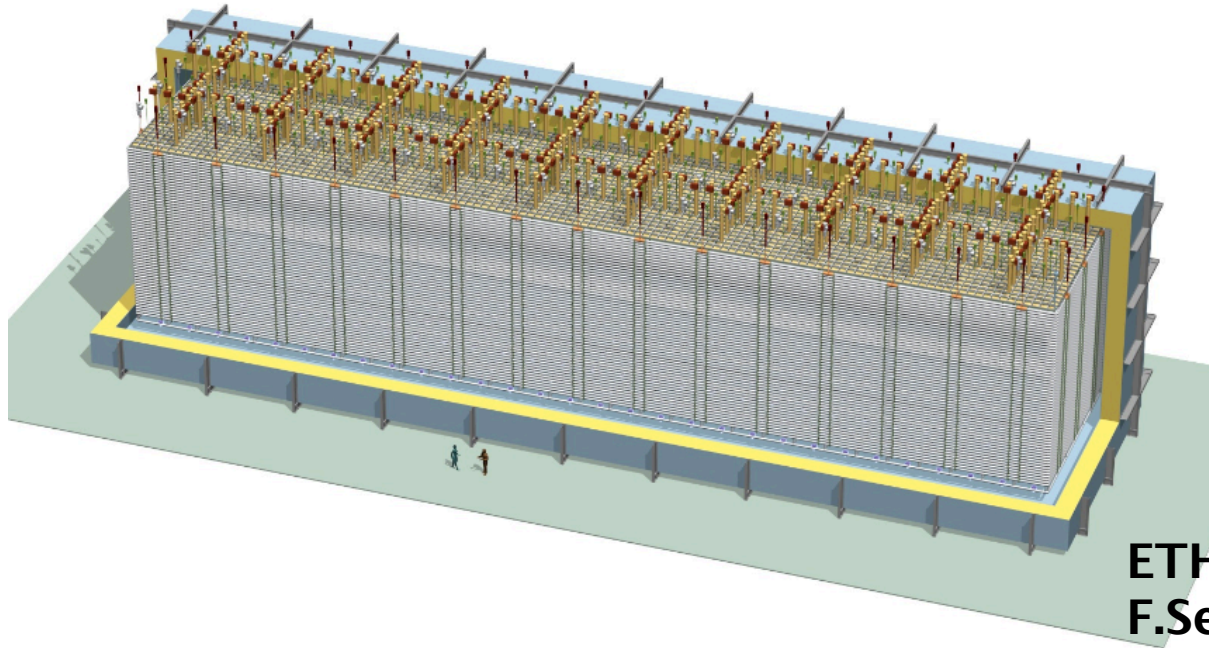
The design of SC/Calib system influences the design of the vessel and TPC!

Some numbers:

- 288 HV channels
- o(300) Pt
- 36 PMTs
- 16 Pressure sensors
- o(100) Pt for Insulation Space monitoring

311 Detector case:
Cabling showed it is better having HV channels not on same flange as signal connectors





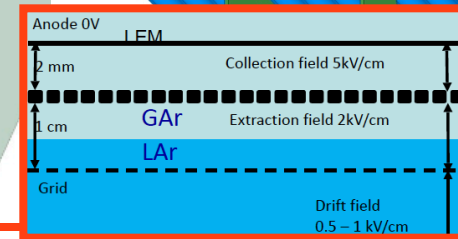
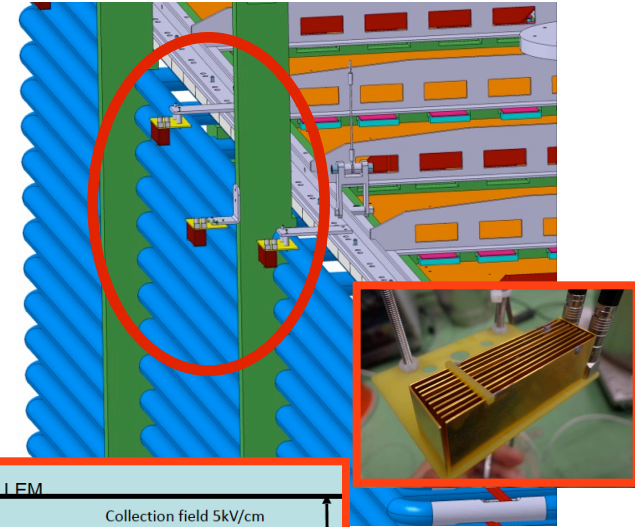
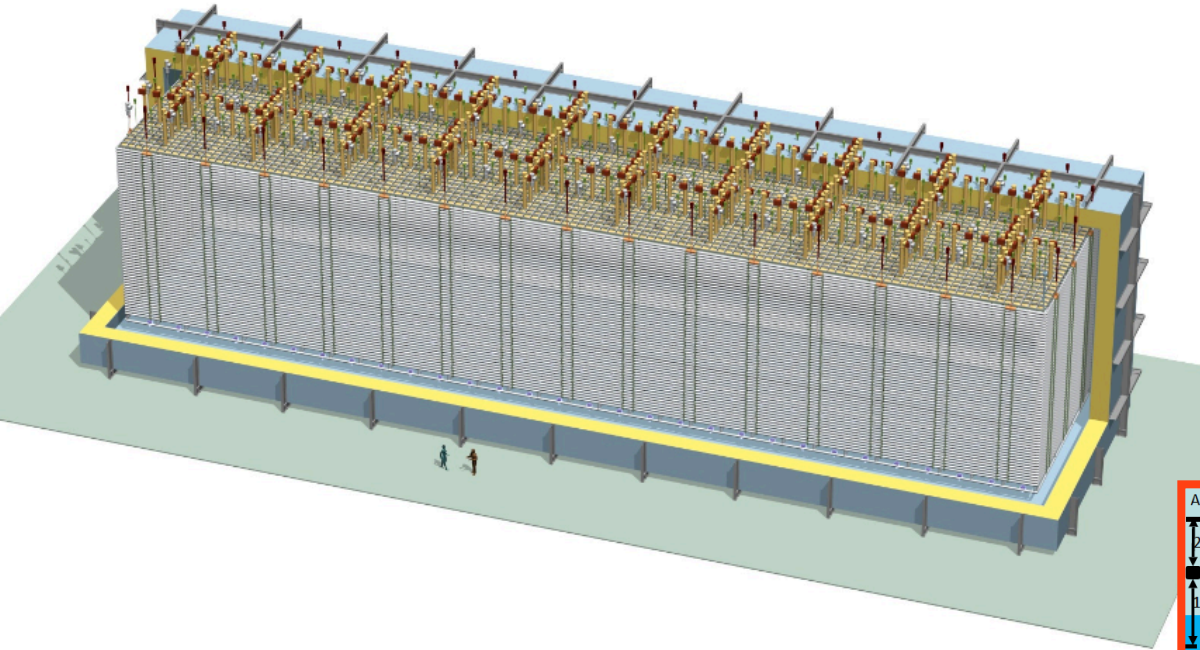
ETH
F.Sergiampietri

Some numbers:

- 5760 HV channels to power 2880 CRP
- 153600 Readout Channels
- o(3000) Pt
- 180 PMTs
- o(1000) Pt for Insulation Space monitoring

- 240 Signal FT
- 80 Slow Control and Instr. FT

3x1x1 Detector:



Some challenges:

- Each FT is additional heat input: implement reduction of HV Channel strategies
- Implement multiplexing of temperature probes signal
- Implement different level meter measuring technique

We can control relative position of each CRP module to LAr level measuring **capacitance between Grid and LEM's bottom electrode.**

- distributed measure
- Can be implemented with **NO ADDITIONAL channels** on FTs
- Can be **tested** in 3x1x1 Detector

- We defined the physical quantities to measure and how to calibrate subsystems/sensors for **Slow Control and Calibration of WA105 Detectors**.
- **Results** on phased testing activities in the last months have been implemented in **3x1x1 Detector** and provided **strong guidelines for SCFT design of 6x6x6 Detector already**.
- Together with CERN/PH DT-Group **we have set up a Slow Control architecture based on National Instruments modules**. The details are been tested and validated within the 3x1x1 m3.
- This **Slow Control** system fulfills our requirements and can be **scaled up to the need of 6x6x6 m3 Detector** and to **even bigger future LAr Detectors, like the one for DUNE FD**.
- In this case, tailored techniques for High Voltage distribution for LEM powering and sensors reading have to be studied and tested **to minimize the number of channel on FT, hence FT numbers** (heat input and cost).