Comments on the ALICE TPC by someone who worked briefly on the project

Alexander Deisting
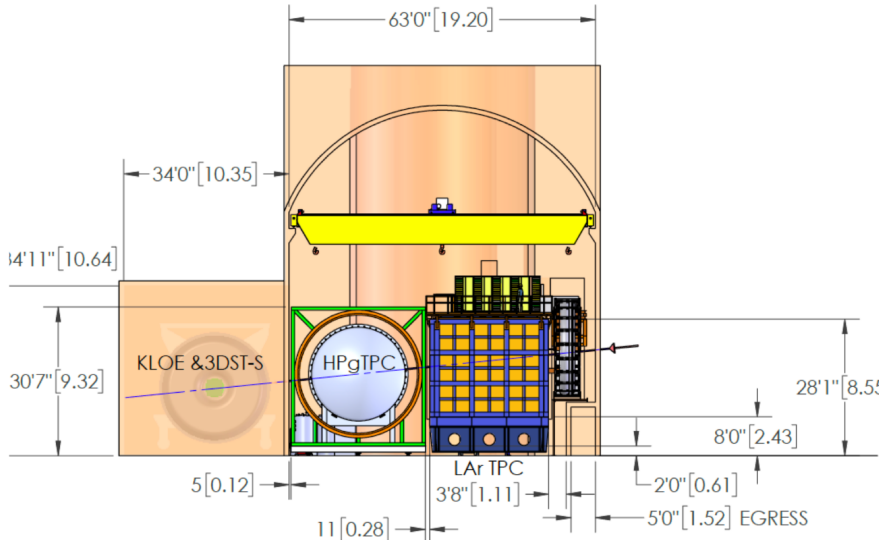
ROYAL HOLLOWAY UNIVERSITY OF LONDON
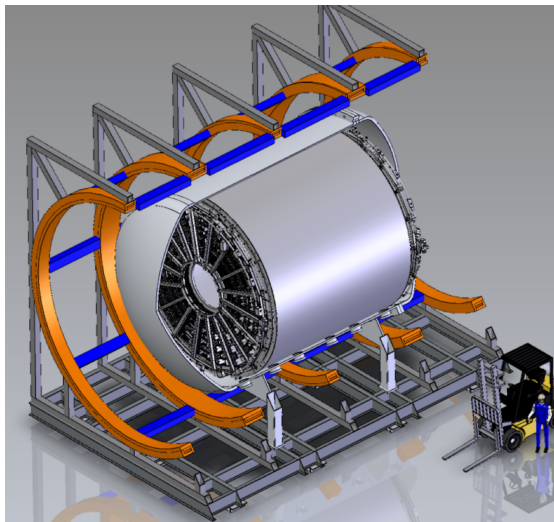
22$^{\text{th}}$ of October, 2019

ALICE Time Projection Chamber and its Readout Chambers (ROCs)
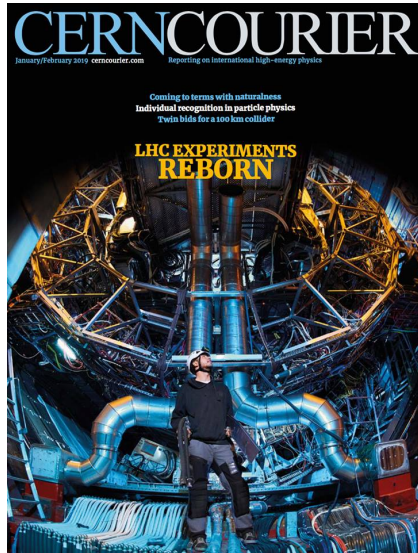
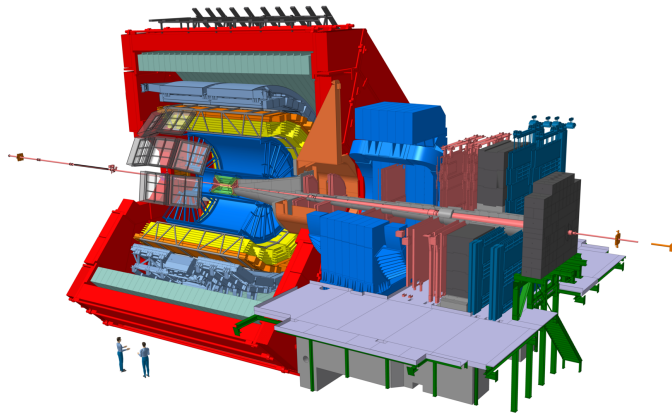# ALICE Time Projection Chamber and its Readout Chambers (ROCs)

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ALICE – A Large Ion Collider Experiment

▶ Dedicated heavy ion experiment at the LHC

▶ Designed to cope with high particle multiplicities and to track and identify low momentum particles ($\sim 200\,\text{MeV}/c$)

▶ Employs a Time Projection Chamber (TPC) as main tracking and particle identification detector in the central barrel
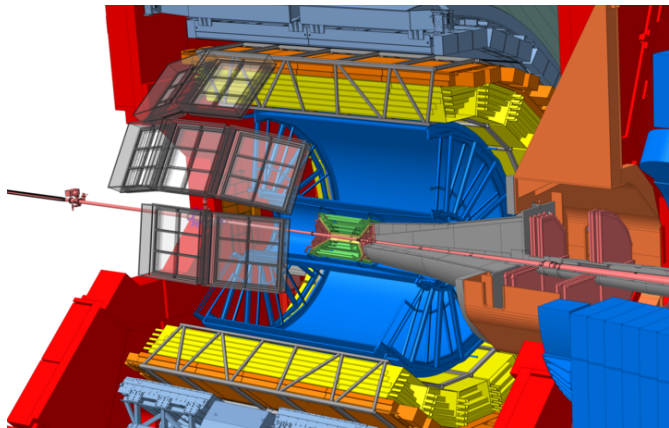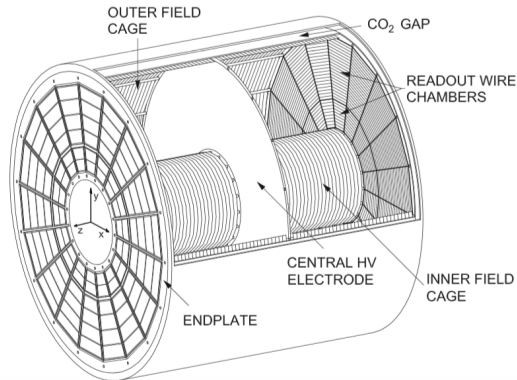
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ALICE time projection chamber

- ▶ About 90 m³ gas volume filled with $Ar\text{-}CO_2$ (88-12) at atmospheric pressure
- ▶ $Ne\text{-}CO_2\text{-}N_2$ (90-10-5) and $Ne\text{-}CO_2$ (90-10) have been used as well
- ▶ Drift field of 400 V cm⁻¹ ($\rightarrow$ central cathode at 100 kV)
- ▶ Maximal electron drift time: ≤ 100 µs
- ▶ Multi Wire Proportional Chambers (MWPCs) with gated read-out
- ▶ Operated successfully in LHC Run 1 and Run 2
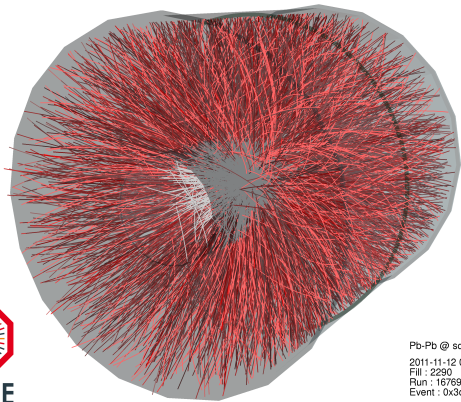
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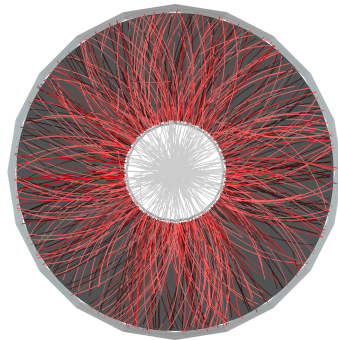- ▶ Operated successfully in LHC Run 1 and Run 2

Pb-Pb @ sqrt(s) = 2.76 ATeV
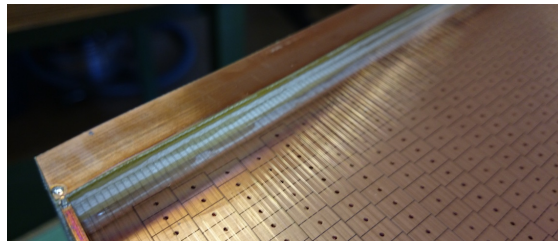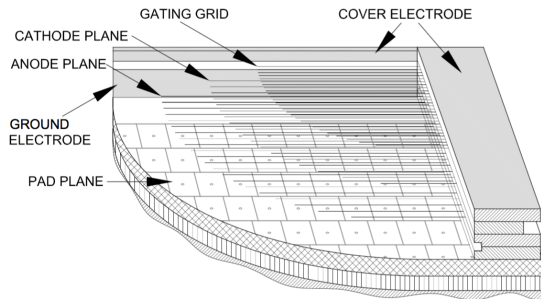2011-11-12 06:51:12
Fill : 2290
Run : 167693
Event : 0x3d94315a

ALICE
A JOURNEY OF DISCOVERY

- ▶ 18 Inner and Outer ReadOut Chambers (IROCs/OROCs) per side
- ▶ Each has three wire planes: Anode wires, cathode wires and gating grid wires
- ▶ Pad sizes: $4 \times 7.5\,\mathrm{mm}^2$, $6 \times 10\,\mathrm{mm}^2$ and $6 \times 15\,\mathrm{mm}^2$, in total 160 pad rows
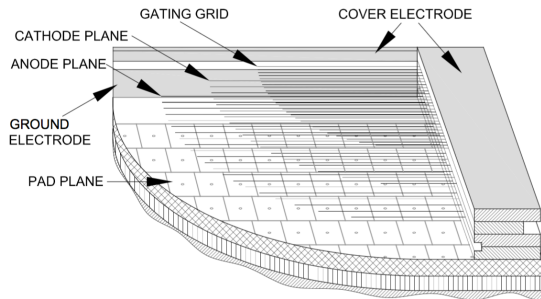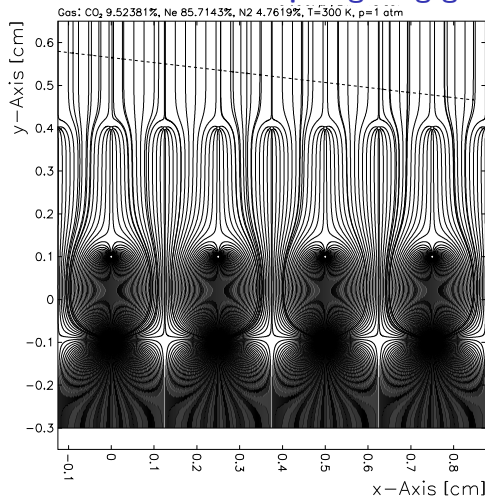
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Ion drift lines with open gating grid

Gas: CO_2 9.52381%, Ne 85.7143%, N2 4.7619%, T=300 K, p=1 atm

- ▶ An alternating potential is applied to switch the gating grid closed, *i.e.* $U_{GG} = U_0 \pm \Delta U$
- ▶ In the closed configuration the gating grid is neither transparent to charge carriers from the drift volume nor from the readout chamber
- ▶ The grid is kept closed for 200 μs to efficiently block the ions from the gas amplification
- ▶ Together with the maximum drift time of ~ 100 μs, the closing time of the grids limits the readout rate to ~ 3 kHz

Field cage

- ► The ALICE TPC field cage is mounted on 18 rods on the inner and the outer side of the TPC
- ► $V_{cathode} = 100$ kV (Drift field: 400 V cm^{-1}) is degraded by a voltage divider network, also supplying the 165 field strips
- ► The high voltage insulation is achieved by a set of guard rings and a CO_2 filled containment module
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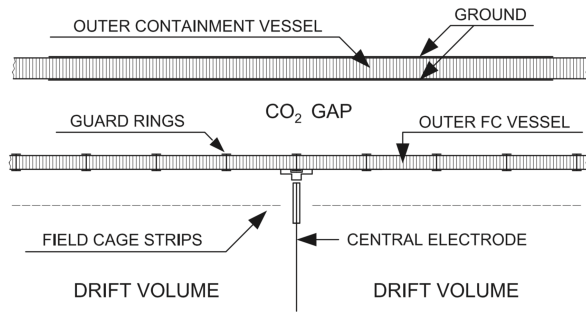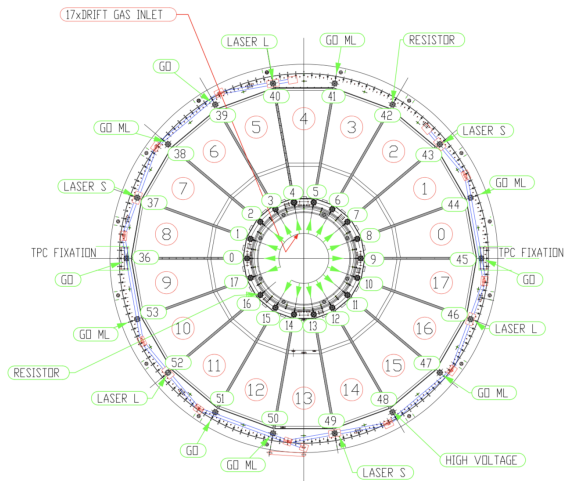# Field cage

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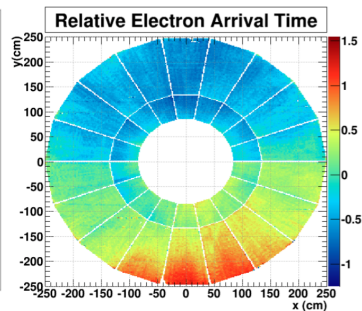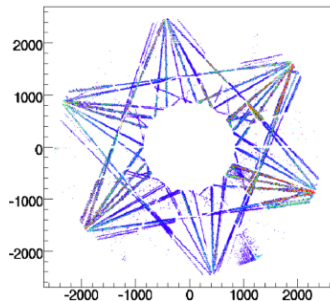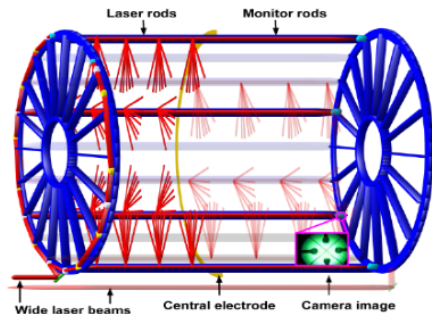
Laser calibration system

- ▶ An ultra-violet laser is guided into the TPC, split and produces tracks at defined positions
- ▶ One laser run consists of 100 laser triggers – the first block occurring 0.5 h in a data taking run and then hourly
- ▶ Stray-light hits the cathode and ejects photo electrons which drift the full drift distance

Pressure and temperature stability

- The temperature homogeneity in the ALICE TPC is better than $0.1\,\mathrm{K}$
- z resolution (E_drift direction) 1250 to $1100\,\mu\mathrm{m}$
- Measuring the arrival time of the electrons of the *cathode disk* allows to map drift field inhomogeneities
- The spread in ALICE is $0.25\,\%$, dominated by the pressure gradient from the top to bottom.

Relative Electron Arrival Time
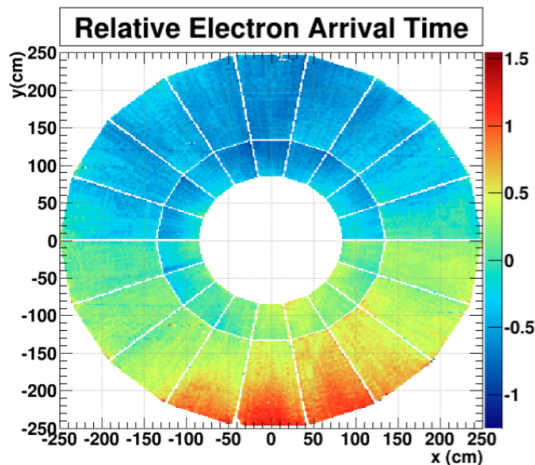
Some performance figures
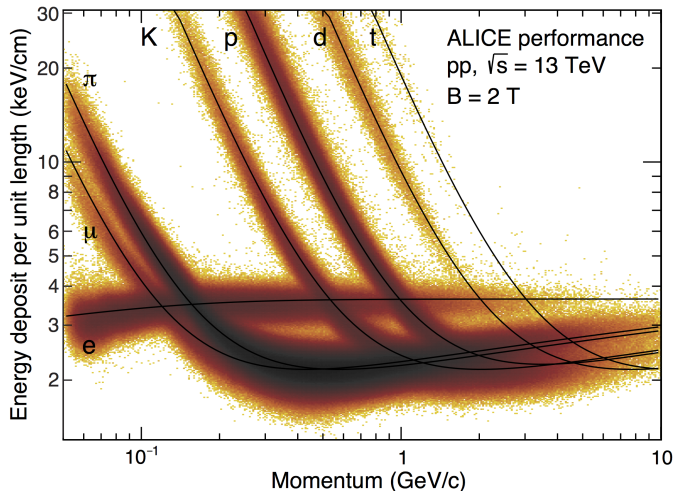
Material budget

- 4.1 % X_0 at the $\eta \sim 0$ region

$\mathrm{d}\varepsilon/\mathrm{d}x$:

- 5.2 % in pp collisions
- 6.5 % in PbPb collisions

Transverse momentum:

- $\sim 6\,\%$ for particles with $p \sim 10\,\mathrm{GeV/c}$
- $< 1\,\%$ for particles with $p \sim 1\,\mathrm{GeV/c}$

Operating at higher than atmospheric pressure – Implications:

- **ALICE TPC @ $1\,atm \Rightarrow$ DUNE HPgTPC @ $10\,atm$**
- Higher interaction probability *i.e.* more ν interactions in the detector volume
- Larger primary ionisation density
- Need for a high pressure vessel
- A **high** voltage power supply is needed to compensate for the E/P scaling
- Readout chambers which can provide the necessary gas amplification at high pressure
- $\Rightarrow$ **Rigorous testing and optimisation needed to find $10\,atm$ settings**

Magboltz simulations

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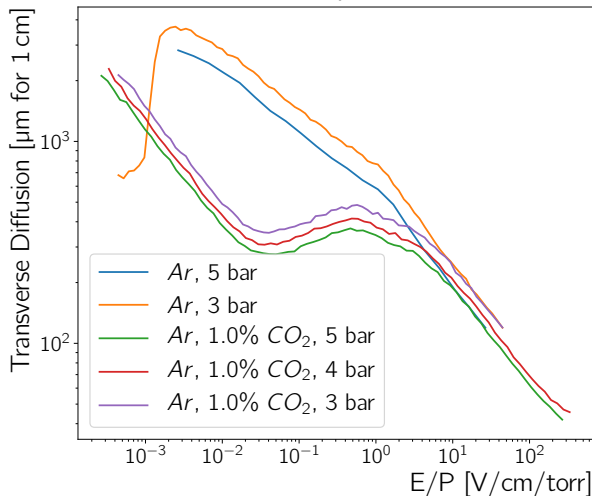- A **high** voltage power supply is needed to compensate for the E/P scaling
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Transverse Diffusion [µm for 1 cm] vs E/P [V/cm/torr]

- Ar, 5 bar
- Ar, 3 bar
- Ar, 1.0% CO_2, 5 bar
- Ar, 1.0% CO_2, 4 bar
- Ar, 1.0% CO_2, 3 bar

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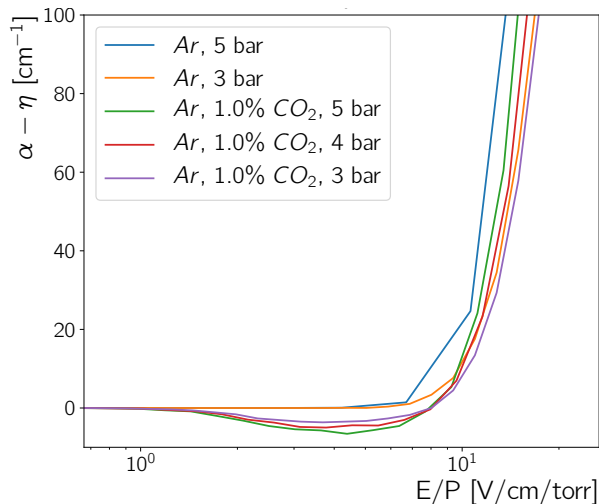- ⇒ **Rigorous testing and optimisation needed to find $10\,\mathrm{atm}$ settings**

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Gas amplification

$$N_e = N_0 \exp\left(\int_{x_0}^{x_1} (\alpha - \eta)\left(\frac{E(x)}{N}\right)\mathrm{d}x\right)$$

Naive approach: Scale voltages

▶ $V_{\text{anode}}^{\text{ALICE}} \sim 1.5\,\text{kV} \rightarrow V_{\text{anode}}^{\text{MPD}} \sim 15\,\text{kV}$

▶ $V_{\text{cathode}}^{\text{ALICE}} \sim -100\,\text{kV} \rightarrow V_{\text{cathode}}^{\text{MPD}} \sim -1\,\text{MV}$

▶ $V_{\text{GG}}^{\text{ALICE}} \sim -120\,\text{V} \rightarrow V_{\text{GG}}^{\text{MPD}} \sim 1.2\,\text{kV}$

$\Rightarrow$ As discussed already in some meetings: This is not feasible

$\Rightarrow$ Find a different gas mixture

Ingredients for a new mixture

▶ Obviously: Ar as main component

▶ Gas gain: What signal to noise is required for the read-out? (V_{anode})

▶ Drift velocity: What maximal drift time can be afforded? (V_{cathode})

▶ What fraction of ν scattering on the quencher will still be tolerable?

▶ Will gating be needed? (V_{GG}, gain $\rightarrow V_{\text{anode}}$, ion drift velocity $\rightarrow V_{\text{cathode}}$)

▶ Diffusion (V_{cathode}, B field)

▶ ... ageing, primary scintillation , ...

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

## Results of wire chamber ageing tests with CH_4- and DME-based gas mixtures

R. Bouclier, M. Capeáns, C. Garabatos *, R.D. Heuer, M. Jeanrenaud, T.C. Meyer,
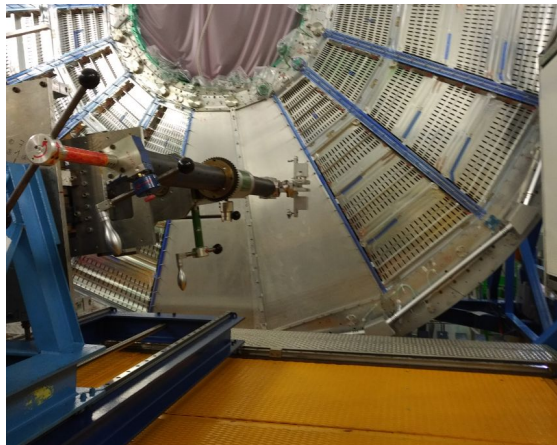F. Sauli, K. Silander [1]

CERN, Geneva, Switzerland

Results are presented of ageing tests performed on single-wire proportional counters under controlled conditions. The rate of the detector ageing with methane mixtures has been found to be independent of the anode and cathode materials used, and also of the purity of the gas. The rate of ageing for DME mixtures, on the other hand, appears to depend on the amount of gas used: it is small when the DME bottle is full, but increases as the cylinder empties. Addition of some water vapour to the Ar–DME mixture provided good lifetime, independently of the amount in the bottle. An explanation of this observation, based on assumptions on the fractional distillation of impurities, is provided.

High pressure vessel
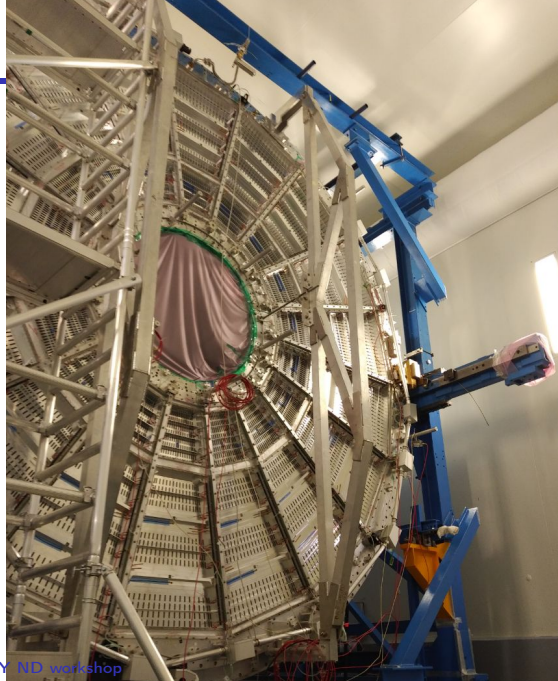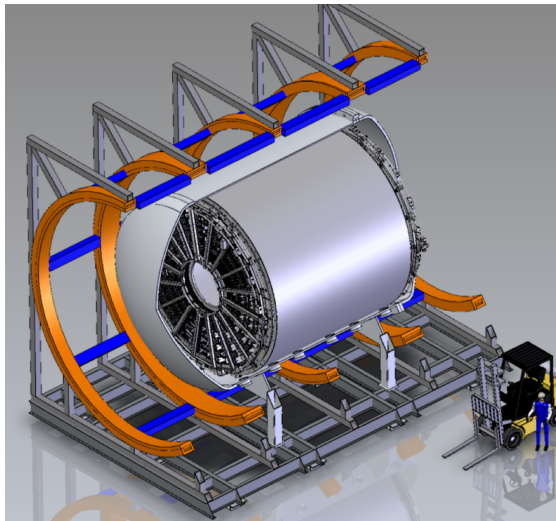
ALICE TPC gas seal and feed-throughs

- ▶ The ALICE TPC ROCs provide:
  - ▶ The connectors to the pads to which the FEEs is connected
  - ▶ The HV feed-throughs for the wire planes / cover electrode
  - ▶ The gas seal against atmosphere.
- ▶ They are mounted from the inside to the end caps
- ▶ **It is not clear that this gas seal can hold** 9 atm **relative pressure** ⇒ **One should estimate/measure this**
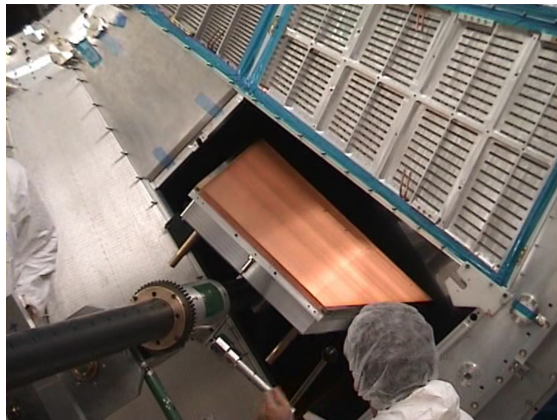- ▶ Let us assume this seal is not sufficient

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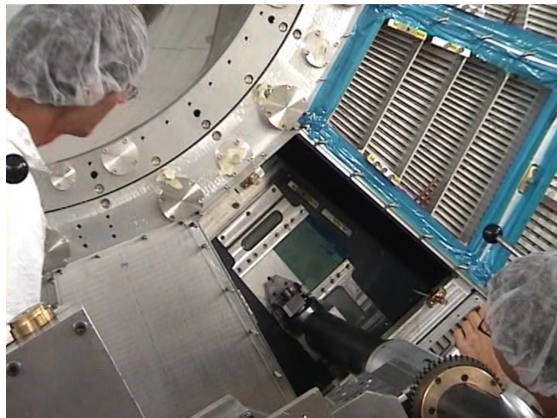
The ALICE seal is not sufficient ⇒ The full ROCs have to be enclosed in a high pressure vessel

► All connectors from back side of the ROC have to be connected to some sort of cable and brought through the high pressure vessel to atmosphere

► The most challenging type of connections: The pad readout – about $550,000/22 \sim 25,000$ signal connectors. (Not including the central region.)

  ► Some data collection / procession in the high pressure vessel seems desirable

  ► Caveats: Doings so, the gas quality must not be compromised as well as the temperature stability

  ► Any processing inside the high pressure vessel has to be extremely reliable

► Having the back planes of the end caps in their separated gas volumes is probably a good idea

Summary

- The performance of the ALICE MWPCs has been accessed at harsh multiplicities and they performed well
- Applying higher pressure helps in terms of physics performance, *i.e.* $d\varepsilon/dx$
- Optimising the gas mixture will probably allow to relive the challenges of naive E/P scaling
- Changing the gas mixture requires rigorous testing of the chamber performance at *non ALICE* mixtures ...
- ... which in turn requires a set of minimal performance requirements for the DUNE ND physics program

Last but not least:

- The answer to the question **Front-end electronics?** can have immediate effects on optimising the detector
- The central region has to be developed, designed and build