ALICE LS3 and LS4 plans

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ALICE upgrade plans

ALICE 2	ALICE 2.1	ALICE 3

Run 3
2022 - 2025
pp, p-Pb, Pb-Pb, p-O, O-O

LS3

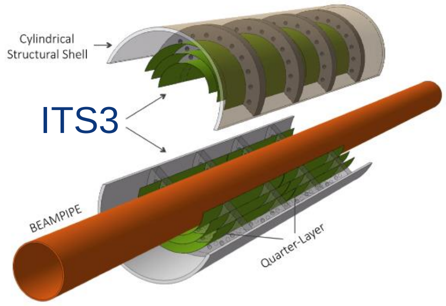
Run 4
2029 - 2032
pp, p-Pb, Pb-Pb

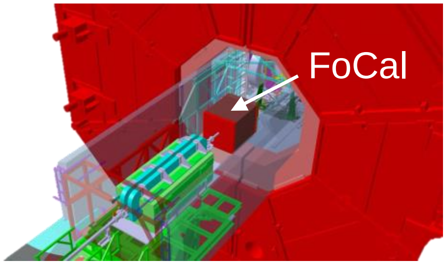
LS4

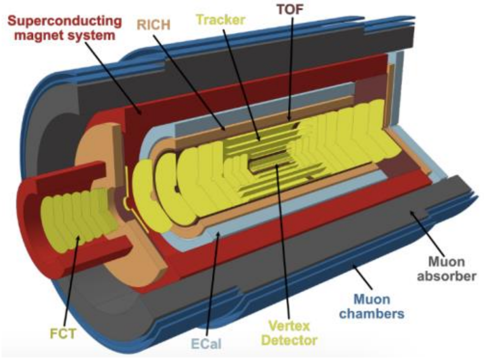
Run 5 + 6

ITS3 & FoCal

ALICE 3







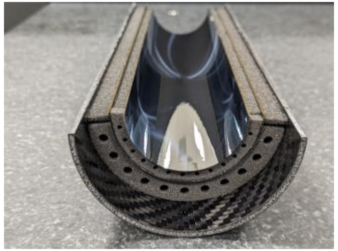
LS3 plans

LS3 upgrade: ITS3 and FoCal detectors

ITS3: a novel vertex detector consisting of **curved** wafer-scale ultra-thin **silicon sensors** arranged in perfectly cylindrical layers, featuring an unprecedented **low material budget** of 0.05 % X0 per layer, with the innermost layer positioned at only **18 mm radial distance** from the interaction point.

EP-DT in ITS3 sensors, mechanics cooling and integration

ITS2



ITS3 mechanical prototype

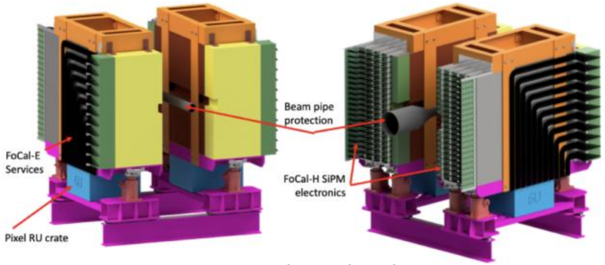
Both TDRs endorsed by Research Board in March 2024

A **new central beampipe** is needed, with smaller radius (outer radius 19 mm → 16.5 mm), reduced thickness (0.8 mm → 0.5 mm) and a conical section on the A-side. See LMC #458 (Mar 2023).

EP-DT in beam pipe design

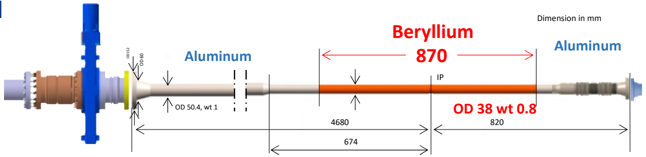
FoCal: a new Forward Calorimeter, located at 7m left from IP2 and requiring low material budget (i.e. a conical beampipe) in 3.2 < η < 5.8.

EP-DT in Focal integration and support design

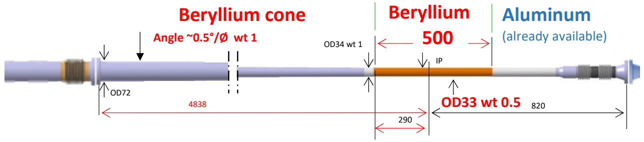


FoCal 3D sketch

LS2 central beampipe

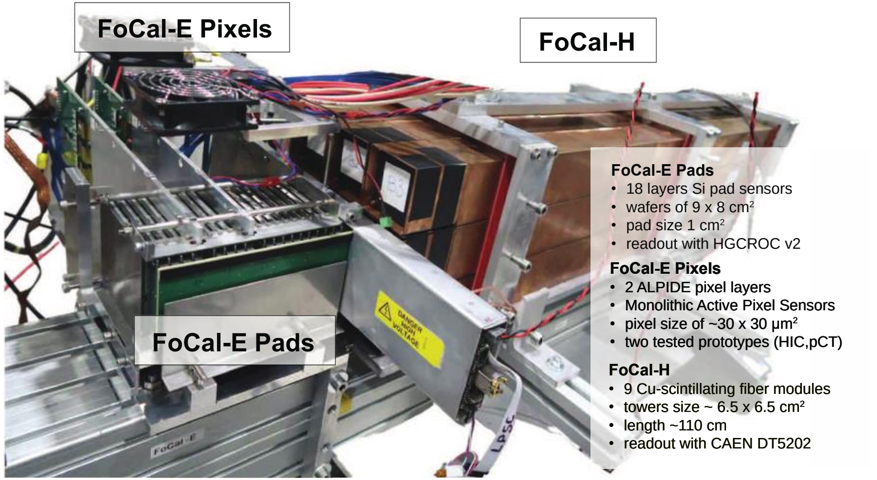


LS3 central beampipe



FoCal detector

- FoCal is a highly granular Si-W sandwich **electromagnet calorimeter (FoCal-E)**, combined with a Cu+scintillating-fiber **hadronic calorimeter (FoCal-H)** optimized to identify decay photons at forward angles (3.2<eta<5.8).
- R&D successfully completed.
- TDR: CERN-LHCC-2024 004 https://inspirehep.net/literature/2797164
- Mass production started for long lead time components, i.e. sensors and ALPIDEs; while details on Cu absorber, and readout still being finalized.
- EP-DT in integration, support platform, installation procedures.



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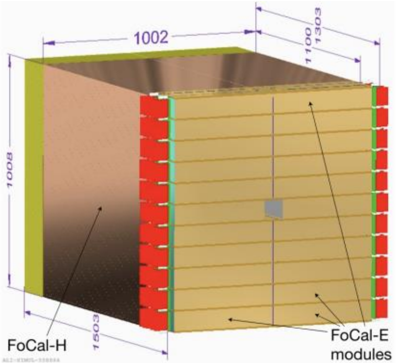

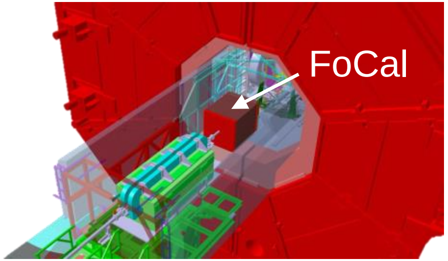

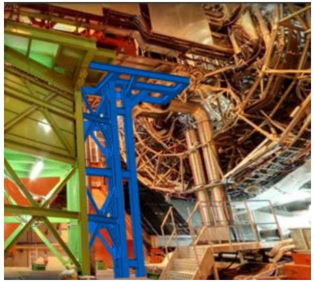

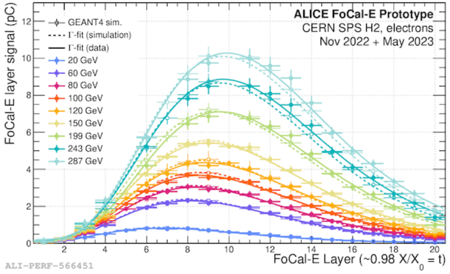

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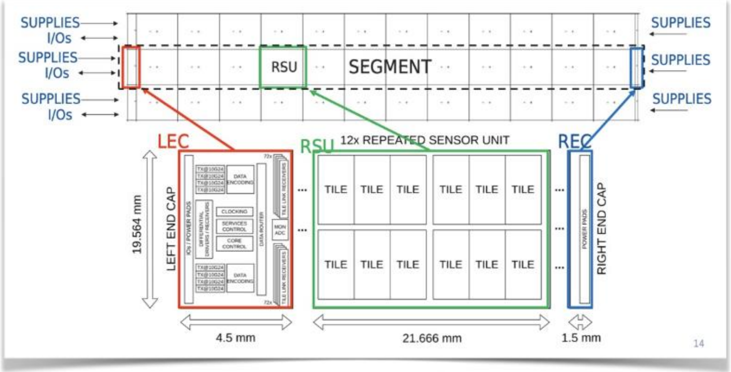
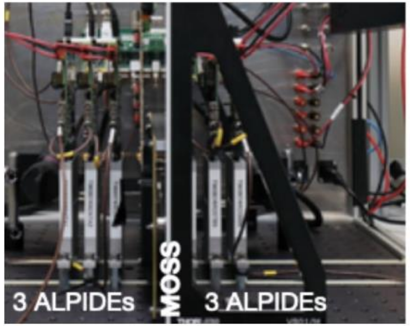
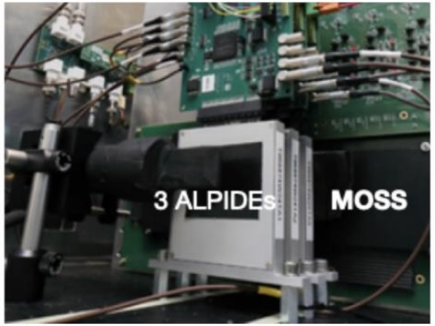
ITS3 recent highlights

✓ MOSAIX (final sensor prototype) design advancing (silicon expected early 2025)



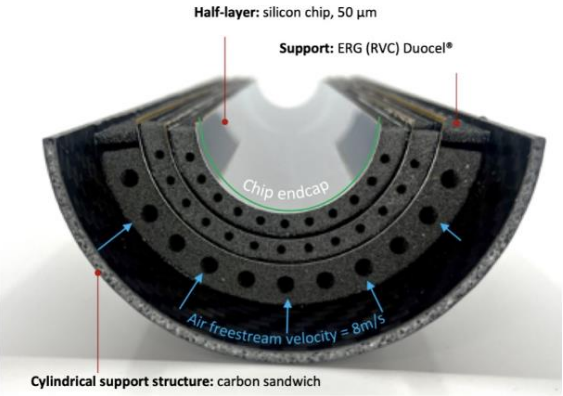
✓ quasi continuous test beams at PS (Jul, Aug, Sep, Oct'23, Mar, May '24)

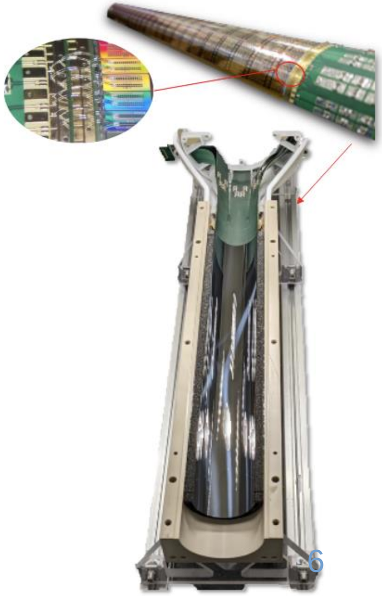




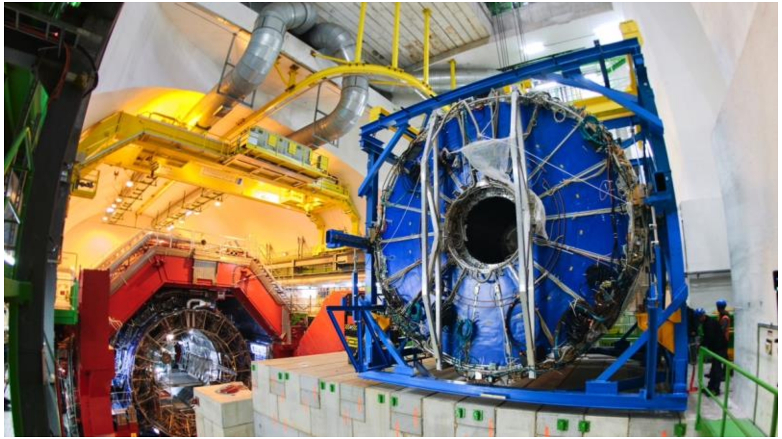
- Sensors
  - preparation of final sensor (ER2, "MOSAIX") prototype
    - design well advanced, test system being prepared
- Mechanics → EP-DT responsibility
  - preparation for final sensor modules
    - all jigs ready, assembly hall and cooling system under preparation

✓ three-layer assembly (final mechanics/jigs; dummy Si)





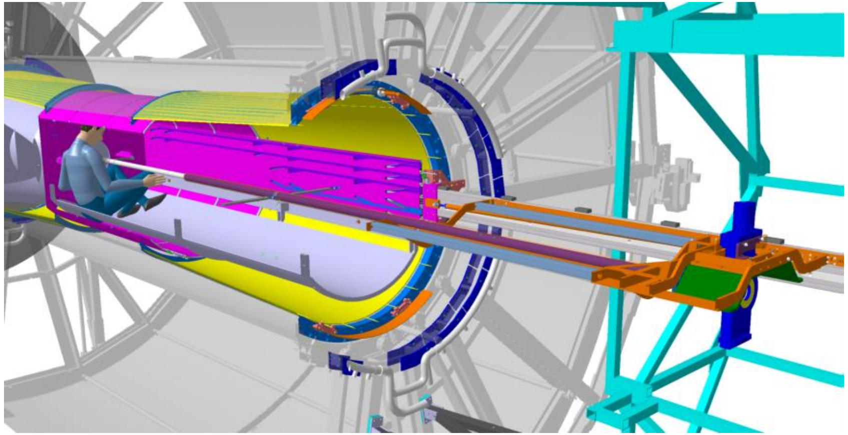
TPC & beampipe



Central beampipe replacement:

- The standard procedure involves moving the TPC to its parking position for the beampipe replacement (access C-side flange)
- An alternative solution is being studied to **replace the central beampipe while the TPC remains in situ**.

EP-DT in procedures and hardware development for beampipe swap

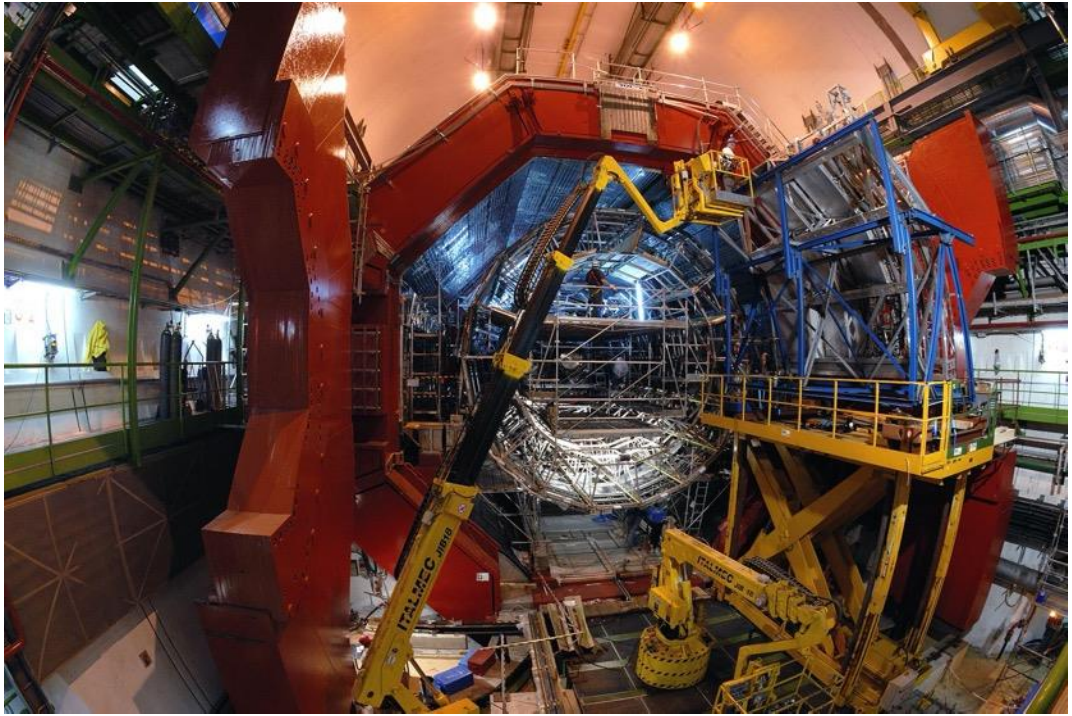


TPC plans:

- The TPC was **extracted during LS2** for a major upgrade using GEM (Gas Electron Multiplier) technology.
- Out of 72 GEM chambers, **only one** has developed a **short** and can be operated in degraded mode.
- If this condition remains stable until the end of Run 3, there will be **no need to extract the TPC during LS3.**
- Keeping the TPC in place during LS3 will significantly **simplify the ALICE shutdown operations**, saving several months of work!

Testing the central beampipe sliding table

HMPID removal



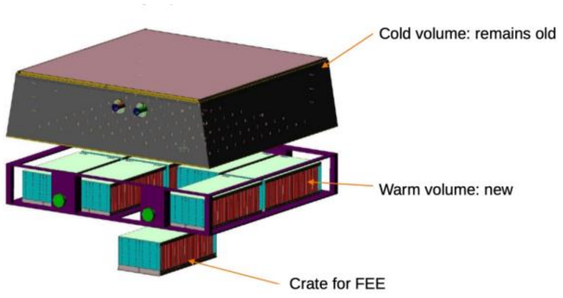
The HMPID (High Momentum Particle Identification Detector) was the first detector installed in ALICE, on 23 September 2006.

Its **gas** and **cooling** systems will have to be removed as well.

EP-DT in procedures and hardware preparation and in de-installation work in the Experimental Cavern

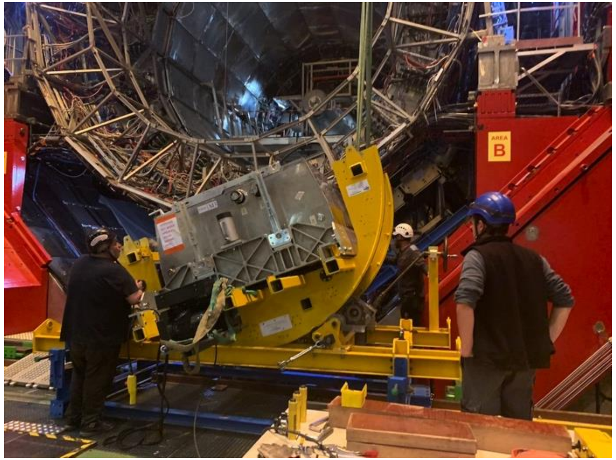
PHOS upgrade

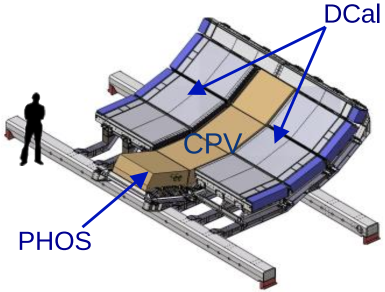
- PHOS is preparing an **upgrade of the electronics** (photodetectors, FEE) **and mechanics** in LS3, which will require extracting all the 4 modules, including the 3 DCal A-side modules.



- This plan depends on the position of Russa at CERN after 2024.

EP-DT in deinstallation work in the Experimental Cavern for PHOS



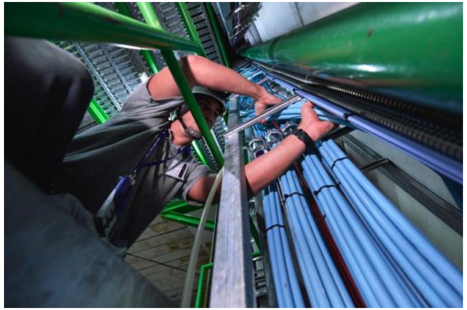


LHC dipole exchanges via PX24

Exchanging LHC dipoles through the low-beta platform (photo LS1)

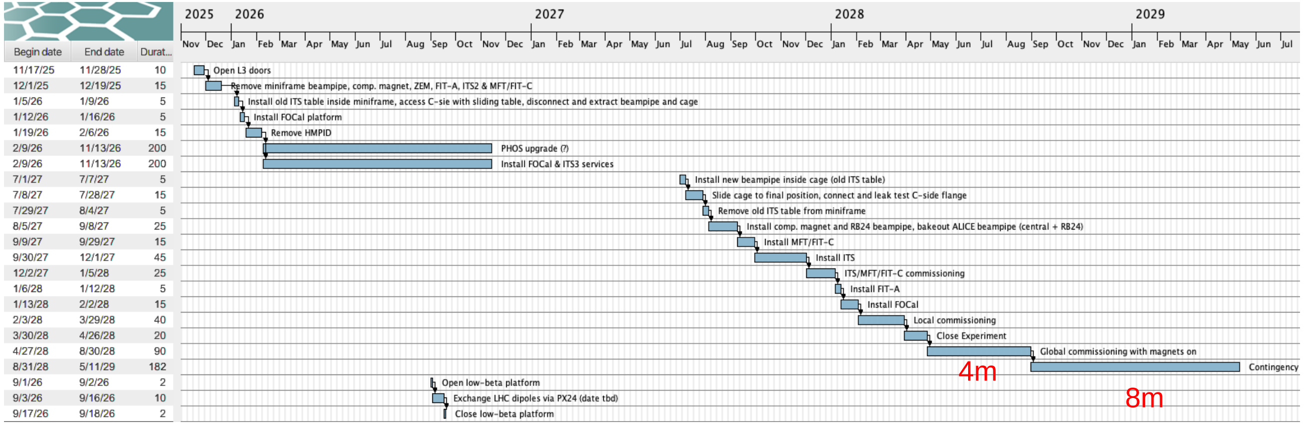
Other LS3 projects (selection)

- **DSS** consolidation (DSS2) (EP-DT)
- Maintenance L3 and Dipole cooling systems (EP-DT)
- Installation **services for ITS3 and FoCal** (BE-EA, EN-EL and EN-CV)
- **Gas** consolidation (dewars) (BE-EA)
- Consolidation **L3 power converter** (TE-VSC)
- **PSS cons**: gas and ODH, evacuation, Sniffer, LASS, Fire Detection (EN-AA)
- Electrical and cooling maintenance & consolidation (EN-EL + EN-CV)
- Replacement of the Hazemeyer TDM switchboards (LEP times) (EN-EL)



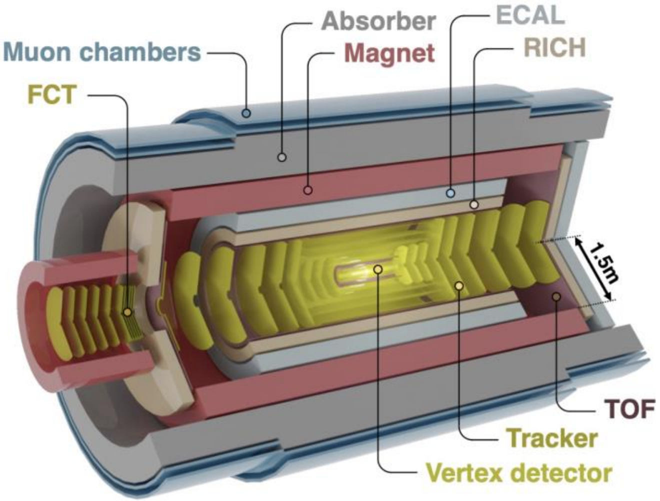
Conclusions about ALICE LS3 upgrade

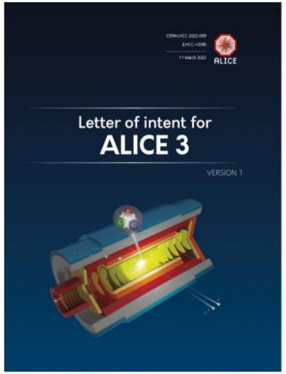
- Two new detectors, **ITS3 and FoCal**, will be installed in ALICE.
- A **new central beampipe**, featuring a reduced inner diameter and a conical section, is required to accommodate the upgrades.
- The **TPC** is expected to **remain in its current position** during LS3.
- Compared to LS2, the shutdown work will be probably **less complex**, assuming the beampipe replacement can proceed without extracting the TPC.
- The **planning** for LS3 includes a substantial **global commissioning** phase lasting 4 months, along with an 8-month **contingency** period to address any unforeseen issues.
- **EP-DT plays a key role in several LS3 activities.**



LS4 plans

ALICE 3 detector for Runs 5-6





CERN-LHCC-2022-009

arXiv:2211.02491

➠ **Novel detector concept**

- Compact and lightweight all-silicon tracker
- Retractable vertex detector with R_{min}= 5 mm
- Extensive particle identification
- Large acceptance $|\eta| < 4$
- Superconducting solenoid, B = 2T
- Continuous read-out and online processing

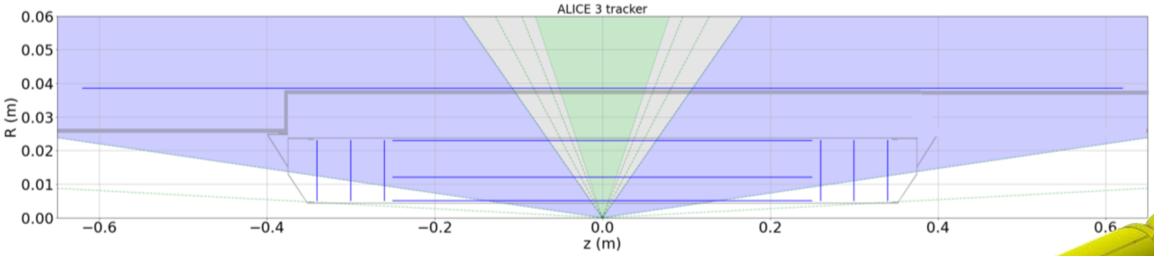
➠ **Scoping Document in preparation**

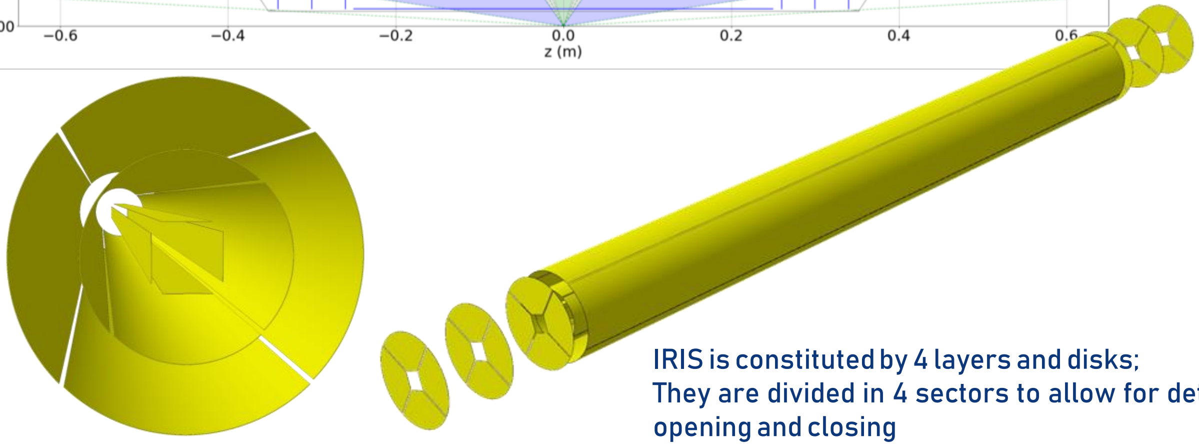
- Definition of reference configuration
- Scoping options: without ECal, reduced magnetic field (1T)
- Detailed assessment of resources and schedule

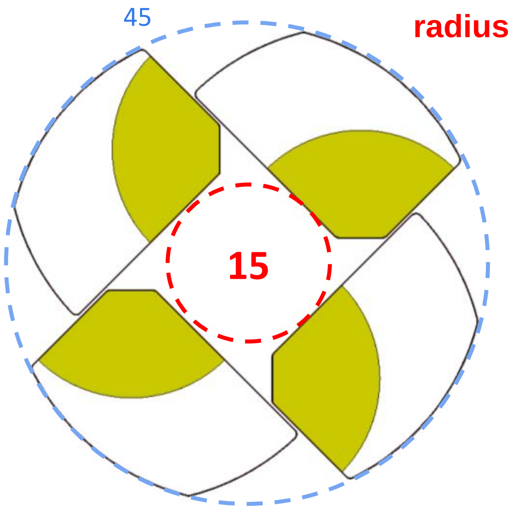
- This project is described in a **letter of intent** and was presented last year to the LHCC.

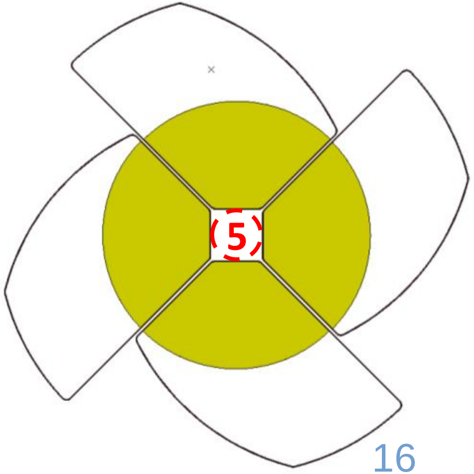
- TDRs in 2026-27.

IRIS layout







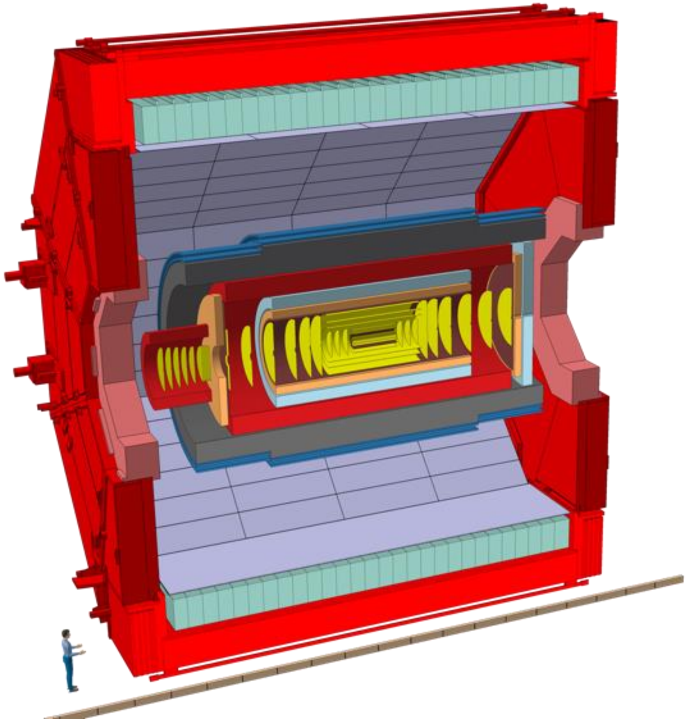


IRIS is constituted by 4 layers and disks;
They are divided in 4 sectors to allow for detector opening and closing
Each sector is contained in a case (petal) with secondary vacuum that prevent contamination of the primary vacuum from detector outgassing

EP-DT: mechanics, cooling and vacuum

Minimum aperture at injection i.e. ~15mm radius
Closes to 5mm radius during operation

The L3 yoke



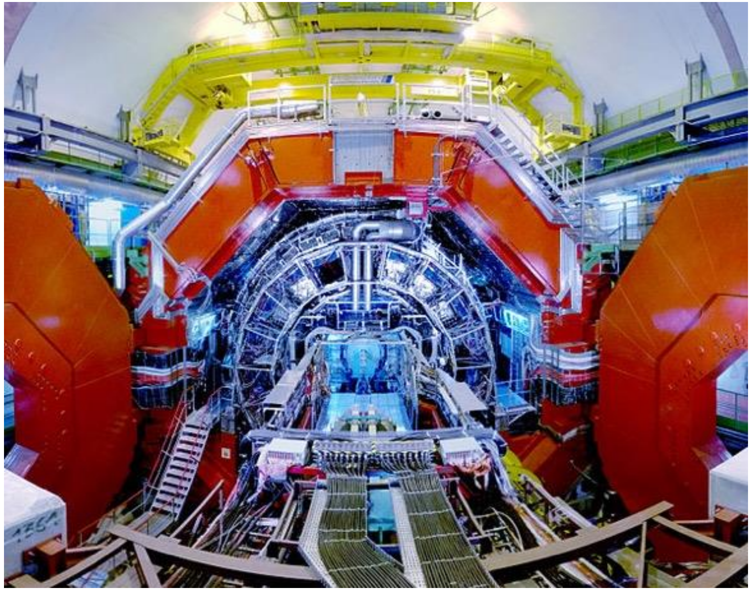
The plan is to remove the entire ALICE detector and just **keep the yoke of the L3 magnet in place** (no time in LS4 to take it out).

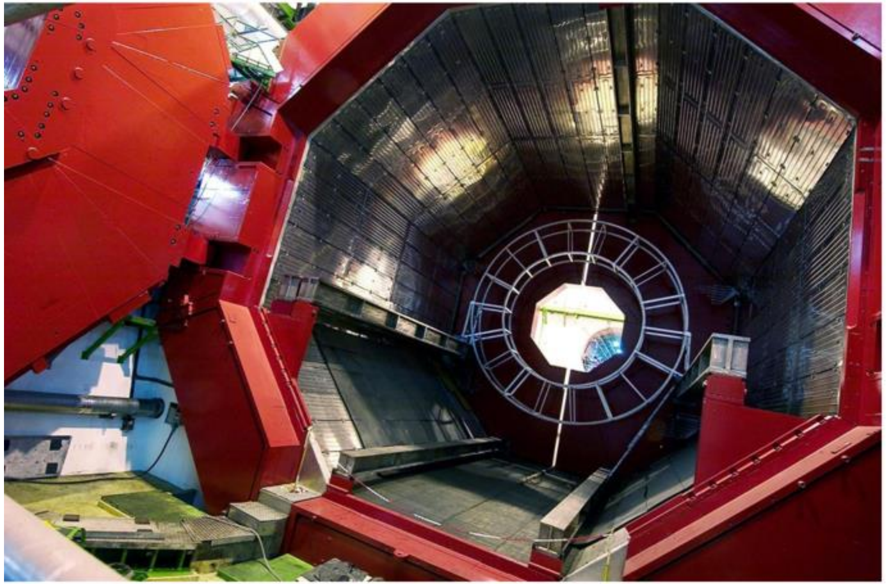
A reinforcement of the L3 bottom part will be needed to hold in place the ALICE 3 setup.

Cradle to hold in place the detector.

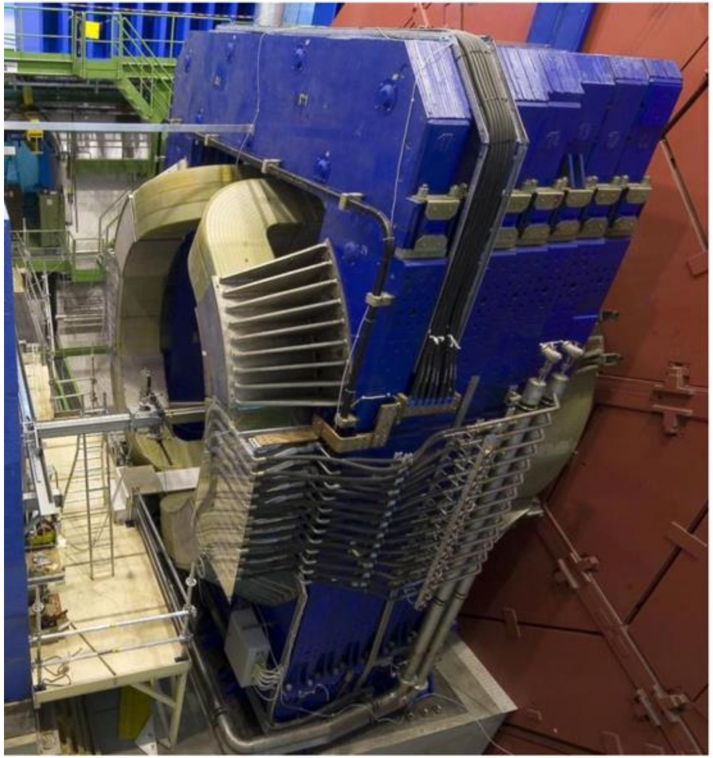
EP-DT in mechanics and integration.

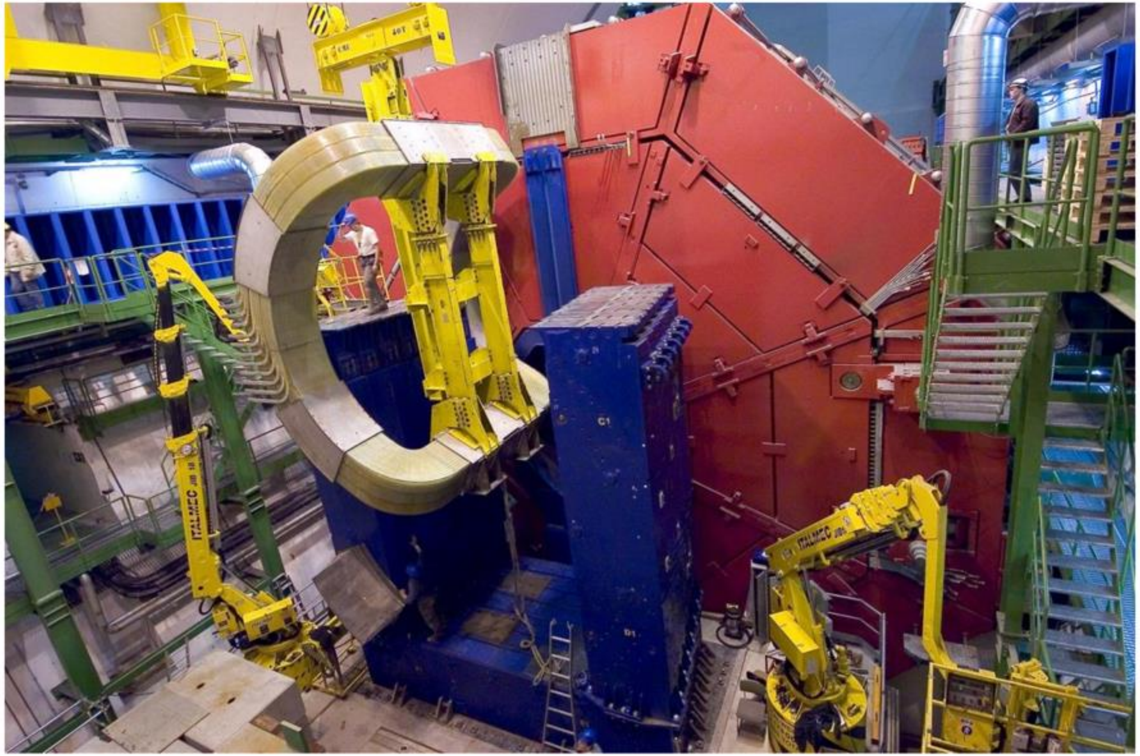
ALICE 2.1 dismantling: central barrel detectors





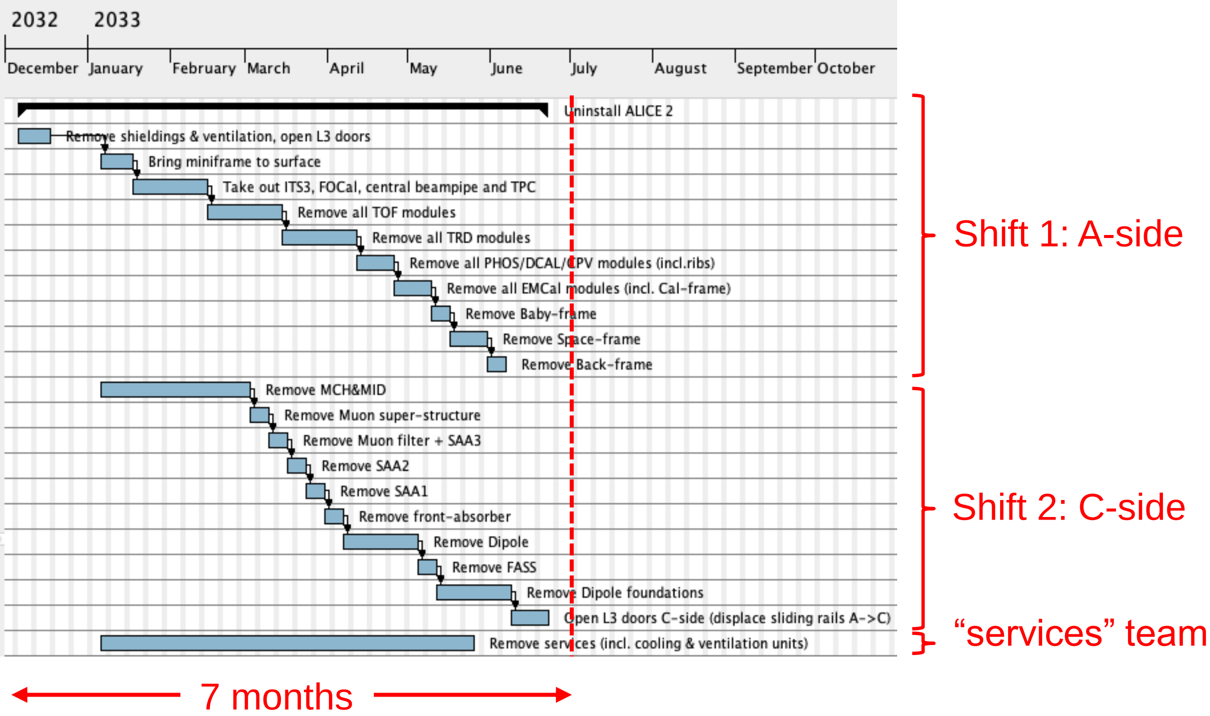
ALICE 2.1 dismantling: Dipole magnet



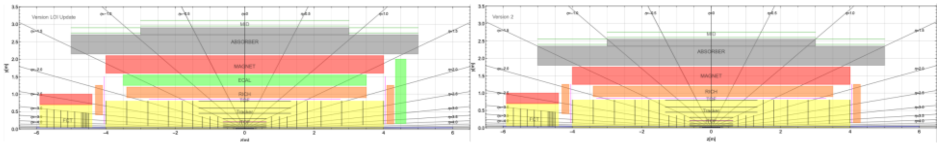


ALICE 2.1 dismantling schedule

Name	Begin date	End date	Durati...
Uninstall ALICE 2	12/6/32	6/22/33	143
Remove shielding...	12/6/32	12/1...	10
Bring miniframe to...	1/6/33	1/17/33	8
Take out ITS3, FO...	1/18/33	2/14/33	20
Remove all TOF ...	2/15/33	3/14/33	20
Remove all TRD ...	3/15/33	4/11/33	20
Remove all PHOS...	4/12/33	4/25/33	10
Remove all EMCal...	4/26/33	5/9/33	10
Remove Baby-frame	5/10/33	5/16/33	5
Remove Space-fr...	5/17/33	5/30/33	10
Remove Back-frame	5/31/33	6/6/33	5
Remove MCH&MID	1/6/33	3/2/33	40
Remove Muon su...	3/3/33	3/9/33	5
Remove Muon filt...	3/10/33	3/16/33	5
Remove SAA2	3/17/33	3/23/33	5
Remove SAA1	3/24/33	3/30/33	5
Remove front-abs...	3/31/33	4/6/33	5
Remove Dipole	4/7/33	5/4/33	20
Remove FASS	5/5/33	5/11/33	5
Remove Dipole fo...	5/12/33	6/8/33	20
Open L3 doors C-...	6/9/33	6/22/33	10
Remove services (...	1/6/33	5/25/33	100



Superconducting magnet options

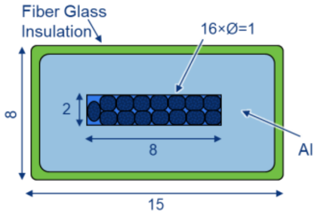


Magnet option	V1-2T	V1-1.5T	V1-1T	V2-2T	V2-1.5T	V2-1T
Type	Solenoid, no end-windings					
Central magnetic field (T)	2	1.5	1	2	1.5	1
Free bore radius (m)	1.6			1.25		
Cold mass length (m)	7.5					

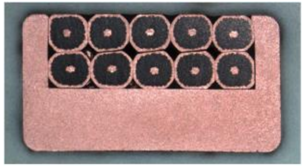
Conductor options

- **Aluminum-stabilized Nb-Ti/Cu:**
  - Historically used in experimental magnets → preferred solution!
  - Availability issues with aluminum co-extrusion.
  - R&D at CERN **(EP-R&D WP8)** to re-establish conductor availability.

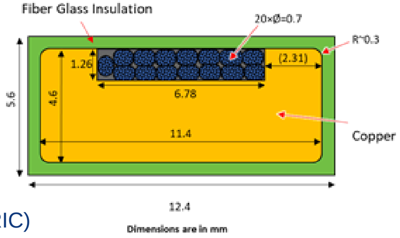
CMS conductor



- **Copper-stabilized Nb-Ti/Cu:**
  - Used in the EPIC magnet (MARCO) at the EIC.
  - Produced by Luvata (USA).
  - Extensive knowledge at CEA Saclay.

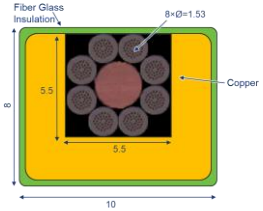


ISEULT Rutherford cable-in-Channel (RIC)



- **Copper-stabilized MgB_2:**
  - Higher critical temperature (39K).
  - Produced as round multi-filamentary wire by ASG (Italy).
  - Ongoing R&D at INFN Genova.

3kA cable for HL-LHC SC link

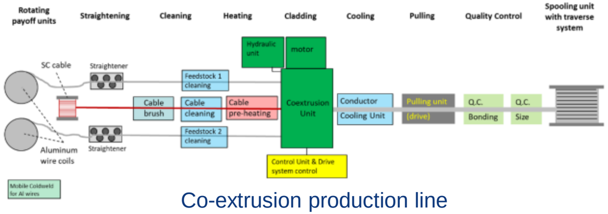


Challenges in Al-stabilized superconductor production

- **Co-extrusion** requires high investment and **is not commercially viable** due to low demand (1 every 5-10 years). The production line has been discontinued.
- Last batches: ATLAS & CMS (1999-2004), Comet, MPD, Mu2e (2007-2022).
- CERN's Sep 2022 workshop addressed the commercial availability of Al-stabilized superconductor technology.
- CERN EP is leading **R&D effort** (EP R&D WP8) to **resume production** with some industrial partners.
- We recently contacted **Wuxy Toly** via Chinese institutes associated with ALICE, as a possible supplier.

统力电工 TOLY ELECTRIC

EP R&D



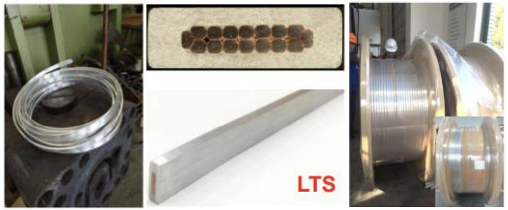
Co-extrusion production line

Al rods

Pre-processing equipment

Extrusion machine

Co-extrusion process



Al stabilized Nb-Ti/Cu superconductor

Magnet design

- **Preliminary design for all 6 configurations with Nb-Ti/Cu cable done by M. Mentink, B. Cure and A. Dudarev (EDMS 2915347).**

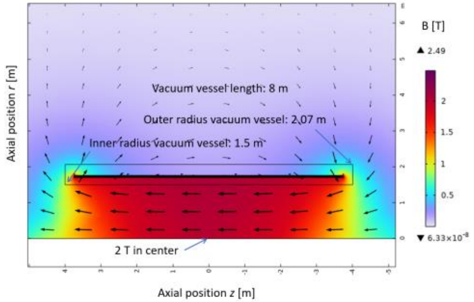
- **Collaboration with INFN-Genova**
  - Established in April 2023.
  - INFN-Genova will design and compare MgB_2 and Nb-Ti/Cu conductors. Relying on long-standing collaboration between INFN-Genova and ASG Superconductors.
  - Goal: determine MgB_2 feasibility by mid-2025.

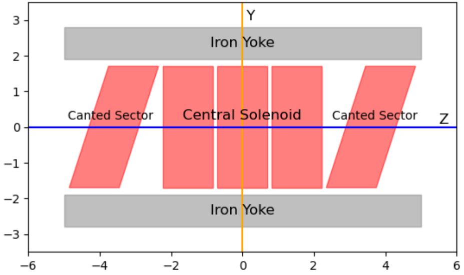
- Quite several scoping options (geometry x field x cable type) → studies focused on **V2-2T** geometry for engineering, adaptable to future decisions.

- **Target: CDR by mid-2025**
- Detailed system-level design:
  - Cold mass, conductor, cryogenics, cryostat, current leads
  - Structural, thermal, mechanical, electrical, material analysis

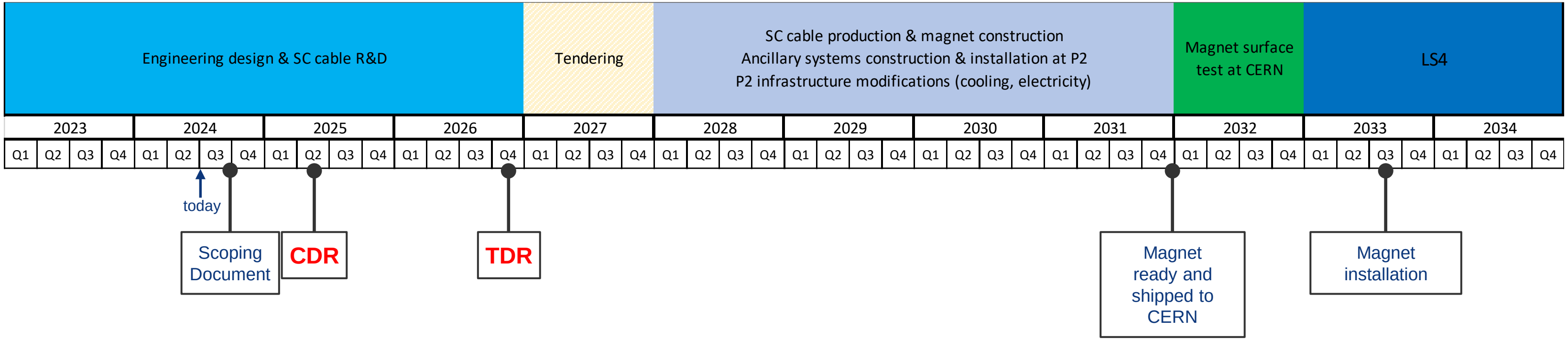
    Quench protection, instrumentation, ramping losses

Magnet parameters	V1-2T		V1-1T		V2-2T		V2-1T		MARCO @ EIC
Conductor type (Cu-cladded)	Nb-Ti	MgB2	Nb-Ti	MgB2	Nb-Ti	MgB2	Nb-Ti	MgB2	Nb-Ti
Central magnetic field [T]	2		1		2		1		2
Free bore radius [m]	1.6				1.25				1.4
Cold mass length [m]	7.5								3.5
Nb. of layers	3	4	1		3	4	1		6
Nb. of turns per layer	620	940	620		600	940	600		278
Conductor length [km]	21.7		7.2		16.5		5.5		19
Stored energy [MJ]	122	116.1	30		74	74.4	19		45
Operating current [kA]	6.61	3.27	9.90		6.77	3.22	10.15		3.9
Inductance [H]	5.0	21.8	0.9		3.1	14.4	0.6		
Operating temperature [K]	4.5	18-20	4.5		4.5	16-18	4.5		4.5



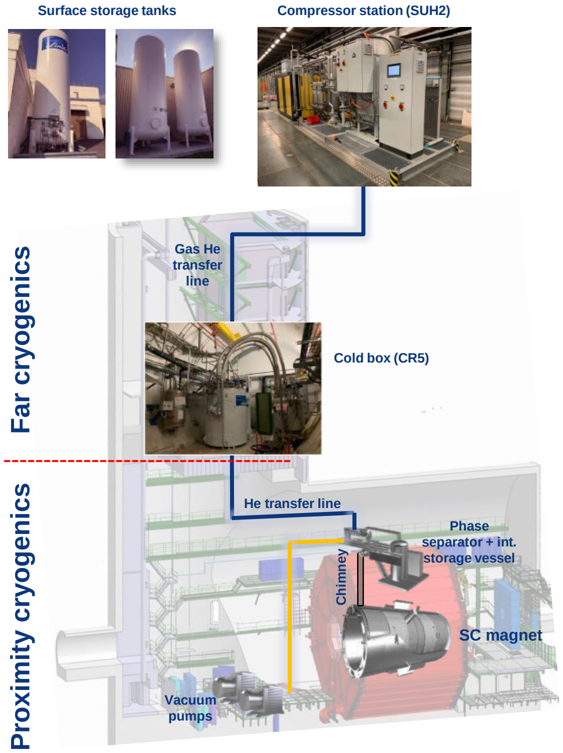


Magnet timeline



- ✓ Magnet **cost estimate** for scoping document.
- ✓ **CDR (Q2 2025)** → detailed system level design of Nb-Ti/Cu and MgB_2 options based on R&D conducted at CERN/ASG. Decision on magnet technology.
- ✓ **TDR (Q4 2026)** → comprehensive description of the design, specifications, and implementation plan. Detailed engineering drawings, specifications, calculations, analysis results, test plans, quality assurance measures, and a finalized cost estimate.

Magnet cryogenics



- **Cold mass** is cooled in indirect mode by liquid helium thermal syphon and **thermal shield** cooled by gas He.

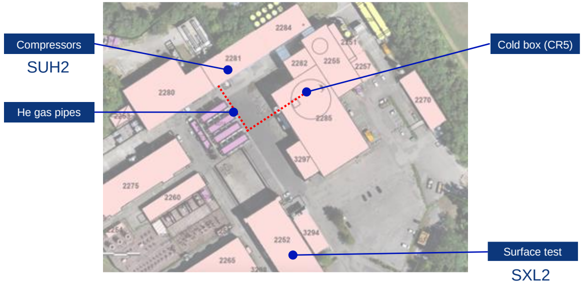
- **Far cryogenics: consolidated expertise at CERN (TE-CRG):**
  - **Compressor station:** compress He stored in **surface storage** tanks → located in bld. SUH2.
  - **Gas He transfer lines:** connecting cryoplant and cold box.
  - **Cold box:** produces liquid & gas He → will be located in CR5.

- **Proximity cryogenics (part of the magnet deliverables):**
  - **Phase separator dewar**: connected with the cold box via dedicated **He transfer line**. Meant to 1) generate sub-cooled He; 2) control the flow and pressure of He into the solenoid and 3) cool the current leads.
  - **Intermediate storage vessel:** He buffer (typically 5-10 m^3) needed for slow discharge of the solenoid.
  - **Vacuum pumps:** for the vacuum insulation of the cryostat.

- **Cost:** a 500 W @ 4.5 Keq cryoplant will cost approximately **4.8 MCHF** (TE-CRG, Dec 2023).

- **Schedule:** 4 years to build the entire system. Cryoplant must be installed in the Run4 YETS to not interfere with LHC operation in bld. SUH2 (unless it is installed in a dedicated building).

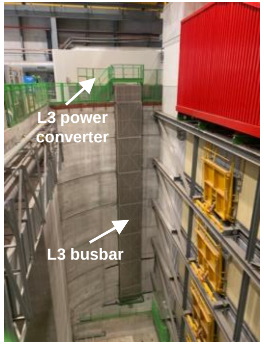
- **Resources:** “best effort” support by TE-CRG until LS3. Hopefully, resources will be liberated during LS3.



Possible layout cryogenic systems

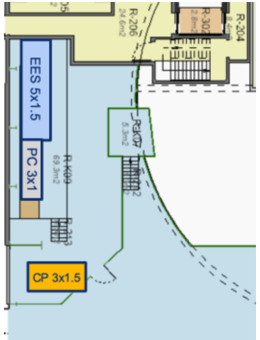
Magnet powering system

- **Power Converter (SY-EPC):** low voltage power converter (n+1 redundant construction) made of [2 kA; 8 V] power bricks. Reuse one of the converters which will be removed from the LHC in LS3 (power rack & power modules).
- **Energy Extraction System (TE-MPE):** upon quench detection the coil is discharged over a **dump resistor** which is switched in series with the magnet. The resistor is sized as to establish a peak resistive voltage of 500 V over the coil terminals. For an operating current of 7 kA, this gives a dump resistor value of 71 mΩ.
- **Integration: current L3 power converter location should be large enough to accommodate both the PC and EES.**
- **Warm busbar** → reuse L3 busbar: R=120uΩ, measured in Nov. 2022. V drop on the busbar = 0.84 V @ 7 kA. It will withstand the 500 V upon magnet quenching. Will need an **extension in the UX25 cavern**, to connect to the current leads. Normal 240 mm^2 cables can be used as well, but interface with current leads to be checked (T instabilities might induce quenches).
- **Current leads:** HTS-based current lead technology, currently under development in the context of EP R&D WP8 at CERN.



L3 warm busbar

Busbar extension



Possible integration of PC, EES and CP in SX2


Power converter (photo HL-LHC)

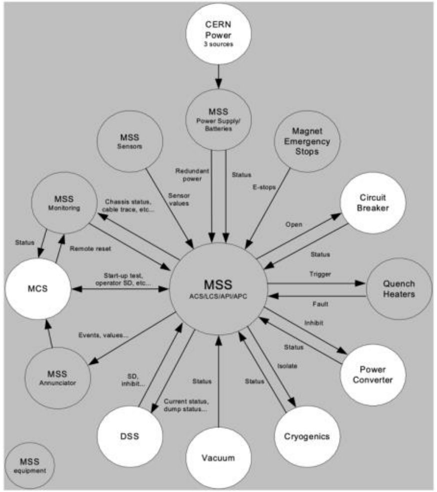
Energy Extraction System (photo HL-LHC)


L3 Power Converter


L3 Power Converter Cooling Plant

Magnet control and quench detection

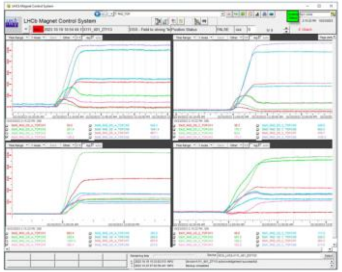
- **Magnet Control Project (MCP)**: rack-based systems developed by EP-DT since the late 1990s for **controlling, protecting, and monitoring** both superconducting and non-superconducting LHC Experimental magnets:
  - **Magnet Safety System (MSS):** main system for quench protection. The MSS includes a Ni-Cd battery bank to enable the safe and independent powering of the quench heaters.
  - **Magnet Control System (MCS):** controls and monitors all subsystems associated with the magnet (including EN-EL, EN-CV, SY-EPC, TE-CRG) and is connected to MSS.
  - **Magnet Diagnostic System (MDS):** reads out additional instrumentation: strain gauges, linear potentiometers, B-field sensors, temperature probes, voltage taps etc.
  - **Magnet Vacuum Control System (VCS):** controls the cryostat vacuum pumps.
- The **estimated cost** for the MCP implementation for the ALICE 3 magnet, established in Oct.2023 by **X. Pons (EP-DT)** (EDMS 2802769), is **0.9 MCHF**. This includes 7 racks and the manpower to assemble and test them. This estimate does not include the magnet instrumentation.



Item	Cost [kCHF]
Redundant MSS	272
MCS	105
MDS	t.b.d.
VCS	432
Manpower	104
TOT.	**913 kCHF**

MCP price estimate (Oct. 2023)

CMS MCS racks



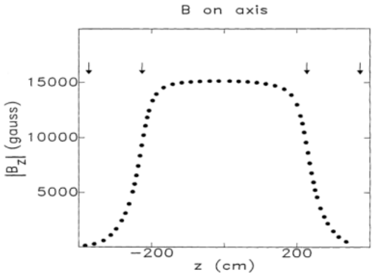
LHCb strain gauges during ramp-up 19-10-2023

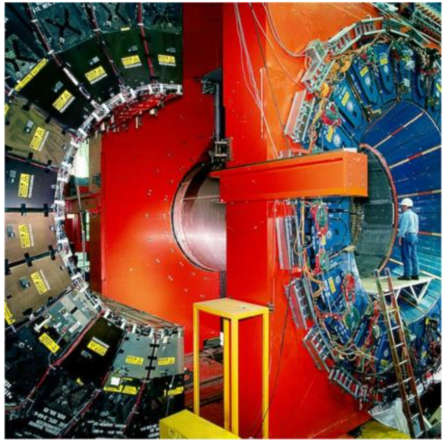
Possible backup magnet option: CDF solenoid

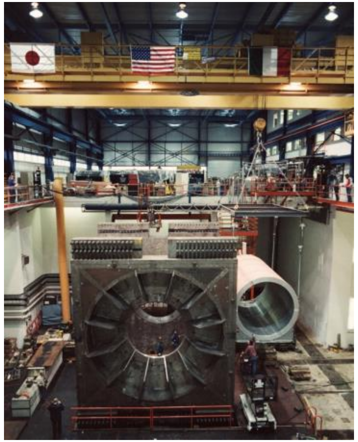
CDF magnet at Fermilab (Hitachi, 1984)

B=1.5 T, r_in=1.4 m, l=5 m

Operated at Fermilab until 2011, when Tevatron was shut down – still in place in experimental hall.







CDF magnet transportation from Japan to US (photo 1984)

Other backup magnet options

BaBar (ASG, 1998)

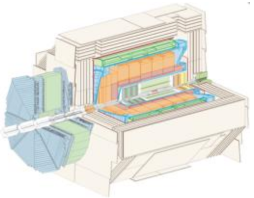
B=1.5 T, r_in=1.5 m, l=3.7 m

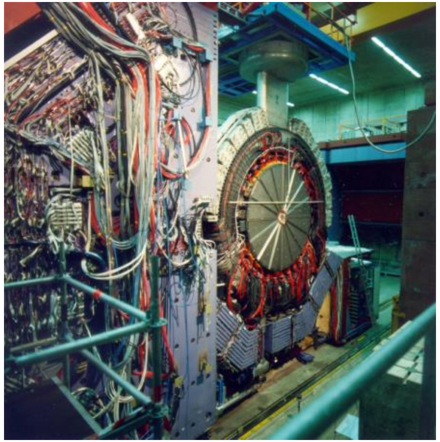
Built for SLAC, relocated to sPHENIX in 2015

H1 magnet (RAL, 1992)

B=1.15 T, r_in=2.6 m, l=5.75 m

Located at Desy





Delphi magnet (RAL, 1985)

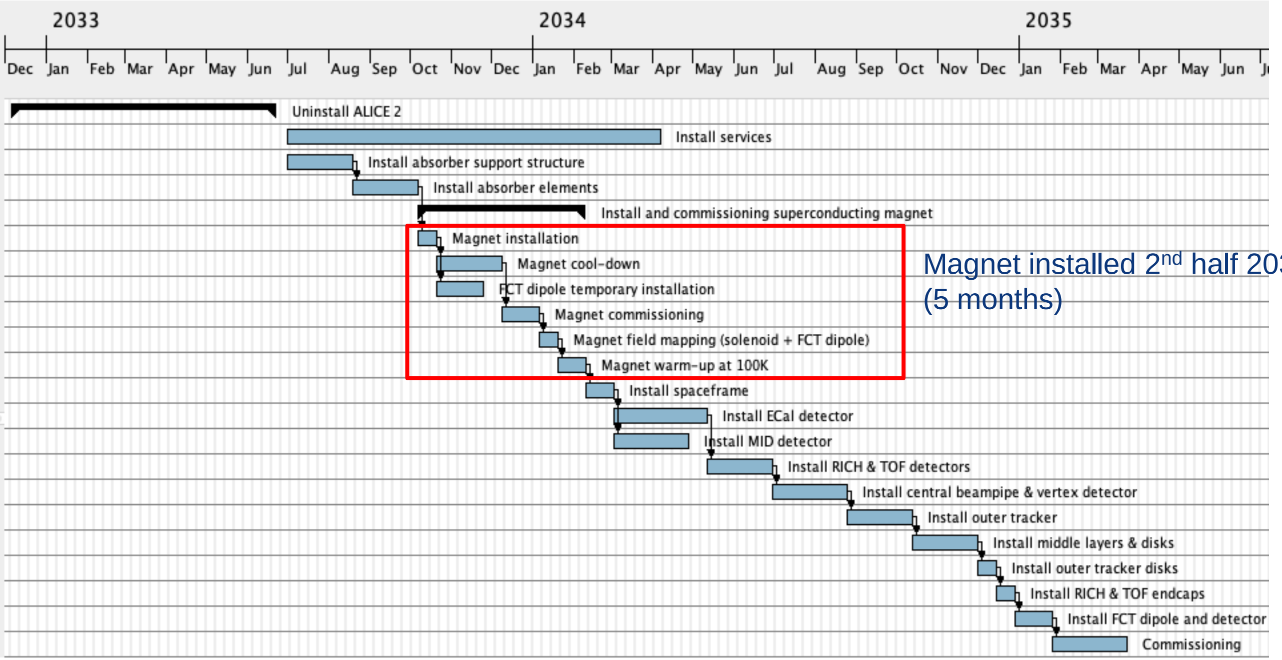
B=1.23 T, r_in=2.6 m, l=7.4 m

Located at LHCb

Close to impossible to take it out from LHCb.

ALICE 3 installation schedule

Begin date	End date	Dura...
12/6/32	6/22/33	143
7/1/33	4/6/34	200
7/1/33	8/18/33	35
8/19/33	10/6/33	35
10/7/33	2/9/34	90
10/7/33	10/20/33	10
10/21/33	12/8/33	35
10/21/33	11/24/33	25
12/9/33	1/5/34	20
1/6/34	1/19/34	10
1/20/34	2/9/34	15
2/10/34	3/2/34	15
3/3/34	5/11/34	50
3/3/34	4/27/34	40
5/12/34	6/29/34	35
6/30/34	8/24/34	40
8/25/34	10/12/34	35
10/13/34	11/30/34	35
12/1/34	12/14/34	10
12/15/34	12/28/34	10
12/29/34	1/25/35	20
1/26/35	3/22/35	40



Magnet installed 2nd half 2033 (5 months)

Conclusions about ALICE 3

- ALICE 3 is a **very ambitious plan**, which entails building a **totally new experiment**.
- A **scoping document** will be submitted later this year.
- A **superconducting magnet** will be needed.
- We will definitely need the involvement of EP-DT
    - ALICE 2.1 deinstallation
    - Superconducting Magnet (cable, control, mechanics…)
    - ALICE 3 design Layout and Detectors interface control
    - ALICE 3 installation hardware design
    - ALICE 3 global mechanics
    - ALICE 3 services
    - IRIS new vertex
    - …

Thank you!