ALICE 3
Summary and Outlook

5th ALICE Upgrade Week,
Kraków, 11 October 2024

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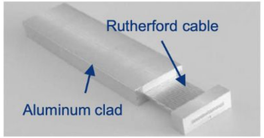
Highlights from subsystems parallel sessions

(much more in the plenary and parallel session talks!)

SC magnet

News on the conductor

- **Baseline → CERN R&D program:** tender early 2025 to set up a development line for coextrusion and coldwork.
- **Since availability of the conductor remains an issue, we decided to design a magnet starting from an available conductor, rather than following the conventional process, i.e. magnet design → conductor design.**
- The Chinese company **Wuxi-Toly** provided specs and a **10m sa** **Experimental Muon Source (EMuS)** magnet:
  - A bit **smaller** than our nominal design: 4.7 x 15 mm^2.
  - Coextruded with **pure Al**.
- We asked **M. Mentink** (CERN EP) to studiy a cold-mass concep



Al-coextruded cable


EMuS conductor sample

+ Concrete interest from Brazil and Pakistan to contribute to magnet (and absorber)

Cold-mass concept based on EMuS conductor 1/2

- Preliminary investigation of using this conductor "as-is" for the ALICE 3 superconducting magnet (v2-2T):
  - **Very stable conductor** with **large operating margin**.
  - The **shear stress** at the interface between the conductor to the support cylinder is modest, with a peak of 1.1 MPa.
  - **Quench protection:** with an energy extraction resistance of 150 mΩ, the adiabatic hotspot temperature may be kept below 100 K, provided quench detection and validation occurs within 1.5 s.
- **Conclusions: the conductor might be used as-is**, even if **it would preferable if the amount of aluminum were increased, while reducing the fraction of Nb-Ti.** Quench protection would be more straightforward if the conductor cross-sectional area were larger (i.e. **more aluminum**).

Property	Value
Inner radius [m]	1.78
Total length of the absorber [m]	10
Length of the thicker part of the absorber in the middle [m]	6
Thickness of the absorber in the middle [m]	0.7
Thickness of the absorber at the edges [m]	0.5

Table 2. Considered geometrical properties of the ferromagnetic absorber

Property	Value
Operating current [A]	4590
Stored magnetic energy [MJ]	74
Inductance [H]	7.0
Peak magnetic field on the conductor at operating current [T]	2.24
Aluminum-alloy cylinder thickness [mm]	35
Number of layers	2
Number of windings per layer	1312
Total number of windings	2624
Total conductor length, including in-coil joints but not external busbars, extra lengths for quality control, etcetera [km]	24.2
Cold mass length [m]	7.44
Cold mass weight, not including cold mass suspension, cooling lines, etc [t]	14.5

Table 3. Considered solenoid geometry

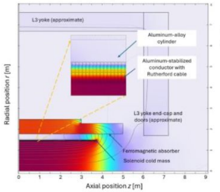
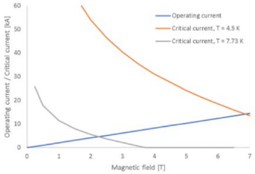
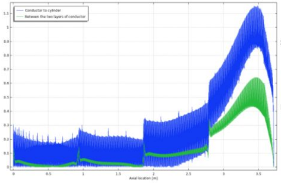
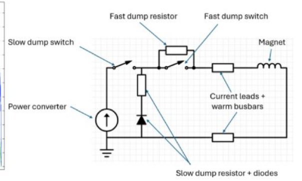


Fig. 1. Considered Alice-3 geometry



Load-line plot of the EMuS conductor


Von Mises stress (peak is at 1.1 MPa)

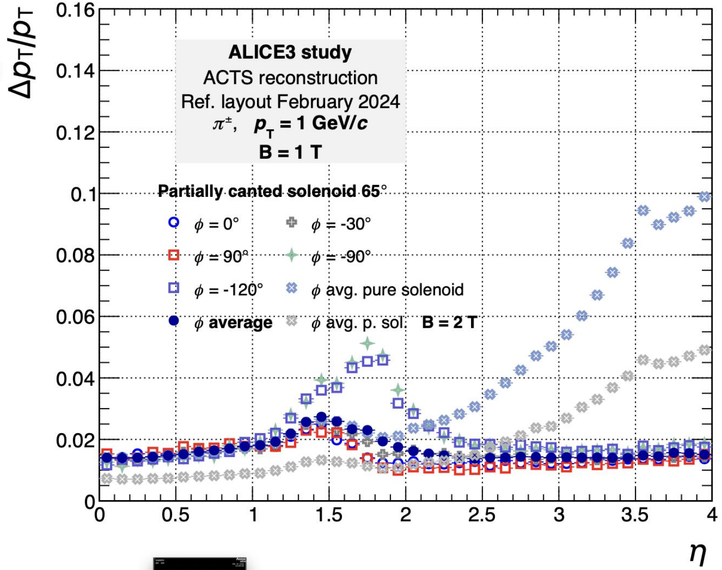


Powering and quench protection circuit

SC magnet

Follow-up on canted design options

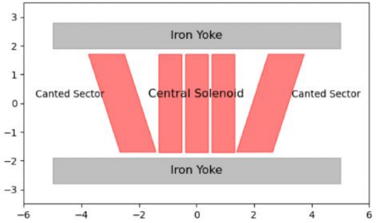
- **Goal:** improve the momentum resolution at rapidity values $2<\eta<4$ (was investigated also in the LoI with dipoles).
- Field maps (1T magnet) produced for two different geometries: **canted** and **partially canted** and different **winding angles**.
- Field maps → pT resolution plots (see Pavel's talk).
- **Results:**
  - ☺ As expected, improved resolution in forward region $\eta>2.2$.
  - ☹ Large phi-asymmetry of pT resolution.
  - ☹ pT resolution in mid rapidity $1.3<\eta<2$ and over large fraction of azimuthal acceptance generally worse than pure solenoid (factor 3-5).
- These implementations present added complexity and cost → **probably more efficient to proceed directly with the 2T option?**



Partially canted

pT resolution → See Pavel's talk

Canted solenoid is interesting, but 2T standard solenoid is a safer option, and probably similar cost



Patrially canted solenoid

Inner Tracker R&D

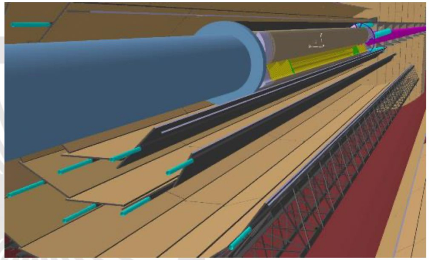
Ongoing studies

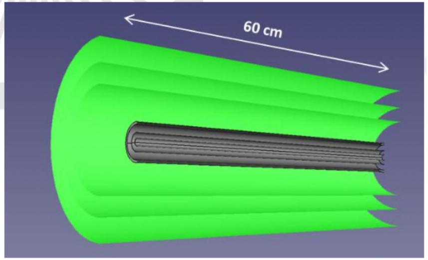
LoI concept

- **Traditional stave-based layout**
- **Same sensor as larger radius layers**
- Mechanics, liquid cooling
- **1% X_0** for normal incidence
- Length = **124 cm**
- **Serial powering**
- Coverage (L4): $|\eta| < 2.9$

Possible optimized layout for L3-L4

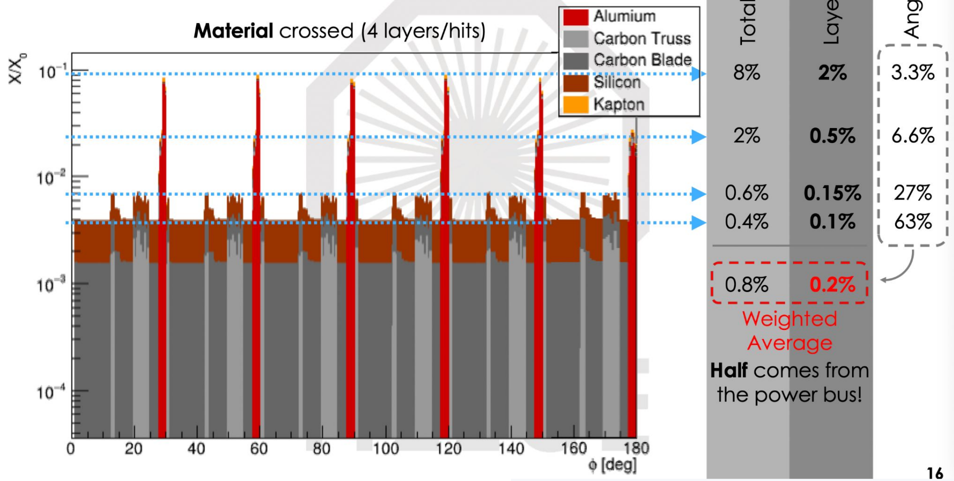
- **Flexible sensors with minimal supports**
- **Stitched sensor**
- Added supports and I/O structures to cover the length
- **0.1% X_0** for normal incidence
- Length = **60 cm**
- Coverage (L4): $|\eta| < 2.4$





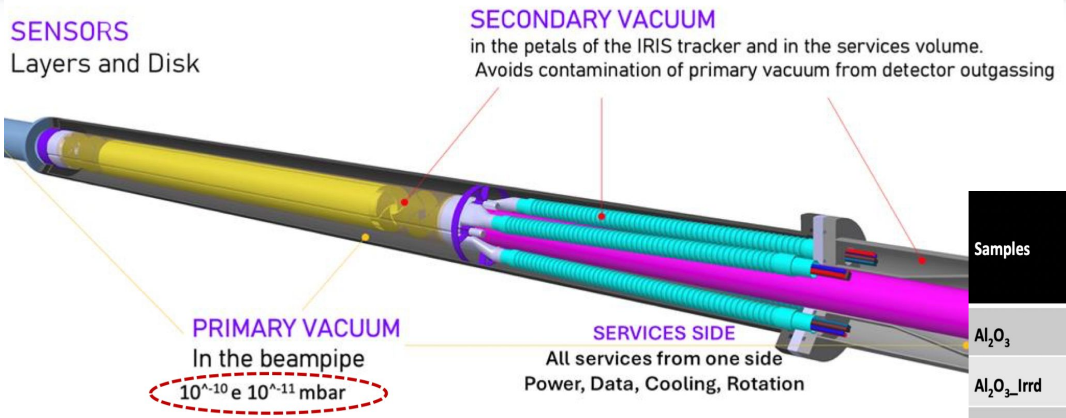
Lightweight ML layout

Material budget η=0 – log scale

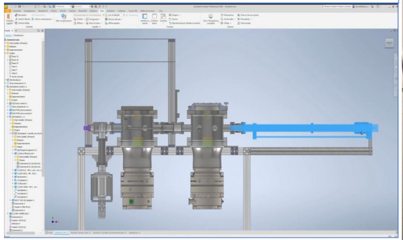


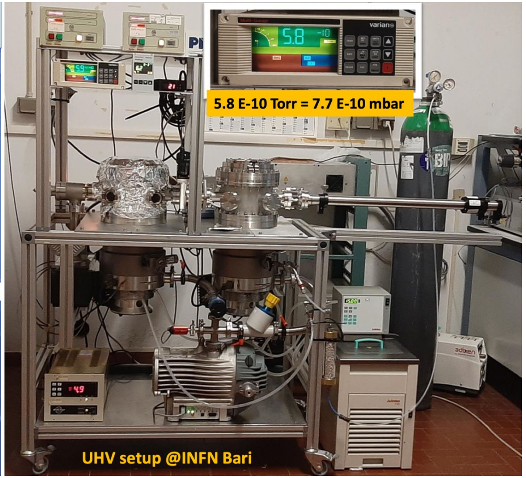
Different options for Middle Layers under study;
Ultralight version could reach x/X0 ~ 0.1-0.2%

Inner Tracker R&D



Sample transportation under vacuum:
from load lock chamber to main test chamber



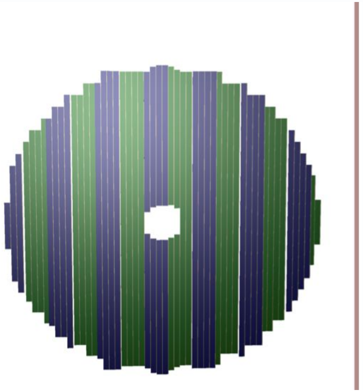


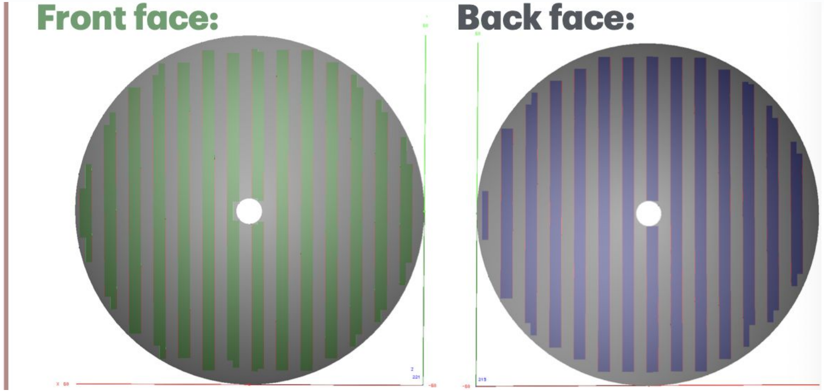
Outgassing tests to qualify material for IRIS vacuum req.

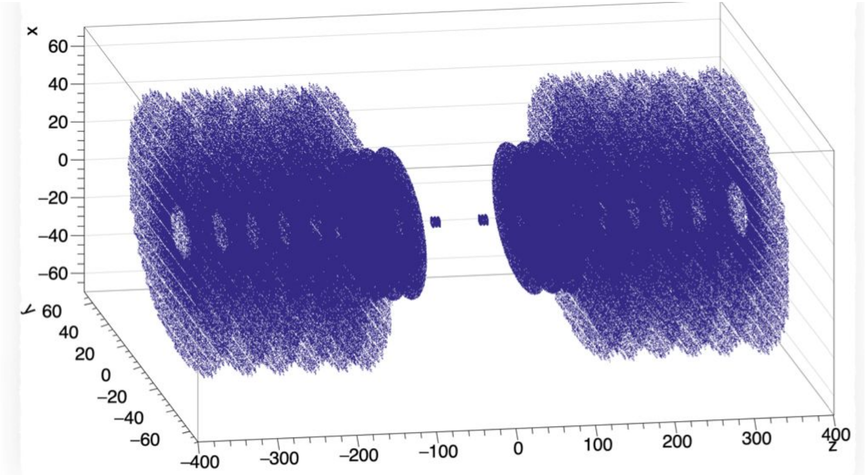
Samples	Initial Mass [mg]	Mass immediately after vacuum treatment [mg]	Mass after vacuum treatment [mg]	TML [%] [Mass loss]	TML [%] [Regain mass]	Remarks
Al_2O_3	4738.5	4738.4	4738.5	0.002	0.002	Vacuum Compatible
Al_2O_3_Irrd	4711.4	4711.4	4711.4	0	0	Vacuum Compatible
AlN	3907.8	3907.9	3907.8	-0.003	-0.003	Vacuum Compatible
AlN_Irrd	3912.7	3912.9	3912.9	-0.005	0	Vacuum Compatible
C_All_Comp_LD	974.4	974.1	973.9	0.03	-0.02	Vacuum Compatible
C_All_Comp_HD	2670.5	2668.9	2669.1	0.06	0.01	Vacuum Compatible
AlSi	7456.9	7456.9	7456.9	0	0	Vacuum Compatible
C_Substrate	483.3	482.5	483.0	0.17	0.10	Vacuum Compatible
Opt_Fiber	976.1	973.4	974.5	0.28	0.11	Shows Outgassing, but TML <1%
C_ERG	225.1	200.9	223.8	12.046	11.398	Shows Outgassing & TML>1%

Outer Tracker R&D

Advance in layout of OT disks, module layout and x/X0 profiling → within 1% target







$$< X/X_0 > = 0.97\,\%$$

$< X/X_0 >$ Si $= 0.12\,\%$

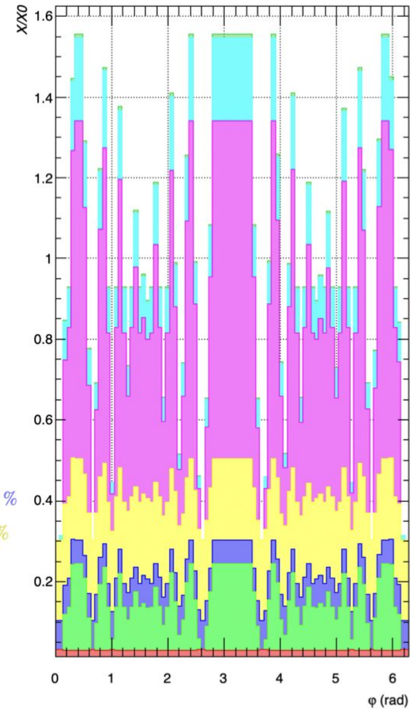
$< X/X_0 >$ Carbon Fiber $= 0.065\,\%$

$< X/X_0 >$ Carbon Foam $= 0.2\,\%$

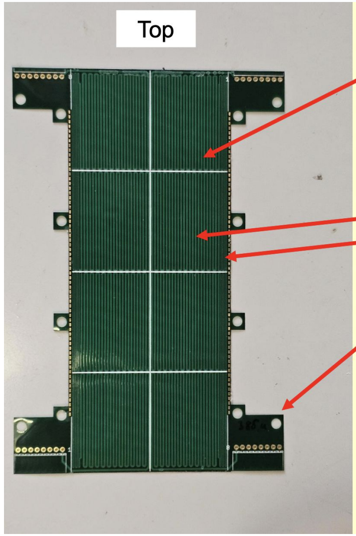
$< X/X_0 >$ Cu $= 0.47\,\%$

$< X/X_0 >$ Kapton $= 0.11\,\%$

$< X/X_0 >$ Epoxy $= 0.007\,\%$



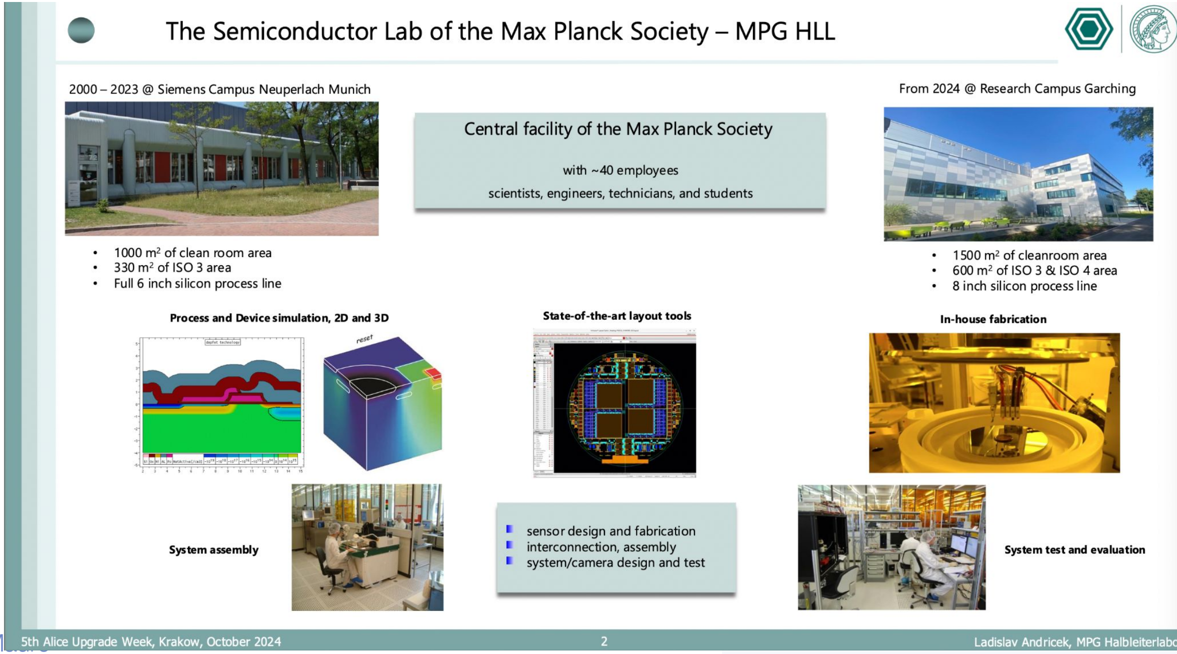
Outer Tracker R&D



- Expected chip positions
- Bonding pads, 1 row on each side
- Heating meander (one per sensor with 5 x higher density at the periphery)
- Connection flaps for Heating and temperature measurement. (just for testing)
- Handling flaps
- 150 μm 2D CF plate glued to the FPC.

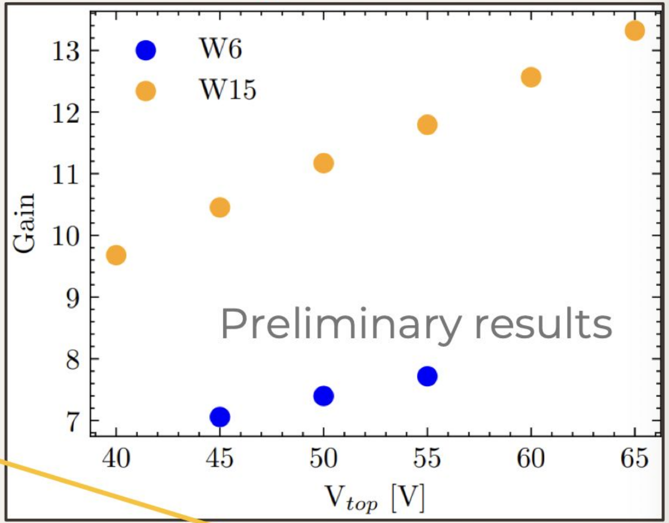
Module design started; FPC connection under study

Exploring collaboration with semiconductor lab of Max Planck Society in Munich



TOF R&D

Fist gain estimation



$$Gain = \frac{Peak\ [V/e]}{Electronics_{gain}\ [V/e]}$$

From electronics simulations matched with data

- → Prototype for timing application in 110nm technology design in the ARCADIA project
  - ↳ **MadPix**
- → Test beam characterization of devices with **low gain ≈ 2.5**
  - ↳ Time resolution ≈ **130ps** (Electronics + Sensor) but **high substrate current**
- → Performed Focused Ion Beam (**FIB**) on multiple samples
  - ↳ Substrate **current: 2 orders of magnitude lower**
- → Laboratory characterization of structure with **improved gain**
  - ↳ **Gain** of the sensor between **5 and 13**

What's next?

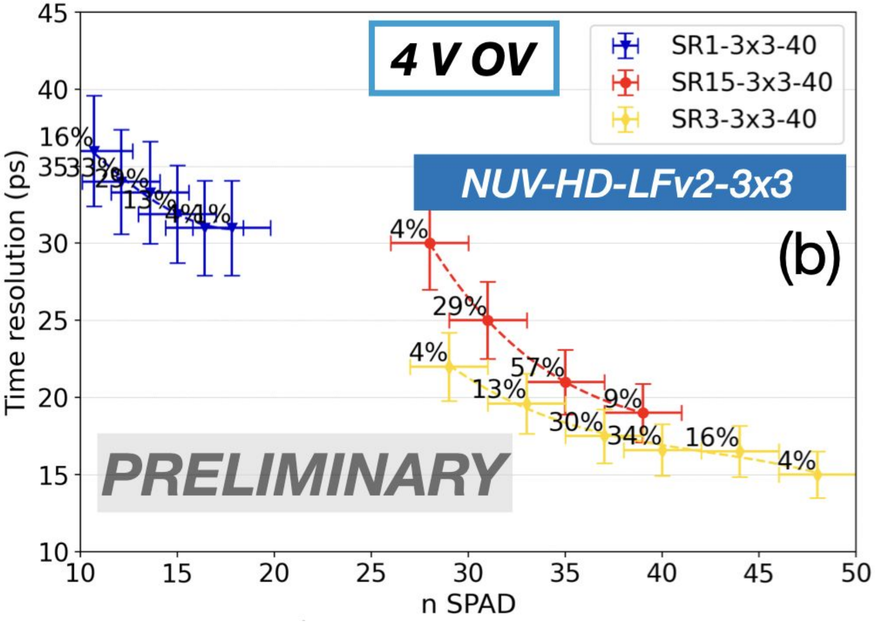
- → Characterization of MadPix with improved gain in the test beam of October 2024

New production of CMOS LGAD prototype sensor shows large gain (up to 15), compatible with simulations.

Will be tested in beam in the next days, expect time resol ~60ps

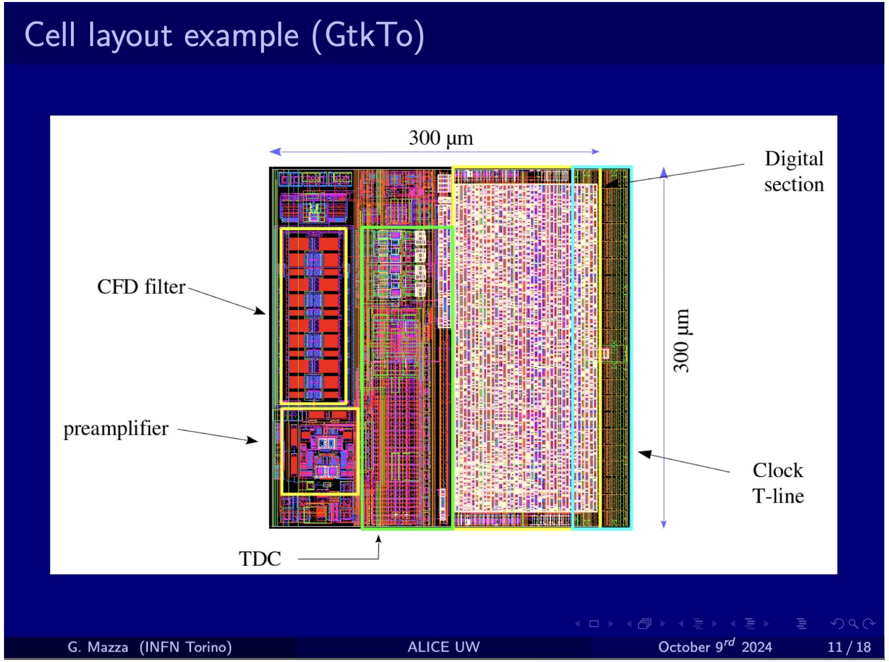
Important step towards target time resol ~20ps with version thinned to 25-30 um

TOF R&D

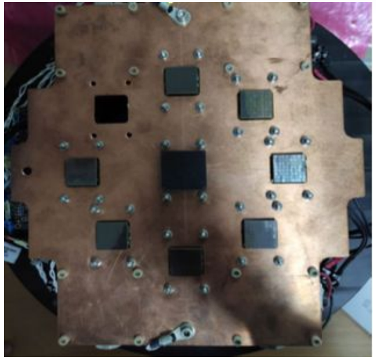


Beam test of new FBK 3x3 mm2 SiPM
Next: include FEE with Liroc and picoTDC

Preliminary specifications of the CMOS-LGAD FEE



RICH R&D

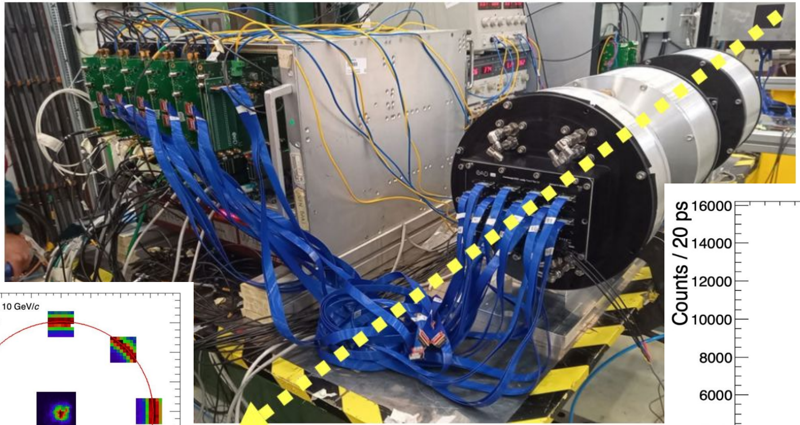


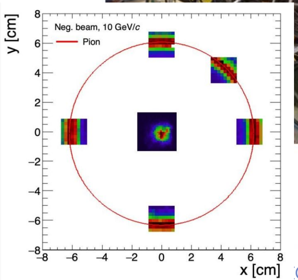
- New Radioroc FE board equipped with picoTDC
- 8x8 matrix of 2x2 mm2 HPK SiPM S13361-2050
- CO_2 as radiator gas to extend e-ID range
- monolithic 2-layer aerogel tile for focusing

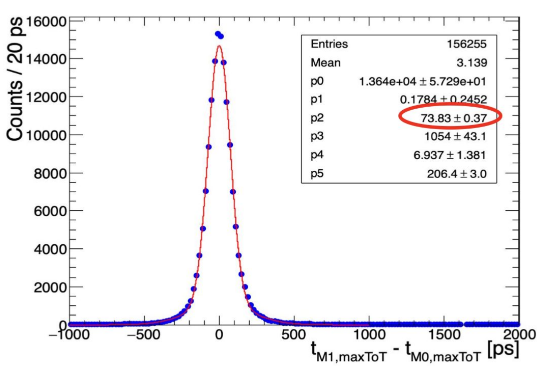
→ testbeam completed on 9/10, data analysis started

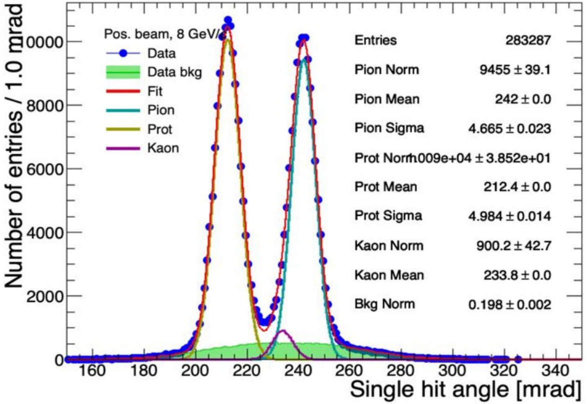
→ measured expected Cherenkov angle resolution with nominal pixel size

→ preliminary time resolution for MIP detection ~ 50 ps (w/o time walk correction)



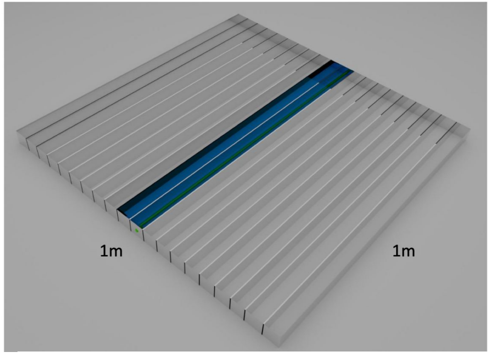


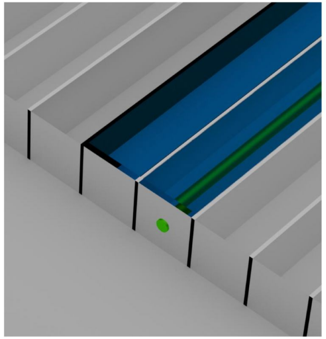




MID R&D

Conceptual design for the complete module





Progress towards conceptual design

Baseline for scintillator chosen (FNAL), but R&D actively ongoing in Mexico

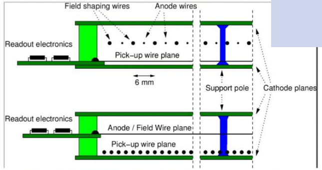
Studies of alternative options for sensors in Hungary and India (MWPCs, RPCs, alternative SiPMs)

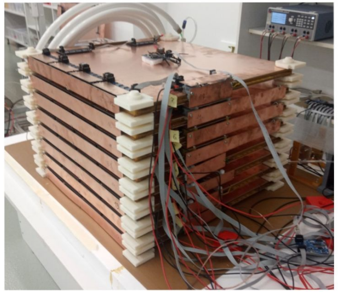
Testbeam (with absorber) ongoing!

Detectors for the test beam

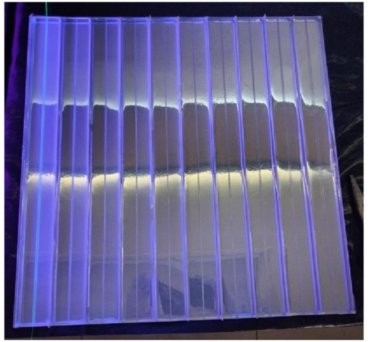
- 8mm segmentation in both directions (in MID, we anticipate 12mm segmentation)
- Field wires (FW, parallel with anode wires)
- Pick-up strips (PW, wires) perpendicularly

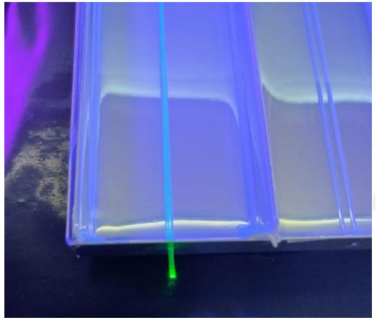
(That is, one chamber provides two directions, 64+64 channels)





Prototype module for the test beam:50 cm x 50 cm x 1 cm



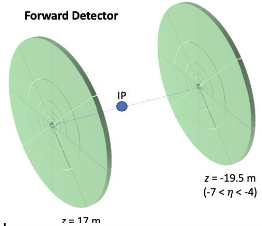


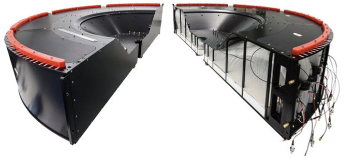
FD R&D

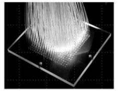
Forward Detector Design

FV0 like design currently considered

- Two segmented scintillator disks
- Light collections with clear fibers
- Standard Hamamatsu Fine-mesh PMTs







Defined baseline layout (FV0-like design: Eljen scintillators and fine-mesh PMT)

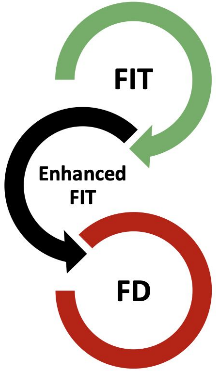
R&D plans:

- different scintillators (PEN/PET)
- alternative PD: SiPM or LAPPD

Started conceptual design of FEE (as FIT evolution)

Main activities at AGH

- Enhancement of analog front-end FIT readout electronics:
  - goal to achieve measurments with:
    - 14 bit charge resolution,
    - system RMS jitter < 20 ps.
  - the pre-amplifier improvement for better signal dynamics
  - new architecture of the charge integrator to increase precision,
  - launch of the ASIC project to increase overall AFE performance.
- High frequency direct sampling of PMT signal



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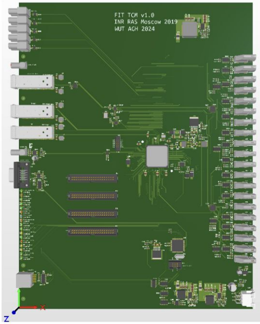
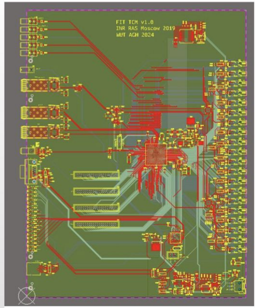
10 Oct. 2024 AUW'24 Krakow 7-11 Oct. 2

FIT PM/TCM upgrade and roadmap

5th ALICE UPGRADE WEEK in Kraków

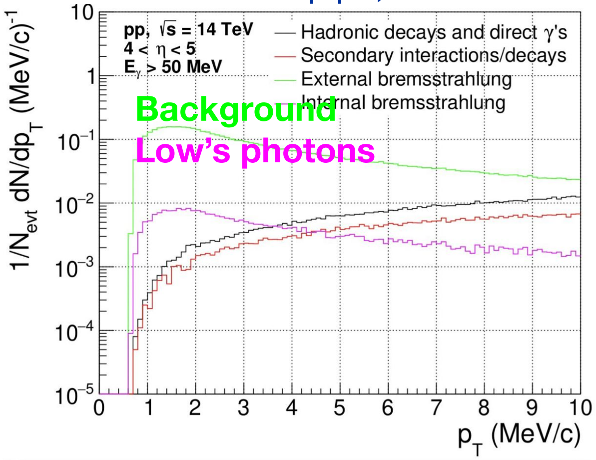
G.Kasprowicz, Warsaw University of Technology



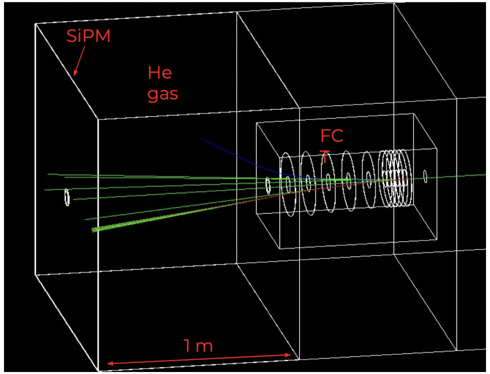


FCT studies

Standard beampipe, no eID

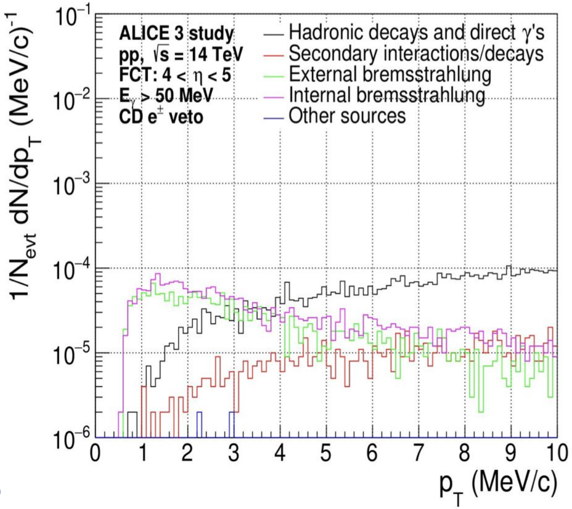


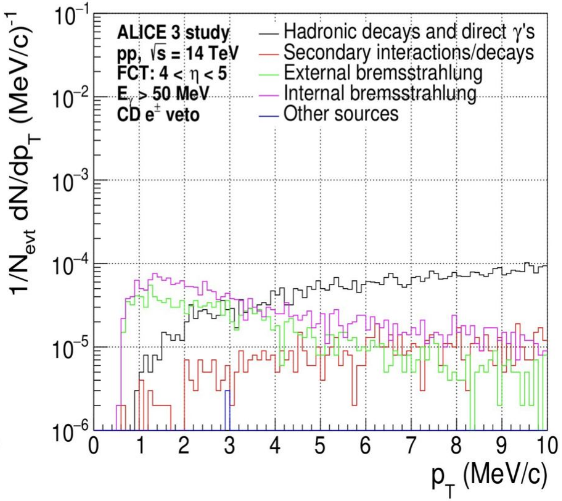
GEANT4 representation, but simulation is done as toy MC



eID is necessary: a RICH behind FCT under study; quite large volume and SiPM area; area and DCR can be reduced with dual RICH layout (mirrors) - large-scale project

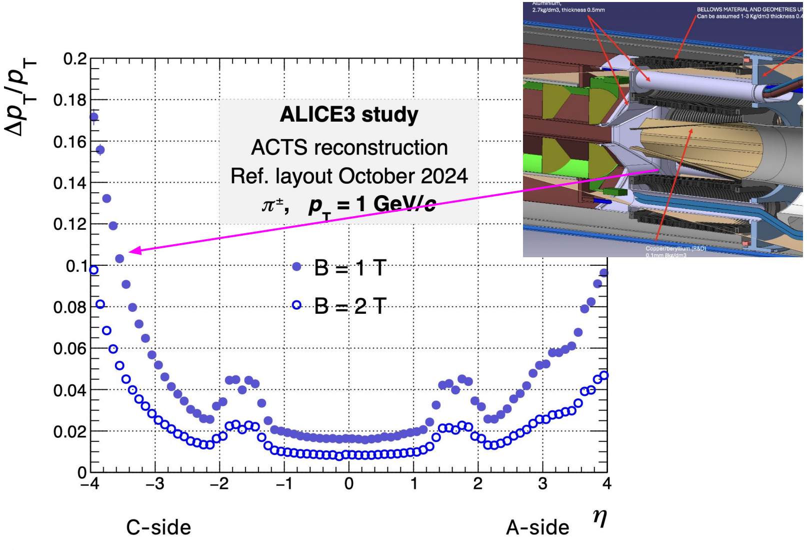
H3050CS	H3075CS
$L = 1.81$ m	$L = 2.45$ m
$N_{\text{Hits th.}} = 2$	$N_{\text{Hits th.}} = 3$



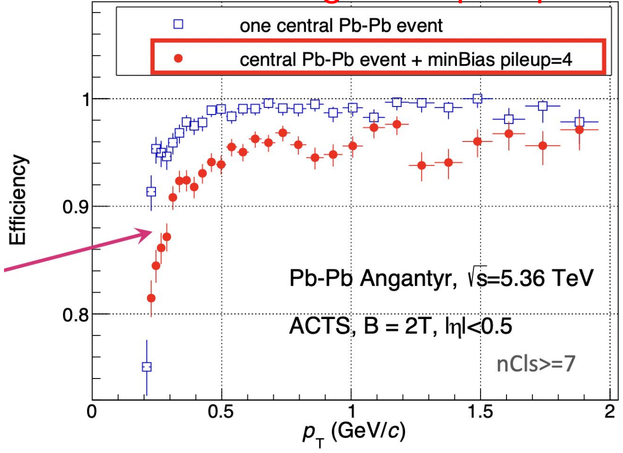


Detector design, R&D ⟷ Simulation

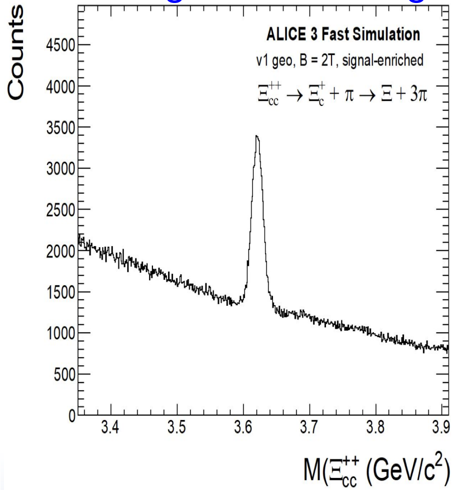
- Crucial to have short-loop feedback between engineering work and simulation
- Some clear examples:
  - Impact of IRIS services material on forward tracking
  - Impact TOF time resolution on physics performance
  - Impact of IT/OT sensor specs (space and time res.) on tracking and physics
- Development of ACTS and of FastTracker in OTF important to enable this feedback



Pb-Pb tracking eff w/ pileup



Xi_cc signal FastTracker + Strangeness tracking

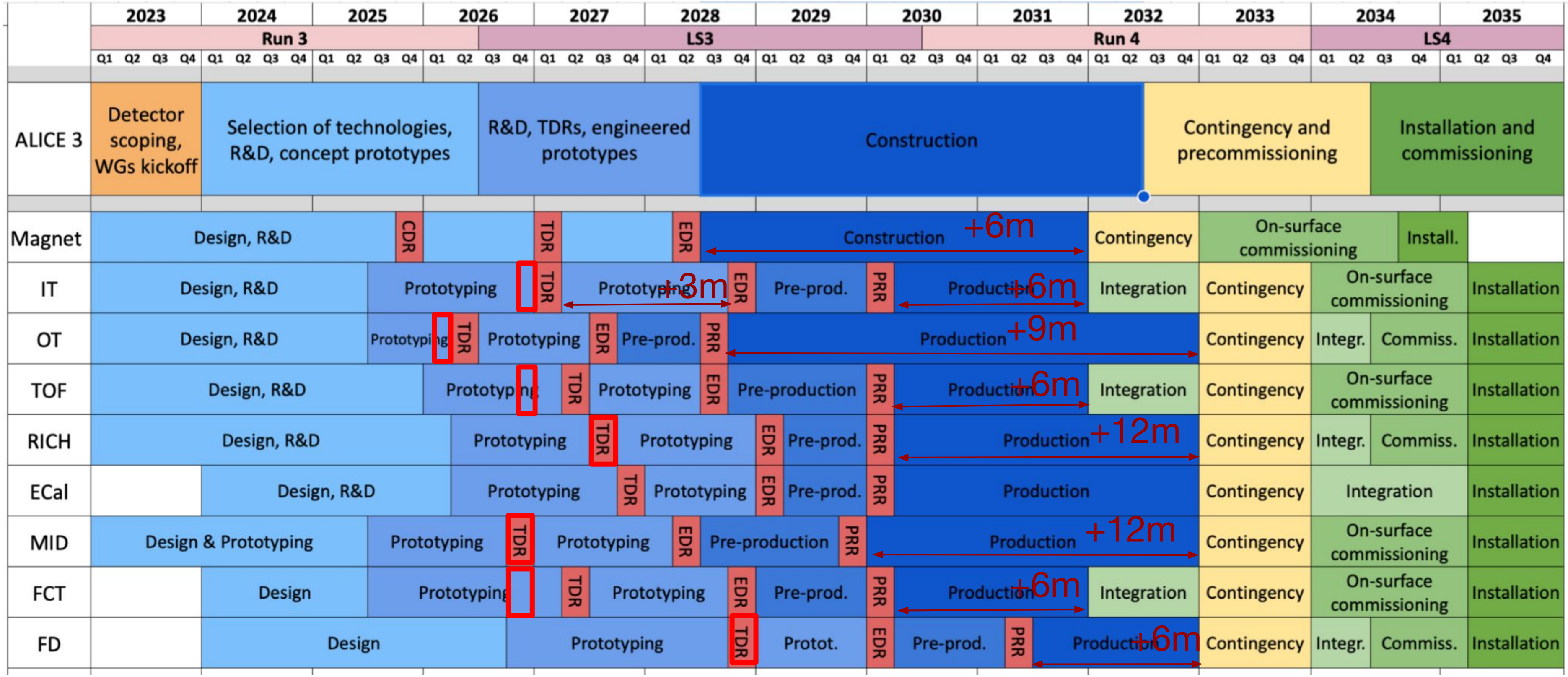


ALICE 3 timeline

New proposed schedule after LS3 shift:

- depending on sub-system original schedule, distribute the 12 months between the R&D/TDR phase and the construction

Updated schedule and milestones



Impact on spending and resource profiles to be assessed to update SD tables

Project planning

- Time to TDRs is limited → setup more fine-grained effort
- Start transition of Subsystem-WGs to Projects
  → Substructure with Work Packages and people in charge
  → Start process of identifying Project Leaders

Work Package proposals: IT

- **Chip design (needs two branches, and two WP leaders dedicated to VD/ML)**
  - Common items:
    - Common blocks
    - Serial powering
    - Front-end optimisation
  - VD-ML optimisation:
    - Development of a small pitch, high radiation tolerance chip
    - Adaptation and configuration for ML
    - Two independent reticle assemblies (VD and ML)
    - Target: submission end of 2025/beginning of 2026
- **Characterisation (shared)**
  - Characterisation of chips and modules in vacuum
  - Testing of existing prototypes at high radi
  - Characterisation of bent chips
- **Sensor integration (VD focussed)**
  - Lightweight module ('MAPS foil')
  - 2.5d / 3d integration of powering and data
  - ML integration (for lightweight version)
- **ML module/stave design *(→ will evolve into production)***
- **Mechanics and integration** (**two WP leaders dedicated to VD/ML – synergy with OT)**
  - VD: retractable in-vacuum mechanics
  - ML: bent or planar module and staves
  - Global integration and interfaces to beam pipe and iTOF/OT
  - Cooling architectures
- **Readout and power supply services** (**two WP leaders dedicated to VD and ML)**
  - Vacuum integration
  - Radiation hardness
  - Serial powering
- **Physics performance and response simulation** *(common to OT)*
- **Detector Control System** (*not starting yet*)
- **Calibration and data quality assurance** *(VD needs to start first)*
  - Alignment procedures for the IRIS

Work Package proposals: OT

WP1	Simulations and performances
WP2	Sensor design
WP3	Sensor post-processing
WP4	Sensor qualification
WP5	Module design and production
WP6	Mechanics and cooling
WP7	Readout, Slow Control and Powering
(WP8)	Integration, installation and transverse perspectives

WP2 - Sensor design

Cross

- Sensor design:
  - Analog part
  - Matrix architecture
  - Numeric part
  - Periphery
  - Powering distribution
- Interface to characterization and mass test
- Interface to DRD3.1 project
- Interface to VD sensor

WP5 - Module design and production

1 Convenor Barrel
1 Convenor Discs

- Module concept:
  - Sensor interconnection
  - FPC
  - “local” readout, cooling, mechanics, slow control
- Industrialization of module production
  - Sensor logistics
  - FPC production and qualification
- Test protocol of modules
  - Test for industry after production
  - Test for institutional sites before stave production

Work Package proposals: TOF

ALICE 3 TOF: proposal for Work Packages

Work Package	Description
WP1: Detector performance simulation, reconstruction	Detector layout optimization via MC simulations
WP2: Sensor simulation	Sensor-grade simulation for sensor design (TCAD and MC simulation): optimization of timing resolution
WP3: Front-end design	• Design of CMOS-LGAD ASIC with integrated electronics • Design of FE for standard LGAD
WP4: Sensors characterization and qualification	Sensors characterization in laboratory and with beams
WP5: Module design, mechanics and cooling	• Module design • Mechanics for module, staves and disks • Cooling plant studies
WP6: Readout, power and services	• Off-sensor readout (lpGBT, VTRx+ up to CRUs) • Power units and services
WP7: Integration	• Service integration: cooling, electrical and optical services • Detector control and safety system

DRAFT

Work Package proposals: RICH

Work package	Description
WP1: Detector and physics performance simulations	Layout optimization by means of MC simulation
WP2: SiPM sensor and module characterization	• Sensor optimization to improve PDE, fill factor, DCR, radiation hardness and timing response • Characterization in lab, beam test and irradiation tests
WP3: SiPM module	Module layout (2.5 D with interposer), sensor interconnection and assembly
WP4: FEE and RO system	FEE ASIC and R/O system (including LPGBT and VTRX+ optical links)
WP5: Aerogel	• Characterization (optical, mechanical) R&D : transmission, refractive index, dimension, flatness, radiation hardness • Mechanics: tooling for handling and mounting, alignment procedure and monitoring
WP6: Cooling and annealing	• Cooling plant and integration in module • Thermal shield design • Annealing system R&D
WP7: Mechanics	• Module and sector design • Leak-tight vessel • Super module mechanics
WP8: Integration	Service integration: gas, cooling, power supply system, detector safety system

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Work Package proposals: MID

Work package	Description
WP1: detector and physics performance simulations	Layout optimisation (MID chambers, absorber) using MC simulations
WP2: Module	SiPM: sensor optimisation to improve PDE, radiation hardness and timing response. Scintillator: transmission, refractive index, dimension, flatness, radiation hardness. MWPC: module design RPC: module design
WP3: FEC and RO system	FEC and RO system (including LPGBT and VTRX+ optical links)
WP4: Mechanics	Super module mechanics Mechanical integration
WP5: integration	Service integration: power supply system, detector safety system, detector control system

Outlook

- The coming year is a crucial phase for ALICE 3
- Review of scoping and resources by LHCC, by March
  - In parallel, continue internal assessment of scope vs feasibility
- R&D has to lead to defining sensor technologies, and move to full-system design phase
  - This week, clear broadening of R&D scope in all subsystems
- Start more structured approach in Working Groups
  - Work Packages to define goals, timeline and consolidate engagement
- Roadmap with milestones to quantify progress towards TDR-level projects

Thanks to our Hosts at IFJ-PAN:
Jacek and Marek, Sándor, Adam, Sahil,
Iwona, Olga, Katarzyna, Andrzey

Thanks, ALICE 3 WG Coordinators!
Thanks, FoCal & ITS3 PLs!

Thanks to all speakers and participants!