Performance and upgrade of ALICE

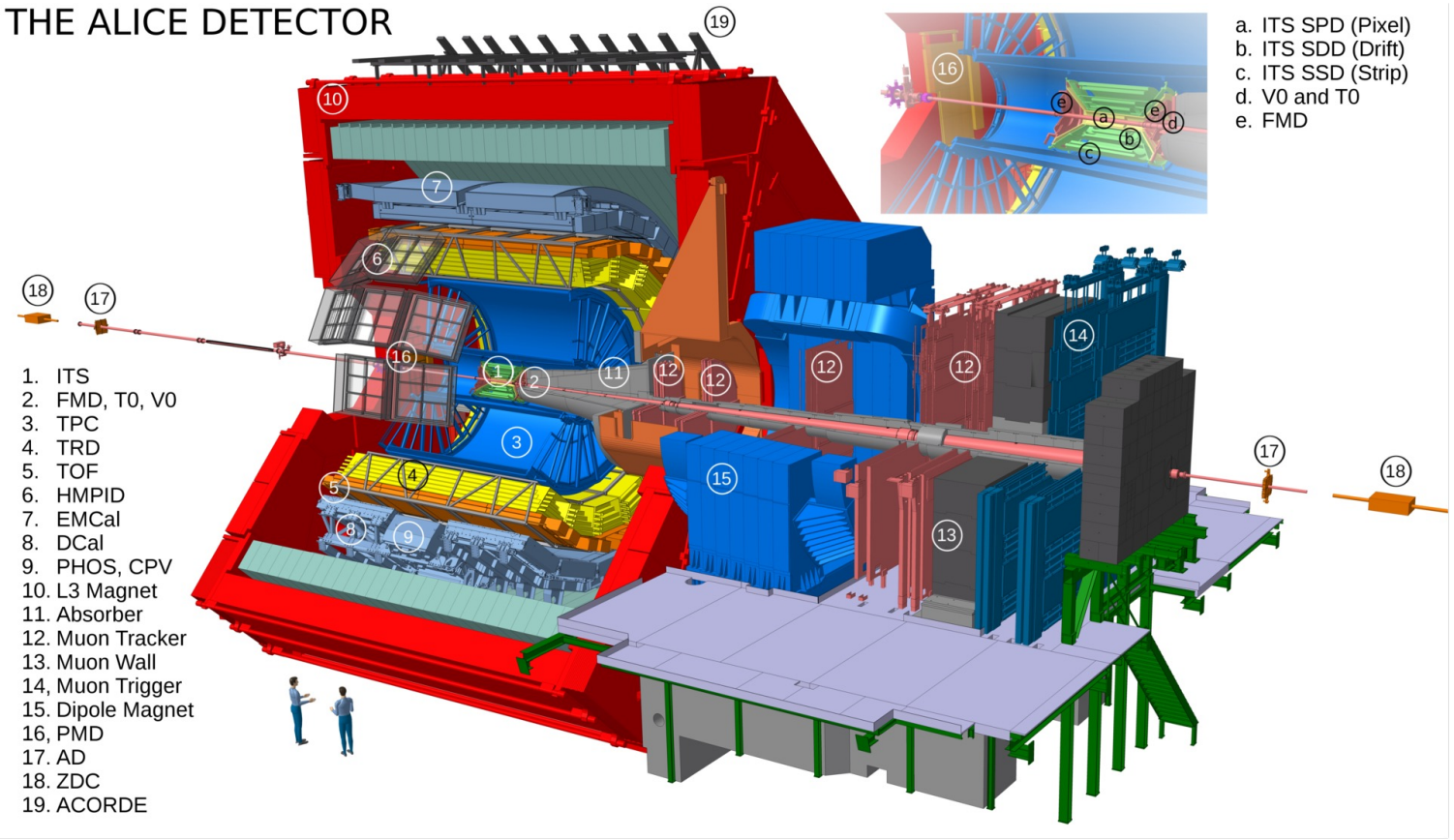
N. Poljak for the ALICE collaboration

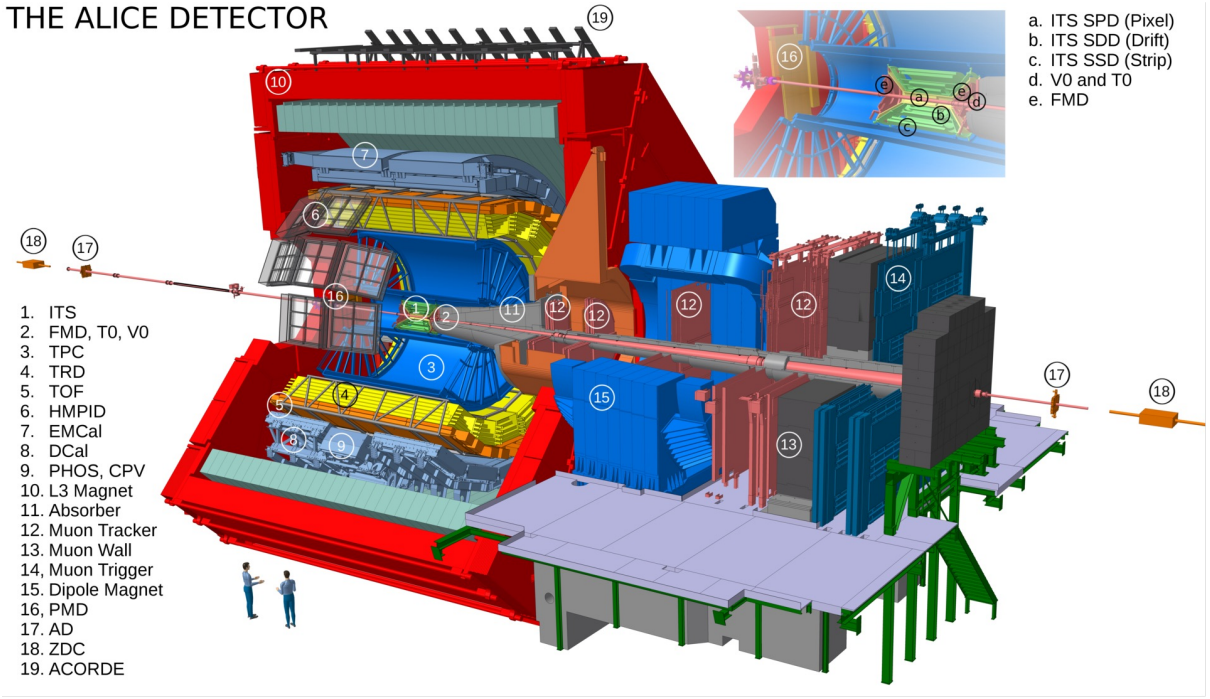
LHC days in Split, 4.10.2022

Outline

- the ALICE detector at CERN
- A recent highlight from Run 2
- Run 2 to Run 3 upgrade: ALICE 2
- first pp collisions: LHC 2021 pilot beam
  - ALICE 2 performance and first analyses
- Current status

The **ALICE** (**A** **L**arge **I**on **C**ollider **E**xperiment) Collaboration - 40 countries, 172 institutes, 2002 members





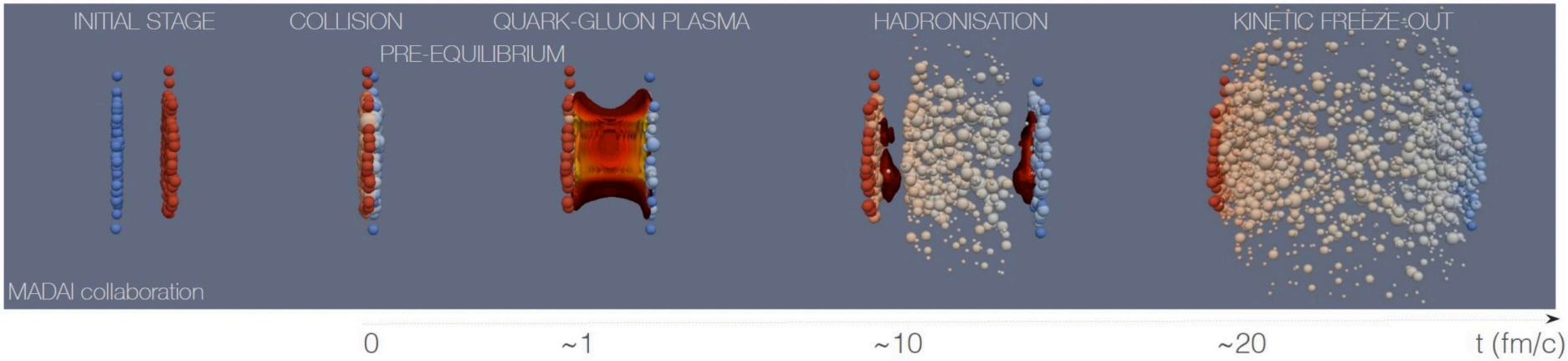
RUN 1 / RUN 2

401 ALICE papers

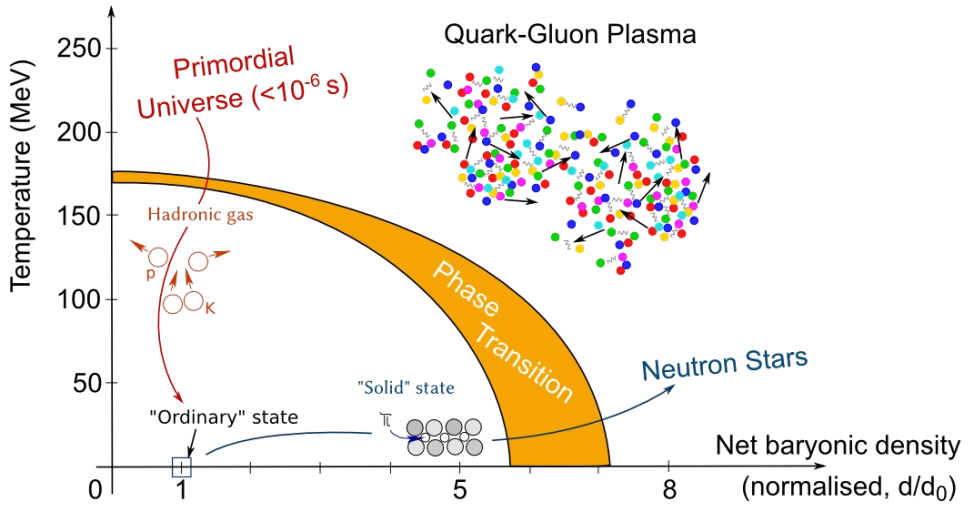
https://alice-publications.web.cern.ch/submitted

- general purpose detector, excellent tracking and particle identification within p_T of 0.01-100 GeV/c
- Low material budget, moderate magnetic field
- Run 2: Pb-Pb collisions at **1 kHz trigger rate**, ~ 1 nb^{-1} collected luminosity
- Central barrel covers $|\eta| < 0.9$, muon spectrometer $-4 < \eta < -2.5$

Physics goals

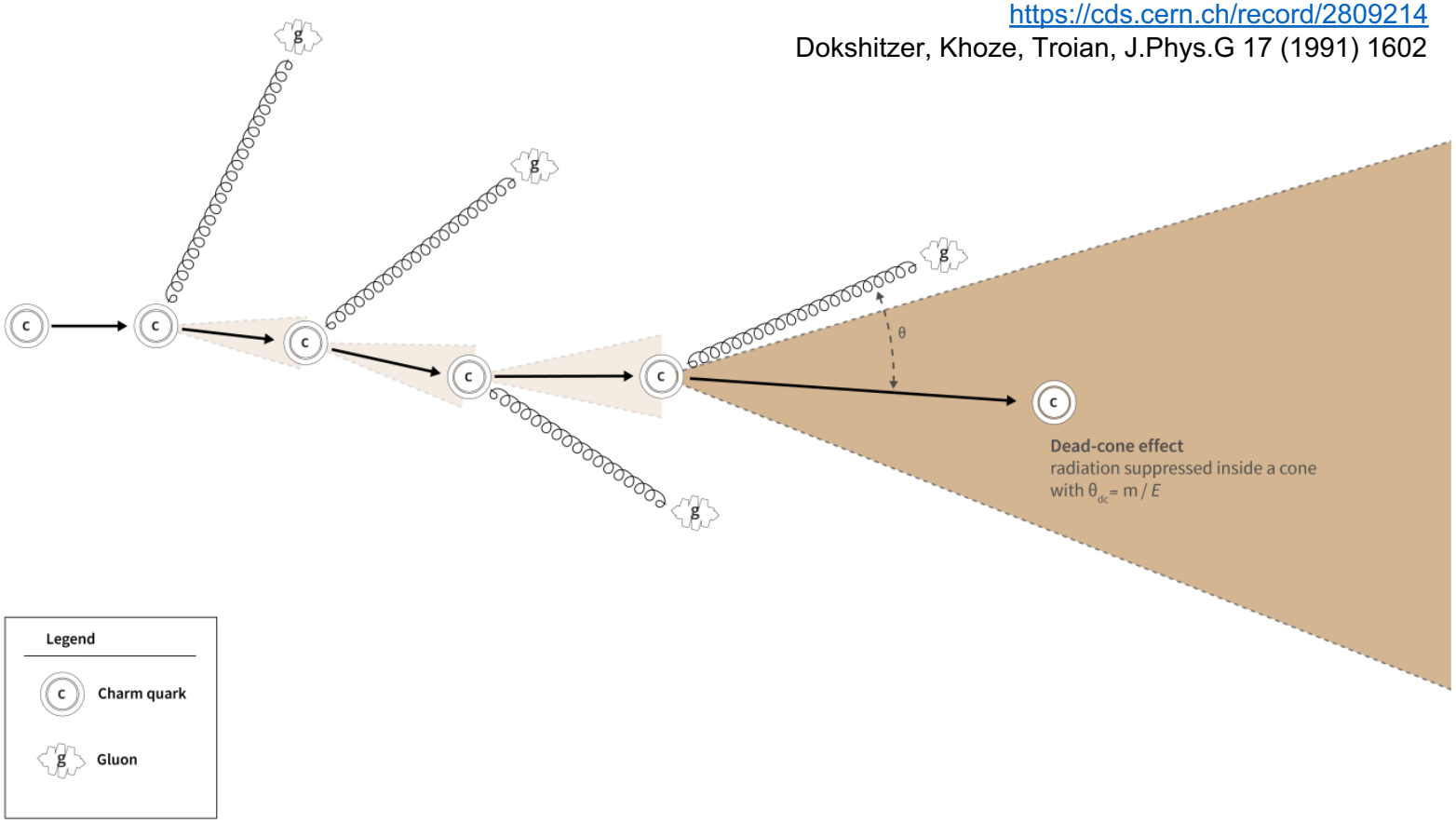


- Study of the quark-gluon plasma
  - Color deconfinement
  - Expansion dynamics and hadronization
  - Parton interactions
- Baryochemical potential
- Quarkonia (J/ψ suppression, color screening)
- Jet properties
- Elliptic flow
- Femtoscopy etc.



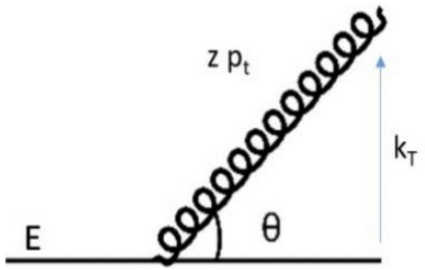
Recent highlight: the dead-cone effect

https://cds.cern.ch/record/2809214
Dokshitzer, Khoze, Troian, J.Phys.G 17 (1991) 1602



- Reduced small-angle gluon radiation from high-mass quarks
- First **direct** observation using iterative analysis containing a D^0 meson

Recent highlight: the dead-cone effect

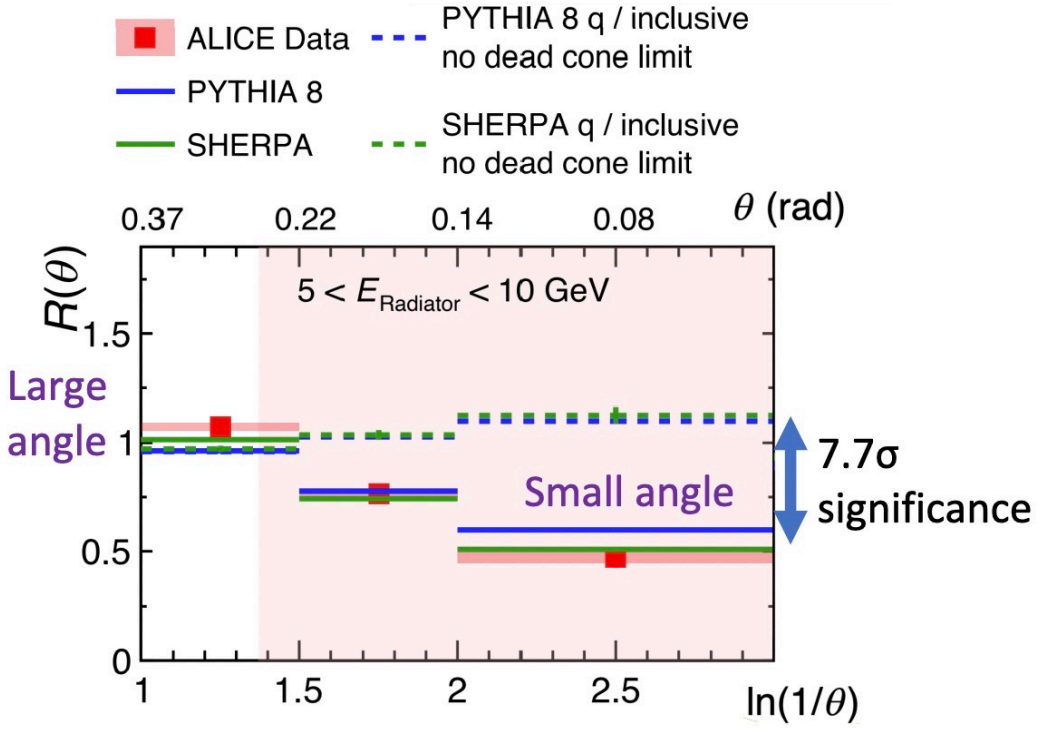


$\theta \sim k_T/zp_t$

$$R(\theta) = \frac{1}{N^{\mathrm{D^0\,jets}}} \frac{\mathrm{d}n^{\mathrm{D^0\,jets}}}{\mathrm{d}\ln(1/\theta)} \Big/ \frac{1}{N^{\mathrm{inclusive\,jets}}} \frac{\mathrm{d}n^{\mathrm{inclusive\,jets}}}{\mathrm{d}\ln(1/\theta)} \Bigg|_{k_T, E_{\mathrm{Radiator}}}$$

Idea: Direct comparison of the angular distribution of charm-quark emissions to emissions from light-quarks and gluons

Nature **605**, 440–446 (2022)



ALICE detector moves to **ALICE 2**

Motivation:

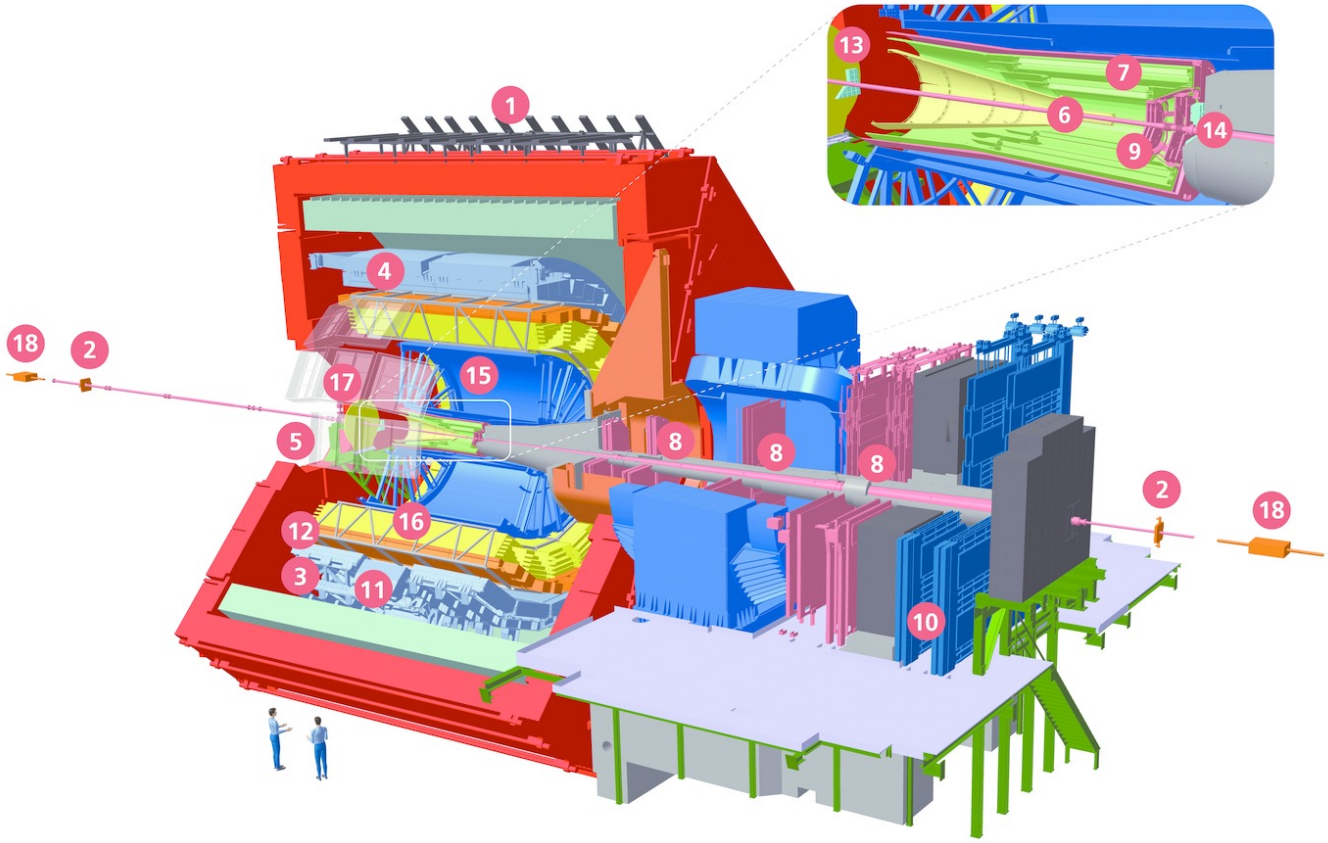
- **Increase statistics** for charmonium states
- Heavy-flavor mesons and baryons down to **very low p_T**
- Dileptons from QGP radiation and low-mass vector mesons
- **High-precision measurements** of light nuclei and hypernuclei

Requirements:

- Move from discrete to **continuous readout**
- Increase the **target interaction rate to 50 kHz** in Pb-Pb collisions (13 nb^{-1} in RUNS 3,4)
- Improve **pointing and transverse momentum resolution**
- Preserve or improve existing **PID performance**
- **Online reconstruction and compression** to reduce data flow (expected 3.5 TB/s)

J. Phys. G 41 (2014) 087001 - LOI

ALICE 2 in RUN3

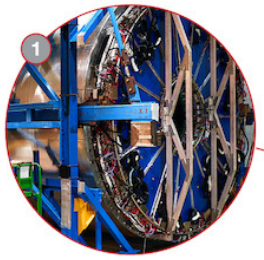


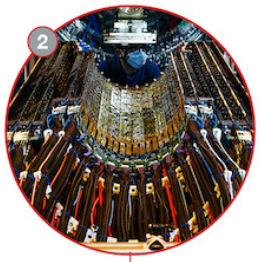
1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter

ALICE

TIME PROJECTION CHAMBER (TPC) UPGRADE

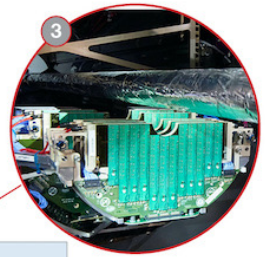
New GEM (gas electron multipliers) technology replaced the old wire chambers to significantly increase the readout rate of the TPC.





NEW INNER TRACKING SYSTEM (ITS)

Seven layers comprising a total of 12.5 billion monolithic active silicon pixel sensors distributed over a 10m^2 surface area, the largest pixel detector ever built.

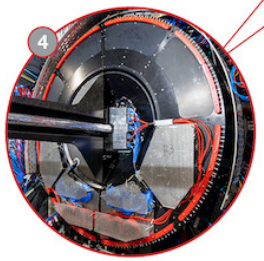


NEW MUON FORWARD TRACKER (MFT)

Five disks of monolithic active silicon pixel sensors, installed in front of the muon spectrometer to extend precision measurements to the forward rapidity region.

NEW READOUT SYSTEM

The new readout system is designed to handle increased data throughput by combining all the computing functionalities needed in the experiment.



NEW FAST INTERACTION TRIGGER (FIT)

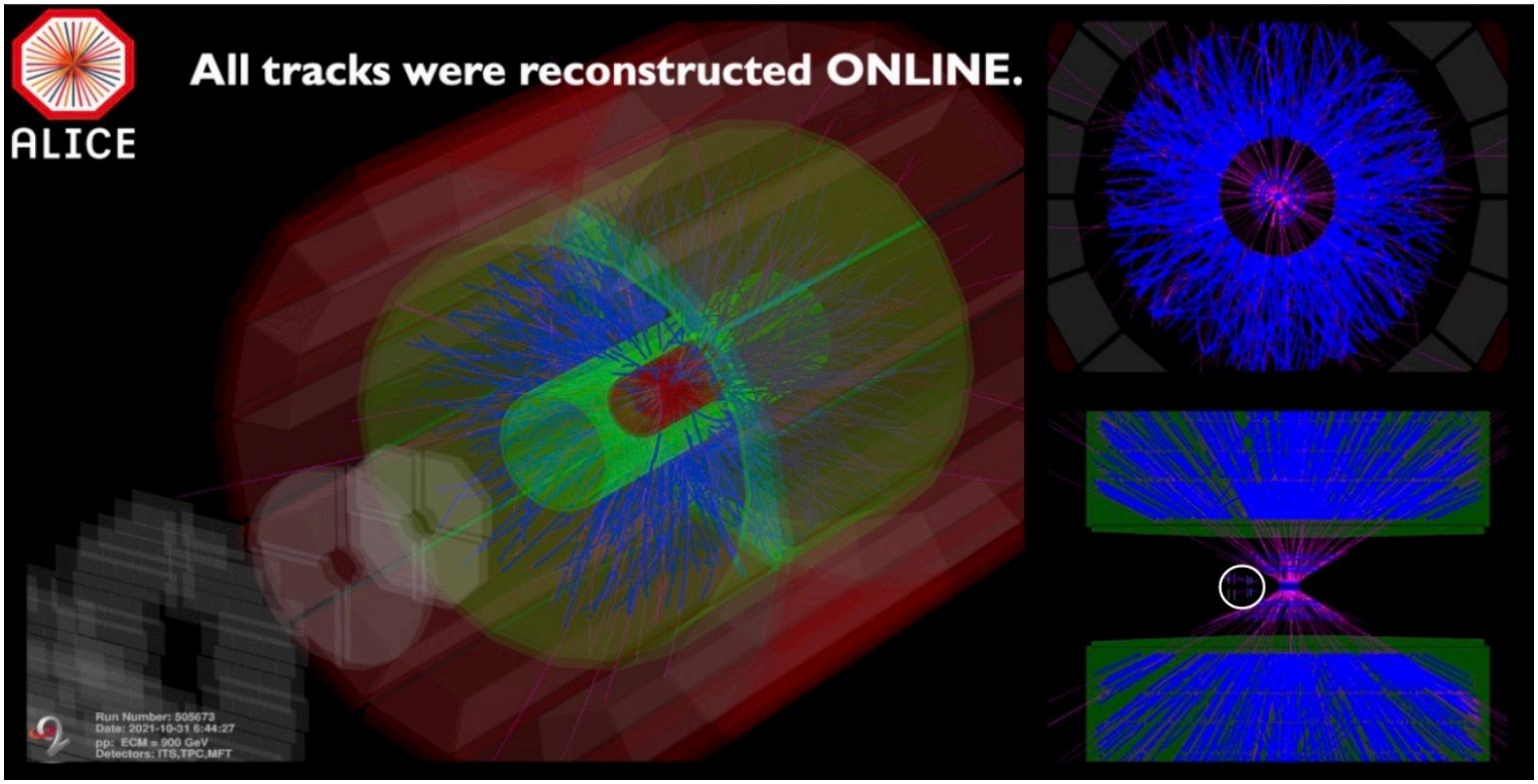
Combining three detector technologies, the FIT detector serves as an interaction trigger, online luminometer, indicator of the vertex position and forward multiplicity counter.

NEW BEAMPIPE WITH A SMALLER DIAMETER (36.4 mm)

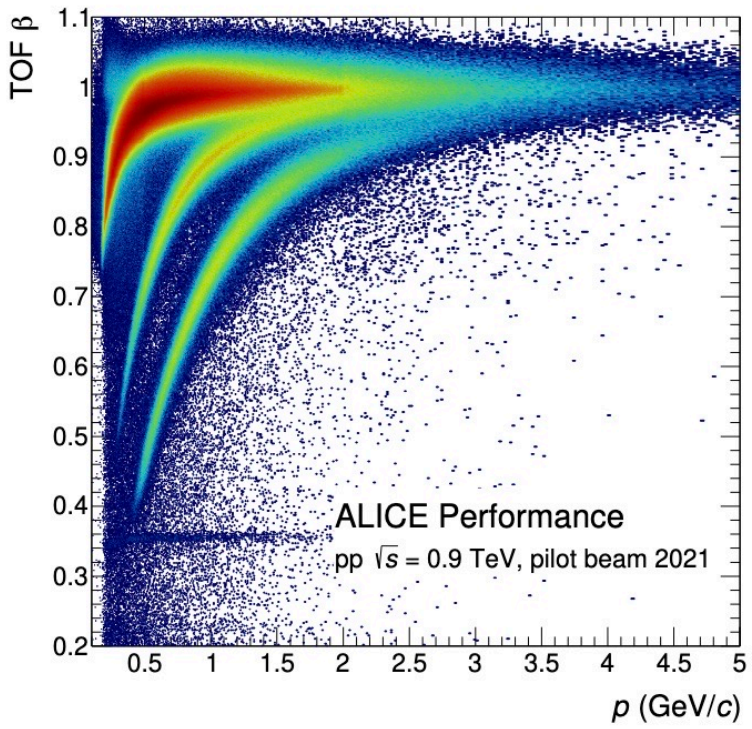
The vacuum tube that carries protons and ions to the collision point inside the detector has an 870-mm-long central beryllium section that has an inner radius of 18.2 mm and measures 0.8 mm in thickness.

Pilot beam in 2021

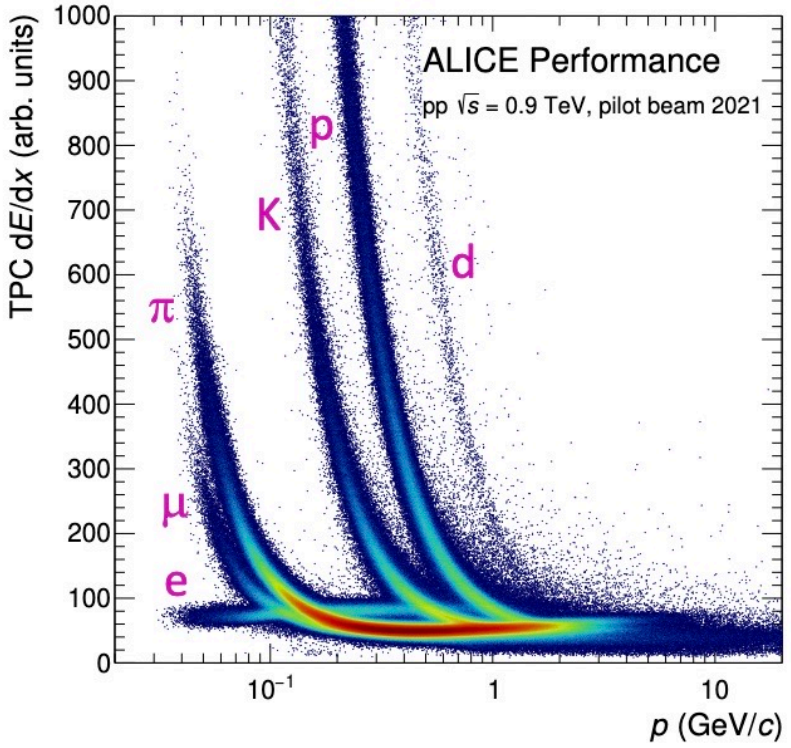
- commissioning run in the last week of October 2021
- 8M p-p collisions at 0.9 TeV, up to 4 kHz rate



Pilot beam performance



ALI-PERF-500446

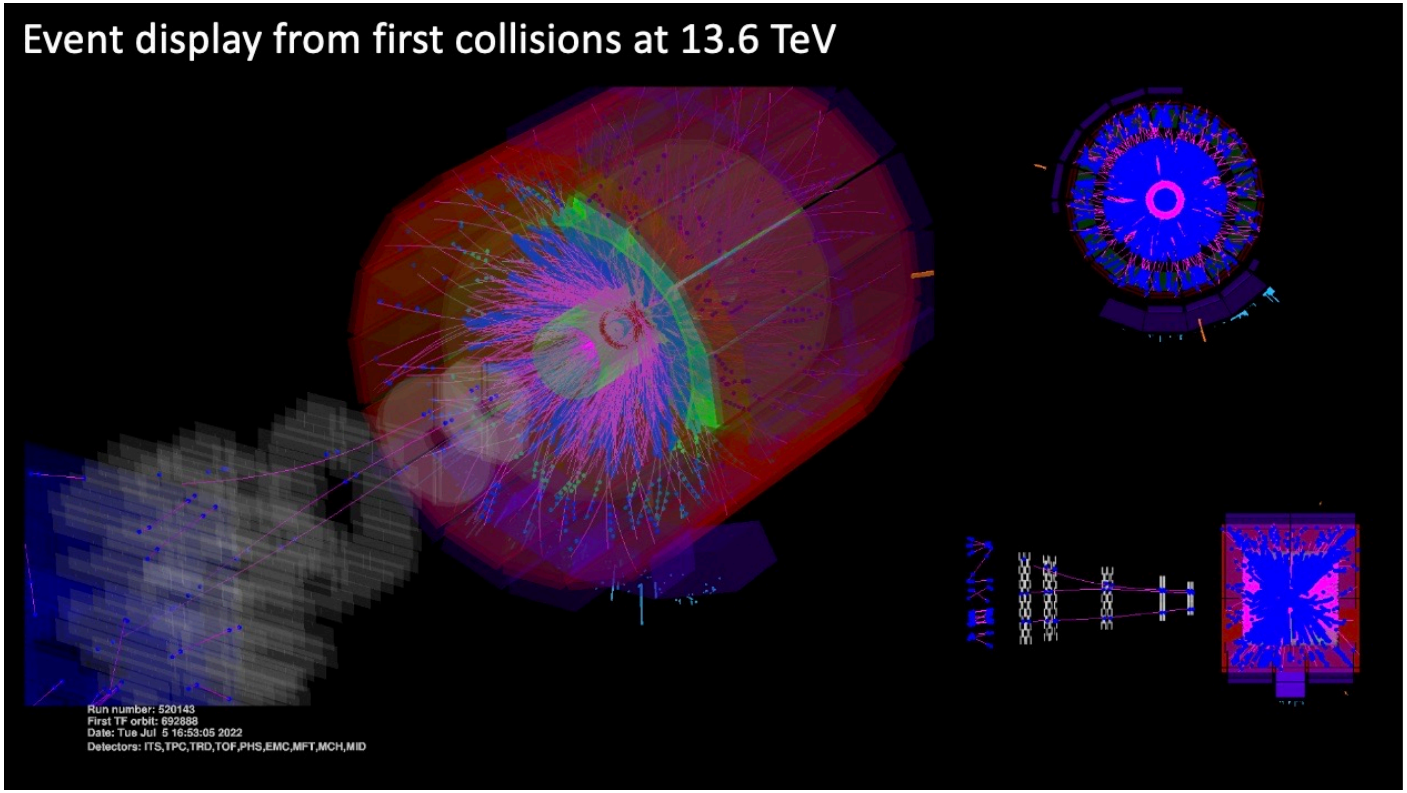


ALI-PERF-500457

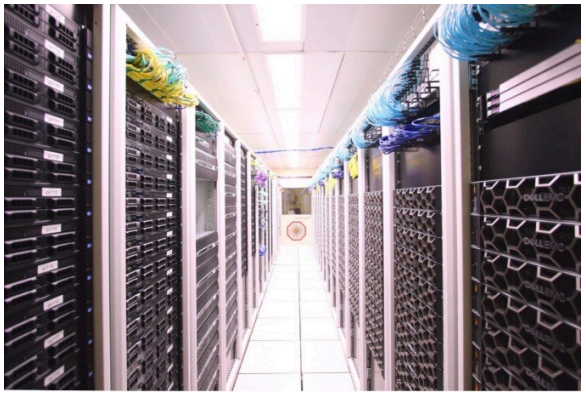
PID performance comparable to that in RUN 1 and RUN 2
Benchmark analyses show good agreement with past data

First collisions in RUN 3 – July 5th 2022

- pp interactions at a rate of about 500 kHz

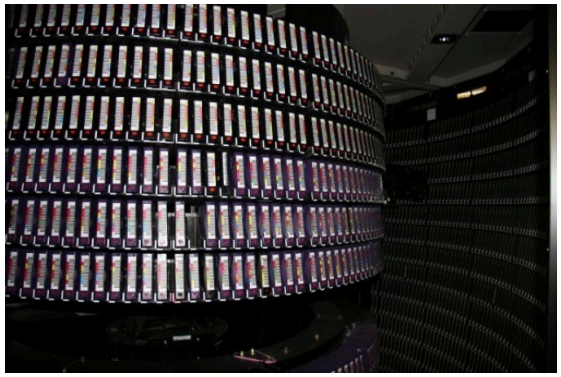


How to deal with data: Online-Offline system



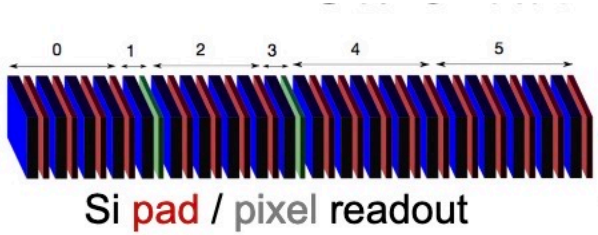
First Level Processors
Raw detector data, reduces 3.5 TB/s to 0.6 TB/s

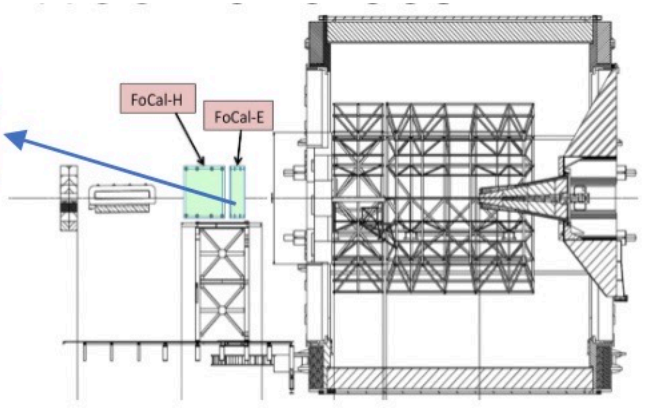
Event Processing Nodes
Calibration and event reconstruction



Mass storage
about 0.1 TB/s

Upgrade plans for LS3

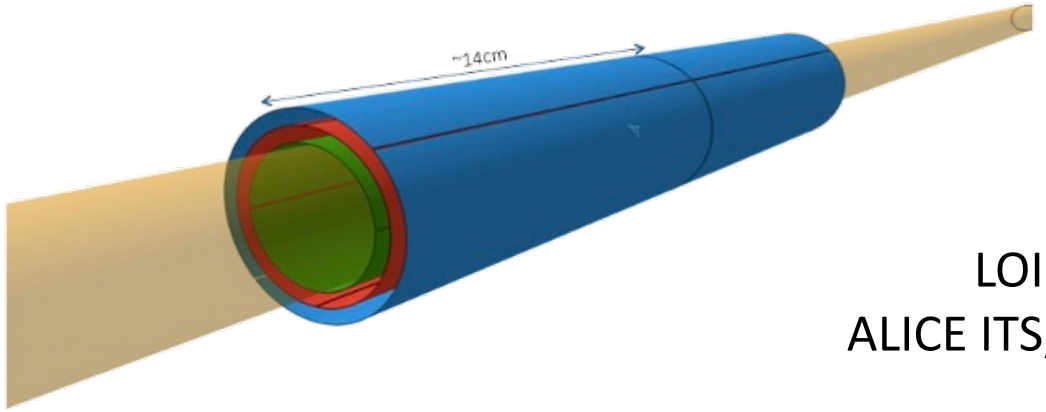




- High granularity EM calorimeter with Si readout for isolated γ measurements
- $3.4 < \eta < 5.8$
- constrain nuclear PDFs down to $x < 10^{-5}$
- TDR submission planned in 2023

FOrward **CAL**orimeter
LOI: CERN-LHCC-2020-009

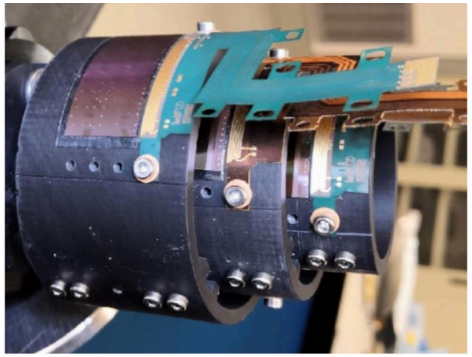
Upgrade plans for LS3



ITS3

LOI: CERN-LHCC-2019-018

ALICE ITS, NIM A 1028, 166280 (2022)

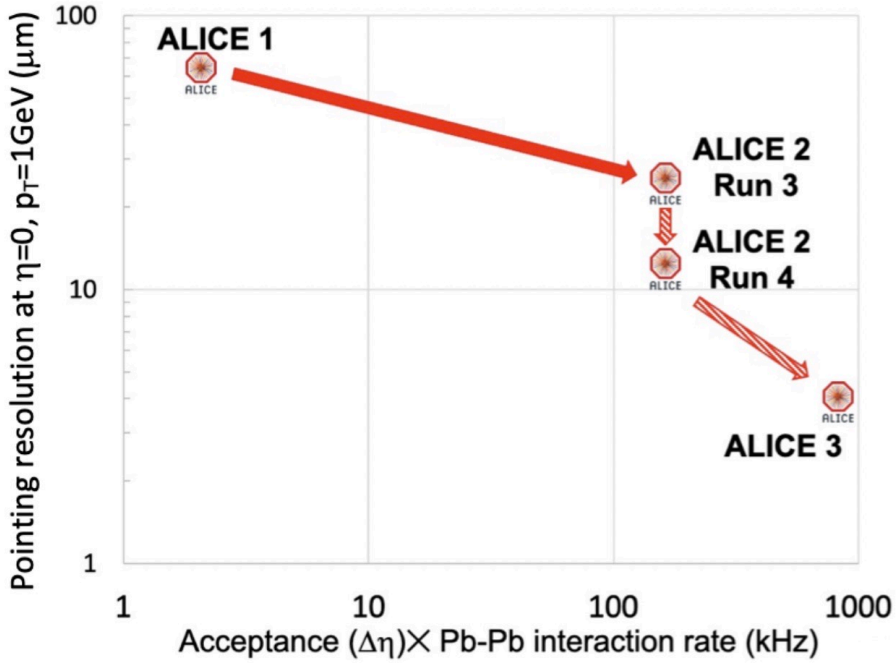


- New inner barrel with 3 cylindrical MAPS layers
- 3x less material budget
- 2x tracking precision and efficiency (low p_T)
- Fully functional ALPIDE sensor curved to 1.8cm
- TDR submission planned in 2023

LS4: ALICE 3 detector

Main physics goals:

- multi-charmed hadrons
- Charm-anticharm azimuthal correlations
- Thermal radiation and its time dependence
- Chiral symmetry restoration in QGP

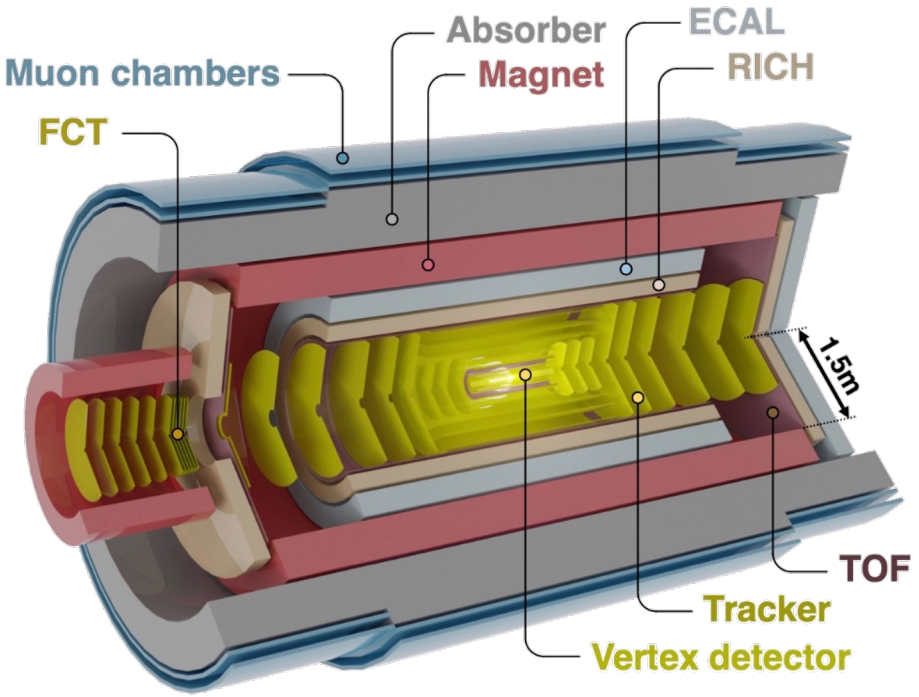


LS4: ALICE 3 detector

Key features:

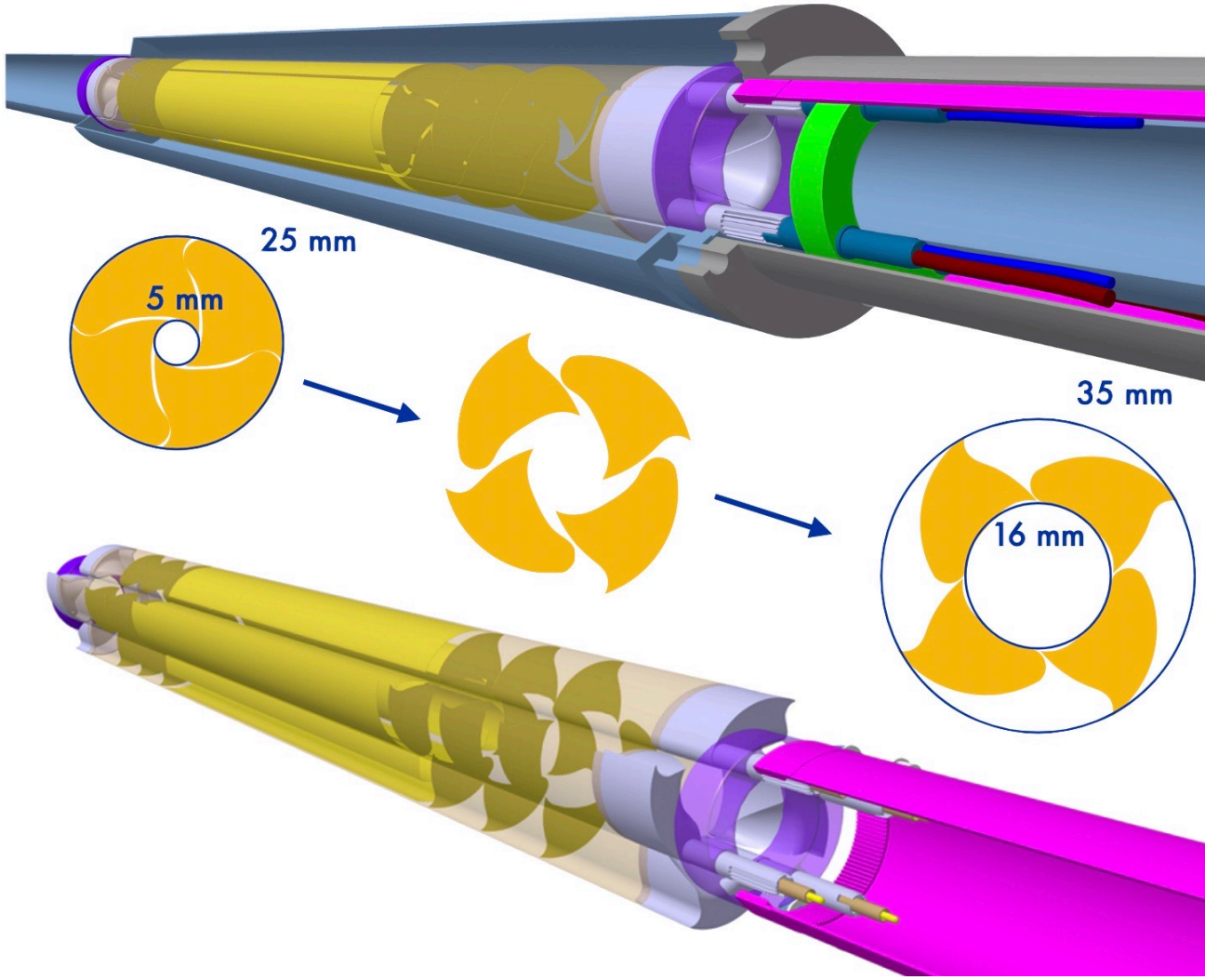
- Increase tracking precision 3x to 10 μm at p_T = 0.2 GeV/c
- Full acceptance in $|\eta| < 4.0$ with identical or better PID
- Pb-Pb rate increase 5x
- p-p rate increase 25x

LOI: CERN-LHCC-2022-009



LS4: ALICE 3 iris tracker

- wafer-sized, bent MAPS
- Rotary petals
- Match beampipe parameters
- R&D on mechanics, cooling, radiation tolerance



Conclusions

The ALICE journey is already more than a decade old (first data acquired in 2010, LOI in 1993)

- Immense amount of knowledge collected in QGP and QCD in general:
  - Quarkonia
  - Jet modifications
  - Heavy quark interactions
  - Elliptic flow etc.
- ALICE 2 successfully commissioned in LHC RUN 3
- The Collaboration is preparing upgrades for LS3 as well as a new detector for RUN 5 and later