ALICE – History
Present & Future

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30 anniversary of ALICE Letter of Intent

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Overview of the talk

- ALICE experiment – history
- Physics highlights Run 1 and 2
- ALICE upgrade for Run 3

  ALICE 2

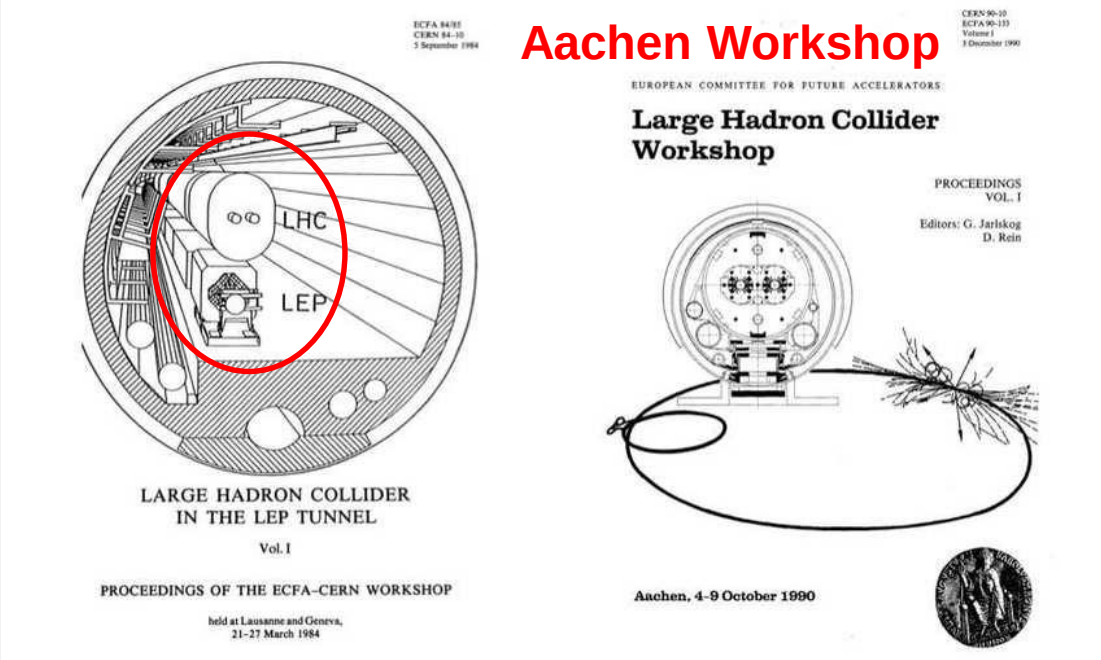
- ALICE future

  Upgrade in LS3
  ALICE 3 project

Heavy Ions @ LHC

- First (sub-)detector concepts of heavy-ion experiment at the LHC
  - Aachen 1990 conference (E.Quercigh, P.Sondereger, H.Specht, …)
- Heavy-ion detector proposal(s)
  - Evian 1992 workshop (dedicated detector, modified DELPHI, CMS)

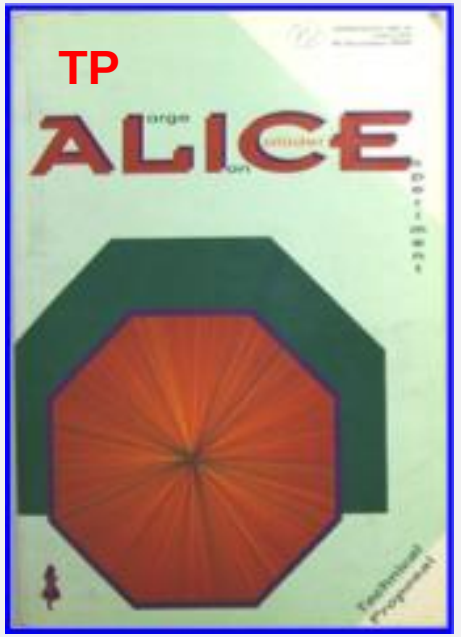
- Letter of Intent 1993 – ALICE experiment (addition of muon spectrometer requested by LHCC)
- Technical Proposal 1995 (1996 – 2006 addenda), approved 1997
- 1998 – 2005 Technical Design Reports



Aachen Workshop

LoI

TP



Early ALICE designs

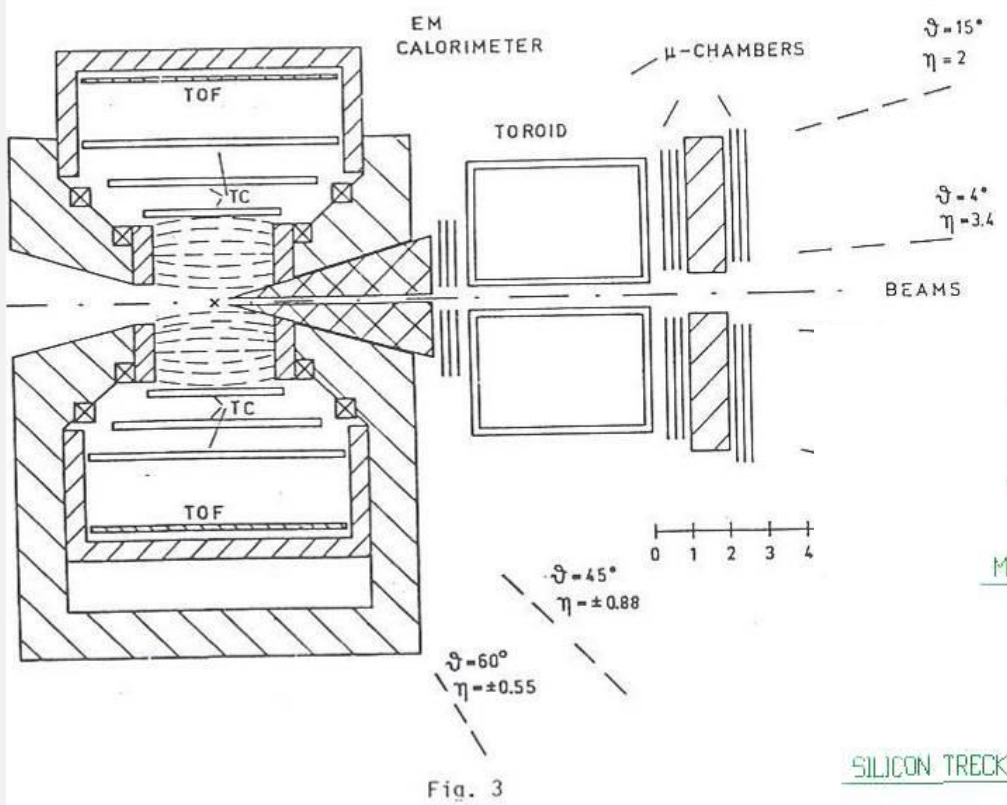
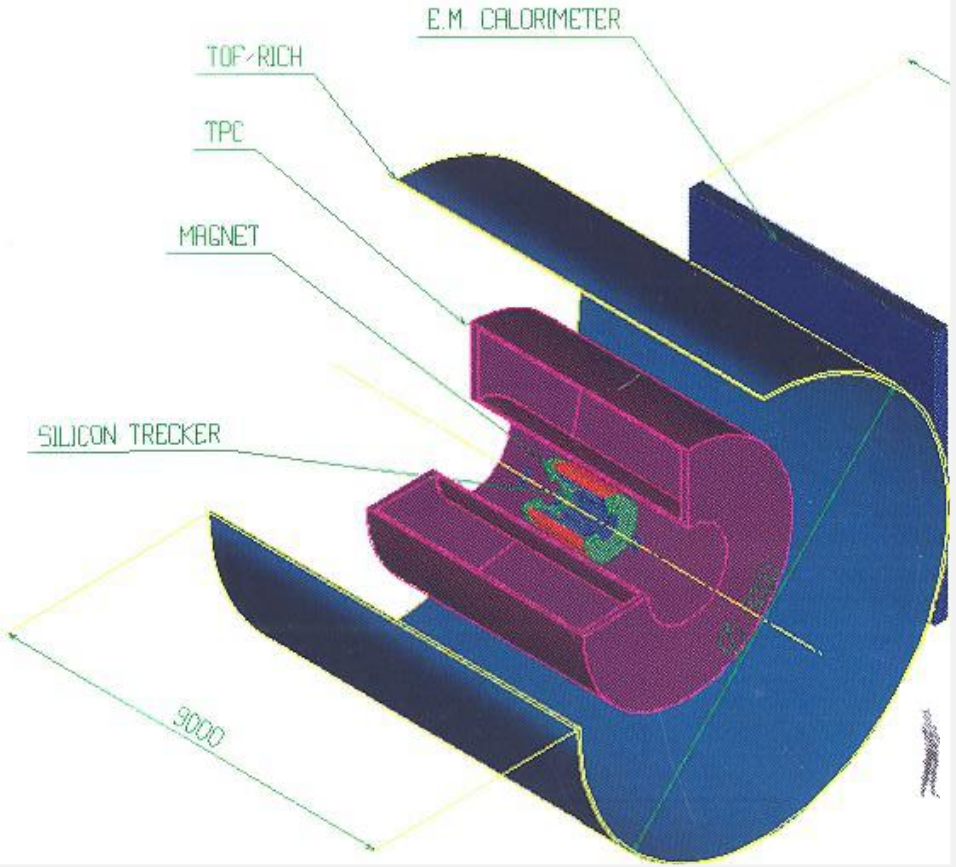


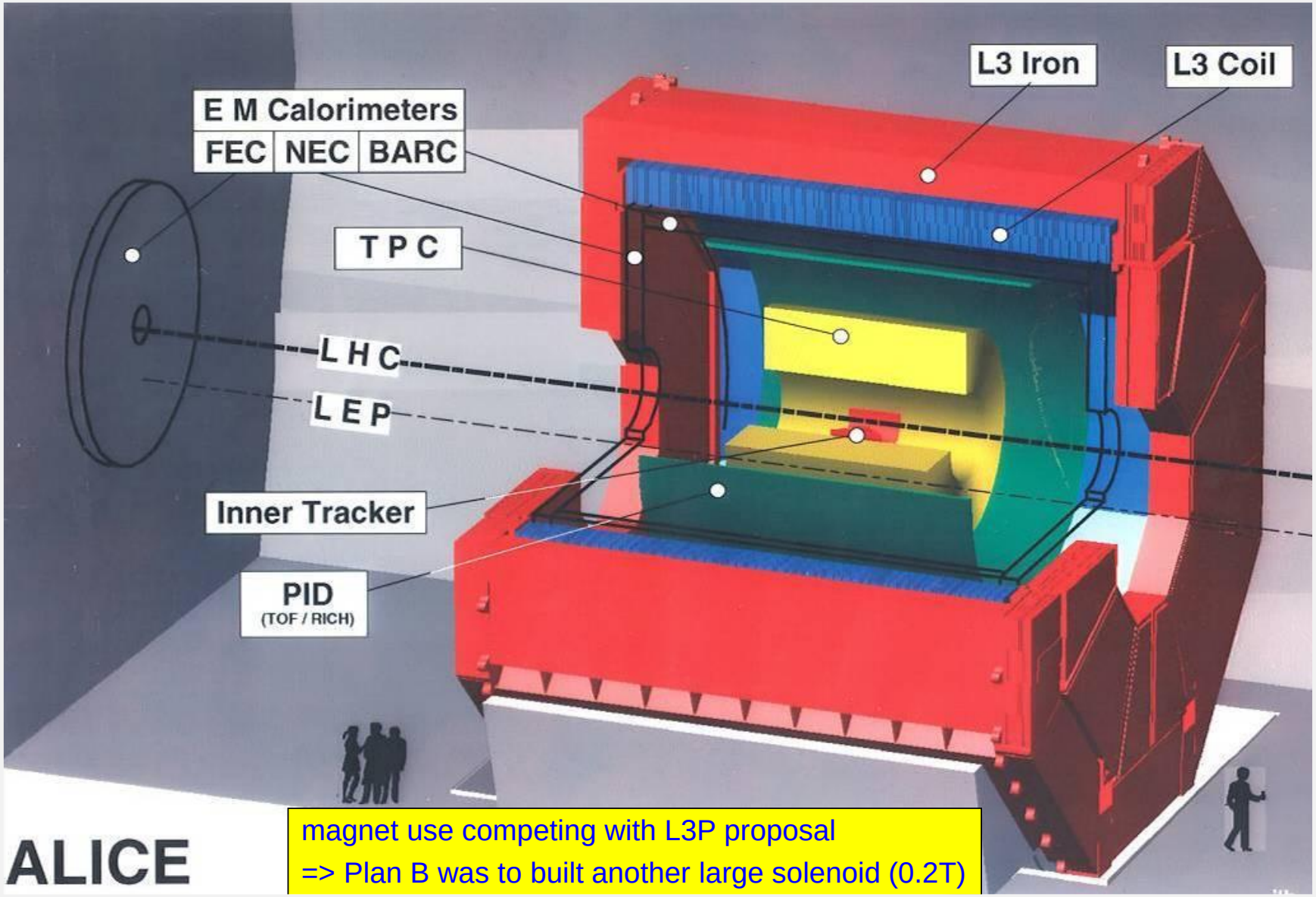
Fig. 3

1990 Design (Aachen)
open axial field magnet
(AFS/ISR, + NA38 muons)

1992 Design (Evian)
no muons
thin (<17%X_0) and small solenoid



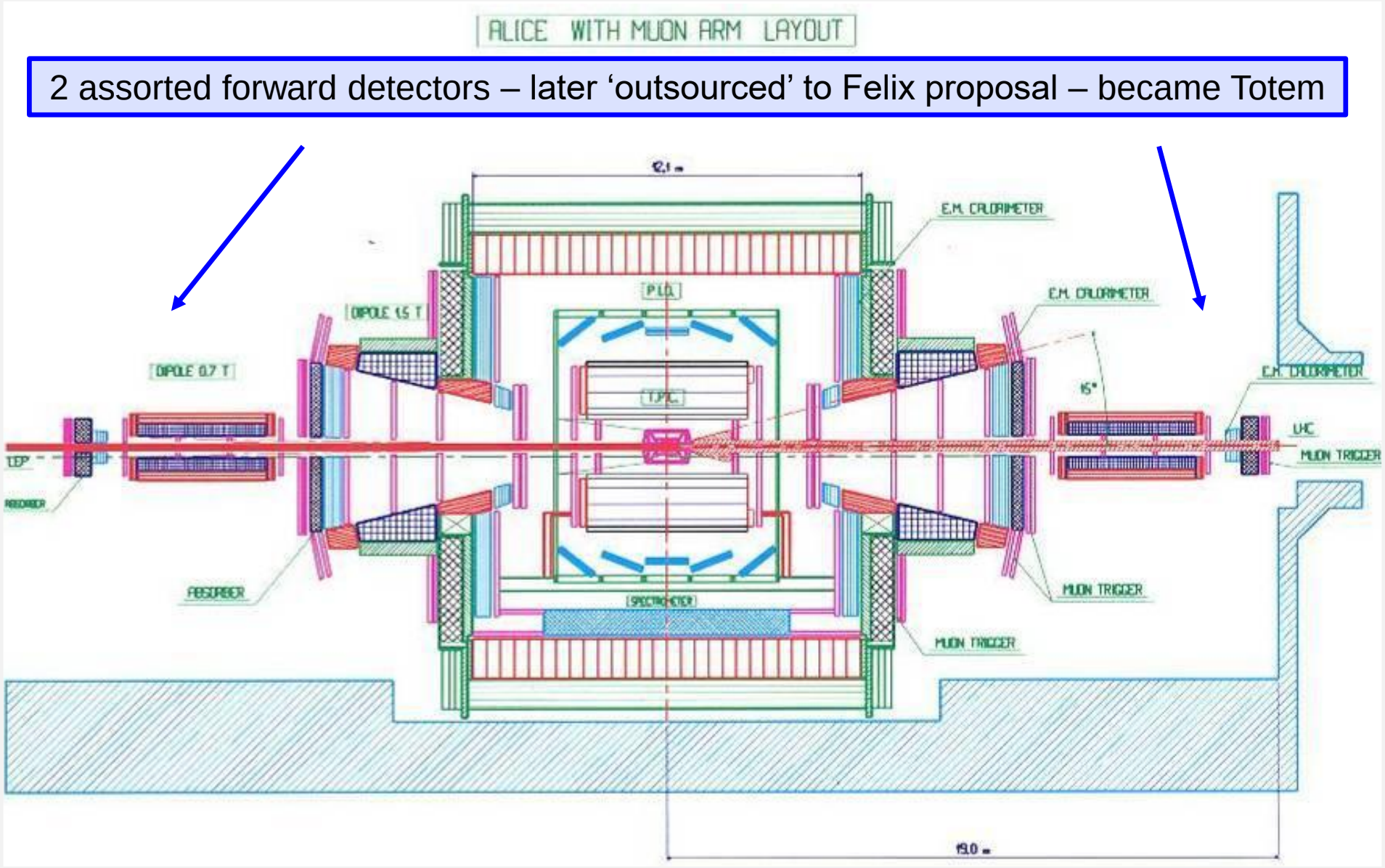
ALICE @ LoI time



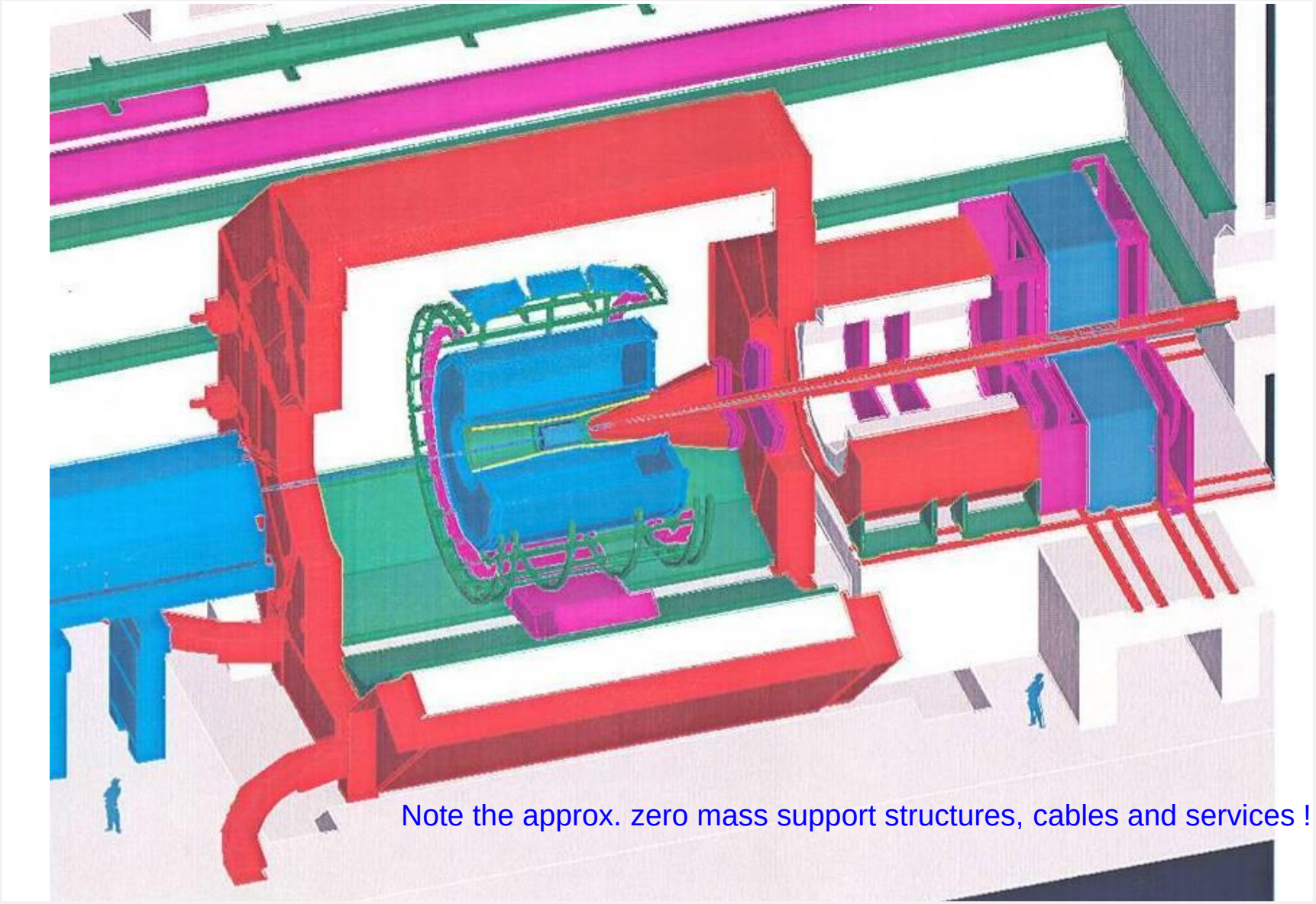
magnet use competing with L3P proposal
=> Plan B was to built another large solenoid (0.2T)

Mega-Alice in 1994

2 assorted forward detectors – later ‘outsourced’ to Felix proposal – became Totem

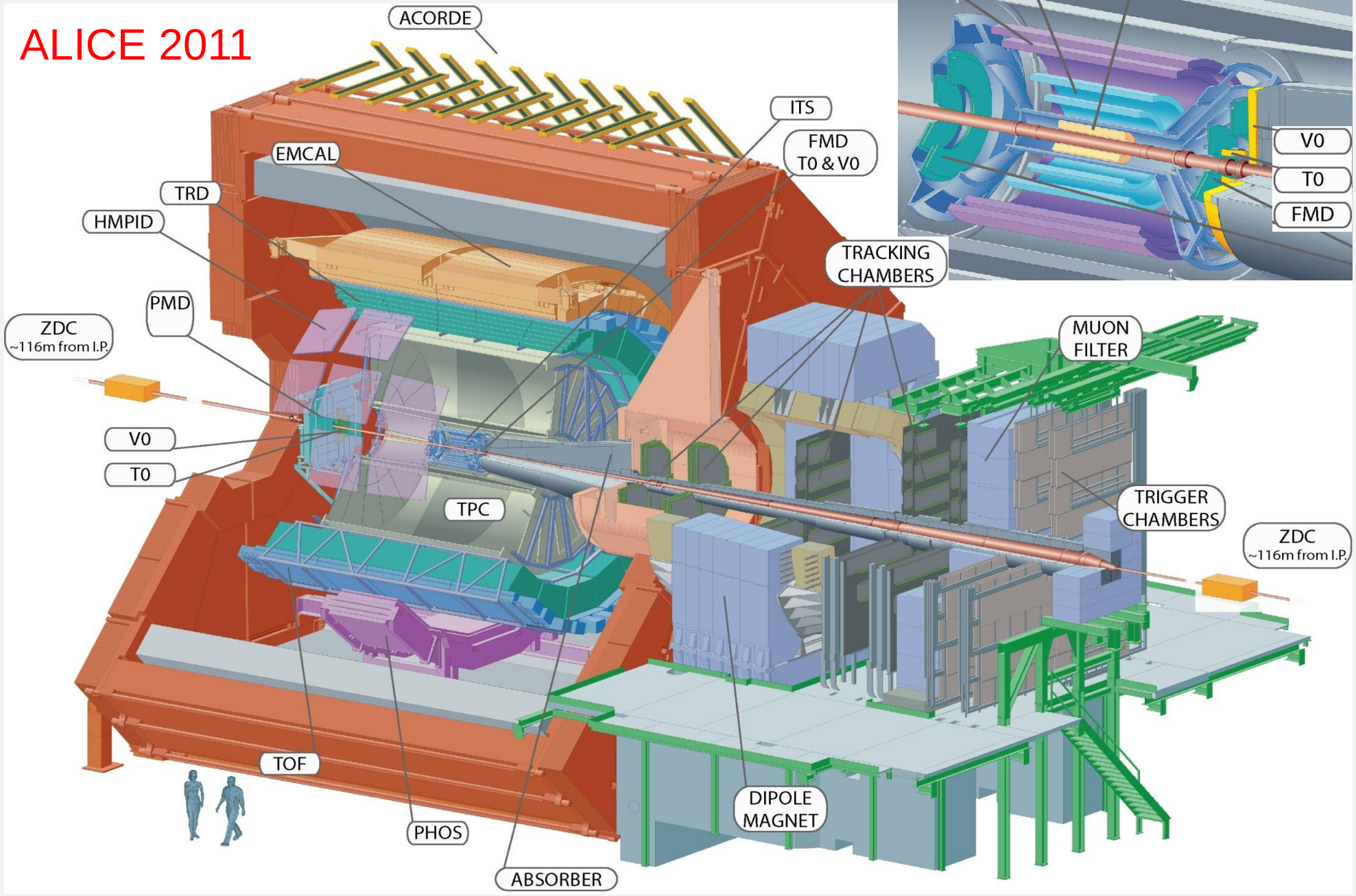


ALICE in TP (1995)



Note the approx. zero mass support structures, cables and services !

ALICE 2011

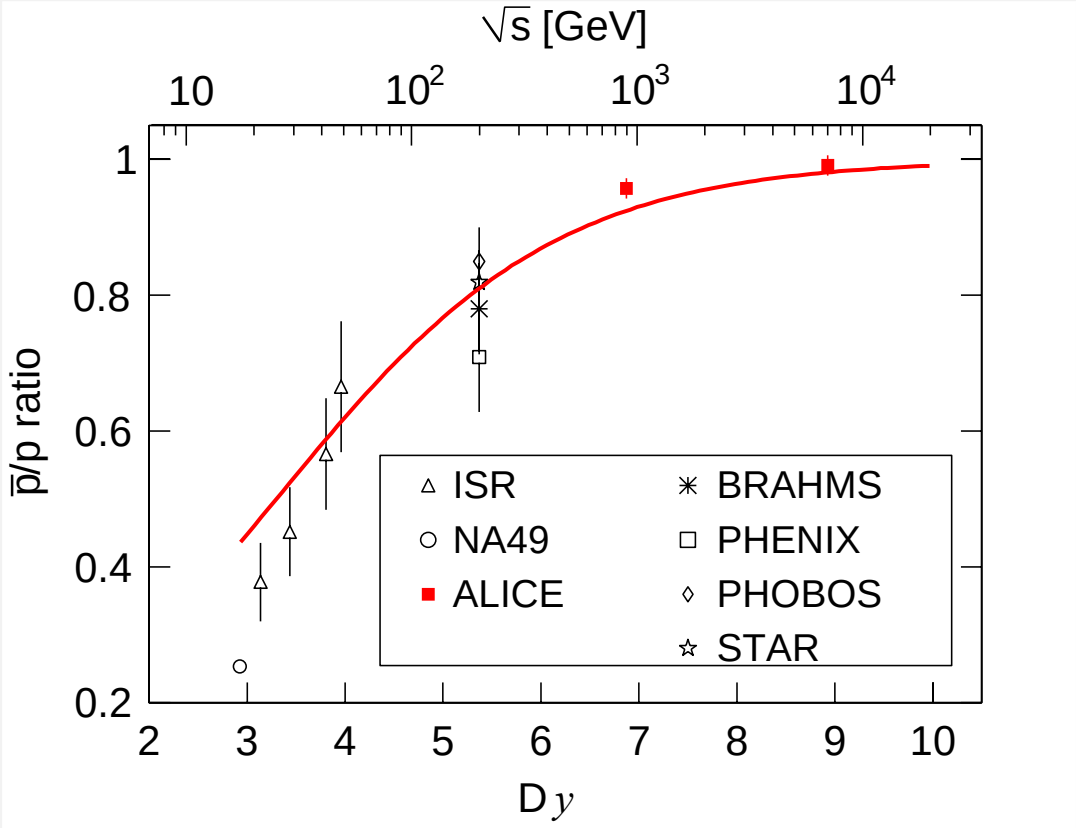

ACORDE
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
TRACKING
CHAMBERS
PMD
ZDC
~116m from I.P.
MUON
FILTER
V0
T0
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
DIPOLE
MAGNET
PHOS
ABSORBER

Strip
Drift
Pixel
V0
T0
FMD

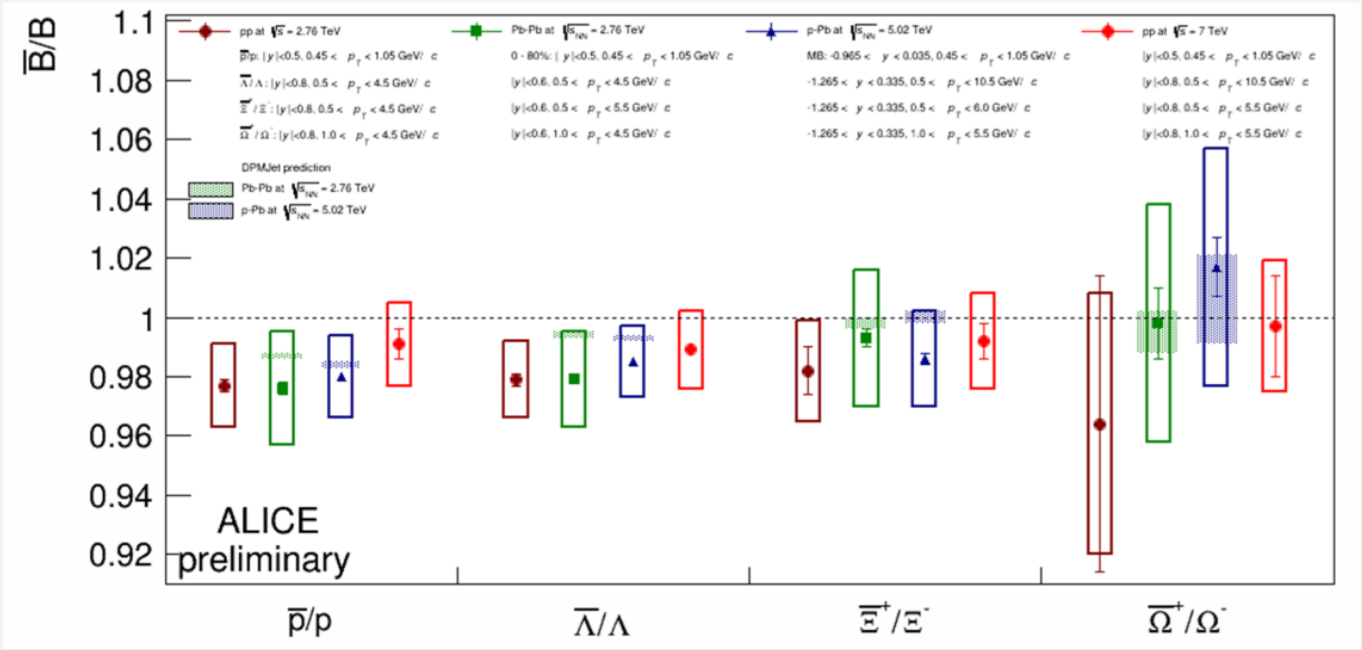
Physics highlights ALICE 1 Run 1 & 2

Anti-p to p ratio at midrapidity

- How easy/difficult is to transfer baryon number at large rapidity distances?
  - is baryon number transported by quarks or a “string junction”?
  - what’s corresponding Regge trajectory intercept?



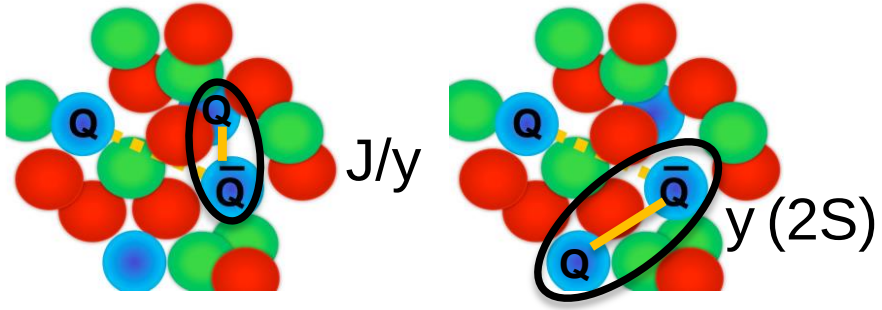
ALICE Collaboration : Midrapidity Antiproton-to-Proton Ratio in pp Collisions at √s=0.9 and 7 TeV Measured by the ALICE Experiment; **Phys. Rev. Lett. 105, 072002 (2010)**



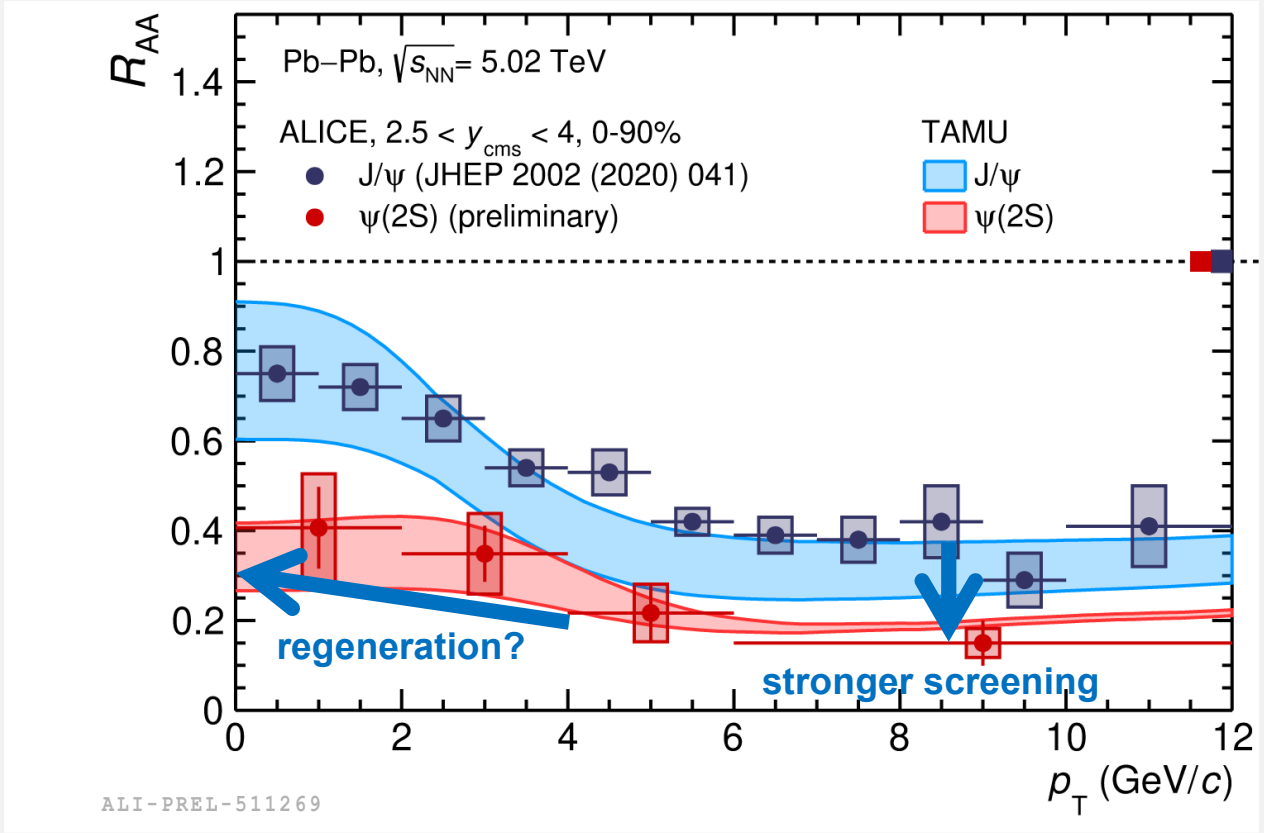
M.Broz (Bratislava, Prague)
M.Mereš (Bratislava)

J/ψ dissociation vs. regeneration

- Reminder: J/y suppression due to **colour screening** in the QGP reduced at low p_T and at central rapidity by **$c\bar{c}$ regeneration**
  - ~100 $c\bar{c}$ pairs per central Pb-Pb

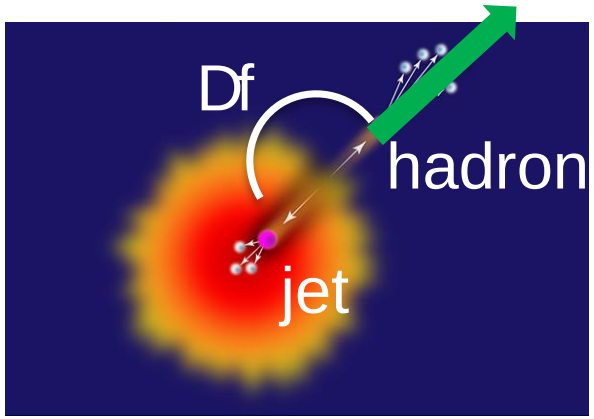


- New result: measured y (2S) – ×10 lower binding energy! – to pin down the role of these two mechanisms
- y (2S) ~ ×2 more suppressed than J/y
- Hint of regeneration at low p_T



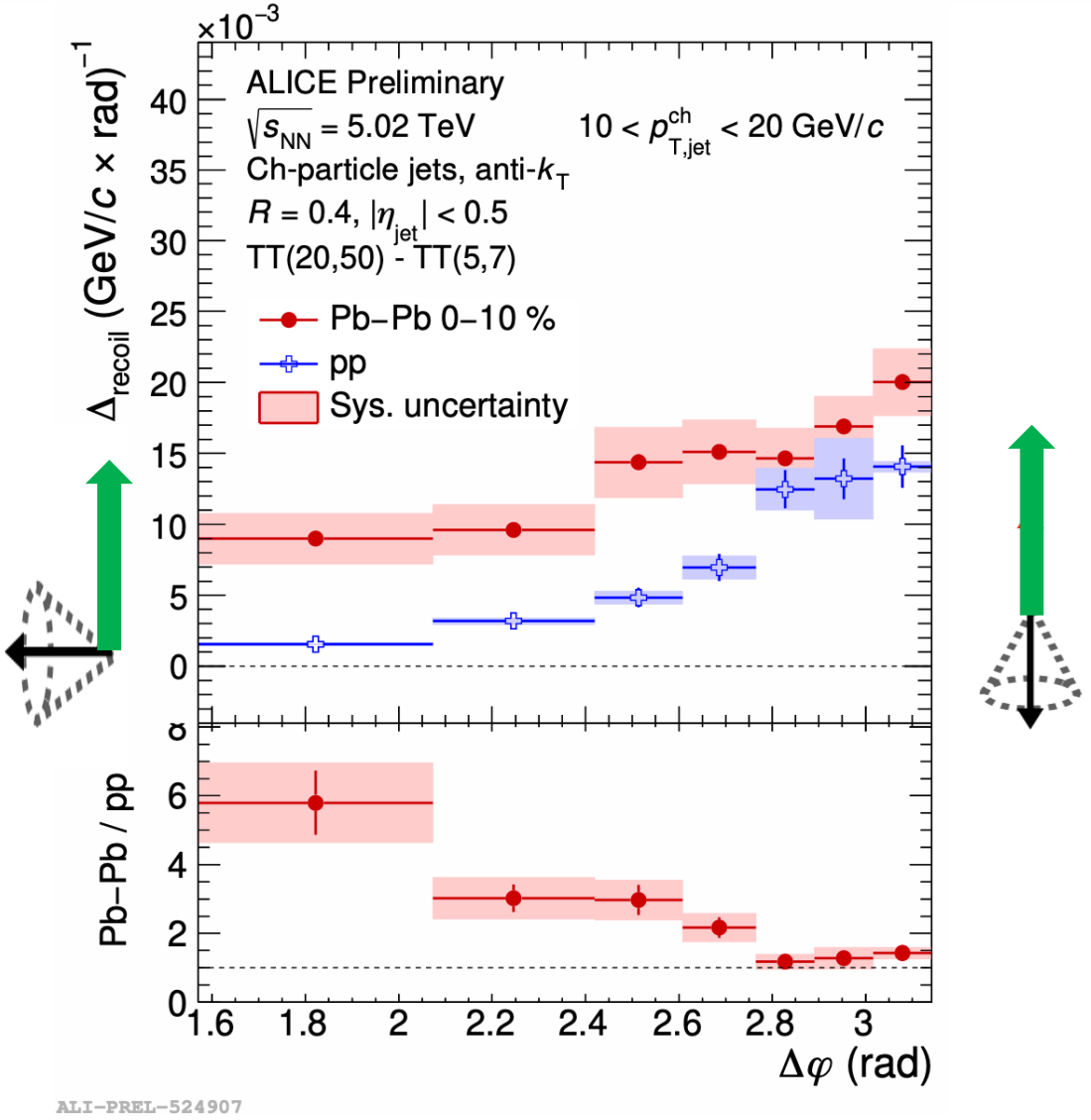
Jet deflection

Jets recoiling against a high-p_T hadron
→ down to jet p_T ~ 10 GeV/c



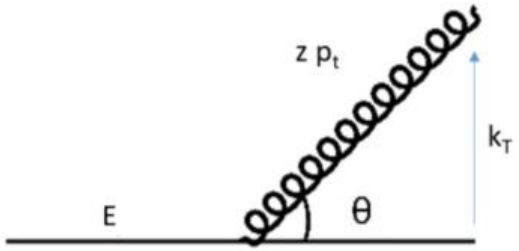
D_{recoil} vs Df broader in Pb-Pb than in pp

Angular deflection of soft large-R jets:
Scattering on QGP constituents?
Medium response to energy loss?



Energy loss: charm vs. beauty

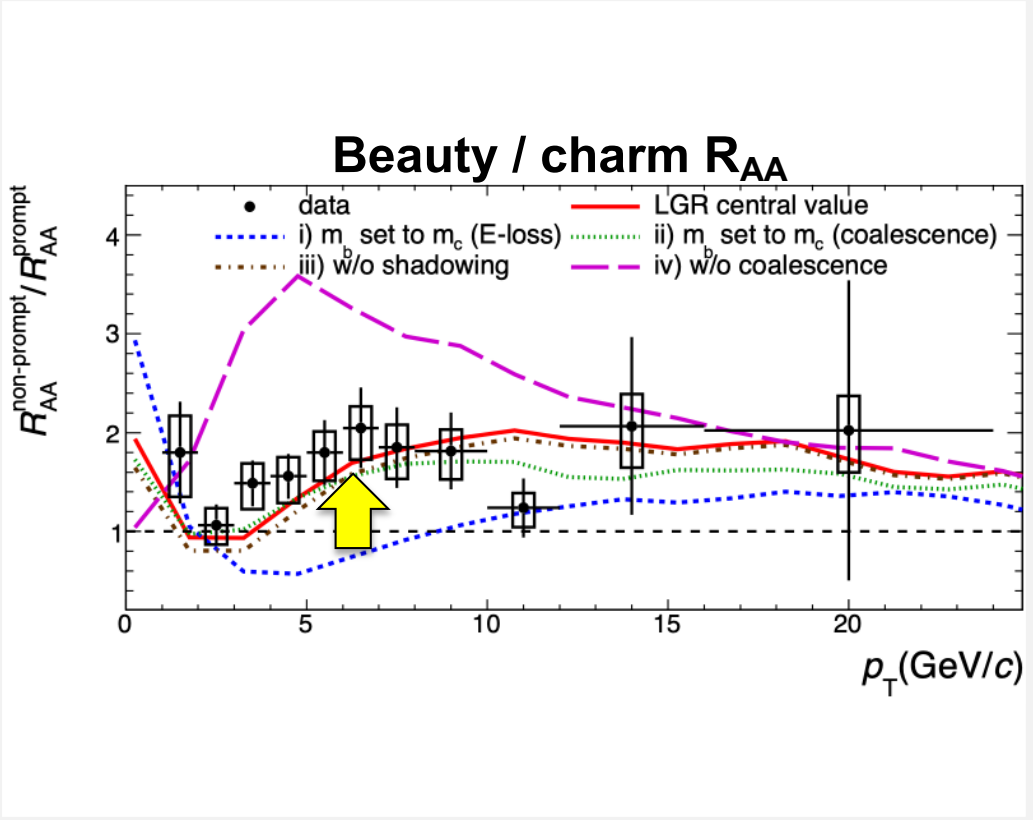
- Energy loss predicted to depend on QGP density, but also on quark mass
- “Dead cone” effect reduces small-angle gluon radiation for high-mass quarks



Suppression of emissions from a radiator (quark) within

$$\theta < \frac{m_q}{E_q}$$

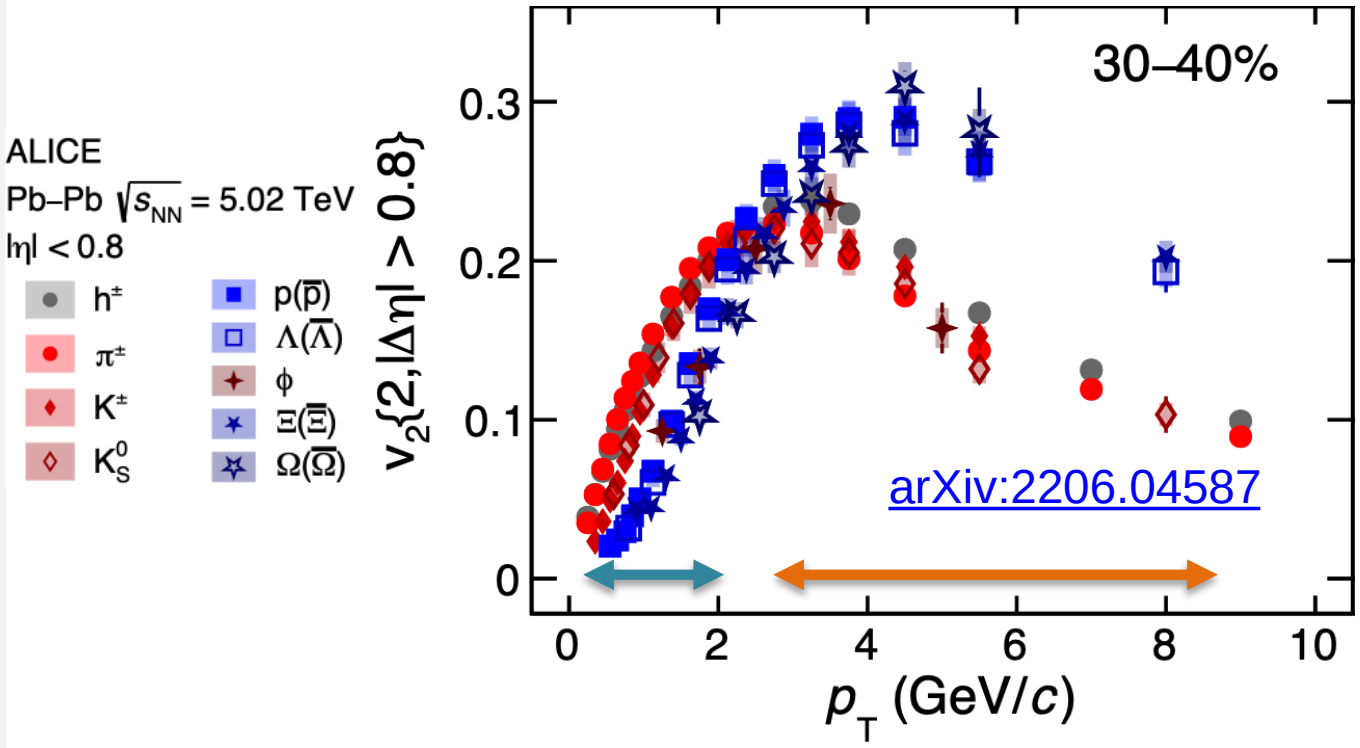
- Less suppression for (non-prompt) D mesons from B decays than prompt D mesons
- Smaller energy loss for b quarks needed to describe the ratio of R_{AA}

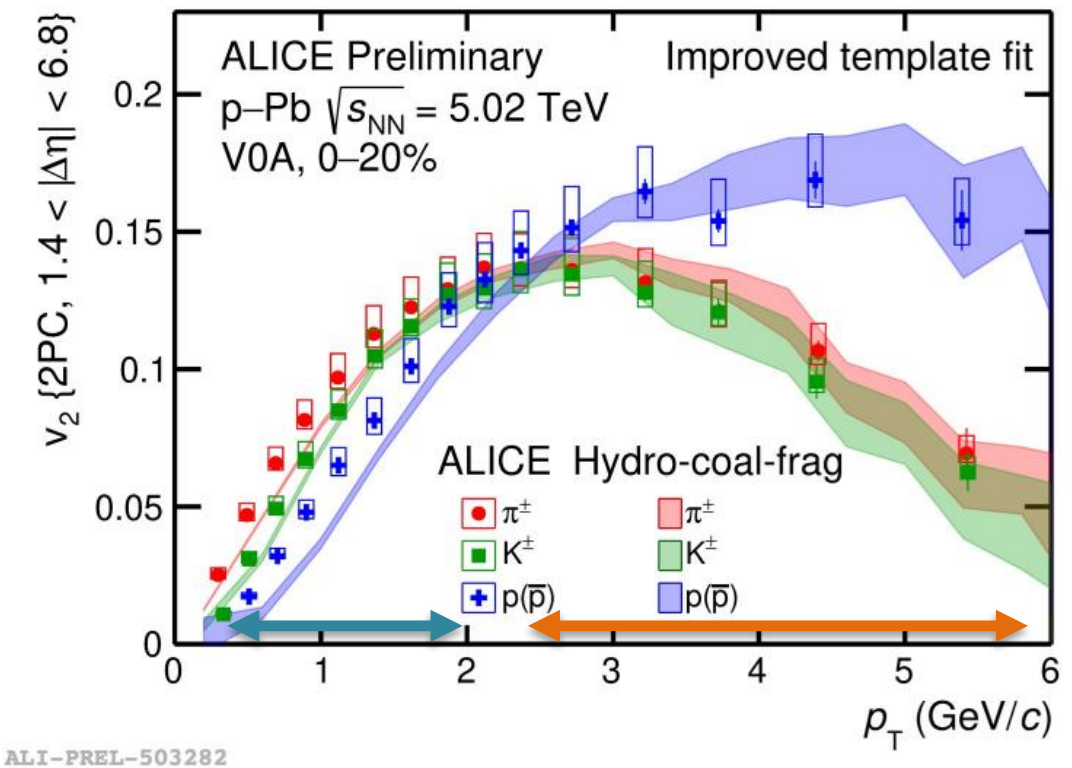


Elliptic flow

- Non-central collisions: elliptical geometry → azimuthal modulation in momentum (expansion (flow))

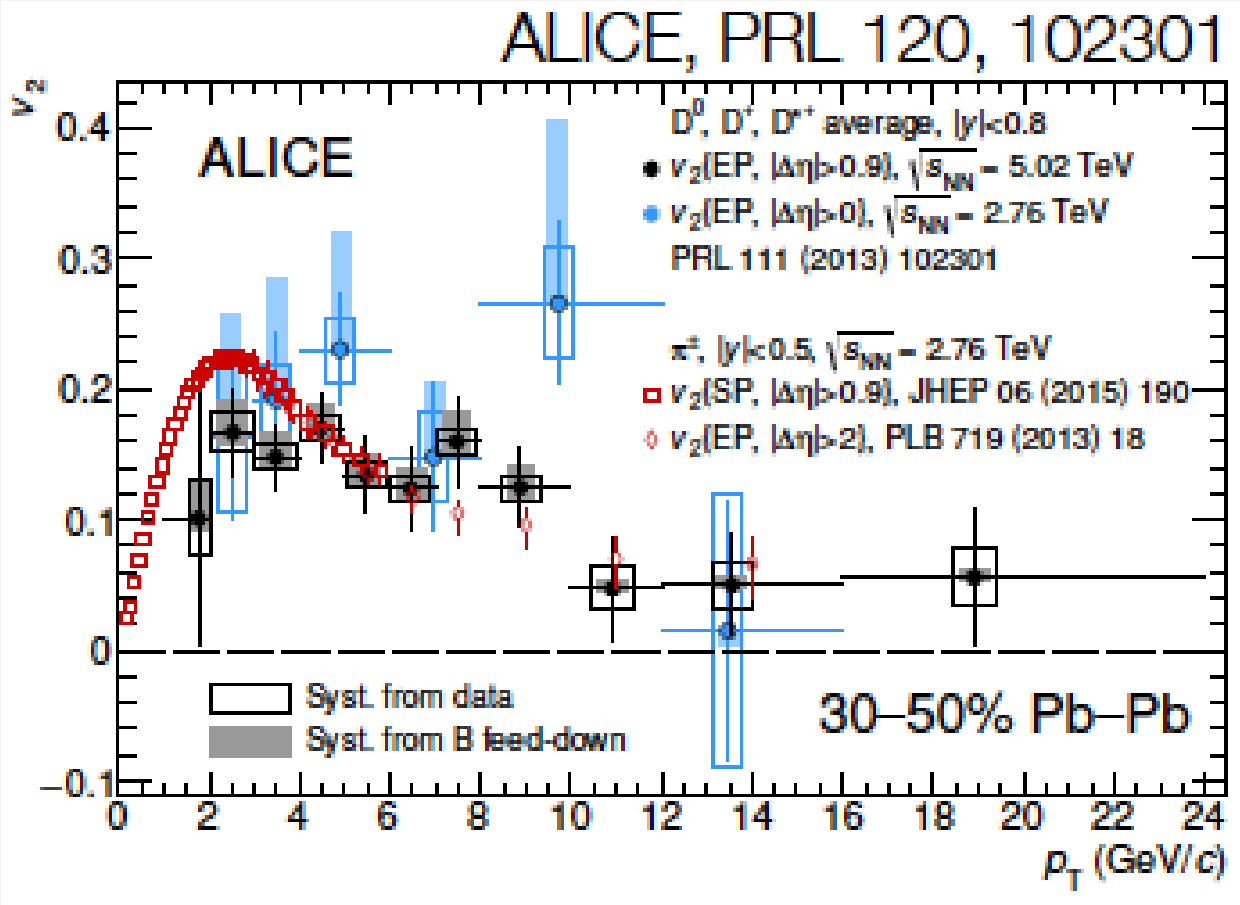
$$\frac{dN}{Nd\phi} = 1 + 2v_2 \cos\left(2(\phi - \Psi_{RP})\right) + \textit{higher harmonics } (v_3, v_4, \ldots)$$





→ quark-level flow + recombination in high-multiplicity p-Pb (and pp)

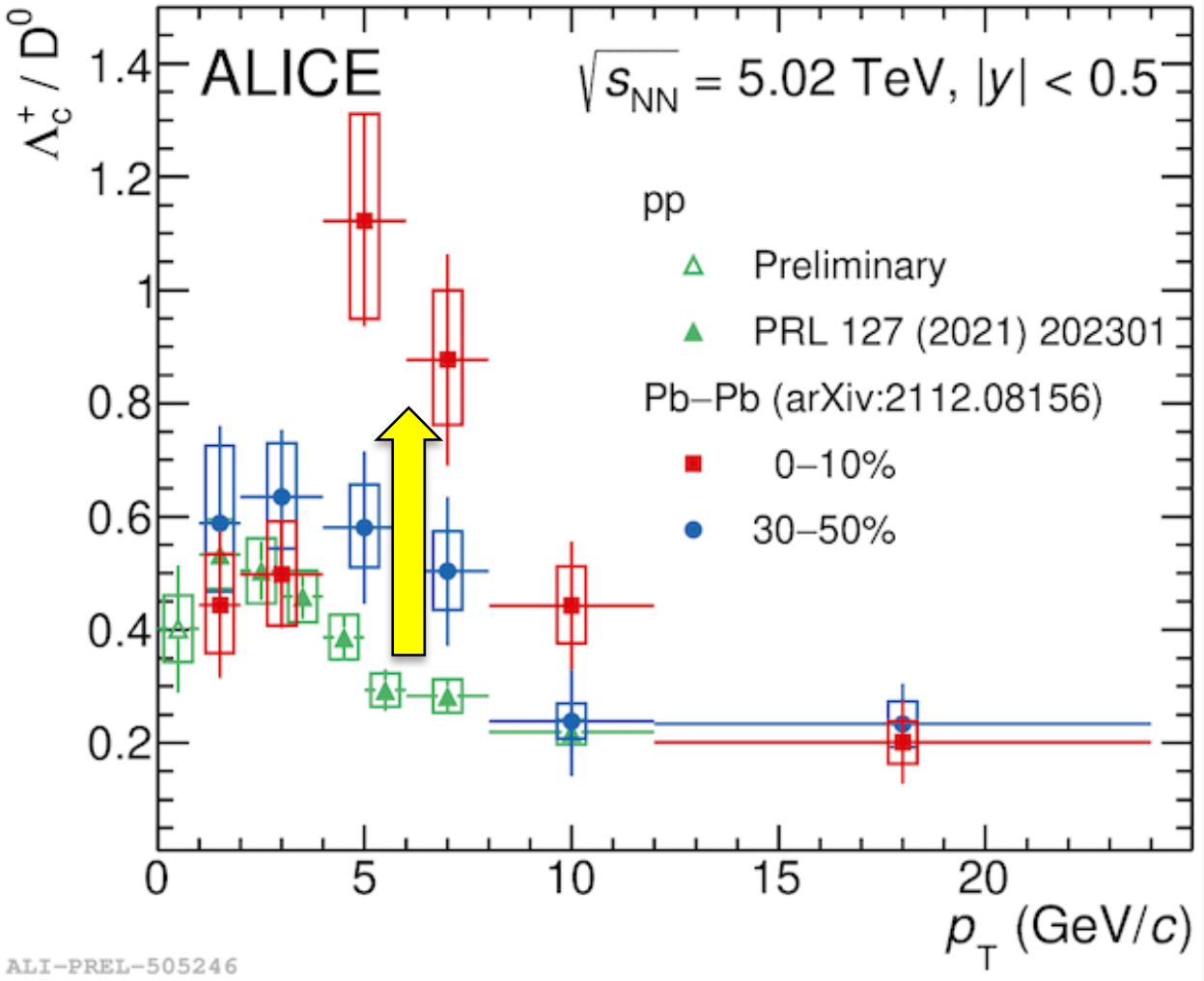
Heavy-flavour flow



Heavy flavour participates in the collective dynamics at LHC energies
Flow strength like the light hadrons

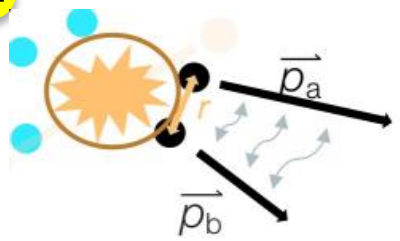
Baryon to meson in charm sector

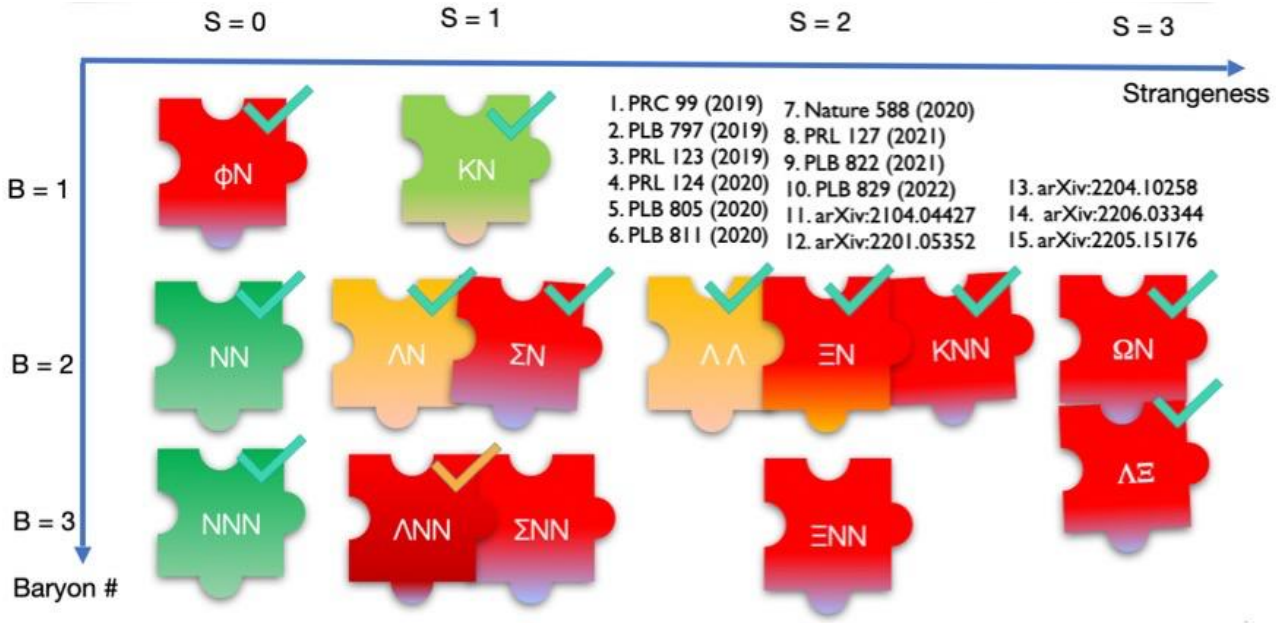
- Additional dynamics in central Pb-Pb collisions: Λ_c/D^0 enhancement at intermediate p_T
- Suggests hadronization by recombination + mass-dependent p_T shift from collective expansion
- Prospects: high-precision, and other baryons, from Run 3 data

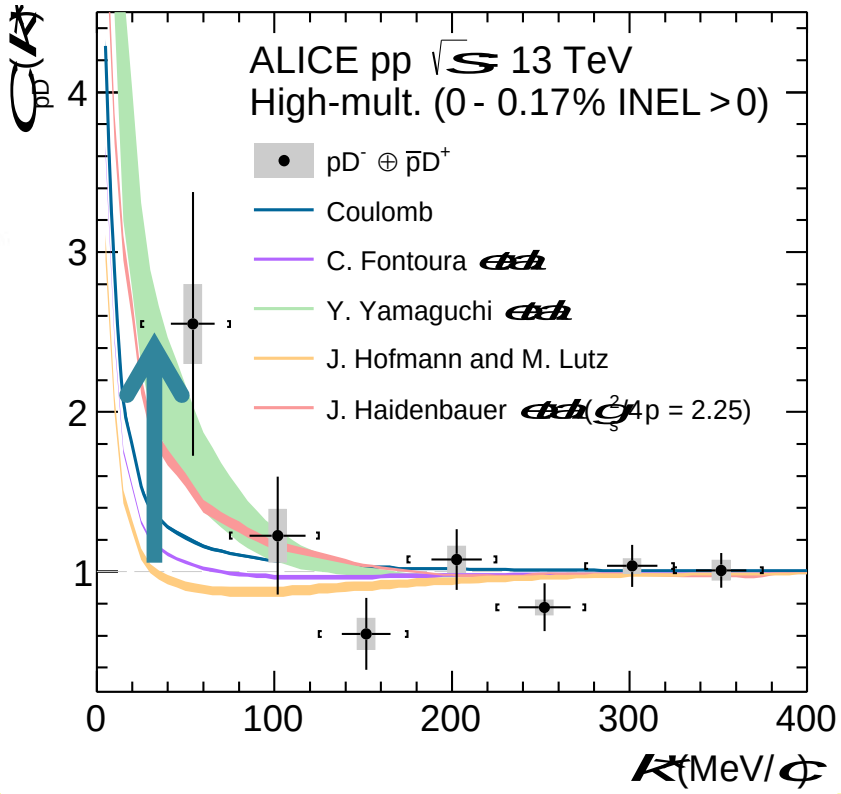


QCD interactions among hadrons

- **Use femtoscopy technique to assess residual strong interaction in h-h and h-h-h**
  - Poorly known for strange baryons
    - Relevant for neutron star modeling
  - Unknown for charm hadrons and 3-body





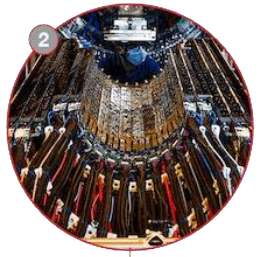


First measurement of p-D correlation function:

- Attractive interaction
- Estimate of QCD scattering parameters

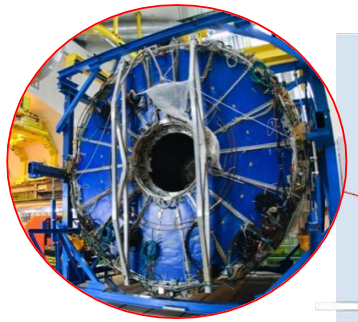
ALICE upgrade for Run 3

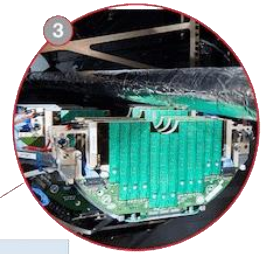
ALICE-2 upgrades



New Inner Tracking System (ITS)
– 7 barrels, 10 m² silicon tracker
based on MAPS (12.5 G pixels`

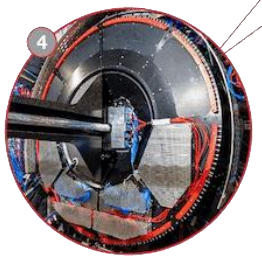
New GEM-based TPC
with continuous readout





New Muon Forward Tracker (MFT) - 5 disks
based on MAPS

New Trigger and Readout
Upgrade of readout electronics of all detector, new Central Trigger Processor



New Online/Offline (O2)

New Fast Interaction Trigger (FIT)
– 3 detector technologies:
interaction trigger, online luminometer, forward multiplicity

New Beampipe
smaller diameter (36.4 mm), first detection layer at 20 mm

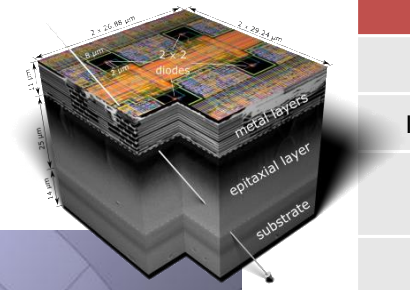
ALICE 2 Upgrade

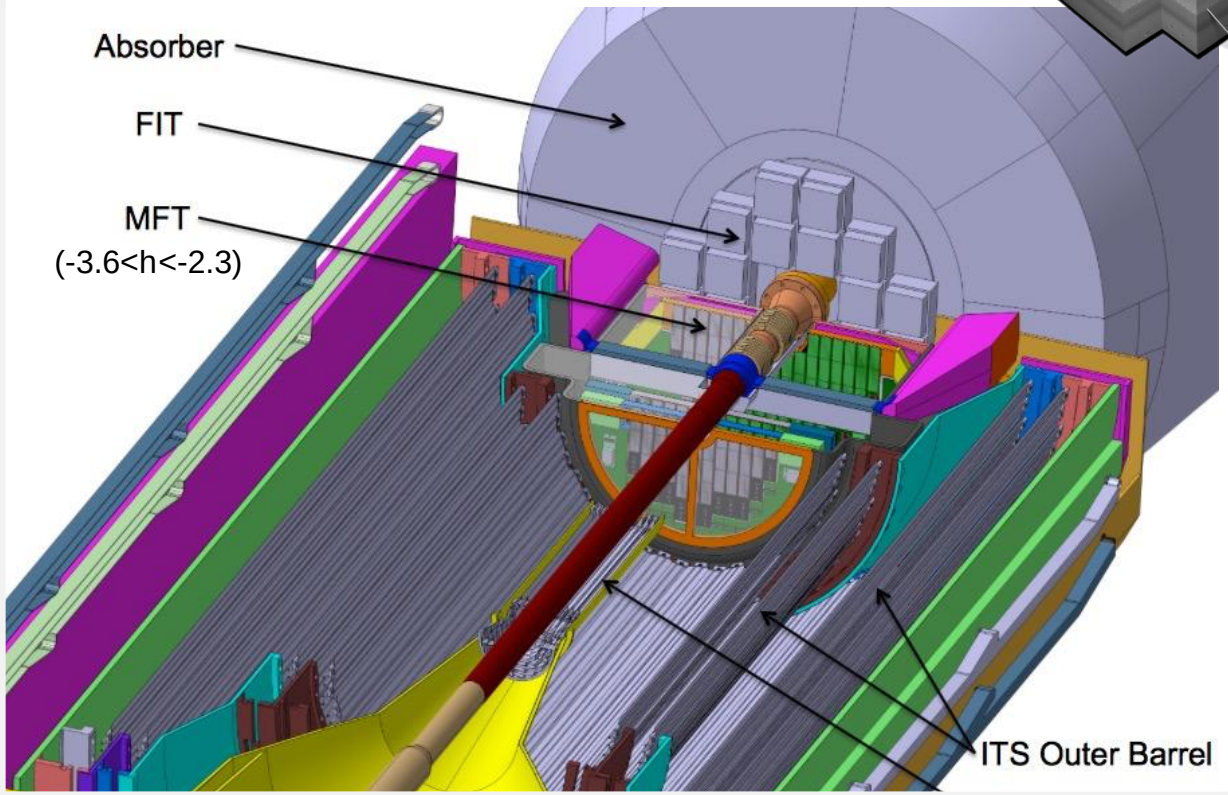
→ Tracking precision ×3
→ Pb-Pb rate ×50

New all-pixel trackers: ITS-2 and MFT

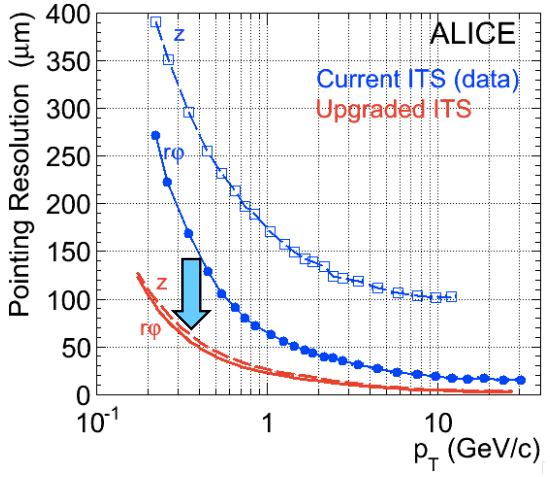
- ITS-2 seven layers monolithic active pixel sensors
- MFT five layers Muon Forward Tracker in front of absorber

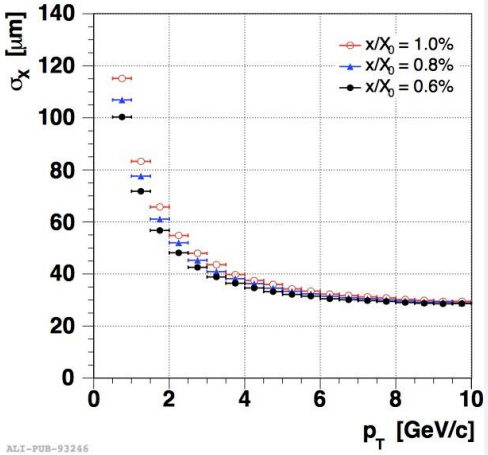
- Monolithic Active Pixel Sensors (MAPS)
  - Low resistivity, high efficiency, low thickness, low power consumption
  - Also chosen by sPHENIX and MPD@NICA





	Current ITS	New ITS2	MFT
N Layers	6	7	5
Inner radius	3.9 cm	2.3 cm	/
Layer thickness	~1.1% X_0	0.3-1.0% X_0	0.8% X_0
Spatial resolution	12x100 ∝m^2 35x20 ∝m^2 20x830 ∝m^2	~5x5 ∝m^2	~5x5 ∝m^2



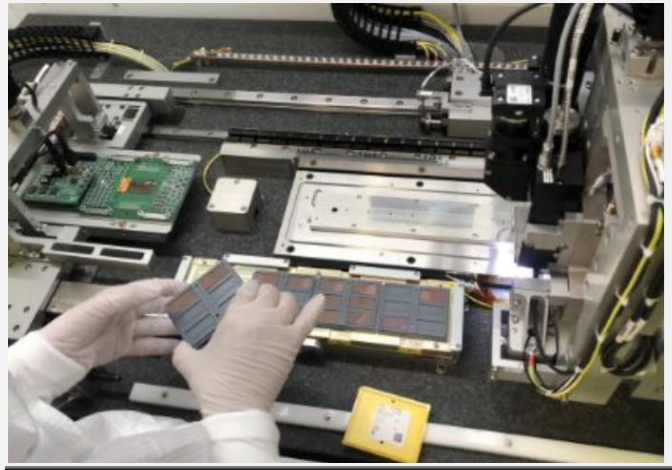


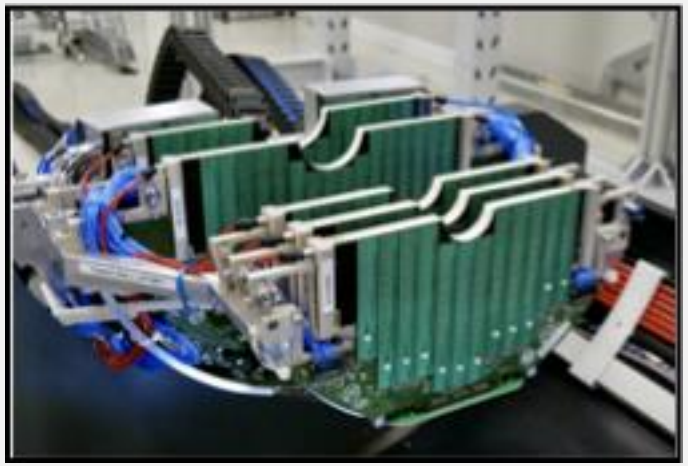
ITS2 tracking precision x3 better in rφ plane, <20 ∝m above 1 GeV/*c*

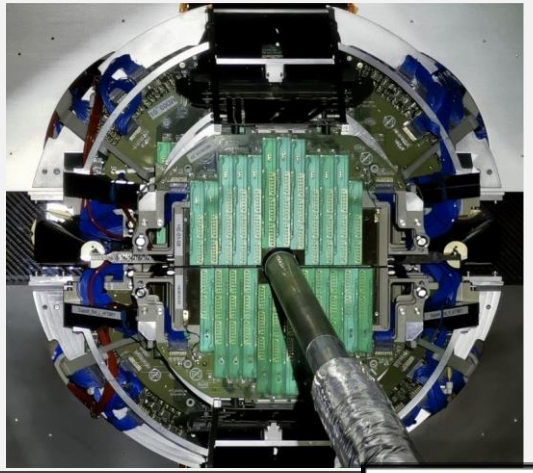
MFT: <100 ∝m above 1 GeV/*c*

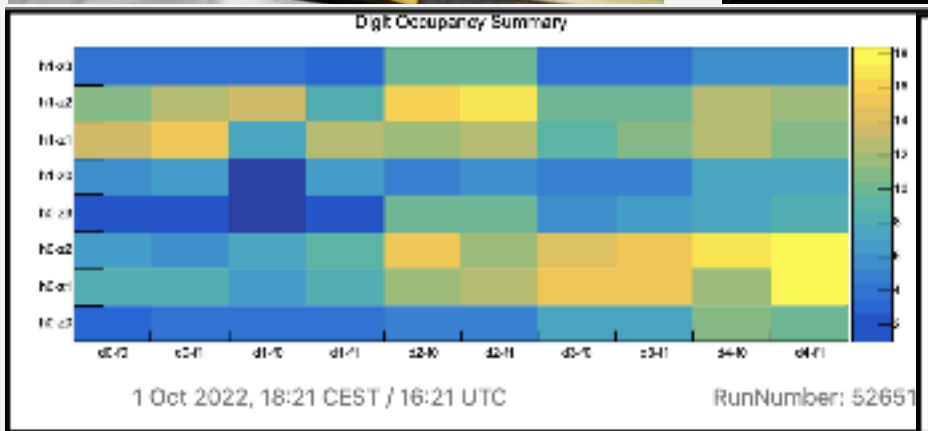
MFT – CTU Prague contribution

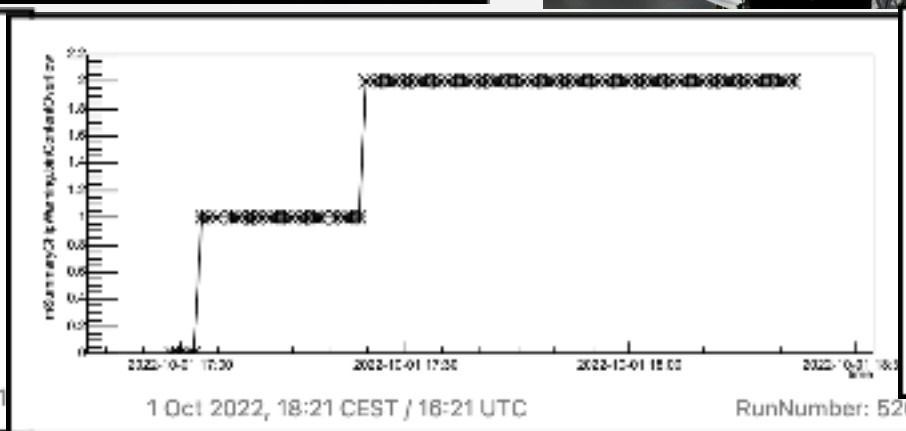
- Muon Forward Tracker at CERN
  - completely new detector for precise tracking in front of muon absorber
  - participation in construction and commissioning
  - system run coordination
  - development of quality control software

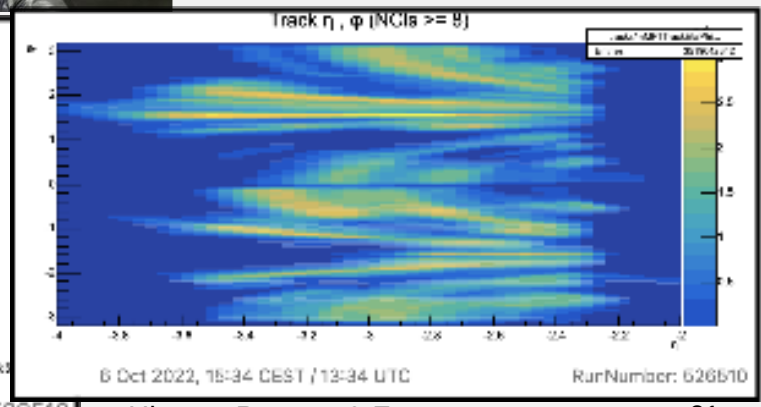








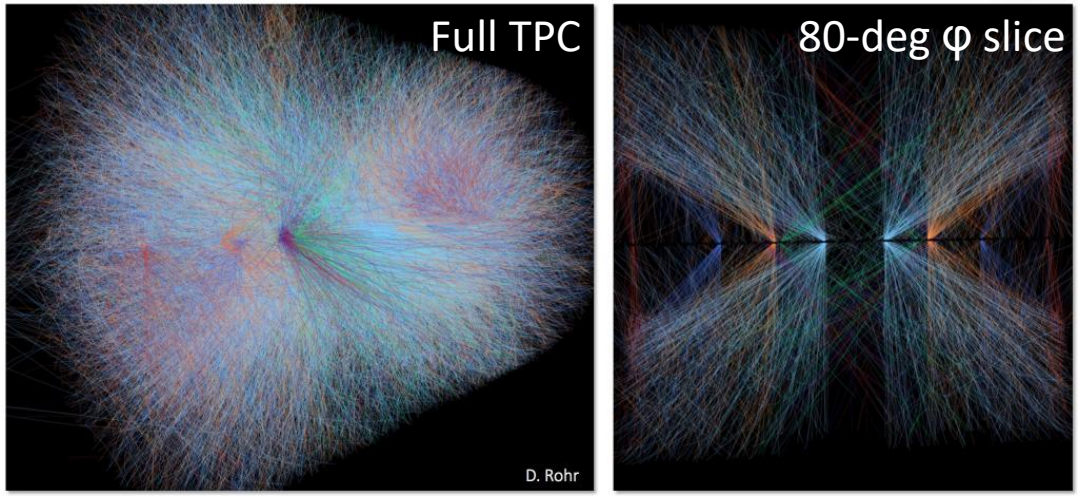




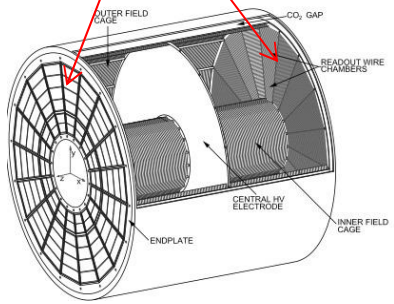
TPC upgrade – GEM readout

- Time Projection Chamber change to continuous readout
  - readout MWPC replaced with GEM chambers
  - Pb–Pb up to 50 kHz

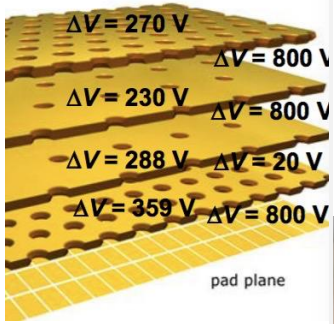
- Current MWPC: readout rate limited by ion backflow
- New readout chambers (GEM): continuous readout of Pb-Pb at interaction rate of 50 kHz
  - preserve p_T and dE/dx resolution
- 5 interactions on average during TPC drift time (90 ∝s)
- Calibration and track-to-event assignment in O^2 system

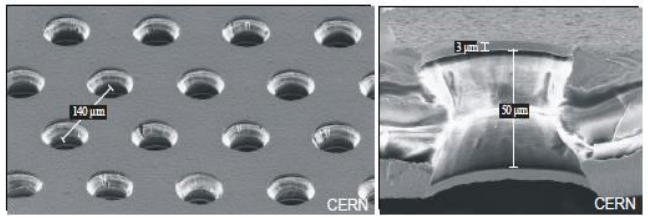


72 readout chambers



Stack of 4-GEM-foils

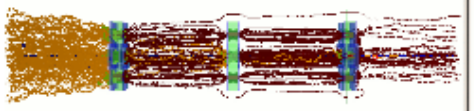




Electron microscope photograph of a GEM foil

CERN-LHCC-2013-020

ion feedback from amplificatio region



Small TPC for drift measurement

ALICE future

ALICE Upgrade

Prague institutions organized ALICE Upgrade Week last year

Upgrade Projects

FoCal

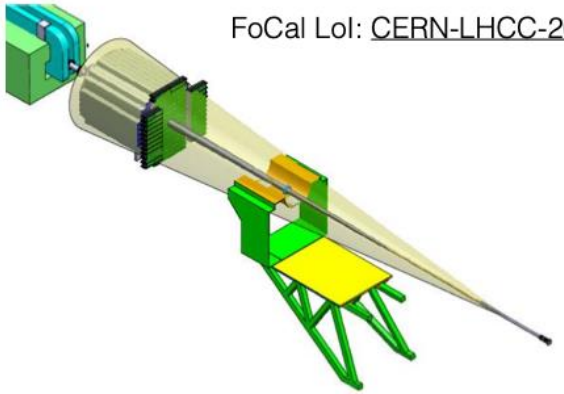
- Test beams with full prototypes
- Sensor radiation tests

ITS3

- Characterisation of 65 nm sensors
- Finalisation of Engineering Run 1
- Testing of engineering models

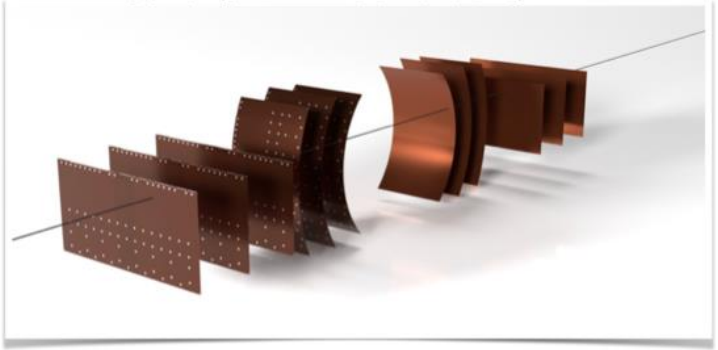
ALICE 3

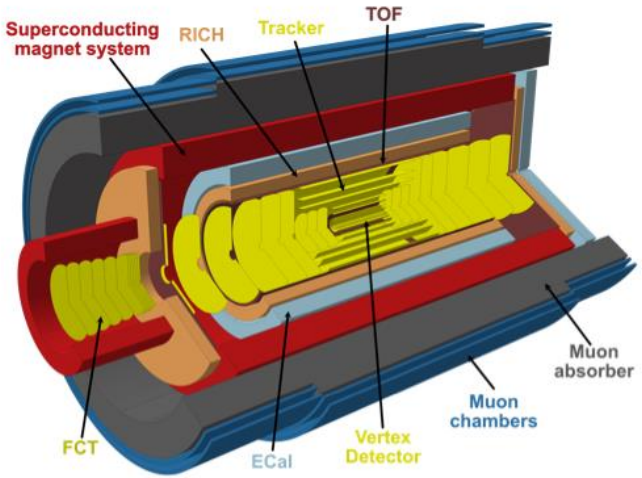
- R&D programme
- Preparation of scoping document
- **Formation of projects and work packages**



FoCal LoI: CERN-LHCC-2020-009

ITS3 LoI: CERN-LHCC-2019-018





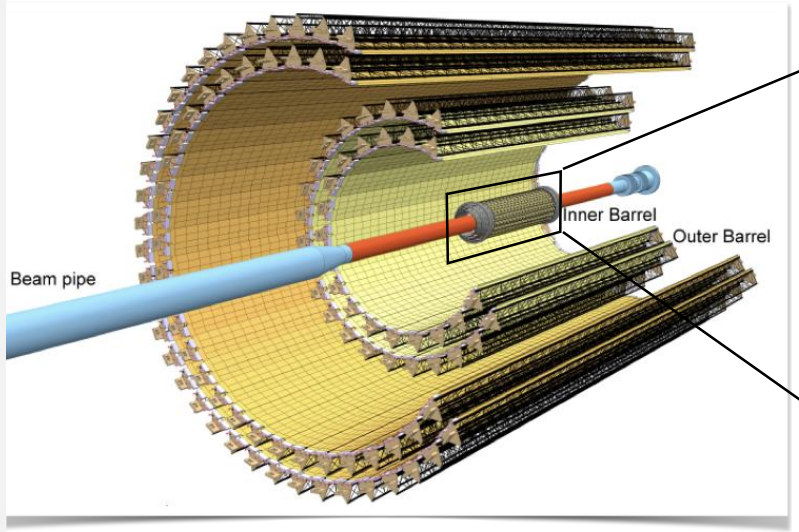
ALICE 3 LoI: CERN-LHCC-2022-009

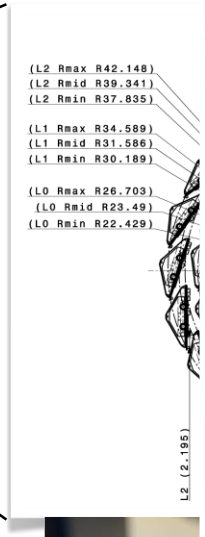
In addition:
Studies on **Fixed Target programme** at IP2

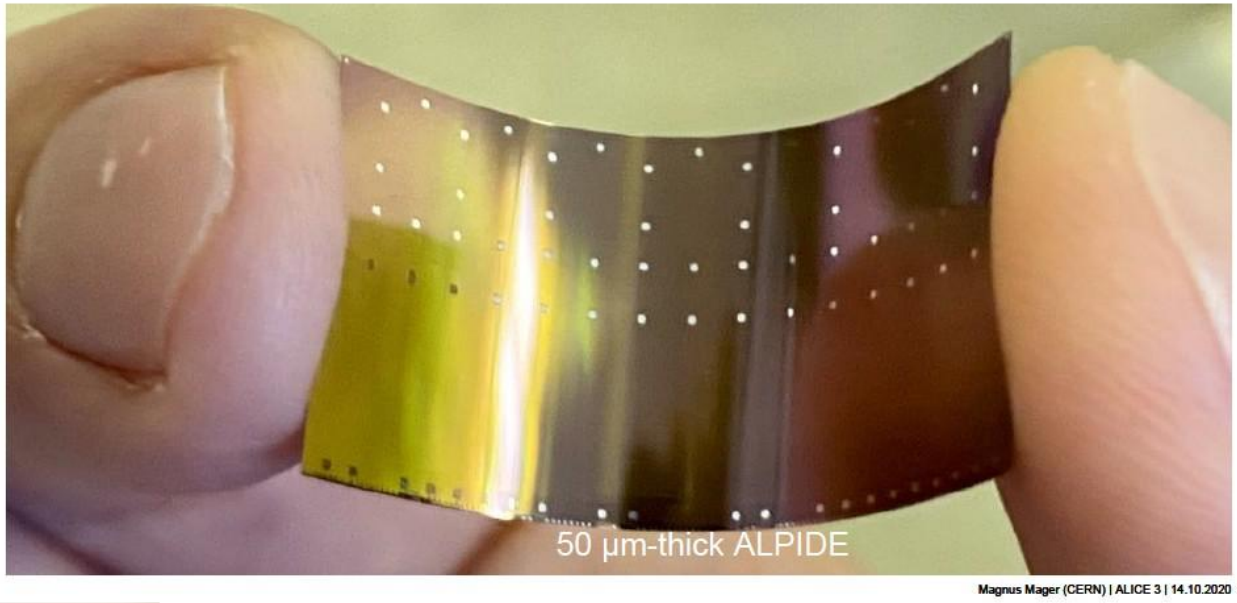
From ITS 2 to ITS 3

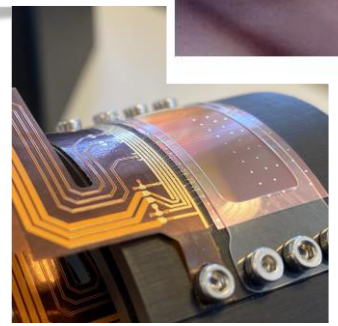
From stave-based inner **Bent Silicon Detectors**

ITS2









- **Improve Inner Tracker performance** by
  - moving closer to the interaction point
  - reducing material budget
- Replace Inner Barrel with **truly cylindrical layers** (ITS3)
  - requires low-power, wafer-scale, bendable sensors (MAPS: 65 nm TowerJazz ISC, stitching, thinning)

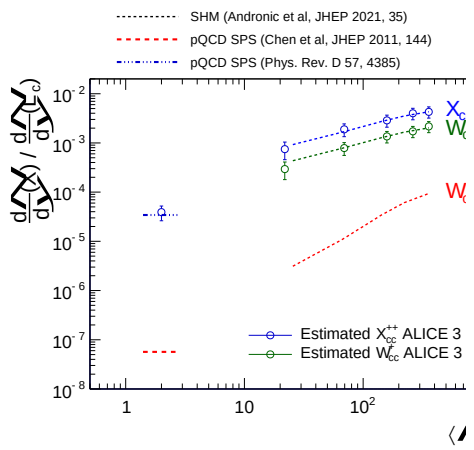
- Operation of bent sensors (ALPIDE) established in many testbeam campaigns
  - Stitching for wafer-scale sensors to be demonstrated with Engineering Run 1 → submission being finalised
  - TDR in preparation for Q4 2023

ALICE 3 Physics Programme

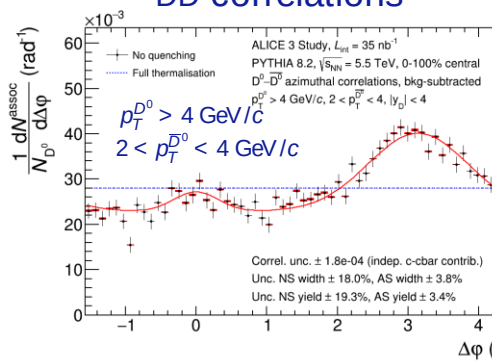
- ALICE 3 – LoI submitted recently – completely new detector for heavy-ion physics at the LHC
  - high-rate, high-resolution, large-acceptance heavy-ion experiment for Run-5 (~2035)

- Thermal radiation, chiral symmetry restauration
  - Di-electron mass, p_T spectra, v_2
- Heavy flavour transport, thermalisation
  - Beauty meson, baryon v_2
  - $D\overline{D}$ azimuthal correlations
  - Multi-charmed baryons
- Hadron interactions, structure
- Net-quantum-number fluctuations
- (Forward) Ultra-soft photon production
- BSM searches, e.g. ALPs

multi-charm baryons



DD̄ correlations



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

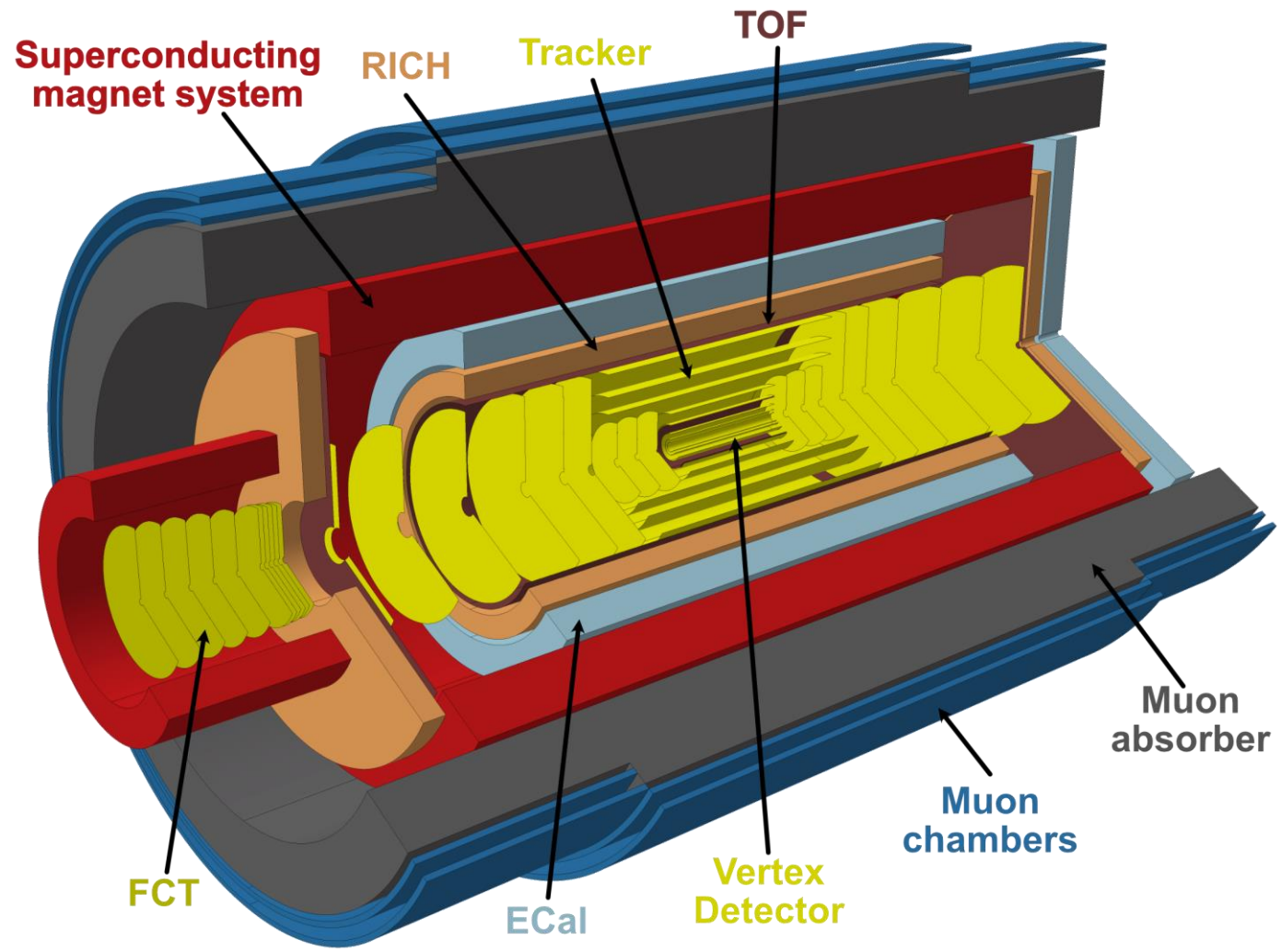
CERN-LHCC-2022-009
LHCC-I-038

Letter of intent for ALICE 3:
A next-generation heavy-ion experiment at the LHC
Version 2

ALICE Collaboration

ALICE 3 Detector

- **Vertex tracker: excellent pointing resolution**
  - Heavy flavour mesons/baryons, multi-charm (yields, flow, correlations)
  - HF rejection in dielectron, dimuon measurements
- **Large acceptance tracker and PID**
  - Correlation measurements
  - Rapidity dependence measurements
- **TOF and RICH**
  - Hadron ID for heavy flavour decays, net-baryon measurements
  - Electron ID (with ECAL) for dielectron radiation (and J/ψ)
- **Muon ID** down to p_T = 1.5 GeV: quarkonia, including P-wave (with ECAL), exotic hadrons
- **ECAL** (+conversions): photon detection for P-wave quarkonia, photon radiation, jets
- **FCT**: ultra-soft photons



ALICE 3 Integration and Runing

Installation of ALICE 3 around nominal IP2

L3 magnet can remain, ALICE 3 to be installed inside Cryostat of ~8 m length, free bore radius 1.5 m, magnetic field configuration to be optimized

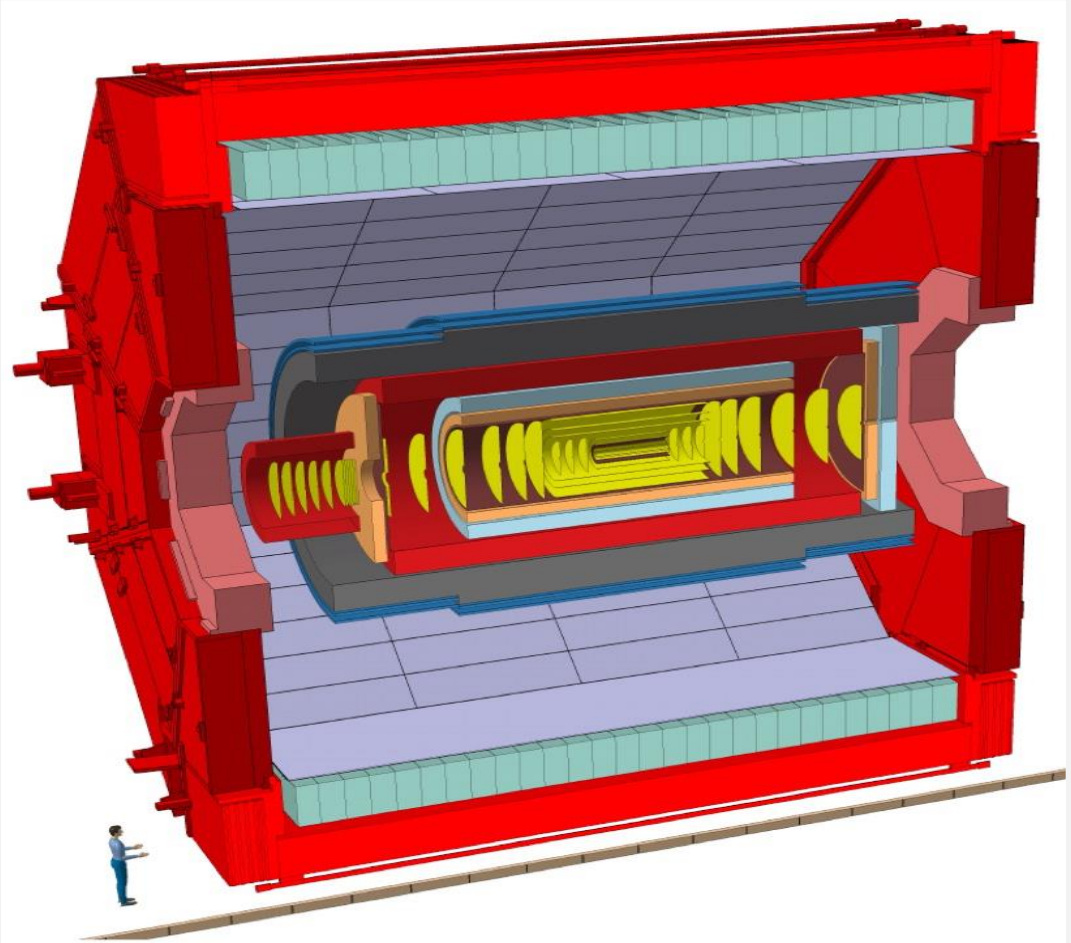
Running scenario:

6 running years with 1 month / year with heavy-ions

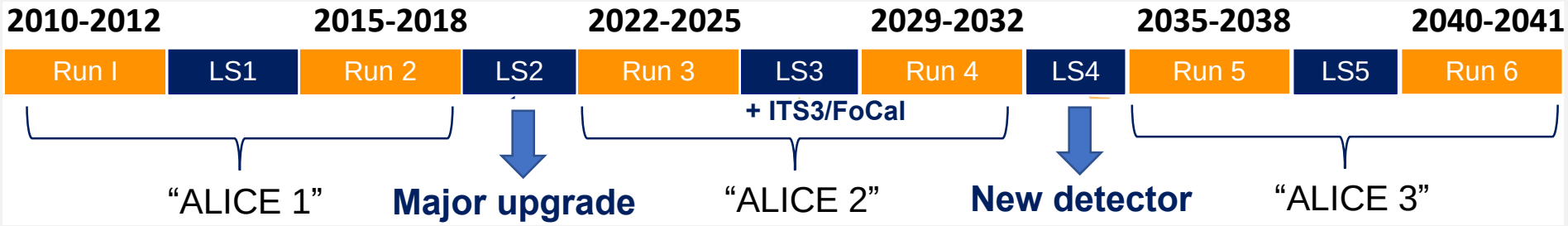
- 35 nb^{-1} for Pb—Pb x 2.5 compared to Run 3 + 4
- Lighter species for higher luminosity under study

pp at s = 14 TeV:

- 3 fb^{-1} / year x 100 compared to Run 3 + 4



Pushing Frontiers of Precision



Enhance physics reach by improving:

- **rate capabilities & acceptance**
- **tracking precision**

→ high precision, reduce backgrounds, access rarer probes