Upgrade of the ALICE experiment for LHC Run 3 and beyond

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Preparing ALICE for Run 3

New opportunities and challenges for ALICE in Run 3

Physics opportunities for ALICE in run3

- Thermalization of (heavy) partons in the QGP
- Charmonia at low-p_T: Probe of deconfinement
- Low-mass dileptons: Chiral symmetry restoration
- Thermal photons: Initial state of the QGP
- Jet substructure, jet-X correlation: partonic energy loss in the medium
- Search for bound states involving strange mesons

Need for an upgrade of several systems of the ALICE experiment

- Improve readout rate
- Improvement of p_T and pointing resolution
- Significant reduction of the data volume
- Preserve particle identification capability

Data taking conditions

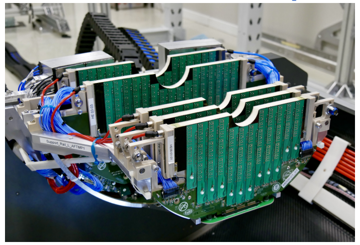
- Run 2: PbPb @ 1 kHz
- Run 3: PbPb @ 50 kHz

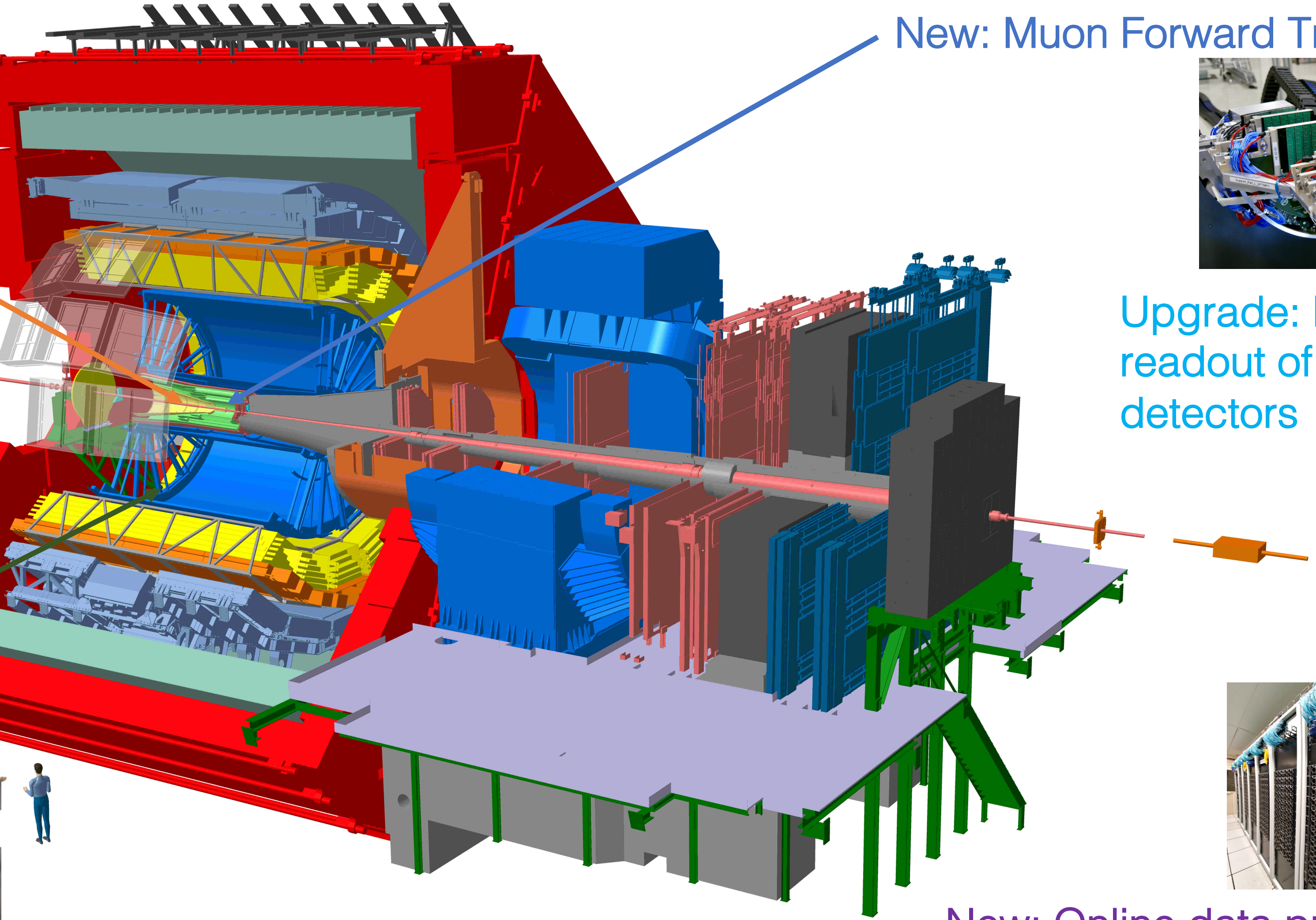
CERN-LHCC-2012-012, CERN-LHCC-I-022, ALICE-UG-001

ALICE in Run 3

New: Inner Tracking System

New: Muon Forward Tracker (MFT)

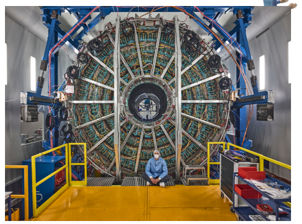


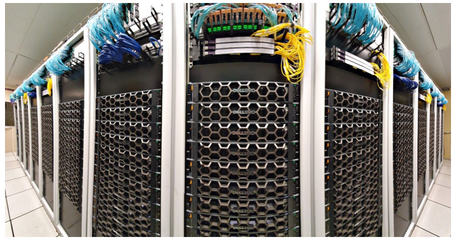


New: Fast Interaction Trigger (FIT)

Upgrade: Frontend readout of various detectors

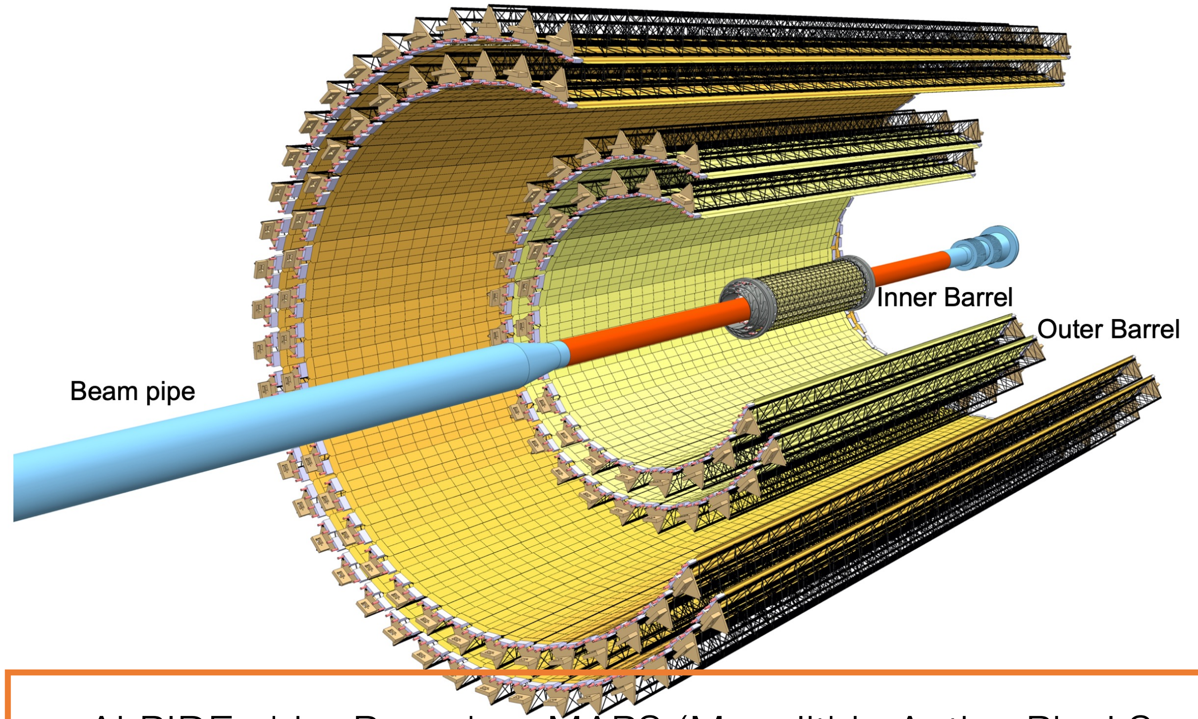
Upgrade: TPC readout based on GEM stacks





New: Online data processing (O^2)

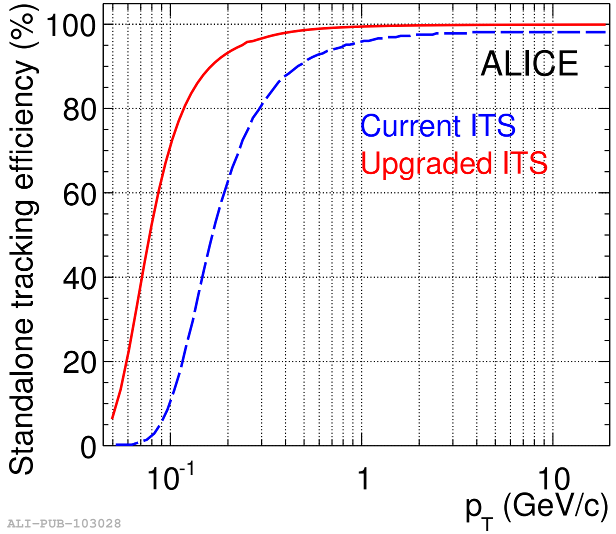
New Inner Tracking System (ITS2)



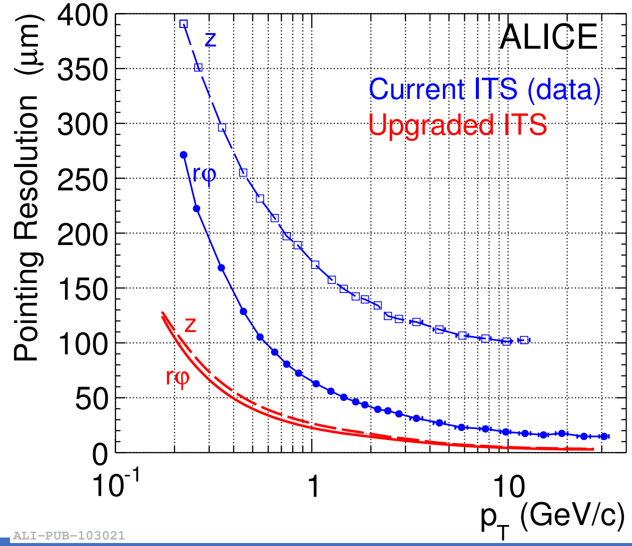
- ALPIDE chip: Based on MAPS (Monolithic Active Pixel Sensor)
  - Thickness: 50 µm
  - Granularity: 2000 pixels/cm^2
- 7 Layers (3 layers Inner Barrel, 4 Layers Outer Barrel)
- ~24k chips -> ~ 12.5G pixels
- Distance from the collision point: 22 mm
- Radiation lengh: 0.35%X_0 (Inner Barrel)
- Readout rate: 100 kHz PbPb, 400 kHz pp

Improved low-p_T tracking efficiency (> 90% for p_T> 200 MeV/c)

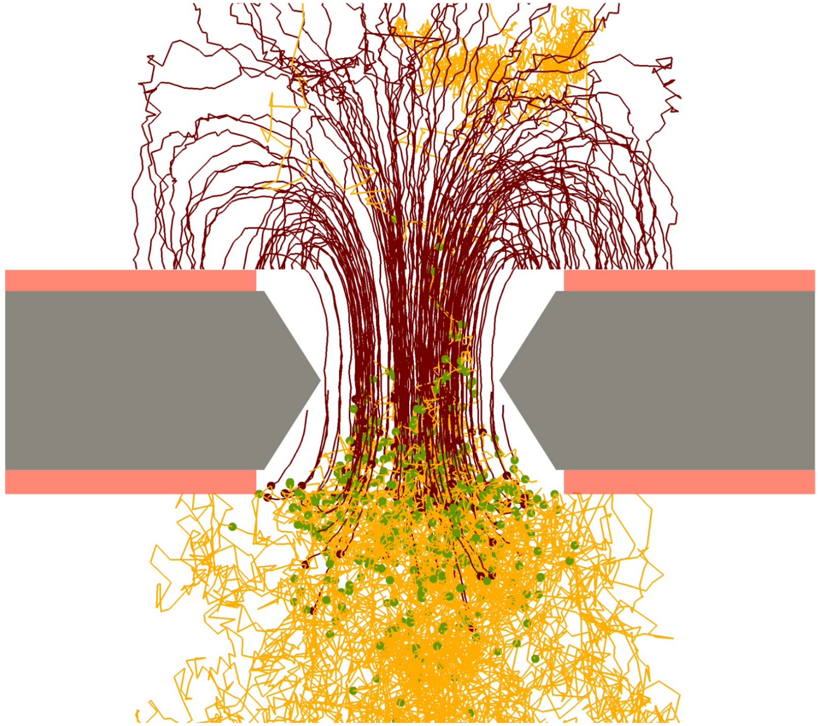
J. Phys. G 41 (2014) 087002



Improved pointing resolution at primary vertex by more than factor 2



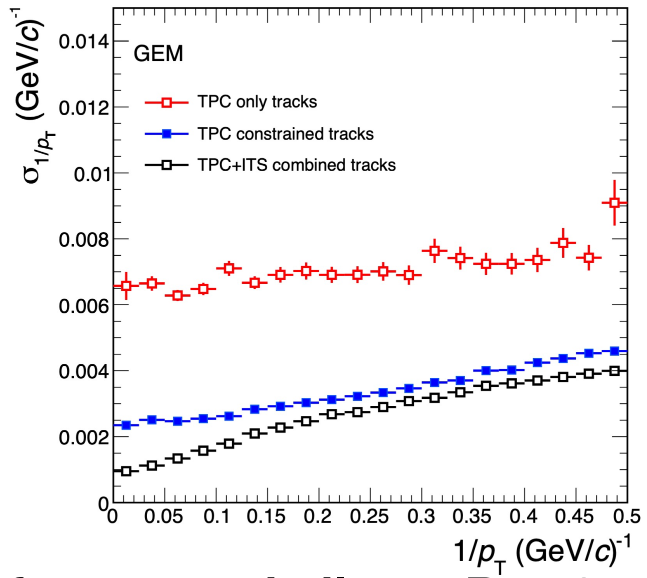
Upgrade of the Time Projection Chamber

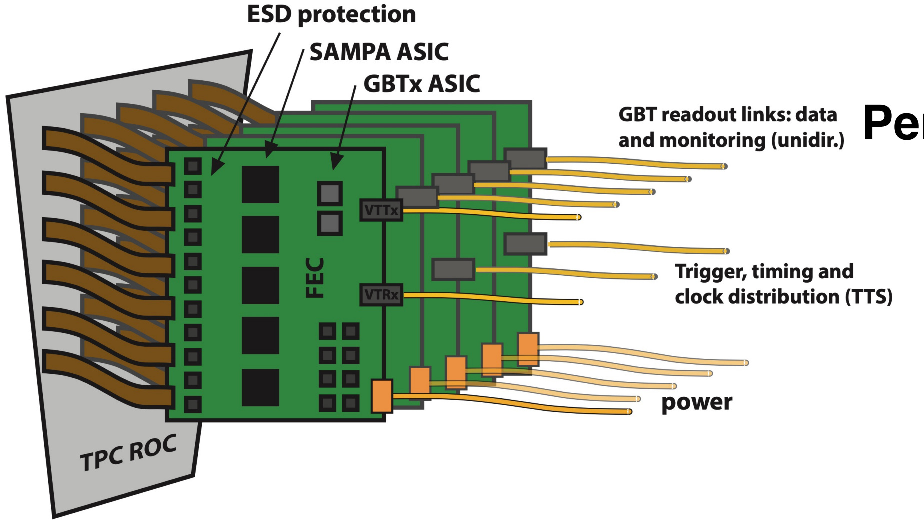


Readout: GEM stacks

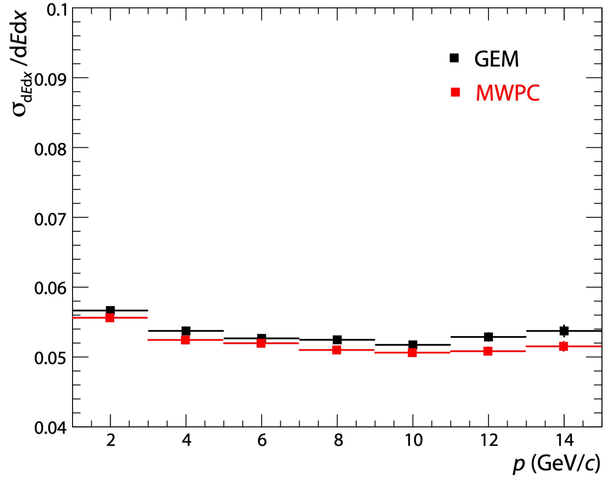
- 4-GEM stack
- Avalanche creation in GEM hole
- Dominant part of ions absorbed on top side of GEM stack
- Ion backflow: < 1%
- No more need for gating grid
- Similar performance (i.e. dE/dx) as for MWPC

CERN-LHCC-2013-020, ALICE-TDR-016





Performance similar to Run 2

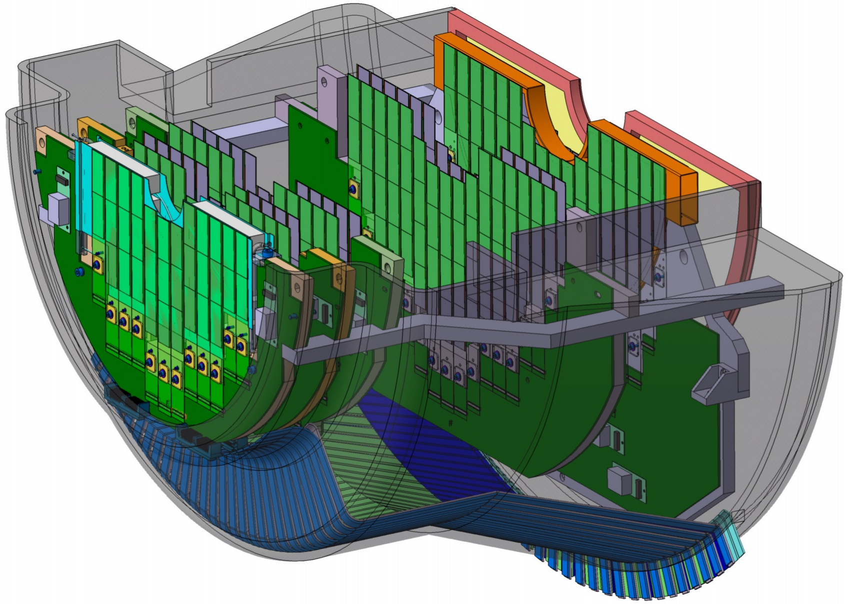


Frontend Electronics: SAMPA

- 130 nm CMOS
- 32 channels / chip
- 10 bit ADC
- Digitization at 5 MHz
- Allows for continuous readout

TPC can be operated at 50 kHz PbPb in continuous mode

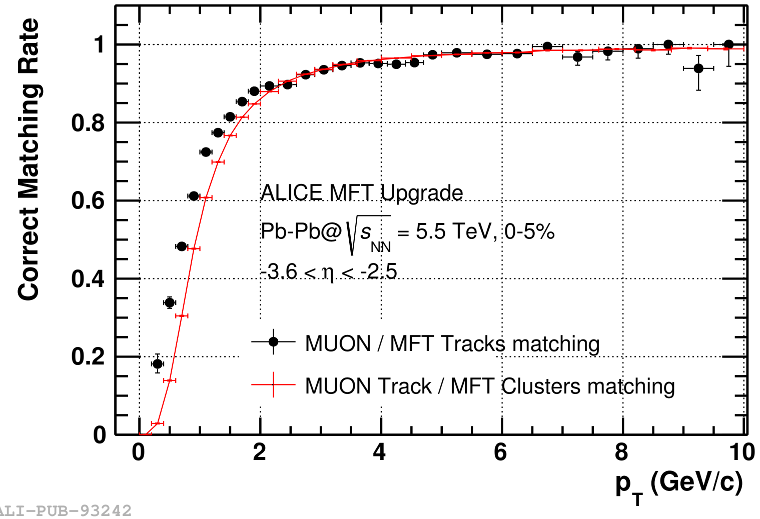
Muon Forward Telescope: Track extrapolation of muon tracks to the collision vertex

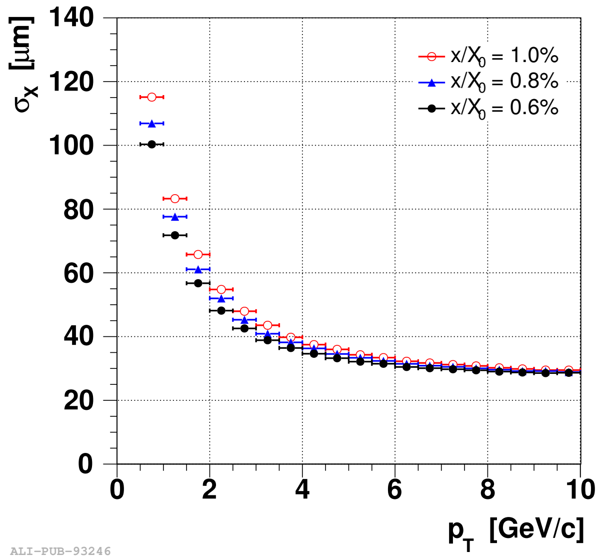


- $-3.6 < \eta < -2.45$
- 5 Layers
- 2 disks / layer
- ALPIDE chips (same as ITS2)
- 920 chips

- Propagation of muons to primary vertex
- Selection of muons from secondary vertices

CERN-LHCC-2015-001. ALICE-TDR-018



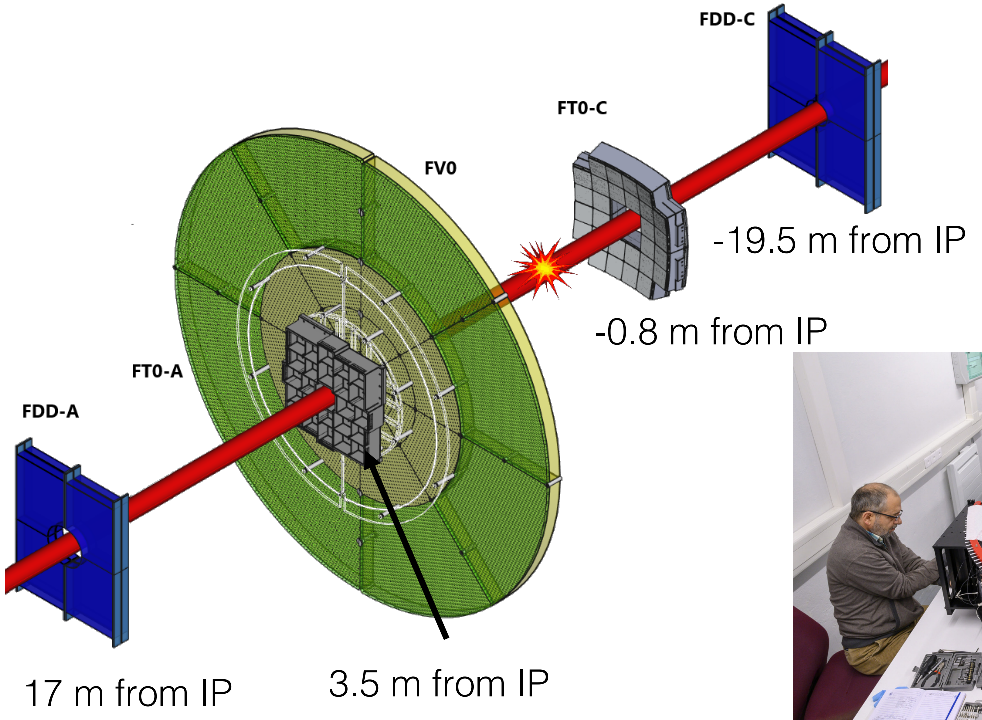


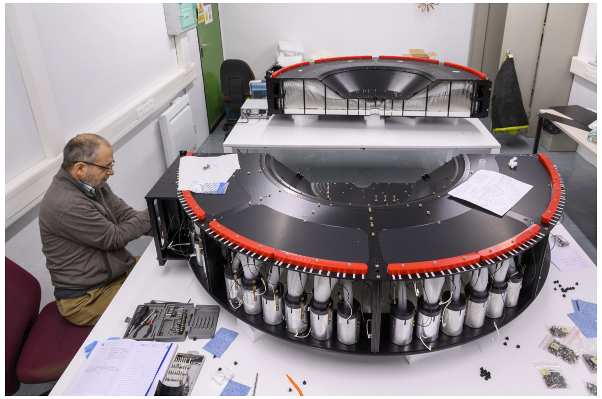
Performance (muon tracks, p_T > 2 GeV)

- 90% matching efficiency to tracks from Muon Spectrometer
- ~30 µm pointing resolution

The Fast Interaction Trigger

CERN-LHCC-2013-019. ALICE-TDR-015

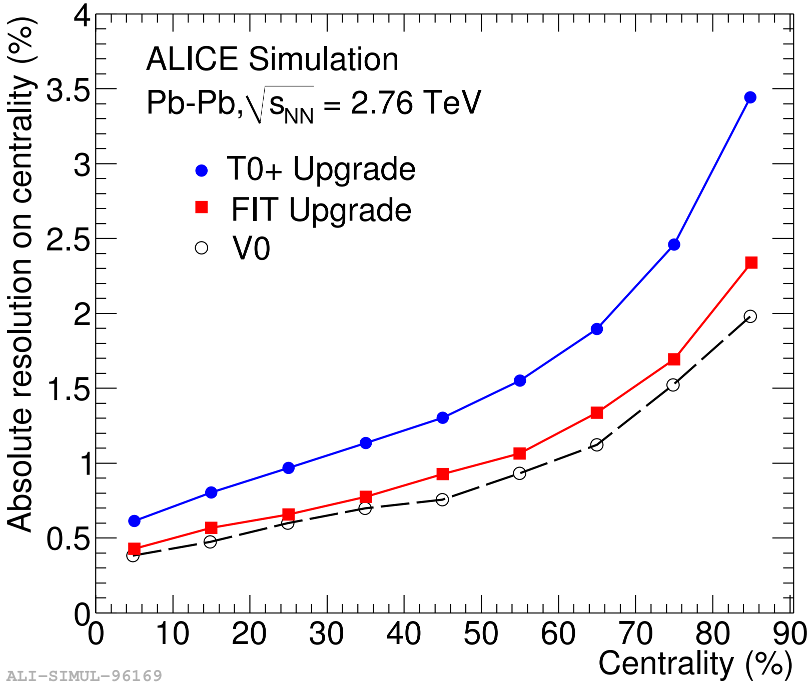




FV0

Detector design similar to Run 2 detectors

- FIT-V0 (FV0): Scintillator
- FIT-T0 (FT0): Cerenkov
- FIT-Diffractive Detector (FDD): Scintillator



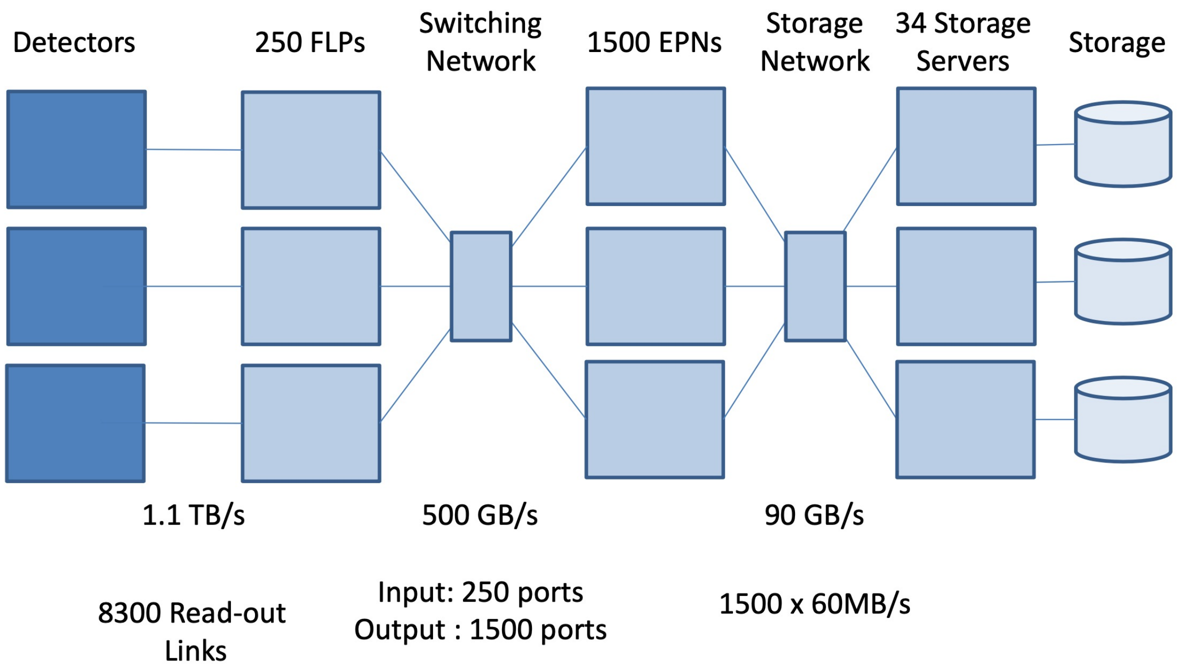
- Fast min. bias collision trigger with latency < 425 ns
- Collision time for TOF with ~ 20 ps time resolution
- Luminosity monitor
- Centrality measurement
- Event plane determination

Online data processing with O^2

CERN-LHCC-2015-006, ALICE-TDR-019

New challenges for data processing in Run 3

- Continuous readout → multiple collisions overlapping in the TPC drift time
- 50 kHz PbPb → Storing all raw data not feasible → significant compression needed



Adaption of workflows to continuous data taking

O^2: The ALICE Online-Offline Computing System

2-level online reconstruction

- First Level Processor (FLP): Receiving and preparing data from the detector
- Event Processing Nodes (EPN): Online reconstruction

EPN: ~2000 GPU & CPU

Compressed raw format to disk

- i.e. only clusters and tracks for the TPC

Online calibration and data quality monitoring

Installation and commissioning

Preparation of the TPC for installation

TPC installation

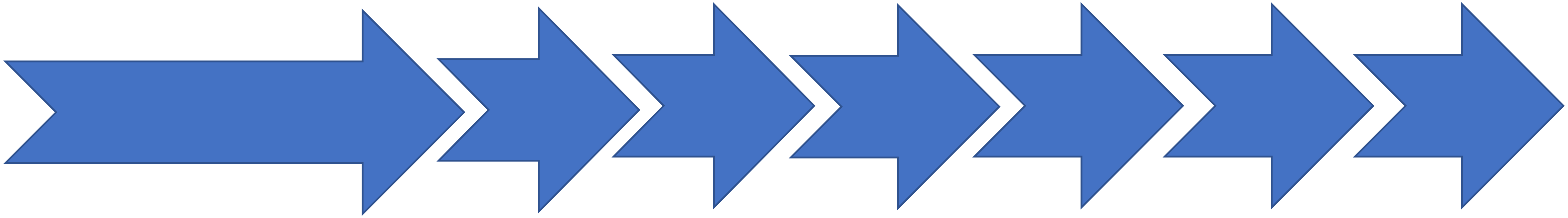
Miniframe installation

MFT, FIT-C installation

ITS installation

First Run 3 collisions at 900 GeV

Global commissioning



R&D, production

Stable beams

Feb. 2020

Aug-Oct. 2020

Nov 2020

Dec 2020

Mar.- Apr 2021

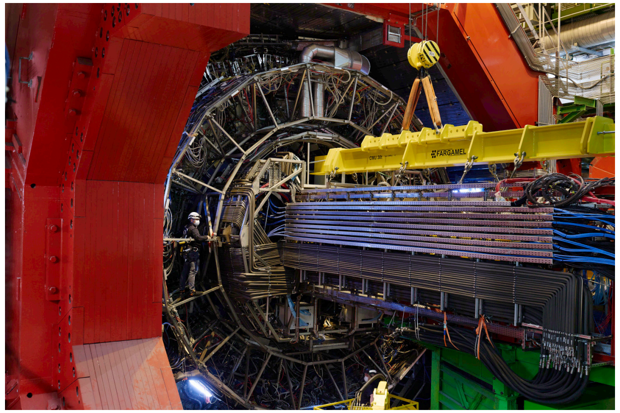
Summer 2021

Feb 2022

O^2 and computing: Will be tested with simulation and analysis challenges starting from Q3 2021

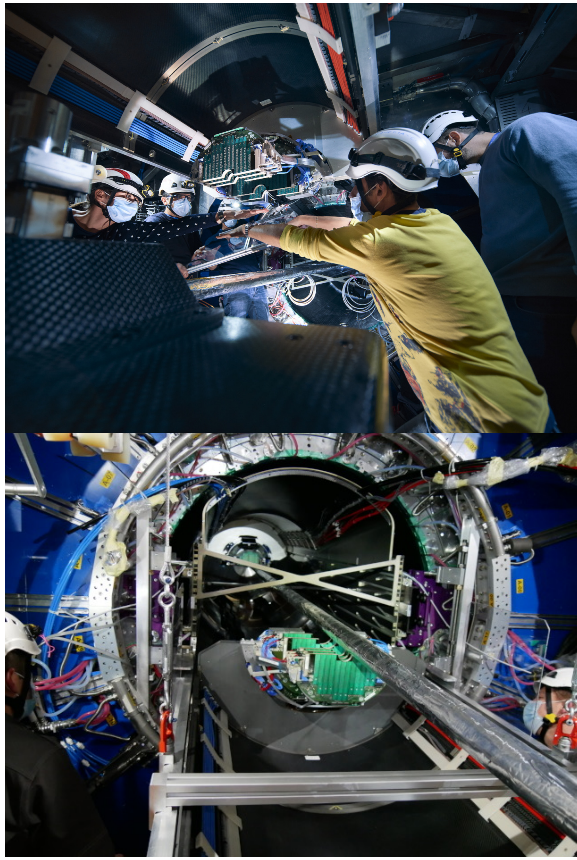
Installation and commissioning

TPC installation (Aug-Oct 2020)



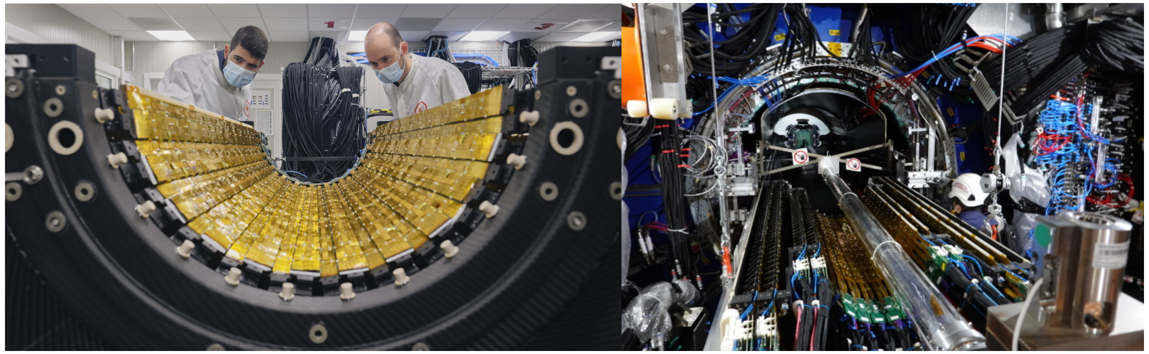
Miniframe installation
(Nov. 2020)

MFT and FIT-C
installation (Dec. 2020)

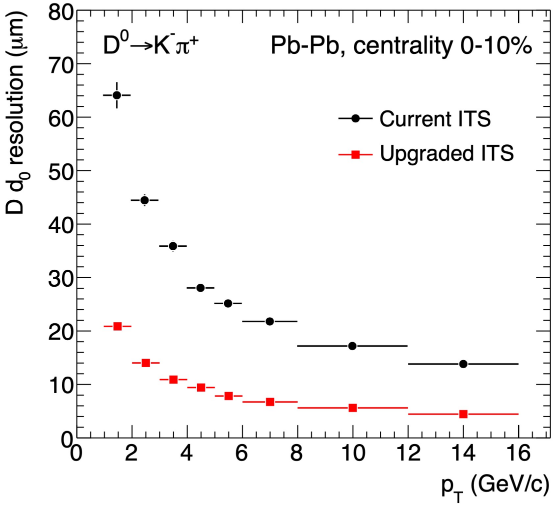


O^2
Commissinoning

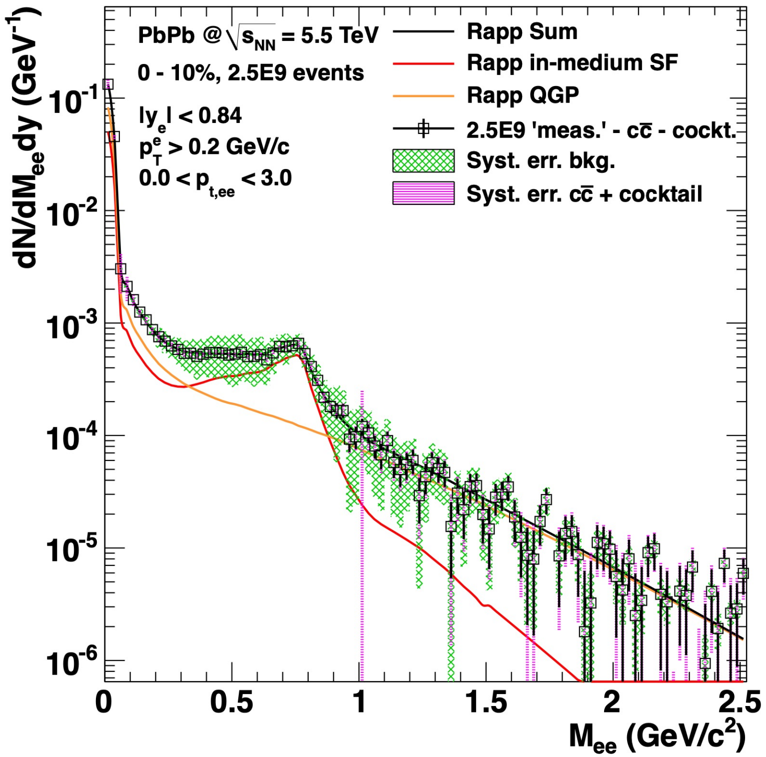
ITS outer barrel installation
March 2021



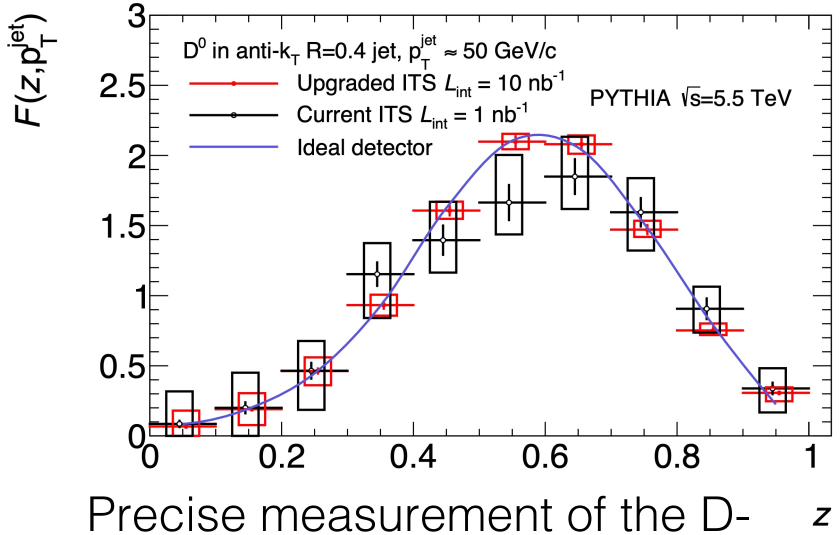
Physics performace with ALICE at Run 3



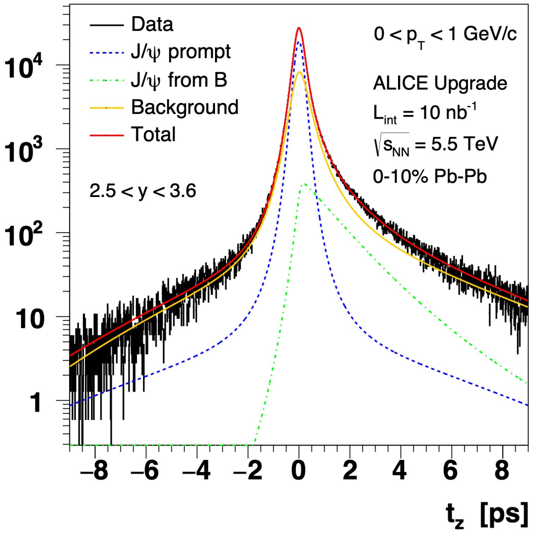
Beauty via non-prompt D-mesons



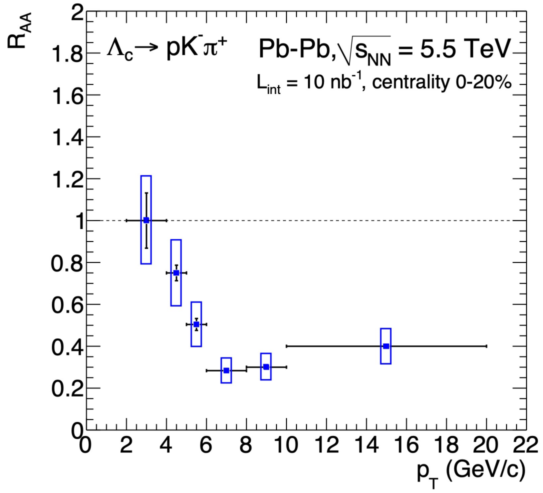
Access to possible ρ-broadening



Precise measurement of the D-meson fragmentation in jets



Beauty via non-prompt J/Ψ in forward direction



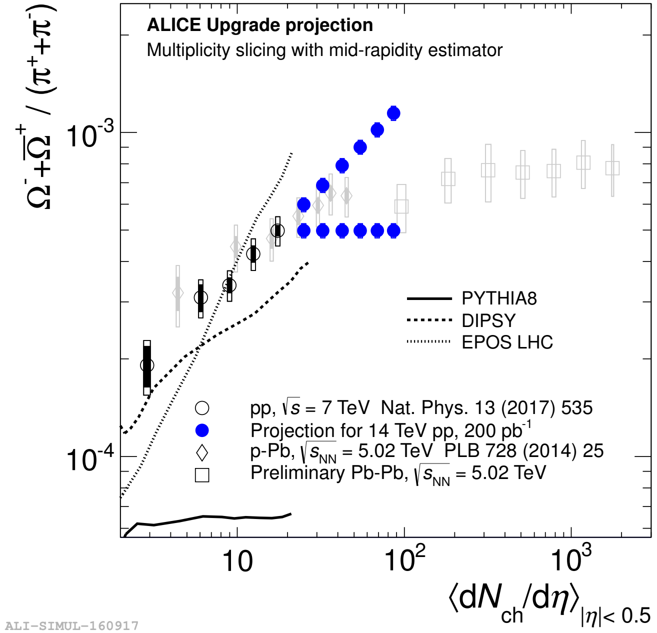
R_{AA} of Λ_c

Physics with ALICE Run 3 in pp collisions at $\sqrt{s}$=14 TeV

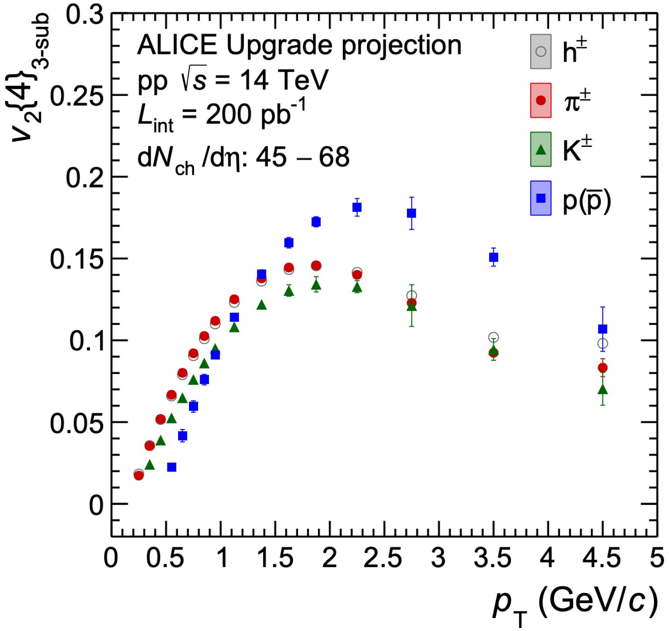
ALICE-PUBLIC-2020-005

Dedicated physics program in pp collisions at $\sqrt{s}$ = 14 TeV in 2022-2024

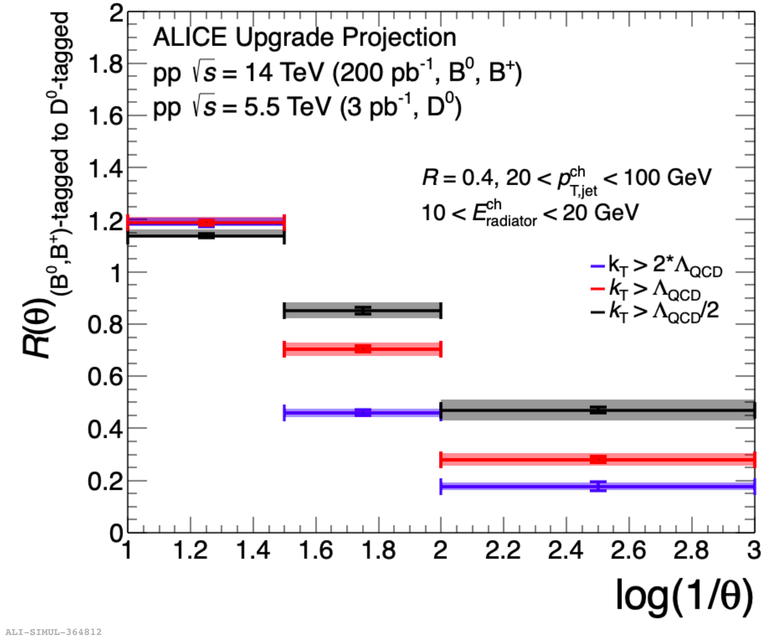
- $\int L dt = 200\ pb^{-1}$
- Interaction rate: 500 kHz
- Selection of interesting events during reconstruction on the EPN



Particle production in high-multiplicity events



Collective effects in small systems at high-multiplicity

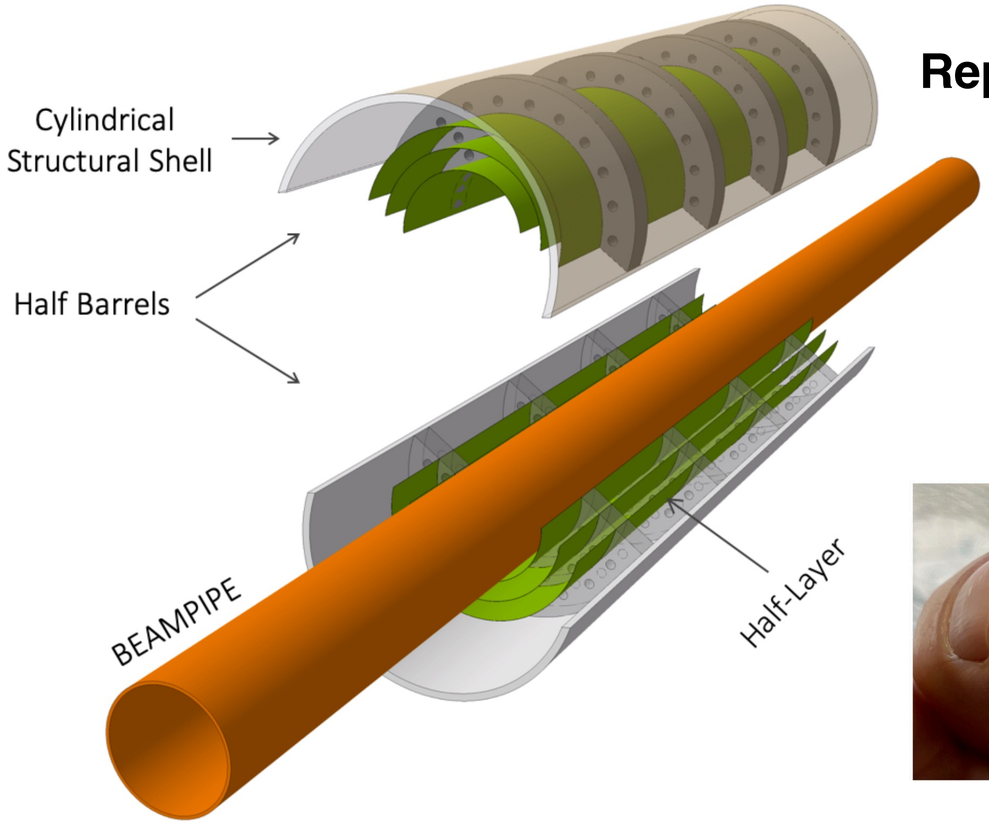


Precision measurement of the dead-cone effect with B-tagged jets

... and more

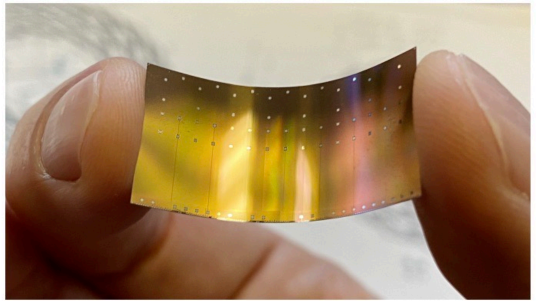
New ITS in Run 4 (ITS3)

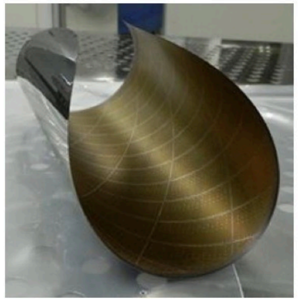
CERN-LHCC-2019-018. LHCC-I-034

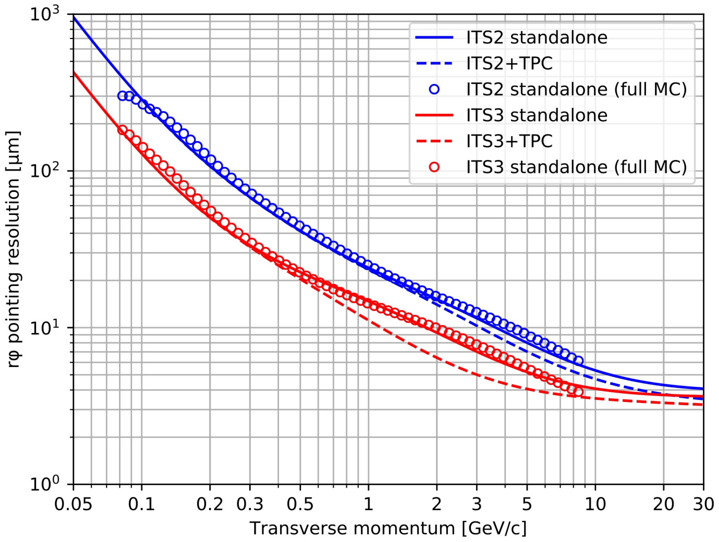


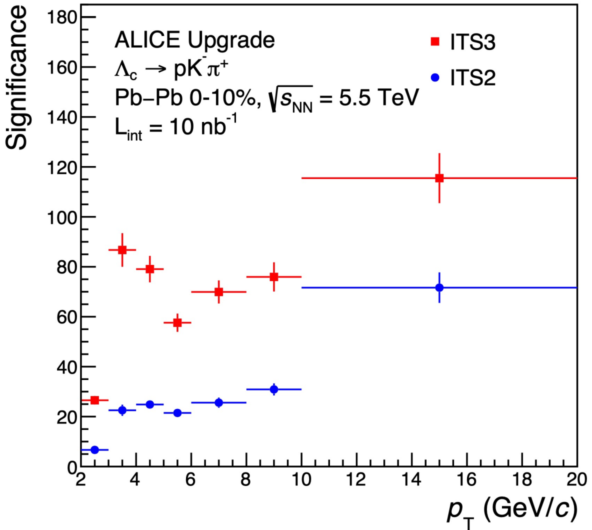
Replacement of 3 Inner Barrel Layers

- Fully cylindrical
- Sensor thickness: 20 – 40 µm
- Material Budget: 0.05% X_0 / layer
- $-2.0 < \eta < 2.0$
- Distance to collision point: 16 mm



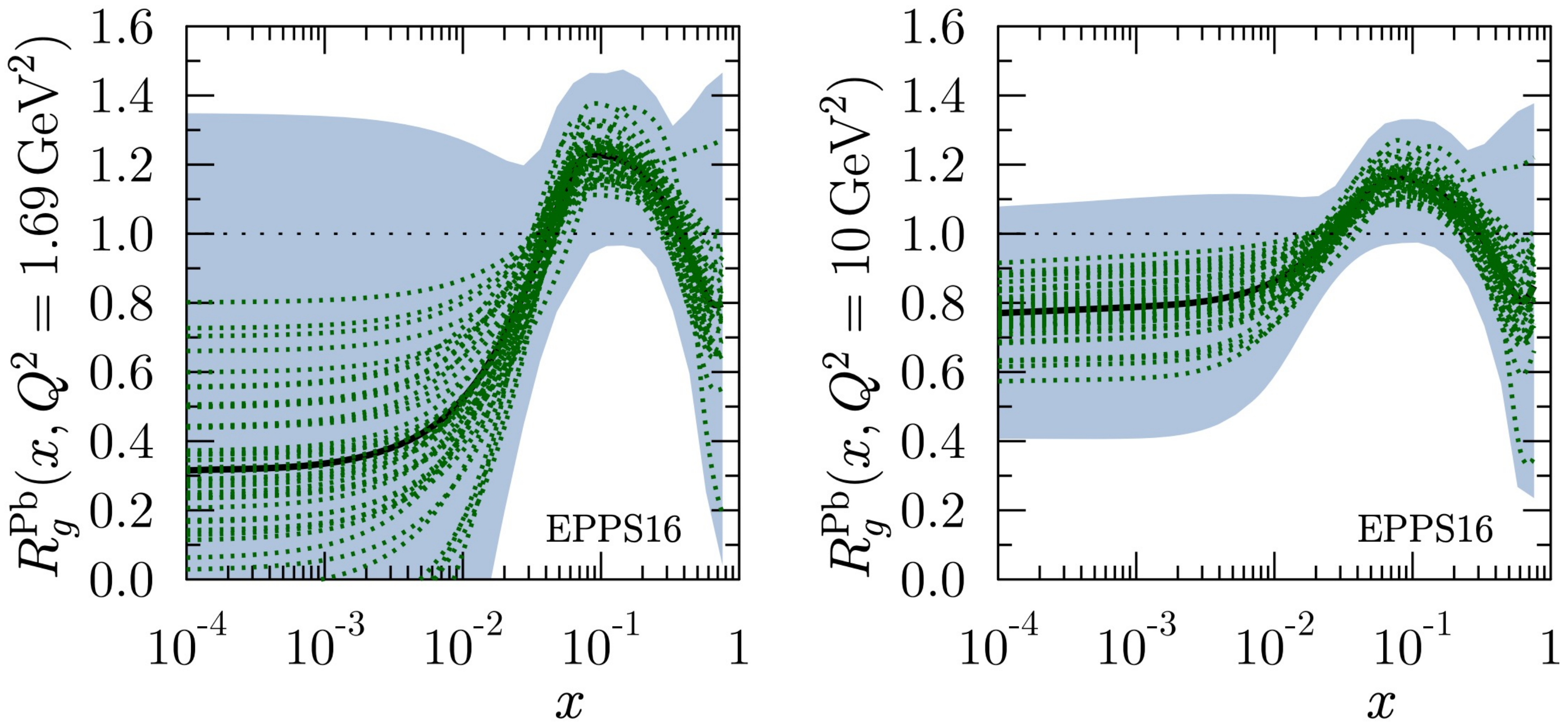






- ~ Factor 2 improvement of the pointing resolution at the primary vertex
- ~ Up to factor 2 inprovement in the tracking efficiency for p_T < 100 MeV/c
- Up to factor 4 increase of the significance of Λ_c in PbPb collisions

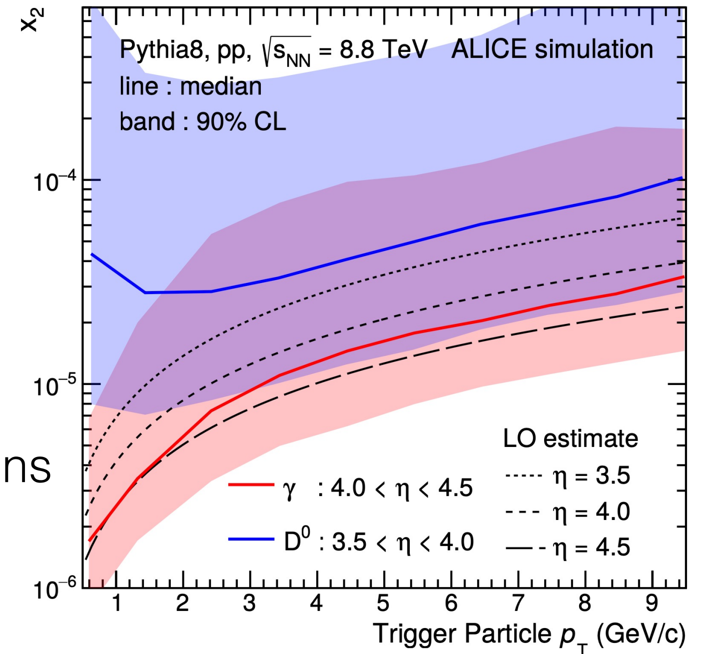
Constraining nuclear PDFs: The FoCal



EPJC 77, 163

Substantial uncertainty on the gluon nuclear PDFs at small-x and low Q^2

$$R_i^{Pb}(x, Q^2) = \frac{f_i^{Pb}(x, Q^2)}{f_i^{p}(x, Q^2)}$$



CERN-LHCC-2020-009, LHCC-I-036

Stronger sensitivity to small-x by direct photons

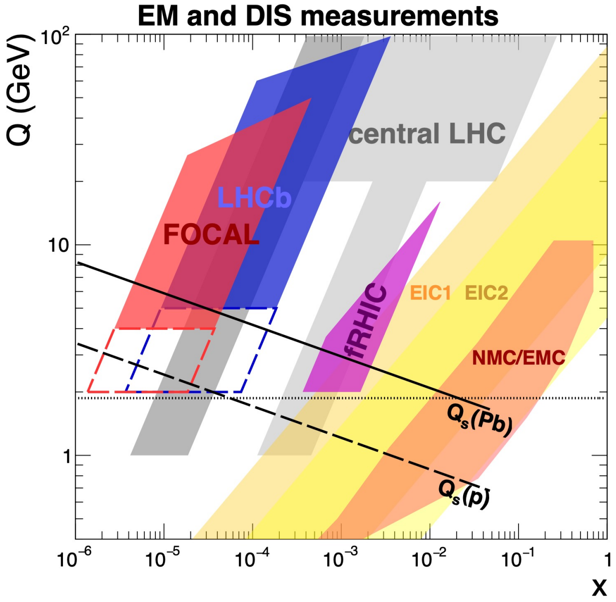
Main observables sensitive to the gluon PDF:

- Direct photons (quark-gluon compton scattering)
- Heavy flavour (gluon fusion)

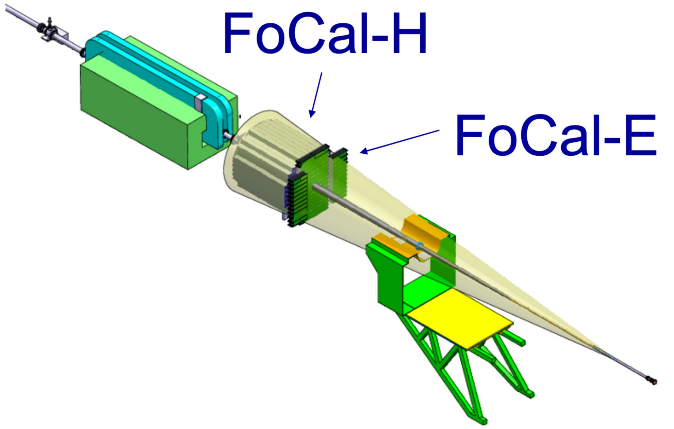
Isolation cut enhancing quark-gluon compton scattering

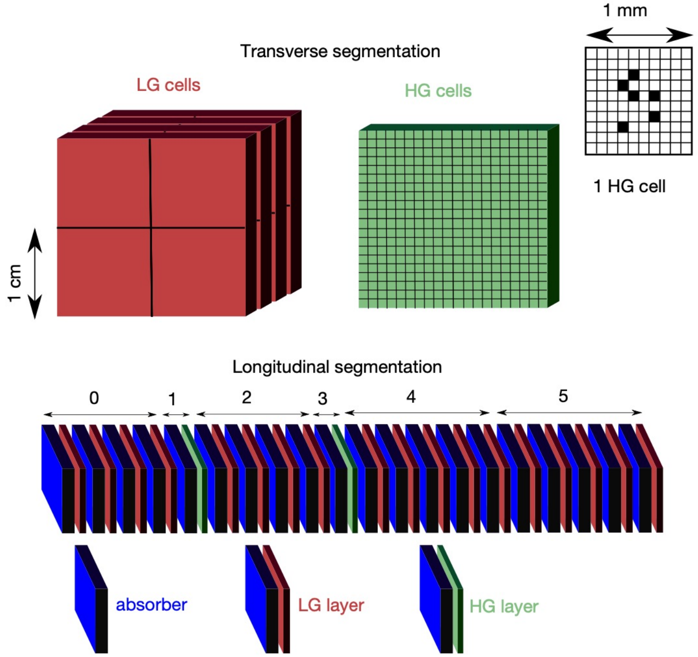
Design of the ALICE FoCal

CERN-LHCC-2020-009, LHCC-I-036



- 3.2 < η < 5.8

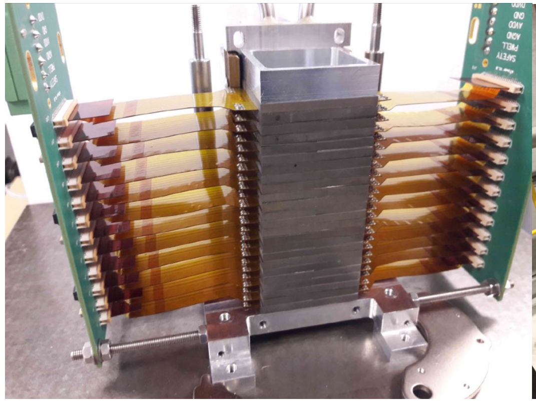




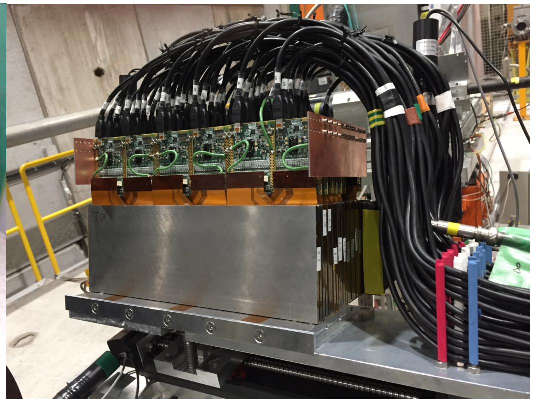
Hadronic and electromagnetic calorimeter
- FoCal-E: Si+W sampling calorimeter
- FoCal-H: conventional sampling hadronic calorimeter

Electromagnetic calorimeter:
- Low Granularity: Si-pad (16 layers)
- High Granularity: MAPS, based on ALPIDE (2 layers)

➡ Shower tracking



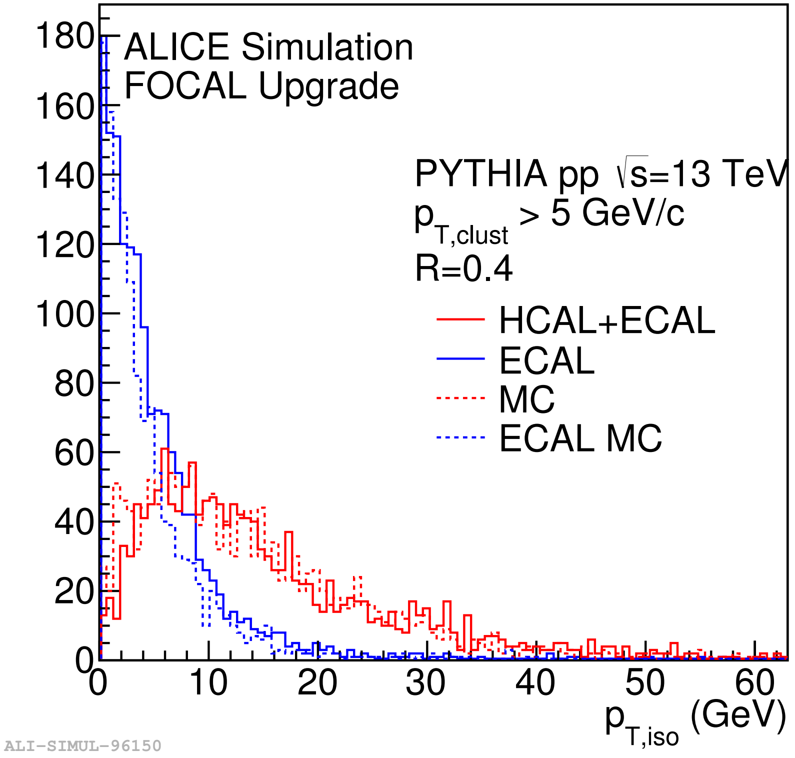
EPICAL (ALPIDE) pixel prototype (proton CT project)

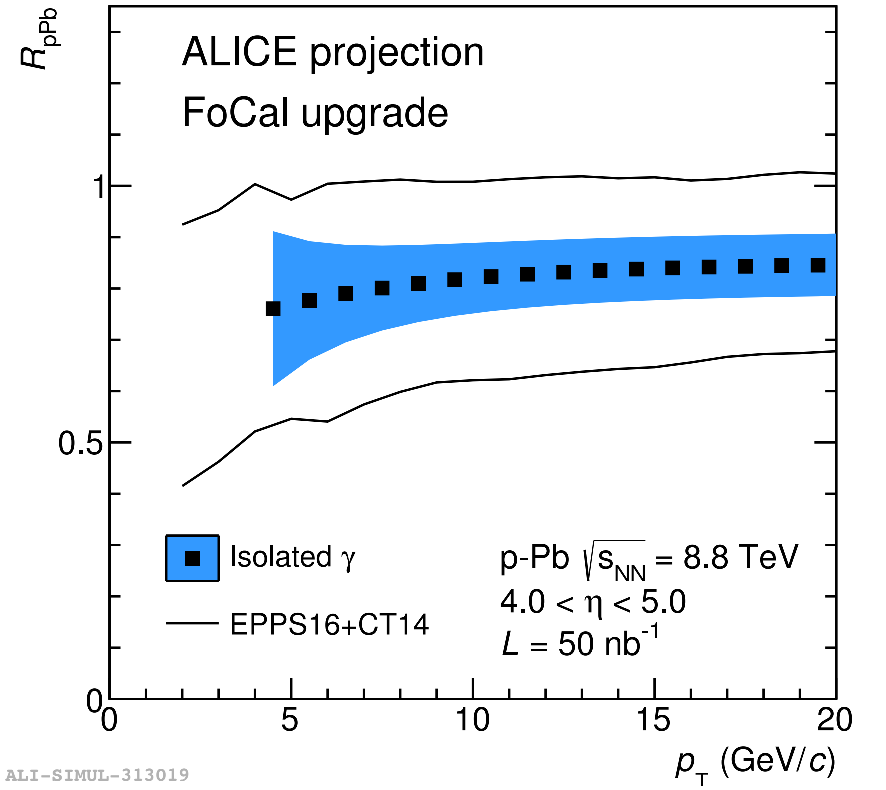


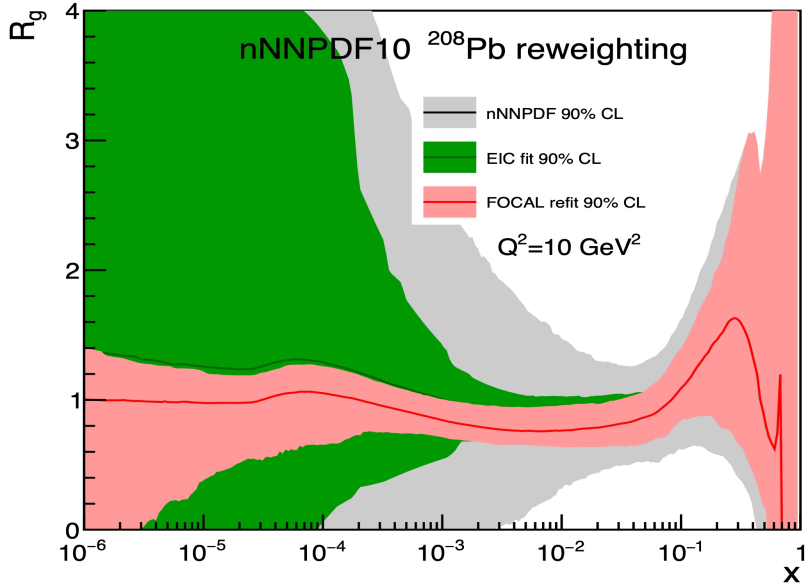
Full (pad-layer only) modules for tests at PS/SPS and in 2018 13 TeV LHC beam

Expected performance of the FoCal

CERN-LHCC-2020-009, LHCC-I-036







Photon isolation: FoCal-E + FoCal-H

Significant constraints on gluon nuclear pdf expected for direct photon measurements with FoCal

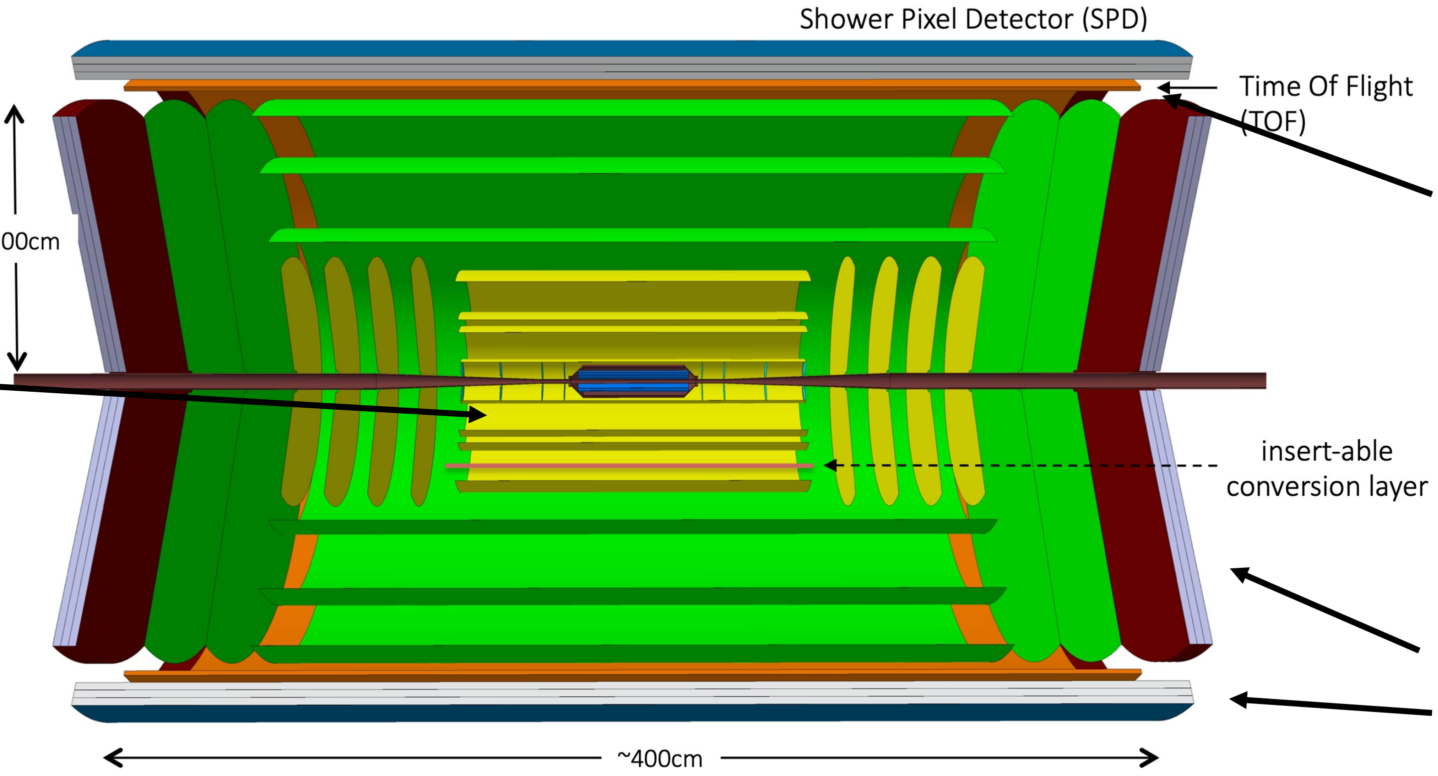
Outlook: New detector beyond Run 4

arXiv:1902.01211

$|\eta| < 4$

Tracking
- CMOS-based silicon pixel
- Barrel and endcaps

B-field: 0.5 T



Particle Identification
- Time-Of-Flight
- Si timing sensors

High-momentum particle identification
- Shower Pixel Detector (SI-based) or RICH
- Barrel and endcaps

- Tracking and particle ID down to ~ tens of MeV
- Excited charmonium states in heavy-ion collisions
- Charmed baryons
- Low-mass dielectron continuum (0 GeV/c^2 < m_{ee} < 6 GeV/c^2)
- And more …

Summary

- Major upgrades for several detectors in Run 3:
  ITS2, TPC, MTF, FIT
- New data processing for the experiment designed to handle increased readout rate and data volume
- Significant improvement in precision, making new probes accessible in heavy-ion collisions in Run 3
- New detectors for Run 4
  - ITS3: Improved precision, for heavy-flavour and dielectron measurements
  - FoCal: Constrain nuclear PDFs at small-x
- New experiment, designed for multi-charm baryons, di-leptons and very low-p_T, for Run 5+