Perspectives *

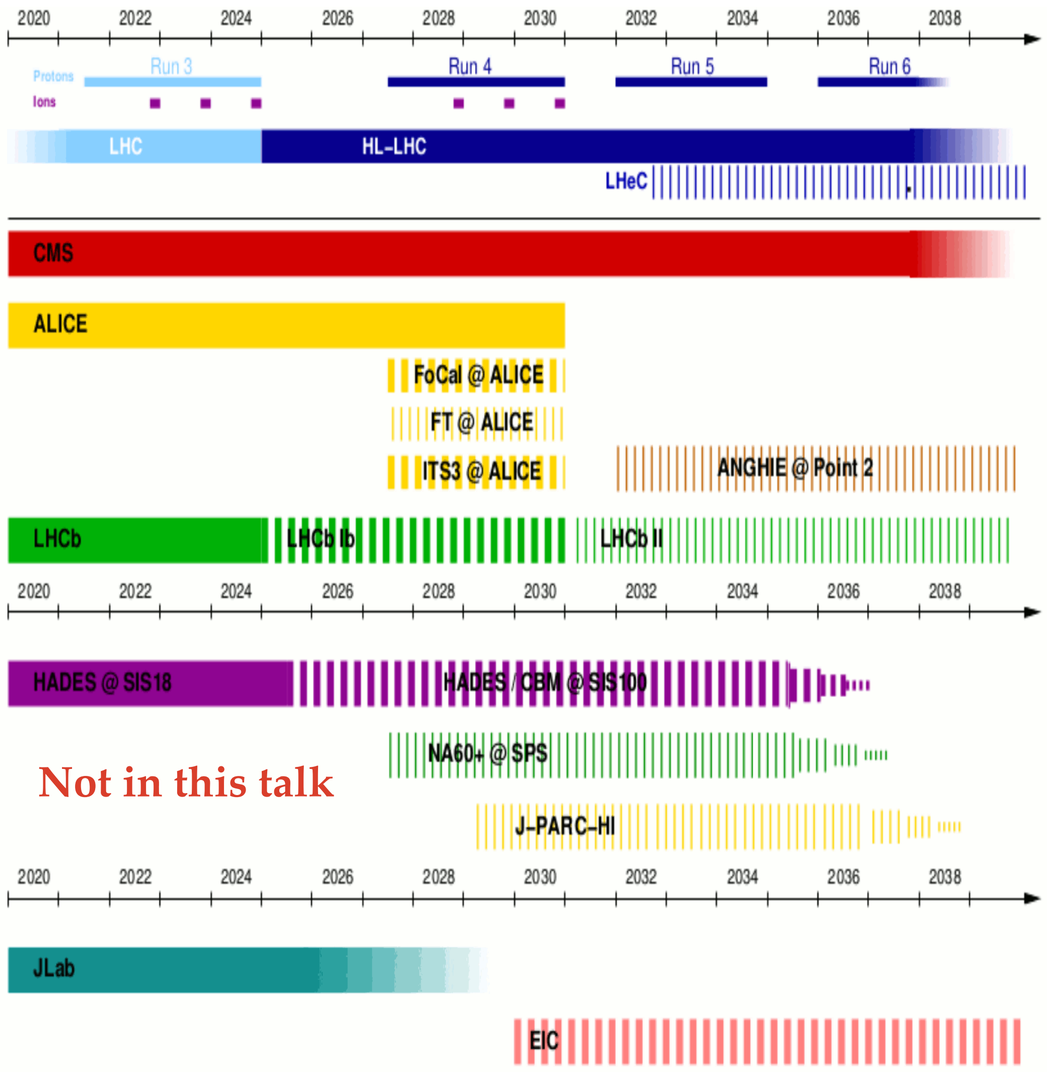
Benjamin Audurier - HF workshop 2022 - 21/10/2022

* from an experimental(ist**) point-of-view

** doing heavy-ion in LHCb…

benjamin.audurier@cern.ch

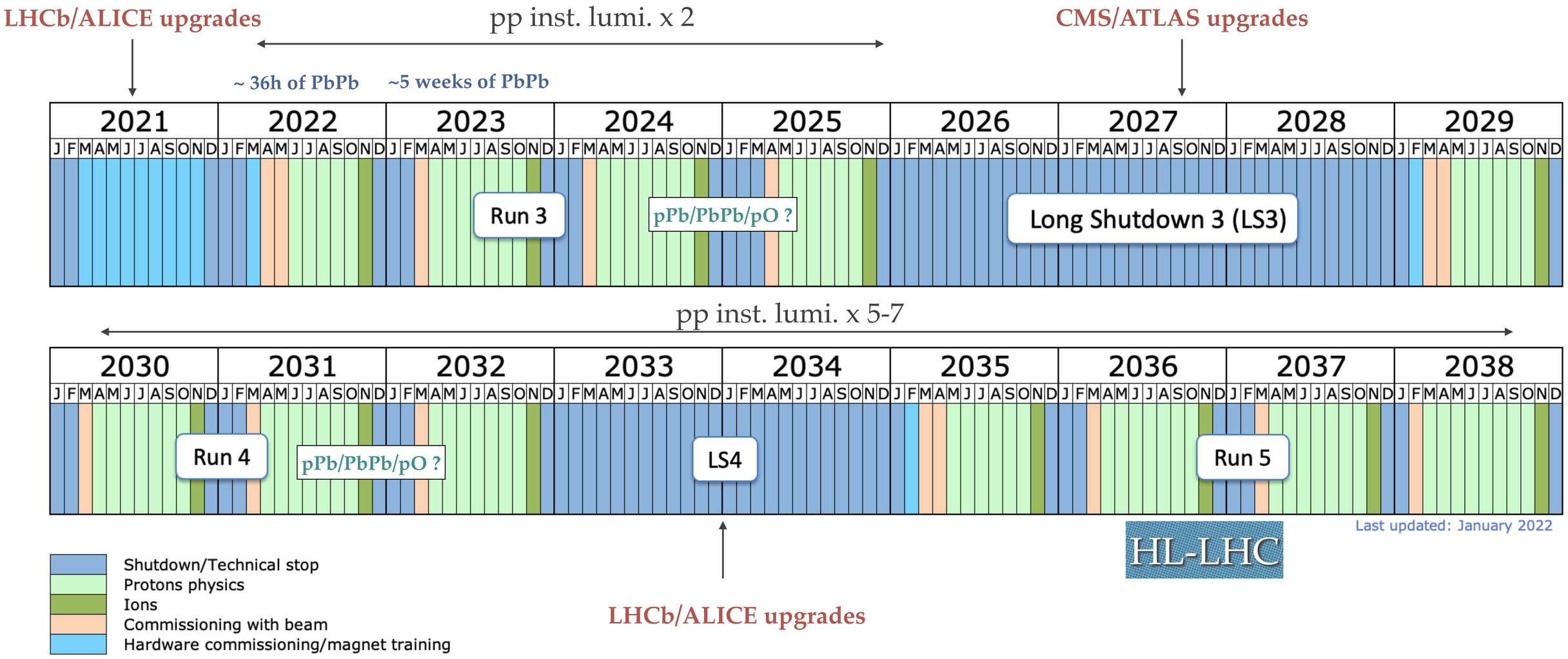
Experiments overview



- Numerous projects for the future.
  - Cannot talk about everything in 20 minutes, and some detectors are probably missing…
  - Mostly focus on LHC.
- Near future:
  - LHC Run 3-Run 4 upgrades.
- Far future:
  - LHC Run 5.
  - EIC

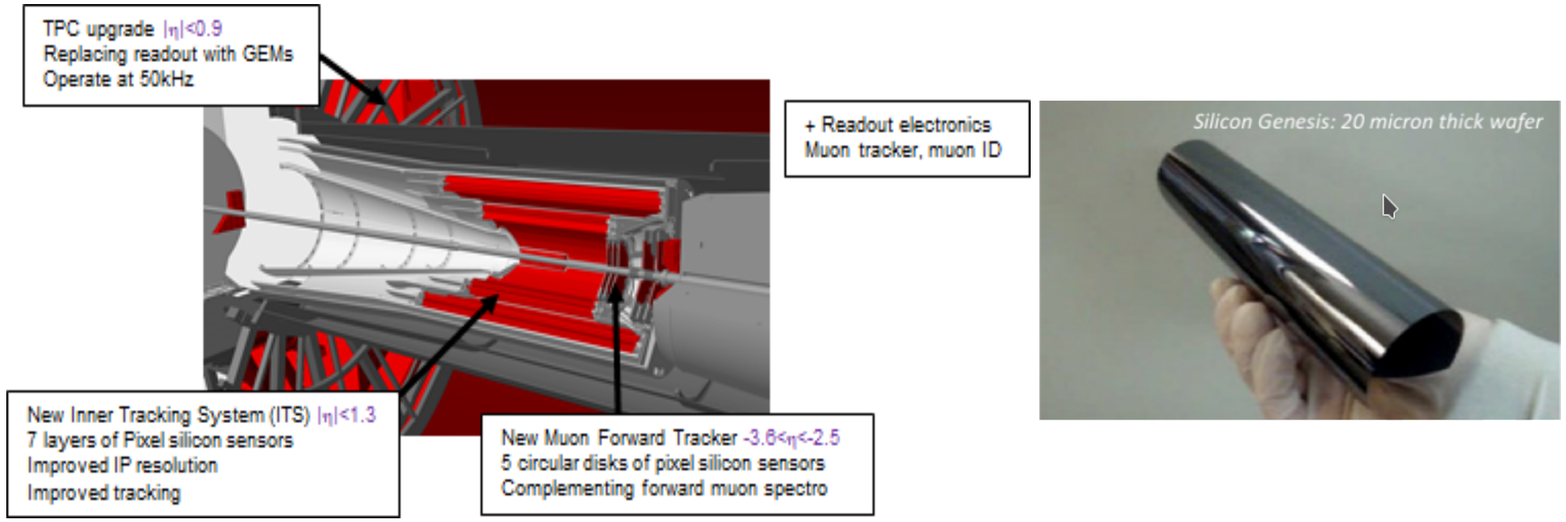
Perspectives at the LHC

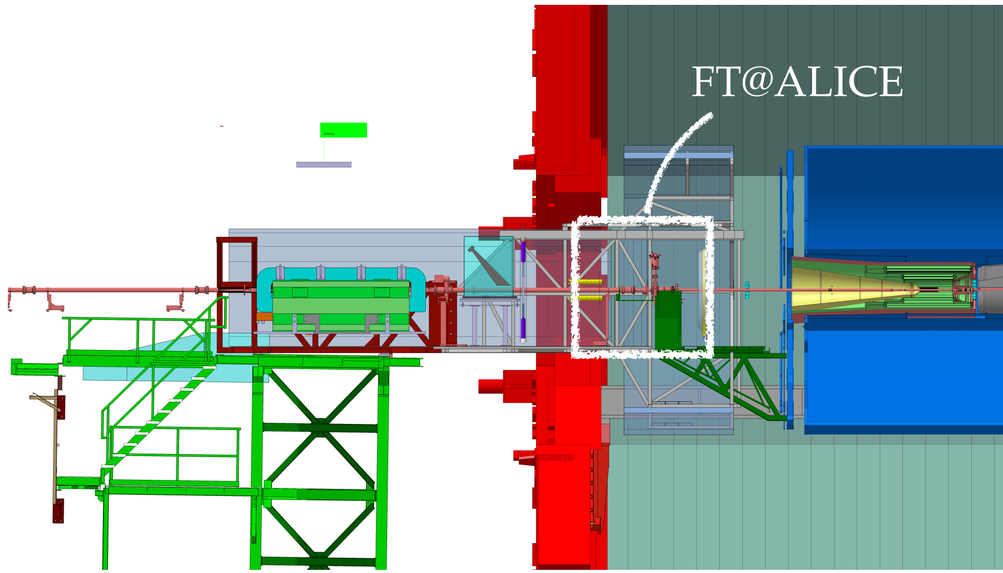
The schedule



ALICE upgrades

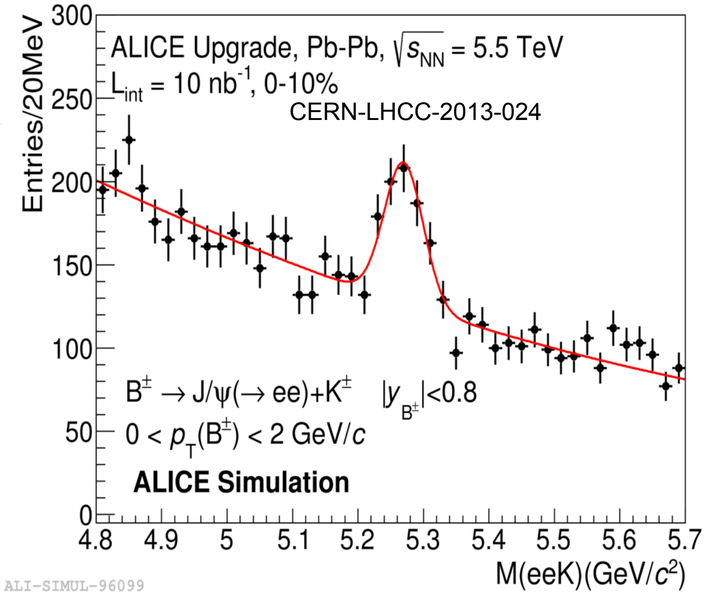
- Upgrades for Run 3:
  - Central region: **ITS2, TPC-GEM**
    - Low material budget, PID, improved tracking,
    - Lumi x 100
  - Forward region: **Muon Tracking+ID, MFT**
    - Capability to separate **promt/non-prompt muons**
- Upgrades for Run 4:
  - Central region: **ITS3** (LoI:CERN-LHCC-2019-018)
    - Replace ITS2 first 3 layers with ultra-thin Si CMOS, closer to the beam
    - **Tracking** of short-lived particles. Better precision and efficiency at low p_T
  - Forward region: **FoCal** $3.2<\eta<5.8$ (LoI:CERN-LHCC-2020-009)
    - **FOCal-E**: fine grain Si-W sampling calorimeter for **3D photon shower reconstruction**
    - Gluon saturation, correlations forward/central rapidities
  - Fixed-target program with bent-crystal and internal solid target under investigation

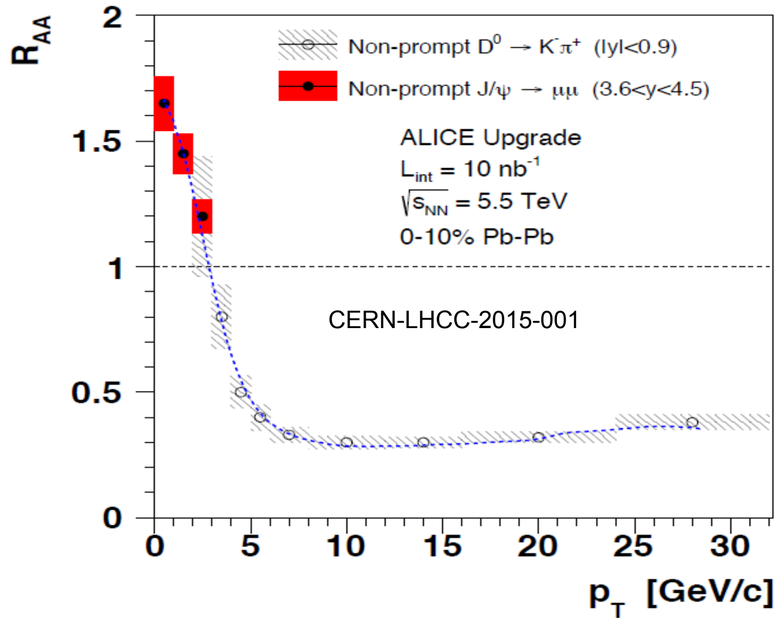




ALICE upgrades

- **Physics program for Run 3 - Run 4:**
  - **Open heavy flavour**
    - charm/beauty meson and baryon production at mid-rapidity.
  - **Quarkonia**
    - J/Ψ and Ψ‘ production at mid and forward rapidity.
    - prompt/non-prompt J/Ψ separation down to lowest p_T.
  - **Low-mass and low-p_T di-leptons**
    - Vector mesons and thermal photons.
  - **Jet quenching and fragmentation**
    - PID of jet particle content.
    - Heavy flavour tagging.

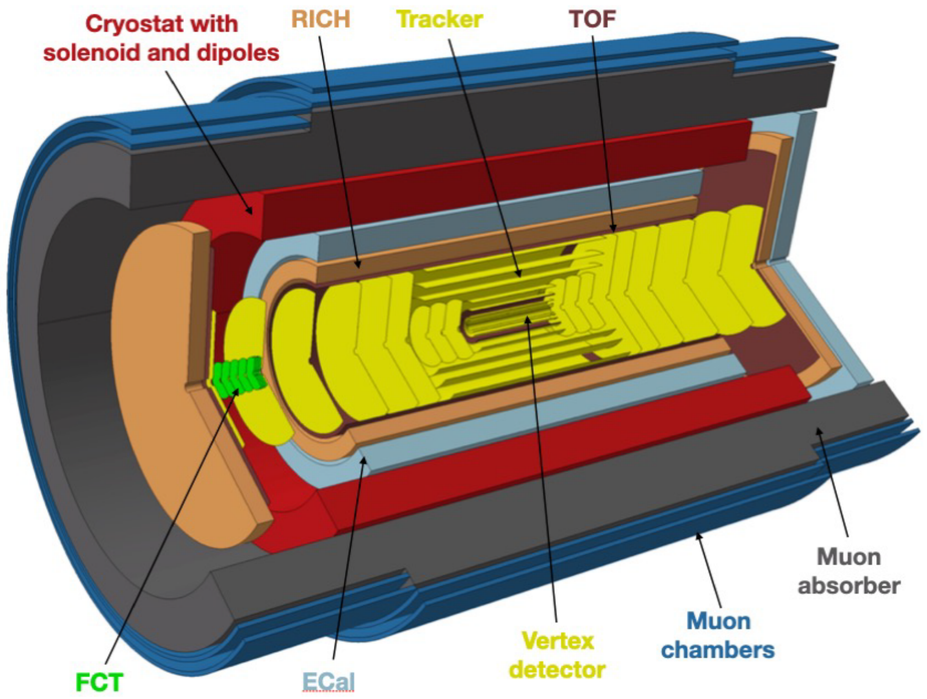




ALICE upgrades

- **Upgrade for Run 5: ALICE 3**
- **Physics goal: Enlarge phase-space exploration towards exhaustive description/understanding of the medium**
  - Excellent tracking and vertex resolution down to low p_T
    - excellent HF resolution
  - Low material budget
    - low background for EM probes
  - Large η acceptance
    - correlations, flow and density dependence
- **LoI submitted to LHCC**

Main characteristics wrt Run 4:
- **more hermetic** ($y \in [-4;+4]$ + $p_T \in [0.05 ; O(10)]$ GeV/c)
- **extended PID** (innerTOF, outerTOF, endcapTOF, RICH, …)
- **faster** (1 MHz continuous readout)

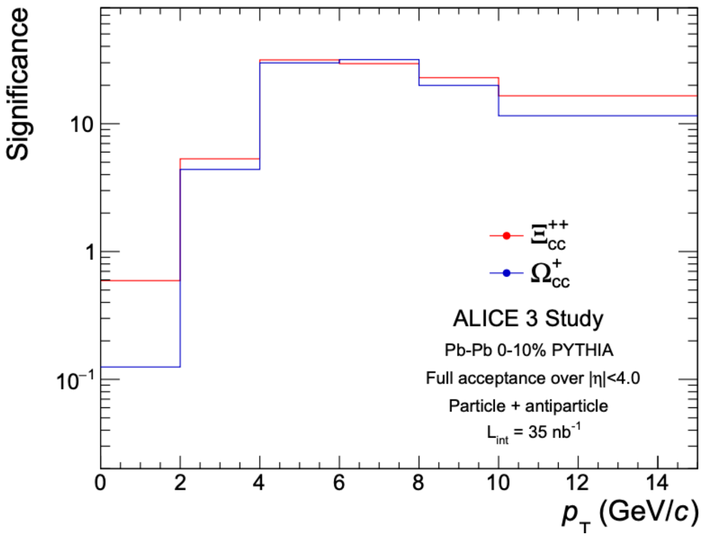


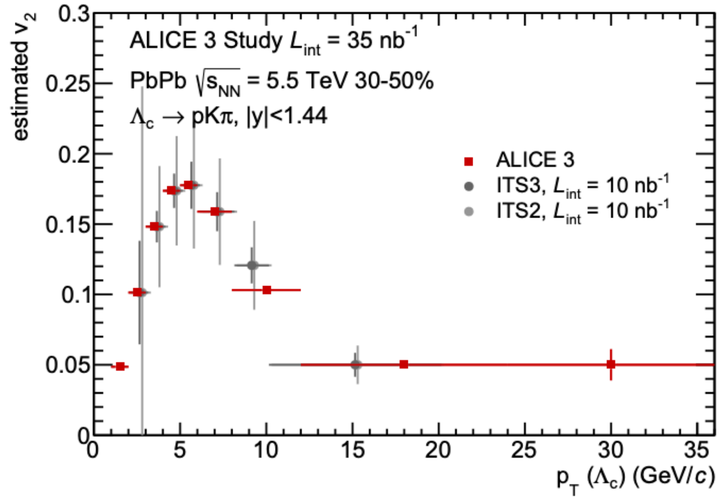
147th LHCC Meeting – open session – sep. 2021
(ALICE status Report)

ALICE upgrades

- **Upgrade for Run 5: ALICE 3**
- **Physics goal: Enlarge phase-space exploration towards exhaustive description/understanding of the medium**
  - Excellent tracking and vertex resolution down to low p_T
    - excellent HF resolution
  - Low material budget
    - low background for EM probes
  - Large η acceptance
    - correlations, flow and density dependence
- **LoI submitted to LHCC**

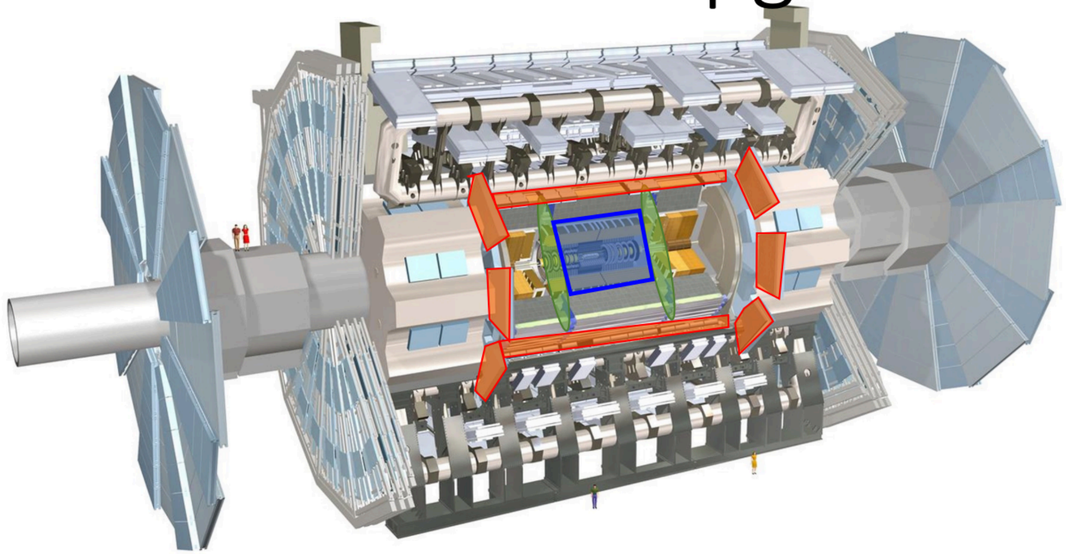
CERN-LHCC-2022-009





ATLAS upgrades

ATLAS HL-LHC Upgrades



Upgraded Trigger and Data Acquisition System

- Single Level Trigger with 1 MHz output
- Improved 10 kHZ Event Farm

Electronics Upgrades

- On-detector/off-detector electronics upgrades of LAr Calorimeter, Tile Calorimeter & Muon Detectors
- 40 MHz continuous readout with finer segmentation to trigger

High Granularity Timing Detector (HGTD)

- Precision time recon. (30 ps) with Low-Gain Avalanche Detectors (LGAD)
- Improved pile-up separation and bunch-by-bunch luminosity

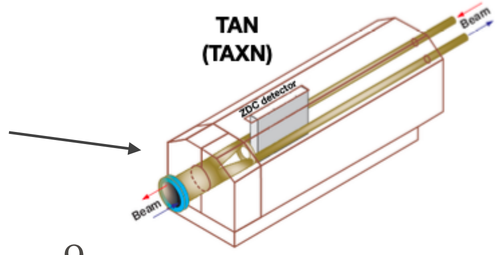
New Muon Chambers

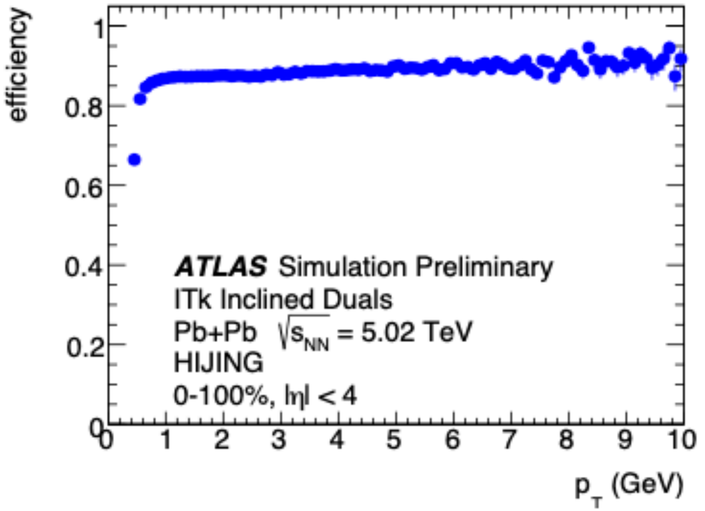
- Inner barrel region with new RPCs, sMDTs, and TGCs
- Improved trigger efficiency/momentum resolution, reduced fake rate

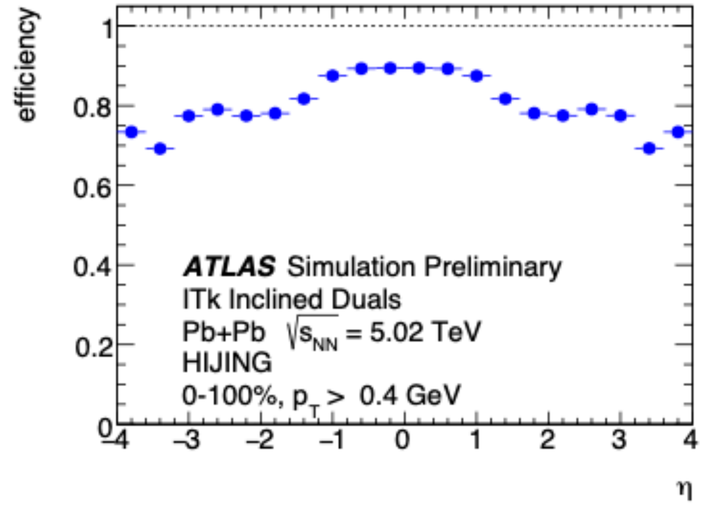
New Inner Tracking Detector (ITk)

- All silicon with at least 9 layers up to $|\eta| = 4$
- Less material, finer segmentation

+ ZDC at very forward rapidity

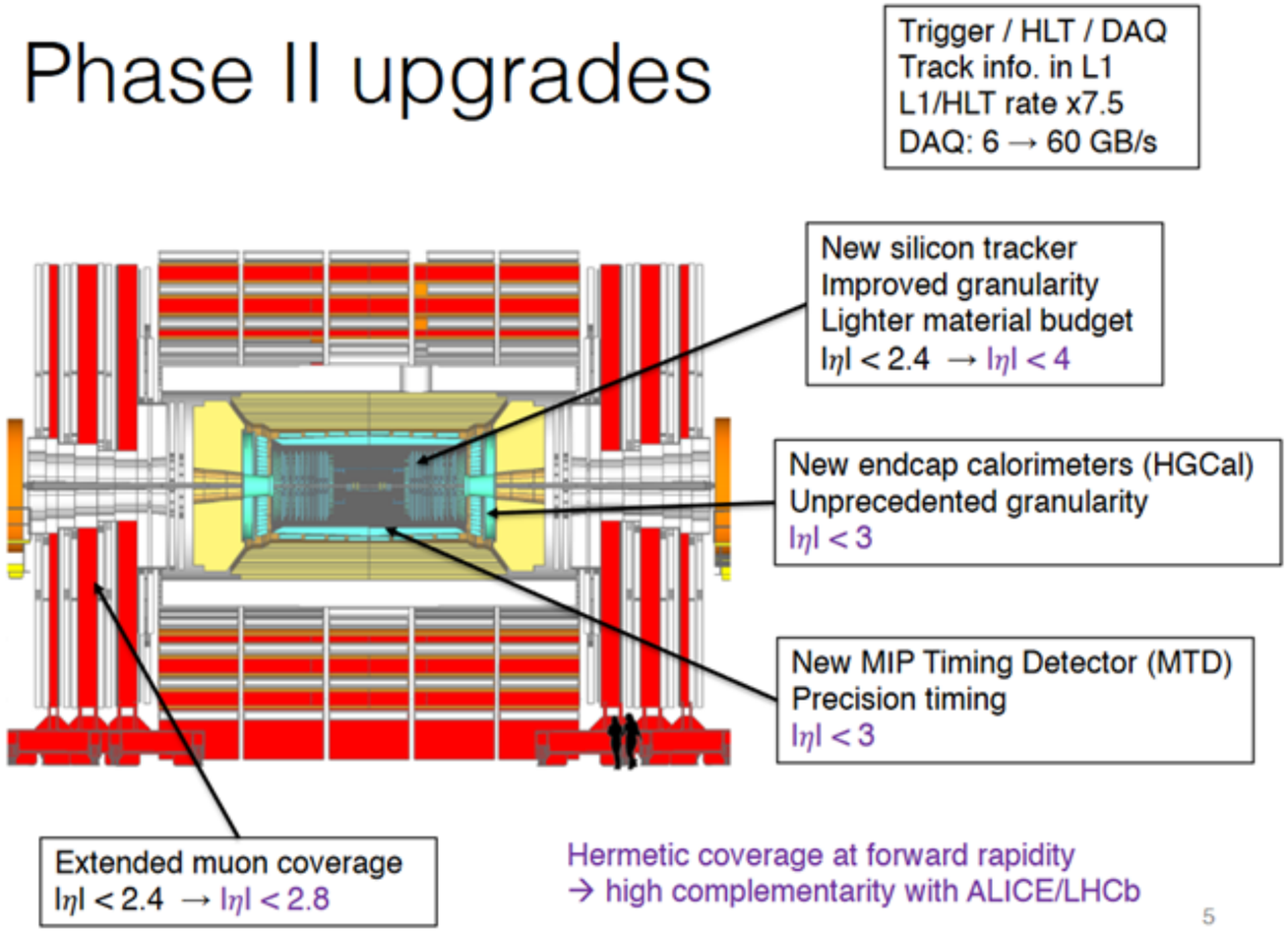






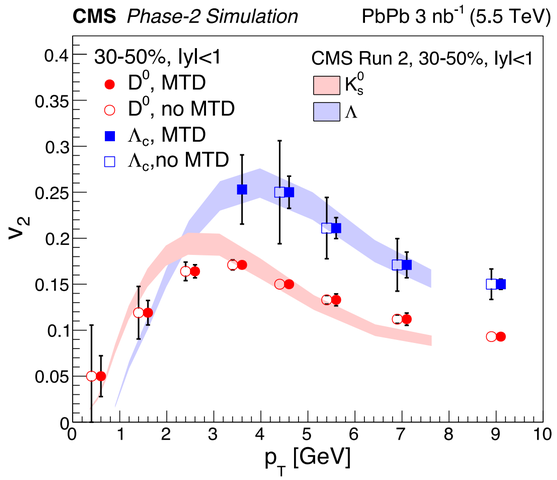
CMS upgrades

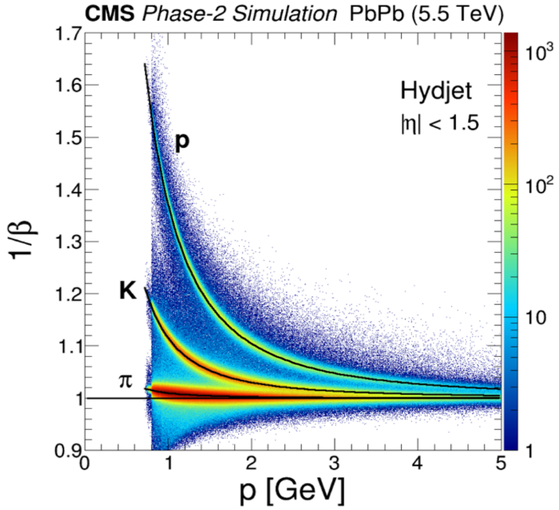
- **Major CMS upgrade for Run 4** (2026+)
  - Objective: maintain current performance in pp for an average pileup of ~200 (curr. ~50)
- The phase II upgrades **enhance the physics potential for heavy ions**
  - **Large acceptance**, full particle flow to |η|~3
    - Lighter, more granular tracker
    - Super-granular endcap calorimeter
    - Extended muon coverage
  - **New PID capabilities** with MTD

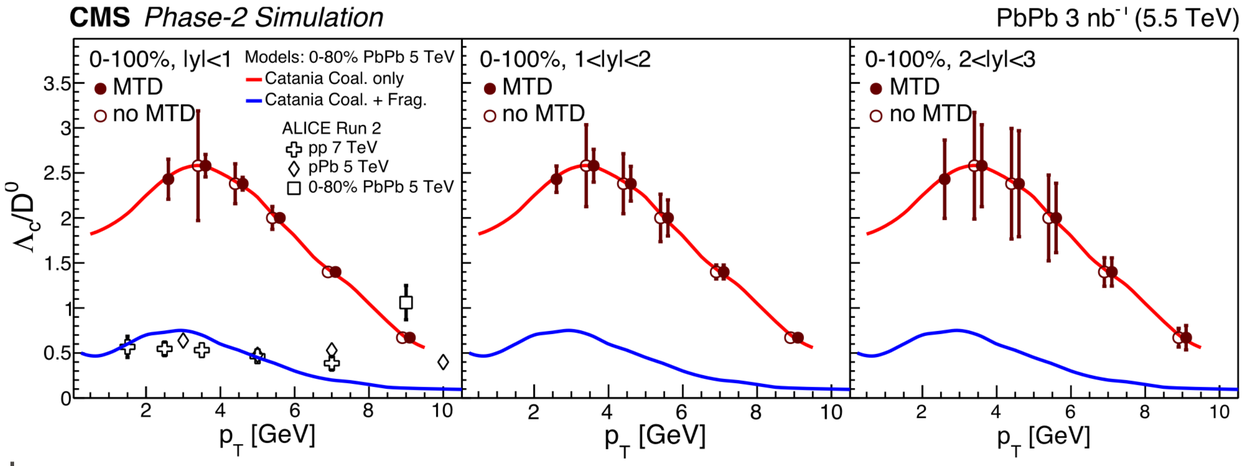


CMS upgrades

- **Precision measurement of jet quenching**
  - High statistics boson (Z/γ) + Jet measurements
  - capture full energy of recoiling jets (thanks to large acceptance calorimeters)
- **Bulk particle production**
  - Long-range correlations (ridge) over 8 units of eta
  - Hadrochemistry (π, K, *p* separation capability thanks to MTD)
- **Heavy Flavour open mesons/baryons at lot p_T**
  - Down to p_T~0 GeV/c for D^0, p_T~2 GeV/c for Λ_c)
- **Quarkonium states**
  - Precisely measure upsilon family (including (3S))

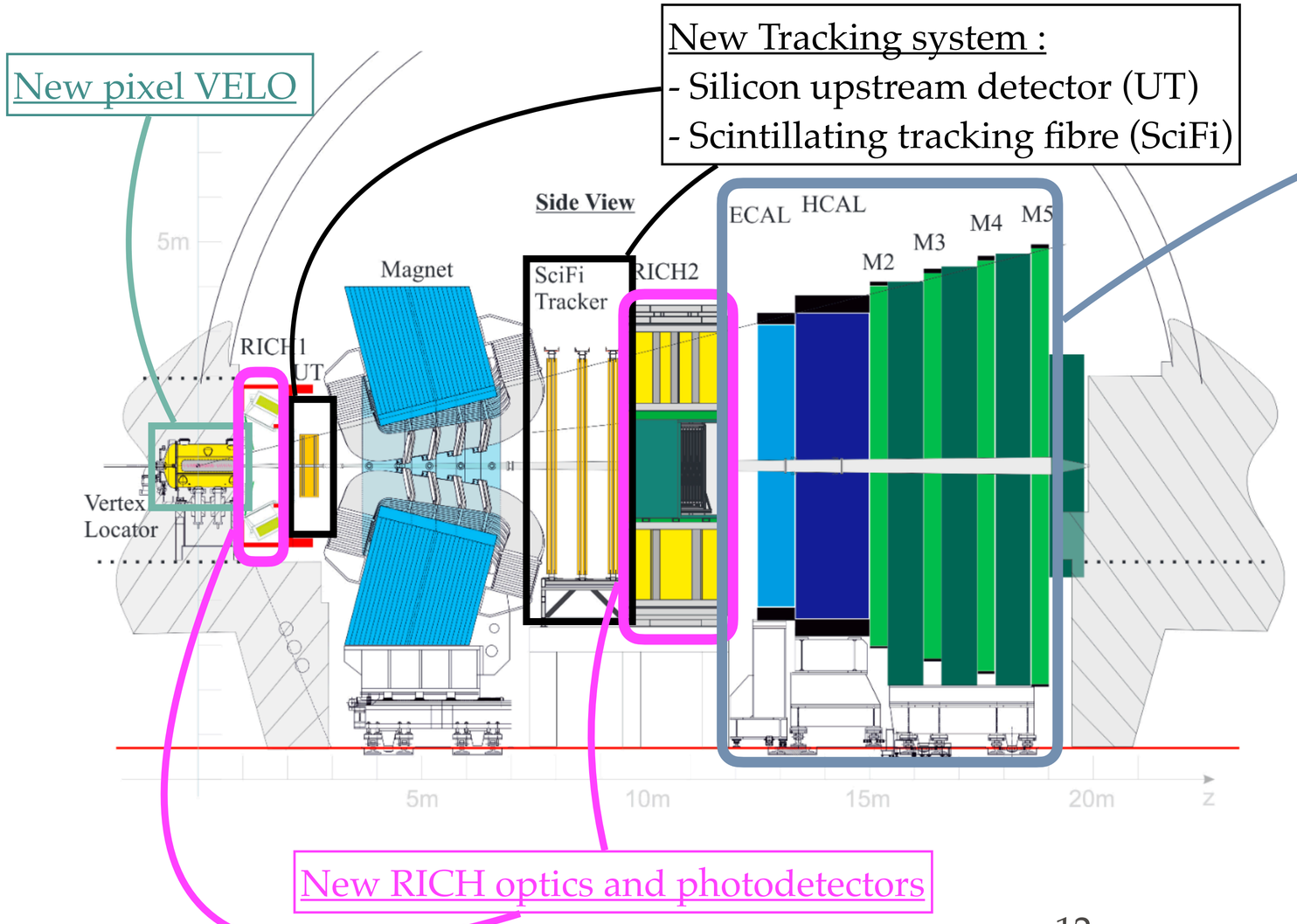






LHCb upgrades

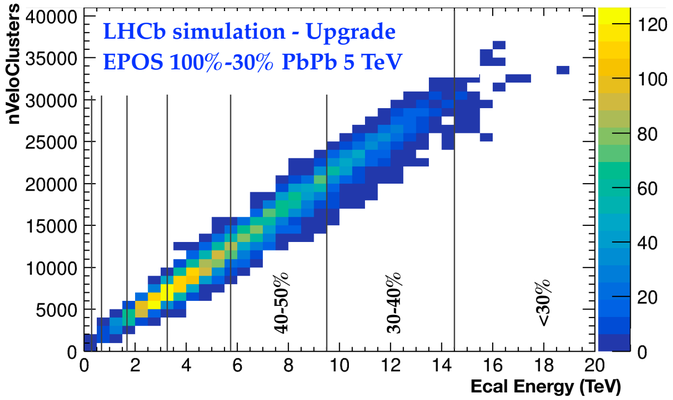
[CERN-LHCC-2012-007]

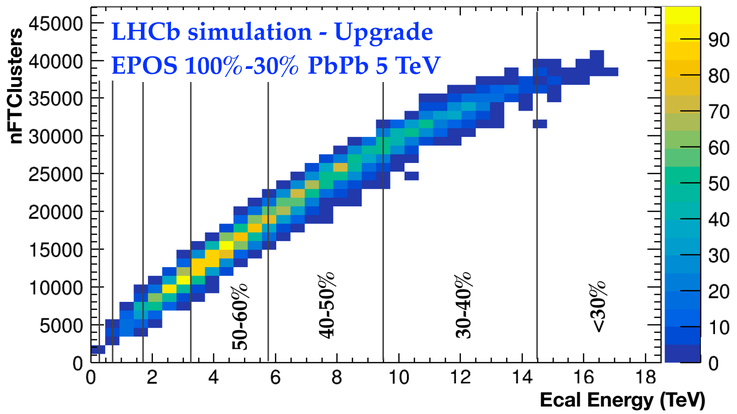


- Upgrade based on pp collision requirements :
  - Collision rate at 40 MHz.
  - Pile-up factor $\mu \approx 5$
- Full **software trigger.**
  - Remove L0 triggers.
  - Read out the full detector at 40 MHz.
  - Replace the entire tracking system.

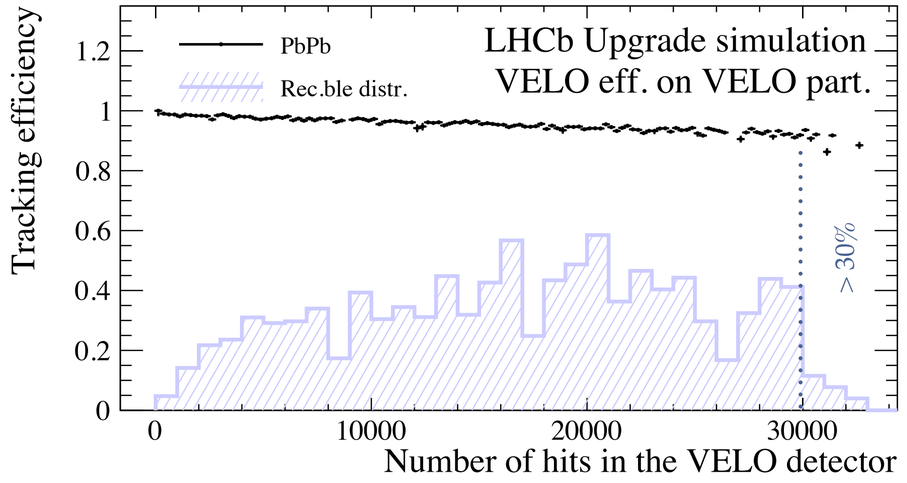
Run 3 and Run 4 prospects for heavy-ion physics with LHCb

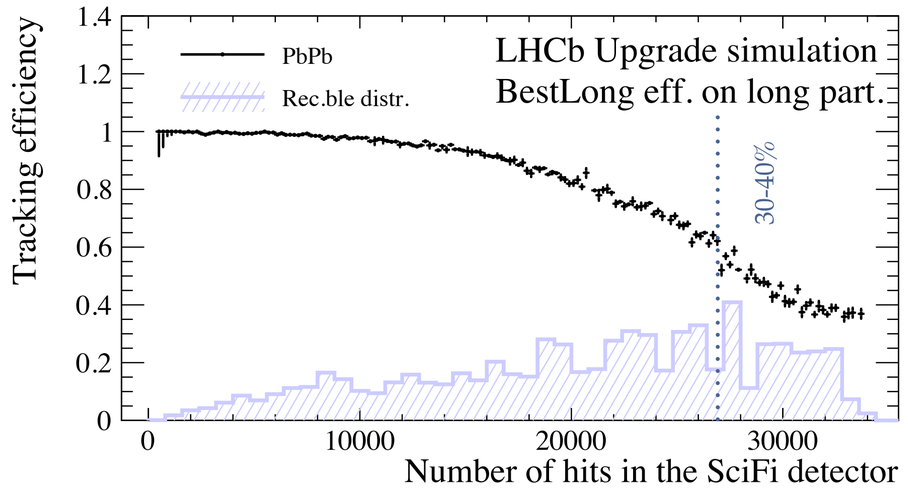
PbPb collisions at LHCb



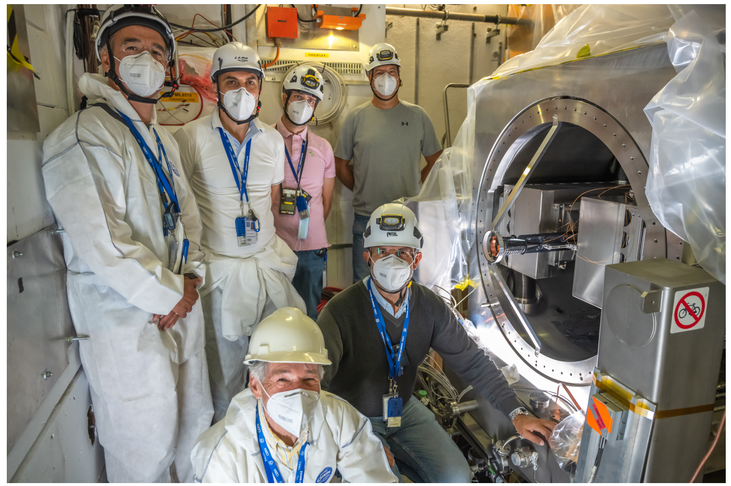


- No significant saturation of the new LHCb detectors **up to 30%!**
- Two proposals for a new tracker :
  - in 2029 → **reach even more central collisions !**
  - In 2035 → **no more limitations !**





LHCb fixed-target program evolution



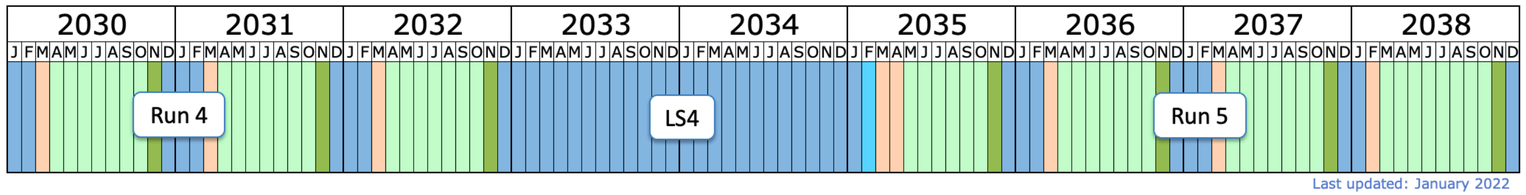
Projection of ~1 year data taking in parallel mode

Int. Lumi.		80 pb^{-1}
Sys.error of J/Ψ	xsection	~3%
J/Ψ	yield	28 M
D^0	yield	280 M
Λ_c	yield	2.8 M
Ψ'	yield	280 k
$\Upsilon(1S)$	yield	24 k
$DY\ \mu^+\mu^-$	yield	24 k

- **SMOG 2** (TDR) : Standalone gas storage cell covering z ϵ [-500;-300] mm :
  - **Up to x100 higher gas density** with same gas flow of current SMOG.
  - Gas feed system measures the **gas density with few % accuracy**.
  - **Possibility to run in parallel of pp collisions and inject non noble Gaz.**

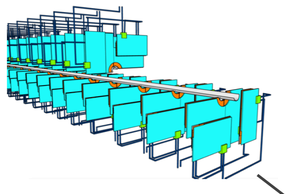
Installation ongoing, to be operational from the start of LHC Run 3.

Phase II in a nutshell

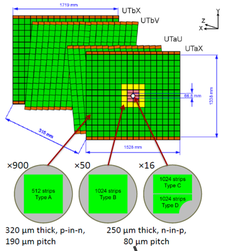


Upgrade II:
- $2\times10^{34}\ \mathrm{cm^{-2}\,s^{-1}}$
- **Pile-up = 42 in pp collisions**

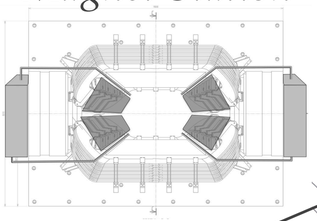
VELO



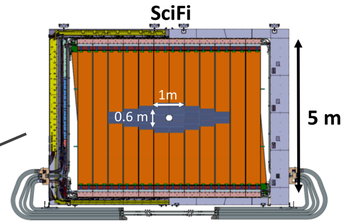
Upstream Tracker



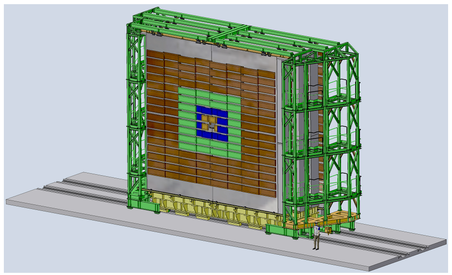
Magnet Station



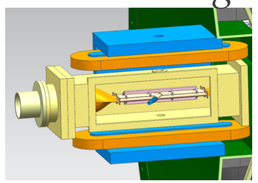
Mighty Tracker

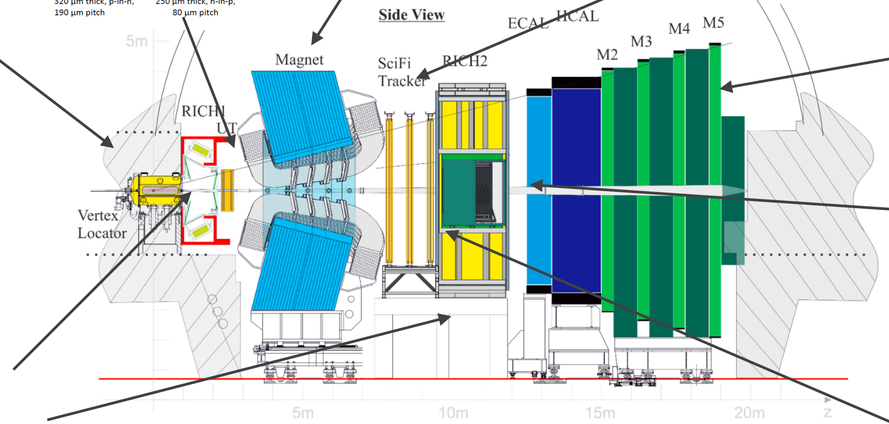


Muon station



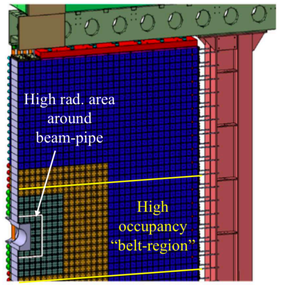
Polarized target





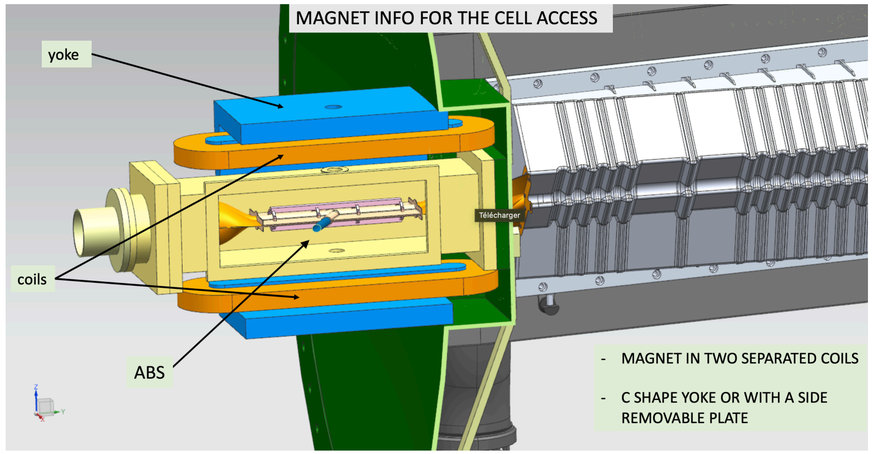
TORCH

Ecal

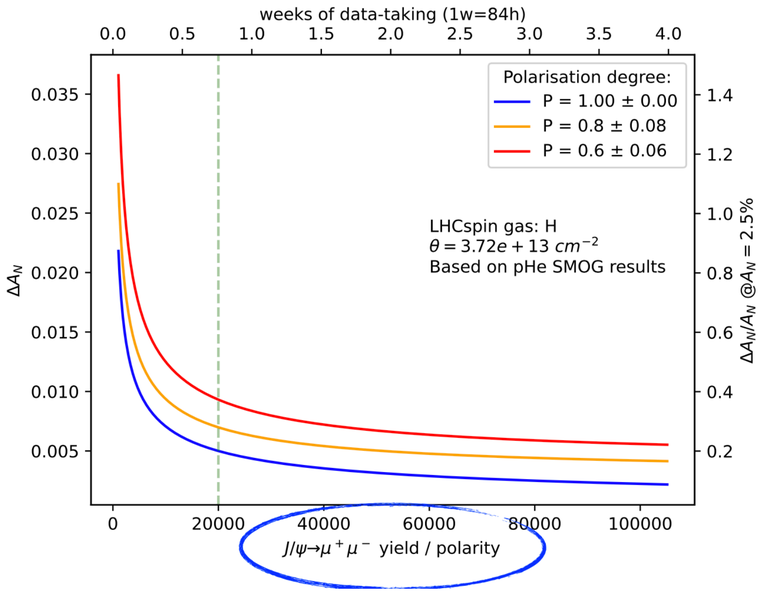


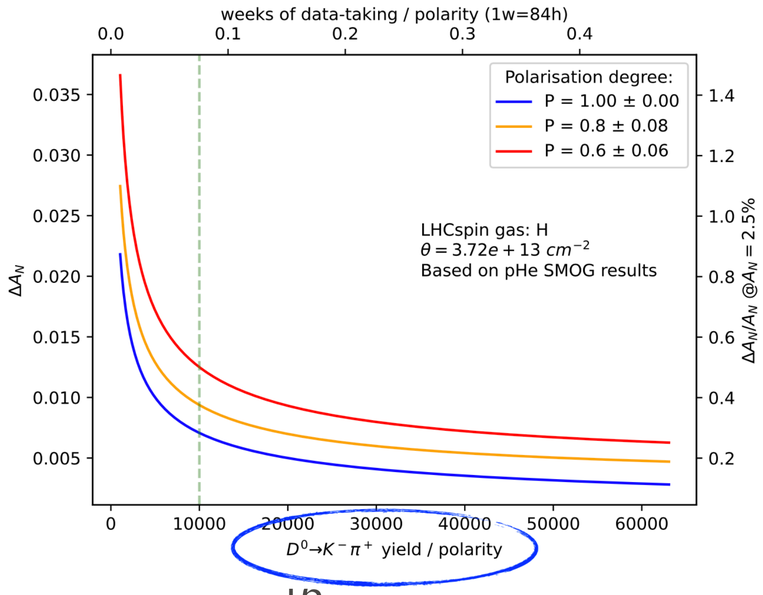
New RICHs

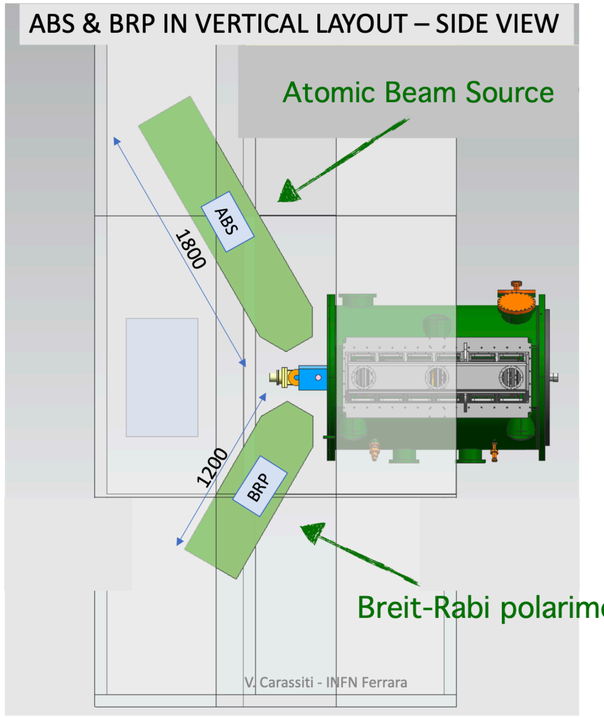
The Polarised Gas Target: LHCspin



- R&D has started!
  - Compact dipole magnet static → transverse field.
  - Superconductive coils + iron yoke configuration fits the space constraints.
  - B = 300 mT, $\Delta B/B \simeq 10$ %, with polarity inversion.
- Achievable Luminosity (HL-LHC): ~ 8×10^{32} cm^{-2} s^{-1}
- Could be installed during LS3!



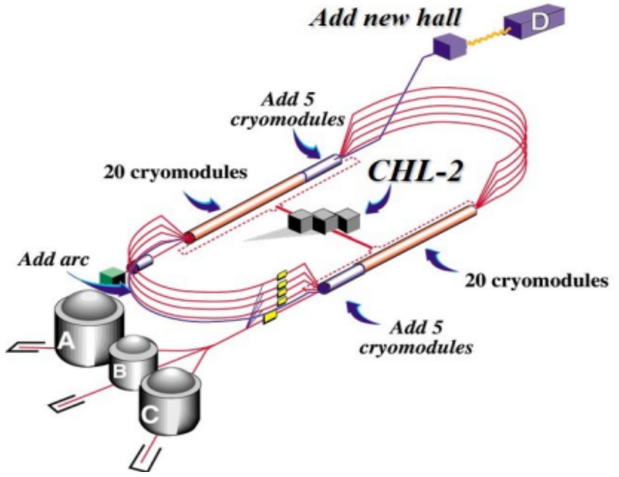


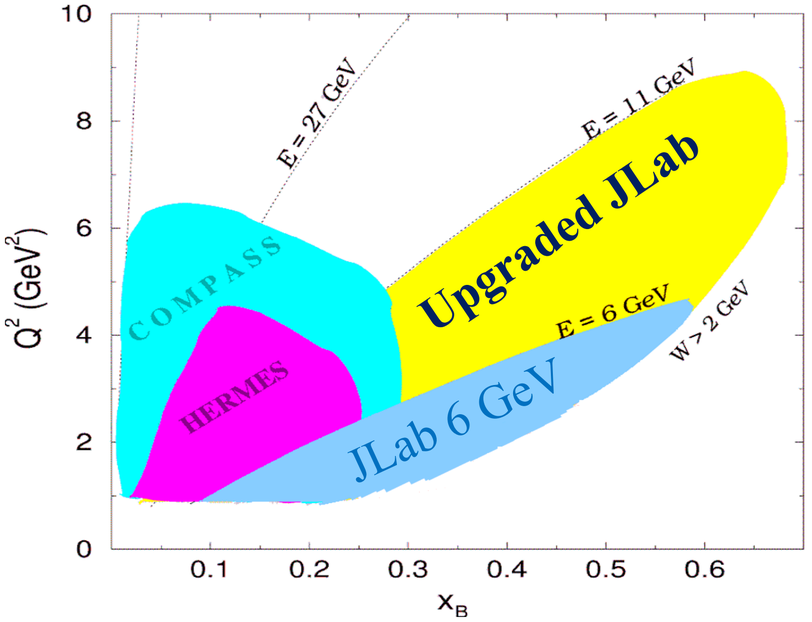


Other perspectives

Structure of nucleon and nuclei: JLab

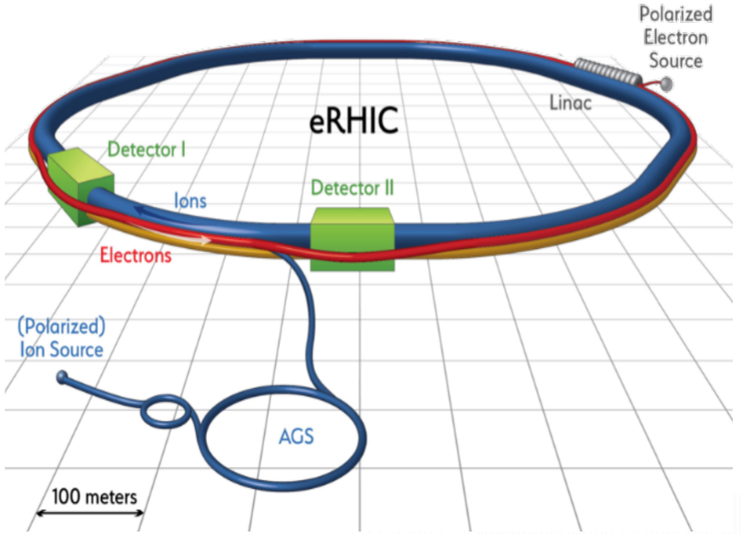
- e-p/A collisions : electromagnetic probes → cleanest access
- Physics goals:
  - Precision study of 3D nucleon structure (**GPDs**, **TMDs**)
  - Hadron spectroscopy
  - Nuclear structure (nuclear-medium effects, hadronization…)
- Recent upgrade of the accelerator to a higher beam energy (6 →11 GeV) & detectors to higher luminosity (x10)
- Physics program well established for the next **10-15+ years.**
- **Step toward the EIC.**

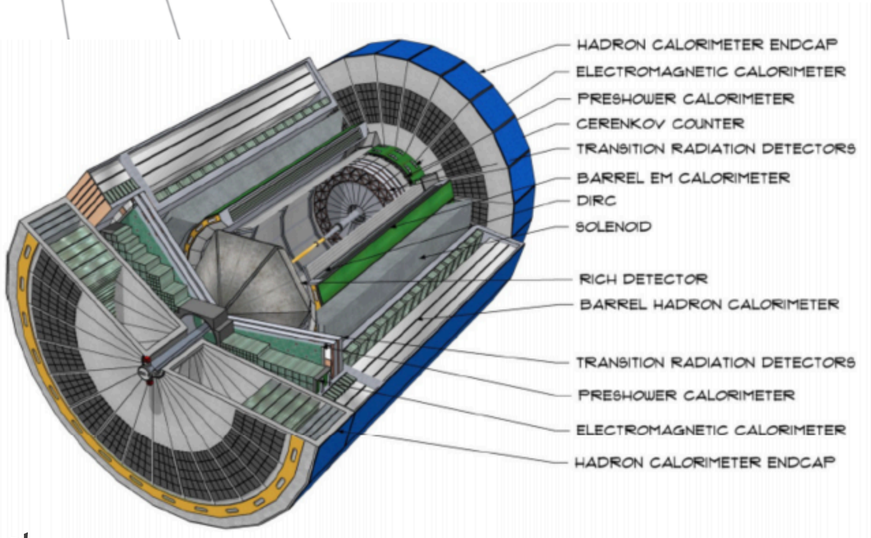




Structure of nucleon and nuclei: EIC

- **Collisions e-p/A:**
  - $\sqrt{s_{NN}}$ = 29-140 GeV, **Polarized beams** : e, p, d/^{3}He
  - Electron beam: 5-18 GeV
  - Luminosity L_{ep}~$10^{33\text{-}34}$ cm^{-2}s^{-1} (100-1000 x HERA)
  - Wide choice of nuclei
- **Project timeline**
  - CD-0 (December 2019): Mission Need
  - CD-1 (July 2021): Start of project execution
  - CD-2 (~Jan'23): R&D completed
  - CD-3 (~Mar'24): TDR completed; start of construction
  - CD-4a (~Jul'31): Start of operations
  - CD-4b (~Jul'33): Projet completion

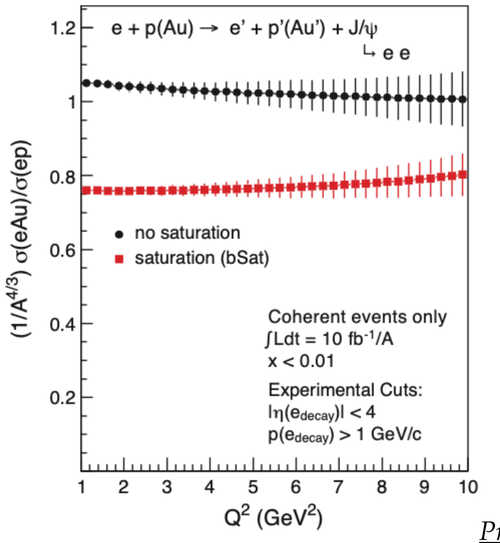


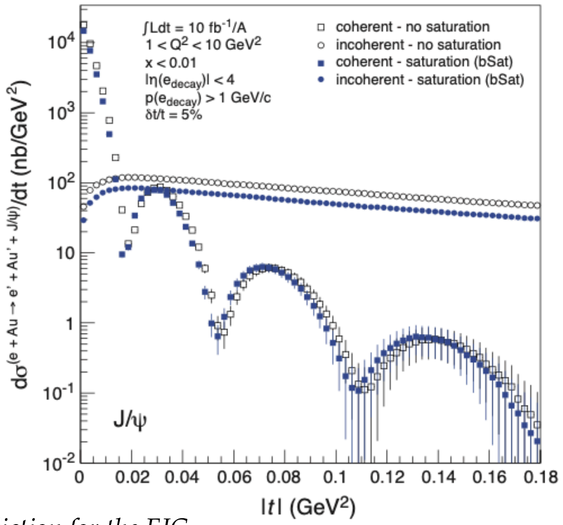


ECCE project

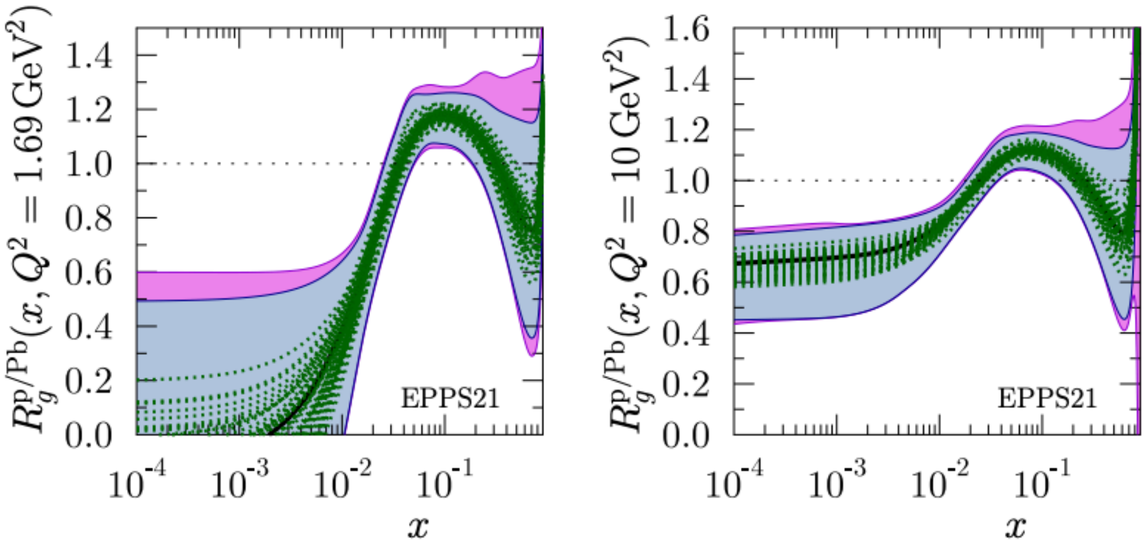
Structure of nucleon and nuclei: EIC

- (Some) physics goals : high Energy / small x
  - Search for saturation.
  - Constraining nPDFs.





Prediction for the EIC



EPPS21 latest prediction

Conclusion

Let start the discussion session !

Some items

- LHC Run 3 - Run 4:
  - Any suggestions to prioritize a given measurement?
  - Shall we talk about the possible exotic (i.e pO/OO) runs?
- Flagships for LHC Run 5?
  - Which one is more important?
  - New ideas?
- Additional detectors
  - Would you like to see a detector installed which is not in this presentation?