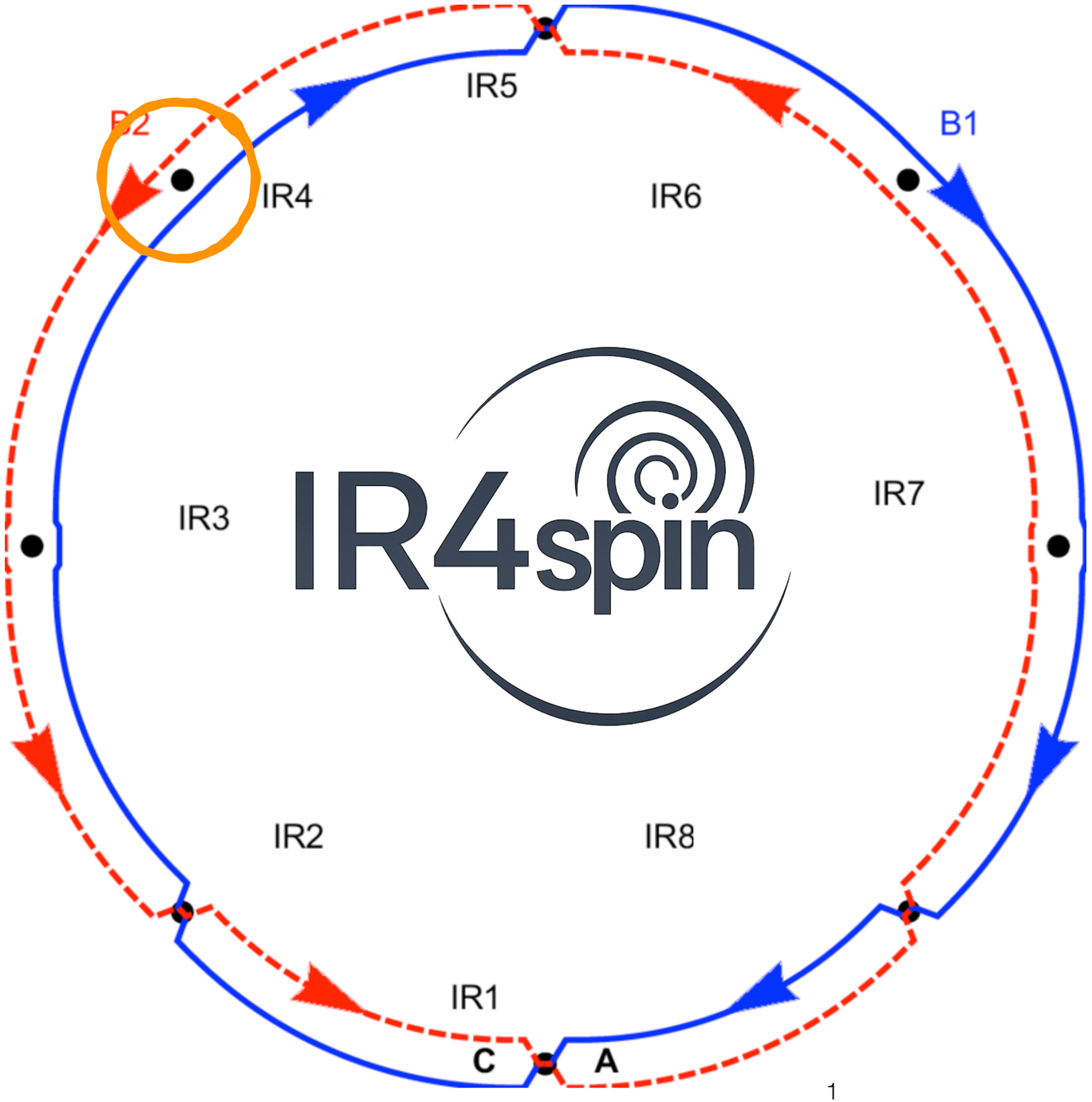


Pasquale Di Nezza

INFN LNF
Istituto Nazionale di Fisica Nucleare

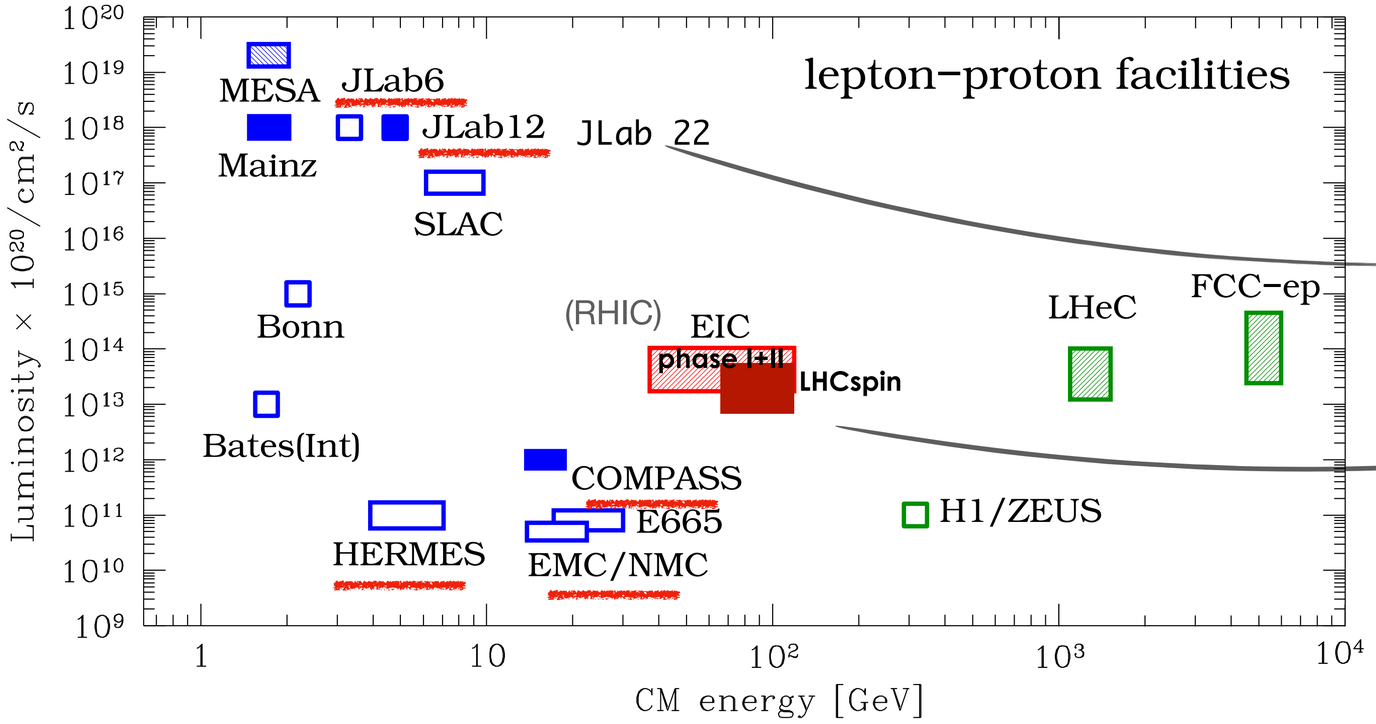
in collaboration with

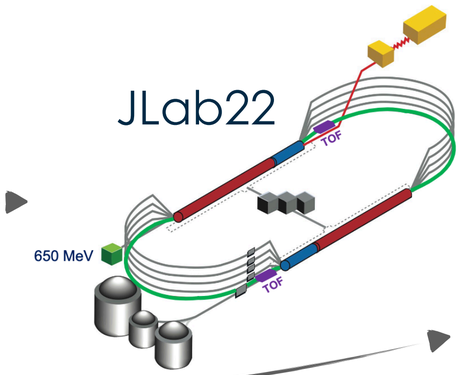
Paolo Lenisa, University of Ferrara

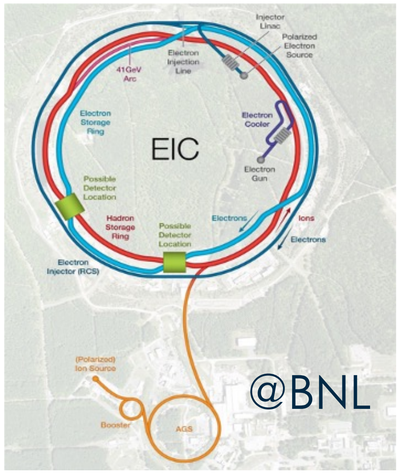
Massimiliano Ferro-Luzzi, CERN

Town Meeting, Nantes 02/07/25

The physics of polarized collisions is at the core of many major future projects, though all are outside the EU

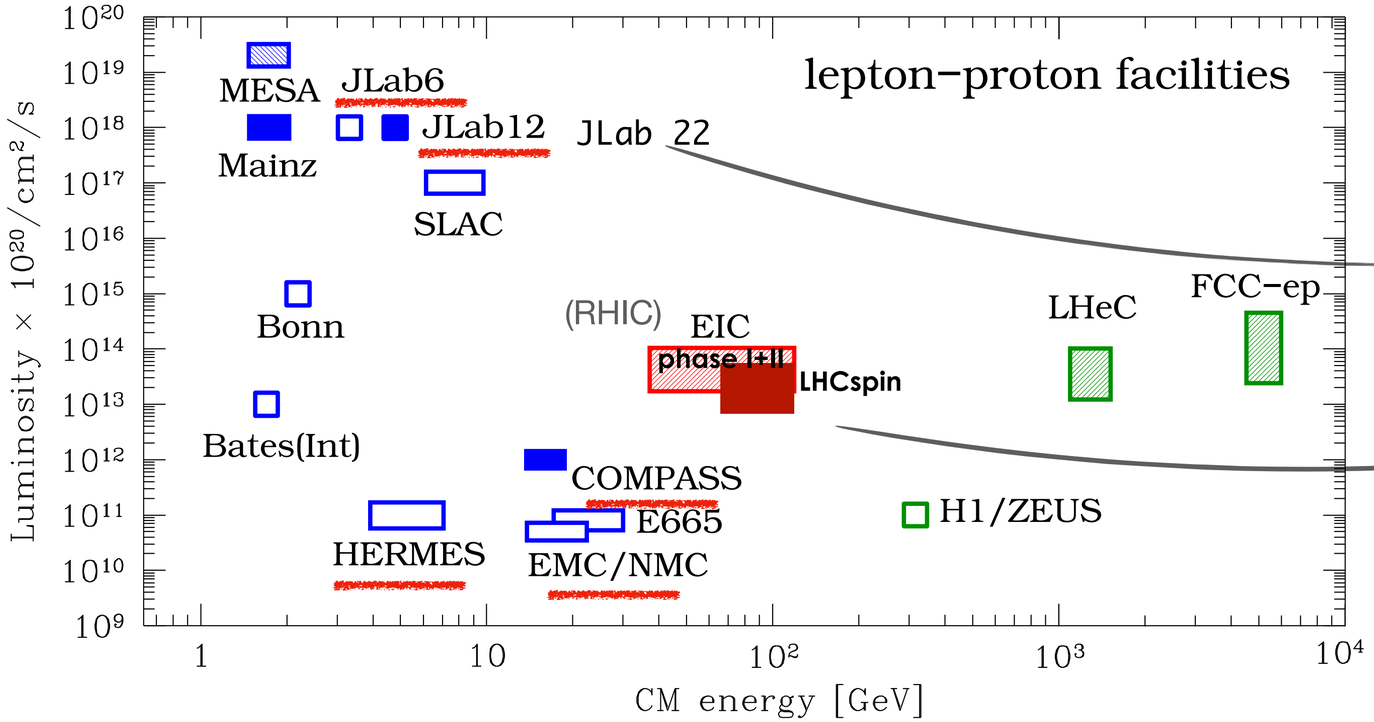


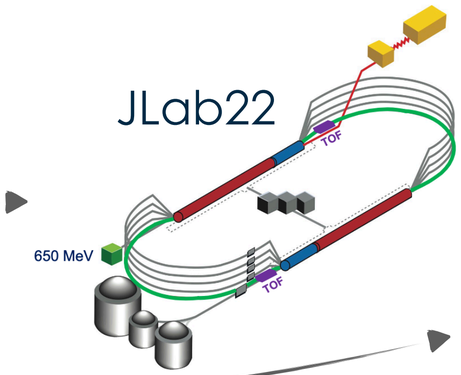


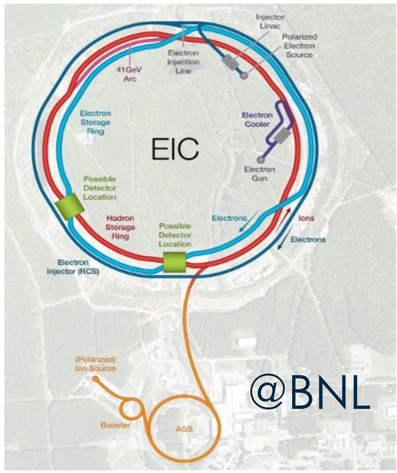


China

The physics of polarized collisions is at the core of many major future projects, though all are outside the EU





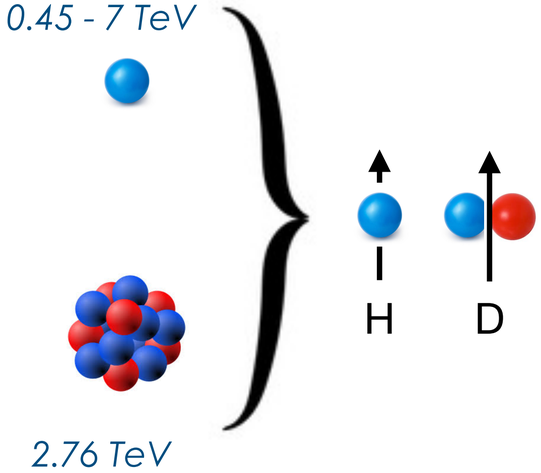


China

In the EU, we have a unique opportunity to explore a broad range of new physics scenarios, offering fundamental insights into the nucleon structure at large

This can happen at the LHC, whose beam energy will open previously unexplored kinematic regions and allow the use of novel probes

The LHC beams cannot be polarized. The only way to achieve polarized collisions is through a polarized fixed target



pp collisions: 0.45 - 7 TeV beam on fix target

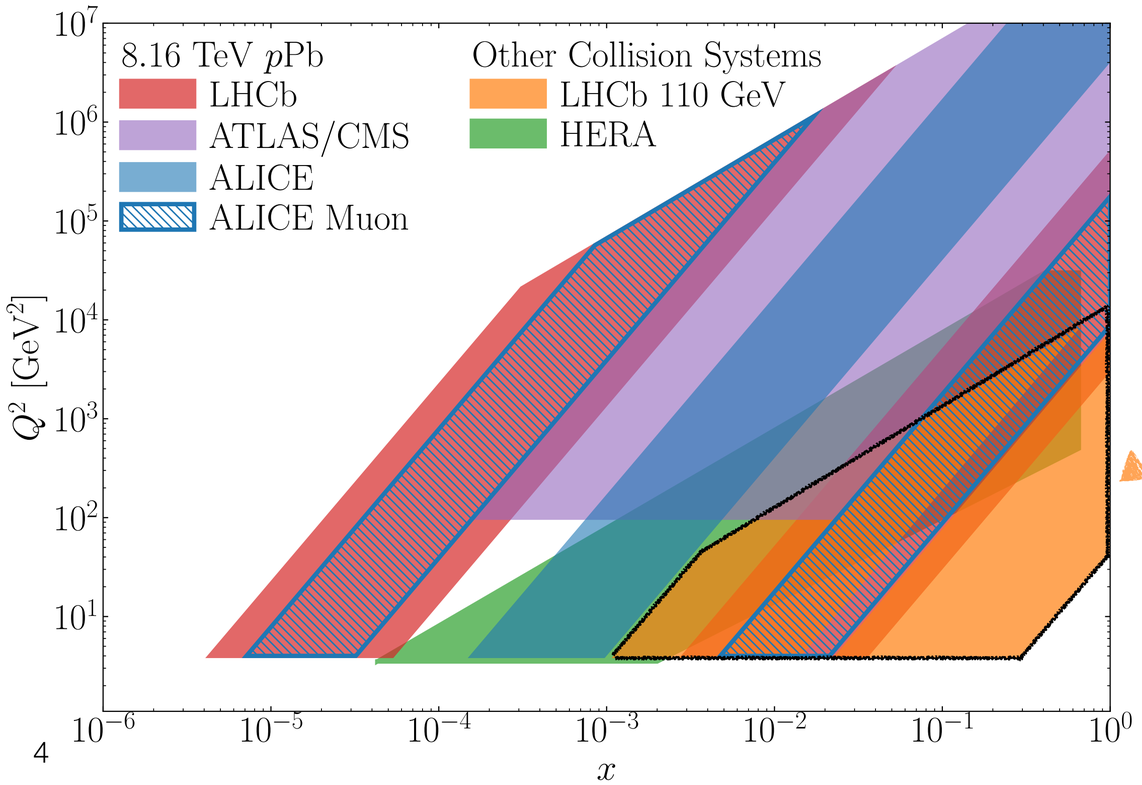
$$\sqrt{s} = \sqrt{2m_N E_p} \simeq 29 - 115\ GeV$$

$$y_{CMS} = 0 \ \rightarrow \ y_{lab} = 4.8$$

Ap collisions: 2.76 TeV beam on fix target

$$\sqrt{s_{NN}} \simeq 72\ GeV$$

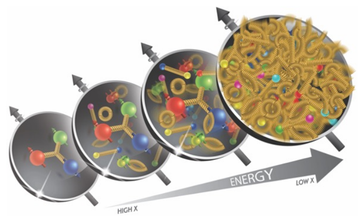
$$y_{CMS} = 0 \ \rightarrow \ y_{lab} = 4.3$$

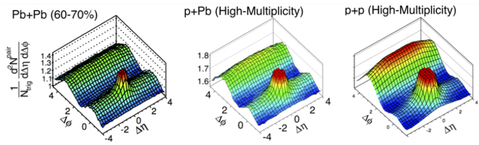


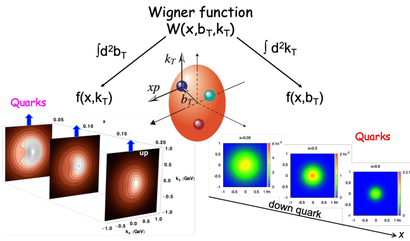
Broad and poorly explored kinematic range

A quick list of some of the main scientific items

- Multi-dimensional nucleon structure in a poorly explored kinematic domain
- Measure experimental observables sensitive to both quarks and gluons TMDs
- Make use of new probes (charmed and beauty mesons)
- Complement present and future SIDIS results
- Test non-trivial process dependence of quarks and (especially) gluons TMDs
- Measure exclusive processes to access GPDs
- Collectivity phenomena
- Ion physics through polarized collisions



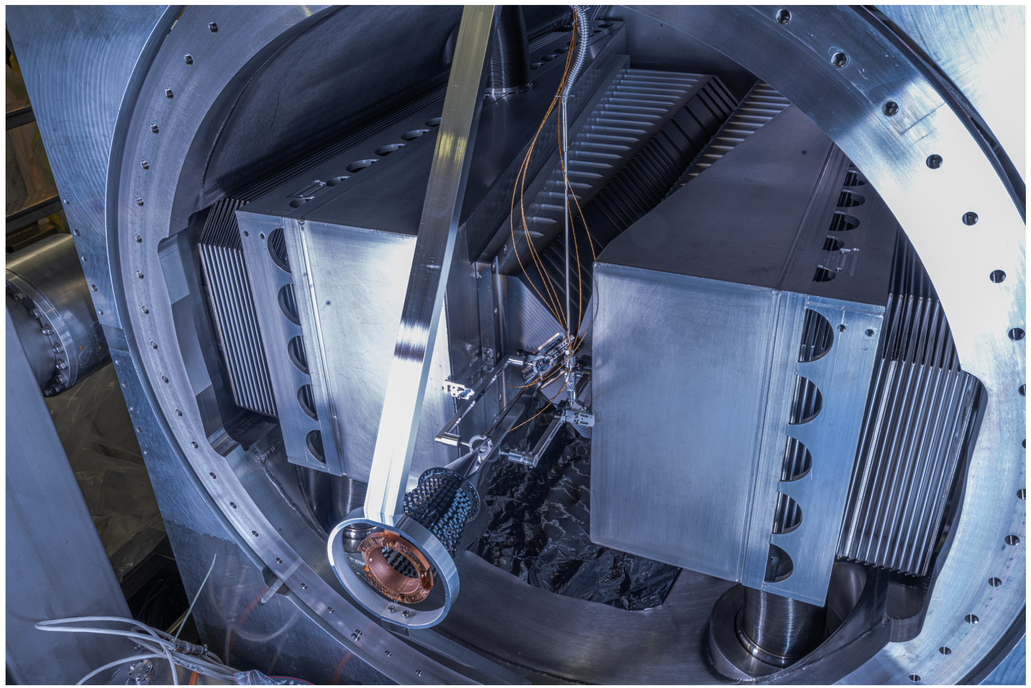




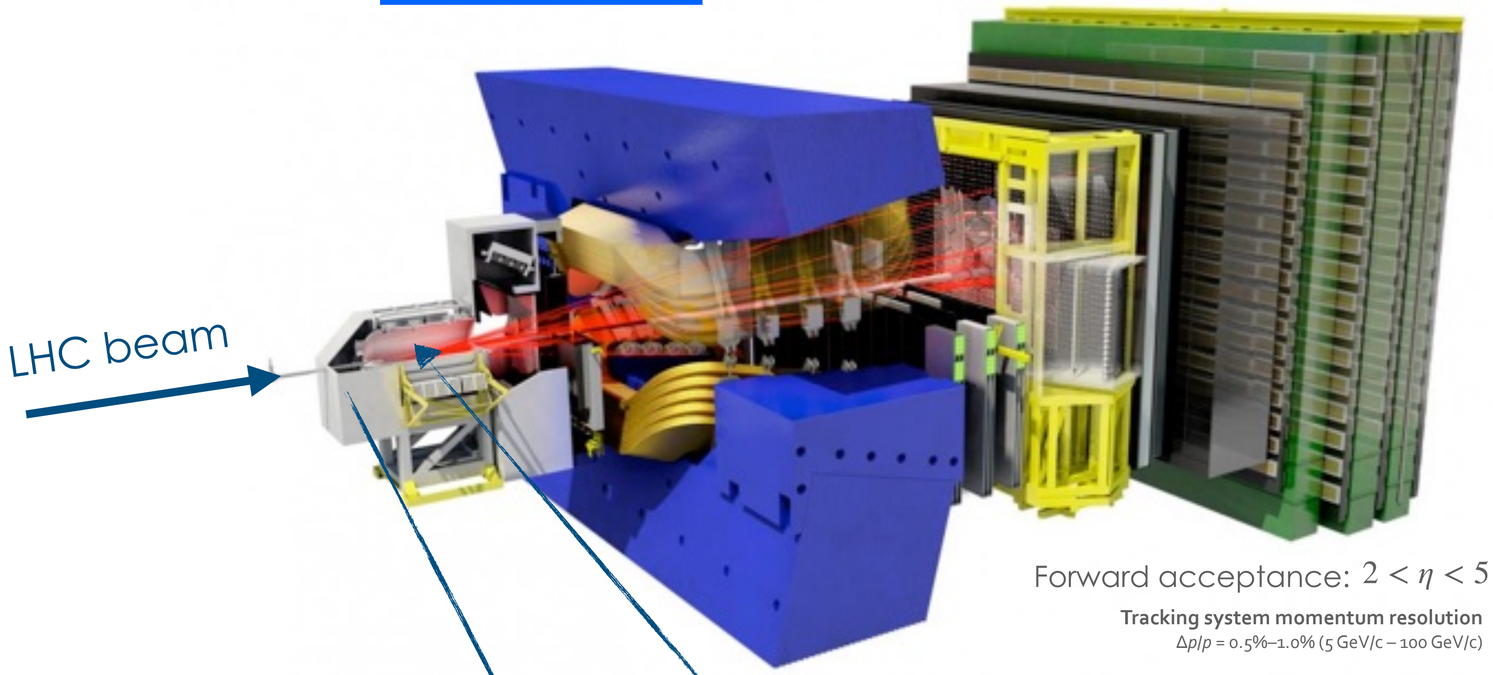
To achieve this challenging goal, the first step is the installation of an unpolarized gas target, which demonstrates the technical and physical feasibility of implementing this technique at the LHC

SMOG2 an unpolarized target at LHCb

JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022



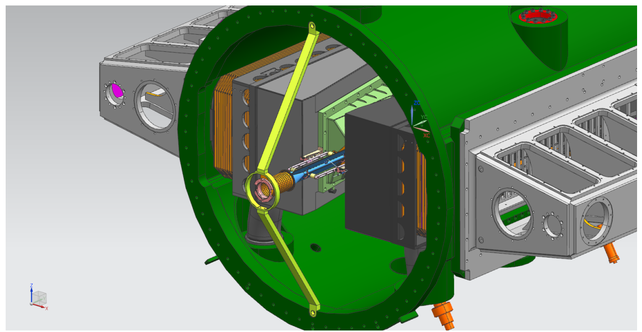
PHYSICAL REVIEW ACCELERATORS AND BEAMS 27, 111001 (2024)



Forward acceptance: $2 < \eta < 5$

Tracking system momentum resolution
$\Delta p/p$ = 0.5%–1.0% (5 GeV/c – 100 GeV/c)

beam-beam collisions



beam-gas collisions

We have already achieved this important result with the help of the Strong H2020 grant

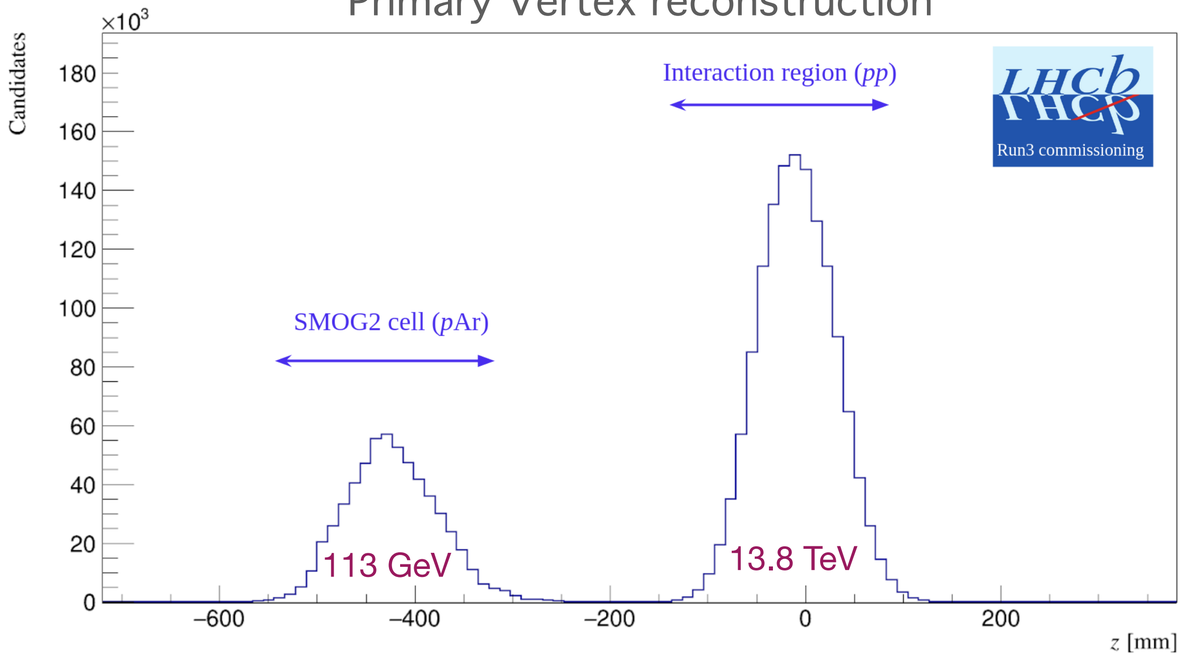
(JRA2- Fixed Target Experiments at the LHC)

SMOG2

STRONG 2020

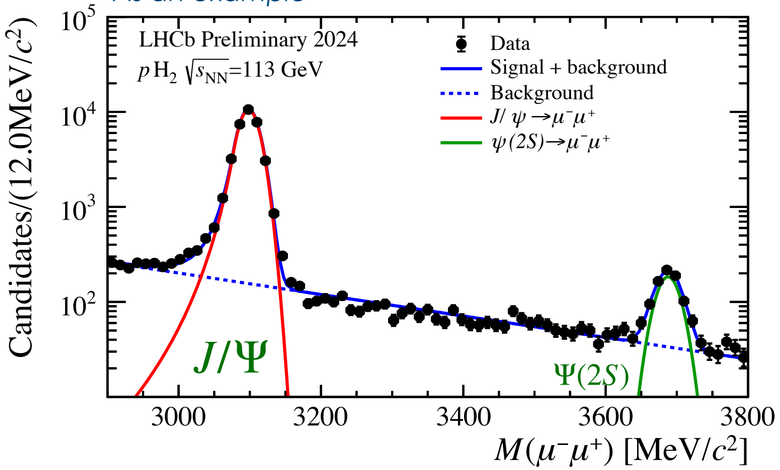
PRAB 27, 111001 (2024)

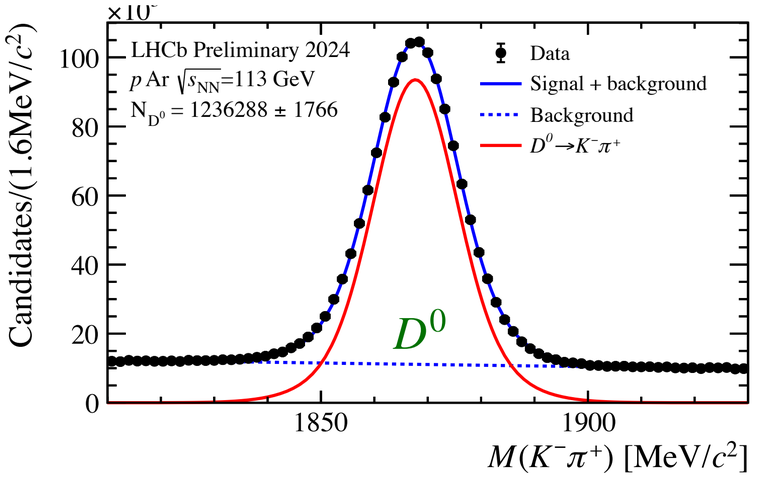
Primary Vertex reconstruction



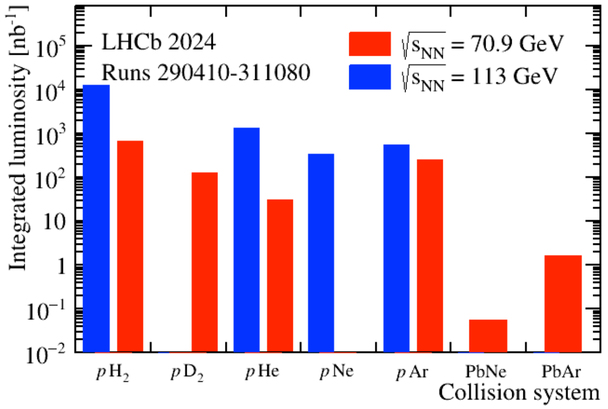
Two well separated and independent Interaction Points working simultaneously

As an example





LHCb-FIGURE-2024-023



Large statistics!

Since the beginning of Run3, LHCb is routinely collecting data in collider and fixed-target mode simultaneously!

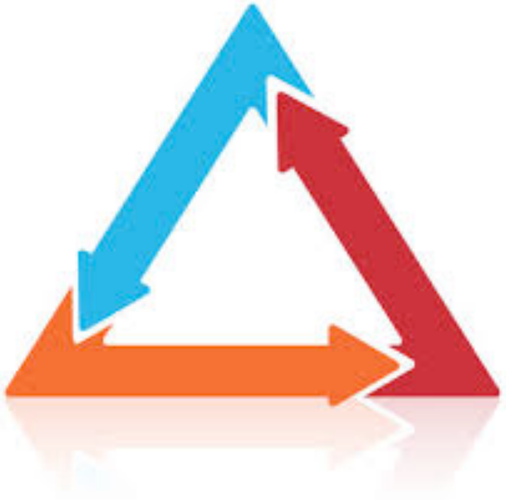
Now we know that a fixed target (with a storage cell) at the LHC is feasible and performs extremely well!

Therefore, we can move to the next step:

-develop a new-generation, high-intensity polarized gas target
-develop an absolute polarimeter
-perform unique measurements (phase 1 and phase 2)

This will happen through a collaborative effort among…

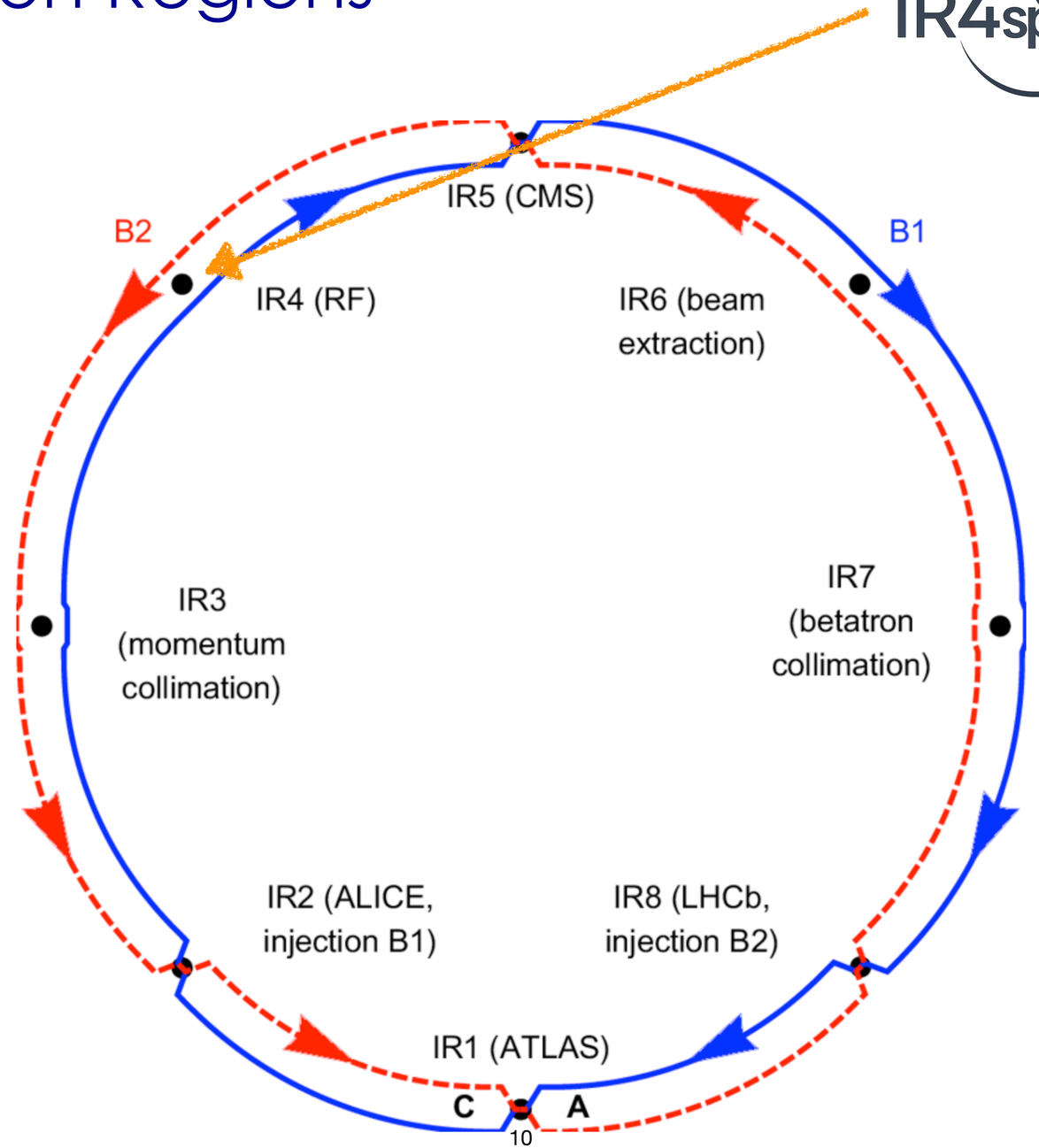
LHC and LHCb communities.
A new working group on polarized physics will be established from the machine side



A laboratory for silicon detectors is available, along with access to the Beam Test Facility (BTF) for R&D of the absolute polarimeter. Development of ML/AI analysis tools is also underway

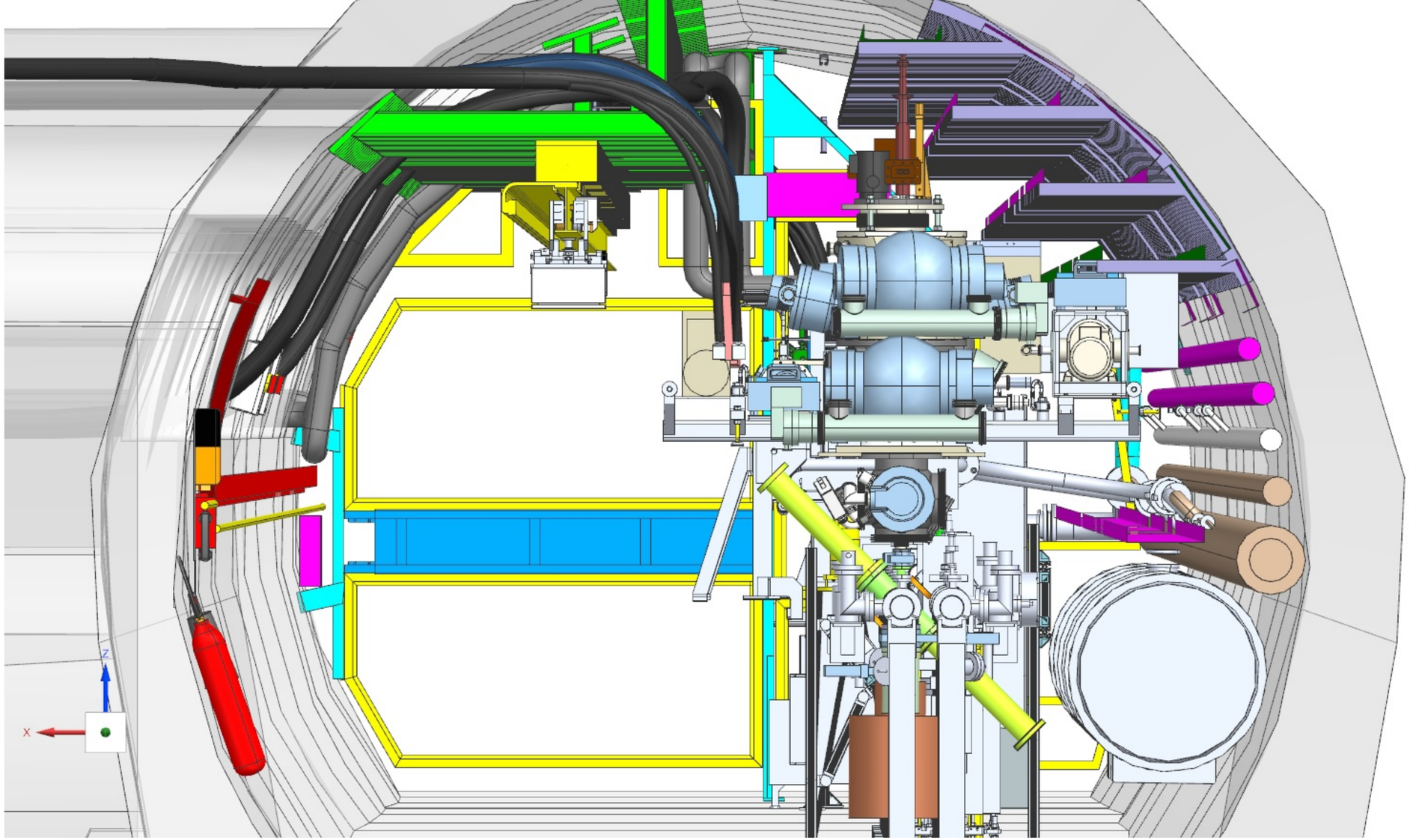
A new generation of polarized gas targets is under development. ML techniques will be applied to optimize the Atomic Beam Source

The LHC Interaction Regions



The LHC Interaction Region 4

Transverse CAD view of the LHC tunnel with the PGT implemented



A bit tight, but no showstoppers have beed identified so far

arXiv: 2504.1603, NIMethods in Physics Research A 1068 (2024) 169707, CERN-LHCC-2024-010

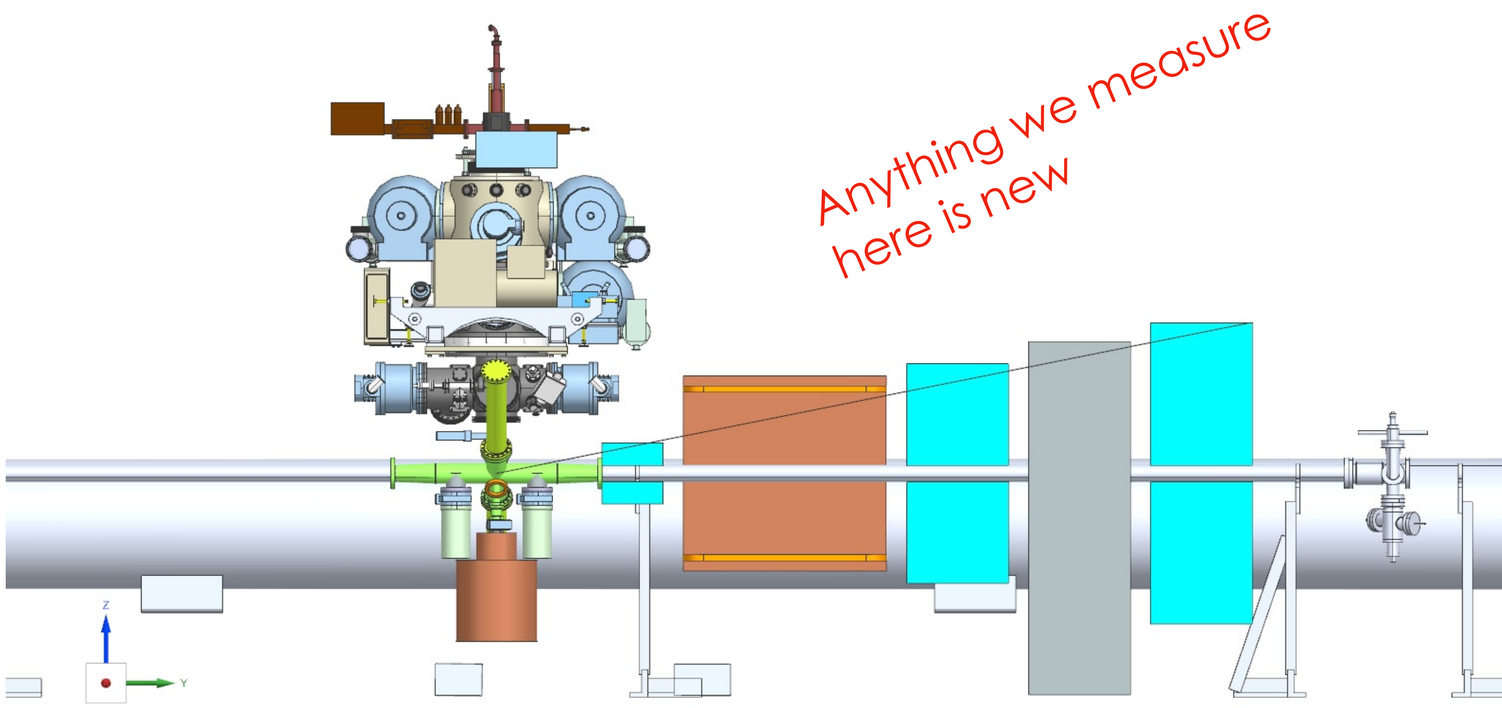
The polarized gas fixed target we are developing in Ferrara

Detector concept at the IR4

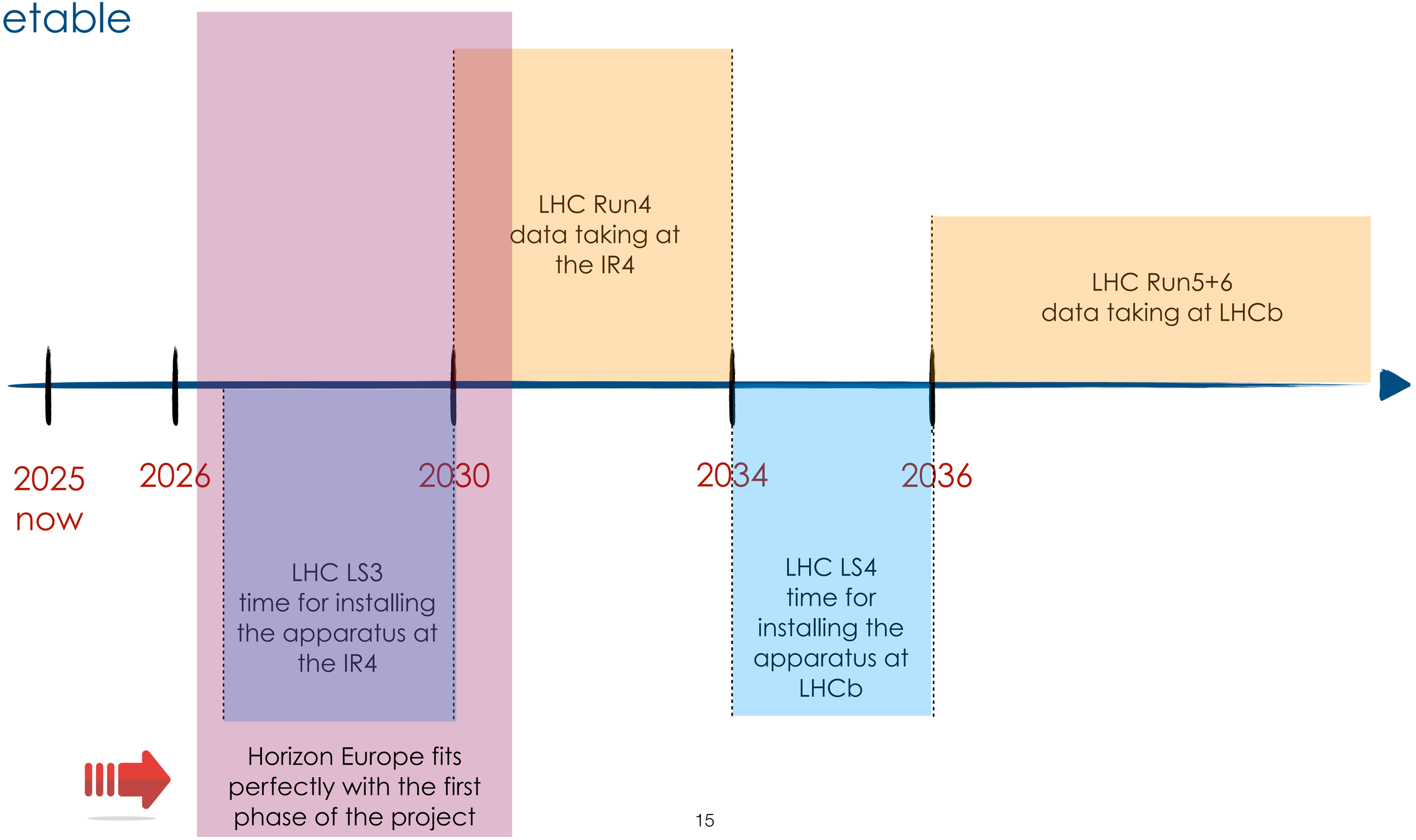
Goals:
- proof of principle of the future (large-scale) experiment with LHCb.
- measurement of single-spin asymmetries in inclusive hadron production in $pH^{\uparrow}$ and $PbH^{\uparrow}$

Apparatus:
- jet-target (but could be done also with storage cell)
- full (minimal) spectrometer: dipole magnet, tracking stations, muon system
- simple PID detectors (Calo, RICH)?

Needed expertise (apart from pol. target):
- dipole magnet
- tracking detectors (Si strip, SciFi, drift chambers?)
- muon chambers (MWPC?)
- electronics
- DAQ
- slow control
- tracking/reconstruction algorithms
- …



Timetable


LHC Run4
data taking at
the IR4
LHC Run5+6
data taking at LHCb
2025
now
2026
2030
2034
2036
LHC LS3
time for installing
the apparatus at
the IR4
LHC LS4
time for
installing the
apparatus at
LHCb
Horizon Europe fits
perfectly with the first
phase of the project

Concreate deliverables:

-Development of a new generation target (pure molecular polarized gas target for H_2 and D_2)
-Development of a new absolute polarimeter (based on the CNI effect)
-Start data taking at the highest polarized fixed target collision energies ever achieved
-Create a collaborative group on polarized physics bringing together machine and detector/analysis experts from Cern, Ferrara, and Frascati

Budget plan:

-4 postdoc contracts (2yr): 430 kE
-2 PhD (3yr): 150 kE
-Travel support: 70 kE
TOTAL 650 kE

IR4spin

is an innovative and unique project conceived to bring polarized physics at the LHC

it could be implemented within a realistic timeframe, with a limited budget, and fits perfectly with the Horizon Europe grant

it establishes a collaborative network among CERN, INFN Frascati, and University of Ferrara

will pave the way for further advances in nucleon structure and spin physics