The LHCspin project

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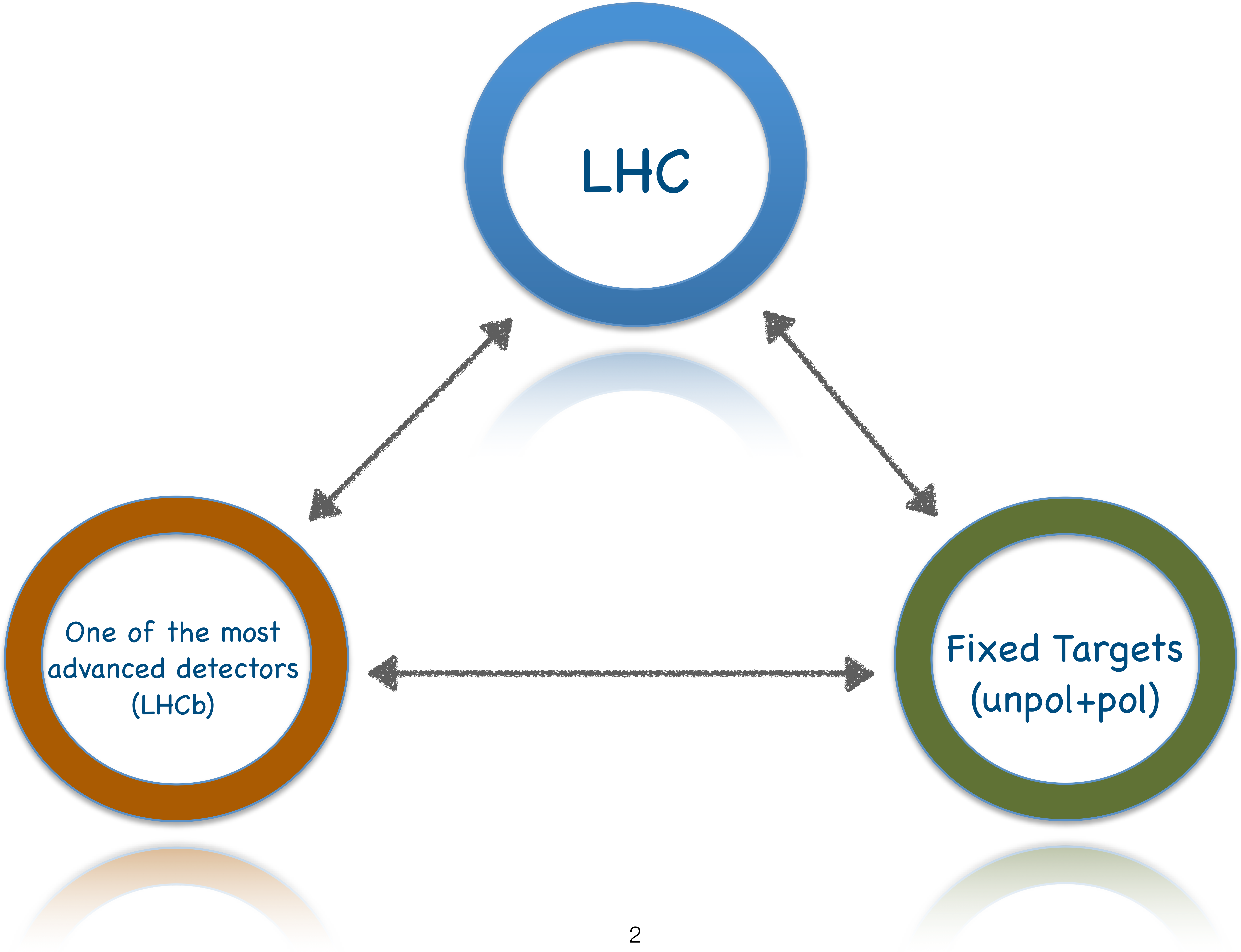
8/9/21

Merging 3 worlds for the first time



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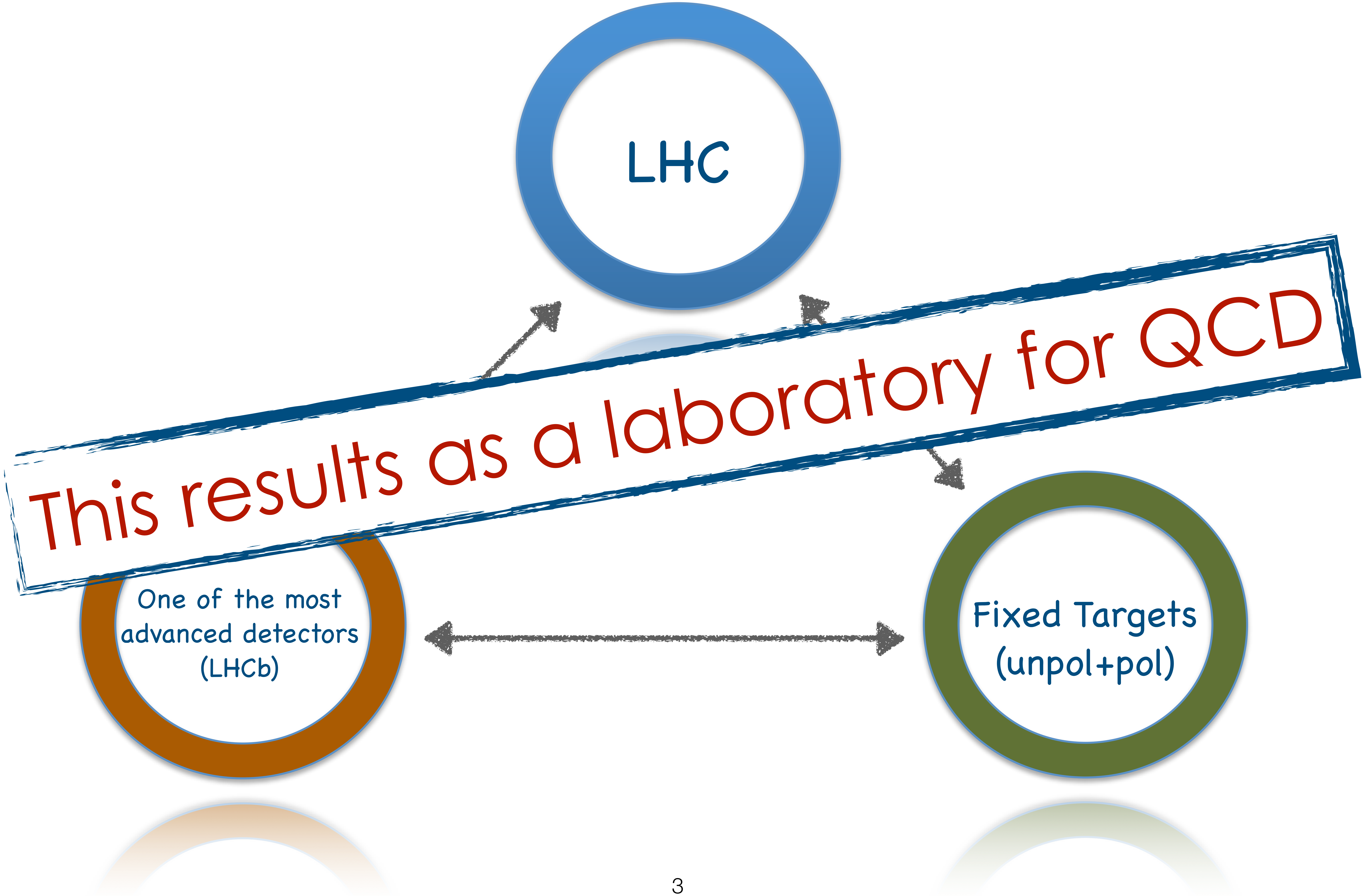
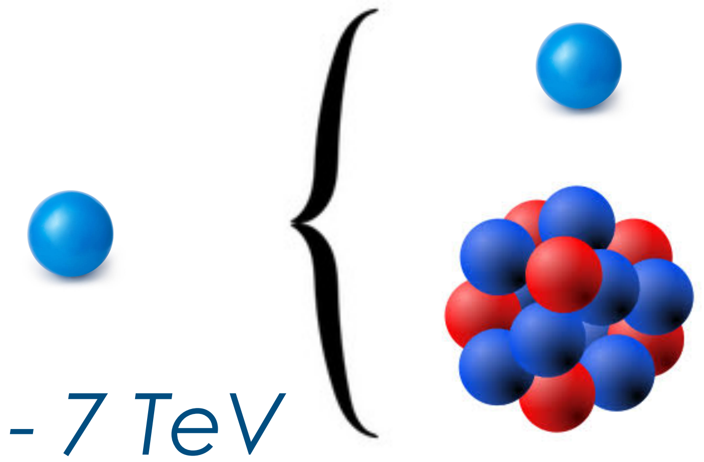


Kinematics on fixed target



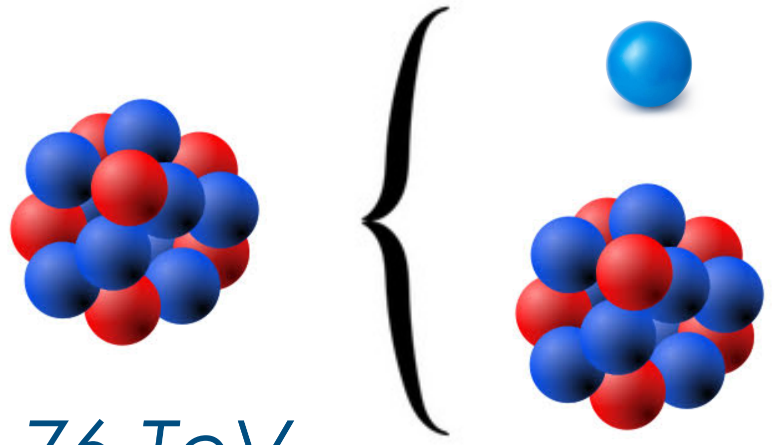
0.45 - 7 TeV

pp or pA collisions: up to 7 TeV beam on fix target

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

$$-3.0 \leq y_{CMS} \leq 0 \ \rightarrow\ 2 \leq y_{lab} \leq 5$$

between SPS & RHIC



2.76 TeV

AA collisions: 2.76 TeV beam on fix target

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

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

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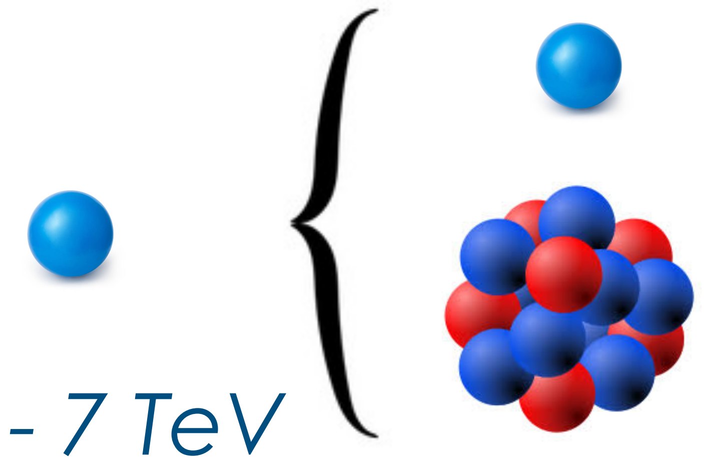

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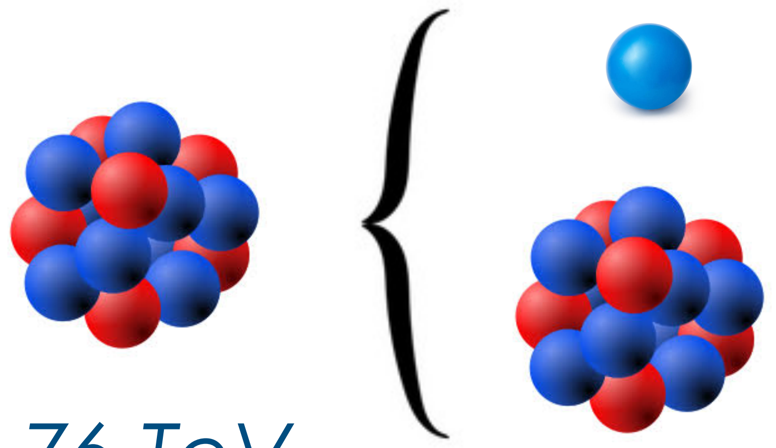

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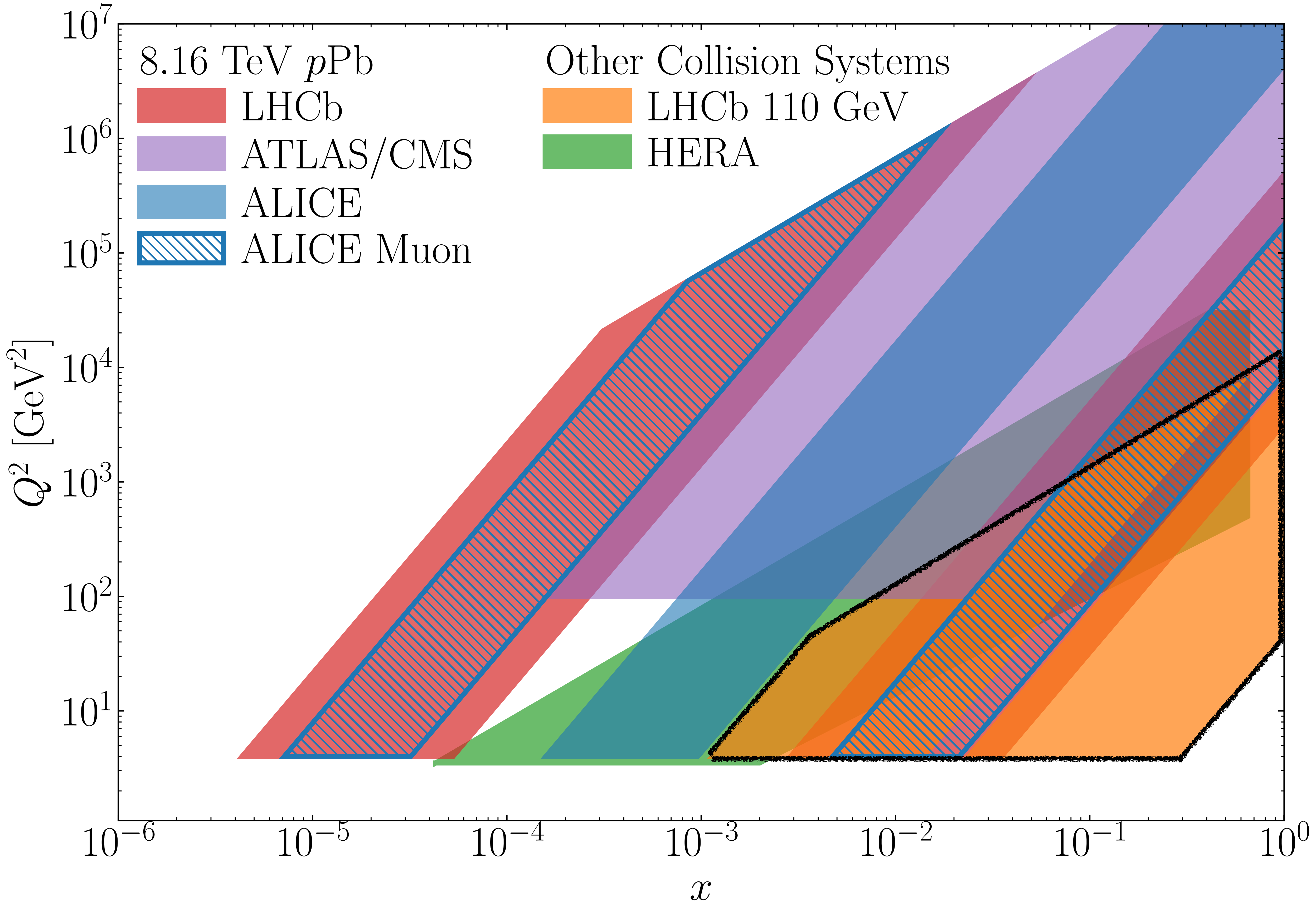
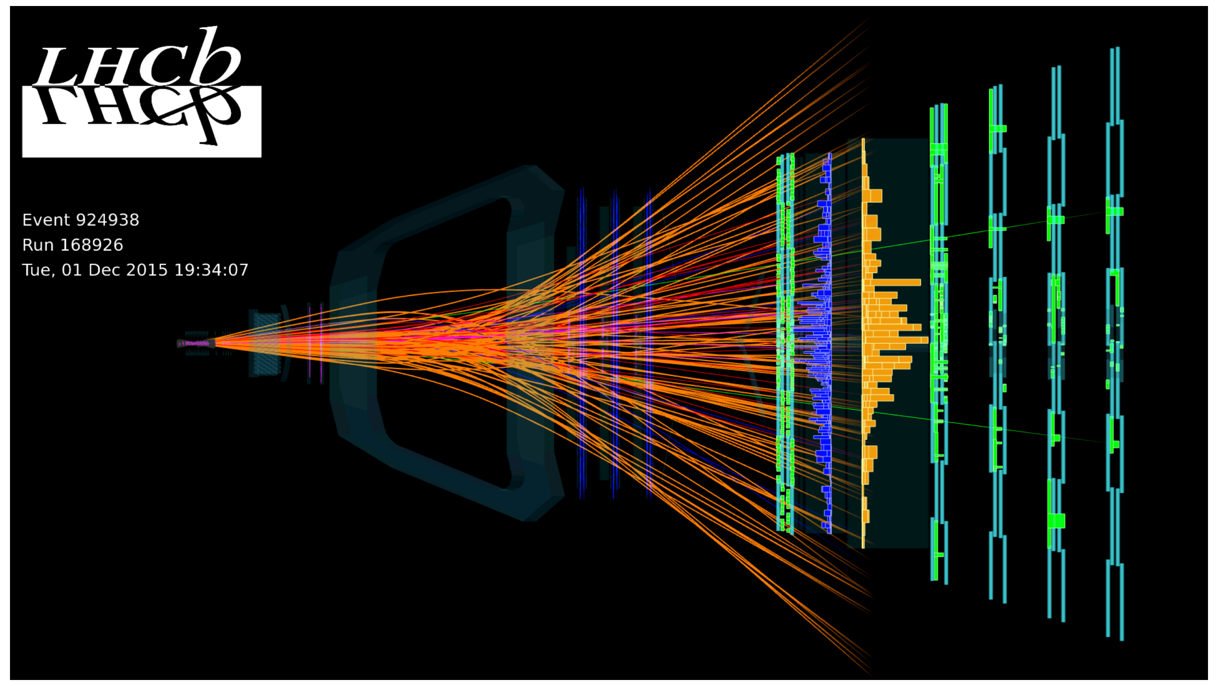
Unique kinematical region

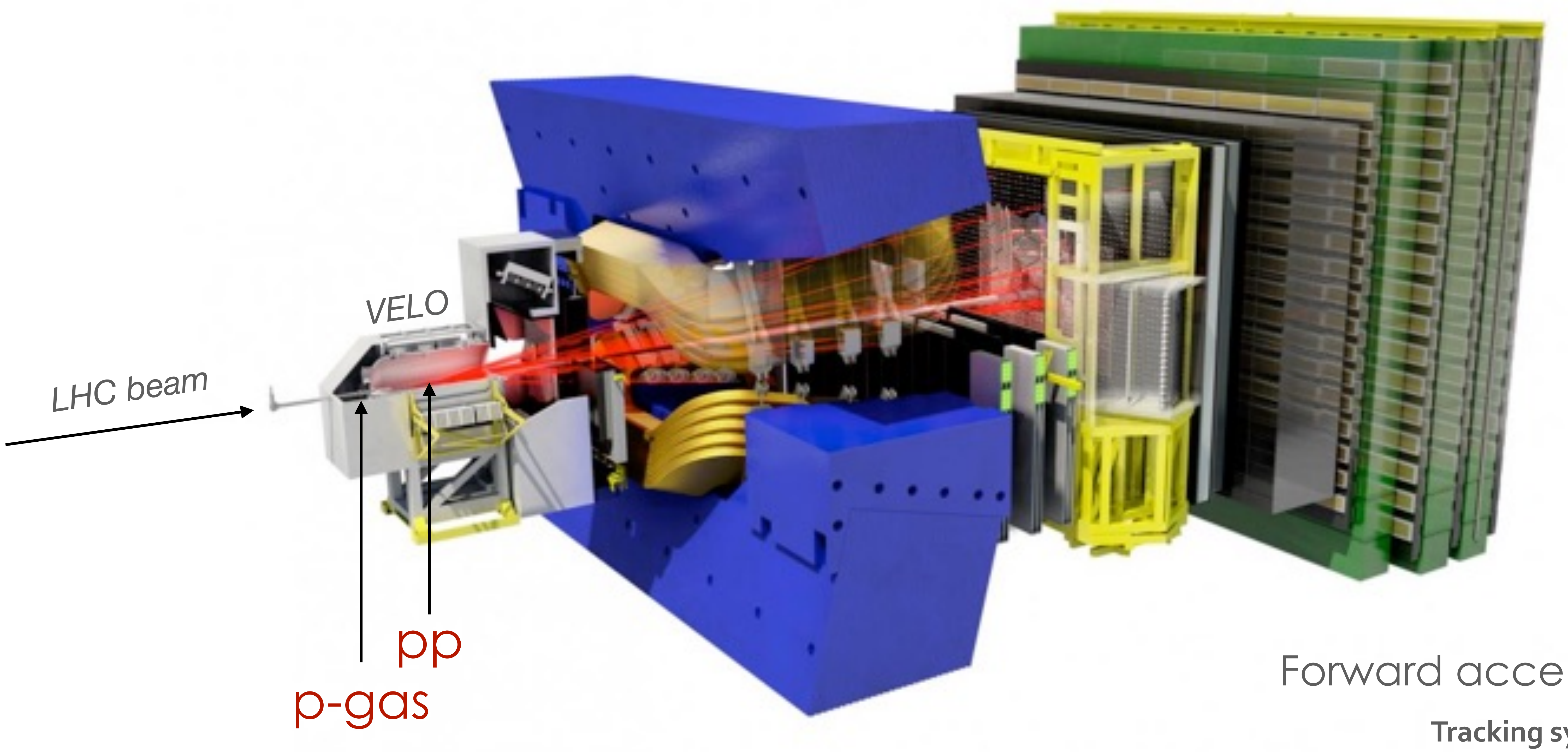
At the LHC fixed target pp, pp↑, pA, Pb-p, Pb-p↑ or Pb-A collisions, one has unique kinematic conditions at the poorly explored energy of √s ~ 100 GeV, up to large x



LHCb, a single-arm forward spectrometer perfectly suited for fixed target collisions



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



Forward acceptance: $2 < \eta < 5$

Tracking system momentum resolution

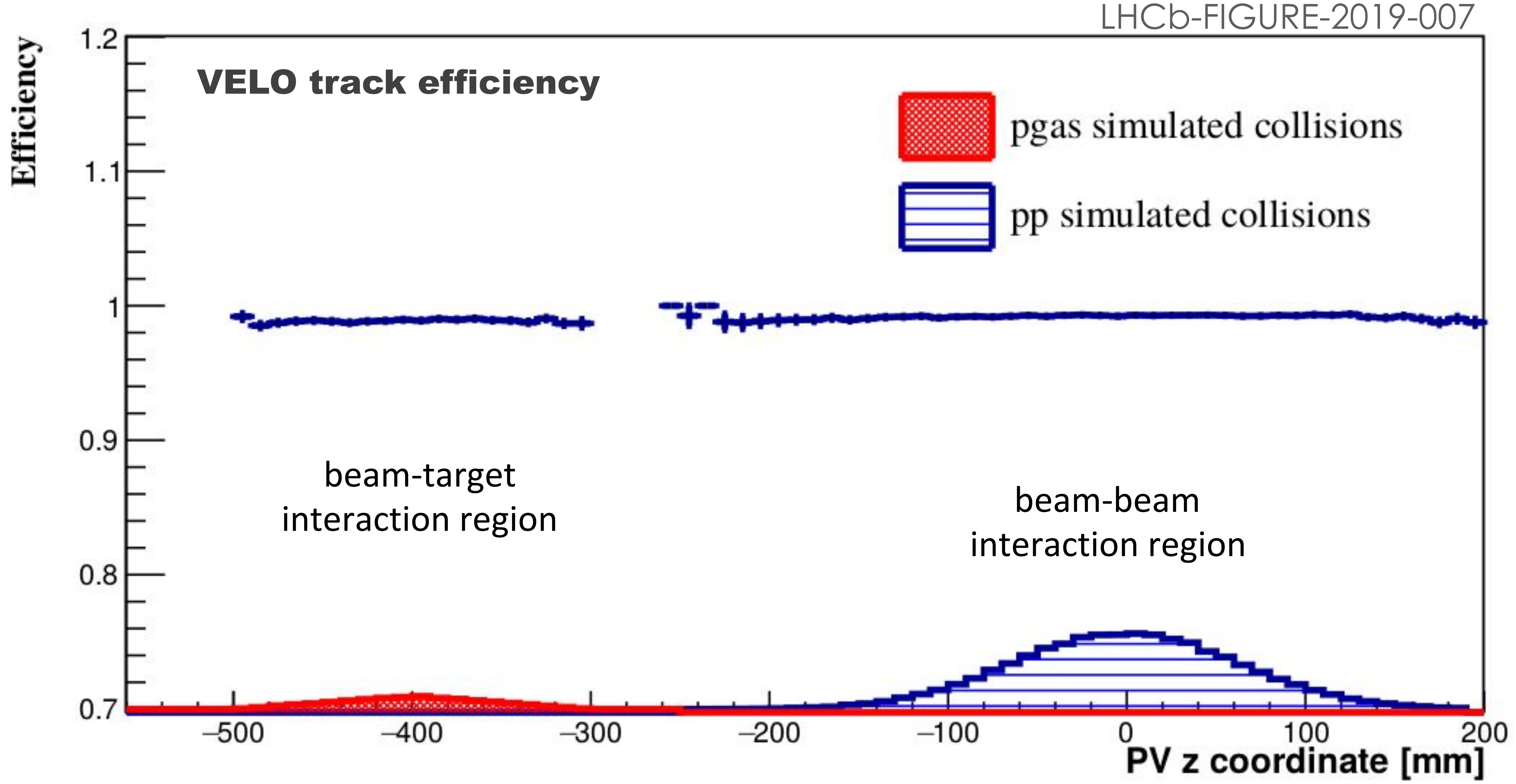
$\Delta p/p$ = 0.5%–1.0% (5 GeV/c – 100 GeV/c)

LHCb upgrade LS2

- Collision rate at 40 MHz
- Pile-up factor $\mu \approx 5$
- Remove L0 triggers (software trigger)
- Read out the full detector at 40 MHz
- Replace the entire tracking system

LHCb is the only experiment able to run both in collider and in fixed-target mode … simultaneously!

Simultaneous run for p-gas @ 115 GeV and pp @ 14 TeV



The two systems don't interfere each other and the reconstruction efficiencies stay unchanged

The DAQ data flow increases of 1-3% only

Why

- -Advance our understanding of the large-x gluon, antiquark and heavy quark content in nucleons and nuclei
- -Advance our understanding of the dynamics and spin distributions of gluons inside (un)polarised nucleons
- -Access relevant measurements for astroparticle (DM, CR)
- -Study heavy-ion collisions between SPS and RHIC energies at large rapidities

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- Unique and large kinematic coverage
- High luminosity and high resolution detectors → rare probes
- Proton or Heavy-Ion Beam (Pb, O_2)
- Large variety of atomic gas targets: $H_2, D_2, He, N_2, O_2, Ne, Ar, Kr, Xe$
- Polarised targets: $H^{\uparrow}, D^{\uparrow}$
- Marginal impact on LHC beam and mainstream physics at current experiments

(beam lifetime reduction for H: $1/e_{\text{lifetime}} > 2000$ days)

Statistics in full synergy mode (1 yr data taking)

LHCb-PUB-2018-015

Storage cell assumptions	gas type	gas flow (s^{-1})	peak density (cm^{-3})	areal density (cm^{-2})	time per year (s)	int. lum. (pb^{-1})
Unpolarised gas	He	1.1×10^{16}	10^{12}	10^{13}	3×10^{3}	0.1
	Ne	3.4×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1
	Ar	2.4×10^{15}	10^{12}	10^{13}	2.5×10^{6}	80
	Kr	8.5×10^{14}	5×10^{11}	5×10^{12}	1.7×10^{6}	25
	Xe	6.8×10^{14}	5×10^{11}	5×10^{12}	1.7×10^{6}	25
	H_2	1.1×10^{16}	10^{12}	10^{13}	5×10^{6}	150
	D_2	7.8×10^{15}	10^{12}	10^{13}	3×10^{5}	10
	O_2	2.7×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1
	N_2	3.4×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1

Reconstructed particles

		example pAr @115 GeV
Int. Lumi.		80/pb
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

All this is going to happen at LHCb

LHC spin

CERN-LHCC-2019-005
LHCB-TDR-020

arXiv:1901.08002
arXiv:2105.10012

Phase I
unpolarised target

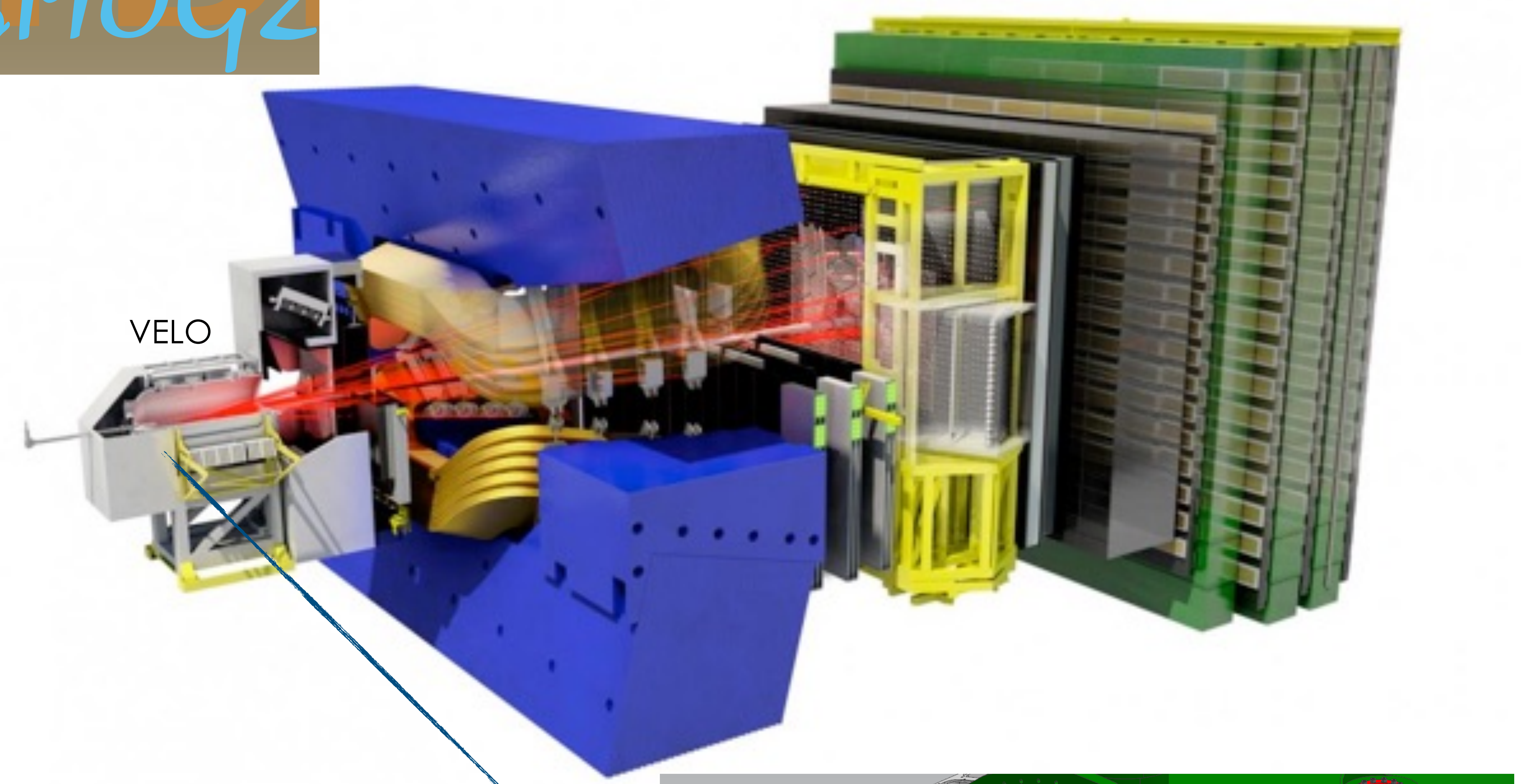
Now!

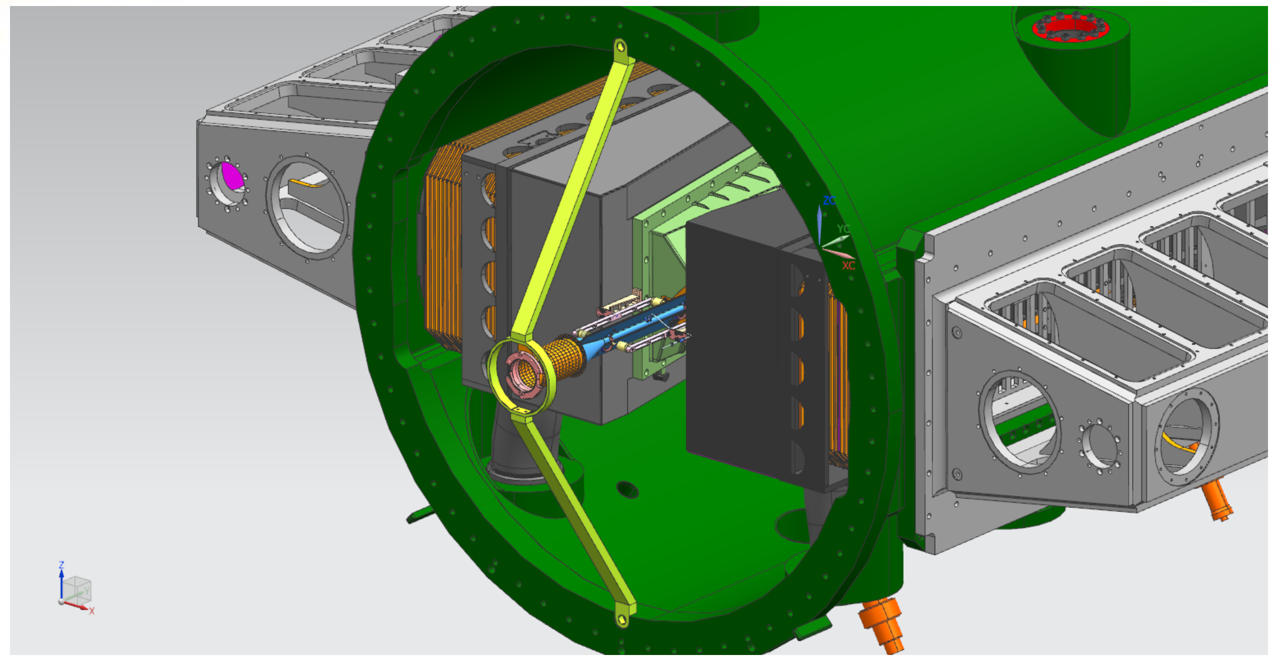
Installation in August 2020
Data taking from LHC Run3 (2022)

Phase II
transversely polarised H and D target

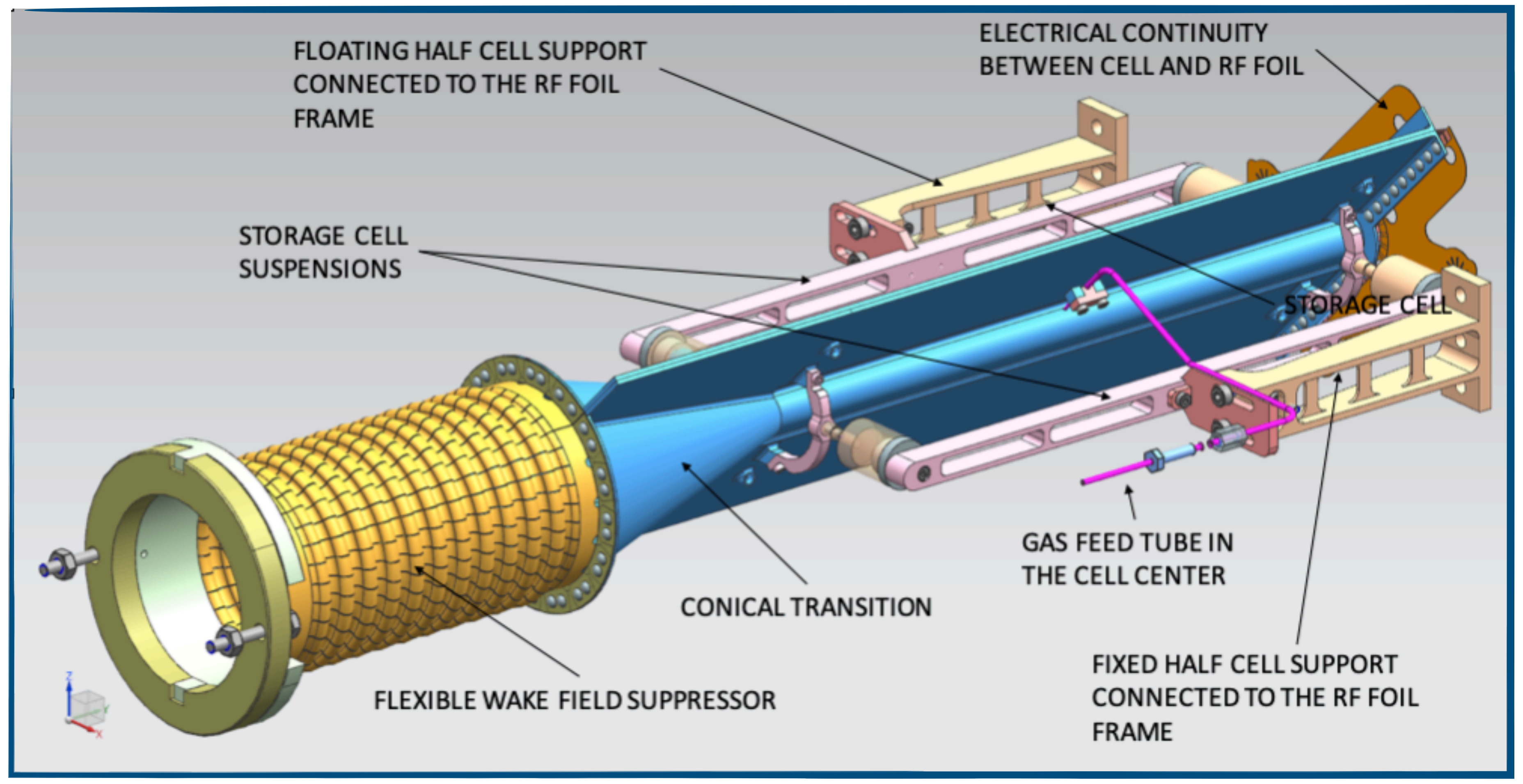
We aim at installing it in the LHC LS3 (2025-2027)

SMOG2

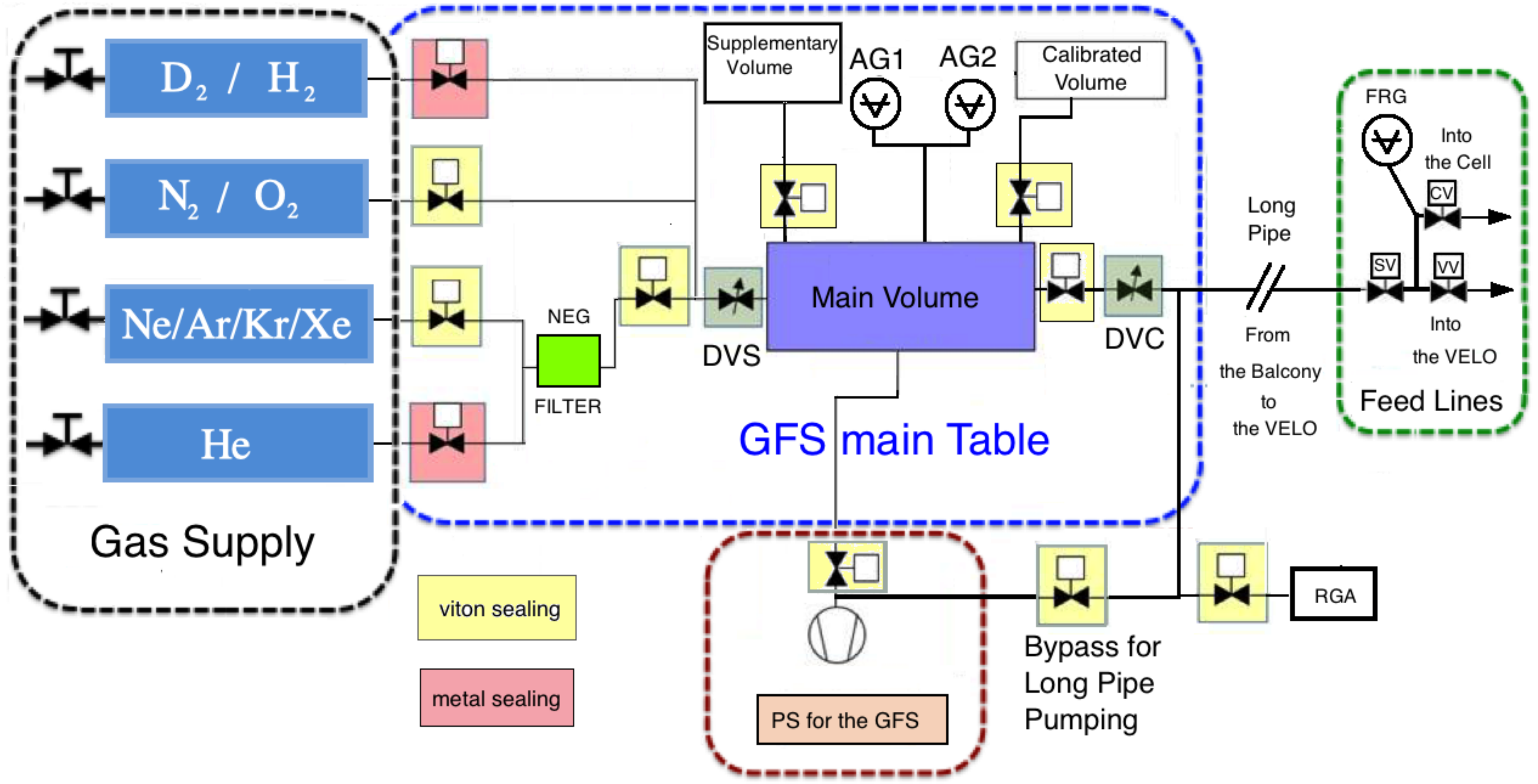




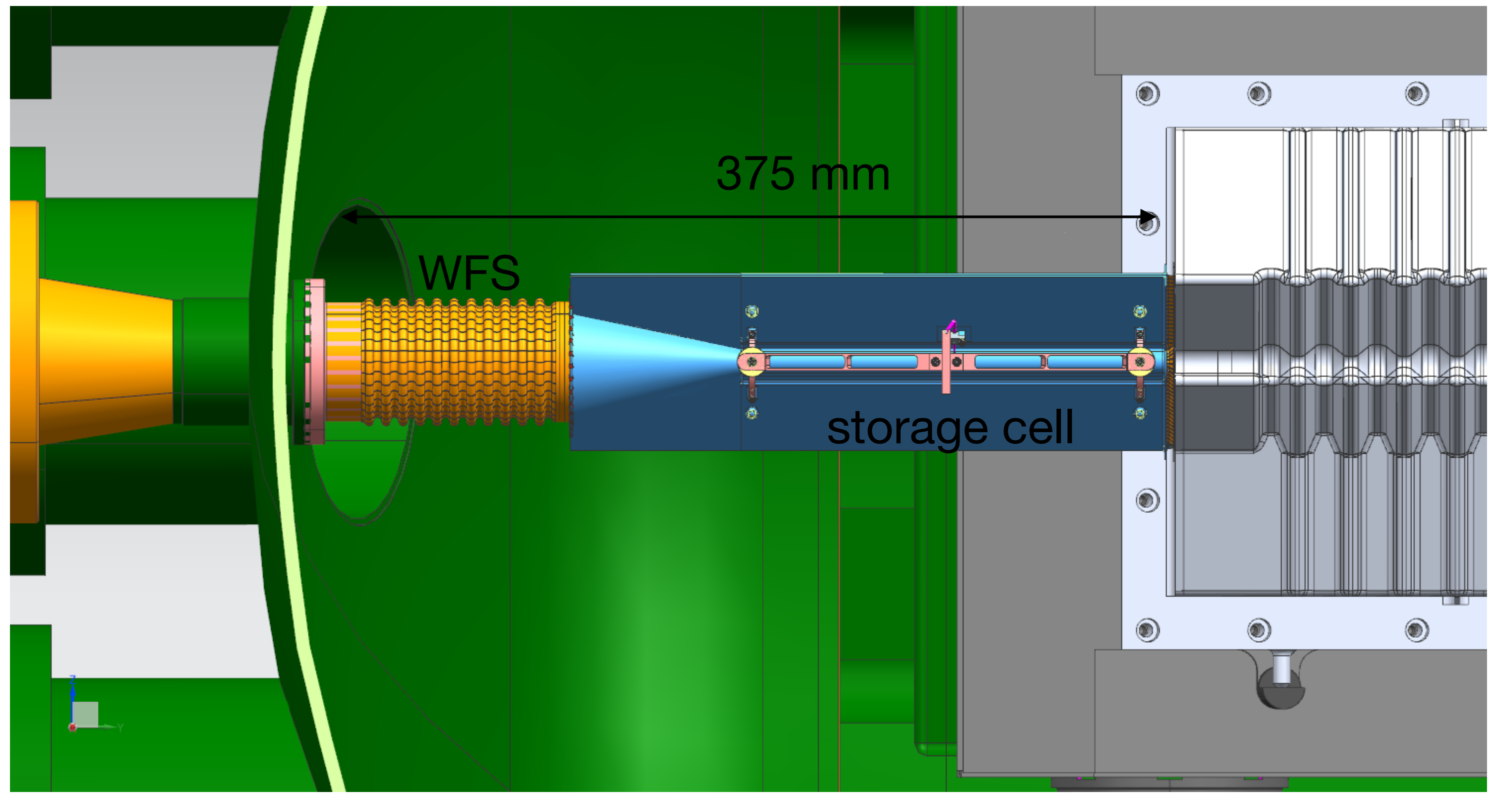
It is the only object into the LHC primary vacuum

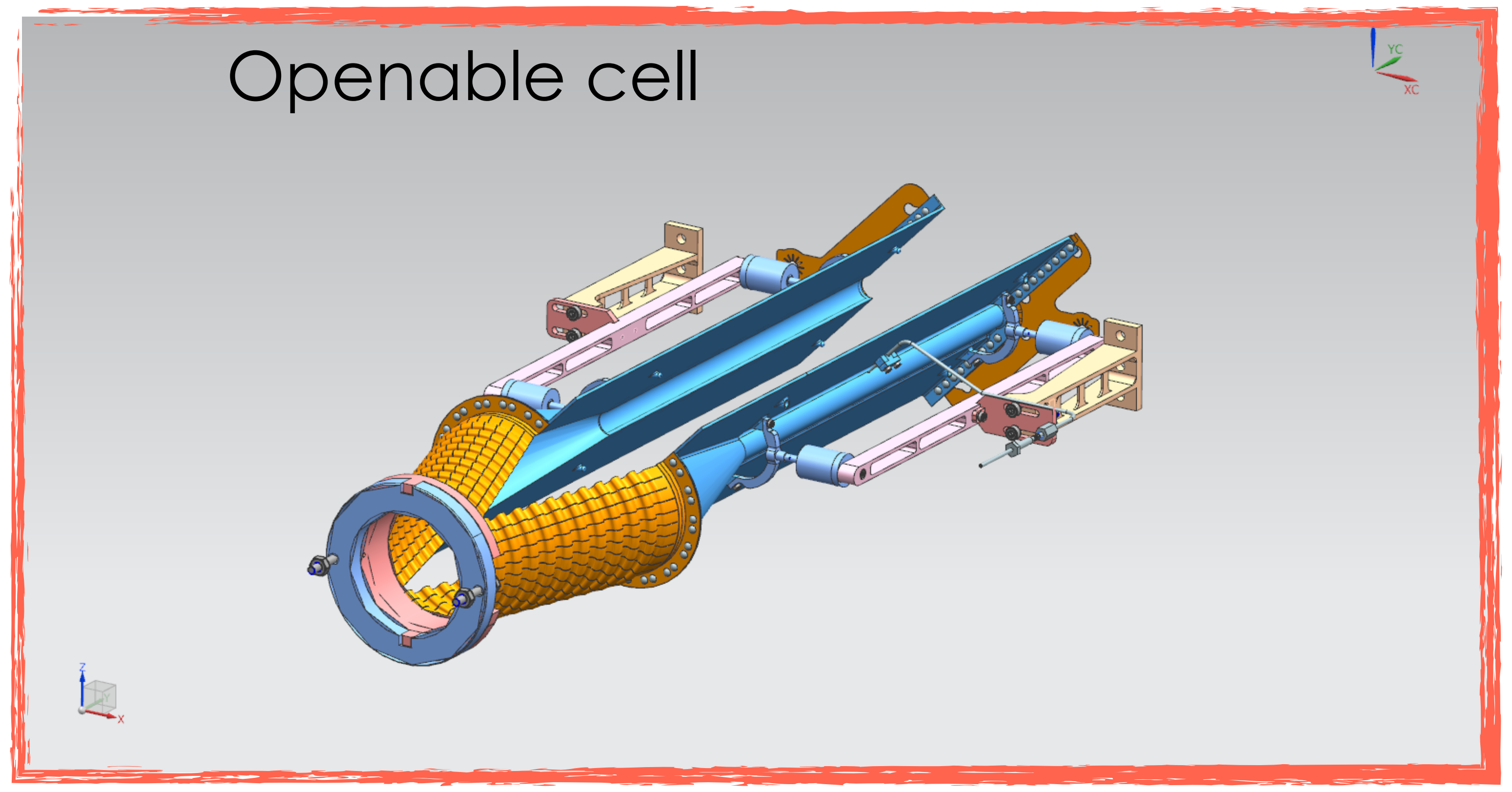


Gas Feed System



Internal side view





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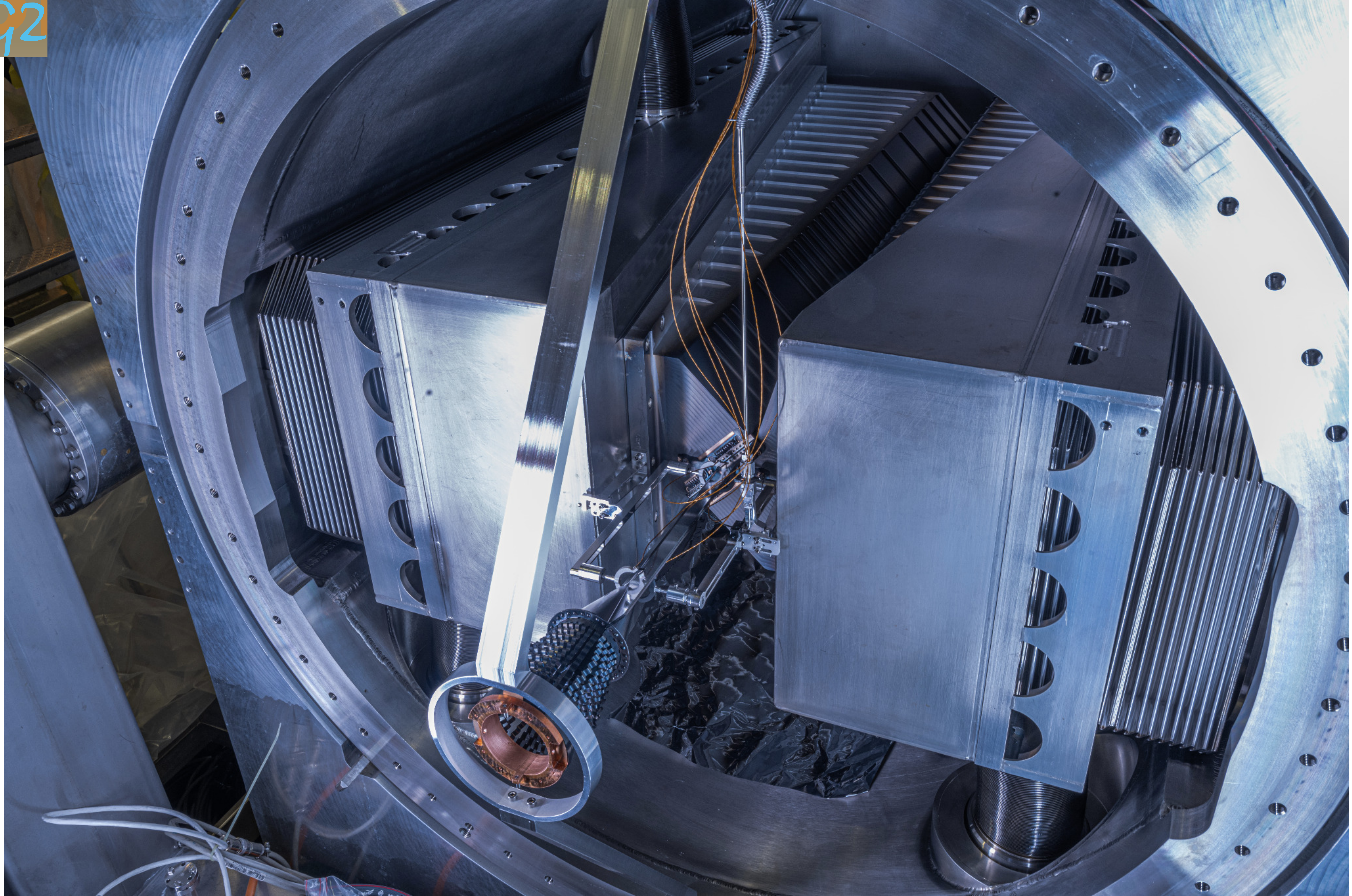

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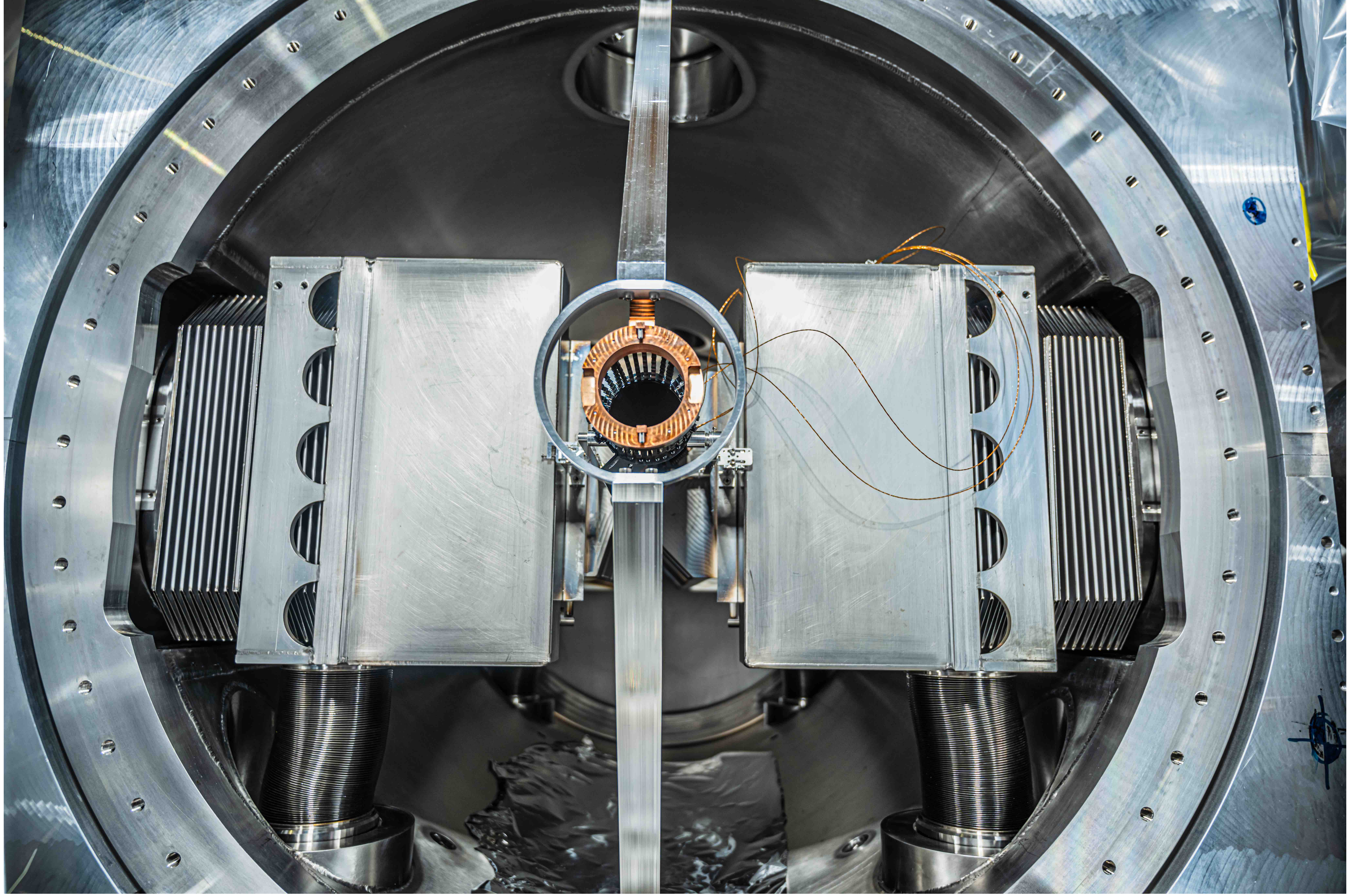
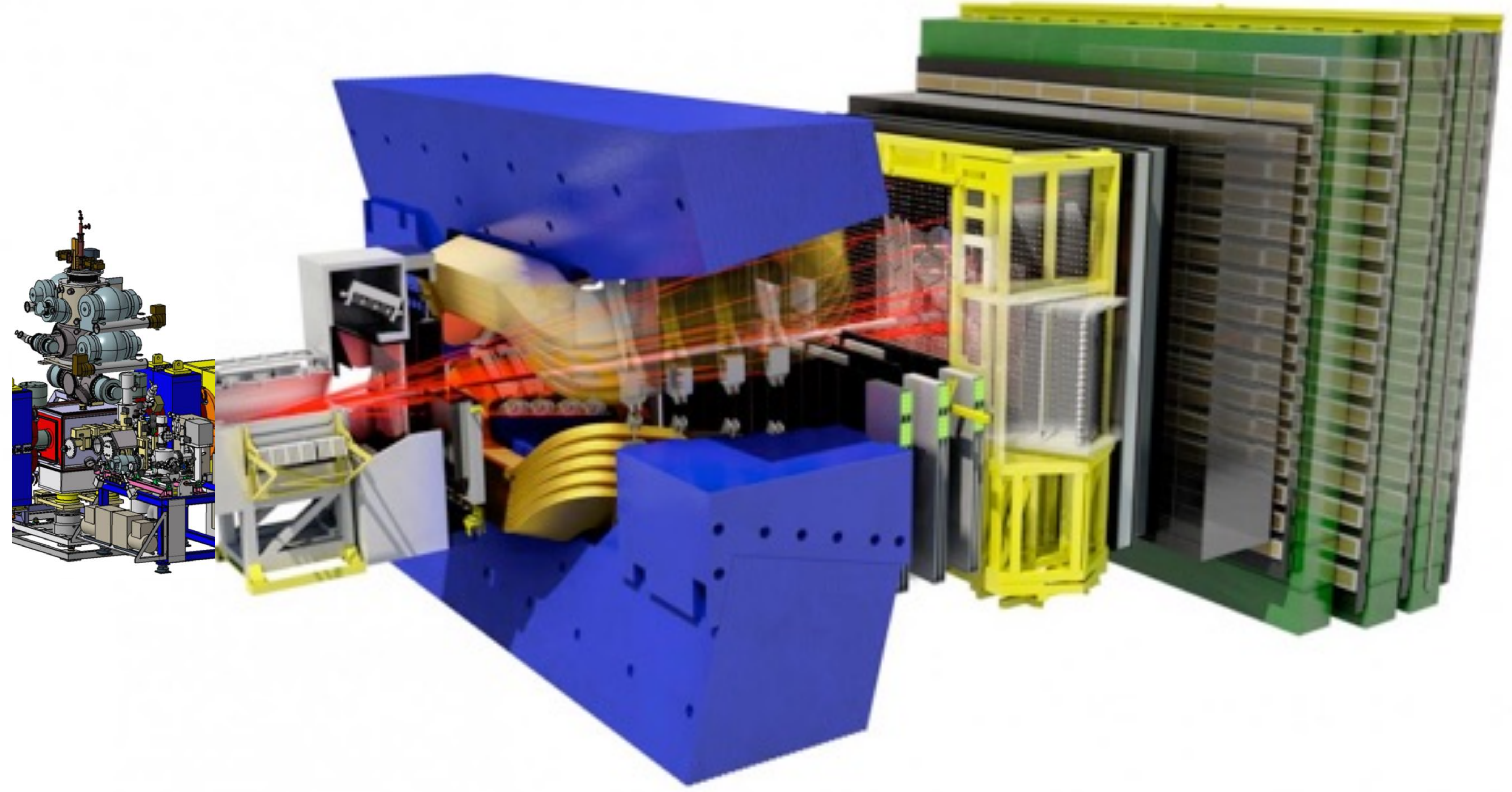


Besides the unique scientific production, the SMOG2 system, during the LHC Run 3 (from 2022), will deliver the first data usable for studying the mutual target-beam interactions providing a fundamental playground for the R&D of LHCspin



Polarised target

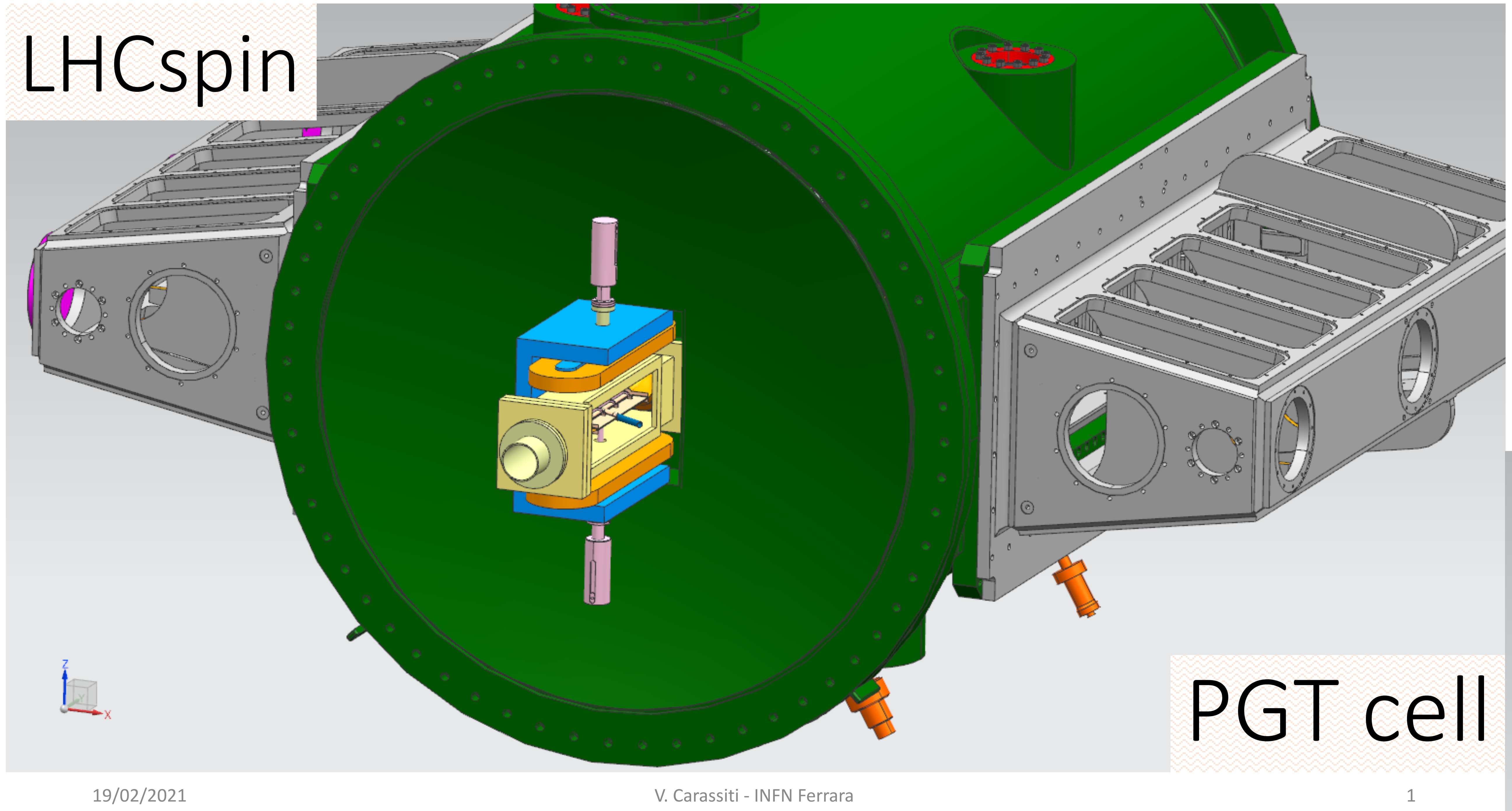
The technique proposed is well consolidated

Design follows the successful HERMES Polarised Gas Target which ran at HERA 1996 – 2007, and the follow-up PAX target operational at COSY (FZ Jülich)

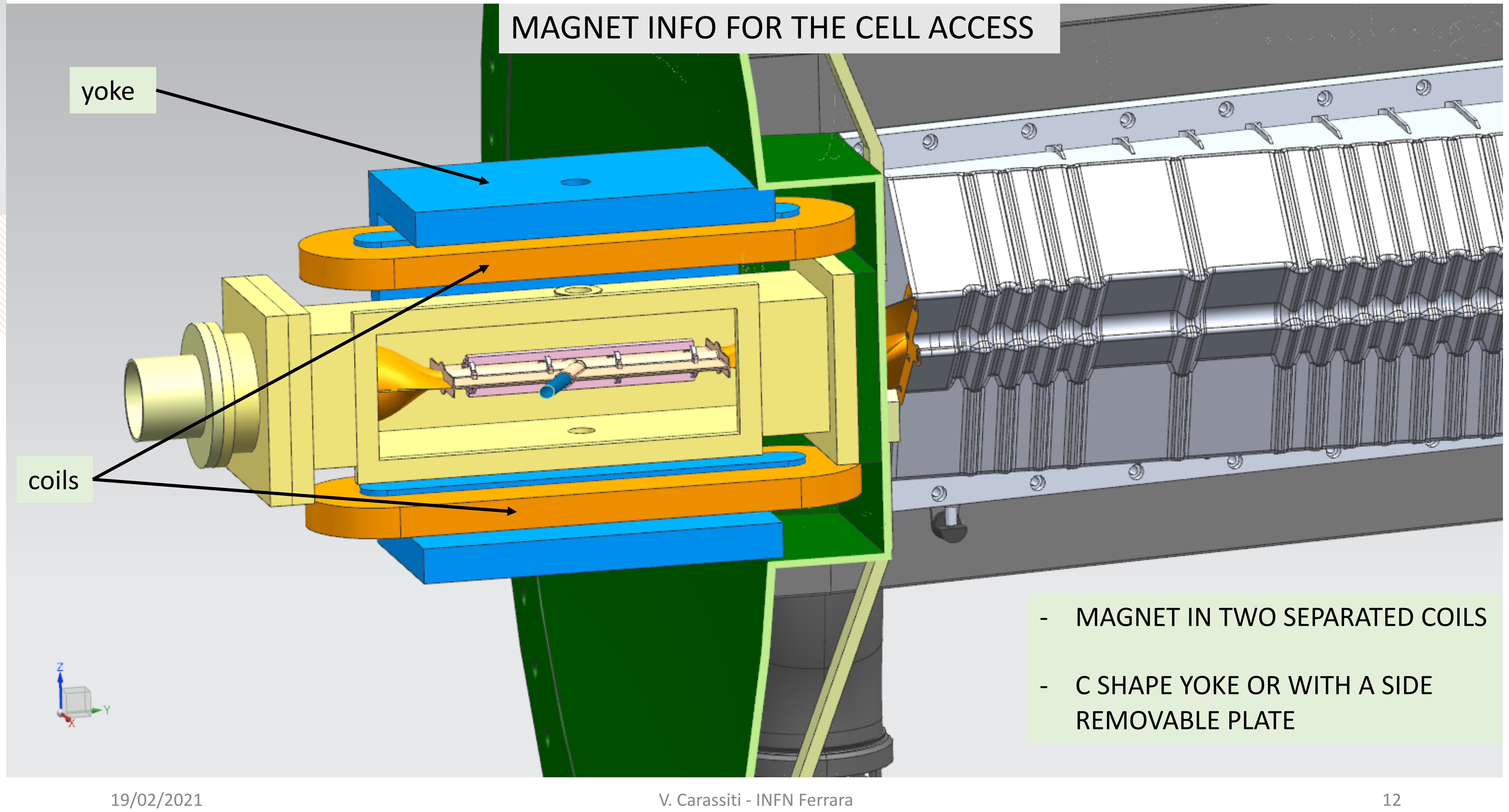
However the R&D is complex and needs several innovative developments

must be compacted in 1.2 m

hermes



The Atomic Beam Source, the Polarimetrer and the Gas Analyzer are not drawn (still in a very early stage of the R&D)



LHCspin represents the only way to have polarised collisions at the LHC

Conclusions

- A lively and fast-growing fixed-target program is being developed at LHC, in particular with the LHCb spectrometer, exploiting the unique kinematic conditions provided by a TeV-scale beam and a fully instrumented forward spectrometer
- The installation of the first storage cell target for unpolarized gases already happened in August 2020 and will start taking data from LHC Run3 (2022). The PGT could come few years later.

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Fixed target collisions at the LHC represent a unique possibility for *a laboratory for QCD and astroparticle* in unexplored kinematic regions … in a realistic time schedule