Unpolarized and polarized high-density gas target at the LHC

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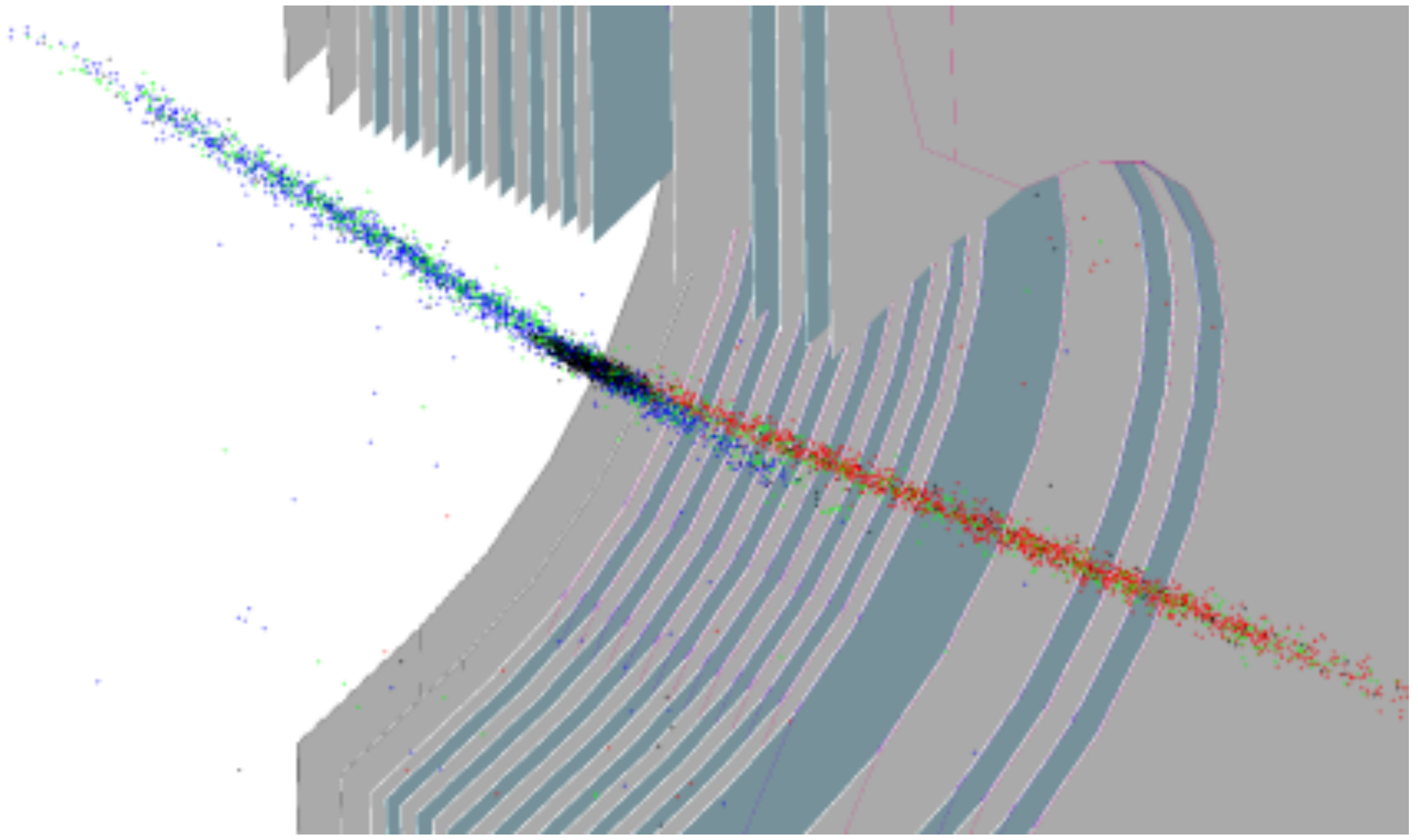
LHCb

Center for Frontiers in Nuclear Science
Exploring a Fixed-Target Program at the EIC: Feasibility and Physics Opportunities

Stony Brook, 19/29/25

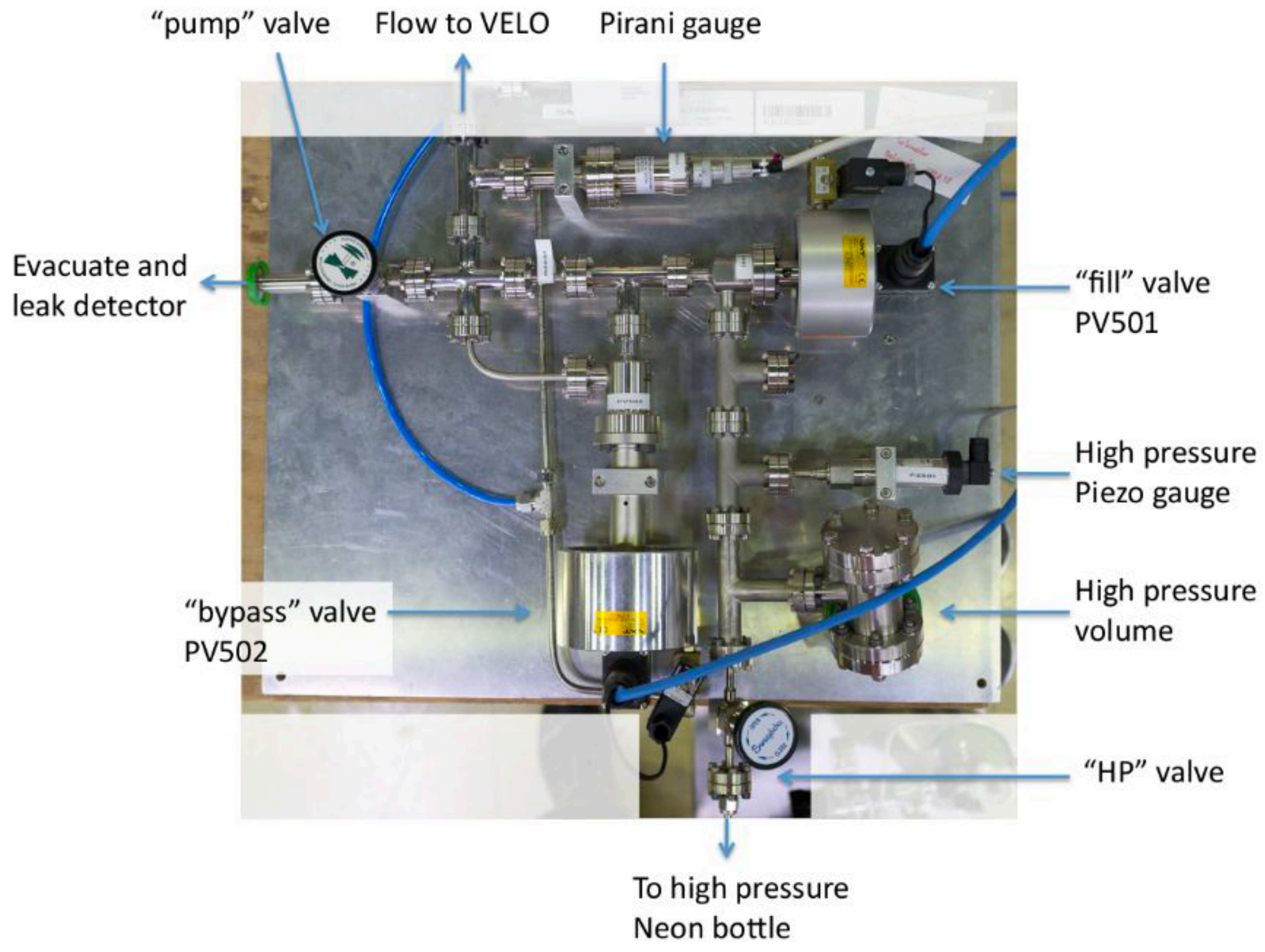
LHCb as fixed gas target experiment

The original idea was to inject gas into the beam pipe to have a precise luminosity measurement via beam-gas imaging technique

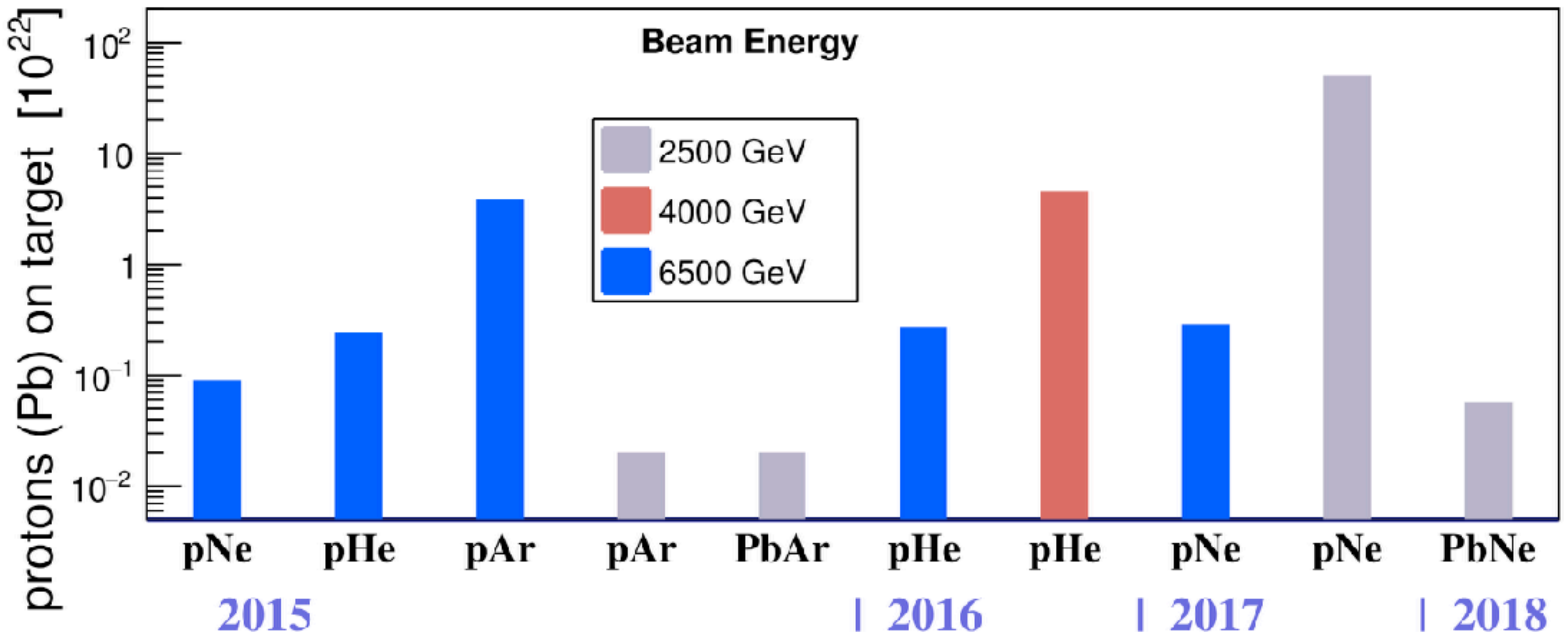


$$\mathcal{L} \simeq 2c \cdot cos^2\alpha \cdot n_b N_1 N_2 \nu_{rev} \int \rho_1(x,y,z,t)\rho_2(x,y,z,t)\, dxdydzdt$$

-Very simple injection system, with only 1 gas reservoir
-Gas spread around ±20 m from the PV
-Trigger rate 0.5 Hz (with 10^{11} protons in the beam), and a vacuum level into the beam pipe 10^{-7} mbar (LHC nominal vacuum 10^{-9} mbar)

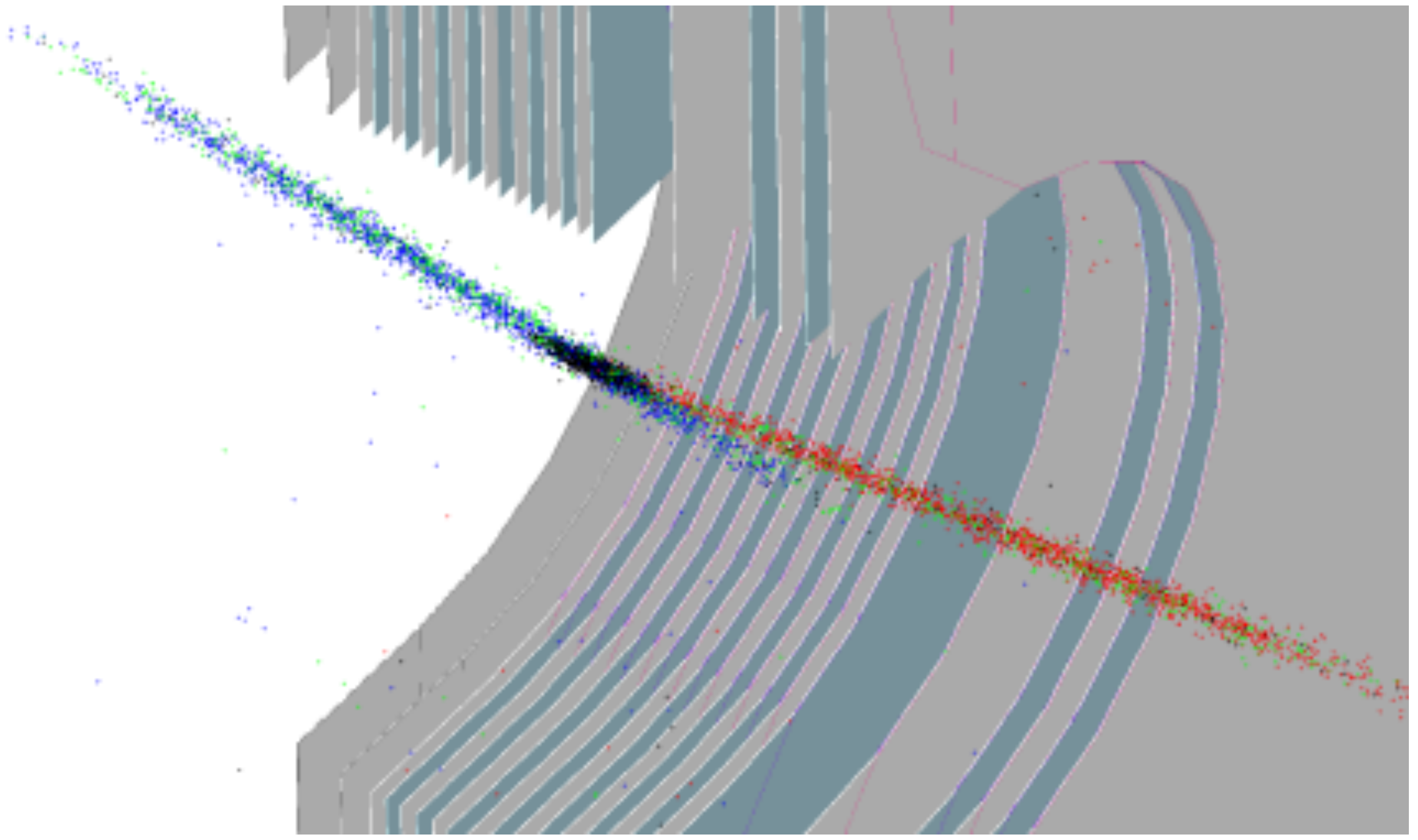


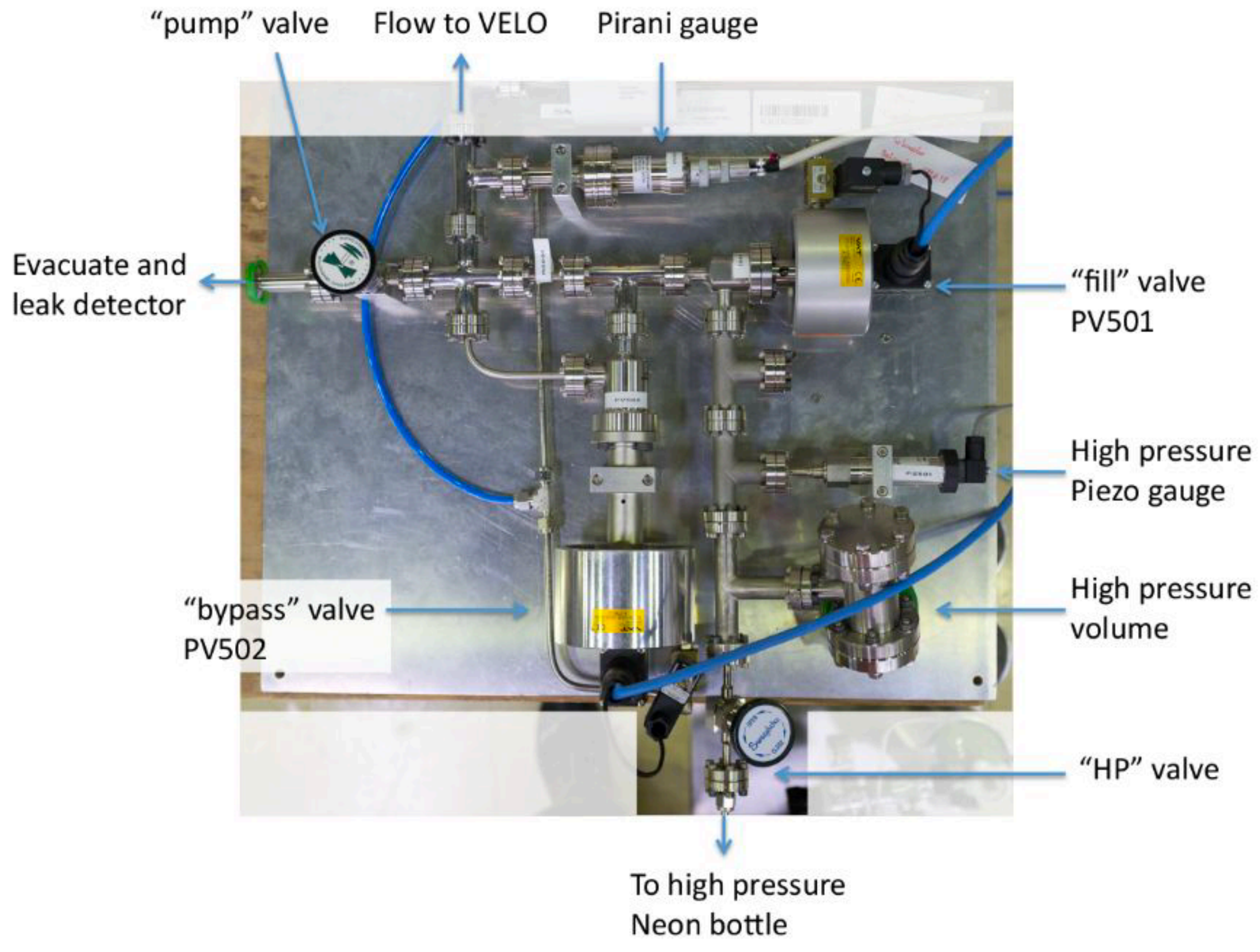
Nucl. Instrum. Meth. A553 (2005) 388

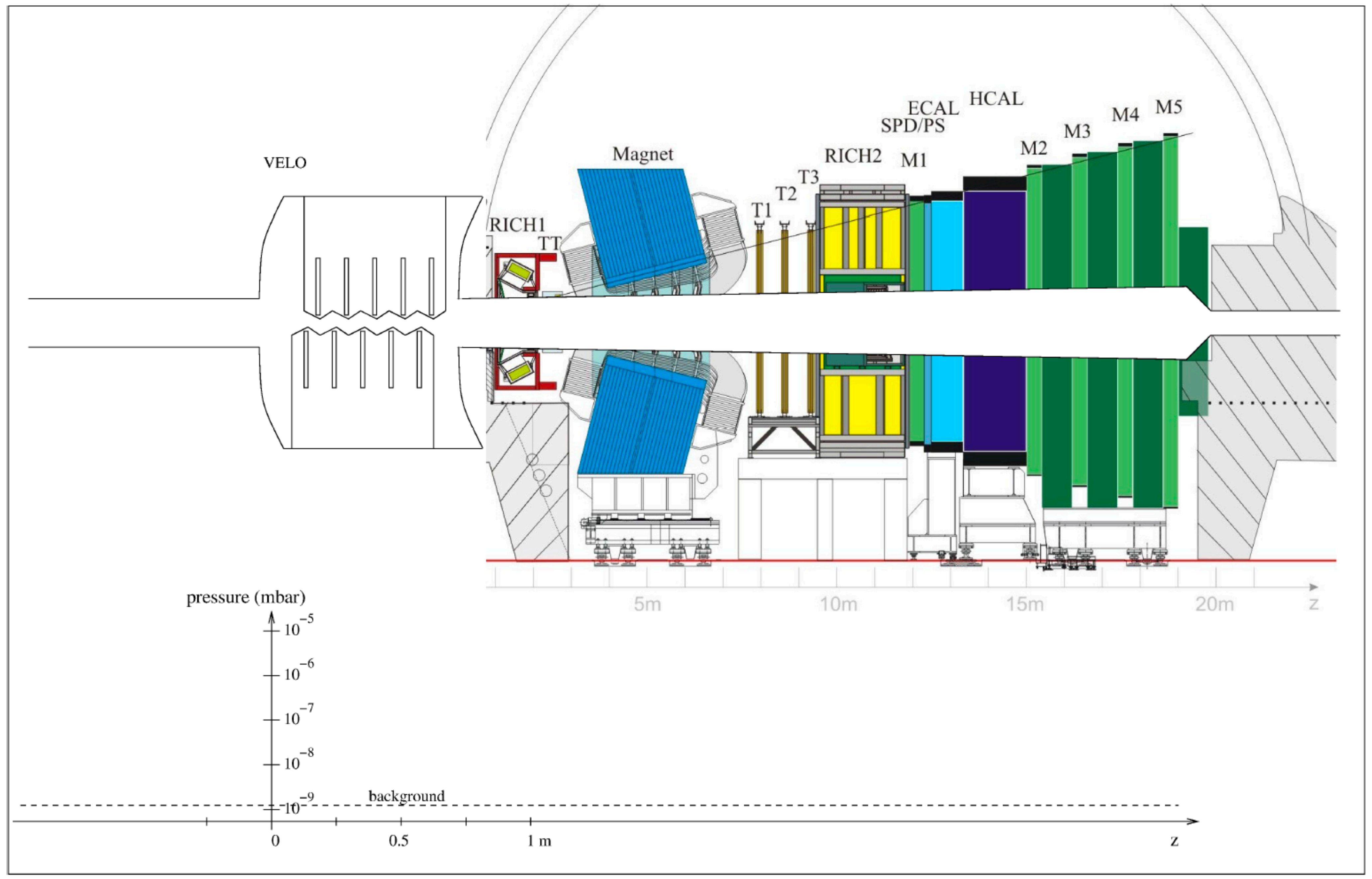


Nevertheless LHCb collected high quality data

LHCb as fixed gas target experiment







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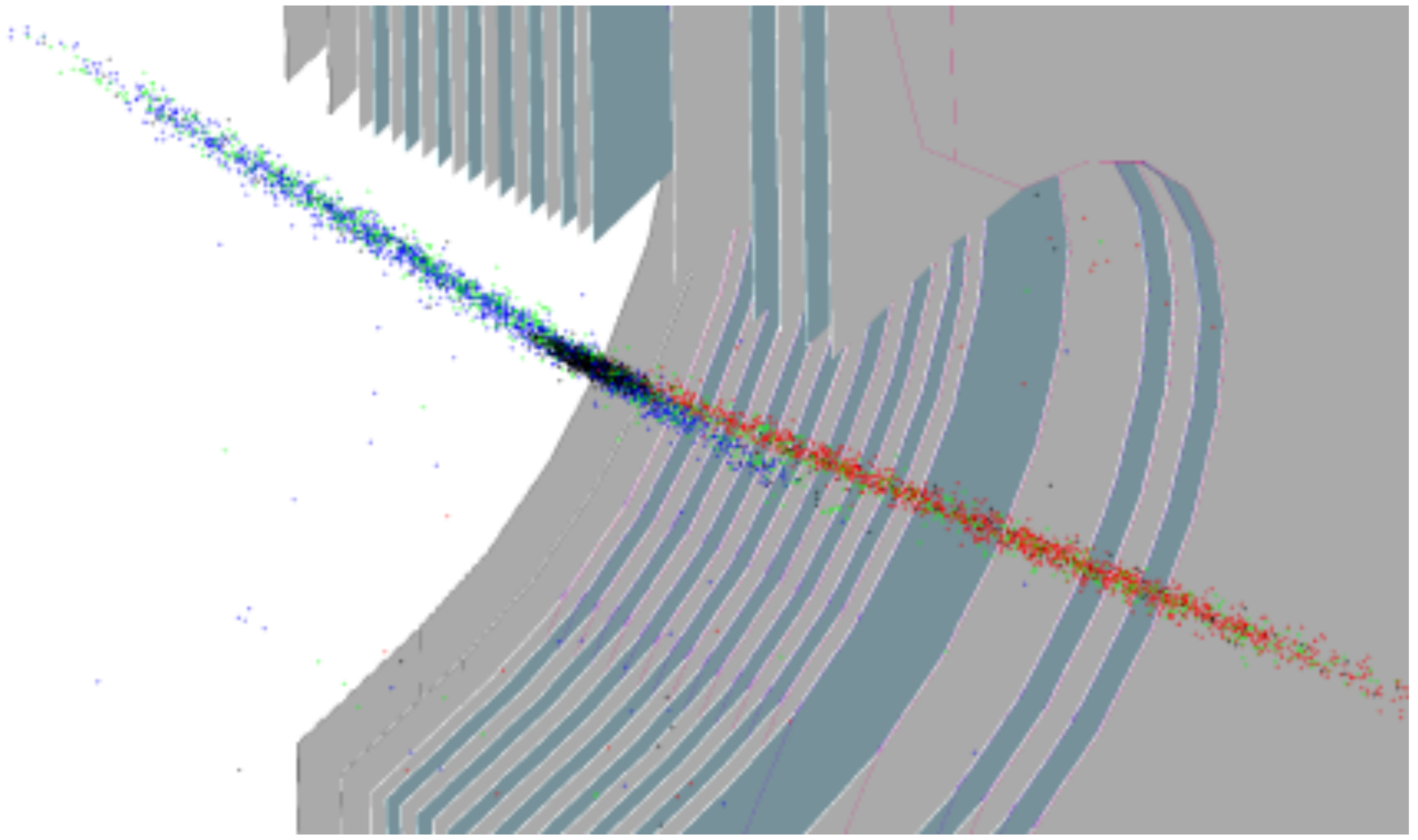
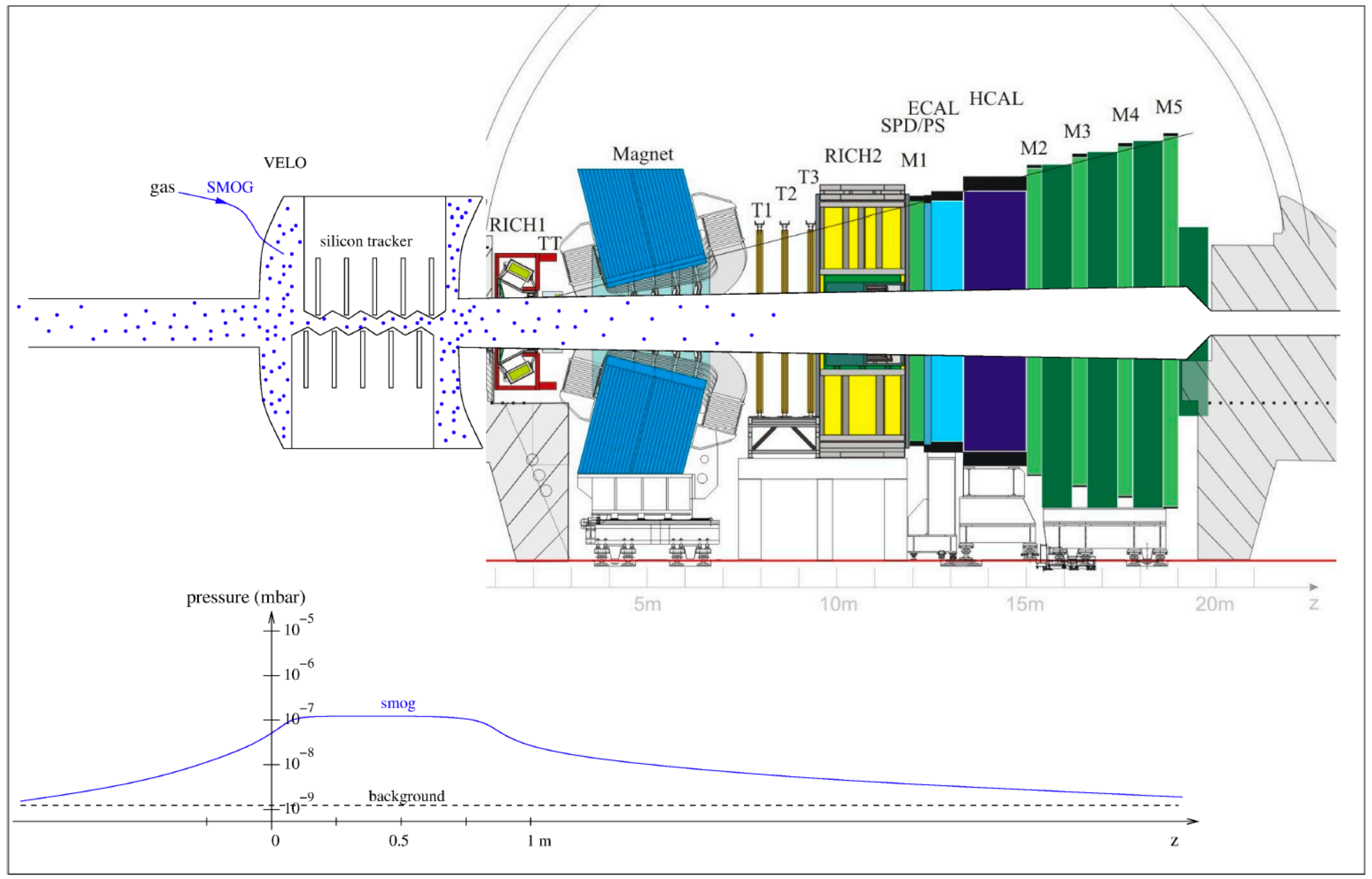
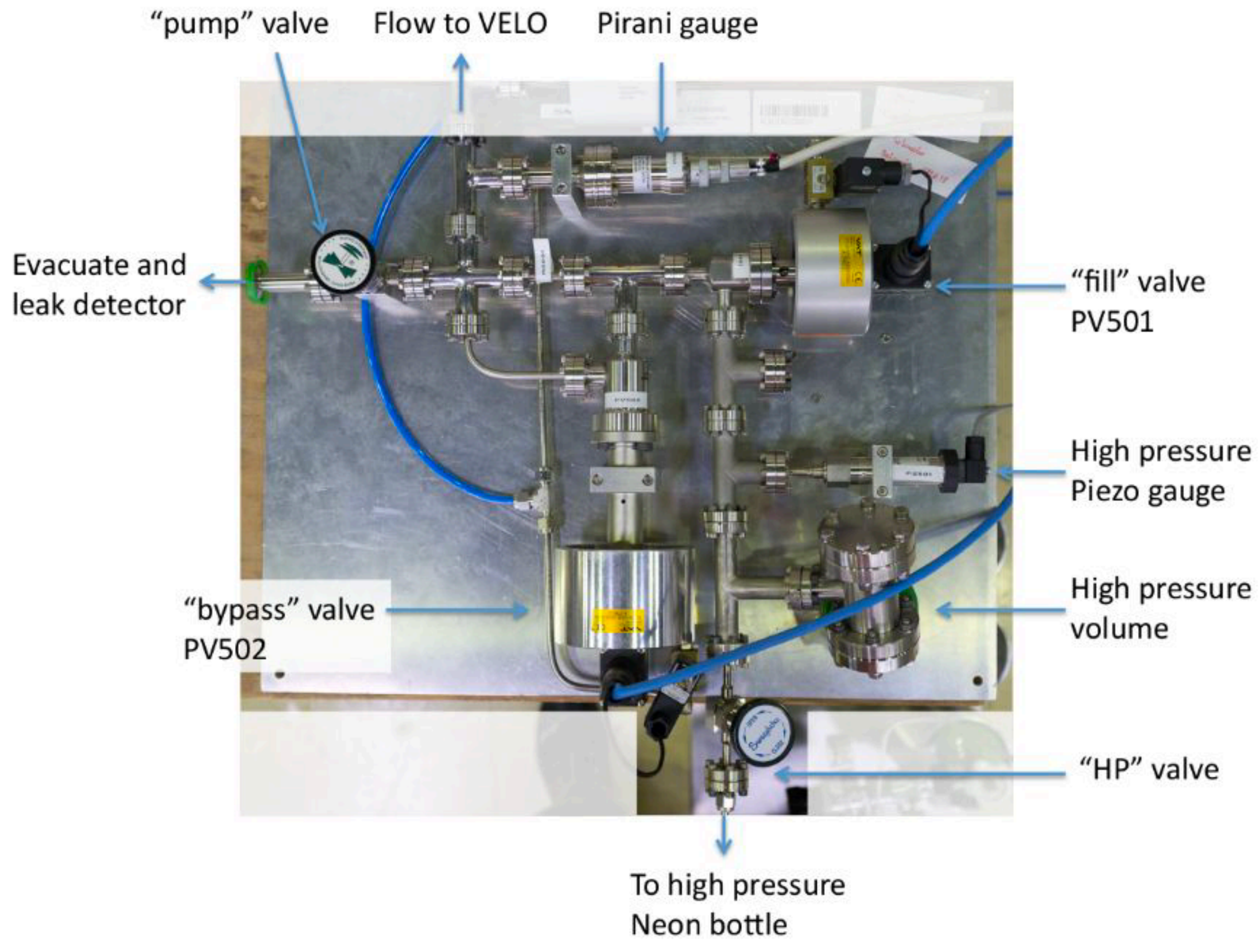


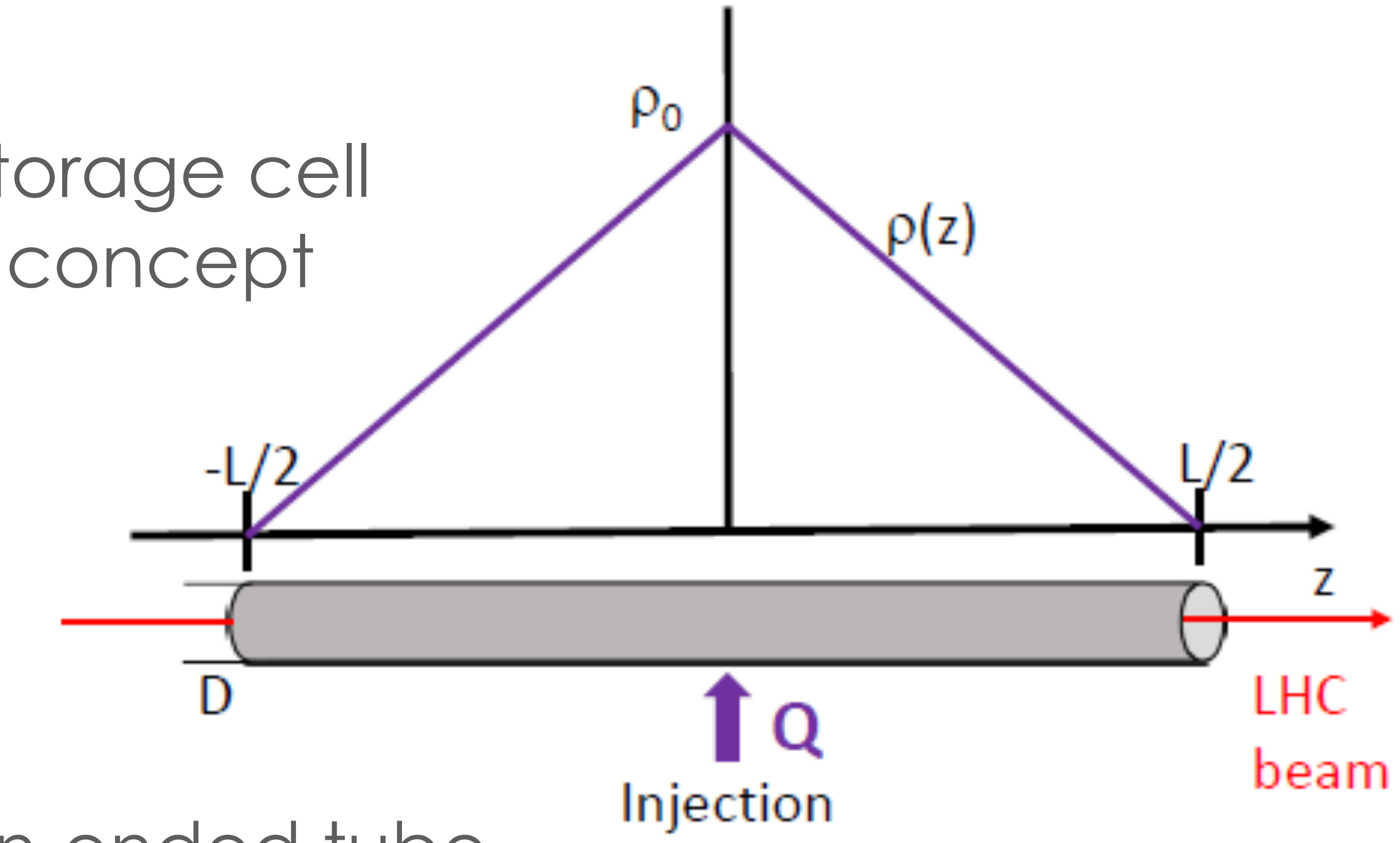




Since 2022 - **SMOG2**, the first LHC internal storage cell

A gas storage cell can boost the gas density by a factor 8-35 for the same flow as in Run2 with SMOG

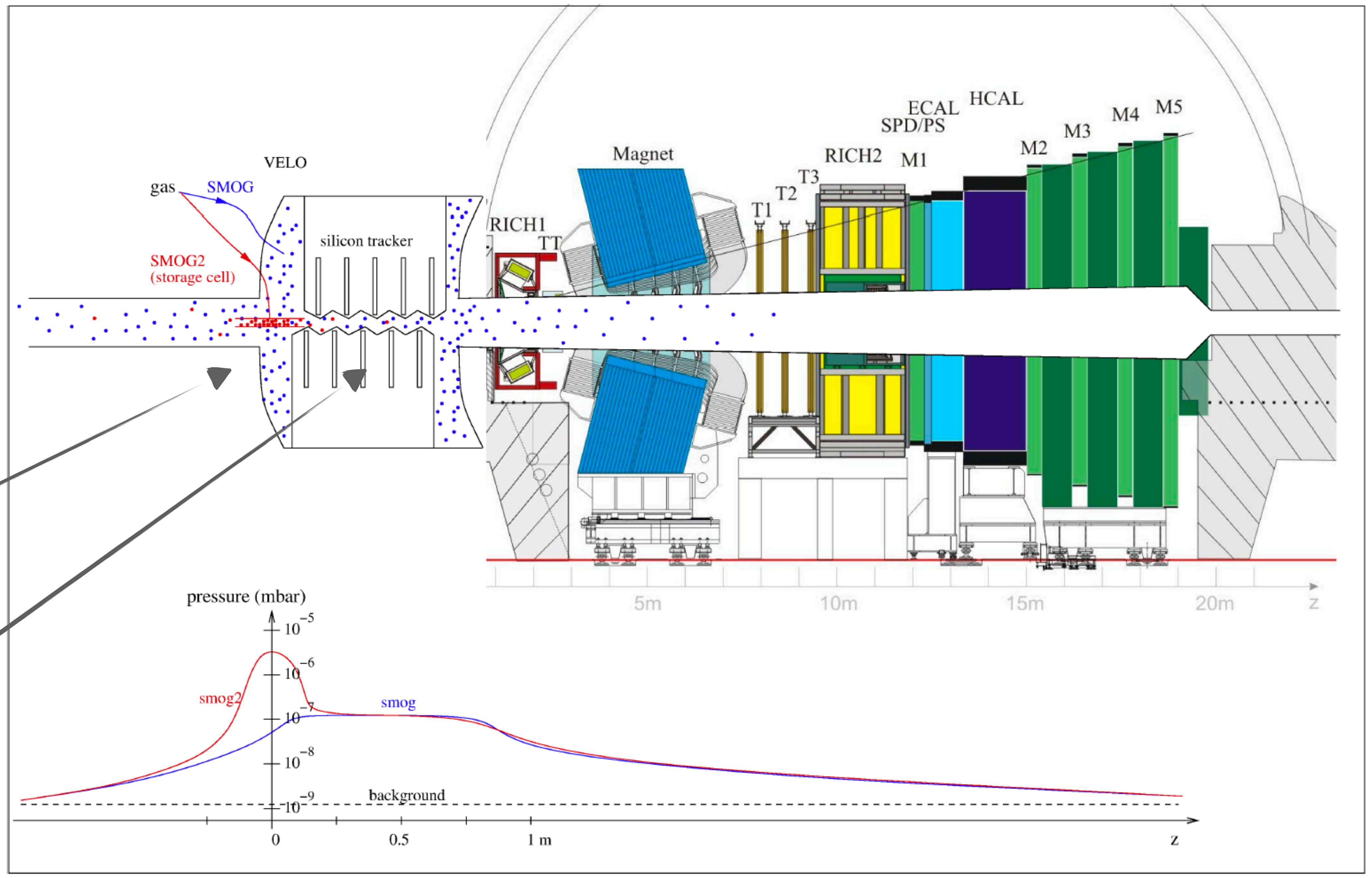
Storage cell concept



Open-ended tube

beam-gas IP

beam-beam IP



The PV$_{p\text{-}gas}$ and PV$_{beam\text{-}beam}$ are well separated, no need for dedicated runs

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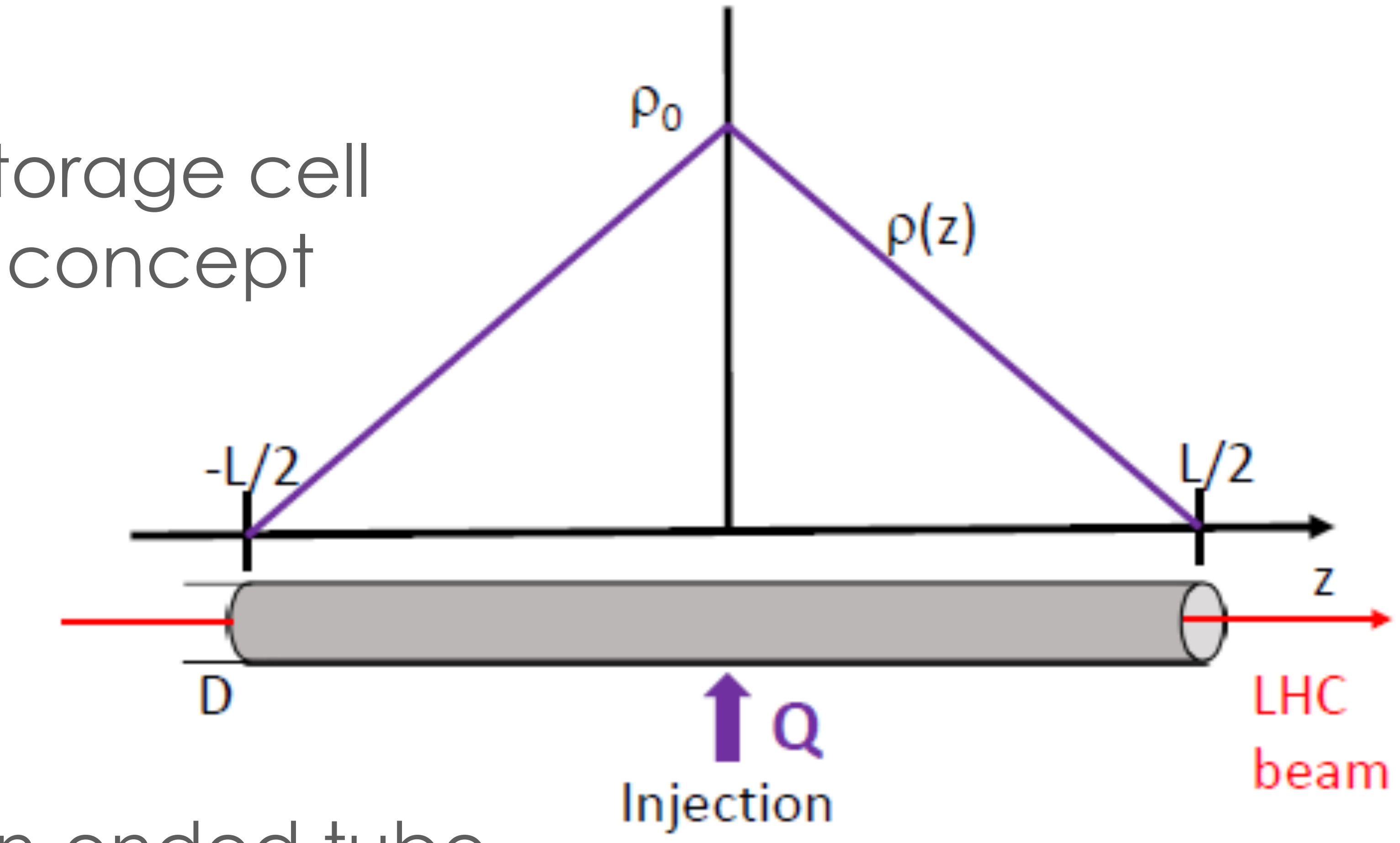

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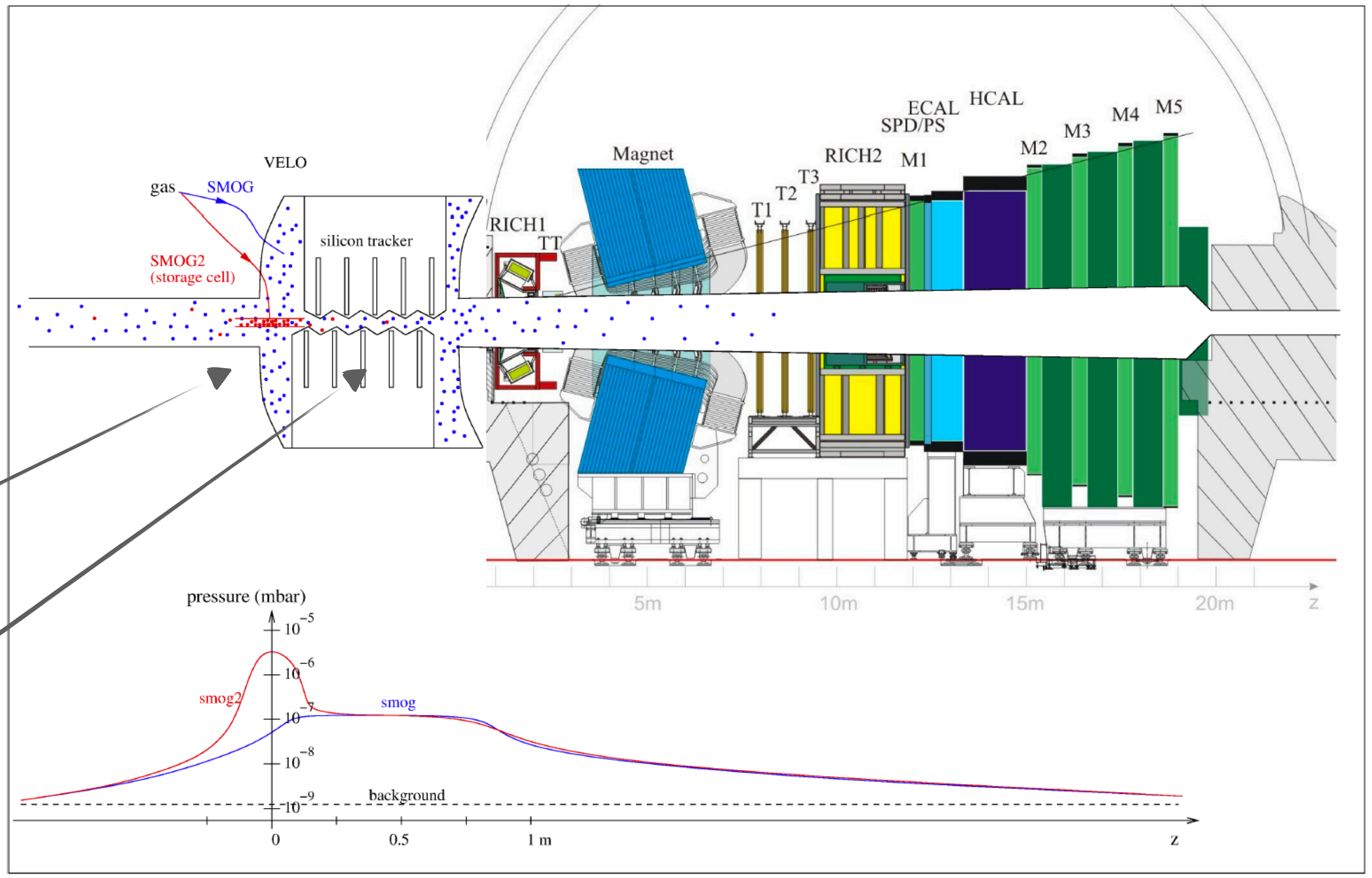


The $PV_{p\text{-}gas}$ and $PV_{beam\text{-}beam}$ are well separated, no need for dedicated runs

Target areal density

$$\theta = \frac{1}{2}\rho_0 L = \frac{1}{2}\frac{\Phi}{C_{tot}}L = \frac{1}{2}\frac{\Phi}{3.81\sqrt{\frac{T}{M}}\cdot\frac{D^3}{L+1.33\cdot D}}L$$

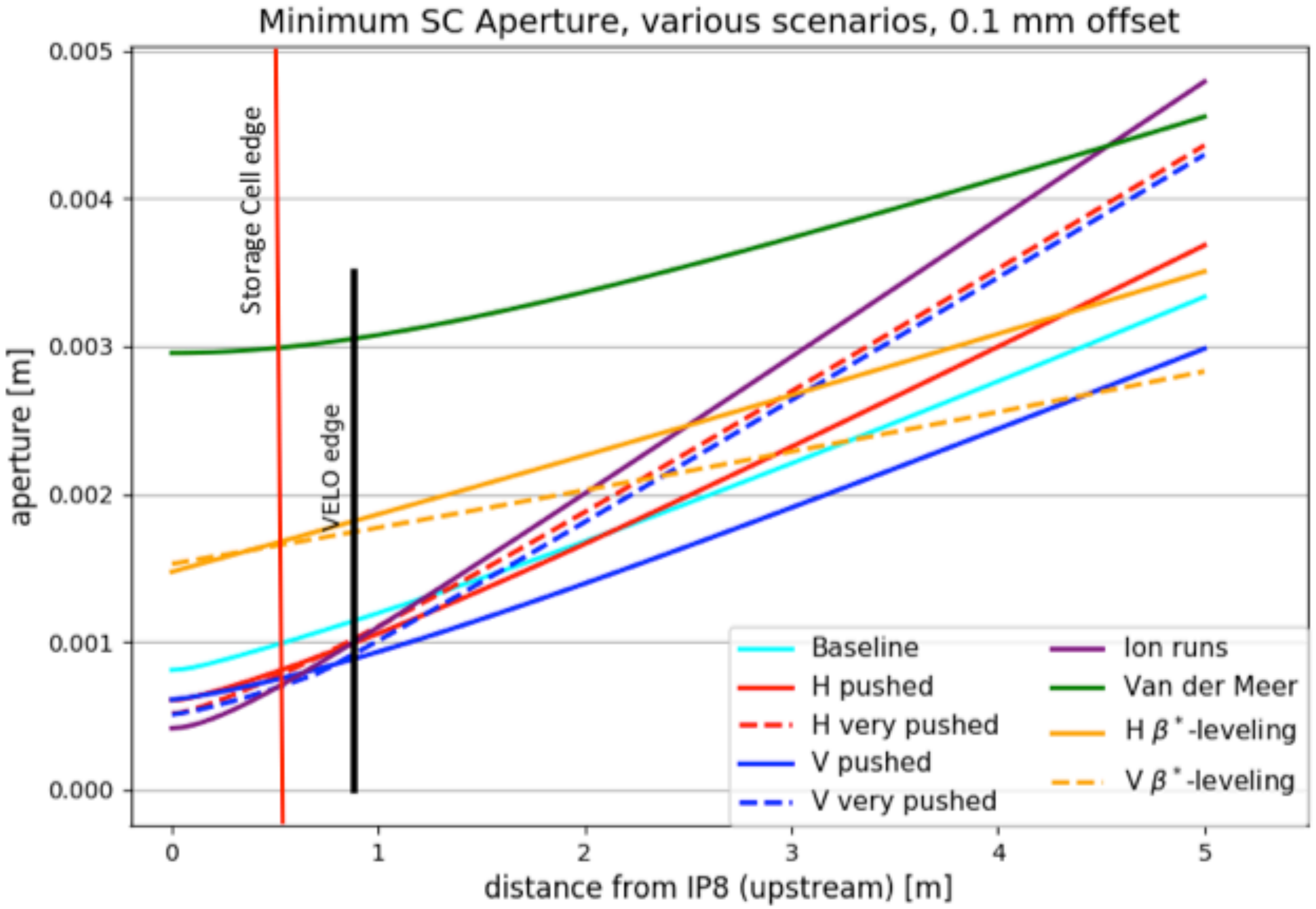
cell length

cell internal diamater

Longer is better, but going far from the tracking detector is a limitation

Smaller is better, but going close to the beam is dangerous

The beam aperture is one of the main parameters to be considered



VdM scan represents the most critical situation, when the beam reaches of 3 mm at the place where the storage cell is installed

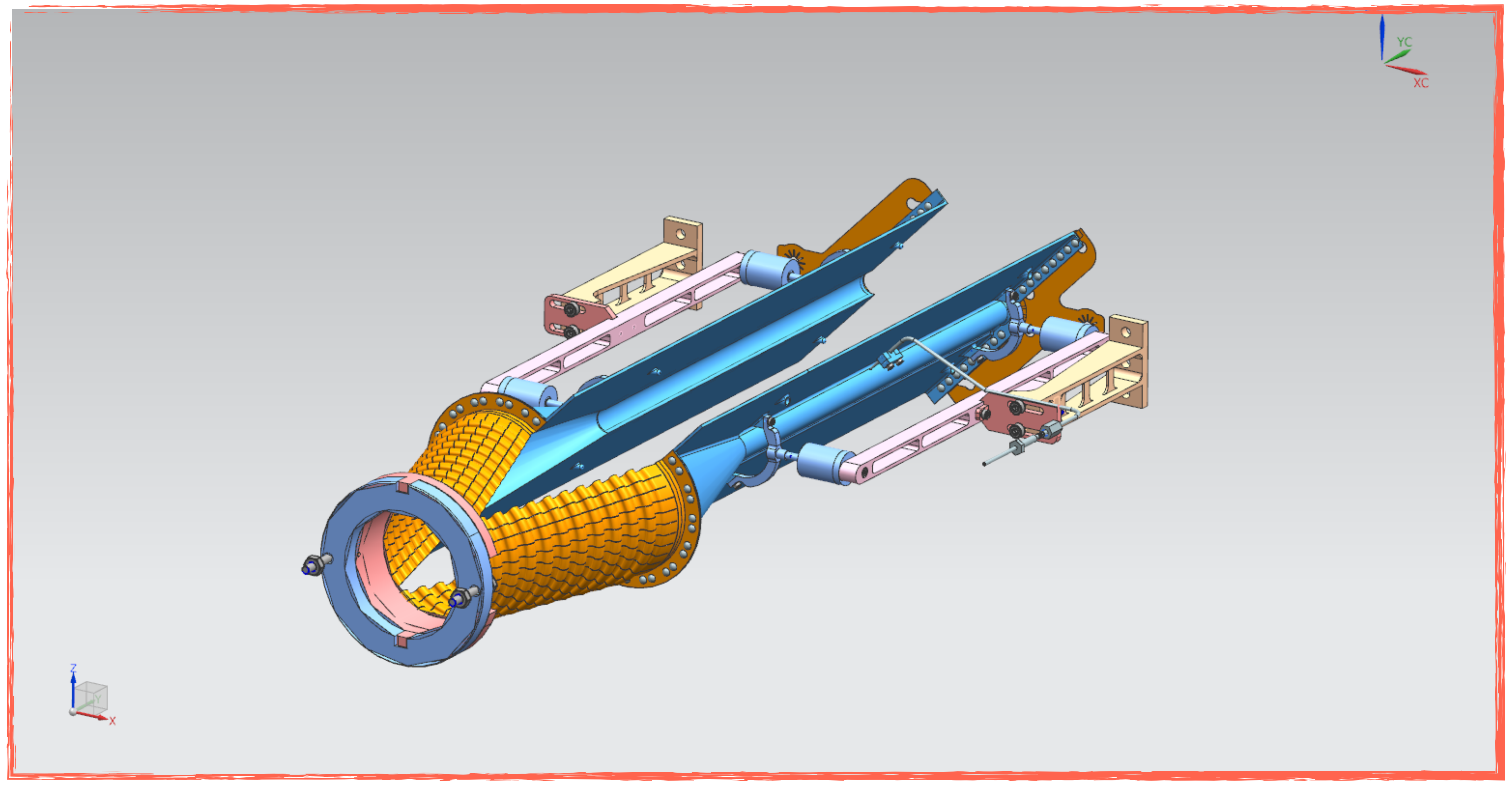
The choice of an openable cell allows for:

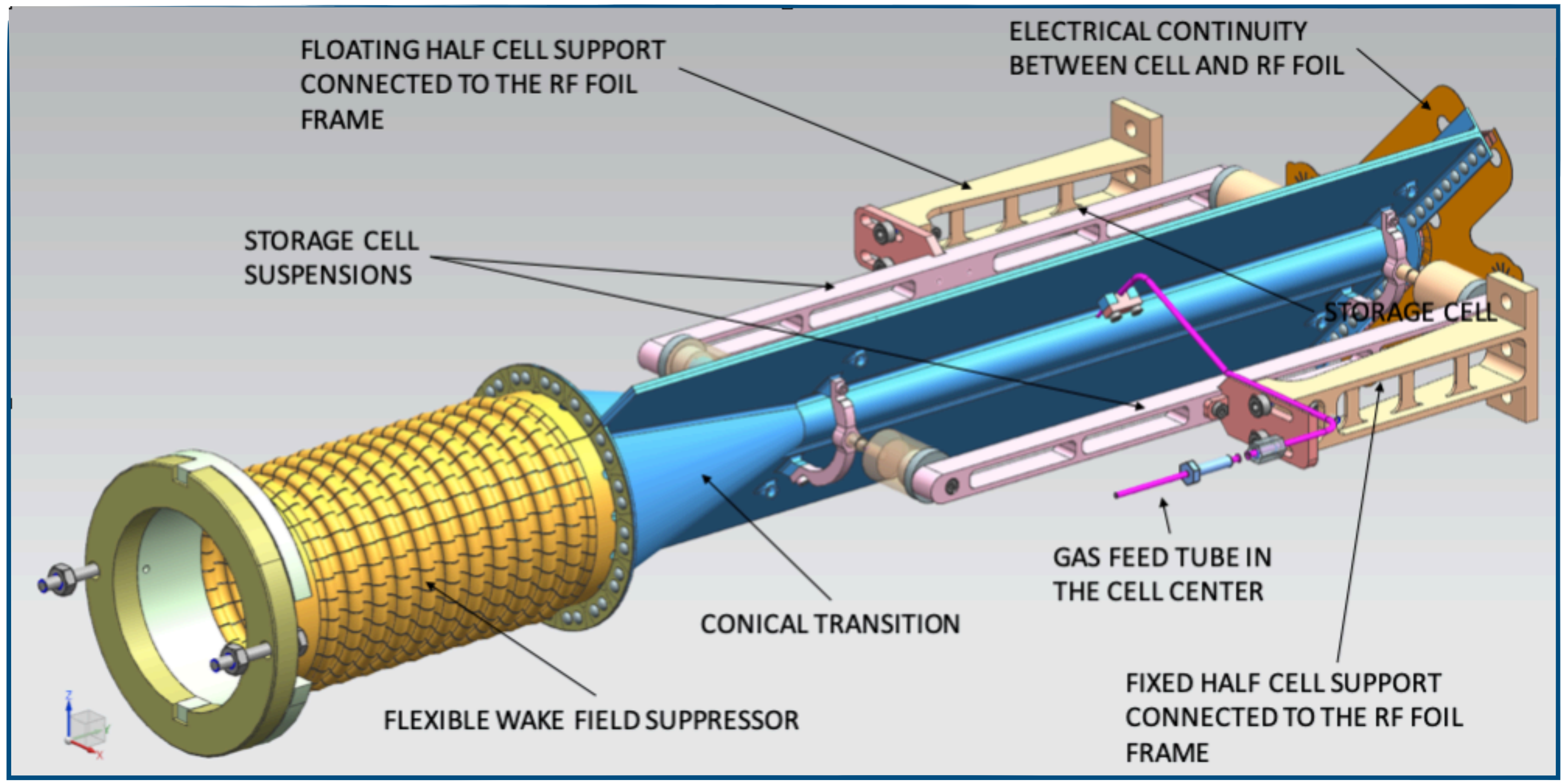
-a large diameter during the injection and tuning phases, when the beam traverse size is large (E_{beam}=450 GeV)

-a small diameter during the lumi run phase (E_{beam}=6.8 TeV)

The LHC requirement is to stay at least 15 σ from the beam transverse size

30 mm (open) 5 mm (closed) radius x 200 mm length

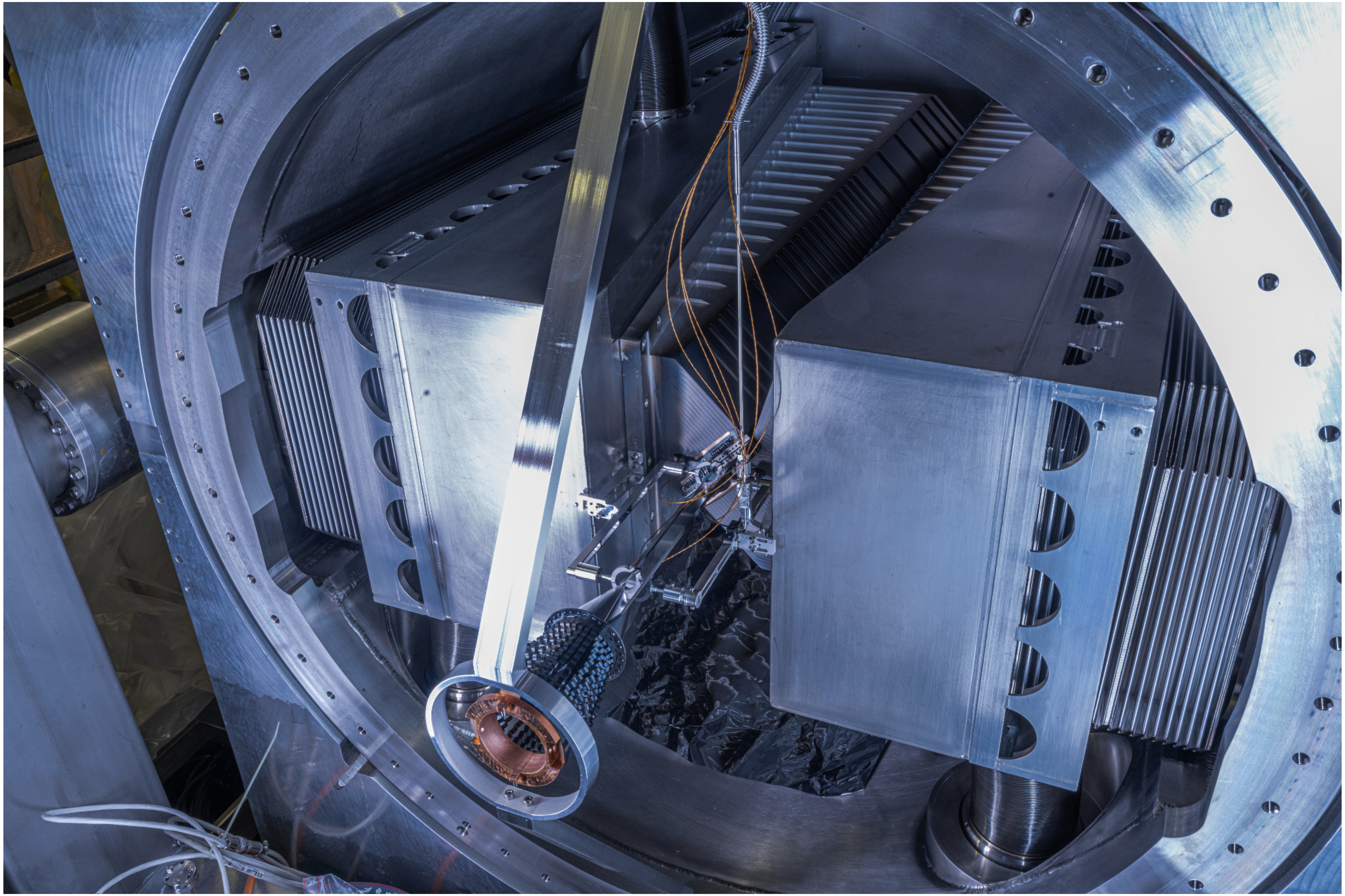




VELO Vessel system + storage cell

SMOG2

High-density gas target at the LHCb experiment
PHYSICAL REVIEW ACCELERATORS AND BEAMS 27, *111001 (2024)*



It is the only system present in the LHC primary vacuum

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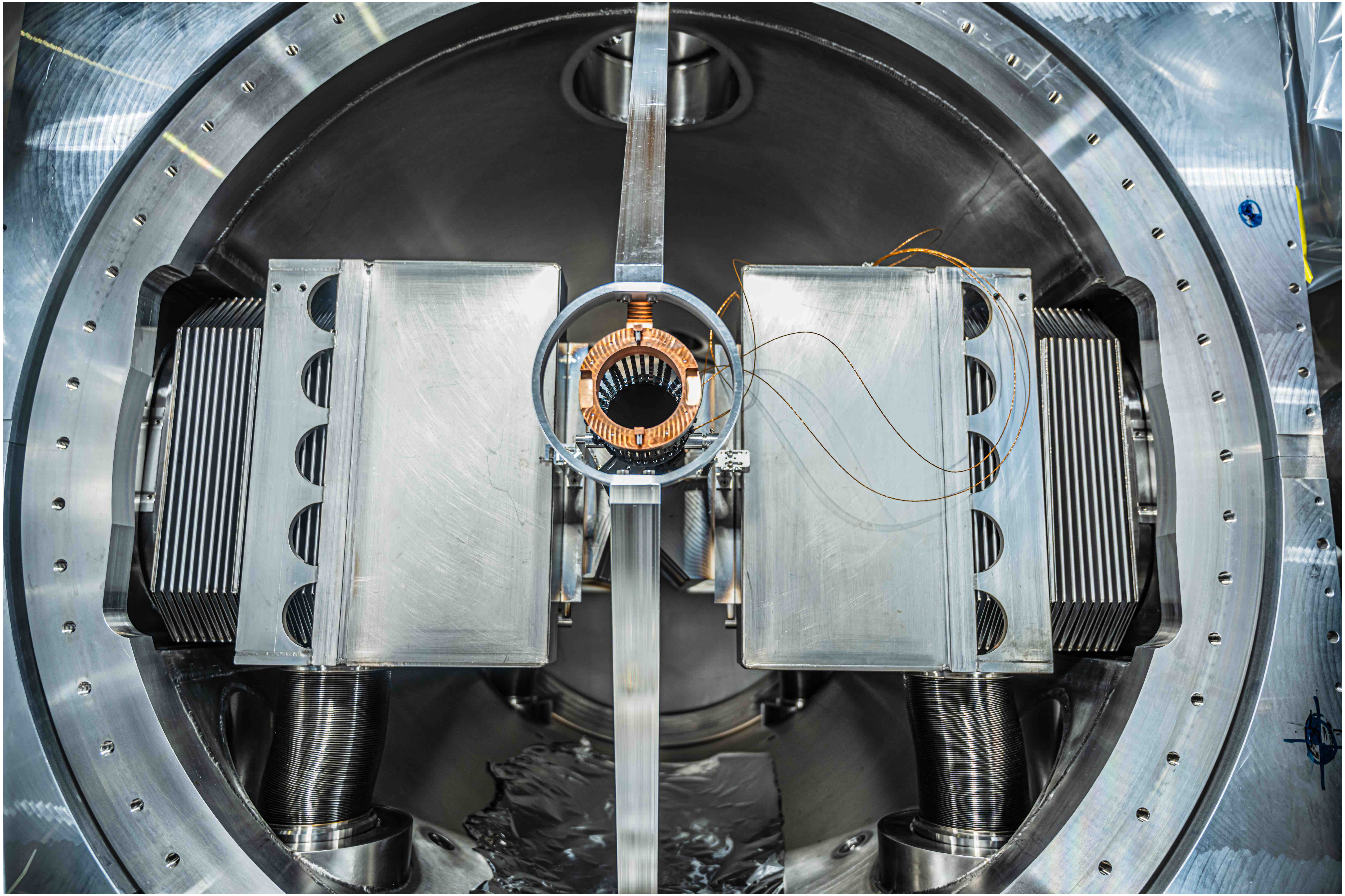
PHYSICAL REVIEW ACCELERATORS AND BEAMS 27, 111001 (2024)



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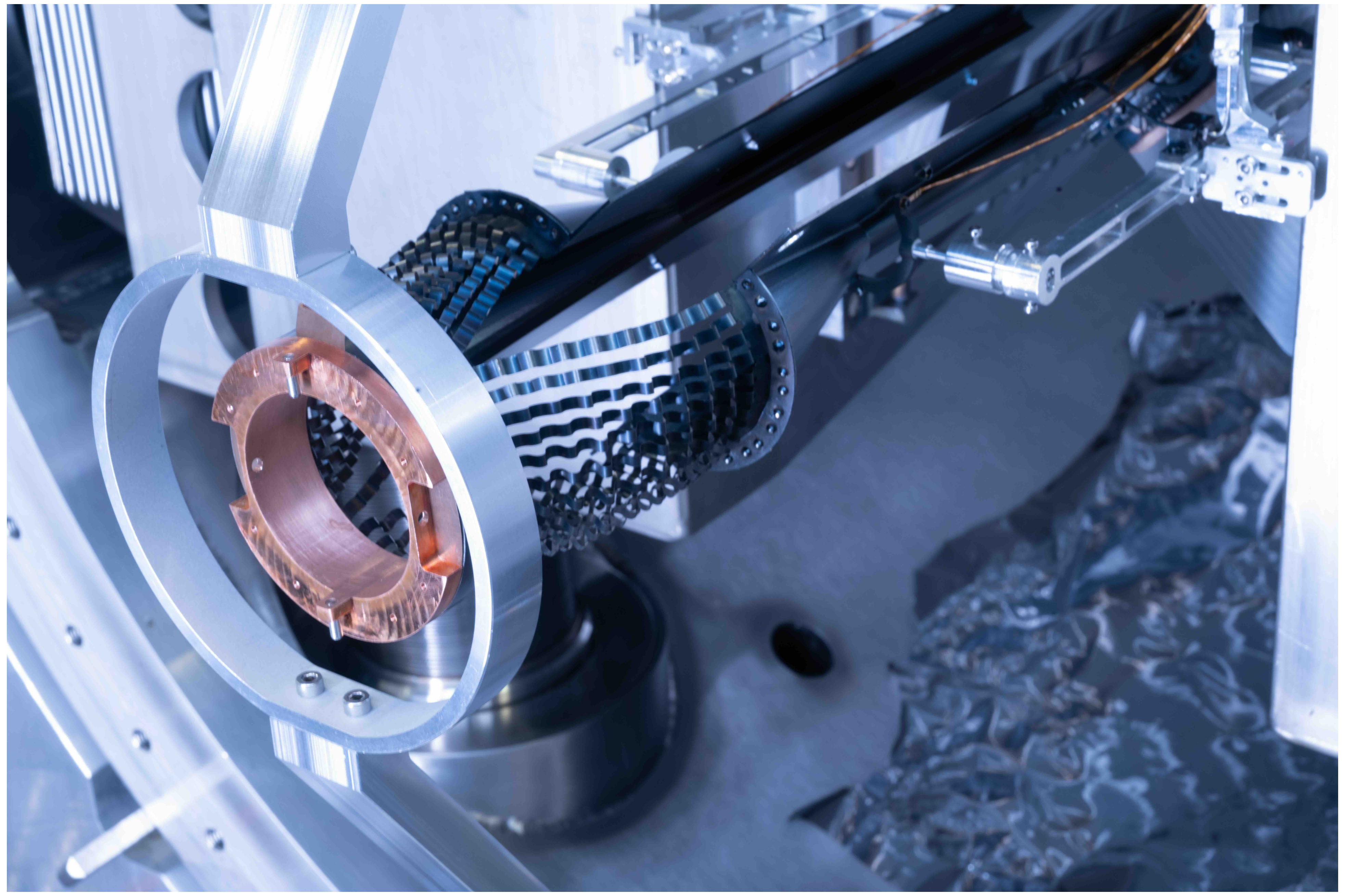


open

close

10 times faster
than normal

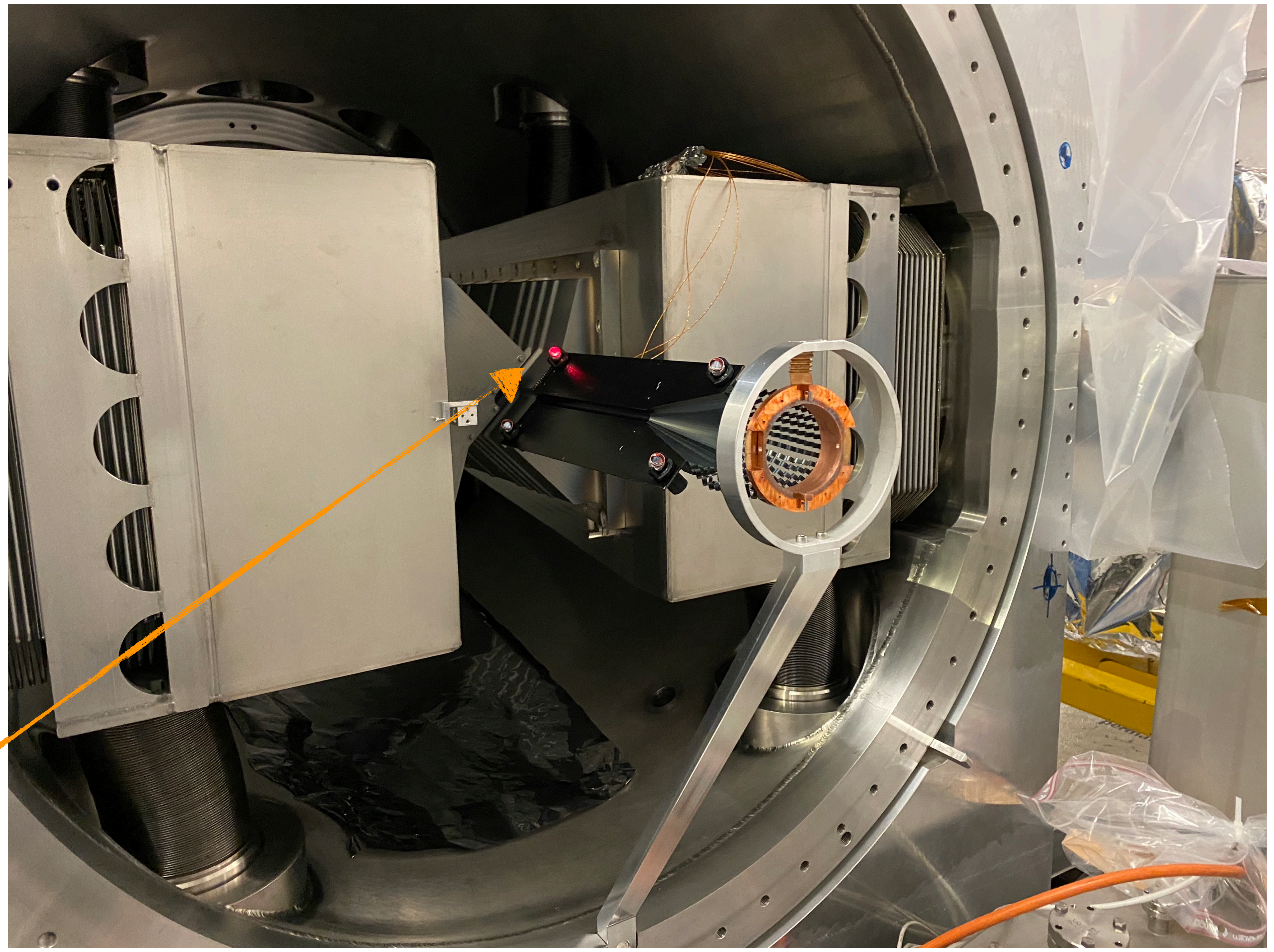
The alignment is a crucial part

Table 9: Final position of the SMOG2 and its offset to the nominal position

Position of SMOG2				Offset to nominal		
Name	**Xphys [m]**	**Yphys [m]**	**Zphys [m]**	**dXphys [mm]**	**dYphys [mm]**	**dZphys [mm]**
S_E	-0.00142	-0.00017	-0.61739	-0.25	0.14	0.11
S_S	-0.00136	-0.00040	-0.33739	-0.19	-0.14	0.11
S_ROLL	-0.00082	0.99983	-0.61658			

Excellent alignment reached: maximum offset of 0.25 mm over 2 mm of available range

Laser + 4 mirrors to measure the position



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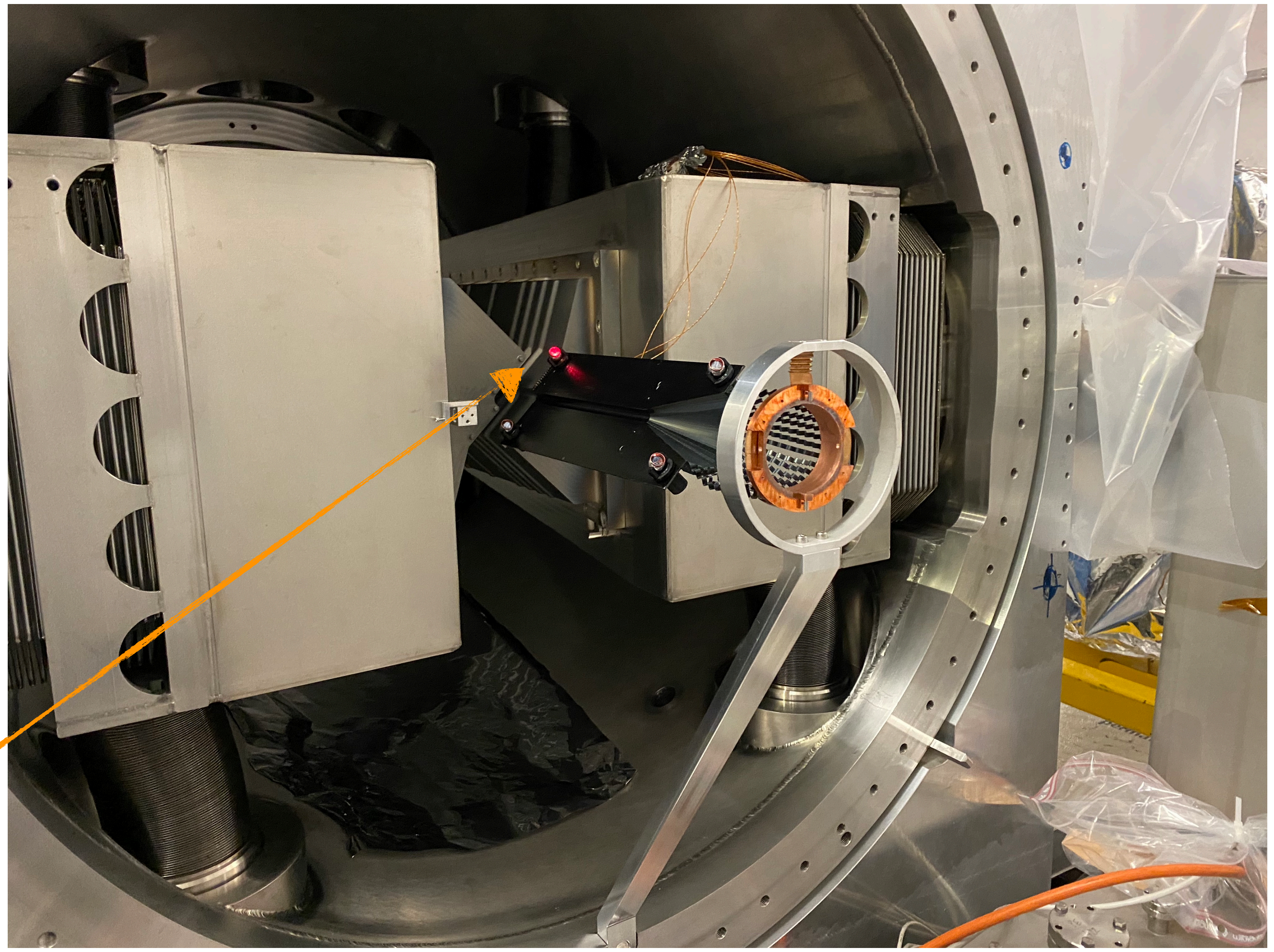
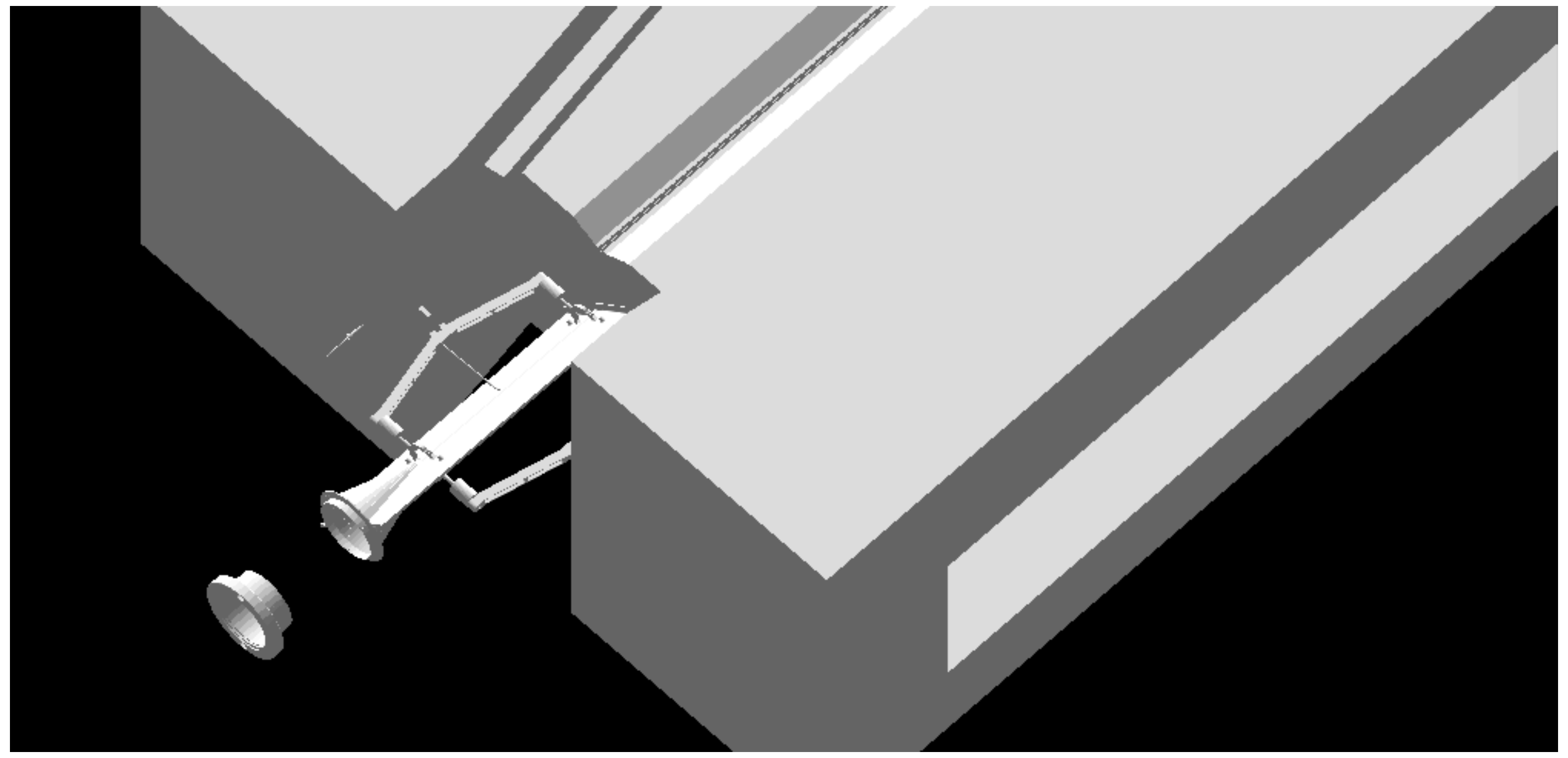


Since new material has been introduced along the beam line, it is important to evaluate the Machine Induced Background

main sources:
-beam-gas interactions in long straight sections leading up to the experiment;
-interactions with the tertiary collimators located upstream the experiment

The MIB alone shows a maximum increase of +16%, when properly scaled and embedded into the beam-beam collisions, the effect of the storage cell becomes negligible (~0.1%)



Gean4+Epos+Pythia8 embedded in a machine code (IEEE Trans. Nucl. Sci. 59 (2011) 16)

Temperature issue

Simulation show that the local power loss could reach up to 1.5 kW if the worst mode is hit by one the main spectral lines of the LHC beam

However, based on simulation and mockup measurements, we found that in the pessimistic case of ±20 MHz resonance shifts, a power dissipation in the cell could reach 14 W. This can increase up to a factor of 4 in case the two beams create the same simultaneous dissipation (extremely unlikely)

The equilibrium temperature can be calculated by considering:

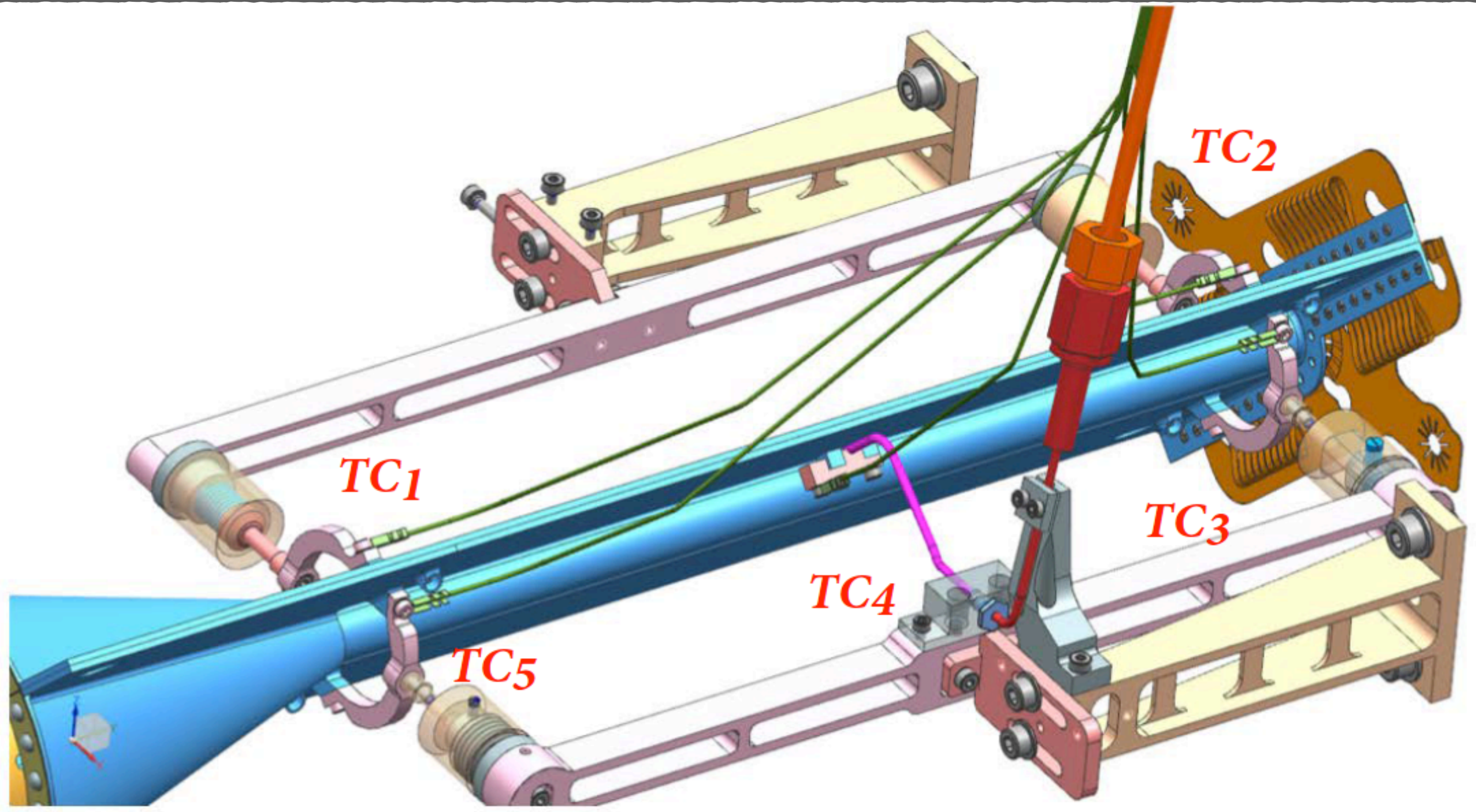
we found that the equilibrium temperature cell must be around 30-40 C depending on the beam conditions

heating power dissipation as

$$P_{cell} = \frac{1.226 \cdot c}{4\pi^2 b \sigma_z^{3/2}} \sqrt{\frac{Z_0}{s\sigma_e}} \frac{\bar{I}^2}{N_b f_r}$$

and the Stefan-Boltzmann dissipation formula

$$P_{rad} = \epsilon \sigma T^4 A$$



cell monitored by 5 thermocouples

Temperature behaviour of the 5 thermocouples

Clear dependance on the beam current

Recorded temperatures always below 41 C
The prototype has been tested up to 130 C

In case of sudden temperature increase, the procedure would be to slightly open the storage cell to avoid hitting the e.m. modes of the beam and to allow the cell to cool down.
From experience, we know that we are very far from this critical condition

The importance of measuring the temperature for the luminosity determination will be discussed in Saverio's talk

The LHCb detector

- LHCb is a general-purpose forward spectrometer, fully instrumented in $2 < \eta < 5$, and optimised for c and b hadron detection
- Excellent momentum resolution with VELO + tracking stations:

$$\sigma_p/p = 0.5 - 1.0\,\% \;\; (p \in [2{,}200] \text{ GeV})$$

- Particle identification with RICH+CALO+MUON

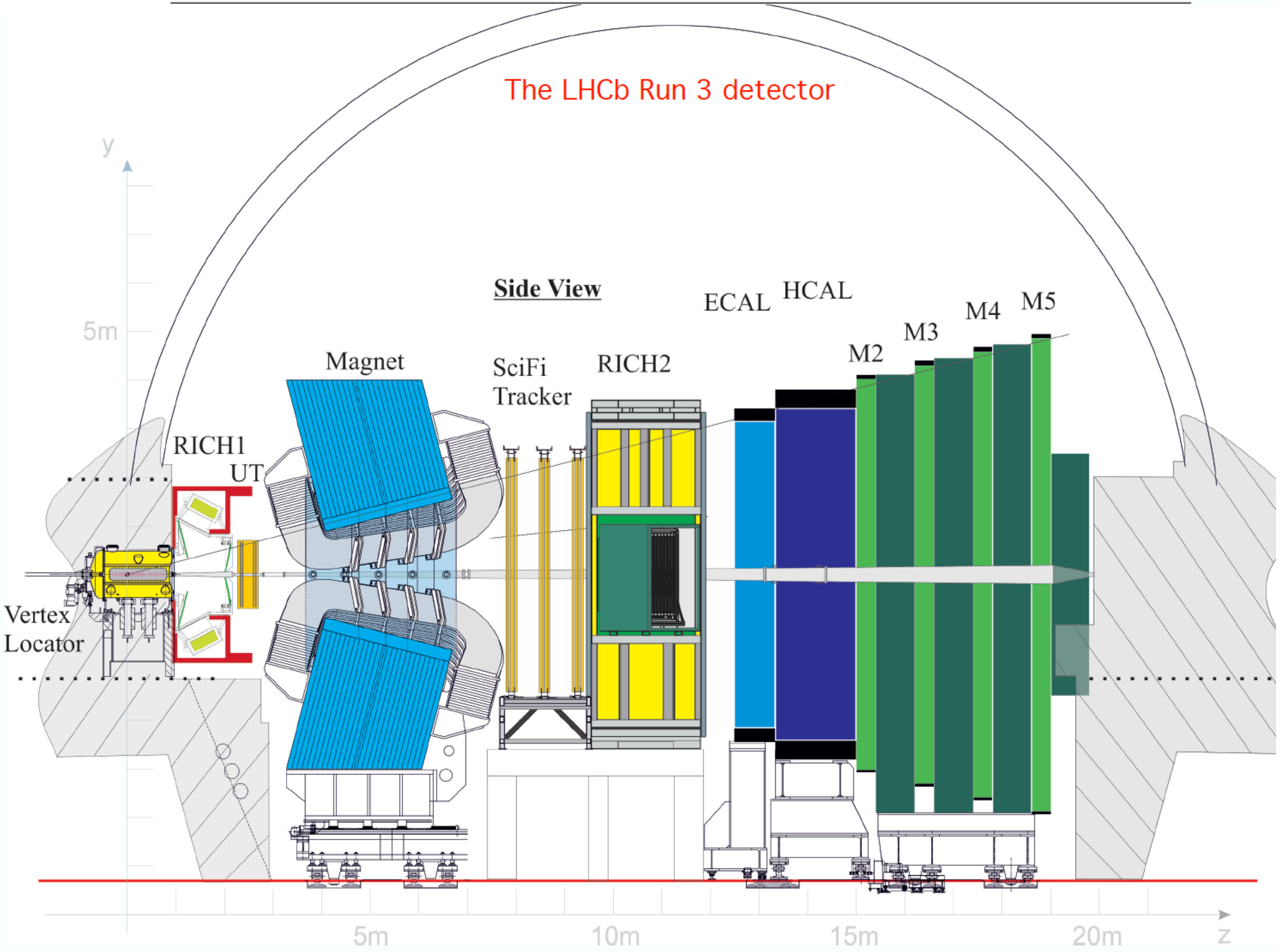
$\epsilon_\mu \sim 98\,\%$ with $\epsilon_{\pi\to\mu} \lesssim 1\,\%$

- Low momentum muon trigger:

$$p_{T_\mu} > 1.75 \text{ GeV (2018)}$$

will be reduced thanks to the new fully-software trigger

- Major detector upgrades performed during LS2 for the Run 3 (5x luminosity)



[JINST 3 (2008) S08005]
[IJMP A 30, 1530022 (2015)]
[Comput Softw Big Sci 6, 1 (2022)]

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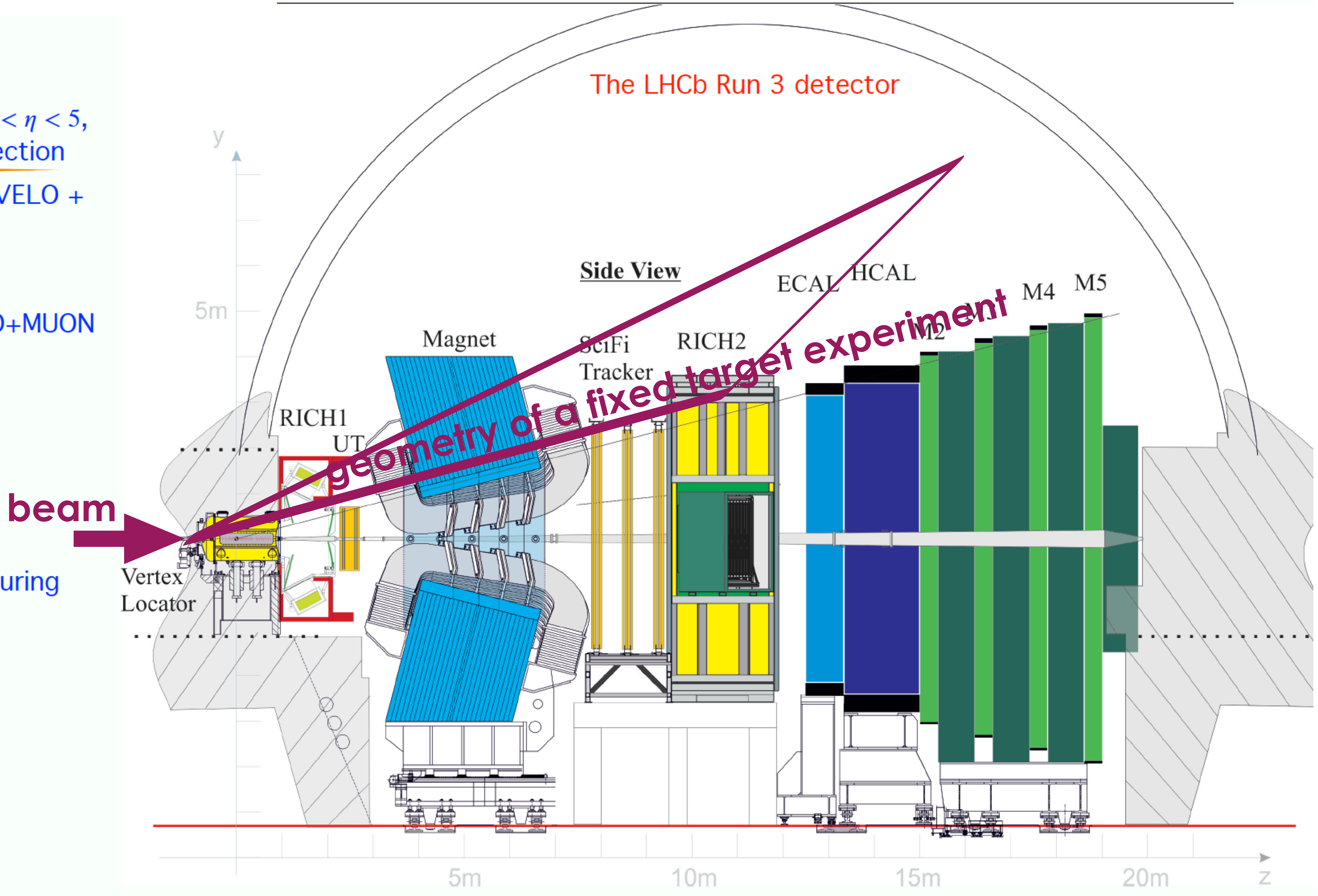
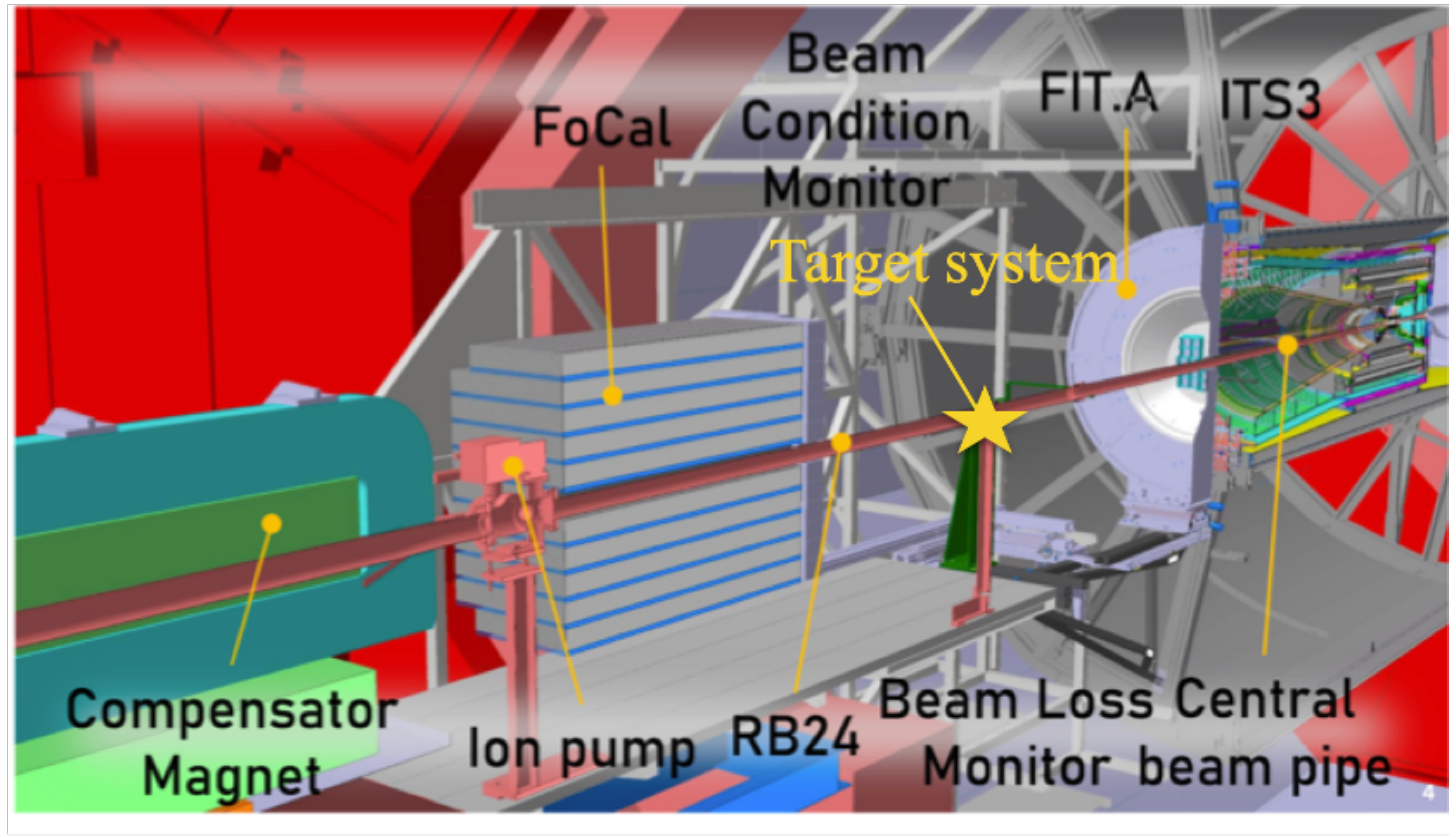


[JINST 3 (2008) S08005]

[IJMP A 30, 1530022 (2015)]

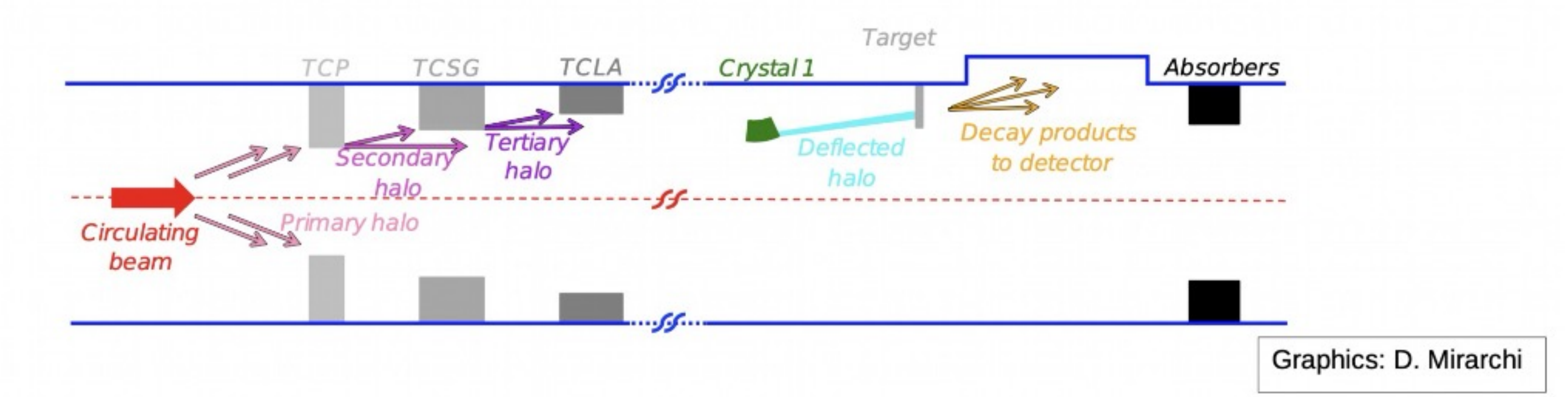
[Comput Softw Big Sci 6, 1 (2022)]

The Alice experience

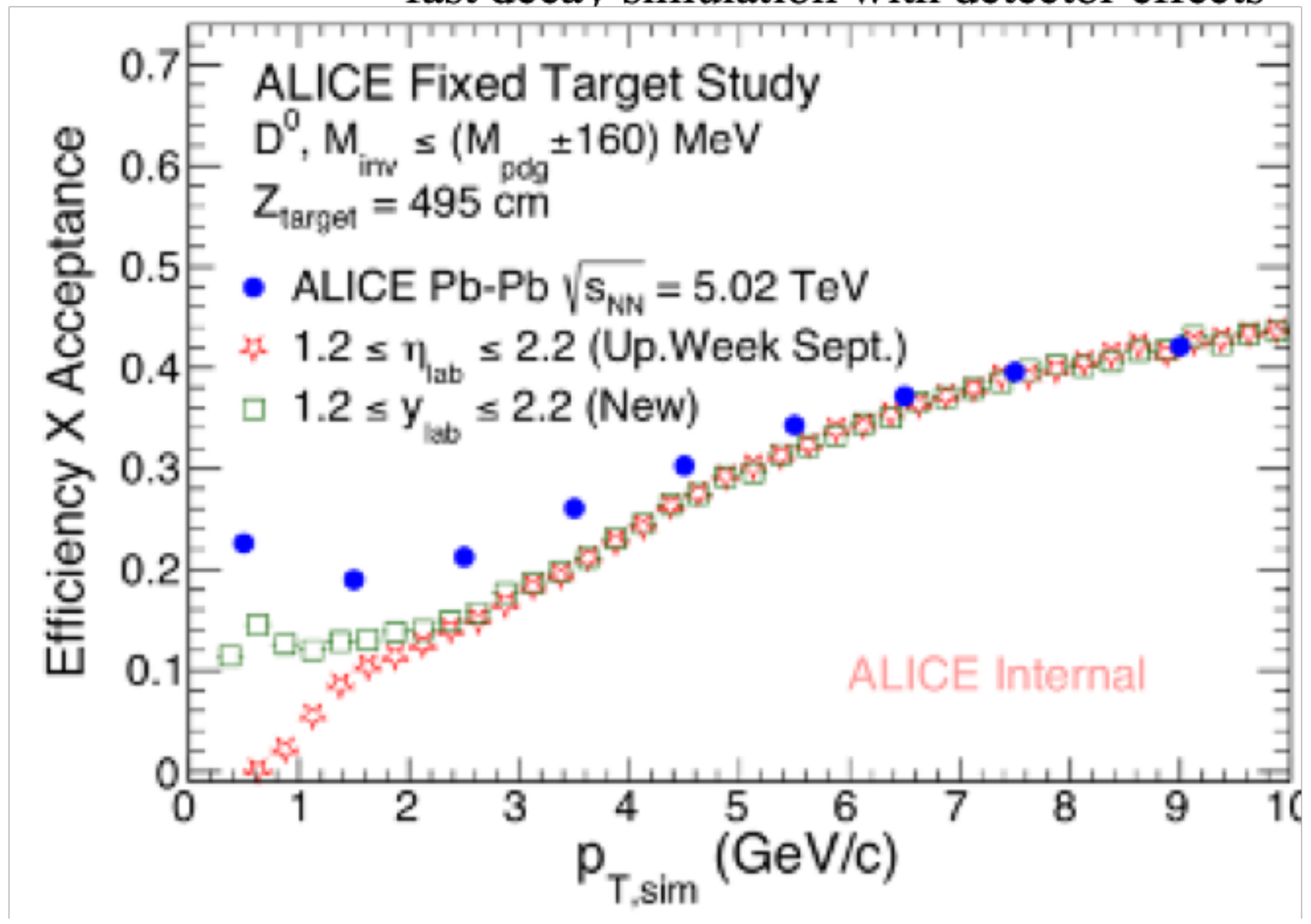


A wire target, located at 5-6 m from the beam-beam IP

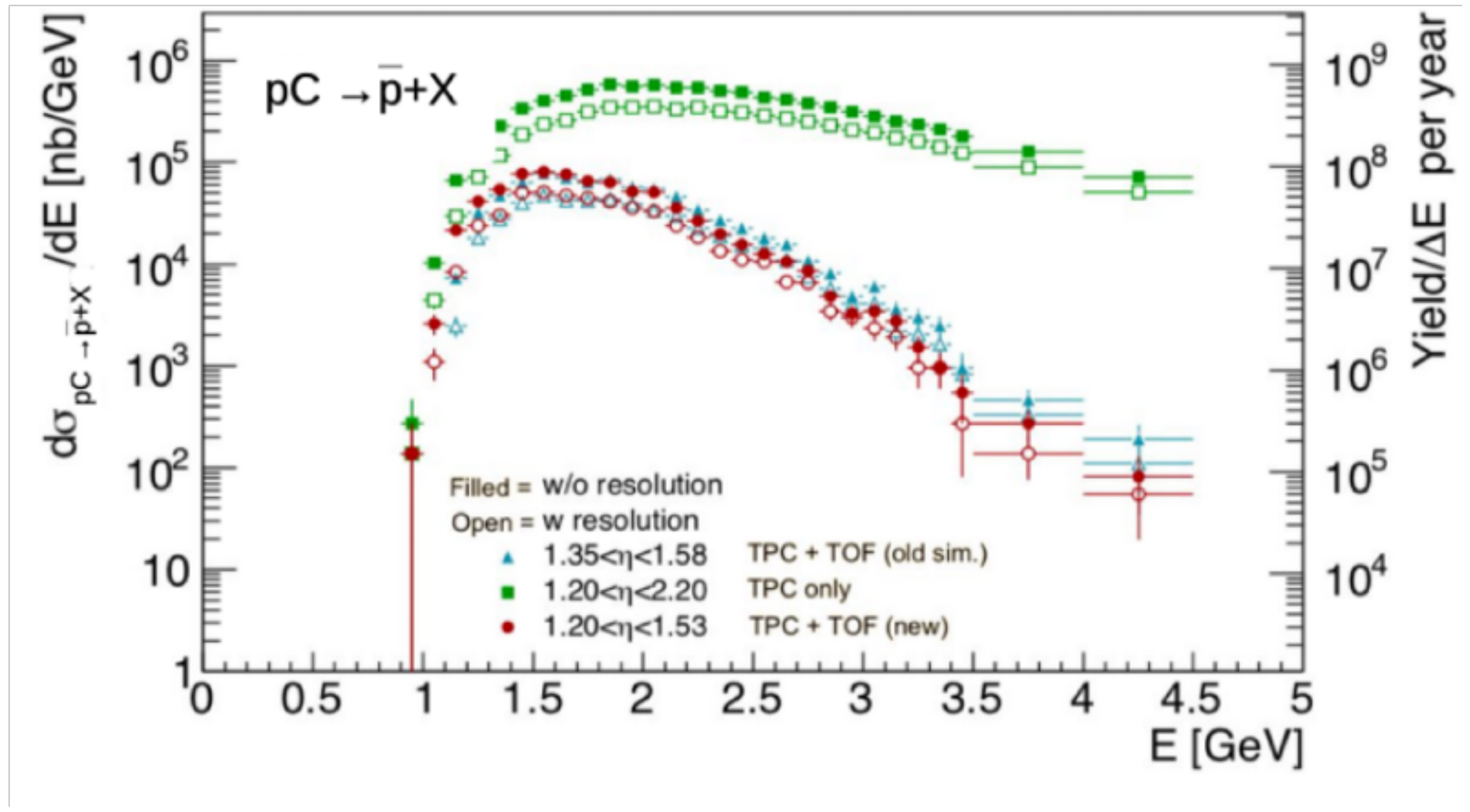
Extraction of the beam halo to collide with the wire target



fast decay simulation with detector effects



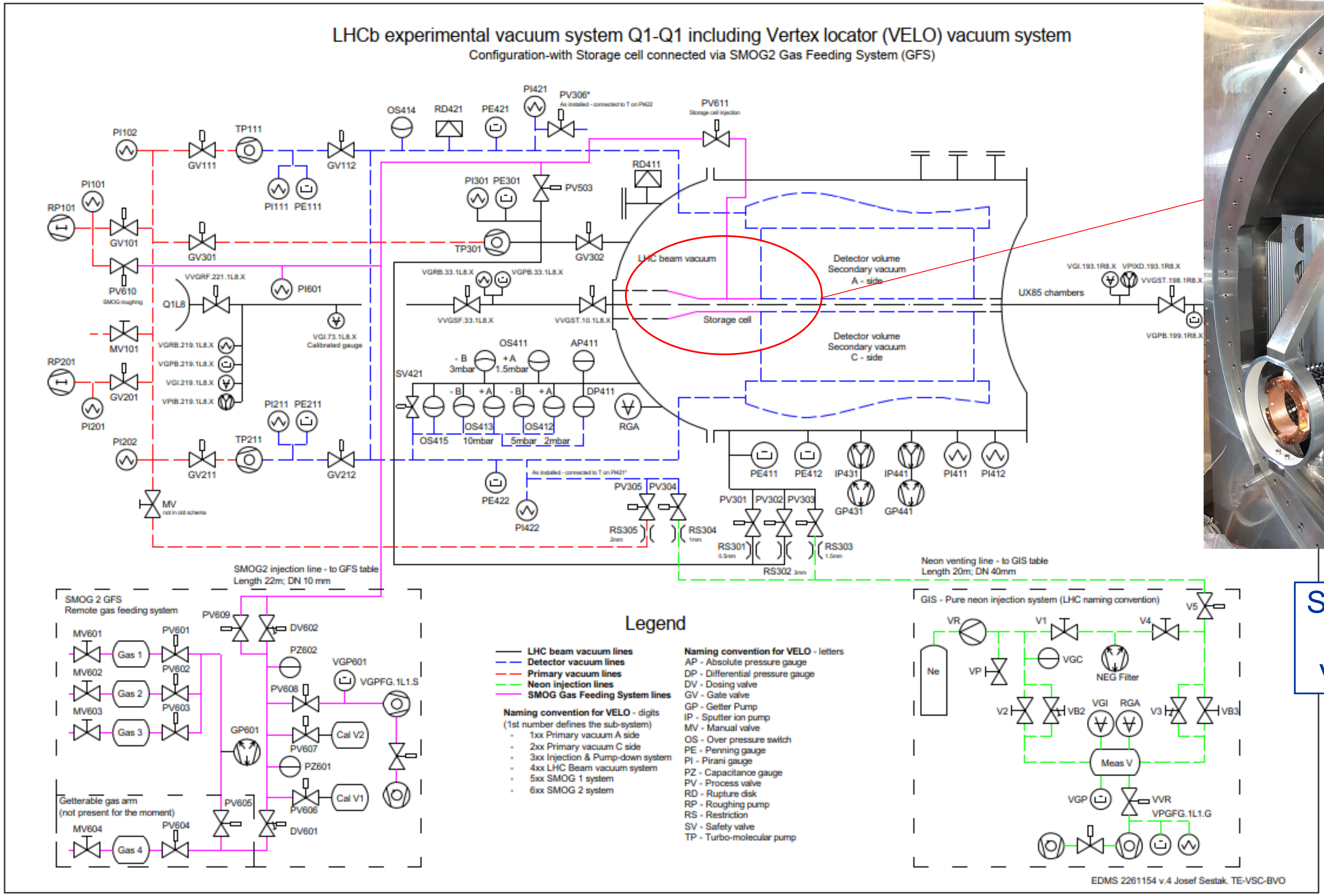
fast simulation with detector effects, no PID simulated



Even though the spectrometer has a cylindrical geometry, the reconstruction efficiency and the relative PID were reasonable

The project was stopped by the ALICE management because it was considered too invasive and incompatible with the already planned upgrade, such as the FOCAL calorimeter

The LHCb Gas Feed System



SMOG 2 Storage cell integration in the VELO vacuum tank

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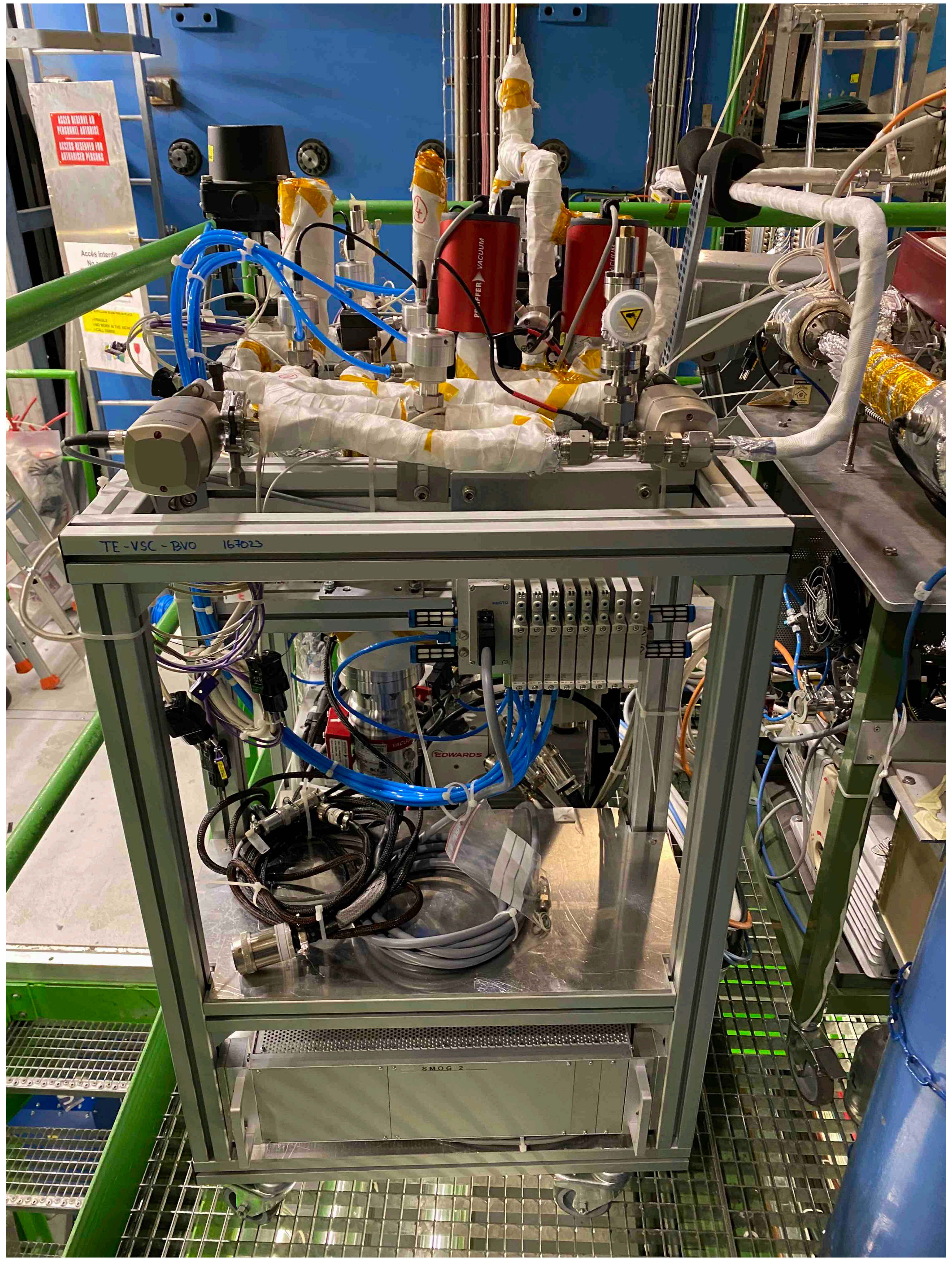
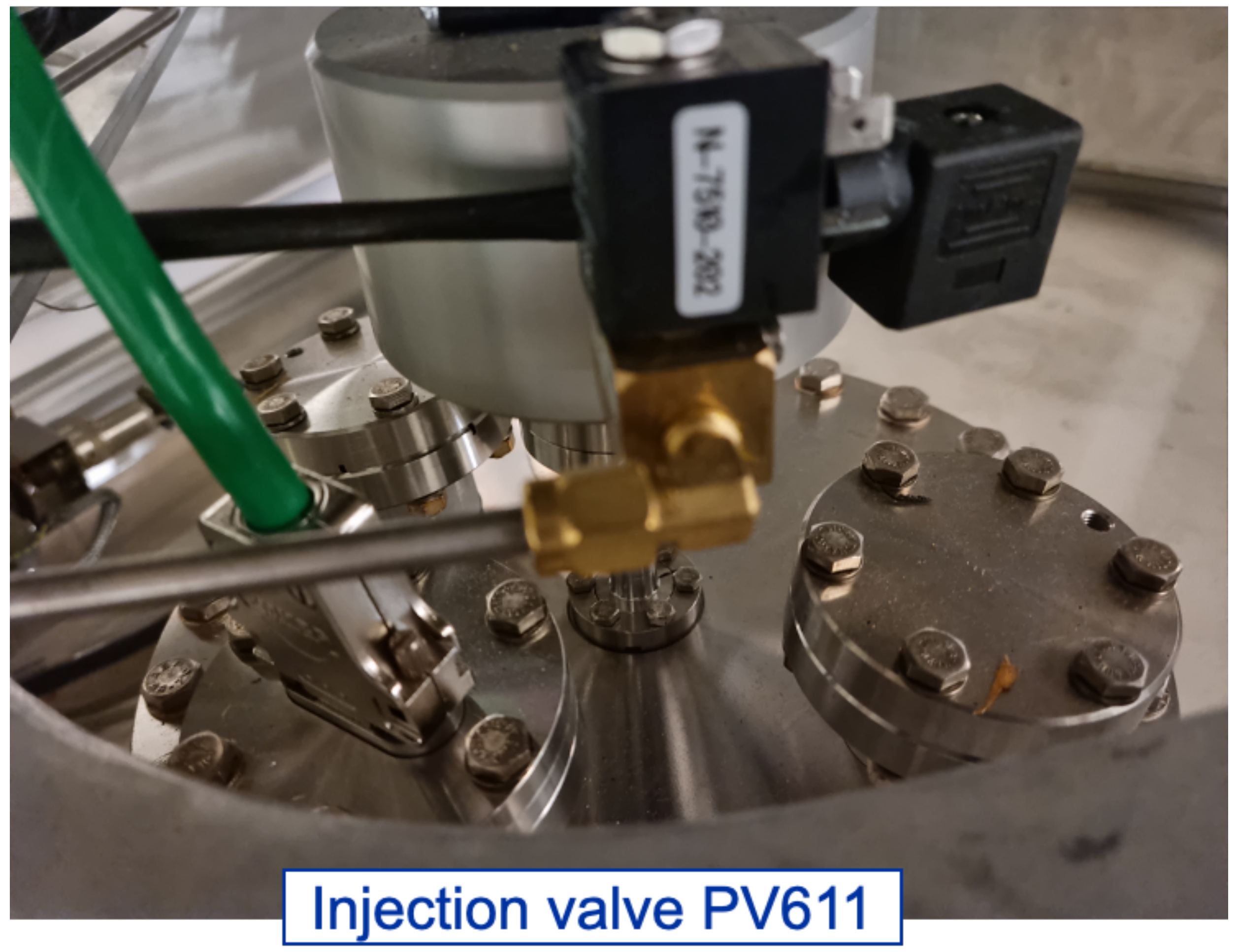
27, 111001 (2024)

The LHCb Gas Feed System



- Advanced Gas Feed System for the gas injection
- Negligible impact on the beam lifetime ($\tau^{p-H_2}_{beam-gas} \sim 2000$ days , $\tau^{Pb-Ar}_{beam-gas} \sim 500$ h)
- Injectable gases (3+1 reservoirs): H_2, D_2, N_2, O_2, He, Ne, Ar, Kr, Xe
- Flux known with $1\,\%$ precision, measured relative contamination 10^{-4}

GFS table installation



Injection valve PV611

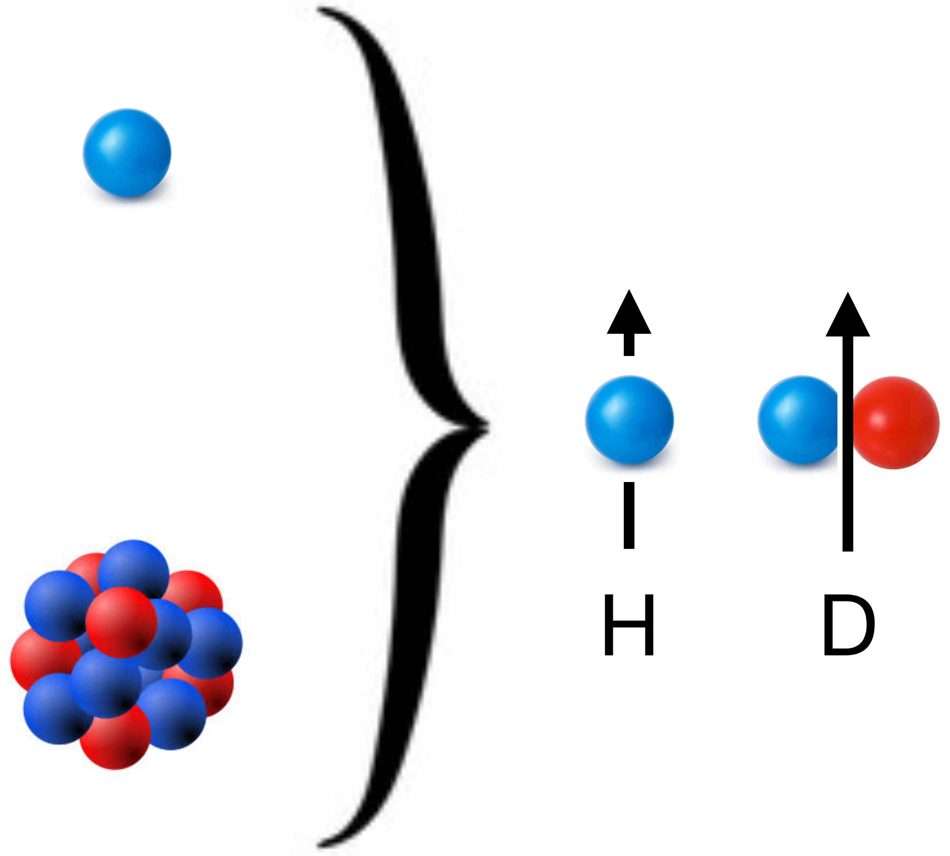
https://cds.cern.ch/record/2673690/

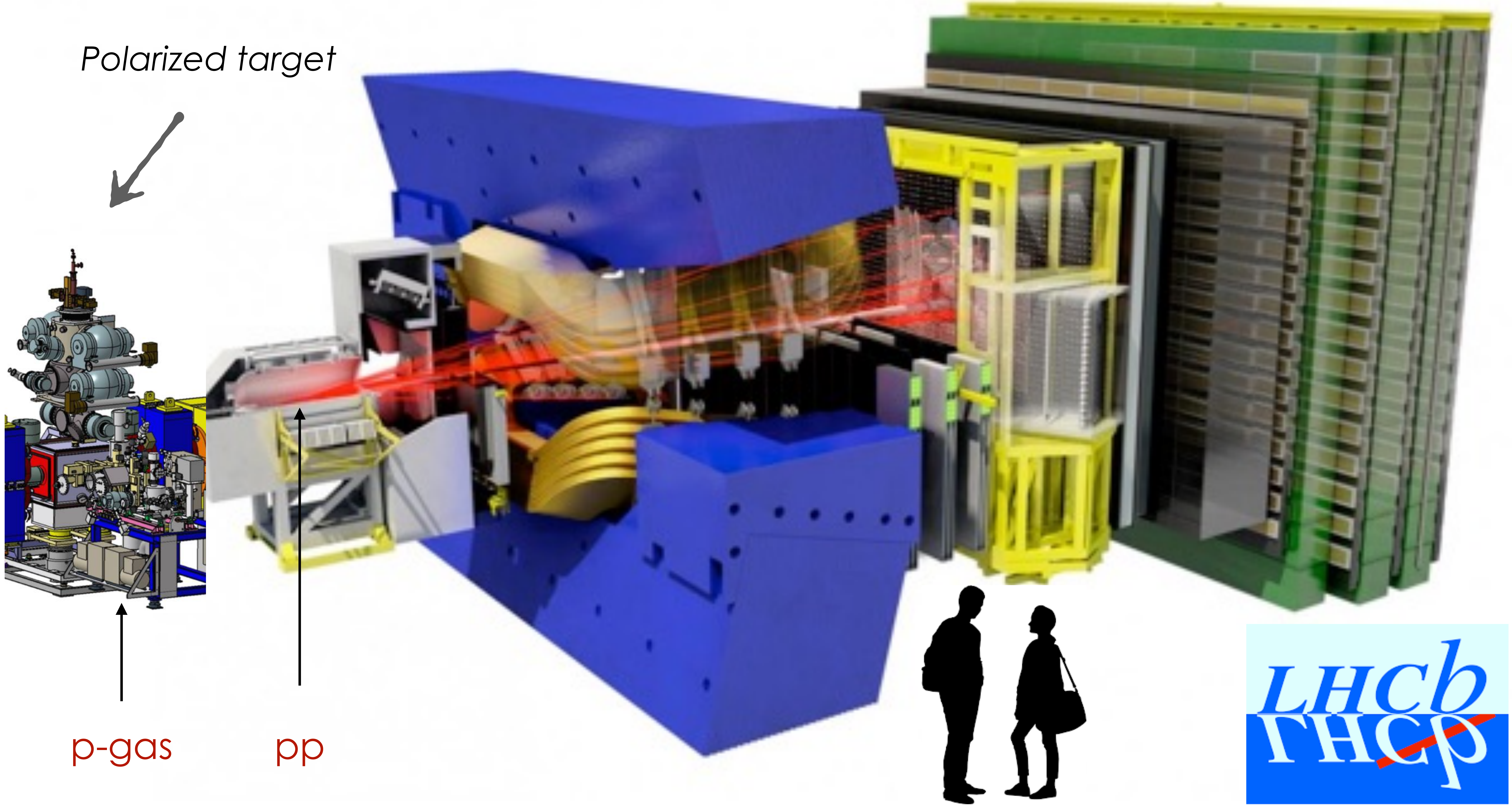
All the details of the data acquisition, results and experience gained from the data taking will be presented by Saverio in his talk later this afternoon

SMOG2 is a very interesting project itself, however, the installation of an unpolarised gas target also proves the technical feasibility of implementing this technique at the LHC … therefore we can proceed to the **next step**

LHC spin

LHCspin a polarized target at LHCb





Successful technology based on HERA and COSY experiments

… but an extensive R&D is also required

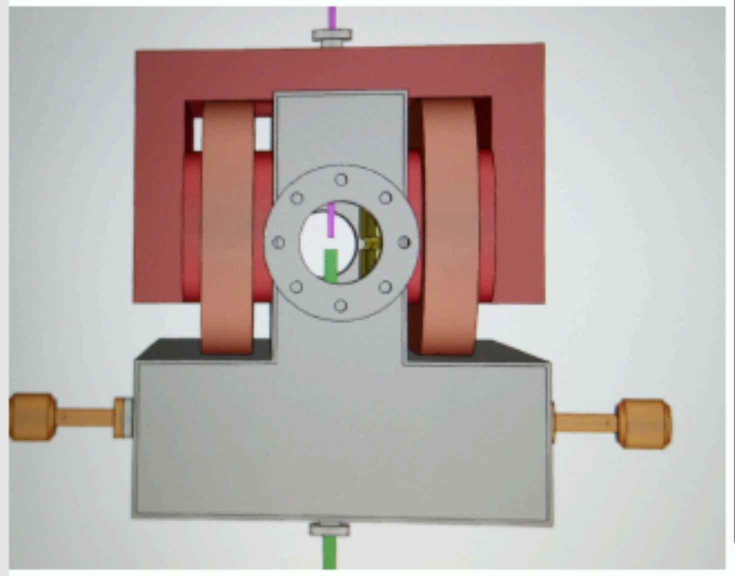
LHCspin experimental setup

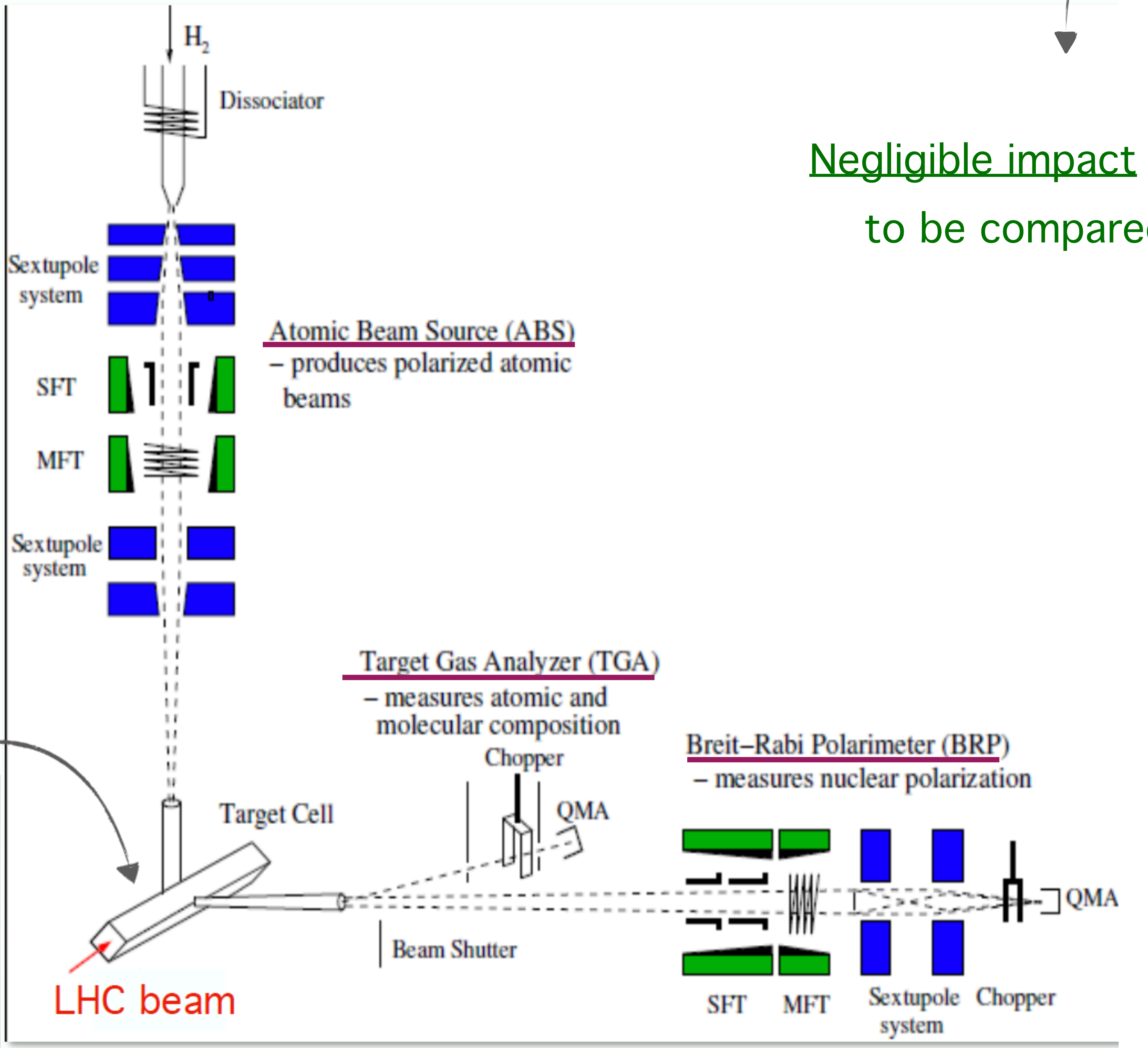
Target density (H) = 3.7×10^{13} cm^{-2}
LHC beam (Run5) = 6.8×10^{18} p s^{-1}

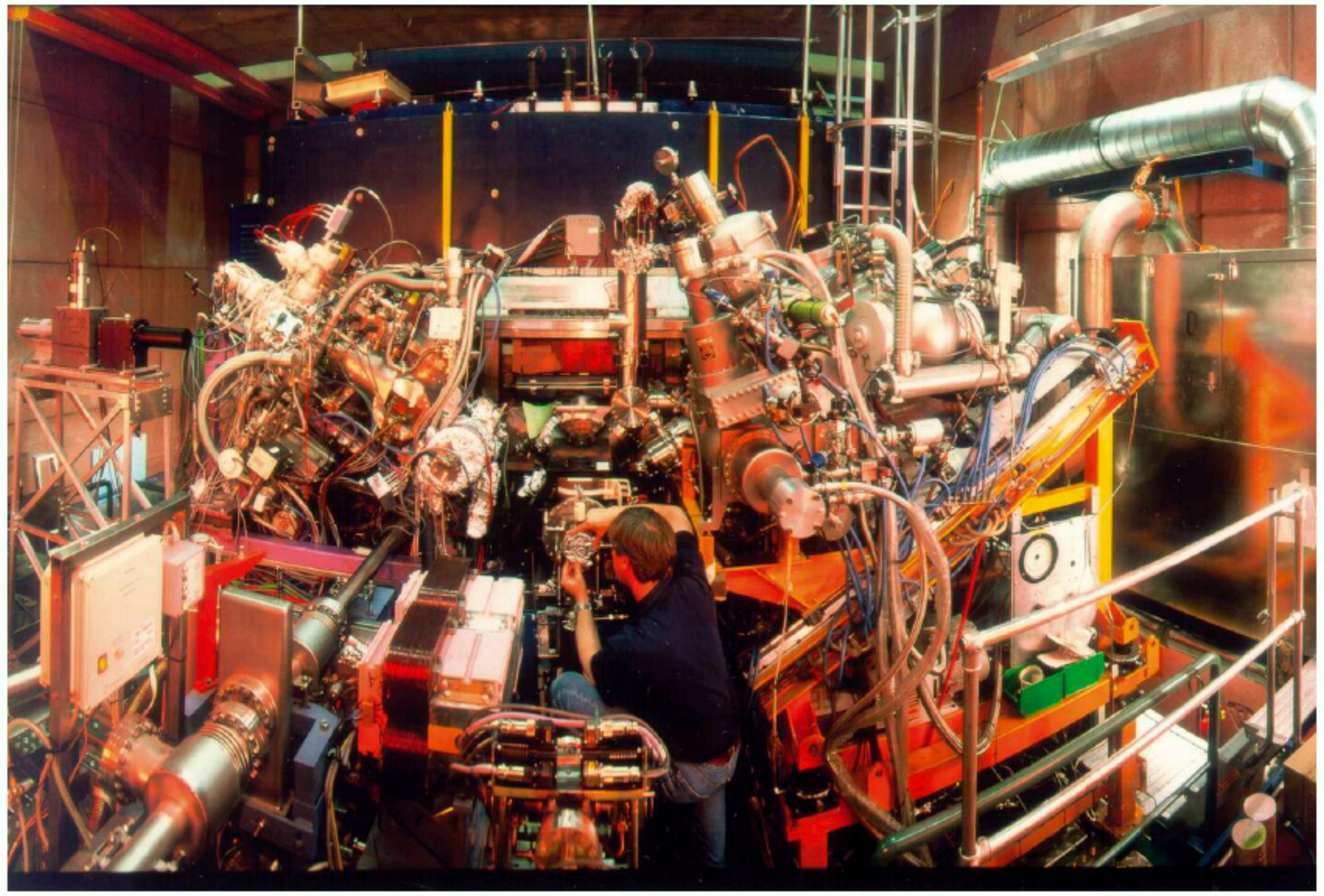
$\mathbf{L_{pH} = 2.5 \times 10^{32}}$ **cm^{-2} s^{-1}**

Negligible impact on the LHC beam lifetime, $\tau^{p-H}_{beam-gas} \sim 2000$ days
to be compared with the typical 10h of the beam lifetime

dipole







[NIMA 540 (2005) 68-101]

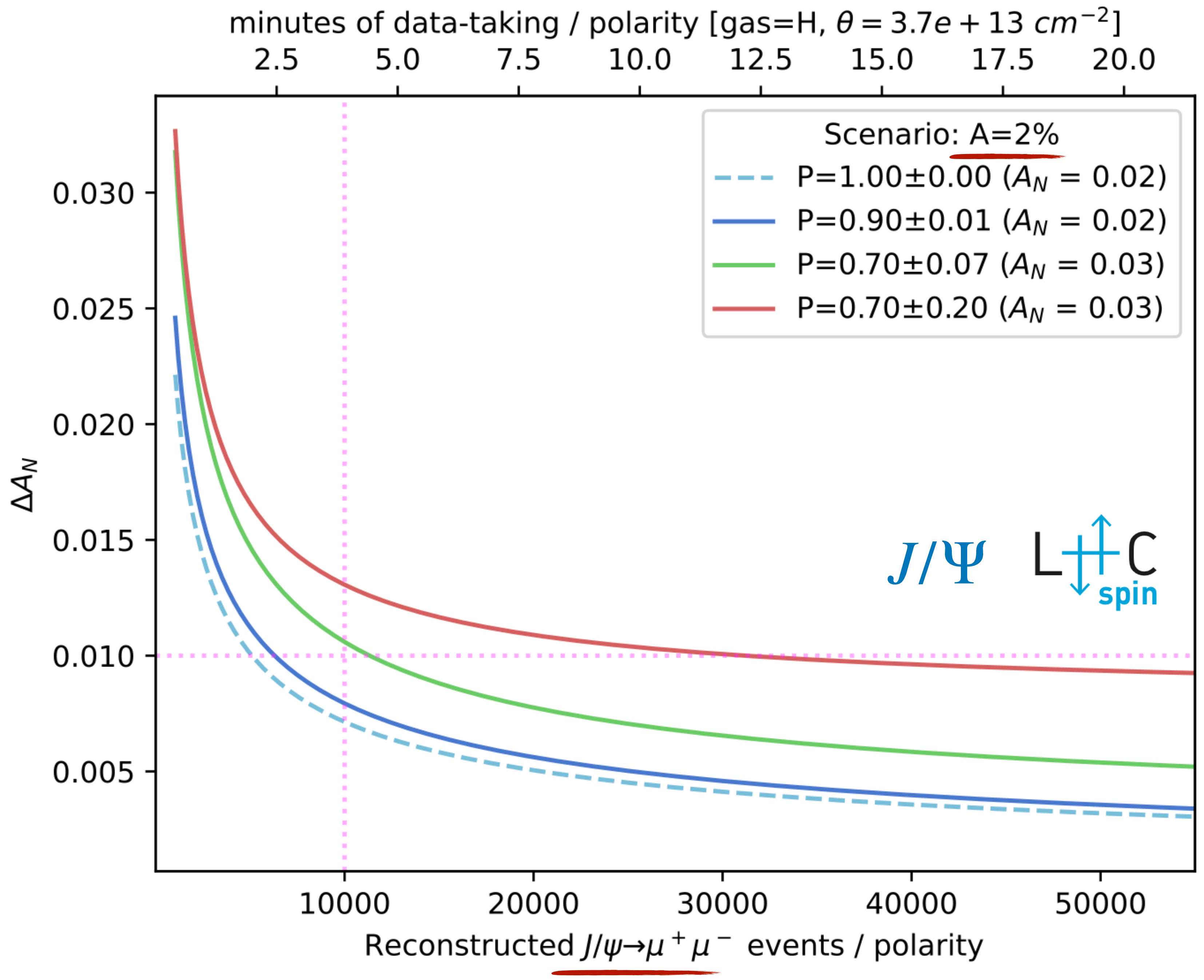
LHCspin event rates

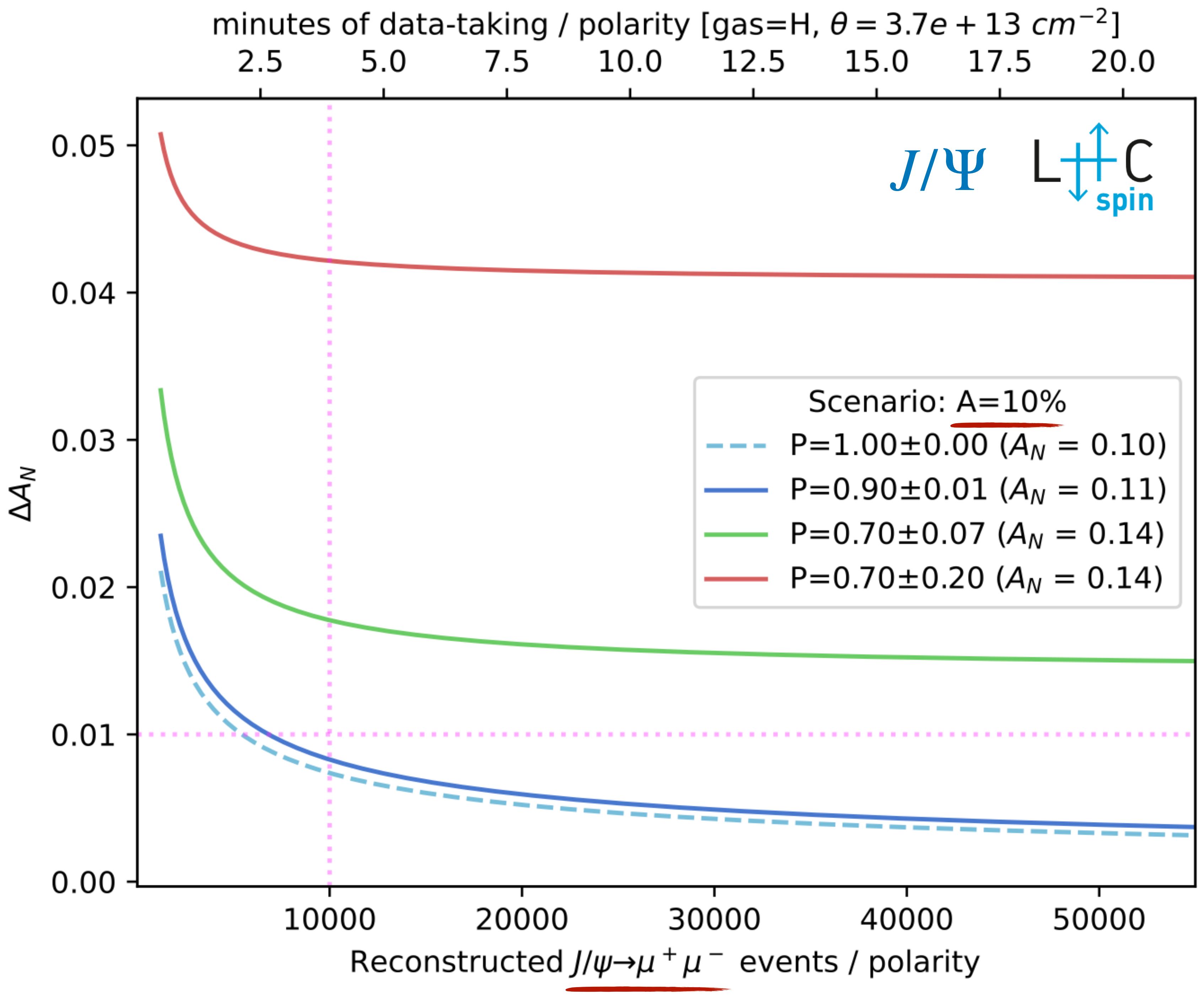
Precise *spin asymmetry* on $J/\Psi \to \mu^+\mu^-$ and $D^0 \to K^-\pi^+$ for $pH^\uparrow$ collisions in just few weeks

Channel	Events / week	Total yield
$J/\psi \to \mu^+\mu^-$	1.3×10^7 !!	1.5×10^9
$D^0 \to K^-\pi^+$	6.5×10^7	7.8×10^9
$\psi(2S) \to \mu^+\mu^-$	2.3×10^5	2.8×10^7
$J/\psi J/\psi \to \mu^+\mu^-\mu^+\mu^-$ (DPS)	8.5	1.0×10^3
$J/\psi J/\psi \to \mu^+\mu^-\mu^+\mu^-$ (SPS)	2.5×10^1	3.1×10^3
Drell Yan ($5 < M_{\mu\mu} < 9$ GeV)	7.4×10^3	8.8×10^5
$\Upsilon \to \mu^+\mu^-$	5.6×10^3	6.7×10^5
$\Lambda_c^+ \to pK^-\pi^+$	1.3×10^6	1.5×10^8

Statistics further enhanced by a factor 3-5 in LHCb upgrade II

Huge statistics





reconstructed particles

Comparing $J/\Psi \to \mu^+\mu^-$

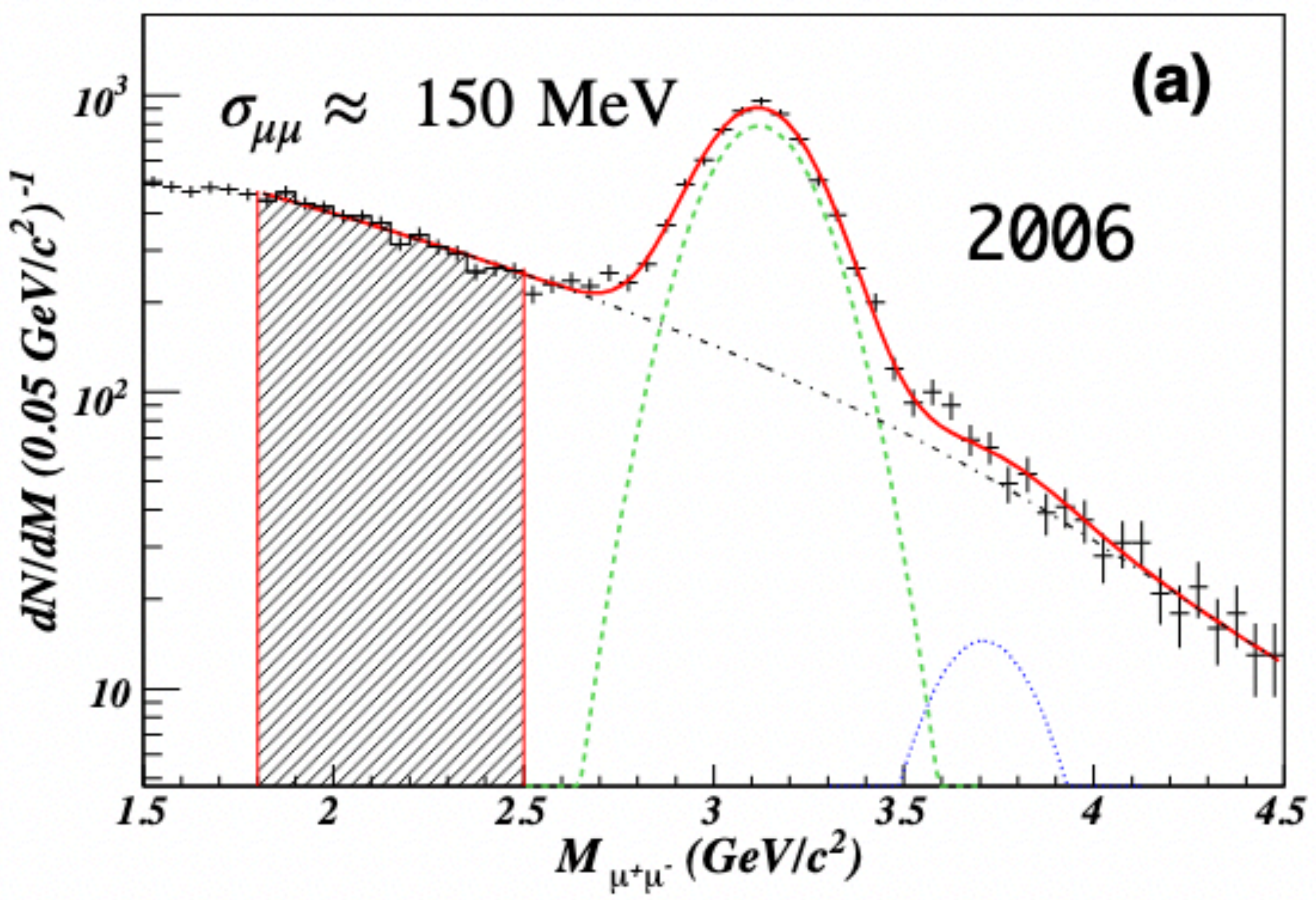
LHCspin strength point and uniqueness will be **heavy flavours**, mostly unexplored by existing facilities with the exception of the J/Ψ, for which measurements have been performed at PHENIX and COMPASS:

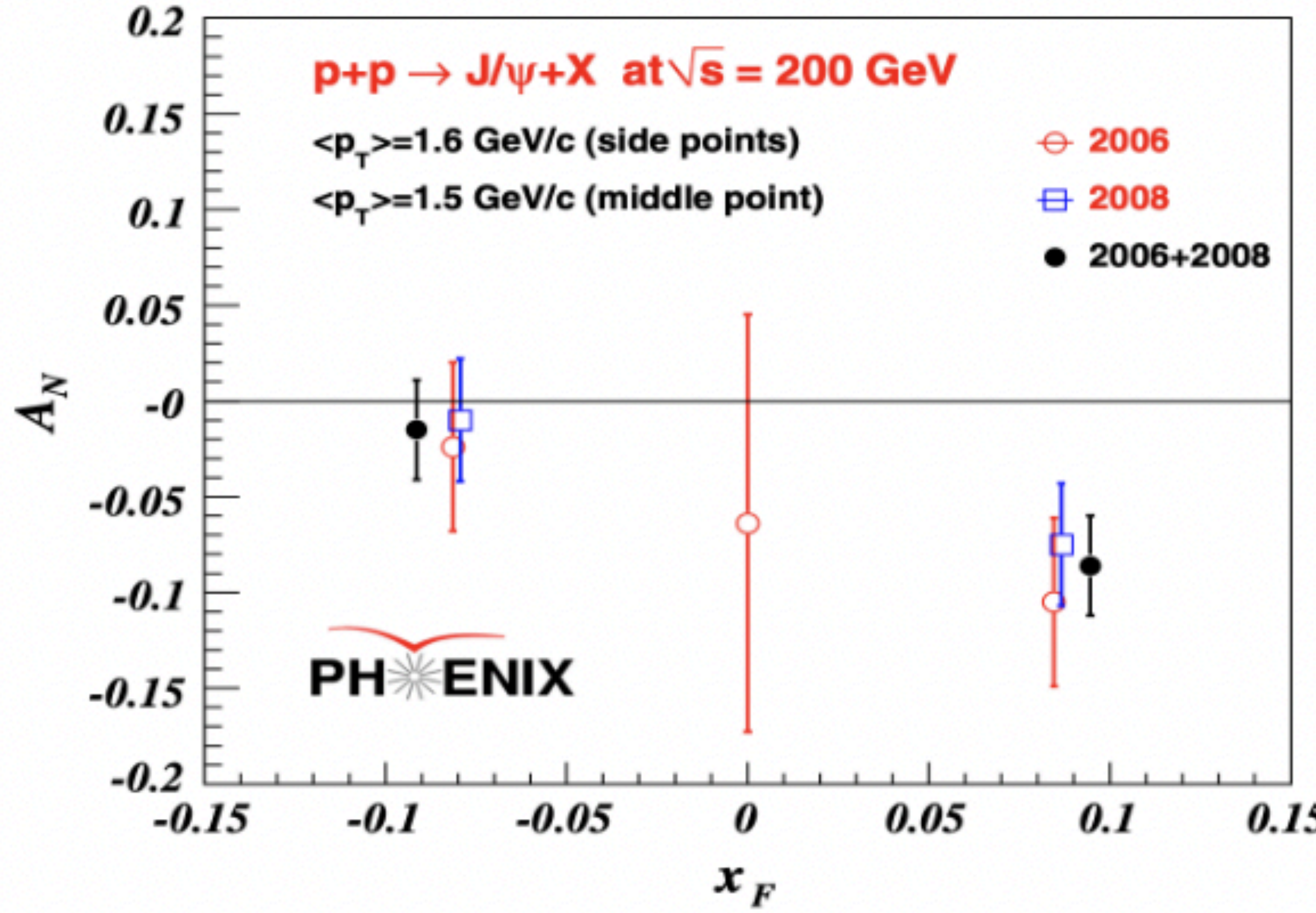
- PHENIX: ~ 21k signal candidates (2006 + 2008 data) at LHCspin they can be collected in ~10 minutes (cell) or ~7 hours (jet)

- Mass resolution: LHCb nominal $\sigma_{\mu\mu} \simeq 13$ MeV at the mass J/Ψ and $\sigma_{\mu\mu} \simeq 42$ MeV at the mass Υ mass

- Can also measure excited states & heavier mesons

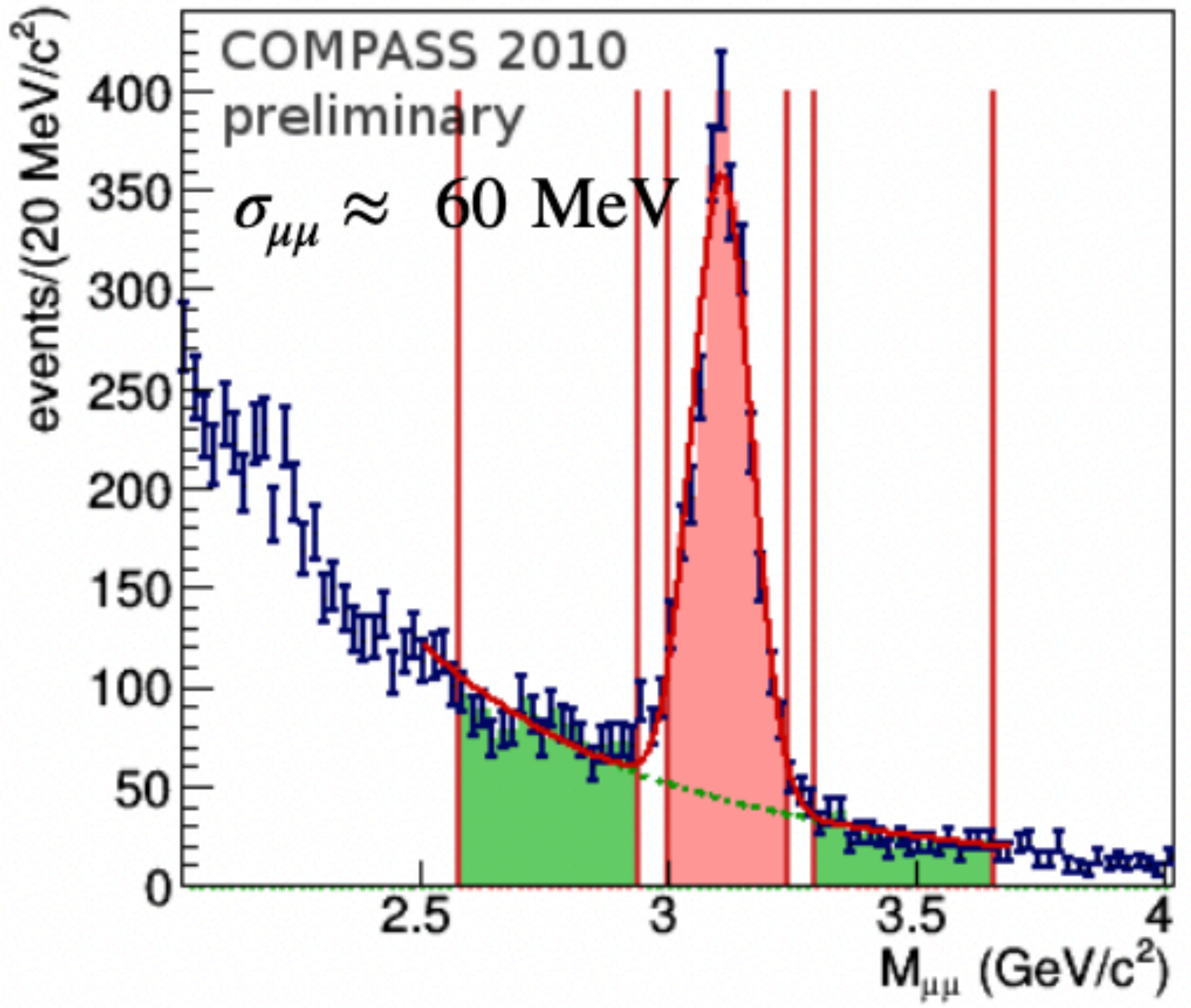
PHENIX: 2006 and 2008 data





[arXiv:1009.4864]

COMPASS: 2010 data



[2016 J. Phys.: Conf. Ser. 678 012050]

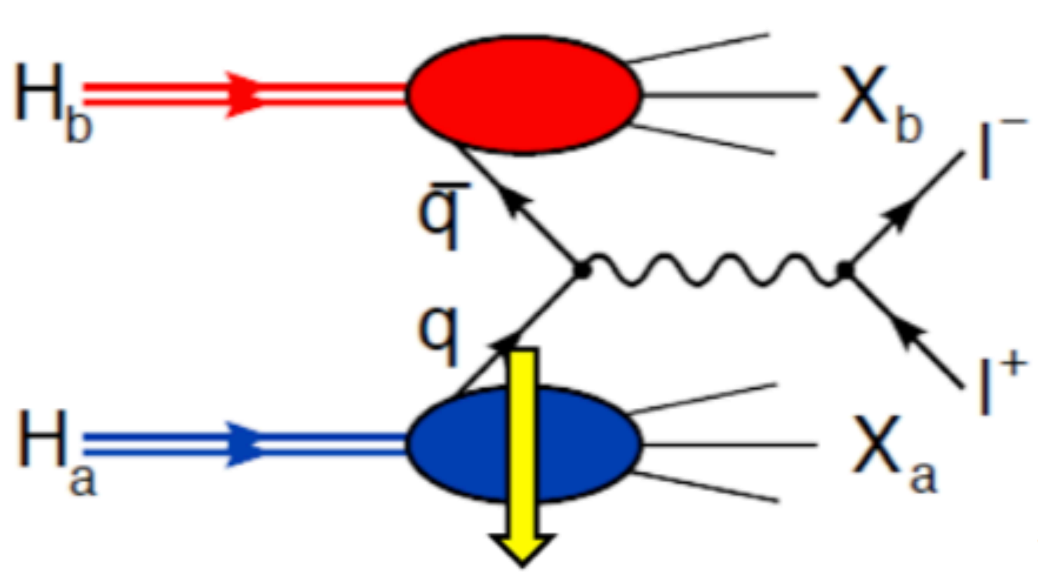
we can greatly complement these results with high precision measurements and much larger kinematic coverage!

Quark TMDs

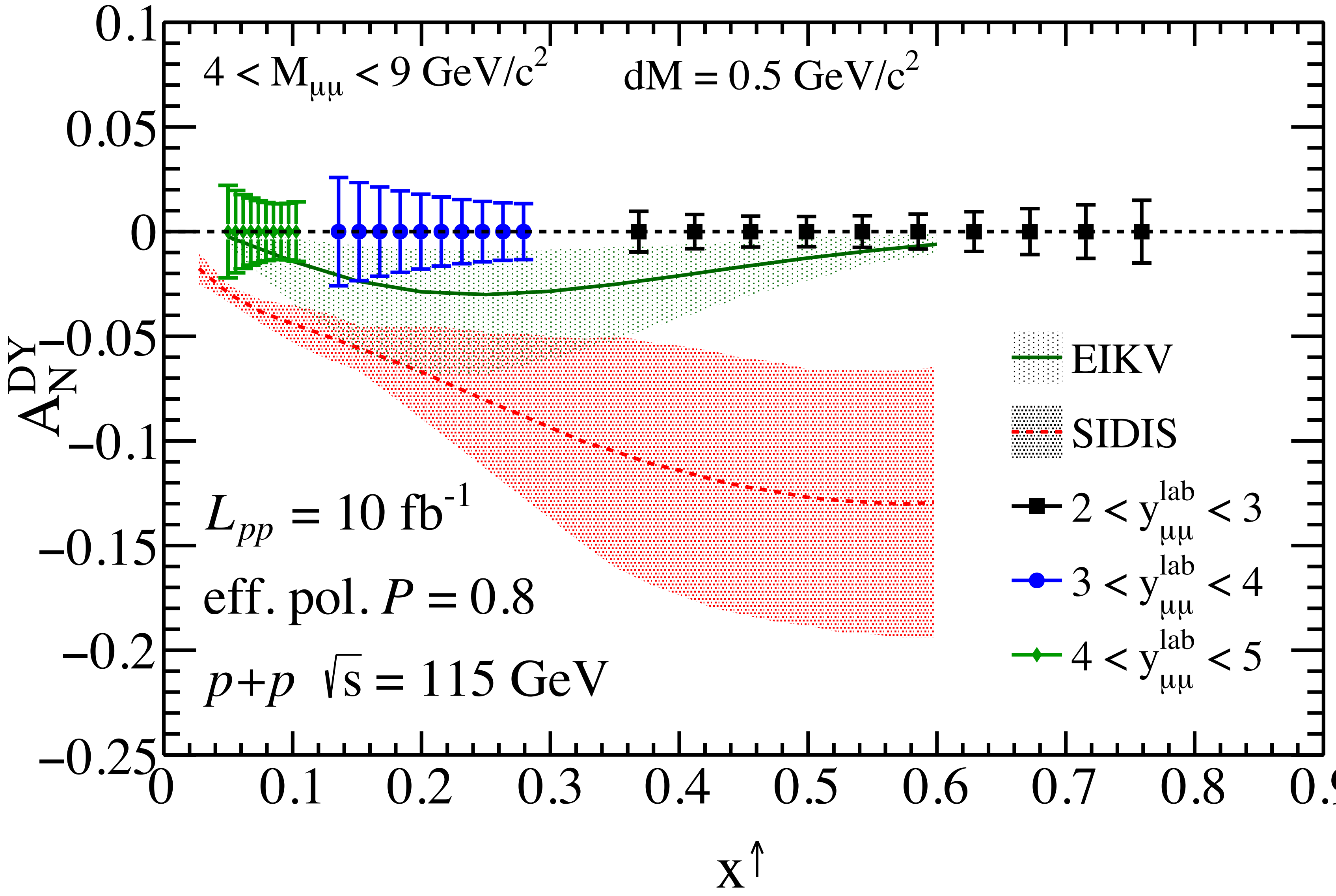
quark pol. / nucleon pol.

	U	L	T
U	f_1		$h_1^{\perp}$
L		g_{1L}	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	g_{1T}	$h_1,\ h_{1T}^{\perp}$

Transv. polarized Drell-Yan



Golden Channel



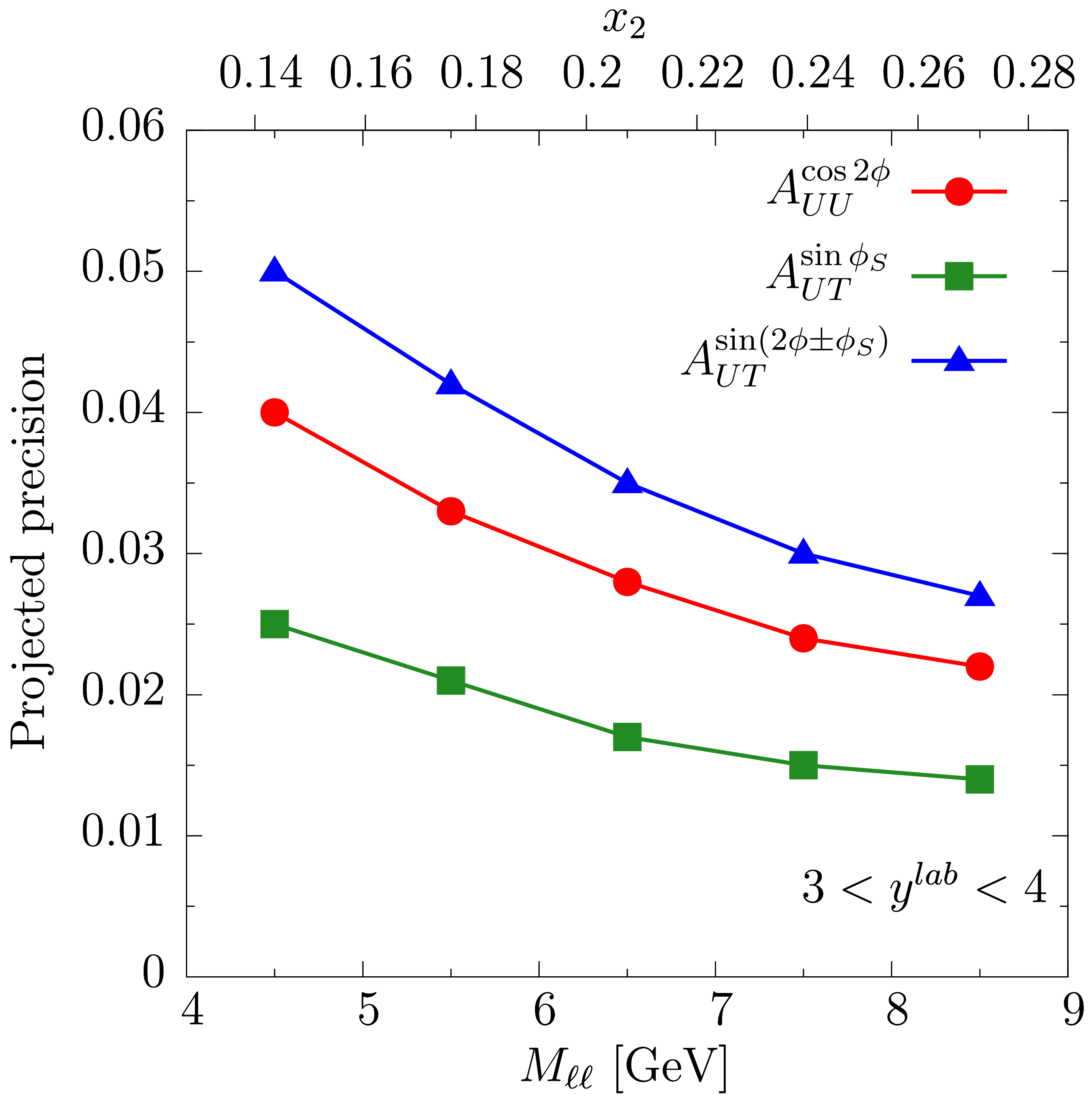
[arXiv:1807.00603]

- **Sensitive to quark TMDs through TSSAs**

$$A_N^{DY} = \frac{1}{P}\frac{\sigma_{DY}^{\uparrow} - \sigma_{DY}^{\downarrow}}{\sigma_{DY}^{\uparrow} + \sigma_{DY}^{\downarrow}} \Longrightarrow \quad A_{UT}^{\sin\phi_S} \sim \frac{f_1^q \otimes f_{1T}^{\perp q}}{f_1^q \otimes f_1^q}, \quad A_{UT}^{\sin(2\phi-\phi_S)} \sim \frac{h_1^{\perp q} \otimes h_1^q}{f_1^q \otimes f_1^q}, \ldots$$

(ϕ: azimuthal orientation of lepton pair in dilepton CM)

LHCb has excellent μ-ID & reconstruction for $\mu^+\mu^-$ ➡ **dominant:** $\bar{q}(x_{beam}) + q(x_{target}) \rightarrow \mu^+\mu^-$
suppressed: $q(x_{beam}) + \bar{q}(x_{target}) \rightarrow \mu^+\mu^-$



[arXiv:1807.00603]

- Extraction of qTMDs does not require knowledge of FF
- Verify sign change of Sivers function wrt SIDIS $f_{1T}^{\perp}|_{DY} = -f_{1T}^{\perp}|_{SIDIS}$
- Test flavour sensitivity using both H and D targets

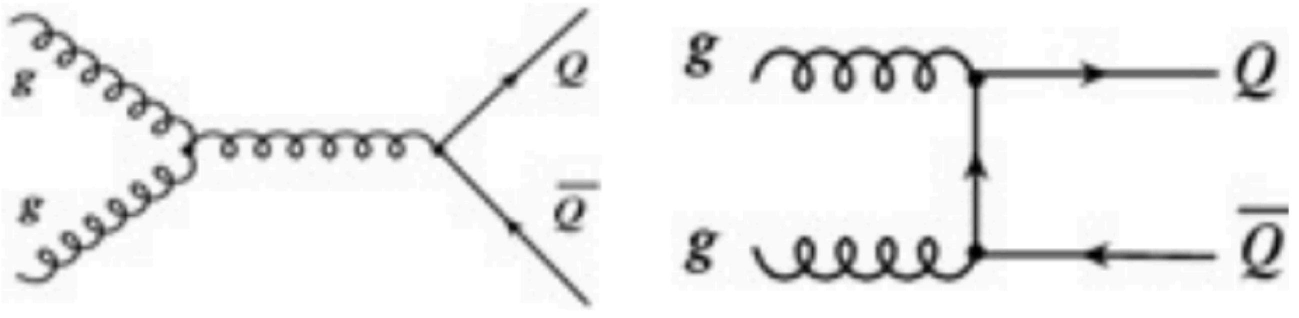
Gluon TMDs

Theory framework well consolidated, but experimental access still extremely limited

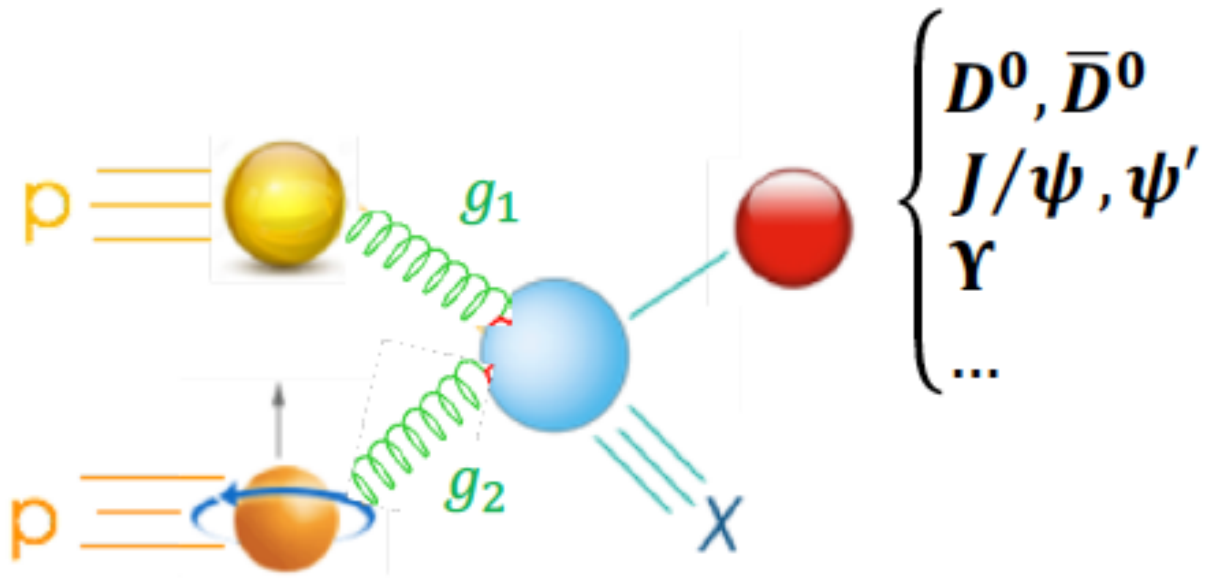
gluon pol.

nucleon pol.	U	Circularly	Linearly
U	f_1^g		$h_1^{\perp g}$
L		g_{1L}^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	$h_1^g,\ h_{1T}^{\perp g}$

The most efficient way to access the gluon dynamics inside the proton at LHC is to measure heavy-quark observables.
At LHC heavy quarks are produced by the dominant gg fusion process



Inclusive quarkonia production in (un)polarized pp interaction turns out to be an ideal observable to access gTMDs



TMD factorisation requires $q_T(Q) \ll M_Q$:

- Can look at associate quarkonia production, where only relative q_T needs to be small (e.g. $pp^{(\uparrow)} \to J/\Psi + J/\Psi + X$)
- Due to the large masses, easier in case of bottomonium where factorisation can hold at large q_T

Gluon TMDs

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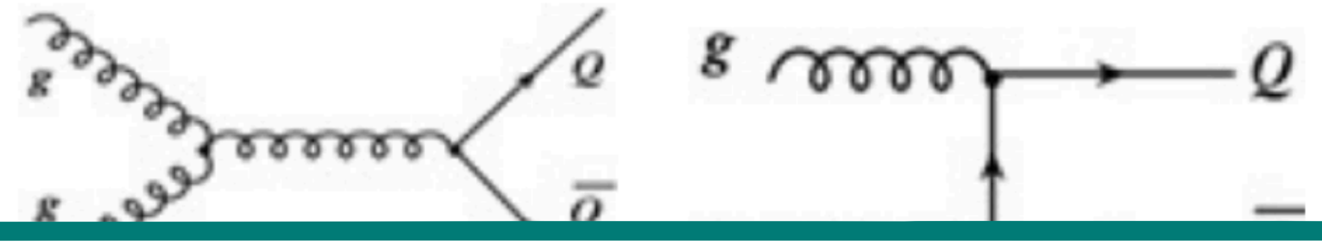
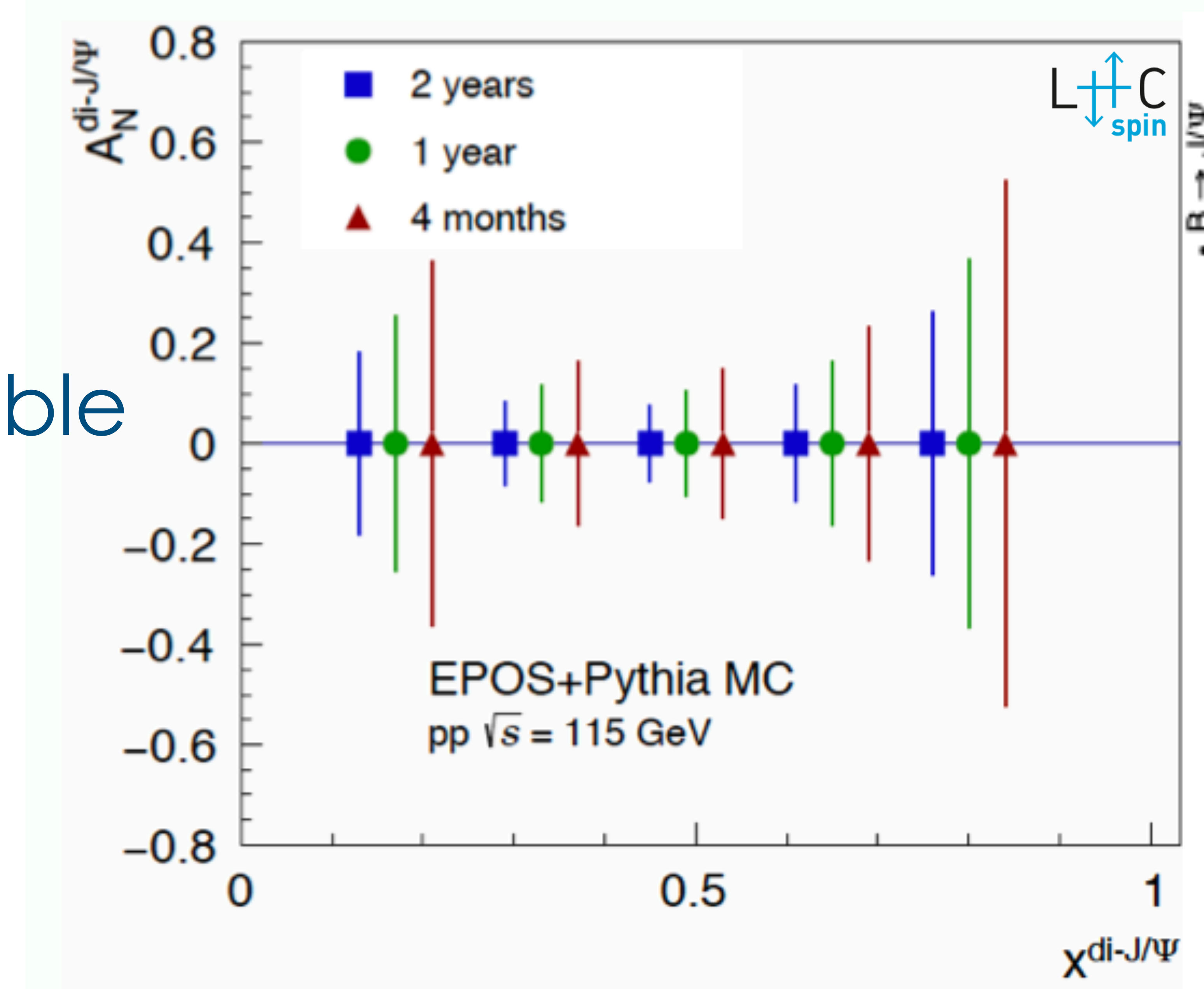
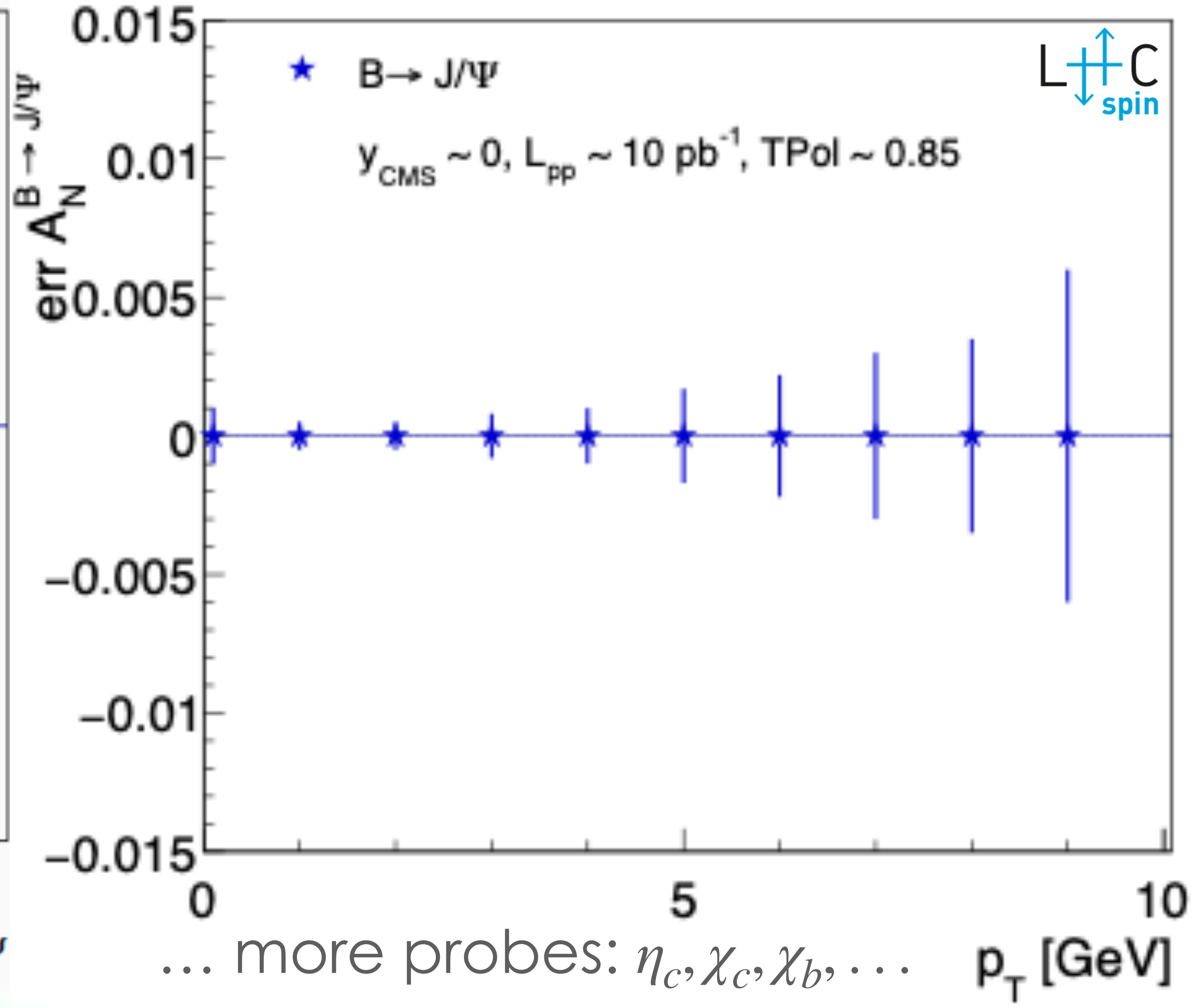


Gluon-induced asymmetries (unconstrained $h_1^{\perp g} + f_1^g$) accessible by, e.g., $di-J/\Psi$ or Υ production

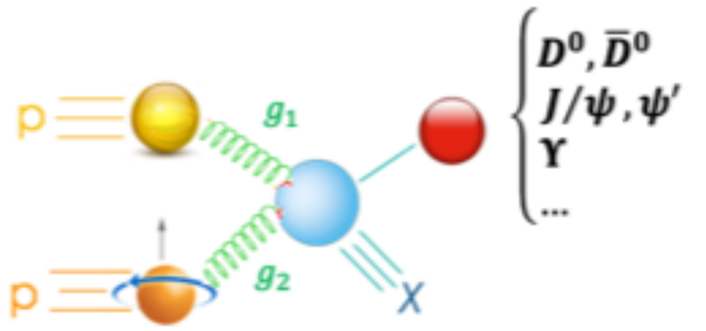




… more probes: $\eta_c, \chi_c, \chi_b, \ldots$

factorisation can hold at large q_T

Probing the Sivers function



gluon pol.

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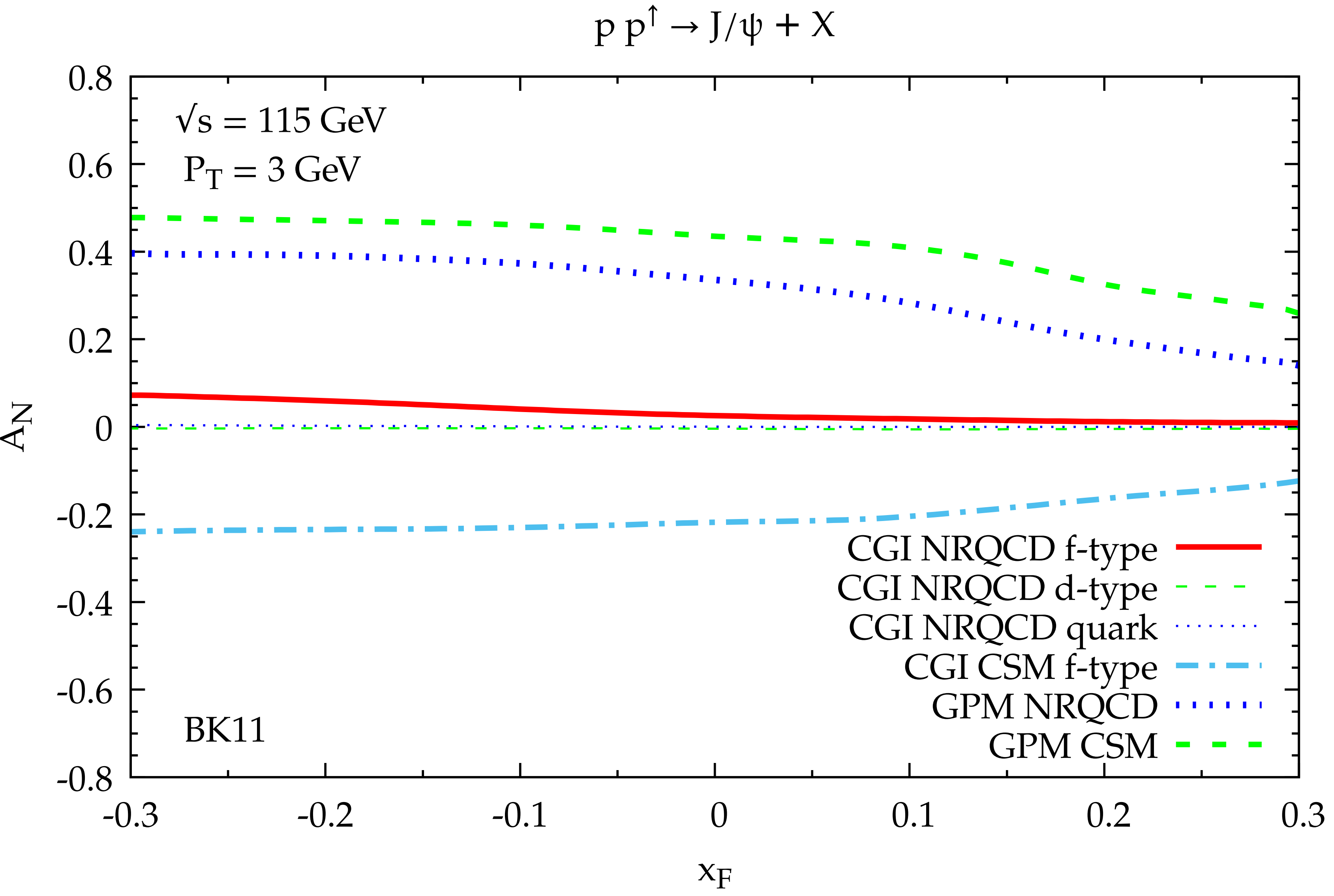
L		g_{1L}^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	h_1^g, $h_{1T}^{\perp g}$

Can be accessed through the Fourier decomposition of the TSSAs for <u>inclusive meson production</u>

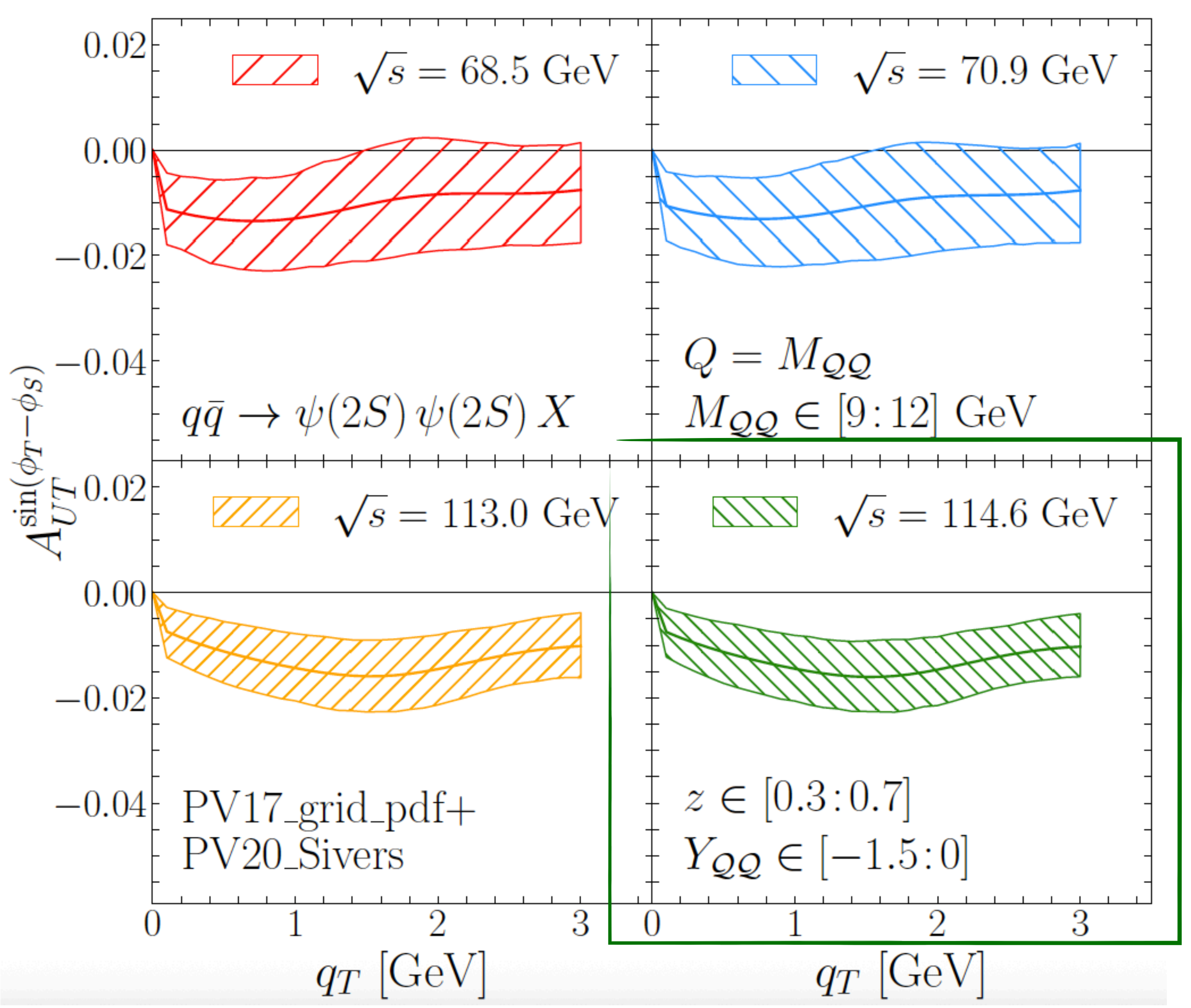
$$A_N = \frac{1}{P}\frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} \propto \left[f_{1T}^{\perp g}(x_a, k_{\perp a}) \otimes f_g(x_b, k_{\perp b}) \otimes d\sigma_{gg\to QQg} \right] \sin\phi_S + \cdots$$

Sensitive to color exchange among IS and FS, and gluon OAM

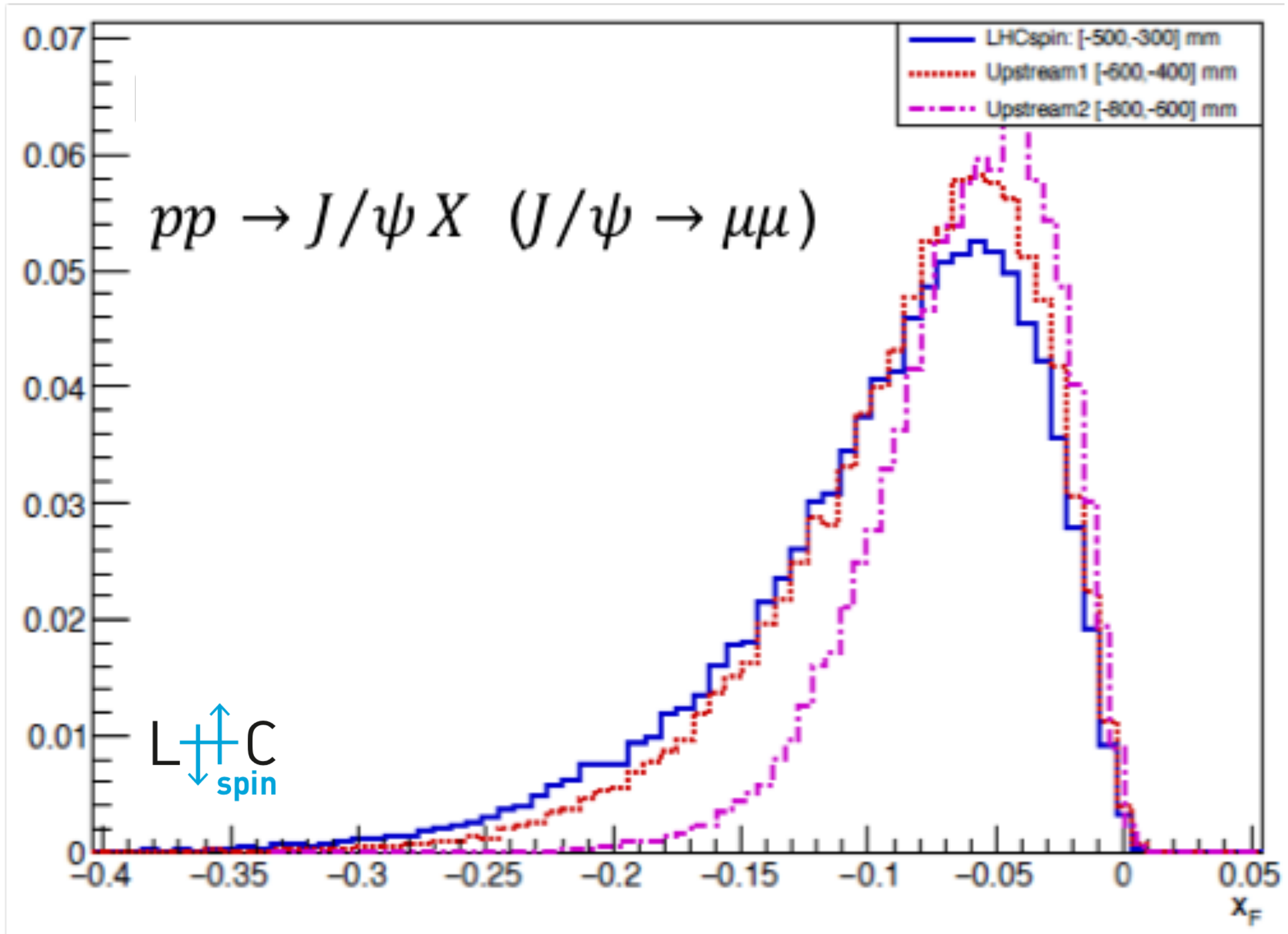
Shed light on spin-orbit correlation of unpolarized gluons inside a transversely polarized proton



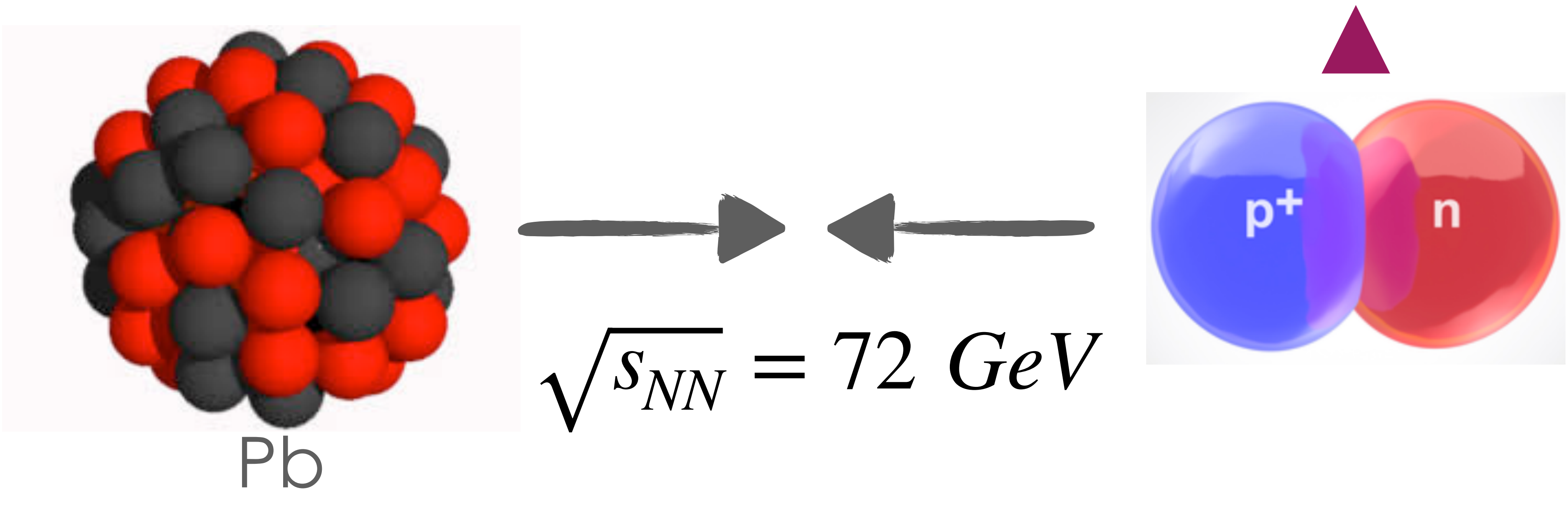
Phys. Rev. D 102, 094011 (2020)



ArXiv:2508.15482

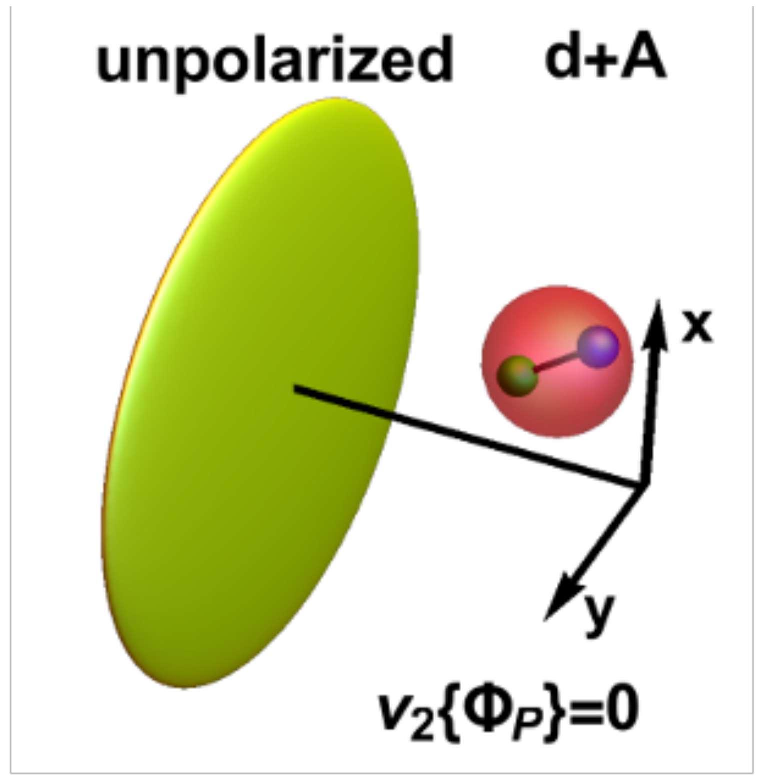


Spin physics in heavy-ion collisions

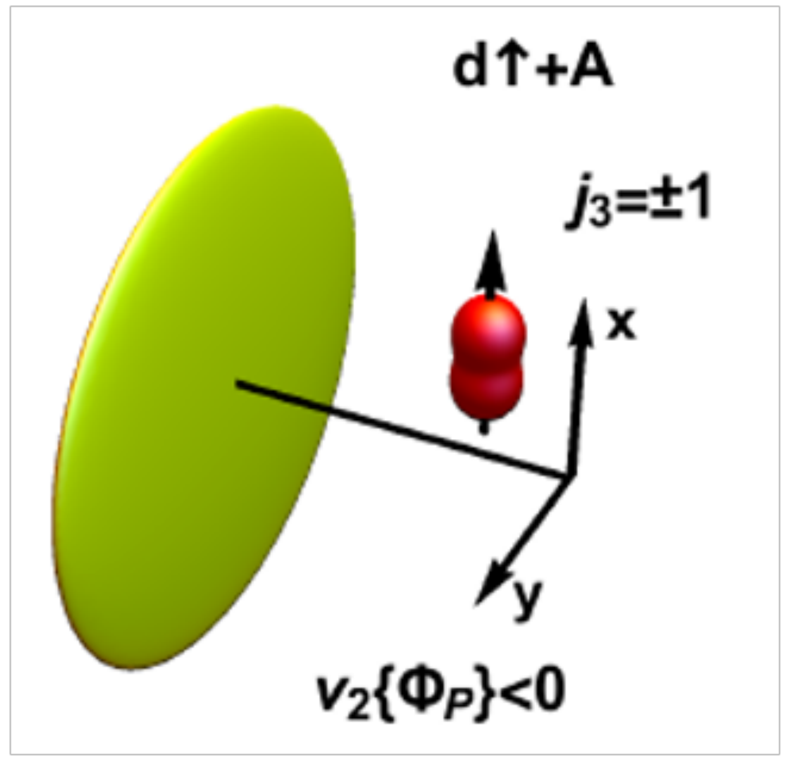


•probe <u>collective phenomena</u> in heavy-light systems through **ultra-relativistic collisions of heavy nuclei with trasv. pol. deuterons**

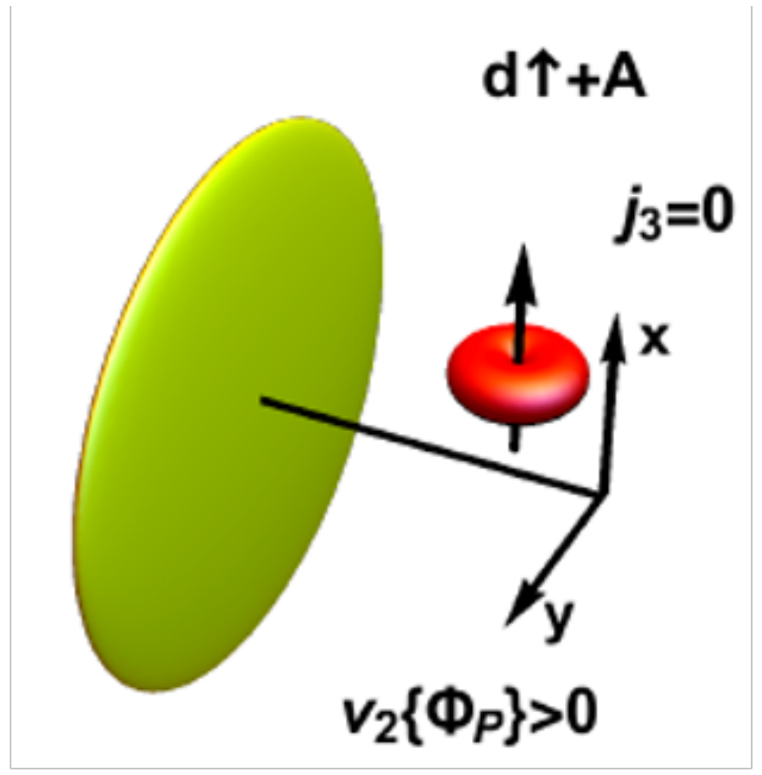
•polarized light target nuclei offer a unique opportunity to control the orientation of the formed fireball by measuring the **elliptic flow** relative to the polarization axis (**ellipticity**).



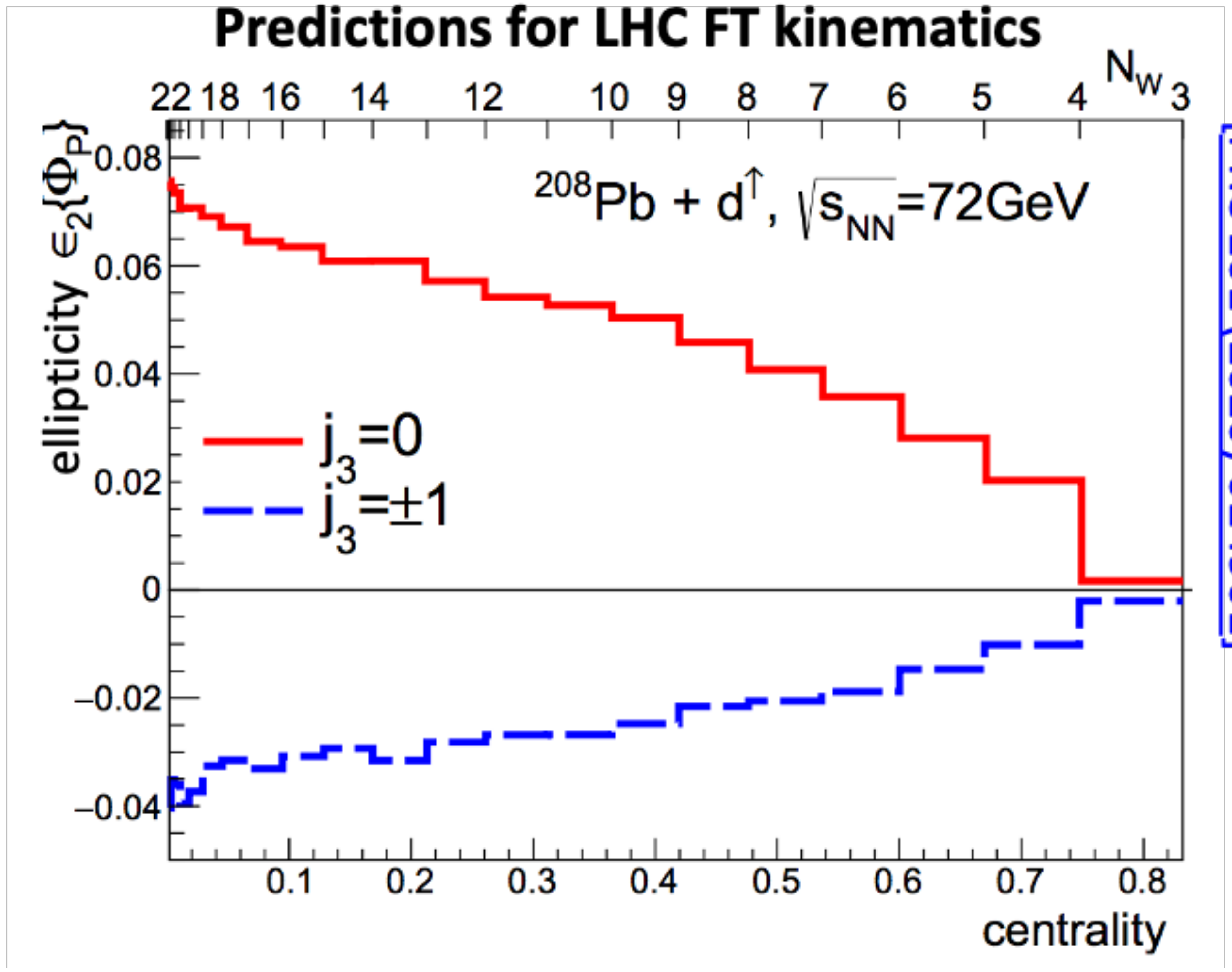
Unpol. deuterons: the **fireball is azimuthally symmetric** and $v_2 \approx 0$.



$j_3 = \pm 1$ → **prolate fireball** stretched along the pol. axis, corresponds to $v_2 < 0$



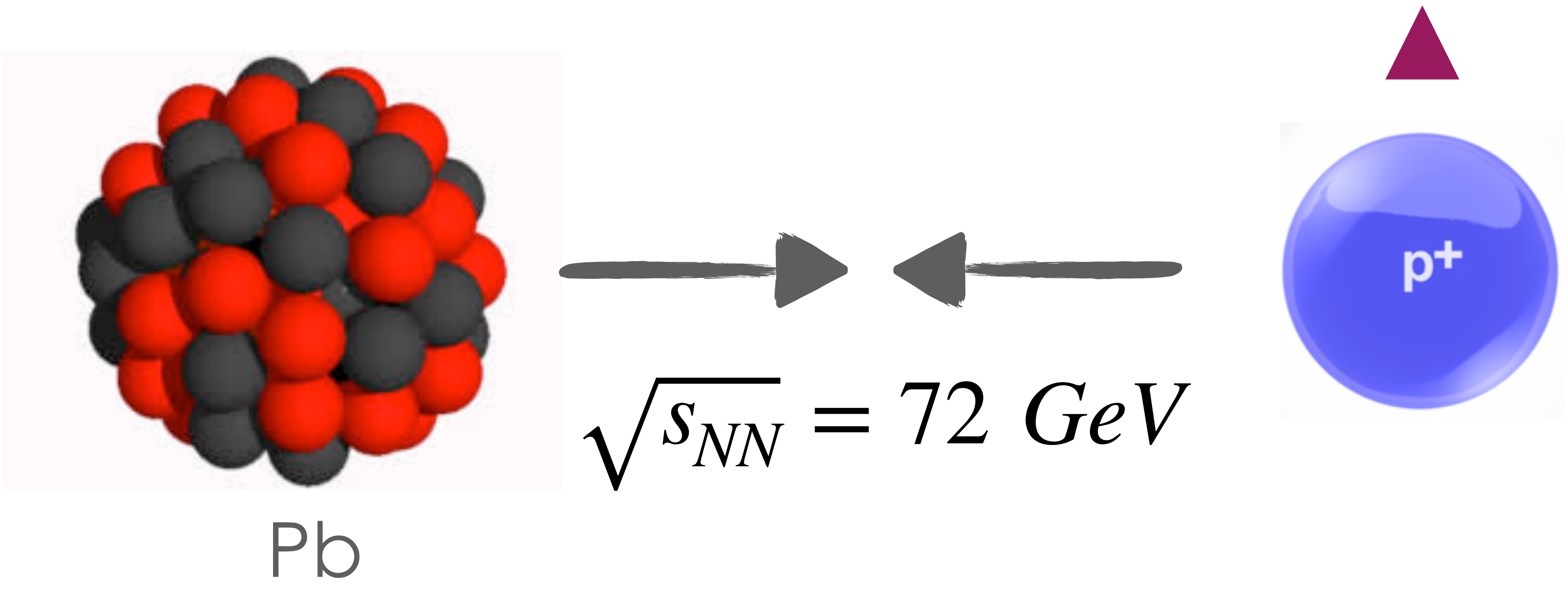
$j_3 = 0$ → **oblate fireball** corresponds to $v_2 > 0$



[PRC 101 (2020) 024901]

Wojciech Broniowski, Piotr Bozek

Spin physics in heavy-ion collisions

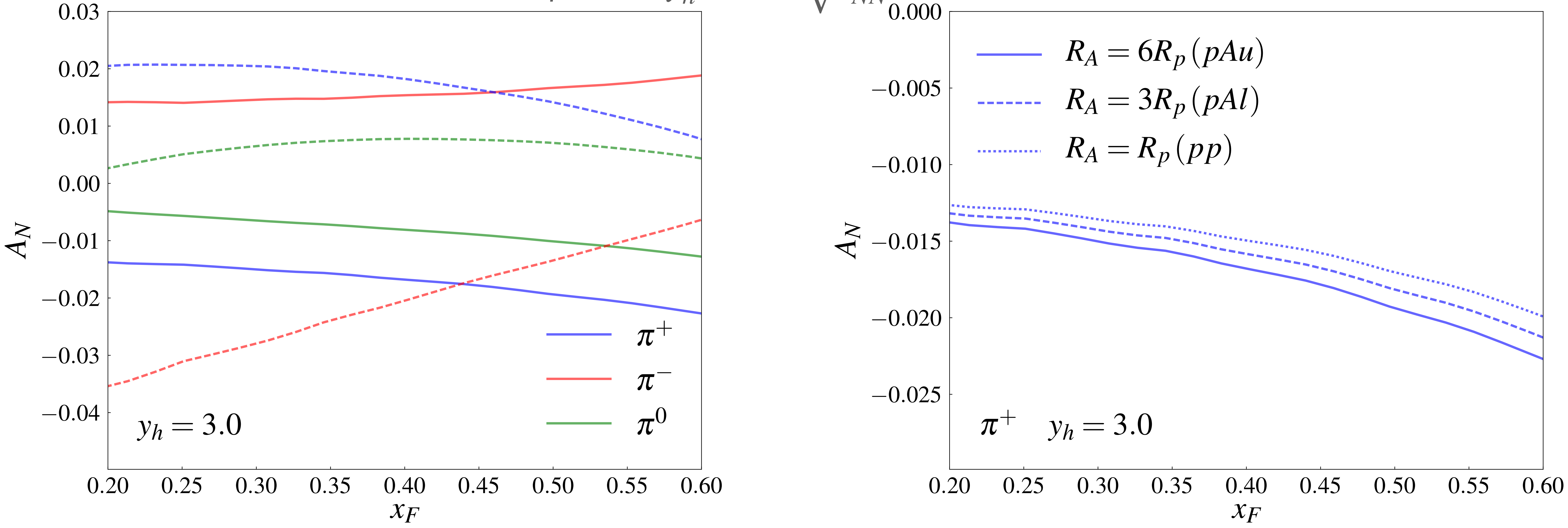


Single spin asymmetries in ultra-peripheral $p^{\uparrow}A \to hAX$ collisions

to test the assumed dominance of the contribution from twist-three fragmentation functions

p+Au, $y_h = 3.0$, $\sqrt{s_{NN}} = 200\ GeV$

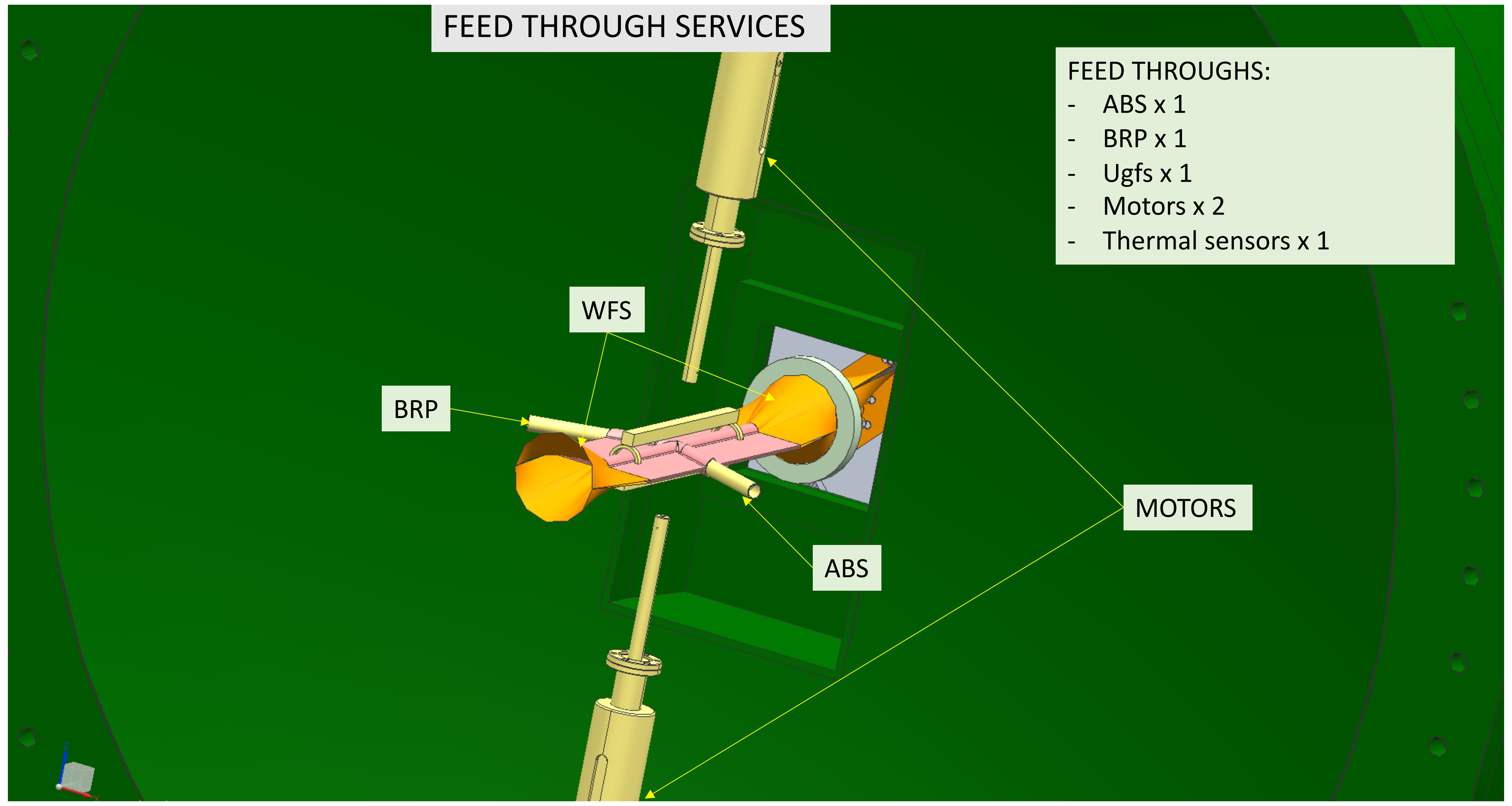
Phys. Rev. D98, 094025 (2018)



kinematic region and required precision well fit the LHCspin potentialities

PGT implementation into LHCb

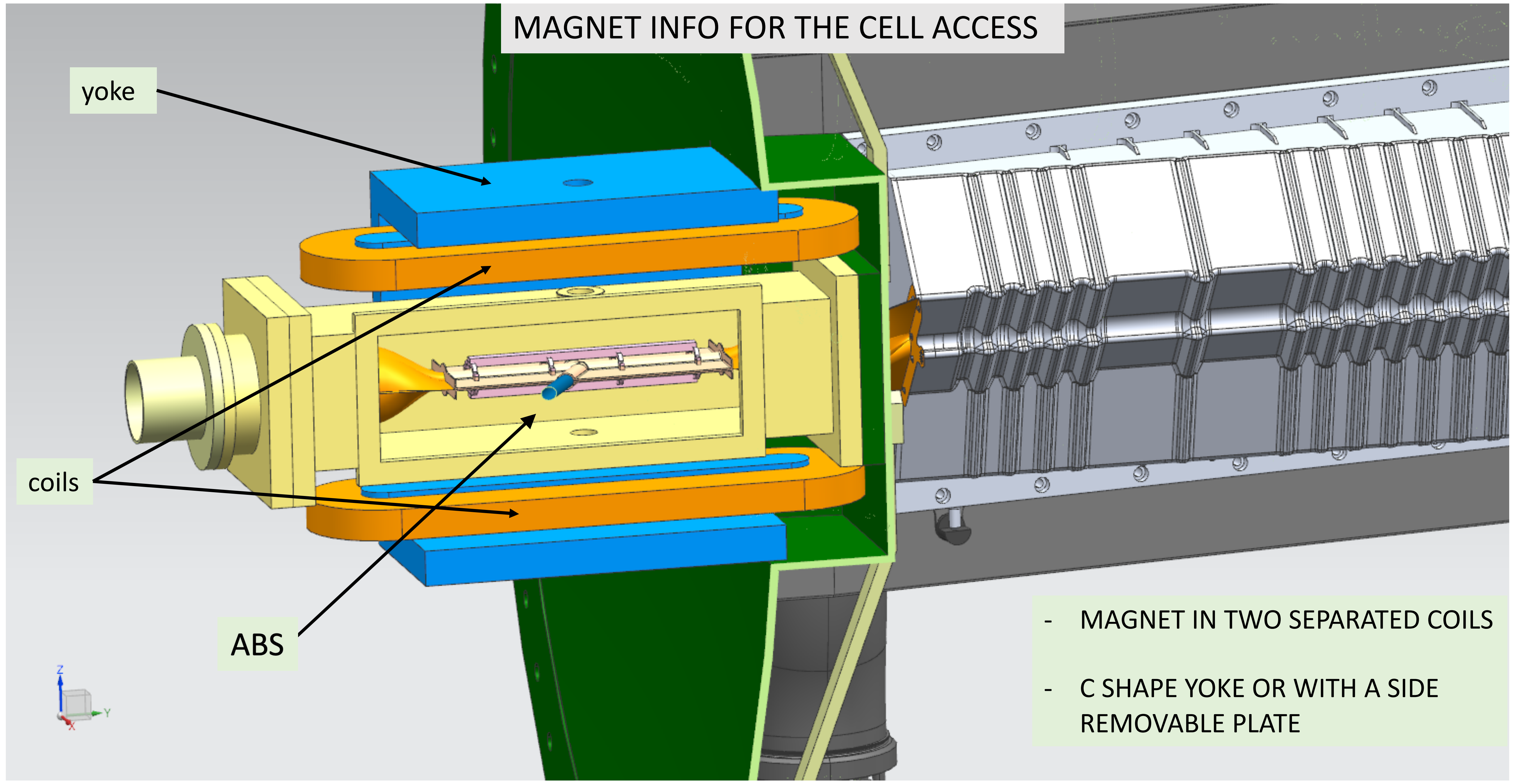
- Inject polarized gas via ABS and unpolarized gas via UGFS

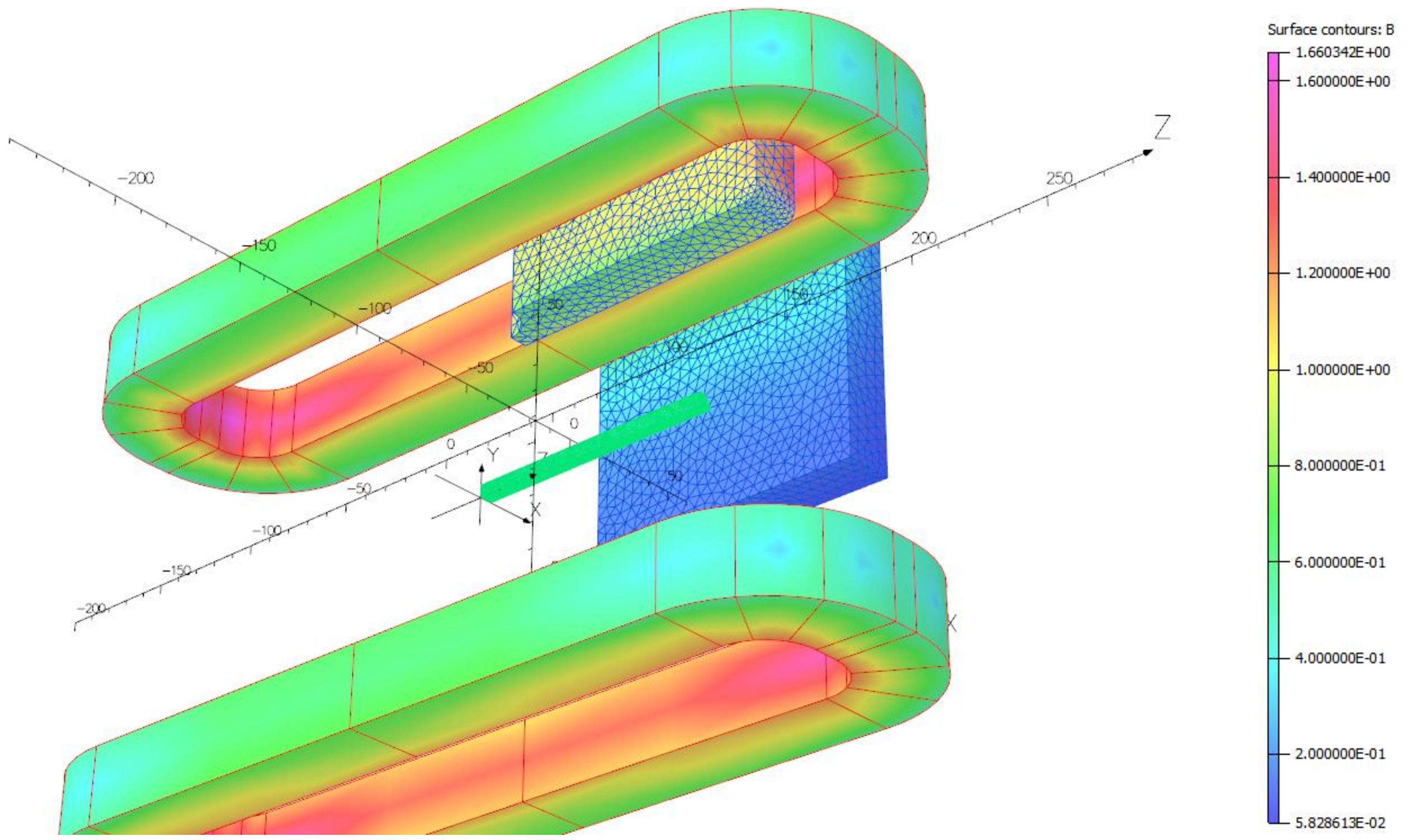


- Compact dipole magnet → static transverse field
- Superconductive coils + iron yoke configuration fits the space constraints
- $B = 300$ mT with polarity inversion, $\Delta B/B \simeq 10\,\%$, suitable to avoid beam-induced depolarization [PoS (SPIN2018)]

Possibility to switch to a solenoid and provide longitudinal polarization

Transverse polarization





Role of the storage cell coating

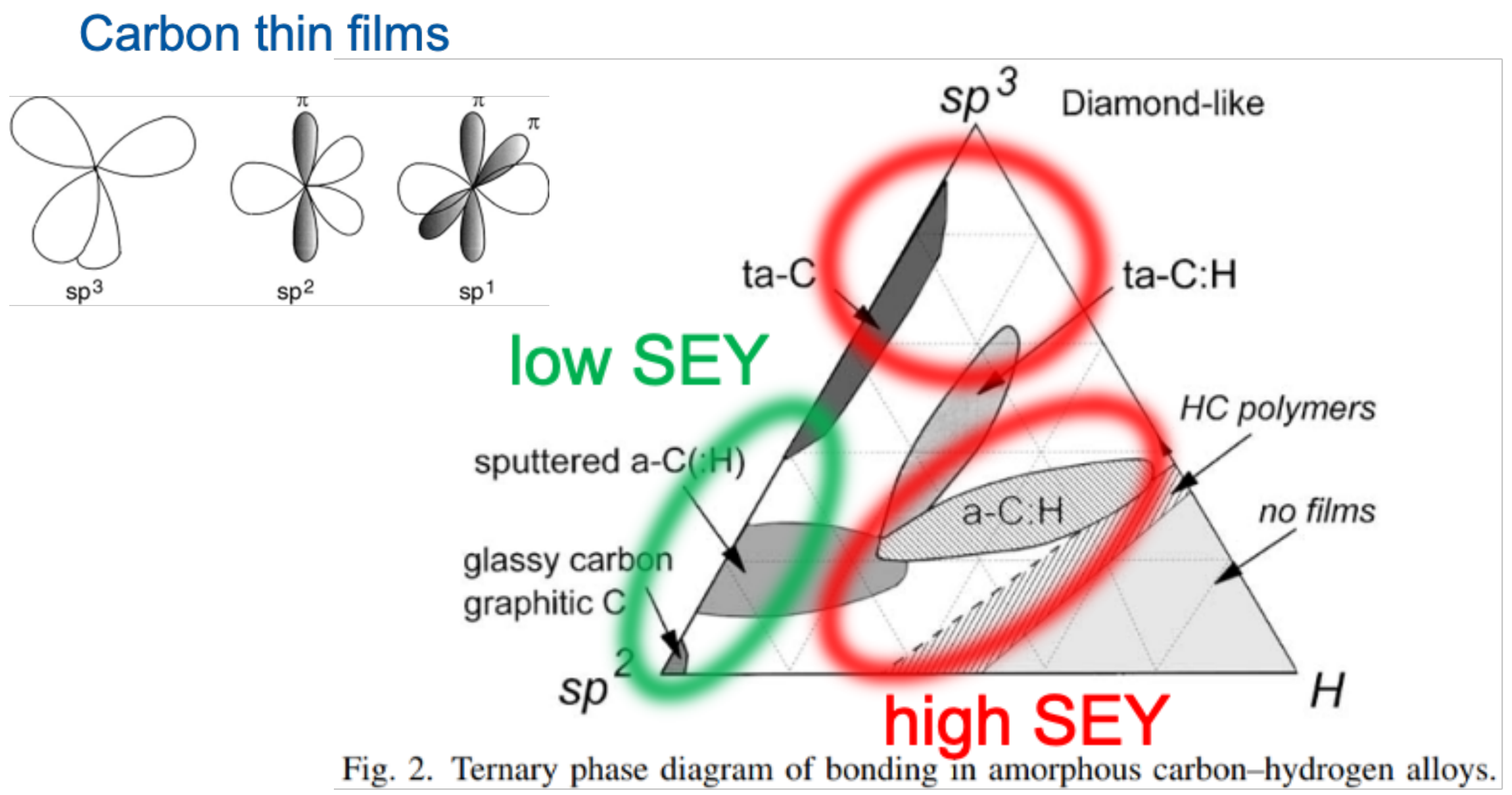
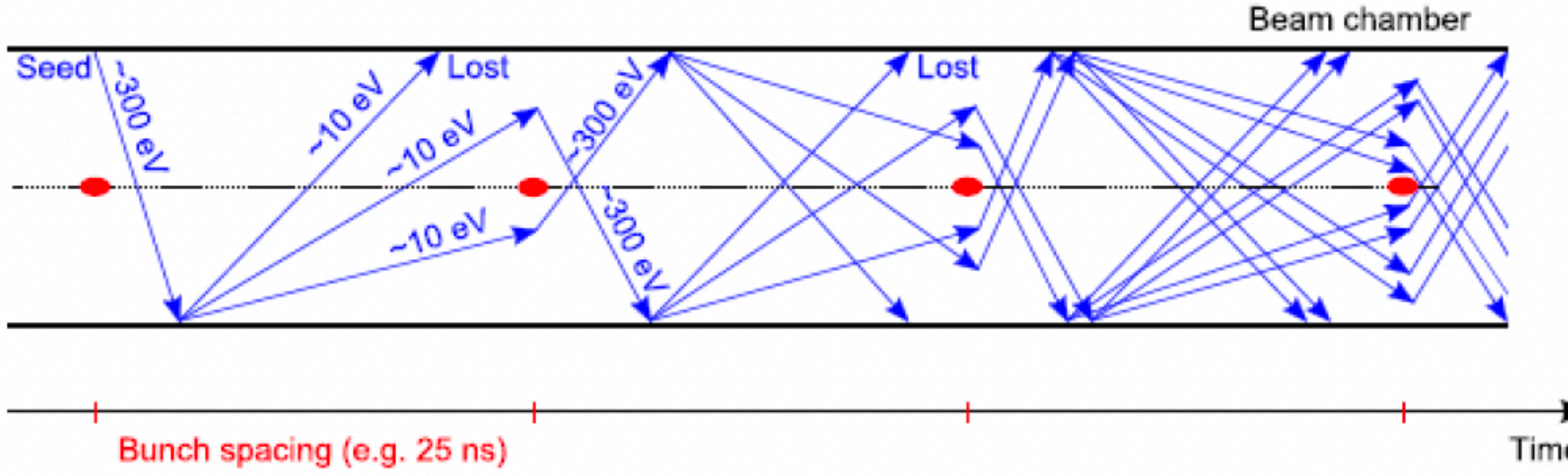


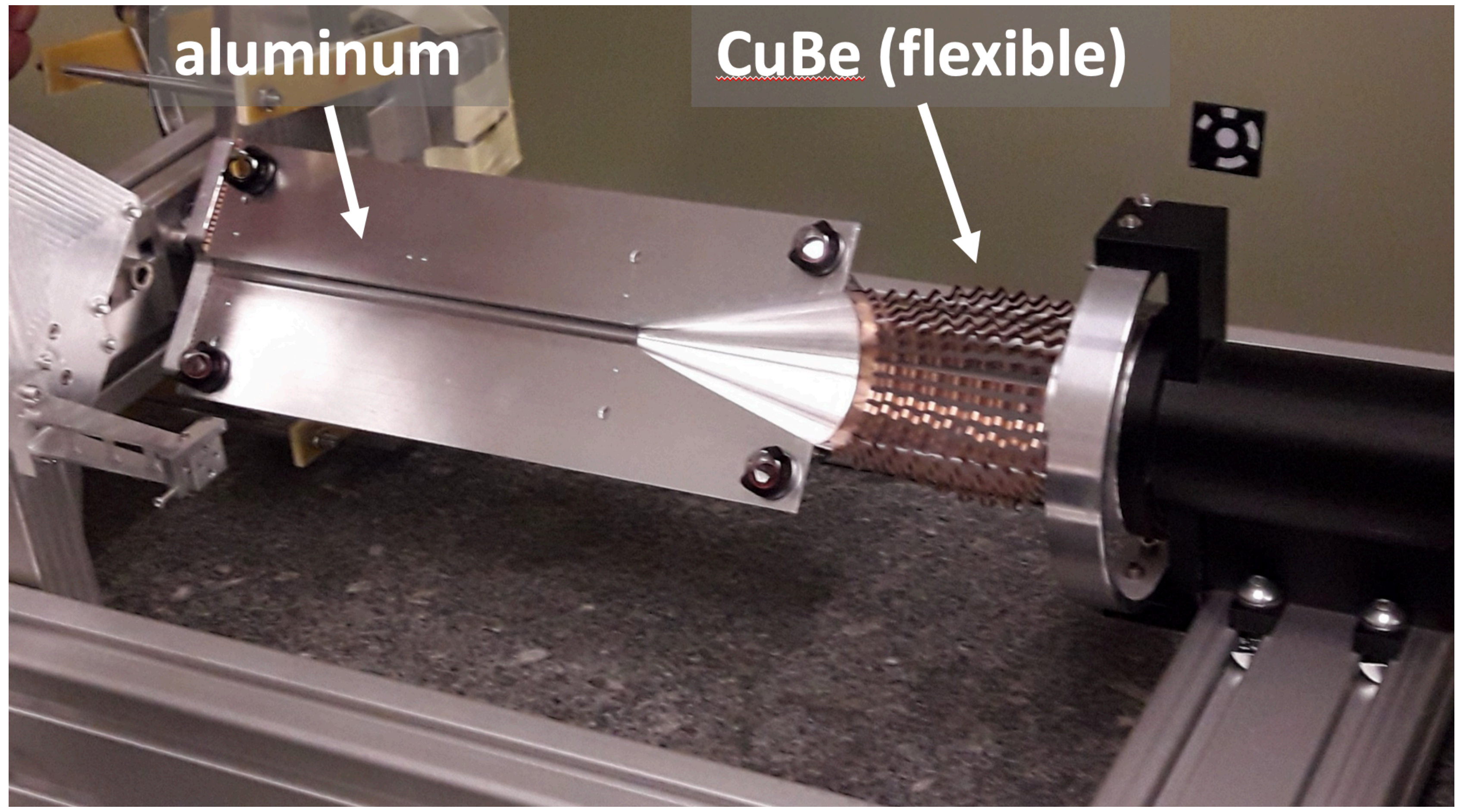
Fig. 2. Ternary phase diagram of bonding in amorphous carbon–hydrogen alloys.

J. Robertson / Materials Science and Engineering R 37 (2002) 129–281

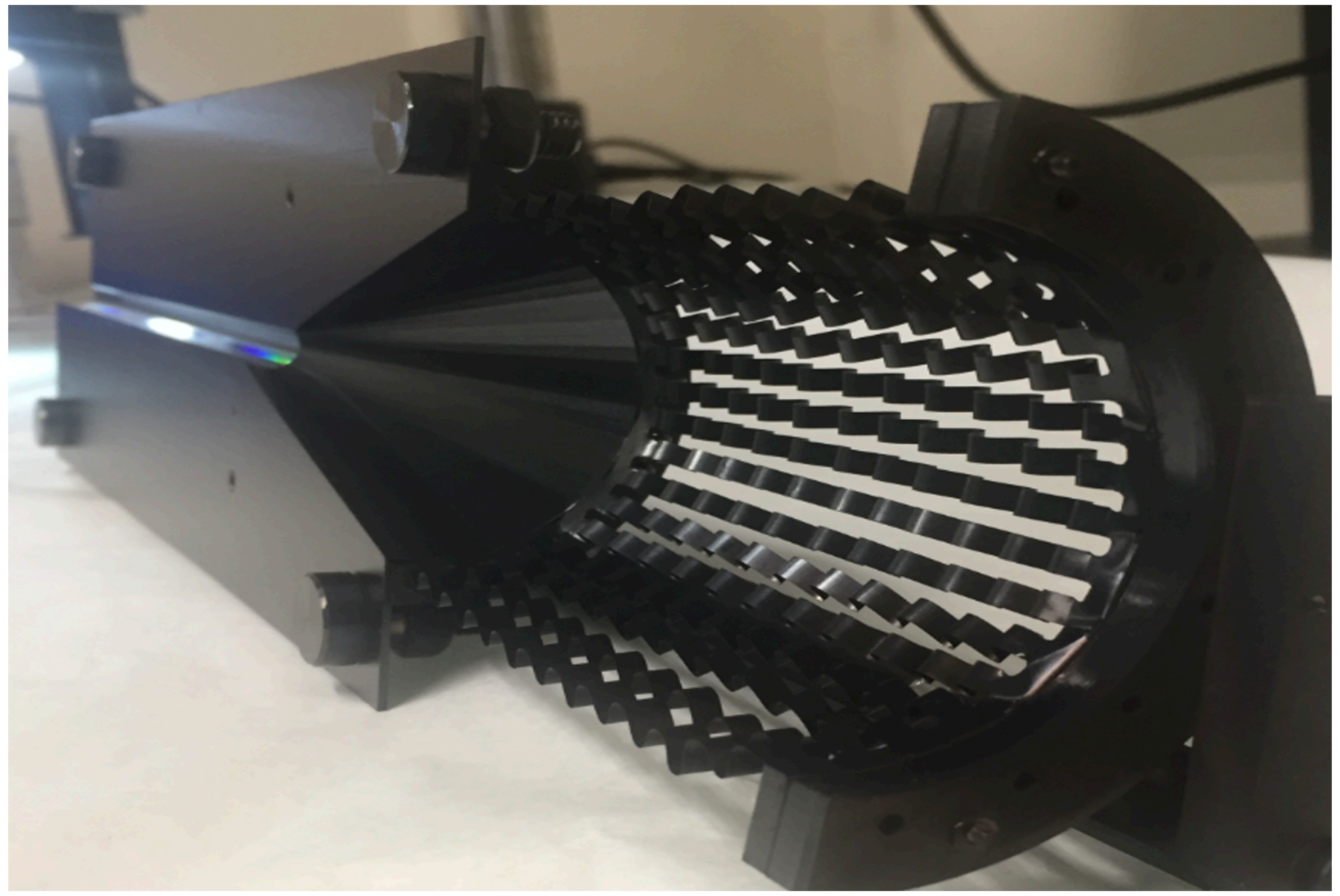


The material of the cell walls must have a low Secondary Electron Yield (e-cloud)

SMOG2 non coated cell

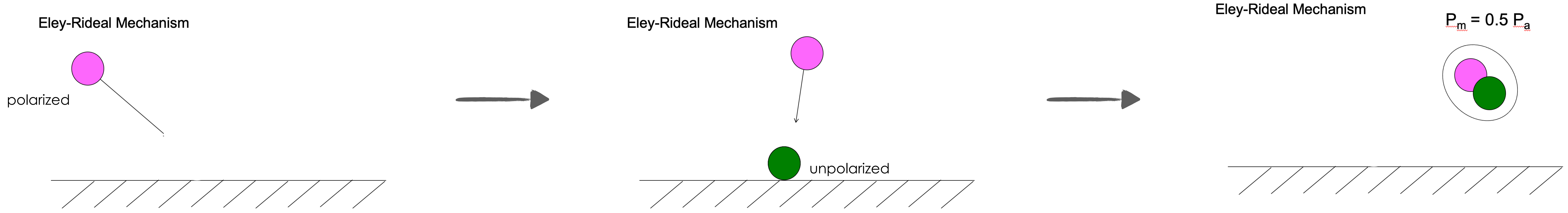


SMOG2 amorphous Carbon coated cell



Coating issues

Amorphous carbon is a very effective coating for maintaining low SEY, as demonstrated by SMOG2. However, what about atomic recombination?



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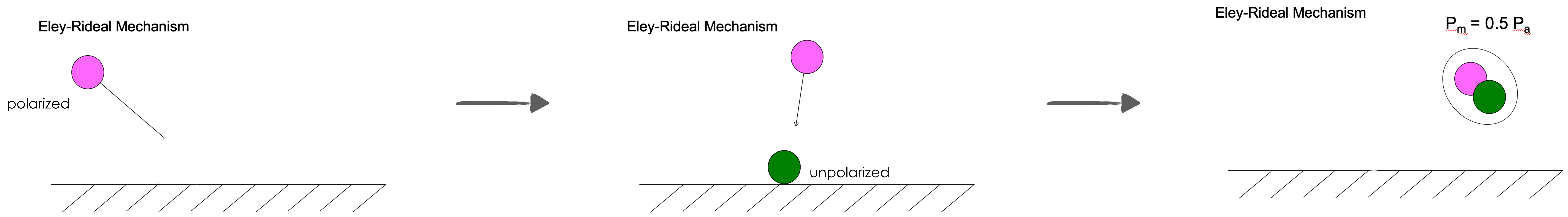

In previous experiments at HERA and COSY, Dryfilm (silicon) or Teflon (fluoride) coating, combined with ice layers, kept the SEY low and prevented recombination

This is not possible at LHC: no fluoride, no silicon materials allowed

Coating issues

Let’s try to change the paradigm and exploit the recombination effects.
This can happen if:

1) the recombination process is “fast enough” to recombine two polarized atoms
2) the recombination into molecules is very high

Coating issues

Let's try to change the paradigm and exploit the recombination effects.
This can happen if:

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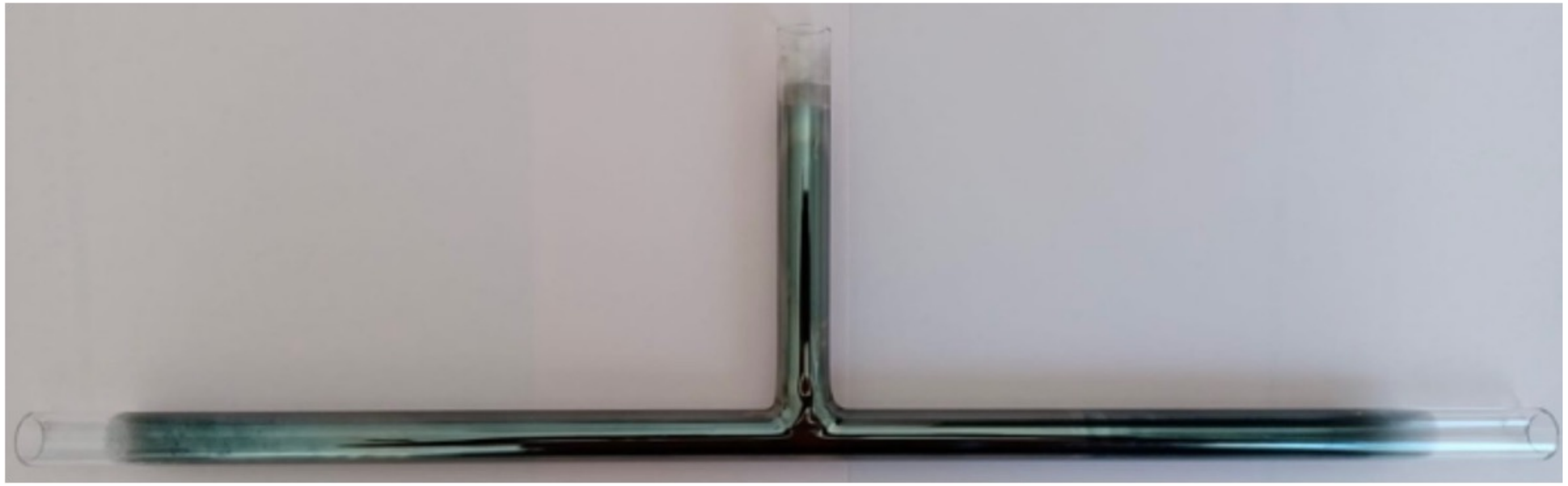
2) the recombination into molecules is very high

A test was performed at FZ-Julich on a quartz storage cell coated at CERN with amorphous carbon, just like the SMOG2 storage cell

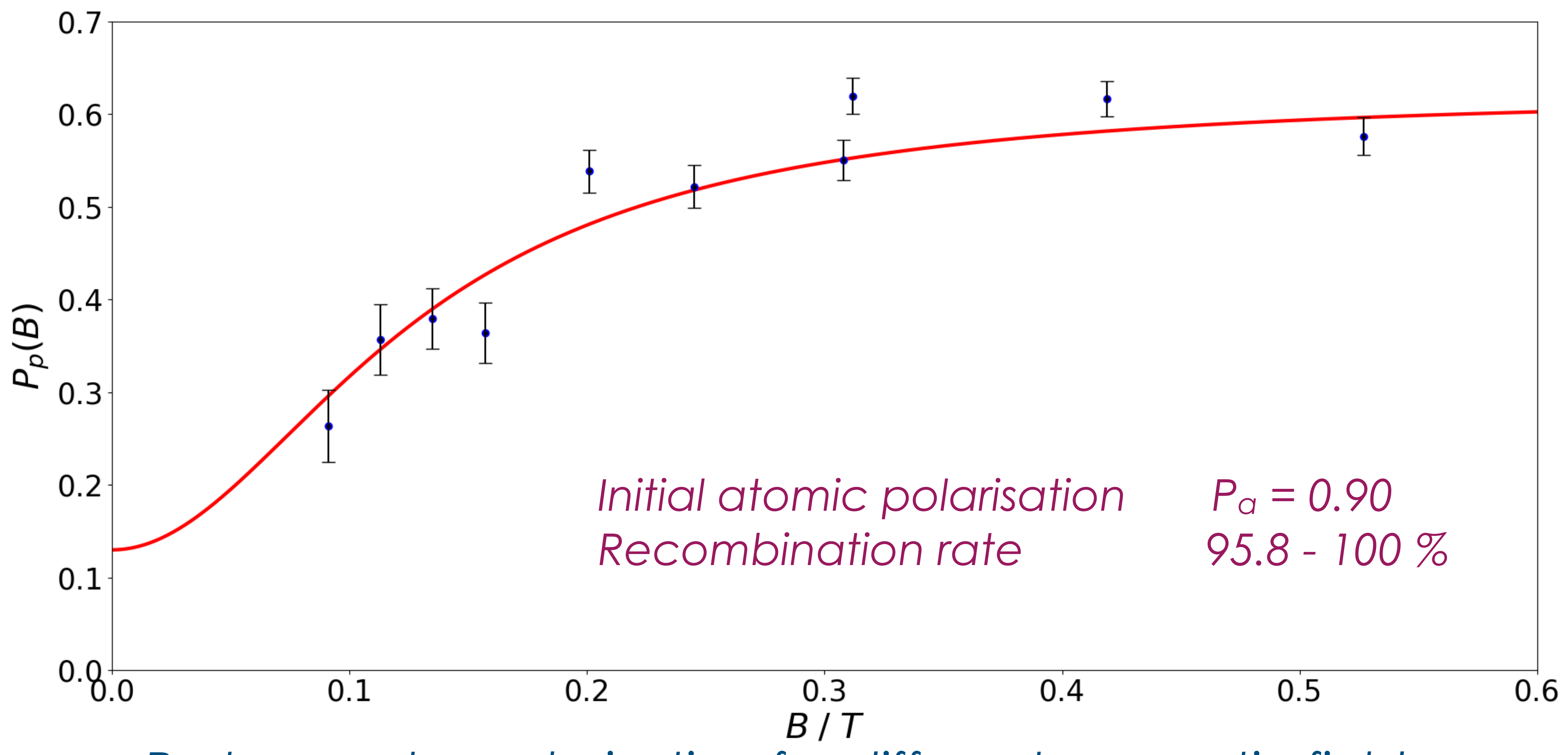


Acknowledgement for the coating process: Yorick DELAUP, Bernard HENRIST, Pedro COSTA PINTO - CERN TE-VSC

Role of the storage cell coating

The amorphous Carbon coating (the one used for SMOG2) provides almost full recombination and keeps a reasonable polarization

PoS PSTP2022 (2023) 036
PRL 124, 113003 (2020)
PRL 115, 113007 (2015)



Proton vector polarization for different magnetic fields

Nuclear Instruments and Methods in Physics Research A 1068 (2024) 169707

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journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Full Length Article

Amorphous carbon-coated storage cell tests for the polarized gas target at LHCb

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[h] Universität zu Köln, Albertus-Magnus-Platz, Köln, 50923, NRW, Germany

We can develop a new storage cell using polarized molecules

→

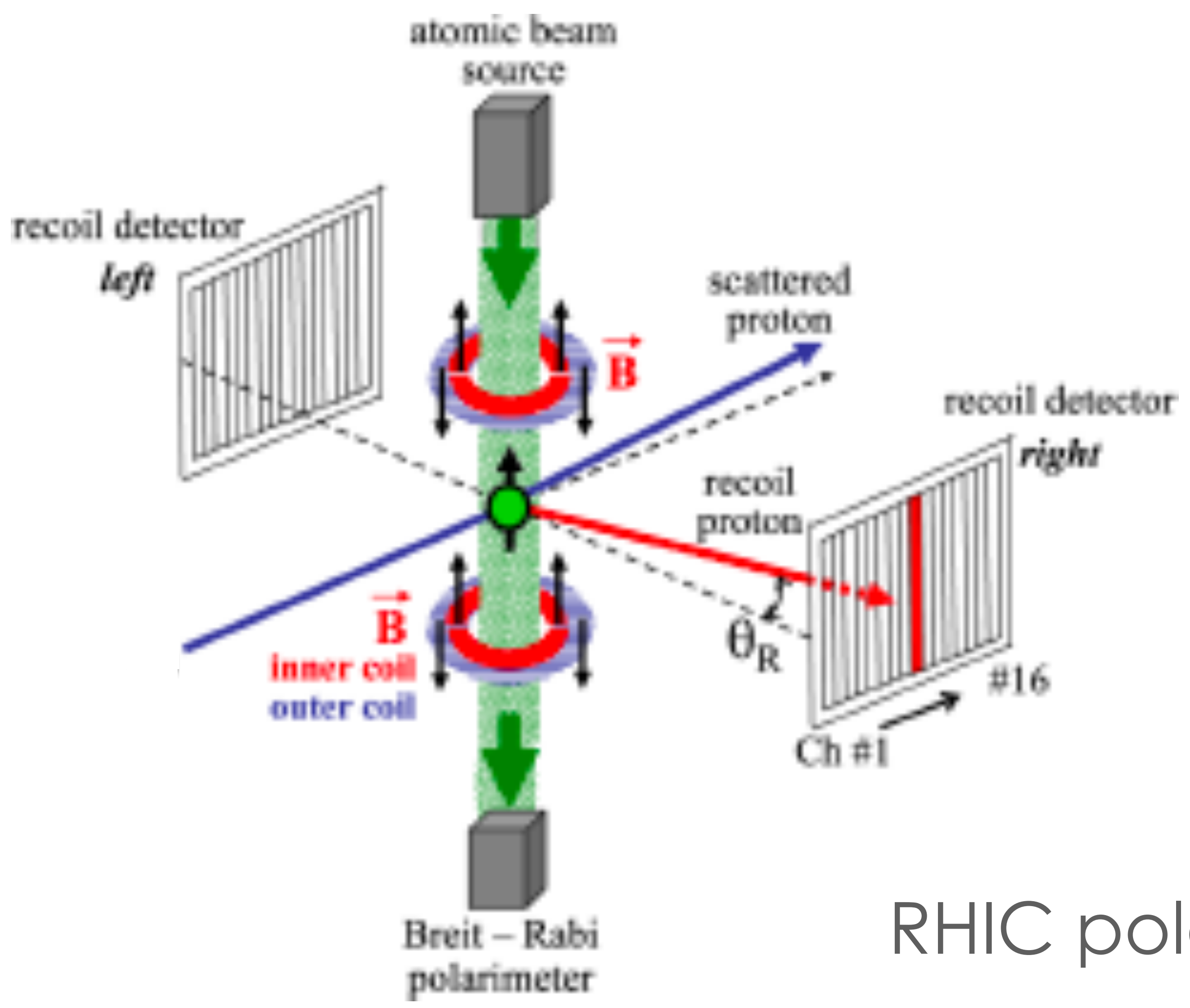
- high density target
- but an absolute polarimeter is needed

Development of an absolute polarimeter

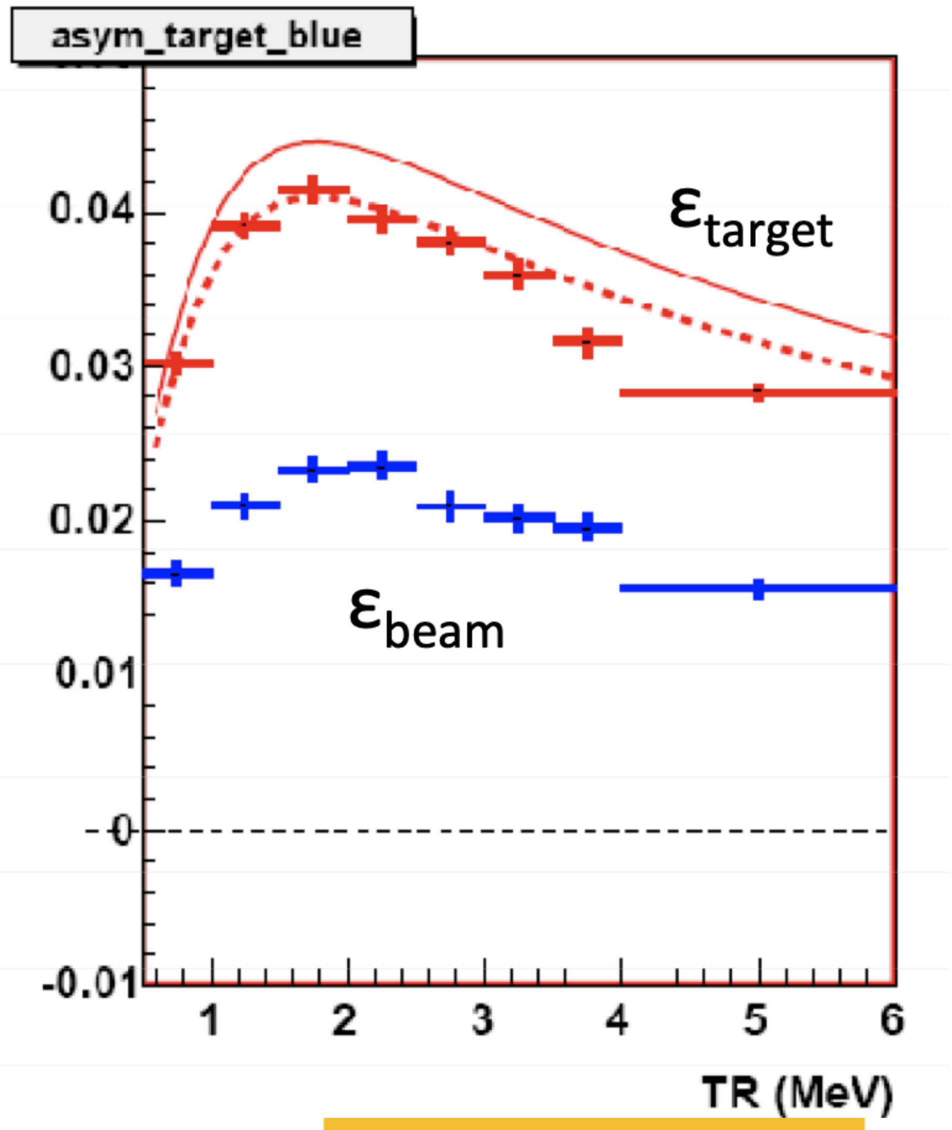
Based on the Coulomb Nuclear Interference (CNI), as done at RHIC

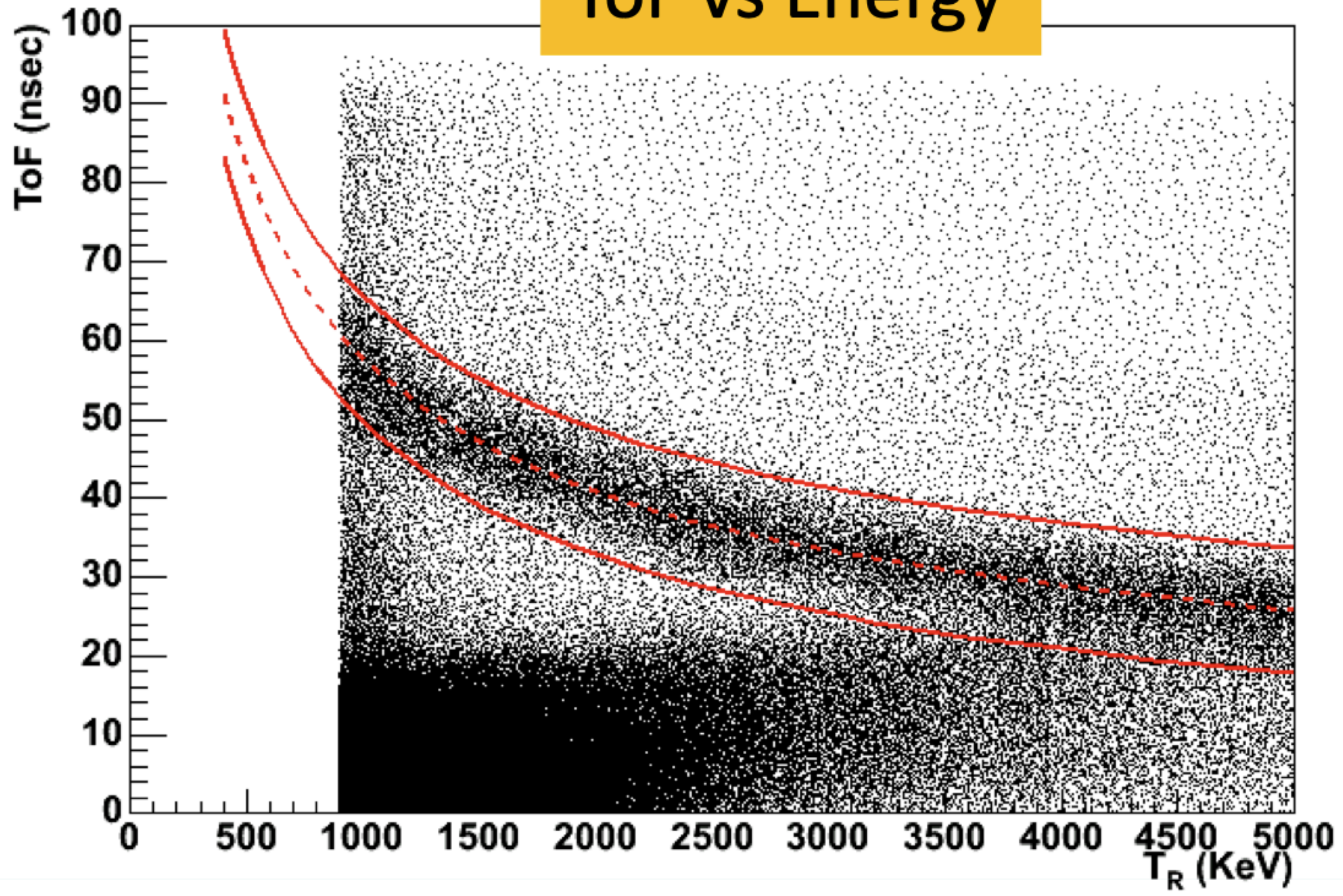
Nuclear Inst. and Methods in Physics Research, A 976 (2020) 164261

JPS Conf. Proc. 37, 021103 (2022)



RHIC polarimeter





To validate the theoretical predictions of the analyzing power at 7 TeV, in addition to evaluating detection efficiency and background, the absolute polarimeter must be installed in coincidence with the standard Breit-Rabi Polarimeter along the beamline

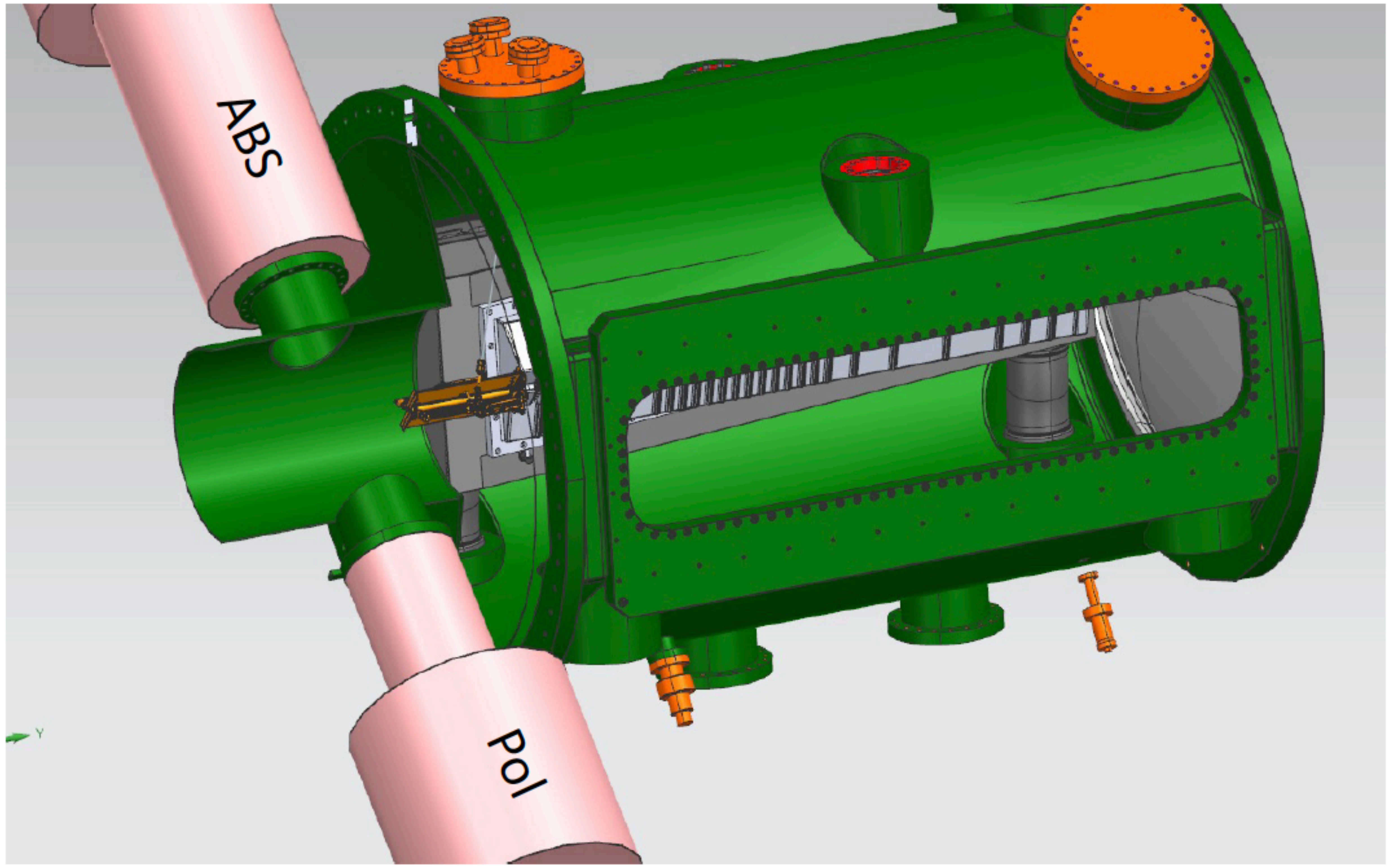
The backup: the jet target

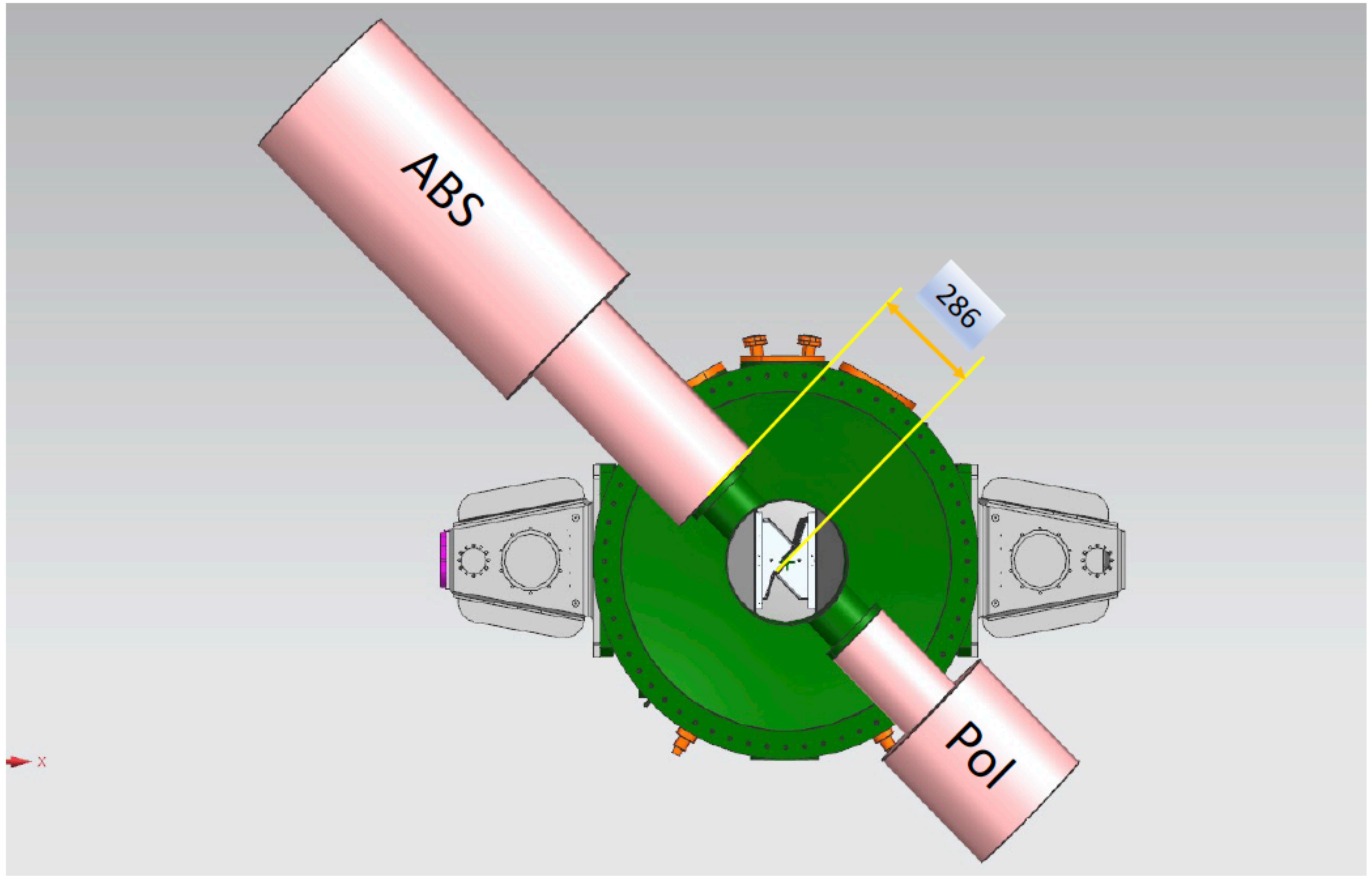
Alternative solution with **jet target** also under evaluation:

- lower density ($\sim 10^{12}$ atoms$/cm^2$)
- higher polarization (up to 90%)
- lower systematics in P measurement (virtually close to 0)

Pro
-no recombination
-high polarisation
-very small systematics on the polarisation measurements

Contra
-x40 less luminosity than the cell solution
(tolerable for the standard channels, relevant for the rare probes)





The plan is to develop the project in 2 phases:

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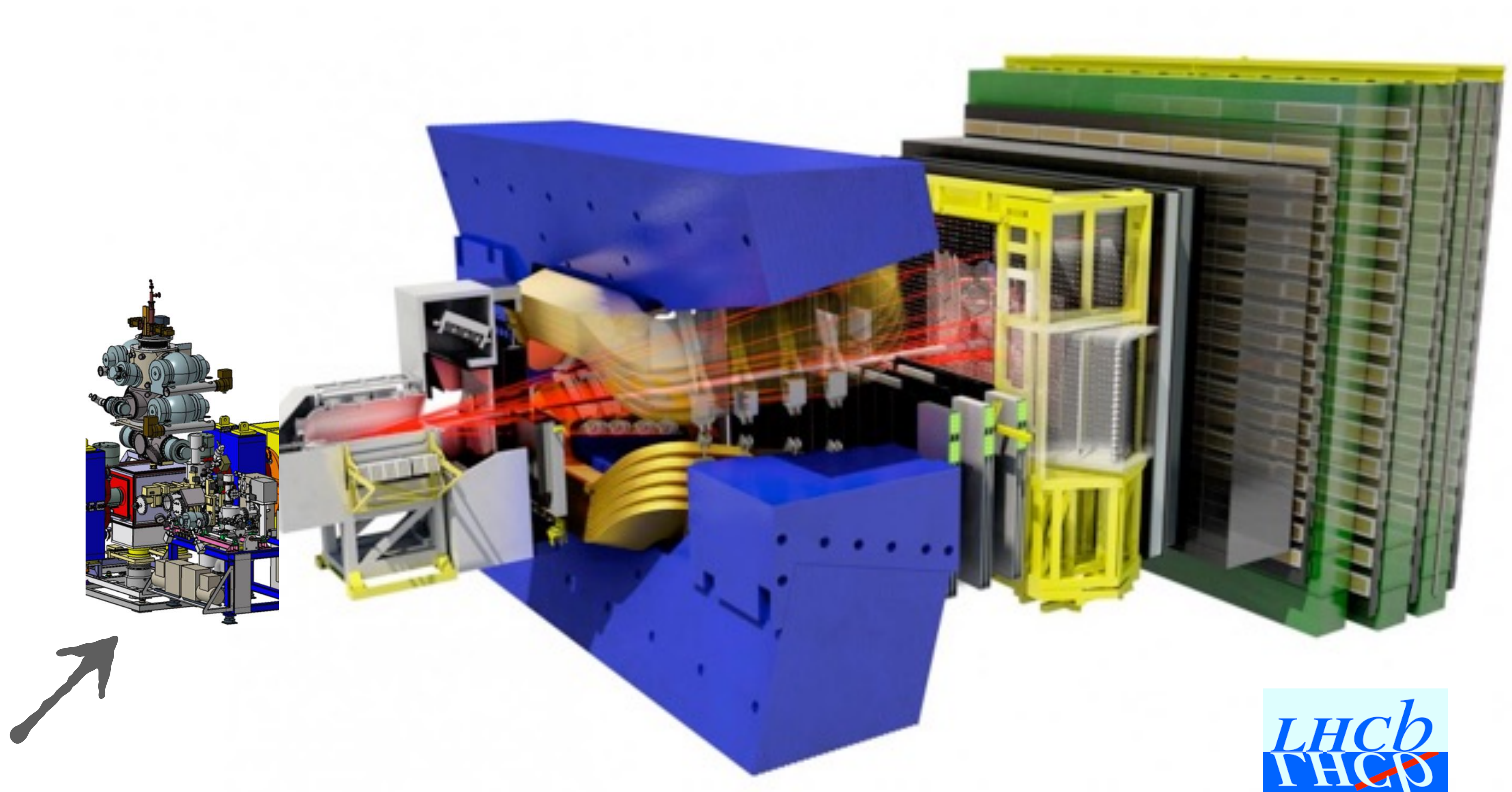
2

Install the PGT in LHCb for the Run5 and exploit all the enormous potentialities due to the LHCb (upgrade II) spectrometer: c-, b-quark reconstruction, rare probes, RTA, …



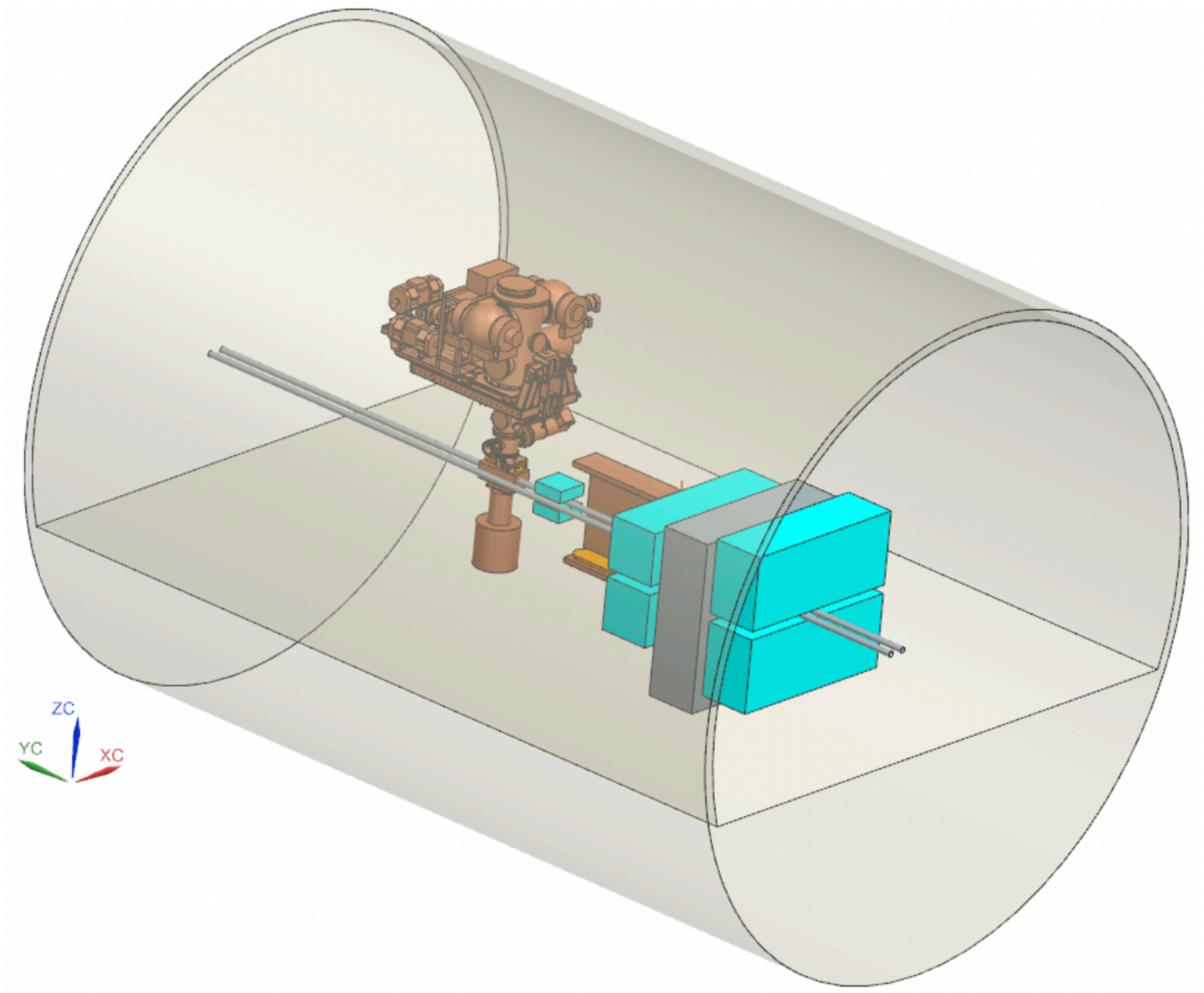
Polarized target

The plan is to develop the project in 2 phases:

1

Develop a compact apparatus capable of:

- conducting R&D to have a “plug & play” PGT for Run5
- perform physics measurements never accessed before
- perform measurements connected to LHC
- etc…



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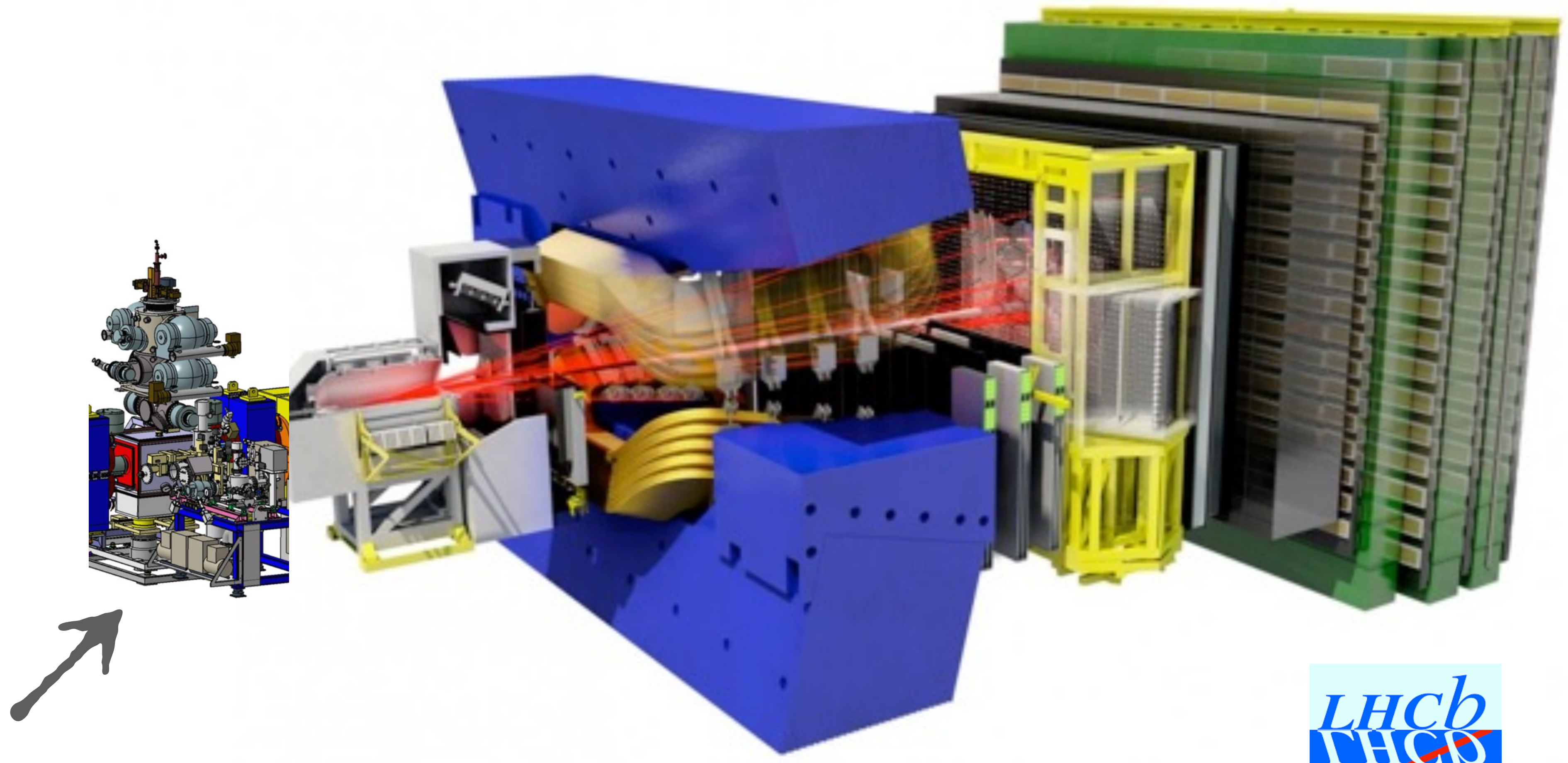
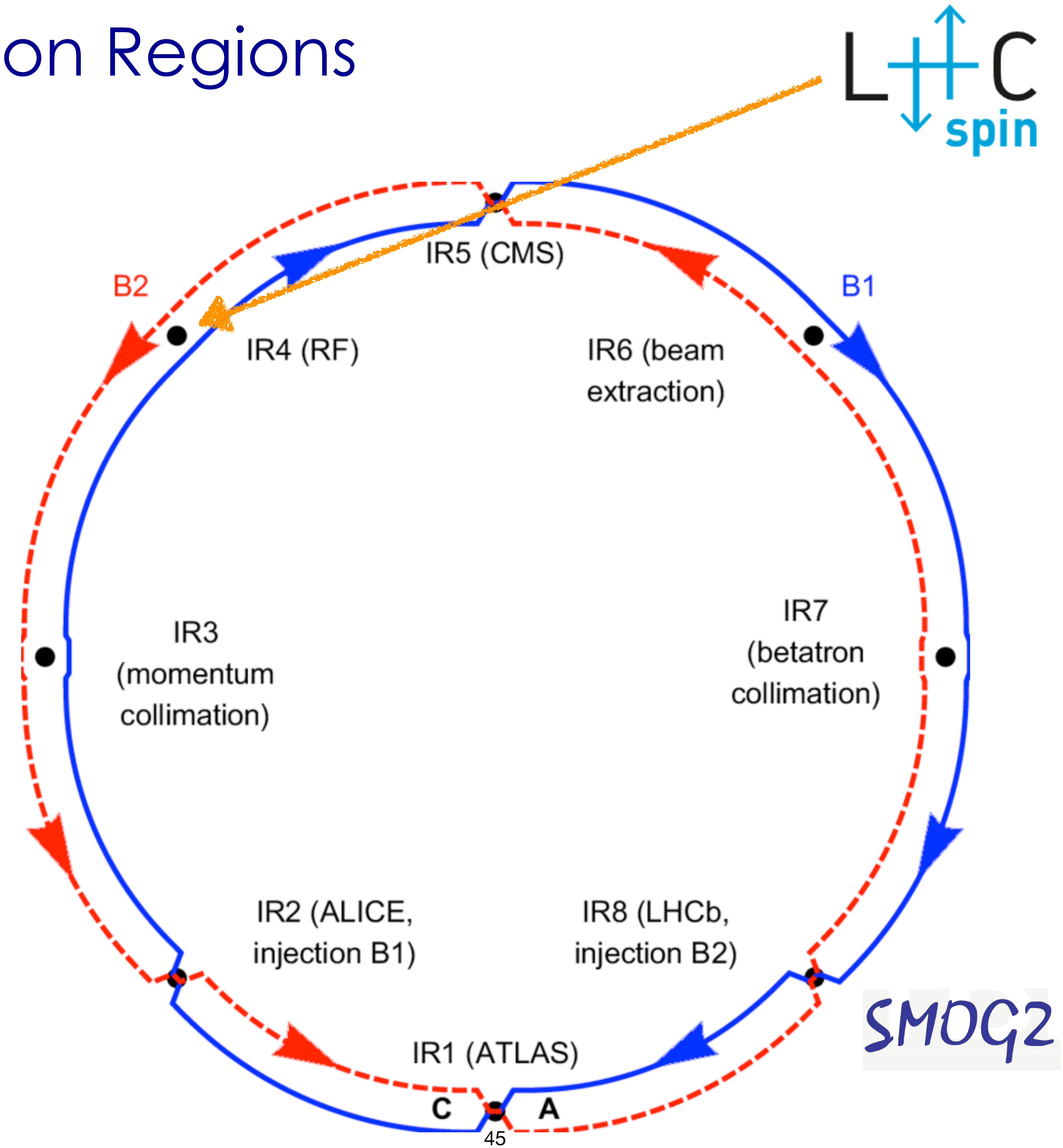
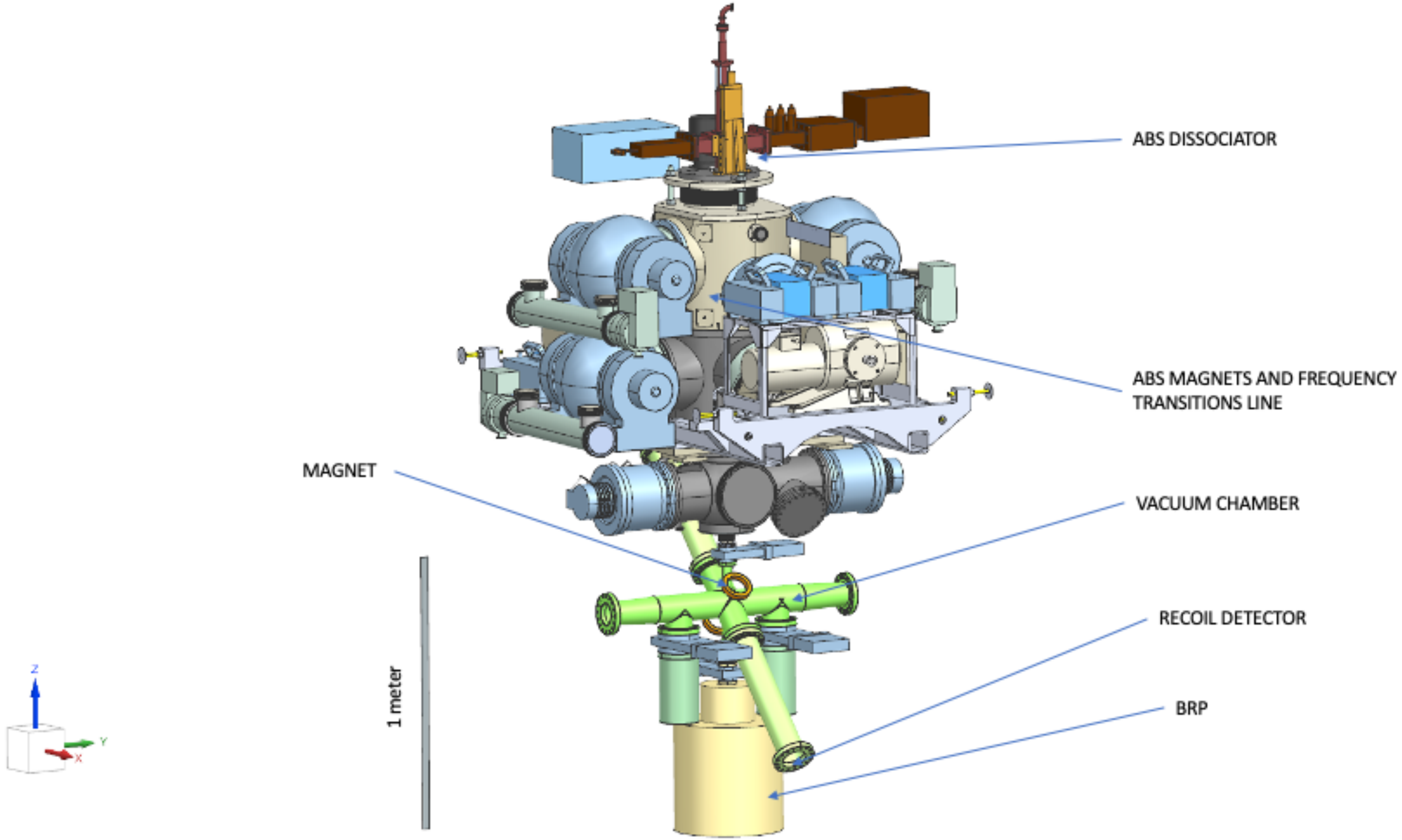


Polarized target

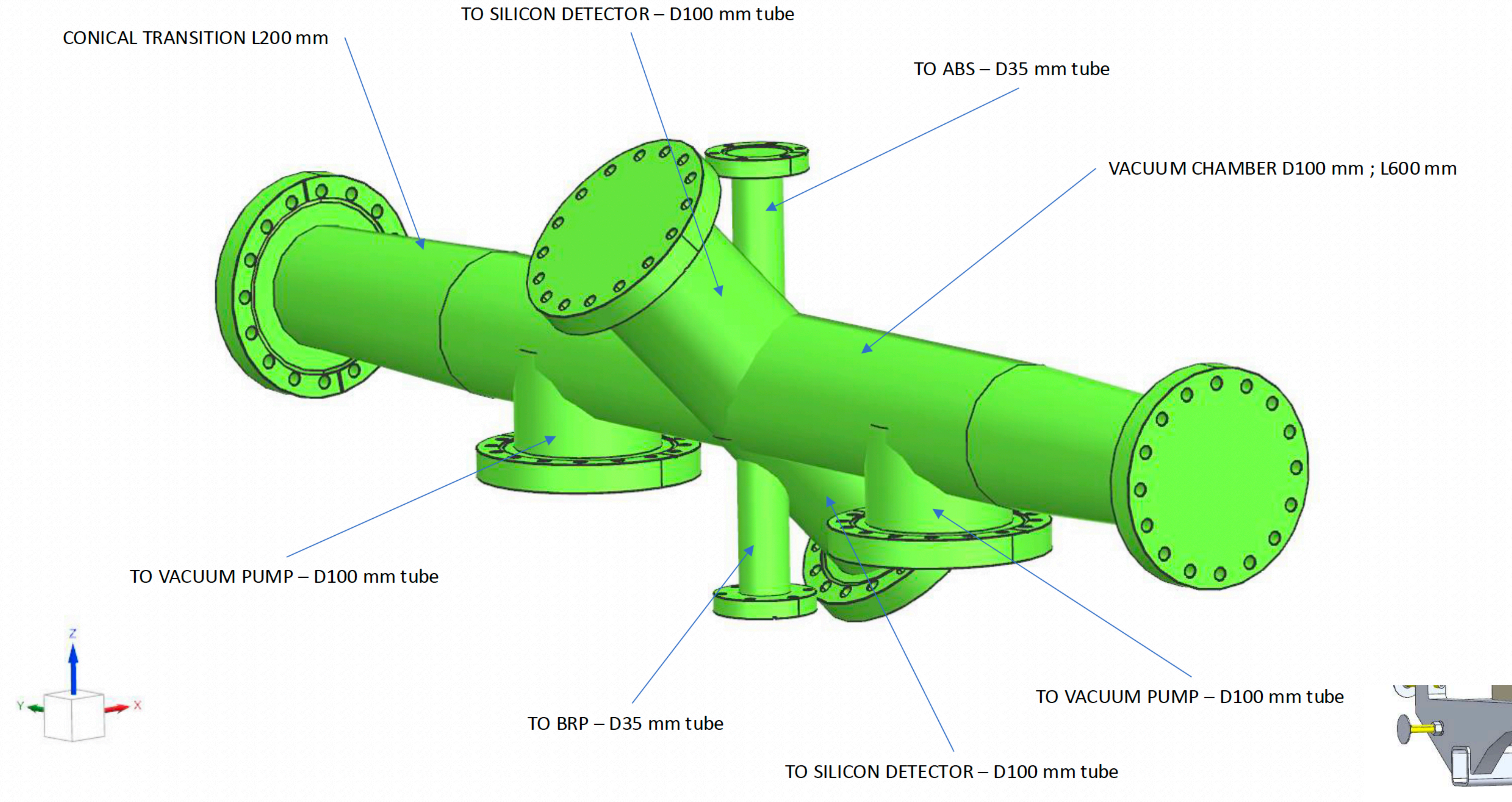
The LHC Interaction Regions

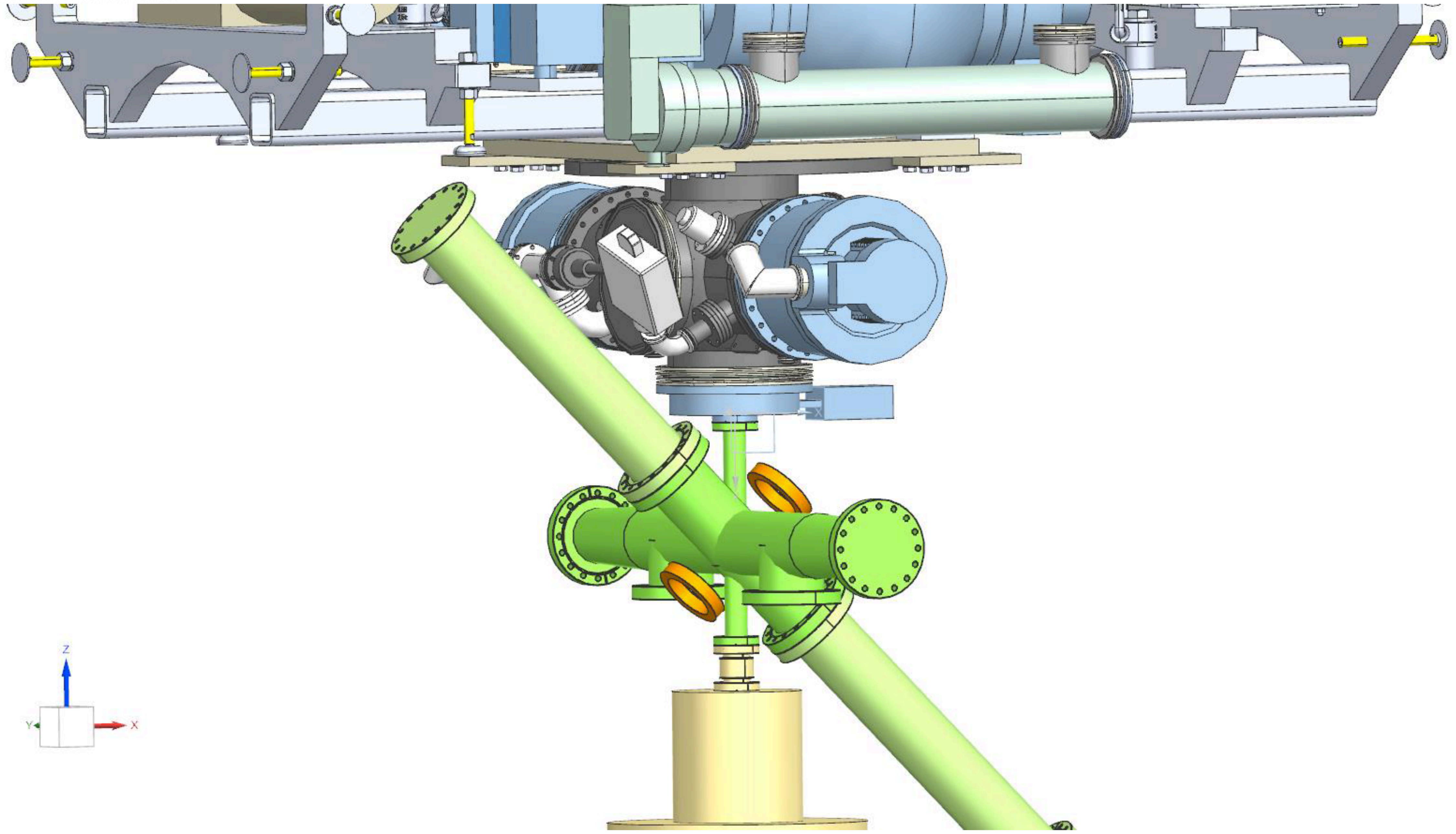


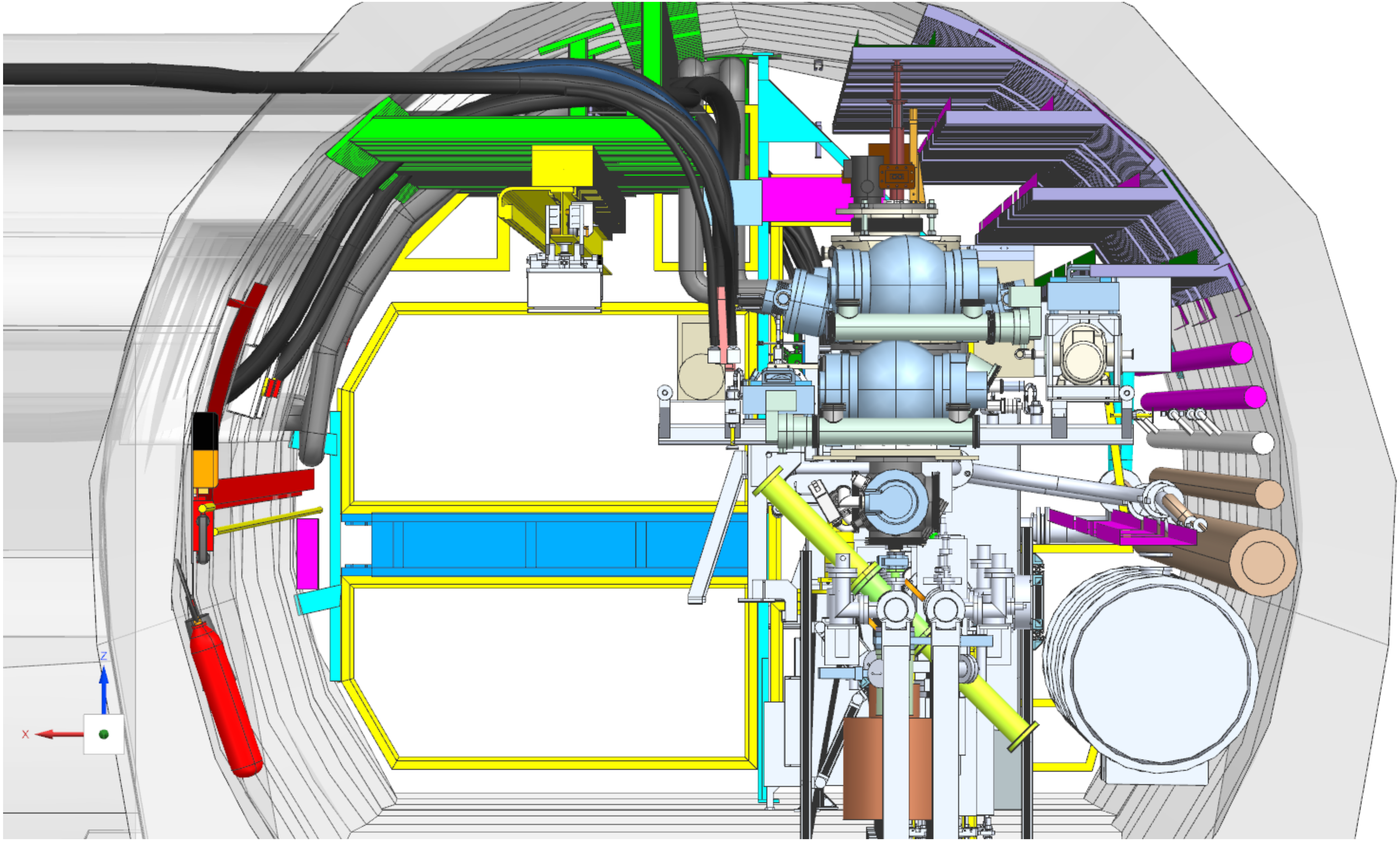
The LHC Interaction Region 4


ABS DISSOCIATOR
ABS MAGNETS AND FREQUENCY
TRANSITIONS LINE
MAGNET
VACUUM CHAMBER
RECOIL DETECTOR
BRP
1 meter

VACUUM CHAMBER 1



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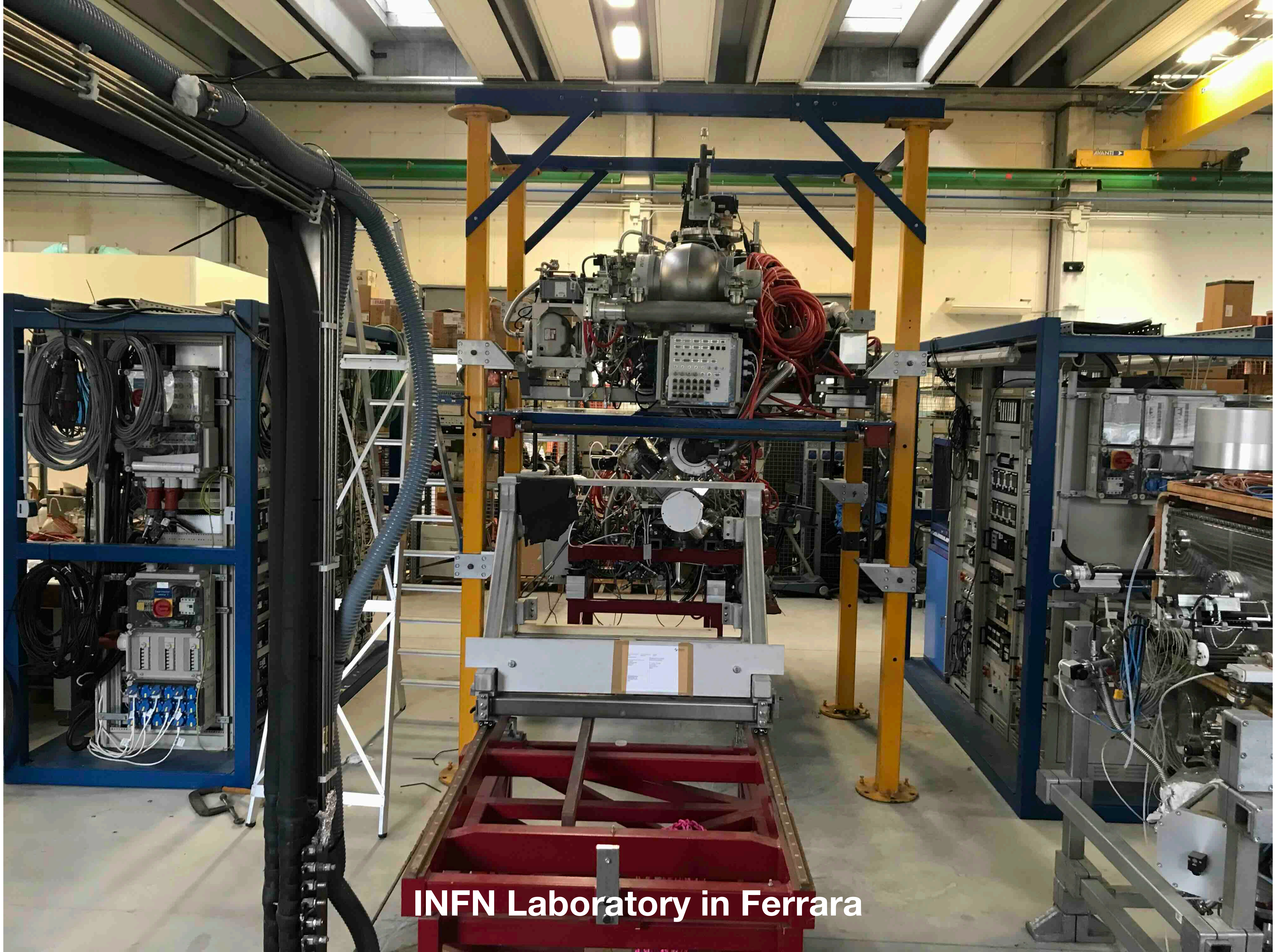
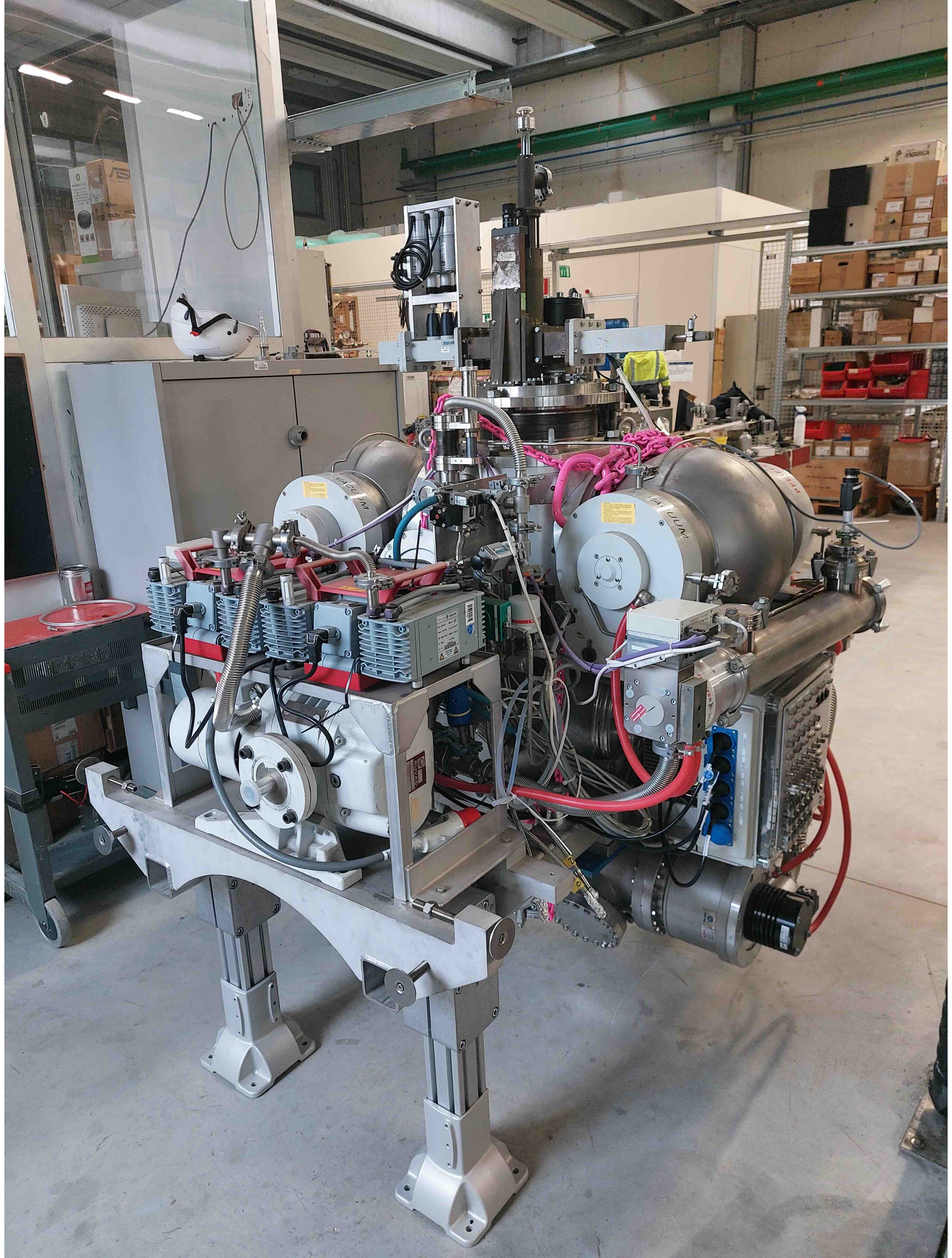


INFN Laboratory in Ferrara

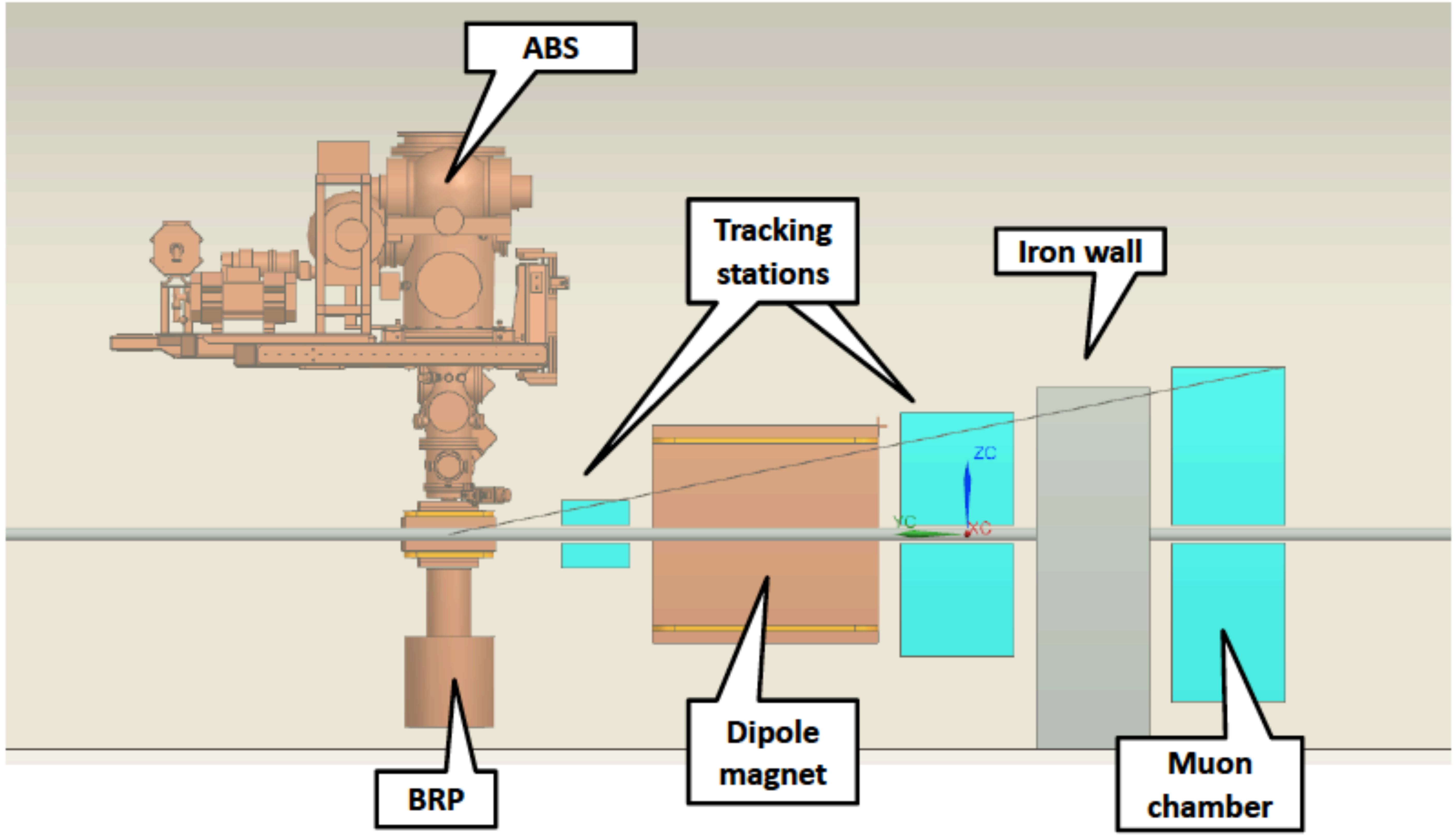


Detector concept at the IR4

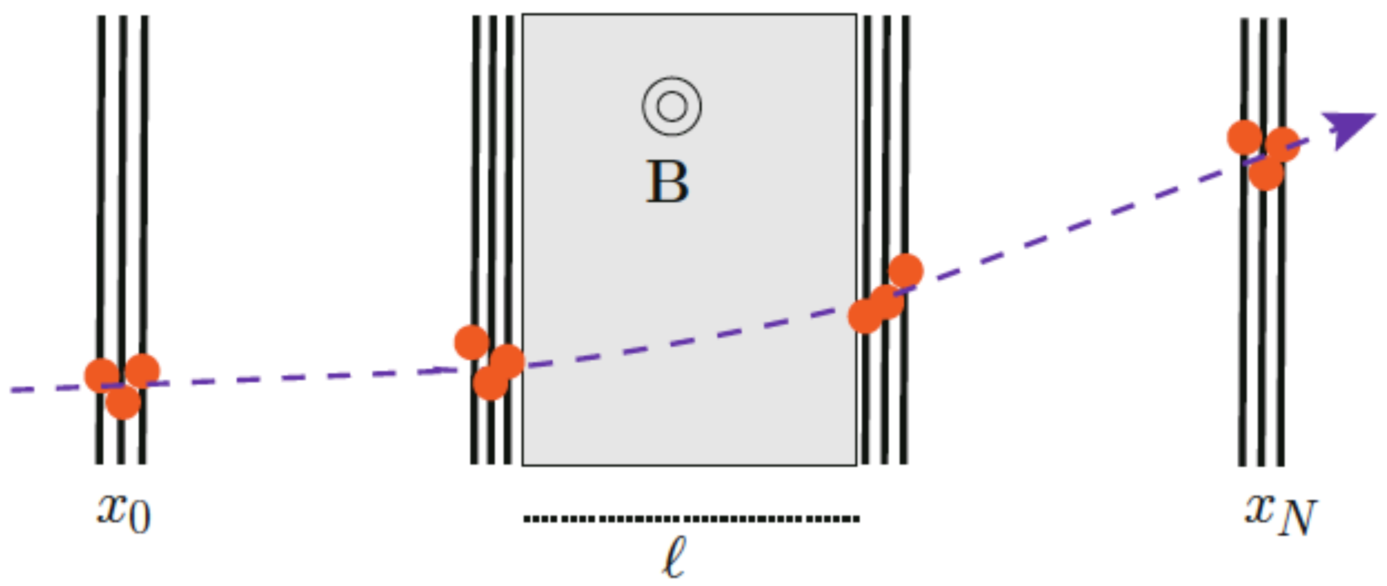
Goals:
- proof of principle of the future (large-scale) experiment with LHCb.
- measurement of single-spin asymmetries in inclusive hadron production in $pH^{\uparrow}$ and $PbH^{\uparrow}$

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)?

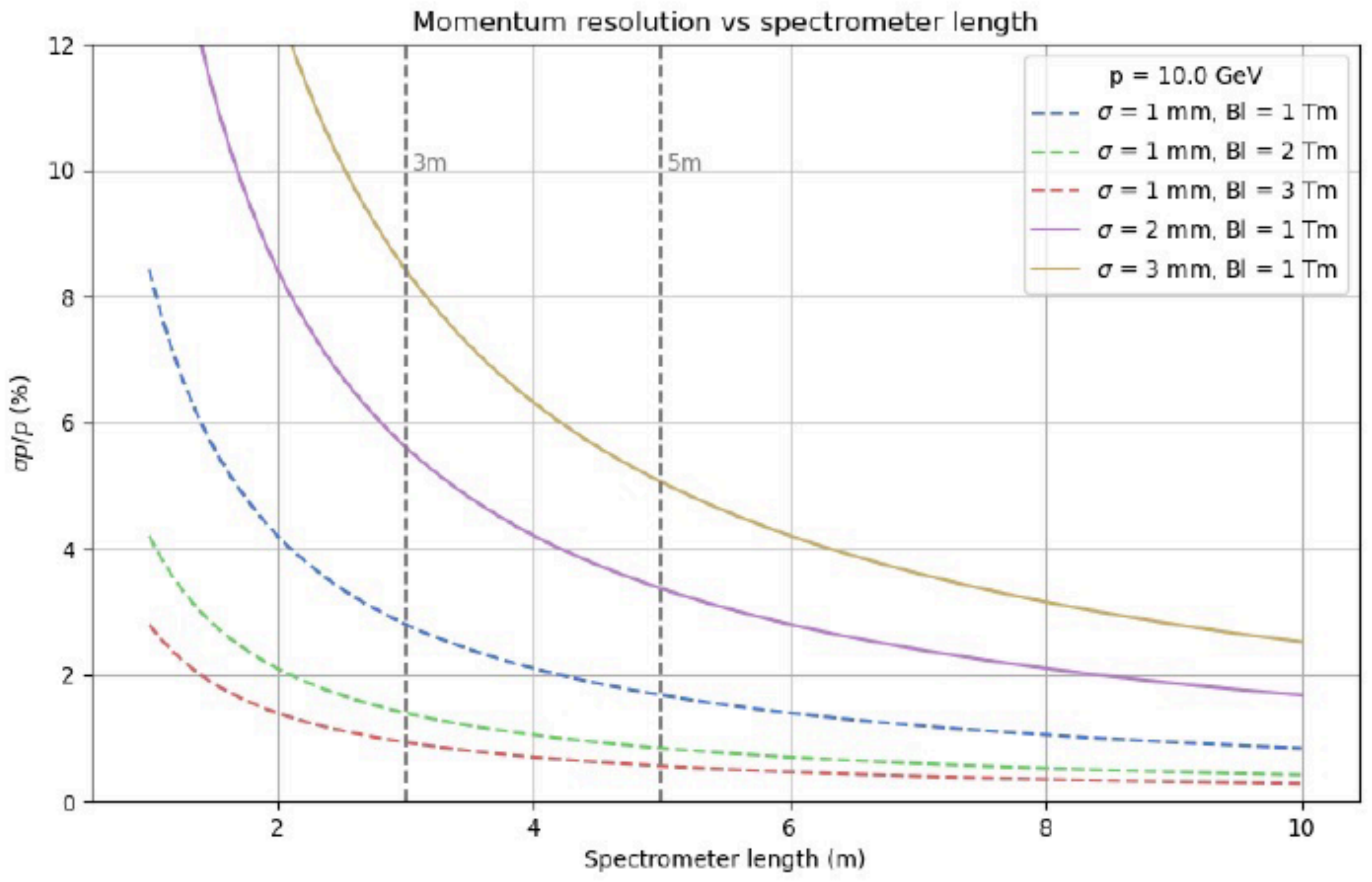
Needed expertise (apart from pol. target):
- dipole magnet
- tracking detectors (Si strip, SciFi, drift chambers?)
- muon chambers (MWPC?)
- electronics
- DAQ
- slow control
- tracking/reconstruction algorithms
- ...



Even though the focus will be on polarimetry and beam interactions, we performed preliminary calculations to determine if a simple detector could meet our needs

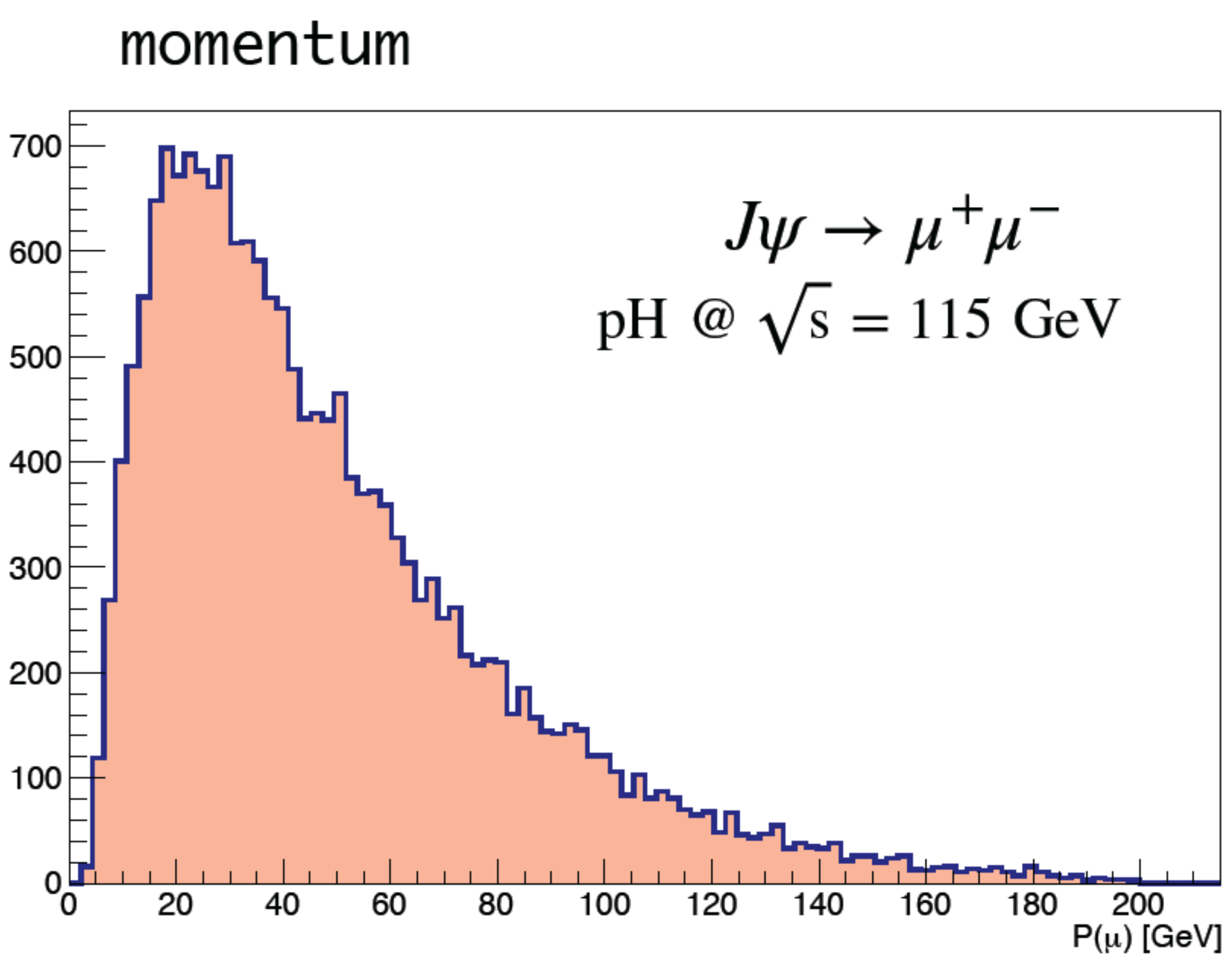


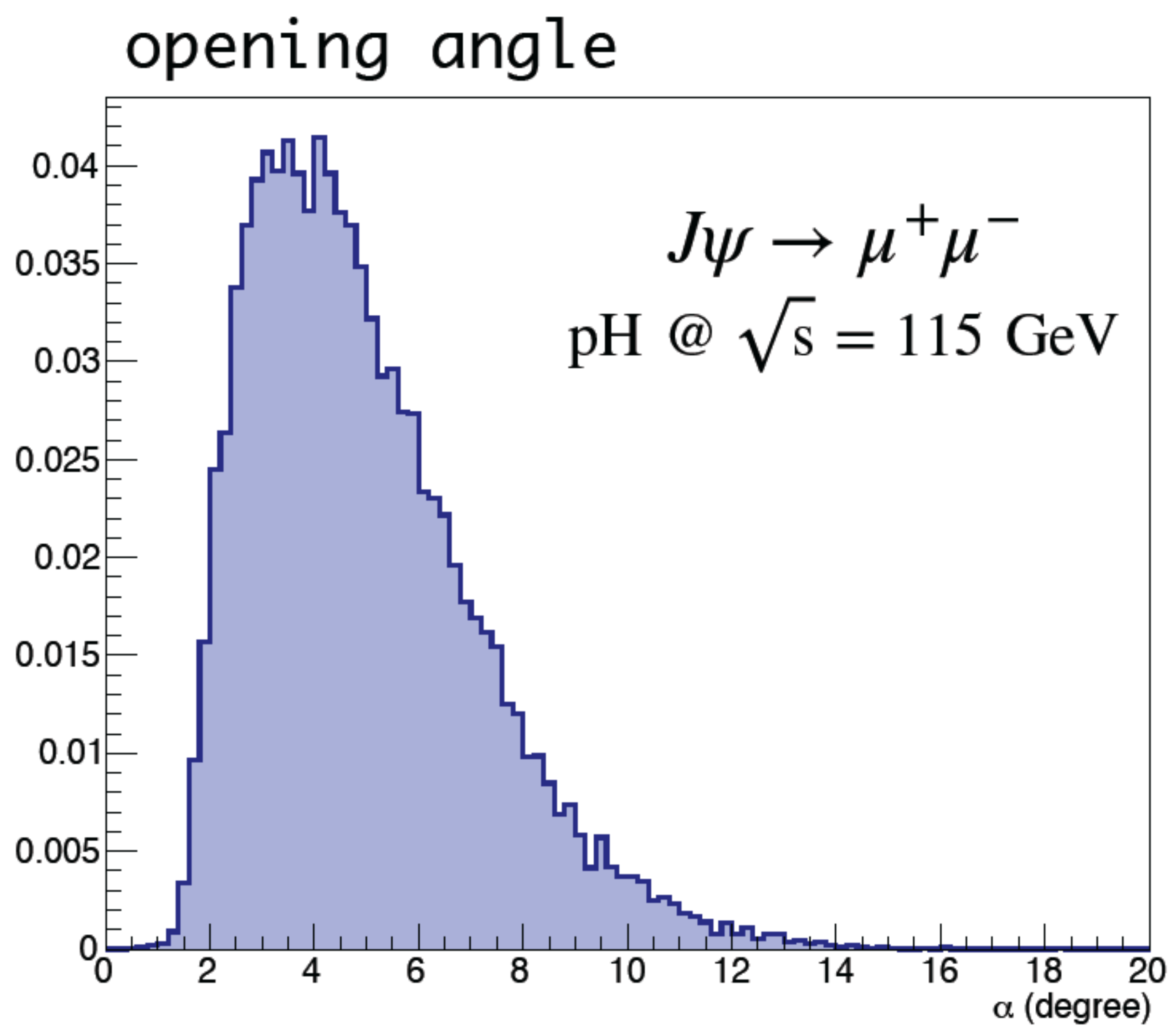
$$\frac{\delta p}{p} = \frac{8\sigma}{\sqrt{N+1}} \frac{1}{0.3z \cdot Bl \cdot L} p$$



we can achieve a resolution $\delta p/p < 1\,\%$ within a few meters of lever arm (depending on space constraints) for momenta up to a few GeV and with N = 10 hit measurements

with $\delta p/p \sim 1\,\%$ we have $\delta m \sim 40$ MeV, excellent for any other measurement





it is even possible to have a ToF PID @3σ level for $\pi - K$
$p \sim 1\ GeV \rightarrow \sigma_T \mathcal{O}(100)\ ps$

Anything we measure is new and worth to be published!

April 23, 2025

LHCspin: a Polarized Gas Target for LHC

A. Accardi[1,2], A. Bacchetta[3,4], L. Barion[5], G. Bedeschi[5,6], V. Benesova[7], S. Bertelli[8], V. Bertone[9], C. Bissolotti[10], M. Boglione[11,12], G. Bozzi[13,14], N. Bundaleski[15], V. Carassiti[5], F.G. Celiberto[16], Z. Chen[17], G. Ciullo[5,6], M. Constantinou[18], P. Costa Pinto[19], A. Courtoy[20], U. D'Alesio[13,14], C. De Angelis[13,14], E. De Lucia[8], I. Denisenko[21], P. Di Nezza[8,*], M. Diehl[22], F. Donato[11,12], N. Doshita[23], O.M.N. Duarte Teodoro[15], M.G. Echevarria[24], T. El-Kordy[25], R. Engels[26,27], F. Fabiano[13,14], I.P. Fernando[28], M. Ferro-Luzzi[19], C. Flore[13,14], L. Gamberg[29], G.R. Goldstein[30], J.O. Gonzalez-Hernandez[11,12], B. Gou[31,32], A. Gridin[21], A. Guskov[19], C. Hadjidakis[33], V. Hejny[26,27], T. Iwata[23], D. Keller[28], N. Koch[34], A. Kotzinian[1]1, J.P. Lansberg[33], P. Lenisa[5,6], X. Li[17], H.W.Lin[35], S. Liuti[28], R. Longo[36], M. Maggiora[11,12], G. Manca[13,14], S. Mariani[19], J. Matousek[7], T. Matsuda[37], A. Metz[38], M. Mirazita[8], Y. Miyachi[23], A. Movsisyan[39], F. Murgia[14], A. Nass[26,27], E.R. Nocera[11,12], C. Oppedisano[1]1, L.L. Pappalardo[5,6], B. Parsamyan[11,19,23,39], B. Pasquini[3,4], M. Pesek[7], A. Piccoli[5,6], C. Pisano[13,14], D. Pitonyak[40], J. Pretz[26,41], A. Prokudin[2,42], M. Radici[4], F. Rathmann[43], M. Rotondo[8], M. Santimaria[8], G. Schnell[24], R. Shankar[5,6], A. Signori[11,12], D. Sivers[44], S. Squerzanti[5], M. Stancari[45], E. Steffens[46], L. Sun[31,32], H. Suzuki[47], G. Tagliente[48], F. Tessarotto[49], C. Van Hulse[16], Q. Xu[17], Z. Ye[50], J. Zhang[17]

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Input to the European Strategy for Particle Physics - 2026 update

Cover page

LHCspin: a Polarized Gas Target for LHC

Contact author: Pasquale Di Nezza (Pasquale.DiNezza@lnf.infn.it)

Abstract

The goal of the LHCspin project is to develop innovative solutions for measuring the 3D structure of nucleons in high-energy polarized fixed-target collisions, exploring new processes and new probes in a unique, poorly explored kinematic regime at LHC beam energies. This ambitious task is being based on the recent experience with the successful installation and exploitation of the SMOG2 unpolarized gas target in front of the LHCb spectrometer. SMOG2 provides an ideal benchmark for studying beam-target dynamics at the LHC and demonstrates the feasibility of simultaneous operation with beam-beam collisions. With the installation of the proposed polarized target system, LHCb will become the first experiment to simultaneously collect data from unpolarized beam-beam collisions at $\sqrt{s}$=14 TeV and polarized and unpolarized beam-target collisions at $\sqrt{s_{NN}}$ ~100 GeV. LHCspin has the potential to open new frontiers in physics by exploiting the capabilities of the world's most powerful collider and one of the most advanced spectrometers.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-LHCC-2024-010
LHCb-TDR-026
September 2, 2024

LHCb Upgrade II Scoping Document

LHCb collaboration

Abstract

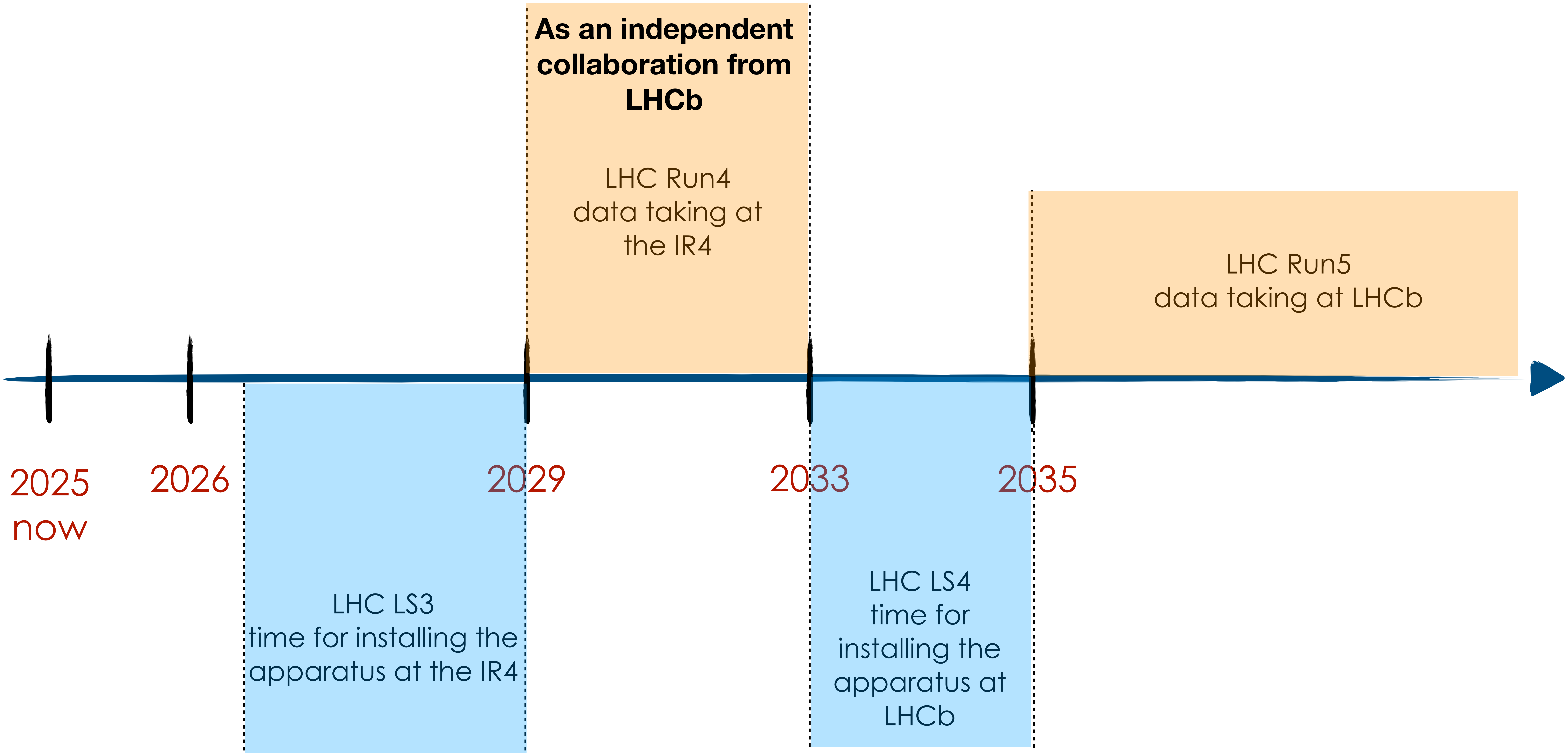
A second major upgrade of the LHCb detector is necessary to allow full exploitation of the LHC for flavour physics. The new detector will be installed during long shutdown 4 (LS4), and will operate at a maximum luminosity of $1.5 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. By upgrading all subdetectors and adding new detection capability it will be possible to accumulate a sample of $300\,\mathrm{fb}^{-1}$ of high energy pp collision data, giving unprecedented and unique discovery potential in heavy flavour physics and other areas. The baseline LHCb Upgrade II detector has been presented in a Framework Technical Design Report that was approved in 2022. Here, updates are presented alongside scoping options with reduced detection capability and operational luminosity. The costs and physics performance of each scenario are discussed, and an overview of the project management plans is presented.

The polarized target is part of the LHCb Scoping Document for the Upgrade II

The project has been submitted to the ESPP

The iter with LHC/PBC has already started

Timetable


As an independent collaboration from LHCb
LHC Run4
data taking at the IR4
LHC Run5
data taking at LHCb
2025
now
2026
2029
2033
2035
LHC LS3
time for installing the apparatus at the IR4
LHC LS4
time for installing the apparatus at LHCb

Conclusions

The fixed targets at LHC are innovative and unique projects with remarkable potential for advancing physics in largely unexplored kinematic domain

SMOG2 faced various technical challenges, but all issues were solved through constructive collaboration with LHC and LHCb experts

LHCspin could be implemented within a realistic timeframe (during LHC LS3 for the LHC Run4, starting data taking around 2030) and with a limited budget, paving the way for other new frontiers of LHC