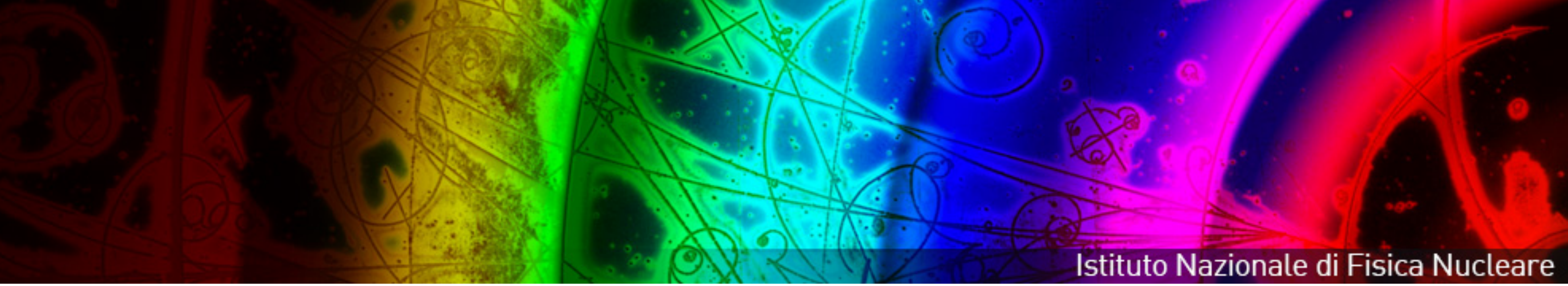


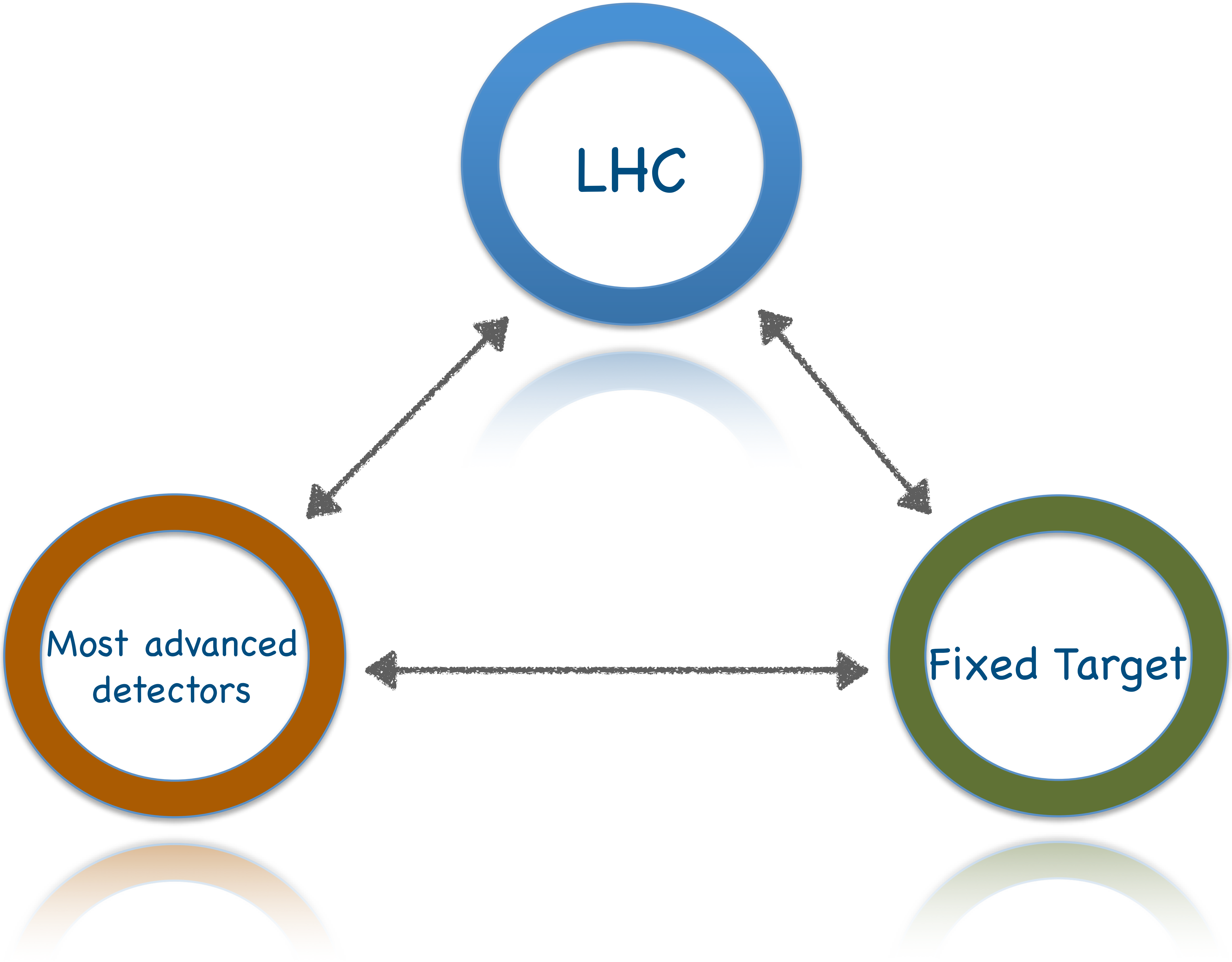
Experimental prospects with polarised fixed targets at LHC

Pasquale Di Nezza

INFN LNF Istituto Nazionale di Fisica Nucleare

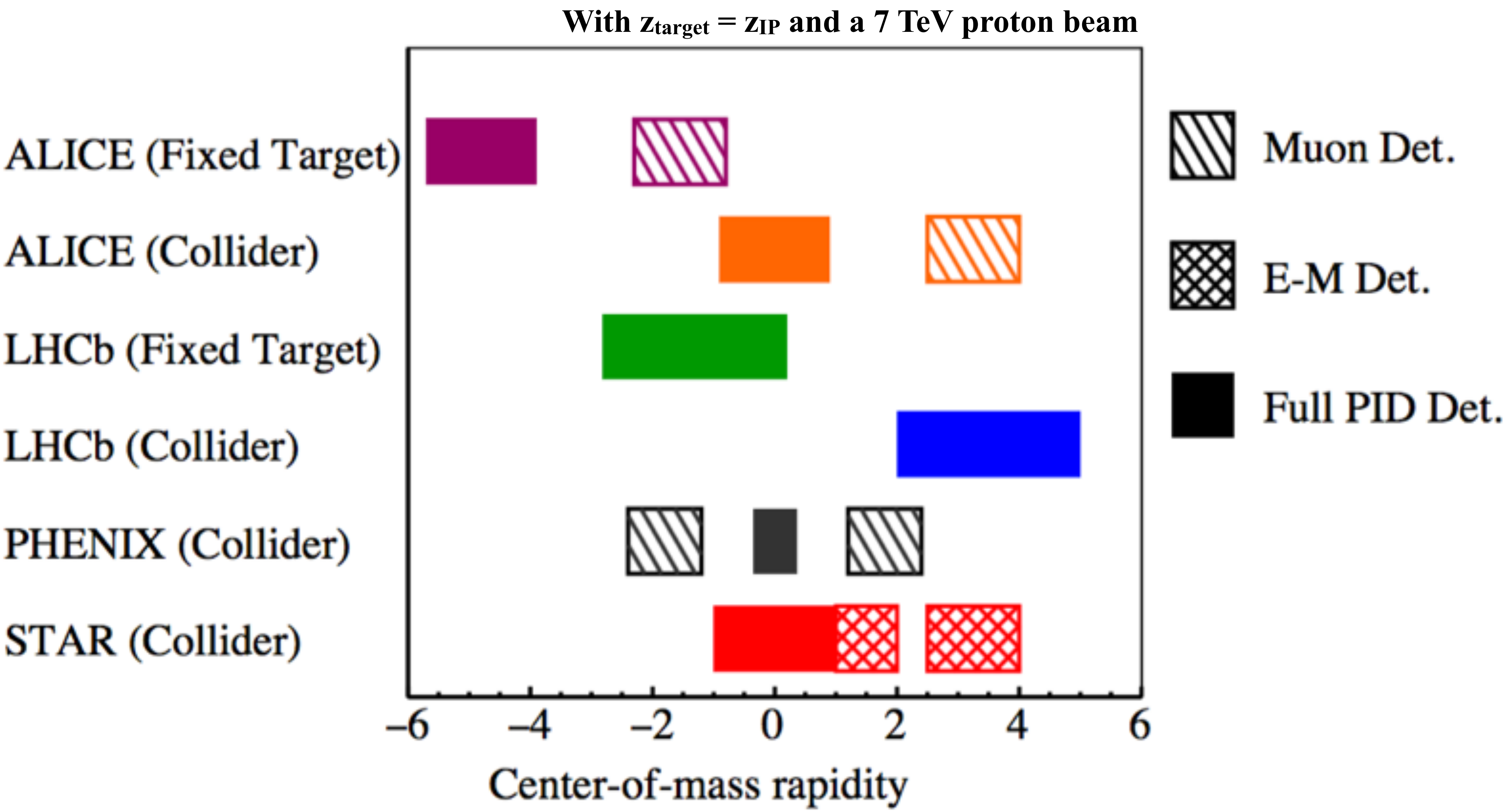
Chia, 06/09/19

Merging 3 worlds … for the first time



The physics motivations have been already discussed in other talks, so here only technical issues will be considered, basically

Acceptance in center-of-mass rapidity



In a fixed-target mode:
– ALICE Central Barrel covers very backward rapidity and Muon Spectrometer covers rapidity interval towards mid-rapidity
– LHCb: wide rapidity range starting from $y_{cms} \sim 0$

Great credit for heaving shown for the first time the potentialities of the fixed target physics at the LHC

Long list of papers:

A selection of physics projections for a high-luminosity fixed-target programme at the LHC

Most of the material from the AFTER review : https://arxiv.org/abs/1807.00603, and ESPP document ID47 :
See also these dedicated papers on simulations from the AFTER@LHC study group:
Adv.High Energy Phys. 2015 (2015) 986348
Few Body Syst. 58 (2017) no.4, 139
Few Body Syst. 58 (2017) no.5, 148
Phys.Lett. B793 (2019) 33-40

Beam splitting by bent-crystal

Motivation: beam collimation

Standard collimation today → Crystal-based collimation
- UA9 (@SPS)
- LUA9 (@LHC)

→ To beam extraction
- CRYSBEAM (@SPS then LHC)
- AFTER@LHC

W. Scandale et al., JINST 6 T10002 (2011)

→ Deflecting the beam halo at 7σ distance to the beam
→ Reduces the LHC beam loss
→ Beam extraction: civil engineering required, new facility with 7 TeV proton beam
→ Beam splitting: intermediate option, might be used with existing experiment

- Dedicated and modern forward geometry spectrometer

- Channeling solution has still open points to be finalized
- Needed: civil engineering, new facility from scratch

Exploring possible target locations in ALICE

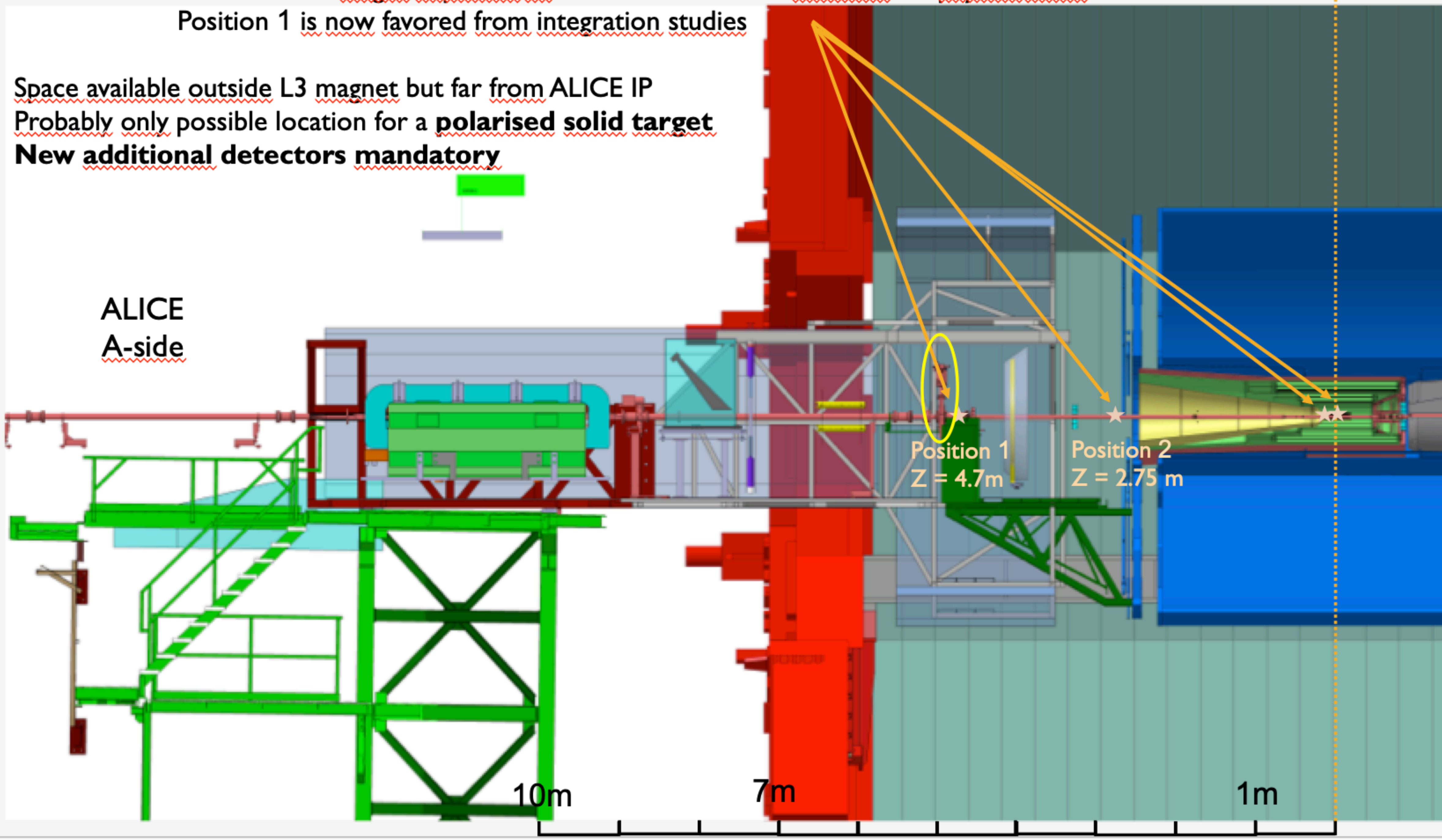
4 locations of target explored so far in simulations to evaluate the physics reach

Position 1 is now favored from integration studies

Space available outside L3 magnet but far from ALICE IP

Probably only possible location for a **polarised solid target**

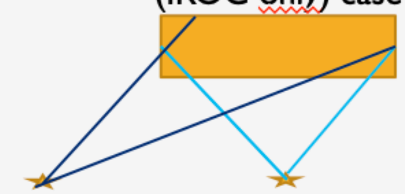
New additional detectors mandatory



ALICE detector acceptance vs z_{target}

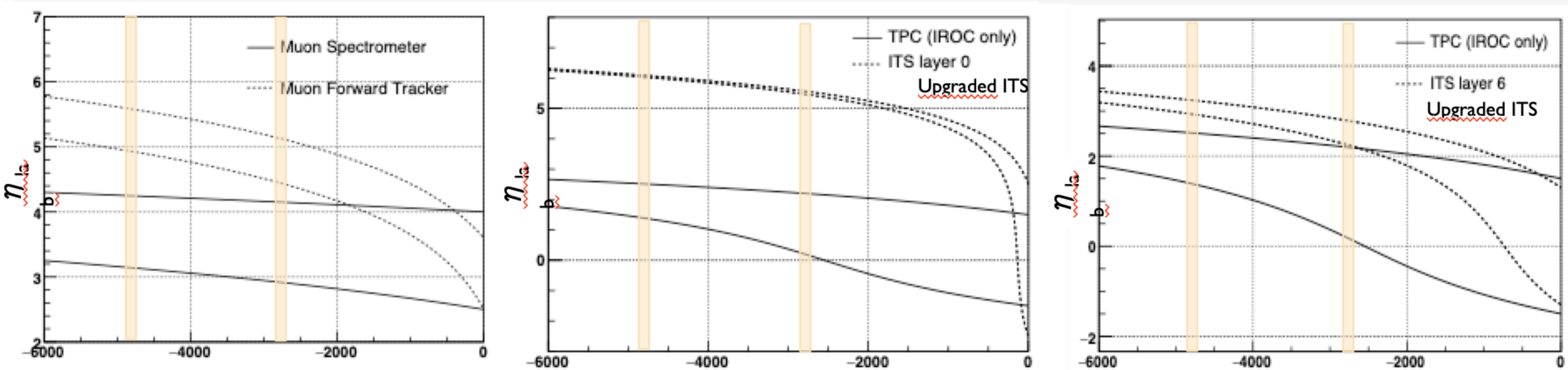
- Considering Z direction negative on A side and forward pseudo-rapidity in the lab defined positively

TPC
(IROC only) case



Position 1 Position2

Caveat: Simple geometrical considerations

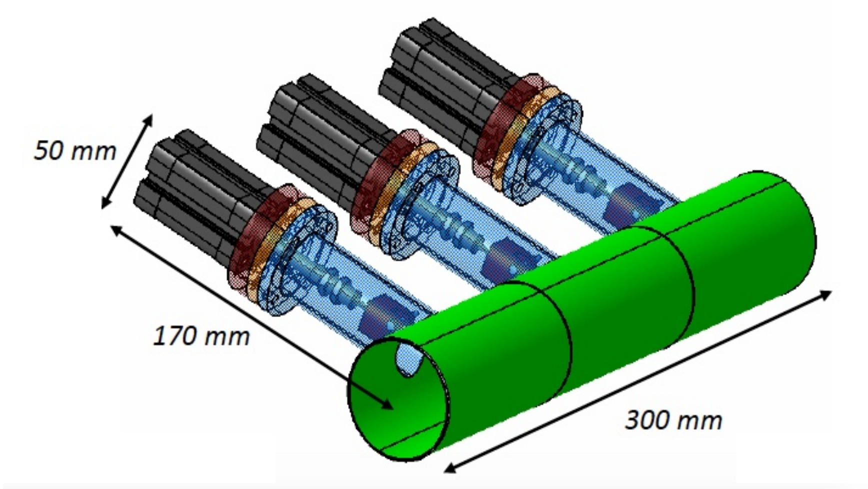


Target position from IP [mm] Target position from IP [mm] Target position from IP [mm]

If target at Z << 0, new vertex detector (and probably other detectors) needed
The tracking performances of the TPC and the effect of material budget for large negative Z have still to be studied
At large Z << 0, no acceptance shared anymore between MFT and muon spectrometer

Unpolarised target

- Feasible (not irrelevant changes in the ALICE spectrometer needed)
- Complementary to LHCb
- R&D in its preliminary phase
- Material Budget can play a relevant role
- Tracking Resolution simulations required due to the gap target-tracking



retractable solid target

Unpolarised target

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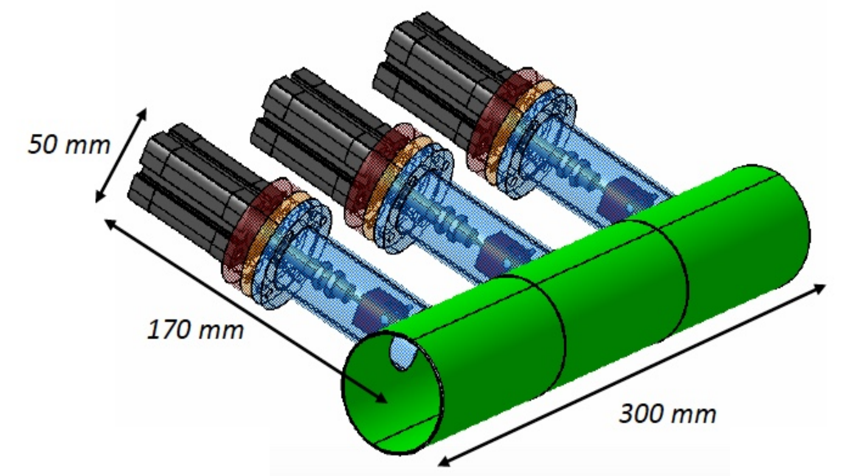
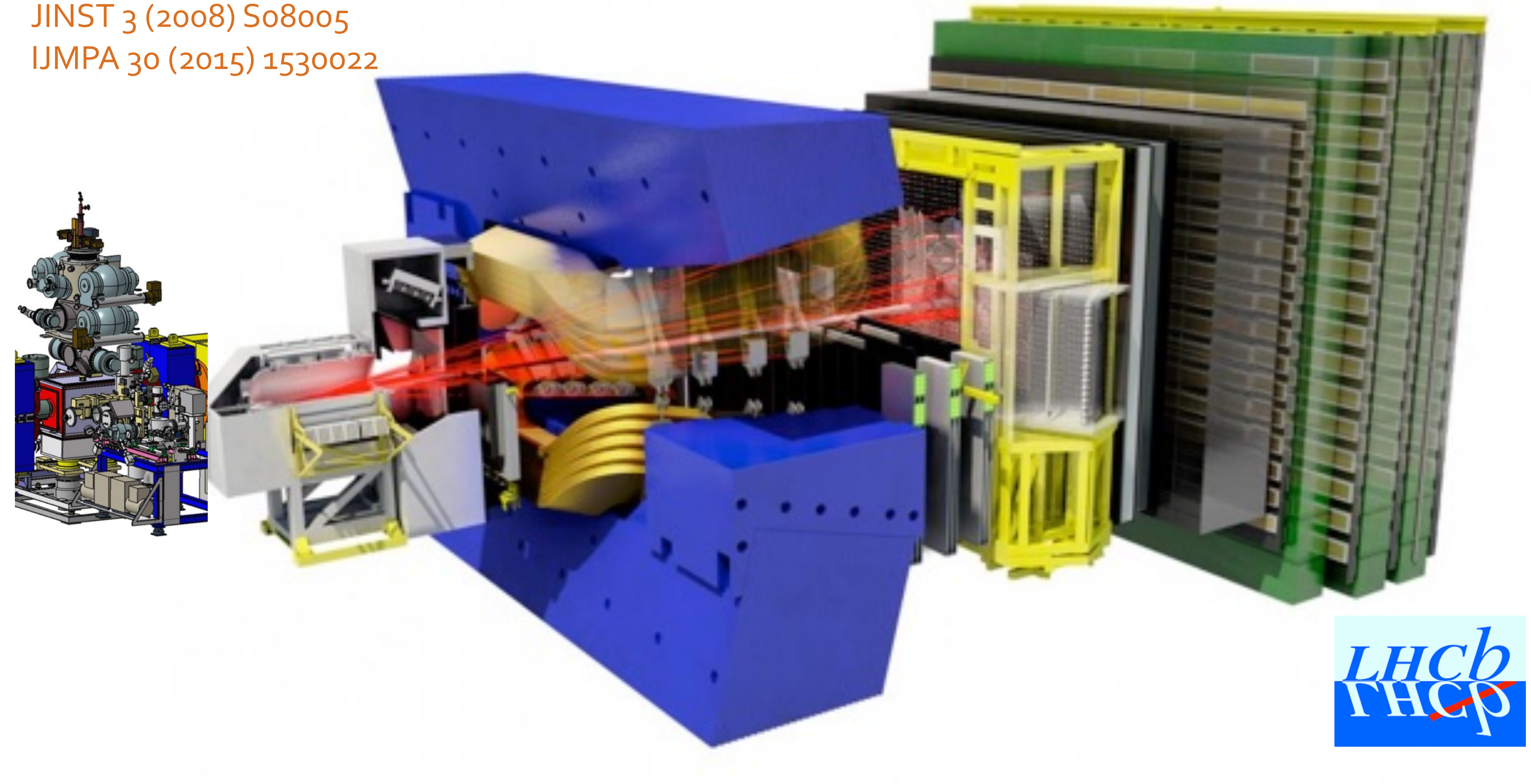


retractable solid target

Polarised target

- Complementary to LHCb
- The possible location is unclear

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



Polarised target

optimised for studying particles containing c- and b-quarks

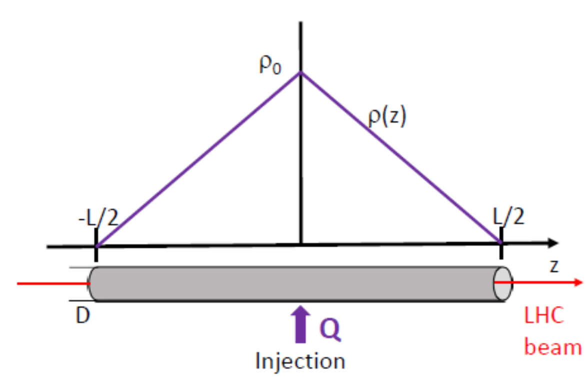
Forward acceptance: $2 < \eta < 5$

Tracking system momentum resolution

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

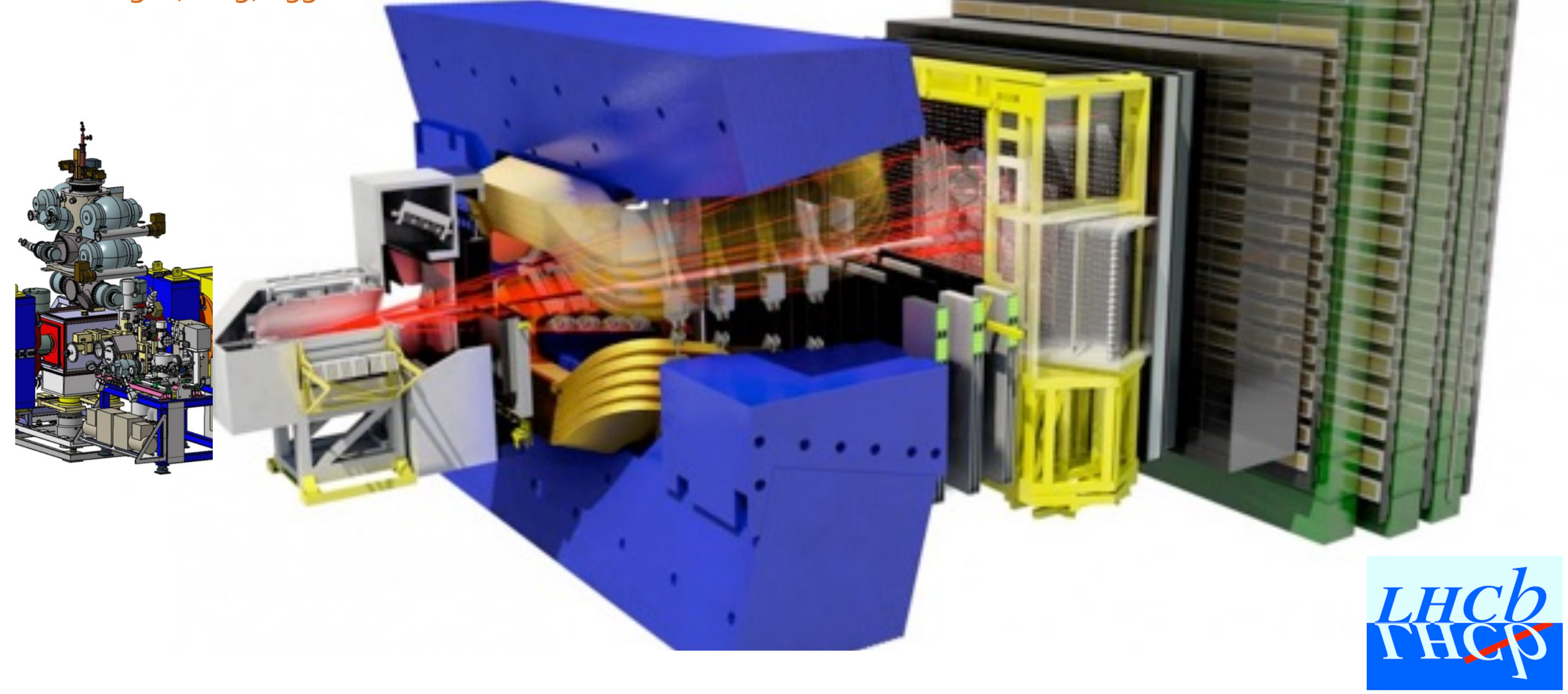
The technique proposed is well consolidated

Design follows the successful HERMES Polarised Gas Target which ran at HERA 1996 – 2005, and the follow-up PAX target operational at COSY (FZ Jülich)



tubular storage cell

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



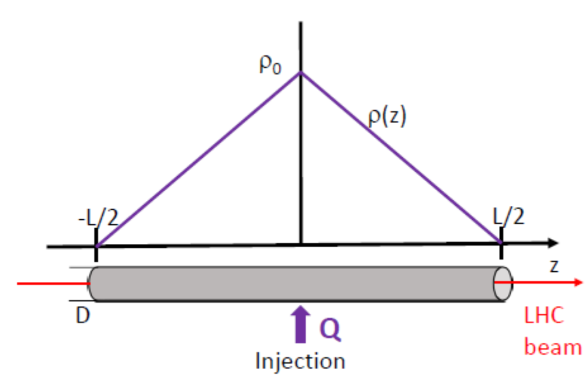
Polarised target

optimised
contain

< η < 5
esolution
0 GeV/c)

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

Design follows the successful HERMES Polarised Gas Target which ran at HERA 1996 – 2005, and the follow-up PAX target operational at COSY (FZ Jülich)



tubular storage cell

We are already on the road ...

R&D

SMOG2

Phase I
unpolarised target

and

LHC spin

Phase II
transversely polarised H and D target

... at LHCb

We are already on the road …

R&D

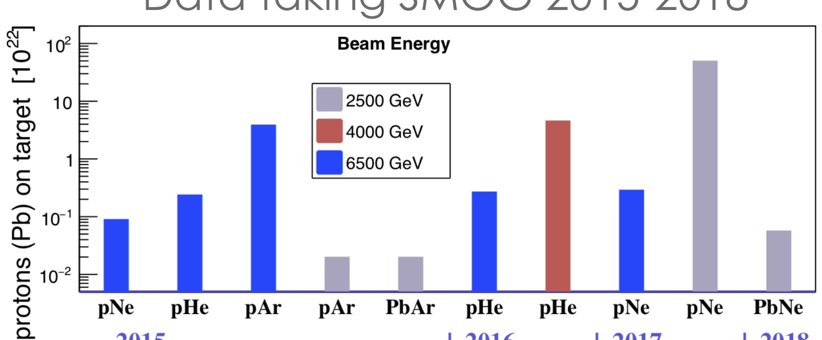
SMOG2 and **LHCspin**

Phase I
unpolarised target

Phase II
transversely polarised H and D target

SMOG

Data taking SMOG 2015-2018



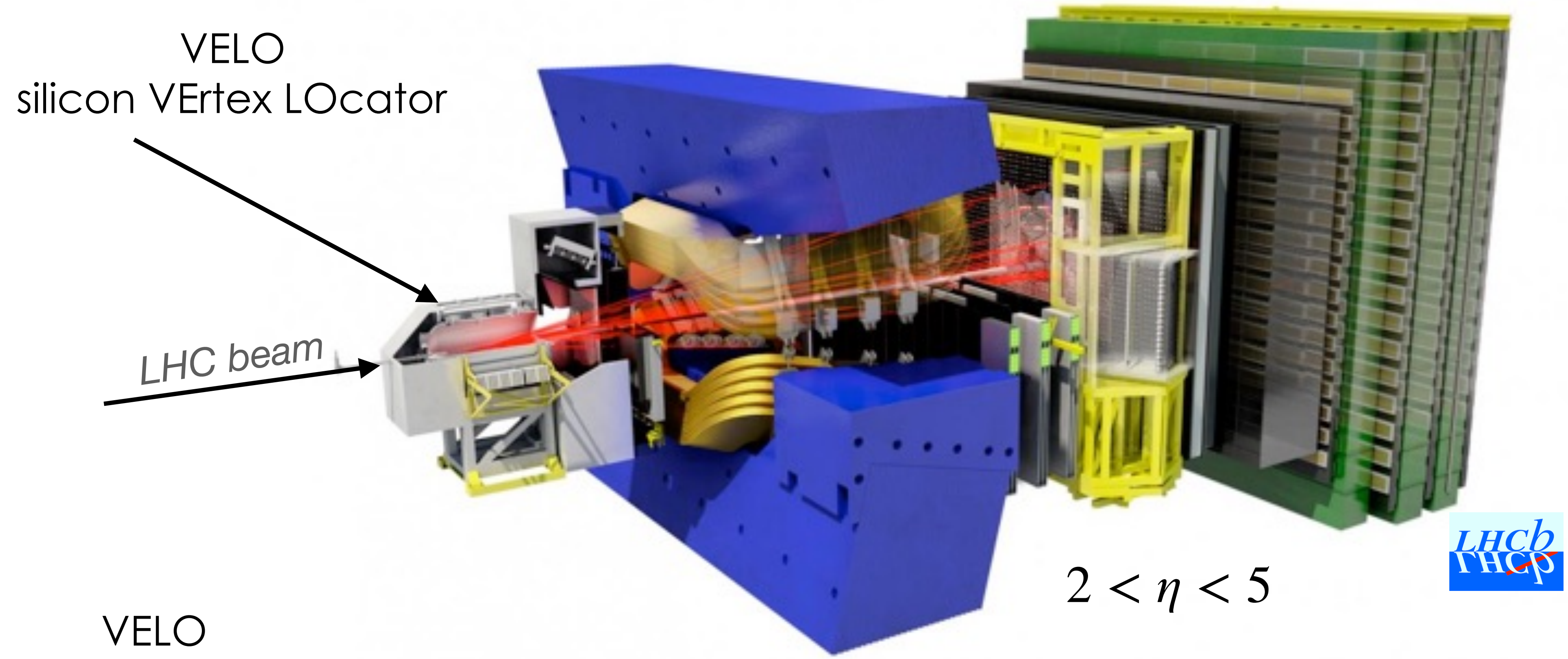
… at LHCb

2 papers published on PRL:

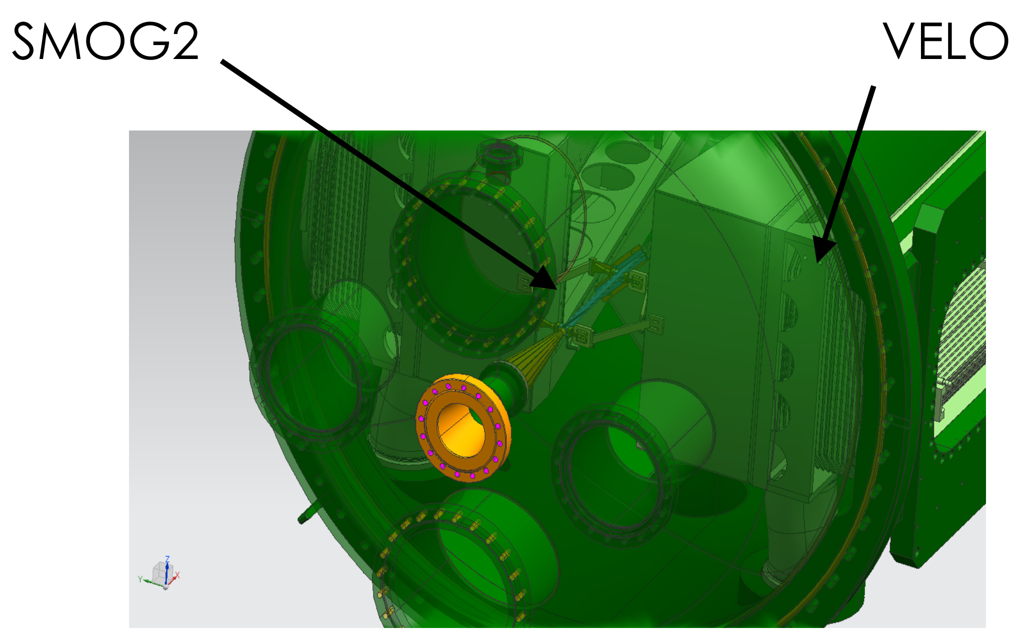
-antiproton production in p-He collisions @ 110 GeV PRL121,222001(2018) (arXiv:1808.06127)

-First measurement of charm production in fixed-target configuration at the LHC - PRL122,132002(2019) (arXiv:1810.07907)

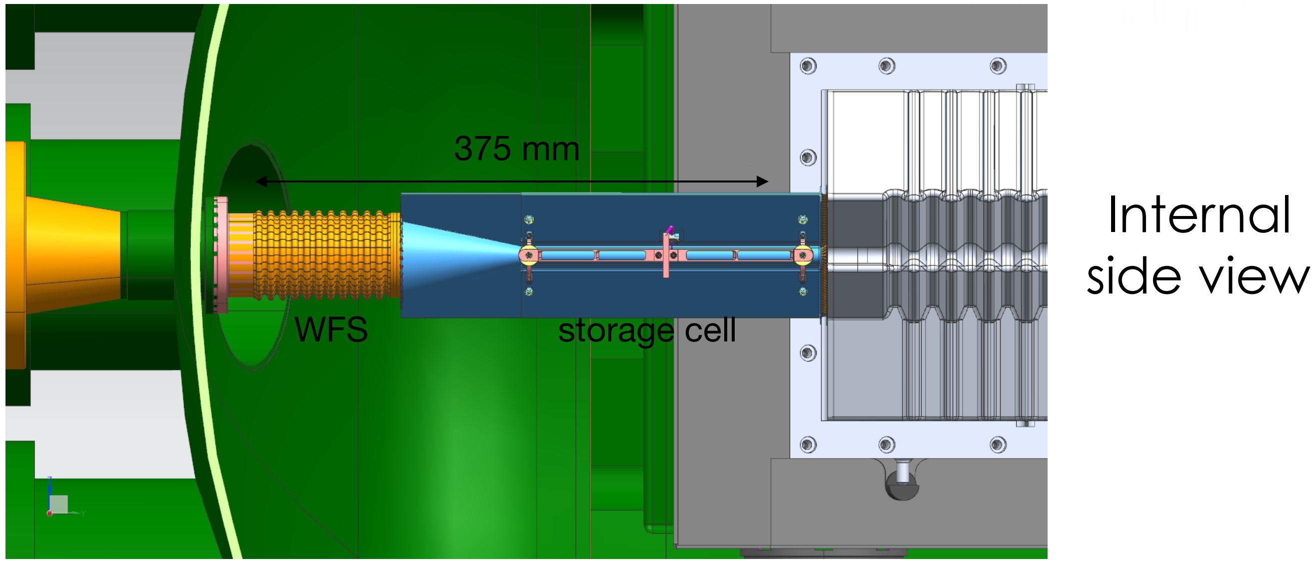
SMOG2



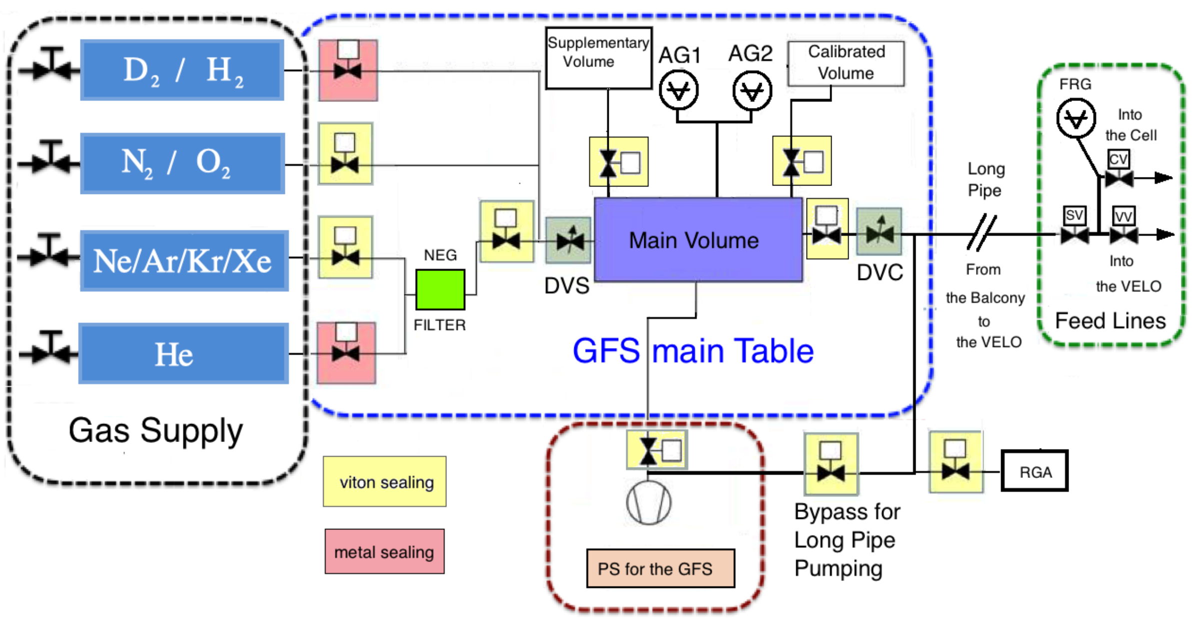
VELO
silicon VErtex LOcator
LHC beam
$2 < \eta < 5$



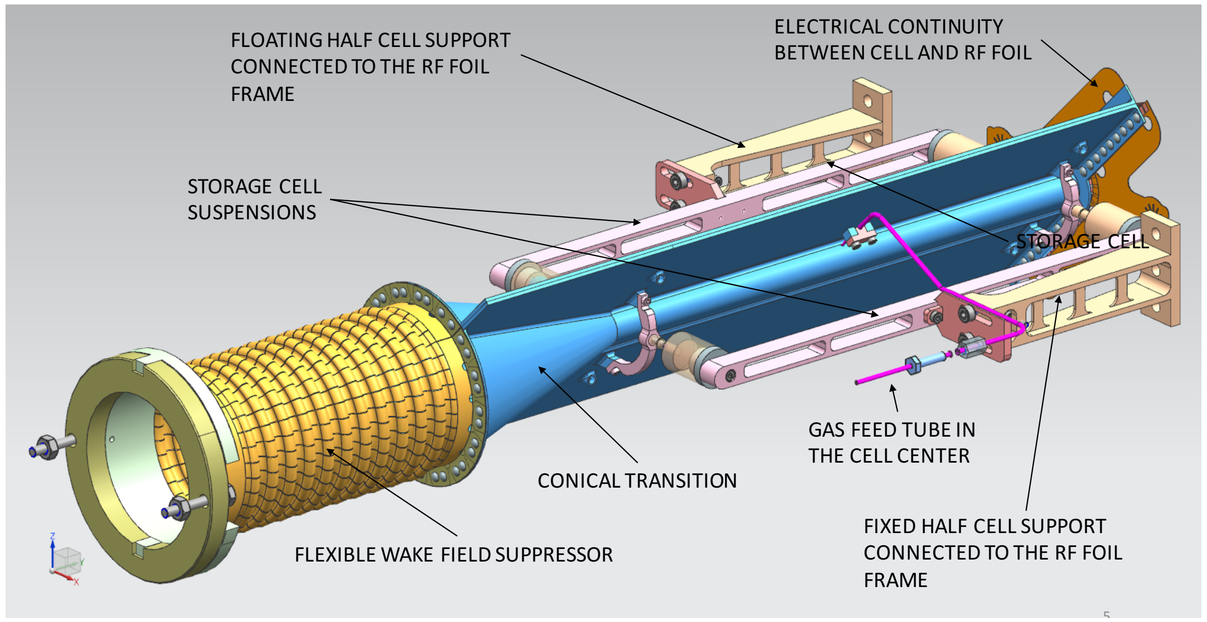
SMOG2
VELO



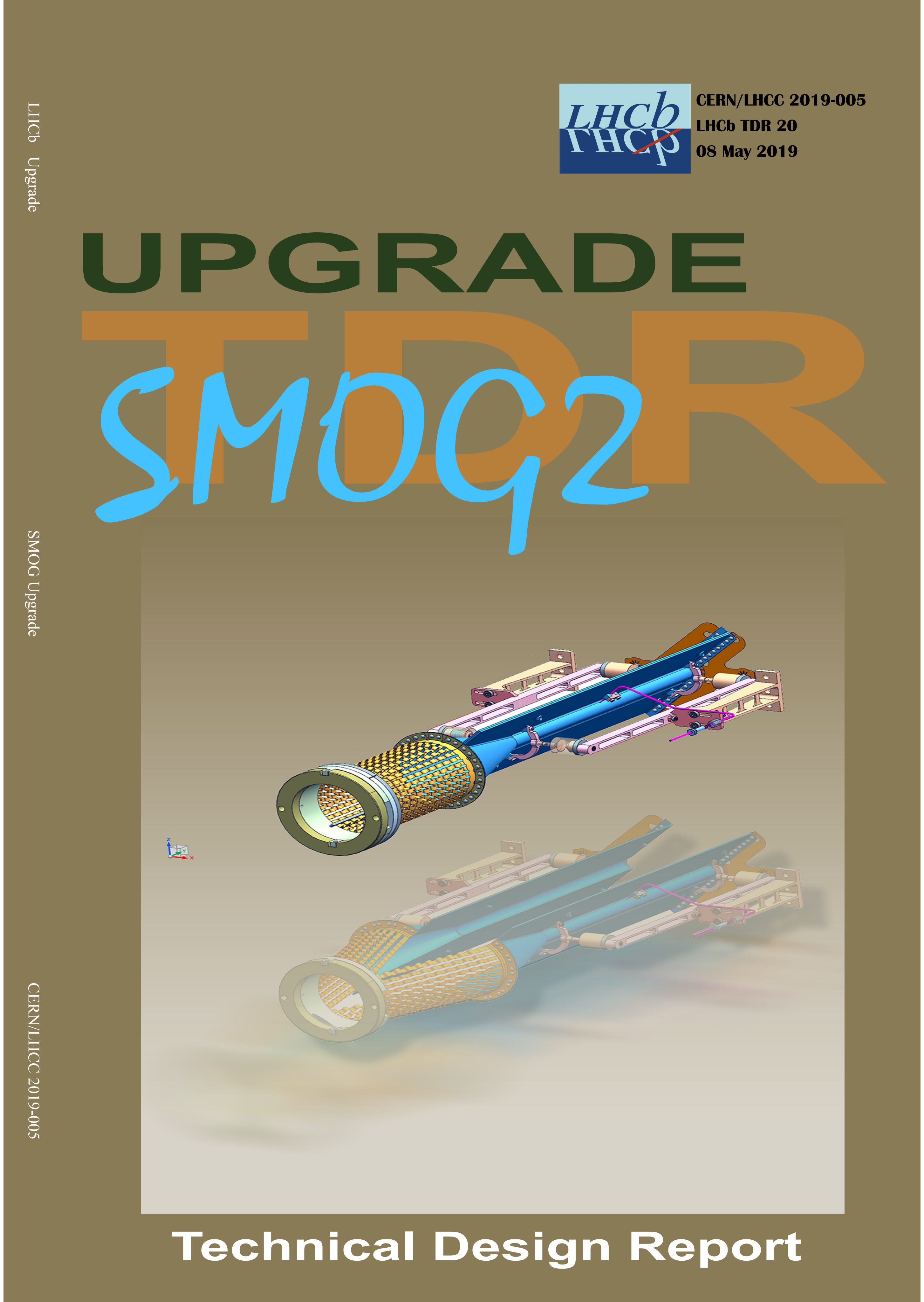
375 mm
WFS
storage cell
Internal side view



D_2 / H_2
N_2 / O_2
Ne/Ar/Kr/Xe
He
Gas Supply
Supplementary Volume
AG1
AG2
Calibrated Volume
NEG
FILTER
DVS
Main Volume
DVC
GFS main Table
Long Pipe
From the Balcony to the VELO
FRG
Into the Cell
CV
SV
VV
Into the VELO
Feed Lines
viton sealing
metal sealing
PS for the GFS
Bypass for Long Pipe Pumping
RGA



FLOATING HALF CELL SUPPORT CONNECTED TO THE RF FOIL FRAME
ELECTRICAL CONTINUITY BETWEEN CELL AND RF FOIL
STORAGE CELL SUSPENSIONS
STORAGE CELL
GAS FEED TUBE IN THE CELL CENTER
CONICAL TRANSITION
FLEXIBLE WAKE FIELD SUPPRESSOR
FIXED HALF CELL SUPPORT CONNECTED TO THE RF FOIL FRAME



Installation scheduled in the second half of November 2019

SMOG2 and LHCspin references:

https://cds.cern.ch/record/2673690/files/LHCB-TDR-020.pdf
LHCb-PUB-2018-015
CERN-PBC-Notes-2018-007, https://cds.cern.ch/record/2651269
PoS(SPIN2018)011, https://pos.sissa.it/346/011/pdf
PoS(SPIN2018)098, https://pos.sissa.it/346/098/pdf
CERN-ESPP-Note-2018-111, arXiv:1901.08002

CERN
Esplanade des Particules 1
1217 Meyrin - Switzerland

LHC

EDMS NO.	REV.	VALIDITY
2085258	0.2	DRAFT

REFERENCE
LHC-X8FTS-EC-0001

Date: 2019-07-19

ENGINEERING CHANGE REQUEST

SMOG2

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

LHCb proposes an upgraded version of the existing gas injection system SMOG. The core idea of the project, called SMOG2, is the use of a storage cell for the injected gas to be installed upstream of the VELO detector. The main advantage of the proposed system is to increase by up to two orders of magnitude the effective target areal density, thus resulting in a significant increase of the luminosity for fixed-target collisions, keeping the same gas flow rate used up to now with SMOG.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
Pasquale Di Nezza EP-ULB Vittore Carassiti EP-ULB Giuseppe Ciullo EP-ULB Luciano Pappalardo EP-ULB Paolo Lenisa (Univ. Ferrara and INFN) Erhard Steffens (Univ. Erlangen)	C. Adorisio, G. Arduini, M. Barberan, M. Bernardini, G Bregliozzi, R. Bruce, R. de Maria, M. Ferro-Luzzi, R. Folch, C. Gaignant, J.- C. Gayde, M. Giovannozzi, G. Iadarola, M. Lamont, A. Masi, T. Otto, M. Pirozzi, B. Salvant, J. Sestak, C. Vollinger, Jorg Wenninger Daniel Wollmann	P. Collier (on behalf of LMC) Rolf Lindner (LHCb Technical Coordinator)

DOCUMENT SENT FOR INFORMATION TO:

Giovanni Passaleva

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:

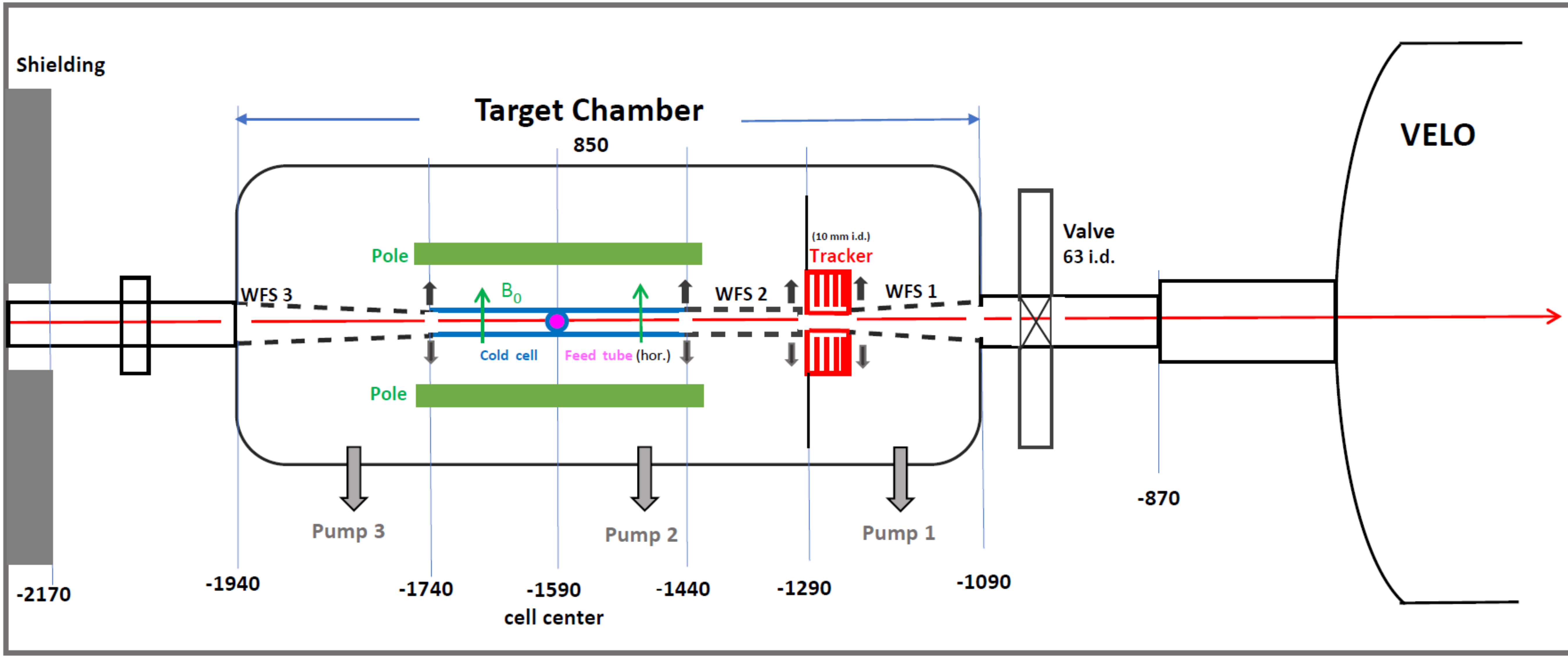
-Installation of an openable storage cell, fixed to the VELO rf-box frame
-Lay cable + gas pipe line into the P8 cavern
-Replacement of the SMOG Gas Feed System located into the P8 cavern

Approved

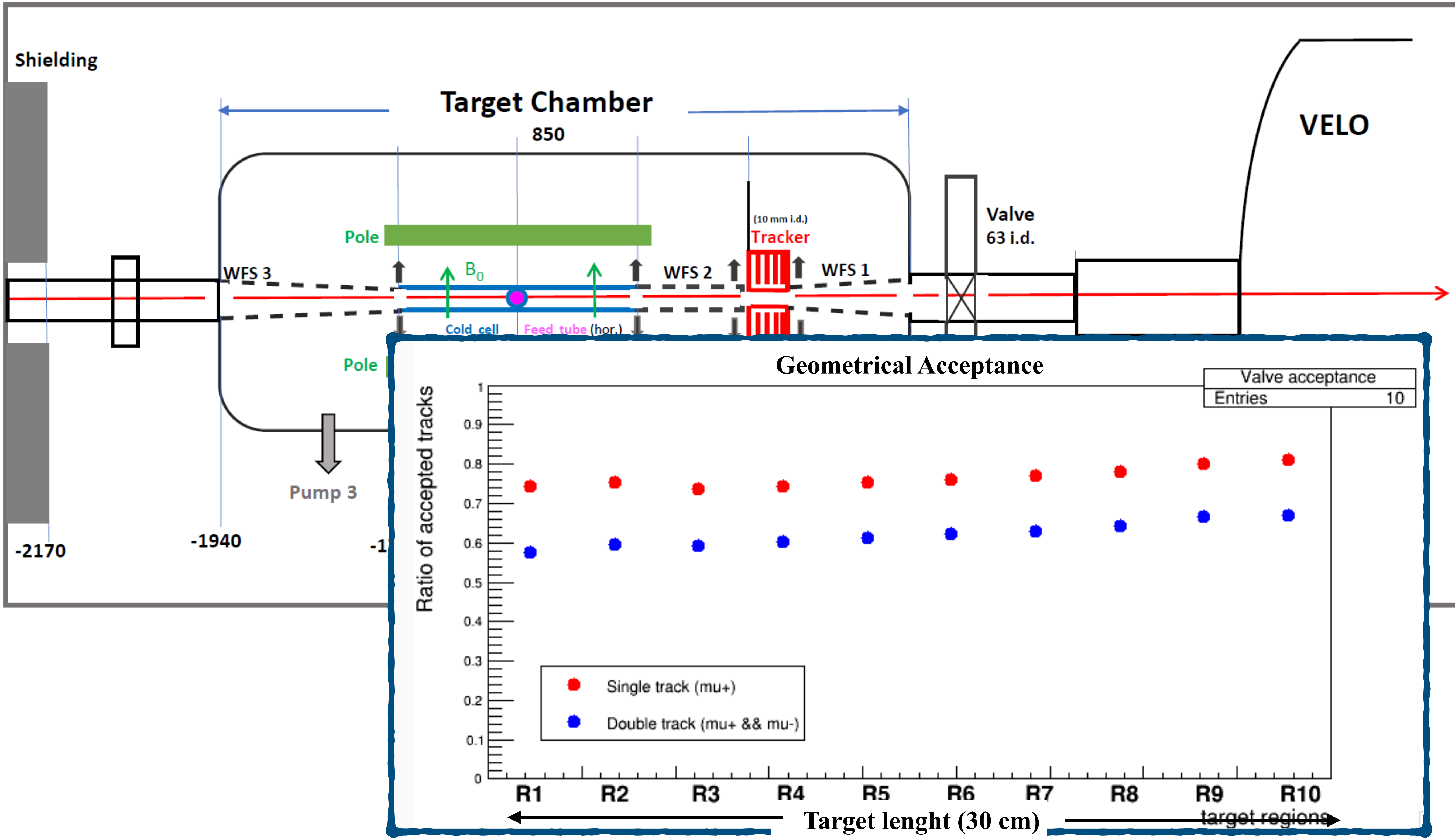
Note: When approved, an Engineering Change Request becomes an Engineering Change Order.
This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use.

The approval from LHC is particularly important because many of the technical solutions found here can be applied to the polarised case

Polarised Gas Target (PGT) topology – a schematic view

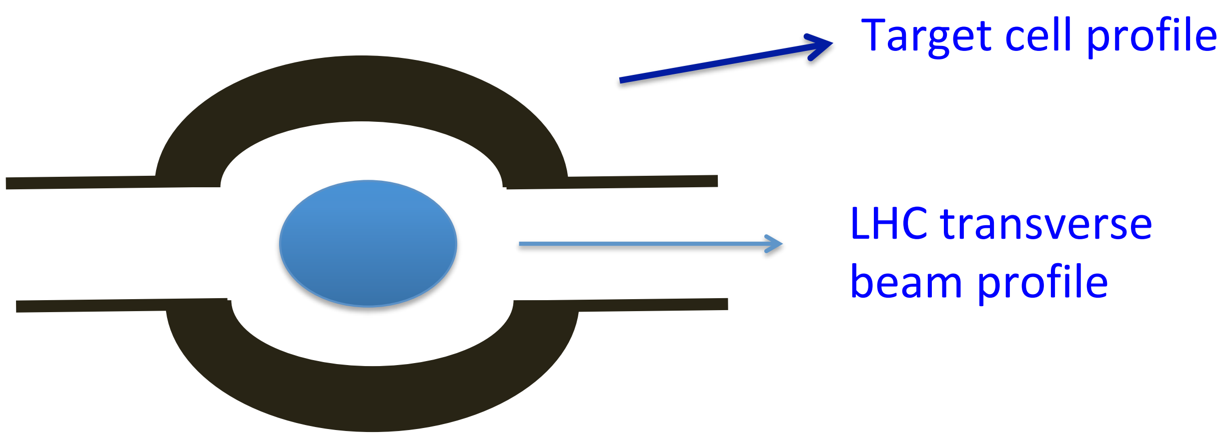


Polarised Gas Target (PGT) topology – a schematic view

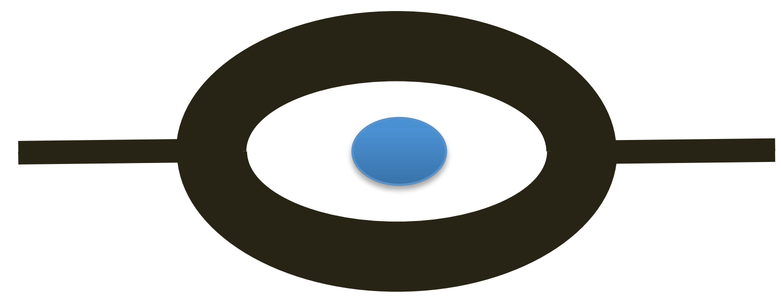


Constraints on the target geometry

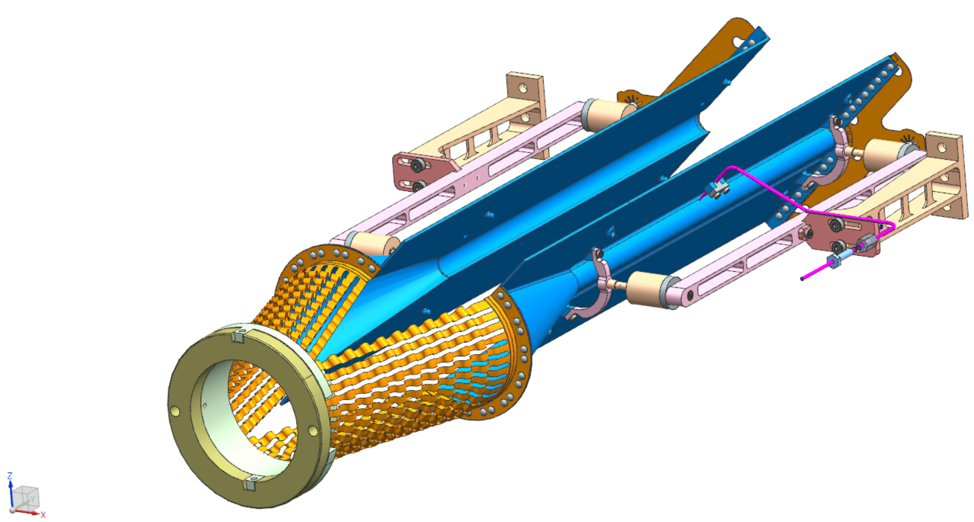
The LHC beam transverse size changes between the injection at 450 GeV (large) and the lumi beam at 7000 GeV (small)

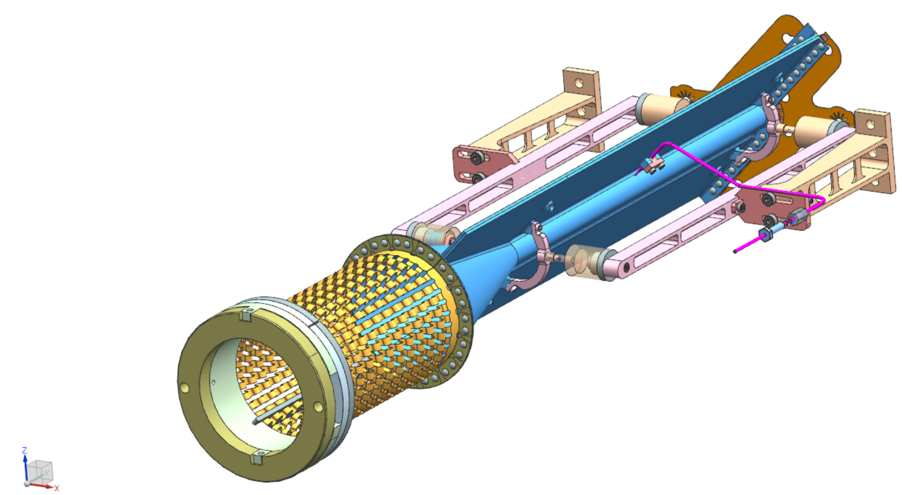


at injection
(450 GeV)



at Lumi Run
(7000 GeV)





Solution adopted for SMOG2: L = 20 cm, R = 0.5 cm
for LHCspin: L = 30 cm, R = 0.5 cm

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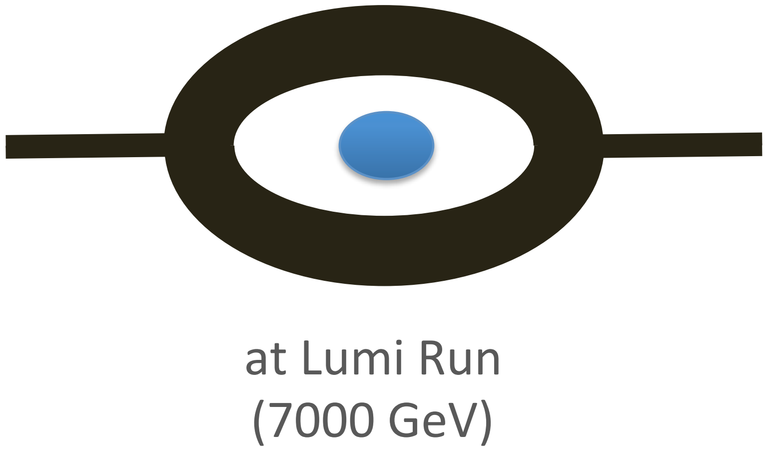
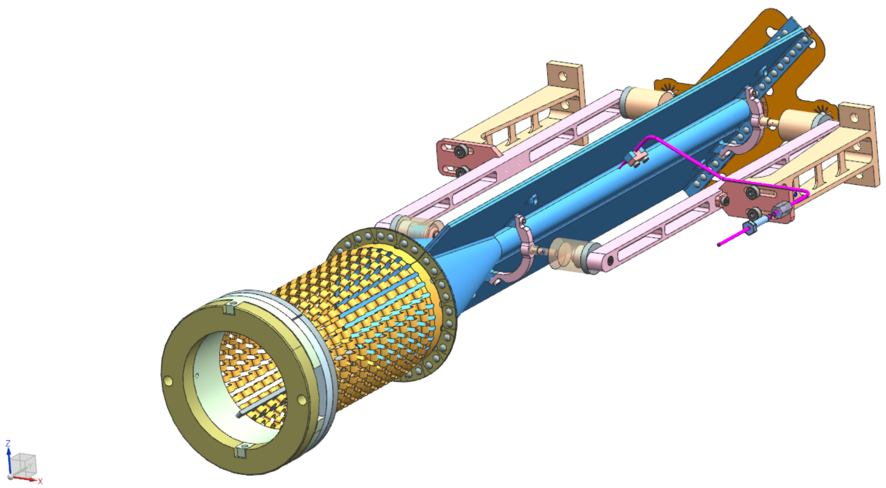


The achievable luminosity critically depends on the geometry of the cell

Aperture issues



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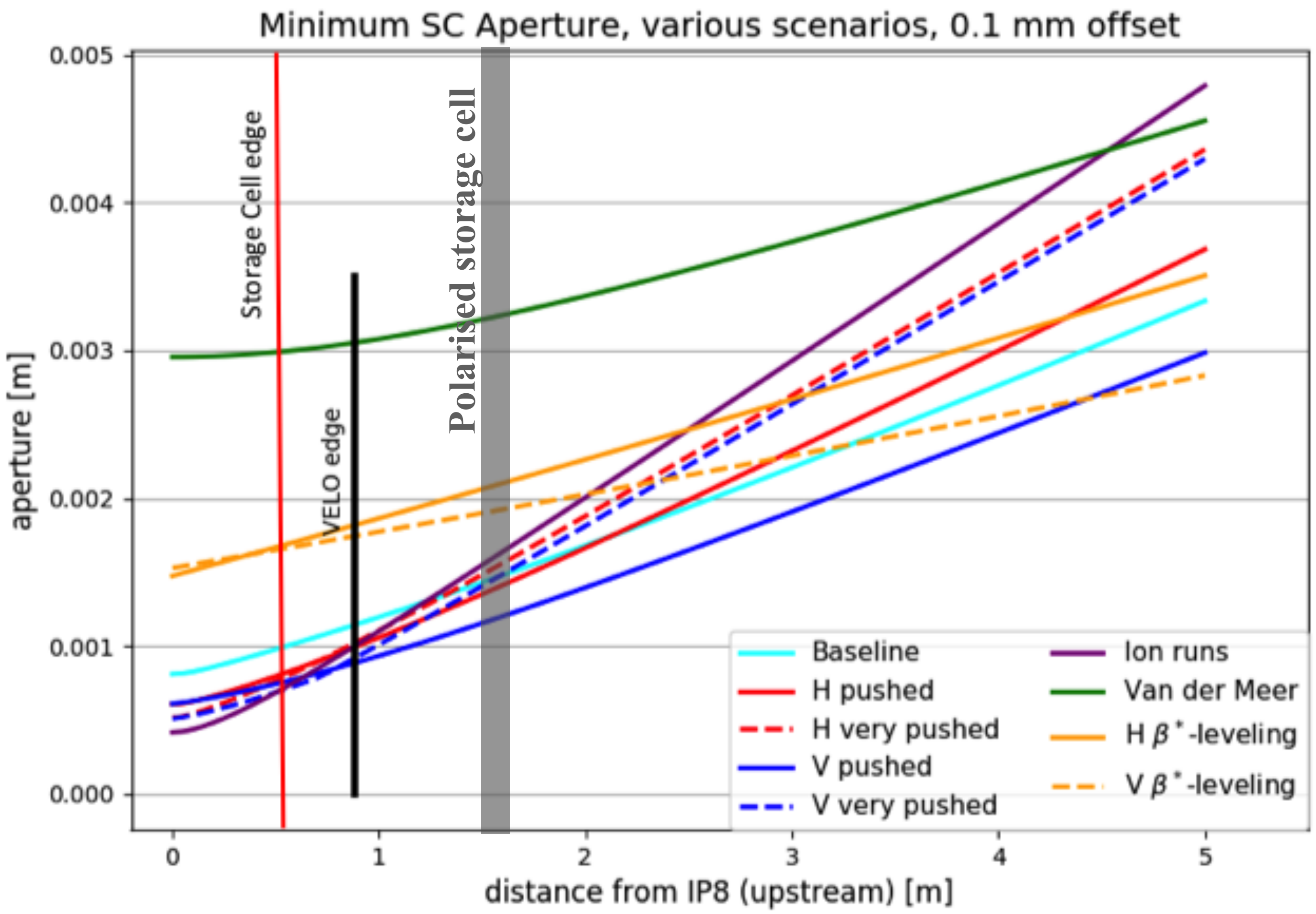
Aperture means luminosity

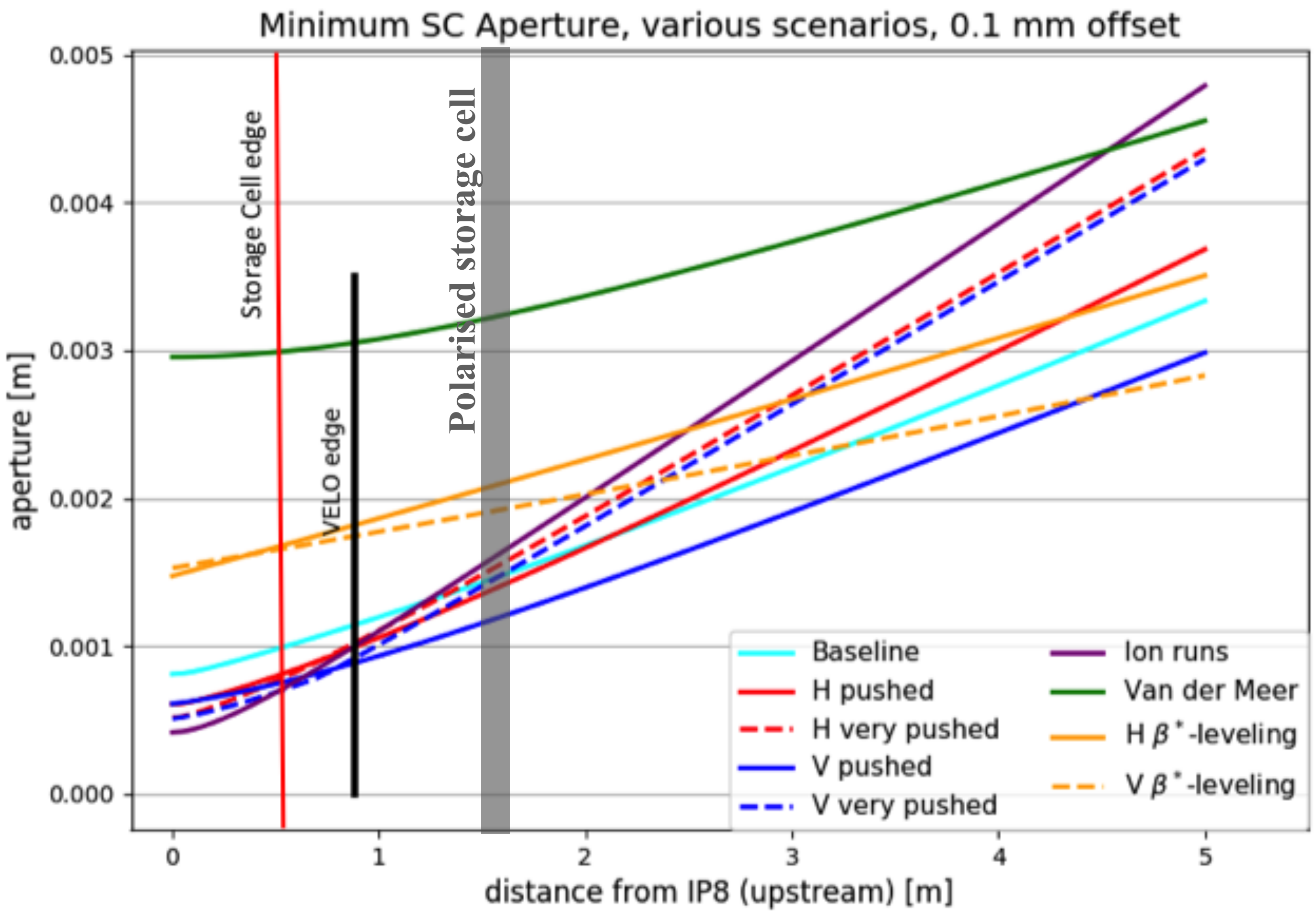
The dynamic aperture is the stability region of phase space in a circular accelerator



a cell with R = 0.5 cm has still a good safe factor for the machine aperture

Aperture means luminosity

The dynamic aperture is the stability region of phase space in a circular accelerator



a cell with R = 0.5 cm has still a good safe factor for the machine aperture

- I_H (100 % HERMES ABS flow) = $6.5 \cdot 10^{16}$ s^{-1}
- Cell 30 cm long, R= 0.5 cm, at 100K, with standard feed tube 10 cm long, 1.0 cm i.d.

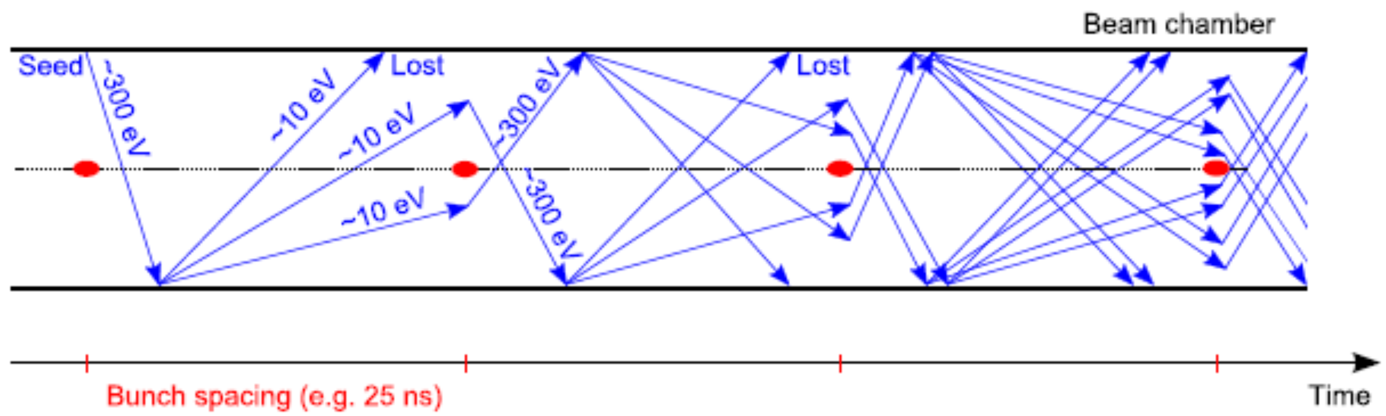
→ target density θ **= 1.2 · 10^{14} cm^{-2}** (comparable with HERMES)

At HL-LHC-25ns, LHCspin can reach L=8.3 · 10^{32} cm^{-2} s^{-1}

Small impact on the LHC beam life-time: reduction ~7%

Electron clouds

in accelerators with positive particles, slow electrons produced by various ionization processes are trapped near the beam. They are accelerated by the bunches, producing Secondary Electrons which may lead to an avalanche multiplication effect, forming dense Electron Clouds (EC) … as a result, transverse instabilities may occur!



As for SMOG2, for LHCspin

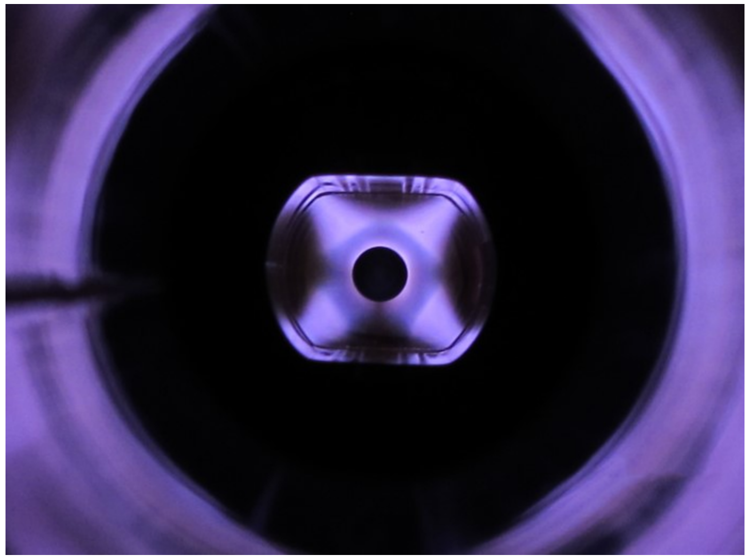
amorphous Carbon (a-C) is a very efficient solution! Amorphous graphite is already applied in accelerators, incl. the SPS and the LHC.

The recombination issue is under study and we have already possible solutions

picture taken during a coating process

Blue light: from Argon discharge for sputtering Carbon.

Image: Vacuum Surfaces and Coatings group of the Technology department (TE-VSC)



CSN5-INFN_ 2020

A R Y A

SurfAce and mateRial studies for Accelerator TechnologY And related topics

2.1.3 WP3. LHCspin: surface properties validation
(Responsible: Pasquale Di Nezza & Roberto Cimino. INFN-LNF and CERN)

→ *INFN dedicated program for coating studies*

Impedance

When a beam of particles traverses a device which

- is not smooth or
- not a perfect conductor

will produce e.m. wakefields (in time domain) or impedance (in frequency domain):

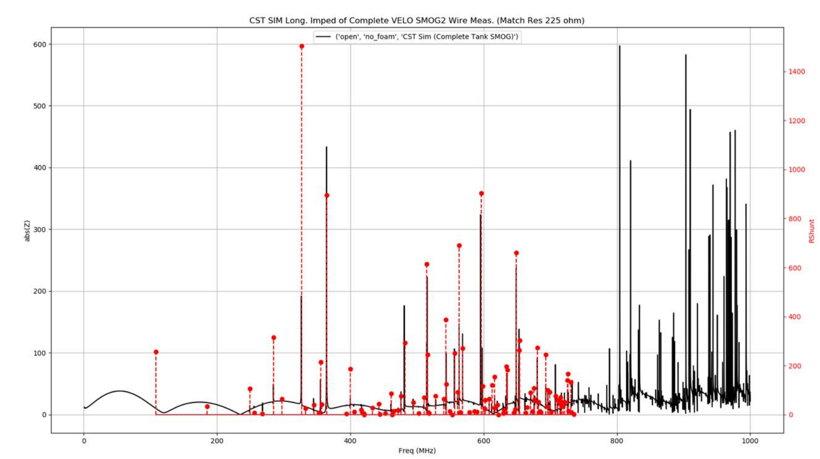
- energy is lost by the beam dissipated in surrounding chambers → beam induced heating!
- resonant kicks to following particles → instabilities → beam loss and blow up!

Simulations show that, in the extremely pessimistic case of resonance shifts of ± 20 MHz, with the <u>open cell</u>, a power dissipation of 14 W into the whole cell have been estimated. This can increase up to a factor 4 in case the two beams create the same simultaneous dissipation.

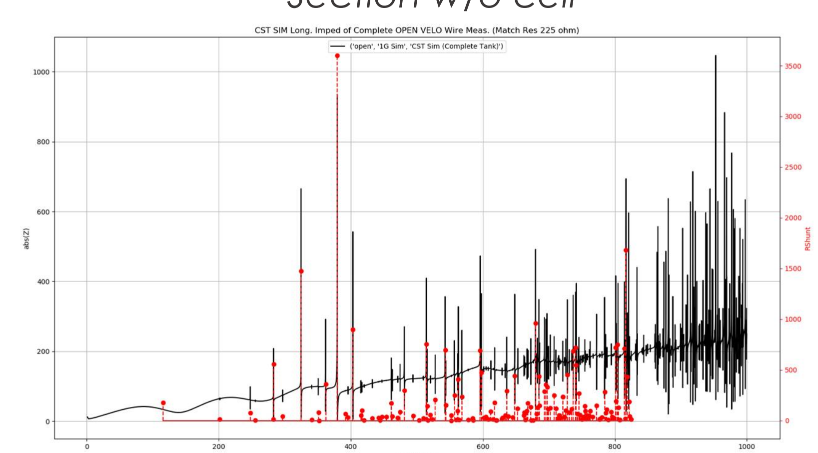
No resonant heating into the <u>closed cell</u> is to be expected.

This dissipation power is affordable by the system

Section with cell



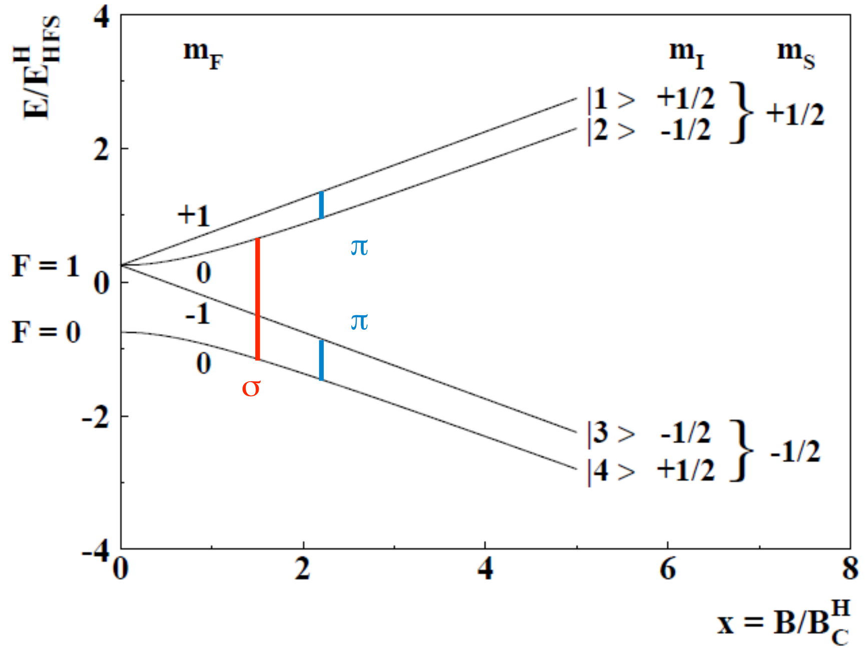
Section w/o cell



Beam Induced Depolarization

BID is based on resonant transitions caused by the beam field acting on the polarized H-atoms in an external guide field

Some of these resonances change nuclear polarization. For longitudinal guide field, only the π resonances are present. For transverse field, like at LHCspin, both π and σ types of resonances are present



Studies have been performed and by comparing the HERA data with LHC, we conclude that resonant depolarization at the LHC via the $\sigma_{2\text{-}4}$ transition is negligible compared to HERA, despite the 25x higher beam current!

In order to resolve the σ_{24} resonances, a field homogeneity in the order of their spacing is required (0.37 mT in the high-field limit) —> extremely homogeneous magnet

… all this gives constraints to the T magnet

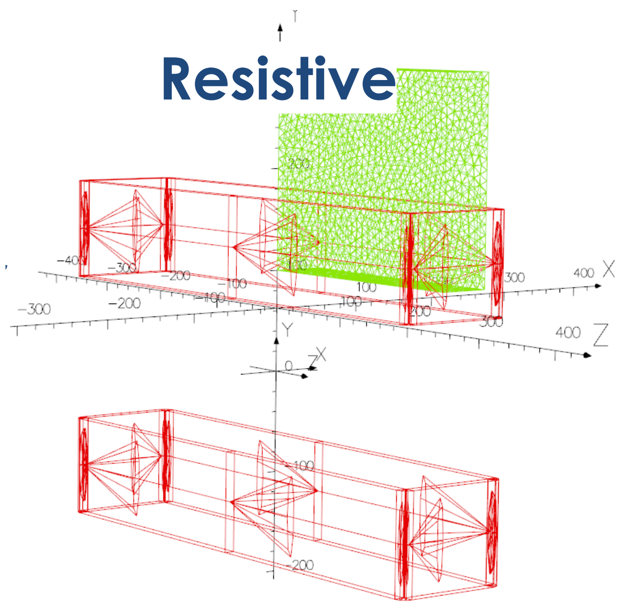
The Transverse Magnet

A transverse magnetic field:

- >300 mm long for 10 mm diam cell
- Field 0.3 T
- Field homogeneity: <1%

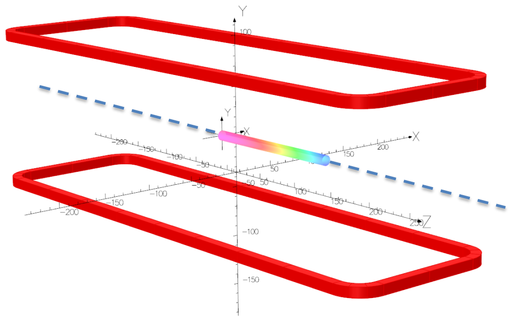
Some of the possible solutions

Resistive

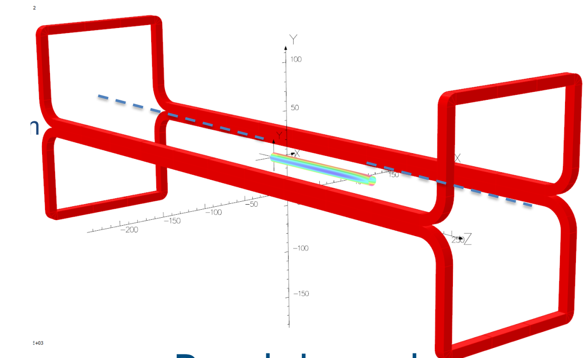


simple and standard
water cooling
HV power converter
heavy

Superconducting



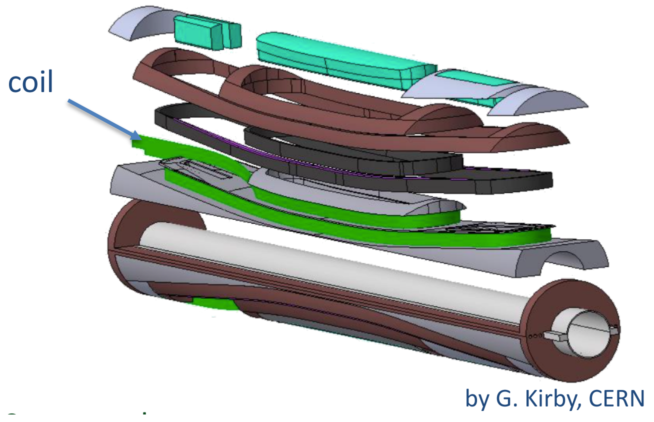
Racetrack



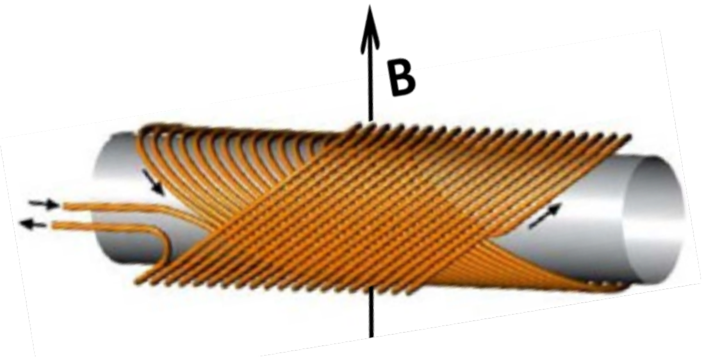
Bedstead

small volume
LV power converter
cryogenics
protection

Flare ends

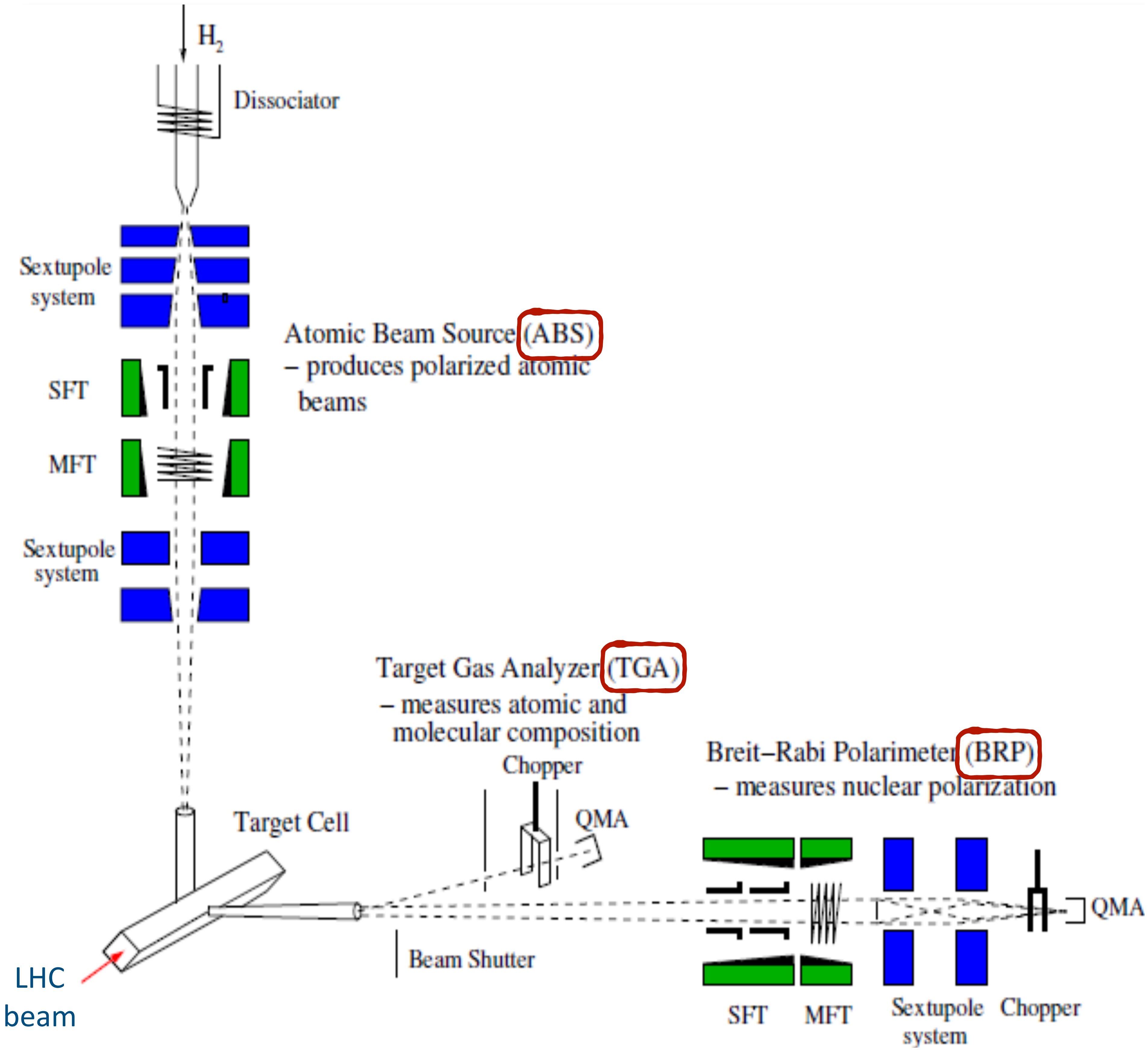


Canted cosine theta

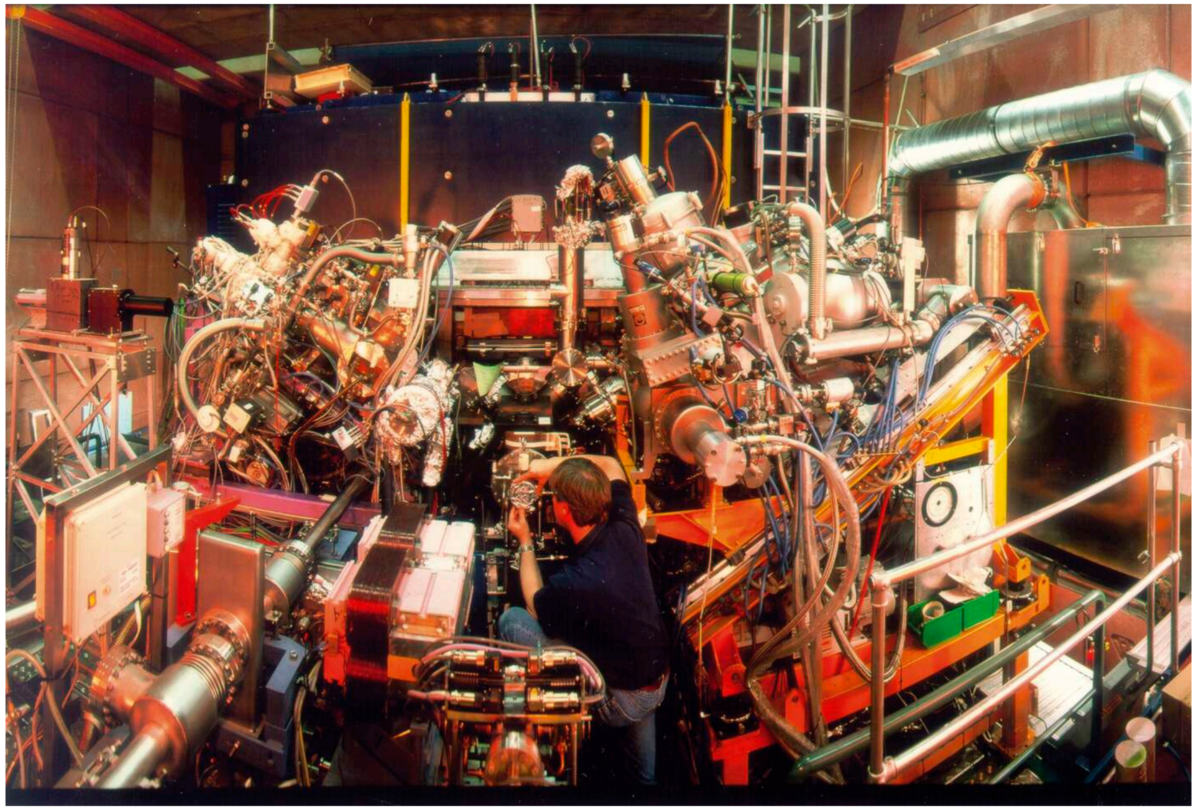


Very good field
Easy to wind
Easy to assembly
Holes for ABS and BRP

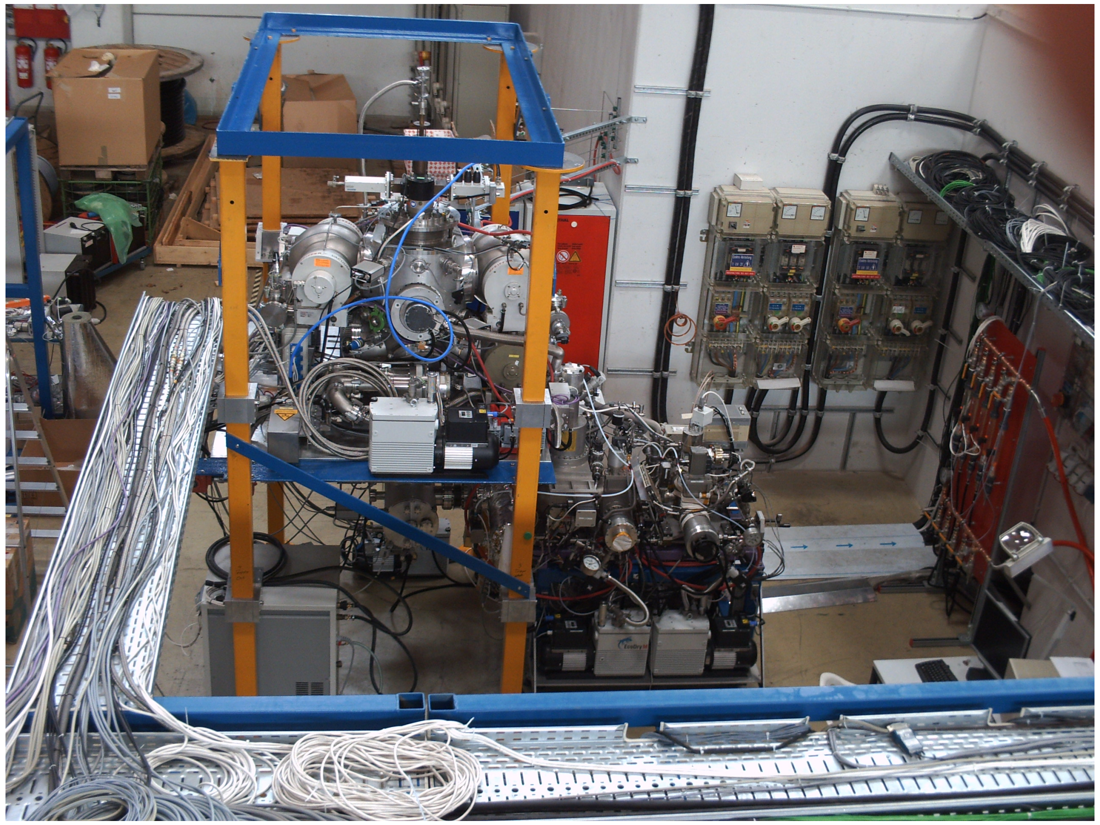
Atomic Beam Source and diagnostic



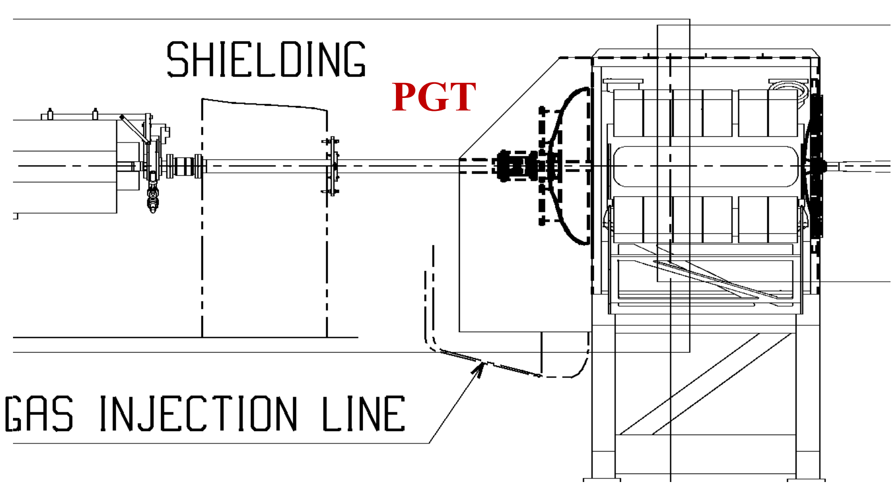
HERMES setup

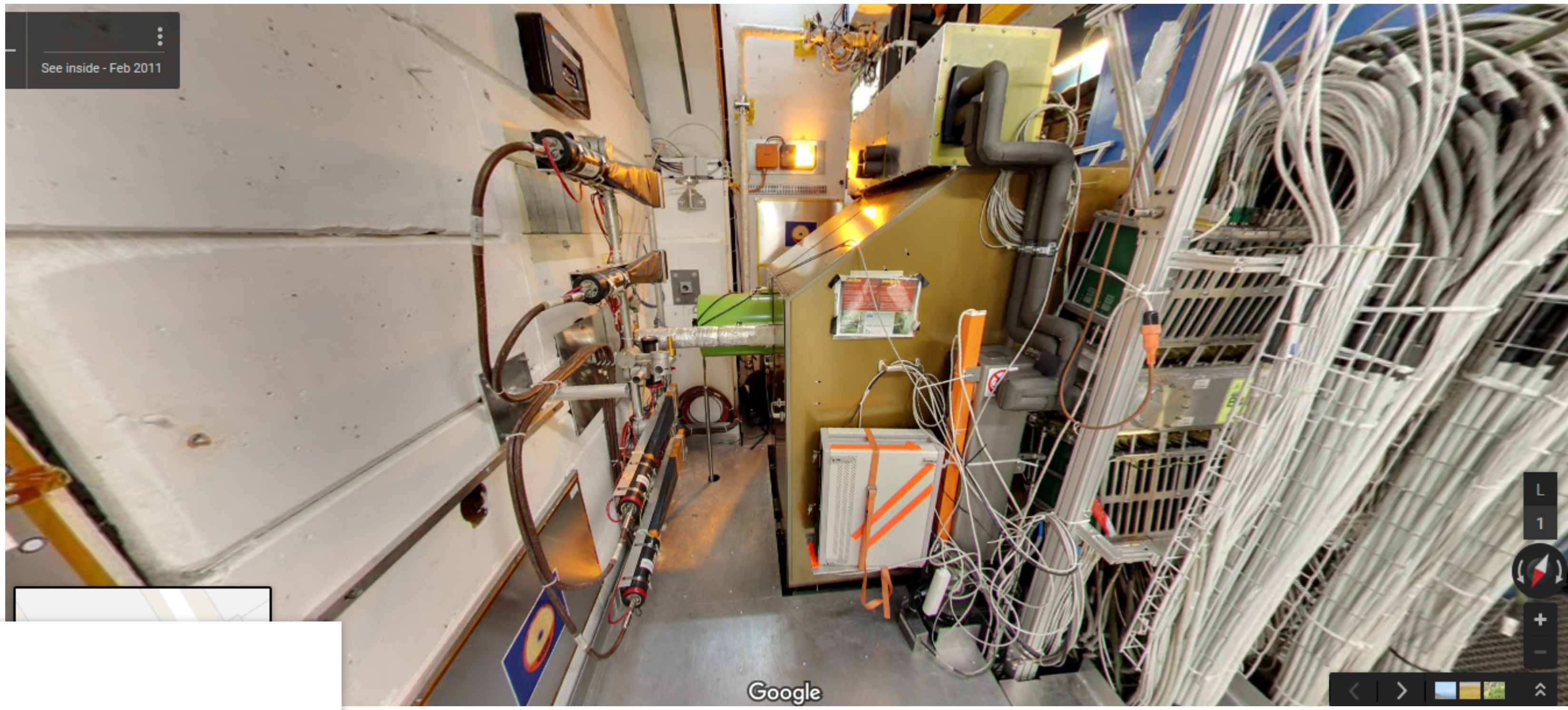


Juelich setup (II generation)



IP8





Space in front of LHCb (~1.5 m)

Possible Solutions:

1) Develop and build compact ABS+diagnostic
2) Move the shielding wall upstream

Increasing interest from CERN and the community

unpolarised target

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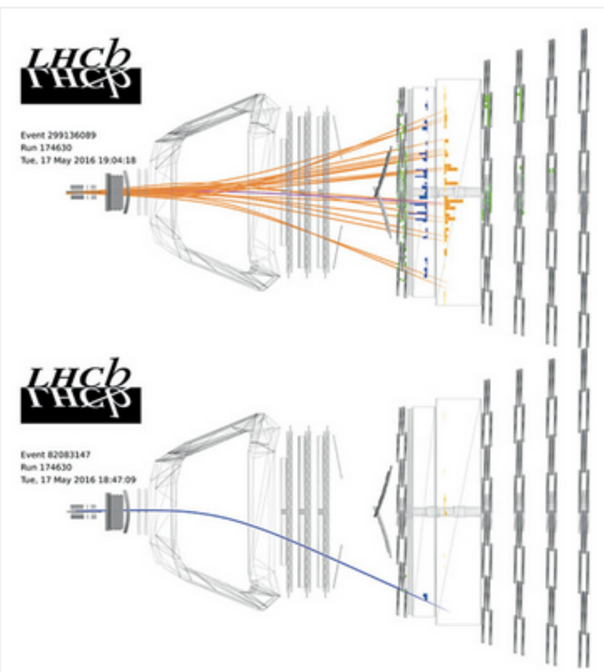
NEWS

LHCb brings cosmic collisions down to Earth

13 April 2017



Collision and scattering events (expand for full image)

In an effort to improve our understanding of cosmic rays, the LHCb collaboration has generated high-energy collisions between protons and helium nuclei similar to those that take place when cosm
interstellar medium. Such collis
produce a certain number of ant
one of the possible explanations
antiprotons (about one per 10,0
cosmic rays outside of the Earth
measuring the antimatter comp
can potentially unveil new high
notably a possible contribution
decay of dark-matter particles.

In the last few years, space-bor
study of cosmic rays have dram
knowledge of the antimatter co
Alpha Magnetic Spectrometer (/

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Cosmic collisions at the LHCb experiment

by Stefania Pandolfi

Posted by Stefania Pandolfi on 27 Mar 2017. Last updated 27 Mar 2017, 16.00.

Voir en français

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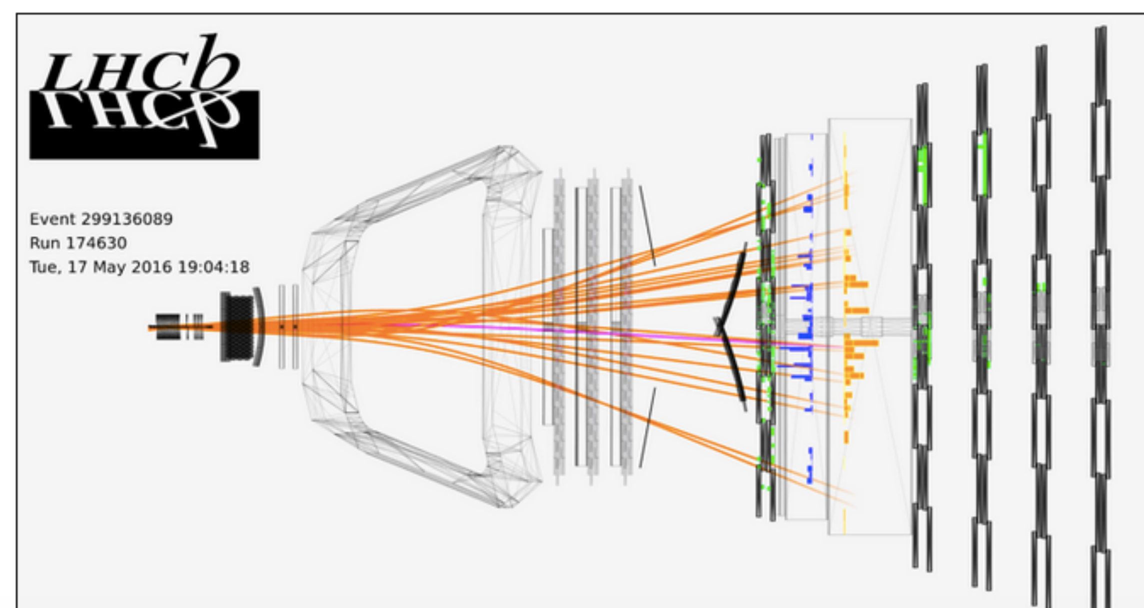
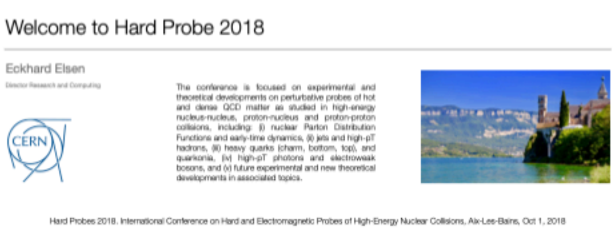


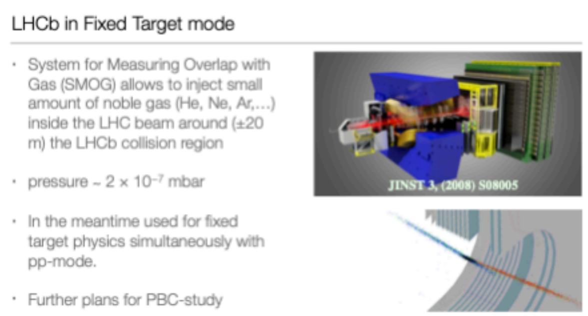
An example of a fully reconstructed proton-helium collision event in the LHCb detector. The particle

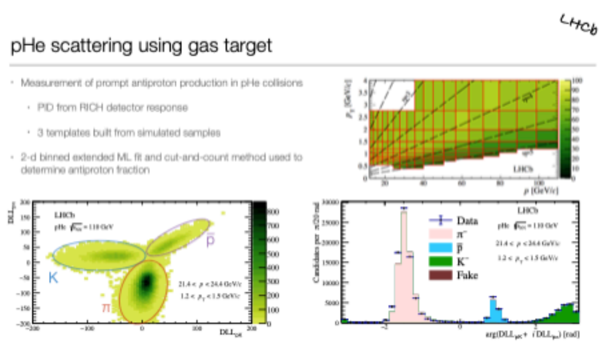
Increasing interest from CERN and the community

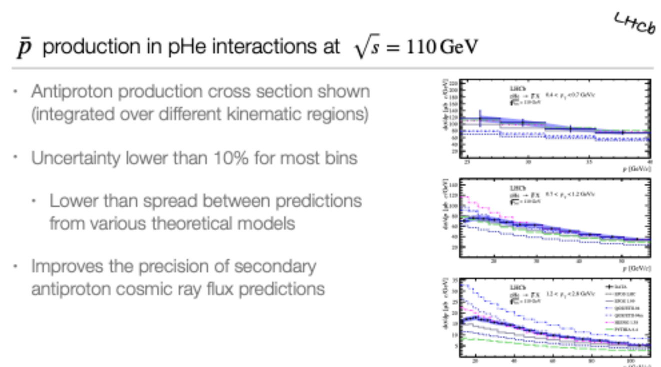
Opening talk of E.Elsen @ Hard Probes

unpolarised target





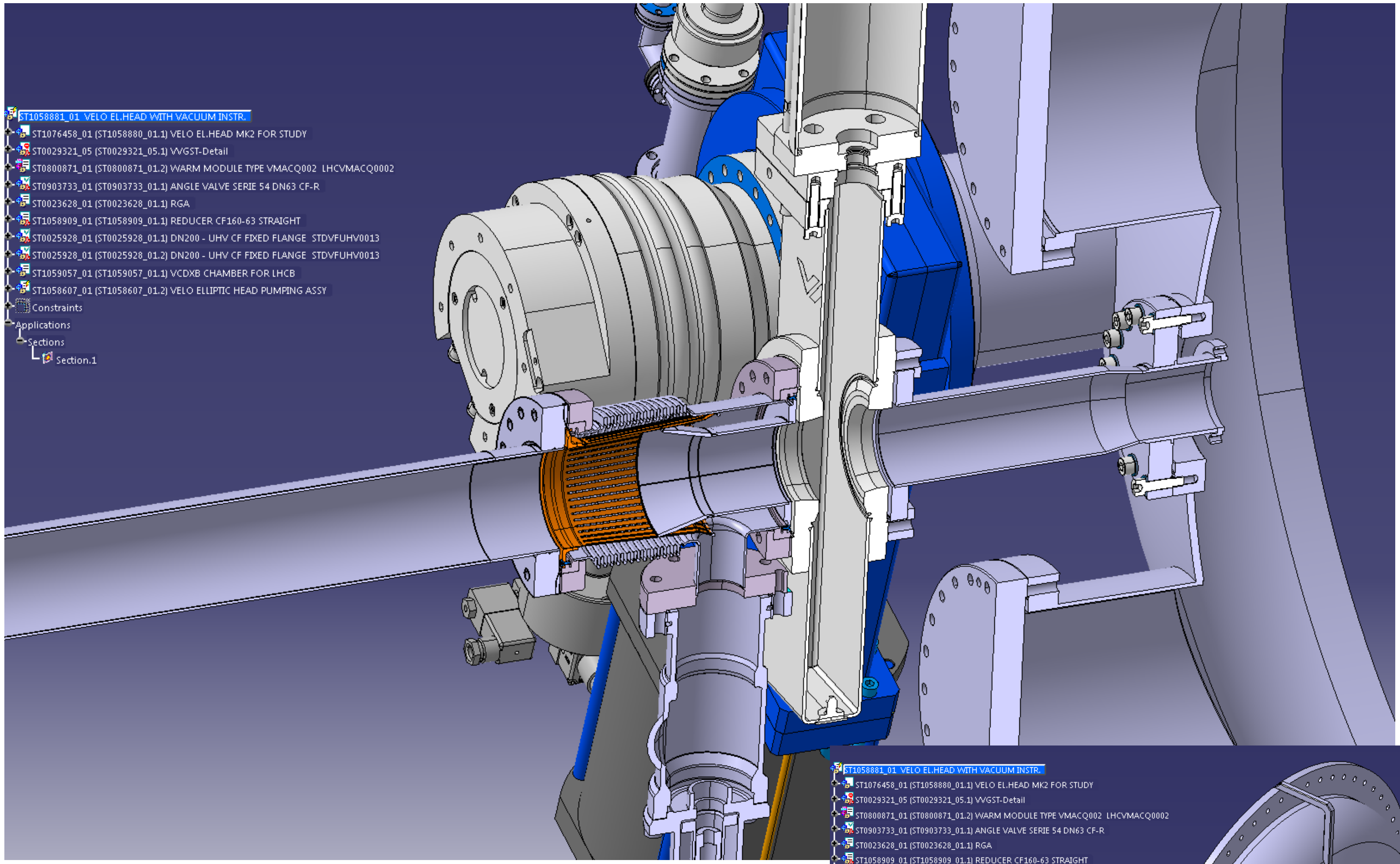


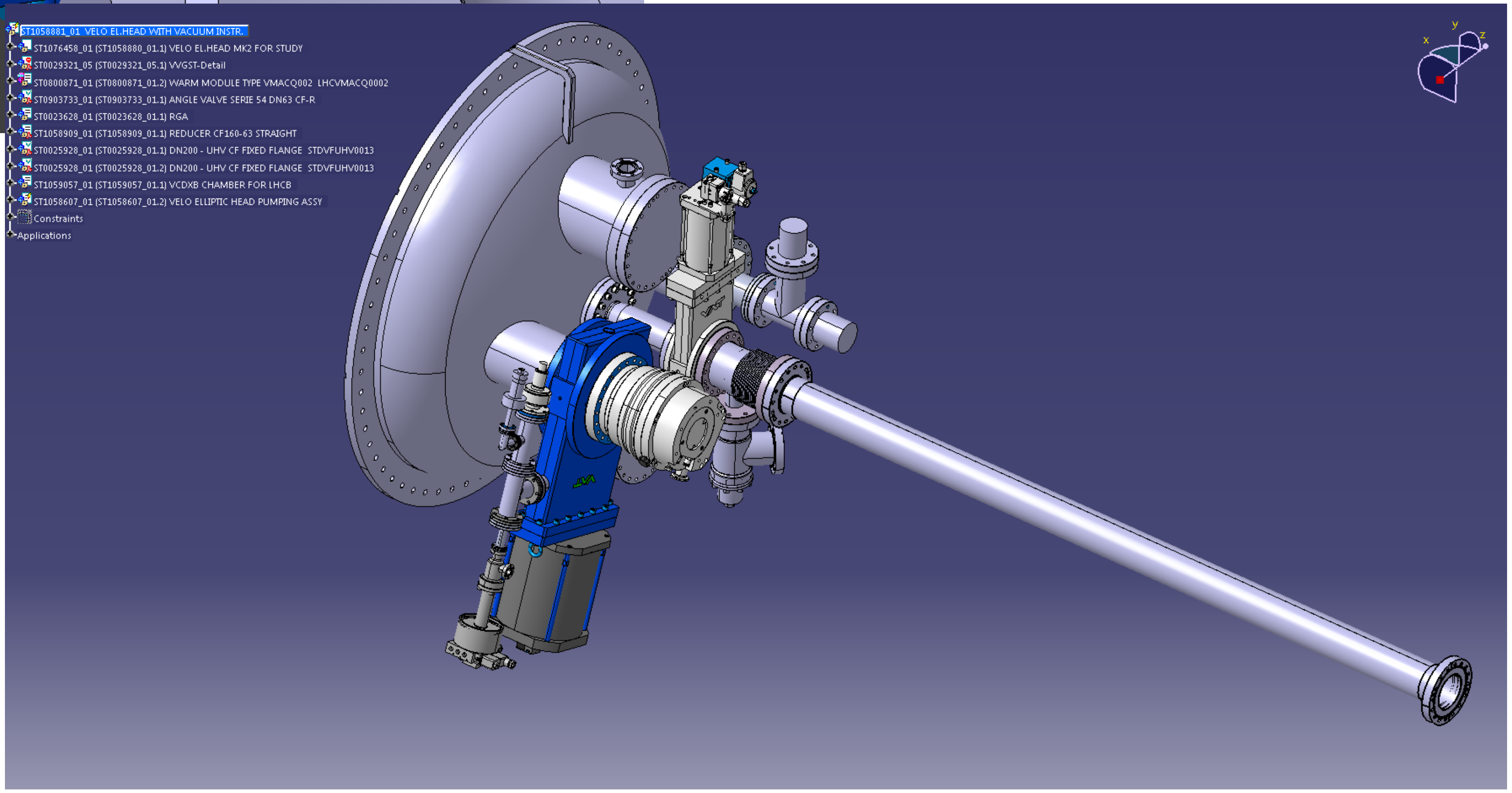


Highlight in the CERN Annual Report

the ATLAS interaction point. An intense preparatory phase took place with a view to installing it during LS2, following approval. Studies for fixed-target experiments in the LHC continued. A gas-storage cell next to the LHCb Velo was approved for installation in LS2, and a number of options

A significant step …





In order to isolate the upstream region of LHCb, a separation valve has been installed, by LHC, during the LS2.
This will allow to install the PGT without venting the LHCb pipe section (+VELO)

Conclusions

Undoubtably, fixed target physics at LHC is an exiting reality. In this panorama, the step towards a polarised target looks easier

AFTER performed a great job showing the physics opportunities in the LHC geometrical and kinematical regions

ALICE has great potentialities in the unpolarised case showing complementarity to LHCb. The polarised case seems extremely hard to reach

LHCspin The R&D made for the unpolarised target constitutes a solid base for the polarised part. The key parameters of the LHCspin system are very promising

Realistic scenario

If built and tested on a test bench during Run3 (2021-24), a PGT could be installed at LHCb during the LS3 (2024-2026) and operated using a gas feed system. Installation of the other components (ABS+diagnostic) during Technical Stops appears feasible