Istituto Nazionale di Fisica Nucleare

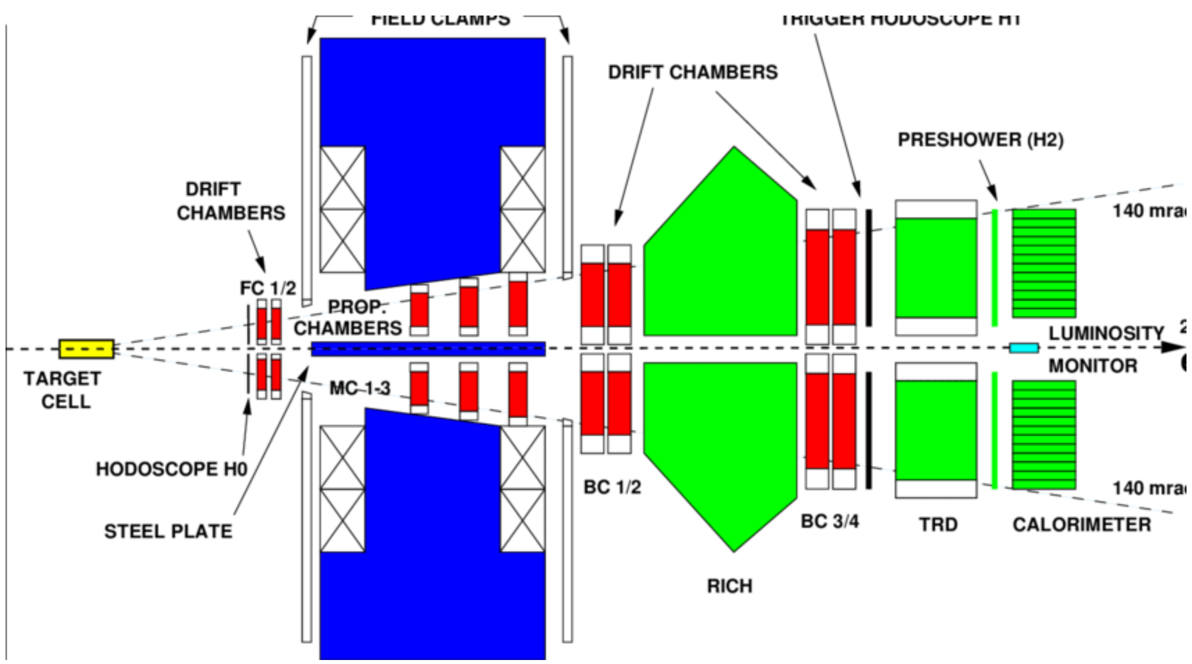
An unpolarised and polarized target at the LHC: where we are

Pasquale Di Nezza

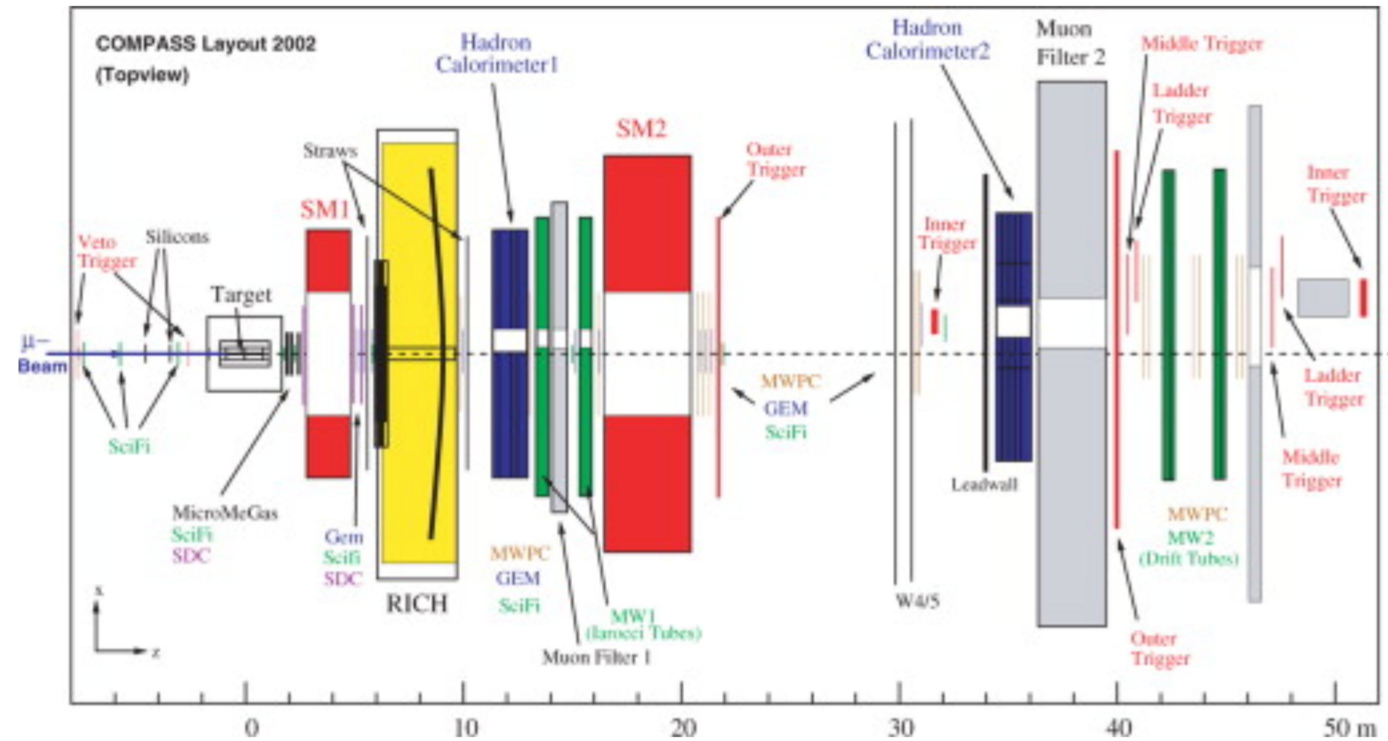
15/07/19

Examples of previous generation experiments for fixed (polarised) target physics

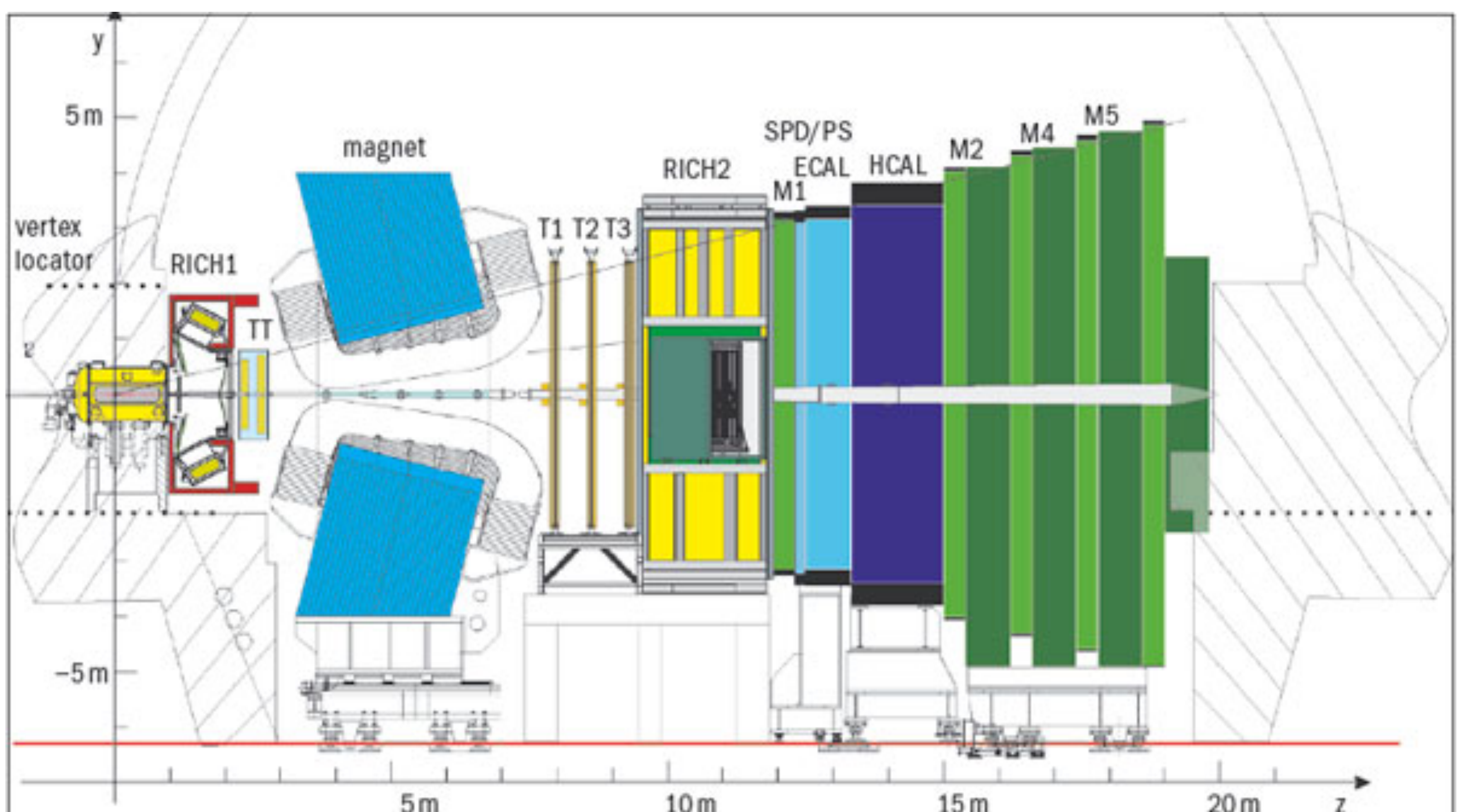
HERMES



COMPASS



our goal …



LHCb detector

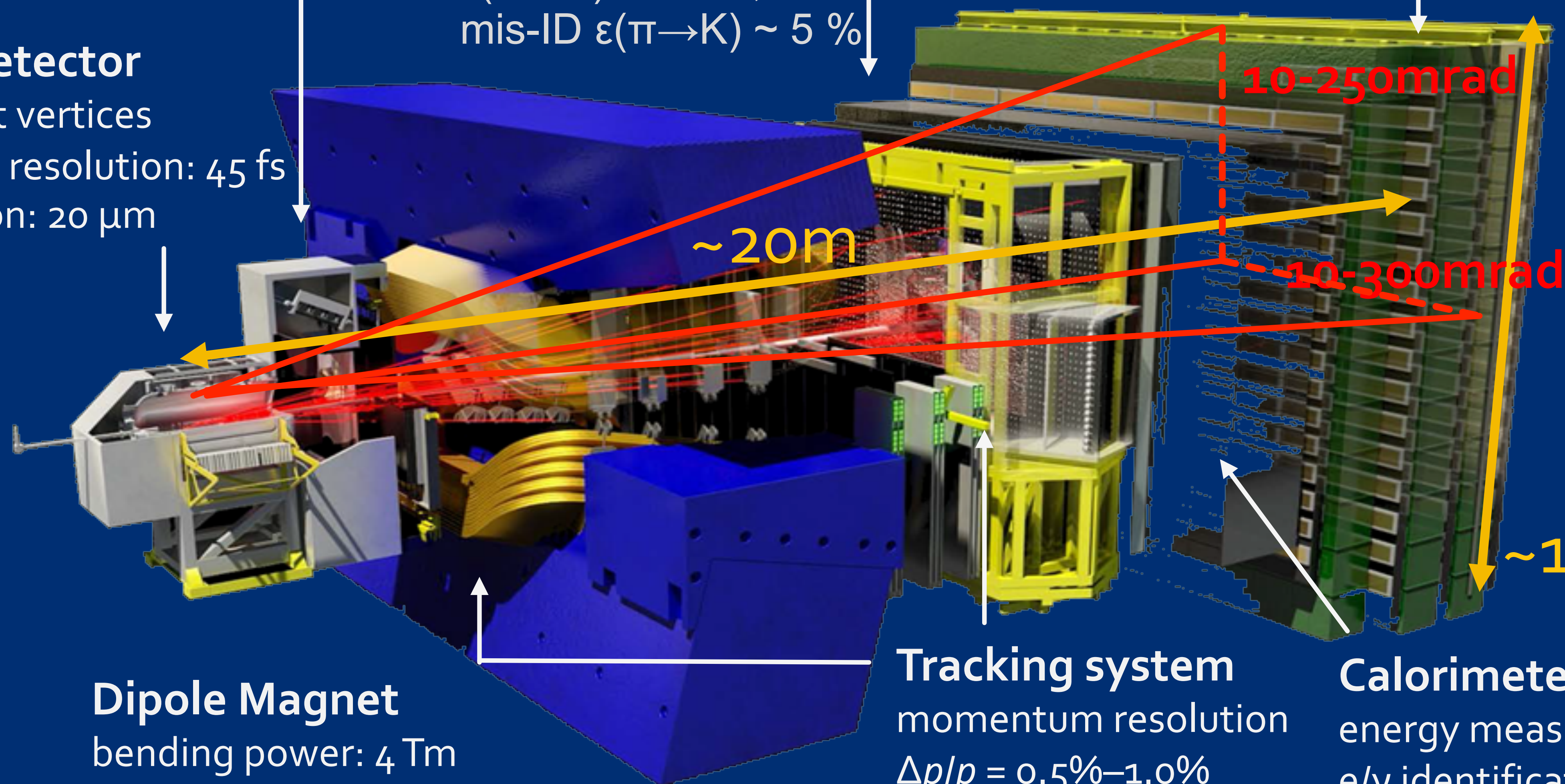
- Single arm spectrometer in the forward direction
  - designed for heavy flavour physics, but capable to address many other topics …
  - fully instrumented in 2 < y < 5 with unique forward kinematics
  - Flexible trigger down to very low p_T

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

RICH detectors
K/π/p separation
ε(K→K) ~ 95 %,
mis-ID ε(π→K) ~ 5 %

Muon system
μ identification ε(μ→μ) ~ 97 %,
mis-ID ε(π→μ) ~ 1-3 %

Vertex Detector
reconstruct vertices
decay time resolution: 45 fs
IP resolution: 20 μm



Dipole Magnet
bending power: 4 Tm

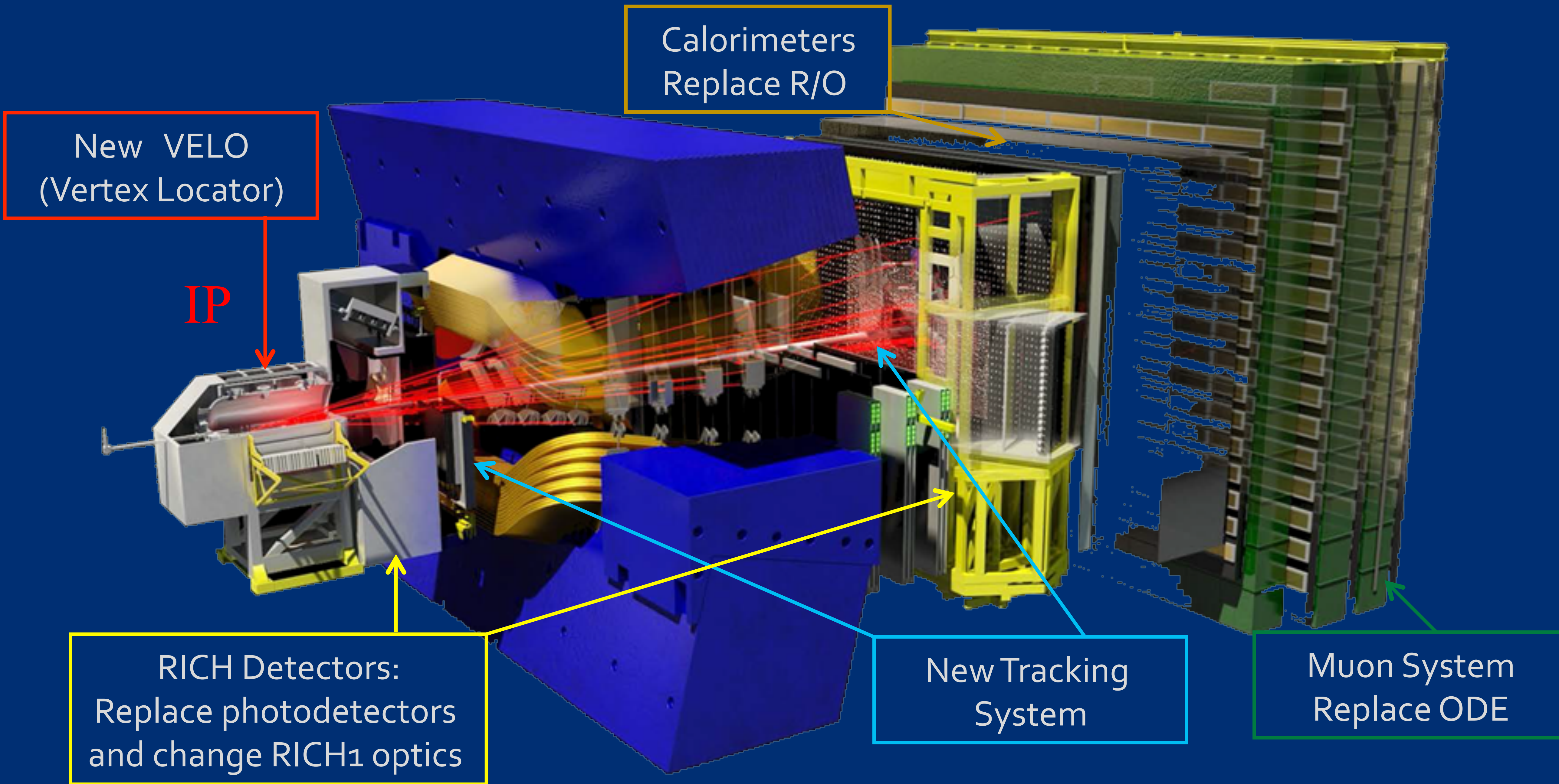
Tracking system
momentum resolution
$\Delta p/p$ = 0.5%–1.0%
(5 GeV/c – 100 GeV/c)

Calorimeters
energy measurement
e/γ identification
$\Delta E/E = 1\,\% \oplus 10\,\%/\sqrt{E}$ (GeV)

LHCb detector - Upgrade I

- Better utilise LHC capabilities: collect > 50 fb^{-1} of *pp* data
- upgrade ALL sub-systems to 40 MHz FE-electronics; fully software trigger
- adapt sub-systems to increased occupancies due to 5 x higher luminosity

→ Go from $4 \times 10^{32}/cm^2/s$ to $2 \times 10^{33}/cm^2/s$ CERN/LHCC-2012-007

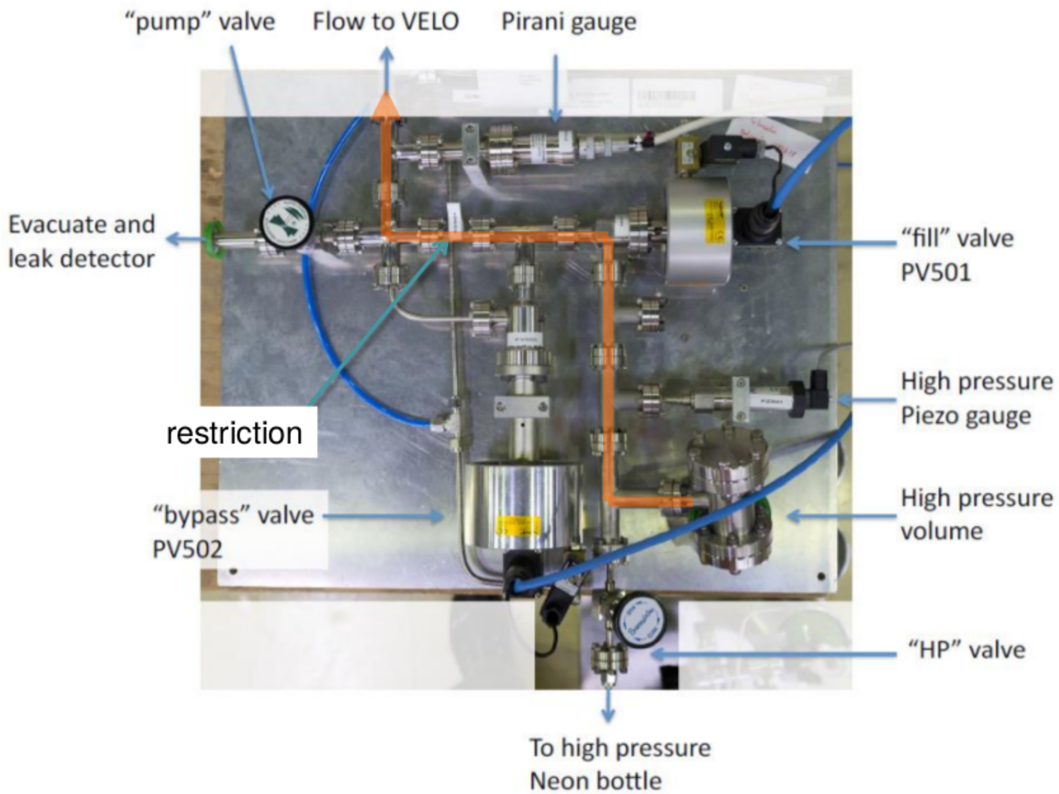


SMOG

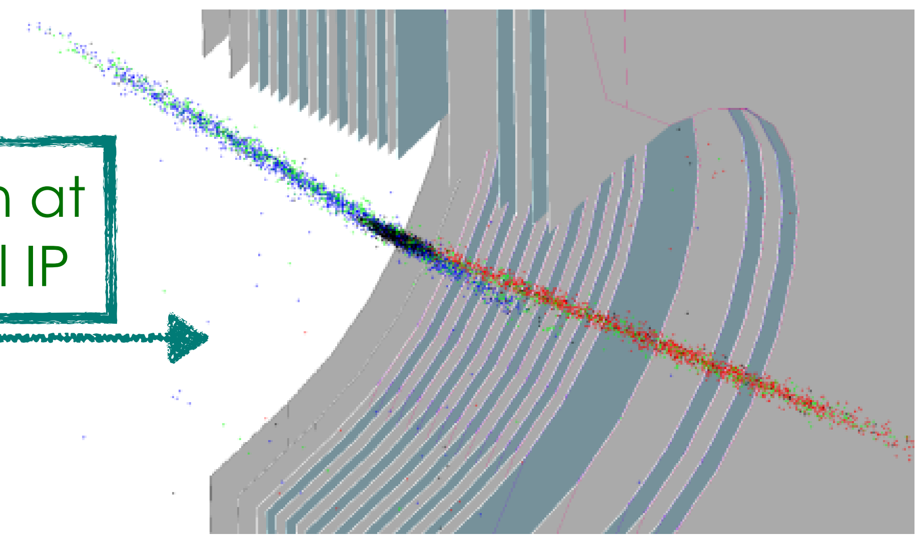
a pseudo-target in operation since **2015**

SMOG, a successful idea and a pseudo-target

System for Measuring Overlap with Gas (SMOG) has been thought for precise luminosity measurements by beam gas imaging, but then it served as a "pseudo-target" producing interesting results

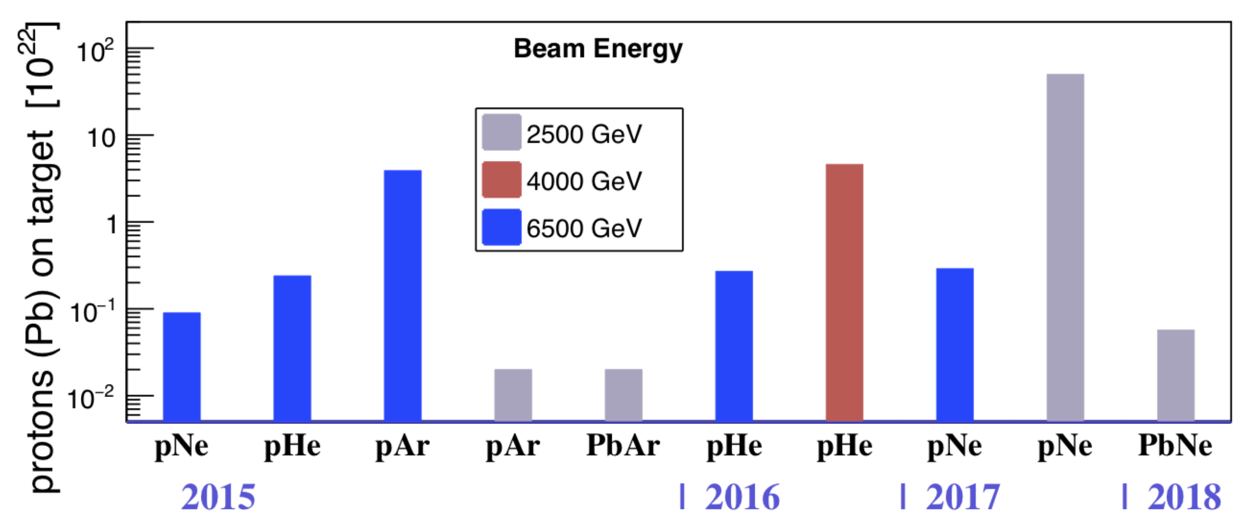


gas injection at the nominal IP



- Low intensity noble gas injected in the VELO vessel (~10^{-7} mbar)
- Gas pressure 2 orders or magnitude higher than LHC vacuum

Data taking SMOG 2015-2018



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)

SMOG

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SMOG2

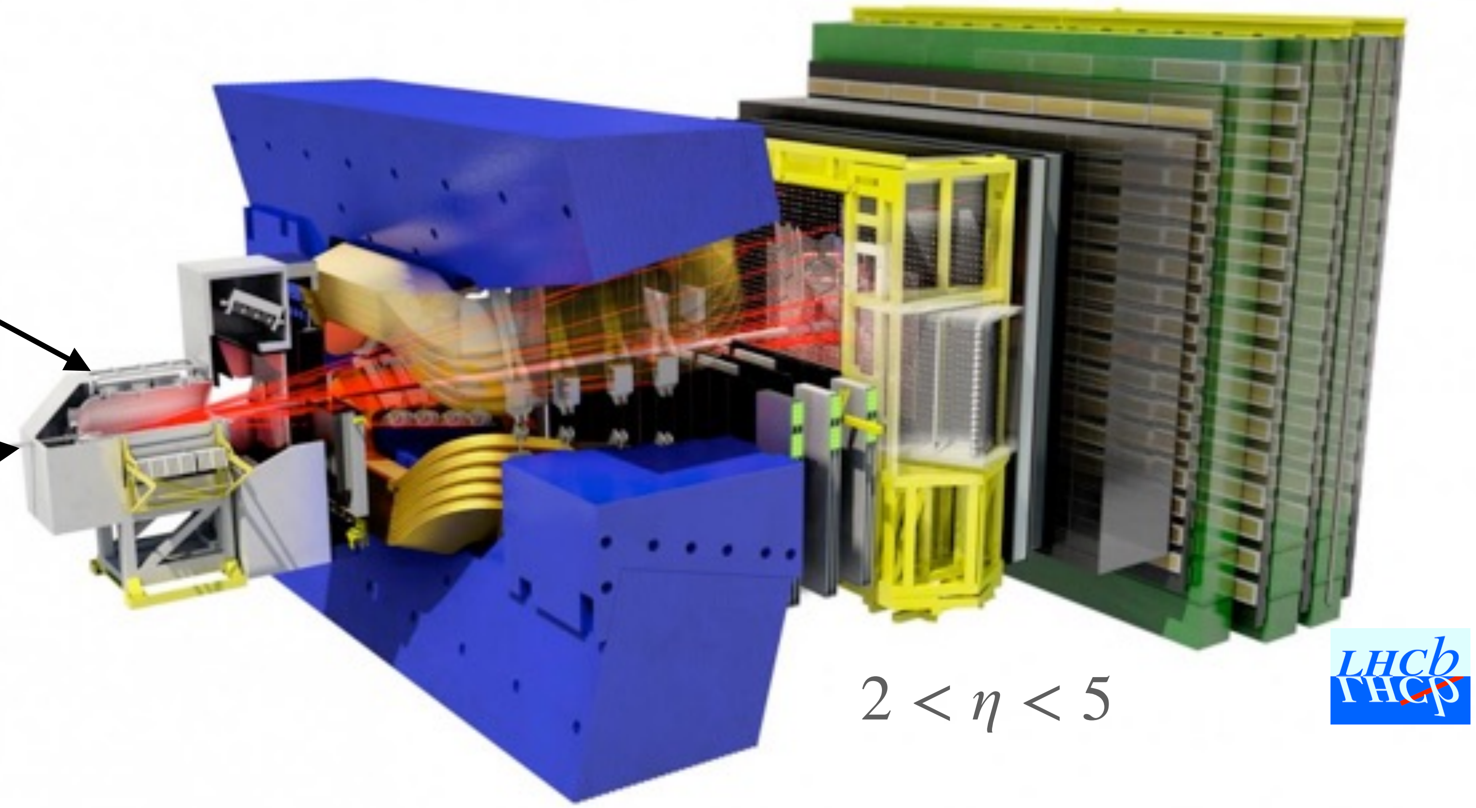
installation of a real storage cell in **2019** data taking foreseen from 2021

- Increase of the luminosity by up to 2 orders of magnitude using the same gas load of SMOG
- Injection of $H_2, D_2, ^{3,4}He, N_2, Ne, Ar, Kr, Xe$
- New Gas Feed System. Gas density (luminosity) measured with high precision
- Well defined interaction region upstream the IP@13TeV:
  - strong background reduction,
  - no mirror charges effect,
  - possibility to use all the bunches,
  - possible simultaneous data taking with pp interactions @13 TeV

SMOG2

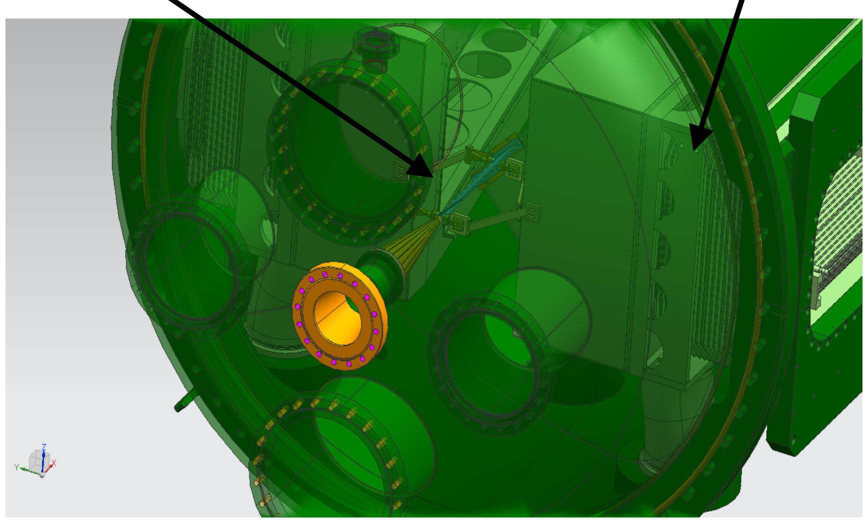
VELO
silicon VErtex LOcator

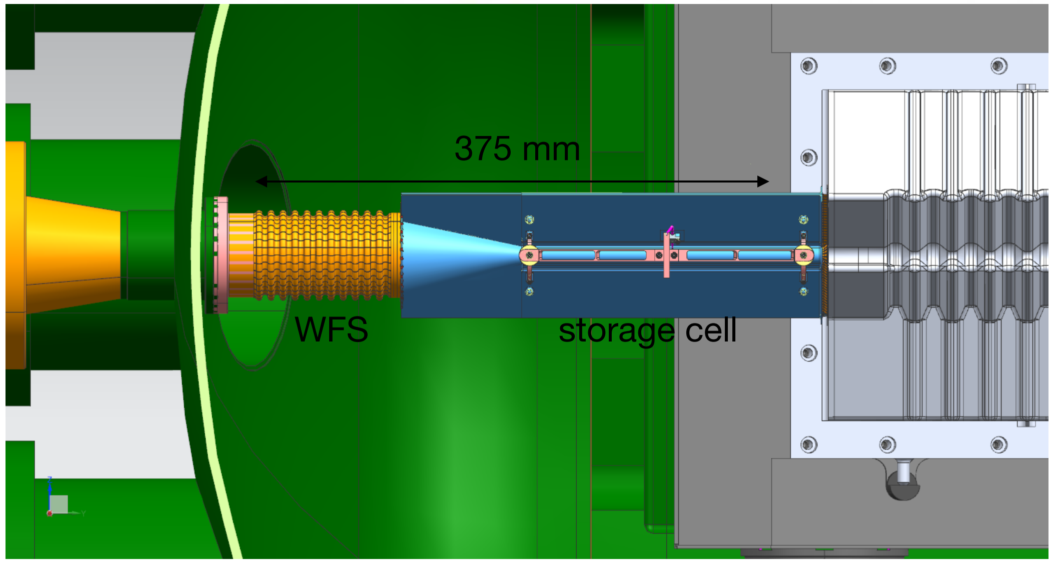
LHC beam



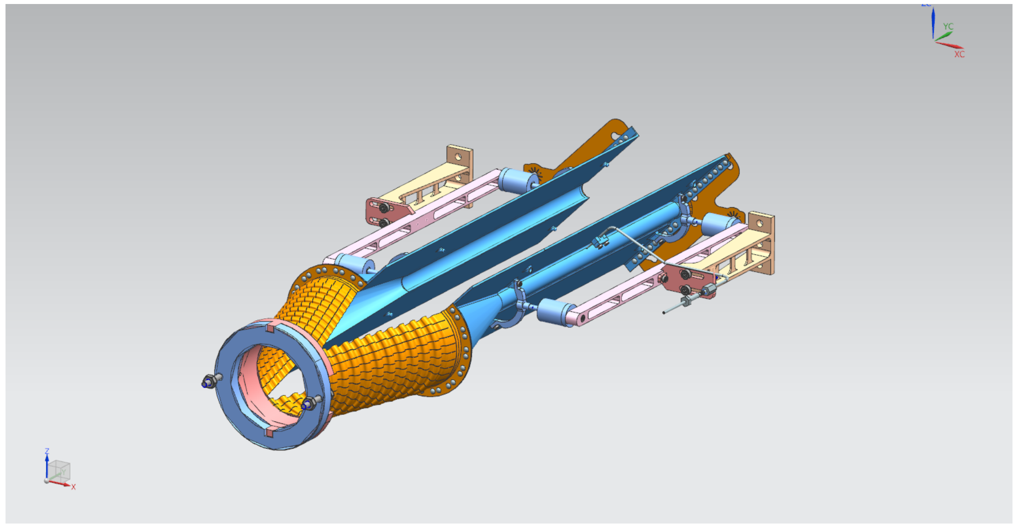
SMOG2

VELO

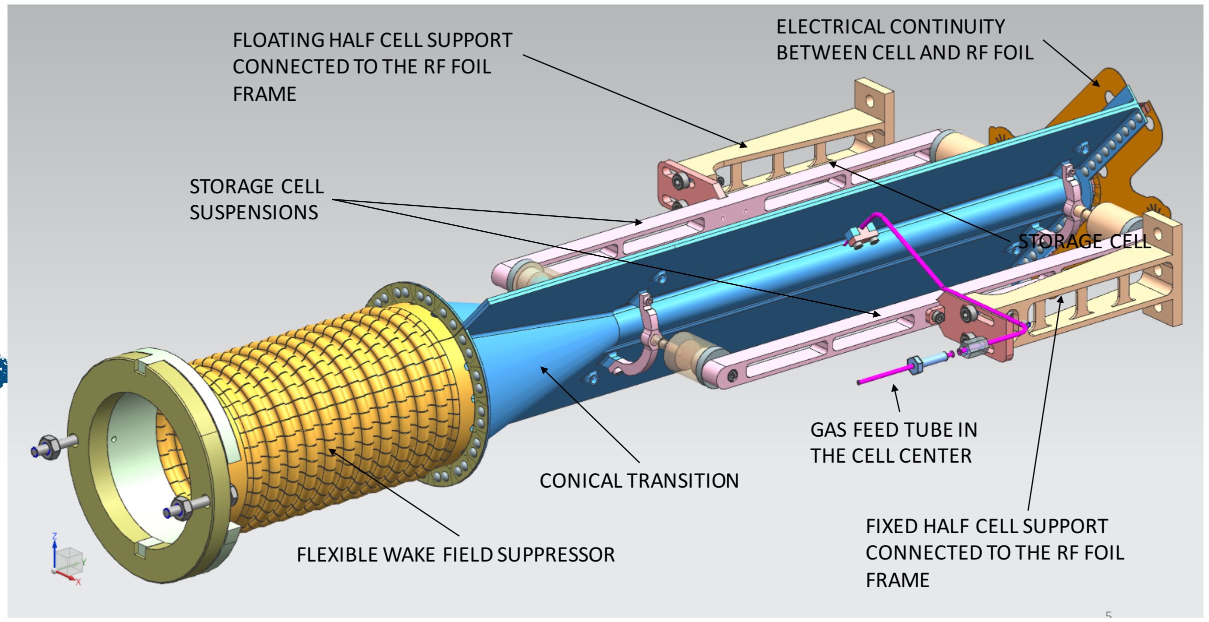


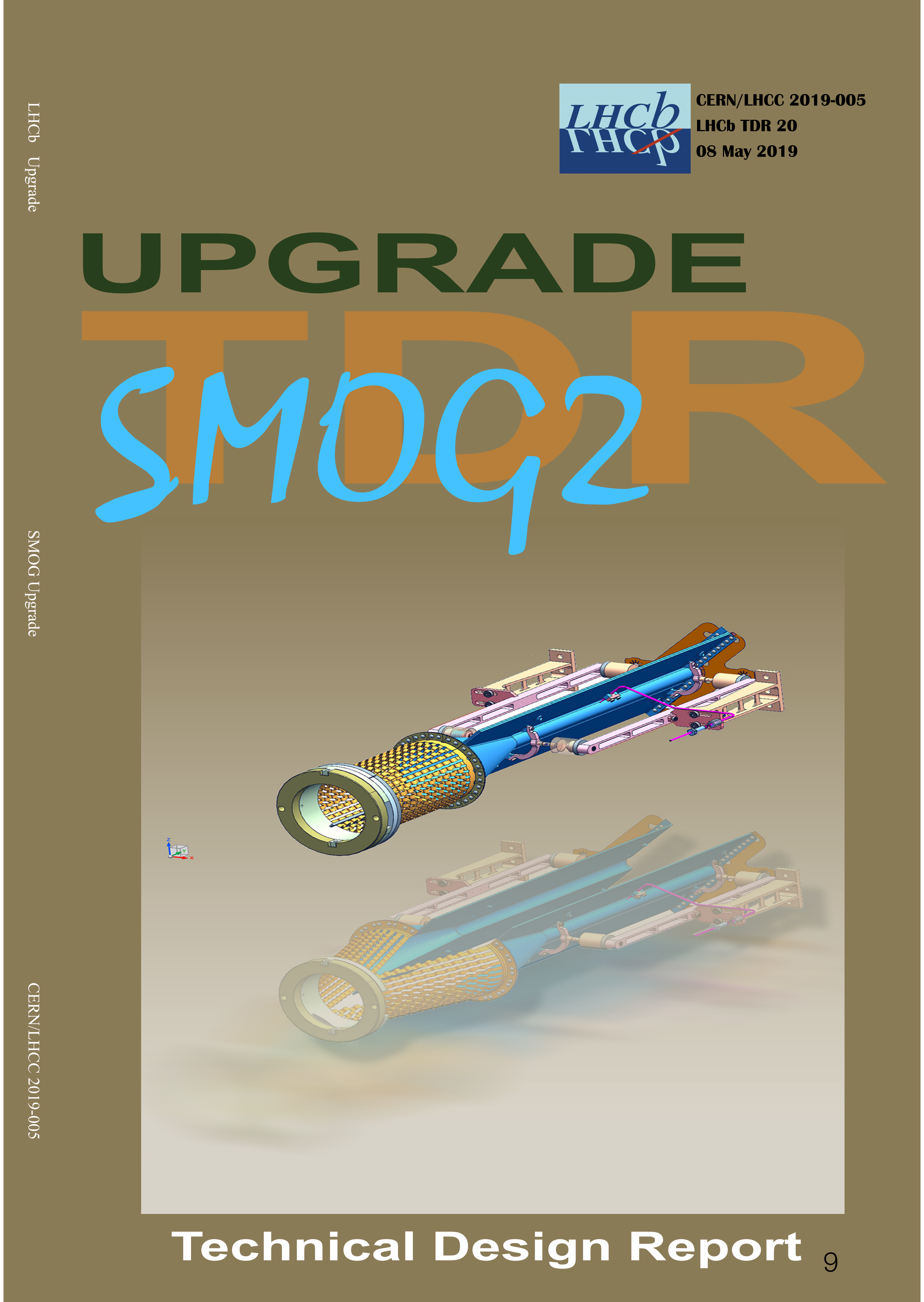


Internal
side view



openable
storage cell





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Installation scheduled in the second half of November 2019

LHCb-PUB-2018-015
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Physics opportunities with the fixed-target program of the LHCb experiment using an unpolarized gas target

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Abstract

The LHCb experiment pioneered fixed-target physics with LHC beams, thanks to the SMOG internal gas target. Collisions of proton and heavy-ion beams on targets with different nuclear size can be recorded at a centre-of-mass energy of $\sqrt{s_{\rm NN}} \sim 100$ GeV. This note summarizes the physics opportunities offered by the current fixed-target setup and its upgrade envisaged for the LHC Run 3. Unique measurements are being performed with Run 2 data, covering in particular heavy flavour production in nuclear collisions over a wide Feynman-x range and light particle production of particular interest to cosmic ray physics. The increase in luminosity and extension of the choice of target material, which are being pursued for Run 3, open many new possibilities which are reviewed in this document.

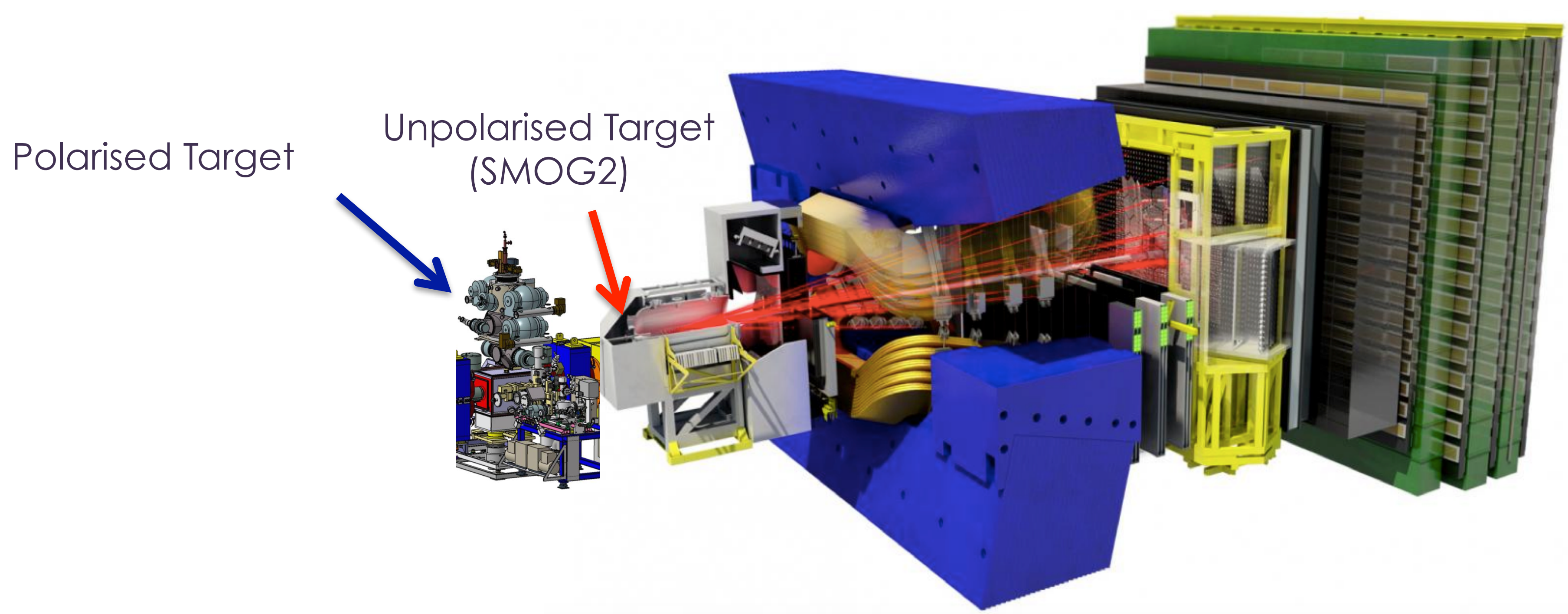
A unique opportunity for *a laboratory for QCD and astroparticle* in unexplored kinematic regions

SMOG

a pseudo-target in operation since **2015**

SMOG2

installation of a real storage cell in **2019** data taking foreseen from 2021



aiming to install during the LHC LS3 (2024-2026)

The LHCSpin Project

C. A. Aidala[1], A. Bacchetta[2,3], M. Boglione[4,5], G. Bozzi[2,3], V. Carassiti[6,7], M. Chiosso[4,5], R. Cimino[8], G. Ciullo[6,7], M. Contalbrigo[6,7], U. D'Alesio[9,10], P. Di Nezza[8], R. Engels[11], K. Grigoryev[11], D. Keller[12], P. Lenisa[6,7], S. Liuti[12], A. Metz[13], P.J. Mulders[14,15], F. Murgia[10], A. Nass[11], D. Panzieri[5,16], L. L. Pappalardo[6,7], B. Pasquini[2,3], C. Pisano[9,10], M. Radici[3], F. Rathmann[11], D. Reggiani[17], M. Schlegel[18], S. Scopetta[19,20], E. Steffens[21], A. Vasilyev[22]

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1 Introduction

LHCSpin aims at installing a **polarized gas target** in front of the LHCb spectrometer [1], bringing, for the first time, polarized physics to the LHC. The project will benefit from the experience achieved with the installation of an unpolarized gas target at LHCb during the LHC Long Shutdown 2 [2, 3]. LHCb will then become the first experiment simultaneously running in collider and fixed-target mode with polarized targets, opening a whole new range of explorations to its exceptional spectrometer.

Among the main advantages of a polarized gas target are the high polarization achievable (>80%), the absence of unpolarized materials in the target (no dilution), the possiblity to flip the nuclear spin state very rapidly (order of minutes) such to efficiently reduce systematic effects and a negligible impact on the beam lifetime.

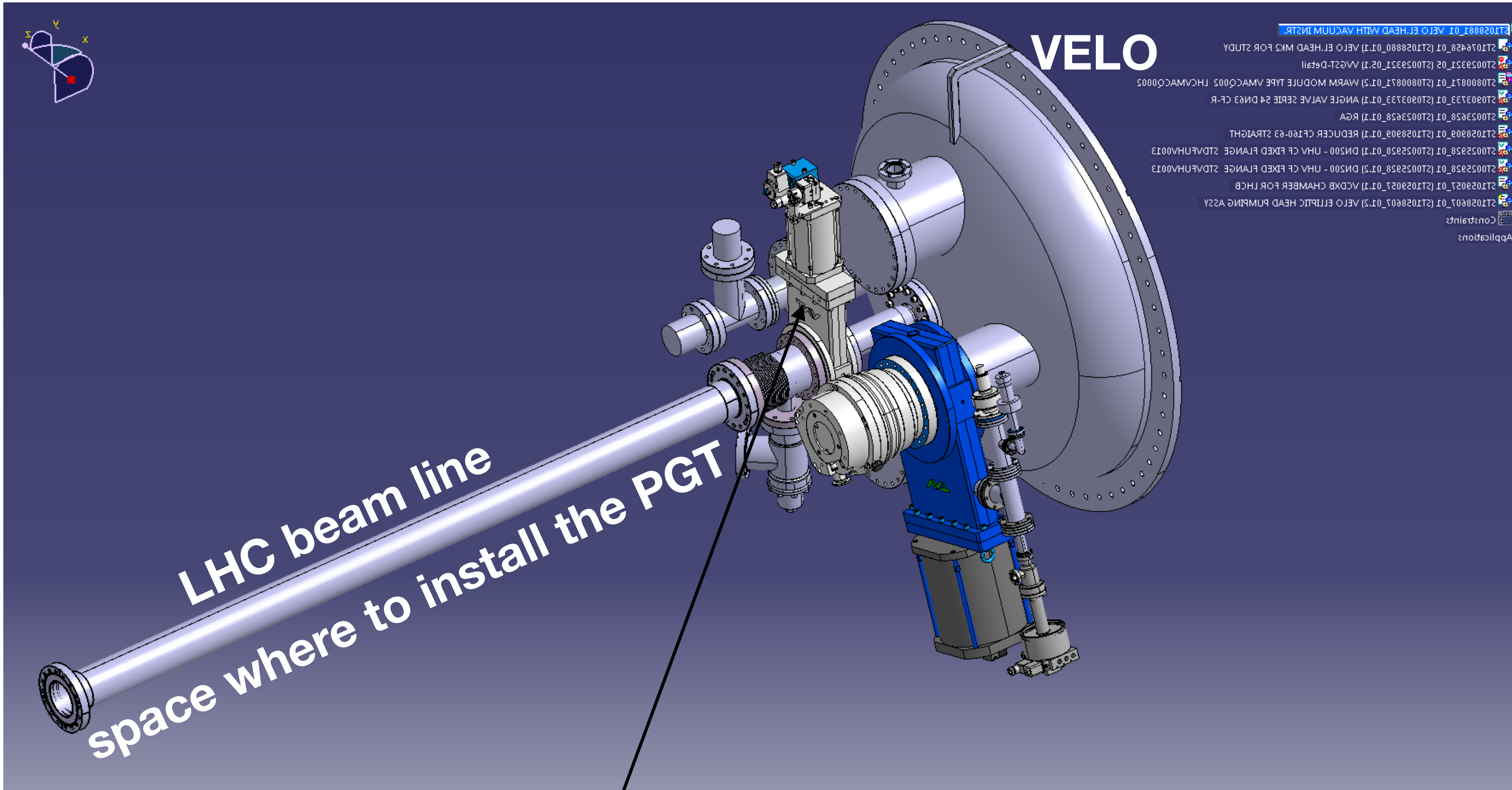
LHCSpin will offer a unique opportunity to probe polarized quark and gluon parton distributions in nucleons and nuclei, especially at **high x and intermediate Q^2**, where experimental data are still largely missing. Beside standard collinear parton distribution functions (PDFs), LHCSpin will make it possible to study multidimensional polarized parton distributions that depend also on parton transverse momentum (transverse-momentum-dependent PDFs, or TMDs).

The study of the multidimensional partonic structure of the nucleon, particularly including polarization effects, can test our knowledge of QCD at an unprecedented level of sophistication, both in the perturbative and nonperturbative regime. At the same time, an accurate knowledge of hadron structure is necessary for precision measurements of Standard Model (SM) observables and discovery of physics beyond the SM.

Due to the intricate nature of the strong interaction, it is indispensable to perform the widest possible suite of experimental measurements. In the time range covered by the next update of the ESPP, it will be ideal to have two new projects complementing each other: a new facility for polarized electron-proton collisions and a new facility for polarized proton-proton collisions. LHCSpin [4] stands out at the moment as the most promising candidate for the second type of project, going beyond the kinematic coverage and the accuracy of the existent experiments, especially on the heavy-quark sector.

The document comprises two main parts, describing the physics case and the hardware implementation, respectively.

… a little first step towards the PGT



Separation valve to be installed at the end of 2019
This will isolate the VELO vessel in order to operate upstream without venting the system

Main items to develop in the next years

- Physics case and simulations
- Vacuum chamber (defines the needed space)
- Openable cell
- Coating (LHC requirements + depolarisation issues)
- Transverse magnet
- Atomic Beam Source and diagnostic
- Additional Tracker
- Funds

Conclusions

- LHCb, one of the most advanced HEP experiments, is perfectly suitable to host a fixed-target system with very specific capabilities and unique acceptance at a hadron collider
- LHCb is already developing a lively and fast growing fixed-target physics program
- Besides the unique physics output, all this constitutes a precious R&D for a polarised fixed-target program

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- Besides the unique physics output, all this constitutes a precious R&D for a polarised fixed-target program

LHCspin is a very ambitious project, but feasible in a realistic time schedule