‘The strong interaction at the frontier of knowledge: fundamental research and applications’

WP20: Fixed-target experiments at the LHC (FTE@LHC)

Cynthia Hadjidakis

IPN Orsay

Spokespersons: Pasquale di Nezza and C.H.

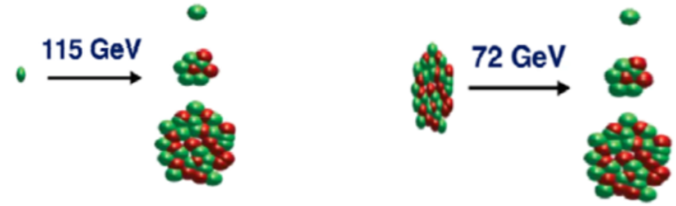
STRONG-2020 Kick-off meeting

October 23-25, 2019

Fixed-target experiments at the LHC

Energy range

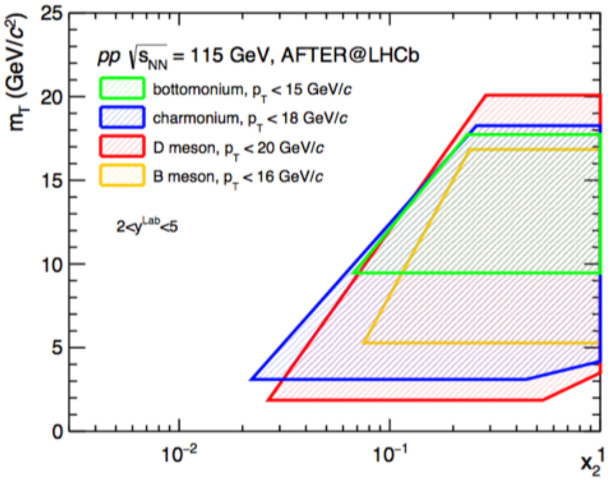
- 7 TeV proton / 2.76 A TeV Pb beam on a fixed target

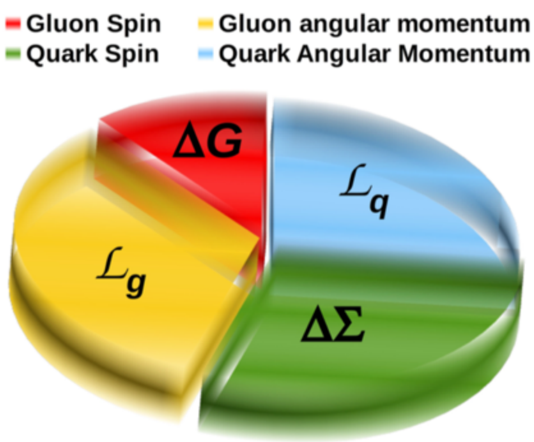


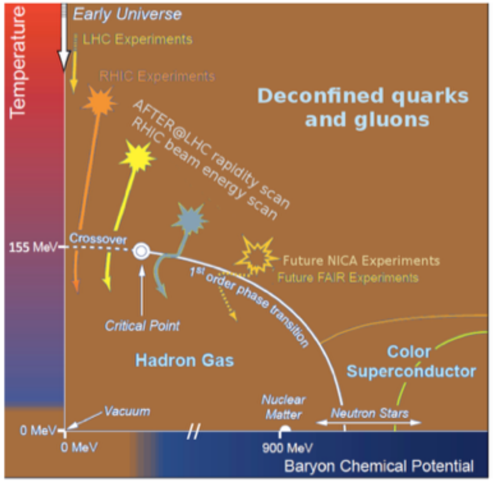
Physics motivations

AFTER@LHC study group arxiv:1807.00603

- Advance our understanding of the high-x gluon, antiquark and heavy-quark content in the nucleon and nucleus and its connection to astroparticles
- Unravel the spin of the nucleon: dynamics and spin distributions of quarks and gluons inside (un)polarised nucleons
- Study the quark-gluon plasma between SPS and RHIC energies towards large rapidity







This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

Fixed-target experiments at the LHC

- WP objectives:
  - Investigation and implementation of high-luminosity fixed-target experiments with ALICE and LHCb detectors
  - Develop new theoretical ideas (rare events, large rapidities, …)
  - Quantify phenomenological opportunities with ALICE and LHCb in fixed-target modes
  - Benchmark selected observables using realistic simulations

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Fixed Target Experiments at the LHC

- Three tasks defined:
  - Task 1: Feasibility studies in ALICE (gas and solid target)
  - Task 2: Gas-target development in LHCb
  - Task 3: Phenomenological and theoretical studies

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JRA2 FTE@LHC : Update on progress

- Many progresses in two years
  - AFTER@LHC study group review
  - PBC-QCD WG report
  - PBC-FT WG report
  - SMOG2 project (LHCb)
  - ESPP proposals:
    - Support for a fixed-target at LHC
    - ALICE-FT proposal
    - LHCSpin proposal

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ALICE-FT progress

Possible fixed-target systems ***CERN-PBC-Note-2019***

- beam splitting with bent crystal and solid target in the beam pipe
- gas target
- large luminosities expected: up to ~40/pb with proton and ~8/nb with lead beam

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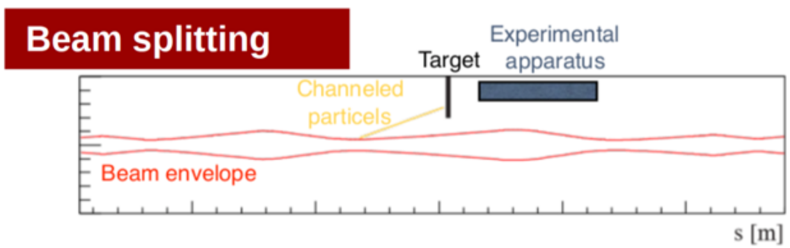
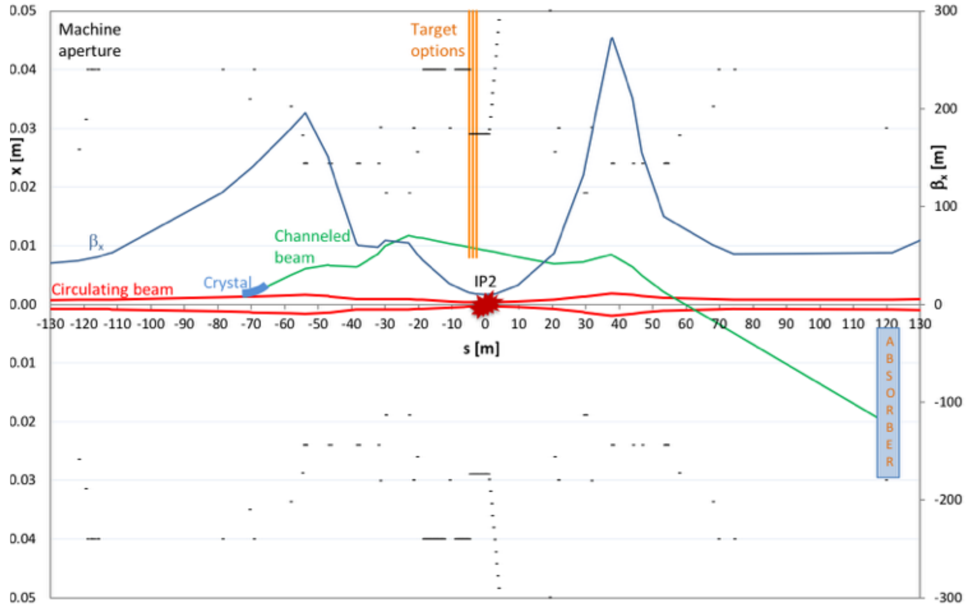
Proposed layout for ALICE with bent crystal (UA9 Collaboration)

– Studies needed for LHC collimation operation and machine protection: ongoing





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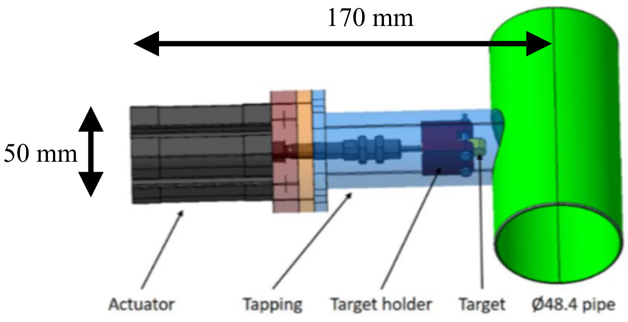
ALICE-FT progress

Solid target setup

- Pneumatic motion system with two target positions (IN and OUT of the beam pipe)
- Various target types possible: from Be to W
- Target length from ~100 um to 1 cm (depending on beam flux on target)



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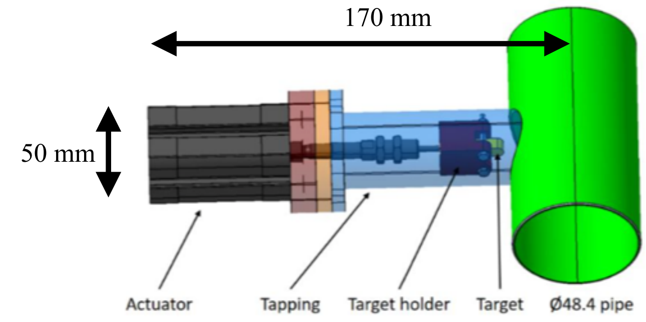
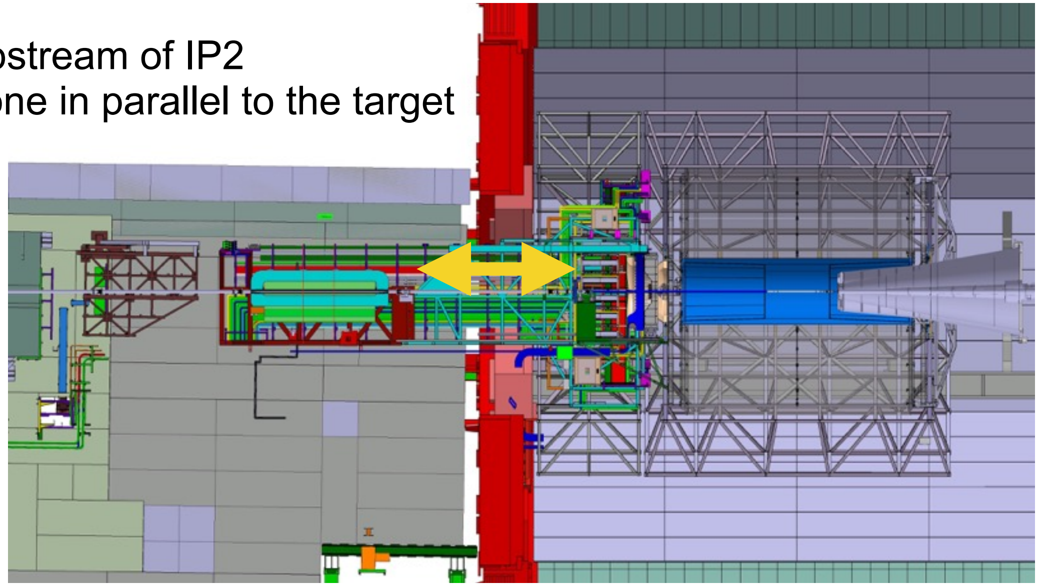


Integration

- Possible space defined: ~8.4 to 4.8 m upstream of IP2
- Impedance and vacuum studies to be done in parallel to the target system design optimization
- Under discussion in ALICE



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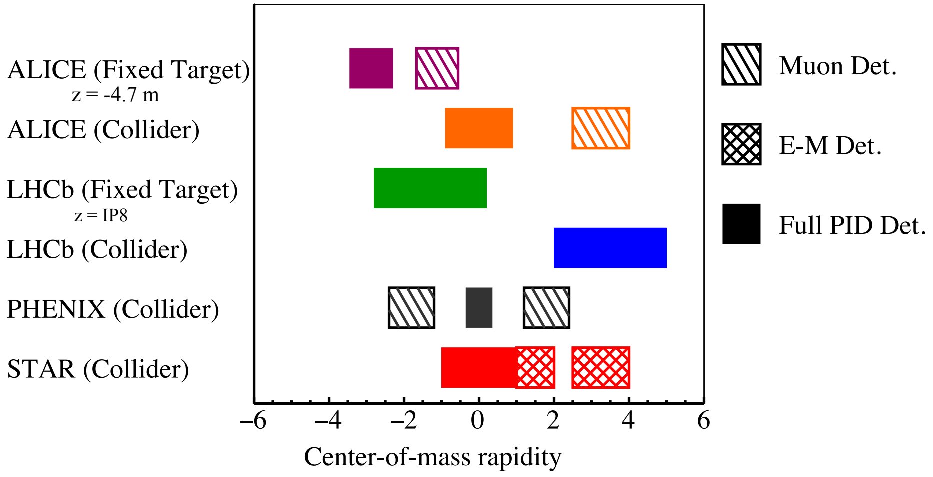
ALICE-FT progress

ALICE detectors in fixed target mode: rapidity range close to the beam rapidity (y_{beam} = 4.8/4.2 in pA/PbA) with full PID



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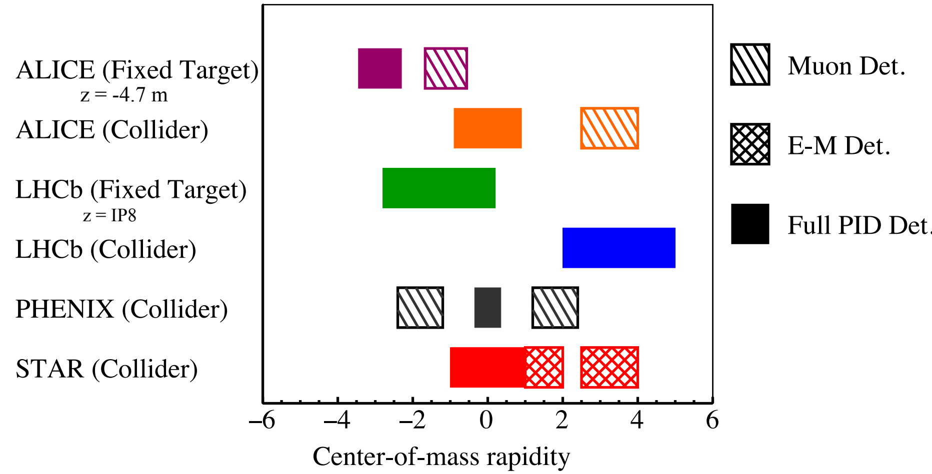

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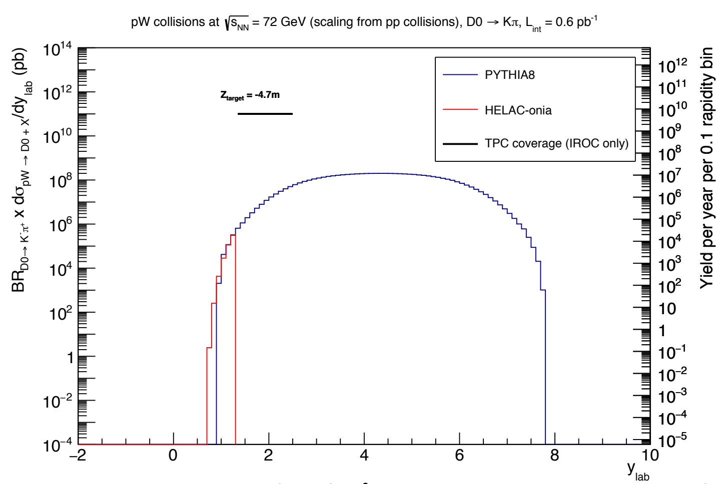
Example of probes

- 10^5 D^0 mesons in p+W per 0.1 rapidity unit at y_{lab}~1.5: access to large *x* gluons in the nucleus
- In Pb+W: investigate the QGP in large rapidity region with identified particles



Yearly luminosity with beam flux of 10^6 p/s on solid target with thickness of 1 cm

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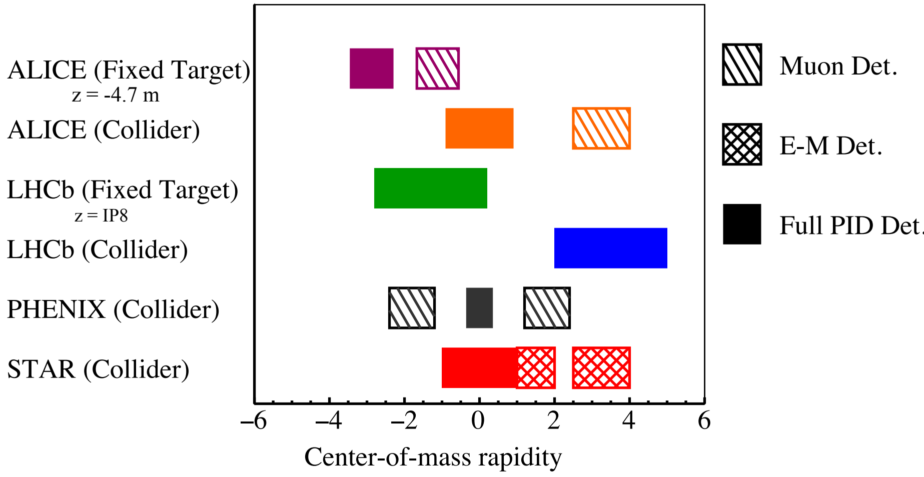
ALICE-FT progress



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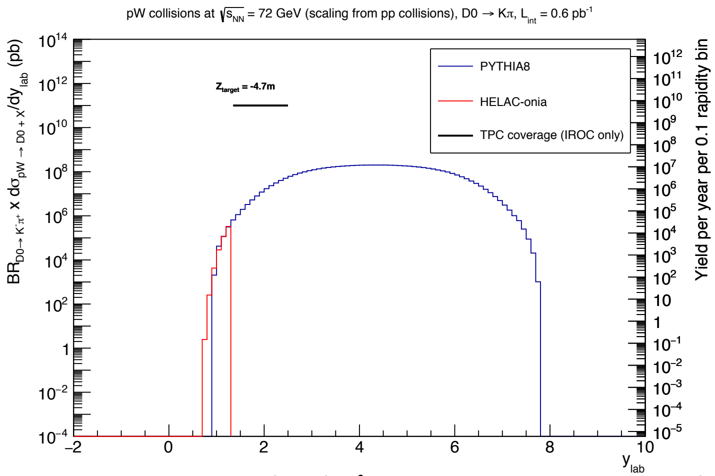
Complementary to LHCb-FT

- Central barrel: access to identified low momentum particles at backward rapidity
- Can reconstruct tracks in high-multiplicity environment
- Could potentially devote proton beam time to fixed-target physics



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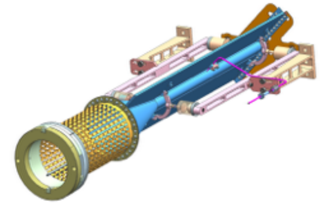
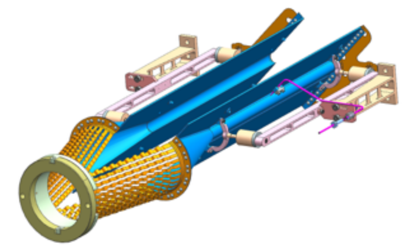
LHCb-FT progress

The R&D of the unpolarised storage cell (SMOG2) is in its final stage:
-Drawings completed
-Impedance simulations, for beam stability, approved by LHC
-Coating process, for SEY emission, defined (amorphous Carbon)
-Stress and thermic test performed for an working time equivalent >15 yr
-Beam Induced Background simulation performed, no additional background
-Beam Aperture simulation performed, safety factor 1.5 mm
-Alignment and mounting procedure defined



Cell in closed configuration



Cell in open configuration

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

Approved !!!

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 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, 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	P. Collier (on behalf of LMC) (LHCb Technical Coordinator)

LHCb

CERN-PBC-Notes-2018-007
Version 2.1

SMOG2 Technical Proposal

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C. Boscolo Meneguolo[1], G. Bregliozzi[1], R. Bruce[1], P.M. Gebolis[1], G. Iadarola[1],
L. Mether[1], G. Pigny[1], B.K. Popovic[1], B. Salvant[1], C. Vollinger[1], C. Zannini[1]

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[4] *Physikalisches Institut, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany*

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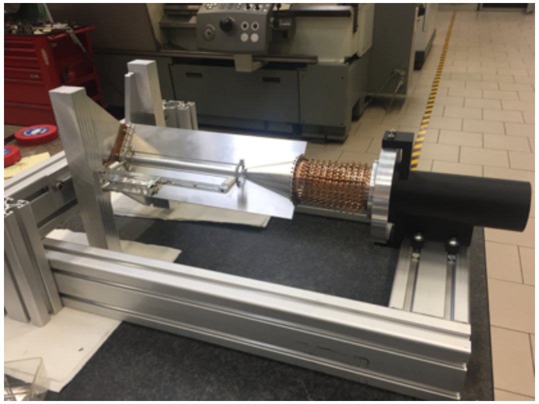
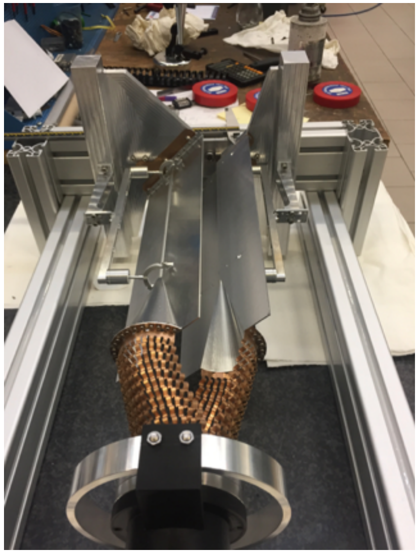
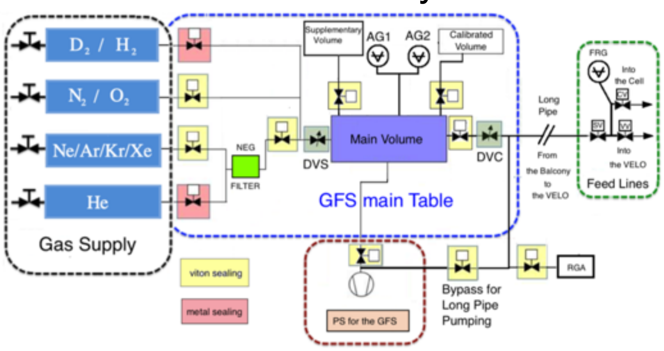
LHCb-FT progress

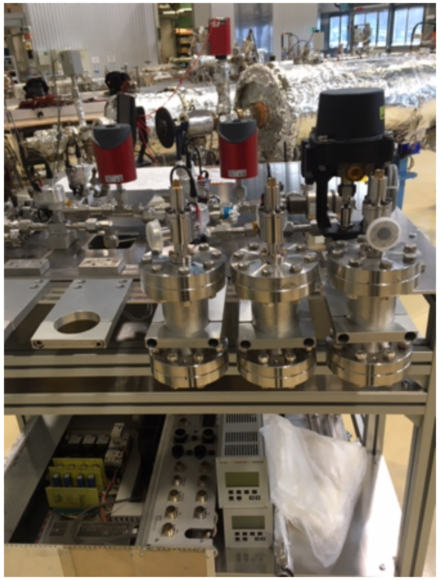
Storage cell prototypes





Gas Feed System

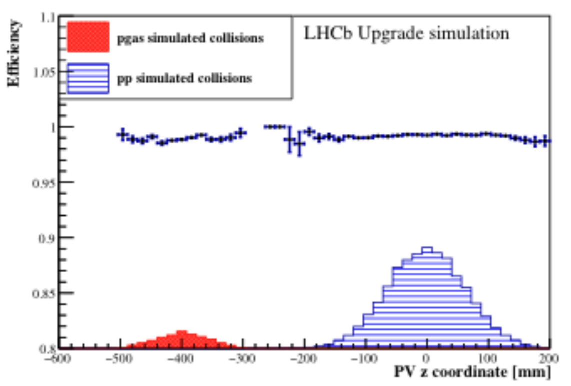




GFS under construction

Trigger and track reconstruction implementation into LHCb system, in progress:

VELO tracking efficiency



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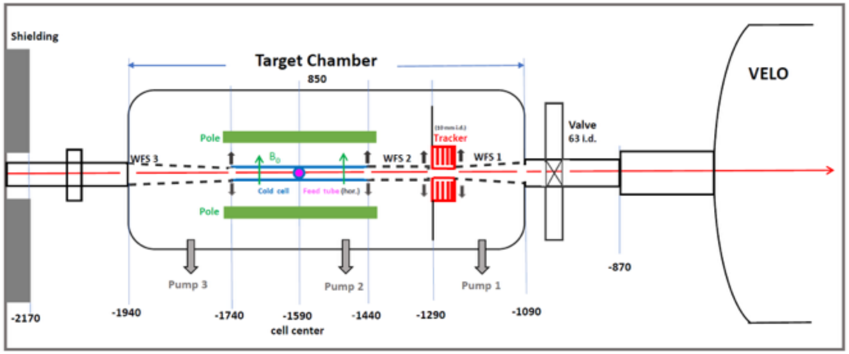
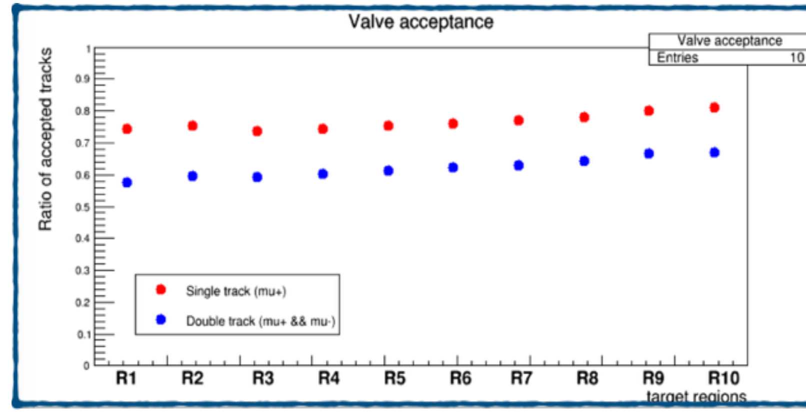
LHCb-FT progress

Several R&D studies already extended to the polarised case (LHCSpin project)

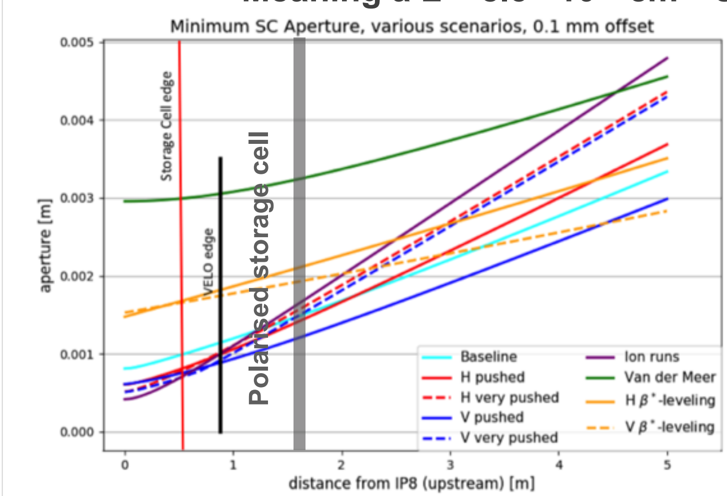


Geometrical acceptance x tracks

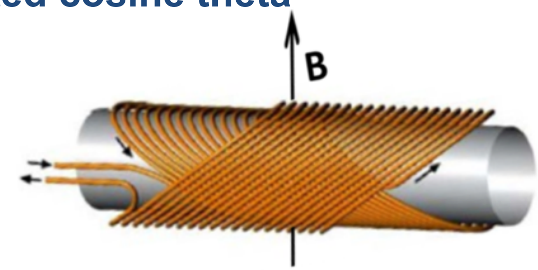


LHC dynamic aperture, with a cell with R = 0.5 cm has still a good safe factor. This will give a target density $\theta = 1.2 \cdot 10^{14}$ cm^{-2}

Meaning a $L = 8.3 \cdot 10^{32}$ cm^{-2} s^{-1}



A possible transverse magnet under study: Canted cosine theta



R&D in progress:
- Impedance
- Electron cloud
- Dissociation and coating
- Beam Induced Depolarization (done, ok)
- Compact ABS and diagnostic

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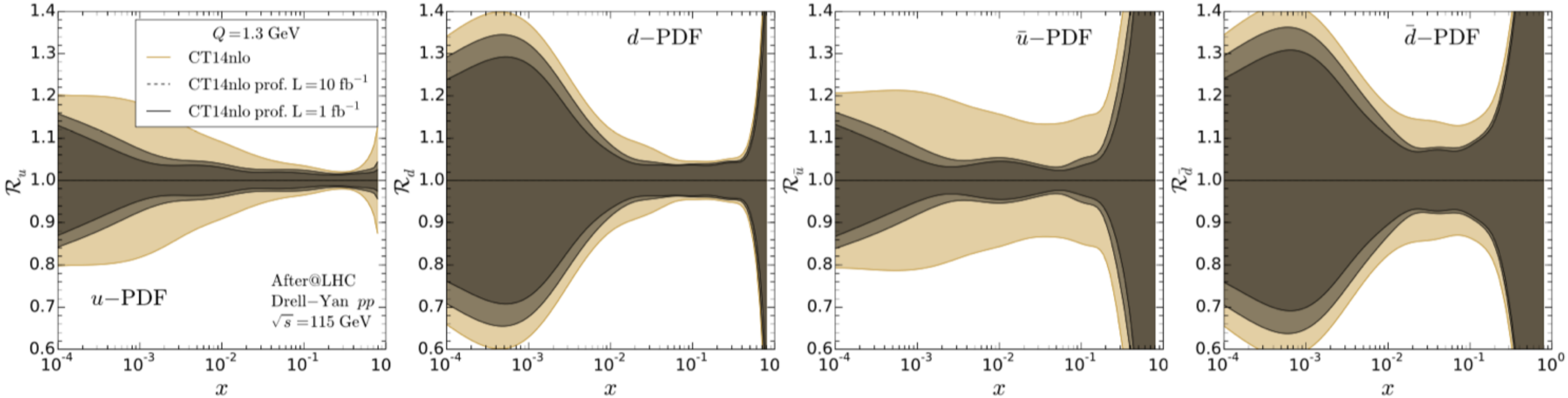
Pheno progress: a selection

AFTER@LHC study group review

Drell-Yan process to probe the nucleon structure towards large-*x*

LHCb-like detector



Substantial reduction of pdfs uncertainties for up and down quarks from x=1e-4 to 1
Using nuclear target leads also to a reduction of uncertainties for npdfs (not shown)

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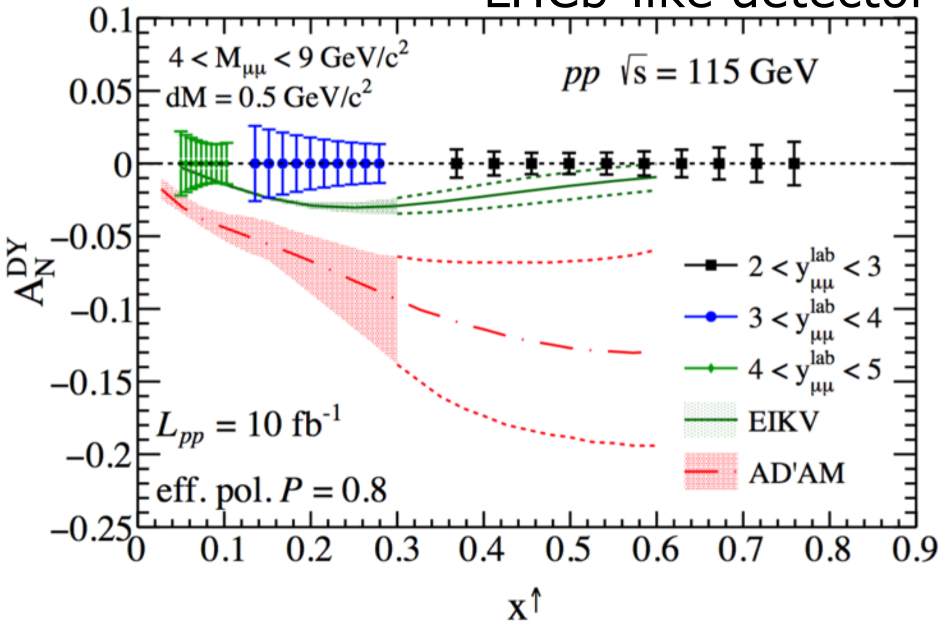
Pheno progress: a selection

AFTER@LHC study group review

Drell-Yan process to probe the spin content of the nucleon

LHCb-like detector



Sign change with SIDIS predicted

No available data for constraining models at $x_{target} > 0.3$

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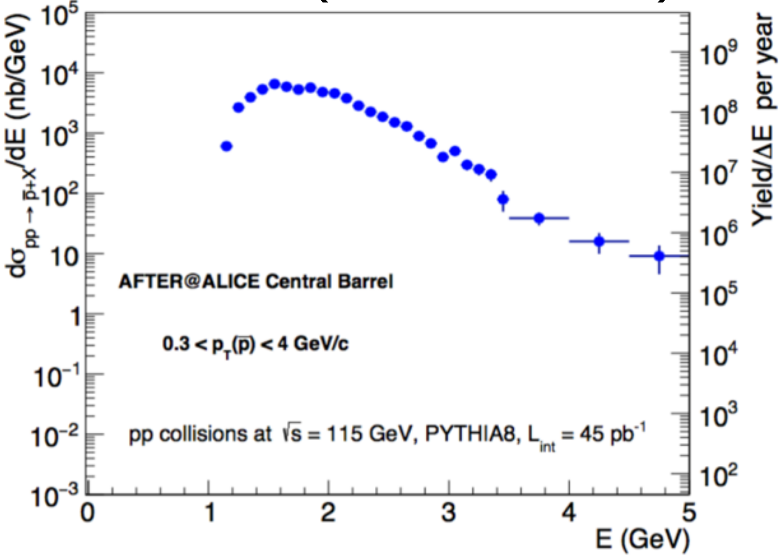
Pheno progress: a selection

AFTER@LHC study group review

Low momentum antiproton production to study the high-energy antiproton production in cosmic rays (inverse kinematics)

ALICE-like (central barrel) detector



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JRA2 FTE@LHC: Deliverables

- Deliverables due for Reporting Period 1 (18 months, June 2019-November 2020): D20.2 and D20.4 are due M18 (November 2020)

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D20.2	Peer-reviewed paper. Design of gas-jet implementation in ALICE	36 - WUT	Report	Public	18
D20.4	Internal report Installation of the unpolarised gas target into LHCb	30 - INFN	Report	Confidential, only for members of the consortium (including the Commission Services)	18

- D20.2
    - ALICE detector performance study with a shifted vertex (common to solid target option)
    - Gas-target design and integration studies will follow
    - Paper on the gas target design expected End 2020

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- D20.4 co-leadership with FZJ
  - Final stage of SMOG2 R&D, approved by LHC (July 2019)
  - Installation foreseen in LS2 (2019 or 2020)

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JRA2 FTE@LHC: Milestones

- MS35 has to be achieved M15

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS35	Code for full simulation in LHCb	1 - CNRS	15	Software released

- MS35
- In progress with SMOG2 (see slides 10)

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JRA2 FTE@LHC: Manpower

- PhD Santiago (1.5 year): start in Nov. 2019 (LHCb + pheno)
- PhD Ferrara (1.5 year): start in Nov. 2019 (LHCb)
- Postdoc WUT (2 years): start in Jan. 2020 (ALICE)
- Postdoc Lisbon (1 year): expected in Jan. 2020 (pheno)
- Postdoc IPNO (1 year): expected in Feb. 2020 (ALICE)
- Postdoc LNF (2 years): expected in March 2020 (LHCb)
- Postdoc NCBJ (1.5 year): expected in Early 2020 (pheno)

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Next

- CERN workshop 7-8 November 2019: FTE@LHC and NLOAccess joint kick-off meeting

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back-up

Why a fixed-target experiment at the LHC?

1. **The high-*x* frontier: advance our understanding of the high-*x* gluon, antiquark and heavy-quark content in the nucleon and nucleus**
    - Structure of nucleon and nuclei at high-x are poorly known ($x > 0.5$)
    - Some longstanding puzzles:
        - Proton charm content is important per se but also for high-energy neutrino and cosmic-ray physics
        - EMC effect is an open problem: studying a possible gluon EMC effect is essential
    - Search and study rare proton fluctuation where one gluon carries most of the proton momentum: test QCD in a new limit never explored

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2. **The nucleon spin and the transverse dynamics of partons**
    - Missing knowledge on the contribution of the quark and gluon orbital angular momentum to the proton spin
    - Access information on the orbital motion of partons bound inside hadrons via Single Spin Asymmetries: Sivers effect with transversally polarised target
    - Test the factorization formalism of Transverse Momentum Dependent functions: sign change of A_N between semi-inclusive DIS and Drell-Yan
    - Determination of linearly polarised gluons in an unpolarised proton (Boer-Mulders effect)

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3. **The Quark Gluon Plasma**
    - Explore the longitudinal expansion of the QGP with new and rare probes (*e.g.* excited quarkonia, identified soft and hard probes in the target rapidity region)
    - Test the factorisation of cold nuclear effects from p+A to A+B collisions by using Drell-Yan
    - Test the formation of azimuthal asymmetries (v_2) at large rapidities: hydrodynamic origin vs initial-state radiation

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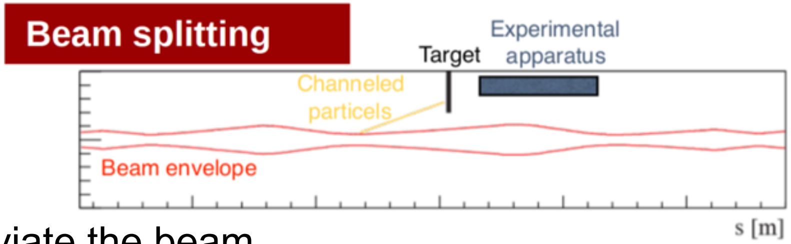
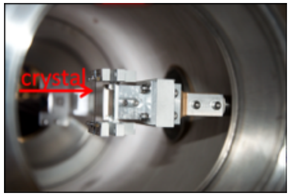
Bent crystal



Bent crystals studied by UA9

- For collimation purpose at the LHC
- Beam splitting for fixed-target experiment:
  - Crystal located ~100 m upstream the target to deviate the beam halo
  - Solid target internal to the beam pipe close to an existing experimental apparatus
  - Absorber ~100 m downstream the detector for non-interacting particles



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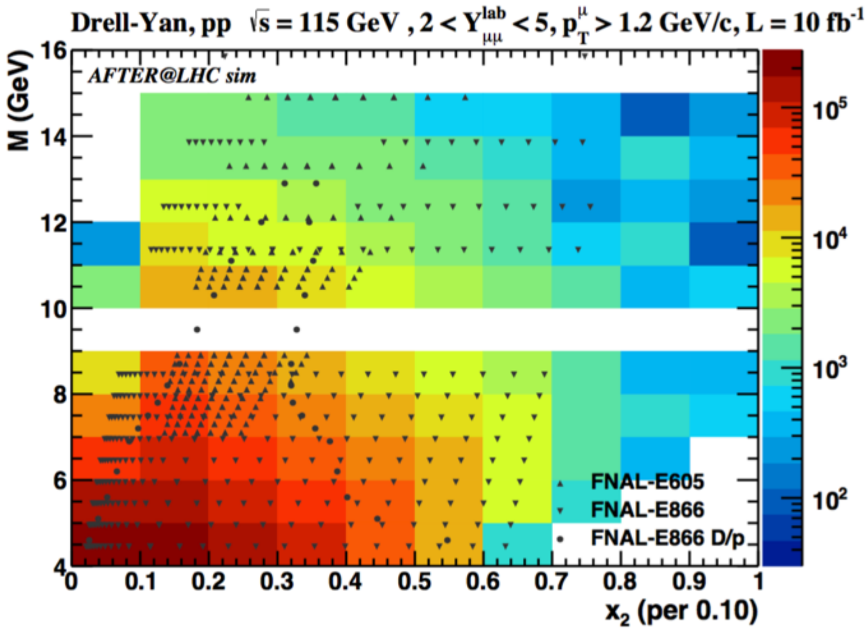
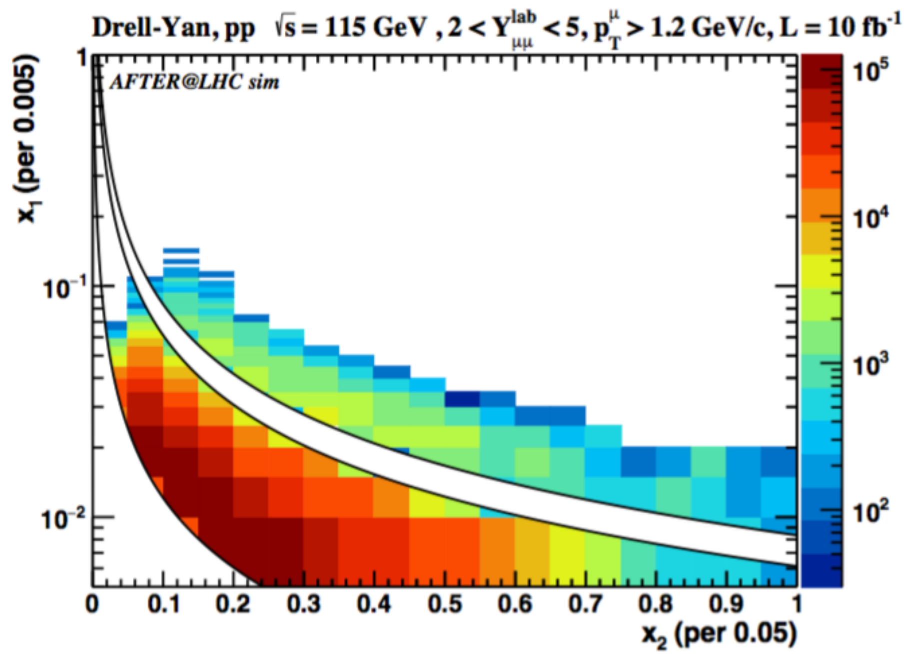
Nucleon structure

LHCb-like detector





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