Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

A fixed-target program in the ALICE experiment

Recent progress

Daniel Kikoła for the ALICE-FT study group

Physics Beyond Colliders Annual Workshop, 8th of November 2022, CERN

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STRONG-2020

Motivations for a Fixed-Target experiment at ALICE

- Access to high negative Feynman x_F domain ($|x_F| = |p_z|/p_{z\,max} \rightarrow 1$) in a **target** via (far) backward rapidity
- Probing high-x gluon, antiquark and heavy-quark content in the nucleon and nucleus
- Provide inputs for astrophysics (charm and antiproton production)
- Study of nuclear-matter properties in heavy-ion collisions (HIC) at $\sqrt{s_{NN}} \approx 72$ GeV over a wide rapidity range

More on physics motivations:

- S. J. Brodsky et al., **Phys. Rept. 522 , 239 (2013), 1202.6585**
- **Physics opportunities for a fixed-target programme in the ALICE experiment, https://cds.cern.ch/record/2671944?ln=en**
- C.Hadjidakis et al., **A fixed-target programme at the LHC: Physics case and projected performances for heavy-ion, hadron, spin and astroparticle studies, Phys.Rept. 911 (2021) 1-83, e-Print: 1807.00603 [hep-ex]**

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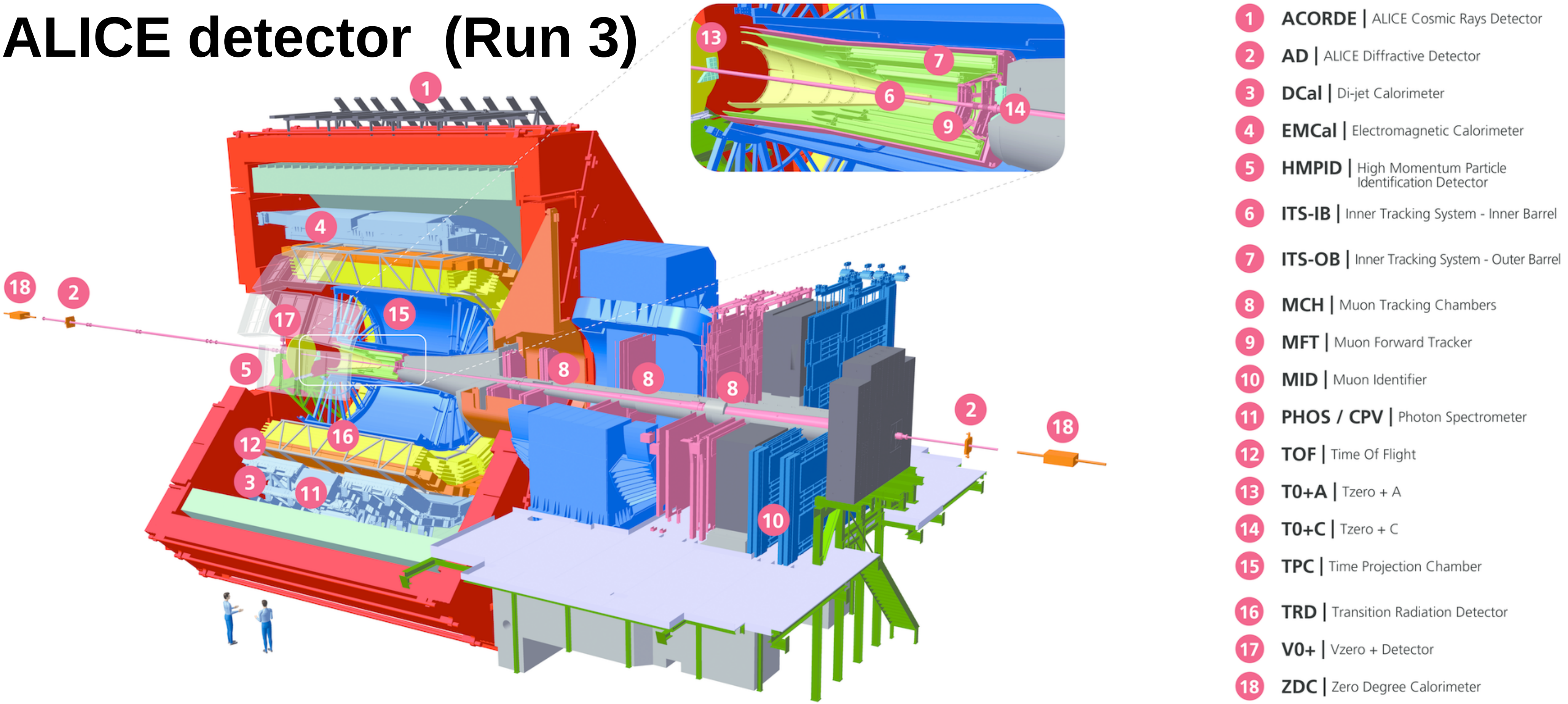
ALICE detector (Run 3)



TPC: $|\eta^{lab}| < 0.9$, **Muon Detector:** $2.5 < \eta^{lab} < 4$

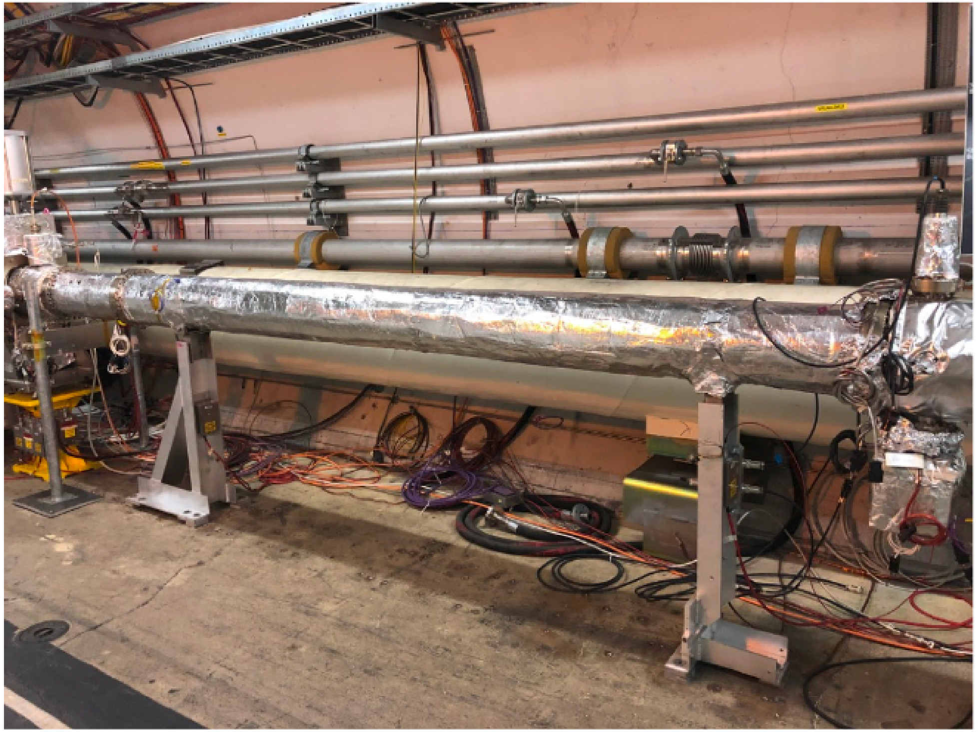
Run 3 and 4: New Inner Silicon Tracker, A Muon Forward Tracker

Continuous readout(*): 50 kHz in Pb-Pb, 200 kHz up to 1 MHz in pp and p-A

(*)The feasible rate also depends on the detector occupancy in a fixed-target mode

Fixed-target implementation

- **Internal solid target + a bent crystal:** a bent crystal installed in front of the LHC Interaction Point 2 deviates the beam halo onto a solid target
- Proposed crystal location: z = 3259 m



M. Patecki, JACoW HB2021 (2022) 146-150 and
Fixed-target experiments at LHC - Strong2020 workshop

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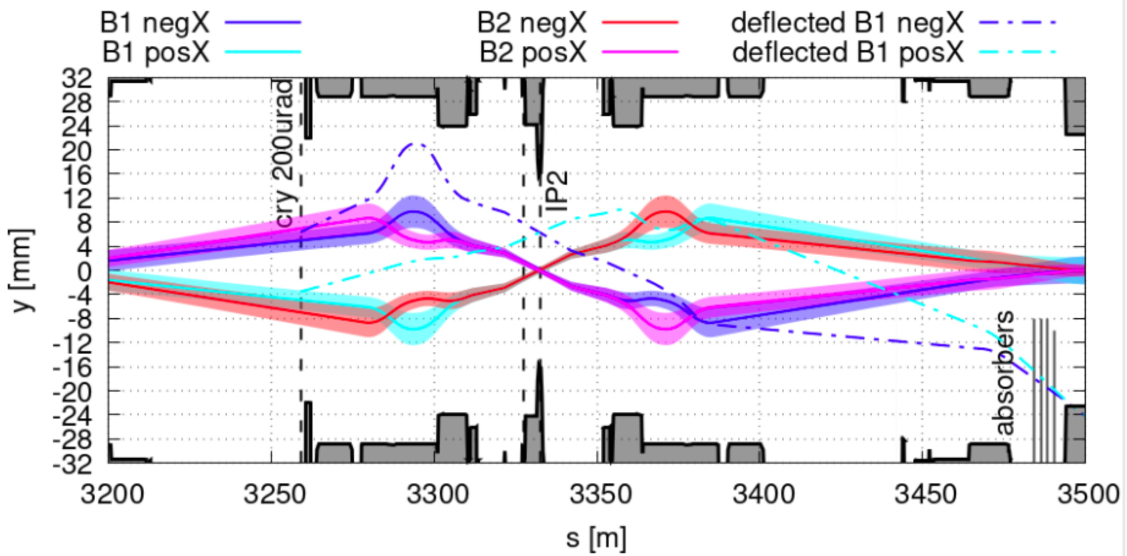
- Proposed crystal location: z = 3259 m
- Expected Proton-on-Target (PoT) rate in Run 4: **10^6 p/s** as a minimal limit in parasitic mode, equivalent to (for 1 cm target length):
  - L = **1.1/pb/year** in pC
  - L = **0.6/pb/year** in pTi and pW



- Ongoing studies to increase PoT and optimize absorber location
- Lead beam studies about to start

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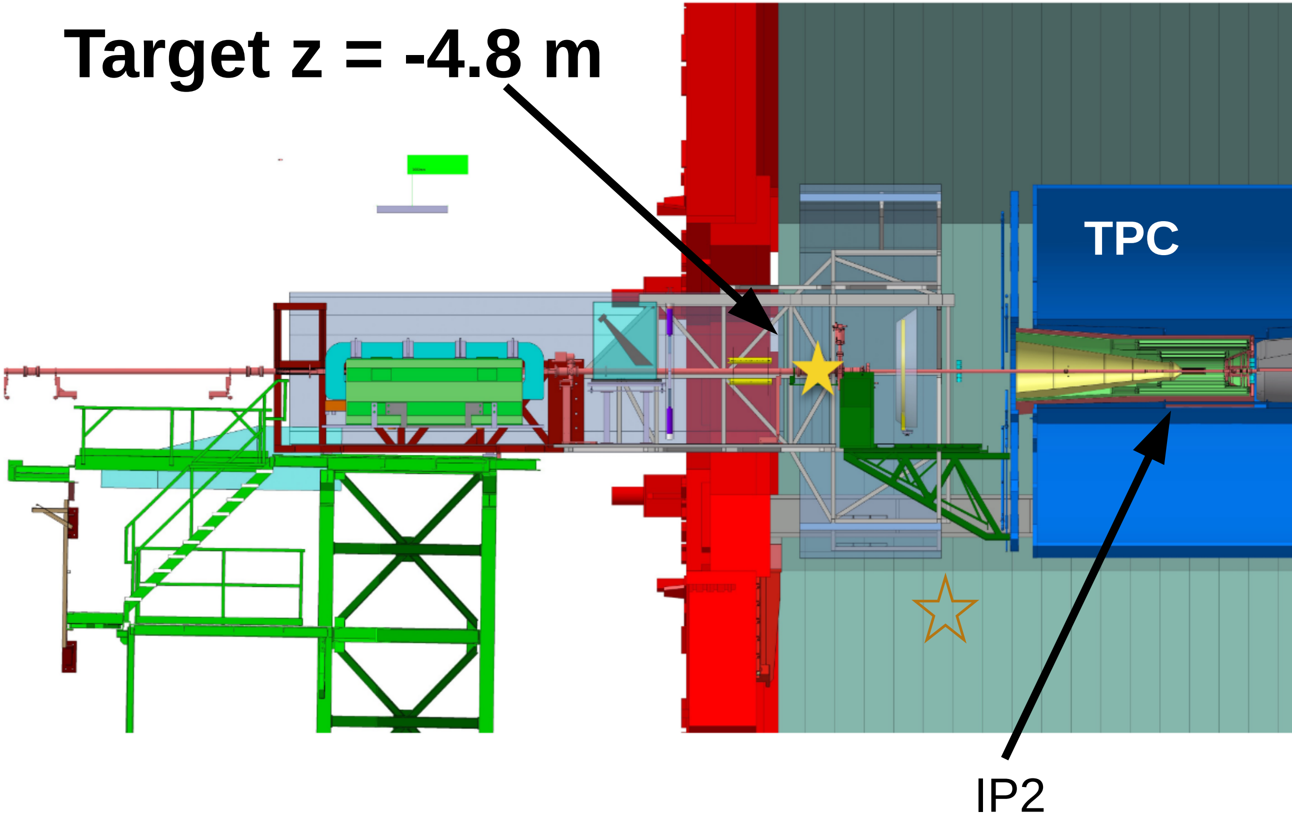
Target location and integration

- Goal: implementation as close to IP2 as possible preferable for the physics case but no space between FIT and IP2 or between z ~ -4.7 m and FIT
- z~-4.8 m from IP2 seems feasible
- Other constraints: possible ITS movements during EYETS, mini-frame structure, FoCal



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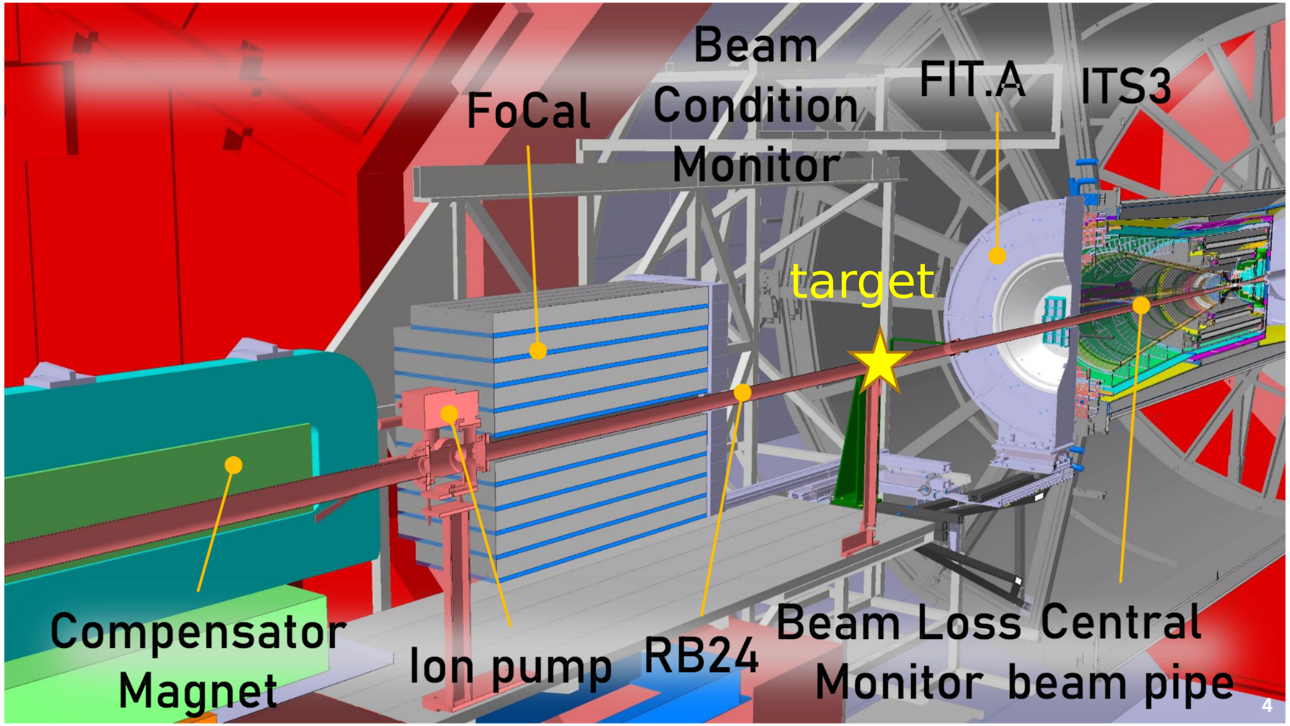
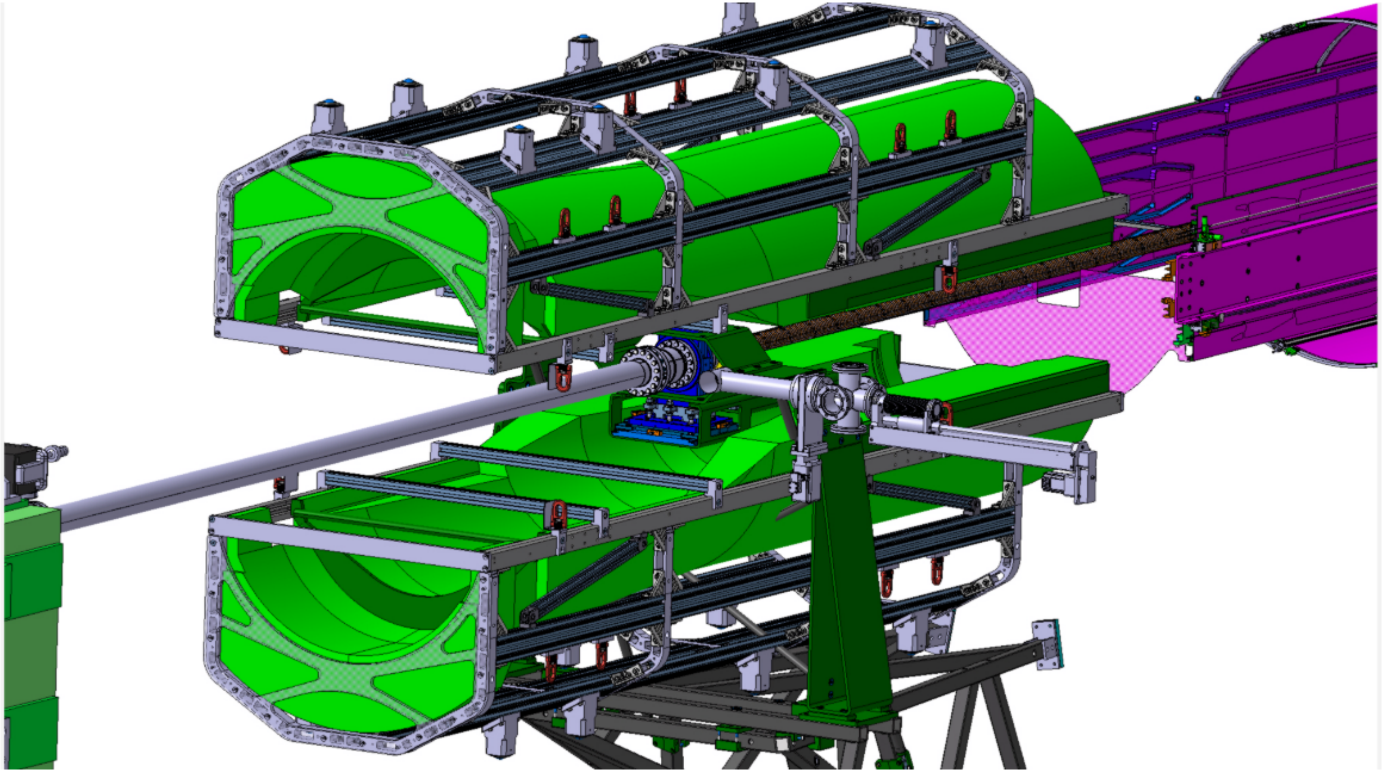
ALICE (A-side) in Run4



Target integration



ITS support in open position at z ~-5m, to allow for interventions on the ITS during EYETS

Integration with so-called miniframe (ITS support) seems feasible with target system positioned in the horizontal plane

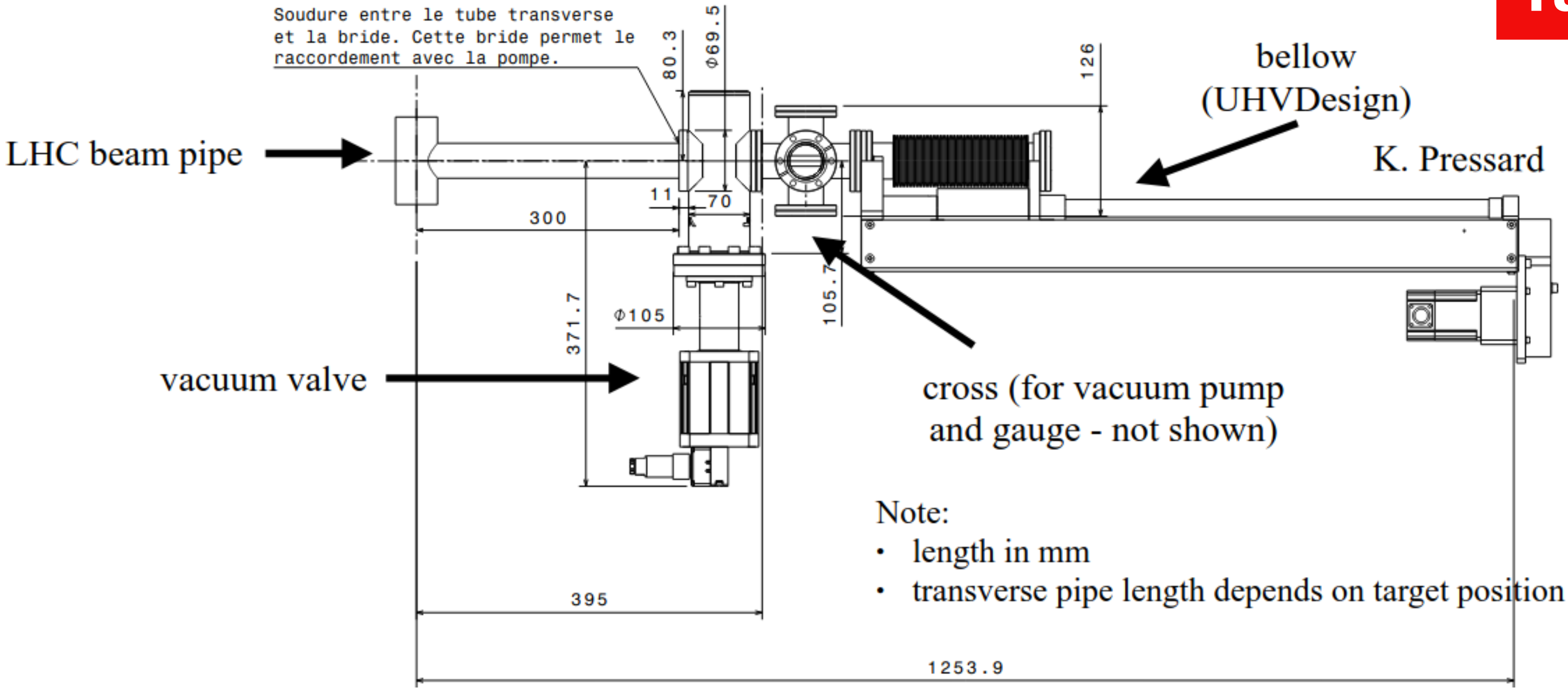
Target design

Target system

- step motor to achieve a better movement resolution
- retractable target with linear motion
- target actuator lies in a vacuum chamber and moves thanks to a step motor that compresses a bellow
- vacuum valve closed when target is fully retracted
- target, crosses and bellow can be removed during EYETS

One valve solution

- vacuum related task must be performed in the cavern
- pumps switch on before opening the valve
- moving speed: 10 mm/s
- accuracy: 10 µm



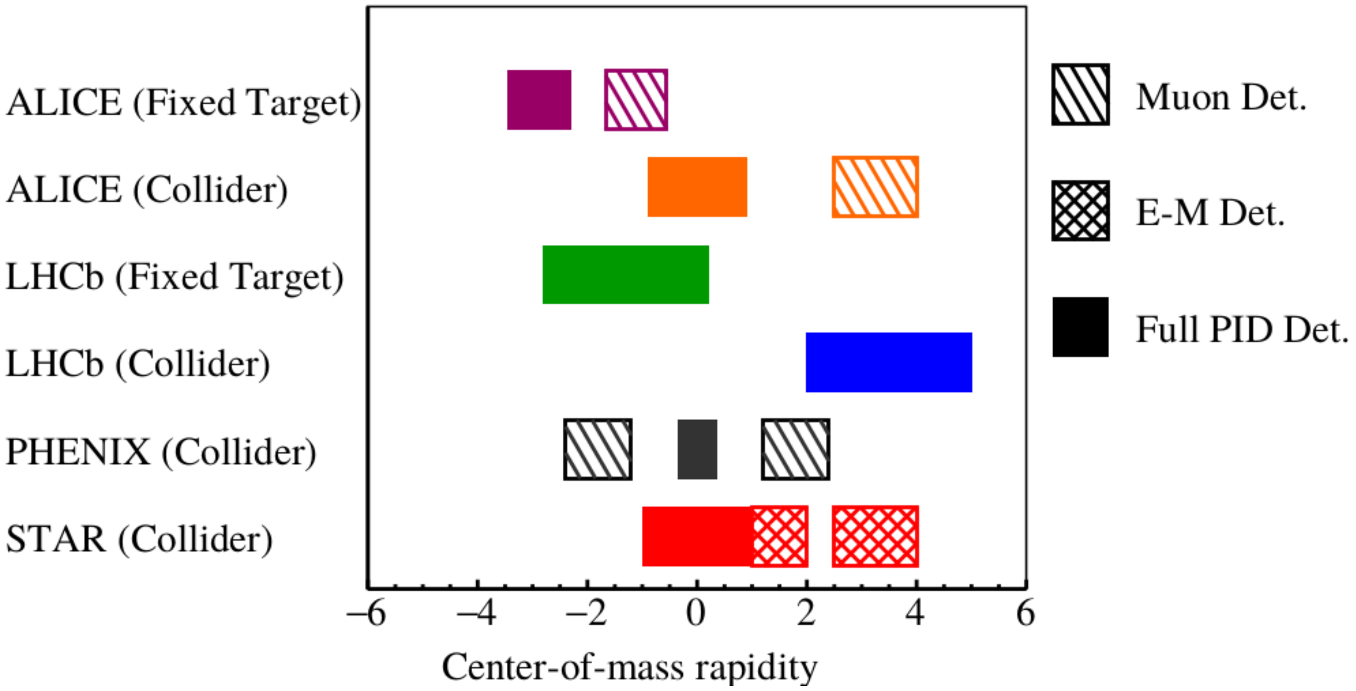
Note:
- length in mm
- transverse pipe length depends on target position

Recent feasibility studies

Rapidity coverage of ALICE FT vs other experiments

ALICE Fixed Target at
z_{target} = -4.7 m

For D meson:
Reach in x up to **0.74**
with the ALICE TPC

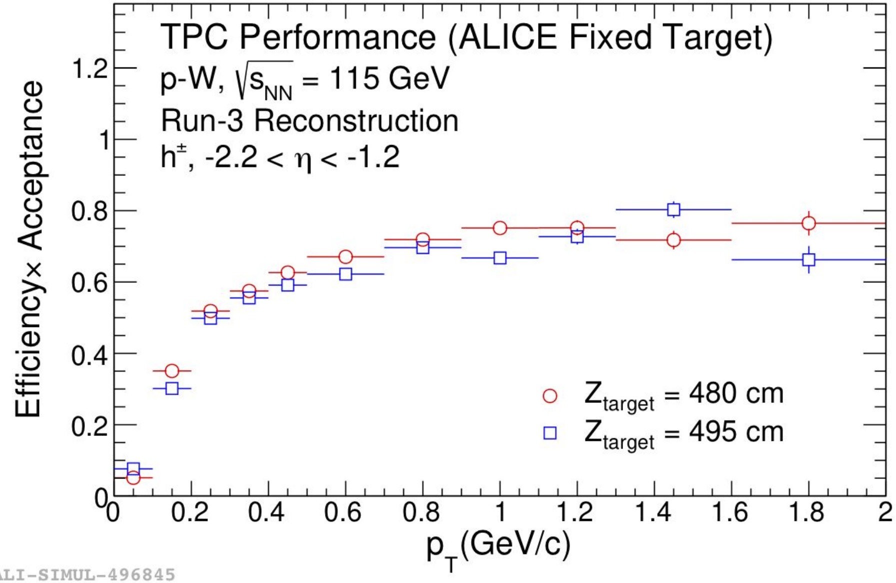


ALICE Central Barrel (CB) in a fixed-target (FT) mode → access to **backward rapidity and high negative x_F domain**

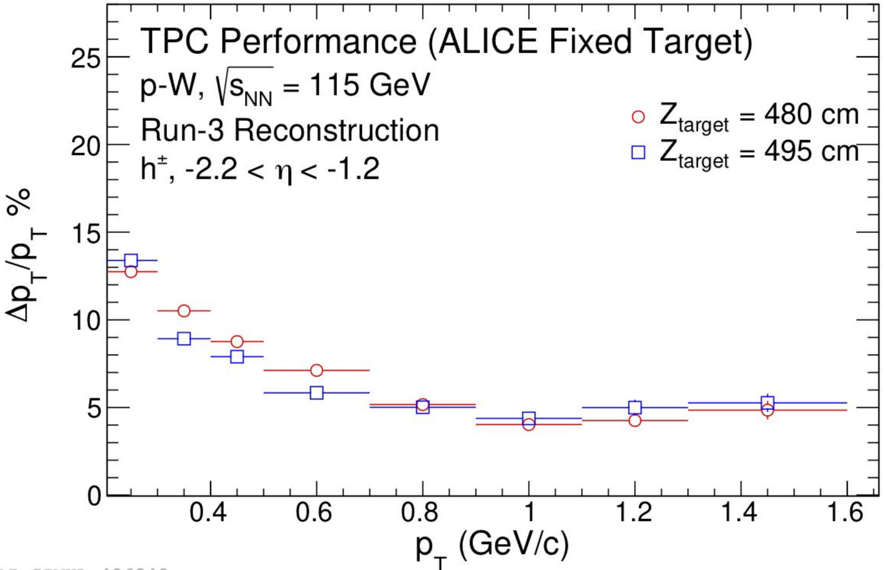
Extended rapidity coverage helps constraining **total charm production cross section** → input for **astrophysics** and **models of heavy-ion collisions**

ALICE detector performance in a fixed-target mode

- Time Projection Chamber (TPC) tracking and event reconstruction
- The TPC response for charged particles are estimated from O2 Simulation study with Run-3 detector setup.
- The efficiency and p_T resolution are sufficient for D^0 and Λ studies without additional vertex detector

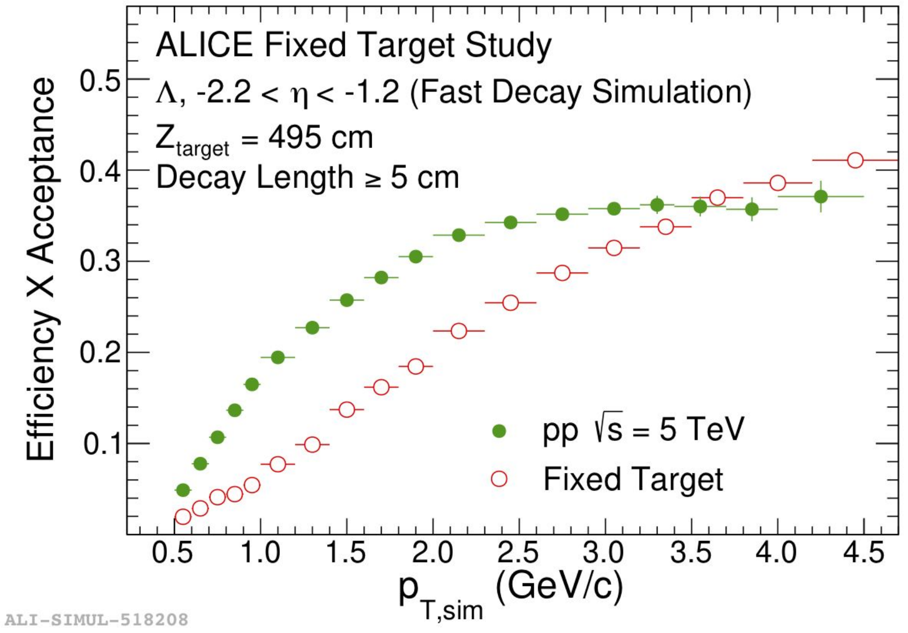


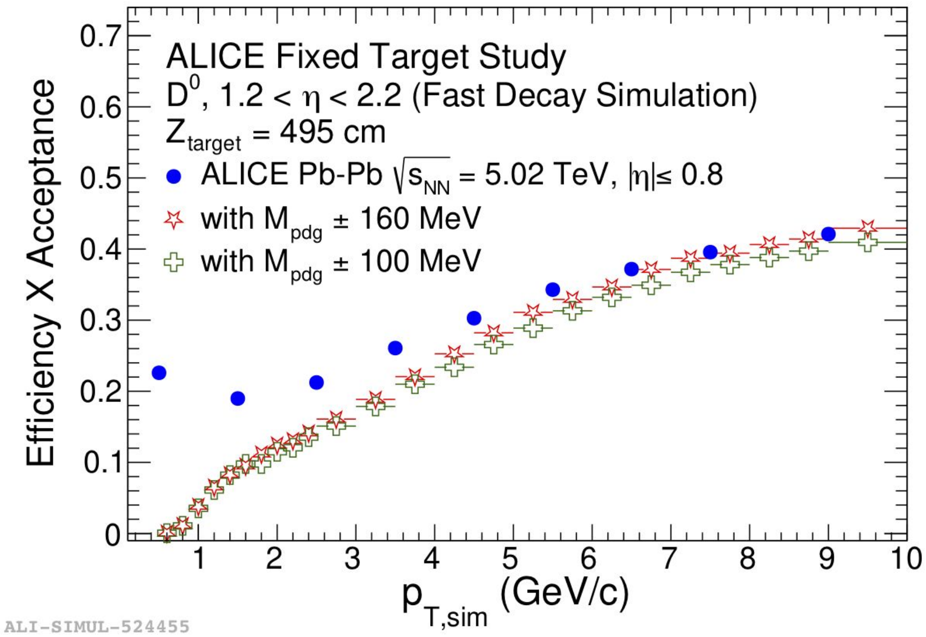
ALI-SIMUL-496845



ALI-SIMUL-496840

Feasibility of D^0 and Λ production measurements



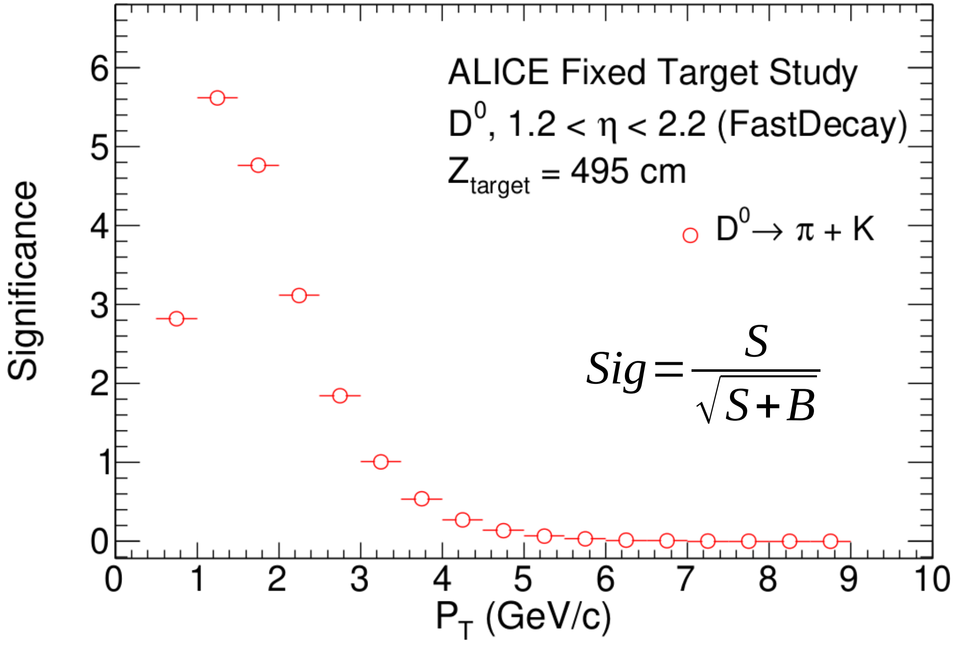


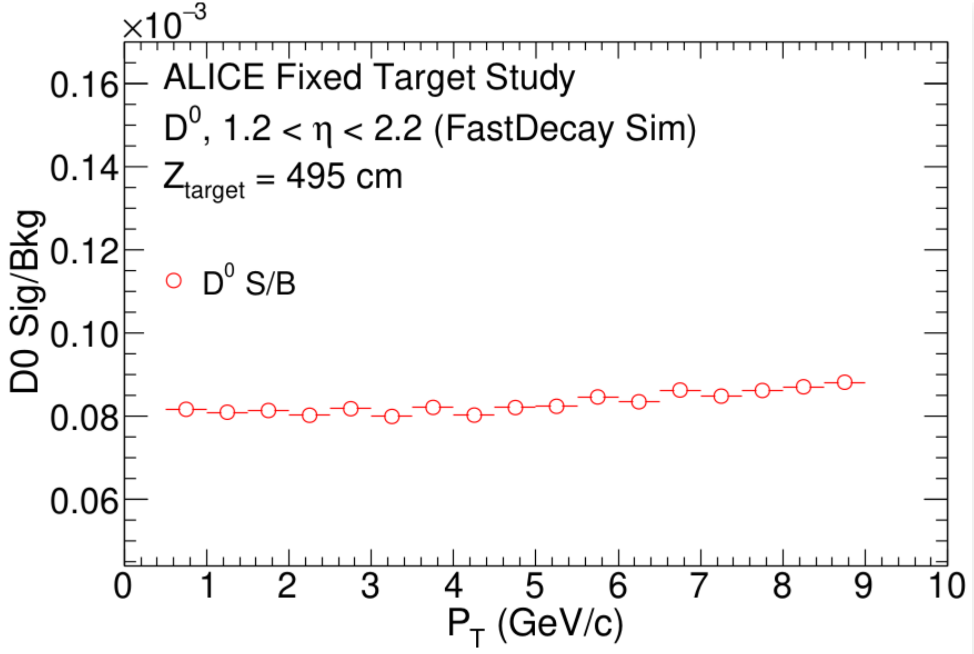
Λ: topological cuts on decay length (DL ≥ 5 cm) and invariant mass (M_{inv} cut: M_{PDG} ± 10 MeV)
D^0: cuts on invariant mass only

The efficiency lower than in the collider mode, but sufficient for D^0 and Λ production studies.

D_0 Significance and S/B ratio

p-W central events at √s = 115 GeV
One year of data taking





Measurement of charm cross section **feasible without additional vertex detector**
Results in the rapidity range complementary to LHCb

→could help with better determination of **total $\sigma_{c\bar{c}}$**

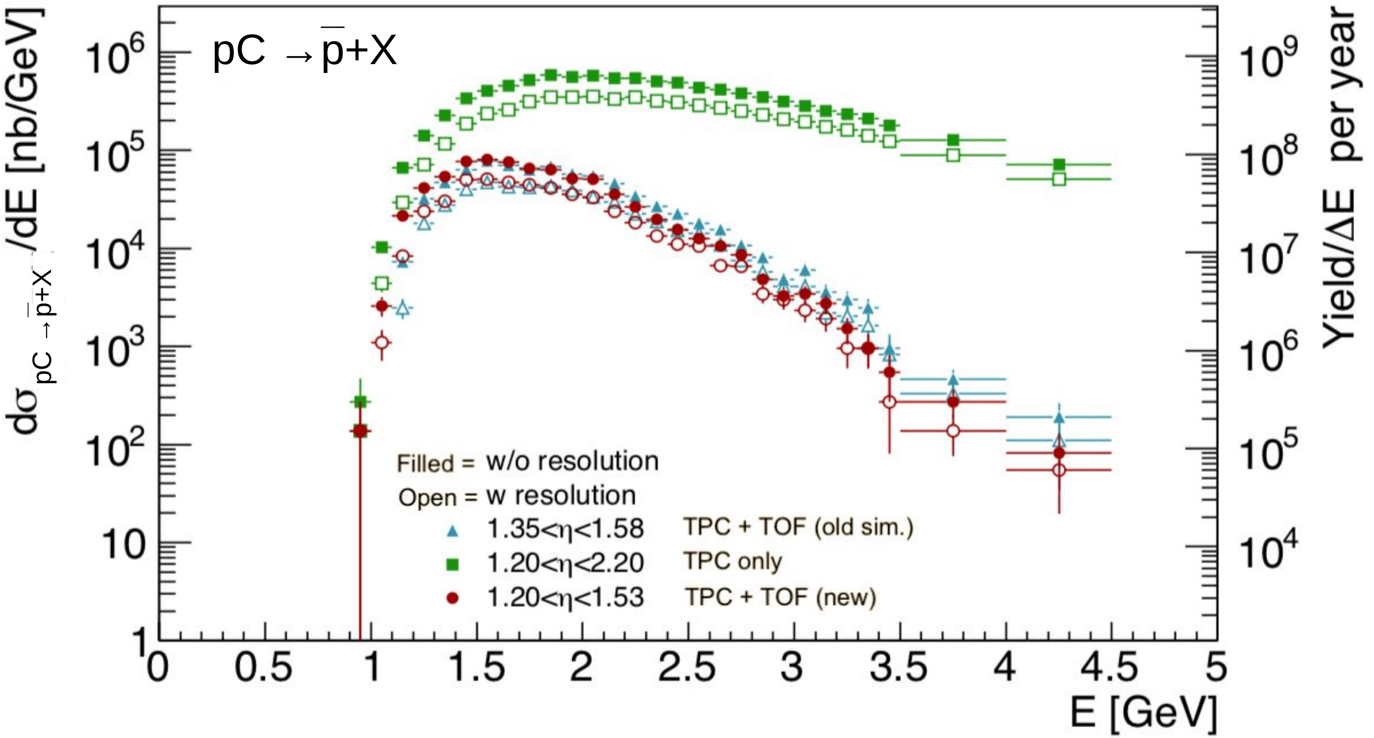
Results for Run 3 geometry (larger material budget compared to Run 4),
→ possibility to improve S/B

Antiproton production in p+A collisions

Cosmic ray $\bar{p}$ formed when high energetic p, He^4, C^{12}, N^{14}, O^{16} collides with interstellar matter (p, He^4)

Measurement of $\bar{p}$ in fixed-targe collisions provide Important inputs for theoretical calculations of the secondary cosmic $\bar{p}$ spectrum.

Example: search for dark matter via study of cosmic $\bar{p}$ excess over secondary $\bar{p}$

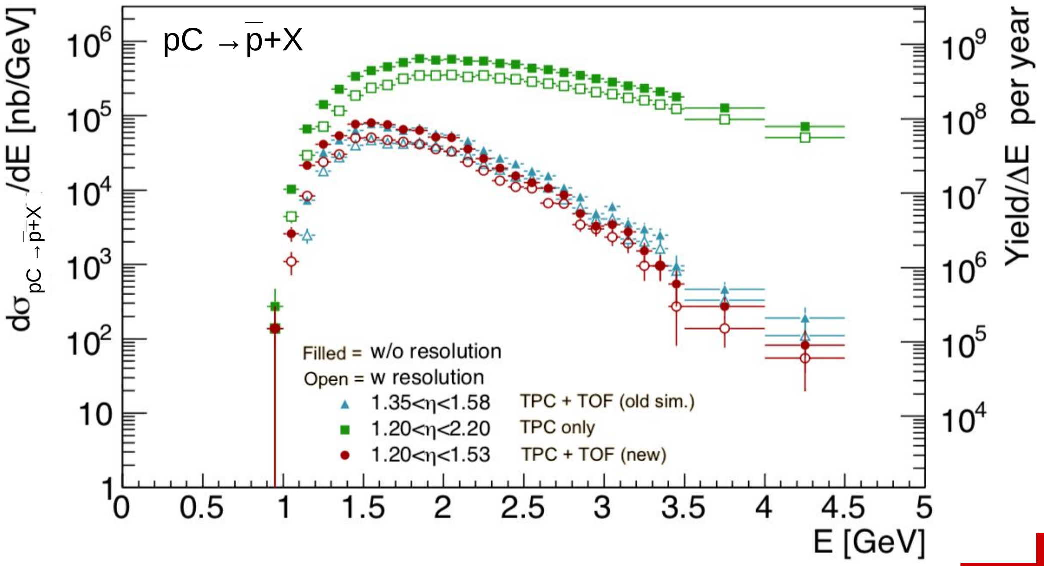


Fast simulations: Pythia + TPC tracking efficiency and TPC/ToF acceptance included

C. Van Hulse, Fixed-target experiments at LHC - Strong2020 workshop, June, 2022

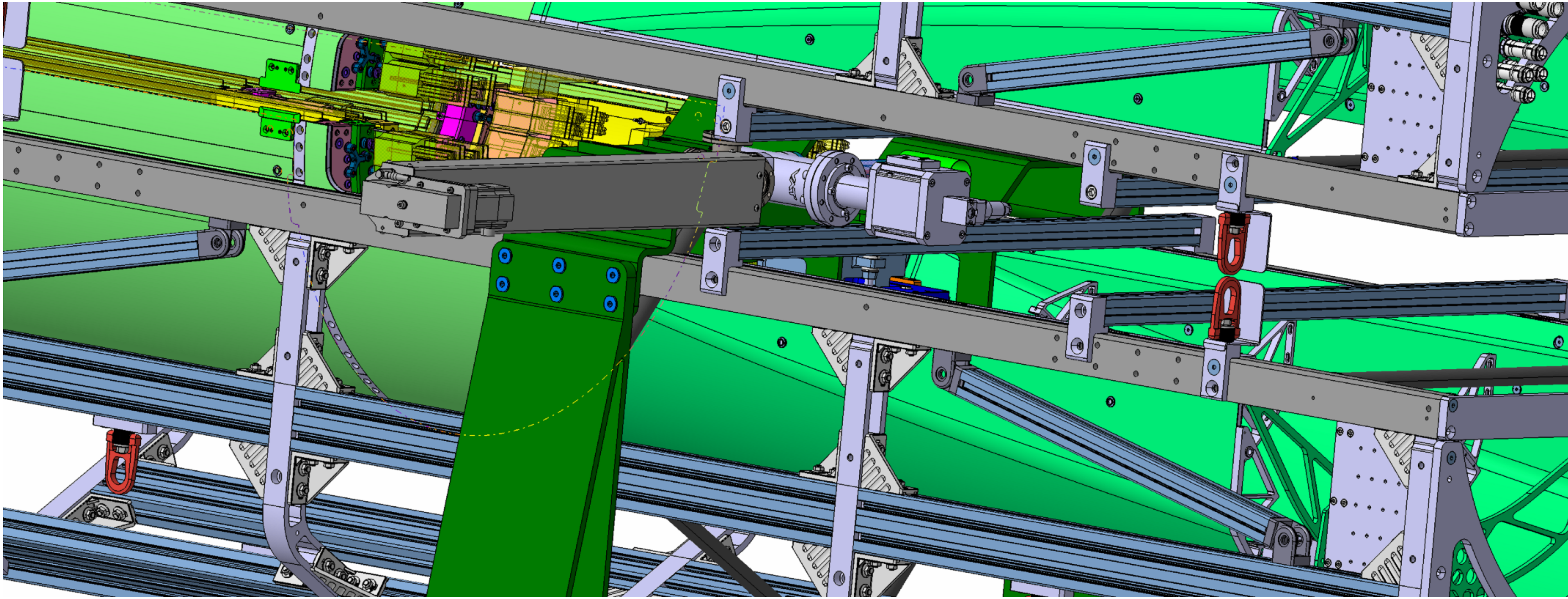
Status and summary

- **Compelling physics case for a Fixed-Target program in ALICE**
- **New feasibility studies for antiproton and D^0 measurements**
- **Resources:** grant of **350k €** for fixed-target studies (a pos-doc and 2 engineering positions at **IJCLab**)
- **Ongoing works**
  - Bent-crystal layout and collimation
  - Technical (target integration) and simulation studies (including particle identification)



Backup

Target integration

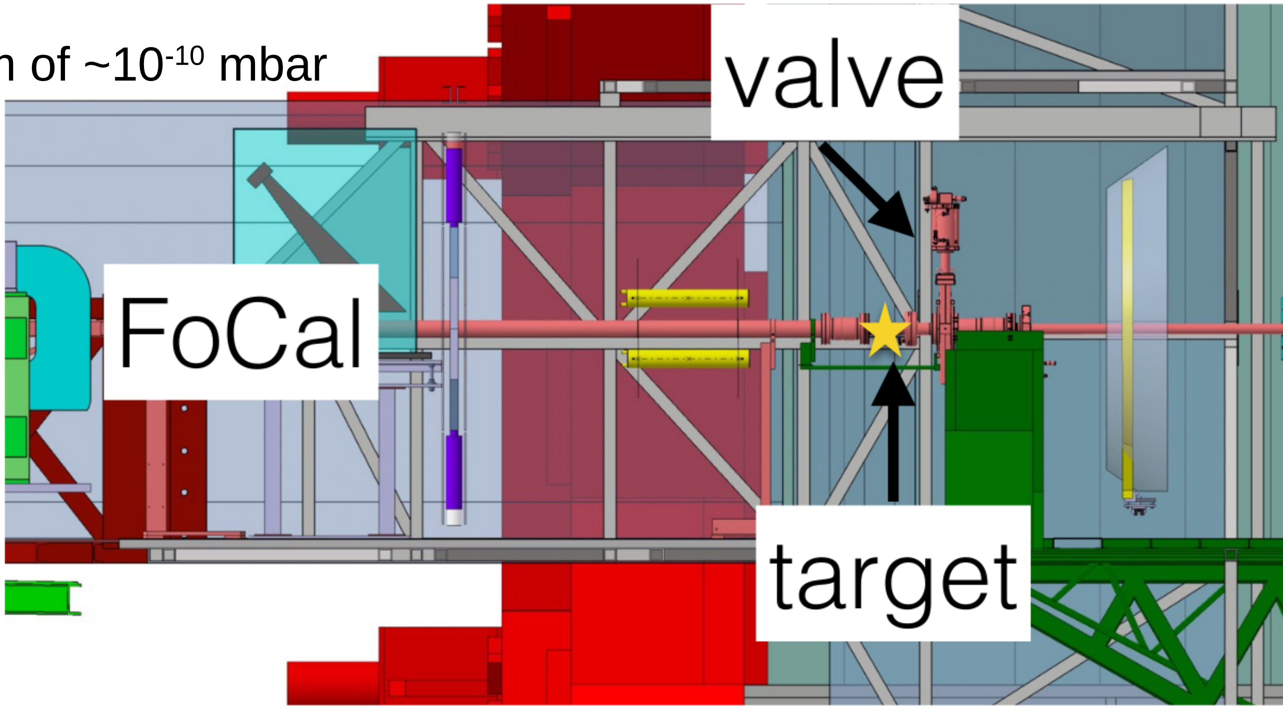


Integration with so-called miniframe (ITS support) seems feasible with target system located in horizontal plane

Target integration

Integration constraints:
- Isolate the pipe region with the target system with a vacuum valve
- Vacuum pumping system for vacuum of ~10^{-10} mbar
- RF shielding needed
- Avoid shadow to FoCal

Run 3 view



More details: C. Hadjidakis**, PBC-FT working group meeting, 16 Dec 2020**