Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

ALICE

A fixed-target program in the ALICE experiment

Recent progress and plans

Daniel Kikoła for the ALICE-FT study group

Physics Beyond Colliders Annual Workshop, 1 March 2021, CERN

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

STRONG-2020

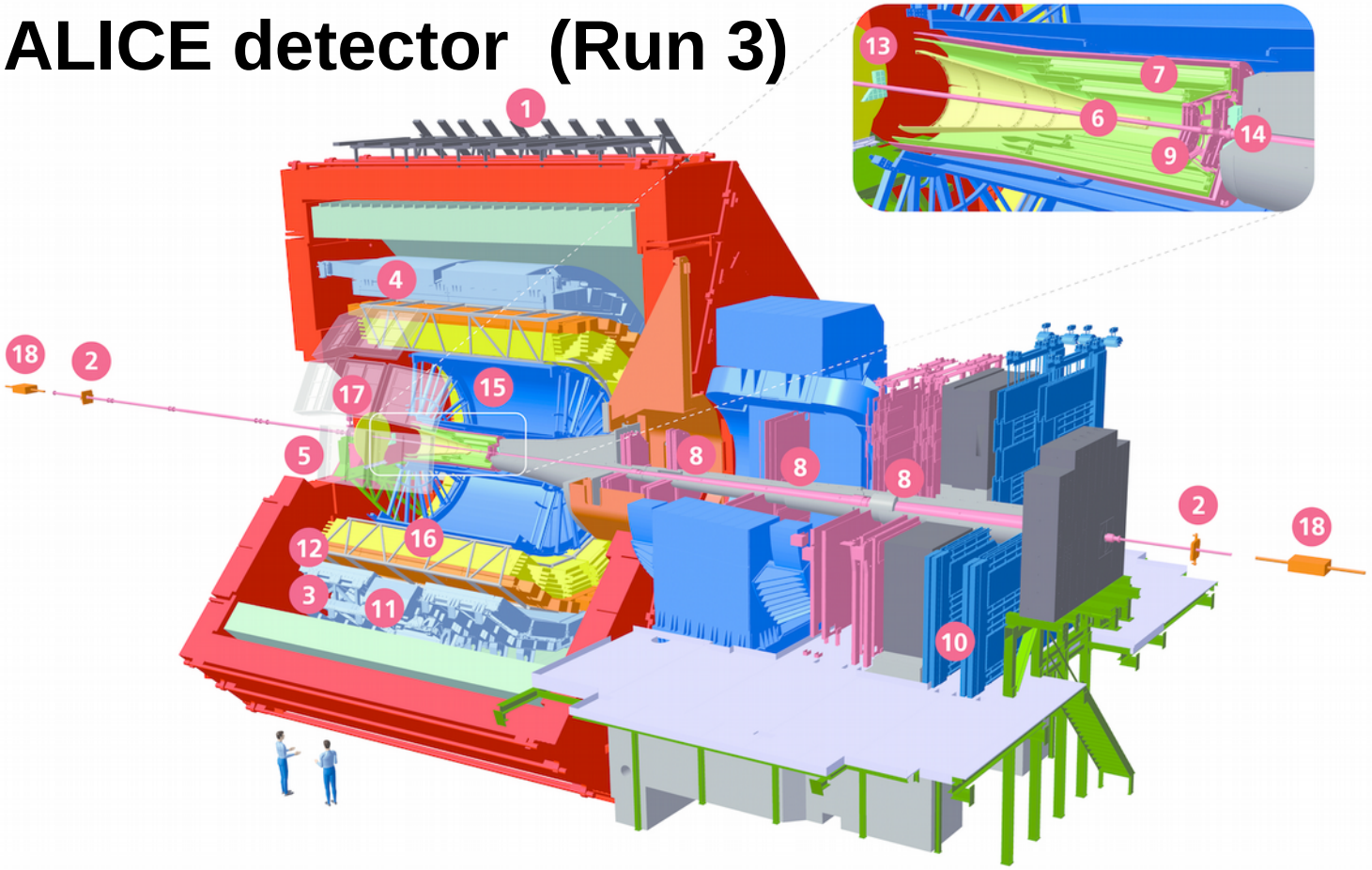
Motivations for a Fixed-Target experiment at ALICE

- Access to high 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, Physics Reports (in press),** arXiv:1807.00603

ALICE detector (Run 3)



1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter

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

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

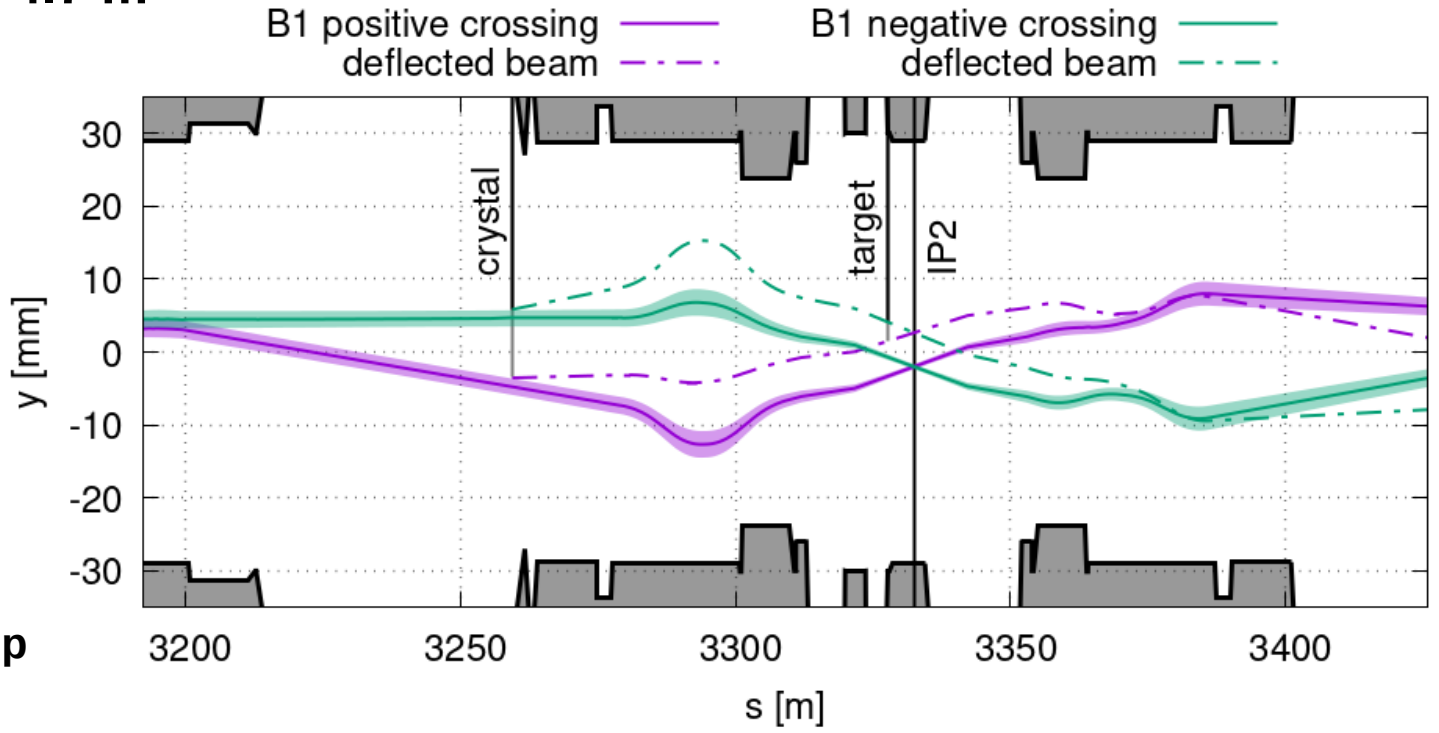
Continuous readout(*): 50 kHz in Pb-Pb, 200 kHz up to 1 MHz in pp and p-A

(*)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
  - bending angle of the crystal: **150 µrad**
  - **Target position: ~ -4.7 m**

Drawing courtesy of M. Patecki

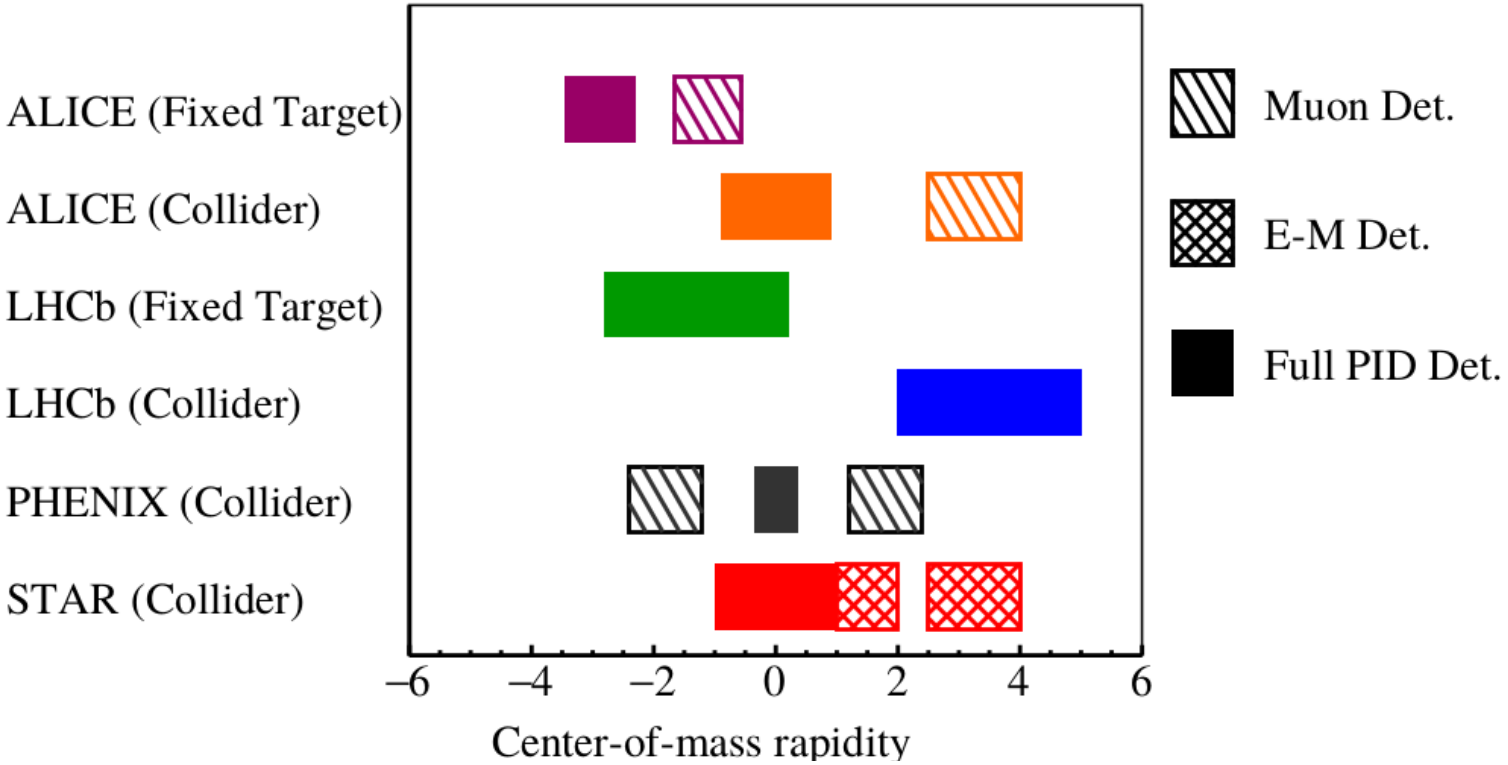


Studies of the crystal layout by A. Fomin, F. Galluccio, W. Scandale, M. Patecki

See talks of A. Fomin and M. Patecki at **PBC-FT working group meeting, 16 Dec 2020** for details

Rapidity coverage of ALICE FT vs other experiments

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



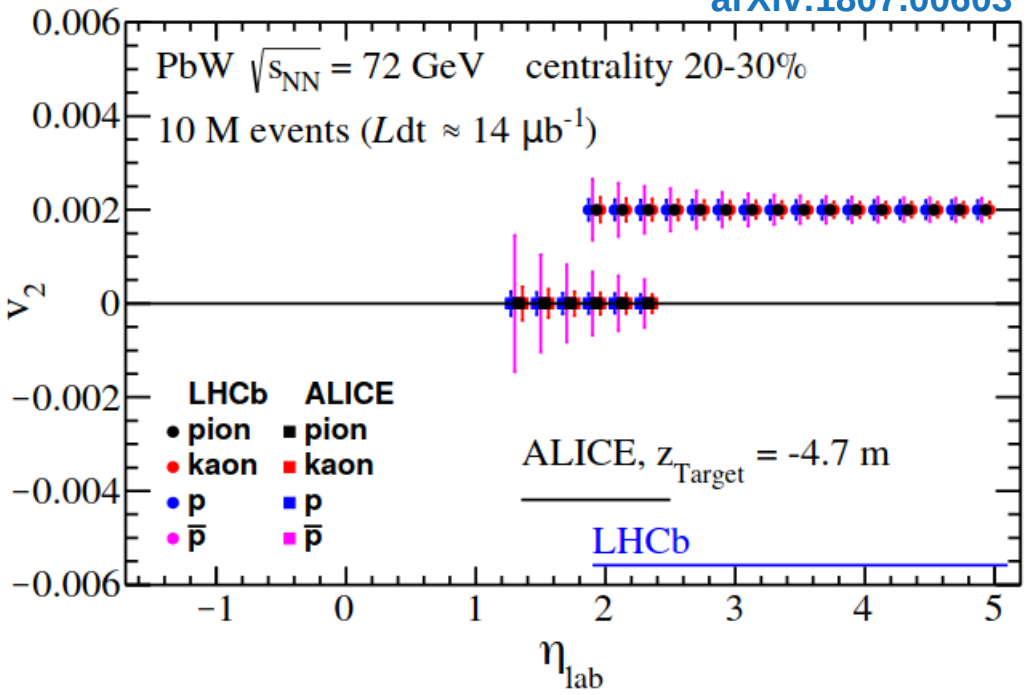
ALICE Central Barrel (CB) in a fixed-target (FT) mode → access to **(far) backward rapidity and high x_F domain**

Examples of physics projections: **Heavy-Ion Collisions**

ALICE excels in HIC studies:

- wide rapidity coverage
- excellent PID capabilities in the central barrel
- designed to cope with high-multiplicity events
- reconstruction of charged particles down to $p_T \sim 0.15$ GeV/c at mid-rapidity
- event rates in a fixed-target mode:
  - p-A: **1 MHz**
  - A-A: **~20 kHz** for 5 mm target,
    up to **50 kHz** for thicker targets

arXiv:1807.00603



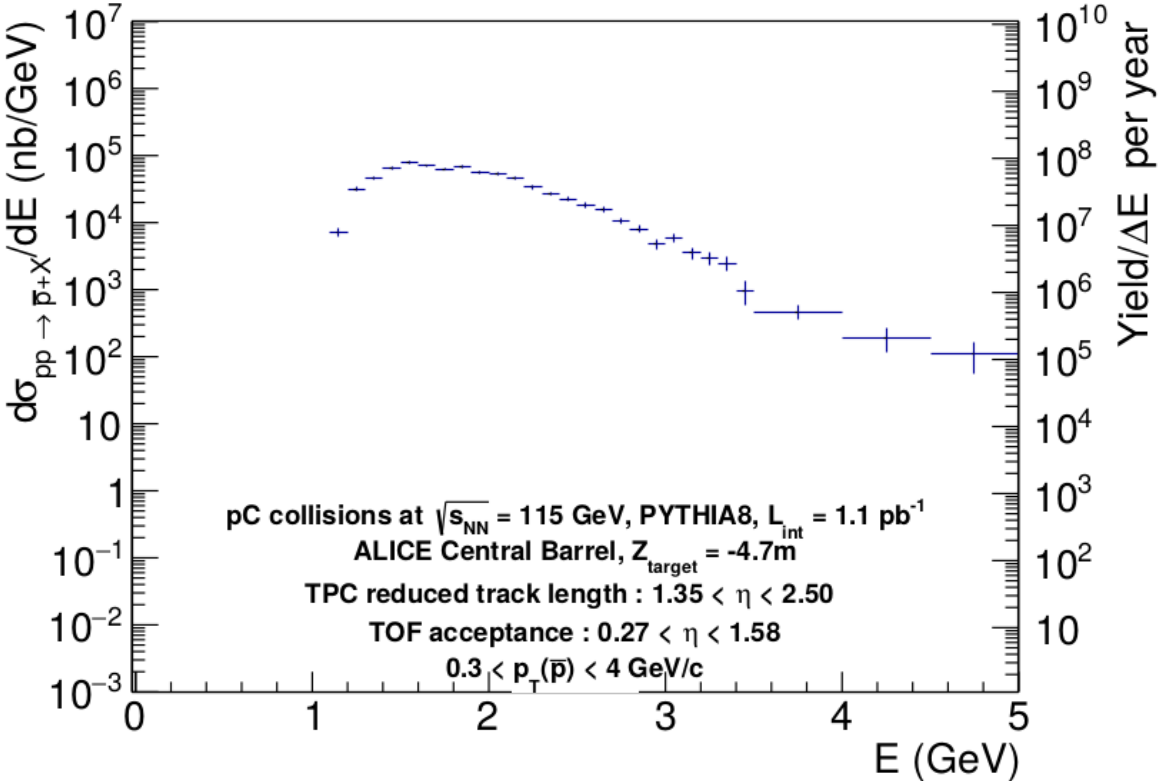
Boost: $y_{cms} = 0 \rightarrow y_{Lab} = 4.3$

Particle yields and azimuthal anisotropy v_N at large rapidities → powerful tool to constrain the temperature dependence of the shear viscosity of the partonic matter

Antiproton production

Production of slow $\bar{p}$ with the LHC proton beam on **A target** equivalent to the nuclear target (C, N, O, He) at TeV energies hitting an interstellar proton at rest and producing a high energy $\bar{p}$. (inverse kinematics)

ALICE CB can measure **very slow antiprotons** down to few hundred MeV momentum (complementary to LHCb)



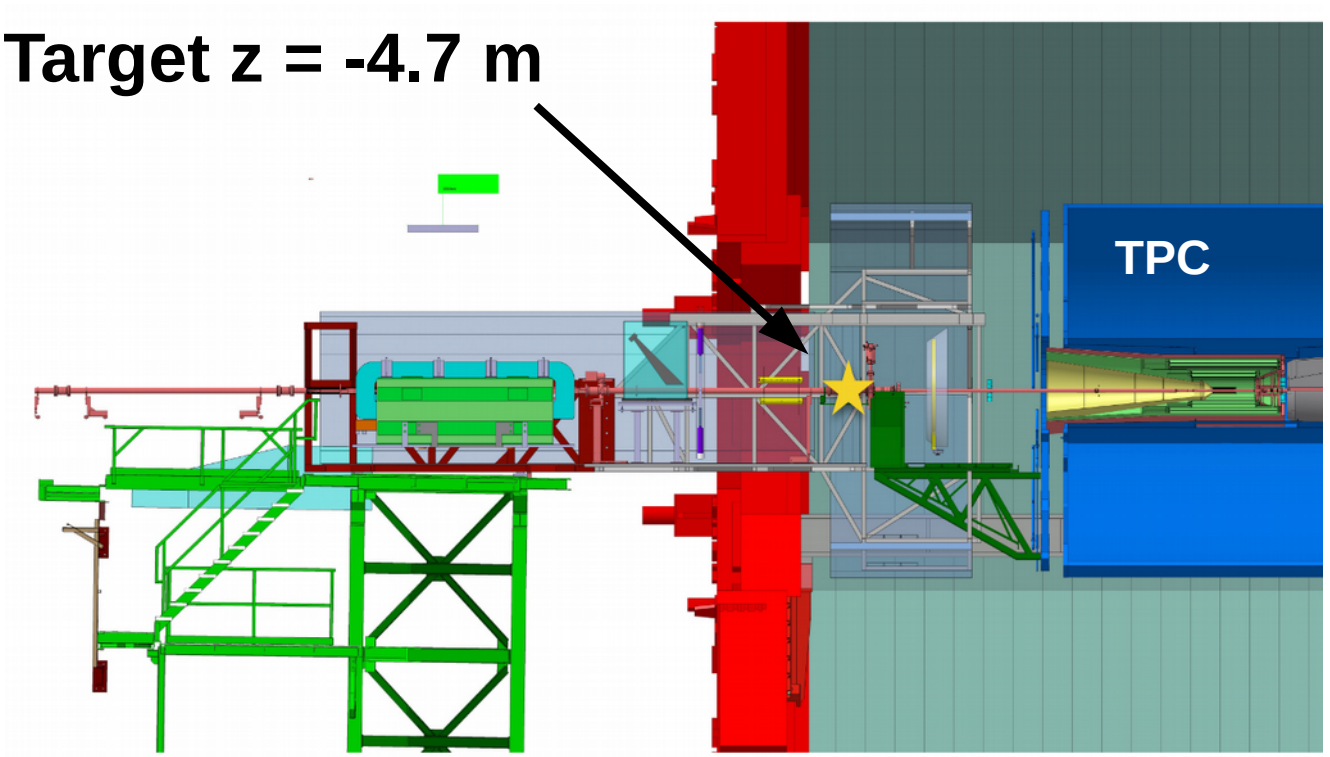
Important inputs for theoretical calculations of the secondary cosmic $\bar{p}$ spectrum.

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

ALICE is well suited to constrain the uncertainty on the antiproton spectrum.

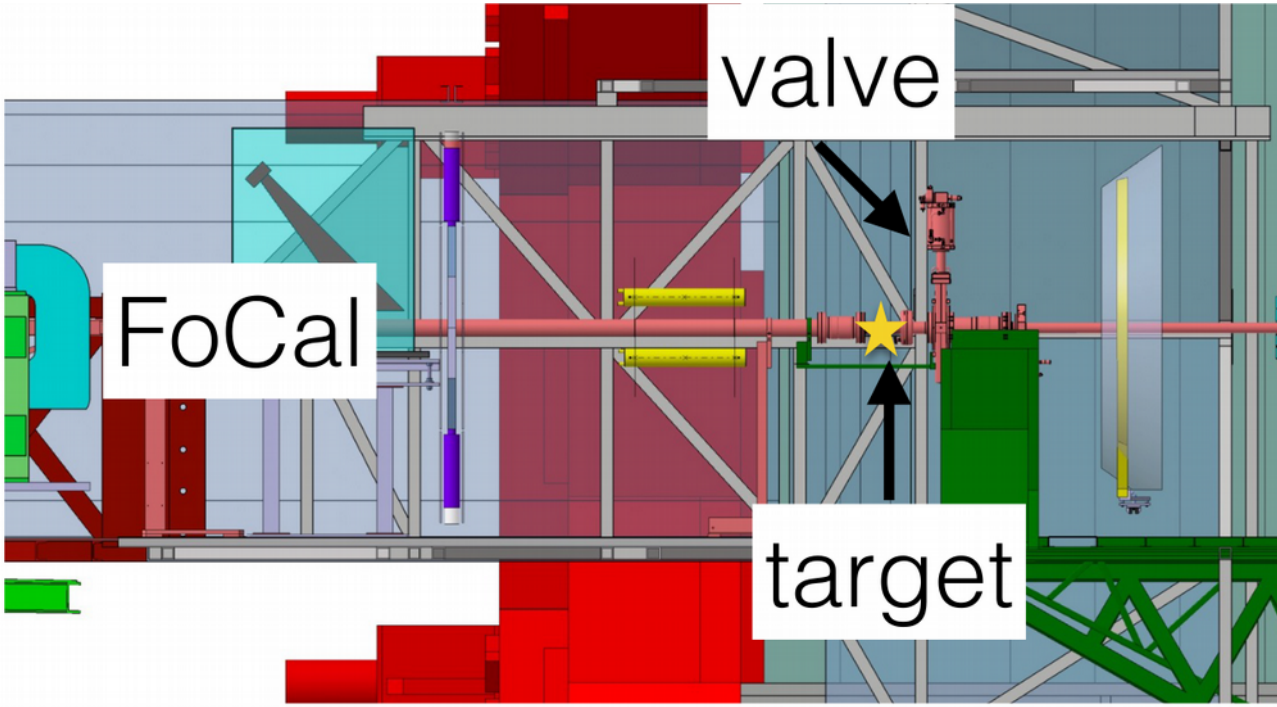
Target locations

- Possible integration at z ~ - 4.7 m from IP2 before an existing valve (inside L3 magnet)
- Insertable target with stepper motor (linear movement) with motorisation outside of L3
- Integration at z ~ -4.7 m imposed by the possible displacement of the Inner Tracking System during extended year-end technical stops



Target integration

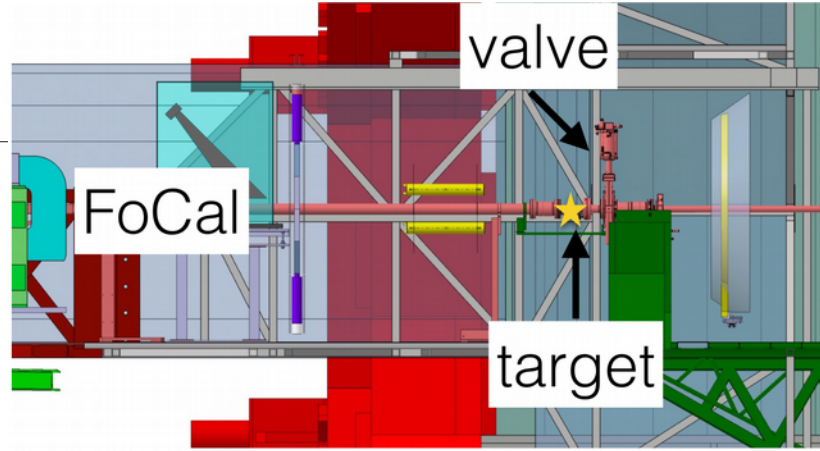
FoCal detector LOI presented to LHCC in June 2020: photon detection for studying gluon saturation in nuclei in p-Pb collisions



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

Target integration

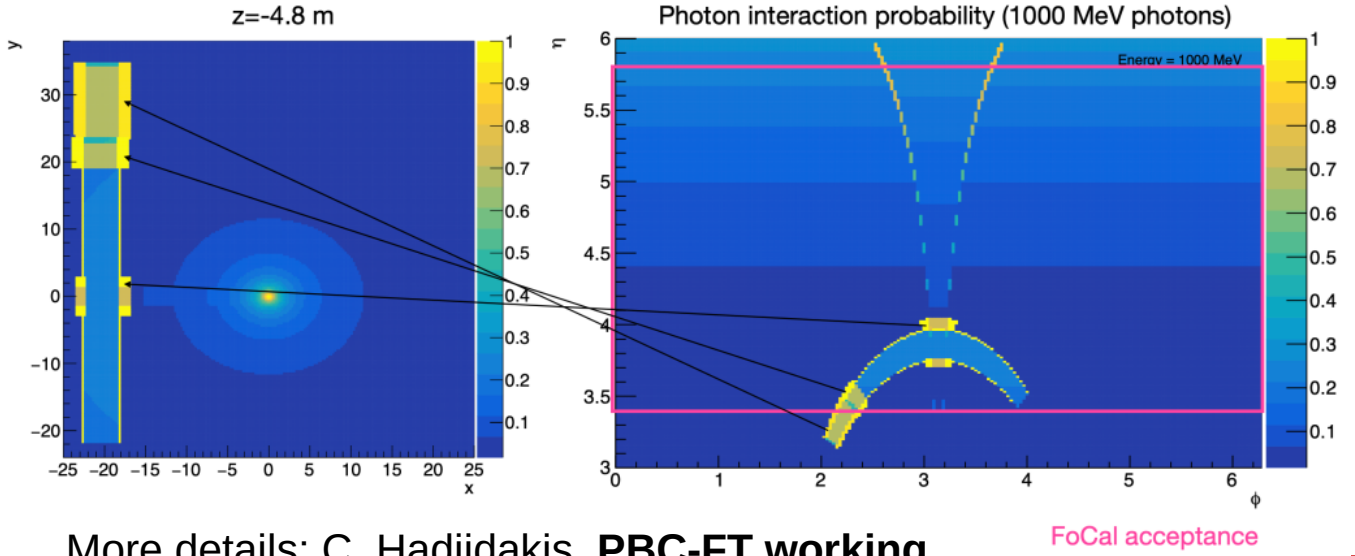
FoCal detector LOI presented to LHCC in June 2020: photon detection for studying gluon saturation in nuclei in p-Pb collisions



Under study:

- Impact of target-system material on FoCal detector: 1 or 2 valves and beam-pipe material
  - 1 valve to isolate the target system from the IP2 vacuum sector
  - 2 valves better to isolate the target sector and be able to remove/add the target system

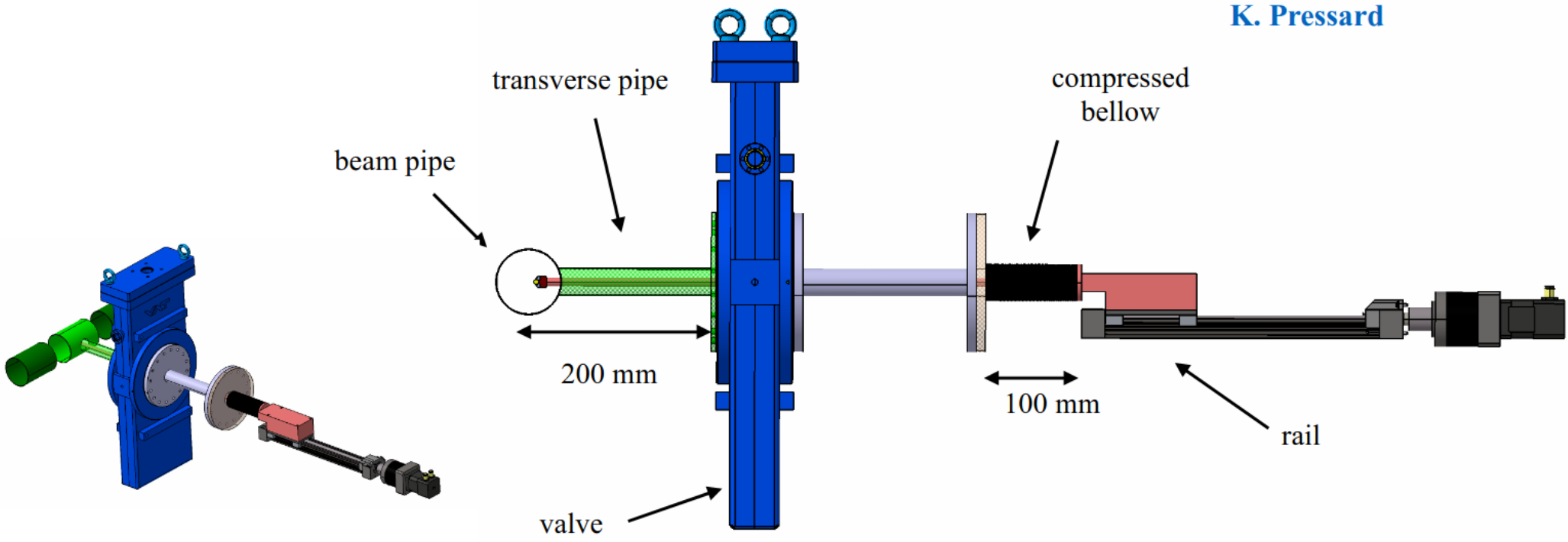
C. Van Hulse



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

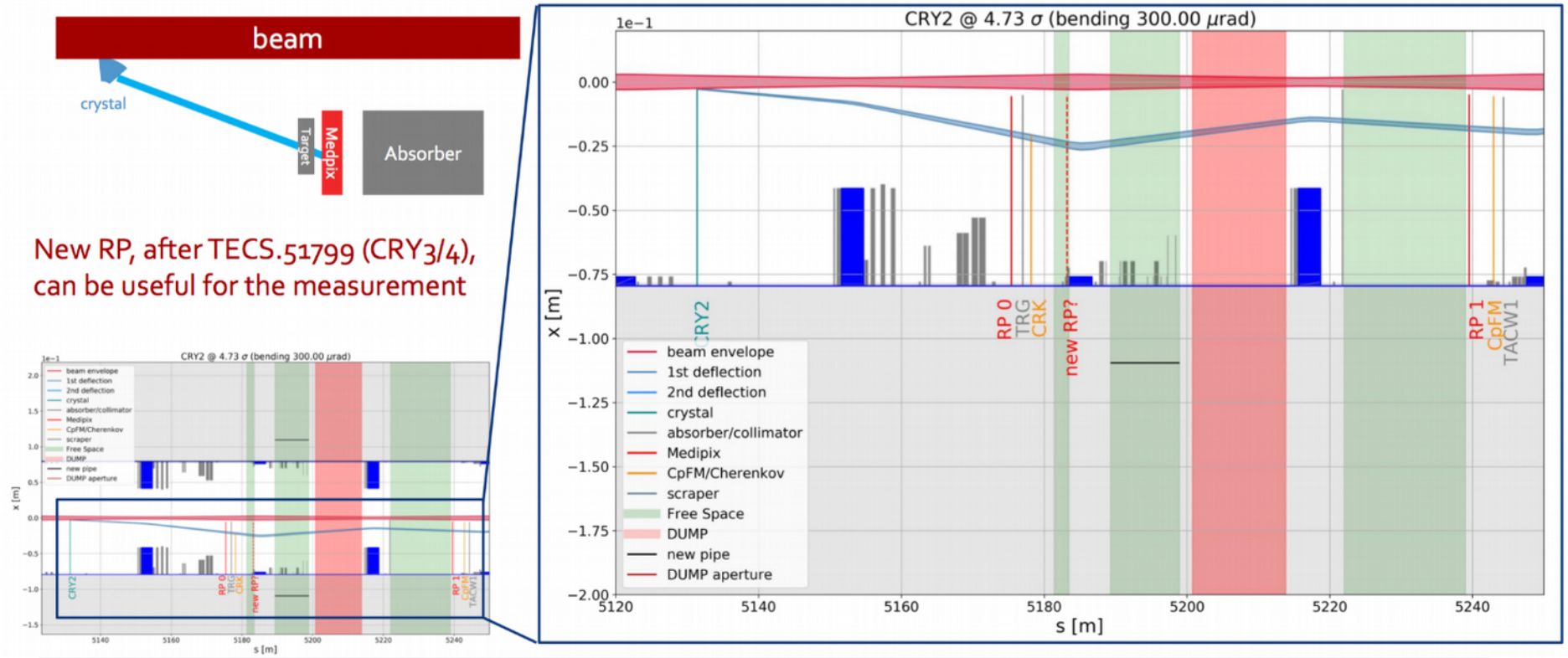
New target design

- Stepper motor to achieve a better movement resolution (5, 10 or 50 µm to be defined)
- Retractable target with linear motion, target actuator in a vacuum chamber, moves thanks to a stepper motor that compresses a bellow
- Few mm radius, length varying from few hundreds of µm up to 1 cm,
- possible targets: Be, C, Ti, W, ...



Preparation for SPS beam test

- Preparation for a test at SPS with the UA9 experiment at LSS 5 in 2022
- Configuration: crystal channeling on a 10 cm long Carbon target



Fixed-Target program in STAR at RHIC

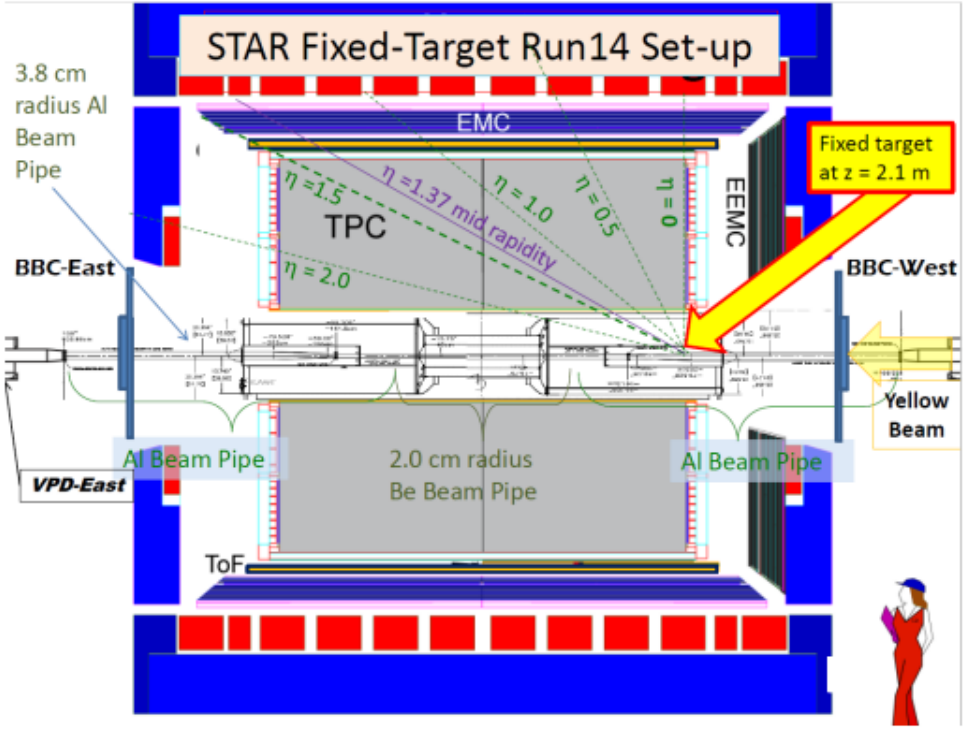
3.9 GeV Au + Au Test Run

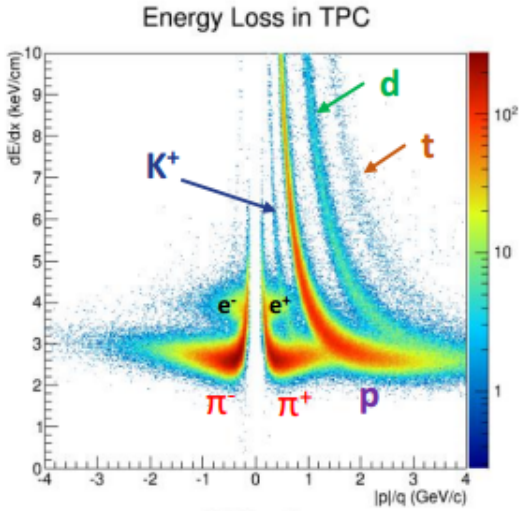
Successful operation of a **collider detector** in a fixed-target mode

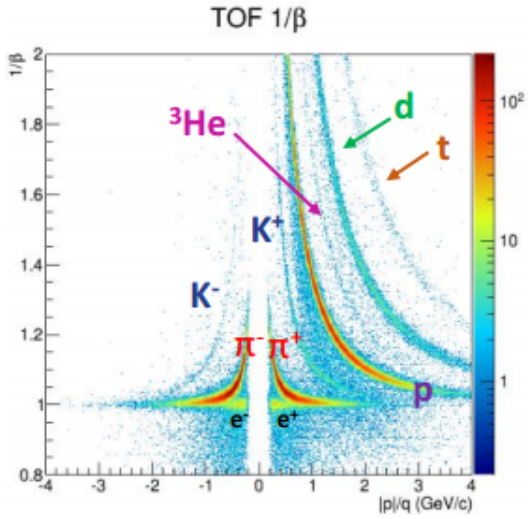
Part of the **Beam Energy Scan II**

Physics results:
Flow and interferometry results from Au+Au collisions at $\sqrt{s_{NN}}$ = 4.5 GeV, arXiv:2007.14005

Excellent PID with Time Projection Chamber (TPC) and Time of Flight (TOF) detectors for fixed target events







ALICE detector performance in a fixed-target mode

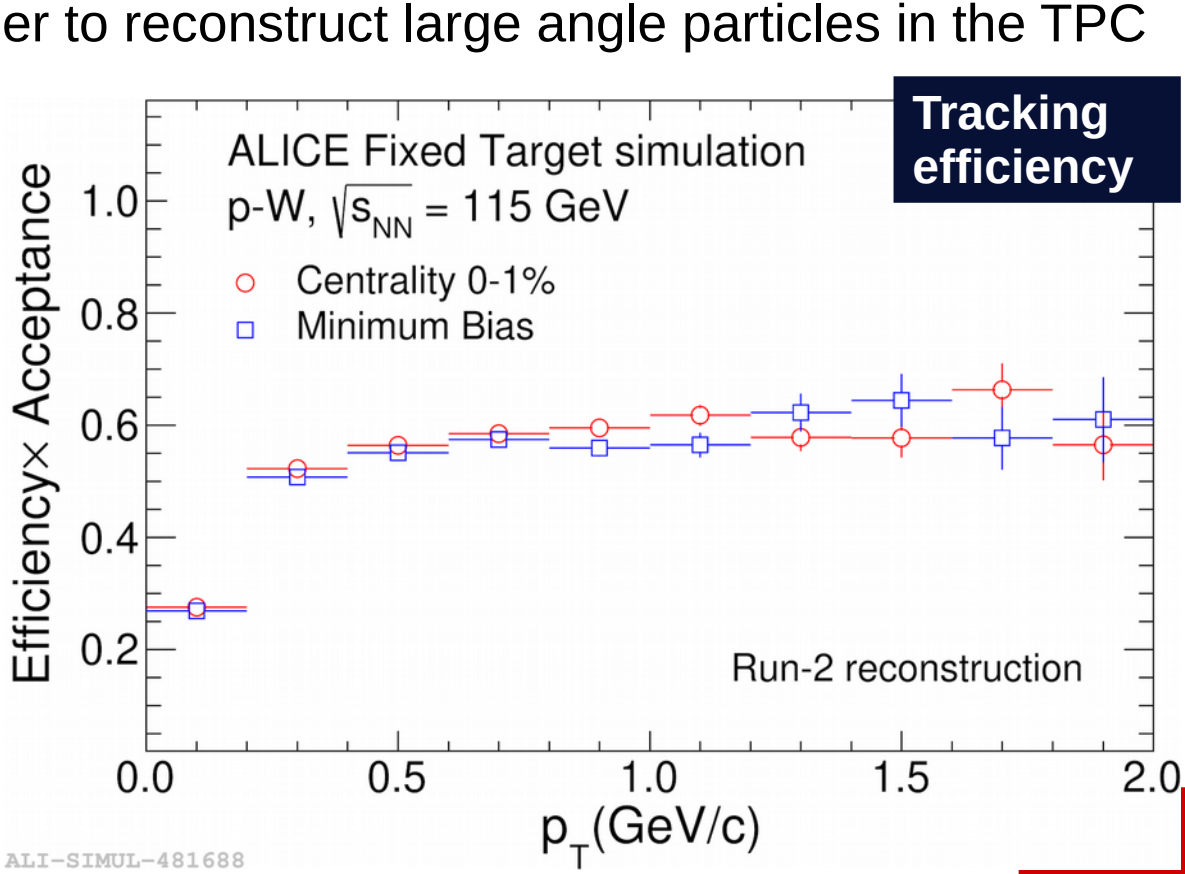
- p-W simulations, $\sqrt{s_{NN}}$ = 115 GeV, **LHC Run 2 setup**
- Time Projection Chamber (TPC) tracking and event reconstruction
- Tracking algorithm improved in order to reconstruct large angle particles in the TPC

Very good TPC tracking efficiency in a fixed-target mode

Ongoing study for Run 3 setup

To be studied:
- data taking scenarios with continuous TPC readout
- using Time-of-Flight in FT mode,
- pile-up removal

Data: p-W collisions from HIJING, results for charged hadrons, TPC acceptance: $-1.38 < \eta_{Lab} < -2.51$

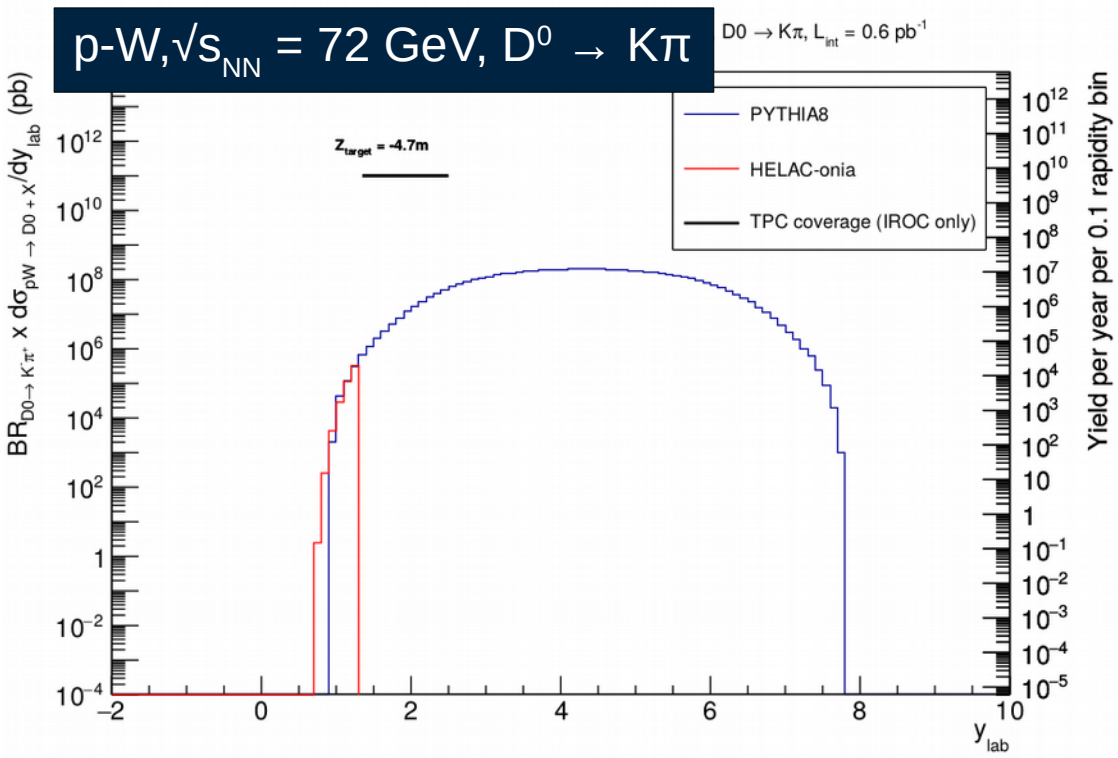


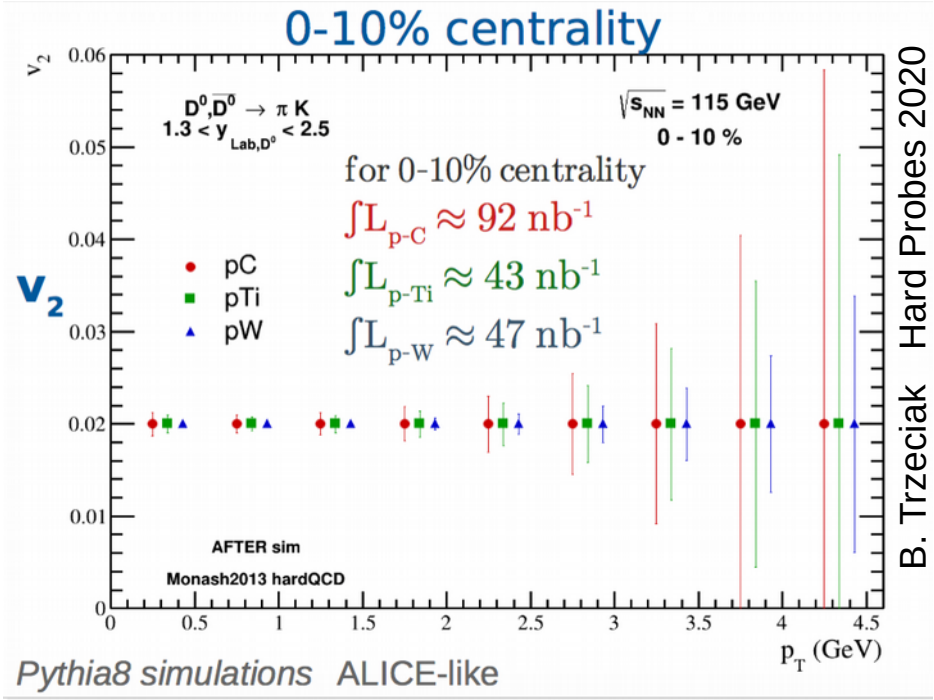
Status and summary

- **Compelling physics case for a Fixed-Target program in ALICE**
- **Ongoing works**
  - feasibility and performance studies for FT collisions in ALICE (data taking scenario, using Time-of-Flight detector, pile-up removal etc.)
  - Bent-crystal layout and collimation under study
  - Technical (target integration) and simulation studies
  - Preparation for a test of target at SPS with the UA9 experiment
- **Next steps**
  - Impedance and vacuum studies for the target system in ALICE cavern
  - Further studies related to crystal channeling (impedance, absorbers, ...)

Backup

Open heavy flavor





Unique measurement: charm prod. in a y_{cms} domain only accessible by ALICE

Measurement of *intrinsic* charm → important input for astrophysics

Access to high-*x* nuclear gluon distribution (the least known nuclear PDF)

Caveat: additional vertex detector is required for charmed meson reconstruction