Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

A fixed-target program in the ALICE experiment

Recent progress and plans

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Physics opportunities for a fixed-target programme in the ALICE experiment

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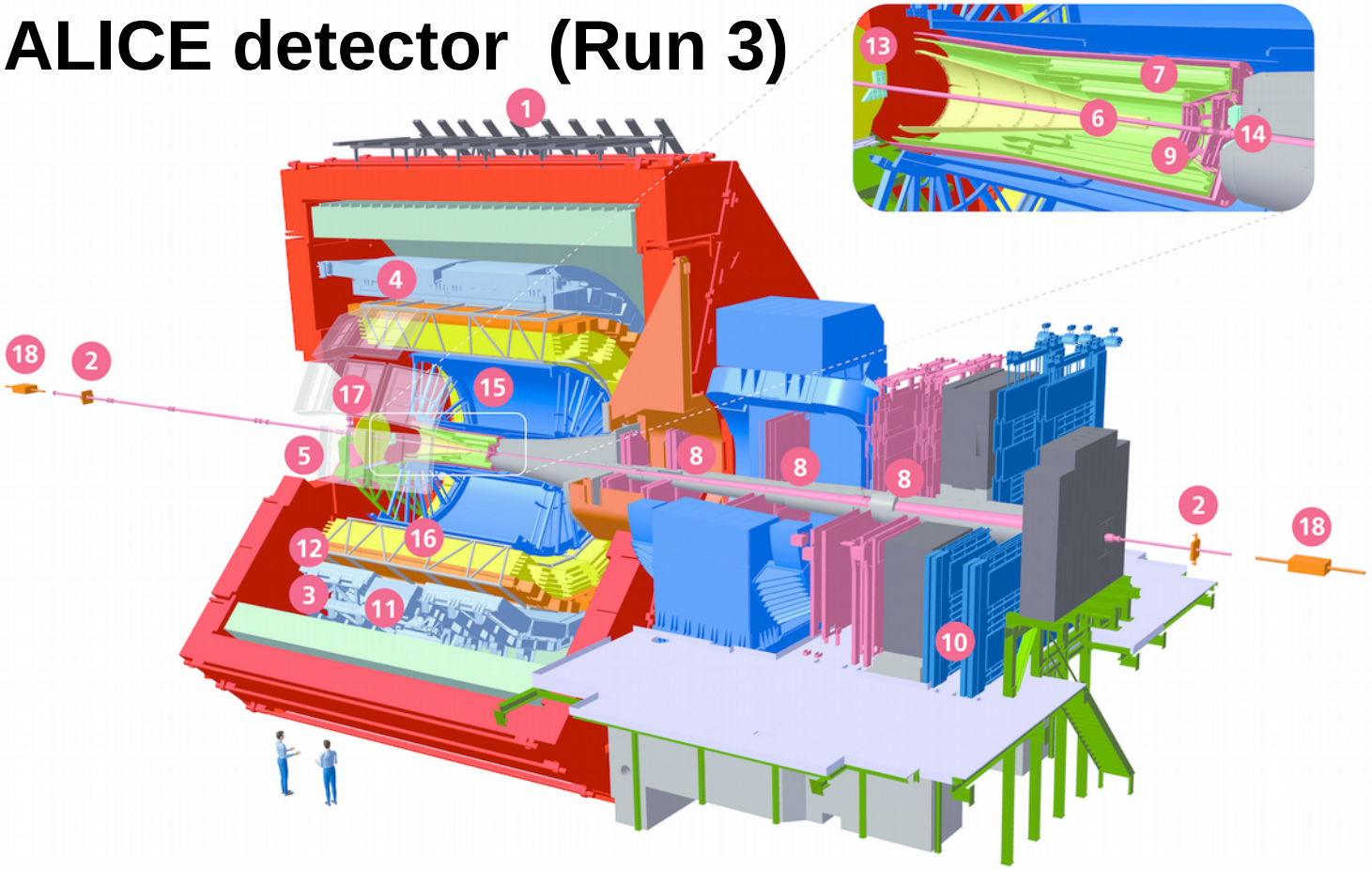
Motivations for a Fixed-Target experiment at ALICE

- Probing high-x gluon, antiquark and heavy-quark content in the nucleon and nucleus and provide inputs for astrophysics
- Study of nuclear matter properties in heavy-ion collisions at $\sqrt{s_{NN}} \sim 72$ GeV over a wide rapidity range
- With a polarized target → access to spin structure of a nucleon at $x \rightarrow 1$
- Access to high Feynman x_F domain ($|x_F| = |p_z|/p_{z\,max} \rightarrow 1$)

More on physics motivations: **S. J. Brodsky et al., Phys. Rept. 522 , 239 (2013), 1202.6585, C. Hadjidakis et al., 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:** $2.5 < \eta^{lab} < 4$

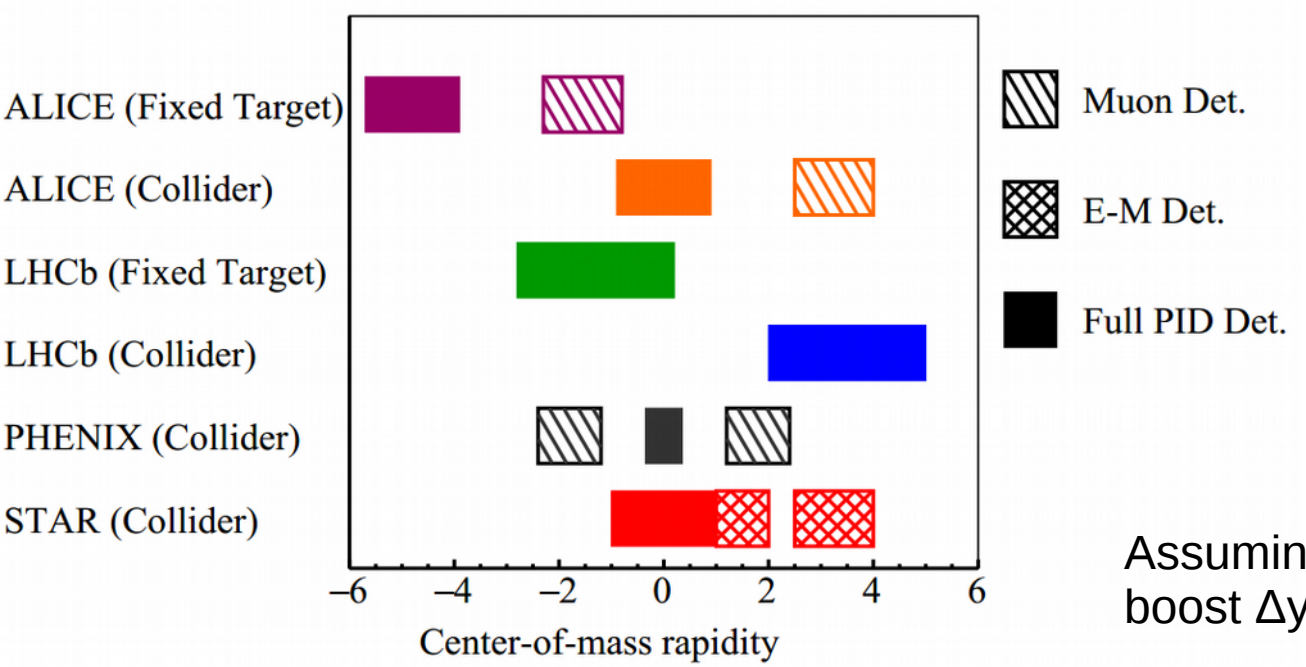
Run 3 and 4: New Inner Silicon Tracker, A Muon Forward Tracker

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

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

Main strengths of the ALICE detector:

- wide rapidity coverage
- excellent PID capabilities in the central barrel
- experiment designed to cope with high-multiplicity events
- reconstruction of charged particles down to $p_T \sim 0.15$ GeV/c at mid-rapidity

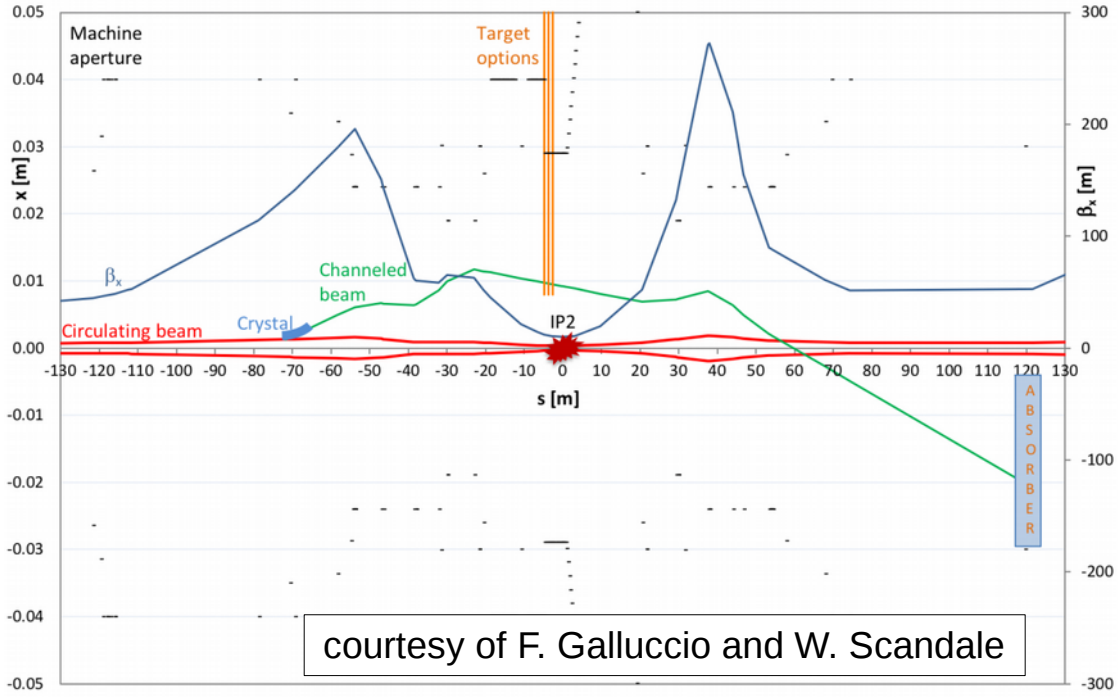


Assuming 7 TeV proton beam and boost $\Delta y = 4.8$

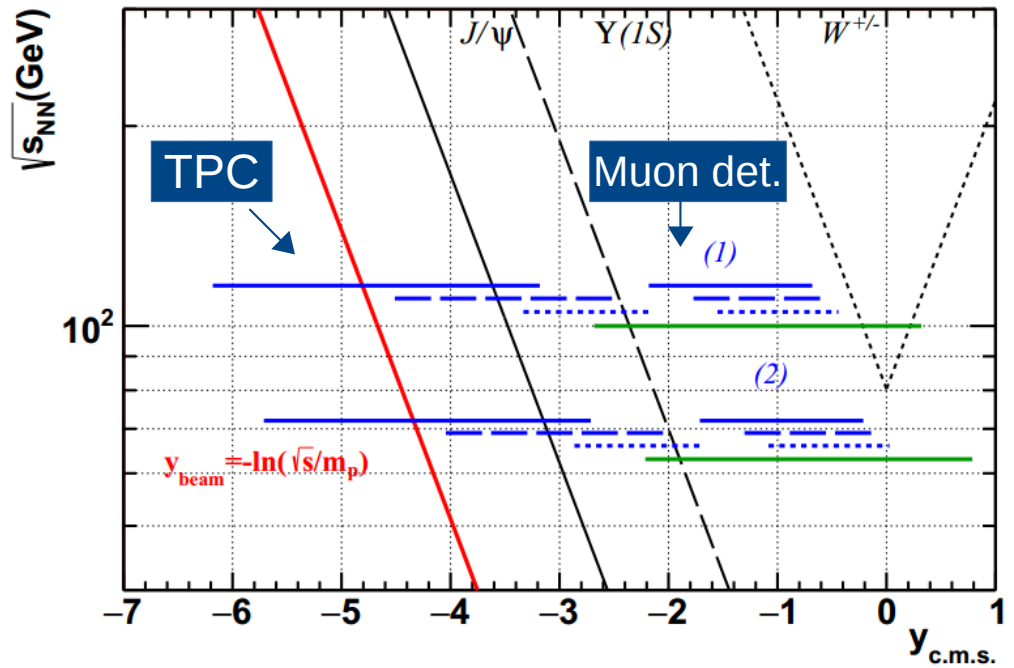
Fixed-target implementations

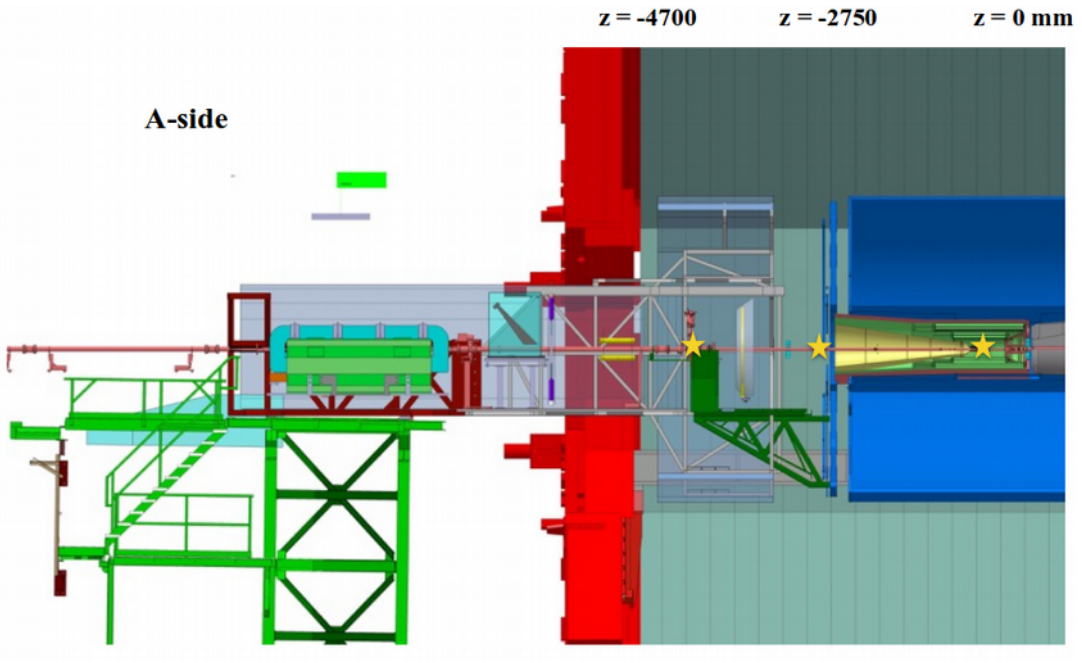
- Internal solid target + a bent crystal
  - a bent crystal installed prior of the LHC Interaction Point 2
  - deviates the beam halo on a solid target

- Internal gaseous target
  - to be studied



Possible target locations and acceptance





Target z = 0

Target z = -2.75 m

Target z = -4.7 m

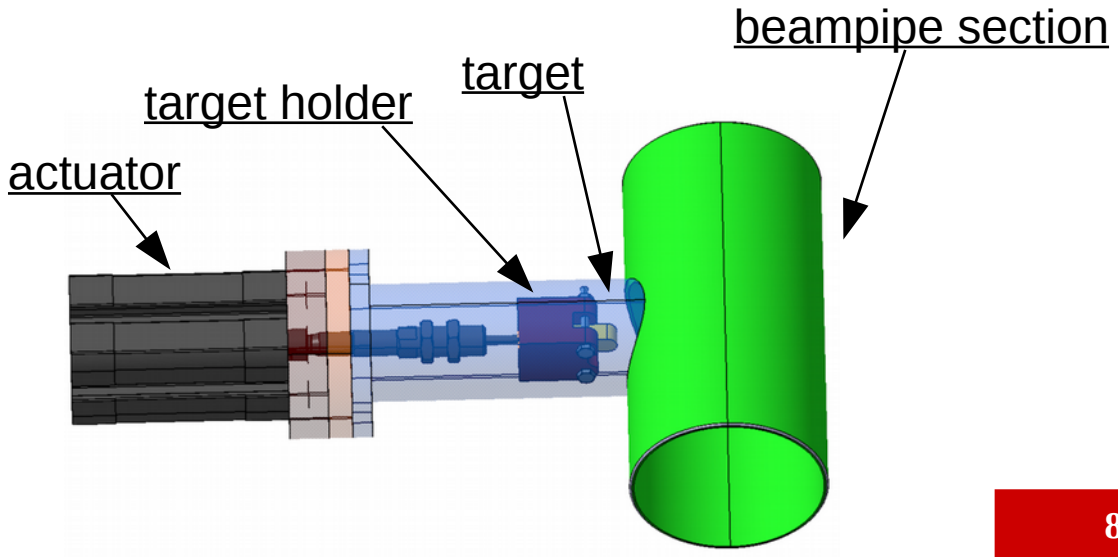
LHCb, target z = 0

The acceptances of the TPC calculated assuming reduced track length (1/3 of the full radial track length), which results in |η|<1.5 in a collider mode.

Solid target setup

- Inside the L3 solenoid
- Pneumatic motion system with two positions (IN and OUT of the beam pipe)
- Examples of possible target types: Be, Ca, C, Ti, Ni, Cu, Os, Ir, W
- Size: 170 x 50 x 50 mm

Setup for an internal solid target with one target system. Design by IPN Orsay.



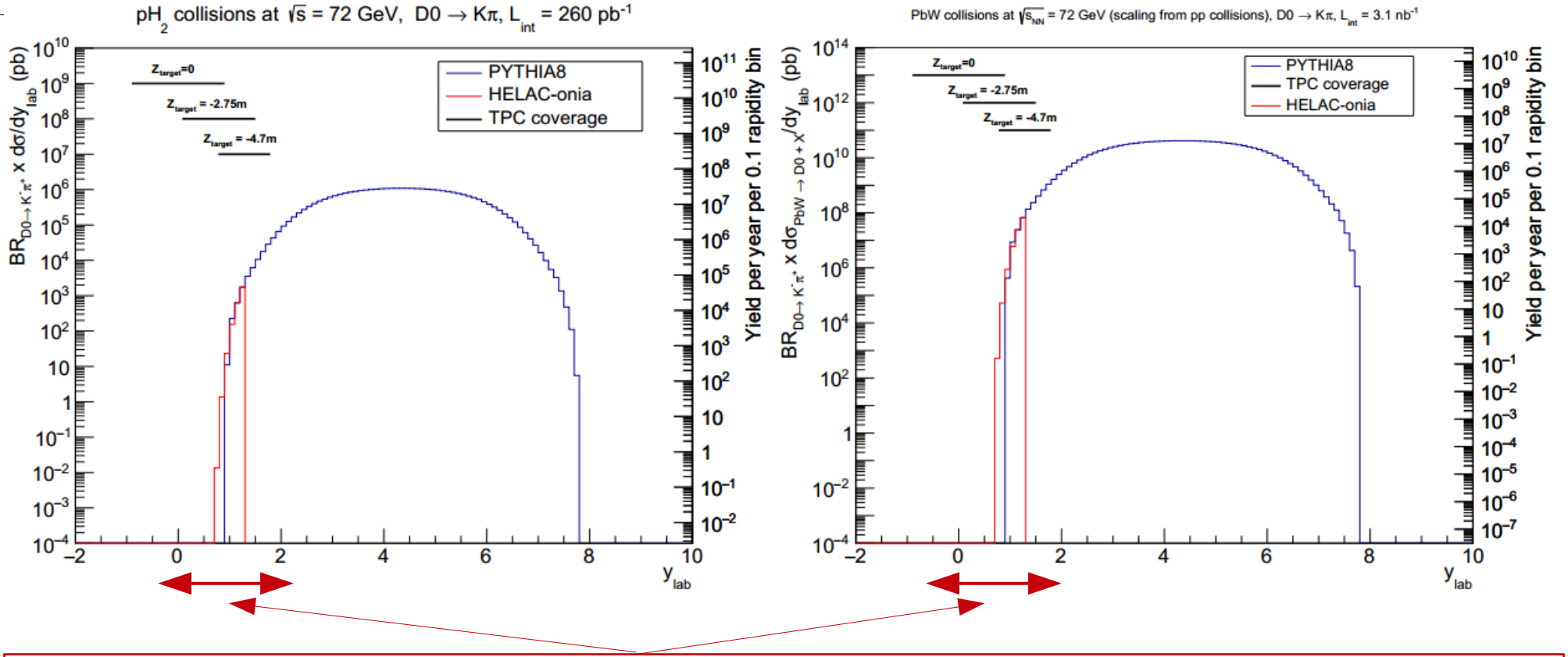
Integrated luminosities with the ALICE detector

		ALICE					
		proton beam ($\sqrt{s_{NN}}$= 115 GeV)			Pb beam ($\sqrt{s_{NN}}$= 72 GeV)		
Target		$\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	Inel. rate [kHz]	$\int \mathcal{L}$	$\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	Inel. rate [kHz]	$\int \mathcal{L}$
Internal gas target (gas-jet option)	$H^{\uparrow}$	4.3×10^{30}	168	43 pb^{-1}	5.6×10^{26}	1	0.56 nb^{-1}
	H_2	2.6×10^{31}	1000	0.26 fb^{-1}	2.8×10^{28}	50	28 nb^{-1}
	$D^{\uparrow}$	4.3×10^{30}	309	43 pb^{-1}	5.6×10^{26}	1.2	0.56 nb^{-1}
	$^3He^{\uparrow}$	8.5×10^{30}	1000	85 pb^{-1}	2.0×10^{28}	50	20 nb^{-1}
	Xe	7.7×10^{29}	1000	7.7 pb^{-1}	8.1×10^{27}	50	8.1 nb^{-1}
Beam splitting	C	3.7×10^{30}	1000	37 pb^{-1}	5.6×10^{27}	18	5.6 nb^{-1}
	Ti	1.4×10^{30}	1000	14 pb^{-1}	2.8×10^{27}	13	2.8 nb^{-1}
	W	5.9×10^{29}	1000	5.9 pb^{-1}	3.1×10^{27}	21	3.1 nb^{-1}

Interaction rate limited to 1 MHz by the expected detector data taking rate capabilities

Selected recent physics opportunities studies

Open heavy flavor

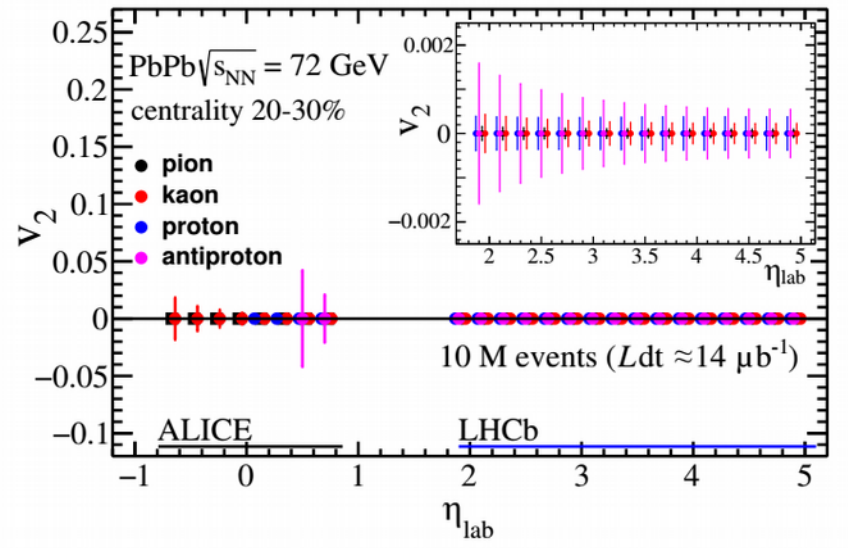


Unique measurement: charm prod. in a y_{cms} domain only accessible by ALICE

Measurement of *intrinsic* charm → important input for astrophysics

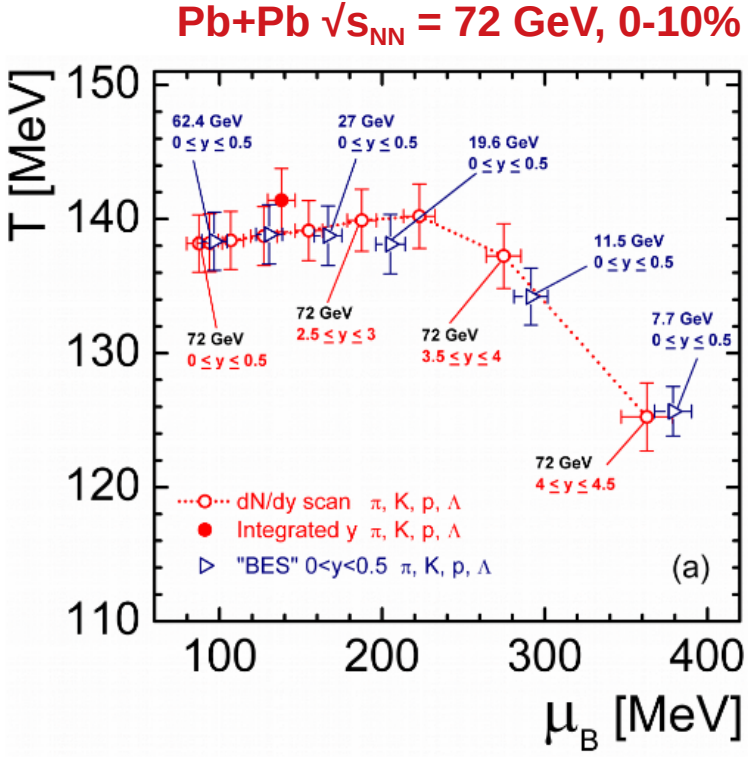
Access to high-x nuclear gluon distribution (the least known nuclear PDF)

Heavy-ion collisions: towards large rapidities



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

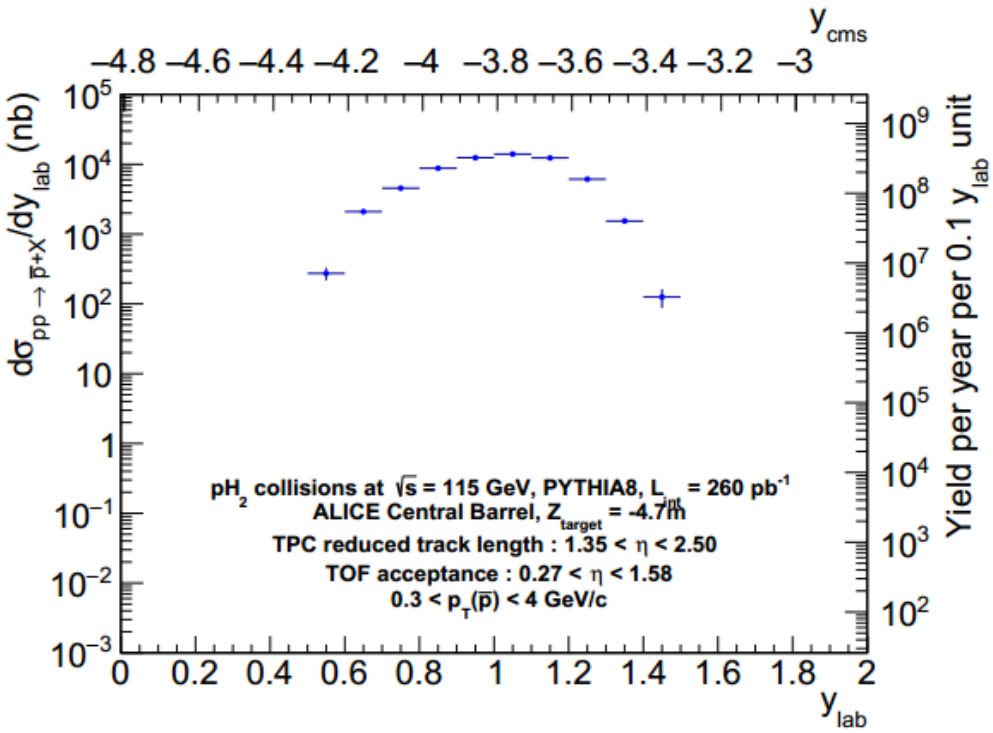
Rapidity scan of the QCD phase diagram

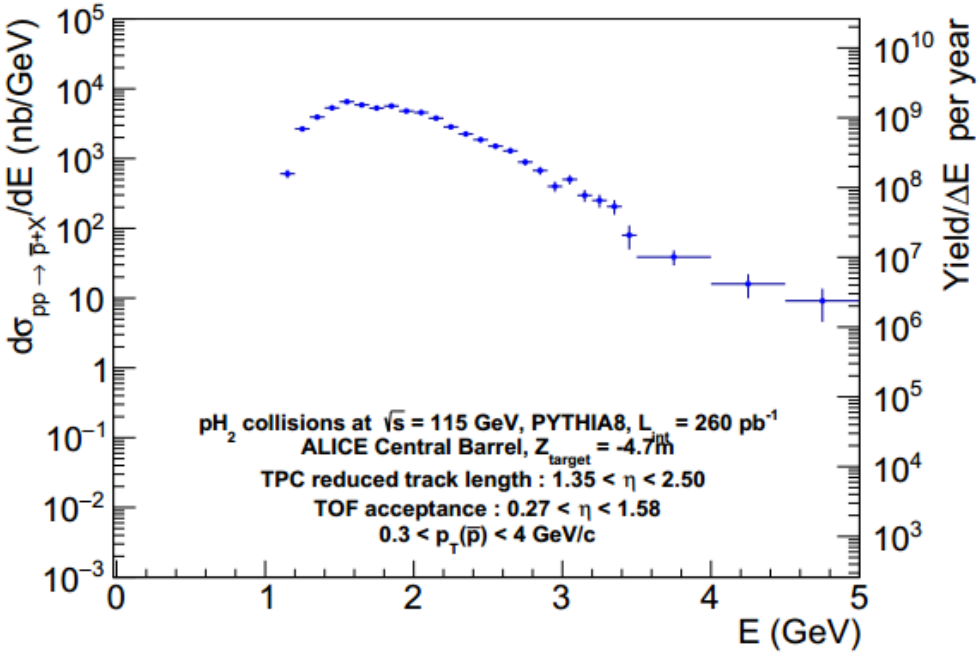


Access to μ_B range comparable to the RHIC Beam Energy Scan

Hadron Resonance Gas model fit to UrQMD simulations, V. Begun et al, PRC98 (2018) 3, 034905

Antiproton measurements → input for astrophysics





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

Example: search of 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.

Plans for the next 2 – 3 years

- Target
  - **Solid target** → pursue integration studies, target location, feasibility of absorber installation
  - **Gas target** → installation feasibility studies
- Simulation studies
  - **Event reconstruction performance**: track reconstruction efficiency for target z = 2.75 m and 4.7 m, track matching, need of an additional vertex tracker? …
  - Possible Impact of FT on ALICE operation in a collider mode

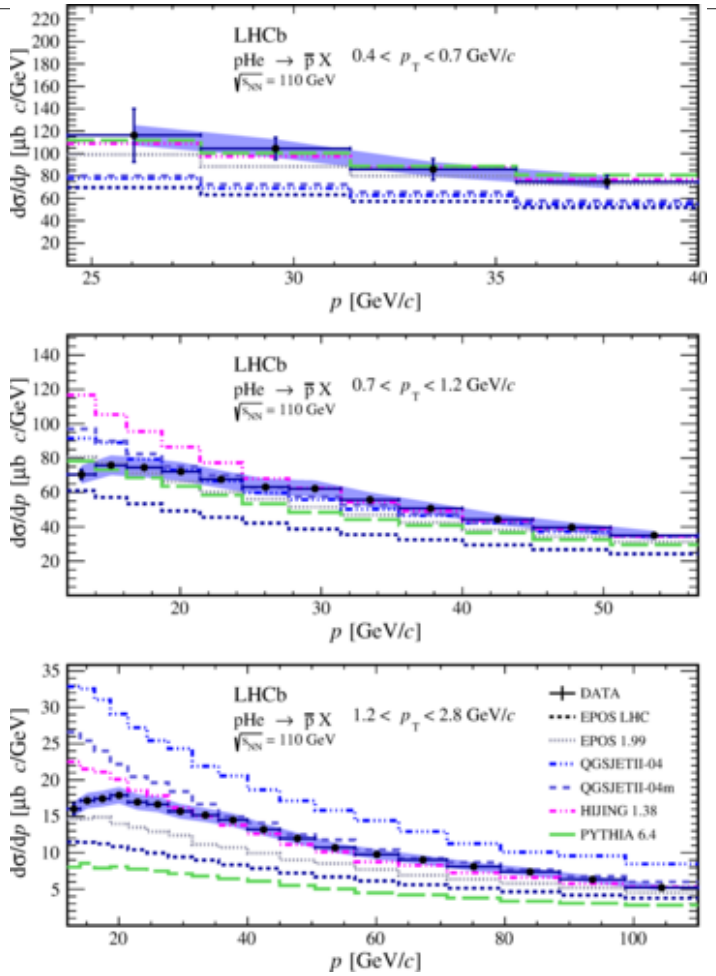
    (possibility of parallel running, impact of the target system material budget on existing or future new detectors)
- *Bent crystal studies with proton and lead beam needed to evaluate the flux*

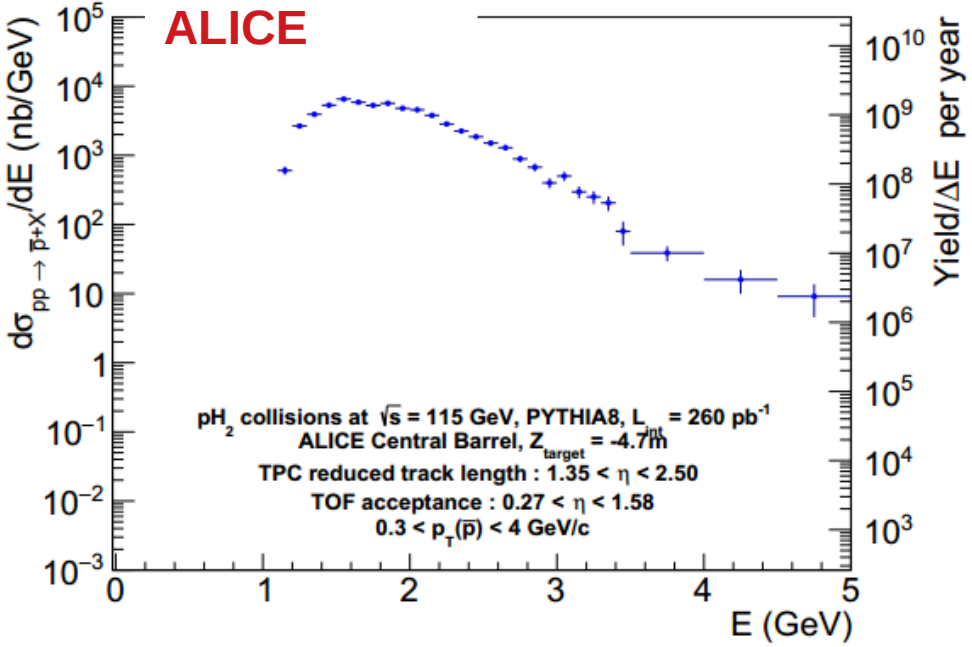
Status and summary

- Rich physics program:
  - high-x (x → 1) structure of nucleon and nuclei
  - heavy-ion collisions
  - antiproton measurements → important input for astroparticle physics
- Ongoing feasibility and performance studies for FT collisions with the ALICE detector
- Technical (target integration) and simulation studies will be continued within the **Horizon 2020 grant STRONG-2020.**
- **If project approved:** aim for a target installation during Long Shutdown 3

Backup

Antiproton measurements → ALICE vs LHCb





ALICE Central Barrel can measure **very slow antiprotons** down to few hundred MeV momentum.

Slow antiprotons produced with the LHC proton beam on a nuclear target equivalent to the case when nuclear target travels at TeV energies, hit an interstellar proton at rest and produces an antiproton with high energy.

R. Aaij et al. PRL 121, 222001