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WARSAW UNIVERSITY OF TECHNOLOGY

AFTER @ LHC

A fixed-target program at the LHC for heavy-ion, hadron, spin and astroparticle physics

Daniel Kikoła

STRONG-2020

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Extensive review, many details, Submitted to Physics Reports

A Fixed-Target Programme at the LHC: Physics Case and Projected Performances for Heavy-Ion, Hadron, Spin and Astroparticle Studies

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Jul 2, 2018 - 102 pages

(2018-08-20)
IFJPAN-IV-2018-11, JLAB-THY-18-2756, SLAC-PUB-17291
e-Print: arXiv:1807.00603 [hep-ex] | PDF

AFTER@LHC *Review*

- General motivations and physics cases
- Comprehensive review of implementation options for a Fixed Target program the LHC
- Detector requirements and expected performances
- Physics Projections
  - **High-x frontier for particle and astroparticle physics**
  - **Spin physics**
  - **Heavy-ion physics**

C. Hadjidakis at al, arXiv:1807.00603

+ extensive review of physics opportunities with projections

C. Hadjidakis at al, arXiv:1807.00603

Why a fixed-target experiment at the LHC?

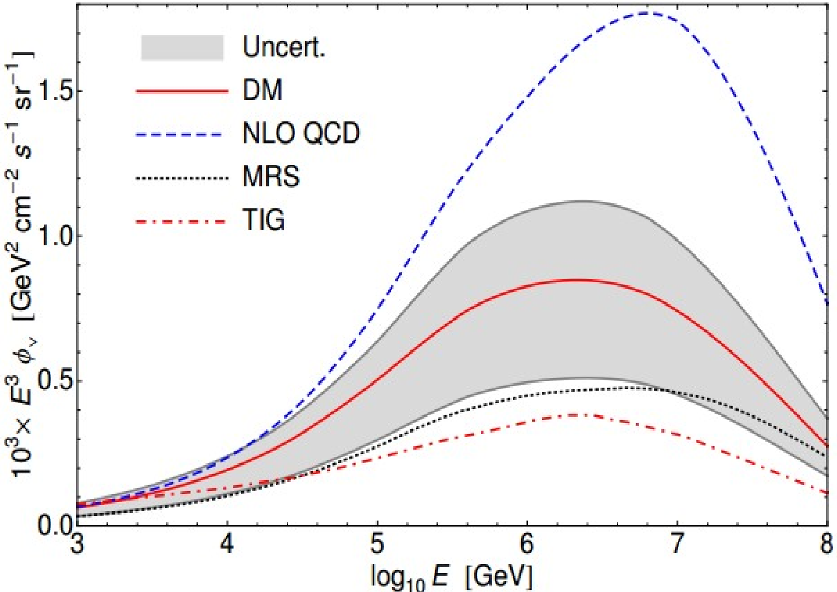
- High luminosities $\rightarrow$ access to rare probes (heavy quarks)
- High precision Heavy-Ion program between SPS and RHIC top energy
- Access to high Feynman x_F domain ($|x_F| = |p_z|/p_{z\,max} \rightarrow 1$)
- Variety of atomic mass of the target,
- Large kinematic coverage
- Polarization of the target $\rightarrow$ spin physics at the LHC

Physics program

High-x frontier

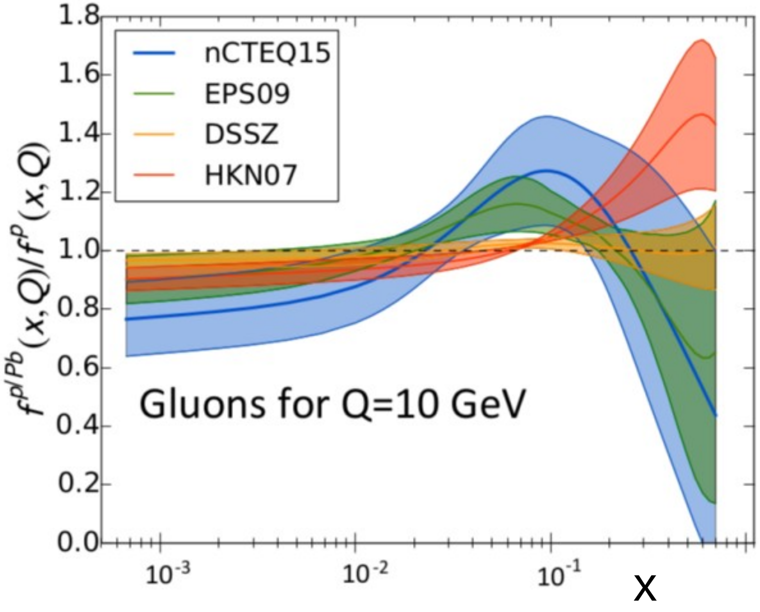
- Advance our understanding of high-x gluons, antiquark and heavy-quark content in the nucleon & nucleus
- AFTER@LHC data → reduce uncertainties on PDFs, astrophysics calculations

Energy spectrum of neutrino flux



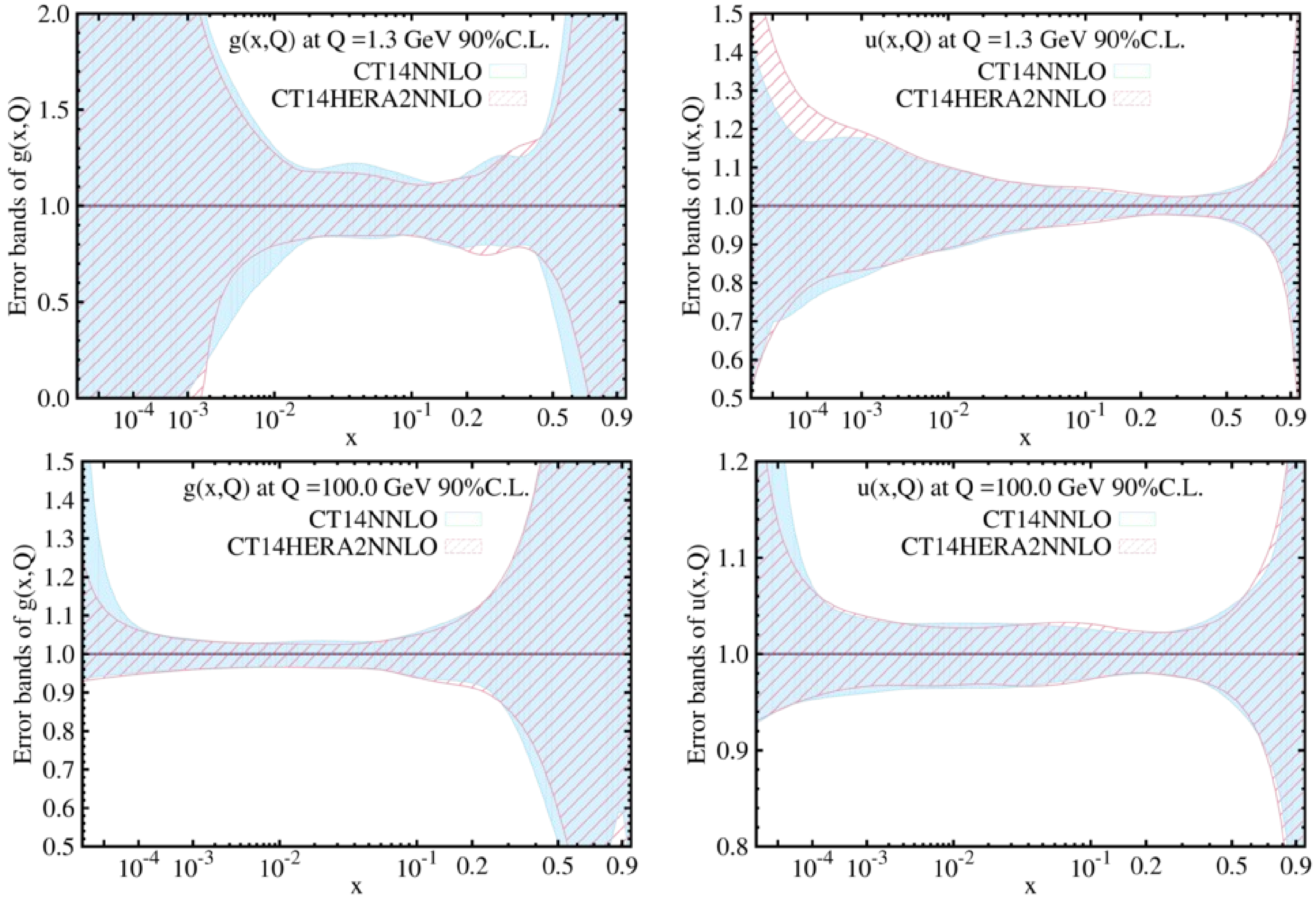
Phys.Rev.D78:043005,2008

Gluon nuclear PDFs



Phys. Rev. D 93, 085037 (2016)

Constraining parton distribution functions



CT14 global analysis, http://hep.pa.msu.edu/cteq/public/

Nucleon spin structure

$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g$$

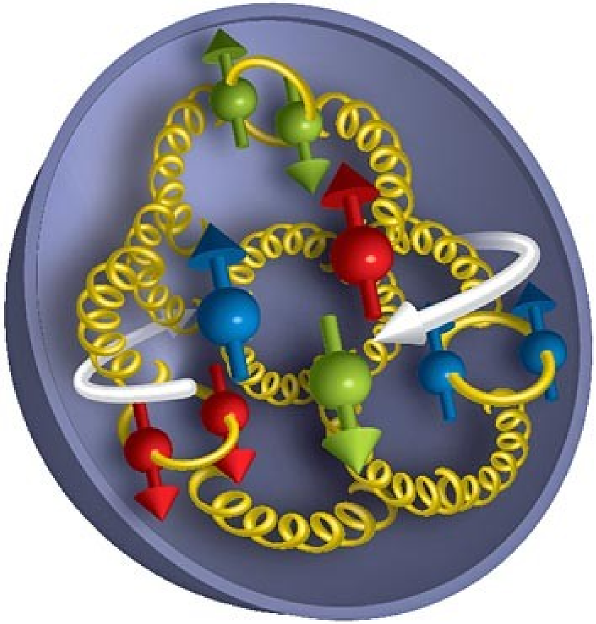


Image: Courtesy Brookhaven National Laboratory.

Nucleon spin structure

$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g$$

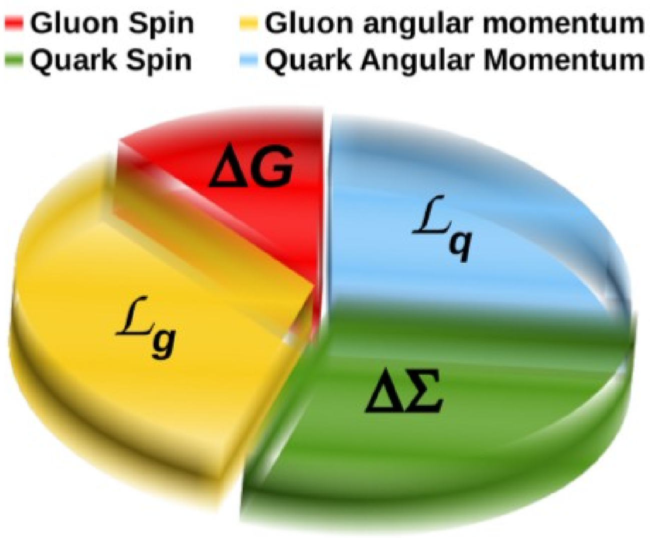
quarks (~30%)

$$\Delta\Sigma = \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s}.$$

Nucleon spin structure

$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g$$

gluons (~20%)



STAR, Phys. Rev. Lett. 115, 092002 (2015)

Nucleon spin structure

$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g$$

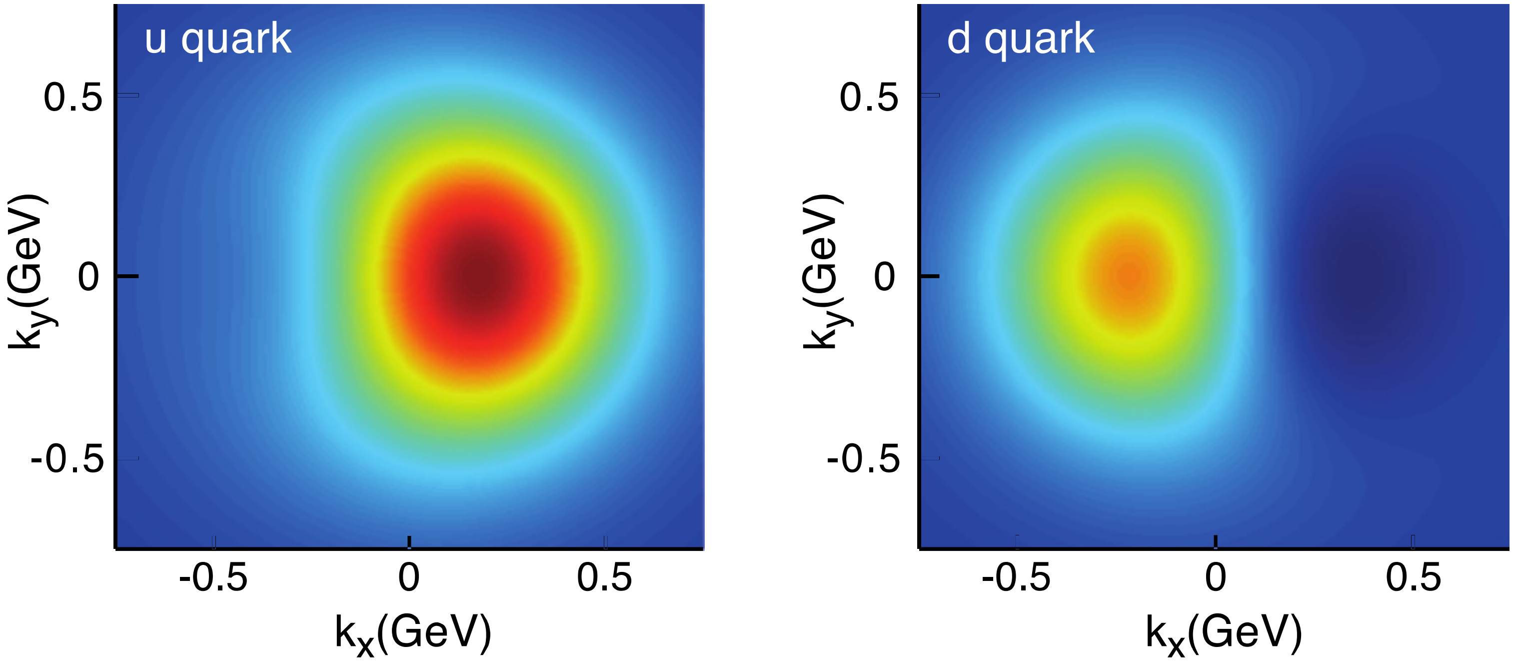
Angular momentum

→ **quark and gluon dynamics**

Transverse Momentum Dependent parton distributions

→ proton "image" in transverse and longitudinal momentum space (2+1 dimensions).

$x\, f_1(x, k_T, S_T)$



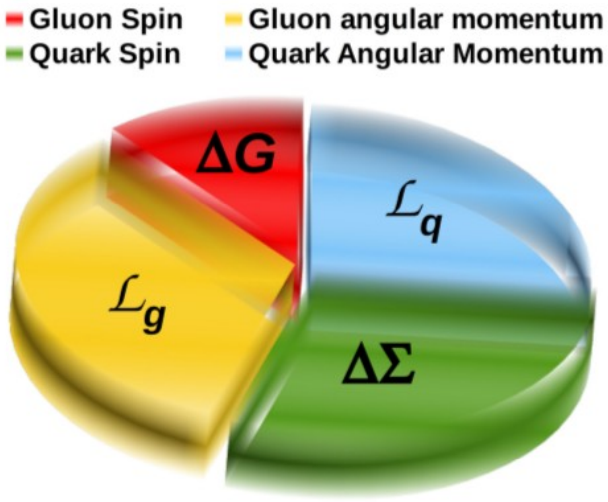
The Spin Physics Program

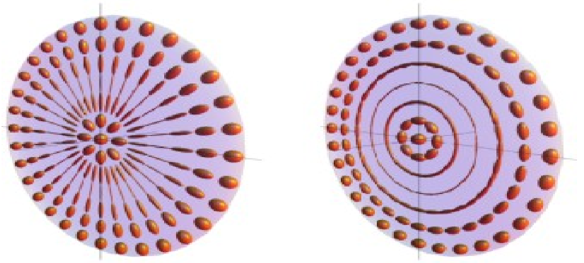
3D mapping of the parton momentum:

- Missing contribution to the proton spin: Gluon and Quark Orbital Angular Momentum L_q and L_g

  p+p↑ → (indirect) access to quark L_q, gluon L_g and gluon transverse-momentum dependent PDF

- Determination of the linearly polarized gluons in unpolarized protons





Phys. Rev. Lett. 112, 212001

Heavy-ion collisions

AFTER@LHC

Heavy-ion collisions at

$\sqrt{s_{NN}}$ = 72 -115 GeV

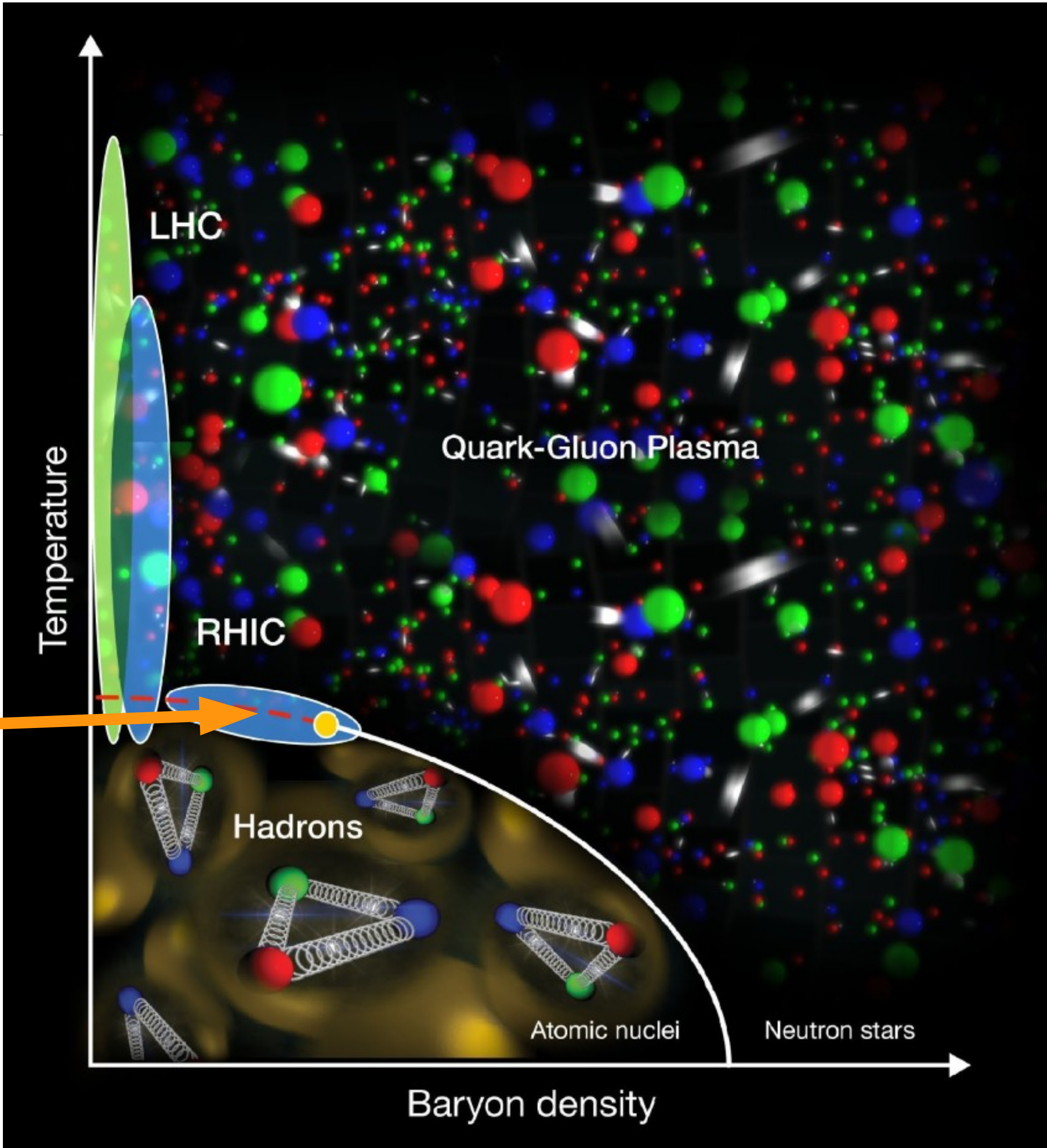
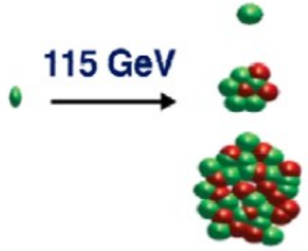


Figure courtesy of Brookhaven National Laboratory

Fixed-target collisions at LHC

Kinematics

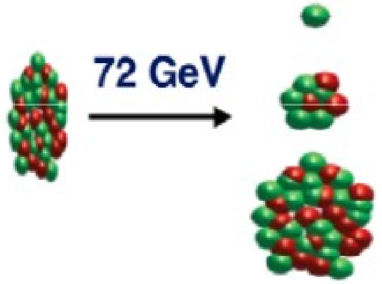
- p+p or p+A with a 7 TeV p on a fixed target



$$\sqrt{s} = \sqrt{2 m_N E_p} \approx 115\,GeV$$

$$y_{CMS} = 0 \rightarrow y_{Lab} = 4.8$$

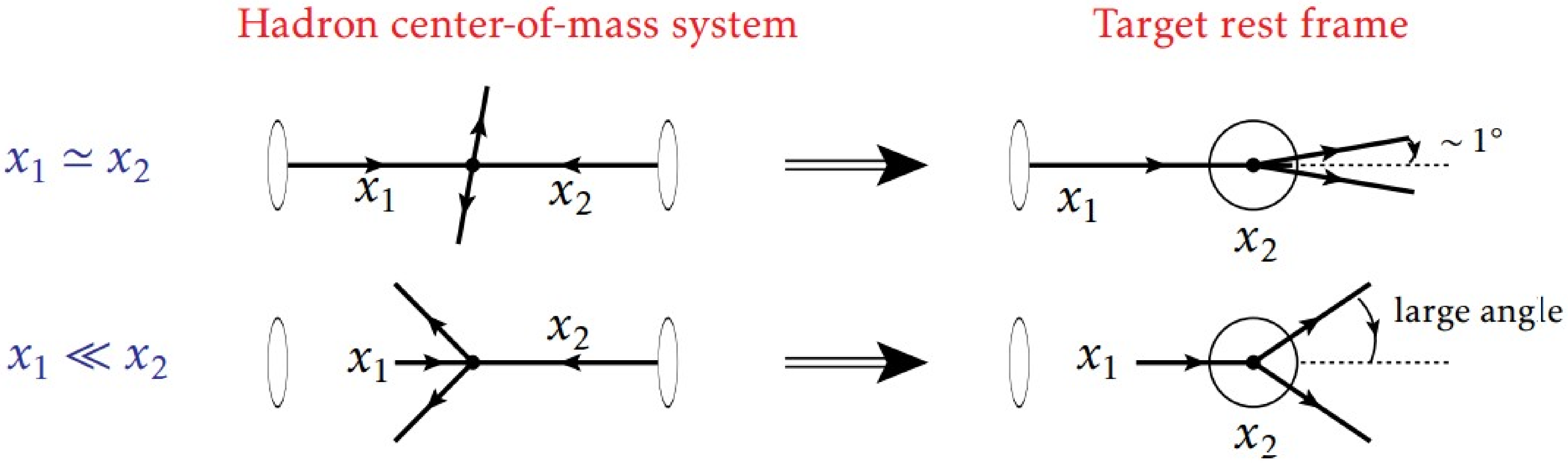
- A+A collisions with a 2.76 TeV Pb beam



$$\sqrt{s} \approx 72\,GeV$$

$$y_{CMS} = 0 \rightarrow y_{Lab} = 4.3$$

Boost effect → access to backward physics

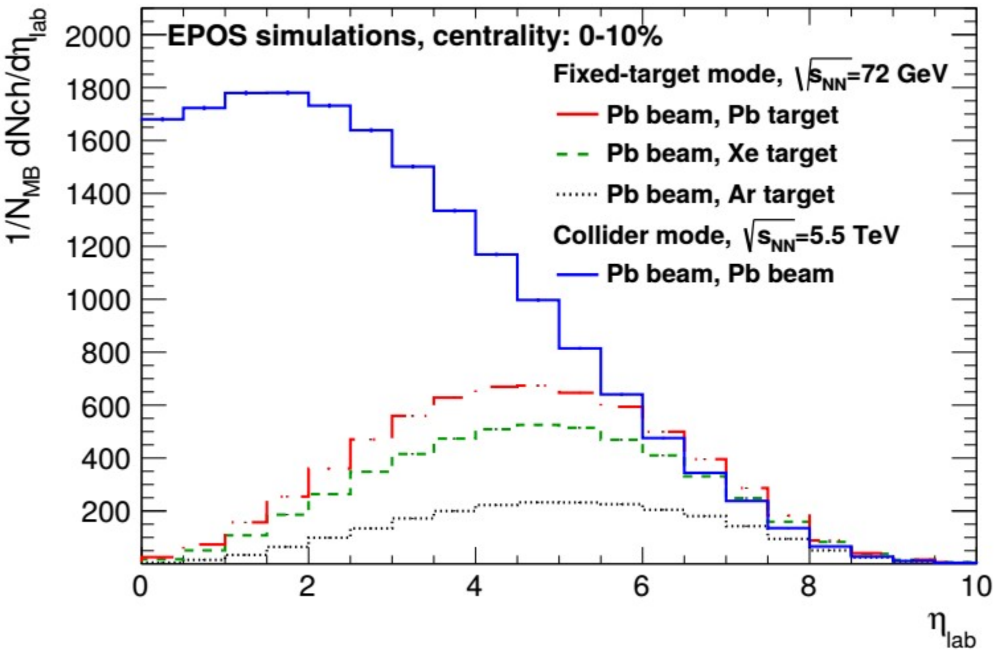


backward physics = large-x_2 physics ($x_F < 0 \rightarrow$ large x_2)

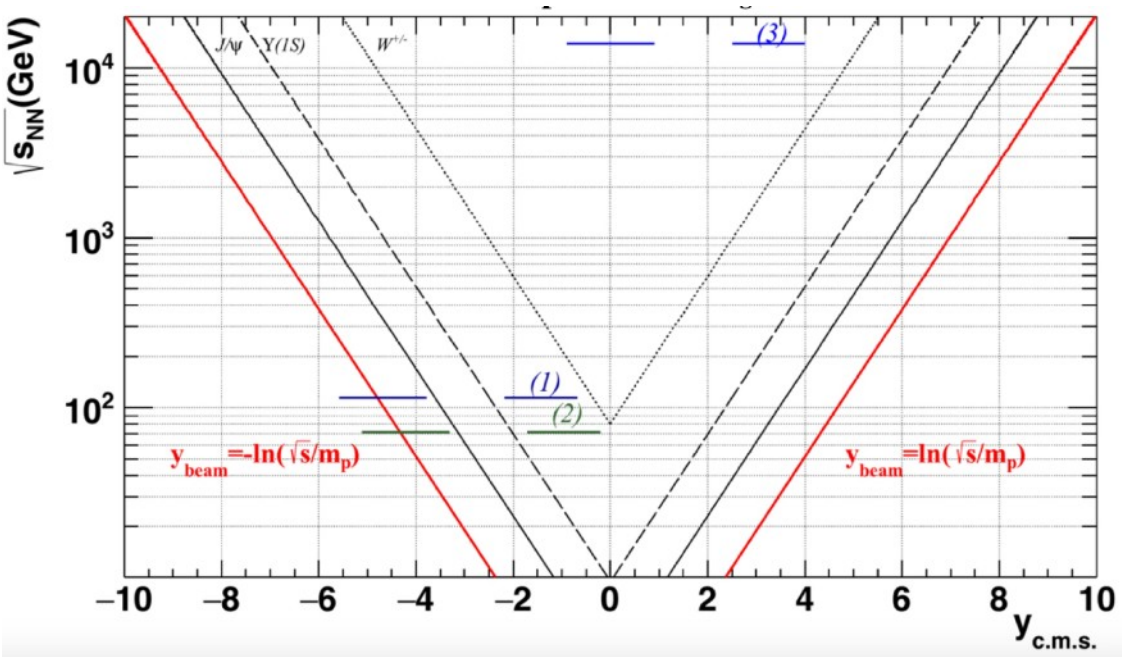
Detector requirements

- Wide rapidity coverage with PID and vertexing capabilities
- Readout rate similar as LHC collider: up to 40 MHz in pp, 300 MHz in pA and 200 kHz in PbA
- Heavy-ion: good detector performance in high-multiplicity events, up to 600 charged tracks per unit of rapidity at η_{lab} ~4

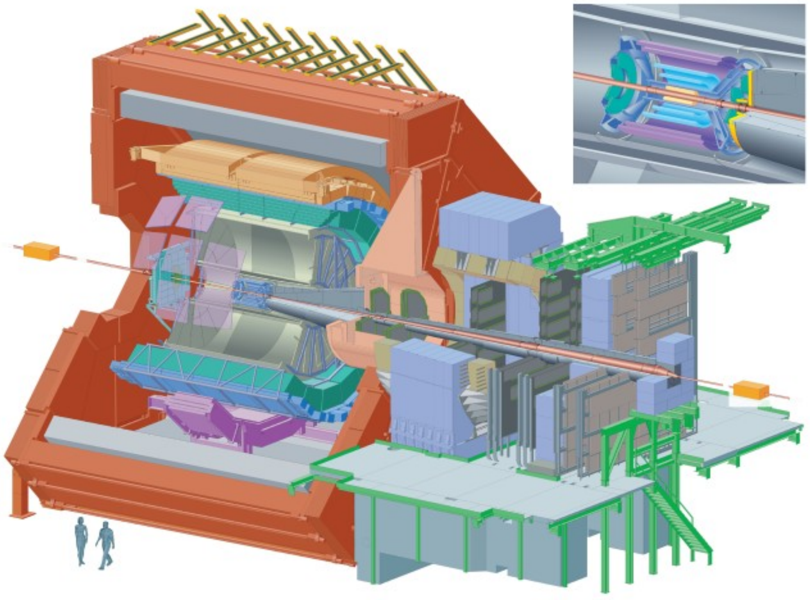
L. Massacrier et al.,
Adv.Hi.En.Phys. (2015) 986348



Kinematic coverage: collider vs fixed target



ALICE detector



ALICE: Muon Det.: $2.5 < \eta^{lab} < 4$,

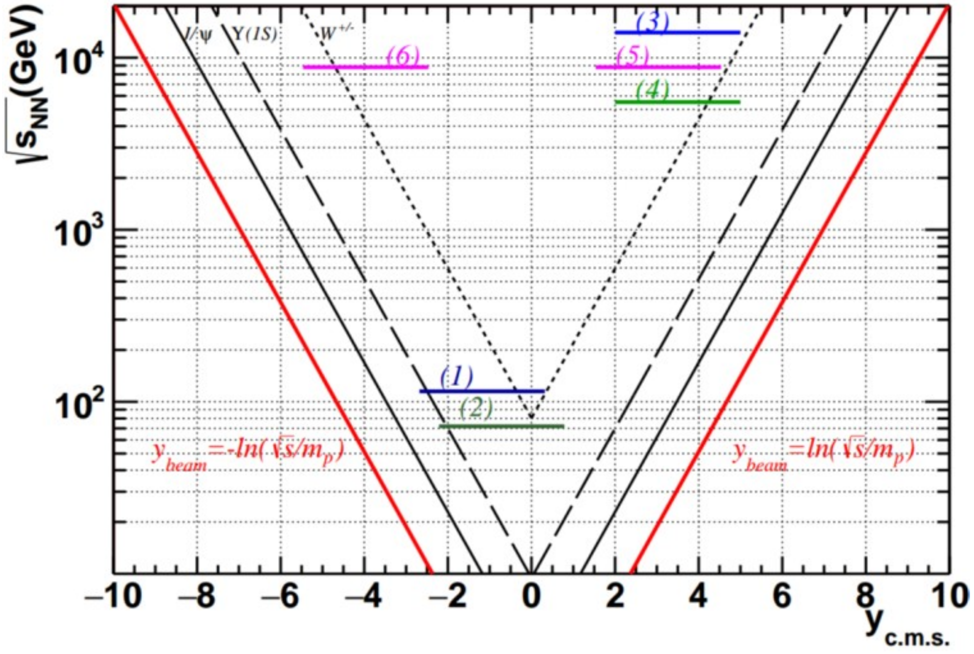
TPC: $|\eta^{lab}| < 0.9$

http://aliceinfo.cern.ch

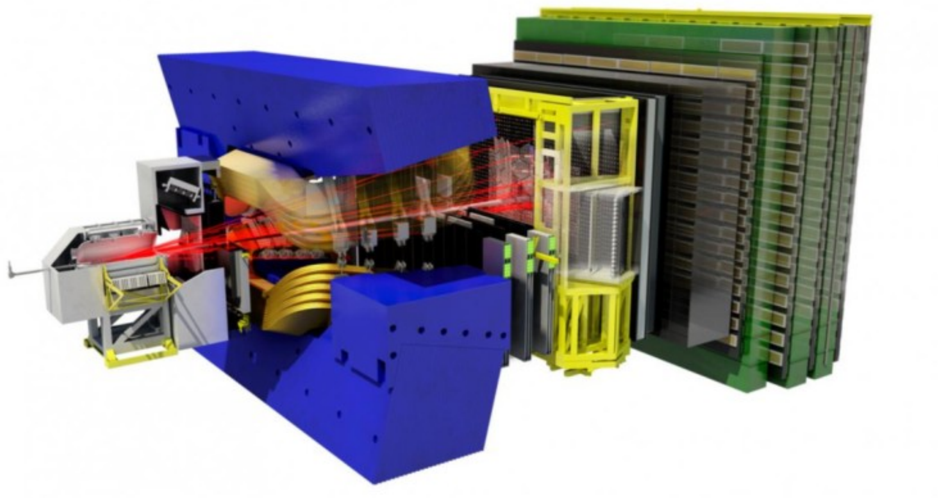
(1) fixed target, $\sqrt{s_{NN}}$ = 115 GeV; (2) fixed target, $\sqrt{s_{NN}}$ = 72 GeV;
(3) collider mode, $\sqrt{s}$ = 14 TeV;

for $Z_{target} \sim 0$

Kinematic coverage: collider vs fixed target



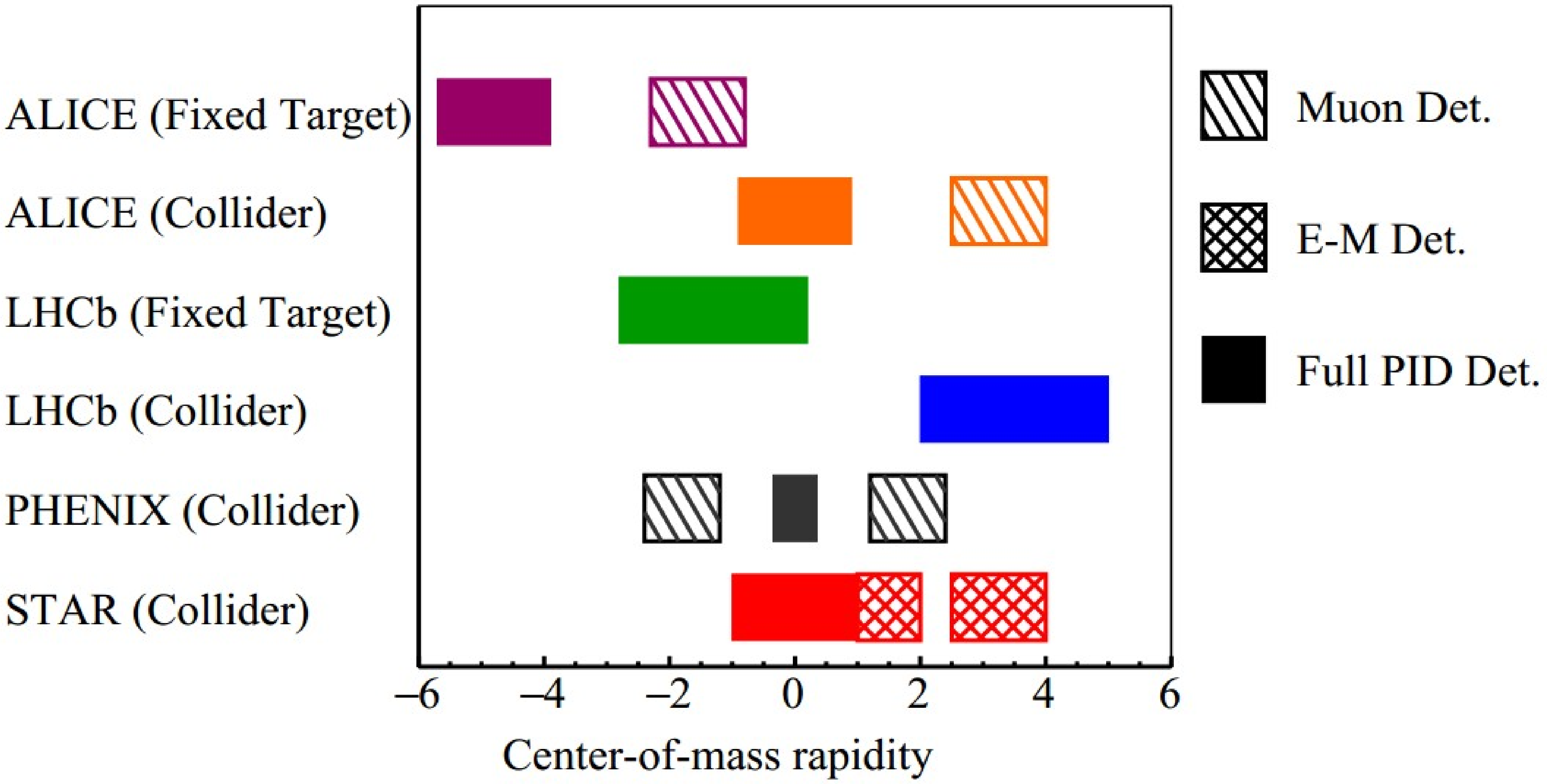
LHCb detector



https://lhcb.web.cern.ch/lhcb

LHCb: $2 < \eta^{lab} < 5$

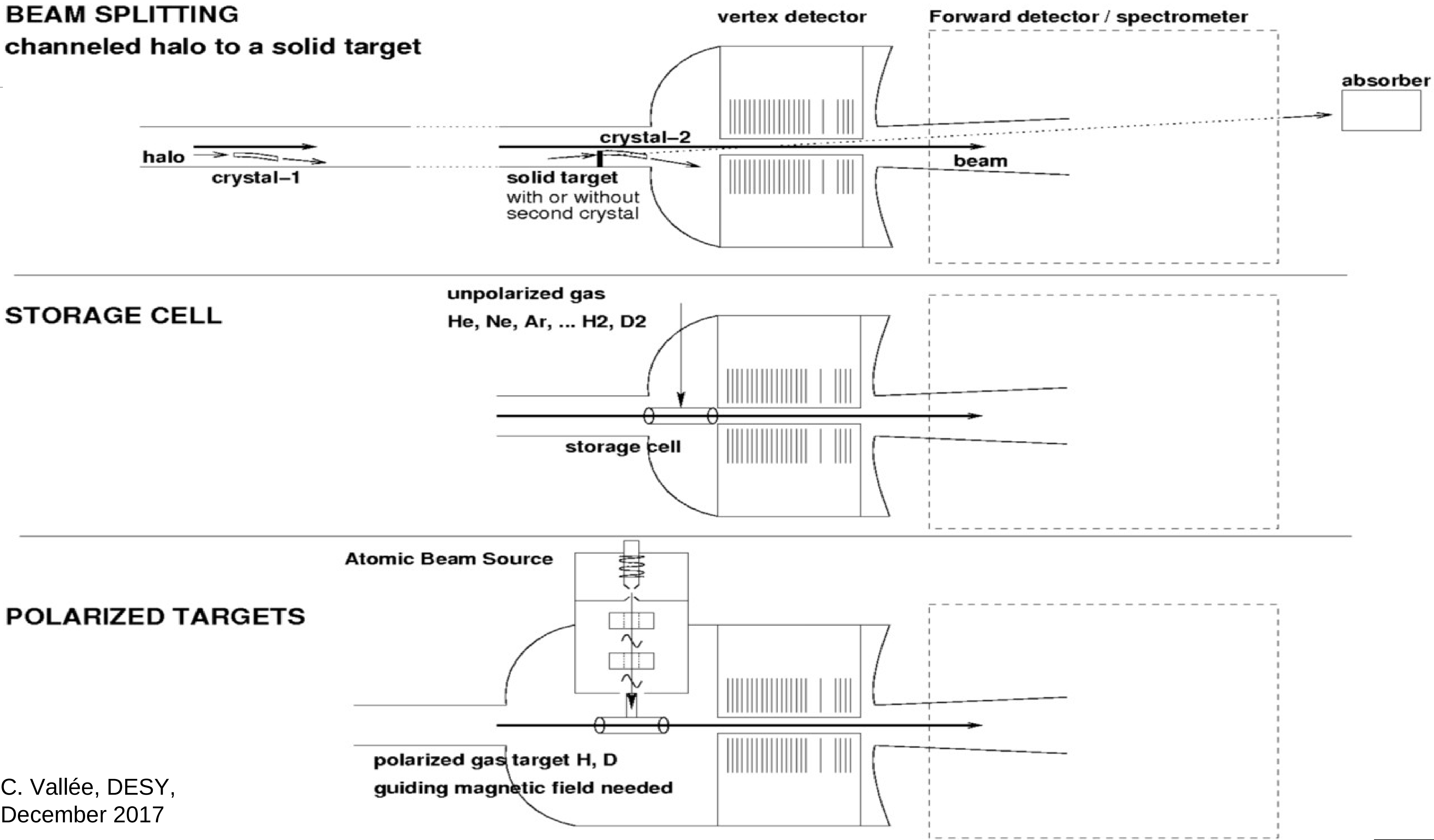
(1) fixed target, $\sqrt{s_{NN}}$ = 115 GeV; (2) fixed target, $\sqrt{s_{NN}}$ = 72 GeV;
(3) collider mode, $\sqrt{s}$ = 14 TeV; (4) collider mode, $\sqrt{s_{NN}}$ = 5.5 TeV, (5),(6) $\sqrt{s_{NN}}$ = 8.8 TeV


ALICE (Fixed Target)
ALICE (Collider)
LHCb (Fixed Target)
LHCb (Collider)
PHENIX (Collider)
STAR (Collider)
Muon Det.
E-M Det.
Full PID Det.
−6
−4
−2
0
2
4
6
Center-of-mass rapidity

How to make fixed-target collisions with the LHC beams?

- Internal (solid or gas) target + existing detector
  - gas target (unpolarized/polarized) and full LHC beam
  - beam splitting by bent-crystal + internal (solid, pol.?) target
  - internal Wire/Foil target (directly in the beam halo)
- Beam extraction by bent-crystal
  - new beam line + new experiment

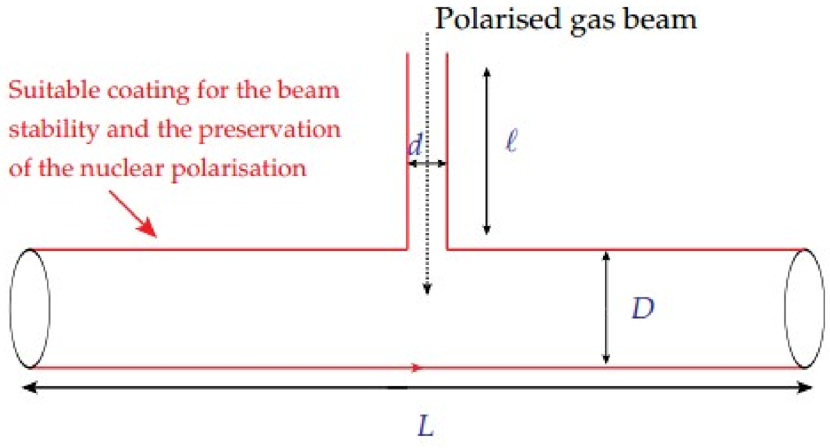
Under study within the Physics Beyond Collider working group (https://pbc.web.cern.ch)
S. Redaelli et al. Proceedings of IPAC2018
Physics Beyond Collider Working Group meeting June 2018: https://indico.cern.ch/event/706741/

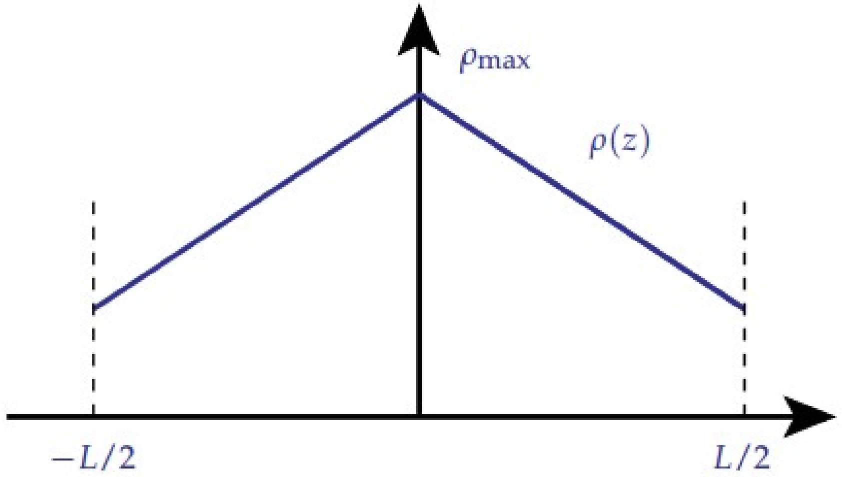


C. Vallée, DESY,
December 2017

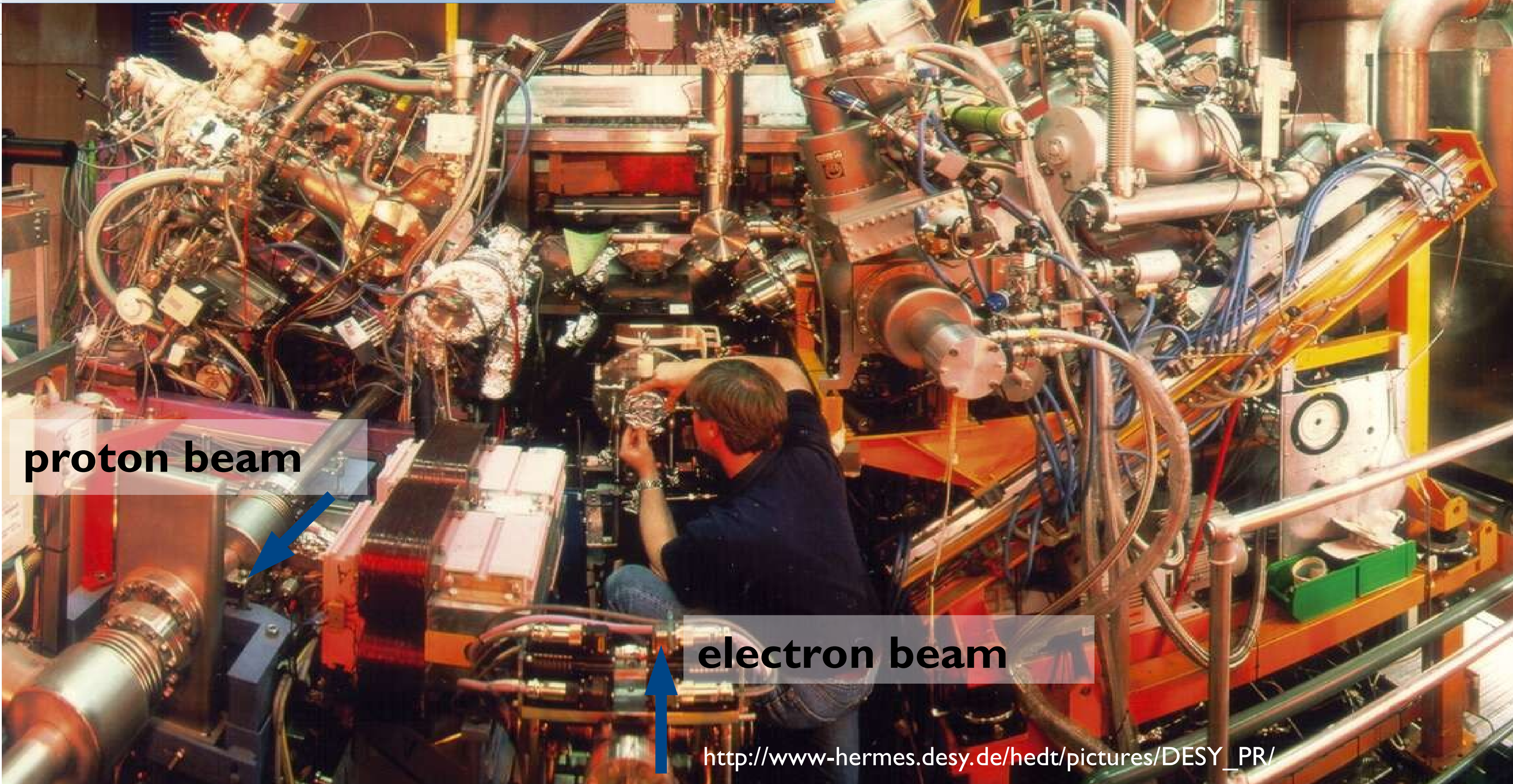
Gas target: storage cell

- Dedicated pumping system
- Polarized $H^{\uparrow}$ and $D^{\uparrow}$ injected in open-end storage cell with polarization P ~80% **(requires additional polarized gas target)**
- Possible polarized $^{3}He^{\uparrow}$ or unpolarized heavy gas (Kr, Xe)
- Expected L_{int} over a year (for 1 m cell):
  - p-H $\sqrt{s_{NN}}$ = 115 GeV, L_{int} ~ 10 fb^{-1}
  - Pb-H $\sqrt{s_{NN}}$ = 72 GeV, L_{int} ~ 100 nb^{-1}
  - Pb-Xe $\sqrt{s_{NN}}$ = 72 GeV, L_{int} ~ 30 nb^{-1}



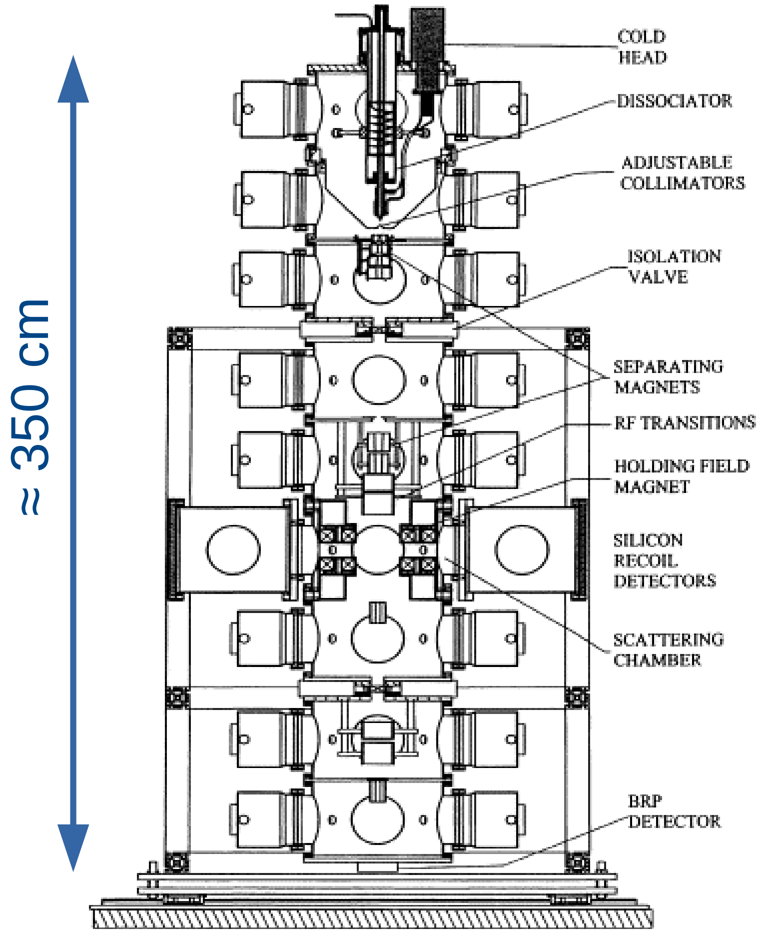


HERMES-target in the HERA tunnel



The hydrogen jet polarimeter

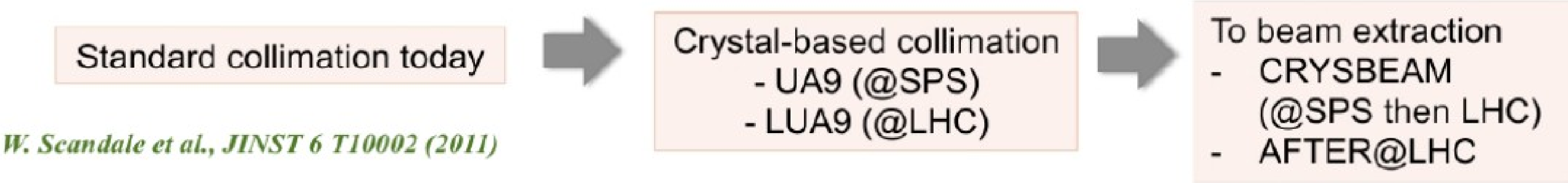
- Used to measure the proton beam polarisation at RHIC
- 9 vacuum chambers, 9 stages of differential pumping
- Polarised free atomic beam source (ABS)
- L_{int} (pH) ~ 50 pb^{-1} per year



NIM A 536 (2005) 248

Beam splitting by bent-crystal

Motivation: beam collimation



→ Deflecting the beam halo at 7σ distance to the beam, reduces beam loss

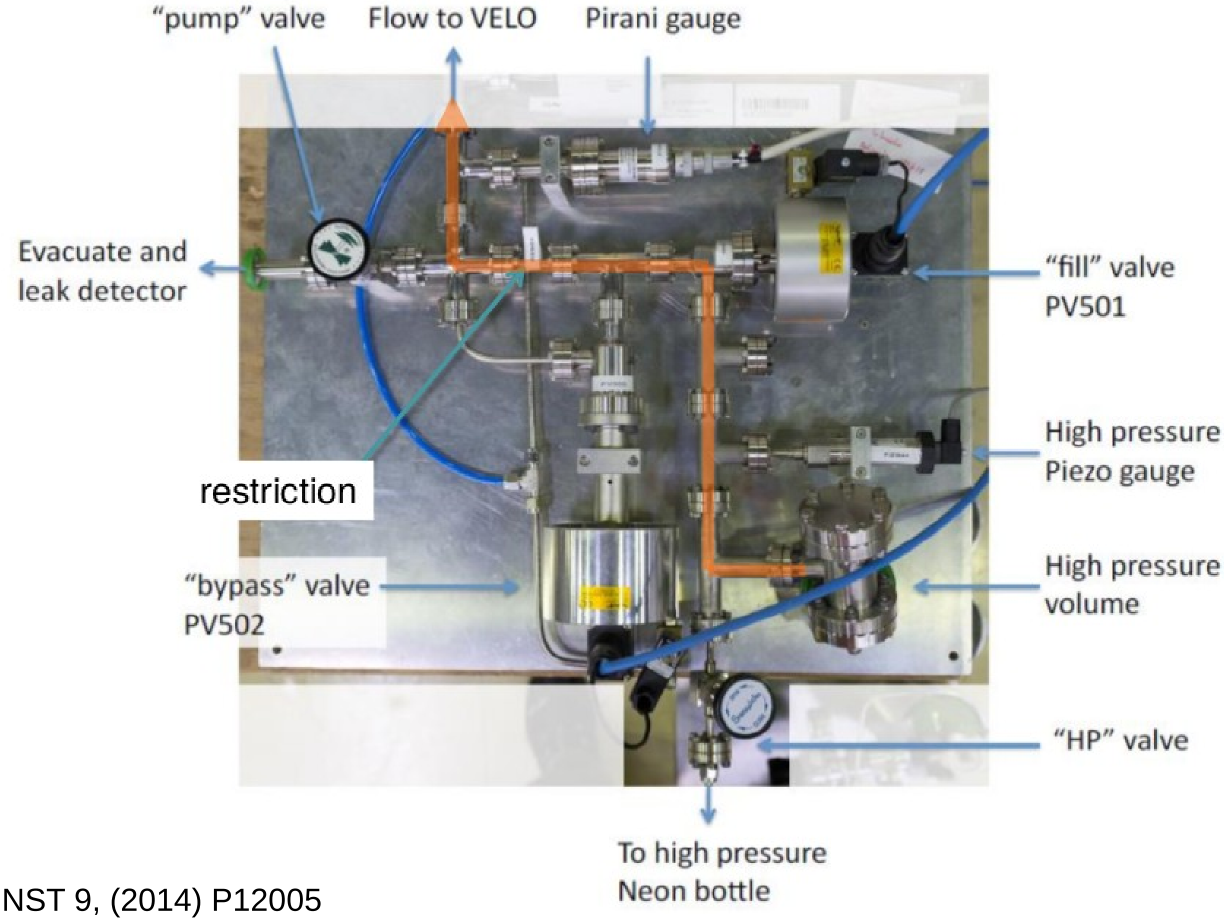
→ Beam splitting: could be used with existing experiment

W. Scandale, PBC workshop 2016, https://indico.cern.ch/event/523655/contributions/2284521/

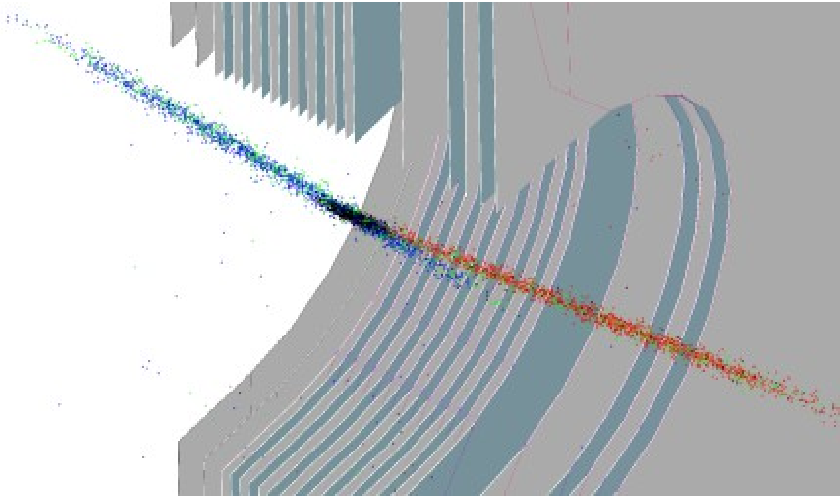
Fixed Target collisions in collider settings

SMOG-LHCb: the demonstrator of a gas target

System for Measuring Overlap with Gas



Luminosity determination with beam gas imaging



JINST 9, (2014) P12005

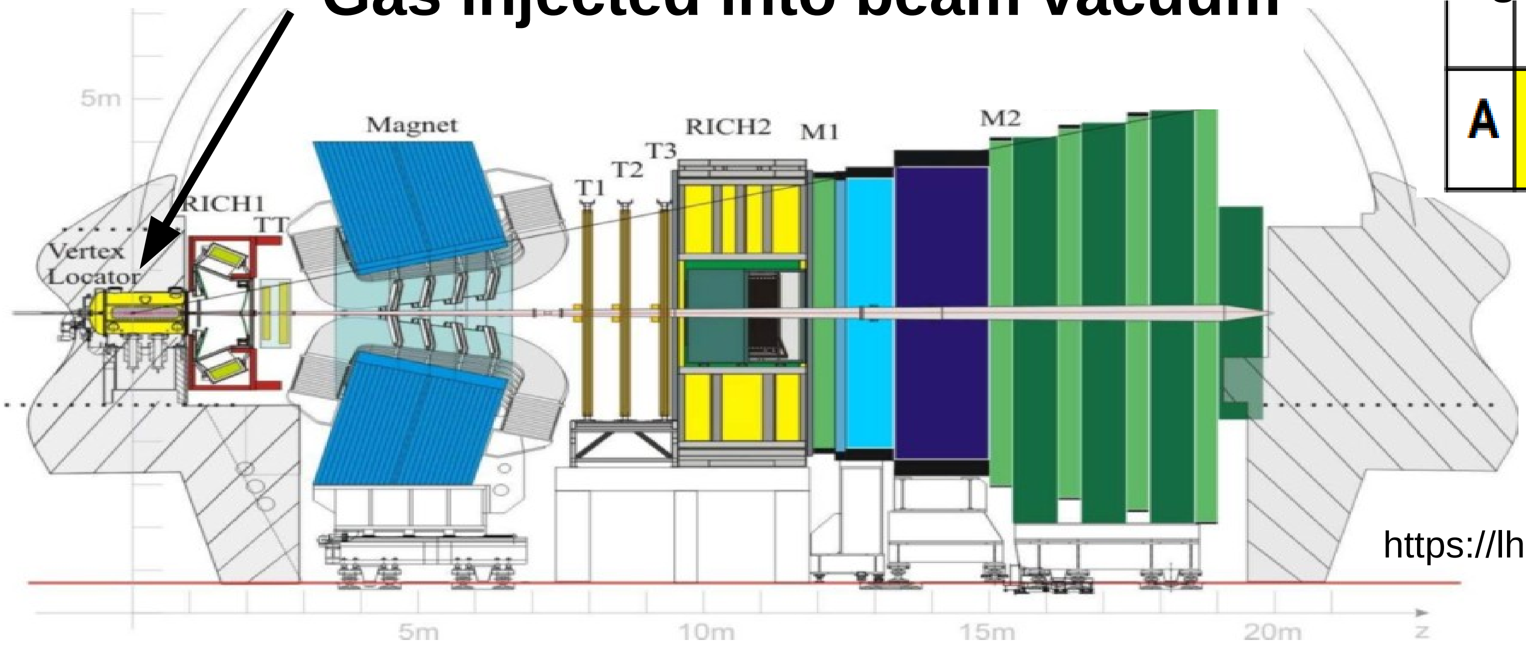
SMOG-LHCb: the demonstrator of a gas target

System for Measuring Overlap with Gas

Target gas: only noble gases

	He	Ne	Ar	Kr	Xe
A	4	20	40	84	131

Gas injected into beam vacuum



https://lhcb.web.cern.ch/lhcb

Successful p+Ne, p+Ar, p+He, Pb+Ar, Pb+Ne data taking

Limitations: Limited luminosities; no p+p baseline; no heavy nuclei yet

SMOG data samples

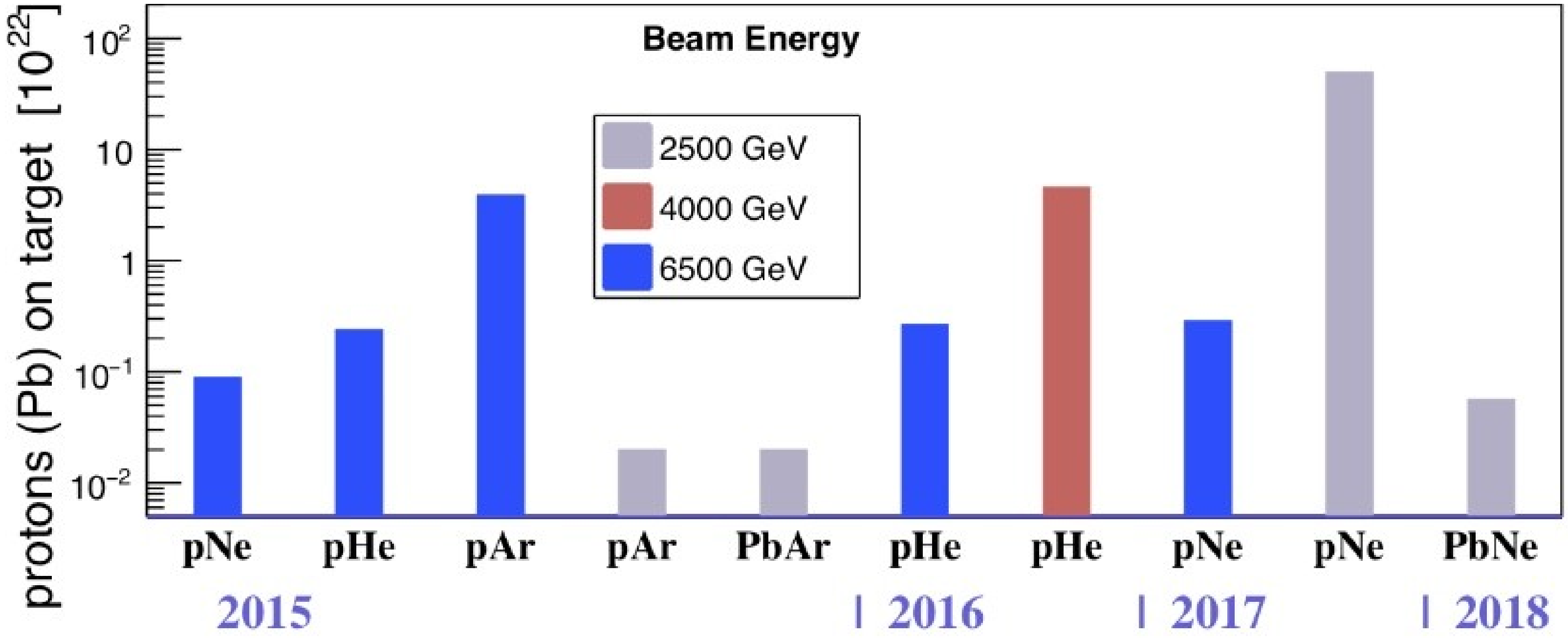
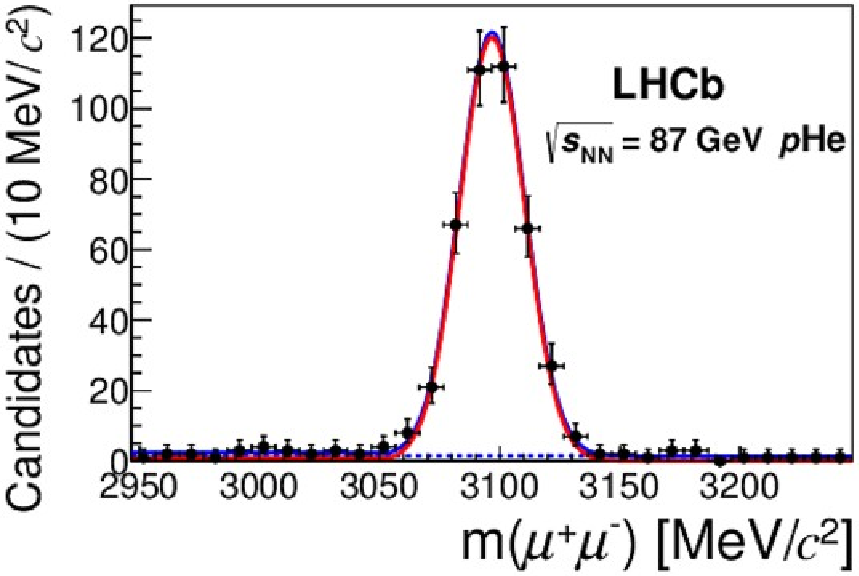


Figure 1: Dedicated SMOG runs collected since 2015. Beam-gas collisions have been recorded using different gas types (He, Ar, Ne) and beam energies.

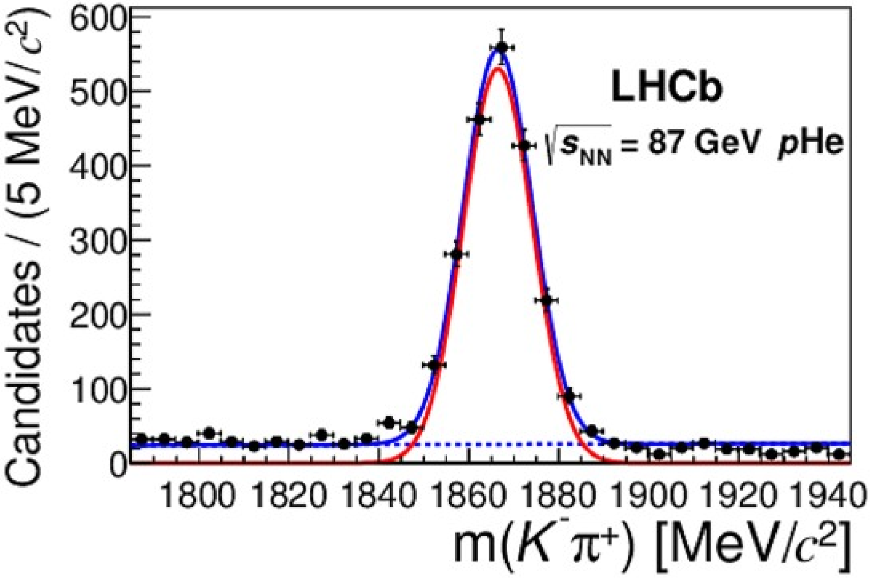
https://cds.cern.ch/record/2673690/files/LHCB-TDR-020.pdf

SMOG-LHCb data

J/ψ



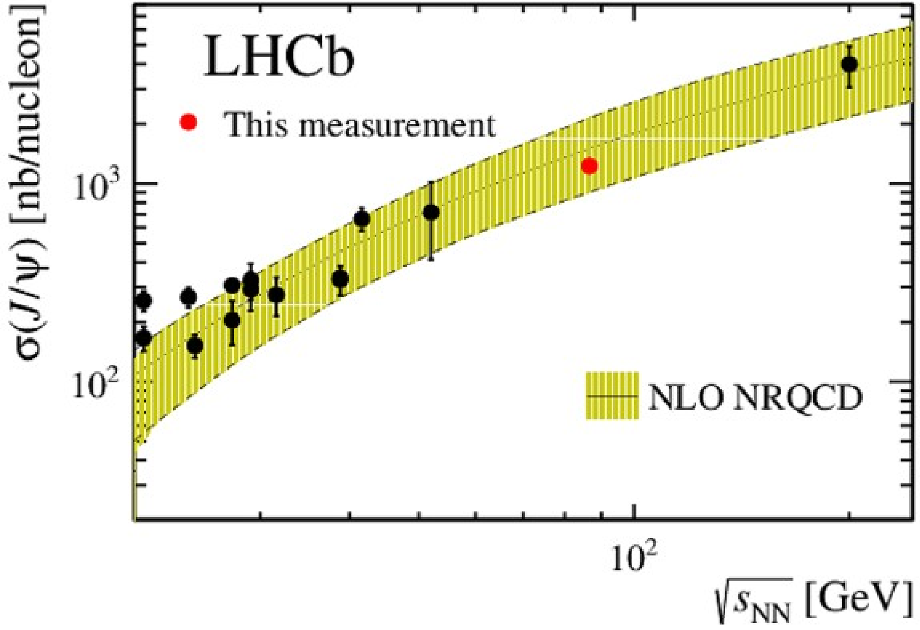
D^0

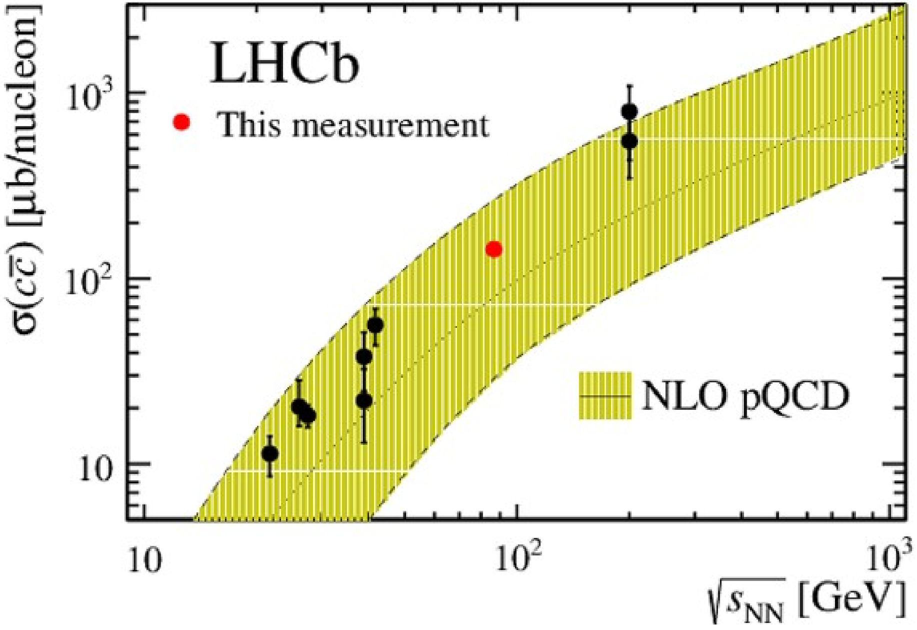


R. Aaij et al. (LHCb Collaboration)
Phys. Rev. Lett. 122, 132002

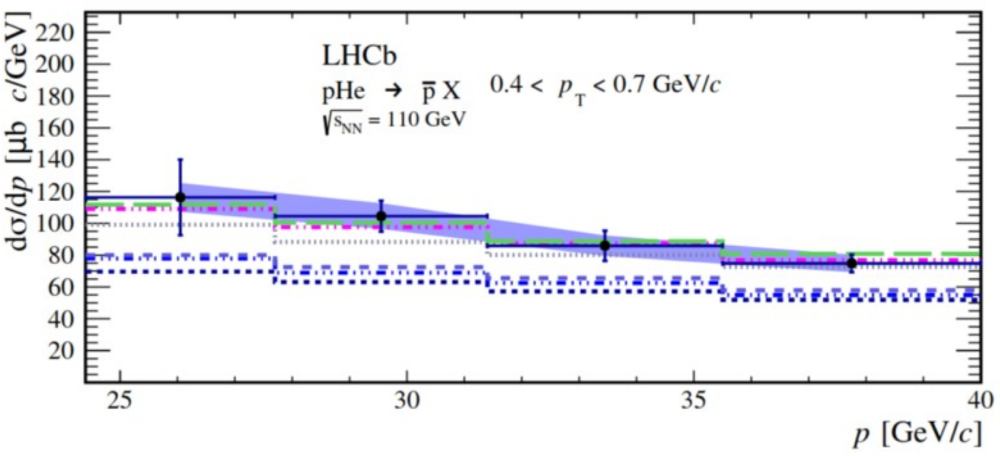
First Measurement of Charm Production in its Fixed-Target Configuration at the LHC

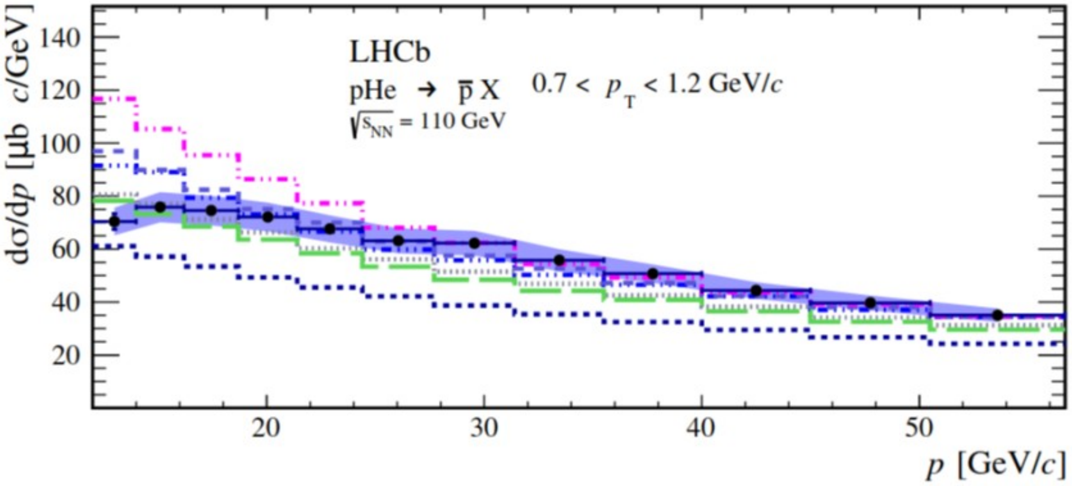
R. Aaij et al. (LHCb Collaboration)
Phys. Rev. Lett. 122, 132002

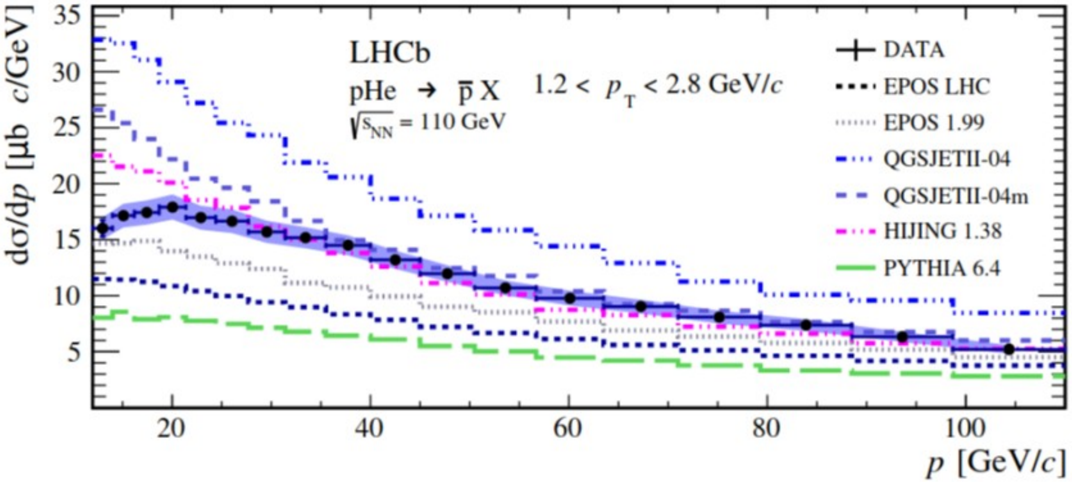




Antiproton production in LHCb Fixed Target

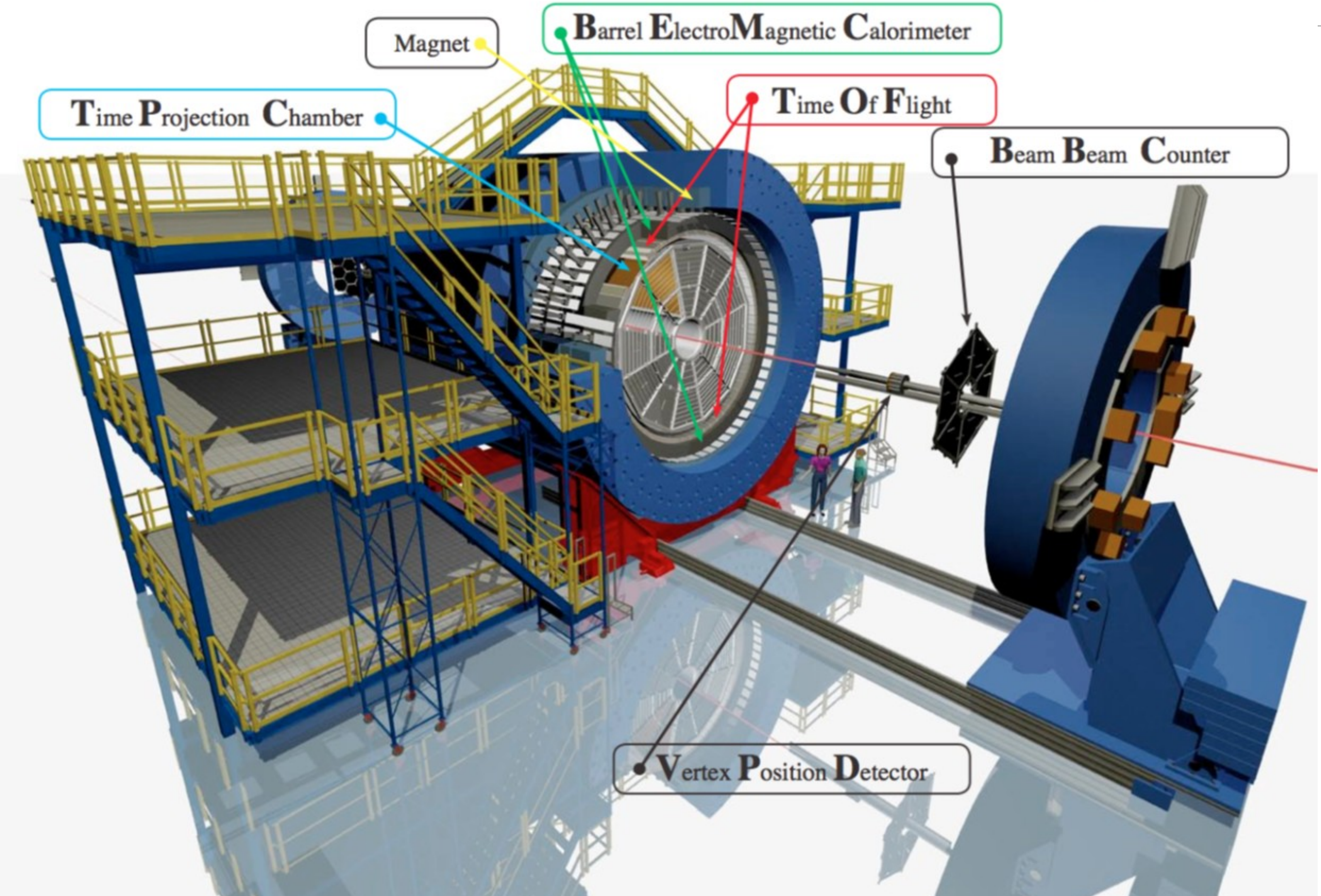






R. Aaij et al. PRL 121, 222001

Solenoidal Tracker At RHIC : $-1 < \eta < 1, 0 < \phi < 2\pi$

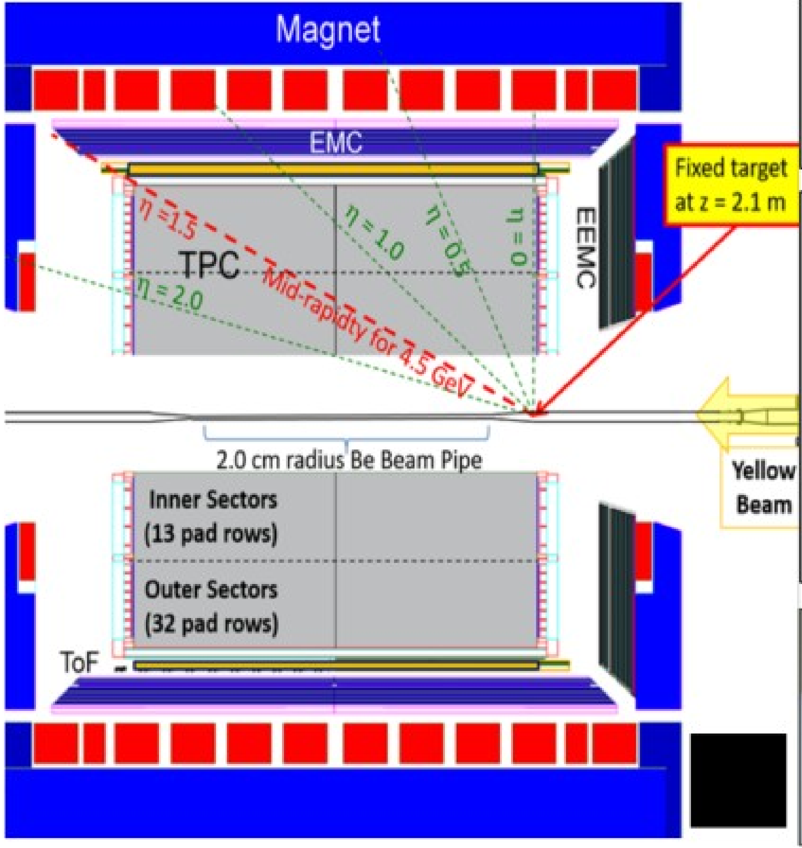


TPC: PID via dE/dx, tracking

TOF: PID.

BEMC: PID via E/p, fast online trigger

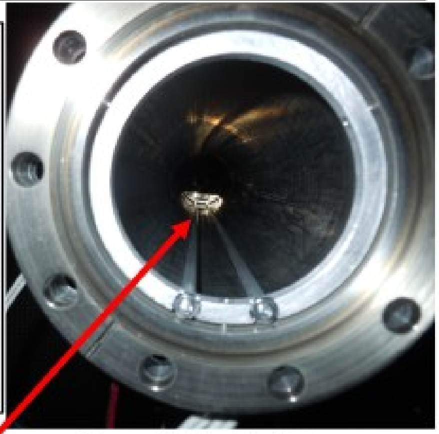
Fixed-Target Geometry

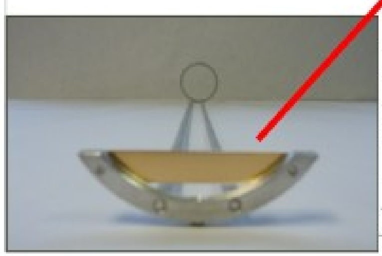


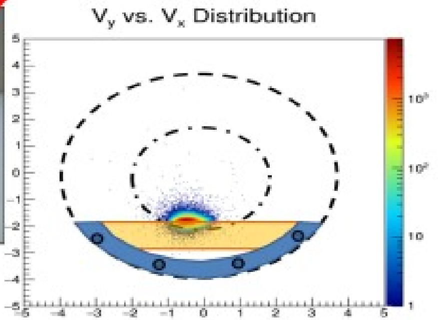
→target is outside of the STAR TPC at ~211 cm

→Gold foil is 1mm thick with about a 4% interaction probability

→1.3M Au+Au events with top 30% centrality trigger



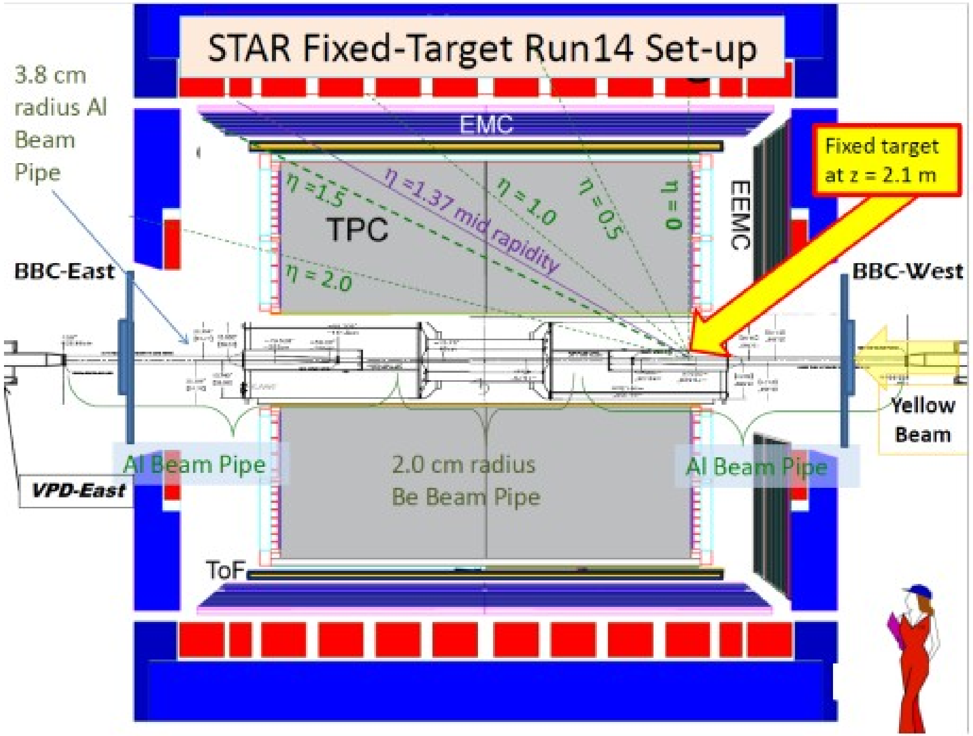


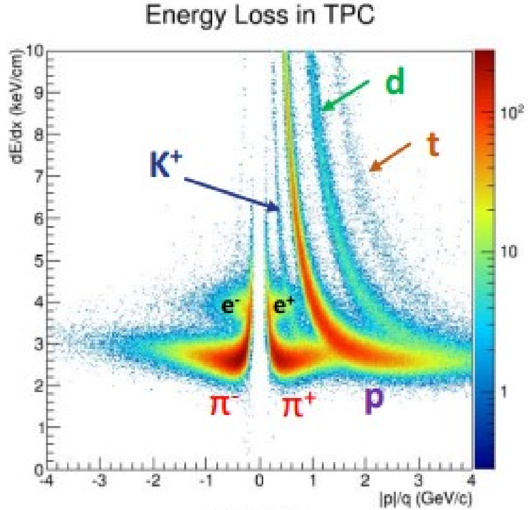


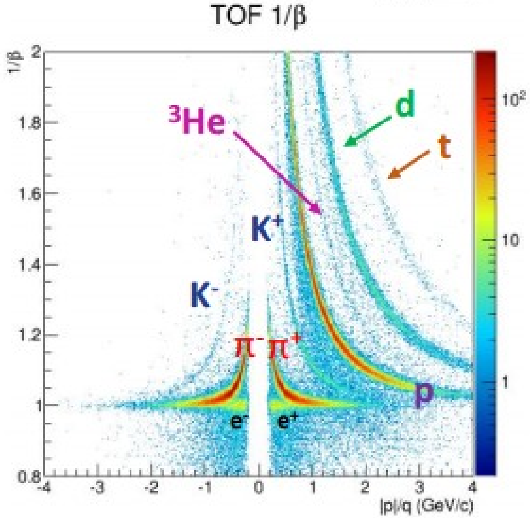
Fixed Target in STAR

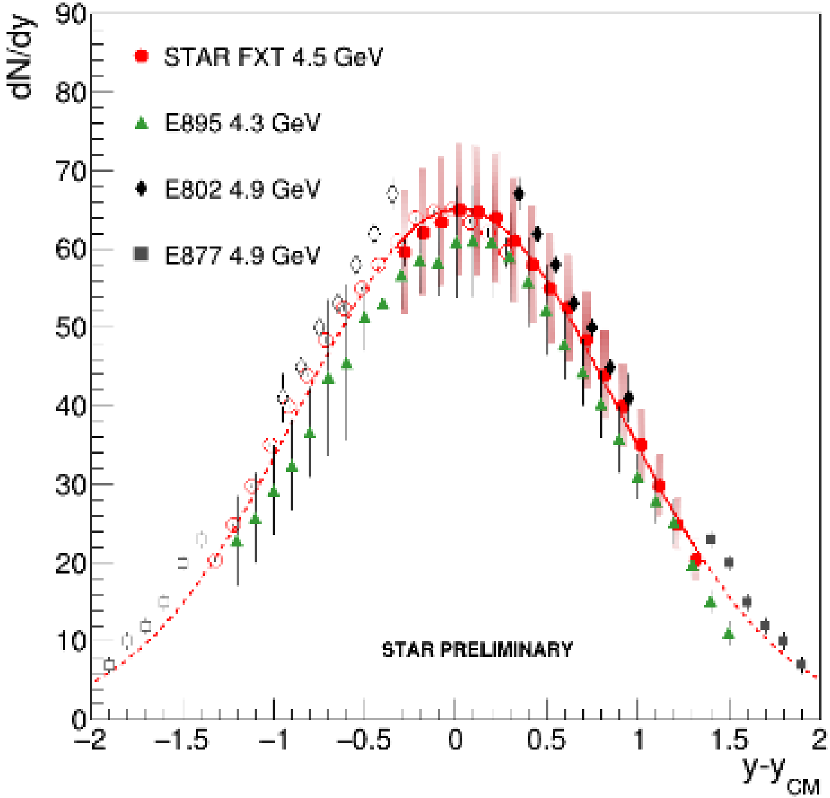
3.9 GeV Au + Au Test Run

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

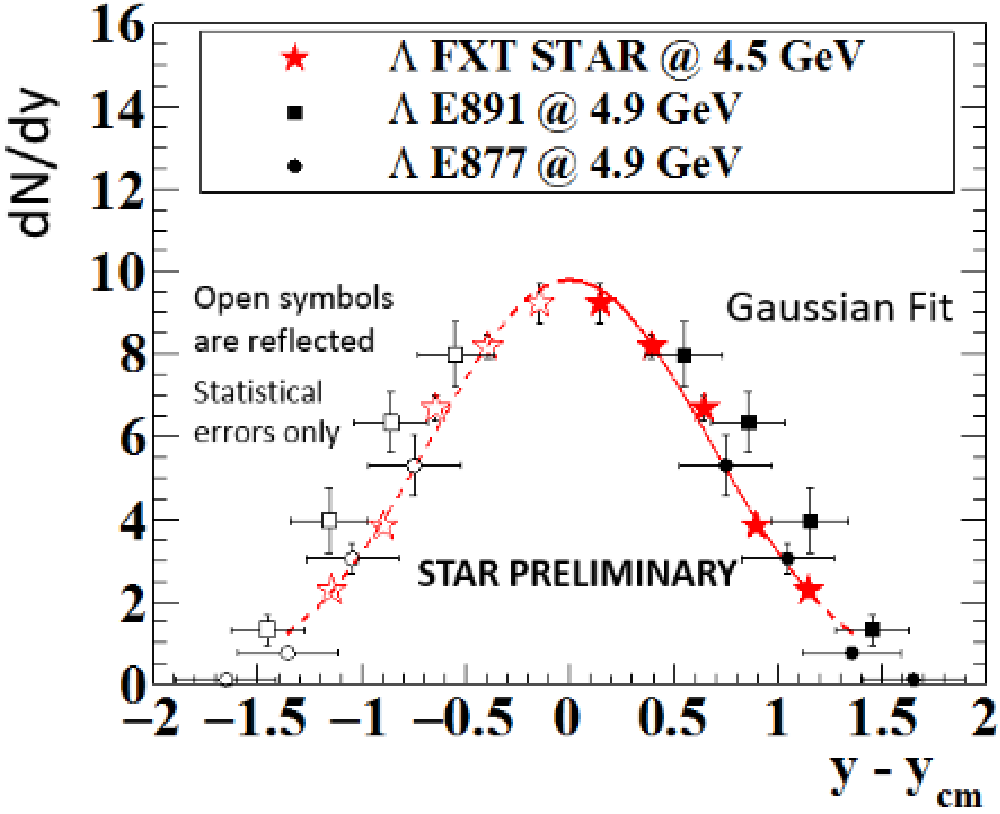








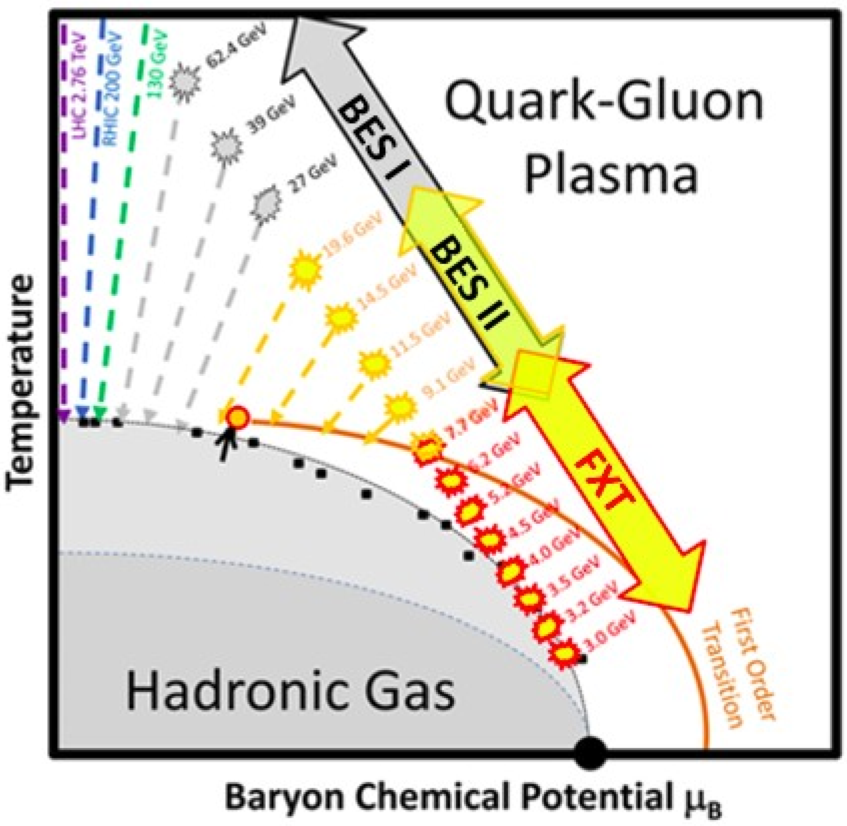
(a) π^- rapidity density distribution. STAR FXT data are plotted in red circles, while the E895, E892, and E877 AGS results are shown with other point styles. STAR FXT and E895 errors include systematic uncertainty. Open symbols are reflected. The red line is a Gaussian fit.



(b) Lambda rapidity density. STAR FXT data are plotted as red stars. E891 and E877 points are plotted for comparison in black.

K. Meehan / Nuclear Physics A 967 (2017) 808–811

STAR Beam Energy Scan program phase II



- 7.7 GeV is the lowest realistic collider energy
- Critical Point studies need results below 7.7 GeV
- FXT program provides control measurements for critical point and onset of deconfinement

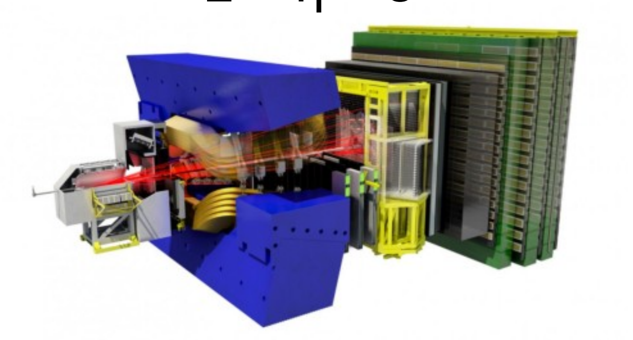
A selection of performance studies

Sensitivity studies - assumptions

LHCb-like

$\sqrt{s_{NN}}$ = 115 GeV, L_{int} (p-H) = 10 fb^{-1} / year
$\sqrt{s_{NN}}$ = 115 GeV, L_{int} (p-Xe) = 100 pb^{-1} / year
$\sqrt{s_{NN}}$ = 72 GeV, L_{int} (Pb-Xe) = 30 nb^{-1} / year
(Ref at same energy:
L_{int} (p-H) = 250 pb^{-1} L^{int} (p-Xe) = 2 pb^{-1})

$2 < \eta < 5$

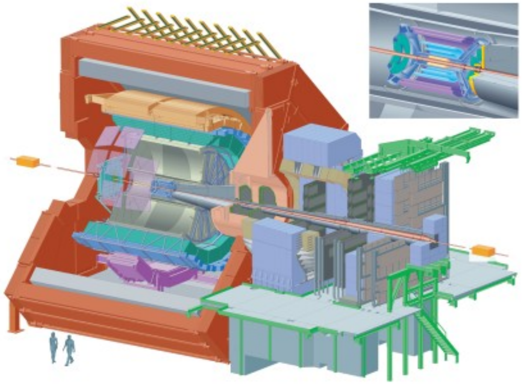


Target Z = 0, microvertexing, particle ID, μ ID

ALICE-like

$\sqrt{s_{NN}}$ = 72 GeV, L_{int} (Pb-Pb) = 1.6 nb^{-1} / year
$\sqrt{s_{NN}}$ = 115 GeV, L_{int} (p-H) = 45 pb^{-1} / year

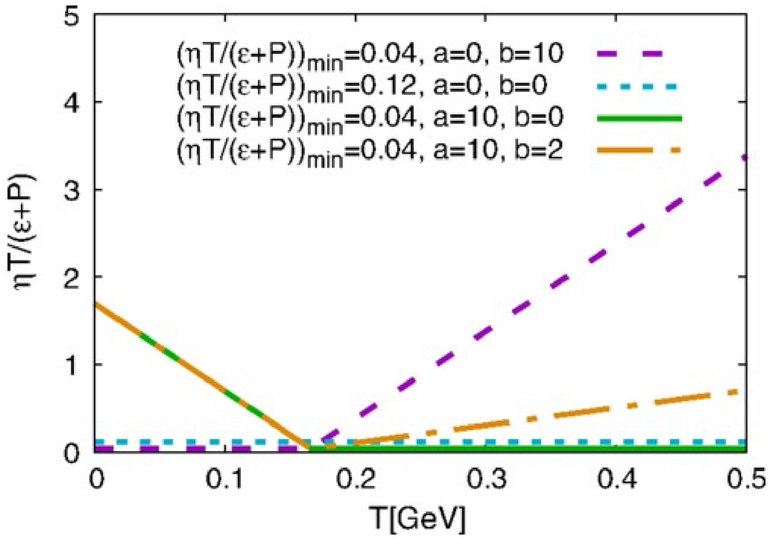
$-0.9 < \eta^{TPC} < 0.9$



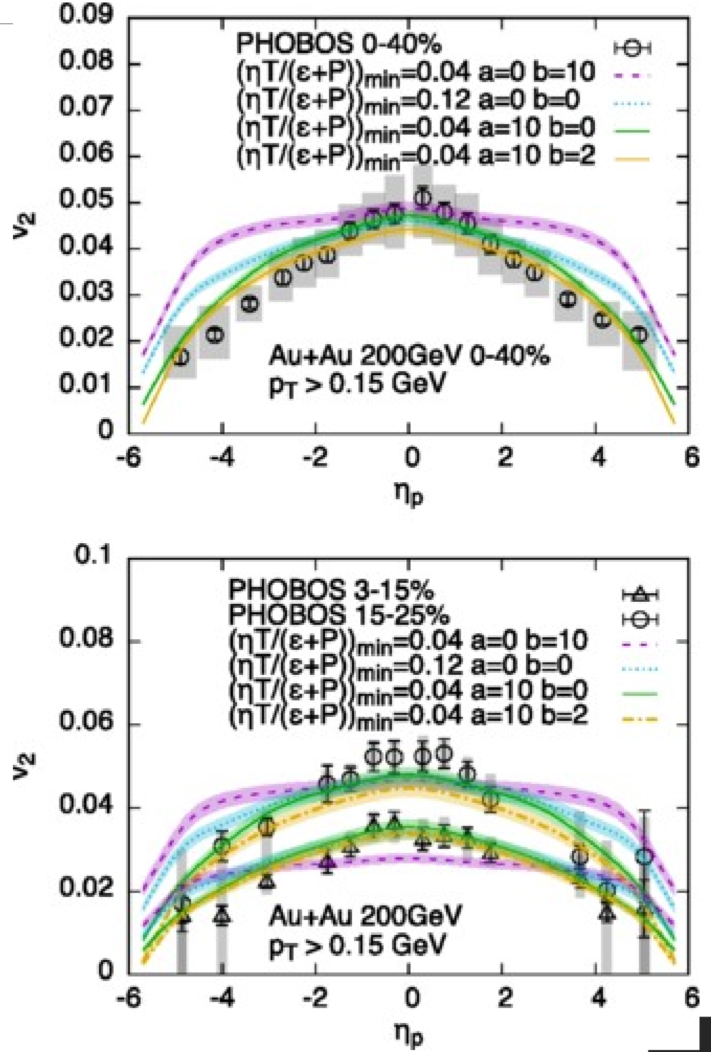
Bent crystal + internal solid target:
Z ~ 0 + ALICE-like acceptance

Heavy-Ion collisions

Heavy-ion collisions: toward large rapidities



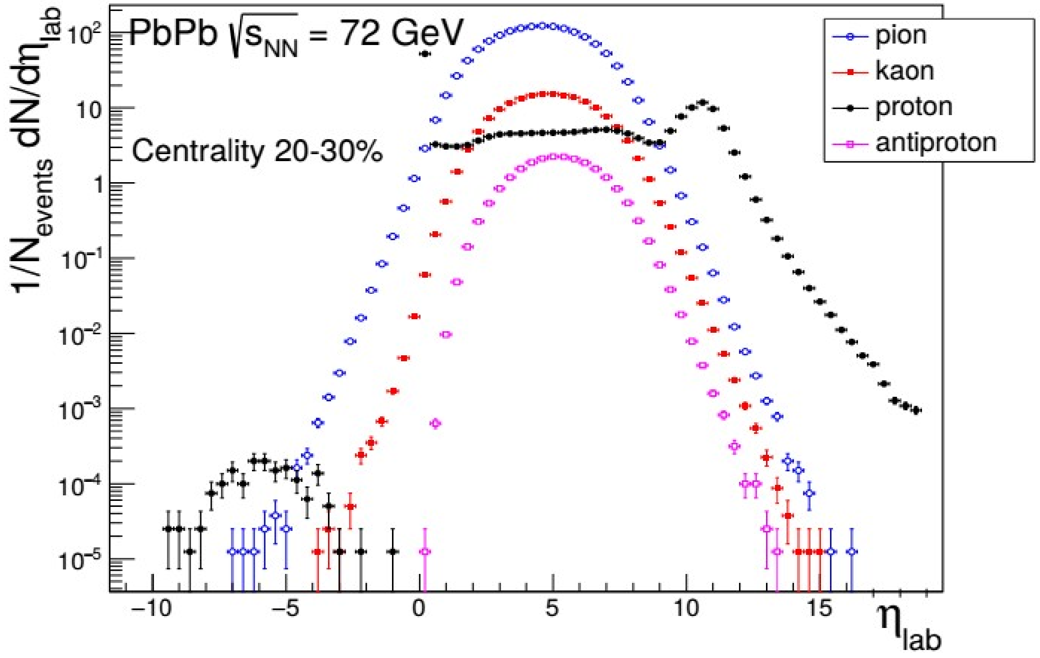
The four scenarios of temperature dependent ηT/(ϵ+P),
G. Denicol et al, PRL. 116, 212301

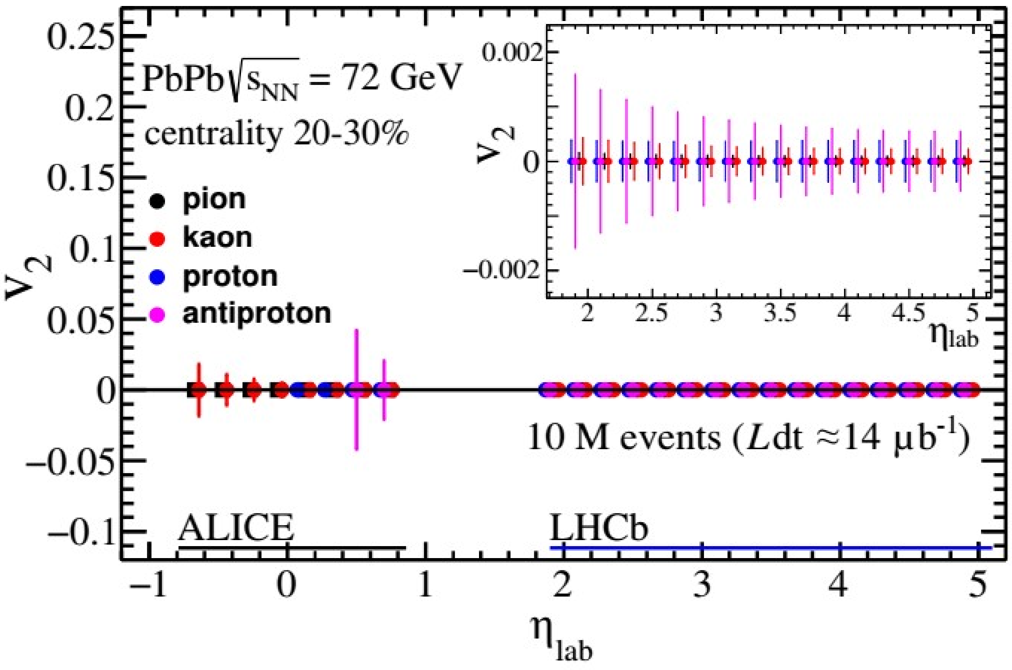


G. Denicol et al, PRL. 116, 212301

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

Heavy-ion collisions: toward large rapidities

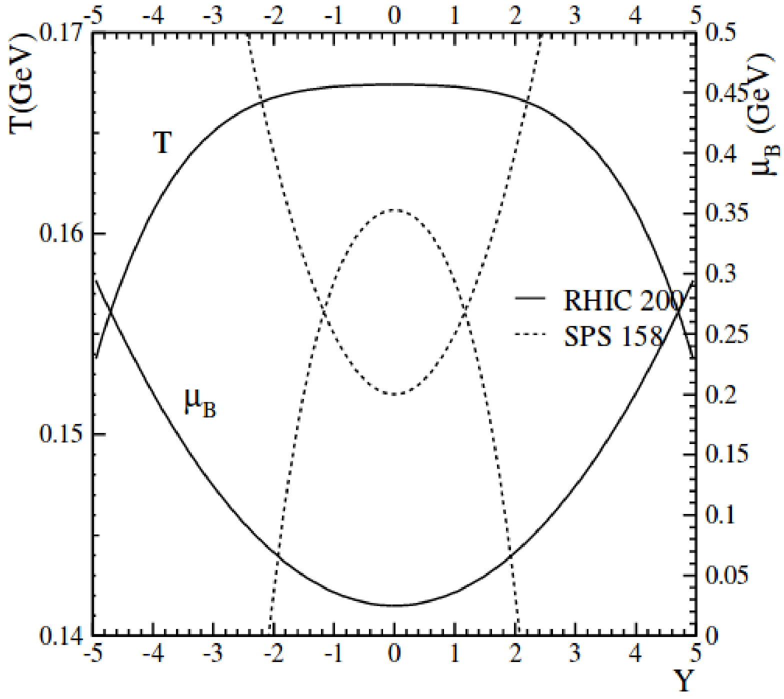




Particle yields and v_N at large rapidities → powerful tool to access the medium shear viscosity and temperature

Rapidity scan of the QCD phase diagram

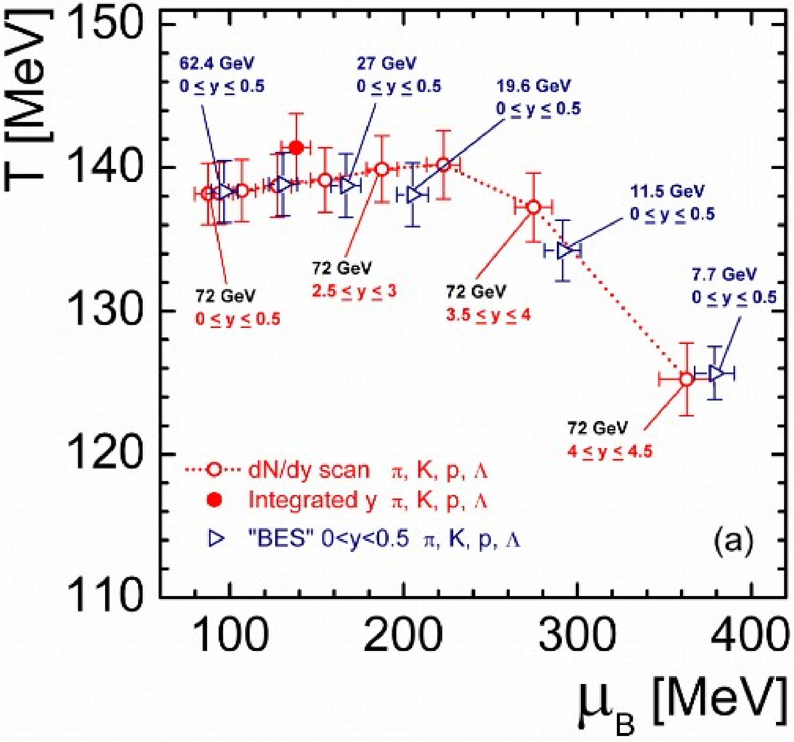
Larger rapidity → larger baryon chemical potential μ_B



F. Becattini, J. Cleymans, J.Phys.G34:S959-964,2007

AFTER@LHC: Comparable μ_B range to the RHIC Beam Energy Scan

Pb+Pb $\sqrt{s_{NN}}$ = 72 GeV, 0-10%

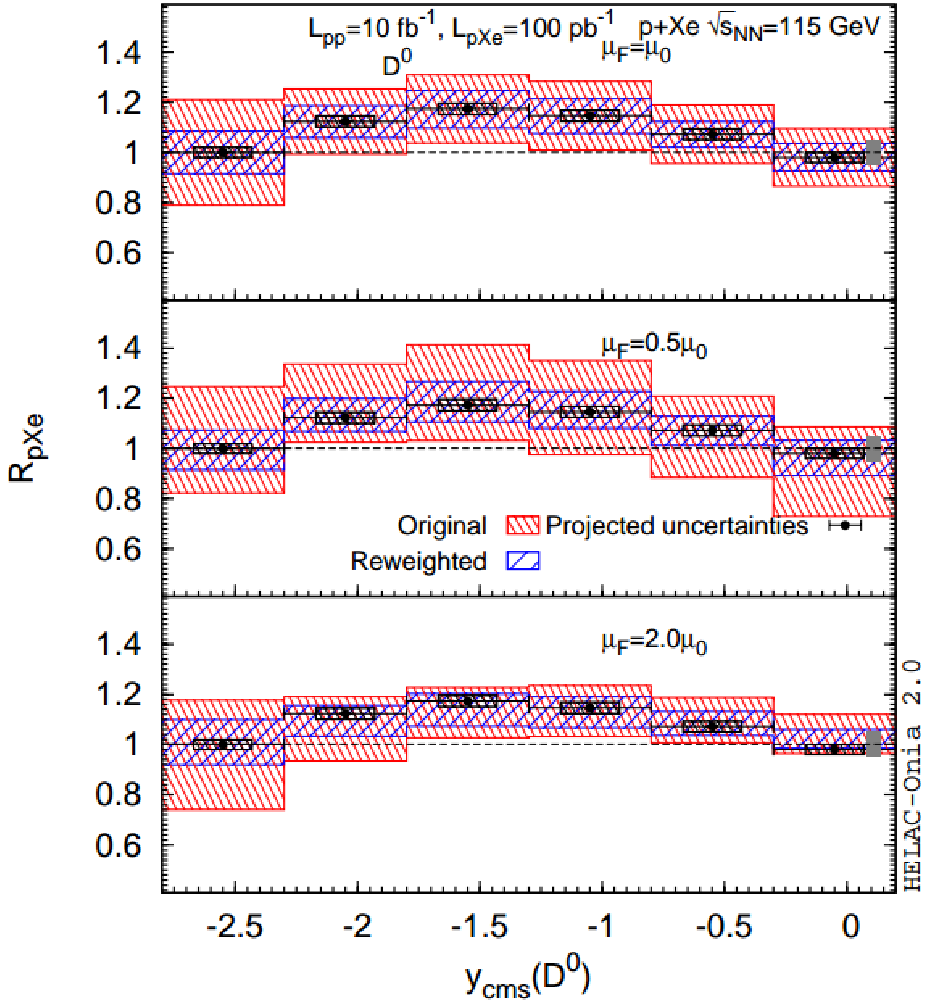


Hadron Resonance Gas model fit to UrQMD simulations,

V. Begun et al, PRC98 (2018) 3, 034905

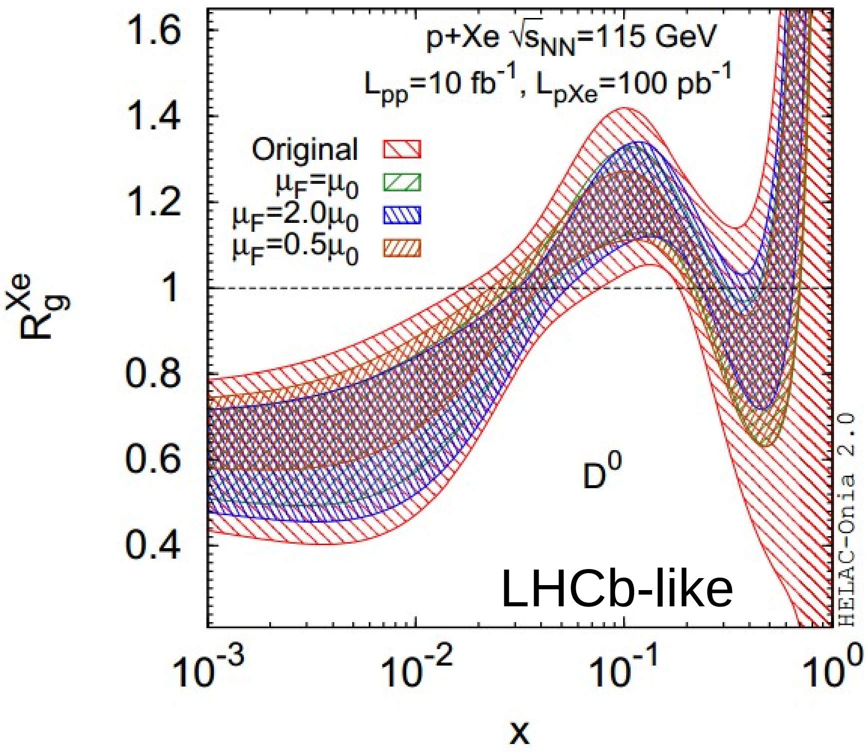
Probing the nuclear structure

Constraining gluon nPDF with heavy quarks



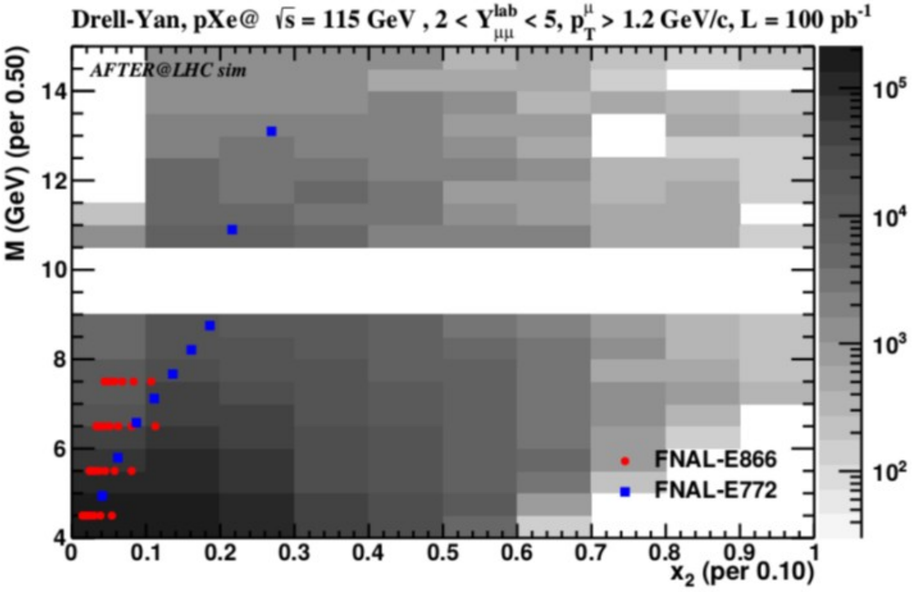
$$R_{pA} = \frac{dN_{pA}}{\langle N_{\rm coll}\rangle dN_{pp}}.$$

*) There are also other CNM effects in R_{pA}



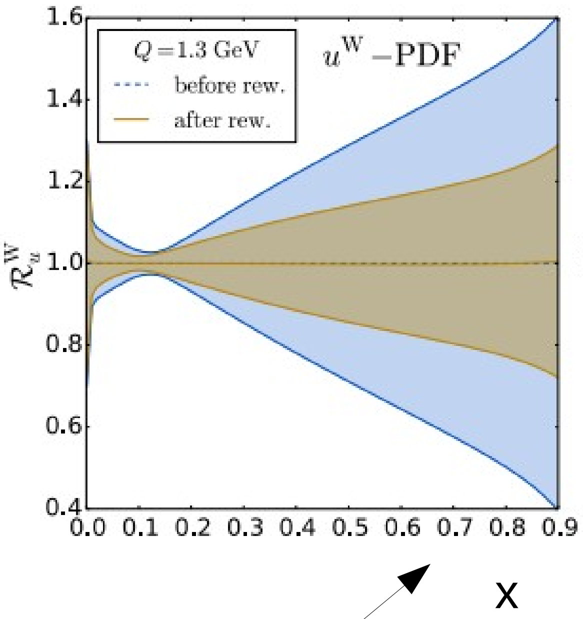
Constraining quark nPDF with Drell-Yan

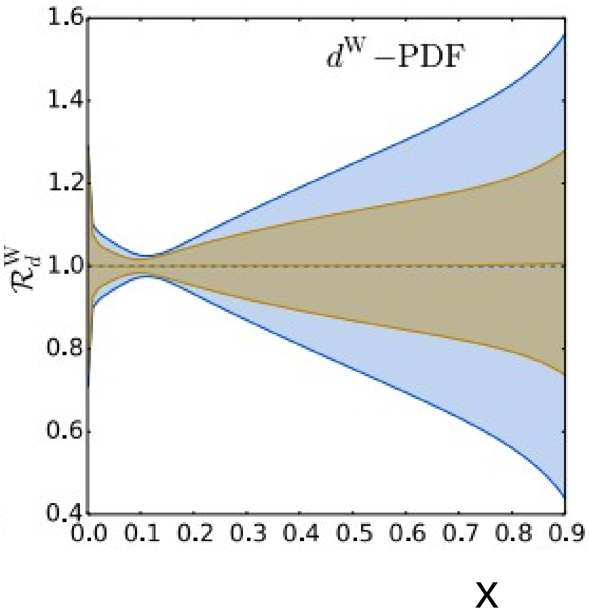
Large Drell-Yan yields, wide kinematic reach ($x_2 \rightarrow 1$), various targets



Few Body Syst. 58 (2017) no.4, 139

LHCb-like





Expected improvement with AFTER@LHC data

Also: ideal test of the extrapolation of initial state effects in pA to AA

Transverse spin asymmetry

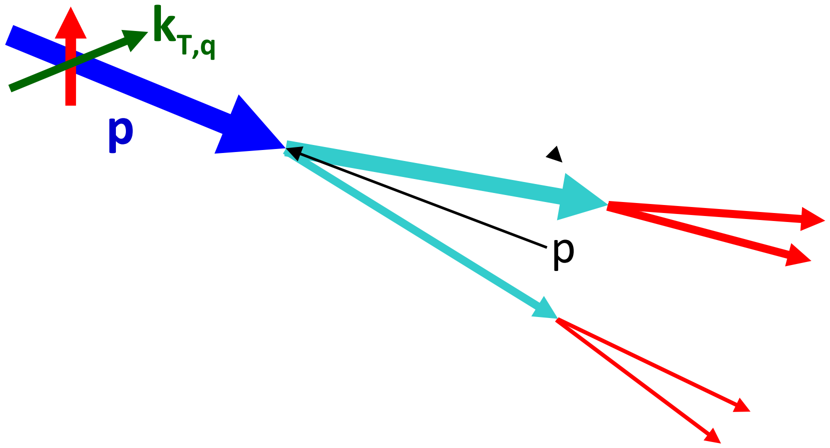
$$A_N = \frac{1}{P}\frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

$\sigma^{\uparrow(\downarrow)}$: production cross sections of particles produced with target spin polarized upward (downward).
P – average beam/target polarization

Possible sources of the asymmetry:

Sivers mechanism

correlation between spin and parton k_T



Collinear Twist-3

quark-gluon/gluon-gluon correlation, tri-gluon correlations

Ilustrations: S. Fazio - RHIC & AGS Users' Meeting 2016

Orbital angular momentum of quarks and gluons

$$A_N = \frac{1}{P}\frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

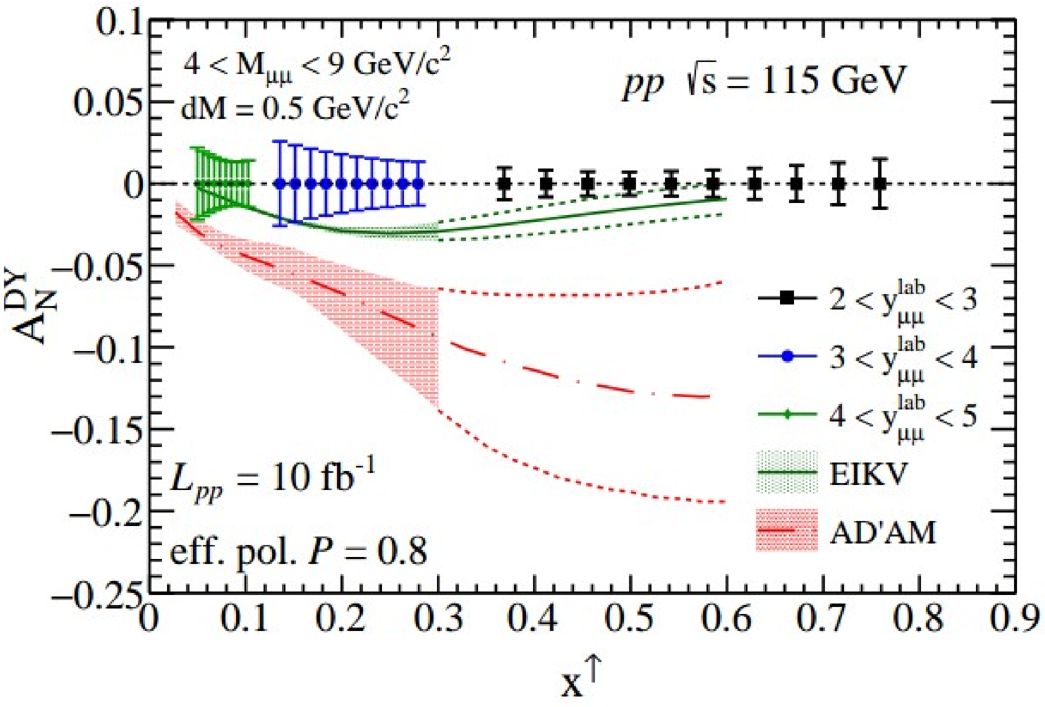
- **$A_N \neq 0$** → non-zero quark/gluon Sivers function → **non-zero quark/gluon OAM**
- Drell-Yan → access to $f_{1T}^{\perp q}(x, \vec{k}_{\perp}^{2})$

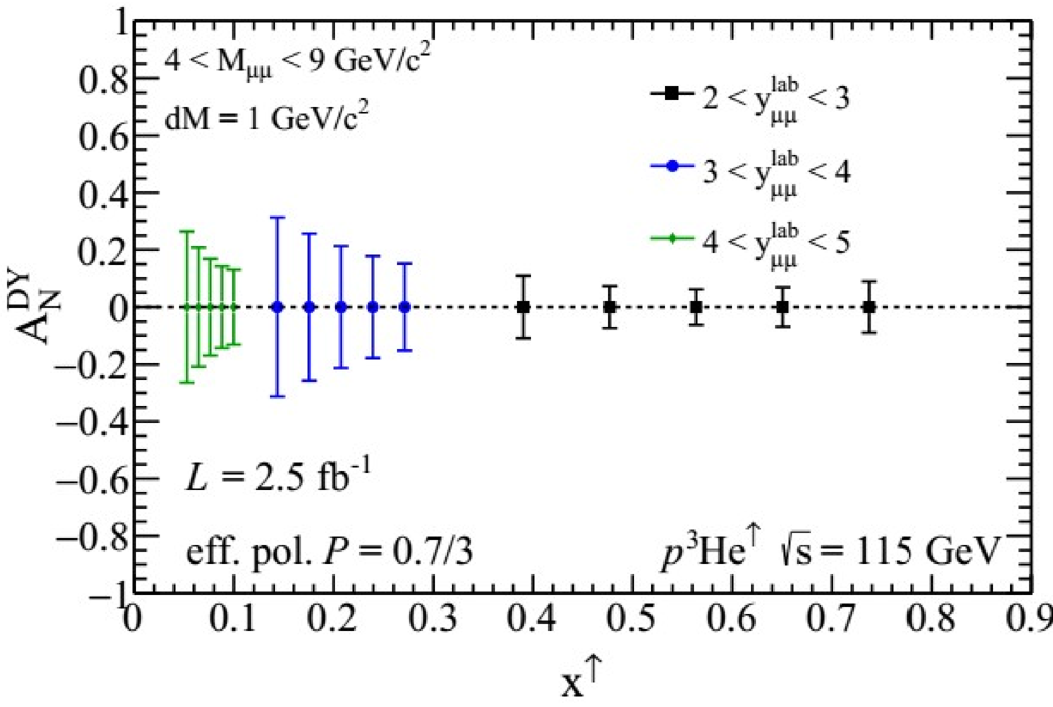
$$f_{1T}^{\perp q}(x, \vec{k}_{\perp}^{2})_{Drell-Yan} = -f_{1T}^{\perp q}(x, \vec{k}_{\perp}^{2})_{Semi-Inclusive\ DIS}$$

- Gluon Sivers effect → access via single spin asymmetry of open charm & quarkonia, J/ψ-J/ψ, $J/\psi+\gamma$

Drell-Yan A_N in AFTER

- Precision study of the quark Sivers function with Drell-Yan over a wide kinematic range

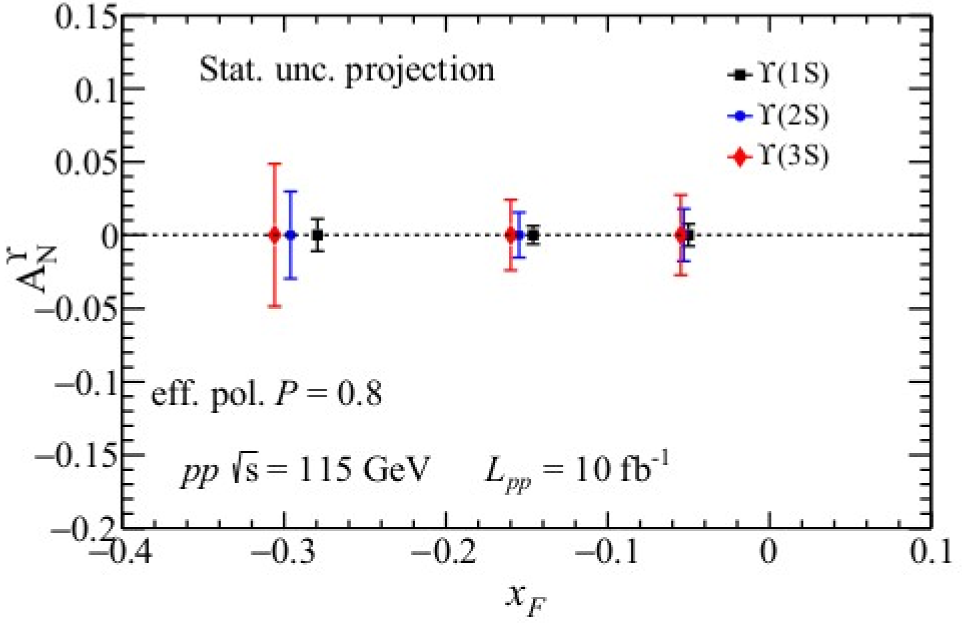


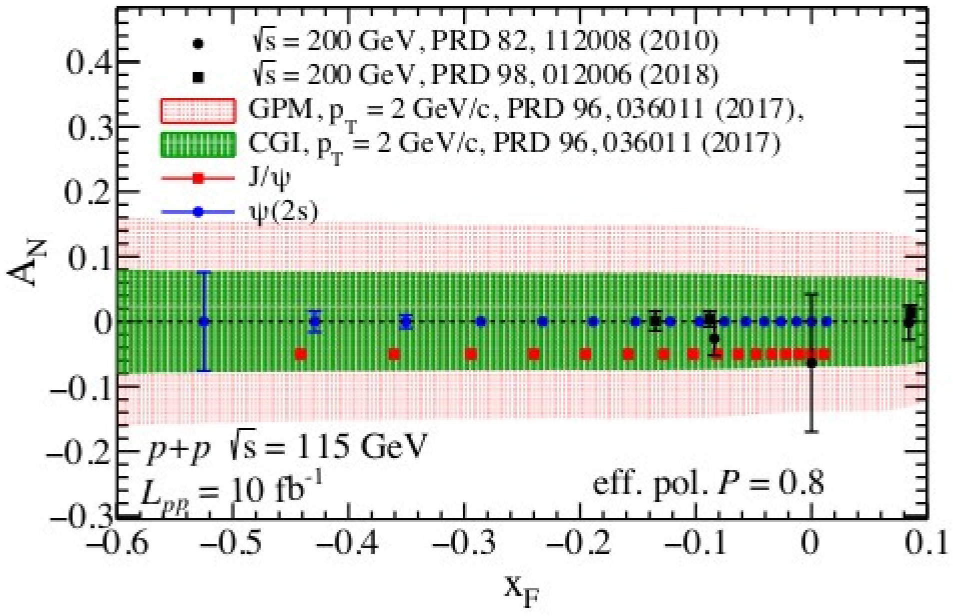


AD'AM → M. Anselmino, U. D'Alesio, and S. Melis, Adv. High Energy Phys. 2015 (2015) 475040
EIKV → M. G. Echevarria, A. Idilbi, Z.-B. Kang, and I. Vitev, Phys. Rev. D89 (2014)

Quarkonia A_N

- Unique access to C-even quarkonia ($\chi_{c,b}$, η_c) + associated production
- A_N for all quarkonia (J/ψ, ψ', χ_c , Υ(nS), χ_b & η_c) can be measured

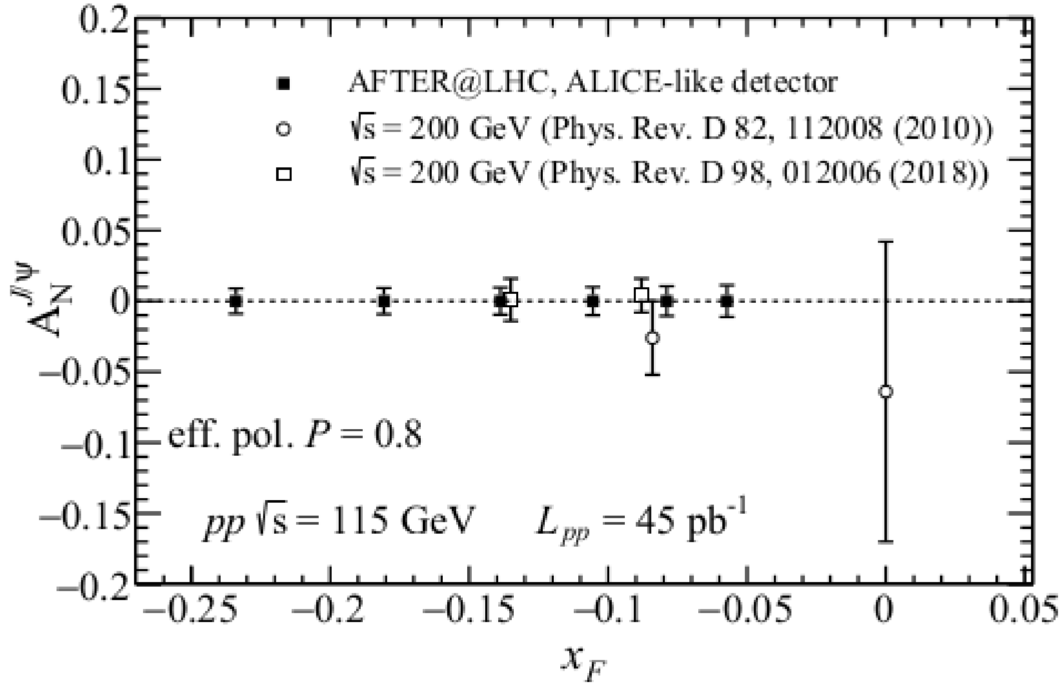




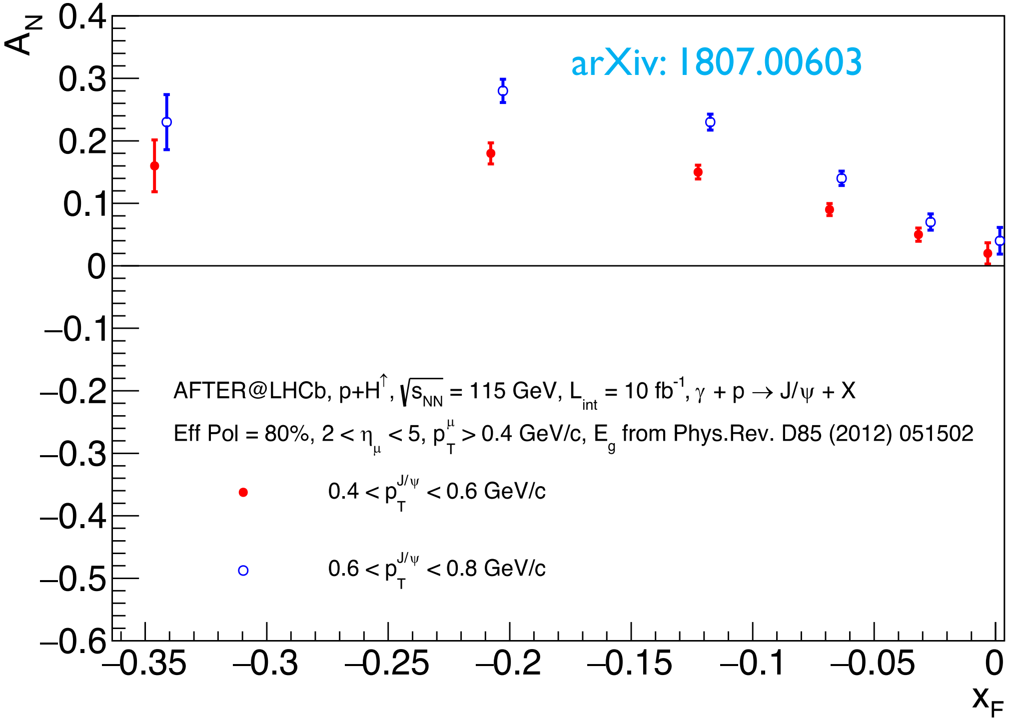
GPM: generalised parton model and the color gauge invariant (CGI) of GPM

Quarkonia A_N

J/ψ A_N in ALICE-like detector



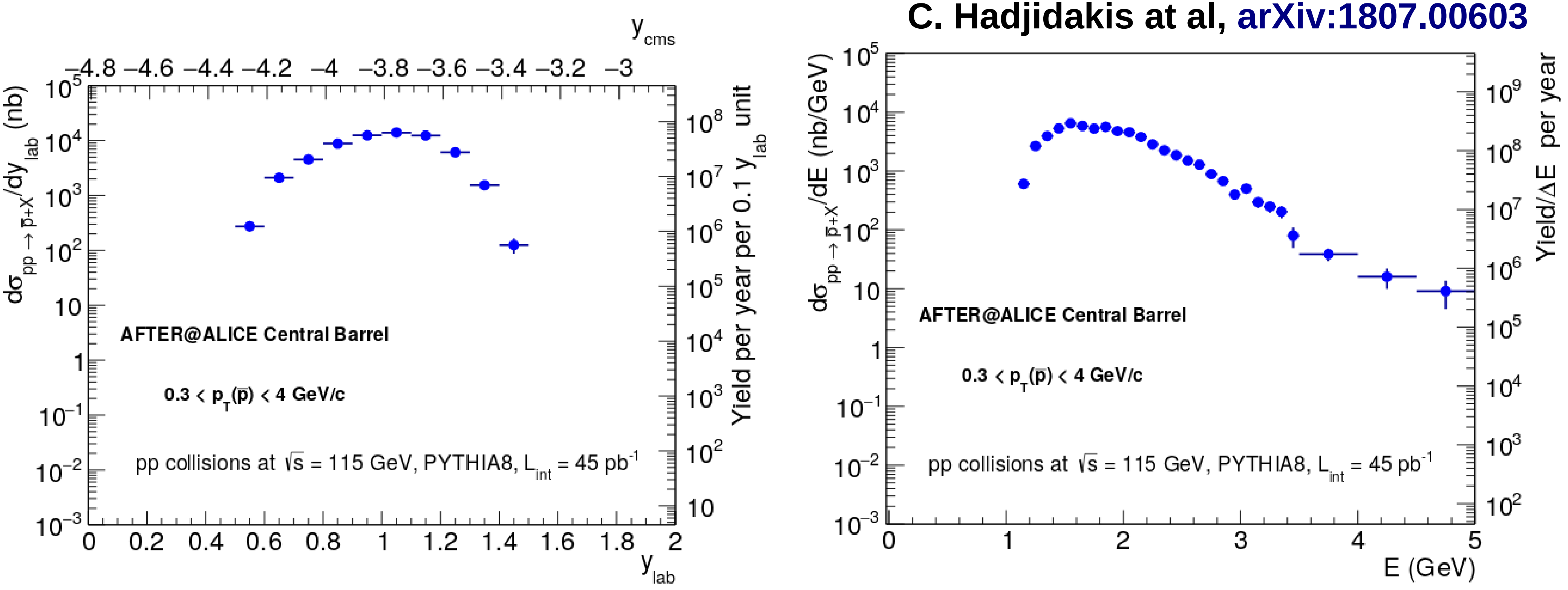
Photoproduced J/ψ to probe the gluon Generalized Parton Dist. Eg



Astroparticle physics

Antiproton production at AFTER@ALICE FT

C. Hadjidakis at al, arXiv:1807.00603

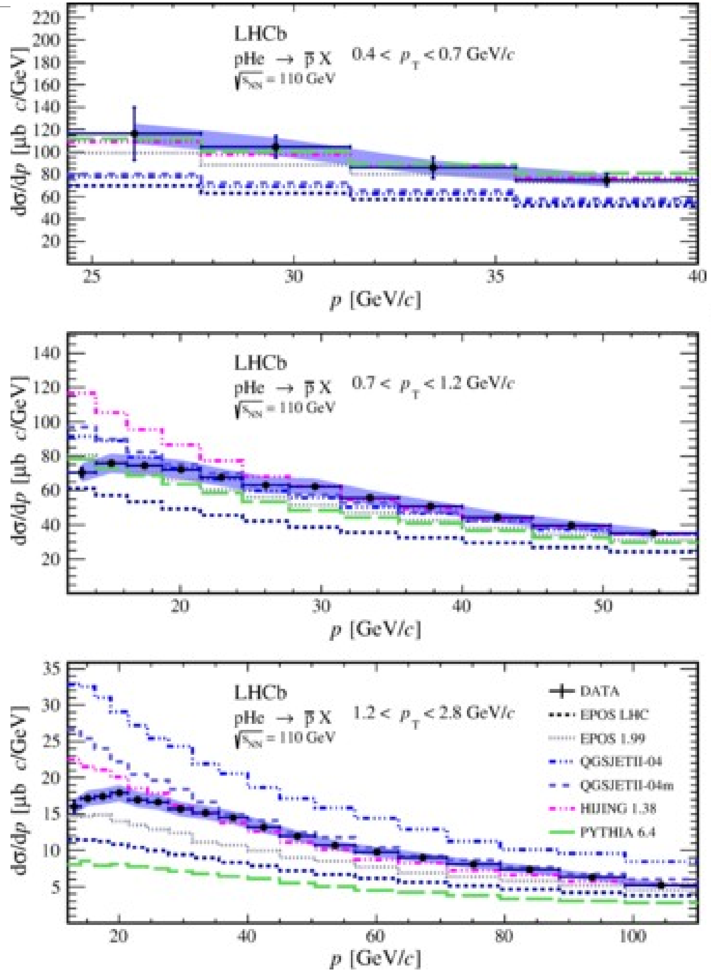


Important inputs for theoretical calculations of the secondary cosmic $\bar{p}$ spectrum.

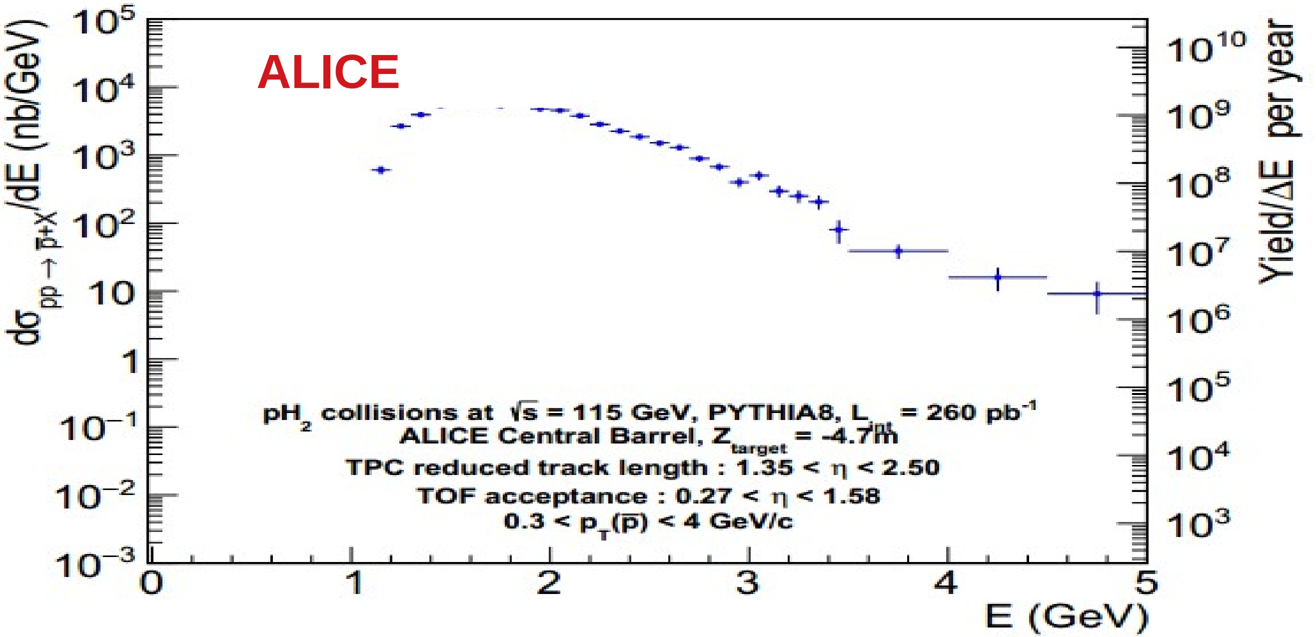
Example: search of dark matter via study of cosmic $\bar{p}$ excess over secondary $\bar{p}$

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

Antiproton measurements → ALICE vs LHCb



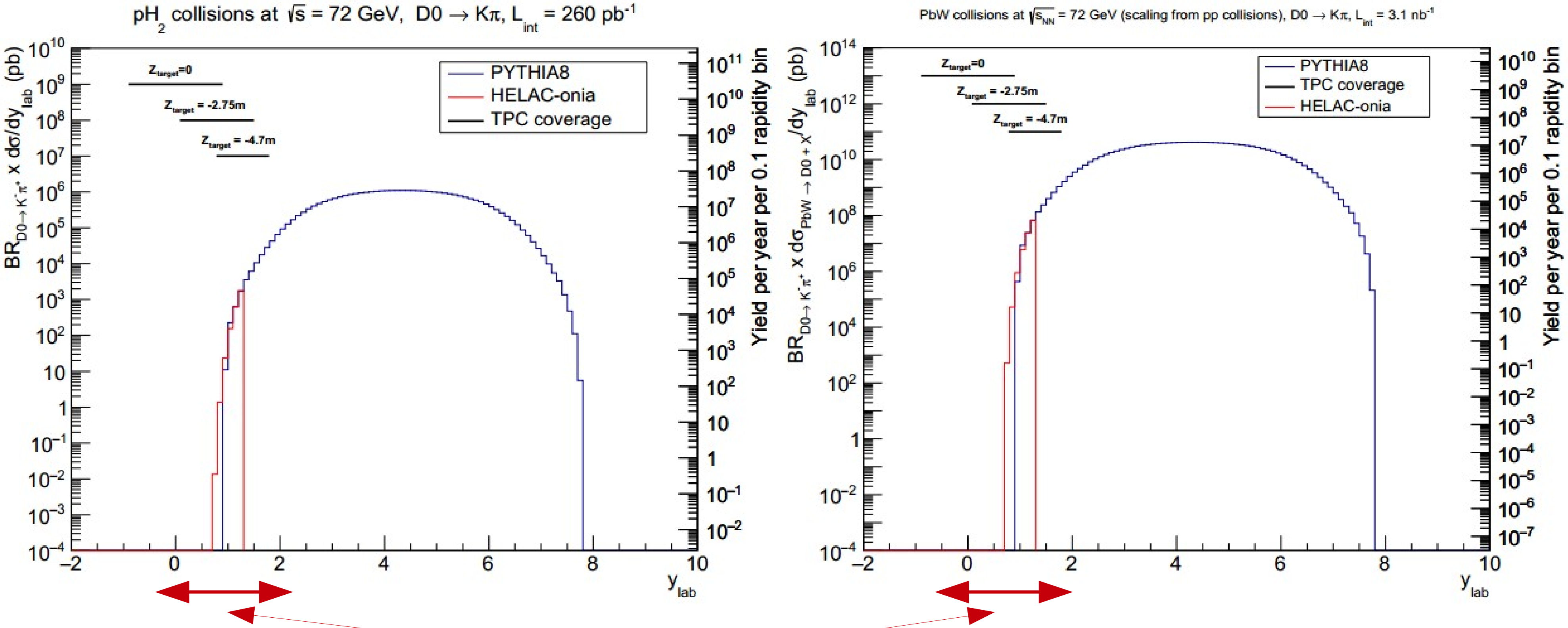
R. Aaij et al. PRL 121, 222001



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.

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)

Status

Implementation options under investigation

- **LHCb**
  - Beam splitting and internal W solid target (with a second crystal) for Electromagnetic Dipole Moment of charmed baryons
  - Polarized storage cell gas target for spin physics (SPIN-LHC)
  - Unpolarized storage cell gas target (SMOG2)

- **ALICE**
  - Beam splitting and internal solid target
  - gas target (to be investigated)

Contribution submitted to

European Particle Physics Strategy Update 2018 – 2020

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

F. Galluccio[a], C. Hadjidakis[b], D. Kikoła[c], A. Kurepin[d], L. Massacrier[b,*], S. Porteboeuf[e], K. Pressard[b], W. Scandale[f], N. Topilskaya[d], B. Trzeciak[g], A. Uras[h]

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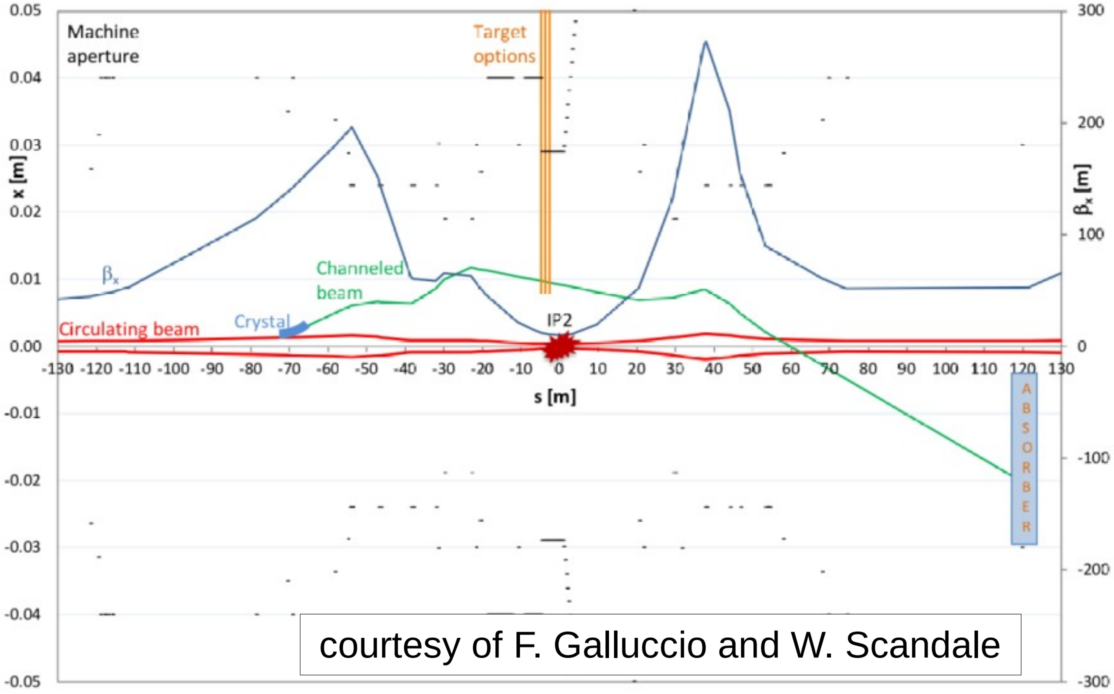
[e]*Université Clermont Auvergne, CNRS/IN2P3, LPC, F-63000 Clermont-Ferrand, France.*
[f]*CERN, European Organization for Nuclear Research, 1211 Geneva 23, Switzerland*
[g]*Institute for Subatomic Physics, Utrecht University, Utrecht, The Netherlands*
[h]*IPNL, Université Claude Bernard Lyon-I and CNRS-IN2P3, Villeurbanne, France*

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



courtesy of F. Galluccio and W. Scandale

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
Beam splitting: assumed flux:**~ 5 x 10^8 p/s**, **~ 2 x 10^5 Pb/s** (could be lower by 2 order of magnitude)

Integrated luminosities with the ALICE detector

Target		ALICE proton beam ($\sqrt{s_{NN}}$= 115 GeV) $\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	Inel. rate [kHz]	$\int\mathcal{L}$	ALICE Pb beam ($\sqrt{s_{NN}}$= 72 GeV) $\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	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}
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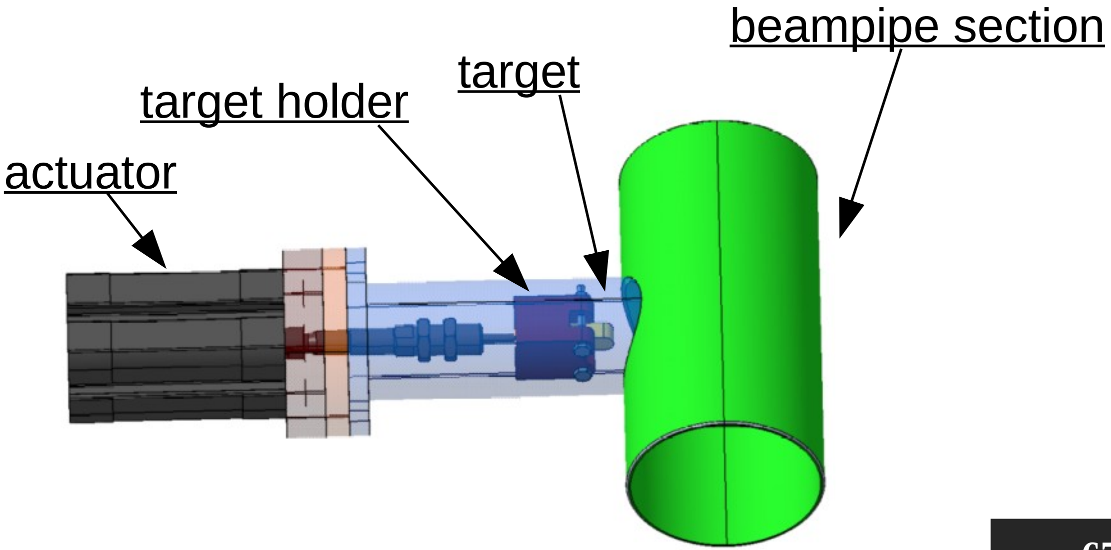
	Ti	1.4×10^{30}	1000	14 pb^{-1}	2.8×10^{27}	13	2.8 nb^{-1}
	W	5.9×10^{29}	1000	5.9 pb^{-1}	3.1×10^{27}	21	3.1 nb^{-1}

Interaction rate limited to 1 MHz by the expected detector data taking rate
Beam splitting: assumed flux:**~ 5 x 10^8 p/s**, **~ 2 x 10^5 Pb/s** (could be lower by 2 order of magnitude) → **gas-jet option worth consideration, but severe tech. constrains**

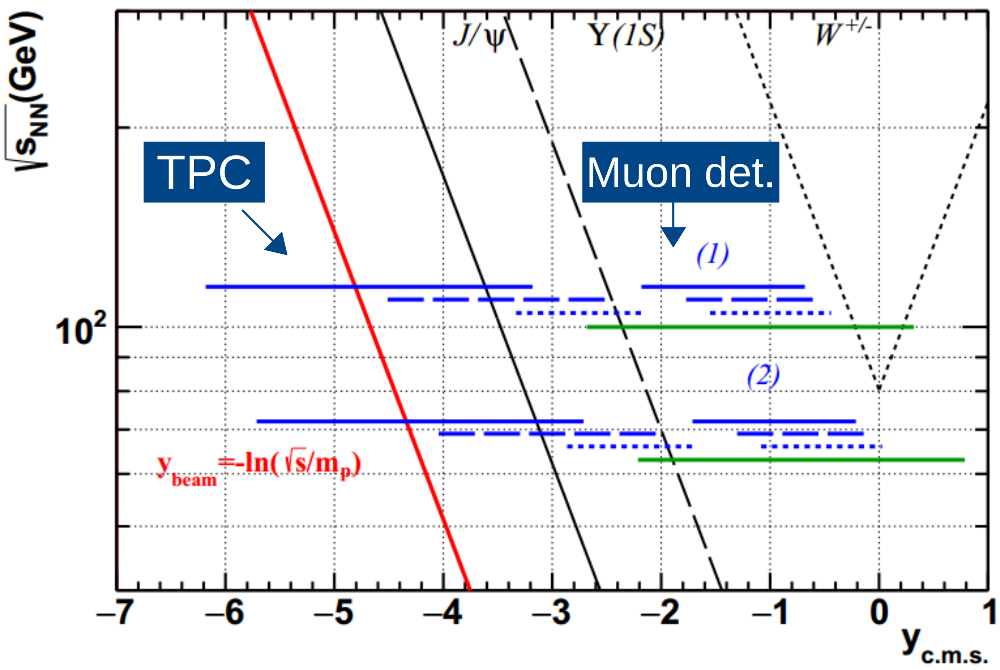
Solid target setup

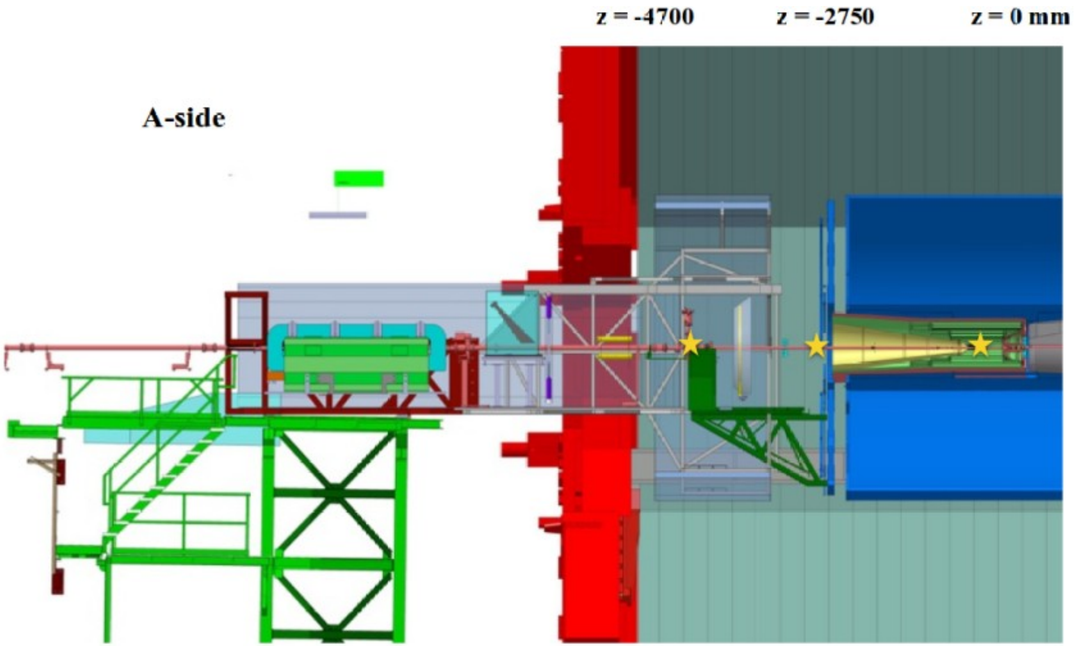
- Inside the L3 solenoid
- Pneumatic motion system with two positions (IN and OUT of the beam pipe)
- Examples of possible target types: Be, Ca, C, Ti, Ni, Cu, Os, Ir, W
- Size: 170 x 50 x 50 mm

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



Possible target locations and acceptance





Target z = 0

Target z = -2.75 m

Target z = -4.7 m

LHCb, target z = 0

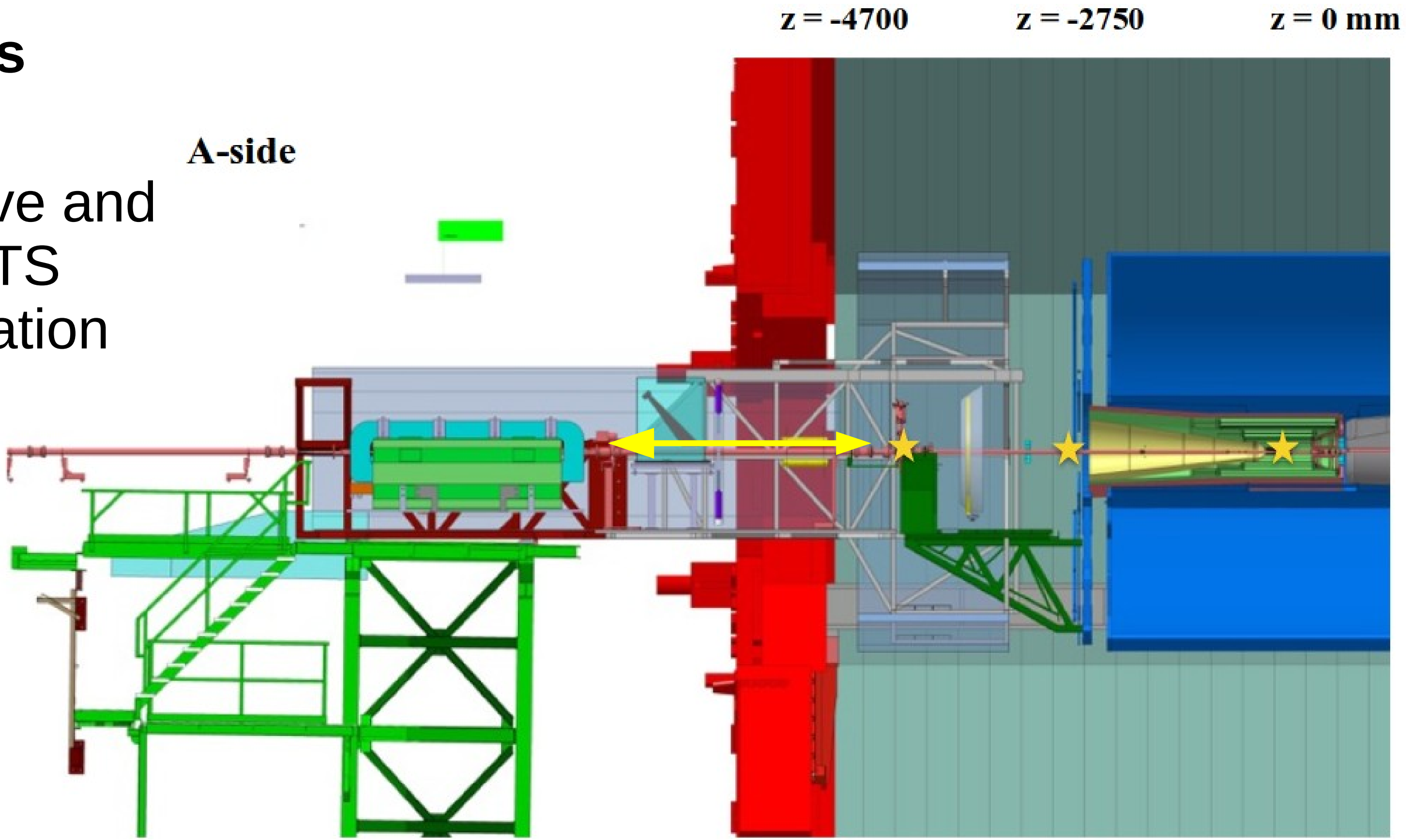
The acceptances of the TPC calculated assuming reduced track length (1/3 of the full radial track length), which results in |η|<1.5 in a collider mode.

Possible target locations and acceptance

Integration constraints

Location of existing valve and ITS motion during EYETS constrain the target location within **-8.3 < Z < -4.8 m**

(downstream from the nominal IP)

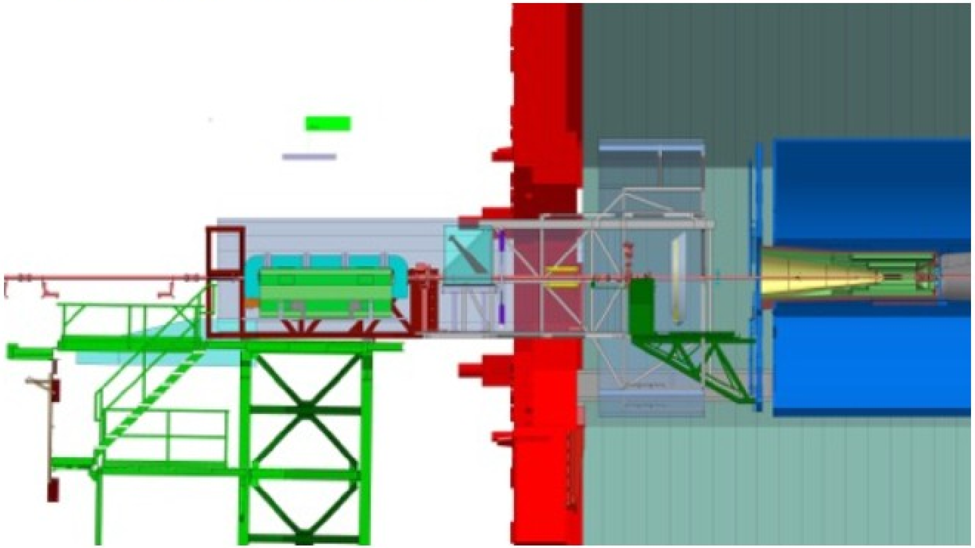


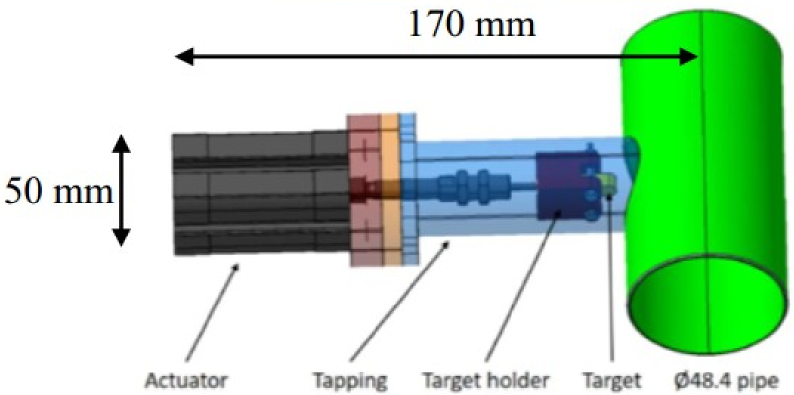
EYETS : Extended Year-End Technical Stop

Recent progress

- Project presented to **ALICE Technical Board** (C. Hadjidakis, March 2019)
  - **Implementation**: Internal solid target + a bent crystal

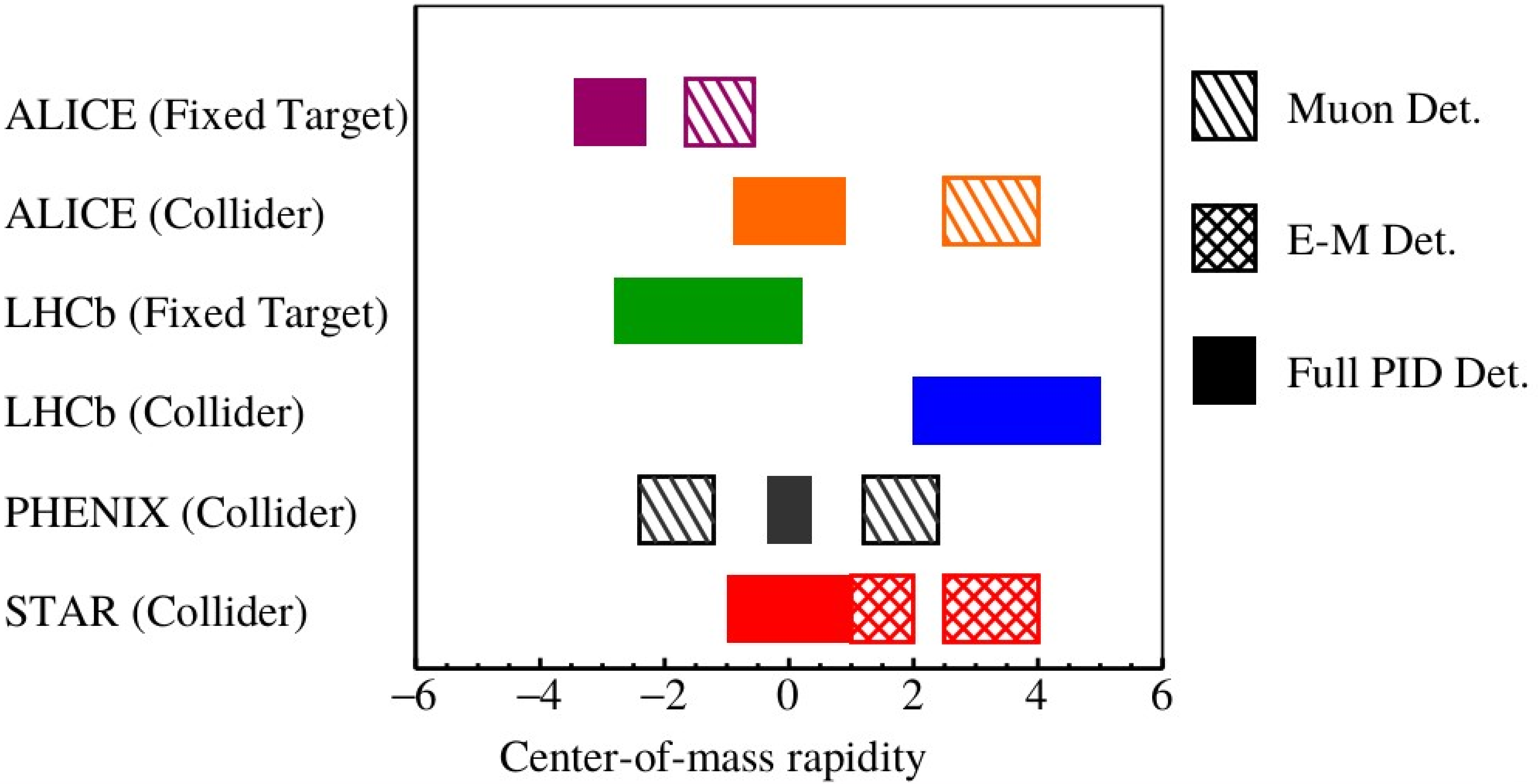
K. Pressard (IPN Orsay)



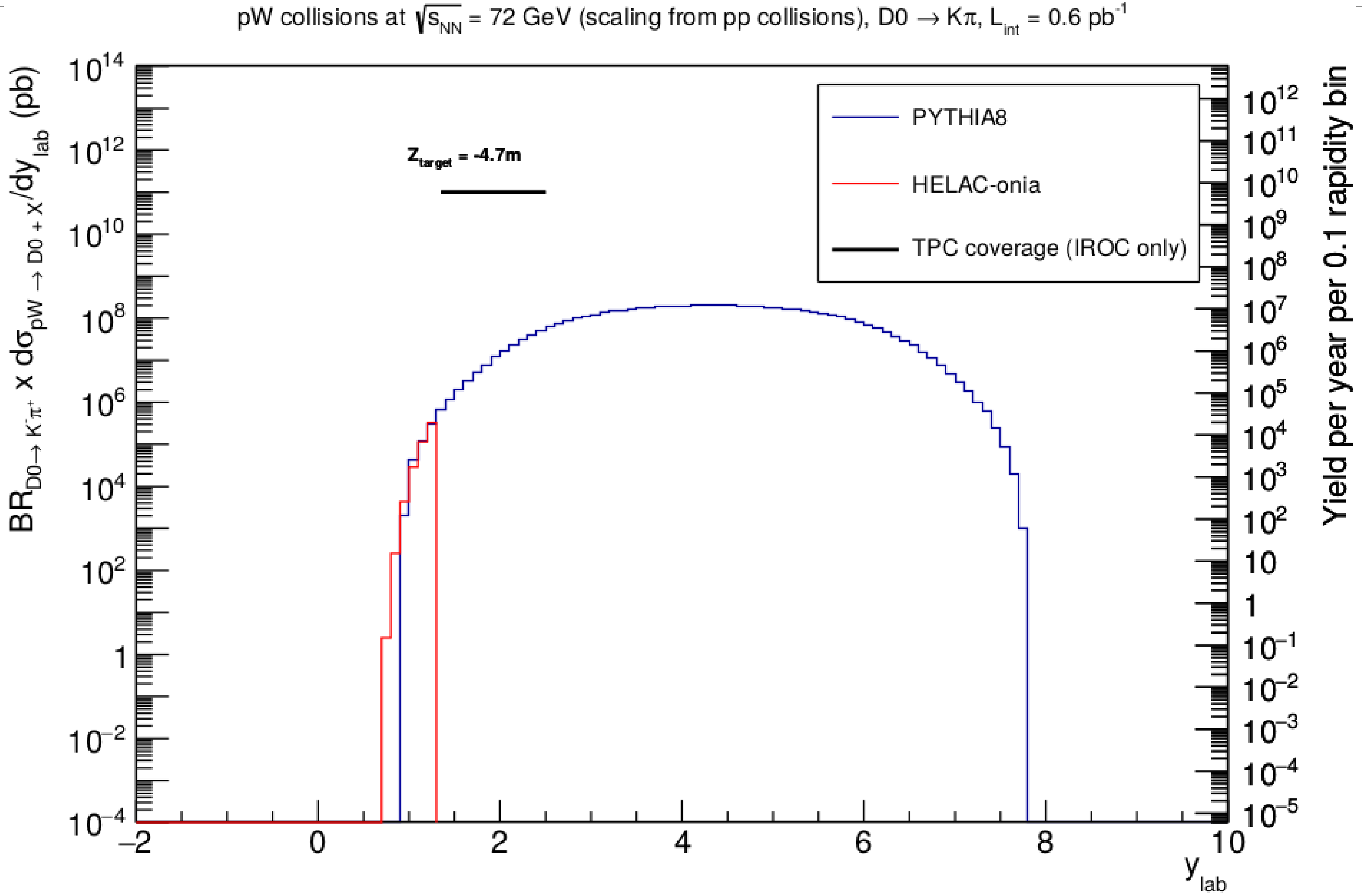


- **Target installation**
  - **Technical constrains** → under discussion
    - Vacuum constraints → vacuum isolation of IP2 needed
    - Impedance → target system can act as an antenna in the pipe, impedance calculation to be carried out in collaboration with/by the LHC impedance group
- Bent crystal
  - Studies ongoing by collimation team for IP8
  - **Required:** LHC study of machine protection, collimation and operation and possible beam proton and lead fluxes for IP2

ALICE Fixed Target for Z_{target} = -4.7 m vs other experiments

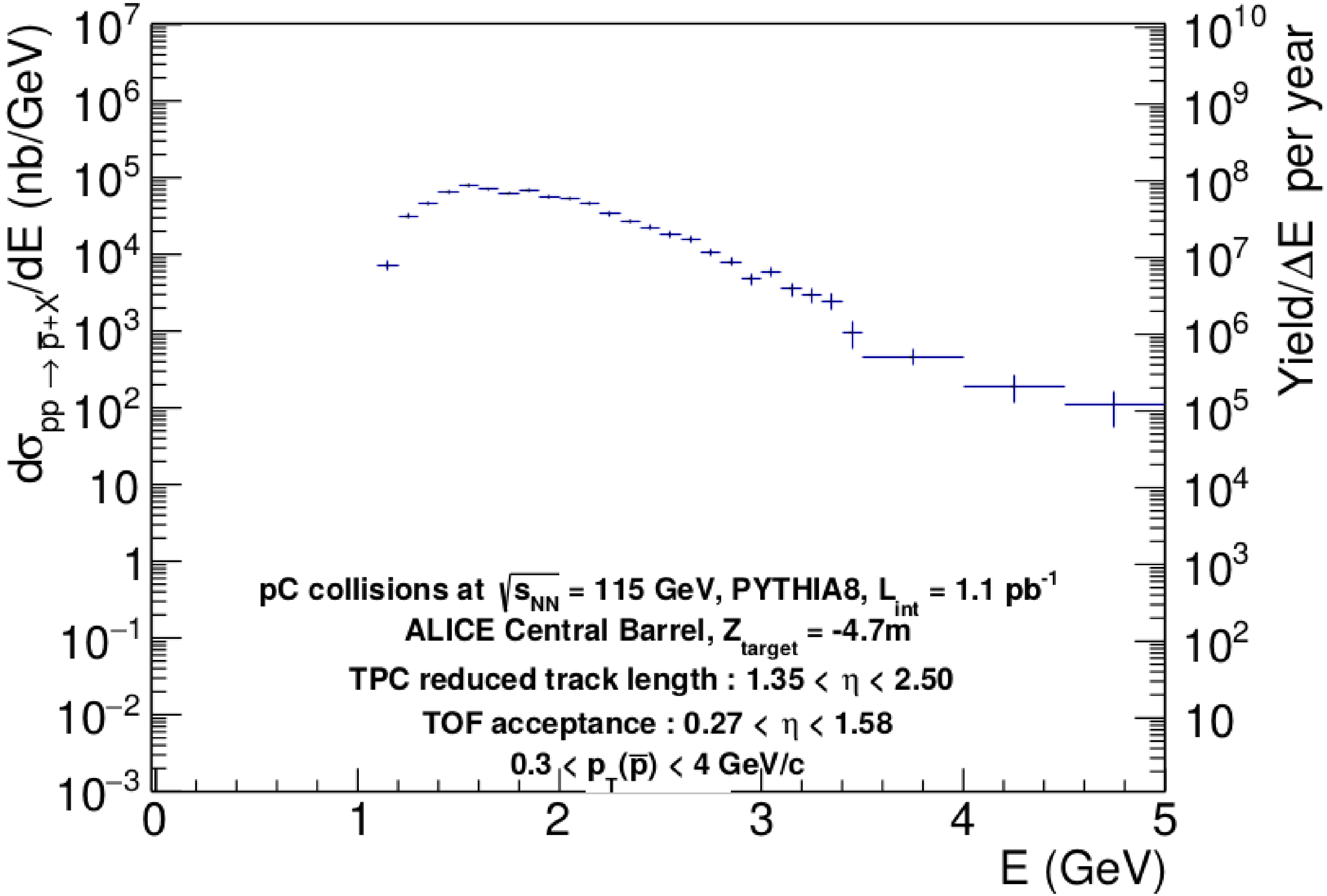


D^0 production in p+W collisions for Z_{target} = -4.7 m



Plot courtesy of
Laure Massacrier

Antiproton production in p+C collisions for Z_{target} = -4.7 m



Plot courtesy of
Laure Massacrier

New projects under investigation in LHCb

See talks from F. Fleuret, B. Audurier

- **SMOG2 (approved) : addition of an unpolarised storage cell target**
  - 20 cm long attached to the VELO
  - Injection of unpolarised gas via capillary
  - Boost local gas density with same gas flow

Gas species	He	Ne	Ar	Kr	Xe	H_2	D_2	N_2	O_2
$\theta_{SMOG2}/\theta_{SMOG}$)	10.9	24.4	34.5	25.0	31.3	7.7	10.9	28.6	30.3

→ And probably up to a factor x 100 SMOG with an increased gas flow

  - Extended target choice : H_2, D_2
  - Better control over injected gas density (i.e over luminosity)
  - Projections for SMOG2:

Reaction	DAQ time	Non coll. bunches	Lumi (nb^{-1})	Decays	SMOG yields	Scale factor	SMOG2 proj. yields
pAr	18 h	684	~ 2	$D^0 \to K^-\pi^+$	6450	62	400 k
				$D^+ \to K^-\pi^+\pi^+$	975		60 k
				$D_s^+ \to K^-K^+\pi^+$	131		8 k
				$D^{*+} \to D^0\pi^+$	2300		140 k
				$\Lambda_c^+ \to pK^-\pi^+$	50		3 k
				$J/\psi^+ \to \mu^+\mu^-$	500		30 k
				$\psi' \to \mu^+\mu^-$	20		1.2 k
pHe	84 h	648	7.6	$J/\psi^+ \to \mu^+\mu^-$	500	19.6	10 k
				$\psi' \to \mu^+\mu^-$	20		0.4 k

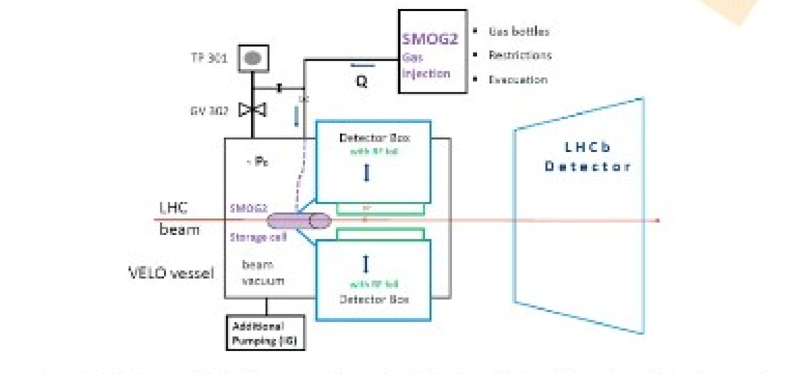
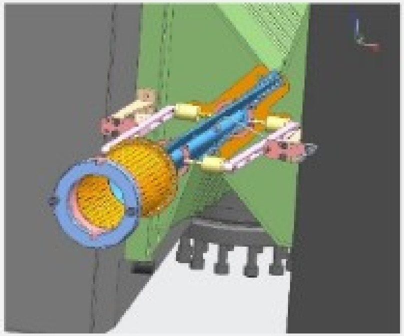
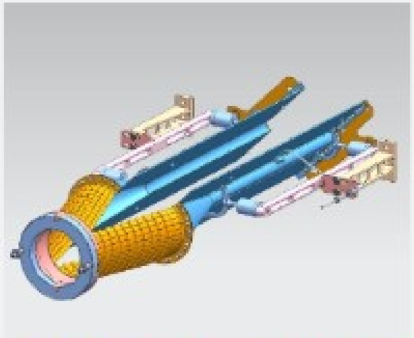


Figure 7: Sketch of the SMOG2 system. The gas is injected via capillary at the center of the storage cell.

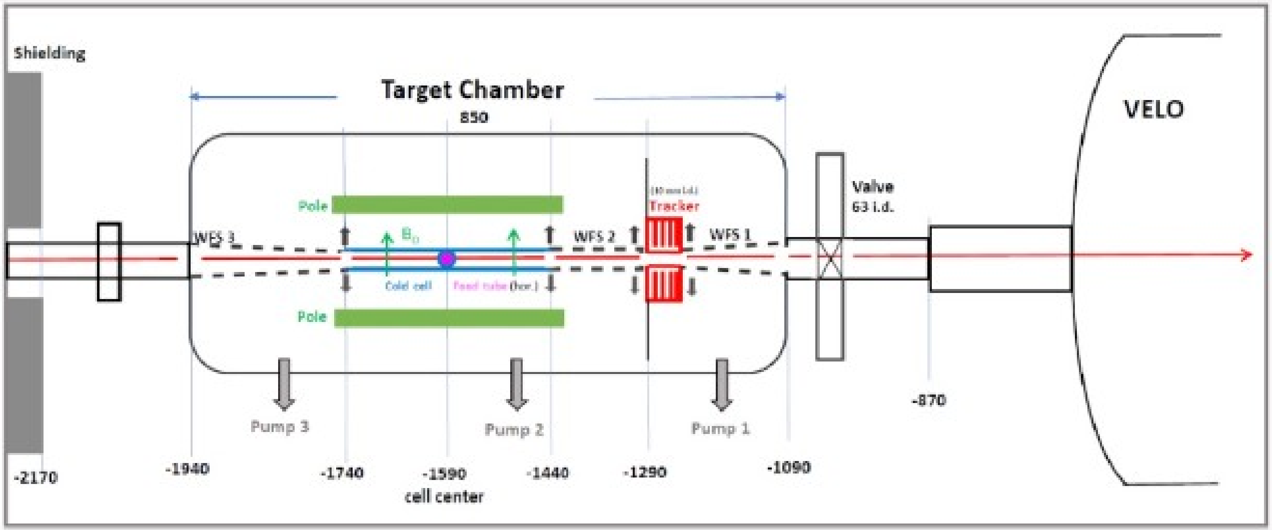




CERN-PBC-Notes-2018-007

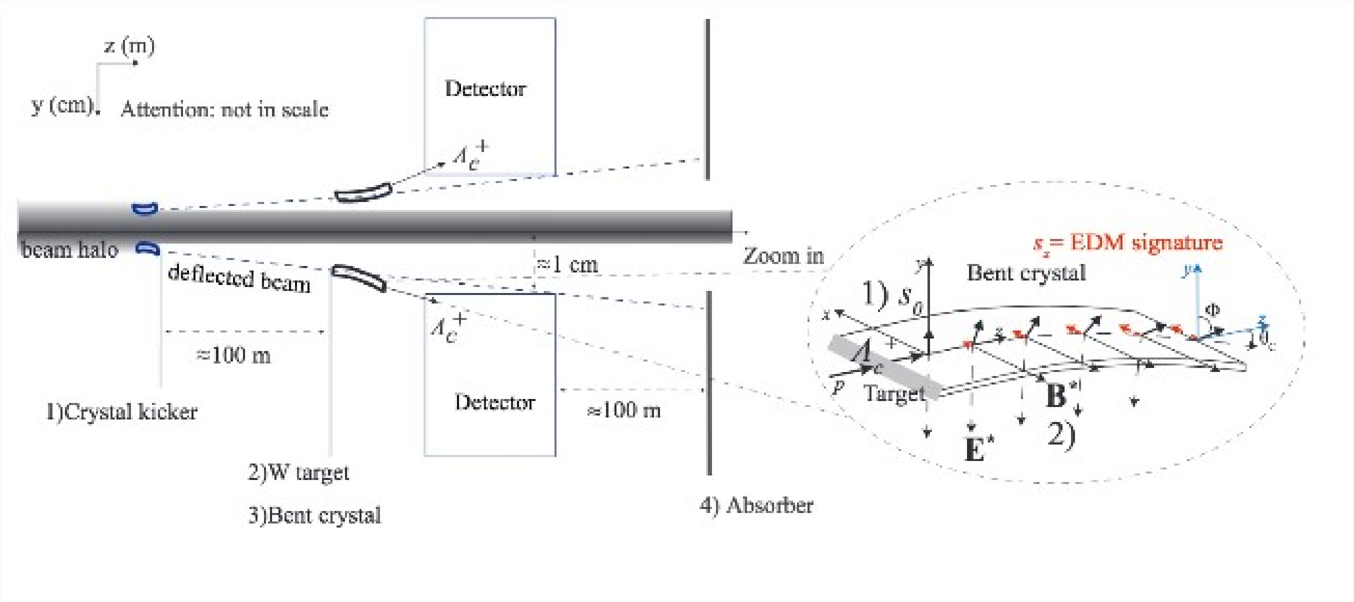
New projects under investigation in LHCb

- **LHCSpin (currently not approved) : polarised storage cell target for spin physics in front of LHCb**
  - Setup with : Atomic beam source, target chamber, diagnostic system and additional tracking detector
  - Integration constraints: target chamber located at least 1m upstream of the LHCb IP → consequences on the « large-x » reach
  - Projections for Run4 → $L_{int} \sim 5$ fb^{-1} for pH↑ collisions ($\Phi \sim 3.8 \times 10^8$ p/s, $L_{inst} \sim 4.7 \times 10^{32}$ cm^{-2}.s^{-1}, t~10^7 s)
  - R&D needed for the coating (depolarisation)



New projects under investigation in LHCb

- **Beam splitting with double crystal setup for the measurement of EDM/MDM of charmed baryon (currently not approved)**
  - Intense magnetic field between crystal atomic planes induces spin precession during the lifetime of the particle
  - Measurement of MDM of heavy baryons never performed due to their short lifetime
    → test of QCD calculations, improve current understanding of internal structure of hadrons
  - Measurement of EDM of heavy and strange baryons powerful to probe physics beyond the standard model



Horizon 2020 project STRONG-2020

http://www.strong-2020.eu

44 institutions from 14 EU Member States,

Budget: 10 M euro for 4 years (2019 - 2023)

JRA2-FTE@LHC: Fixed Target Experiments at the LHC

Development of novel gas-target techniques to be able to carry out the most energetic fixed-target collisions ever performed in the lab, using the LHC beams at ALICE and LHCb. Evaluation of the novel expected constraints on PDFs at high-x in the proton and nucleus, parton spin dynamics, as well as QGP properties via unique quarkonia measurements.

Horizon 2020 project STRONG-2020

http://www.strong-2020.eu

JRA2-FTE@LHC: Fixed Target Experiments at the LHC

Lead beneficiary: CNRS – France, Co-leadership: INFN

Spokespersons: Pasquale Di Nezza, Cynthia Hadjidakis

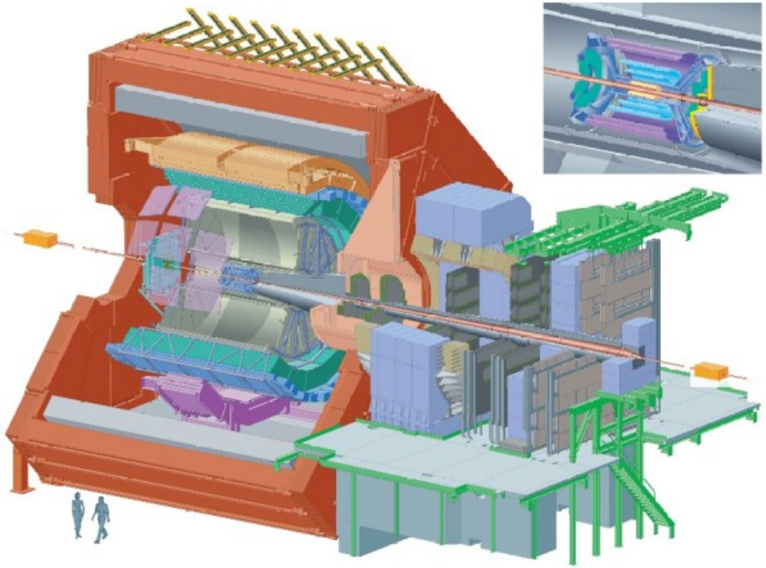
Partners: FZJ - Frank Rathmann, USC - Elena Ferreiro,

INFN - Pasquale Di Nezza, NCBJ - Jakub Wagner,

WUT - Daniel Kikola, LIP - Joao Seixas

ALICE Fixed Target group at Warsaw University of Technology

Cooperation with Laboratoire de physique des deux infinis Irène Joliot-Curie, Orsay, France; and Czech Technical University in Prague



Dr Daniel Kikoła (leader)

Dr Md. Rihan Haque (post-doc, funded by **Horizon 2020** grant *The strong interaction at the frontier of knowledge: fundamental research and applications*)

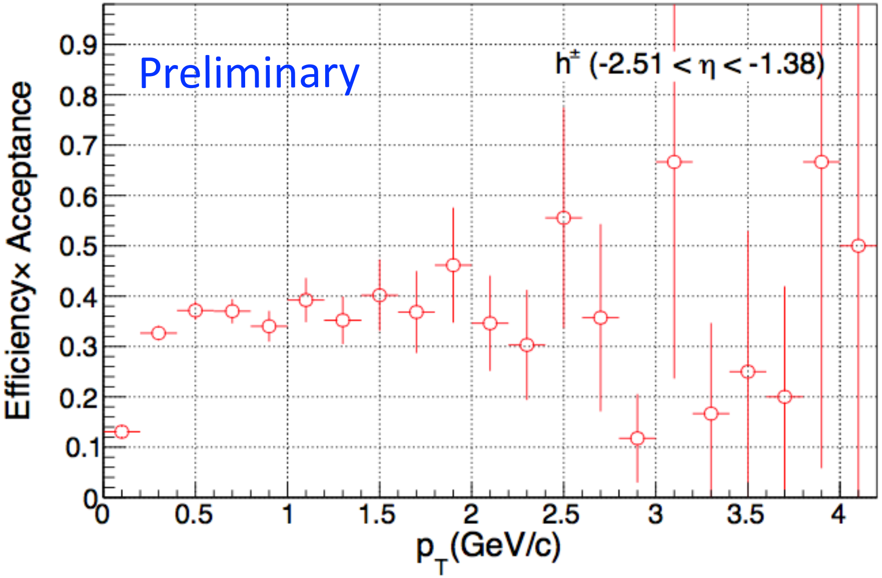
Dr Marcin Patecki (Marie Skłodowska-Curie Individual Fellowship: *The ALICE fixed-target programme layout using bent crystals at the CERN Large Hadron Collider*.)

STRONG-2020 Annual Meeting, October 14-15, 2020

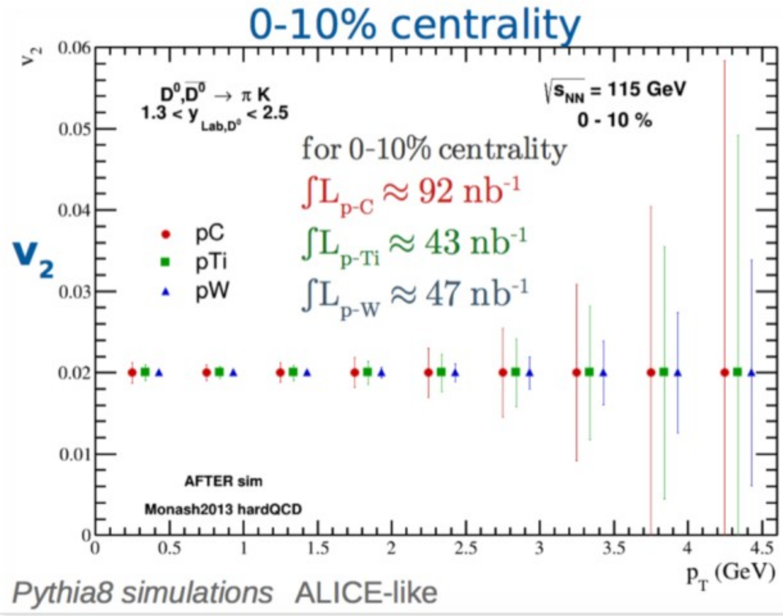
Study of performance of ALICE detector with a shifted vertex

First simulations started to study the Time Projection Chamber performance located in the ALICE central barrel with a shifted vertex

Feasibility studies for v_2 and R_{CP}



Md Rihan Haque



B. Trzeciak HP2019

New SMOG on the horizon

https://cerncourier.com/a/new-smog-on-the-horizon/

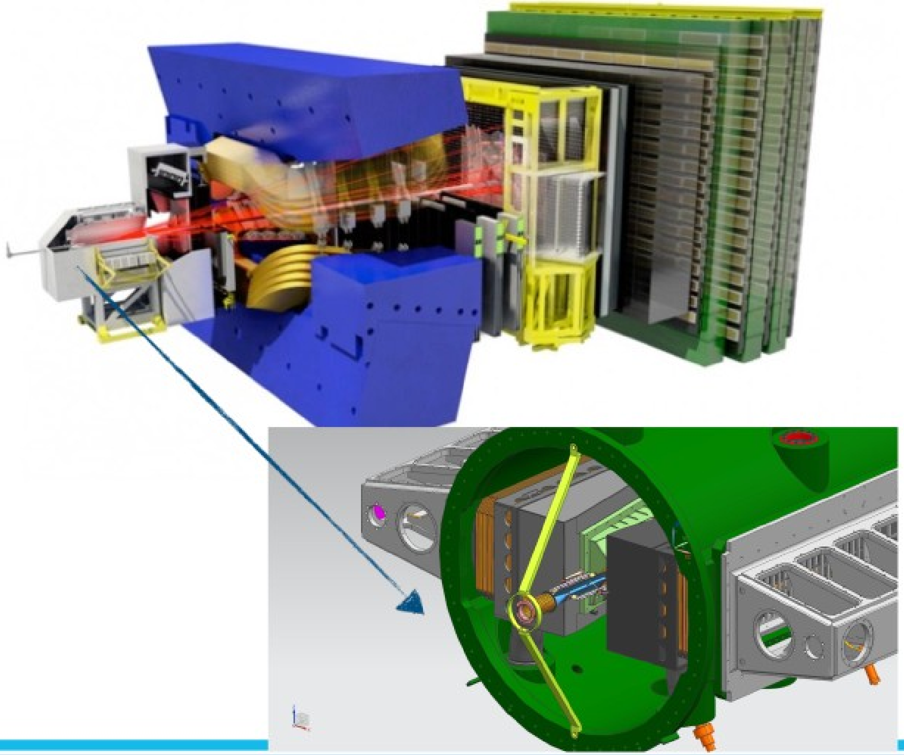
8 May 2020

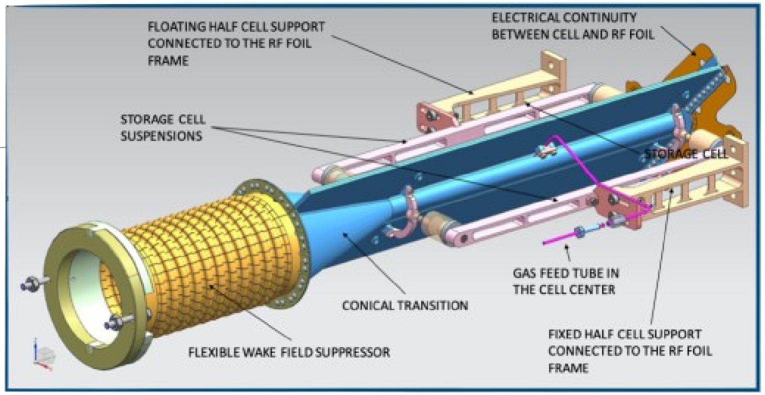
A report from the LHCb experiment

Fig. 1. Half of the SMOG2 storage cell (black), attached to its wake-field suppressor (black, right) and the VELO RF foil (grey, left). Credit: LHCb

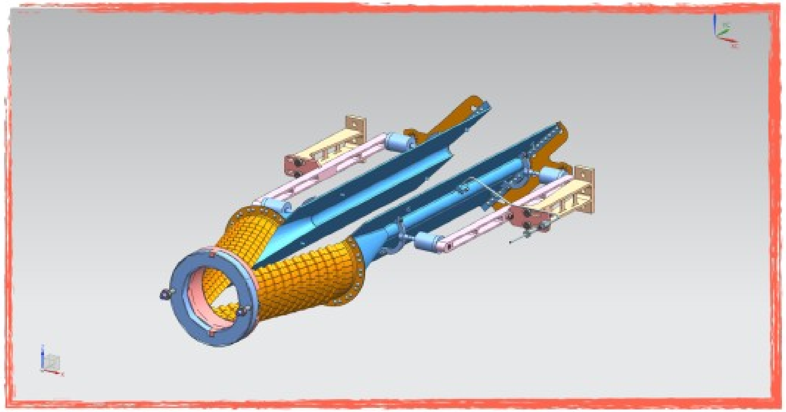
LHCb will soon become the first LHC experiment able to run simultaneously with two separate interaction regions. As part of the ongoing major upgrade of the LHCb detector, the new SMOG2 fixed-target system will be installed in long shutdown 2. SMOG2 will replace the previous System for Measuring the Overlap with Gas (SMOG), which injected noble gases into the vacuum vessel of LHCb's vertex detector (VELO) at a low rate with the initial goal of calibrating luminosity measurements. The new system has several advantages, including the ability to reach effective area densities (and thus luminosities) up to two orders of magnitude higher for the same injected gas flux.

LHCb – The storage cell



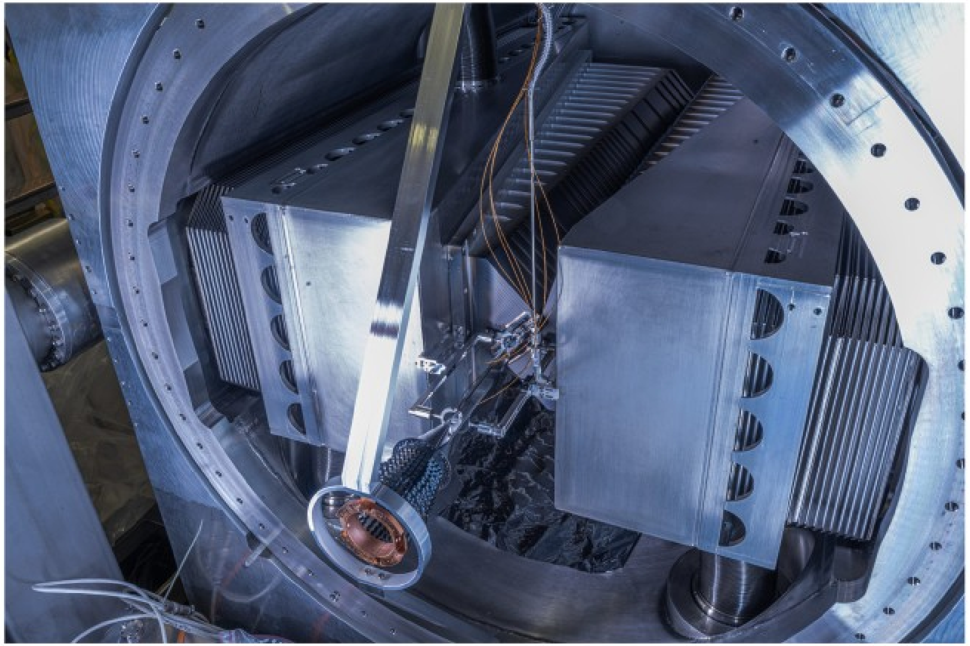


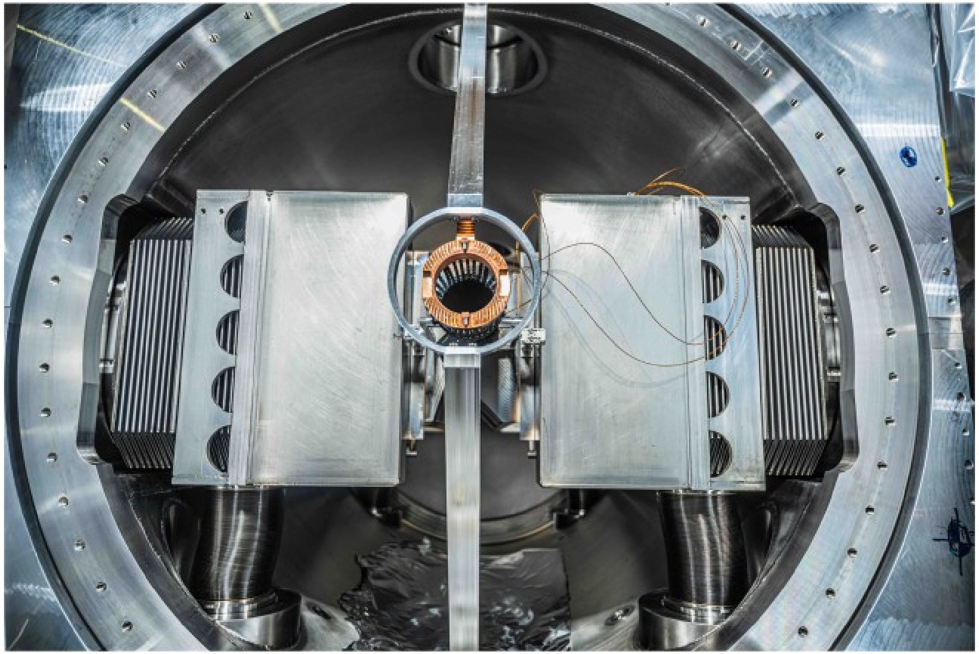
Openable cell



The storage cell has been installed

It is the only object present in the LHC primary vacuum





August 2020

Status and summary

- Topic of the Physics Beyond Collider study http://pbc.web.cern.ch/ → **LHC fixed target** working group
- 3 contributions to European Particle Physics Strategy submitted, positive reception at **EPPS Update meeting in Granada 2019**
- CERN yellow report: **LHC fixed target experiments : Report from the LHC Fixed Target Working Group of the CERN Physics Beyond Colliders Forum,**

  CERN-2020-004, http://cds.cern.ch/record/2653780
- Ongoing technical and Performance studies within the **Horizon 2020 grant STRONG-2020**
- **ALICE: If FT project approved:** aim for a target installation during Long Shutdown 3

Backup

Maximum achievable luminosities with the LHCb detector*

Target			LHCb proton beam ($\sqrt{s_{NN}}$ = 115 GeV) $\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate kHz	$\int\mathcal{L}$	Pb beam ($\sqrt{s_{NN}}$ = 72 GeV) $\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate kHz	$\int\mathcal{L}$
Internal gas target	Gas-Jet	$H^\uparrow$	4.3×10^{30}	39 mb	168	43 pb^{-1}	5.6×10^{26}	1.8 b	1	0.56 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^\uparrow$	4.3×10^{30}	72 mb	309	43 pb^{-1}	5.6×10^{26}	2.2 b	1.2	0.56 nb^{-1}
		$^3He^\uparrow$	3.4×10^{32}	117 mb	40000	3.4 fb^{-1}	4.7×10^{28}	2.5 b	118	47 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	2.3×10^{28}	6.2 b	186	23 nb^{-1}
	Storage Cell	$H^\uparrow$	0.92×10^{33}	39 mb	35880	9.2 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^\uparrow$	5.6×10^{32}	72 mb	40000	5.6 fb^{-1}	8.82×10^{28}	2.2 b	194	88 nb^{-1}
		$^3He^\uparrow$	1.3×10^{33}	117 mb	40000	13 fb^{-1}	8.25×10^{28}	2.5 b	206	83 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	3.0×10^{28}	6.2 b	186	30 nb^{-1}

* Assuming LHCb runs the full year in parallel in fixed target and collider mode. The storage cell is considered to be 1m long.

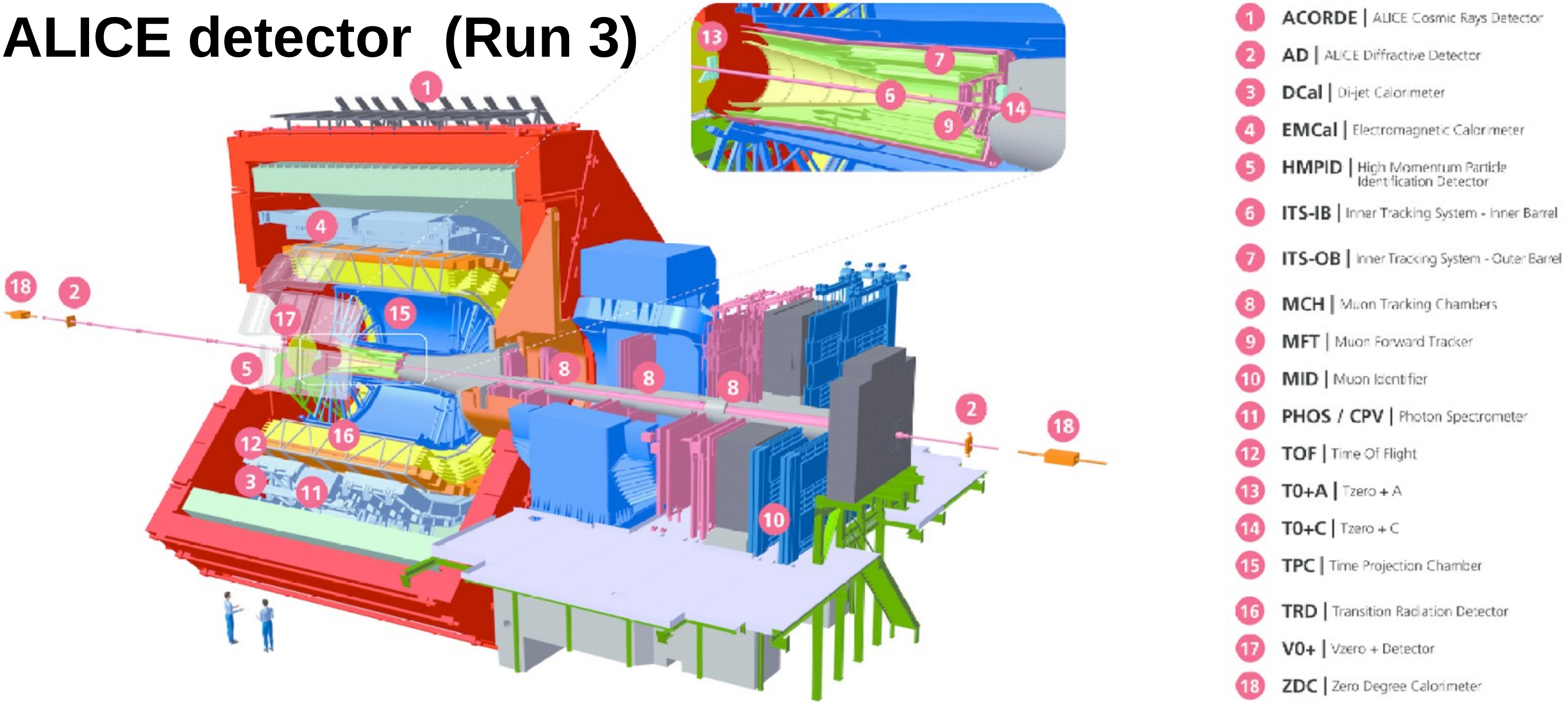
Maximum readout rate considered (40MHz in pp and 5MHz in AA). In PbA collisions, the rate is also limited by the beam lifetime (no more than 15% of the Pb beam flux used)

Max. integrated luminosities with the LHCb detector

Target			LHCb							
			proton beam ($\sqrt{s_{NN}}$ = 115 GeV)				Pb beam ($\sqrt{s_{NN}}$ = 72 GeV)			
			$\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	σ_{inel}	Inel rate kHz	$\int\mathcal{L}$	$\mathcal{L}$ [$cm^{-2}\ s^{-1}$]	σ_{inel}	Inel rate kHz	$\int\mathcal{L}$
Internal gas target	Gas-Jet	$H^{\uparrow}$	4.3×10^{30}	39 mb	168	43 pb^{-1}	5.6×10^{26}	1.8 b	1	0.56 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^{\uparrow}$	4.3×10^{30}	72 mb	309	43 pb^{-1}	5.6×10^{26}	2.2 b	1.2	0.56 nb^{-1}
		$^3He^{\uparrow}$	3.4×10^{32}	117 mb	40000	3.4 fb^{-1}	4.7×10^{28}	2.5 b	118	47 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	2.3×10^{28}	6.2 b	186	23 nb^{-1}
	Storage Cell	$H^{\uparrow}$	0.92×10^{33}	39 mb	35880	9.2 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^{\uparrow}$	5.6×10^{32}	72 mb	40000	5.6 fb^{-1}	8.82×10^{28}	2.2 b	194	88 nb^{-1}
		$^3He^{\uparrow}$	1.3×10^{33}	117 mb	40000	13 fb^{-1}	8.25×10^{28}	2.5 b	206	83 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	3.0×10^{28}	6.2 b	186	30 nb^{-1}

Maximum readout rate considered (40 MHz in pp and 5 MHz in AA).
1 m long storage cell

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

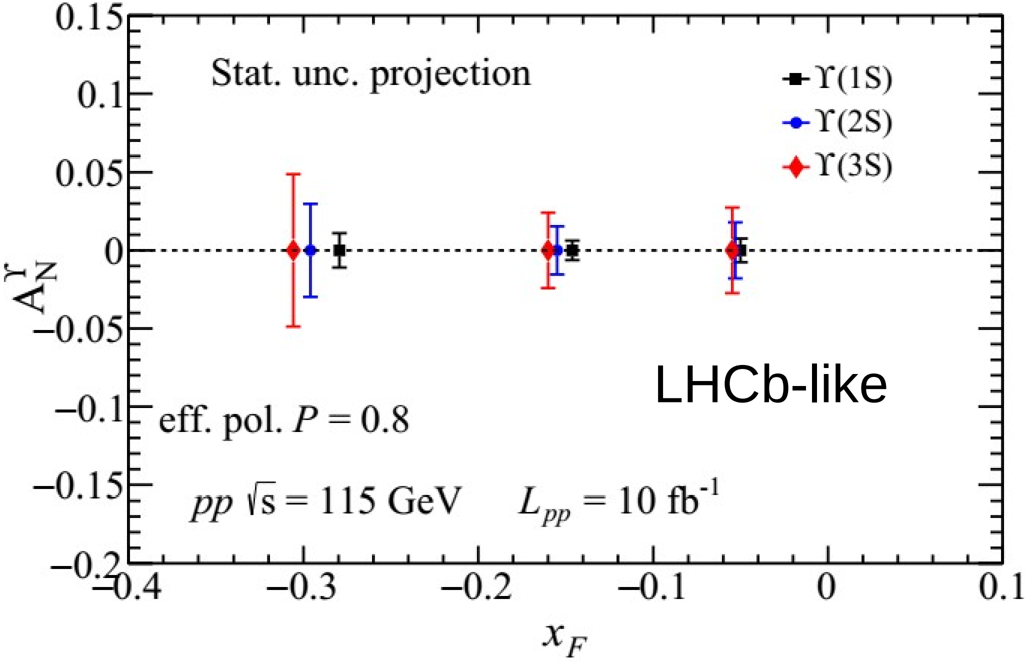
Continuous readout(*): 50 kHz in Pb-Pb, 200 kHz up to 1 MHz in p-p and p-A

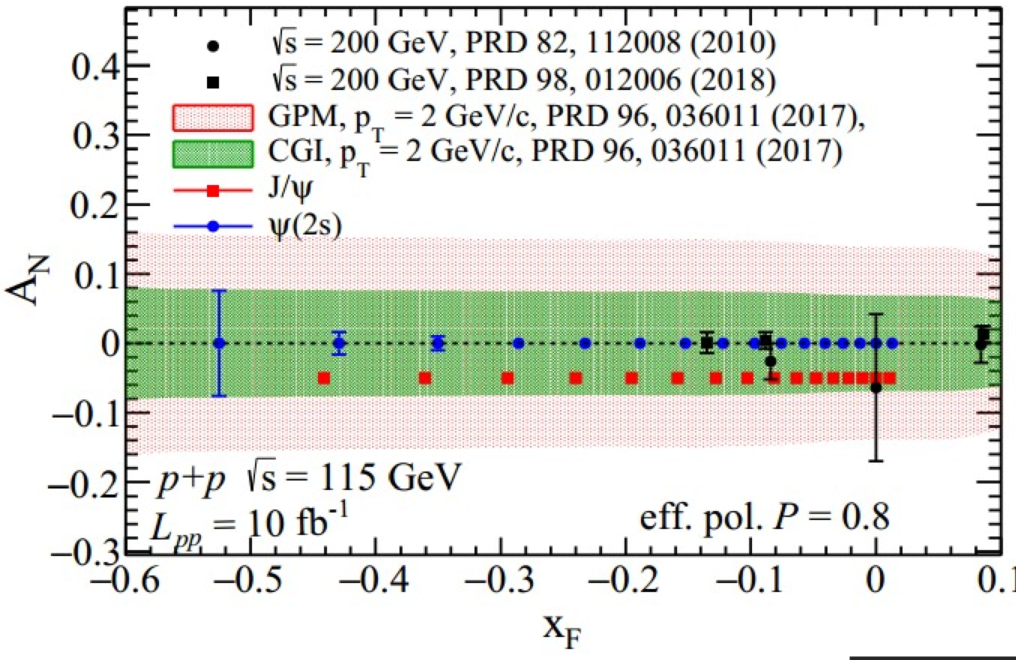
(*)The feasible rate also depends on the detector occupancy in a fixed target mode

J/ψ and ϒ in p+p

$$A_N = \frac{1}{\mathcal{P}_{\text{eff}}} \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

- Typically 10^9 charmonia, 10^6 bottomonia per year
- Unique access to C-even quarkonia ($\chi_{c,b}$, η_c) + associated production
- A_N for all quarkonia (J/ψ, ψ', χ_c , ϒ(nS), χ_b & η_c) can be measured





Available Luminosities

ALICE

Target			ALICE							
			proton beam ($\sqrt{s_{NN}} = 115$ GeV)				Pb beam ($\sqrt{s_{NN}} = 72$ GeV)			
			$\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate [kHz]	$\int \mathcal{L}$	$\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate [kHz]	$\int \mathcal{L}$
Internal gas target	Gas-Jet	$H^{\uparrow}$	4.3×10^{30}	39 mb	168	43 pb^{-1}	5.6×10^{26}	1.8 b	1	0.56 nb^{-1}
		H_2	2.6×10^{31}	39 mb	1000	0.26 fb^{-1}	2.8×10^{28}	1.8 b	50	28 nb^{-1}
		$D^{\uparrow}$	4.3×10^{30}	72 mb	309	43 pb^{-1}	5.6×10^{26}	2.2 b	1.2	0.56 nb^{-1}
		$^3He^{\uparrow}$	8.5×10^{30}	117 mb	1000	85 pb^{-1}	2.0×10^{28}	2.5 b	50	20 nb^{-1}
		Xe	7.7×10^{29}	1.3 b	1000	7.7 pb^{-1}	8.1×10^{27}	6.2 b	50	8.1 nb^{-1}
	Storage Cell	$H^{\uparrow}$	2.6×10^{31}	39 mb	1000	0.26 fb^{-1}	2.8×10^{28}	1.8 b	50	28 nb^{-1}
		H_2	2.6×10^{31}	39 mb	1000	0.26 fb^{-1}	2.8×10^{28}	1.8 b	50	28 nb^{-1}
		$D^{\uparrow}$	1.4×10^{31}	72 mb	1000	140 pb^{-1}	2.2×10^{28}	2.2 b	50	22 nb^{-1}
		$^3He^{\uparrow}$	8.5×10^{30}	117 mb	1000	85 pb^{-1}	2.0×10^{28}	2.5 b	50	20 nb^{-1}
		Xe	7.7×10^{29}	1.3 b	1000	7.7 pb^{-1}	8.1×10^{27}	6.2 b	50	8.1 nb^{-1}
Internal solid target with beam halo	Wire Target	C (500 μm)	2.8×10^{30}	271 mb	760	28 pb^{-1}	5.6×10^{26}	3.3 b	1.8	0.56 nb^{-1}
		Ti (500 μm)	1.4×10^{30}	694 mb	971	14 pb^{-1}	2.8×10^{26}	4.7 b	1.3	0.28 nb^{-1}
		W (184 μm)	5.9×10^{29}	1.7b	1000	5.9 pb^{-1}	–	–	–	–
		W (500 μm)	–	–	–	–	3.1×10^{26}	6.9 b	2.1	0.31 nb^{-1}
Beam splitting	E1039	$NH_3^{\uparrow}$	2.6×10^{31}	39 mb	1000	0.26 fb^{-1}	1.4×10^{28}	1.8 b	25	14 nb^{-1}
		$ND_3^{\uparrow}$	1.4×10^{31}	72 mb	1000	140 pb^{-1}	1.4×10^{28}	2.2 b	30	14 nb^{-1}
	Unpol-arised solid target	C (658 μm)	3.7×10^{30}	271 mb	1000	37 pb^{-1}	–	–	–	–
		C (5 mm)	–	–	–	–	5.6×10^{27}	3.3 b	18	5.6 nb^{-1}
		Ti (515 μm)	1.4×10^{30}	694 mb	1000	14 pb^{-1}	–	–	–	–
		Ti (5 mm)	–	–	–	–	2.8×10^{27}	4.7 b	13	2.8 nb^{-1}
		W(184 μm)	5.9×10^{29}	1.7b	1000	5.9 pb^{-1}	–	–	-	–
		W(5 mm)	–	–	–	–	3.1×10^{27}	6.9 b	21	3.1 nb^{-1}

FT Luminosities comparable with nominal LHC luminosities

Available Luminosities

LHCb

Target			LHCb							
			proton beam ($\sqrt{s_{NN}}$ = 115 GeV)				Pb beam ($\sqrt{s_{NN}}$ = 72 GeV)			
			$\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate kHz	$\int \mathcal{L}$	$\mathcal{L}$ [cm^{-2} s^{-1}]	σ_{inel}	Inel rate kHz	$\int \mathcal{L}$
Internal gas target	Gas-Jet	$H^{\uparrow}$	4.3×10^{30}	39 mb	168	43 pb^{-1}	5.6×10^{26}	1.8 b	1	0.56 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^{\uparrow}$	4.3×10^{30}	72 mb	309	43 pb^{-1}	5.6×10^{26}	2.2 b	1.2	0.56 nb^{-1}
		$^{3}He^{\uparrow}$	3.4×10^{32}	117 mb	40000	3.4 fb^{-1}	4.7×10^{28}	2.5 b	118	47 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	2.3×10^{28}	6.2 b	186	23 nb^{-1}
	Storage Cell	$H^{\uparrow}$	0.92×10^{33}	39 mb	35880	9.2 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		H_2	1.0×10^{33}	39 mb	40000	10 fb^{-1}	1.18×10^{29}	1.8 b	212	118 nb^{-1}
		$D^{\uparrow}$	5.6×10^{32}	72 mb	40000	5.6 fb^{-1}	8.82×10^{28}	2.2 b	194	88 nb^{-1}
		$^{3}He^{\uparrow}$	1.3×10^{33}	117 mb	40000	13 fb^{-1}	8.25×10^{28}	2.5 b	206	83 nb^{-1}
		Xe	3.1×10^{31}	1.3 b	40000	0.31 fb^{-1}	3.0×10^{28}	6.2 b	186	30 nb^{-1}
Internal solid target on beam halo	Wire Target	C (500 μm)	2.8×10^{30}	271 mb	760	28 pb^{-1}	5.6×10^{26}	3.3 b	1.8	0.56 nb^{-1}
		Ti (500 μm)	1.4×10^{30}	694 mb	972	14 pb^{-1}	2.8×10^{26}	4.7 b	1.3	0.28 nb^{-1}
		W (500 μm)	1.6×10^{30}	1.7 b	2720	16 pb^{-1}	3.1×10^{26}	6.9 b	2.1	0.31 nb^{-1}
Beam splitting	E1039	$NH_3^{\uparrow}$	7.2×10^{31}	39 mb	2808	0.72 fb^{-1}	1.4×10^{28}	1.8 b	25	14 nb^{-1}
		$ND_3^{\uparrow}$	7.2×10^{31}	72 mb	5100	0.72 fb^{-1}	1.4×10^{28}	2.2 b	30	14 nb^{-1}
	Unpolarised solid target	C (5 mm)	2.8×10^{31}	271 mb	7600	280 pb^{-1}	5.6×10^{27}	3.3 b	18	5.6 nb^{-1}
		Ti (5 mm)	1.4×10^{31}	694 mb	9720	140 pb^{-1}	2.8×10^{27}	4.7 b	13	2.8 nb^{-1}
		W (5 mm)	1.6×10^{31}	1.7 b	27200	160 pb^{-1}	3.1×10^{27}	6.9 b	21	3.1 nb^{-1}

Physics opportunities in AFTER @ LHC

Physics opportunities of a fixed-target experiment using LHC beams

Physics Reports 522 (2013) 239

Ideas for a fixed target experiment at LHC in a Special Issue in Advances in High Energy Physics:

Advances in High Energy Physics, Volume 2015 (2015)

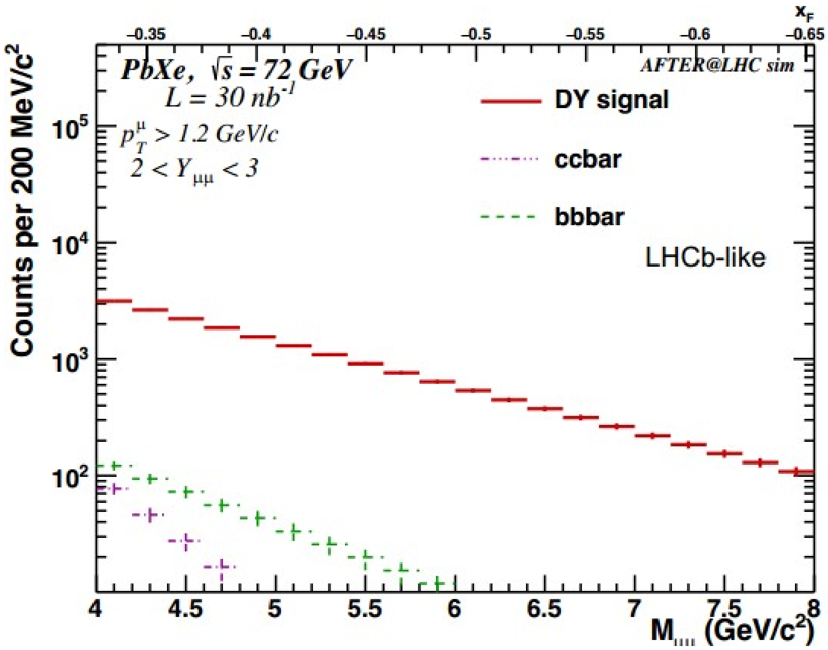
- **Heavy-ion physics**
- **Exclusive reactions**
- **Spin physics studies**
- **Hadron structure**
- **Feasibility study and technical ideas**

Test o factorization of initial state effects in A+A

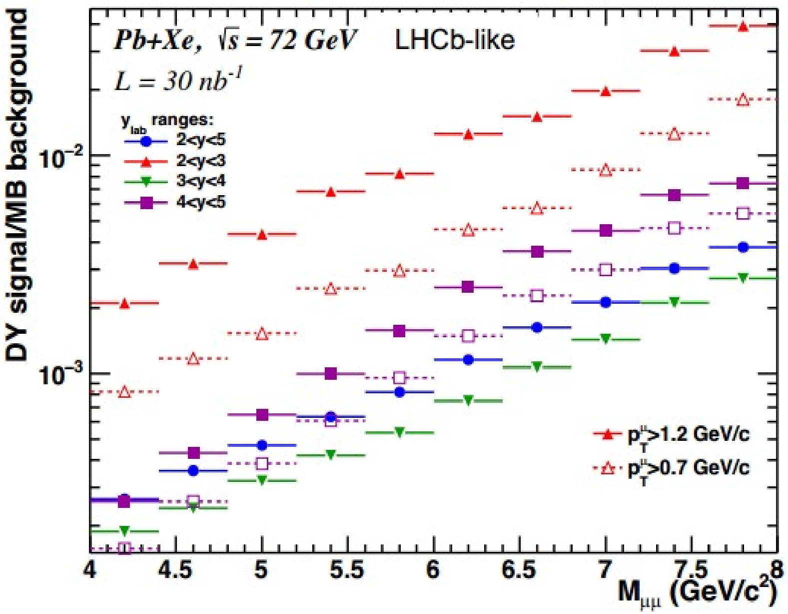
Drell Yan:

Few Body Syst. 58 (2017) no.4, 139

- initial state production, not significant interaction with nuclear medium
- ideal test of the extrapolation of initial state effects in pA to AA



Few Body Syst. 58 (2017) no.5, 148

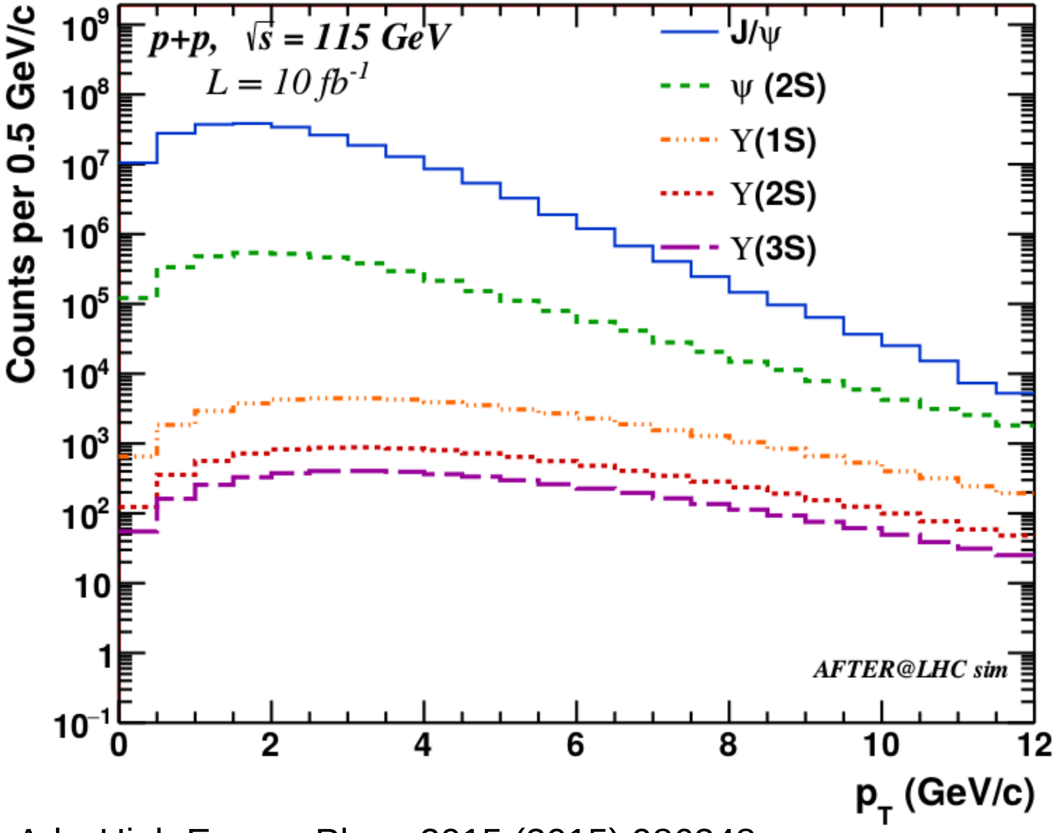


LHCb-like

J/ψ and Υ yields

Typically 10^9 charmonia, 10^6 bottomonia per year

LHCb-like

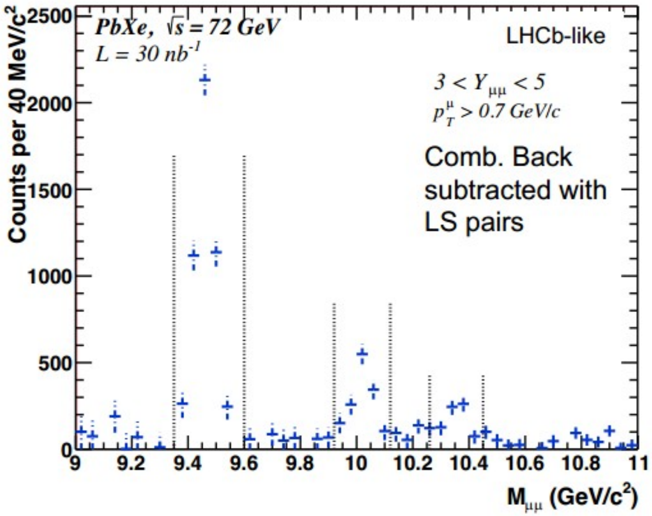


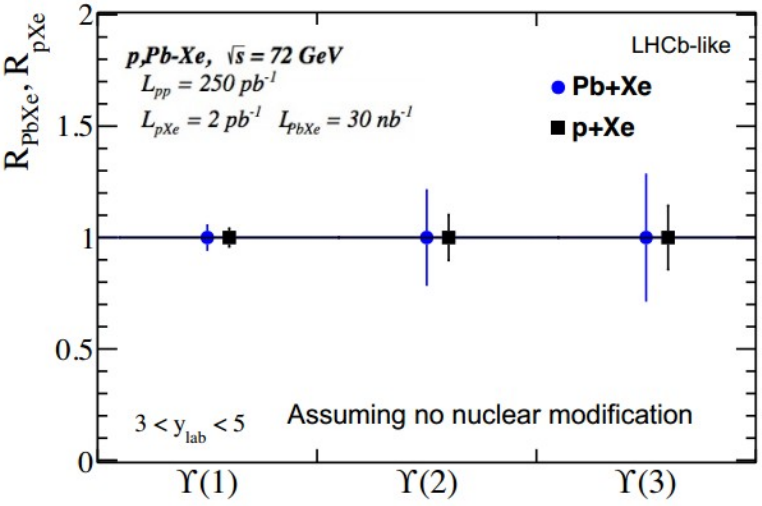
Adv. High Energy Phys. 2015 (2015) 986348

Quarkonium in “cold” and “hot” mater studies

Determination of thermodynamic properties of QGP + cold nuclear matter effects with Υ(nS) production in pp, pA, AA

Few Body Syst. 58 (2017) no.5, 148





Yields		signal	S/B
$\Upsilon(1S)$	pp	1.33×10^3	29.0
	pXe	1.39×10^3	7.8
	PbXe	4.33×10^3	1.8×10^{-1}
$\Upsilon(2S)$	pp	2.92×10^2	8.2
	pXe	3.06×10^2	2.2
	PbXe	9.56×10^2	5.0×10^{-2}
$\Upsilon(3S)$	pp	1.37×10^2	10.3
	pXe	1.44×10^2	2.8
	PbXe	4.49×10^2	6.2×10^{-2}

LHCb-like

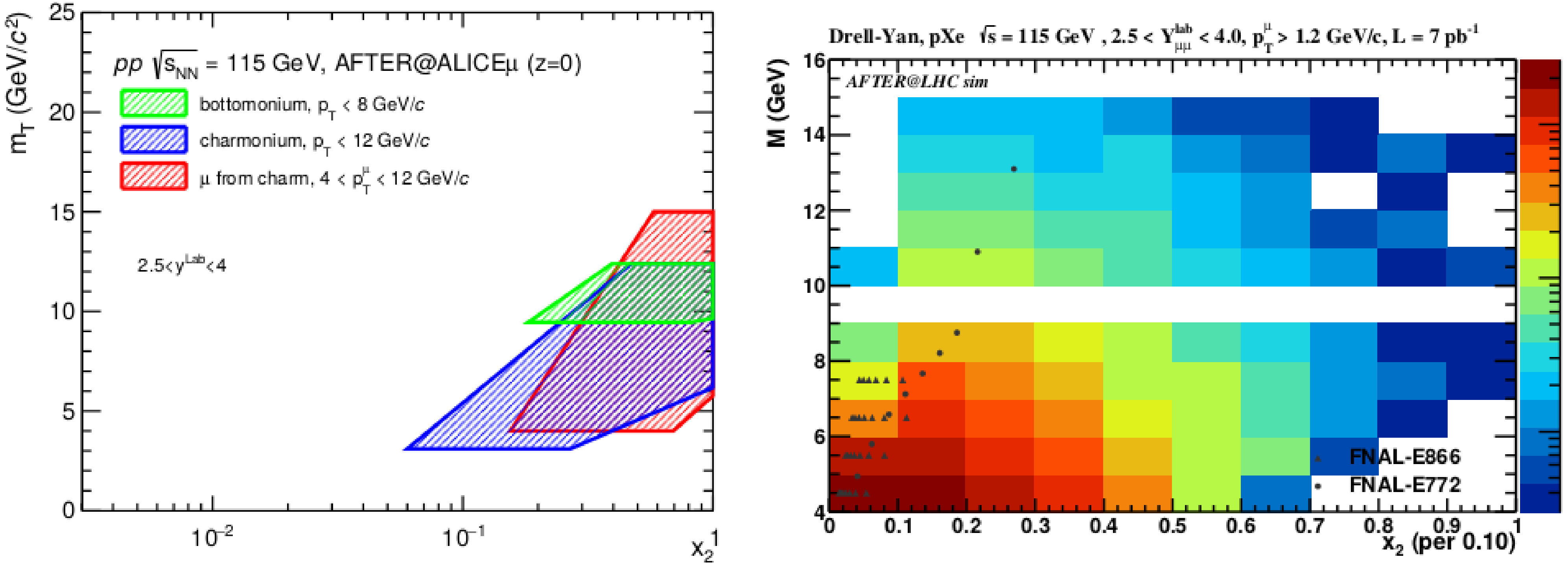
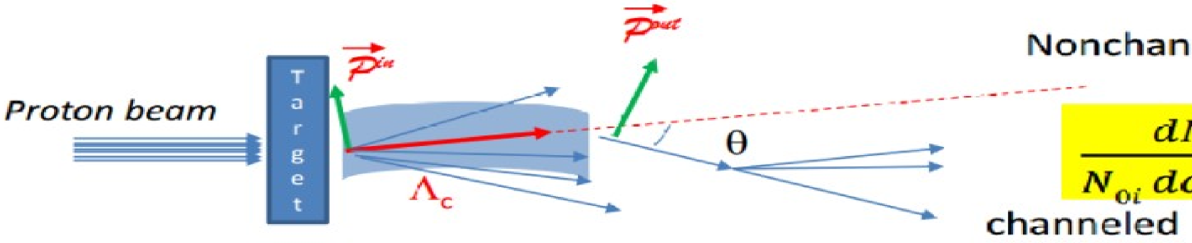


Figure 3: Left: Typical kinematical reach in x_2 and the scale (chosen to be m_T) of the fixed-target mode with a detector acceptance like ALICE. Right: Kinematical reach for Drell-Yan lepton-pair production with an ALICE-like detector in pXe collisions at $\sqrt{s} = 115$ GeV with an acceptance of $2.5 < \eta_\mu^{\rm lab} < 4$ and $p_T^\mu > 1.2$ GeV. Colours correspond to expected yields of the Drell-Yan signal in each kinematical region, and each coloured cell contains at least 30 events.

Measuring Magnetic and Electric Moments of charm baryons with bended crystal

The basic principle of the measurement - II

Protons are channeled by a crystal put in the halo and sent against a target.
Polarised charm baryons are produced and channeled by a second long crystal



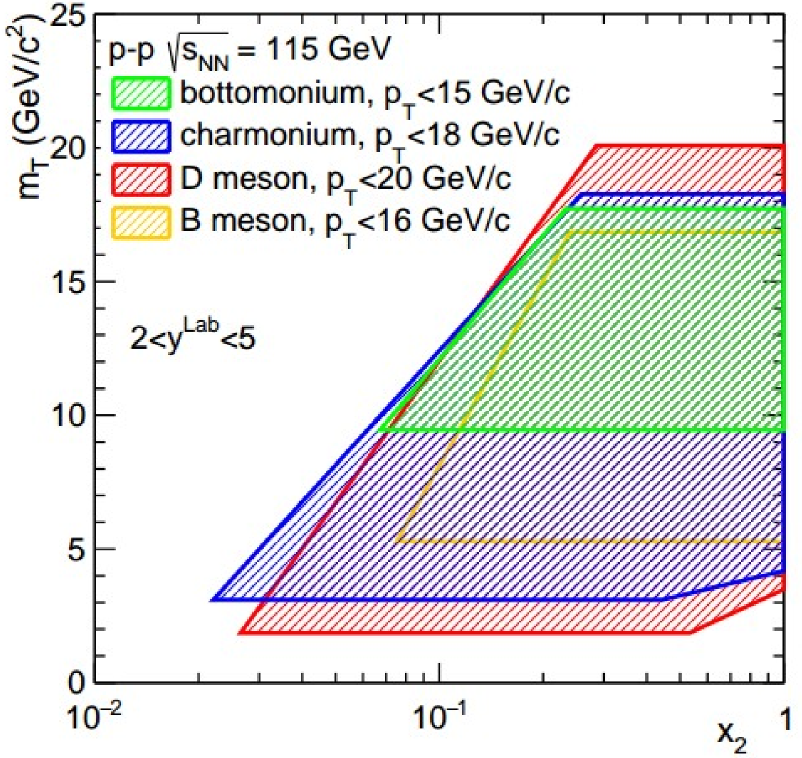
$$\frac{dN_i}{N_{0i}\, d\cos\theta_i} = \frac{1}{2}\left(1+\alpha P_i \cos_i\theta_i\right)$$

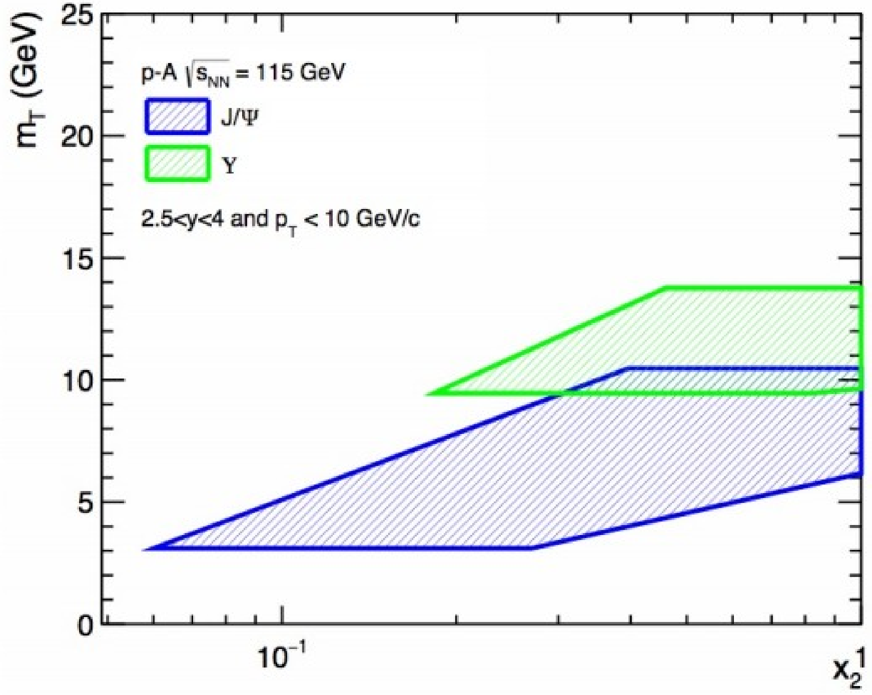
Fixed target experiment to produce polarised baryons
Angular analysis of baryon decays to measure the final polarisation.

Two crucial parameters α and P

, Physics Beyond Colliders annual workshop, CERN, 2017,
https://indico.cern.ch/event/644287/contributions/2724478/

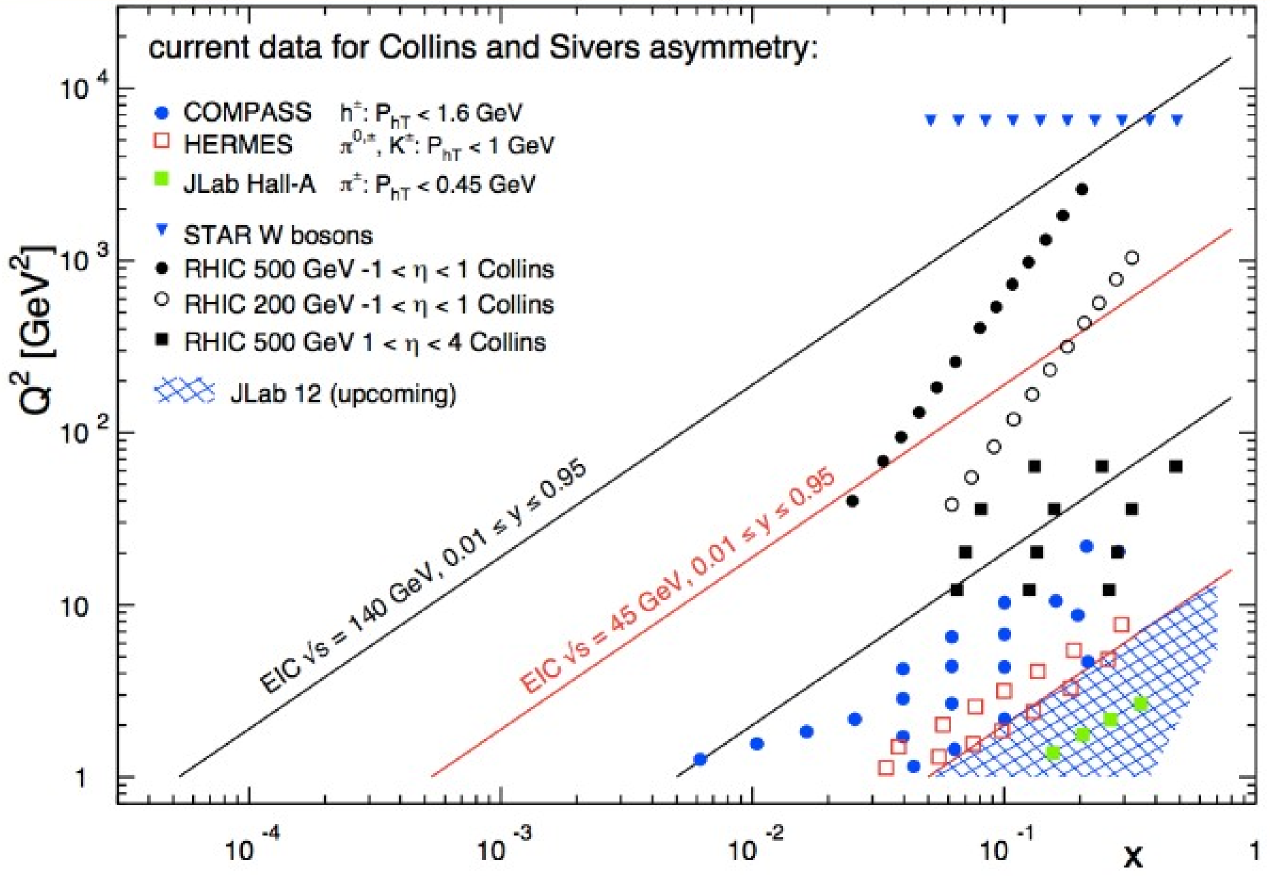
Heavy-favour studies: kinematical ranges



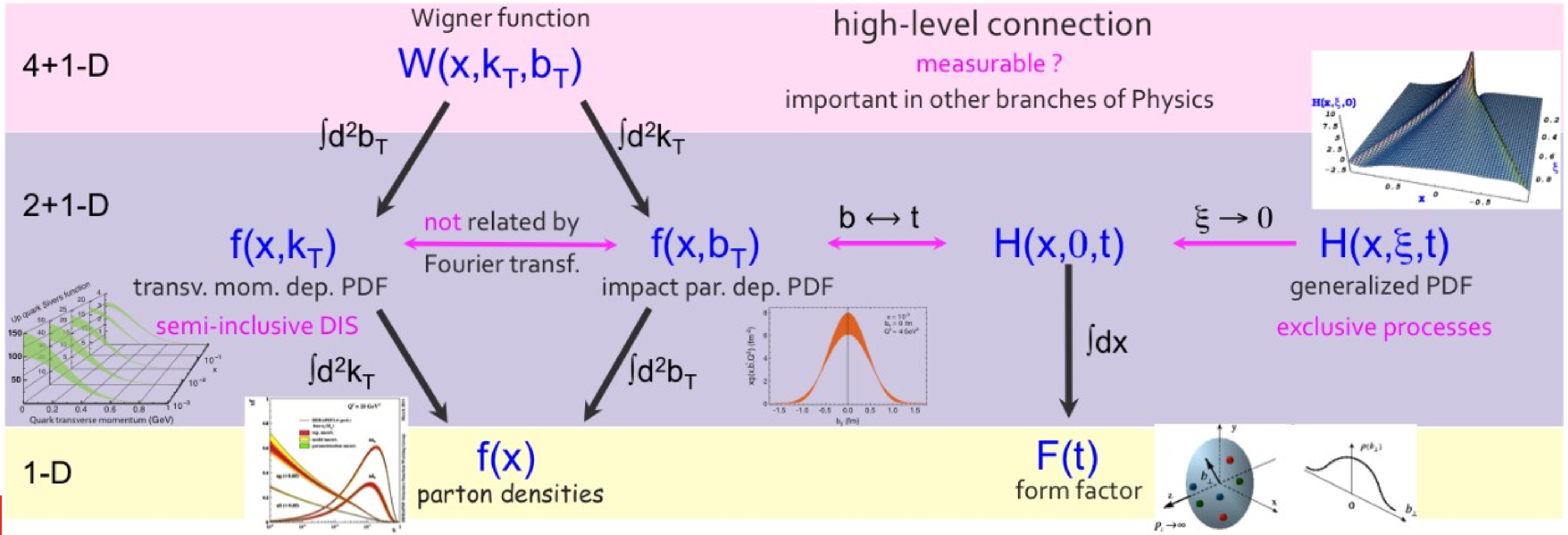


- Left: for LHCb based on 10 fb^{-1} of data
- Right : for ALICE based on a P_T cut (to be improved with 0.25 fb^{-1} of data)

R. Fatemi, *The RHIC cold QCD plan for 2017 to 2023: a portal to the EIC*, https://indico.cern.ch/event/570680/contributions/2310058/



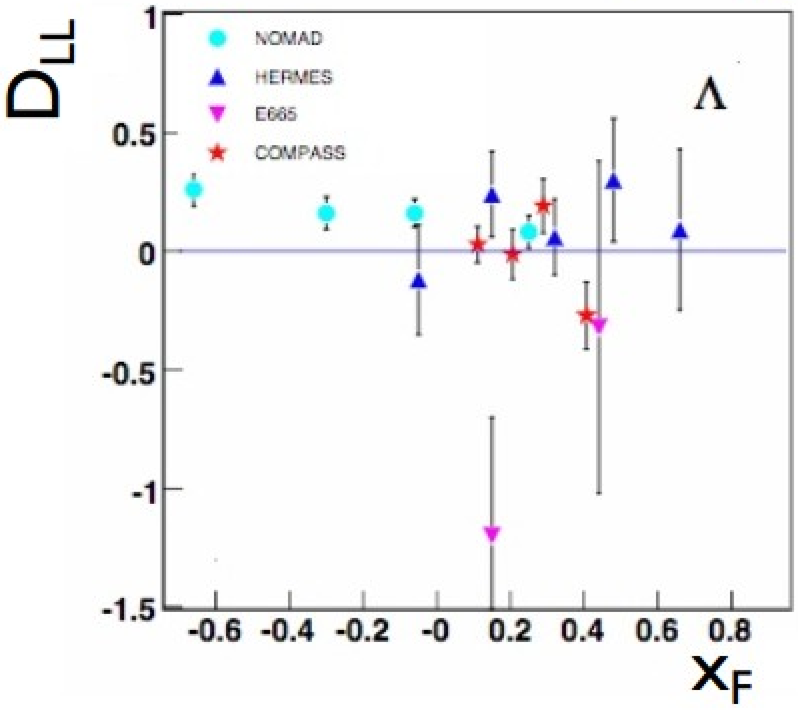
*The range in a quark (or gluon) momentum fraction x vs. the square of the momentum transfer Q^2 in a given process, accessible in the proposed Electron-Ion Collider (**EIC**), future experiments with 12 GeV electron beam in the Thomas Jefferson National Accelerator Facility (Jefferson Lab, **Jlab 12**), compared to existing data..*

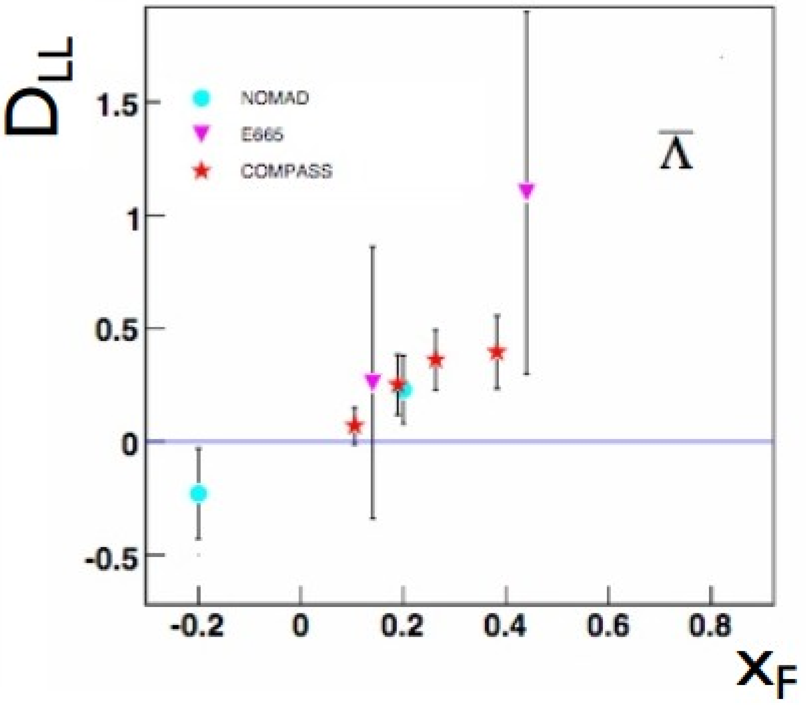


The full spatial (b_T) and transverse momentum (k_T) dependent structure of partons in the nucleon as a function of the longitudinal momentum fraction of the partons is encoded in the Wigner function $W(x,k_T,b_T)$, which currently is not accessible in experiments

Arxiv:1501.01220

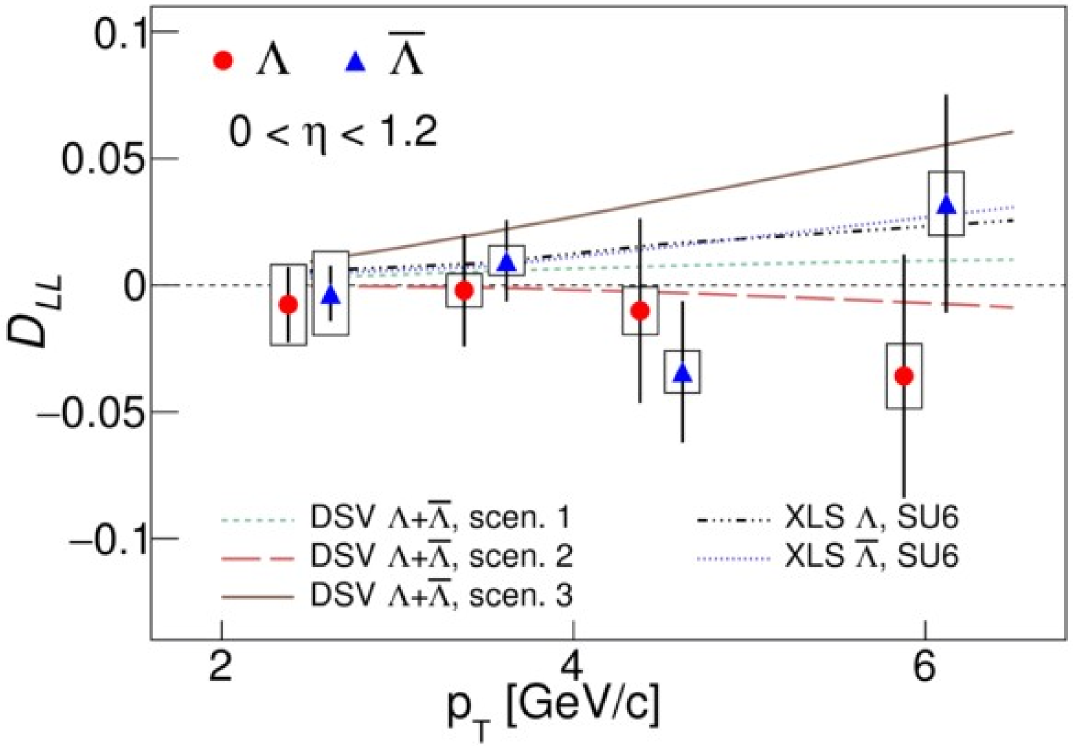
COMPASS, Eur.Phys.J. C64 (2009) 171-179. Polarised Muon DIS

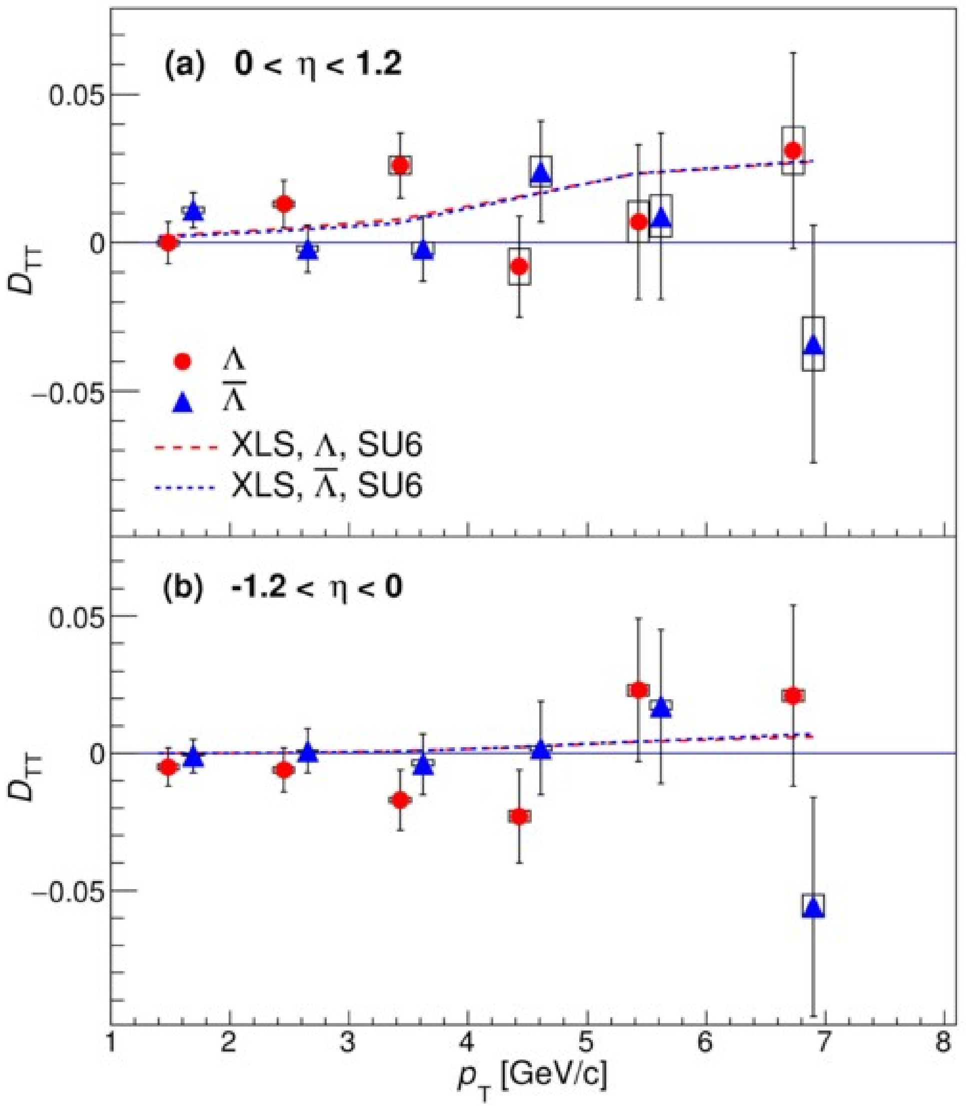




Little D_{LL} data at large negative x_F

STAR

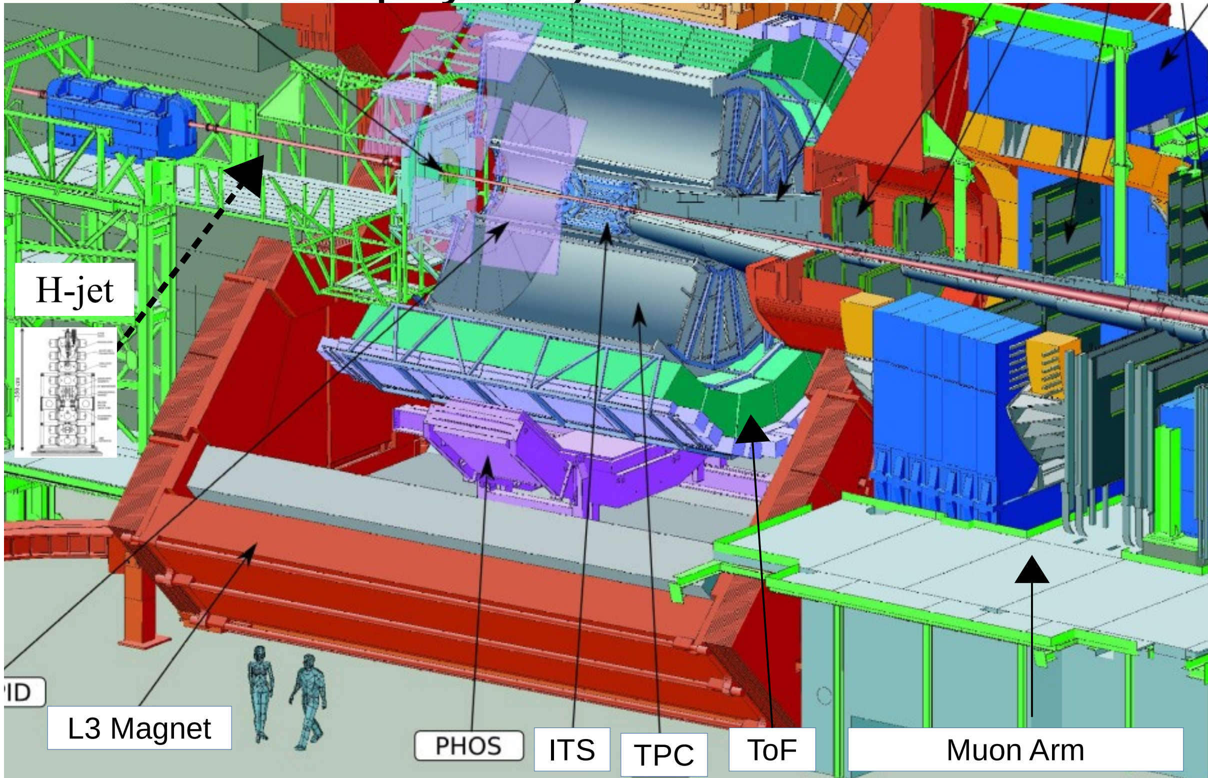

0.1
0.05
0
−0.05
−0.1
D_{LL}
Λ
$\overline{\Lambda}$
$0 < \eta < 1.2$
DSV $\Lambda+\overline{\Lambda}$, scen. 1
DSV $\Lambda+\overline{\Lambda}$, scen. 2
DSV $\Lambda+\overline{\Lambda}$, scen. 3
XLS Λ, SU6
XLS $\overline{\Lambda}$, SU6
2
4
6
p_T [GeV/c]


(a) $0 < \eta < 1.2$
0.05
0
−0.05
D_{TT}
Λ
$\overline{\Lambda}$
XLS, Λ, SU6
XLS, $\overline{\Lambda}$, SU6
(b) $-1.2 < \eta < 0$
0.05
0
−0.05
D_{TT}
1
2
3
4
5
6
7
8
p_T [GeV/c]

Polarized target at ALICE

- ALICE – excellent PID,x→1
- Measurement of spin transfer D_{LL} to strange barons
  - access to Δs and $\Delta\bar{s}$ (implications for astrophysics)

$$D_{\mathrm{LL}} \equiv \frac{\sigma_{pp^+ \to \Lambda^+} - \sigma_{pp^+ \to \Lambda^-}}{\sigma_{pp^+ \to \Lambda^+} + \sigma_{pp^+ \to \Lambda^-}}$$



D_{LL} sensitive to polarized quark densities, and polarized fragmentation functions.

Longitudinal spin transfer D_{LL} to Λ baryons

- Unique rapidity coverage with the ALICE central barrel
- Access to the strange quark polarized PDF at $x \rightarrow 1$

$$D_{LL} \equiv \frac{\sigma_{pp^+ \rightarrow \Lambda^+} - \sigma_{pp^+ \rightarrow \Lambda^-}}{\sigma_{pp^+ \rightarrow \Lambda^+} + \sigma_{pp^+ \rightarrow \Lambda^-}}$$

ALICE-like, $Z_{target} \sim 0$