LHCspin

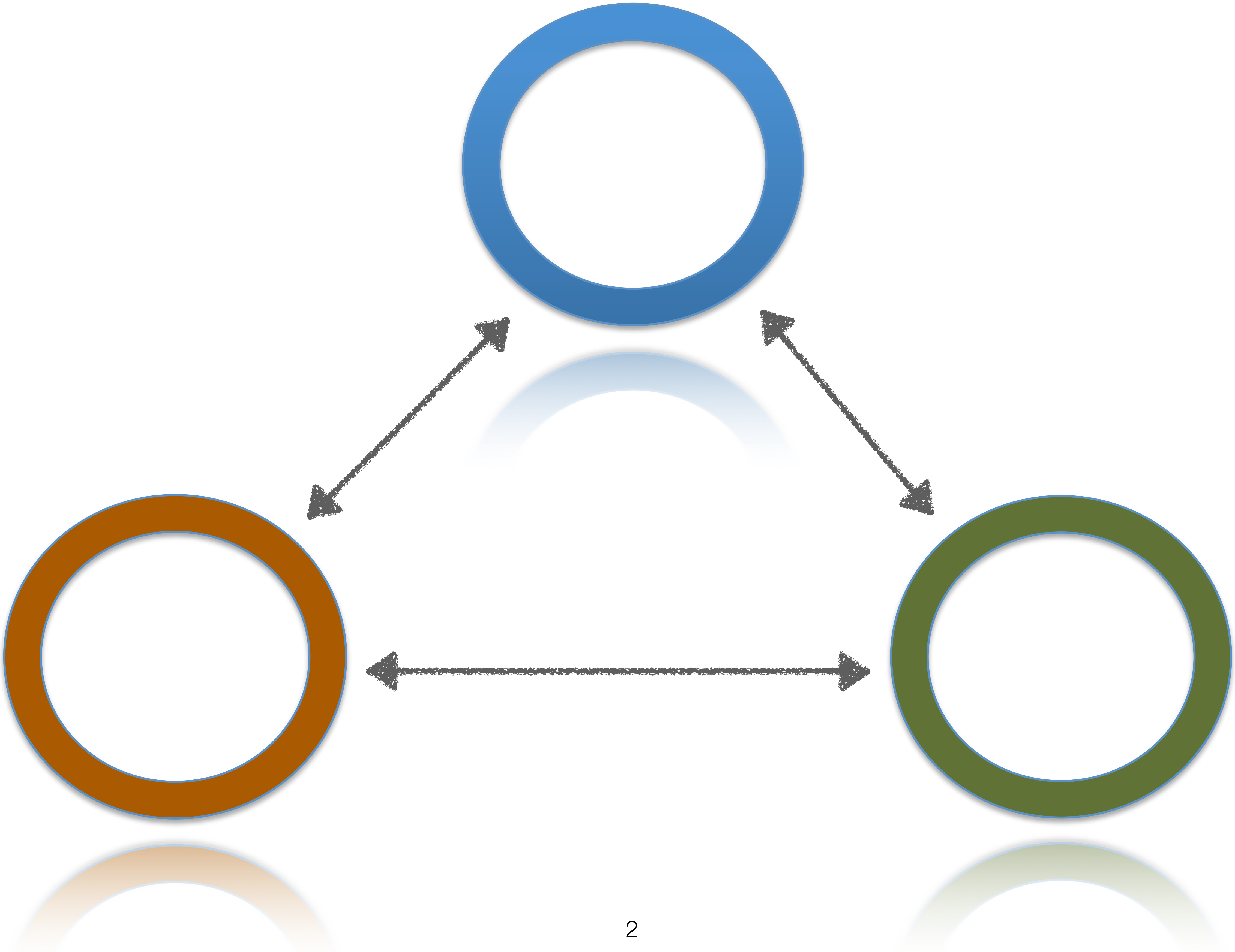
Pasquale Di Nezza

INFN LNF Istituto Nazionale di Fisica Nucleare

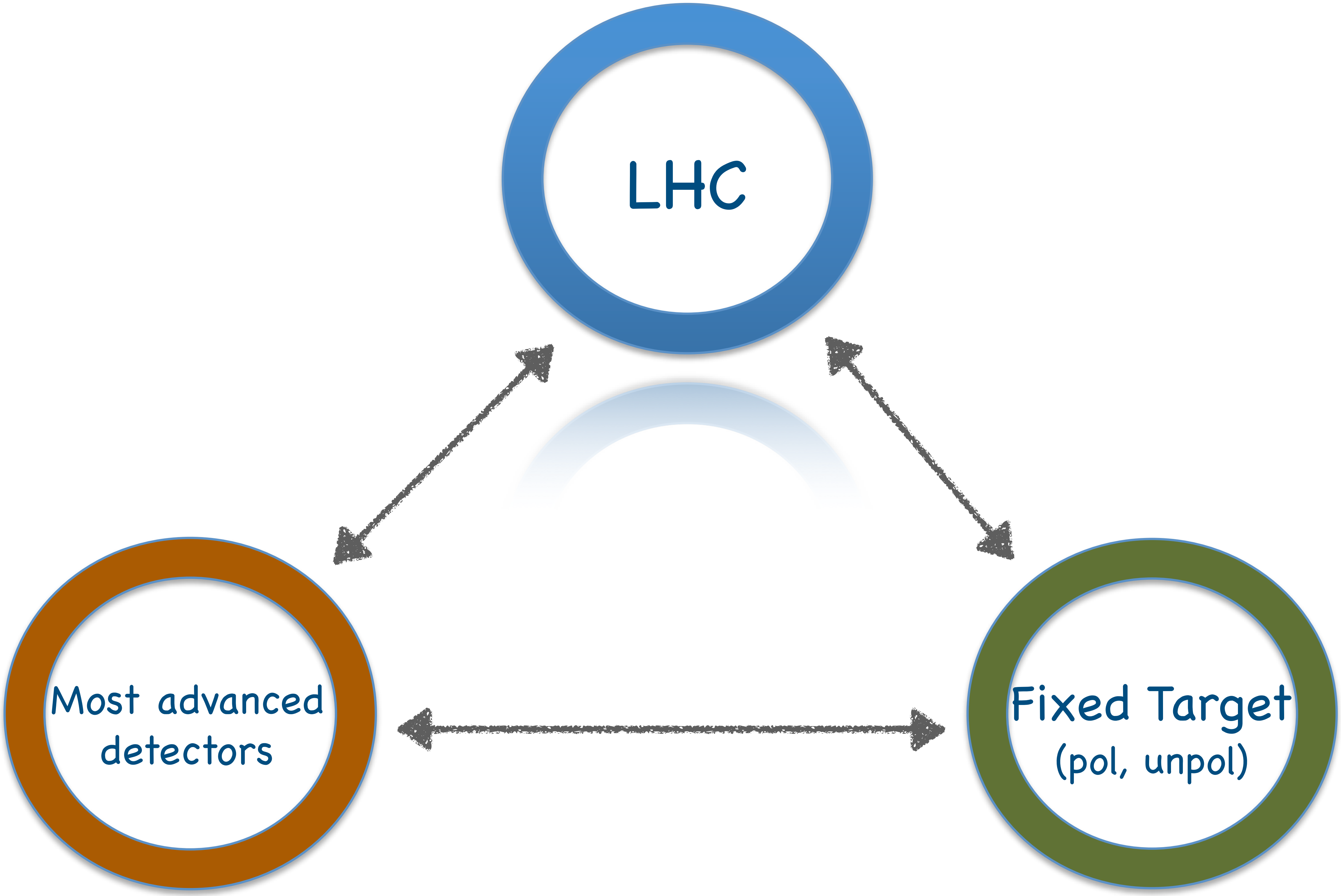
LHCb

In collaboration with: V.Carassiti, G.Ciullo, P.Lenisa, L.Pappalardo, E.Steffens

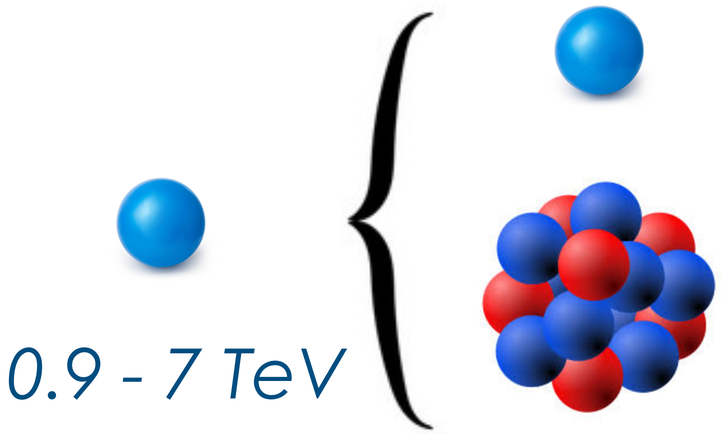
Merging 3 worlds



Merging 3 worlds



Kinematics

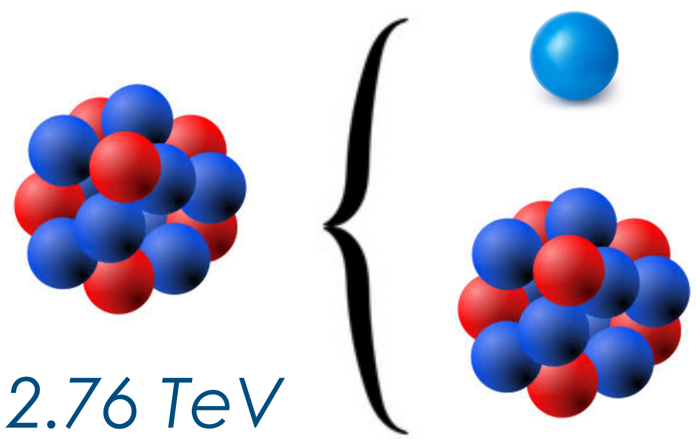


pp or pA collisions: 0.9 - 7 TeV beam on fix target

$$\sqrt{s} = \sqrt{2m_N E_p} \simeq 41 - 115\ GeV$$

between SPS & RHIC

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

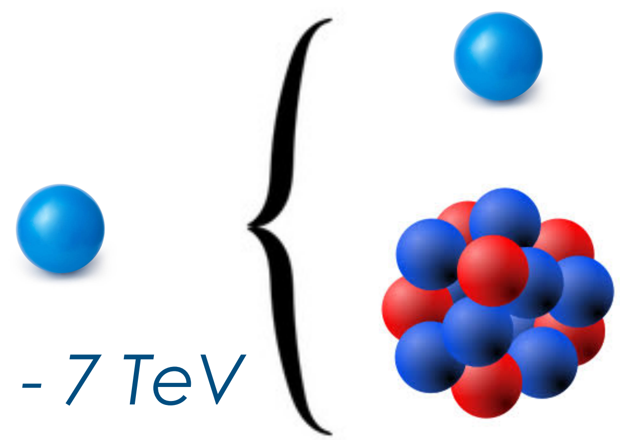


AA collisions: 2.76 TeV beam on fix target

$$\sqrt{s_{NN}} \simeq 72\ GeV$$

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

Kinematics

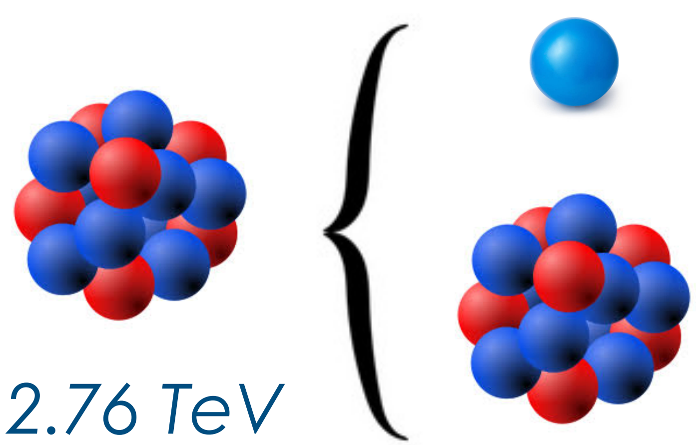


pp or pA collisions: 0.9 - 7 TeV beam on fix target

$$\sqrt{s} = \sqrt{2m_N E_p} \simeq 41 - 115\ GeV$$

between SPS & RHIC

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



AA collisions: 2.76 TeV beam on fix target

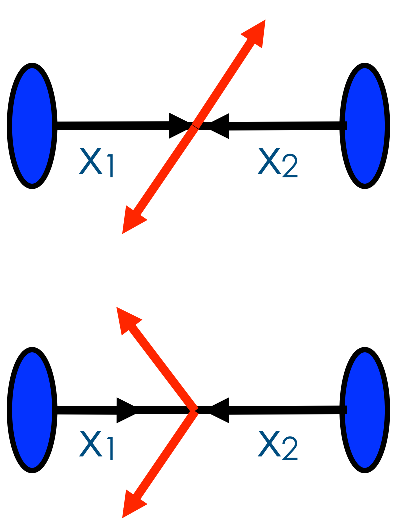
$$\sqrt{s_{NN}} \simeq 72\ GeV$$

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

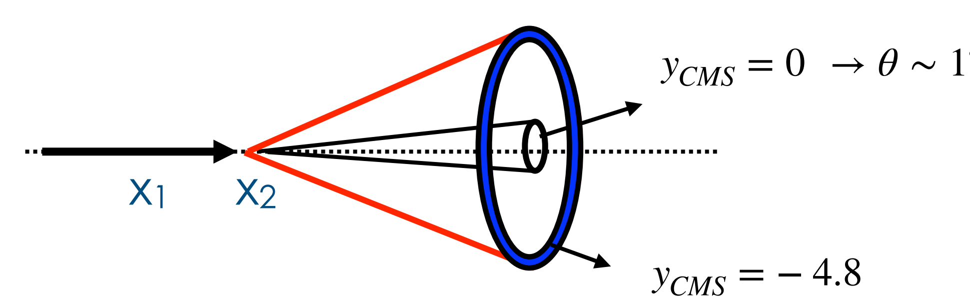
Boost effect → access to large x_2 physics ($-1<x_F<0$)

$x_1 \sim x_2$

$x_1 << x_2$



CMS → **Target rest frame**



Why

- Advance our understanding of the large-x gluon, antiquark and heavy quark content in nucleons and nuclei
- Advance our understanding of the dynamics and spin distributions of gluons inside (un)polarised nucleons
- Study heavy-ion collisions between SPS and RHIC energies at large rapidities

Why

-Advance our understanding of the large-x gluon, antiquark and heavy quark content in nucleons and nuclei

-Advance our understanding of the dynamics and spin distributions of gluons inside (un)polarised nucleons

-Study heavy-ion collisions between SPS and RHIC energies at large rapidities

- Unique and large kinematic coverage
- High luminosity and high resolution detectors → rare probes
- Proton or Heavy-Ion Beam
- Large variety of atomic gas targets: $H_2, D_2, He, N_2, Ne, Ar, Kr, Xe$
- Polarised targets: $H^\uparrow, D^\uparrow$

Physics Motivations
(non exhaustive list)

High-x physics

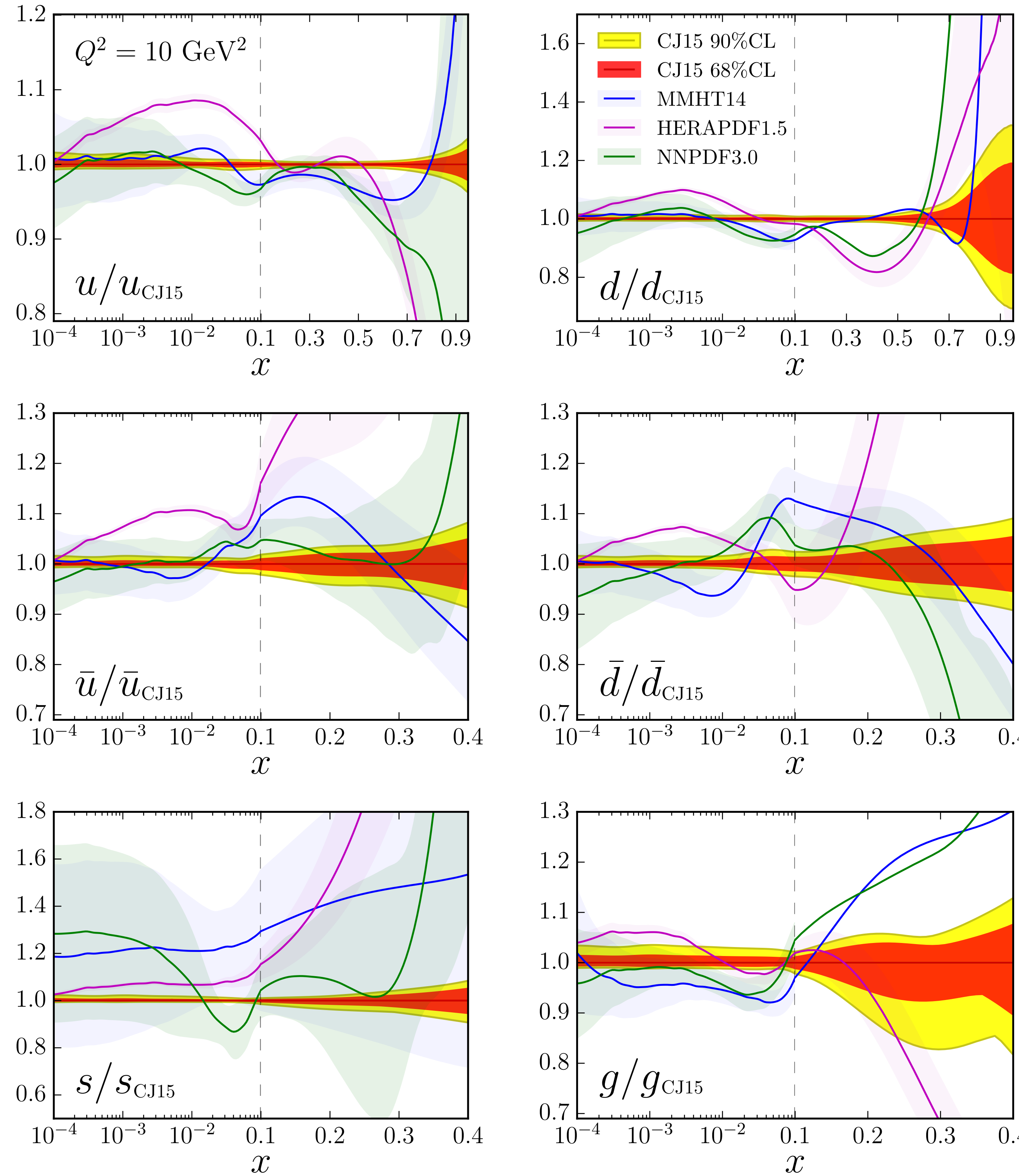
Very large uncertainties on the partonic structure of nucleons and nuclei at large-x

Δ>50% for x>0.6 on d(x)

Δ>50% for x>0.2 on g(x)

very large on sea quarks

Ratio of PDFs to the CJ15 central values for various PDF sets:

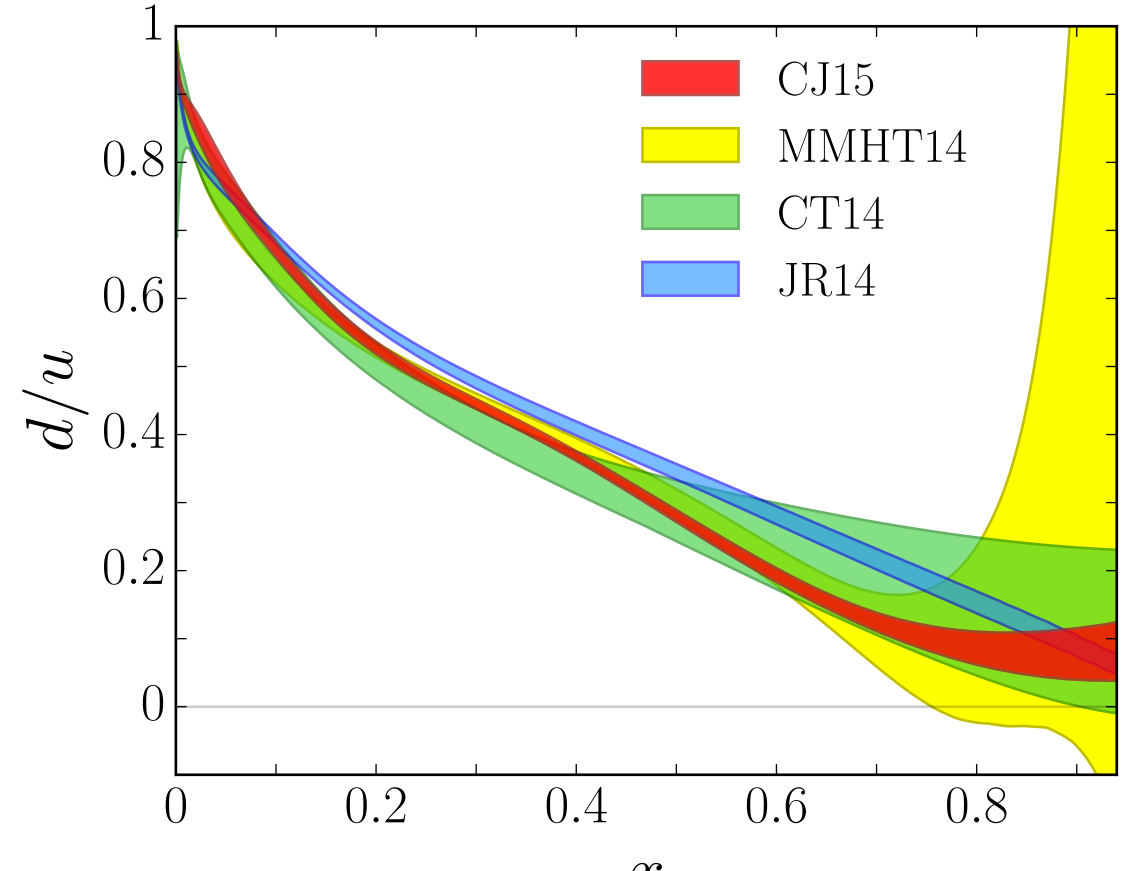


PRD 93, 114017 (2016)

High-x physics

Smaller uncertainty could better constraint models on hadron structure, e.g. for x—>1

- d/u —> 1/2 : SU(6) spin-flavour symmetry
- d/u —> 0 : scalar diquark dominance
- d/u —> 1/5 : pQCD power counting
- d/u —> 0.42 : local quark-hadron duality

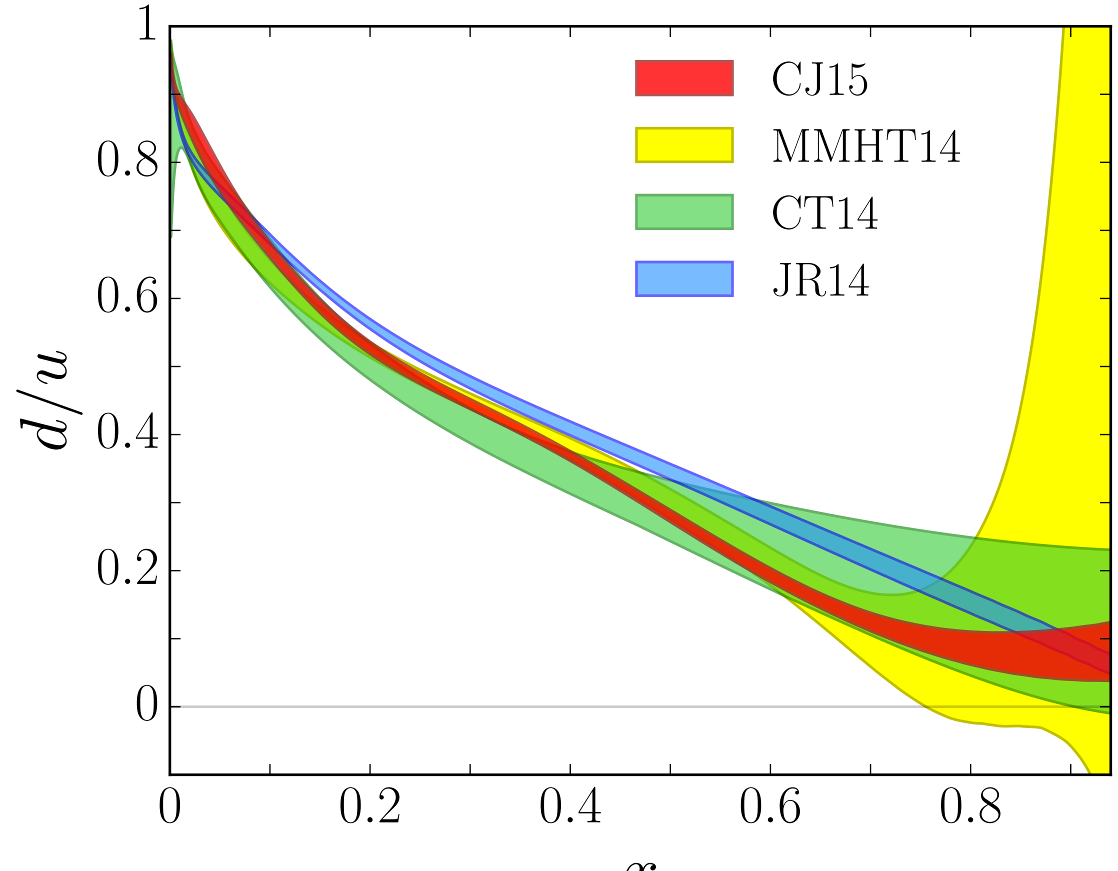


PRD 93, 114017 (2016)

High-x physics

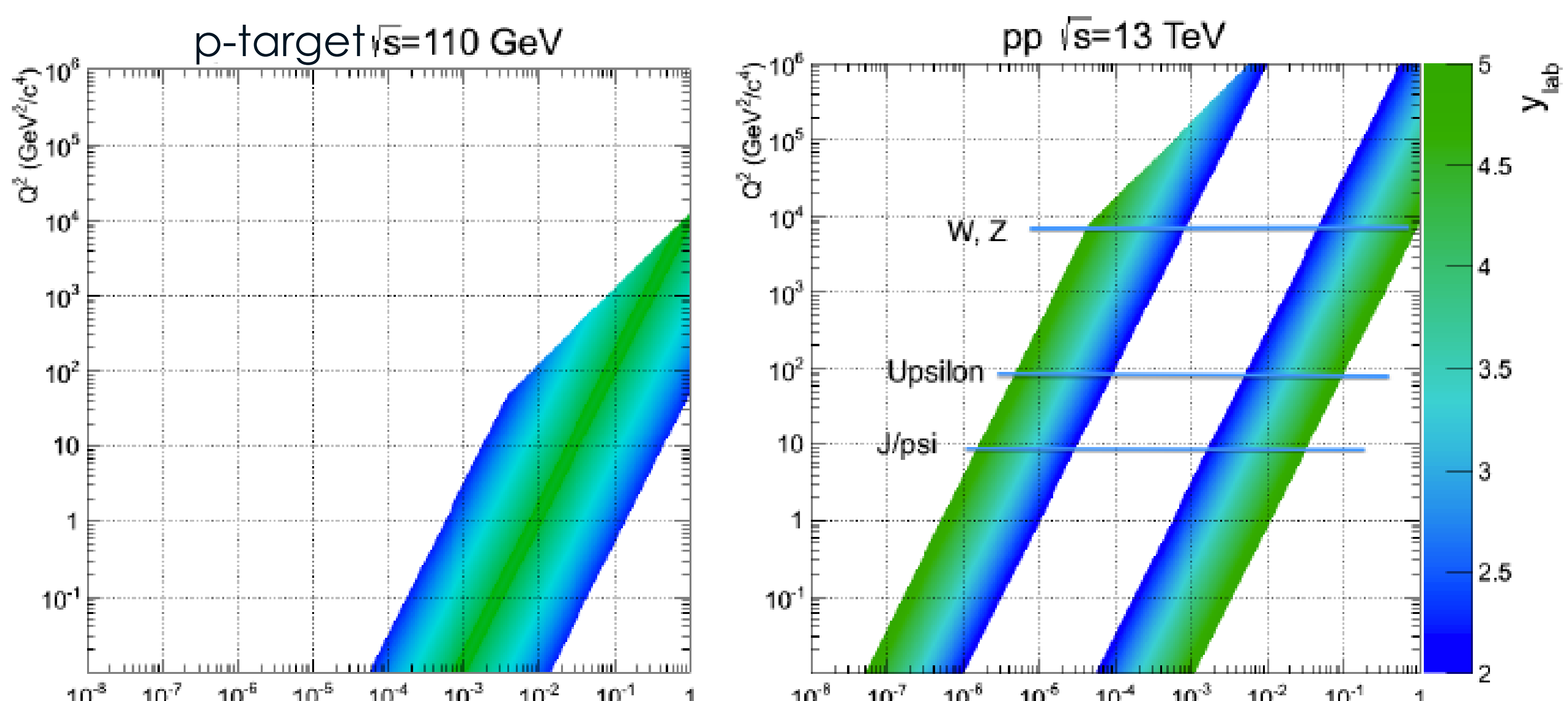
Smaller uncertainty could better constraint models on hadron structure, e.g. for x—>1

- d/u —> 1/2 : SU(6) spin-flavour symmetry
- d/u —> 0 : scalar diquark dominance
- d/u —> 1/5 : pQCD power counting
- d/u —> 0.42 : local quark-hadron duality



PRD 93, 114017 (2016)

At the LHC fixed target pp, pA, Pb-p and Pb-A collisions one has unique kinematic conditions at the poorly explored energy of √s ~ 100 GeV

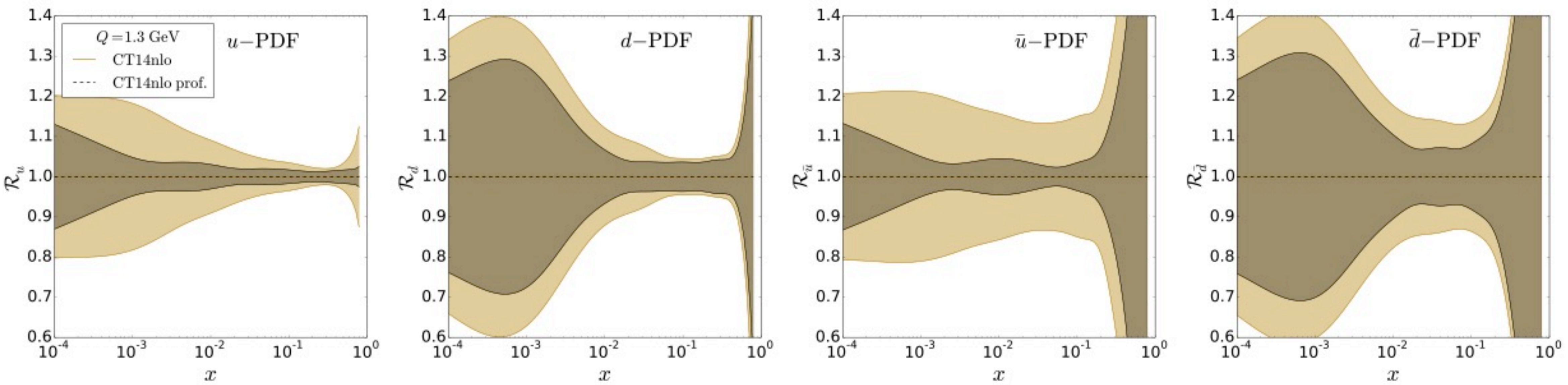


Fermi motion in the nucleus can allow to access the exotic $x > 1$ region, where parton dynamics depends on the interaction between the nucleons within the nucleus.

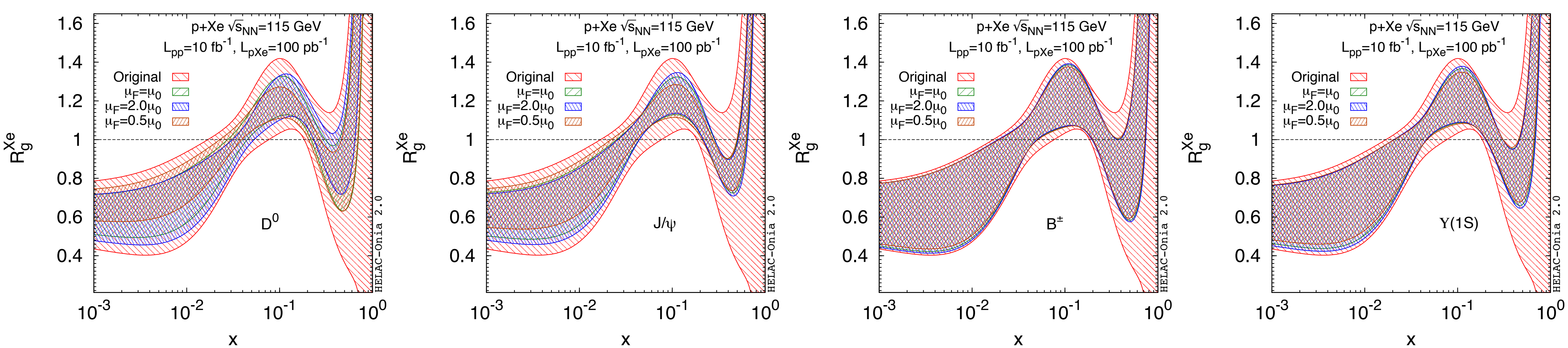
A bridge between QCD and nuclear physics

High-x physics

arXiv:1807.00603



PDF



nPDF (gluon)

Substantial improvement of the uncertainties

estimation with 10 fb^{-1}

- Intrinsic heavy-quark:

-recent global QCD analyses support the existence of non-perturbative intrinsic charm (not generated perturbatively by g-splitting)

-5-quark Fock state (uudQQ) of the proton may appear at high x

-charm PDFs at large x could be larger (EMC, SELEX) than the one obtained from conventional fits

- $W^{\pm}$ boson production near threshold … never measured before

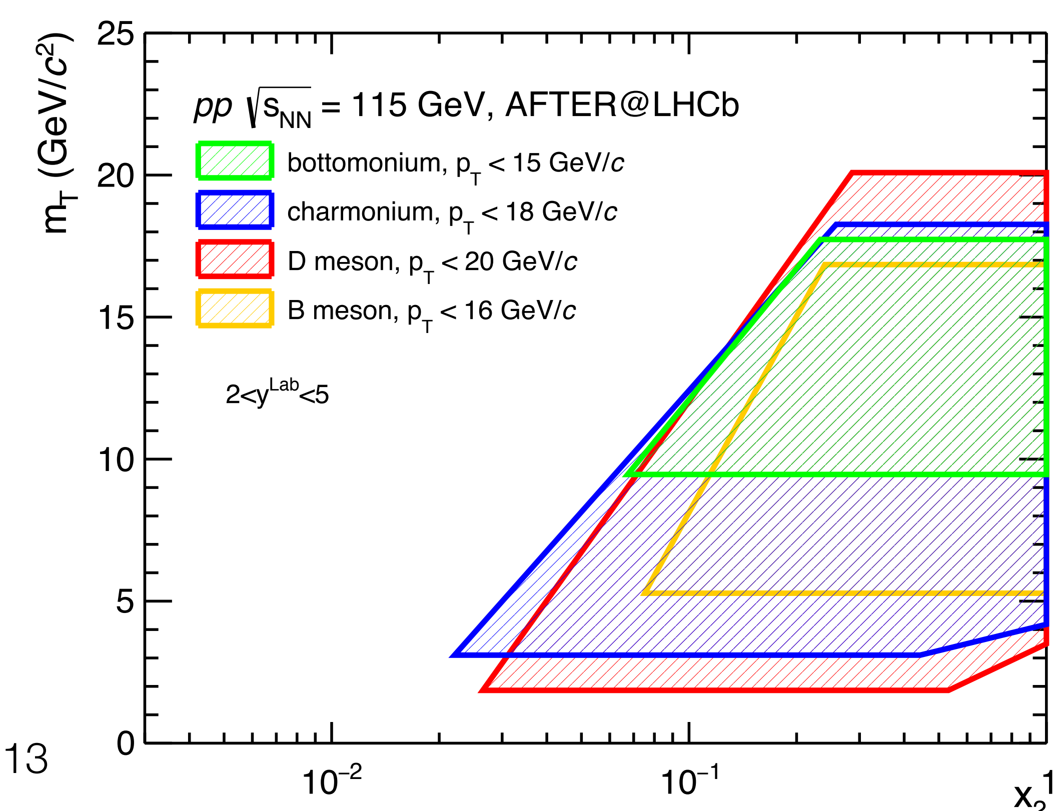
-strongly dependent on quark PDFs at large x

-search for heavy partners of the gauge bosons (predicted by many extensions to SM)

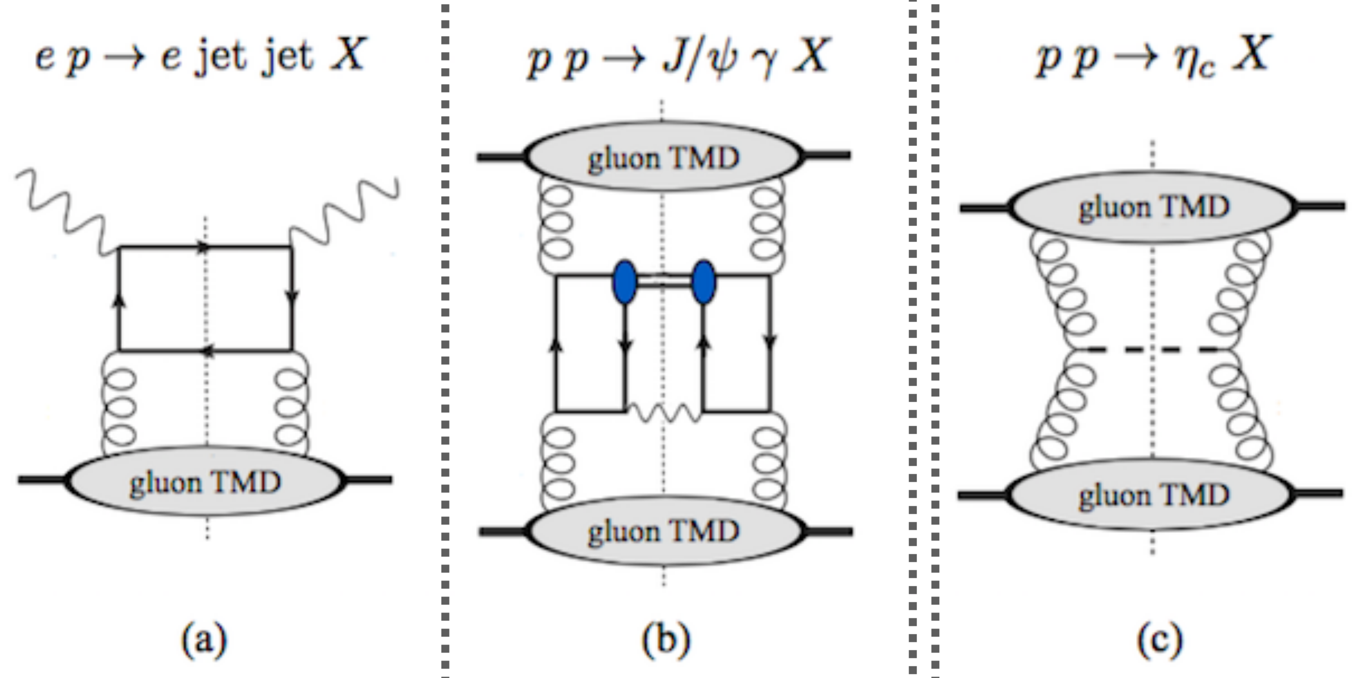
-access to the barely known ratio $\bar{d}/\bar{u}$ at high-x

- Complementary D and B-physics done at high energies

arXiv:1807.00603



Transverse Momentum Distributions (TMDs)



Leading-order diagrams representing some of the processes relevant for the extraction of gluon TMDs.

Channels measured with high efficiency "also" at LHC+LHCb

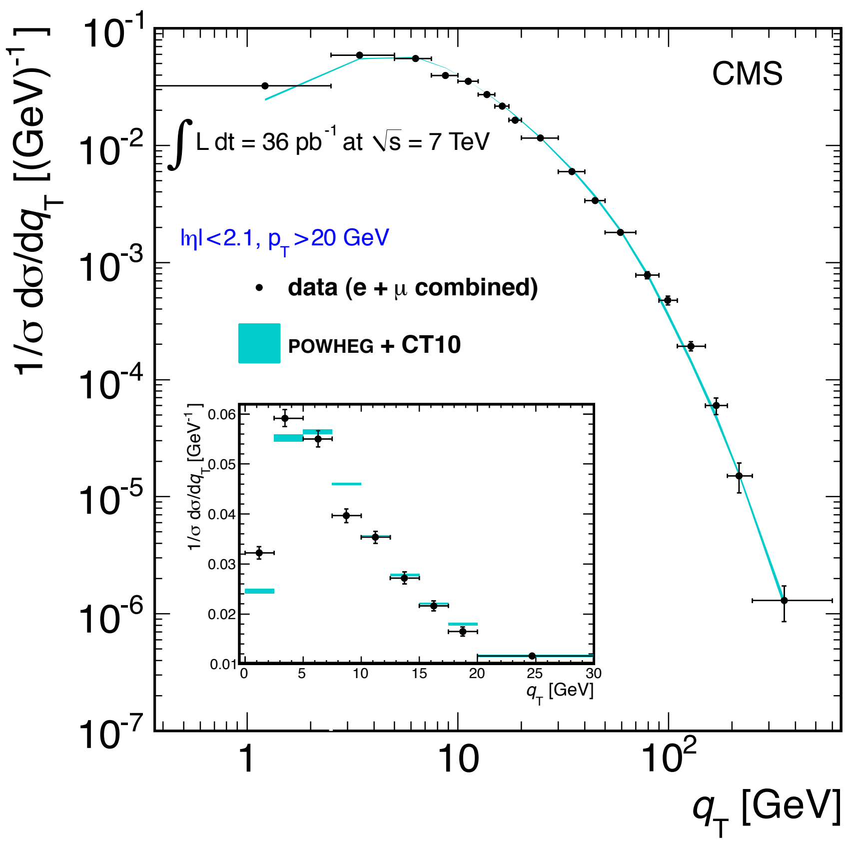
Channels measured with high efficiency "only" at LHC+LHCb

Phys. Rev. Lett. 111, 032002 (2013)

TMDs effects can have a significant impact on LHC physics: from the Higgs sector to the BSM physics, from the understanding of the J/Ψ polarisation to the quarkonia world, …

Transverse Momentum Distributions (TMDs)

Z-boson transverse momentum q_T spectrum in pp by CMS



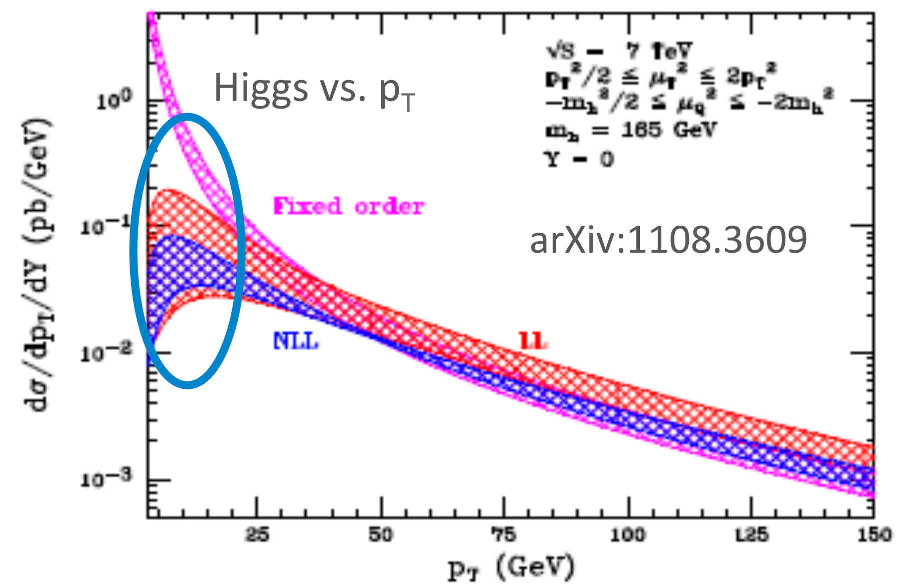
The small q_T region cannot be explained by usual collinear PDF factorization: needs TMD-PDFs

(Phys. Rev. D85 (2012) 032002)

… still unsolved

Effective field theories

Soft Collinear Effective Theory
p_T distribution for gg-Higgs



TRANSVERSE MOMENTUM DISTRIBUTIONS FROM EFFECTIVE FIELD THEORY

Sonny Mantry*
University of Wisconsin at Madison
Madison, WI 53706, USA
mantry147@gmail.com

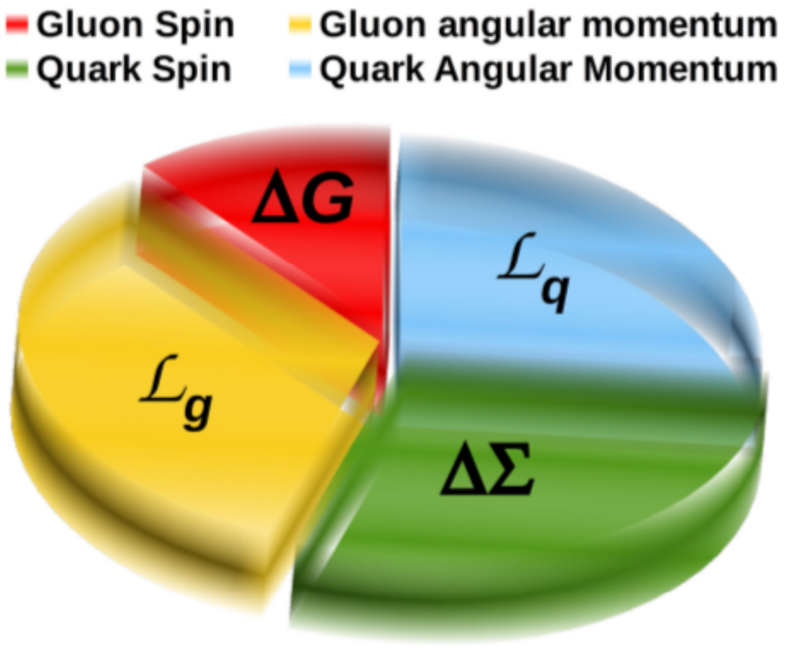
Frank Petriello
High Energy Physics Division, Argonne National Laboratory
Argonne, IL 60439, USA

Department of Physics & Astronomy, Northwestern University
Evanston, IL 60208, USA
f-petriello@northwestern.edu

…then the SPIN

3D mapping of the parton momentum: access to …

-quark and gluon orbital angular momentum L_q and L_g
-gluon transverse-momentum dependent PDF (TMDs)
-linearly polarised gluons in unpolarised protons
-…



Probing the gluon PDFs

Hadron	Quark TMDs: U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

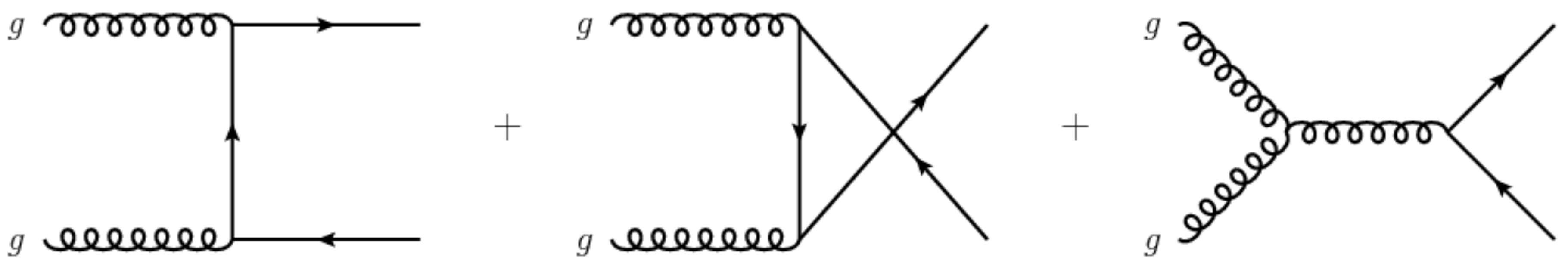
Hadron	Gluon TMDs: Unpol	Circularly pol.	Linearly pol.
U	f_1^g		$h_1^{\perp g}$
L		g_1^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	$g_{1T}^{\perp g}$	h_{1T}^g $h_{1T}^{\perp g}$

- Very significant progress in the last 15 years!
- Many experiments involved: HERMES, COMPASS, JLAB, RHIC, BELLE, BABAR, …
- First extractions from global analyses
- Now entering into the precision era!

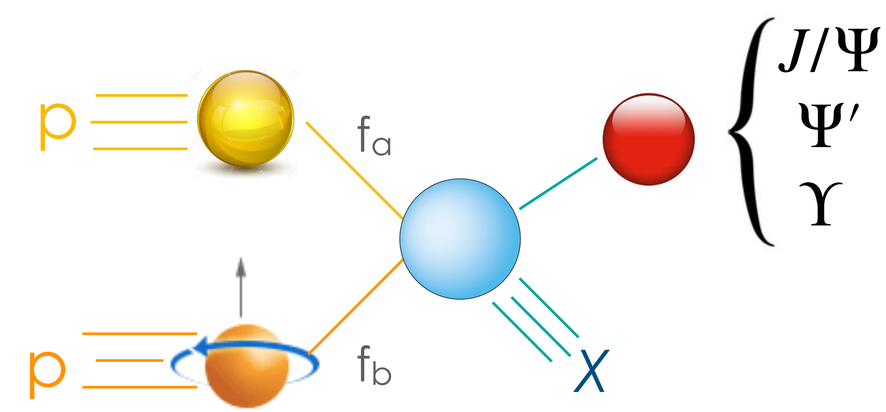
- Theory framework consolidated
- … but experimental access still extremely limited
- **LHCSpin can provide a significant contribution to the field, already with an unpolarised target**

Note: gluons with non-zero p_T inside an unpolarised hadron can be linearly polarized!

Probing the gluon PDFs



- Being heavy quarks dominantly produced through gluon-gluon interactions, one can probe the gluon dynamics within the proton by measuring **heavy-flavor** observables

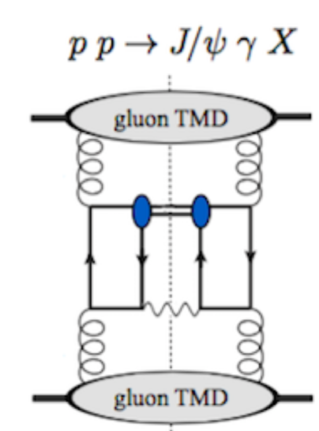


- At LHC **quarkonia** production is dominated by gluon fusion

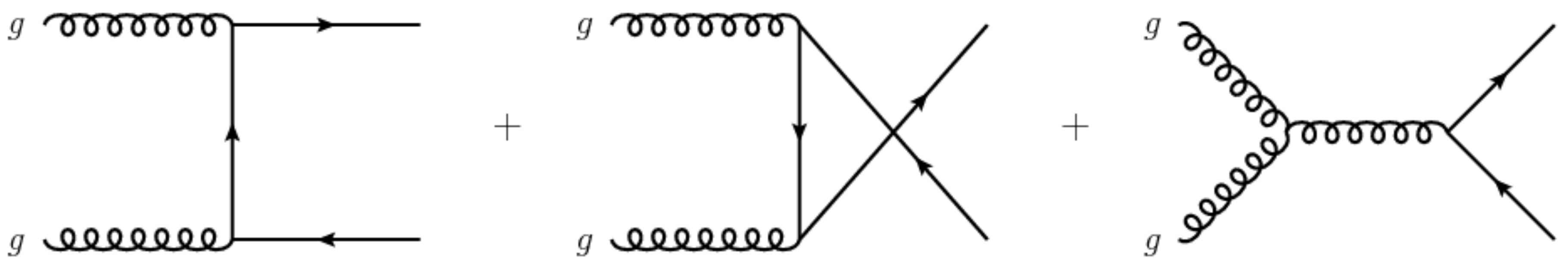
- Heavy quarks and quarkonium production turns out to be an ideal gluon-sensitive observable

TMD factorisation requires $p_T(Q) \ll M_Q$. At the LHC one can look at the back-to-back production of quarkonia and isolated photon or associated production, where only relative p_T is small:

$$pp \to J/\psi + \gamma + X \qquad pp \to \Upsilon + \gamma + X \qquad pp \to J/\psi + J/\psi + X$$



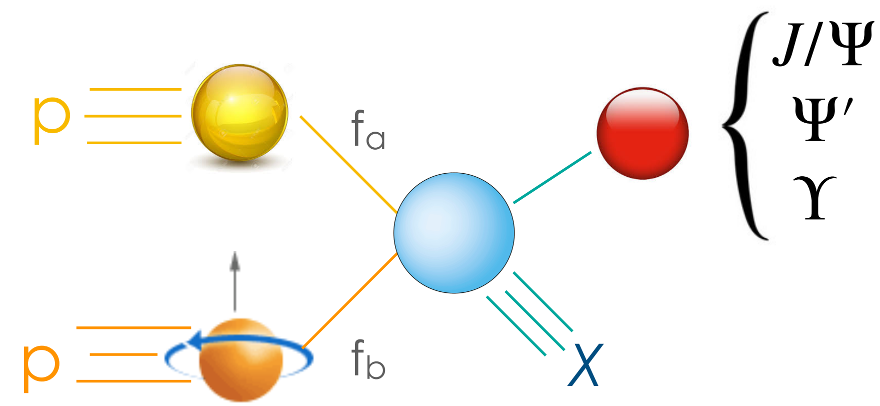
Probing the gluon PDFs



- Being heavy quarks dominantly produced through gluon-gluon interactions, one can probe the gluon dynamics within the proton by measuring **heavy-flavor** observables

- At LHC **quarkonia** production is dominated by gluon fusion

- Heavy quarks and quarkonium production turns out to be an ideal gluon-sensitive observable



For instance, LHCb can measure nearly all quarkonia states (including C-even) with high precision!

The expected yields are much larger than previous fixed-target experiments

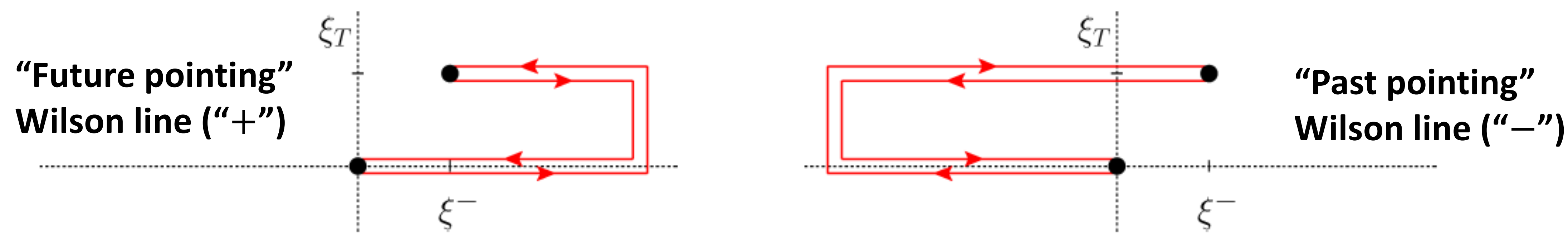
Mesons are unique observables, poorly accessible from other hadron-hadron experiments
[unique channels: pseudoscalar quarkonia (η, η_c, $\eta_c(2S)$, $\chi_{c,b}$), Υ, J/Ψ, Ψ', di–J/Ψ, $\Upsilon(1,2,3S)$, D, B-mesons, DY ($\mu^+\mu^-$)]

Probing the gluon PDFs

As for quark TMDs, also the gluon TMD phenomenology is enriched by the **process dependence** originating from ISI/FSI and encoded in the **gauge links**.

The gluon correlator depends on two path-dependent gauge links [D. Boer: arXiv:1611.06089]

$$\Gamma^{\mu\nu\,[\mathcal{U},\mathcal{U}']}(x,\boldsymbol{k}_T) \equiv \int \frac{d(\xi\cdot P)\,d^2\xi_T}{(P\cdot n)^2(2\pi)^3} e^{i(xP+k_T)\cdot\xi} \langle P|\mathrm{Tr}_c\left[F^{n\nu}(0)\,\mathcal{U}_{[0,\xi]}\,F^{n\mu}(\xi)\,\mathcal{U}'_{[\xi,0]}\right]|P\rangle$$



Both f_1^g and $h_1^{\perp g}$ are process dependent! Each of them can be of two types:

$[+\,+] = [-\,-]$ Weizsacker-Williams (WW) $[+\,-] = [-\,+]$ DiPole (DP)

- **can differ in magnitude and width (!)**
- **can be probed by different processes**

Probing the gluon PDFs

[D. Boer: arXiv:1611.06089]

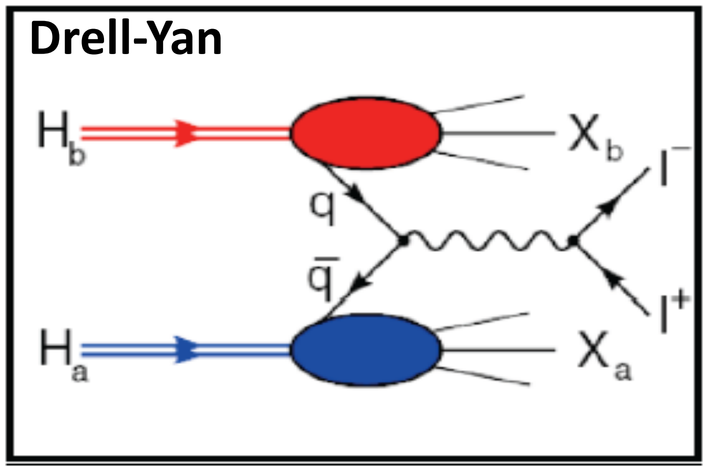
	DIS	DY	SIDIS	$pA \to \gamma\,\text{jet}\,X$	$e\,p \to e'\,Q\,\overline{Q}\,X$ $e\,p \to e'\,j_1\,j_2\,X$	$pp \to \eta_{c,b}\,X$ $pp \to H\,X$	$pp \to J/\psi\,\gamma\,X$ $pp \to \Upsilon\,\gamma\,X$
$f_1^{g\,[+,+]}$ (WW)	$\times$	$\times$	$\times$	$\times$	$\surd$	$\surd$	$\surd$
$f_1^{g\,[+,-]}$ (DP)	$\surd$	$\surd$	$\surd$	$\surd$	$\times$	$\times$	$\times$

	$pp \to \gamma\,\gamma\,X$	$pA \to \gamma^*\,\text{jet}\,X$	$e\,p \to e'\,Q\,\overline{Q}\,X$ $e\,p \to e'\,j_1\,j_2\,X$	$pp \to \eta_{c,b}\,X$ $pp \to H\,X$	$pp \to J/\psi\,\gamma\,X$ $pp \to \Upsilon\,\gamma\,X$
$h_1^{\perp\,g\,[+,+]}$ (WW)	$\surd$	$\times$	$\surd$	$\surd$	$\surd$
$h_1^{\perp\,g\,[+,-]}$ (DP)	$\times$	$\surd$	$\times$	$\times$	$\times$

Can be measured at EIC (pink)

Can be measured at the LHC, in particular at LHCb (blue)

... then the *quark* PDFs



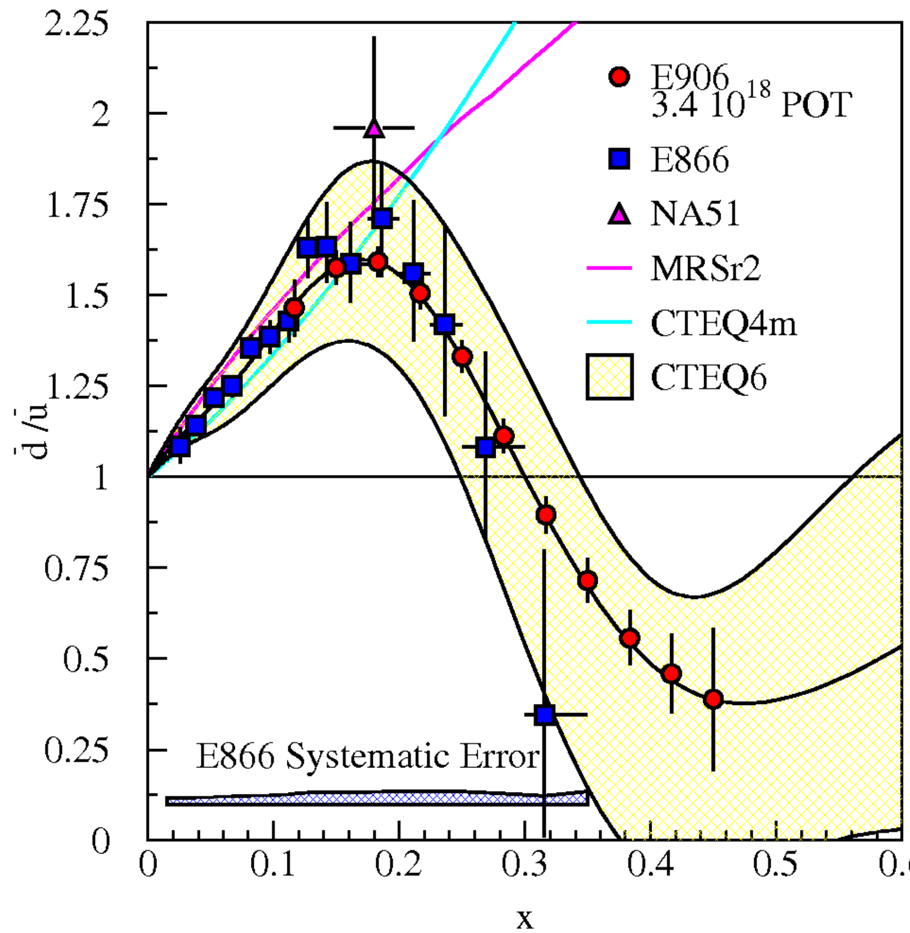
- Clean process
- LHCb has excellent reconstruction capabilities for $\mu\mu$ channel!

- Dominant process: $\bar{q}(x_{beam}) + q(x_{target}) \rightarrow \mu\mu$
- But also possible: $q(x_{beam}) + \bar{q}(x_{target}) \rightarrow \mu\mu$

- Allows to study the **antiquark content of the nucleon!**

- **Provides sensitivity to unpolarized and BM TMDs up to high x_2**

$$\sigma_{UU} \propto f_1 f_1 + \cos 2\phi \, h_1^{\perp} h_1^{\perp}$$

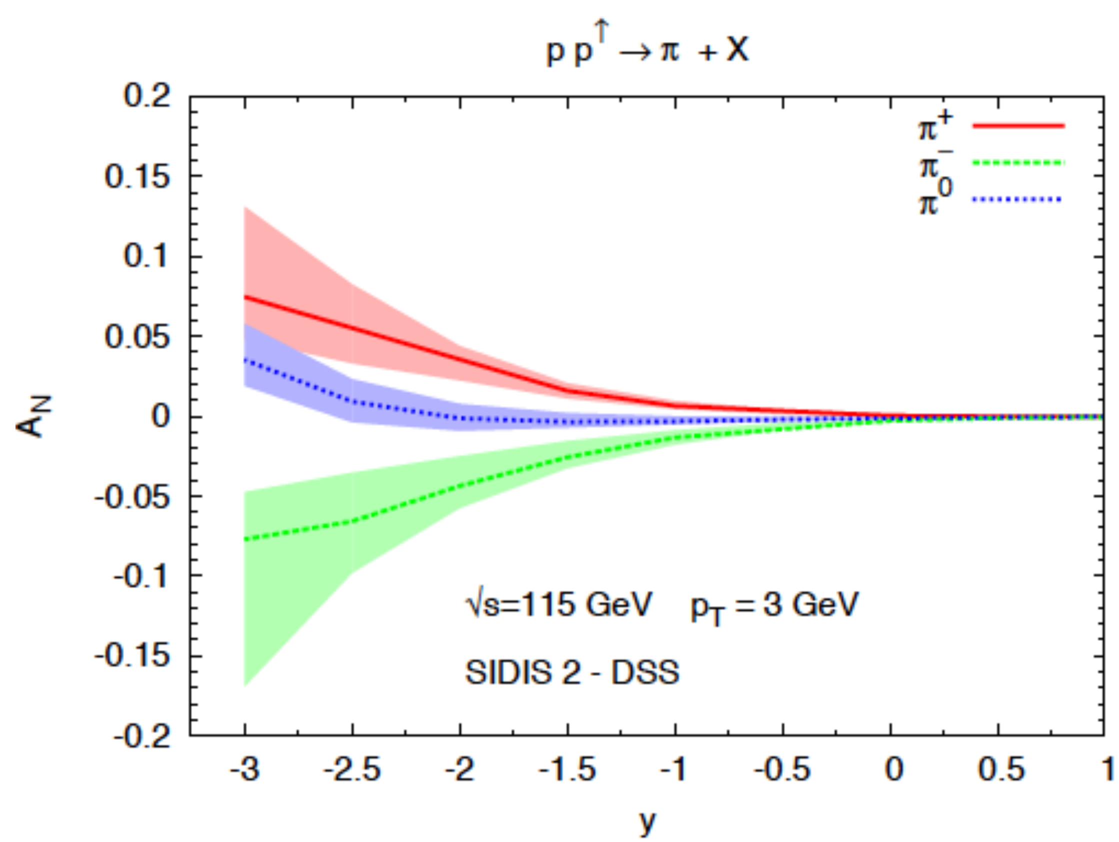


$\bar{d}(x) \neq \bar{u}(x)$!!

- sea is not flavour symmetric!
- hints that: $\bar{s}(x) \neq s\,(x)$
- Brodsky et al. arXiv:1809.04975
- **intrinsic sea quarks**?

Single Spin Asymmetries: non-collinear (leading twist) approach

-involves TMD PDFs and FFs
-requires 2 scales (p_T<<Q), but is not supported by TMD factorization
-can be considered as an effective model description (Generalized Parton Model)
-SSAs arise mainly from Sivers effects



-Asymmetries above 10%! (for pions)

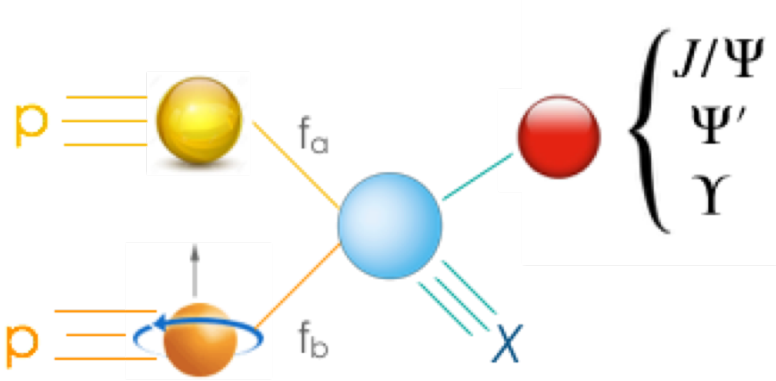
-The effect increases with more negative CM rapidity

Anselmino et al. arXiv:1504.03791v2

Probing the polarised gluon PDFs

Inclusive pion production provides sensitivity to the quark PDFs, but a fixed polarized target at LHC can also open the way to the **extraction of polarized gluon PDFs through heavy-flavour observables:**

Polarized inclusive hard scattering



Hadron		Gluon TMDs: Unpol	Gluon TMDs: Circularly pol.	Gluon TMDs: Linearly pol.
	U	f_1^g		$h_1^{\perp g}$
	L		g_1^g	$h_{1L}^{\perp g}$
	T	$f_{1T}^{\perp g}$	$g_{1T}^{\perp g}$	h_{1T}^g $h_{1T}^{\perp g}$

One main achievement would be accessing the **gluon Sivers function through STSAs:**

- first hints by RHIC and COMPASS, but still basically unknown!
- shed light on spin-orbit correlations of gluons inside the proton
- sensitive to gluon orbital angular momentum!

The measured STSAs can be related (GPM) to the convolution of the gluon Sivers function for the target proton and the unpolarized gluon pdf for the beam proton:

$$A_N = \frac{1}{P}\frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} \sim \frac{1}{P}\frac{N_h^\uparrow - N_h^\downarrow}{N_h^\uparrow + N_h^\downarrow} \propto \left[f_{1T}^{\perp g}(x_a, k_{\perp a}) \otimes f_g(x_b, k_{\perp b}) \otimes d\sigma_{gg\to QQg}\right] \sin\phi_S + \cdots$$

Process dependence of the GSF

Two independent gluon Sivers functions can be defined from the different combinations of Wilson lines in the gluon correlator:

$f_{1T}^{\perp g[+,+]}$ **"f-type"** → antisymmetric colour structures

$f_{1T}^{\perp g[+,-]}$ **"d-type"** → symmetric colour structures

Can differ in magnitude and width (!)

Can be probed by different processes:

[D. Boer: arXiv:1611.06089, D. Boer et al. HEPJ 08 2016 001]

	DY	SIDIS	$p^\uparrow A \to h X$	$p^\uparrow A \to \gamma^{(*)}\,\text{jet}\, X$	$p^\uparrow p \to \gamma\gamma X$ $p^\uparrow p \to J/\psi\,\gamma X$ $p^\uparrow p \to J/\psi\, J/\psi\, X$	$e\,p^\uparrow \to e'\,Q\bar{Q}\,X$ $e\,p^\uparrow \to e'\,j_1\,j_2\,X$
$f_{1T}^{\perp g\,[+,+]}$ (WW)	×	×	×	×	√	√
$f_{1T}^{\perp g\,[+,-]}$ (DP)	√	√	√	√	×	×

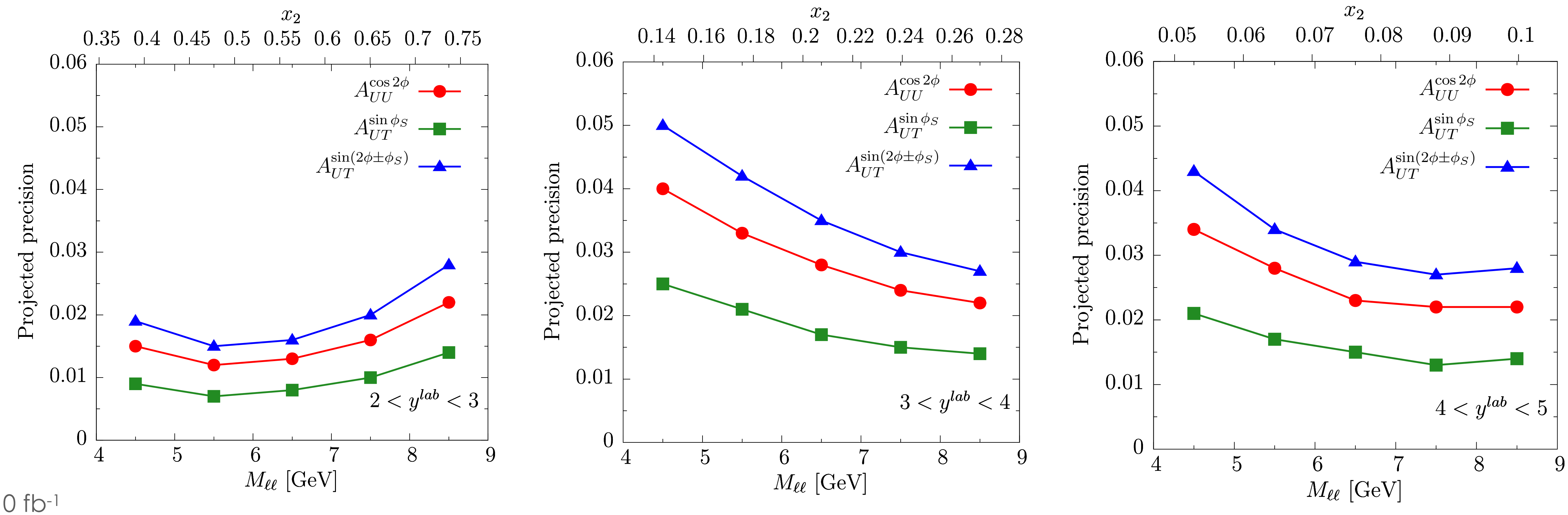
Can be measured at the EIC   Can be measured at the LHCb with a PGT

$$[+,+] \longleftrightarrow \quad f_{1T}^{\perp g[e\,p^\uparrow \to e'\,Q\bar{Q}\,X]}(x, p_T^2) = -f_{1T}^{\perp g[p^\uparrow\, p \to \gamma\,\gamma\, X]}(x, p_T^2) \quad \longleftrightarrow [-,-]$$

Same sign-change relation expected for the other T-odd gTMDs h_1^g and $h_{1T}^{\perp g}$!

Quark TMDs: a golden channel like DY

arXiv:1807.00603
and J.P.Lansberg, PBC CERN 2018



L_{pp}~10 fb^{-1}

Expected statistical uncertainty on asymmetries in DY production at LHCb-like experiment

$$A_{UU}^{cos2\phi} \sim \frac{h_1^{\perp q} \otimes h_1^{\perp q}}{f_1^q \otimes f_1^q} \qquad A_{UT}^{sin\phi_S} \sim \frac{f_1^q \otimes f_{1T}^{\perp q}}{f_1^q \otimes f_1^q} \qquad A_{UT}^{sin(2\phi+\phi_S)} \sim \frac{h_1^{\perp q} \otimes h_{1T}^{\perp q}}{f_1^q \otimes f_1^q} \qquad A_{UT}^{sin(2\phi-\phi_S)} \sim \frac{h_1^{\perp q} \otimes h_1^q}{f_1^q \otimes f_1^q}$$

Excellent precision achievable for observables connected to (i.e.) the transversity, the Boer-Mulders function, the pretzelosity and the Sivers TMDs

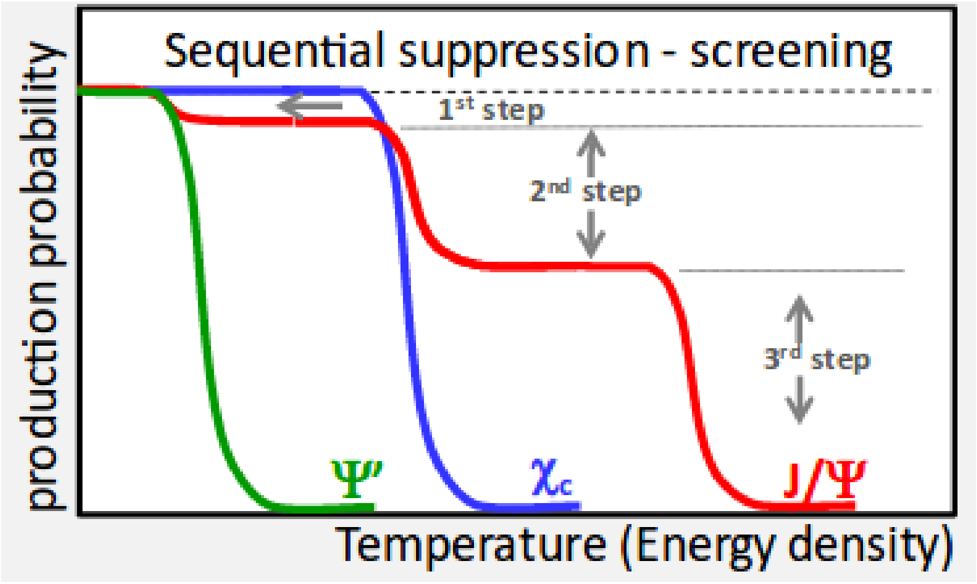
HI collisions

- pA collisions:

-nuclear matter effects on PDFs (special sensitivity to high-x, e.g. poorly understood gluon anti-shadowing)
-studies of parton energy-loss in cold nuclear matter

- PbA collisions at $\sqrt{s_{NN}} \approx 72$ GeV

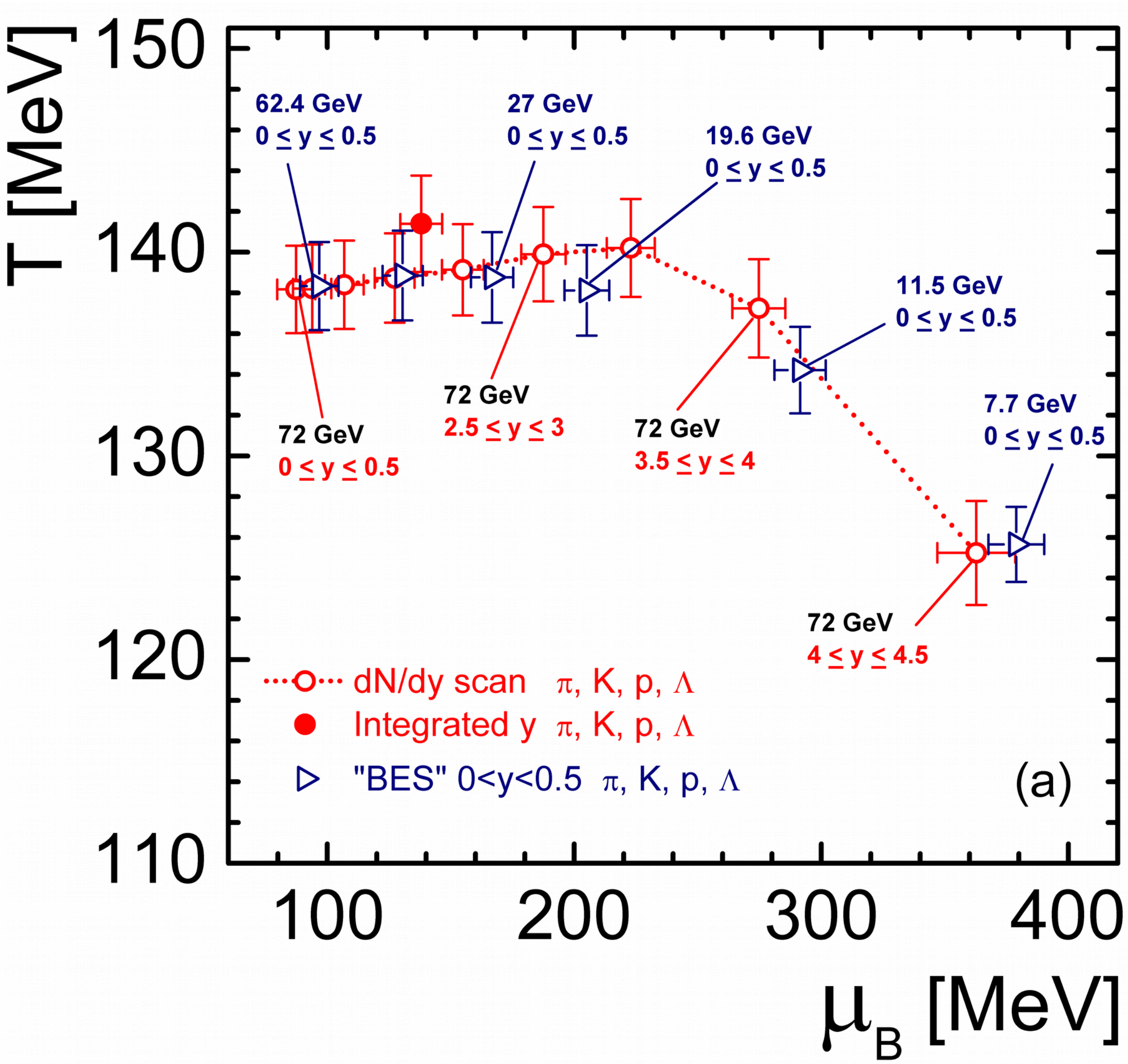
-study of QGP formation (quarkonium suppression, jet-quenching in hot nuclear matter)
-fixed target kinematics allows to study the nucleus remnants in its rest frame (after QGP formation)

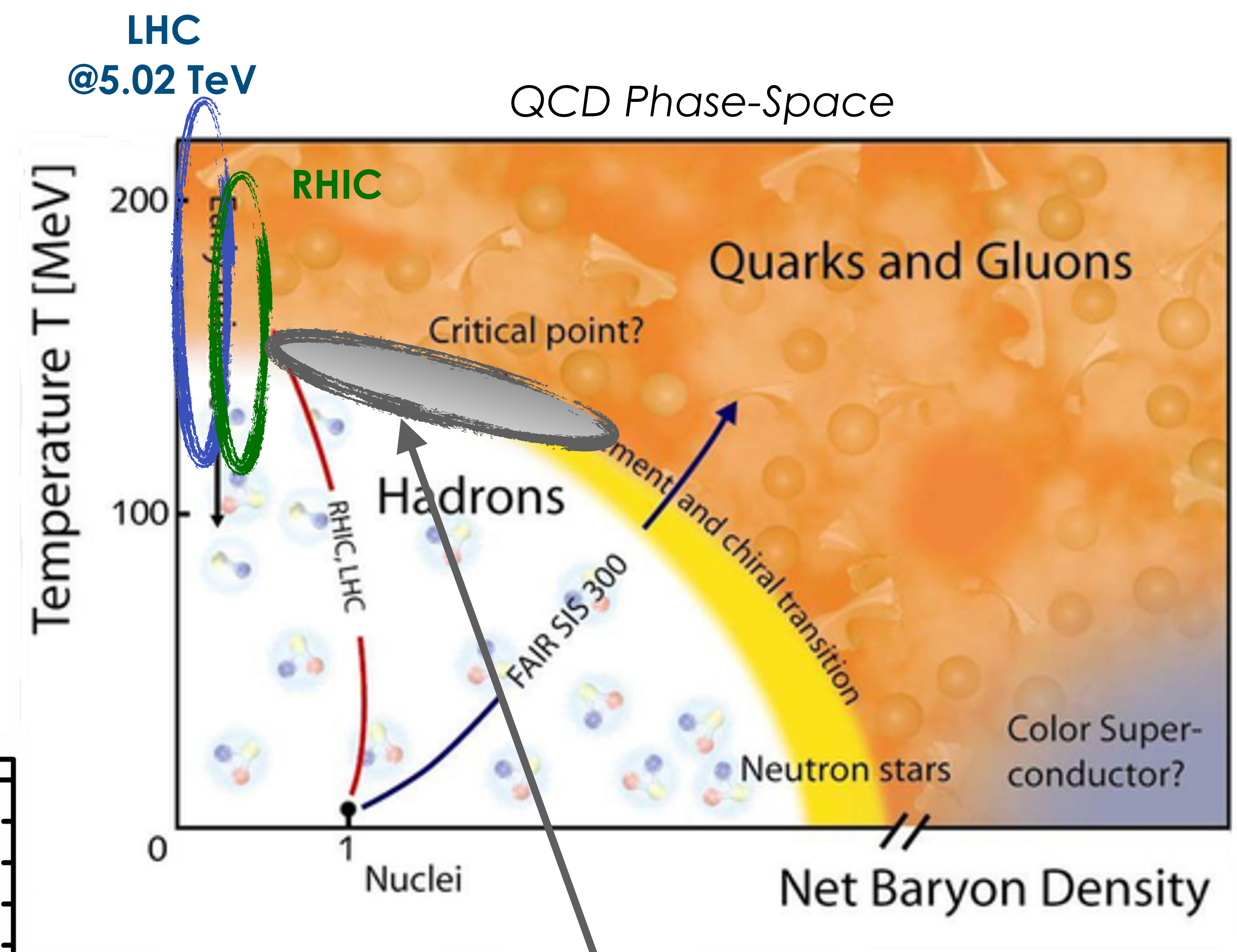


$c\bar{c}$ bound states: J/ψ, χ_c , ψ', … different binding energy, different dissociation temperature

- AA collisions (QGP)

Phys. Rev. C98 (2018) 58:148





LHC Fixed-target

Moving on the μ_B-T plane by rapidity scan

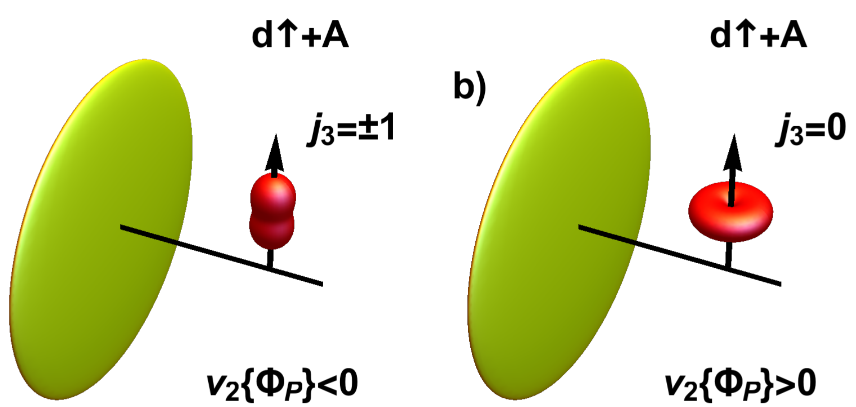
Elliptic flow in ultra-relativistic collisions with polarised deuterons

arXiv:1808.09840

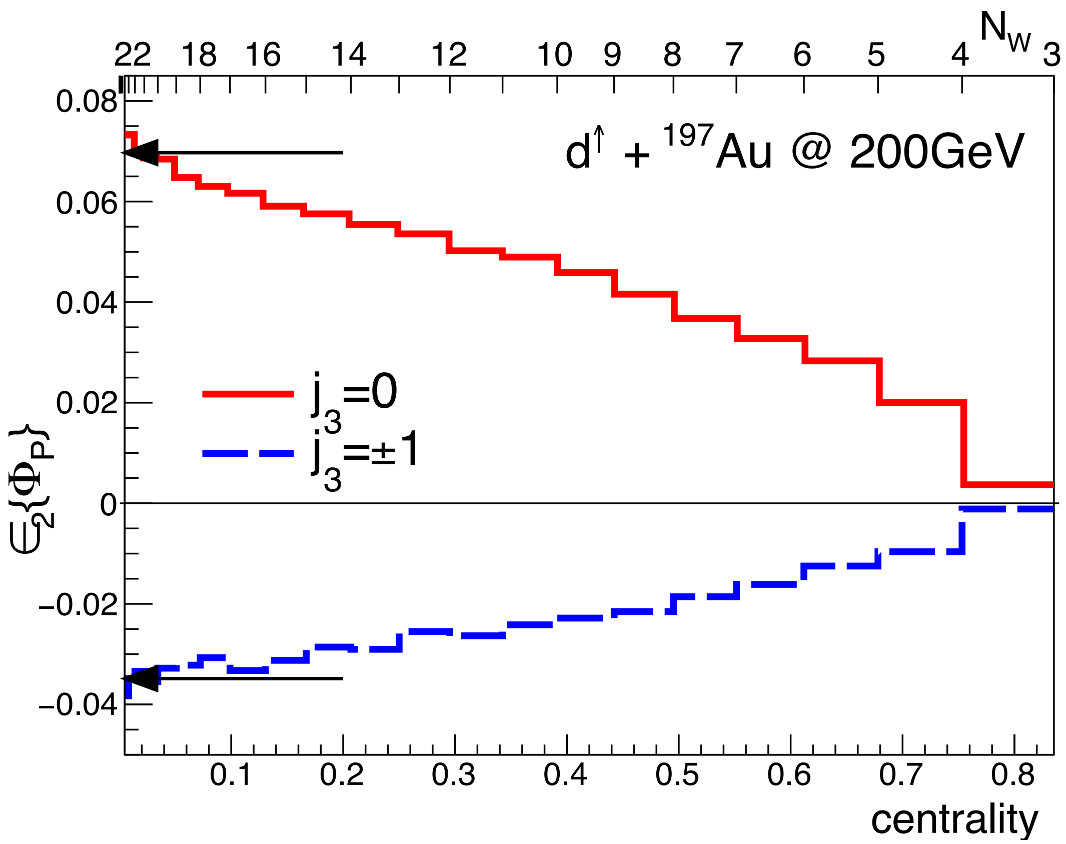
Ridge and flow measurements, connected to collectivity phenomena, are among the most interesting results achieved in the last years in the QGP physics.

We can put this in connection with spin clarifying the nature of dynamics in small systems

its experimental confirmation would prove the presence of the shape-flow transmutation mechanism, typical of hydrodynamic expansion, or rescattering in the later stages of the fireball evolution



ultra-relativistic d+A collision, where the deuteron is polarised along the axis ΦP perpendicular to the beam



Ellipticities of the fireball

A polarised D-beam at BNL will not come in a near future

A polarised target at LHC can easily provide Pb $D^{\uparrow}$ collisions

We are already on the road ...

SMOG2 *and* LHCspin

We are already on the road …

SMOG2

Phase I
unpolarised target

and

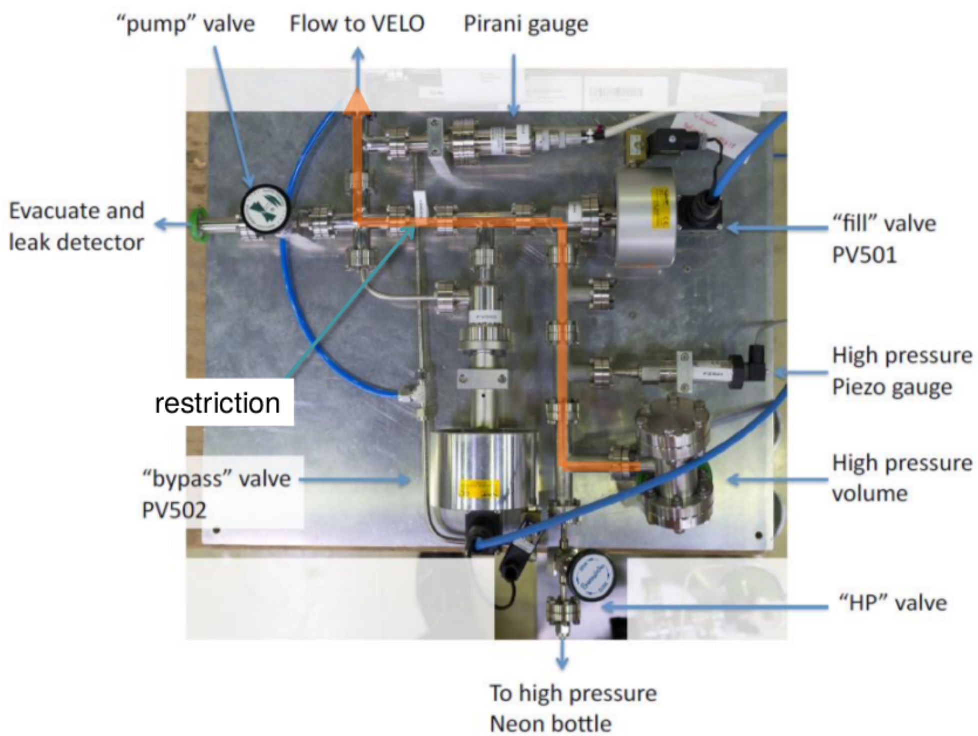
LHCspin

Phase II
transversely polarised H and D target

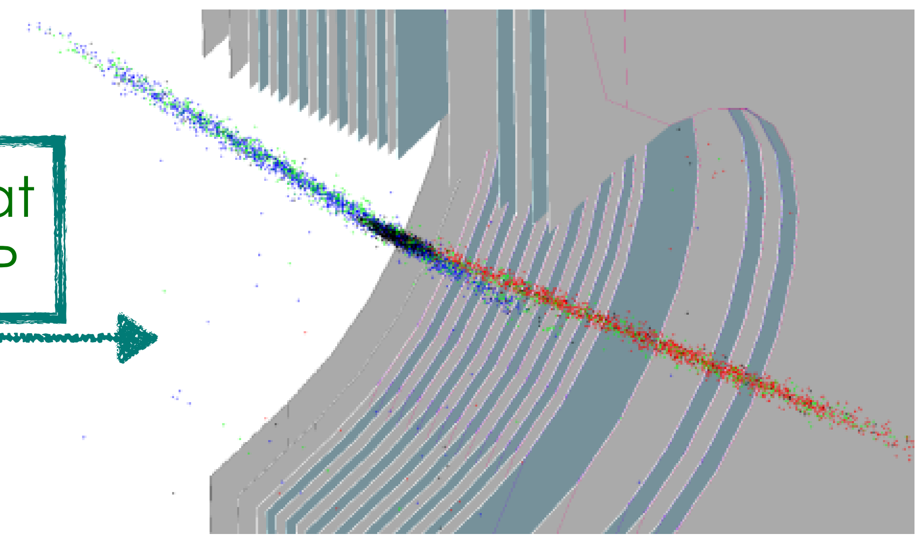
… at LHCb

SMOG, a successful idea and a pseudo-target

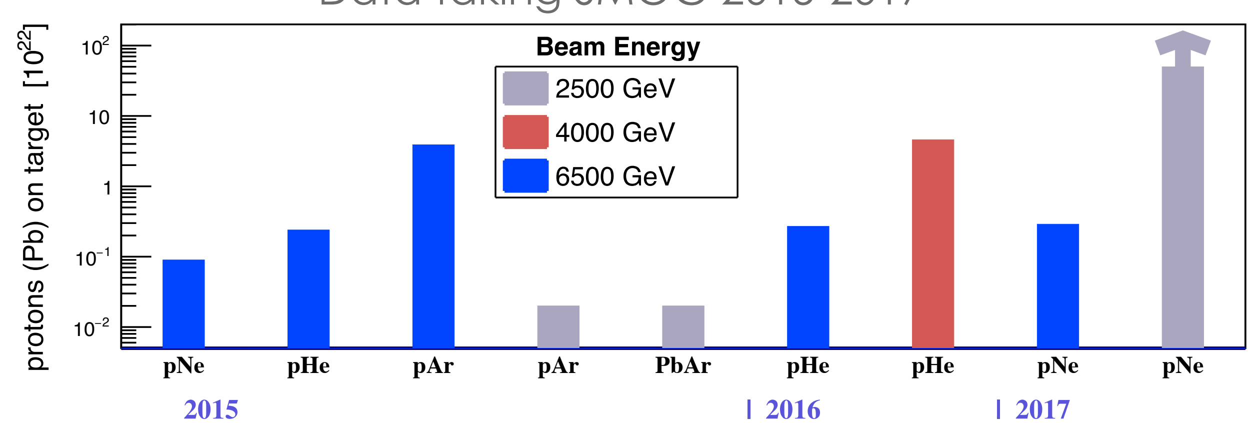
System for Measuring Overlap with Gas (SMOG) has been thought for precise luminosity measurements by beam gas imaging, but then it served as a “pseudo-target” producing interesting results



gas injection at the nominal IP



Data taking SMOG 2015-2017



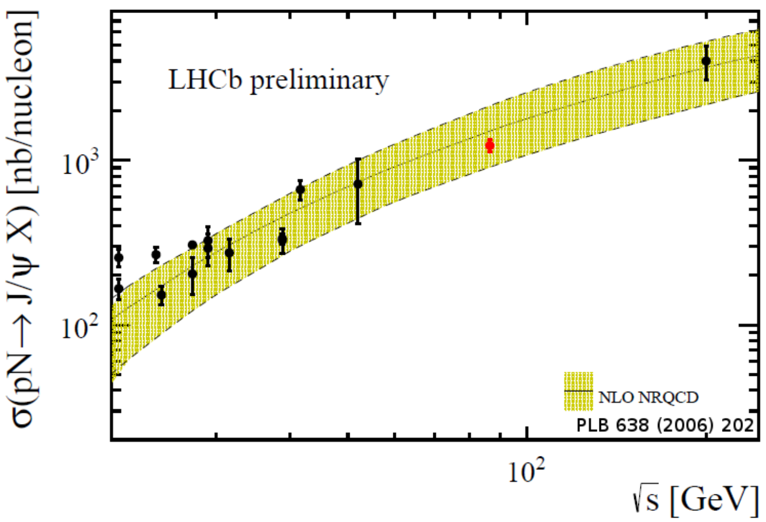
2 papers are going to be published on PRL:

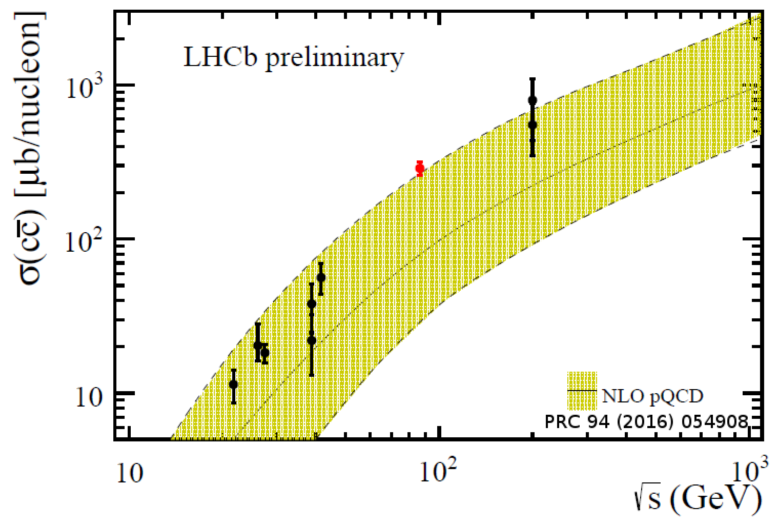
-antiproton production in p-He collisions @ 110 GeV — In print on PRL (arXiv:1808.06127)

-charm (D^0 and J/ψ) production in p-Ar collisions @ 110 GeV — Submitted to PRL (arXiv:1810.07907)

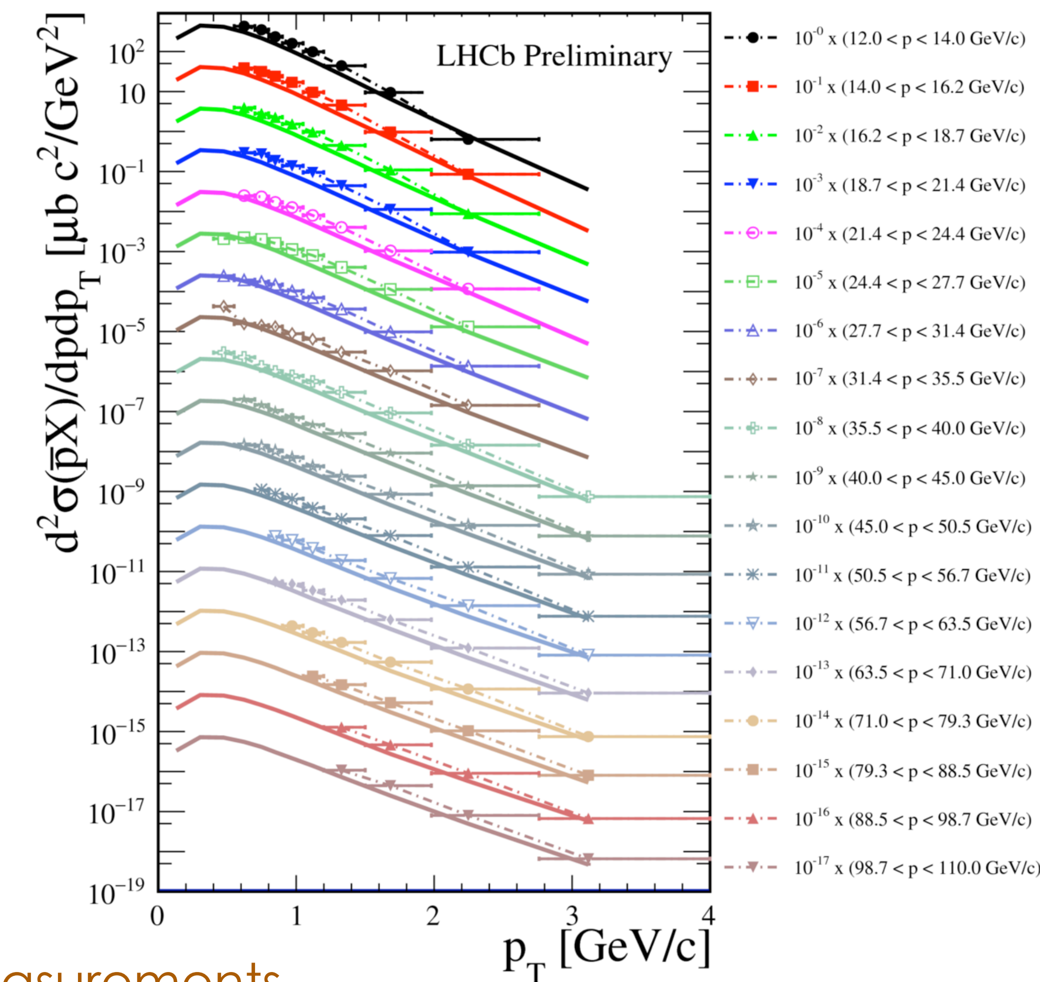
New perspectives in QCD and soft QCD for Cosmic Ray Physics

J/ψ e $c\bar{c}$ cross section as a function of the c.m. energy

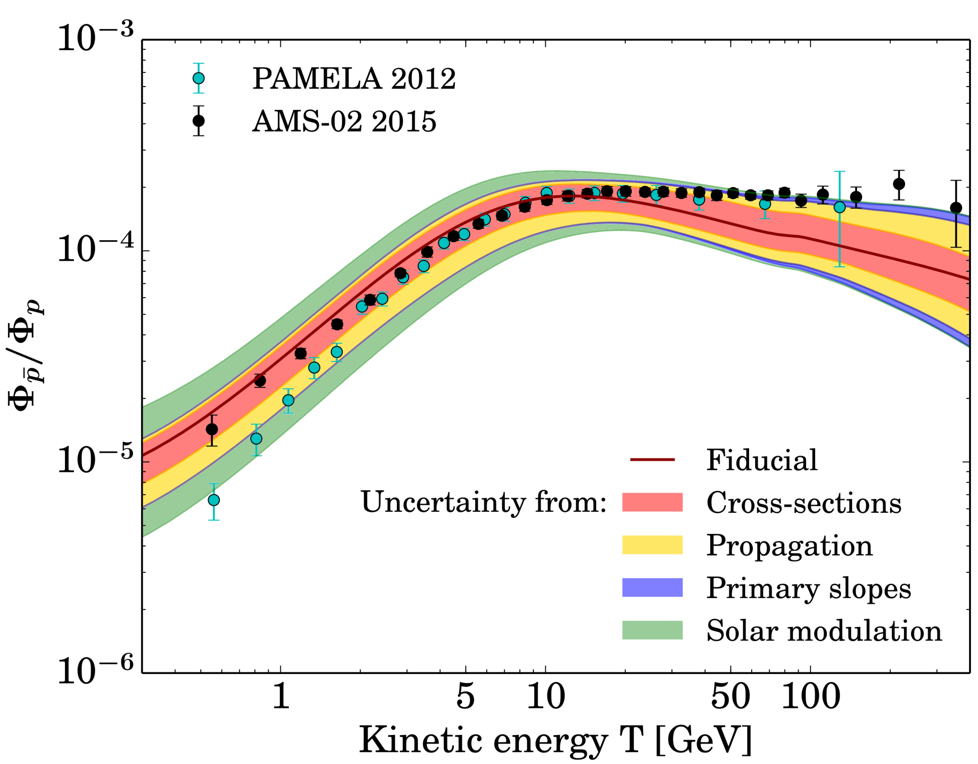


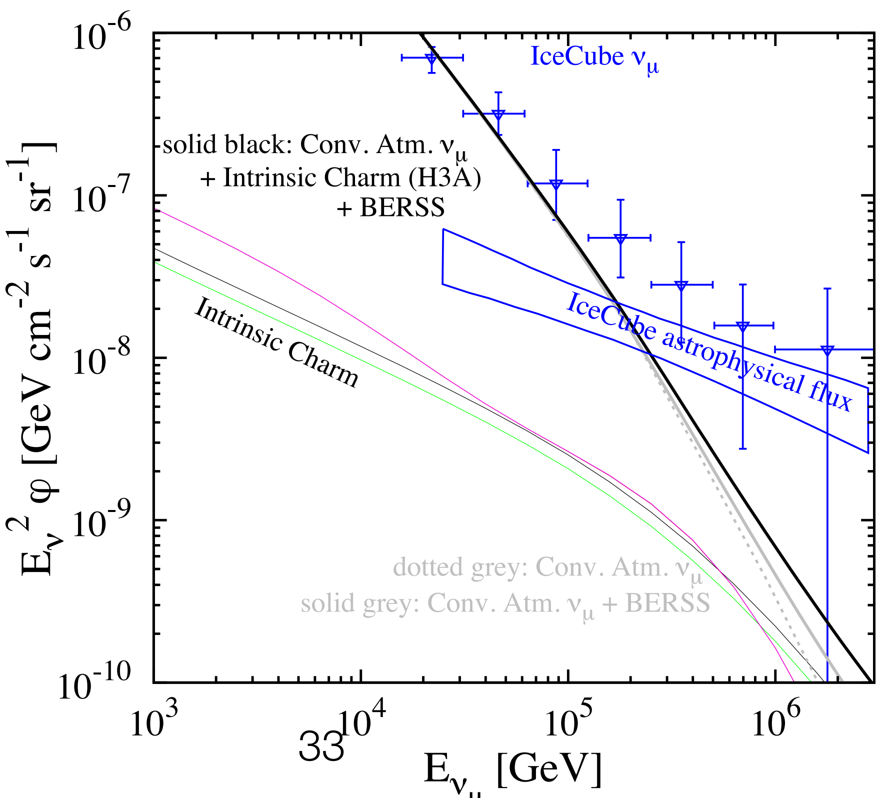


anti-p xsection



Large impact on the AMS (anti-p) and ICECUBE (open-charm) measurements



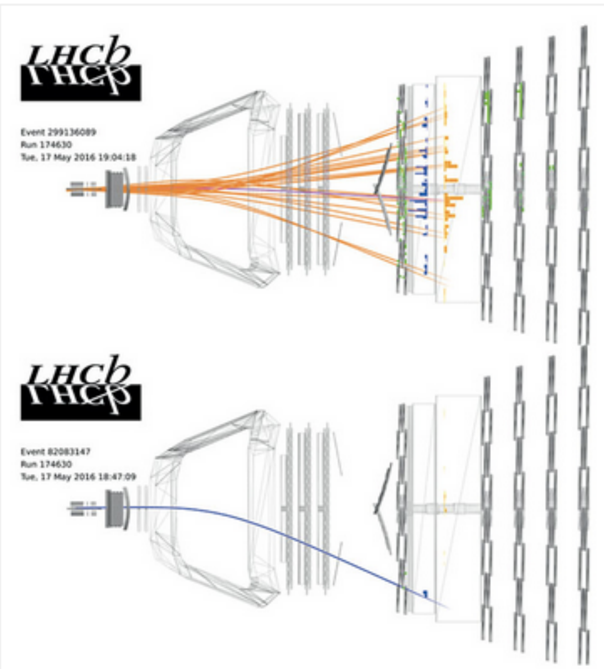


SMOG p-Neon data represent a valid model of the interaction in air. The energy corresponds to the 3rd-4th interaction for a 10^{10} GeV shower. Mid-rapidity measurements are useful for the lateral development of the showers

NEWS

LHCb brings cosmic collisions down to Earth

13 April 2017



Collision and scattering events (expand for full image)

In an effort to improve our understanding of cosmic rays, the LHCb collaboration has generated high-energy collisions between protons and helium nuclei similar to those that take place when cosmic rays strike the interstellar medium. Such collisions are expected to produce a certain number of antiprotons, and are currently one of the possible explanations for the small fraction of antiprotons (about one per 10,000 protons) observed in cosmic rays outside of the Earth's atmosphere. By measuring the antimatter compon… can potentially unveil new high-e… notably a possible contribution fro… decay of dark-matter particles.

In the last few years, space-borne… study of cosmic rays have dramati… knowledge of the antimatter comp… Alpha Magnetic Spectrometer (AM…

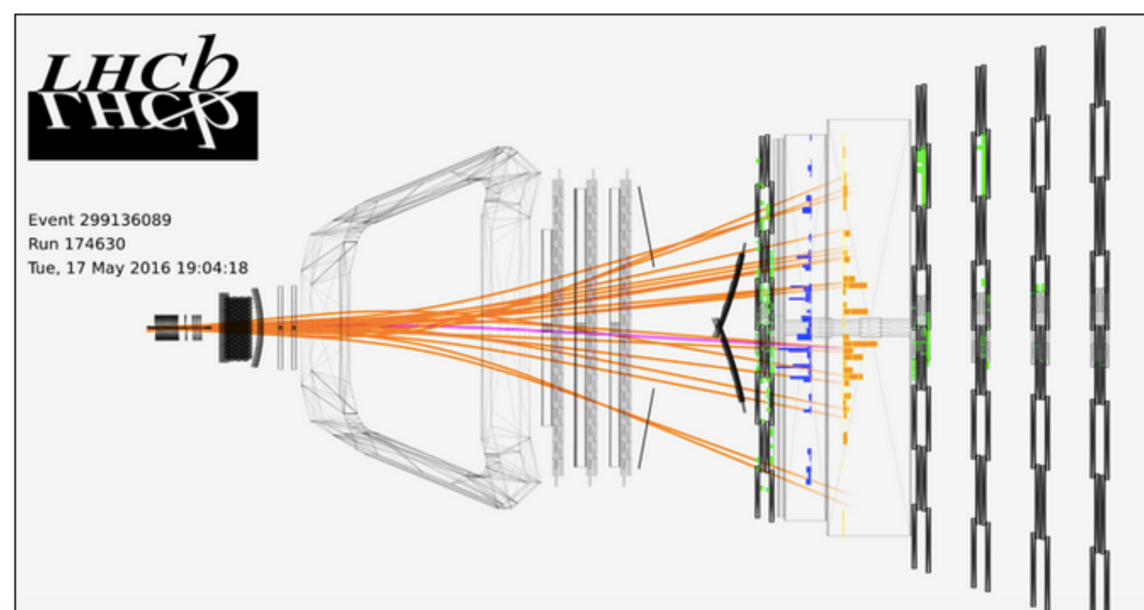
Cosmic collisions at the LHCb experiment

by *Stefania Pandolfi*

Posted by Stefania Pandolfi on 27 Mar 2017. Last updated 27 Mar 2017, 16.00.

Voir en français

This content is archived on the CERN Document Server



An example of a fully reconstructed proton-helium collision event in the LHCb detector. The particle

SMOG2 aims to built a real gas target (storage cell) in order to improve the SMOG performances and open the ground to the physics cases shown before

SMOG2 vs SMOG

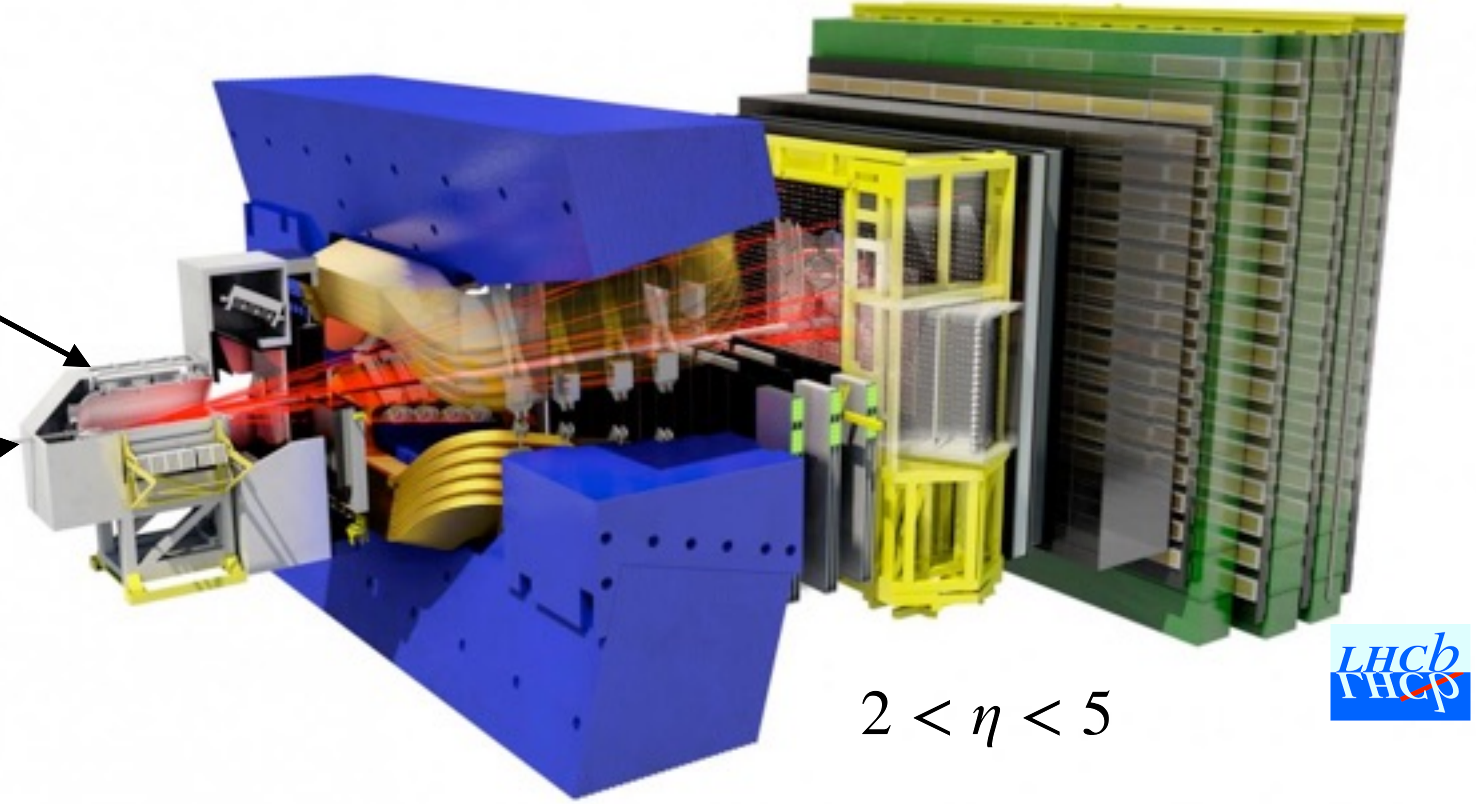
- Increase of the luminosity by up to 2 orders of magnitude using the same gas load of SMOG
- Injection of $H_2, D_2, He, N_2, Ne, Ar, Kr, Xe$
- Multiple gas lines
- New Gas Feed System. Gas density measured with high precision
- Well defined interaction region upstream the nominal IP: strong background reduction, no mirror charges effect, possibility to use all the bunches

SMOG2 can run in synergy with the high-energy pp physics

VELO
silicon VErtex LOcator

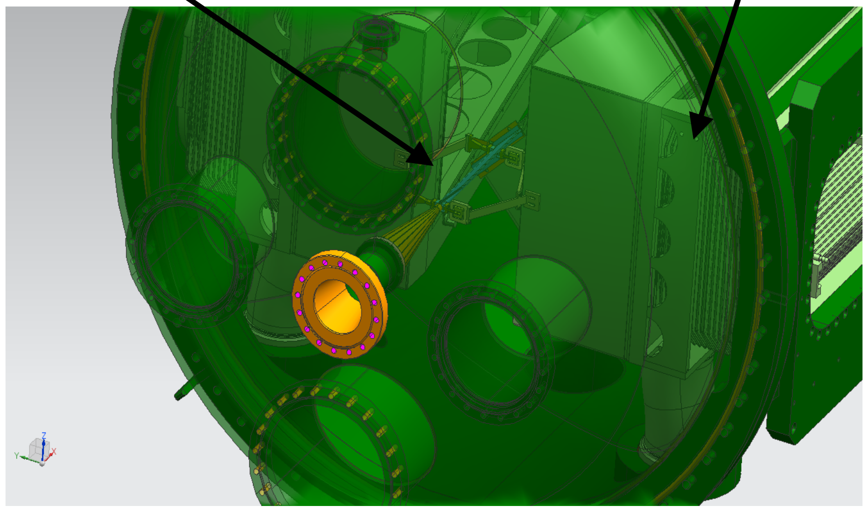
No changes are requested to the main spectrometer

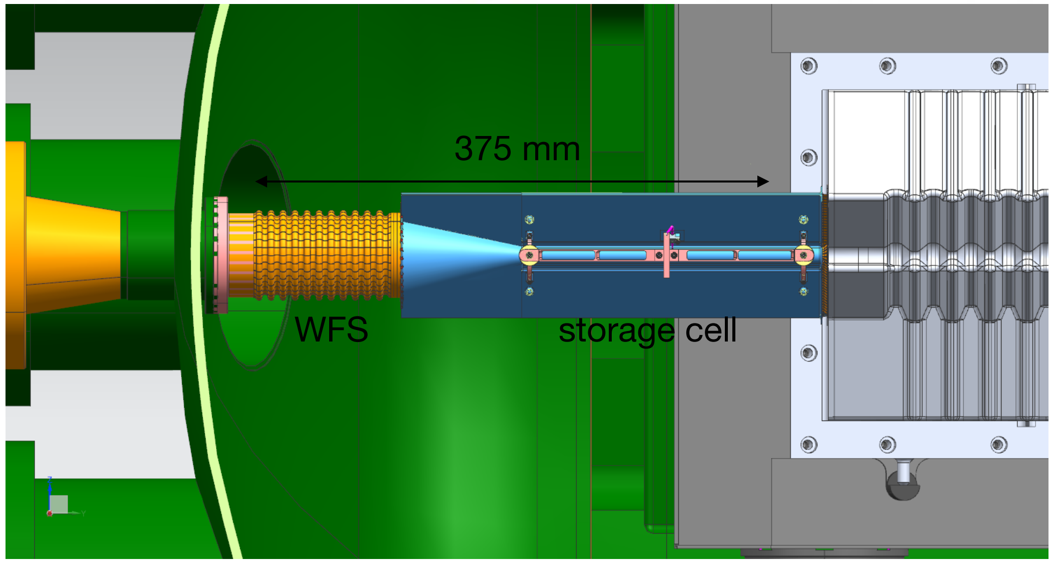
LHC beam



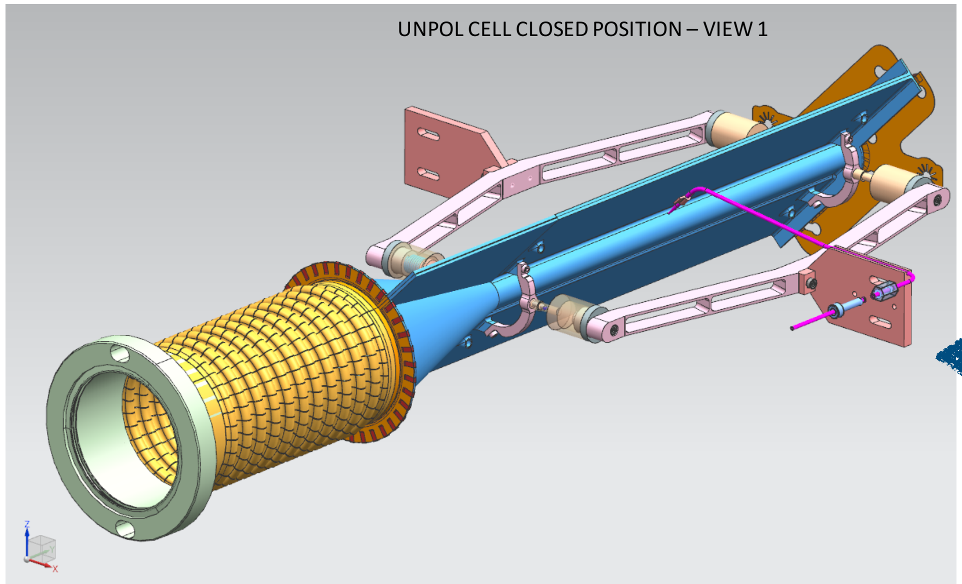
SMOG2

VELO

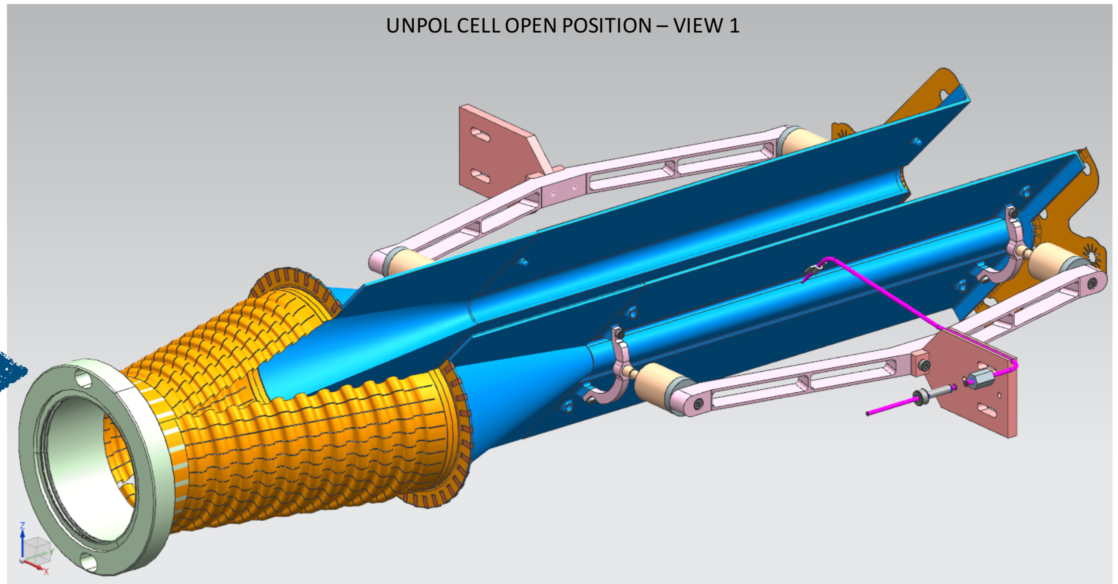




Internal side view



openable storage cell



Statistics in full synergy mode (1 yr data taking)

Storage cell assumptions	gas type	gas flow (s^{-1})	peak density (cm^{-3})	areal density (cm^{-2})	time per year (s)	int. lum. (pb^{-1})
SMOG2 SC	He	1.1×10^{16}	10^{12}	10^{13}	3×10^{3}	0.1
	Ne	3.4×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1
	Ar	2.4×10^{15}	10^{12}	10^{13}	2.5×10^{6}	80
	Kr	8.5×10^{14}	5×10^{11}	5×10^{12}	1.7×10^{6}	25
	Xe	6.8×10^{14}	5×10^{11}	5×10^{12}	1.7×10^{6}	25
	H_2	1.1×10^{16}	10^{12}	10^{13}	5×10^{6}	150
	D_2	7.8×10^{15}	10^{12}	10^{13}	3×10^{5}	10
	O_2	2.7×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1
	N_2	3.4×10^{15}	10^{12}	10^{13}	3×10^{3}	0.1

SMOG2 example pAr @115 GeV

Int. Lumi.		80/pb
Sys.error of J/Ψ xsection		~3%
J/Ψ	yield	28 M
D^0	yield	280 M
Λ_c	yield	2.8 M
Ψ'	yield	280 k
$\Upsilon(1S)$	yield	24 k
$DY\ \mu^+\mu^-$	yield	24 k

R&D basically completed

- *reconstruction efficiencies of major physics channels*
- *interaction with LHC:*
  - *-vacuum*
  - *-impedence*
  - *-aperture*
  - *-coating*
  - *-beam stability (SEY)*
- *target prototypes and tests*
- *induced heating and bake-out stress*
- *WFS prototypes and stress test (15.000 cycles)*
- *Material budget and Background Induced on LHCb*

Informal green lights from both LHC and LHCb
Formal approval in Fall after the EDR (15/11/2018) and the LMC meetings

Installation foreseen during the LHC LS II (2019-2020)

R&D

SMOG2

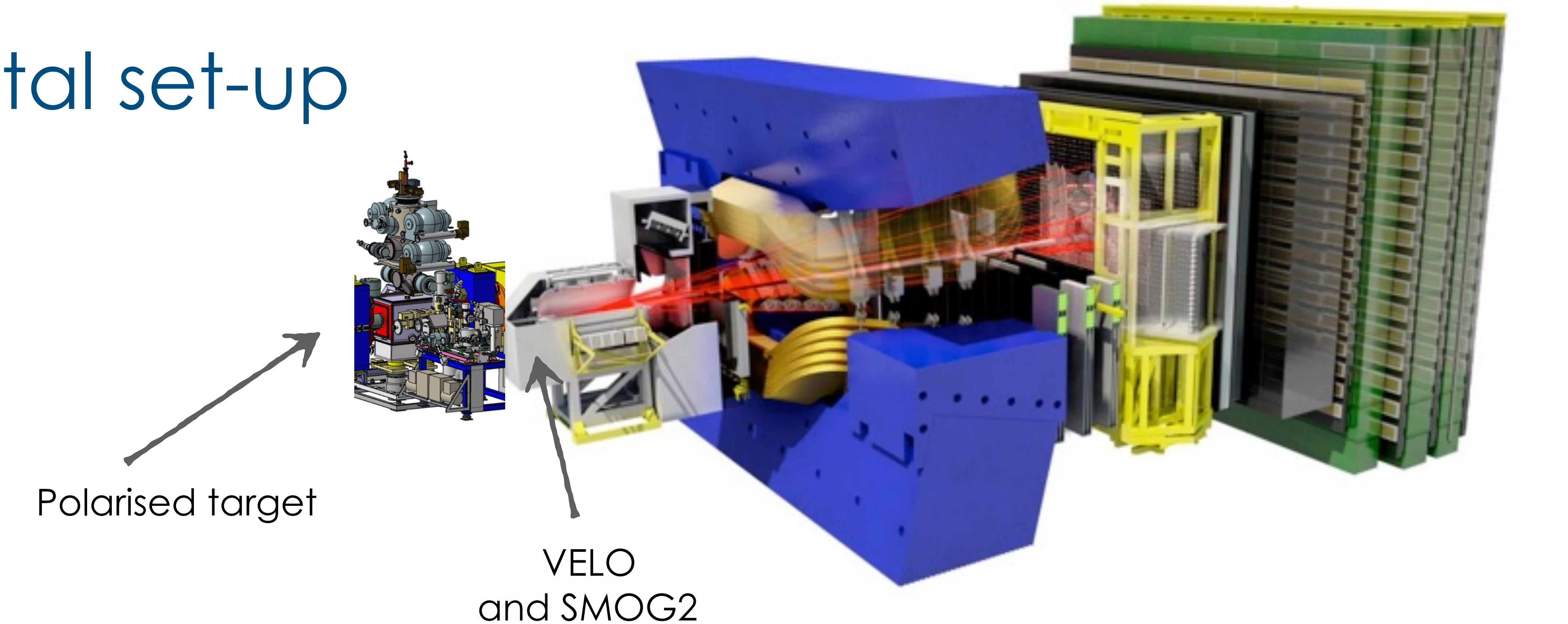
not only a project itself

LHCspin

Phase II transversely polarised H and D target

... at LHCb

Experimental set-up

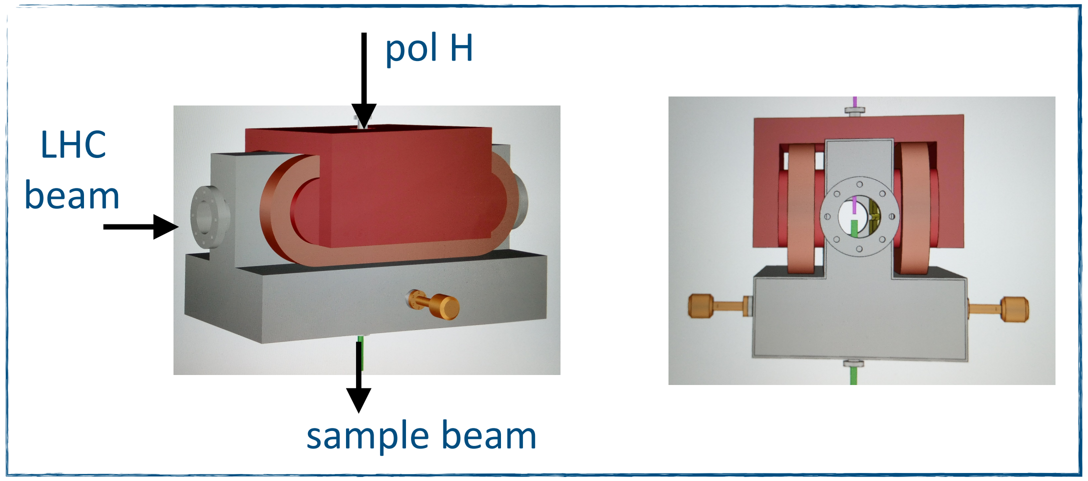


Well consolidated technique

Design follows the successful HERMES Polarised Gas Target which ran at HERA 1996 – 2005, and the follow-up PAX target operational at COSY (FZ Jülich)

Important differences (i) HERA: multi-user facility (together with ZEUS, H1, HERA-B), but in case of problems usually access was granted quite timely; (ii) COSY: single-user, so access by decision of experimental group.
Requirements for LHC: (i) extreme reliability of all safety systems, in particular the vacuum interlock ABS-TC; (ii) very long running times without possibility of interventions

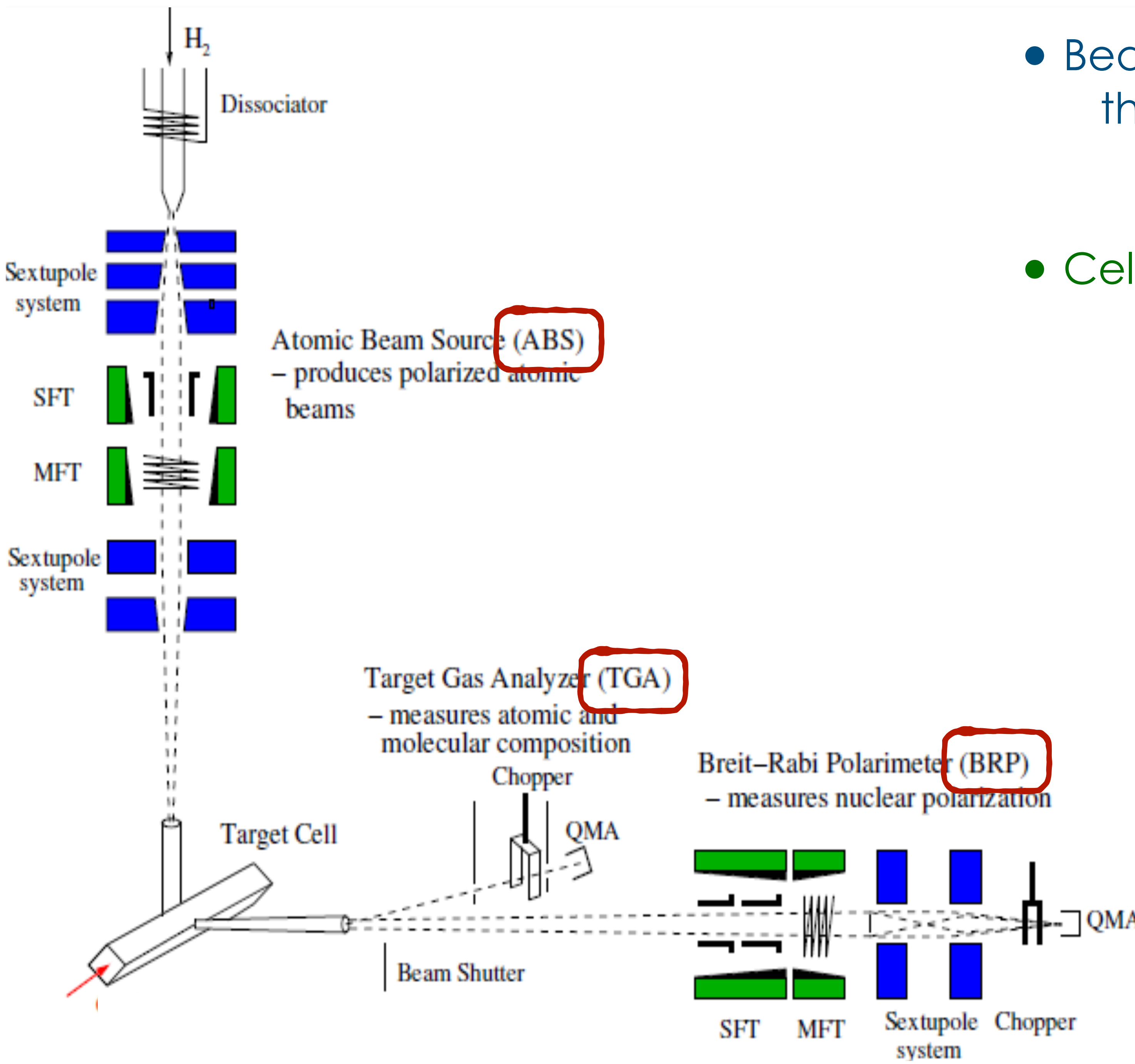
Completely different requirements for coating of surfaces



- Injected intensity of H-atoms = 6.5 10^{16}/s
- Standard Feed Tube 1.0 cm i.d., 10 cm long
- Beam tube 30x1 cm
- Cell temperature T ~ 100K
- Areal Density ≈ 1.2 · 10^{14} cm^2

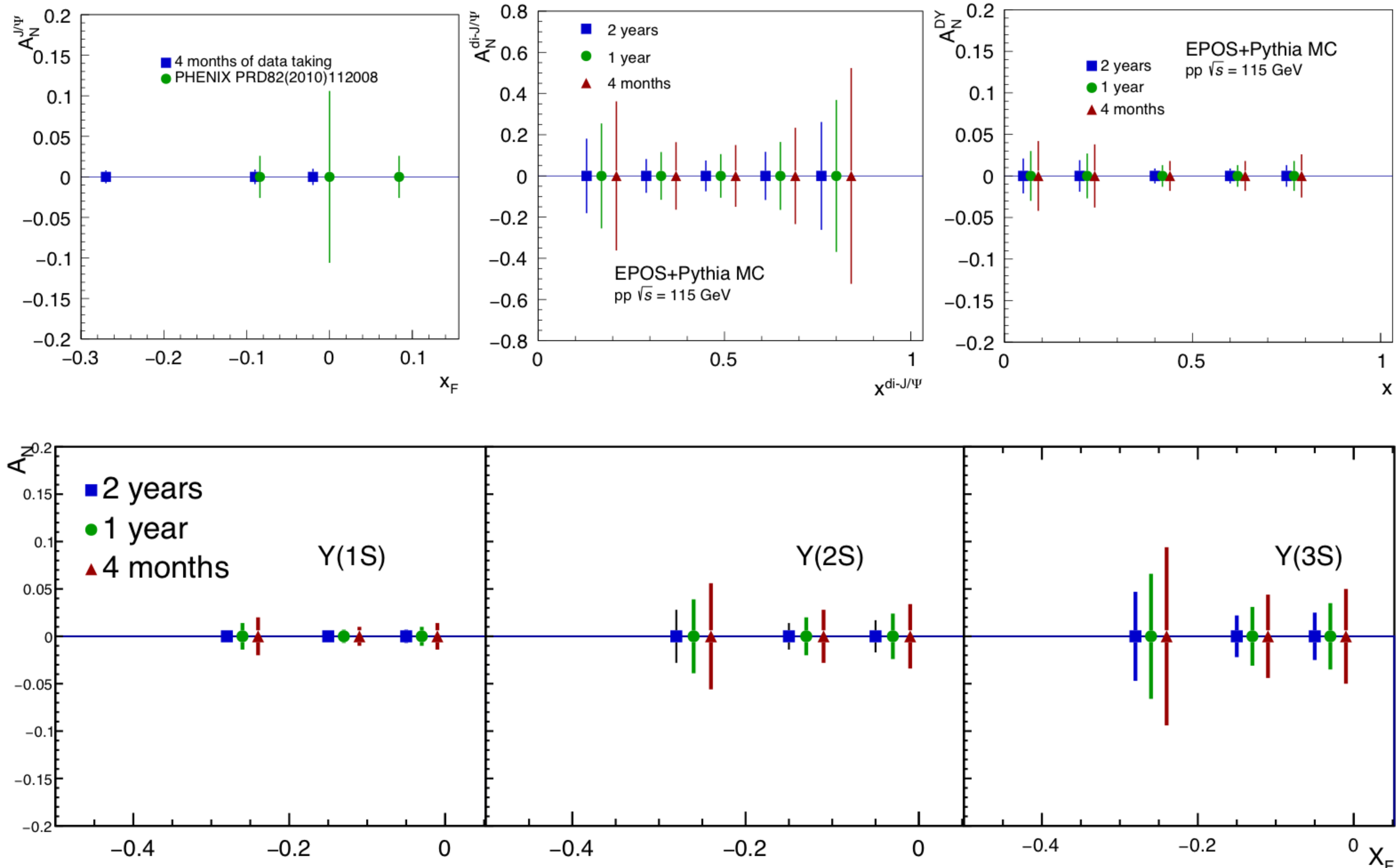
- Beam Induced Depolarisation better in LHC than at HERA

- Cell coating: the proven Drifilm surface as a polymere is forbidden at the LHC. Carbon-type surfaces + ice layer seems the best solution for the target coating in order to prevent the atomic recombination



Statistics error projection for some of the possible channels (within the LHCb reconstruction framework)

Synergic pp / p-target data taking:
- 8 h per day
- 20 d per month
- 200 d per year



LHC beam life time and synergic data taking

The PGT, at maximum intensity, will give a relative proton loss rate of $N/N_p = 1.6 \times 10^{-7}$ /s, corresponding to a reduction of 1/3 of the beam lifetime of 74 days —> completely negligible for synergic data taking pp/p-target

The R&D is going on and it will speed up after the SMOG2 approval

We aim for the installation during the LHC LSIII(2024-…)

Conclusions

Fixed target collisions at the LHC represent a unique possibility for *a laboratory for QCD* in unexplored kinematic regions … in a realistic time schedule

Conclusions

Fixed target collisions at the LHC represent a unique possibility for *a laboratory for QCD* in unexplored kinematic regions … in a realistic time schedule

LHCb is very focussed on the project:

- SMOG2 is a reality and is foreseen to take data from 2021
- The R&D for LHCspin represents a fantastic challenge and is on its road