Hadron structure studies with
A Fixed-Target Experiment at the LHC
- AFTER@LHC -

Andrea Signori

7th APS-**GHP** workshop

on behalf of the **AFTER@LHC study group**

http://after.in2p3.fr

Jefferson Lab

JSA

About the speaker

Nov. 2016 - present | postdoc
Jefferson Lab (VA, USA)

2012 - 2016 | PhD candidate
Nikhef and Vrije Universiteit
Amsterdam (NL)

2012 | Summer intern
DESY - Hermes collaboration (GE)

2012 | Master student
"Hadron structure and QCD" group
Pavia U. (IT)

Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DI PAVIA

Outline of the talk

- AFTER@LHC

- TMD physics

- Intrinsic charm

Outline of the talk

- **AFTER@LHC**

- **TMD physics** $\Longleftarrow$ my expertise and field of contribution to the study group for AFTER

- **Intrinsic charm**

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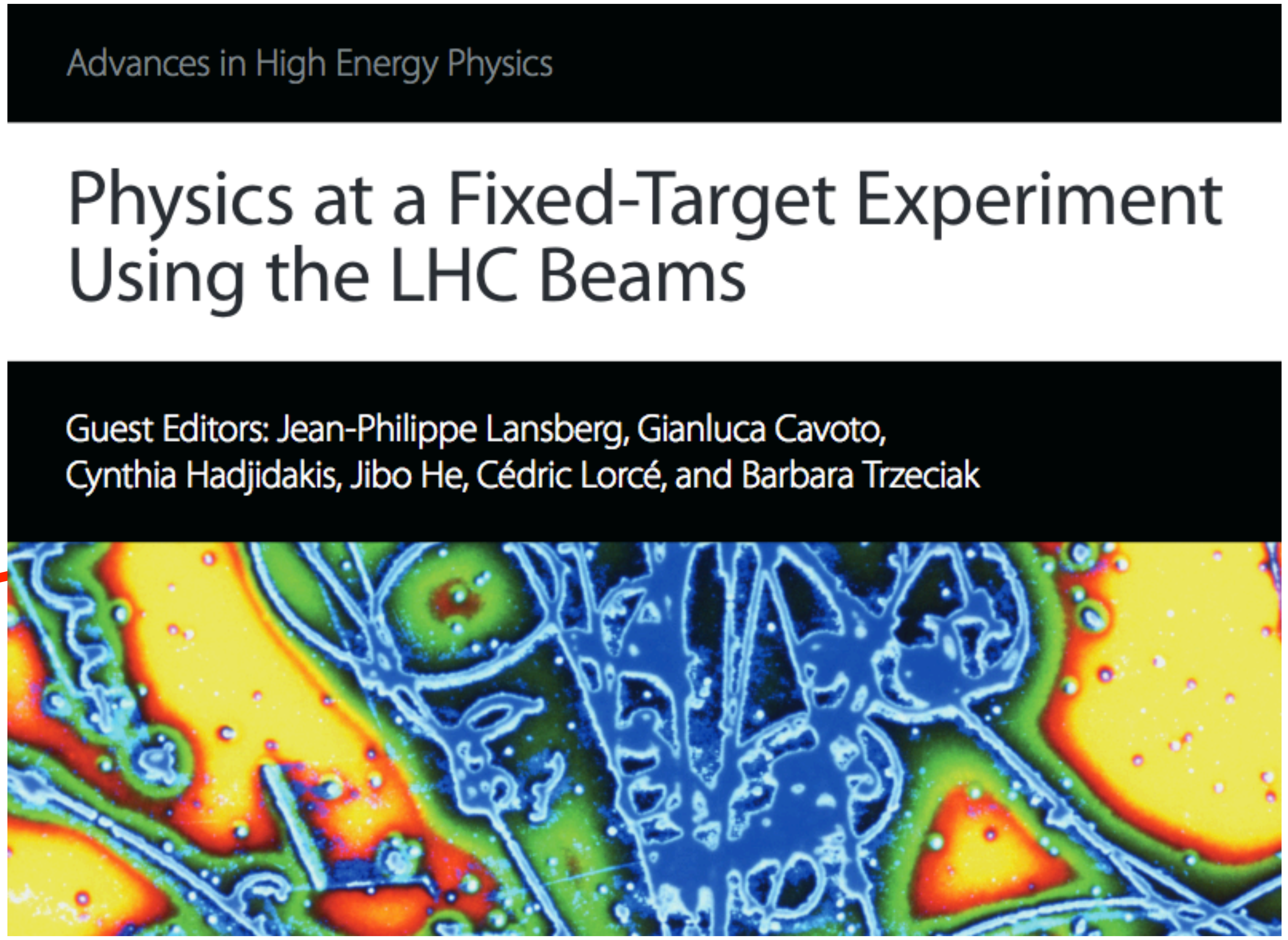
AFTER @ LHC



http://www.hindawi.com/journals/ahep/si/354953/

References:

- Brodsky, Fleuret, Hadjidakis, Lansberg : Phys.Rept. 522 (2013) 239-255
- Physics at A Fixed Target Experiment using the LHC beams : http://www.hindawi.com/journals/ahep/si/354953/
- Expression Of Interest (EOI) for AFTER@LHC (work in progress)

and references therein

AFTER @ LHC

Important features :

- **high luminosity** (exploits LHC beams)
- explore **high-x** and **backward rapidity** region (thanks to the boost)
- **target polarization**
- vary the atomic mass of the target
- $\sqrt{s}$ = 115 GeV (p beam)

→ can reach 10 fb^{-1}/year

→ target x range for DY : $0.05 < x_{targ} < 0.95$

backward rapidity : almost unexplored in other fixed-target experiments

→ spin physics program

Which are useful to ... :

- advance our understanding of the **high-x partonic content** of nucleons&nuclei

- explore **3D structure** of (un)polarized hadrons in **momentum space**

- get new insights into **heavy ion physics**

AFTER @ LHC

1D structure in momentum space :

- improve (g, heavy quarks) PDFs at high-x ==> important for new physics searches
- constrain "**intrinsic**" **charm** effects ==> important for **particle** and **astroparticle** physics (neutrino flux from cosmic rays)

- provide data for nuclear PDF studies
- new insights into the EMC effects ?

3D structure in momentum space :

- investigation of (un)polarized TMD PDFs via spin asymmetries
- inputs to the proton spin puzzle ?
- tests for generalized universality of TMDs

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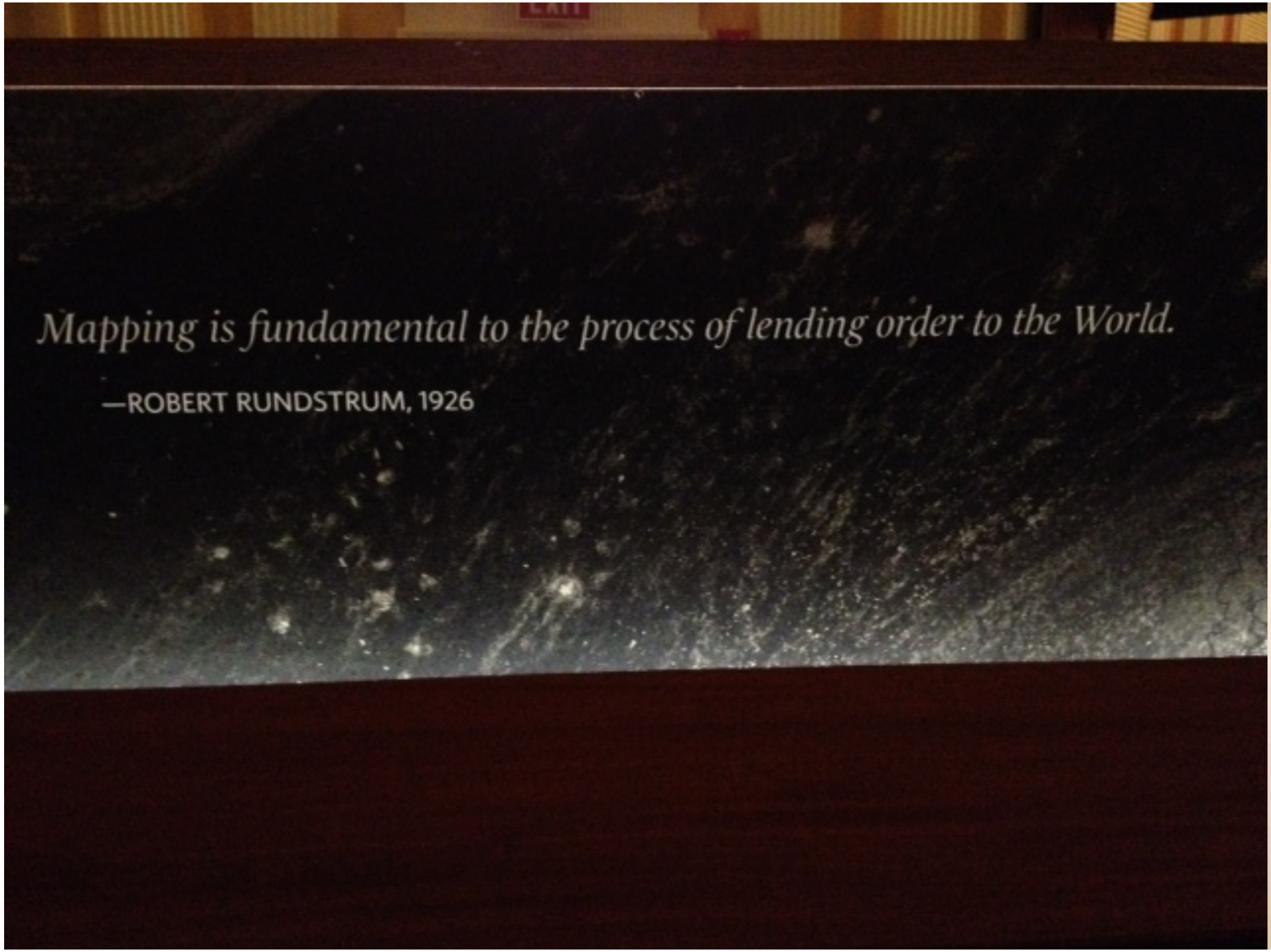
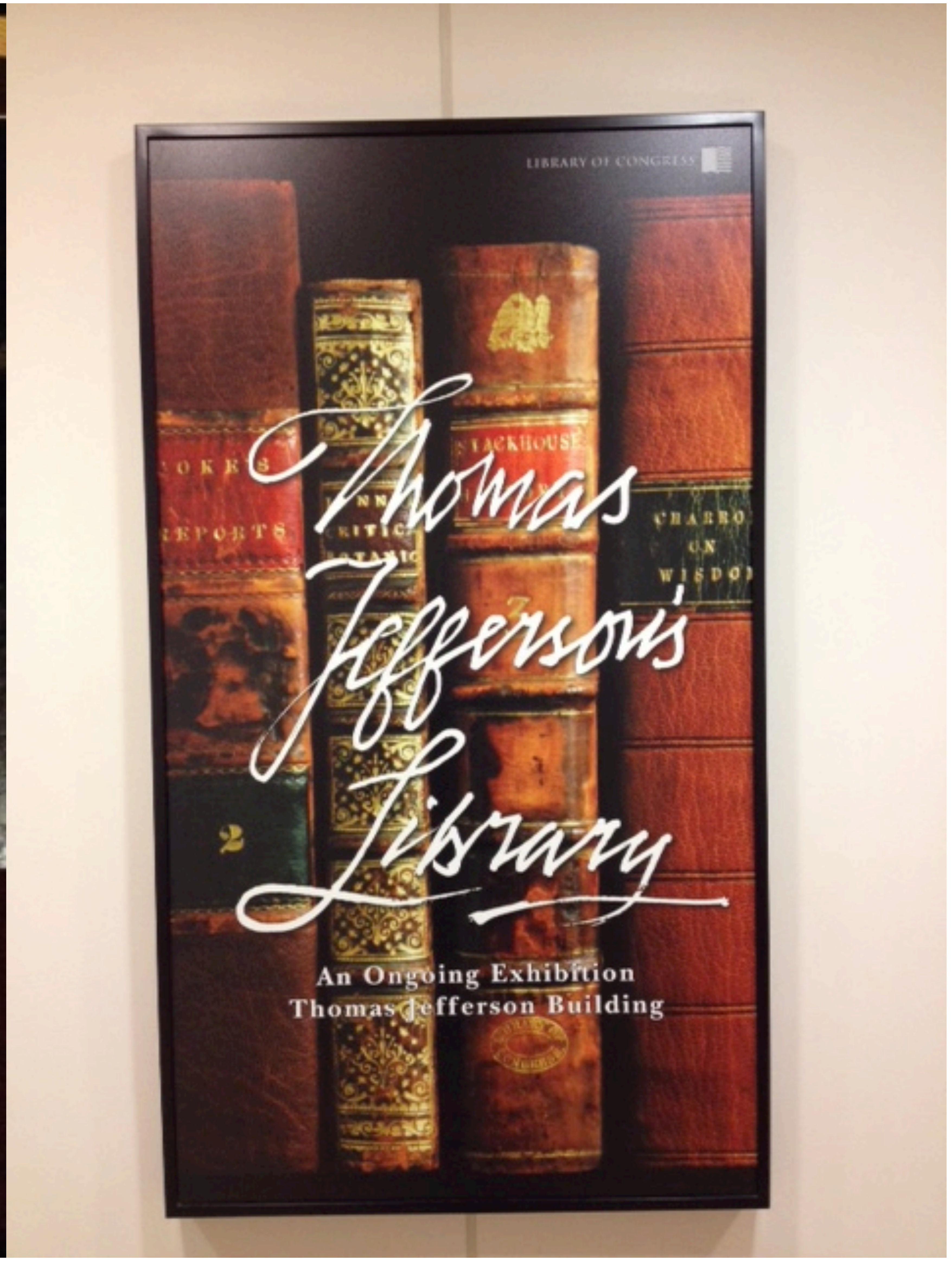
Mapping



Mapping is fundamental to the process of lending order to the World.
—ROBERT RUNDSTRUM, 1926



Thomas Jefferson's Library
An Ongoing Exhibition
Thomas Jefferson Building

Two proposals

Inject gas into the beam … :

"A polarized gas target inside the LHC beam"

C. Barschel, P. Lenisa, A. Nass, and E. Steffens, Adv.Hi.En.Phys. (2015) 463141

… **or extract the beam** :

"LHC beam extracted by a bent crystal"

E. Uggerhøj, U.I Uggerhøj, NIM B 234 (2005) 31, Rev. Mod. Phys. 77 (2005) 1131

- no observed decrease for the LHC performance
- both currently under investigation at LHC and (unpolarized) **gas option already tested (Smog)**

- estimated luminosity per year : 10 fb^{-1}

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TMDs and spin physics

References:

- Liu, Lorcé : Few Body Syst. 57 (2016) no.6, 379-384
- Bacchetta : Eur.Phys.J. A52 (2016) no.6, 163
- Kanazawa, Koike, Metz, Pitonyak : Adv.High Energy Phys. 2015 (2015) 257934
- Anselmino, D'Alesio, Melis : Adv.High Energy Phys. 2015 (2015) 475040
- AFTER study group (Feasibility of SSA studies at AFTER) - arxiv 1702.* * * * *

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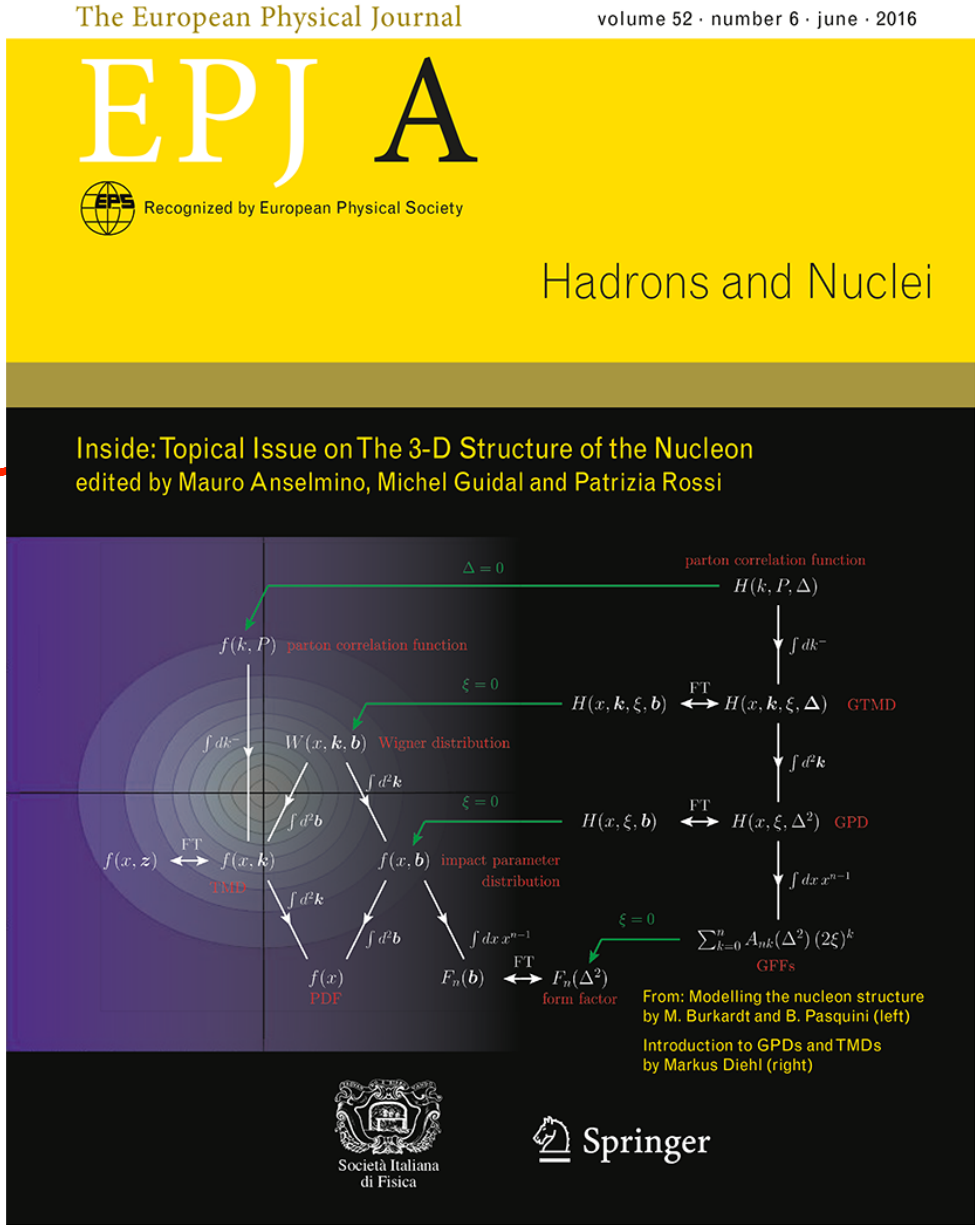
The European Physical Journal A

Volume 52 / No 6 (June 2016)



TMDs and spin physics

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- AFTER study group (Feasibility of SSA studies at AFTER) - arxiv 1702.* * * * *

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Quark TMD PDFs in a proton

$$\Phi_{ij}(x, \mathbf{k}_T) \sim \langle P|\bar{\psi}_j(0)\, U_{[0,\xi]}\, \psi_i(\xi)|P\rangle_{|\mathrm{LF}}$$

extraction of a **quark not collinear** with the proton

quark pol.

nucleon pol.	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1,\ h_{1T}^\perp$

Twist-2 TMDs

$f_1^q(x, k_T^2)$

involve all 3 components:
richer than 1D PDFs

spin-spin and **spin-orbit** interactions

Contain nonperturbative information, need (possibly global) fits!

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Quark TMD PDFs in a proton

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extraction of a **quark not collinear** with the proton

quark pol.

nucleon pol.

	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1,\ h_{1T}^\perp$

Twist-2 TMDs

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involve all 3 components:
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spin-spin and **spin-orbit** interactions

Contain nonperturbative information, need (possibly global) fits!

Where can we observe TMDs ?

processes with two separate energy scales:

$$\Lambda_{\mathrm{QCD}} \ll q_T \ll Q$$

- Drell-Yan like
- SIDIS
- e+e- into two hadrons

How well do we know TMDs ?

- Good knowledge about unpolarized TMDs
- limited knowledge of the polarized structures (each one to a different extent)

A LOT of theoretical, experimental and phenomenological work is needed

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Why TMDs ..?

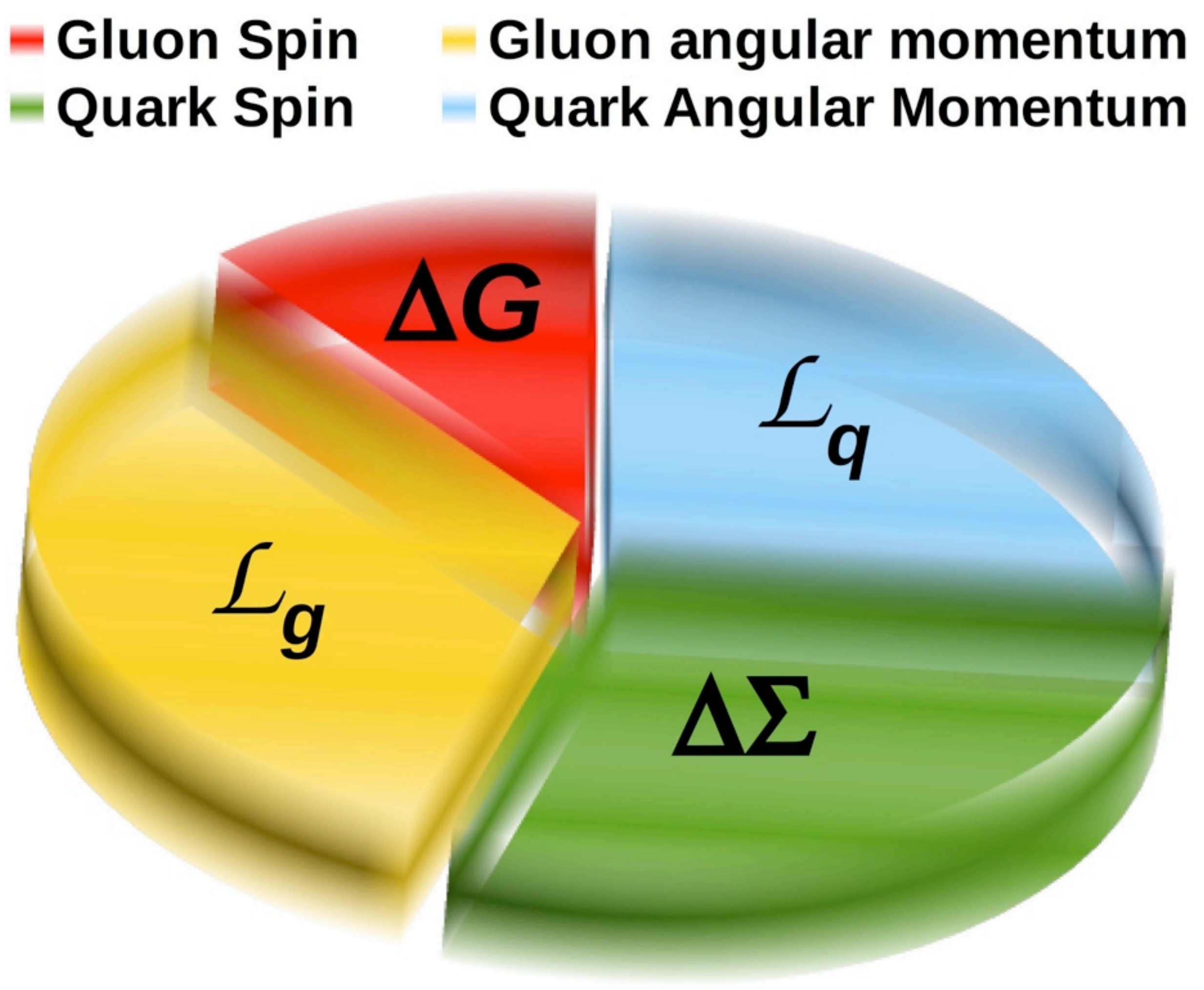
- TMDs in unpolarized protons :

see the manifestation of proton structure at work in collisions of unpolarized hadrons

* Boer-Mulders effect
* $W^{\pm}$ production from unpolarized proton collisions => important for flavor decomposition of quark TMDs

- TMDs in polarized protons :

for example to address the orbital angular momentum **(OAM)** of partons (e.g. the Sivers case)



A useful **experimental handle to tackle polarized TMDs** is a single transverse **spin asymmetry** :

the arrow represent the direction of the transverse spin of the target

$$A_N \sim \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

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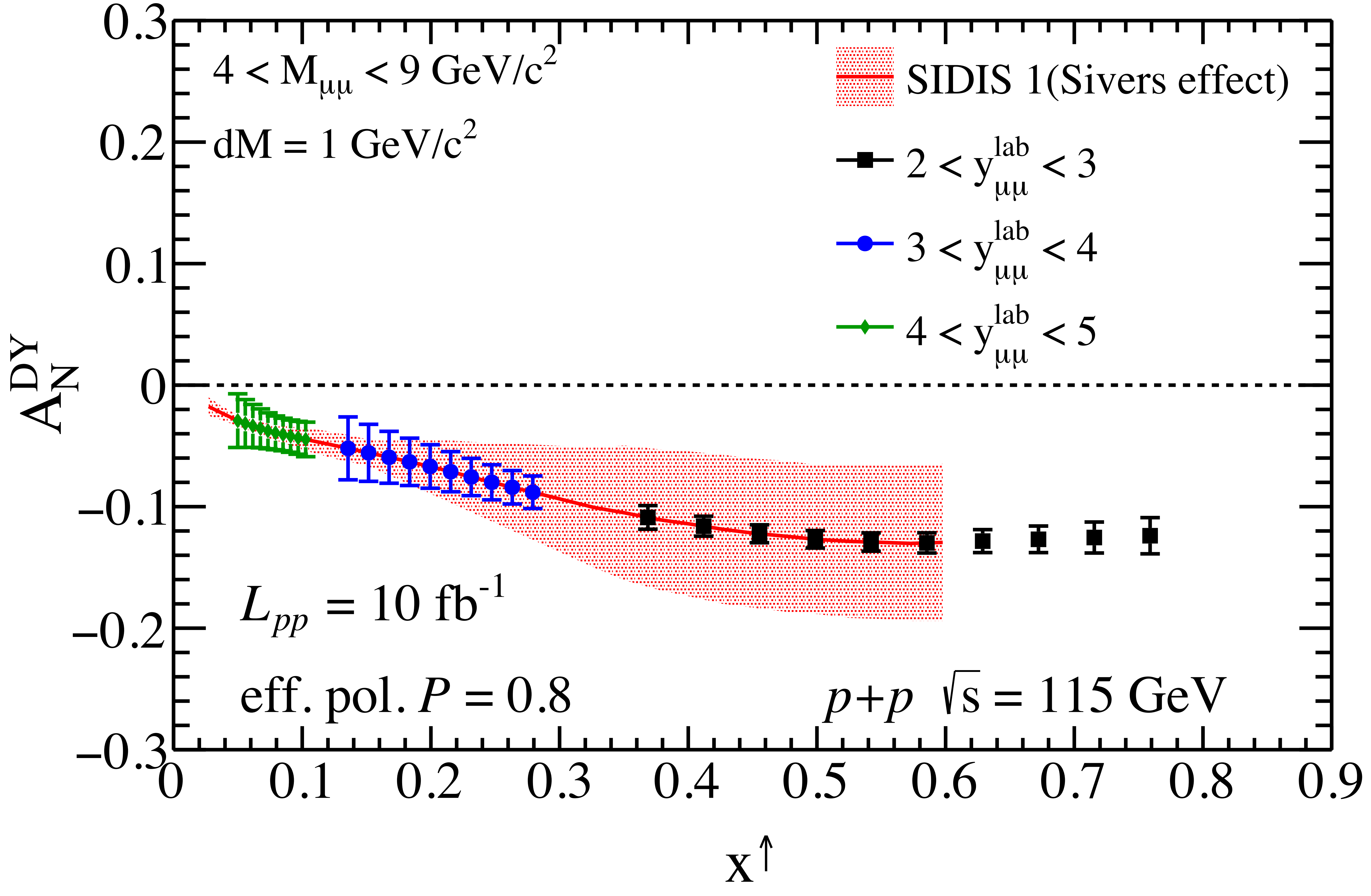
A_N in Drell-Yan

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections

$f_{1T}^{\perp q/P}(x, k_T^2)$



proton target and LHCb-like detector

Measurements with very good precision (per cent level)

accuracy of 5% up to $x^{\uparrow} \simeq 0.95$

test for the generalized universality of the Sivers function

Anselmino, D'Alesio, Melis : Adv.High Energy Phys. 2015 (2015) 475040

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Gluon-induced A_N

multiple probes available, for example :

quarkonia
(Yuan, PRD 78 (2008) 014024; Schaefer, J. Zhou, PRD (2013))

B - D meson production
(M. Anselmino et al. PRD 70 (2004) 074025)

photon, photon-jet, di-photon production
(A. Bacchetta et al., PRL 99 (2007) 212002; J.W. Qiu et al., PRL 107 (2011) 062001)

J/Psi + photon production
(W. den Dunnen, J.P. Lansberg, C. Pisano, M. Schlegel, PRL 112, 212001 (2014))

...

All these measurements can be done with AFTER@LHC with the very high precision

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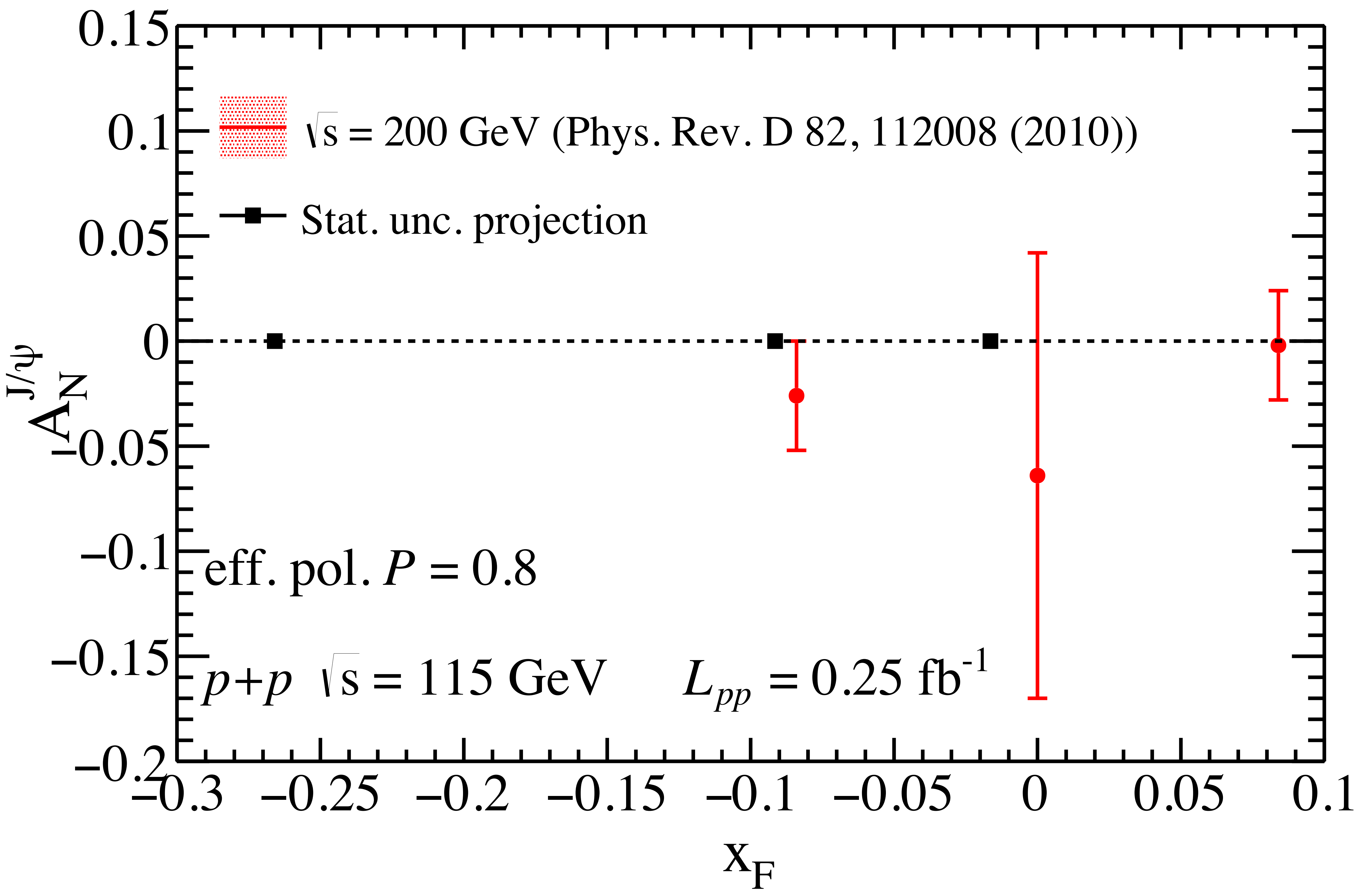
A_N in J/Ψ production

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections

comparison to STAR (RHIC)



proton target and LHCb-like detector

precision : per mill level

small uncertainties are **crucial for phenomenology**.

Models can be constrained in a much more effective way

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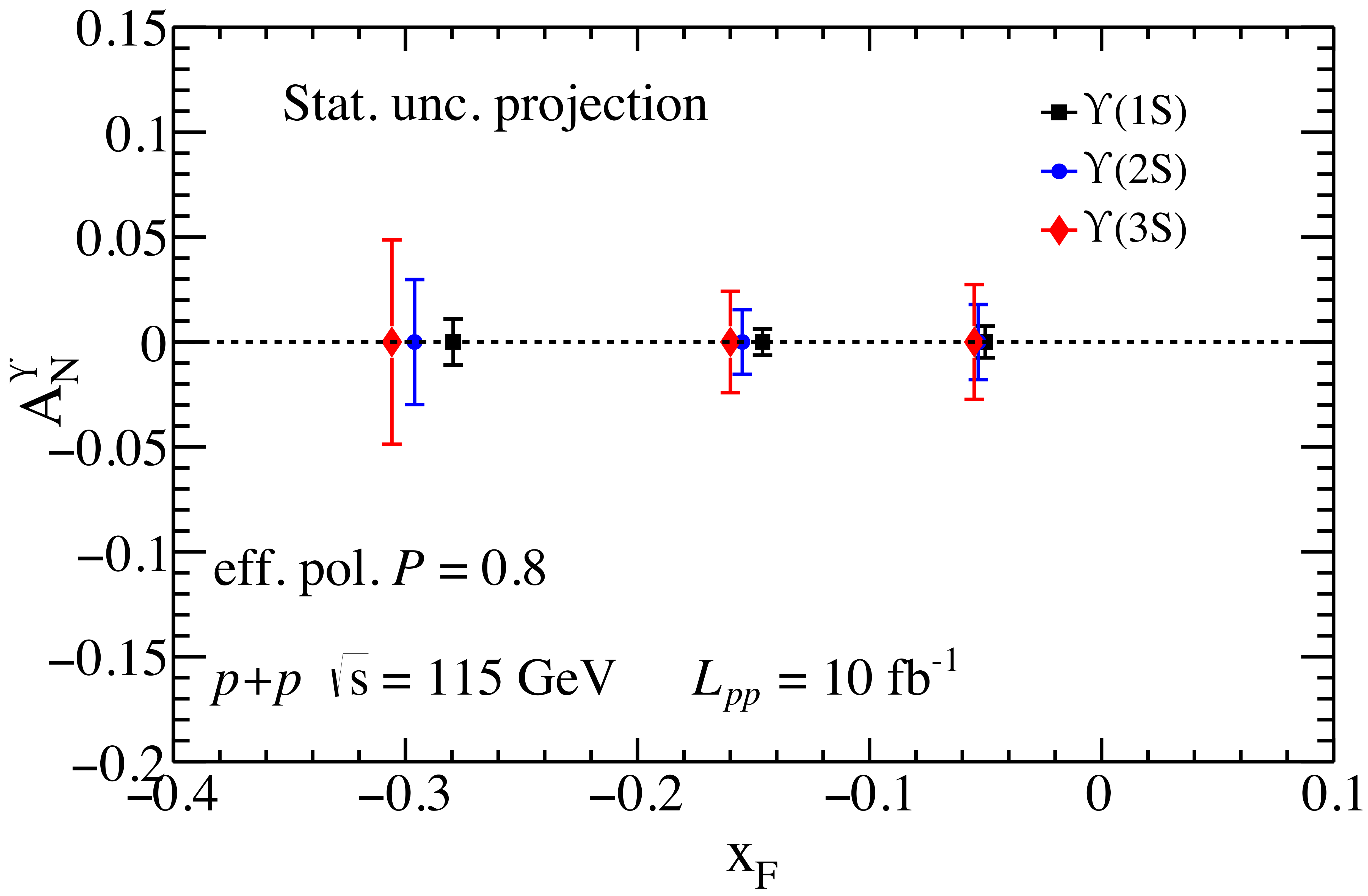
A_N in Υ production

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections



proton target and LHCb-like detector

precision : per cent level

small uncertainties are **crucial for phenomenology**.

Models can be constrained in a much more effective way

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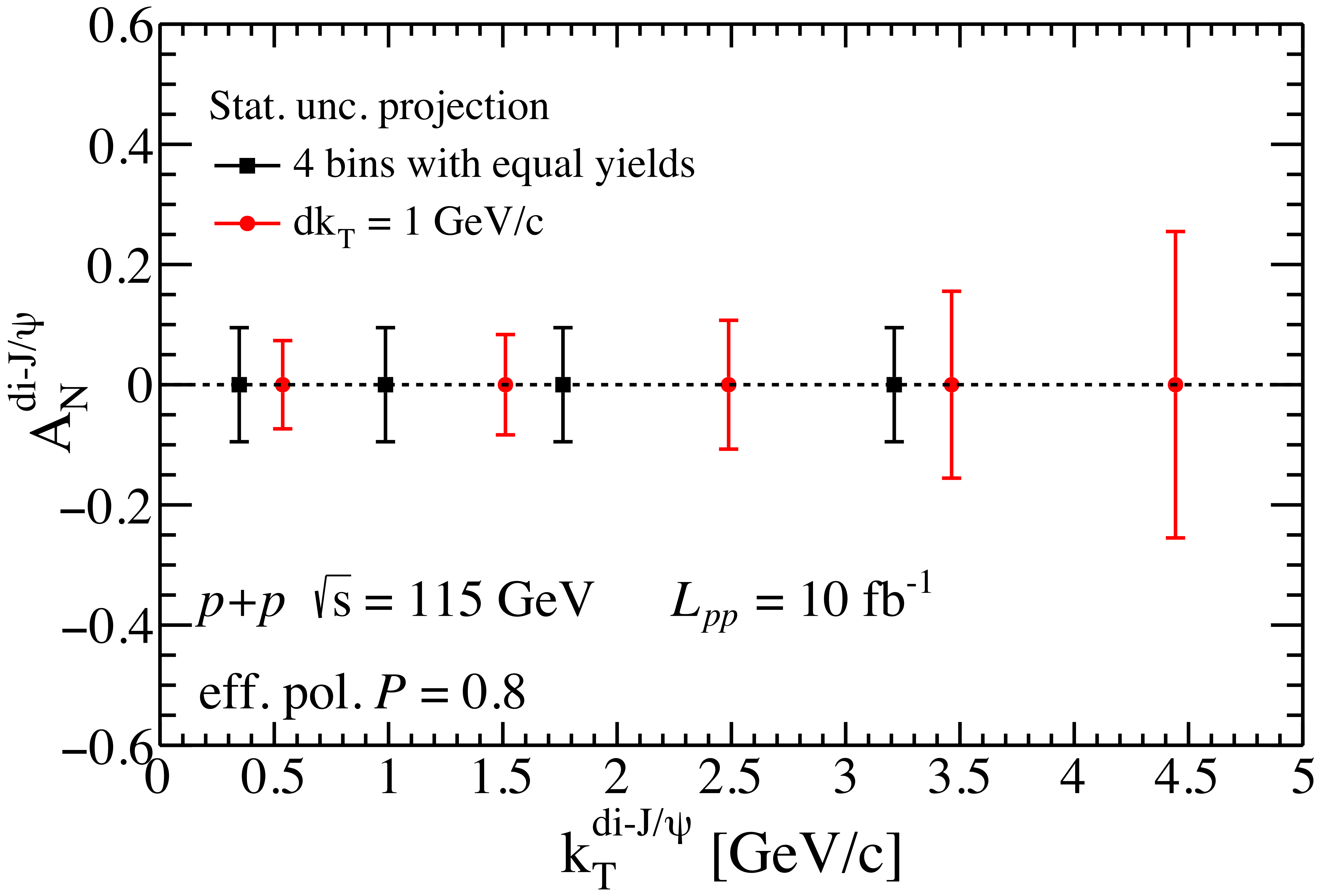
A_N in di - J/Ψ production

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections

one of the most practical observables, due to the high yield



proton target and LHCb-like detector

precision : few per cent level

small uncertainties are **crucial for phenomenology**.

Models can be constrained in a much more effective way

IC - Intrinsic Charm

References:

- Hobbs : arXiv:1612.05686
- Brodsky, Kusina, Lyonnet, Schienbein, Spiesberger, Vogt: Adv.High Energy Phys. 2015 (2015) 231547
- Expression Of Interest for AFTER@LHC (work in progress)

and references therein

Intrinsic sea quarks in the proton

a component **of non-perturbative origin**
to the sea quark content of the proton

$$\langle N|\bar{Q}Q|N\rangle - \langle 0|\bar{Q}Q|0\rangle$$

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Intrinsic sea quarks in the proton

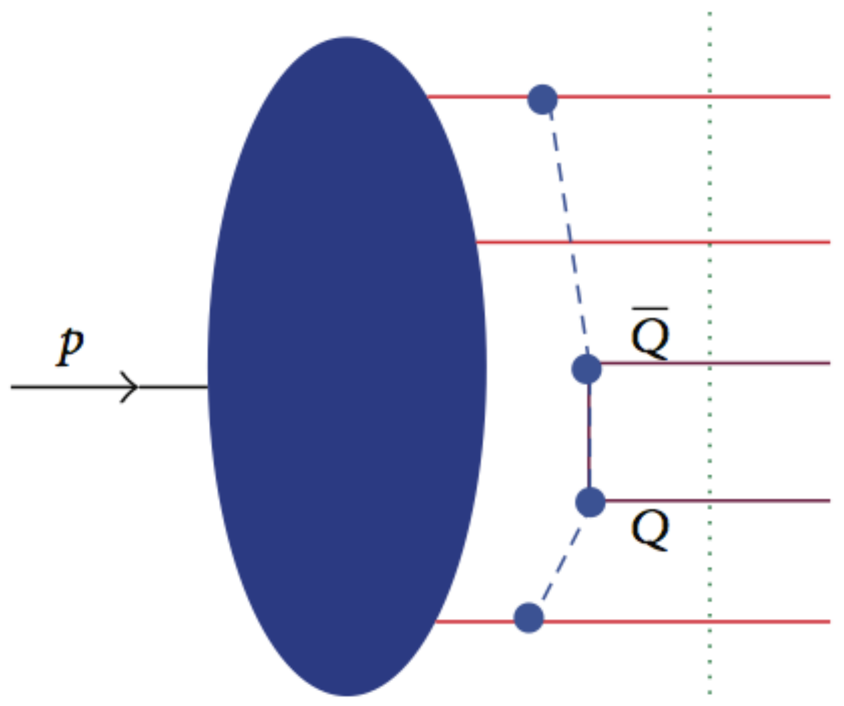
a component **of non-perturbative origin**
to the sea quark content of the proton

$$\langle N|\bar{Q}Q|N\rangle - \langle 0|\bar{Q}Q|0\rangle$$

Brodsky, Ma - hep-ph/9707408

[...] Two distinct types of quark and gluon contributions to the nucleon sea [...]: "intrinsic" and "extrinsic".

"**Intrinsic**" sea quarks are multi-connected to the valence quarks of the nucleon



$|uudQ\bar{Q}\rangle$

In contrast, "**extrinsic**" sea quarks are generated from the QCD hard bremsstrahlung and gluon splitting
In this case, the sea quark structure is associated with the *internal composition of gluons, rather than the proton itself*.

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IC - why & where

measurements consistent (to different extents) with the hypothesis of IC :

EMC measurements of the large x F_{2c} in muon DIS off iron
EMC collaboration : Nucl.Phys. B213 (1983) 31-64 → the first and "most discussed"
Harris, Smith, Vogt: Nucl.Phys. B461 (1996) 181-196

lattice calculation : MILC collaboration (IC & IS) Phys.Rev. D88 (2013) 054503

A number of **open charm observables** (e.g. Lambda and D production)
in hadroproduction at CERN and Fermilab - Adv.High Energy Phys. 2015 (2015) 231547

J/Psi production from pA events in fixed-target mode at CERN
Phys.Lett. B246 (1990) 217-220

double J/Psi production from πA events (NA3 - CERN)
Phys.Lett. B349 (1995) 569-575

Global analyses of PDFs (?)

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Essentially we need more data :
AFTER@LHC can play a role

Global analyses of PDFs (?)

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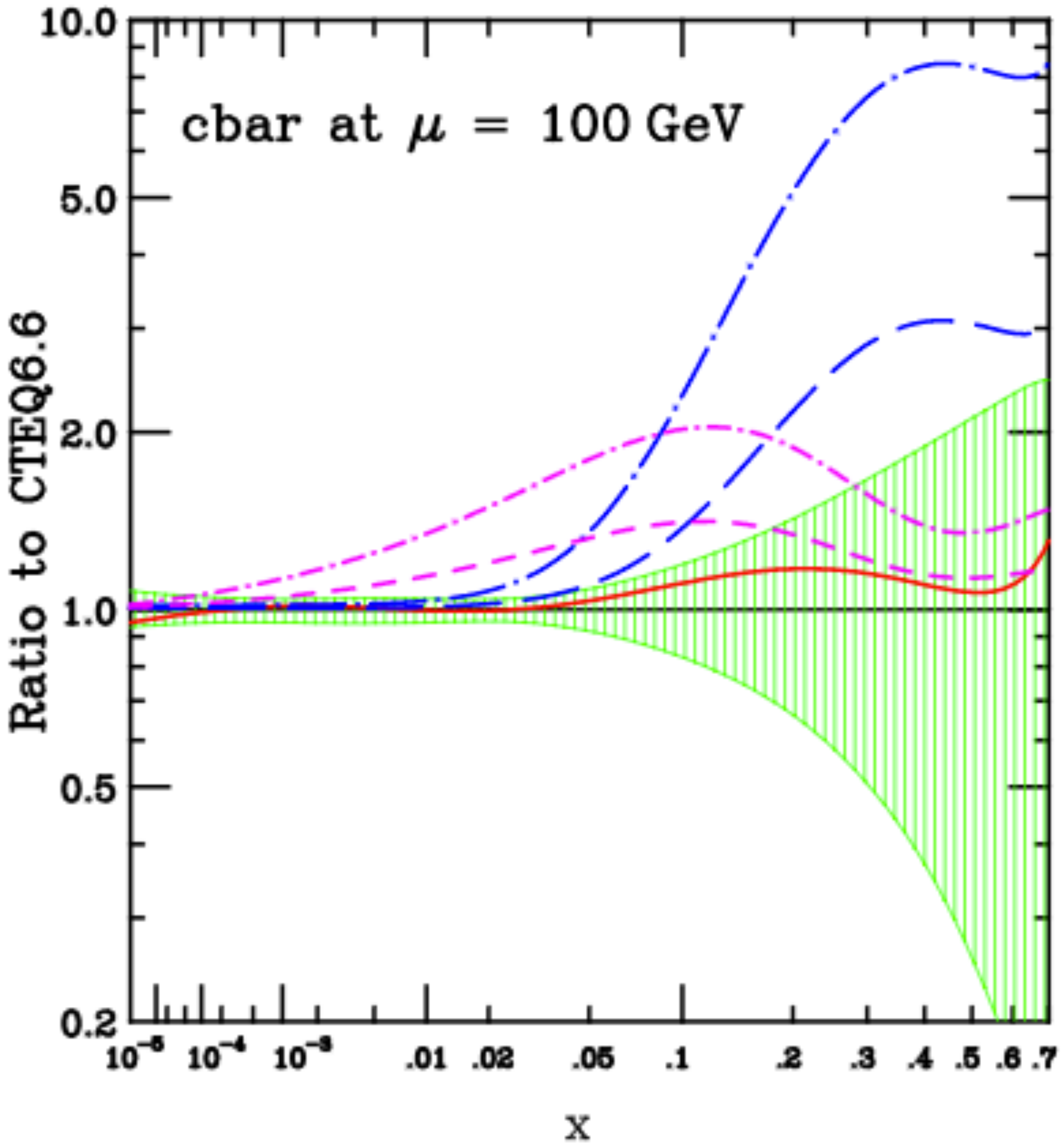
Global fits of PDFs & IC

The **first global analysis** of proton PDFs including IC : **2007**
CTEQ Phys.Rev. D75 (2007) 054029 ,
Phys.Rev. D78 (2008) 013004

Ratio of anticharm distributions with and without IC contribution to anticharm PDF in CTEQ 6.6.
Green: uncertainty with radiative charm.
Other colors: impact of different IC models.



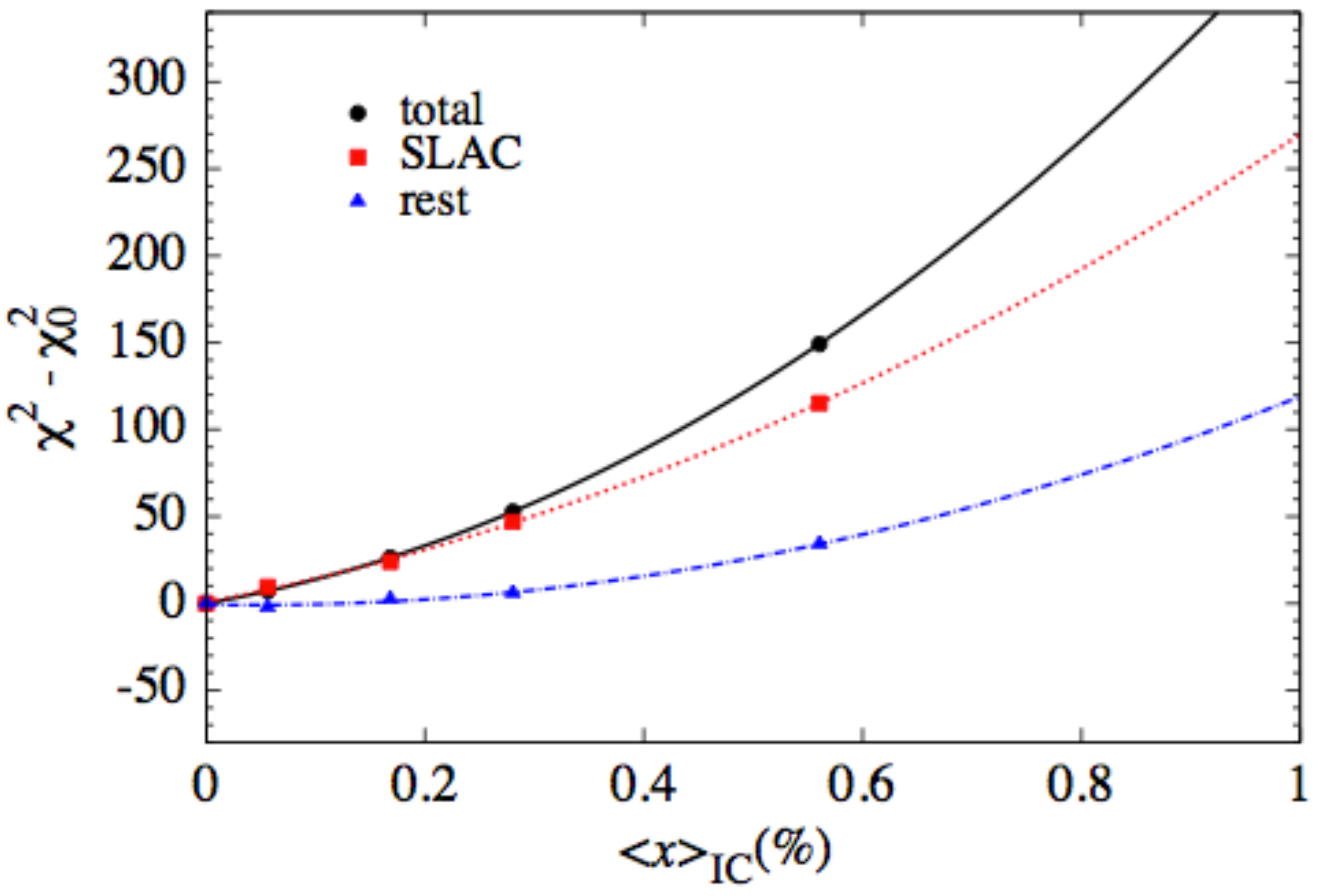
2014 different assumptions for IC

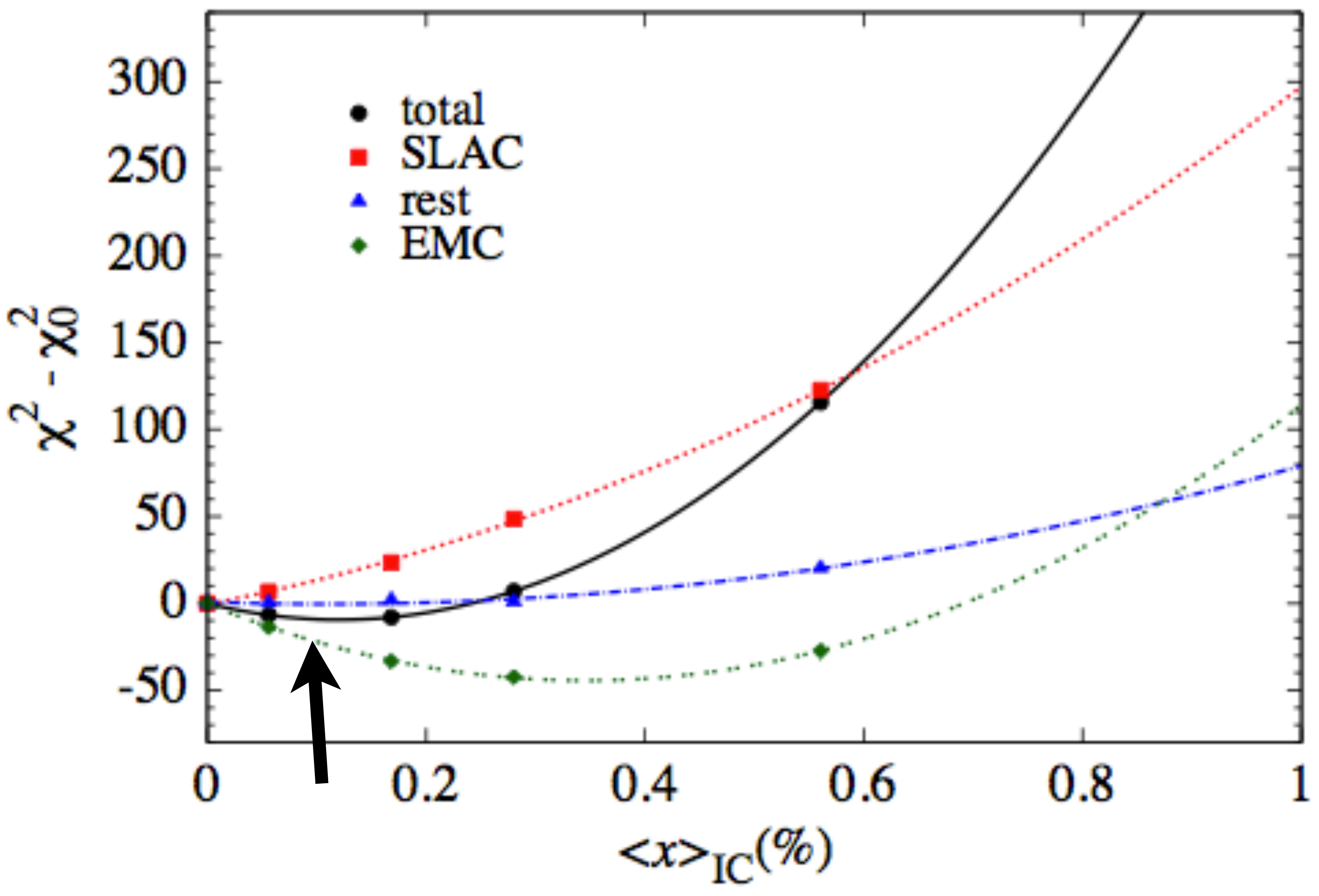
CTEQ - TEA global analysis
Phys. Rev. D89 (2014) no.7, 073004

<x_{ic}> found to be **"broader" than in 2007** analysis

Distributions in transverse momentum and y for W±/Z can be affected but effect is comparable to PDF uncertainties

Global fits of PDFs & IC





2015

J.Delgado, Hobbs, Londergan, Melnitchouk Phys.Rev.Lett. 114 (2015) no.8, 082002

$$F_2^c = F_2^{c\bar{c}} + F_2^{IC}$$

formalism including higher twist effect, target mass corrections, nuclear effects

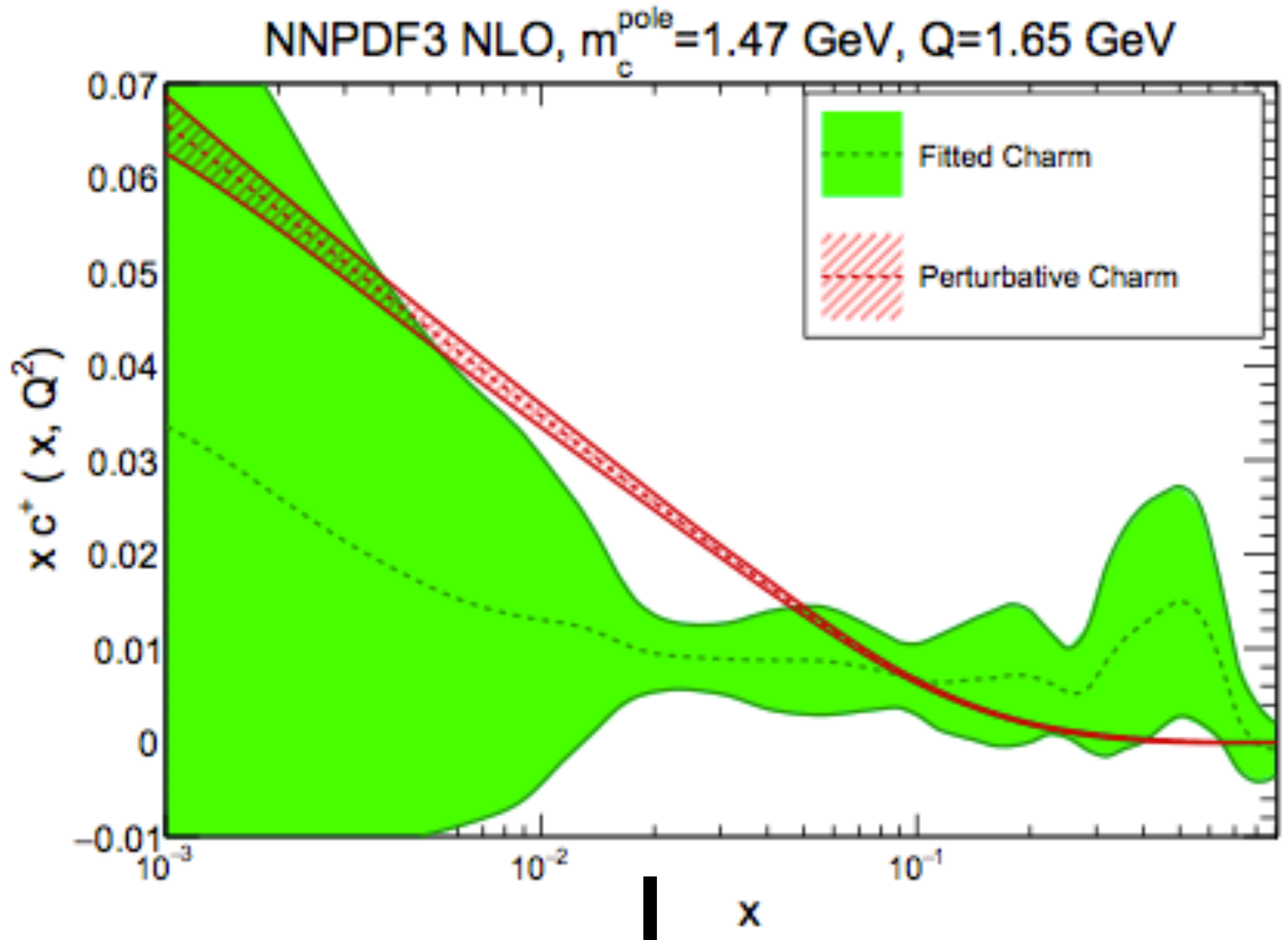
without EMC data : $\langle x_{ic} \rangle = 0$, and <0.1% at 5 sigma **(with caution!)**

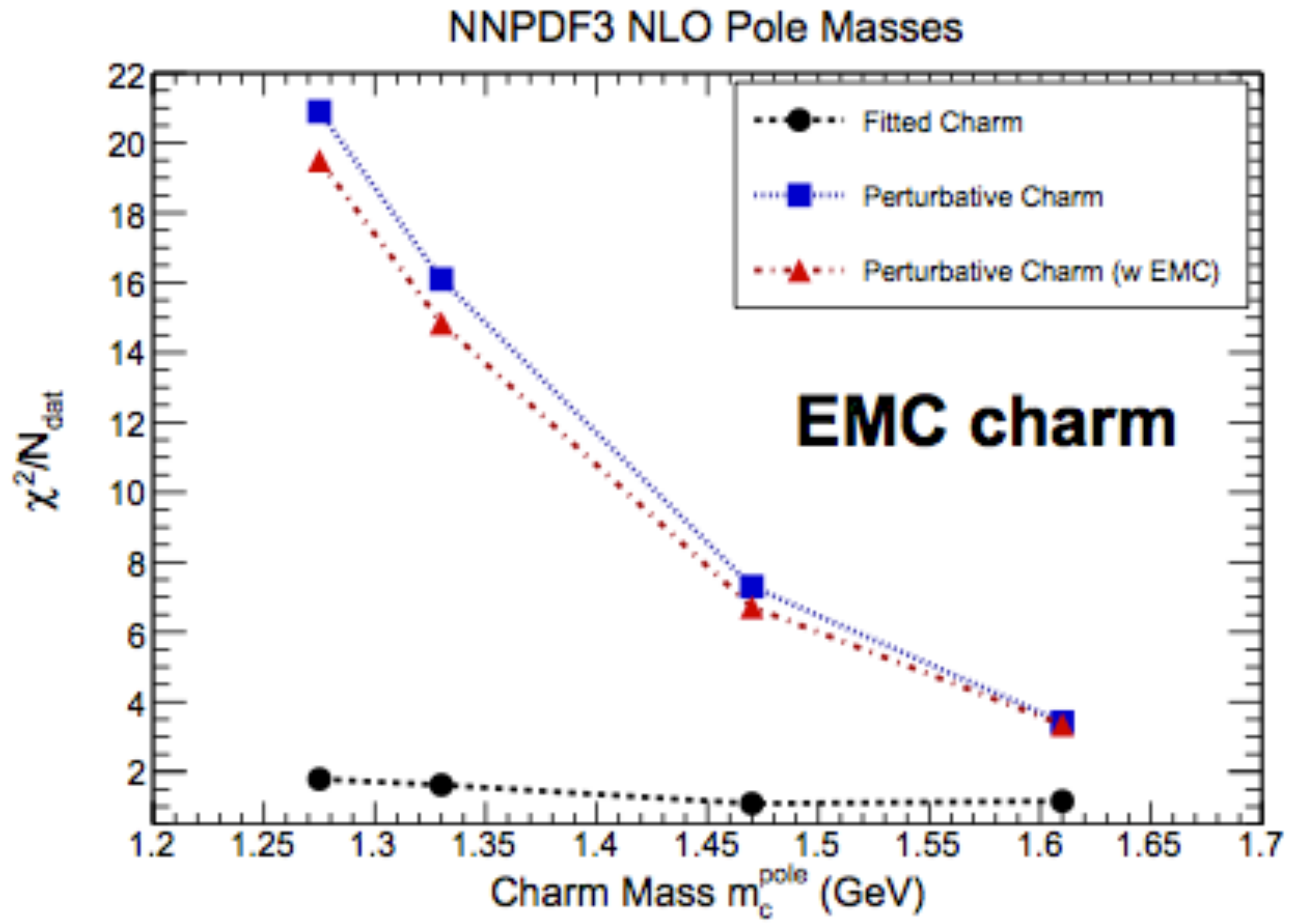
including EMC data : $\langle x_{ic} \rangle = 0.15 \pm 0.09\%$

authors report EMC data in **tension** with the other data sets

→ demand for additional experimental measurements and analyses

Global fits of PDFs & IC





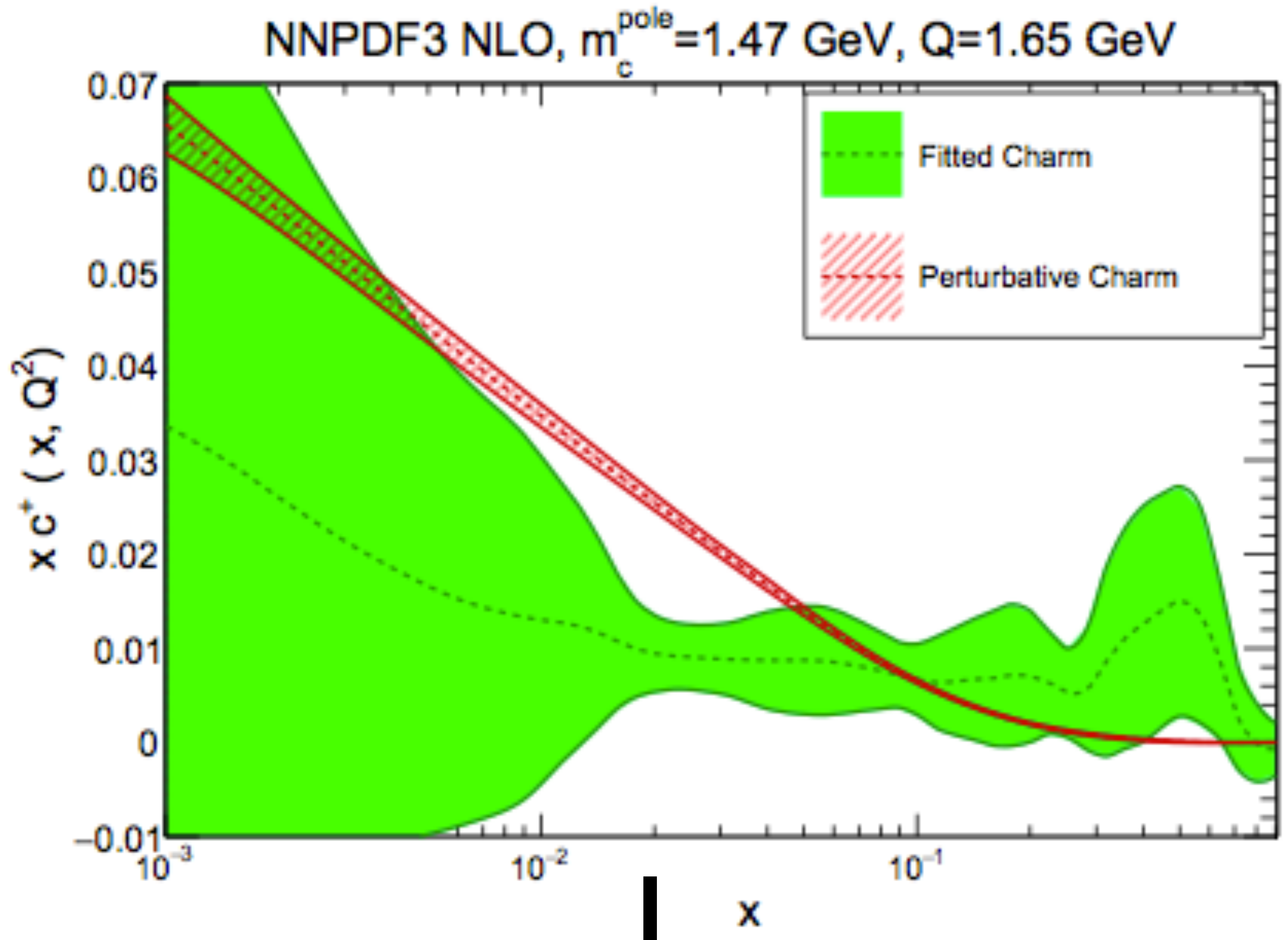
2016

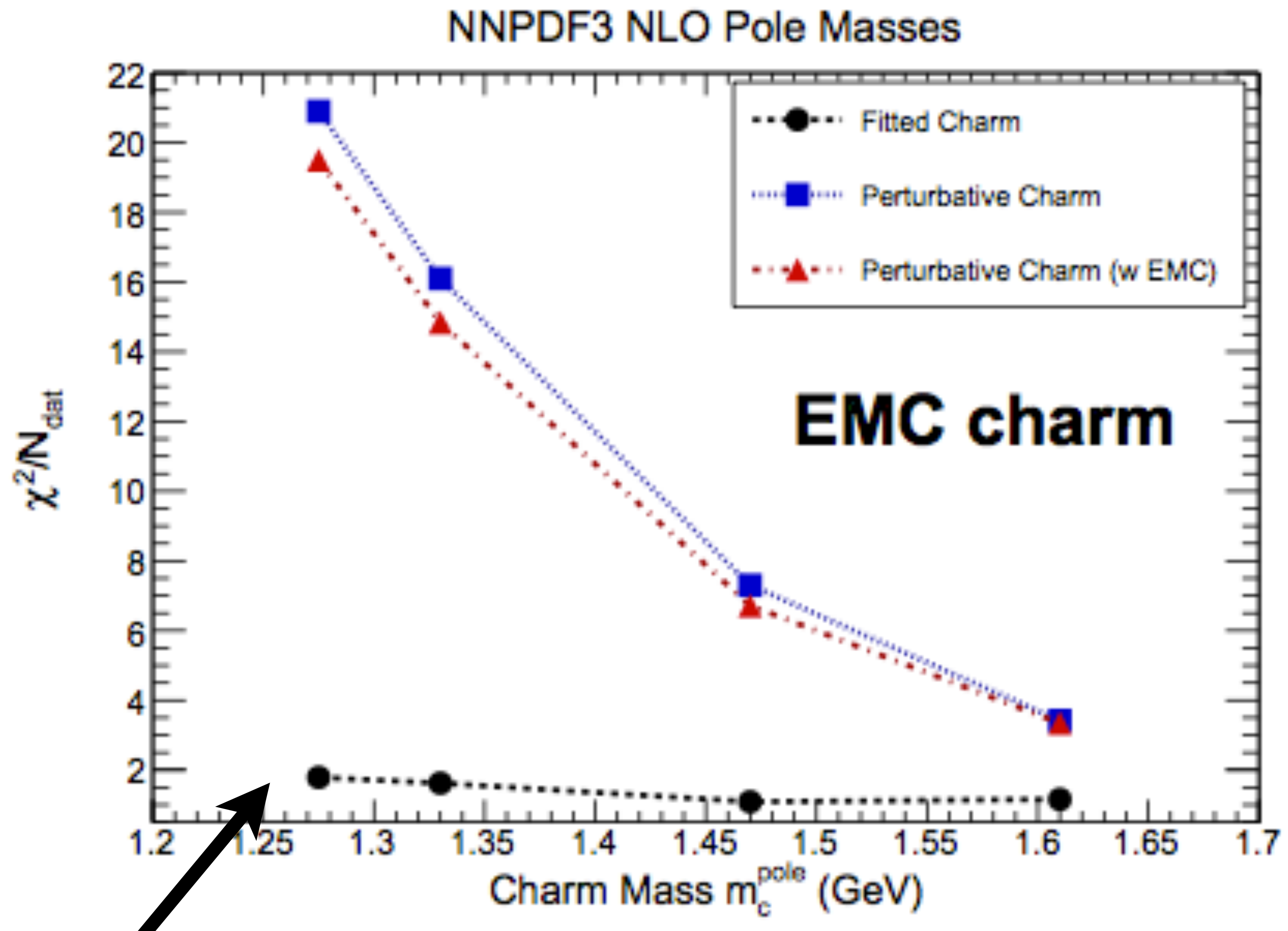
NNPDF analysis
with EMC data
Eur.Phys.J. C76 (2016)
no.11, 647

$$F_2^c = F_2^{pert} + F_2^{fitted}$$

with EMC data : <x_ic> = 0.7 ± 0.3 %

Global fits of PDFs & IC





2016

NNPDF analysis
with EMC data
Eur.Phys.J. C76 (2016)
no.11, 647

$$F_2^c = F_2^{pert} + F_2^{fitted}$$

No other data set in the fit
behaves in this way

with EMC data : <x_ic> = 0.7 ± 0.3 %

Essentially we need more data :
AFTER@LHC can play a role

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The role of AFTER@LHC

provide **additional experimental input** with **high luminosity** for processes sensitive to charm quarks at **high-x**, such as:

- inclusive charm-hadron production

- photon + charm-jet production

- EW boson production

- At LHC : Z + c production

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Adv.High Energy Phys. 2015 (2015) 231547

- At LHC : Z + c production

see P. Ilten's talk
and Phys.Rev. D93 (2016) no.7, 074008

in general, effects are more evident
at high transverse momenta
or forward rapidities

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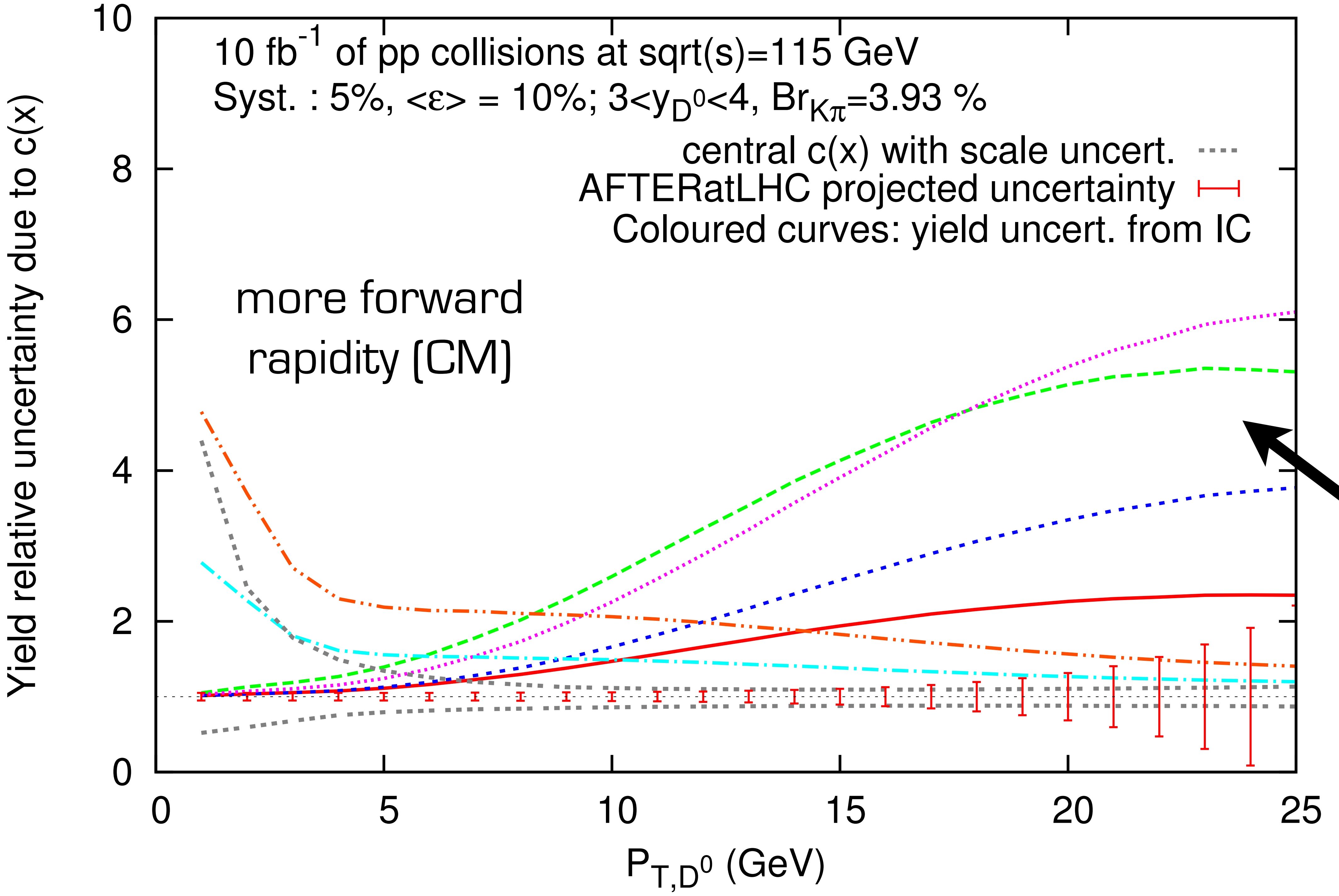
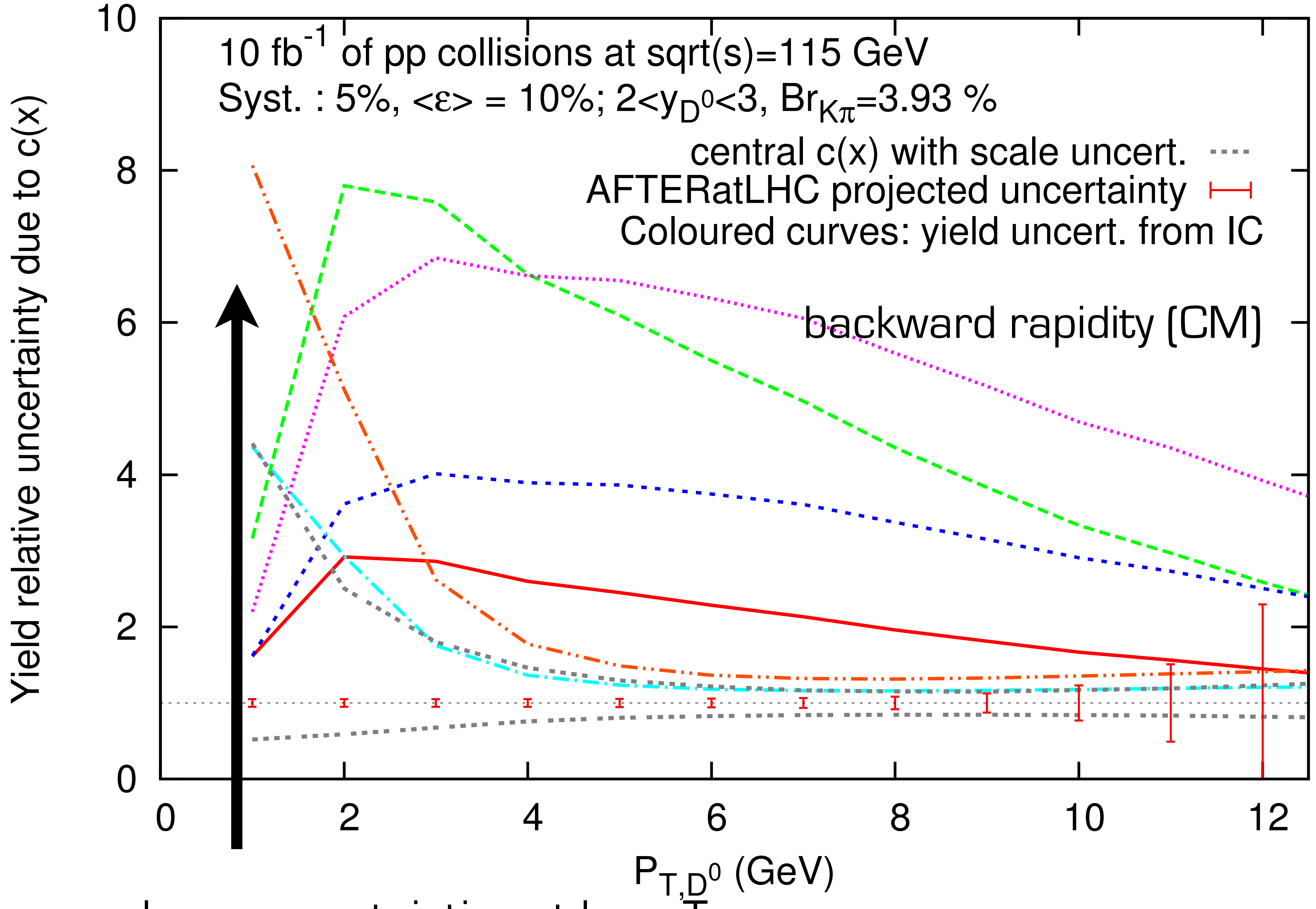
D^0 meson production at AFTER

uncertainties on the number of produced D^0
generated from different models for IC,
normalized to the number of produced D^0

systematical **5% uncertainties**
assumed, considering LHCb-like performance





very large uncertainties at low pT

large uncertainties at high pT
and smaller value for
the QCD coupling

a combination could be
an optimal solution

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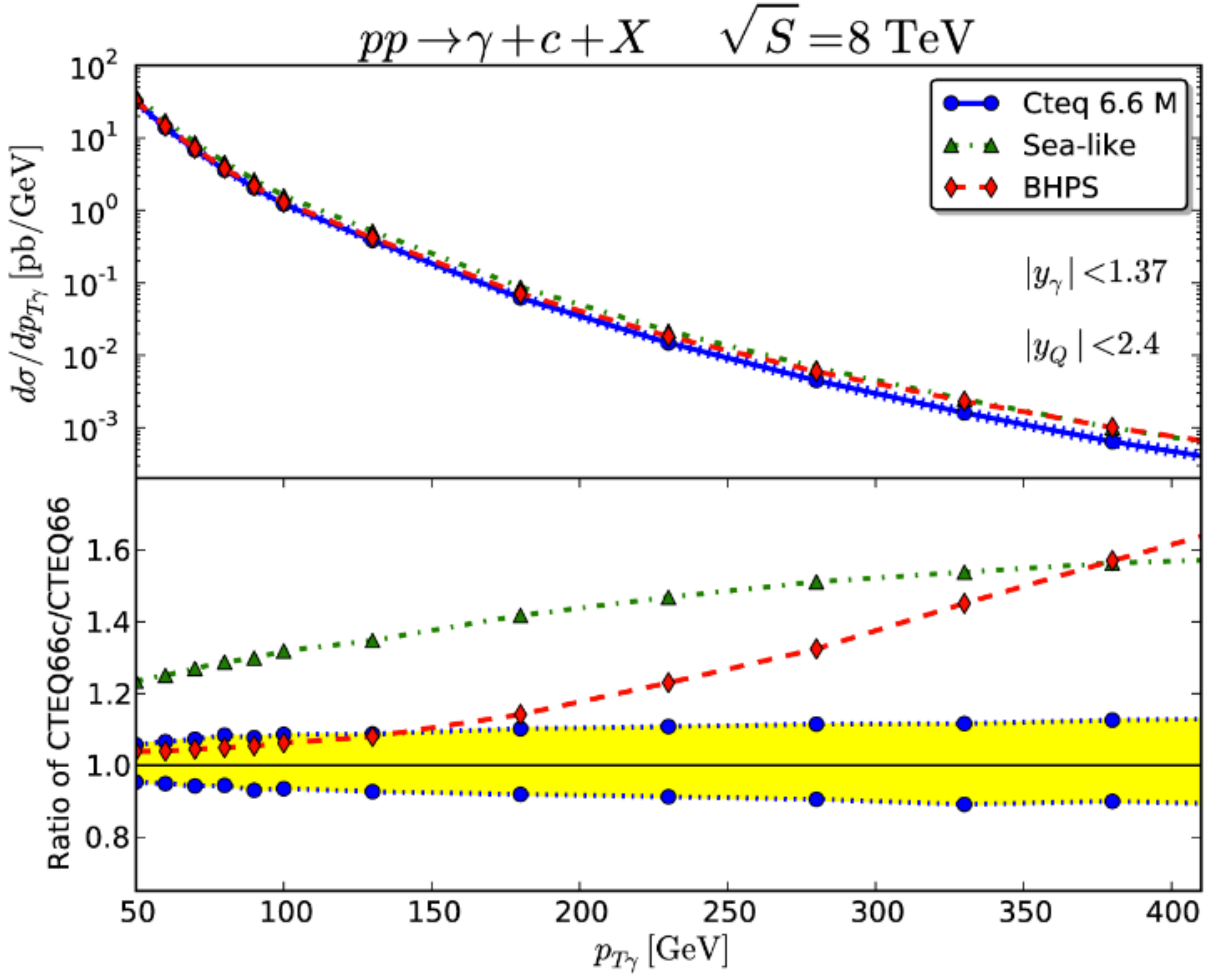
γ + c production at LHC



QCD predictions at NLO based on **CTEQ6.6M** (solid blue line),

BHPS CTEQ6c2 (dashed red line)

and **sea-like CTEQ6c4** (dash-dotted green line).

The ratio of the cross sections with respect to the CTEQ6.6M (solid blue line) distribution (bottom).

the cross section decreases fast with t.m., so this measurement is limited by statistics

Phys.Lett. B728 (2014) 602-606

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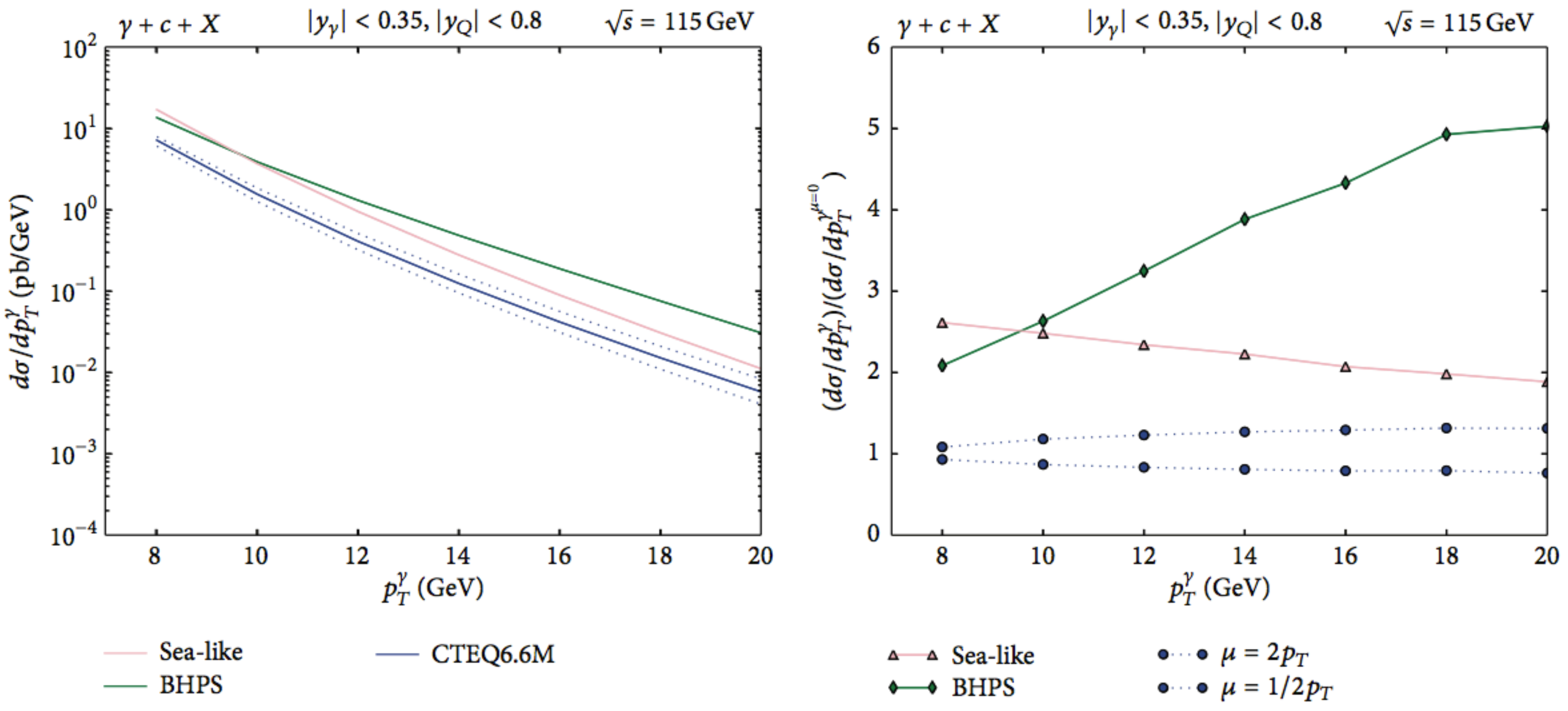
γ + c production at AFTER



Adv.High Energy Phys. 2015 (2015) 231547

At AFTER the **impact of IC** would be **relevant at lower pT**, with **higher cross section** with respect to the LHC

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Conclusions

AFTER@LHC :

- **high luminosity** (exploits LHC beams)
- explore **high-x** and **backward rapidity** region
- **target polarization**

- **outstanding performances for studies of spin asymmetries**

The **effects of IC** are **larger** at experimets with a **lower center-of-mass energy** .

Therefore, a fixed target experiment like AFTER@LHC operating at a center-of-mass energy 115 GeV would be ideally suited to constrain IC effects.

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Backup

Includes material from :

- J.P. Lansberg's talk at DIS 2016
- D. Kikola's talk at SPIN 2016

For more details about the experimental setup see :

http://after.in2p3.fr

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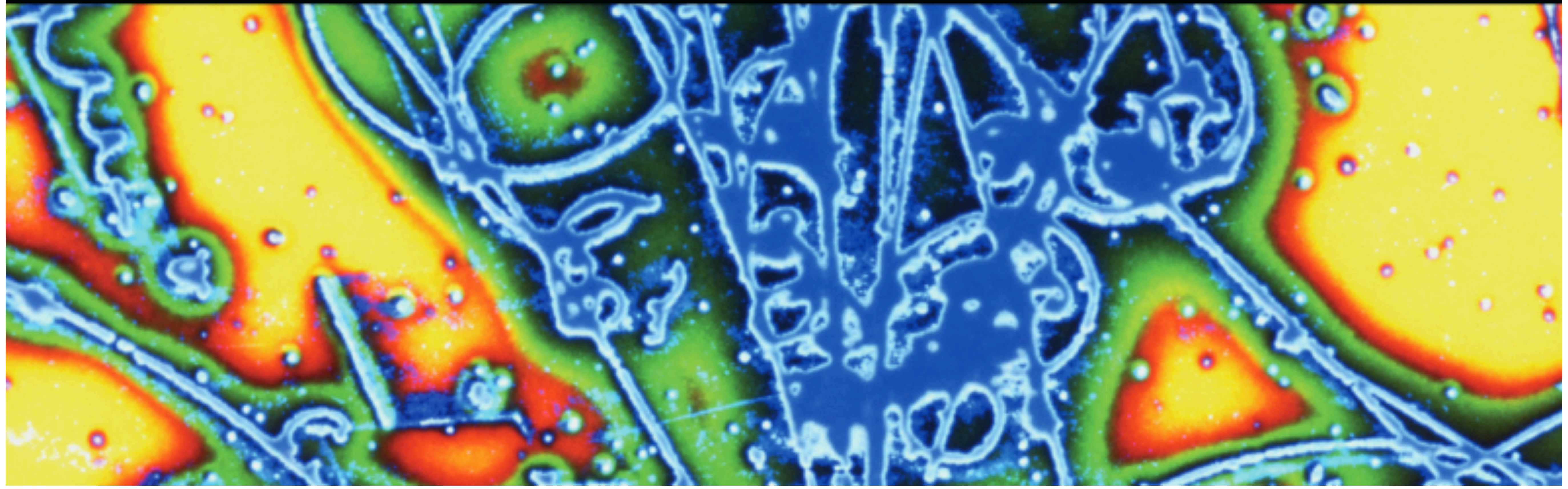
Special issue

http://www.hindawi.com/journals/ahep/si/354953/

Advances in High Energy Physics

Physics at a Fixed-Target Experiment Using the LHC Beams

Guest Editors: Jean-Philippe Lansberg, Gianluca Cavoto, Cynthia Hadjidakis, Jibo He, Cédric Lorcé, and Barbara Trzeciak



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Further references

Feasibility study and technical ideas

Feasibility studies for quarkonium production at a fixed-target experiment using the LHC proton and lead beams (AFTER@LHC) by L. Massacrier, B. Trzeciak, F. Fleuret, C. Hadjidakis, D. Kikola, J.P.Lansberg, and H.S. Shao arXiv:1504.05145 [hep-ex]. Adv.Hi.En.Phys. (2015) 986348

A Gas Target Internal to the LHC for the Study of pp Single-Spin Asymmetries and Heavy Ion Collisions by C. Barschel, P. Lenisa, A. Nass, and E. Steffens. Adv.Hi.En.Phys. (2015) 463141

Quarkonium production and proposal of the new experiments on fixed target at LHC by N.S. Topilskaya, and A.B. Kurepin. Adv.Hi.En.Phys. (2015) 760840

Generalities

Physics Opportunities of a Fixed-Target Experiment using the LHC Beams
By S.J. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg. [arXiv:1202.6585 [hep-ph]]. Phys.Rept. 522 (2013) 239.
C.

Further references

Spin physics

Transverse single-spin asymmetries in proton-proton collisions at the AFTER@LHC experiment by K.Kanazawa, Y. Koike, A. Metz, and D. Pitonyak. [arXiv:1502.04021 [hep-ph]. Adv.Hi.En.Phys. (2015)257934.

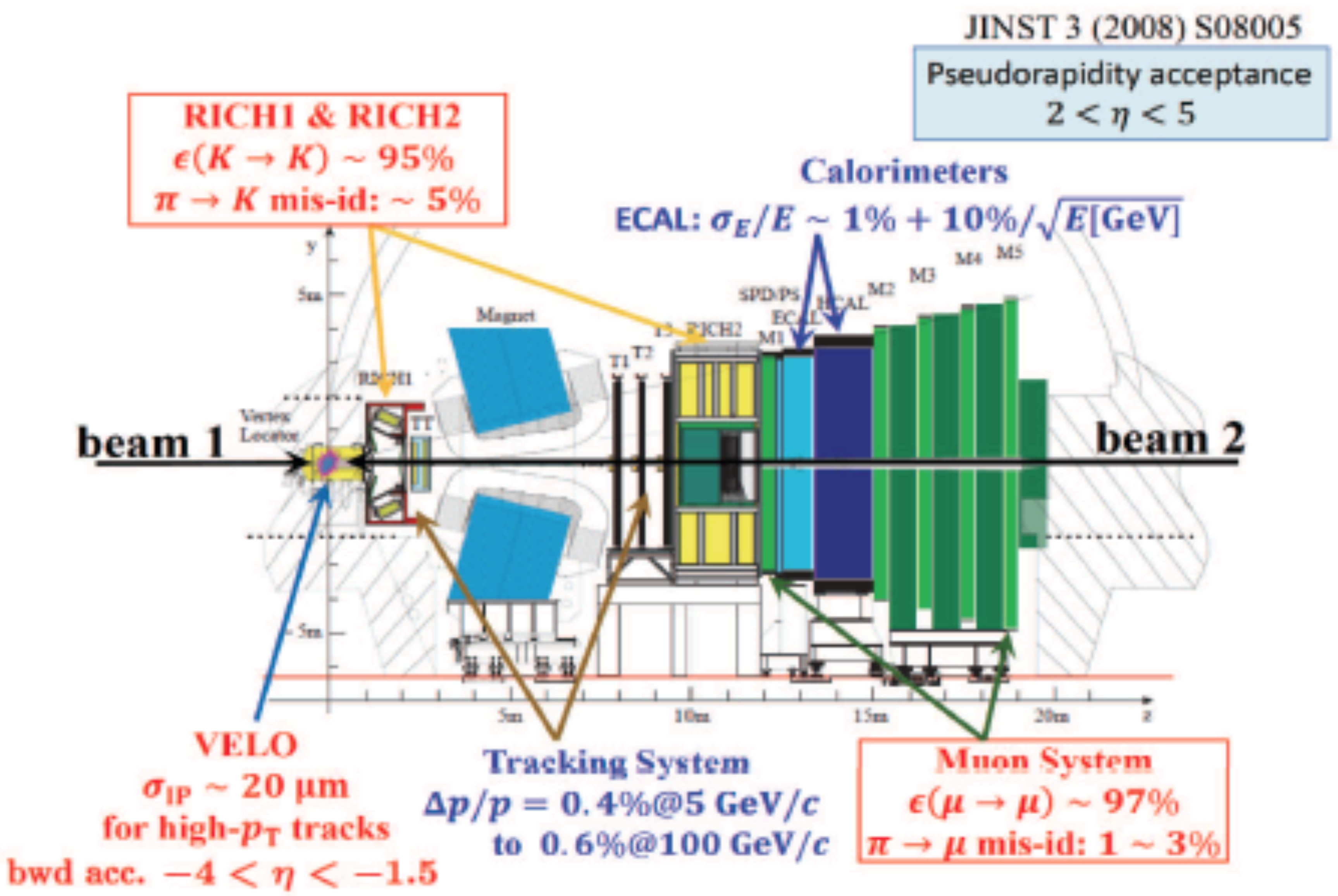
Transverse single-spin asymmetries in proton-proton collisions at the AFTER@LHC experiment in a TMD factorisation scheme by M. Anselmino, U. D'Alesio, and S. Melis. [arXiv:1504.03791 [hep-ph]]. Adv.Hi.En.Phys. (2015) 475040.

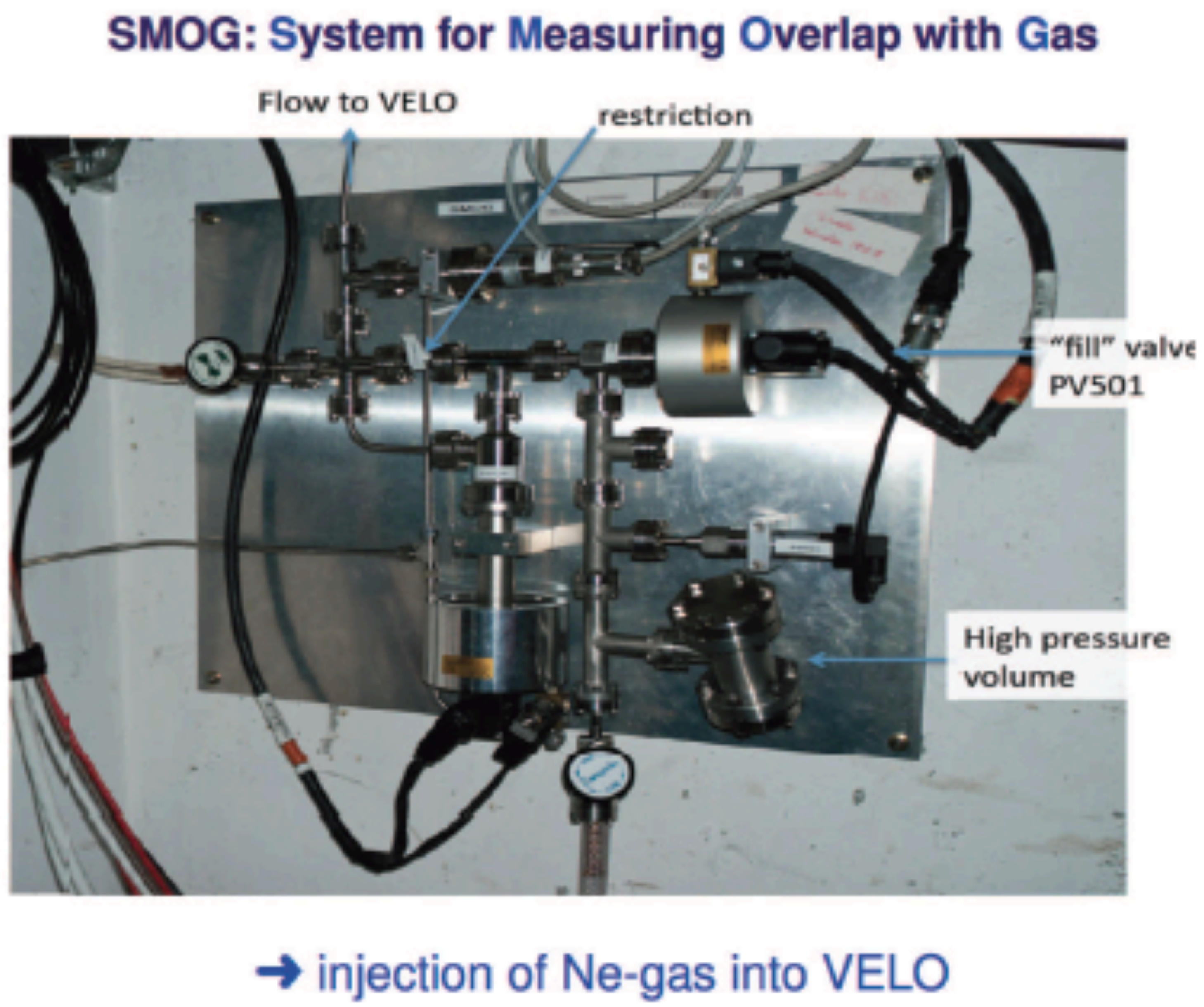
The gluon Sivers distribution: status and future prospects by D. Boer, C. Lorcè, C. Pisano, and J. Zhou. [arXiv:1504.04332 [hep-ph]]. Adv.Hi.En.Phys. (2015) 371396

Azimuthal asymmetries in lepton-pair production at a fixed-target experiment using the LHC beams (AFTER) By T. Liu, B.Q. Ma. Eur.Phys.J. C72 (2012) 2037.

Polarized gluon studies with charmonium and bottomonium at LHCb and AFTER By D. Boer, C. Pisano. Phys.Rev. D86 (2012) 094007

Internal gas target - Smog





- Initially: low density Ne-gas injected into LHCb Vertex Locator [LHCb-CONF-2012-034]
- Short pilot runs: 2012 pNe at $\sqrt{s_{NN}}$ = 87 GeV & 2013 PbNe at $\sqrt{s_{NN}}$ = 54 GeV
- 12 hours of pNe and 8 hours pHe (09/2015); 3 days of pAr in (10/2015)
- 1 week of PbAr (12/2015)
- Noble gases favoured
- Target unpolarised with the current SMOG system
- SMOG test : no decrease of LHC performances observed

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Internal gas target - Smog

- Similar luminosities for pA than with the extracted beam options (up to 60 μb^{-1} s^{-1})
- To get 10 fb$^{-1}y^{-1}$ for pp, P should reach 10^{-7} bar

  This can be achieved with a target storage cell which **can be polarised**

  C. Barschel, P. Lenisa, A. Nass, and E. Steffens, Adv.Hi.En.Phys. (2015) 463141; See E. Steffens's talk at PSTP 2015
- Simply scaled up, this would give, for Pbp or PbA, 100 nb$^{-1}y^{-1}$.

⇒ For PbA, limitations would come first from the beam lifetime, pile-up and exp. DAQ

A specific gas target is a competitive alternative to the beam extraction

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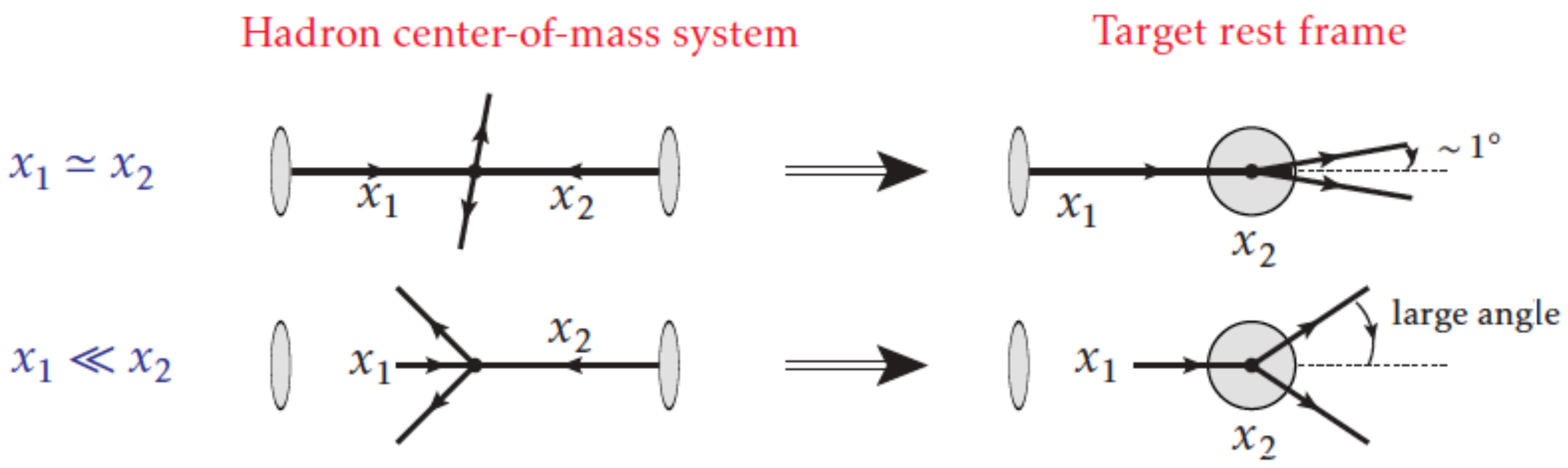
Frames and rapidities

Boost effect: LHCb becomes a backward detector

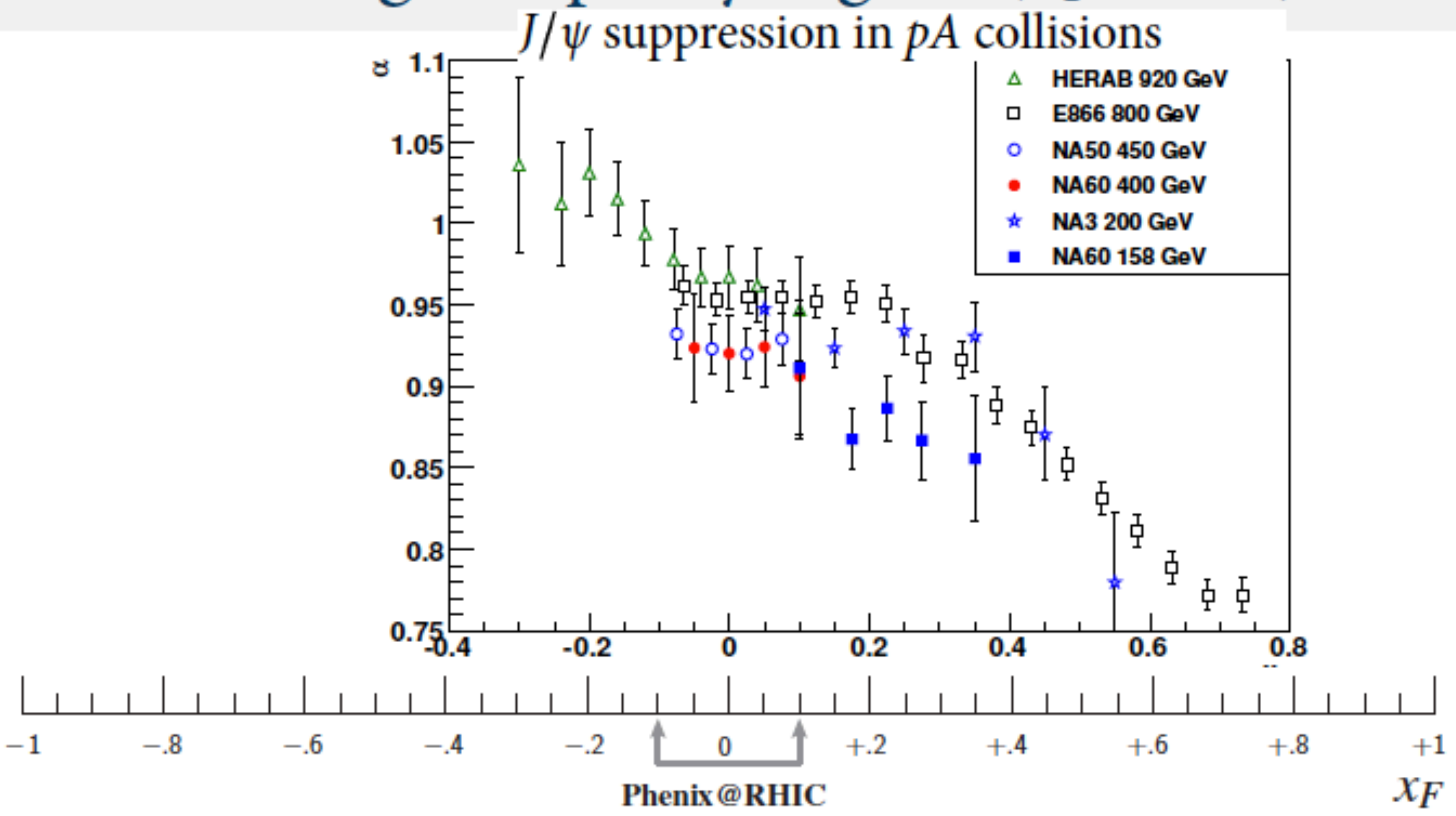
- Because of the boost $y_{CM} = 0 \Rightarrow y_{Lab} \simeq 4.8$
- The pseudo-rapidity coverage of LHCb, $2 \leq \eta \leq 5$, approximately translates to a rapidity coverage in the *CM* of roughly $-2.8 \leq y_{CM} \leq 0.2$
- ALICE muon arm: $2.5 \leq \eta \leq 4 \Rightarrow -2.3 \leq y_{CM} \leq -0.8$

· **access to partons with momentum fraction $x \to 1$ in the target**



x_F range - comparisons

Complementarity with former fixed-target experiments: access to the target-rapidity region ($x_F \rightarrow -1$)



the target rapidity region is almost completely unexplored !

- x_F systematically studied at fixed target experiments up to +1
- Hera-B (E_p = 920 GeV) was the only one to really explore $x_F < 0$, up to -0.3
- PHENIX @ RHIC: $-0.1 < x_F < 0.1$ [could be wider with Υ, but low stat.]
- CMS/ATLAS: $|x_F| < 5 \cdot 10^{-3}$; LHCb-collider: $5 \cdot 10^{-3} < x_F < 4 \cdot 10^{-2}$

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Luminosity

AFTER working group - arXiv 1702.*****

Experiment	particles	beam energy (GeV)	$\sqrt{s}$ (GeV)	$x^{\uparrow}$	$\mathcal{L}$ (cm^{-2}s^{-1})	$\mathcal{P}_{\rm eff}$	$\mathcal{F}$ (cm^{-2}s^{-1})
AFTER@LHCb	$p + p^{\uparrow}$	7000	115	$0.05 \div 0.95$	$1 \cdot 10^{33}$	80%	$6.4 \cdot 10^{32}$
AFTER@LHCb	p+^{3}He$^{\uparrow}$	7000	115	$0.05 \div 0.95$	$2.5 \cdot 10^{32}$	23%	$1.4 \cdot 10^{31}$
AFTER@ALICE$_{\mu}$	$p + p^{\uparrow}$	7000	115	$0.1 \div 0.3$	$2.5 \cdot 10^{31}$	80%	$1.6 \cdot 10^{31}$
COMPASS (CERN)	$\pi^{\pm} + p^{\uparrow}$	190	19	$0.2 \div 0.3$	$2 \cdot 10^{33}$	18%	$6.5 \cdot 10^{31}$
PHENIX/STAR (RHIC)	$p^{\uparrow} + p^{\uparrow}$	collider	510	$0.05 \div 0.1$	$2 \cdot 10^{32}$	50%	$5.0 \cdot 10^{31}$
E1039 (FNAL)	$p + p^{\uparrow}$	120	15	$0.1 \div 0.45$	$4 \cdot 10^{35}$	15%	$9.0 \cdot 10^{33}$
E1027 (FNAL)	$p^{\uparrow} + p$	120	15	$0.35 \div 0.9$	$2 \cdot 10^{35}$	60%	$7.2 \cdot 10^{34}$
NICA (JINR)	$p^{\uparrow} + p$	collider	26	$0.1 \div 0.8$	$1 \cdot 10^{32}$	70%	$4.9 \cdot 10^{31}$
fsPHENIX (RHIC)	$p^{\uparrow} + p^{\uparrow}$	collider	200	$0.1 \div 0.5$	$8 \cdot 10^{31}$	60%	$2.9 \cdot 10^{31}$
fsPHENIX (RHIC)	$p^{\uparrow} + p^{\uparrow}$	collider	510	$0.05 \div 0.6$	$6 \cdot 10^{32}$	50%	$1.5 \cdot 10^{32}$
PANDA (GSI)	$\bar{p} + p^{\uparrow}$	15	5.5	$0.2 \div 0.4$	$2 \cdot 10^{32}$	20%	$8.0 \cdot 10^{30}$

Table 3: Compilation inspired from [11, 50] of the relevant parameters for the future or planned polarised DY experiments. The effective polarisation ($\mathcal{P}_{\rm eff}$) is a beam polarisation (where relevant) or an average polarisation times a (possible) dilution factor (for a gas target, similar to the one developed for HERMES [46, 105, 106]) or a target polarisation times a dilution factor (for the NH_3 target used by COMPASS and E1039). For AFTER@LHC the numbers correspond to a gas target. $\mathcal{F}$ is the (instantaneous) spin figure of merit of the target defined as $\mathcal{F} = \mathcal{P}^2_{\rm eff} \times \mathcal{L}$, with $\mathcal{L}$ being the instantaneous luminosity.

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Simulation setup

Fast simulation using LHCb reconstruction parameters

Projection for a LHCb-like detector — L. Massacrier, B. Trzeciak, *et al.*, *Adv.Hi.En.Phys. (2015) 986348*

- Simulations with Pythia 8.185
- HELAC-Onia for quarkonium, $c\bar{c}$, $b\bar{b}$ and Drell-Yan signal
- Fast LHCb simulation with realistic resolution, analysis cuts, efficiencies
- Requirements:
  - Momentum resolution : $\Delta p/p = 0.5\%$
  - Muon identification efficiency: 98%
- Cuts at the single muon level
  - $2 < \eta_\mu < 5$
  - $p_{T\mu} > 0.7$ GeV
- Muon misidentification:
  - If π and K decay before the calorimeters (12m), they are rejected by the tracking
  - otherwise a misidentification probability is applied following: F. Achilli et al, *JINST 8 (2013) P10020*

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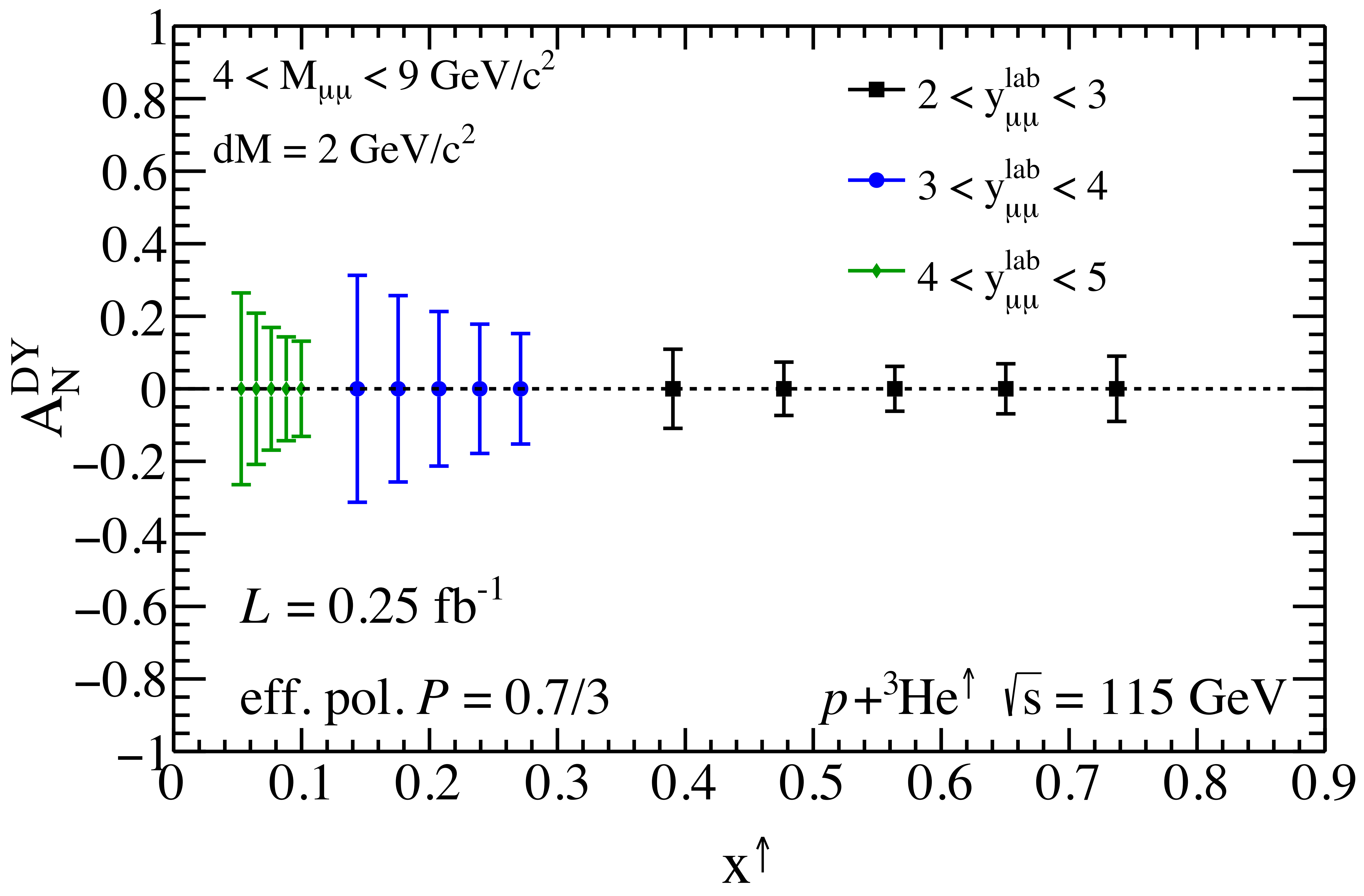
A_N in Drell-Yan - neutron

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections

$f_{1T}^{\perp q/N}(x, k_T^2)$



LHCb like detector

He3 target

important for neutron studies :
Sivers function in a neutron

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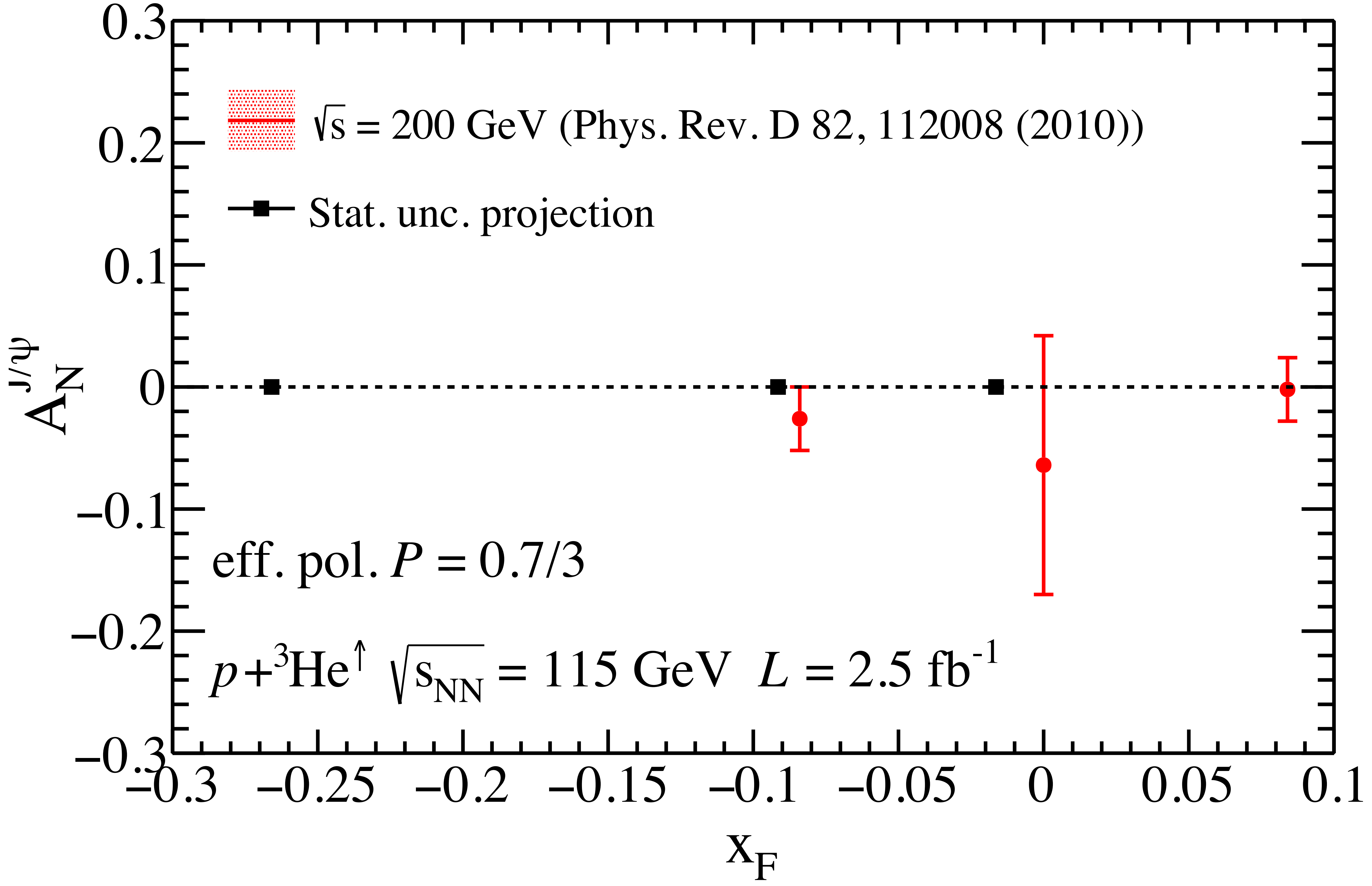
A_N in J/Ψ production

AFTER working group - arXiv 1702.*****

AFTER@LHC - projections

comparison to STAR (RHIC)



LHCb like detector

target: He3 : neutron studies

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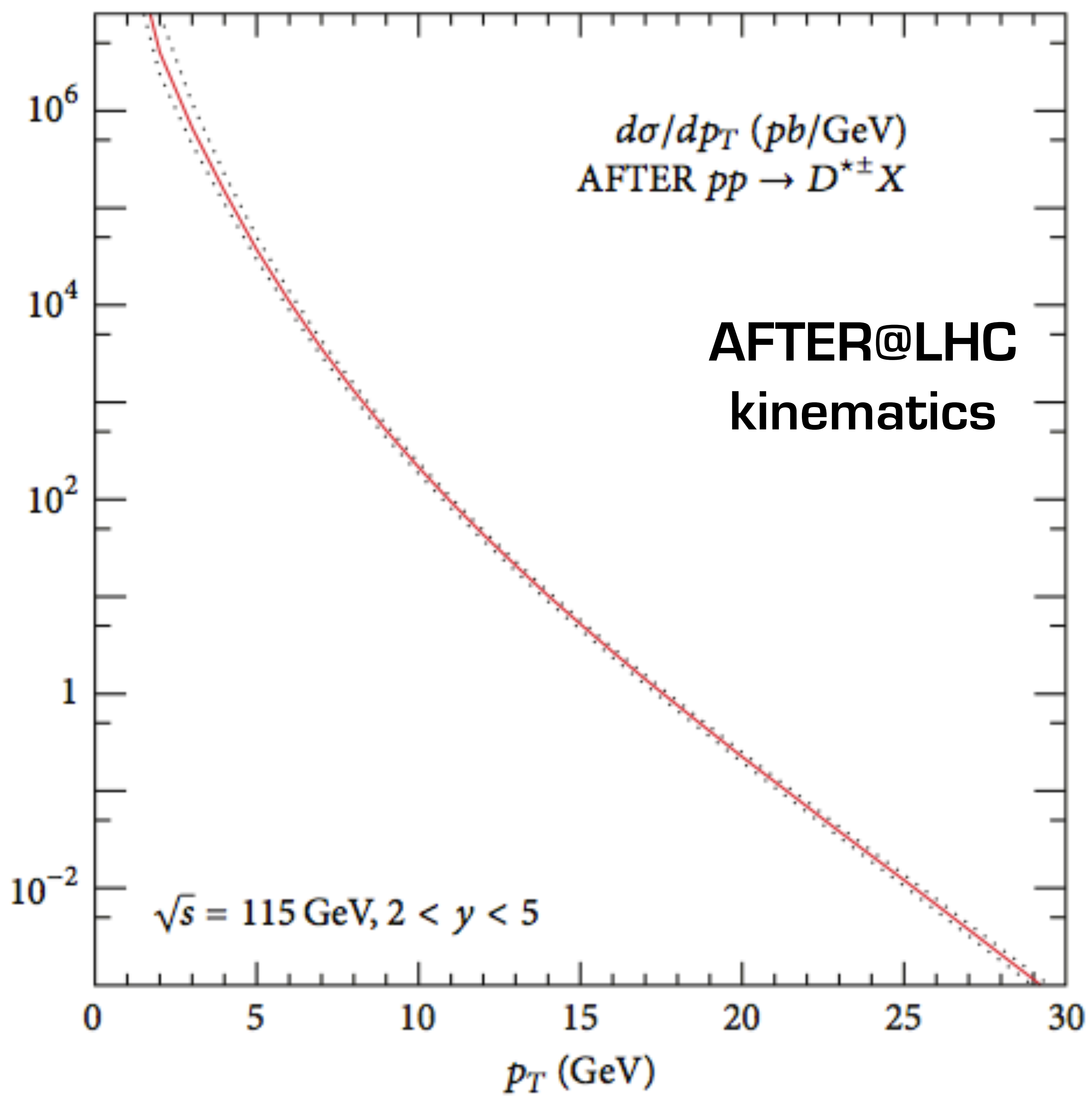
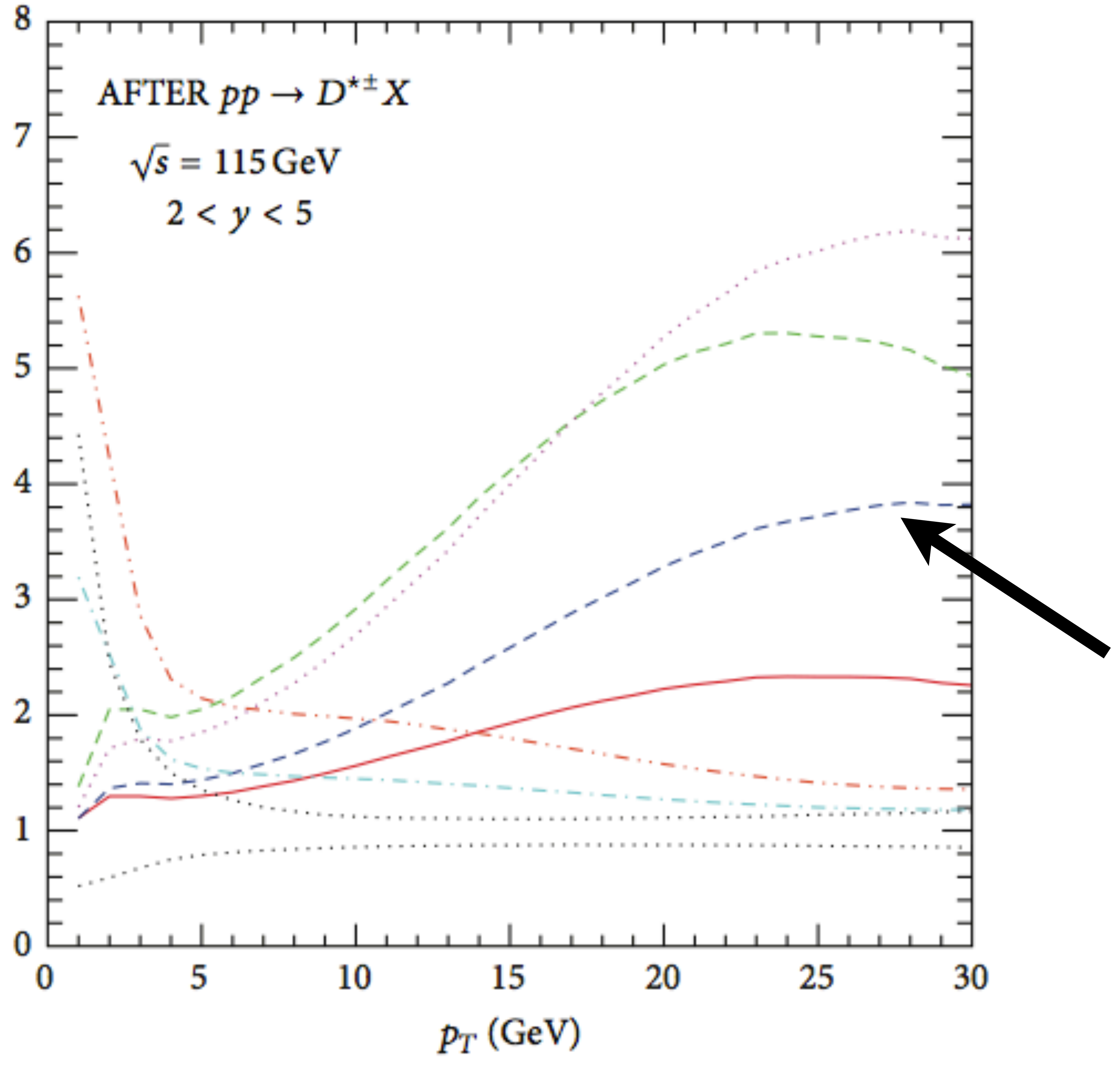
$D^{\pm/*}$ meson production at AFTER





cross section without IC

ratio of cross sections with different CTEQ6.6 PDF members (= different IC models) to cross section w/o IC

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