12^{th} MPI at LHC

summary of the experimental talks in working group 4
small x and diffraction

Albert Frithjof Bursche

South China Normal University

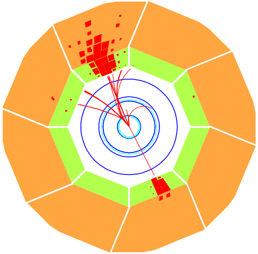
October 15, 2021

jet lepton correlations

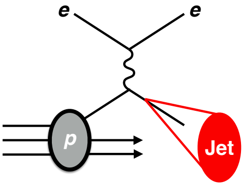
H1 @ HERA

H1 was one of two multipurpose experiments at HERA.

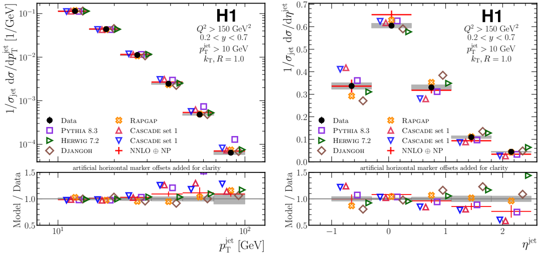
For this talk: 2006-2007 data, 136 pb^{-1}, 320 GeV



I'll present a measurement of the electron-jet inbalance



Results



Parton shower Monte Carlo programs also provide excellent agreement with the data across the spectra.

publish unbinned data

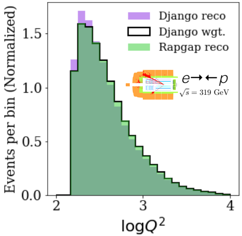
- Due to the unfolding method the result is not intrinsically binned
- Infrastructure to publish such data is needed

Classification for reweighting

25

Neural networks are naturally unbinned and readily process high-dimensional data.

We use a trick whereby classifiers can be repurposed as reweighters



N.B. the distribution is binned for illustration, but the reweighting is unbinned.

leptoproduction of ρ mesons

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Extracting ρ^0 Cross Section

$$\frac{d\sigma_{\pi^+\pi^-}}{dm_{\pi\pi}}(m_{\pi\pi}) = \frac{N}{(1+f_\omega+f_{nr})^2}\cdot\left|\mathcal{RBW}_\rho(m_{\pi\pi}) + f_\omega e^{i\phi_\omega}\mathcal{RBW}_\omega(m_{\pi\pi}) + f_{nr}e^{i\phi_{nr}}\frac{B_{nr}(m_{\pi\pi})}{B_{nr}(m_\rho)}\right|^2$$

Fitted parameters:

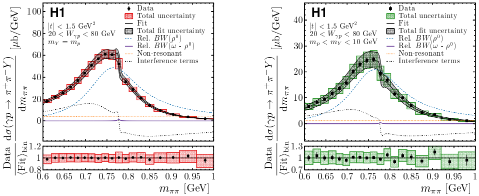
$m_{\rho^0} = 770.8 \pm 2.6$ MeV

$\Gamma_{\rho^0} = 151.3 \pm 3.2$ MeV

$m_\omega = 777.9 \pm 4.0$ MeV

non-res term: $B_{nr} = \left(\frac{m_{\pi\pi}-2m_\pi}{(m_{\pi\pi}-2m_\pi)^2+\Lambda_{nr}^2}\right)^{\delta_{nr}}$

$\chi^2/n_{dof} = 24.6/24$



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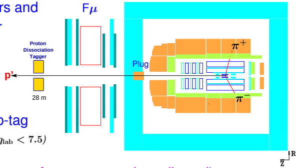
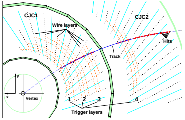
H1 Detector

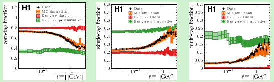
- Central Tracker: drift chambers and two-layer silicon strip detector
  ($20° < \theta < 160°$ used in VM analyses)
- EM+Had Calorimeters
  ($4° < \theta < 178°$)
- Forward Detectors: Fμ,Plug,p-tag
  (effective pseudorapidity coverage $3.5 < \eta_{\text{lab}} < 7.5$)



Powerful fast track trigger (allows soft γp events to be collected)



Separation of EL and PD events using Fwd tagging



leptoproduction of ρ mesons

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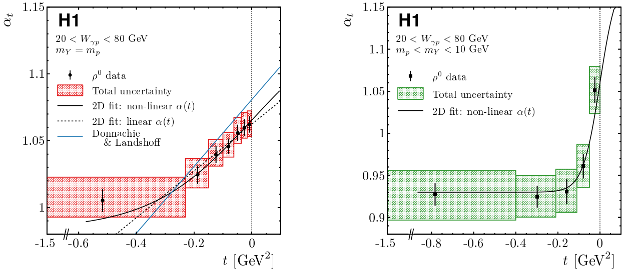
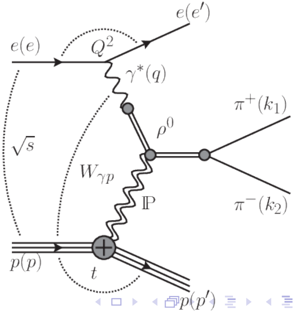
Effective Pomeron trajectory





Points: $\alpha(t)$ as measured separately in each t bin by fitting a simple power law $\propto W_{\gamma p}^{4(\alpha_t - 1)}$ with free fit parameters α_t

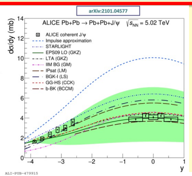
Curves: The trajectories extracted from a simultaneous 2D-fit to the $W_{\gamma p}$ and t dependencies (*see in the Appendix*).

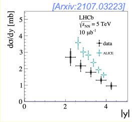
$\Rightarrow$ Clear non-linearity at large $|t|$

ultra peripheral collisions - ALICE and LHCb

Results

- Impulse approximation: Exclusive photoproduction data off protons, neglecting all nuclear effects except coherence.
- STARlight: Vector Meson Dominance model with Glauber-like formalism to calculate cross section in Pb-Pb
- GKZ: EPS09 LO parametrization of the nuclear shadowing data
- GKZ: Leading twist approximation (LTA) of nuclear shadowing
- CCK: Color dipole model with the structure of the nucleon described by the hot spots
- BCCM: Color dipole approach coupled to the solutions of the Balitsky-Kovchegov equation
- GM, LM, LS: Color dipole approach coupled to the Color Glass Condensate formalism with different assumptions on the dipole-proton scattering amplitude



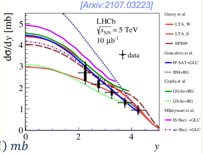


→ *Results are within 1.3σ*

→ ALICE Extracted R_g=0.65±0.03 at Bjorken-x (0.3,1.4)×10^{-3}

→ pQCD calculation [PRC 93 (2016) 055206]

→ Color dipole models [PRD 96 (2017) 094027] [PRC 97 (2018) 024901] [PLB 772 (2017) 832]



→ LHCb Integrated over y [2.0–4.5]:

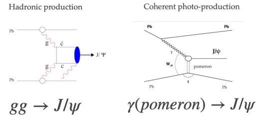
$$\sigma^{\psi}_{coherent} = 4.45 \pm 0.24(stat) \pm 0.18(syst) \pm 0.58(lumi)\ mb$$

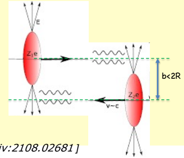
13.10.2021 G.Manca, MPI@LHC2021 9

Prompt J/ψ production in peripheral PbPb collisions

→ Peripheral: the nuclei barely touch each other with < 2 R Pb

- Possible to identify also hadronic component !



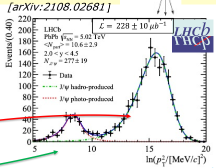


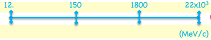
→ Motivated by excess seen by Alice [Phys. Rev. Lett. 116 (2016) 222301]

→ Selection similar to UPC analyses, at very low p_T (< 0.3 GeV/c)

Use p_T distribution of the J/ψ mesons

- Hadronic : mean p_T 1-2 GeV/c,
- Coherent : mean p_T < 300 MeV/c





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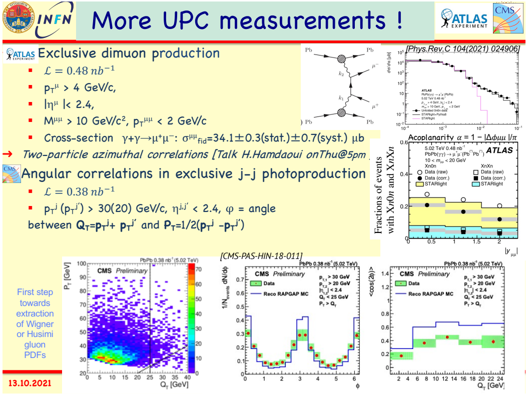
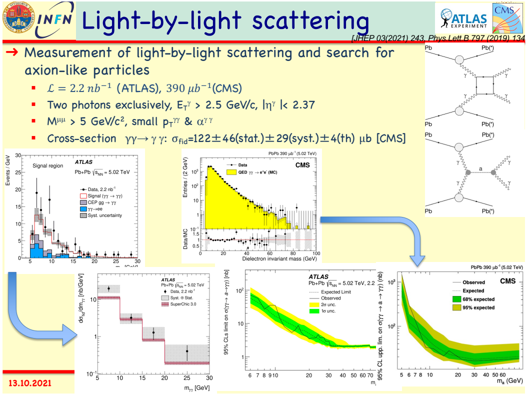
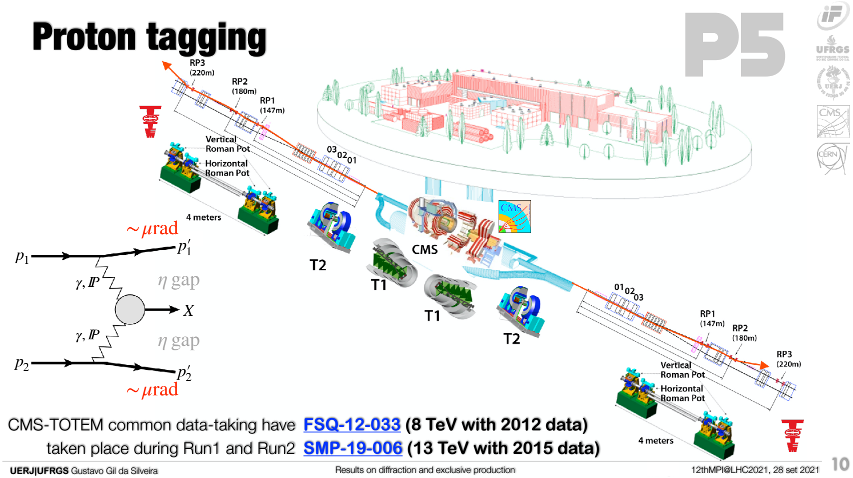
light by light - CMS and Atlas





point five


Proton tagging
P5
RP3 (220m)
RP2 (180m)
RP1 (147m)
Vertical Roman Pot
Horizontal Roman Pot
4 meters
03 02 01
T2
T1
CMS
T1
T2
01 02 03
RP1 (147m)
RP2 (180m)
RP3 (220m)
Vertical Roman Pot
Horizontal Roman Pot
4 meters
~ μrad
p_1
p_1'
$\gamma, I\!P$
η gap
X
$\gamma, I\!P$
η gap
p_2
p_2'
~ μrad
CMS-TOTEM common data-taking have taken place during Run1 and Run2
FSQ-12-033 (8 TeV with 2012 data)
SMP-19-006 (13 TeV with 2015 data)
UERJ|UFRGS Gustavo Gil da Silveira
Results on diffraction and exclusive production
12thMPI@LHC2021, 28 set 2021
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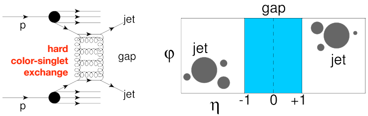
single diffractive jets

Jet-gap-Jet

[PRD 104 (2021) 032009](#)
[SMP-19-006](#)

- Diffrative dijet production has been measured via **pseudorapidity gaps** as experimental signature
  - Important measurement for testing pQCD and the **BFKL dynamics** at energy of 13 TeV



MPI can further decrease it

may not be entirely kinematic independent

- Soft rescattering corrections are accounted by a **survival probability** of $|\mathcal{S}|^2 = 1 - 10\,\%$
- Measurements in CMS+TOTEM common data-taking at **13 TeV** (2015) of **0.66/pb** + **0.40/pb** (TOTEM)
  - Special run with $\beta^* = 90\,\mathrm{m}$ where $-4 < t < -0.025\,\mathrm{GeV}^2$ and $0.05 - 0.10$ pileup/event
- Intact proton largely reduces the soft interactions and improves **survivability** of the gaps

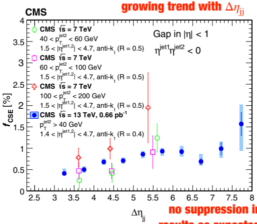
Marquet *et al*
PRD 87 (2013) 034010

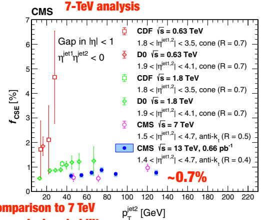
Color-singlet exchange Fraction with CMS data

[PRD 104 (2021) 032009](#)
[SMP-19-006](#)

Latest data confirm growing trend with $\Delta\eta_{jj}$

Improvement compared to 7-TeV analysis





no suppression in comparison to 7 TeV
results as expected by survival probability

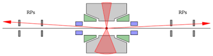
exclusive dilepton production with tagged protons

Matching CMS and PPS

JHEP 07 (2018) 153
PPS-17-001

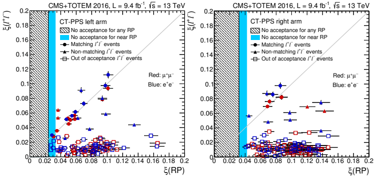
- Events with one proton observed in one of the PPS arms are related to the central system:

$$\xi(\ell^+\ell^-) = \frac{1}{\sqrt{s}}\left[p_T(\ell^+)e^{\pm\eta(\xi^+)} + p_T(\ell^-)e^{\pm\eta(\xi^-)}\right]$$



expression ~holds for semi-elastic

2016



9.4/fb

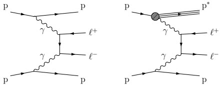
UERJ|UFRGS Gustavo Gil da Silveira — Results on diffraction and exclusive production — 12thMPI@LHC2021, 28 set 2021 — 24

(Semi)exclusive dilepton observation

JHEP 07 (2018) 153
PPS-17-001

- Early **2016** data of PPS with **9.4/fb** (CMS 15.6/fb)

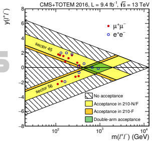
$$p_T^\ell > 50\,\text{GeV}$$
$$a = 1 - |\Delta\phi(\ell^+\ell^-)|/\pi)$$
$$a(e^+e^-) < 0.006 \qquad a(\mu^+\mu^-) < 0.009$$
$$m(\ell^+\ell^-) > 110\,\text{GeV}$$



$pp \to p\ell^+\ell^-p$ — $|\mathcal{S}|^2 = 0.89$

$pp \to p\ell^+\ell^-p^*$ — $|\mathcal{S}|^2 = 0.76$

2016



- Overall selection with **one** proton reconstructed in either arm of PPS above 110 GeV:

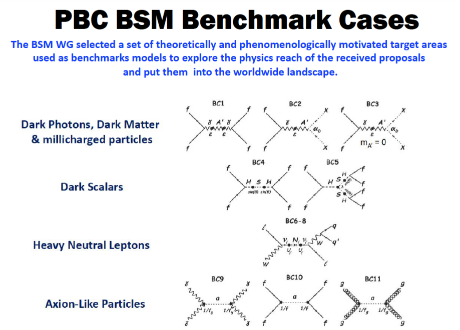
12 events $\gamma\gamma \to \mu^+\mu^-$ 8 events $\gamma\gamma \to e^+e^-$

13 events with a track in both near/far RPs

two independent ξ measurements agree within 4%

UERJ|UFRGS Gustavo Gil da Silveira — Results on diffraction and exclusive production — 12thMPI@LHC2021, 28 set 2021 — 26

long lived particles



from M. Lamont, PBC presentation @ MITP, november 2020

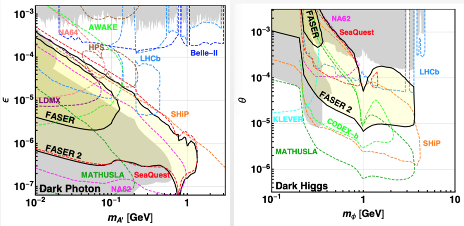
∗ 11 models for light, weakly-interacting particles (LLPs, FIPs)

∗ BC1, BC4-11 covered by FASER, FASER2; BC2 and BC3: FPF.

BCs 1, 4-11: LLPs at FASER and FASER2

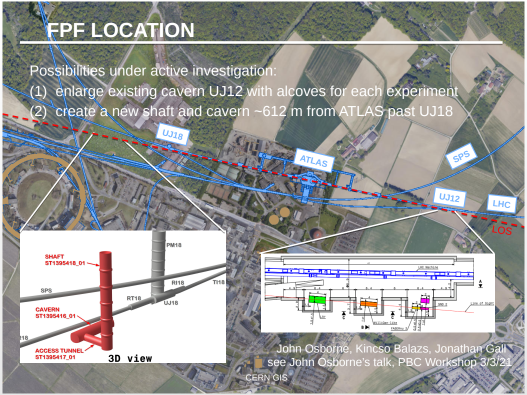
∗ Run-3 integrated luminosity is enough for FASER to discover new physics for some of the Benchmark Cases.

∗ FPF will provide space to upgrade FASER (R = 10 cm, L = 1.5 m) to FASER2 (R = 1.0 m, L = 5 m), either greatly enhancing sensitivity (e.g. for A' - visible mode) or by providing new prospects (e.g. for S), complementary to other experiments.



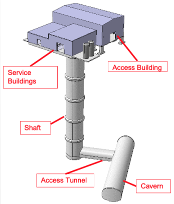
from FASER Collaboration, [arXiv:1811.12522]

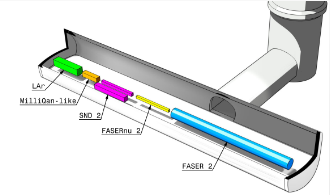
long lived particles



The Forward Physics Facility @ HL-LHC

A new large infrastructure, capable of simultaneously hosting a suite of experiments dealing with forward ν and BSM particles.





- Access possible during LHC operation
- Easier access than in LHC side caverns.
- It might be designed around the need of the experiments.

Summary WG4: theory talks

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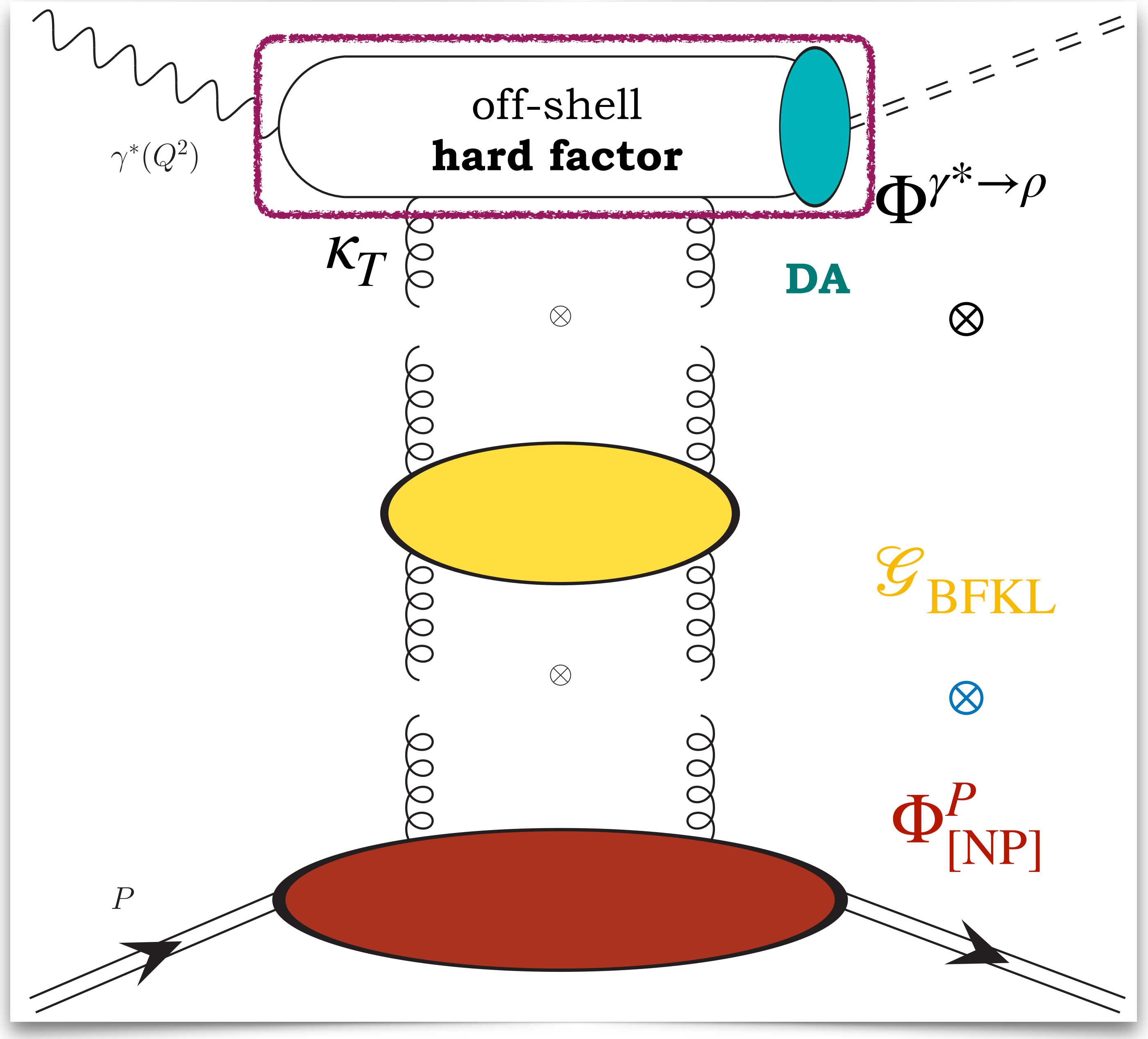
12th International Workshop on Multi-Parton-Interactions at the LHC

With a tendency towards EIC

- Exclusive Vector Mesons at HERA and EIC
- SuperChic and photon-photon process
- Parton Distribution Functions
- Future - MPI at the Electron Ion Collider (and Color Glass Condensate)

Franceso G. Celiberto: Accessing the proton UGD via exclusive polarized ρ -meson leptoproduction at HERA and the EIC

A factorization...of factorizations



$\gamma \to \rho$ impact factor

$$\Phi^{\gamma^*\to\rho} \propto \int_0^1 {\rm d}z\, T_H^{\gamma^*\to\rho}(z, \kappa_T, Q, \mu_R, \mu_F)\, \phi^{\lambda_\rho}(z, \mu_F)$$

Collinear convolution ⇔ large κ_T (!)

* $\gamma_L^* \to \rho_L$ transition:

$$\frac{1}{\kappa_T^2}\Phi^{\gamma_L^*\to\rho_L} \underset{\kappa_T\to 0^+}{\sim} \text{constant}$$

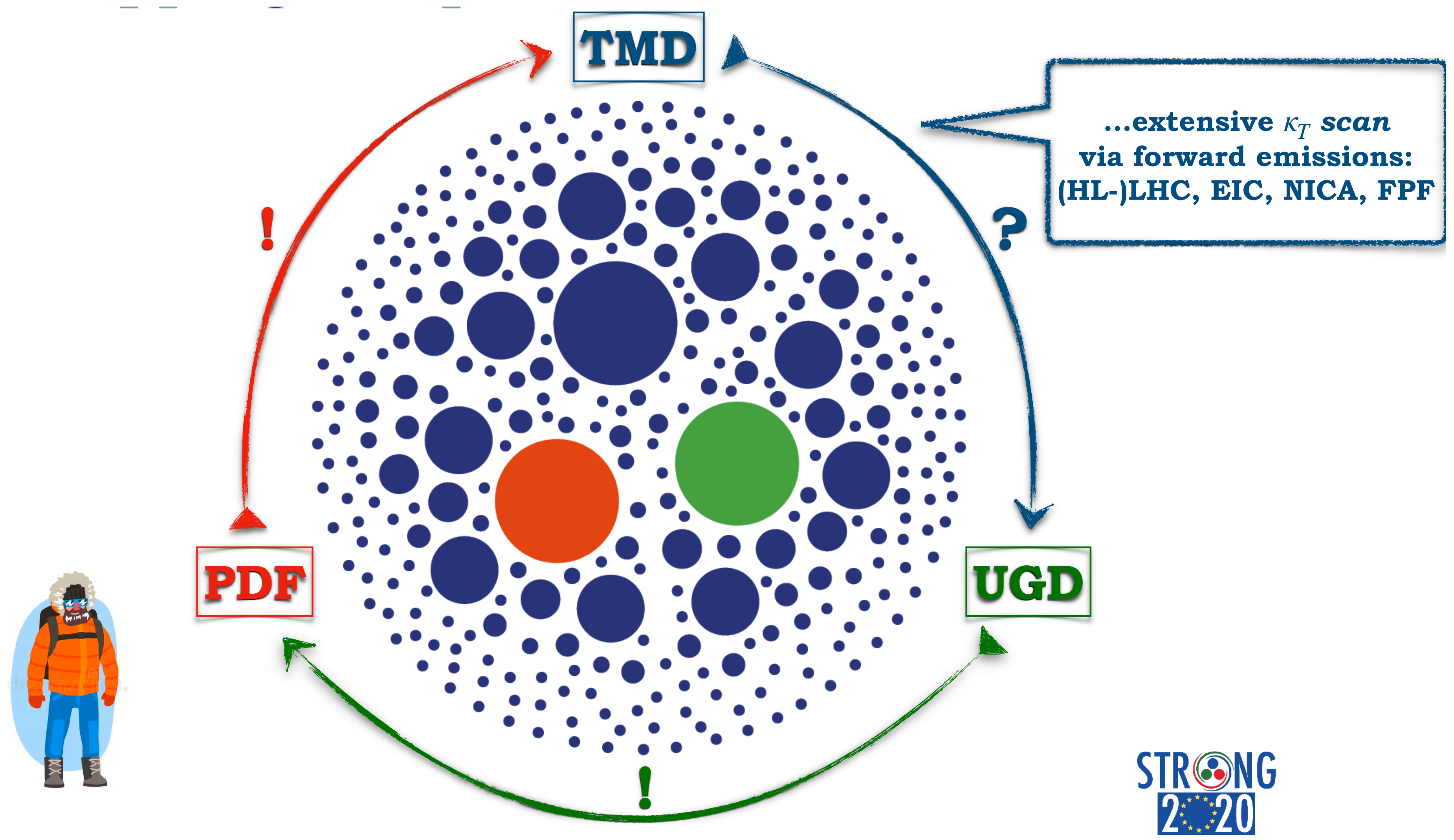
* $\gamma_T^* \to \rho_T$ transition:

$$\frac{1}{\kappa_T^2}\Phi^{\gamma_T^*\to\rho_T} \underset{\kappa_T\to 0^+}{\sim} \ln\frac{\kappa_T^2}{Q^2}$$

UGD

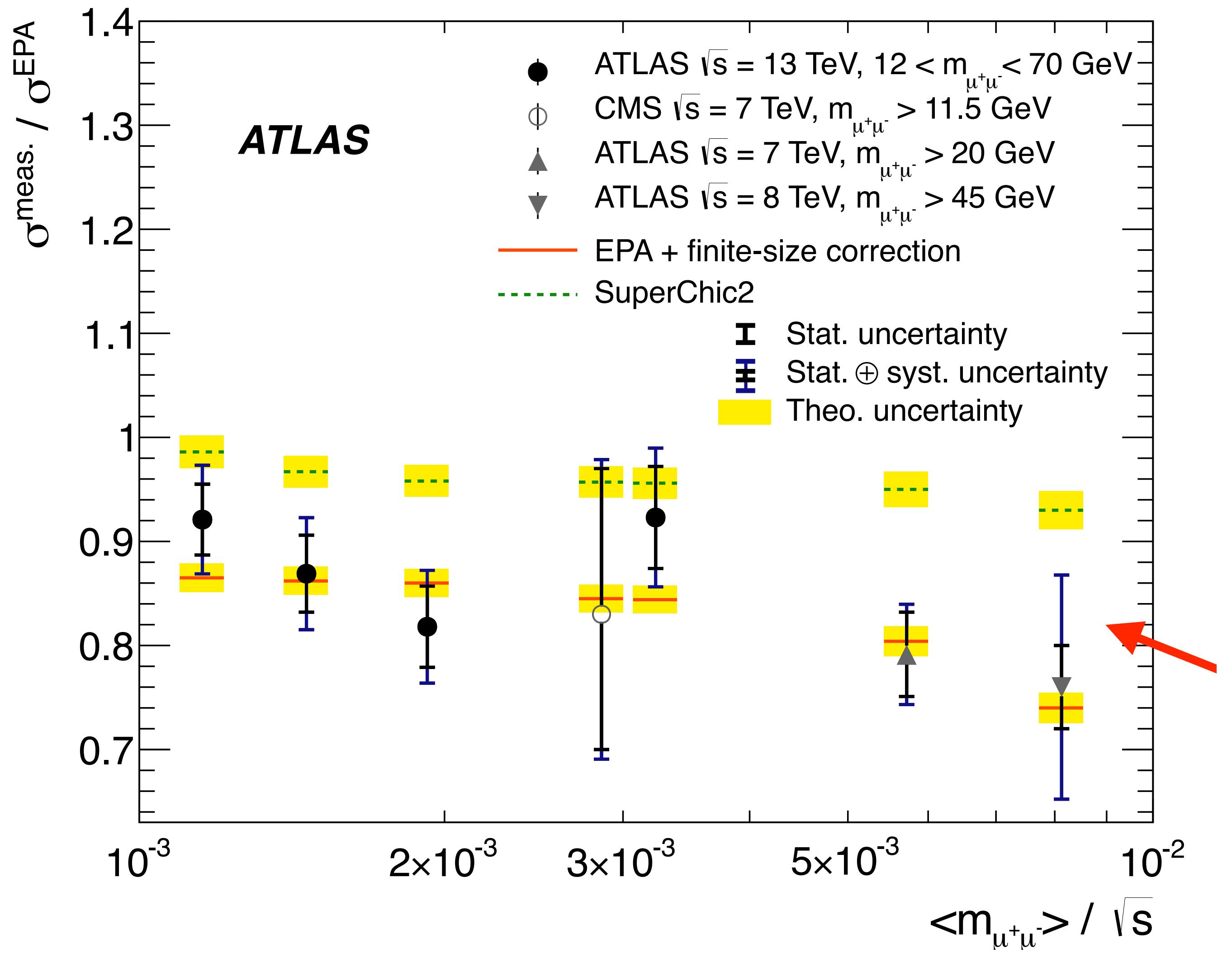
BFKL factorization

3.0 Forward mesons



Lucian Harland-Lang: Elastic photon-initiated production at the LHC: the role of hadron-hadron interactions

ATLAS, M. Aaboud et al., Phys. Lett. B777, 303 (2018)

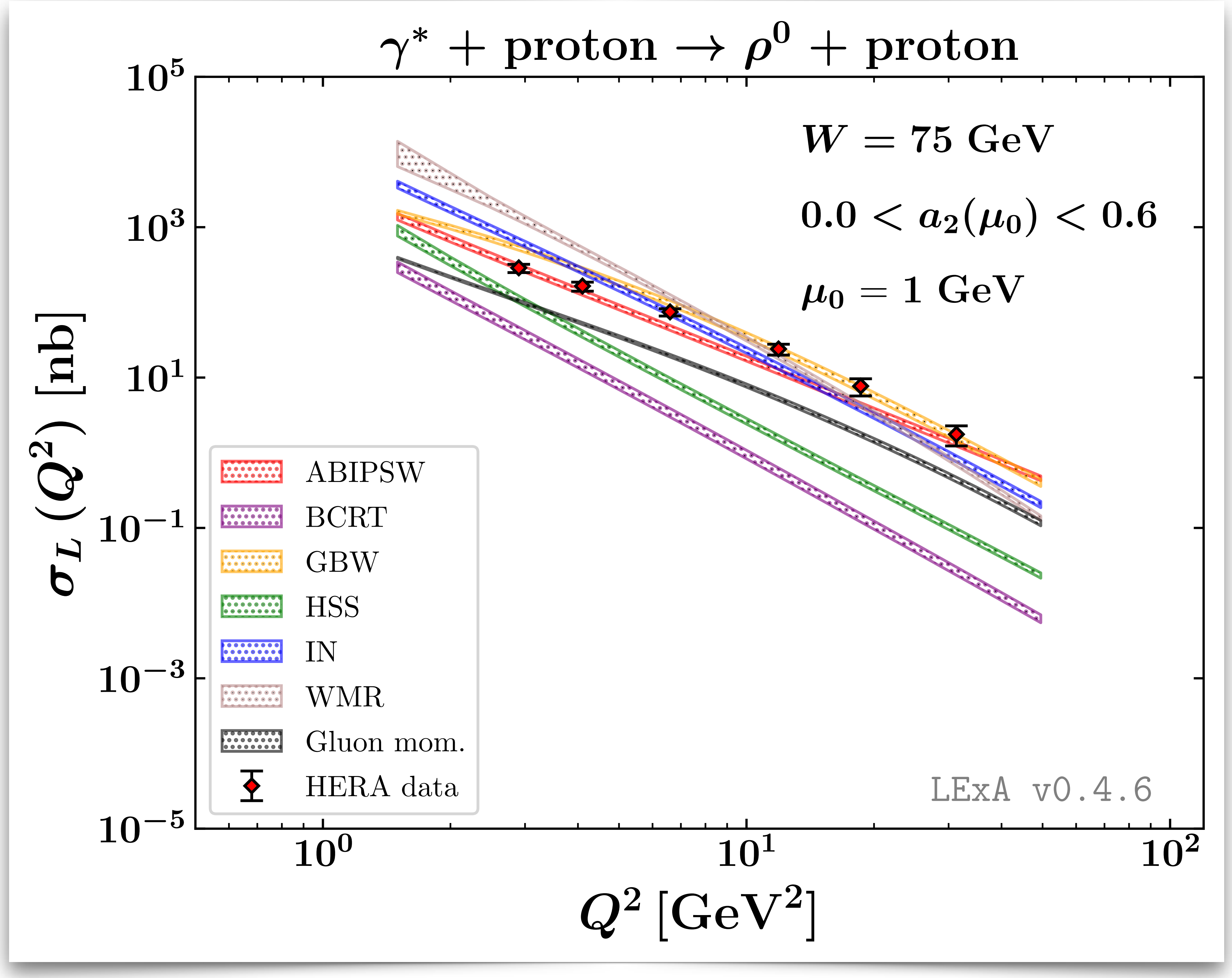


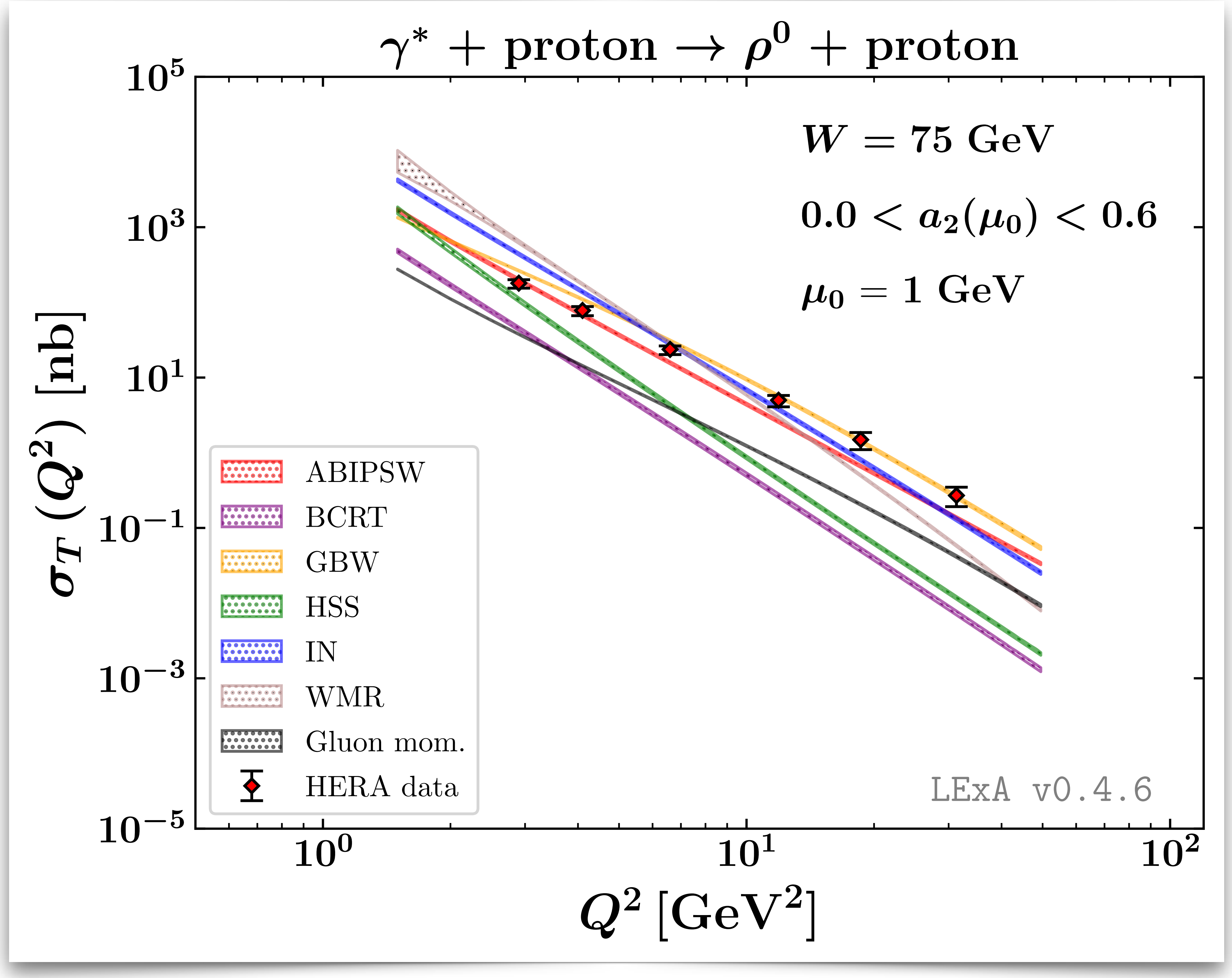
Data/theory discrepancy in dilepton channel (pp & PbPb)

- Natural candidate (at first): model for survival factor
- Careful study: seems not to be the case
- Problem to be sorted out

Dependence on the photon virtuality Q^2:

Exclusive forward ρ-meson production at HERA





[A.D. Bolognino, F.G.C., D.Yu. Ivanov, A. Papa (2018)]

(extension to ϕ-meson emissions) [A.D. Bolognino, A. Szczurek, W. Schäfer (2020)]

[A.D. Bolognino, PhD Thesis (2021)]

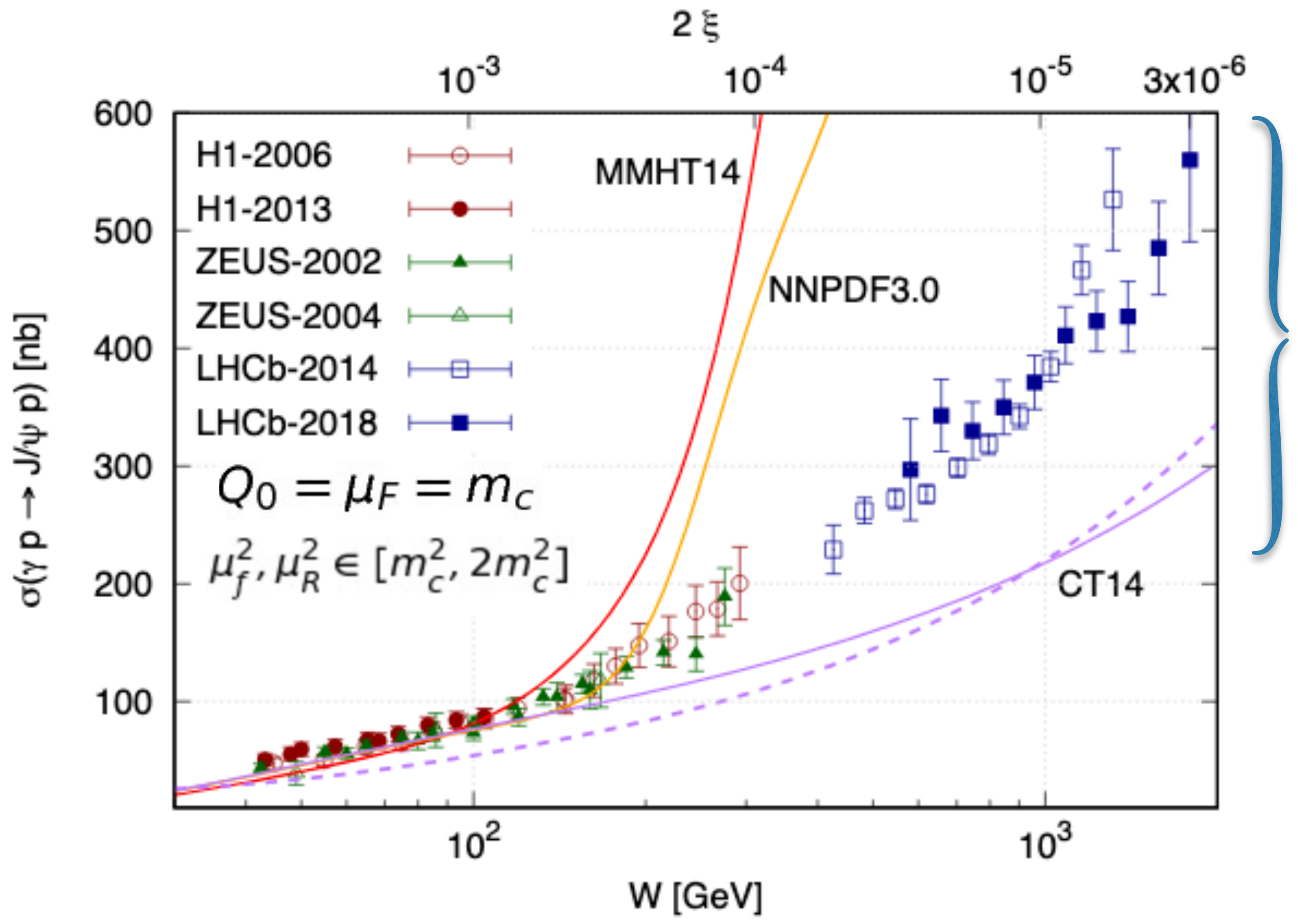
(in this slide) [A.D. Bolognino, F.G.C., D.Yu. Ivanov, A. Papa, W. Schäfer, A. Szczurek (2021)]

Chris A. Flett: Small x gluon PDF from LHCb exclusive J/Psi data

- NLO accuracy
- Huge differences between different PDF sets in the LHCb region

Towards the bigger picture

Plot demonstrates good scale stability of our NLO predictions in LHCb regime
Predictions at optimal scale (solid) agree better with HERA data



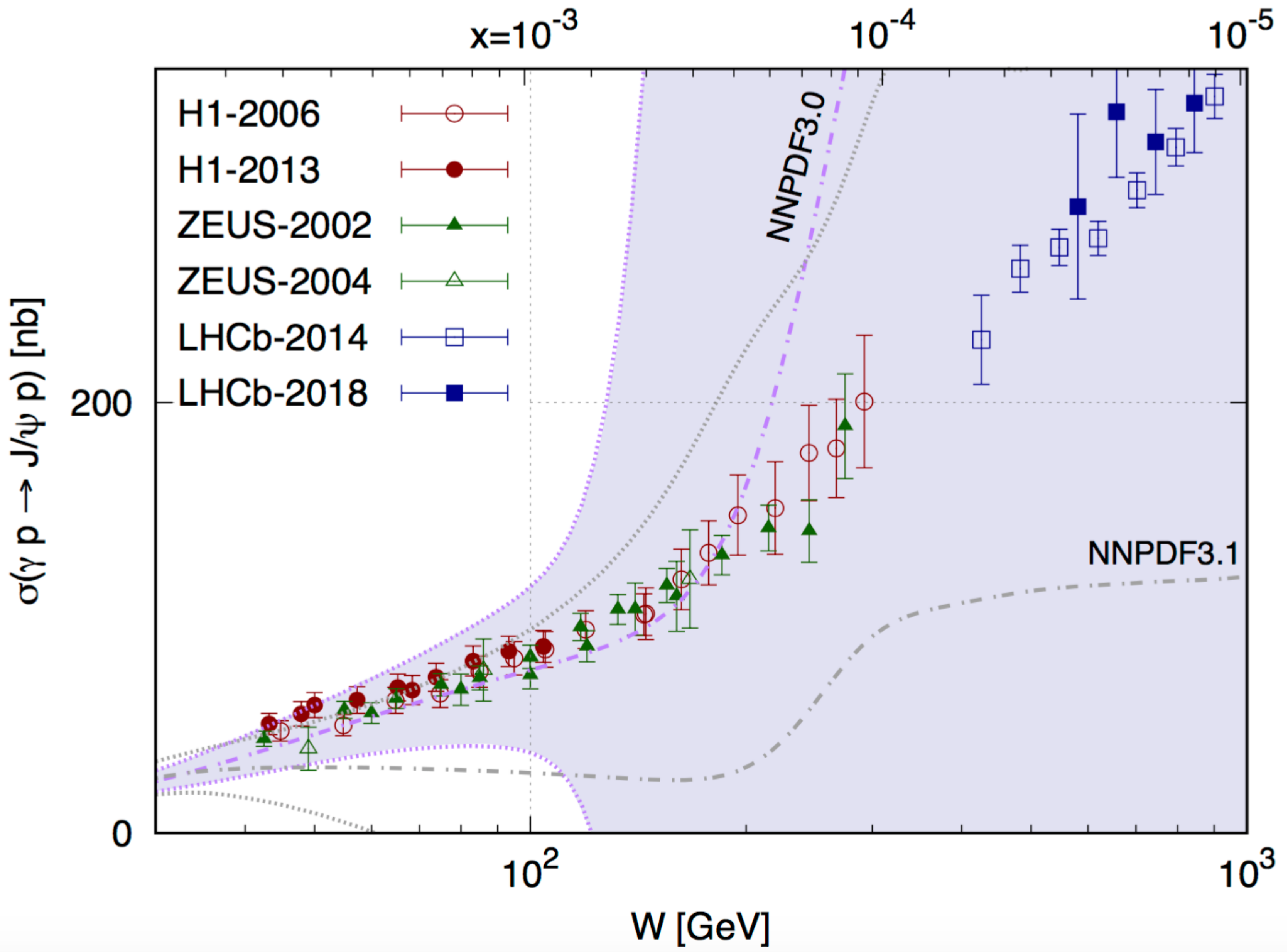
CAF, S.P.Jones, A.D.Martin, M.G.Ryskin, T.Teubner, 1907.06471 & 1908.08398

Diversity between predictions based on current global PDFs in unconstrained phase space -> important message

Repeat Disclaimer:
Convoluting with existing global partons. Here, MMHT14, NNPDF3.0 & CT14

$$\frac{\mathrm{Re}\mathcal{M}}{\mathrm{Im}\mathcal{M}} \sim \frac{\pi}{2}\lambda = \frac{\pi}{2}\frac{\partial \ln \mathrm{Im}\mathcal{M}/W^2}{\partial \ln W^2} \quad \text{with} \quad \mathcal{M} \sim x^{-\lambda}$$

7



Strategy:
- combine HERA data and LHCb data

Extraction of low x gluon PDF via exclusive J/psi

Left
Approach 1: Fit a low x gluon PDF ansatz to the data

Right
Approach 2: Bayesian reweight current global PDF analyses

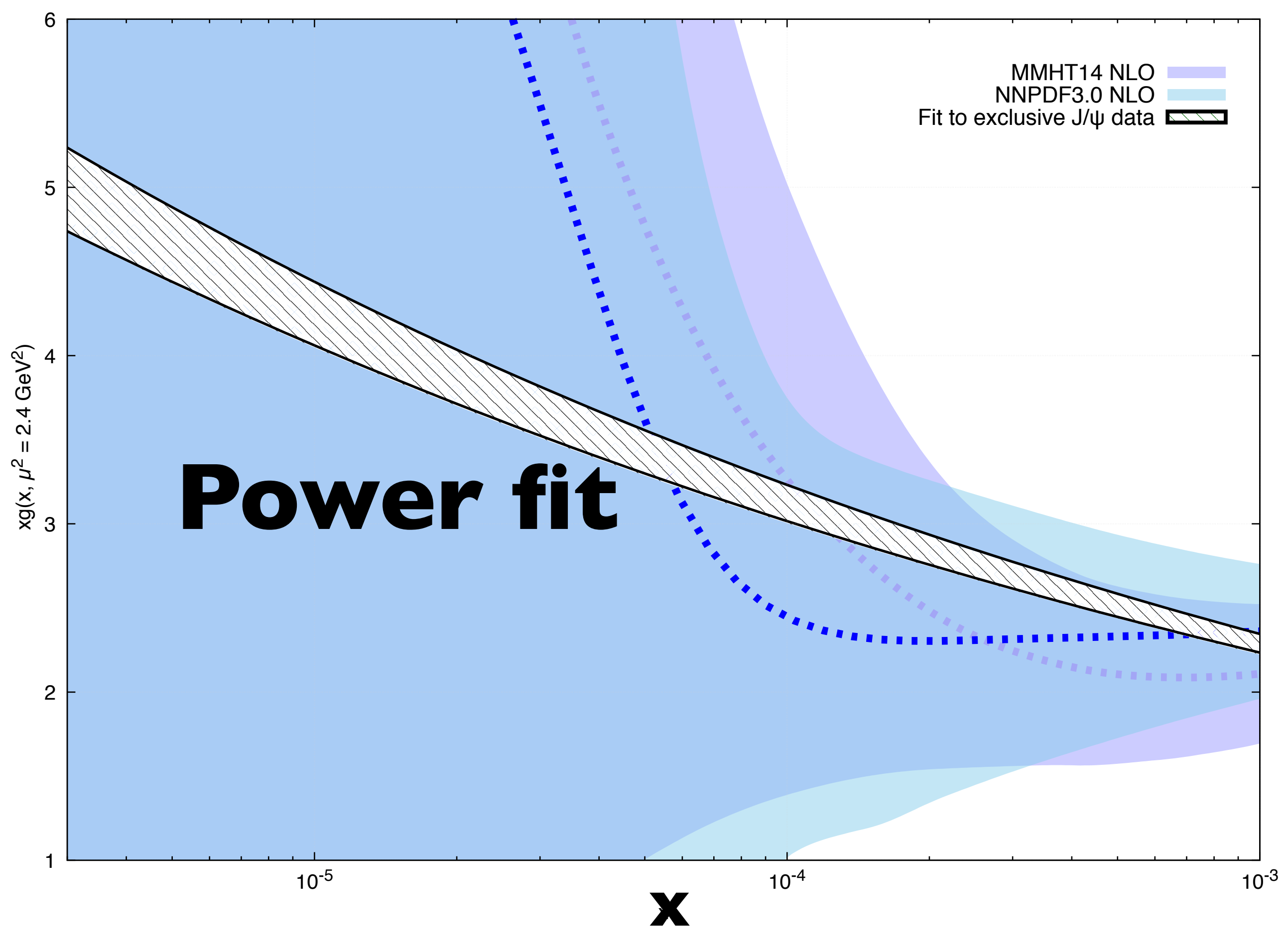
	λ	n	$\chi^2_{\rm min}$	$\chi^2_{\rm min}$/d.o.f
NNPDF3.0	0.136	0.966	44.51	1.04
MMHT14	0.136	1.082	47.00	1.09
CT14	0.132	0.946	48.25	1.12

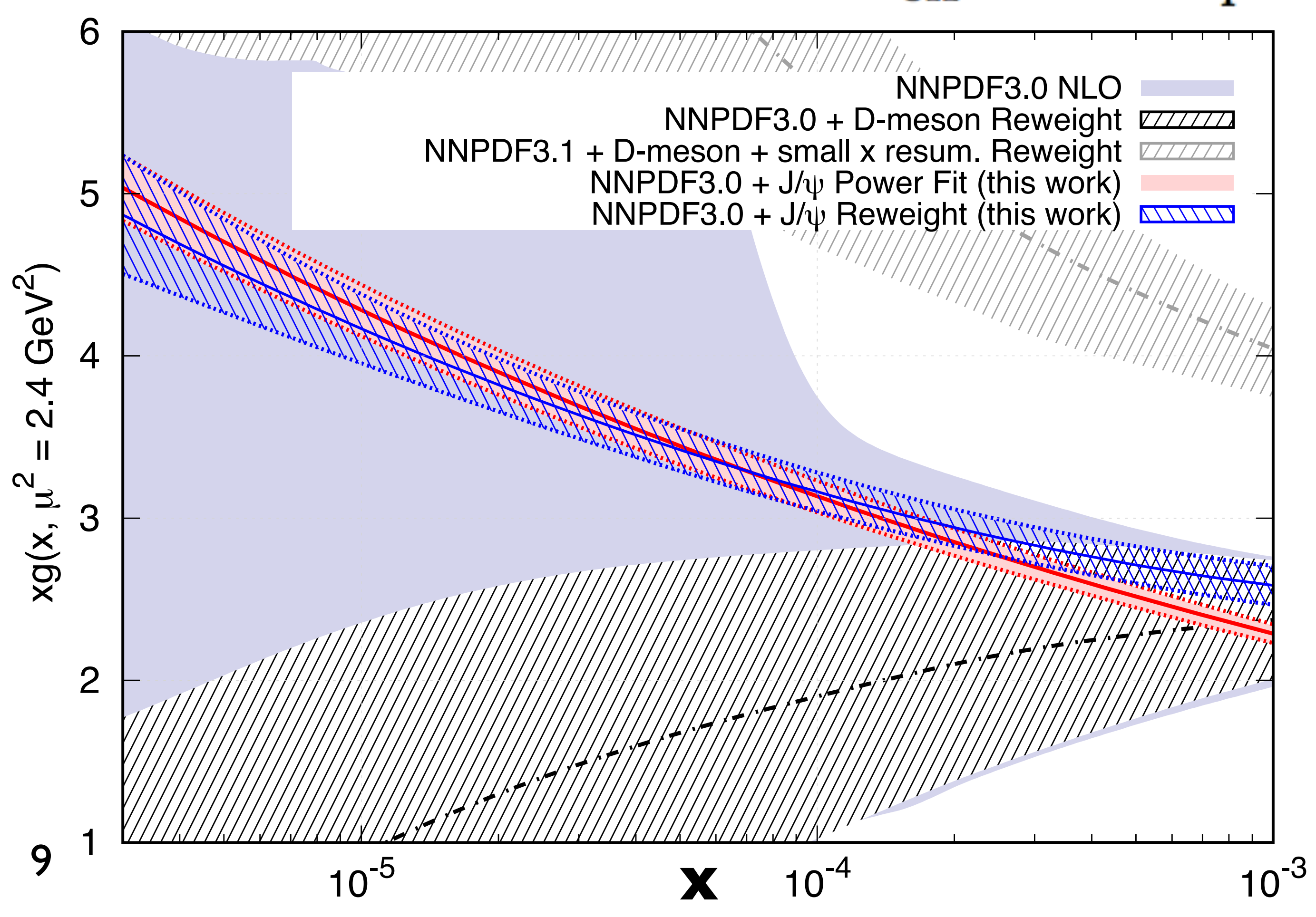
$$xg^{\rm new}(x,\mu_0^2) \; = \; nN_0\,(1-x)\,x^{-\lambda}$$

lambda = 0.136 +/- 0.006
n = 0.966 +/- 0.025

CAF, A.D.Martin, M.G.Ryskin, T.Teubner, 2006.13857

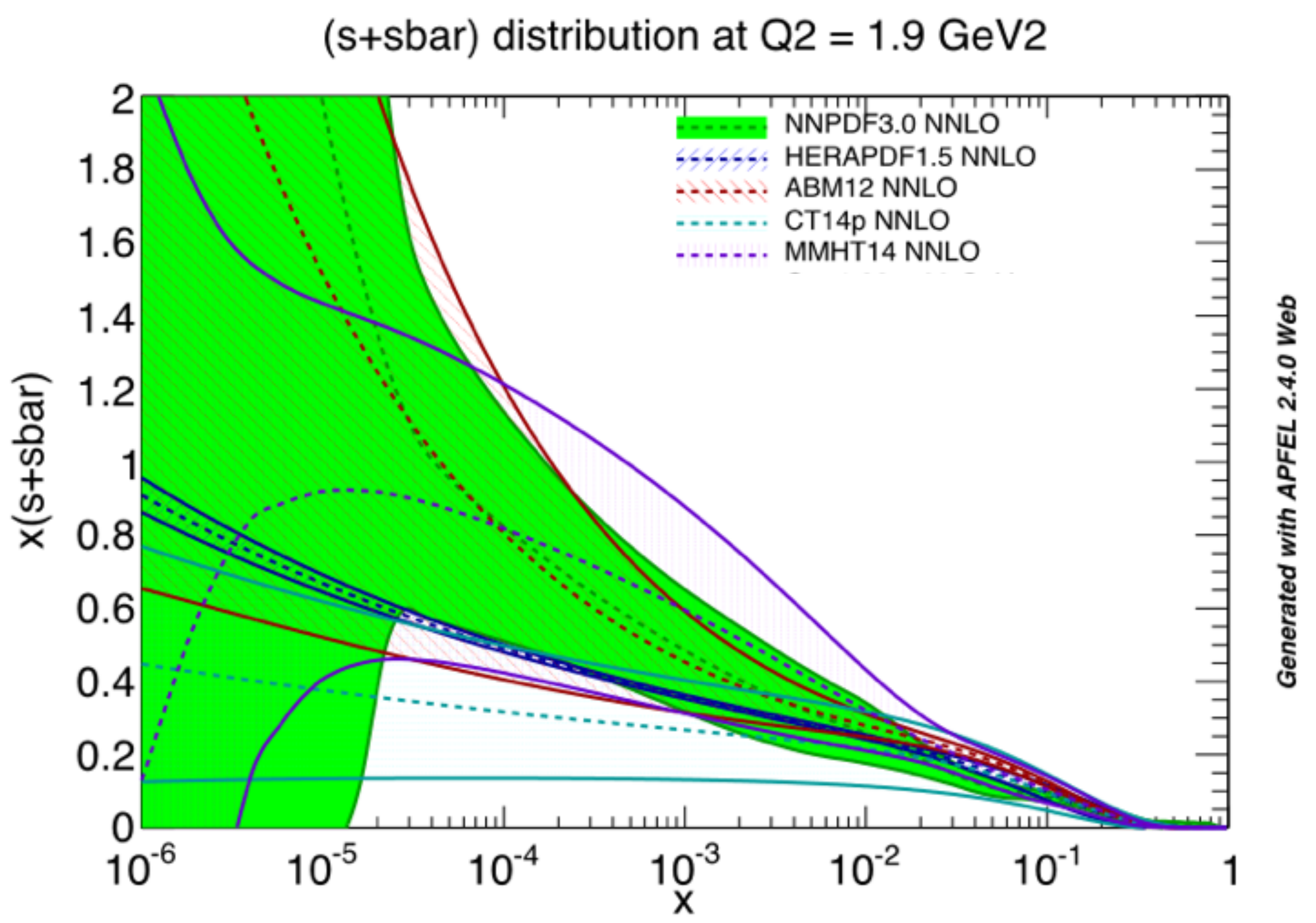
$N_{\rm eff} \ll N_{\rm rep}$





Mark Sutton: Parton Distribution functions: measurements and interpretations

PDF uncertainty important element of LHC uncertainties



The proton is more strange than we imagined …

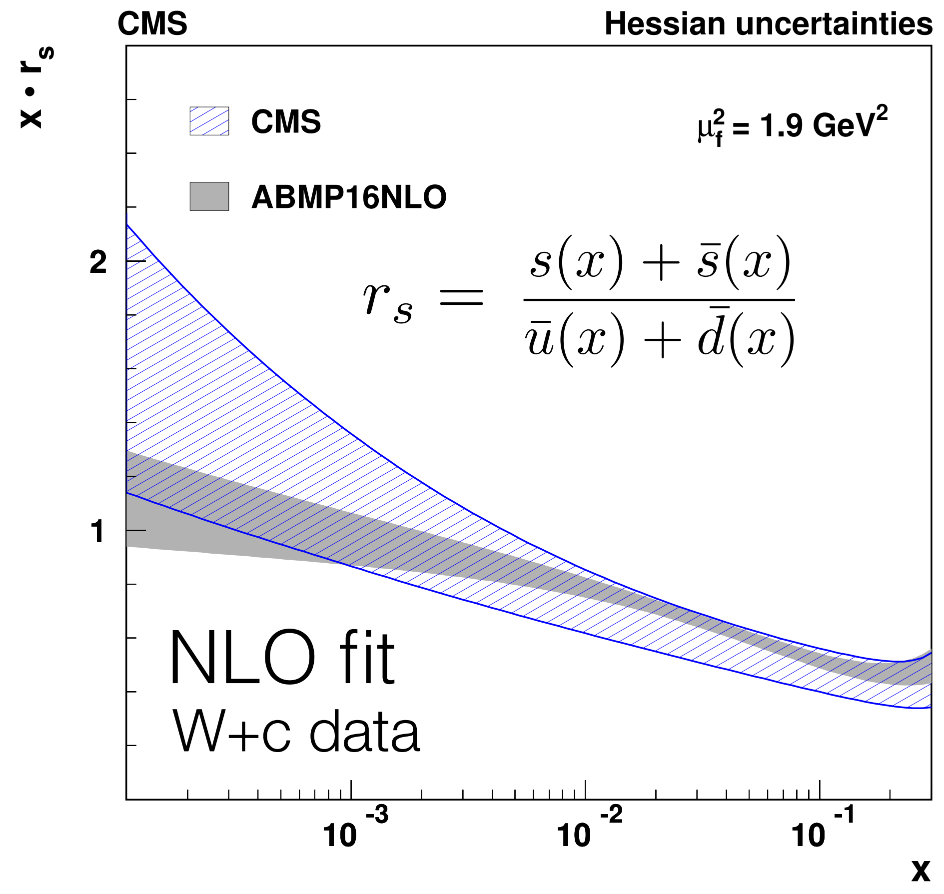
- Strange quark density poorly known
  - Often assumed sbar ~ 0.5 dbar from s→Wc in NuTeV, CCFR data
  - Large c fragmentation and nuclear corrections uncertainties
- Early ATLAS epWZ12 fit to 2010 inclusive Z and W± data found an unsuppressed strangeness contribution

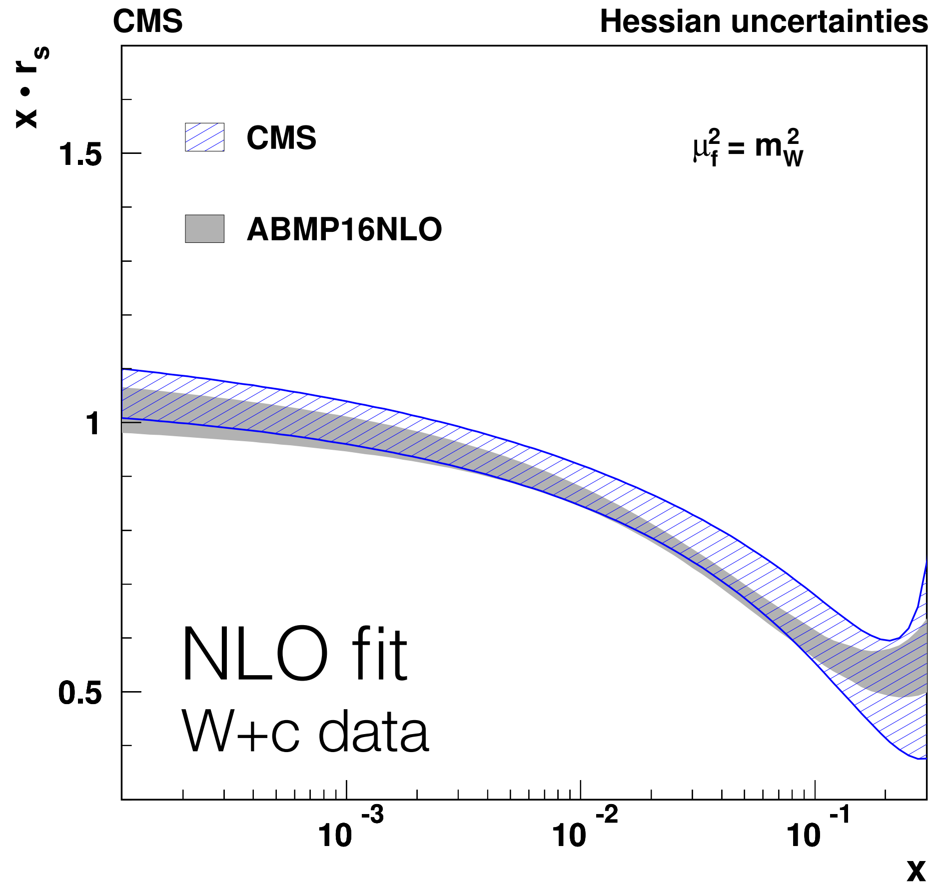
$$r_s = \frac{1}{2}(s+\bar{s})/\bar{d} = 1.00 \pm 0.07(\text{exp}) \pm 0.03(\text{mod})^{+0.04}_{-0.06}(\text{par}) \pm 0.02(\alpha_s) \pm 0.03(\text{th})$$

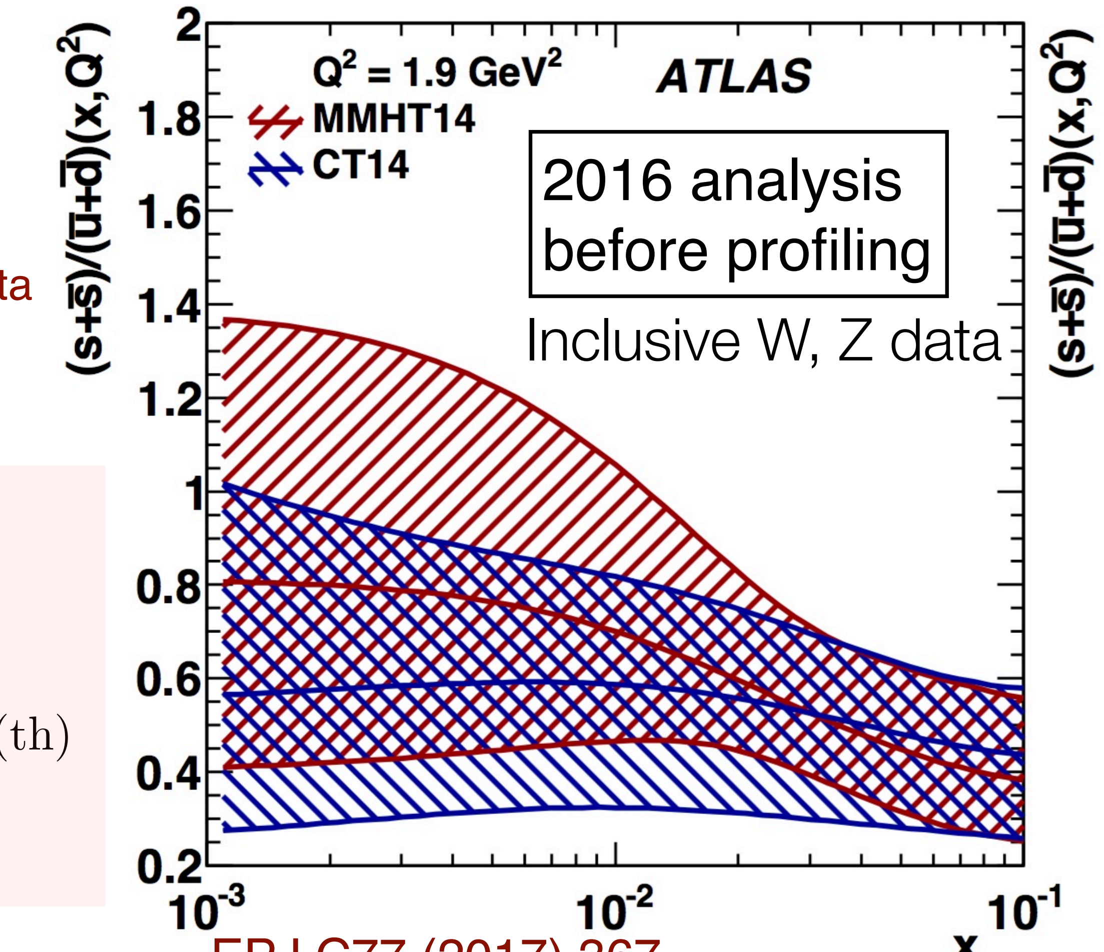
- Subsequent data and fits to ATLAS and CMS data still suggest unsuppressed strange at low-x

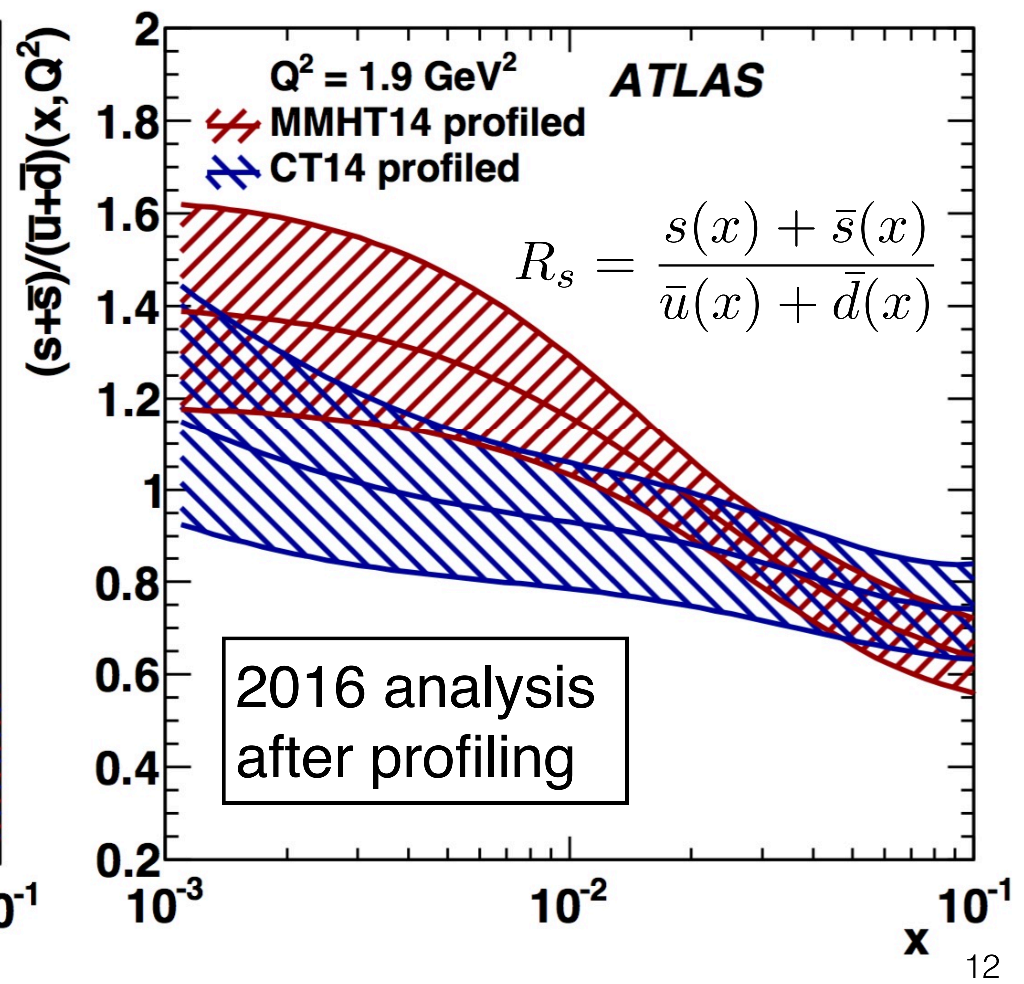
The 12th International Workshop on Multi-Parton Interactions, Lisbon, 2021

EPJ C79 (2019) 269









EPJ C77 (2017) 367

M Sutton - The proton PDF including W+jet data at ATLAS

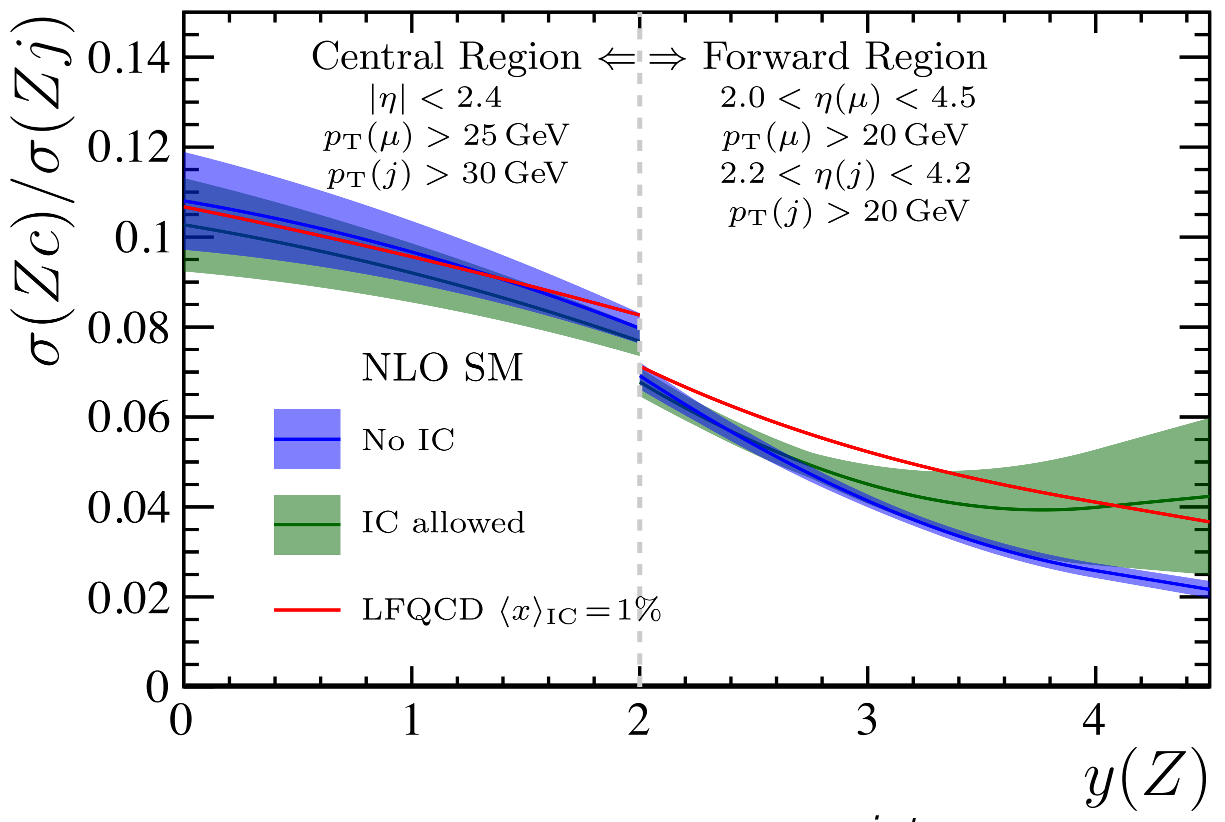
12

LHCb arxiv:2109.08084

Evidence for intrinsic charm?

radiation (g → ccbar).

proton:



- Previous measurements hampered by nuclear effects
- Intrinsic charm only excluded for contributions above ~ 1%
- Full Run 2 pp dataset
- Z→ μμ events + one jet with $p_T > 20$ GeV
- Charm jets identified using a displaced vertex tagger

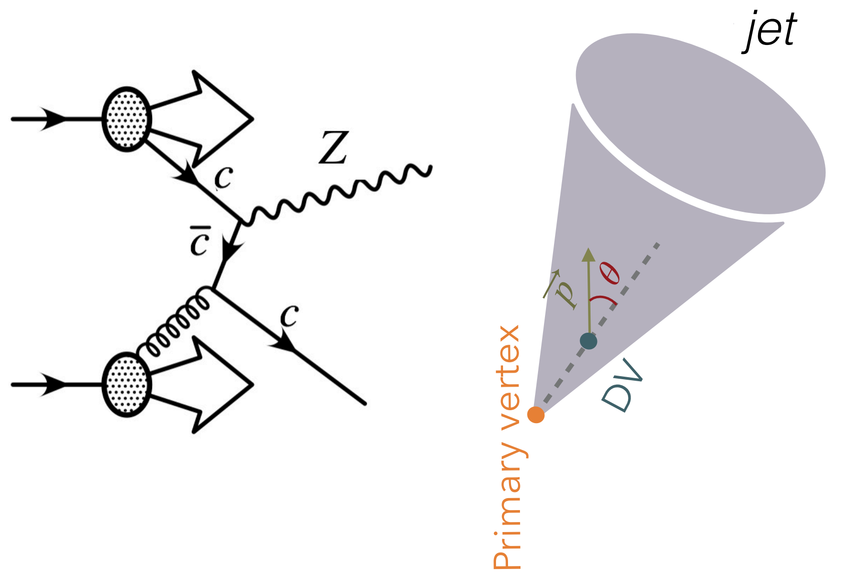
$$\mathcal{R}_j^c \equiv \sigma(Zc)/\sigma(Zj)$$

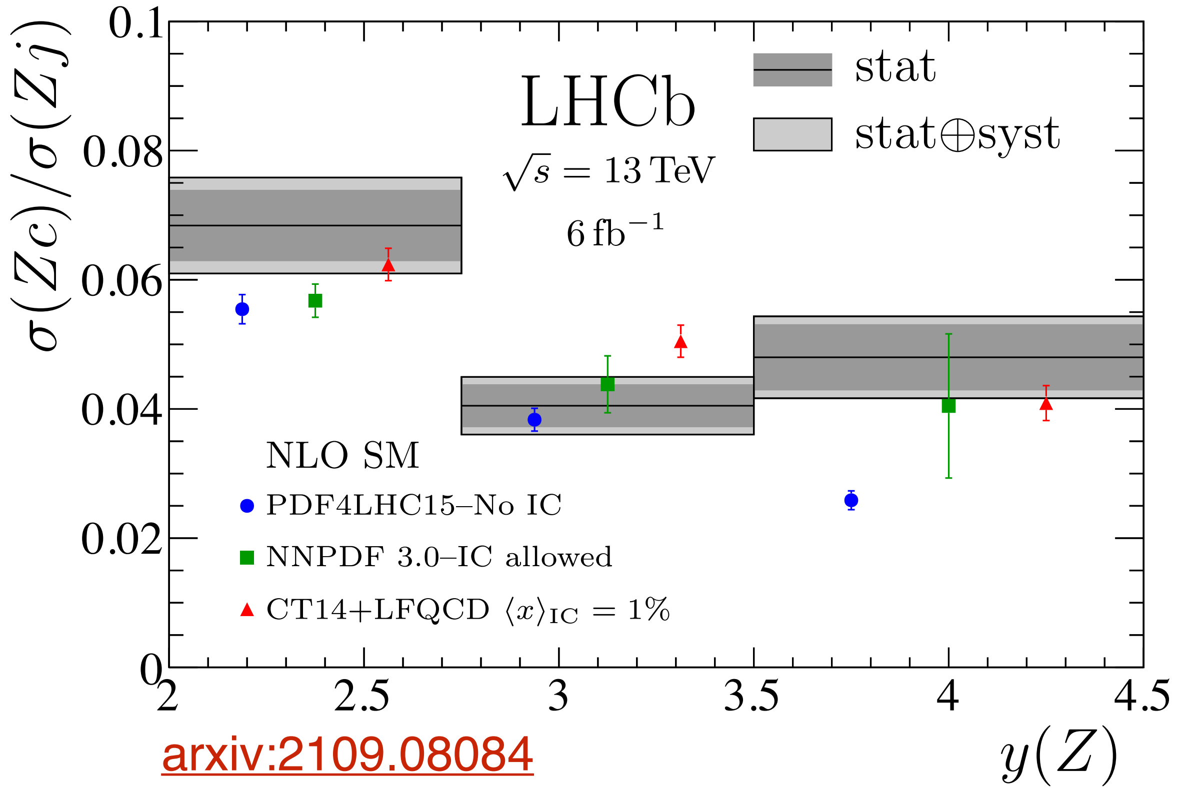
- Investigate possibility of Intrinsic Charm in the proton

m production in the very forward

her ATLAS or CMS

ctor configuration





arxiv:2109.08084

$y(Z)$	$\mathcal{R}_j^c$ (%)
2.00–2.75	$6.84 \pm 0.54 \pm 0.51$
2.75–3.50	$4.05 \pm 0.32 \pm 0.31$
3.50–4.50	$4.80 \pm 0.50 \pm 0.39$
2.00–4.50	$4.98 \pm 0.25 \pm 0.35$

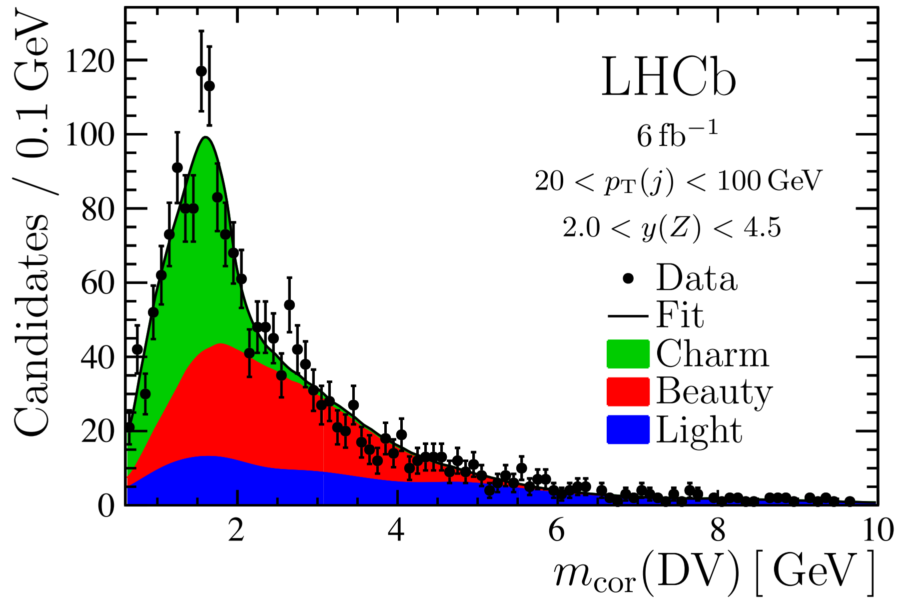
$$\mathcal{R}_j^c \equiv \sigma(Zc)/\sigma(Zj)$$

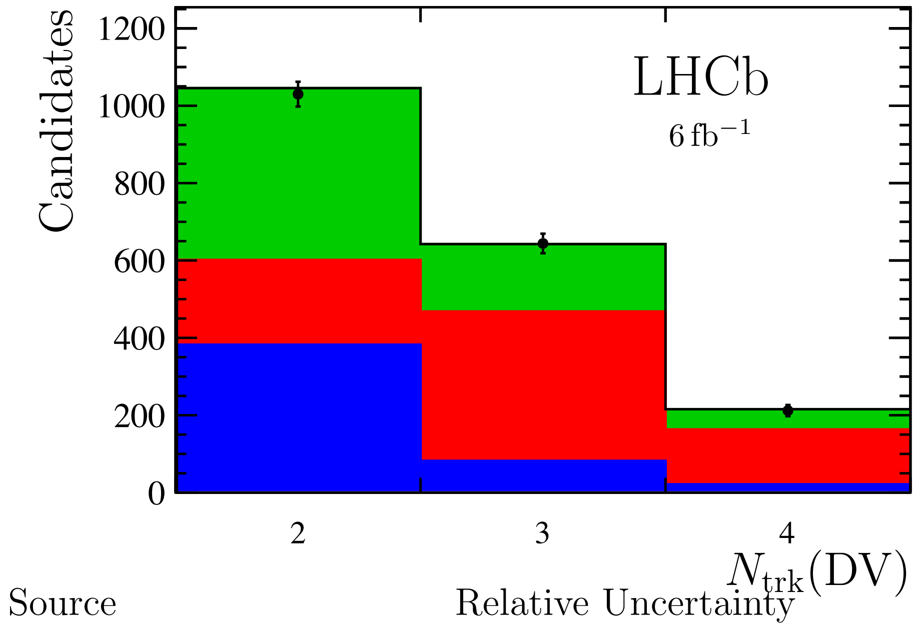
Forward Z+charm from LHCb

Table 1: Definition of the fiducial region.

Z bosons	$p_T(\mu) > 20$ GeV, $2.0 < \eta(\mu) < 4.5$, $60 < m(\mu^+\mu^-) < 120$ GeV
Jets	$20 < p_T(j) < 100$ GeV, $2.2 < \eta(j) < 4.2$
Charm jets	$p_T(c \text{ hadron}) > 5$ GeV, $\Delta R(j, c \text{ hadron}) < 0.5$
Events	$\Delta R(\mu, j) > 0.5$

- With the NLO analysis, suggestion of consistency with NO intrinsic charm at less forward rapidities …
- But greater than 3σ excess observed over non-intrinsic charm contribution in the most forward rapidity bin, consistent with Intrinsic charm
- Interesting to see the effect of these data with the global fits

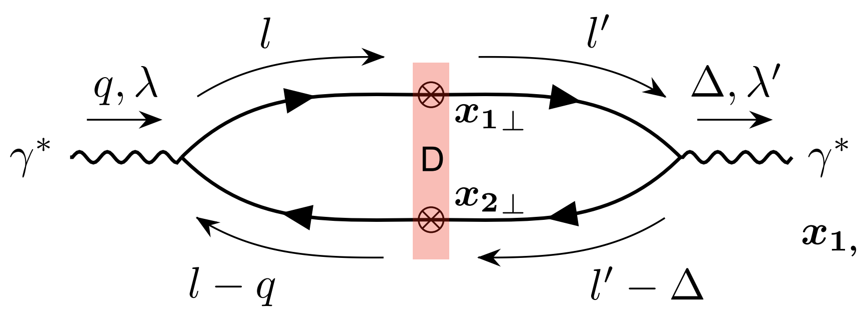




Source	Relative Uncertainty
c tagging	6–7%
DV-fit templates	3–4%
Jet reconstruction	1%
Jet p_T scale & resolution	1%
Total	8%

Heikki Mäntysaari: The Electron Ion Collider and Gluon imaging using azimuthal correlations at EIC

Deeply Virtual Compton Scattering*



$$x_{1,2\perp} = b_\perp \pm \frac{r_\perp}{2}$$

$$\mathcal{M}_{\pm1,\mp1} \sim \int_{\mathbf{b}} e^{-i\boldsymbol{\Delta}\cdot\mathbf{b}} \int_{\mathbf{r}} e^{\pm 2i\phi_{r\Delta}} D(\mathbf{r},\mathbf{b}) \int_z e^{-i\delta\cdot\mathbf{r}} z\bar{z}Q\varepsilon K_1(\varepsilon r)\varepsilon' K_1(\varepsilon' r)$$

Two sources of correlations between $\mathbf{r}$ (which knows about the electron in DIS) and $\boldsymbol{\Delta}$

- *Intrinsic*: correlation between $\mathbf{r}$ and $\mathbf{b}$ in the dipole $D(\mathbf{r},\mathbf{b})$
  - Related to elliptic gluon GPD Hatta, Yuan, Xiao, 1703.02085
- *Kinematic*: off-forward phase $e^{-i\delta\cdot\mathbf{r}}$ with $\delta = (z-\bar{z})\boldsymbol{\Delta}/2$
  - Different propagation axis, mixes polarizations

Azimuthal correlations in DVCS in DIS

Full calculation at $Q'^2 = 0$ including the photon flux $f(y)$ in 2011.02464

In agreement with hatta, Yuan, Xiao, 1703.02085

$$\frac{\mathrm{d}\sigma^{ep\to e\gamma p}}{\mathrm{d}t\mathrm{d}\phi_{e\Delta}} \sim f_{TT}(y)[\mathcal{M}^2_{\pm1,\pm1} + \mathcal{M}^2_{\pm1,\mp1}] + f_{TT,\text{flip}}(y)\mathcal{M}^2_{0,\pm1}$$
$$- f_{LT}(y)\mathcal{M}_{0,\pm1}[\mathcal{M}_{\pm1,\pm1} + \mathcal{M}_{\pm1,\mp1}]\cos(\phi_{e\Delta})$$
$$+ f_{TT,\text{flip}}(y)\mathcal{M}_{\pm1,\pm1}\mathcal{M}_{\pm1,\mp1}\cos(2\phi_{e\Delta})$$

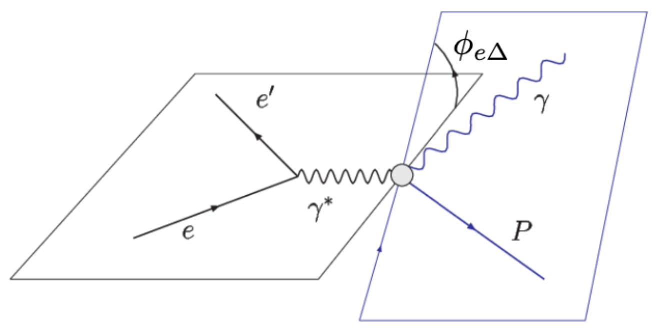


Figure: CLAS

The $\cos(2\phi_{e\Delta})$ modulation in $ep \to e\gamma p$:
Access to $\mathbf{r}, \mathbf{b}$ correlations in the dipole D via $\mathcal{M}_{\pm1,\mp1}$
$\Rightarrow$ elliptic gluon GPD / Wigner distribution

y is the inelasticity in DIS

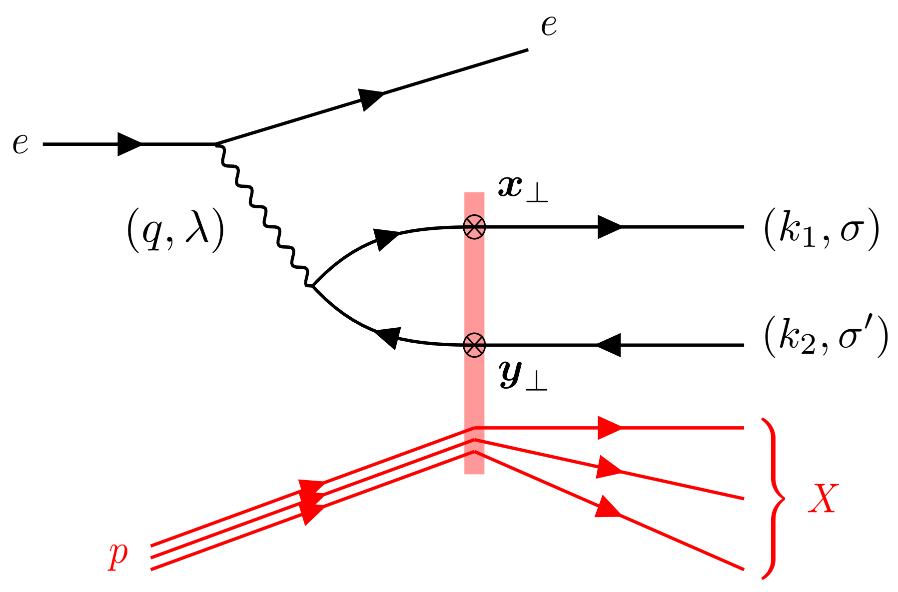
Farid Salazar: Forward dijets at the EIC beyond TMDs

Dijet production beyond TMDs

Computation in the CGC: Wilson Lines

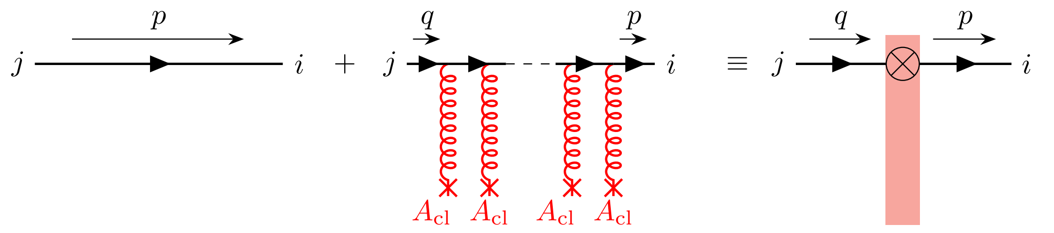
Dominguez, Marquet, Xiao, Yuan (2011)

For more on CGC see Alex's talk on Tuesday.



LO diagram for $q\bar{q}$ production in the CGC EFT

Dense gluon field $A_{\rm cl} \sim 1/g$ **needs resummation of multiple gluon interactions**



$$V_{ij}(\boldsymbol{x}) = P\exp\left\{ig\int dx^- A^{+,a}_{cl}(\boldsymbol{x},x^-)t^a\right\}$$

Amplitude (modulo leptonic part):

$$\mathcal{M}^{\lambda\sigma\sigma'}_{\rm LO} = \Psi^{\gamma^*_\lambda\to q\bar{q}}(Q,\mathbf{r}_{xy},z_q) \otimes_{\rm LO} \left[1 - V(\boldsymbol{x}_\perp)V^\dagger(\boldsymbol{y}_\perp)\right]$$

perturbatively computable — non-perturbative

$$\otimes_{\rm LO} \equiv \frac{ee_f q^-}{\pi}\int \mathrm{d}^2\boldsymbol{x}_\perp \mathrm{d}^2\boldsymbol{y}_\perp e^{-i\boldsymbol{k}_{1\perp}\cdot\boldsymbol{x}_\perp} e^{-i\boldsymbol{k}_{2\perp}\cdot\boldsymbol{y}_\perp}$$

Dijet cross-section in the CGC will contain dipoles and quadrupole:

$$\frac{1}{N_c}\left\langle \mathrm{Tr}\left[V(\boldsymbol{x}_\perp)V^\dagger(\boldsymbol{y}_\perp)\right]\right\rangle_Y$$

$$\frac{1}{N_c}\left\langle \mathrm{Tr}\left[V(\boldsymbol{x}_\perp)V^\dagger(\boldsymbol{y}_\perp)V(\boldsymbol{y}'_\perp)V^\dagger(\boldsymbol{x}'_\perp)\right]\right\rangle_Y$$

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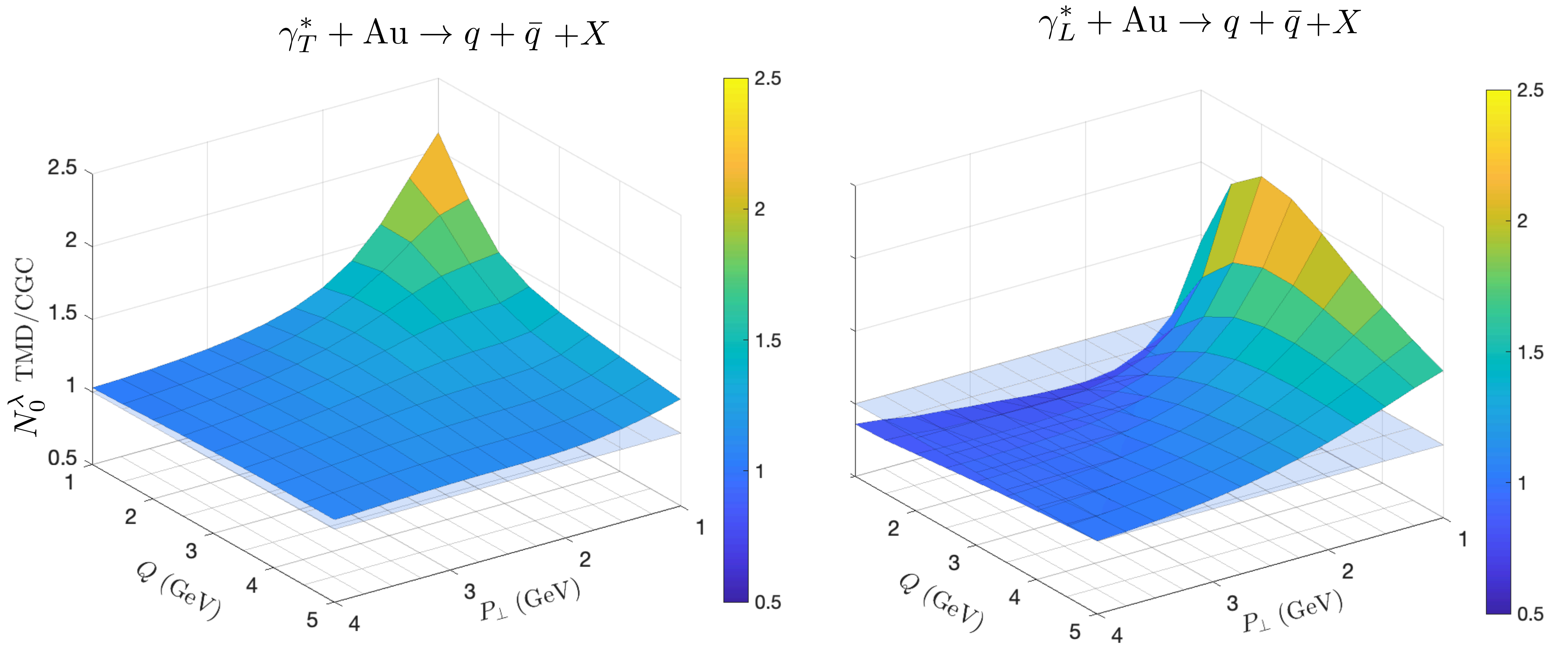
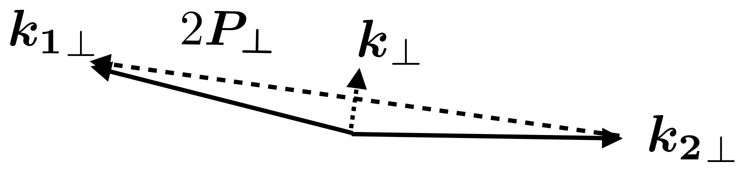
Dijet production beyond TMDs

Q^2 and $P_\perp$ dependence of genuine saturation

R. Boussarie, H. Mäntysaari, FS, B. Schenke (2021)

At exactly back-to-back $k_\perp \approx 0$ the ratio of CGC/TMD is sensitive to genuine twists





$$\frac{\mathrm{d}N^{\gamma^*_\lambda+A\to q\bar{q}+X}}{\mathrm{d}^2\boldsymbol{P}_\perp \mathrm{d}^2\boldsymbol{k}_\perp \mathrm{d}\eta_1\mathrm{d}\eta_2} = N_0^\lambda(P_\perp,k_\perp)\left[1+2\sum_{k=1}^{\infty} v_{k,\lambda}(P_\perp,k_\perp)\cos(k\phi)\right]$$

$$\phi \equiv \phi_{\boldsymbol{k}_\perp} - \phi_{\boldsymbol{P}_\perp}$$

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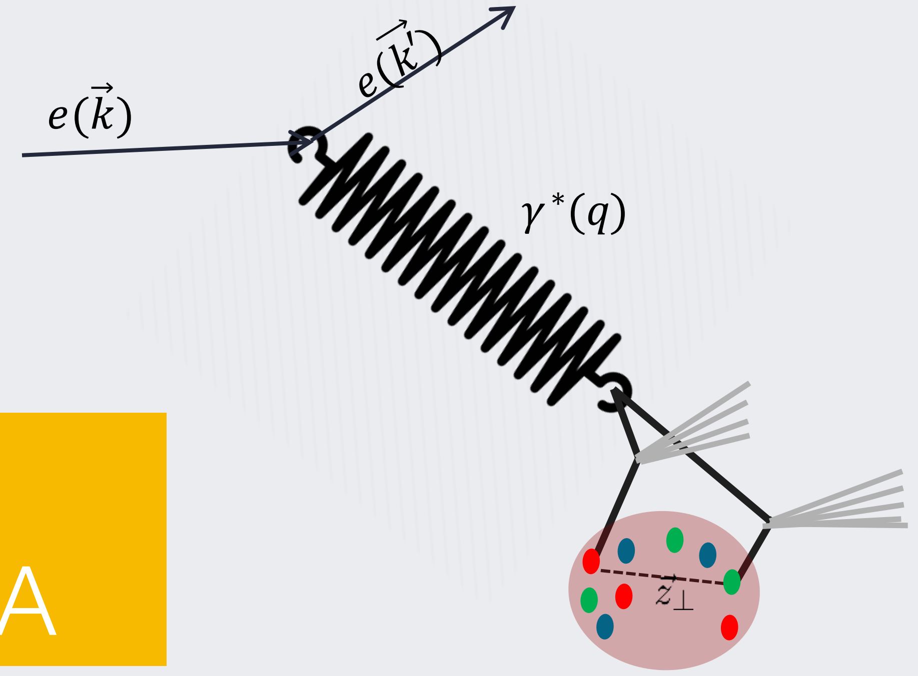
Matteo Rinaldi: Double parton scattering via photon-proton interactions and the transverse proton structure

6 New Idea: DPS via γ-p interaction

We consider the possibility offered by a DPS process involving a photon FLACTUATING in a quark-antiquark pair interacting with a proton:



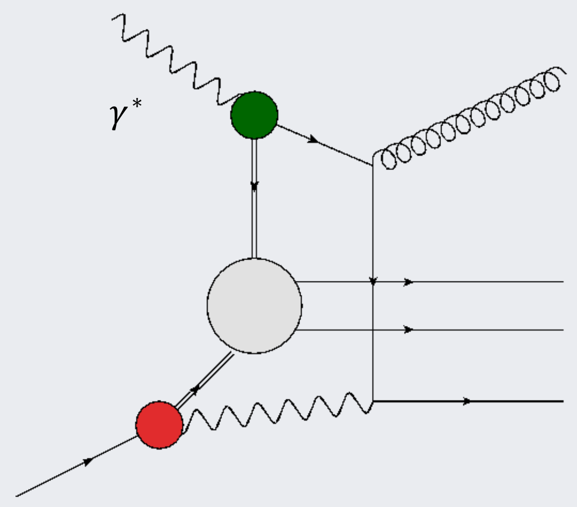
Through 4 jet production at HERA

Matteo Rinaldi

We could access for the first time the <u>mean transverse distance between partons in the proton</u>

6 New Idea: DPS via γ-p interaction

In order to study the impact of the DPS contribution to a process initiated via photon-proton interactions we evaluated the 4-JET photoproduction at HERA **(S. Checkanov et al. (ZEUS), Nucl. Phys B792, 1 (2008))**



For this first investigation, we make use of the POCKET FORMULA:

$$d\sigma^{4j}_{DPS} = \frac{1}{2}\sum_{ab,cd}\int dy\, dQ^2 \frac{f_{\gamma/e}(y,Q^2)}{\sigma^{\gamma p}_{eff}(Q^2)} \times$$
$$\times \int dx_{p_a} dx_{\gamma_b} f_{a/p}(x_{p_a}) f_{b/\gamma}(x_{\gamma_b}) d\hat{\sigma}^{2j}_{ab}(x_{p_a}, x_{\gamma_b}) \quad \text{SPS*}$$
$$\text{x}$$
$$\times \int dx_{p_c} dx_{\gamma_d} f_{c/p}(x_{p_c}) f_{d/\gamma}(x_{\gamma_d}) d\hat{\sigma}^{2j}_{cd}(x_{p_c}, x_{\gamma_d}) \quad \text{SPS}$$

Flux Factor
P. Nason et al, PLB319 339 (1993)

p-PDF **(J. Pumplin et al. JHEP 07, 012 (2002))**

γ-PDF **(M. Gluck et al. PRD46, 1973 (1992))**

*Single Parton Scattering (SPS)

Matteo Rinaldi 32

Dependence of $\sigma^{\gamma p}_{\rm eff}(Q^2)$ on Q^2 can unveil the mean distance of pardons in the proton