WG4 Summary: Diffraction & Small-x

Cristian Baldenegro Barrera
Francesco Giovanni Celiberto

MPI@LHC 2023, Manchester

OVERVIEW

Experiment

- Soft and hard diffraction @LHC

  Christophe Royon 🇺🇸 [Wednesday, remote] 🔗

- Forward particle production & energy flow @LHC

  Oscar Adriani 🇮🇹 [Thursday] 🔗

- Recent results of the FASER experiment

  Michaela Queitsch-Maitland 🇬🇧 [Thursday] 🔗

- Two-photon fusion processes @LHC

  Lydia Audrey Beresford 🇩🇪 [Friday] 🔗

- Photonuclear interactions @LHC

  Orlando Villalobos Baillie 🇬🇧 [Friday] 🔗

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Theory

- Neutrinos & New Physics: forward heavy hadron

  Luca Rottoli 🇨🇭 [Tuesday] 🔗

- Small-x resummation for PDFs

  Federico Silvetti 🇬🇧 [Thursday] 🔗

- DPS @EIC & double J/ψ photo production

  Matteo Rinaldi 🇮🇹 [Friday] 🔗

- High-energy logarithmic corrections within `HEJ`

  Emmet Byrne 🇬🇧 [Friday] 🔗

- NLO BFKL predictions for Mueller-Tang jets @LHC

  Dimitri Colferai 🇮🇹 [Friday] 🔗

MATTEO RINALDI

Double Parton Scattering @EIC

Matteo Rinaldi
INFN sezione di Perugia

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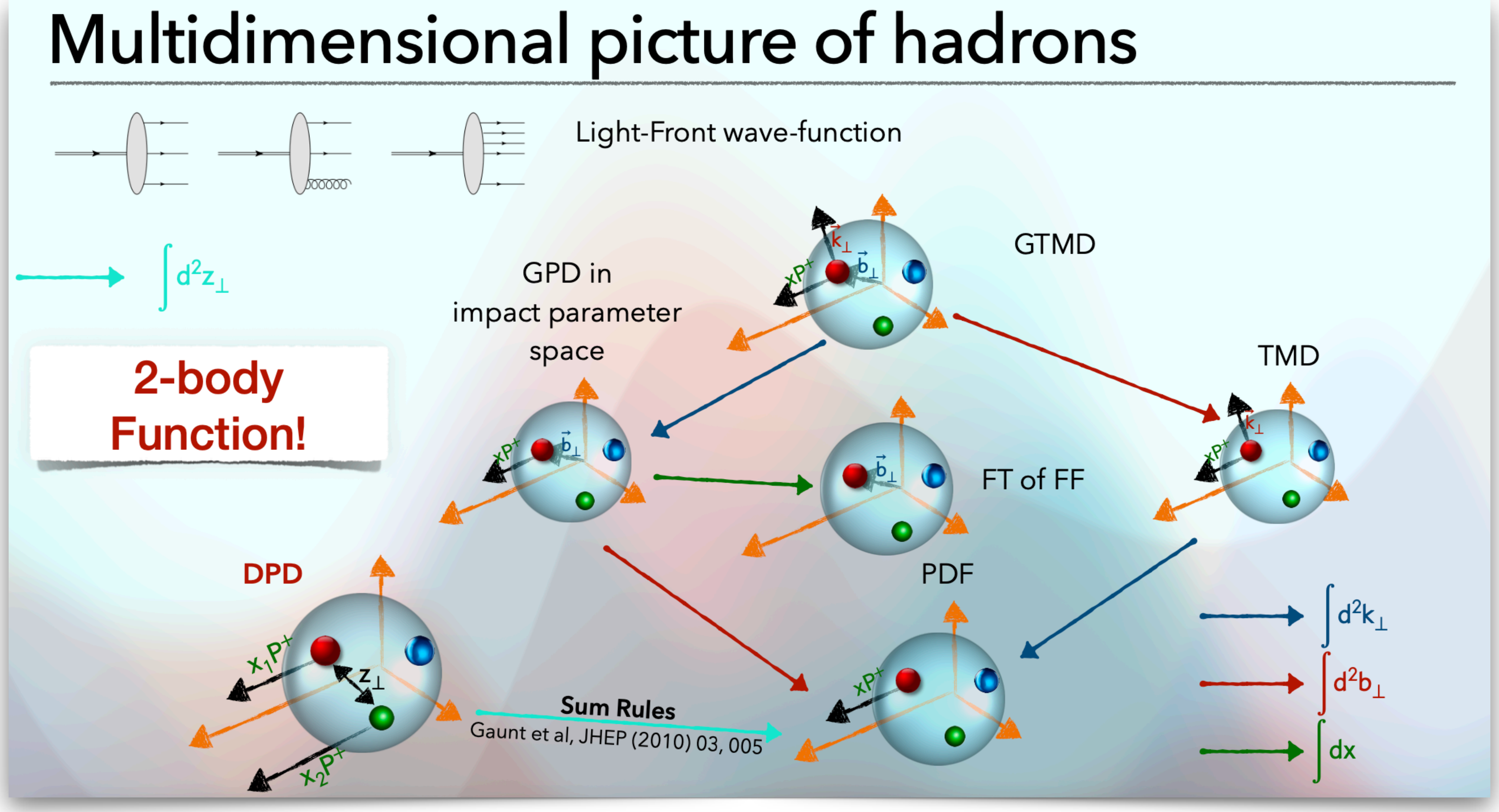

Multidimensional picture of hadrons

Light-Front wave-function

$\int d^2 z_\perp$

2-body Function!

GPD in impact parameter space

GTMD

TMD

FT of FF

DPD

PDF

Sum Rules

Gaunt et al, JHEP (2010) 03, 005

$\int d^2 k_\perp$

$\int d^2 b_\perp$

$\int dx$

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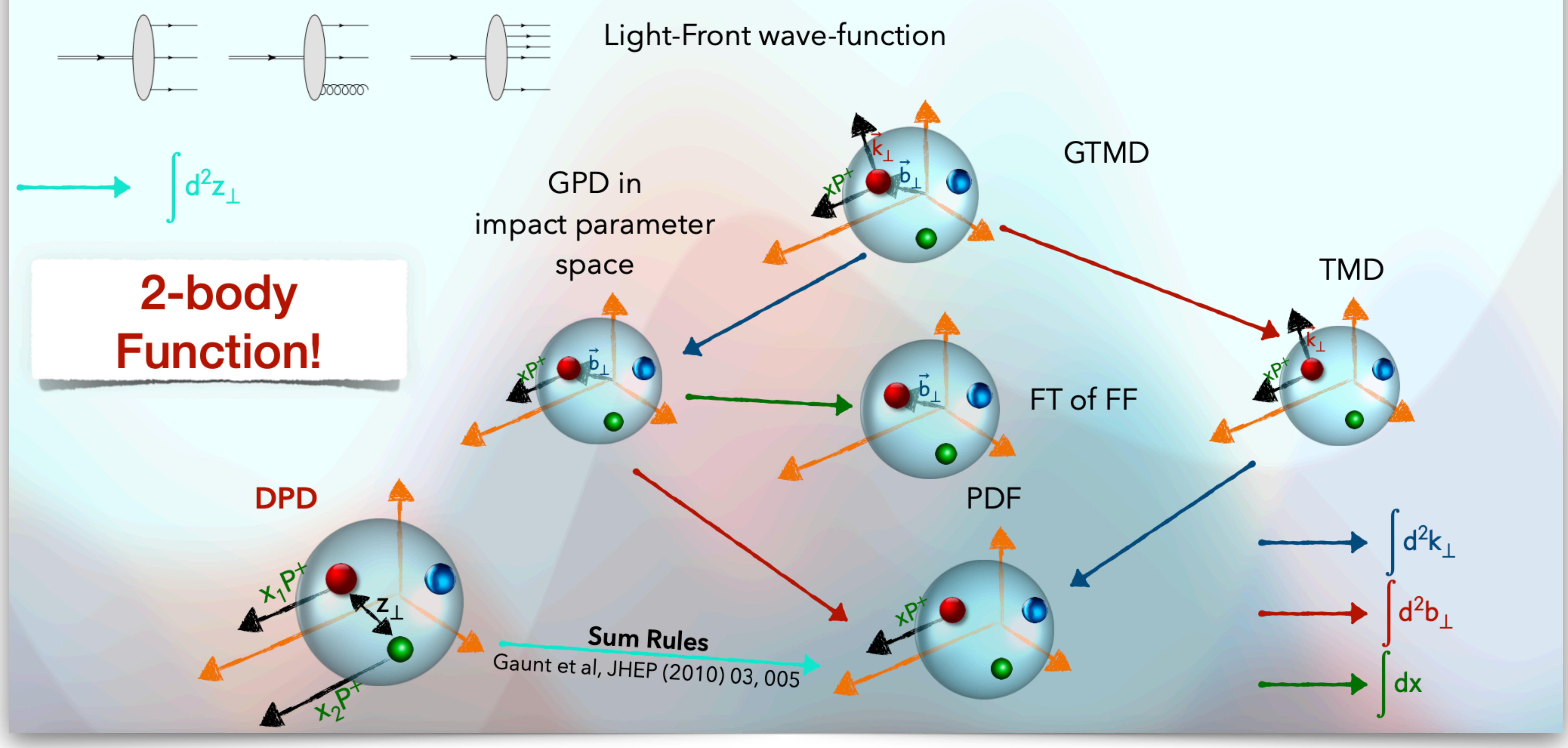
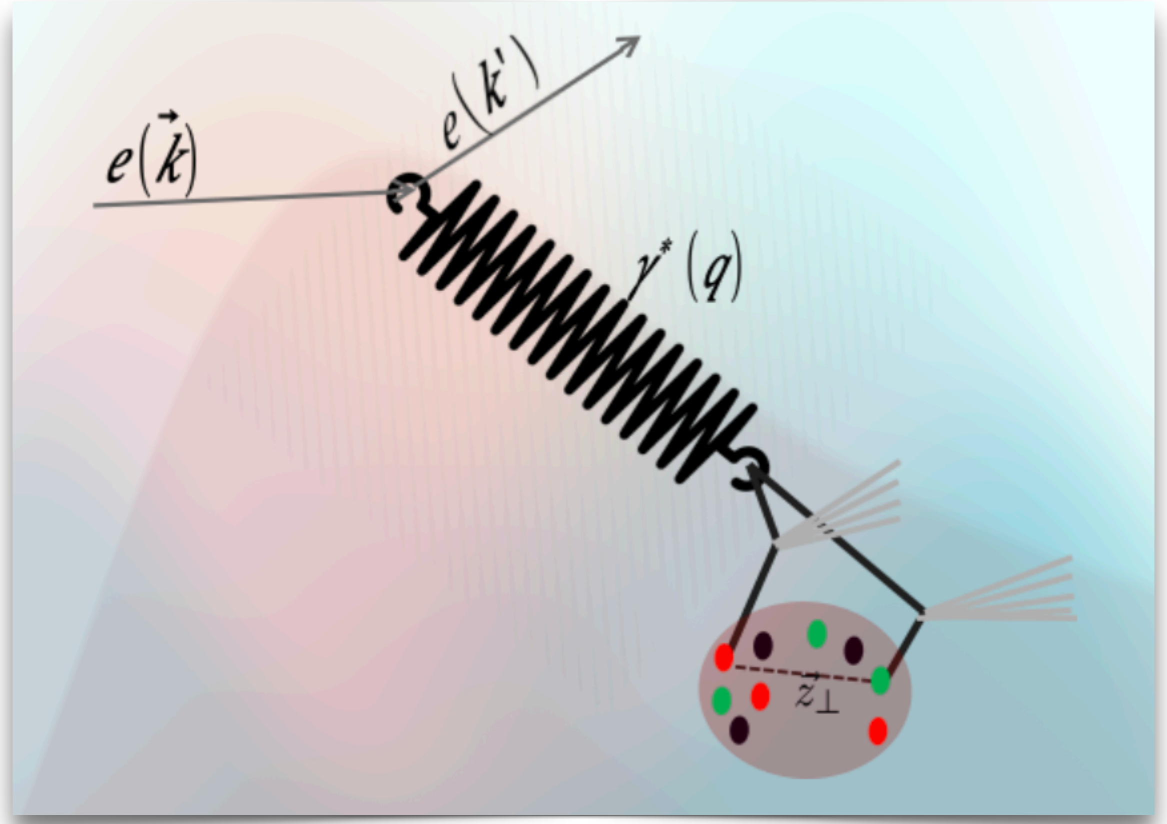


DPS in $\gamma - p$ interactions



M. R. and F. A. Ceccopieri, PRD 105 (2022) L011501

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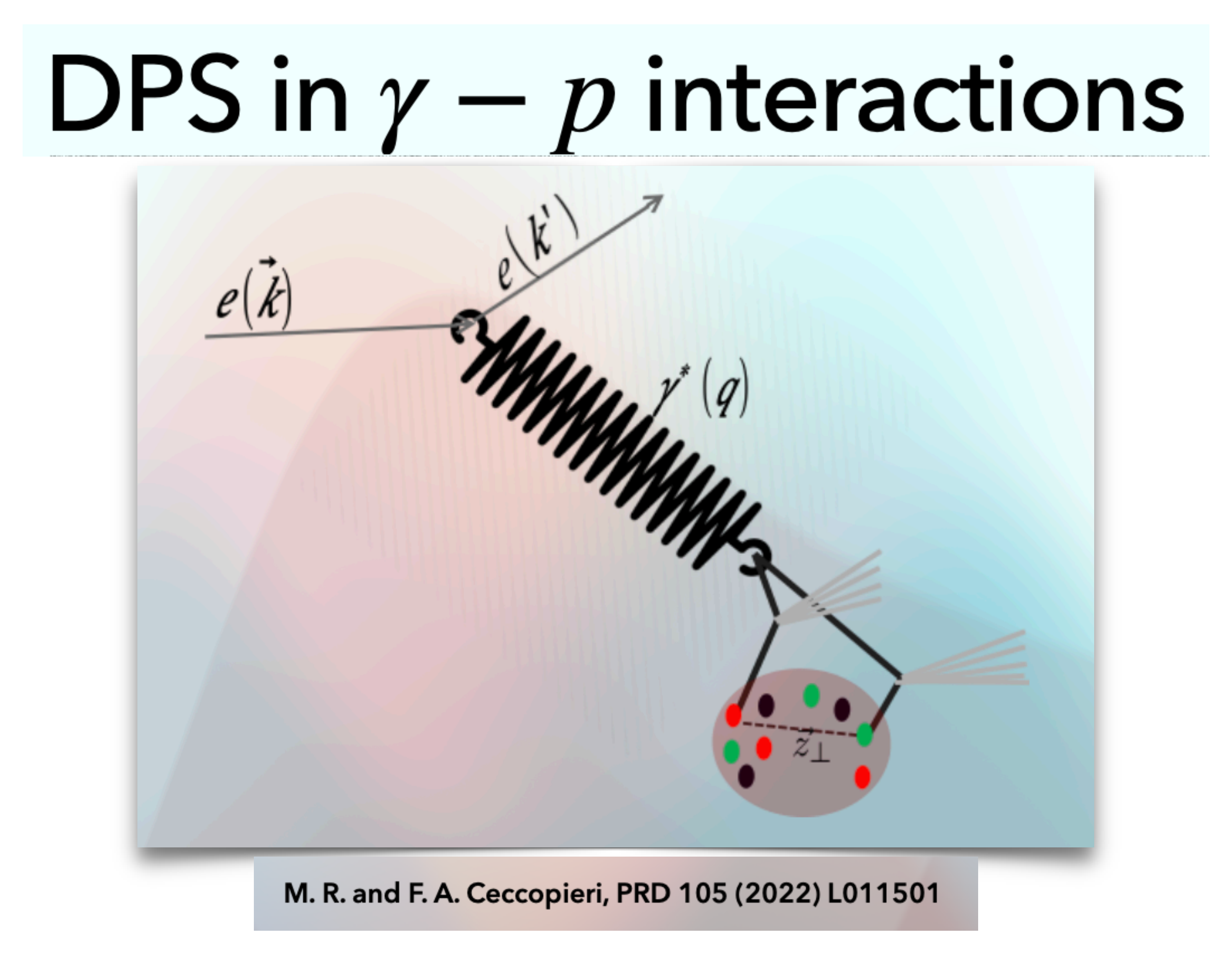

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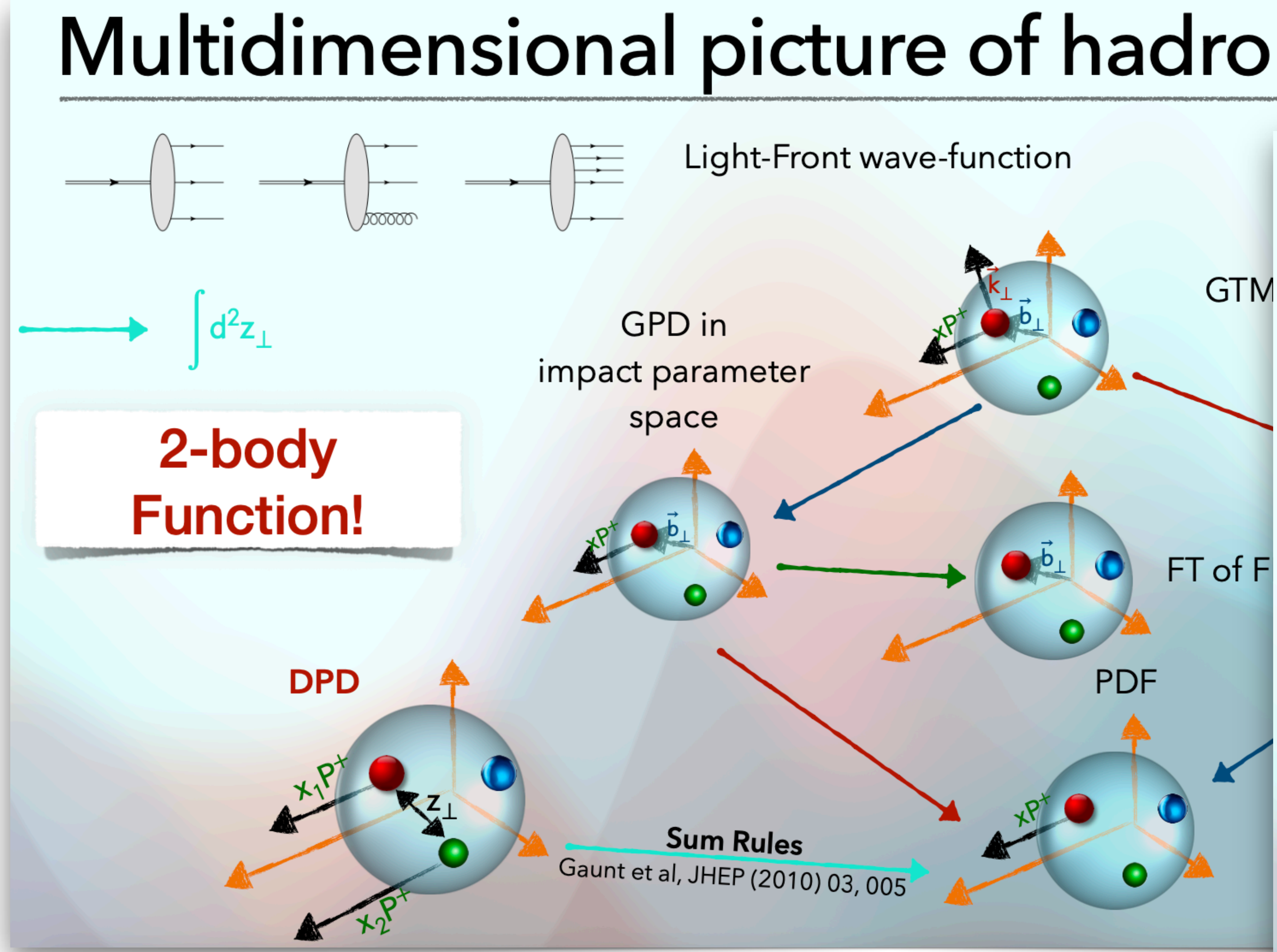

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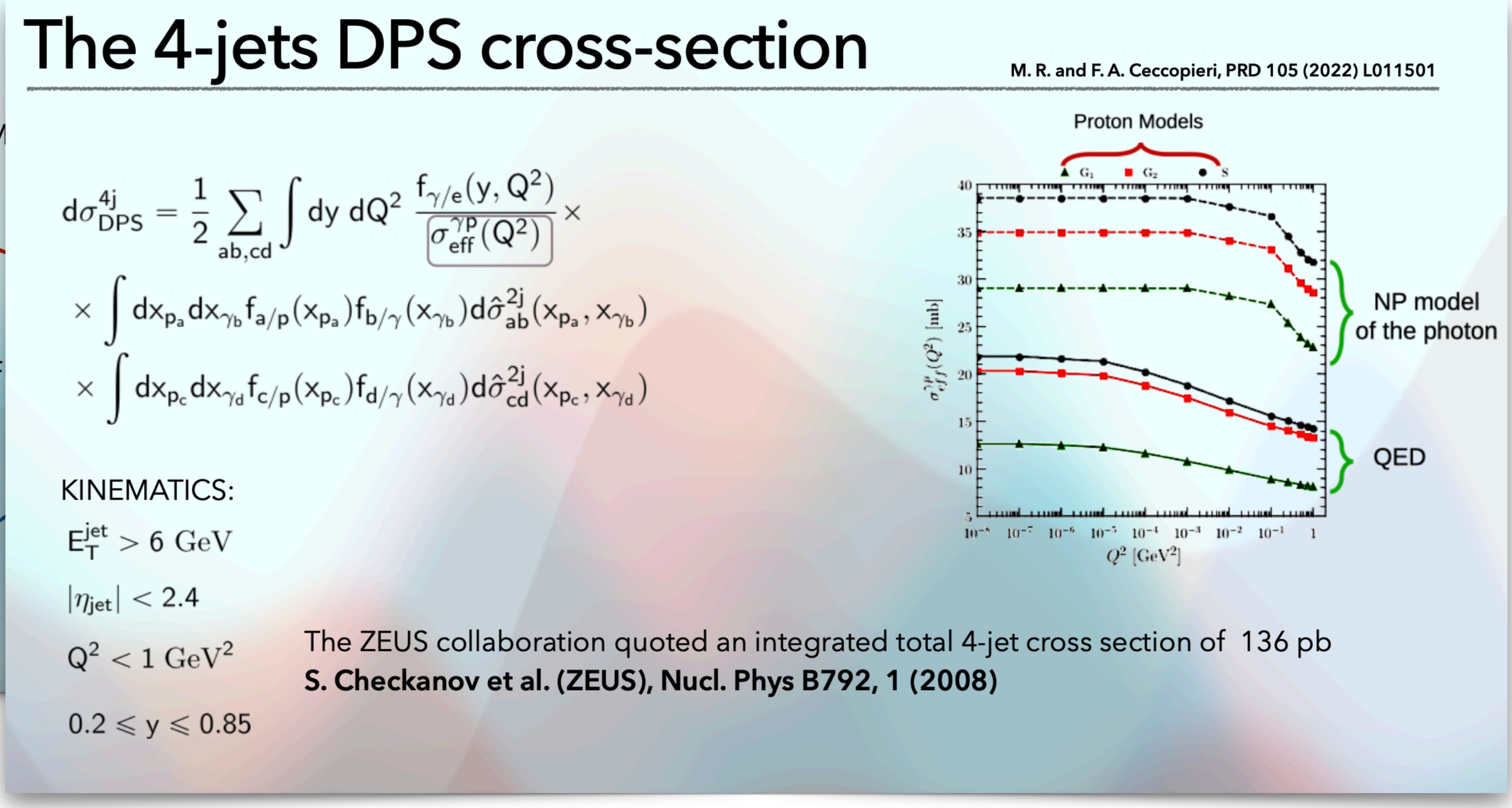


The 4-jets DPS cross-section

M. R. and F. A. Ceccopieri, PRD 105 (2022) L011501

$$d\sigma^{4j}_{DPS} = \frac{1}{2}\sum_{ab,cd}\int dy\, dQ^2 \frac{f_{\gamma/e}(y,Q^2)}{\boxed{\sigma^{\gamma p}_{eff}(Q^2)}} \times$$

$$\times \int dx_{p_a} dx_{\gamma_b} f_{a/p}(x_{p_a}) f_{b/\gamma}(x_{\gamma_b}) d\hat{\sigma}^{2j}_{ab}(x_{p_a}, x_{\gamma_b})$$

$$\times \int dx_{p_c} dx_{\gamma_d} f_{c/p}(x_{p_c}) f_{d/\gamma}(x_{\gamma_d}) d\hat{\sigma}^{2j}_{cd}(x_{p_c}, x_{\gamma_d})$$

KINEMATICS:

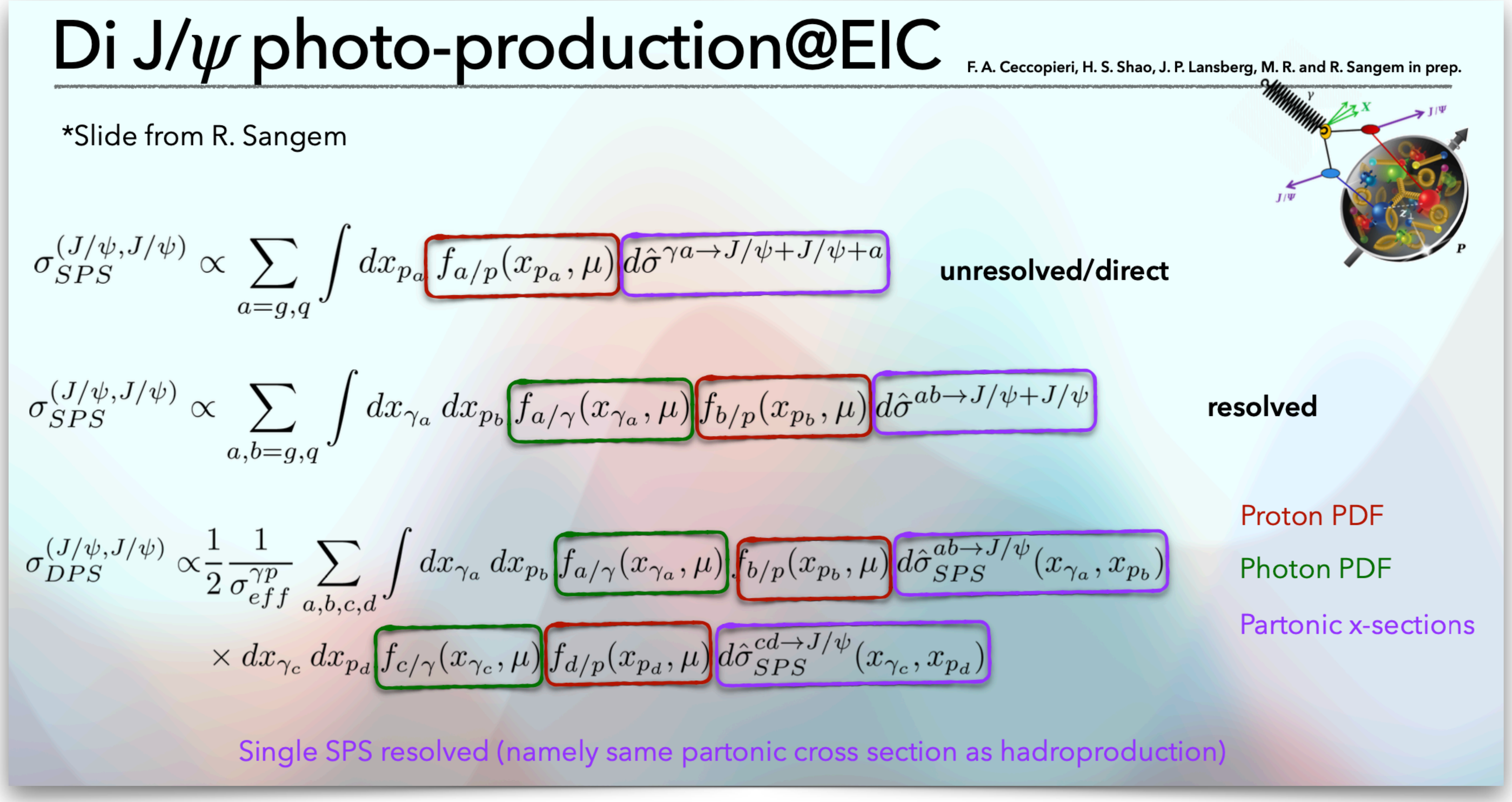
$E^{jet}_T > 6$ GeV

$|\eta_{jet}| < 2.4$

$Q^2 < 1$ GeV^2

$0.2 \leqslant y \leqslant 0.85$

The ZEUS collaboration quoted an integrated total 4-jet cross section of 136 pb
S. Checkanov et al. (ZEUS), Nucl. Phys B792, 1 (2008)



Di J/ψ photo-production@EIC

F. A. Ceccopieri, H. S. Shao, J. P. Lansberg, M. R. and R. Sangem in prep.

*Slide from R. Sangem

$$\sigma^{(J/\psi,J/\psi)}_{SPS} \propto \sum_{a=g,q} \int dx_{p_a} \boxed{f_{a/p}(x_{p_a},\mu)} \boxed{d\hat{\sigma}^{\gamma a \to J/\psi+J/\psi+a}}$$

unresolved/direct

$$\sigma^{(J/\psi,J/\psi)}_{SPS} \propto \sum_{a,b=g,q} \int dx_{\gamma_a}\, dx_{p_b} \boxed{f_{a/\gamma}(x_{\gamma_a},\mu)} \boxed{f_{b/p}(x_{p_b},\mu)} \boxed{d\hat{\sigma}^{ab \to J/\psi+J/\psi}}$$

resolved

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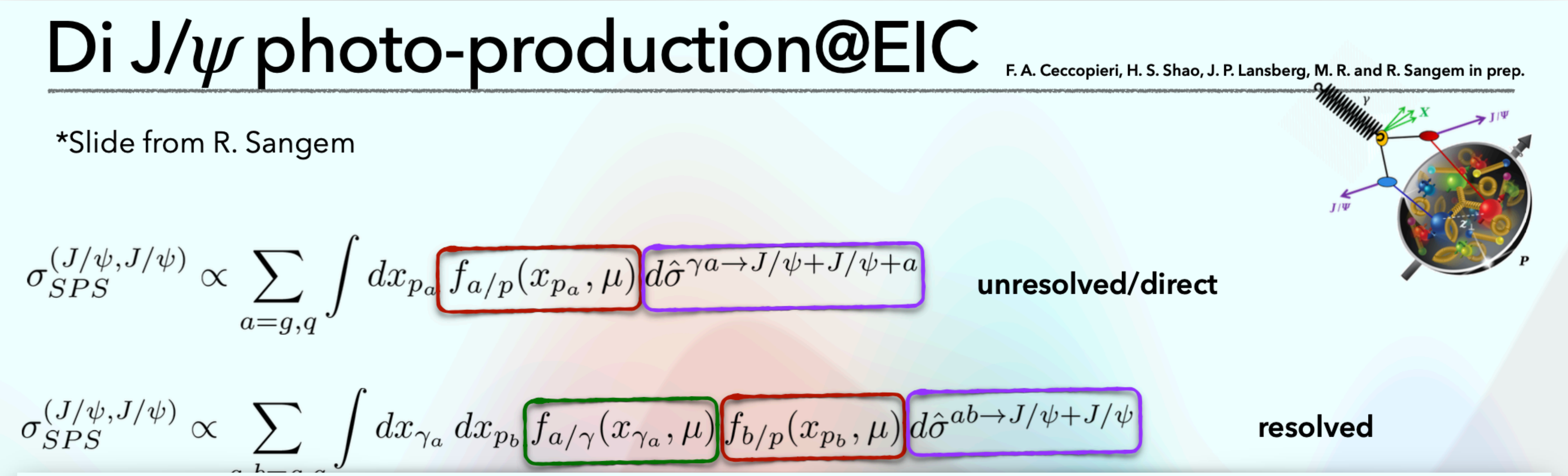
$$\times\, dx_{\gamma_c}\, dx_{p_d} \boxed{f_{c/\gamma}(x_{\gamma_c},\mu)} \boxed{f_{d/p}(x_{p_d},\mu)} \boxed{d\hat{\sigma}^{cd\to J/\psi}_{SPS}(x_{\gamma_c},x_{p_d})}$$

Proton PDF

Photon PDF

Partonic x-sections

Single SPS resolved (namely same partonic cross section as hadroproduction)



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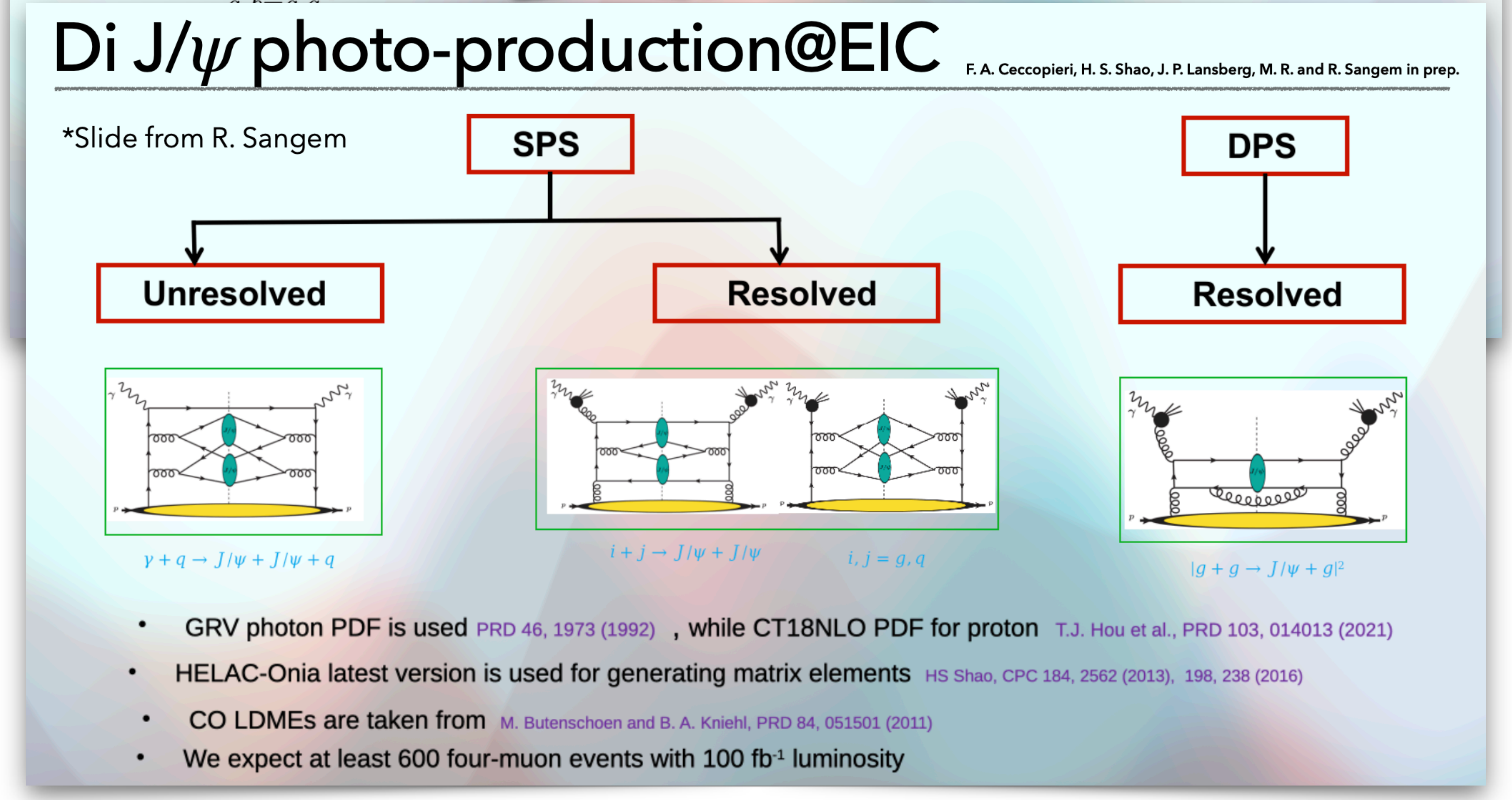
resolved



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SPS

Unresolved

Resolved

DPS

Resolved

$\gamma + q \to J/\psi + J/\psi + q$

$i + j \to J/\psi + J/\psi$ $\quad i, j = g, q$

$|g + g \to J/\psi + g|^2$

- GRV photon PDF is used PRD 46, 1973 (1992) , while CT18NLO PDF for proton T.J. Hou et al., PRD 103, 014013 (2021)
- HELAC-Onia latest version is used for generating matrix elements HS Shao, CPC 184, 2562 (2013), 198, 238 (2016)
- CO LDMEs are taken from M. Butenschoen and B. A. Kniehl, PRD 84, 051501 (2011)
- We expect at least 600 four-muon events with 100 fb^{-1} luminosity

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unresolved/c

$$\sigma_{SPS}^{(J/\psi,J/\psi)} \propto \sum \int dx_{\gamma_a}\, dx_{p_b} \boxed{f_{a/\gamma}(x_{\gamma_a},\mu)} \boxed{f_{b/p}(x_{p_b},\mu)} \boxed{d\hat{\sigma}^{ab \to J/\psi + J/\psi}}$$

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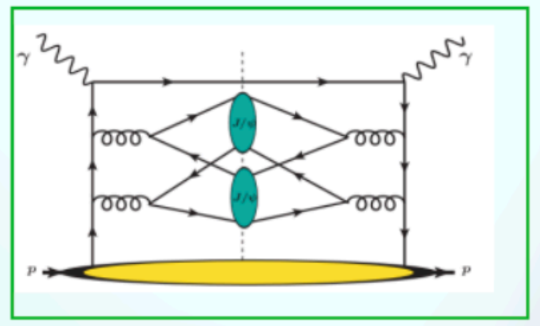
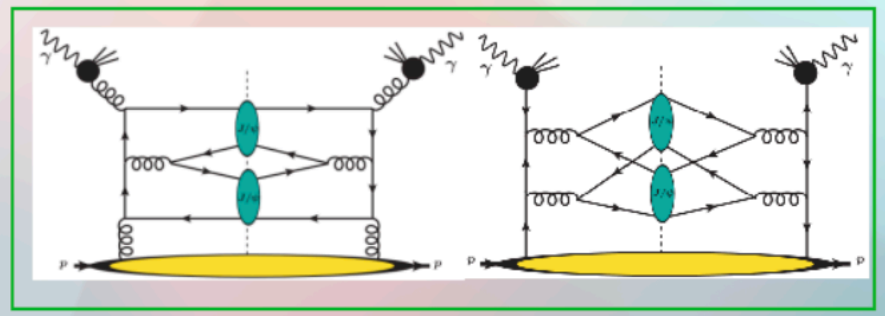
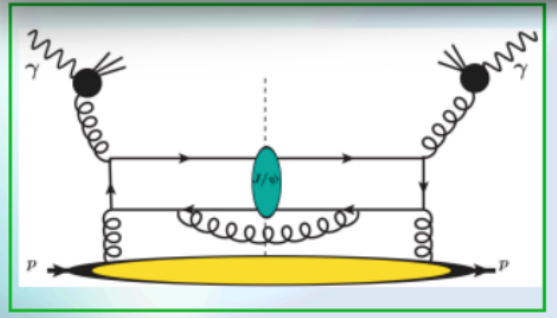


$\gamma + q \to J/\psi + J/\psi + q$



$i + j \to J/\psi + J/\psi$ $i, j = g, q$



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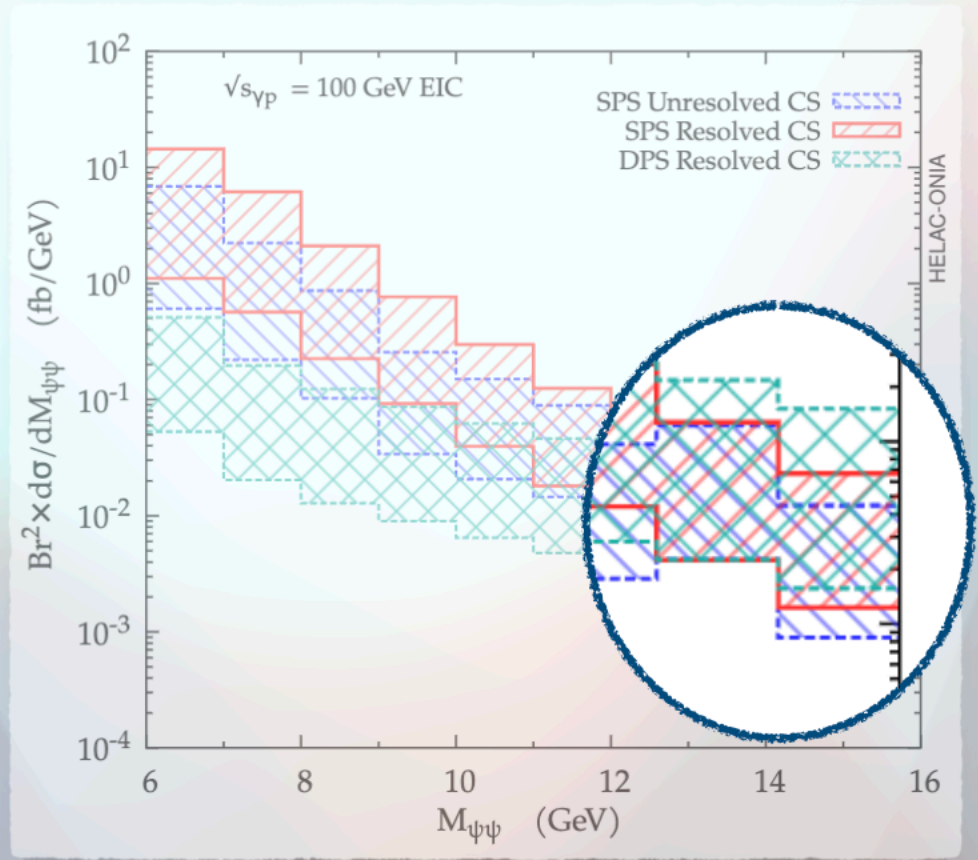
Numerical Results

PRELIMINARY

F. A. Ceccopieri, H. S. Shao, J. P. Lansberg, M. R. and R. Sangem in prep.

Invariant mass of the J/ψ pair

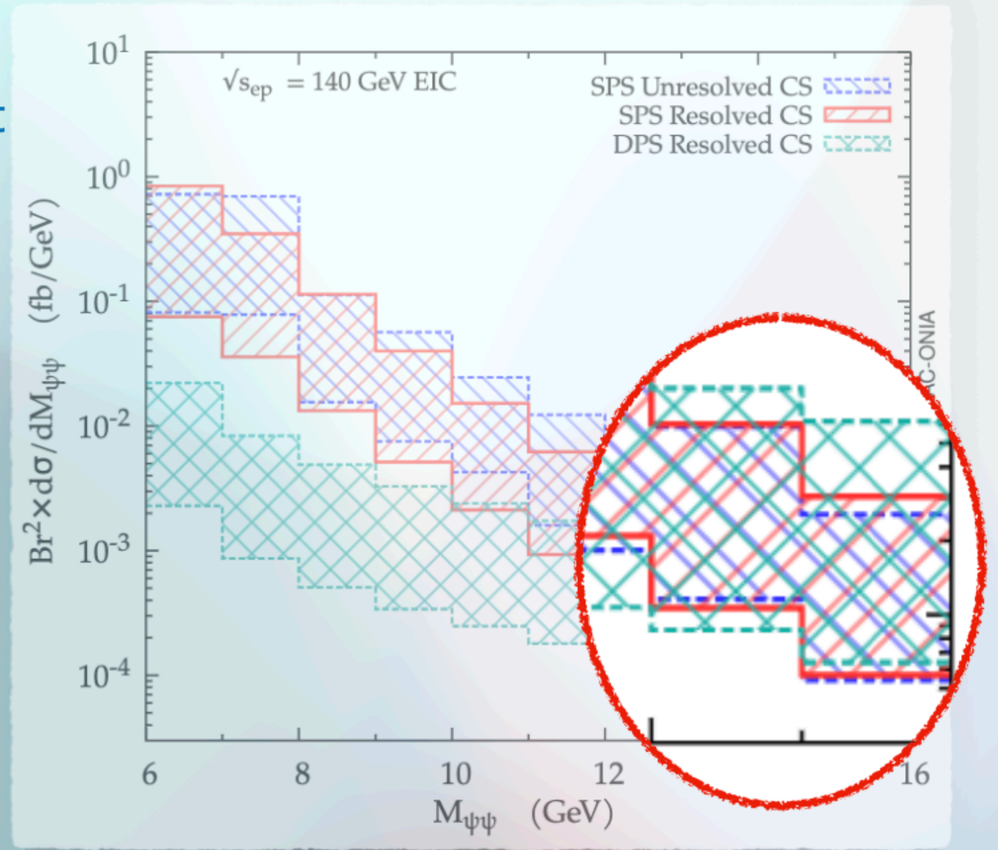
$\sqrt{s_{\gamma p}} = 100$ GeV



a) at low invariant mass:
- DPS smaller then SPS, but not negligible
- DPS negligible

b) at low invariant mass:
- DPS bigger then SPS
- DPS similar to SPS

$\sqrt{s_{\gamma p}} = 140$ GeV



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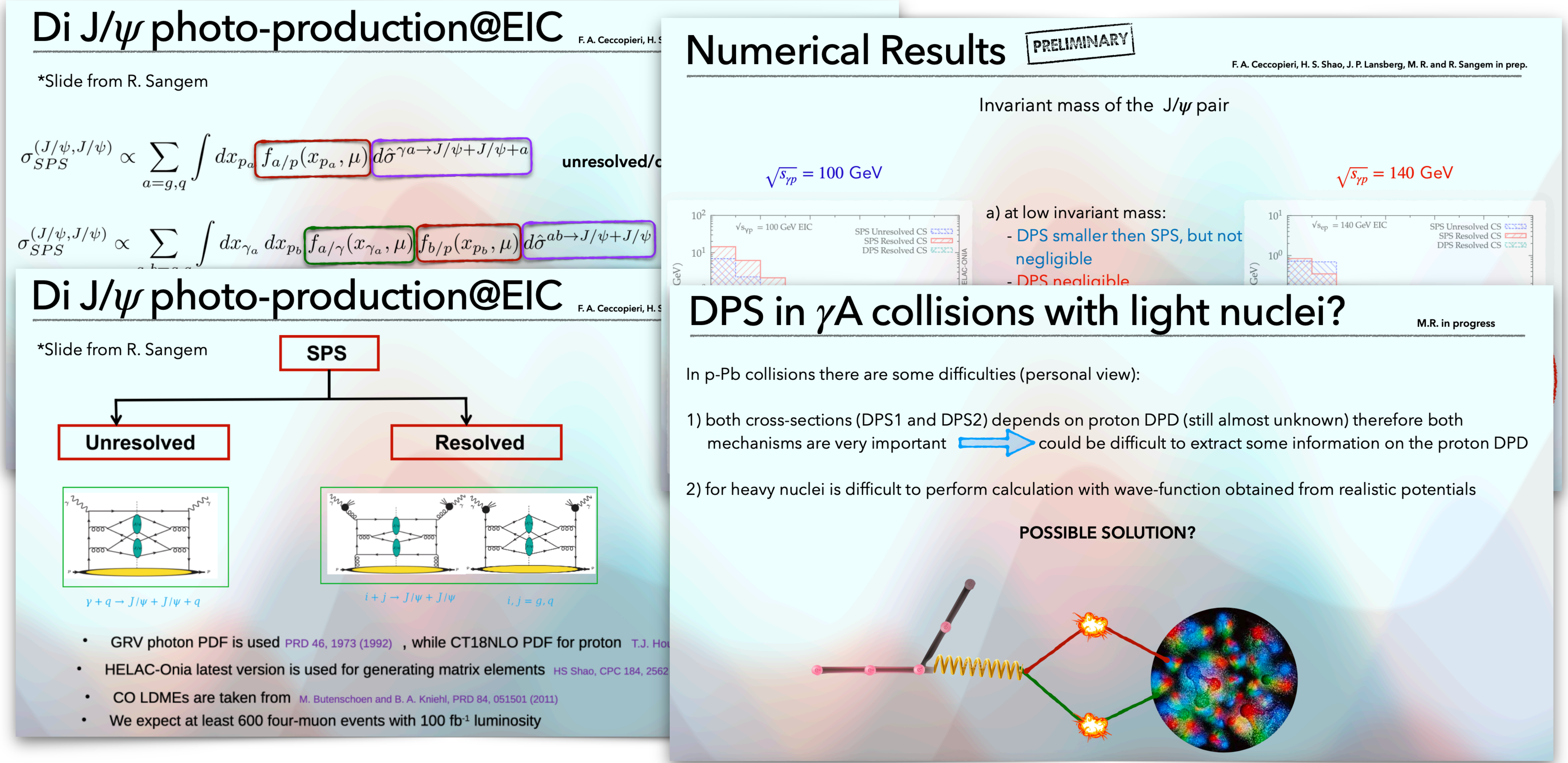

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DPS in γA collisions with light nuclei?

M.R. in progress

In p-Pb collisions there are some difficulties (personal view):

1) both cross-sections (DPS1 and DPS2) depends on proton DPD (still almost unknown) therefore both mechanisms are very important ⇒ could be difficult to extract some information on the proton DPD

2) for heavy nuclei is difficult to perform calculation with wave-function obtained from realistic potentials

POSSIBLE SOLUTION?

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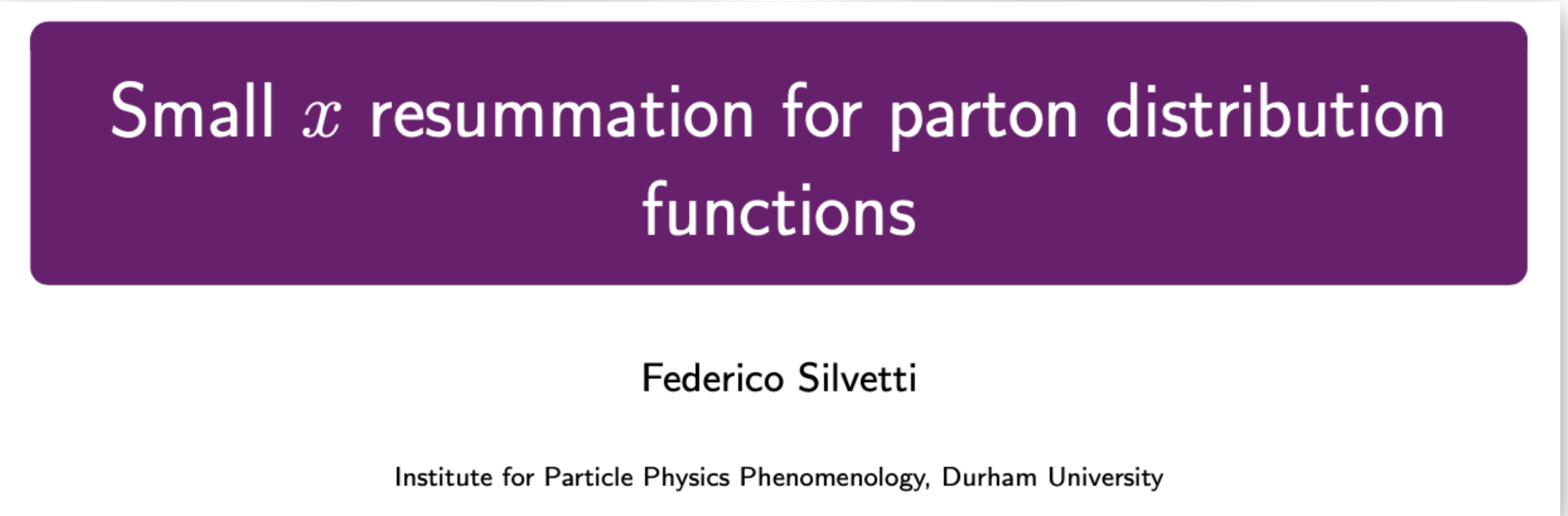

Small x resummation for parton distribution functions

Federico Silvetti

Institute for Particle Physics Phenomenology, Durham University

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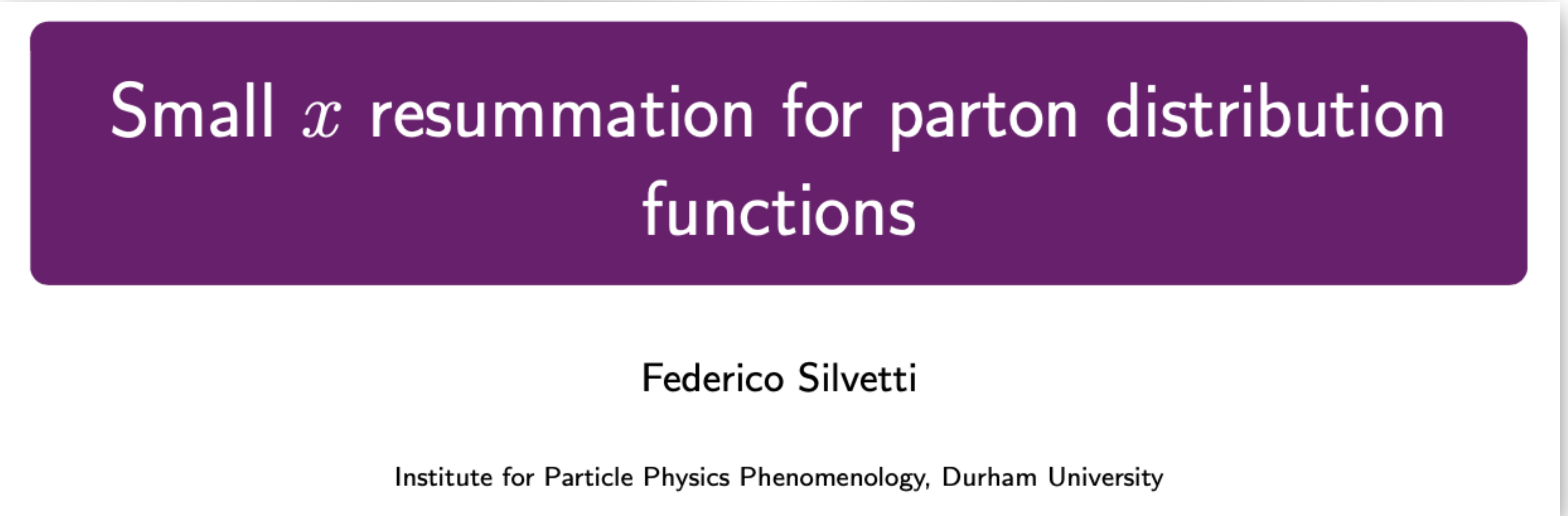

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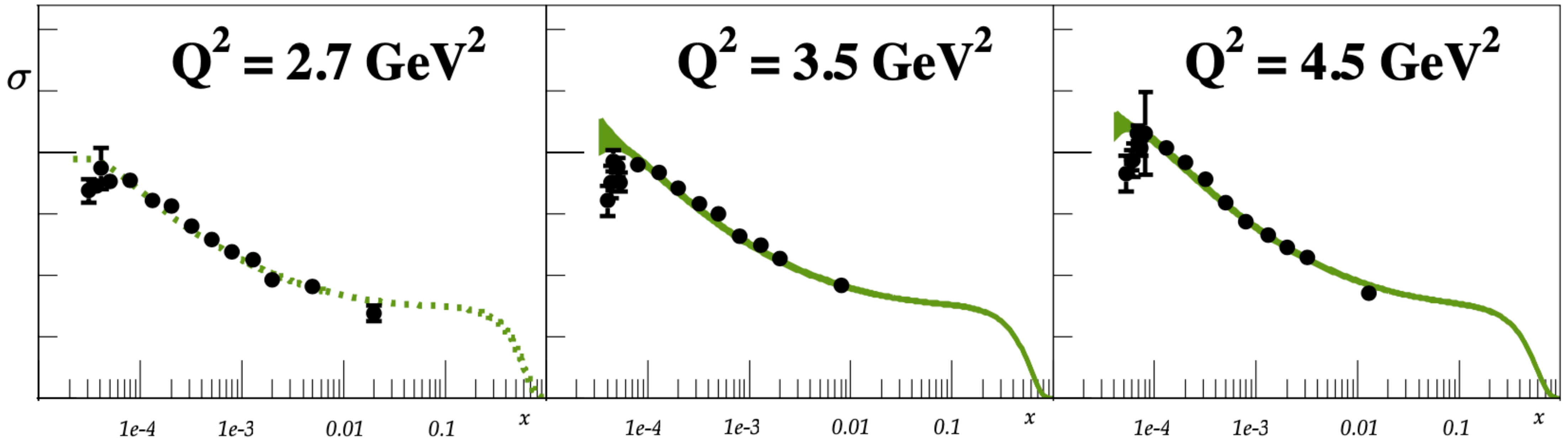
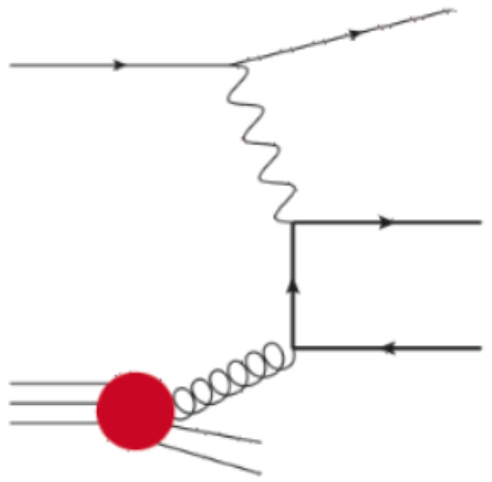
Deep-inelastic scattering (DIS) data from HERA extend down to $x \sim 3 \times 10^{-5}$

Tension between HERA data with theory at low Q^2 and low x





deterioration of the χ^2 when including low-Q^2 data

$F_L = \mathcal{O}(\alpha_s)$ and gluon dominated

→sensitivity to small-x resummation

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Small-x resummation

Collinear factorisation:

$$\sigma(x,Q^2) = \int_x^1 \frac{\mathrm{d}z}{z} C_i(z,\alpha_s(Q^2)) f_i\left(\frac{x}{z},Q^2\right)$$

DGLAP evolution:

$$\mu^2 \frac{\mathrm{d}f_i(x,\mu^2)}{\mathrm{d}\mu^2} = \int_x^1 \frac{\mathrm{d}z}{z} P_{ij}(z,\alpha_s(\mu^2)) f_j\left(\frac{x}{z},\mu^2\right)$$

k_t-factorisation: [Catani, Hautmann hep-ph/9405388]

$$\sigma(x,Q^2) = \int_x^1 \frac{\mathrm{d}z}{z} \int \mathrm{d}k_t^2\, \mathcal{C}_g\left(\frac{x}{z},\alpha_s,Q^2,k_t^2\right) \mathcal{F}_g(z,Q^2,k_t^2) + \ldots$$

BFKL equation singlet sector, $t = \log(1/x)$:

$$\frac{\mathrm{d}}{\mathrm{d}t} f(t,q^2) = \int_0^\infty \frac{\mathrm{d}k^2}{k^2} K\left(\frac{q^2}{k^2},\alpha_s\right) f(t,k^2)$$

for further reading: [Altarelli, Forte hep-ph/9703417], [Bonvini 1212.0480]

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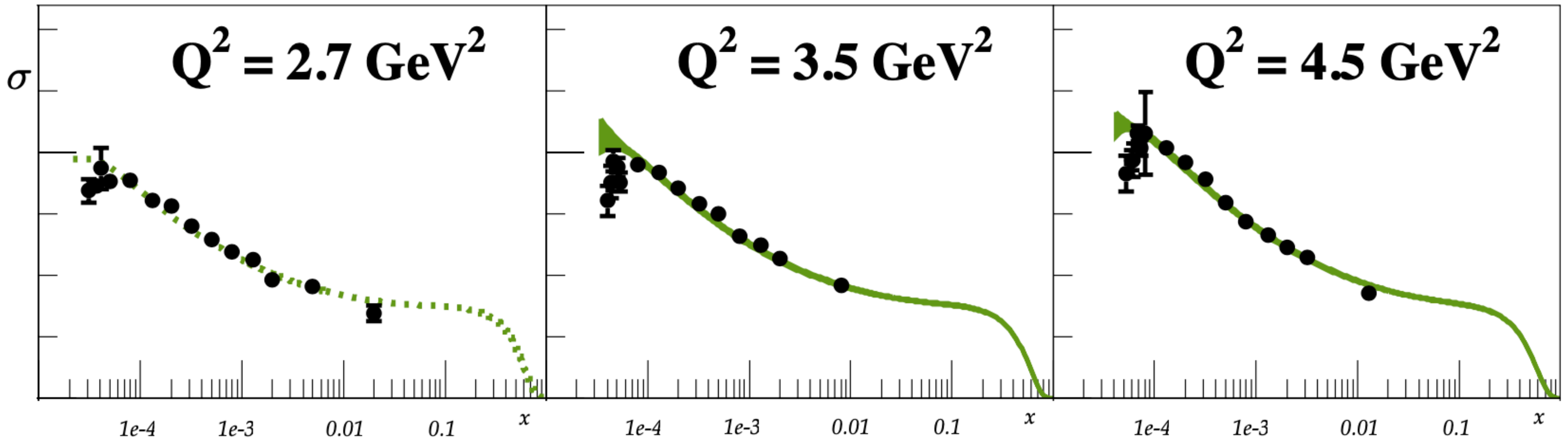

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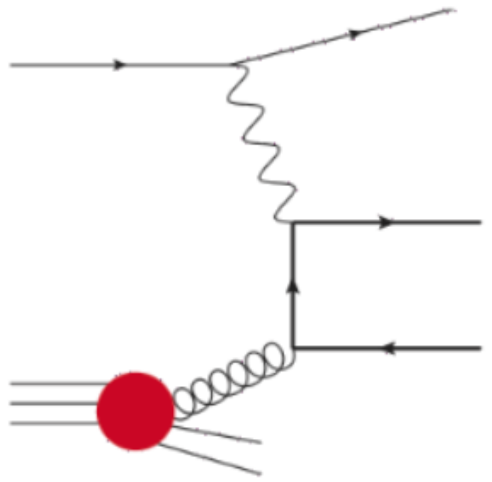

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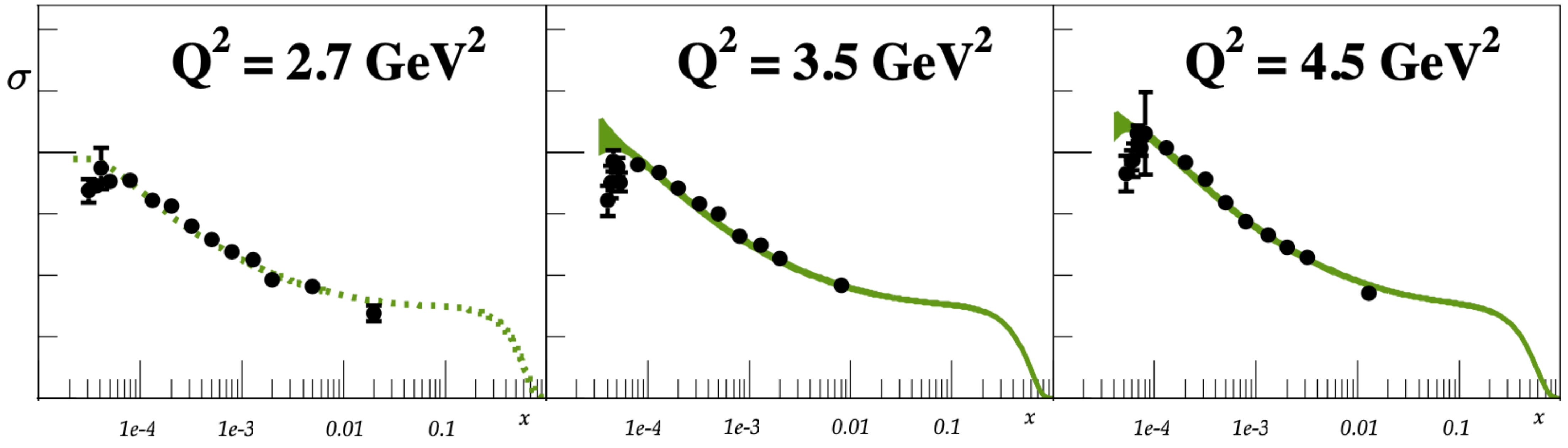

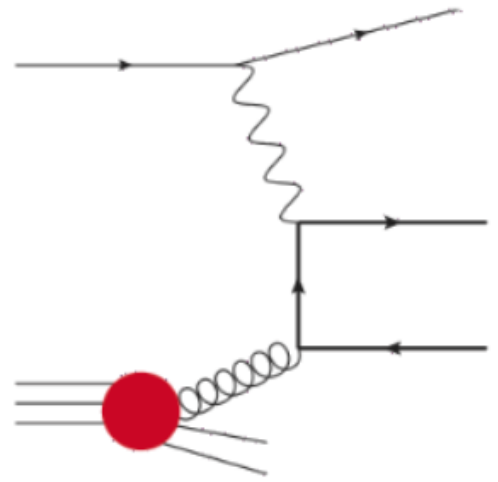

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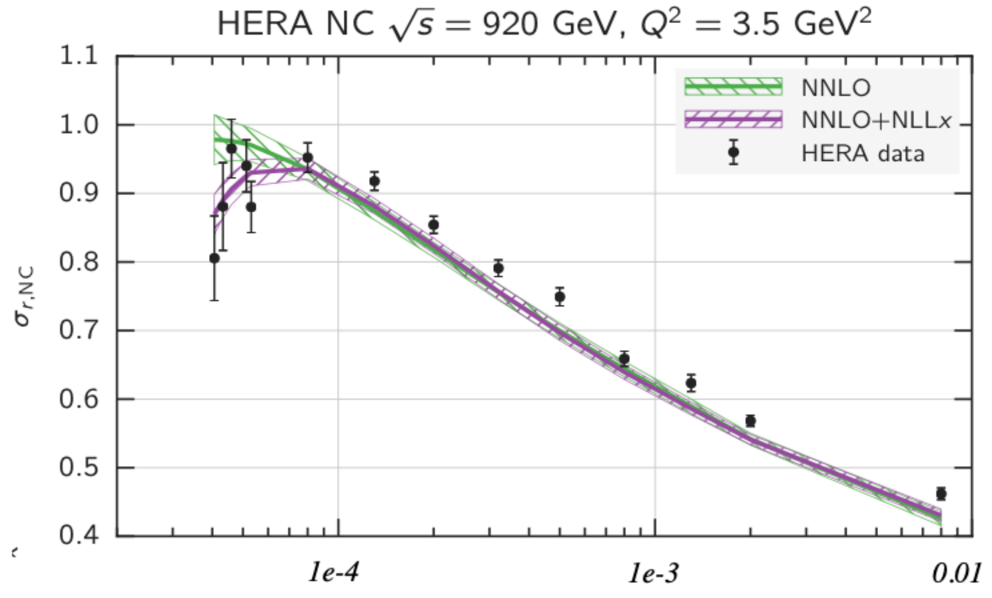
Successful description of this region when including small-x resummation!

- NNPDF3.1 framework [Ball,Bertone,Bonvini,Marzani,Rojo,Rottoli 1710.05935]
- xFitter framework [xFitterCollaboration,Bonvini 1802.00064]

Turnover reproduced →

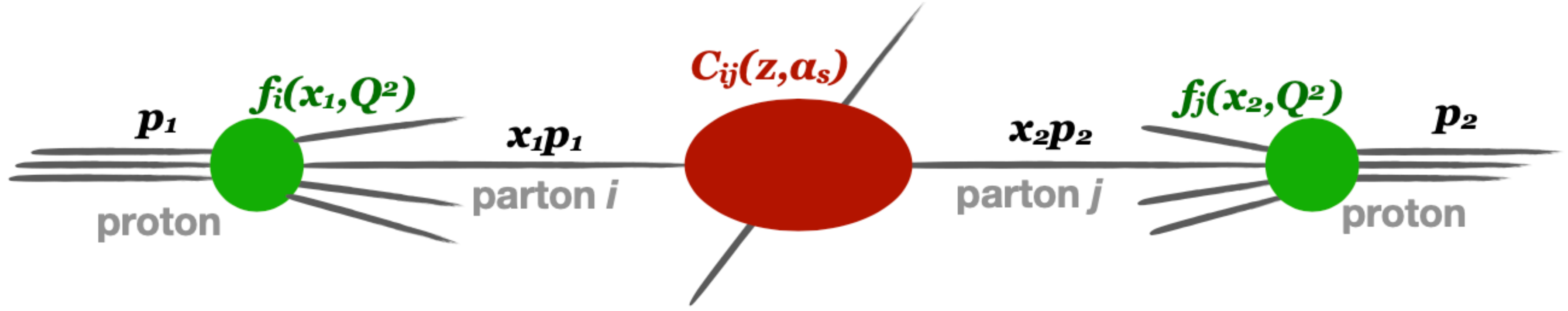


Resummation of LHC observables

Differential cross section in collinear factorization

$$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2\mathrm{d}Y\dots} = \int_x^1 \frac{\mathrm{d}z}{z}\int \mathrm{d}\hat{y}\,\mathscr{L}_{ij}\left(\frac{x}{z},\hat{y},Q^2\right)\frac{\mathrm{d}C_{ij}}{\mathrm{d}y\dots}(z,Y-\hat{y},\dots,\alpha_s)$$

$$\mathscr{L}_{ij}(x,\hat{y},Q^2) = f_i(\sqrt{x}e^{\hat{y}},Q^2)\,f_j(\sqrt{x}e^{-\hat{y}},Q^2)\,\vartheta(e^{-2|\hat{y}|}-x)$$



$\frac{Q^2}{s} = x < z$

note: typically $\sqrt{z}e^{\pm\hat{y}} \sim \sqrt{x}$

Processes considered so far in `HELL`:

- $gg \to H$ (inclusive cross section) →(pending fully differential)
  [Bonvini,Marzani 1802.07758] [Bonvini 1805.08785]
- $c\bar{c}$, $b\bar{b}$ pair production (fully differential) [Bonvini,FS 2211.10142]
- Drell-Yan (fully differential) *(in progress)*

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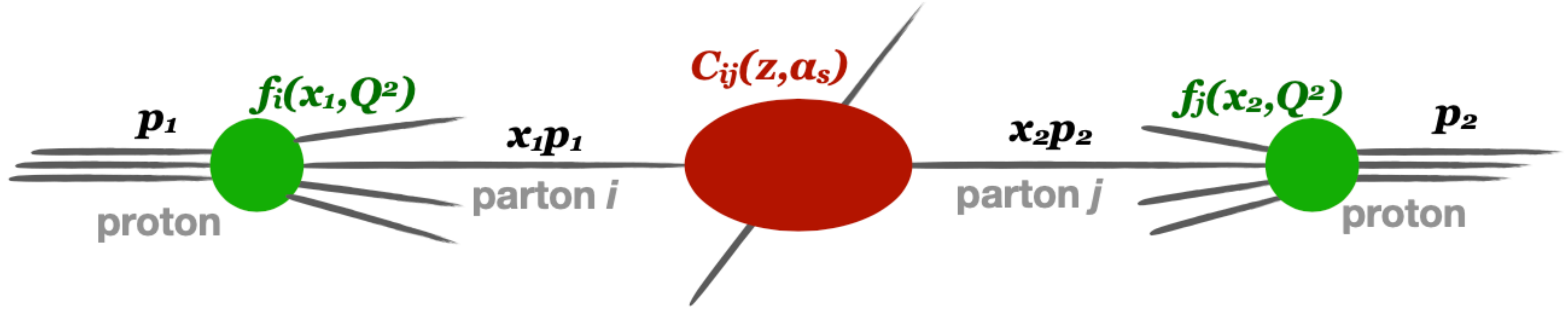

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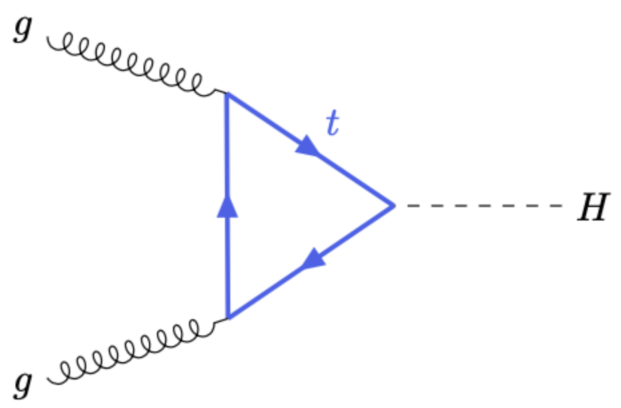

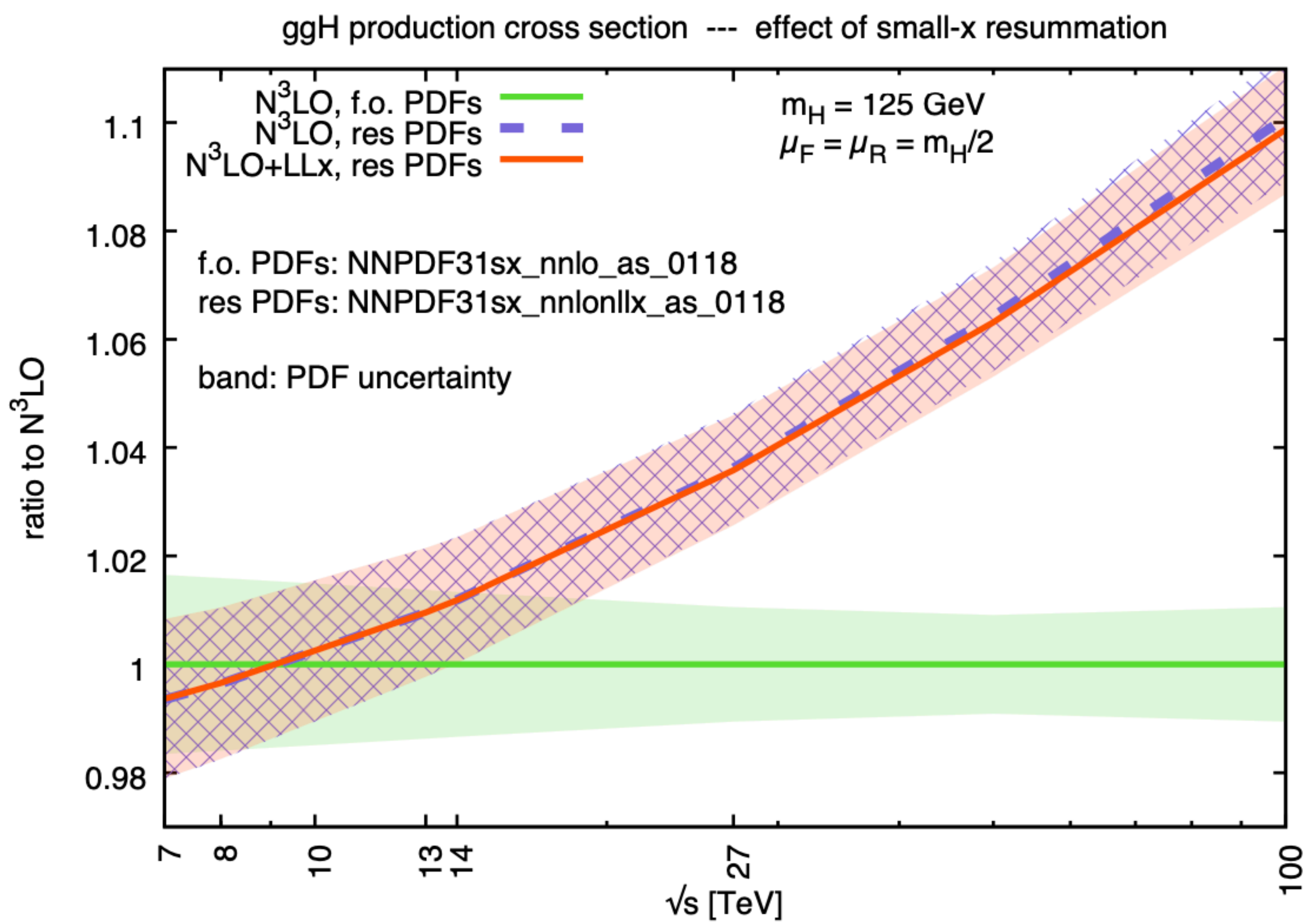

Resummation of LHC observables

Differential cross section in collinear factorization

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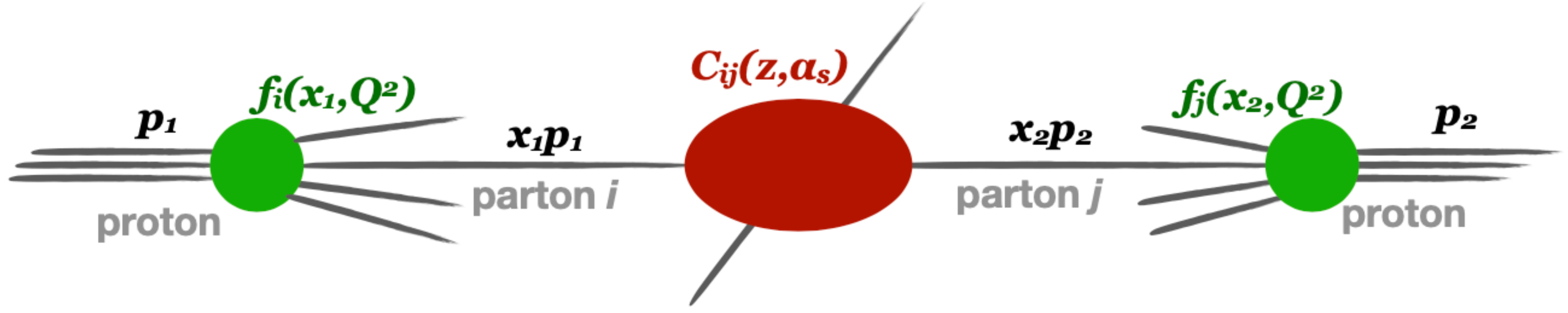

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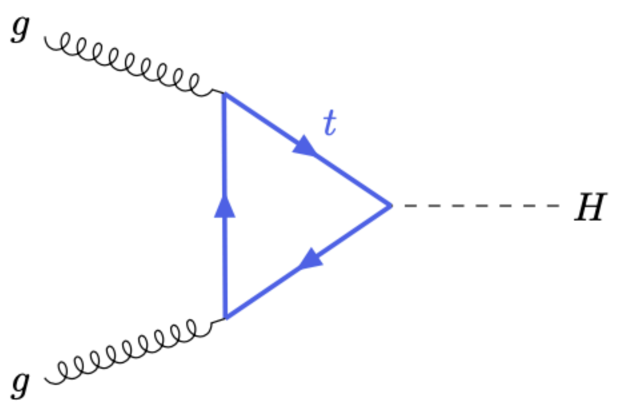
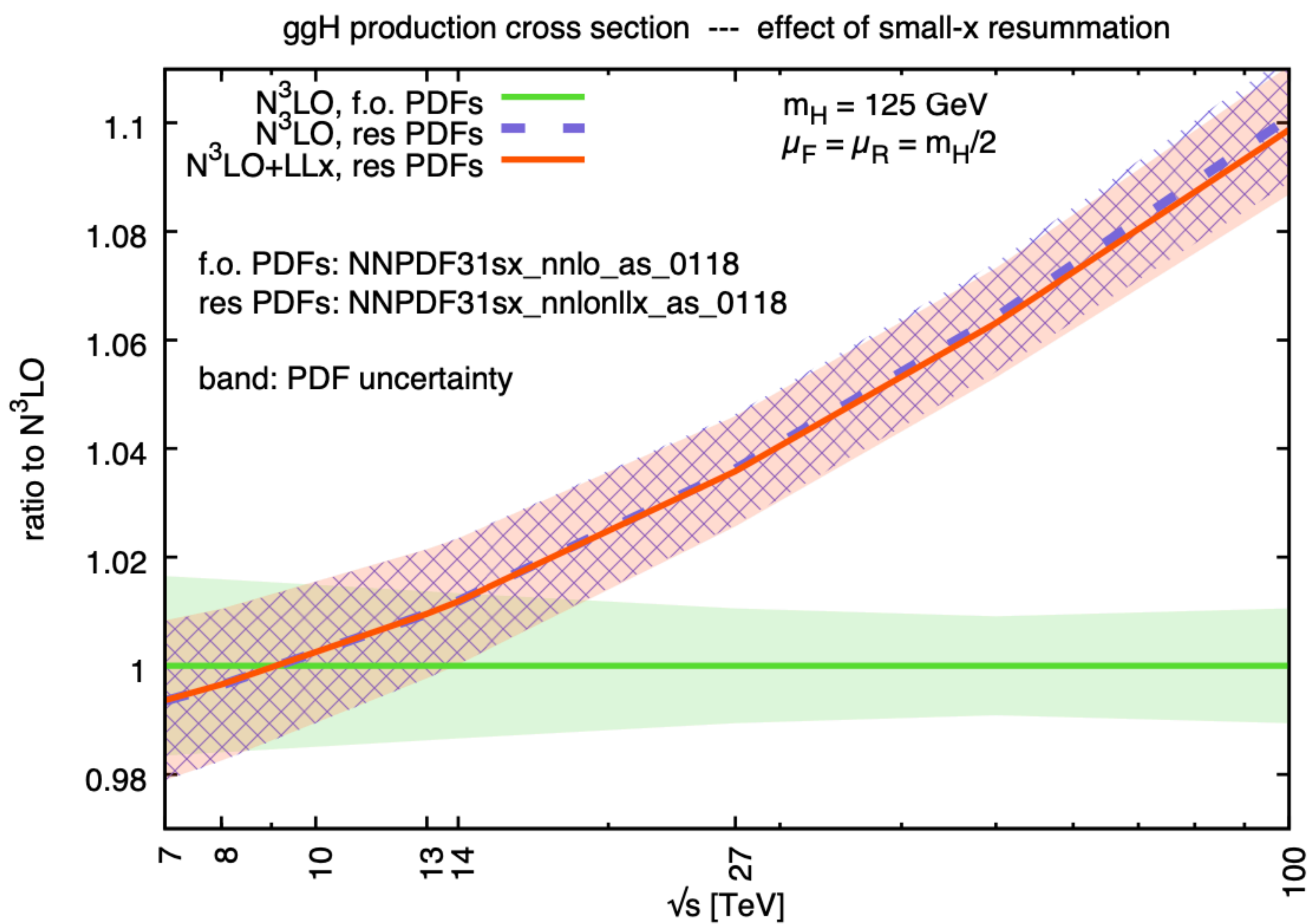
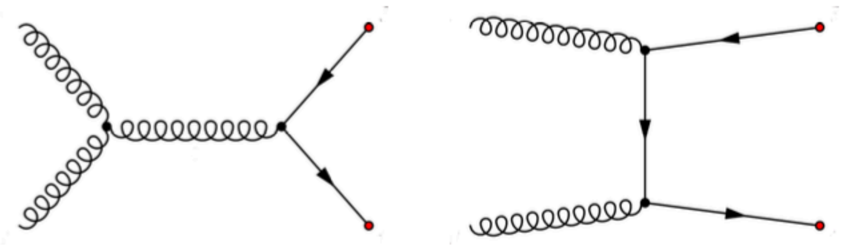




Fully differential heavy-quark pair production [Bonvini,FS 2211.10142]



$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2\,\mathrm{d}Y\,\mathrm{d}q_t} \to$ pair kinematics

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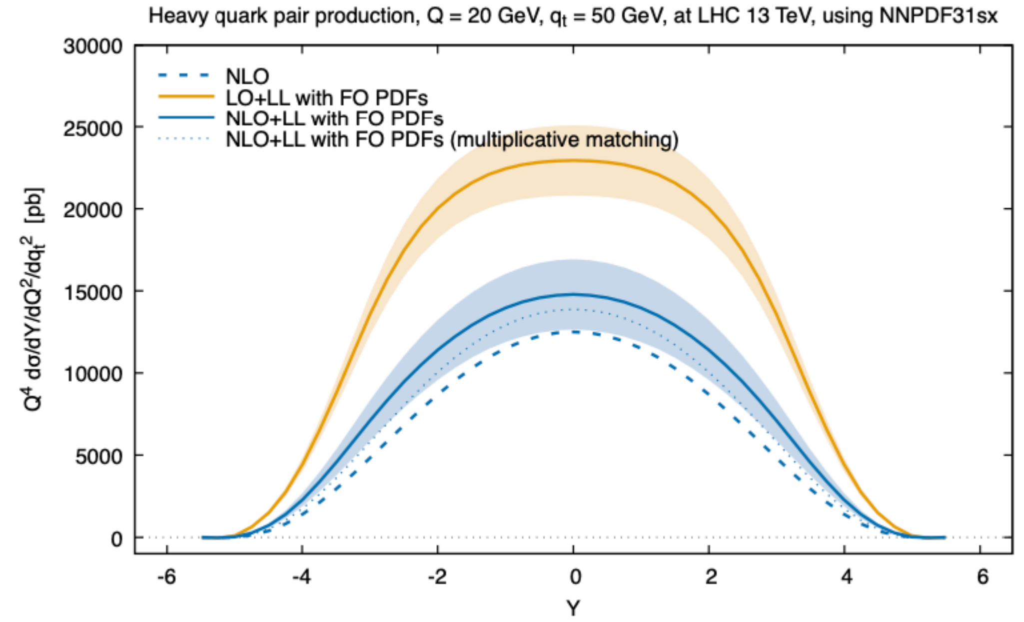
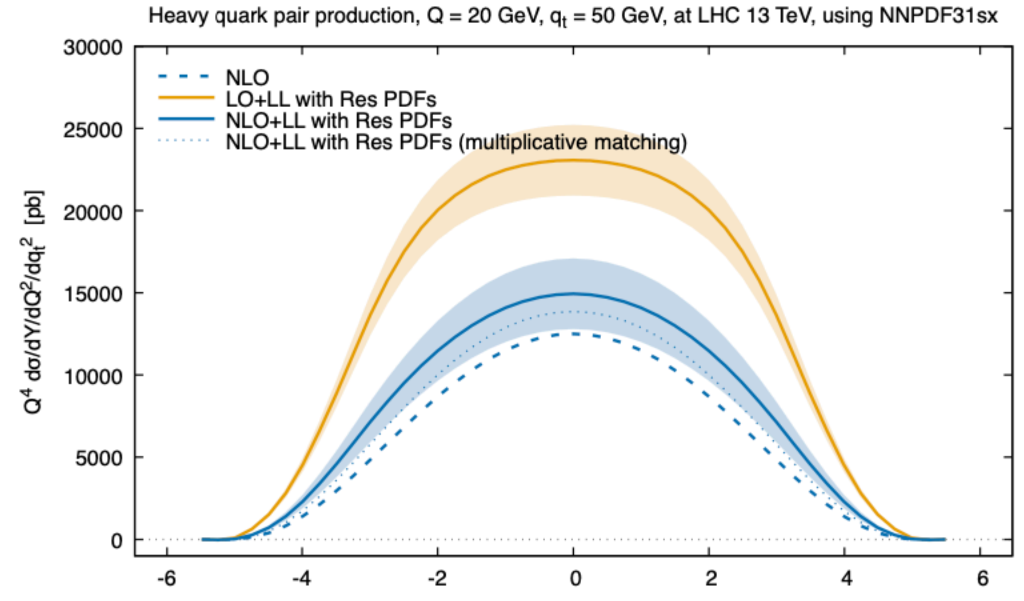
Small-x resummation crucial for **charm and bottom production**

Key process at forward physics experiment e.g. FPF [Feng et al 2203.05090]



FO PDFs ↑ **↓ Resummed PDFs**



FEDERICO SILVETTI

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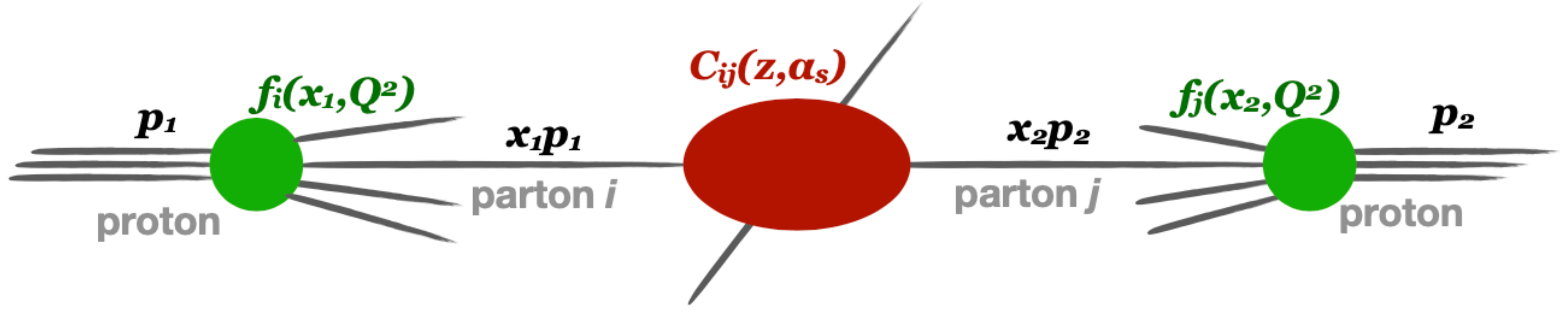

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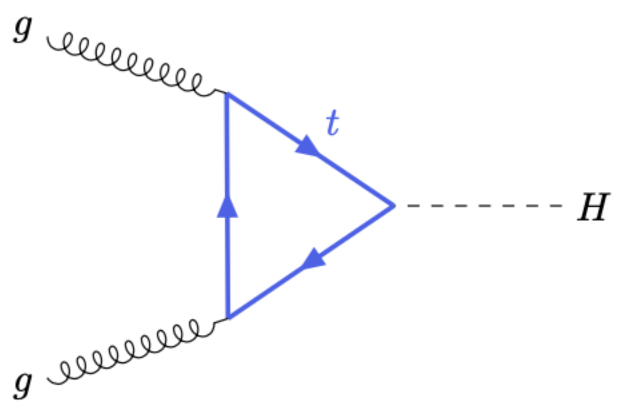
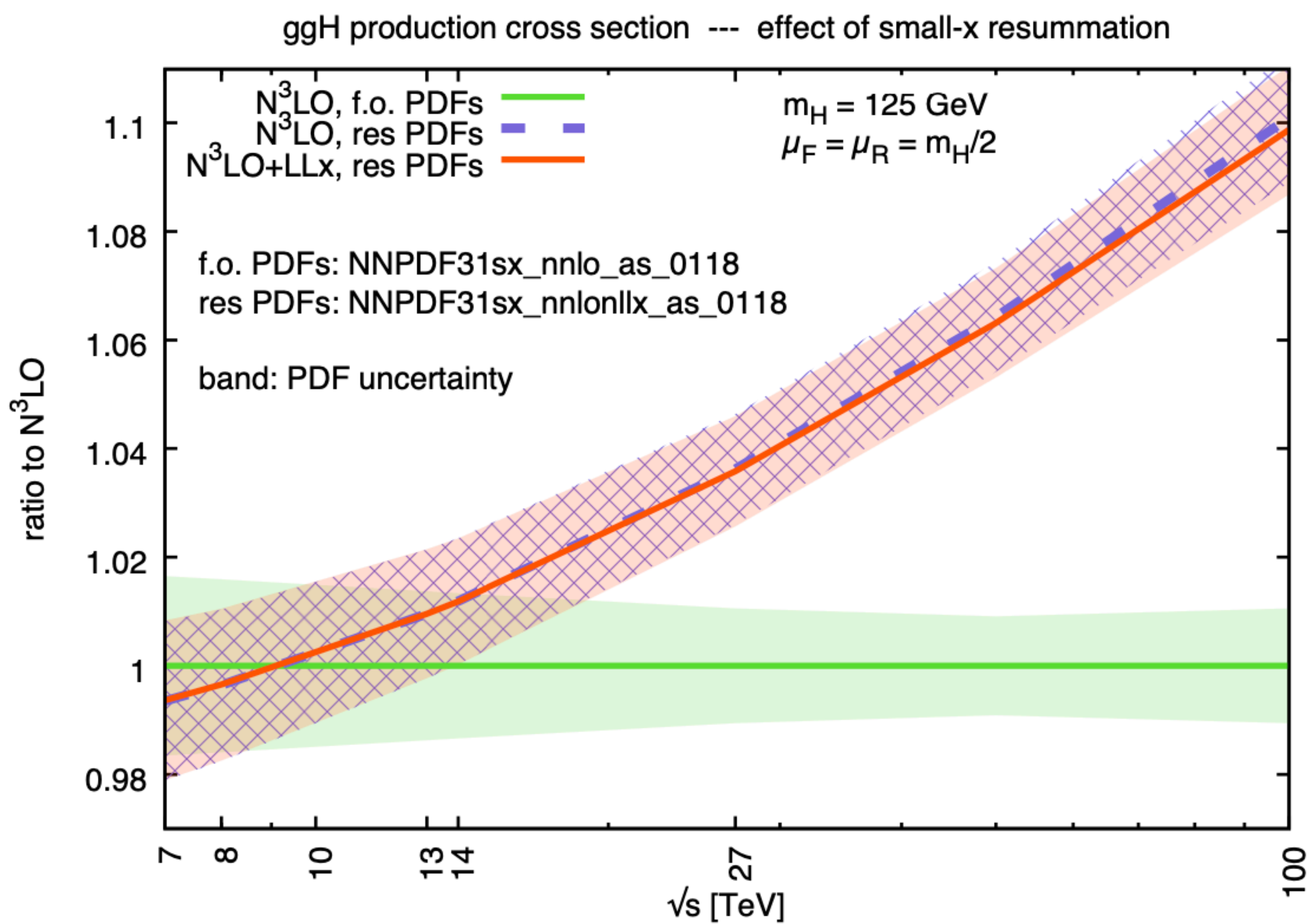
Key messages:

- Resummation is needed at small-x, especially $x \lesssim 10^{-3}$
- Significant impact expected at LHC at low invariant mass and large rapidity
- Future colliders will be sensitive to this effect

$gg \to H$ inclusive cross section [Bonvini,Marzani 1802.07758] [Bonvini 1805.08785]





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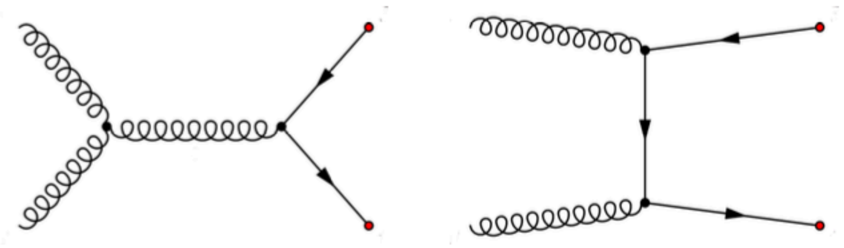

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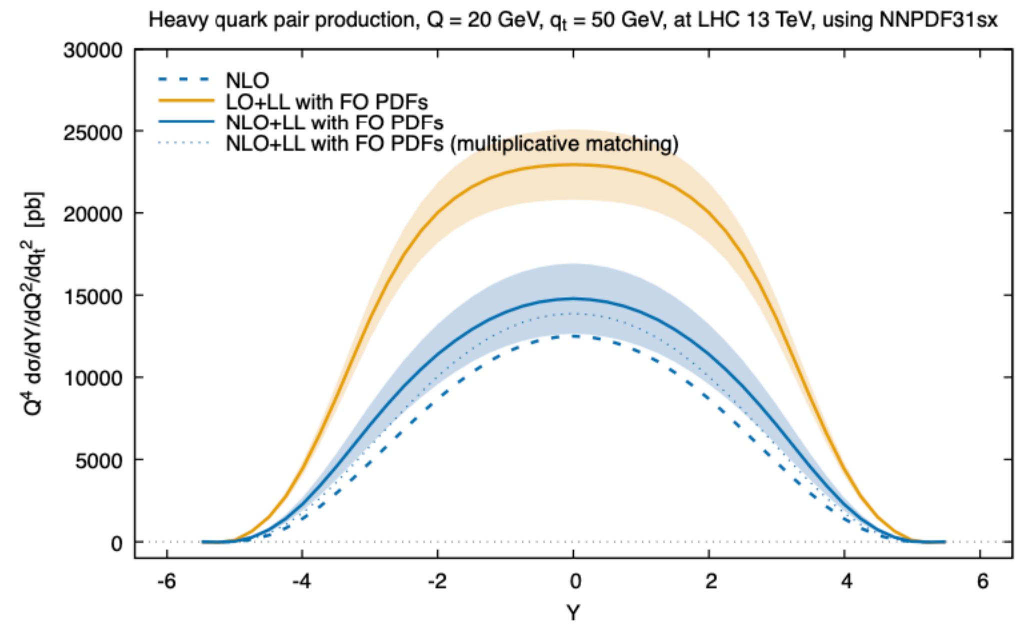

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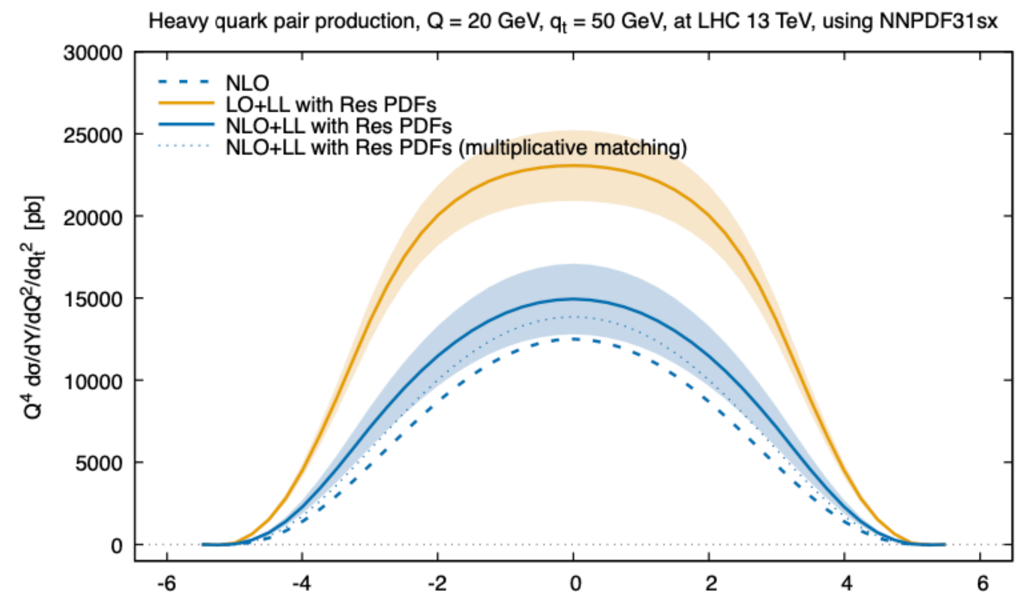

LUCA ROTTOLI

Hadron production at the LHC: predictions for long-lived particles at forward facilities

Luca Rottoli

University of Zurich^{UZH}

FNSNF
SWISS NATIONAL SCIENCE FOUNDATION

Based on 2309.12793 in collaboration with Luca Buonocore, Felix Kling and Jonas Sominka

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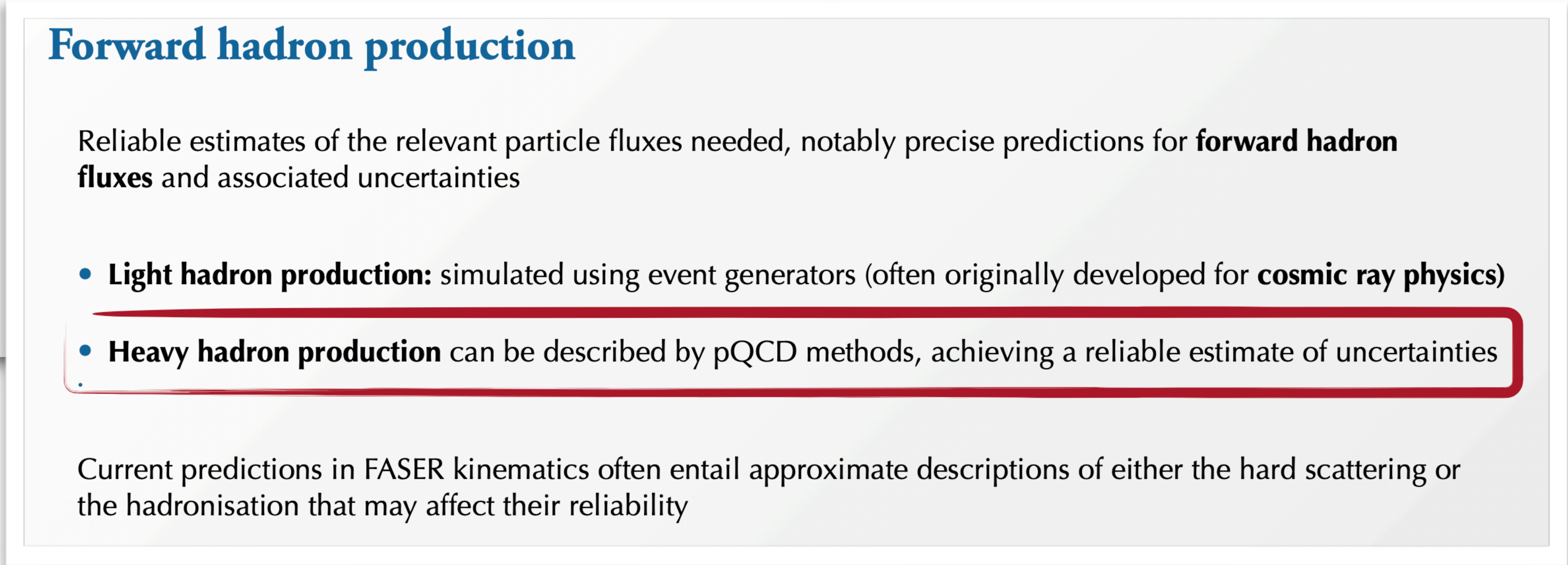

Forward hadron production

Reliable estimates of the relevant particle fluxes needed, notably precise predictions for **forward hadron fluxes** and associated uncertainties

- **Light hadron production:** simulated using event generators (often originally developed for **cosmic ray physics)**
- **Heavy hadron production** can be described by pQCD methods, achieving a reliable estimate of uncertainties

Current predictions in FASER kinematics often entail approximate descriptions of either the hard scattering or the hadronisation that may affect their reliability

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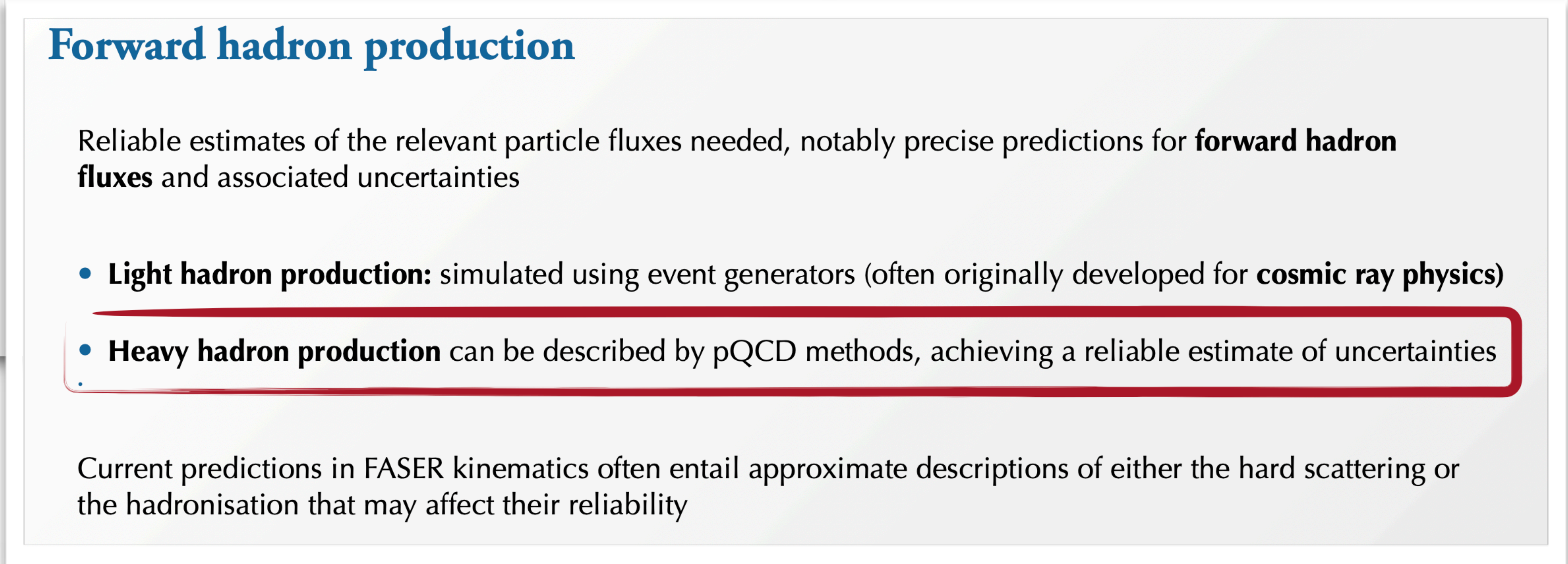

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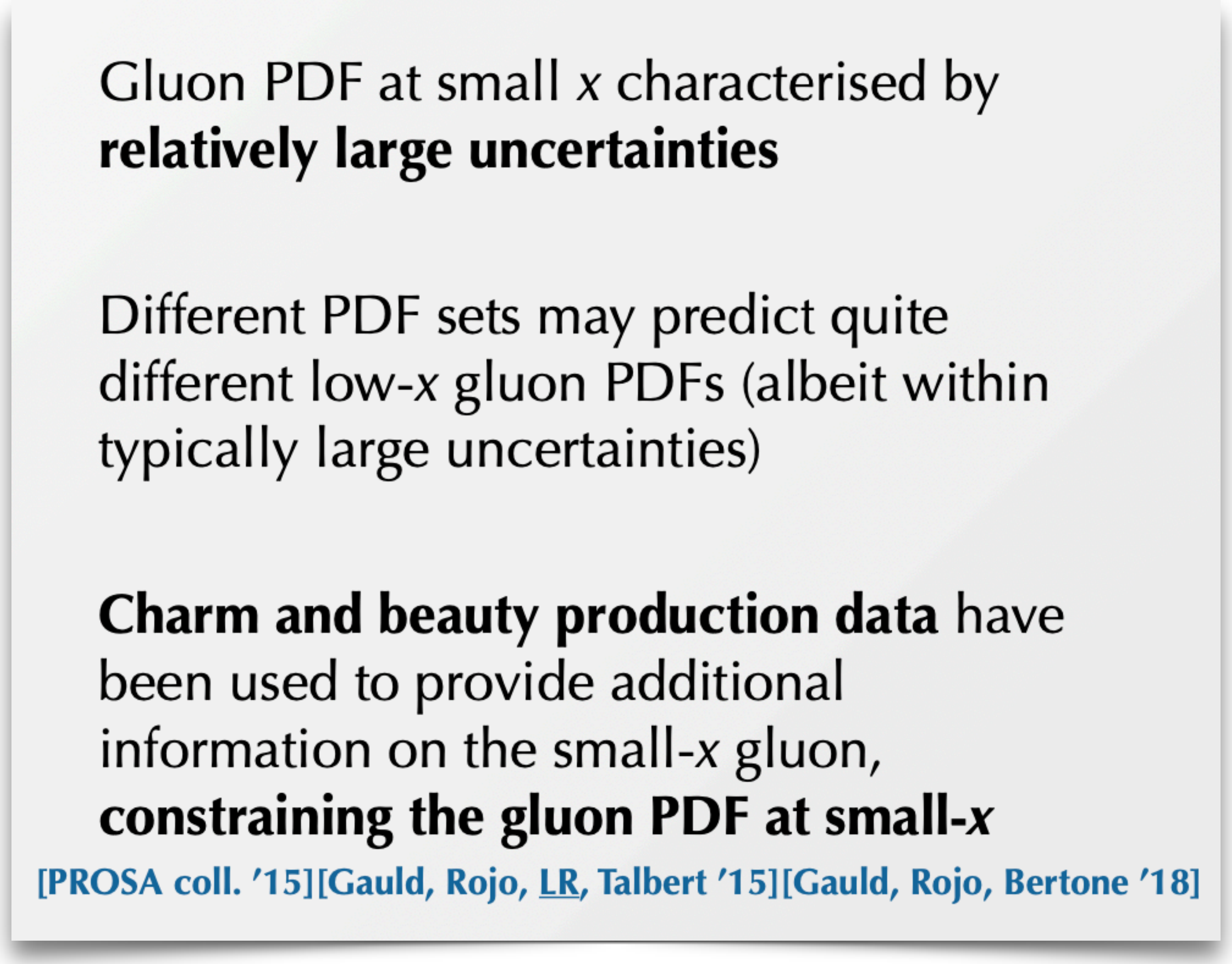

Gluon PDF at small x characterised by **relatively large uncertainties**

Different PDF sets may predict quite different low-x gluon PDFs (albeit within typically large uncertainties)

Charm and beauty production data have been used to provide additional information on the small-x gluon, **constraining the gluon PDF at small-x**

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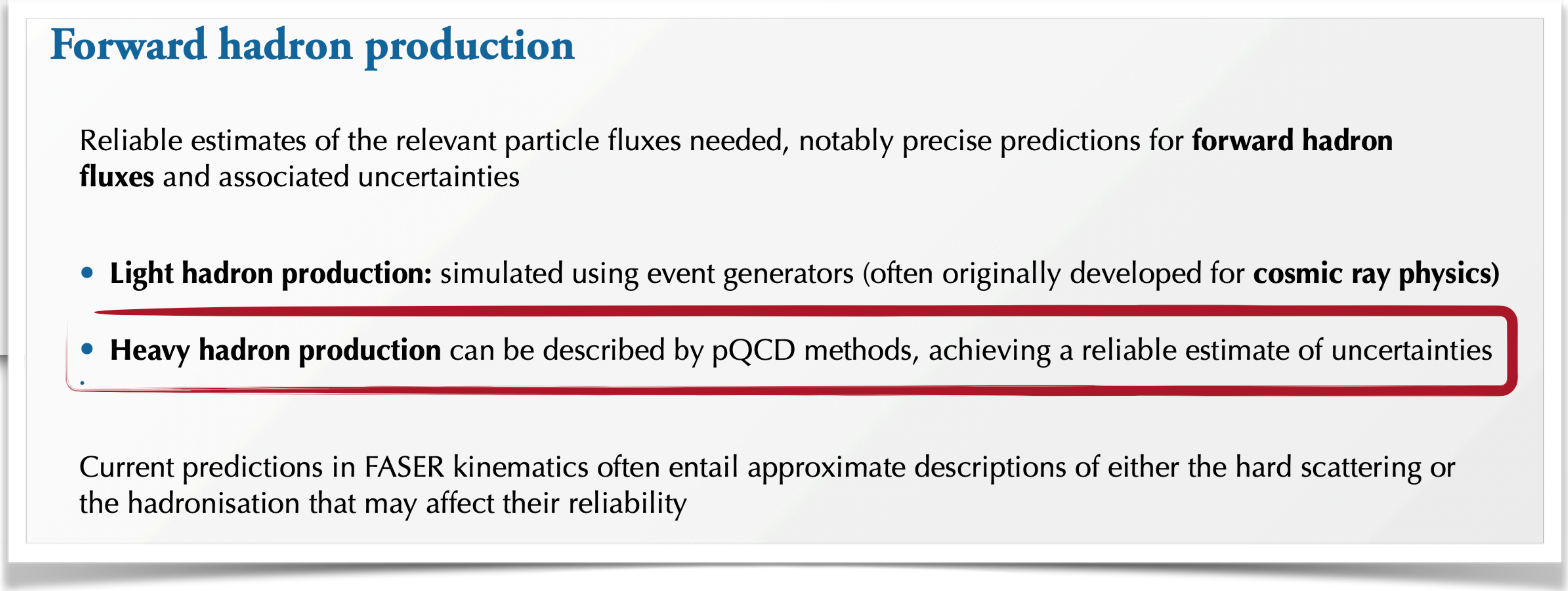

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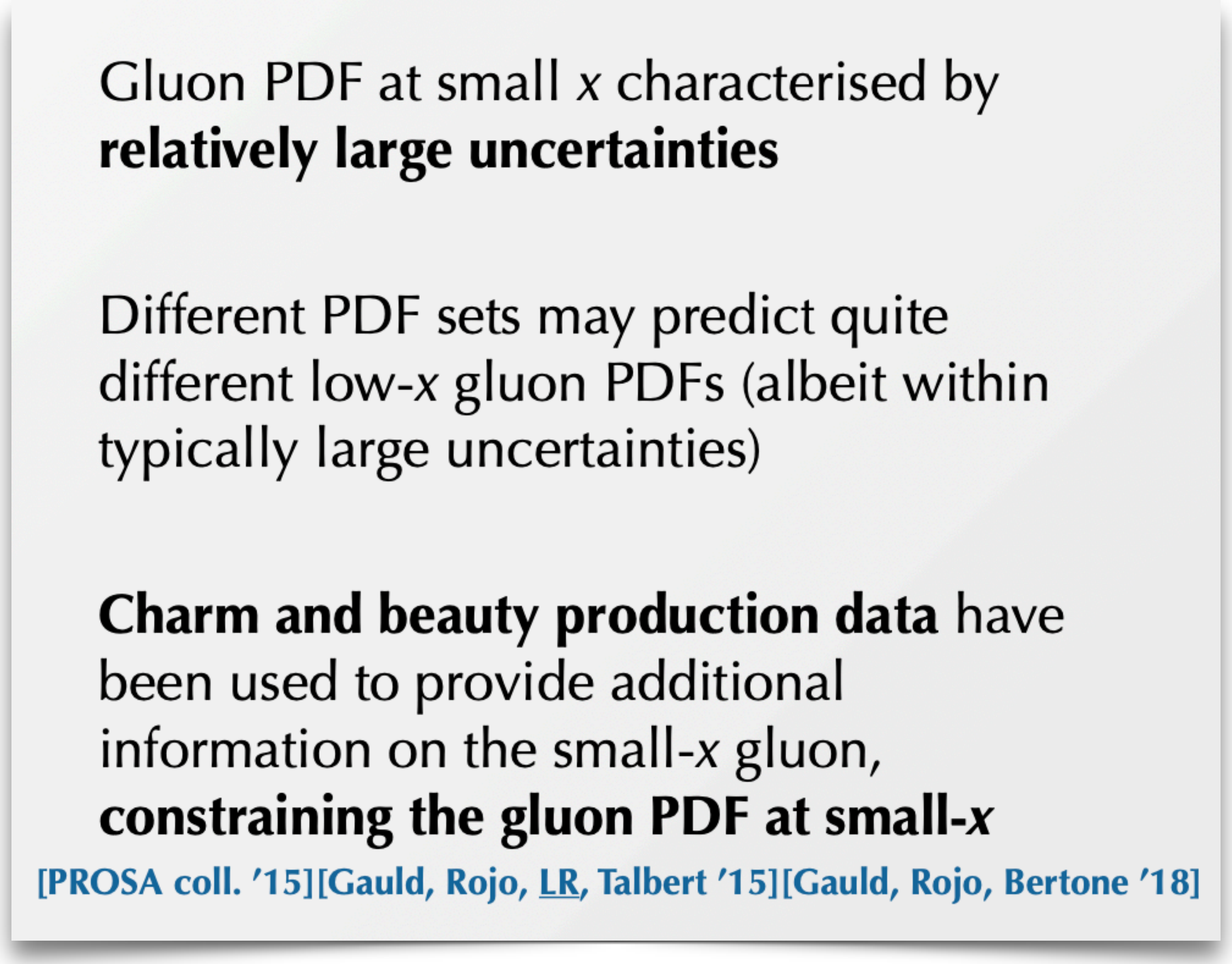

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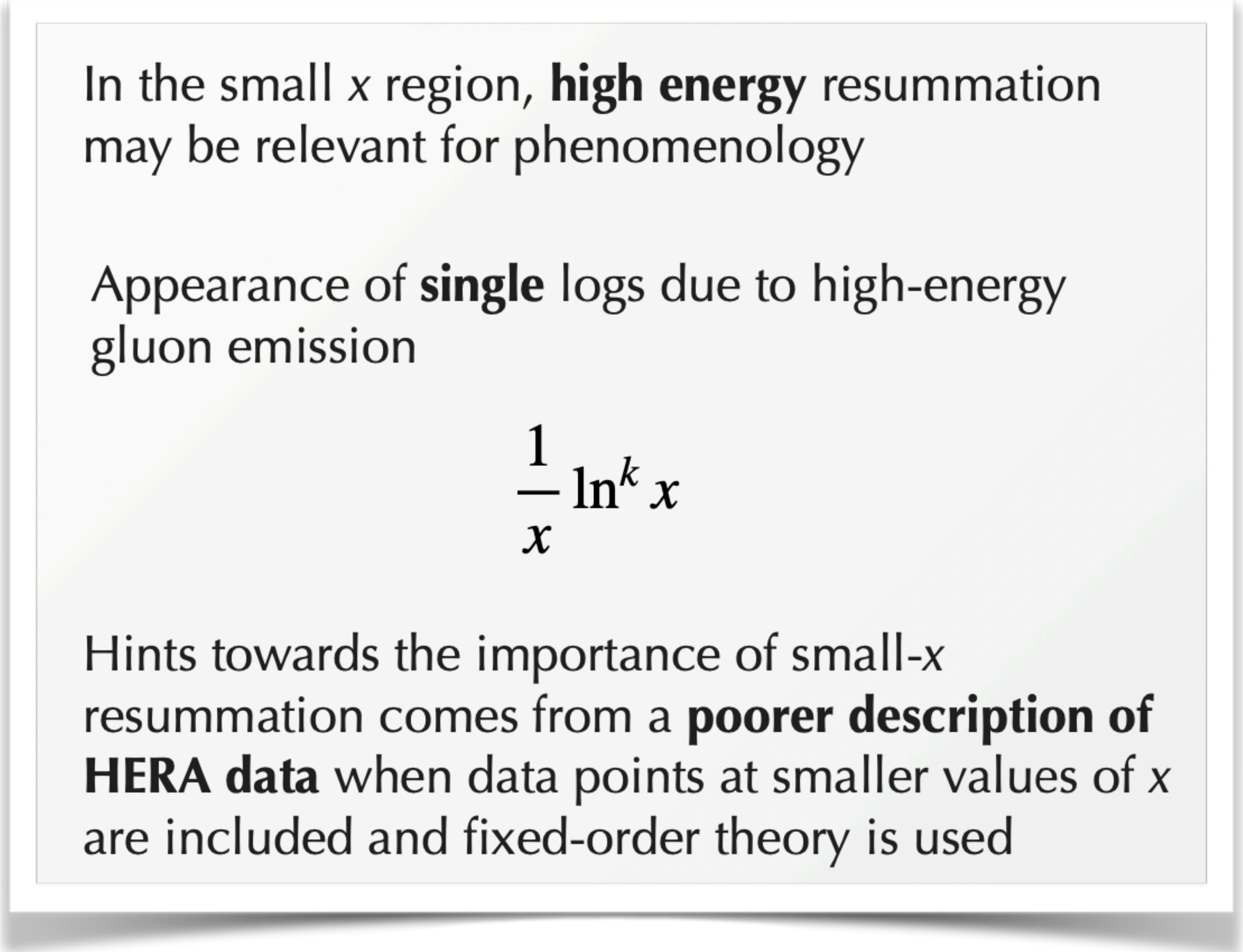

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Appearance of **single** logs due to high-energy gluon emission

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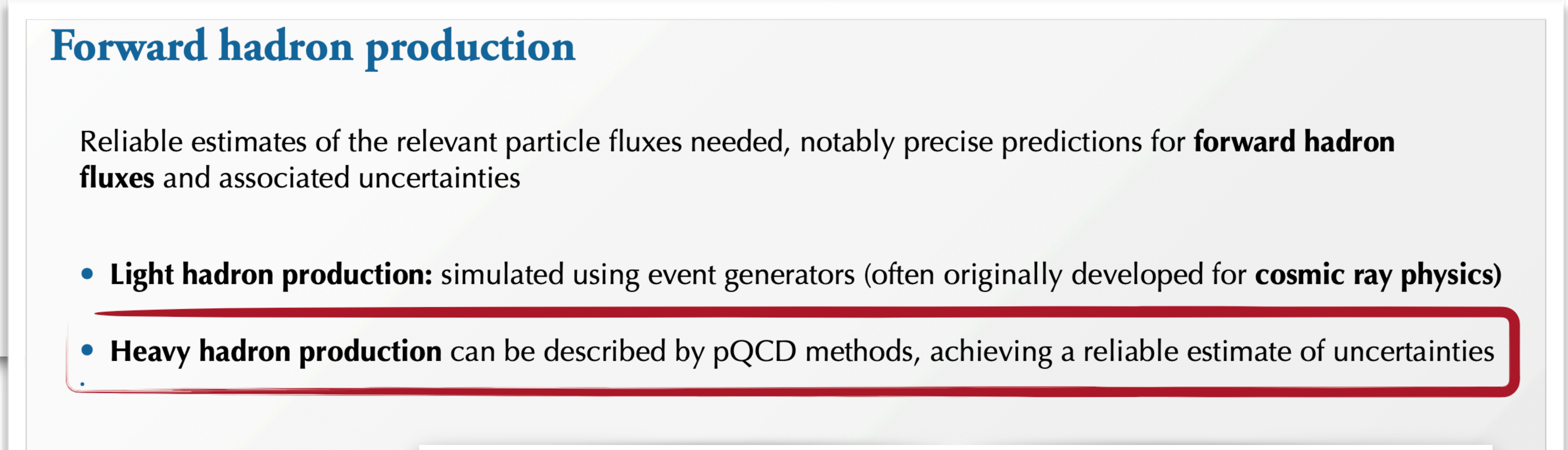

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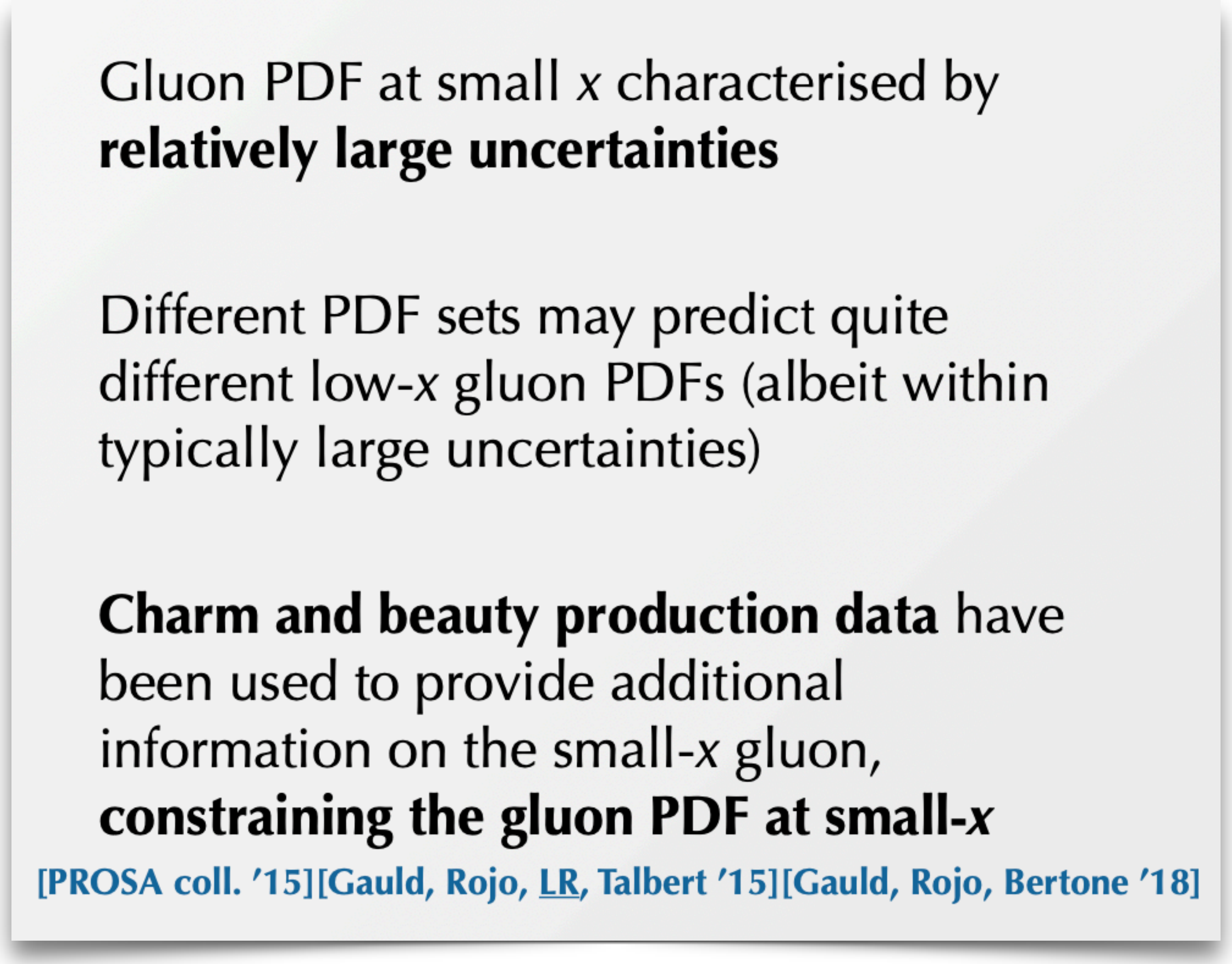

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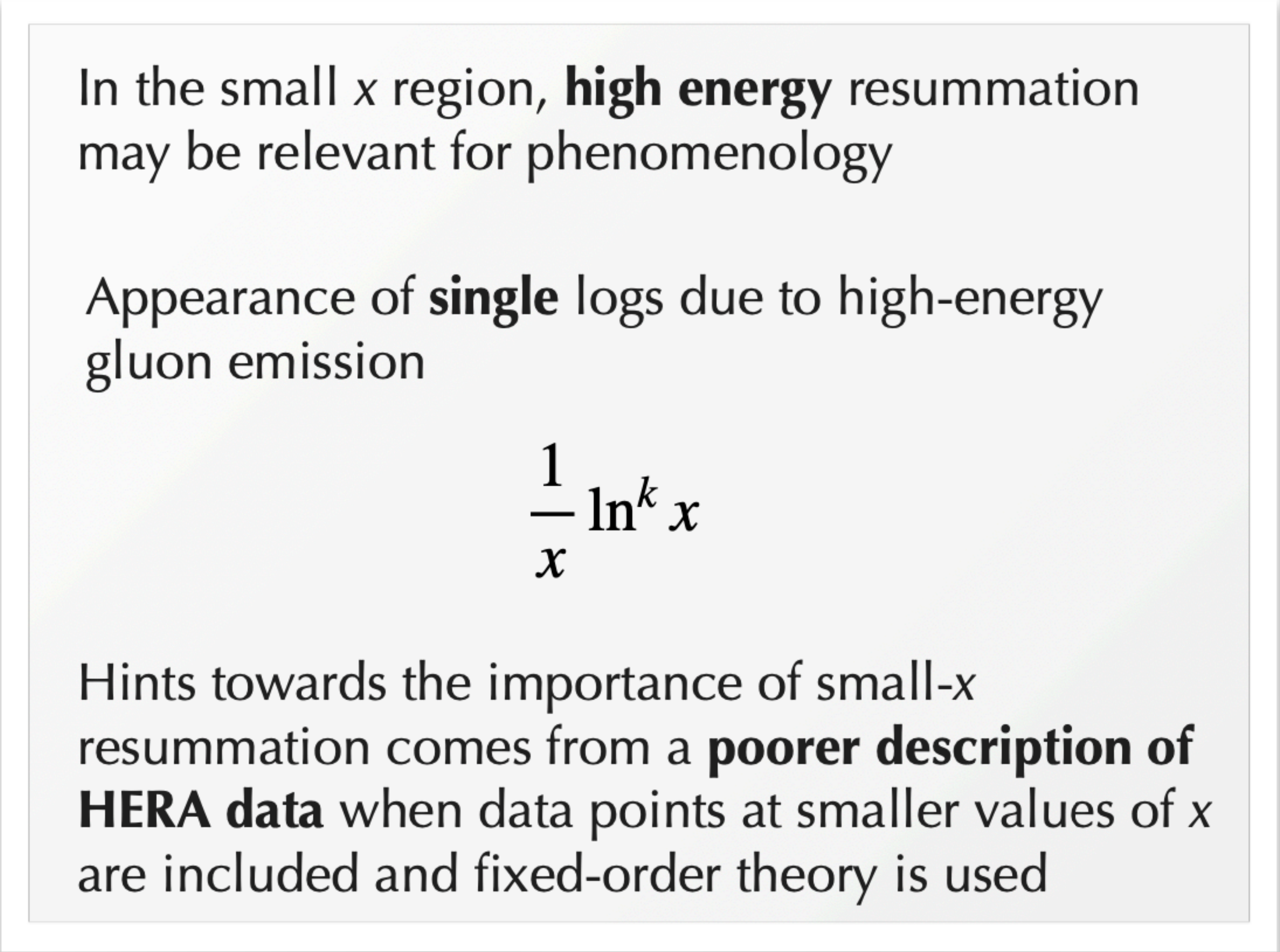

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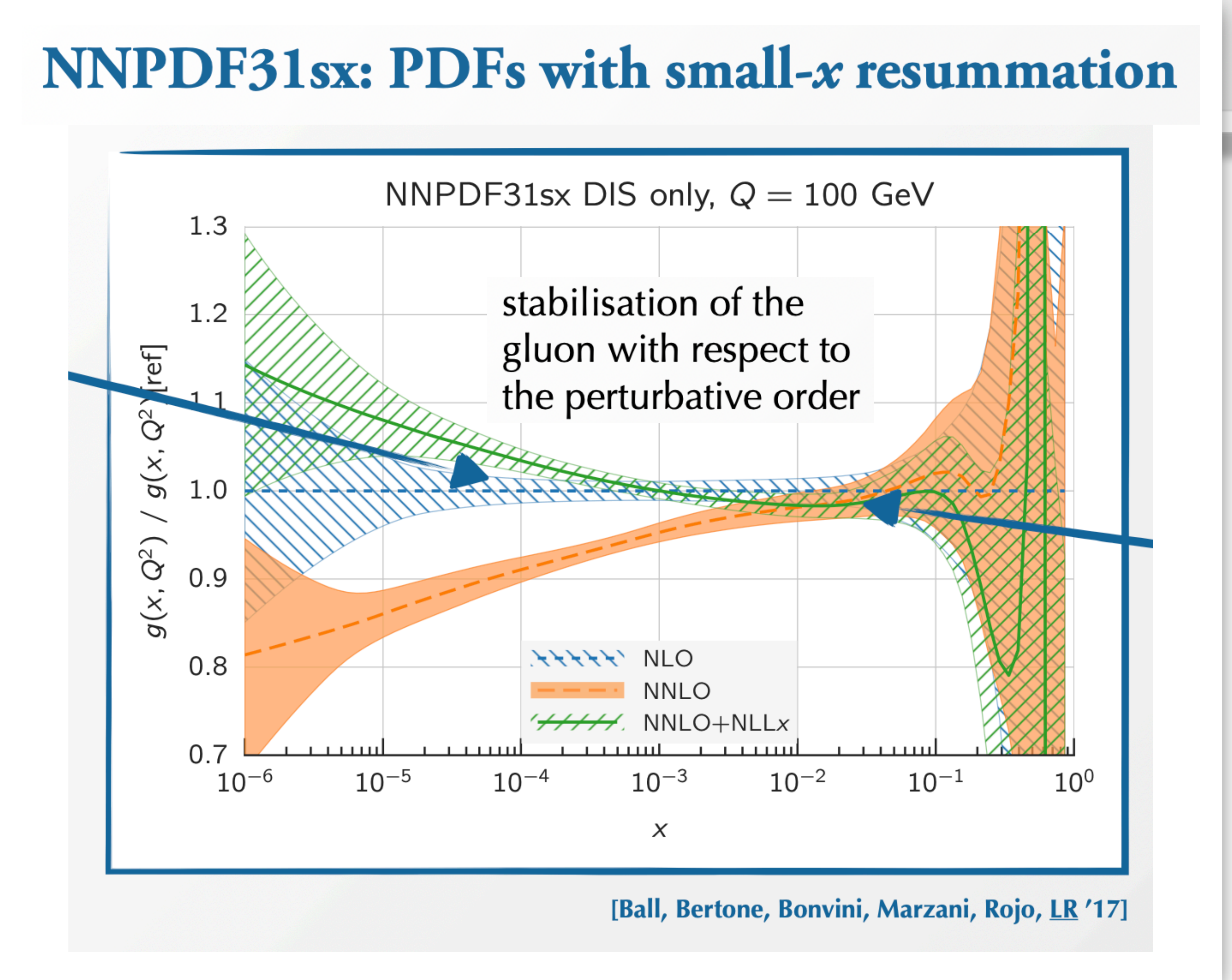

NNPDF31sx: PDFs with small-x resummation

stabilisation of the gluon with respect to the perturbative order

[Ball, Bertone, Bonvini, Marzani, Rojo, LR '17]

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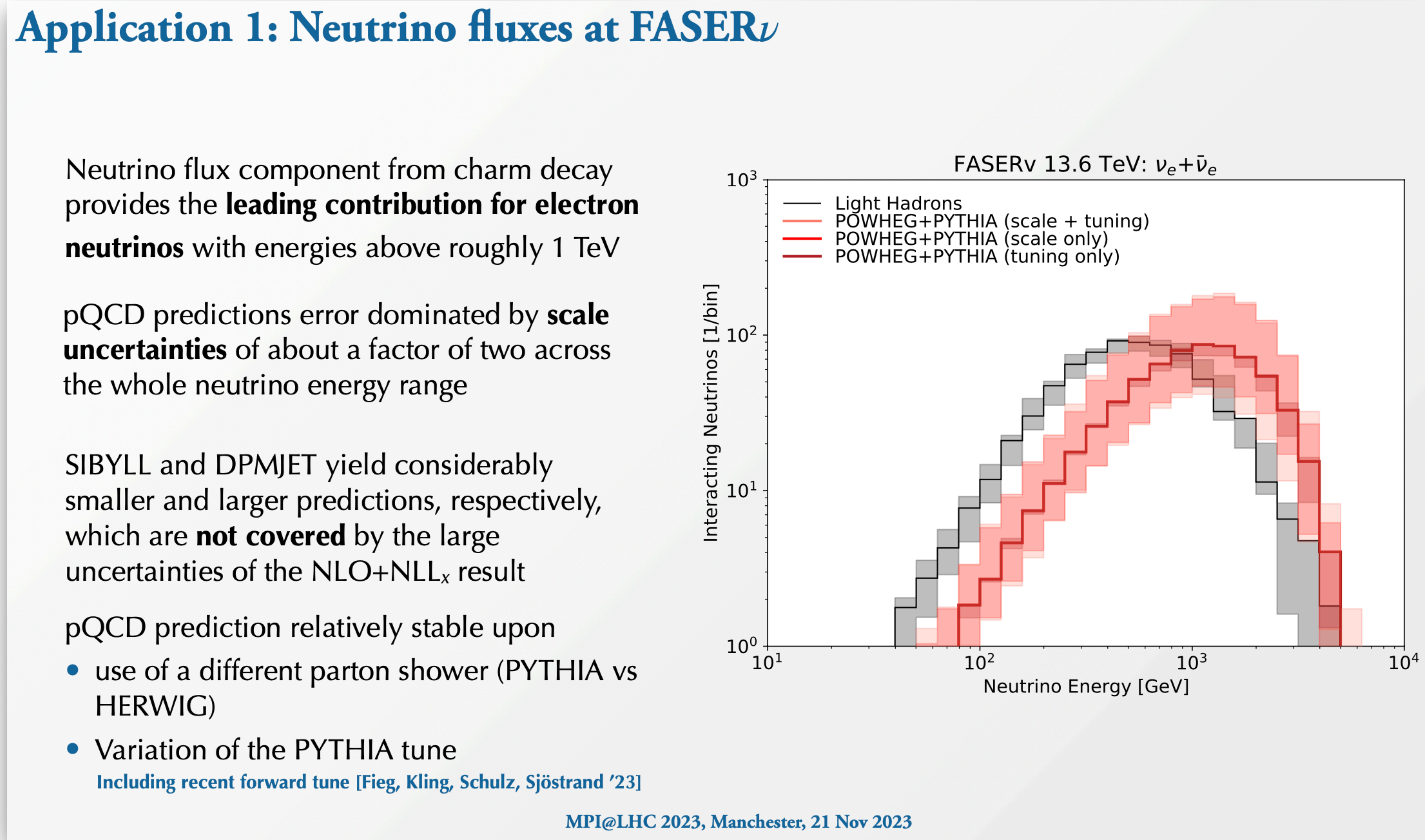

Application 1: Neutrino fluxes at FASERν

Neutrino flux component from charm decay provides the **leading contribution for electron neutrinos** with energies above roughly 1 TeV

pQCD predictions error dominated by **scale uncertainties** of about a factor of two across the whole neutrino energy range

SIBYLL and DPMJET yield considerably smaller and larger predictions, respectively, which are **not covered** by the large uncertainties of the NLO+NLL$_x$ result

pQCD prediction relatively stable upon

- use of a different parton shower (PYTHIA vs HERWIG)
- Variation of the PYTHIA tune
  Including recent forward tune [Fieg, Kling, Schulz, Sjöstrand '23]

MPI@LHC 2023, Manchester, 21 Nov 2023

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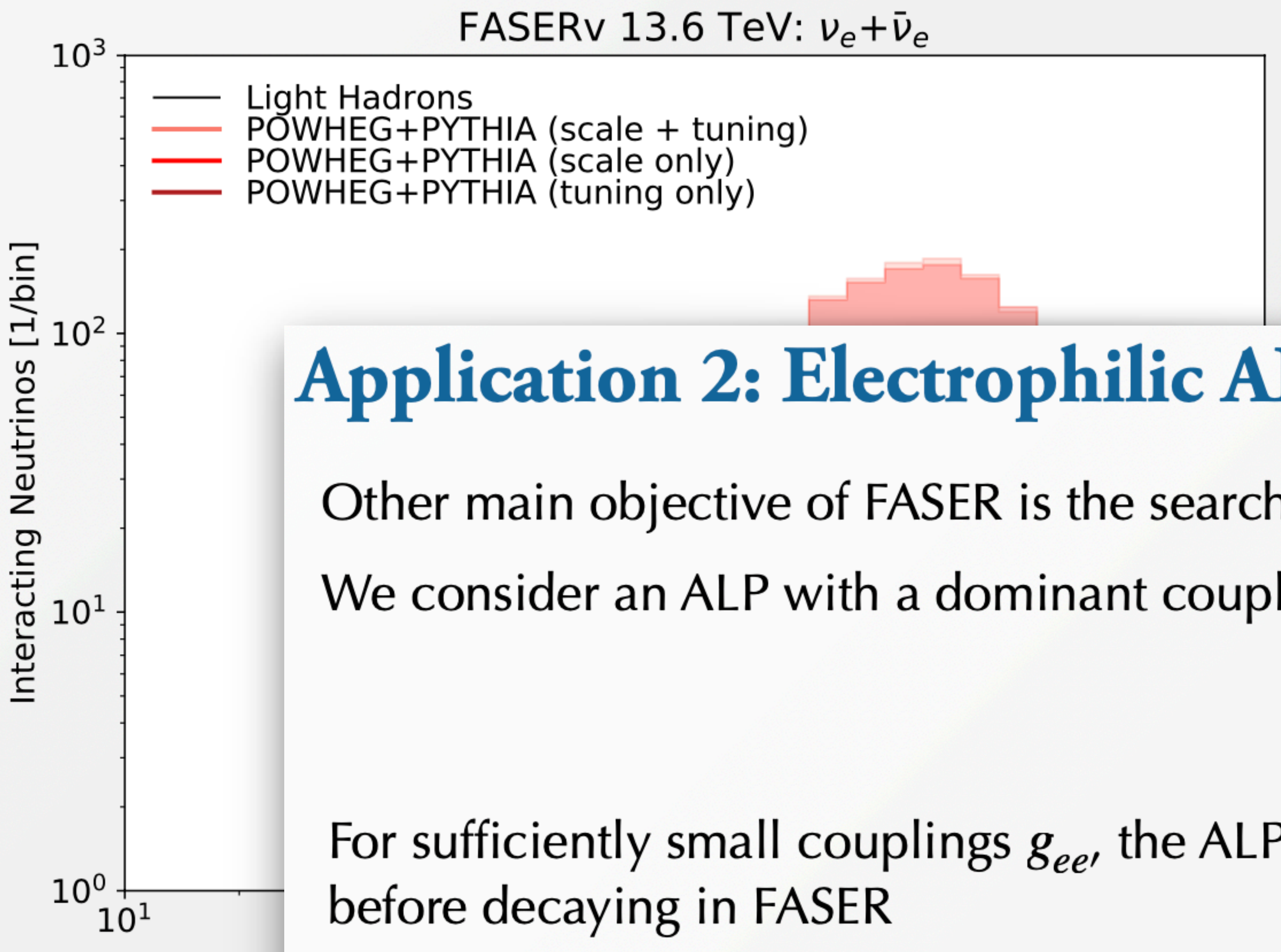

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Application 2: Electrophilic ALPs at FASER and FASER2

Other main objective of FASER is the search for light long-lived particles predicted by BSM models, notably ALPs

We consider an ALP with a dominant coupling to electrons (electrophilic ALP) with Lagrangian [Altmannshofer, Dror, Gori '22]

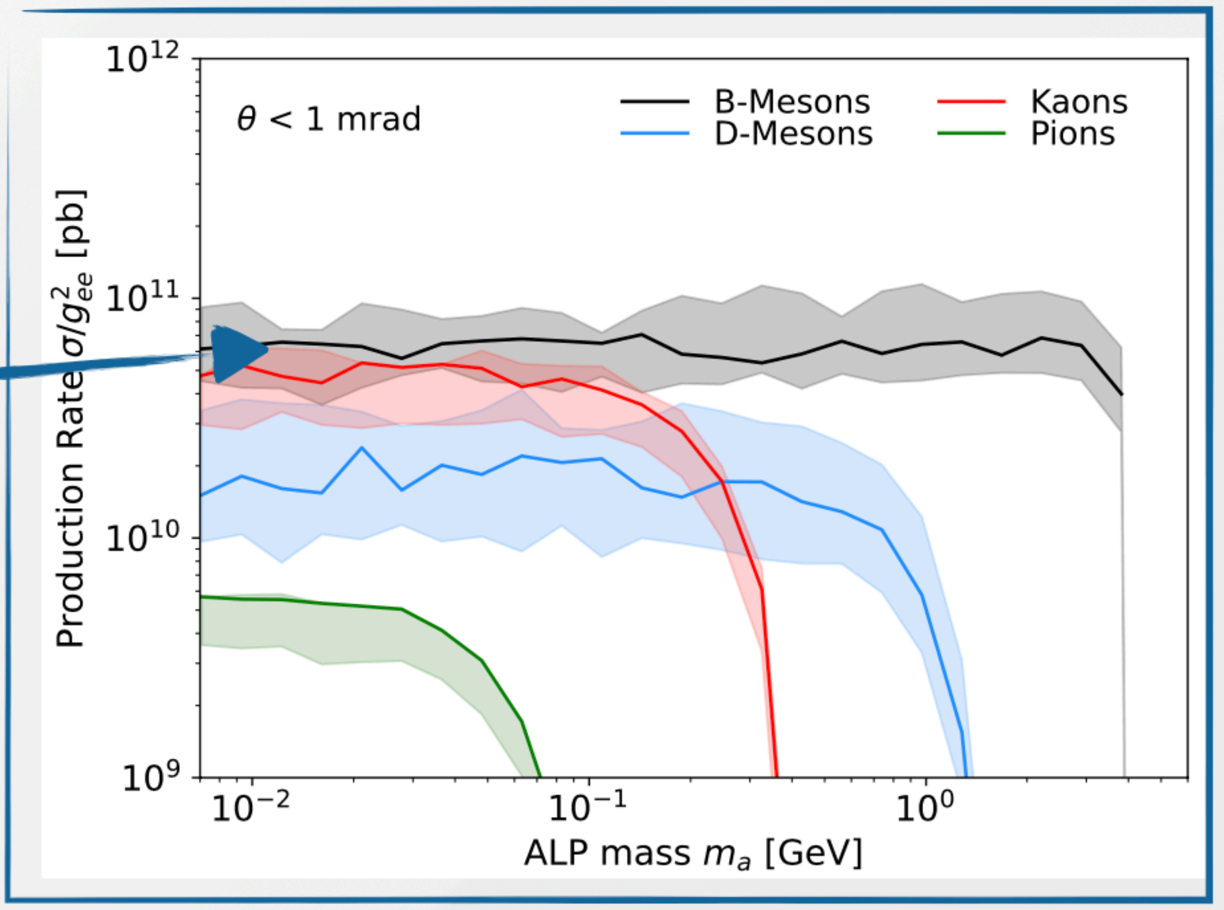
$$\mathscr{L} = \frac{g_{ee}}{2m_e}\partial_\mu a \bar{e}\gamma^\mu\gamma_5 e$$

For sufficiently small couplings g_{ee}, the ALP becomes long-lived, allowing it to travel a macroscopic distance before decaying in FASER

The ALP acquires couplings to the weak gauge bosons through the chiral anomaly which implies that it can be produced in flavor-changing hadron decays

In the forward region of the LHC, the dominant production channel of such are rare ***B*-meson** decays as well as kaon decays*

* light hadron production uncertainty obtained by computing the envelope of several MC generators originally developed for cosmic ray physics: EPOS-LHC (central), SYBILL, QGSJET



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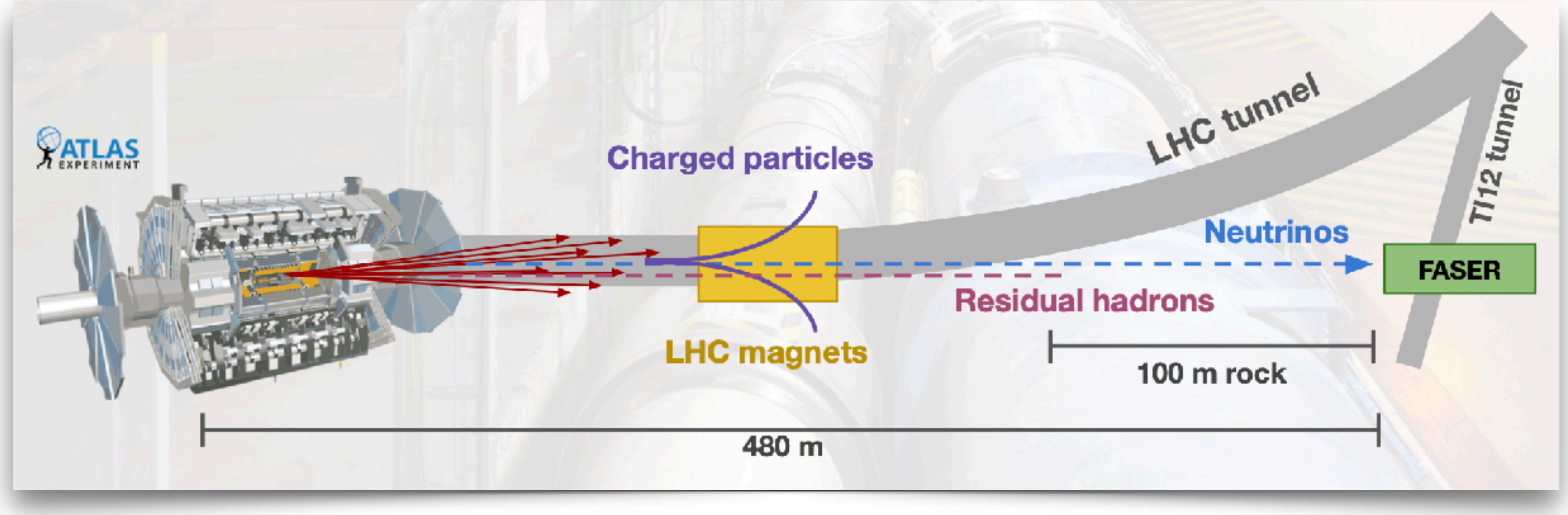
Recent results from the FASER experiment



Neutrino **production** at the ATLAS IP probes **forward hadron production**

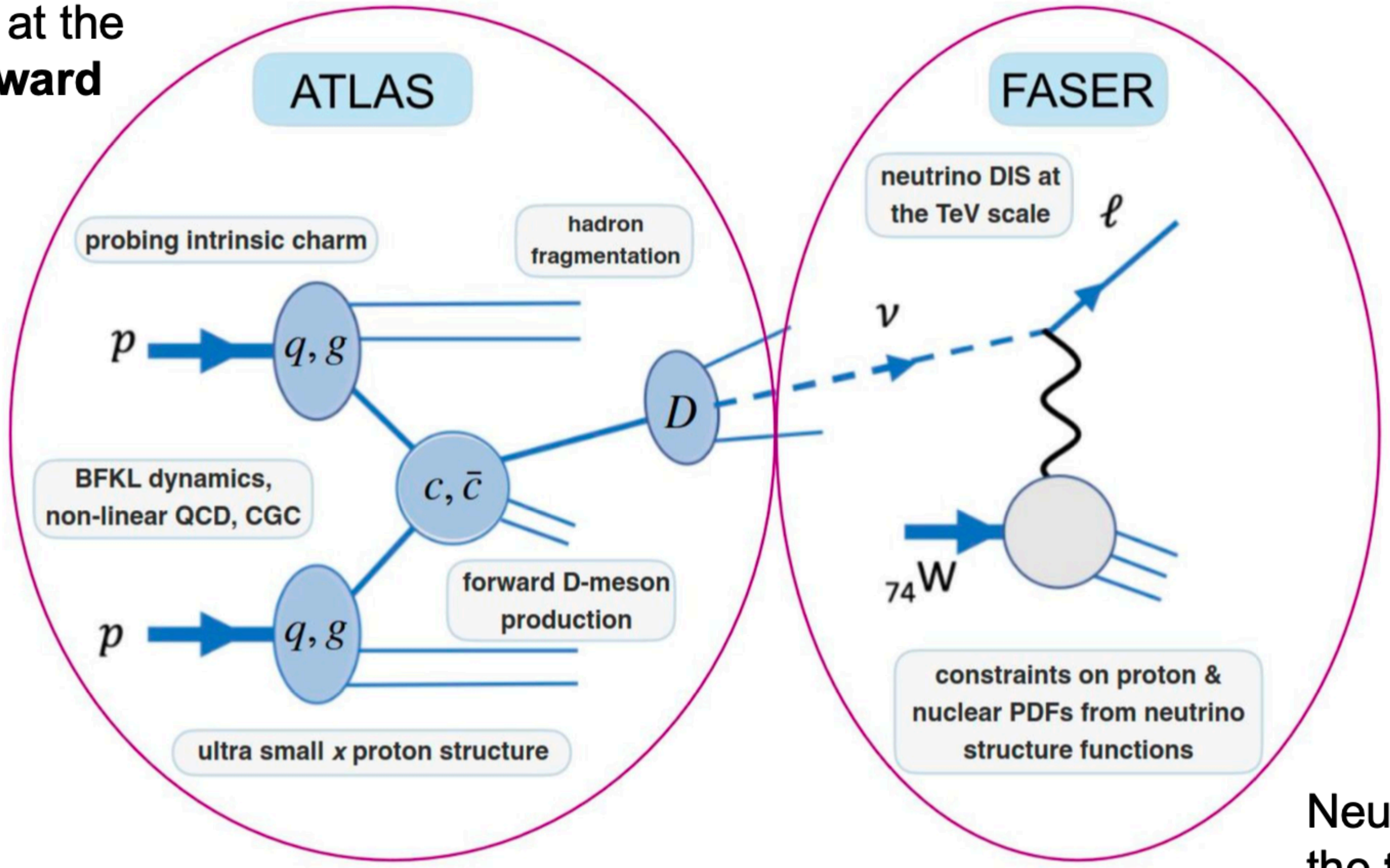
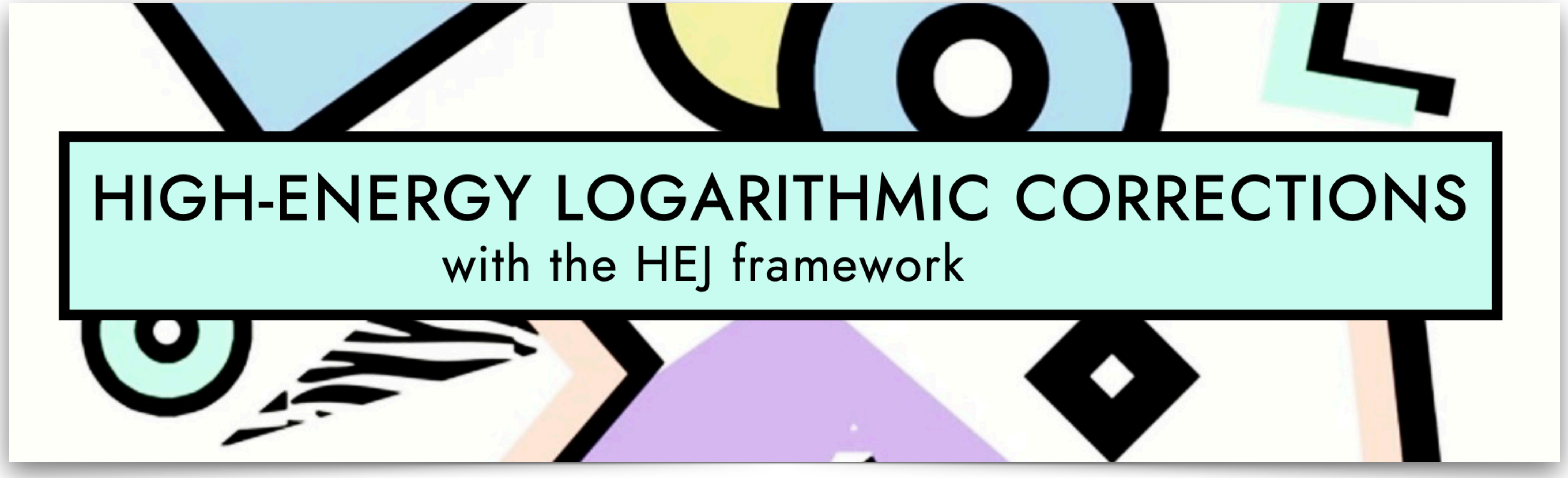


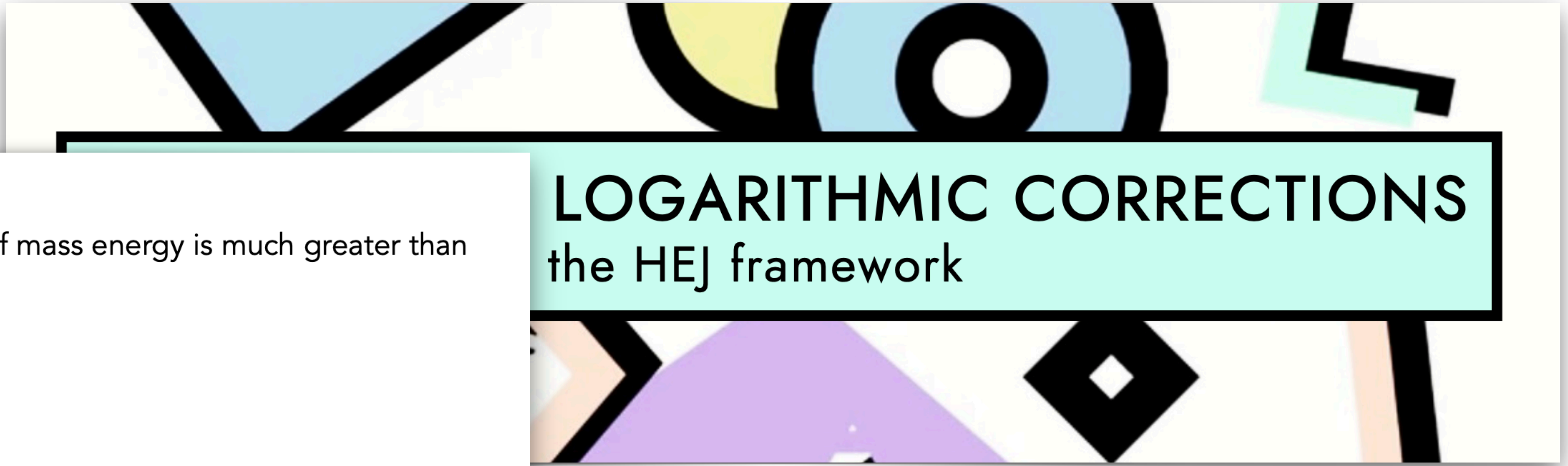
Figure adapted from: J. Phys. G 50 (2023) 3, 030501

Neutrino **interaction** with the **target** (Deep Inelastic Scattering) probes the **proton/nuclear PDF**

EMMET BYRNE



HIGH-ENERGY LOGARITHMIC CORRECTIONS
with the HEJ framework



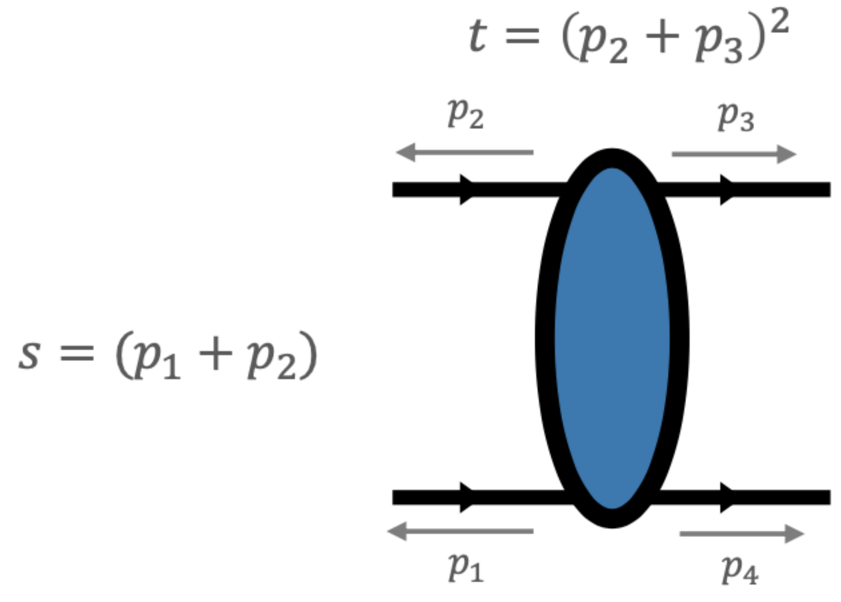
LOGARITHMIC CORRECTIONS

the HEJ framework

HIGH-ENERGY LOGARITHMS

At each order in perturbative QCD, large logarithms arise when the centre of mass energy is much greater than the transverse momenta of the produced partons.

Consider the partonic cross section for inclusive dijet production:



$$L \equiv \log\left(\frac{s}{-t}\right) \gg 1$$

$$\alpha_s \ll 1$$

$$\alpha_s L \sim 1$$

$$\begin{array}{lccccccc}
 & \text{LL} & & \text{NLL} & & \text{NNLL} & & \\
\sigma^{(0)}/\sigma^{(0)} = & 1 & & & & & & \\
\sigma^{(1)}/\sigma^{(0)} = & \alpha_s L c_0^{(1)} & + & \alpha_s c_1^{(1)} & & & & \\
\sigma^{(2)}/\sigma^{(0)} = & \alpha_s^2 L^2 c_0^{(2)} & + & \alpha_s^2 L\, c_1^{(2)} & + & \alpha_s^2 c_2^{(2)} & & \\
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\vdots & \vdots & & \vdots & & \vdots & &
\end{array}$$

We need to sum the whole tower of logarithms in order to restore stability to perturbative predictions.

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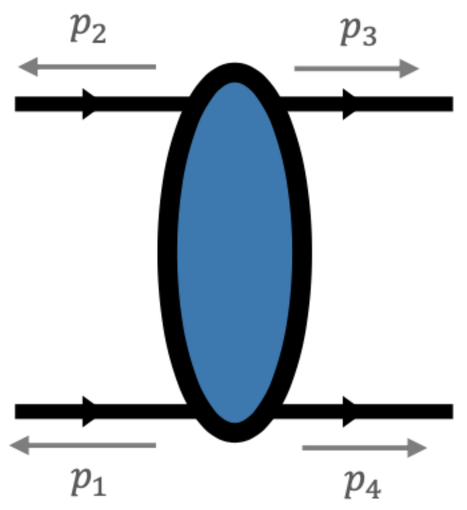
$t = (p_2 + p_3)^2$



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$\vdots$

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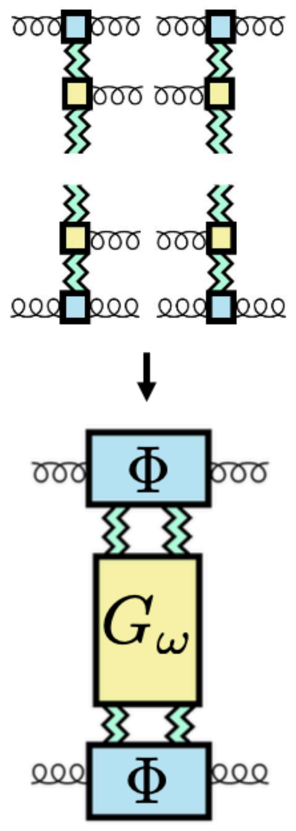
LOGARITHMIC CORRECTIONS

the HEJ framework

COMPARISON OF BFKL AND HEJ

One way to derive the BFKL equation is to combine the Regge-factorised amplitudes with *s-channel unitarity* [5]

$$\mathrm{Disc}_s\left[\overline{\mathcal{M}}_{f_1 f_2 \to f_1' f_2'}(s, t=0)\right] = \frac{1}{2}\sum_{n=4}^{\infty}\sum_{f_i, a_i, \lambda_i}\int \mathrm{d}\Phi_{n-2}\,\mathcal{M}_{f_1 f_2 \to f_3 \cdots f_n}\left(\mathcal{M}_{f_1' f_2' \to f_3 \cdots f_n}\right)^*,$$



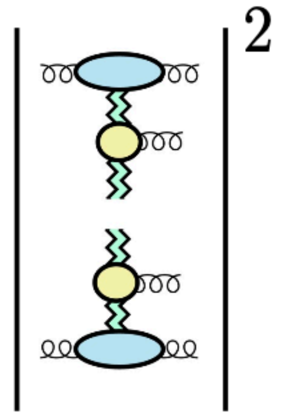
A Mellin transform allows the longitudinal integrals to be performed analytically over MRK phase space.

The central physics is captured by the gluon Green's function, G_ω , which obeys a recursive integral equation. For the case of forward scattering and vacuum quantum numbers, this is the BFKL equation [4], which can be solved analytically. The partonic cross section can be written

$$\hat{\sigma}_{f_1 f_2}(s) = \int_{\delta - i\infty}^{\delta + i\infty}\frac{d\omega}{2\pi i}\int d^{D-2}q_{1\perp}d^{D-2}q_{(n-3)\perp}\left(\frac{s}{s_0}\right)^{\omega}\times\frac{\Phi_{f_2}(\vec{q}_1)}{\vec{q}_1^{\,2}}\times G_\omega\left(\vec{q}_1, \vec{q}_{(n-3)}\right)\times\frac{\Phi_{f_1}\left(-\vec{q}_{(n-3)}\right)}{\vec{q}_{(n-3)}^{\,2}}$$

On the other hand, the starting point of HEJ [6] is to only use a Regge-factorised approximation to amplitudes to compute the partonic cross section *directly*:

$$\hat{\sigma}_{f_1 f_2} = \int \mathrm{d}\Phi_X \frac{\left|\mathcal{M}_{f_1 f_2 \to X}\right|^2}{2\,\hat{s}}$$



There are many benefits to performing the phase space numerically, not least the fact that the momentum fractions can be reconstructed exactly.

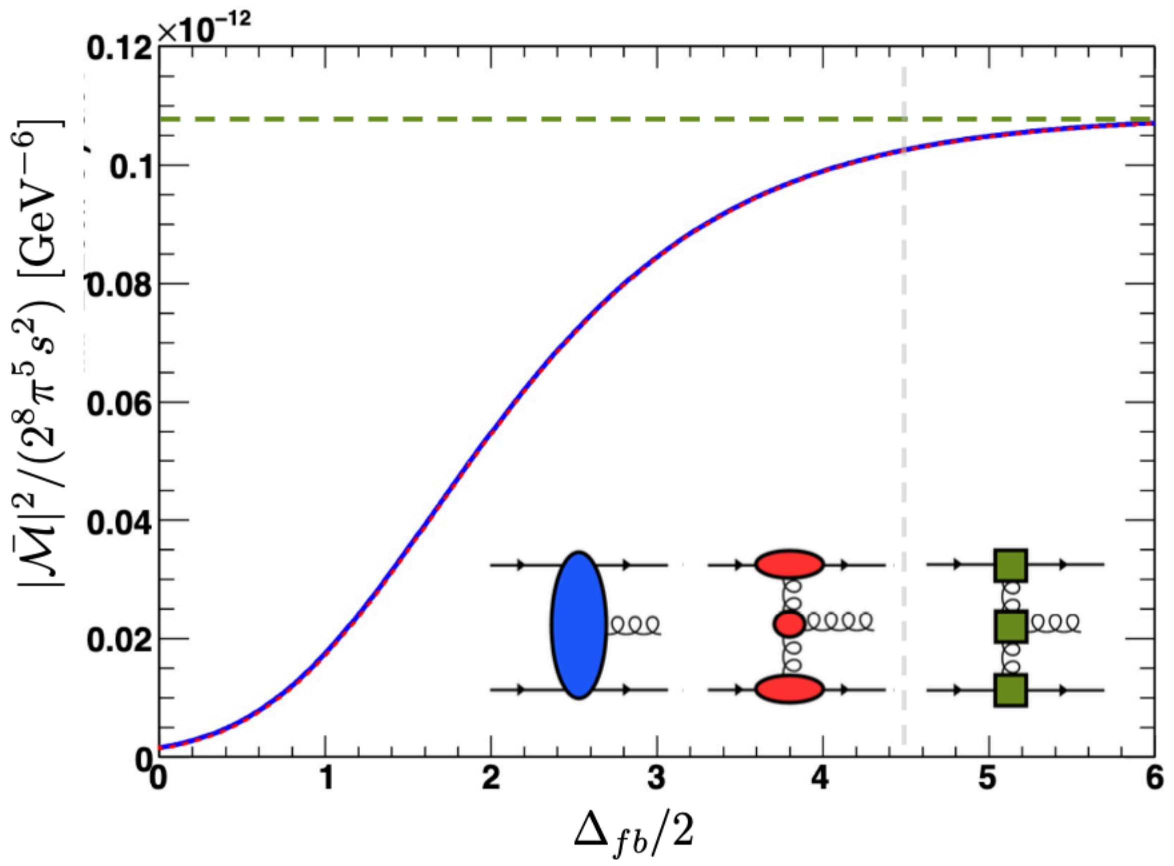
$$x_{f_1} = \frac{1}{\sqrt{s_{\mathrm{had}}}}\left(\sum_{i=3}^{n}|p_{i\perp}|\,e^{y_i}\right)\xrightarrow[\mathrm{LL}]{}\frac{|p_{3\perp}|}{\sqrt{s_{\mathrm{had}}}}e^{y_3}$$

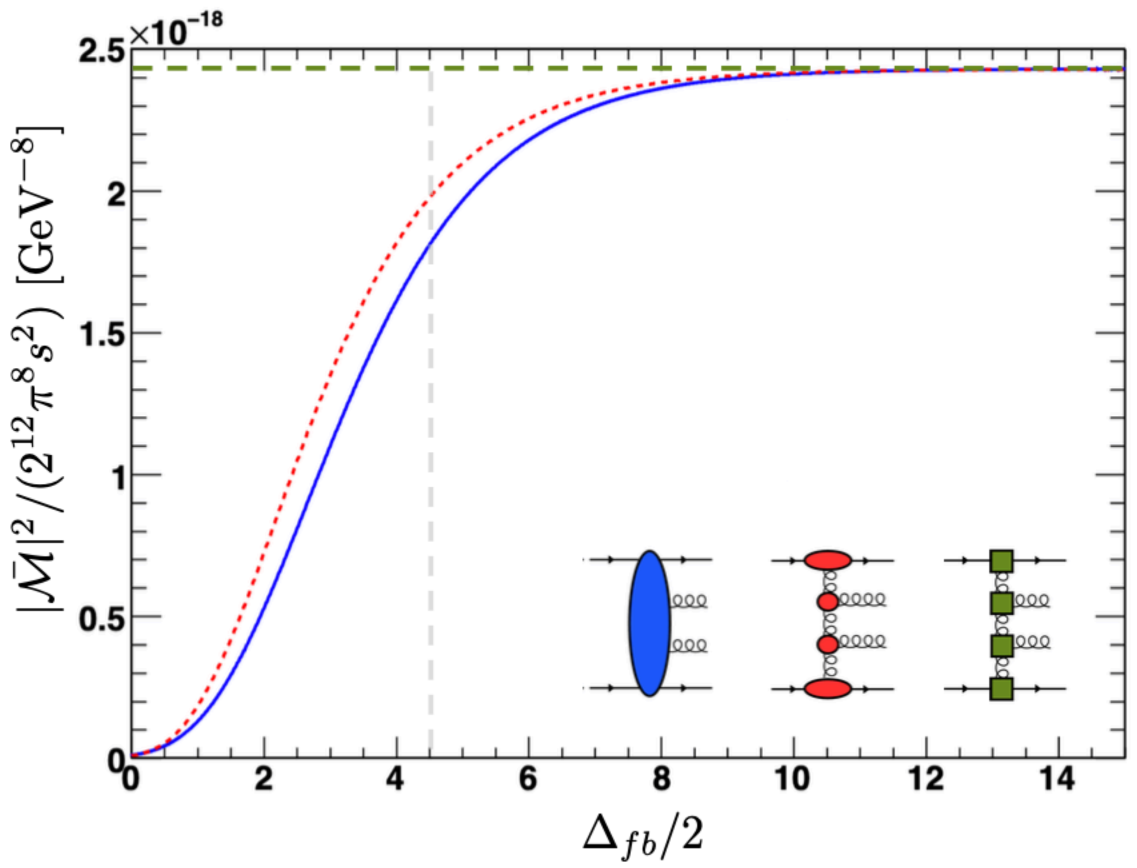
Other benefits: LO matching, exclusive observables, cuts, interfacing with standard HE tools such as Rivet.

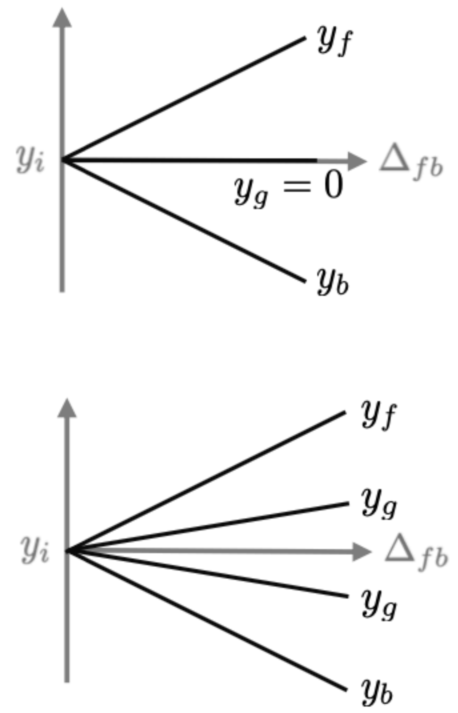
[5] hep-ph/9807528: Fadin, [6] 0910.5113: Andersen, Smillie

LO NUMERICAL COMPARISON

Comparing the two factorised approximations to amplitudes, we see the HEJ amplitudes capture much of the LO physics:







We see that the HEJ approximation to the LO matrix element is reasonable, even within LHC phase space. Integrating the strict approximation would lead to a massive overestimate of the cross section.

Of course, HEJ matrix elements are matched point-by-point to LO matrix elements where they are available.

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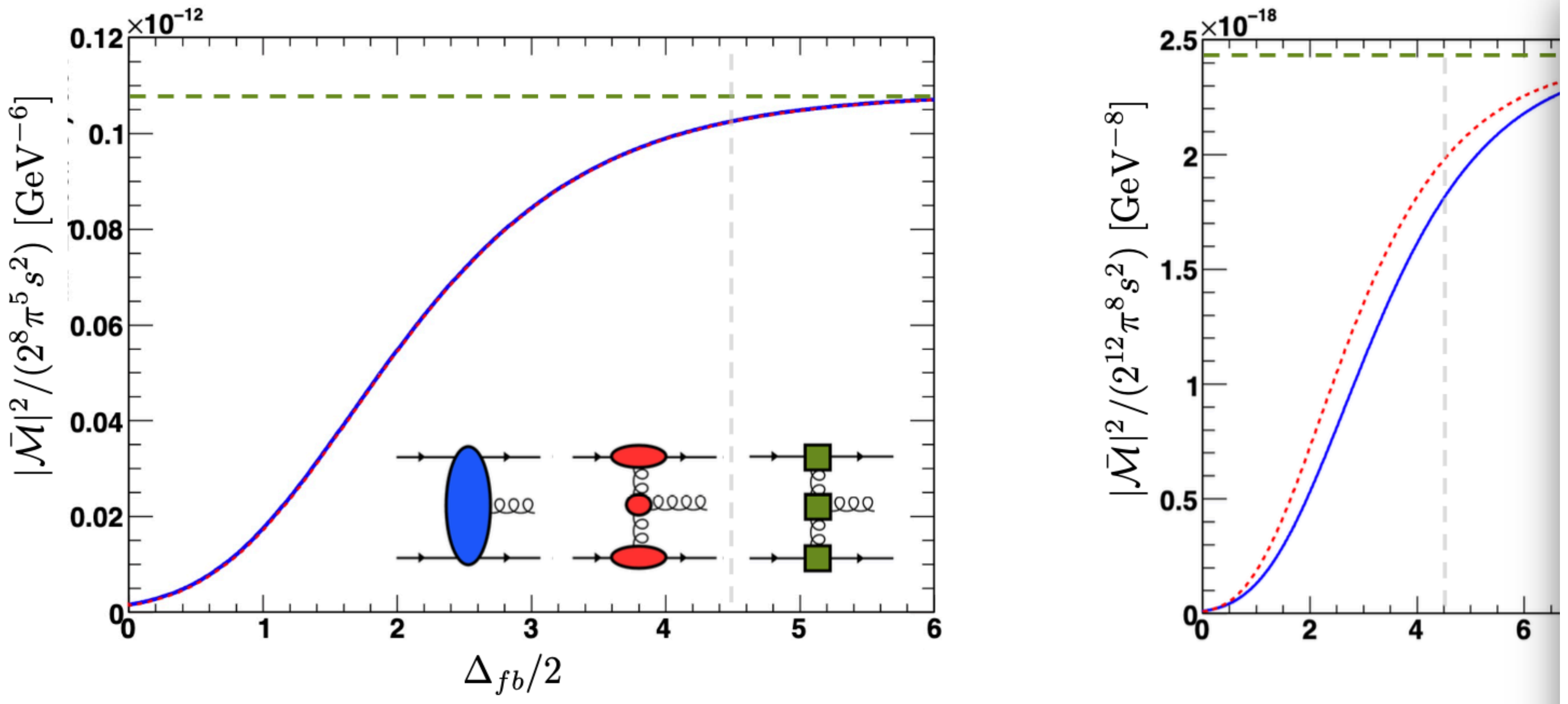

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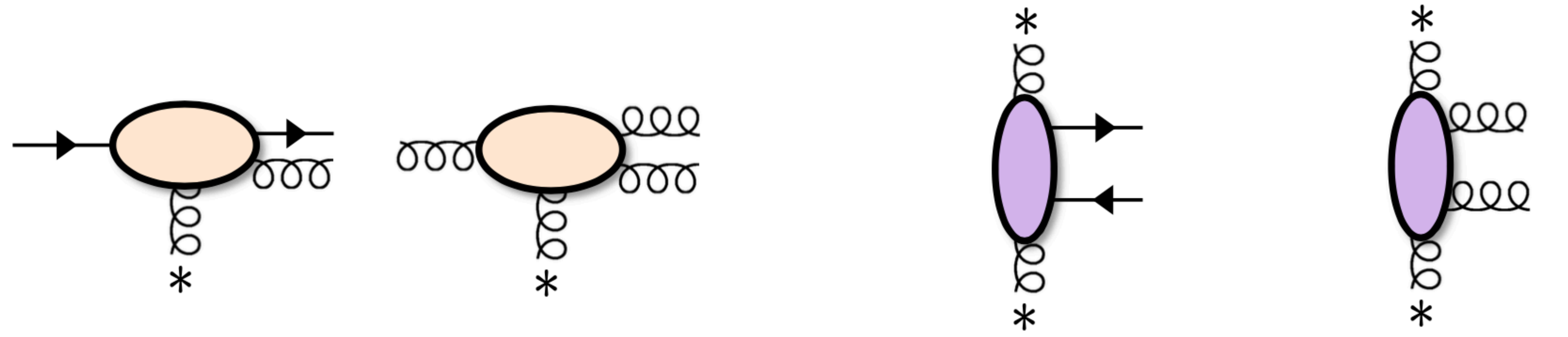
REAL NLL CORRECTIONS IN HEJ

In order to move to NLL accuracy, we need both real and virtual corrections to the building blocks. We have recently completed the calculation of the real corrections with the minimal-approximation approach of HEJ:



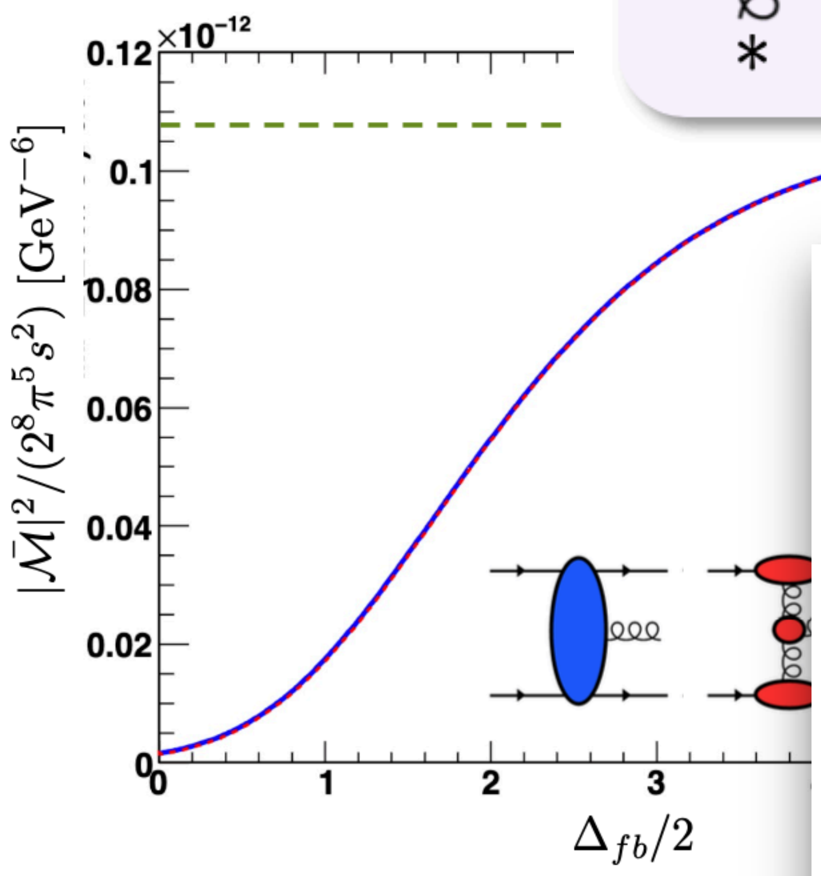
[9] 1706.01002 [via sWard] [10] 2012.10310 [In preparation]

Regulating the IR divergences of these improved vertices requires almost all of the machinery of a NLO calculation. We are using a minimally modified FKS subtraction to perform this regularisation.

In the meantime, we can use these factorised expressions to improve the accuracy of HEJ by imposing jet clustering requirements to regulate IR divergences.

LO NUMERICAL

Comparing the two fa
physics:



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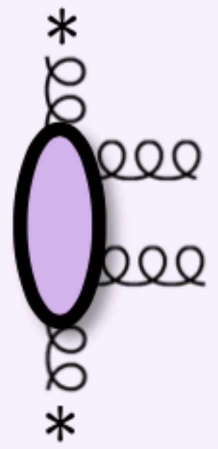

$$\mathcal{V}^{\mu_{t_1}\mu_{t_3}a_{t_1}a_{t_3}}_{g^*ggg^*}(-p_{t_1},p_{g_1},p_{g_2},p_{t_3}) = \sum_{\sigma\in S_2} \mathrm{tr}\left(T^{a_{t_1}}T^{a_{t_3}}T^{a_{\sigma_1}}T^{a_{\sigma_2}}\right) V^{\mu_{t_1}\mu_{t_3}}_{g^*g^*gg}\left(-p_{t_1},p_{t_3},p_{g_{\sigma_1}},p_{g_{\sigma_2}}\right)$$
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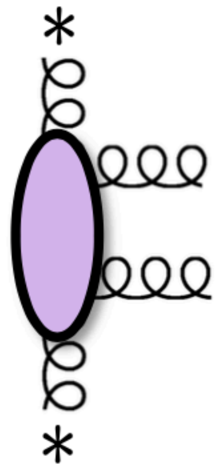


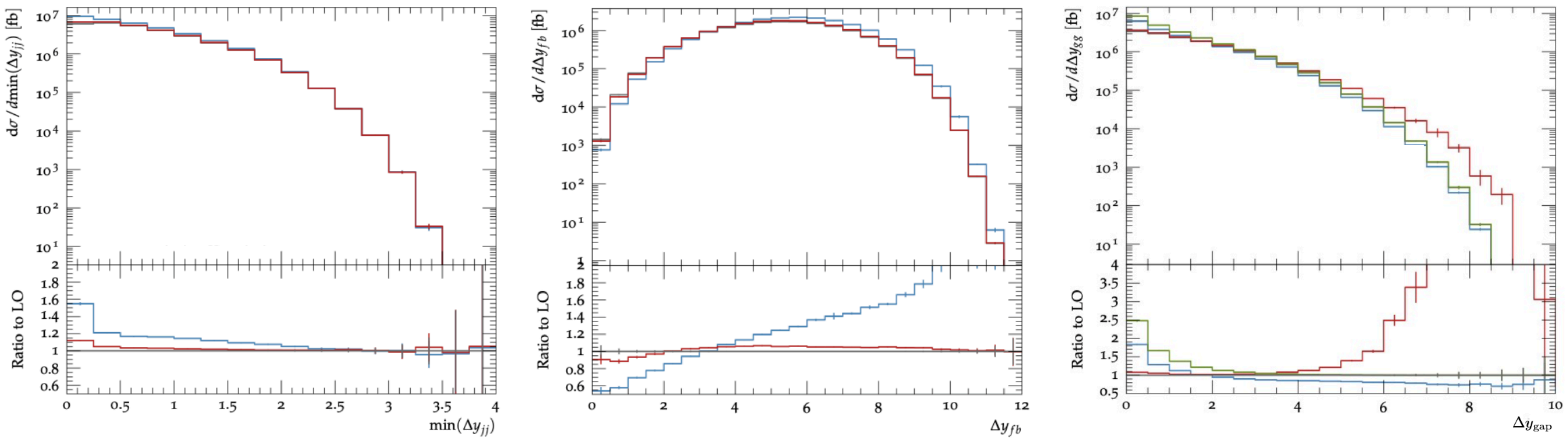
[In preparation]

of the machinery of a NLO
is regularisation.

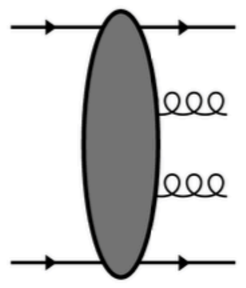
uracy of HEJ by imposing jet

NUMERICAL TEST OF g*ggg* VERTEX: CROSS SECTION

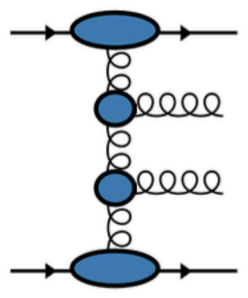
How well do the factorised expressions describe LO cross sections, within LHC phase space?



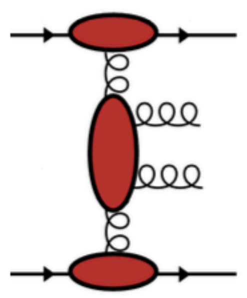
In these plots we compare the following factorised approximations to the exact LO amplitude:



$\mathcal{M}_{qq\to qggq}$



$\mathcal{C}_{q\to q}\frac{1}{t_1}\mathcal{V}_g\frac{1}{t_2}\mathcal{V}_g\frac{1}{t_3}\mathcal{C}_{Q\to Q}$



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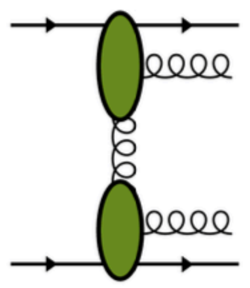

$\mathcal{C}_{q\to qg}\frac{1}{t_2}\mathcal{C}_{Q\to gQ}$

EMMET BYRNE

LO NUMERICAL

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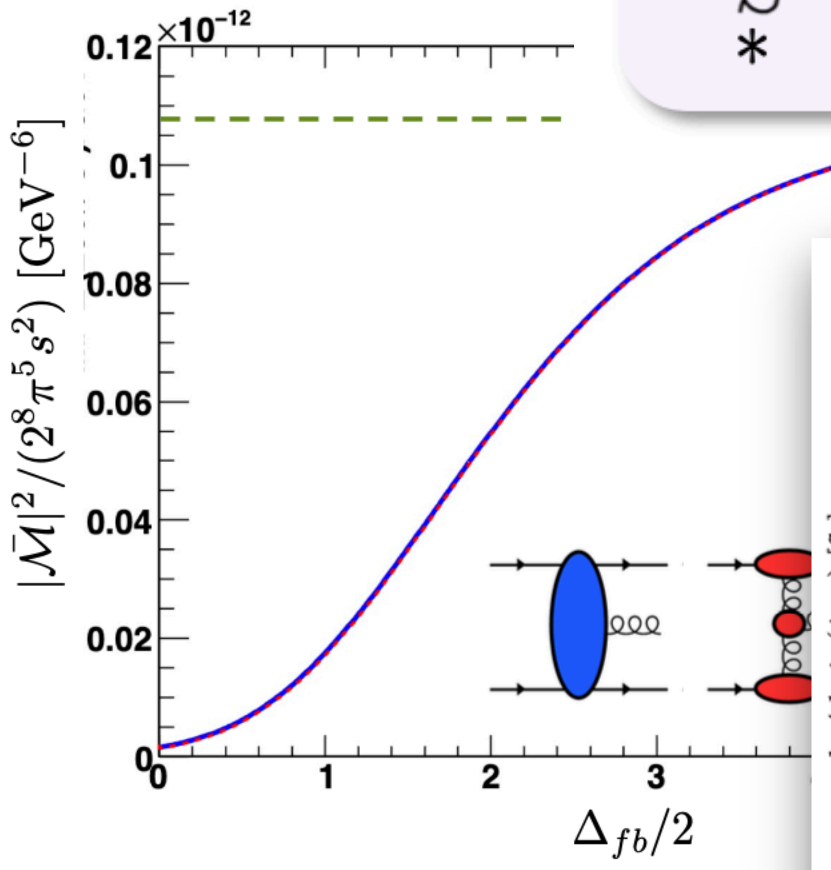

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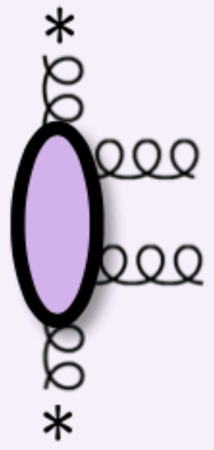

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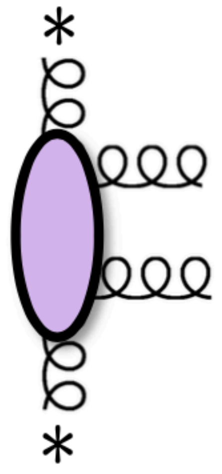

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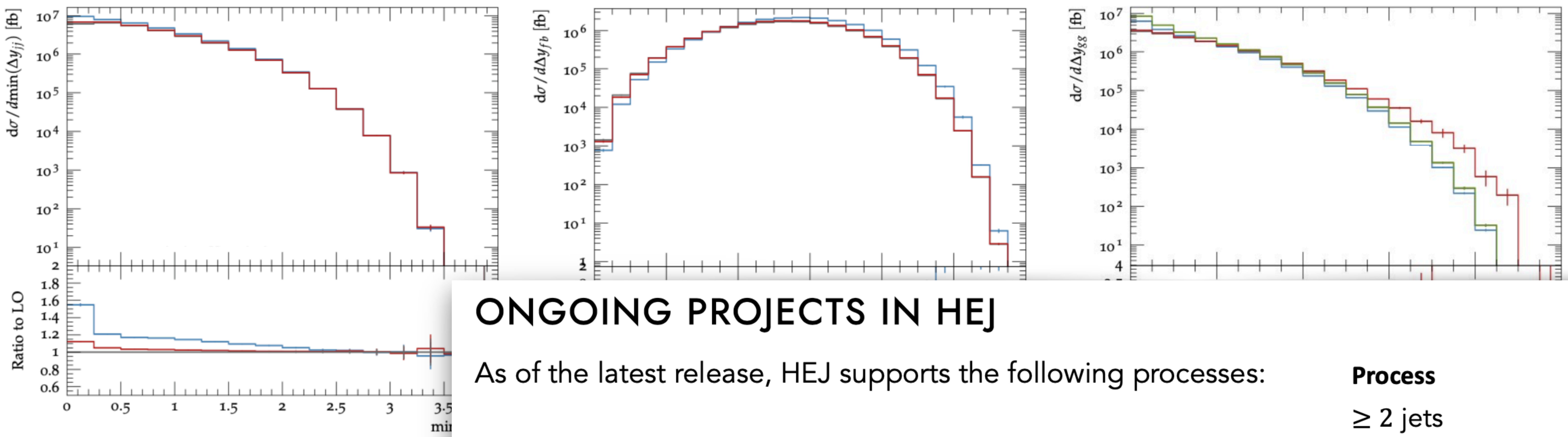

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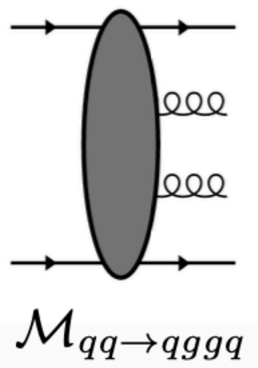


ONGOING PROJECTS IN HEJ

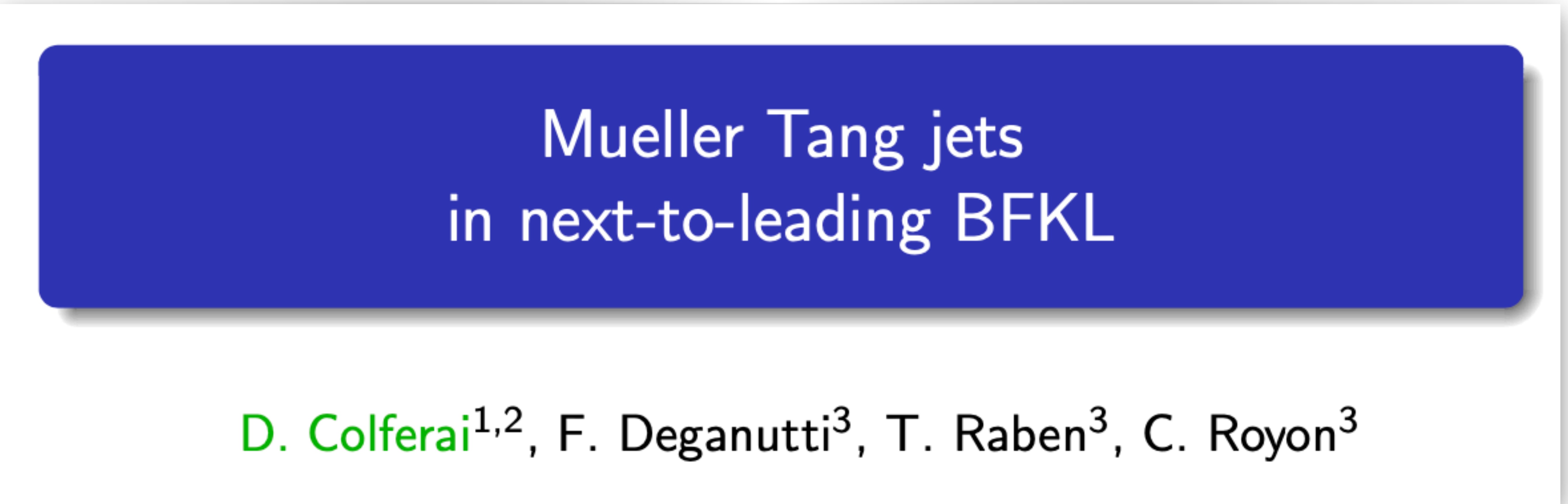
As of the latest release, HEJ supports the following processes:

	Process	**LL**	**Extremal g**	**Central qq**
	≥ 2 jets	✓	✓	✓
[2210.10671]	H + ≥ jet	✓	n/a	n/a
	H + ≥ 2 jets	✓	✓	
	W + ≥ 2 jet	✓	✓	✓
	Z/γ + ≥ 2 jet	✓	✓	
[2107.06818]	W± W± + ≥ 2 jet	✓		

Current ongoing projects include:

- Merging with Pythia
- Full NLL accuracy

DIMITRI COLFERAI



Mueller Tang jets
in next-to-leading BFKL

D. Colferai[1,2], F. Deganutti[3], T. Raben[3], C. Royon[3]

DIMITRI COLFERAI

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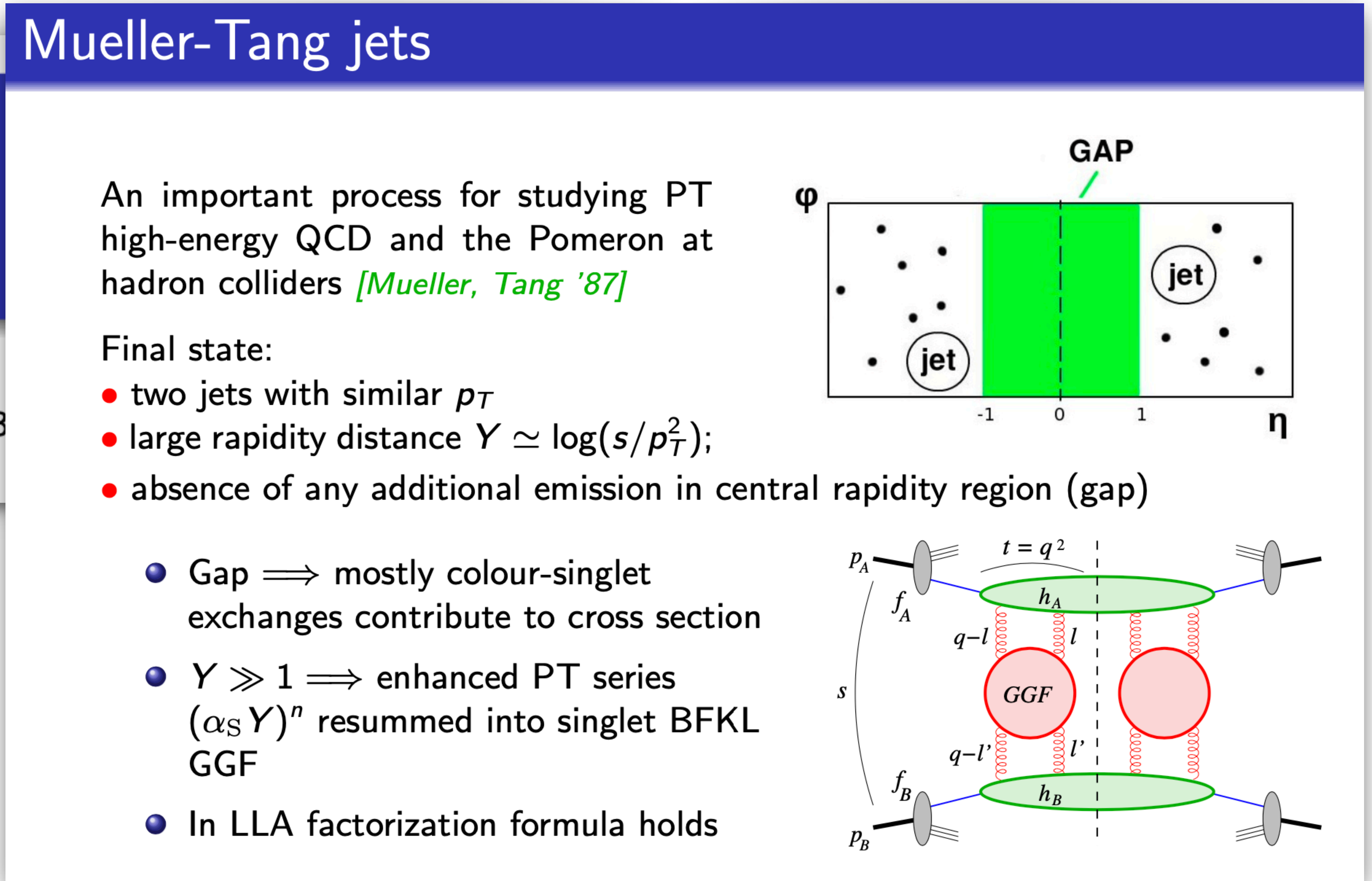

Mueller-Tang jets

An important process for studying PT high-energy QCD and the Pomeron at hadron colliders *[Mueller, Tang '87]*

Final state:

- two jets with similar p_T
- large rapidity distance $Y \simeq \log(s/p_T^2)$;
- absence of any additional emission in central rapidity region (gap)

- Gap $\Longrightarrow$ mostly colour-singlet exchanges contribute to cross section
- $Y \gg 1 \Longrightarrow$ enhanced PT series $(\alpha_S Y)^n$ resummed into singlet BFKL GGF
- In LLA factorization formula holds

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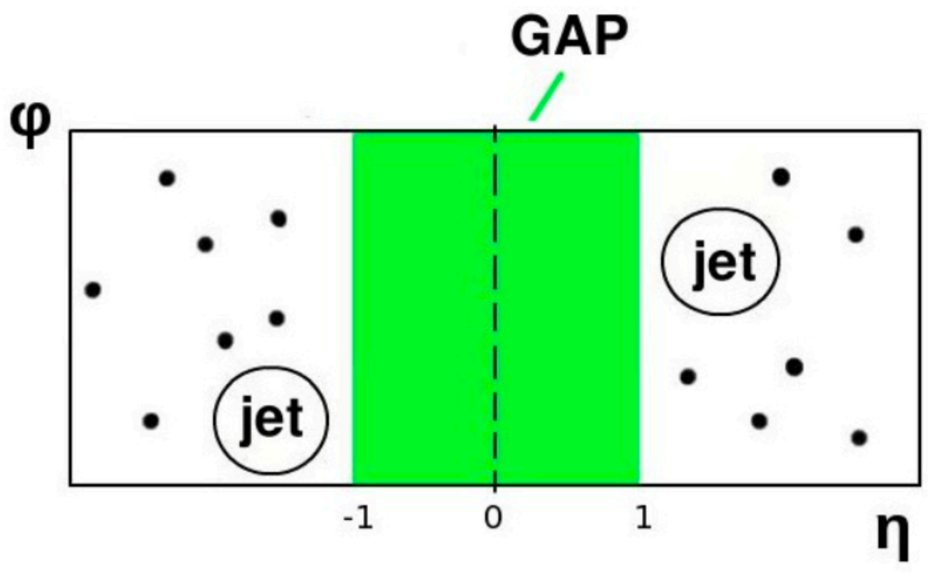

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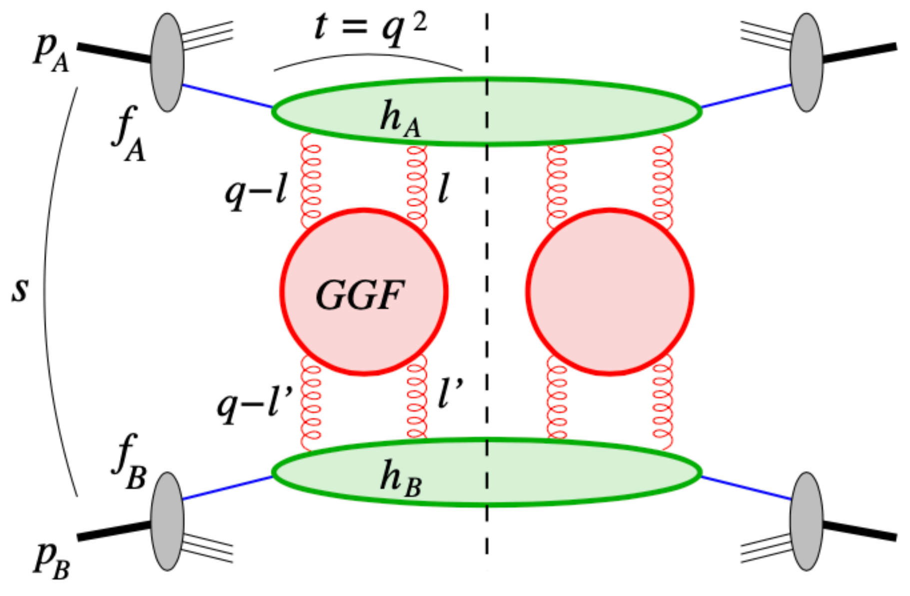
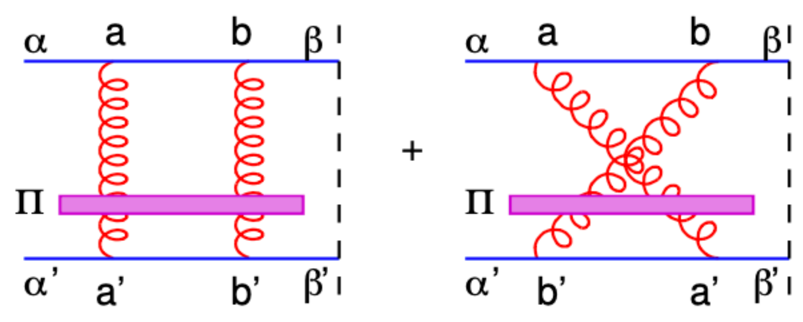
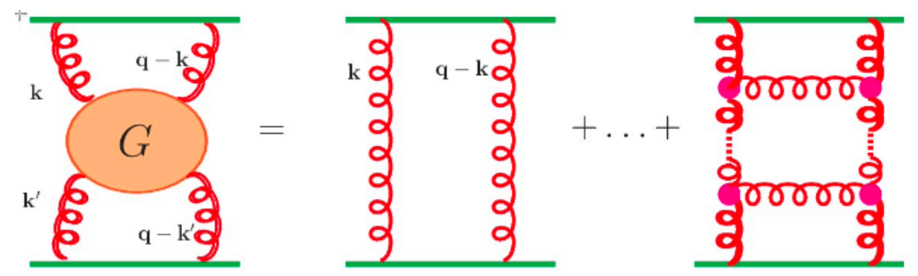


Mueller-Tang jets at LO and LL

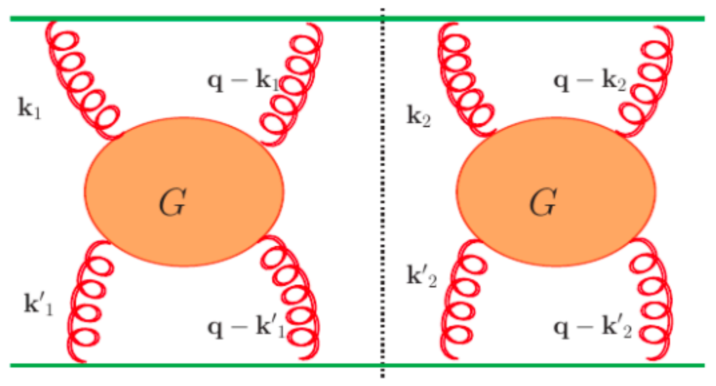
- LO amplitude: box + crossed diagrams projected onto colour-singlet $\Pi^{ab,a'b'} = \delta^{ab}\delta^{a'b'}/(N_c^2-1)$



- Elastic amplitude at higher orders: affected by large $\log^n s$ due to gluon-ladder diagrams (UV and IR finite)
- All LL resummed in (colour-singlet) gluon Green function (GGF)



- LL partonic cross section: 2 GGF $*$ 2 (trivial) impact factors
- Two outgoing partons to be identified with the (back-to-back) jets



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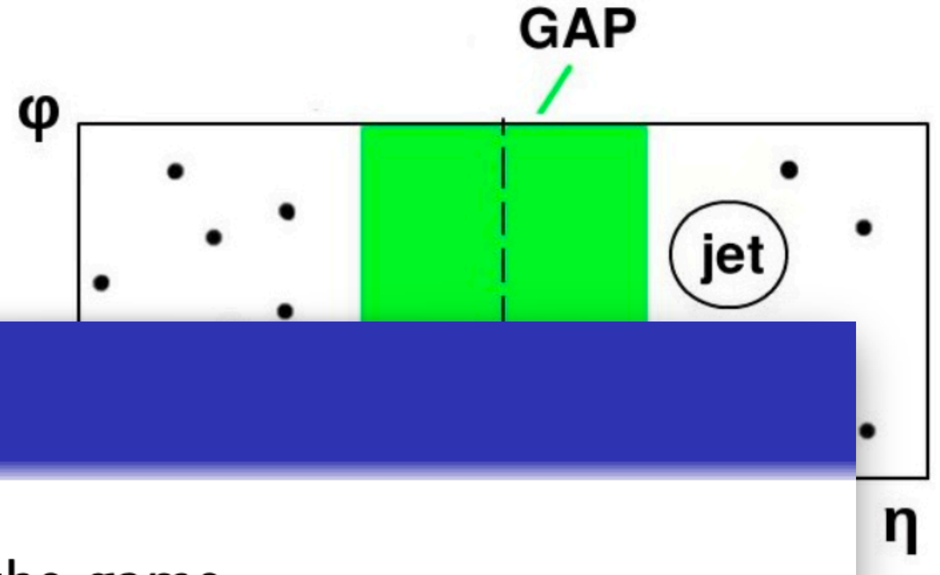

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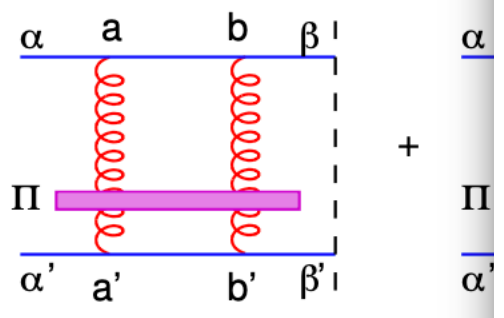

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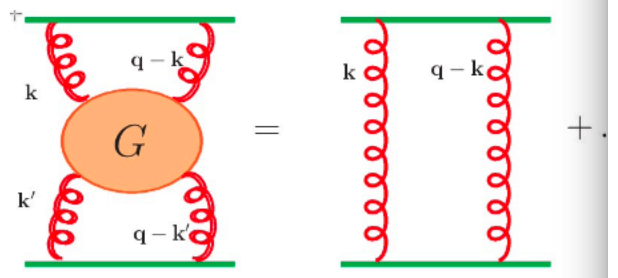

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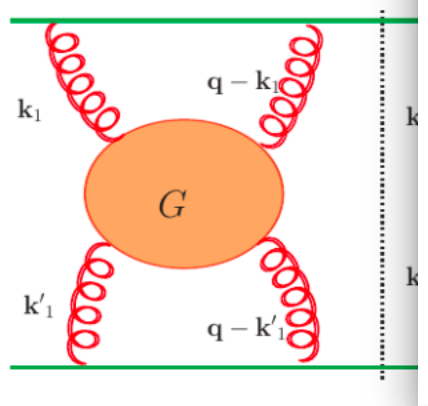
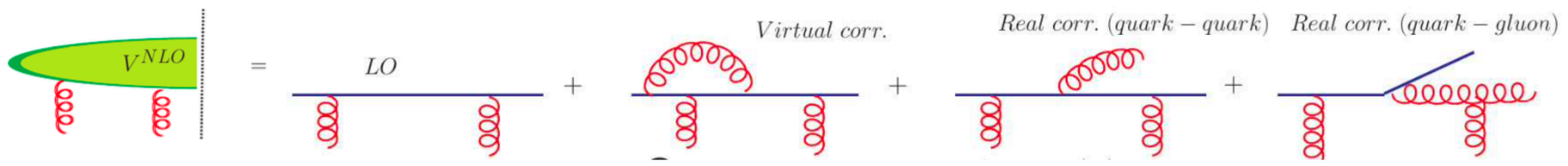
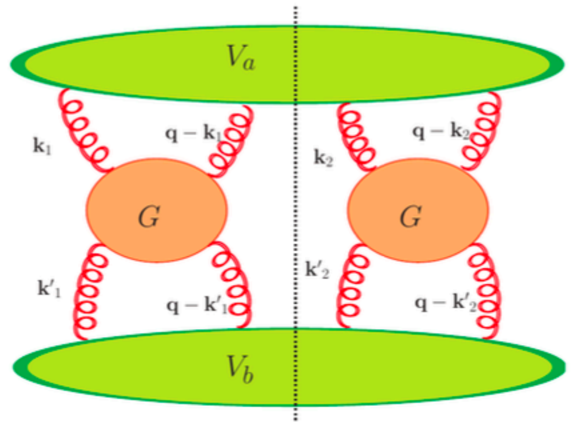


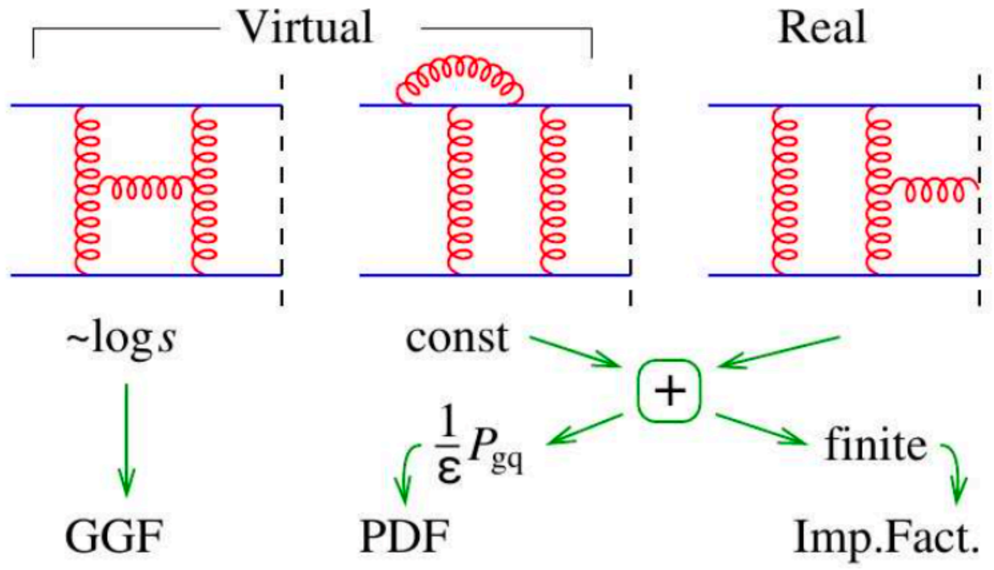
NL impact factors

- Compelling to include all NLL corrections into the game



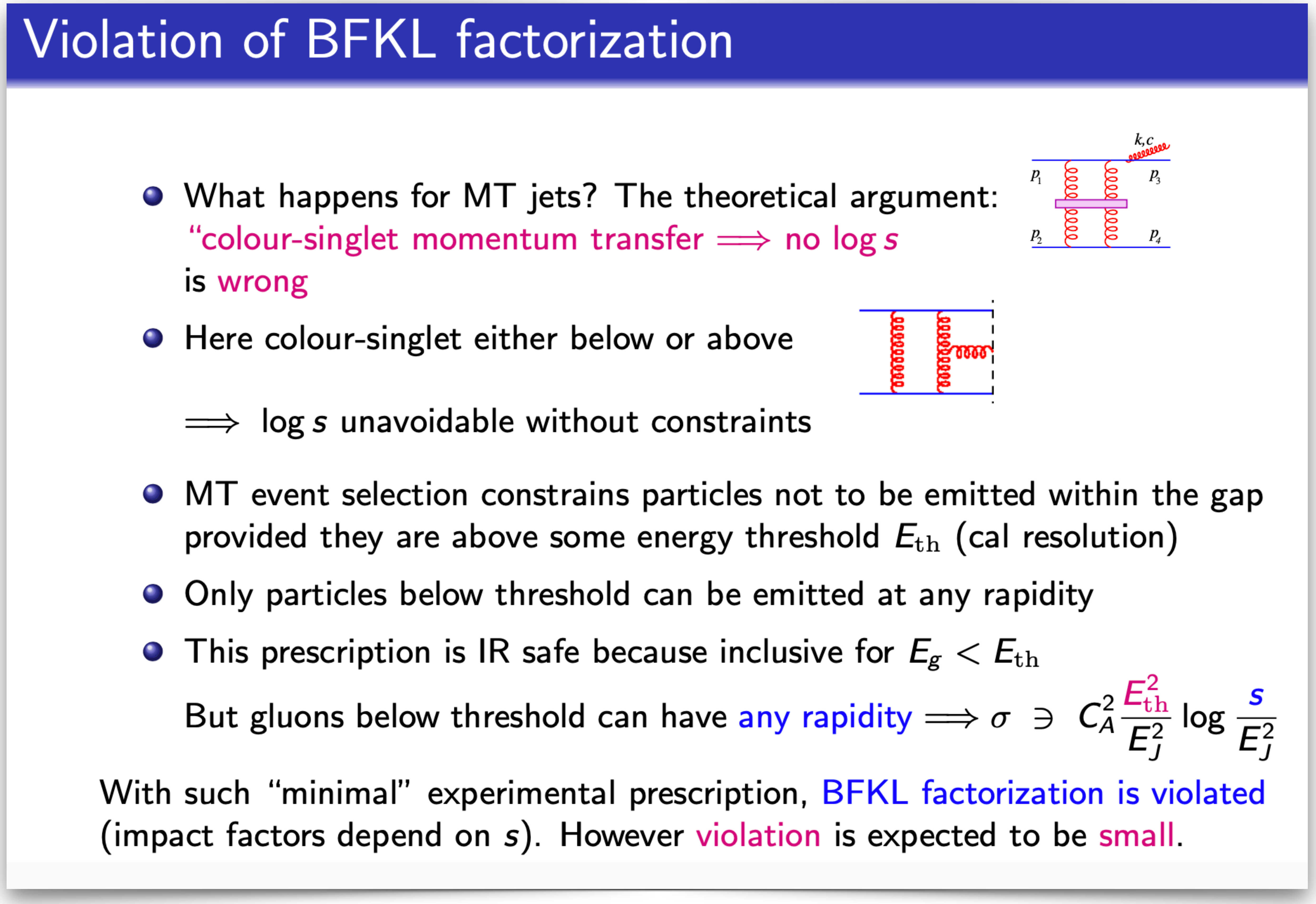
- Idea: generalize MT factorization formula at NLL
- BFKL GGF at NLL known since long *[Fadin, Fiore et al.]*
- NL impact factors determined by NLO calculation, with IR (soft and collinear) divergencies





Not a trivial statement:

- all log(s) terms must reproduce LL kernel (GGF at 1st order)
- all IR singularities (taken away collinear ones proportional to splitting functions) must cancel



Violation of BFKL factorization

- What happens for MT jets? The theoretical argument: "colour-singlet momentum transfer $\Longrightarrow$ no $\log s$" is wrong
- Here colour-singlet either below or above

  $\Longrightarrow$ $\log s$ unavoidable without constraints

- MT event selection constrains particles not to be emitted within the gap provided they are above some energy threshold $E_{\rm th}$ (cal resolution)
- Only particles below threshold can be emitted at any rapidity
- This prescription is IR safe because inclusive for $E_g < E_{\rm th}$

  But gluons below threshold can have any rapidity $\Longrightarrow \sigma \ni C_A^2 \frac{E_{\rm th}^2}{E_J^2} \log \frac{s}{E_J^2}$

With such "minimal" experimental prescription, BFKL factorization is violated (impact factors depend on s). However violation is expected to be small.

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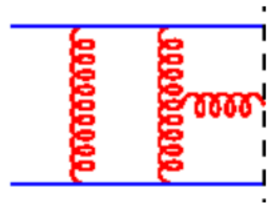

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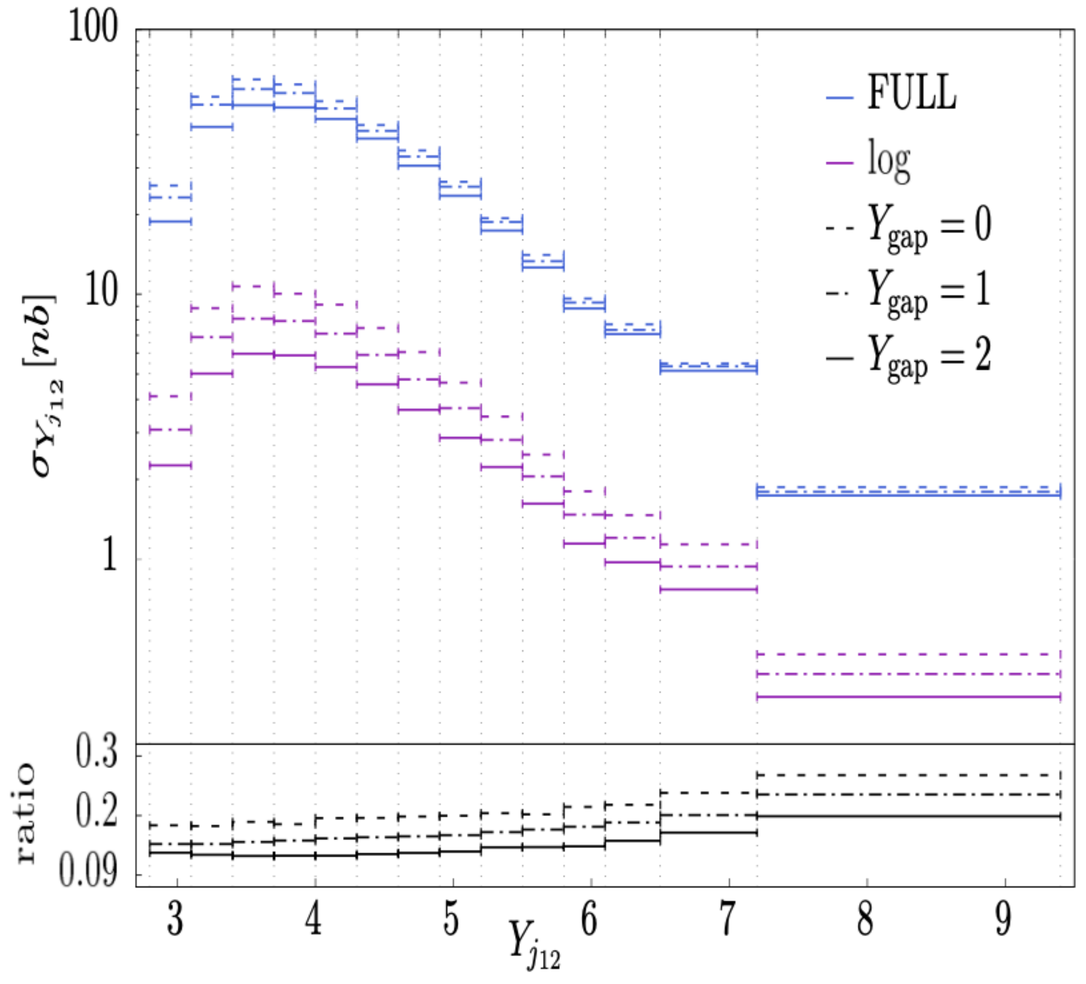
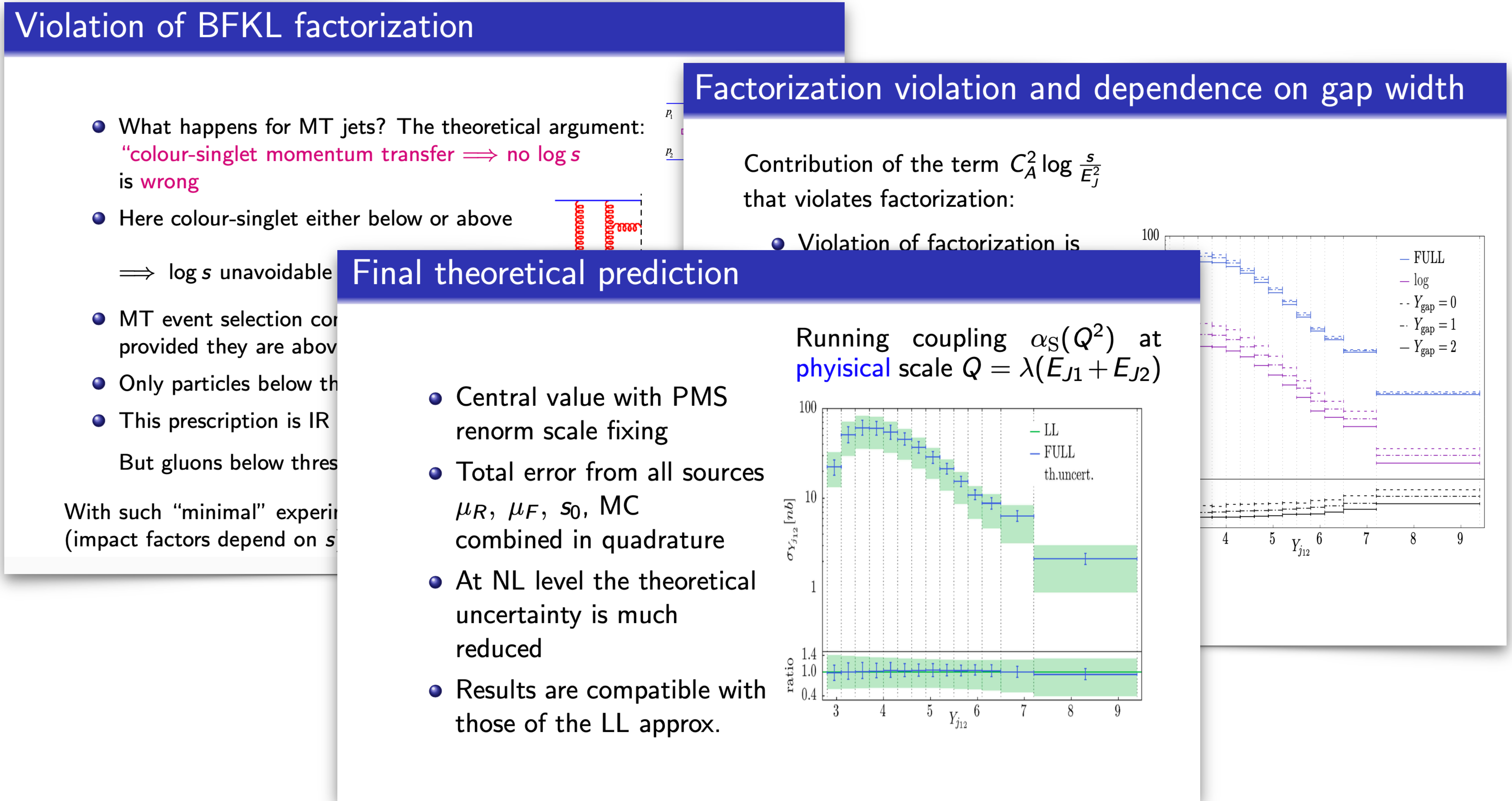
Factorization violation and dependence on gap width

Contribution of the term $C_A^2 \log \frac{s}{E_J^2}$ that violates factorization:

- Violation of factorization is small, $\sim 10\%$ (with $Y_{\rm gap} = 2$)
- Resummation of such logarithms not necessary for phenomenology
- Cross section slightly increases while decreasing $\Delta Y_{\rm gap}$ and saturates with no gap
- Emission from singlet exchange in central region is dynamically suppressed





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Final theoretical prediction

- Central value with PMS renorm scale fixing
- Total error from all sources μ_R, μ_F, s_0, MC combined in quadrature
- At NL level the theoretical uncertainty is much reduced
- Results are compatible with those of the LL approx.

Running coupling $\alpha_S(Q^2)$ at phyisical scale $Q = \lambda(E_{J1} + E_{J2})$

¡ Thanks to All the Speakers !