Towards Exclusive HVM Production at NLO

$\sigma(\gamma p \to p + J/\psi)$ & $\mathrm{d}\sigma/\mathrm{d}y(pp \to p + J/\psi + p)$

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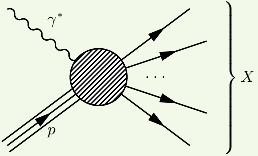
Workshop on Photon-induced Collisions at the LHC

2nd June

Forward physics: Exclusive & Diffractive Processes

Inclusive Processes - Included in global analyses



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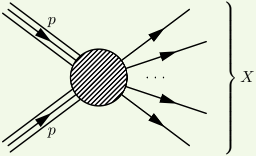
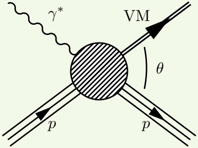
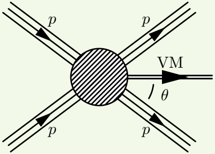


Inclusive pp Scattering

Exclusive & Diffractive Processes

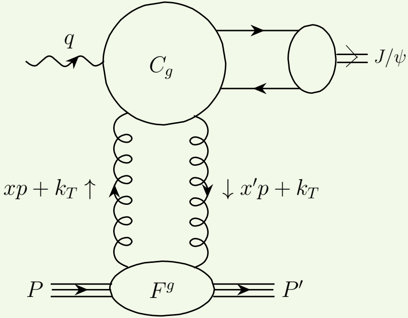


Exclusive HVM Electroproduction



Ultraperipheral HVM production

J/ψ Photo(electro)-production



General Setup & Assumptions

- Factorises: $\phi^{\gamma}_{c\bar{c}} \otimes T_{c\bar{c}+p} \otimes \phi^{J/\psi}_{c\bar{c}}$
- Non-relativistic J/ψ wave function $\propto \Gamma_{ee}$
- 'Maximal skew': $x' = 0$, outgoing gluon carries only k_T^{μ}
- Compute Im, restore Re via dispersion relation

- $Q^2 = -q^2$ - photon virtuality
- Scale: $\bar{Q}^2 = (Q^2 + M^2_{J/\psi})/4$
- W - CM energy of $\gamma^* p$
- $x = (Q^2 + M^2_{J/\psi})/(W^2 + Q^2)$

Amplitude (k_T Factorisation)

$$A \propto \int \frac{\mathrm{d}k_T^2}{2k_T^4} \left(\frac{1}{\bar{Q}^2} - \frac{1}{\bar{Q}^2 + k_T^2} \right) \alpha_s(k_T^2) f(x, k_T^2, \mu^2)$$

LO Result (LLA, Im Part)

- Leading log approximation (LLA): $k_T^2 \ll \bar{Q}^2$
- $\int \mathrm{d}k_T^2/k_T^2 \, f(x, k_T^2, \mu^2) \to xg(x, \mu^2)$

$$\left.\frac{\mathrm{d}\sigma}{\mathrm{d}t}(\gamma^* p)\right|_{t=0} = \frac{\Gamma_{ee} M_{J/\psi}^3 \pi^3}{48\alpha} \frac{\alpha_s(\bar{Q}^2)^2}{\bar{Q}^8} \left[R_g \, xg(x, \bar{Q}^2) \right]^2 \left(1 + \frac{Q^2}{M_{J/\psi}^2} \right)$$

[Ryskin 1993]

- R_g - skewing factor [Shuvaev et. al 1999]

(Mandelstam) t dependence

- Assume form $\exp(-bt)$, fit slope parameter b from experiment
- $b(W) = (4.9) + 4\,(0.06)\,\ln(W/90 \text{ GeV}) \text{ GeV}^{-2}$

Beyond LO Result

- Above IR scale $Q_0^2 = 1\ \mathrm{GeV}^2$ up to kinematic upper bound perform explicit k_T^2 integration in the last step of the evolution

$$\mathrm{Im}A \sim \mathrm{IR\ Part} + \int_{Q_0^2}^{(W^2-M_{J/\psi}^2)/4} \frac{\mathrm{d}k_T^2}{k_T^2} \frac{\alpha_s(\mu^2)}{\bar{Q}^2(\bar{Q}^2 + k_T^2)} f(x, k_T^2, \mu^2)$$

- Use ‘Unintegrated’ PDF

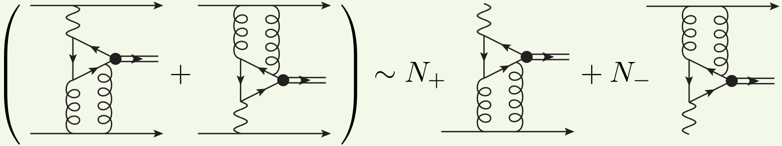
$$f(x, k_T^2, \mu^2) = \frac{\partial[R_g\, xg(x, k_T^2)\sqrt{T(k_T^2, \mu^2)}]}{\partial \ln k_T^2}$$

- T - Sudakov factor (hard gluon emits no additional partons)
- Disclaimer: Not an NLO matrix element!

Ultraperipheral Production (pp)

- Ultraperipheral cross-section vs rapidity y receives contributions from two γp CM energies: $(W_\pm)^2 = M_{J/\psi}\sqrt{s}\exp\left(\pm|y|\right)$

$$\frac{\mathrm{d}\sigma(pp)}{\mathrm{d}y} = S_+^2 N_+ \sigma_+(\gamma p) + S_-^2 N_- \sigma_-(\gamma p)$$



- $N_\pm = k_\pm \left(\mathrm{d}n/\mathrm{d}k\right)_\pm$ - photon flux (EPA)
- $S_\pm^2$ - gap survival factors (KMR Model) [Khoze et al. 2002]

Extracting Small-x Gluon

- Try two different ansätze for small-x gluon

LO Approach

- Power law: $xg(x, \mu^2) = Nx^{-\lambda}$ with $\lambda = a + b\ln(\mu^2/0.45\text{GeV}^2)$

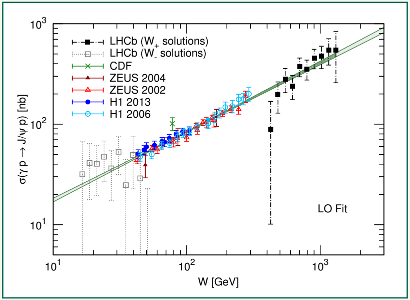
Beyond 'LO' Approach

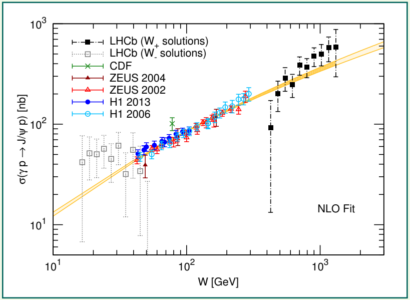
- Resum leading $(\alpha_s \ln(1/x) \ln \mu^2)^n$ contributions
- $xg(x, \mu^2) = Nx^{-a}(\mu^2)^b \exp\left[\sqrt{16N_c/\beta_0 \ln(1/x) \ln(G)}\right]$
- $G = \ln(\mu^2/\Lambda^2_{\text{QCD}})/\ln(Q_0^2/\Lambda^2_{\text{QCD}})$ with $\Lambda_{\text{QCD}} = 200\text{ MeV}$

Fitting Procedure

- Non-linear χ^2 fit to data
- Obtain best fit N, a, b and full covariance matrix for error estimate

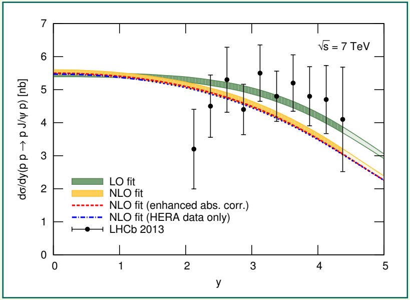
J/ψ Fit HERA & LHCb 2013

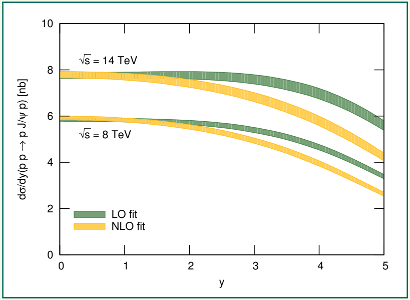




- Extends to $x \sim 10^{-6}$
- LHCb $W_{\pm}$ points calculated with our S^2, $\mathrm{d}n/\mathrm{d}k$, $\sigma(\gamma p)$
- Recall: LO and 'NLO' parameters have different meaning

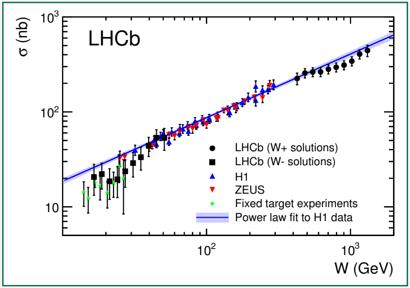
	LO	'NLO'
N	1.20	0.29
a	0.05	-0.10
b	0.08	-0.20
$\chi^2_{d.o.f}$	0.5	0.6

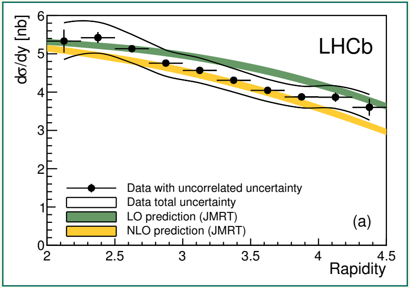




- Can use fitted gluon for $\mathrm{d}\sigma(pp)/\mathrm{d}y$ prediction (stable at 14 TeV)
- W_- component accounts for $\mathcal{O}(30-40\%)$ of $\mathrm{d}\sigma(pp)/\mathrm{d}y$
- HERA fit is consistent with LHCb 2013 data
  (LHCb not constraining)

J/ψ Prediction vs LHCb 2014

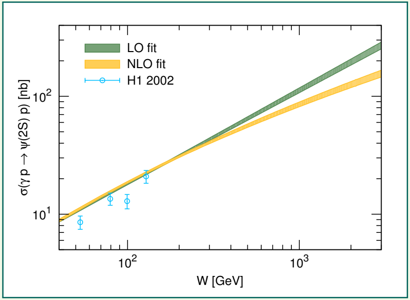


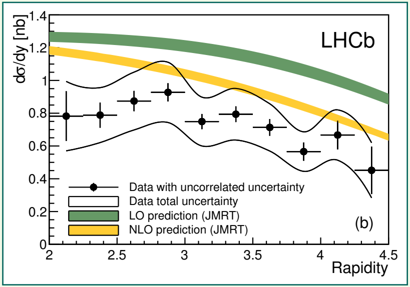


- 2014 data ($\sqrt{s} = 7$ TeV) ~halves error on integrated σ [LHCb 2014]
- Still consistent with HERA power law
- Good agreement with predictions without refitting (not quite distinguishing)

$\Psi(2S)$ Prediction vs LHCb 2014

- Use gluon fit extracted from J/ψ data
- Γ_{ee}, M, S^2 for $\psi(2S)$
- $\sigma(\gamma p)$ related to $\mathrm{d}\sigma(pp)/\mathrm{d}y$ as for J/ψ

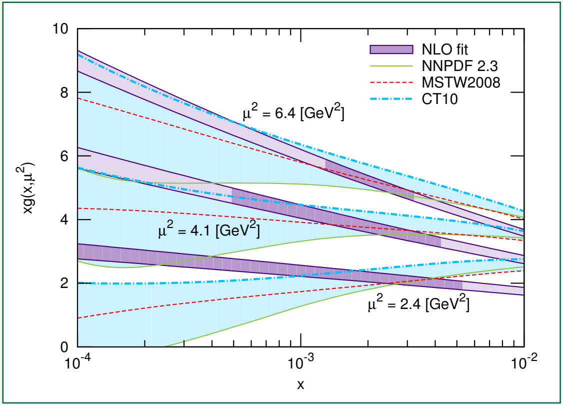




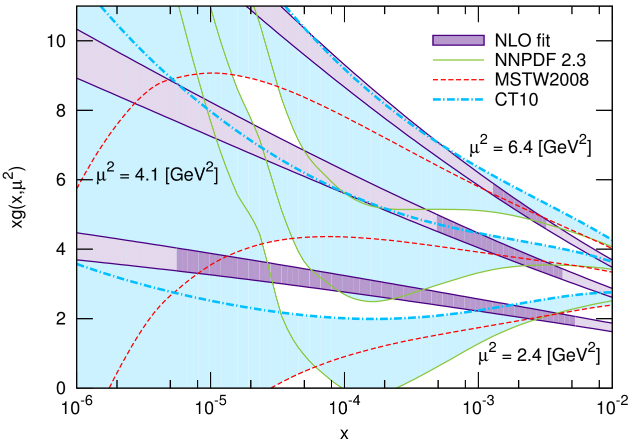
- Expect bigger relativistic corrections for $\psi(2S)$ than J/ψ
  - Some relativistic corrections accounted for in Γ_{ee}
  - Further corrections not accounted for

Gluon

- Scale dependence from k_T^2 integral and HERA electroproduction data
- Fitted gluons below global partons for higher $x \sim 10^{-2}$



- J/ψ data diminish the huge uncertainty on global gluons at low scale & small-x

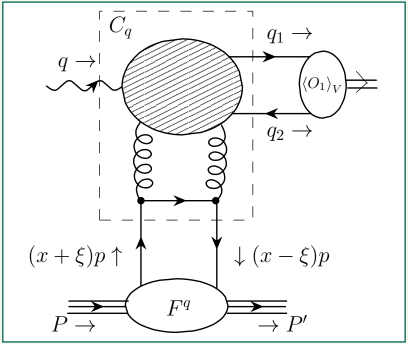


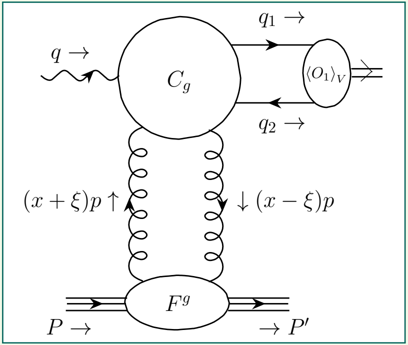
- LHCb data provides support for fit down to $x \sim 10^{-6}$
- 14 TeV data will probe even lower x

Towards full NLO Matrix Element

Collinear factorisation + NRQCD framework

Quark & Gluon Contribution



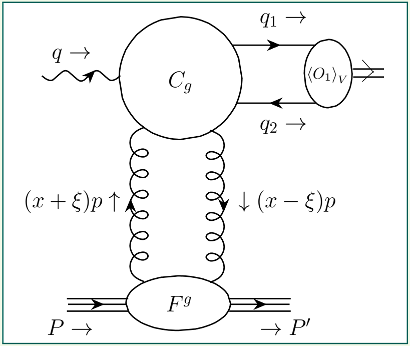


[Fig:Ivanov et al. 2004]

- Collinear factorisation (omitting μ_F and t): [Ji 1997, Collins et al. 1998]

$$A \propto \int_{-1}^{1} \mathrm{d}x \left[C_g\left(\frac{x}{x_B}, \frac{\xi}{x_B}\right) F^g(x,\xi) + C_q\left(\frac{x}{x_B}, \frac{\xi}{x_B}\right) F^q(x,\xi) \right]$$

- Set-up identical to [Ivanov et al. 2004]
  - Computed NLO matrix element for photoproduction using dispersive approach



- Our aim: check this result with standard integral reduction
- $\langle O_1 \rangle_V$ - NRQCD long distance matrix element
- Heavy quarks may have relative momenta, $r^\mu = q_1^\mu - q_2^\mu$

- $F^g(x, \xi, t, \mu_F)$ - Generalised Parton Distribution (GPD)
  - Related $\mathcal{O}(\xi)$ to PDFs via Shuvaev Transform [Shuvaev et. al 1999]
- Full dependence on momentum fraction ξ and skew x

NRQCD (HVM Formation)

- Effective field theory for production of heavy quarkonium [Bodwin et al. 1995]

$$\sigma_V = \sigma_{q\bar{q}} \cdot \langle O \rangle_V$$

- Relativistic corrections systematically computed by expanding matrix elements in powers of r:

$$\mathcal{M}[J/\psi] \propto (\mathcal{A}_\rho + \mathcal{B}_{\rho\sigma} r^\sigma + \mathcal{C}_{\rho\sigma\tau} r^\sigma r^\tau + \ldots)\epsilon^\rho_{J/\psi}$$

  $\mathcal{A}$, $\mathcal{B}$, $\mathcal{C}$ - matrix elements $\epsilon^\rho_{J/\psi}$ - J/ψ polarization

- We will compute to leading order in relative quark velocity v, for J/ψ:

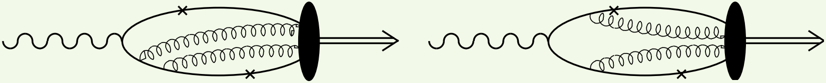
$$\mathcal{M}[J/\psi] = \left(\frac{\langle O_1 \rangle_{J/\psi}}{2N_c m_C} \right)^{\frac{1}{2}} \mathcal{A}_\rho \epsilon^\rho_{J/\psi}$$

- Compute $\Gamma_{ee} \propto \langle O_1 \rangle_{J/\psi}$
  - Extract $\langle O_1 \rangle_{J/\psi}$ from measurement of Γ_{ee}
  - Justification for using Γ_{ee} in k_T factorisation model

Relativistic Effects: J/ψ Formation

Hoodbhoy Study [Hoodbhoy 1997]

- Accounts for Fermi motion of the $c\bar{c}$ pair
  - Work in J/ψ rest frame using Coulomb gauge
  - Expand in powers of heavy quark relative velocity upto $\mathcal{O}(v^2)$
  - Necessary to include extra gluon fields to maintain gauge invariance
  - Procedure accounts for largest contribution from Fermi motion



Result

- Correction factor due to Fermi motion ≈ 0.94 (for cross-section)

NLO Matrix Element

Linearly dependent momenta

- GPDs: $(x+\xi)p^\mu \propto (x-\xi)p^\mu$
- Non-relativistic limit: $q_1^\mu = q_2^\mu$

$$I^{\mu_1 \ldots \mu_m} = \int [\mathrm{d}k] \frac{k_1^\mu \ldots k_m^\mu}{N_0 \cdots N_n}$$

1. Tensor (Integral) Decomposition

- Perform Sudakov decomposition:

$$q^\mu = (q \cdot n)p^\mu + (q \cdot p)n^\mu + q_T^\mu$$

$p^2 = n^2 = p \cdot q_T = n \cdot q_T = 0$ and $p \cdot n = 1$

- Kinematics: all q_T^μ vanish
- Choose basis constructed from just p^μ, n^ν and $\eta^{\mu\nu}$

$$I^{\mu\nu} = \eta^{\mu\nu} I_{00} + p^\mu p^\nu I_{11} + p^\mu n^\nu I_{12} + n^\mu p^\nu I_{21} + n^\mu n^\nu I_{22}$$

2. Integral Reduction

- Linearly dependent momenta ⇒ relation between propagators N_i
- Example:
  - Suppose $\sum_{i=0}^{3} a_i N_i = 1, \quad a_i \in \mathbb{R} \setminus \{0\}$

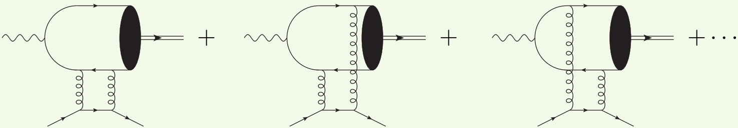
$$\frac{N_2}{N_0 N_1} = \frac{1}{a_2}\frac{1}{N_0 N_1} - \frac{a_0}{a_2}\frac{1}{N_1} - \frac{a_1}{a_2}\frac{1}{N_0}$$

- Retains initial basis of propagators
- Reduces N-point integrals to $(N-1)$-point
- Finally: Apply Laporta Algorithm, all integrals reduced to masters

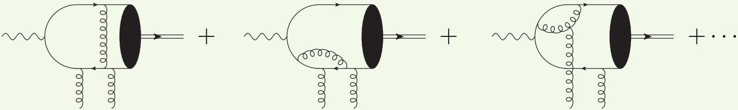
3. Master Integrals

- Known at 1-loop
  - Analytic: ['t Hooft, Veltman 1979] [Ellis et al. 2004]
  - Many numerical implementations: `QCDLoop`, `LoopTools`, ...

Quark



Gluon



Diagrams	Tree	1-Loop
Quark	0	6
Gluon	6	81

- Quark NLO complete!
  - Agrees with Ivanov et al.
- Gluon NLO underway

Conclusion

- In k_T factorisation:
  - Updated MNRT gluon fit to include recent LHCb data [Martin et al. 2008]
  - Provided predictions for J/ψ, $\psi(2S)$ ultraperipheral production $\sqrt{s} =$ 7, 8 & 14 TeV
  - Not a complete NLO analysis (main kinematic effects included)
  - Considerable scale uncertainty remains
  - Can not directly identify extracted gluon with e.g. $\overline{\text{MS}}$ partons

- In Collinear factorisation:
  - Work under way to include NLO gluon diagrams
  - Better estimation of scale & check of scale variation
  - Clear scheme choice ($\overline{\text{MS}}$)
  - Can use same techniques to compute electroproduction

Extra

Scale Uncertainty

Observations from MNRT Study

- Varying μ from $\mu/2$ to 2μ in Sudakov factor (T) gives small effect
  - Inclusion of T at all only slightly alters the behaviour of the gluon
  - Reason: T mostly contributes in k_T^2 integral where derivative is taken
- Varying μ in α_s causes strong scale dependence
- Varying scale in both α_s and T simultaneously from $\mu/2$ to 2μ gives large effect $\pm 20\%$
  - Even including scale variation still obtain better gluon certainty than global partons!
  - Most scale variation is absorbed into the normalisation of the gluon
  - x-behaviour reasonably stable

GPDs

- Off-forward $P \neq P'$ generalisation of parton distribution functions
- Nonperturbative contribution factored into density matrix

$$M^q_{\alpha\beta} = \int \frac{\mathrm{d}\lambda}{2\pi} e^{-i\lambda x} \langle P' | \bar{\psi}_\beta \left(\frac{\lambda}{2} n\right) \mathcal{P}\{\} \psi_\alpha \left(-\frac{\lambda}{2} n\right) | P \rangle$$
$$= \frac{1}{2} F^q(x,\xi) \not{p}_{\alpha\beta} + \ldots$$

- Omitted higher-twist, terms relevant for polarized case

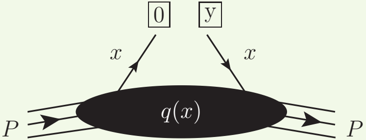
Universal

- Same distribution in other off-forward processes (eg... DVCS)

GPDs vs PDFs

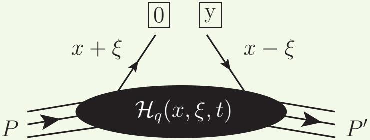
- Unpolarized, neglecting nucleon helicity flip: $F^q = \sqrt{1-\xi^2}\mathcal{H}_q$

PDF



$$\langle P|\,\overline{\psi}_q(y)\mathcal{P}\{\}\psi_q(0)\,|P\rangle$$

GPD



$$\langle P'|\,\overline{\psi}_q(y)\mathcal{P}\{\}\psi_q(0)\,|P\rangle$$

$$\mathcal{H}_q(x,0) = q(x) \qquad x > 0$$
$$\mathcal{H}_q(x,0) = -\bar{q}(-x) \qquad x < 0$$

Shuvaev Transform

- In small-x and ξ limit GPDs are related to PDFs via Shuvaev transform [Shuvaev et. al 1999]

Outline

- Anomalous dimensions of Gegenbauer moments, G_N of $\mathcal{H}(x,\xi)$, are equal to anomalous dimensions of conventional Mellin moments, $M_N = \int_0^1 x^N \mathcal{H}(x,0)\mathrm{d}x$
- Polynomiality: $G_N = \sum_{n=0}^{N} c_n^N \xi^{2n}$, allows all Gegenbauer moments to be determined $\mathcal{O}(\xi^2)$ from conventional PDFs ($c_0^N = M_N$) [1]

Regge-based Assumption

- No singularities in the right half N-plane of diagonal small-x input distributions [Martin et al. 2009]

[1] reduces to $\mathcal{O}(\xi)$ at NLO

Skewing & Real Part

- We use 'maximal skewing' limit ($\xi = x$), pure power PDF ($xg \sim x^{-\lambda}$) in transform which gives skewing factor

$$R_g = \frac{2^{2\lambda+3}}{\sqrt{\pi}} \frac{\Gamma(\lambda + \frac{5}{2})}{\Gamma(\lambda + 4)}$$

- $\mathcal{O}(20 - 30\%)$ error on cross section compared to full transform
  [Harland-Lang 2013]
- $\mathcal{O}(10 - 15\%)$ on gluon parameters

Real Part

- Real contribution included via dispersion relation assuming in the low x region $A \propto x^{-\lambda} + (-x)^{-\lambda}$

$$\frac{\mathrm{Re}A}{\mathrm{Im}A} \simeq \frac{\pi}{2}\lambda$$

IR Part and Scale Choices

IR Part

- For $k_T < Q_0$ assume linear behaviour of gluon at small k_T^2

$$xg(x, k_T^2)\sqrt{T(k_T^2, \mu^2)} = xg(x, Q_0^2)\sqrt{T(Q_0^2, \mu_{\mathrm{IR}}^2)}k_T^2/Q_0^2$$

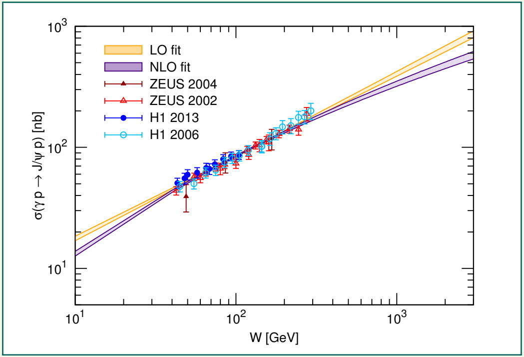
- Gives IR Part:

$$\ln\left(\frac{\bar{Q}^2 + Q_0^2}{\bar{Q}^2}\right)\frac{\alpha_s(\mu_{\mathrm{IR}}^2)}{\bar{Q}^2 Q_0^2}xg(x, Q_0^2)\sqrt{T(Q_0^2, \mu_{\mathrm{IR}}^2)}$$

Scale Choice

- Scale choice ambiguity remains (is extracted gluon e.g. $\overline{\mathrm{MS}}$?)
- Choose $\mu^2 = \max(k_T^2, \bar{Q}^2)$ and $\mu_{\mathrm{IR}}^2 = \max(Q_0^2, \bar{Q}^2)$
- Scale in IR Part matches lowest scale in integral
- Electroproduction typically contributes at higher scale
- $Q_0^2 = 1\ \mathrm{GeV}^2$ (fit relatively insensitive to this)

HERA $(\gamma^* p \to J/\psi + p)$



Parameters

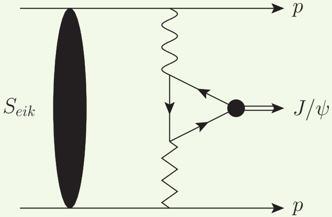
	LO	'NLO'
N	1.21	0.30
a	0.05	-0.11
b	0.08	-0.20
$\chi^2_{d.o.f}$	0.5	0.6

- Update to MNRT fit
  [Martin et al. 2008]

- Probes gluon for $10^{-4} \lesssim x \lesssim 10^{-2}$
- Note: Electroproduction data included in fit (not shown here)

Survival factors

- For $pp \to p + J/\psi + p$ non-negligible interactions between spectator quarks
- Can populate rapidity gap
- Event not selected



KMR Model

$$S^2 = \langle S^2(b_t) \rangle = \frac{\int \sum_i |\mathcal{M}_i(s, b_t^2)|^2 \exp\left[-\Omega_i(s, b_t^2)\right] \mathrm{d}^2 b_t}{\int \sum_i |\mathcal{M}_i(s, b_t^2)|^2 \mathrm{d}^2 b_t}$$

- $\mathcal{M}_i$ - process dependent matrix elements
- b_t - impact parameter, Ω_i - ‘universal’ proton opacities

[Khoze et al. 2002] [Khoze et al. 2013]

KMR Model

- Fitted to diffractive pp and $p\bar{p}$ data:
  - σ_{tot} - Total cross section ($\sigma_{\mathrm{el}} + \sigma_{\mathrm{inel}}$)
  - $\mathrm{d}\sigma/\mathrm{d}t$ - Elastic cross section
  - $\sigma^{\mathrm{D}}_{\mathrm{lowM}}$ - Low mass dissociation ($pp \to N^* + p$)
  - $\mathrm{d}\sigma/\mathrm{d}(\Delta\eta)$ - High mass dissociation
- Data from:
  - CERN ISR 1975–1980
  - CERN SPS 1982–1993
  - TEVATRON (CDF, DØ) 1990–2012
  - TOTEM 2011–2013
  - ATLAS 2012
- Two-channel eikonal model with one 'effective pomeron'
- Proton wave function written as superposition of two diffractive Good-Walker eigenstates $|p\rangle = \sum_i a_i|\phi_i\rangle$ with $i = 1, 2$

KMR Model (II)

- Use an opacity matrix Ω_{ik} corresponding to one-pomeron-exchange between states ϕ_i and ϕ_k
- Observables in terms of GW eigenstates depend on this opacity e.g.

$$\sigma_{\text{inel}} = \int \mathrm{d}^2 b_t \sum_{i,k} |a_i|^2 |a_k|^2 (1 - \exp\left[-\Omega_{ik}(b_t)\right])$$

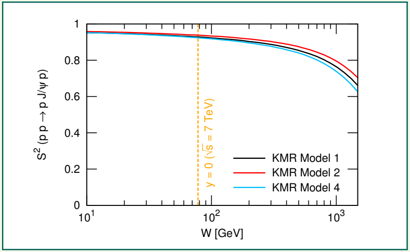
- Each GW eigenstate $|\phi_i\rangle$ independently parametrised by a form factor

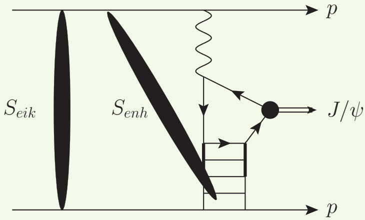
$$F_i(t) = \exp\left[-(b_i(c_i - t))^{d_i} + (b_i c_i)^{d_i}\right]$$

- 3 parameters per eigenstate + 1 relative weighting
- 'Effective' pomeron has energy dependent coupling to eigenstates
- 6 pomeron trajectory parameters: intercept (Δ), slope (α') and couplings (gives $b_0 = 4.9$, $\alpha' = 0.06$ for b slope)

KMR Model (III)

- Survival factors reasonably certain ($\mathcal{O}(5\%)$ difference between KMR models)
- Less certain for high rapidity





- Possibility of 'enhanced rescattering'
- Interaction between spectator quarks and parton in ladder

- Include this possibility using method of KMR [Ryskin et al. 2009]
- Find small effect from including S_{enh}

Photon Flux

$$\frac{\mathrm{d}n}{\mathrm{d}k} = \frac{\alpha}{\pi k}\int_0^\infty \mathrm{d}q_T^2 \frac{q_T^2 F_p^2(q_T^2)}{(t_{\min} + q_T^2)^2}$$

- k - photon energy
- q_T - photon trans. momentum
- $t_{\min}$ - kinematic q^2 cut-off

- Proton form factor:

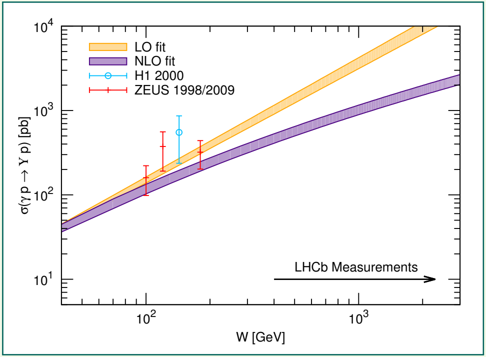
$$F_p(q_T^2) = \left(1 + \frac{t_{\min} + q_T^2}{0.71\ \mathrm{GeV}^2}\right)^{-2}, \qquad t_{\min} \approx \frac{(x_\gamma m_p)^2}{1 - x_\gamma}$$

- Photon flux consistent with KMR model
  - Similar to equivalent photon approximation (EPA)
  - But: neglect terms $\propto$ anomalous magnetic moment of the proton

Accuracy

- Neglected terms $\propto q_T^2$ have no singularity at $q_T^2 \to 0$
- Contributions from $q_T \sim 1/R_p$ are concentrated at small b_t, suppressed by large opacities

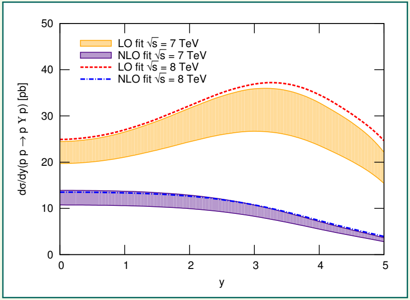
Υ Postdiction ($\gamma p \to \Upsilon + p$)

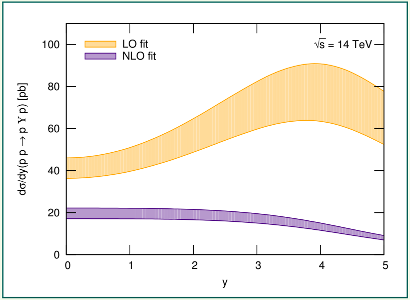


- Very little data available for comparison
- Need high energy Υ to determine scale dependence
- Huge discrepancy between extrapolated LO and 'NLO' fits

- Υ scale $\bar{Q}^2 \approx 23\,\mathrm{GeV}^2$ vs J/ψ scale $\bar{Q}^2 \approx 2.4\,\mathrm{GeV}^2$
- Future: Use full DGLAP evolution
  - Approximate treatment within our gluon uncertainty for $x \gtrsim 10^{-4}$
  - DGLAP gives $\approx 30\%$ larger gluon for $x \sim 10^{-5}$

Υ Prediction ($pp \to p + \Upsilon + p$)





- 'NLO' gluon parametrisation grows $1/x$ and $\ln(\mu^2)$ less steep than $xg \propto x^{-\lambda}$
- Large discrepancy between LO and 'NLO' due to poor high energy constraints on scale behaviour
- Large real and skewing corrections when W_- is small
- But: W_- component only $\mathcal{O}(15 - 20\%)$ of $\mathrm{d}\sigma(pp)/\mathrm{d}y$

NRQCD

- To compute $\gamma p \to J/\psi + p$
  - First $\gamma p \to c\bar{c} + p$ with $c\bar{c}$ on shell
  - Project onto quarkonium state $v\bar{u} \to \ldots \not{\epsilon}_{J/\psi}$
- Leading order in v: set $q_1^\mu = q_2^\mu$

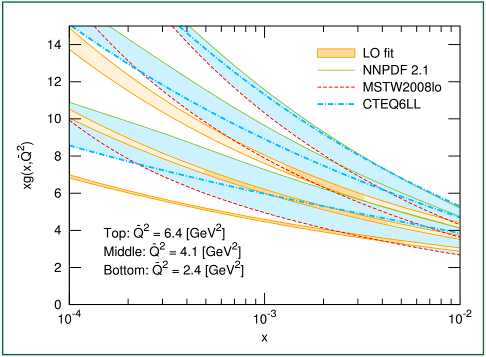
NRQCD Long Distance Matrix Element

- Can compute electronic decay rate

$$\Gamma[J/\psi \to e^+e^-] = \frac{2e_c^2\pi\alpha^2}{3}\frac{\langle O_1\rangle_{J/\psi}}{m_c^2}\left(1 - \frac{8\alpha_s}{3\pi}\right)^2$$

- Experimentally measure Γ_{ee} to determine $\langle O_1\rangle_{J/\psi}$
- Justification for using Γ_{ee} in k_T factorisation model

LO Gluon Fit



- Decreased uncertainty
- Steeply rising behaviour as for global partons
- Receive sizeable correction when including NLO effects (Like global partons)