Vector Meson Production

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Outline

Introduction

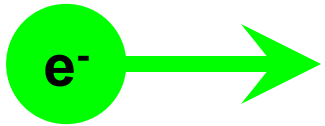
Models
- Light-Front Holography
- CGC Model
- b-CGC Model

Vector Meson Production
- Summer Work
- Results

Conclusion

Introduction

- Scattering experiments are used to find properties of subatomic particles.
- Deep inelastic scattering is the scattering of an electron off a proton.



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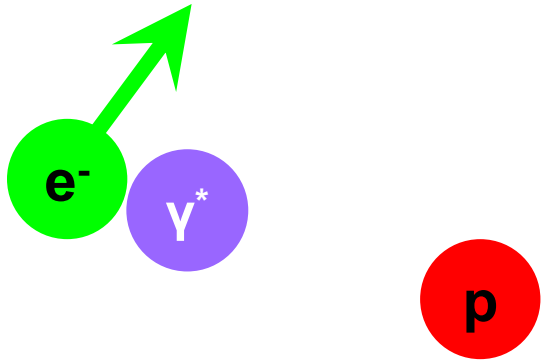

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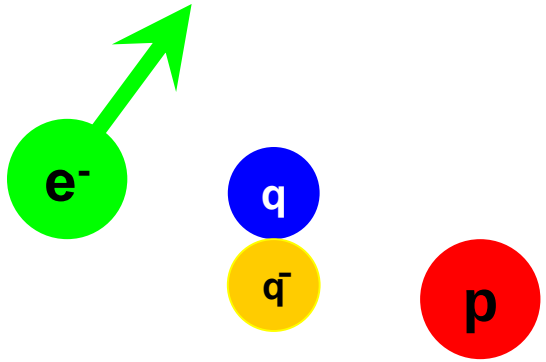
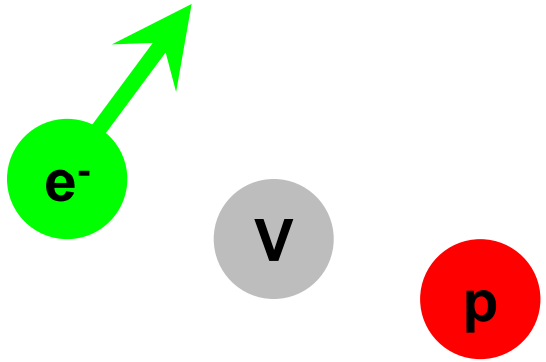
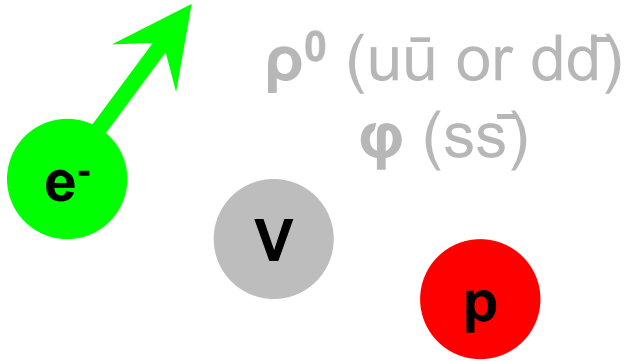
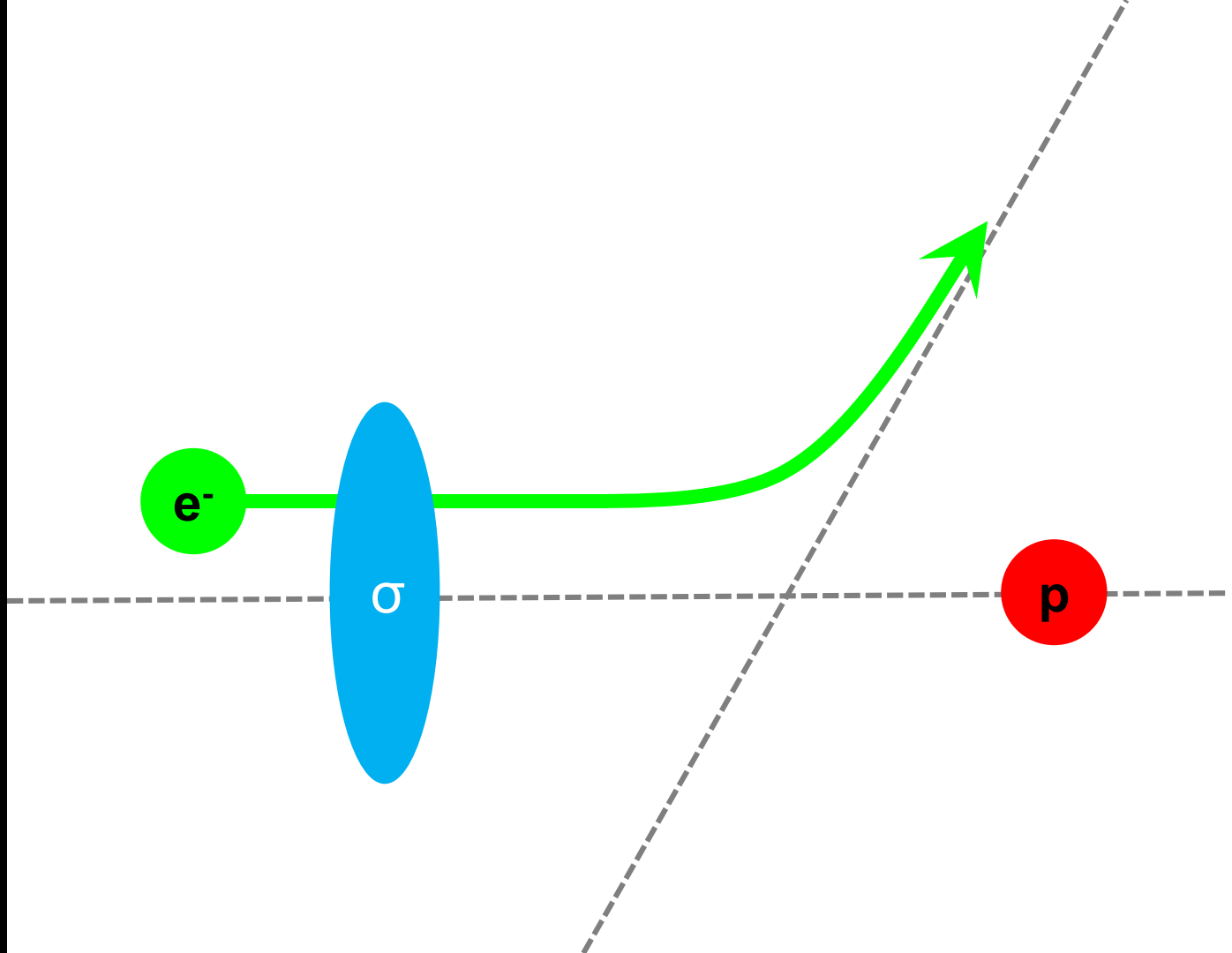


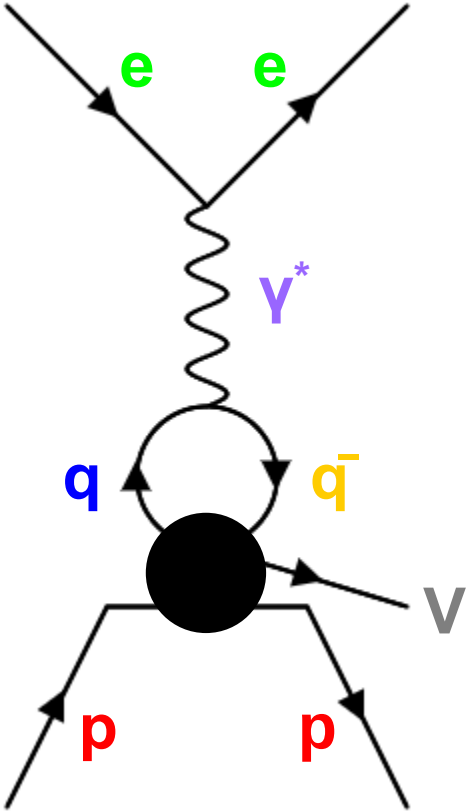






The HERA Collider

The Model



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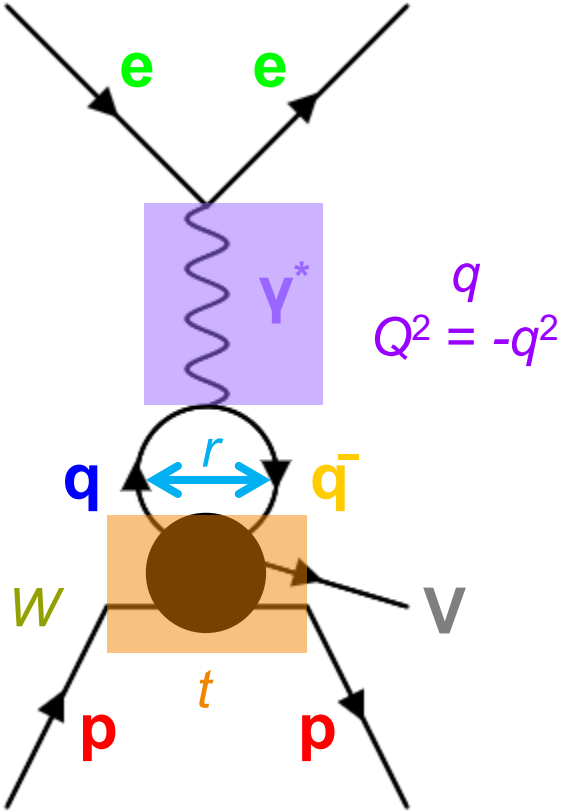
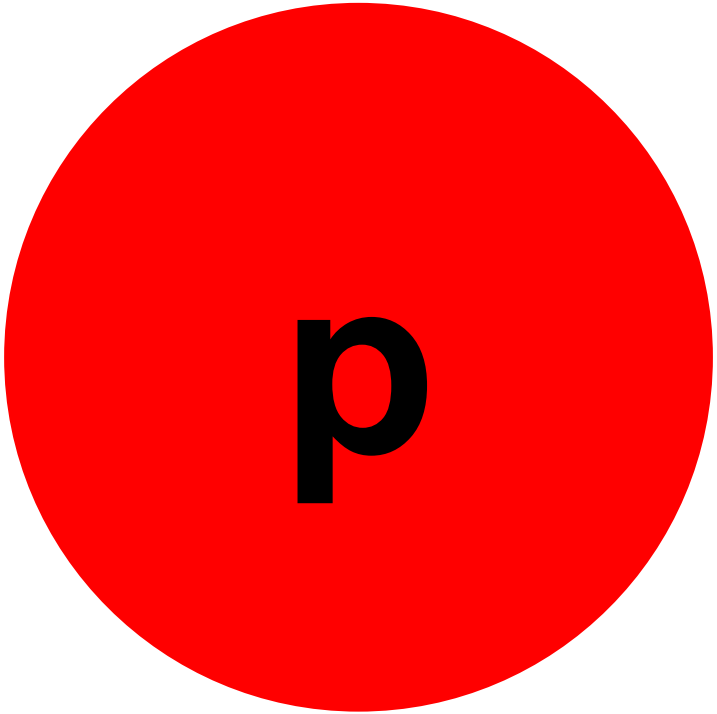


$$x_{Bj} = \frac{Q^2}{W^2}$$

The Proton



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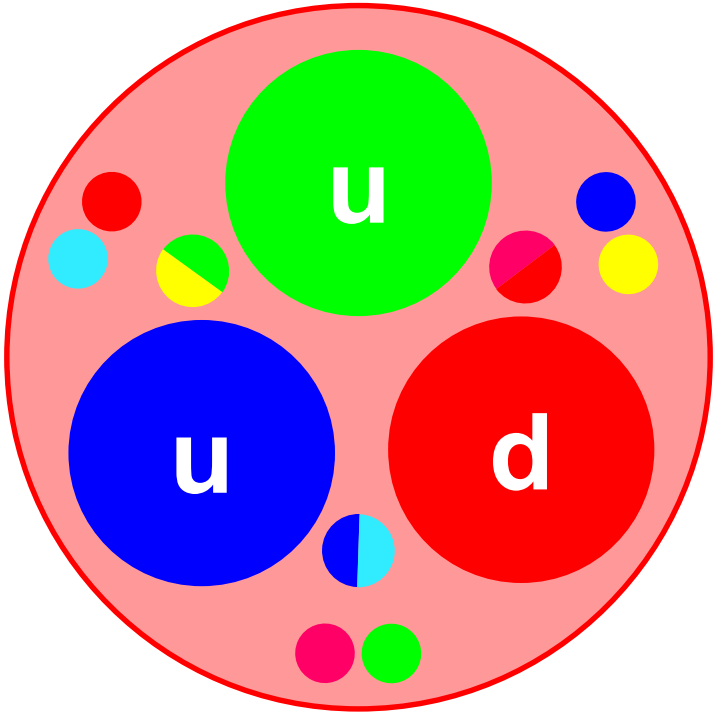

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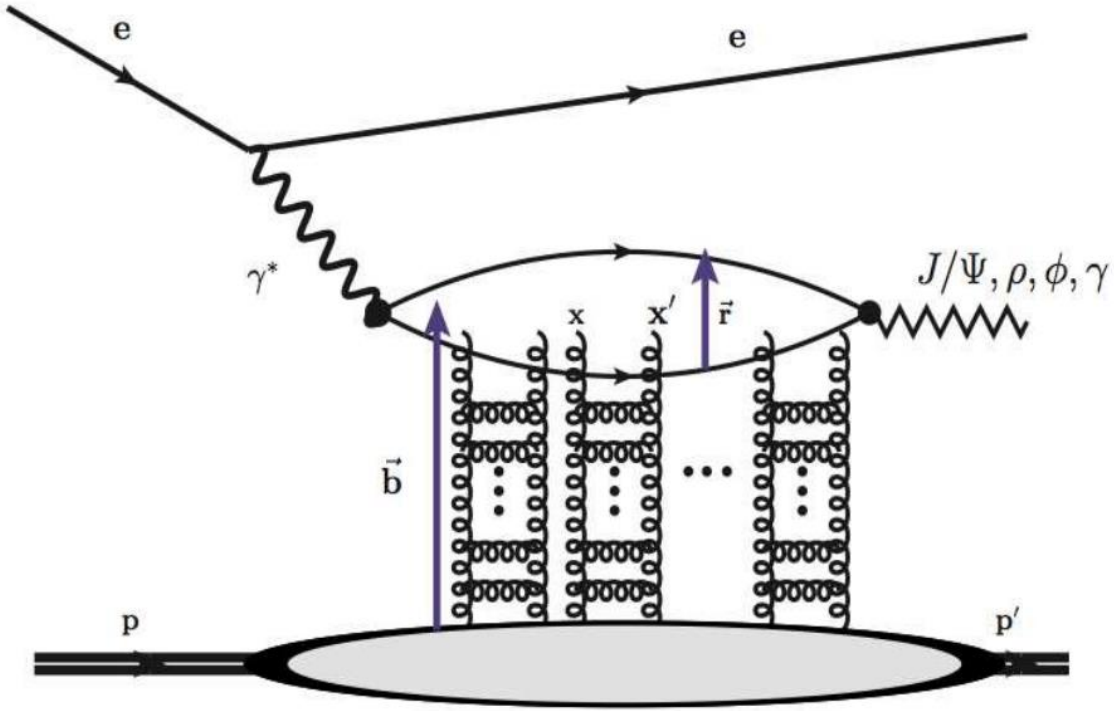

Light-Front Holography

Use light-front dynamics and its holographic mapping to gravity in a higher-dimensional anti-de Sitter (AdS) space to get a relativistic light-front wave equation for arbitrary spin (Brodsky, et al., 2015).

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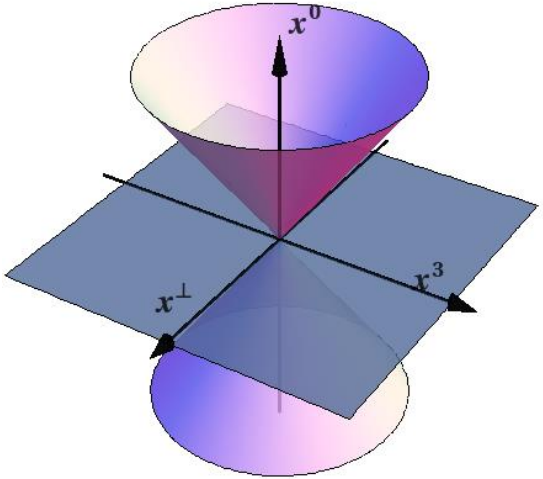
Light-Front Dynamics



- From relativistic dynamics
- Use the light-front form of wavefunction, rather than the instant form
- Represented as the plane on the edge of the light cone

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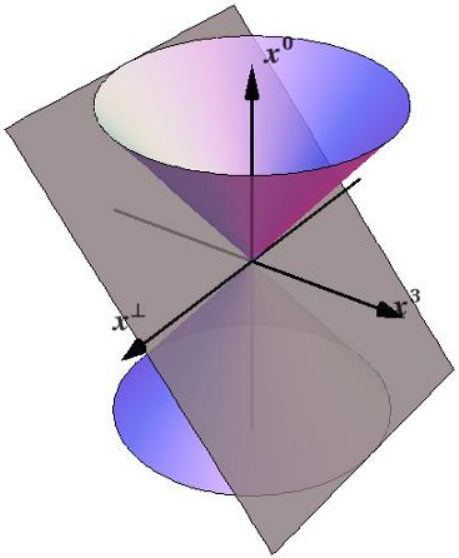

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Holographic Mapping

- If a theory in one space, of dimension d_1, corresponds to a separate theory in another space, of dimension d_2, they are holographic duals.
- Mappings can be defined to go from one to the other.
- Strong interactions in 5D and weak interactions in 4D are holographic duals.

Light-Front Holography

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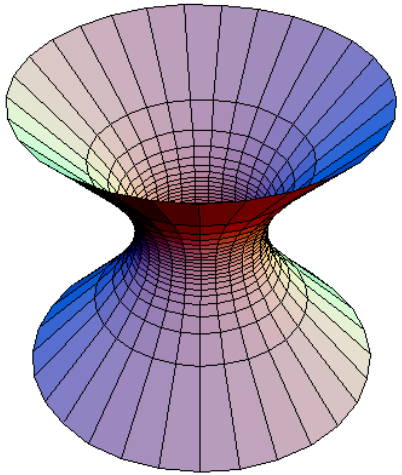
Anti-de Sitter Space



- A maximally-symmetric Lorentzian manifold with constant negative curvature.
- AdS/QCD mapping
- Work in five-dimensional anti-de Sitter space.

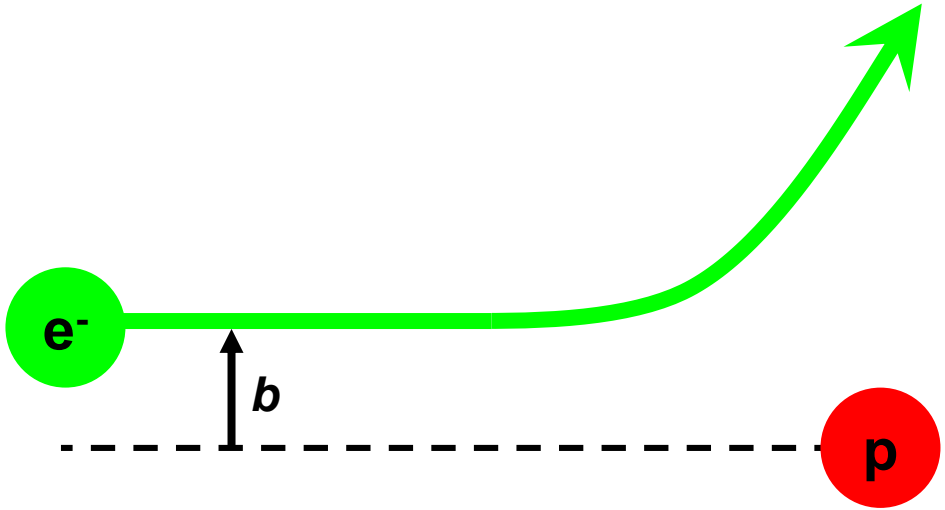
Colour Glass Condensate Model

- The quark-antiquark-proton interaction can be modelled using the colour glass condensate model.
- High density of gluons in the proton
- They act like a solid over short timescales, but as a liquid over long timescales.
- Four free parameters:

$$\gamma \qquad \sigma_0 \qquad x_0 \qquad \lambda$$

Impact-Parameter Dependence

- Dependence on the impact-parameter ***b*** was introduced by G. Watt and H. Kowalski (2008).



Impact-Parameter Dependence

- Five free parameters:

$$B_{CGC} \qquad \gamma \qquad N_0 \qquad x_0 \qquad \lambda$$

- Used an inherited Python code written with the `curve_fit()` package to fit these parameters to the 2015 high precision HERA data.

- Light quark mass of 0.14 GeV and charm quark mass of 1.27 GeV were used. N_0 was fixed at 0.558.
- Goodness of fit: find reduced chi-square value by dividing by the number of degrees of freedom

```
Best Fit Estimates:
B0: 6.51384545963 +/- 0.190047008786
x0: 9.67573820879e-06 +/- 2.98905926743e-06
gammas: 0.545418479496 +/- 0.00935223272521
lambda: 0.140655603202 +/- 0.0035384521905

Total Chi-Squared: 678.93399952
Degrees of Freedom : 520
Reduced Chi-Squared: 1.30564230677
P Value: 3.08505653052e-06
```

Vector Meson Production

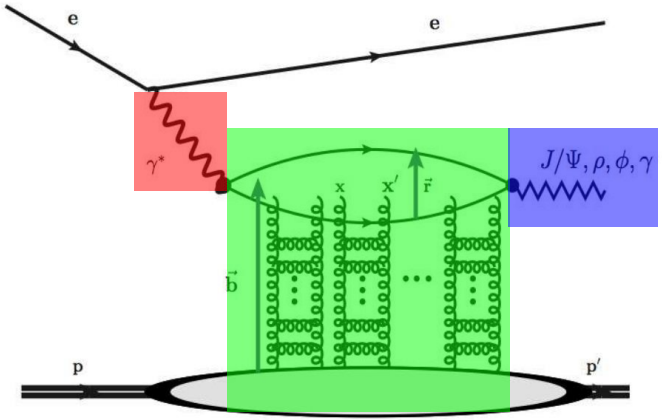
- A mathematical model for vector meson production can now be written:

$$\mathfrak{Im}A_\lambda(s,t;Q^2) = \sum_{h,\bar{h}} \int d^2\mathbf{r}dx\, \Psi^{\gamma^*,\lambda}_{h,\bar{h}}(r,x;Q^2)\, \Psi^{V,\lambda}_{h,\bar{h}}(r,x)^* e^{-ix\mathbf{r}\cdot\boldsymbol{\Delta}} N(x_m, r, \boldsymbol{\Delta})$$

Photon wavefunction

Vector meson wavefunction

Quark-antiquark-proton interaction



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Photon wavefunction

Vector meson wavefunction

Quark-antiquark-proton interaction

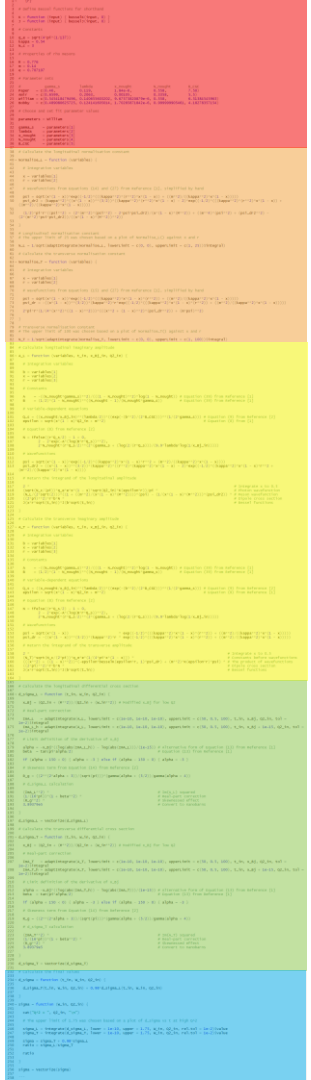
- CGC: $\dfrac{d\sigma_\lambda}{dt} = \dfrac{1}{16\pi}|\mathfrak{Im}A_\lambda(s,t=0)|^2\left(1+\beta_\lambda^2\right)e^{-B_D t}$
- b-CGC: $\dfrac{d\sigma_\lambda}{dt} = \dfrac{1}{16\pi}|\mathfrak{Im}A_\lambda(s,t=0)|^2\left(1+\beta_\lambda^2\right)$

Summer Work

- R code was written to calculate cross sections for rho and phi production.
- Used the new parameter values fit by the Python fit code in calculations.
- Made use of the adaptive integration package, `adaptIntegrate()`, to calculate multidimensional integrals.

$$\sigma = \sigma_T + 0.98\sigma_L$$

$$R = \frac{\sigma_L}{\sigma_T}$$



Define constants and set the fit parameter values

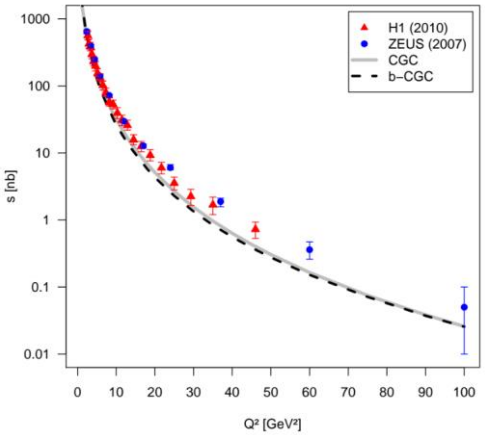
Calculate L and T normalisation constants for wavefunctions

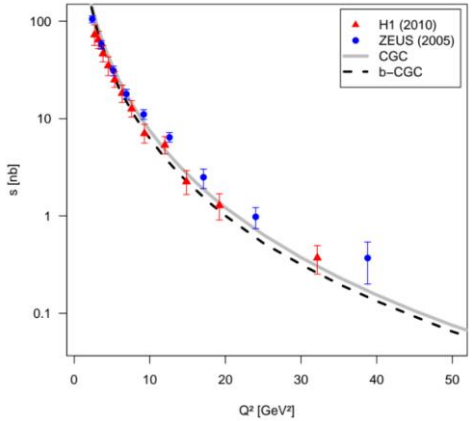
Calculate imaginary L and T scattering amplitudes

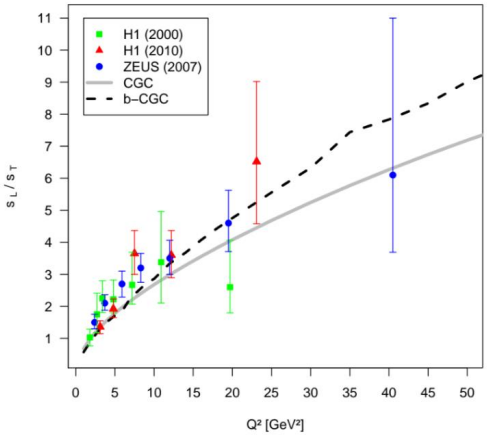
Calculate L and T differential cross sections

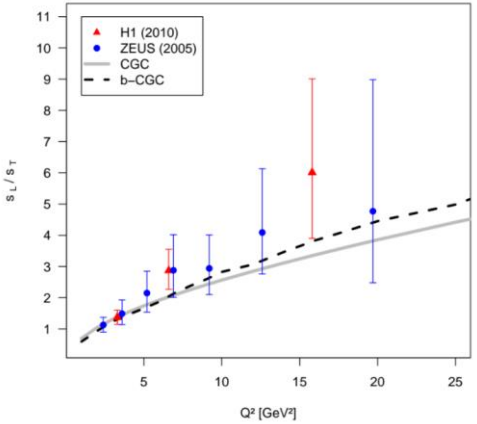
Calculate final values

Results









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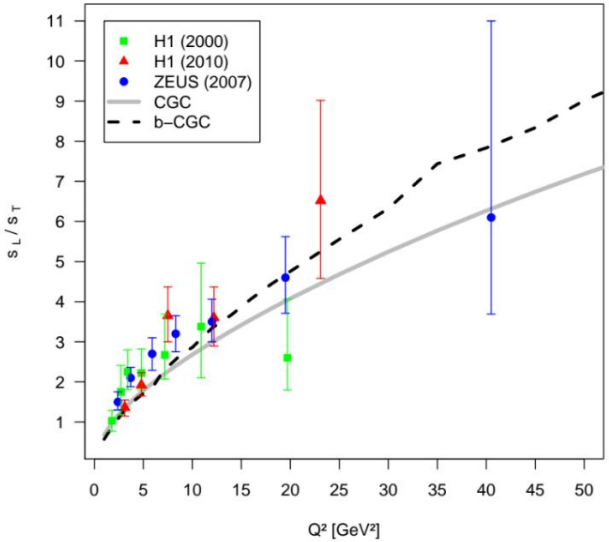

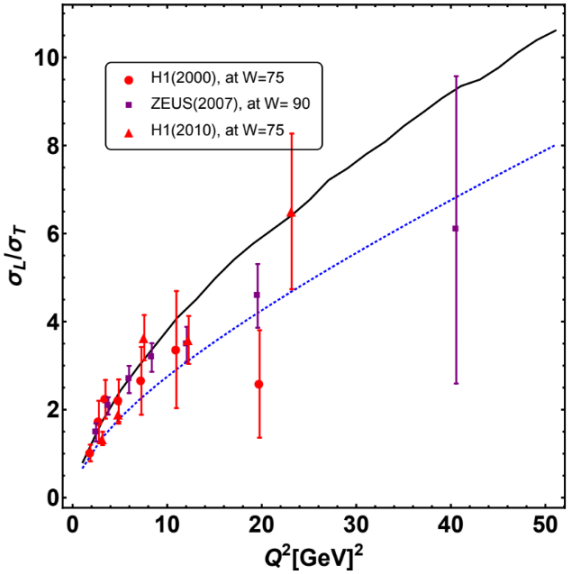

Conclusion

- The b-CGC parameter values were successfully updated using the 2015 data set.
- There is still work to be done to improve the cross section predictions.
- However, preliminary results show the model does fit the data reasonably well.

Acknowledgements

Dr Mohammad Ahmady

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