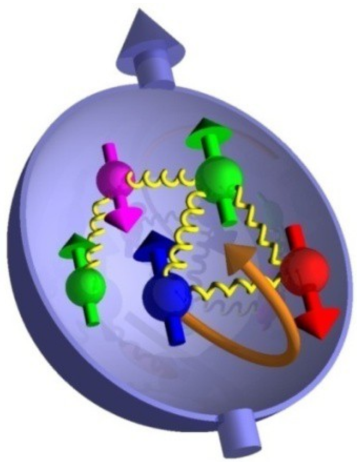
Internal structure of the nucleon inspired by AdS/QCD correspondence



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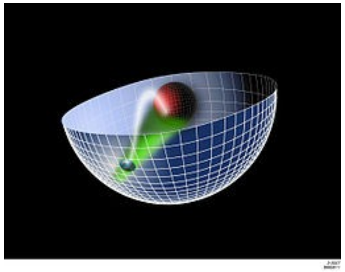
Summary

Part I – Ingredients
Parton Distributions
Light-Front Wave Functions (LFWFs)
AdS/QCD correspondence

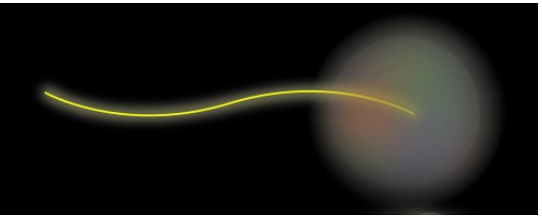
Part II - Recipe
LFWFs inspired by AdS/QCD

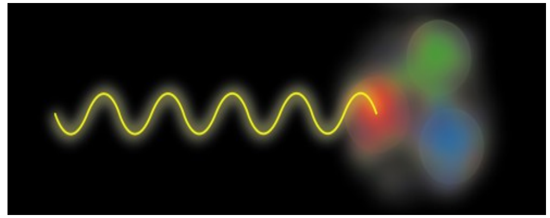


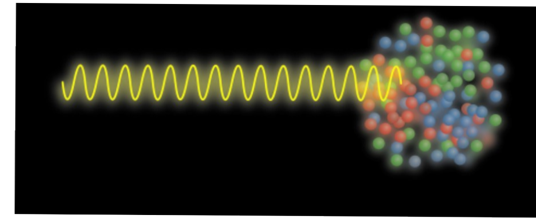
Part III - Phenomenology

Conclusions

Part I – Understanding the nucleon structure

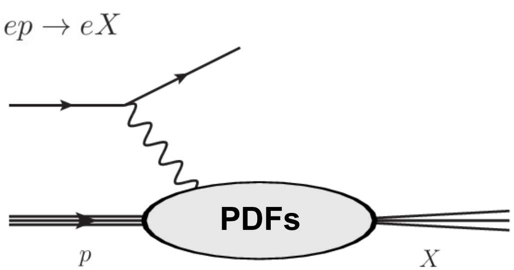






How? → High energy processes → Soft nonperturbative part + Hard perturbative part

Deep Inelastic Scattering



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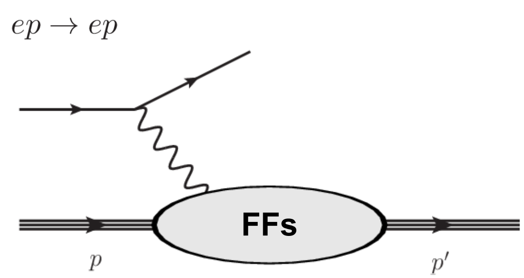
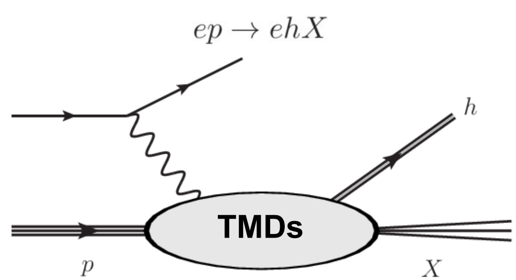


Semi-Inclusive DIS



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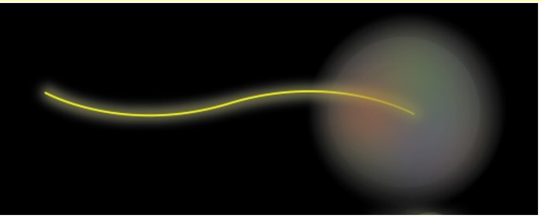
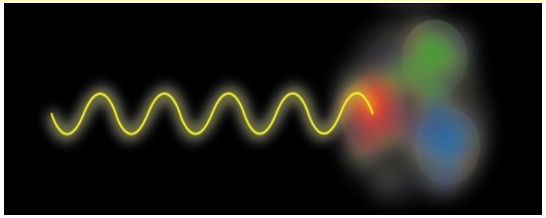
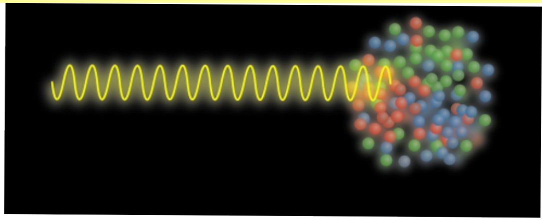

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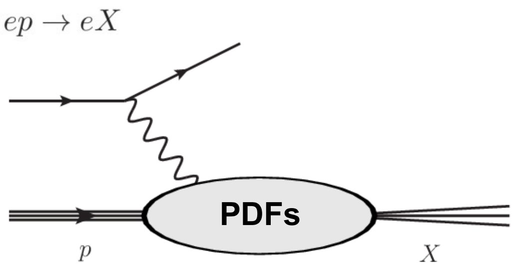

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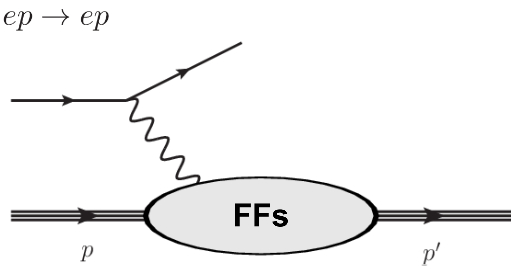

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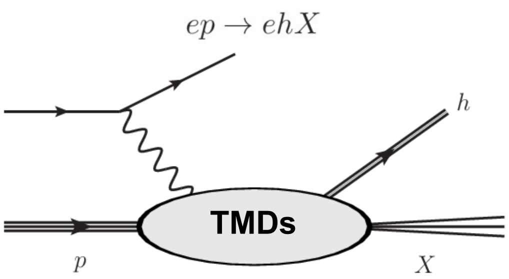
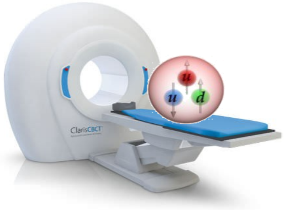


Knowledge of all the parton distributions → Tomography of the proton

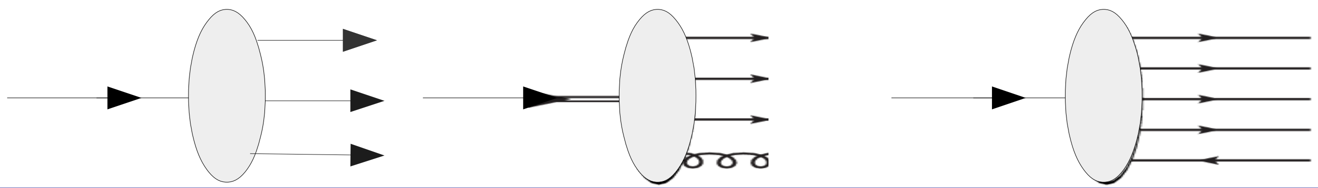


Part I – Fock-state expansion and Light Front quantization

Goal: evaluate hadronic matrix elements in which the proton state appears.

Fock state expansion of the proton state.

$$|P\rangle = \psi_{qqq}\,|qqq\rangle + \psi_{qqqg}\,|qqqg\rangle + \psi_{qqqq\bar{q}}\,|qqqq\bar{q}\rangle + \dots$$



$$|P,\Lambda\rangle = \sum_{N,\beta}\int\left[\frac{dx}{\sqrt{x}}\right]_N \left[d^2k_\perp\right]_N \,\Psi^{\Lambda}_{N,\beta}\left(r_1,\cdots,r_N\right)\Big|N,\beta;\tilde{k}_1,\ldots,\tilde{k}_N\Big\rangle$$

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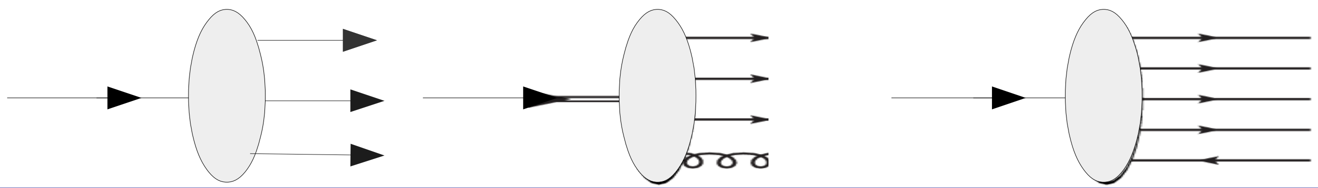

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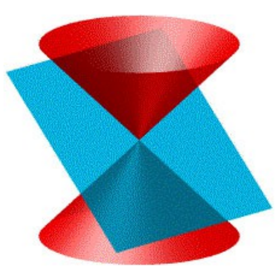
Convenient formalism → Light Cone quantization

$$\mathrm{x}^+ = \frac{1}{\sqrt{2}}\left(x^0 + x^3\right); \quad x^- = \frac{1}{\sqrt{2}}\left(x^0 - x^3\right)$$



Part I – LFWFs Overlap representations

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Light-front Wave Functions

ψ_N → Probability amplitude to find the N-th state inside the proton

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Light-front Wave Functions

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Once they are known, the LFWFs allow us to model all the parton distributions.

When possible, the probabilistic interpretation is evident, e.g.

PDF → $$f^{\Lambda}_{1q}(x) = \frac{1}{2}\sum_{\beta}\int \frac{d^2\boldsymbol{k}_\perp}{16\pi^3}\left|\psi^{\Lambda}_{\beta}(x,\boldsymbol{k}_\perp)\right|^2$$

Problem:

The LFWFs are highly non perturbative objects → No easy way to access them.

Possible approach: Duality.

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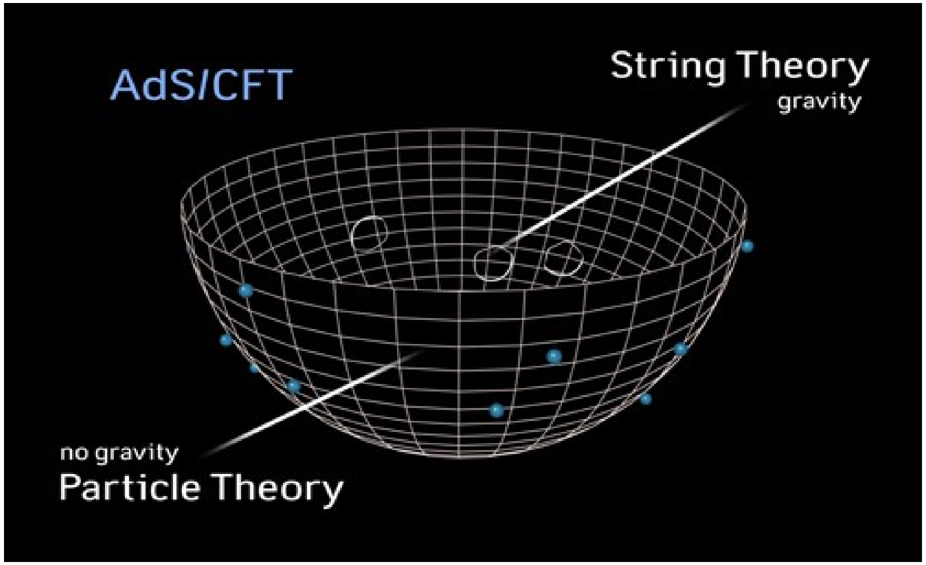

$$ds^2 = \frac{R^2}{z^2}\left(\sum_{i=1}^{3} dx_i dx^i - dz^2\right)$$

Non gravitational dual field theory → Supersymmetric conformal Theory

Part I – Applicability to QCD

- Massless quarks and constant coupling:

$$\mathcal{L}_{QCD} = \bar{\psi}_i \left(i\gamma^\mu D_\mu\right)_{ij} \psi_j - \frac{1}{4} G^a_{\mu\nu} G^{\mu\nu}_a$$

Inclusion of confinement (bottom-up approach):

- Modifications of AdS metric → Insertion of a dilaton field in order to simulate confinement:

$$S = \int d^4x dz \sqrt{|g|} e^{\varphi(z)} \left(g^{MN} \partial_M \Phi(x,z) \partial_N \Phi(x,z) - \mu^2 \Phi^2(x,z)\right)$$

$\varphi(z) = \lambda z^2$ Soft-wall model

$e^{\varphi(z)} \to 1 \quad z \to 0$ AdS_5 metric

Meson form factor

$$\int d^4x \int dz \sqrt{g}\; A^M(x,z)\, \Phi^*_{P'}(x,z) \overleftrightarrow{\partial}_M \Phi(x,z)$$

$$\Updownarrow$$

$$(2\pi)\,\delta^{(4)}(P'-P-q)\,\epsilon_\mu\,(P'+P)^\mu\,F(q^2)$$

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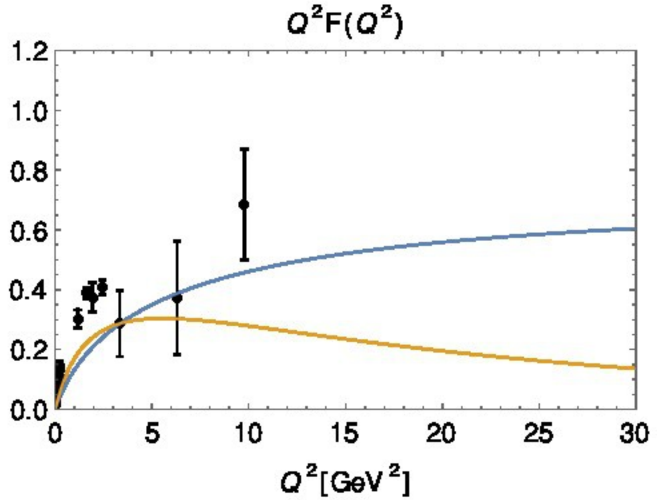
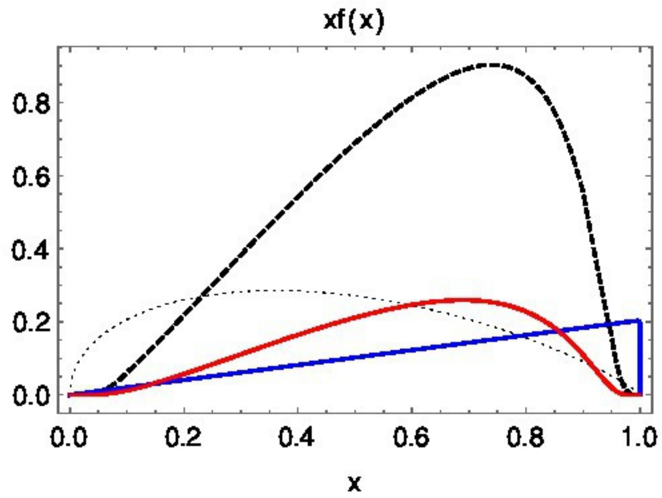
⇕

$$(2\pi)\, \delta^{(4)}(P' - P - q)\, \epsilon_\mu (P' + P)^\mu F(q^2)$$





Quark-diquark model for the nucleon

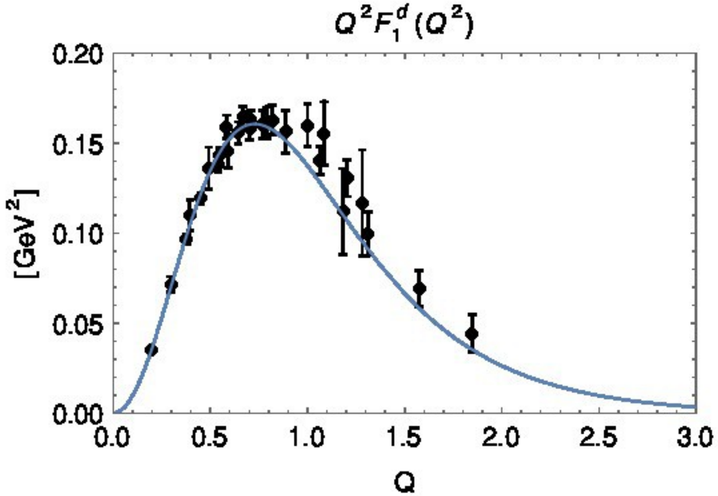
Phenomenological parameters

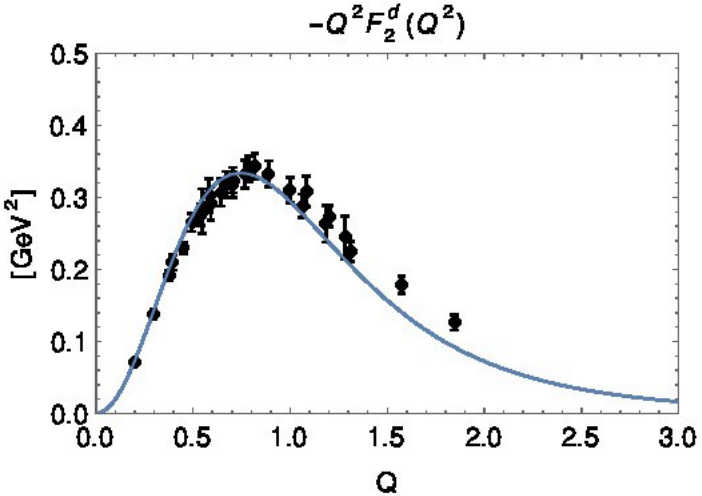
$$\varphi^{(i)}(x,\,\mathbf{k}_\perp) = \boxed{N_q^{(i)}} 4\pi \frac{\sqrt{\log\left(\frac{1}{x}\right)}}{\kappa(1-x)} \boxed{x^{a_q(i)}(1-x)^{b_q(i)}} \exp\left\{-\frac{\mathbf{k}_\perp^2}{2\kappa^2}\frac{\log(1x)}{(1-x)^2}\right\}.$$

Procedure:

- Fitting the experimental data of flavor separated form factors,
- Fitting the PDFs parametrizations,
- Using the fitted parameters to obtain predictions for TMDs.

Down quark





Summary, Conclusions and outlooks

•Importance of the LFWFs to model parton distributions.
•Need for a model which provides the hadronic LFWF.
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- Phenomenological LFWF for the pion (in progress).
- Improvement of nucleon TMDs analysis, including QCD evolution.
- Analysis of other parton distributions.