Studying GPD in Gravity Dual

Elastic and Diffractive Scattering

Dec.17 (Sat) at Qui Nhon

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based on arXiv:1105.2907 and 1105.2999 [hep-ph]
in collaboration with **Ryoichi Nishio** (IPMU)

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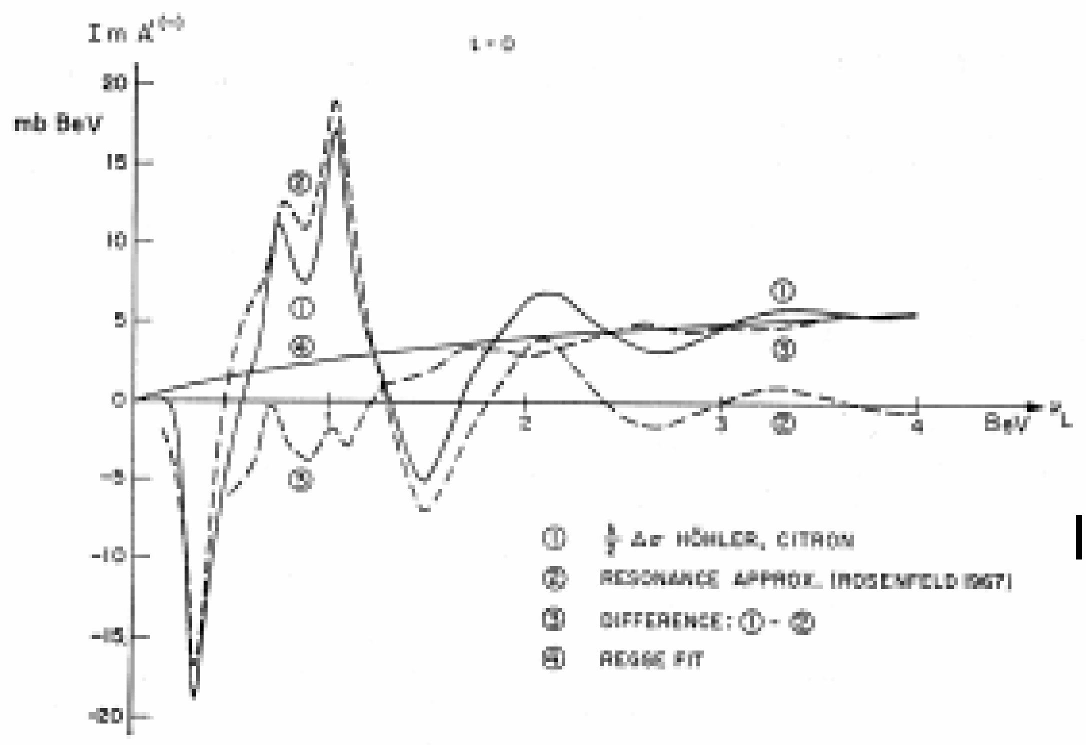
string theory for hadron scattering



S-T duality in
$\pi - N$ elastic scattering

Large angle scattering

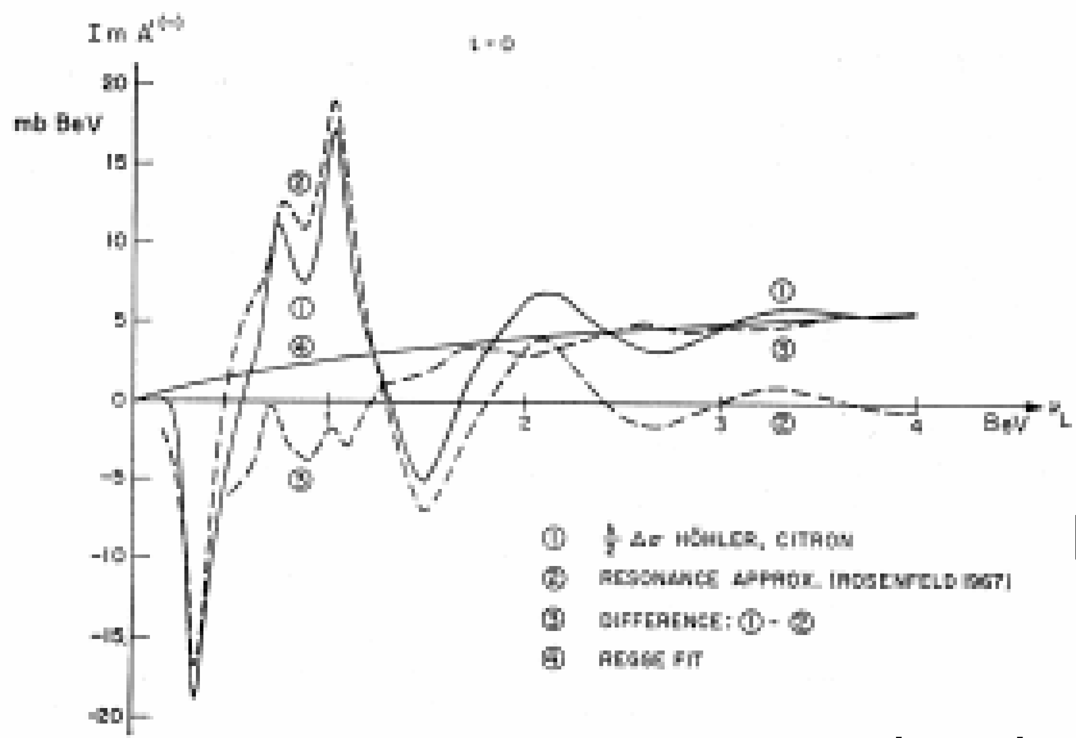
In string theory on 3+1-dim.

$e^{\alpha' t}$ exp. fall-off

string

- hadron spectrum
- scattering

string theory for hadron scattering



S-T duality in
$\pi - N$ elastic scattering

Large angle scattering

In string theory on 3+1-dim.

$e^{\alpha' t}$ exp. fall-off

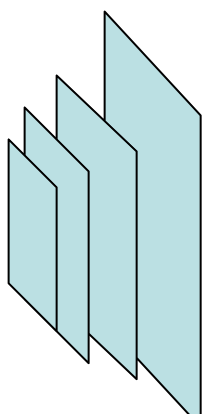
In string theory on a warped spacetime

string on warped spaces

- hadron spectrum
- scattering

exp. fall-off at small |t|

power law for large |t|



Maldacena '98, Polchinski—Strassler '01

limitation in the string approach

large Q^2, small x (large W)

but

small |t| $(|t| \leq \Lambda_{QCD}^2)$

$\lambda \ll 1$

perturbative QCD

real world QCD
interpolates both.

$1 \ll \lambda = \alpha_s N_c$

gravity dual (string theory)

experimental data

- qualitative understanding of data (if possible)
- provide ideas for fitting function
- not for quantitative predictions

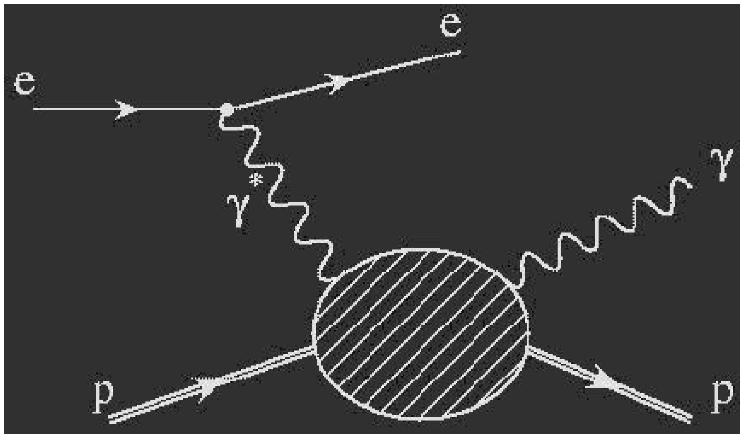
partons in strongly coupled theories??

$\gamma^{(*)} - h$ scattering

$$\int d^4x\, e^{iq_2 \cdot x} \langle h(p_2) | T\{J^\mu(x) J^\nu(0)\} | h(p_1) \rangle$$

$$= iT^{\mu\nu}$$

$$= \sum_I C_I^{\mu\nu}(q) \ \langle h(p_2) | O_I(0) | h(p_1) \rangle.$$



OPE

partons (PDF/GPD) ⟺ twist-2 oprtrs.

Polchinski Strassler ‘02
Brower Polchinski Strassler Tan ‘06

⟺ leading trajectory in string theory

Gubser et.al. ’02
BPST ‘06

$$A(s,t) \simeq \frac{c_s}{2\kappa_5^2} \frac{\pi}{2R^3} \int dz \sqrt{-g(z)} P(z) \int dz' \sqrt{-g(z')} P(z') \mathcal{K}(s,t;z,z'),$$

$$\mathcal{K}(s,t;z,z') = -8R\sqrt{\lambda} \int_0^\infty d\nu \frac{1}{2\pi i} \int_{C_1(\nu)} dj\, \frac{1+e^{-i\pi j}}{\sin \pi j} \frac{1}{\Gamma^2(j/2)}$$

$$\left(\frac{\alpha' \tilde{s}}{4}\right)^j \frac{1}{j - \left(j_\nu + \frac{\delta_j}{2\sqrt{\lambda}}\right)} e^{-jA(z)} \Psi_\nu^{(j)}(t,z)\, e^{-jA(z')} \Psi_\nu^{(j)}(t,z').$$

pion cloud
not included

Basic Properties of PDF / GPD

Hatta Iancu Mueller '07
Brower Djurici Sarcevici Tan '10
Nishio TW '11

- parton contribution

$$A(s,t) \simeq \frac{c_s}{2\kappa_5^2}\frac{\pi}{2R^3}\int dz\sqrt{-g(z)}P(z)\int dz'\sqrt{-g(z')}P(z')\mathcal{K}(s,t;z,z'),$$

$$\mathcal{K}(s,t;z,z') = -8R\sqrt{\lambda}\int_0^\infty d\nu\frac{1}{2\pi i}\int_{C_1(\nu)} dj\,\frac{1+e^{-i\pi j}}{\sin\pi j}\frac{1}{\Gamma^2(j/2)}$$
$$\left(\frac{\alpha'\tilde{s}}{4}\right)^j\frac{1}{j-\left(j_\nu+\frac{\delta_j}{2\sqrt{\lambda}}\right)}\,e^{-jA(z)}\Psi_{i\nu}^{(j)}(t,z)\,e^{-jA(z')}\Psi_{i\nu}^{(j)}(t,z').$$

Polchinski Strassler '02
Brower Polchinski Strassler Tan '06
Hatta Iancu Mueller '07
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Basic Properties of PDF / GPD

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- parton contribution

$$\mathrm{Im}\, I_i \simeq \int dj\, f(j) \left(\frac{1}{\sqrt{\lambda} x}\right)^{j} \left(\frac{\Lambda}{q}\right)^{\gamma(j)} g_j(t).$$

$$\gamma(j) \simeq \sqrt{4 + 2\sqrt{\lambda}(j-2)} - j$$

anomalous dim. (BPST ’06)

- find a saddle point for large (but finite) $\lambda,\ N_c,\ \ln(1/x)$ and $\ln(q/\Lambda)$

$$\mathrm{Im}\, I_i \simeq x^{-j^*} \left(\Lambda/q\right)^{\gamma(j^*)} g_{j^*}(t).$$

$$\left.\frac{\partial\gamma(j)}{\partial j}\right|_{j=j^*} = \frac{\ln(1/x)}{\ln(q/\Lambda)}.$$

(in conformal theories)

Basic Properties of PDF / GPD

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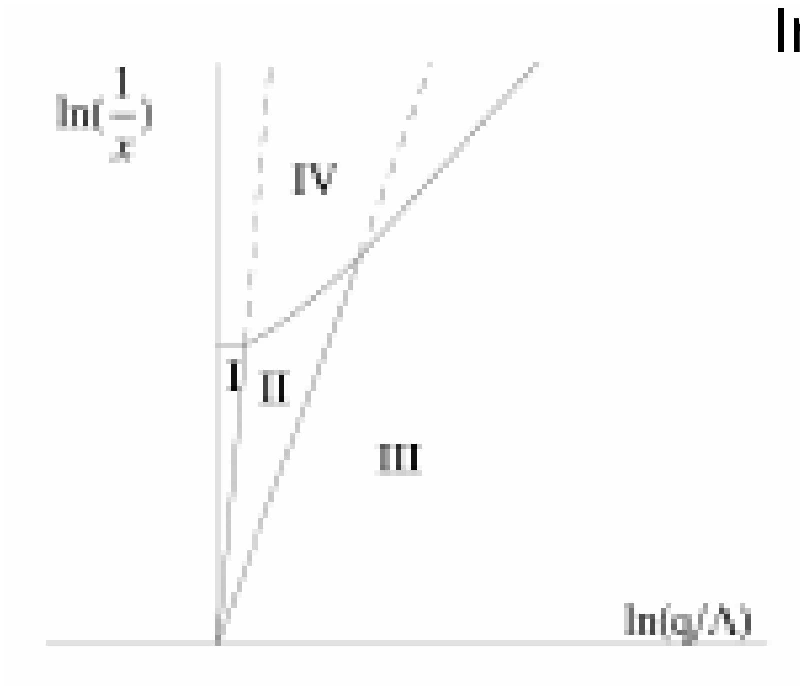
Nishio TW '11

Phase Diagram (fixed t)



In the II + III phase

DGLAP evolution

$$\frac{\partial \ln \mathrm{Im}\, I_i(q,x)}{\partial \ln (q/\Lambda)} = \gamma_{BPST}(j^*(q,x,t)).$$

$\ln(1/x)$ **evolution**

$$\frac{\partial \ln \mathrm{Im}\, I_i(q,x)}{\partial \ln (1/x)} = j^*(q,x,t) - 1.$$

DVCS x-sect.

$$\frac{d\sigma}{dt} \sim \frac{\alpha_{QED}^2}{\Lambda^4}\left(\frac{W}{\Lambda}\right)^{4(j^*-1)}\left(\frac{\Lambda^2}{q^2}\right)^{\gamma(j^*)+2j^*}$$

IV: multi-Pomeron exchange important

I: low-energy regime vs II+III: high-energy regime

$$j^*(q,x,t) \prec \alpha_{IP,1}(t) \quad \text{or} \quad \alpha_{IP,1}(t) \prec j^*(q,x,t).$$

GPD model and t-slope B

Nishio TW '11

$$\mathrm{Im}\, I_i \simeq \int dj\, f(j) \left(\frac{1}{\sqrt{\lambda} x}\right)^j \left(\frac{\Lambda}{q}\right)^{\gamma(j)} g_j(t).$$

similar model D.Mueller '06

$$g_j(t)|_{\varepsilon=1/\Lambda} \sim \frac{(1-t/\Lambda^2)^{-n}}{j-\alpha_{IP}(t)}.$$

- analytic expression

$$g_j(t) \times (\varepsilon\Lambda)^{\gamma(j)}$$

$$= \frac{1}{\kappa_5^2} \int dz \sqrt{-g} P_{hh} e^{-2jA} (R\Lambda)^j \left(\frac{\sqrt{-t}}{2\Lambda}\right)^{-j} \frac{2}{\Gamma(i\nu_j)} (\epsilon\Lambda)^{\gamma(j)}$$
$$\times \left[e^{(j-2)A} \left(K_{i\nu_j}(\sqrt{-t}z) - \frac{K_{i\nu_j}(\sqrt{-t}/\Lambda)}{I_{i\nu_j}(\sqrt{-t}/\Lambda)} I_{i\nu_j}(\sqrt{-t}z) \right) \right] = \sum_n \frac{g_{nhh}(j) F_{j,n}(\varepsilon)}{t - m_{j,n}^2}.$$

Kaluza-Klein tower of Pomeron trajectories

- model in collinear factorization approach (dual parametrization)

Belitsky, Geyer, Mueller, Schafer, Polyakov Shuvaev, Kumericki '97--

GPD model and t-slope B

Nishio TW '11

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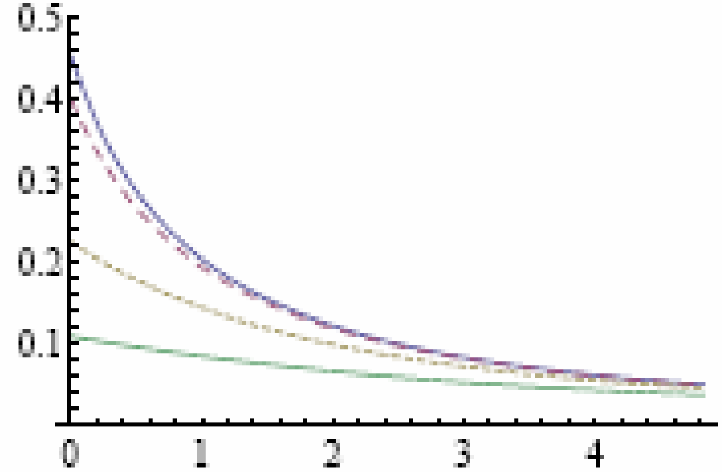

- analytic expression

$$g_j(t) \times (\varepsilon\Lambda)^{\gamma(j)}$$

$$= \frac{1}{\kappa_5^2} \int dz \sqrt{-g} P_{13} e^{-2jA} (R\Lambda)^j \left(\frac{\sqrt{-t}}{2\Lambda}\right)^{-\nu_j} \frac{2}{\Gamma(i\nu_j)} (\epsilon\Lambda)^{\gamma(j)}$$
$$\times \left[e^{(j-2)A} \left(K_{i\nu_j}(\sqrt{-t}z) - \frac{K_{i\nu_j}(\sqrt{-t}/\Lambda)}{I_{i\nu_j}(\sqrt{-t}/\Lambda)} I_{i\nu_j}(\sqrt{-t}z) \right) \right]$$

B: decreacing fcn of j^* and of q^2

consistent with H1 DVCS data

- t-slope

$$B = 2\frac{\partial \ln g_j(t)}{\partial t}$$

depends on q and x (W) through $j^*(q, x)$.

sensitive to q if x<<1