Regge behavior in effective field theory

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arXiv:1405.1731 (PRD)

related work:

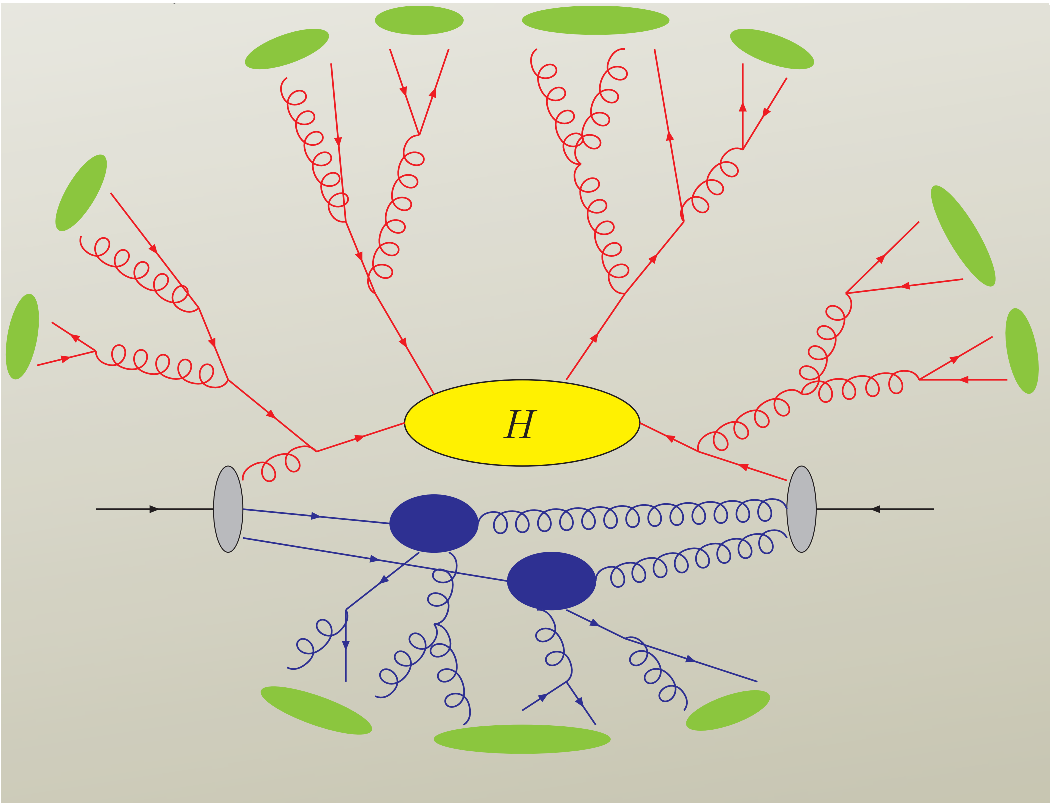
S. Fleming arXiv:1404.5672 (PLB)

Outline

- Motivation
- Regge behavior from method of regions
- SCET with Glauber gluons
- Conclusions

Motivation

- Events at LHC in proton proton collisions are tricky
- Parton Distributions
- Hard
- Multiple Interactions
- Radiation
- Hadronization



In many cases the inclusive cross sections are perturbatively calculable

Parton Shower is a Monte-Carlo generator that allows to calculate the cross sections at the most exclusive level (limited only to leading Log)

What does parton shower do?

Markov process with probabilities to:

- Knock a parton out of the proton (PDF)
- Collinear splittings (radiation)
- Hadronization

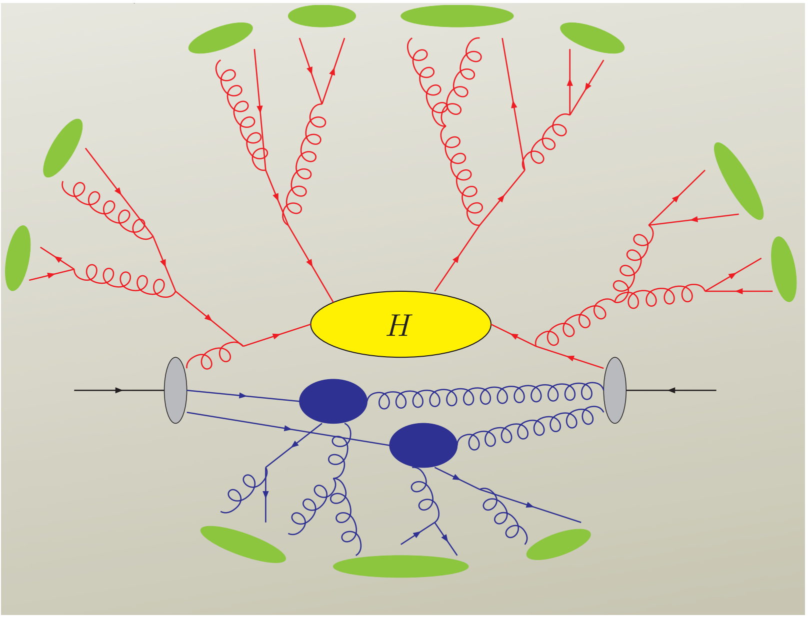
$$r_{\mathrm{hard}} \sim \frac{1}{\sqrt{s}}$$

$$r_{\mathrm{shower}} \sim \frac{1}{p_\perp}$$

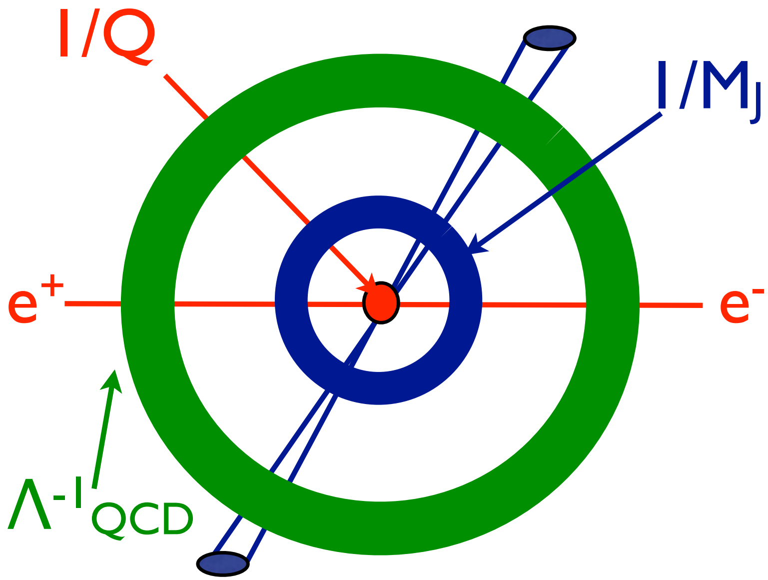
$$r_{\mathrm{soft}} \sim \frac{1}{\Lambda_{\mathrm{QCD}}}$$

Parton Shower includes resummation of Sudakov logarithms

In last decade Effective Field Theory methods allowed for precise predictions using factorization and RG evolution

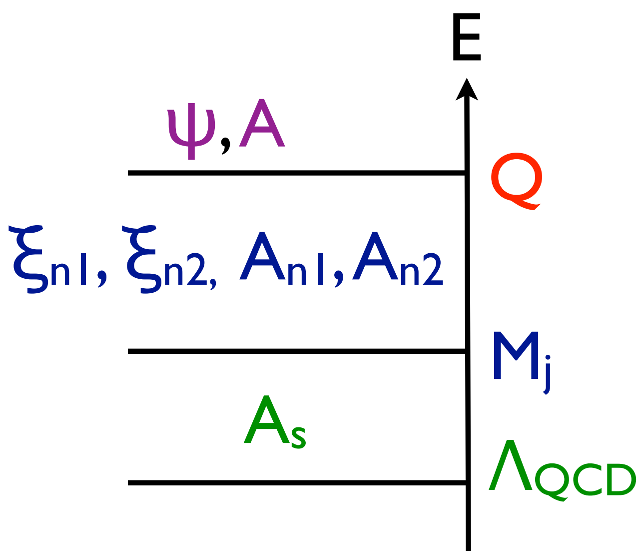


Soft Collinear Effective Theory



Bauer, Fleming, Luke, Pirjol, Stewart, (00-01)

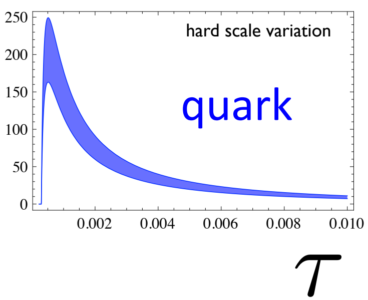
- Clear separation of scales between hard emission, collinear splittings and soft radiation
- In SCET the small parameter λ describes how close to the jet axis the collinear emissions occur
- Power counting of SCET requires couplings between collinear quarks, collinear gluons, and soft gluons

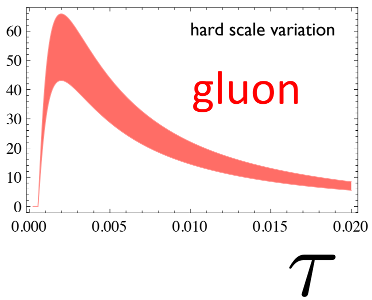


Sudakov logarithms via SCET

$e^+e^- \to \text{jets}$

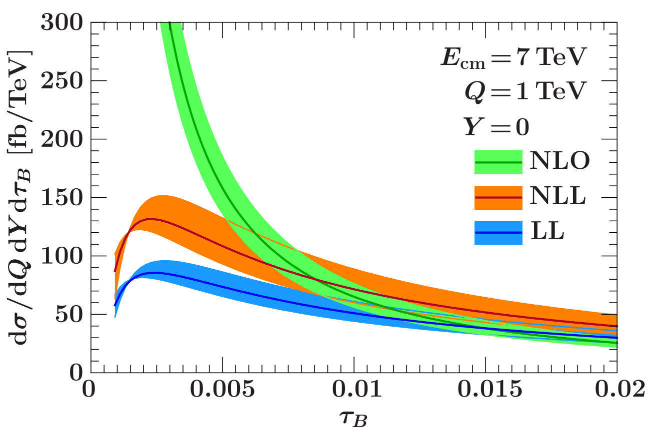
Ellis, Vermilion, Walsh, Hornig, Lee, 2010





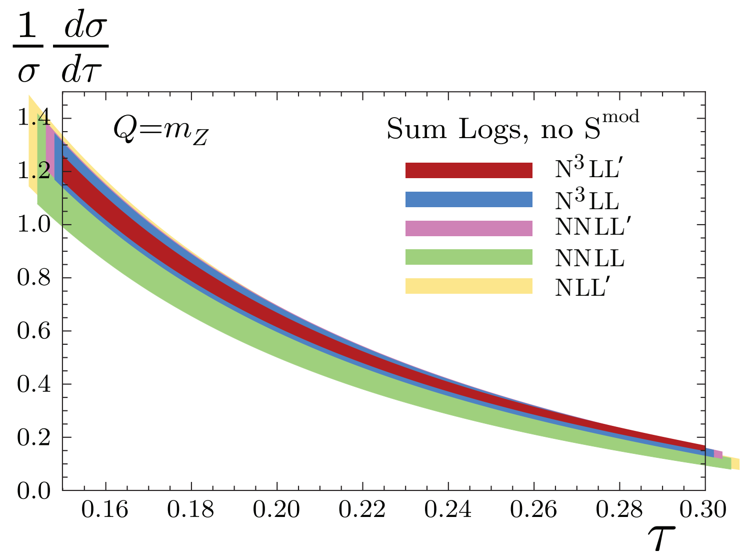
$pp \to l^+l^- + 0\,\text{jets}$

Stewart, Tackmann, Waalewijn, 2010



$e^+e^- \to \text{jets}$

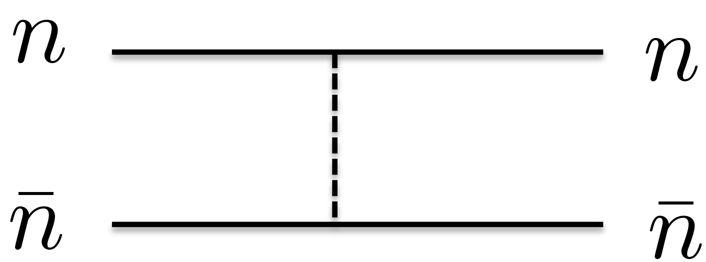
Abbate, Fickinger, Hoang, Mateu, Stewart, 2010



Sudakov logarithms have been understood to high level of accuracy using SCET

Regge behavior in QCD

- Consider forward scattering amplitude (tree level):



$$p_n \sim (\lambda^2, 1, \lambda)$$

$$p_{\bar{n}} \sim (1, \lambda^2, \lambda)$$

$$s = (p_n + p_{\bar{n}})^2 \gg t = q^2$$

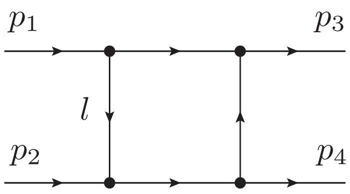
The momentum transfer falls into the Glauber region (outside of SCET)

$$q = p_n - p_{\bar{n}} \sim (\lambda^2, \lambda^2, \lambda)$$

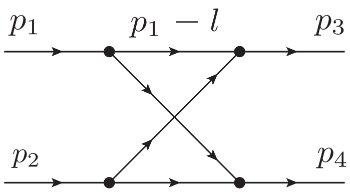
Regge behavior in QCD

- Forward scattering at one loop

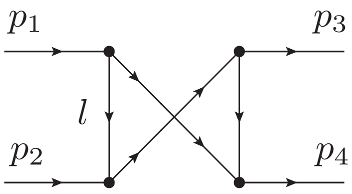
Box (s channel)



Box (t channel)



Box (u channel), suppressed



$$i\mathcal{M}^{\text{box}}_{\text{QCD}} = i\frac{g^4}{16\pi^2}\int dx_1 dx_2 dy_1 dy_2 \frac{\delta(1-x_1-x_2-y_1-y_2)}{[x_1x_2 s + y_1 y_2 t - m^2(1-(x_1+x_2)(y_1+y_2))]^2}$$

$$\beta(t) = \frac{g^2}{16\pi^2}\int dy_1 dy_2 \frac{\delta(1-y_1-y_2)}{[m^2 - y_1 y_2 t]}$$
$$= \frac{g^2}{4\pi}\int \frac{d^2\boldsymbol{l}_\perp}{(2\pi)^2}\frac{1}{[\boldsymbol{l}_\perp^2 + m^2][(\boldsymbol{l}_\perp + \boldsymbol{q}_\perp)^2 + m^2]}.$$

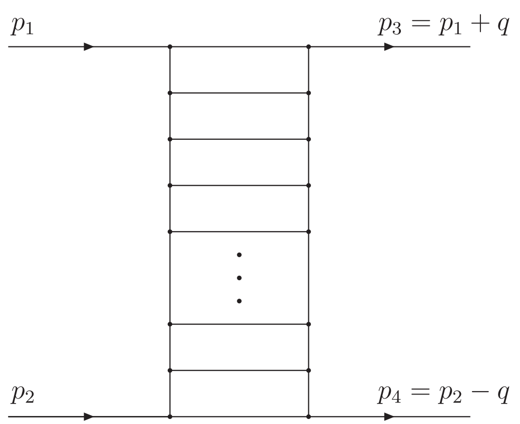
$$\mathcal{M}^{\text{box+crossed}}_{\text{QCD}} = -g^2\beta(t)\left[\frac{1}{s}\ln(-s) + \frac{1}{-s}\ln(s)\right] = \frac{i\pi}{s}g^2\beta(t).$$

One-loop correction to Regge scattering is purely imaginary
Thus, it must arise from on-shell intermediate states

Regge behavior in QCD

- Forward scattering at N loops

Polkinghorne, 1963



Strong ordering

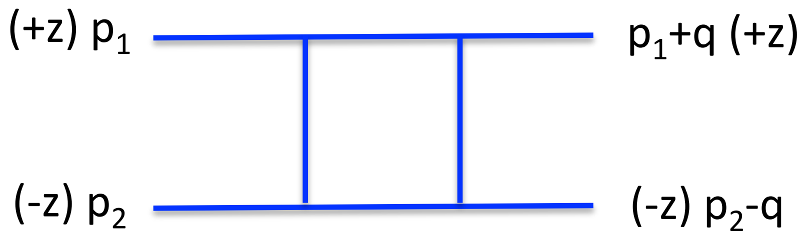
$$|l_1^+| \ll |l_2^+| \cdots \ll |l_k^+| \ll |l_{k+1}^+| \ll \cdots \ll |l_N^+|,$$
$$l_1^- \gg l_2^- \cdots \gg l_k^- \gg l_{k+1}^- \gg \cdots \gg l_N^-.$$

Donoghue, Wyler, 2010

Summation of ladder graphs leads to Regge behavior:

$$\mathcal{M}_{\mathrm{QCD}} \sim a_0 s^a \sum_{n=0}^{\infty} \frac{\beta^n(t)}{n!} \ln^n s + \cdots \to a_0 s^{a+\beta(t)} + \cdots.,$$

Our Goal



- Our goal is to understand the leading Regge behavior from effective theory point of view
- In QCD resummation of ladder diagrams leads to: $M_{\text{Regge}} \sim \frac{1}{s}(\beta(t)\ln(-s))^n$
- In EFT what are the degrees of freedom that reproduce such a behavior ? (Glauber gluons?)
- Ultimate goal is to understand the Regge behavior on same grounds as Sudakov resummation

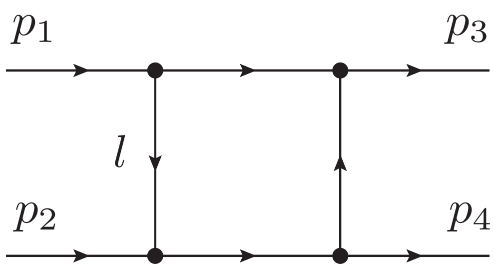
Regge behavior from Method Of Regions

With J. Donoghue, B. El-Menoufi arXiv:1405.1731 (PRD)

One loop box graph

We study Regge behavior on the example of toy scalar ϕ^3 theory

$$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{g}{3!}\phi^3$$



$$s \gg m^2, t$$

$$\mathcal{M}^{(1)}_{\mathrm{QCD}} = \frac{i\pi g^2\beta(t)}{s},$$

$$\beta(t) = \frac{g^2}{8\pi^2(-t)\chi(t)}\ln\frac{\chi(t)+1}{\chi(t)-1},$$

$$\chi(t) = \sqrt{1-\frac{4m^2}{t}} > 1.$$

The massive box graph, including the crossed box, evaluated at equal and finite masses

Method of regions

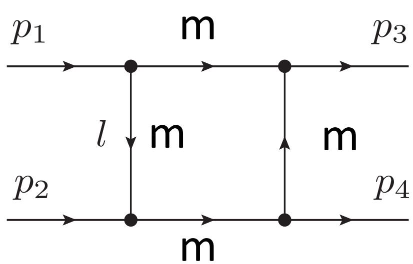
Beneke, Smirnov, 1997
Jantzen arXiv: 1111.2589 (a review)

- Method of regions is a powerful method to analyze multi-loop integrals
- When there is a hierarchy of scales in the problem, such as $s \gg m^2$, t, etc, the loop integral can be represented as power series
- Each term in the series can be found by expanding the integrand in the corresponding momentum region
- By recovering all leading order regions we recover the asymptotic behavior
- The expanded loop integrals in practice are much easier to evaluate

Power counting

$s \gg t, m^2$

Full theory

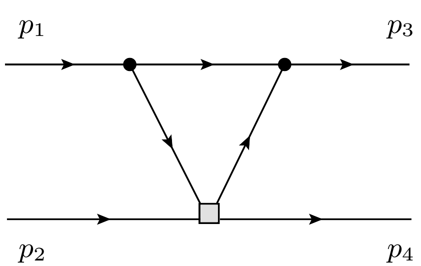


$$\mathcal{M}^{(1)}_{\rm QCD} = (-i)g^4 \frac{1}{2}\int \frac{d^4 l}{(2\pi)^4} \frac{1}{(l^2 - m^2 + i0)\,((l+q)^2 - m^2 + i0)} \left(\frac{1}{(l-p_1)^2 - m^2 + i0} + \frac{1}{(l+p_3)^2 - m^2 + i0} \right) \times \left(\frac{1}{(l+p_2)^2 - m^2 + i0} + \frac{1}{(l-p_4)^2 - m^2 + i0} \right)$$

(Hard)

$$\sim \frac{1}{st} \sim \lambda^{-2}$$

Collinear $(\lambda^2, 1, \lambda)$



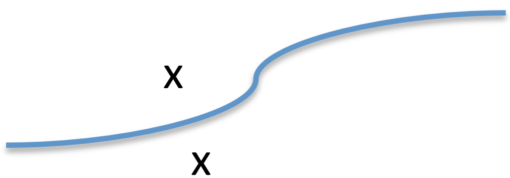
$$\mathcal{M}^{(1)}_{n} = (-i)g^4 \frac{1}{2}\int \frac{d^4 l}{(2\pi)^4} \frac{1}{(l^2 - m^2 + i0)\,(l^-(l+q)^+ - (\boldsymbol{l}_\perp + \boldsymbol{q}_\perp)^2 - m^2 + i0)} \times \left(\frac{1}{(l^- - \sqrt{s})l^+ - \boldsymbol{l}_\perp^2 - m^2 + i0} + \frac{1}{(l^- + \sqrt{s})(l+q)^+ - (\boldsymbol{l}_\perp + \boldsymbol{q}_\perp)^2 - m^2 + i0} \right) \times \left(\frac{1}{\sqrt{s} l^- + i0} + \frac{1}{-\sqrt{s} l^- + i0} \right).$$

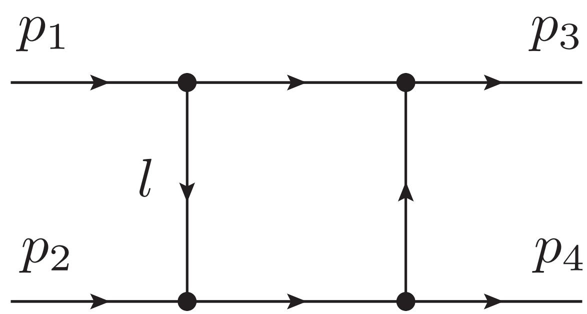
$$\sim \lambda^4 \frac{1}{\lambda^2 \lambda^2 \lambda^2 \lambda^0} = \lambda^{-2}$$

$$\frac{1}{x + i\epsilon} - \frac{1}{x - i\epsilon} = -2i\pi\,\delta(x)$$

The collinear region is leading order. Much easier to compute

Leading Regions





Collins, Soper, Sterman, 1983-1986

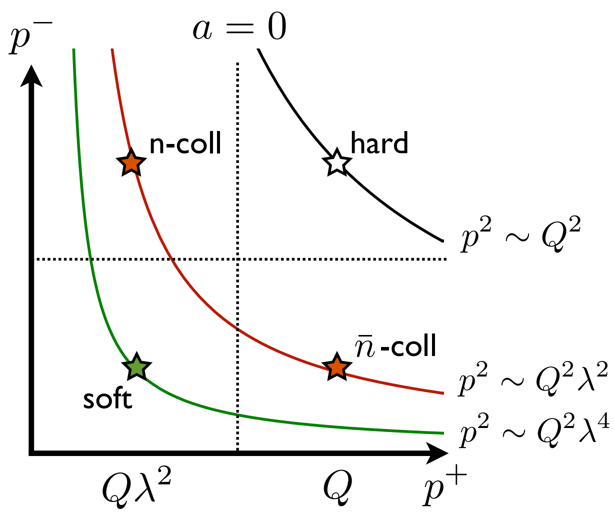
Beneke, Smirnov, 1997

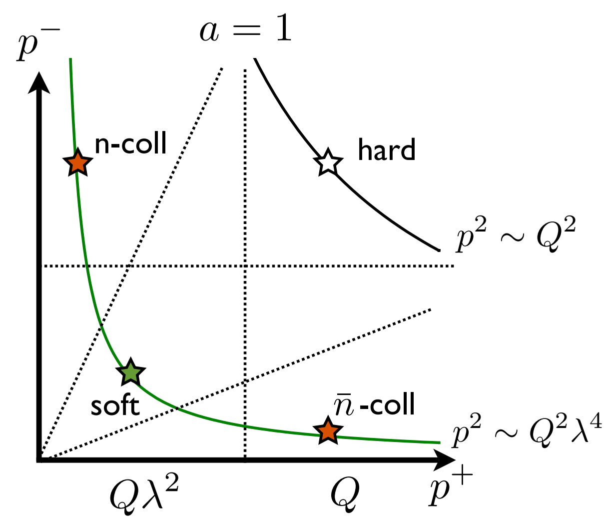
- n-collinear $(\lambda^2, 1, \lambda)$ (pinched)
- $\bar{\text{n}}$-collinear $(1, \lambda^2, \lambda)$ (pinched)

SCET$_\text{I}$

- Glauber $(\lambda^2, \lambda^2, \lambda)$ (not pinched)
- Soft $(\lambda, \lambda, \lambda)$ (not pinched)
- Ultrasoft (sub-leading for massive box)

SCET$_{\mathrm{I}}$ vs SCET$_{\mathrm{II}}$





SCET$_{\mathrm{I}}$

SCET$_{\mathrm{II}}$

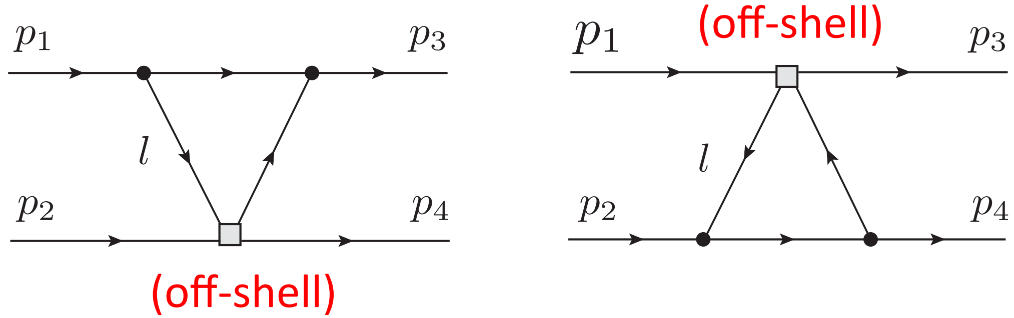
$$p_{\mathrm{soft}} = (\lambda^2, \lambda^2, \lambda^2)$$

ultrasoft

$$p_{\mathrm{soft}} = (\lambda, \lambda, \lambda)$$

soft

Modes of SCET$_\mathrm{I}$



$$\mathcal{M}_n^{(1)} = \mathcal{M}_{\bar{n}}^{(1)} = \mathcal{M}_{\mathrm{QCD}}^{(1)}.$$

$$\mathcal{M}_{\mathrm{SCET}}^{(1)} = \mathcal{M}_n^{(1)} + \mathcal{M}_{\bar{n}}^{(1)} - \mathcal{M}_{n/\bar{n}}^{(1)} = \mathcal{M}_{\mathrm{QCD}}^{(1)}.$$

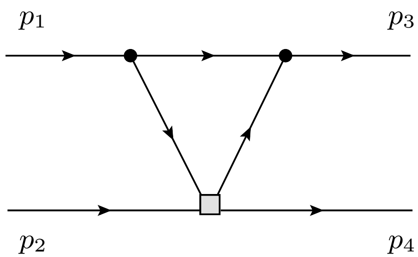
Combining box and crossed box regulates the light-cone divergence

Adding the two collinear graphs gets the answer off by factor of 2

In the method of regions one has to account for overlap between them

$$\mathcal{M}_{\mathrm{QCD}}^{(1)} = \frac{i\pi g^2 \beta(t)}{s},$$

Conceptual problem



$$\mathcal{M}^{(1)}_{\rm QCD} = \frac{i\pi g^2 \beta(t)}{s}\,,$$

$$\frac{1}{p^2} \to \frac{1}{(p^2)^{1+\delta}}$$

Smirnov uses analytic regulator and also finds the correct Regge limit

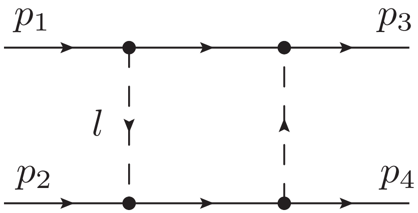
Both Smirnov and our $\mathrm{SCET}_{\mathrm{I}}$ with mass as a regulator suffer from the same problem (unitarity)

The fact that overlaps play role hints that the true region responsible for Regge behavior is hiding inside these regions

This motivates us to consider one more mode, the Glauber…

$$l \sim (\lambda^2, \lambda^2, \lambda)$$

Modes of SCET$_I$ with Glauber mode



$$\mathcal{M}^{(1)}_{n/G} = \mathcal{M}^{(1)}_{\bar{n}/G} = \mathcal{M}^{(1)}_{n/\bar{n}/G} = \mathcal{M}^{(1)}_{G} = \mathcal{M}^{(1)}_{\rm QCD}.$$

$$\mathcal{M}^{(1)}_{\rm SCET_G} = \mathcal{M}^{(1)}_{n} + \mathcal{M}^{(1)}_{\bar{n}} + \mathcal{M}^{\rm box}_{G} - \mathcal{M}^{(1)}_{n/\bar{n}} - \mathcal{M}^{(1)}_{n/G} - \mathcal{M}^{(1)}_{\bar{n}/G} + \mathcal{M}^{(1)}_{n/\bar{n}/G} = \mathcal{M}^{(1)}_{G} = \mathcal{M}^{(1)}_{\rm QCD}.$$

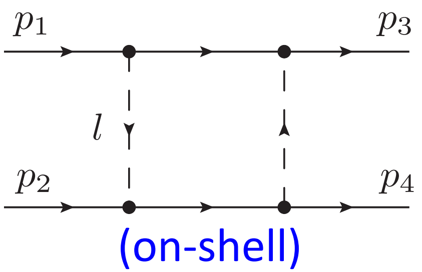
In SCET$_G$ we again reproduce the QCD result, but now we have allowed a physical interpretation that the true momentum region to give imaginary part is the Glauber mode

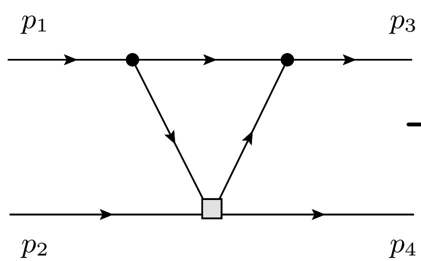
Interpretation: zero-bin substructed true collinear mode does not contribute to the imaginary part

Thus with our regulator and the Glauber mode, we resolved the conceptual problem with unitarity

Using the analytic regulator does not allow this, because the Glauber contribution vanishes in Dim. Reg.

Modes of SCET$_{\text{I}}$ with Glauber mode





$+\text{overlap} \to 0$

$$\mathcal{M}^{(1)}_{n/G} = \mathcal{M}^{(1)}_{\bar{n}/G} = \mathcal{M}^{(1)}_{n/\bar{n}/G} = \mathcal{M}^{(1)}_{G} = \mathcal{M}^{(1)}_{\text{QCD}}.$$

$$\mathcal{M}^{(1)}_{\text{SCET}_\text{G}} = \mathcal{M}^{(1)}_{n} + \mathcal{M}^{(1)}_{\bar{n}} + \mathcal{M}^{\text{box}}_{G} - \mathcal{M}^{(1)}_{n/\bar{n}} - \mathcal{M}^{(1)}_{n/G} - \mathcal{M}^{(1)}_{\bar{n}/G} + \mathcal{M}^{(1)}_{n/\bar{n}/G} = \mathcal{M}^{(1)}_{G} = \mathcal{M}^{(1)}_{\text{QCD}}.$$

In SCET$_\text{G}$ we again reproduce the QCD result, but now we have allowed a physical interpretation that the true momentum region to give imaginary part is the Glauber mode

Interpretation: zero-bin substructed true collinear mode does not contribute to the imaginary part

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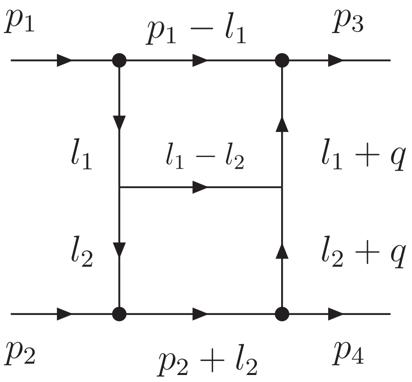
Two-loop ladder: full theory



We simplify the two loop graph by directly taking the imaginary cut using Cutkosky rule:

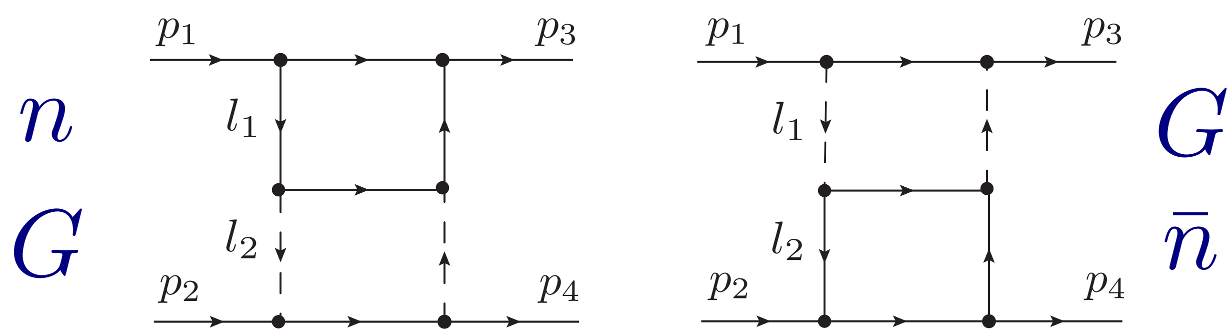
$$\mathrm{Im}\mathcal{M}^{(2)}_{\mathrm{QCD}} = \frac{g^6}{64\pi^5}\int d^4l_1 d^4l_2 \frac{\delta_+[(p_1-l_1)^2-m^2]\delta_+[(l_1-l_2)^2-m^2]\delta_+[(p_2+l_2)^2-m^2]}{(l_1^2-m^2)(l_2^2-m^2)((l_1+q)^2-m^2)((l_2+q)^2-m^2)},$$

In the high energy limit s>>m^2, t we get:

$$\mathrm{Im}\mathcal{M}^{(2)}_{\mathrm{QCD}} \approx \frac{\pi g^2\beta^2(t)}{s}\ln s.$$

Based on what we have learned from the one-loop calculation we only consider the relevant modes of SCET$_G$ that leave the intermediate states on-shell

Two-loop ladder: mode expansion



Only two leading graphs in $\mathrm{SCET_G}$ that have the intermediate states on-shell

$$\mathrm{Im}\mathcal{M}_{nG}^{(2)} = \frac{g^6}{64\pi^5}\int d^4l_1 d^4l_2 \frac{\delta_+[(-l_1^+)(\sqrt{s}-l_1^-)-\Delta_1]\delta_+[(l_1^+-l_2^+)l_1^- - \Delta_{12}]\delta_+[\sqrt{s}l_2^- - \Delta_2]\theta(\sqrt{s}+l_2^+)}{(l_1^+l_1^- - \Delta_1)(-\Delta_2)((l_1^+ + q^+)l_1^- - \Delta_{1q})(-\Delta_{2q})},$$

In the high energy limit we get that this graph reproduces the full theory behavior

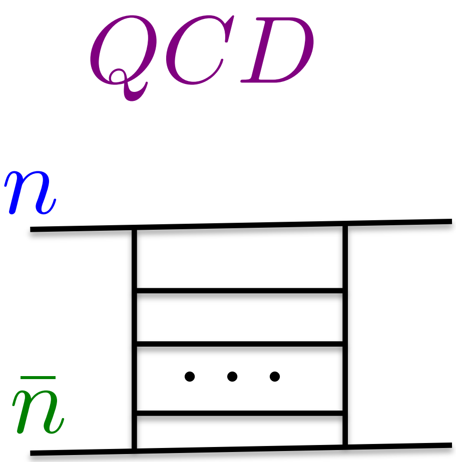
$$\mathrm{Im}\mathcal{M}_{nG}^{(2)} \approx \frac{\pi g^2 \beta^2(t)}{s}\ln s.$$

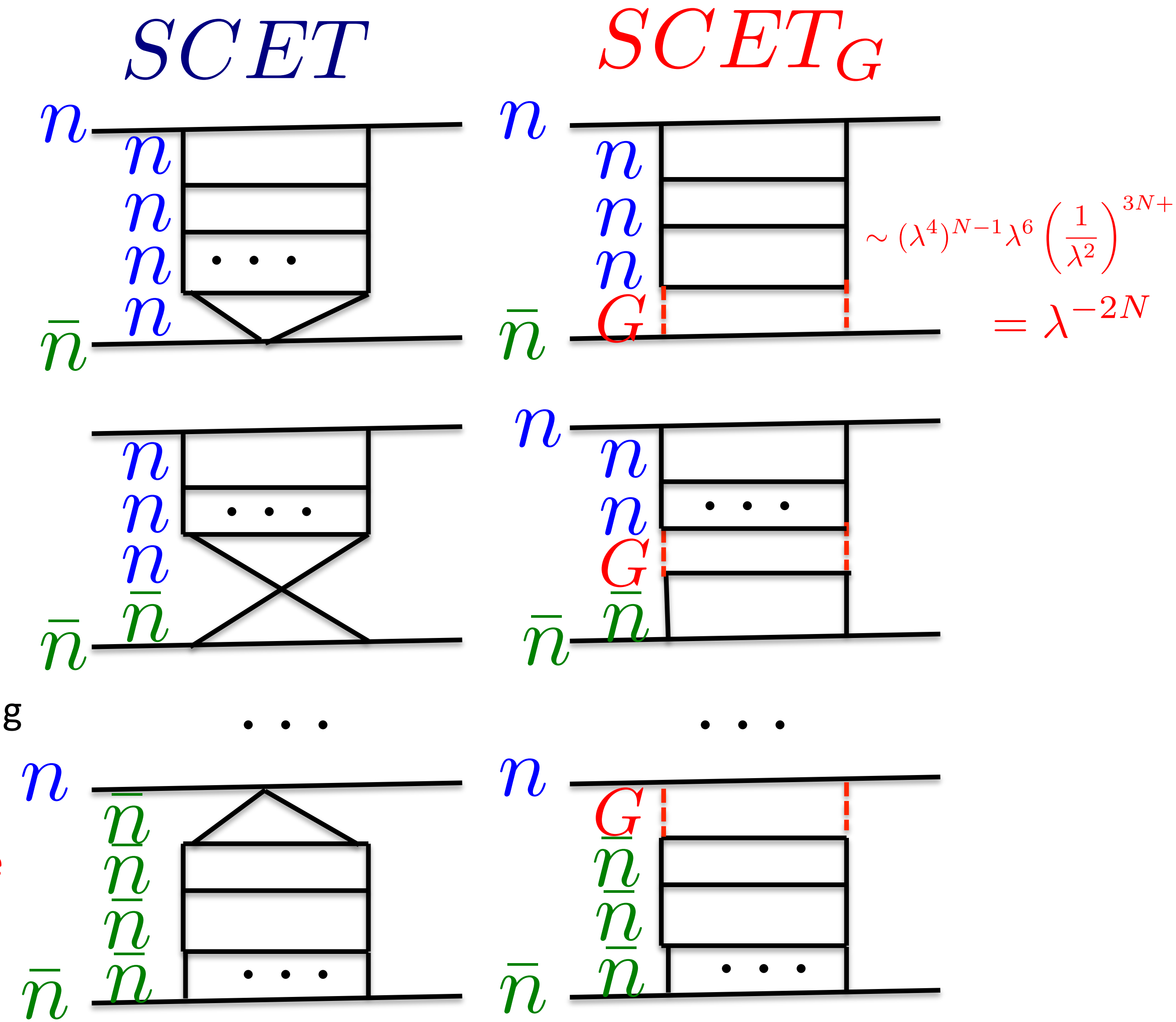
Adding the two graphs and taking the overlap into account matches the full theory:

$$\mathrm{Im}\mathcal{M}_{\mathrm{SCET_G}}^{(2)} = \mathrm{Im}(\mathcal{M}_{nG}^{(2)} + \mathcal{M}_{G\bar{n}}^{(2)} - \mathcal{M}_{nG/G\bar{n}}^{(2)}) = \mathrm{Im}\mathcal{M}_{\mathrm{QCD}}^{(2)}$$

for t=0 verified including the finite terms

General Picture





$$|l_1^+| \ll |l_2^+| \cdots \ll |l_k^+| \ll |l_{k+1}^+| \ll \cdots \ll |l_N^+|,$$
$$l_1^- \gg l_2^- \cdots \gg l_k^- \gg l_{k+1}^- \gg \cdots \gg l_N^-.$$

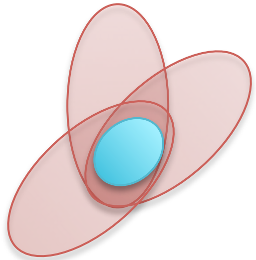
It Is easy to convince yourself that strong ordering Is the sub-region of all of these graphs

Thus, we expect all of these modes give same leading behavior as in QCD

General Picture

By keeping only the mutual multi-overlap of N leading region (Regge mode)

$$\mathrm{Im}\mathcal{M}^{(N)}_{n\ldots nG/n\ldots nG\bar{n}\ldots\bar{n}/\ldots/G\bar{n}\ldots\bar{n}} = \frac{\pi g^2 \beta(t)}{s} \frac{(\beta(t)\ln s)^{N-1}}{(N-1)!},$$



We reproduce the correct Regge behavior in QCD (to all orders)

$$\mathcal{M}_{\mathrm{QCD}} \sim a_0 s^a \sum_{n=0}^{\infty} \frac{\beta^n(t)}{n!} \ln^n s + \cdots \to a_0 s^{a+\beta(t)} + \cdots,$$

We identified the corresponding momentum regions that give us the ladder sum, with on-shell intermediate states

Lots of overlapping regions which we trace down to strong ordering

Other Literature

- In QCD literature the Regge behavior is considered in numerous papers, including some textbooks: either derived from ladder graphs summation or Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation (1976-1978).
- In SCET community exploration just started

S. Fleming, 1404.5672 (PLB)

BFKL equation derived in
$\mathrm{SCET_{II}}$ with Glauber gluons using rapidity RG

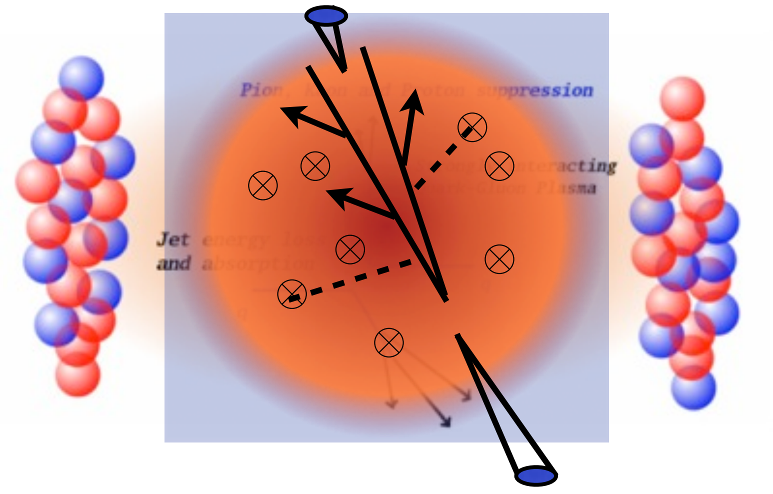
As a result the leading Regge behavior recovered for QCD

SCET with Glaubers ($SCET_G$)

Gyulassy-Wang model

Gyulassy, Wang, 94

- The medium is modeled with a finite number of scattering centers with static Debye-screened potential



$$H = \sum_{n=1}^{N} H(q; x_n) = 2\pi\delta(q^0)\, v(q) \sum_{n=1}^{N} \mathrm{e}^{iqx_n}\, T^a(R) \otimes T^a(n)$$

$$v(q) = \frac{4\pi\alpha_s}{q_z^2 + \mathbf{q^2} + \mu^\mathbf{2}}$$

- The momentum scaling of the exchange gluon is that of the Glauber gluon: $q(\lambda^2, \lambda^2, \lambda)$

Lagrangian of SCET$_G$

The SCET Lagrangian contains everything :)

$$\mathcal{L}_{\rm SCET}(\xi_n, A_n, A_s) = \bar{\xi}_n \left[in\cdot D + i\not{D}^\perp \frac{1}{i\bar{n}\cdot D}\, i\not{D}^\perp \right] \frac{\not{\bar{n}}}{2} \xi_n + \mathcal{L}_{\rm YM}(A_n, A_s) \ ,$$

$$\mathcal{L}_{\rm YM}(A_n, A_s) = \frac{1}{2g^2} {\rm tr} \left\{ \left[iD_s^\mu + gA^\mu_{n,q}, iD_s^\nu + gA^\nu_{n,q'} \right] \right\}^2 + \mathcal{L}_{\rm G.F.} \ ,$$

$$\mathcal{L}_{\rm G.F.}(R_\xi) = \frac{1}{\xi} {\rm tr} \left\{ \left[iD_{s\mu}, A^\mu_{n,q} \right] \right\}^2 ,$$

$$\mathcal{L}_{\rm G.F.}({\rm LCG}(b)) = \frac{1}{\xi} {\rm tr} \left\{ b_\mu A^\mu_{n,q} \right\}^2 \ .$$

$$iD^\mu = i\partial^\mu + g(A^\mu_s + A^\mu_c + A^\mu_G)$$

All we need in order to derive all interactions between collinear(and soft) particles with Glaubers is the scaling rule for the vector potential

covariant gauge $A^\mu_G \propto (\lambda^4, \lambda^2, \lambda^3)$

Anti-collinear source of Glaubers

light-cone gauge $A^\mu_G \propto (\lambda^2, 0, \lambda)$

Idilbi, Majumder, 08

Lagrangian of $\mathrm{SCET_G}$

GO, Vitev, 2011

$$\mathcal{L}_{\mathrm{G}}\left(\xi_n, A_n, \eta\right) = \sum_{p,p',q} \mathrm{e}^{-i(p-p'+q)x} \left(\bar{\xi}_{n,p'} \Gamma^{\mu,a}_{\mathrm{qqA_G}} \frac{\bar{\not{n}}}{2} \xi_{n,p} - i \Gamma^{\mu\nu\lambda,abc}_{\mathrm{ggA_G}} \left(A^b_{n,p'}\right)_\nu \left(A^c_{n,p}\right)_\lambda \right) \bar{\eta}\, \Gamma^{\nu,a}_{\mathrm{s}}\, \eta\, \Delta_{\mu\nu}(q)$$

- Our Glauber Lagrangian is invariant under the gauge symmetries of SCET $\quad \mathcal{L}_{\mathrm{G}}\left(\xi_n, A_n, \eta\right) \to \mathcal{L}_{\mathrm{G}}\left(W_n^\dagger \xi_n, \mathcal{B}_n(A_n), \eta\right) \equiv \mathcal{L}_{\mathrm{G}}\left(\chi_n, \mathcal{B}_n, \eta\right)$

- We will use the static source and three gauge choices:

- covariant(A_G, A_c)

- light-cone(A_G, A_c) and

- hybrid($A_c^+=0$, covariant(A_G)) (used in GLV calculations)

Jet Quenching from SCET$_G$

Kang, Lashof-Regas, GO, Saad, Vitev, 2014

$$R_{AA}(p_T) = \frac{\sigma_{AA}(p_T)}{\langle N_{\rm coll}\rangle \sigma_{pp}(p_T)}$$

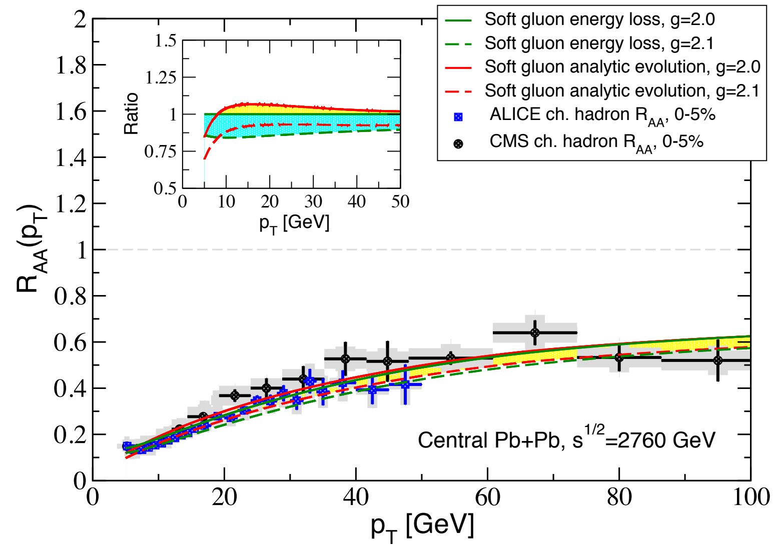
$$\frac{\mathrm{d}f_q(z,Q)}{\mathrm{d}\ln Q} = \frac{\alpha_s(Q^2)}{\pi}\int_z^1 \frac{\mathrm{d}z'}{z'}\left\{P_{q\to qg}(z',Q) f_q\left(\frac{z}{z'},Q\right) + P_{g\to q\bar{q}}(z',Q) f_g\left(\frac{z}{z'},Q\right)\right\},$$

$$\frac{\mathrm{d}f_{\bar{q}}(z,Q)}{\mathrm{d}\ln Q} = \frac{\alpha_s(Q^2)}{\pi}\int_z^1 \frac{\mathrm{d}z'}{z'}\left\{P_{q\to qg}(z',Q) f_{\bar{q}}\left(\frac{z}{z'},Q\right) + P_{g\to q\bar{q}}(z',Q) f_g\left(\frac{z}{z'},Q\right)\right\},$$

$$\frac{\mathrm{d}f_g(z,Q)}{\mathrm{d}\ln Q} = \frac{\alpha_s(Q^2)}{\pi}\int_z^1 \frac{\mathrm{d}z'}{z'}\Bigg\{P_{g\to gg}(z',Q) f_g\left(\frac{z}{z'},Q\right)$$

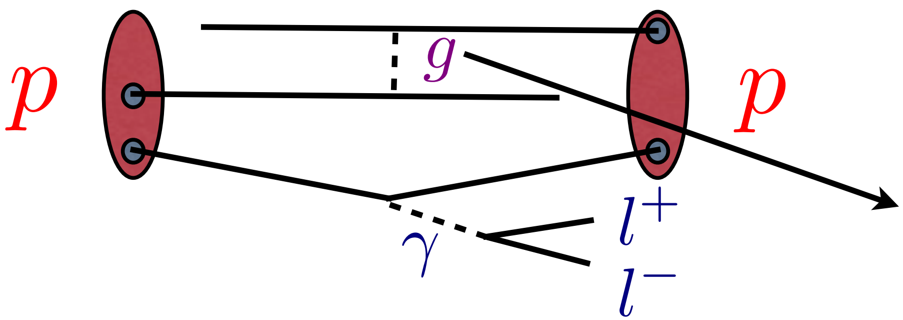
$$+P_{q\to gq}(z',Q)\left(f_q\left(\frac{z}{z'},Q\right) + f_{\bar{q}}\left(\frac{z}{z'},Q\right)\right)\Bigg\}.$$

Real emission calculated in GO, Vitev, 2011 using SCET$_G$



- Using SCET$_G$ and DGLAP equations, we improved the previous state-of-the art energy loss predictions for jet quenching

SCET$_G$: effective theory for Drell-Yan



Bowdin, Brodsky, Lepage, (81)
Collins, Soper, Sterman, (82)
Bauer, Lange, GO(10)

Glauber gluon: $q(\lambda^2, \lambda^2, \lambda)$

- An explicit calculation shows that for consistency of effective theory, SCET should be expanded with Glauber modes to describe Drell-Yan process
- It would be interesting to add the spectator interactions into the factorization analysis of Drell-Yan. SCET$_G$ would be the consistent EFT for purpose.

Conclusions

- We derived the Regge behavior for scalar QCD from method of regions
- The method of regions (EFT) with only collinear modes (SCET) gives the correct QCD result, however imaginary part comes from off-shell modes (sub-regions)
- Using SCET+Glauber, also reproduces the correct QCD behavior, but has the advantage that the imaginary part comes from the true on-shell region
- At one and two loops we explicitly recovered the leading Regge behavior and we made a simple conjecture at an arbitrary order
- More work is needed for consistent EFT formulation of Regge physics.
- Having a further developed SCET with Glauber gluons will be beneficial for applications in heavy ion and hadron collisions, including Regge physics