Queen Mary University of London

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Soft Radiation

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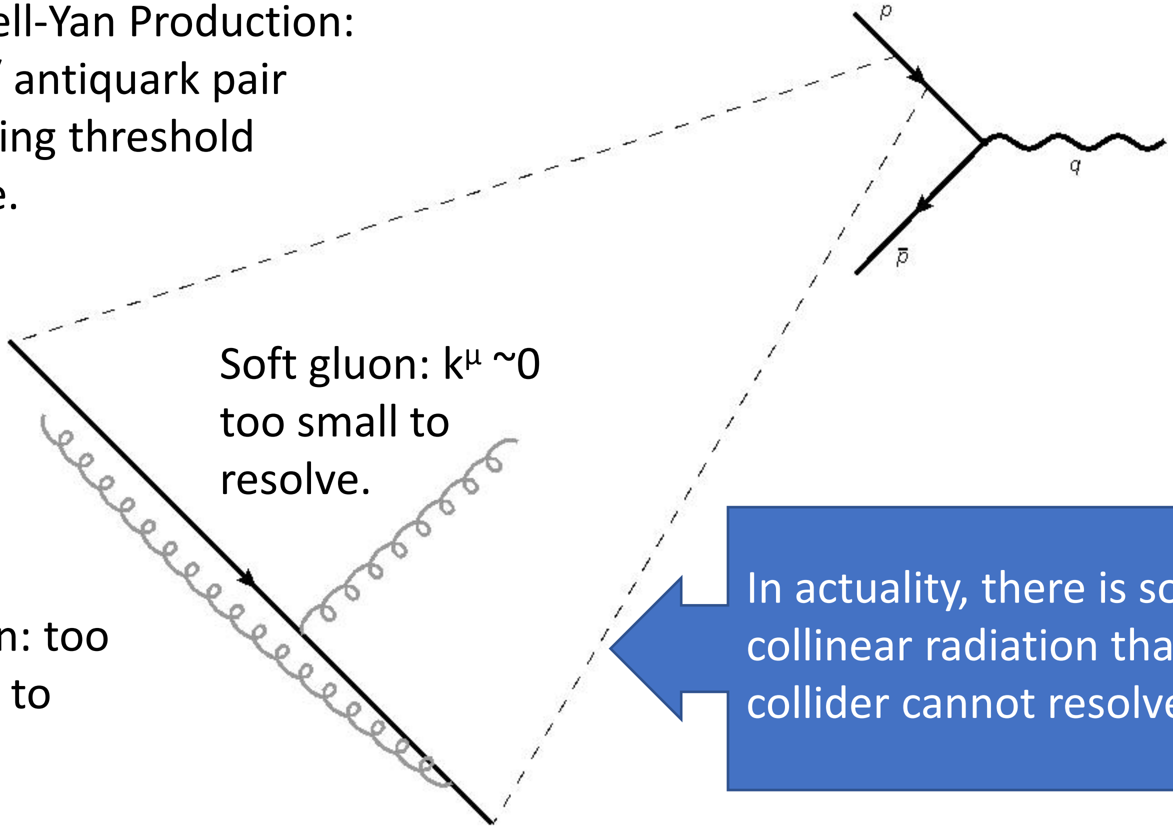
1. Soft Radiation – what is it and why do we care about it?

- Differential cross section – key theory prediction in the search for massive particles produced near threshold at the LHC.
- Improve predictive accuracy by including the effect of ***soft*** (near zero momentum) radiation, a physical phenomenon always present near threshold production.

E.g. Drell-Yan Production: quark / antiquark pair producing threshold particle.



The collider "sees" this because of resolution limits.

Soft gluon: k^{μ} ~0 too small to resolve.

Collinear gluon: too close to quark to resolve.

In actuality, there is soft and collinear radiation that the collider cannot resolve.

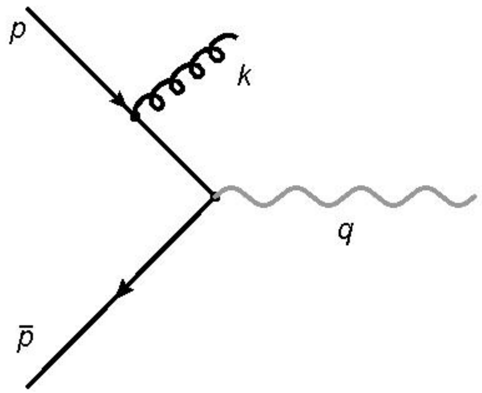
So, how do we keep track of and account for softness?

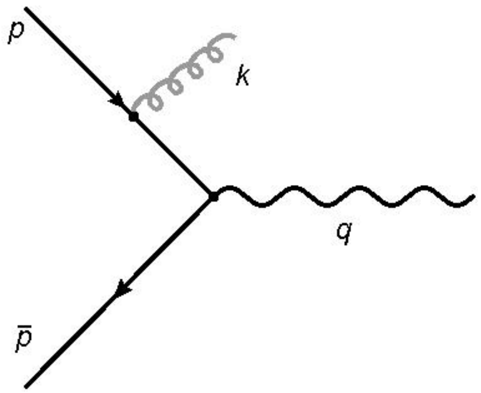
2. Softness accountancy : z

- Parameter “z” keeps track of radiation softness by indicating how much of the centre of mass (c.o.m.) energy squared (Mandelstam “s”) is carried away by a heavy particle or photon :

$$z = \frac{Q^2}{s} = \frac{(\text{outgoing photon energy})^2}{(\text{incoming energy})^2} \quad ; \quad s = (p + \bar{p})^2$$

z -> 0 : most of s is lost to gluon radiation leaving little energy for heavy particle or photon.





z -> 1 : soft gluon limit. Most of s goes to heavy particle or photon.

- Now just use perturbation theory to calculate fixed order differential cross sections in z…

But, this creates a problem...

3. Divergence: large logs in differential cross section

- Differential cross section including soft radiation at threshold will take the form: (see e.g. Bonocore et al. 2015)

$$\frac{d\sigma}{dz} = \sum_{n=0}^{\infty} \left(\frac{\alpha_s}{\pi}\right)^n \sum_{m=0}^{2n-1} \left[c_{nm}^{-1} \frac{\log^m(1-z)}{1-z} + c_{nm}^{0} \log^m(1-z) + \cdots \right]$$

Leading Power (LP) terms.
These are the most divergent as z -> 1
Very well known.

Next-to Leading Power (NLP) terms.
These are the next most divergent as z -> 1
Less well-known – **OUR FOCUS**.

- Some hope: Individual terms may be divergent but their combination may be finite and small through *resummation.* Conceptually:

LHS: not divergent for large x

$$e^{-\alpha_s x} = 1 + \alpha_s(-x) + \alpha_s^2 \frac{(-x)^2}{2!} + \alpha_s^3 \frac{(-x)^3}{3!} + \cdots$$

RHS: Individual terms divergent for large x

We need to collect NLP log data…

4. Our contribution

- The state of the art at present is next-to-next-to leading order (NNLO), i.e. 2 gluons.

- We are deriving key components of differential cross sections for:

  - N^3LO (3 gluons) – to directly gather actual NLP log data
  - N^nLO (*any* number of gluons) – to learn about substructure and sources of NLP logs.

- Next steps could involve applications to LHC processes.

Thank you!

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