Parton-Shower Improvements

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Color coherence and the dipole picture

- Gluons with large wavelength cannot resolve charges within emitting color dipole → angular ordering [Marchesini,Webber] NPB310(1988)461 (also known as soft double counting, collinear anomaly, ...)
- Soft radiation pattern correct if evolution reformulated in terms of color dipoles [Gustafsson,Pettersson] NPB306(1988)746, [Kharraziha,Lönnblad] hep-ph/9709424
- Dipole subtraction preserves parton picture by partial fractioning soft enhanced splitting function [Catani,Seymour] hep-ph/9605323

$$\frac{p_ip_k}{(p_ip_j)(p_jp_k)} \to \underbrace{\frac{1}{p_ip_j}\frac{p_ip_k}{(p_i+p_k)p_j}}_{(i,k)\to(ij,k)} + \underbrace{\frac{1}{p_kp_j}\frac{p_ip_k}{(p_i+p_k)p_j}}_{(k,i)\to(kj,i)}$$

- "Spectator"-dependent kernels, singular in soft-collinear region only → capture dominant coherence effects (3-parton correlations)

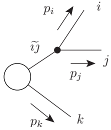
$$\frac{1}{1-z} \to \frac{1-z}{(1-z)^2+\kappa^2} \qquad \kappa^2 = \frac{k_\perp^2}{Q^2}$$

- For correct soft evolution, ordering variable must be identical in both "dipole ends" (→ recombine eikonal factor at integrand level)

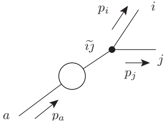
The midpoint between dipole and parton showers

[Prestel,SH] arXiv:1506.05057

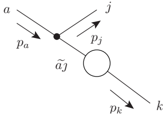
- Choose parametrization such that soft term identical in all dipole types



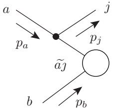
$$\kappa^2 = \frac{p_i p_j\, p_j p_k}{(p_{\widetilde{ij}} p_{\tilde{k}})^2} \qquad z_j = \frac{p_j p_k}{p_{\widetilde{ij}} p_{\tilde{k}}}$$



$$\kappa^2 = \frac{p_i p_j\, p_j p_a}{(p_{ij} p_a)^2} \qquad z_j = \frac{p_j p_a}{p_{ij} p_a}$$



$$\kappa^2 = \frac{p_a p_j\, p_j p_k}{(p_{jk} p_a)^2} \qquad z_j = \frac{p_j p_k}{p_{jk} p_a}$$



$$\kappa^2 = \frac{p_a p_j\, p_j p_b}{(p_a p_b)^2} \qquad z_j = \frac{p_j p_b}{p_a p_b}$$

- z_j - light-cone momentum fraction of gluon (maps to collinear limit)
  $\rightarrow$ Full splitting function from adding collinear bits & enforcing sum rules

$$P_{qq}(z,\kappa^2) = 2\,C_F\left[\left(\frac{1-z}{(1-z)^2+\kappa^2}\right)_+ - \frac{1+z}{2}\right] + \gamma_q\,\delta(1-z)$$

$$P_{gg}(z,\kappa^2) = 2\,C_A\left[\left(\frac{1-z}{(1-z)^2+\kappa^2}\right)_+ + \frac{z}{z^2+\kappa^2} - 2 + z(1-z)\right] + \gamma_g\,\delta(1-z)$$

$$P_{qg}(z,\kappa^2) = 2\,C_F\left[\frac{z}{z^2+\kappa^2} - \frac{2-z}{2}\right] \qquad P_{gq}(z,\kappa^2) = T_R\left[z^2+(1-z)^2\right]$$

Dire anomalous dimensions

In the notation of NPB244(1984)337, $\gamma_{ab}(N,\kappa^2)=\int_0^1 \mathrm{d}z\, z^N P_{ab}(z,\kappa^2)$:

$$\gamma_{qq}(N,\kappa^2) = 2C_F\,\Gamma(N,\kappa^2) - \frac{C_F\,(2N+3)}{(N+1)(N+2)} + \gamma_q$$

$$\gamma_{gq}(N,\kappa^2) = 2C_F\,\mathrm{K}(N,\kappa^2) - \frac{C_F\,(N+3)}{(N+1)(N+2)}$$

$$\gamma_{gg}(N,\kappa^2) = 2C_A\,\Gamma(N,\kappa^2) + 2C_A\,\mathrm{K}(N,\kappa^2) - \frac{2C_A\,(N+3)}{(N+1)(N+2)} - \frac{2C_A}{N+3} + \gamma_g$$

$$\gamma_{qg}(N,\kappa^2) = -\frac{T_R\,N}{(N+1)(N+2)} + \frac{2T_R}{N+3}$$

where

$$2\Gamma(N,\kappa^2) = \frac{2\,{}_3F_2\left(1,1,\tfrac{3}{2};\tfrac{N+3}{2},\tfrac{N+4}{2};-\kappa^{-2}\right)}{(N+1)(N+2)\,\kappa^2} - \ln\frac{1+\kappa^2}{\kappa^2}$$

$$2\mathrm{K}(N,\kappa^2) = \frac{2\,{}_2F_1\left(1,\tfrac{N+2}{2};\tfrac{N+4}{2};-\kappa^{-2}\right)}{(N+2)\,\kappa^2}\,.$$

The midpoint between dipole and parton showers

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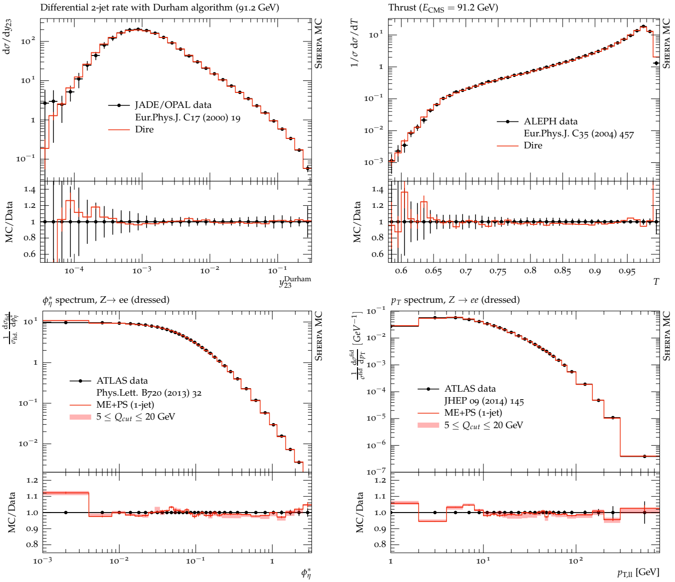


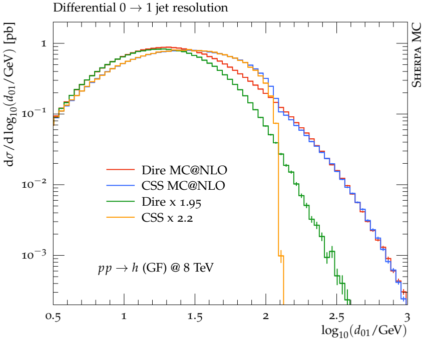
Extension to a subtraction method and MC@NLO

[SH] TBP?

- Can view new shower model as modification of CS subtraction
- IR-finite counterterms computed and implemented in Sherpa (improved cancellation in $pp \to h + j$ due to regulated $1/z$ terms)

- Sherpa MC@NLO based on exponentiation of CS dipole subtraction terms

  [Krauss,Siegert,Schönherr,SH]
  arXiv:1111.1220, arXiv:1208.2815
- Dire modified CS subtraction automatically available for MC@NLO matching
- Interesting differences due to evolution variables and kernels



Towards higher logarithmic accuracy

[Krauss,Li,Prestel,Schönherr,SH] TBP!

- Big drawback of parton showers is lack of higher-order kernels
- Start improving with spacelike NLO splitting functions
  [Curci,Furmanski,Petronzio] NPB175(1980)27, PLB97(1980)437
- 2-loop cusp term subtracted & combined with LO soft contribution (similar to CMW rescaling [Catani,Marchesini,Webber] NPB349(1991)635)
- Implemented using weighting algorithms [Schumann,Siegert,SH] arXiv:0912.3501