

What do Monte-Carlo tools do

Need to know amplitude for the process and be able to compute it fast

$$\sigma_{LO} = \int d(\text{PS})_2 |\mathcal{M}_{LO}|^2$$

Numerical integration

Phase-space algorithm

Beyond LO, need to cancel IR singularities with a scheme, but principle is the same

NLO is automated for most processes (sometimes NNLO)

What about effects that are important but arise at NN...NLO?

$$e^+e^- \rightarrow p^+p^- \quad \text{diagram} = \mathcal{M}^{(0)} = \frac{e^2}{s} (\bar{v} \gamma^\mu u)(\bar{u} \gamma_\mu v) \quad (LO)$$

$$\sigma = \int (dPS)_2 |\mathcal{M}|^2 = \frac{4\pi\alpha^2}{3s}$$

$$NLO: \mathcal{M}_R = \text{diagram 1} + \text{diagram 2} + \text{diagram 3} + \text{diagram 4}, \quad \text{Real correct}^o$$

IR: photon soft

$$\mathcal{M}_V = \text{diagram 5} + \text{diagram 6} + \text{diagram 7}$$

$$e^{\alpha_Y} \pi(\alpha_S) = \alpha_0 + \alpha_1 \alpha_S + \dots \quad (NLO)$$

virtual correct^o

$$\mathcal{M}_{div} = e^Y \mathcal{M}_{non div}$$

$$NNLO: \mathcal{M}^{(1)} = \mathcal{M}_R + \mathcal{M}_V \equiv \log\left(\frac{s}{m_e^2}\right), \log\left(\frac{s}{m_p^2}\right) + \dots$$

$$\mathcal{M}^{(n)} = \alpha^n \log^n\left(\frac{s}{m_e^2}\right) + \dots$$

$$\mathcal{M}^{(0)} = e^Y (+) + \dots$$

row-by-row sum: normal summation 😞

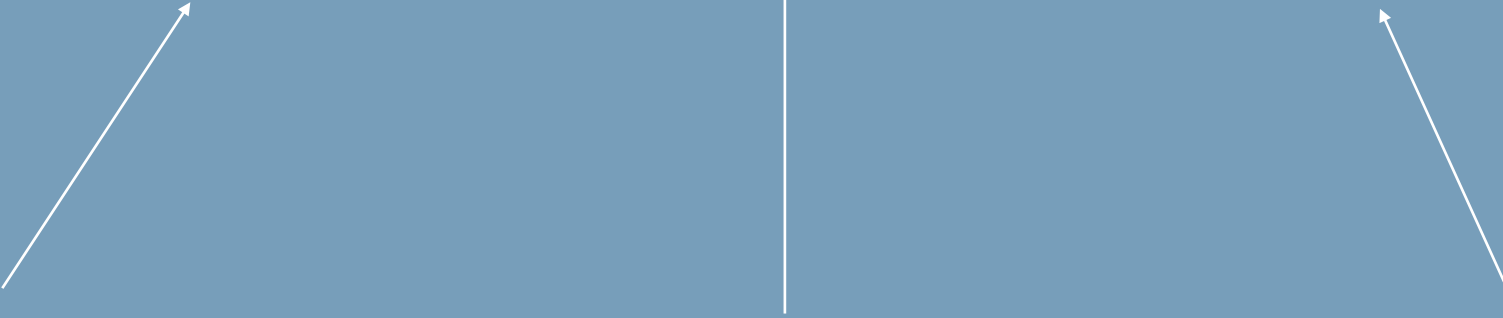
$$\begin{aligned} \rightarrow M^0 &= a_0 \\ \rightarrow M^1 &= a_0' \log(\cdot) + a_1^2 \\ \rightarrow M^2 &= a_0'' (\log(\cdot))^2 + a_1' \log(\cdot) + a_2^2 \end{aligned}$$

column-by-column sum: that's the RESUMMATION! 😊

One clever trick: resummation

$$d\sigma = \sum_{n_\gamma=0}^{\infty} \frac{e^{2\alpha(B+\tilde{B}(\Omega))}}{n_\gamma!} d\Phi_Q \left[\prod_{i=1}^{n_\gamma} d\Phi_i^\gamma \tilde{S}(k_i) \Theta(k_i, \Omega) \right] \left(\tilde{\beta}_0 + \sum_{j=1}^{n_\gamma} \frac{\beta_1(k_j)}{\tilde{S}(k_j)} + \dots \right)$$

Form Factor



Phase-Space Integration

IR safe amplitude

Thank you



Any questions?