

Recent developments in GENEVA

Davide Napoletano, HP2, 20/09/2022 (on behalf of the GENEVA Collaboration)



European Research Council
Established by the European Commission

Introduction

- Broadly speaking, a method to get fully differential events (at NNLO!)
- Improve this with resummation of resolution variable
- Match to the shower!

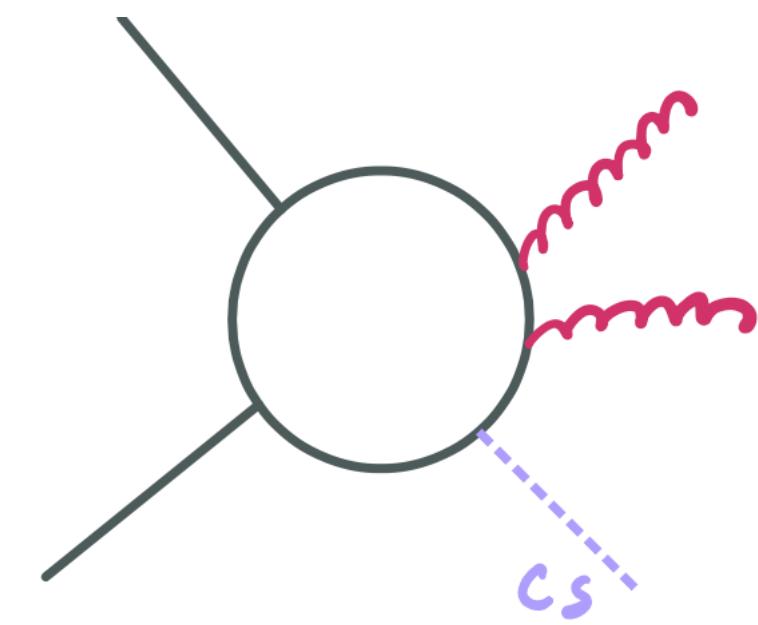
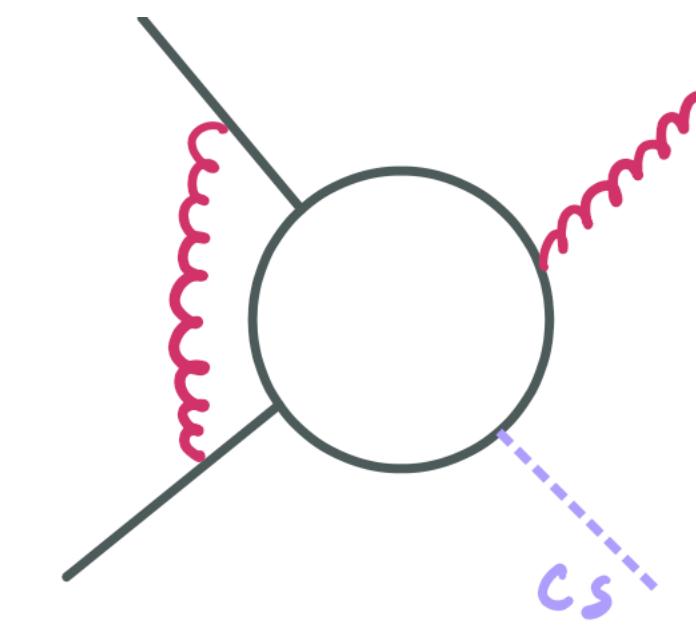
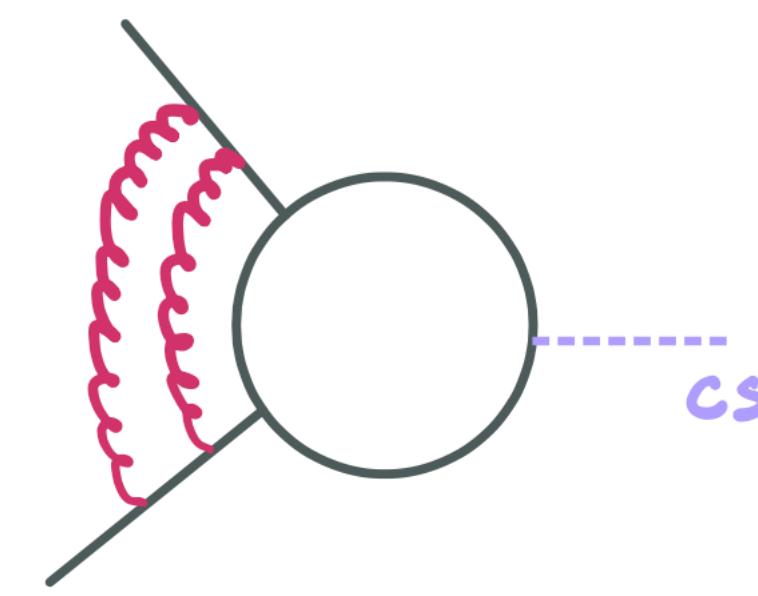
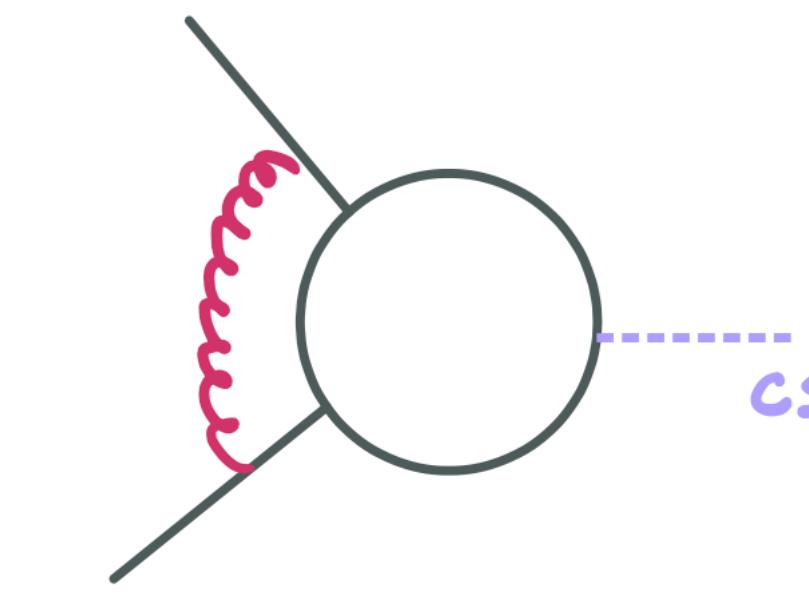
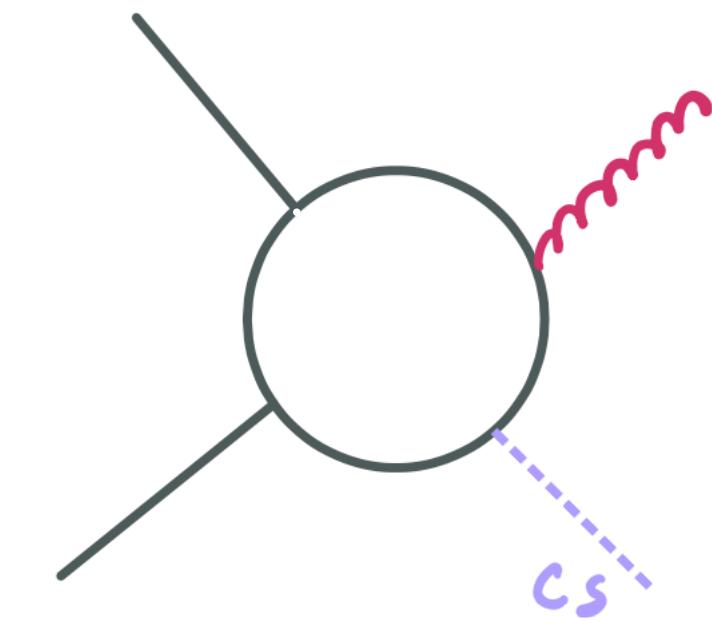
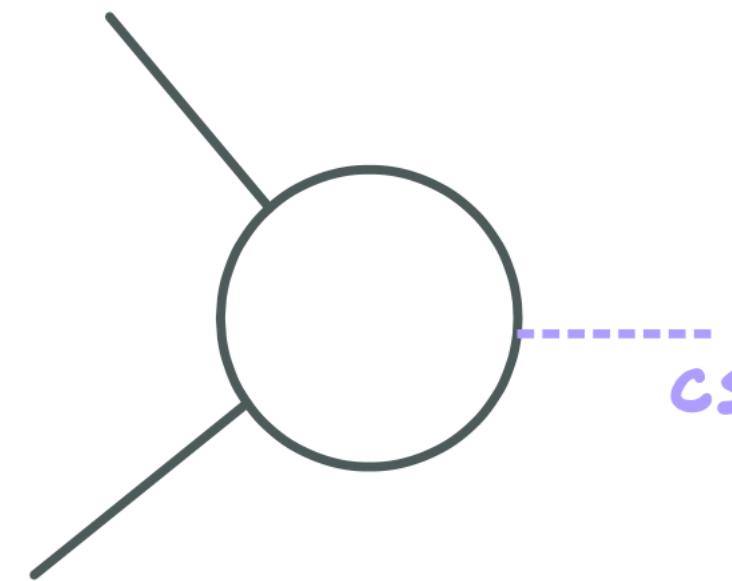
Introduction

- To get the best of all worlds: use separation variable you know the resummation of

$$\begin{aligned}\sigma(X) &= \int d\Phi_0 \frac{d\sigma_0^{\text{MC}}}{d\Phi_0} (r_0^{\text{cut}}) M_X(\Phi_0) \\ &+ \int d\Phi_1 \frac{d\sigma_1^{\text{MC}}}{d\Phi_1} (r_0 > r_0^{\text{cut}}, r_1^{\text{cut}}) M_X(\Phi_1) \\ &+ \int d\Phi_2 \frac{d\sigma_{\geq 2}^{\text{MC}}}{d\Phi_2} (r_0 > r_0^{\text{cut}}, r_1 > r_1^{\text{cut}}) M_X(\Phi_2)\end{aligned}$$

Introduction

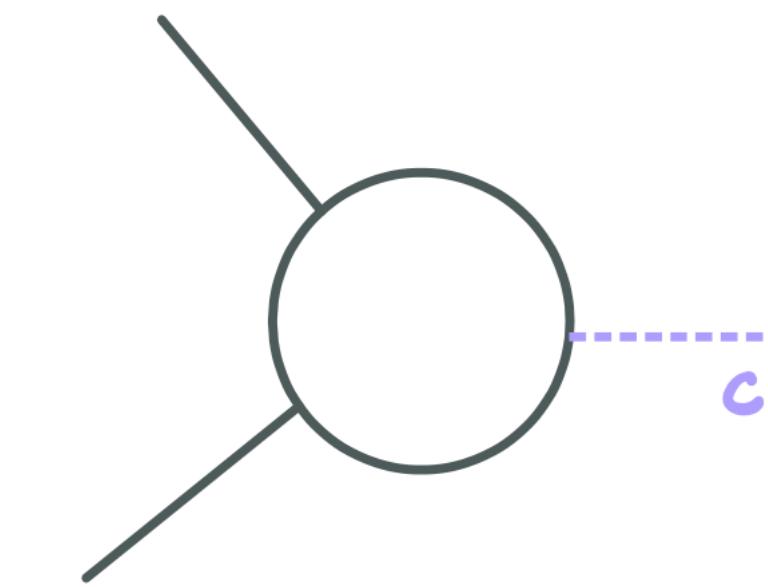
$$\sigma(X) = \int d\Phi_0 \frac{d\sigma_0^{\text{MC}}}{d\Phi_0} (r_0^{\text{cut}}) M_X(\Phi_0)$$
$$+ \int d\Phi_1 \frac{d\sigma_1^{\text{MC}}}{d\Phi_1} (r_0 > r_0^{\text{cut}}, r_1^{\text{cut}}) M_X(\Phi_1)$$
$$+ \int d\Phi_2 \frac{d\sigma_{\geq 2}^{\text{MC}}}{d\Phi_2} (r_0 > r_0^{\text{cut}}, r_1 > r_1^{\text{cut}}) M_X(\Phi_2)$$



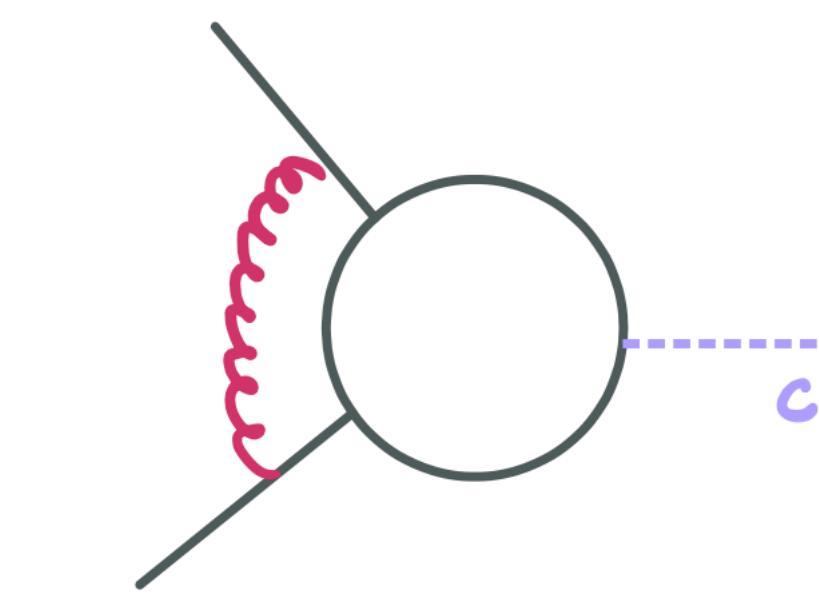
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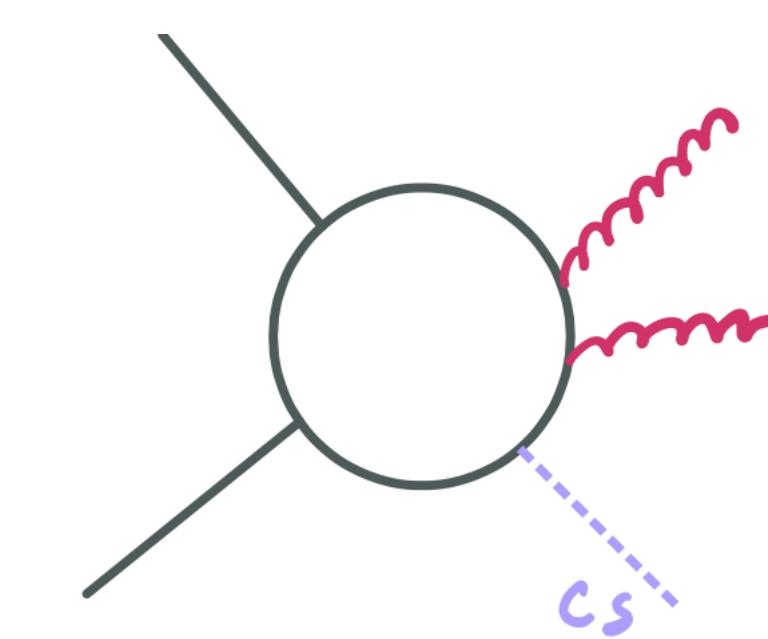
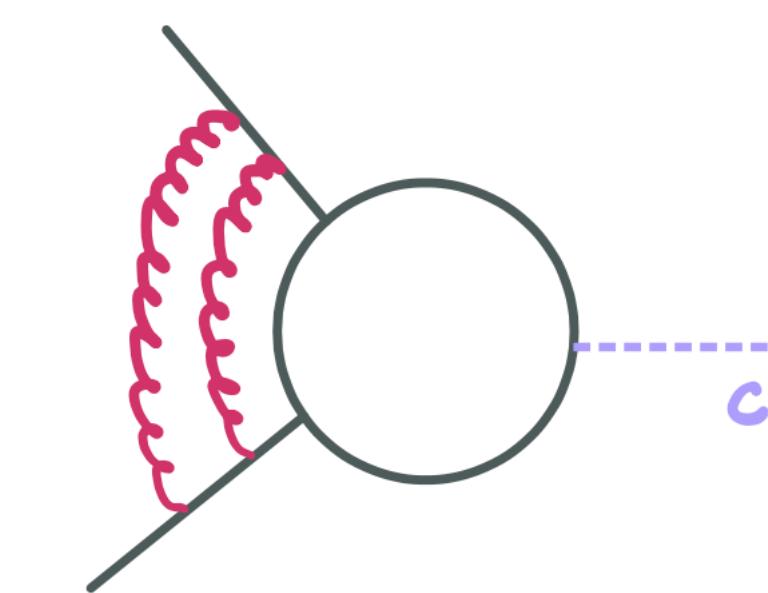
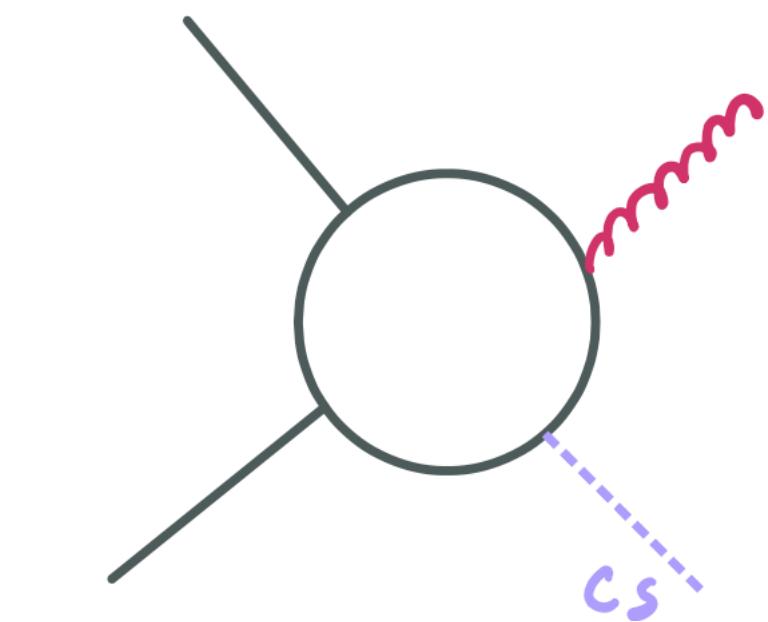
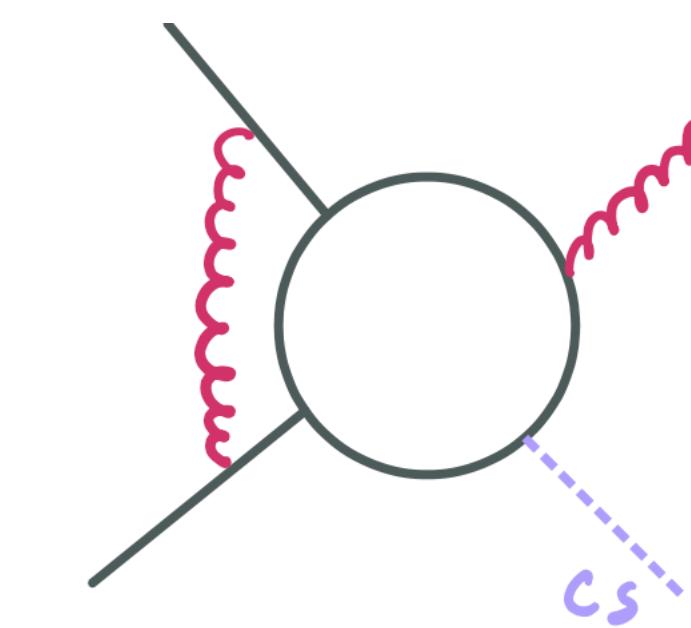
Φ_0 Event



Φ_1 Event



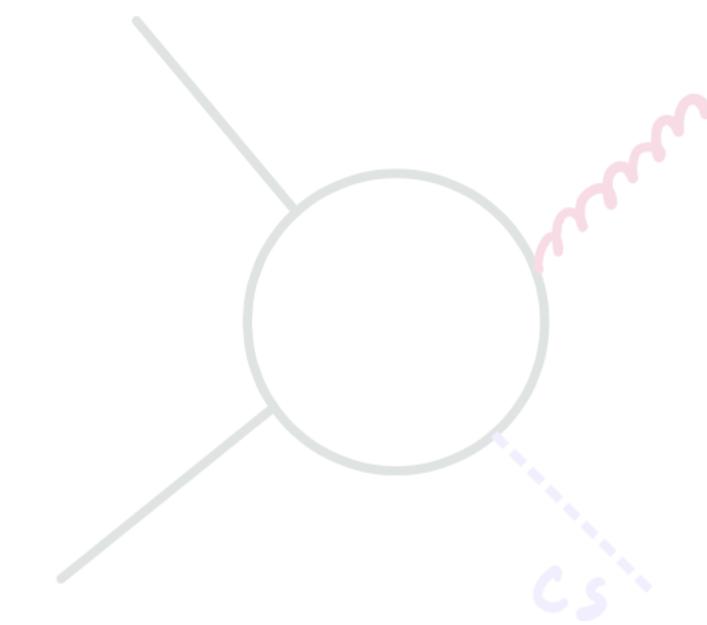
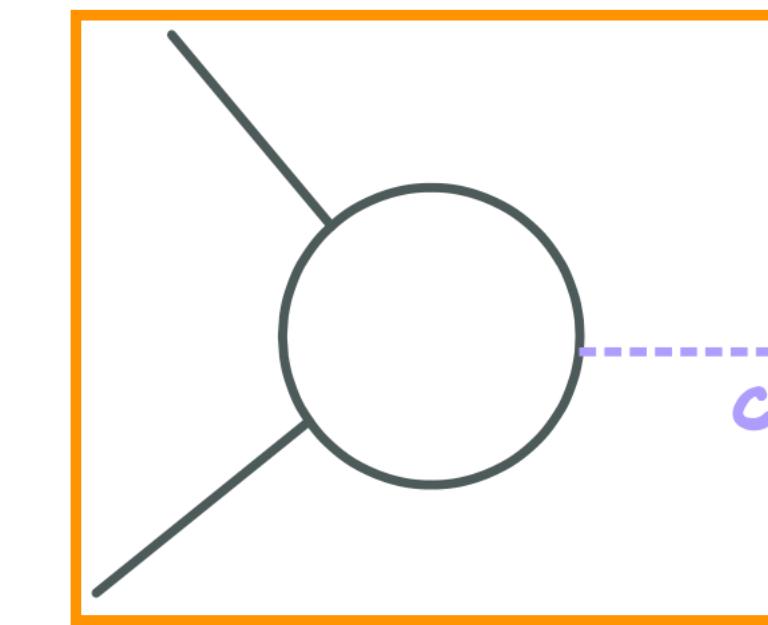
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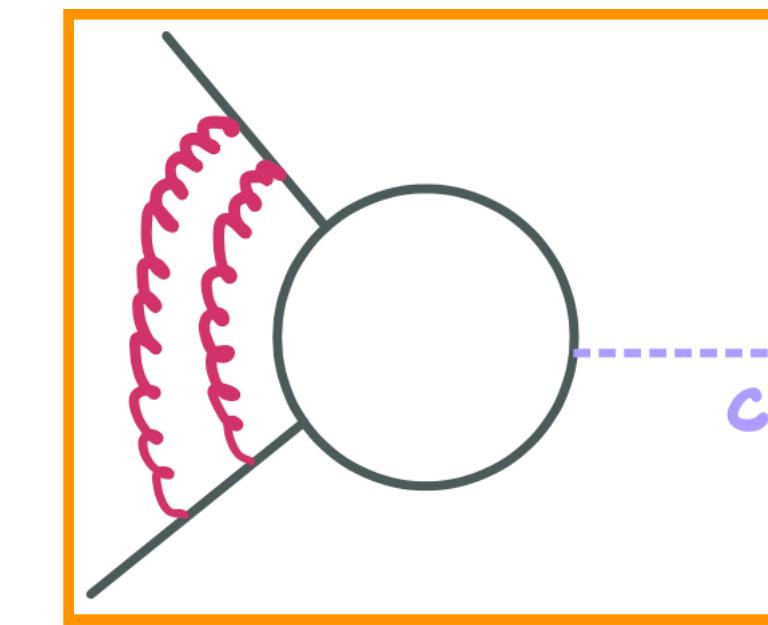
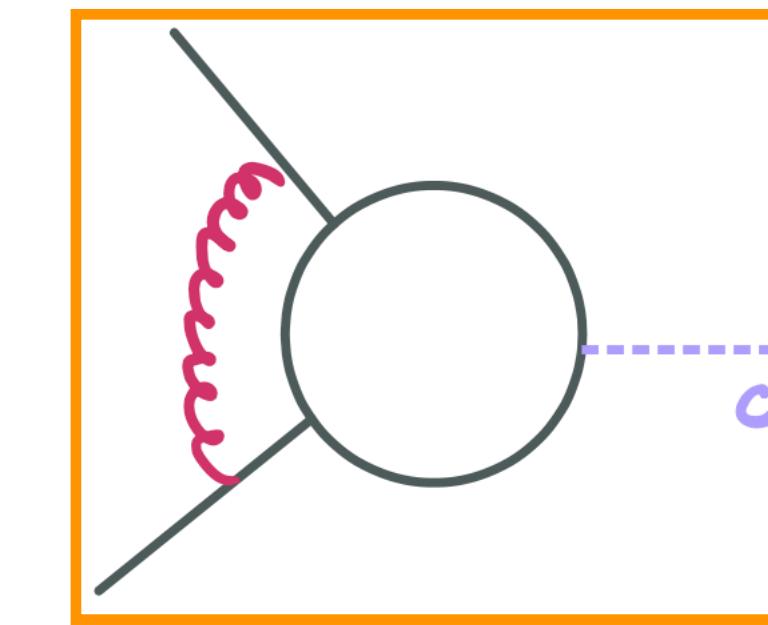
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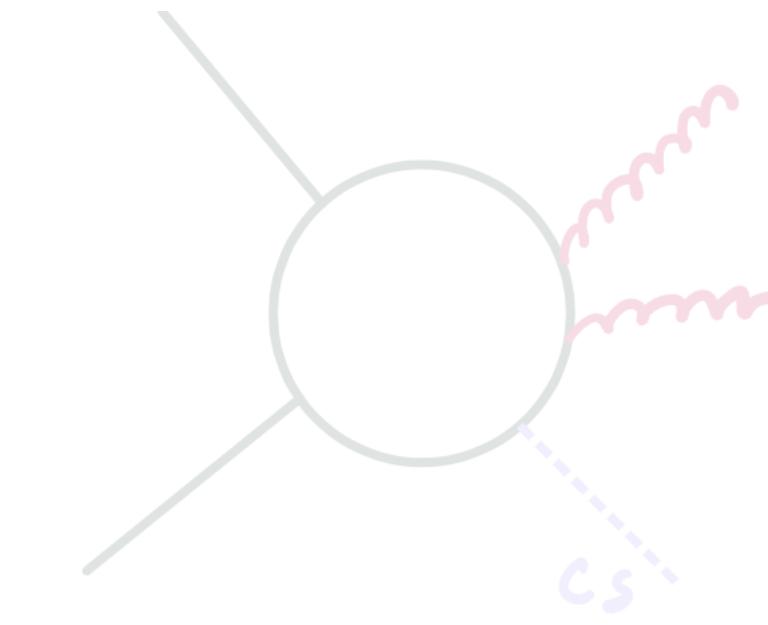
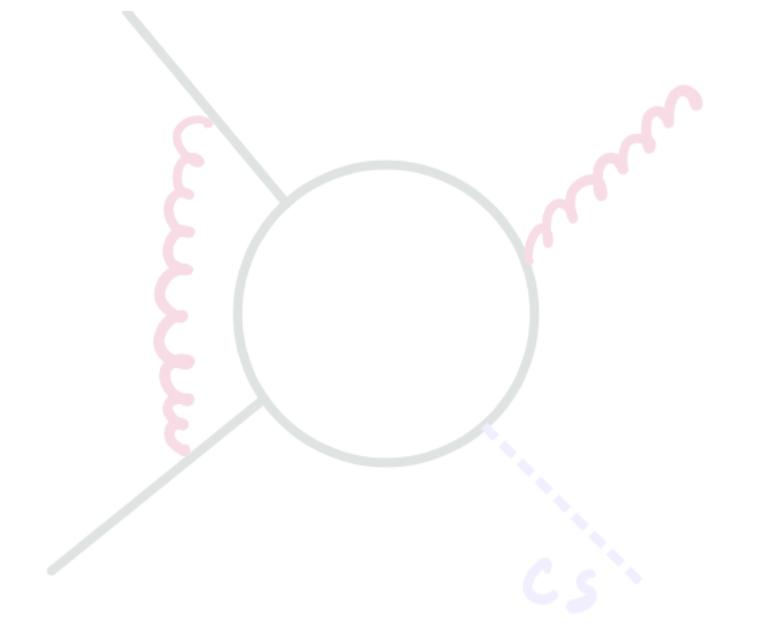
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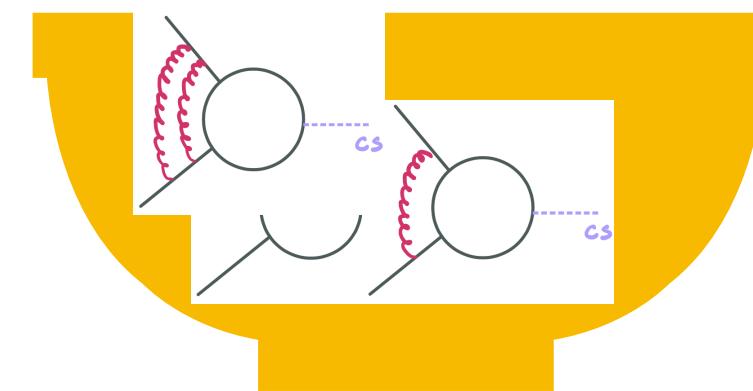
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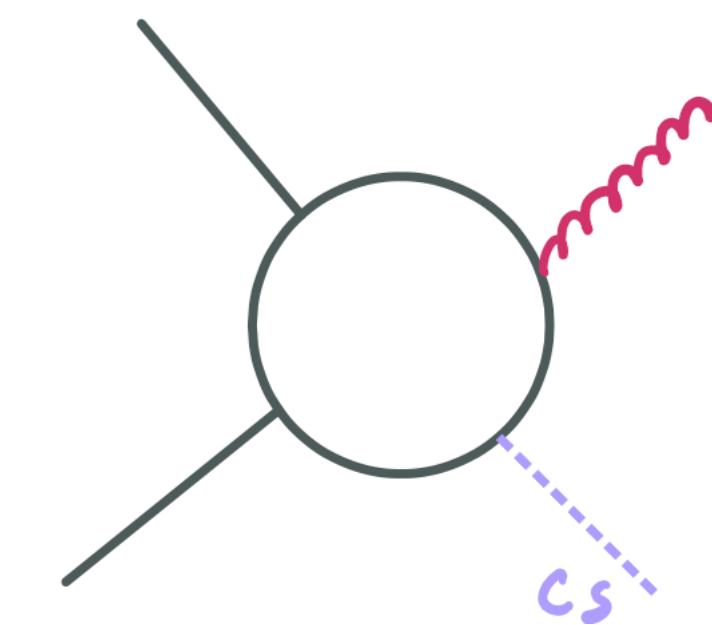
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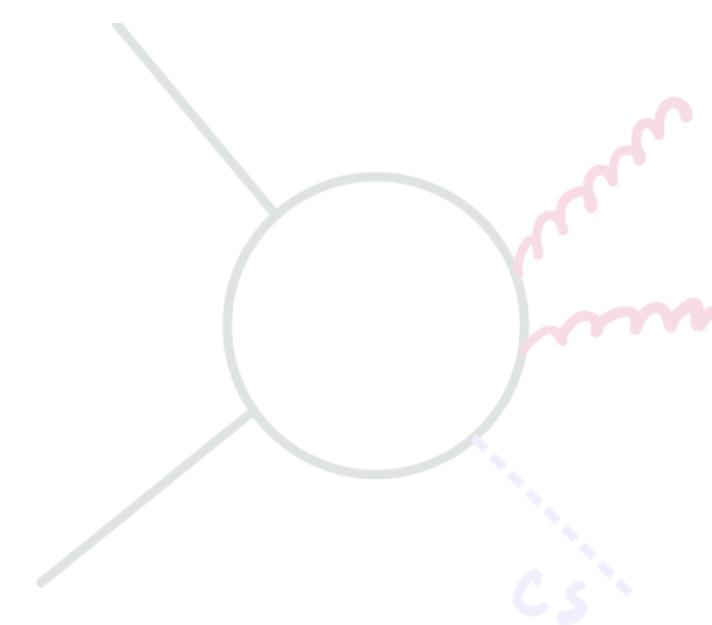
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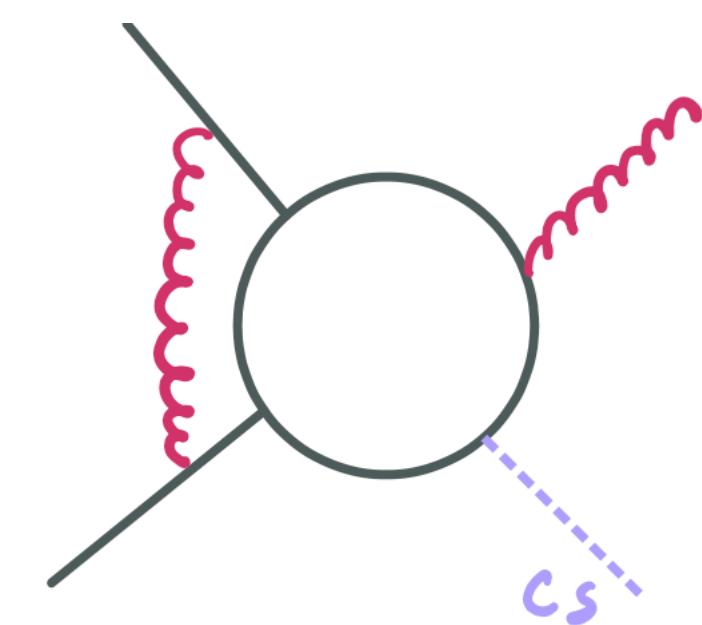
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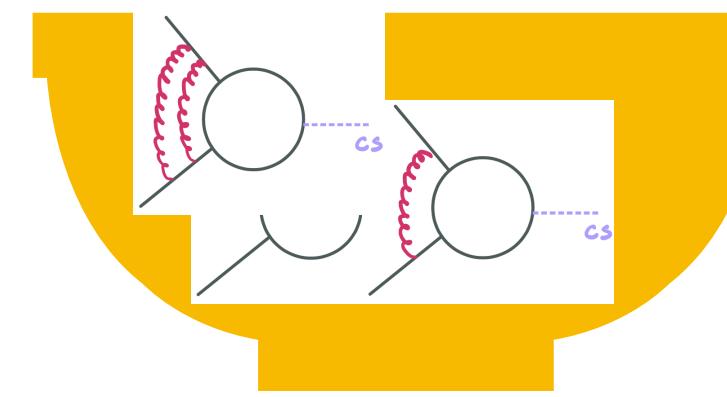
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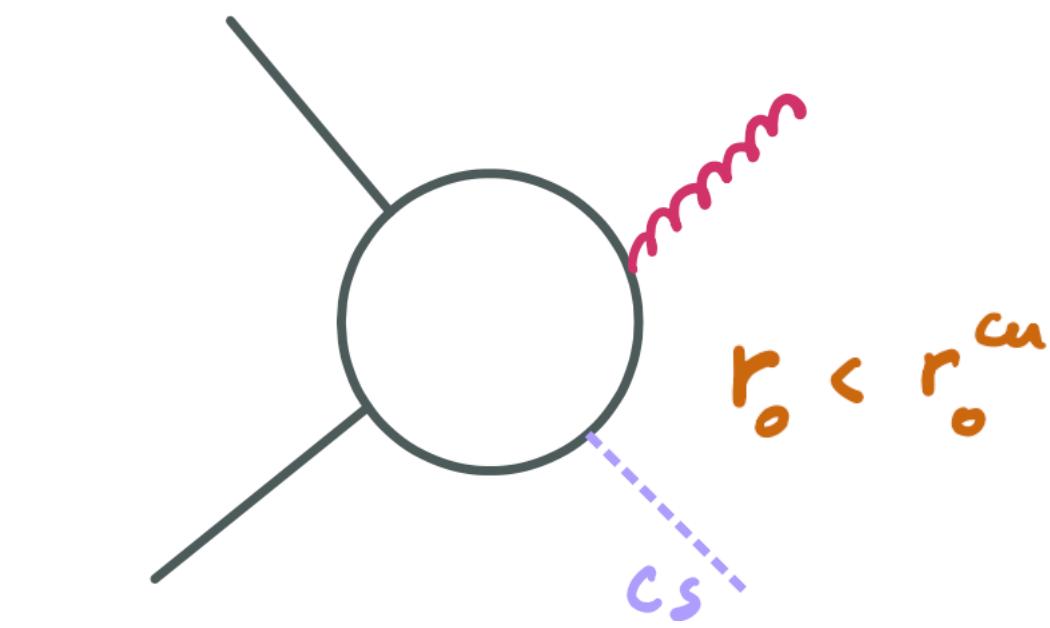
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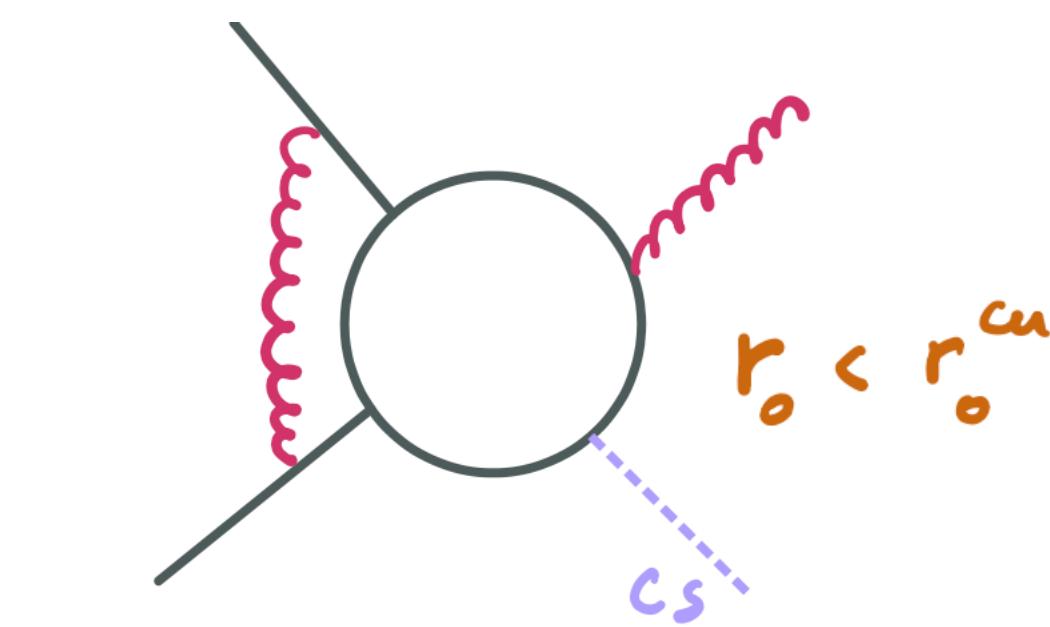
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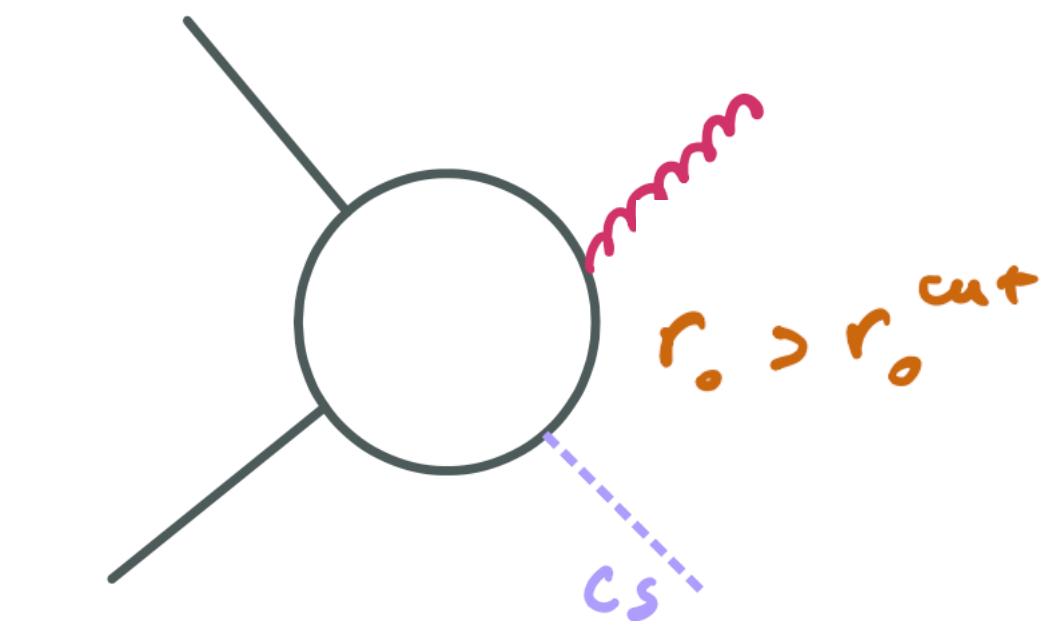
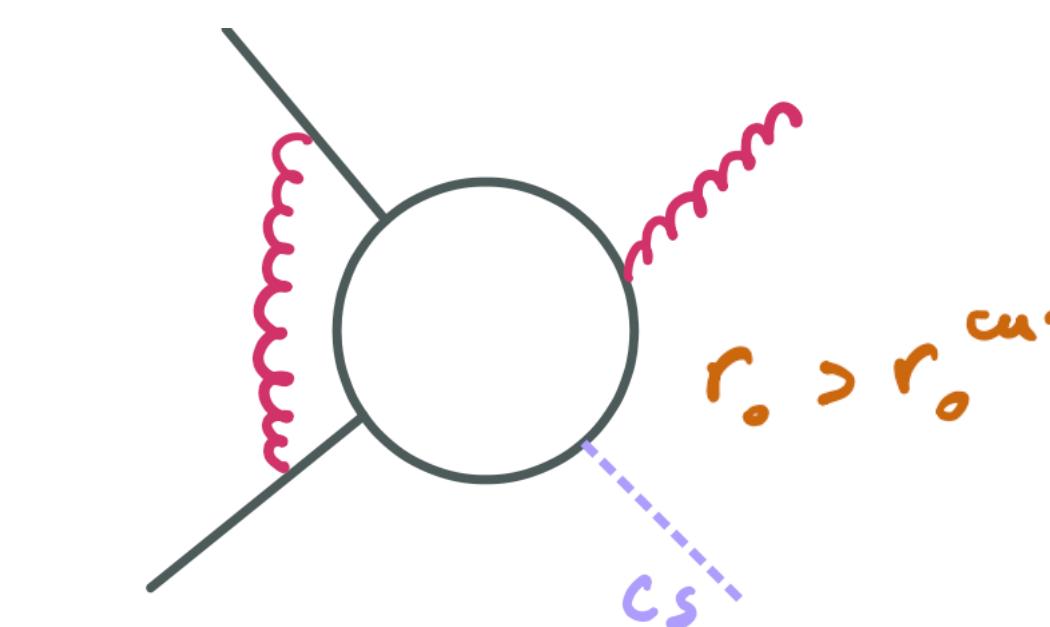
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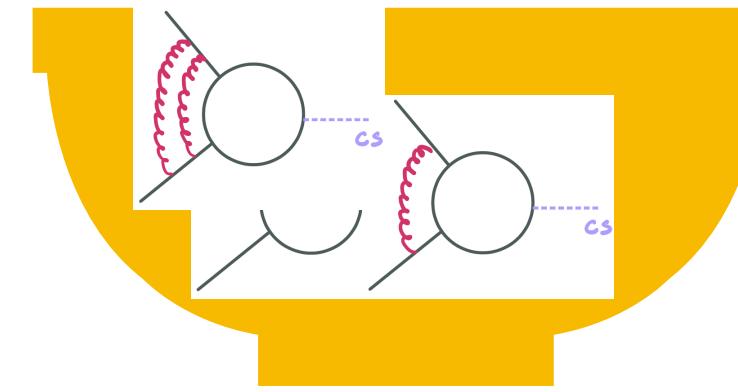
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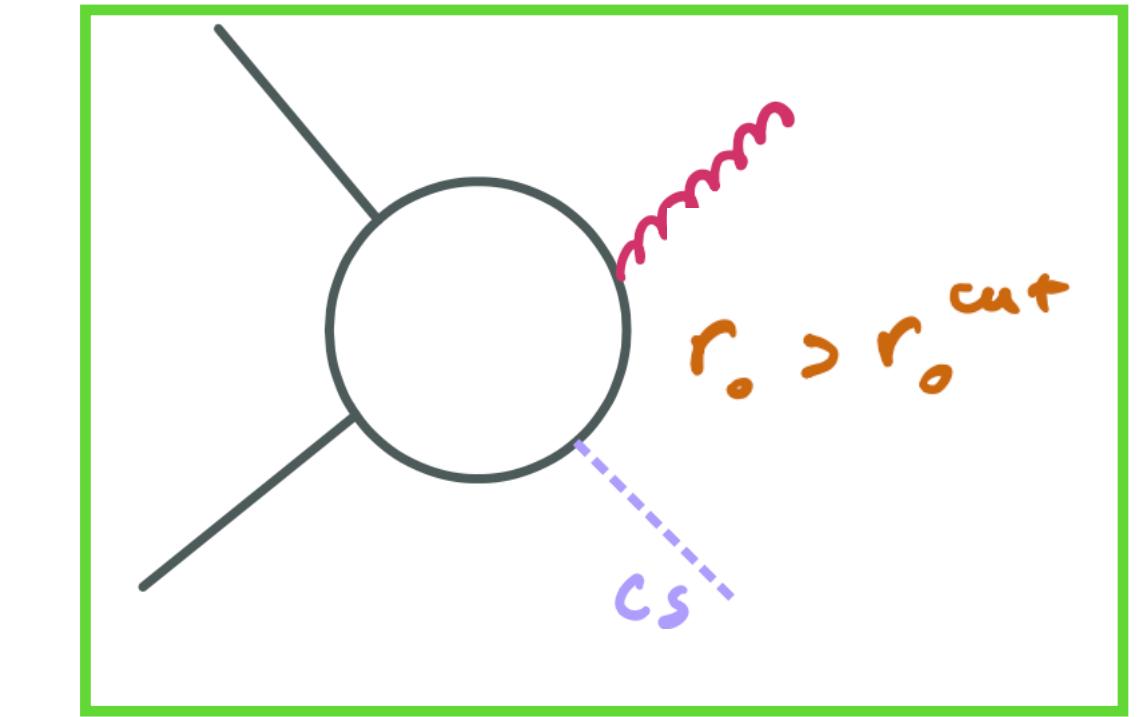
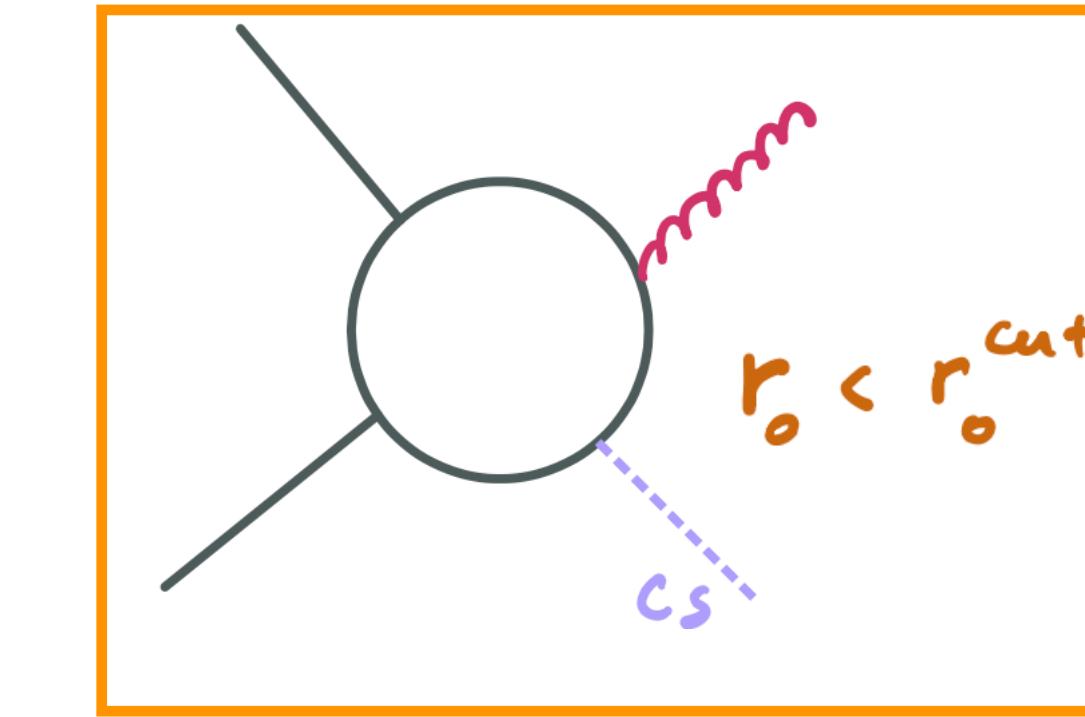
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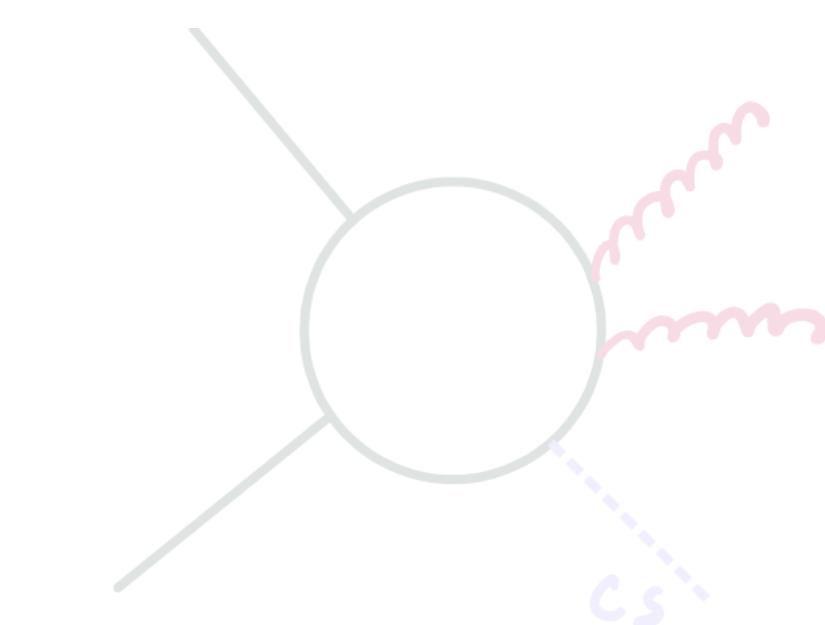
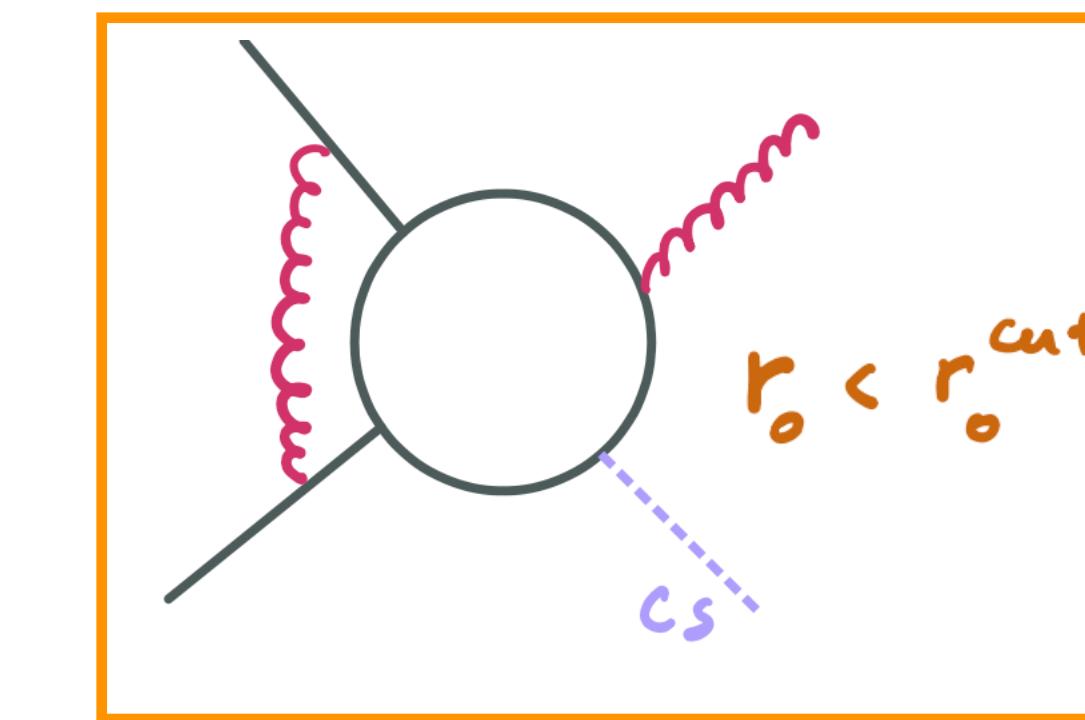
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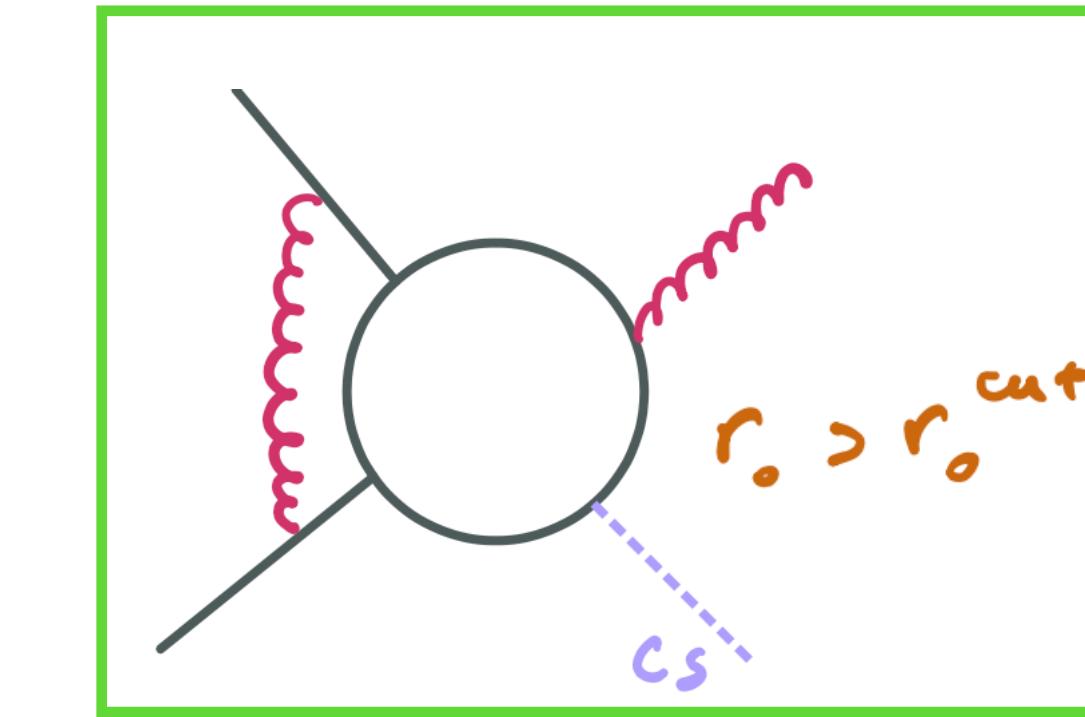
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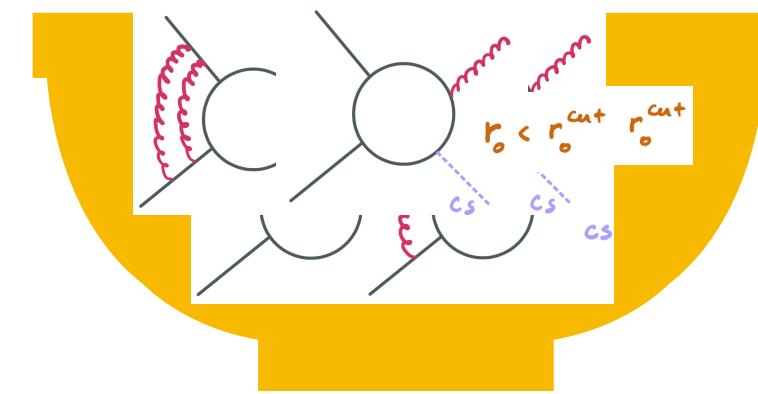
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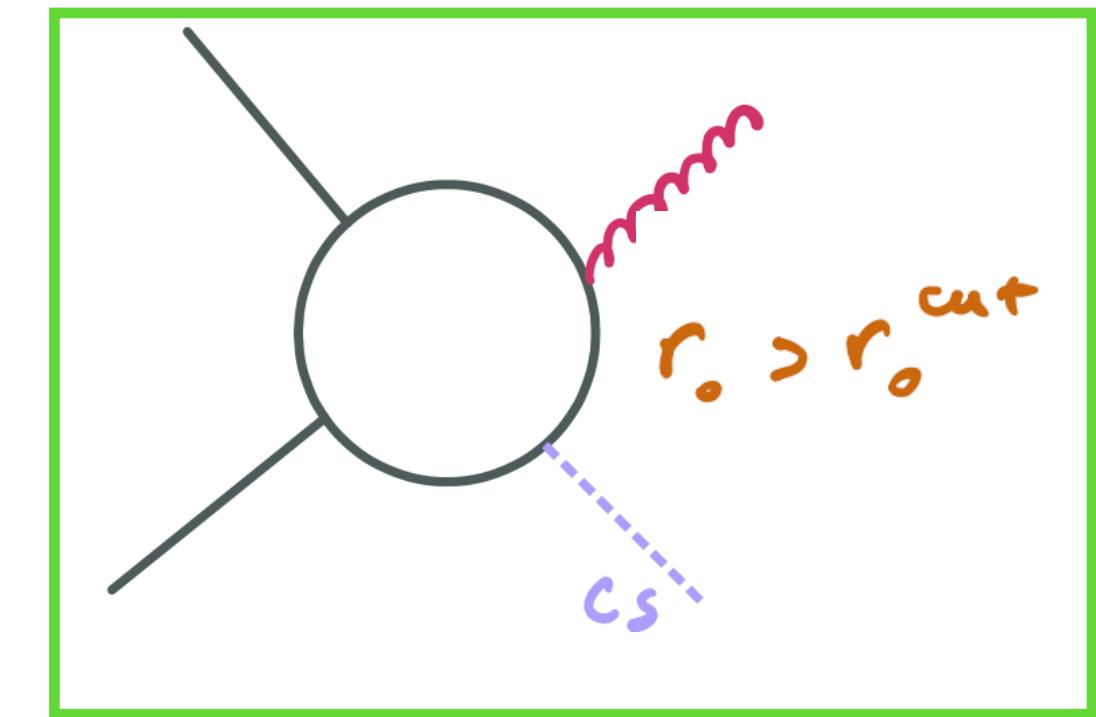
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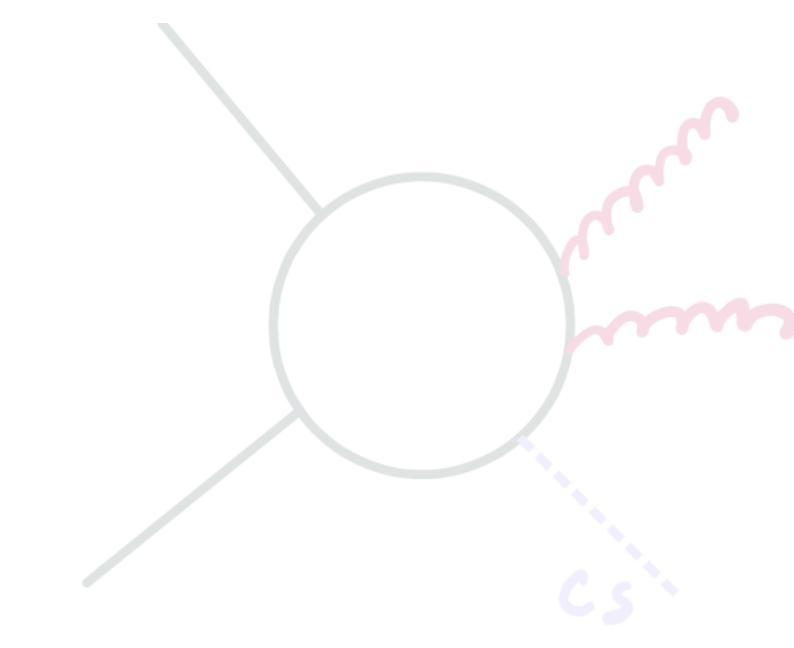
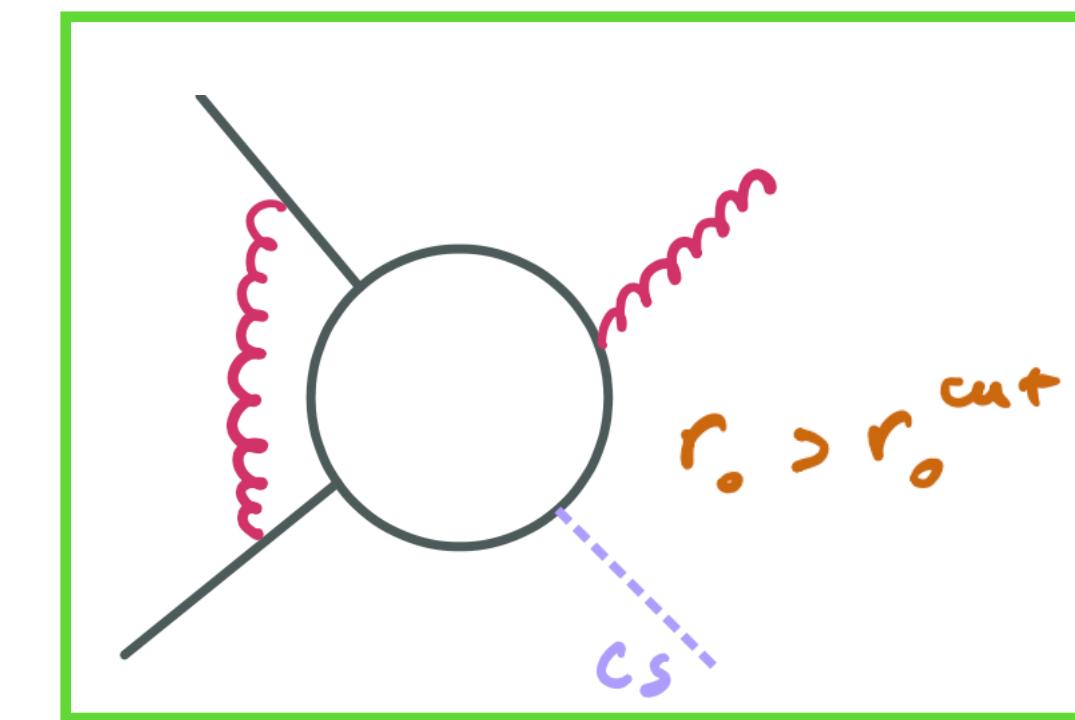
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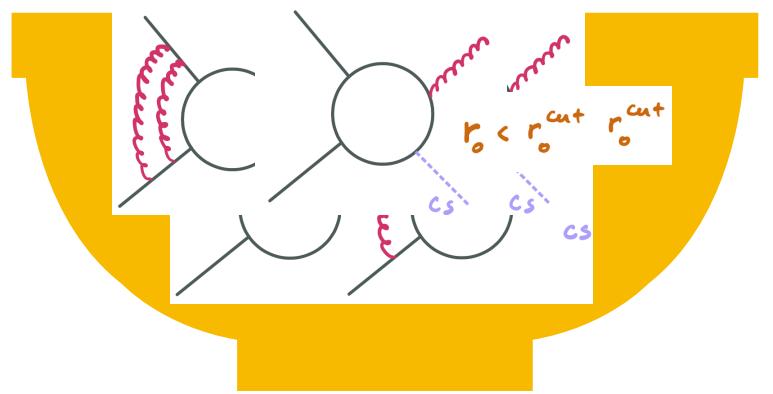
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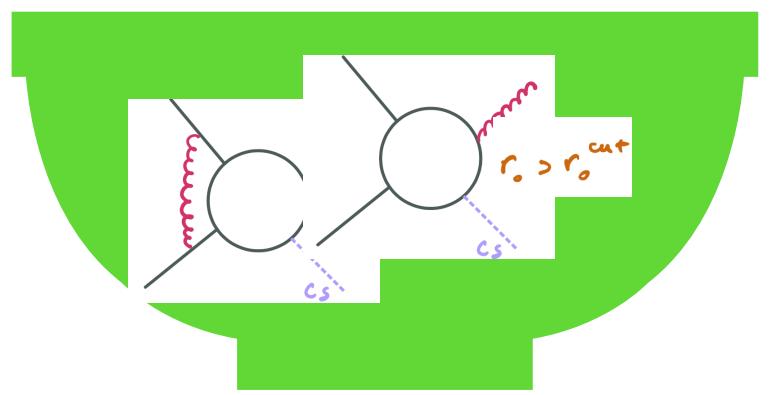
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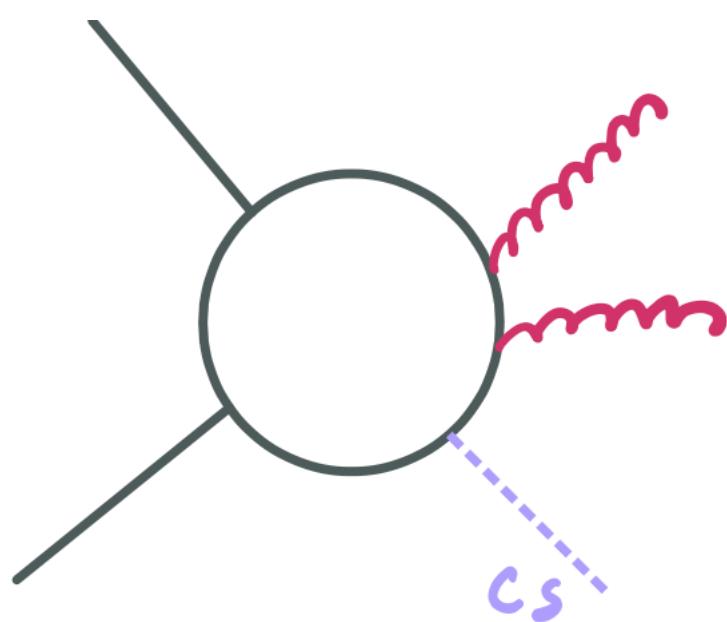
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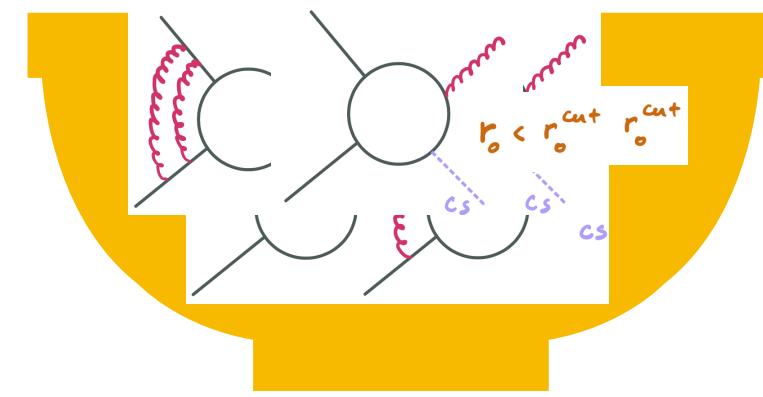
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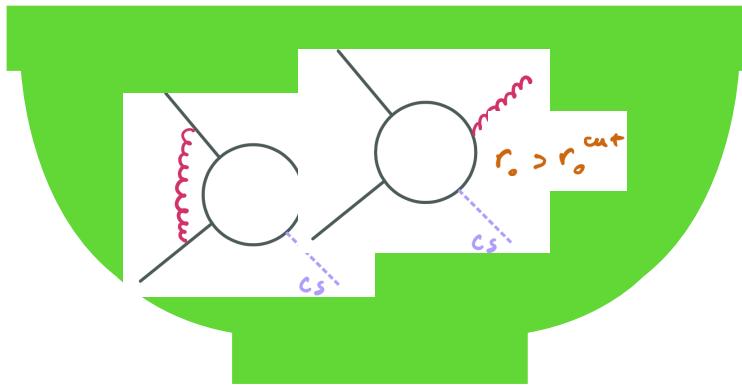
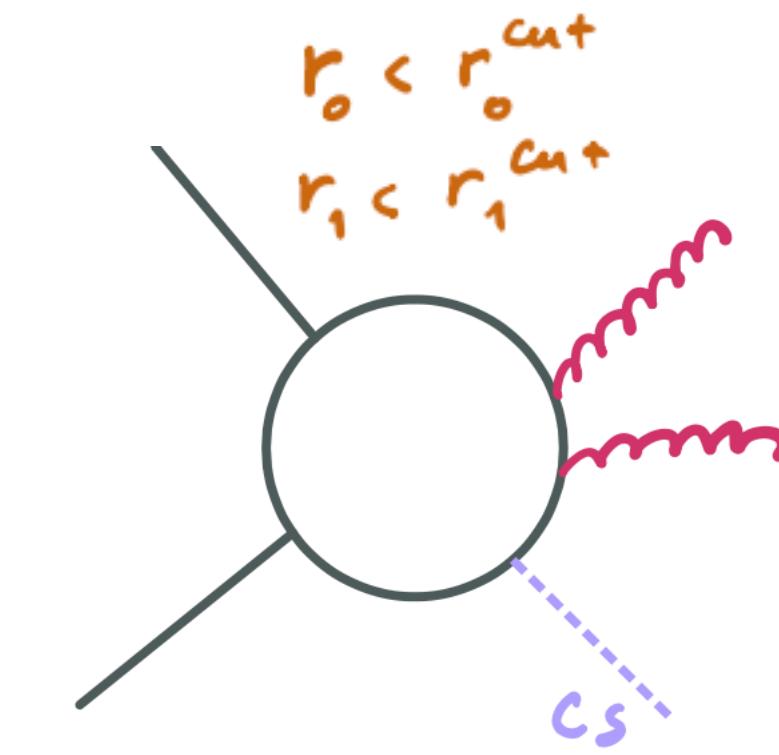
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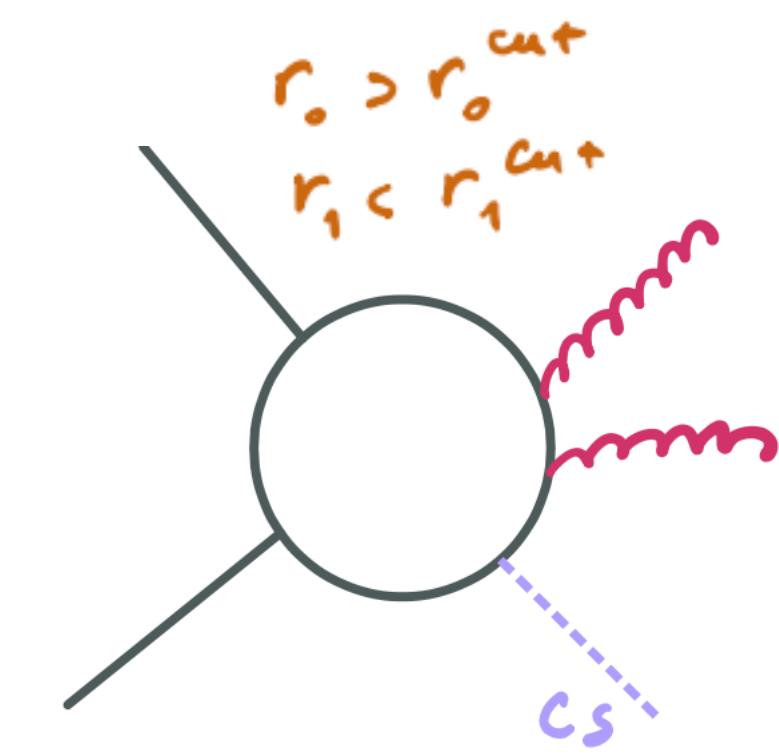
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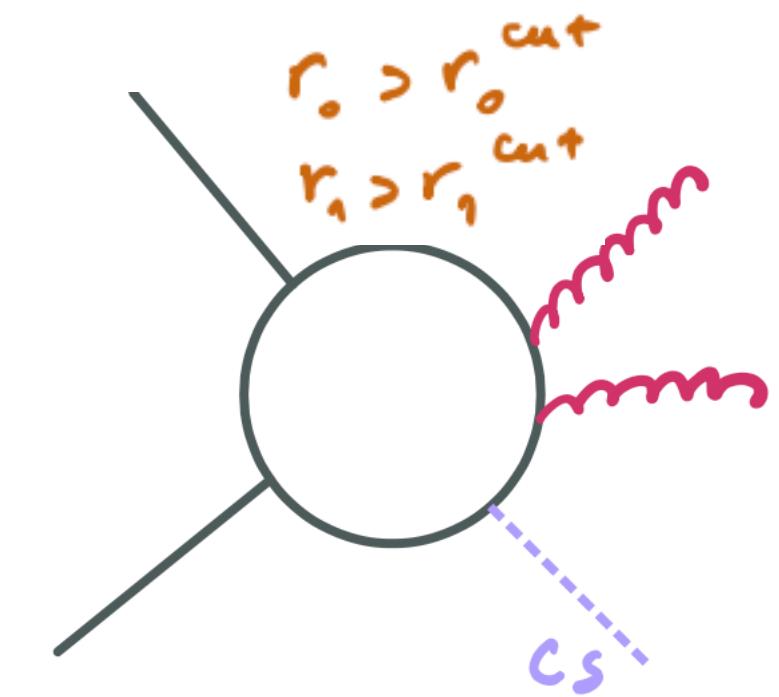
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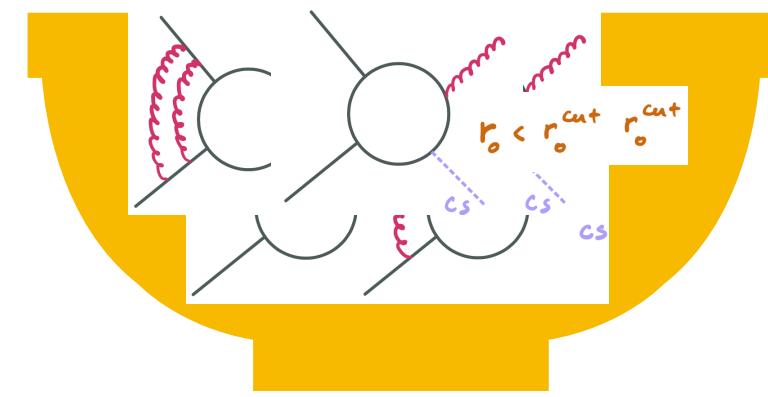
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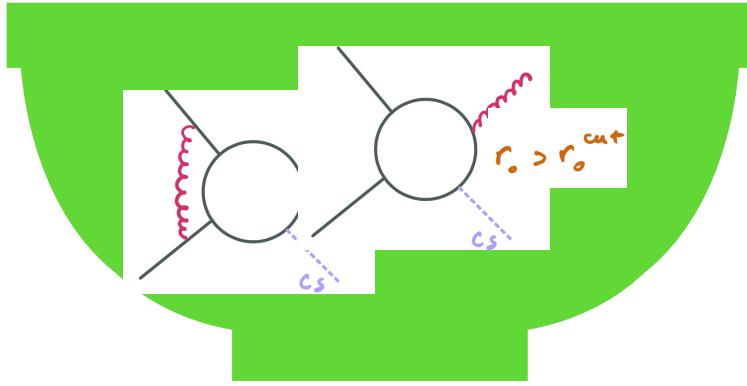
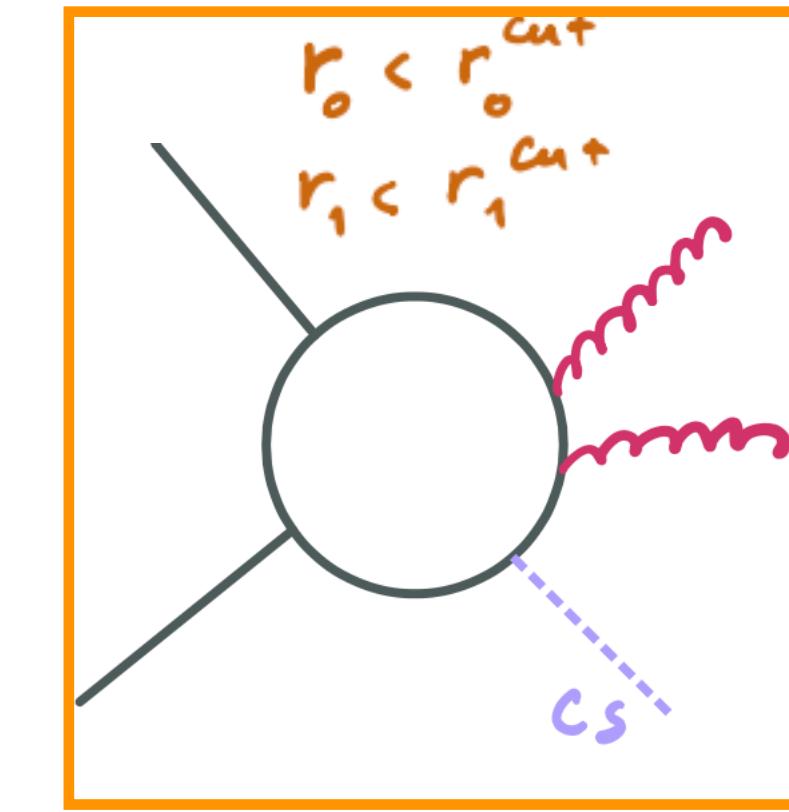
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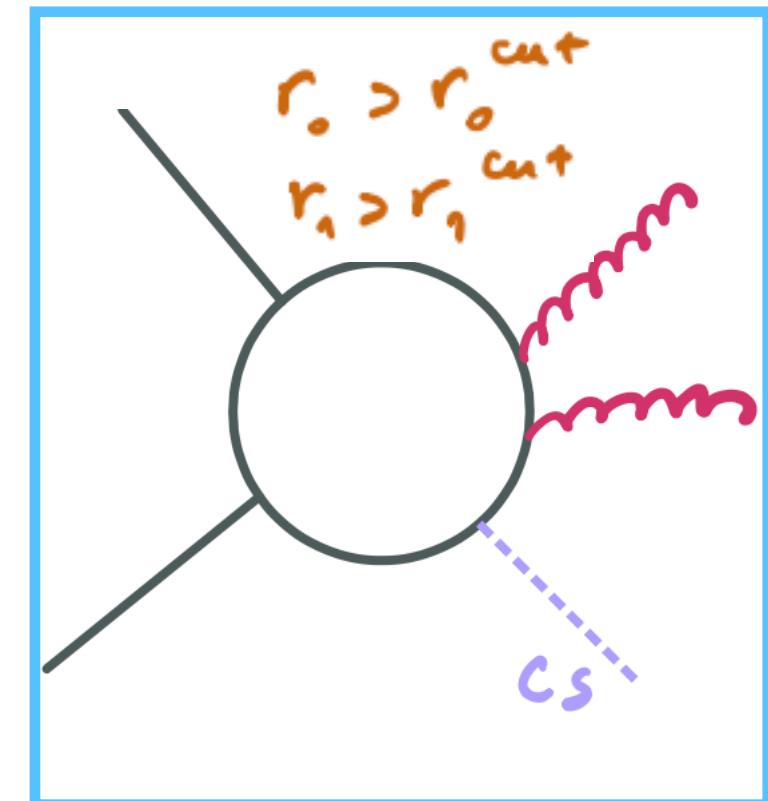
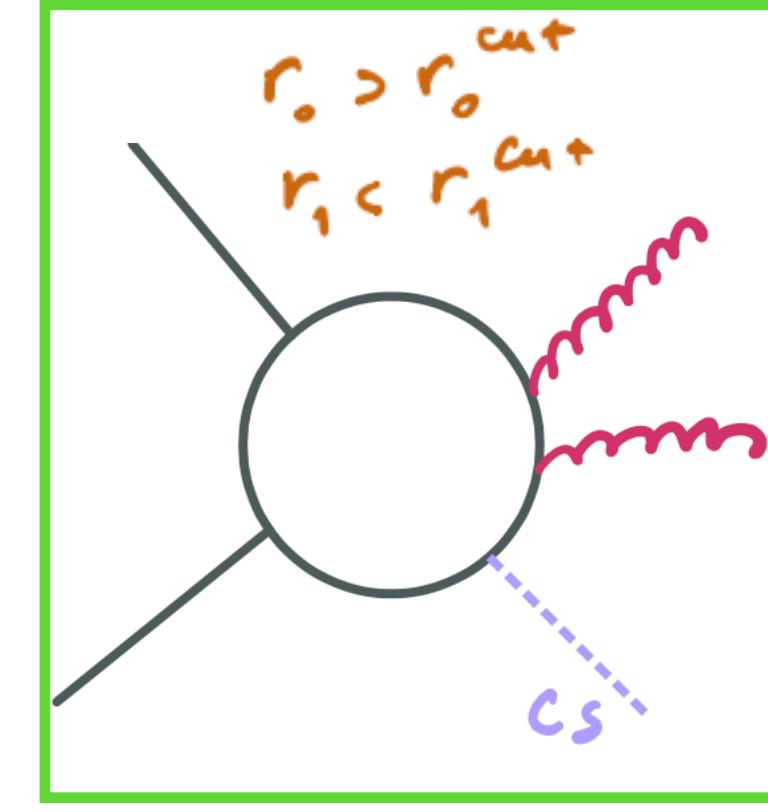
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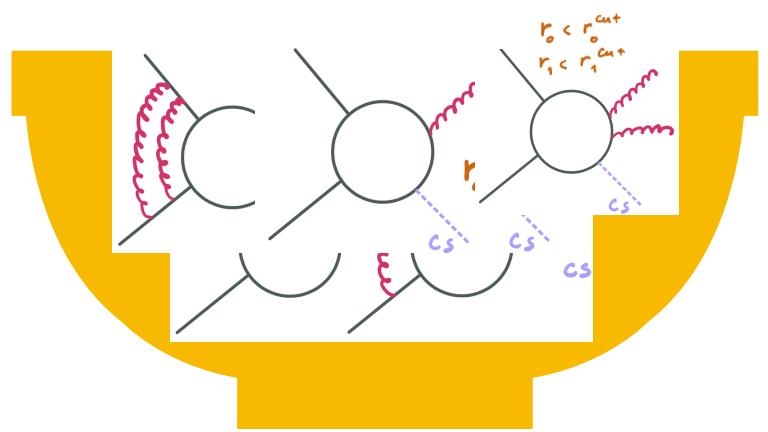
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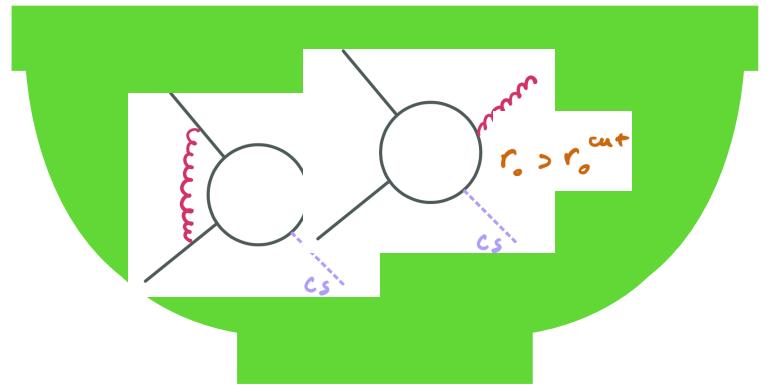
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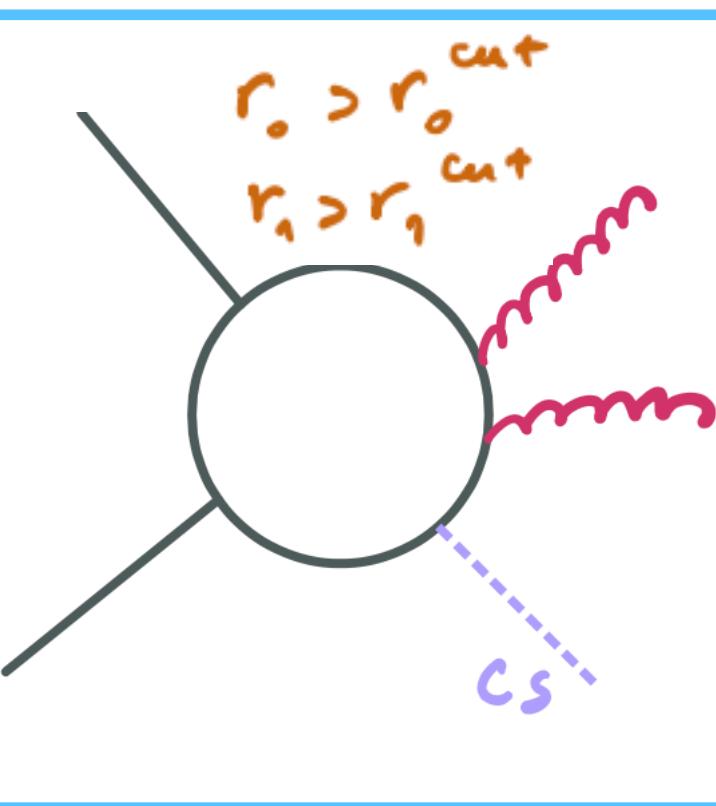
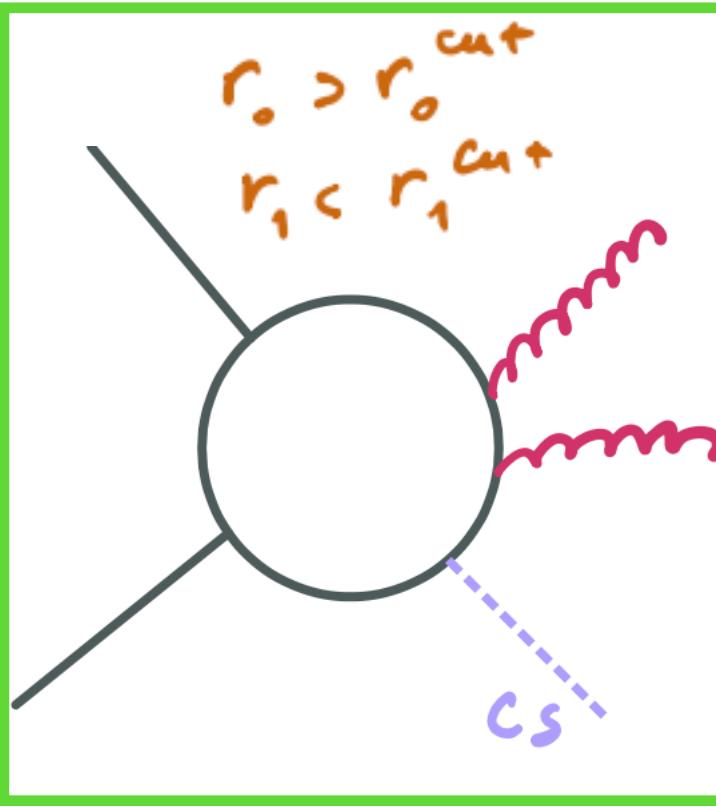
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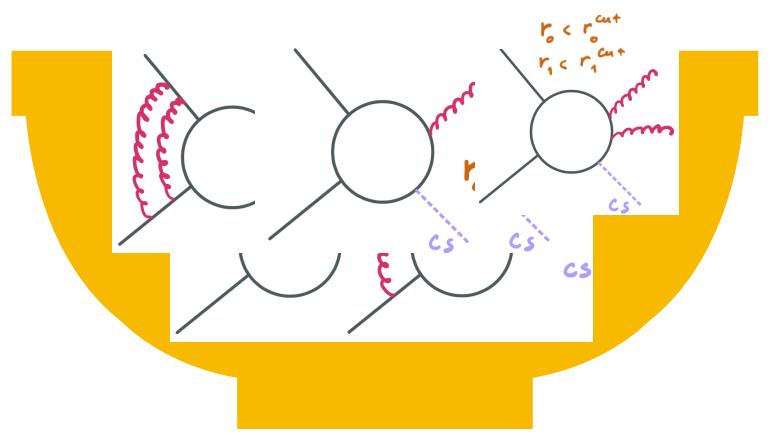
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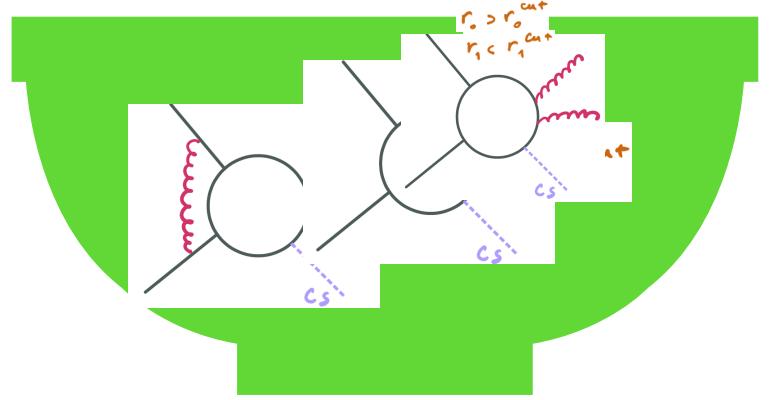
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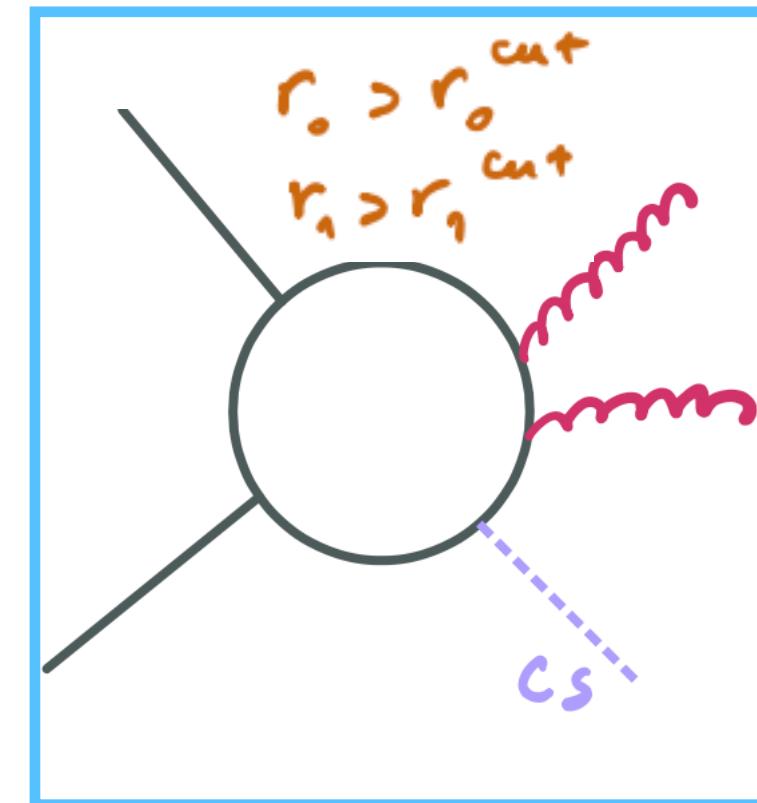
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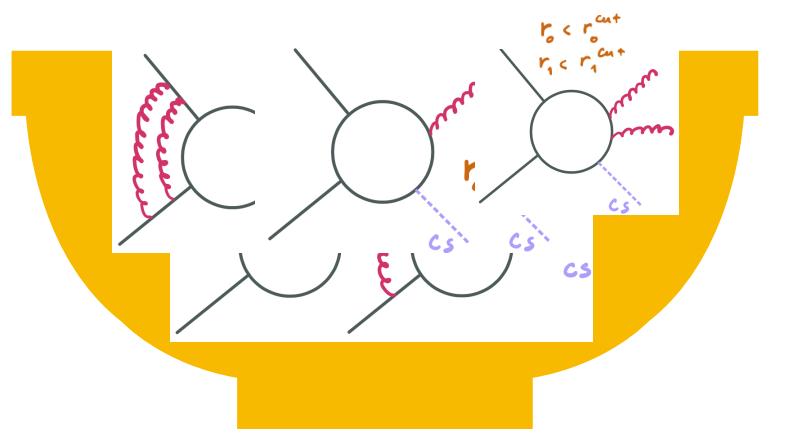
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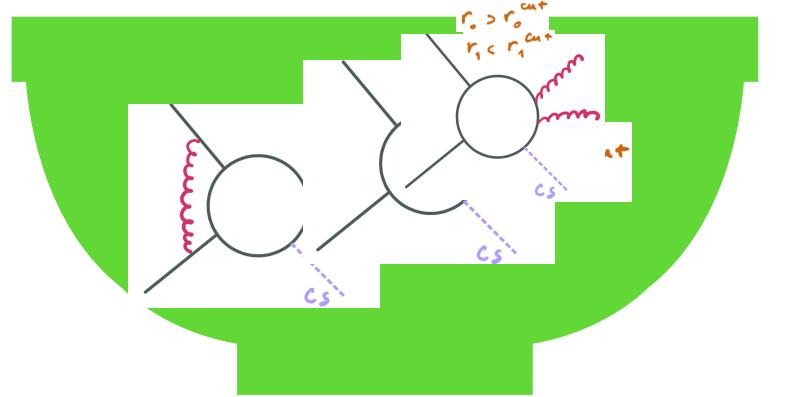
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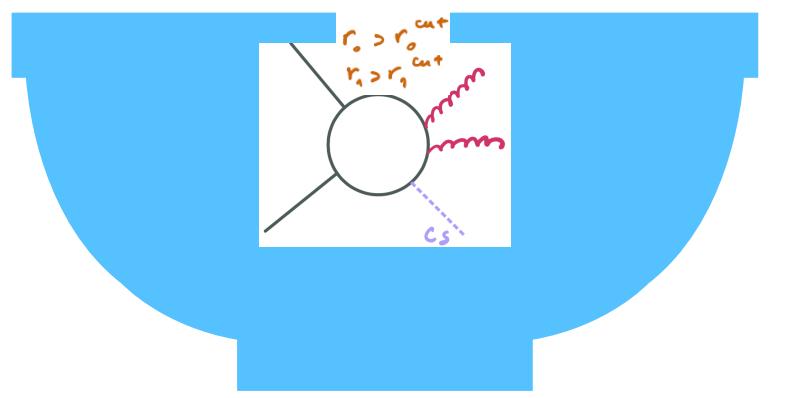
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Φ_0 Event

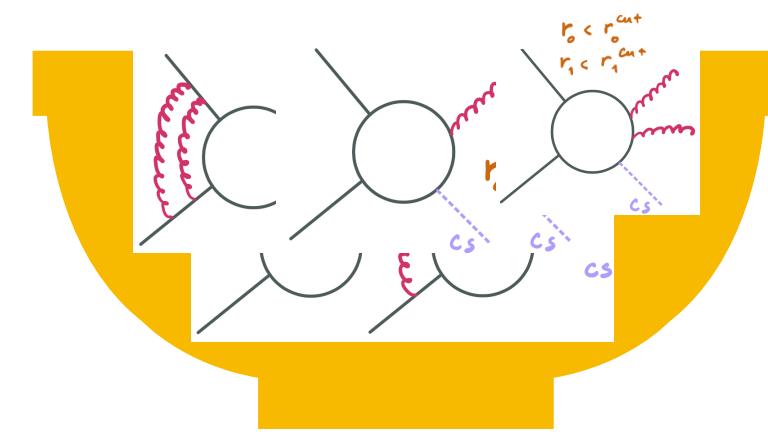


Φ_1 Event



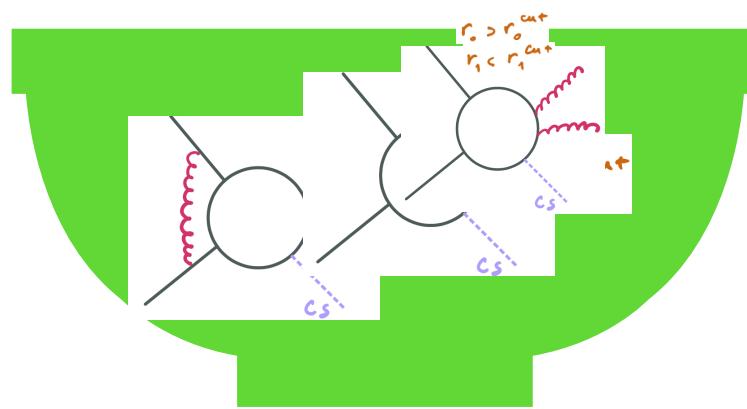
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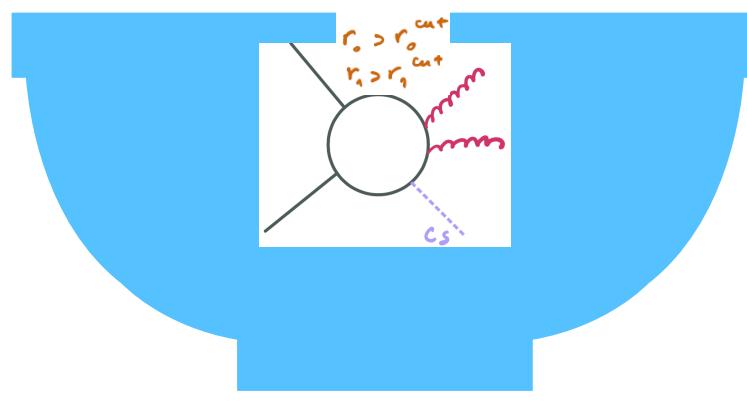
Φ_0 Event

- Effectively replacing IR div with logs of res var!
- Phase spaces are based on projections

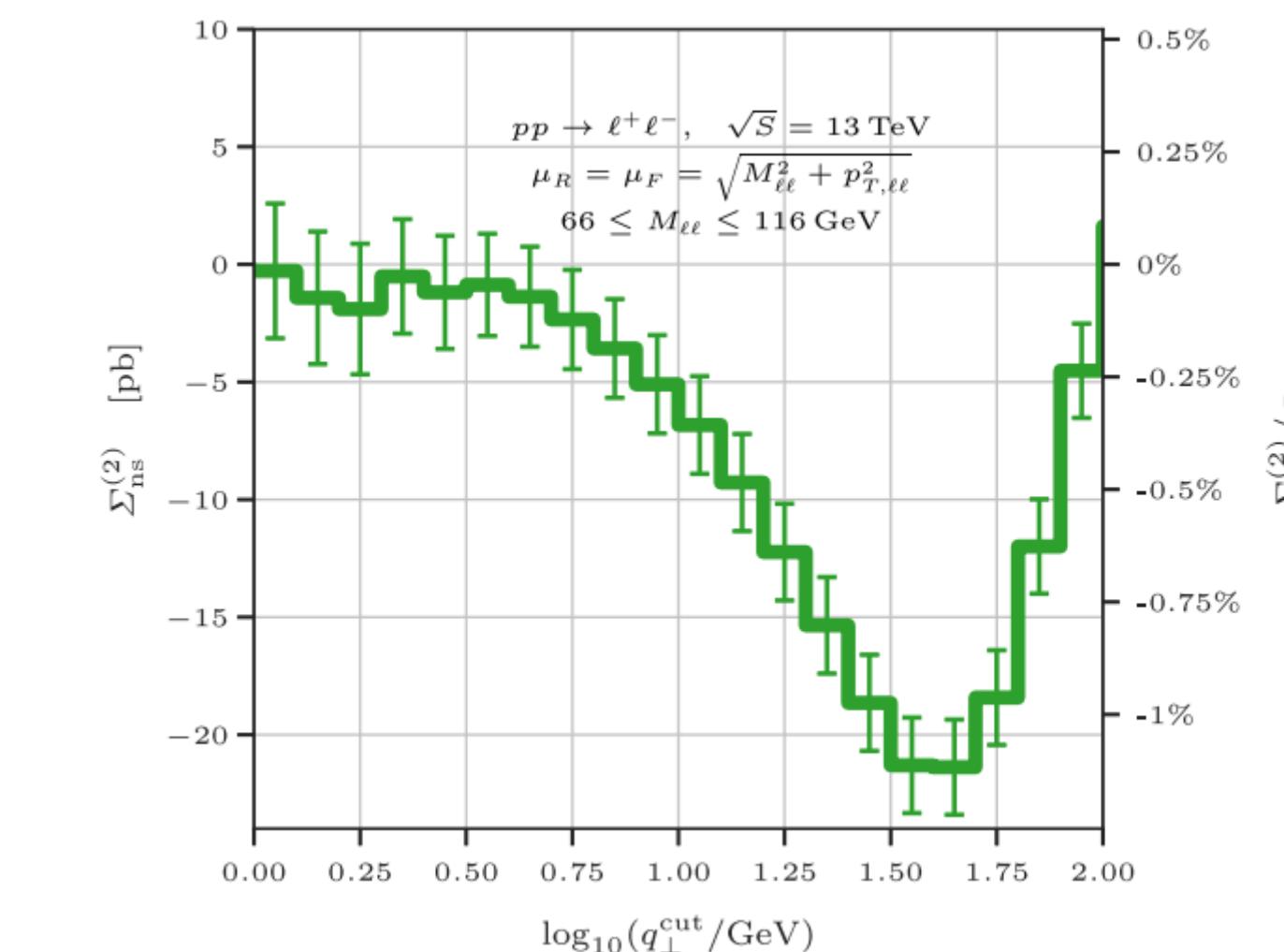


Φ_1 Event

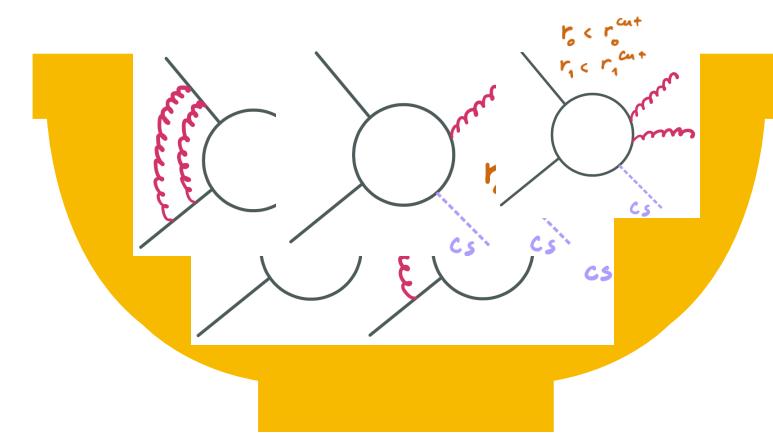
- => Need to lower cut as much as possible



Φ_2 Event

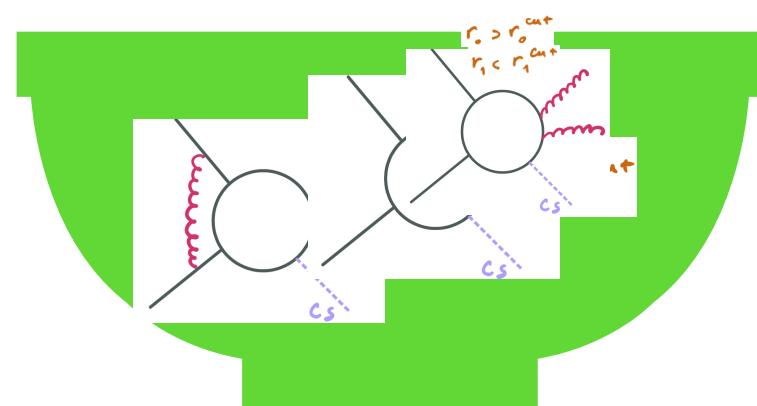


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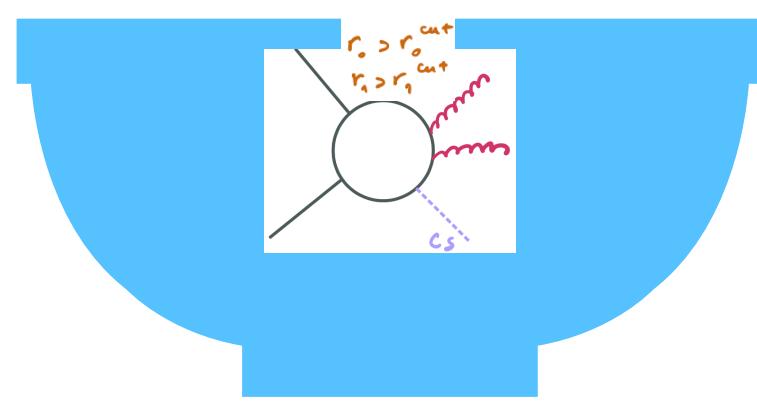
Φ_0 Event

- => Resummation to tame large logs from sep



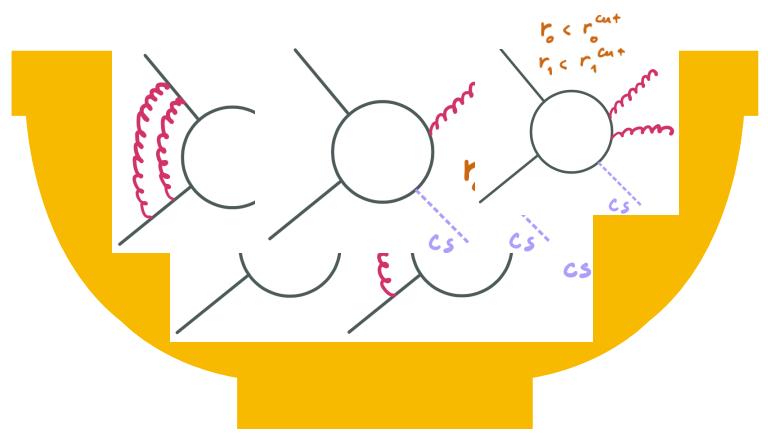
Φ_1 Event

$$\bullet \frac{d\sigma}{d\Phi dr} = \frac{d\sigma^{\text{NNLL}'}}{d\Phi dr} - \frac{d\sigma^{\text{resExp}}}{d\Phi dr} + \frac{d\sigma^{\text{FO}}}{d\Phi dr}$$



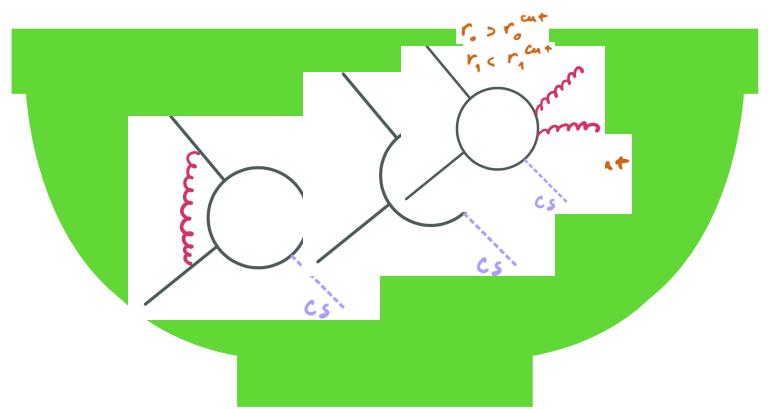
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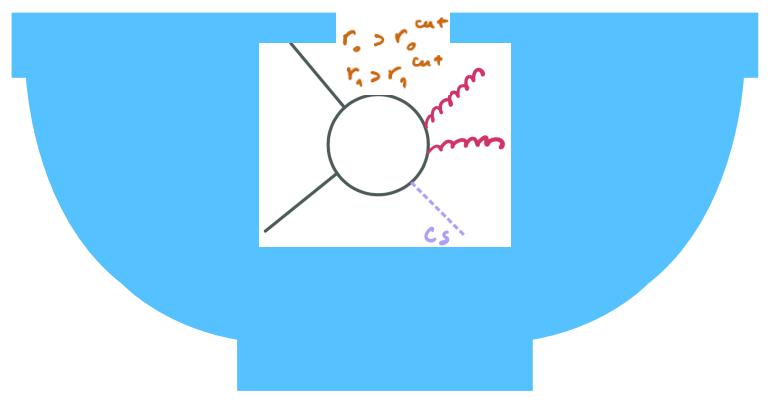
Φ_0 Event

- => Resummation to tame large logs from sep



Φ_1 Event

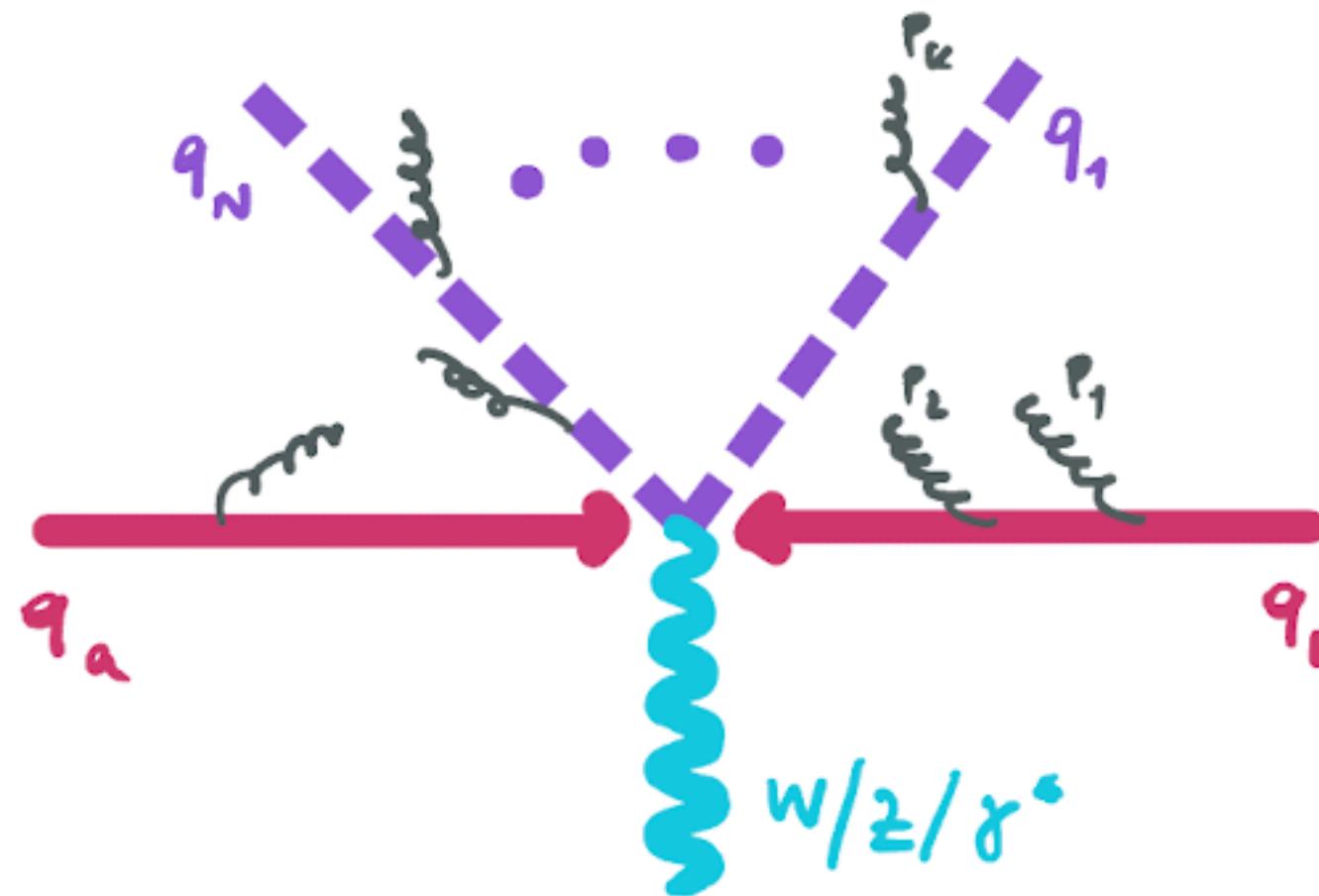
- We spread the effect of resummation and matching terms through unitarised splitting functions (more in Giulia's talk).



Φ_2 Event

N-Jettiness

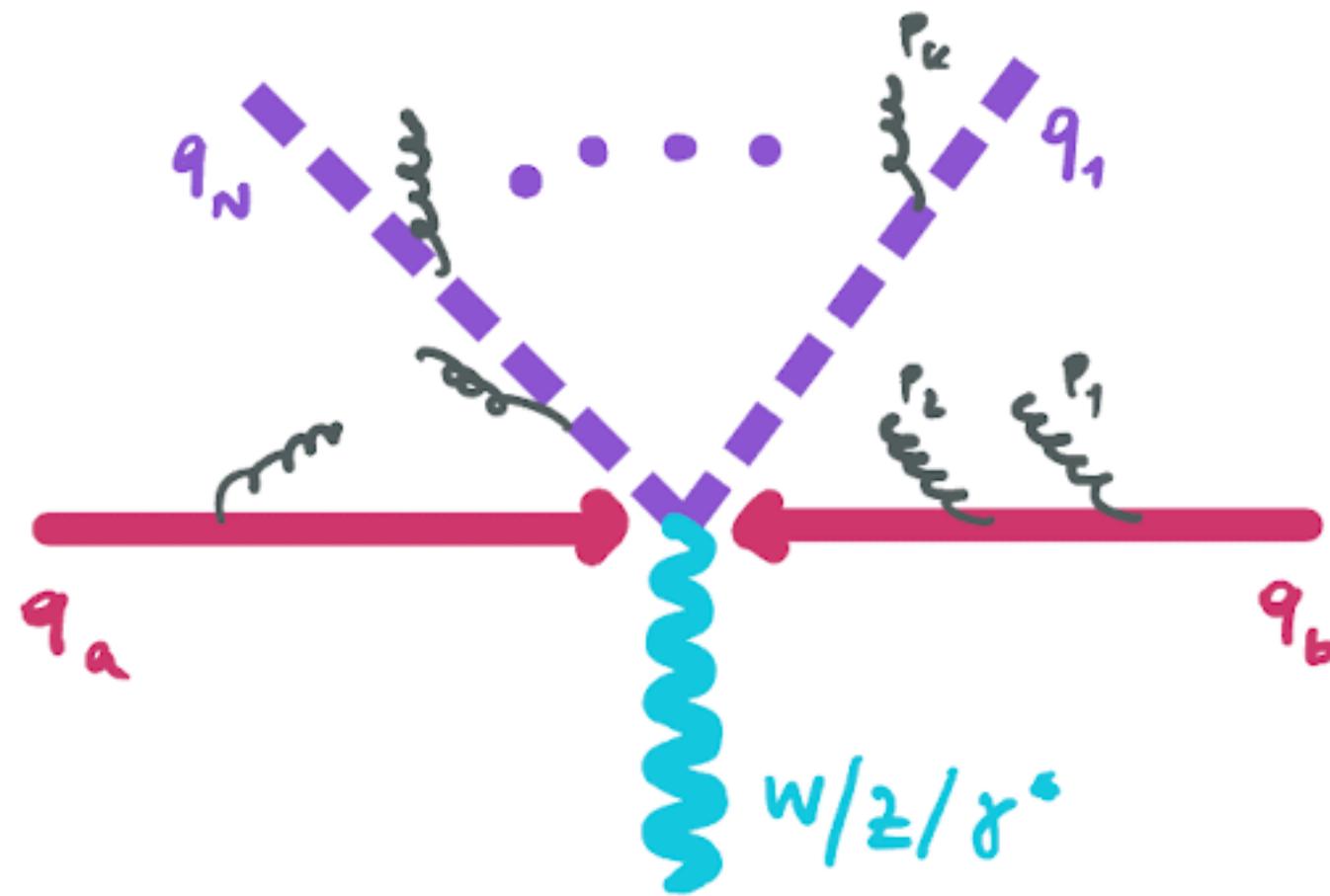
- Historically only variable used in GENEVA (now also pT)
- Geometric measure to tell how N-Jett like an event is:



$$\tau_N = \sum_{k=1} \min \left(2 p_k \cdot \hat{q}_a, 2 p_k \cdot \hat{q}_b, 2 p_k \cdot \hat{q}_1, \dots, 2 p_k \cdot \hat{q}_N \right)$$

N-Jettiness

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- Resummation \mathcal{T}_0 known up to NNLL', and we need NNLL' to get δ terms correctly

\mathcal{T}_1 Resummation

- Separation between 1 and 2 jets is done with 1-jettiness: Need also resummation (NLL)

$$\frac{d\sigma^{\text{NLL}}}{d\Phi_1 \, d\mathcal{T}_1} \propto \sum_{\kappa} H_{\kappa}^{(0)}(\Phi_1, \mu_H) f_{\kappa_a}(x_a, \mu_B) f_{\kappa_b}(x_b, \mu_B) \\ \exp \left\{ \mathcal{F}_{\kappa} \left(\dots, C_{\kappa_a} \ln \left(\frac{Q_a^2 u}{st} \right), C_{\kappa_b} \ln \left(\frac{Q_b^2 t}{su} \right), C_{\kappa_J} \ln \left(\frac{Q_J^2 s}{tu} \right), \dots \right) \right\}$$

\mathcal{T}_1 Resummation

$$\frac{d\sigma^{\text{NLL}}}{d\Phi_1 \, d\mathcal{T}_1} \propto \sum_{\kappa} H_{\kappa}^{(0)}(\Phi_1, \mu_H) f_{\kappa_a}(x_a, \mu_B) f_{\kappa_b}(x_b, \mu_B) \exp \left\{ \mathcal{F}_{\kappa} \left(\dots, C_{\kappa_a} \ln \left(\frac{Q_a^2 u}{st} \right), C_{\kappa_b} \ln \left(\frac{Q_b^2 t}{su} \right), C_{\kappa_J} \ln \left(\frac{Q_J^2 s}{tu} \right), \dots \right) \right\}$$

- Hard function (flavour dependent, κ)

\mathcal{T}_1 Resummation

$$\frac{d\sigma^{\text{NLL}}}{d\Phi_1 \, d\mathcal{T}_1} \propto \sum_{\kappa} H_{\kappa}^{(0)}(\Phi_1, \mu_H) f_{\kappa_a}(x_a, \mu_B) f_{\kappa_b}(x_b, \mu_B) \exp \left\{ \mathcal{F}_{\kappa} \left(\dots, C_{\kappa_a} \ln \left(\frac{Q_a^2 u}{st} \right), C_{\kappa_b} \ln \left(\frac{Q_b^2 t}{su} \right), C_{\kappa_J} \ln \left(\frac{Q_J^2 s}{tu} \right), \dots \right) \right\}$$

• Hard function (flavour dependent, κ)

• Beam Functions

\mathcal{T}_1 Resummation

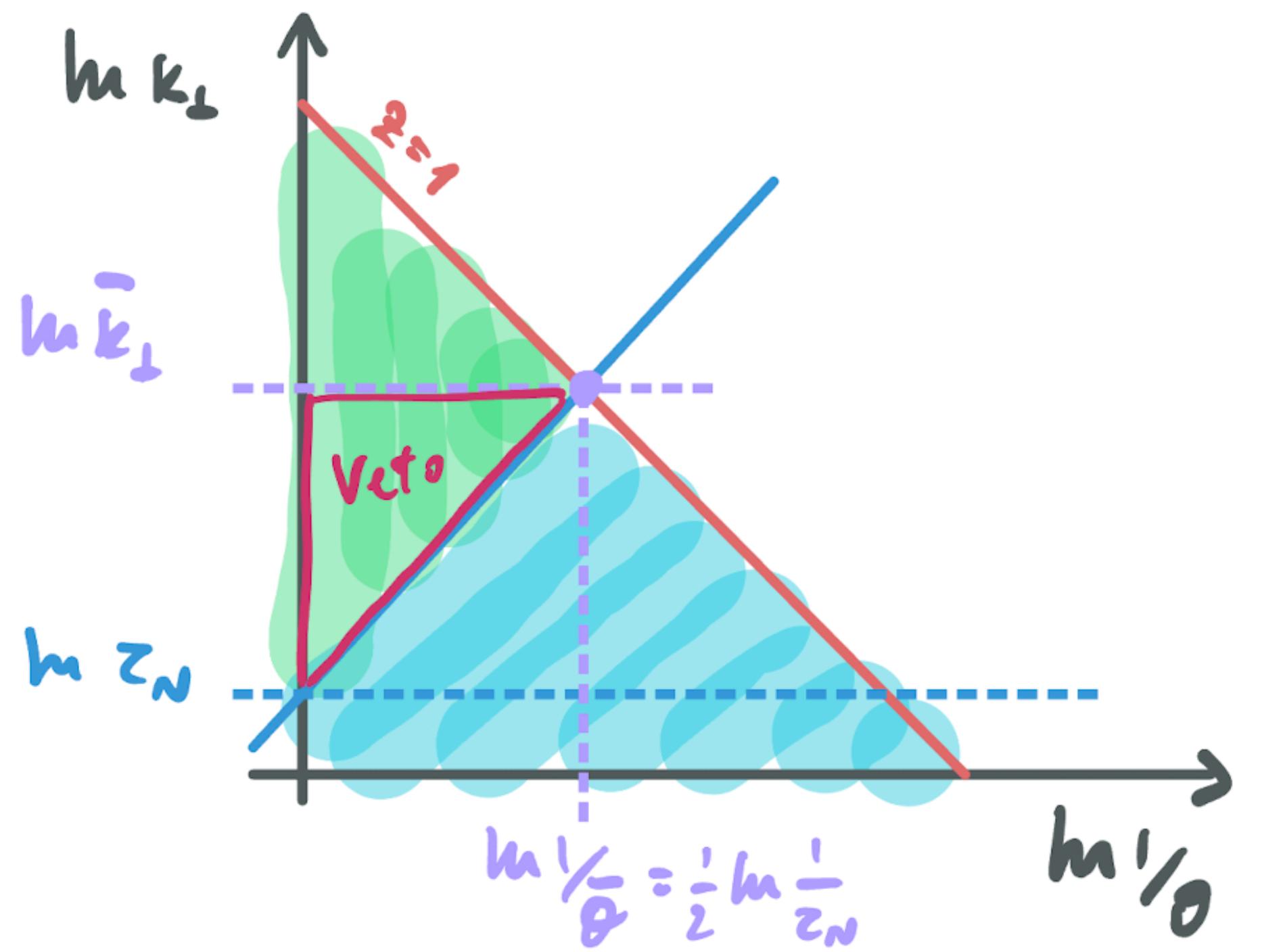
$$\frac{d\sigma^{\text{NLL}}}{d\Phi_1 d\mathcal{T}_1} \propto \sum_{\kappa} H_{\kappa}^{(0)}(\Phi_1, \mu_H) f_{\kappa_a}(x_a, \mu_B) f_{\kappa_b}(x_b, \mu_B) \exp \left\{ \mathcal{F}_{\kappa} \left(\dots, C_{\kappa_a} \ln \left(\frac{Q_a^2 u}{st} \right), C_{\kappa_b} \ln \left(\frac{Q_b^2 t}{su} \right), C_{\kappa_j} \ln \left(\frac{Q_j^2 s}{tu} \right), \dots \right) \right\}$$

• Hard function (flavour dependent, κ)

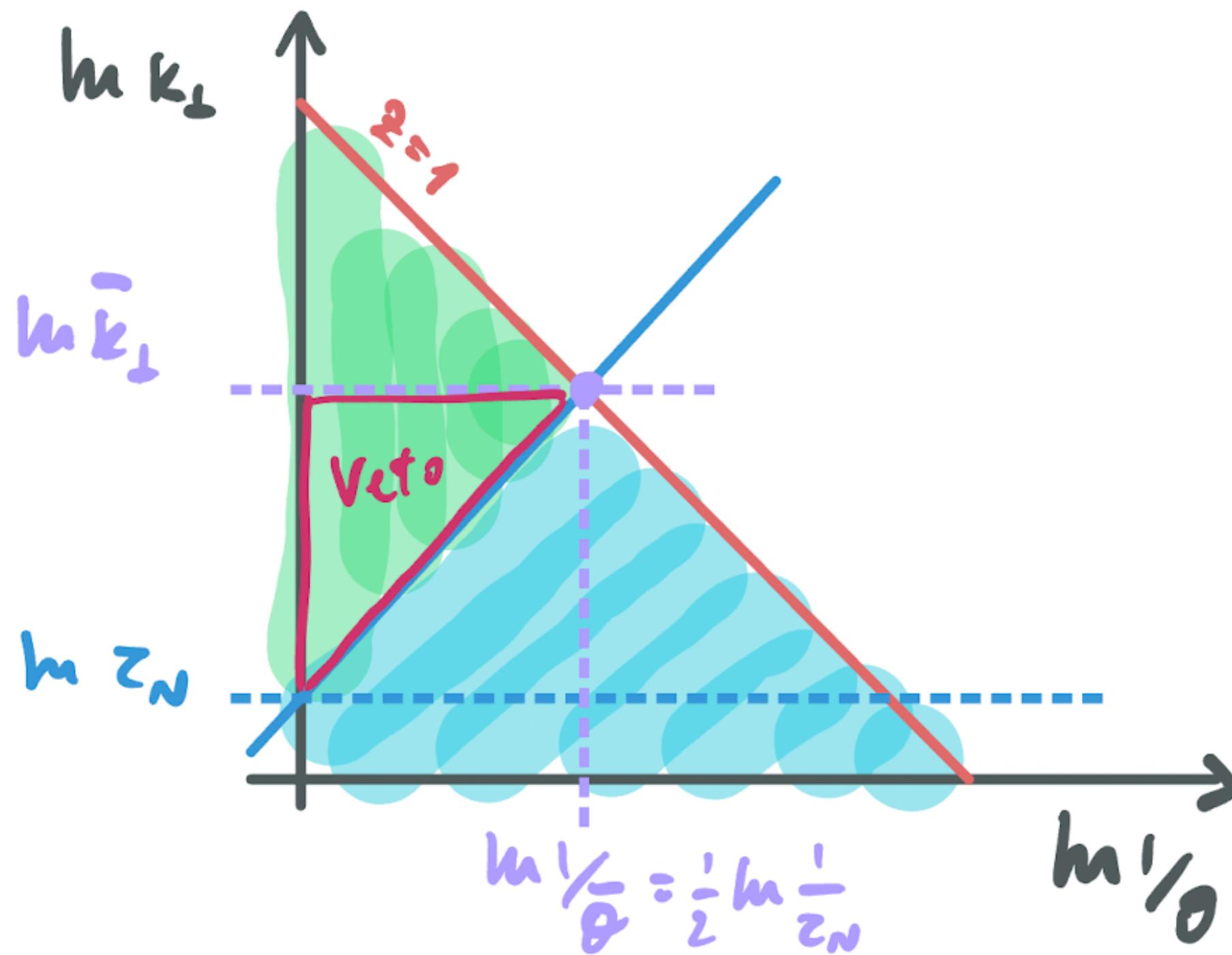
• Beam Functions

• Soft function: Flavour and kinematic dependent terms (Q_i)

Shower Matching

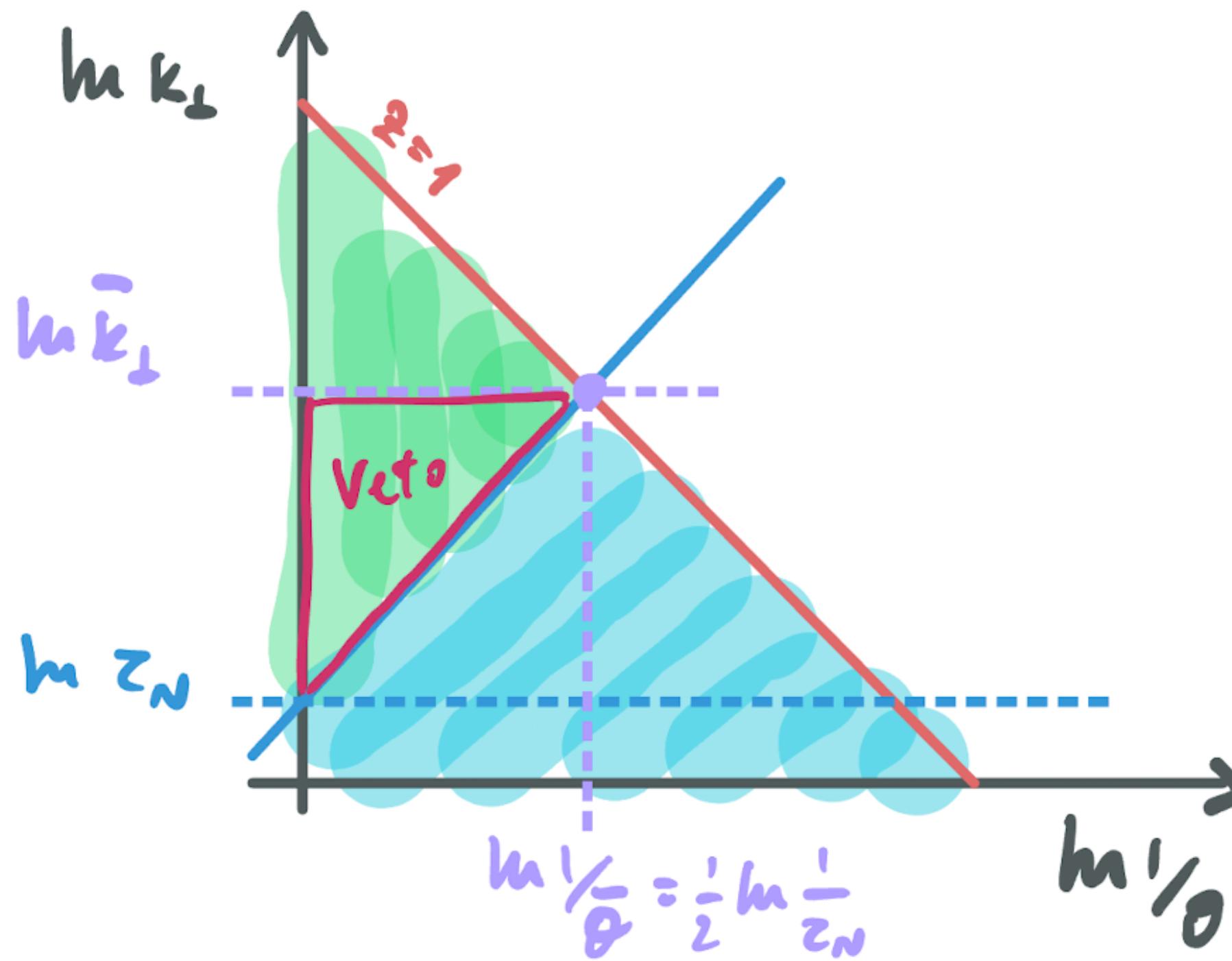


Shower Matching



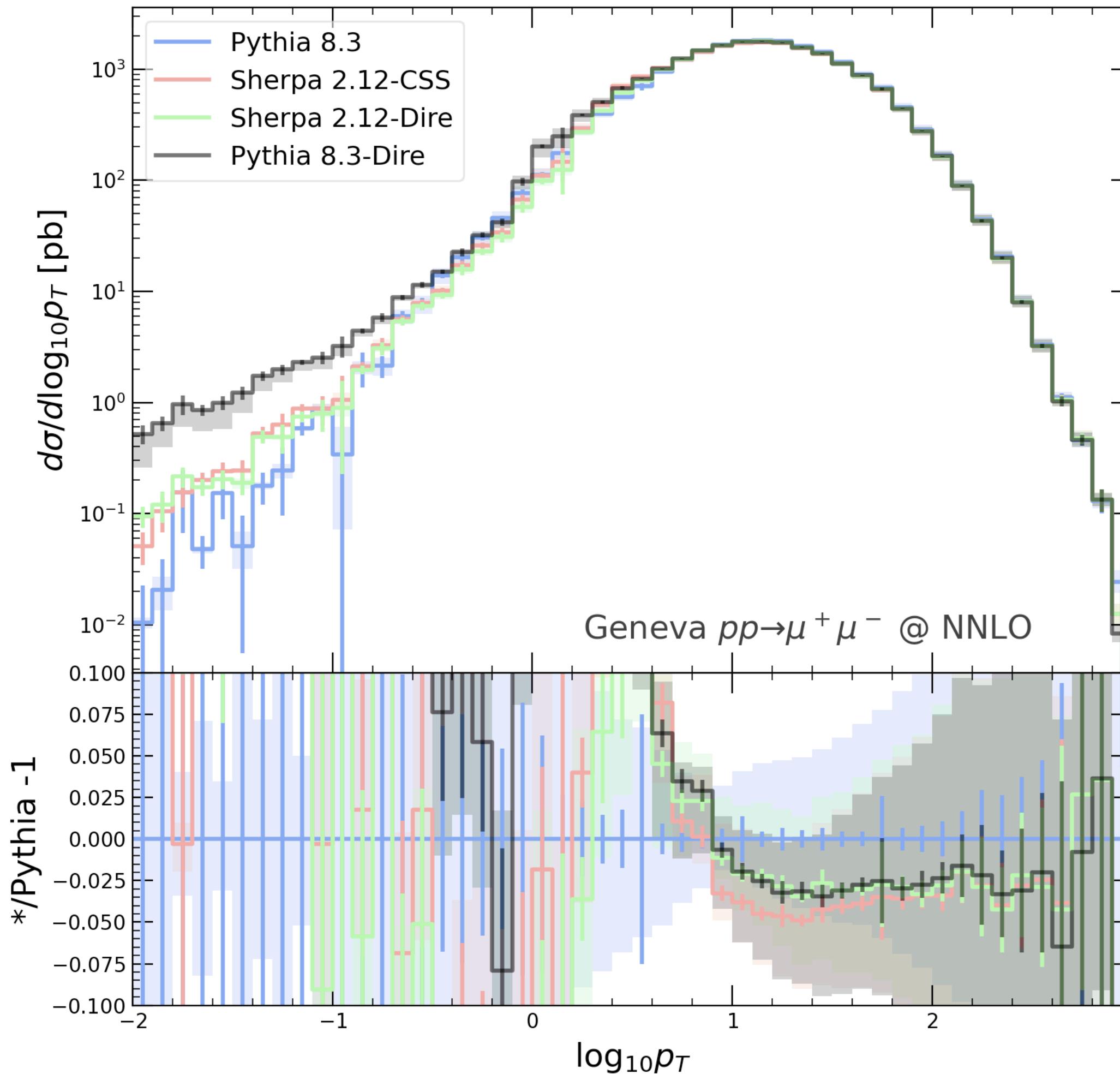
- With N partons and 1 emission we can use $\mathcal{T}_N(\Phi_N + 1)$ to measure its hardness
- Select largest corresponding k_{\perp} from the res scale
- Let the shower go!

Shower Matching



- With N partons and 1 emission we can use $\mathcal{T}_N(\Phi_{N+1})$ to measure its hardness
- Select largest corresponding k_\perp from the res scale
- Let the shower go!
- Veto an event if (after M emission)
$$\mathcal{T}_N(\Phi_{N+M}) > \mathcal{T}_N$$

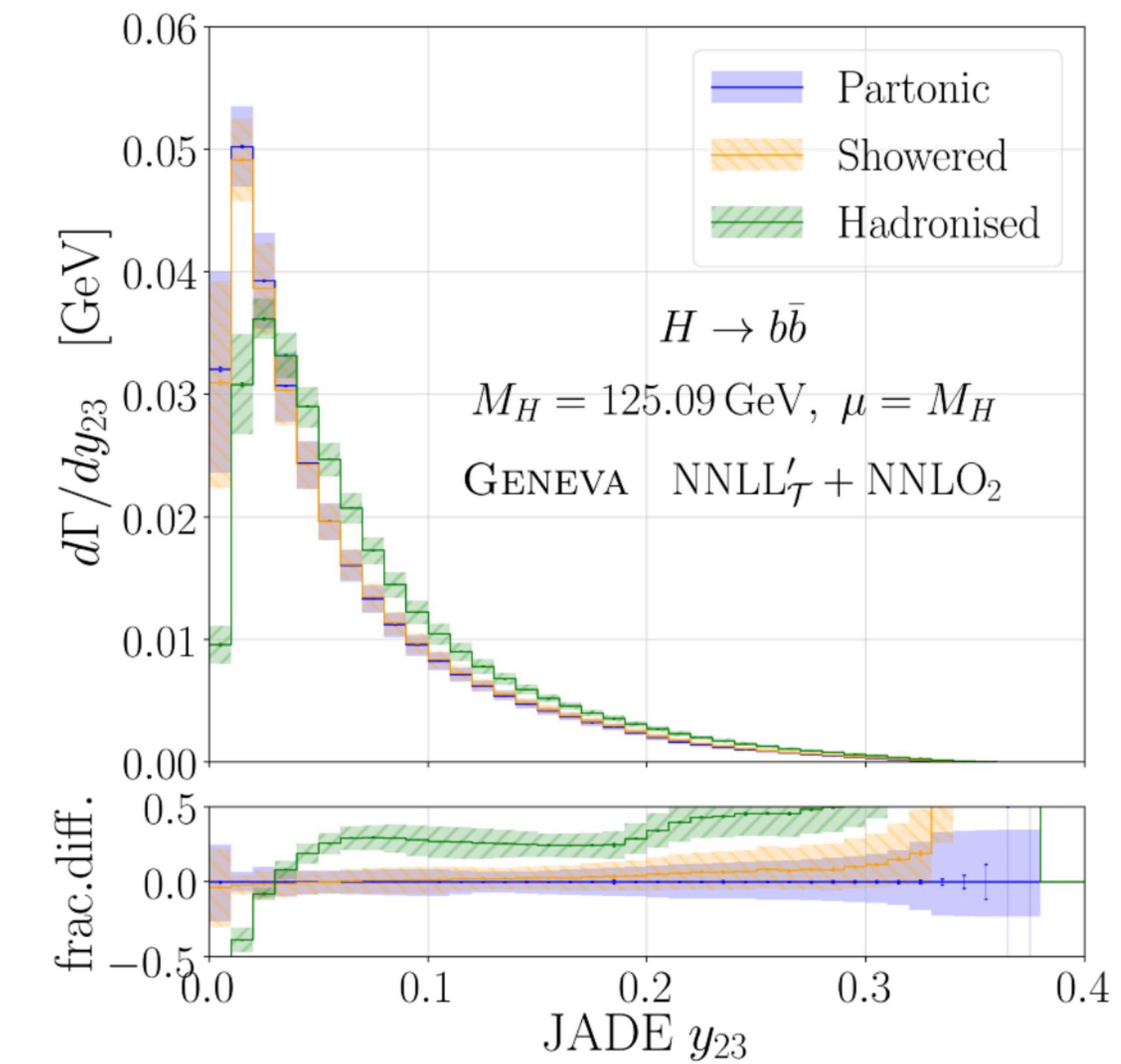
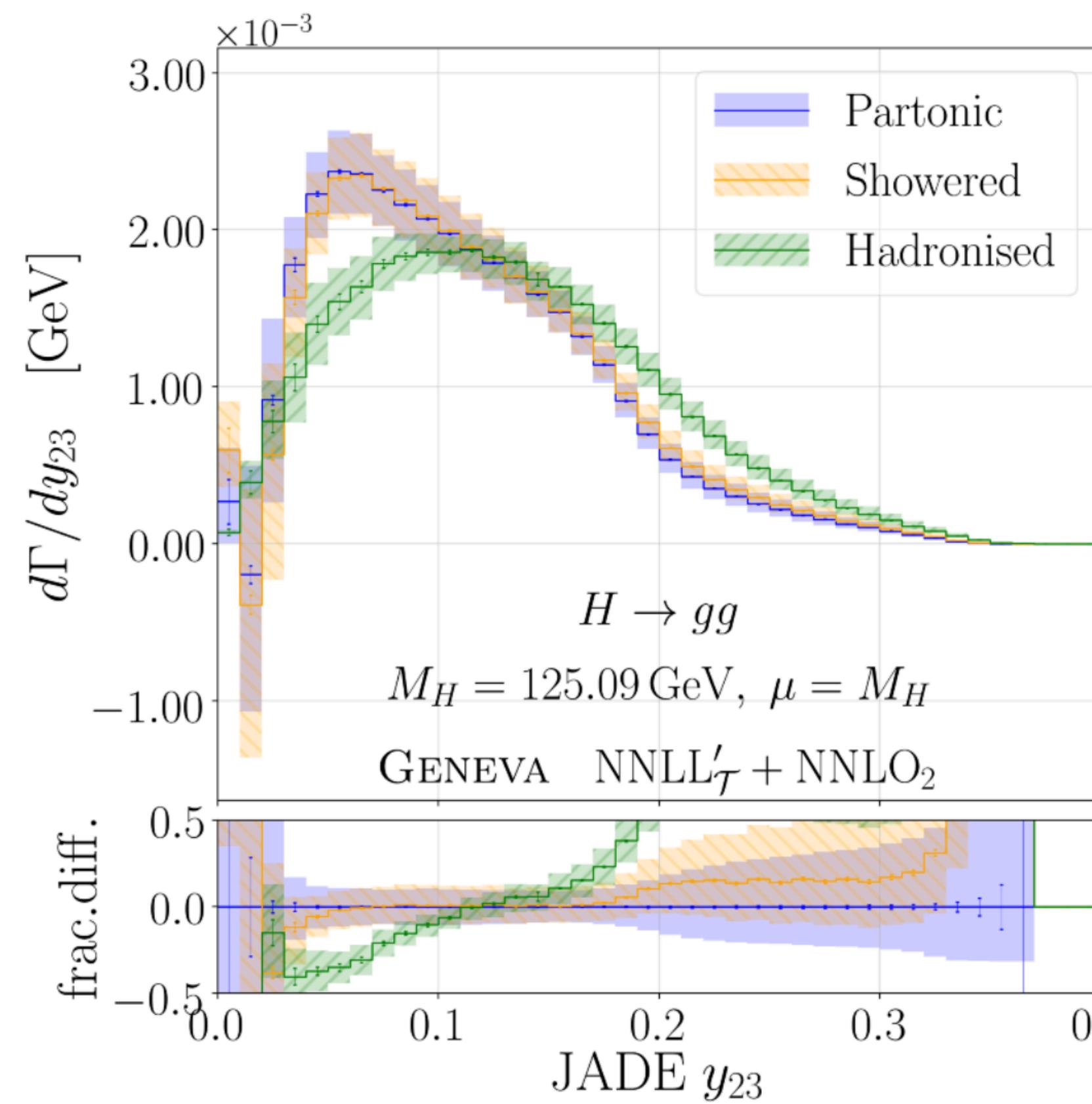
Shower Matching



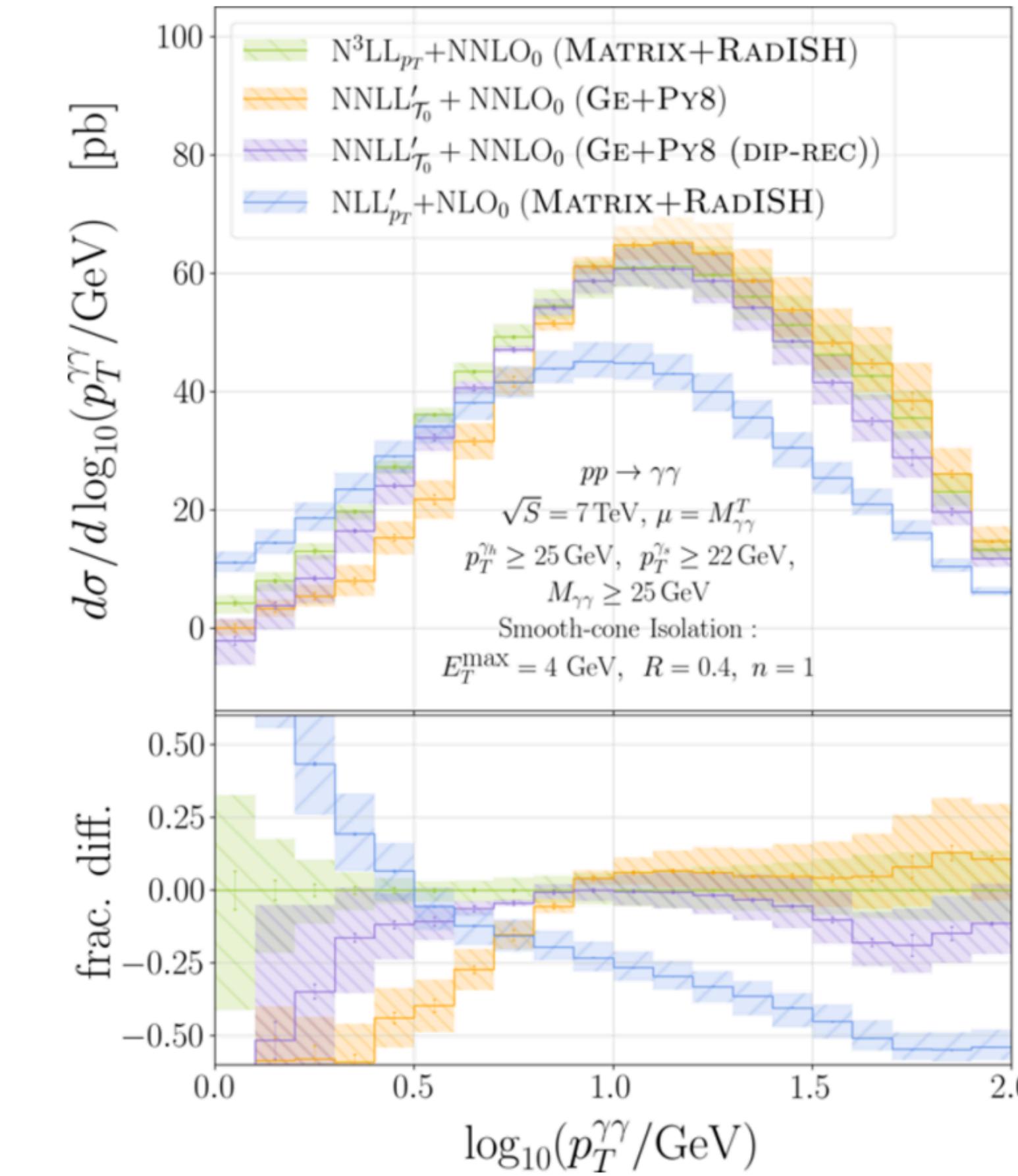
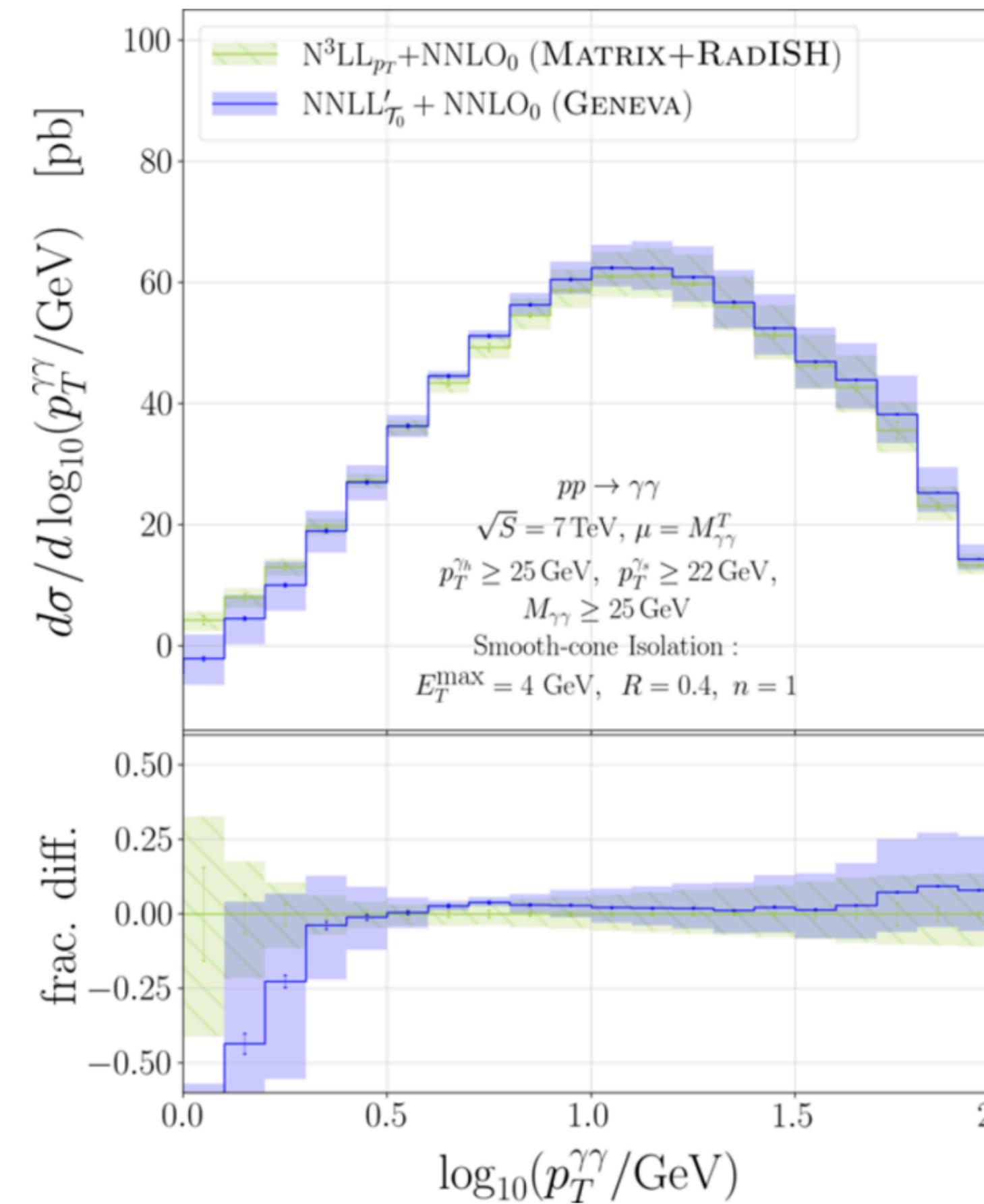
- Updated shower interface!
- Now we have all of Pythia's and Sherpa's PSs!

Recent Applications

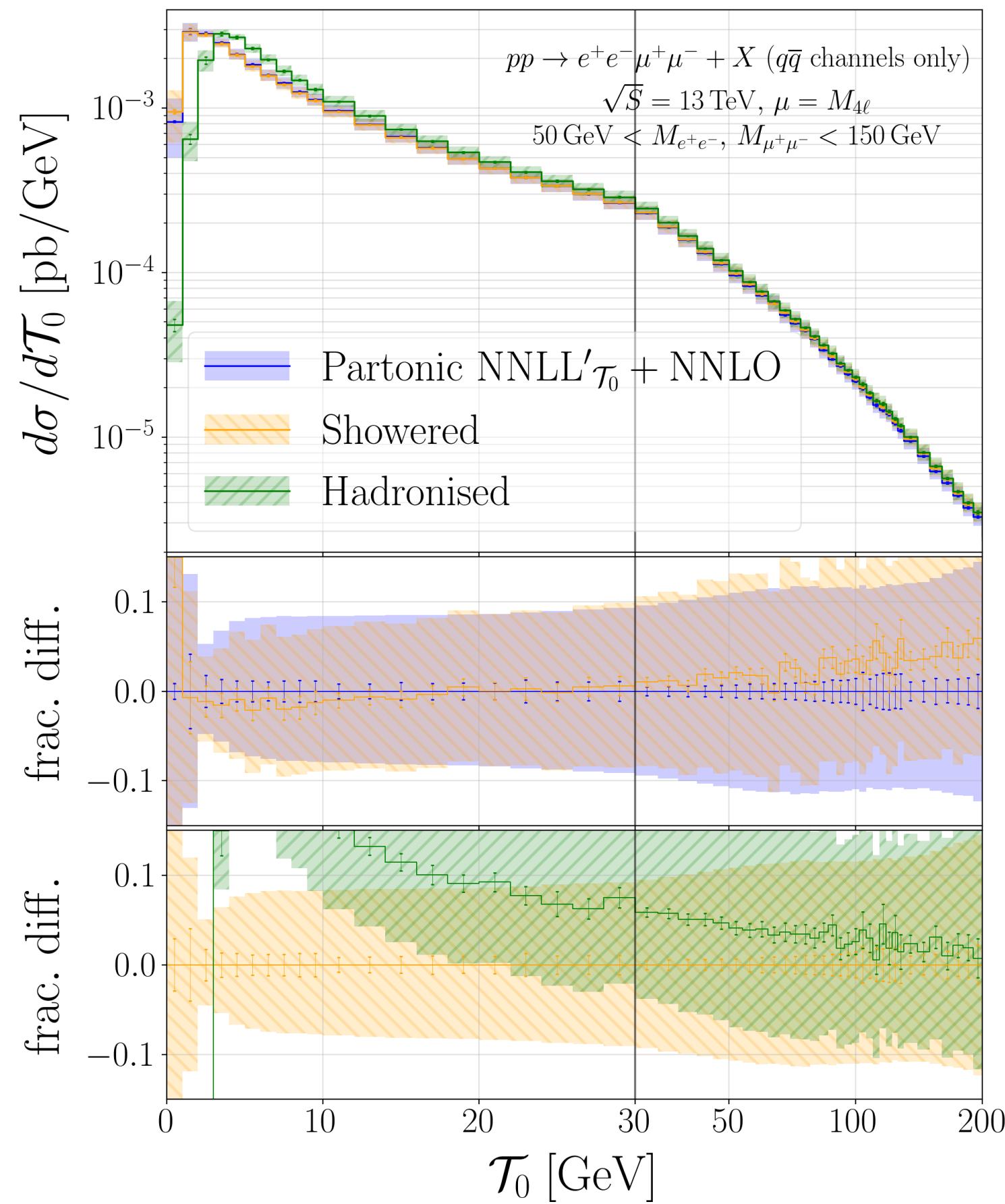
- Lately we have applied all of the above to a variety of CS-related procs!



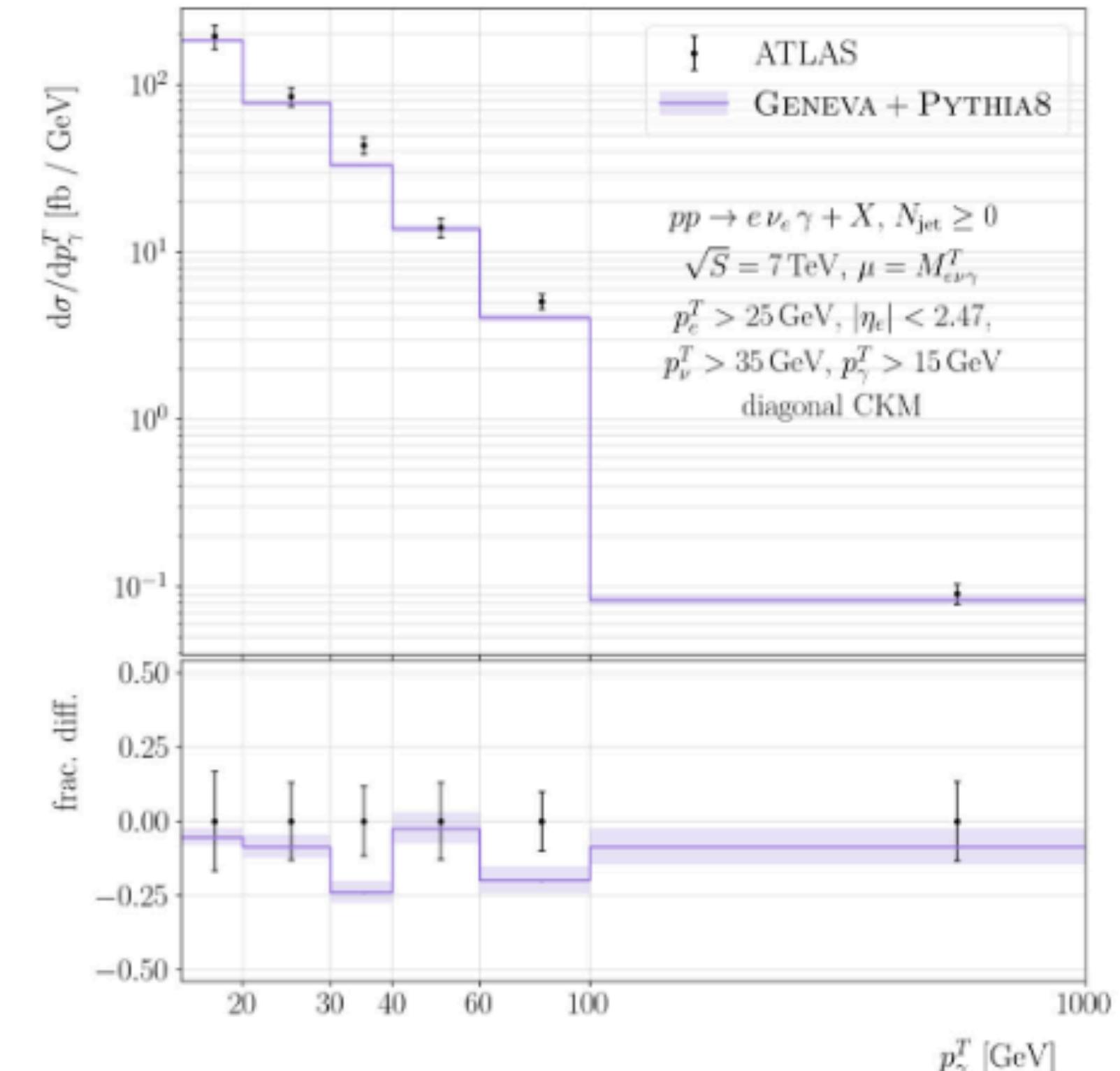
- **H->XX is a necessary ingredient to be able to build a V+XX (Signal) NNLO generator**



- Photon Isolation requires extension of the method (Singularities at Born lev)
- Comparison with higher-order resummation

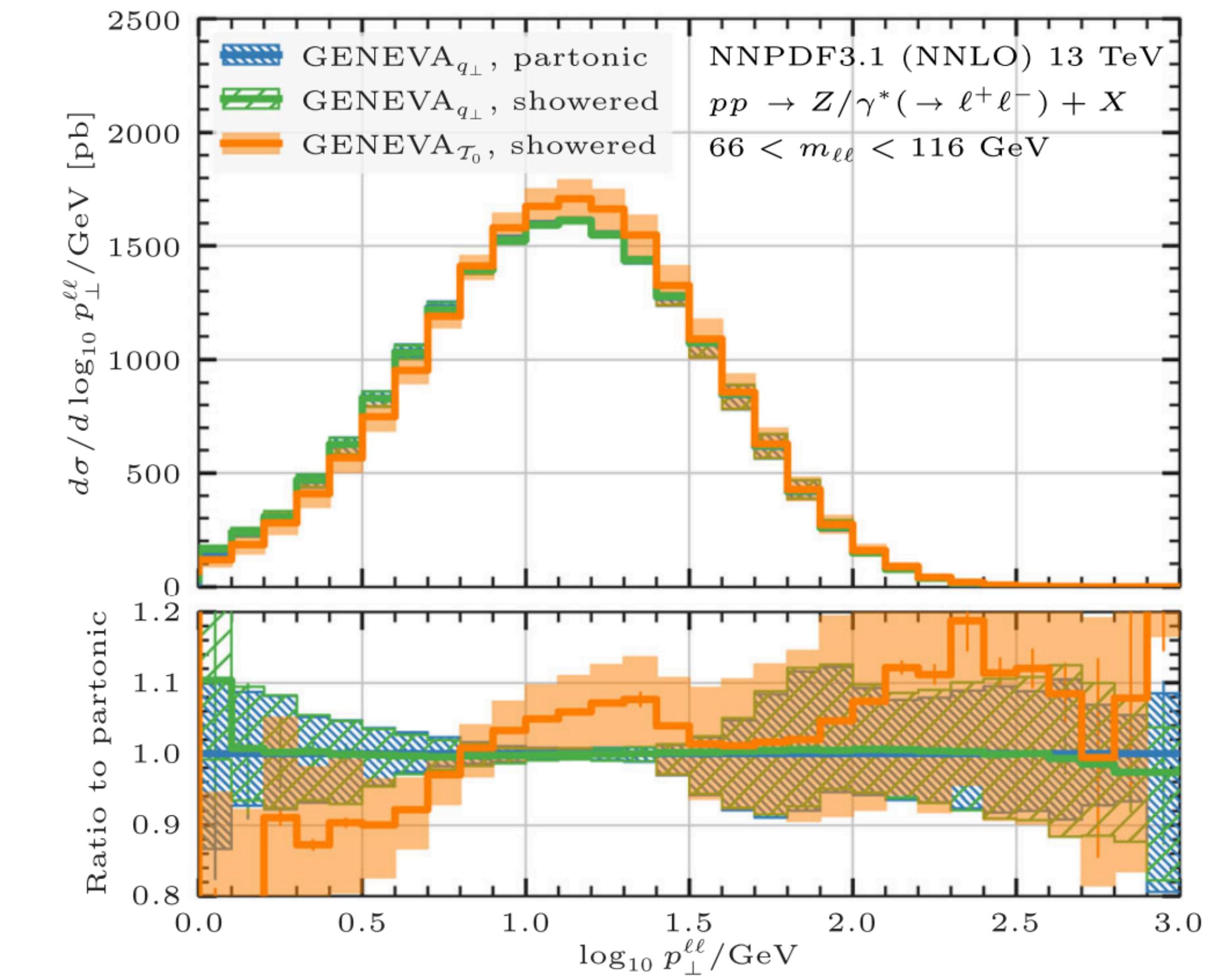
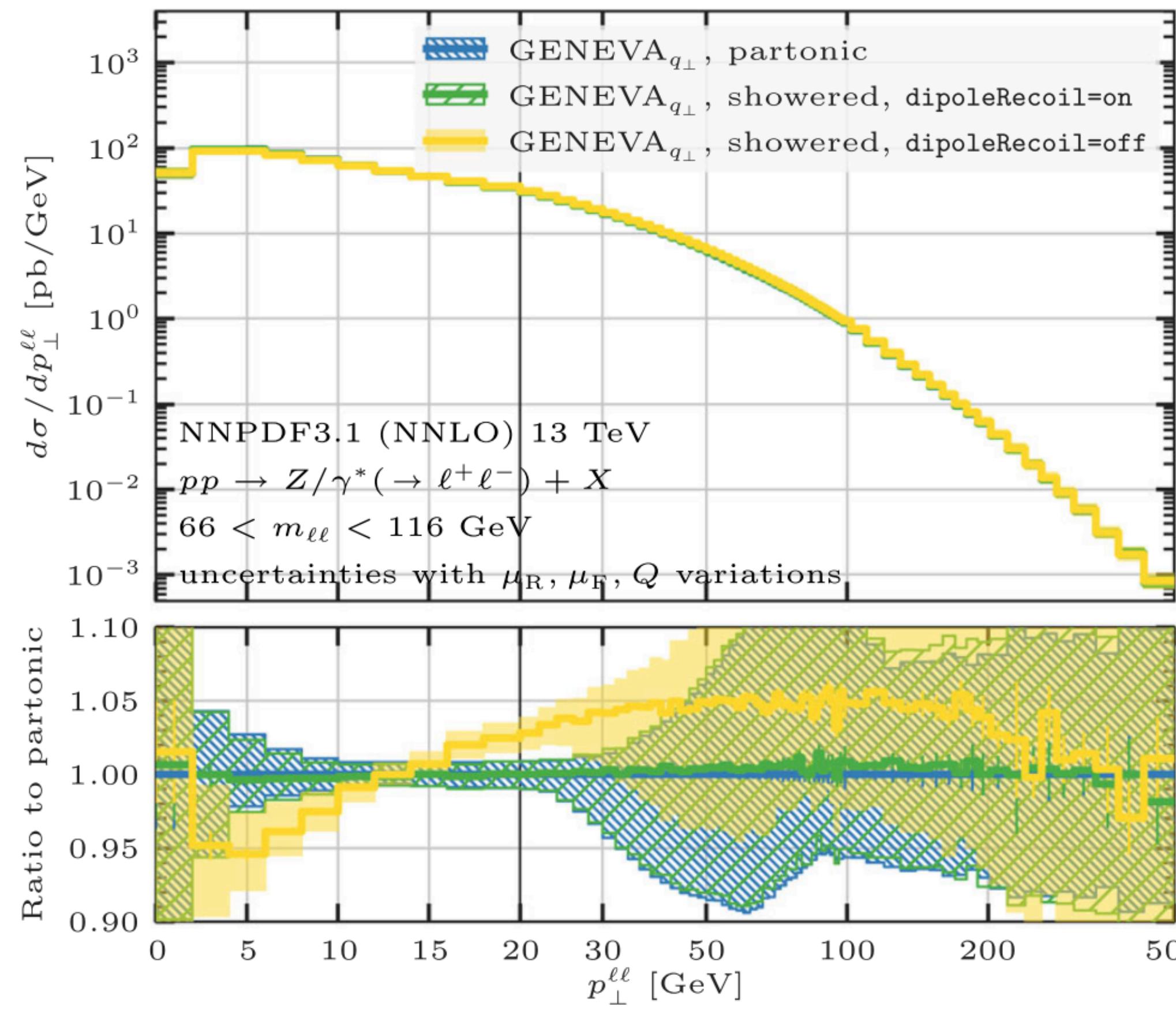


- **Natural extensions from diphoton**
- **Non-trivial correlations in final state**



pT-Resummation

[Phys.Rev.D 104 (2021) 9, 094020]



- First application of different resolution variable, and higher resummation accuracy

Conclusions

- **Although at the minute only CS processes have been successfully addressed:**
- **A variety of them have been studied with different difficulties (see also gg initiated procs in talk by Giulia)**
- **In addition, study of different resolution variables as well as study of effects of matching to different PS generators**