Electroweak corrections in SHERPA

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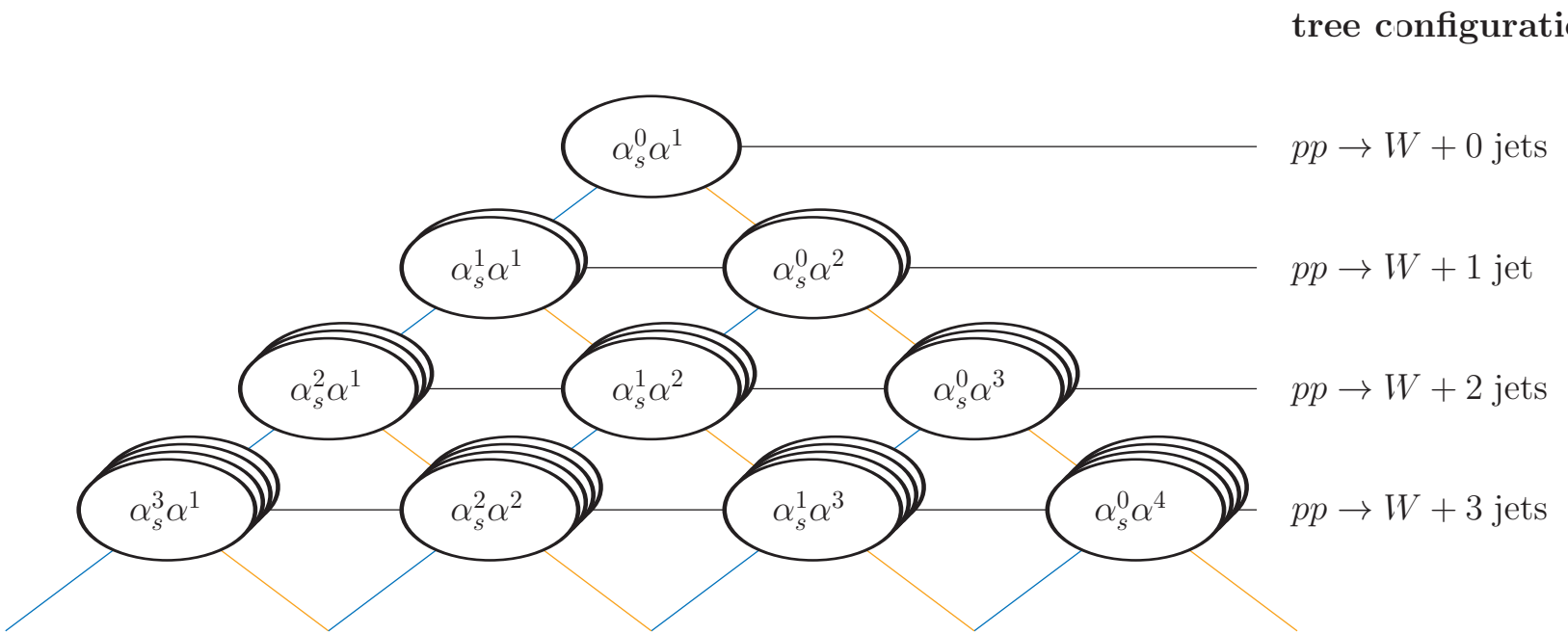
Universität Zürich[UZH]

FNSNF

FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

Process management

- consistent definition of orders and signature to be calculated needed



- if LO $\mathcal{O}(\alpha_S^n\alpha^m)$, then NLO QCD $\mathcal{O}(\alpha_S^{n+1}\alpha^m)$, NLO EW $\mathcal{O}(\alpha_S^n\alpha^{m+1})$
- incl. tree $\mathcal{O}(\alpha_S^{n-1}\alpha^{m+1})$ for cancel α_S scale dependence in NLO EW

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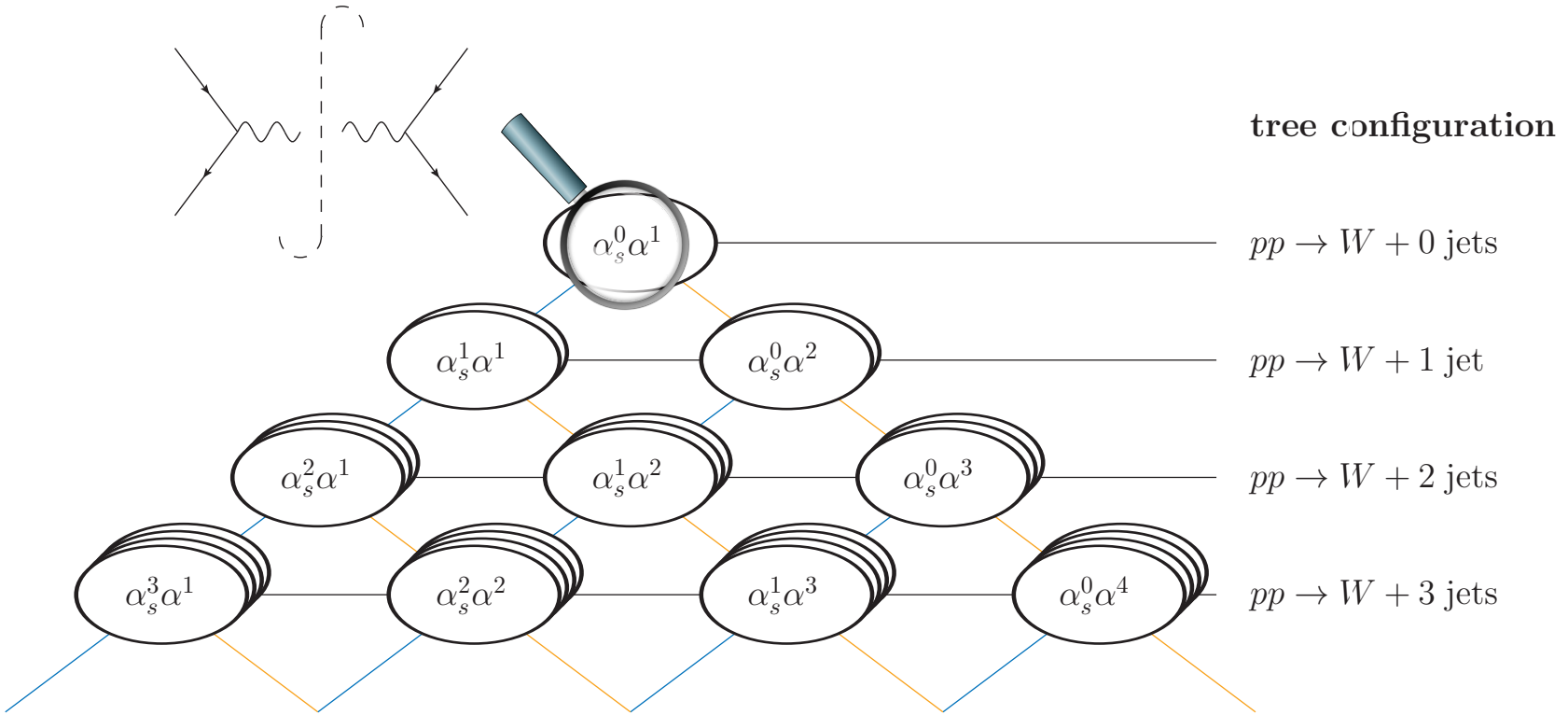

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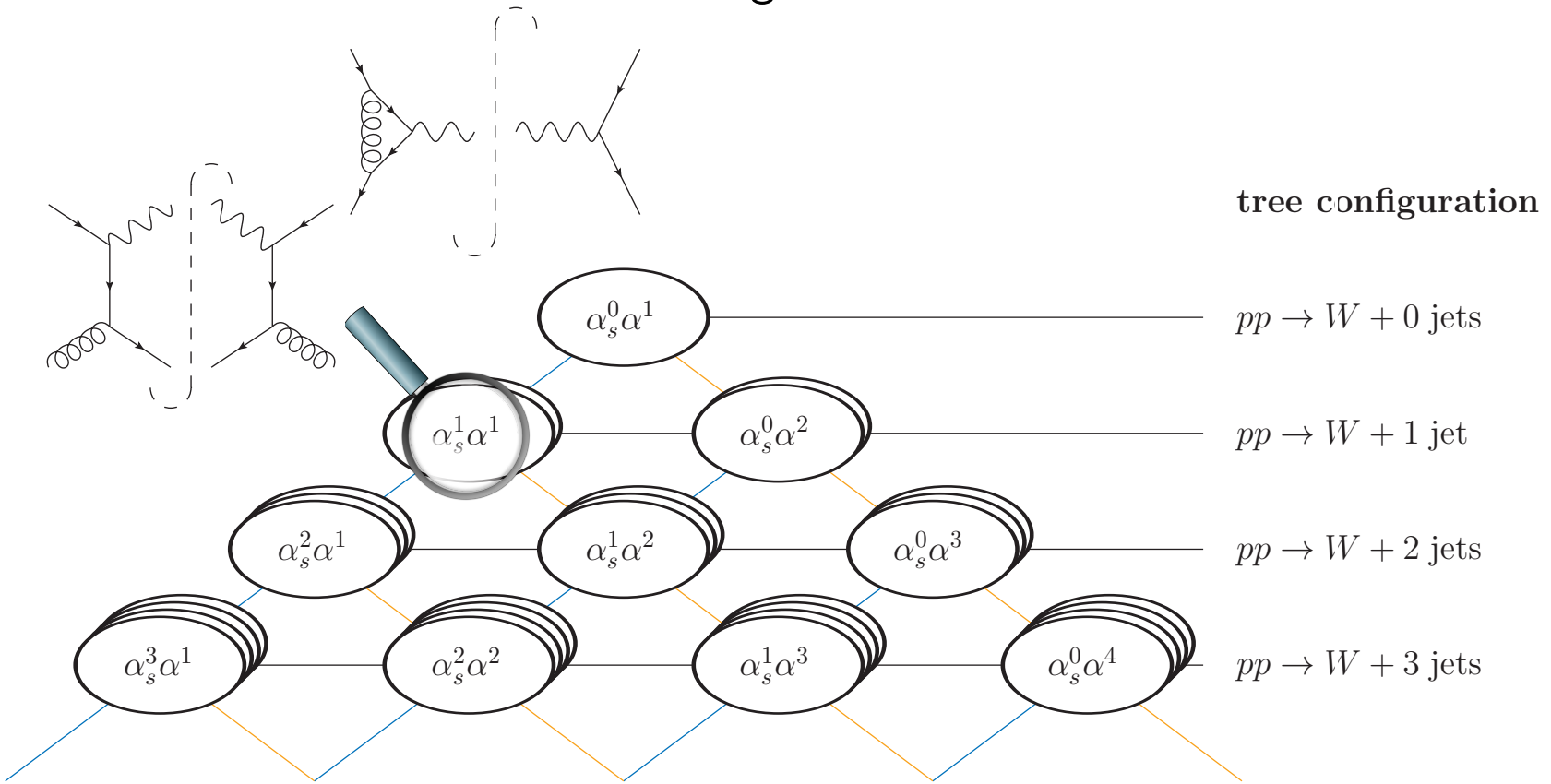

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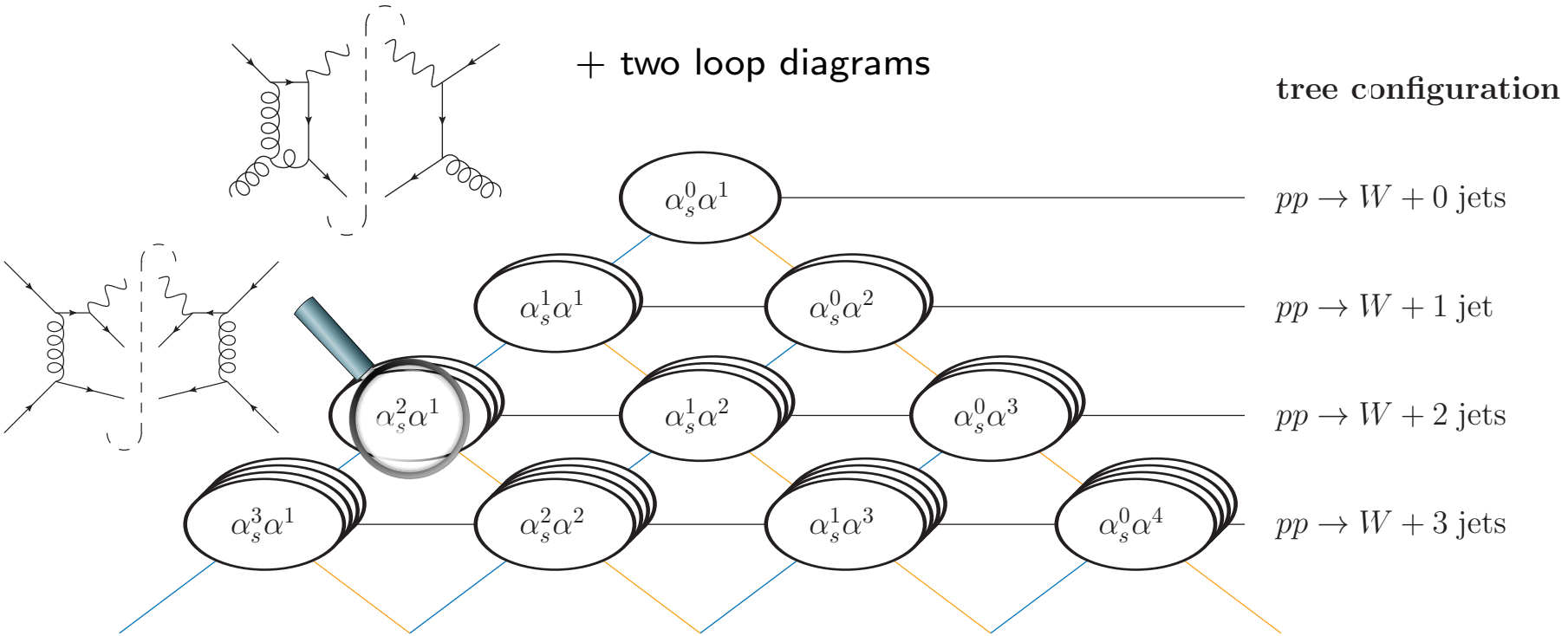

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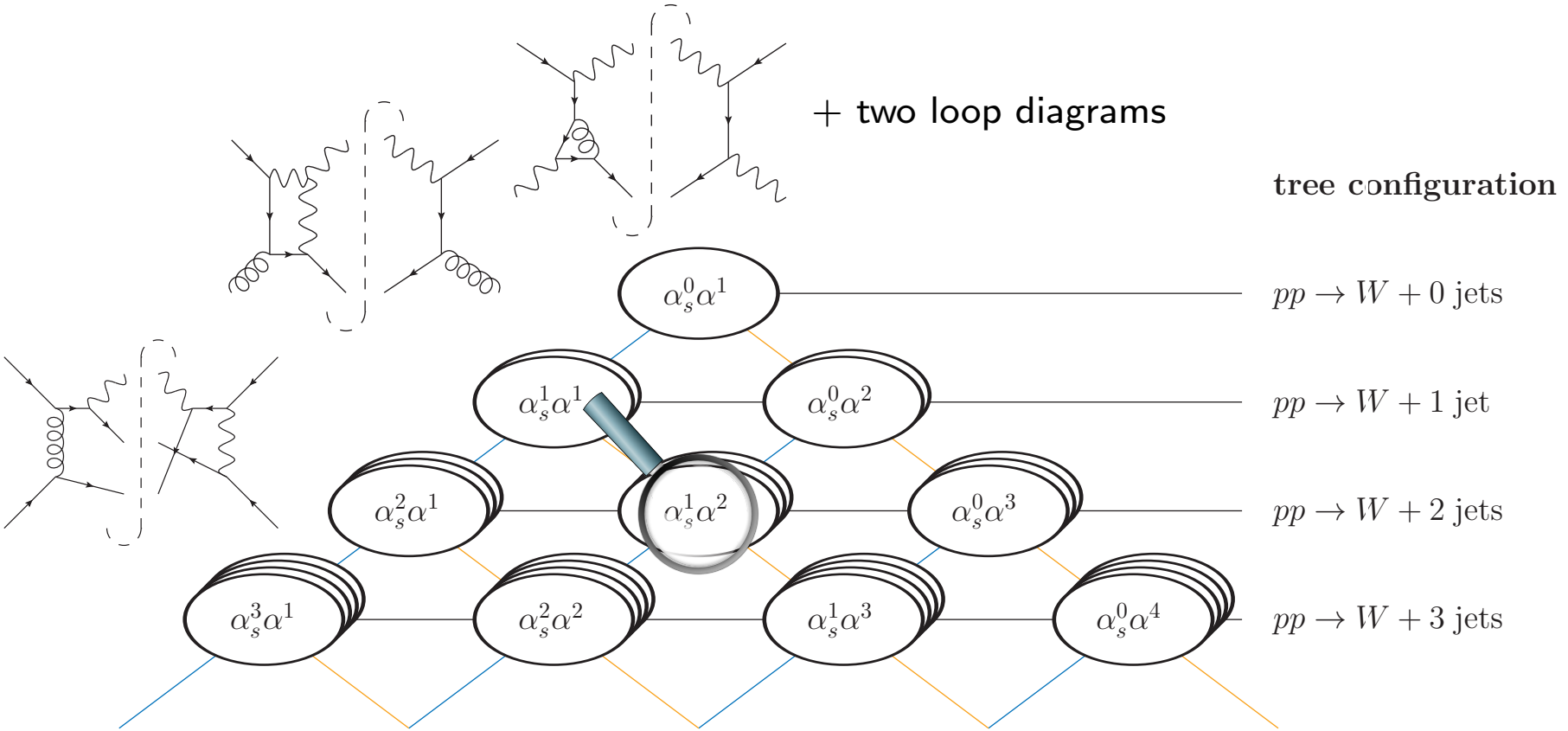

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Process management

NLO QCD process setup

```
(processes){
  Process 98 98 -> 11 -11 98 98;
  NLO_Mode Fixed_Order;
  NLO_Part BVIRS;
  NLO_Order (1,0);
  Order (2,2);
  Print_Graphs Graphs;
  Loop_Generator OpenLoops;
  End process;
}(processes);
```

NLO EW process setup

```
(processes){
  Process 98 98 -> 11 -11 98 98;
  NLO_Mode Fixed_Order;
  NLO_Part BVIRS;
  NLO_Order (0,1);
  Order (2,2);
  Print_Graphs Graphs;
  Loop_Generator OpenLoops;
  End process;
}(processes);
```

- `NLO_Order` specifies the relative coupling powers to Born process
- for `RS` additional 98 added in final state
- 98 contains 93 + 22 (photon)
  $\rightarrow$ need to add leptons for processes with photons at Born level

Generalised infrared safe phase space boundaries

```
(selector){
  DressedParticleSelector {
    DressingAlgorithm Cone 0.1
    % selectors on dressed momenta
    Jet_Selector {
      Input_Particles 98;
      Jet_Algorithm antikt PT:30. R:0.4 ETA:4.5;
      Identify_As 22 E>0.5[rel];
      NMin 2;
      % selectors on clustered jets
      PT      -11 25.    E_CMS;
      Y       -11 -2.5     2.5;
      PT       11 25.    E_CMS;
      Y        11 -2.5     2.5;
      Mass 11 -11 66.     116.;
      DR   11 -11  0.2   1000.;
      DR   93  11  0.5   1000.;
      DR   93 -11  0.5   1000.;
    }
  }
}(selector);
```

Infrared safe scale setting

```
(run){
  ..
  % standard BlackHat HT'/2 (not infrared-safe in NLO EW)
  SCALES VAR{FSF*H_Tp2}{RSF*H_Tp2};
  ..
  % infrared safe definition HT'/2 by dressing partons first
  SCALES VAR{FSF*DH_Tp2(Cone,0.1)}{RSF*DH_Tp2(Cone,0.1)};
  ..
}(run);
```

- scales like `H_T2`, `H_TM2` are infrared safe by constructions
- `H_Tp2`, `DH_Tp2(<dressing-algo>,<dR>)` expect two leptons

QED subtraction

- QED real subtraction terms (RS)

$$|\mathcal{M}_{n+1}|^2 \propto \sum_{i,j}\sum_{k\neq i,j}\mathcal{D}_{ij,k} + \sum_{i,j}\sum_{a}\mathcal{D}_{ij}^{a} + \sum_{a,j}\sum_{k\neq j}\mathcal{D}_{k}^{aj} + \sum_{a,j}\sum_{b\neq a}\mathcal{D}_{aj,b}$$

with

$$\mathcal{D}_{ij,k} = -\frac{1}{(p_i+p_j)^2 - m_{\widetilde{ij}}^2}\,\frac{Q_{\widetilde{ij}}Q_{\tilde{k}}\theta_{\widetilde{ij}}\theta_{\tilde{k}}}{Q_{ij}^2}\;{}_m\langle\ldots,\widetilde{ij},\ldots,\tilde{k},\ldots|\mathbf{V}_{ij,k}|\ldots,\widetilde{ij},\ldots,\tilde{k},\ldots\rangle_m$$

- inspect all parton pairs, check whether combination leads to divergence (splitting function exist, underlying Born exist), build subtraction term, either QCD or QED
- external massive charged bosons can be subtracted using heavy fermion, heavy boson or pure eikonal subtraction

  `DIPOLE_V_SUBTRACTION_MODE=<scalar|fermionic|eikonal>`

QED subtraction

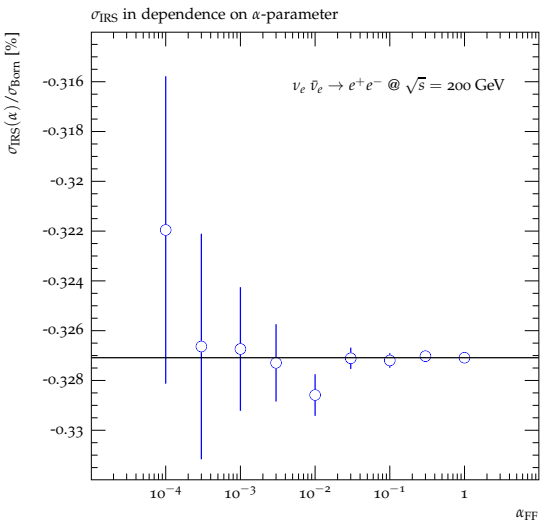
- QED integrated subtraction ($\boldsymbol{I}$,$\boldsymbol{K}$,$\boldsymbol{P}$)

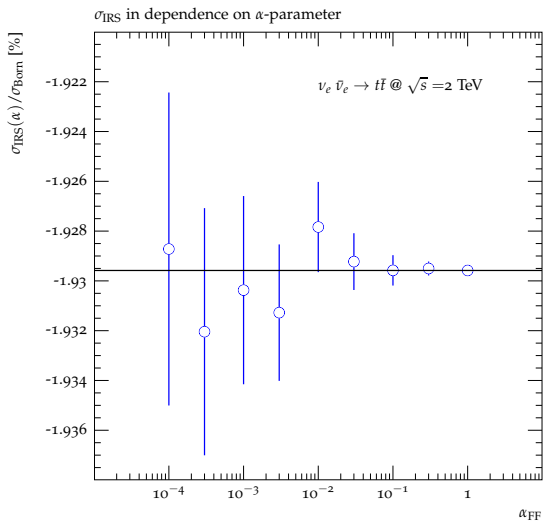
$$\boldsymbol{I}(\epsilon,\mu^2;\kappa,\{\alpha_{\text{dip}}\}) = -\frac{\alpha}{2\pi}\frac{(4\pi)^\epsilon}{\Gamma(1-\epsilon)}\sum_i\sum_{k\neq i} Q_i Q_k \theta_i\theta_k \left(\frac{\mu^2}{s_{ik}}\right)^\epsilon F_{ik}(\epsilon,\mu^2;\kappa,\{\alpha_{\text{dip}}\})$$

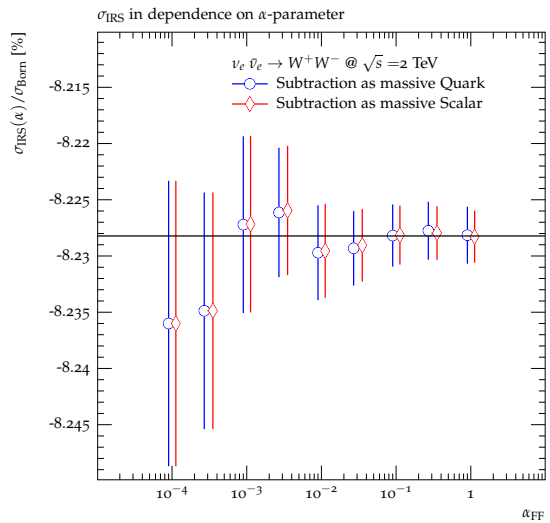
$$\boldsymbol{KP}(\mu^2;\kappa,\{\alpha_{\text{dip}}\}) = -\frac{\alpha}{2\pi}\sum_i\sum_{k\neq i} Q_i Q_k \theta_i\theta_k \left[\boldsymbol{K}_{ik}(\kappa,\{\alpha_{\text{dip}}\}) + \boldsymbol{P}_{ik}(\mu^2;\kappa,\{\alpha_{\text{dip}}\})\right]$$

- pair all QCD and QED partons, check whether underlying Born exists, build dipole

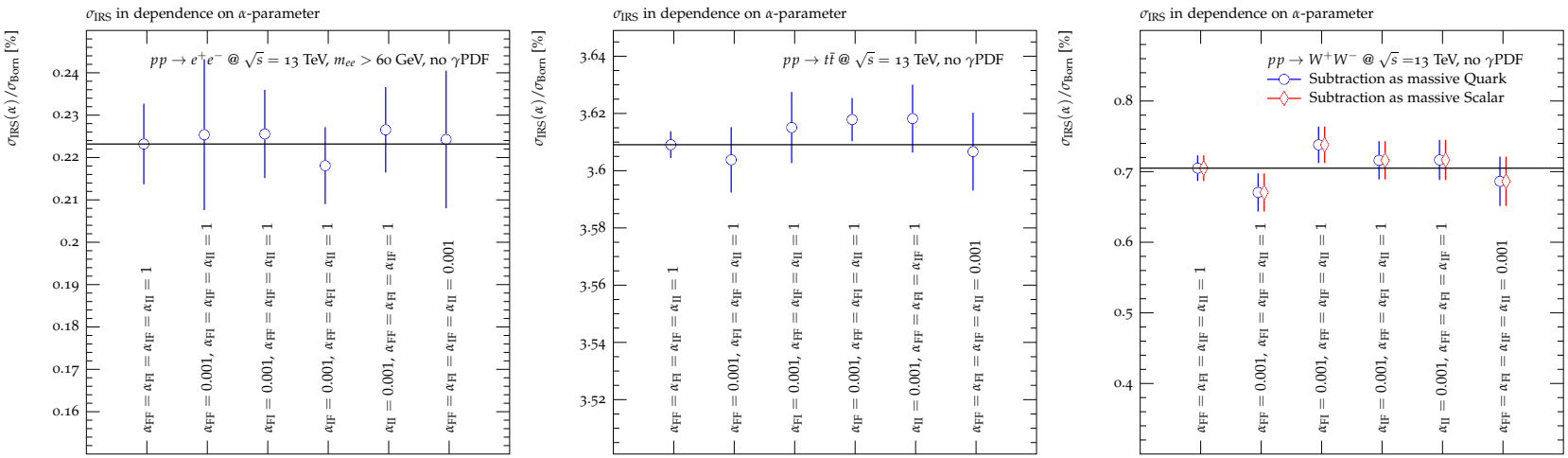
$\{\alpha_{\text{dip}}\}$ dependence – FF dipoles



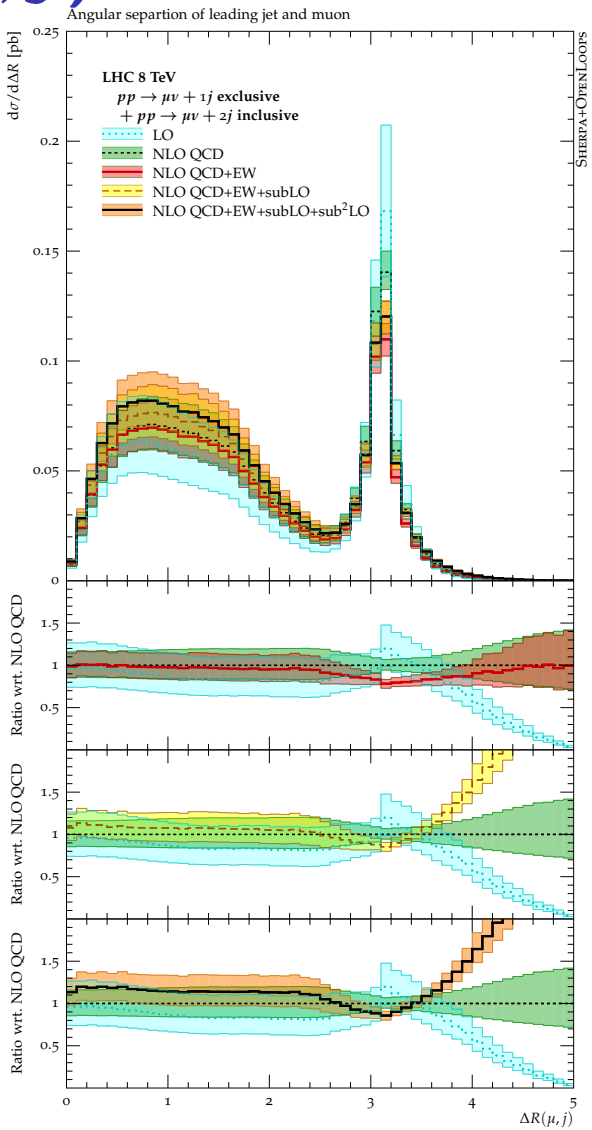


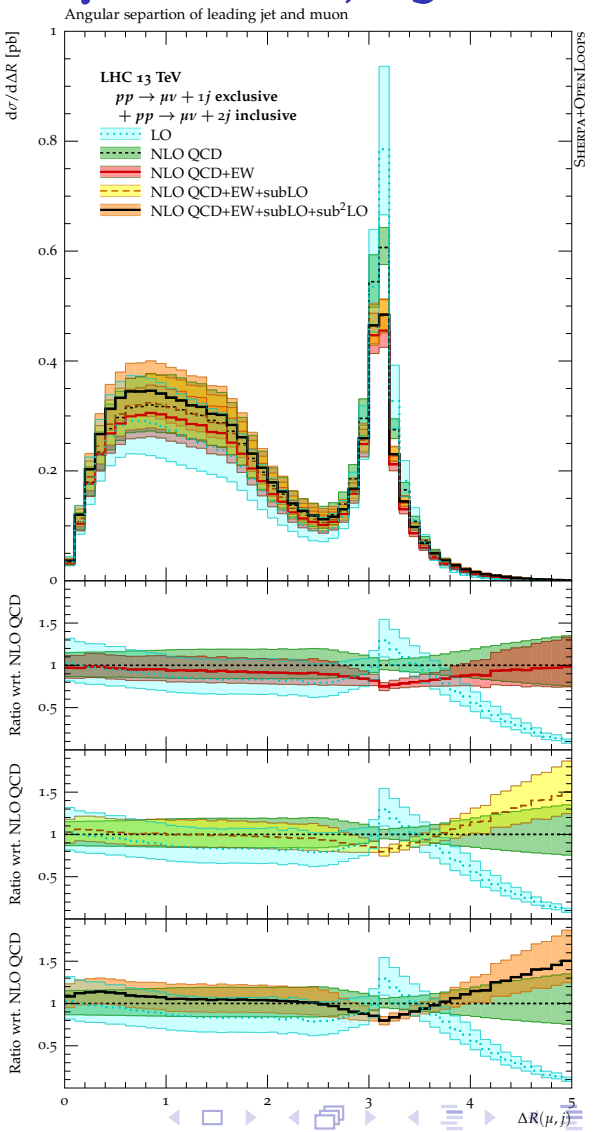


$\{\alpha_{\text{dip}}\}$ dependence – all dipoles



$\Delta R(\mu, j)$ – exclusive sums $pp \to \mu\nu + 1, 2j$





External photons in Born process

- external photons need special treatment as $Q_{\widetilde{ij}} = 0$
- only $\gamma \to f\bar{f}$ splittings, no soft singularity
  $\Rightarrow$ no dipole-like subtraction needed
- choose any spectator(s) for momentum conservation only
  `DIPOLE_PFF_IS_RECOIL_SCHEME/DIPOLE_PFF_FS_RECOIL_SCHEME=<scheme>`
  ```
  0 .. only initial state partons (default)
  1 .. only final state partons
  2 .. only charged partons
  3 .. only neutral partons
  ```
- real subtraction:
  $\to$ straight forward from $g \to f\bar{f}$
- integrated subtraction terms:
  $\to$ separate terms $\propto T_R$ from $\propto C_A$ in g results
- carefully check $\{\alpha_{\text{dip}}\}$-dependence

Conclusion

- implementation basically done, extensive checks to be finished
- will go into trunk, should be in the next major release
- will then need extensive checks of matching/merging machinery

Thank you for your attention!