The computation of the non-global logarithms with jet grooming techniques for Z+jet process

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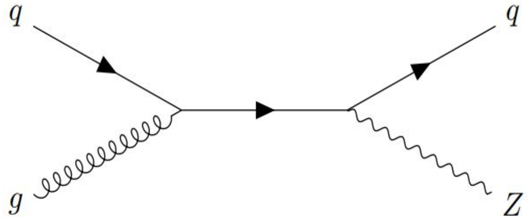
Motivation

- Among the major goals of the LHC is the discovery of new particles and the making of precision measurements (eg. EW couplings, masses, …).
- The production of heavy Z/W bosons provide a good environment for such precision measurements.
- Jet substructure tools are widely used to achieve clean signal extraction from larger backgrounds



- Many observable distributions are logarithmically enhanced requiring resummation, usually achieved by parton showers
- Analytical treatment provides more insight (e.g. perturative accuracy, logarithmic accuracy, removing double counting in matching vs. merging)
- For non-trivial resummation (e.g. non-global observables) we employ the large-N_c approximation , also used in MC partons showers.

Substructure in a nutshell

- Jets can result from QCD partons or from the decay of heavy particles
  Sufficiently boosted heavy particles can result in fat jets with substructure
- Energy deposit in the jet is influenced by the originating splitting partons
- The soft emitter will create 1-prong energy while the hard one will create 2-prongs of energy
- The picture will be mudded by non-perturbative contributions (pile-up , UV, hadronization)
- Jet substructure procedure takes two steps:

STEP 1

→ Grooming: which is cleaning the jet from soft emissions

→ Re-defines the new jet with a new jet-Radius

STEP 2

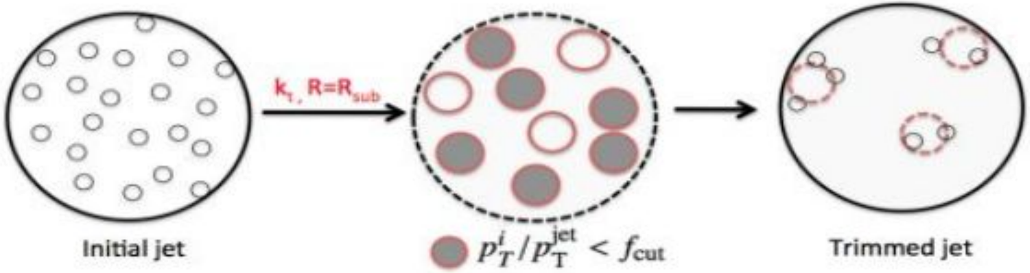
→ Tagging which is identify the features of hard decays and cut on them

Jet grooming technique: Trimming

- In this work we use the Trimming method [Arxiv: 0912.1342]
- Starts by clustering the partons into jets using anti-kt with a large R
- Recluster the constituents of a jet with a smaller radius $R_{Trimming}$
- Selection criteria: sub-jets with $p^i_T/p_T^{jet} < f_{cut}$ are removed

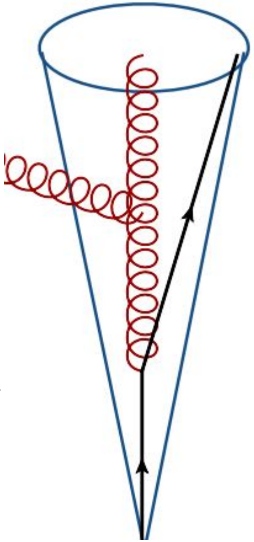
f_{cut} is a fixed parameter and p^i_T is the transverse momentum of the sub-jet i

- Recombine the sub-jets and form a trimmed jet



Non-global observables and non-global logarithms

- Non-global observables are those sensitive to emissions in restricted regions of phase-space, e.g. **the jet mass observable**.
  They are associated with so called Non-Global Logs.
- Those logs occur due to mis-cancellation of real/virtual contributions from secondary non-Abelian emissions
- While some jet substructure methods remove NGLs (e.g. Prunning, Soft-drop), the trimming groomer does not.
- To achieve the NLL resummation for the trimmed jet mass distribution, NGLs must be treated.



Resummation

- Many observables distributions suffer from the presence of large logarithms impeding perturbative convergence. Resummation to all orders is required.
- For many observables, we can organize the resummed distribution as:

$$\sigma(V) \propto \exp\left[L\, g_1(\alpha_s L) + g_2(\alpha_s L) + \alpha_s g_3(\alpha_s L) + \alpha_s^2 g_4(\alpha_s L)\right]$$

L: are the large logs which depend on the observable V

- g1 resums LL, g2 resums NLL, g3 resums NNLL, and so on
- Resummation of non-global logs is usually achieved using Monte Carlo approach in the large N_C limit

NGLs contribution to the jet mass distribution

- The integrated jet mass distribution is written as

$$\sigma(\rho) = \sum_{\delta} \int dB_\delta \frac{d\sigma_{0\delta}}{dB_\delta} \Theta_{\mathcal{B}} f_{\mathcal{B},\delta}(\rho) S_\delta(\rho) C_\delta(\rho) \left(1 + \alpha_s C_1(B_\delta) + \mathcal{O}(\alpha_s^2)\right)$$

The ungroomed NGLs numerical resummation is parameterized as a series in the exponent:

$$\mathcal{S}^{\text{ungr}}_{(i\ell)}(t) = \exp\left(-\frac{\mathcal{C}_{i\ell}}{\mathrm{C_A}} \sum_{n=2}^{\infty} \mathcal{I}^{(n)}_{i\ell} \frac{(-2\mathrm{C_A} t)^n}{n!}\right)$$

With: $t(L) = -\frac{1}{4\pi\beta_0} \ln(1 - 2\alpha_s\beta_0 L)$

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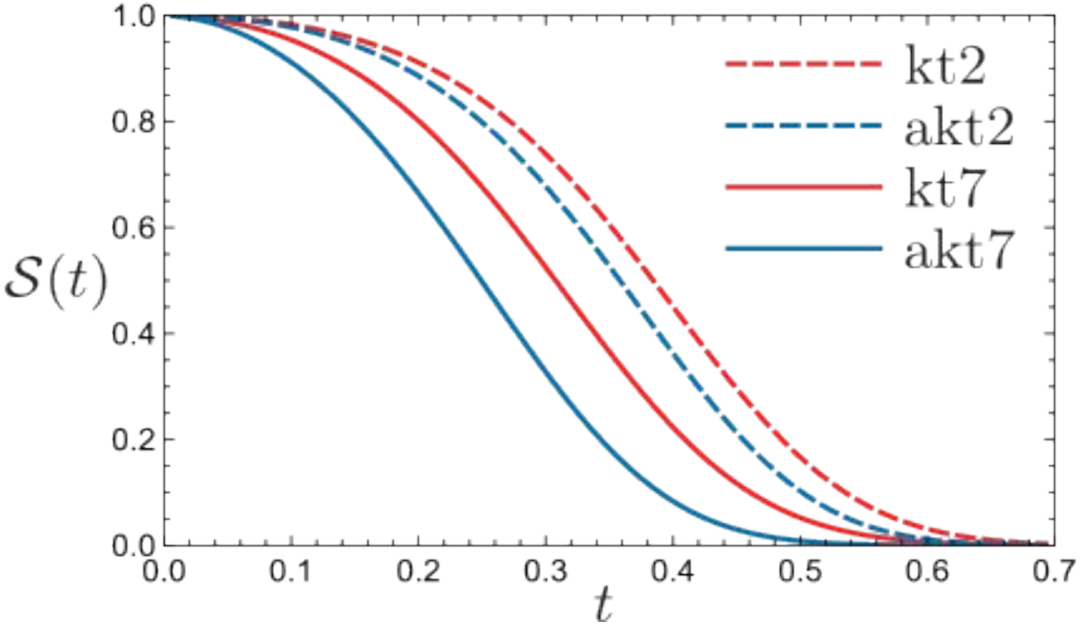

- Non-global logs are reduced with kt (the form factor getting close to unity)
- Anti-kt is preferred

NGLs contribution after trimming

- The resummation of NGLs to all orders in the large N_C approximation, modified to include trimming.

$$S_\delta^{\mathrm{trim}}(t) = \Theta(t_{\mathrm{cut}} - t) S_\delta^{\mathrm{ungr}}(t) + \Theta(t - t_{\mathrm{cut}}) S_\delta^{\mathrm{ungr}}(t_{\mathrm{cut}}) \exp\left(- \sum_{(i\ell)} \frac{C_{i\ell}}{C_A} \sum_{n=2} \tilde{I}_{i\ell}^{(n)} \frac{(-2C_A[t - t_{\mathrm{cut}}])^n}{n!} \right)$$

$$t_{\mathrm{cut}} = t(L_{\mathrm{cut}})$$

NGLs contribution after trimming

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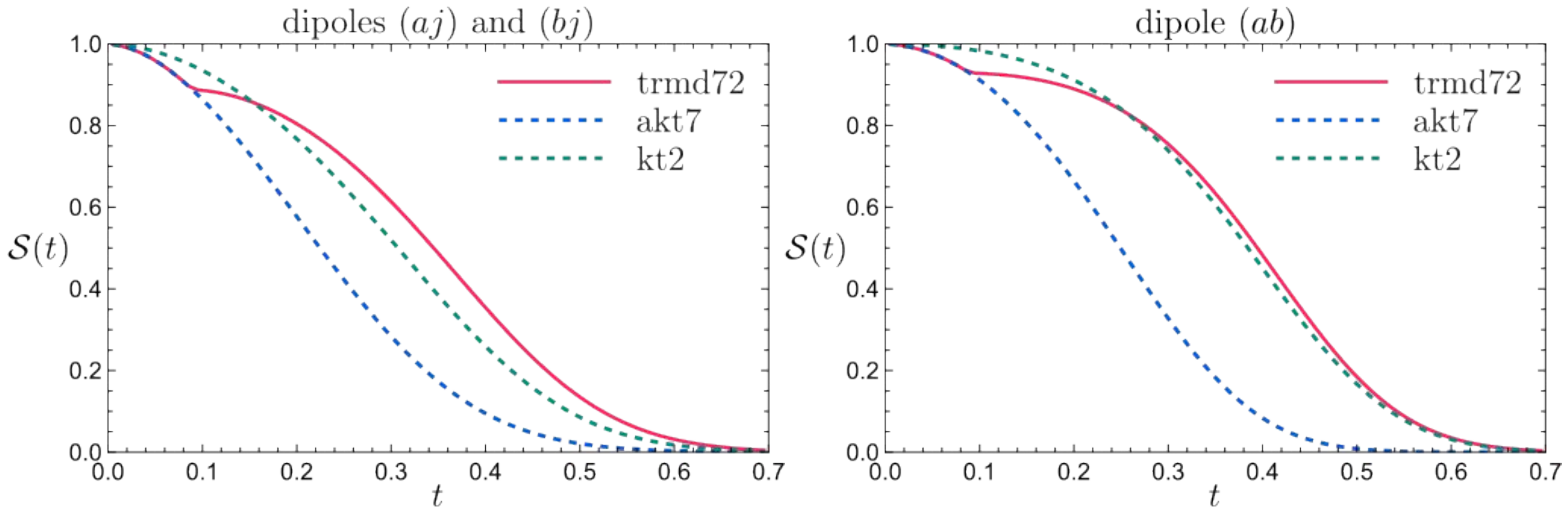
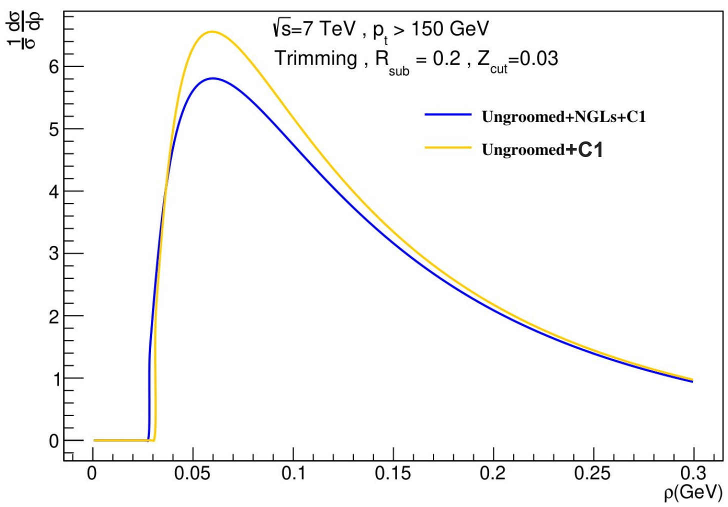


- The trimmed distribution features the akt7 at small value of t. while for higher values of t is resembles more to the kt2 results

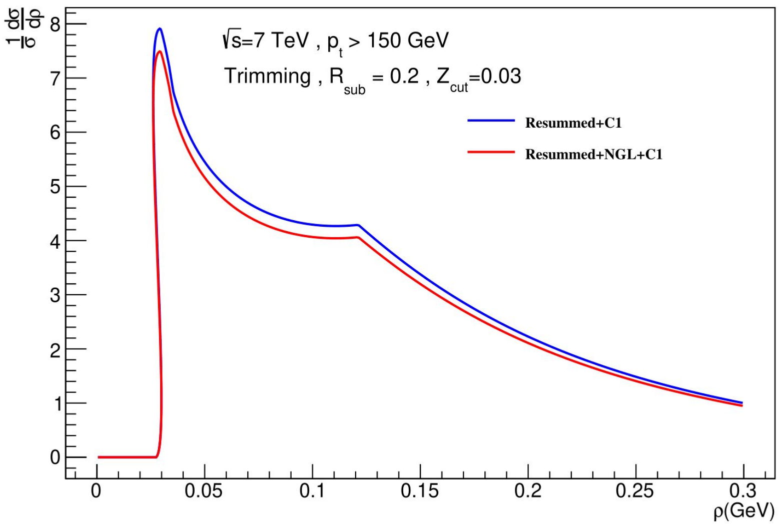
All orders resummation trimming results

- Comparison of the results for jet mass distribution before and after including NGLs
- Work is in progress to establish a comparison with parton shower results (pythia-herwig-sherpa).

Without trimming



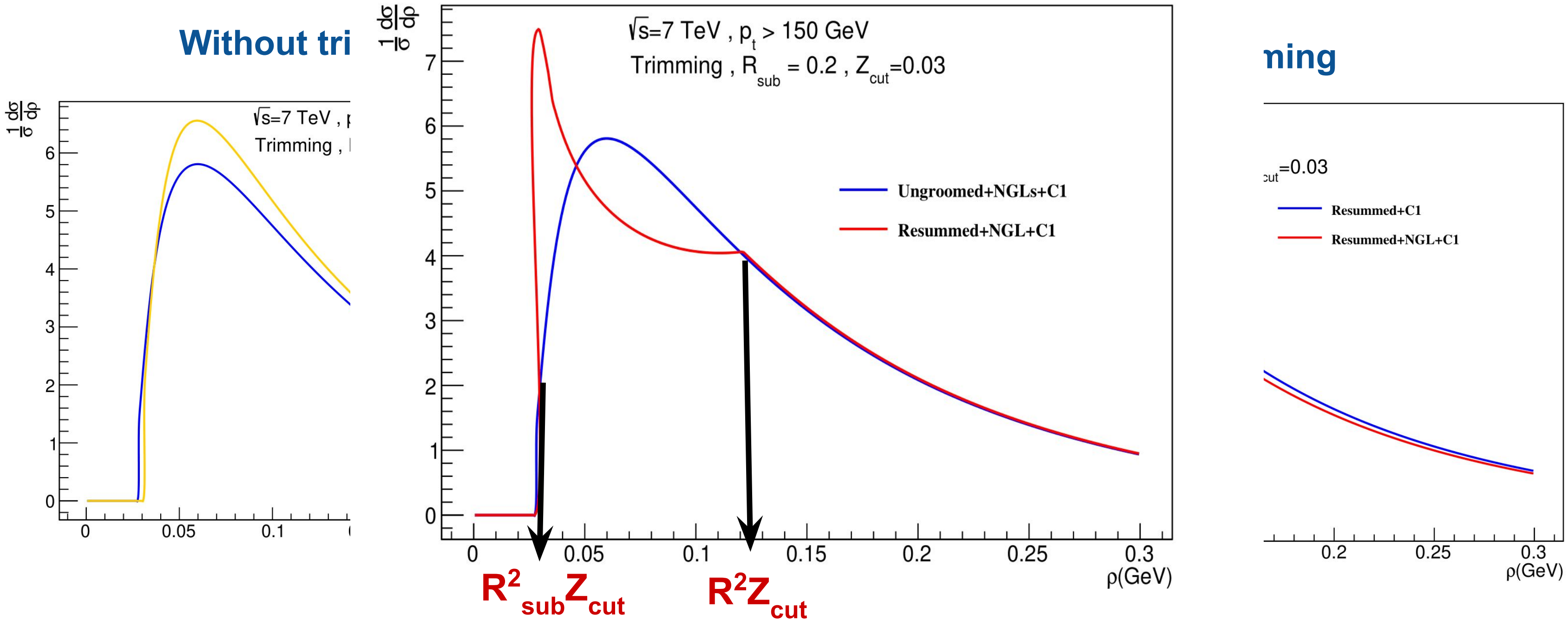
After trimming



All order trimming results comparison

Trimming introduces two transition points in the distribution and three different regions with distinct features

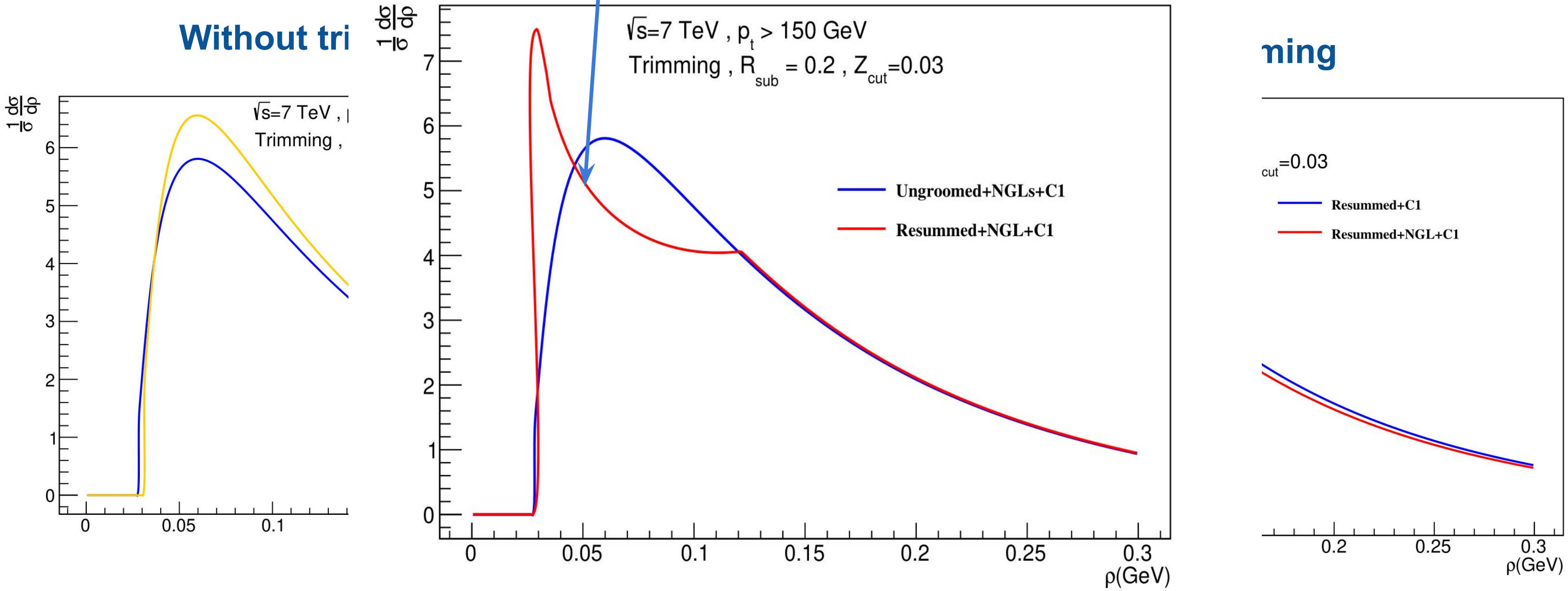
1 **Large-mass region is unaffected by trimming**



All order trimming results comparison

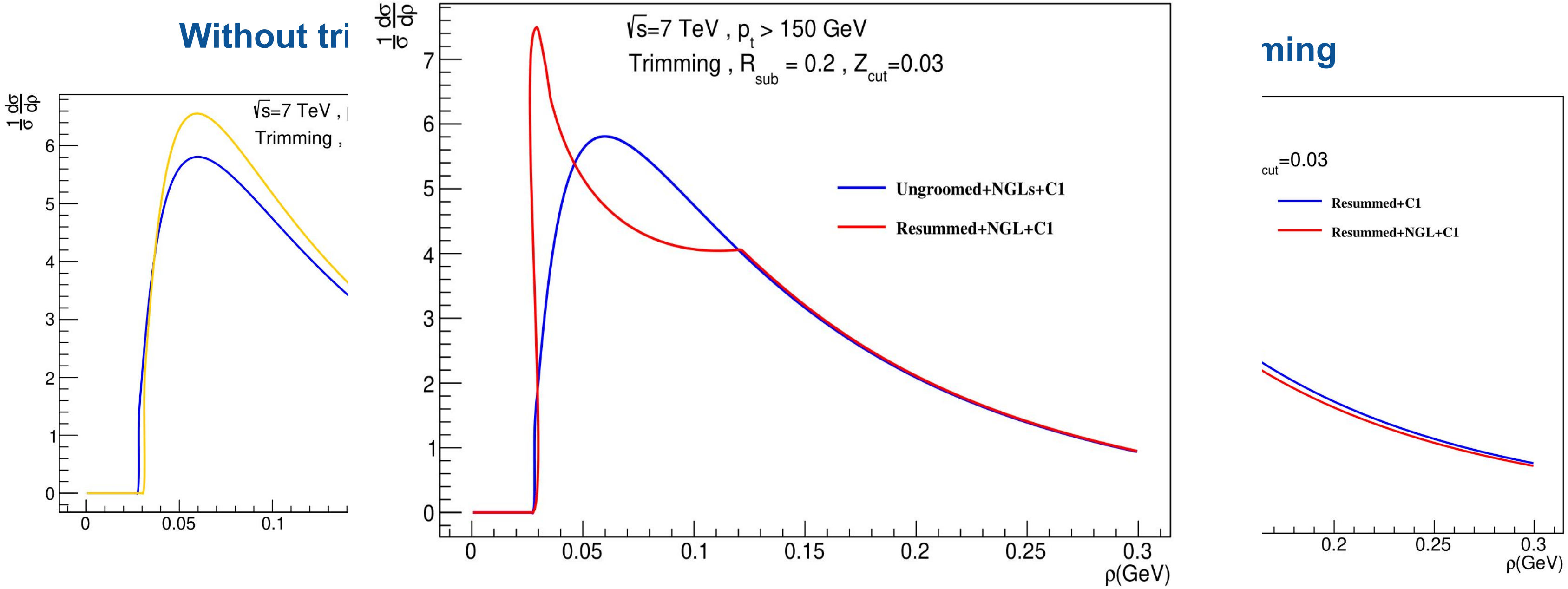
2

Intermediate-mass region: no double logs
NGLs freeze



All order trimming results comparison

3 **Low-mass region: double logs restored with different coefficient (depend on Rsub)**
NGLs restored but smaller (depend on Rsub)



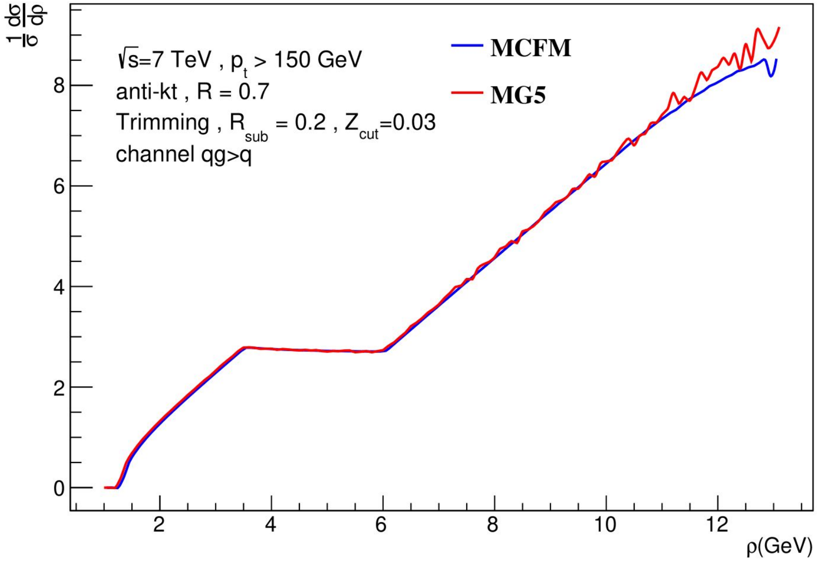
Conclusions

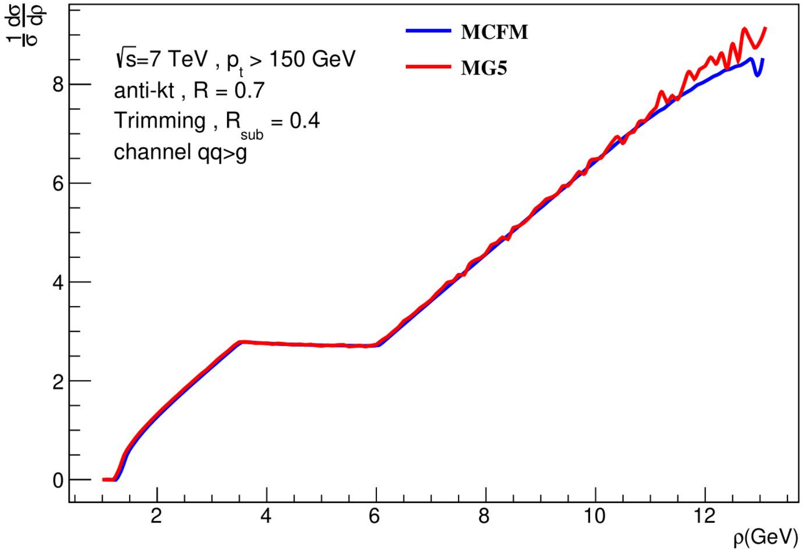
- Jet grooming techniques are widely used with aim to discriminate QCD background from signal.
- The resummation to all orders is essential for distributions which receive contributions from logarithmically enhanced terms
- The non-global logs are double logs and are not analytically trivial for calculations
- The large-Nc approximation simplifies the theoretical framework, making the resummation of non-global logarithms more tractable
- Trimming affects the distribution, removing double logs in intermediate mass-region (near the peak) and freezing NGLs

Backup

jet mass distribution fixed-order

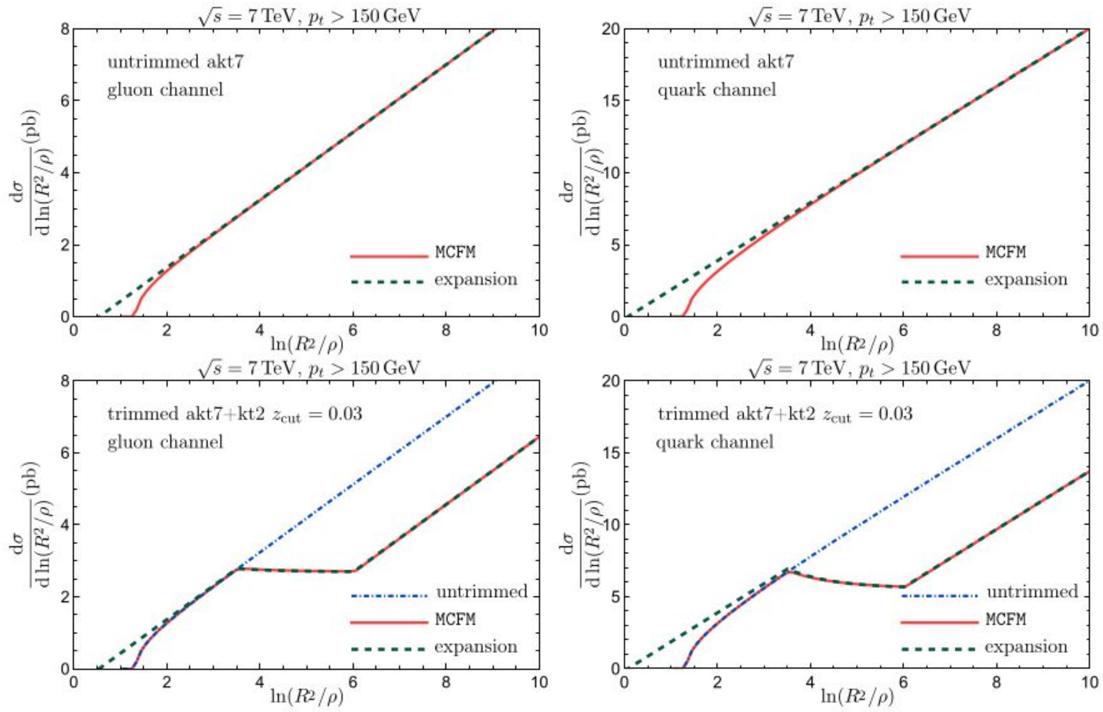
- Leading order fixed-order jet mass distribution (MCFM and Madgraph for double checking).
- MCFM is giving better results. Generating more events is needed.
- The intermediate region the distribution exhibits a single log behaviour





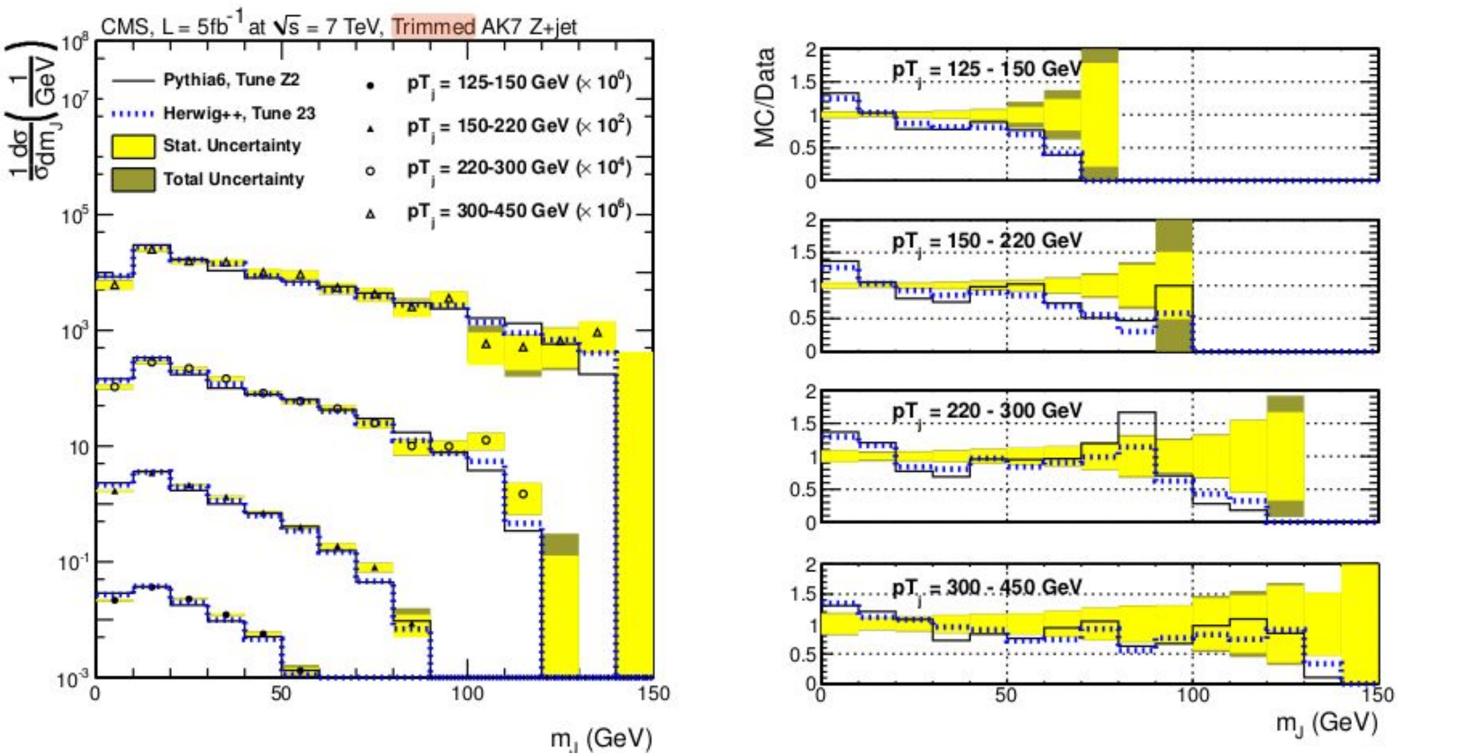
Differential distribution fixed-order

- We use the plots to check the consistency of the previous results
- We have good agreement between Monte-carlo and analytical results



The differential distribution $d\sigma/dL$

Experimental results: CMS collaboration



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