QCD AND RESUMMATION

[GUIDO BELL]

TP1 Theoretical Particle Physics

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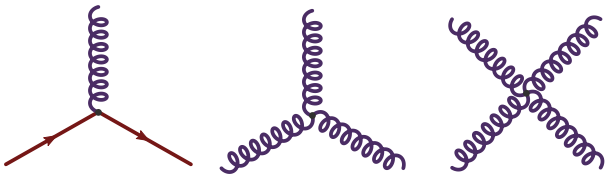
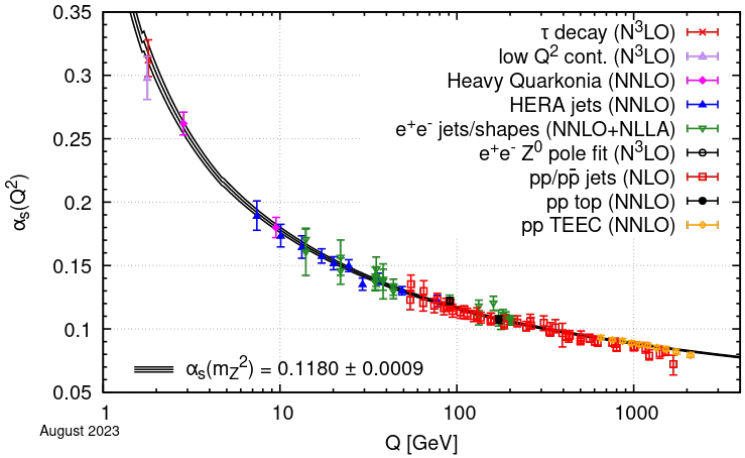
Remember QCD

SU(3) gauge theory

$$\mathcal{L} = \bar{\psi}(i\not{D} - m)\psi - \frac{1}{4} G^A_{\mu\nu} G^{A,\mu\nu}$$



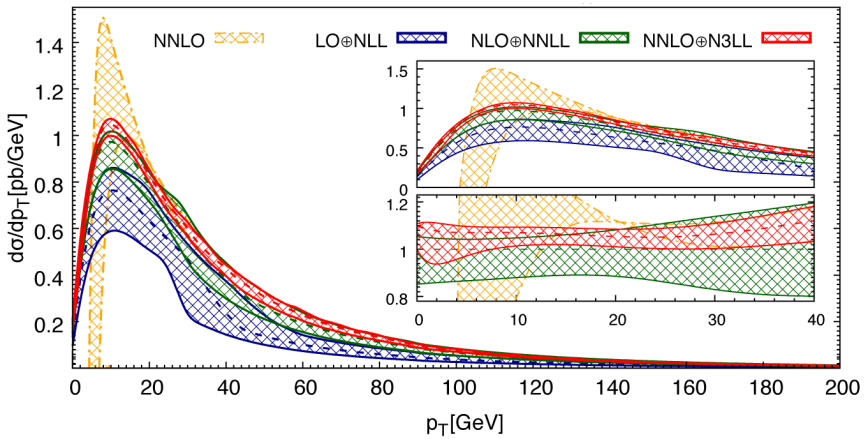


Key properties

- asymptotic freedom $\Rightarrow$ $\alpha_s(M_Z) \simeq 0.12$ $\Rightarrow$ perturbation theory (LO,NLO, . . .)
- soft+collinear emissions generate large logs $\Rightarrow$ resummation (LL,NLL, . . .)
- transition from parton to hadron level $\Rightarrow$ model-dependent estimates
- realistic collider environment (MPI, PU,. . .) $\Rightarrow$ model or suppress?

Examples

Higgs p_T spectrum



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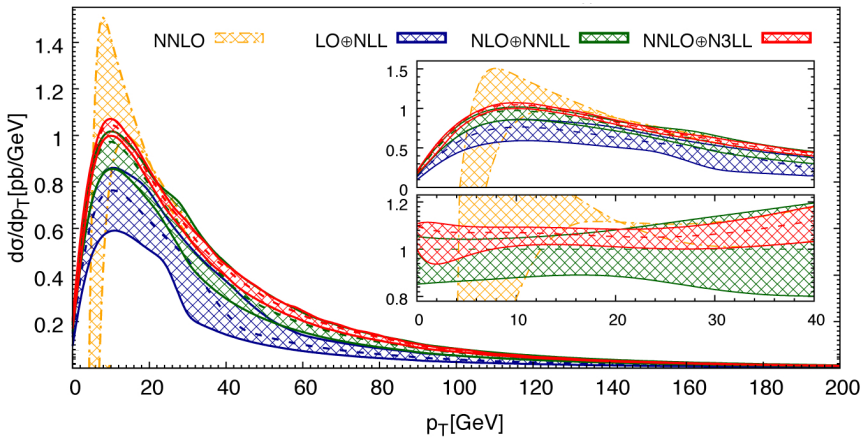

For $p_T \ll m_H$ all emissions are soft or collinear to the beam directions

$\Rightarrow$ large Sudakov corrections $\sim \ln^2\left(\frac{p_T}{m_H}\right)$ spoil the perturbative expansion

$\Rightarrow$ resummation

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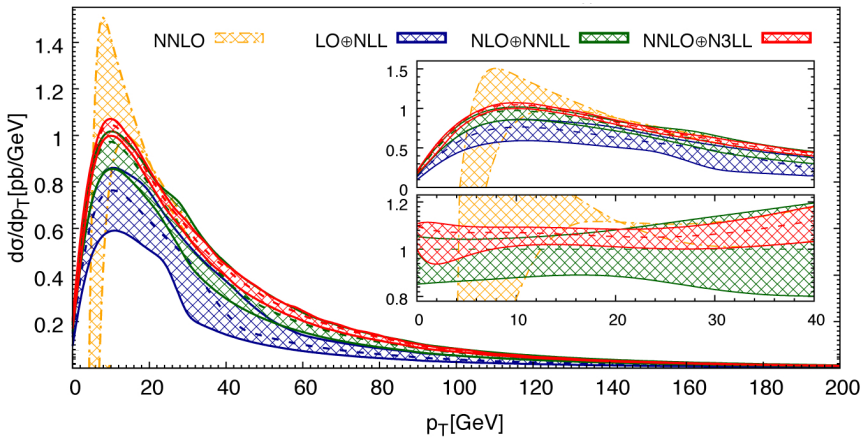

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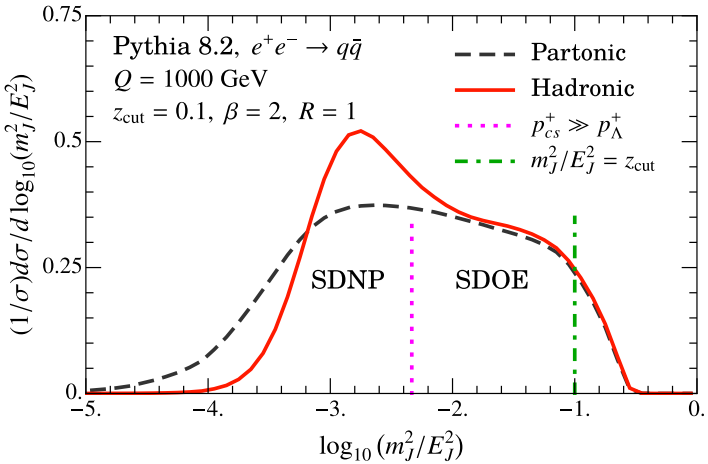
Groomed jet mass



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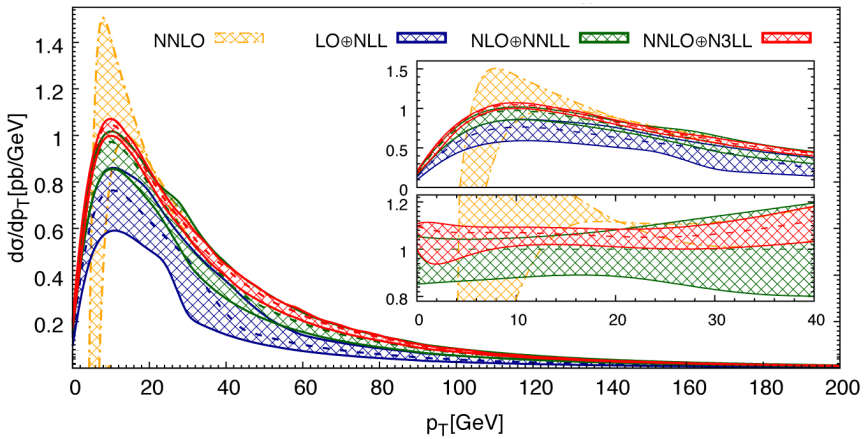

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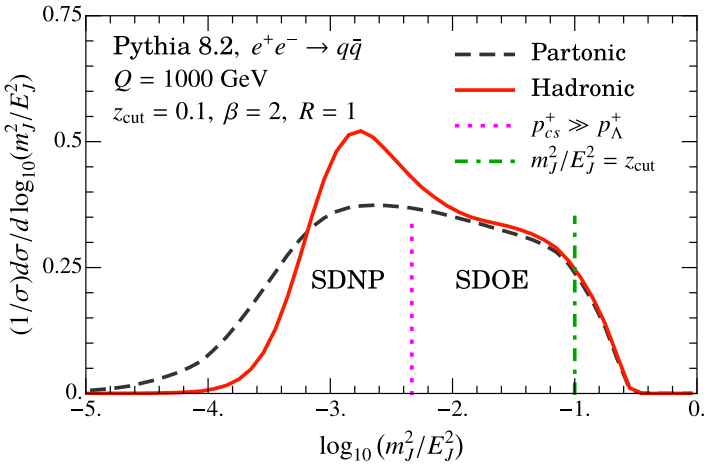

Huge impact of hadronisation corrections

$\Rightarrow$ is the modelled shape correct?

$\Rightarrow$ can one understand the shape analytically in QCD?

$pp \to t\bar{t}X$

$t\bar{t}$ production currently known at NNLO+PS accuracy `(MiNNLO-PS)`

$t\bar{t}H$ and $t\bar{t}Z$ at NLO+PS (two-loop virtual amplitudes are currently not known)

$\Rightarrow$ we are working on an alternative implementation using `GENEVA`

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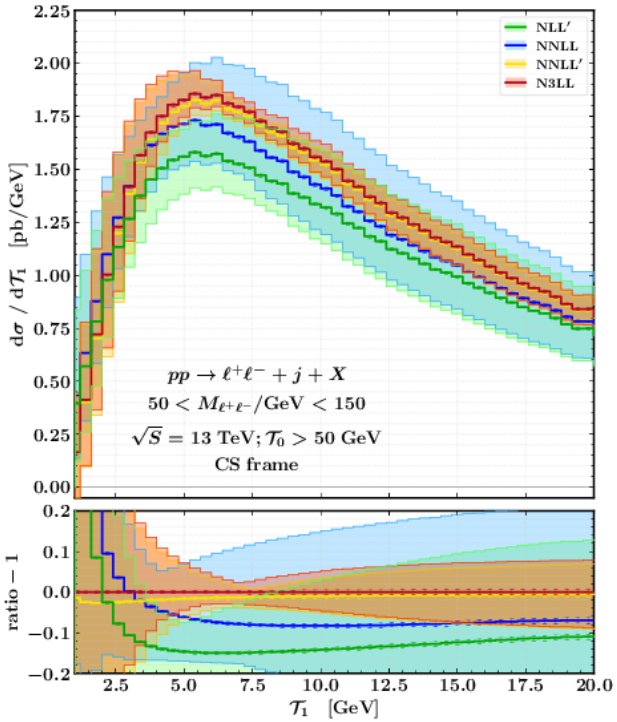
1-jettiness in Z+jet production



`GENEVA` uses N-jettiness as a resolution parameter

$$\frac{d\sigma}{d\mathcal{T}_1} \simeq H_{ij\to k} \cdot B_i \otimes B_j \otimes J_k \otimes S_{ij\to k} + \mathcal{O}(\mathcal{T}_1)$$

Similar factorisation theorem for 0-jettiness in $t\bar{t}X$

- different hard functions for $t\bar{t}$, $t\bar{t}H$, $t\bar{t}Z$
- beam functions known at NNLO
- NNLO soft function currently missing

High-precision resummations

Parton shower resums the leading soft-collinear logarithms (LL) – can one do better?

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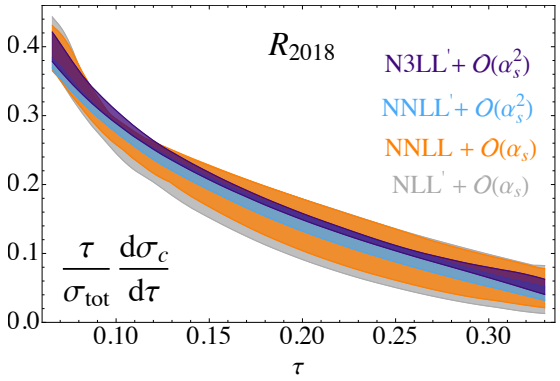
- event shapes



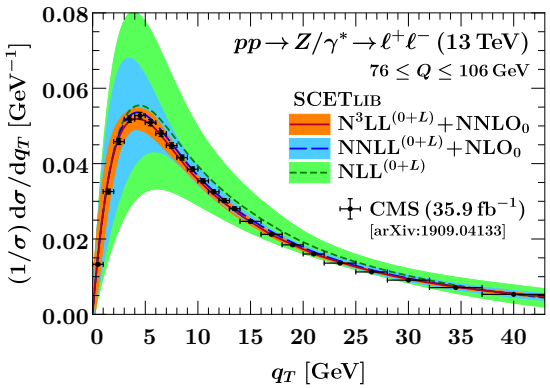
distinguish jet-like topologies from multi-jet events without using a jet algorithm

$\Rightarrow$ free from non-global logarithms

High-precision resummations

Parton shower resums the leading soft-collinear logarithms (LL) – can one do better?

- event shapes
- transverse-momentum distributions



$\mathrm{N^3LL}$ resummation for generic processes fully automated

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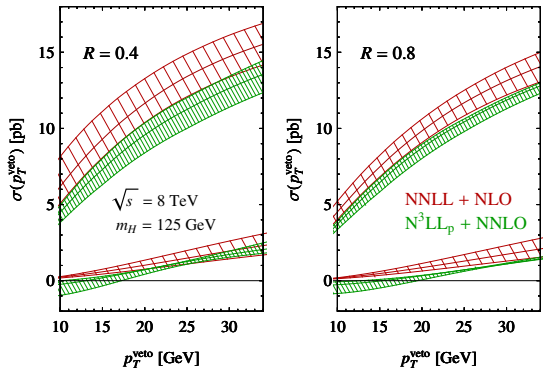
- transverse-momentum distributions
- jet vetoes



vetoing hard jets with $p_T^{\text{veto}} \ll Q$ induces

large Sudakov-type corrections

High-precision resummations

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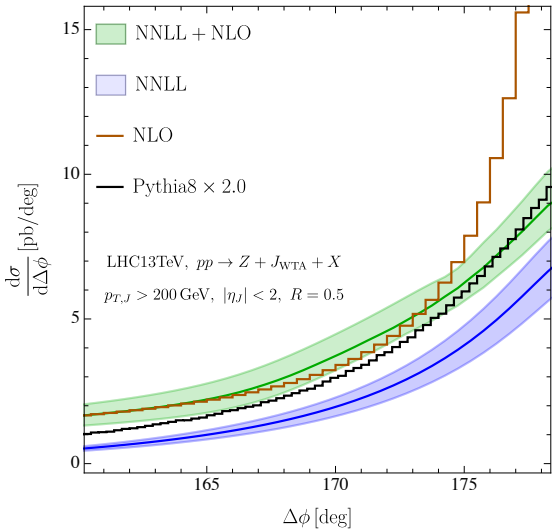
- event shapes
- transverse-momentum distributions
- jet vetoes
- Z+jet azimuthal decorrelation



Specific jet observables are free of non-global logarithms and allow for high-precision resummations