Higgs production at the LHC: transverse-momentum and rapidity dependence

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Outline

1. Overview of recent results for $gg \to H$
   - Total cross section
   - Differential distributions
2. The main ideas of resummation
   - Resummation
   - Exponentiation
   - Matching
3. Numerical results at the LHC
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- NNLO ($\mathcal{O}(\alpha_s^4)$): another 15-20% enhancement ($m_t \to \infty$)

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- Higher-order perturbative contributions reliably estimated by resumming multiple soft-gluon emissions
- NNLL+NNLO: perturbative uncertainty reduced to $\pm 10\%$

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- Soft-gluon terms at NNNLO: effects consistent with NNLL+NNLO uncertainty

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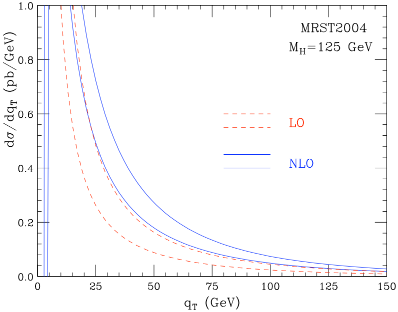
The small-q_T region ($q_T \ll M_H$)

- Bulk of the events in the region $q_T \ll M_H$
- Kinematical unbalance between real and virtual contributions

$\rightarrow$ perturbative coefficients enhanced by $\alpha_S^n \log^m(\frac{M_H^2}{q_T^2})$

$\rightarrow$ convergence of perturbative result completely spoiled



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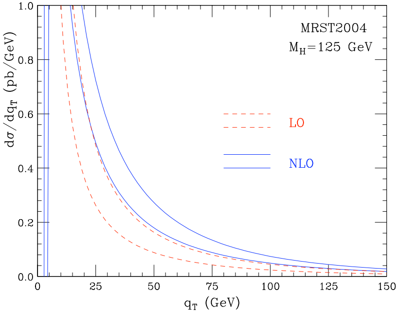

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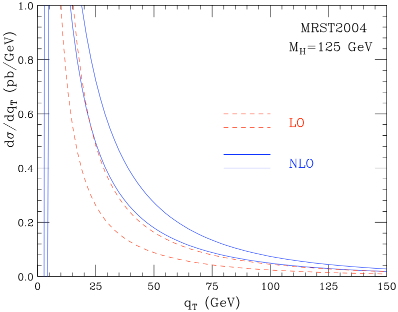

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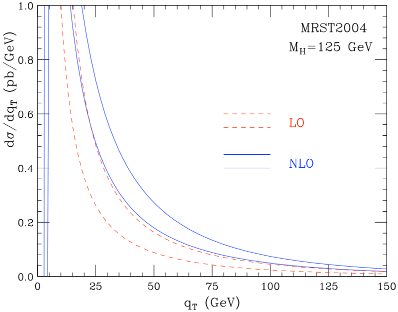

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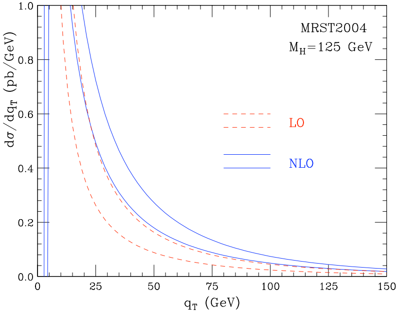

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Resummation: the main idea

$\alpha_s L^2$	$\alpha_s L$	...	...	$\mathcal{O}(\alpha_s)$	(LO)
$\alpha_s^2 L^4$	$\alpha_s^2 L^3$	$\alpha_s^2 L^2$	$\alpha_s^2 L$	$\mathcal{O}(\alpha_s^2)$	(NLO)
...	...	...	...	...	...
$\alpha_s^n L^{2n}$	$\alpha_s^n L^{2n-1}$	$\alpha_s^n L^{2n-2}$	...	$\mathcal{O}(\alpha_s^n)$	$(N^n LO)$
LL	NLL	NNLL	...	...	

- Ratio of two successive rows: $\mathcal{O}(\alpha_s L^2)$
- improved expansion
  - *reorganization* of the terms into *towers of logs*
  - *all-order summation* of the terms in each class
- key-point: *exponentiation*

$$\sigma^{res} \sim \exp\left[Lg_1(\alpha_s L) + g_2(\alpha_s L) + \alpha_s g_3(\alpha_s L) + \ldots\right]$$

- Ratio of two successive columns: $\mathcal{O}(1/L)$

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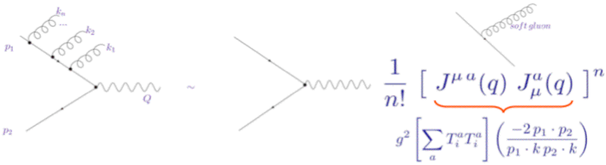
- dynamics (matrix element)

  → in the soft limit, multigluon amplitudes fulfill *generalized factorization formulae* given in terms of *single gluon emission probability*



- kinematics (phase space)

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$$\delta^{(2)}(q_T - q_{T1} - \cdots - q_{Tn}) = \int d^2b\; e^{ib\cdot q_T}\,\Pi_i\, e^{ib\cdot q_T}$$

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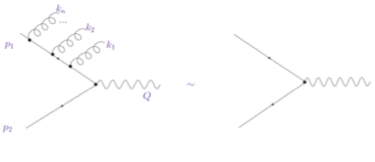

$$\frac{1}{n!}\Big[\underbrace{J^{\mu\,a}(q)\;J^{a}_{\mu}(q)}_{g^2\left[\sum_a T^a_i T^a_i\right]\left(\frac{-2\,p_1\cdot p_2}{p_1\cdot k\,p_2\cdot k}\right)}\Big]^n$$

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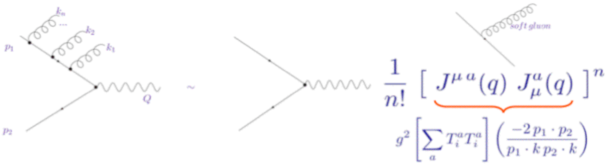

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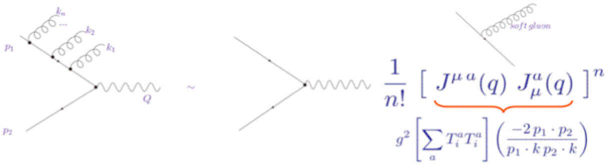

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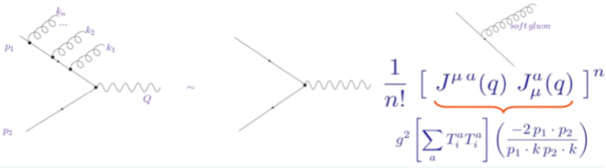

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- NNLL [deFlorian,Grazzini(2000,2001)]

The resummed result has to be properly matched with the fixed-order calculation to avoid double counting

$$\sigma = \sigma^{res} + \sigma^{fix} - \sigma^{asym}$$

where σ^{asym} = expansion of resummed result to same order

- $q_T \ll M_H$: $\sigma^{fix} \sim \sigma^{asym} \rightarrow \sigma = \sigma^{res}$
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where σ^{asym} = expansion of resummed result to same order

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- $q_T > M_H$: $\sigma^{res} \sim \sigma^{asym} \rightarrow \sigma = \sigma^{fix}$
- intermediate q_T: matching $\rightarrow \sigma$

Matching with fixed-order

In the Higgs case, resummation has been explicitly performed up to

- NLL [Catani,D'Emilio,Trentadue(1988)]
- NNLL [deFlorian,Grazzini(2000,2001)]

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- Extension including Higgs rapidity
- Impact parameter and double Mellin moments used
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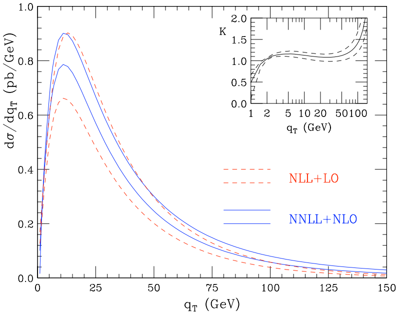
Outline

1. Overview of recent results for $gg \to H$
   - Total cross section
   - Differential distributions
2. The main ideas of resummation
   - Resummation
   - Exponentiation
   - Matching
3. Numerical results at the LHC
4. Summary

The q_T spectrum [BCdFG(2003,2005)]



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  - $\sim$ 1.1-1.2 in the central region
  - increase (decrease) drastically for $q_T > 50$ ($q_T < 2$)
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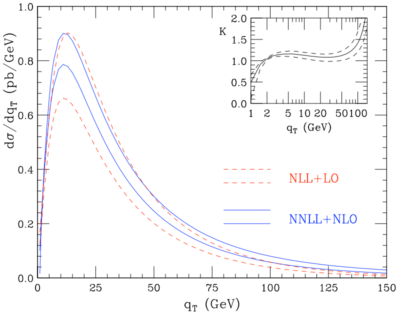

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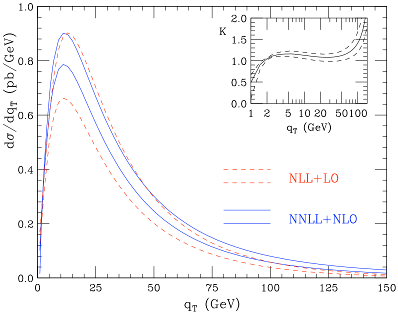

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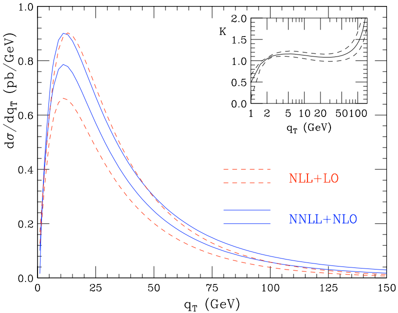

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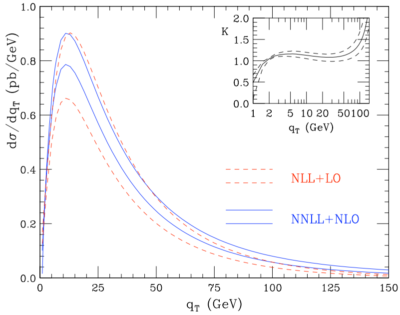

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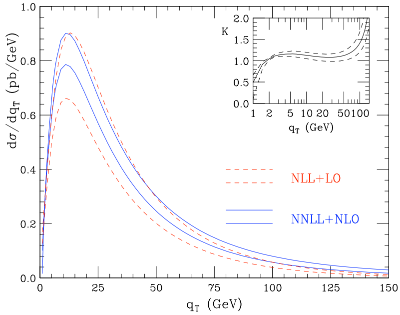

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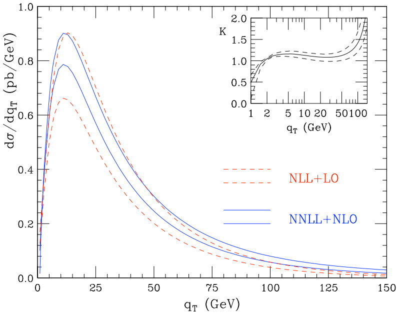

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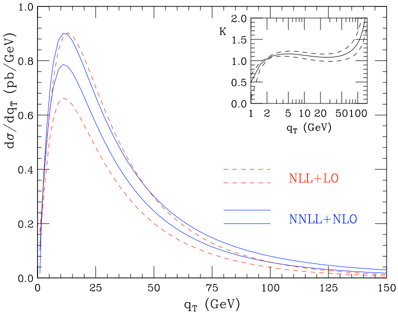

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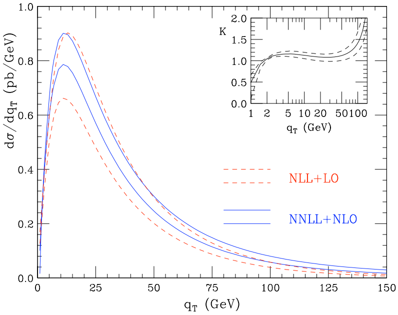

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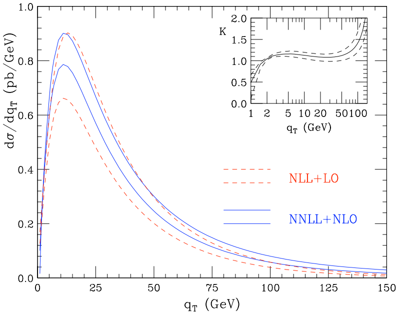

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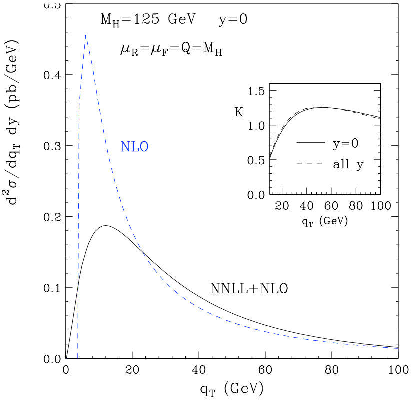

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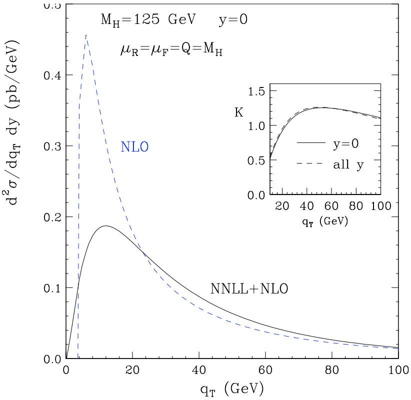

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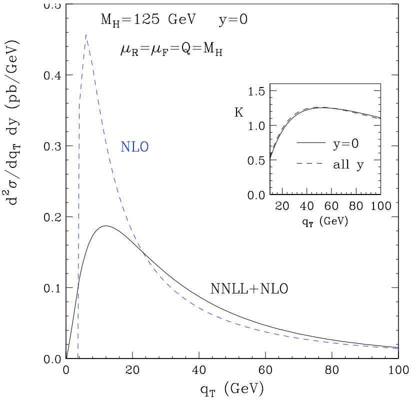

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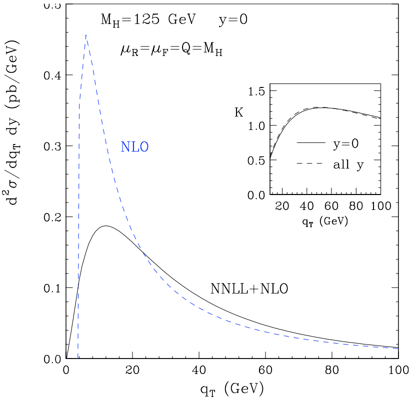

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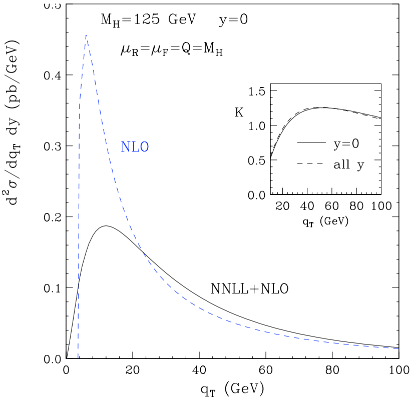

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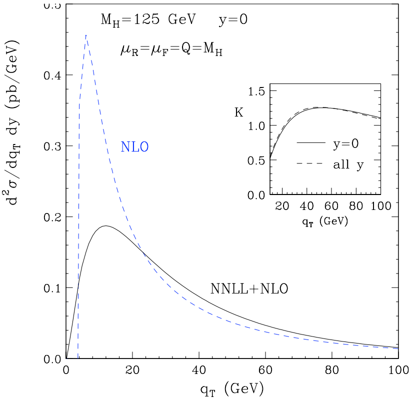

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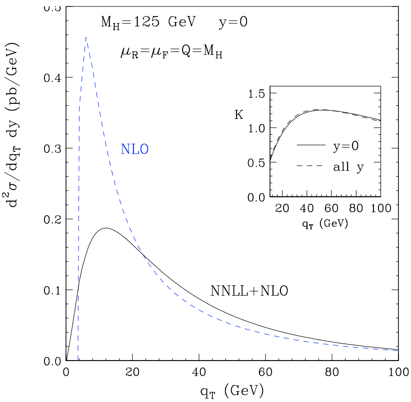

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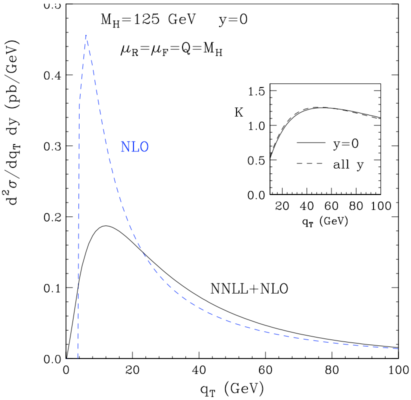

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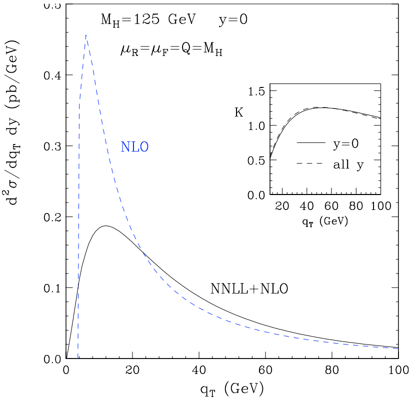

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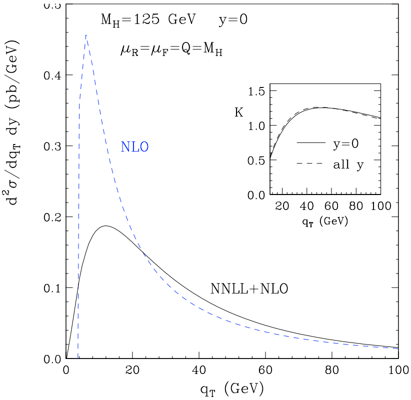

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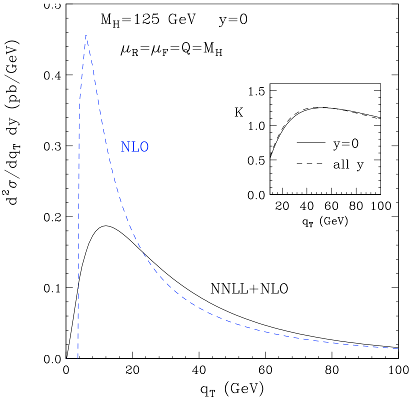

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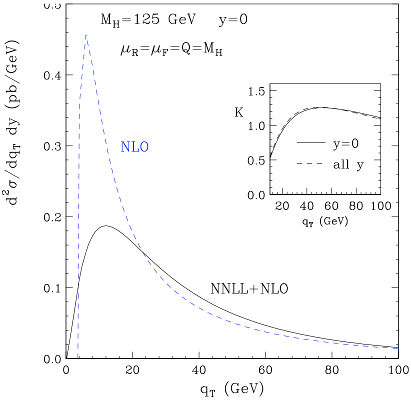

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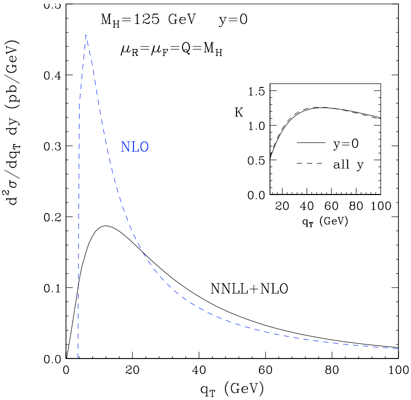

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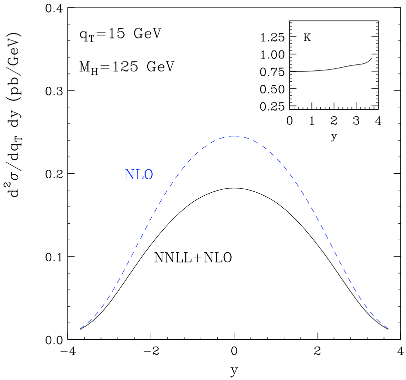

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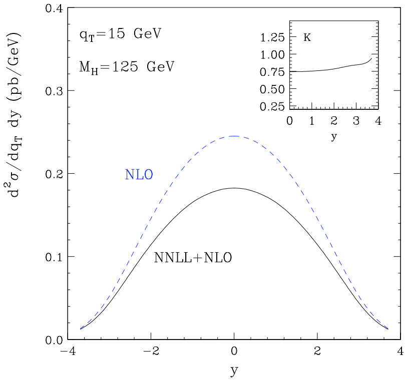

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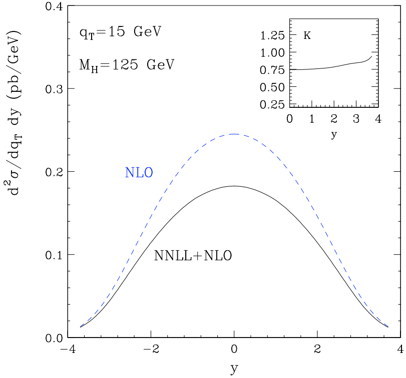

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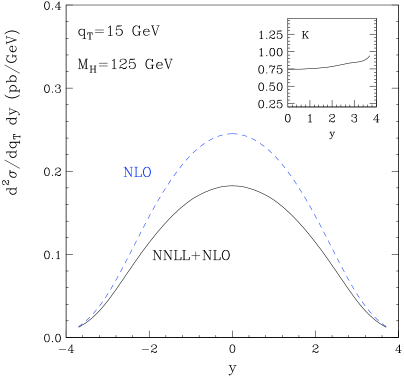

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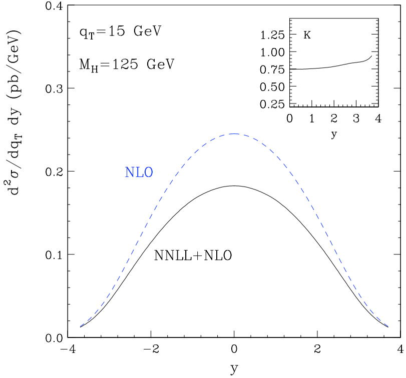

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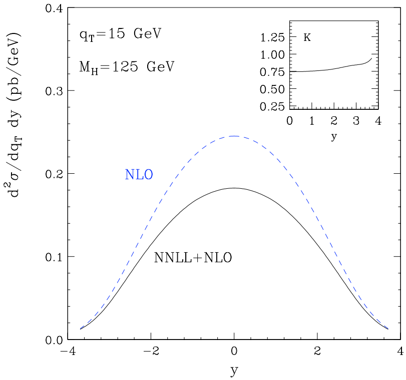

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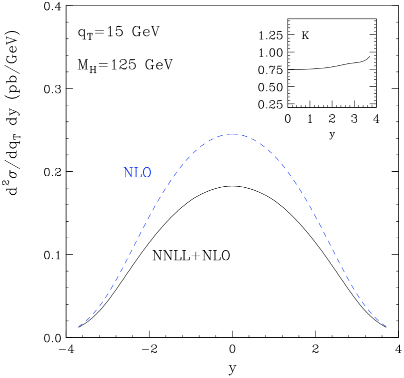

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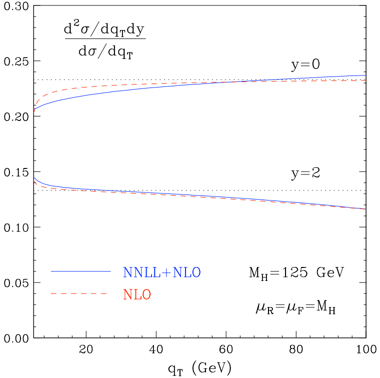

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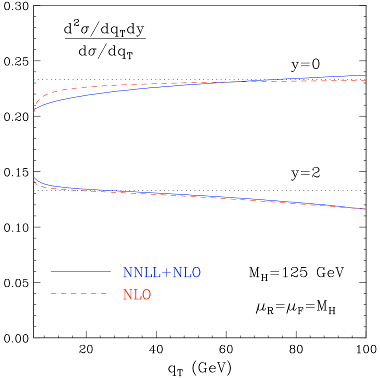

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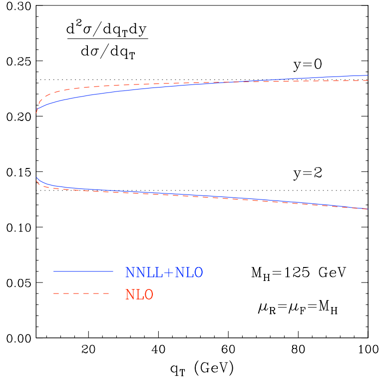

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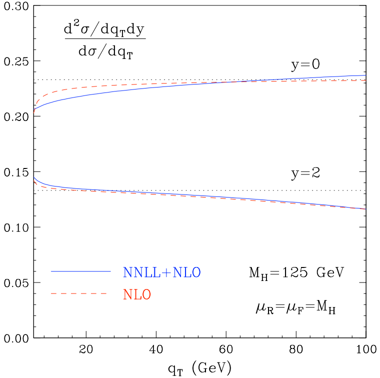

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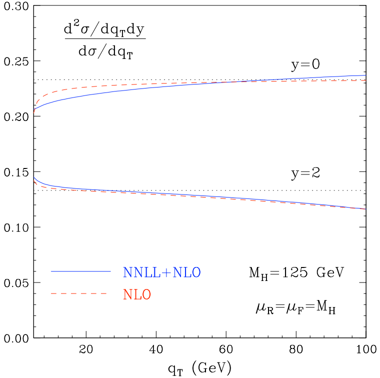

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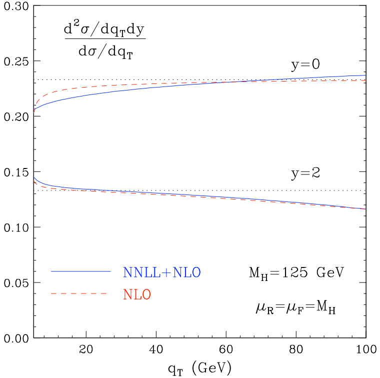

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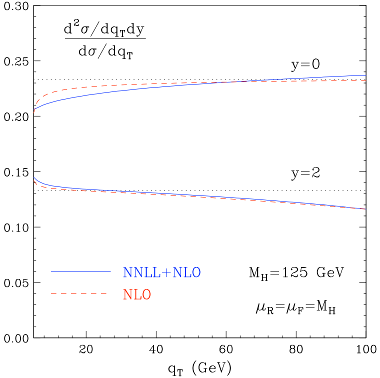

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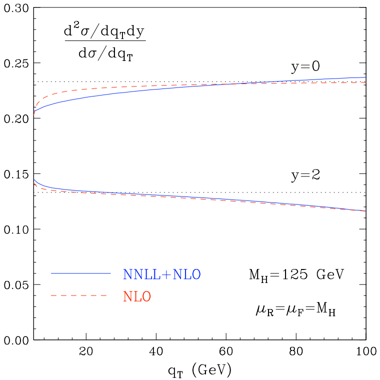

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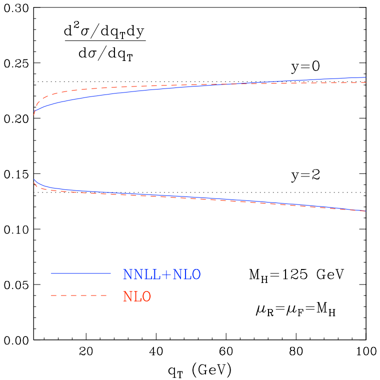

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Outline

Summary

- Precise knowledge of Higgs q_T and y spectrum very important to improve statistical significance
- Enormous theoretical effort in the last years
- Our contribution: $d\sigma/(dq_T\ dy)$ at NNLL+NLO
  - → importance of resummation at low and intermediate q_T
  - → stability of the main features with respect to perturbative uncertainties
- If the Higgs boson exists, no escape route for it at the LHC!

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