Higher-order corrections for $t\bar{t}$ production at high energies

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- **Soft-gluon corrections**
- **Top-antitop pair production**
- **aN^{3}LO cross sections**

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Soft-gluon corrections

partonic processes at LO: $q\bar{q} \to t\bar{t}$ **and** $gg \to t\bar{t}$

in 1PI kinematics $f_1(p_1) + f_2(p_2) \to t(p_t) + X$

we define $s = (p_1 + p_2)^2$, $t = (p_1 - p_t)^2$, $u = (p_2 - p_t)^2$ **and** $s_4 = s + t + u - 2m_t^2$

At partonic threshold $s_4 \to 0$

Soft corrections $\left[\frac{\ln^k(s_4/m_t^2)}{s_4}\right]_+$ **with** $k \leq 2n-1$ **for the order** α_s^n **corrections**

Factorization and Resummation of these soft-gluon corrections

Soft anomalous dimension $\Gamma_S^{f_1 f_2 \to tX}$ **controls the evolution of the soft function**

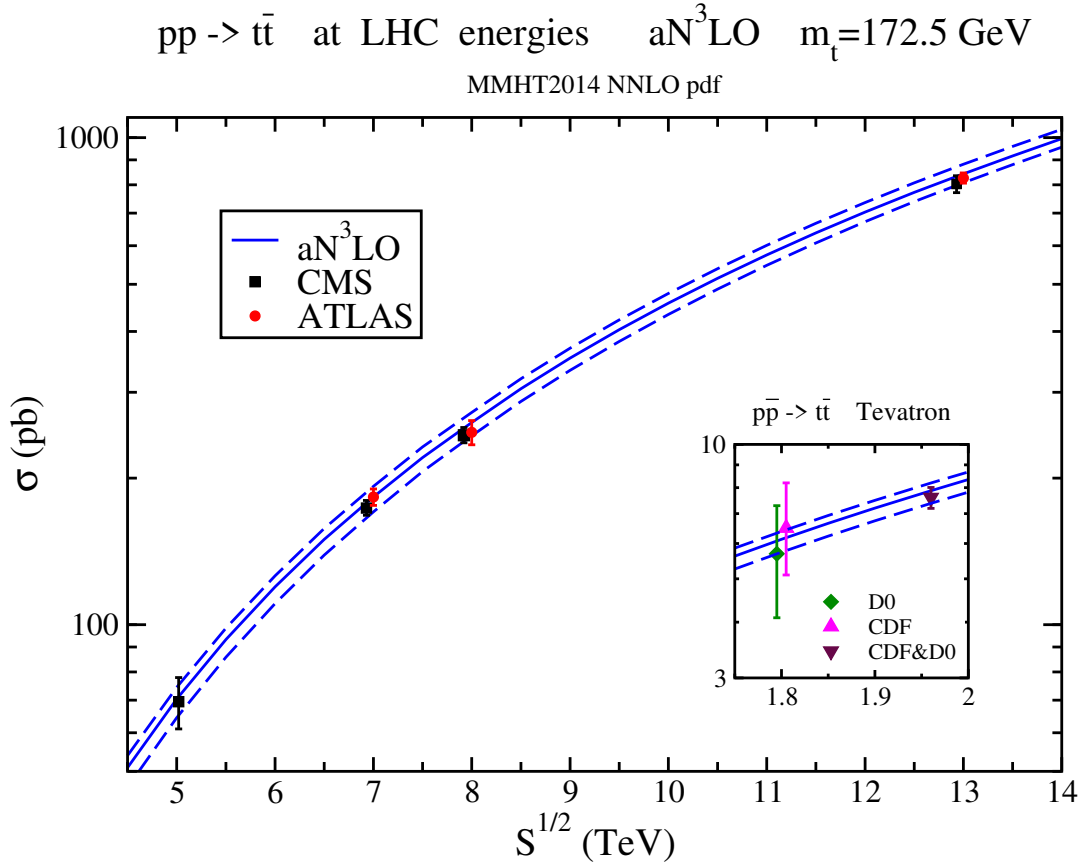
At NNLL accuracy we need two-loop results

only partial three-loop results are known

Finite-order expansions → no prescription needed

Approximate N^{3}LO (aN^{3}LO) predictions for total cross sections
and for (single and double) differential distributions

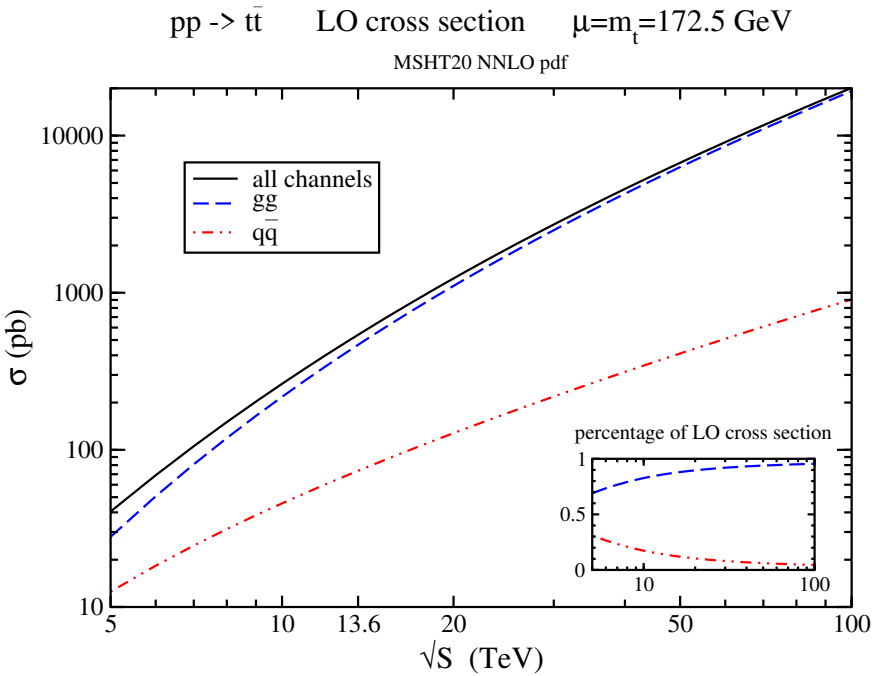
Top-antitop pair production

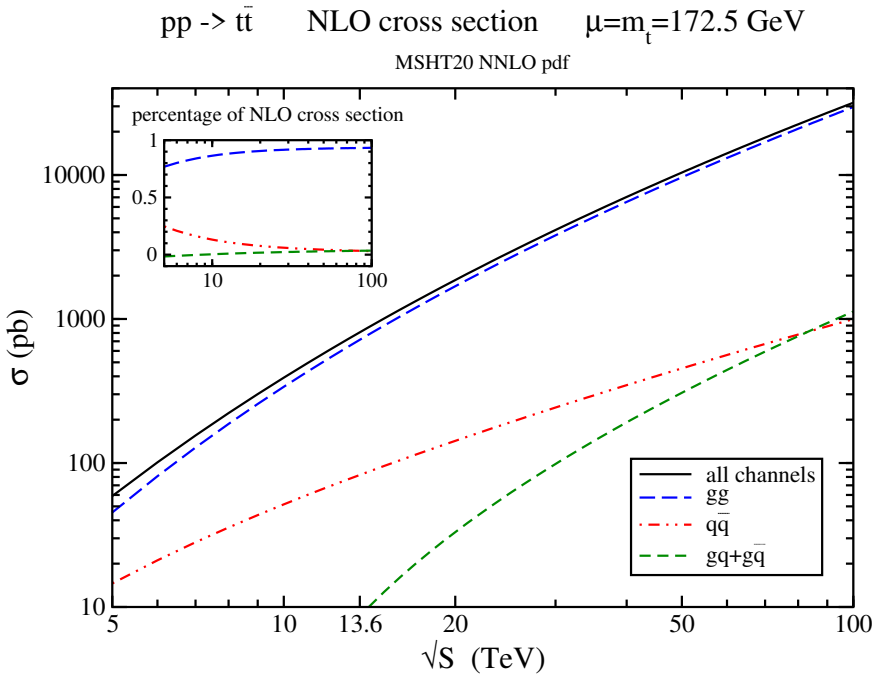


soft-gluon corrections are dominant in total & differential cross sections

excellent agreement with collider data

$t\bar{t}$ production at high energies





the $gg \to t\bar{t}$ channel is increasingly dominant at higher energies

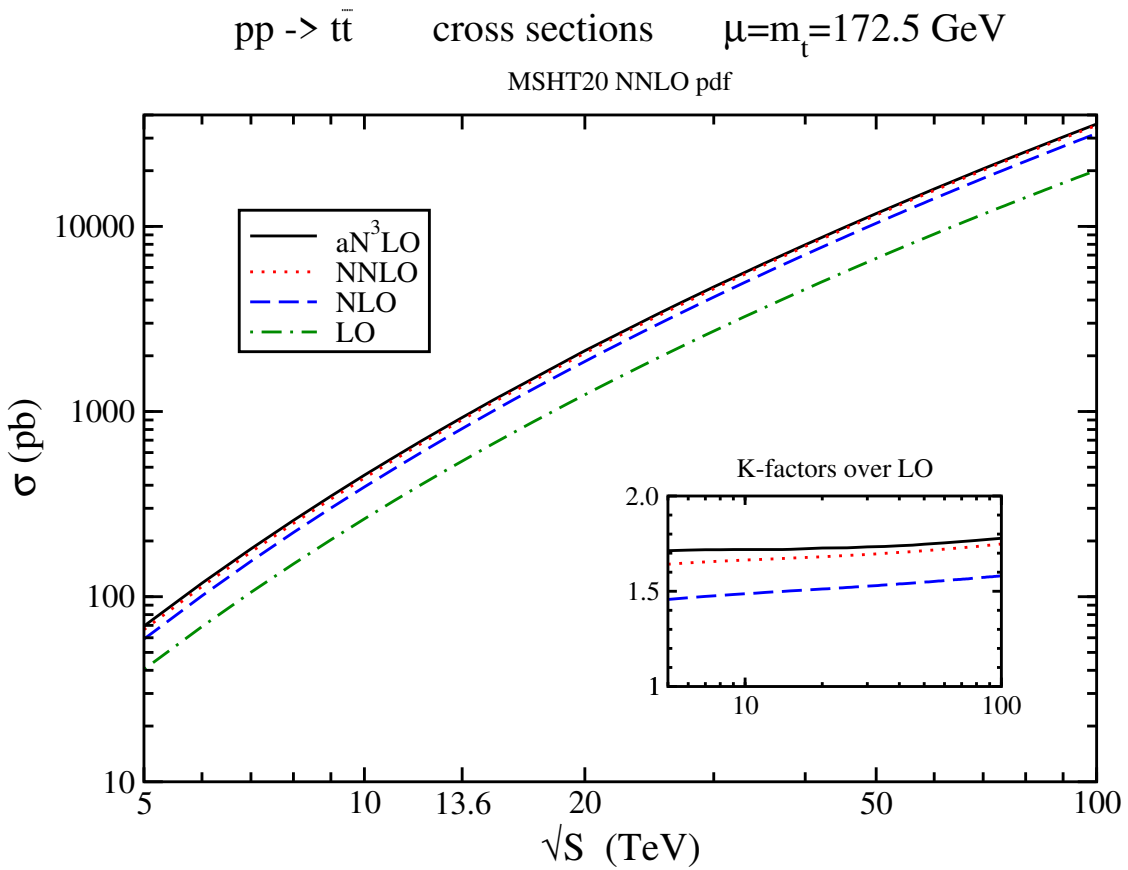
$t\bar{t}$ production cross sections

$t\bar{t}$ cross sections at LHC energies					
σ in pb	7 TeV	8 TeV	13 TeV	13.6 TeV	14 TeV
LO	106	150	488	540	576
NLO	155	222	730	809	864
NNLO	174	249	814	902	963
aN^{3}LO	181	258	839	928	990

aN^{3}LO = NNLO + soft-gluon N^{3}LO corrections

$t\bar{t}$ cross sections in high-energy pp collisions			
σ in pb	27 TeV	50 TeV	100 TeV
LO	2.23×10^3	6.72×10^3	20.1×10^3
NLO	3.39×10^3	10.4×10^3	31.8×10^3
NNLO	3.77×10^3	11.5×10^3	35.1×10^3
aN^{3}LO	3.86×10^3	11.7×10^3	35.8×10^3

aN^{3}LO $t\bar{t}$ cross sections



aN^{3}LO cross section at 13 TeV $\rightarrow 839^{+23+17}_{-18-11}$ **pb**

at 13.6 TeV $\rightarrow 928^{+25+18}_{-20-12}$ **pb**

at 14 TeV $\rightarrow 990^{+27+19}_{-22-13}$ **pb**

K-factors at LHC and higher energies

K-factors for $t\bar{t}$ production at LHC energies					
K-factor	7 TeV	8 TeV	13 TeV	13.6 TeV	14 TeV
NLO/LO	1.47	1.48	1.50	1.50	1.50
NNLO/LO	1.65	1.66	1.67	1.67	1.67
aN^{3}LO/LO	1.72	1.72	1.72	1.72	1.72
aNLO/NLO	1.01	1.00	0.99	0.99	0.99
aNNLO/NNLO	1.01	1.01	1.00	1.00	1.00

aNLO = LO + soft-gluon NLO corrections

aNNLO = NLO + soft-gluon NNLO corrections

K-factors for $t\bar{t}$ production in pp collisions			
K-factor	27 TeV	50 TeV	100 TeV
NLO/LO	1.52	1.55	1.58
NNLO/LO	1.69	1.71	1.75
aN^{3}LO/LO	1.73	1.75	1.78
aNLO/NLO	0.97	0.95	0.92
aNNLO/NNLO	1.00	0.99	0.98

Summary

- **top-antitop pair production in high-energy pp collisions**
- **quality of soft-gluon approximation at LHC energies is excellent and it remains very good even at much higher energies**
- **soft-gluon corrections are dominant and they are significant through aN^{3}LO**