determination of the top-quark mass from single top-quark production in hadronic collisions

Stephan Thier
in collaboration with
Sergey Alekhin and Sven-Olaf Moch

single top production channels

http://seigner.deviantart.com/art/Feynman-wallpaper-242758506

13.04.2016, STEPHAN THIER, DIS16

# production channels for single top quarks
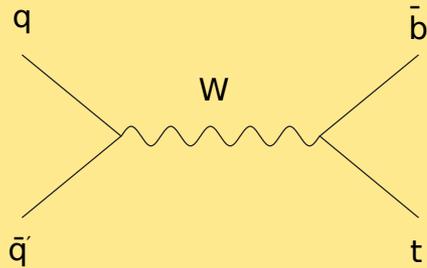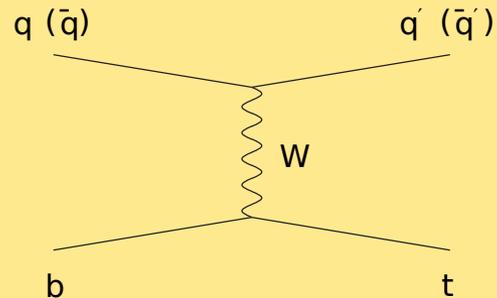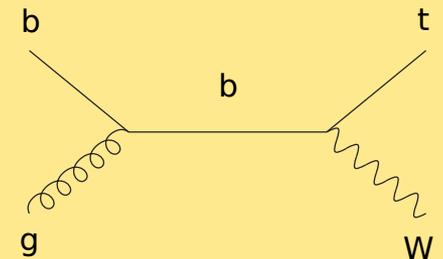
independent of gluon PDFs at LO

cross section measurements: s-channel

S

q $\bar{b}$

W

$\bar{q}'$ t
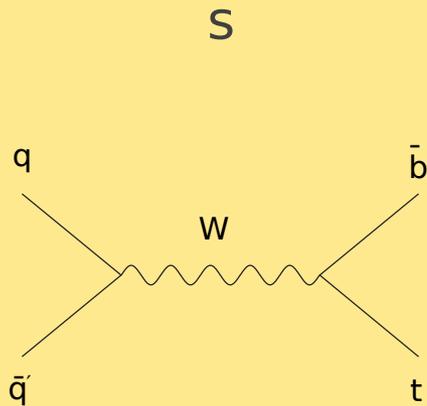
	Tevatron	LHC	
	CDF & D0	ATLAS	CMS
	1.96 TeV	8 TeV	
	(1.29 ± 0.26)pb	(4.8 ± 2.4)pb	(13.4 ± 7.3)pb
	6.3σ	3.2σ	2.5σ
	1402.5126	1511.05980	1603.02555

cross section measurements: t-channel

t

q $(\bar{q})$ q´ $(\bar{q}´)$

W

b   t
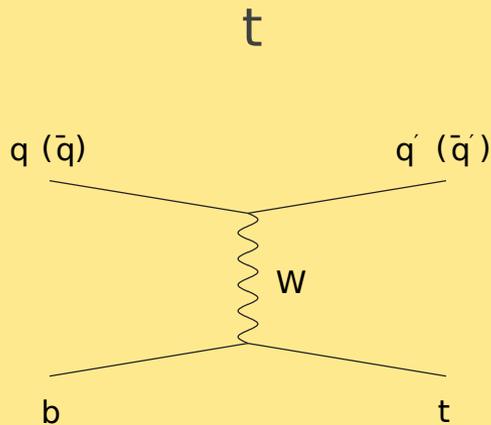
Tevatron	LHC
CDF & D0	ATLAS & CMS
1.96 TeV	8 TeV
(2.25±0.31)pb	(85±12)pb
1503.05027	CMS-PAS-TOP-12-002 &
	ATLAS-CONF-2013-098

single top: impact of NLO corrections

- s-channel (Smith & Willenbrock hep-ph/9604223)

  – Tevatron: +54%

  – LHC: +50%

- t-channel (Stelzer, Sullivan & Willenbrock hep-ph/9705398)

  – Tevatron: -8%

  – LHC: -9%

s-channel NNLO approximation calculation and software implementation

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

s-channel: soft gluon corrections

virtual + real

$$\alpha_s^n \left[\frac{\ln^k(s_4/m_t^2)}{s_4} \right]_+$$
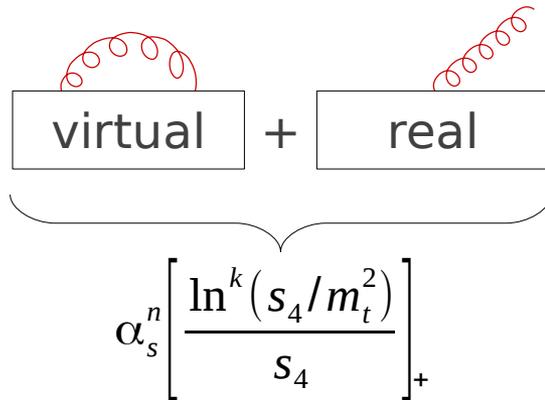
$$s = (p_1 + p_2)^2$$
$$t = (p_1 - p_3)^2$$
$$u = (p_2 - p_3)^2$$
$$s_4 = s + t + u - m_t^2$$
$$k \leq 2n - 1$$

q   t
W
q̄′

invariant mass s_4
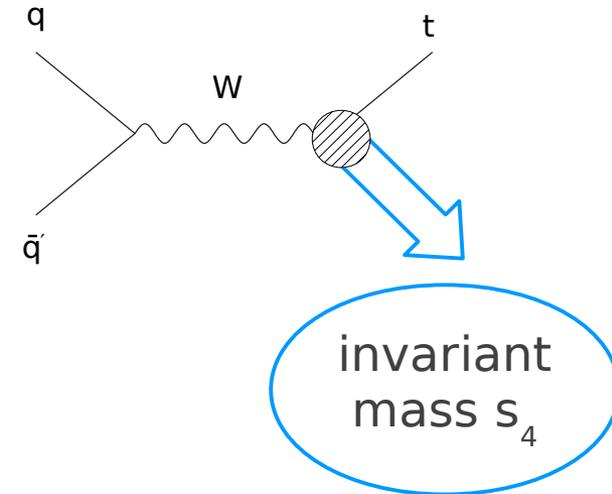
fixed order: α_s^n	NLO	NNLO	N3LO
LL: $\alpha_s^n \ln^{2n-1}$	$\alpha_s^1 \ln^1$	$\alpha_s^2 \ln^3$	$\alpha_s^3 \ln^5$
NLL: $\alpha_s^n \ln^{2n-2}$	$\alpha_s^1 \ln^0$	$\alpha_s^2 \ln^2$	$\alpha_s^3 \ln^4$
NNLL: $\alpha_s^n \ln^{2n-3}$		$\alpha_s^2 \ln^1$	$\alpha_s^3 \ln^3$
N3LL: $\alpha_s^n \ln^{2n-4}$		$\alpha_s^2 \ln^0$	$\alpha_s^3 \ln^2$
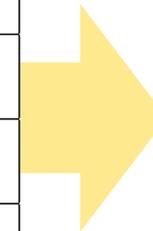
Kidonakis
hep-ph/0609287

s-channel: NNLO approximation in Hathor

$$\frac{d\sigma}{du\,dt}$$
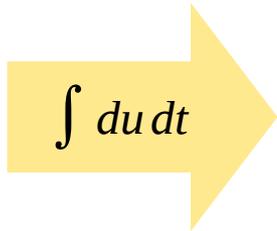
$\int du\,dt$ → Alekhin, Moch, ST ← code Hathor 2.0
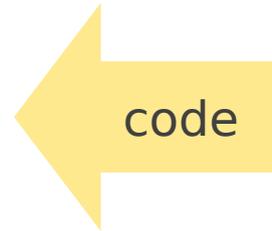
Kidonakis

hep-ph/0609287

Uwer et al.
1007.1327
1406.4403

s-channel NNLO approximation: impact

- m_{top} pole = 170 GeV
- CT14nnlo

$p\bar{p}$ 1.96 TeV:

perturbative order	cross section [pb]
LO	0.727
NLO	1.024
NNLO approx	1.101

+7.6%

pp 8 TeV:

perturbative order	cross section [pb]
LO	2.756
NLO	3.730
NNLO approx	3.981

+6.7%

pole mass (172.5 GeV): scale variation

- pp 8 TeV, abm12lhc_5_nnlo
- scales relative to top mass
- cross section relative to central value

μ_R

NLO

μ_F

	0.5	1	2
0.5	1.0222	0.9965	
1	1.0256	1	0.9789
2		1.0046	0.9831

+2.6%   -2.1%

NNLO approx

	0.5	1	2
0.5	1.0179	0.9885	
1	1.0295	1	0.9752
2		1.0133	0.9882

+3.0%   -2.5%

$\overline{\mathrm{MS}}$ mass (163 GeV): scale variation

- pp 8 TeV, abm12lhc_5_nnlo
- scales relative to top mass
- cross section relative to central value

μ_R

μ_F

NLO

	0.5	1	2
0.5	1.0136	0.9981	
1	1.0147	1	0.9877
2		1.0037	0.9915

+1.5% -1.2%

NNLO approx

	0.5	1	2
0.5	0.9962	0.9875	
1	1.0092	1	0.9917
2		1.0158	1.0069

+1.6% -1.3%

impact of perturbative corrections

- s-channel single top
- CT14nnlo
- Tevatron
- 1.96 TeV

- LO
- NLO
- NNLO approx
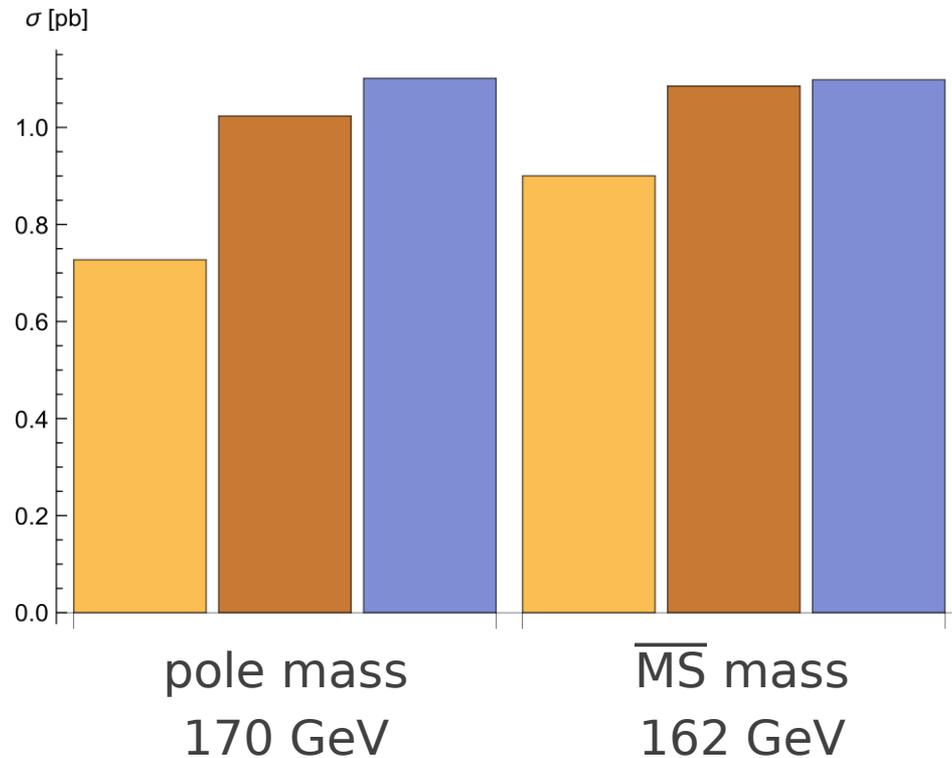
impact of perturbative corrections

- s-channel single top
- CT14nnlo
- LHC
- 8 TeV

■ LO

■ NLO

■ NNLO approx
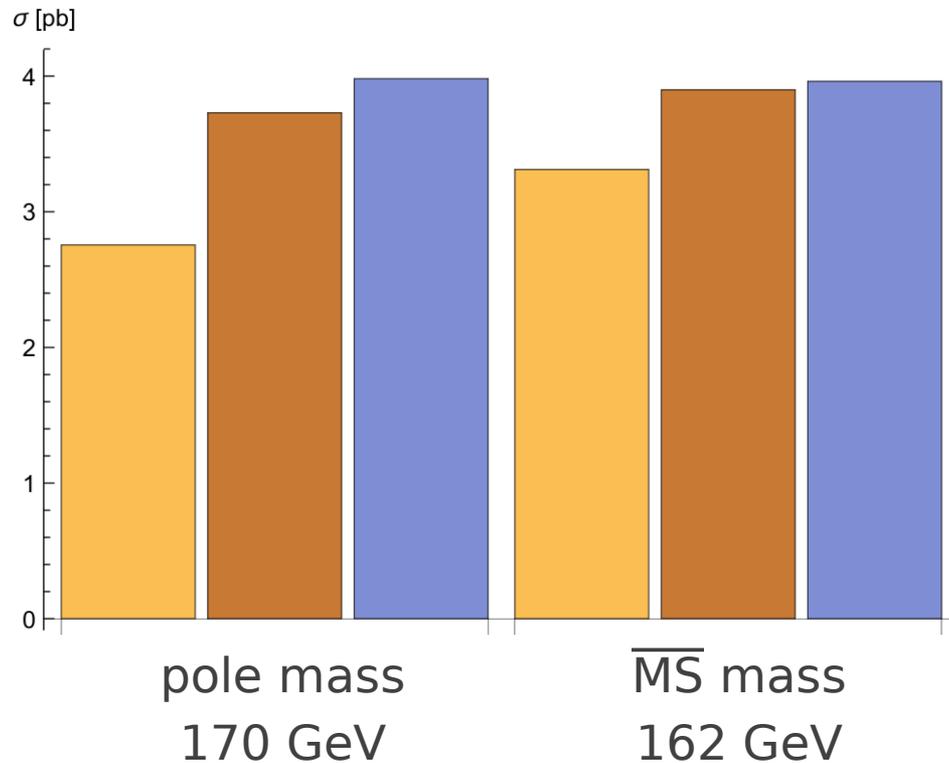
top quark
mass fits
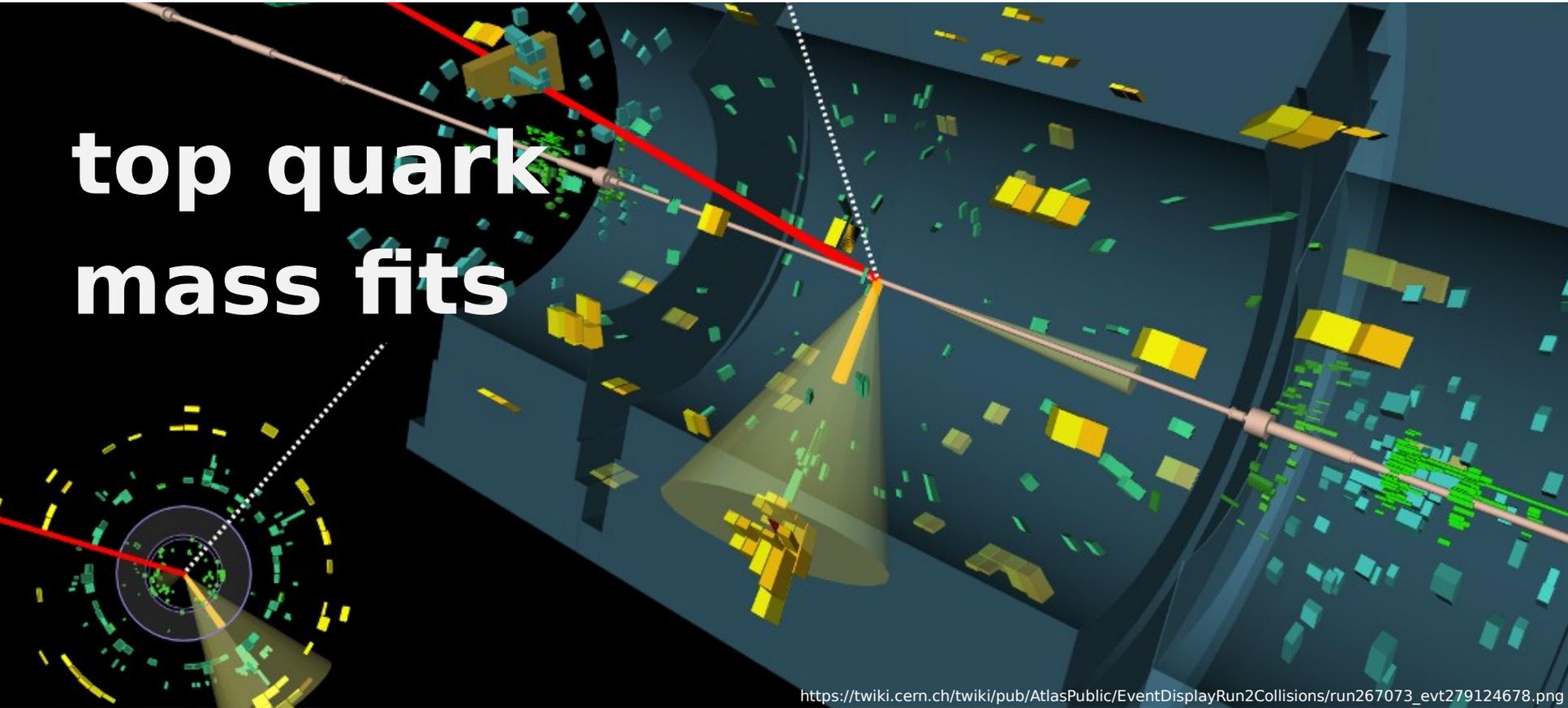
13.04.2016, STEPHAN THIER, DIS16

$\overline{\text{MS}}$ mass fit: $t\bar{t}$

- ATLAS, CMS: LHCtopWG Sep, Nov 2015
- CDF & D0: 1309.7570
- NNLO
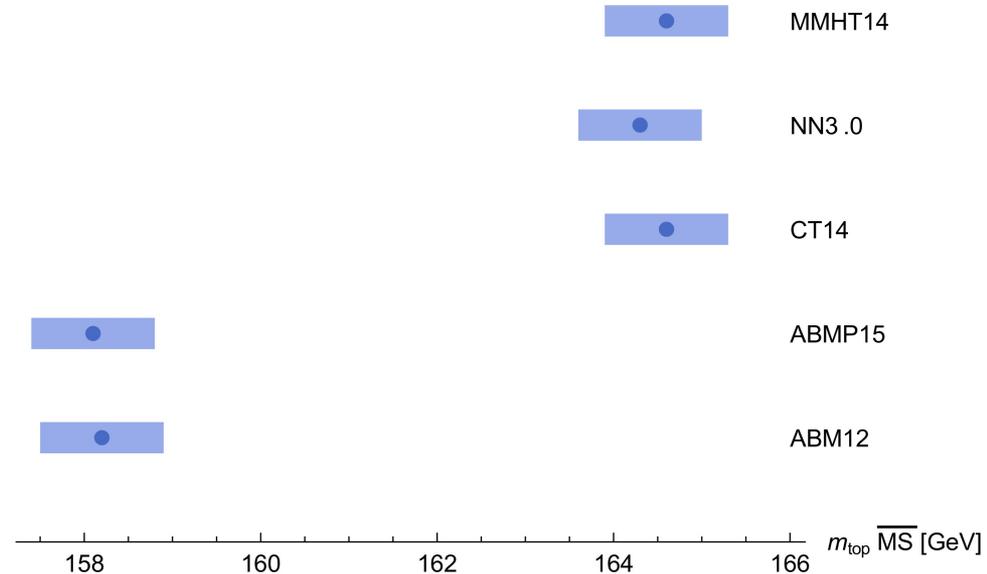
$\overline{\text{MS}}$ mass fit: single top t-channel

- ATLAS: 1406.7844, 1411.7627
- CMS: 1209.4533, 1403.7366
- CDF & D0: 1503.05027
- t: NLO times k-factor 0.984
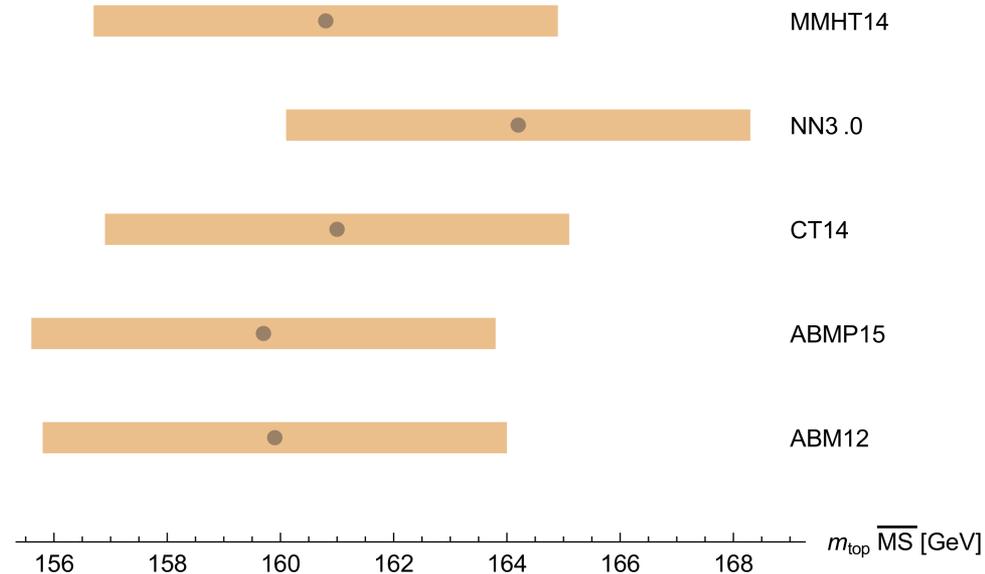
$\overline{\text{MS}}$ mass fit: single top t- & s-channel

- ATLAS: 1406.7844, 1411.7627
- CMS: 1209.4533, 1403.7366
- CDF & D0: 1503.05027
- t: NLO times k-factor 0.984
- s: NNLO threshold approx
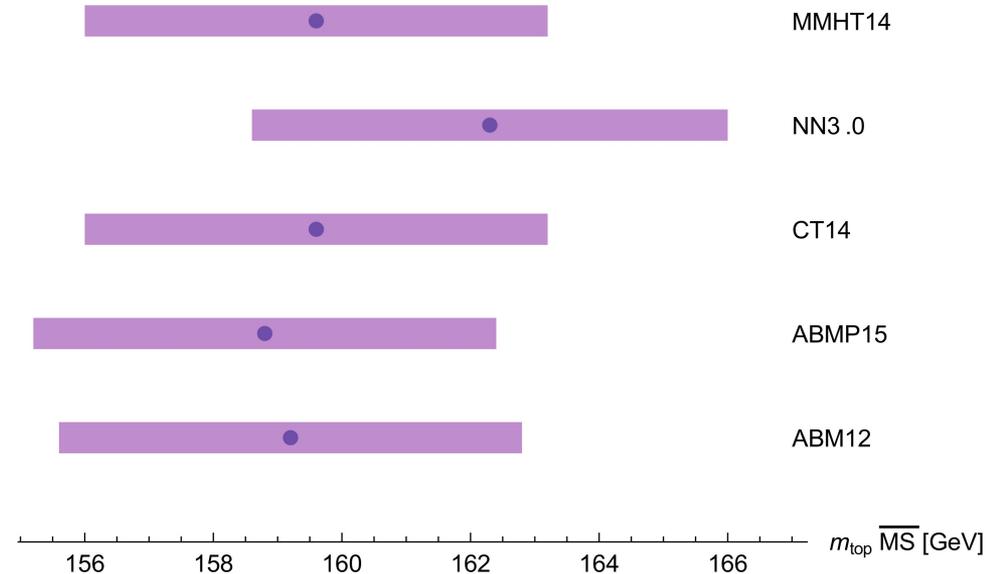
$\overline{\text{MS}}$ mass fit: comparison

$m_{\text{top}}\ \overline{\text{MS}}$ [GeV]
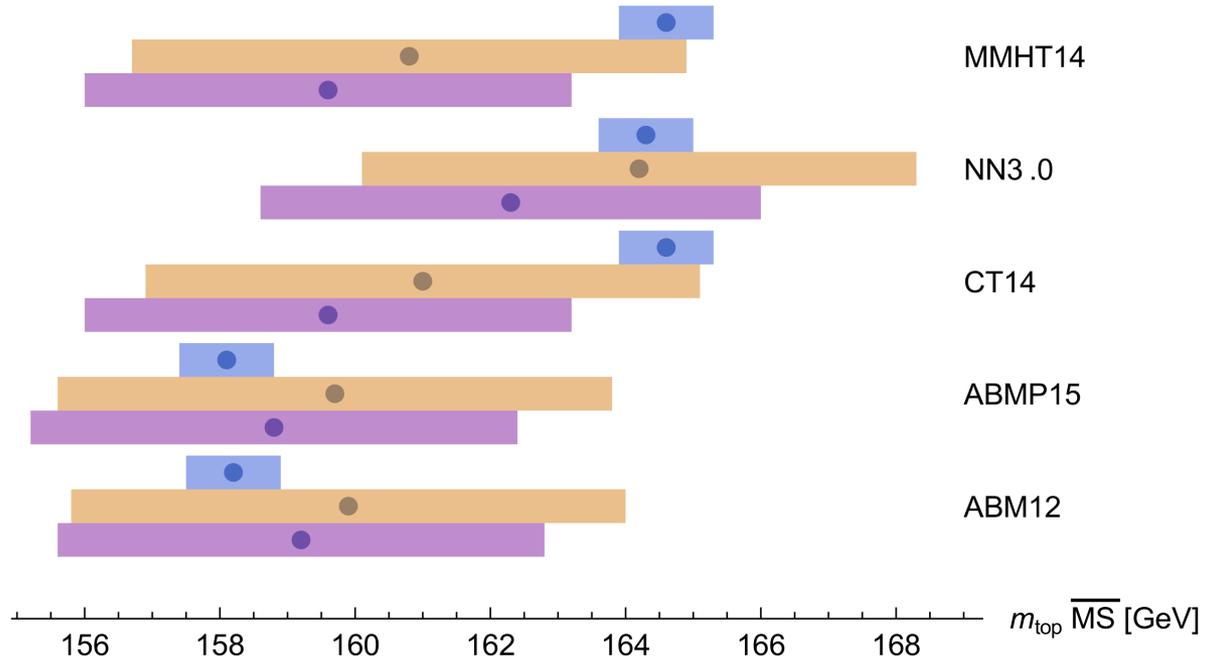
- $t\bar{t}$
- single top t–channel
- single top t– & s–channel

summary

- single-top production as complementary way to determine the top-quark mass
- implementation of approximate NNLO terms for s-channel single-top production in Hathor
- $\overline{MS}$ mass: less sensitivity to scale variations and faster convergence of perturbative expansion
- mismatch of extracted top-quark masses for various PDFs based on measured $t\bar{t}$ cross section
- better agreement of extracted top-quark masses for various PDFs based on measured single top cross sections

THANK YOU FOR YOUR ATTENTION!

backup

single top cross sections at the LHC
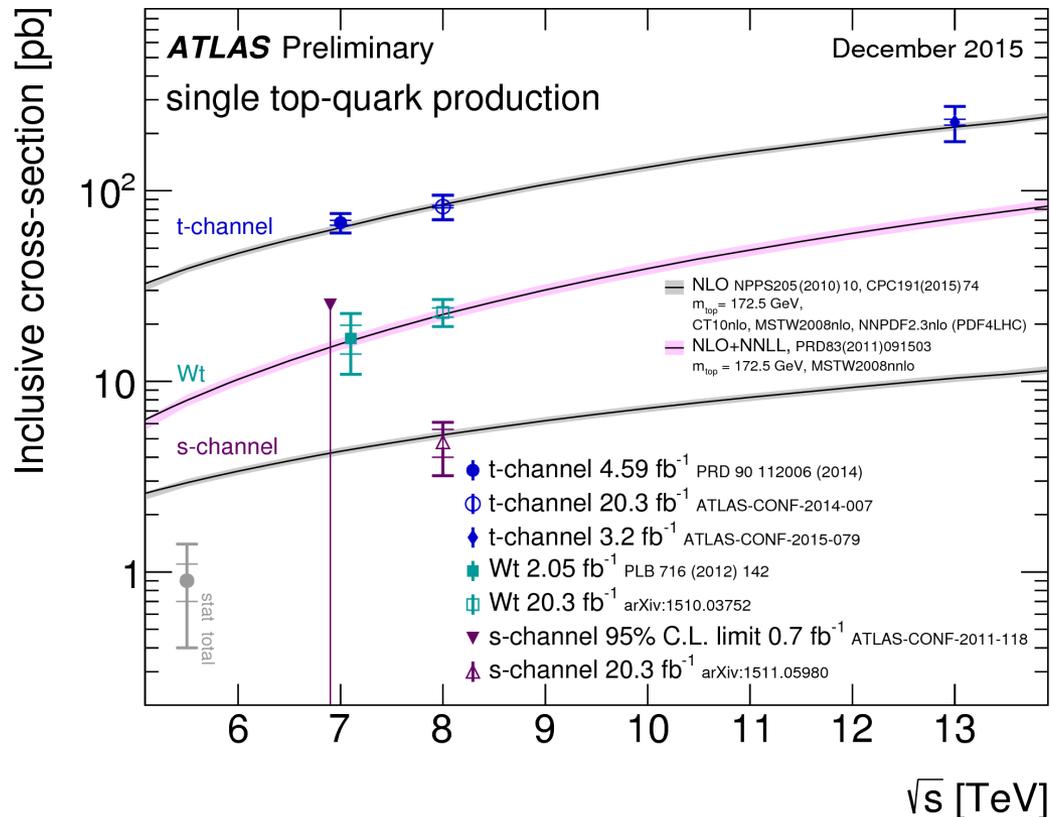
pole mass fit: single top s-channel

- CDF & D0 1503.05027: (1.29 ± 0.26)pb
- Hathor NLO + NNLO approximation