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

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in collaboration with
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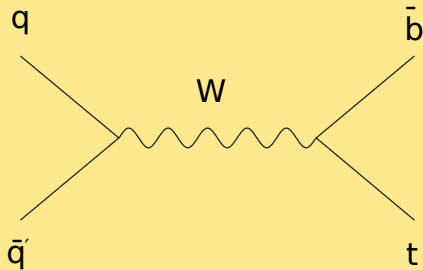
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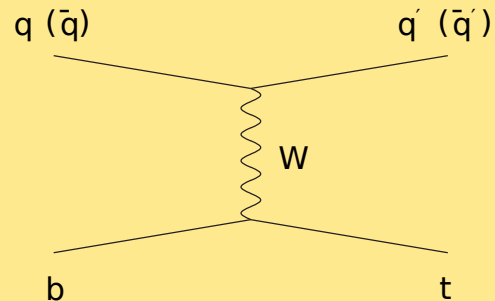
<http://seigner.deviantart.com/art/Feynman-wallpaper-242758506>

production channels for single top quarks

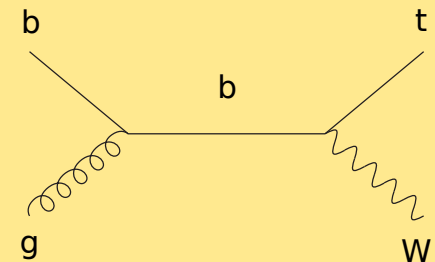
s



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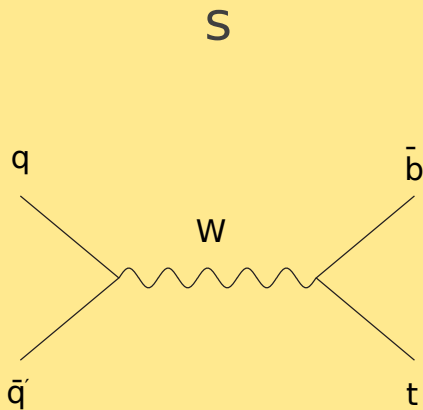


associated tW



independent of gluon PDFs at LO

cross section measurements: s-channel



Tevatron

LHC

CDF & D0

ATLAS CMS

1.96 TeV

8 TeV

$(1.29 \pm 0.26) \text{ pb}$

$(4.8 \pm 2.4) \text{ pb}$ $(13.4 \pm 7.3) \text{ pb}$

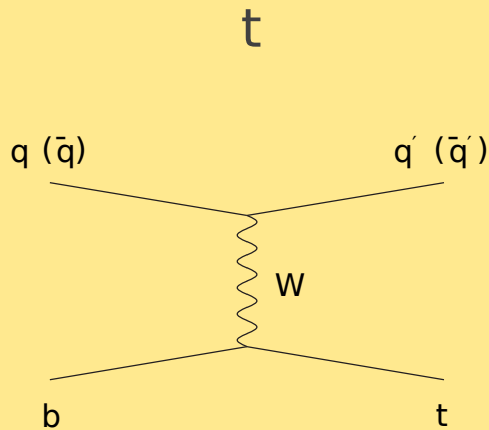
6.3σ

3.2σ 2.5σ

1402.5126

1511.05980 1603.02555

cross section measurements: t-channel



Tevatron

CDF & D0
1.96 TeV
 $(2.25 \pm 0.31) \text{ pb}$
1503.05027

LHC

ATLAS & CMS
8 TeV
 $(85 \pm 12) \text{ pb}$
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

```
#define SYMBOL_TABLE

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <stdbool.h>

/**
 * @brief singly linked list data structure#
 */
struct symbol_node {
    char *name;
    struct symbol_node *next;
};

// Singly linked list
struct symbol_node *symbol_table;

/**
 * @brief Add new element to symbol_table
 *
 * @param name The name of the element to add
 */
void add_symbol(const char *name);

/**
 * @brief Look up element in symbol_table
 *
 * @param name The name of the element to look up
 * @return true if found, false otherwise
 */
bool lookup_symbol(const char *name) {
    for (struct symbol_node *it = symbol_table; it != NULL; it = it->next) {
        if (strcmp(it->name, name) == 0) {
            /* printf("found %s\n", name); */
            return true;
        }
    }
    return false;
}

struct symbol_node *new_symbol = malloc(sizeof(struct symbol_node));
new_symbol->name = strdup(name);
new_symbol->next = symbol_table;
symbol_table = new_symbol;
} else {
    symbol_table = malloc(sizeof(struct symbol_node));
    symbol_table->name = strdup(name);
    symbol_table->next = NULL;
}
}

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s-channel: soft gluon corrections

virtual + real

$$\alpha_s^n \left[\frac{\ln^k(s_4/m_t^2)}{s_4} \right]_+$$

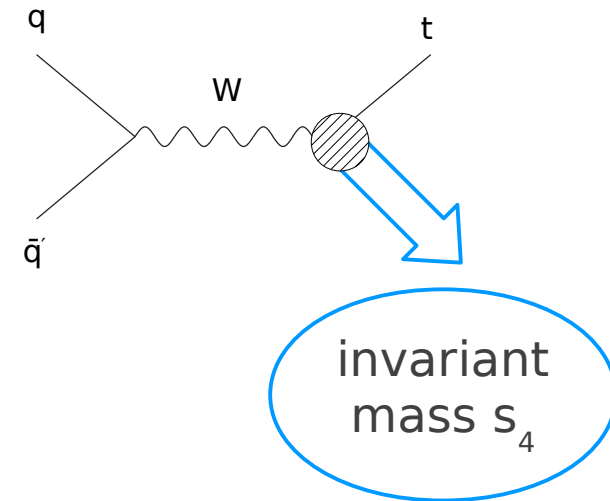
$$s = (p_1 + p_2)^2$$

$$t = (p_1 - p_3)^2$$

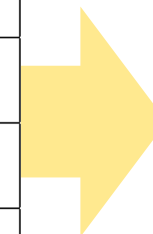
$$u = (p_2 - p_3)^2$$

$$s_4 = s + t + u - m_t^2$$

$$k \leq 2n - 1$$



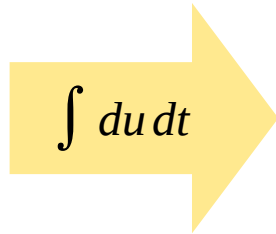
fixed order: α_s^n	NLO	NNLO	N3LO
LL: $\alpha_s^n \ln^{2n-1}$	$\alpha_s^1 \ln^1$	$\alpha_s^2 \ln^3$	$\alpha_s^3 \ln^5$
NLL: $\alpha_s^n \ln^{2n-2}$	$\alpha_s^1 \ln^0$	$\alpha_s^2 \ln^2$	$\alpha_s^3 \ln^4$
NNLL: $\alpha_s^n \ln^{2n-3}$		$\alpha_s^2 \ln^1$	$\alpha_s^3 \ln^3$
N3LL: $\alpha_s^n \ln^{2n-4}$		$\alpha_s^2 \ln^0$	$\alpha_s^3 \ln^2$



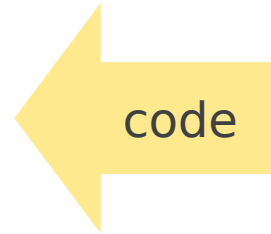
Kidonakis
hep-ph/0609287

s-channel: NNLO approximation in Hathor

$$\frac{d\sigma}{du dt}$$



Alekhin, Moch, ST



Hathor 2.0

Kidonakis
hep-ph/0609287

Uwer et al.
1007.1327
1406.4403

s-channel NNLO approximation: impact

- $m_{\text{top pole}} = 170 \text{ GeV}$
- 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			
		μ_F			
NLO			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%

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

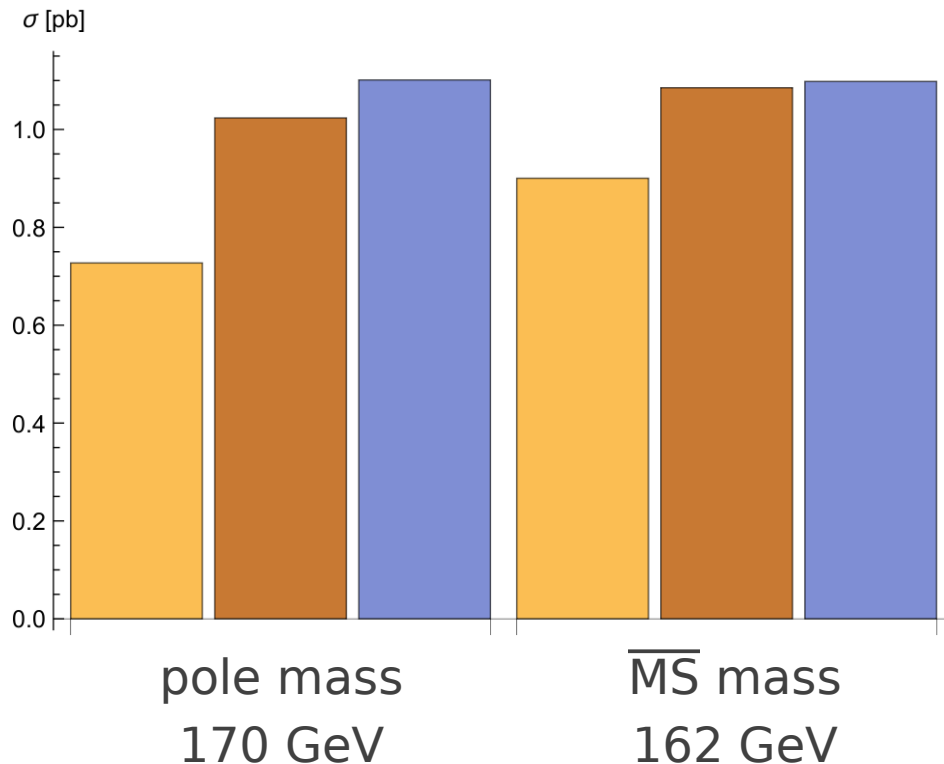
- pp 8 TeV, abm12lhc_5_nnlo
- scales relative to top mass
- cross section relative to central value

		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

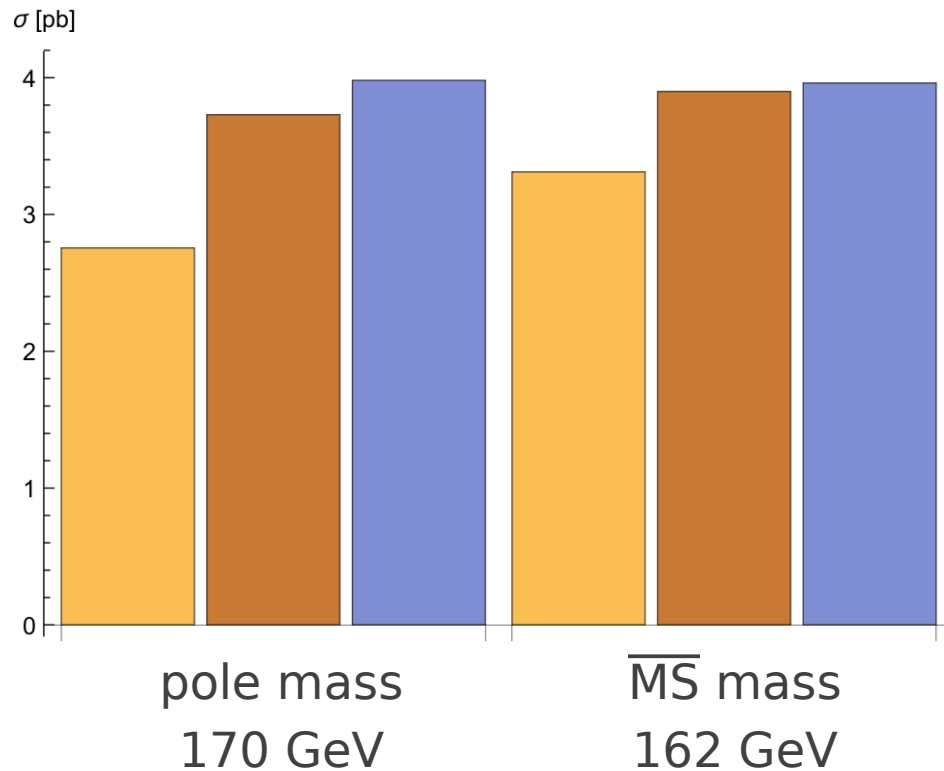
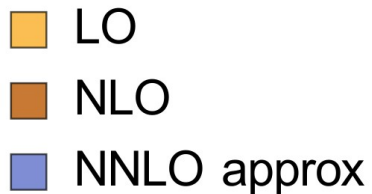
- s-channel single top
- CT14nnlo
- Tevatron
- 1.96 TeV

- LO
- NLO
- NNLO approx



impact of perturbative corrections

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

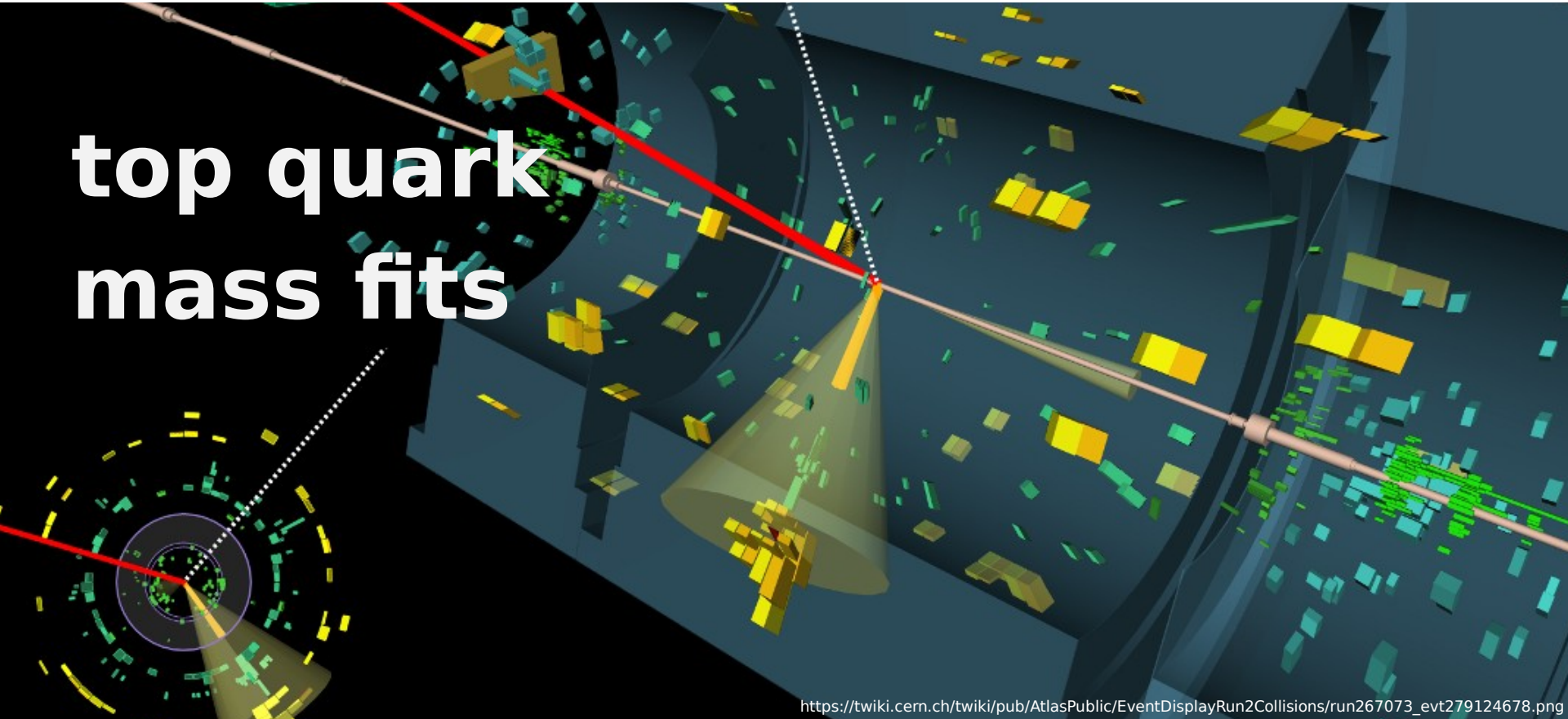




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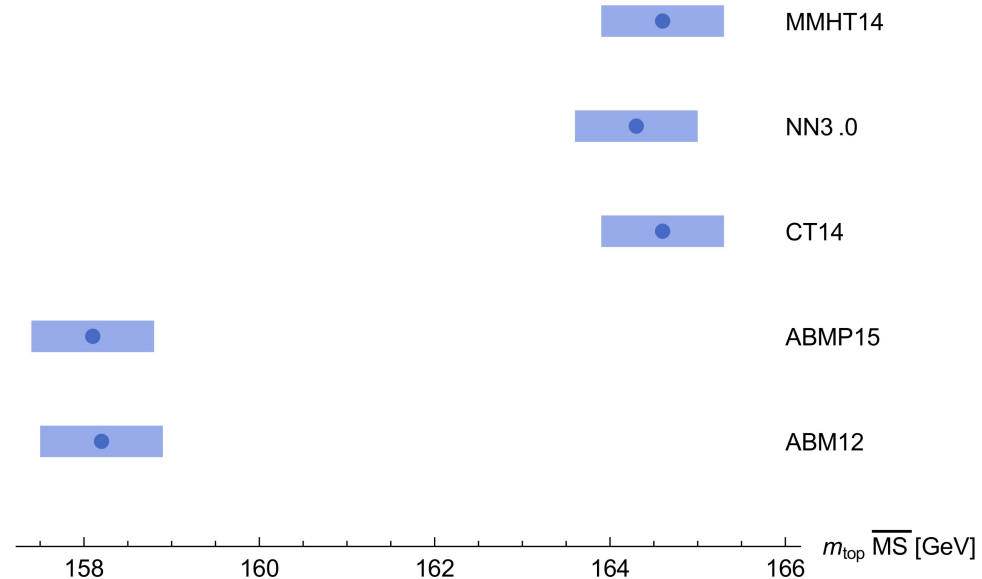
top quark mass fits



https://twiki.cern.ch/twiki/pub/AtlasPublic/EventDisplayRun2Collisions/run267073_evt279124678.png

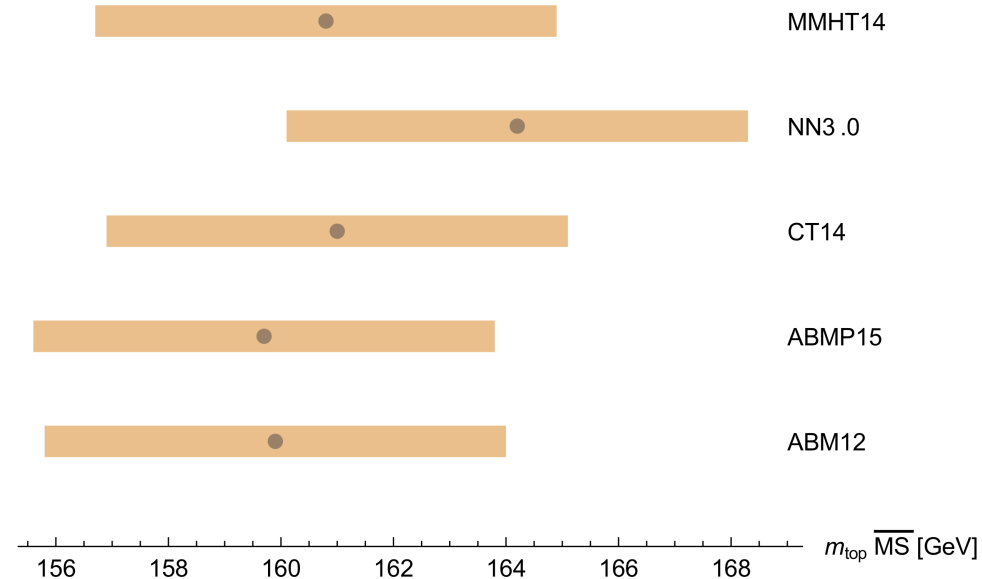
\overline{MS} mass fit: $t\bar{t}$

- ATLAS, CMS: LHCtopWG Sep, Nov 2015
- CDF & D0: 1309.7570
- NNLO



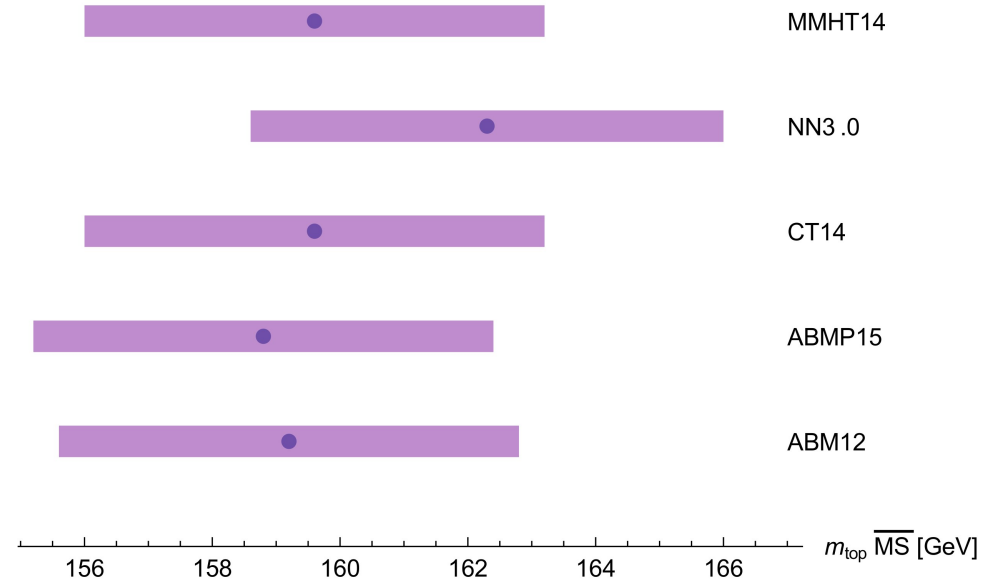
\overline{MS} mass fit: single top t-channel

- ATLAS: 1406.7844, 1411.7627
- CMS: 1209.4533, 1403.7366
- CDF & D0: 1503.05027
- t: NLO times k-factor 0.984

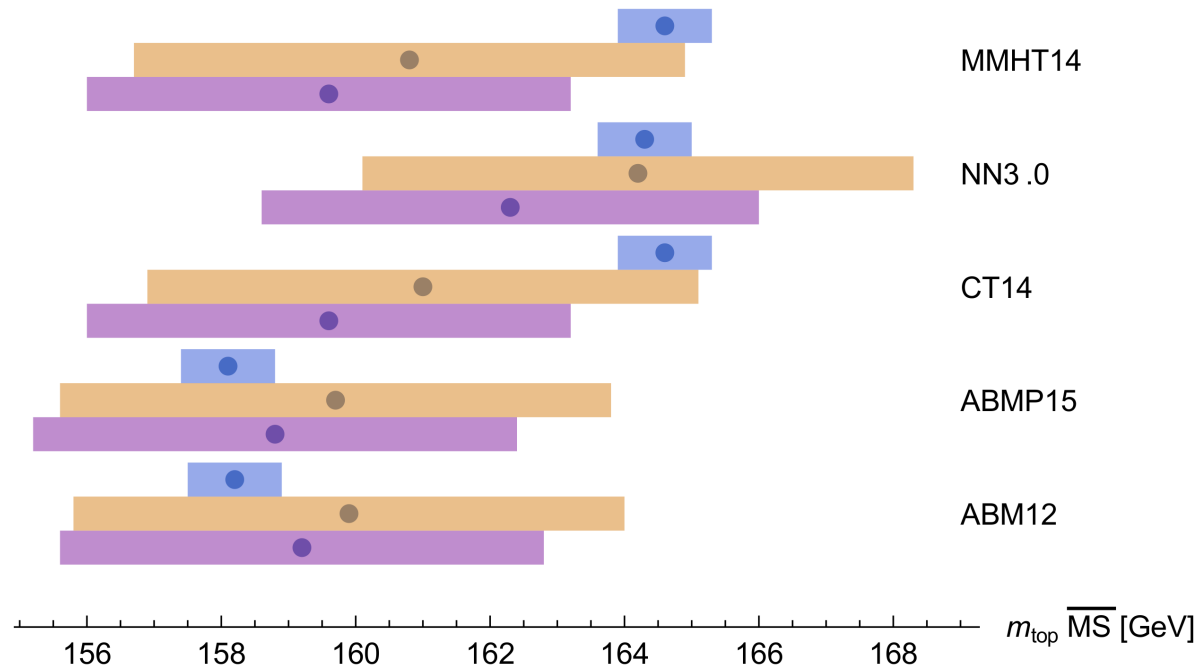


\overline{MS} mass fit: single top t- & s-channel

- 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



- $t\bar{t}$
- 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!



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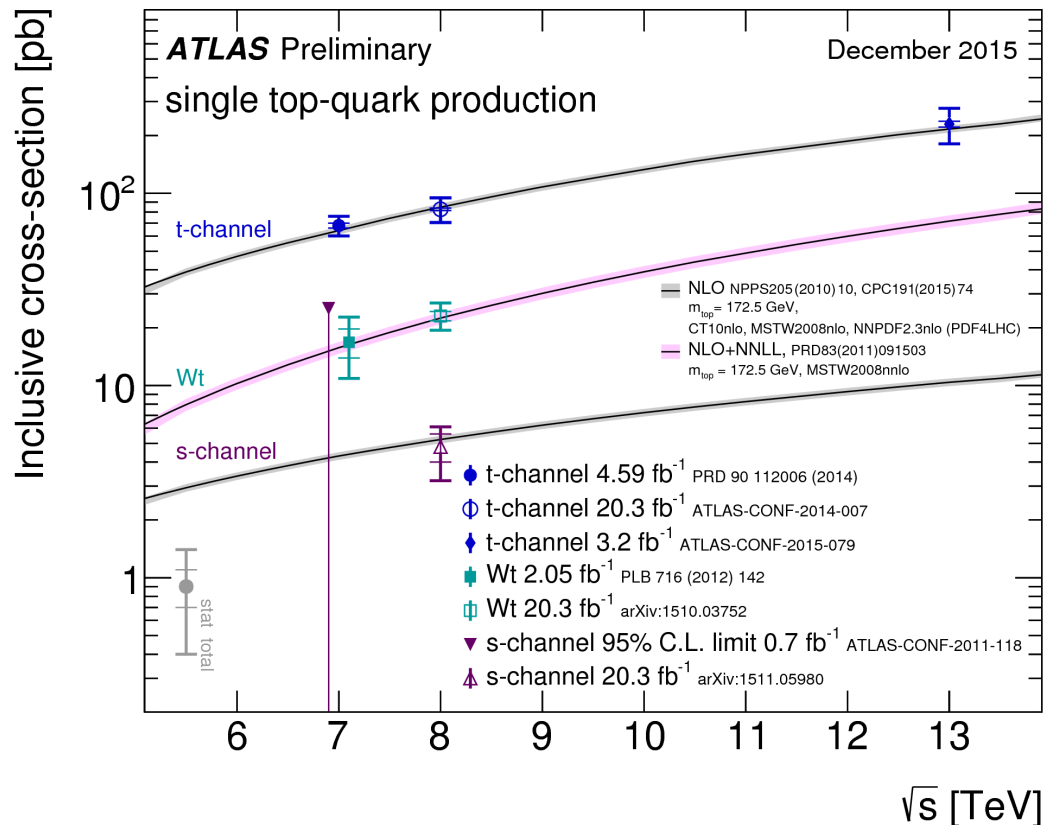
backup



<https://cdn2.artstation.com/p/assets/images/images/001/717/182/large/teodor-lys-perspective.jpg?1451606060>

13.04.2016, STEPHAN THIER, DIS16

single top cross sections at the LHC



pole mass fit: single top s-channel

- CDF & D0 1503.05027: $(1.29 \pm 0.26)\text{pb}$
- Hathor NLO + NNLO approximation

