WHEN MEASURING TOP QUARK RUNNING MASS

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杭州师范大学

CEPC @ 线上
2022-10-26

STRONG COUPLING CONSTANT

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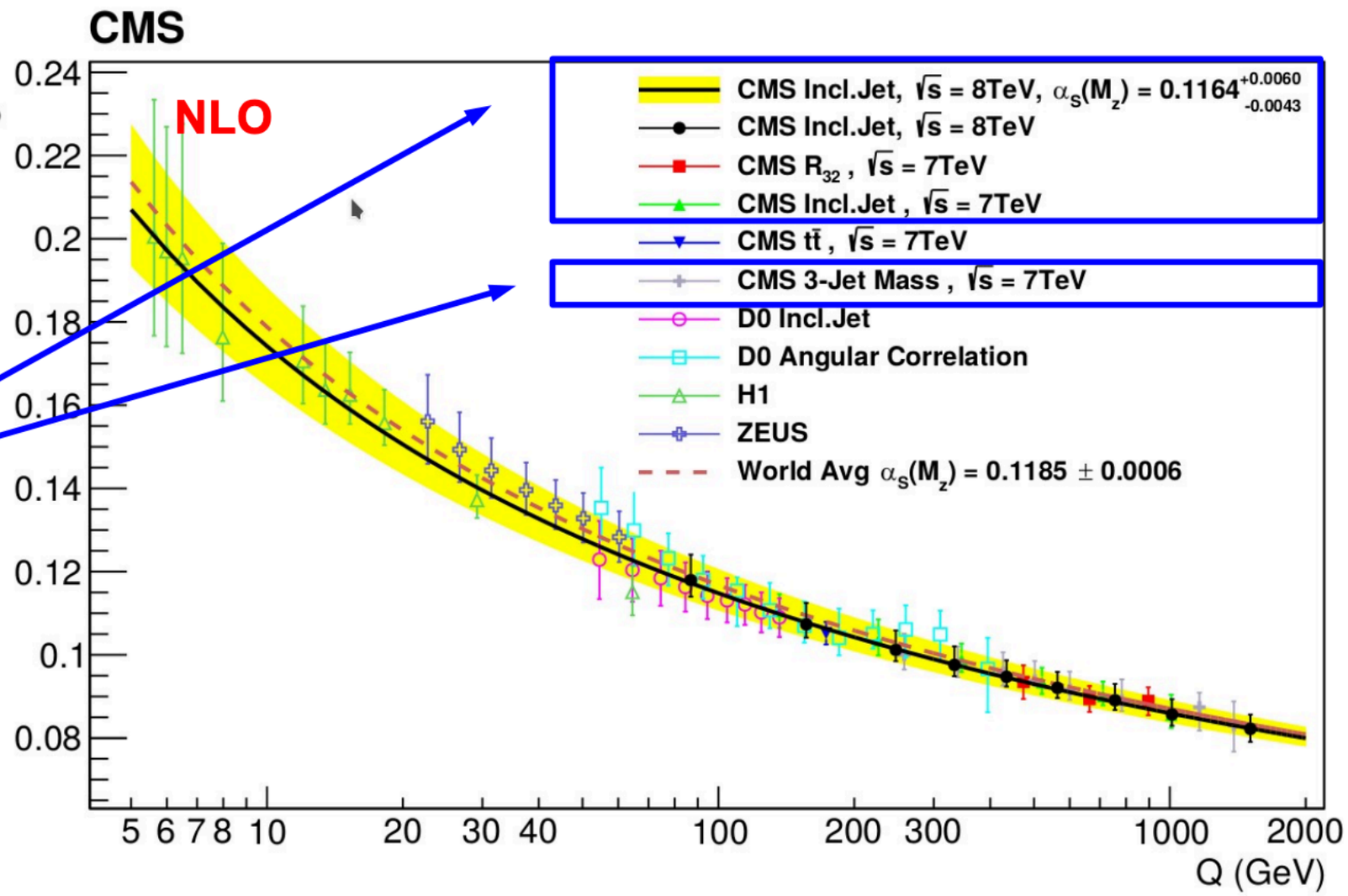
Perform fits in fixed intervals of the chosen scale Q

$\alpha_s(Q)$

Jet cross sections and ratios at NLO



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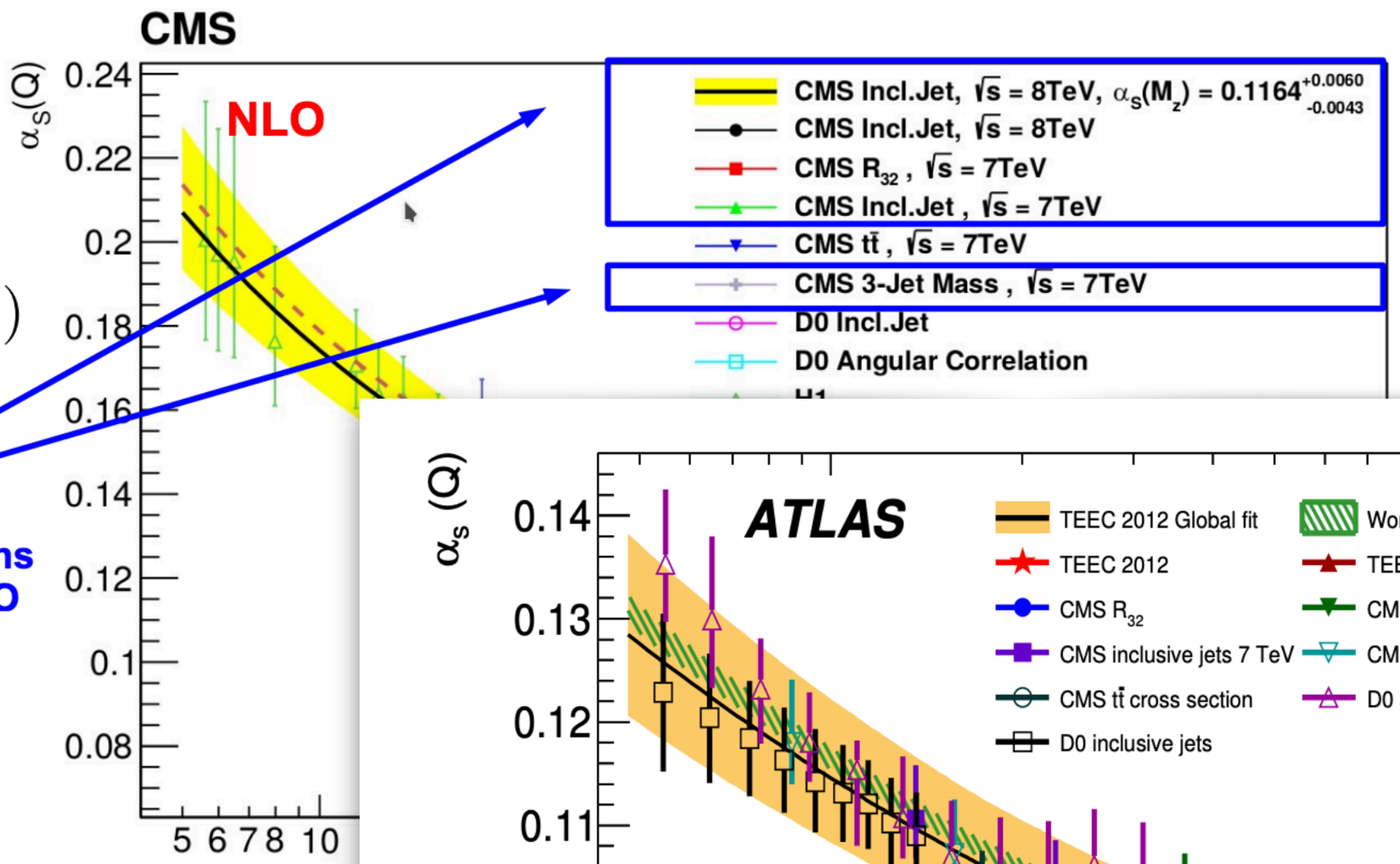

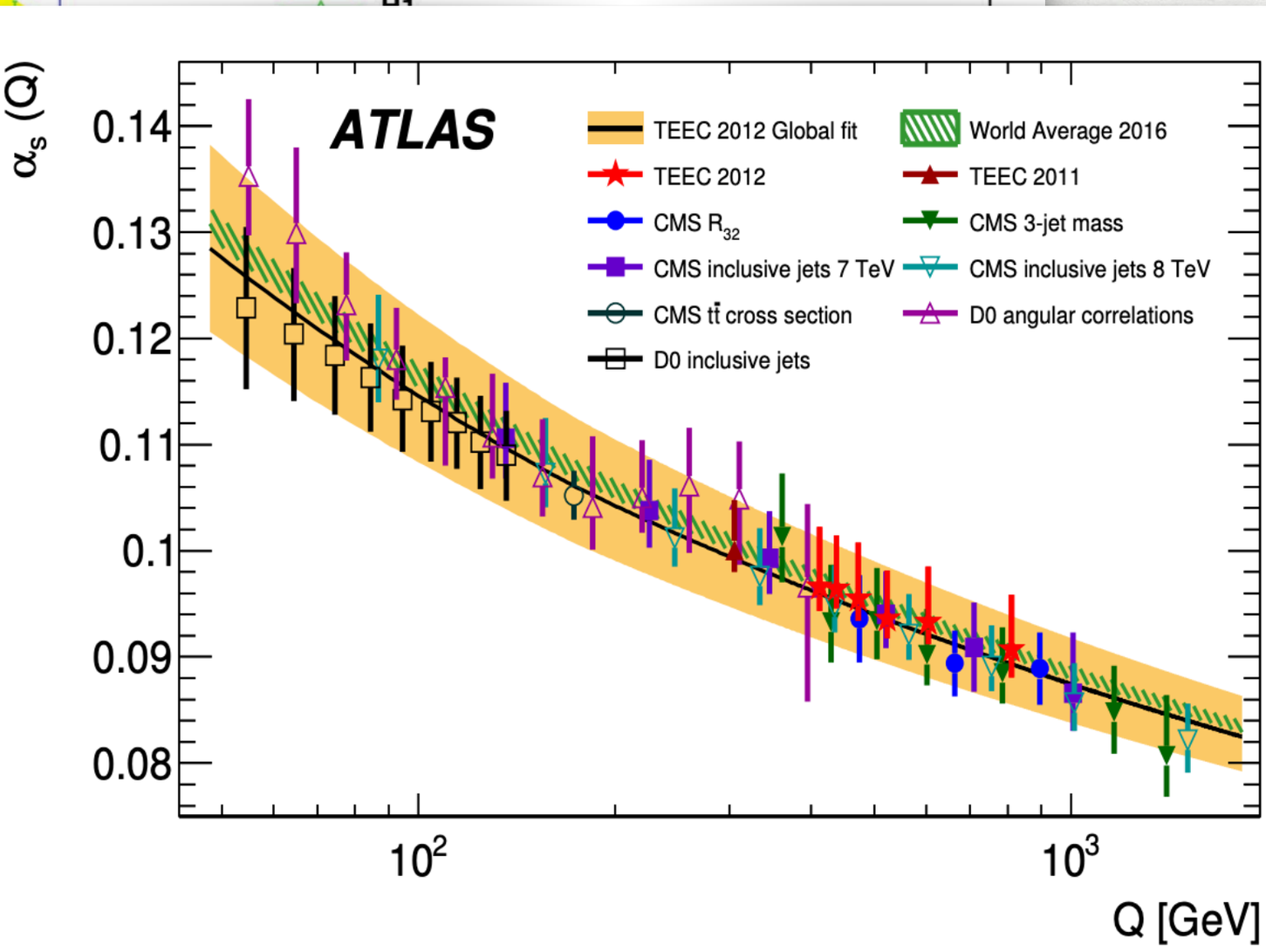

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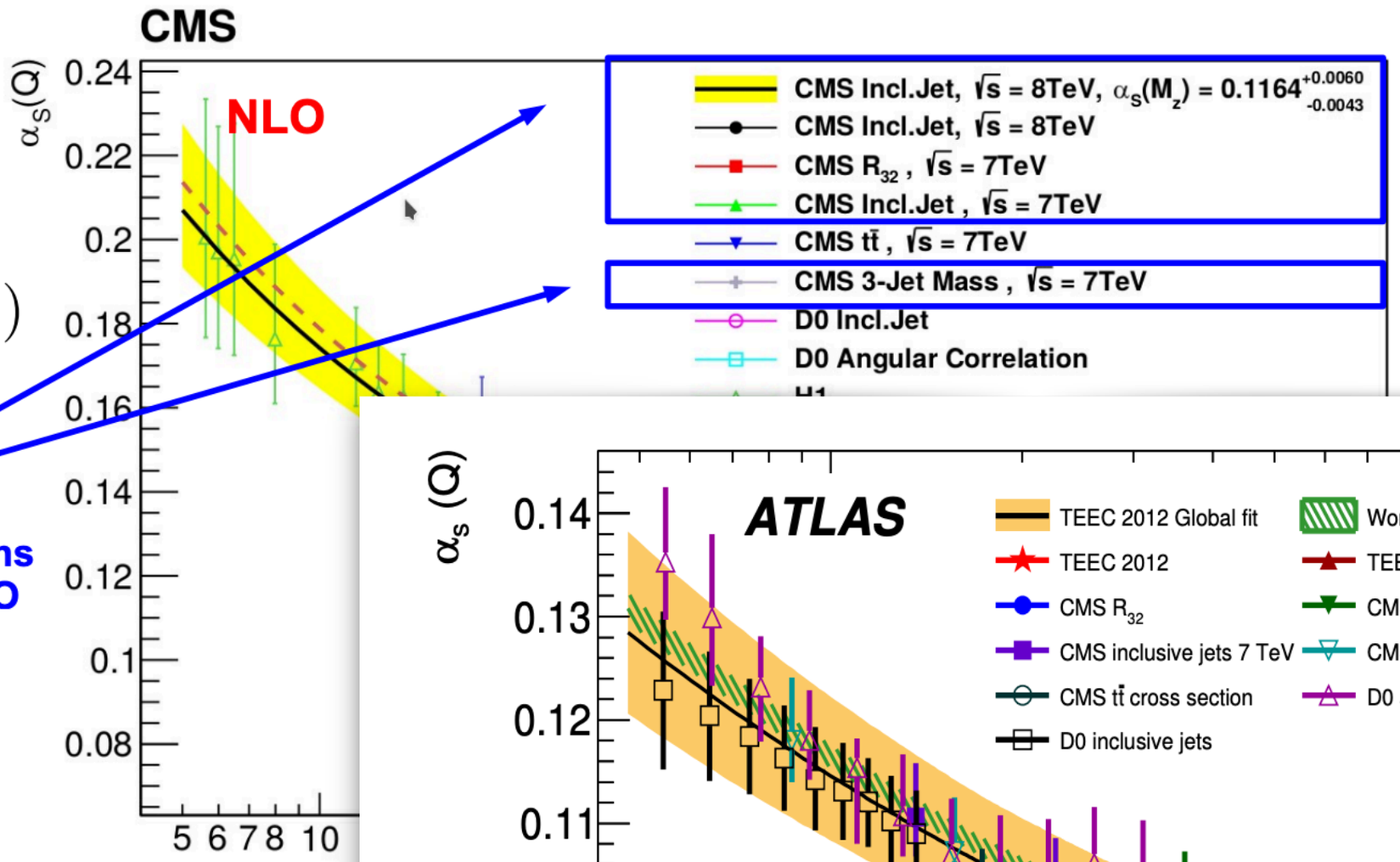

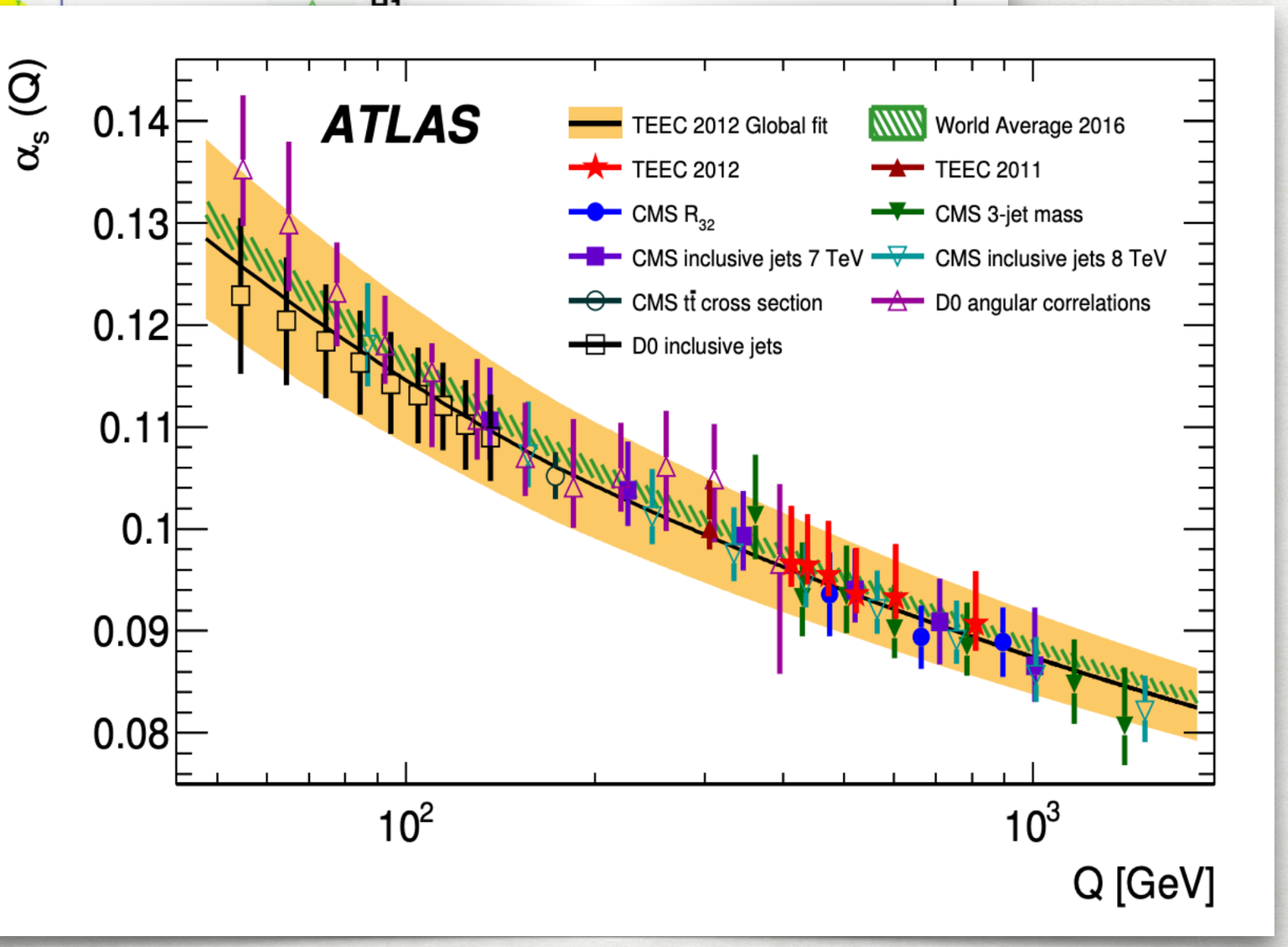

CMS: 1412.1633

ATLAS: 1707.02562

STRONG COUPLING CONSTANT

CONSTRAINTS ON COLORED PARTICLES:

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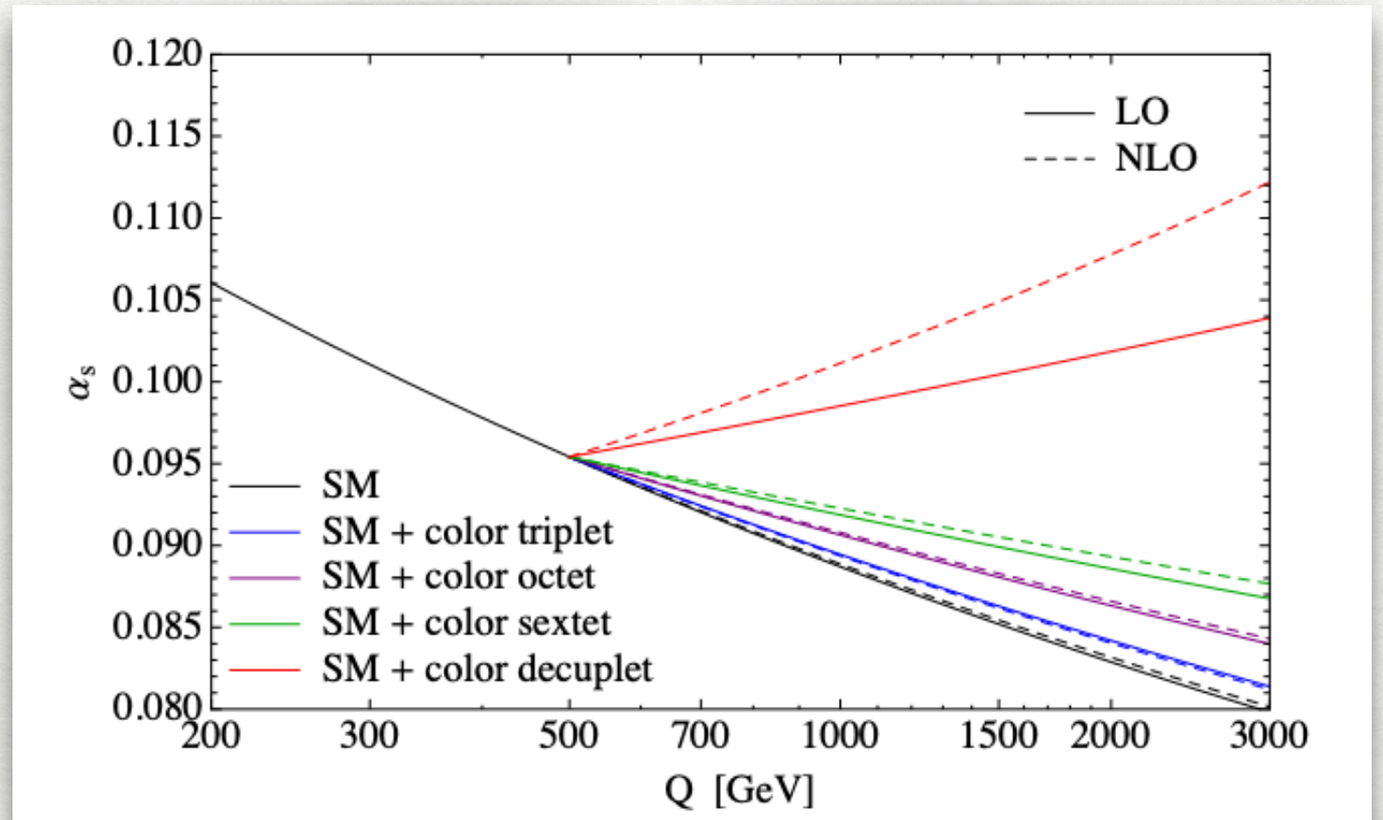

1403.7411

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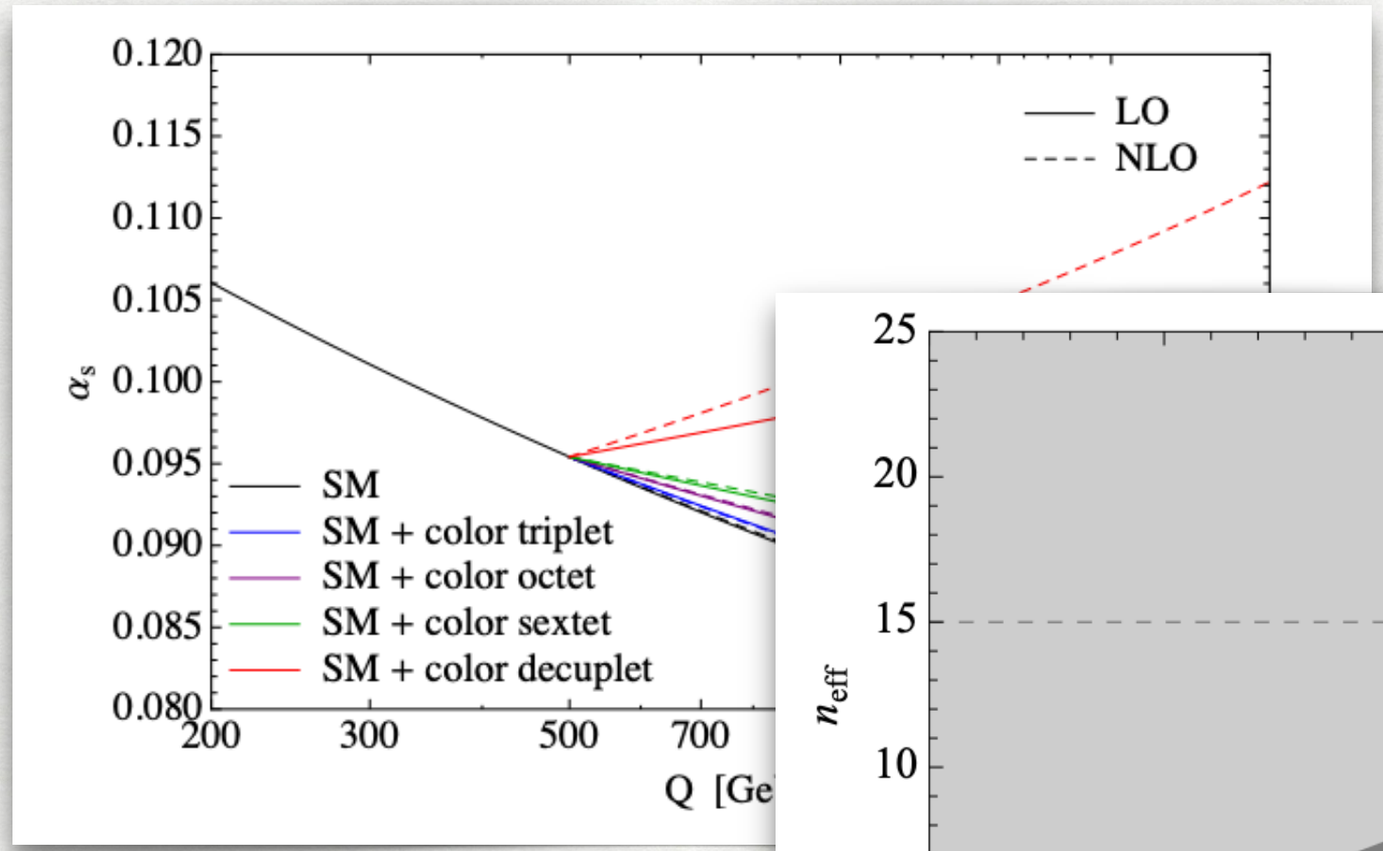
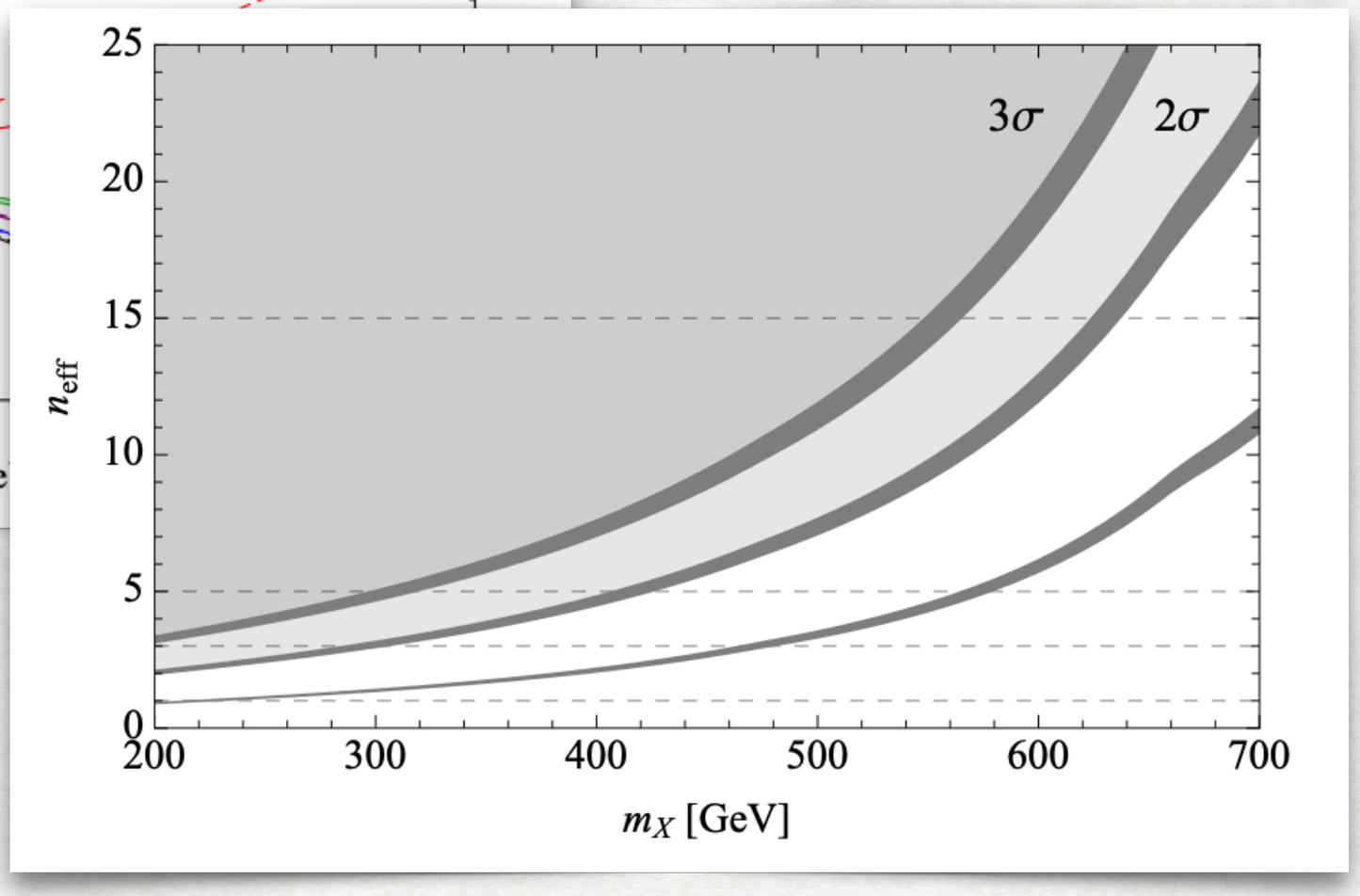


1403.7411

color content	n_{eff}	m_X in GeV
Gluino	3	280
Dirac sextet	5	410
MSSM	6	450
Dirac decuplet	15	620



1511.09022

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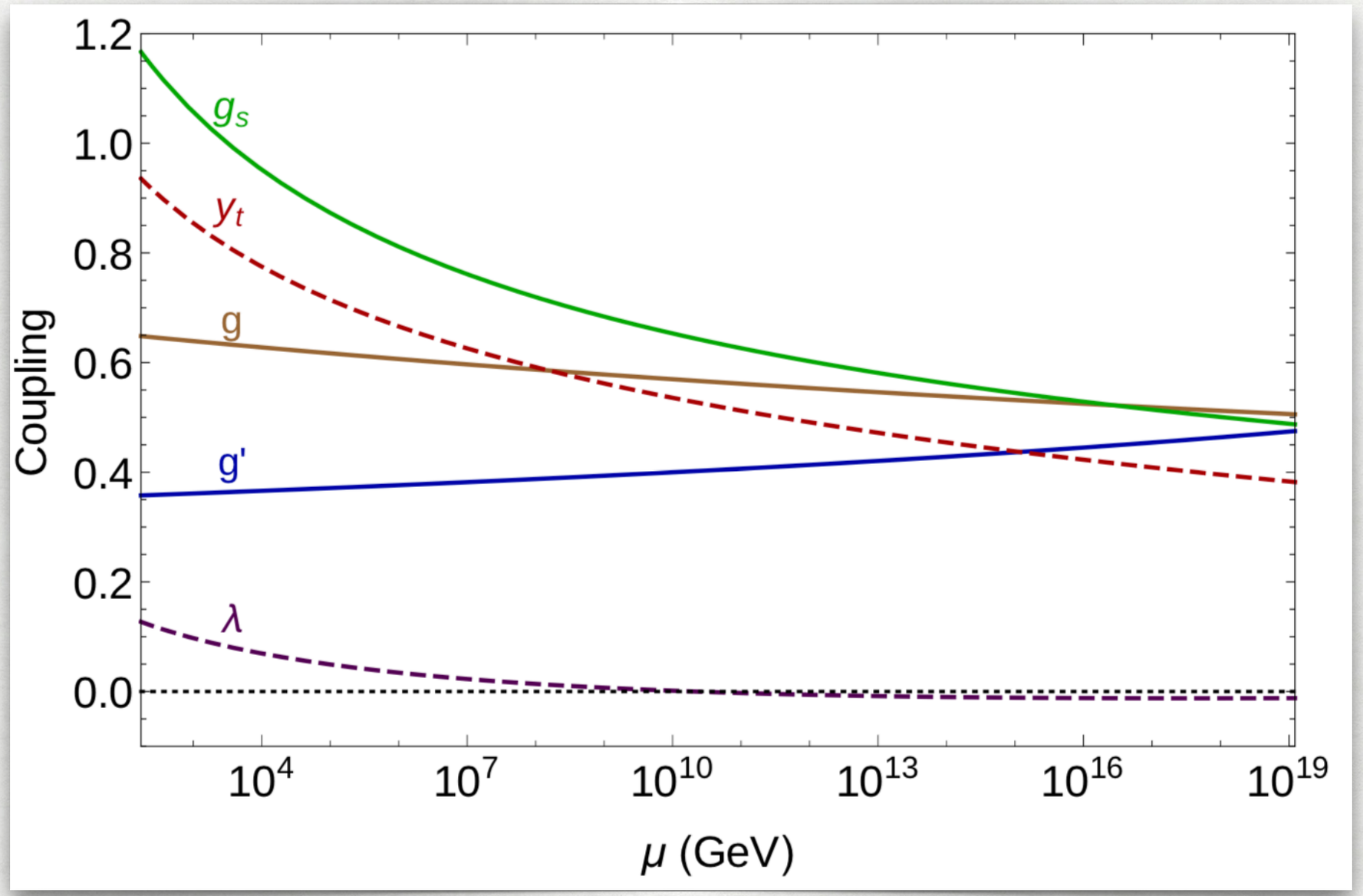

Two Loop Renormalization Group Equations *RGErun 2.0*

FERMION MASS RUNNING

SOME PDG VALUE:

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$$m_c = 1.275 \text{ GeV}$$
$$m_\tau = 1.777 \text{ GeV}$$

$$m_f = y_f v/\sqrt{2}$$

$$\approx 3\left(\frac{m_c}{m_\tau}\right)^2 ?$$

$$Br_{h\to c\bar{c}} = 2.884\%$$
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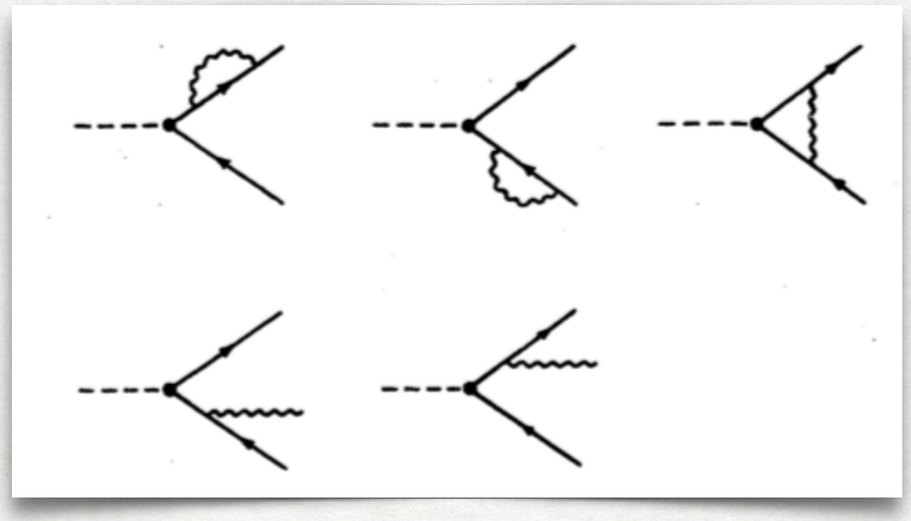

E. Braaten et al. (1980)

$$\Gamma = \Gamma_0 \left(\frac{\log(2m/\Lambda_{QCD})}{\log(M_h/\Lambda_{QCD})}\right)^{24/(3N_c-2N_f)}$$

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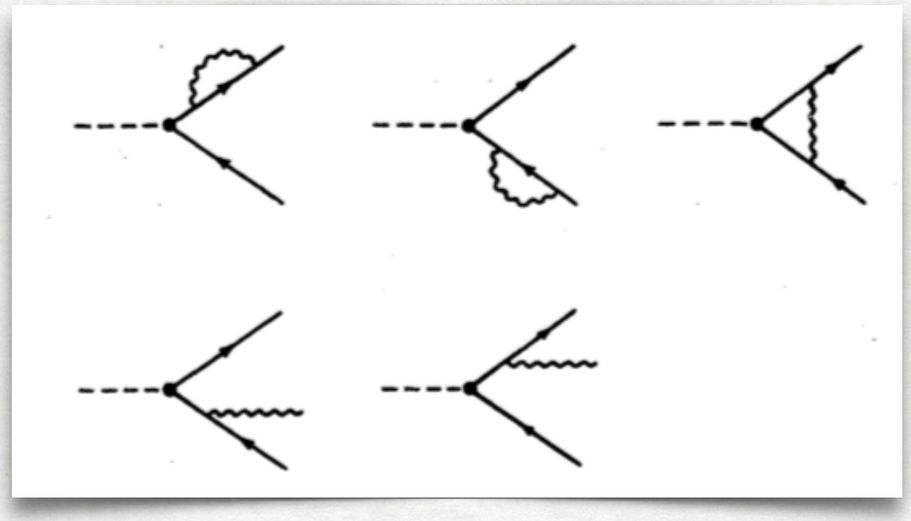

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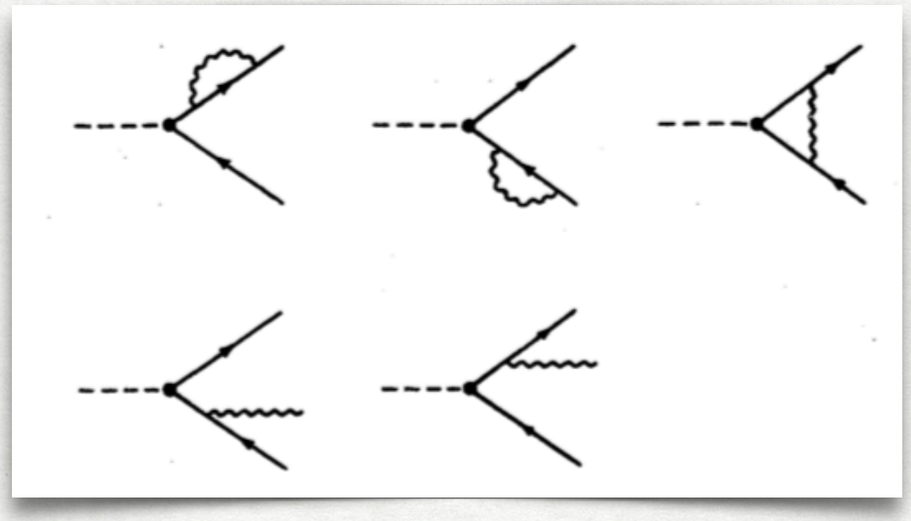

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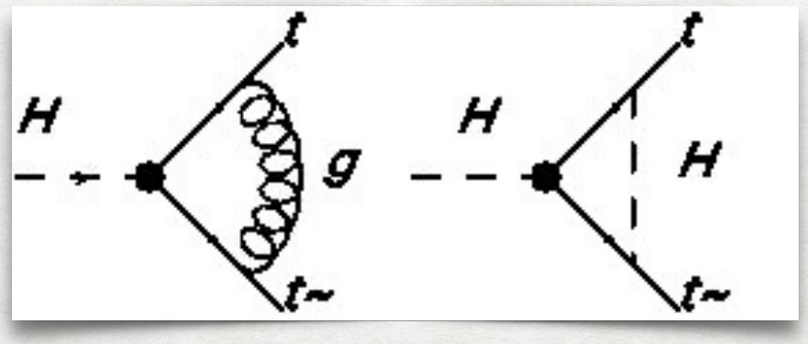

FOR TOP RUNNING, YUKAWA CONTRIBUTION ALSO SIZABLE.

FERMION MASS RUNNING

TOP YUKAWA/MASS RUNNING (LEADING ORDER):

$$\frac{dy_t}{dt} = \beta_{y_t}^{\mathrm{SM}} = \frac{y_t}{16\pi^2}\left(\frac{9}{2}y_t^2 - 8g_3^2 - \frac{9}{4}g_2^2 - \frac{17}{20}g_1^2\right)$$

1412.1633(mb(mt)), 1704.00540 (tt+1j), 1903.06574(review)

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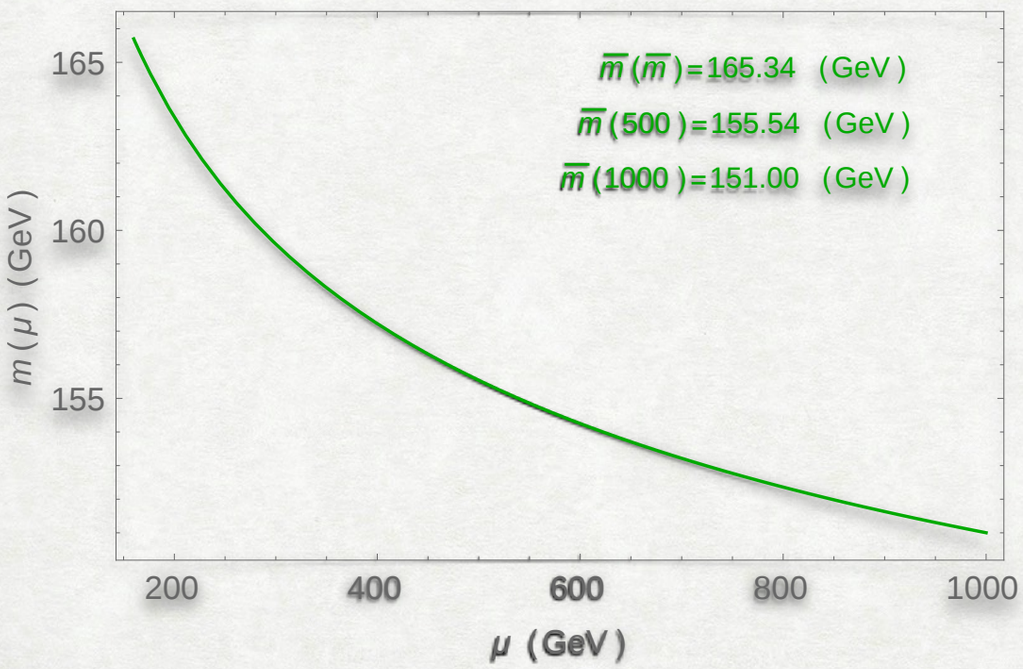
N.B.: Running Yukawa and mass are equivalent in the broken phase where vev. taken as physical/fixed



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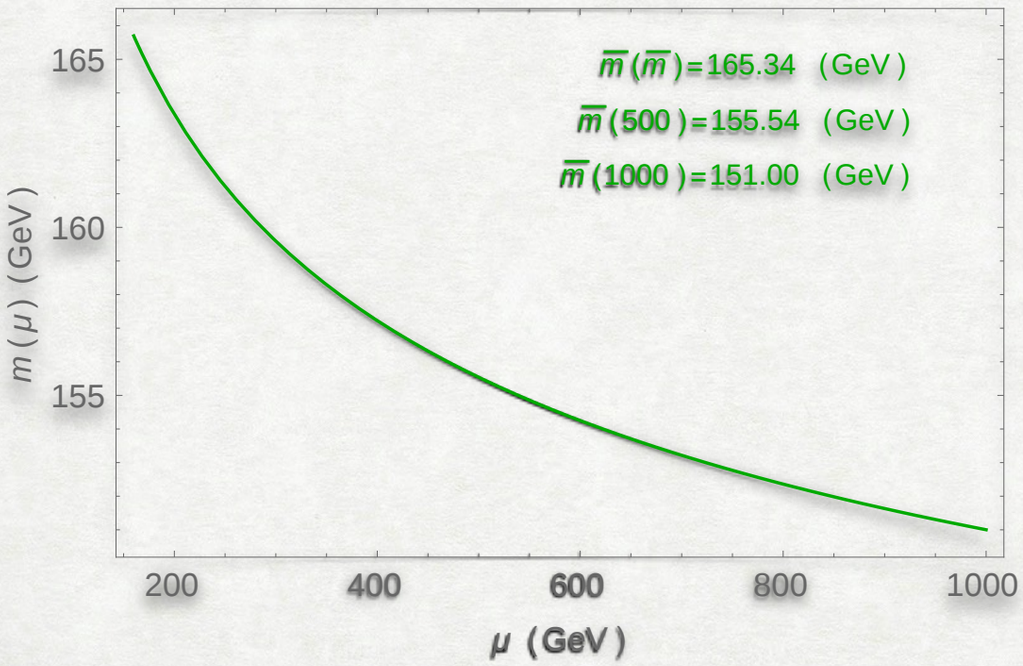

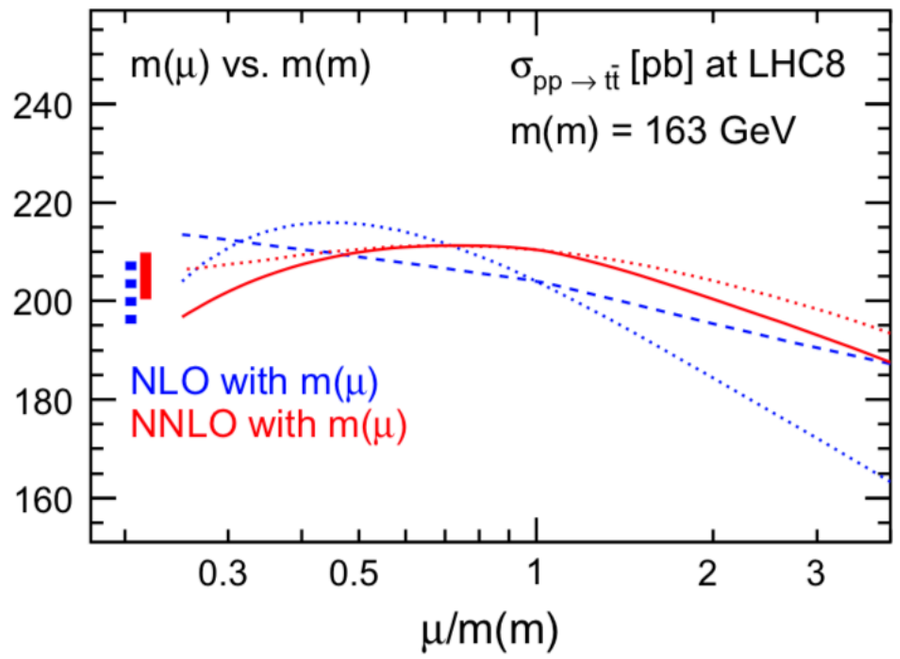

Fig. 3 The scale dependence of the total cross section at LHC ($\sqrt{S} =$ 8 TeV) as a function of $m(\mu)$ in the $\overline{\rm MS}$ scheme for the NLO (*blue*, *dashed*) and NNLO (*red*, *solid*) QCD predictions with the choice $\mu = \mu_{\rm r} = \mu_{\rm f}$ and using the PDF set ABM11 [30]. The scale variation is normalized to $m(m) = 163$ GeV. The *vertical bars* indicate the size of the scale variation in the standard range $\mu/m_t^{\rm pole} \in [1/2, 2]$ and $\mu/m(m) \in [1/2, 2]$, respectively. The *dotted curves* display the results for the mass at the fixed scale $m(m) = 163$ GeV as shown in Fig. 2 (right) for comparison

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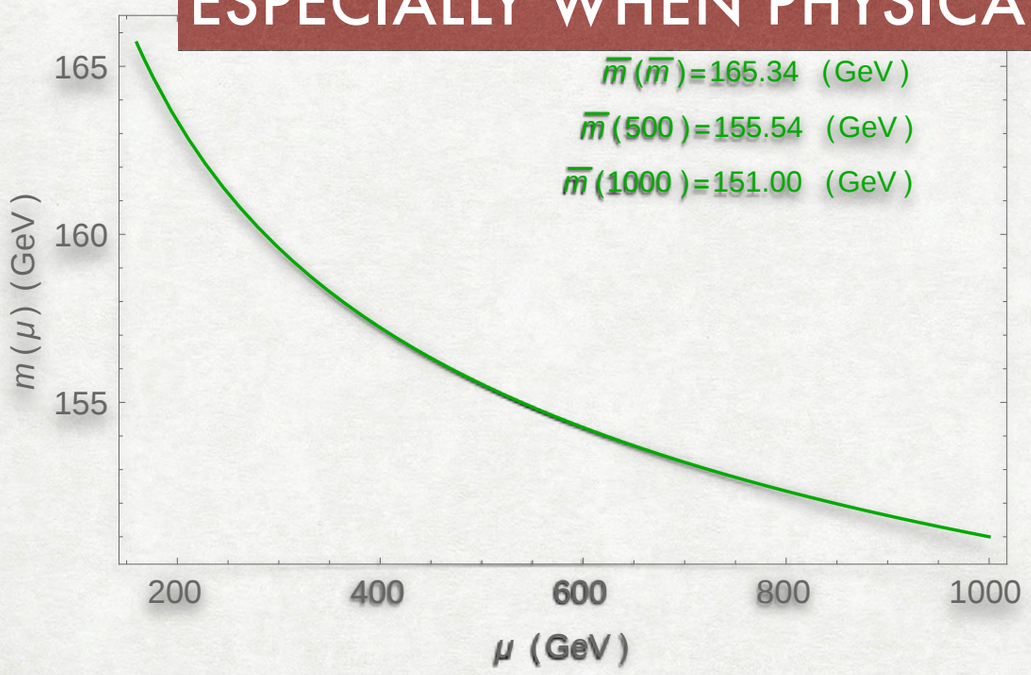
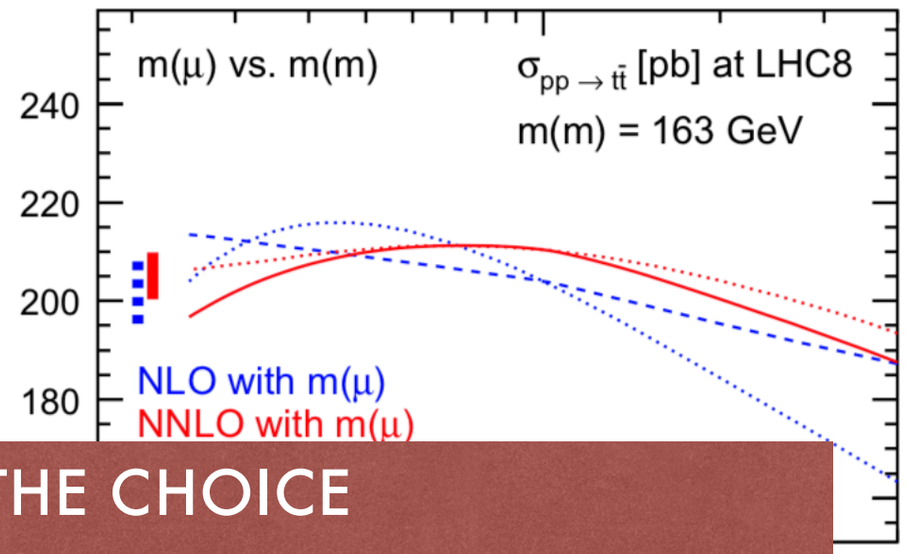
N.B.
the br

RUNNING YUKAWA/MASS M(μ) IS THE CHOICE

ESPECIALLY WHEN PHYSICAL SCALE IN THE PROCESS: Q >> MF





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FERMION MASS RUNNING

SCHEME TRANSFORMATION:
RE-EXPRESS CROSS SECTION AS A FUNCTION OF MSBAR MASS

$$\sigma^{OS}(m^p, \alpha, s, ...) \text{ and } \sigma^{\overline{MS}}(\overline{m}(\mu), \alpha(\mu), \mu; s, m^p ...)$$

0906.5273 et al.,
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$$\sigma^{NLO}(m_t^p) \Rightarrow \sigma^{NLO}(\overline{m}(\mu)) + \frac{\partial \sigma^{Born}}{\partial m}|_{\overline{m}(\mu)} \delta\overline{m} + O(\alpha_s^2).$$

$$m_t^{pole} = \overline{m}(\mu)\left(1 + \frac{\alpha_s(\mu)}{\pi}\left(\frac{4}{3} + ln\frac{\mu^2}{(\overline{m}(\mu))^2}\right) + O(\alpha_s^2)\right) = \overline{m}(\mu) + \delta\overline{m}(\mu)$$

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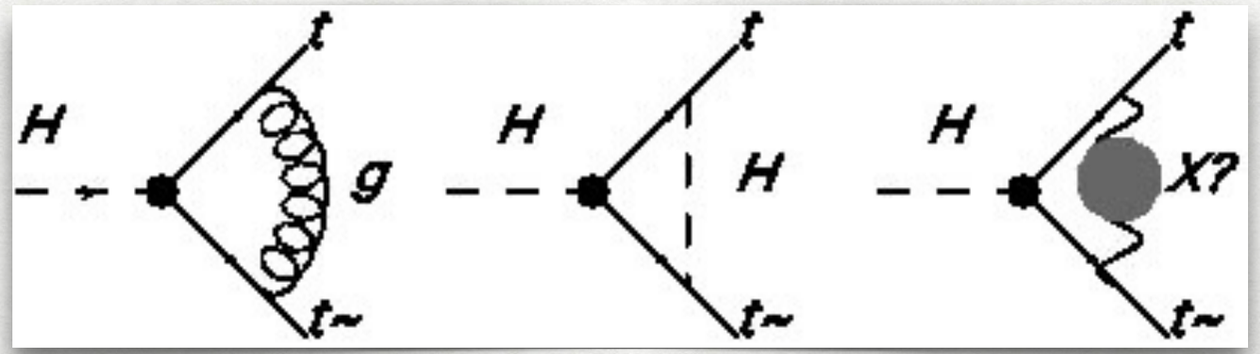
MT(Q) AS A PROBE FOR NEW PHYSICS?

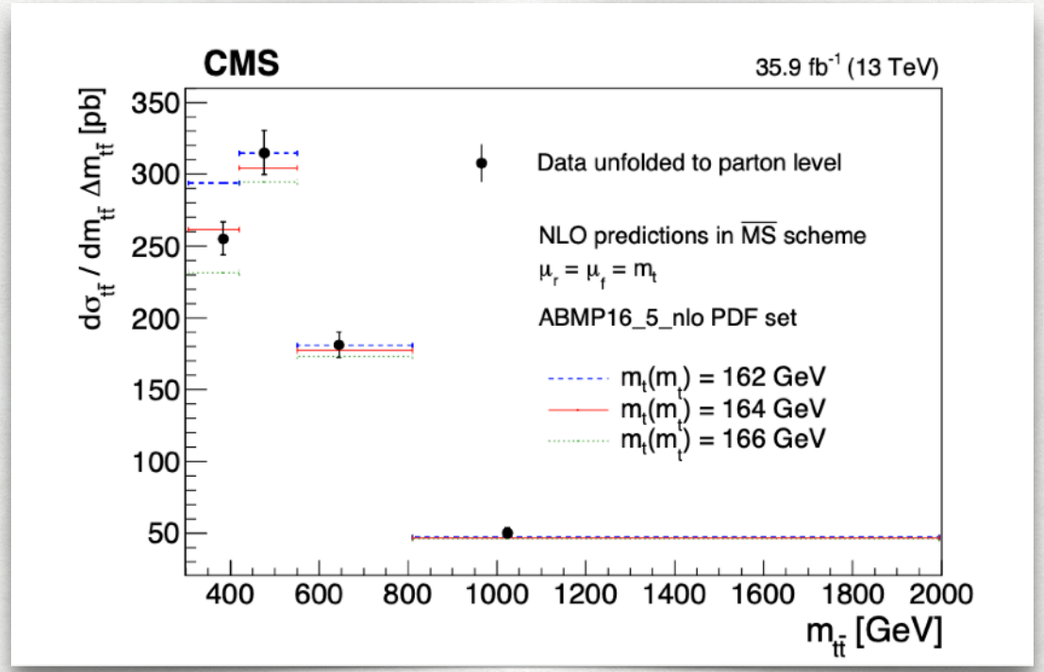


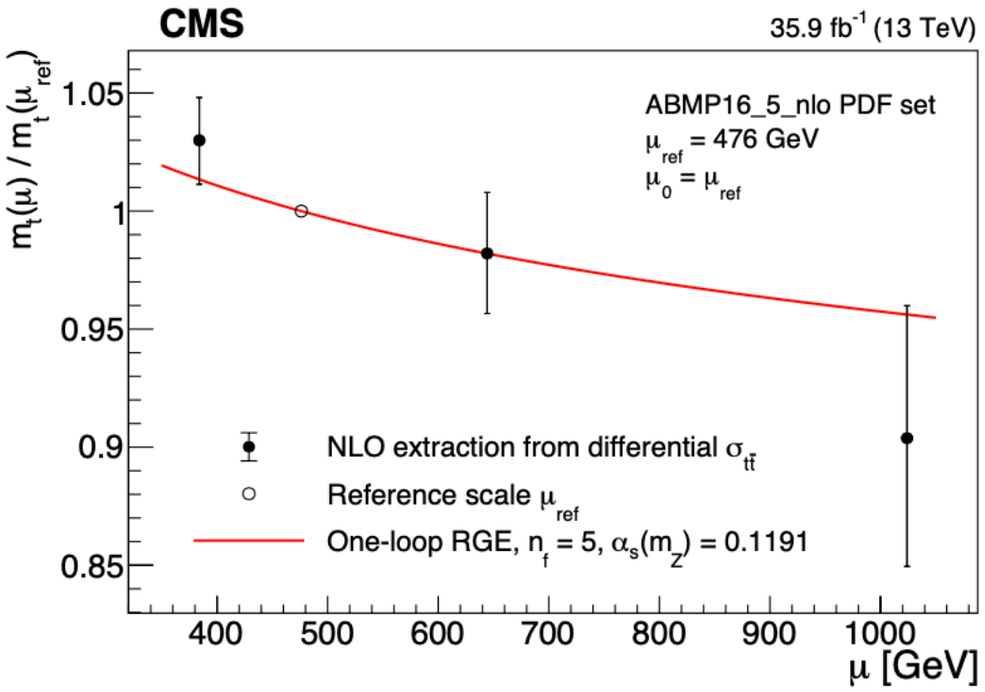
RUNNING MASS MEASURE: *pp*

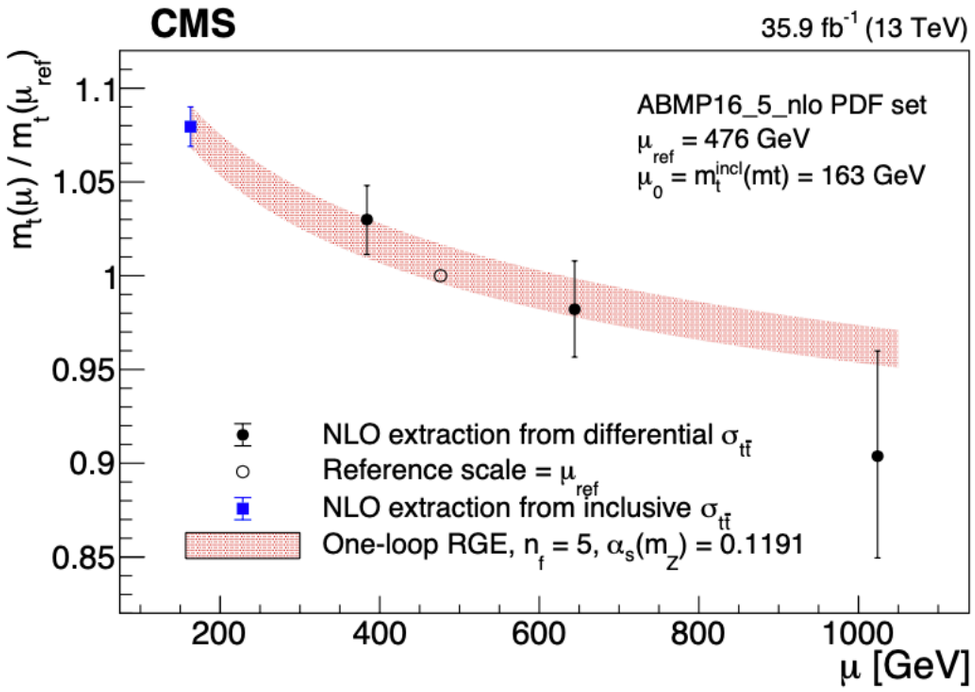
CMS ($pp \to t\bar{t}j$): $d\sigma^{inc}/dm_{t\bar{t}}$

$\mu = m_{t\bar{t}}$

Bin	$m_{t\bar{t}}$ [GeV]	Fraction [%]	μ_k [GeV]
1	<420	30	384
2	420–550	39	476
3	550–810	24	644
4	>810	7	1024







M_t (1000 GeV) ⊂ [131,147] GeV is extracted given reference pt at 500 GeV

1909.09193(CMS)

RUNNING MASS MEASURE: e^+e^-

1. OBSERVABLE SENSITIVE TO MT / YT:
   MT2 (LHC), THRESHOLD SHAPE (EE-COLLIDER), σ_{TOT}, $R_{3/2}$ ETC.
2. THE SCALE FOR RUNNING MASS:

Total rate, $\sigma_{t\bar{t}}^{\text{inc}}$ (LO, NLO) with different scheme expression

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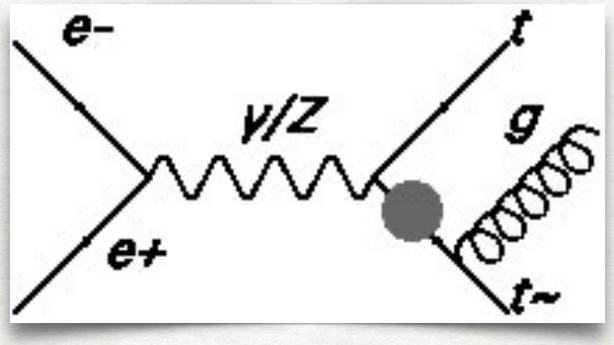

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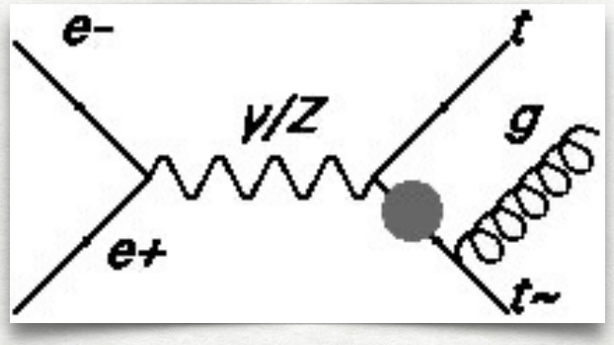

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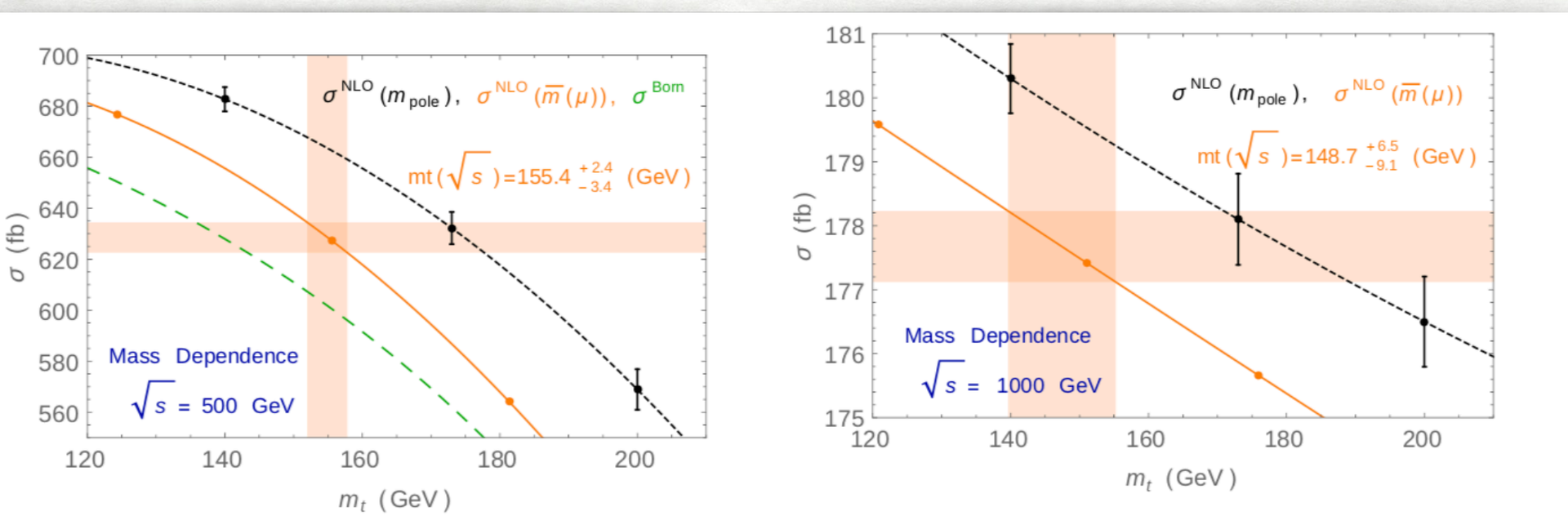

Figure 4: NLO cross section as a function of pole and running mass at 500 GeV and 1000 GeV c.m. The error bars/bands are scale variation errors $\mu_R/\sqrt{s} \sim [0.5, 2]$, read off from

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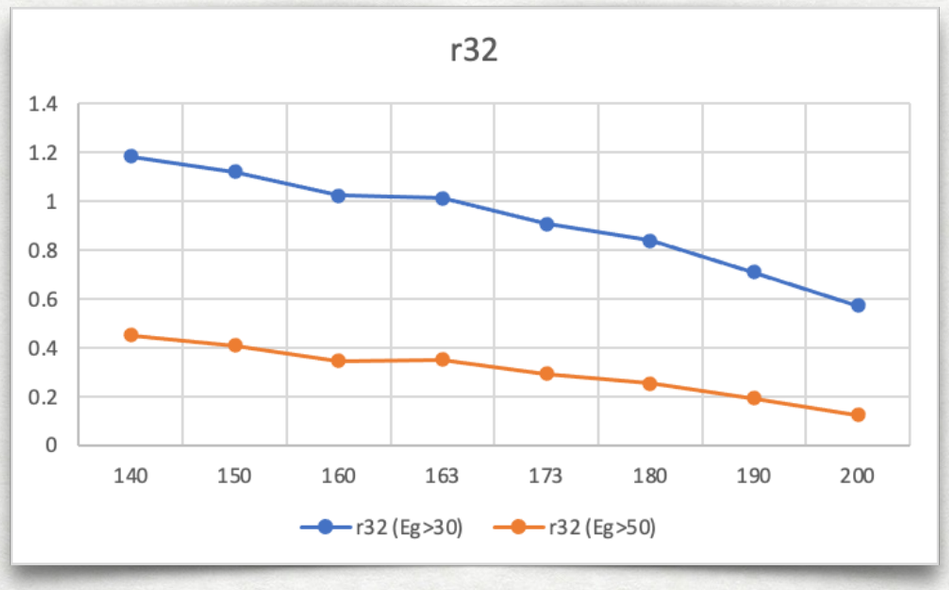
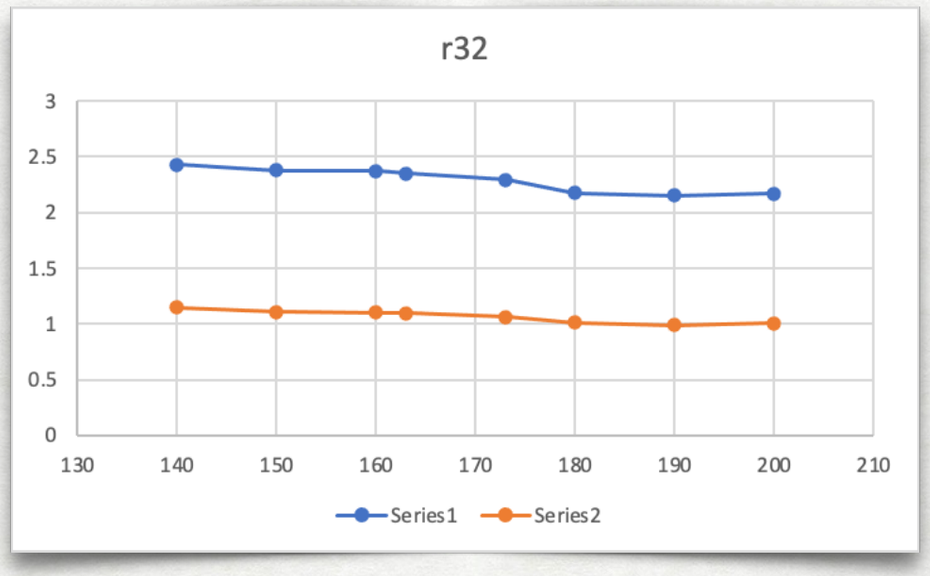
$$\sigma_{t\bar{t}j}$$

$$E_g > \mu'_{min}$$

LO:





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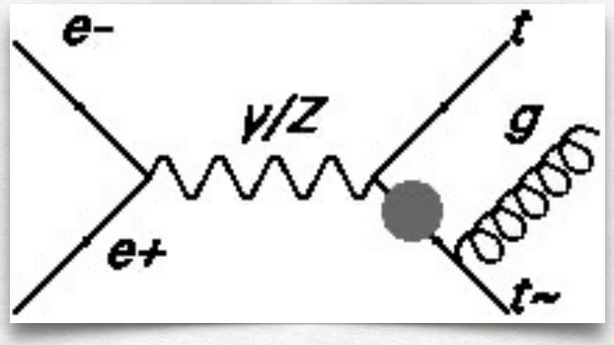
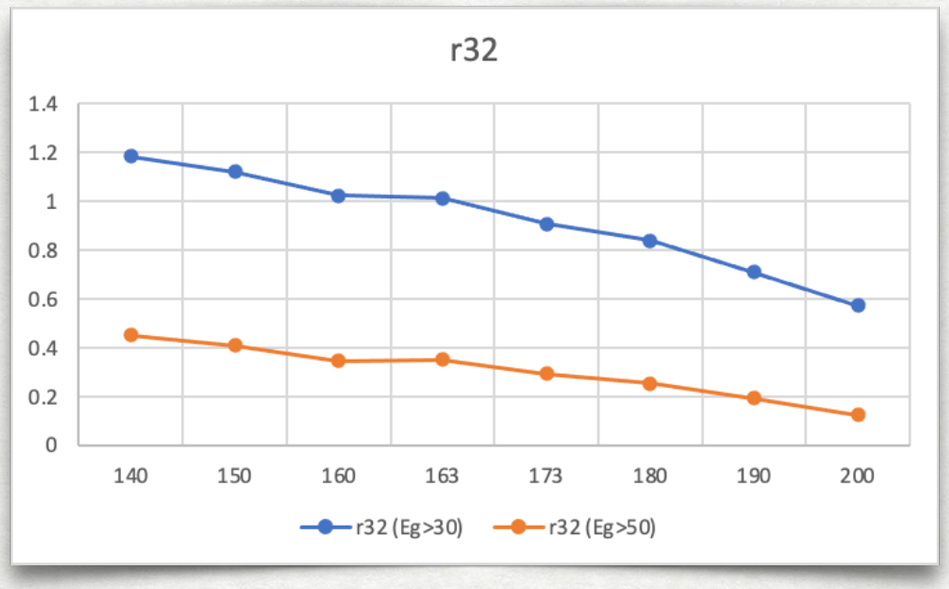
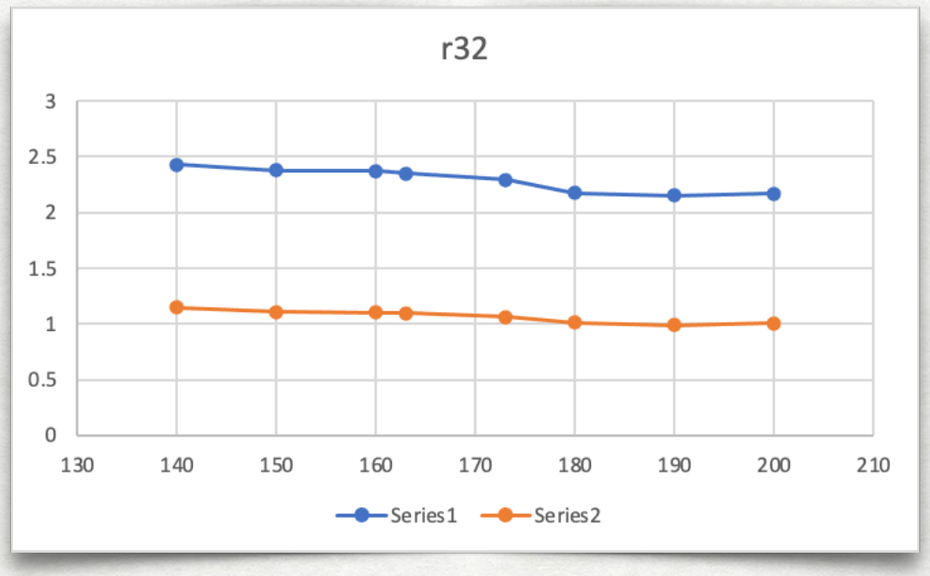


$$\sigma_{t\bar{t}j} \qquad R_{32} = \frac{\sigma_{t\bar{t}j}}{\sigma_{t\bar{t}}},\ m_{jt} > \mu_{\min}$$

$$E_g > \mu'_{min}$$

LO:





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Parton level analysis with (syst error only) from $\sigma_{t\bar{t}}^{\mathrm{inc,NLO}}$:

M_t (500 GeV) $\subset$ [152,158] GeV
M_t (1000 GeV) $\subset$ [140,155] GeV

$\Rightarrow r_{1TeV/500GeV} \subset [0.9,1]$

N.B.: COMPARED TO CURRENT CMS [0.85,0.95]
A SIMILAR 15 GEV ERROR AT $\mu = 1$TEV IS ENVISIONED.

** SM NLO $m_t(\mu)$ RUNNING PREDICTION CENTRES AT 0.95.

Discussion:

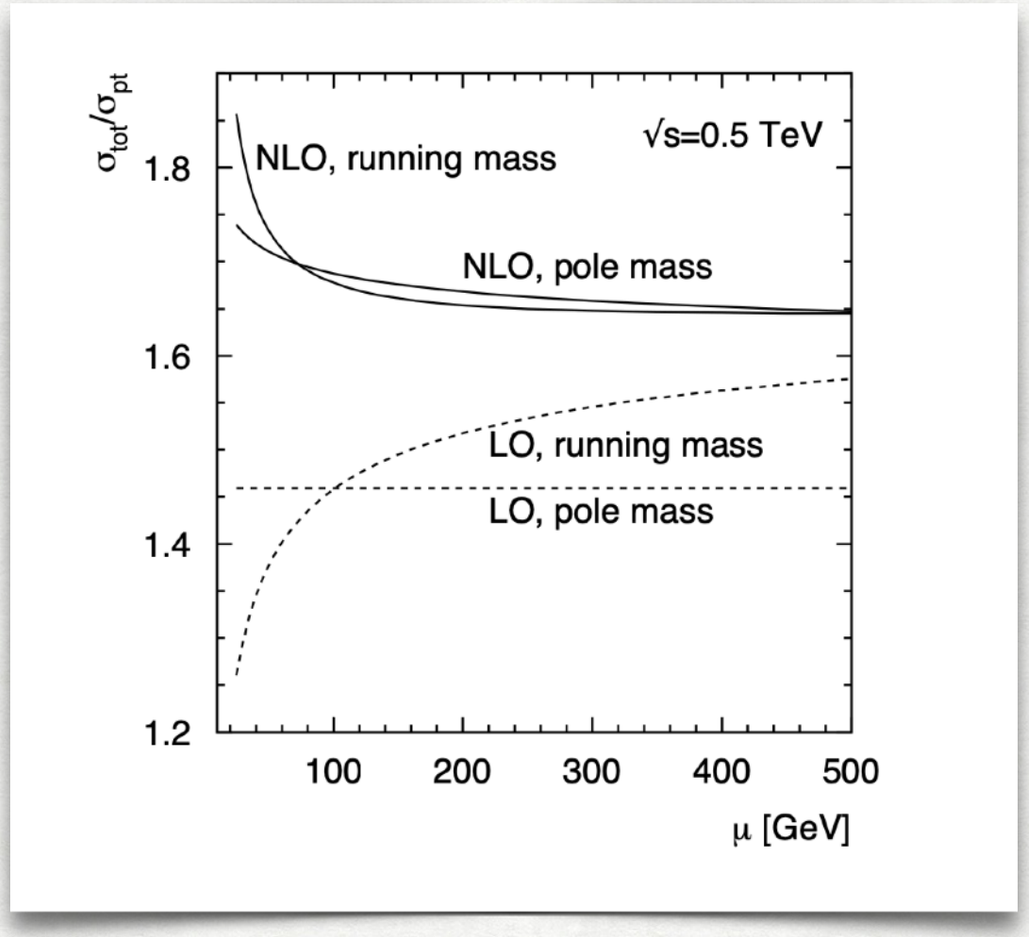
- Sensitivity on phase space top mass, and internal propagator:

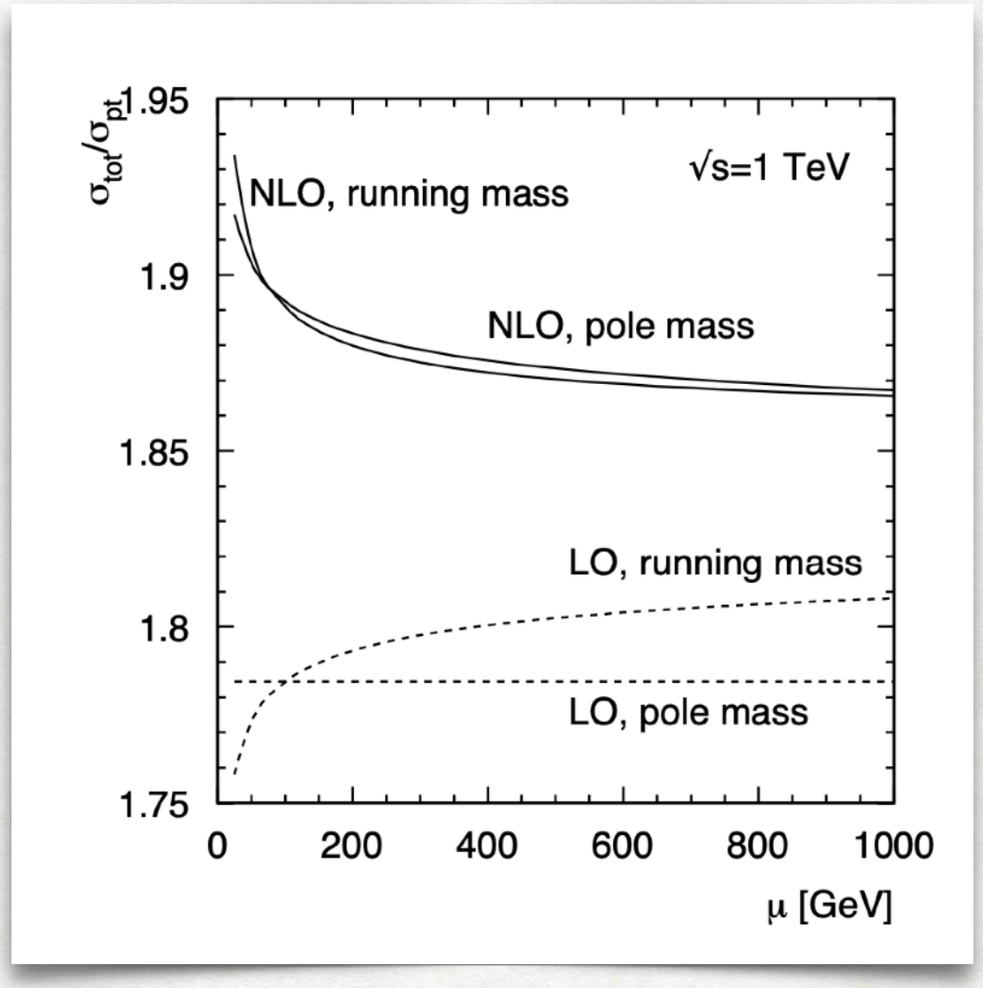
$$\sigma_{tot}^{inc,LO}\left(\sqrt{1-4\frac{4m_t^2}{s}}\right),\ \sigma_3^{LO}\left(\sqrt{1-4\frac{4m_t^2}{s}},\frac{1}{s_1-m_t^2}\right).$$

- Statistic error estimate with full simulation & background including top decays.
- Additional observable: $m_{tg}, r(x_{cut}=E_g/\sqrt{s}), etc$.

RUNNING MASS MEASURE: e^+e^-

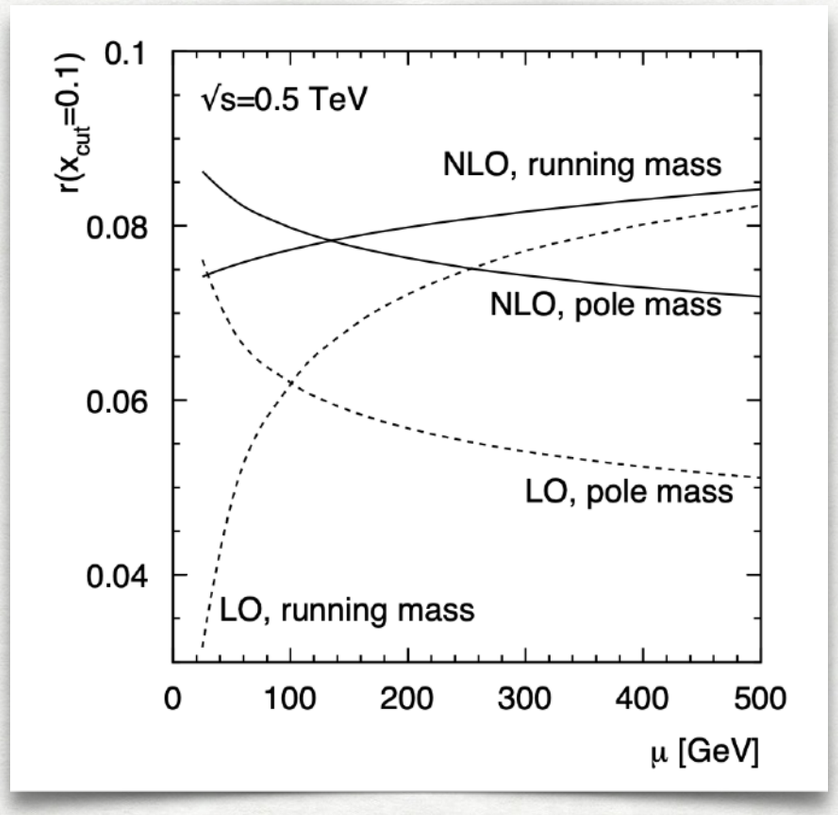
PARTON: $\sigma_{t\bar{t}}^{\text{inc}}(\mu = \sqrt{s})$

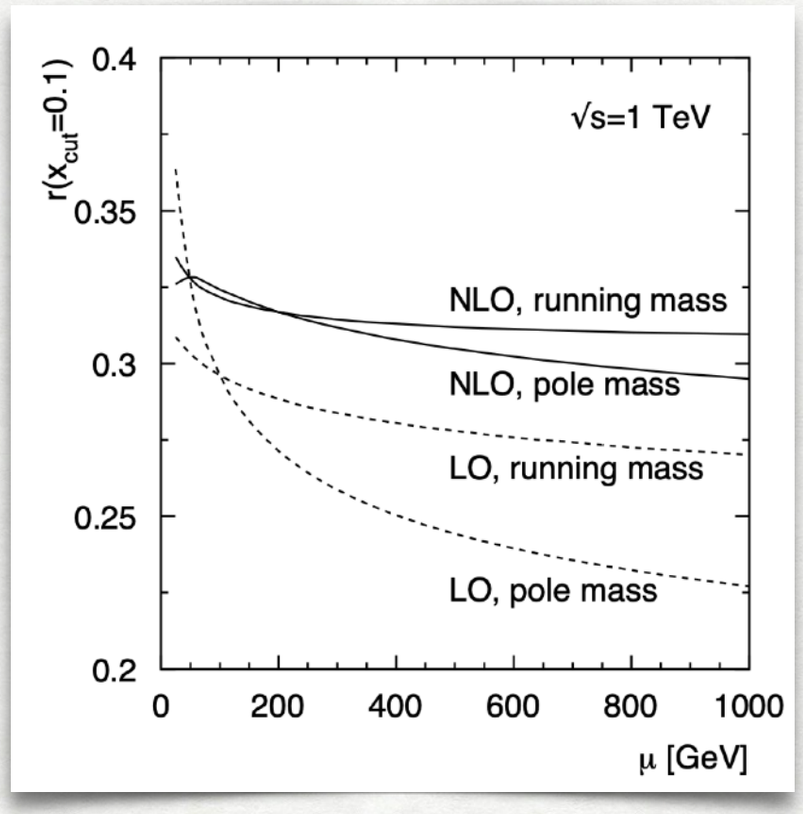


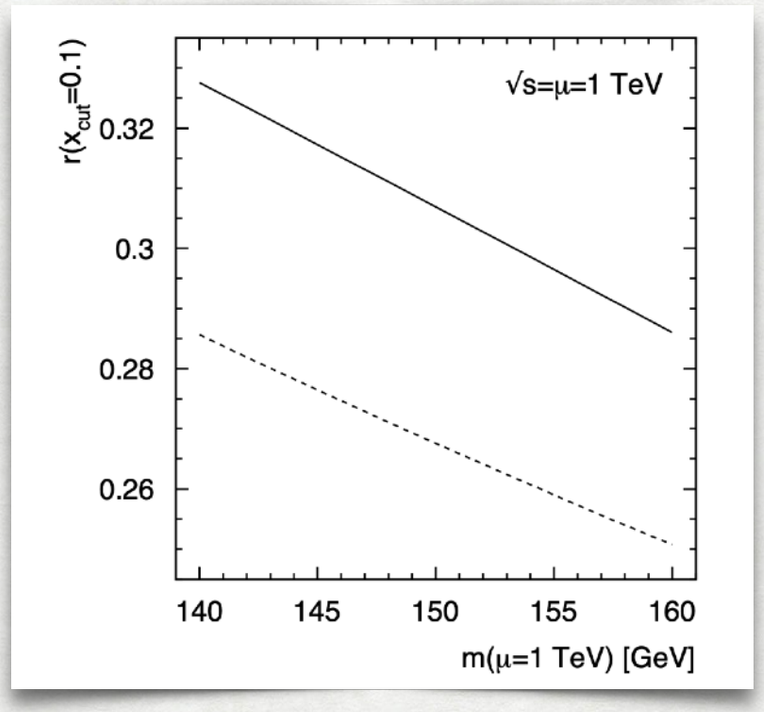


9904251 ($t\bar{t} + g$), 980279($m_b(m_Z)$) and SLAC, DELPHI

RUNNING MASS MEASURE: e^+e^-







N.B.: COMPARED TO CURRENT CMS [0.85,0.95]
A SIMILAR 15 GEV ERROR AT $\mu = 1$TEV IS ENVISIONED.

A 1% SYSTEMATIC ERROR ON $r(x = 0.1)$ GIVES 5 GEV ERROR

9904251 ($t\bar{t} + g$), 980279($m_b(m_Z)$) and SLAC, DELPHI

End