Toward Determination of m_t at 50 MeV Accuracy

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PLAN :

§ Motivation

§ New Results

§ Order Counting After Renormalon Cancellation

§ Motivation

At LCWS '99 (Sitges),

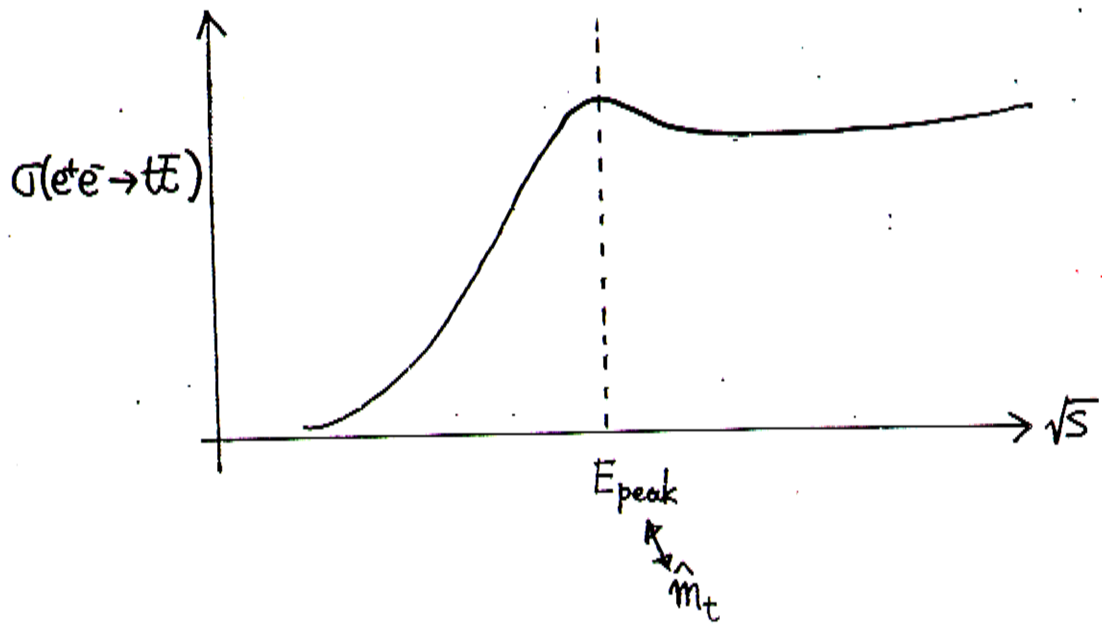
Significant theoretical progress reported: (Hoang, Teubner; Melnikov, Yelkhovsky; ⋮)

- higher order calculations of threshold cross sections
- renormalon cancellation (Hoang, Smith, Stelzer, Willenbrock; Beneke)

⇒ Precise determination of $\hat{m}_t \equiv m_{\overline{MS}}(m_{\overline{MS}})$

$$\delta \hat{m}_t \sim \begin{cases} 50 \text{ MeV} & \text{Exp. error (stat.)} \\ 150-200 \text{ MeV} & \text{Theor. uncertainty} \end{cases}$$

(Peralta, Martinez, M. ; Cinabro) (Top Theory WG)



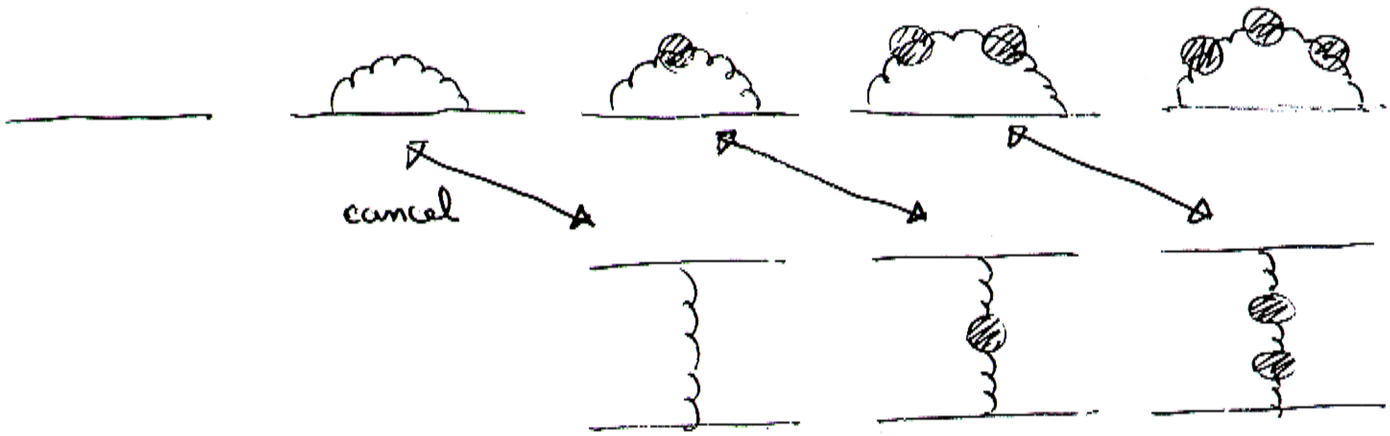
…w to cancel renormalons in the quarkonium spectrum

…enormalon cancellation takes place between the terms of shifted orders:

$$2m_{pole} = 2m_{\overline{MS}}\left(1 + \star\alpha_s + \star\alpha_s^2 + \star\alpha_s^3 + \cdots\right)$$

$$E_{binding} = 2m_{\overline{MS}}\left(\qquad\qquad \star\alpha_s^2 + \star\alpha_s^3 + \cdots\right)$$

Hoang, Ligeti, Manohar



↑

• $-\langle C_F \frac{\alpha_s}{r}\rangle = -C_F\alpha_s \underbrace{\langle r^{-1}\rangle}_{\sim\, \alpha_s m} \sim \alpha_s^2 m$

• $E_{binding} = 2m_{\overline{MS}} \sum_{n=2}^{\infty} \underbrace{P_n(\log\alpha_s)}_{\sim\, \alpha_s^{-1} \text{ for } n \gg 1} \alpha_s^n$

"Toponium" 1S-state spectrum

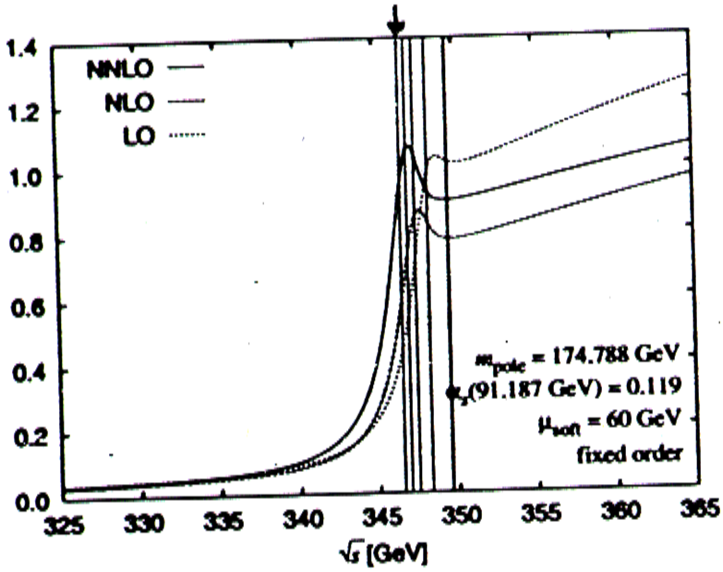
For $\hat{m}_t = 165$ GeV ($\Longleftrightarrow$ $m_{pole} = 174.79$ GeV)

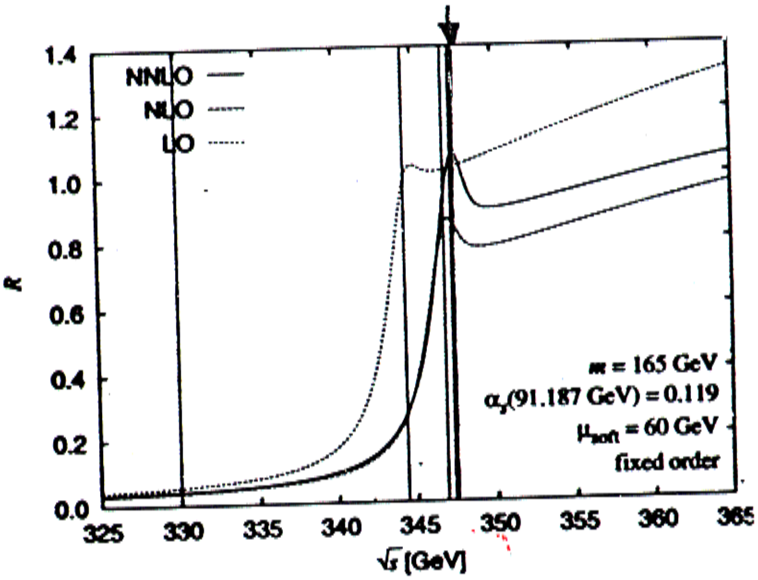
expansion parameter $= \alpha_s^{(5)}(\hat{m}) = 0.1092$

$$M_{1S} = 2\times(174.79 - 0.46 - 0.39 - 0.28 - 0.19^*)\ \text{GeV} : \text{Pole-mass scheme}$$

$$= 2\times(165.00 + 7.21 + 1.24 + 0.22 + 0.052^*)\ \text{GeV} : \overline{\text{MS}}\ \text{scheme}$$

Kiyo + Y.S.





Nagano + Y.S.

The present perturbative evaluation of $M_{1S}(m_{\overline{MS}}, \alpha_s)$ has a "genuine accuracy" at $\mathcal{O}(\alpha_s^3 m)$.

Formally $\mathcal{O}(\alpha_s^n m)$ term

= "Leading renormalon part" + "genuine $\mathcal{O}(\alpha_s^n m)$ part"

$V\!\!\!\!\!\!\wr$

Λ_{QCD}

In order to achieve a "genuine $\mathcal{O}(\alpha_s^4 m)$ accuracy", it is sufficient to calculate further

(I) $\mathcal{O}(\alpha_s^4 m)$ relation between m_{pole} and $m_{\overline{MS}}$

⇒ replaiced by large-β_0 approx.

(II) E_{bin} at $\mathcal{O}(\alpha_s^5 m)$ in the large-β_0 approx.

⇒ computed

i.e. The full $\mathcal{O}(\alpha_s^5 m)$ corrections are not necessary!

Renormalon cancellation

Chetyrkin, Steinhauser
Melnikov, Ritbergen

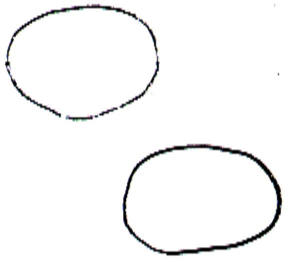
known

$$2\, m_{\text{pole}} = 2\, m_{\overline{MS}} \left(1 + \star\alpha_s + \star\alpha_s^2 + \star\alpha_s^3 + \star\alpha_s^4 + \star\alpha_s^5 + \dots \right)$$

$$E_{\text{bin}} = 2\, m_{\overline{MS}} \left(\star\alpha_s^2 + \star\alpha_s^3 + \star\alpha_s^4 + \star\alpha_s^5 + \dots \right)$$

known

our calculation in large-β_0 approx.



Consistency checks

- Toponium 1S

$$M_{1S} = 2\times(\underset{1}{165.00} + \underset{\alpha_s}{7.21} + \underset{\alpha_s^2}{1.24} + \underset{\alpha_s^3}{0.22} + \underset{\alpha_s^4}{0.052^*})\ \text{GeV}$$

$\Downarrow$ (under the α_s^3 term 0.22)

0.22

0.31

- Bottomonium 1S

$$M_{1S} = 2\times(4.20 + 0.36 + 0.13 + 0.040 + 0.0051^*)\ \text{GeV}$$

$\Downarrow$ (under 0.040)

0.043

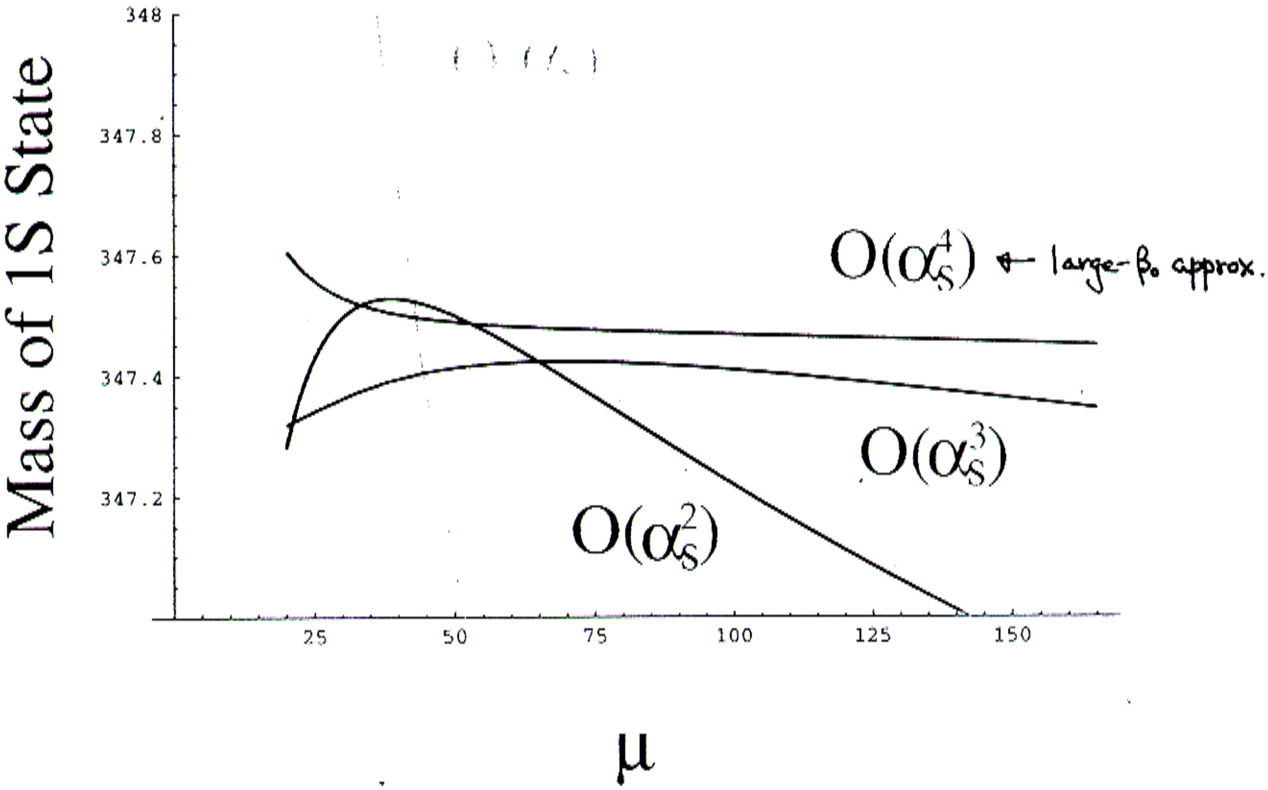
0.056

(1) $\mathcal{O}(\alpha_s^4 m)$ term of E_{bin} is replaced by large-β_0 approx.

(2) $\mathcal{O}(\alpha_s^3 m)$ term of $m_{pole} \Leftrightarrow m_{\overline{MS}}$ relation is replaced by large-β_0 approx.

Scale dependences

$$M_{1S} = M_{1S}(\alpha_s(\mu), \hat{m}_t) \qquad ; \qquad \hat{m}_t \equiv m_{\overline{MS}}(m_{\overline{MS}})$$



Other necessary calculations to achieve 50 MeV accuracy

- 4-loop relation $m_{pole} \longleftrightarrow m_{\overline{MS}}$
- Final-state interaction corrections to $\sigma(e^+e^- \to t\bar{t})$ at NNLO
- EW corrections (Non-resonant / 1-loop)