Top Mass at Threshold:
Impact of α_s Uncertainties

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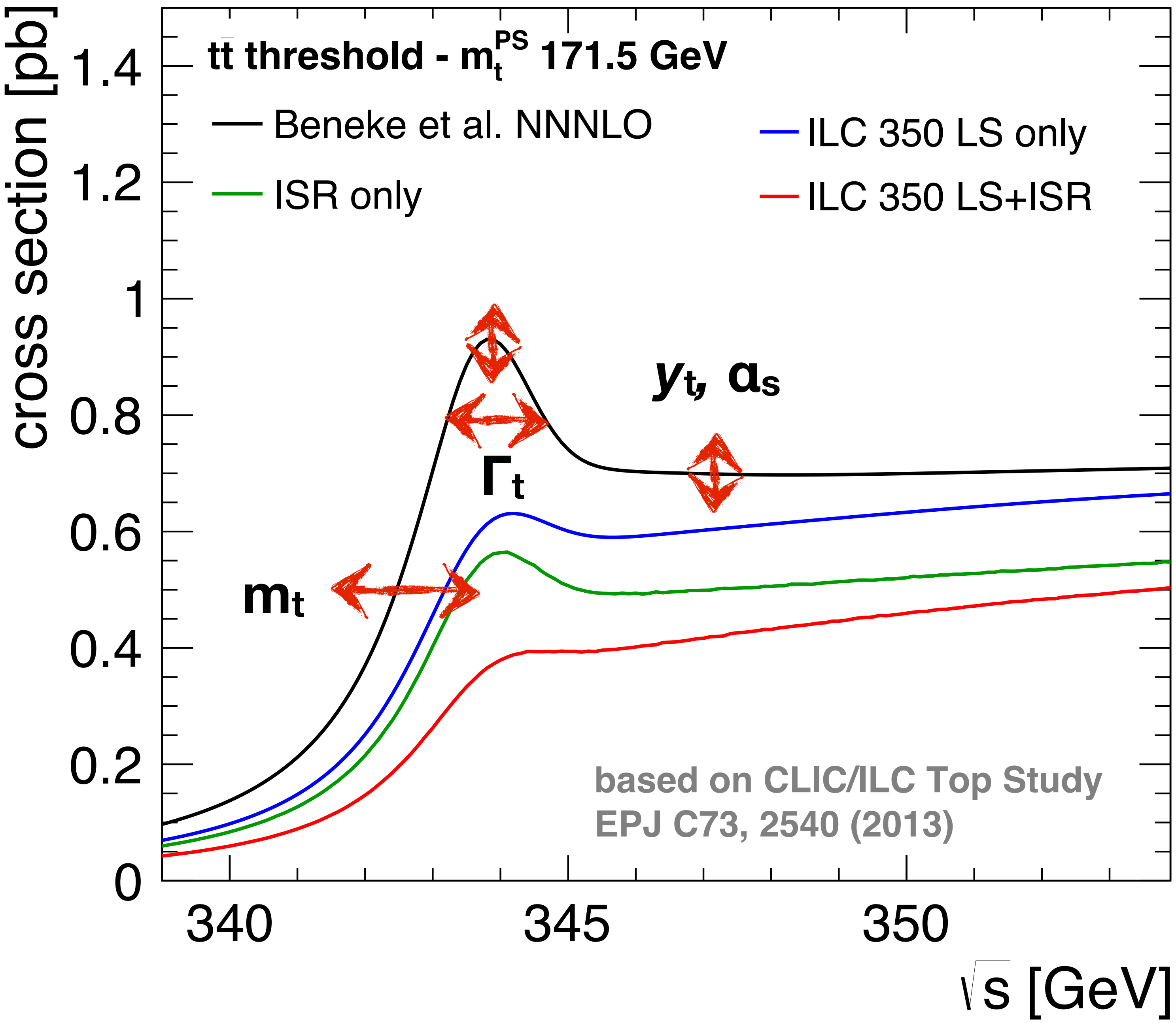
Outline

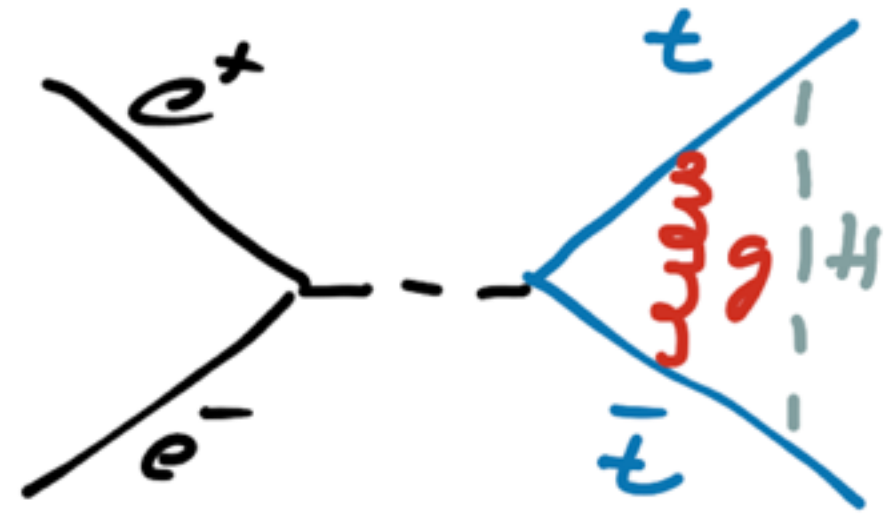
- Relevance of α_s for final m_t, msbar precision
- Impact of α_s when fitting with NNNLO QCD theory uncertainties included

NB: This is not a full talk, but a discussion starter!

Threshold Scans: The Motivation

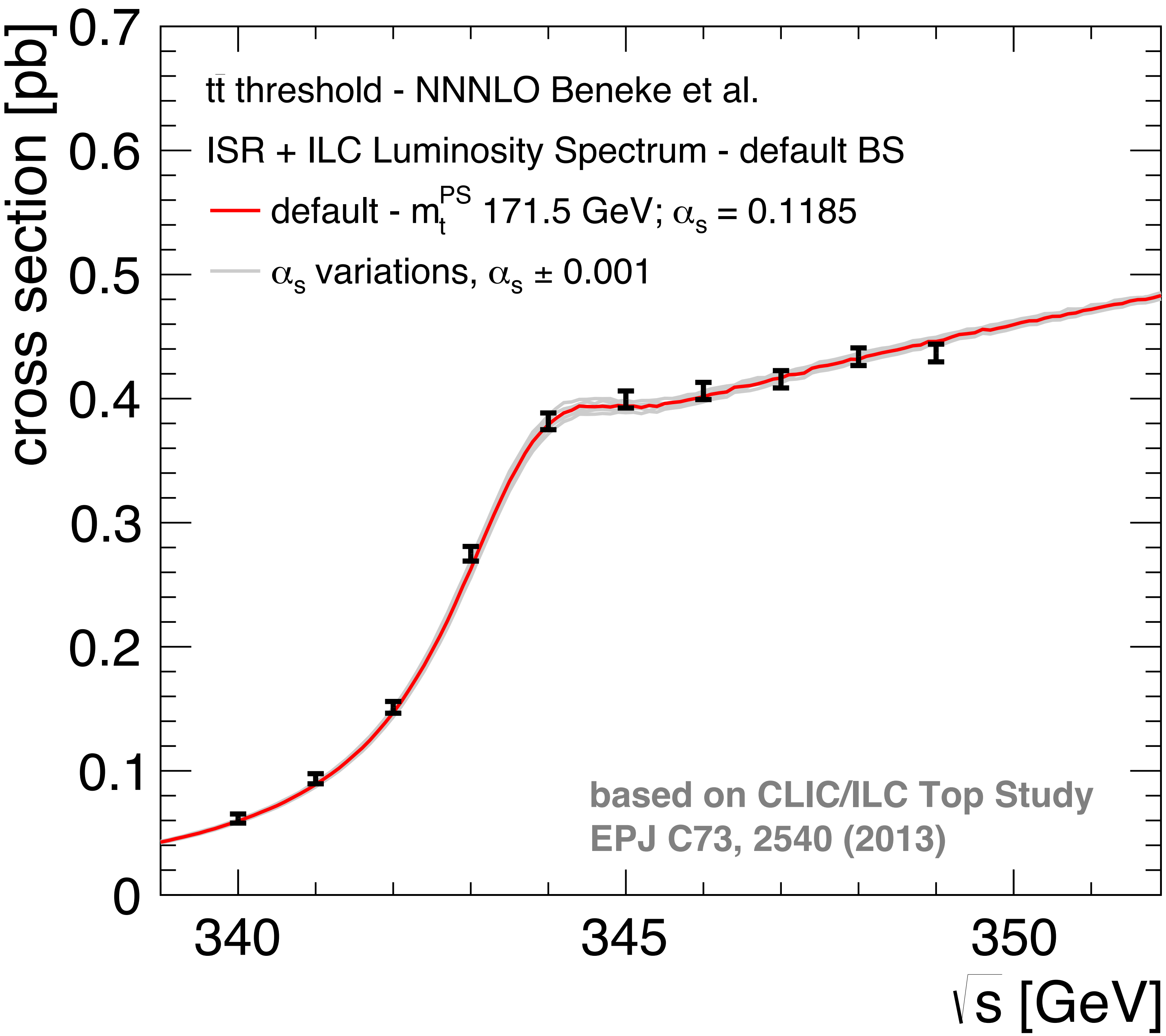


- The cross-section around the threshold is affected by several properties of the top quark and by QCD
  - Top mass, width, Yukawa coupling
  - Strong coupling constant



- Effects of some parameters are correlated; dependence on Yukawa coupling rather weak - precise external α_s helps

Threshold Scan - Sensitivity to α_s Variations



- The assumption:
  10 x 10 fb^{-1}, points spaced by 1 GeV from 340 to 349 GeV

Valencia Analysis: m_t vs α_s vs V_{tb}

- Width expressed in terms of V_{tb} (assuming SM)
- The study:
  - Based on WHIZARD threshold simulations (NLO), ILC LS + ISR, no detector / reconstruction effects, no background
  - 10 point scan, 10 fb^{-1} per point (standard)

Fit	Δm_{1S} [MeV]	$\Delta m^{\overline{MS}}$ [MeV]	ΔV_{tb}	$\Delta \alpha_s$
Only m_{1S}	10	12	-	-
m_{1S} vs V_{tb}	10	12	0,0095	-
m_{1S} vs α_s	15	51	-	0,0007
m_{1S} vs V_{tb} vs α_s	32	122	0,023	0,0017

- Little impact of Vtb on the mass extraction, a_s **hits harder**.
- 3 floating-parameters strategy aggravates the uncertainties estimation.
- The negative impact of the multi-parameter fit must be canceled by reducing the number of floating-parameters.

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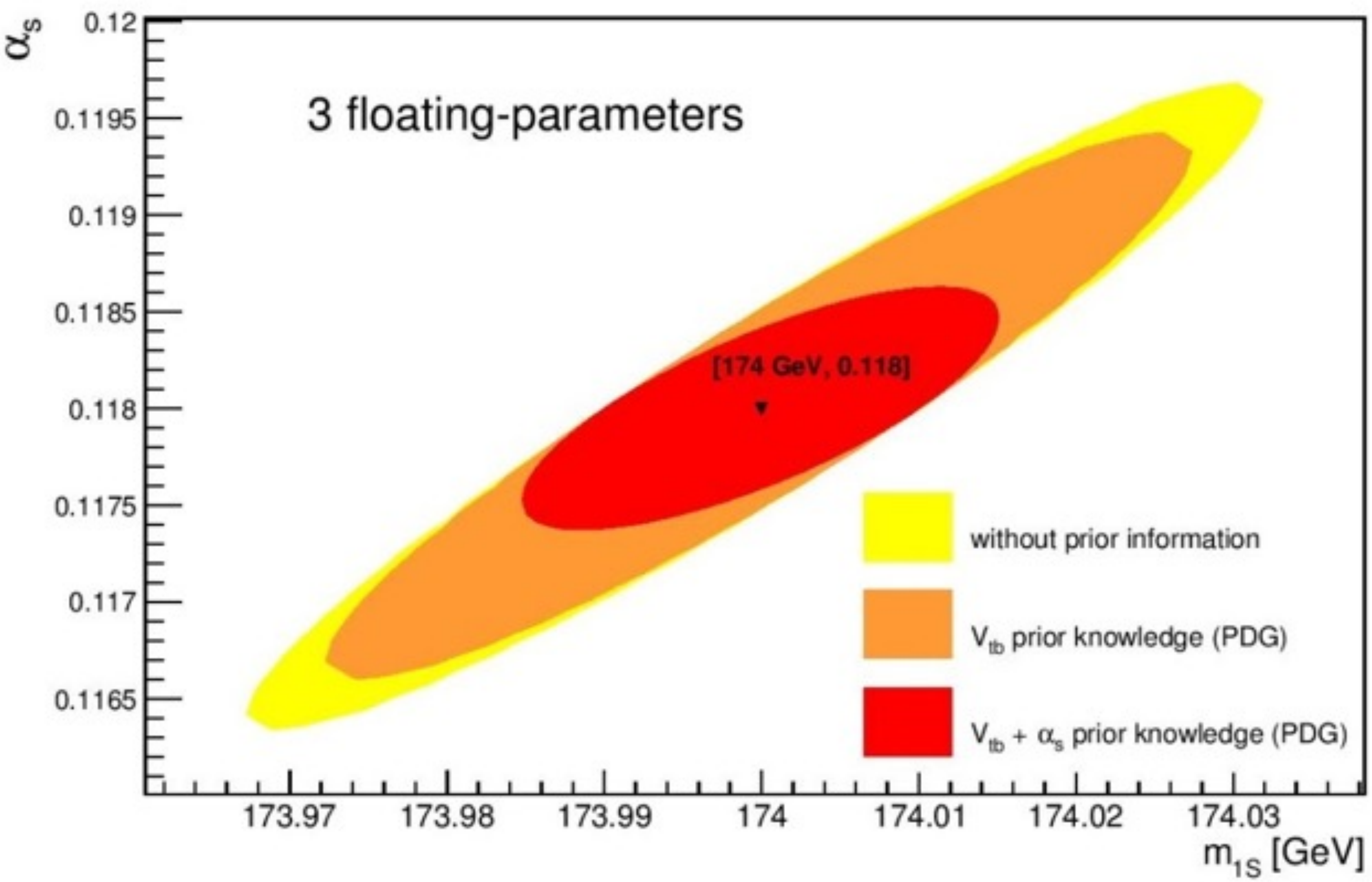
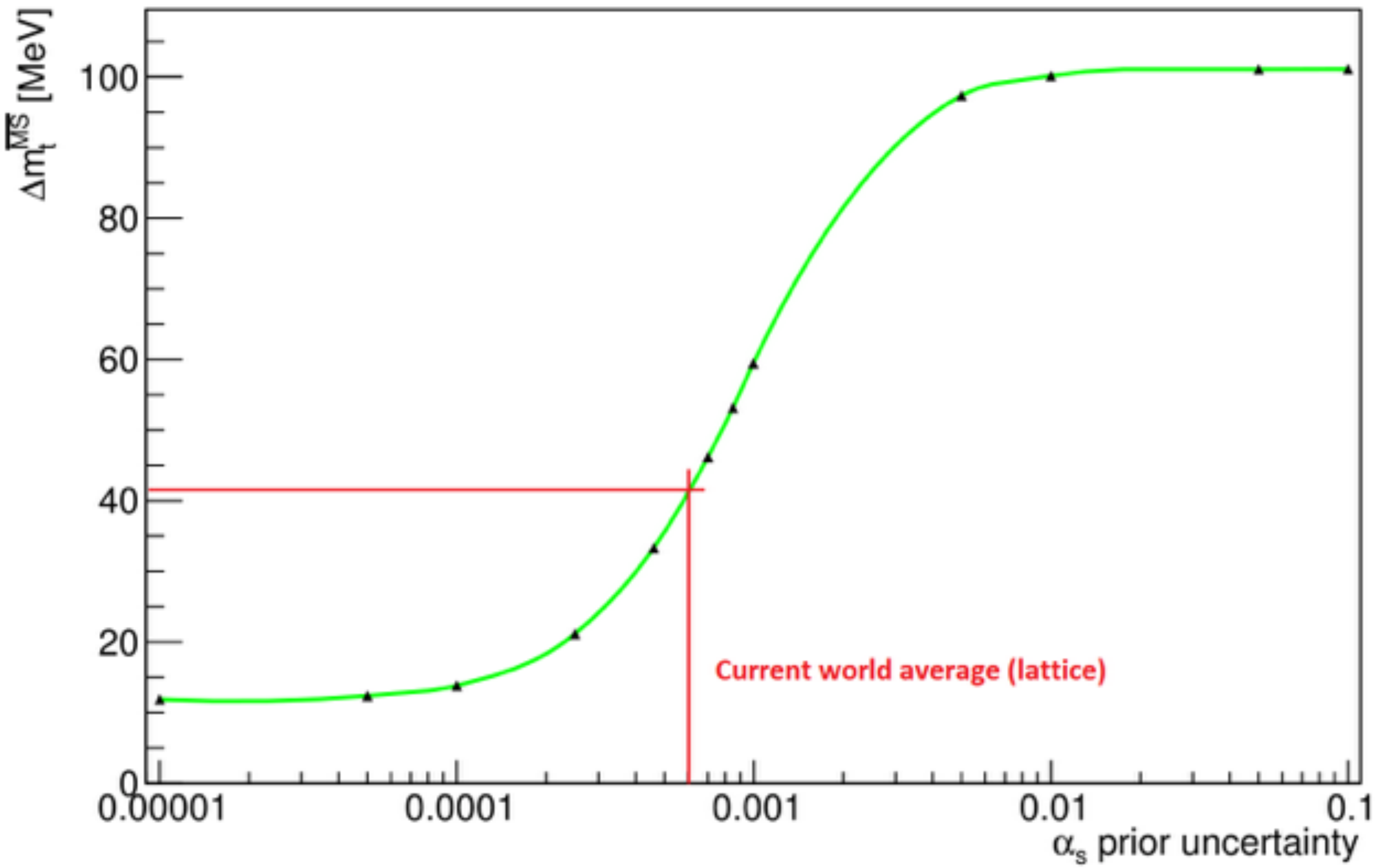
Valencia Analysis: Using Prior Knowledge

- **a_s and V_{tb} (PDG2014 world average).**
- V_{tb} prior does not have an important impact in the interplay.
- a_s prior reduces considerably the uncertainties



Valencia Analysis: Impact of α_s on Mass Conversion

- α_s hits twice: the conversion to the MS mass leads to an additional parametric uncertainty due to the strong coupling constant



Top quark mass precision vs. prior knowledge of strong coupling constant

If the α_s uncertainty improves very considerably, a 12 MeV precision on the top quark MS mass is achieved.

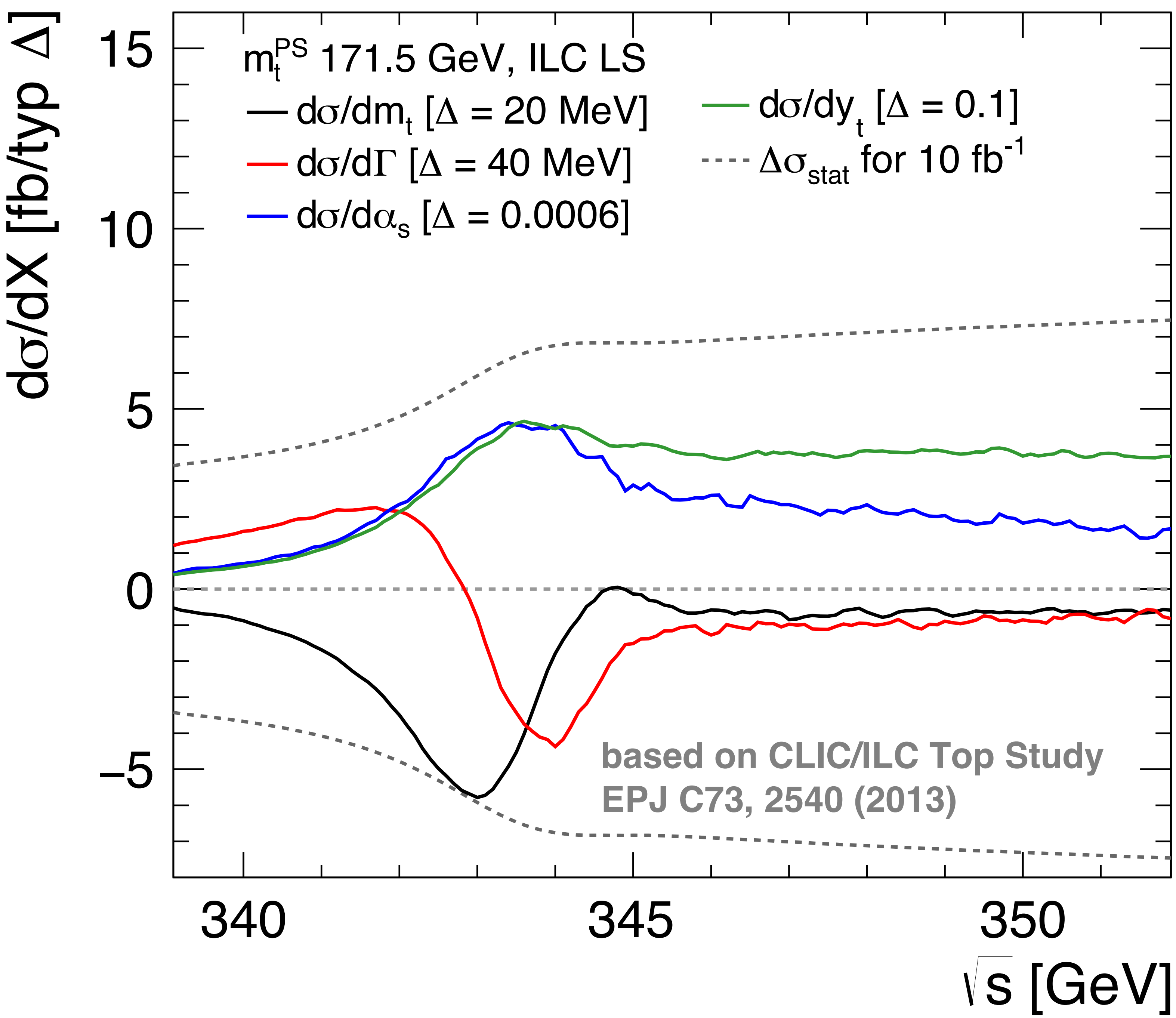
Valencia Analysis: Prospects for α_s at 500 GeV ILC

- **Extrapolating LEP2 results on Z-pole and WW threshold, TLEP/FCCee predicts 0.0001 precision**
- **LC prospects seem rather bleak**
- **What about tt + 1jet cross-section at 500 GeV?**
  - Similar sensitivity to as threshold, but very small top mass dependence
  - Single parameter extraction through the cross-section

Integ. Lumin.	$500\ fb^{-1}$	$4\ ab^{-1}$ (Lumi – upg.)
$\Delta\alpha_s$	0,0005	0,0002

Only competitive if the theory uncertainties are controlled at 0.5% - few per mil.

Threshold Scan - Sensitivity to Parameters



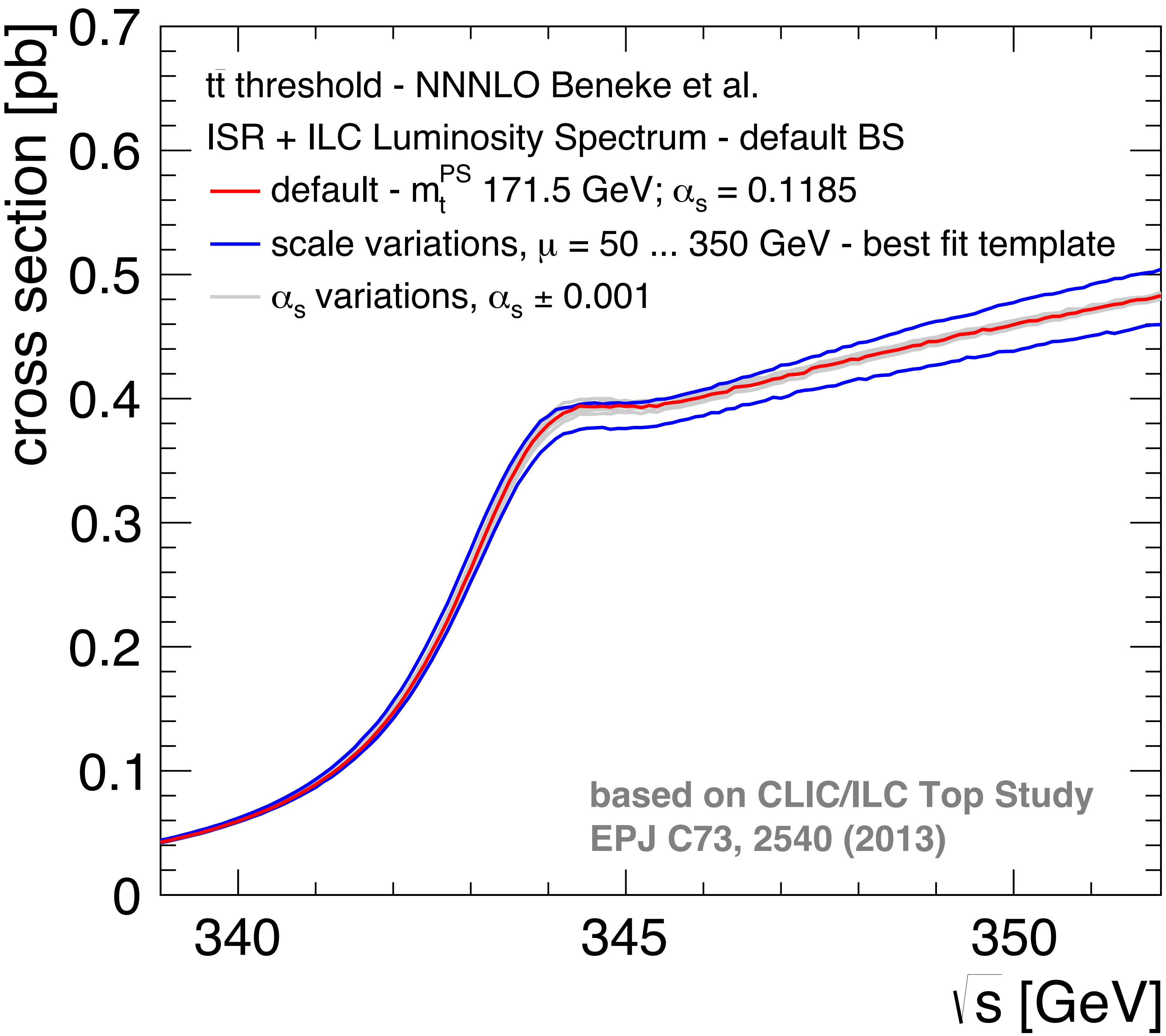
- Illustration of sensitivity: Variation of cross section for typical uncertainties assumed on parameters
  - typical LC stat uncertainty for m_t, Γ_t
  - WA for α_s
  - 10% for y_t

➡ Strong correlation between y_t and α_s

➡ Mass sensitivity maximum in steepest region of cross-section

➡ Width the only one changing sign

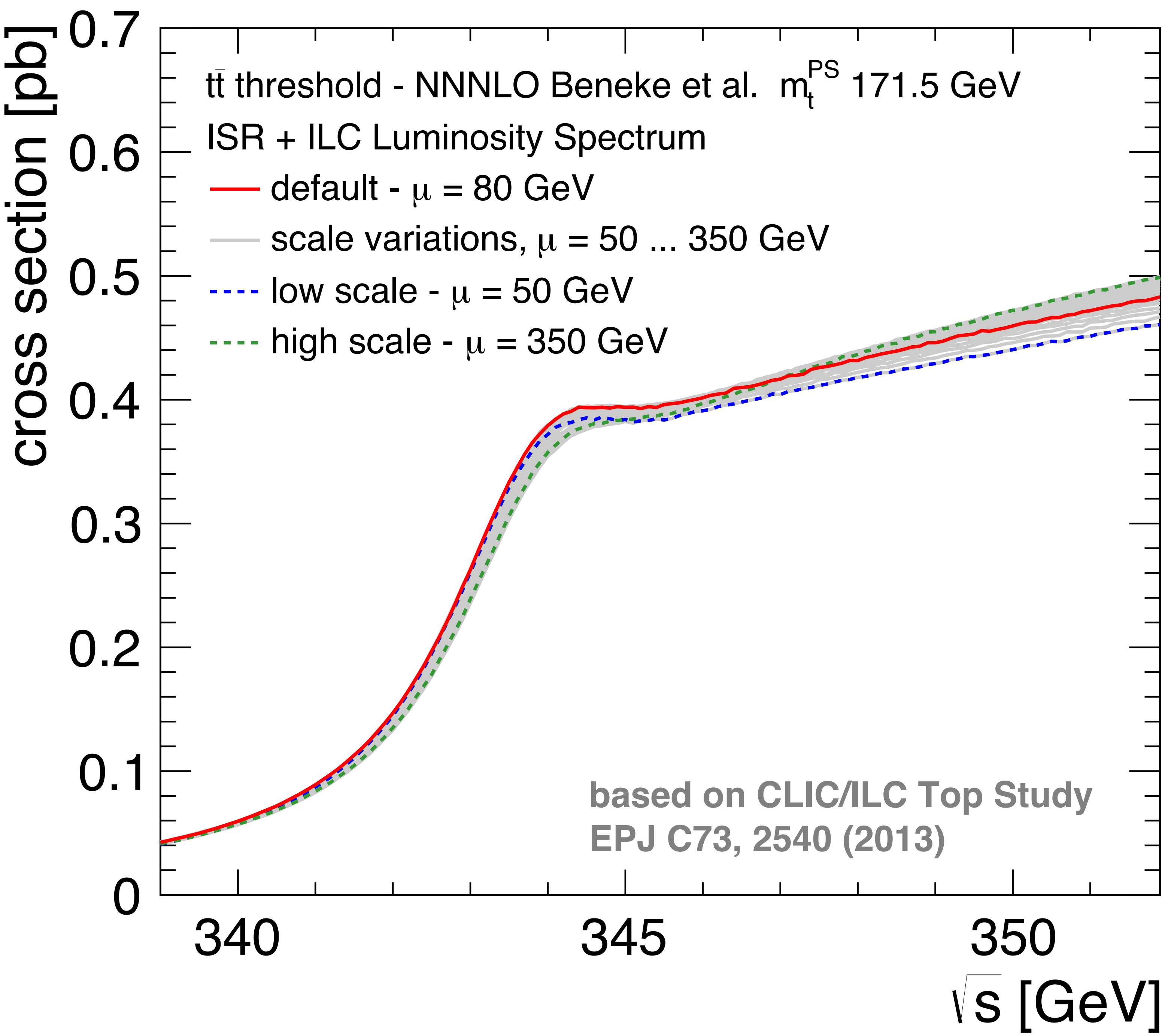
Sensitivity to α_s Variations vs Scale Uncertainties



- For scale uncertainties: "Best Fit Template" shown - covers extremes of scale variations for m_t^{PS} = 171.45 GeV

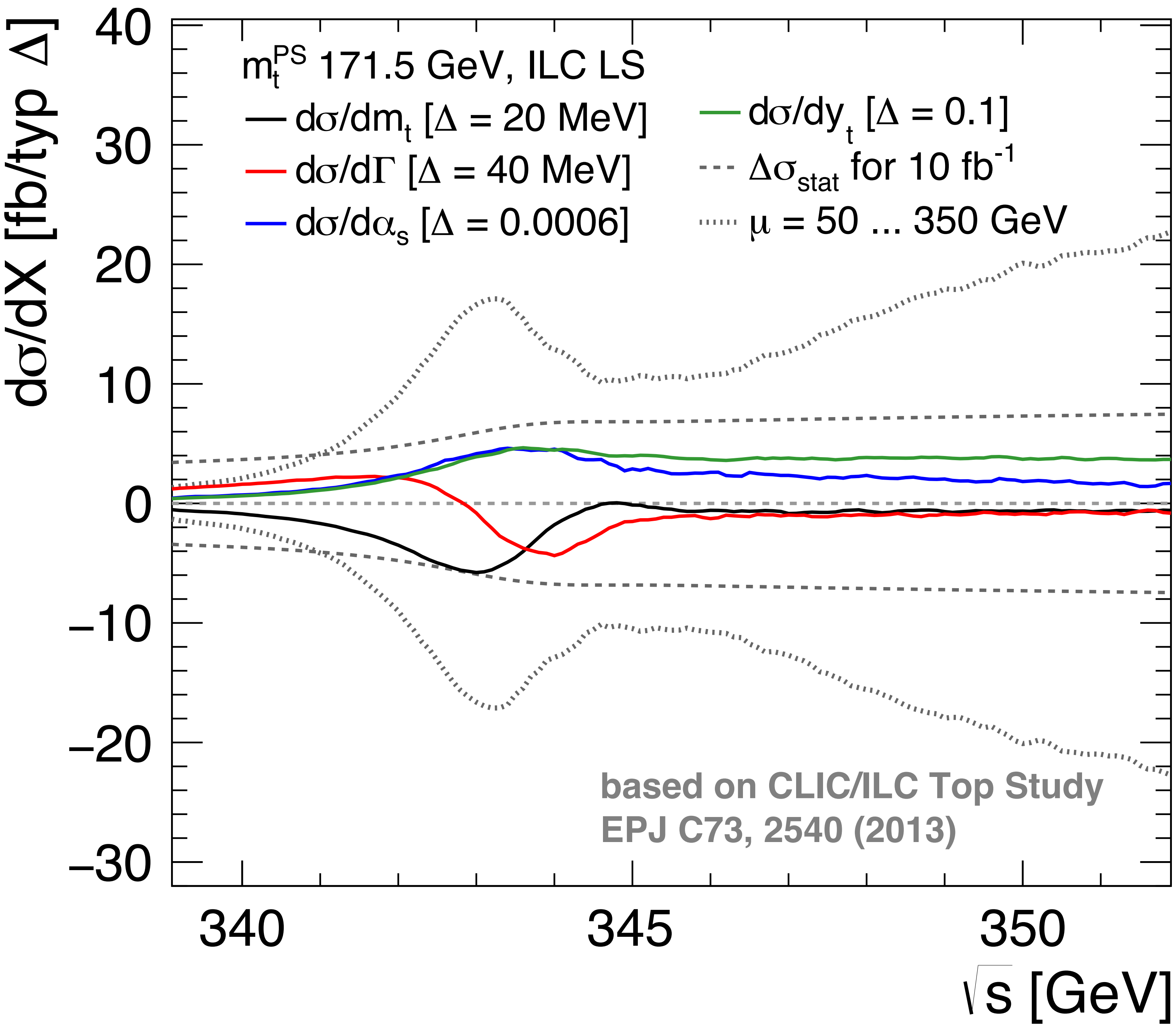
➯ Scale uncertainties substantially larger than α_s variations

Impact of Scale Uncertainties on Threshold Scan



- Include scale variations in cross section calculation
  - Default scale: 80 GeV
  - Scales below 50 GeV lead to instable behavior - are not considered

Impact of Scale Uncertainties on Threshold Scan



- Include scale variations in cross section calculation
  - Default scale: 80 GeV
  - Scales below 50 GeV lead to instable behavior - are not considered
- Substantial variations of cross section - beyond variations induced by parameters based on projected stat. uncertainties alone

Impact of α_s

- Studied for fit with scale uncertainties included
  - 2.7 MeV / 10^{-4} uncertainty of α_s : 16 MeV for current WA - Not a leading systematic

- For “alternative” fit scenarios
  - Single point at optimum: slightly reduced impact 2.3 MeV/10^{-4}
  - Three & Five points: 2.6 MeV / 10^{-4}

➾ Threshold scan strategies (choice of energy points) have very little influence on impact of strong coupling uncertainty

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NB: Not considered here: "Interpretation uncertainty - m_t^{PS} / m_t^{1S} transformation into msbar mass

Conclusions

- The strong coupling plays an important role in top physics - when considering transformation of masses measured at threshold to msbar mass it is currently among the leading limitations
- Discussion: How good does it have to be - and what are the prospects to get there?