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Top Threshold Developments: Theory

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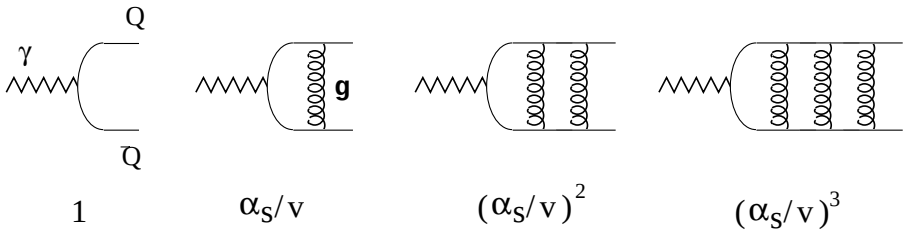
- Towards a full understanding of EW effects in $e^+e^- \longrightarrow t\bar{t}$
- Differential distributions for the threshold scan
- Threshold effects in $t\bar{t}H$ production
- $t\bar{t}$ production at NNNLO $\longrightarrow$ Yuichiro Kiyo

Why the top threshold?



- ⋆ We want m_t with better than per mille accuracy

  → EWSB (indirect m_H det.), SUSY parameters, low energy...GUT connection

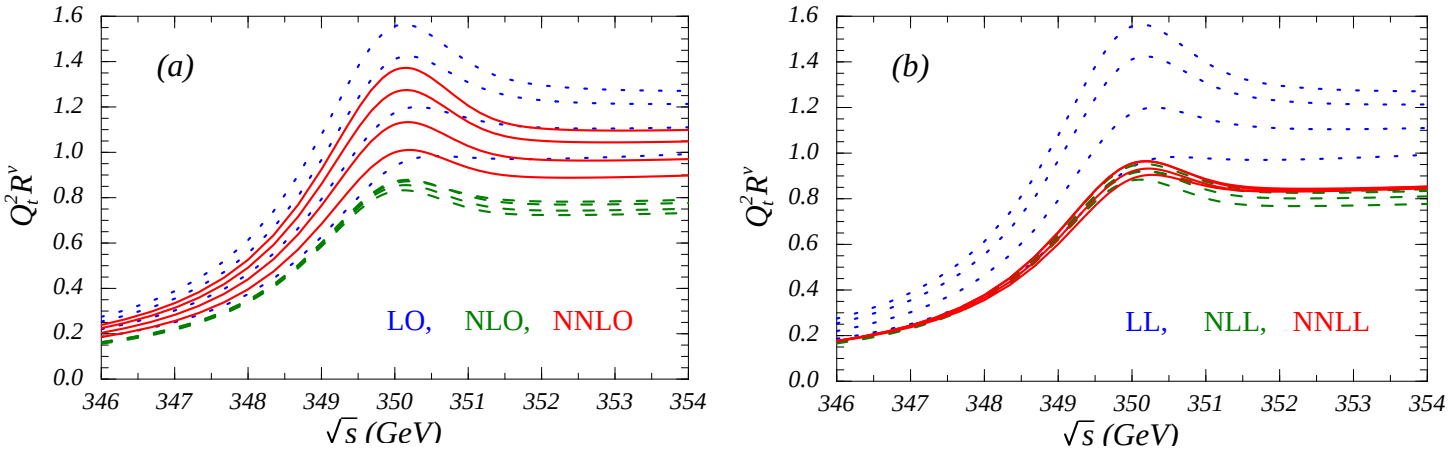
- ⋆ Threshold scan $e^+e^- \to t\bar{t}$ the only known way to achieve $\Delta m_t < \Lambda_{\rm QCD}$

  → *counting* $bW^+\bar{b}W^-$ colour singlett states

- ⋆ Threshold dynamics understood at NNLL (soon also N^{3}LO)

  → *Effective Field Theories* (v,p)NRQCD

$\sigma(e^+e^- \to t\bar{t})$ in a) 'fixed order', b) RG-improved: (Hoang+Manohar+Stewart+T)



Towards a full understanding of ElectroWeak effects

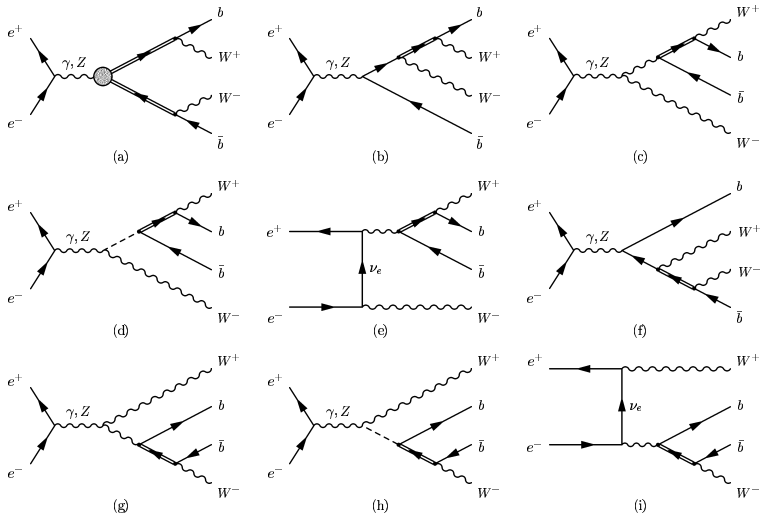
⋆ Top decays fast: $\Gamma(t \to bW) \sim 1.5$ GeV

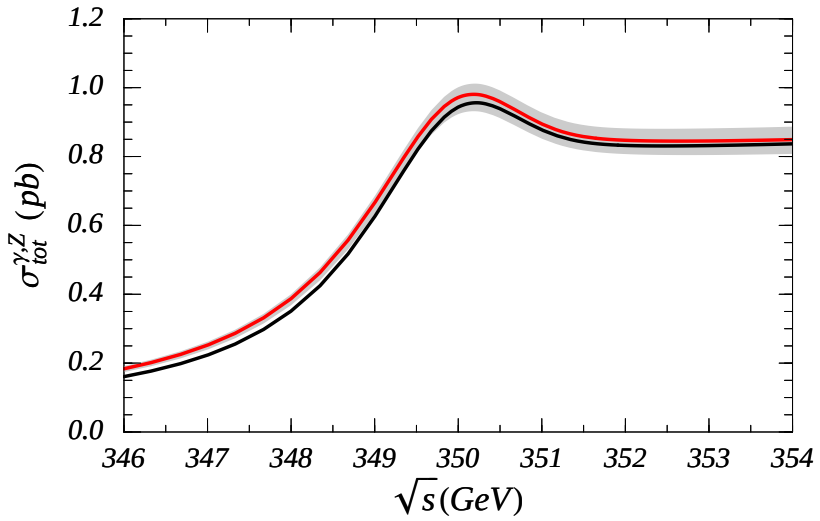
⋆ Up to now: $E = \sqrt{s} - 2m_t \to E + i\Gamma_t$ in NRQCD. But: Not sufficient beyond NLO!

⋆ Talk from André Hoang: *'Top decay and EW corrections at the $t\bar{t}$ threshold'*

→ First results about consistent treatment of EW effects in vNRQCD:

Incl. e.g. irreducible non-resonant $WWbb$ final states. Result for $\sigma_{\rm tot}$





Reduction of cross section and peak-shift!

⋆ See also talk from Giulia Zanderighi: *'Effective theories for unstable particle production'*

Differential distributions for the threshold scan

⋆ $t\bar{t}$ threshold scan is mainly a *counting experiment* of $bW^+\bar{b}W^-$ coulour singlett states. However:

– Cuts needed to select $t\bar{t}$ from background

– Distributions needed to build realistic (higher order) Monte Carlo generators for the signal process

– Use of additional observables [not only $\sigma_{tot}(e^+e^- \to t\bar{t})$] will

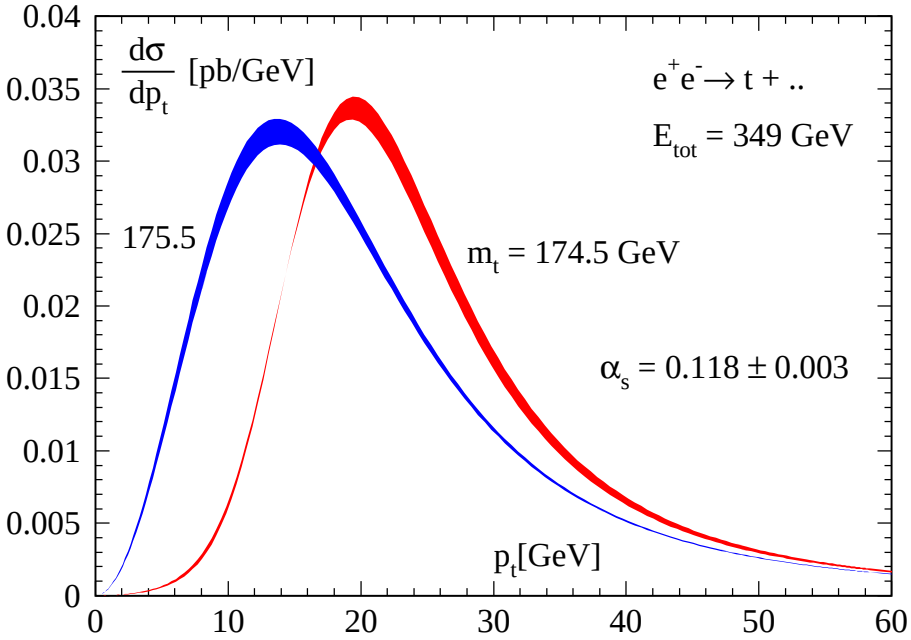
- add information,
- help to disentangle correlations between parameters $(m_t, \alpha_s, \Gamma_t, y_t)$,
- increase sensitivity to possible New Physics in production and decay.

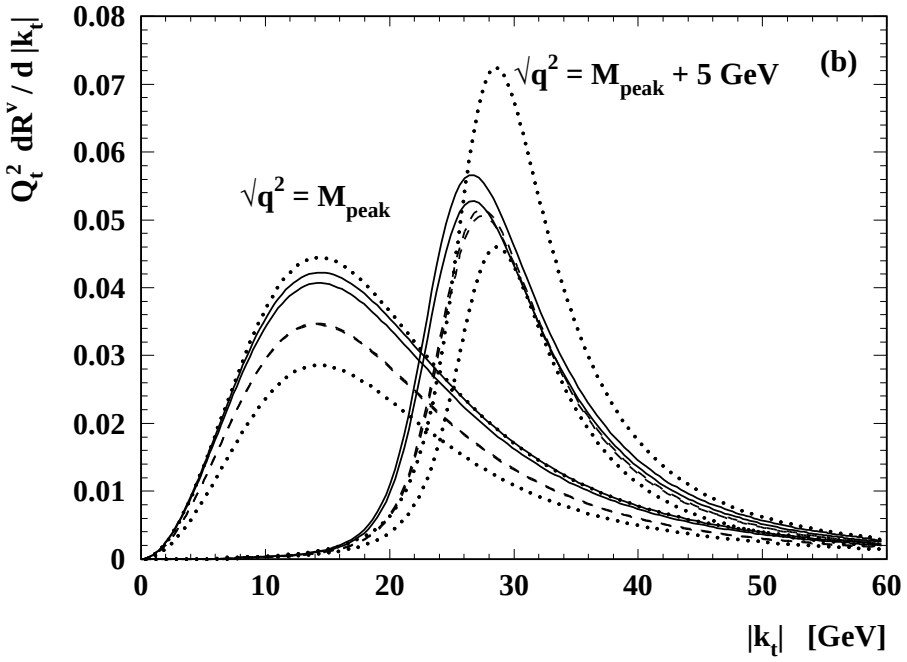
• Observables are e.g. top momentum distribution, Forward-Backward Asymmetry, top polarization, W decay lepton spectra..

- Top momentum distribution $\mathrm{d}\sigma/\mathrm{d}p_t$ ($\sim$ |wave function in momentum space|^2)

  $\rightarrow$ available at NNLO (modulo rescattering corrections, see below) ✓

LO, NLO, NNLO with $\mu = 15...60$ GeV (Hoang+T)

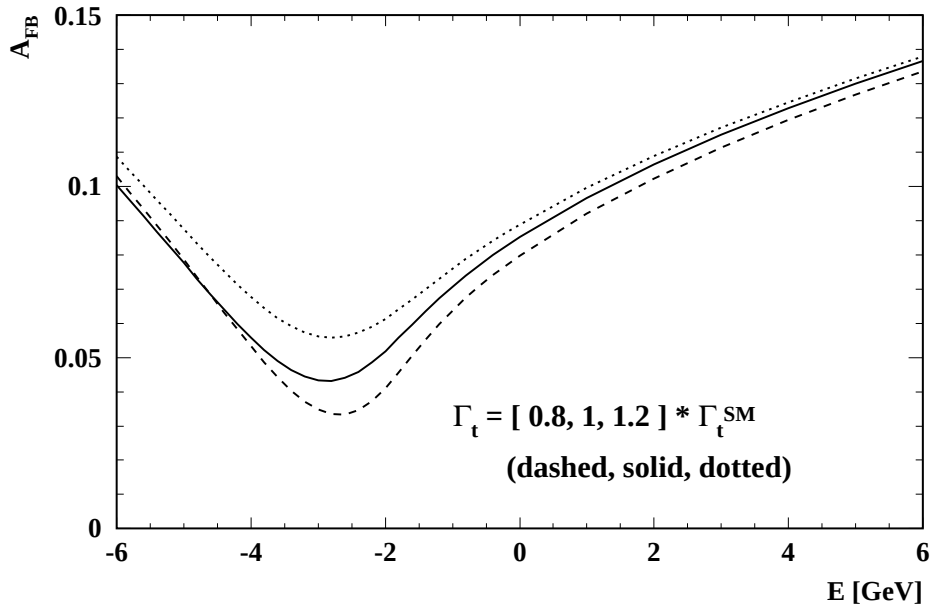


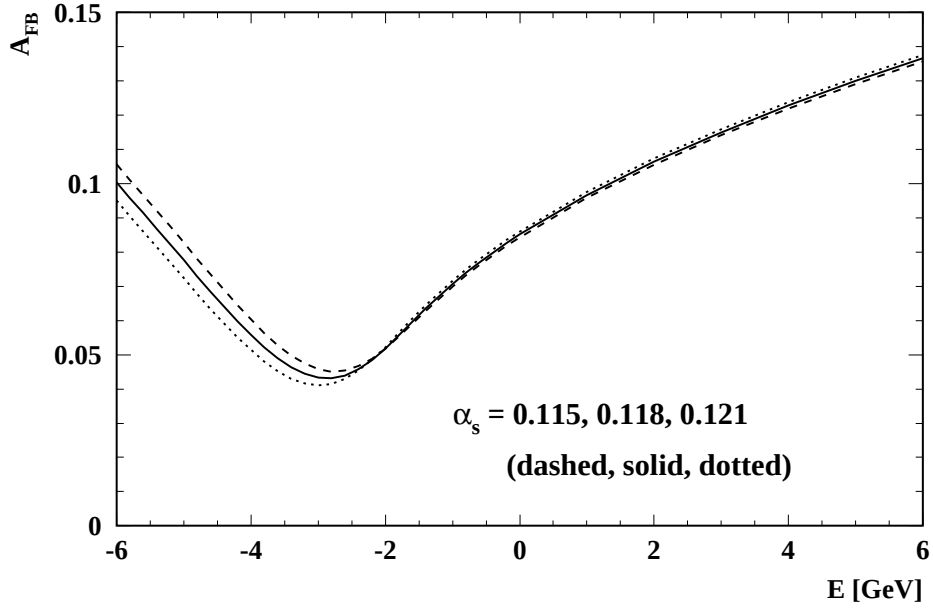


$\rightarrow$ The peak of the top momentum distribution depends strongly on m_t, but is not very sensitive to α_s ($\rightsquigarrow$ help against correlation of m_t and α_s in σ_{tot})

- Forward-Backward Asymmetry A_{FB} (NNLO, modulo resc. corrections) ✓

$t\bar{t}$ production through a virtual Z leads to a (small) P wave contribution. Interference with the leading S wave results in A_{FB}, depending strongly on the width Γ_t, less on α_s.





• Polarization

– Unpolarized beams: -40% (longitudinal) polarized top quarks

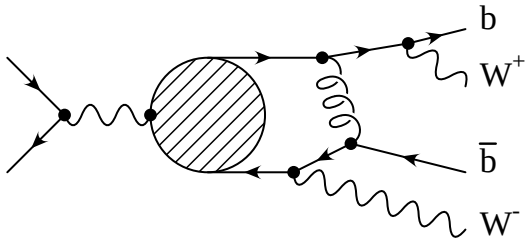
– Polarized beams: highly polarized tops

→ all three polarization components calculable (NLO ✓)

→ sensitive e.g. to EDM's of top (BSM CP-violation), anomalous coupl. (like $V + A$)

⟶ Experimental analysis needed!

• Rescattering corrections



– Cross-talk between $t - \bar{b}$, $\bar{t} - b$ and $b - \bar{b}$

– Strongly suppressed (zero at NLO) for inclusive σ_{tot}

– Numerical results for rescattering corrections to $\mathrm{d}\sigma/\mathrm{d}p_t$, A_{FB} and top polarization

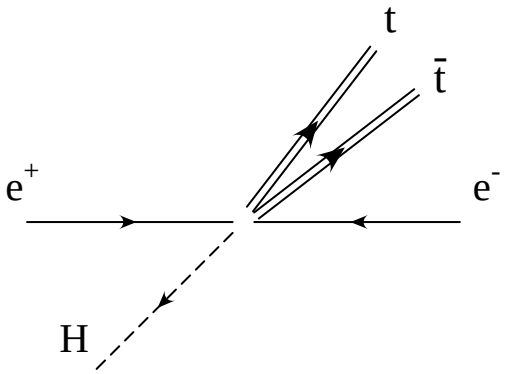
NLO ✓, effect typically 10% (should be included for realistic Monte Carlo)

▶ Project started in Snowmass:

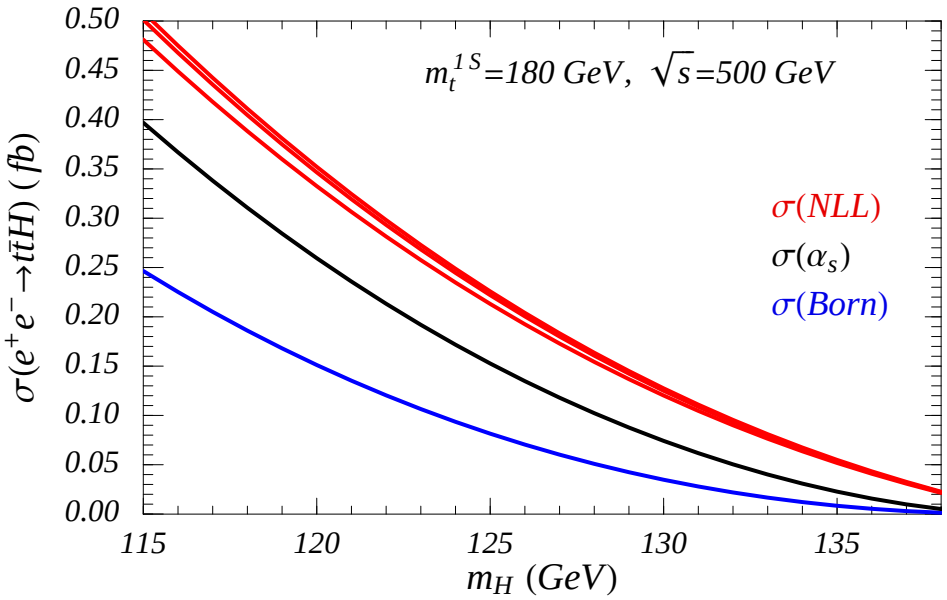
⟶ Threshold analysis incl. distributions and rescattering, see talk from Stewart Boogert

Threshold effects in $t\bar{t}H$ production

(talk from André Hoang)



- ⋆ In the region of large Higgs energy $t\bar{t}$ is collinear; must be treated as a non-relativistic system.
- ⋆ For $\sqrt{s} = 500$ GeV the $t\bar{t}$ threshold dynamics is crucial.
- ⋆ Enhancement of $t\bar{t}H$ at NLL:



- ▶ Project at Snowmass: ⟶ Aurelio Juste