Top quark mass and α_s at a LC

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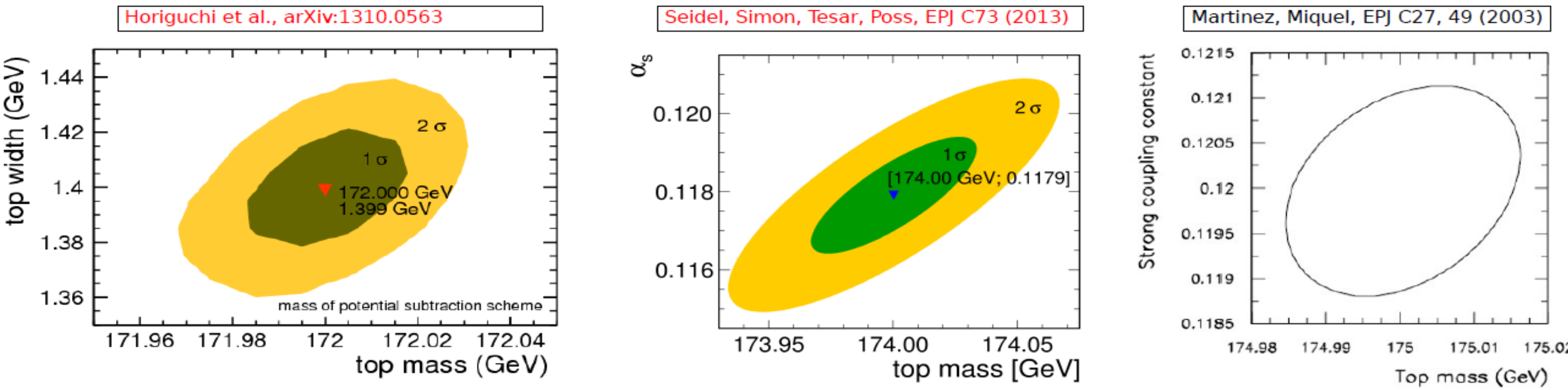
Introduction



- Several authors have applied **multi-parameter fits to cross-section obtained in scan** (+ other distributions) at future linear colliders.

- Statistical precision on 1S or PS mass for 10 x 10/fb: **16 – 30 MeV** (*range of results can be understood from assumptions and fit details*).

- This study tries to contribute to the previous works through new developments.

Signal sample

- Inclusive process: $\boldsymbol{e^+e^- \rightarrow W^+bW^-\bar{b}}$
  - To avoid single top mis-identification.

See: Fuster, Garcia, et al. Study of single top production at high energy electron-positron colliders, arXiv:1411.2355

$\sqrt{s}$	10 points around ttbar threshold : 344-353 GeV
Luminosity	$10fb^{-1}$ ($100fb^{-1}$ in the total threshold scan)
Beam structure	ISR+beamstrahlung
Beams polarization	$P(e^-, e^+) = (-80\%, +30\%)$
MC generator	Whizard 2.2.6 (SM_tt_threshold) – LO+NLL

- **Parton-level study**: preliminary study of theoretical and systematic uncertainties, but NOT included in the minimization.

Multi-parameter fit

1) Top quark mass at the 1S threshold scheme: m_{1S}

- Conversion from 1S to $\overline{MS}$:

(P. Marquard et al., arXiv:1502.01030, PRL114 (2015))

$$\frac{m_t(m_t)}{GeV} = 163.643 \pm 0.007 + 0.069\,\delta_{\alpha_s} - 0.096\,\delta_{m_t}^{1S}$$

$$\delta_{\alpha_s} = [0.1185 - \alpha_s]/0.001$$

$$\delta_{m_t}^{1S} = [172.227\,GeV - m_t]/0.1$$

2) Is the top width a free parameter?

$$\Gamma\,(t \to Wb)_{SM} = \frac{G_F m_t^3}{8\pi\sqrt{2}} |V_{tb}|^2 \left(1 - \frac{M_W^2}{m_t^2}\right)\left(1 + 2\frac{M_W^2}{m_t^2}\right)\left[1 - \frac{2\alpha_s}{3\pi}\left(\frac{2\pi^2}{3} - \frac{5}{2}\right)\right]$$

- ***Change to a Vtb analysis*** *(see F. Bach's talk,* https://indico.desy.de/contributionDisplay.py?sessionId=11&contribId=19&confId=10353*).*

3) The strong coupling constant, α_s.

Statistical analysis

- **χ^2 minimization (LS method):**

$$\chi^2(m_{1S}, V_{tb}, \alpha_s) = \sum_{i=1}^{10} \left(\frac{y_i - \sigma(\sqrt{s_i};\ m_{1S}, V_{tb}, \alpha_s)}{\delta y_i} \right)^2$$

- **Factorization method:**

$$\sigma(m_{1S}, V_{tb}, \alpha_s) = \sigma(m_{1S})\sigma(V_{tb})\sigma(\alpha_s) \frac{\sigma(174\ GeV; 1; 0{,}118)}{\sigma(174\ GeV)\sigma(1)\sigma(0{,}118)}$$

Only valid around the factorization point.

1 vs 2 vs 3 floating-parameters strategy

Fit	Δm_{1S} [MeV]	ΔV_{tb}	$\Delta\alpha_s$
Only m_{1S}*	10	-	-
m_{1S} vs V_{tb}	10	0,0095	-
m_{1S} vs α_s	15	-	0,0007
m_{1S} vs V_{tb} vs α_s	32	0,023	0,0017

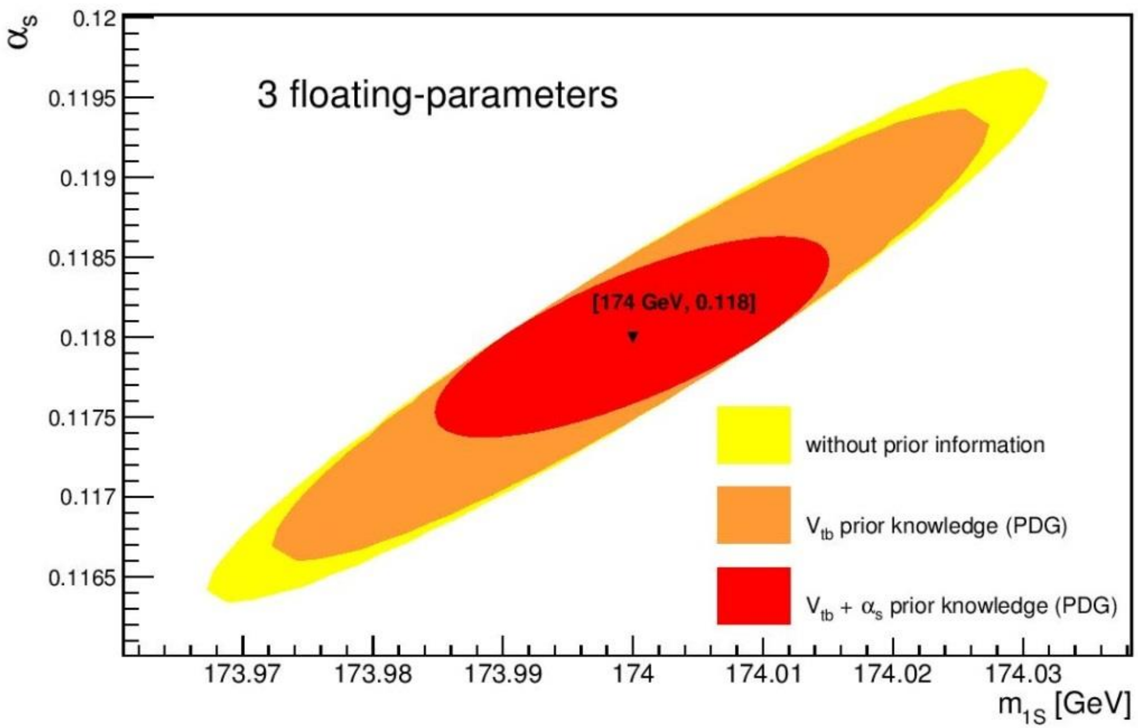
**Vtb and α_s fixed to their respective nominal values.*

- Little impact of Vtb to the mass extraction, **α_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.

Using prior knowledge (current values)

Adding prior information on the χ^2 minimization...

- **$\Delta V_{tb} = 0,032$ (PDG2014) $\Delta\alpha_s = 0,0006$ (world average).**
- Vtb prior does not have an important impact in the $m_{1S} - \alpha_s$ interplay.
- α_s prior reduces considerably the uncertainties

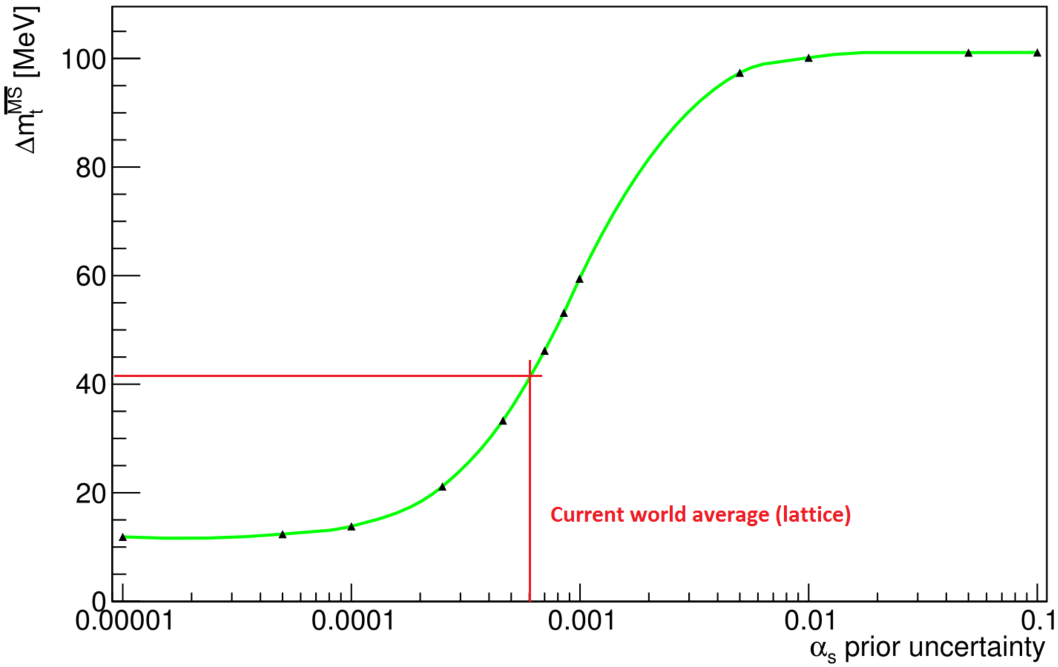


Achieved uncertainties:

- $\Delta m_{1S} = 14$ MeV
- **$\Delta m^{\overline{MS}} = 41$ MeV**
- $\Delta V_{tb} = 0{,}011$
- $\Delta\alpha_s = 0{,}00055$

Using prior knowledge (α_s role)

- The $\overline{\text{MS}}$ mass uncertainty can be reduced with a more precise value of α_s.



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

$$\Delta m^{\overline{MS}} = \mathbf{41\ MeV}$$
(3 floating-params.)
$$\rightarrow \mathbf{12\ MeV}$$
(2 floating-params.)

With an uncertainty of $\lesssim 0.0001$ on α_s a limit of 12 MeV on the top quark mass is reached (higher value considering systematics).

α_s scenarios – Z & W boson physics

ILC

- Giga-Z program (TDR: Z boson hadronic-to-b-quark ratio): $\Delta\alpha_s \sim 0{,}0005$

Results scaling from a TLEP study… ***(See arXiv:1308.6176v2)***

- W had. branching-fract. through WW events at 500 GeV at high-luminosity program: $\Delta\alpha_s \sim 0{,}0005$

$$\downarrow$$

$$\Delta\alpha_s \sim 0{,}0004$$

ALTERNATIVE SCENARIOS??

α_s scenarios – 500 GeV Tour

- **Study: cross-section from WbWb + 1jet at $\sqrt{s} = 500$ GeV**
  - Similar sensitivity to α_s as threshold, but very small top mass dependence.
  - Single α_s 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.

Not very optimistic for a big α_s uncertainty reduction from ILC

Summary and plan

PRESENT…

- Previous results at a $t\bar{t}$ threshold are confirmed through a WbWb study.
- α_s limits the statistical precision of the top quark mass even using the current world-average ($\Delta m^{\overline{MS}} = 41$ MeV).
- Including a precise value of α_s ($\Delta\alpha_s \sim 0.0001$) can reduce the mass uncertainty to $\Delta m^{\overline{MS}} = 12$ MeV.

FUTURE…

- Complete study at detector level.
- Theoretical and systematic uncertainties.

THANK YOU!!