Top Quark Physics Chapter

Motivation

Material to be included

1) Profile of t : decay modes

2) Threshold production : top mass

3) Continuum $t\bar{t}$ production

   $\sigma_{t\bar{t}}$, t charge

   (anomalous) couplings in $t\bar{t}$ prod. & decay

4) polarization issues (to be included)

Comparison with LHC

t most massive matter particle known to date

m_t curiously close to scale of EWSB

likely to play key role in

pinning down origin of EWSB

e.g. measurement of y_t

search for clues to solve flavour problem

precision measurements of its properties and int.

mandatory for any future collider

e^+e^- LCs most suitable instruments

to study top under clean exp. cond.

Importance of precise measurement of m_t

which can be made at LC:

ingredient in { EW precision analysis
test Higgs mech. at quantum level
theory of flavour

precision measurement of NC couplings to γ, Z

helicity analysis

1) Profile of top

SM decay , width Γ_{SM}

decay distrib. of (polarised) $t \to b \, l \, \nu_e$

width Γ_t from A_{FB} near threshold

previous simulation: $\frac{\delta \Gamma_t}{\Gamma_t} = 10-20\%$

will be updated

non-SM decays

examples: $t \to H^+ b$, $t \to \tilde{t} \chi^0$ within MSSM

plots of Br J. Guasch

incl. present exp. constraints

$Br(t \to H^+ b) \gtrsim 1\%$

assume: seen at LHC and mass m_{H^+} known

LC: measure Br

previous simulation: $\frac{\delta Br}{Br}$ as function of Br

simul. $Br(t \to \tilde{t} \chi^0) > 0.6\%$

with $100 \, fb^{-1}$

2) $t\bar{t}$ threshold : top mass

emphasize: m_t from counting $t\bar{t}$ (color singlet)
as opposed to $t \to$ jets

theory input: recent calcs. of $\sigma^{\text{threshold}}_{t\bar{t}}$
at NNLO
using proper mass definitions
M_t^{1S}, M_t^{PS} ...

top momentum dist.

theory plot of $\sigma^{\text{threshold}}_{t\bar{t}}$

simulation: see plot

- 2 parameter fit : α_s, M_t
- α_s input : fit to M_t

simulation: Peralta, Martinez, Miquel

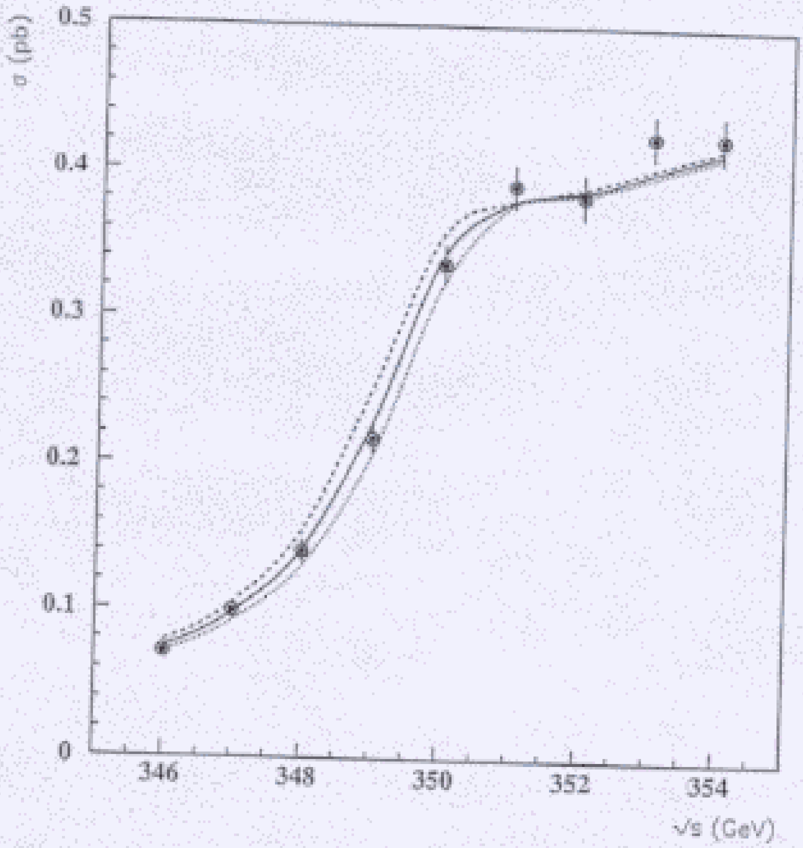
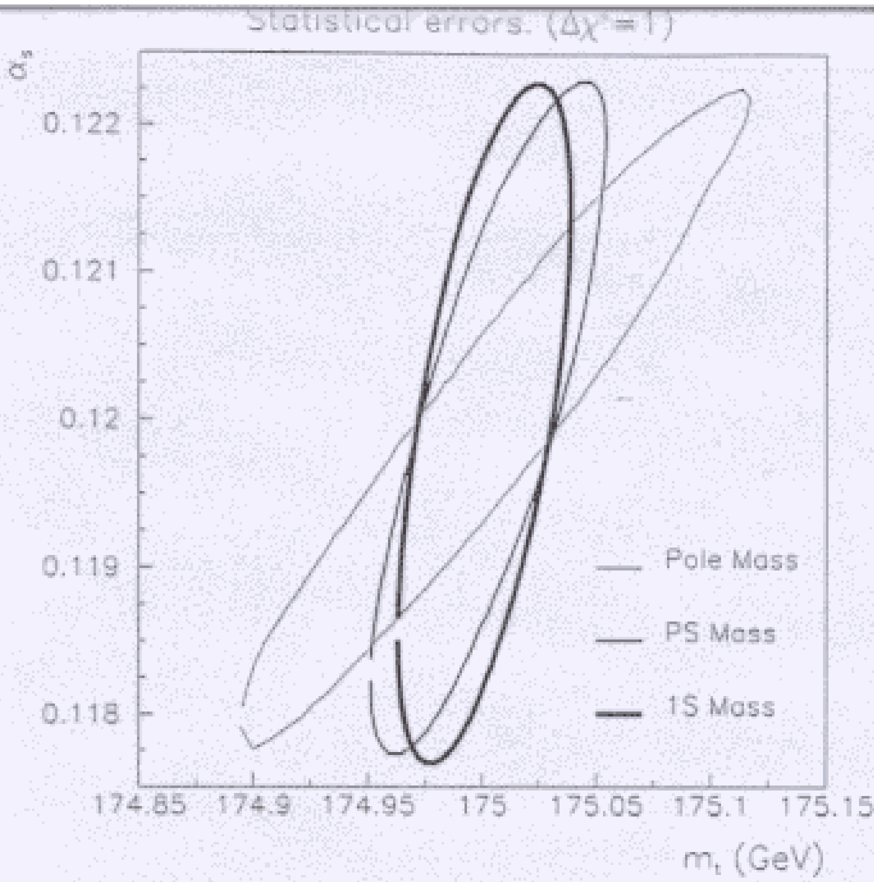


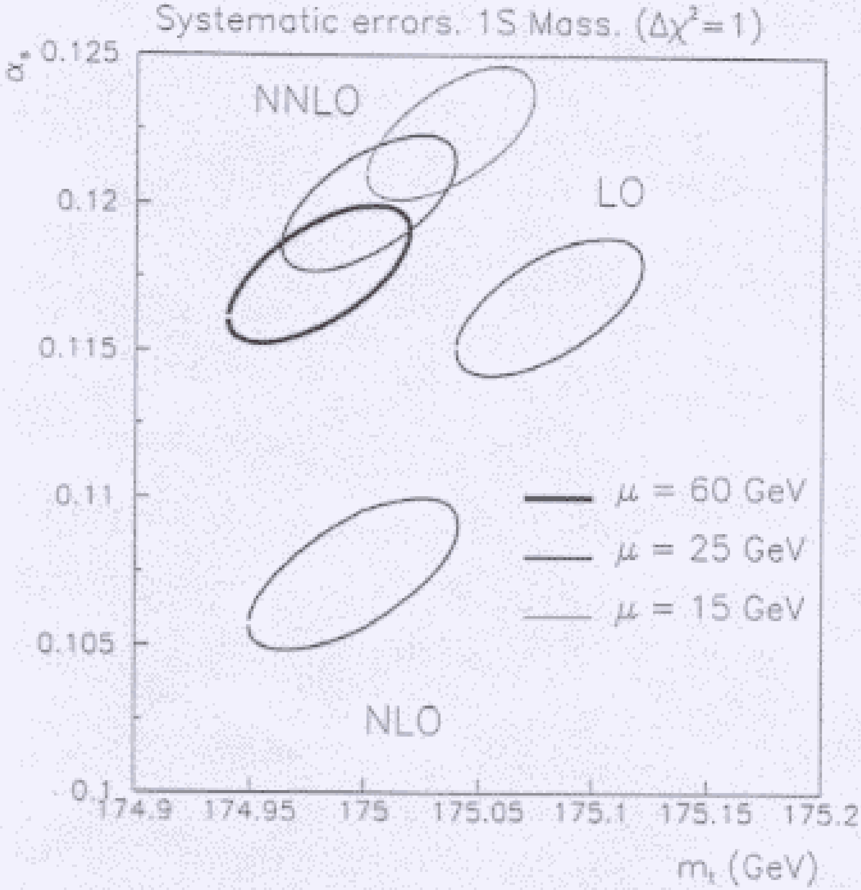
Figure 3.3.4: *Excitation curve of the top quarks including initial-state radiation and beamstrahlung [32]. The errors of the data points correspond to an integrated luminosity of* $\int \mathcal{L} = 100\ fb^{-1}$. *The dotted curves indicate shifts of the top mass by ± 100 MeV.*



2 parameter fit

will be updated

3.3.5: *Statistical errors on α_s and the top mass resulting from a 2-parameter fit ulated data of the tbart excitation curve, using the NNLO cross-section predic- with the top threshold mass parameters indicated. Here m_t denotes the top mass of the conventions given in the figure. An integrated luminosity of 100 fb^{-1} was ed. From Ref.[32].*



3.3.6: *Theoretical errors on the fitted values of α_s and the so-called 1S mass, ng from the dependence of the NNLO cross-section prediction on the renormali- scale μ. From Ref.[32].*

results:

2 parameter fit:

$(\delta M_t^{1S})_{sim} \simeq 40$ MeV , $(\delta \alpha_s)_{sim} \simeq 0.0024$

$(\delta M^{1S})_{th} \simeq 40$ MeV, $(\delta \alpha_s)_{th} \simeq 0.013$

1 parameter fit:

input α_s with $\delta \alpha_s = 0.001$

$(\delta M_t^{1S})_{sim} \simeq 30$ MeV, $(\delta M_t^{PS})_{sim} \simeq 40$ MeV

$(\delta M_t^{1S})_{th} \simeq 110$ MeV , $(\delta M_t^{PS})_{th} \simeq 180$ MeV

will be updated

eventually convert into $\overline{MS}$ mass $\overline{m}_t(\overline{m}_t)$

3) Continuum $t\bar{t}$ production

theory plot of $\sigma_{t\bar{t}}(s)$ including $O(\alpha_s^2)$ corr.
+ 1 loop EW corr.

plot will be provided by
Kühn et al.

top couplings:

LR asymmetry at threshold

$$\frac{\sigma_L - \sigma_R}{\sigma_1} \propto g_{vt}^Z / Q_t$$

$e^-_L e \to t\bar{t}$ at threshold

100% polarized t decay

ideal to study decay coupl.

search for anomalous couplings:

helicity analysis in cont. (using pol. e^-)

form factor decomp. of $t\bar{t}$ prod. & decay vertices

chirality conserving / flipping   CP-inv. / CP

$(g-2)_t$, EDM$_t$, V+A admixture, ...

analysis done mostly at parton level
possible strategy: find CP
then input to determine CP-inv. couplings

theory at 500 GeV

Form factor	SM value	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 800$ GeV	
		$p = 0$	$p = -0.8$	$p = 0$	$p = -0.8$
F_{1V}^{γ}	1				
F_{1V}^{Z}	1		0.019	← from R. Frey	
F_{1A}^{Z}	1		0.016		
F_{1A}^{γ}	0				
$F_{2V}^{\gamma,Z}$	0	0.015	0.011	0.011	0.008
$\mathrm{Re}F_{2A}^{\gamma}$	0	0.035	0.007	0.015	0.004
$\mathrm{Re}F_{2A}^{Z}$	0	0.012	0.008	0.008	0.007
$\mathrm{Im}F_{2A}^{\gamma}$	0	0.010	0.008	0.006	0.005
$\mathrm{Im}F_{2A}^{Z}$	0	0.055	0.010	0.037	0.007
F_{1R}^{W}	0	0.030	0.012		
$\mathrm{Im}F_{2R}^{W}$	0	0.025	0.010		

g-2 ($F_{2V}^{\gamma,Z}$) — $O(\alpha_s)$ QCD: -0.009

CP ($\mathrm{Re}F_{2A}$, $\mathrm{Im}F_{2A}$) — 0.02 for Higgs sector CP

V+A (F_{1R}^{W})

CP ($\mathrm{Im}F_{2R}^{W}$)

Table 3.3.1: *1 s.d. statistical sensitivities to (non) SM form factors in $t\bar{t}$ production [9, 19] and in t decay to Wb [9, 18]. The second column contains the respective SM value to lowest order, p denotes the polarisation of the electron beam. For the c.m. energy $\sqrt{s} = 500$ GeV (800 GeV) an integrated luminosity of 300 fb^{-1} (500 fb^{-1}) was used.*

4) Polarisation issues

- beam pol. obvious tool
  for top physics

- e^- pol. has been used
  to some extent

- $\frac{\delta Pol}{Pol} \simeq 1\%$ seems
  sufficient
  for top studies

Comparison with LHC

	LC	LHC
m_t	$\lesssim 200$ MeV (threshold)	1 – 2 GeV
Γ_t	~ 10%	no, but $\lvert V_{tb}\rvert^2$ ~ 10% (stat.) from single top
"static" parameter ($g-2$, EDM, V_{tb}, ...)	$\lesssim$ few %	
	rare decays	
$t \to H^+ b$	$B_r \lesssim 1\%$	~ 3%
$t \to \tilde{t}\chi^0$	$B_r < 1\%$	no
$t \to cZ$	~ 10^{-3}	~ 10^{-4}
$t \to c\gamma$	not studied	~ 10^{-4}