LIA TYL ILC-top

(one aspect of it)

$$e^+e^- \to t\,\bar{t} \to \mu^+\mu^- b\,\bar{b}\,\nu_\mu\bar{\nu}_\mu$$

The Matrix Element Method
Conjugate (optimal) variables
Results
Kinematics
Conclusion

D. Atwood and A. Soni : Phys. Rev. D45 (1992) (Pioneering work in that direction, among others)

The Matrix Element Method

$$| \mathcal{M} |^2$$

All information per event is used
(Petra->LEP->Tevatron->LHC)

H.J. Behrends et al., CELLO Collab. Z. Phys. C43 (1989)

Here, we are dealing with a rich 9-dimension Phase Space:

$$\mathrm{dLips} = \mathrm{d}\cos\theta_t \; \mathrm{d}\cos\theta_b \; \mathrm{d}\phi_b \; \mathrm{d}\cos\theta_{\bar{b}} \; \mathrm{d}\phi_{\bar{b}} \; \mathrm{d}\cos\theta_{\mu^+} \; \mathrm{d}\phi_{\mu^+} \; \mathrm{d}\cos\theta_{\mu^-} \; \mathrm{d}\phi_{\mu^-}$$

and 16^2 amplitudes^2

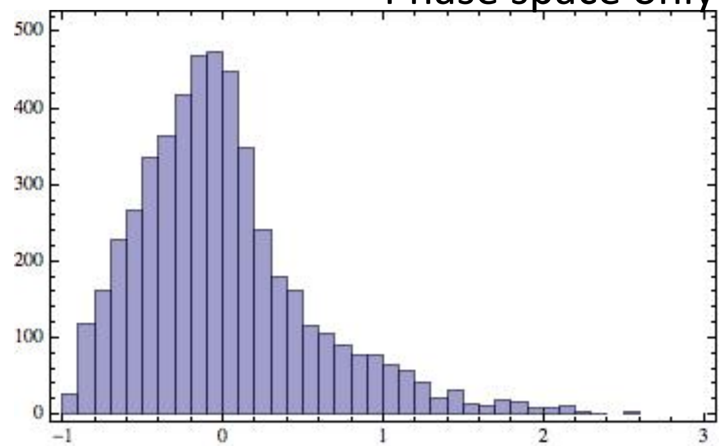
Example :

Correction term due to interferences between the helicity amplitudes

$$| t^{\uparrow}\bar{t}^{\uparrow} + t^{\uparrow}\bar{t}^{\downarrow} + t^{\downarrow}\bar{t}^{\uparrow} + t^{\downarrow}\bar{t}^{\downarrow} |^2 =$$

$$\left(| t^{\uparrow}\bar{t}^{\uparrow} + | t^{\uparrow}\bar{t}^{\downarrow} + | t^{\downarrow}\bar{t}^{\uparrow} + | t^{\downarrow}\bar{t}^{\downarrow} |^2\right)(1+\rho)$$

Phase space only



ρ

$$\alpha \leftarrow \text{theoretical parameters}$$

$$\mathcal{L}(\alpha)$$

A likelihood analysis of events easily handle the 9-dimension analysis

It can be shown that, in effect, the Likelihood analysis implicitly makes use of “conjugate” kinematical variables defined by:

$$\omega_i = \frac{\partial \mid \mathcal{M} \mid^2 (\alpha)}{\partial \alpha_i}_{|\alpha^0} \frac{1}{\mid \mathcal{M} \mid^2 (\alpha^0)}$$

$$\Omega_i = \frac{\partial N(\alpha)}{\partial \alpha_i}_{|\alpha^0} \frac{1}{N(\alpha^0)}$$

Using only the distribution of events in Phase Space:

$$V_{ij}^{(-1)} \equiv \Lambda_{ij} = N \; \langle (\omega_i - \Omega_i)(\omega_j - \Omega_j) \rangle_0$$

Using also the yields:

$$V_{ij}^{(-1)} \equiv \Lambda_{ij} = N \; \langle \omega_i \omega_j \rangle_0$$

Simultaneous 10-parameter fit

$\mathcal{R}e\ \delta\tilde{F}^{\gamma}_{1V}$	$\mathcal{R}e\ \delta\tilde{F}^{Z}_{1V}$	$\mathcal{R}e\ \delta\tilde{F}^{\gamma}_{1A}$	$\mathcal{R}e\ \delta\tilde{F}^{Z}_{1A}$	$\mathcal{R}e\ \delta\tilde{F}^{\gamma}_{2V}$	$\mathcal{R}e\ \delta\tilde{F}^{Z}_{2V}$	$\mathcal{R}e\ \delta\tilde{F}^{\gamma}_{2A}$	$\mathcal{R}e\ \delta\tilde{F}^{Z}_{2A}$	$\mathcal{I}m\ \delta\tilde{F}^{\gamma}_{2A}$	$\mathcal{I}m\ \delta\tilde{F}^{Z}_{2A}$
0.0037	−0.18	−0.09	+0.14	+0.62	−0.15	0	0	0	0
	0.0063	+.14	−0.06	−0.13	+0.61	0	0	0	0
		0.0053	−0.15	−0.05	+0.09	0	0	0	0
			0.0083	+0.06	−0.04	0	0	0	0
				0.0105	−0.19	0	0	0	0
					0.0169	0	0	0	0
						0.0068	−0.15	0	0
							0.0118	0	0
								0.0069	−0.17
									0.0100

$0.4 \rightarrow 1.7\%$

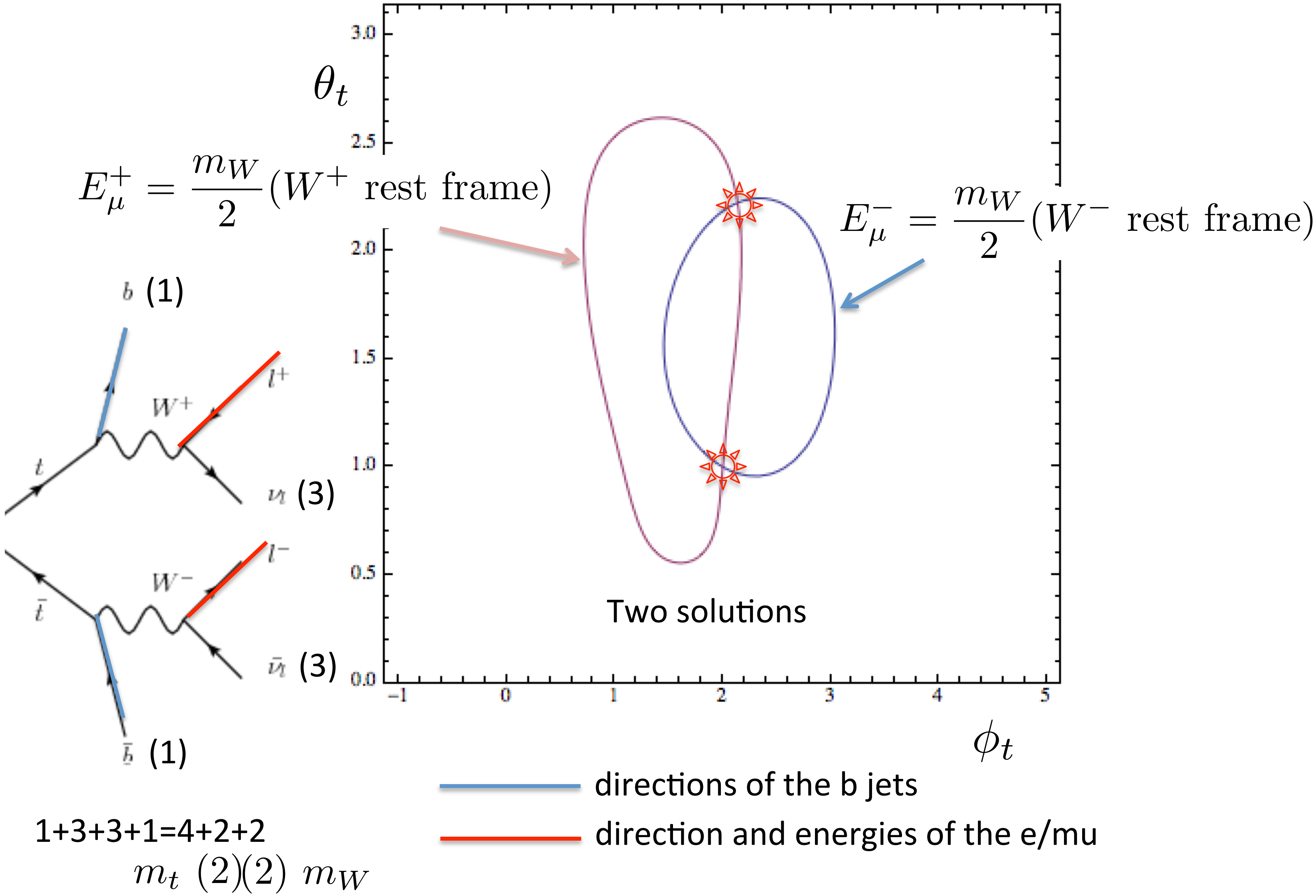
$500\ \mathrm{GeV}\ \&\ 500\ \mathrm{fb}^{-1}$

Luminosity split 50/50 between $\pm\,80\%\,\mp\,30\%$ beam polarizations

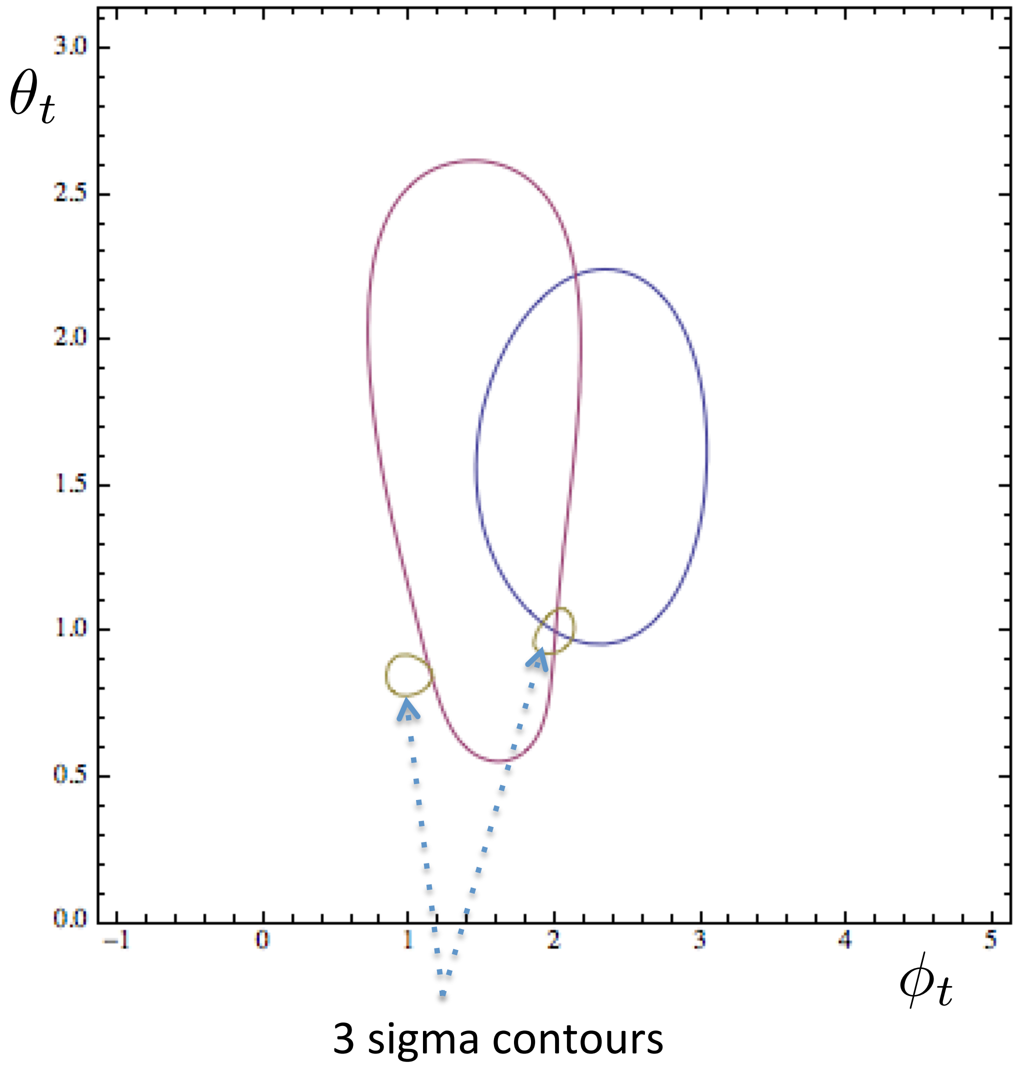
17 500 events produced

(no reconstruction & detector & background & Physics effects taken care of)

Kinematical reconstruction

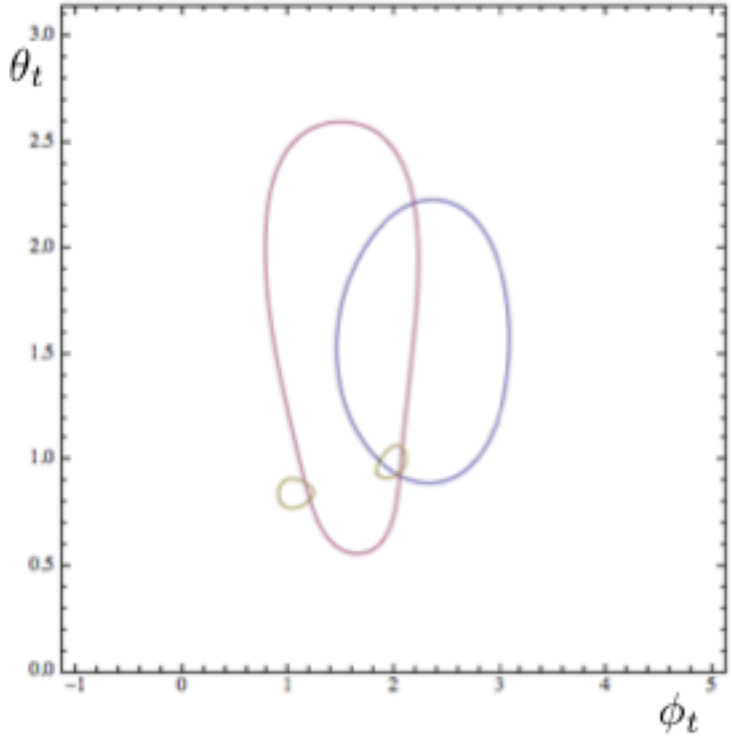


The energies of the b jets are used to select the right solution



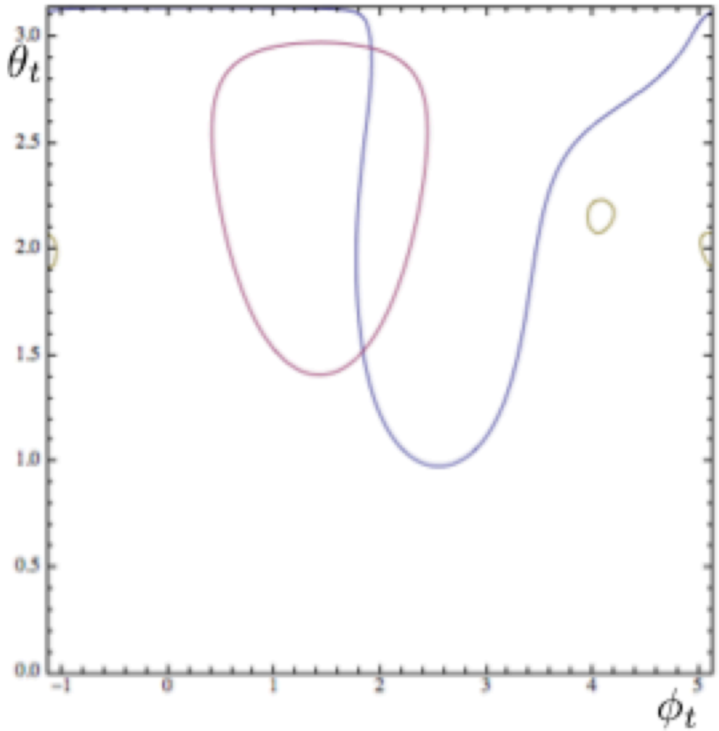
… and some complications.

The W and top widths do not help : remain manageable

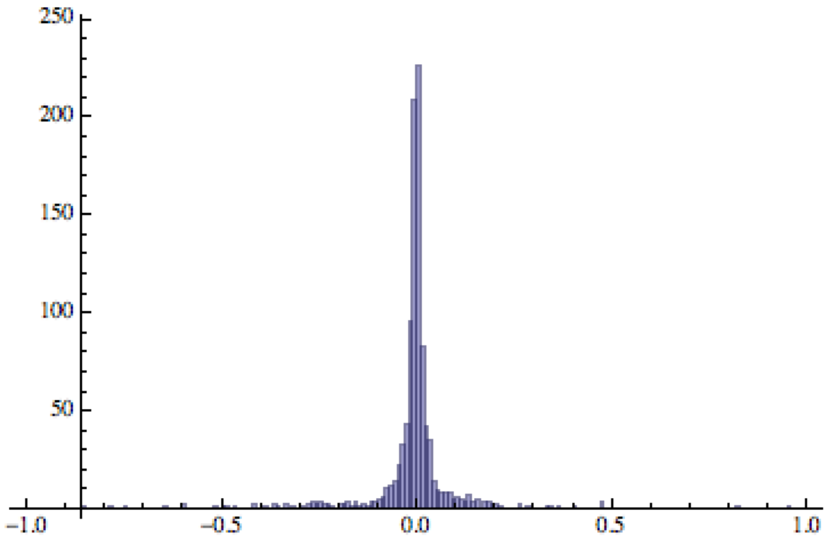


Picking up the best solution (unperfect) works

If one select the wrong b assignment : no solution

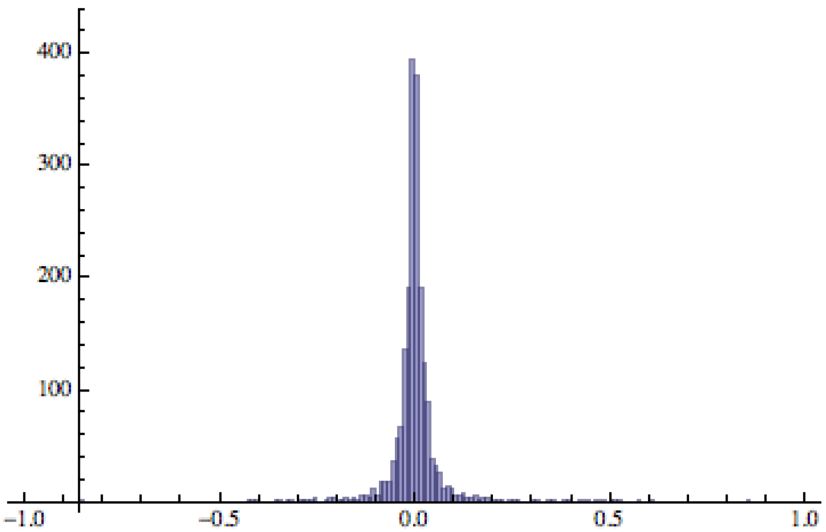


… in fact, 5% about manage to pass through



$\cos\theta_t^{\rm reco} - \cos\theta_t^{\rm true}$ (in ILC frame)

Using GRACE events, and letting the masses free to vary



$\cos\theta_b^{\rm reco} - \cos\theta_b^{\rm true}$ (in top CMS)

Conclusion :

The final state

$$e^+e^- \rightarrow t\;\bar{t} \rightarrow \mu^+\mu^- b\;\bar{b}\;\nu_\mu\bar{\nu}_\mu$$

Appears promising for top studies :
The sensitivity to top couplings are similar to the semi-leptonic mode, but with different limitations.

A lot of work ahead