Strong Symmetry Breaking Signals in $e^+e^- \to W^+W^-$ at $\sqrt{s} = 800$ GeV

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The process $e^+e^- \rightarrow W^+W^-$ is affected in two ways as $M_H \rightarrow \infty$

1. **Non-SM TGC's induced**

2. **$e^+e^- \rightarrow W_L^+W_L^-$ amplitude modified**

Chiral Lagrangian

$$\mathcal{L}_{SB} = \mathcal{L}^{(2)} + \mathcal{L}^{(4)} + \cdots$$

where

$$\begin{aligned}
\mathcal{L}^{(2)} &= \frac{1}{4} v^2 \mathrm{Tr} D^\mu \Sigma^\dagger D_\mu \Sigma, \\
\mathcal{L}^{(4)} &= \frac{L_1}{16\pi^2} [\mathrm{Tr}(D^\mu \Sigma^\dagger D_\mu \Sigma)]^2 + \frac{L_2}{16\pi^2} \mathrm{Tr}(D_\mu \Sigma^\dagger D_\nu \Sigma) \mathrm{Tr}(D^\mu \Sigma^\dagger D^\nu \Sigma) \\
& -ig \frac{L_{9L}}{16\pi^2} \mathrm{Tr}(W^{\mu\nu} D_\mu \Sigma D_\mu \Sigma^\dagger) - ig' \frac{L_{9R}}{16\pi^2} \mathrm{Tr}(B^{\mu\nu} D_\mu \Sigma^\dagger D_\nu \Sigma) \\
& +gg' \frac{L_{10}}{16\pi^2} \mathrm{Tr}(\Sigma B^{\mu\nu} \Sigma^\dagger W_{\mu\nu}) \quad .
\end{aligned}$$

$$\begin{aligned}
\kappa_\gamma &= 1 + \frac{e^2}{32\pi^2 s_w^2} (L_{9L} + L_{9R}) \\
\kappa_Z &= 1 + \frac{e^2}{32\pi^2 s_w^2} (L_{9L} - \frac{s_w^2}{c_w^2} L_{9R}) \\
g_1^Z &= 1 + \frac{e^2}{32\pi^2 s_w^2} \frac{L_{9L}}{c_w^2}
\end{aligned}$$

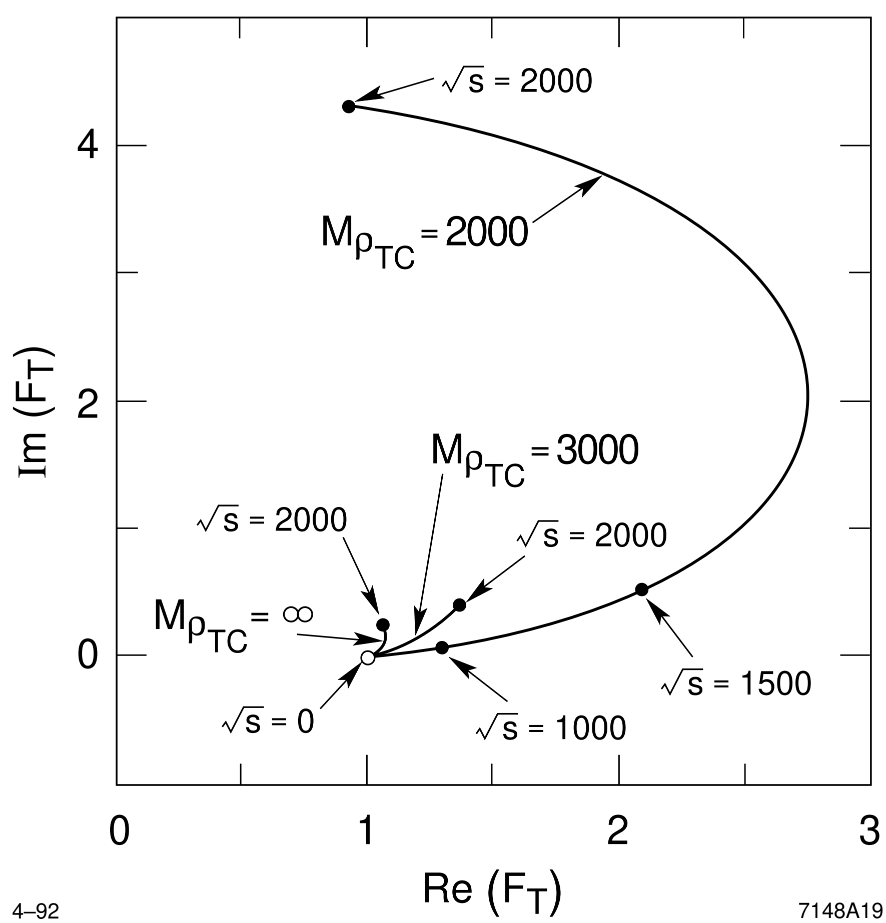
QCD values for L_{9L}, $L_{9R} \Rightarrow \ \Delta\kappa_\gamma \sim -3 \times 10^{-3}$

SM loop corrections also $\mathcal{O}(10^{-3})$

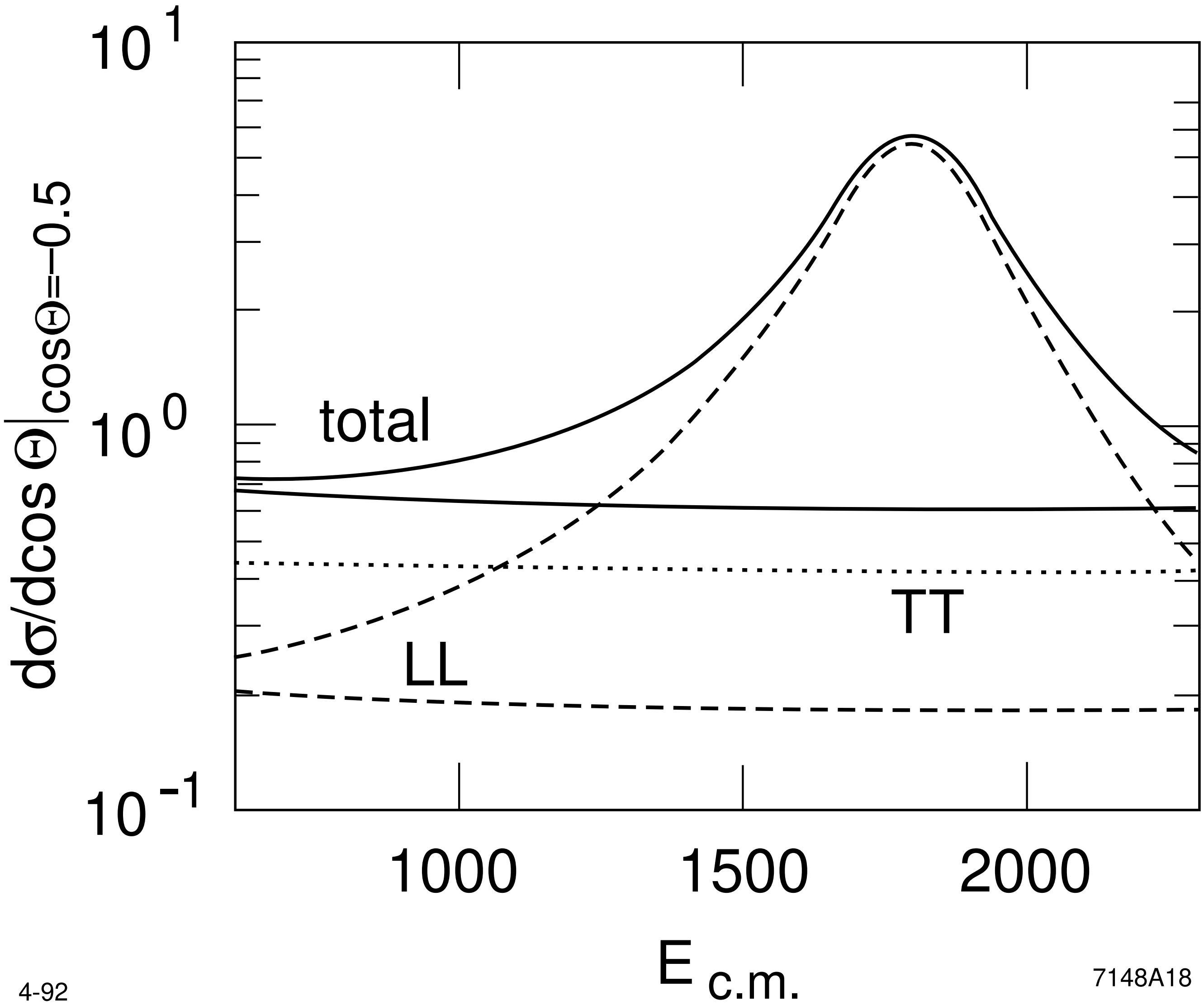
$e^+e^- \to W_L^+ W_L^-$ Amplitude

$$F_T = \exp[\frac{1}{\pi}\int_0^\infty ds' \delta(s', M_\rho, \Gamma_\rho)\{\frac{1}{s' - s - i\epsilon} - \frac{1}{s'}\}]$$

$$\delta(s) = \frac{1}{96\pi}\frac{s}{v^2} + \frac{3\pi}{8}\left[tanh(\frac{s - M_\rho^2}{M_\rho \Gamma_\rho}) + 1\right]$$



$e^+e^- \to W^+W^-$ Cross-section in the Presence of 1.8 TeV Technirho



vector resonance widths (same as ATLAS TDR):

M_ρ (TeV)	Γ_ρ (TeV)
1.234	0.104
1.600	0.224
2.500	0.844

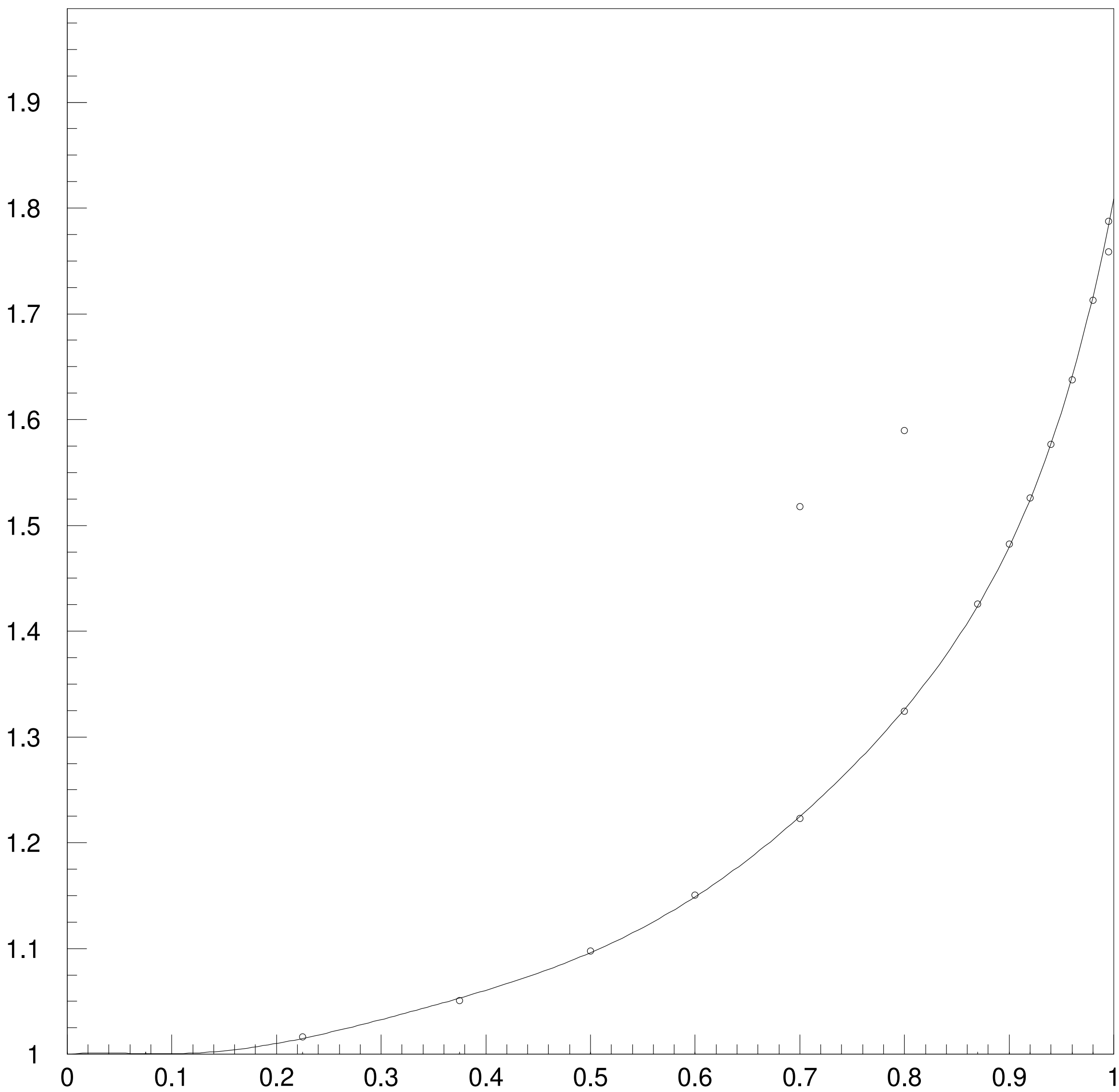
unitarization scheme:

$$\delta(s) = \begin{cases} \frac{s}{96\pi v^2} & \text{if } s < s^0 \\ \\ \frac{s^0}{96\pi v^2} & \text{if } s \geq s^0 \end{cases}$$

where $s^0 = (2.8\ \text{TeV})^2$.

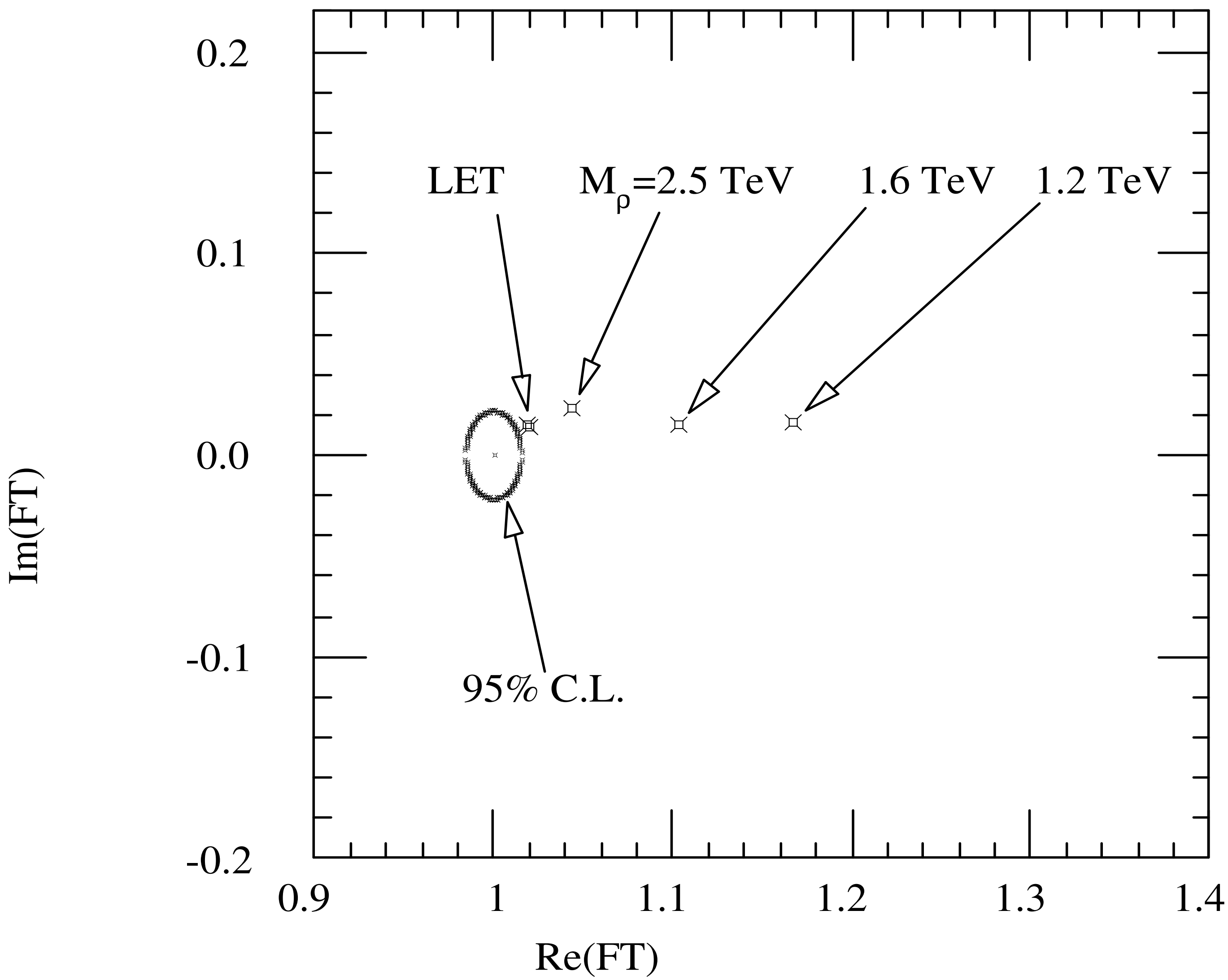
$e^+e^- \to W^+W^-$ Analysis

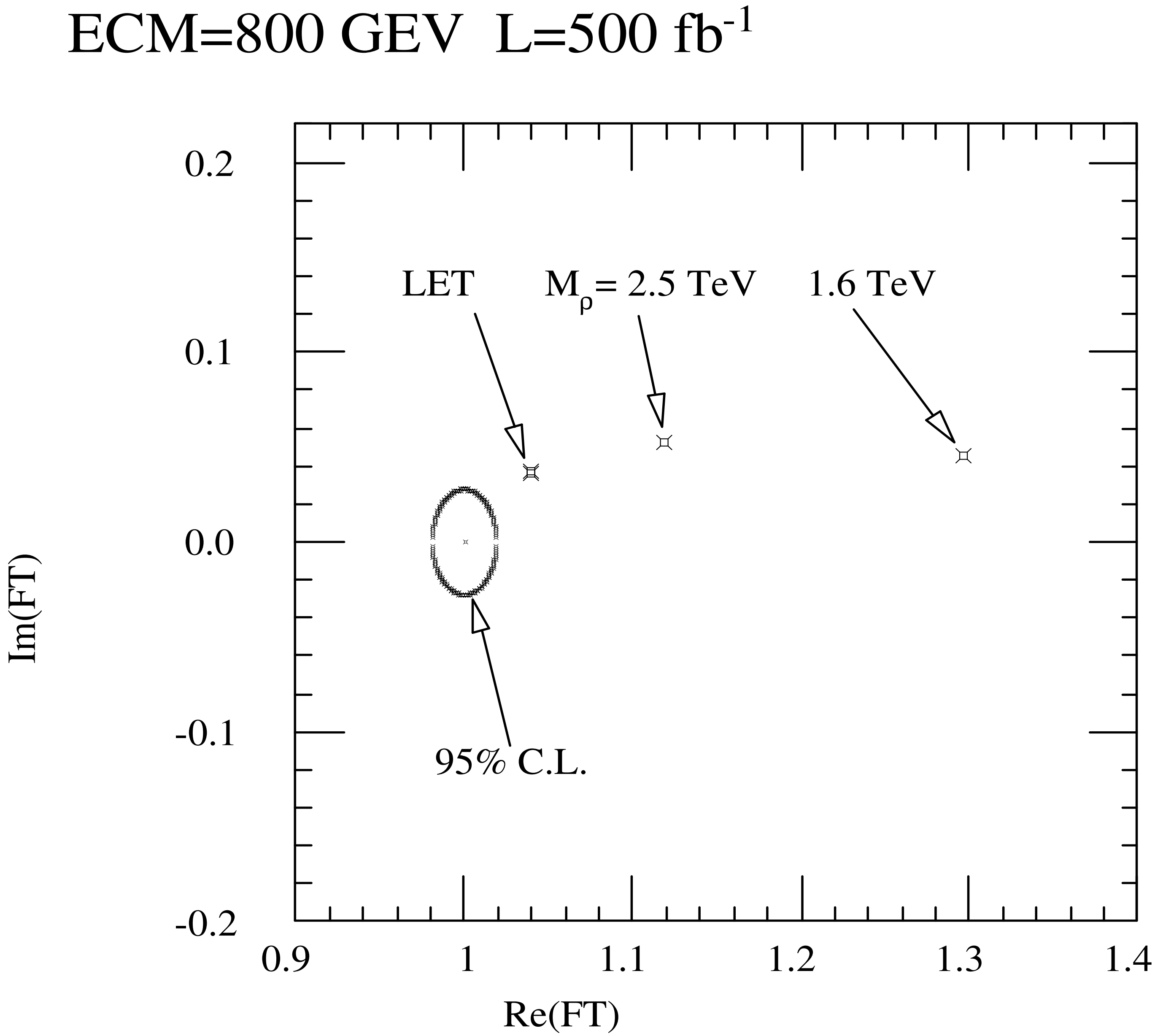
- 80/0% e^-/e^+ polarization – all e^-_L
- Likelihood fit of production angle & 4 decay angles
- $e\nu q\overline{q}$ and $\mu\nu q\overline{q}$ channels only
- Charm jets tagged with 100/65% purity/efficiency
- Solid angle $|\cos\Theta| < 0.9$
- Statistical errors only

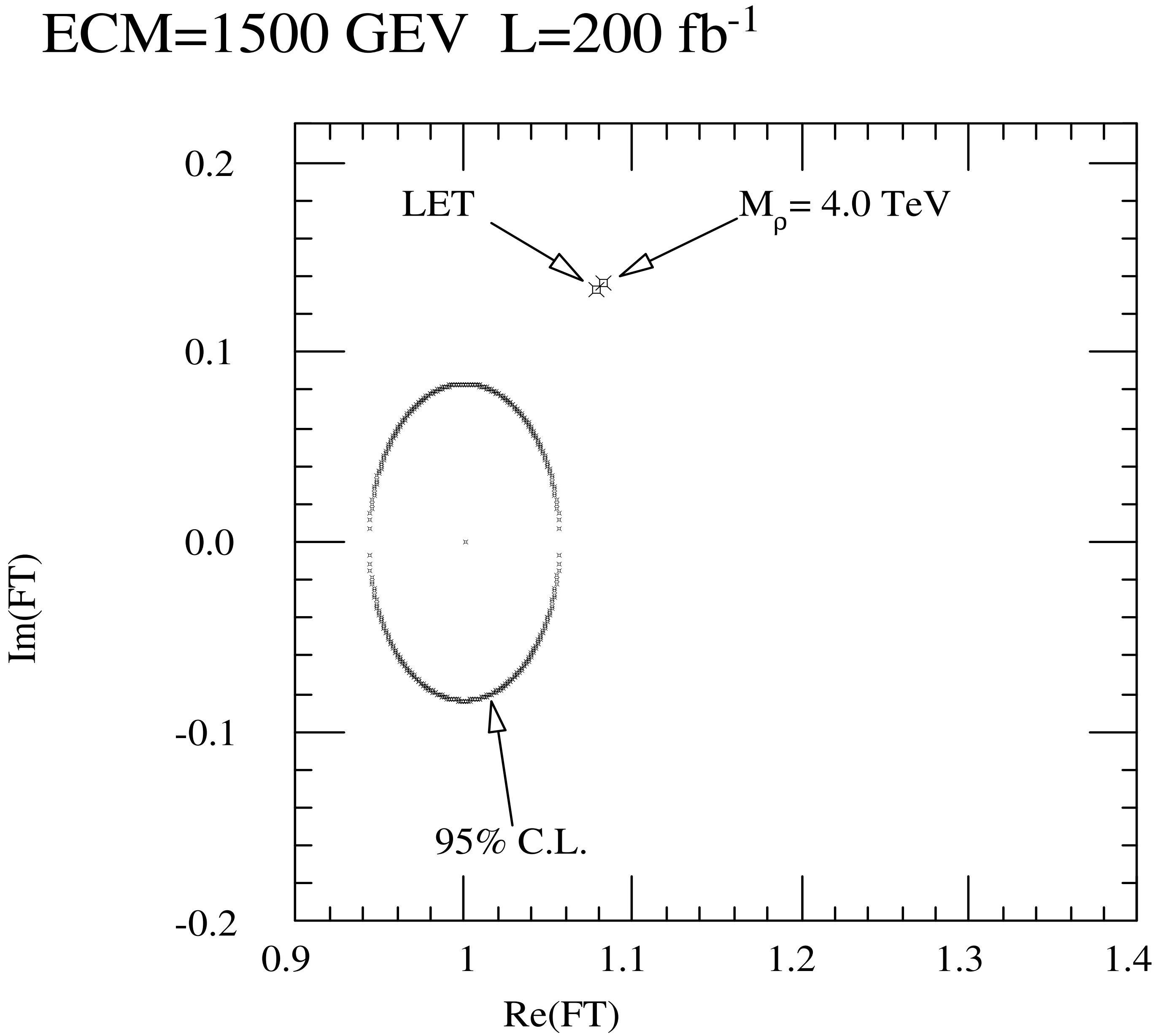


equiv. lumi gain vs. flavor tag eff. (fitted points = kapg, isolated points = LET)

ECM=500 GEV L=300 fb^{-1}




ECM=800 GEV L=500 fb-1
0.2
0.1
0.0
-0.1
-0.2
0.9
1
1.1
1.2
1.3
1.4
Re(FT)
Im(FT)
LET
Mρ= 2.5 TeV
1.6 TeV
95% C.L.


ECM=1500 GEV L=200 fb^{-1}
0.2
0.1
0.0
-0.1
-0.2
0.9
1
1.1
1.2
1.3
1.4
LET
M_ρ = 4.0 TeV
95% C.L.
Im(FT)
Re(FT)

write F_T as

$$F_T = e^{\lambda + i\delta}$$

where

$$\lambda = \frac{s}{96\pi^2 v^2}\left[\ln(\frac{s^0 - s}{s}) + \frac{s^0}{s}\ln(\frac{s^0}{s^0 - s})\right] \quad .$$

Values for λ and δ for $\sqrt{s} = 800$ and 1500 GeV:

$\sqrt{s}$ (TeV)	λ LET	δ LET
0.8	0.0389	0.0351
1.5	0.0829	0.1233

Although δ scales with s, λ does not due to the logarithm terms.

LC / LHC Comparison

	Final State	$\sqrt{s}$ TeV	$\mathcal{L}$ fb^{-1}	$M_\rho =$ 1.2 TeV	$M_\rho =$ 1.6 TeV	$M_\rho =$ 2.5 TeV	LET
TESLA	W^+W^-	0.5	300	27σ	16σ	7σ	3σ
TESLA	W^+W^-	0.8	500	73σ	38σ	16σ	6σ
NLC	W^+W^-	1.5	200	114σ	204σ	24σ	5σ
LHC	qqW^+Z	14	100	8σ	6σ	–	–
LHC	qqW^+W^+	14	100	1σ	1σ	–	5σ

LET Signal versus c-tag efficiency

				c tag efficiency			
	Final State	$\sqrt{s}$ TeV	$\mathcal{L}$ fb^{-1}	0%	65%	80%	100%
TESLA	W^+W^-	0.8	500	4.6σ	5.6σ	5.8σ	6.1σ

Conclusions

- e^+e^- **Linear Colliders provide a significant enhancement over LHC in I=J=1 W^+W^- scattering channel. Even at $\sqrt{s} = 500$ GeV TESLA outperforms LHC in this scattering channel.**
- **TESLA with 500 fb^{-1} at $\sqrt{s} =$ 800 GeV gives a larger LET signal than LHC with 100 fb^{-1}**
- **TESLA with 500 fb^{-1} at $\sqrt{s} =$ 800 GeV gives a larger LET signal than NLC with 200 fb^{-1} at $\sqrt{s} =$ 1500 GeV.**
- **Charm tagging in $e\nu q\bar{q}$ & $\mu\nu q\bar{q}$ channels improves LET signal; improvement is equivalent to a 50% increase in luminosity.**