DIS 2004

Vector resonances from strong electroweak symmetry breaking at e^+e^- colliders

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Outline

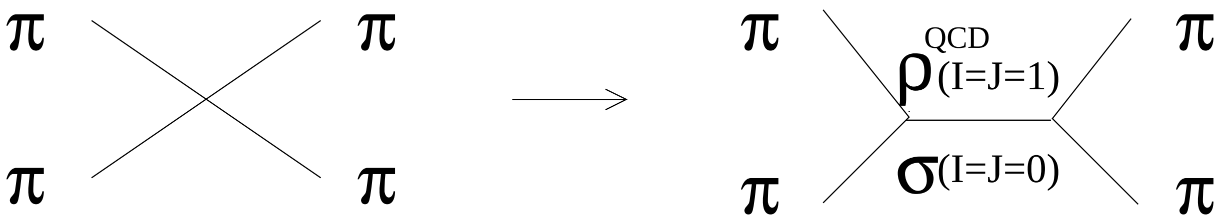
- motivation for new vector (ρ) resonances search

- ρ model

- cross section calculations for ρ production

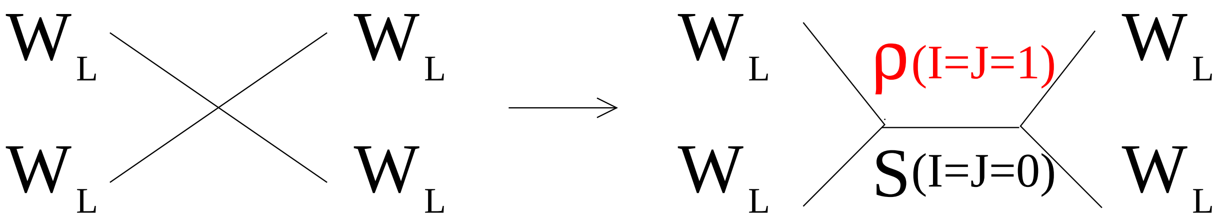
Chiral SB in QCD:

$SU(2)_L \times SU(2)_R \to SU(2)_V, \quad v \sim 90$ MeV

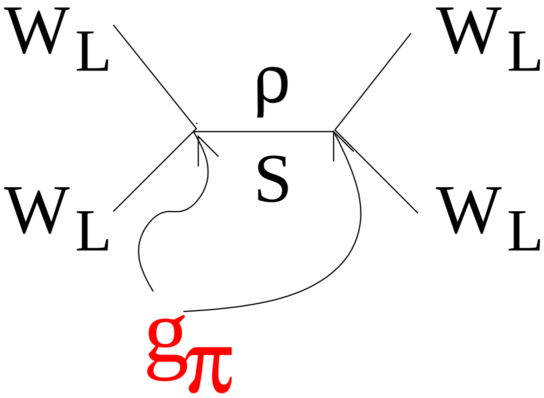


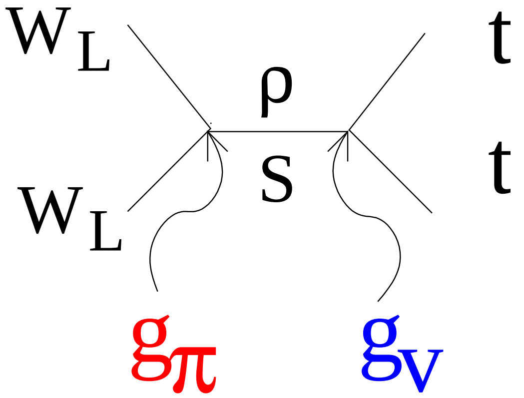
EWSB:

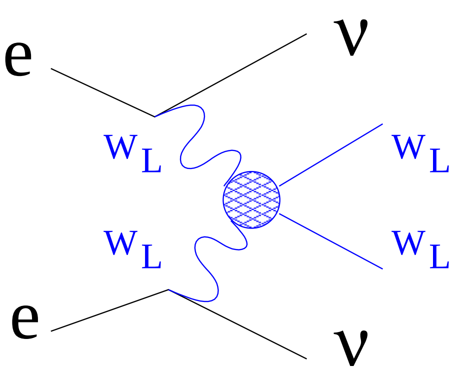
$SU(2)_L \times SU(2)_R \to SU(2)_V, \quad v \sim 246$ GeV

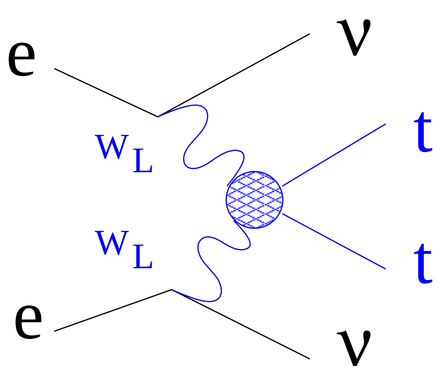


$W_LW_L \to t\bar{t}$ scattering









A natural Lagrangian

$$\mathcal{L}_{\rho\pi\pi} = +ig_\pi \frac{M_\rho}{v}(\pi^- \partial^\mu \pi^+ - \pi^+ \partial^\mu \pi^-)\rho^0_\mu$$
$$\mathcal{L}_{\rho tt} = g_V \bar{t}\gamma^\mu t\ \rho^0_\mu + g_V \bar{t}\gamma^\mu\gamma^5 t\ \rho^0_\mu;$$

Chiral effective $\mathcal{L}$

$SU(2)_L \times SU(2)_R$, $SU(2)_L \times U(1)_Y$

$$\mathcal{L} = -v^2 \mathrm{Tr}[\mathcal{A}_\mu \mathcal{A}^\mu] - a\frac{v^2}{4}\mathrm{Tr}[(\omega_\mu + ig''\ \vec{\rho}_\mu.\vec{\tau}/2)^2] + b_1 I^b_L + b_2 I^b_R + \ldots$$

2 sets are related

$$g_\pi = \frac{M_\rho}{2\,v}\frac{1}{g''}$$
$$g_V \doteq \frac{g''}{4}\frac{b_2}{1+b_2}$$
$$M_\rho \doteq \sqrt{a}\ v\ \frac{g''}{2}$$

Unitarity constraints

$W_L W_L \to W_L W_L, \quad W_L W_L \to t\bar{t}, \quad t\bar{t} \to t\bar{t}$

$$
\begin{aligned}
g_\pi &\leq 1.5 \qquad (M_\rho = 1 \text{ TeV}) \\
g_V &\leq 2.0 \qquad (M_\rho = 1 \text{ TeV})
\end{aligned}
$$

Low energy constraints

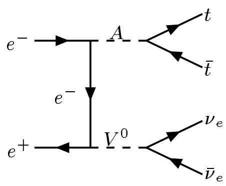
$$\mathcal{L}_{lowE} = +\frac{g}{2c_W}\left(-\frac{4}{3}s_W^2 + \frac{b_2}{2}\right)\bar{t}_R\gamma^\mu t_R\, Z_\mu + \ldots$$

$$\delta\epsilon_1 = \frac{3m_t^2 G_F}{2\sqrt{2}\pi^2}\,\frac{b_2}{2}\,\ln\frac{\Lambda^2}{m_t^2}$$

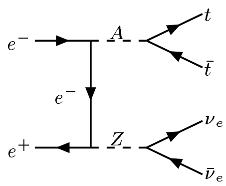
Limits on free parameters are given by

$$
\begin{aligned}
g'' &\gtrsim 10 \\
|b_2| &\lesssim 0.08
\end{aligned}
$$

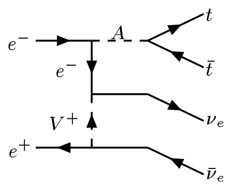
$e^+e^- \to \nu\bar{\nu}t\bar{t}$ (12 of 66 diagrams)



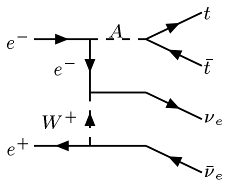
diagr.1



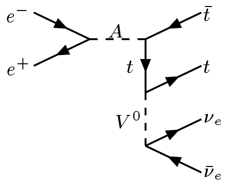
diagr.2



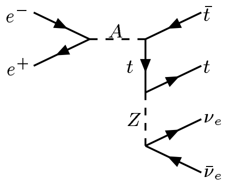
diagr.3



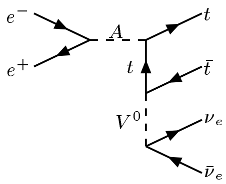
diagr.4



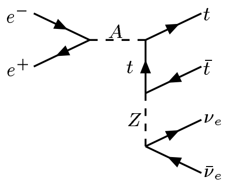
diagr.5



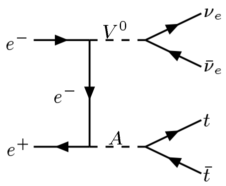
diagr.6



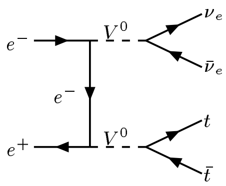
diagr.7



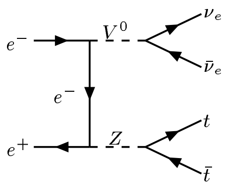
diagr.8



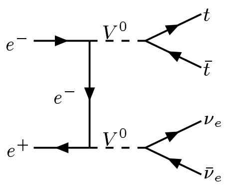
diagr.9



diagr.10

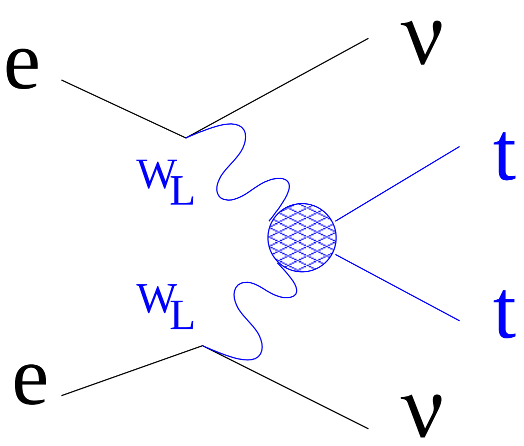


diagr.11



diagr.12

Subset of fusion diagrams + approximations (Pythia)



Full calculation of 66 diagrams at tree level (CompHEP)

ρ (M = 700 GeV, Γ = 12.5 GeV):

$\sigma(\sqrt{s} = 0.8$ TeV$)$ = 0.66 fb $\rightarrow$ 0.21 fb

$\sigma(\sqrt{s} = 1.5$ TeV$)$ = 3.33 fb $\rightarrow$ 0.86 fb

Backgrounds

$e^+e^- \to t\bar{t}\gamma \quad + \quad e^+e^- \to e^+e^- t\bar{t}$

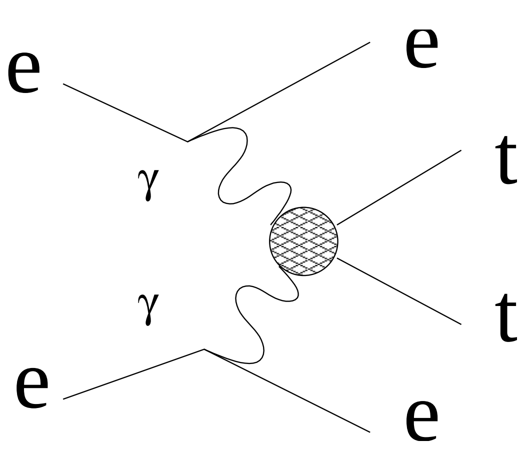
Pythia:

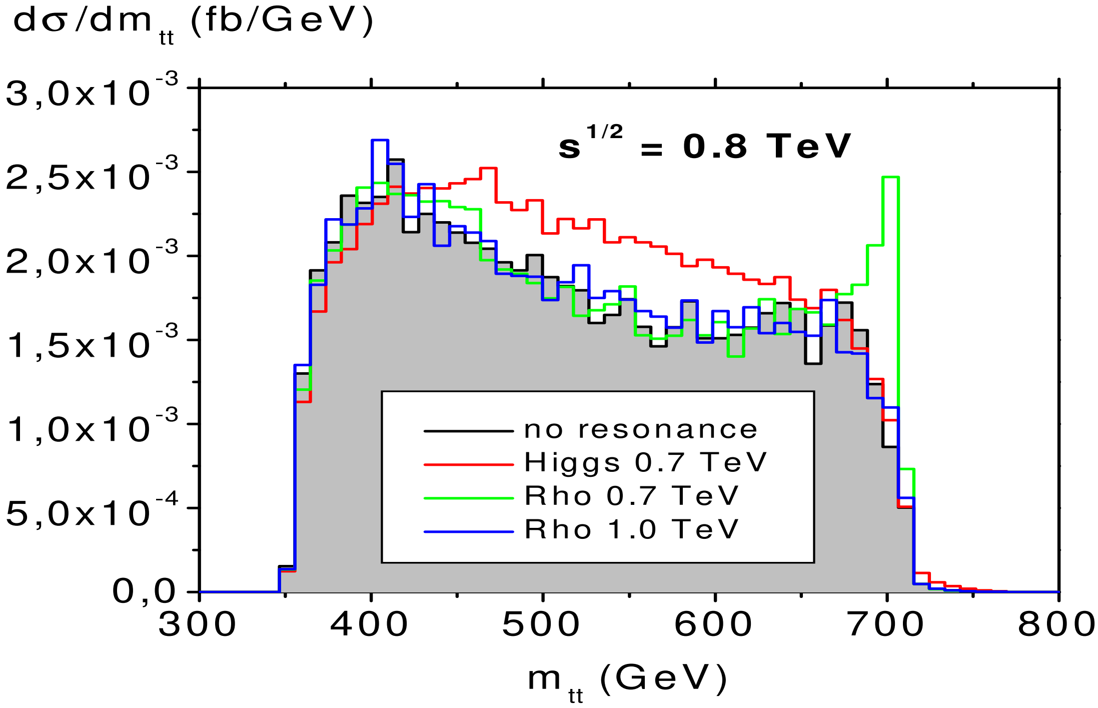
$\sigma(0.8\ \text{TeV}) = 301 + 1.2\ \text{fb} \ \to\ 1.76\ \text{fb}$

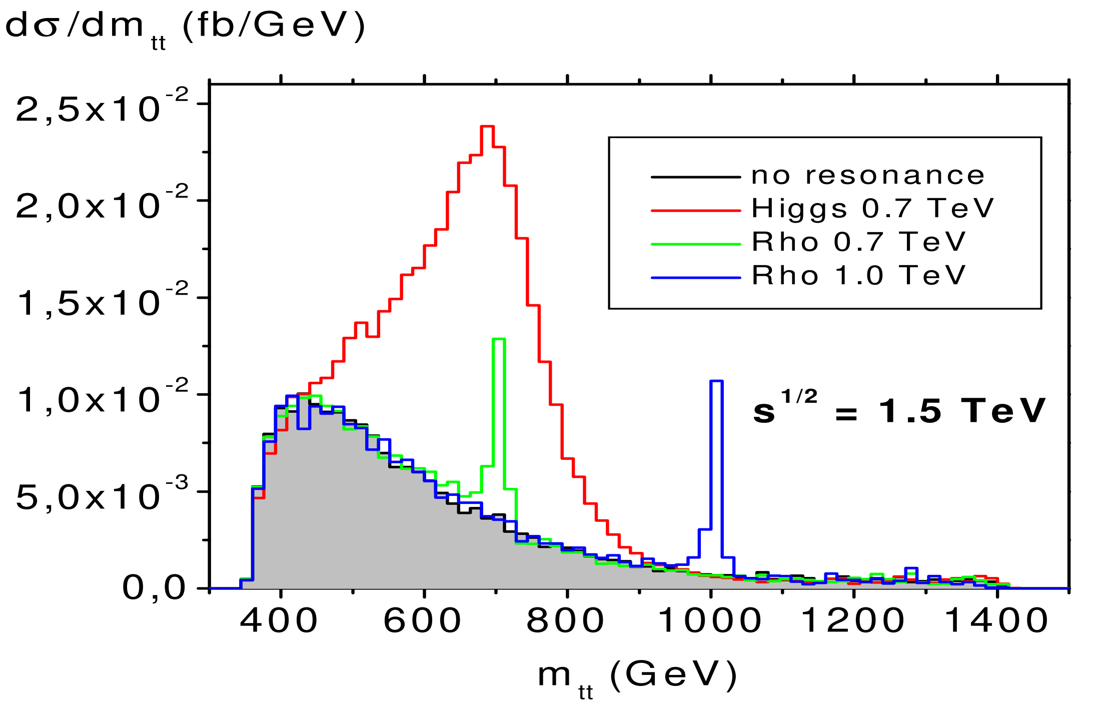
(0.21 fb)

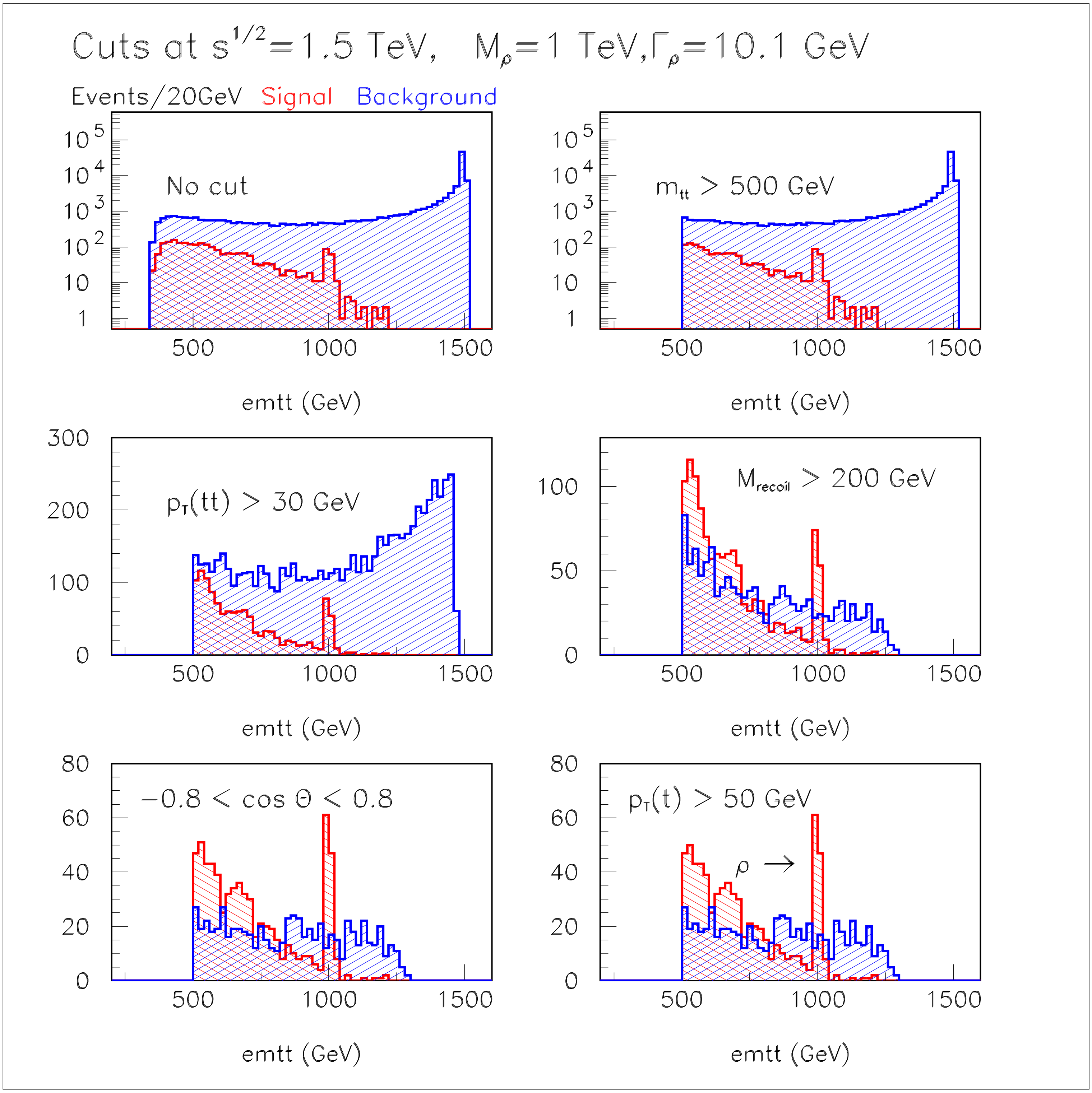
$\sigma(1.5\ \text{TeV}) = 99.4 + 5.2\ \text{fb} \ \to\ 0.71\ \text{fb}$

(0.86 fb)



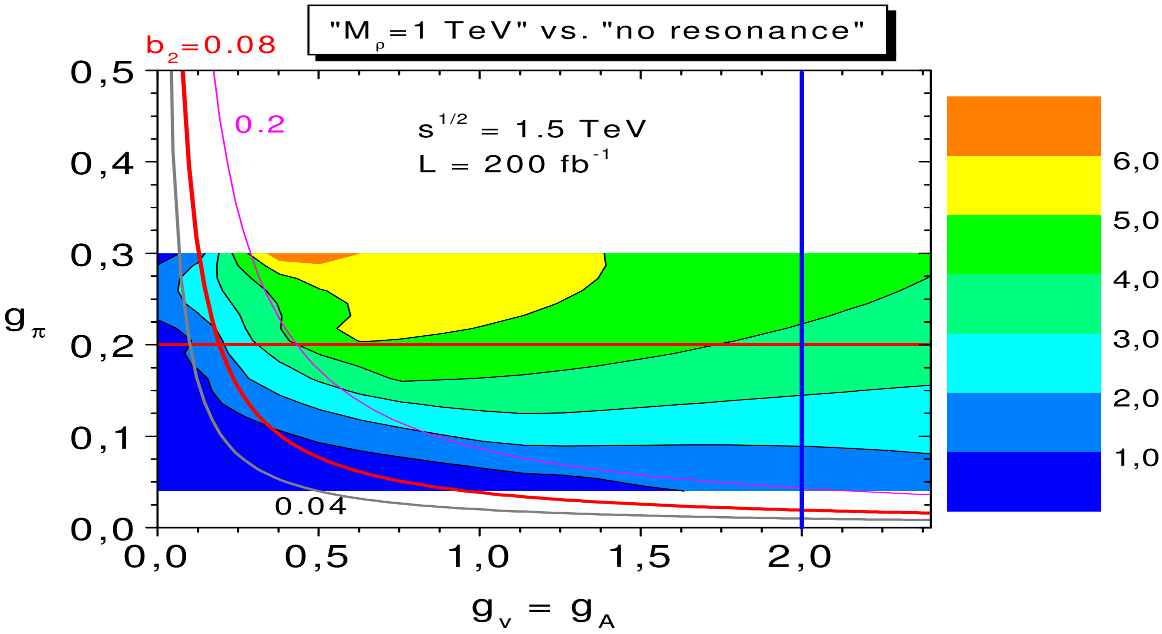

dσ/dm_tt (fb/GeV)
3,0x10^-3
2,5x10^-3
2,0x10^-3
1,5x10^-3
1,0x10^-3
5,0x10^-4
0,0
300
400
500
600
700
800
m_tt (GeV)
s^1/2 = 0.8 TeV
no resonance
Higgs 0.7 TeV
Rho 0.7 TeV
Rho 1.0 TeV

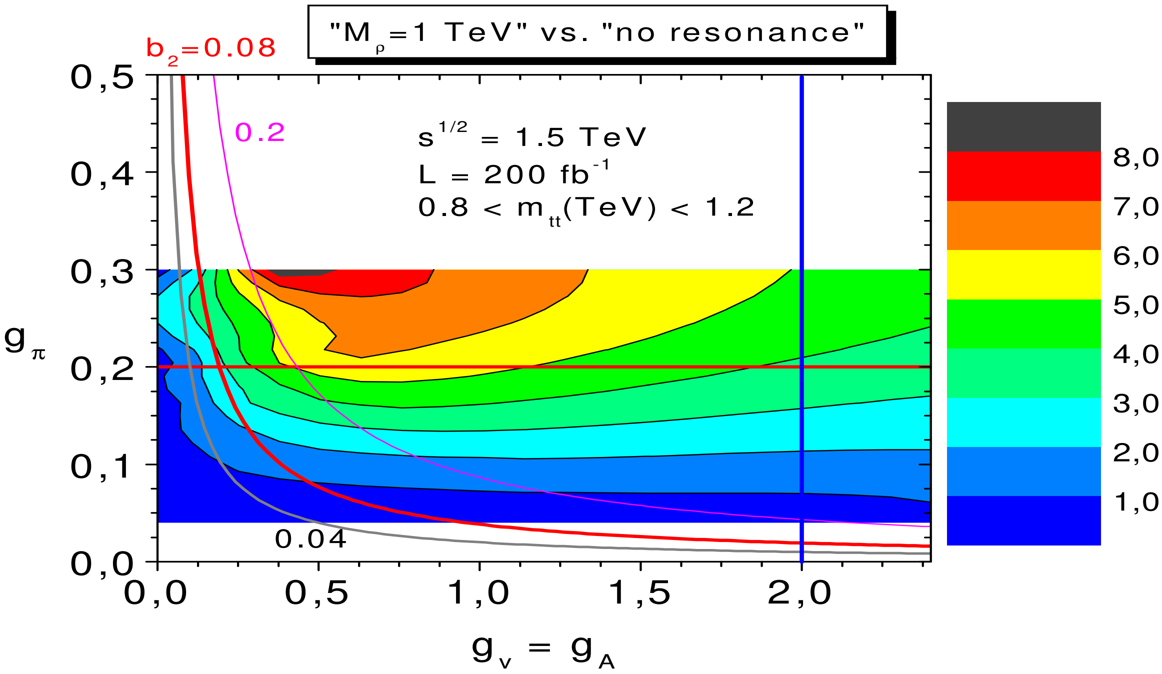

dσ/dm_tt (fb/GeV)
2,5x10^-2
2,0x10^-2
1,5x10^-2
1,0x10^-2
5,0x10^-3
0,0
400
600
800
1000
1200
1400
m_tt (GeV)
no resonance
Higgs 0.7 TeV
Rho 0.7 TeV
Rho 1.0 TeV
s^1/2 = 1.5 TeV

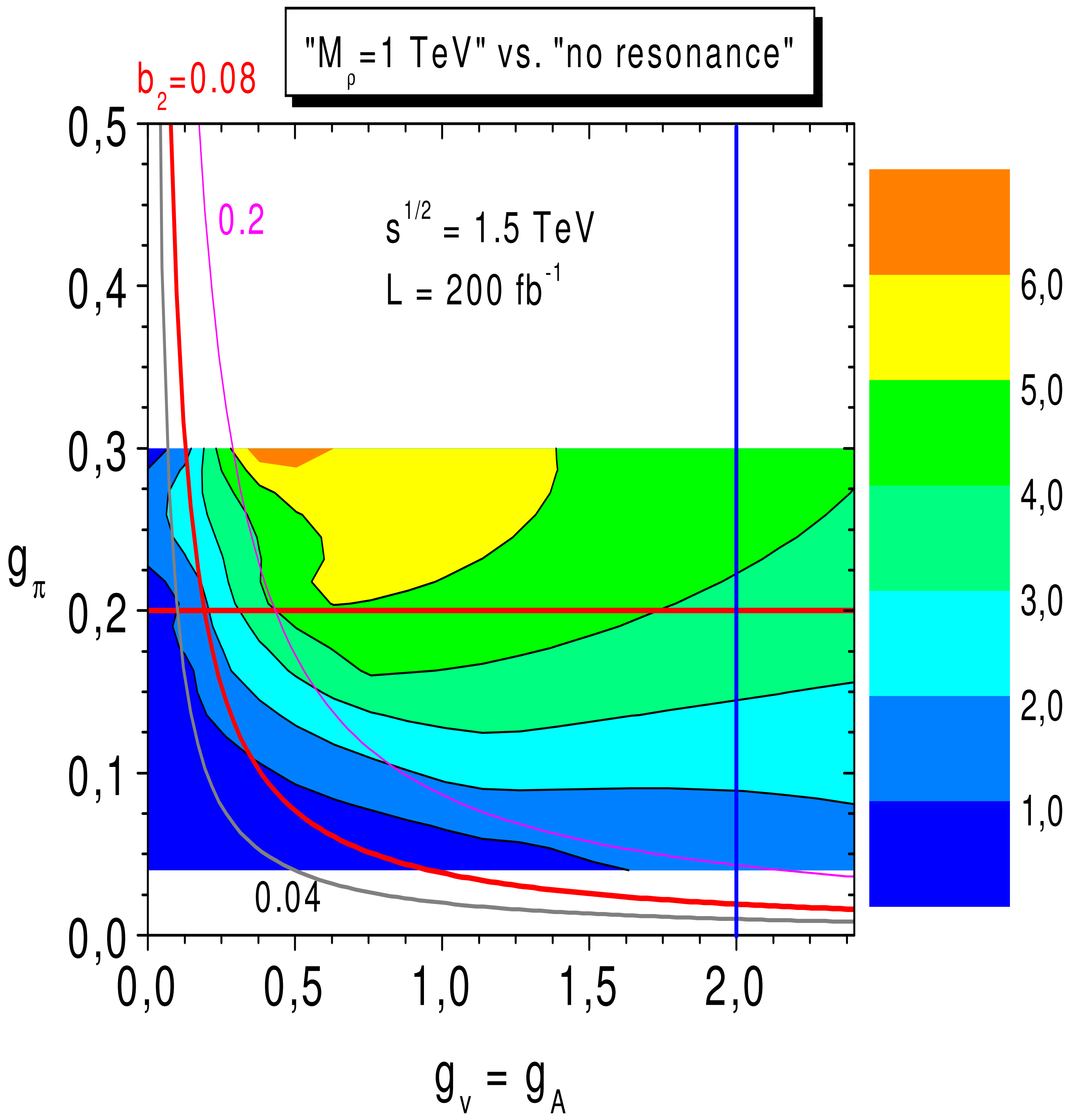


Cuts at $s^{1/2}$=1.5 TeV, M_ρ=1 TeV,Γ_ρ=10.1 GeV
Events/20GeV
Signal
Background
No cut
m_{tt} > 500 GeV
$p_T(tt)$ > 30 GeV
M_{recoil} > 200 GeV
−0.8 < cos Θ < 0.8
$p_T(t)$ > 50 GeV
ρ →
emtt (GeV)

$$R = \frac{|N(\rho) - N(\text{no resonance})|}{\sqrt{N(\text{Background}) + N(\text{no resonance})}}$$






"M_ρ=1 TeV" vs. "no resonance"
b_2=0.08
0.2
$s^{1/2}$ = 1.5 TeV
L = 200 fb^{-1}
0.04
0,5
0,4
0,3
0,2
0,1
0,0
g_π
0,0
0,5
1,0
1,5
2,0
$g_V = g_A$
6,0
5,0
4,0
3,0
2,0
1,0

Conclusions

$e^+e^- \to \nu\bar{\nu}t\bar{t}$ in Pythia and CompHEP

- agreement within 10 %
- no t decays

$\sigma(0.8\text{ TeV}) = 0.21 \;\; (1.76)$ fb
$\sigma(1.5\text{ TeV}) = 0.86 \;\; (0.71)$ fb

- optimize cuts
- finalize analysis for all models considered
- $e^+e^- \to \nu\bar{\nu}W^+W^-$