

ECFA - Durham

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Signatures of new vector resonances from strong EWSB in
 $e^+e^- \rightarrow \nu\bar{\nu}t\bar{t}$

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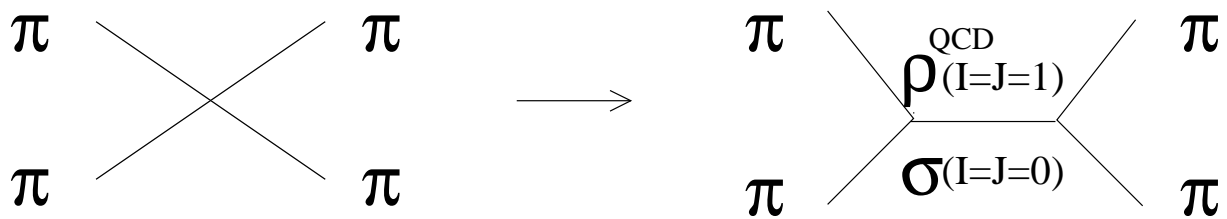
I.Melo (University of Zilina)

Outline

- motivation for new vector (ρ) resonance search
- ρ resonance model
- cross section calculations of ρ production at $\sqrt{s} = 800$ and 1000 GeV

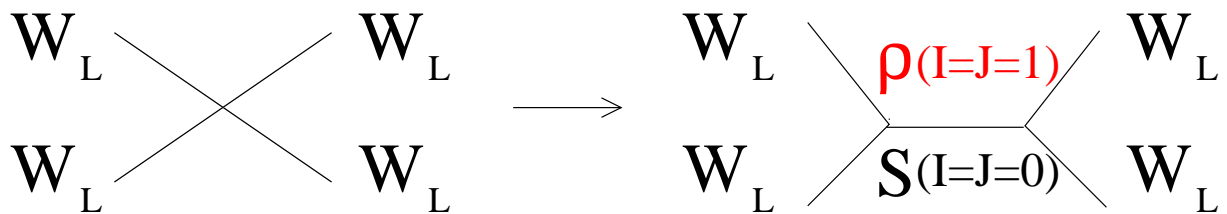
Chiral SB in QCD:

$$SU(2)_L \times SU(2)_R \rightarrow SU(2)_V, \quad v \sim 90 \text{ MeV}$$

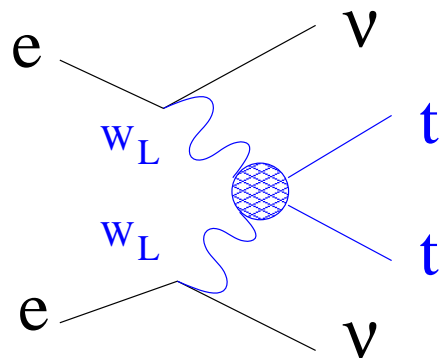
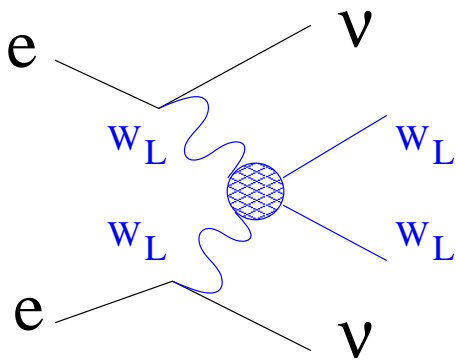
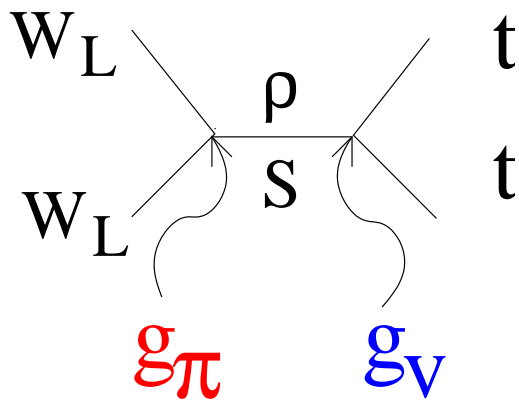
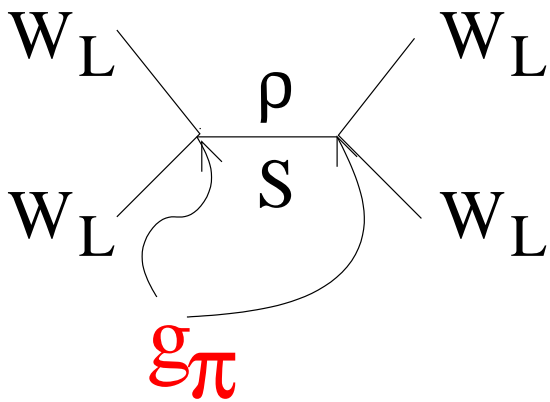


EWSB:

$$SU(2)_L \times SU(2)_R \rightarrow SU(2)_V, \quad v \sim 246 \text{ GeV}$$



$W_L W_L \rightarrow t\bar{t}$ scattering



A natural Lagrangian

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

Chiral effective \mathcal{L}

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

$$\begin{aligned}\mathcal{L} &= -v^2\text{Tr}[\mathcal{A}_{\mu}\mathcal{A}^{\mu}] - a\frac{v^2}{4}\text{Tr}[(\omega_{\mu} + ig''\vec{\rho}_{\mu}\cdot\vec{\tau}/2)^2] \\ &\quad + b_1I_L^b + b_2I_R^b + \dots\end{aligned}$$

2 sets are related

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

Unitarity constraints

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

$$g_\pi \leq 1.75 \quad (M_\rho = 700 \text{ GeV})$$

$$g_V \leq 1.7 \quad (M_\rho = 700 \text{ GeV})$$

Low energy constraints

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

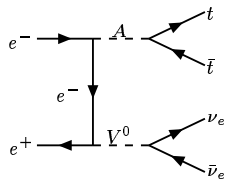
$$\delta\epsilon_1 = \frac{3m_t^2 G_F}{2\sqrt{2}\pi^2} \frac{b_2}{2} \ln \frac{\Lambda^2}{m_t^2}$$

Limits on free parameters are given by

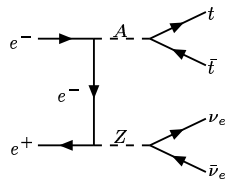
$$g'' \gtrsim 10$$
$$|b_2| \lesssim 0.08$$

$$e^+e^- \rightarrow \nu\bar{\nu}t\bar{t}$$

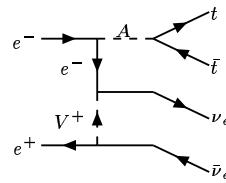
(12 of 66 diagrams)



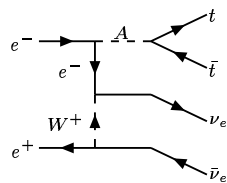
diagr.1



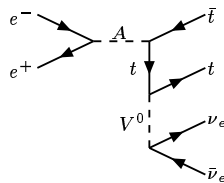
diagr.2



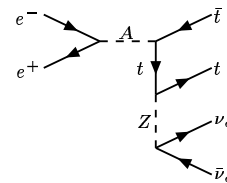
diagr.3



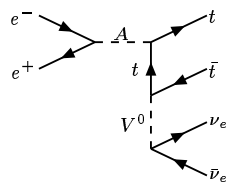
diagr.4



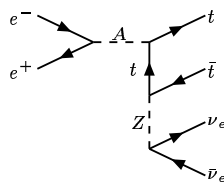
diagr.5



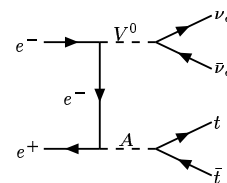
diagr.6



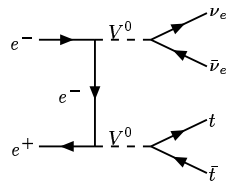
diagr.7



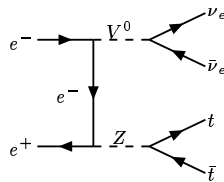
diagr.8



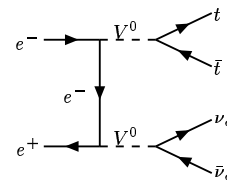
diagr.9



diagr.10

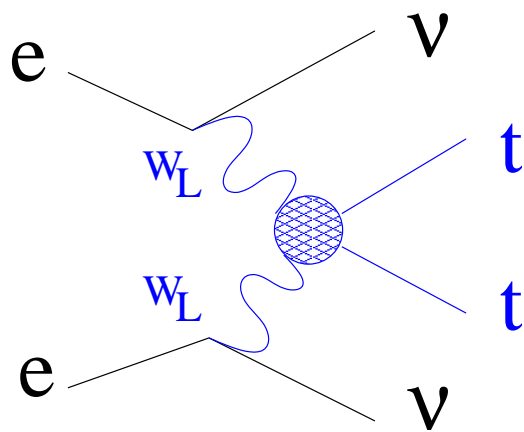


diagr.11



diagr.12

Subset of fusion diagrams + approximations
(Pythia)



Full calculation of 66 diagrams at tree level
(CompHEP)

Pythia vs CompHEP

ρ ($M = 700$ GeV, $\Gamma = 12.5$ GeV, $b_2 = 0.08, g'' = 20$)

Before cuts

\sqrt{s} (GeV)	800	1000	1500
Pythia (fb)	0.31	0.81	3.00
CompHEP (fb)	0.66	1.16	3.33

After cuts

\sqrt{s} (GeV)	800	1000
Pythia (fb)	0.05	0.16
CompHEP (fb)	0.20	0.16

Backgrounds

$$e^+e^- \rightarrow t\bar{t}\gamma + e^+e^- \rightarrow e^+e^-t\bar{t}$$

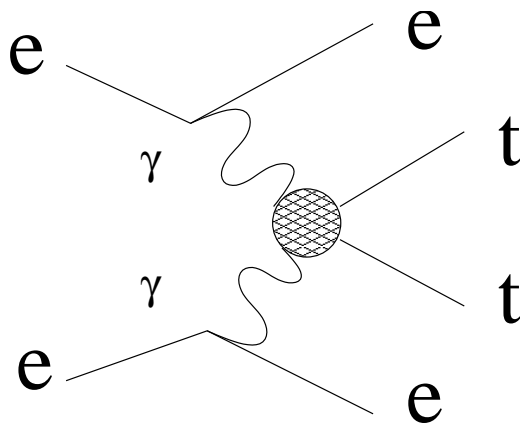
Pythia:

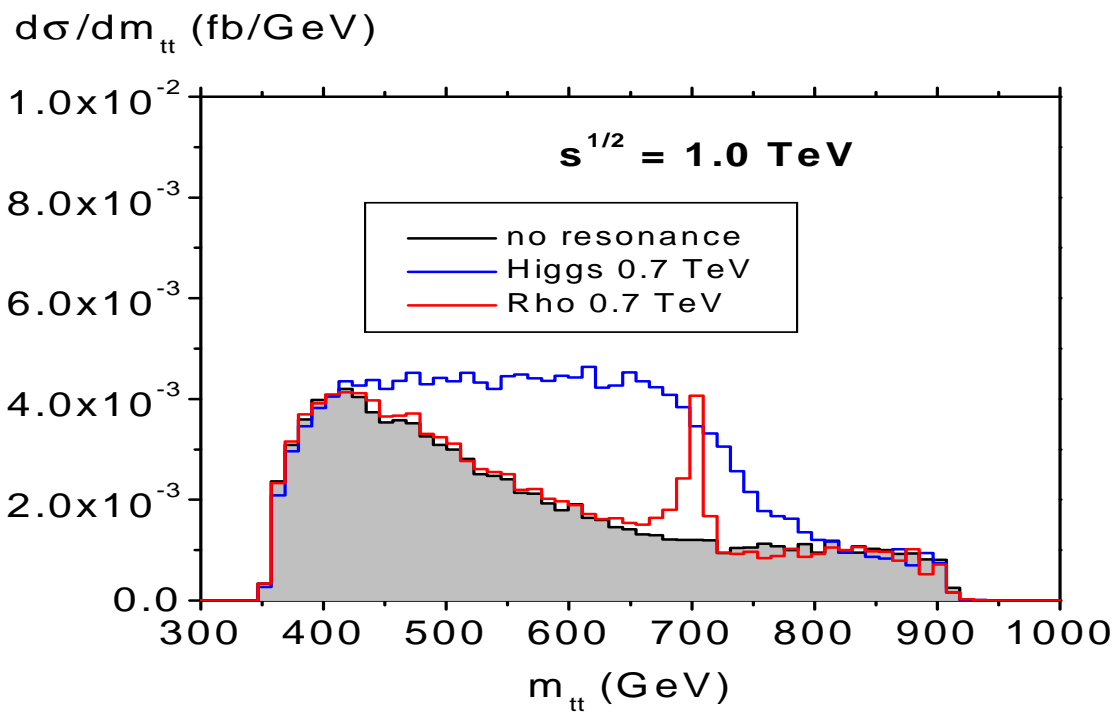
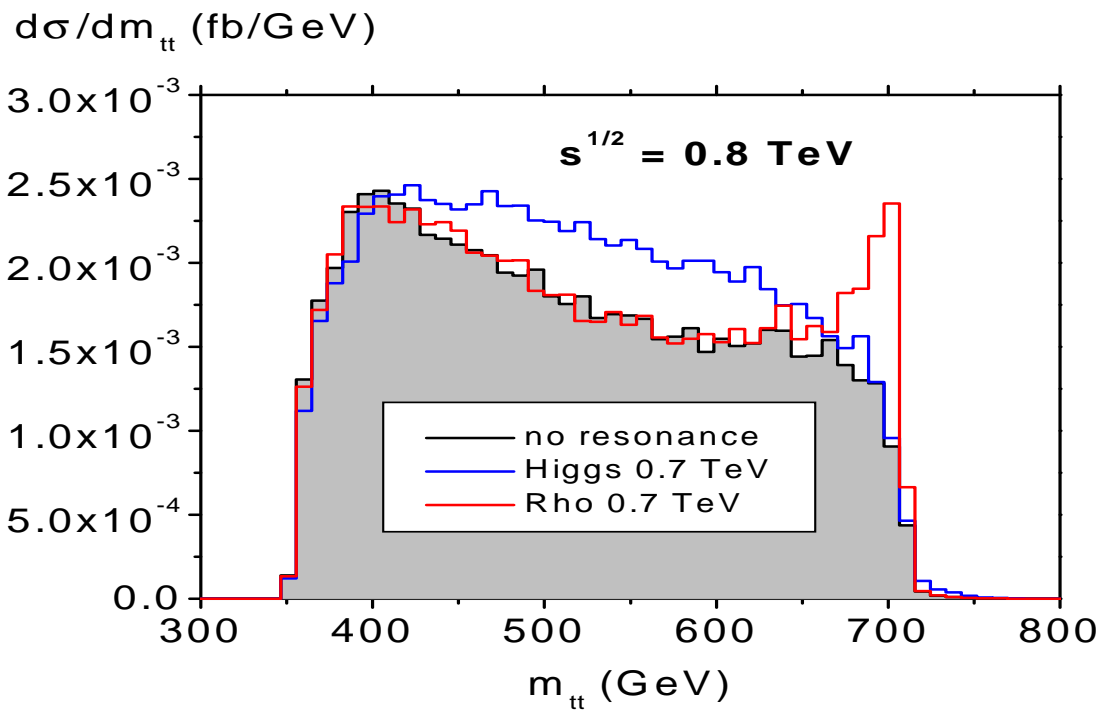
$$\sigma(0.8 \text{ TeV}) = 300.3 + 1.3 \text{ fb} \rightarrow 0.13 \text{ fb}$$

(0.20 fb)

$$\sigma(1.0 \text{ TeV}) = 204.9 + 2.4 \text{ fb} \rightarrow 0.035 \text{ fb}$$

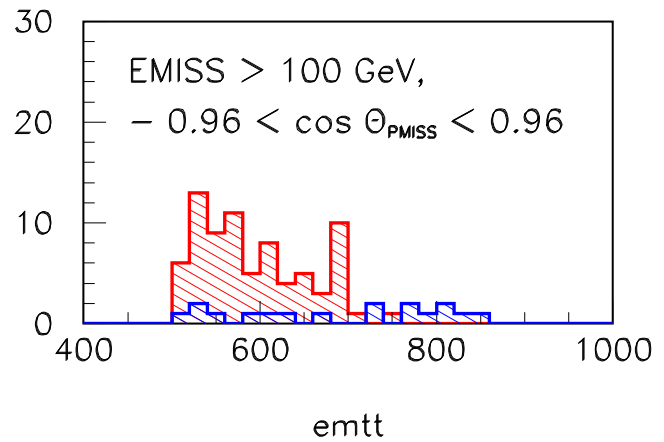
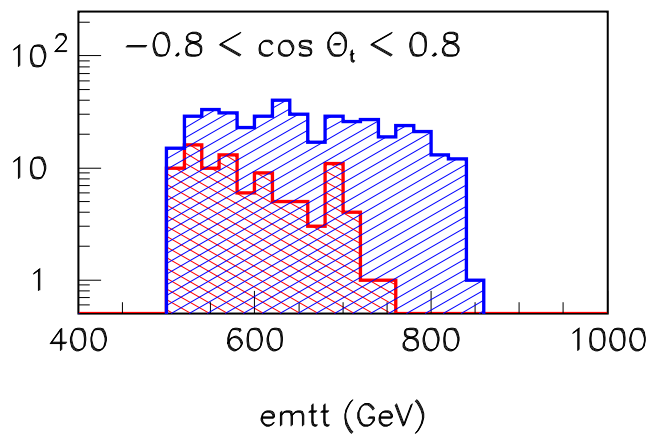
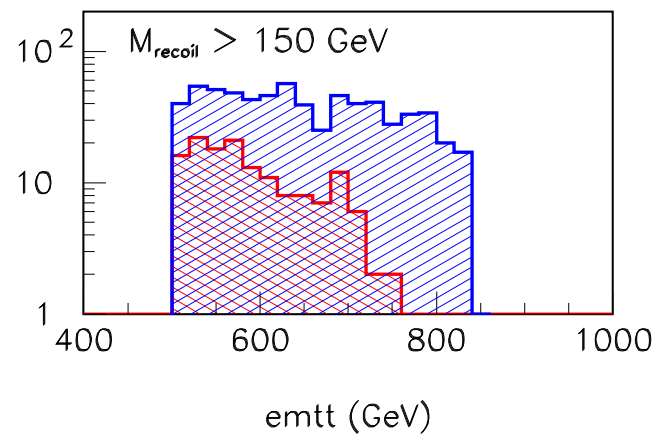
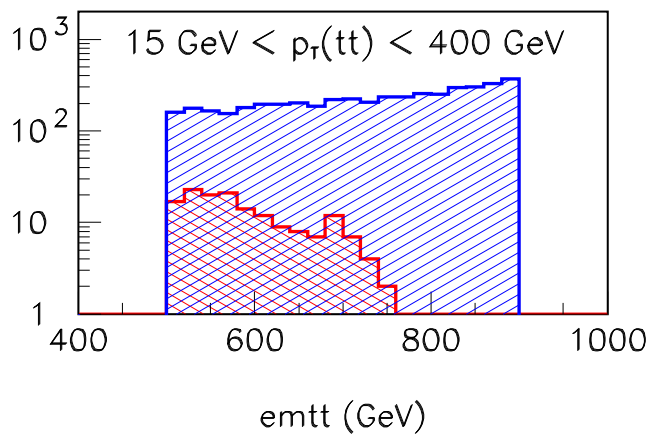
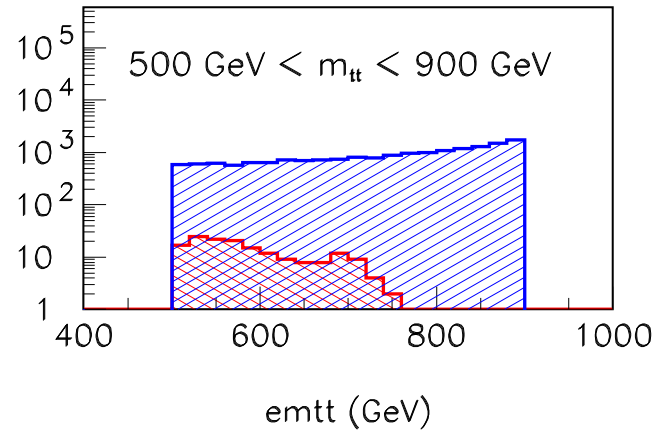
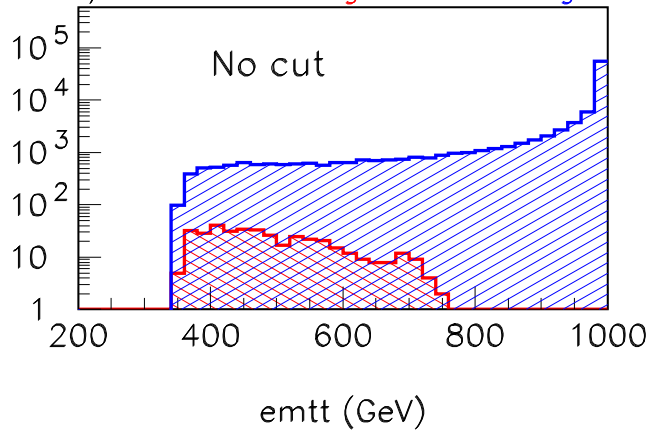
(0.16 fb)





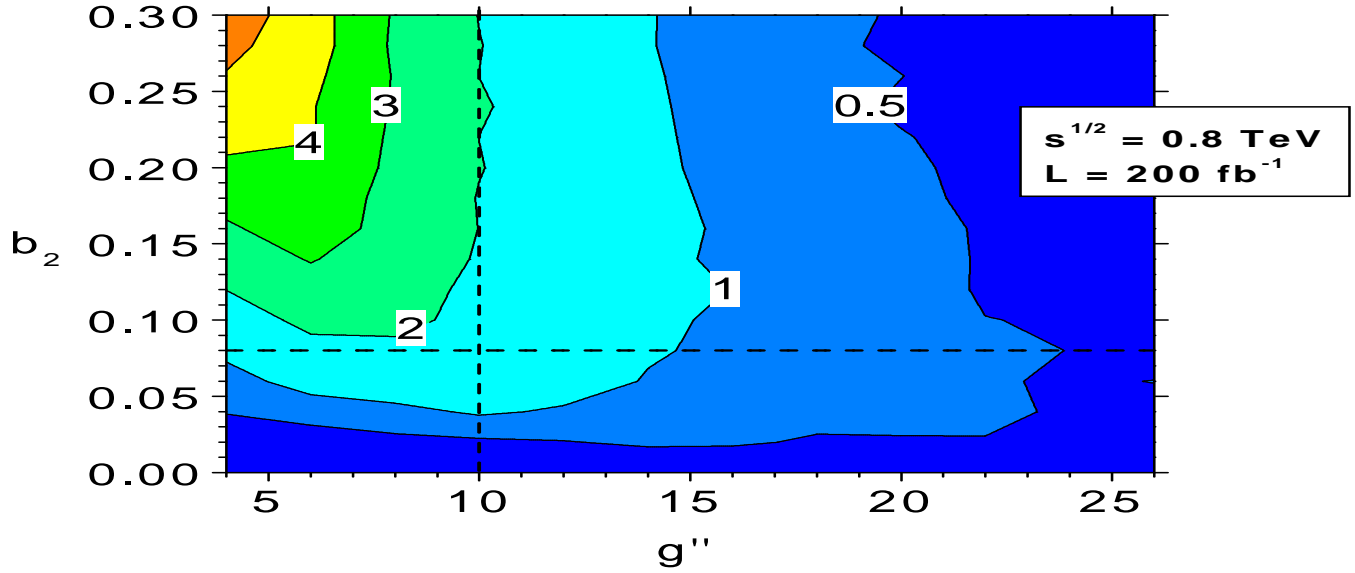
Cuts at $s^{1/2}=1.0$ TeV, $M_\rho=700$ GeV, $\Gamma_\rho=12.5$ GeV (500 fb⁻¹)

Events/20GeV Signal Background

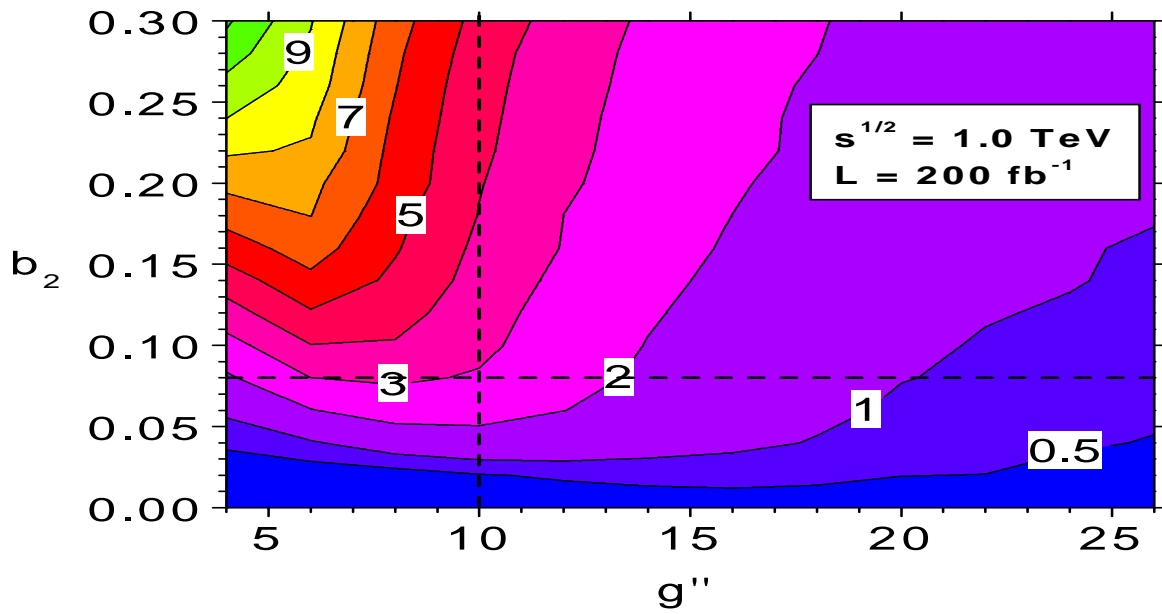


$$R = \frac{|N(\rho) - N(\text{no resonance})|}{\sqrt{N(\text{Background}) + N(\text{no resonance})}}$$

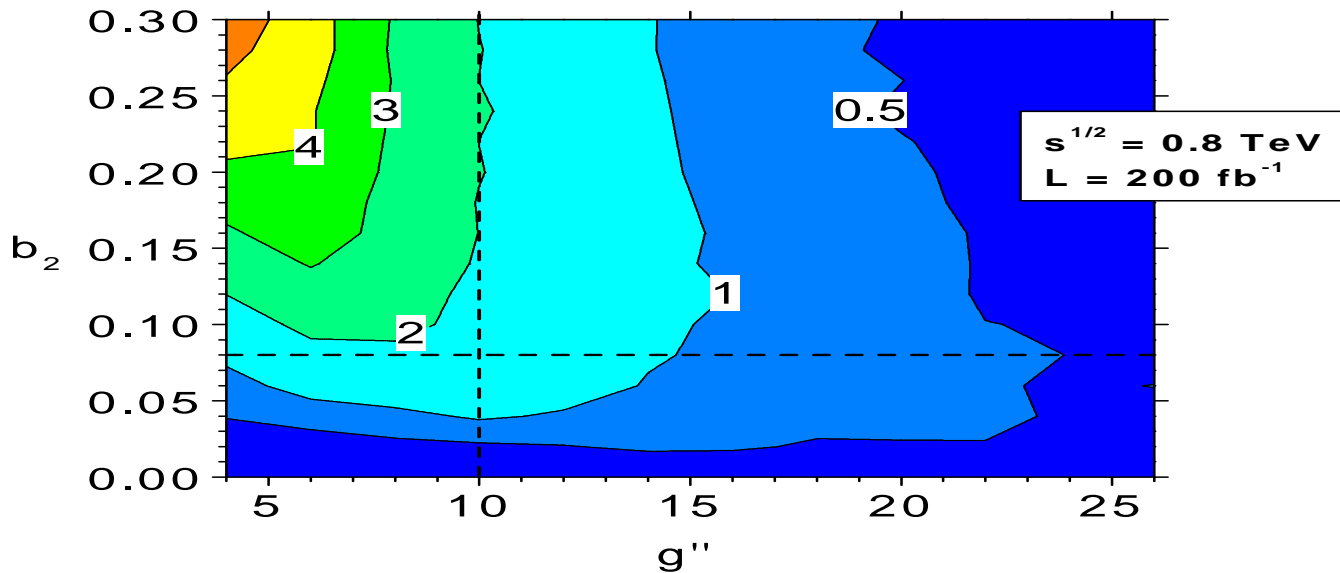
" $M_\rho = 0.7 \text{ TeV}$ " vs. "no resonance".



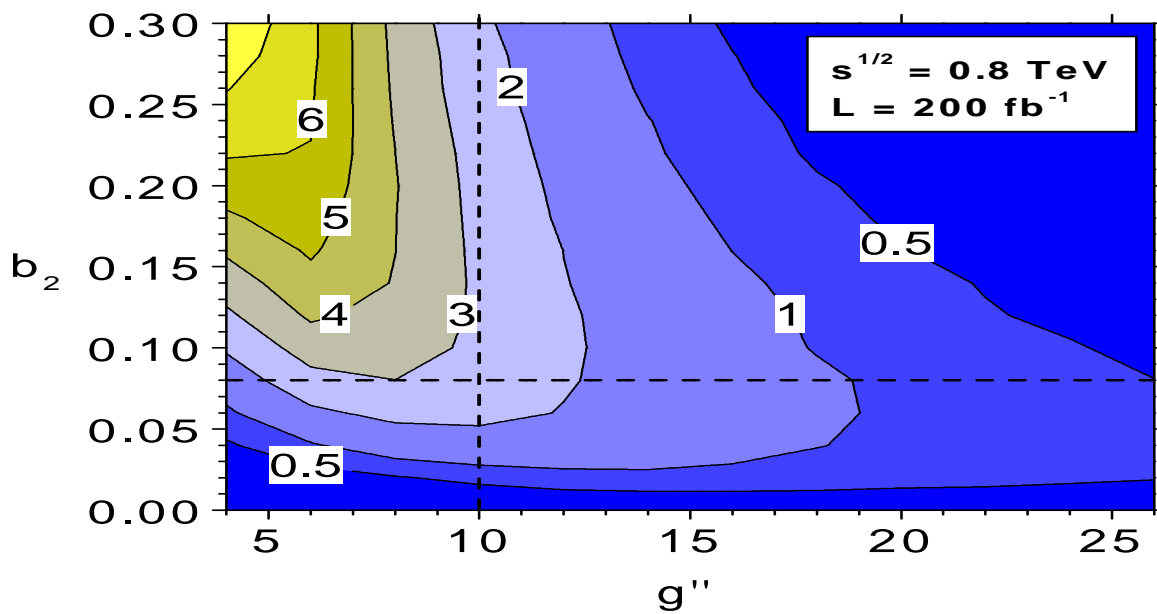
" $M_\rho = 0.7 \text{ TeV}$ " vs. "no resonance".



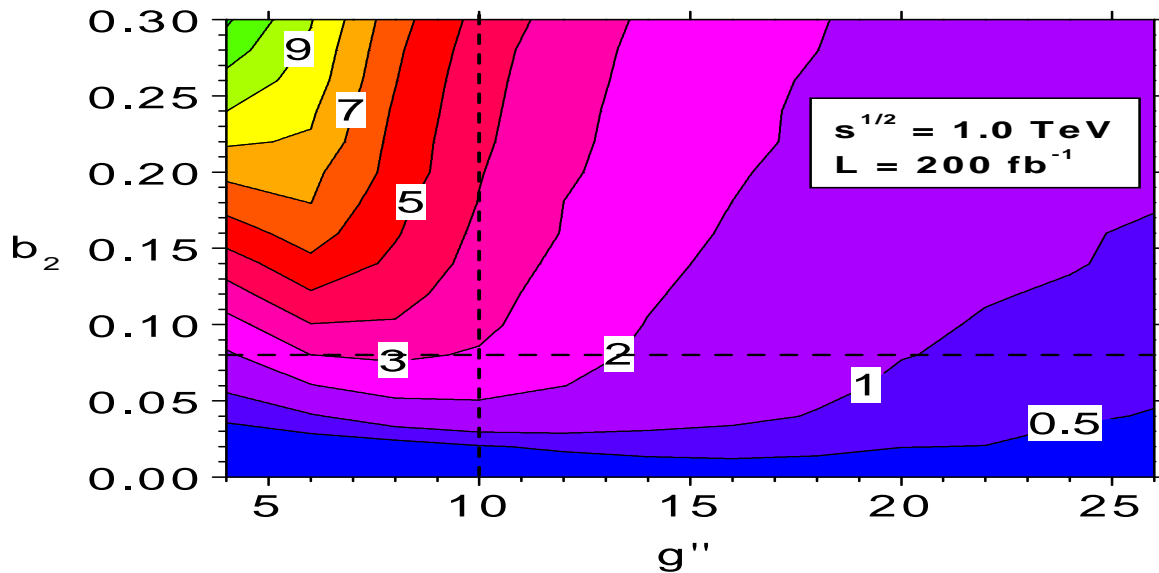
" $M_\rho = 0.7$ TeV" vs. "no resonance".



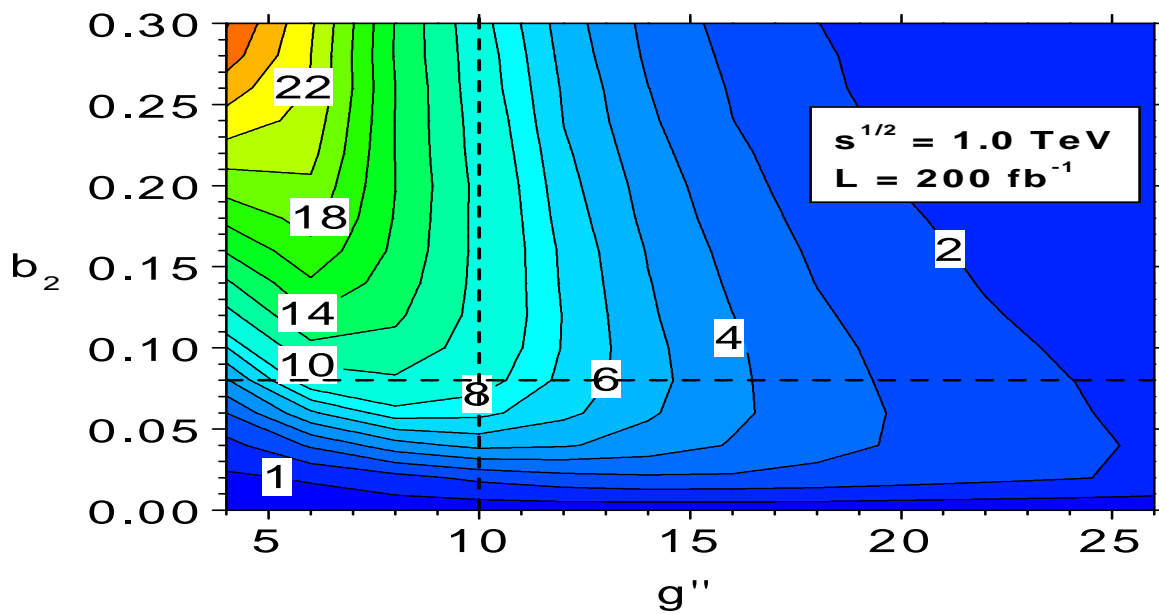
" $M_\rho = 0.7$ TeV" vs. "no resonance".



" $M_p = 0.7 \text{ TeV}$ " vs. "no resonance".



" $M_p = 0.7 \text{ TeV}$ " vs. "no resonance".



Conclusions

ρ in $e^+e^- \rightarrow \nu\bar{\nu}t\bar{t}$ (Pythia and CompHEP)

- agreement within 10 %
- no t decays

$$\sigma(0.8 \text{ TeV}) = 0.20 \text{ (0.13) fb}$$

$$\sigma(1.0 \text{ TeV}) = 0.16 \text{ (0.035) fb}$$

R (ρ vs no resonance) values up to 8

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

Appendix with more details

$$\sqrt{s} = 800 \text{ GeV}$$

Clean events only

Cuts:

$$500 < m_{tt} < 750 \text{ GeV}$$

$$p_T(tt) > 15 \text{ GeV}, p_T(tt) < 300 \text{ GeV}$$

$$E_t, E_{\bar{t}} < 380 \text{ GeV}$$

$$M_{rec} > 50 \text{ GeV}$$

$$|\cos \theta_{t,\bar{t}}| < 0.8$$

$$20 < p_T(t), p_T(\bar{t}) < 330 \text{ GeV}$$

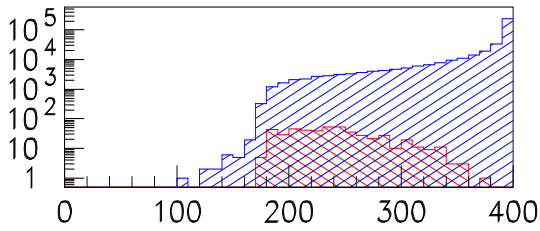
$$\text{no central } \gamma: E_\gamma > 50 \text{ GeV}, |\cos \theta_\gamma| < 0.99$$

$$E_{miss} > 90 \text{ GeV}$$

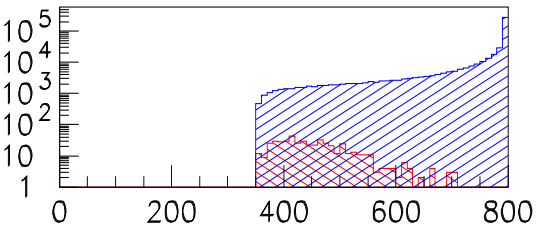
$$|\cos \theta_{miss}| < 0.984 \text{ (0.96)}$$

$$\text{Detector angle : } \cos \theta = 0.99 \text{ (8 degrees)}$$

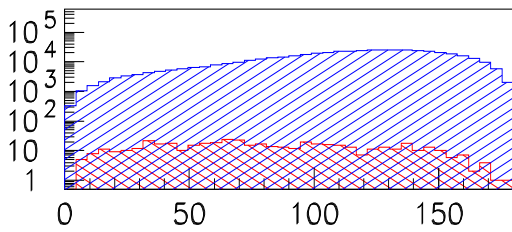
ee-nunu tt, E = .8 TeV, NEV=5E5



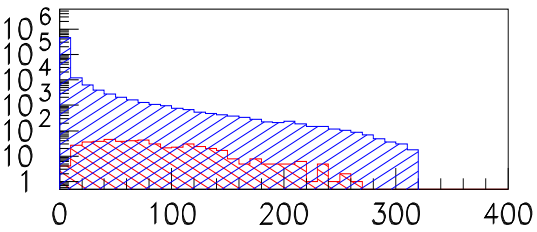
E_{top}



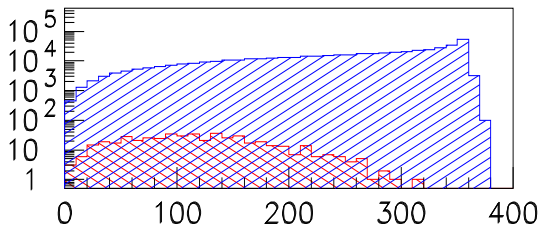
$e_{m_{tt}}$



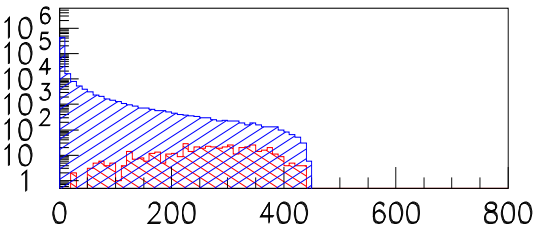
θ_{top}



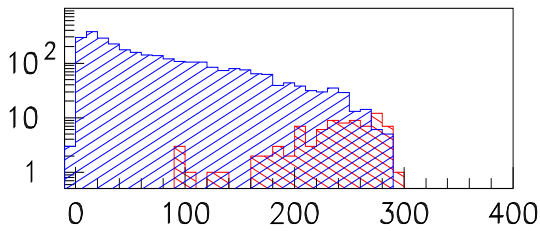
p_{ttt}



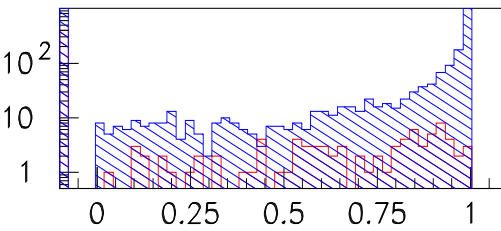
$p_{t_{top}}$



$e_{M_{rec}}$



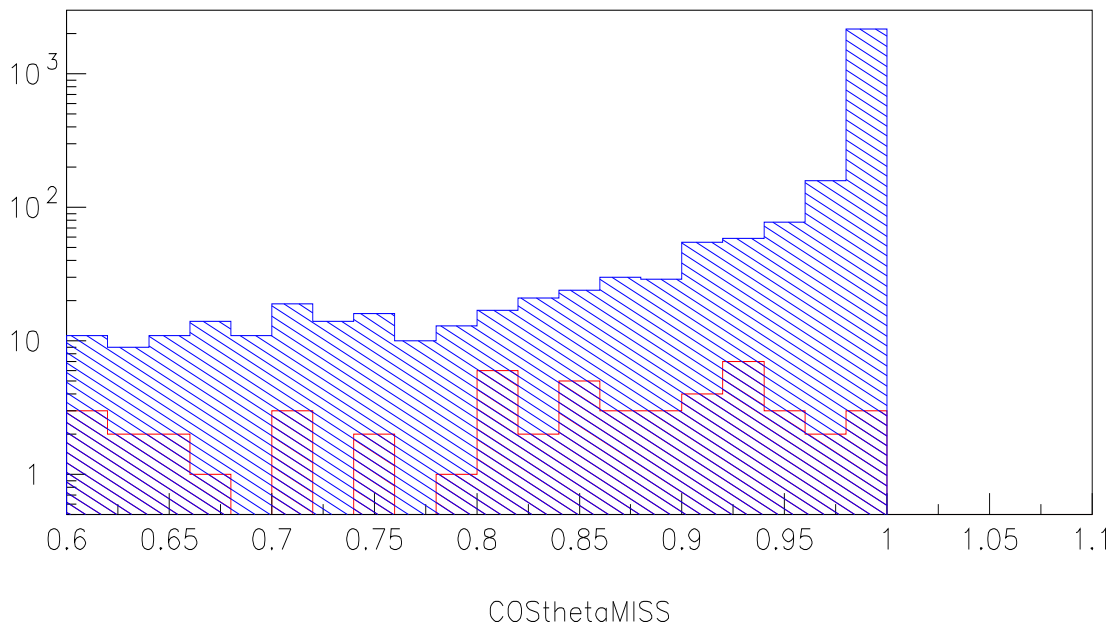
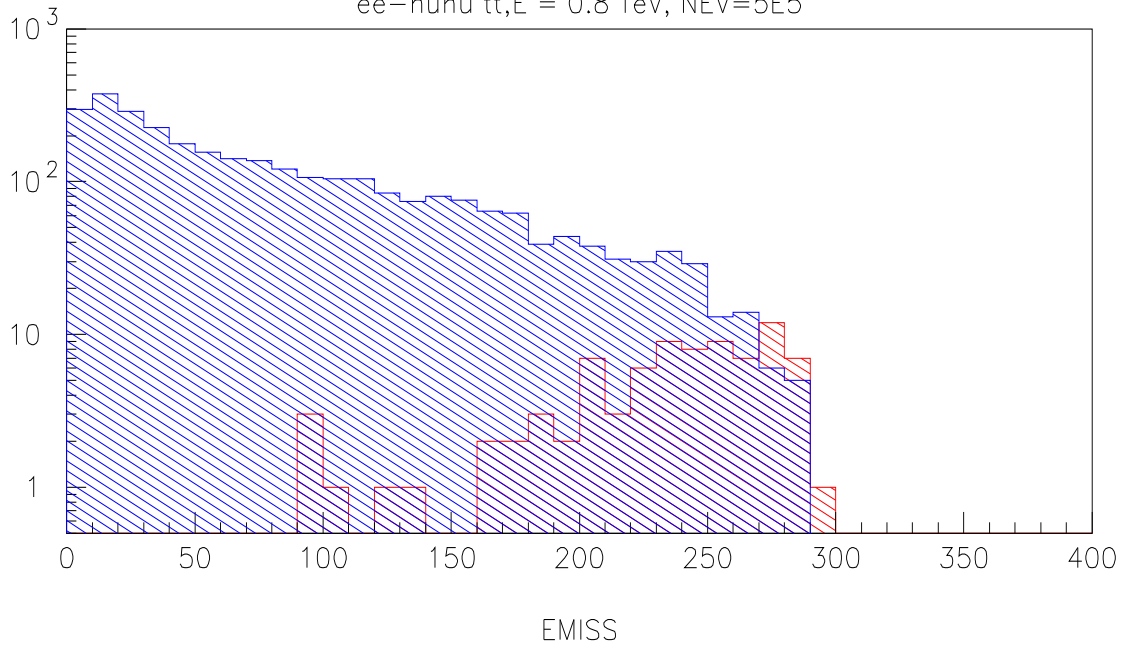
E_{MISS}



$\cos\theta_{MISS}$

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ee-nunu tt, E = 0.8 TeV, NEV=5E5

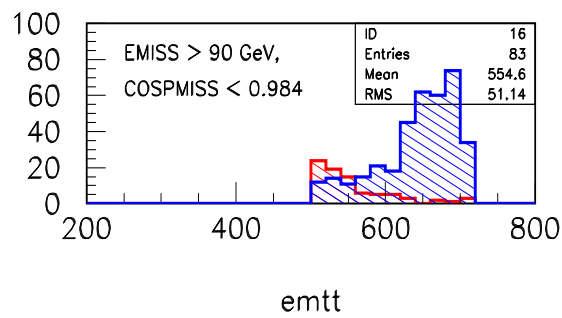
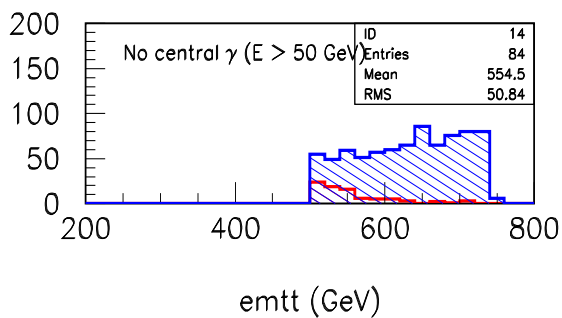
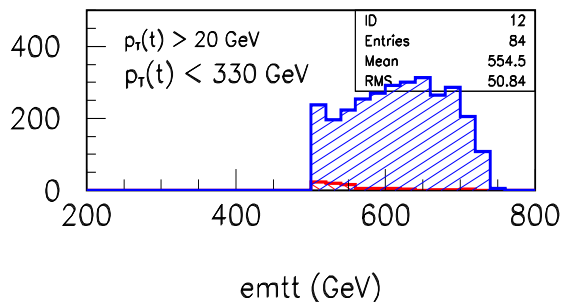
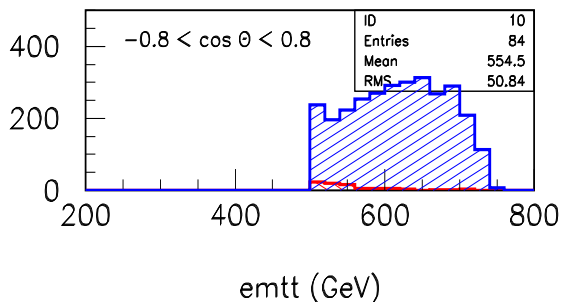
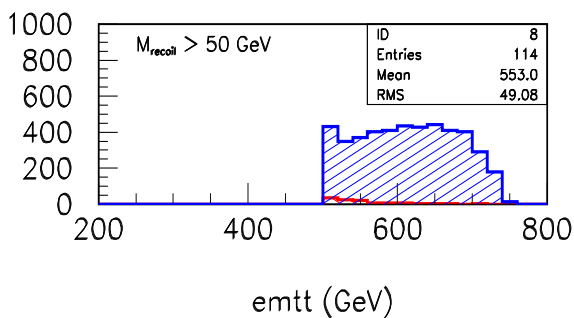
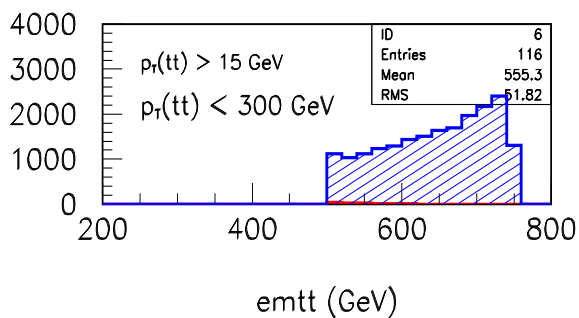
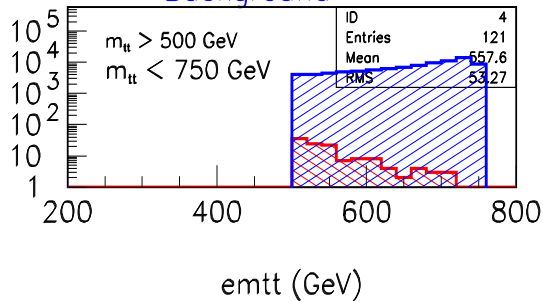
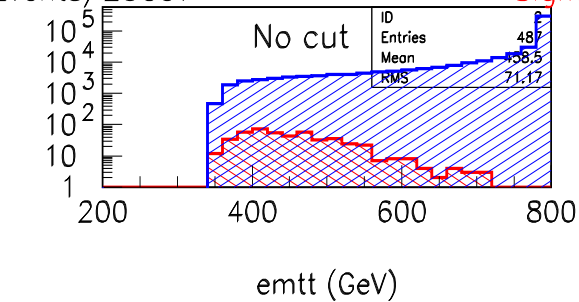


Cuts at $s^{1/2}=0.8$ TeV, $M_\rho = 700$ GeV, $\Gamma_\rho = 12.5$ GeV (500 000 events)

Events/20GeV

Signal

Background



$$\sqrt{s} = 1000 \text{ GeV}$$

Clean events only

Cuts:

$$500 < m_{tt} < 900 \text{ GeV}$$

$$p_T(tt) > 15 \text{ GeV}, p_T(tt) < 400 \text{ GeV}$$

$$E_t, E_{\bar{t}} < 480 \text{ GeV}$$

$$M_{rec} > 150 \text{ GeV}$$

$$|\cos \theta_{t,\bar{t}}| < 0.8$$

$$20 < p_t, p_{\bar{t}} < 420 \text{ GeV}$$

$$\text{no central } \gamma: E_\gamma > 50 \text{ GeV}, |\cos \theta_\gamma| < 0.99$$

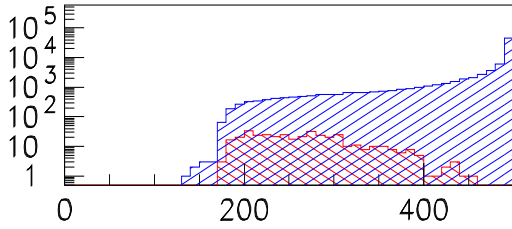
$$E_{miss} > 100 \text{ GeV}$$

$$|\cos \theta_{miss}| < 0.984 \text{ (0.96)}$$

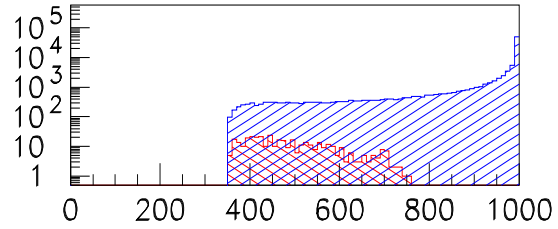
$$\text{Detector angle : } \cos \theta = 0.99 \text{ (8 degrees)}$$

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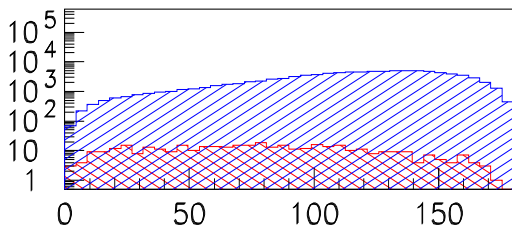
ee-nunu tt, E = 1.0 TeV, NEV=1E5



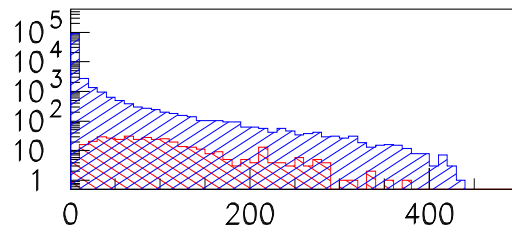
E_{top}



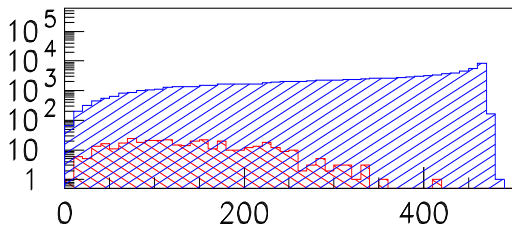
$e_{m_{tt}}$



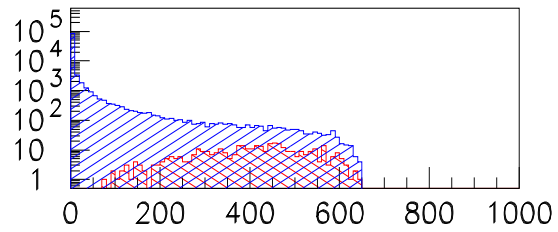
θ_{top}



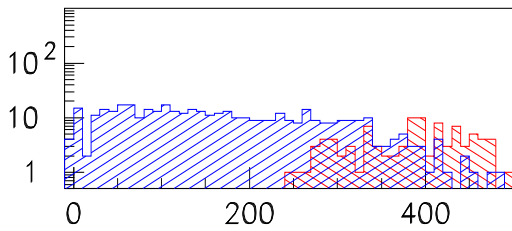
p_{ttt}



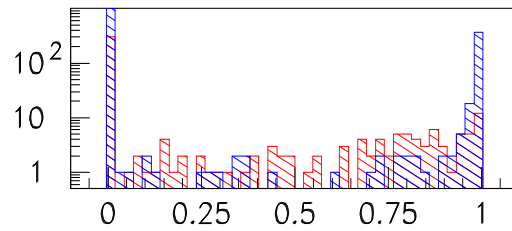
$p_{t_{top}}$



$e_{M_{rec}}$



E_{MISS}



$\cos\theta_{MISS}$

2004/08/18 11.25

ee-nunu tt,E = 1.0 TeV, NEV=1E5

