ECFA - Durham

Sep 2004

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

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Outline

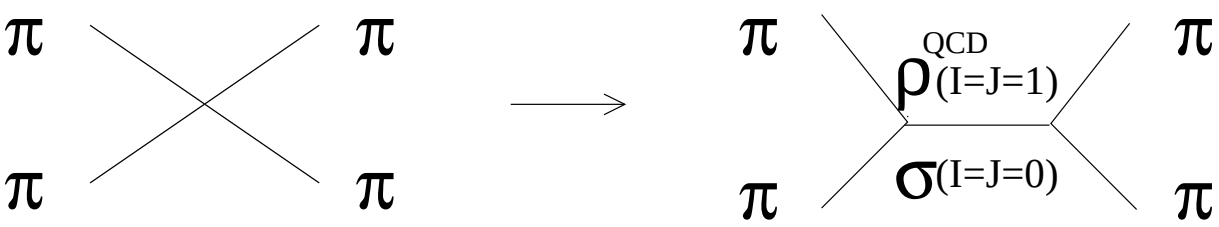
- motivation for new vector (ρ) resonance search

- ρ resonance model

- cross section calculations of ρ production at $\sqrt{s} = 800$ and 1000 GeV

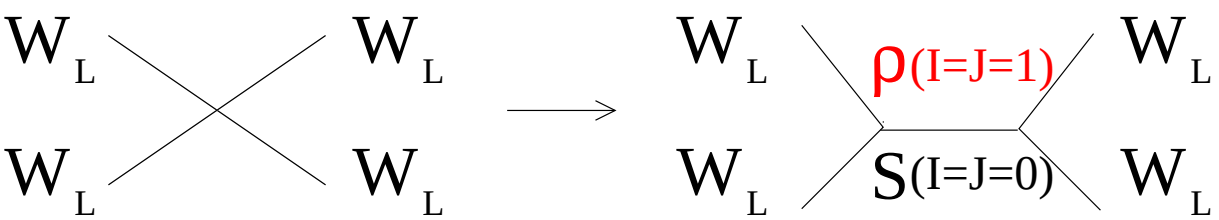
Chiral SB in QCD:

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

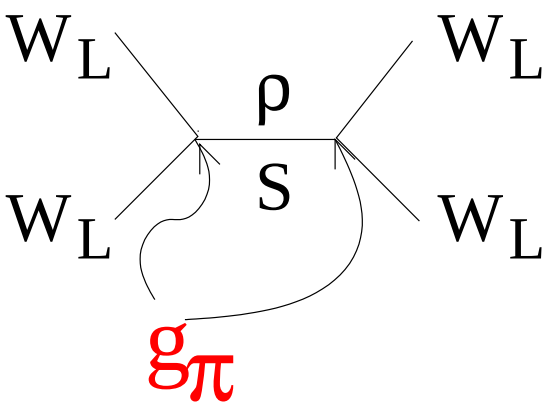


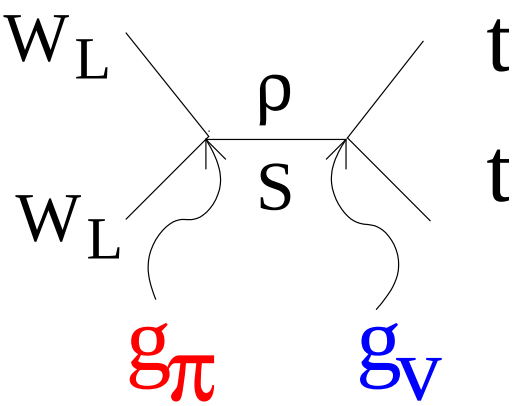
EWSB:

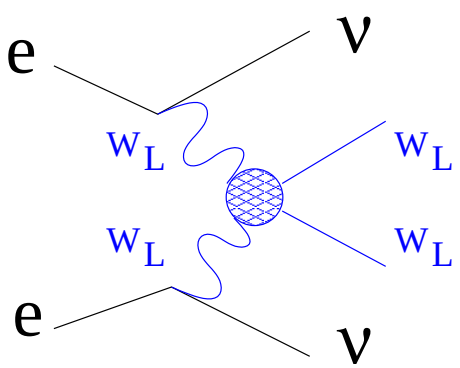
$SU(2)_L \times SU(2)_R \to SU(2)_V, \quad v \sim 246$ GeV

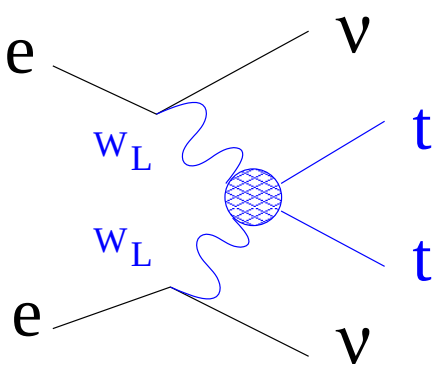


$W_L W_L \to t\bar{t}$ scattering









A natural Lagrangian

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

Chiral effective $\mathcal{L}$

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

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

2 sets are related

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

Unitarity constraints

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

$$g_\pi \leq 1.75 \quad (M_\rho = 700 \text{ GeV})$$
$$g_V \leq 1.7 \quad (M_\rho = 700 \text{ GeV})$$

Low energy constraints

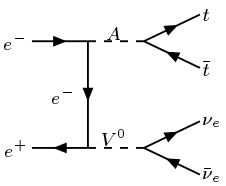
$$\mathcal{L}_{lowE} = +\frac{g}{2c_W}\left(-\frac{4}{3}s_W^2 + \frac{b_2}{2}\right)\bar{t}_R\gamma^\mu t_R\, Z_\mu + \ldots$$

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

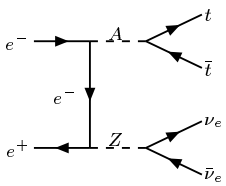
Limits on free parameters are given by

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

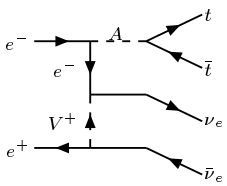
$e^+e^- \to \nu\bar{\nu}t\bar{t}$ (12 of 66 diagrams)



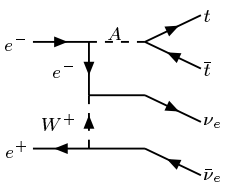
diagr.1



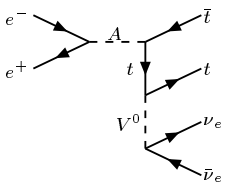
diagr.2



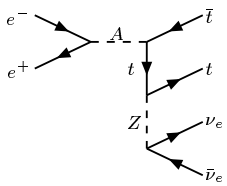
diagr.3



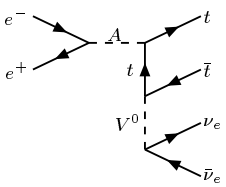
diagr.4



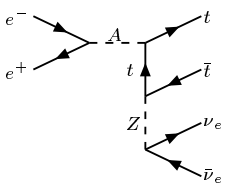
diagr.5



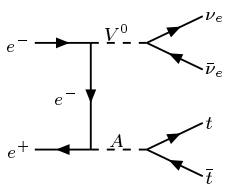
diagr.6



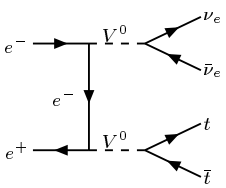
diagr.7



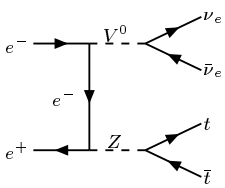
diagr.8



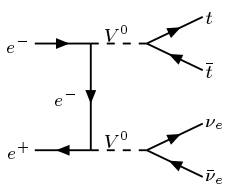
diagr.9



diagr.10

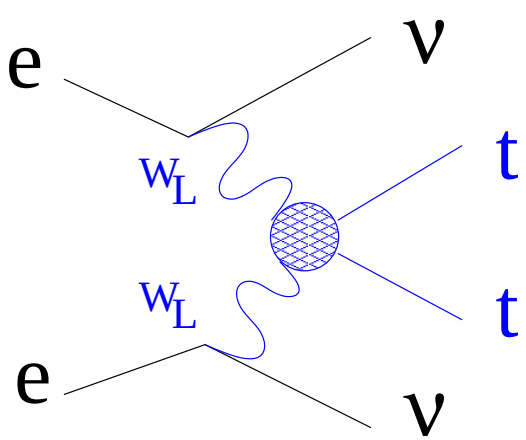


diagr.11



diagr.12

Subset of fusion diagrams + approximations (Pythia)



Full calculation of 66 diagrams at tree level (CompHEP)

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

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

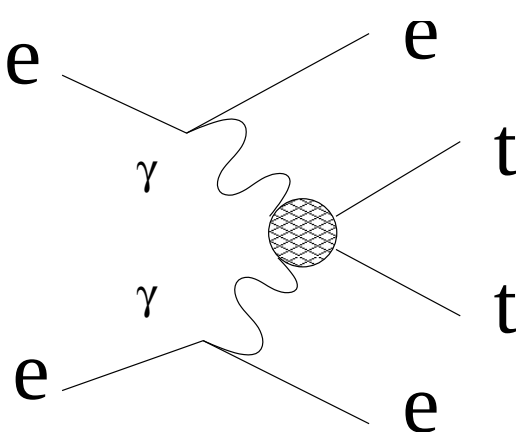
Pythia:

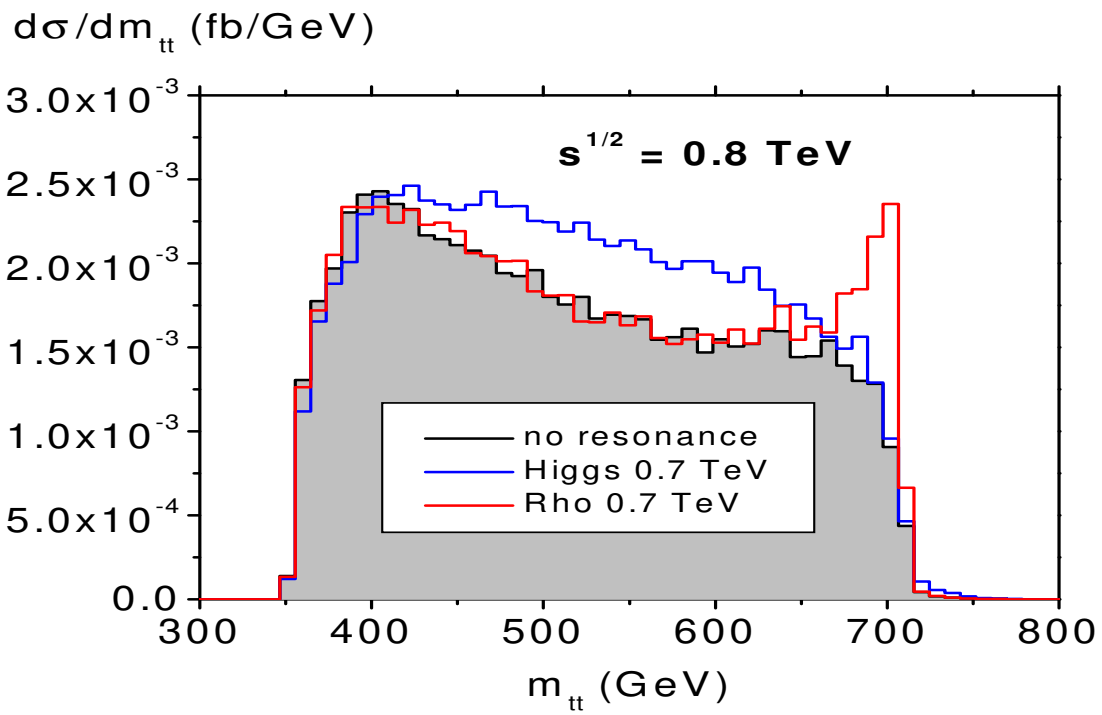
$\sigma(0.8\ \text{TeV}) = 300.3 + 1.3\ \text{fb} \ \to\ 0.13\ \text{fb}$

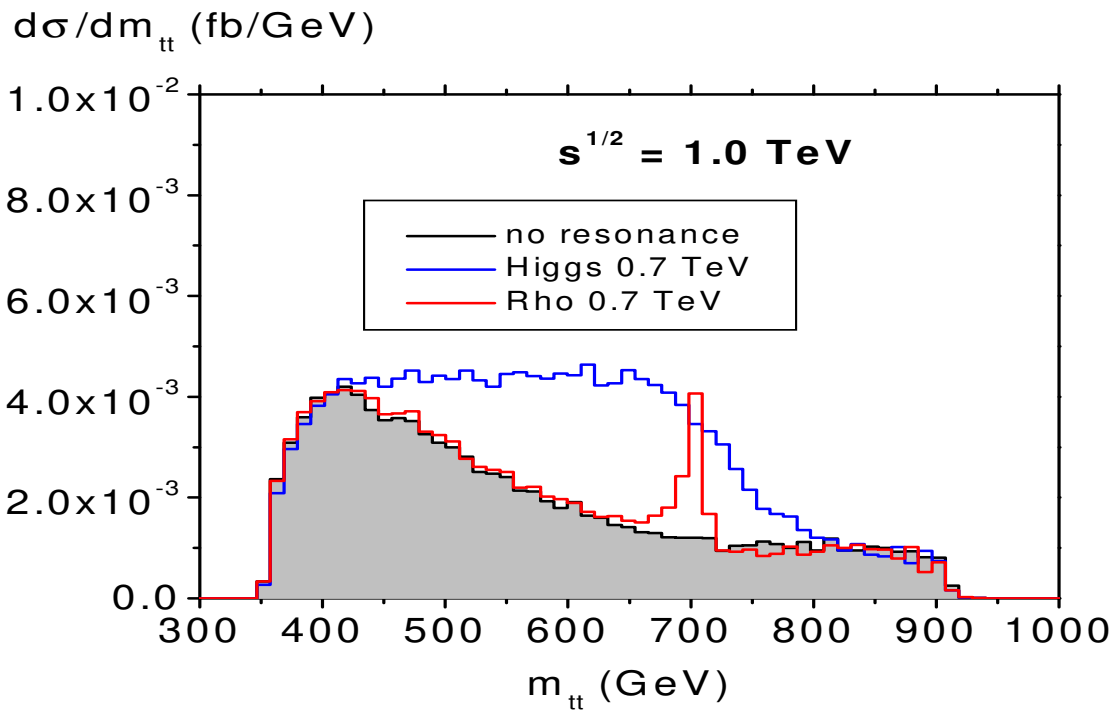
(0.20 fb)

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

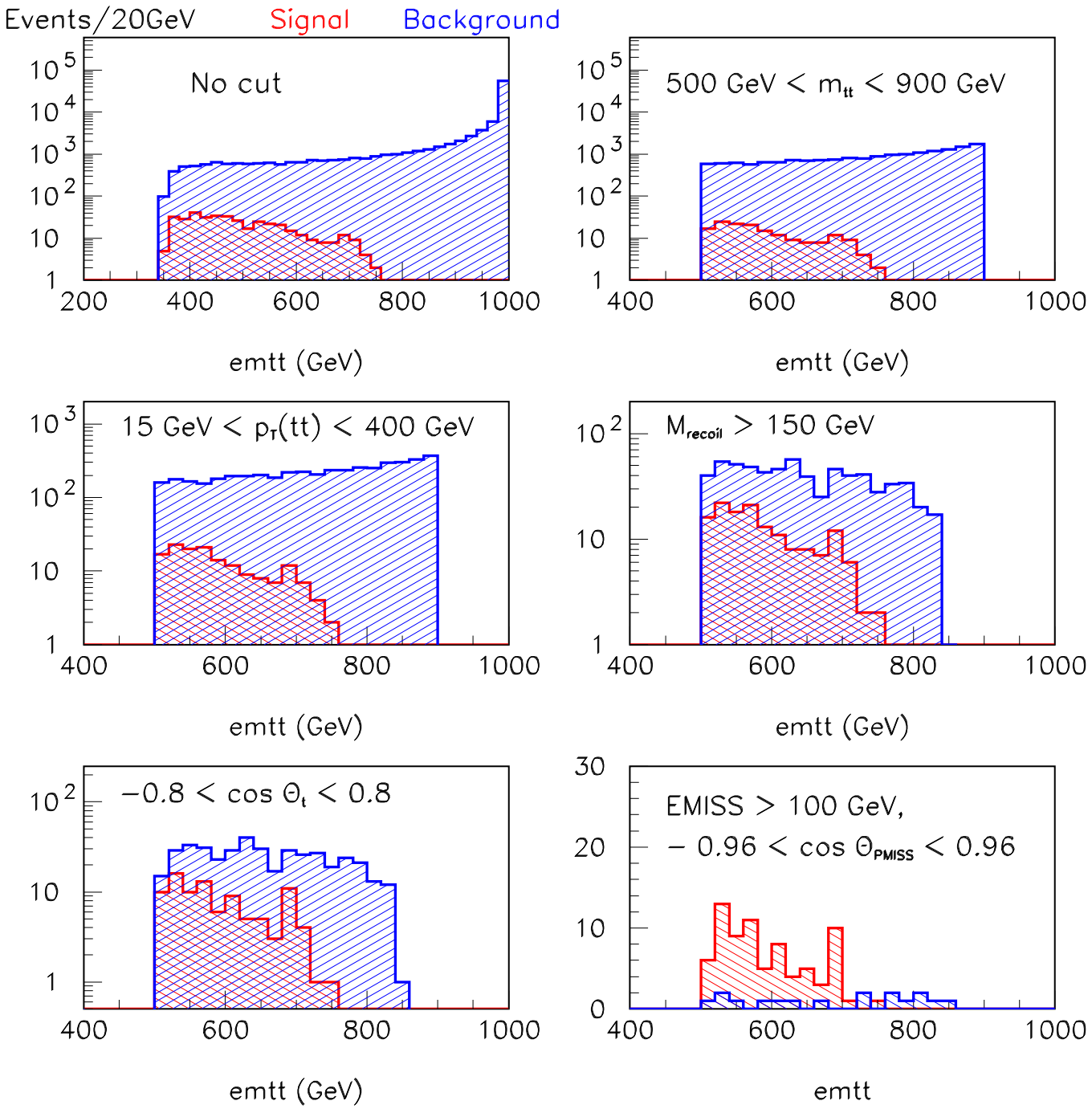
(0.16 fb)



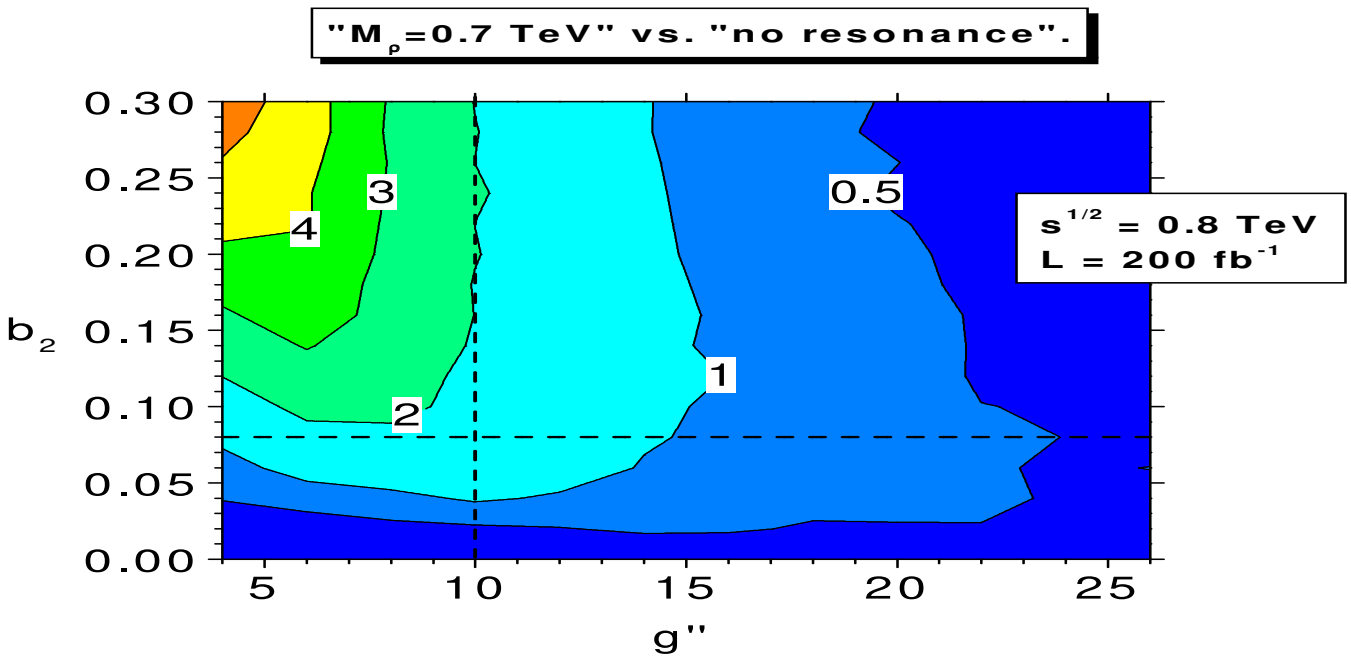

dσ/dm_tt (fb/GeV)
3.0x10^-3
2.5x10^-3
2.0x10^-3
1.5x10^-3
1.0x10^-3
5.0x10^-4
0.0
s^1/2 = 0.8 TeV
no resonance
Higgs 0.7 TeV
Rho 0.7 TeV
300
400
500
600
700
800
m_tt (GeV)

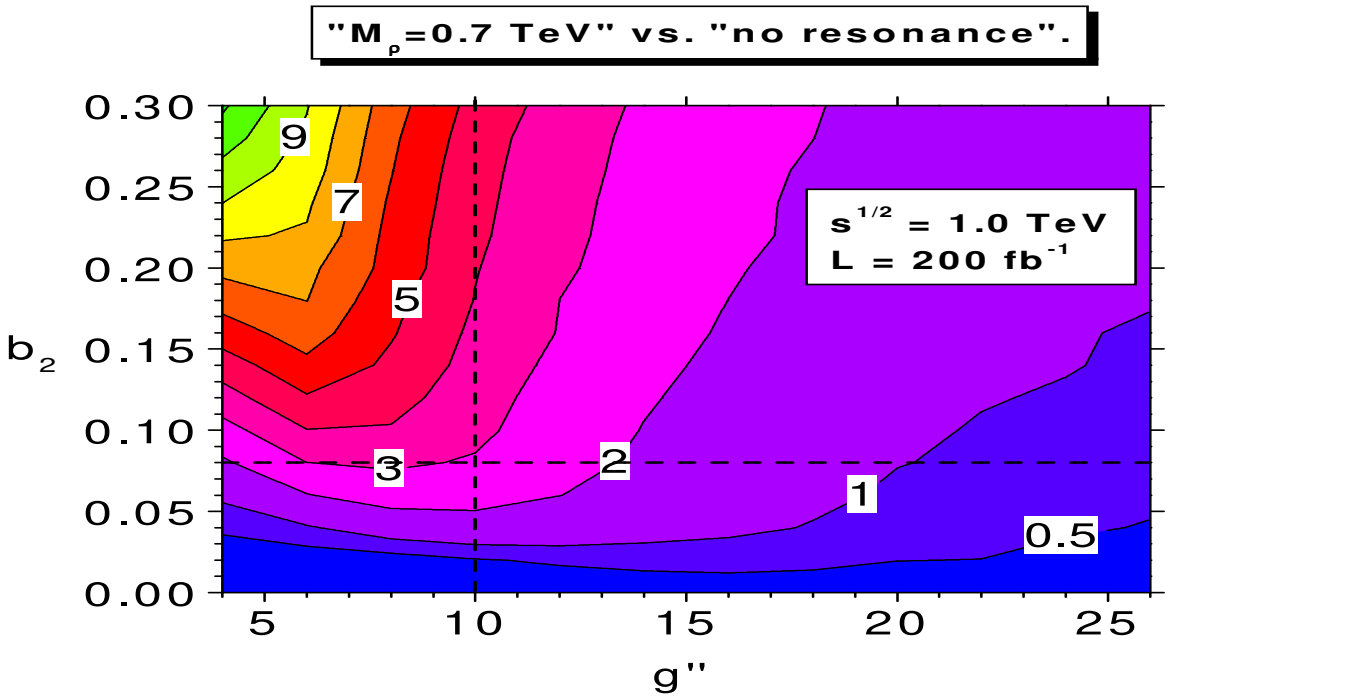

dσ/dm_tt (fb/GeV)
1.0x10^-2
8.0x10^-3
6.0x10^-3
4.0x10^-3
2.0x10^-3
0.0
s^1/2 = 1.0 TeV
no resonance
Higgs 0.7 TeV
Rho 0.7 TeV
300
400
500
600
700
800
900
1000
m_tt (GeV)

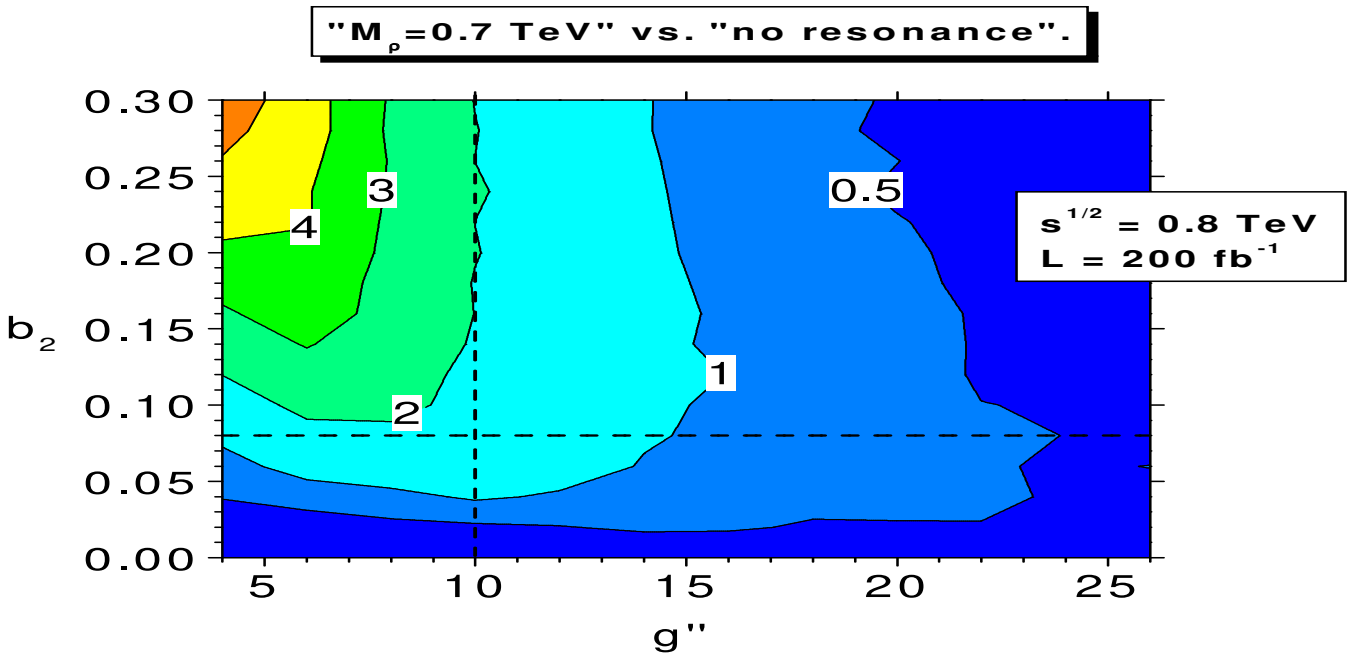
Cuts at $s^{1/2}$=1.0 TeV, M_ρ= 700 GeV, Γ_ρ=12.5 GeV (500 fb^{-1})

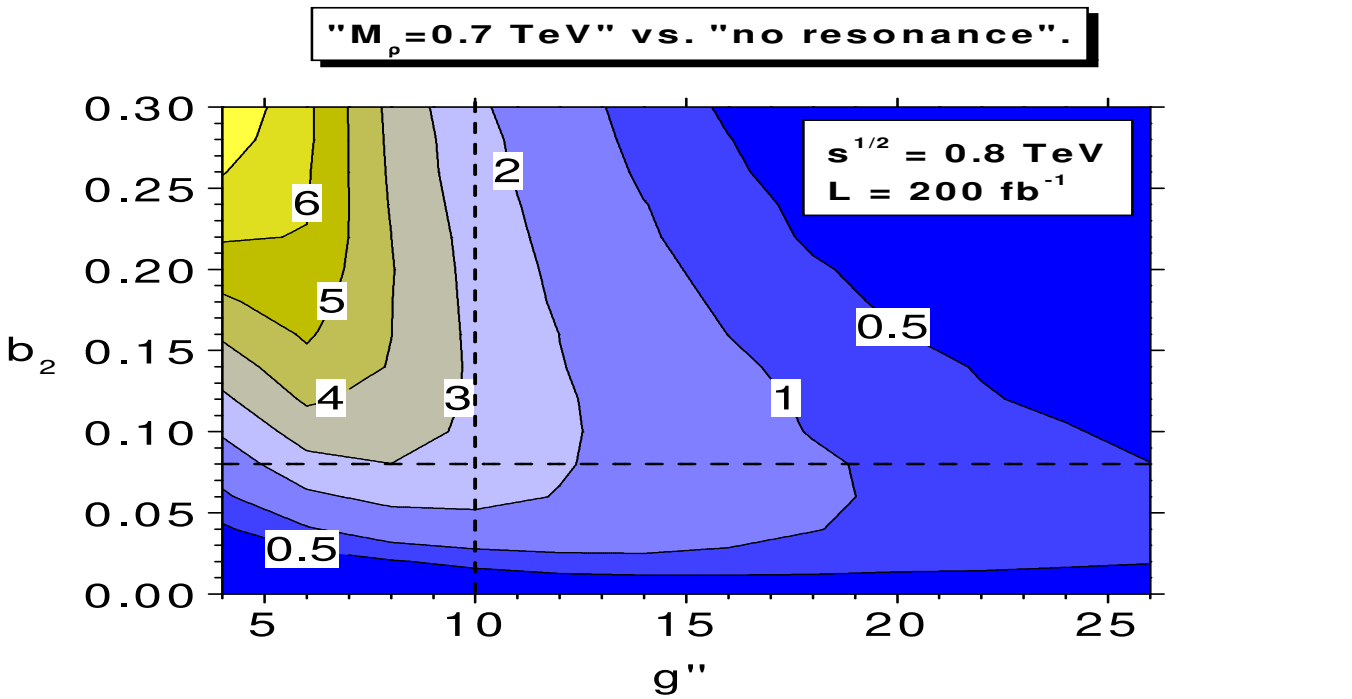


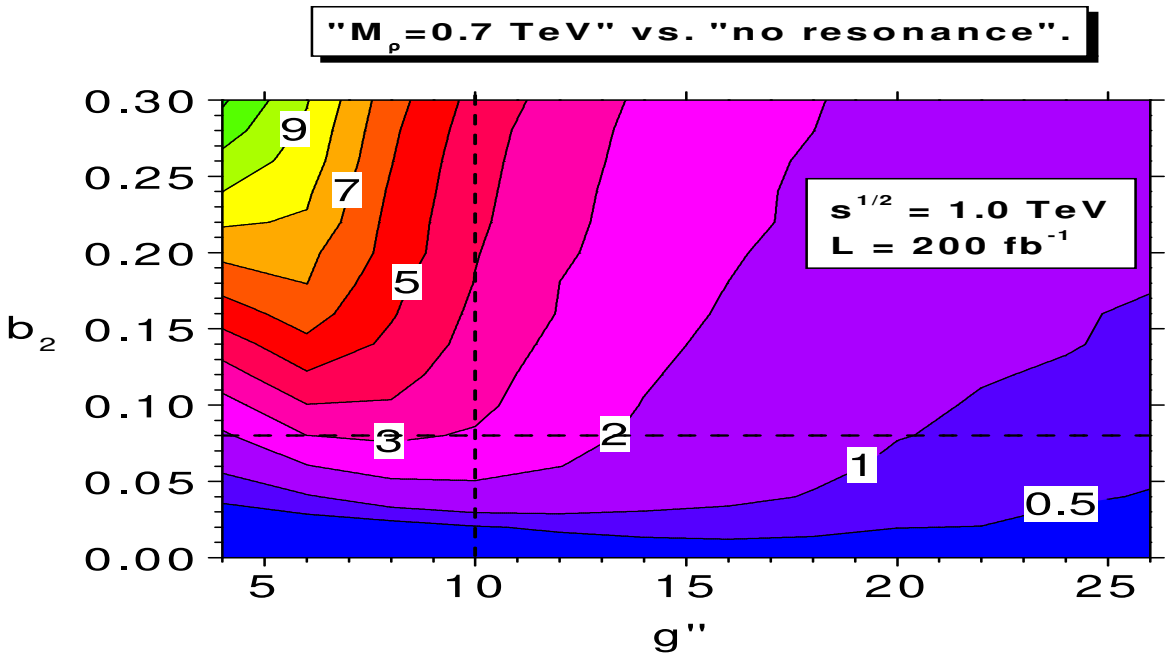
$$R = \frac{|N(\rho) - N(\text{no resonance})|}{\sqrt{N(\text{Background}) + N(\text{no resonance})}}$$

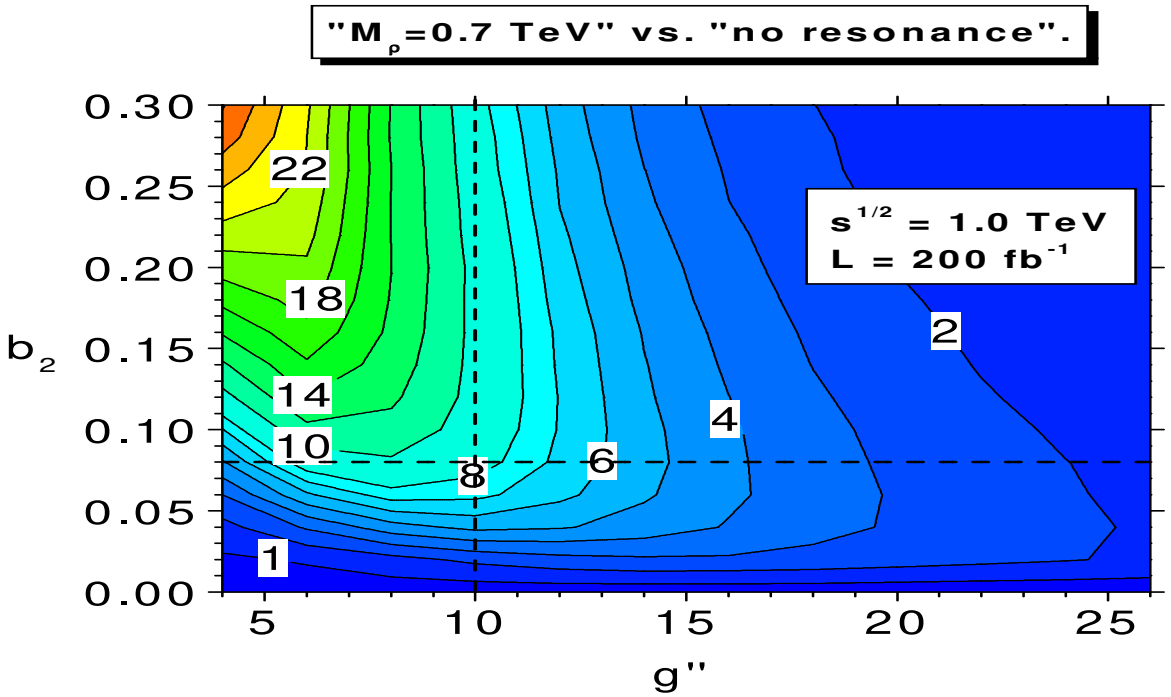





"M$_\rho$=0.7 TeV" vs. "no resonance".
s$^{1/2}$ = 0.8 TeV
L = 200 fb^{-1}
b$_2$
g''
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
20
25
0.5
1
2
3
4


"M$_\rho$=0.7 TeV" vs. "no resonance".
s$^{1/2}$ = 0.8 TeV
L = 200 fb^{-1}
b$_2$
g''
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
20
25
0.5
1
2
3
4
5
6


"M$_\rho$=0.7 TeV" vs. "no resonance".
s$^{1/2}$ = 1.0 TeV
L = 200 fb^{-1}
9
7
5
3
2
1
0.5
b$_2$
g''
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
20
25


"M$_\rho$=0.7 TeV" vs. "no resonance".
s$^{1/2}$ = 1.0 TeV
L = 200 fb^{-1}
22
18
14
10
8
6
4
2
1
b$_2$
g''
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
20
25

Conclusions

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

- agreement within 10 %
- no t decays

$\sigma(0.8\ \text{TeV}) = 0.20\ \ (0.13)$ fb
$\sigma(1.0\ \text{TeV}) = 0.16\ \ (0.035)$ fb

R (ρ vs no resonance) values up to 8

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

Appendix with more details

$\sqrt{s} = 800$ GeV

Clean events only

Cuts:

$500 < m_{tt} < 750$ GeV

$p_T(tt) > 15$ GeV, $p_T(tt) < 300$ GeV

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

$M_{rec} > 50$ GeV

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

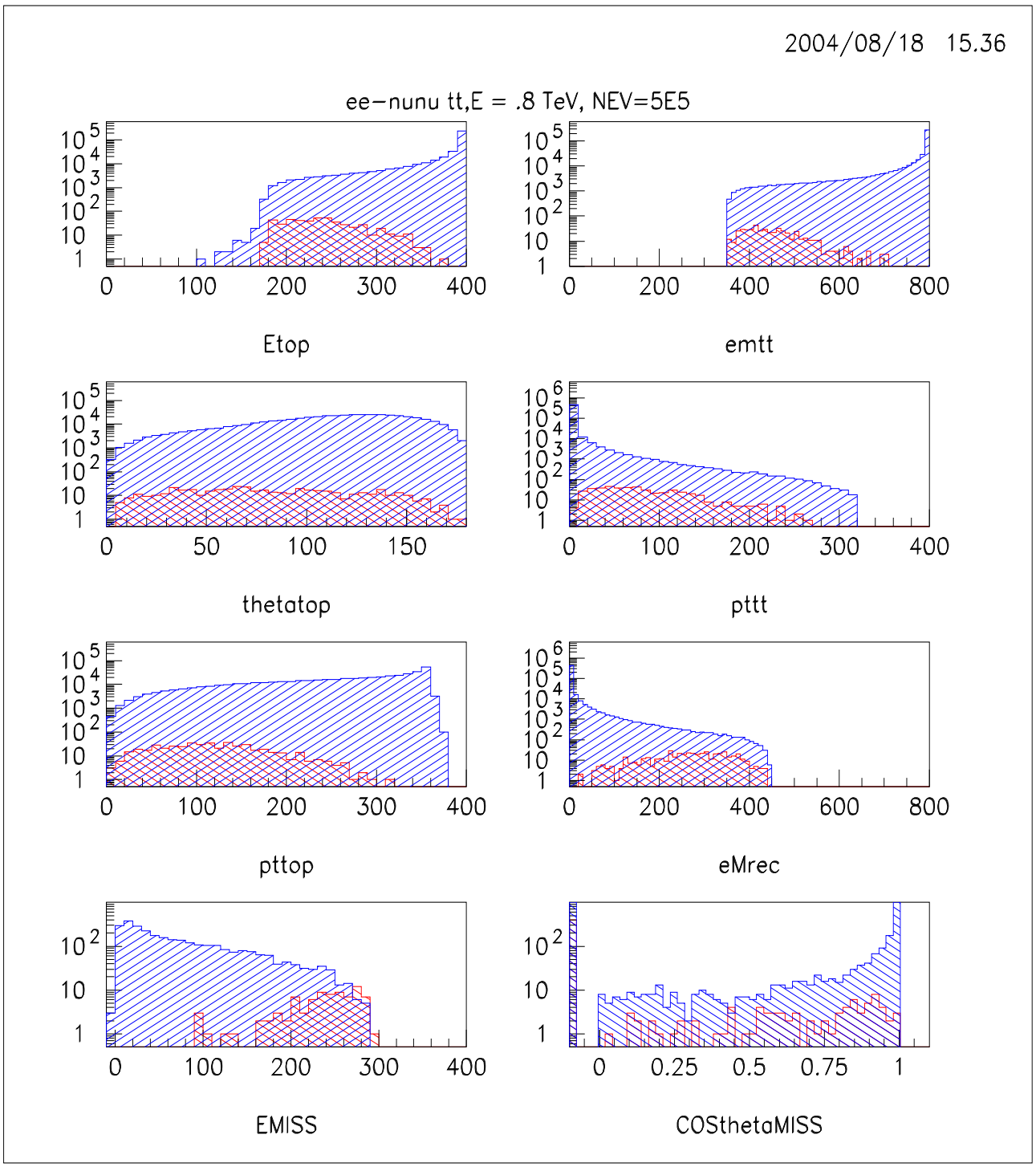
$20 < p_T(t), p_T(\bar{t}) < 330$ GeV

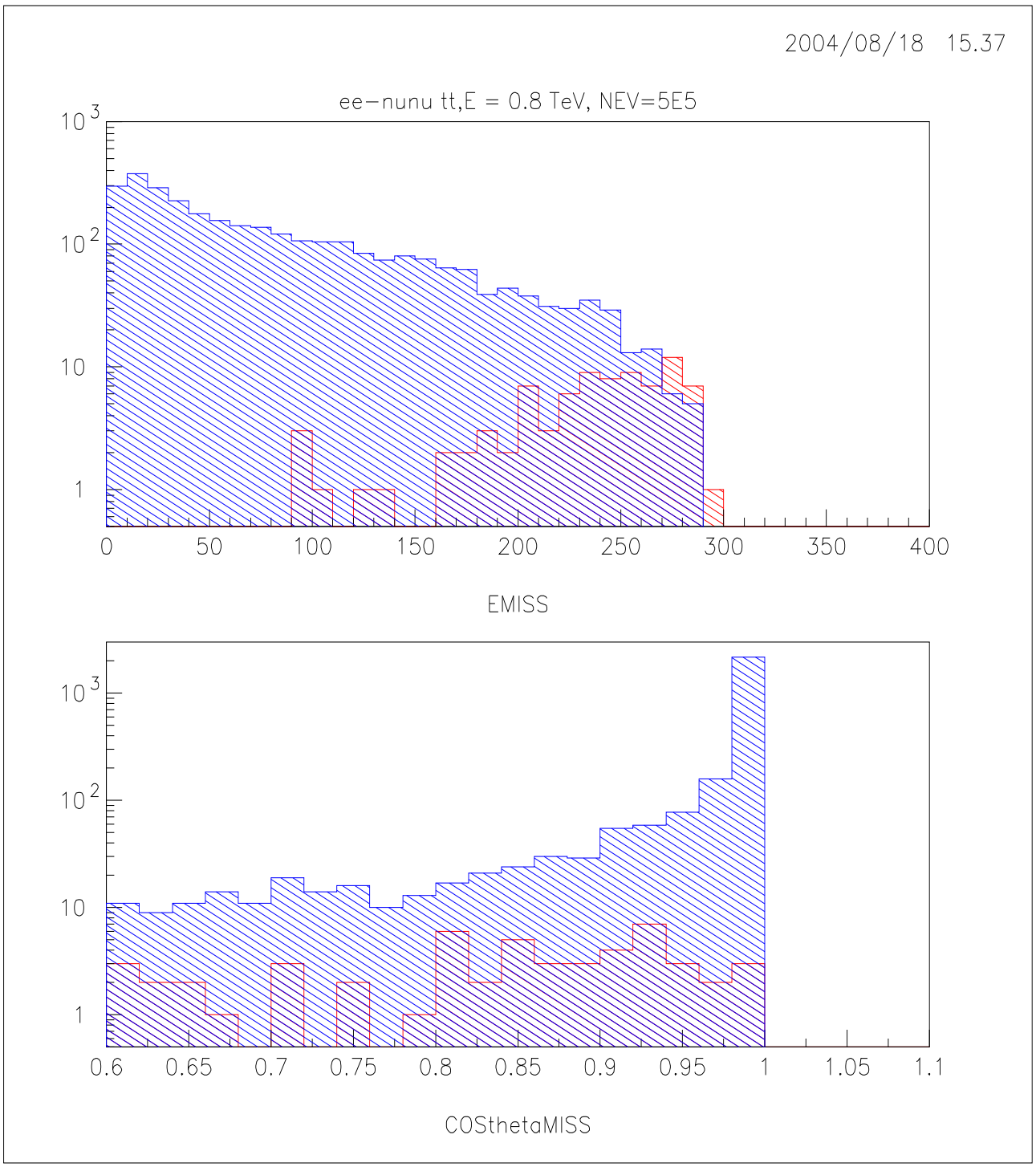
no central γ: $E_\gamma > 50$ GeV, $|\cos\theta_\gamma| < 0.99$

$E_{miss} > 90$ GeV

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

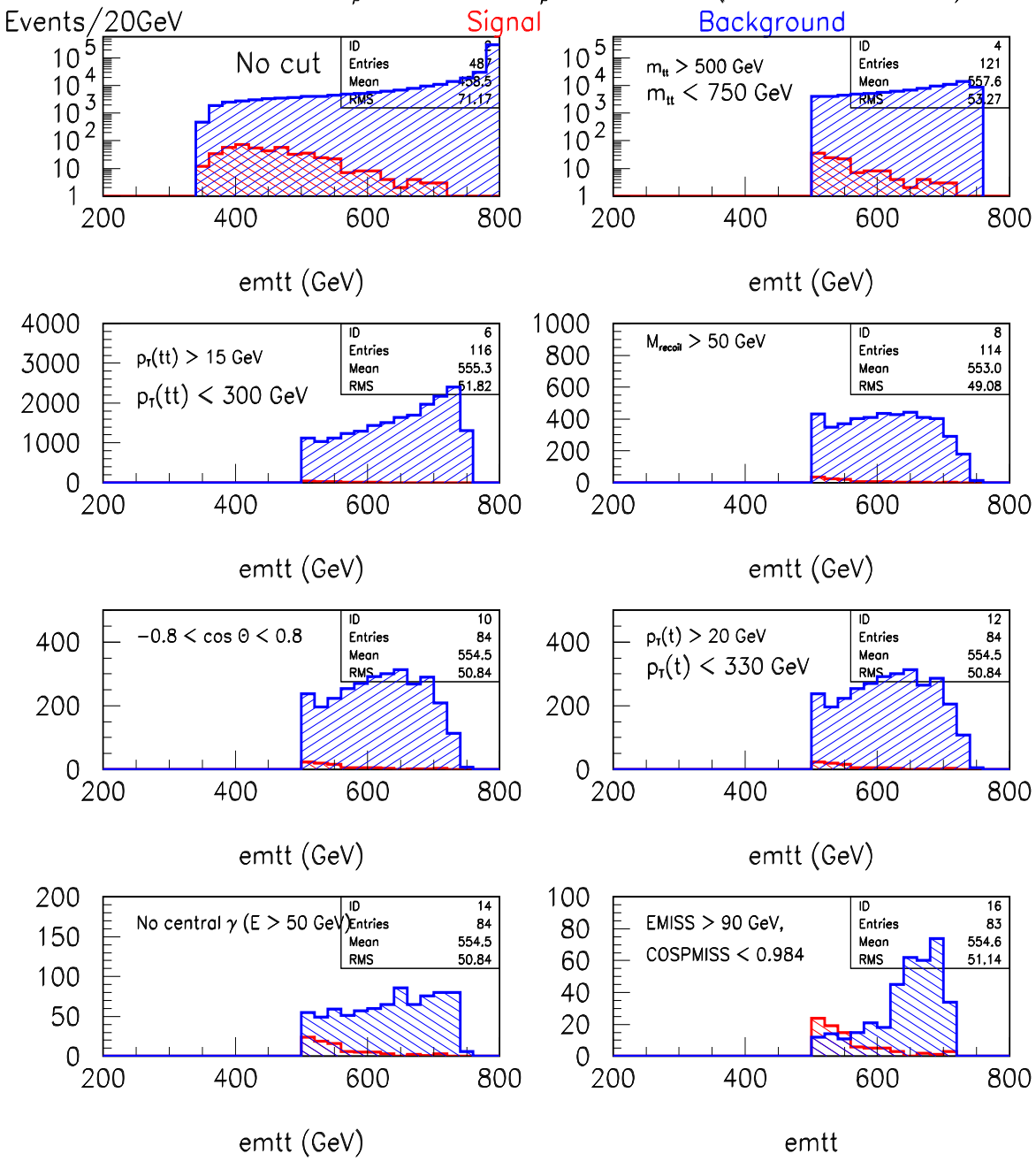
Detector angle : $\cos\theta = 0.99$ (8 degrees)


2004/08/18 15.36
ee−nunu tt,E = .8 TeV, NEV=5E5
Etop
emtt
thetatop
pttt
pttop
eMrec
EMISS
COSthetaMISS


2004/08/18 15.37
ee−nunu tt,E = 0.8 TeV, NEV=5E5
10 3
10 2
10
1
0
50
100
150
200
250
300
350
400
EMISS
10 3
10 2
10
1
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
COSthetaMISS

2004/08/18 15.54

Cuts at $s^{1/2}$=0.8 TeV, M_ρ= 700 GeV,Γ_ρ=12.5 GeV (500 000 events)



$\sqrt{s} = 1000$ GeV

Clean events only

Cuts:

$500 < m_{tt} < 900$ GeV

$p_T(tt) > 15$ GeV, $p_T(tt) < 400$ GeV

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

$M_{rec} > 150$ GeV

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

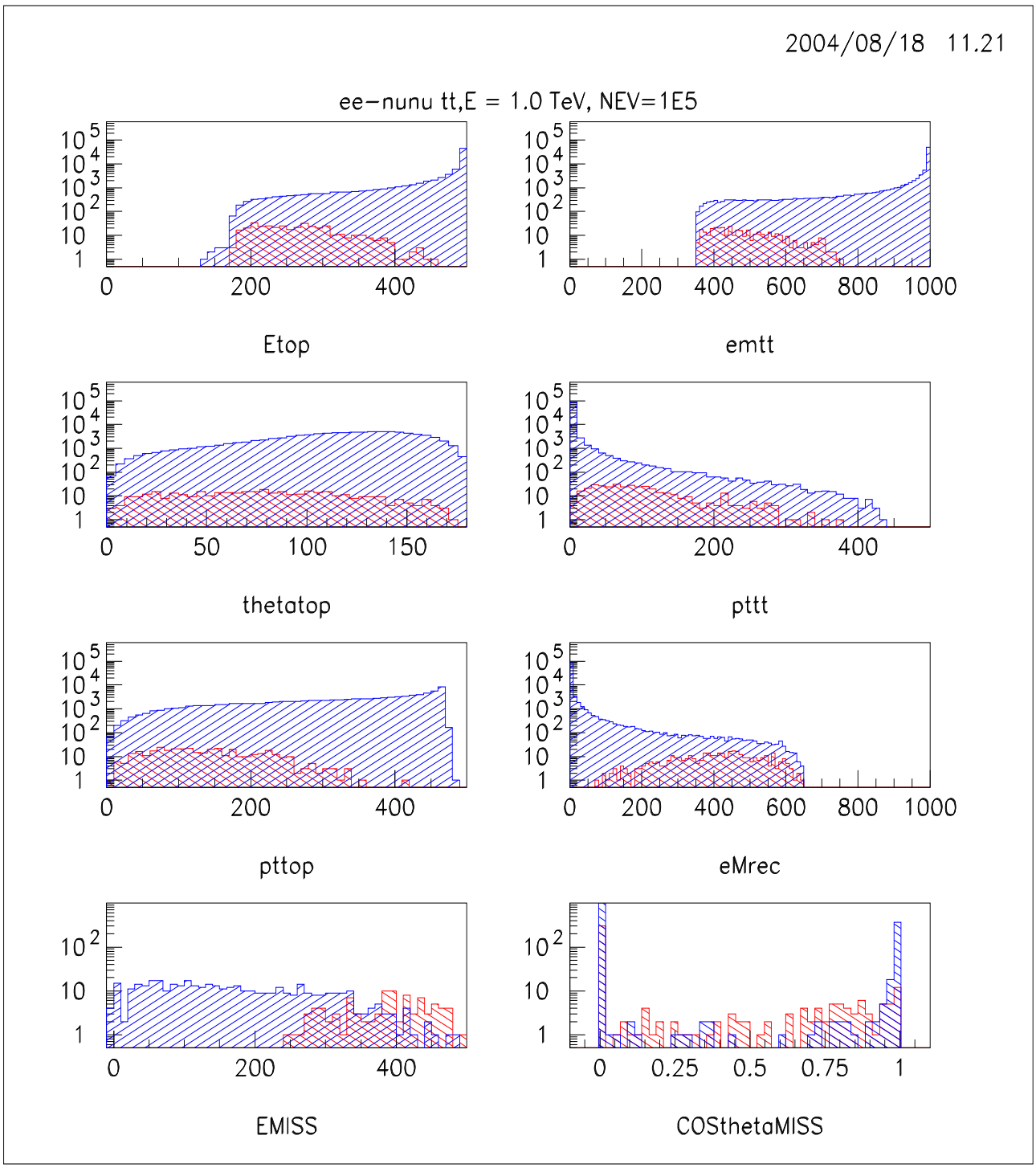
$20 < p_t, p_{\bar{t}} < 420$ GeV

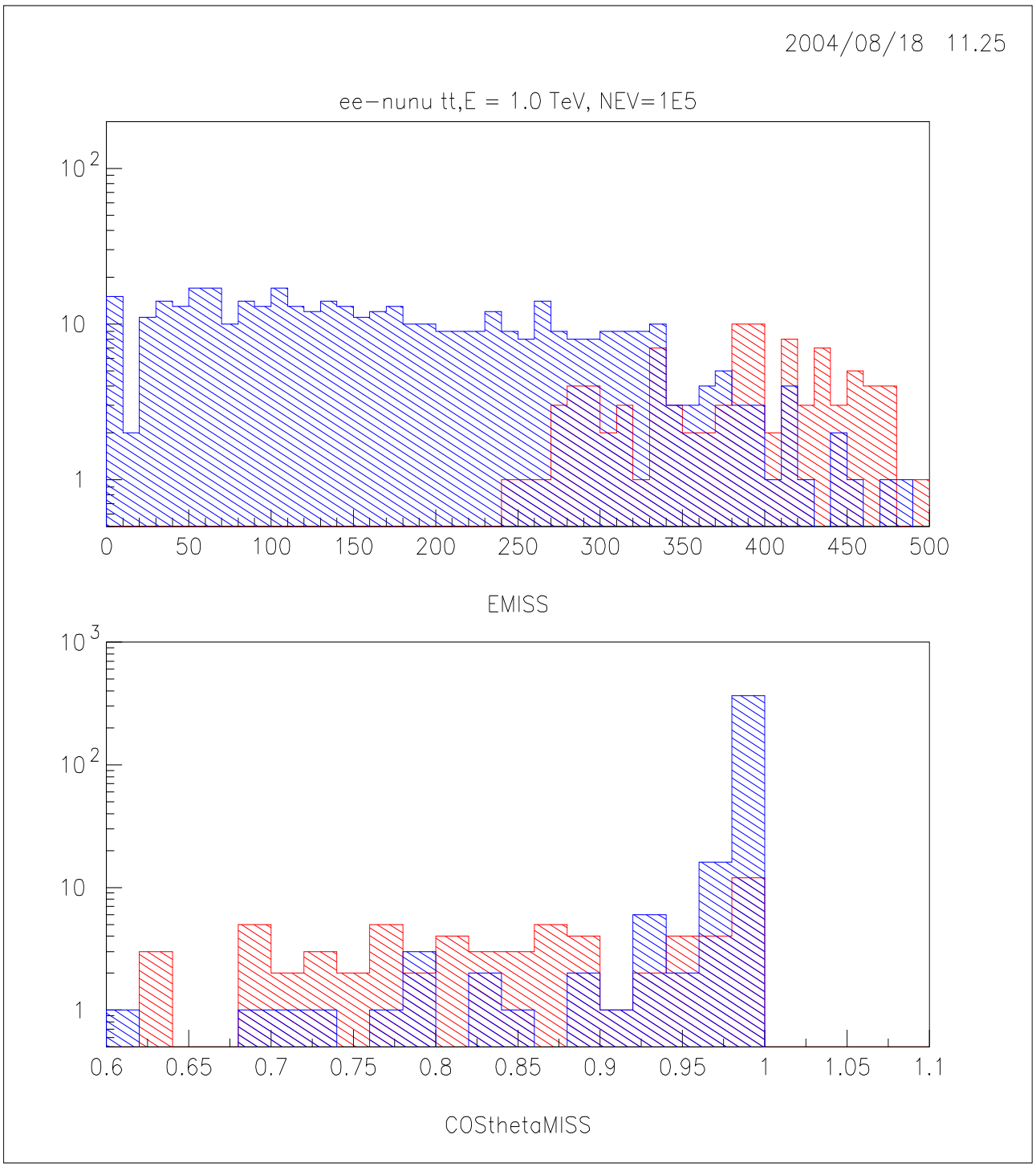
no central γ: $E_\gamma > 50$ GeV, $|\cos\theta_\gamma| < 0.99$

$E_{miss} > 100$ GeV

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

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


2004/08/18 11.21
ee−nunu tt,E = 1.0 TeV, NEV=1E5
Etop
emtt
thetatop
pttt
pttop
eMrec
EMISS
COSthetaMISS


2004/08/18 11.25
ee−nunu tt,E = 1.0 TeV, NEV=1E5
10 2
10
1
0 50 100 150 200 250 300 350 400 450 500
EMISS
10 3
10 2
10
1
0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1 1.05 1.1
COSthetaMISS