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Outline

- Rapidity and pseudorapidity

- No photon cut to reduce $e^-e^+ \to n\gamma t\bar{t}$

- E_{miss} and cos($\theta_{P_{miss}}$) cut

- No central e^-, e^+ cut

Rapidity y

is defined such that rapidity transforms under a boost along z-axis by adding rapidity of the boost

shape of rapidity distribution is invariant under boosts in the z-direction

$$y = \tanh^{-1}\frac{v}{c} = \tanh^{-1}\frac{p_z}{E} = \frac{1}{2}\ln\frac{1+p_z/E}{1-p_z/E}$$

$$= \frac{1}{2}\ln\frac{\sqrt{1+m^2/p^2}+\cos\theta}{\sqrt{1+m^2/p^2}-\cos\theta}$$

Pseudorapidity η

$$\eta = -\ln\tan\frac{\theta}{2} = \frac{1}{2}\ln\frac{1+\cos\theta}{1-\cos\theta}$$

η is a good approximation of y when a particle is relativistic

$\theta = 10 \to \eta = 2.436$
$\theta = 90 \to \eta = 0$
$\theta = 170 \to \eta = -2.436$

No central photon cut (reduces $e^+e^- \to n\gamma t\bar{t}$)

Pythia study at 1500 GeV, 10 000 events
Background: $e^+e^- \to n\gamma t\bar{t}$ (process 1) & $e^+e^- \to e^+e^- t\bar{t}$ (process 85)
Signal: $e^+e^- \to \nu\bar{\nu}t\bar{t}$ (process 379, ρ: 1000-0.08-10)

66 Bgr. events (52 events Bgr. 1, 14 events Bgr. 85) and 65 signal events survived all standard cuts

Bgr.1 contains energetic photons ($E > 50$ or 100 GeV) emitted centrally $|\eta| < 2.436$ ($\theta > 10$ and $\theta < 170$) $\to$ convenient cut

1) $E_\gamma > 100$ GeV

Bgr. 1: all 52 events have photon with $E_\gamma >$ 100 GeV - 43 central photon (which can be cut out), 9 noncentral photon

1 of 43 emitted from t (not e^+, e^-)

Signal: 2 of 65 events have photon with $E_\gamma >$ 100 GeV, both noncentral

Before the no photon cut:

$\frac{S}{\sqrt{B}} = \frac{65}{\sqrt{66}} = 8.0$

After the no photon cut:

$\frac{S}{\sqrt{B}} = \frac{65}{\sqrt{66-43}} = 13.5$

Note: this strongly depends on the angle that defines central photon ! Changing this angle from 10 to 5 degrees suppresses 5 more out of remaining 9 Bgr. 1 events

1) $E_\gamma > 50$ GeV

Changes from $E_\gamma > 100$ GeV case above:
1st central photon event for Bgr. 85 (photon comes from μ^+)
3 events from remaining 9 noncentral Bgr. 1 events became central
1 event of 43 above replaced 'true' central photon with central 'jet photon'
3 new signal energetic photon events, 1 central 'jet photon', 2 noncentral

$\frac{S}{\sqrt{B}} = \frac{65-1}{\sqrt{66-43-4}} = 14.6$

E_{miss} and $\cos(\theta_{P_{miss}})$ cut

Ref.: R. Chierici, S. Rosati and M. Kobel
(TESLA study of $e^+e^- \to W^+W^-\nu\bar{\nu}$ at 800 GeV)

They use:
$200 < E_{miss} < 650$ GeV, $|\cos(\theta_{P_{miss}})| < 0.99$

Motivation: even though backgr. events with missing (radiated close to beam axis) γ or e^+, e^- look like signal, we can remove them precisely on the basis of missing momentum P_{miss} for the backgr. (less so for the signal) being directed close to the beam axis: $|\cos(\theta_{P_{miss}})| < 0.99$ ($\theta_{P_{miss}} < 8$ (> 172) degrees)

(of course, γ or e^+, e^- radiated to $\theta > 8$ (< 172) degrees are visible and we can apply 'no central photon (no e^- or e^+) cut)

E_{miss} and $\cos(\theta_{P_{miss}})$ definition

$$\vec{P_{vis}} = \vec{P}_t + \vec{P}_{\bar{t}} + \vec{P}_{e^-_{vis}} + \vec{P}_{e^+_{vis}} + \vec{P}_{\gamma_{vis}}$$

$$|\cos(\theta_{P_{miss}})| = |-P_{z_{vis}}/P_{vis}|$$

$$E_{miss} = \sqrt{s} - E_t - E_{\bar{t}} - E_{e^-_{vis}} - E_{e^+_{vis}} - E_{\gamma_{vis}}$$

$\sqrt{s} = 1500$ GeV, NEVENTS = 100 000
$\mathbf{1} \equiv e^+e^- \to (n\gamma)t\bar{t}$ (Background),
$\mathbf{85} \equiv e^+e^- \to e^+e^-t\bar{t}$ (Background),
$\mathbf{379} \equiv e^+e^- \to \nu\bar{\nu}t\bar{t}$ (Signal: $\rho = 1$TeV)

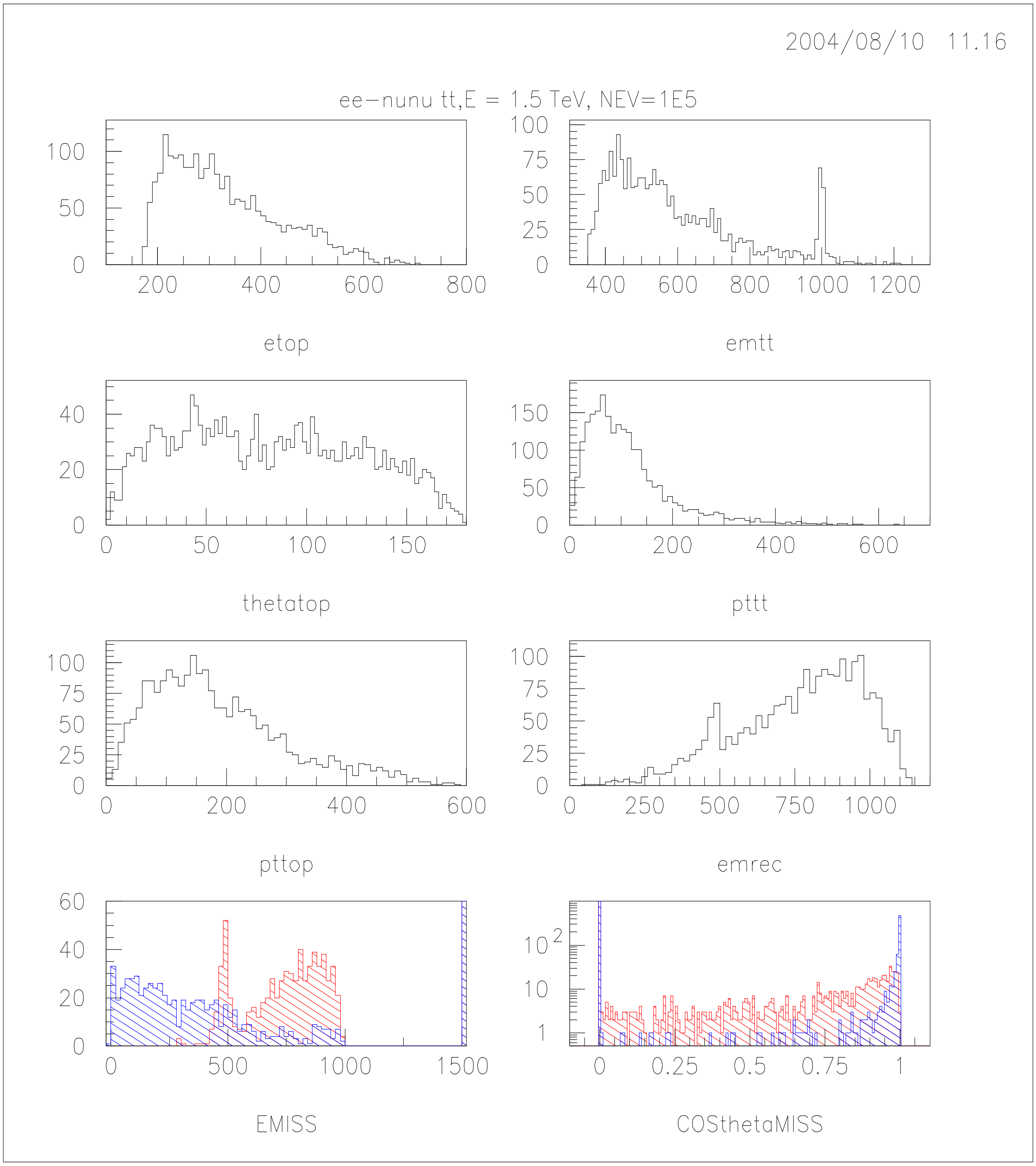
Clean events $\equiv$ only photons from ISR and only final state e^-, e^+ from $e^+e^- \to e^+e^-t\bar{t}$ are considered

Unclean events $\equiv$ all photons and e^-, e^+ are considered (clean plus those from $t, \bar{t}$-decay products plus photons from $t, \bar{t}$)

E_{miss} and cos($\theta_{P_{miss}}$) distributions

Fig.1: Distributions in E_{miss} and cos($\theta_{P_{miss}}$) show only clean events which survive all standard cuts: 692 for $\mathbf{379}$ (shown in red) and 659 for $\mathbf{1+85}$ (shown in blue). First 6 distributions are for 2 268 generated signal ($\mathbf{379}$) events before any cuts

Fig. 2: Detail view of E_{miss} and cos($\theta_{P_{miss}}$) distributions



2004/08/10 11.16
ee−nunu tt,E = 1.5 TeV, NEV=1E5
etop
emtt
thetatop
pttt
pttop
emrec
EMISS
COSthetaMISS


2004/08/10 14.27
ee−nunu tt,E = 1.5 TeV, NEV=1E5
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
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

New cuts applied at $\sqrt{s} = 1500$ GeV

$E_\gamma > 50\text{GeV}$,

$E_{miss} > 100\text{GeV}, |\cos(\theta_{P_{miss}})| < 0.984$

b1 ... No. of events with $E_{miss} < 0$ for proc **1**

b2 ... No. of events with $E_{miss} < 0$ for proc **85**

i1 ...counts unclean γ from t, b, μ, e; $t \to Wb \to e\mu\nu b$ $(I \leq 30)$

i2 ... counts unclean γ from jets $(I > 30)$

i3 ... counts all unclean e^-

i3a ... counts unclean e^- from jets $(I > 30)$

i4 ... counts all unclean e^+

i4a ... counts unclean e^+ from jets $(I > 30)$

C: clean U: unclean

- $\sigma(\mathbf{1+85}) = (99.57 + 5.29)$ fb $= 104.86$ fb

C: $97\ 732 \longrightarrow 659 \xrightarrow{E_\gamma} 204 \xrightarrow{E_{miss},\theta_{P_{miss}}} 80$

$97\ 732 \longrightarrow 659 \xrightarrow{E_{miss},\theta_{P_{miss}}} 85 \xrightarrow{E_\gamma} 80$

U: $97\ 732 \longrightarrow 659 \xrightarrow{E_\gamma} 197 \xrightarrow{E_{miss},\theta_{P_{miss}}} 90$

b1=44, b2=2, i1=11, i2=23, i3=87, i3a=30, i4=80, i4a=27

- $\sigma(\mathbf{379}) = 2.475$ fb

C: $2\ 268 \longrightarrow 692 \xrightarrow{E_\gamma} 688 \xrightarrow{E_{miss},\theta_{P_{miss}}} 646$

U: $2\ 268 \longrightarrow 692 \xrightarrow{E_\gamma} 668 \xrightarrow{E_{miss},\theta_{P_{miss}}} 621$

b1=0, b2=0, i1=5, i2=20, i3=149, i3a=29, i4=132, i4a=28

• $\sigma(\mathbf{1}) = 99.57$ fb

C: 92 845 $\longrightarrow$ 526 $\xrightarrow{E_\gamma}$ 71 $\xrightarrow{E_{miss},\theta_{P_{miss}}}$ 32

U: 92 845 $\longrightarrow$ 526 $\xrightarrow{E_\gamma}$ 68 $\xrightarrow{E_{miss},\theta_{P_{miss}}}$ 39

b1=44, b2=0, i1=8, i2=21, i3=75, i3a=27, i4=76, i4a=27

• $\sigma(\mathbf{85}) = 5.29$ fb

C:

U: 4 887 $\longrightarrow$ 133 $\xrightarrow{E_\gamma}$ 129 $\xrightarrow{E_{miss},\theta_{P_{miss}}}$ 51

b1=0, b2=2, i1=3, i2=2, i3=12, i3a=3, i4=4, i4a=0

• $\sigma(\mathbf{1+85}) = (99.57 + 5.29)$ fb $=$ 104.86 fb

C: 97 732 $\longrightarrow$ 659 $\xrightarrow{E_\gamma}$ 204 $\xrightarrow{E_{miss},\theta_{P_{miss}}}$ 80

U: 97 732 $\longrightarrow$ 659 $\xrightarrow{E_\gamma}$ 197 $\xrightarrow{E_{miss},\theta_{P_{miss}}}$ 90

b1=44, b2=2, i1=11, i2=23, i3=87, i3a=30, i4=80, i4a=27

New cuts push DIS2004 background figure significantly down:

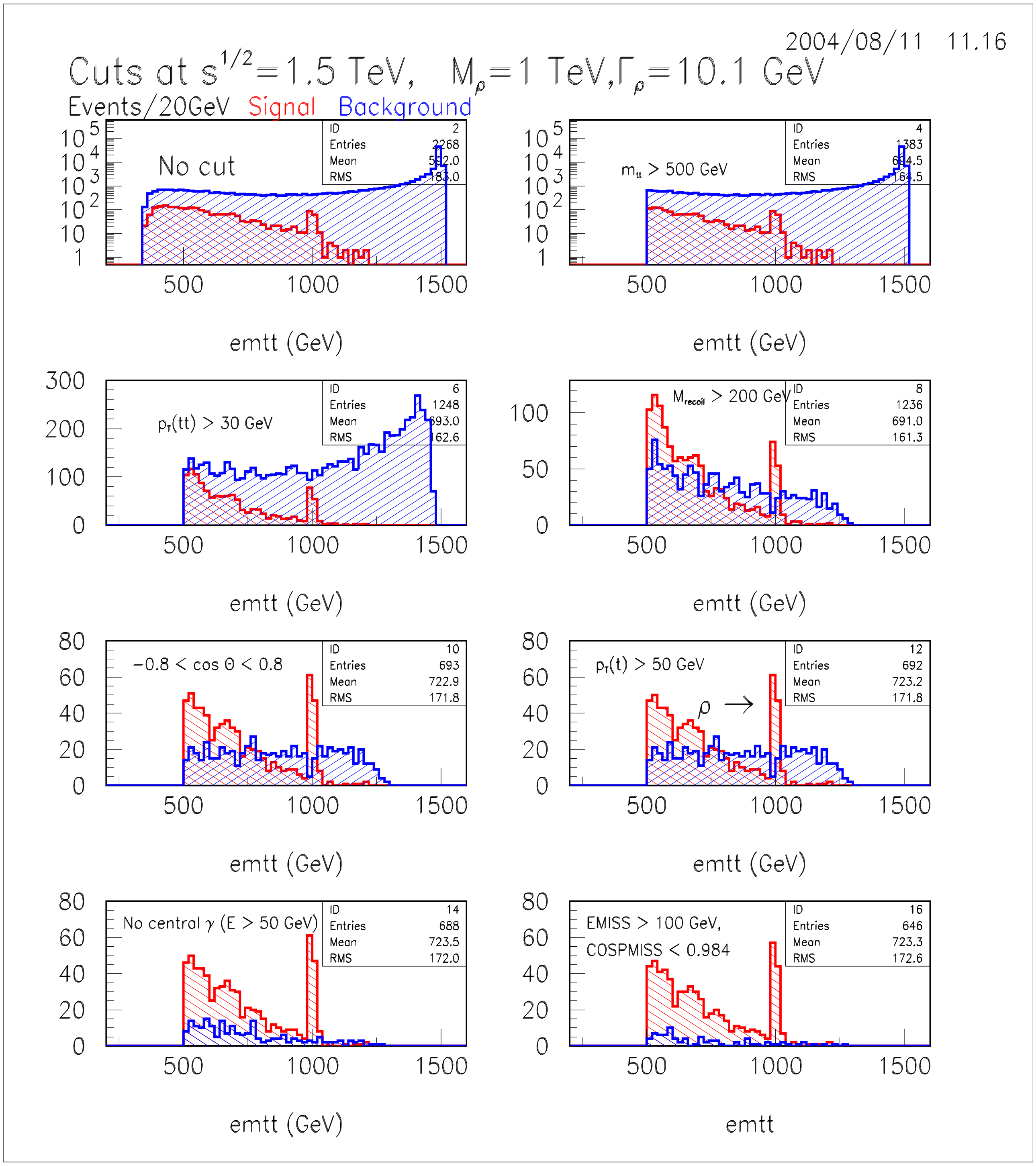
C: $S/\sqrt{B} = 692/\sqrt{659} \to 646/\sqrt{80}$

$$27.0 \to 72.2$$

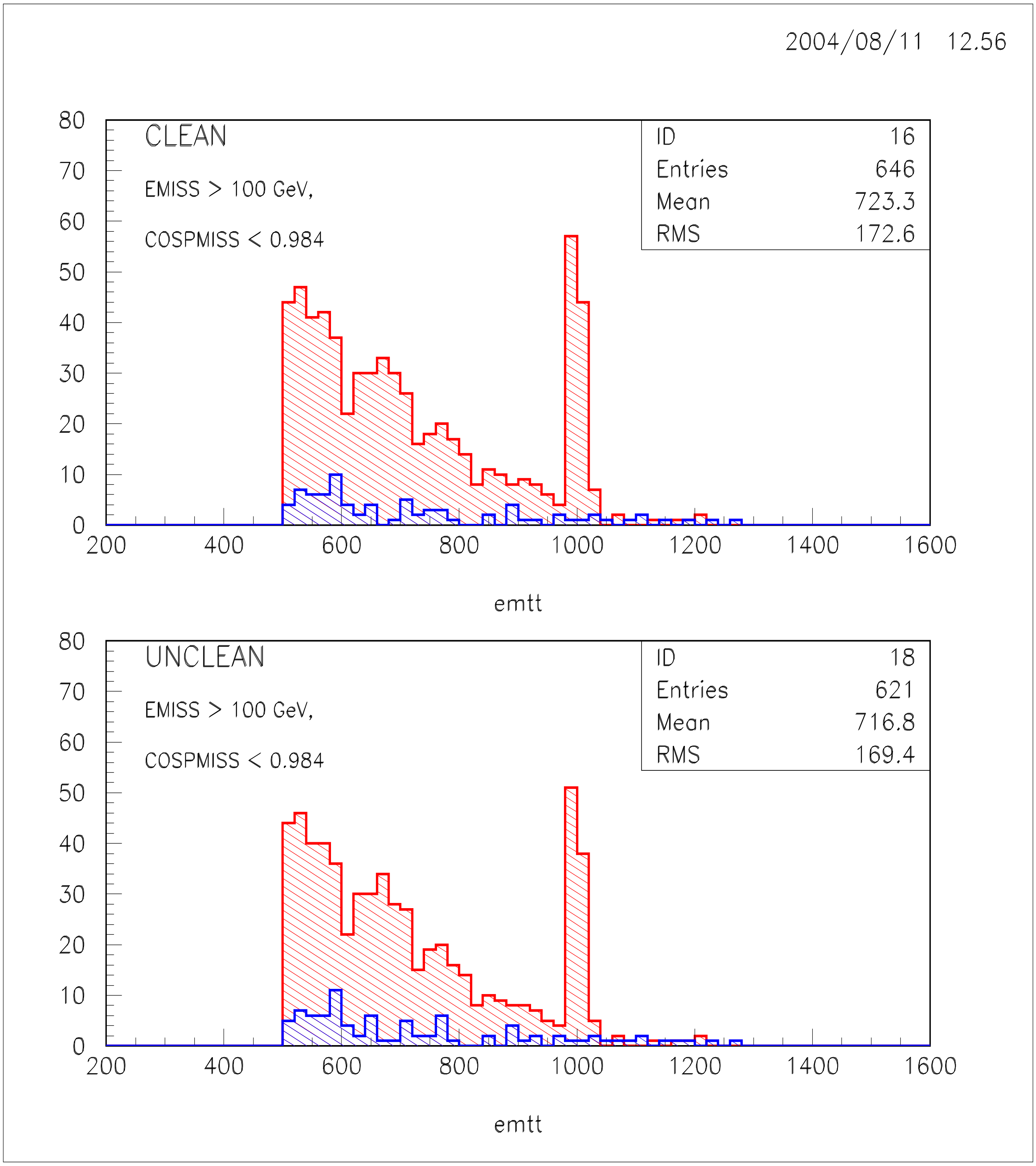
$m_{t\bar{t}}$ distributions at $\sqrt{s} = 1500$ GeV

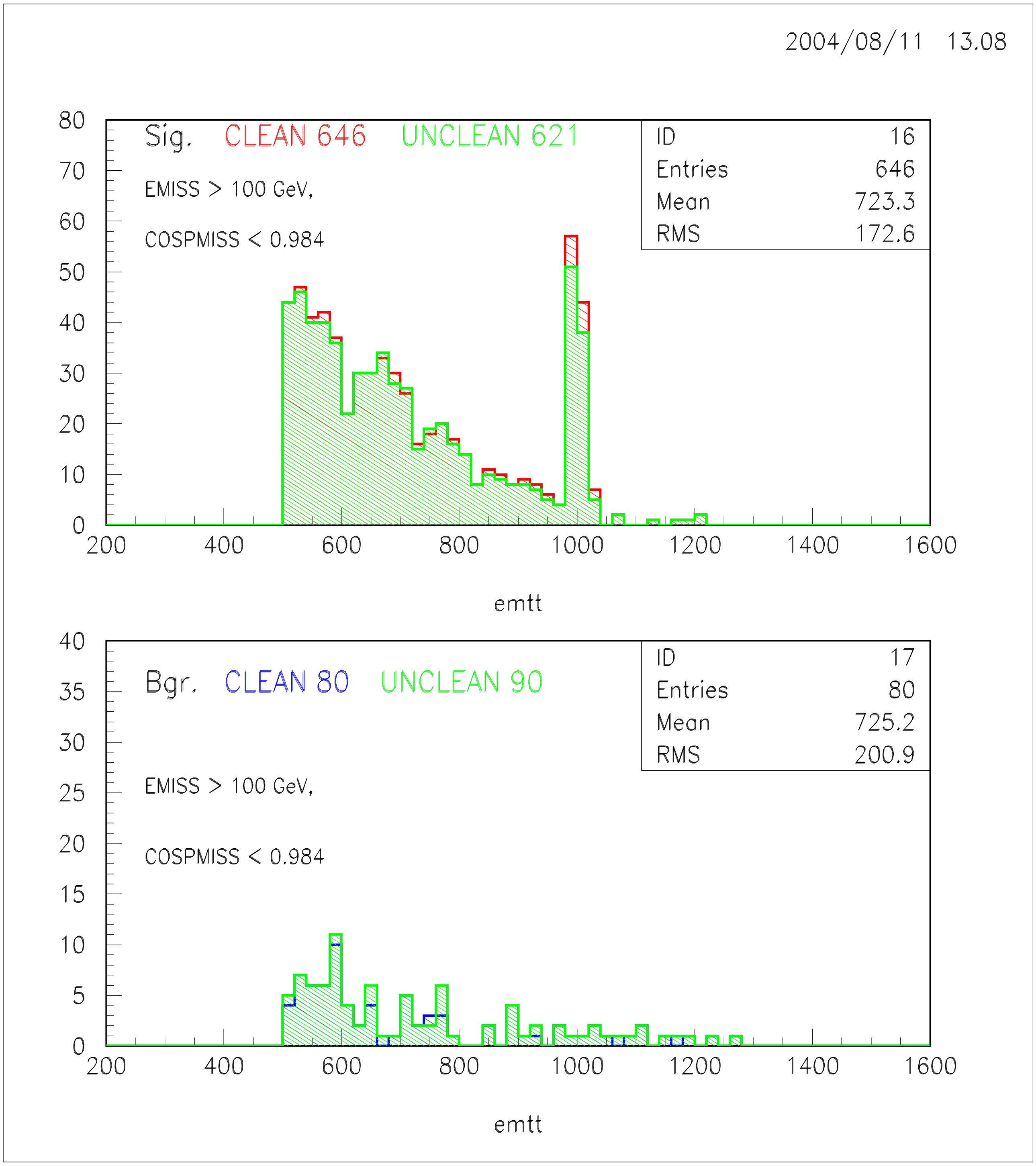
Fig. 3: Clean signal and clean ($\mathbf{1+85}$) background

Fig. 4,5: Clean vs unclean signal and background



2004/08/11 11.16
Cuts at $s^{1/2}$=1.5 TeV, M_ρ=1 TeV,Γ_ρ=10.1 GeV
Events/20GeV Signal Background
No cut
ID 2 Entries 2268 RMS
m_{tt} > 500 GeV
ID 4 Entries Mean RMS
p_T(tt) > 30 GeV
ID 6 Entries 1248 Mean RMS
M_{recoil} > 200 GeV
ID 8 Entries 1236 Mean 691.0 RMS 161.3
−0.8 < cos Θ < 0.8
ID 10 Entries 693 Mean 722.9 RMS 171.8
p_T(t) > 50 GeV
ID 12 Entries 692 Mean 723.2 RMS 171.8
ρ →
No central γ (E > 50 GeV)
ID 14 Entries 688 Mean 723.5 RMS 172.0
EMISS > 100 GeV,
COSPMISS < 0.984
ID 16 Entries 646 Mean 723.3 RMS 172.6
emtt (GeV)
emtt


2004/08/11 12.56
CLEAN
EMISS > 100 GeV,
COSPMISS < 0.984
ID 16
Entries 646
Mean 723.3
RMS 172.6
emtt
UNCLEAN
EMISS > 100 GeV,
COSPMISS < 0.984
ID 18
Entries 621
Mean 716.8
RMS 169.4
emtt


2004/08/11 13.08
Sig. CLEAN 646 UNCLEAN 621
EMISS > 100 GeV,
COSPMISS < 0.984
ID 16
Entries 646
Mean 723.3
RMS 172.6
emtt
Bgr. CLEAN 80 UNCLEAN 90
EMISS > 100 GeV,
COSPMISS < 0.984
ID 17
Entries 80
Mean 725.2
RMS 200.9
emtt

$\boxed{E_{miss} > 300 \text{ GeV}}$

- $\sigma(\mathbf{1+85}) = (99.57 + 5.29)$ fb $= 104.86$ fb

C: $\quad 97\ 732 \longrightarrow 659 \xrightarrow{E_\gamma} 204 \xrightarrow{E_{miss},\theta_{P_{miss}}} 78(80)$

- $\sigma(\mathbf{379}) = 2.475$ fb

C: $\quad 2\ 268 \longrightarrow 692 \xrightarrow{E_\gamma} 688 \xrightarrow{E_{miss},\theta_{P_{miss}}} 643(646)$

Tougher $|\cos(\theta_{P_{miss}})|$ cuts

$E_\gamma > 50$ GeV , $E_{miss} > 100$ GeV

$\lvert\cos(\theta_{P_{miss}})\rvert$	**379**	**1+85**	$\frac{S}{\sqrt{B}}$
0.984	646	80	72.2
0.99	667	94	68.8
0.98	638	75	73.7
0.97	604	64	75.5

$\boxed{\text{No central } e^-, e^+ \text{ cut}}$

I tried this cut on **85** after all previous cuts, however, it did not change anything:

$E_\gamma > 50$ GeV
$E_{miss} > 100$ GeV, $|\cos(\theta_{P_{miss}})| < 0.984$

- $\sigma(\mathbf{85}) = 5.29$ fb

$$4\ 887 \longrightarrow 133 \xrightarrow{E_\gamma} 122 \xrightarrow{E_{miss},\theta_{P_{miss}}} 44 \xrightarrow{\text{no } e^-, e^+} 44$$

Detector angle $\cos\theta = 0.9848 \to 0.99$

All previous work assumed detector angle $\cos\theta = 0.9848$ (about 10 degrees). We change it now to $\cos\theta = 0.99$ (about 8 degrees)

We assume the same standard cuts plus no central photon with $E_\gamma > 50$ GeV plus $E_{miss} > 100$ GeV and $|\cos(\theta_{P_{miss}})| < 0.9848$

- $\sigma(\mathbf{1+85}) = (99.57 + 5.29)$ fb $= 104.86$ fb

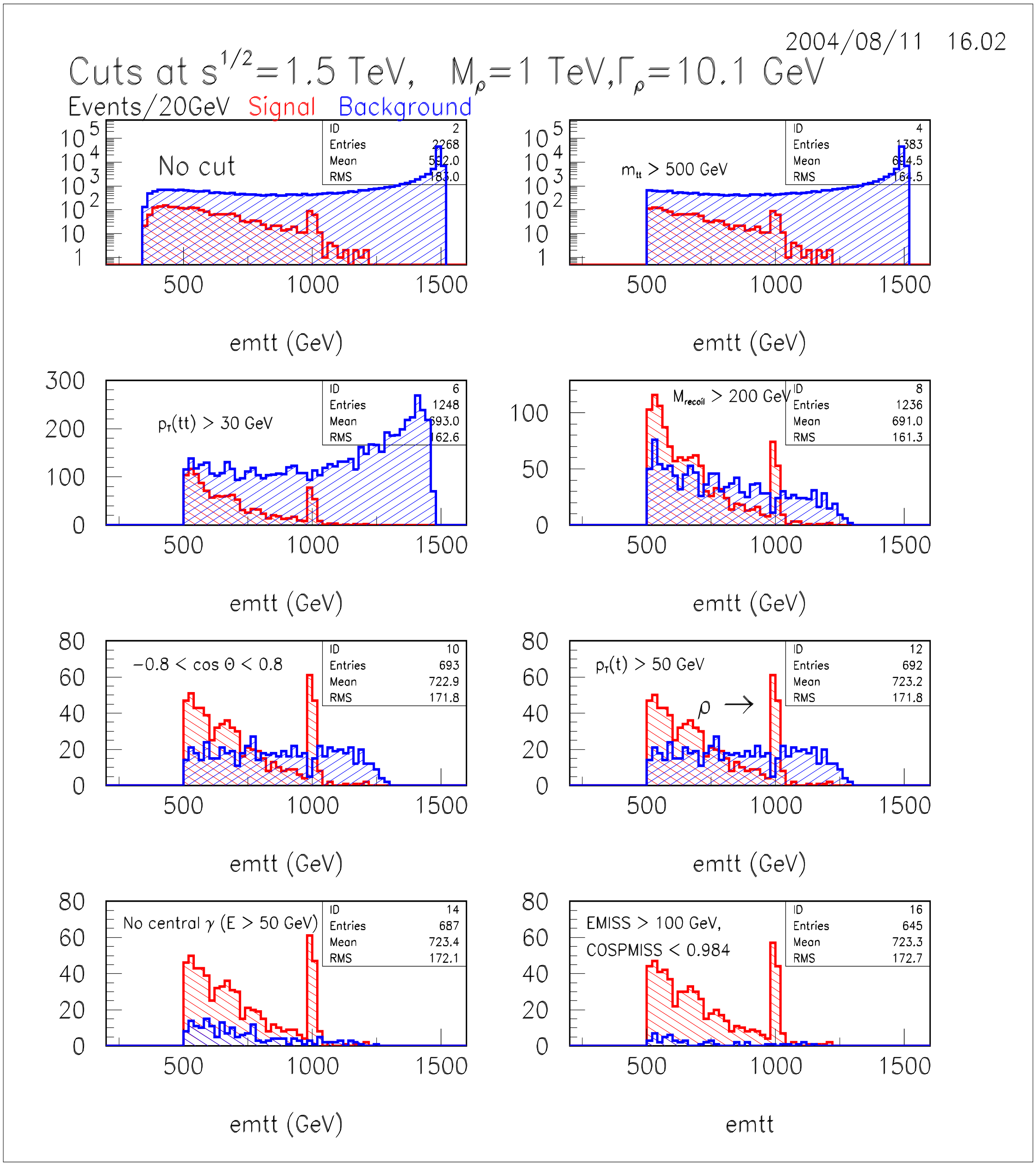
C: $\quad 97\,732 \longrightarrow 659 \xrightarrow{E_\gamma} 188 \xrightarrow{E_{miss},\theta_{P_{miss}}} 50(80)$

- $\sigma(\mathbf{379}) = 2.475$ fb

C: $\quad 2\,268 \longrightarrow 692 \xrightarrow{E_\gamma} 687 \xrightarrow{E_{miss},\theta_{P_{miss}}} 645(646)$

$$\frac{S}{\sqrt{B}} = 91.2\ (72.2)$$

Fig.6: Signal and Background


2004/08/11 16.02
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 →
No central γ (E > 50 GeV)
EMISS > 100 GeV,
COSPMISS < 0.984
emtt (GeV)
emtt