Search for $e^+ \; e^- \rightarrow \boldsymbol{\mu}^{\pm}\boldsymbol{\tau}^{\mp}$

in BaBar

Gian Gopal
(RAL)
21st October 2002

LFV - $e^+ \ e^- \rightarrow \mu^\pm \tau^\mp$

- $\tau^\pm \rightarrow \mu^\pm \gamma$ **Predicted in most extensions to the SM**. Hence $e^+ \ e^- \rightarrow \mu^\pm \tau^\mp$ must occur.
- **Rate may be lower/higher than the decay process - Model Dependent**

(Bordes, Chan & Tsou - hep-ph/0103205)

From rotation of the Lepton Mass Matrix with $\sqrt{s}$ kinematics alone predicts:

$\tau^\pm \rightarrow \mu^\pm \gamma$ Decay Rate is **Zero** !

whereas **Production** rate at $\sqrt{s} = 10.58$ has X-Section $\approx$ 80 fb.

With $80 fb^{-1}$ data $\Rightarrow$ 6400 events !

Event Pre-Selection - 1

Filtering

- an L3 Tag - either DCH/EMC
- ≥ 1 muon/electron "Loose"
- $2 \leq$ nGoodTrkLoose < 5

Selection/Cleaning

- Accept event if $n_\gamma = 0$ - with $E_\gamma > 0.10$ & Lateral shower spread consistent
- Look for Converted photons:

  Accept event if $n_\gamma^{conv} = 0$

  n_γ^{conv} is number of opp. charged track pairs with combined mass $< 0.15\ GeV/c^2$

Remove $\tau^\pm \to \pi^o X^\pm$ decays.

Event Pre-Selection - 2

Selection/Cleaning - contd.

- Charged tracks accepted if:
  - $\delta p < p$
  - $28^o \leq \cos\Theta < 145.5^O$ (DCH Acceptance)
  - xy-Impact Parameter $d_0^{xy} < 1.0$, and
  - z-Impact Parameter $d_0^z < 5.0$.
- Accept Event if $n_{ChgTrk} \geq 2$
- Perform PID on charged tracks with p $> 1\ GeV/c^2$
  - Muons: "loose"
  - Electrons: "vTight"
  - all others accepted as $\pi^{\pm}$
- BhaBhas & DiMuon Events with $n_{ChgTrk} = 2$
  removed if tracks are back-to-back
  i.e. $|\cos\Theta_{xy}| < 0.9975$

Event Pre-Selection - 3

Each selected event ($\geq$ 1 identified lepton), determine following C.o.M. Variables:

- Missing (against observed Charged particles) 4-Vector.
- For each identified Lepton in the event
  - the Mass Recoiling (M_{Rec}) against the Lepton
  - the Energy difference
    $\delta E = \frac{M_{lepton}^2 - M_\tau^2}{2\sqrt{s}} = (E^*_{lepton} - E^*_{beam})$
    For $\mu^\pm \tau^\mp$ candidates $\delta E =$ -0.150.
  - the Energy Constrained Recoil Mass
    $M_{ES} = \sqrt{E^{*2}_{Beam} - 2E^*_{Beam}\delta E + \delta E^2 - p^{*2}_\mu}$
    NB: δE and M_{ES} not independent variables but maybe useful for looking at a possible signal ($\sigma M_{ES} < \sigma M_{Rec}$)

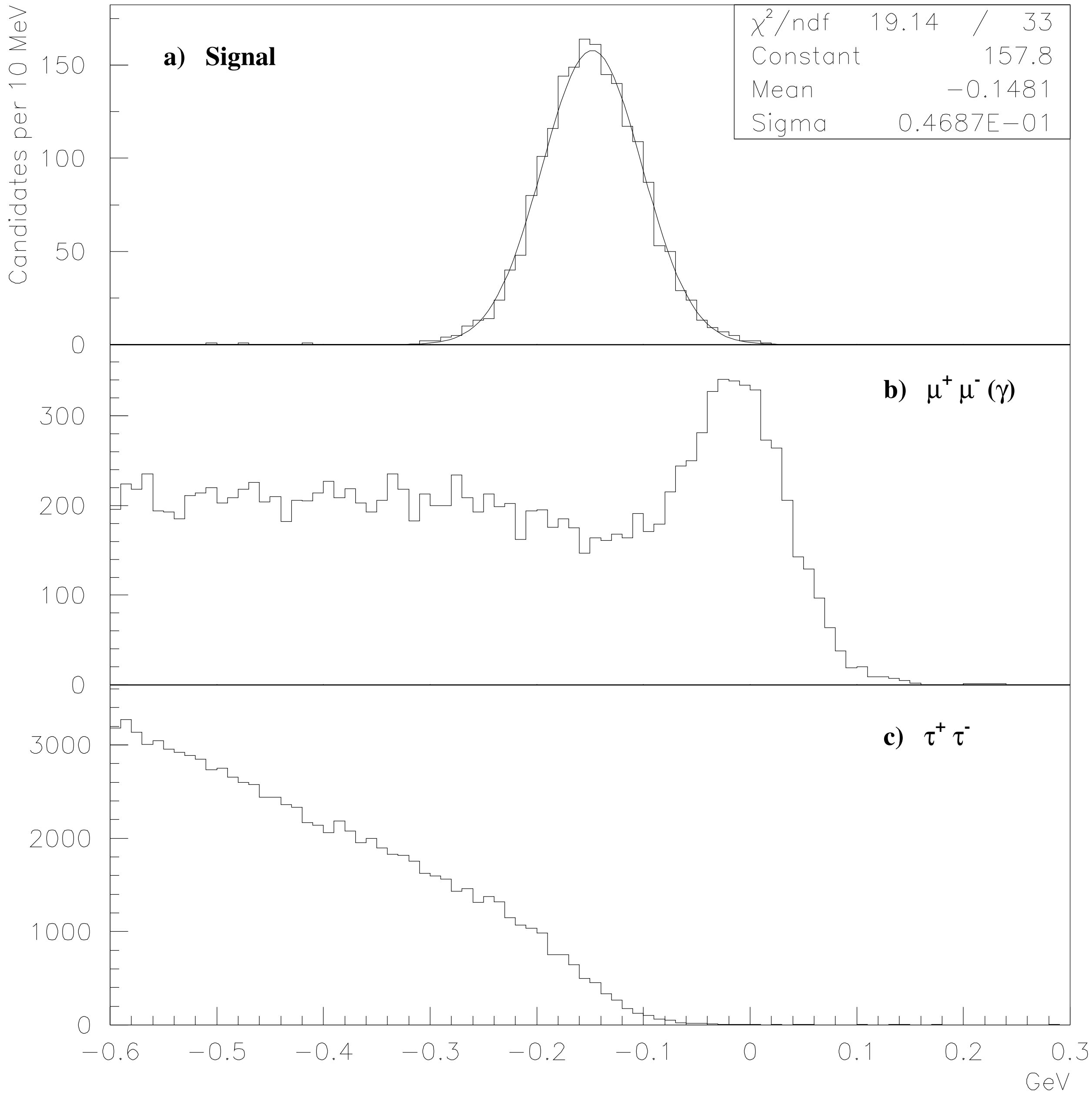
An event with an identified muon accepted as possible Candidate

if $\quad -0.6 \leq \delta E < 0.30$

$\varepsilon = 37.6\%$

Event Pre-Selection - 3

MC ΔE distributions:



Data Samples Analysed

- MC: Signal, $e^+e^-(\gamma)$, $\mu^+\mu^-(\gamma)$, $\tau^+\tau^-$and Hadronics (equal samples of each quark flavor pair).
- Data: Run 1 (1999-2000 - 19.26 fb^{-1}) & (2001-2002 - 57.60 fb^{-1})

Event Samples Analysed

Event Sample	Total	Pre-Selected
Generic τ decay Signal	5000	1881
Hadronics	1.8598 $\times 10^8$	1030
$e^\pm e^\mp(\gamma)$	3.3349 $\times 10^6$	67955
$\mu^+\mu^-\gamma$	3.5650 $\times 10^6$	30188
$\tau^+\tau^-$	9.5099 $\times 10^7$	1.2426 $\times 10^5$
Data	1.1125 $\times 10^9$	1.4055 $\times 10^6$

No candidates from $e^\pm e^\mp(\gamma)$ for $\mu^\pm\tau^\mp$

Pre-Selection Efficiencies

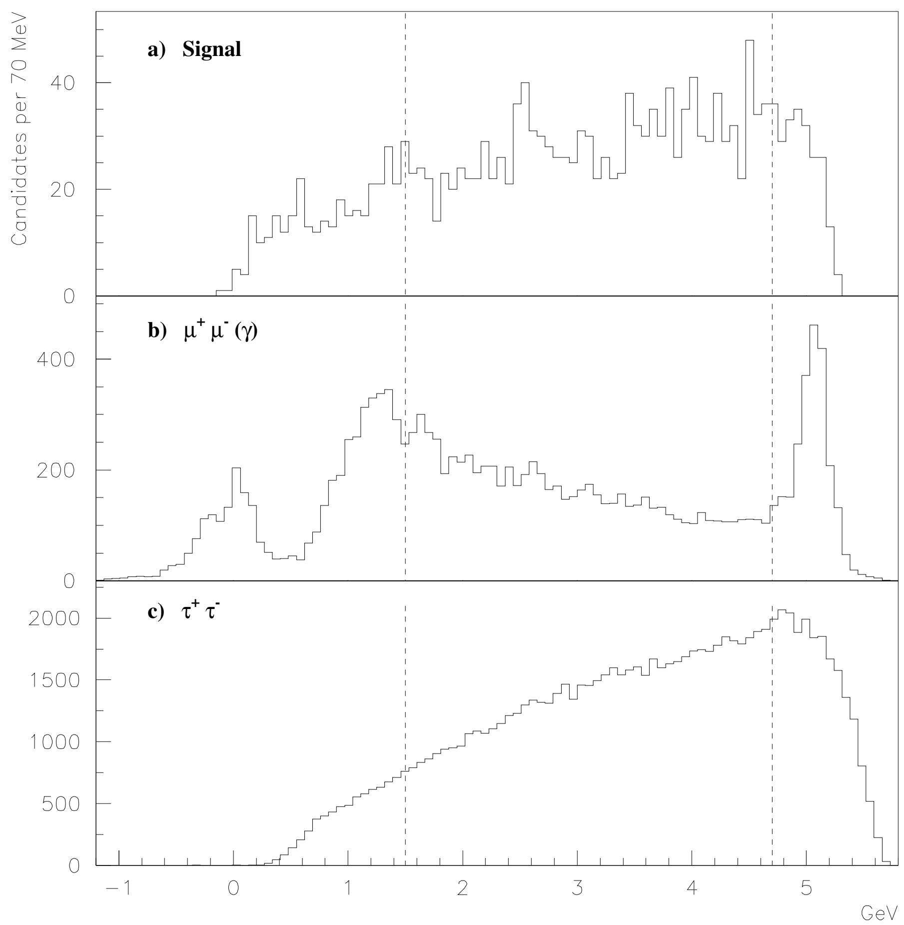
Cut	Efficiency				
	Signal	$\mu^+\mu^-(\gamma)$	$\tau^+\tau^-$	Hadronics	Data
Tag Filter	0.71	0.79	0.47	8.54×10^{-2}	0.36
$N_\gamma = 0$	0.83	0.84	0.30	1.24×10^{-2}	0.35
$\geq 1\mu/e$	0.91	0.97	0.77	0.36	0.70
Tk. Fid.	0.85	0.75	0.88	0.88	0.75
Acollinear	0.86	3.27×10^{-2}	0.92	0.98	0.30
ΔE	0.96	0.47	1.53×10^{-2}	1.69×10^{-2}	6.13×10^{-2}
Culmulative	0.376	7.31×10^{-3}	1.31×10^{-3}	5.54×10^{-6}	1.26×10^{-3}

Candidate Selection - 1

Possible Bckgd. & Signal discriminating Variables are:

- Event Missing Energy (ME),
- Missing-Mass-Squared. (MMSq) and
- Cosine of the angle between the muon & recoiling-all-charged system in the lateral plane ($Cos\Theta_{XY}$)

MC Missing Energy Distributions:



Candidate Selection - 2

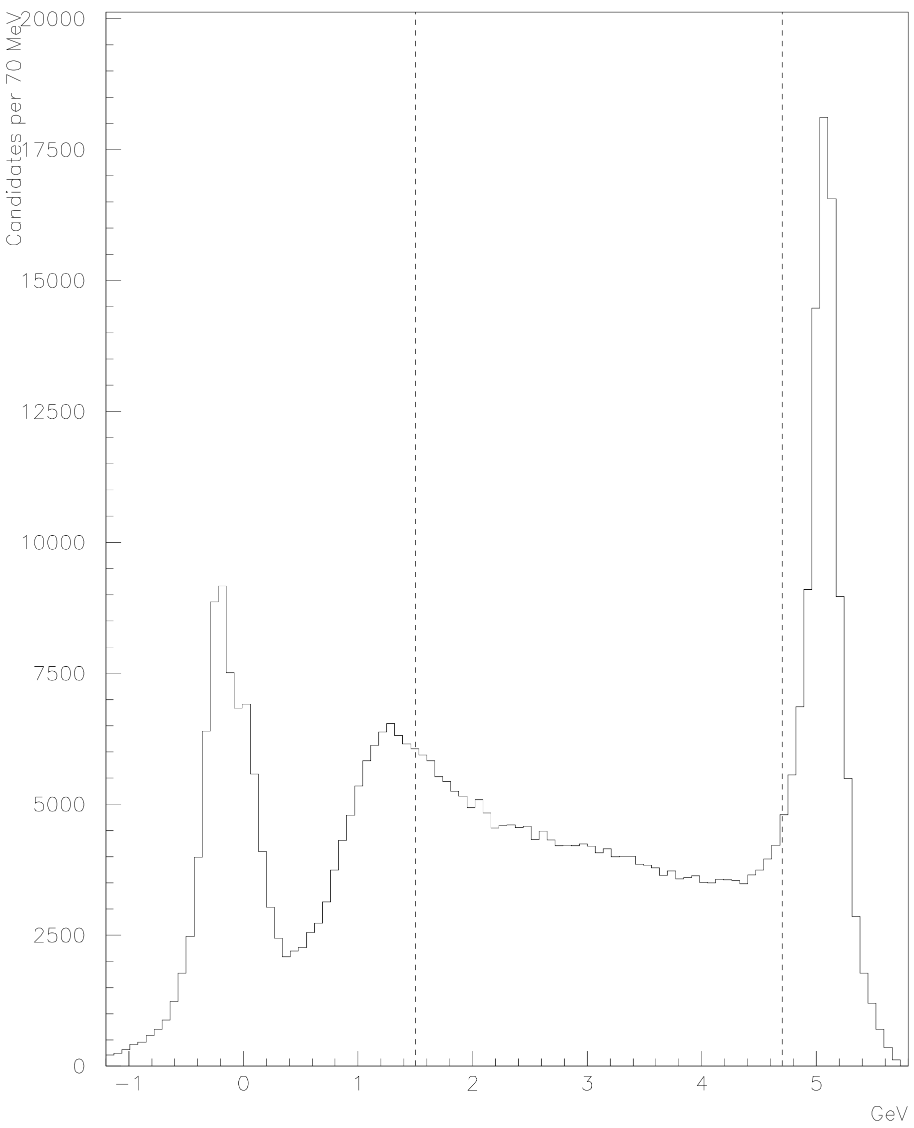
Signal/Background optimum for $1.5 <$ME < 4.7 Gev.

$\varepsilon = 26.3 \pm 0.7\%$

Backgd. reduction factors:

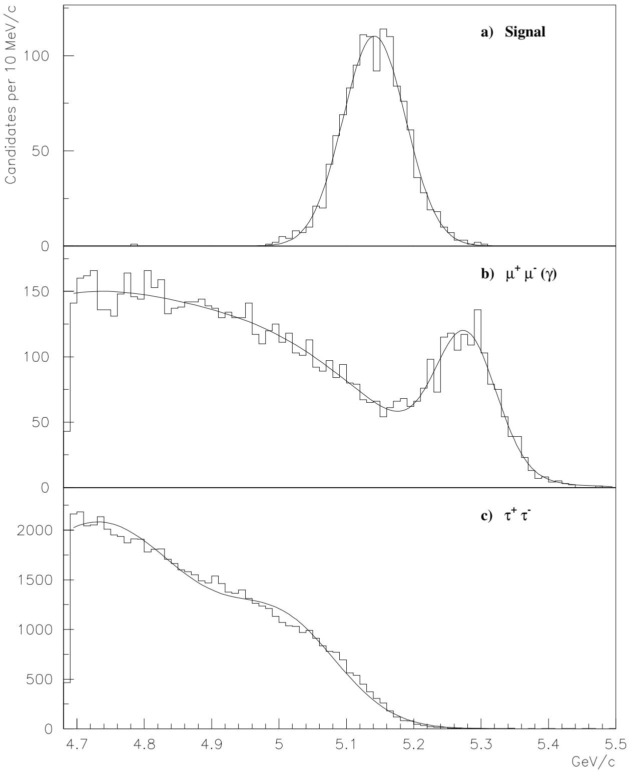
- $\mu^+\mu^-(\gamma)$ = 0.72 and
- $\tau^+\tau^-$ = 0.48

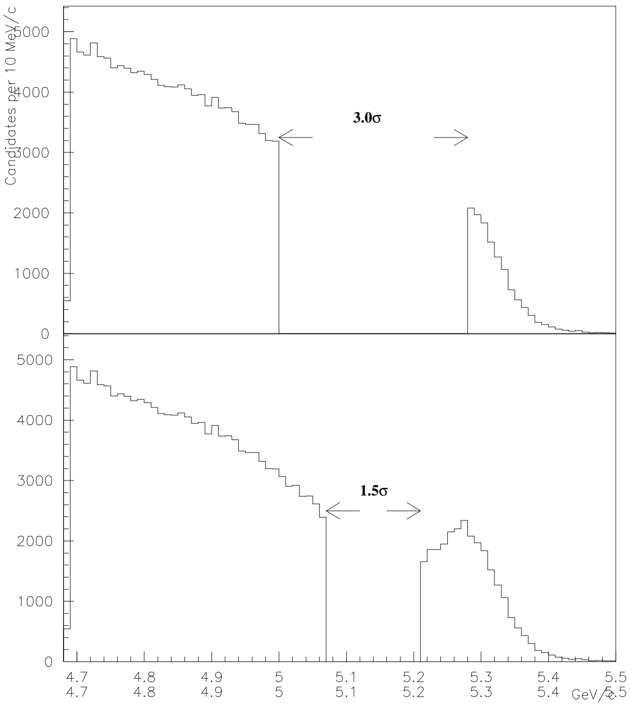
Data = 0.56



Candidate Selection - 3

C.o.M. muon Momentum distributions:





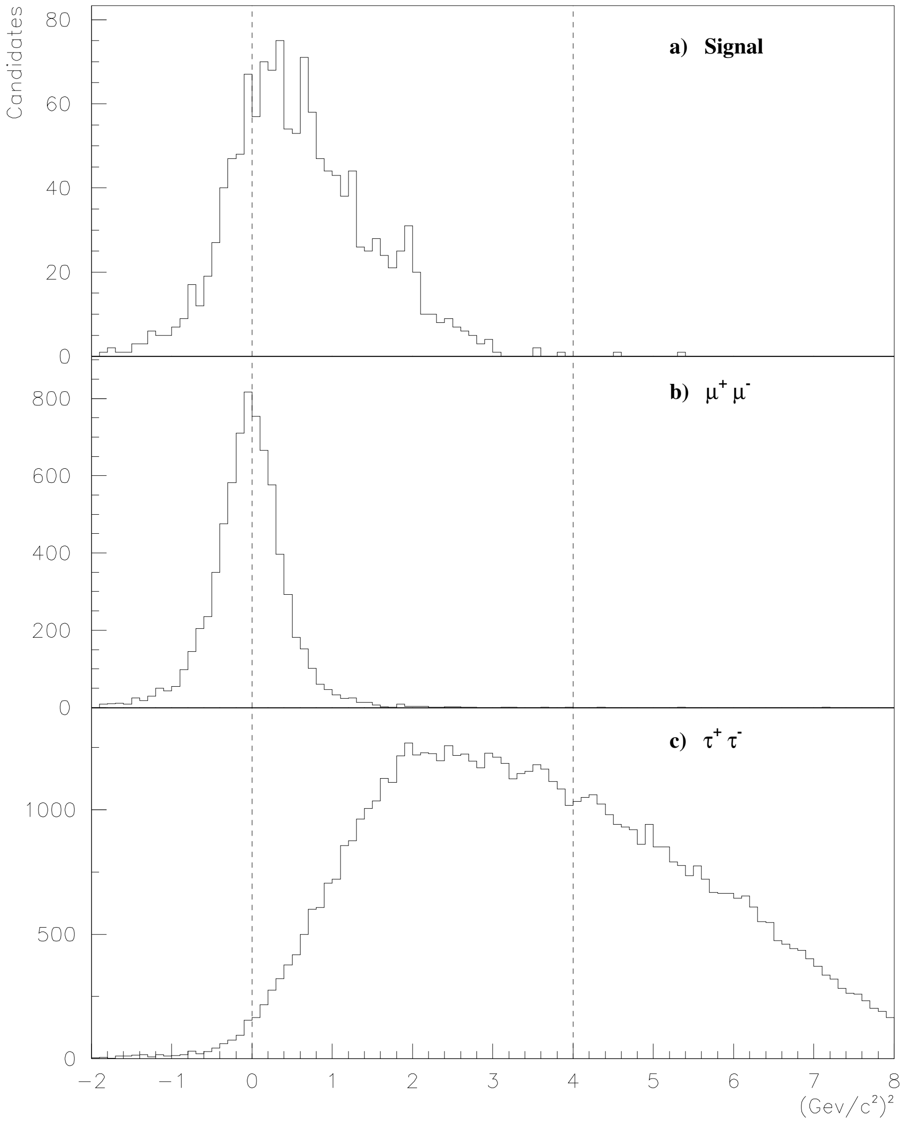
Candidate Selection - 4

Another factor 2 reduction

in $\mu^+\mu^-(\gamma)$ and $\tau^+\tau^-$ bkgds. with

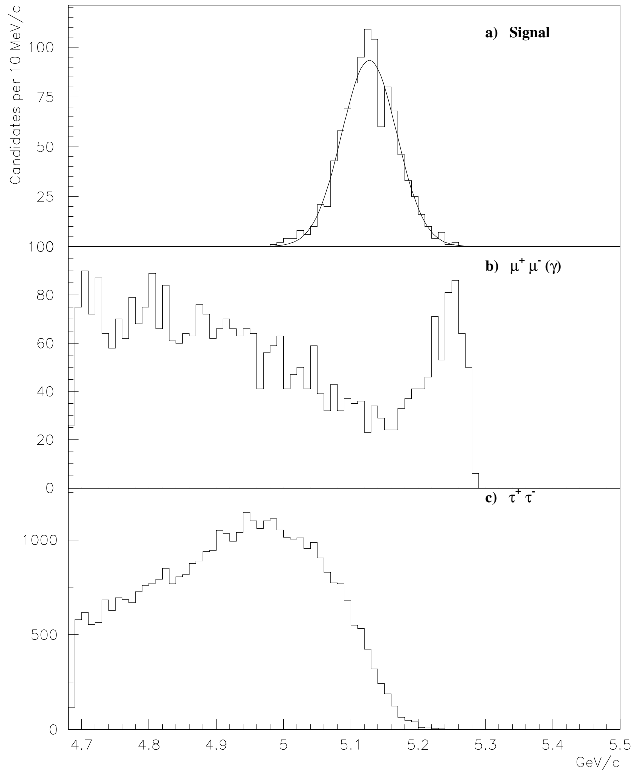
$0.0 <$ MMSq $< 4.0 (GeV/c^2)^2$

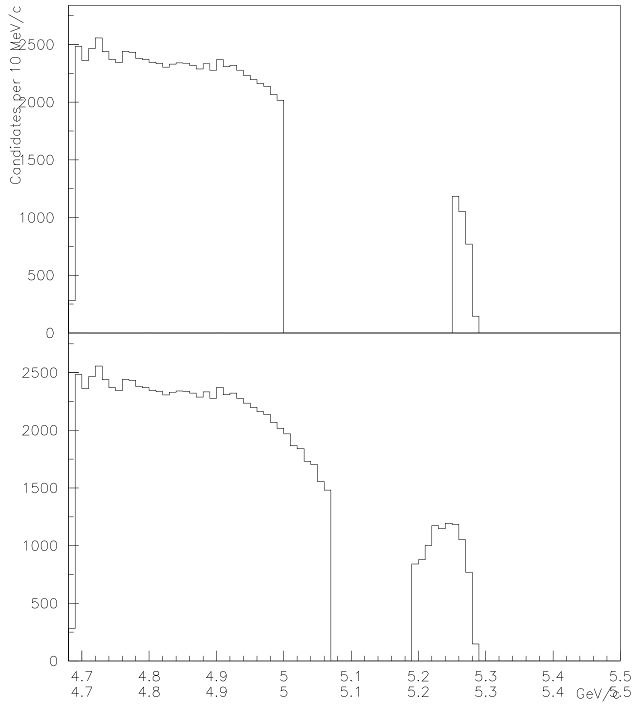
MC Missing-Mass-Squared Distributions:



Candidate Selection - 5

BUT P_μ^* distribution distorted !

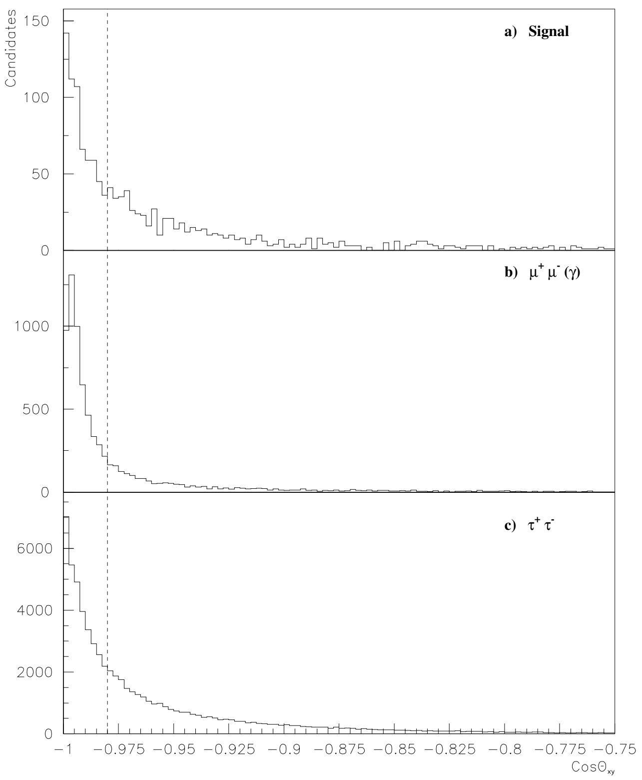




Candidate Selection - 6

Better Descrimination with $Cos\Theta_{XY}$ - Cosine of the angle between the muon & recoiling-all-charged system in the lateral plane.

$\mid Cos\Theta_{XY} \mid < 0.98$



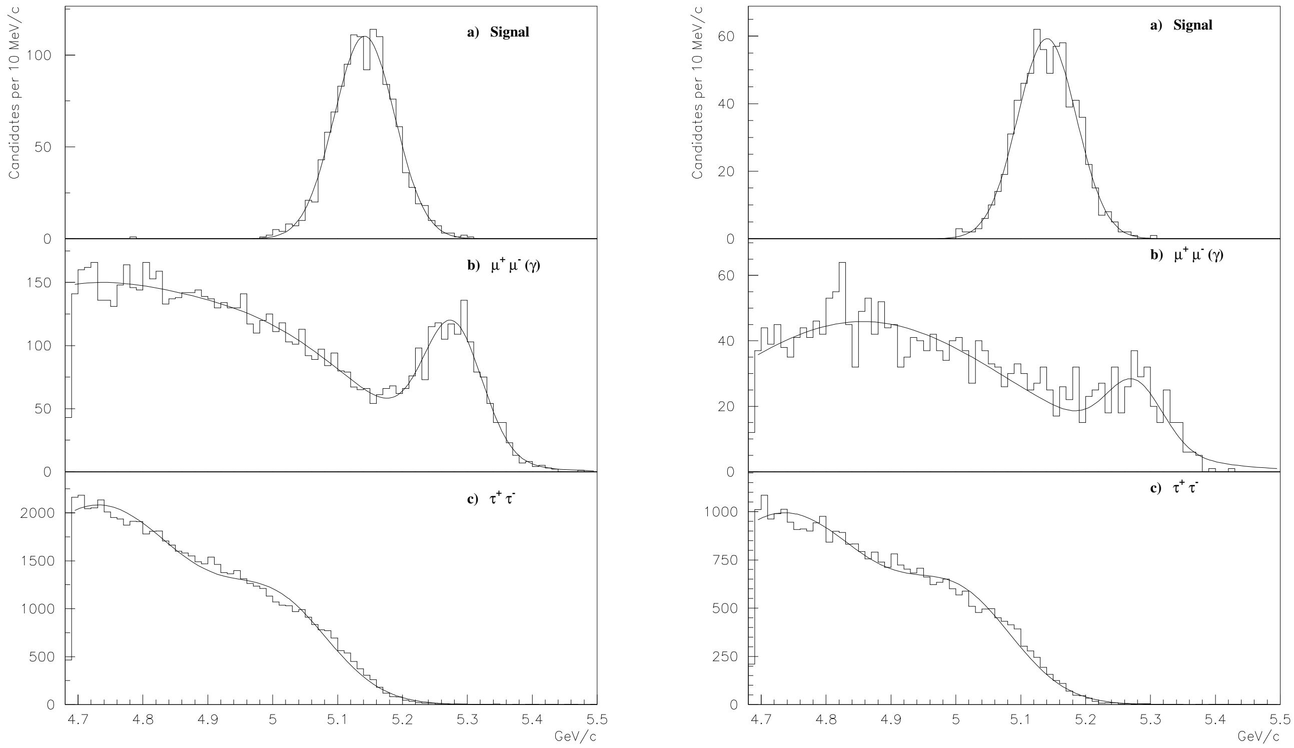
MC Event Samples Analysed

Event Sample	$1.5 <$ ME $\leq 4.5 GeV$	$\mid \cos\theta_{XY} \mid < 0.98$
Signal	1,313	685
$\mu^+\mu^-\gamma$	4,645	2,299
$\tau^+\tau^-$	64,620	32,222

Candidate Selection - 7

P^*_μ distributions:

ME Cut only | ME + $Cos\Theta_{XY}$ Cut



$\varepsilon = 13.7 \pm 0.5\%$

Backgd. reduction factors:

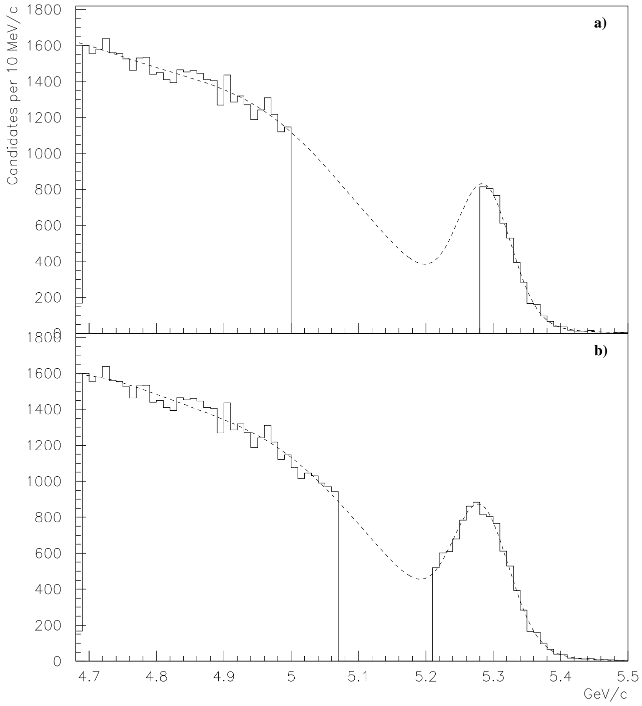
- $\mu^+\mu^-(\gamma)$ = 0.49 and
- $\tau^+\tau^-$ = 0.50

Data = 0.35

Result:

BaBar enforced BLINDNESS !

Data P_μ^* distribution:



PDF 3-Gaussians centred at ≈ 5.3, ≈ 5.0 and $\approx\ 4.7\ GeV/c^2$

Data Candidates Fit Results

Cut	No. in Fit	No Pred. in Cut	Total	Prob. (%)
$\pm 3.0\sigma$	48,721	19,078 $\pm$ 705	67,799	11.8
$\pm 2.5\sigma$	54,388	13,782 $\pm$ 475	68,170	14.3
$\pm 2.0\sigma$	57,697	10,991 $\pm$ 322	68,688	14.5
$\pm 1.5\sigma$	60,732	8,663 $\pm$ 240	69,395	7.3

Result - 2

- $\pm 1.5\sigma$ Cut $\Rightarrow$ 90% signal removed !
- Error on # of candidates predicted in Signal region $\pm$ 240
- Signal Efficiency $\varepsilon = 13.7 \pm 0.5\%$
- Luminosity $76.86 fb^{-1}$

$\Rightarrow$ 95% CL Upper Limit for

$e^+e^- \rightarrow \mu^\pm\tau^\mp$ X-Section $=$ 50.6 $\pm$ 1.8 fb. at $\sqrt{s} = 10.58 GeV$

OR $\frac{\sigma(e^+e^- \rightarrow \mu^\pm\tau^\mp)}{\sigma(e^+e^- \rightarrow All)} < 1.34 \pm 0.05 \times 10^{-6}$ at 95% CL.

Pseudo unblinded Result:

Fill cut region with predicted values and fit with additional gaussian for Signal with

$<>= 5.1405\ GeV/c$ and $\sigma = 45.4 MeV/c$

101 $\pm$ 62 'events' for Signal

$\Rightarrow$ 95% CL Upper Limit of 47 fb^{-1}

Conclusions

While still BLIND using

- the P^*_μ distribution from candidates selected from $76.86 fb^{-1}$ of data and
- the Selection Efficiency from the Signal MC

$e^+e^- \rightarrow \mu^\pm\tau^\mp$ X-Section at $\sqrt{s} = 10.58\ GeV$
$< 50.6 \pm 1.8 fb$ at 95% CL.

cf - 80 fb predicted by Bordes, Chan & Tsou
hep-ph/0103205

- based on simple kinematic effects of the rotation of the mass matrix with $\sqrt{s}$

$\Rightarrow$

a) Wrong Rotation Speed ?

b) Other re-normalisation effects ?

Both ?

Br. Fraction limit of $< 1.34 \pm 0.05 \times 10^{-6}$ at
$\sqrt{s} = 10.58 GeV$

cf - Br. Fr.$(Z^o \rightarrow \mu^\pm\tau^\mp) < 1.2 \times 10^{-5}$ from DELPHI

expect a small improvement in Limit when allowed to UNBLIND