

# Search for $\tau \rightarrow \mu\gamma$ at *BABAR*

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***BABAR* Collaboration**

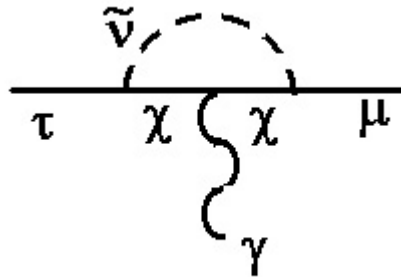
**XXXI International Conference on High Energy Physics**

**Amsterdam 2002**

**In standard model, extended to include  $\nu$  mixing  
mixing and mass,  $\text{BR}(\tau \rightarrow \mu\gamma) \sim \mathcal{O}(10^{-34})$**

**But lepton number is violated in many  
extensions to the standard model**

**e.g.**



**Current 90%CL limits on  $\text{BR}(\tau \rightarrow \mu\gamma)$**

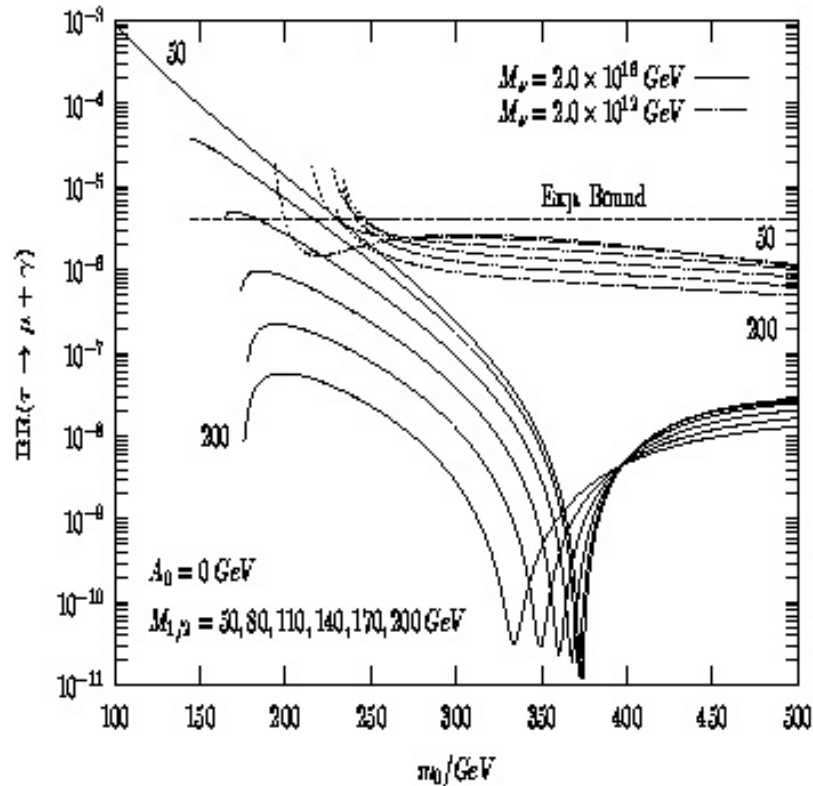
**$1.1 \times 10^{-6}$  @90%CL (CLEO on 13.8/fb, 1999)**

**$1 \times 10^{-6}$  @90%CL (Belle, unpublished 21.3/fb, 2001)**

Predictions reach as high as  $10^{-6}$  even in light of  $\text{BR}(\mu \rightarrow e\gamma) < 1.2 \times 10^{-11}$  @90%CL (MEGA 1999)

$\text{BR}(\tau \rightarrow \mu\gamma)$

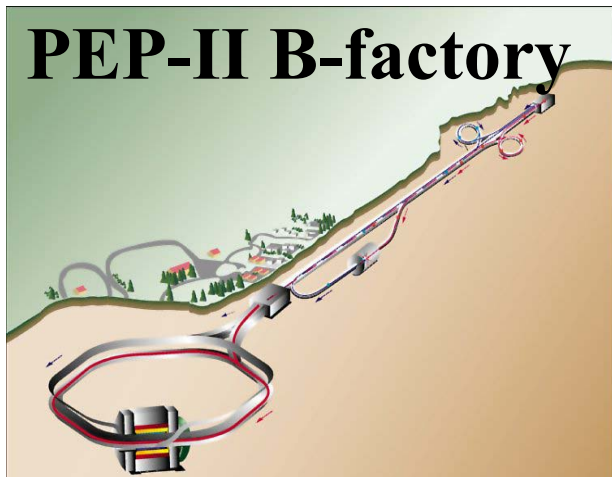
$10^{-6} \rightarrow$



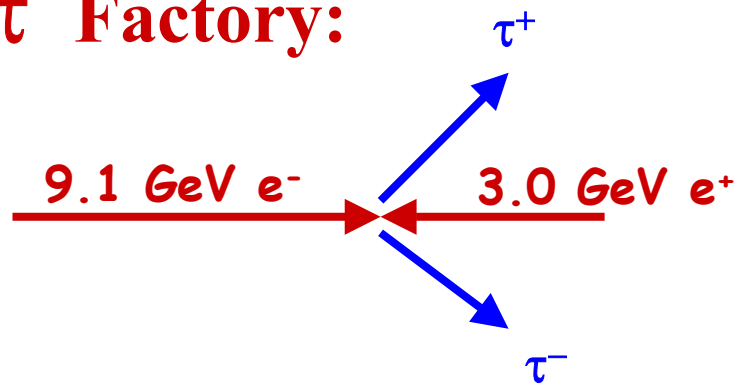
$m_0$  parameter in a string-inspired model

**Figure 16.** Branch ratio for  $\tau \rightarrow \mu + \gamma$  for a range of  $m_0 < 500$  GeV and several values of  $M_{1/2} < 200$  GeV. Two extremes values of  $M_\nu$  are displayed : solid lines correspond to  $M_\nu = M_{GUT}$ , while dotted lines to  $M_\nu = 2 \times 10^{12}$  GeV.

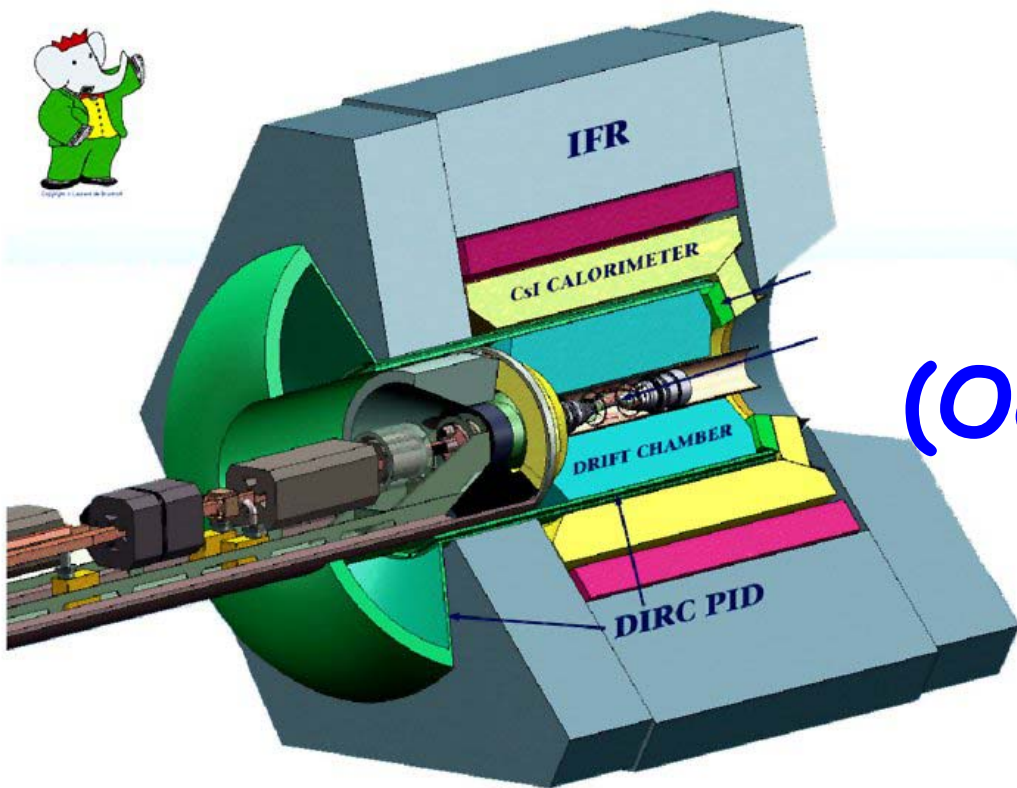
# PEP-II B-factory



is also a  $\tau$  Factory:



Peak Luminosity  $4.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$



## Data Set

$56 \times 10^6 \tau^+ \tau^-$   
(Oct. 99 - Dec. 01)

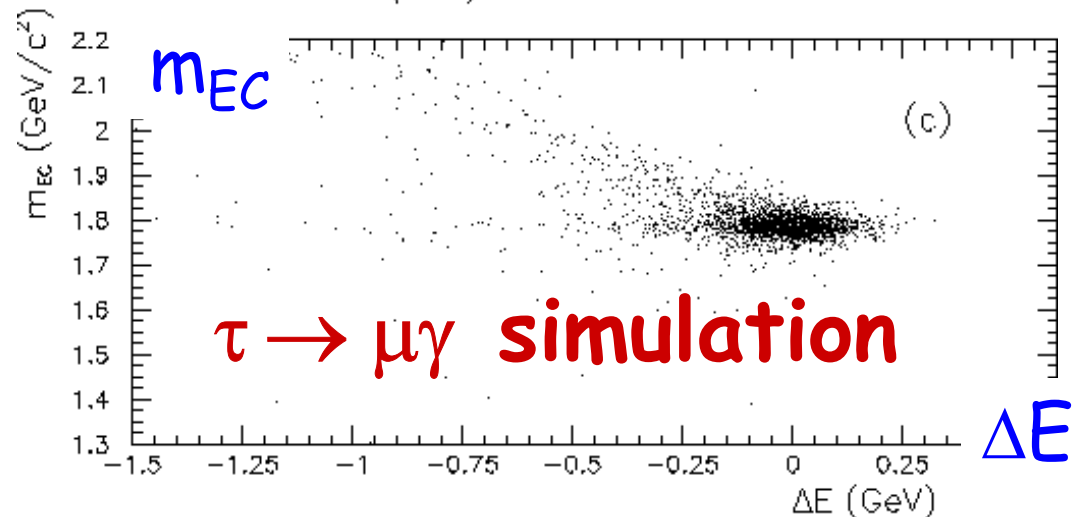
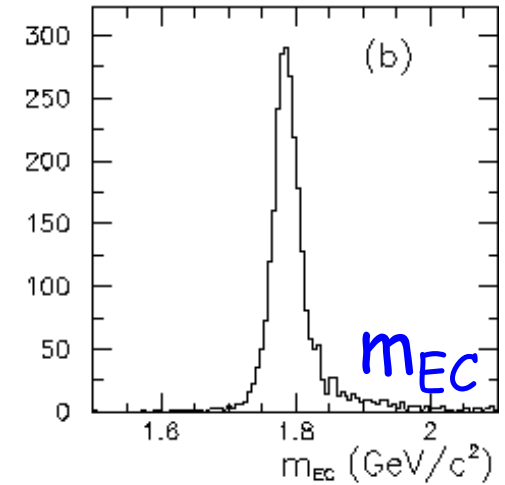
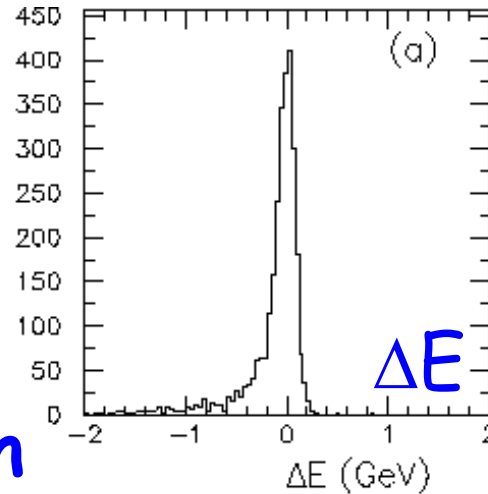
on  $\Upsilon(4S)$ :  $56.4 \text{ fb}^{-1}$

off  $6.4 \text{ fb}^{-1}$

# Signal: mass of $\tau$ and beam energy

beam-energy  
constrained mass:  $m_{EC}$

$\Delta E = E_{\mu\gamma} - E_{beam} \sim 0$   
in absence of radiation



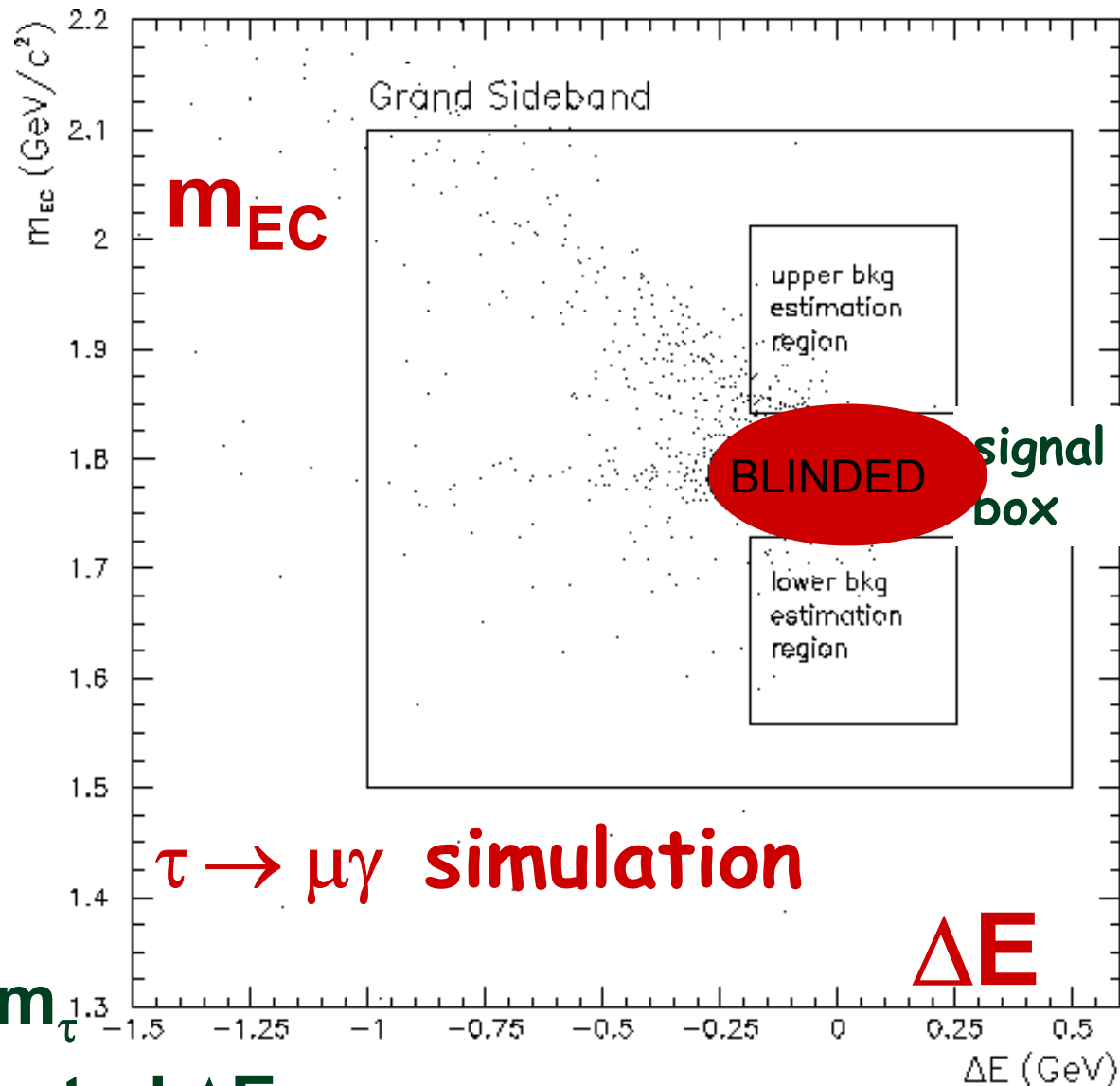
$m_{EC}$  resolution:  $19 \text{ MeV}/c^2$   
 $\Delta E$  resolution :  $88 \text{ MeV}$

# Selection:

Blinding box:  
hide data  
within  $\pm 3\sigma$  of  
expected  
 $\Delta E$  and  $m_{\tau}$

Signal box:

$\pm 3\sigma$  of expected  $m_{\tau}$   
 $-2\sigma \rightarrow + 3\sigma$  of expected  $\Delta E$



# Selection:

$$\tau_{\text{signal}} \rightarrow \mu\gamma$$

$$\tau_{\text{tag}} \rightarrow e\nu\nu \quad (\text{BR}=18\%)$$

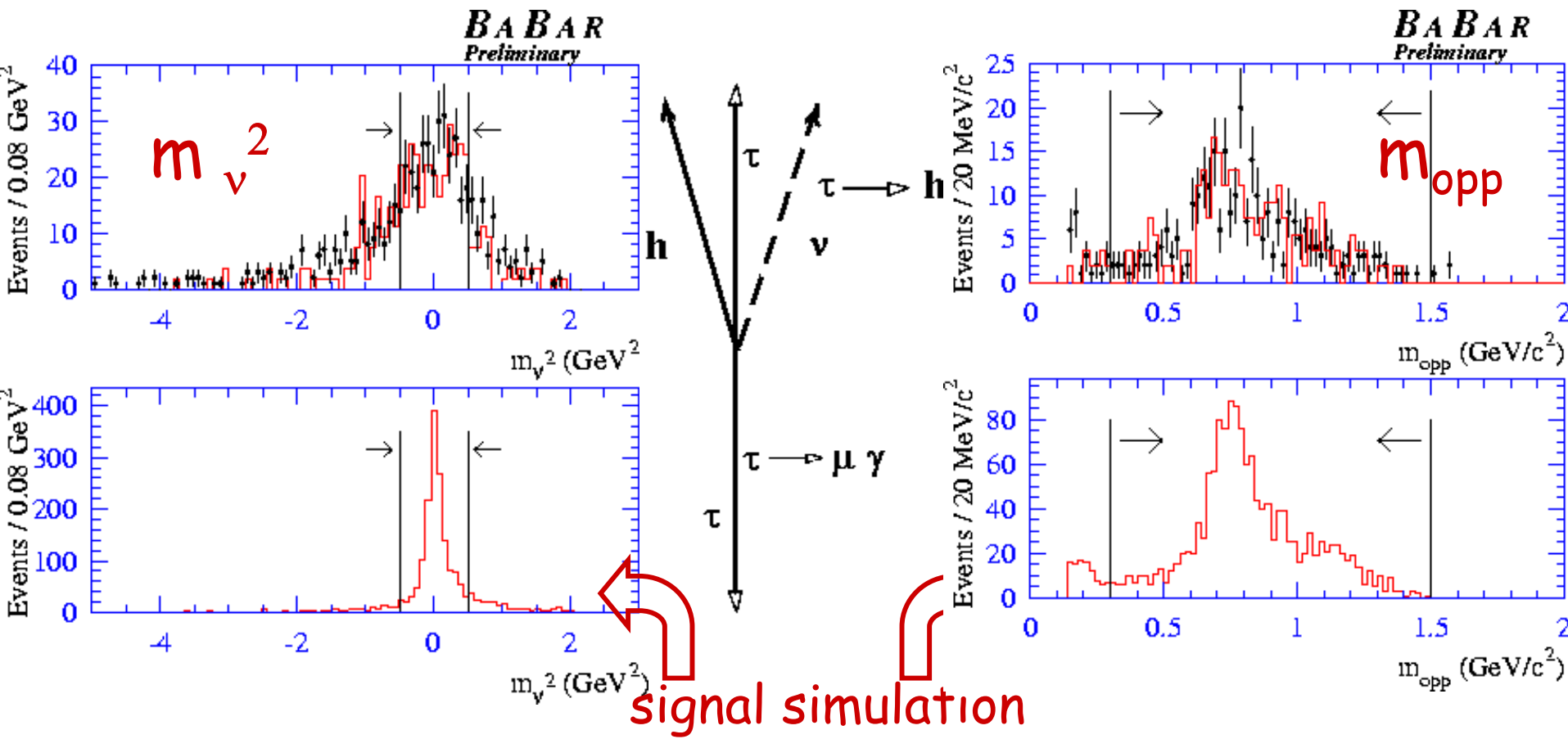
$$\tau_{\text{tag}} \rightarrow h \geq 1 \pi^0 \nu \quad (\text{BR}=37\%)$$

Also Require: visible energy on tagging side  $< 0.8 E_{\text{beam}}$  in CMS

- muon ID:
  - low calorimeter energy
  - track matched into IFR
  - IFR signature for muon
- 1 calorimeter cluster:
  - above 400MeV
- electron ID
  - E/p, dE/dx, DIRC, cal.
- multi-hadron decay
  - mass in tagging hemisphere
  - not a muon, using IFR and calorimeter
  - $|m_{\nu}^2| < 0.5 \text{ GeV}^2$

# Selection in Grand Side Band:

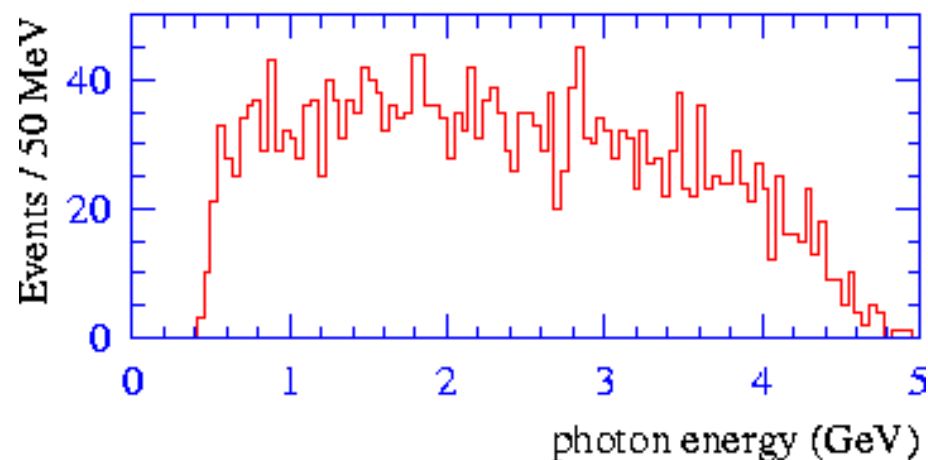
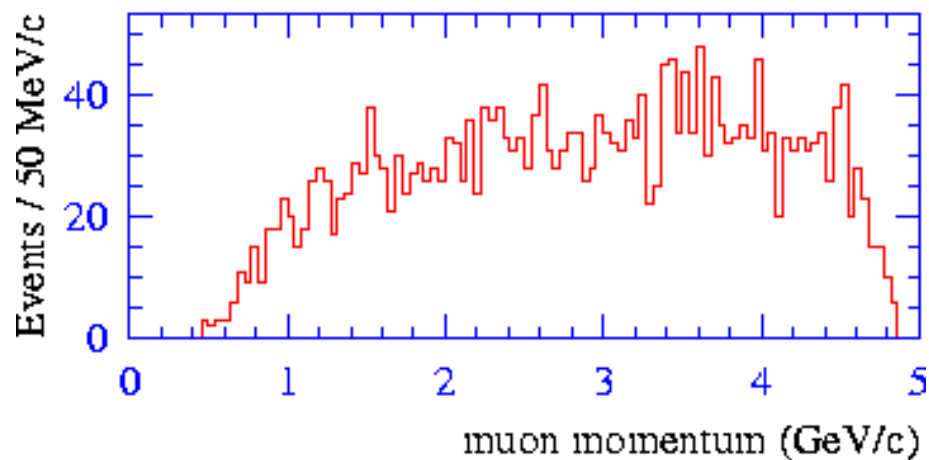
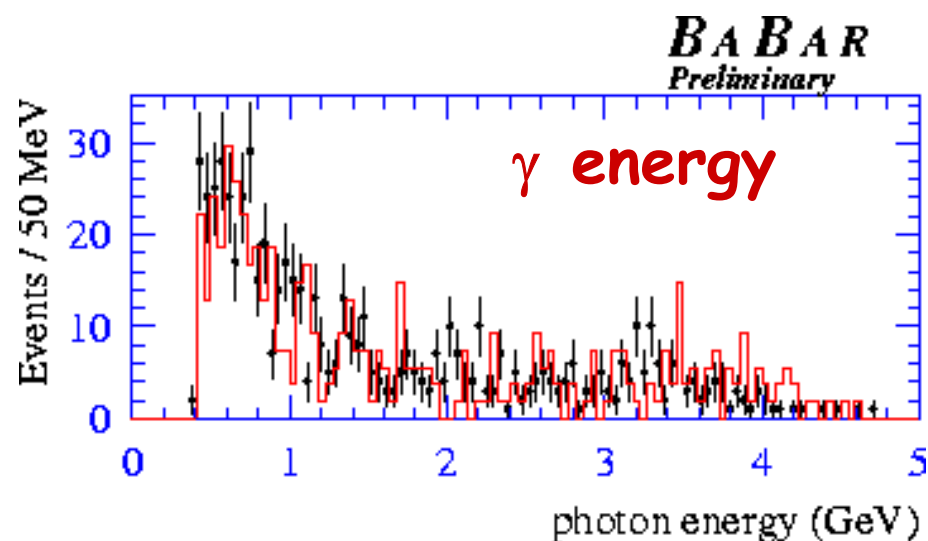
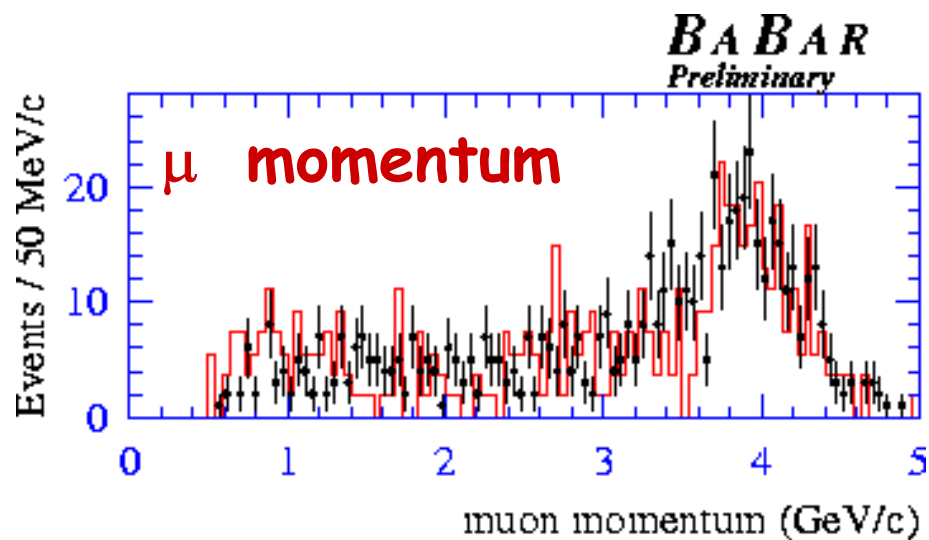
$\tau$  background: data (points) & simulation





# Signal Selection:

Efficiency using signal simulation with corrections from data control samples. Also, Grand Side Band events have nearly identical signature as signal  $\rightarrow$  obs./expected =  $1.022 \pm 0.069 \pm 0.025$



# Signal Efficiency: including BR from tags $5.2 \pm 0.1 \pm 0.5 \%$

Systematic Influence on the Signal Efficiency	Relative Error (%)
selection	$\pm 7.3$
Track and Ecal resolution:	
$\Delta E$ scale	$\pm 0.8$
$\Delta E$ resolution	$\pm 3.4$
$m_{EC}$ scale	$\pm 0.3$
$m_{EC}$ resolution	$\pm 0.6$
Ecal Scale	$\pm 3.3$
Momentum Scale	small
beam energy scale and spread	$\pm 0.3$
Total	$\pm 8.8$



## includes

- Trigger efficiency
- Tracking reconstr..
- photon reconstr.
- electron tag eff.
- hadronic tag eff.
- $\mu$  - PID requirements

# Backgrounds:

- $e^+e^- \rightarrow \mu\mu\gamma$  Removed with tag and visible energy on tag side
- $e^+e^- \rightarrow q\bar{q}$  (uds &  $c\bar{c}$ ) Removed with  $\mu\gamma$  requirements and tags
- Residual background:

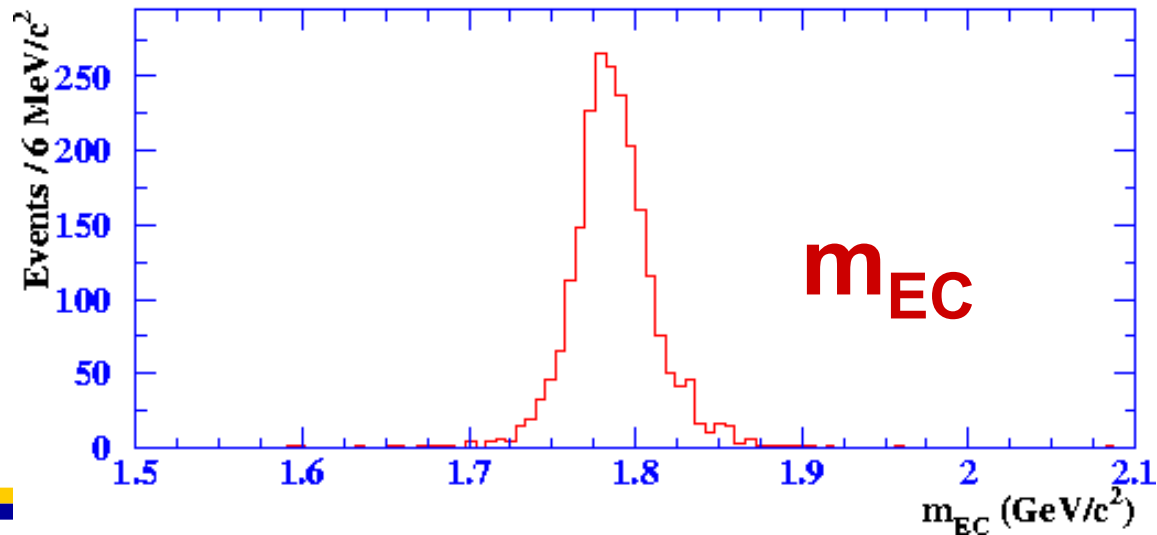
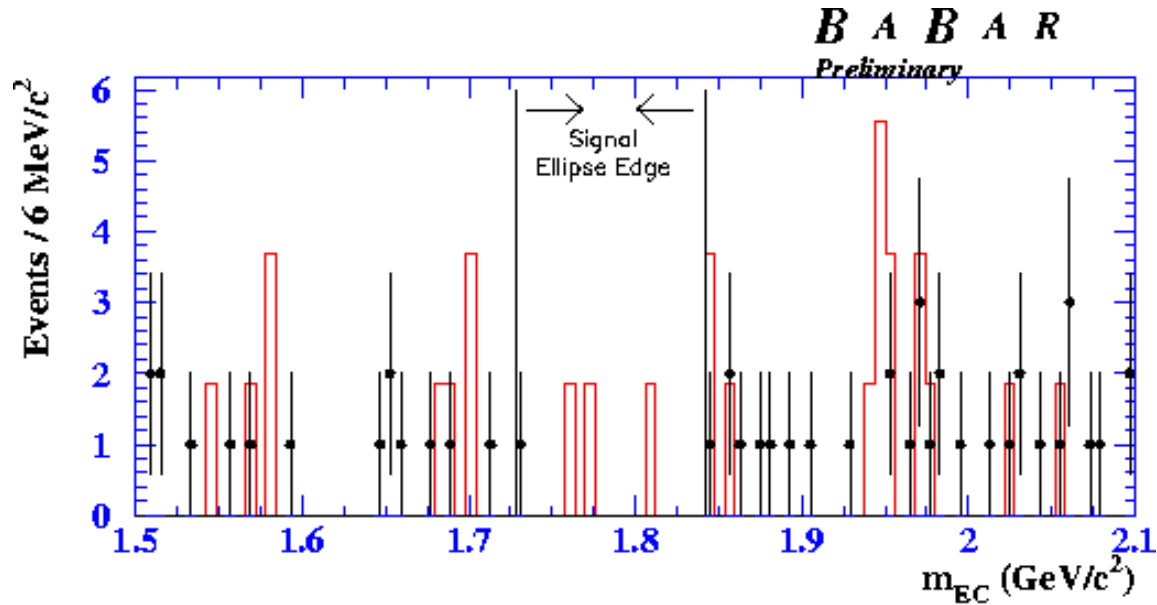
$$e^+e^- \rightarrow \tau\tau\gamma$$

- $\tau \rightarrow \mu\nu\nu$  (86%)
- $\tau \rightarrow \pi(K)\nu$  (10.6%)
- $\tau \rightarrow \pi(K)\pi^0\nu$  (3.5%)

$m_{EC}$  blinded  
background  
 $7.8 \pm 1.4$  events

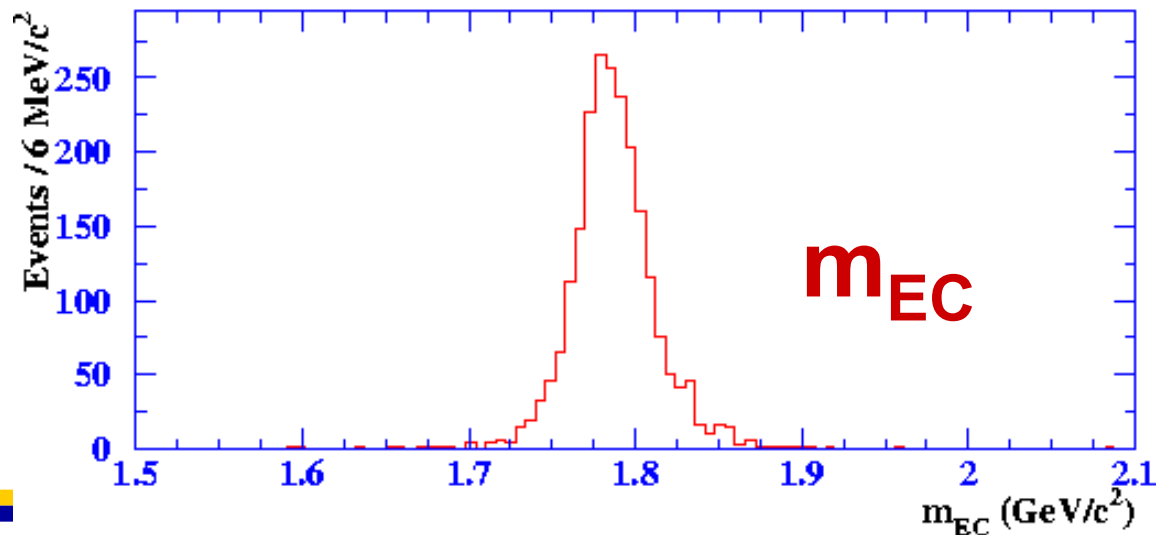
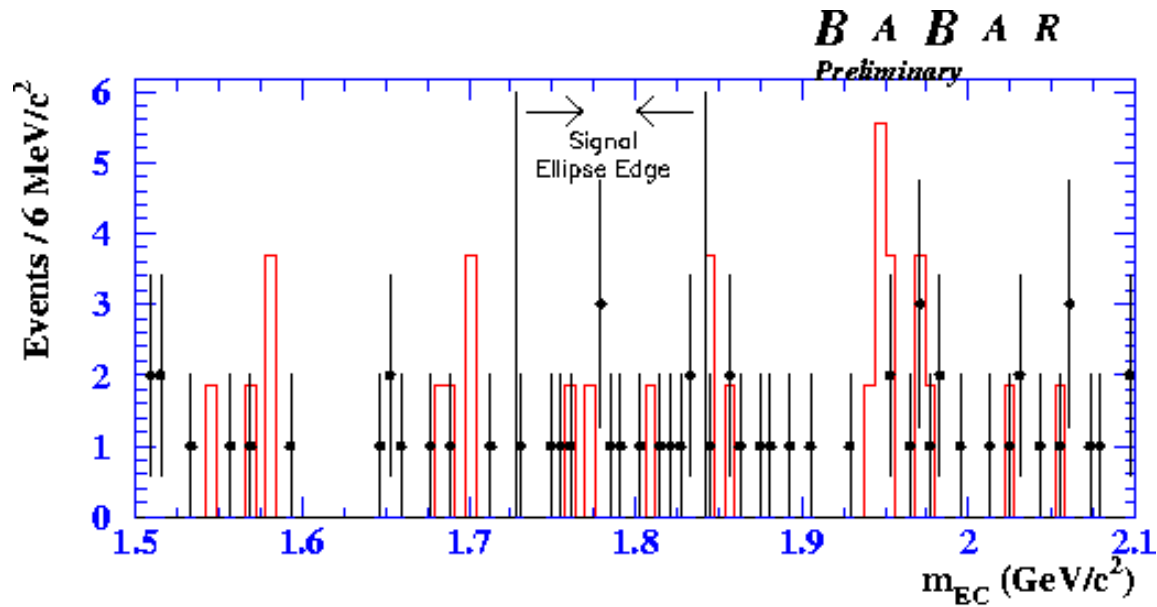
from data  
sidebands

[if 8 events observed,  
expect a limit of  
 $BR(\tau \rightarrow \mu\gamma) < 9.5 \times 10^{-7} @ 90\%CL$ ]

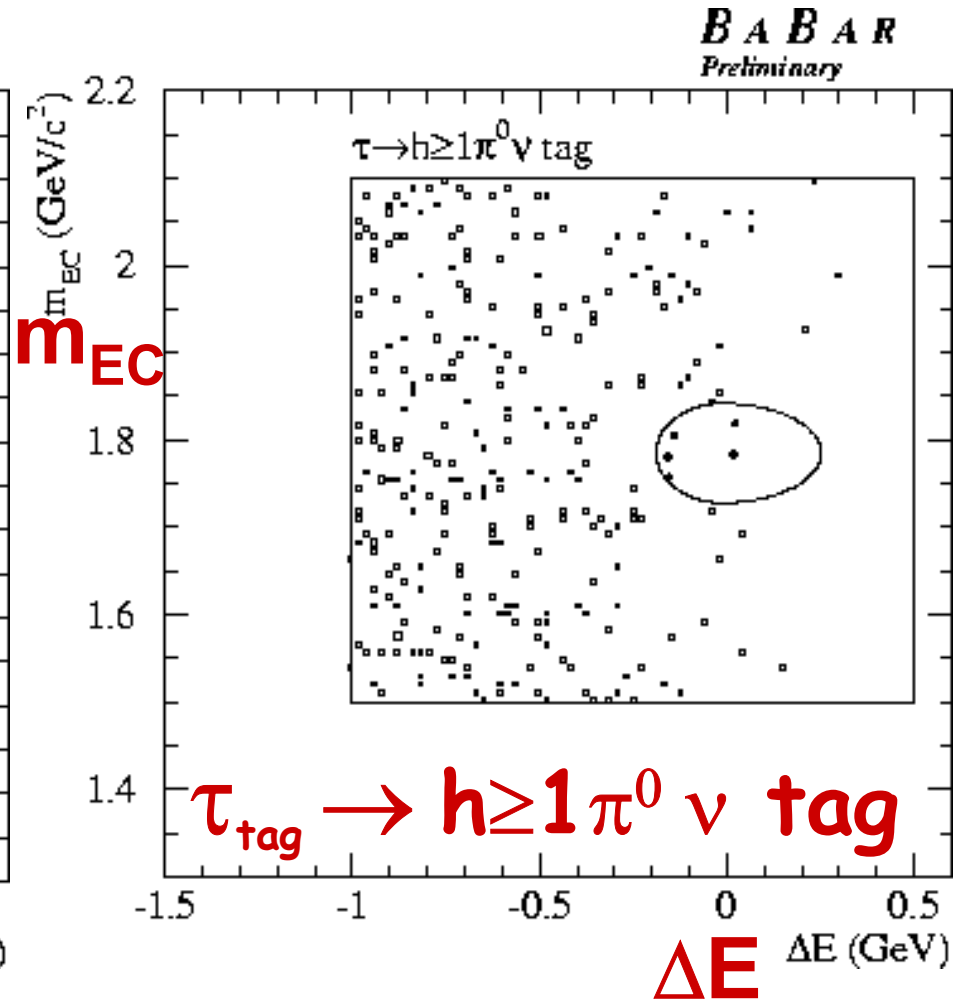
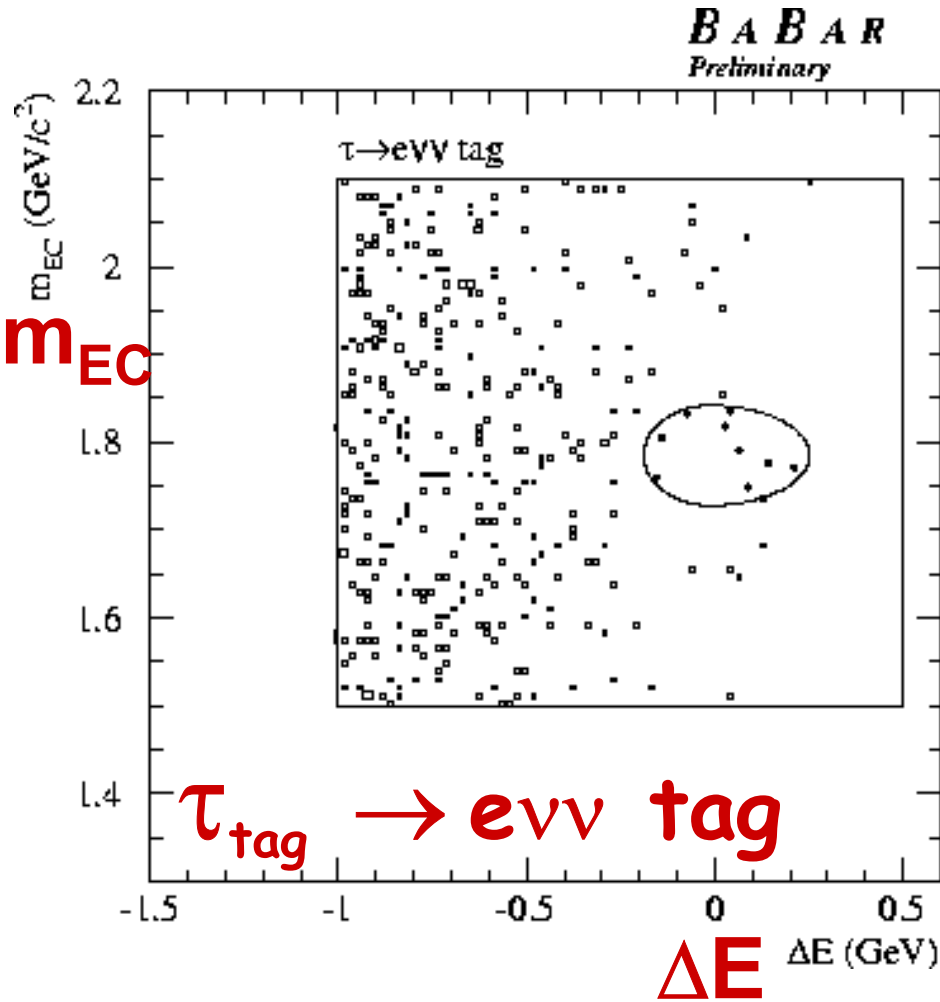


# $m_{EC}$ unblinded

13 events  
observed



# $m_{EC}$ vs $\Delta E$ Unblinded



# Limit

- 13 observed
- $7.8 \pm 1.4$  events expected

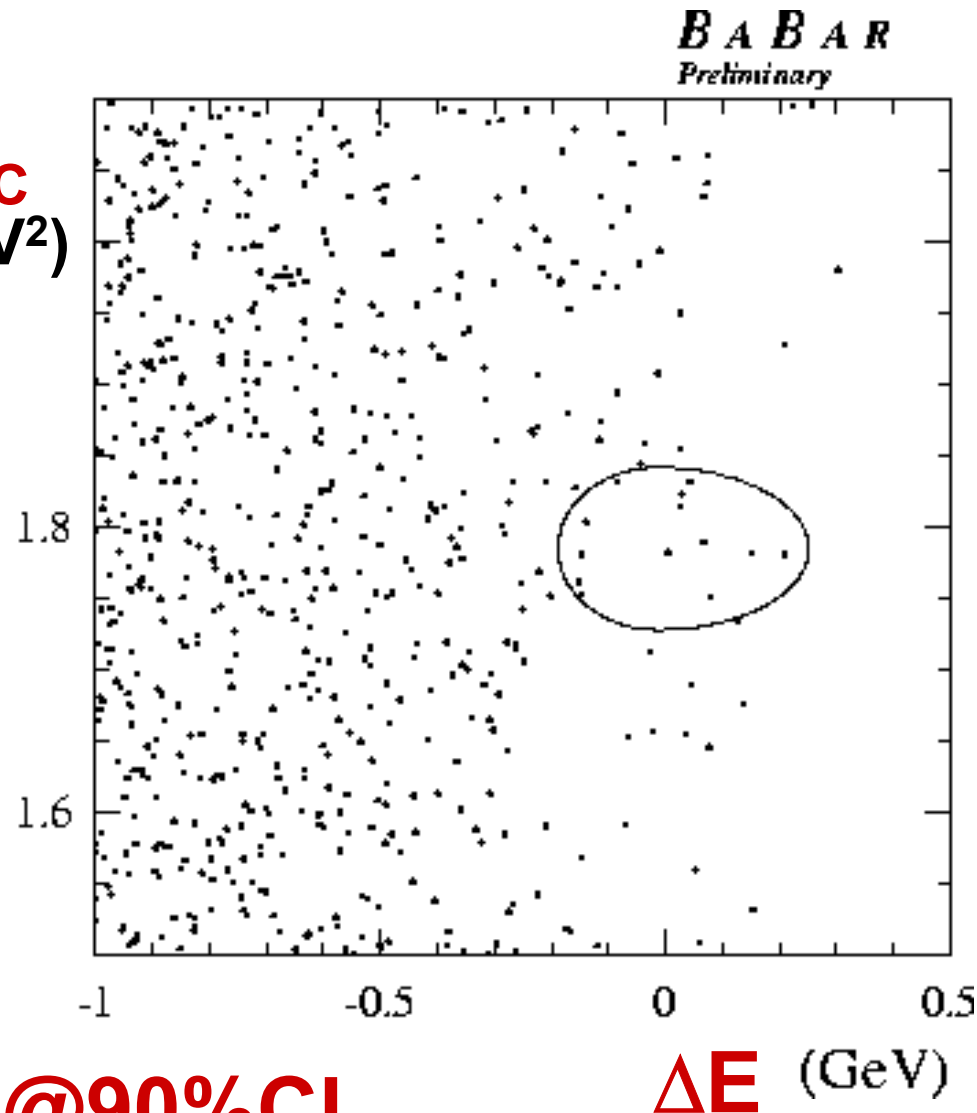
Prob. of  $7.8 \pm 1.4$  events fluctuating to 13 or more in absence of signal is 7.6%.

efficiency =  $5.2 \pm 0.1 \pm 0.5\%$

$N_{\tau\tau} = 56$  million

**$BR(\tau \rightarrow \mu\gamma) < 2.0 \times 10^{-6} @ 90\% CL$**

$m_{EC}$   
(GeV<sup>2</sup>)



# Prospects

- sensitivity to increase:
  - use of likelihood fit
- sample size to increase:
  - 2002 data ( $30\text{fb}^{-1}$ )
  - 2005 sample will approach  $\sim \frac{1}{2} \text{ab}^{-1}$
- search for  $\tau \rightarrow e\gamma$



# Summary

*A search for the lepton number violating decay  $\tau \rightarrow \mu\gamma$  in the 56 Million  $e^+e^- \rightarrow \tau^+ \tau^-$  events produced in BABAR results in 13 events being observed with an expected background of  $7.8 \pm 1.4$  events.*

$$\mathbf{BR(\tau \rightarrow \mu\gamma) < 2.0 \times 10^{-6} @ 90\% CL}$$

## Supplementary:

### Comparisons with CLEO & Belle analyses

- *BABAR*: if 8 events had been observed, limit would have been  $\text{BR}(\tau \rightarrow \mu\gamma) < 9.5 \times 10^{-7}$  with 56M  $\tau$ -pair pair
- CLEO likelihood fit gives  $\text{BR}(\tau \rightarrow \mu\gamma) < 1.1 \times 10^{-6}$  and cross-checks with a cut-and-count approach, which gives:  $\text{BR}(\tau \rightarrow \mu\gamma) < 1.8 \times 10^{-6}$  (6 observed and  $5.5 \pm 0.5$  events expected) with 12.6M  $\tau$ -pair
- BELLE (2001 prelim.):  $1.0 \times 10^{-6}$  (3 events observed, observed,  $5.9 \pm 0.6$  events expected) with 19.3M  $\tau$ -pair pair (if 6 events had been observed, limit would have been  $1.3 \times 10^{-6}$ )