# Measurement of Tau Leptonic Branching Ratios


The L3 Collaboration

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## $\tau$ decay into leptons

$$\Gamma(\tau \to \nu_\tau l \bar{\nu}_l(\gamma)) \quad = \quad \frac{G_\tau G_l m_\tau^5}{192\pi^3} \, f\left(\frac{m_l^2}{m_\tau^2}\right) \, \delta_W^\tau \delta_\gamma^\tau$$

masses well known, small corrections $\delta_W^\tau \delta_\gamma^\tau$

The decay rate is obtained from the leptonic branching fractions $B_l$ $(\tau \to \nu_\tau l \bar{\nu}_l)$ $\mathrm{B}_l = \frac{\Gamma(\tau \to \nu_\tau l \bar{\nu}_l)}{\Gamma(\tau \to all)} = \Gamma(\tau \to \nu_\tau l \bar{\nu}_l)\, \tau_\tau$

we measure it applying a method which avoids selection of the natural composition of a tau event sample

# Method

**the method:**

- selection of $\mathbf{e^+e^-} \rightarrow \tau^+\tau^-$ events by applying cuts to one **hemisphere** only.
- Lepton identification on the **opposite hemisphere**.(which is a 'bias free' sample of $\tau$ decays)

ideal situation:

$N$ $\tau^+\tau^-$ events with $B_l$

no cuts that change $\frac{N_l}{N_\tau}$ in the hemisphere under consideration.

# Method

$$\boxed{B_l(\tau \to \nu_\tau l \bar{\nu}_l) = \frac{N_l(1 - f_l^{non\ \tau} - f_{h\to l}^{\tau})}{N_\tau(1 - f_{\tau\tau}^{non\ \tau})}\,\frac{1}{\varepsilon_l^{ID}}}$$

| | |
|---|---|
| $N_l$ | number of identified leptons |
| $f_l^{non\ \tau}$ | non $\tau$ background in the lepton sample |
| $f_{h\to l}^{\tau}$ | faked leptons from hadronic $\tau$ decays |
| $N_{\tau\tau}$ | selected $\tau\tau$ events |
| $f_{\tau\tau}^{non\ \tau}$ | background in the $\tau\tau$ sample |
| $\varepsilon_l^{ID}$ | lepton identification efficiency |

# Method

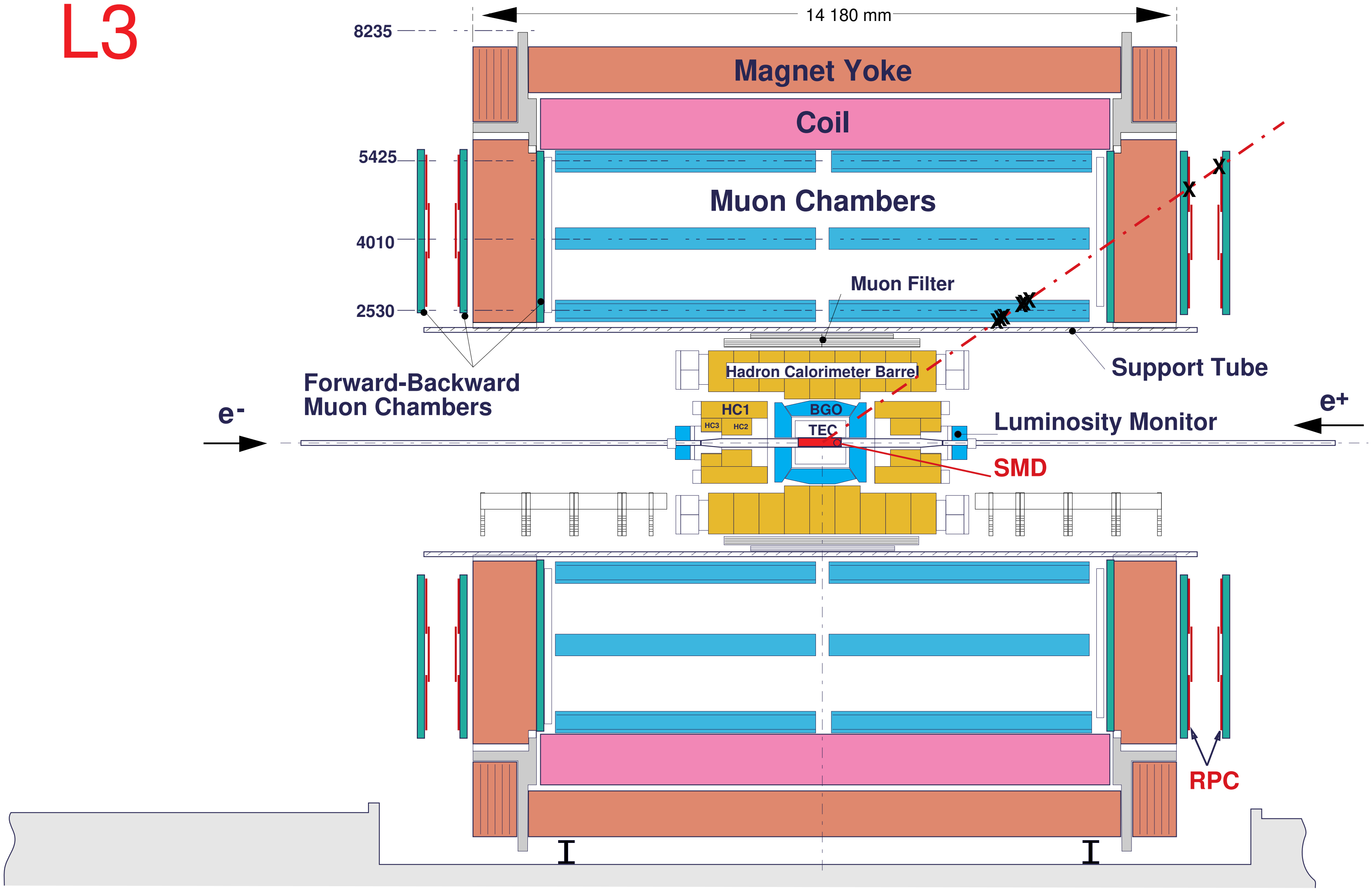
| lepton | | events per side | | |
|---|---|---|---|---|
| side 1 | side 2 | cuts on side 1 | | cut on side 2 |
| no | yes | $C_1 \cdot$ | $N \cdot (1-B) \cdot B$ | $\cdot C_2$ |
| no | no | $C_1 \cdot$ | $N \cdot (1-B) \cdot (1-B)$ | $\cdot C_1$ |
| yes | no | $C_2 \cdot$ | $N \cdot B \cdot (1-B)$ | $\cdot C_1$ |
| yes | yes | $C_2 \cdot$ | $N \cdot B \cdot B$ | $\cdot C_2$ |

summing up shows: $$\frac{N_l}{N_\tau} = B$$

no contribution to $\frac{\varepsilon_{\tau\tau}^{sel}}{\varepsilon_l^{sel}}$ from this method

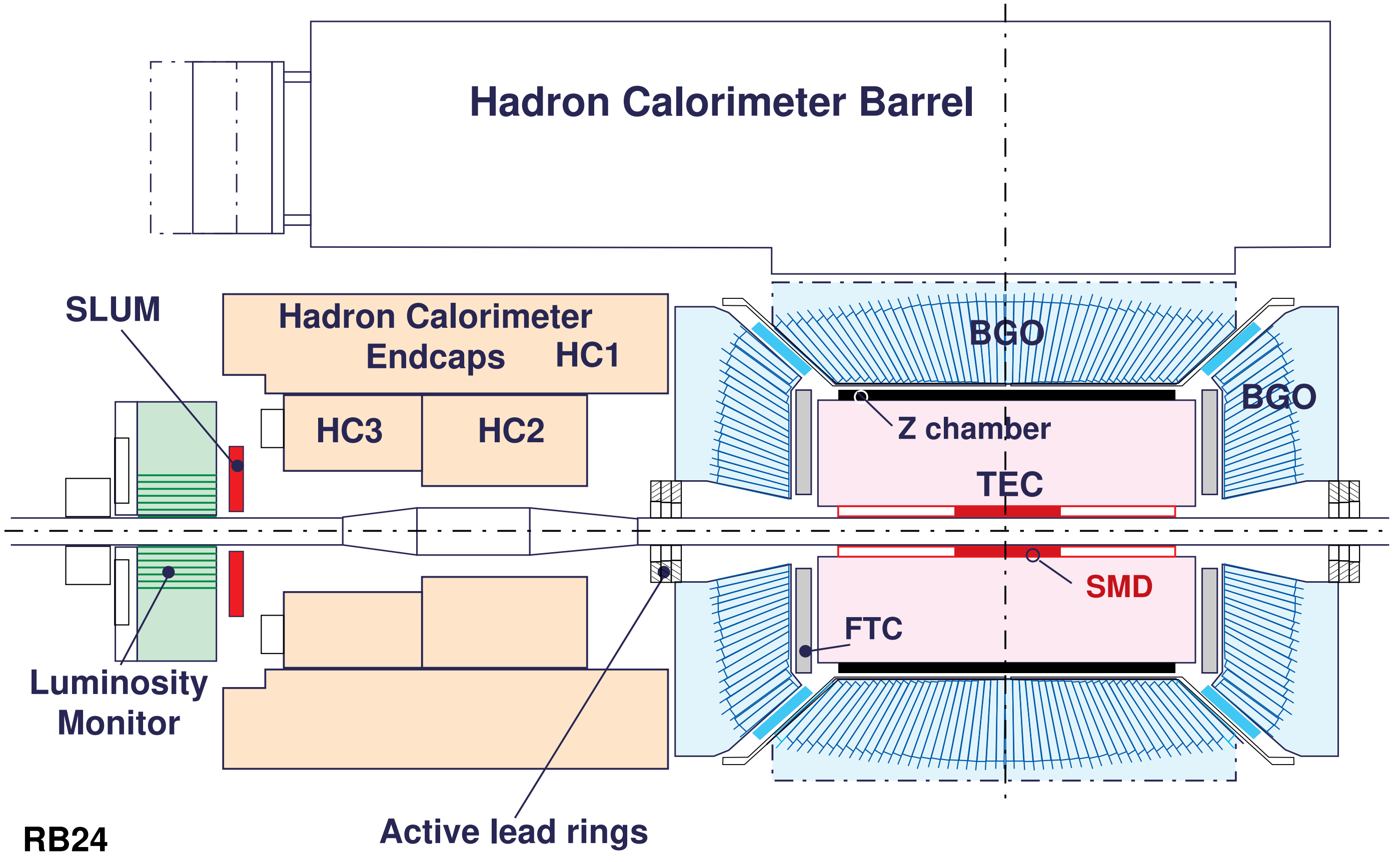
# Detector

## L3




y934col

# Detector


Hadron Calorimeter Barrel
SLUM
Hadron Calorimeter Endcaps HC1
HC3
HC2
BGO
BGO
Z chamber
TEC
SMD
FTC
Luminosity Monitor
RB24
Active lead rings

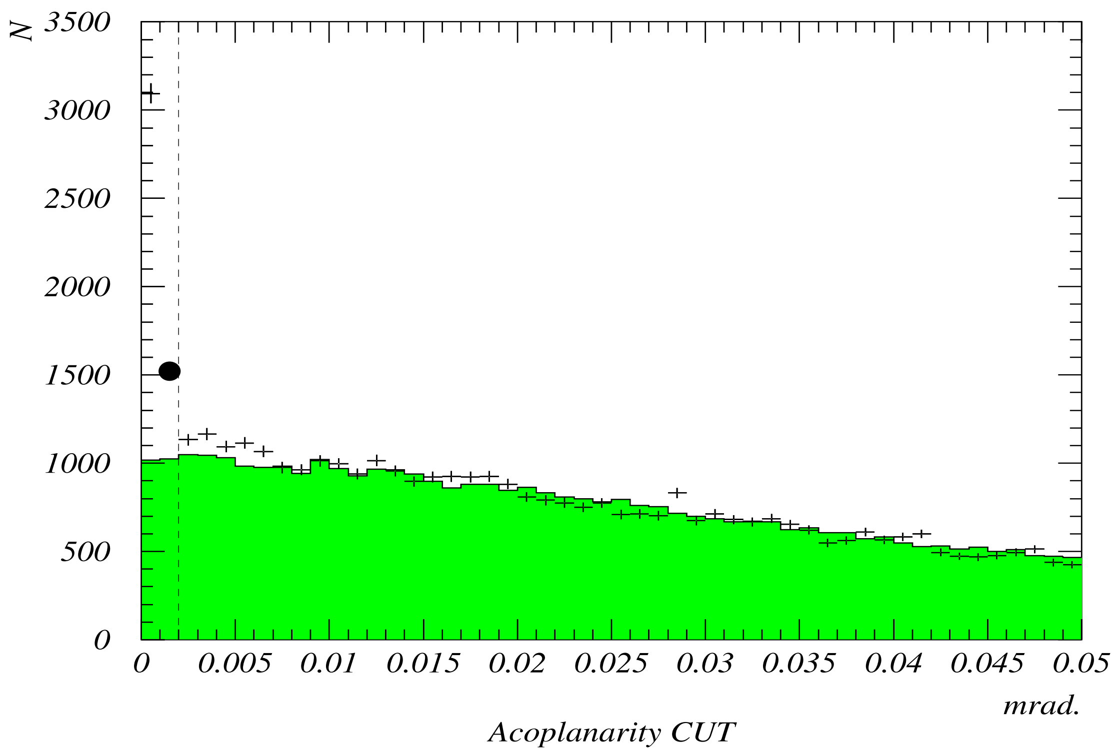
# Analysis

barrel region (geometry) $\boxed{58.90\%}$

- $|cos(\Theta_{thrust})| < 0.72$
- $|cos(\Theta_{TEC})| < 0.71$

correlated cuts (for $\tau$-selection) $\boxed{90.57\%}$

- all tracks in a $20^0$ cone
- space angle $> 2.9$ rad
- acoplanarity $> 0.002$ rad



**final selection:**

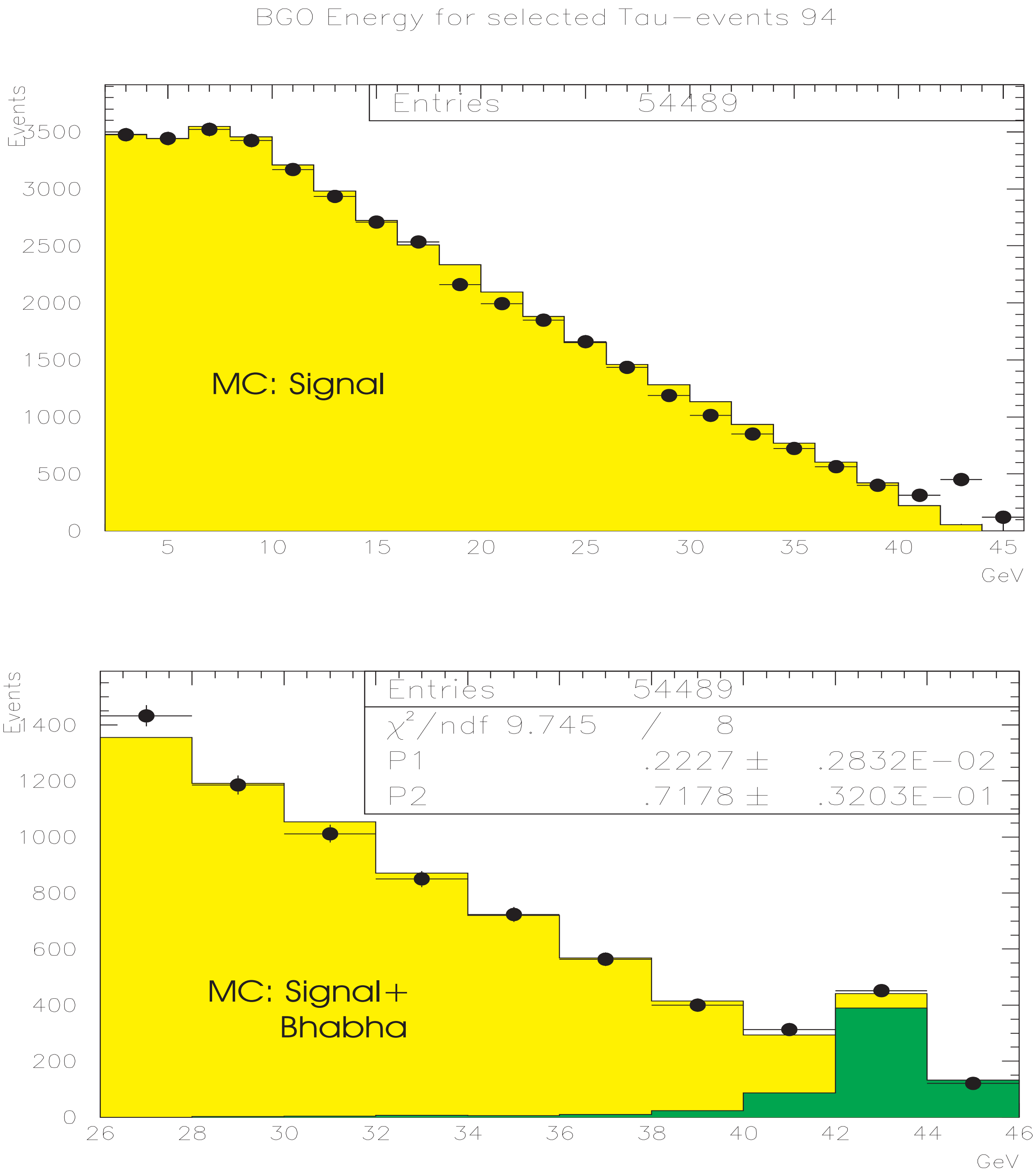
cuts in opposite hemisphere $\boxed{61.68\%}$

- inconsistency with a MIP signature
- $E_{BGO} < 32GeV$
- 1 or 3 tracks

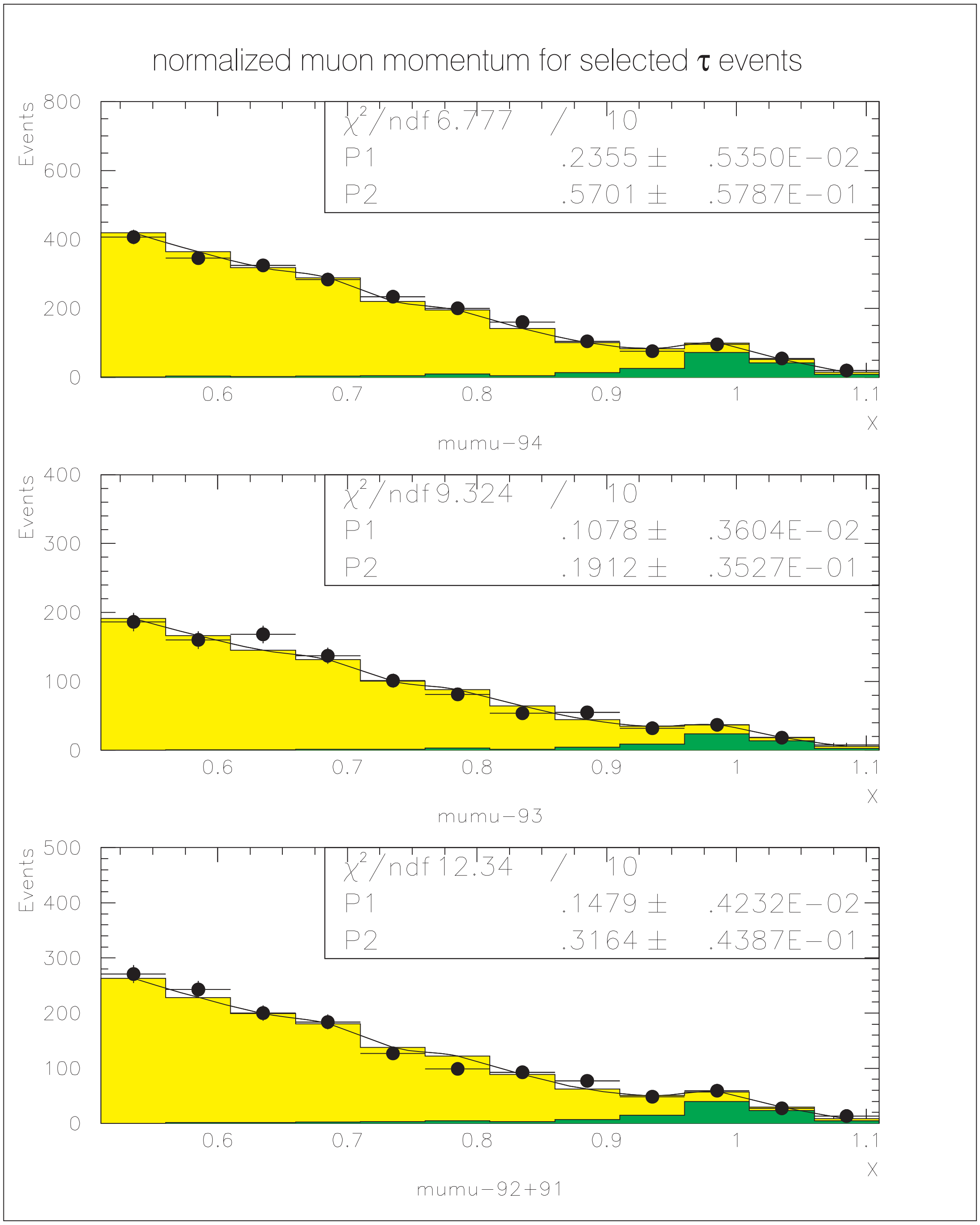
remnant background from Bhabha and dimuon events is estimated from data

# Analysis

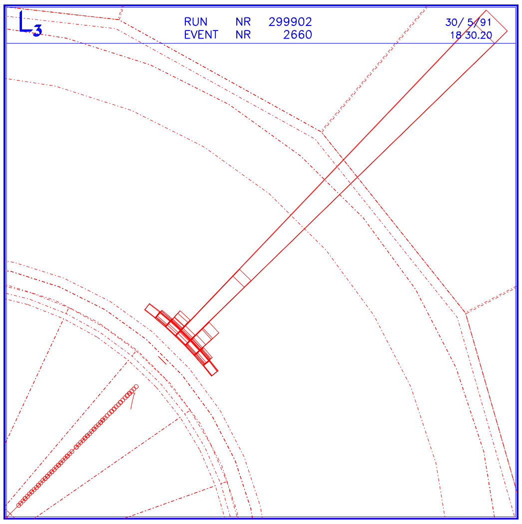
## background from $e^+e^- \rightarrow e^+e^-$



## background from $e^+e^- \to \mu^+\mu^-$



## lepton identification

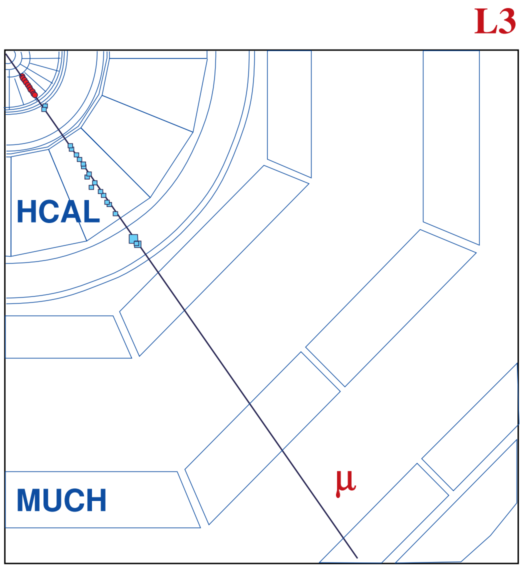



electron identification

A narrow shower in BGO with a matching TEC track. Little HCAL deposit.

$2GeV < E_e < 40GeV$

identification efficiency: $\boxed{86.5\%}$




muon identification

A minimum ionizing track in HCAL with a matching TEC track and hits in the muon spectrometer,

$2GeV < E_\mu < 40GeV$

identification efficiency: $\boxed{75.0\%}$

# Analysis

lepton identification efficiencies are compared

- with Bhabha, dimuon (at high energies)
- two photon events (for electrons at low energies)

some discrepancies between data and Monte Carlo are found for electrons in:

- TEC-BGO (track-cluster) matching
- net effect of cracks between BGO crystals

**correction factors:**

| | |
|---|---|
| 1991-1992 | 1.034 |
| 1993 | 1.044 |
| 1994 | 1.034 |

# Analysis

**Data from 1991-1994 (124 nb$^{-1}$)**

(procedure for 1991-92, 1993 and 1994 done separatly)

**selected $\tau$-decays:** 113356

| | | |
|---|---|---|
| background: | Bhabha | 1.5% |
| | $\gamma\gamma \rightarrow ee$ | 0.4% |
| | dimuon | 0.7% |
| | cosmics | 0.2% |

**identified electrons:** 17052

| | | |
|---|---|---|
| background: | $\gamma\gamma \rightarrow ee$ | 2.5% |
| | $\tau \rightarrow$ hadrons | 2.5% |
| | Bhabha | 0.5% |

**identified muons:** 14481

| | | |
|---|---|---|
| including | $\tau \rightarrow$ hadrons | 1.1% |
| | dimuon | 0.3% |

# Analysis

| $\tau \longrightarrow \nu_\tau e \bar{\nu}_e$ | 1991+92 | 1993 | 1994 |
|---|---|---|---|
| total statistical error | 1.44% | 1.70 % | 1.15 % |
| systematical error | 1.2% | 1.4 % | 1.0 % |

| $\tau \longrightarrow \nu_\tau \mu \bar{\nu}_\mu$ | 1991+92 | 1993 | 1994 |
|---|---|---|---|
| total statistical error | 1.50% | 1.80 % | 1.20 % |
| systematical error | 1.5% | 1.7% | 1.2 % |

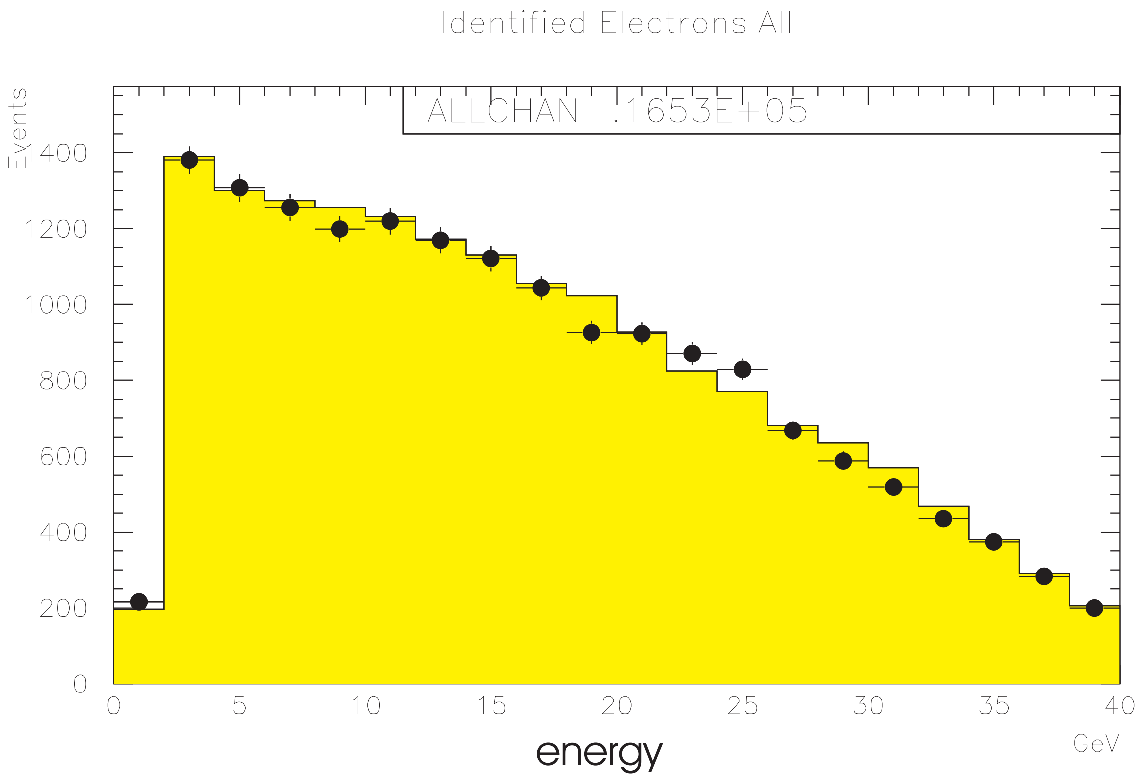
total statistical error:

- real statistics
- corrections

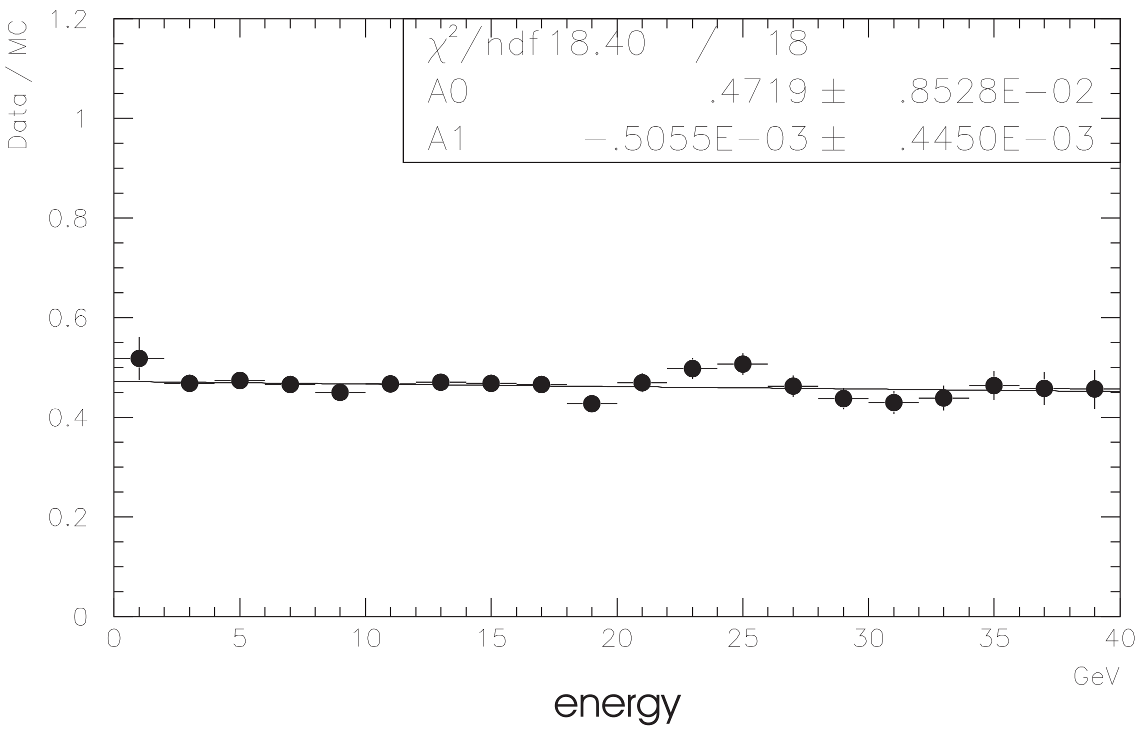
systematical error:

vary slope of DATA/MC-Distribution
ratio fixed at high energies Bhabha/dimuons

# Analysis



Identified Electrons All
Events
ALLCHAN .1653E+05
0
200
400
600
800
1000
1200
1400
0 5 10 15 20 25 30 35 40
GeV
energy

Data / MC
$\chi^2$/ndf 18.40 / 18
A0 .4719 ± .8528E−02
A1 −.5055E−03 ± .4450E−03
0
0.2
0.4
0.6
0.8
1
1.2
0 5 10 15 20 25 30 35 40
GeV
energy

**preliminary results**

$$\boxed{B(\tau \rightarrow \nu_\tau e \bar{\nu}_e)}$$

| | |
|---|---|
| 1994 | $(17.47 \pm 0.21 \pm 0.18)\%$ |
| 1993 | $(18.12 \pm 0.31 \pm 0.25)\%$ |
| 1991 – 92 | $(17.55 \pm 0.26 \pm 0.21)\%$ |
| *total* | $(17.67 \pm 0.14 \pm 0.13)\%$ |

$$\boxed{B(\tau \rightarrow \nu_\tau \mu \bar{\nu}_\mu)}$$

| | |
|---|---|
| 1994 | $(17.31 \pm 0.22 \pm 0.21)\%$ |
| 1993 | $(17.41 \pm 0.32 \pm 0.30)\%$ |
| 1991 – 92 | $(17.32 \pm 0.27 \pm 0.26)\%$ |
| *total* | $(17.34 \pm 0.15 \pm 0.15)\%$ |

**summary**

the leptonic branching ratios of the $\tau$ have been measured with a new method which avoids almost any bias from 'correlated cuts'

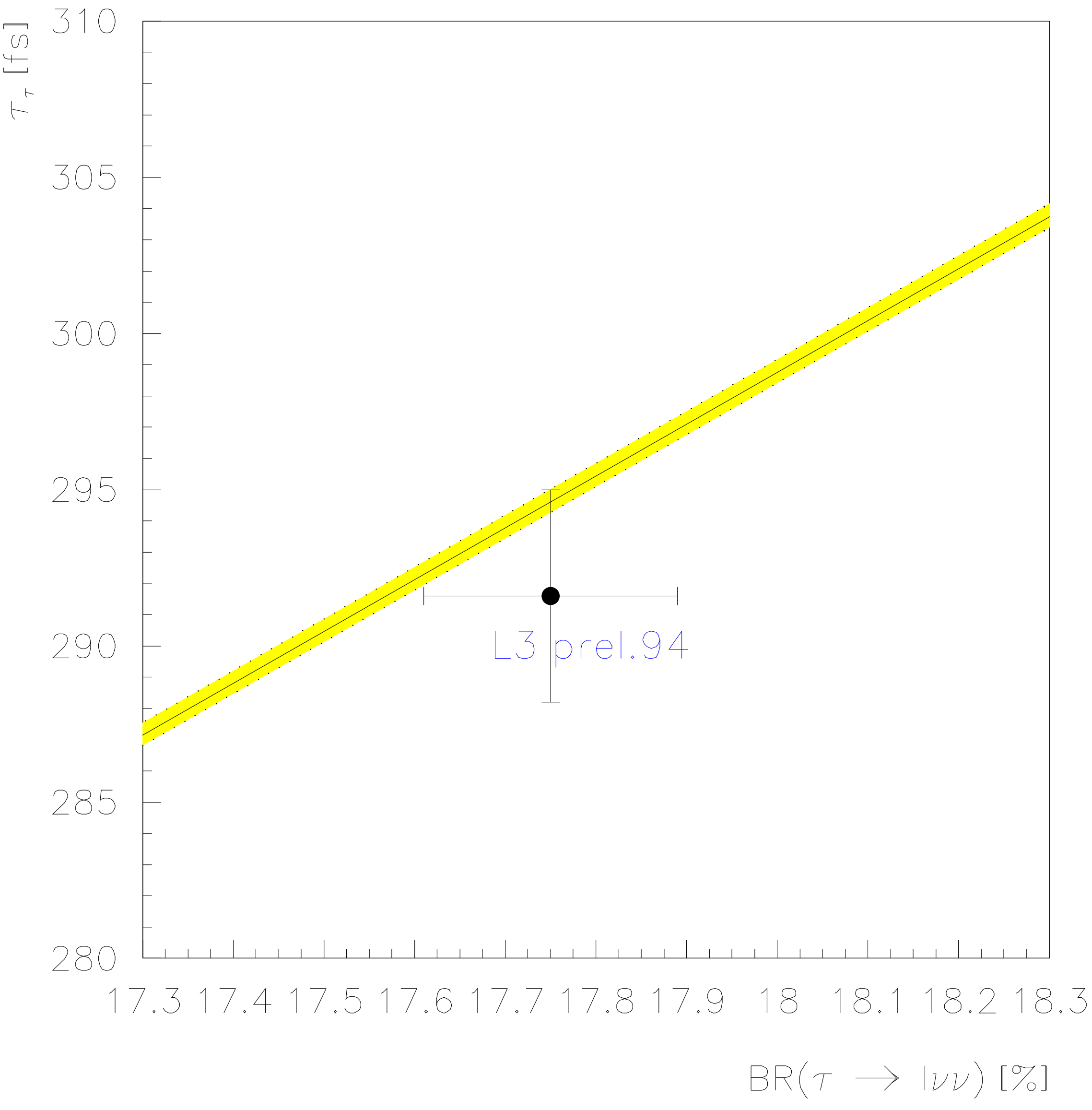
preliminary results from data taken between 1991 and 1994:

$B(\tau \to \nu_\tau e \bar{\nu}_e) = (17.67 \pm 0.14 \pm 0.13)\%$
$B(\tau \to \nu_\tau \mu \bar{\nu}_\mu) = (17.34 \pm 0.15 \pm 0.15)\%$

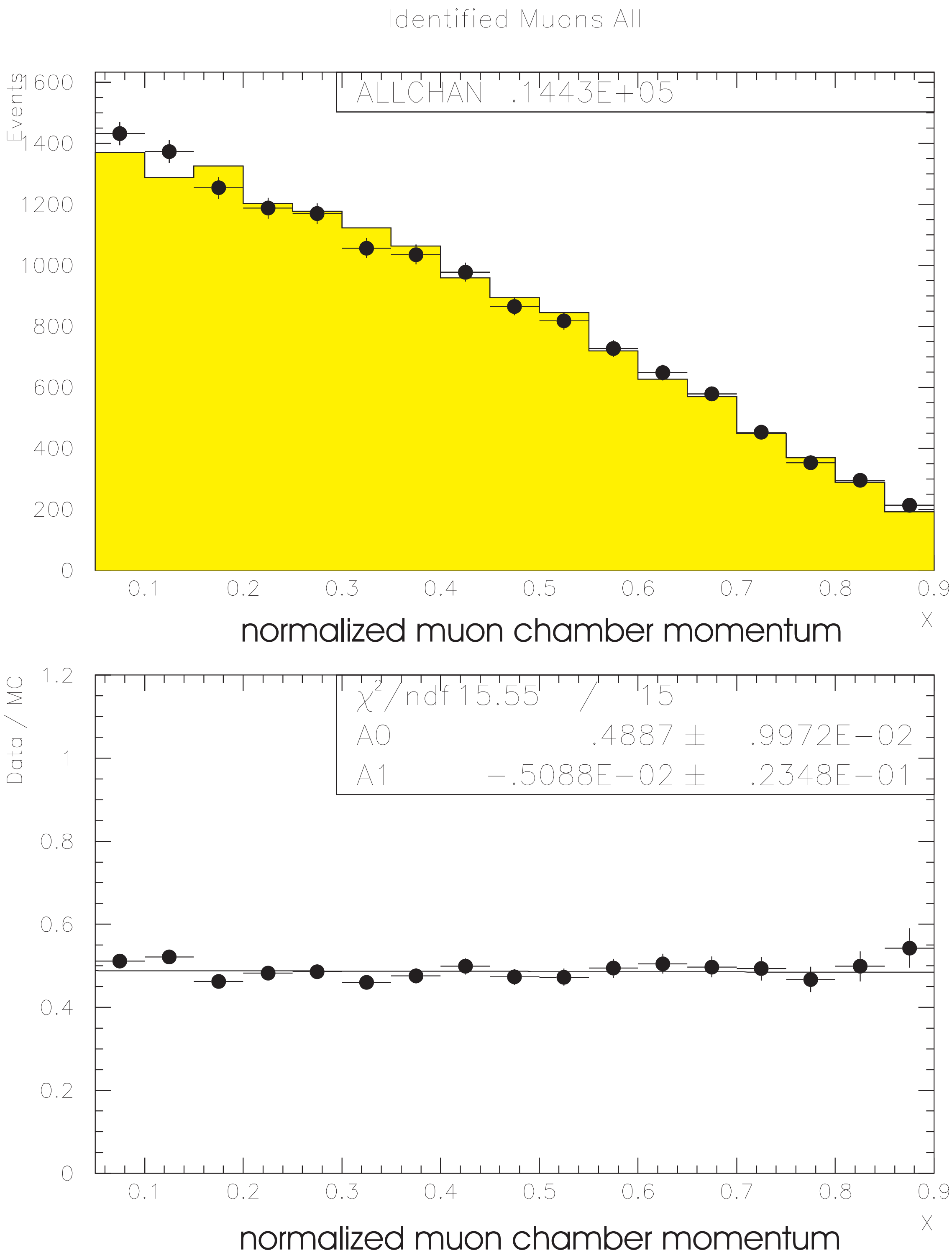
this is in excellent agreement with lepton universality:

$$\frac{g_e}{g_\mu} = 0.996 \pm 0.008$$

# Summary



$\tau_\tau$ [fs]
310
305
300
295
290
285
280
17.3 17.4 17.5 17.6 17.7 17.8 17.9 18 18.1 18.2 18.3
L3 prel.94
BR($\tau \rightarrow l\nu\nu$) [%]


Identified Muons All
Events
ALLCHAN .1443E+05
0
200
400
600
800
1000
1200
1400
1600
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
X
normalized muon chamber momentum
Data / MC
$\chi^2$/ndf 15.55 / 15
A0 .4887 ± .9972E−02
A1 −.5088E−02 ± .2348E−01
0
0.2
0.4
0.6
0.8
1
1.2
normalized muon chamber momentum