The measurement of the topological and hadronic tau decay branching ratio with L3 detector

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(L3 Collaboration)

- Introduction
- Topological branching ratio
- Hadronic decay branching ratio
- Conclusion

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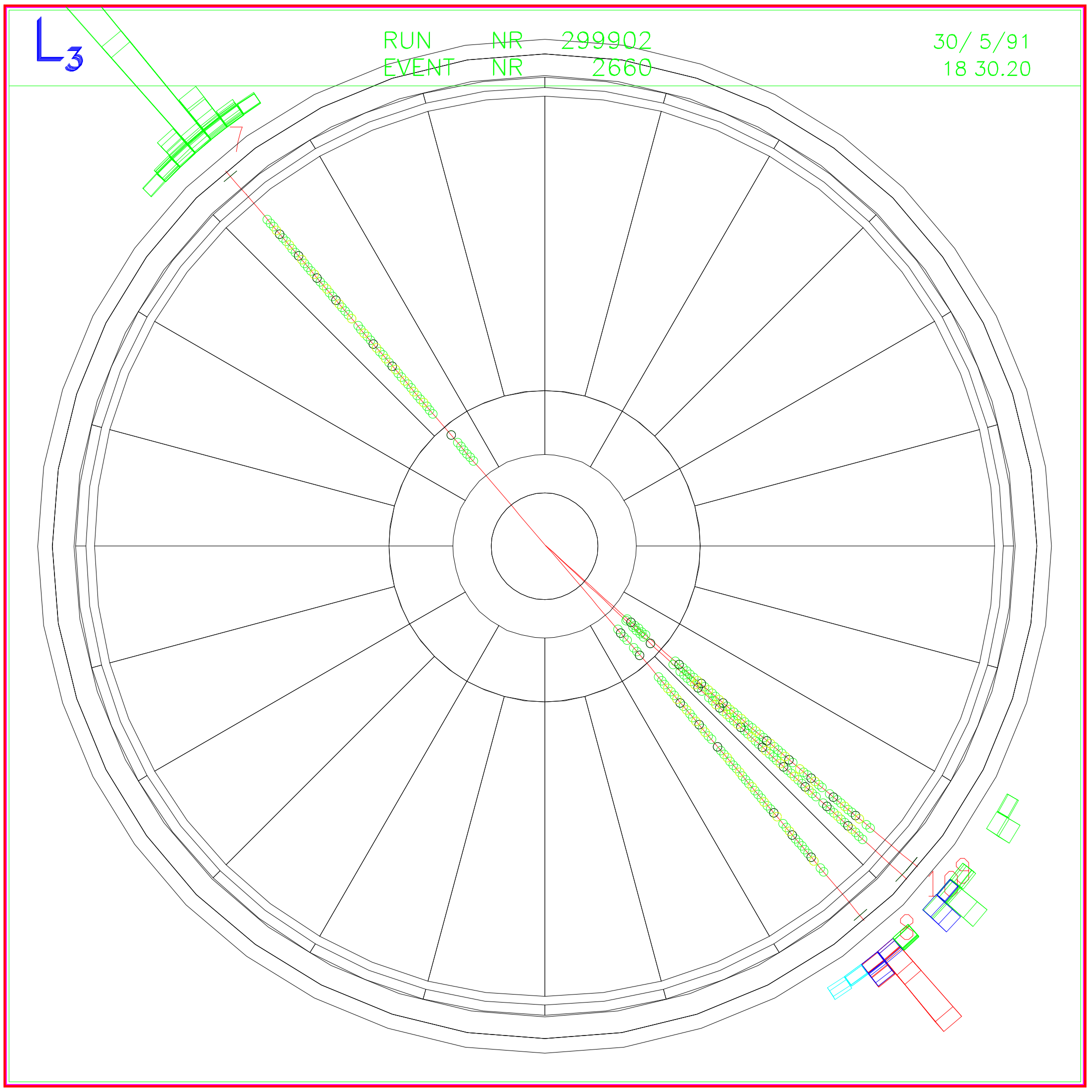
The Experiment

LEP: $e^+e^- \rightarrow \tau^+\tau^-(\gamma)$; $\sqrt{s} \simeq \mathrm{M_Z}$

1992-95: $\mathcal{L} = 92.6\ \mathbf{pb}^{-1} \Longrightarrow N \simeq 138 \times 10^3$

All the subdetector efficiency has been studied using control samples



Topological branching ratio measurement

- $\tau\tau$ event selection
  - in the barrel region
  - reject $q\bar{q}$ by the multiplicity in the ECAL
  - reject bhabha, $\mu\mu$, cosmic and two photon events

- Counting the number of tracks in each τ decay
  - reject $K_s \to \pi^+\pi^-$ tracks
  - reject back scattering tracks
  - reject tracks from γ conversion
  - double track resolution

$\tau\tau$ events selection

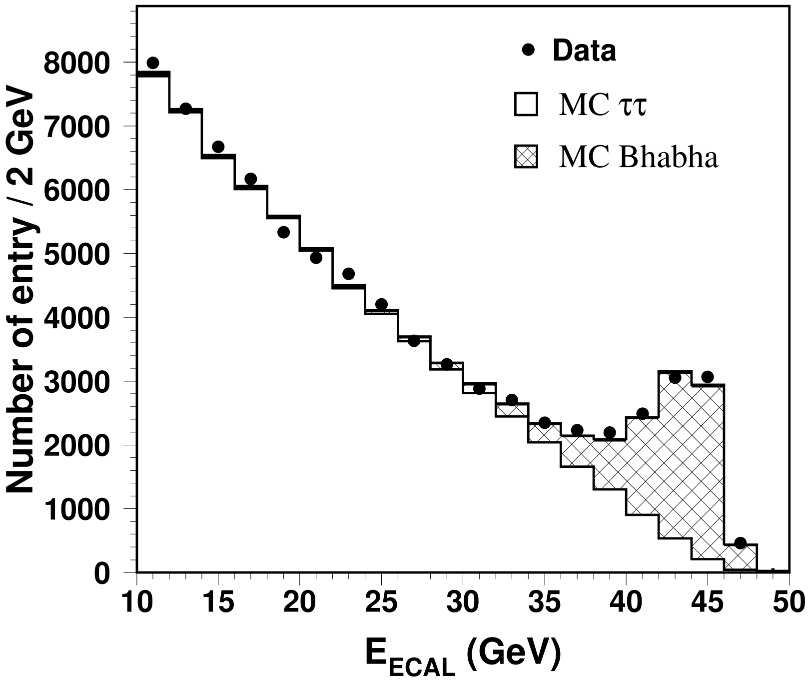
$N_{\tau\tau}$ = 72036
L=$92.63pb^{-1}$
during 1992–1995 LEP run

MC shows:
Efficiency: 79.49$\% \pm 0.16\%$

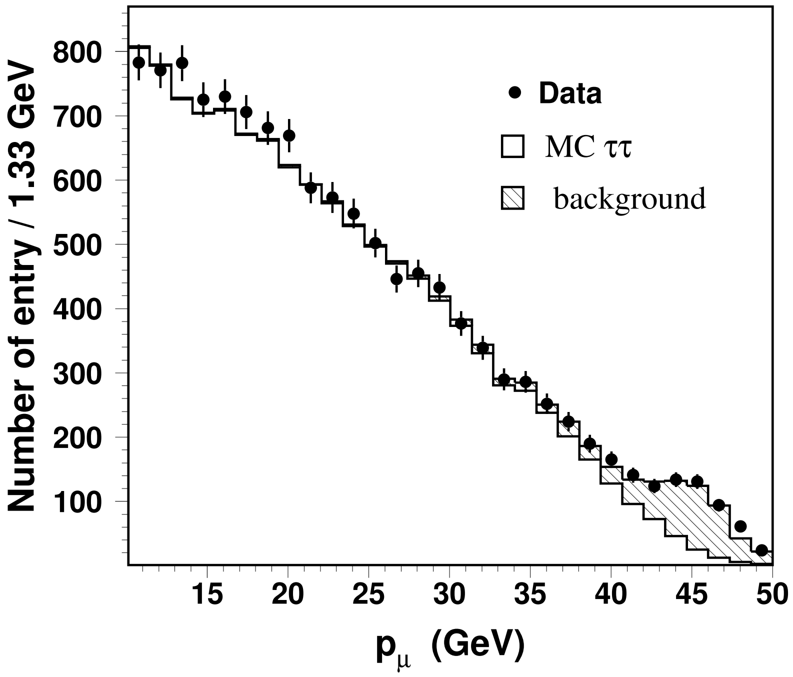
Background from:

- Bhabha:0.16%
- $\mu\mu$:0.68%
- $q\bar{q}$:1.94%
- Two photon: 0.16%

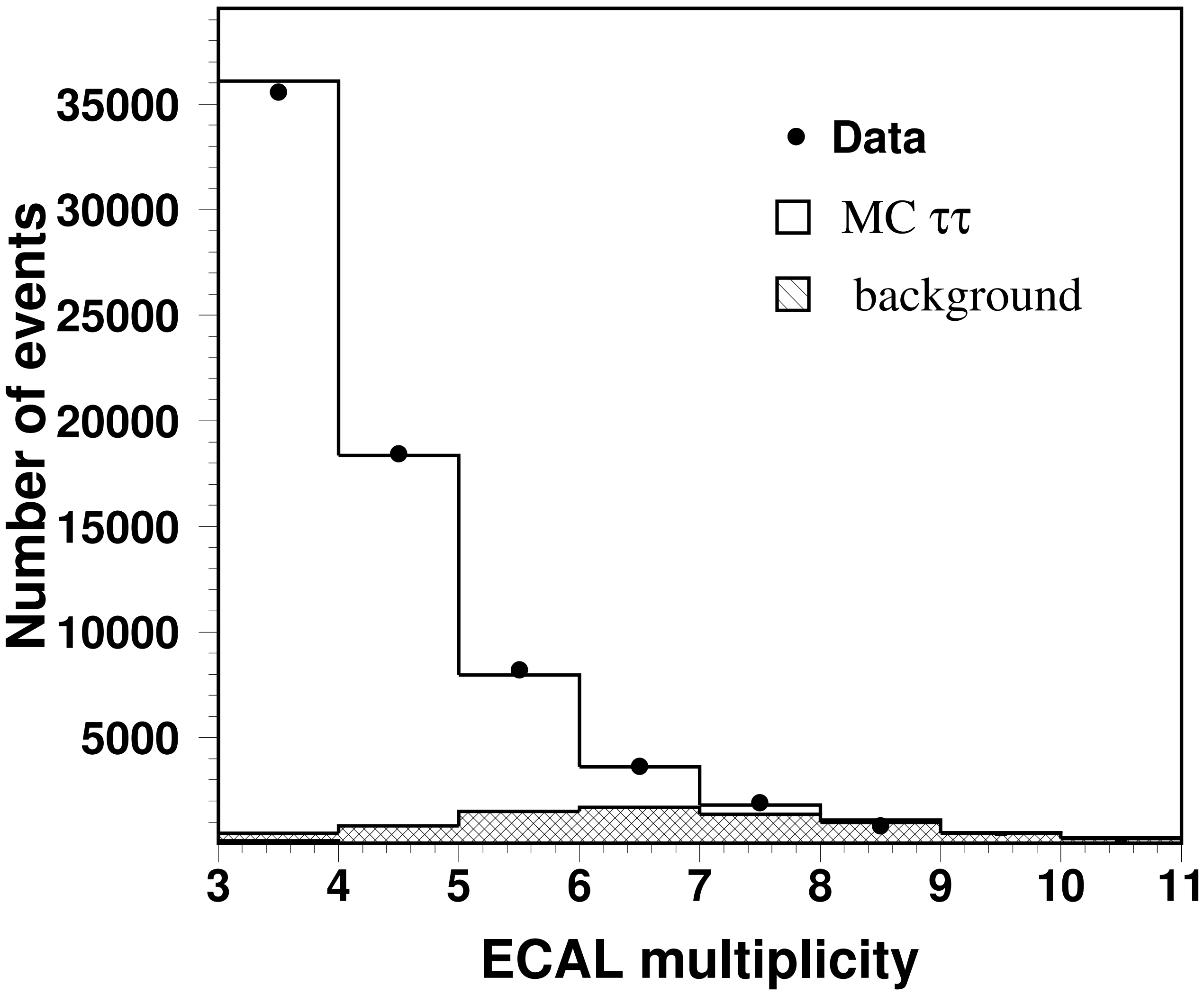
ECAL energy (Before final selection)

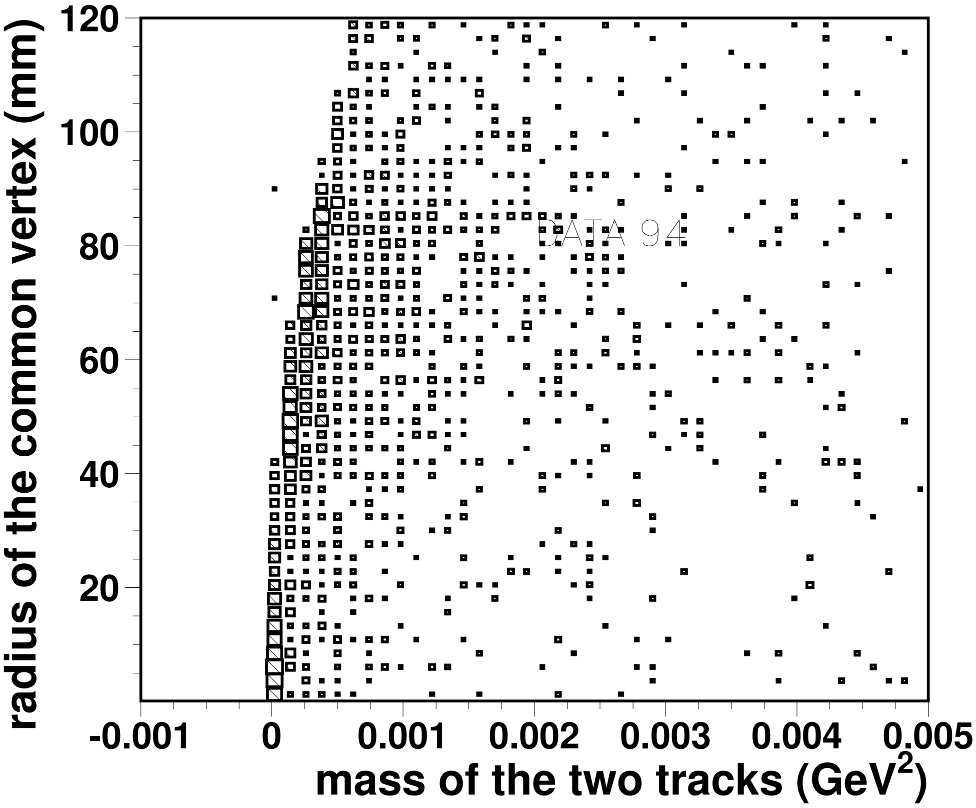


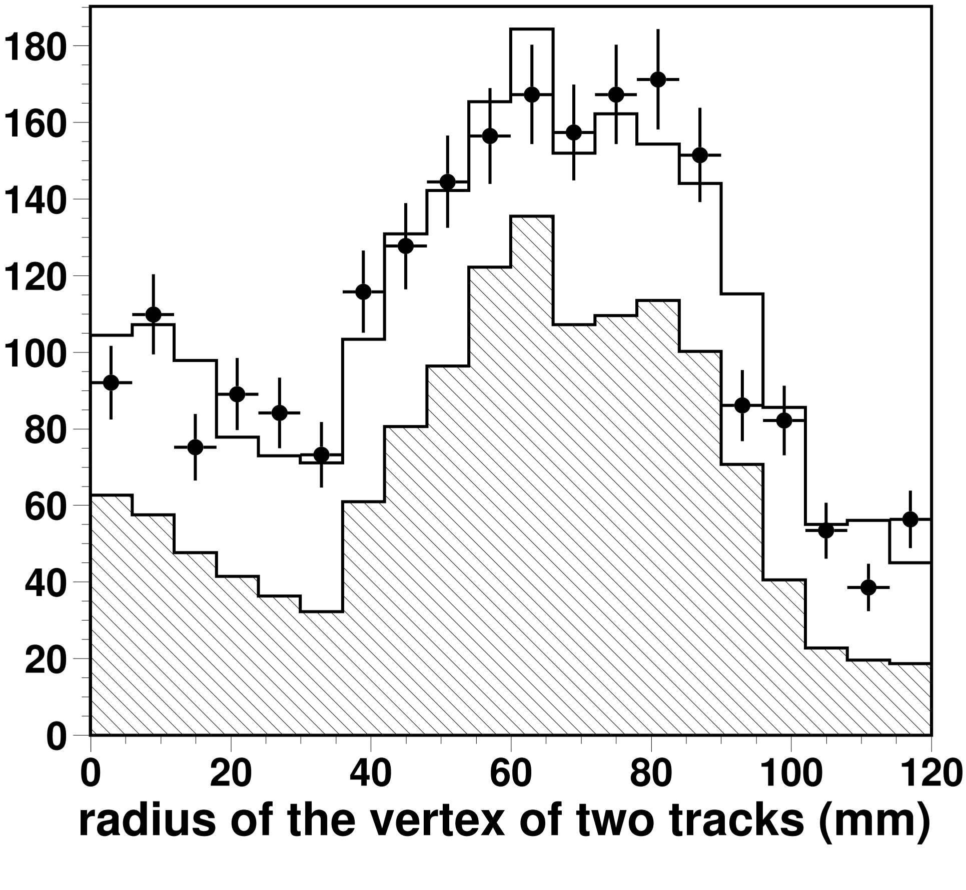
μ Momentum (Before final selection)



ECAL multiplicity (Before final seletion)

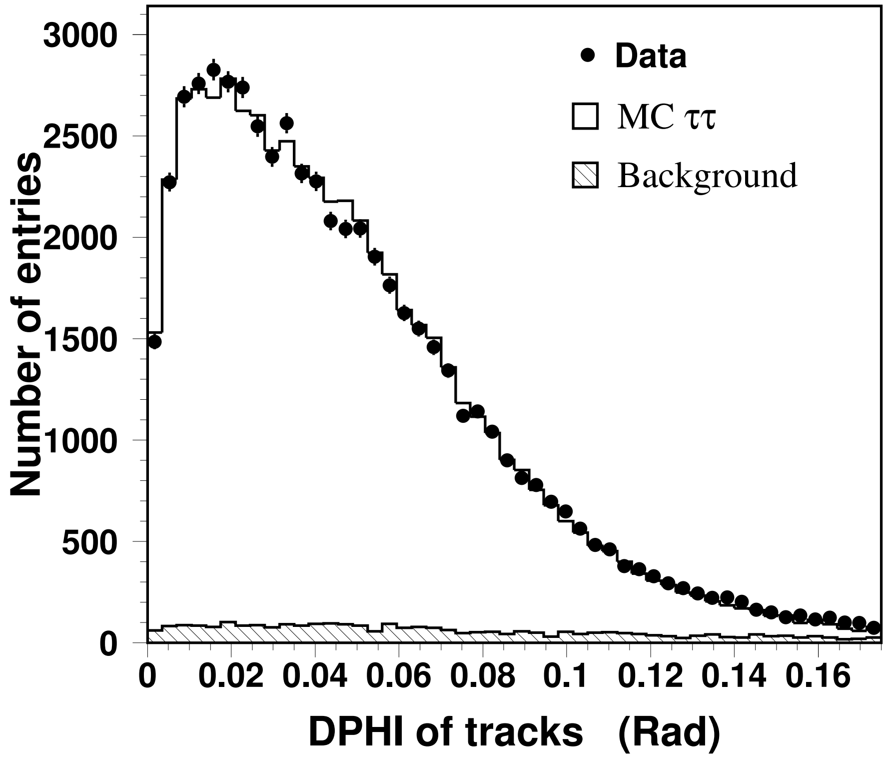



radius of the common vertex (mm)
120
100
80
60
40
20
-0.001
0
0.001
0.002
0.003
0.004
0.005
mass of the two tracks (GeV^2)
DATA 94


180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
radius of the vertex of two tracks (mm)

Double Track Resolution

From $\Delta\phi$ of tracks:



$\Delta\phi$ of any two tracks in a τ decay

From γ conversion events:

$R_2 = N_2/(N_2 + N_1)$

$R_2(data) = 59.6\% \pm 1.6\%$

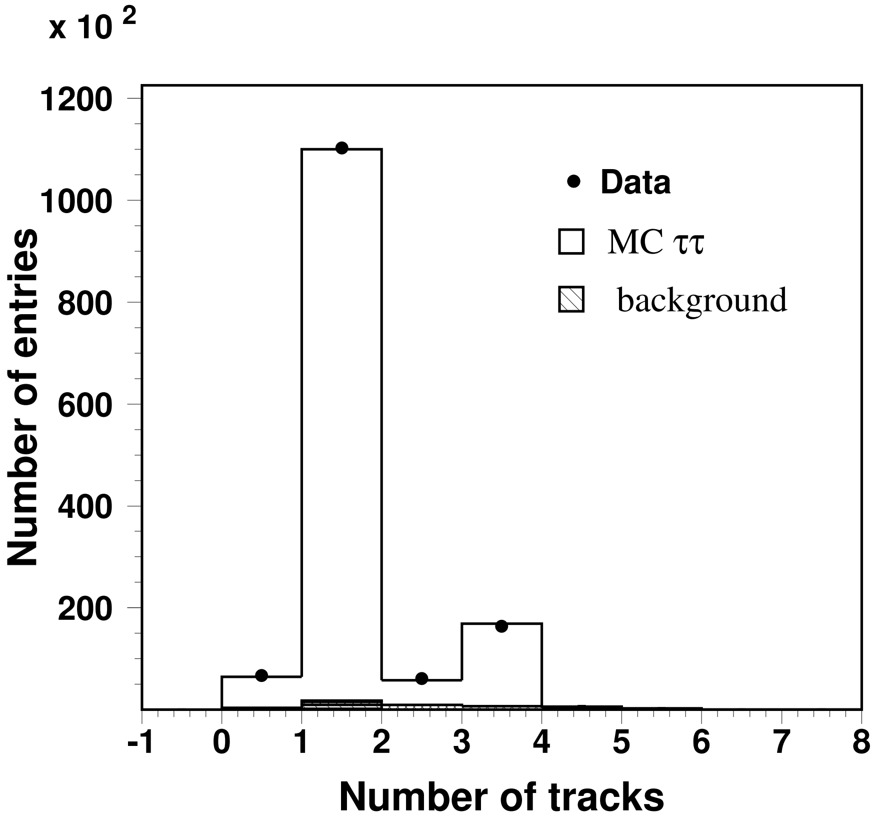
$R_2(MC) = 61.2\% \pm 0.9\%$

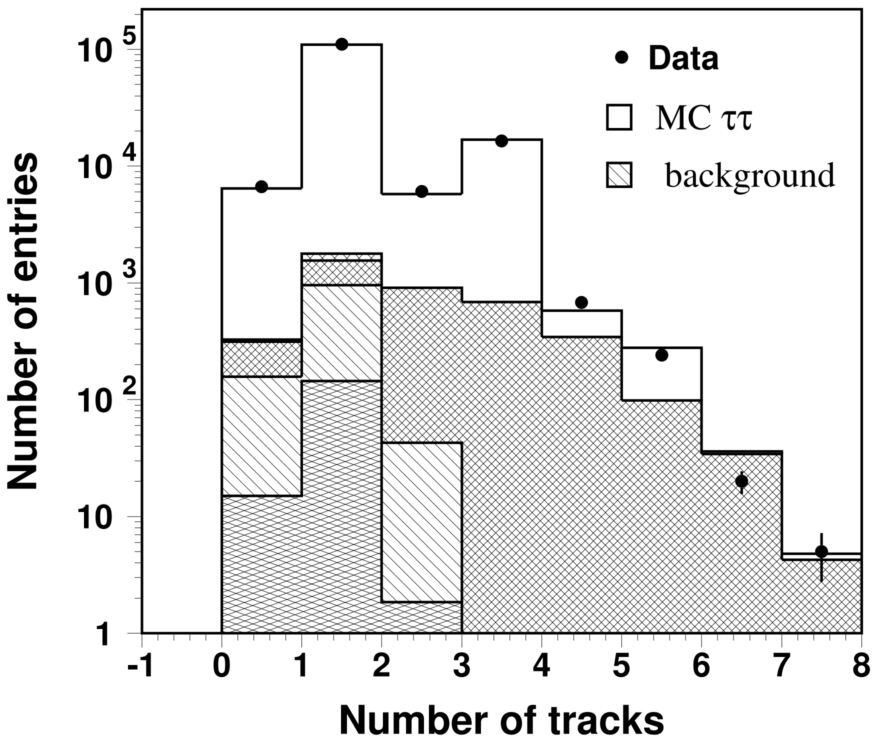
Track efficiency

The track efficiency is: $97\% \pm 0.25\%$

Both in data and MC

The number of tracks from τ decay





Efficiency matrix

	REC	0	1	2	3
	1	4.03 ± 0.02	72.83 ± 0.09	0.40 ± 0.01	0.32 ± 0.01
MC	3	0.44 ± 0.02	4.32 ± 0.06	16.43 ± 0.11	60.93 ± 0.21
Gen	5	0.30 ± 0.18	2.09 ± 0.47	2.13 ± 0.87	14.47 ± 1.36
	REC	4	5	6	7
	1	0.01 ± 0.00	0.003	0	0
MC	3	0.51 ± 0.02	0.17 ± 0.01	0.00	0
Gen	5	23.21 ± 1.57	33.43 ± 1.88	0.13 ± 0.12	0.11 ± 0.11

Fitting Procedure

Maximum Likelihood Function:

$$L = \prod_{i=0}^{7} P(N^i_{obs},\ N^i_{exp})$$

$$N^i_{exp} = \mathcal{L}(\sum_j 2\sigma_{\tau\tau} BR(j)\varepsilon^{ij}) + \sum N^i_{bg}$$

It has been normalised to the number of τ's observed

Result

Topological Branching Ratio:

- BR(1-prong) = $(85.14 \pm 0.27 \pm 0.17)\%$
- BR(3-prong) = $(14.63 \pm 0.13 \pm 0.10)\%$
- BR(5-prong) = $(0.23 \pm 0.01 \pm 0.05)\%$

Correlation coefficients

Source	Br1	Br3	Br5
Br1	1.	-0.196	-0.344
Br3	-0.196	1.	0.057
Br5	-0.344	0.057	1.

Sysmatic error:

- Detector efficiency was studied using data sample
- Background was estimated realistically

Source	Br1	Br3	Br5
MC stat.	0.10	0.05	0.02
$\tau\tau$ sele	0.13	0.08	0.04
MC corr.	0.05	0.04	0.01
total	0.17	0.10	0.05

Topo. systematic summary

Hadronic decay branching ratio measurement

To measure:

- $\tau^- \to h^- + n\pi^0 + \nu$
  n=0, 1, 2, 3 or more
- $\tau^- \to h^- h^+ h^- + m\pi^0 + \nu$
  m=0,1, 2 or more

Procedure:

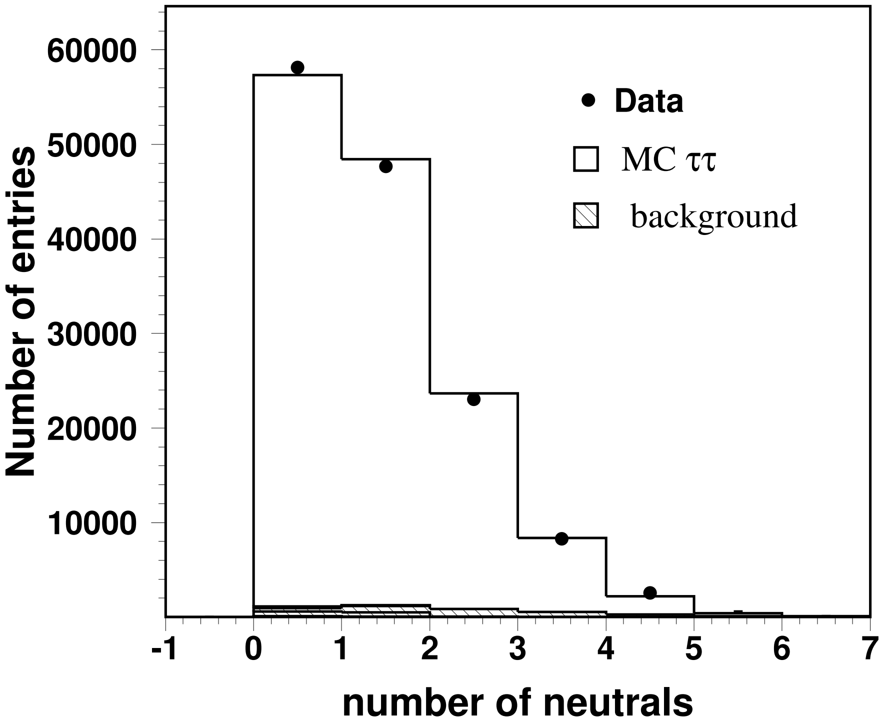
- Using the same sample: consistent measurement
- Reject $\tau \to$ e,μ decay
- Reject τ decay with neutral kaon
- Neutral cluster study: reject fake photon
- Neural network discrimination

Neutral cluster

A neutral cluster is the ECAL cluster that not related to a track.
May be:

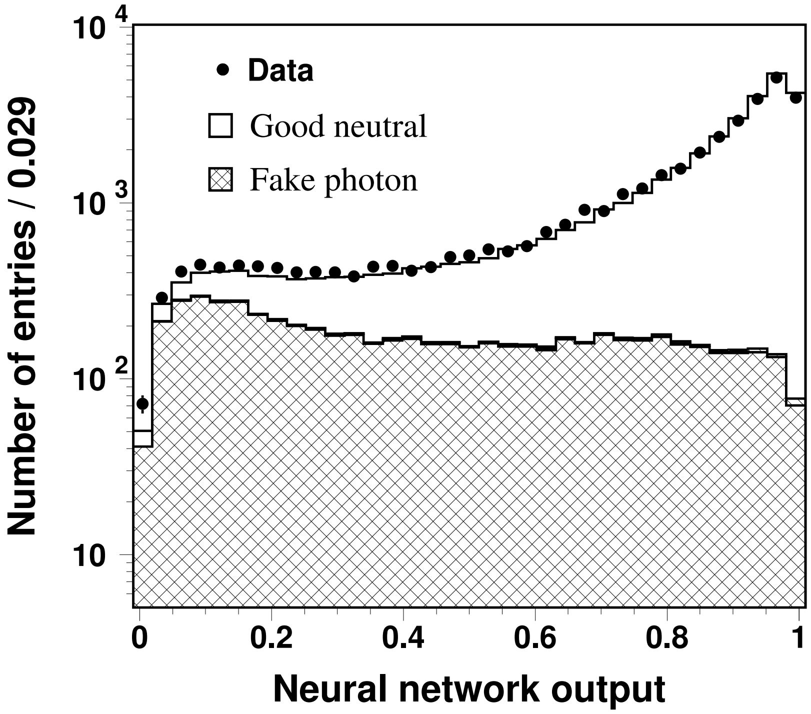
- fake photon
- photon
- unresolved $\pi^0 \rightarrow \gamma\gamma$

The number of neutral clusters per τ decay

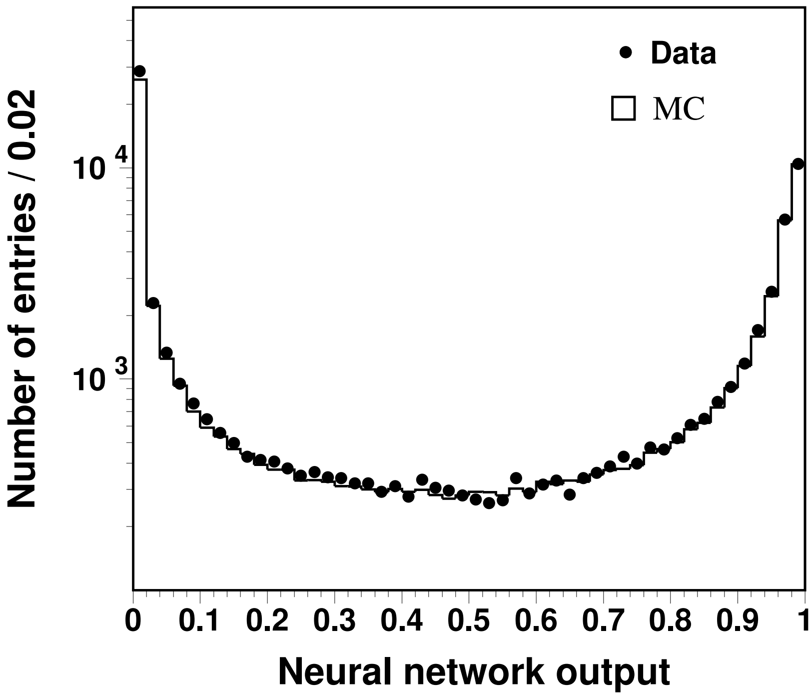


Neutral cluster identification

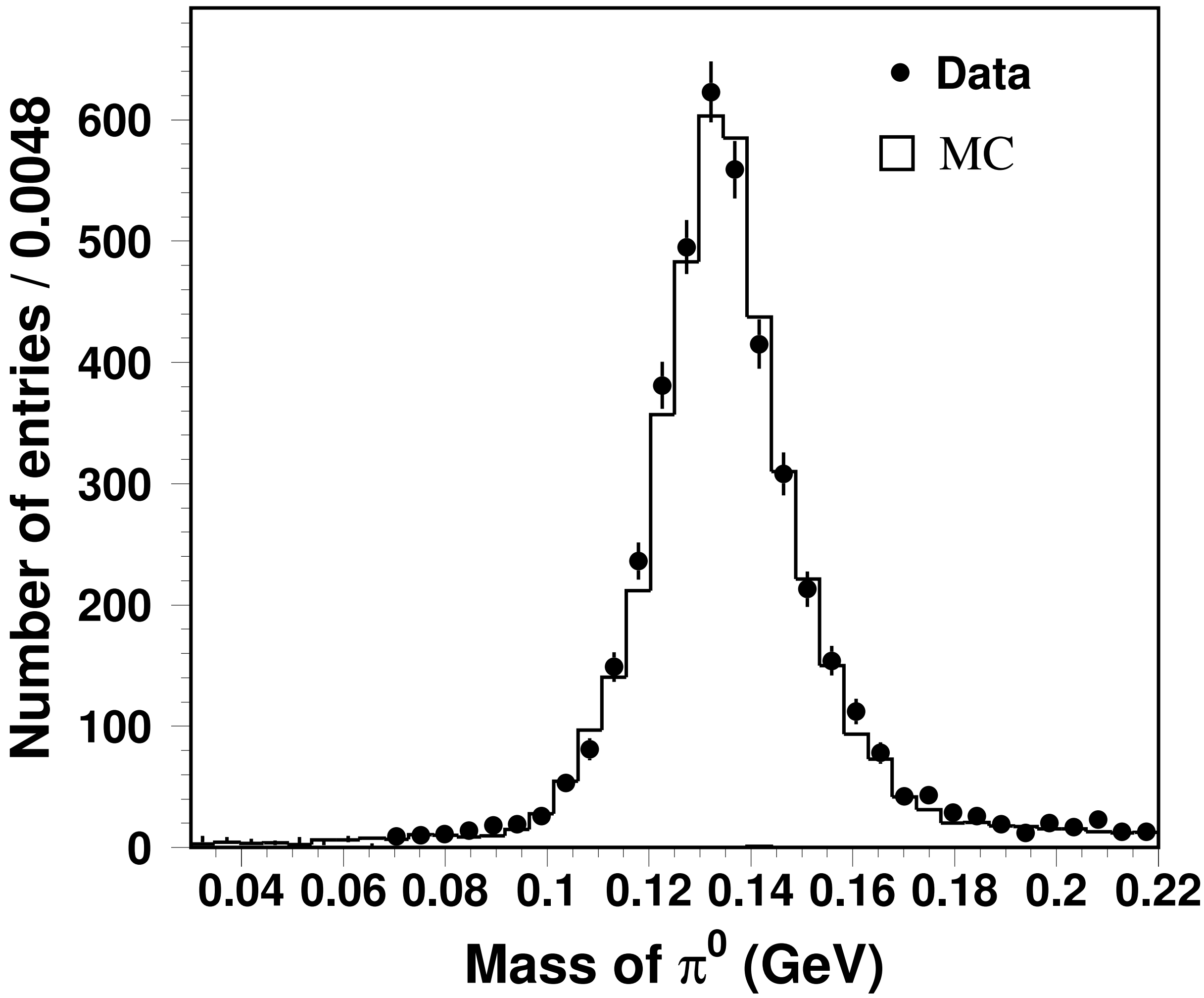
Separate fake/good neutral



separate γ/π^0

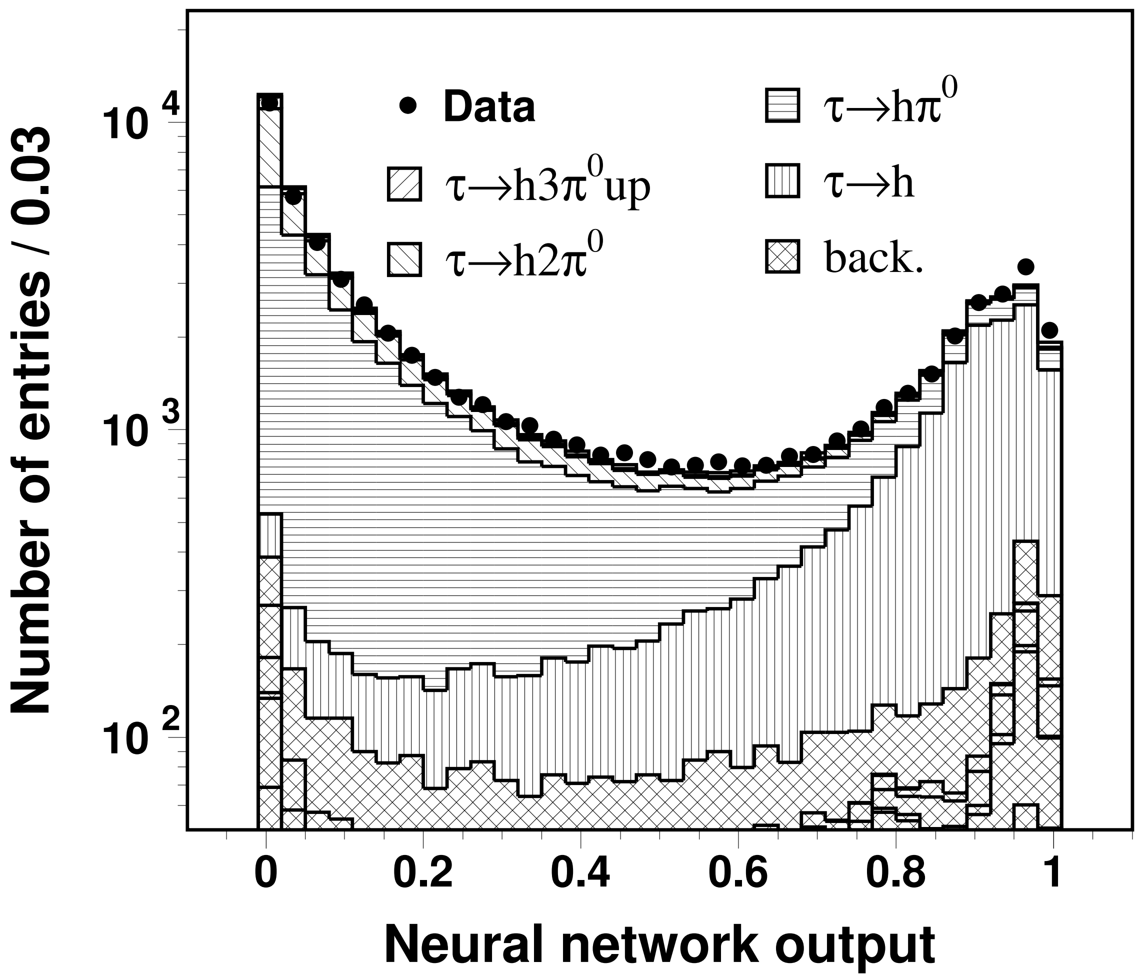


The reconstructure of $\gamma\gamma$ mass



Neural network discrimination

Identify $\tau \to h\nu : Y_h$

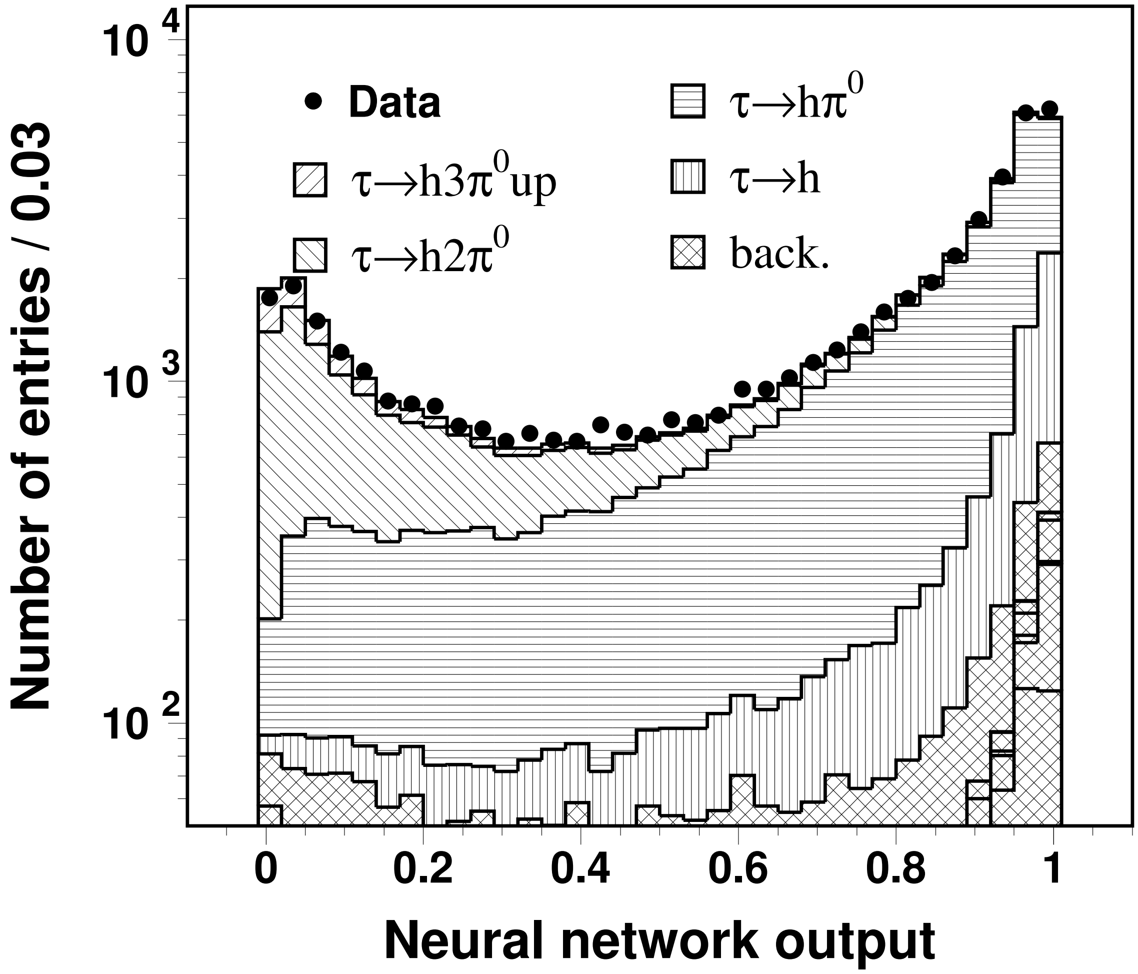


Signal: $\tau \to h\nu$

Background: $\tau \to h + n\pi^0\nu, n > 0$

Neural network discrimination

Identify $\tau \to h + \pi^0\nu$: $Y_{h\pi^0}$

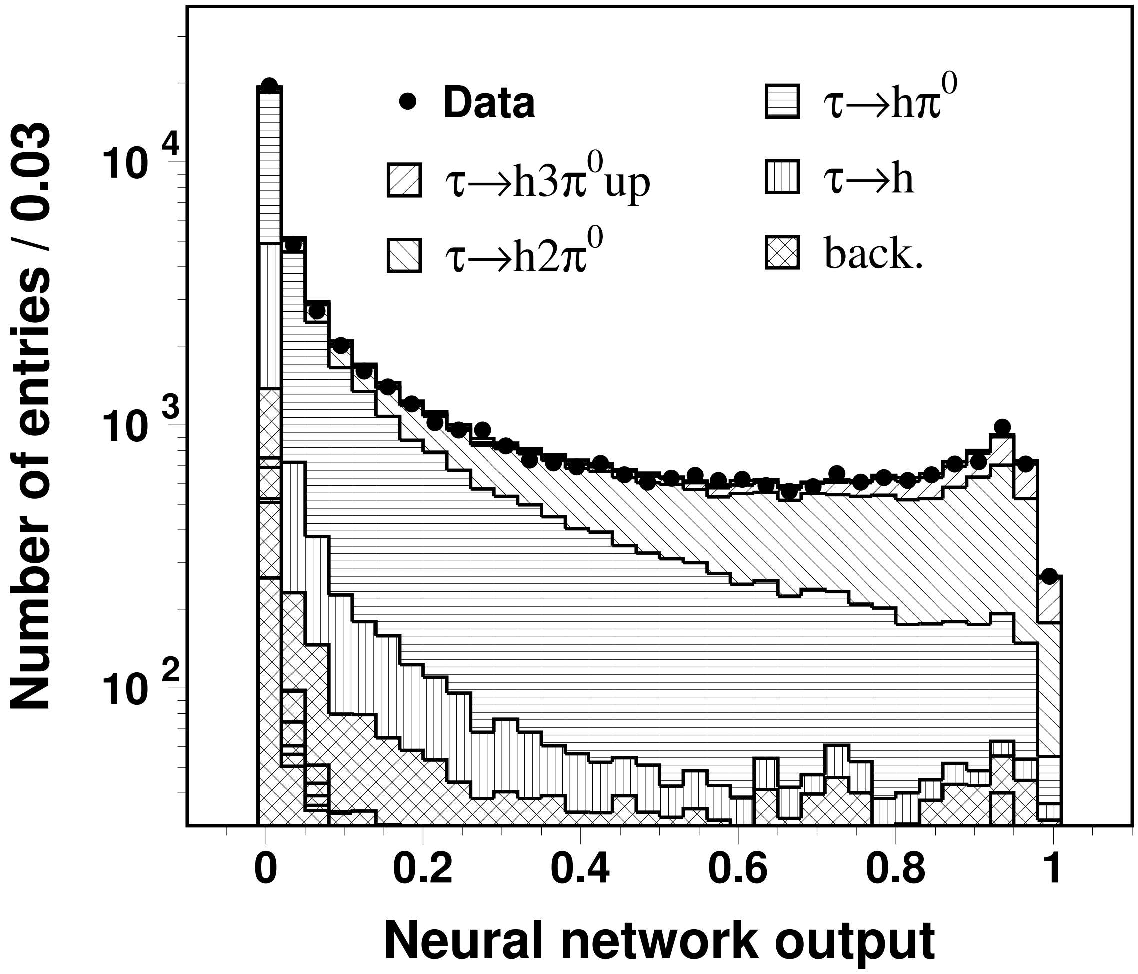


Signal: $\tau \to h + \pi^0\nu$

Background: $\tau \to h + n\pi^0\nu, n > 1$

Neural network discrimination

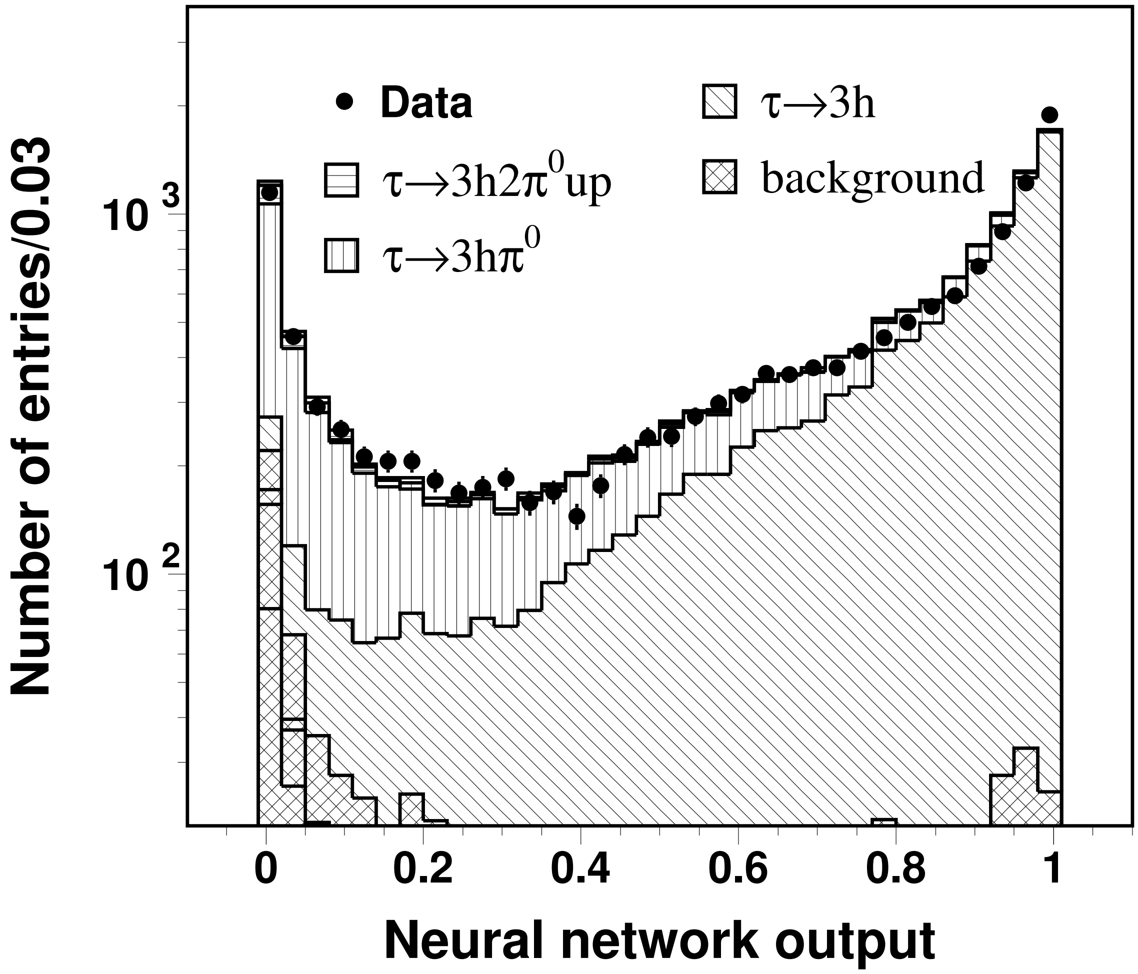
Identify $\tau \to h+ \geq 3\pi^0\nu : Y_{h3\pi^0}$



Signal: $\tau \to h+ \geq 3\pi^0\nu$
Background: $\tau \to h + n\pi^0\nu, n < 3$

Neural network discrimination

Identify $\tau \longrightarrow 3h + \nu : Y_{3h}$

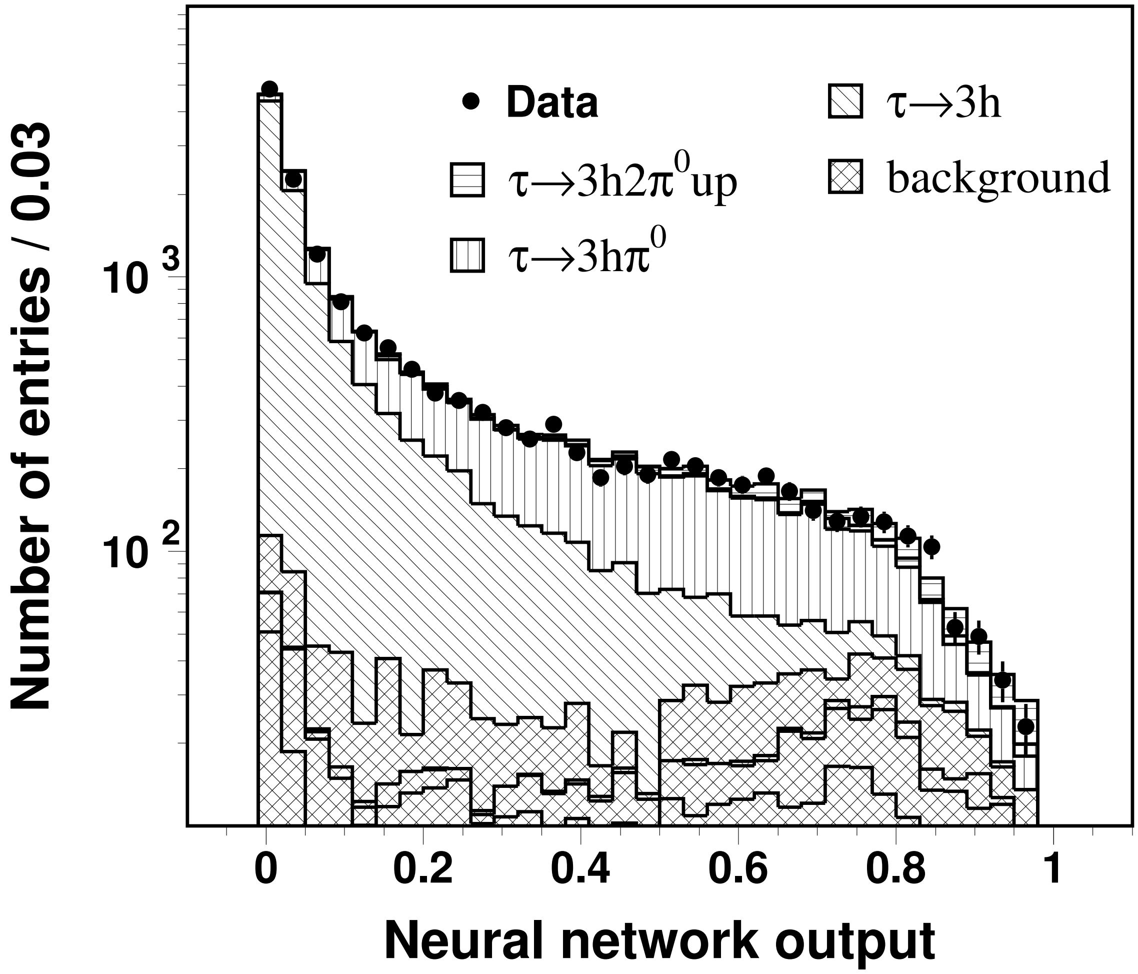


Signal: $\tau \longrightarrow 3h + \nu$

Background: $\tau \longrightarrow 3h + n\pi^0\nu, n > 0$

Neural network discrimination

Identify $\tau \to 3h+ \geq 2\pi^0\nu$: $Y_{3h2\pi^0}$



Signal: $\tau \to 3h+ \geq 2\pi^0\nu$

Background: $\tau \to 3h + n\pi^0\nu, n < 2$

Fitting method

$$\log L = \log L_1 \cdot L_2$$

Tau 1-prong hadronic decays:

$$\log L_1 = \log \prod_i P_1(N^i_{obs},\ N^i_{exp})$$

where i runs through 3 dimensional bins: $Y_h, Y_{h\pi^0}, Y_{h\geq 3\pi^0}$

Tau 3-prong hadronic decays:

$$\ln L_2 = \ln \prod_i P_2(N^i_{obs},\ N^i_{exp})$$

where i runs through 2 dimensional bins: $Y_{3h} Y_{3h2\pi^0}$

$$N^i_{exp} = \mathcal{L}(\sum_j 2\sigma_{\tau\tau} BR(j)\varepsilon^{ij}) + \sum N^i_{bg}$$

Hadronic decay branching ratio

τ hadronic decay branching ratio :

$$
\begin{aligned}
BR(h\nu) &= (12.51 \pm 0.12 \pm 0.12)\ \% \\
BR(h\pi^0\nu) &= (25.38 \pm 0.18 \pm 0.12)\ \% \\
BR(h2\pi^0\nu) &= (8.98 \pm 0.21 \pm 0.19)\ \% \\
BR(h+\geq 3\pi^0\nu) &= (1.77 \pm 0.14 \pm 0.15)\ \% \\
BR(3h\nu) &= (9.11 \pm 0.15 \pm 0.07)\ \% \\
BR(3h\pi^0\nu) &= (4.77 \pm 0.19 \pm 0.08)\ \% \\
BR(3h+\geq 2\pi^0\nu) &= (0.45 \pm 0.10 \pm 0.11)\ \%
\end{aligned}
$$

Correlation coefficients

Tau 1-prong decays	$h\nu$	$h\pi^0\nu$	$h2\pi^0\nu$	$h \geq 3\pi^0\nu$
$h\nu$	1.000	-.055	-.119	-.045
$h\pi^0\nu$	-.055	1.000	-.358	.203
$h2\pi^0\nu$	-.119	-.358	1.000	-.796
$h \geq 3\pi^0\nu$	-.045	.203	-.796	1.000
Tau 3-prong decays	3hν	3h$\pi^0\nu$	3h$\geq$2$\pi^0\nu$	
3hν	1.000	-.482	.117	
3h$\pi^0\nu$	-.482	1.000	-.662	
3h$\geq$2$\pi^0\nu$	.117	-.662	1.000	

Systematic error source:

- $\tau\tau$ selection
- Backgrounds
- fake photon rejection
- Scale uncertainty
- Binning

Conclusion

Topological Branching Ratio:

- BR(1-prong) = $85.14 \pm 0.27 \pm 0.17\%$
- BR(3-prong) = $14.63 \pm 0.13 \pm 0.10\%$
- BR(5-prong) = $0.23 \pm 0.01 \pm 0.05\%$

Sum up L3 exclusive 1-prong decay: $85.46\% \pm 0.49\%$
Sum up L3 exclusive 3-prong decay: $14.33\% \pm 0.30\%$

Hadronic Decay Branching Ratio:

$$
\begin{aligned}
BR(h\nu) &= (12.51 \pm 0.12 \pm 0.12)\ \% \\
BR(h\pi^0\nu) &= (25.38 \pm 0.18 \pm 0.12)\ \% \\
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BR(3h+\geq 2\pi^0\nu) &= (0.45 \pm 0.10 \pm 0.11)\ \%
\end{aligned}
$$

Other related L3 measurements:

- BR(e$\nu\bar{\nu}$) = $(17.81 \pm 0.10 \pm 0.08)\%$
- BR($\mu\nu\bar{\nu}$) = $(17.34 \pm 0.11 \pm 0.07)\%$
- BR(decay with K^0) = $(1.67 \pm 0.10 \pm 0.06)\%$