RESULTS FROM LSND

— Final Oscillation Analysis —

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R. Imlay (L.S.U.)

LSND Collaboration:

U.C. Riverside, U.C. San Diego

U.C. Santa Barbara, Linfield College

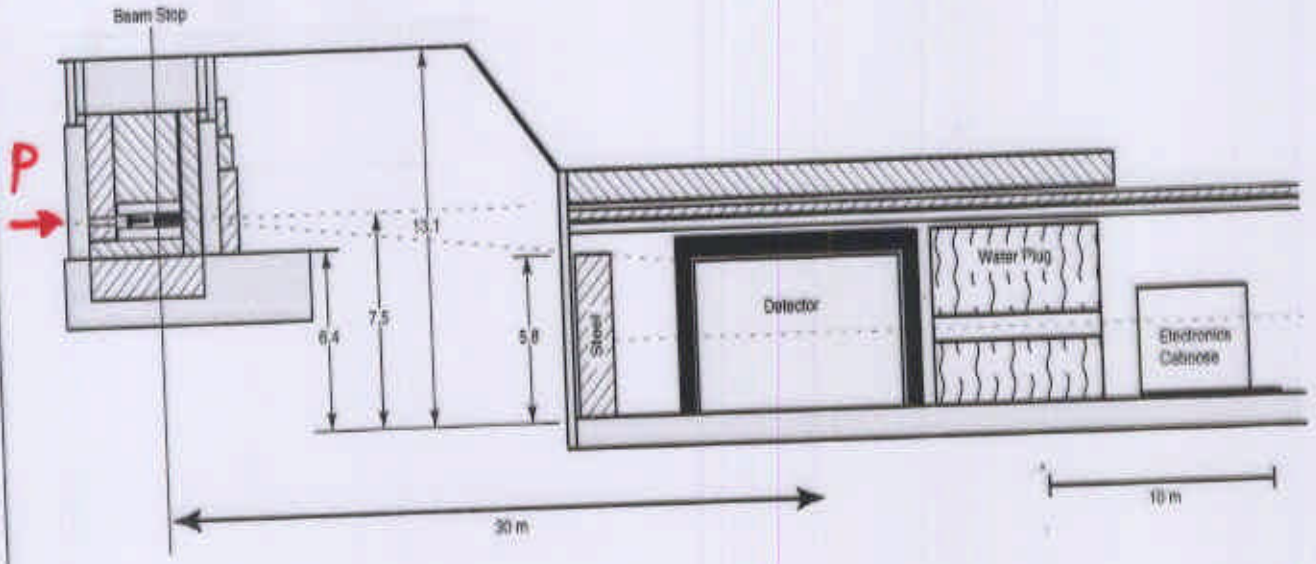
Embry Riddle Aeronautical University

Los Alamos National Laboratory

Louisiana State University

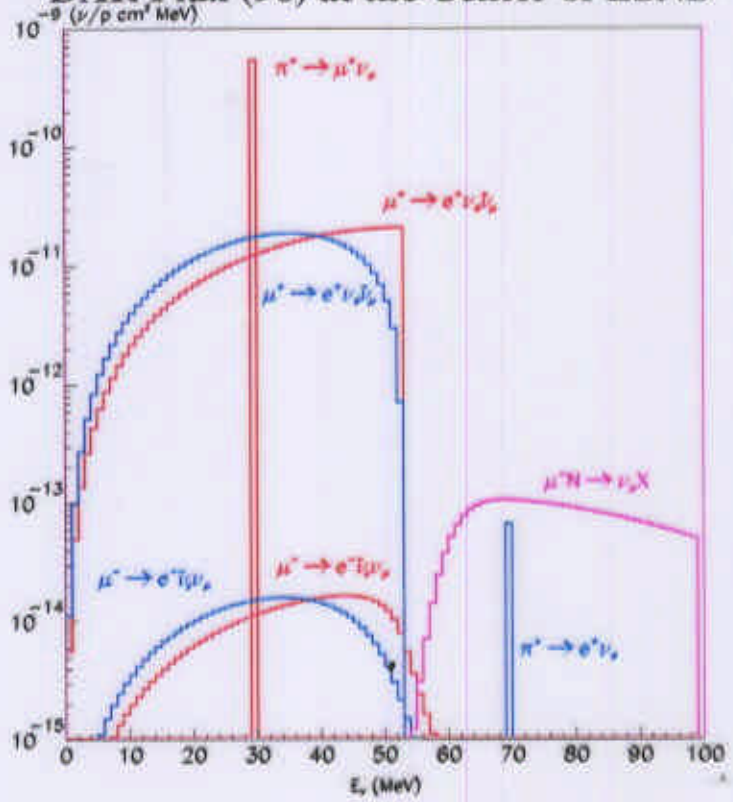
Southern University

Schematic View of Proton Beam Dump and LSND Detector

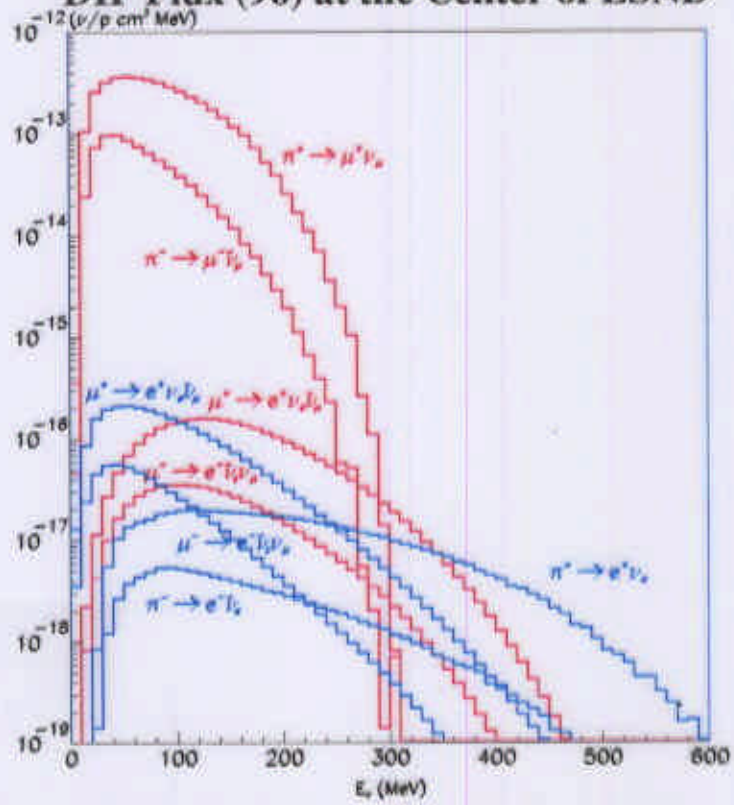


- Proton Beam: 800MeV, 1mA, ~6% duty ratio
- Pion Production: $\pi^+/\pi^- \sim 8$
- Decay-at-rest: $\pi^+ \to \mu^+ + \nu_\mu$, $\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$
- Decay-in-flight: $\pi^+ \to \mu^+ + \nu_\mu$, $\pi^- \to \mu^- + \bar{\nu}_\mu$
- Detector: 1220 8-inch PMT's
  167 tons of Mineral Oil (CH_2)
- Veto Shield: 292 5-inch PMT's

DAR Flux (96) at the Center of LSND



DIF Flux (96) at the Center of LSND



ν Oscillation Events Signature

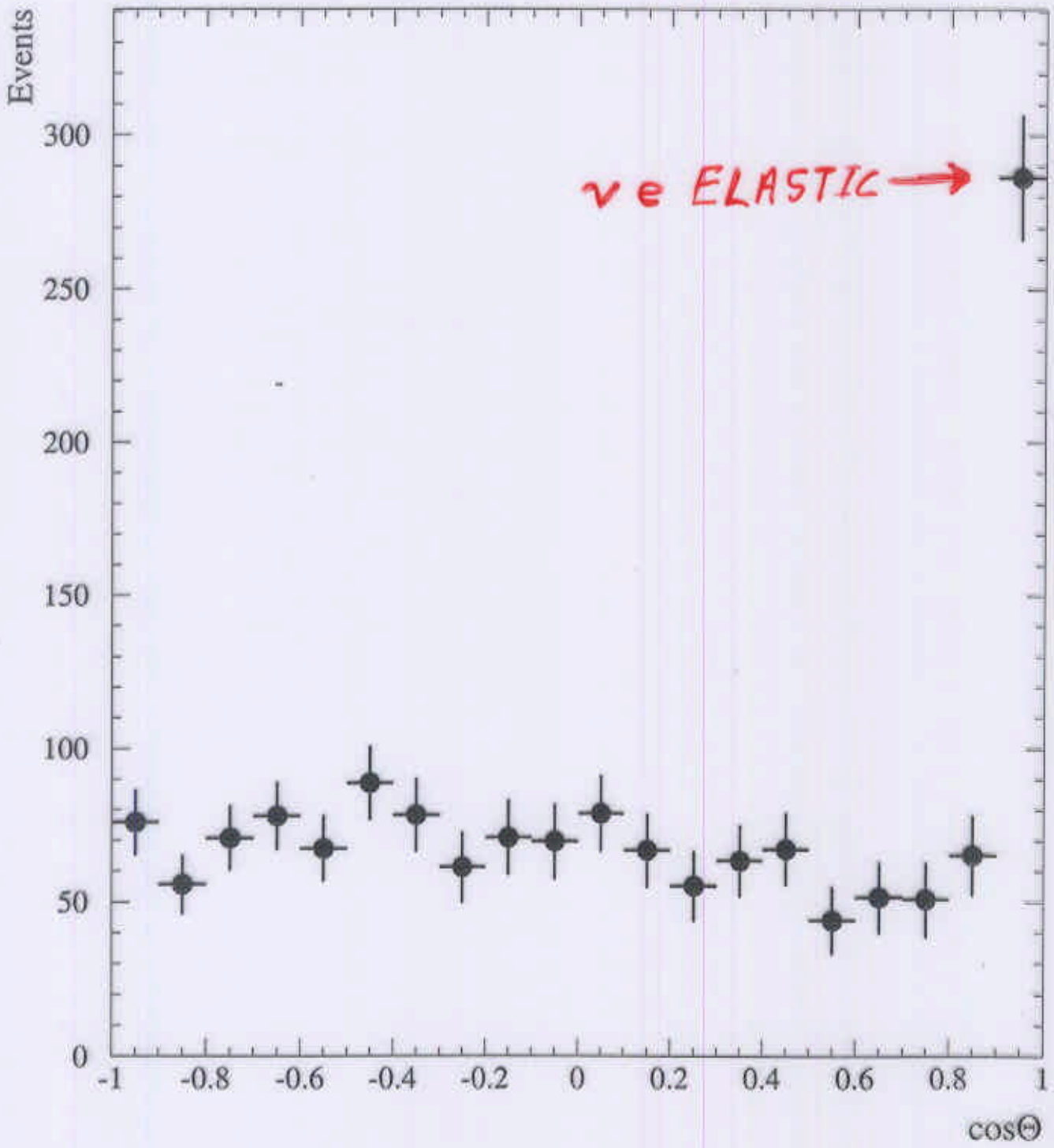
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation

$\bar{\nu}_e + p \rightarrow e^+ + n$

$\downarrow \ \tau = 186\mu s$

$n + p \rightarrow d + \gamma(2.2\text{MeV})$

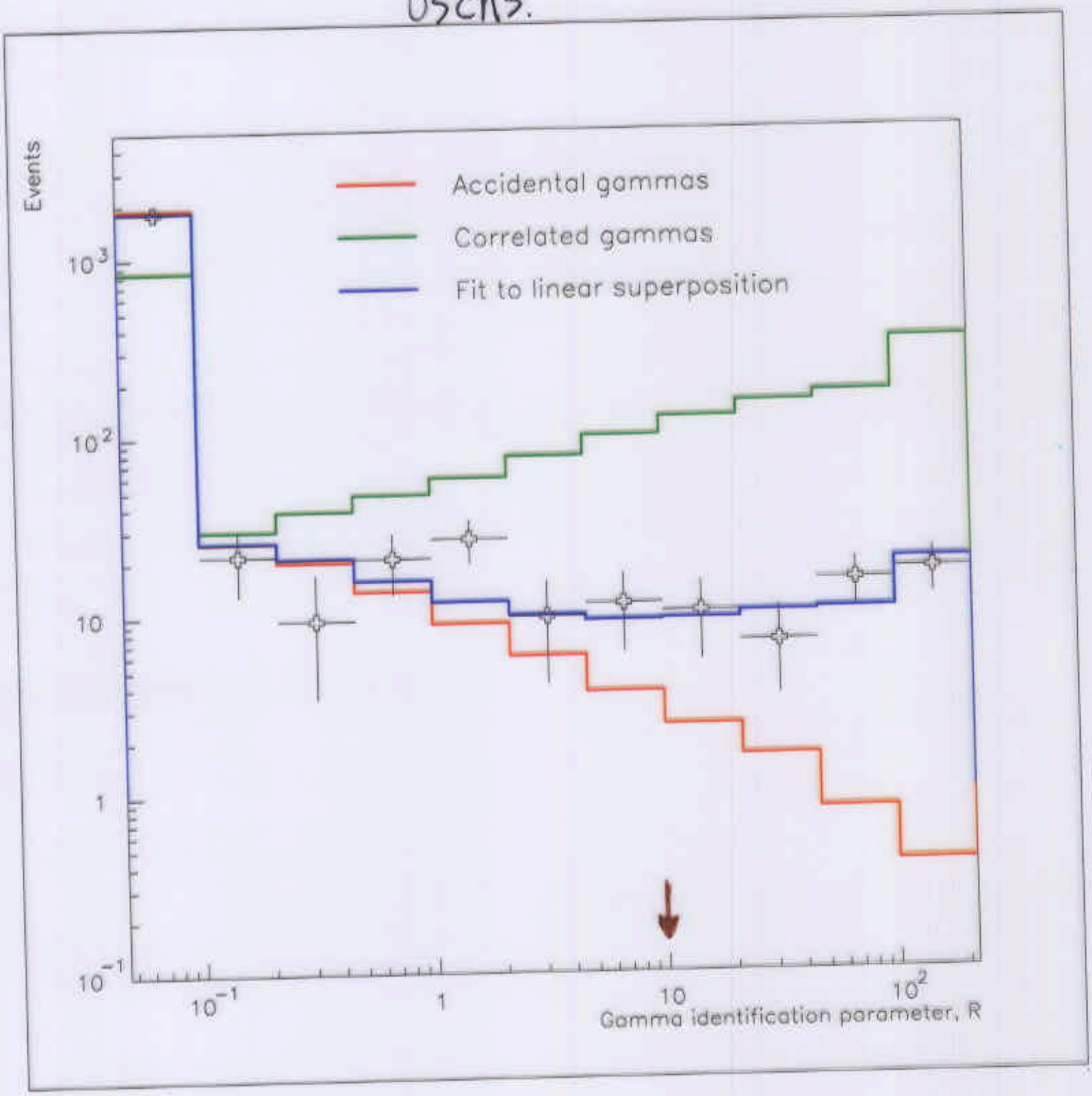
- e^+ selection
  - Particle ID — cut cosmic n's, $\mu^\pm$'s
  - d_{PMT} >35cm — fiducial volume
  - $\Delta t_{previous} > 12\mu s$ — cut $\mu^\pm$ decay event
  - $\Delta t_{next} > 8\mu s$ — cut $\mu^\pm$ decay event
  - $N_\gamma < 2$ — cut cosmic neutrons
  - <4 veto hits — cut cosmics
- γ selection
  - Likelihood ratio, R method (temporal and spatial correlation, PMT's hit)


Events
300
250
200
150
100
50
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
cosΘ
ν e ELASTIC

Analysis Improvements

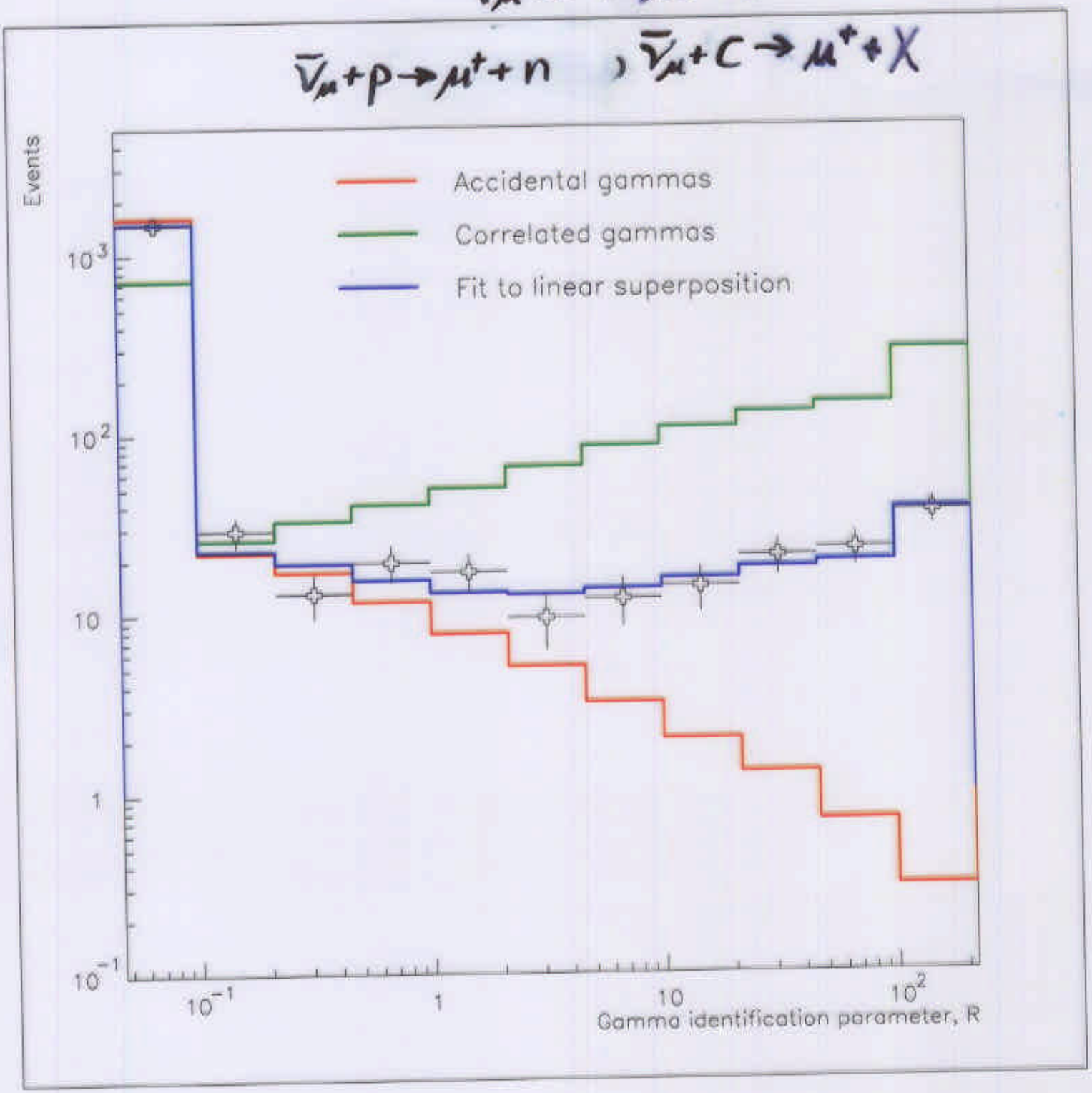
- Improved position resolution for 2.2MeV γ's
  - correlated γ efficiency 23% $\rightarrow$ 40%
  - accidental γ acceptance 0.6% $\rightarrow$ 0.23%
- Global fit to all neutrino processes in order to constrain backgrounds
- Combined decay-at-rest + decay-in-flight treatment when determining oscillation parameters

OSCNS.

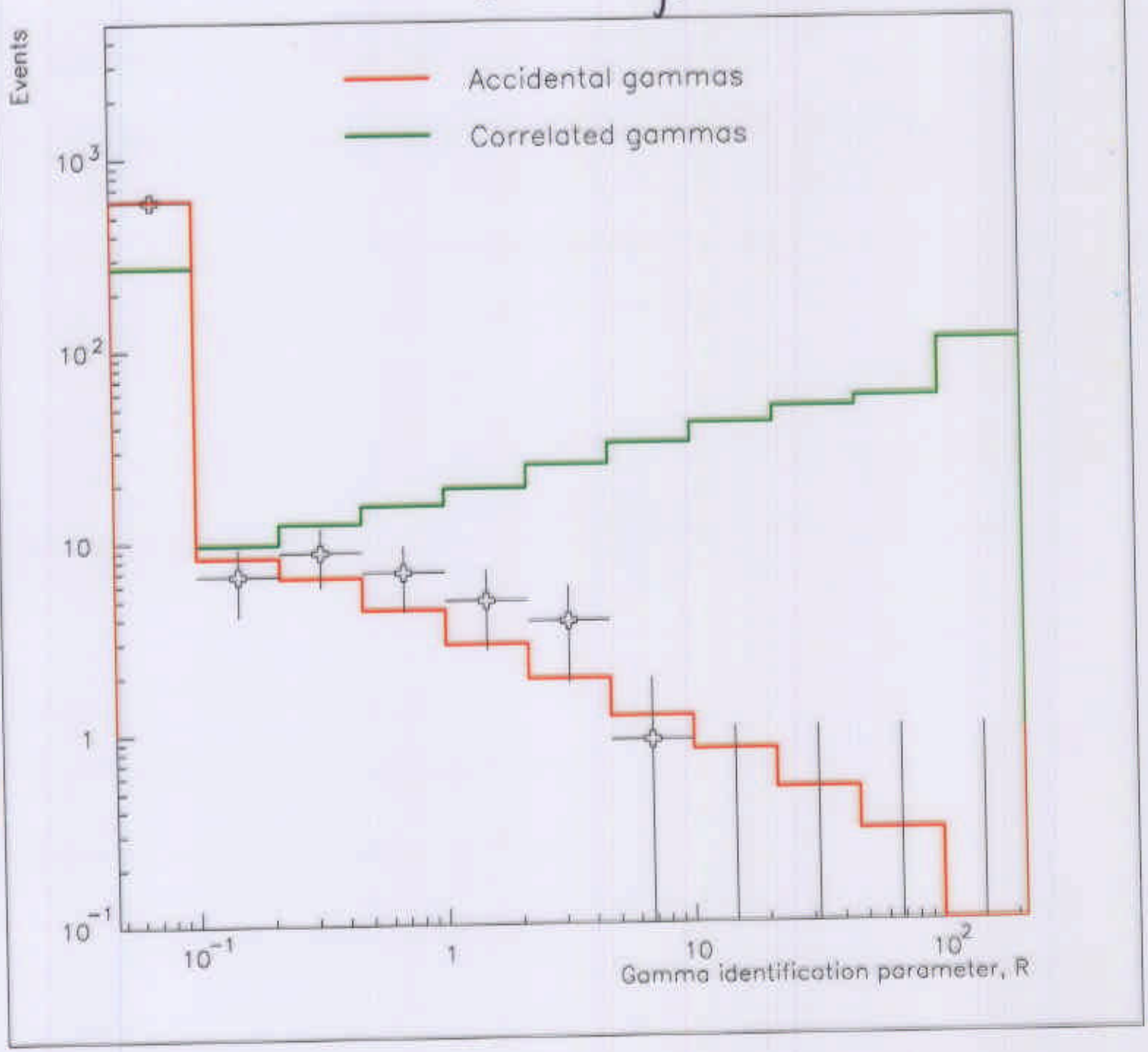

Events
Accidental gammas
Correlated gammas
Fit to linear superposition
10^3
10^2
10
1
10^{-1}
10^{-1}
1
10
10^2
Gamma identification parameter, R

$\nu_\mu C \to \mu^- + X$

$\bar{\nu}_\mu + p \to \mu^+ + n$, $\bar{\nu}_\mu + C \to \mu^+ + X$



$\nu_e C \rightarrow N_{gs} + e^-$



Neutrino Oscillations 20-60MeV

- R>10 Selection

on	off	ν bkgd	excess
83	(-)33.7	(-)16.6	32.7±9.2

  - ν bkgd with neutron
    * 8.5 events

      $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$ in beam dump

      $\bar{\nu}_e + p \rightarrow e^+ + n$ in detector
    * 3.5 events

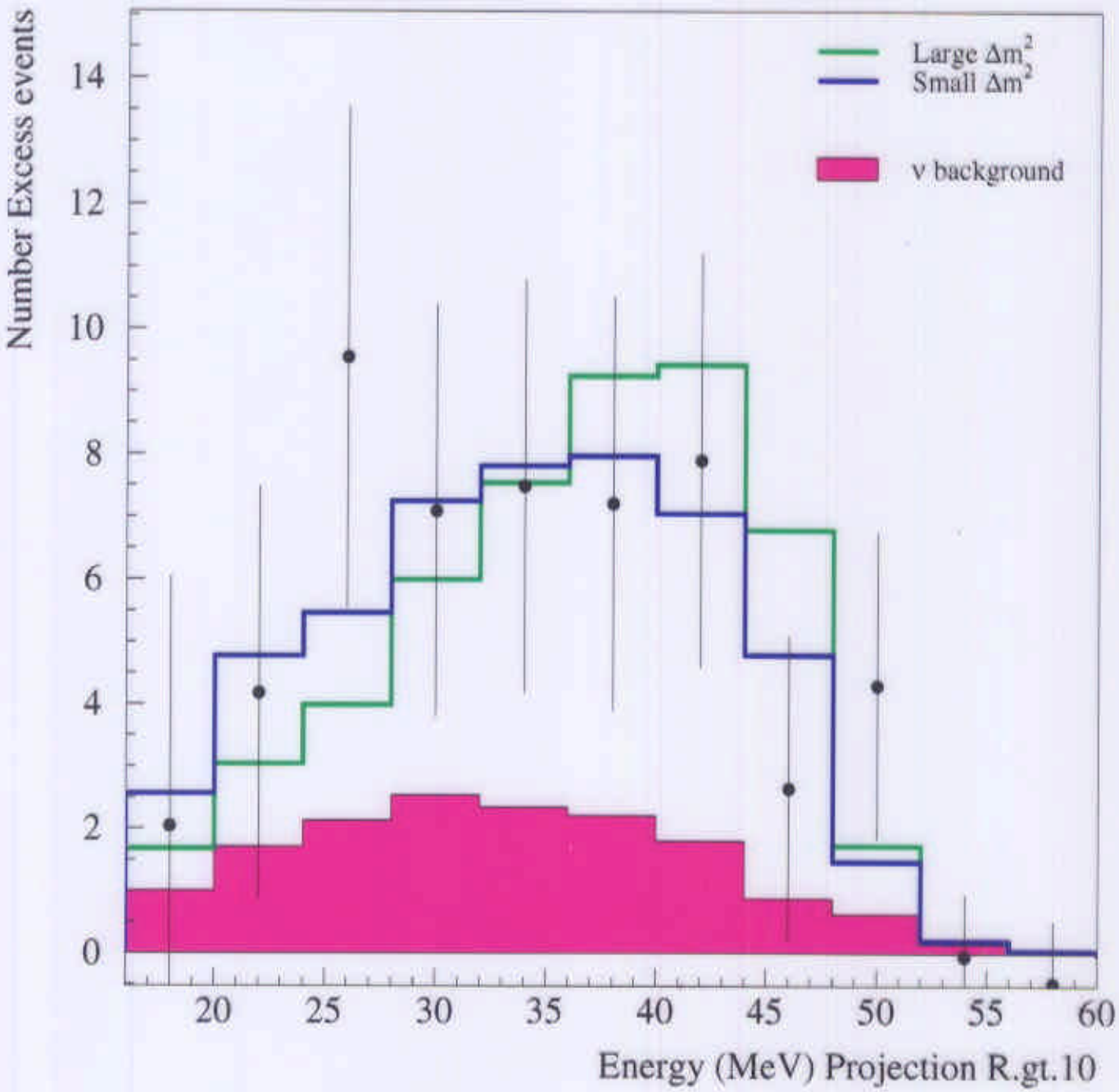
      $\bar{\nu}_\mu + p \rightarrow \mu^+ + n$ (also $\bar{\nu}_\mu C$ and $\nu_\mu C$)

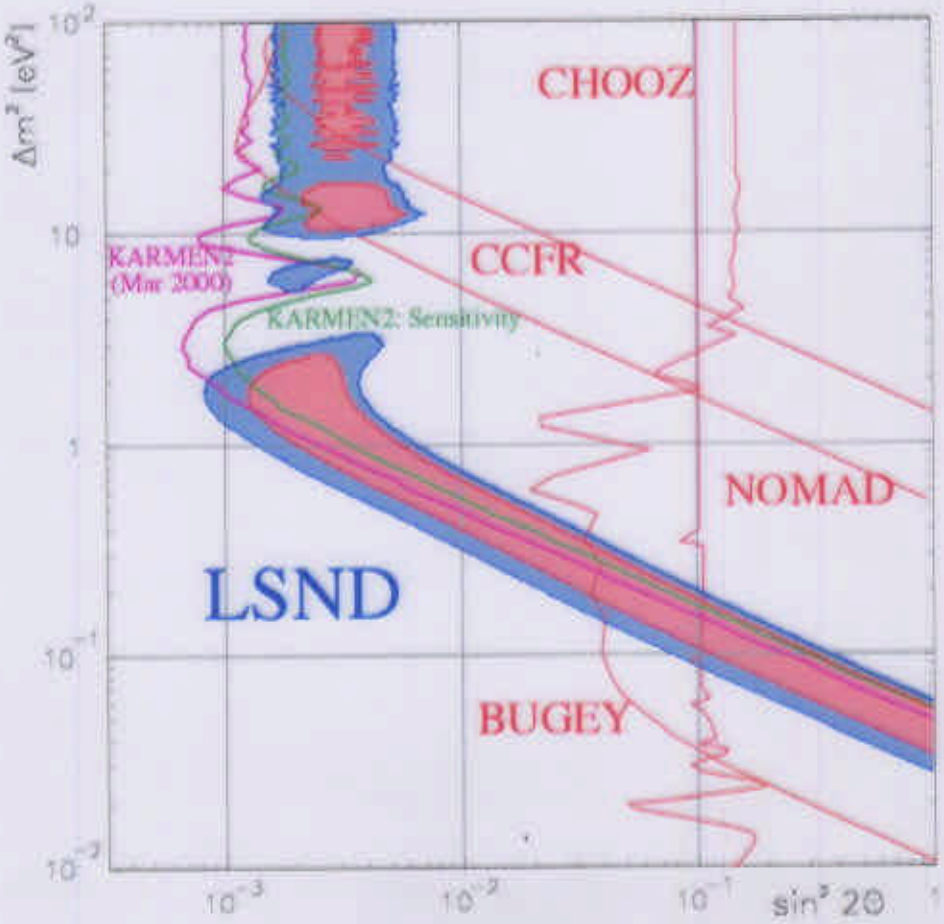
      see e^+ from μ^+ decay

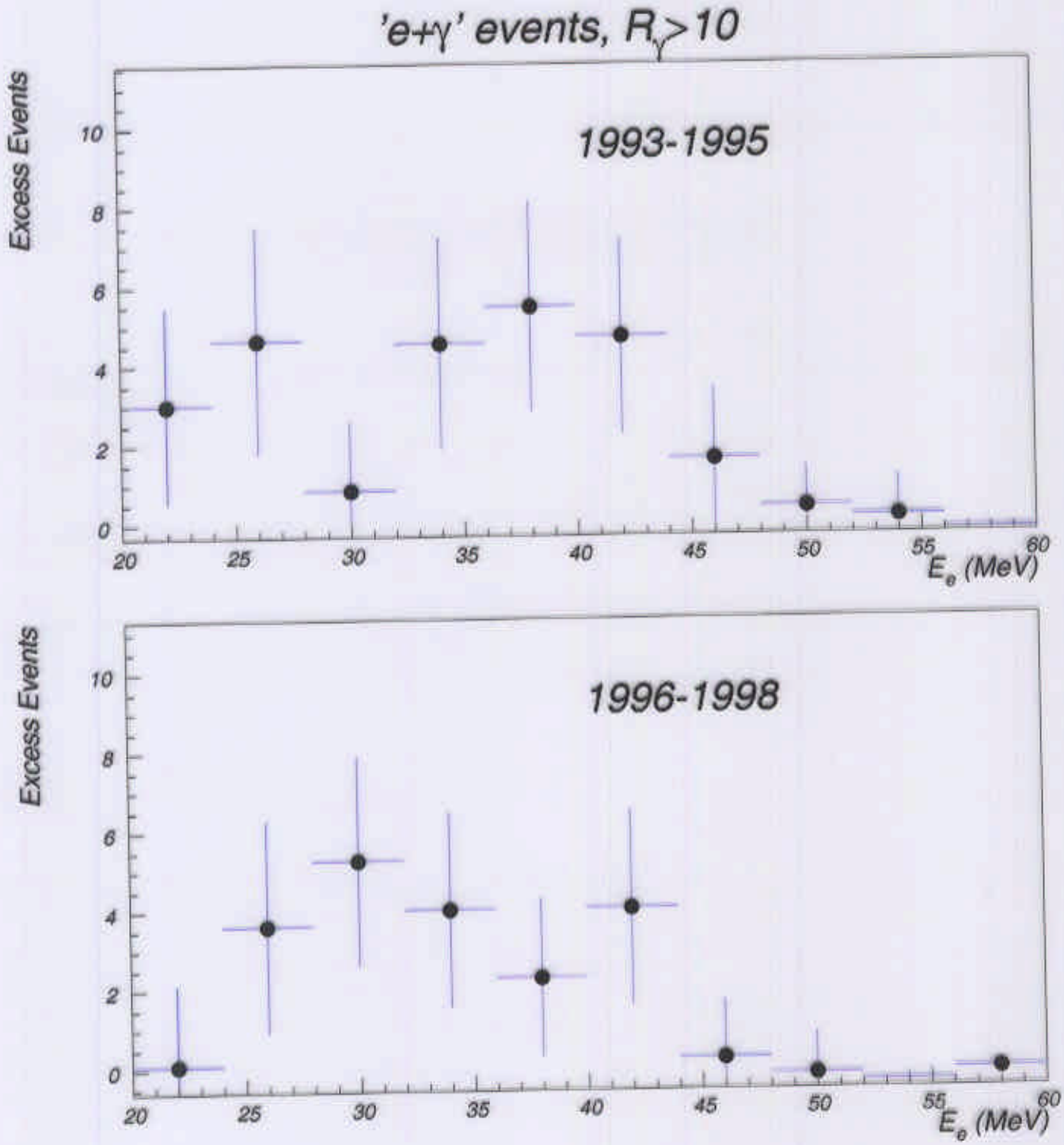
      miss μ^+

- Fit to R distribution

Oscillation Excess	Oscillation Probability
83.3±21.2	(0.25±0.06±0.04)%


Number Excess events
14
12
10
8
6
4
2
0
20
25
30
35
40
45
50
55
60
Energy (MeV) Projection R.gt.10
Large Δm²
Small Δm²
ν background


CHOOZ
CCFR
KARMEN2
(May 2000)
KARMEN2: Sensitivity
NOMAD
LSND
BUGEY
Δm^2 [eV^2]
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-2}
10^{-1}
sin^2 2Θ


'e+γ' events, R_γ>10
Excess Events
1993-1995
0
2
4
6
8
10
20
25
30
35
40
45
50
55
60
E_e (MeV)
Excess Events
1996-1998
0
2
4
6
8
10
20
25
30
35
40
45
50
55
60
E_e (MeV)

Conclusion

- LSND observes excess of events consistent with $\bar{\nu}_e + p \rightarrow e^+ + n$
- A natural explanation is $\bar{\nu}_e$ appearance due to flavor oscillation with probability $(0.25 \pm 0.06 \pm 0.04)\%$ and $\Delta m^2 > 0.2 eV^2$
- Mini-BooNE experiment at Fermilab will either establish or rule out oscillation explanation of LSND signal. Mini-BooNE can measure $\sin^2 2\theta, \Delta m^2$.