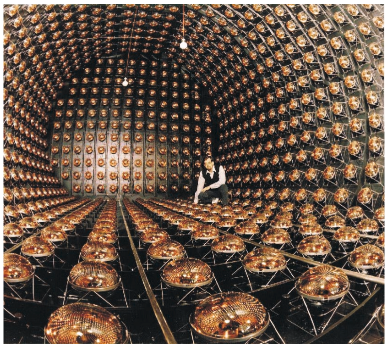
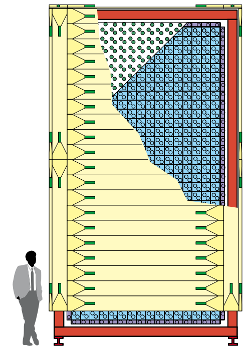
Final LSND and KARMEN-2 Neutrino Oscillation Results



EPS HEP 2001
Budapest, 12.7. - 18.7.2001

Joachim Wolf
KARMEN Collaboration
University of Karlsruhe



Physics	LSND	KARMEN
Search for Neutrino Oscillations		
$\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e$ (DAR)	●	●
$\nu_\mu \leftrightarrow \nu_e$ (DAR)	-	●
$\nu_\mu \leftrightarrow \nu_e$ (DIF)	●	-
Neutrino-Nucleus Cross Sections		
$^{12}C(\nu_e, e^-)^{12}N_{gs}$ (CC, DAR)	●	●
$^{12}C(\nu_e, e^-)^{12}N^*$ (CC, DAR)	●	●
$^{13}C(\nu_e, e^-)^{13}N$ (CC, DAR)	●	●
$^{56}Fe(\nu_e, e^-)^{56}Co$ (CC, DAR)	-	●
$^{12}C(\nu, \nu)^{12}C^*(15.1\,\mathrm{MeV})$ (NC, DAR)	-	●
ν-e scattering	●	-
$^{12}C(\nu_\mu, \mu^-)^{12}N_{gs}$ (CC, DIF)	●	-
$^{12}C(\nu_\mu, \mu^-)^{12}N^*$ (CC, DIF)	●	-

LSND Collaboration

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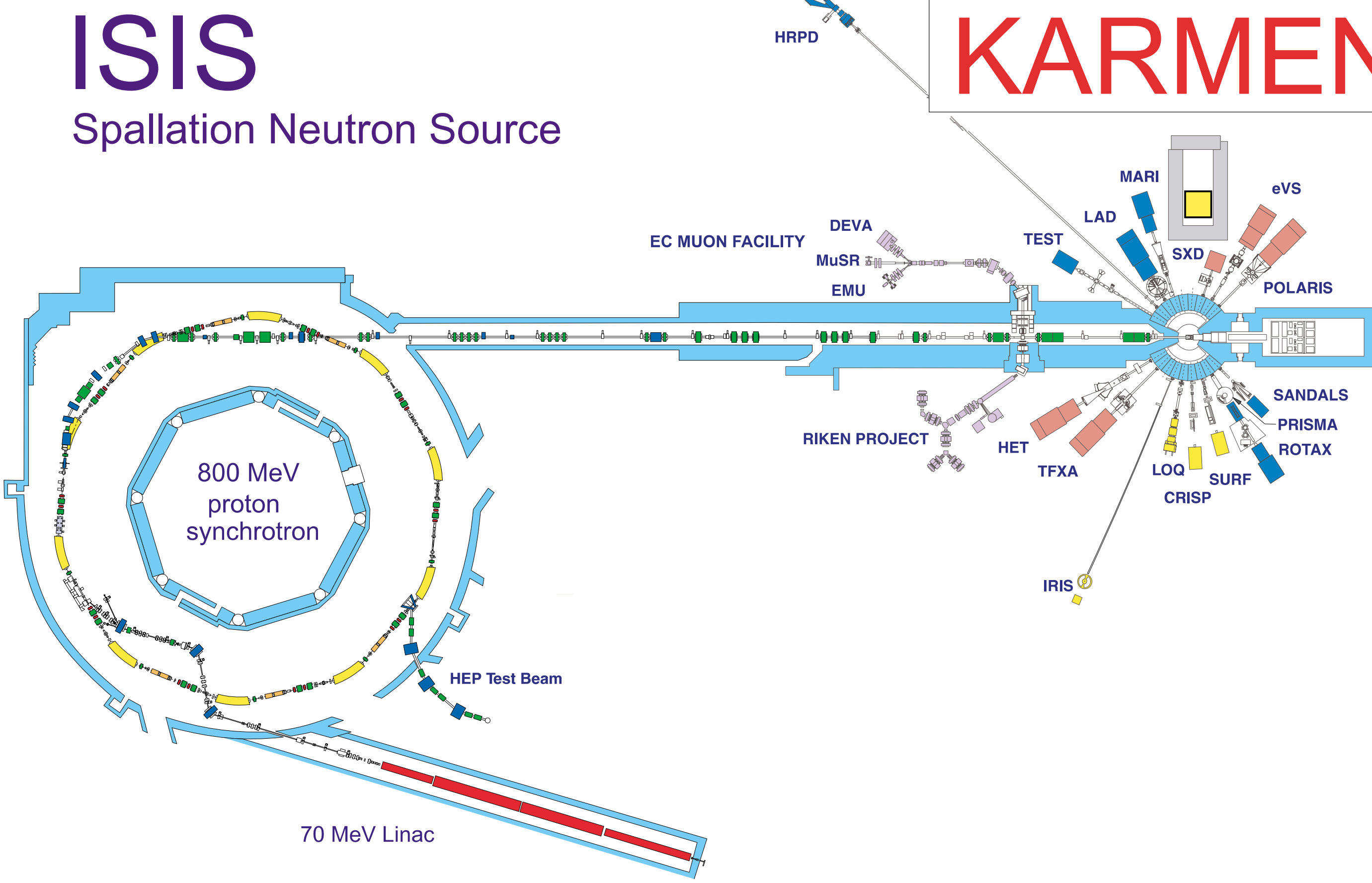
ISIS

Spallation Neutron Source

KARMEN



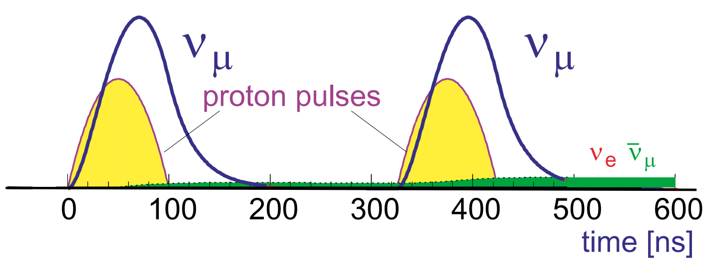
200 μA beam
800 MeV protons
50 Hz repetition
100 ns double-pulse

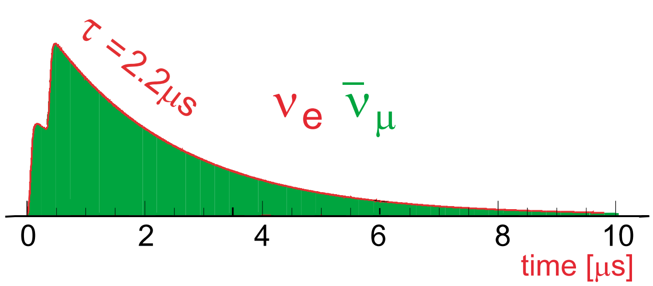
ν production at ISIS

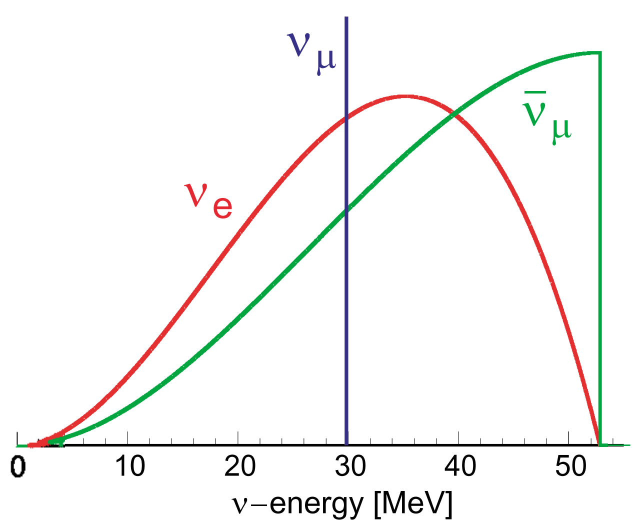
$$\pi^+ \xrightarrow[26\ \text{ns}]{} \mu^+ + \nu_\mu$$

$$\downarrow 2.2\ \mu\text{s}$$

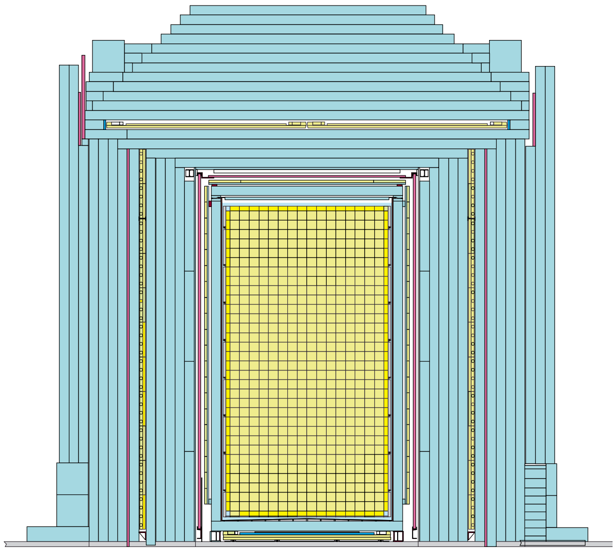
$$e^+ + \nu_e + \bar{\nu}_\mu$$





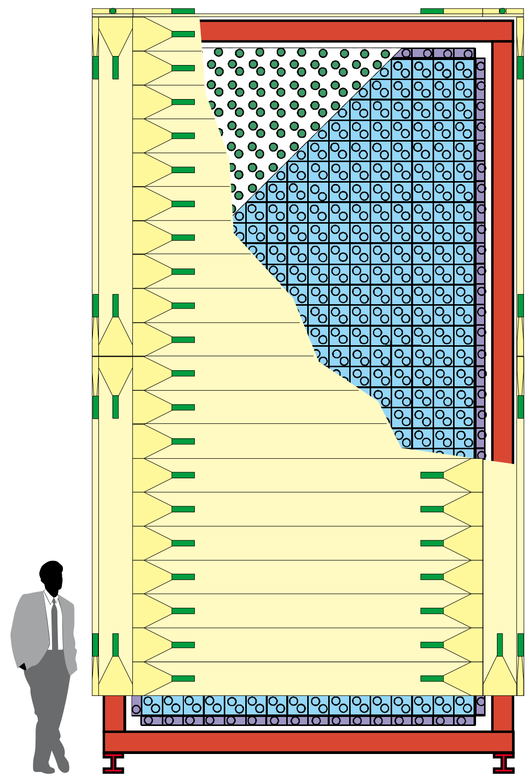


KARMEN Detector



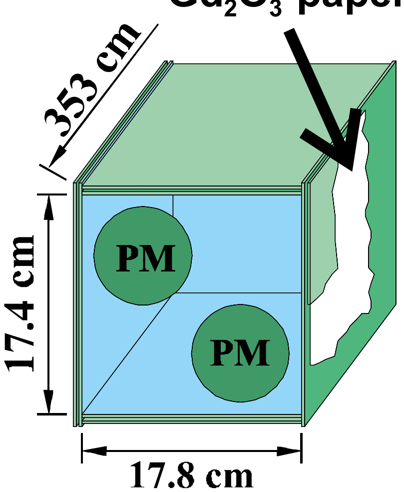
Shielding

- 7000 t steel blockhouse
- 400 m^2 active veto counter in bunker walls



Detector

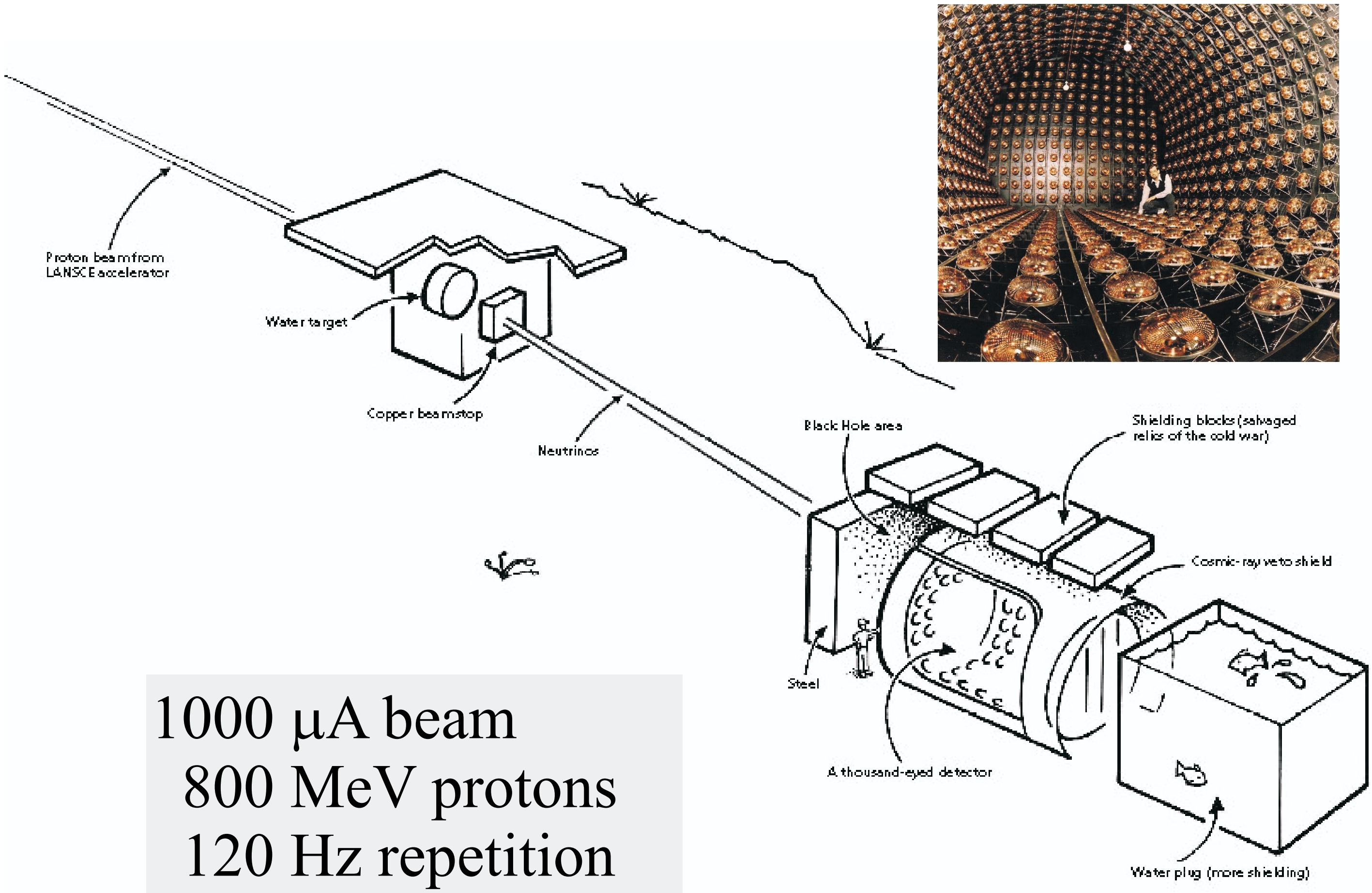
- 512 cells with 56 t of liquid scintillator
- 96 inner veto cells
- passive shielding
- 136 plastic veto counters



Detector cell

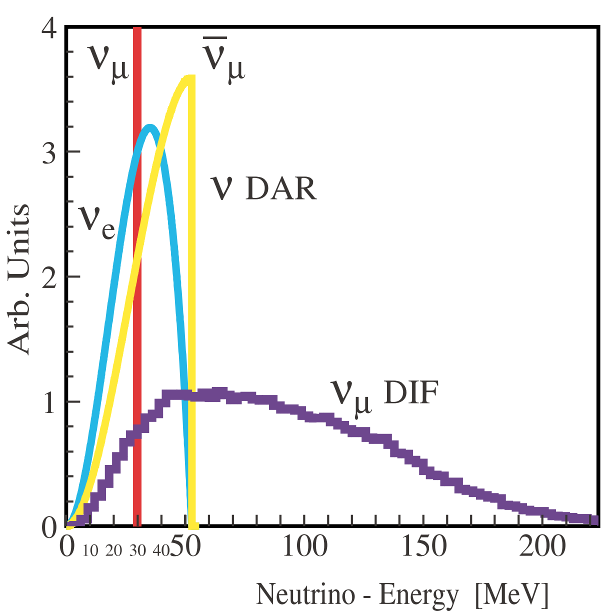
- 2 PMTs at each end
- Gd in acrylic walls for neutron capture

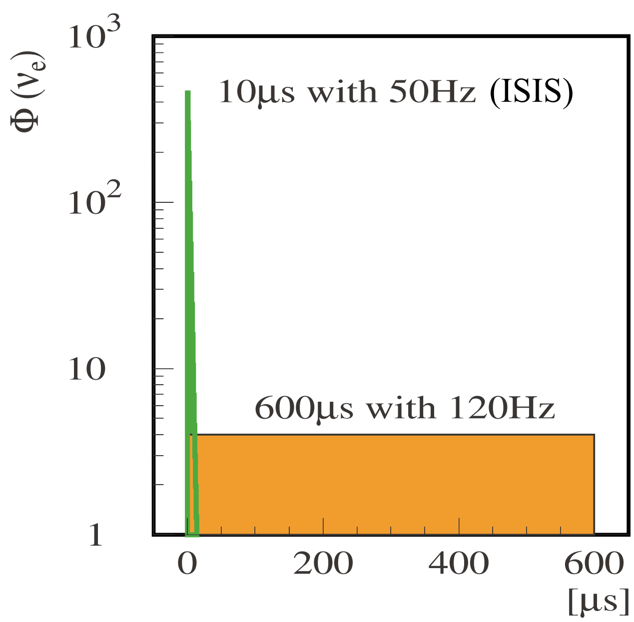
LSND at LANSCE



1000 μA beam
800 MeV protons
120 Hz repetition
600 μs pulse length

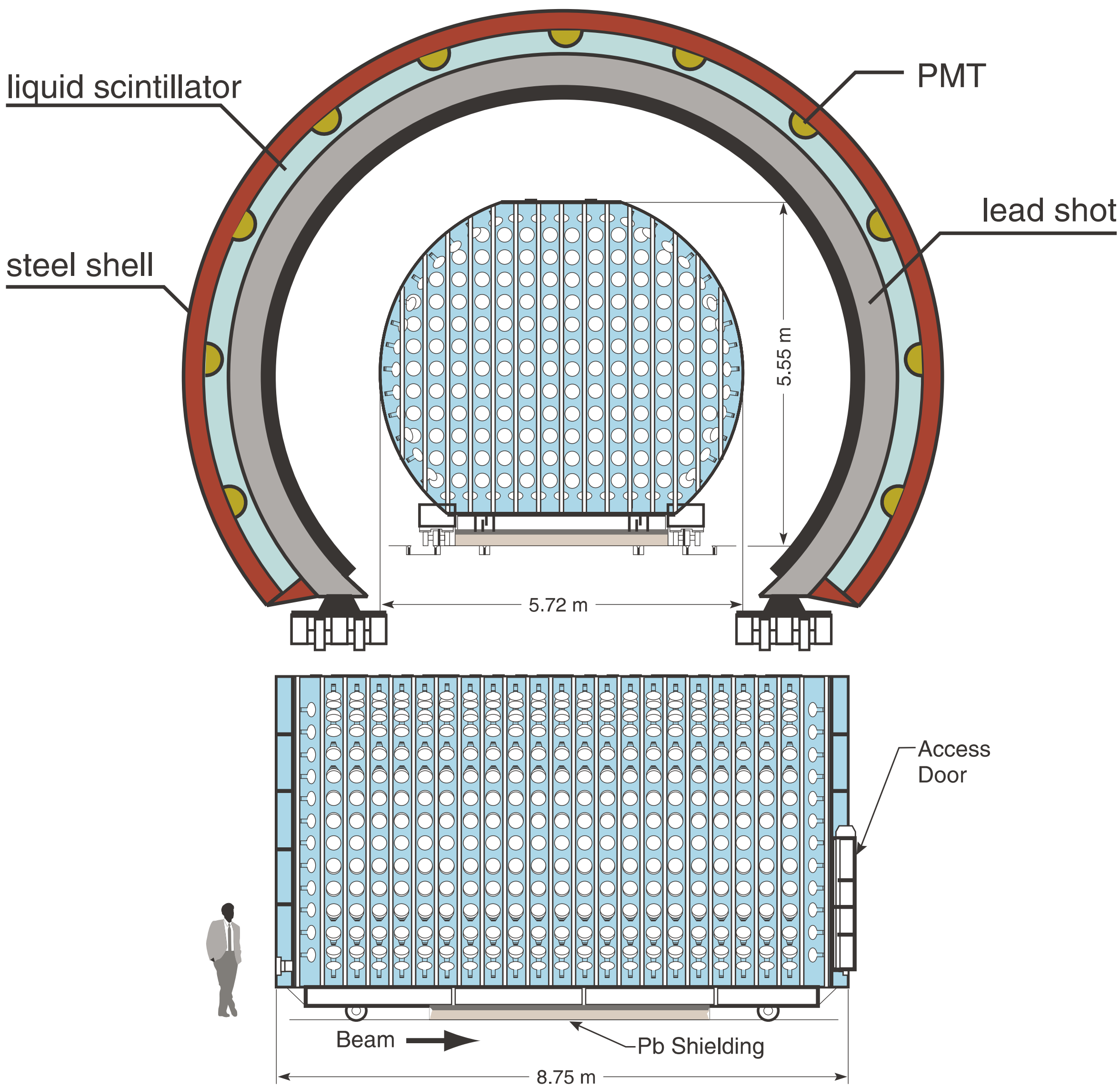
π and μ decay at rest and in flight



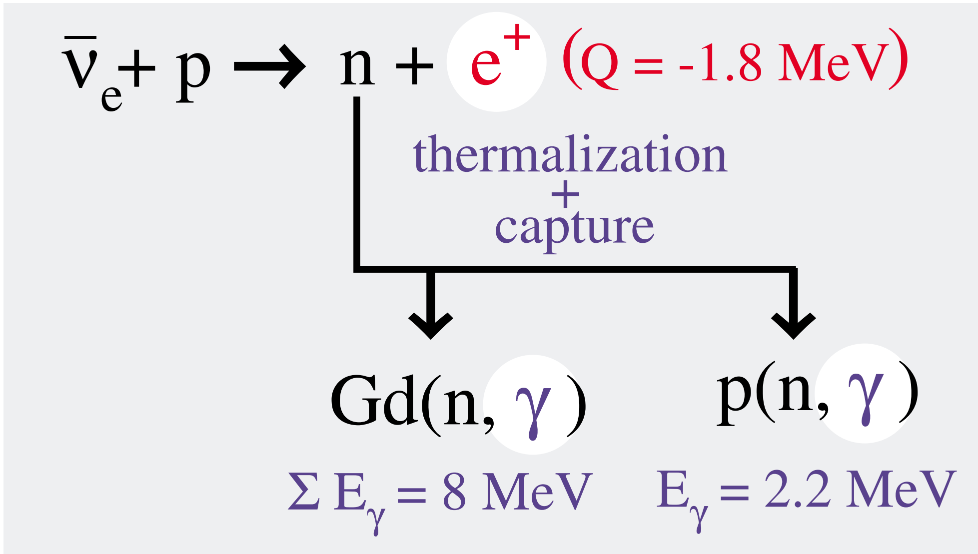


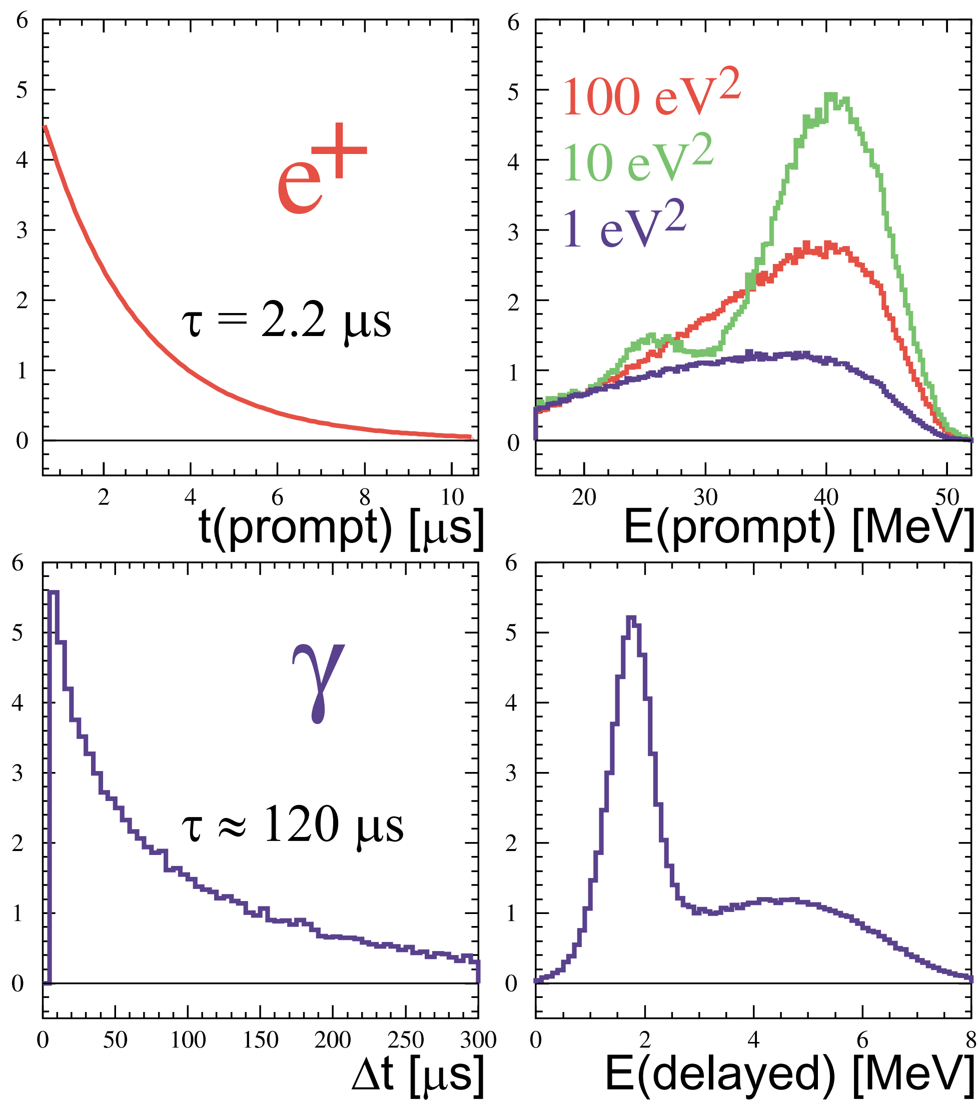
LSND Detector

- 167 t hybrid oil Cherenkov detector
- sees Cherenkov and scintillation light
- Central detector:1220 8"-PMTs
- Veto detector: 292 5"-PMTs
- Shielding: 8m iron equivalent



Signature of the KARMEN Oscillation Signal





KARMEN2 : chronology of the oscillation candidates 1997-2000

Cuts for FC- event likelihood analysis

Cuts on prompt events

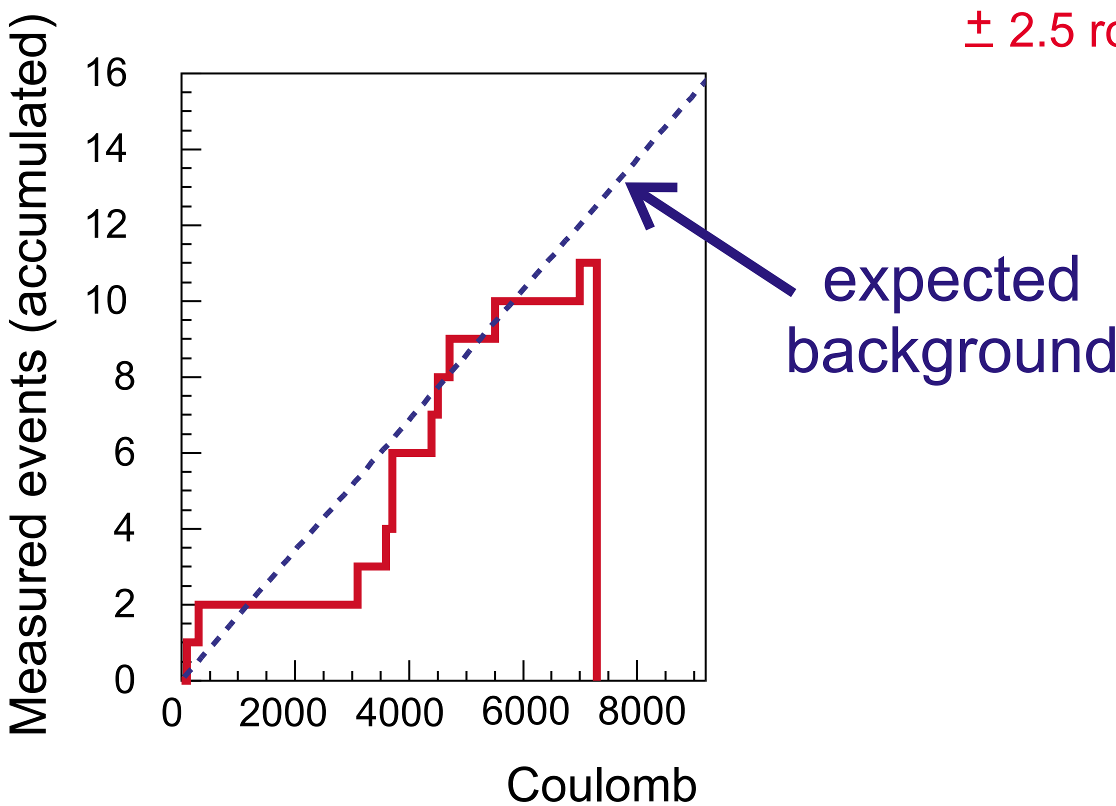
visible energy : 16 - 50 MeV
time cut : 0.6 - 10.6 μs

no fiducial cut

no activities in any detector part in previous 24 μs.

Cuts on delayed events

visible energy : 0-8 MeV
time diff. : 5- 300 μs
spatial correlation: Δx< 80 cm, ± 2.5 row/col



expected signals for maximum mixing : 2443 events ($\Delta m = 100\ eV^2$)

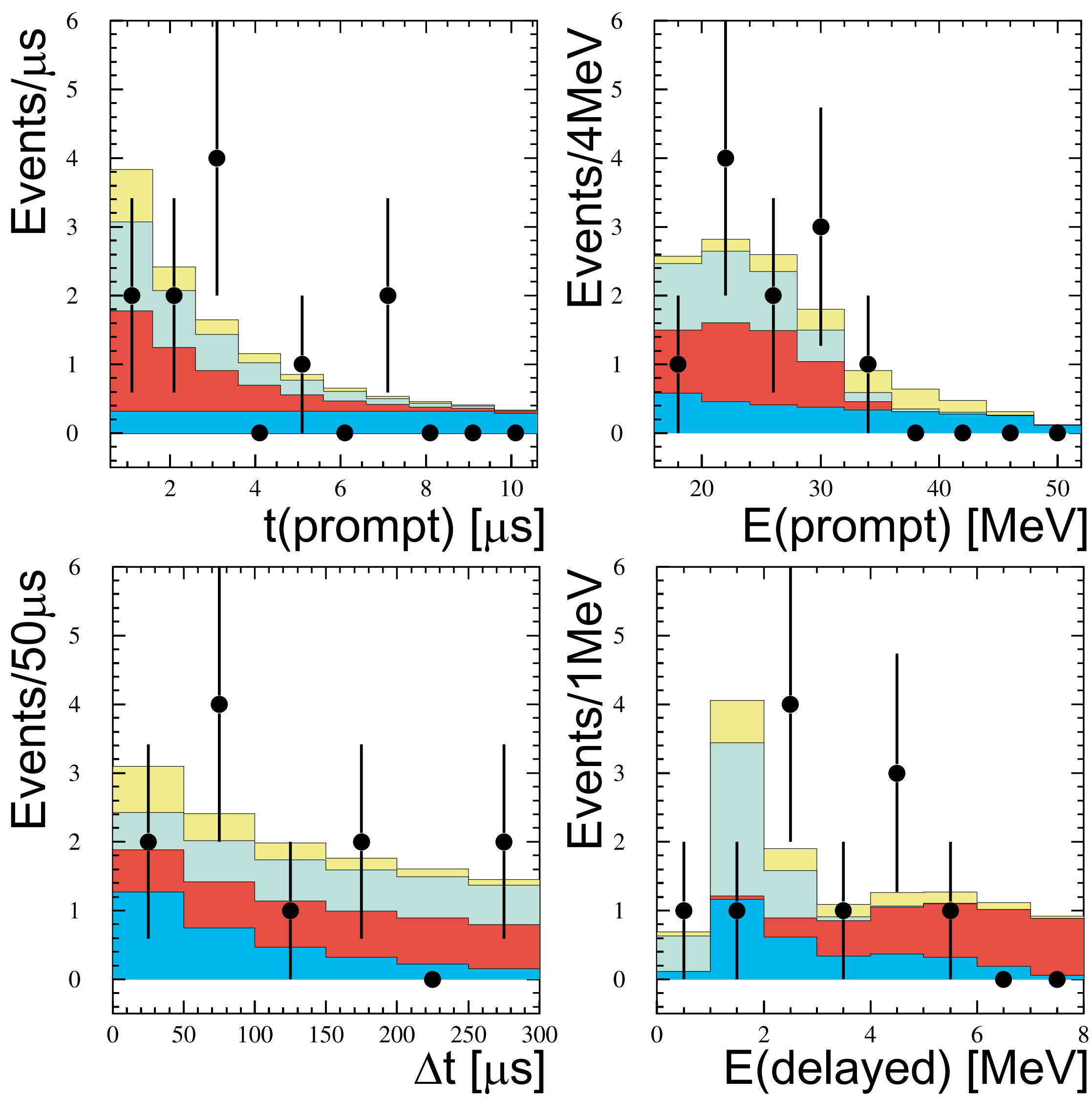
KARMEN-II Result

Analysed:	**Feb. 1997 - Mar. 2000**	**7160 C protons**
Total data:	Feb. 1997 - Mar 2001	~ 9400 C protons

11 candidates ⟶ **no osci signal**

3.9 +- 0.5	ν_e-induced CC sequ.
3.5 +- 0.3	ν-induced random bg.
1.7 +- 0.2	$\bar{\nu}_e$ intrinsic contamin.
3.2 +- 0.2	cosmic background
12.3 +- 0.6	total background

Bayes:
signal > 6.3 evts
excluded @ 90% C.L.



Signature of the LSND Oscillation Signal

DAR neutrinos

$$\bar{\nu}_e + p \rightarrow n + e^+ \quad (Q = -1.8\ \text{MeV})$$

thermalization + capture

$$p(n, \gamma)$$

$$E_\gamma = 2.2\ \text{MeV}$$

$$20\ \text{MeV} < E_e < 60\ \text{MeV}$$

DIF neutrinos

$$\nu_e + {}^{12}C \rightarrow {}^{12}N + e^- \quad (Q = -17.3\ \text{MeV})$$

$$60\ \text{MeV} < E_e < 200\ \text{MeV}$$

Improvements of the analysis

- position reconstruction
- better separation of uncorrelated γ's
- combined fit on DAR and DIF neutrinos

LSND $\nu_\mu \rightarrow \nu_e$ Results for 1993–1998

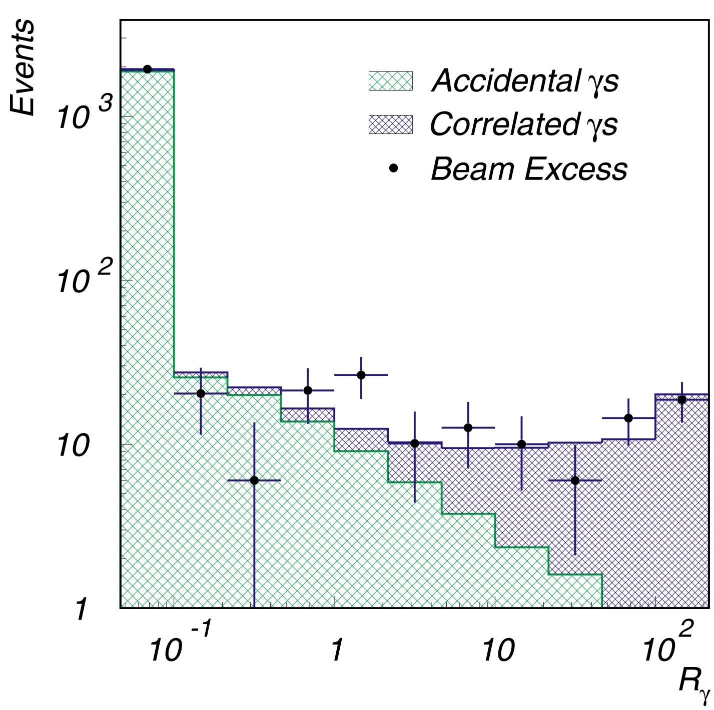
20<E<60 MeV

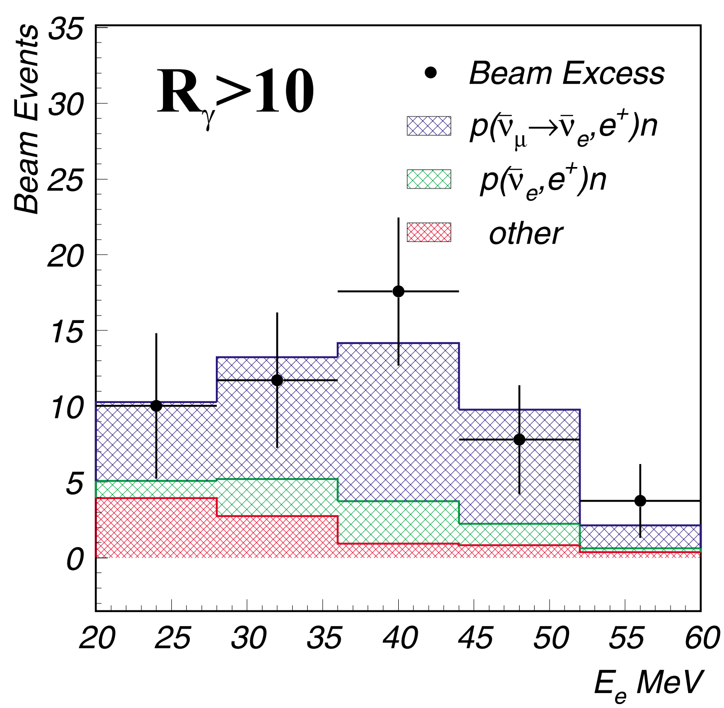
Selection	Beam On	Beam Off	ν Background	Total Excess
R>100	27	8.3+–0.7	5.4+–1.0	13.3+–5.2+–1.0
R>10	86	36.9+–1.5	16.9+–2.3	32.2+–9.4+–2.3
R>1	205	106.8+–2.5	39.2+–3.1	59.0+–14.5+–3.1

Fit on R_γ after beam-off background subtraction

Fit (beam on-off)	: 117.9 ± 22.4 correlated events
background (DAR)	: 19.5 ± 3.9
background (DIF)	: 10.5 ± 4.6
100% $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	: 33300 ± 3300 events expected (protons on target = 28896 C)

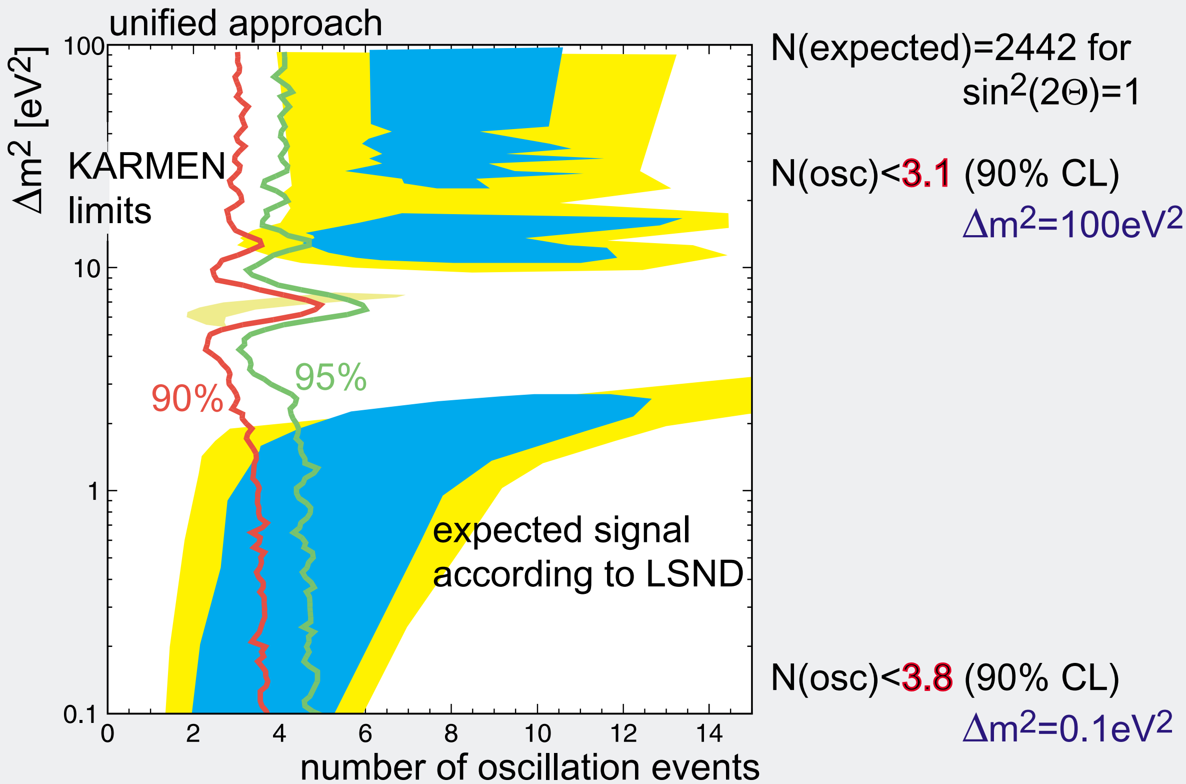
Data Sample	Fitted Oscillation Excess	Oscillation Prob.
1993–1998	87.9+–22.4+–6.0	(0.264+–0.067+–0.045)%



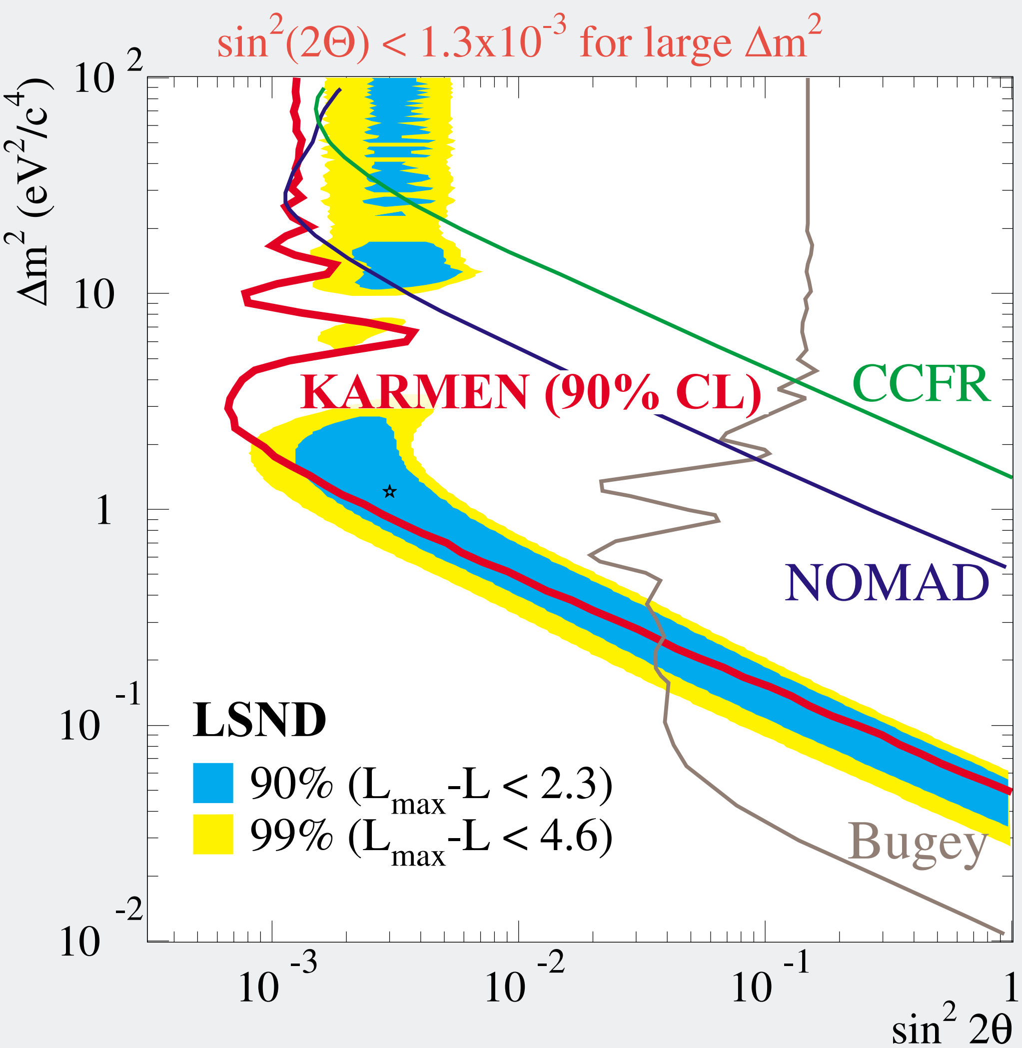


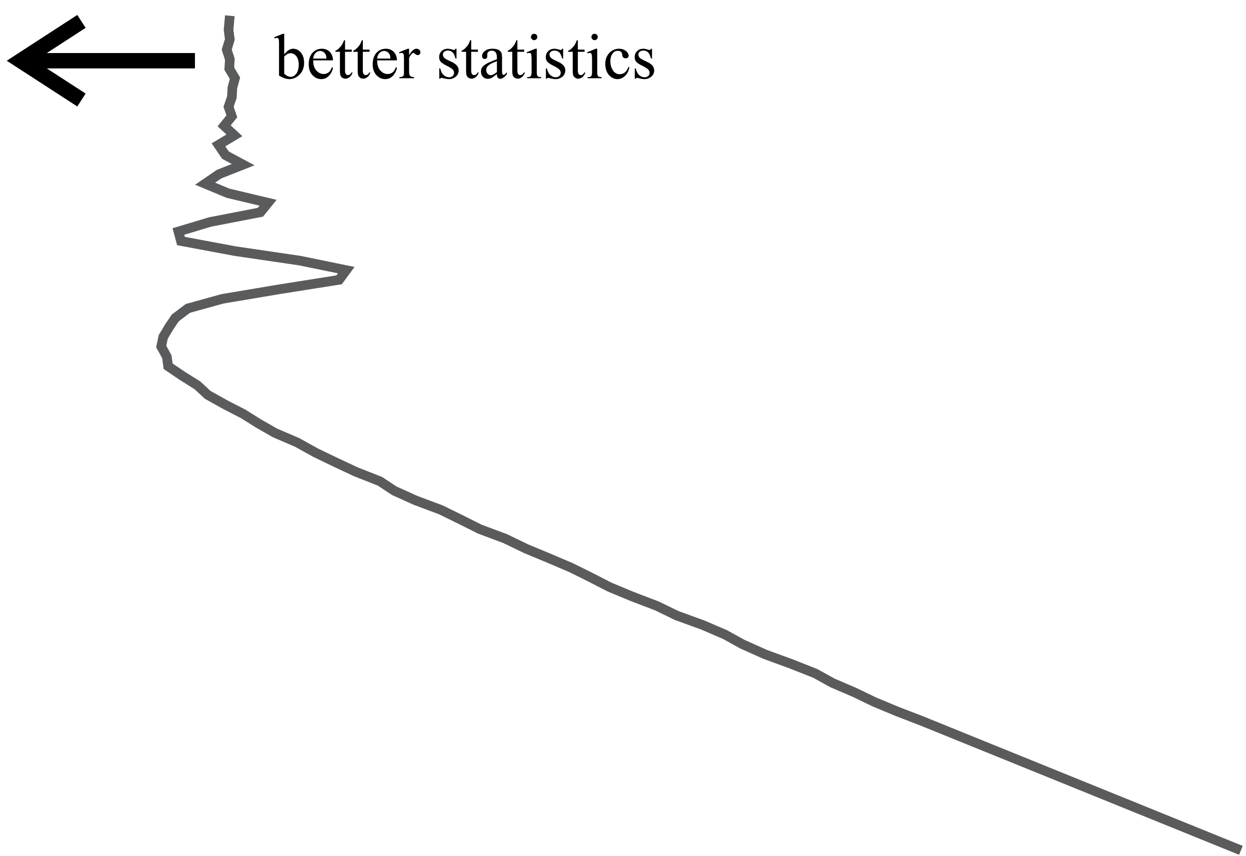
LSND and KARMEN Oscillation Plot

Expected Events in KARMEN



Oscillation Plot




better statistics

Conclusion

- LSND observes evidence for ν-oscillation
- total excess: $87.9 \pm 22.4_{stat} \pm 6.0_{syst}$
- Best fit: $sin^2 2\theta = 0.003$, $\Delta m^2 = 1.2\ eV^2$
- KARMEN excludes large Δm^2 solutions
- low Δm^2 solutions are still possible

Future: MiniBooNE

- definitive test of the LSND signal
- ~1000 events/year if LSND is true
- Start: 2002 (detector ready by the end of 2001)