Introduction

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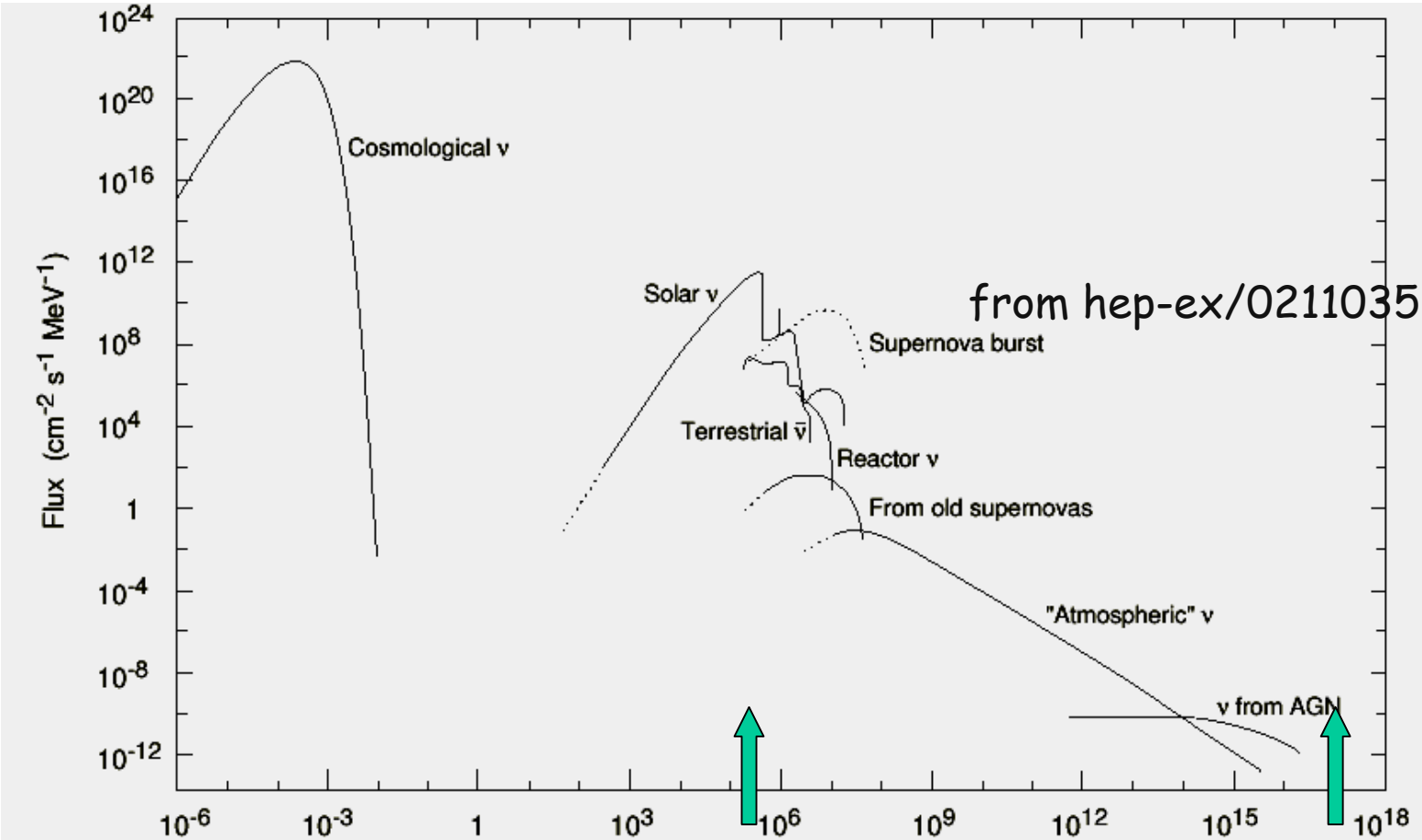
Epiphany Conference on Neutrinos and Dark Matter, 6.01.2006

2006 Epiphany Conference on Neutrinos and Dark Matter

as compared to

2000 Epiphany Conference on Neutrinos in Physics and Astrophysics

Neutrino sources



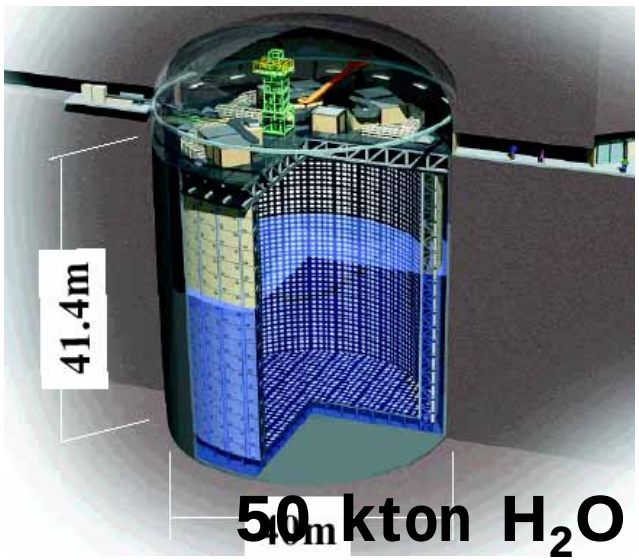
Experiments study solar, reactor, atmospheric, accelerator and UHE astrophysical neutrinos

At the time of Epiphany 2000

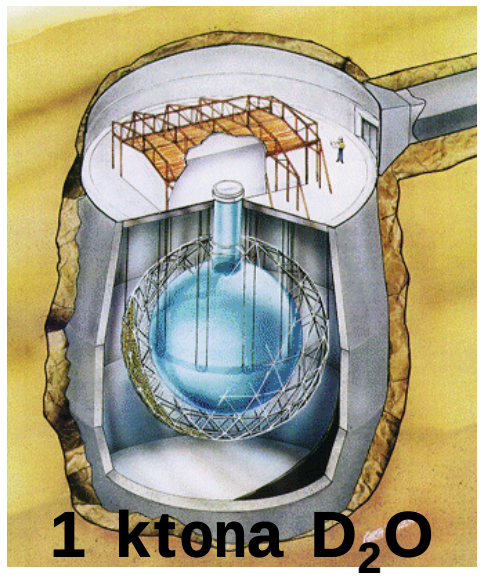
- The main conference highlight was the evidence for oscillations of atmospheric neutrinos in SuperKamiokande
- „Solar puzzle" was not yet resolved: SNO was at startup of data taking
- Accelerator experiments: K2K had collected data for less than one year, Minos and MiniBOONE were under construction, CNGS experiments were before a formal approval
- Reactor experiments: CHOOZ analysis was well advanced, KamLAND was under construction
- Astrophysical HE neutrinos: experiments under construction
- Many interesting theoretical ideas

Between 2000 and 2006

- Solid experimental evidence for neutrino oscillations coming from the SuperKamiokande, K2K, SNO and KamLAND experiments (J.Zalipska on K2K)



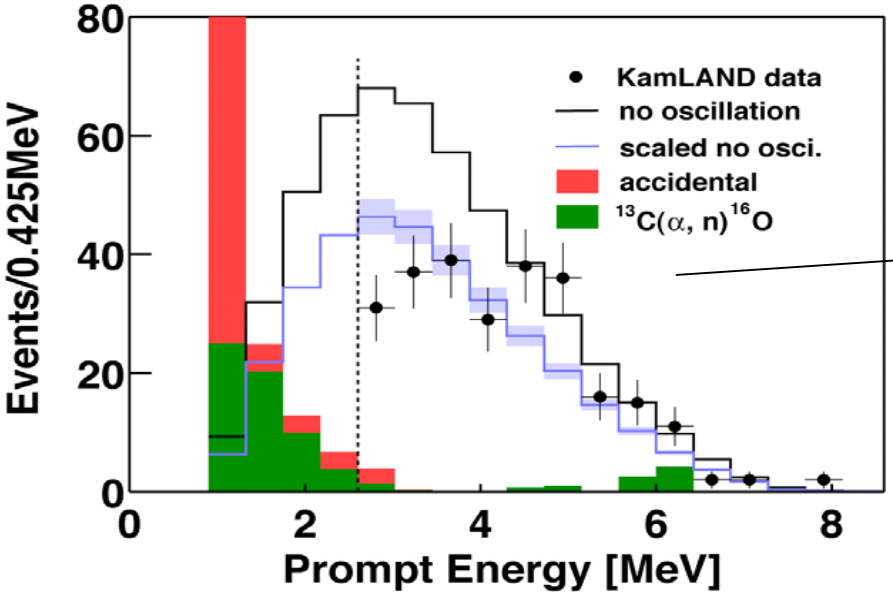
SuperKamiokande



SNO

KamLAND

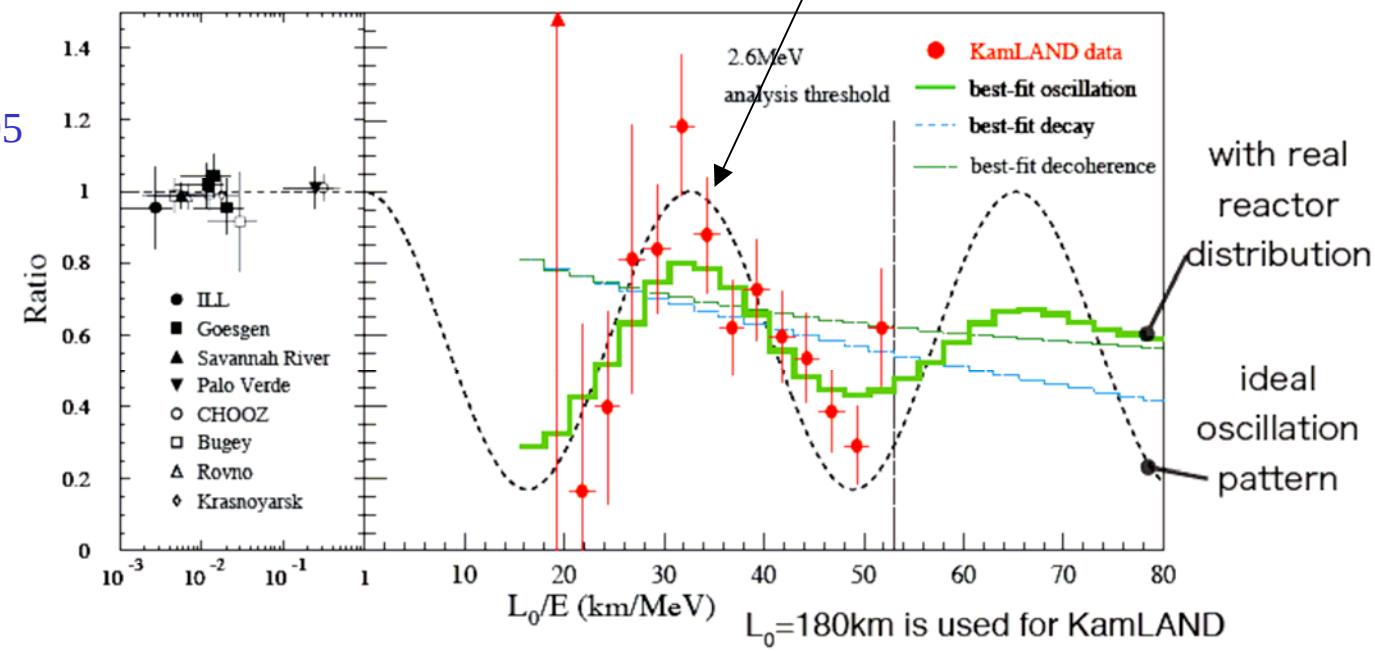
KamLAND: Testing the Model with L/E Behavior



• Rate + Shape: Oscillations at 99.999995% C.L.

$$P_{\upsilon_e \to \upsilon_e} = 1 - \sin^2 2\theta_{12} \sin^2\left(\frac{1.27\Delta m_{12}^2 L}{E}\right)$$

KamLAND, PRL 94, 2005
J.Klein, EPS HEP2005



A.Zalewska, Epi

Three neutrino mixing

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Oscillation parameters: 3 mixing angles, 2 differences of mass squared, 1 phase

If neutrino is a Majorana particle, 2 additional phases

Atmospheric neutrinos — CP phase — solar neutrinos

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

connects solar and atmospheric regions

If $\delta \neq 0, \pi, 2\pi \ldots$ then CP is violated for leptons (like for quarks), θ_{13} is very important for a measurement of δ

Oscillation parameters

The most probable values:

$\theta_{23} = 45^0$ (maximal mixing), $\theta_{12} = 33^0$ (large), $\theta_{13} < 10^0$ (small),

$\Delta m^2_{23} \approx 2.5 \times 10^{-3}$ eV^2, $\Delta m^2_{12} \approx 8 \times 10^{-5}$ eV^2,

$| \Delta m^2_{13} | = | \Delta m^2_{23} - \Delta m^2_{12} |$

Why this scheme of mixing angles is so much different from the scheme for quark mixing?

Between 2000 and 2006

- MINOS started data taking at the beginning of 2005 (first results from the beam are discussed these days at the collaboration meeting in Oxford) (D. Kiełczewska)

- MiniBOONE has been running since 2002 - first results should be presented during the first half of 2006

- OPERA will start data taking in 2006 (R. Zimmermann)

- Big LAr detector „a la Icarus" should be redesigned

Three oscillation regions

Two oscillation regions with a very solid experimental evidence:

atmospheric region

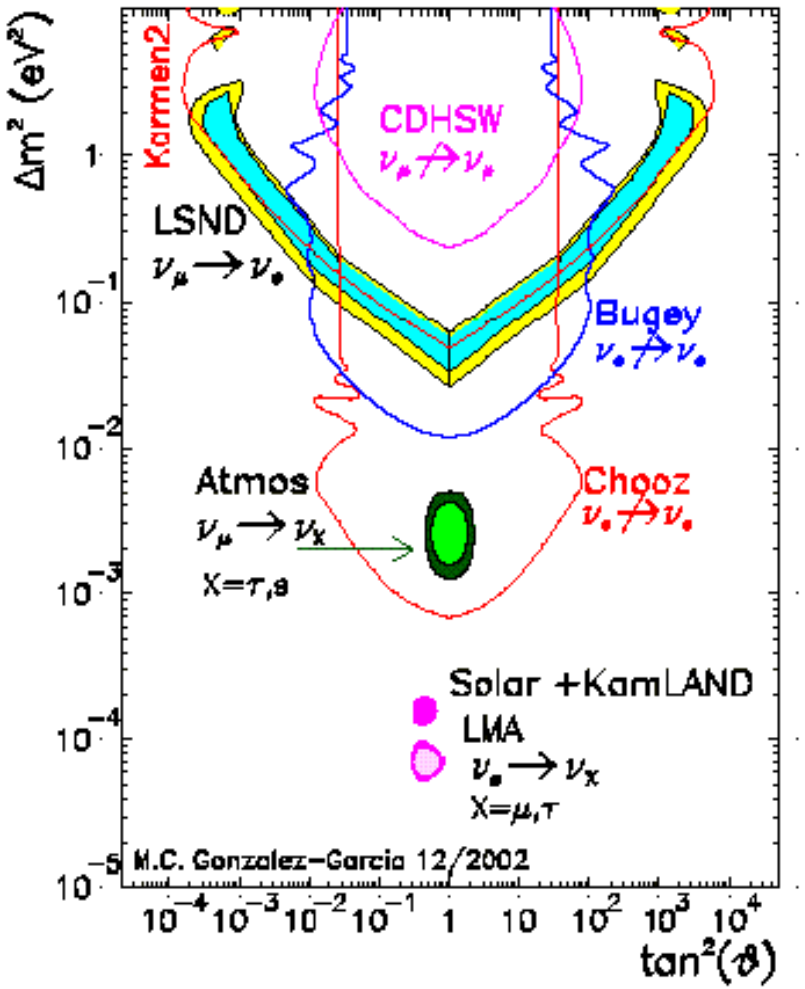
solar region

Third region:

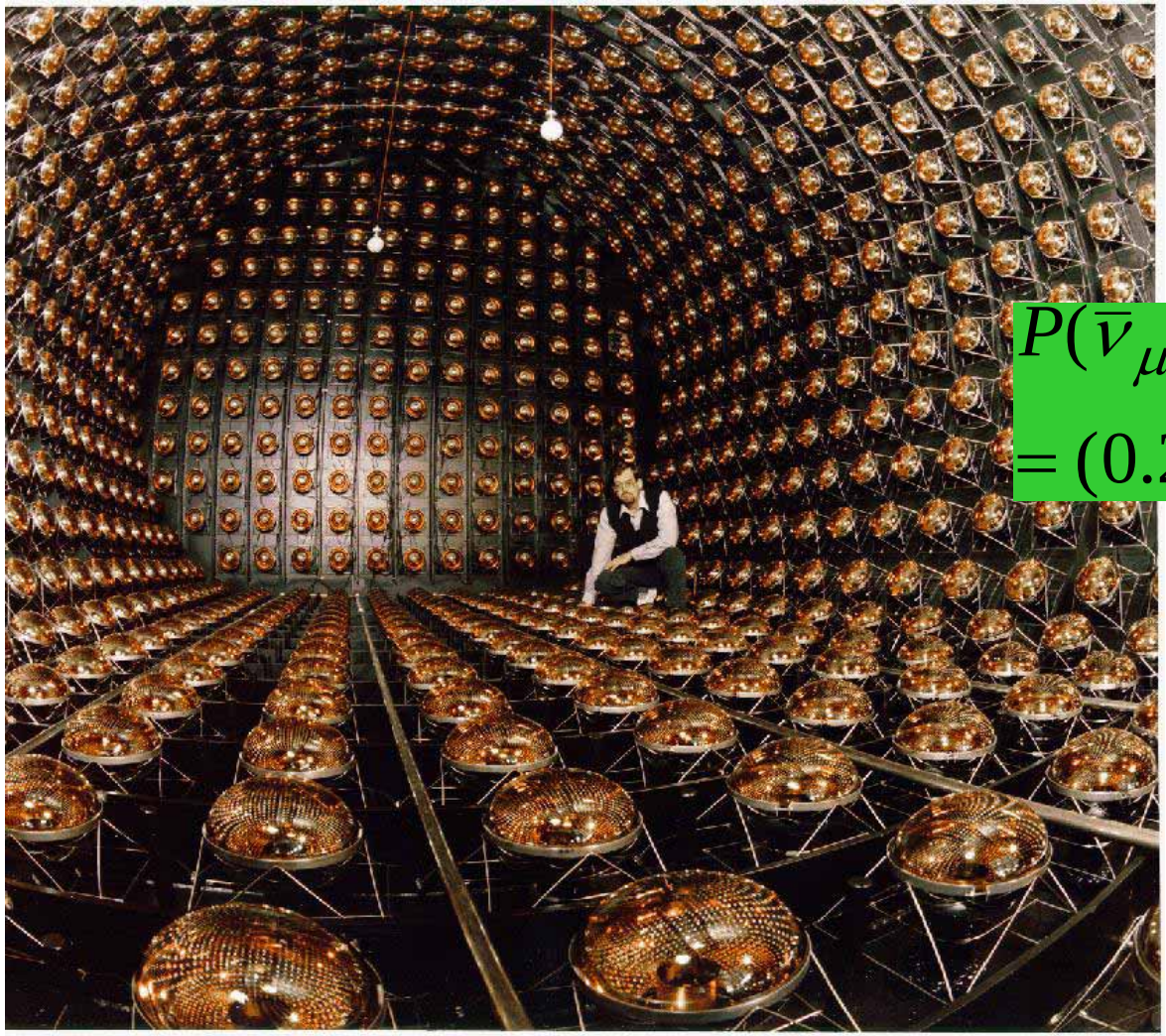
LSND

being checked by the MiniBOONE experiment

If confirmed, a 4th neutrino is required



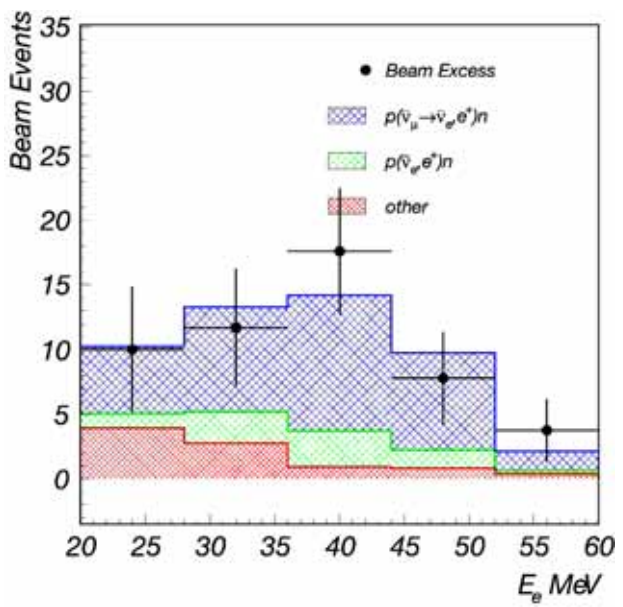
LSND effect



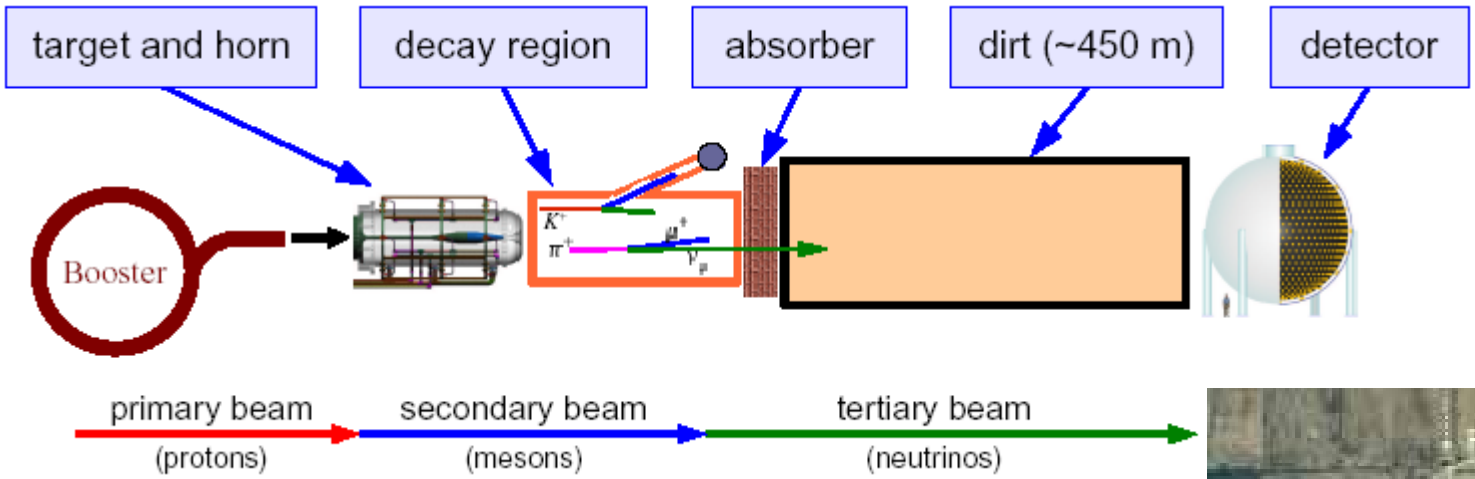
Excess of positrons above background interpreted as anty-ν_e appearance due to oscillations

$$P(\bar{\nu}_\mu \to \bar{\nu}_e)$$

$$= (0.264 \pm 0.067 \pm 0.045)\%$$



➢ MiniBooNE – checking the LSND effect



Ú 8 GeV protons from the Fermilab booster neutrino beam of energy about 1 GeV

Ú detector at a distance of 500 m from the target

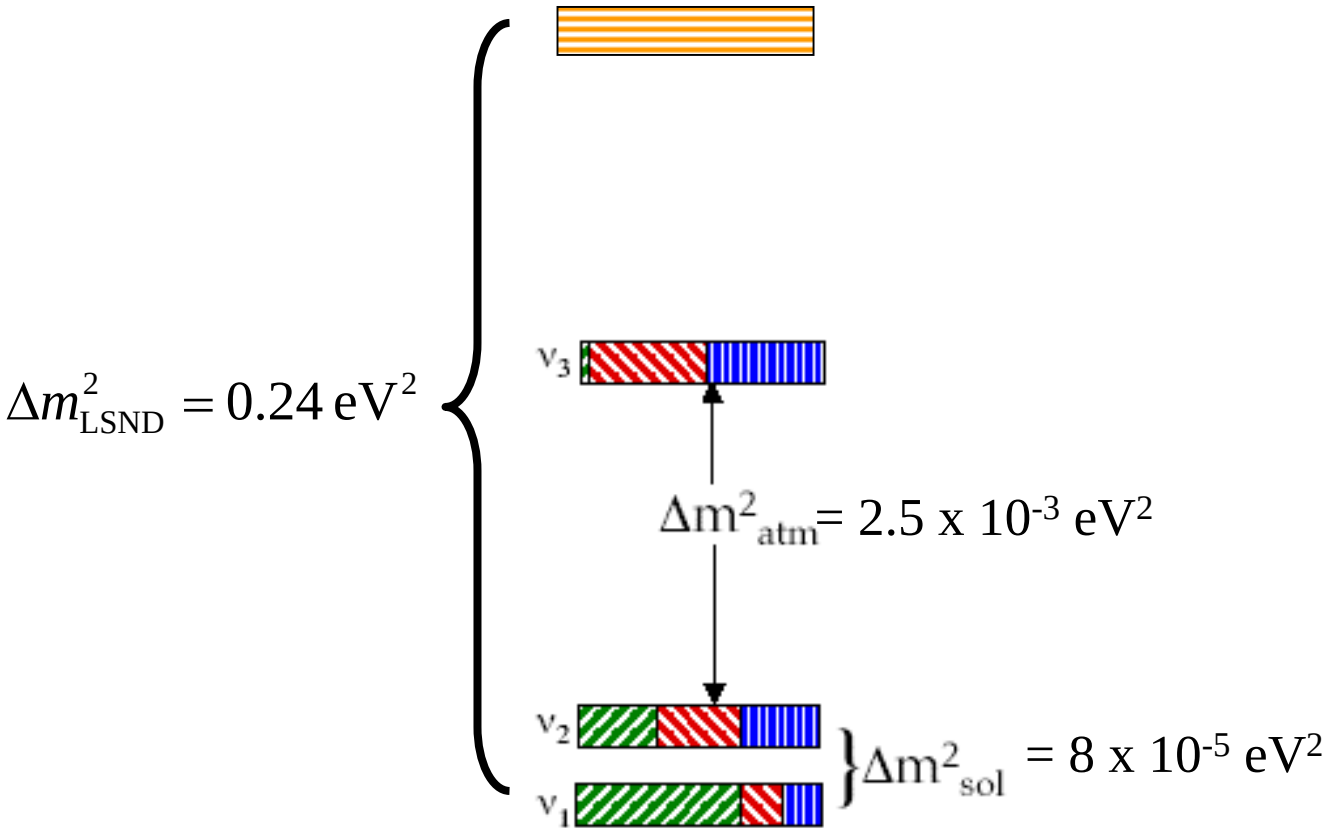
Ú 10^{21} p.o.t. to confirm/exclude the LSND effect

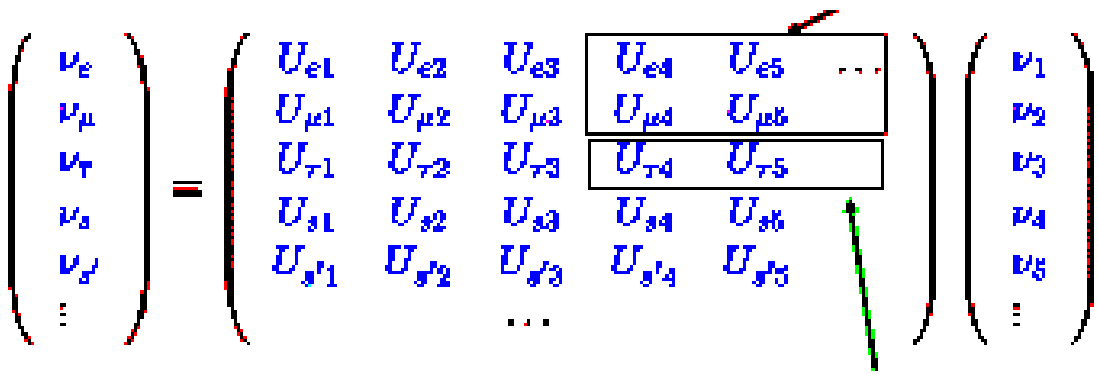
$$P(\nu_\mu \to \nu_e) = \sin^2 2\theta \sin\left(\frac{1.27\Delta m^2 L}{E}\right)$$

Results expected ~end of 2005

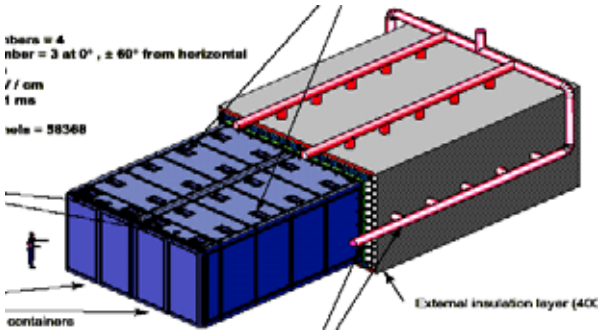
A.Zalewska, Epiphany 2006

If MiniBOONE confirms LSND... revolution !



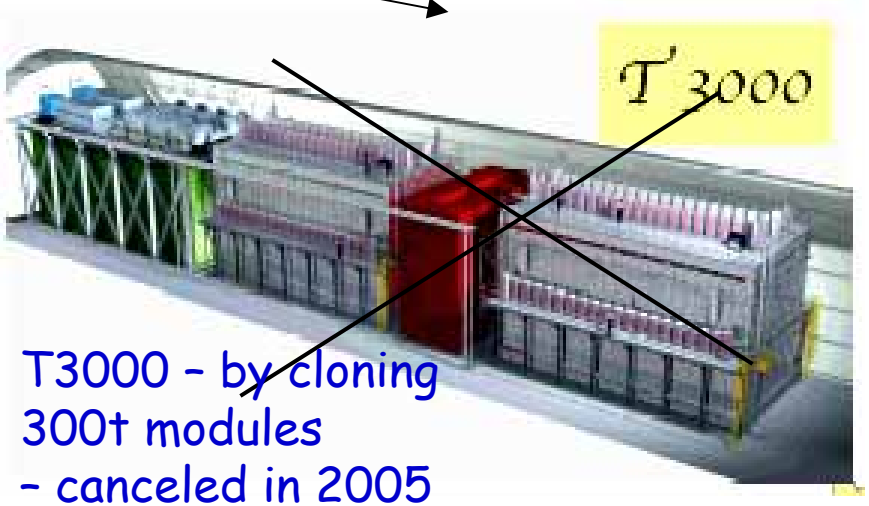


The ICARUS experiment



Existing T600 detector – 600t of LAr

40m

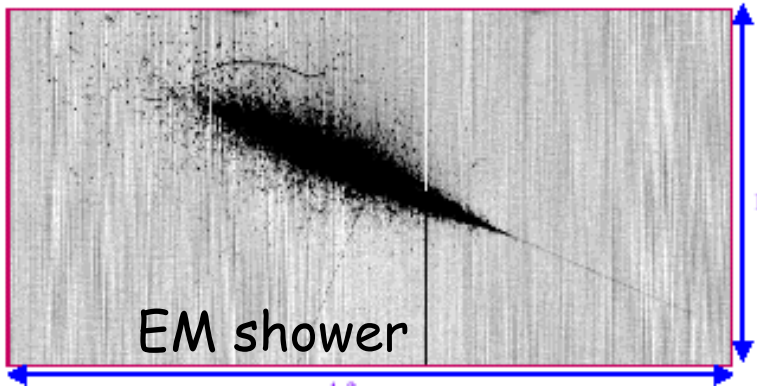


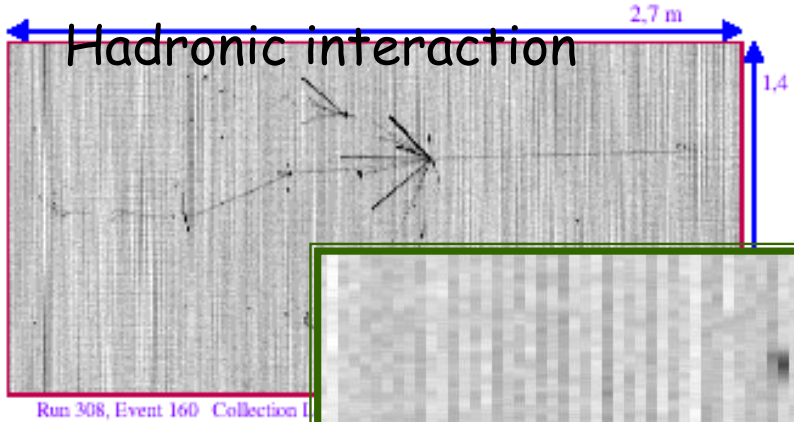
T3000 – by cloning 300t modules – canceled in 2005

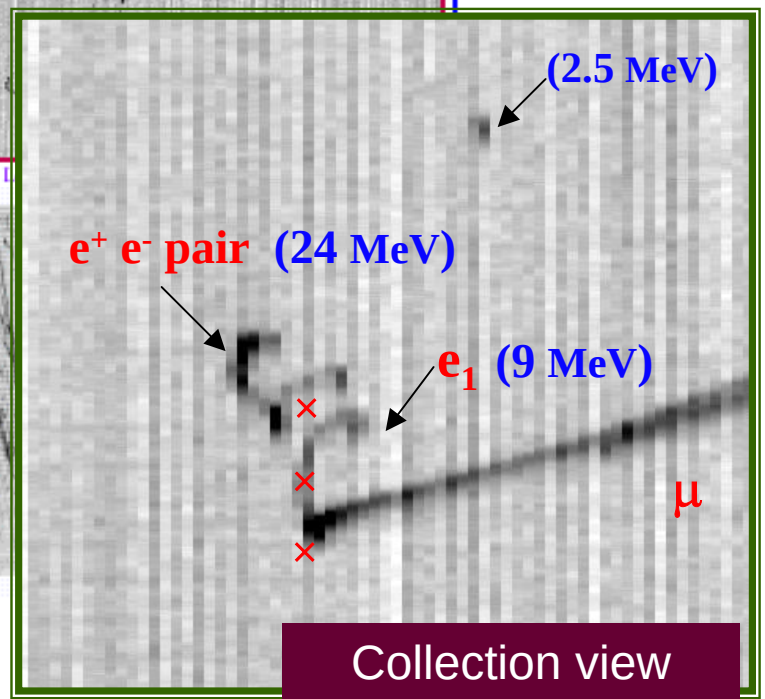
T600 detector – installation in Gran Sasso

Bigger monolithic detector – worshop in March 2006

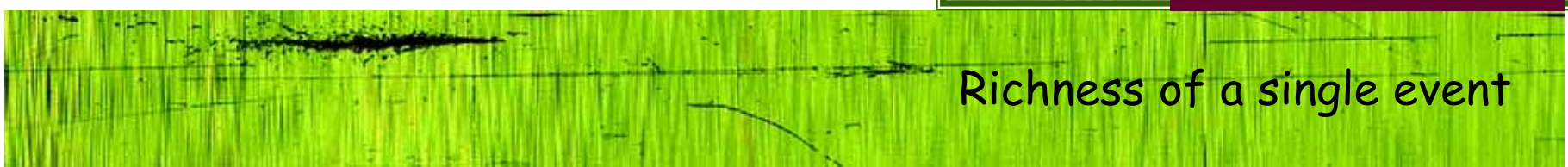
T600 – data quality – from 2001 tests







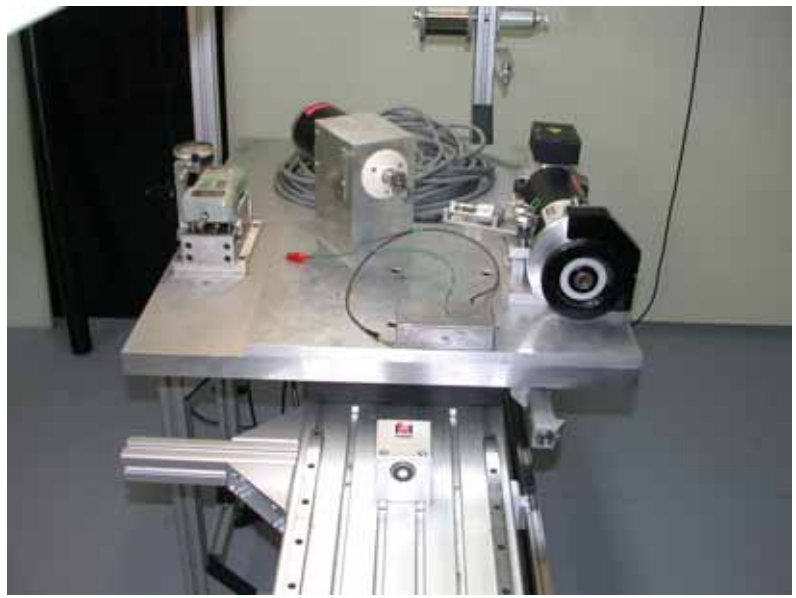
„Electronic bubble chamber"



7 publications based on this data

ICARUS experiment

Original plan for the detector upgrade: four modules, each of 300 tons of LAr, to be constructed in the years 2005-2007



Responsibility of the Polish groups: production of anode wires (about 55000 in total) for TPC chambers of the future modules

At the time of Epiphany 2006

- Neutrino oscillations:

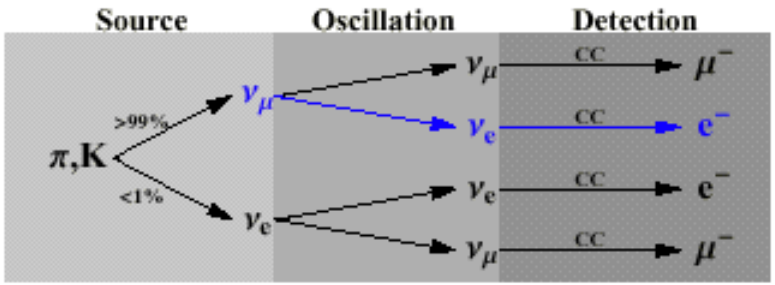
Oscillation experiments enter a period of precise measurements – intense sources of neutrinos and huge detectors are needed as well as good theoretical tools to answer the following questions:

Is θ_{23} really maximal?
How small is θ_{13}?
Mass hierarchy – normal or inverted?
Is CP violated for neutrinos?

- talks by D.Kiełczewska, D.Motta, K.Long, A.Blondel, S.Katsanevas, J.Sobczyk, M.Rolinec

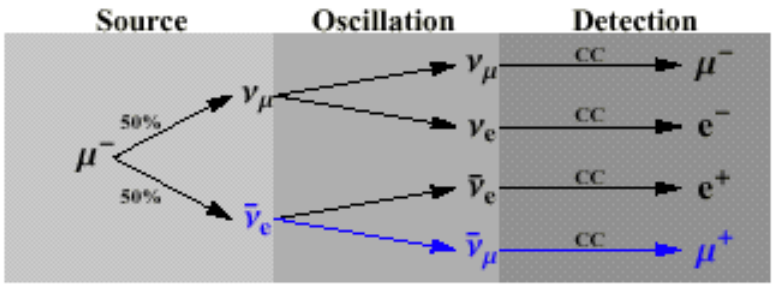
High intensity sources of neutrinos

Superbeams



Conventional beams
of v. high intensity
(D.Kiełczewska)

Neutrino Factories

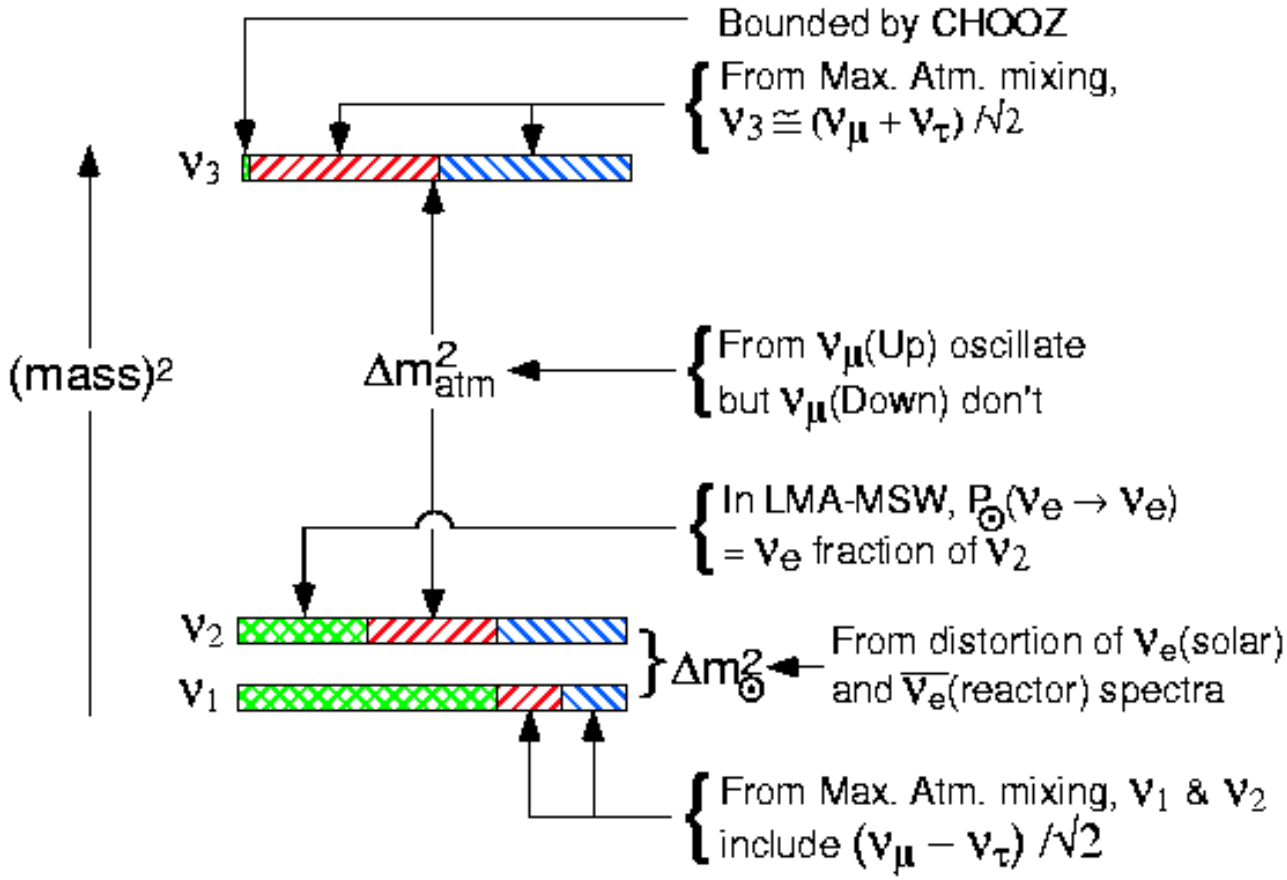


New type of accelerator:
neutrinos from decays of accelerated muons
(K.Long, A.Blondel)

β beams
recent idea

New type of accelerator:
neutrinos (antineutrinos) from accelerated ^{18}Ne (^{6}He)
(S.Katsanevas)

Neutrino mass hierarchy



Two important questions:

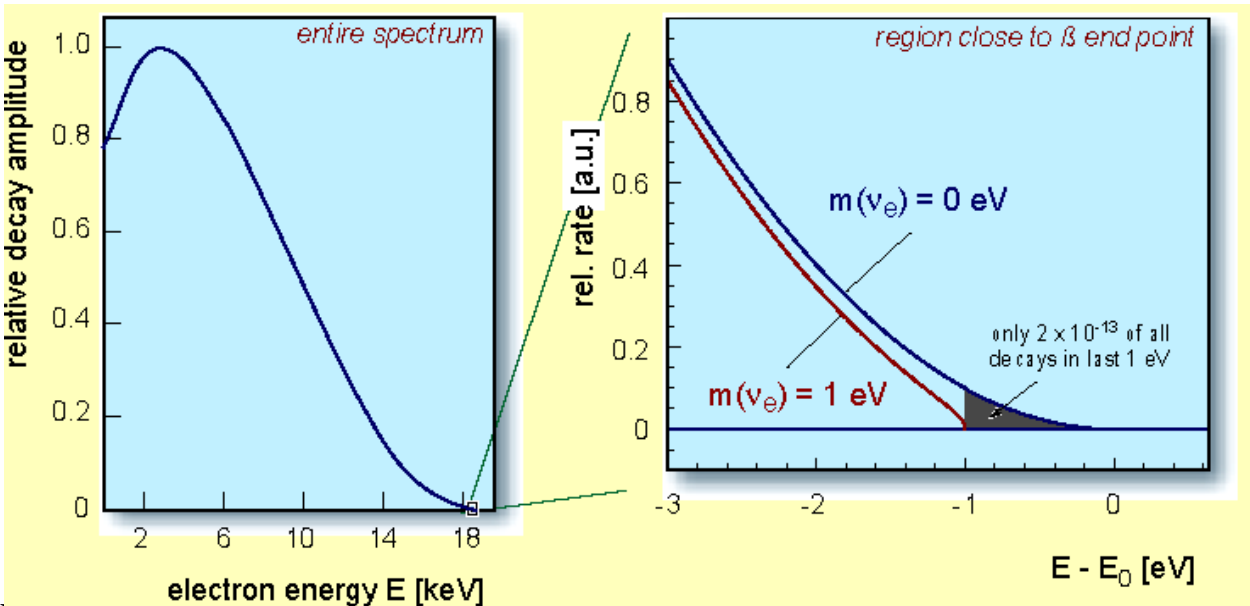
Normal hierarchy (above) or inverted hierarchy (w.r.t. Δm^2_{atm})

How far from zero the whole picture is?

At the time of Epiphany 2006

- Neutrino mass:

Direct measurement based on the electron spectrum from the Tritium β decay in the KATRIN experiment (J.Bonn)

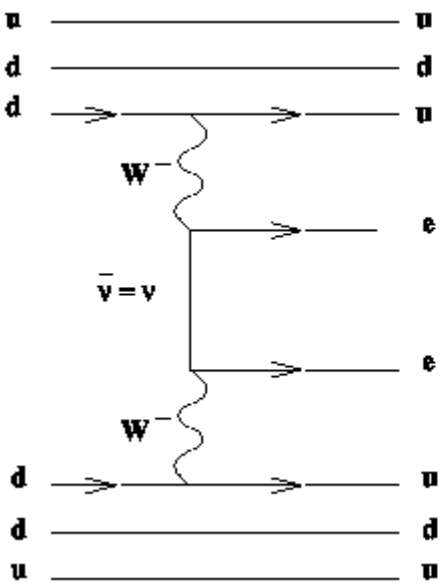


At the time of Epiphany 2006

- Is neutrino a Majorana or a Dirac particle?

Searches for neutrinoless double beta decays – many experiments proposed – observation of such a decay would be a great discovery

- talks by K.Zuber, M.Wójcik, A.Bobyk



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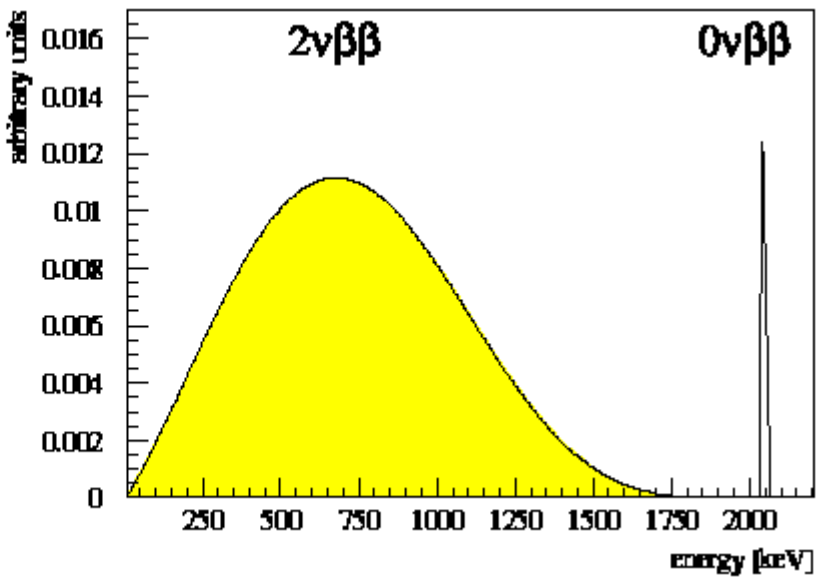
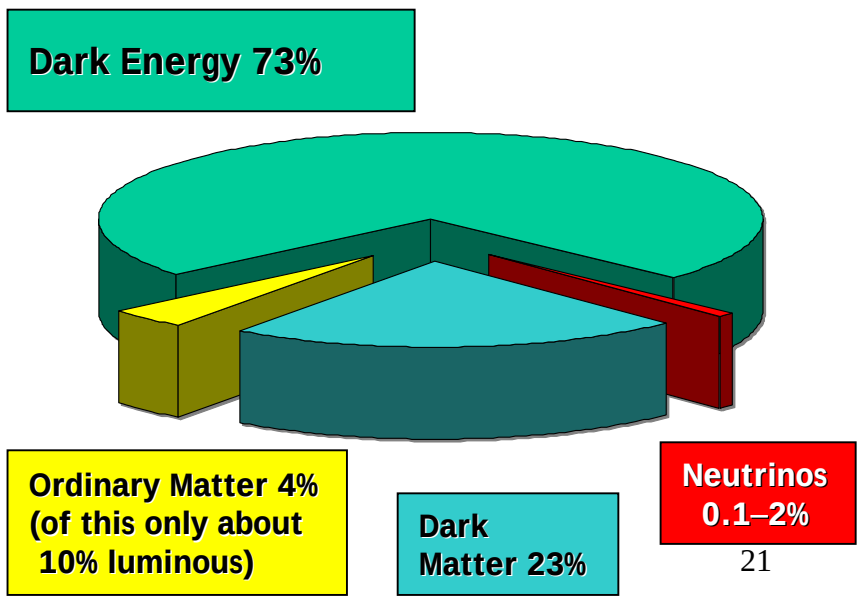


At the time of Epiphany 2006

- Dark Matter searches

One should remember that only 15 years ago neutrinos were serious candidates for Dark Matter, nowadays WIMPs (Weakly Interacting Massive Particles) are in fashion
- talks by Ch.Sander, B.Baret, M.Sapiński, A.Szelc

- High level theory
  by B.F.L. Ward



At the time of Epiphany 2006

- Increasing synergy between particle physics and astrophysics and intense discussions about the future initiatives in both fields

Will be reflected by many talks but especially
by S.Katsanevas, J.Engelen, Ch.Spiering and S.Pokorski