A multipurpose detector for low energy neutrino physics: LENA

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Outline

LAGUNA

Large Apparatus for Grand Unification and Neutrino Astrophysics

- APC, Paris, France
- CEA, Saclay, France
- CPPM, IN2P3-CBRS, Marseille, France
- CUPP, Pyhäsalmi, Finland
- ETHZ, Zürich, Switzerland
- Institute for Nuclear Research, Moscow, Russia
- IPNO, Orsay, France
- LAL, IN2P3-CNRS, Orsay, France
- LPNHE, IN2P3-CNRS, Paris, France
- Max Planck für Kernphysik, Heidelberg, Germany
- Max Planck für Physik, München, Germany
- Technische Universität München, Germany
- Universidad de Granada, Spain
- Universität Hamburg, Germany
- University of Bern, Switzerland
- University of Helsinki, Finland
- University of Jyväskylä, Finland
- University of Oulu, Finland
- University of Padova, Italy
- University of Silesia, Katowice, Poland
- University of Sheffield, UK

Physics of LAGUNA: Proton Decay

Non supersymmetric Grand Unified Theories

Dominant decay mode: $p \to e^+\pi^0$ $\quad \tau \leq 1.4 \cdot 10^{36}$ y

Supersymmetry (SUSY)

Dominant decay mode: $p \to K^+\overline{\nu}$ $\quad \tau \sim (0.3 - 3) \cdot 10^{34}$ y

Extra dimensions (6D)

Dominant decay mode: $p \to e^+\pi^0$ $\quad \tau \sim 10^{35}$ y

(Limits from P. Nath 2006 and S. Raby 2002)

- Superkamiokande: $\tau(p \to e^+\pi^0) \gtrsim 5.4 \cdot 10^{33}$ y (90% C.L.)
  $\tau(p \to K^+\overline{\nu}) \gtrsim 2.3 \cdot 10^{33}$ y (90 % C.L.)

Physics of LAGUNA: Low Energy Neutrino Astrophysics

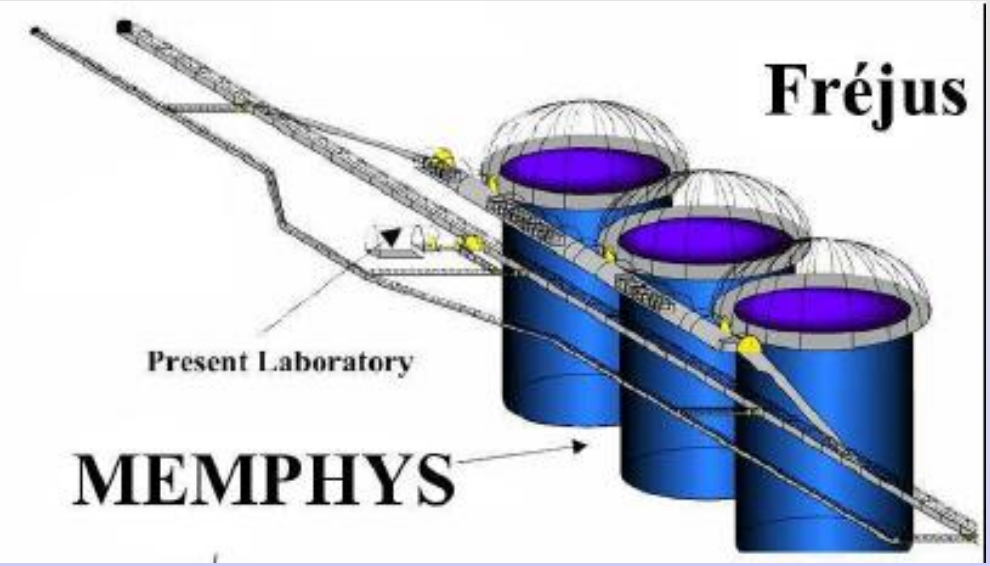
- Supernovae explosion
  - High statistics in the energy spectrum of different ν-flavours
  - Time evolution of the neutrino emission
  - Neutrino properties: oscillation parameters
- Diffuse background of supernova neutrinos
  - Understanding of the explosion mechanism of a SN
- Solar neutrinos
  - High statistics measurements
- and Geophysics
  - Measuring radioactivity of the Earth with geoneutrinos

Physics of LAGUNA: Neutrino Properties

- Atmospheric neutrinos:
  - Improve the measurement of $D_{23} \equiv \sin^2\theta_{23} - 1/2$
- Reactor:
  - Precise measurement on $\Delta^2 m_{12}$ and $\sin^2\theta_{12}$
- Detectors for accelerator experiments: θ_{13} and δ_{CP}
  - Beta beams
  - Super beams
  - Neutrino factories

MEMPHYS - MEgaton Mass PHYSics

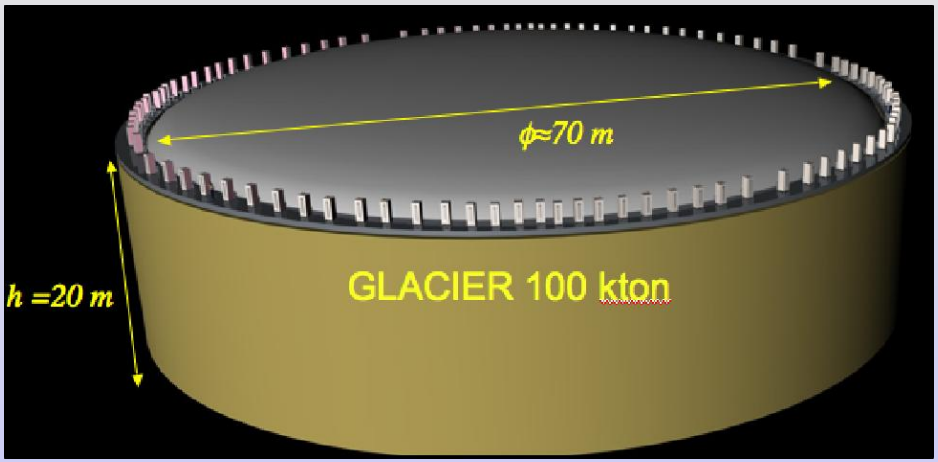
Detector scheme



- Size of each shaft
  - 80 m heigth
  - 65 m ∅
- Water Cherenkov Effect
  - $\sim$ 500 kton pure water
- Photomultipliers
  - 81 000 units per shaft
  - 30% coverage

GLACIER - Giant Liquid Argon Charge Imaging ExpeRiment

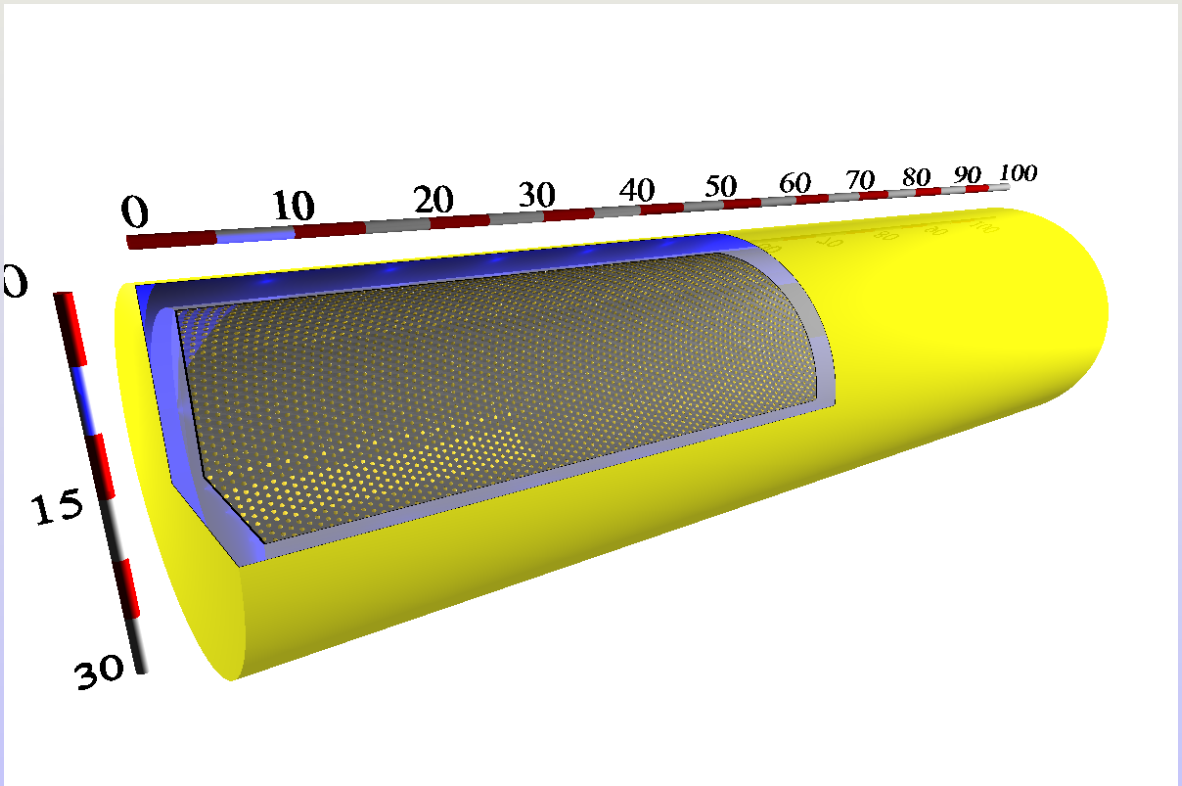
Detector scheme



- Size
  - 20 m heigth
  - 70 m ∅
- Liquid Argon TPC
  - $\sim$ 100 kton liquid argon
- Readout system
  - e^- drift: amplification with LEMs in the gas phase
  - Cherenkov Light: 27 000 PMTs 20% coverage
  - Scintillation Light: 1 000 PMTs

LENA - Low Energy Neutrino Astronomy

Detector scheme



- Size
  - 100 m length
  - 30 m ∅
- Liquid Scintillator
  - ∼ 50 kton PXE
- Photomultipliers
  - 13 500 units
  - 30% coverage
- Photoelectron yield
  - 110 pe/MeV

Possible locations

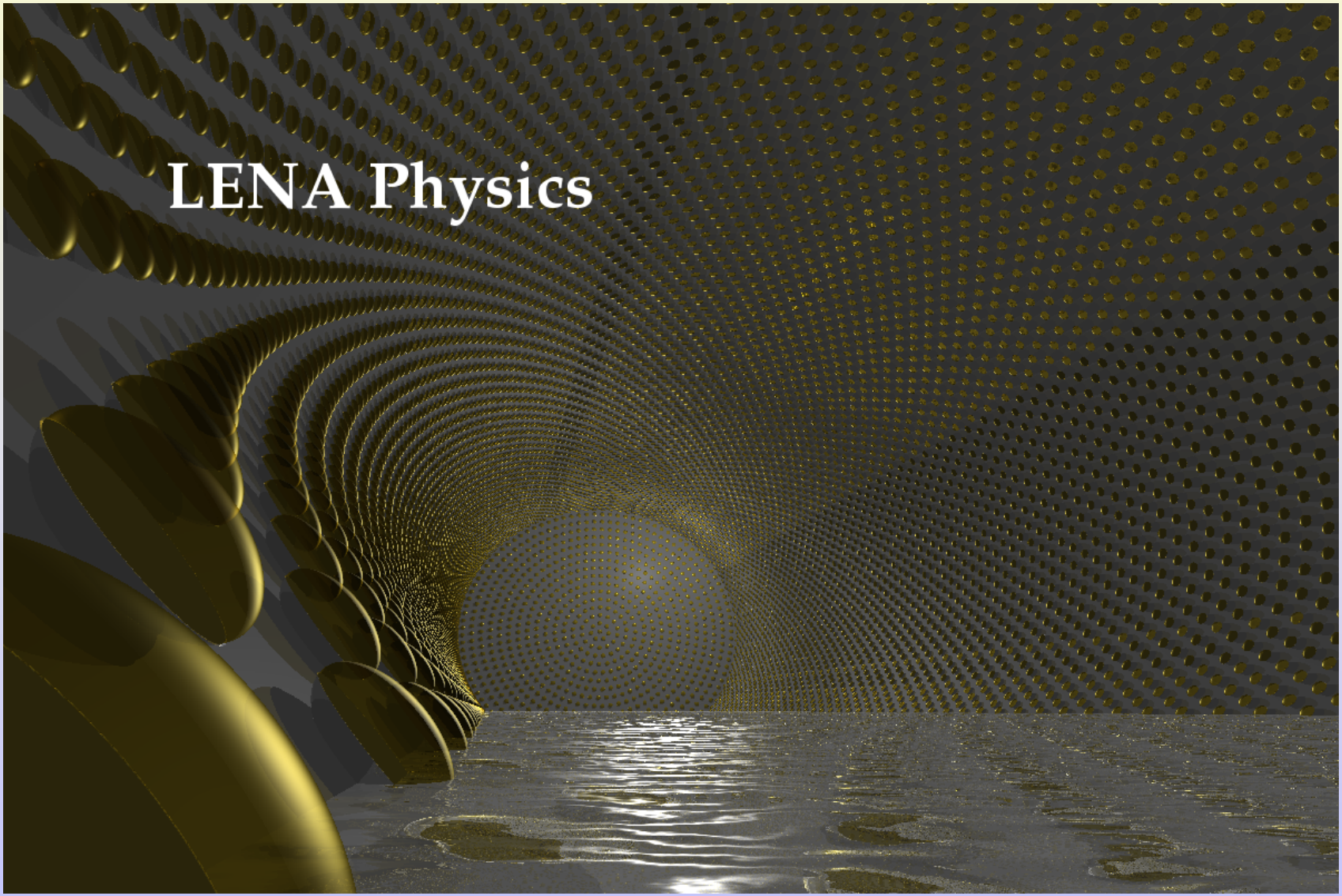
- New facilities or extensions are required!
- Criteria:
  - Depth, distance to reactors, distance to accelerators ...

Candidate laboratories:

- Underground Science in Boulby mine (UK)
- Underground Science in Pyhäsalmi mine (Finland)
- Polkowice-Sieroszowice mine (Poland)
- Laboratoire Souterrain de Modane (France)
- Laboratorio Subterráneo de Canfranc (Spain)
- Laboratori Nazionali del Gran Sasso (Italy)

LAGUNA working activities: $\sim$60 scientists

- A scientific case document has been drafted ($\sim$ 30 pages)
- An European proposal for a Design Study is on-going
- Since April 2006 regularly meetings coordinate LAGUNA
- Working groups:
  - WP1: Underground infrastructure
  - WP2: Underground tanks
  - WP3: Tank instrumentation
  - WP4: Pure liquid procurement
  - WP5: Safety and environment
  - WP6: Underground science optimization and outreach
  - WP7: Management and coordination


LENA Physics

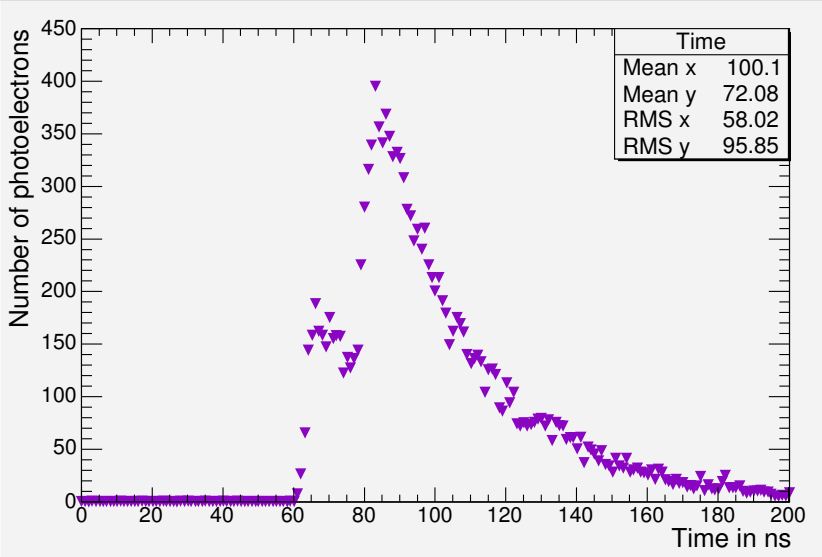
Free Proton Decay: $p \to K^+ \overline{\nu}$

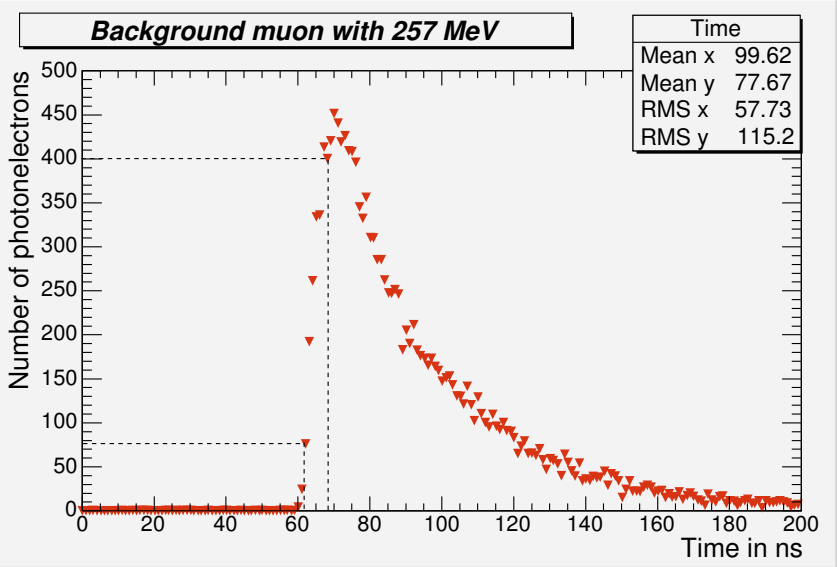
$$T(K^+) = 105 \text{ MeV} \quad \tau(K^+) = 12.8 \text{ ns}$$

- $K^+ \to \mu^+ \nu_\mu$ 63.43%
- $K^+ \to \pi^+ \pi^0$ 21.13%

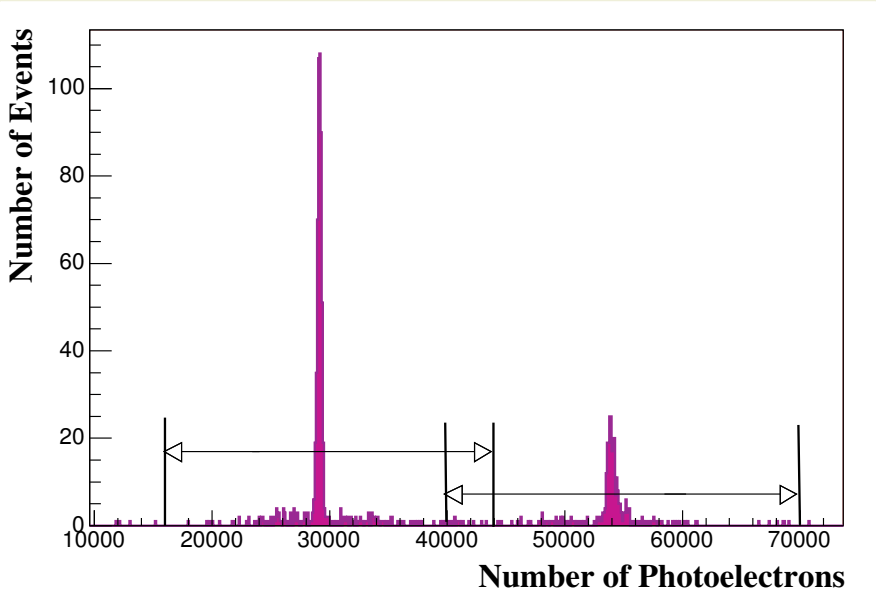
Detection efficiency: $\varepsilon_T = 0.65$

Background suppression: B $\sim 5 \cdot 10^{-5}$





Background Rejection: Energy cut



- Energy spectrum: 110 pe/MeV
- Two peaks:
  - Kaon + Muon: ~ 257 MeV
  - Kaon + Pions: ~ 459 MeV
- Efficiency: $\varepsilon_E = 0.995$
- Included: protons from ^{12}C

Potential of LENA (10 y measuring time)

- For Superkamiokande current limit: $\tau = 2.3 \cdot 10^{33}$ y
  - 40 events in LENA und $\lesssim 1$ background
- No signal in LENA: $\tau > 4 \cdot 10^{34}$ y 90% (C.L)

Supernovae Neutrinos

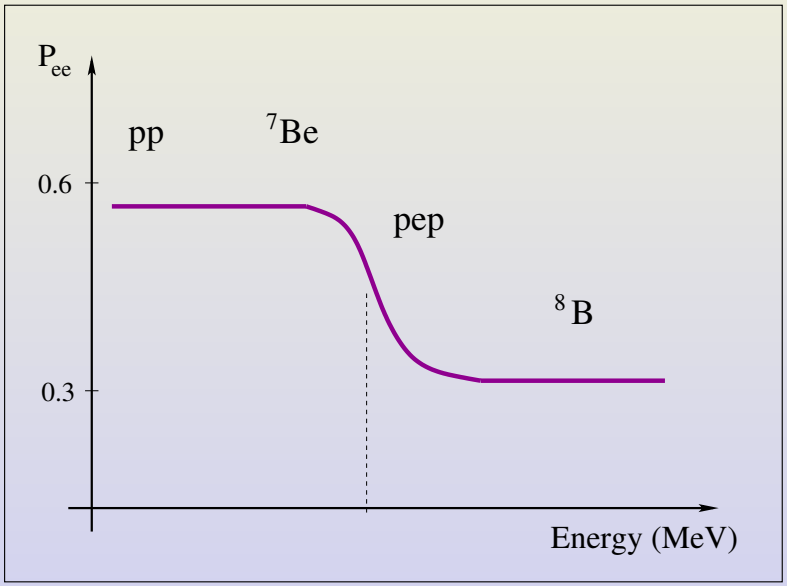
- Current supernova explosion

  (Talk by Jürgen Winter 601.2)

- Diffuse background of supernova neutrinos

  (Talk by Michael Wurm 601.3)

Solar Neutrinos



Spectrum deformation due to the MSW effect

Rates of solar neutrino events

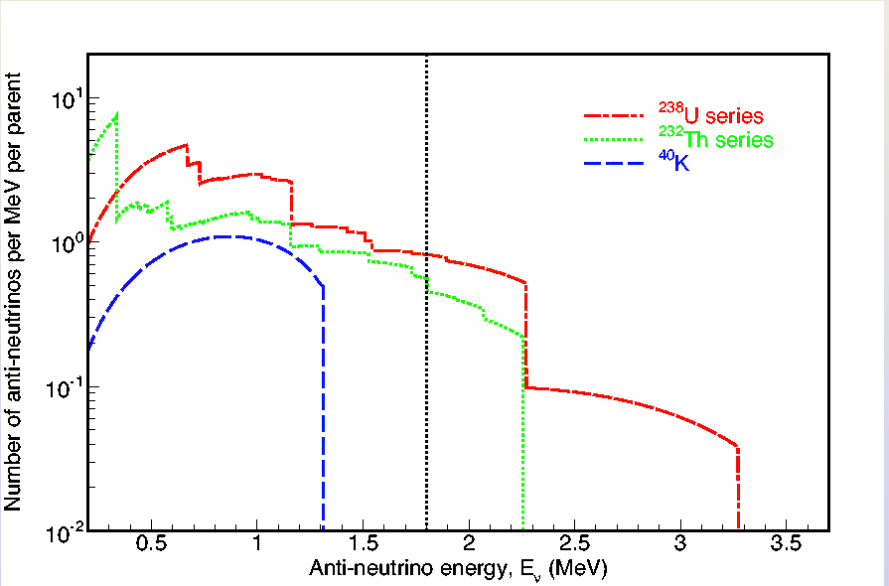
In the LENA fiducial volume:

$$18 \cdot 10^3 \text{ m}^3$$

- ^{7}Be ν's: ~ 5400 d^{-1}
  - Small time fluctuations
- pep ν's: ~ 150 d^{-1}
  - Solar luminosity in ν's: information about the pp-flux
- CNO ν's: ~ 210 d^{-1}
  - Important for heavy stars
- ^{8}B ν's: CC on ^{13}C: ~ 360 y^{-1}

Geoneutrinos

- Unexplained source of heat flow on Earth
- Unknown contribution of natural radioactivity
- How are ^{238}U, ^{232}Th distributed in core, mantle and crust?



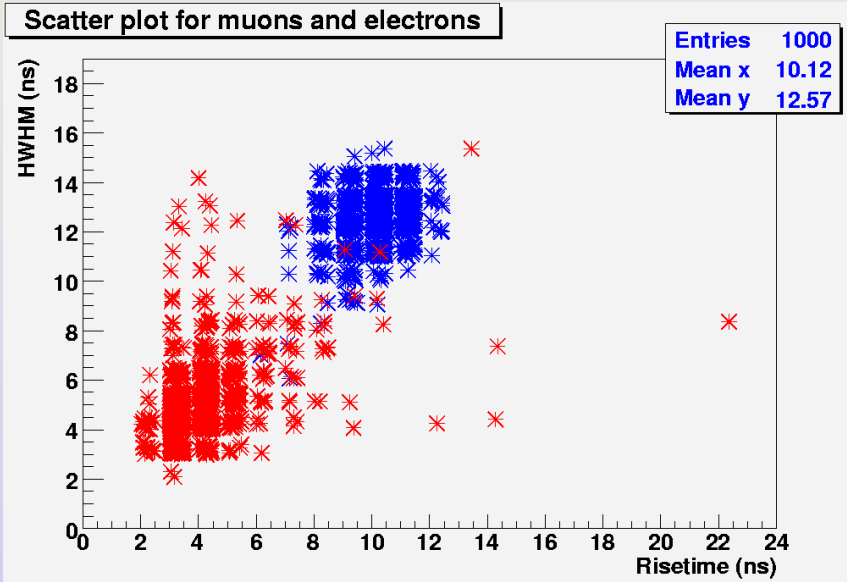
In liquid scintillator:

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

- In LENA detector:
  $\sim$ (400-4000) events/y

On going work: LENA for Betabeams

HWHM (ns) vs. risetime (ns)



Scatter plot for muons and electrons of 1.2 GeV

- Electron/muon separation:
  - Pulse shape discrimination
  - Electron detection from the decay of the muon
- For energies between 0.2 and 1.2 GeV
  - Muon appearance: $\sim$ 90 %
  - Electron background: $\sim$ 0.5 %
- Good energy resolution
- Background due to π or kaon production

Summary

- LAGUNA
  - The physics motivation of this comunity has been presented
  - Three detector approaches are proposed
  - Work together is going on to solve common problems
- LENA
  - Good sensivitivy for proton decay via $p \rightarrow K^+ + \overline{\nu}$
  - Detection of solar and supernova neutrinos
  - High statistics on geoneutrinos
  - Feasibility studies for LENA as beta beam detector
  - Technical feasibility studies (Talk 601.4)