The Neutrino Observatory LENA

Frühjahrstagung der DPG 2012 - Göttingen

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Overview

Motivation

What do we gain from a next-generation neutrino detector?

- better understanding of astrophysical an terrestrial ν sources
- investigation of neutrino properties
- target for neutrino beam
- search for proton decay

- large LS detector offers a this range of physics!
- KamLAND and Borexino show the outstanding physics potential of liquid scintillator detectors
- increase detection sensitivity and precision $\rightarrow$ higher target masses

LAGUNA – LAGUNA-LBNO

Large Apparatus for Grand Unification and Neutrino Astrophysics

LAGUNA design study

- 2008–2011
- 3 detector types

GLACIER	100 kt LAr TPC
MEMPHYS	440 kt water
LENA	50 kt liquid scintillator

- physics potential
- 7 locations in Europe
- cavern design

LAGUNA-LBNO

- follow up study (2011–2014)
- Long Baseline Neutrino Oscillations
- possible beam @ CERN
- detector tank
- instrumentation

Neutrino Detection

Detection principle

ν: elastic scattering

$\nu + e^- \rightarrow \nu + e^-$

$\bar{\nu}_e$: inverse β-decay

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

Spectral Measurement

- energy deposit related to incident particle

$\Rightarrow$ count photo electrons

Advantages of LS

- very low energy threshold ($\approx$ 200 keV)
- good energy resolution ($\approx$ 7% @ 1 MeV)
- high purity

Background Rejection

- pulse shape analysis
- coincidence signals

Randolph Möllenberg – T 110.3, Mi, 17:20–17:35

Jürgen Winter – T 110.5, Mi, 17:50–18:05

Detector Design

Egg shaped cavern

- $\updownarrow$ 115 m
- $\varnothing >$ 36 m

Detector Tank

- concrete wall
- cylindrical –
  $\updownarrow =$ 100 m
  $\varnothing =$ 32 m
- 29600 12" PMTs

Target

- 50 kt scintillator

Electronics hall

- 15 m high
- top muon veto

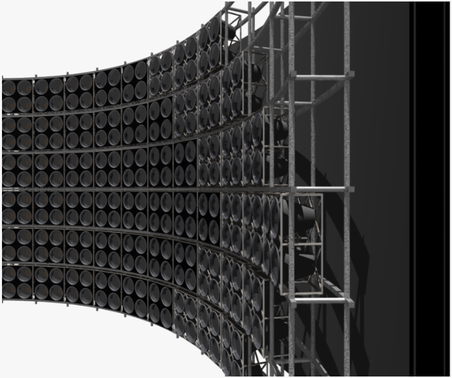
Water-filled cavern

- 4000 8" PMTs
- veto for inclined muon tracks
- shielding for fast neutrons

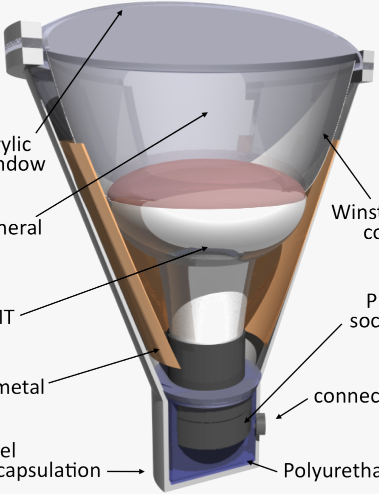
PMT Support Structure

- scaffolding 2 m from tank wall
- optical separation of inner volume by non-reflective plastic sheets

⇒ reduces impact of γ activity from concrete tank wall



Optical Modules



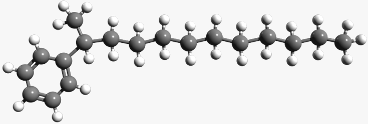
- Winston cones for light concentration
- 29600 12" PMTs
- 30% optical coverage
- pressure encapsulation
- non-scintillating buffer volume included in front of the PMT
- total weight: 30 kg
- contained within PSS

Marc Tippmann – T 110.4, Mi, 17:35–17:50

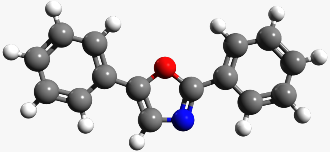
LENA Scintillator

- linear-alkyl-benzene as solvent
- high flashpoint 140°C
- PPO + bisMSB as wavelength shifters
- emission @ 430 nm
- time response: 5.2 ns
- high light yield $\sim$ 10000 γ per MeV
- high transparency $\sim$ 20 m
- low cost ($<$ 1.30 €/ℓ)

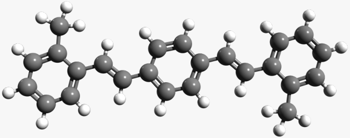
LAB ($C_{18}H_{30}$)



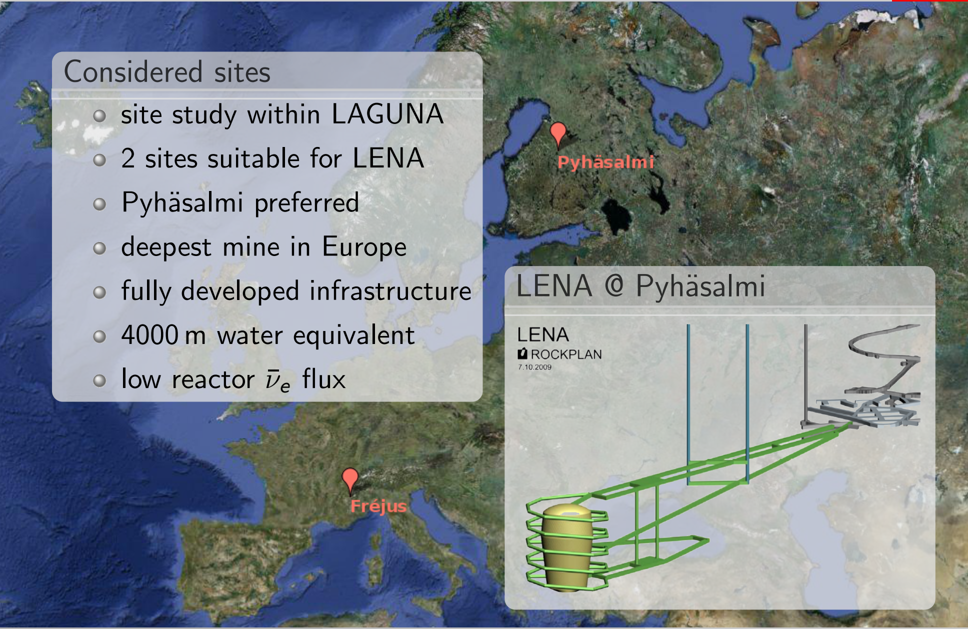
+3 g/l PPO ($C_{15}H_{11}NO$)



+20 mg/l bisMSB ($C_{24}H_{22}$)



LENA Sites



Considered sites

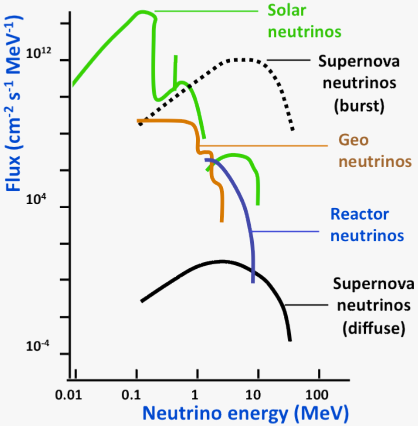
- site study within LAGUNA
- 2 sites suitable for LENA
- Pyhäsalmi preferred
- deepest mine in Europe
- fully developed infrastructure
- 4000 m water equivalent
- low reactor $\bar{\nu}_e$ flux

LENA @ Pyhäsalmi

Physics Program

Neutrino Physics

- Galactic supernova neutrinos
- Diffuse supernova background
- Solar neutrinos
- Geoneutrinos
- Reactor neutrinos
- Neutrino oscillometry
- Neutrino beams
- Atmospheric neutrinos
- π DAR beam



Also

- Indirect dark matter search
- Proton Decay

Multi-channel signatures

- core collapse supernova produces (ν_e) neutrino burst
- $\nu\bar{\nu}$-pairs during cooling phase

$\rightarrow$ individual, time dependent spectra for different neutrinos

- 15000 ν interactions expected for SN in galactic center
- different detection channels for individual neutrino types
- energy and flavor resolved real-time analysis

$\Rightarrow$ follow different stages of core collapse

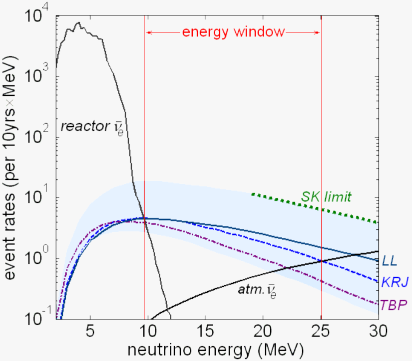
$\Rightarrow$ oscillations of SNνs sensitive to θ_{13} and mass hierarchy

- SNEWS

Markus Kaiser – T 110.2, Mi, 17:05–17:20

Diffuse Supernova Neutrino Background

- only 1–3 galactic supernovae per century
- isotropic neutrino background from SN on cosmic scales
- information on average neutrino spectrum
- redshifted by cosmic expansion
- expected flux: 100 $\nu/\text{s}/\text{cm}^2$
- not yet observed
- LENA: 2 – 20 events per year



Solar Neutrinos

Spectral measurements

- high statistics energy dependent flux measurements
- $\sim$ 10000 events per day
- $\sim$ 200 CNO neutrinos
- test transition region of MSW effect
- fiducial mass: $\sim$ 30 kt to reduce γ background

Investigation of the Sun

- metallicity
- precise determination of SSM neutrino rates
- search for time variations in flux
- helioseismic g-modes

Terrestrial $\bar{\nu}_e$

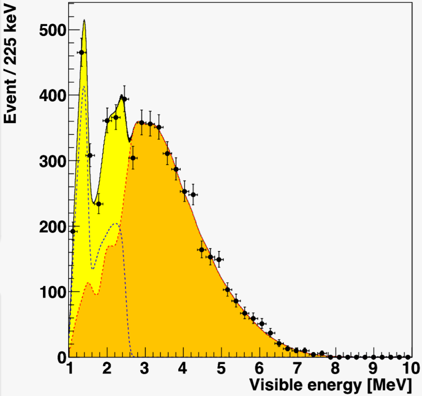
Lena will detect $\mathcal{O}(10^3)$ events from terrestrial $\bar{\nu}_e$ per year

Geoneutrinos

- 10 years LENA: 11% precision of U/TH flux ratio
- direct messengers $\rightarrow$ abundances and distribution of radioactive elements in Earth
- test radiogenic contribution to the heat flux of Earth

Reactor Neutrinos

- background for geo-ν and DSNB
- high statistics study of oscillation parameters



Neutrino Oscillometry

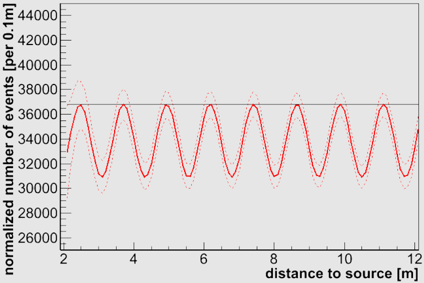
- monoenergetic ν_e source
- ν_e disappearance can be detected within the length of the detector
- reactor antineutrino anomaly $\Rightarrow$ sterile neutrinos?

$\rightarrow$ several oscillations within the first 10 m

EC Sources

Type	Element	Energy
ν_e	^{51}Cr	747 keV
ν_e	^{37}Ar	811 keV
$\bar{\nu}_e$	^{90}Sr	1.8–2.3 MeV

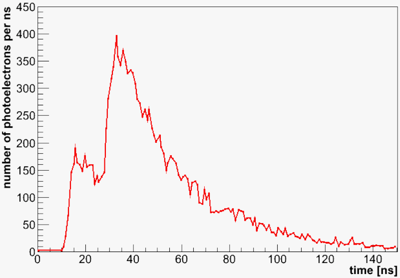
55 days – 5 MCi ^{51}Cr source



LENA can set a limit of $\tau_p > 4 \times 10^{34}$ years for the lifetime of the proton in the channel

$$p \rightarrow K^+ + \bar{\nu}$$

- distinct pulse shape
- signal generated by kinetic energy deposition of kaon (cherenkov light)
- prompt signal followed by signals from decay products
- background free for 10 years
- special for LS – cherenkov threshold not reached in e.g. water



LAGUNA-LBNO

- use LENA as a far detector
- possible beam e.g. from CERN
- baseline: $\sim 2300\,\text{km}$

$\Rightarrow$ 1^{st} oscillation maximum 4.65 GeV

conventional beam: appearance mode $\nu_\mu \rightarrow \nu_e$ ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$)

- (multi-particle) tracking currently under investigation
- use charge and time distributions $\rightarrow$ looks promising
- NC background discrimination (e.g. $\pi^0 \rightarrow \gamma\gamma$)

Sebastian Lorenz – T 31.3, Fr, 10:00–10:15

Dominikus Hellgartner – T 31.4, Fr, 10:15–10:30

Conclusions

- LENA can explore a wide range of interesting physics
- LS is a cost effective option for a next generation neutrino detector
- design and construction could be realized in 8 to 10 years
- LENA Whitepaper `arXiv:1104.5620` accepted for publication in Astroparticle Physics

LENA Talks @ Göttingen 2012

Markus Kaiser – T 110.2, Mi, 17:05–17:20

Supernova-Neutrinos in LENA: Diskrimination der Detektionskanäle

Randolph Möllenberg – T 110.3, Mi, 17:20–17:35

Alpha-Beta Discrimination in LENA

Marc Tippmann – T 110.4, Mi, 17:35–17:50

Development of an Optical Module for LENA

Jürgen Winter – T 110.5, Mi, 17:50–18:05

Proton Recoils in Organic Liquid Scintillator

Sebastian Lorenz – T 31.3, Fr, 10:00–10:15

Diskriminierung von NC π^0 Ereignissen im Flüssigszintillatordetektor LENA

Dominikus Hellgartner – T 31.4, Fr, 10:15–10:30

Track reconstruction in unsegmented liquid scintillator detectors