LENA

Low Energy Neutrino Astrophysics

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www.e15.physik.tu-muenchen.de/research/lena.htlm

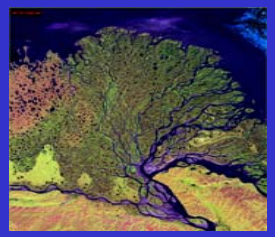
Groups interested in LENA

- TU Munich, Germany
- Univ. Hamburg, Germany (C. Hagner)
- CUPP, Finland (J. Peltoniemi)
- Univ. Jyväskylä, Finland (J. Aysto)
- INR, Russia (L. Bezrukov)

Similar initiative:

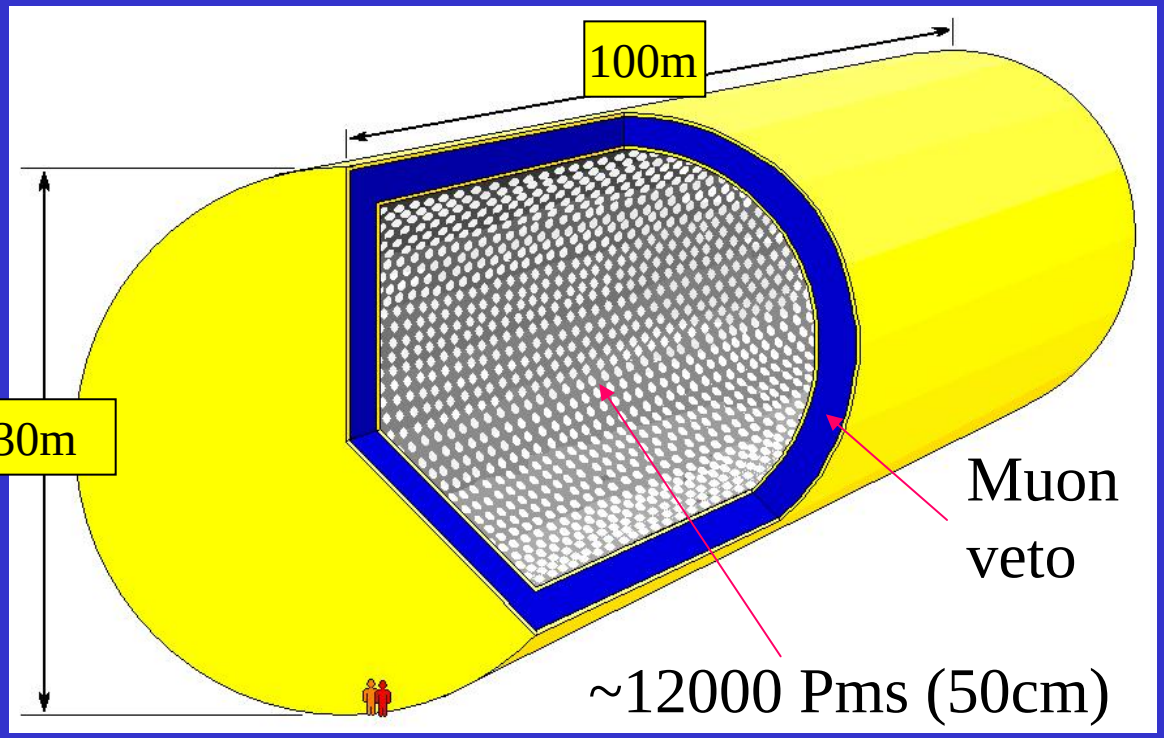
- HSD („Hyper-Scintillation-Detector“) Kimballton mine, Virginia, USA

LENA



Proposal: A large (~50 kt) liquid scintillator underground detector for

• Baryon number violation	Proton decay
• Gravitational collapse	SN ν detection
• Star formation in the early universe	Relic SN ν
• Solar thermonuclear fusion processes	CNO, pep, ^{7}Be
• Geophysical models	U, Th - ν
• Neutrino properties	Long baseline - ν



LENA

Detector and scintillating liquid

Scintillator solvent: PXE, or PXE/mineral oil mixture

- **non hazardous, flashpoint 145° C → easy handling**
- **density 0.99 → high self shielding**
- **high light yield → low energy events**
- **low background level U, Th → solar ν, geo ν, srn ν**

PXE as scintillating solvent

- PXE tests @ Counting Test Facility from BOREXINO at Gran Sasso (physics/0408032)

- 372 pe / MeV @ 20% coverage
  $\lambda_{attenuation}$ ~ 4 m @ 430 nm
  $\lambda_{attenuation}$ ~ 12 m after purification
  (alumina-column, S. Schönert MPIK Hd for LENS)

- **=> ~ 120 pe / MeV in LENA** (central events)

  => low energy threshold (sub-MeV)
  => good resolution in energy and position reconstruction

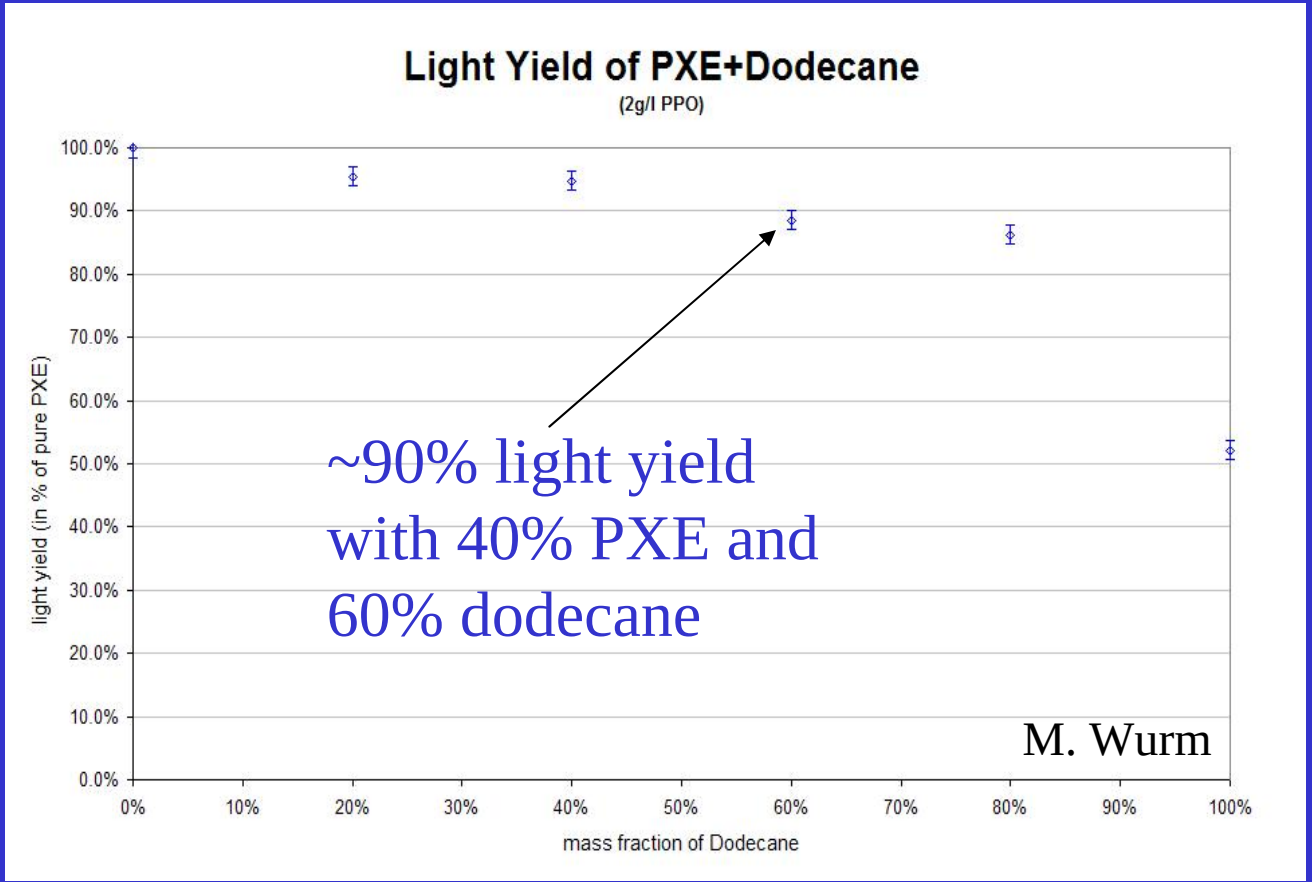
Program for investigations of PXE / dodecane mixtures

C, Buck et al., MPIK Heidelberg

(Double-Chooz)

M. Wurm, K. Hochmuth, TUM

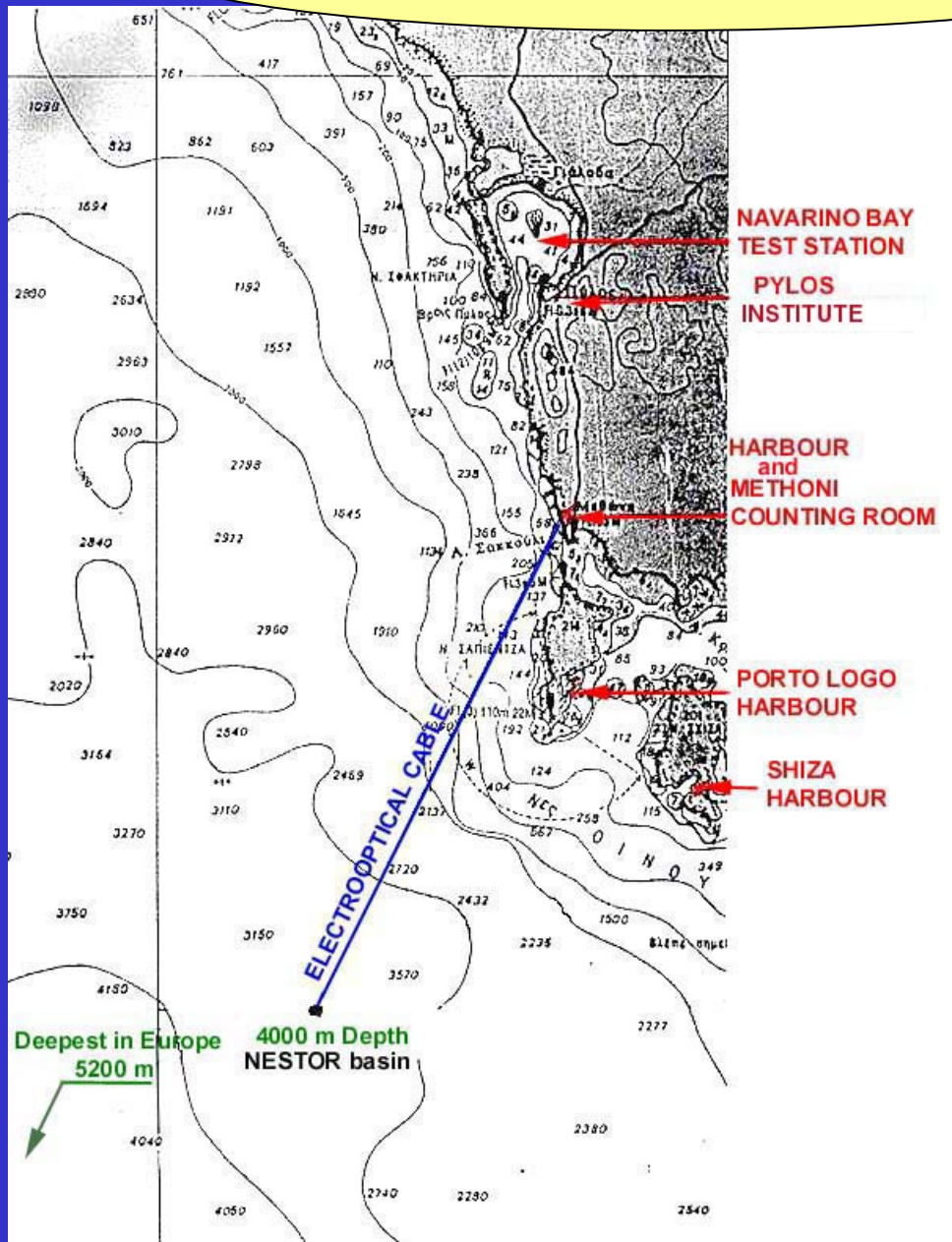
- improve compability with detector materials
- improve further transparency?
- increase free H number (by ~30%)



LENA at CUPP

- **transport** of PXE via **railway**
- **loading** of detector via direct **pipeline**
- **no fundamental security problem with PXE !**
- no fundamental problem for **excavation**
- standard technology (PM-encapsulation, electronics etc.)
- **LENA is feasible in Pyhäsalmi !**

Pylos (Nestor Institute) in Greece

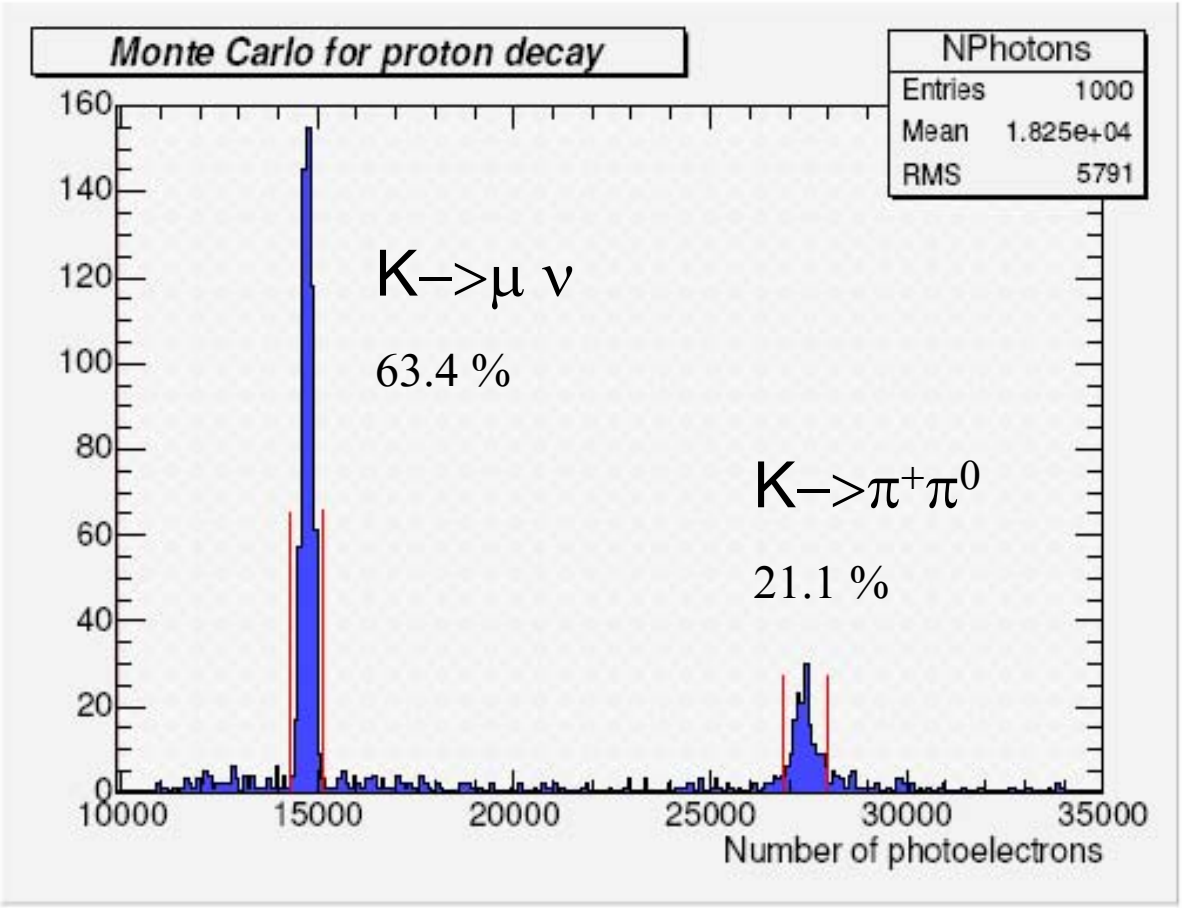


Proton Decay and LENA

$$p \rightarrow K \nu$$

- This decay mode is favoured in ***SUSY*** theories
- The primary decay particle K is ***invisible*** in Water Cherenkov detectors
- The Kaon and the K-decay particles are visible in LENA
- Better energy solution further ***reduces background***

Background Rejection: Energy cut



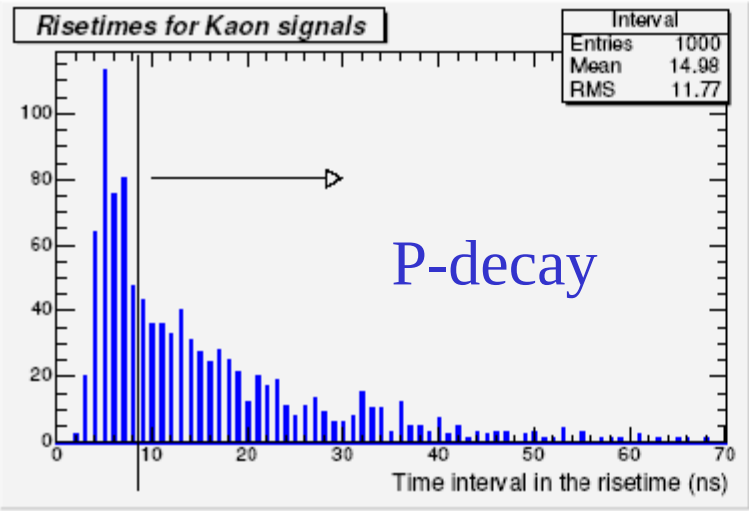
- Two peaks:
  - Kaon + Muon
    ~ 257 MeV
  - Kaon + Pions
    ~ 459 MeV
- Efficiency:
  $\varepsilon_E = 0.719$

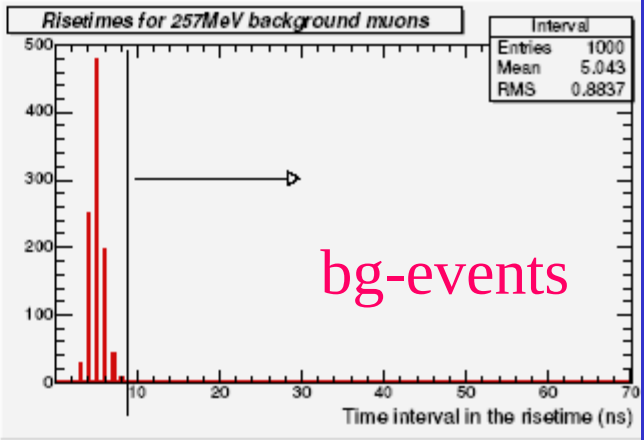
Teresa Marrodan

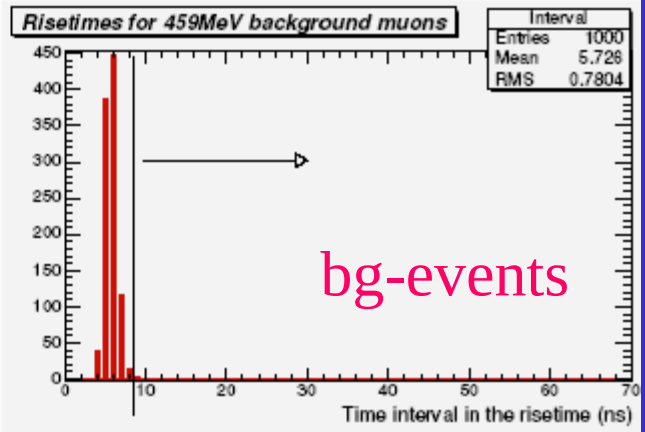
TECHNISCHE UNIVERSITÄT MÜNCHEN

Background Rejection: Timing

- Time cut
  - Background suppression: B ~ 0.001
  - Efficiency: $\varepsilon_T = 0.600$







- **Event structure $p \rightarrow K \nu$ plus K – decay ($T_{1/2}$ = 12.8 ns)**
- **3-fold delayed coincidence from μ - decay**

Potential of LENA for p –> Kν

SuperK current limit $\tau = 1.6 \times 10^{33}$ y:

27 events in 10 years in LENA

(0.7 bg events)

No signal:

$\tau > 3 \times 10^{34}$ y

Galactic Supernova neutrino detection with Lena

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

(2) $\bar{\nu}_e + {}^{12}C \rightarrow e^+ + {}^{12}B$ (Q = 13.4 MeV)

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

(4) $\nu_x + {}^{12}C \rightarrow \nu_x + {}^{12}C^*$ with ${}^{12}C^* \rightarrow {}^{12}C + \gamma$ ($Q = E_\gamma = 15.1$ MeV)

(5) $\nu_x + e^- \rightarrow \nu_x + e^-$ (elastic scattering off electrons)

(6) $\nu_x + p \rightarrow \nu_x + p$ (elastic scattering off protons).

Electron Antineutrino spectroscopy ***~7800***

Electron ν spectroscopy ***~ 65***

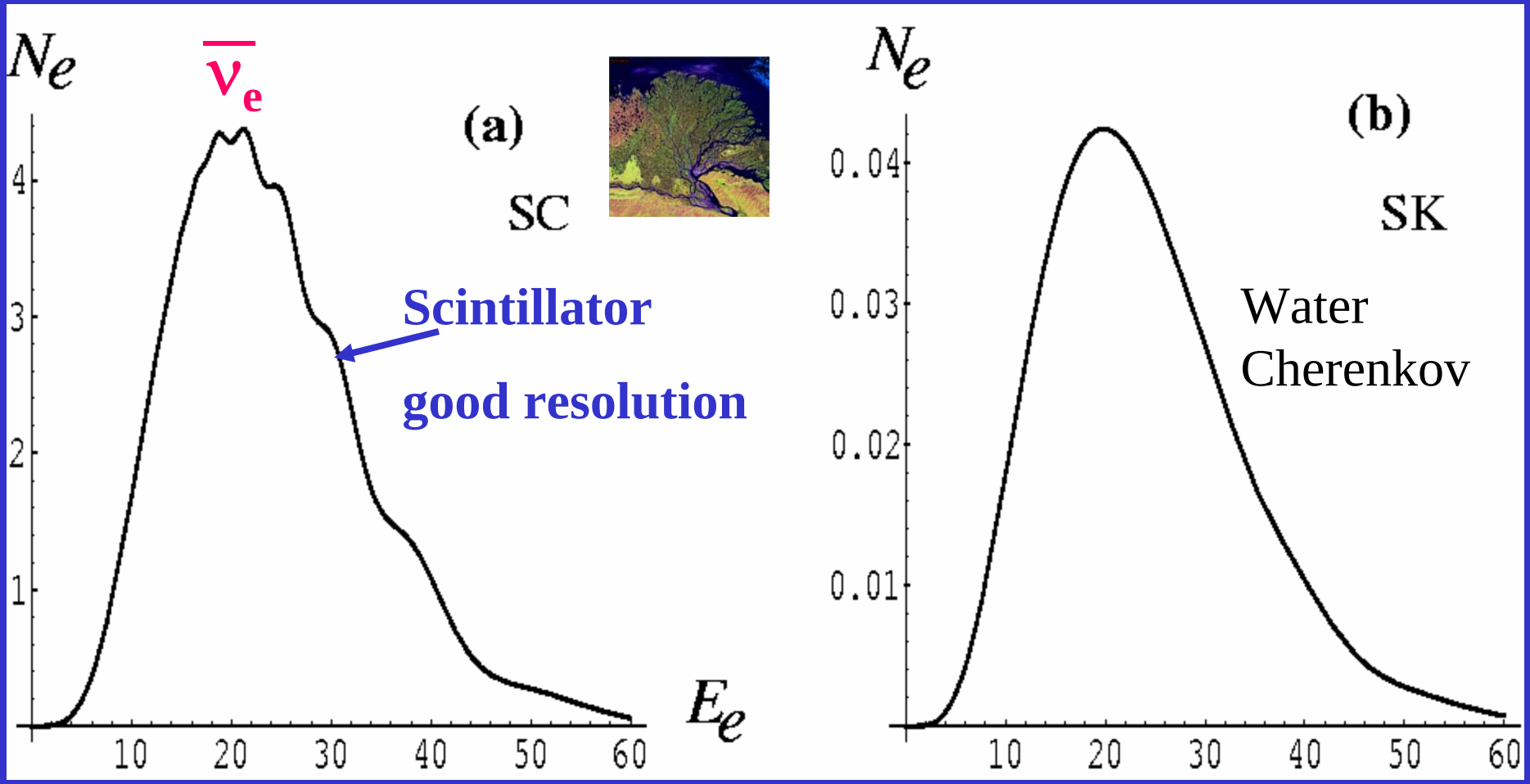
~ 480

Neutral current interactions; info on all flavours

~ 4000 and ~ 2200

Event rates for a SN type IIa in the galactic center (10 kpc)

SNN-detection and neutrino oscillations

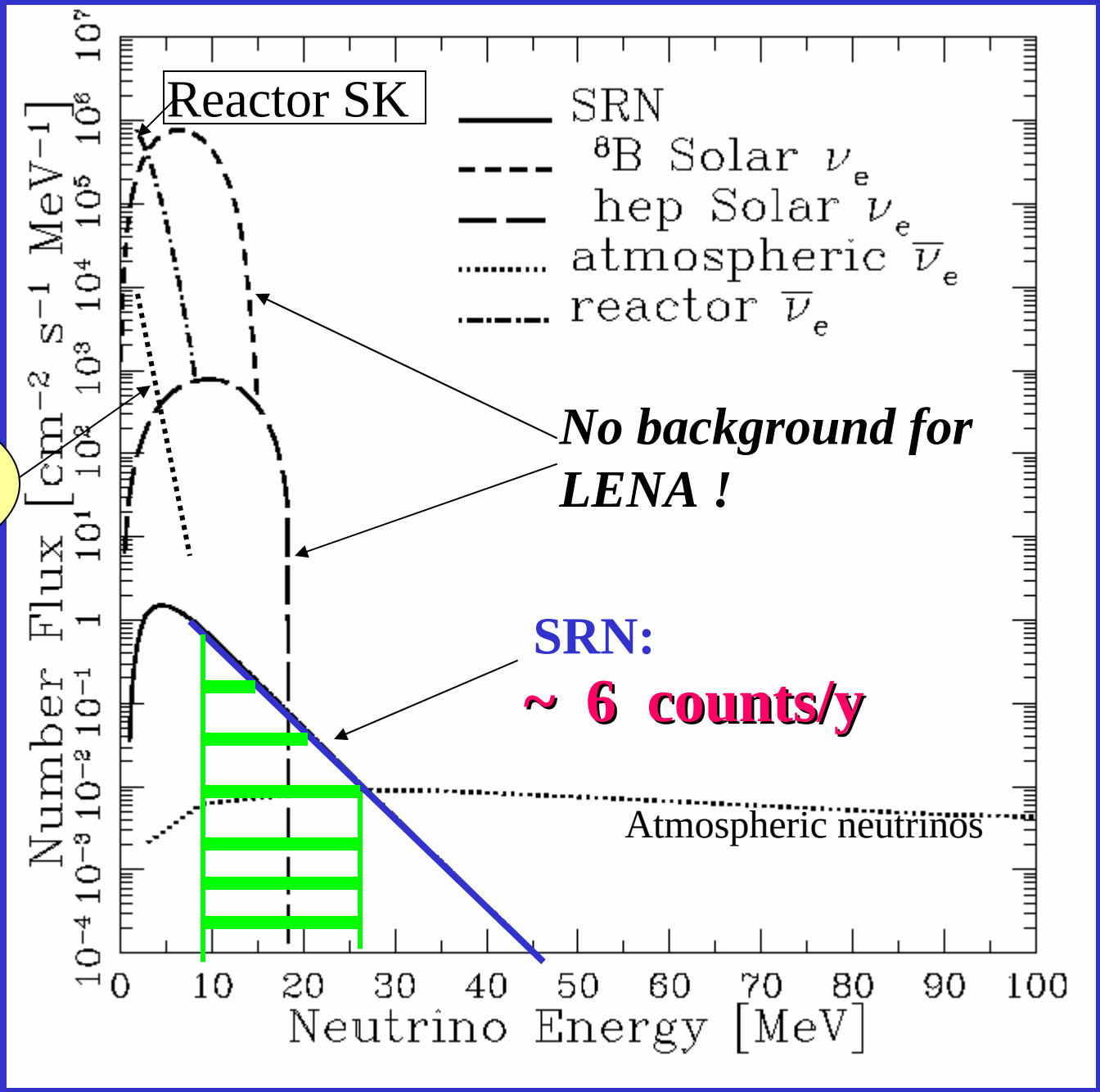


Modulations in the energy spectrum due to matter effects in the Earth

Dighe, Smirnov, Keil, Raffelt

LENA and relic Supernovae Neutrinos !

- SuperK limit very close to theoretical expectations
- Threshold reduction from ~19 MeV (SuperK) to ~ **9 MeV** with **LENA**
- Method: delayed coincidence of $\bar{\nu}_e$ **p –> e n**
- **Low** reactor neutrino **background** !
- Information about **star formation in the early universe**



Reactor bg LENA !

Thermal nuclear fusion and LENA

- high statistic ^{7}Be-solar ν detection (~10^{4} d^{-1})

  → test of even small flux variations

  look for coincidences with helioseismological data !

- CNO – and pep-ν (~300 d^{-1})

  → solar neutrino luminosity

- precise determination of solar nuclear fusion processes

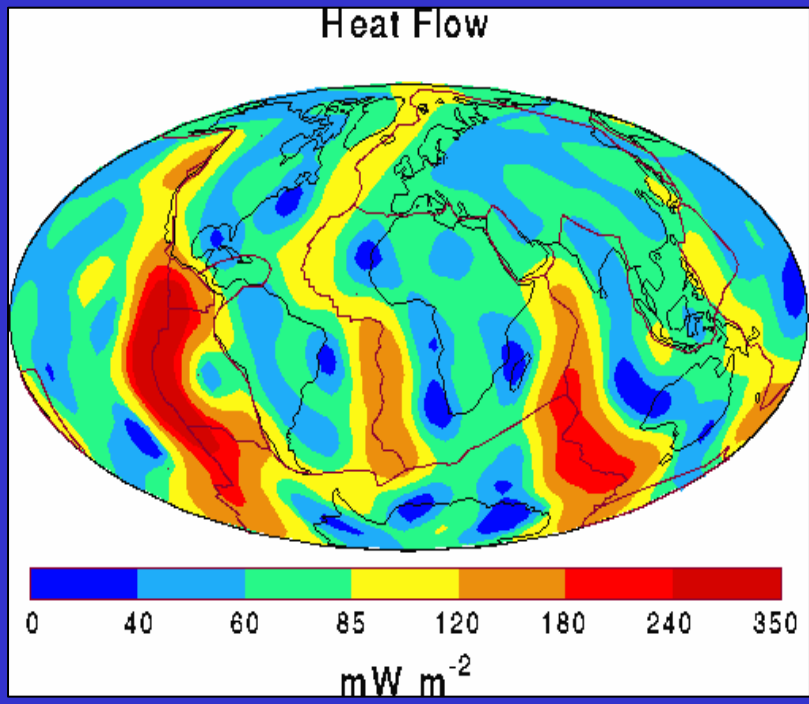
Long baseline ν - oscillations and LENA ?

To be investigated in detail:

- ν spectrum (off-axis)
- e, μ - separation potential
- potential in Θ_{13}

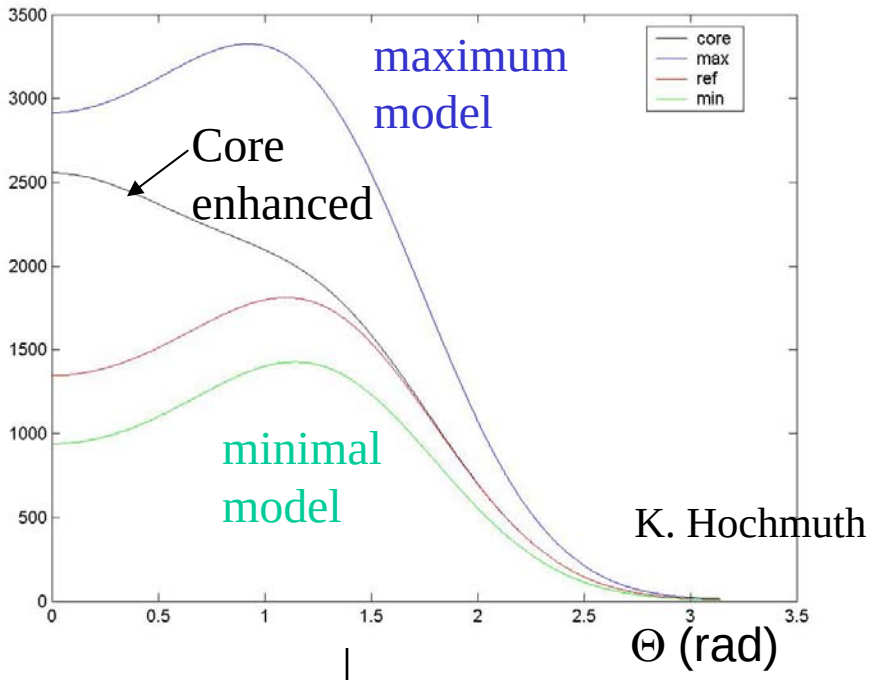
Geo - neutrinos and LENA

- what is the source of the terrestrial heat flow ?
- what is the contribution of natural radioactivity ?
- how much of U, Th is in the mantle ?
- is there a natural reactor at the Earth‘s center?



Angular distribution information

- reconstruct vertices of prompt and delayed events
- resolution ~ 30º (MonteCarlo)



Events per year	$0° < \theta < 60°$	$60° < \theta$	total
ref	618 ± 25	822 ± 29	1440 ± 38
min	453 ± 21	653 ± 27	1106 ± 33
max	1255 ± 35	1365 ± 37	2620 ± 51
core	950 ± 31	858 ± 29	1807 ± 43

Conclusions

- **LENA** a new observatory
- complemntary to high energy neutrino astrophysics
- fundamental impact on e.g. **proton decay, astrophysics, neutrino physics, geophysics**
- feasibility studies very promising (CUPP, **Pyhäsalmi)**
- costs ca. 100 - 200 M€