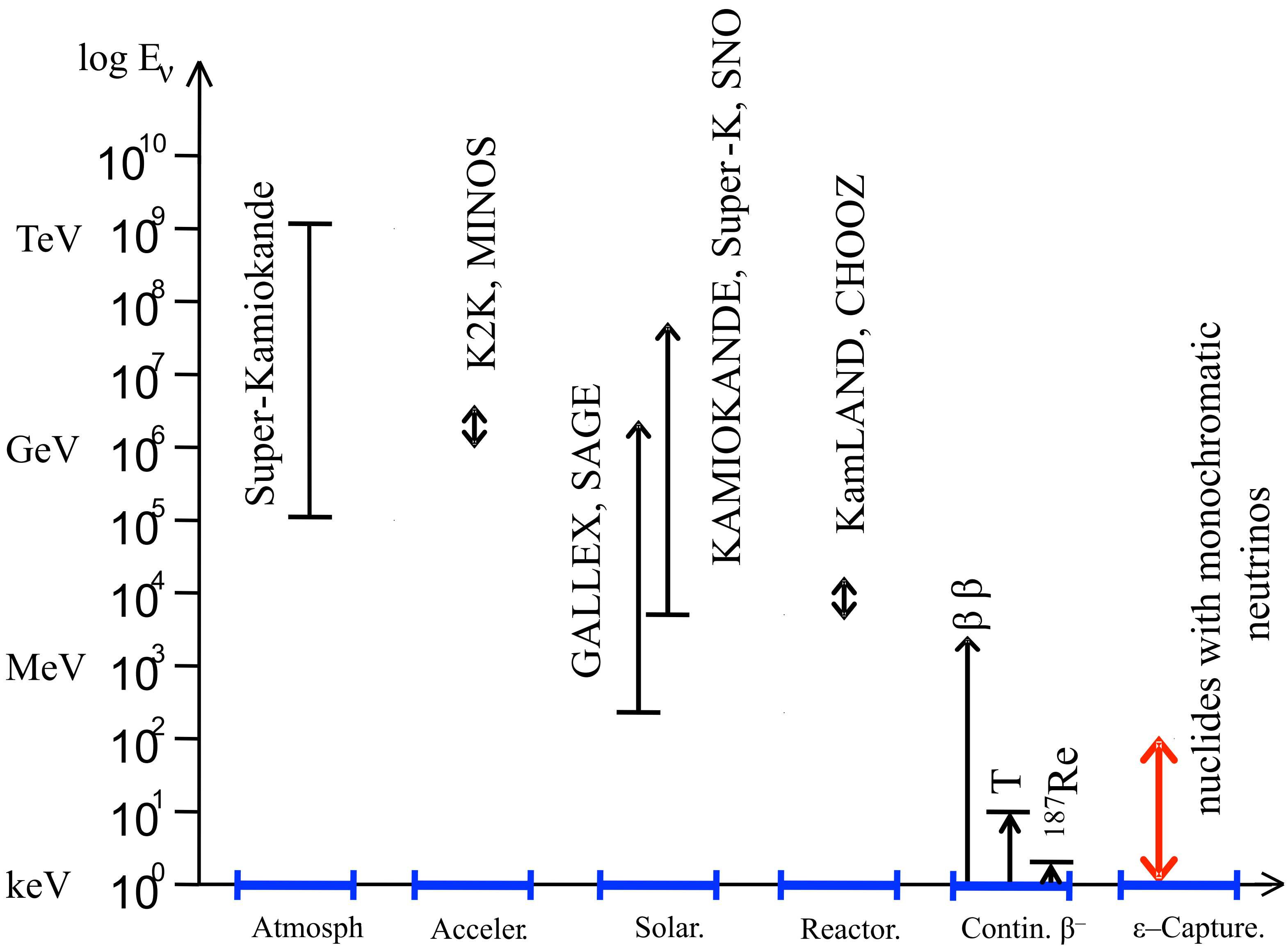
Neutrino oscillometry at LENA

(LENA collaboration meeting in Zeuthen, 17.11.2011)

Agenda:

1. Specific feature of oscillometry (reminder)
2. New results (sterile neutrinos, oscillometry of antineutrinos)
3. Impact of oscillometry
4. New technical proposals. Working plan

ν-Energy regions available for different detectors

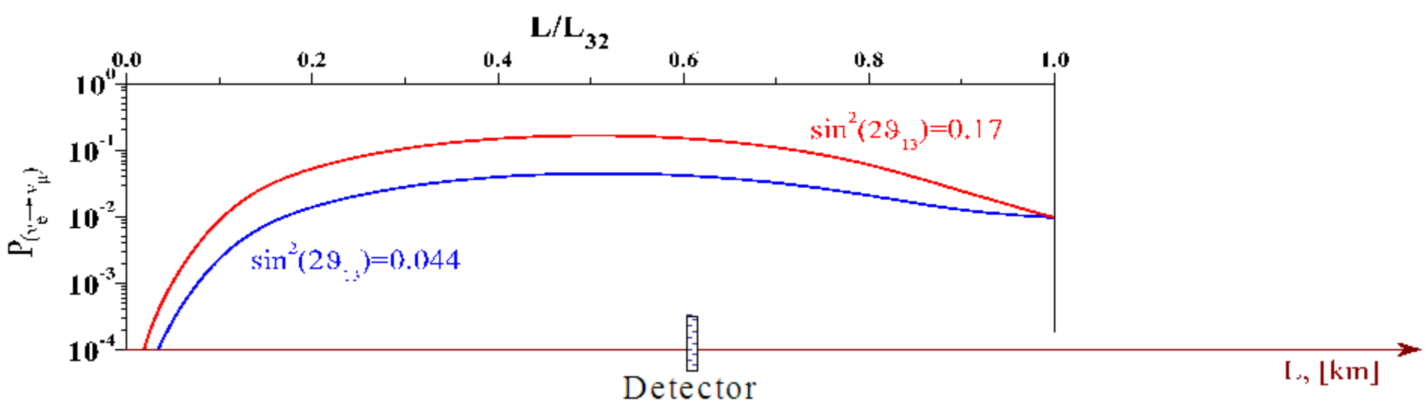


Yu. Novikov Zeuthen-17-11-2011

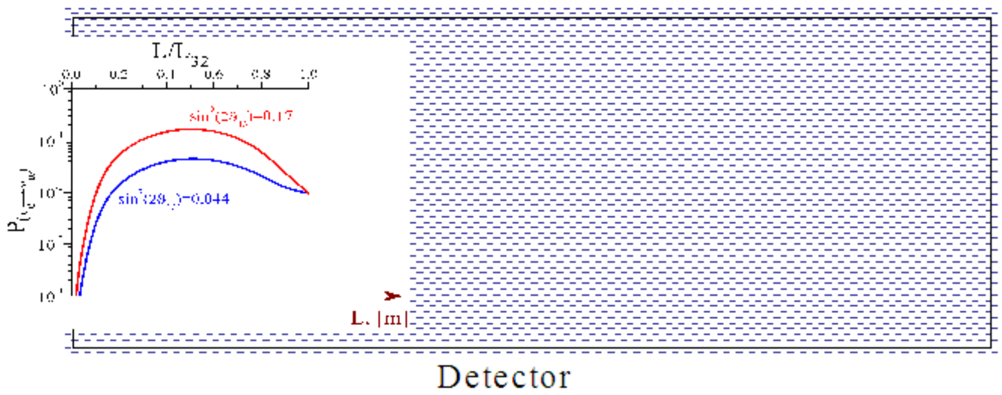
A dot long baseline oscillation versus continuous short baseline oscillometry

Comparison of *"one-point" oscillation* identification with the *continuous oscillometry* within the sizes of detector

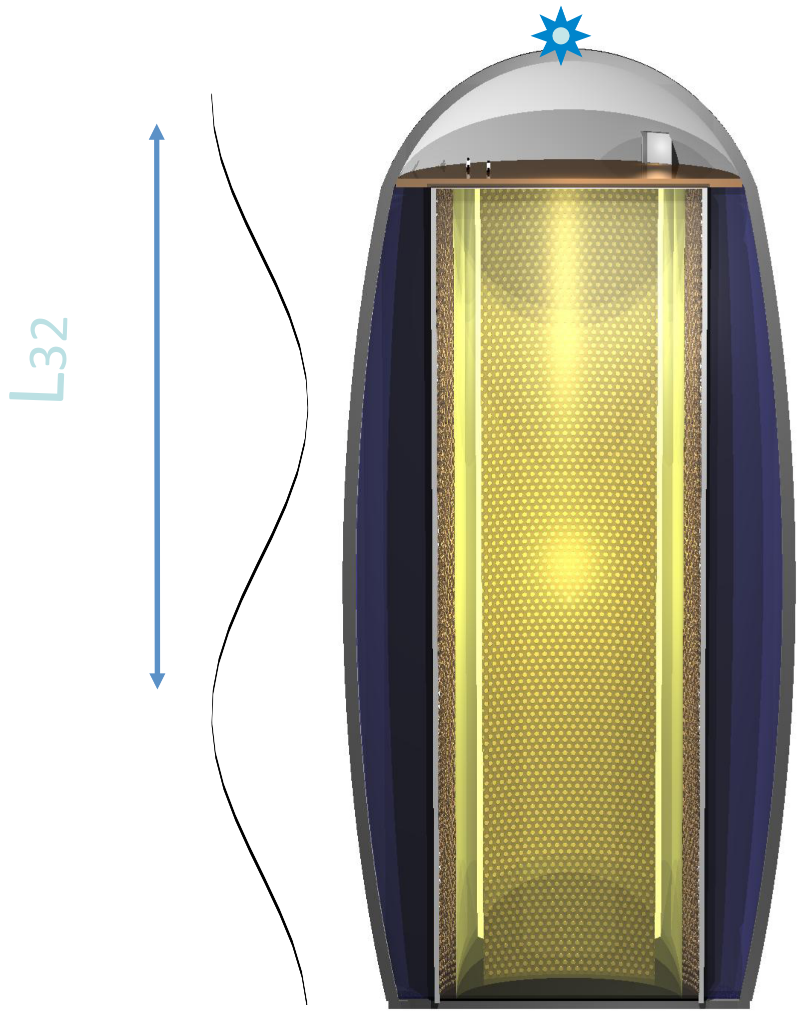
Long baseline ($E_?$>> 1 MeV)? L in [km]



Short baseline ($E_?$ << 1 MeV)? L in [m] - **oscillometry**



Advantages of mononeutrino oscillometry in the νe-scattering



- Neutrino from the capture process is monochromatic: Only single corresponding L_{32}
- This monochromatic energy of neutrino is small (< 100 keV) for some nuclides.
- Because of it the oscillation length L_{32}, equal in meters to the neutrino energy (in keV), preferably should be < 100 meters.
- Thus, oscillations can be scanned within the dimensions of detector.
- The neutrino source can be prepared by irradiation at the reactor.
- The source can be removable in the case of LENA-detector which allows to measure the background.
- Background of geo-neutrinos also should be scanned along the detector length !

Oscillometry requirements

- ➔ Monoenergetic, monochromatic and monoisotopic neutrinos ≡> **mononeutrino**
- ➢ Neutrino energies should be «1 MeV, however »250 keV for LS ≡> **250 keV<< E_ν << 1000 keV**
- ➔ Half-lives of the neutrino source should be <1000 days, however >10 days ≡> **10 d < $T_{1/2}$ < 1000 d**
- ➔ Source intensity should be > 1 MCi in order to compensate the smallness of the νe cross-section (<10^{-44} cm^2)

  ≡> **I_ν > 1 MCi**

Relevant candidates for mononeutrino oscillometry

Nuclide	$T_{1/2,}$ days	Q_{EC} (keV)	E_ν (keV)	$E_{e,\ max}$(keV)	Irradiated target during 10 days	υ-intensity (per 1 kg of target, per s)
^{37}Ar	35	814	811 (100%)	617	^{40}Ca, Ar	$8.3x10^{15}$
^{51}Cr	28	753	747 (90%)	560	^{50}Cr	$2.3x10^{16}$
^{75}Se	120	863	450 (96%)	287	Se	$1.1x10^{14}$
^{113}Sn	116	1037	617 (98%)	436	Sn	$8x10^{11}$
^{145}Sm	340	616	510 (91%)	340	Sm	$2x10^{12}$
^{169}Yb	32	910	470 (83%)	304	Yb	$1.1x10^{15}$

Oscillometry with the “active” mono-neutrinos

Oscillometry with active neutrinos

$0 < \sin^2 2\theta_{13} < 0.15$ *(T2K, MINOS, CHOOZ)*

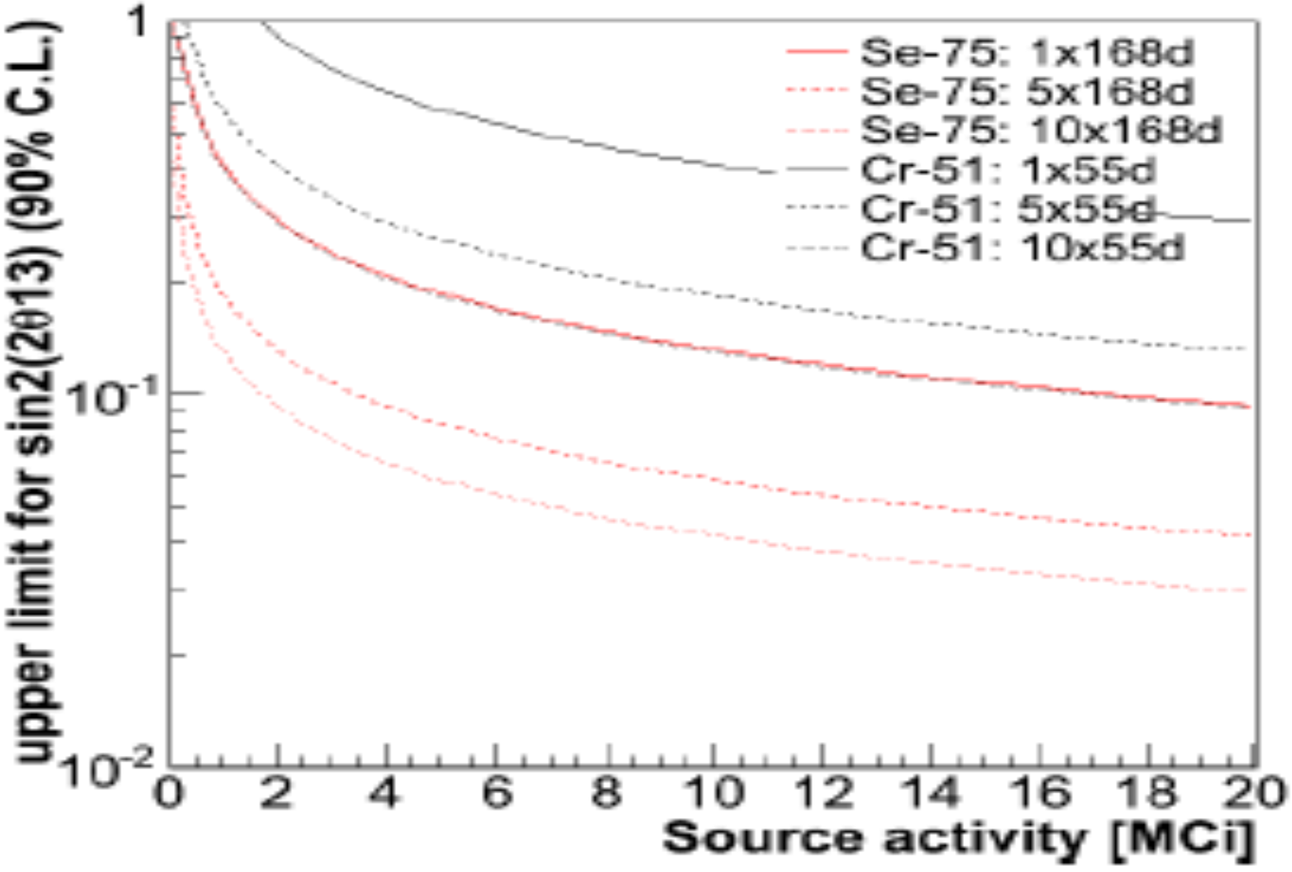
L_{13} [m] ≈ E_ν [keV] *(from «global» analysis)*

Accelerator experiments observe the flavour appearance, the reactor experiments -disappearance,

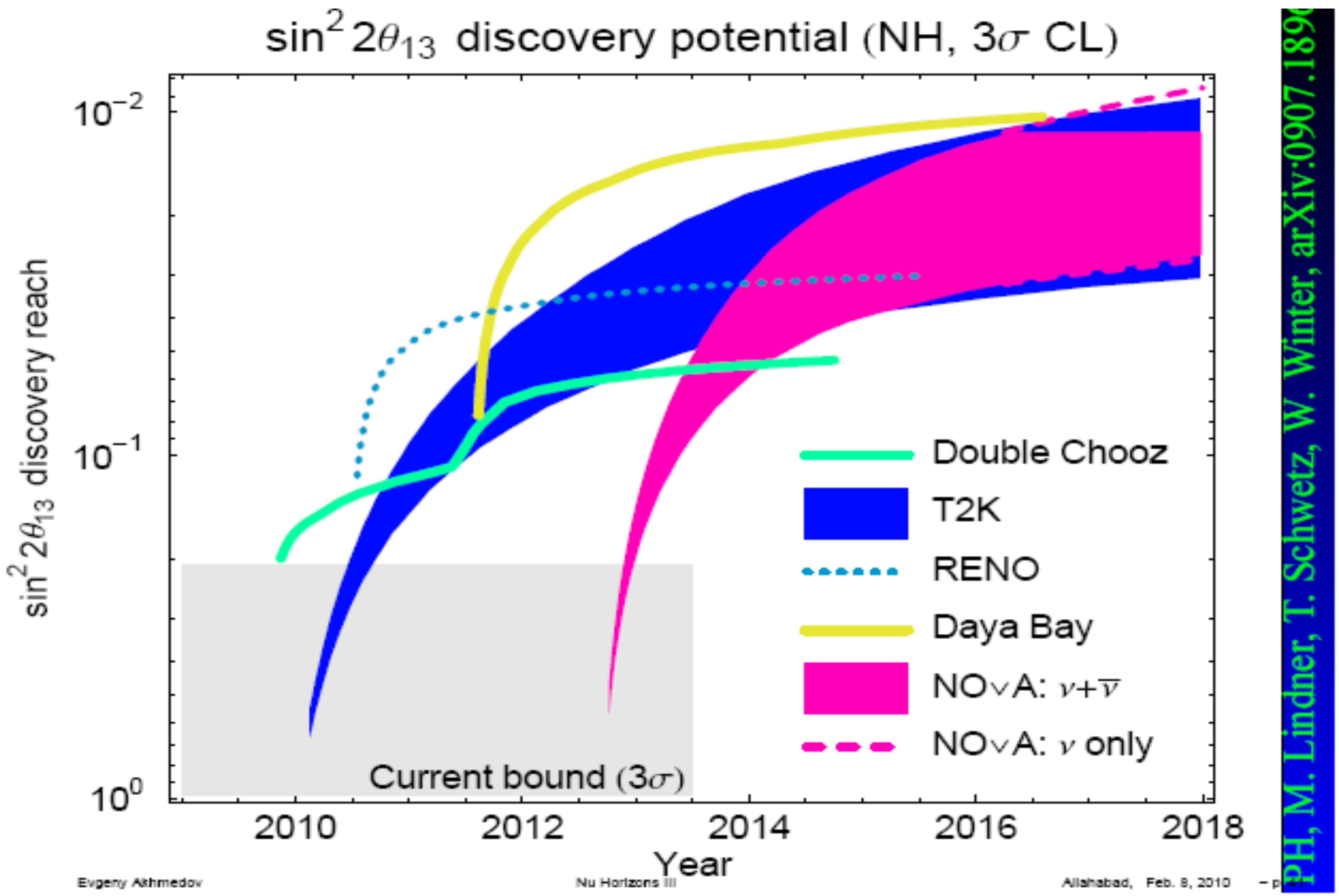
whereas

Oscillometry deals with both disappearance and appearance with no matter dependence in one experiment with the «hand-made» radioactive sources

Sensitivity to $\sin^2 2\theta_{13}$



Long baseline projects for θ_{13} in the forthcoming decade



Courtesy of E. Akhmedov

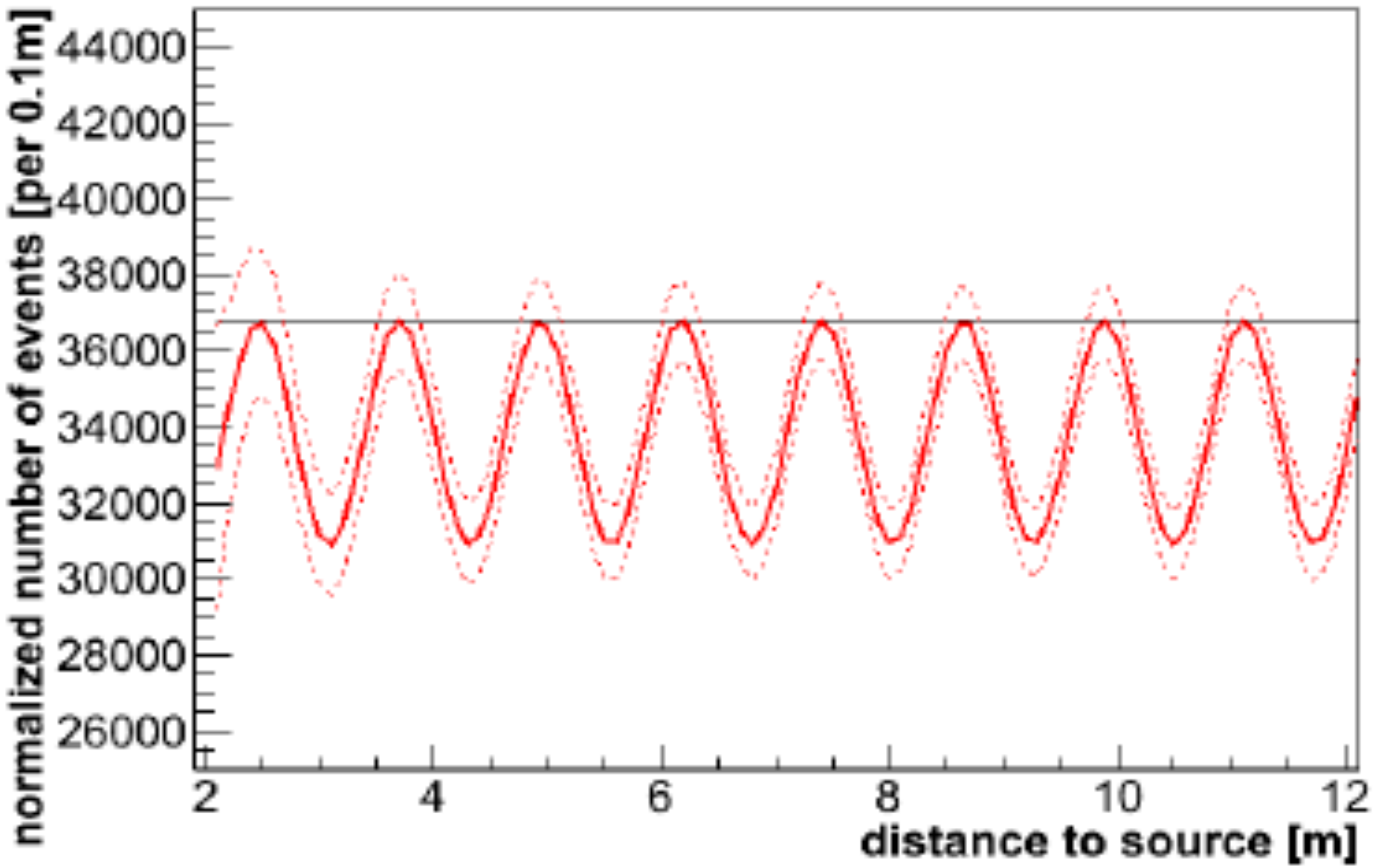
Oscillomertry with the sterile neutrinos

Sterile neutrino exploration with LENA

Neutrino states (i,f)	Δm_{ij}^2 (eV)^2	$\sin^2(2\theta_{ij})$	L_{ij} (m)
1,2	7.6×10^{-5}	0.85	$\approx 32 E_\nu$ (keV)
1,3	2.4×10^{-3}	< 0.15	$\approx E_\nu$ (keV)
1,4	$\approx 0.5 - 5$	≈ 0.15	$\approx 5E_\nu(10^{-3} - 10^{-4})$
1,5	$\approx 0.9 - 1.6$	?	$\approx 10^{-3} E_\nu$ (2.8-1.6)
1,6 (?)	?	?	?

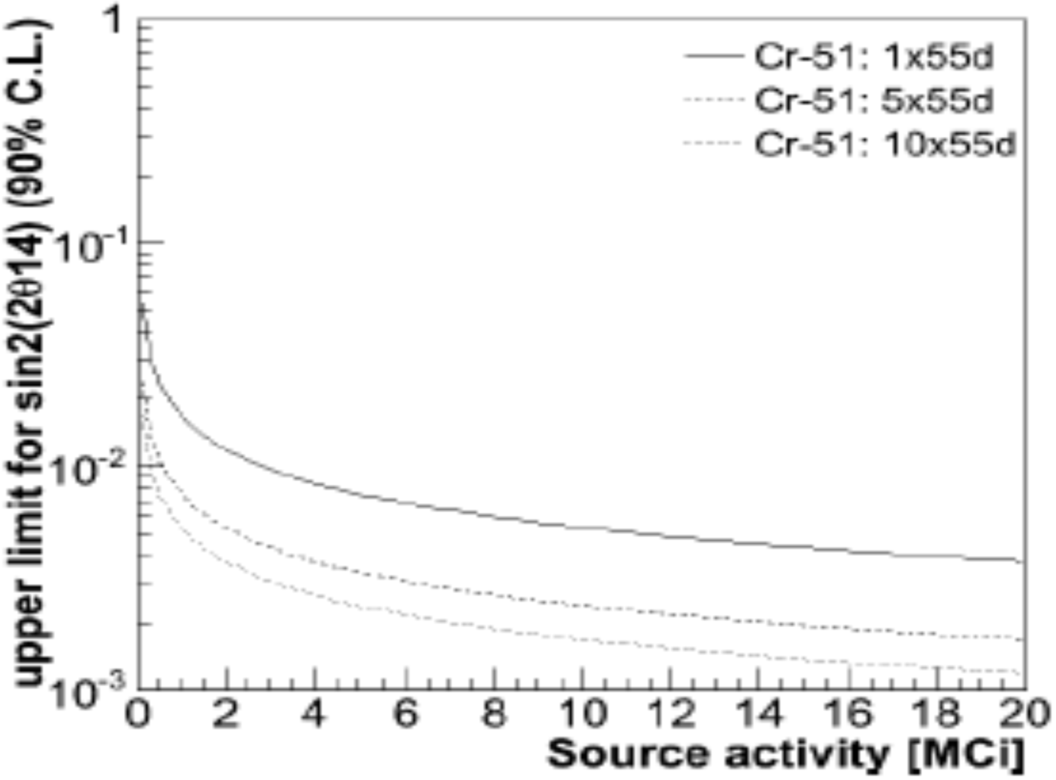
Base-lines for oscillations with the sterile neutrinos {1,5} and/or {1,4} are on the level of 1 m for ^{51}Cr. Therefore numerous patterns can be seen in the oscillometry curve in the LENA-cylinder with the source at the top. It should provide unprecedented accuracy for determination of L_{1j} and θ_{1j}.

Oscillometry with the sterile neutrinos
(a 5MCi 51Cr for a 55-day run)



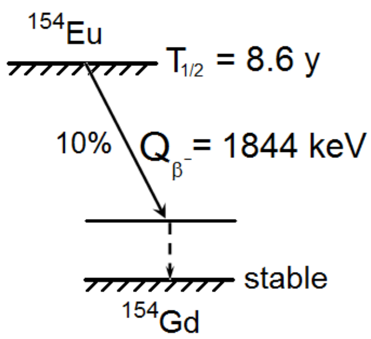
Courtesy of M. Wurm

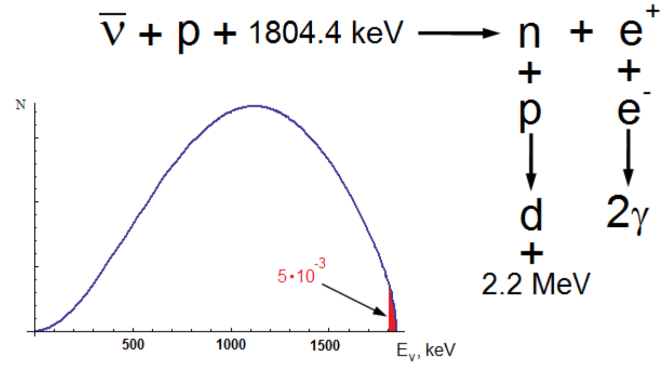
Sensitivity to θ_{14}

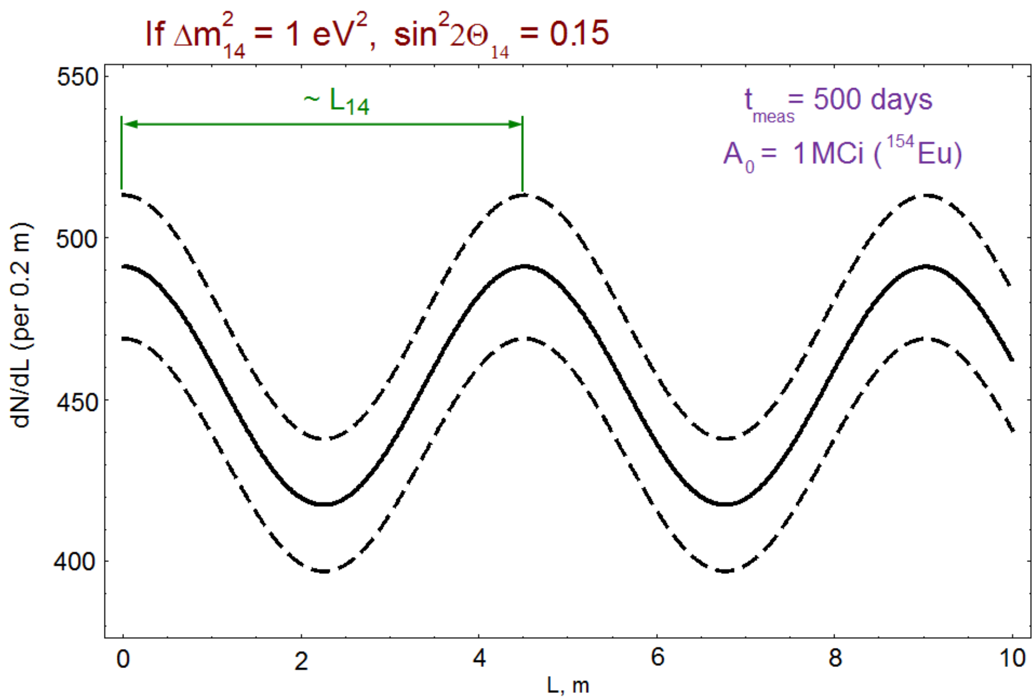


Oscillometry with the sterile antineutrinos

Oscillometry for antineutrinos





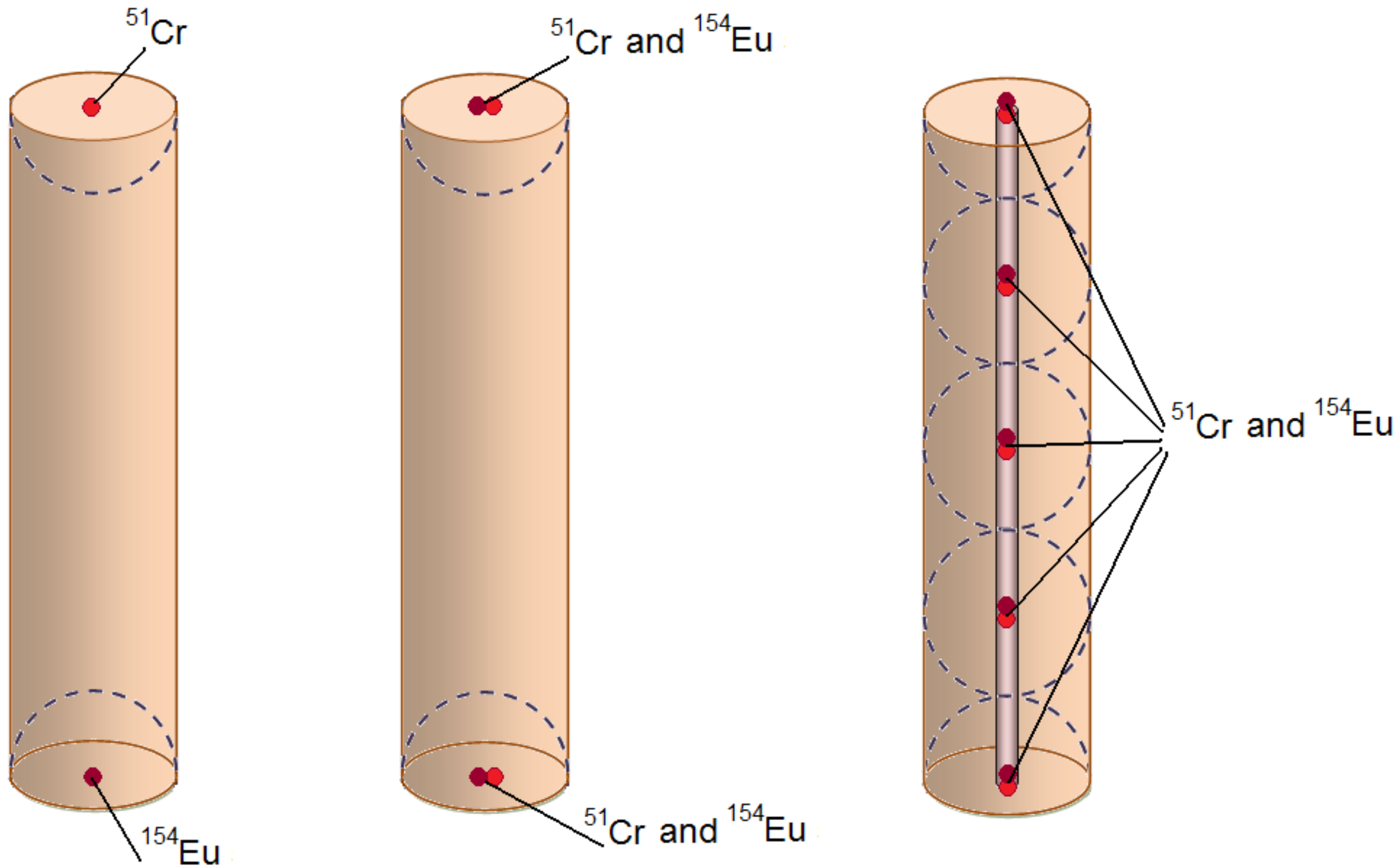


Cortesy of D. Nesterenko

Impact of Oscillometry on the Neutrino Science

- Determination of θ_{13} and **L13** independent on the matter effect and a check of **L_{32}[m]=Q_v[keV]** and conceptual results of the "global analysis"
- Search for the sterile neutrinos in the wide region of masses $\Delta m1i^2$ from 0.02 to 2 eV^2
- Exploration of sterilized multiplicity ("anatomy" of oscillations)
- Simultaneous neutrino and antineutrino oscillometry- a prerequisite for the CPT-validity

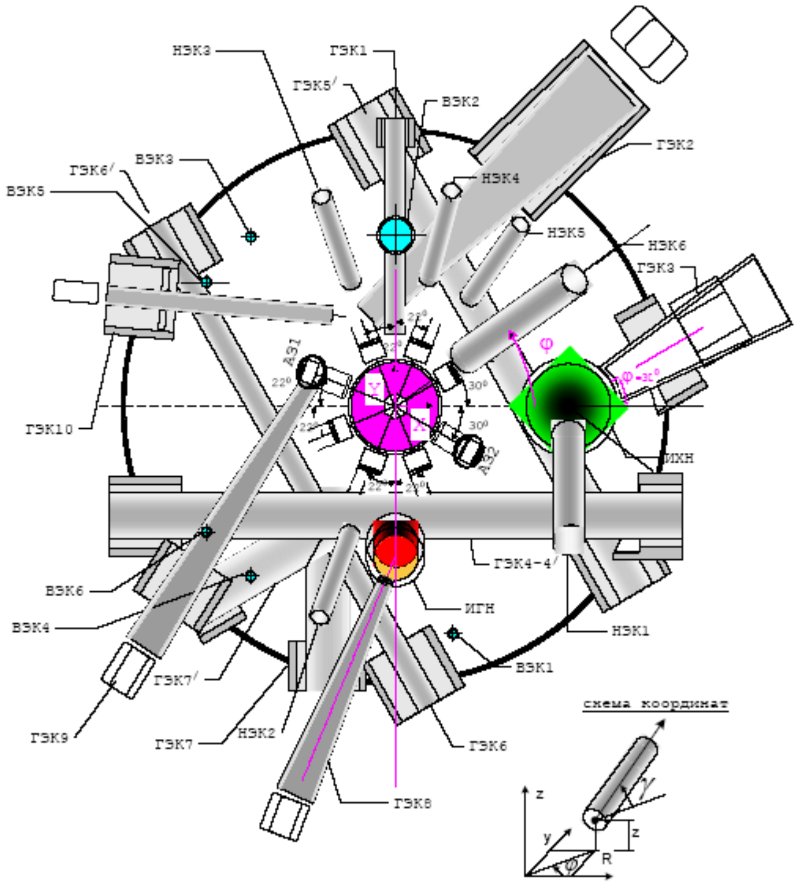
«Partitioning» of the LENA-cylinder for the oscillometry analysis



Cortesy of D. Nesterenko

Removable neutrino source production at the nuclear reactors

Setup of the high-flux reactor PIK in St.Petersburg



- A power: **100 MW**
- Φ_{th} (in the D_2O reflector): ≈ **10^{15} n/cm^{2}s**
- There are 10 horizontal and 6 inclined neutron beams
- Produced antineutrino intensity: ≈ **10^{17} ν/s** which at the LENA-place in Pyhäsalmi

ν **2 -3 ν/cm^{2}s**

Expected commissioning: in a f ew years

Courtesy of A. Erykalov

Conclusions.

Unique advantages of LENA

Observation of oscillometry curve: a flavour appearance and disappearance inside one detector

For active neutrinos:

Simultaneous determination of θ13 and L13 and check of consistency of the «global» neutrino analysis.

For sterile neutrinos/antineutrinos:

Search for sterile neutrinos,

Search for the multiplicity of «steralization».

Anatomy of simultaneous exploration of neutrino-antineutrino oscillometry (CPT?)

Work plan for 2012:

1. R & D for the antineutrino oscillometry at LENA
2. Calculation of the neutrino source performance at the new high flux nuclear reactor PIK
3. Estimation of the background conditions in the simultaneous neutrino-antineutrino oscillometry
4. Brainstorming towards new ideas for the further applications of oscillometry in the particle physics