The possibility of experiments to determine parameters of neutrino oscillations on a short baseline

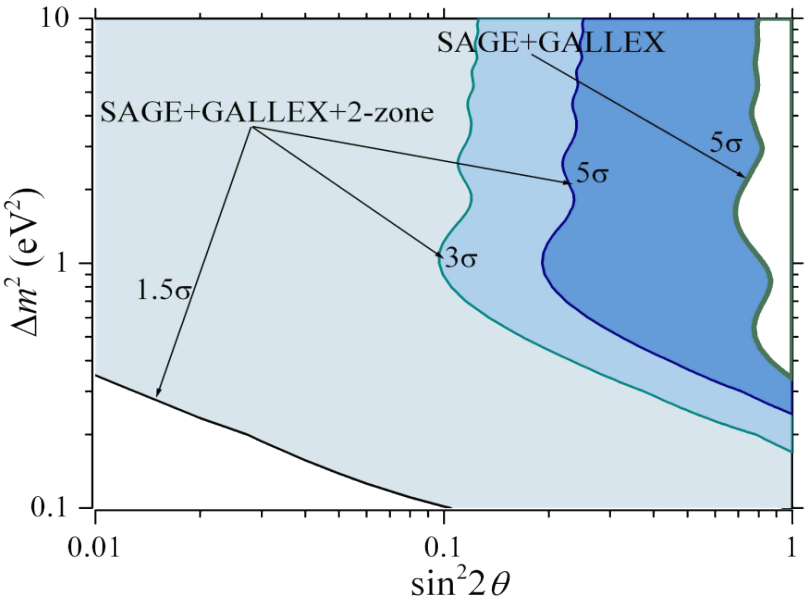
V.V.Gorbachev (BEST)
BNO, Institute for Nuclear Research, RAS

International Session-Conference of the Section of Nuclear Physics PSD RAS 2017
Nalchik, Russia, June 6-8, 2017

Oscillations on a short baselines

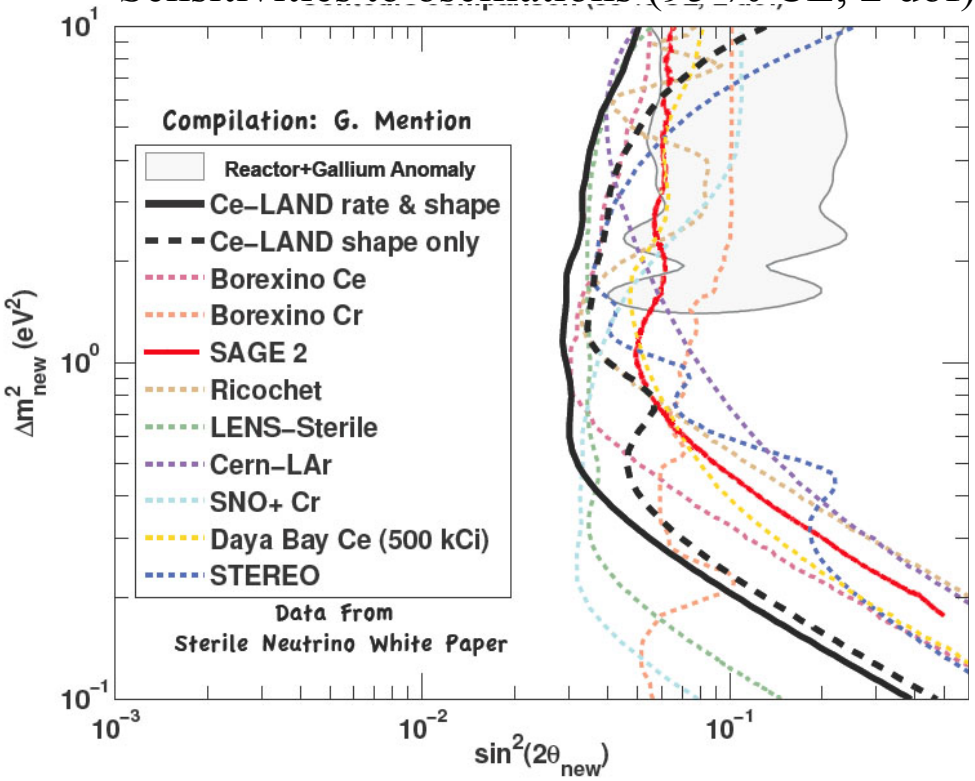
$$P_{ee} = 1 - \sin^2 2\theta \cdot \sin^2\left(1.27 \frac{\Delta m^2(eV^2) \cdot L(m)}{E_\nu\ (MeV)}\right)$$

Sensitivity of BEST



[V. Gavrin et all. Phys. Part. Nucl. 46 (2015) 131]

Sensitivities to oscillations (95 % CL, 2 dof)



[Th. Lasserre, Neutrino 2012]

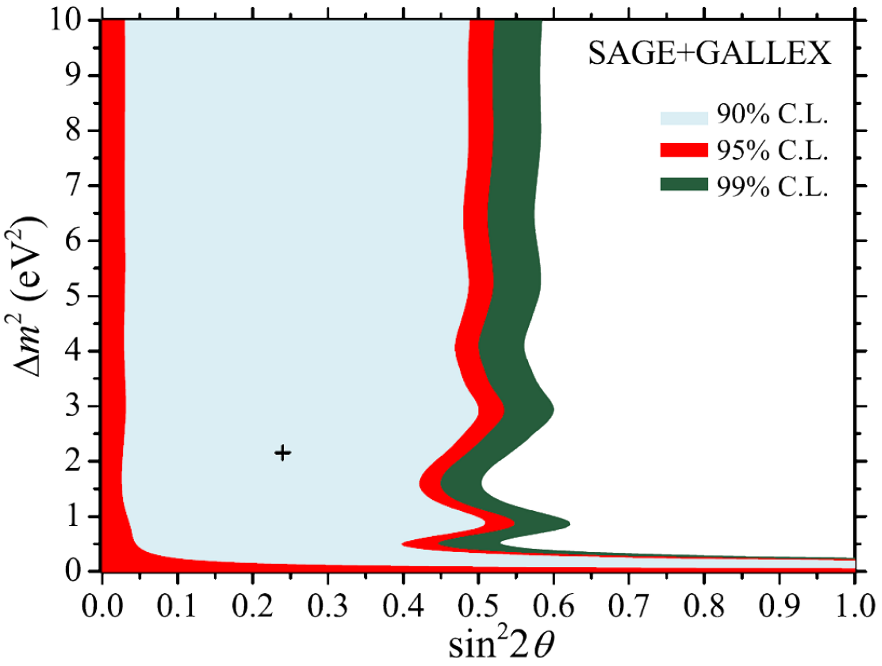
Sensitivity to oscillations

$\neq$

Posibility of determining the parameters of oscillations

4 Ga source experiments:

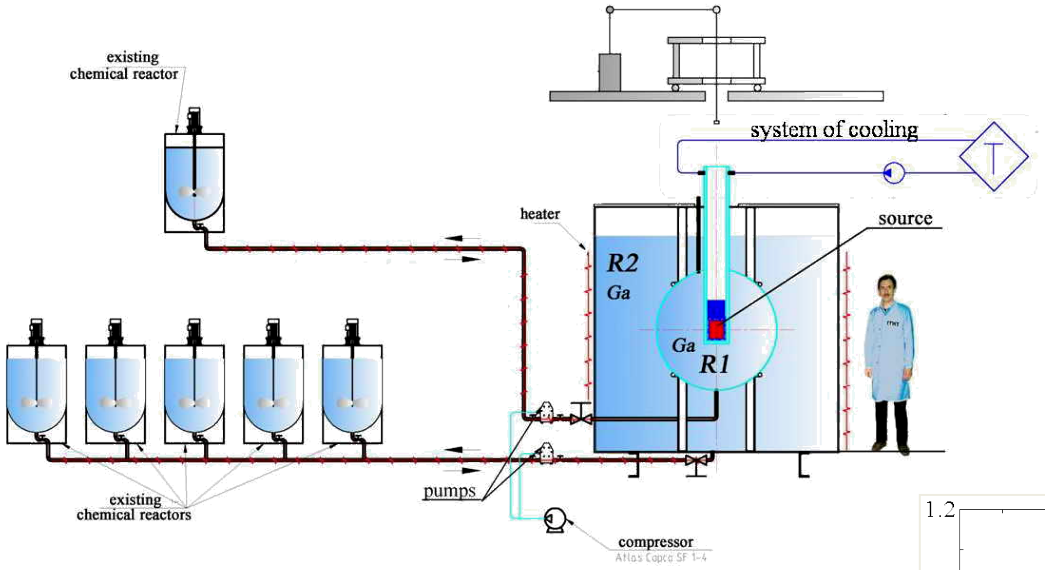
$\Delta m^2 = 2.15\ eV^2$ and $\sin^2(2\theta) = 0.24$



The real parameters of oscillations with almost equal probability can take values in the half of the entire area of the allowed values

Can the proposed experiments to determine the actual oscillation parameters?

Ga experiment BEST



Target – 50 t Ga metal

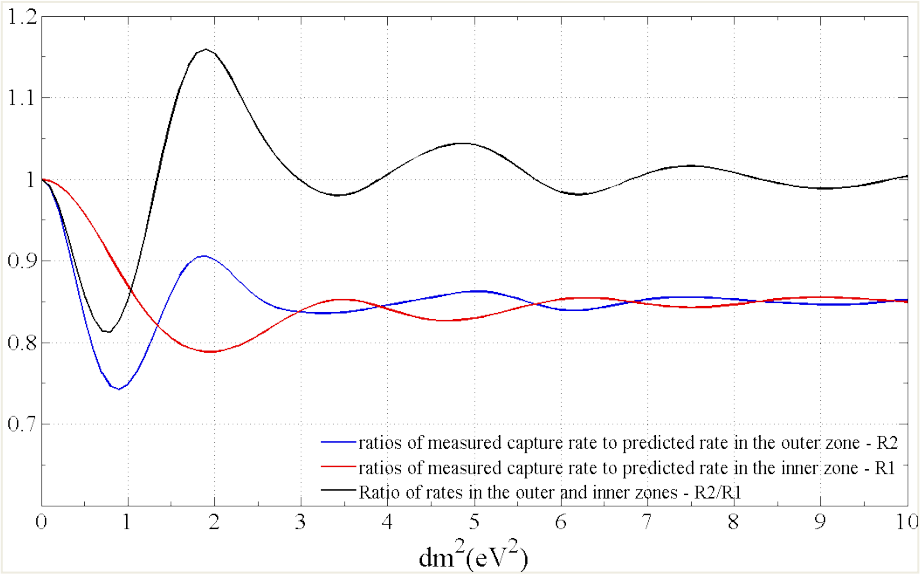
Masses of the zones 8 t and 42 t

Path length in each zone <L>=55 cm

^{51}Cr source: $T_{1/2}$=27.7 d, 3 MCi

E_ν = 750 keV (90%), >95 % captures

430 keV (10%)



- 2 baseline measurement
- Nuclear capture experiment

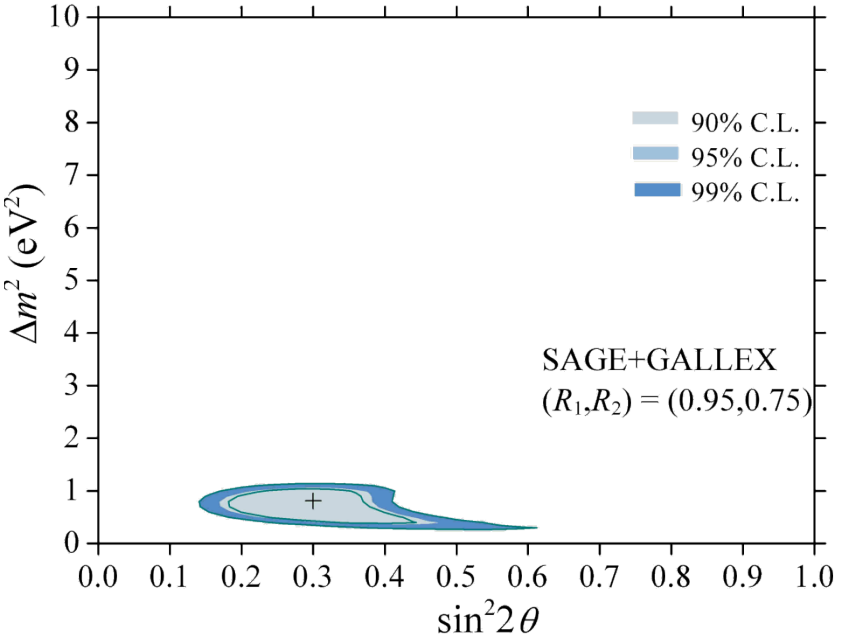
$^{71}Ga + \nu_e \rightarrow {}^{71}Ge + e^-$

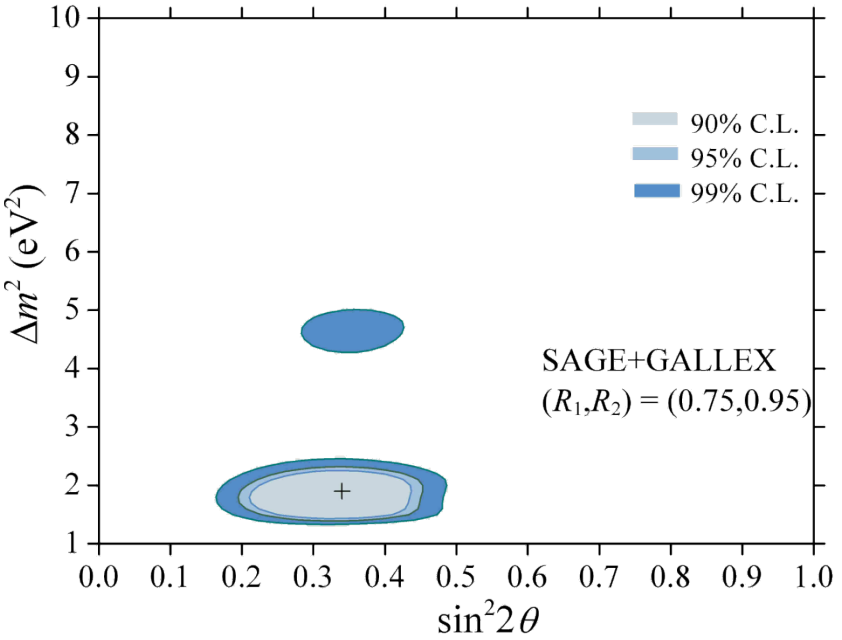
Indication of oscillations:

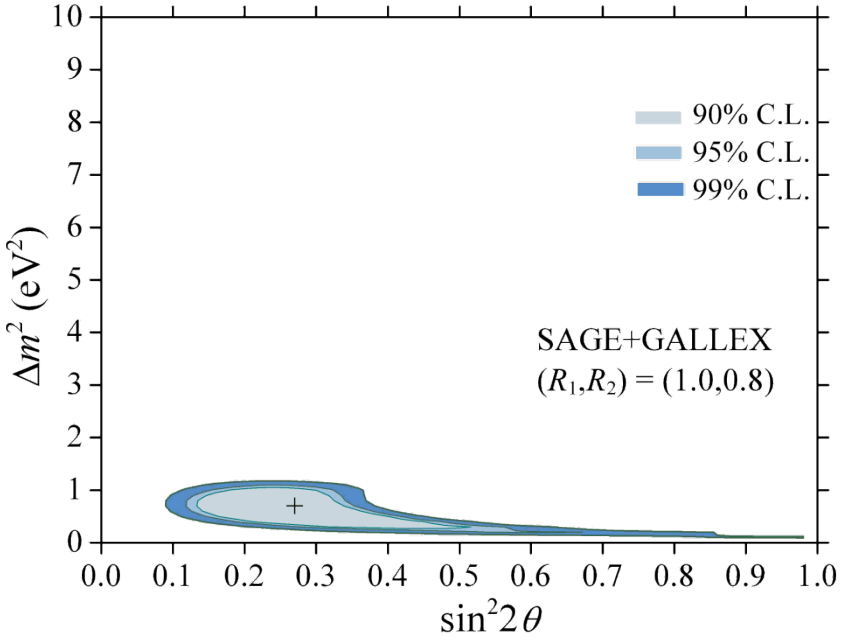
1) capture rates in two zones are different

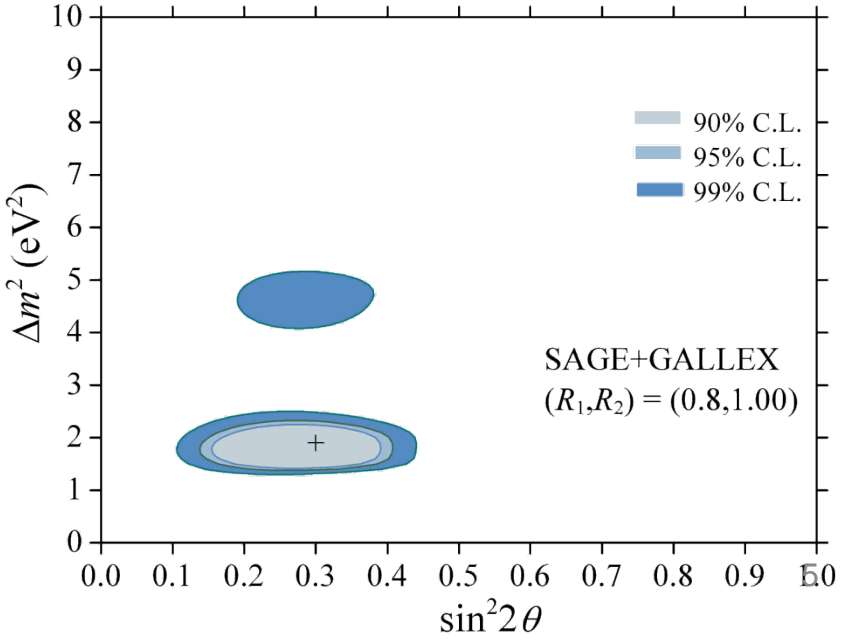
2) capture rates in both zones are suppressed

Examples of allowed oscillation parameters in the experiment BEST

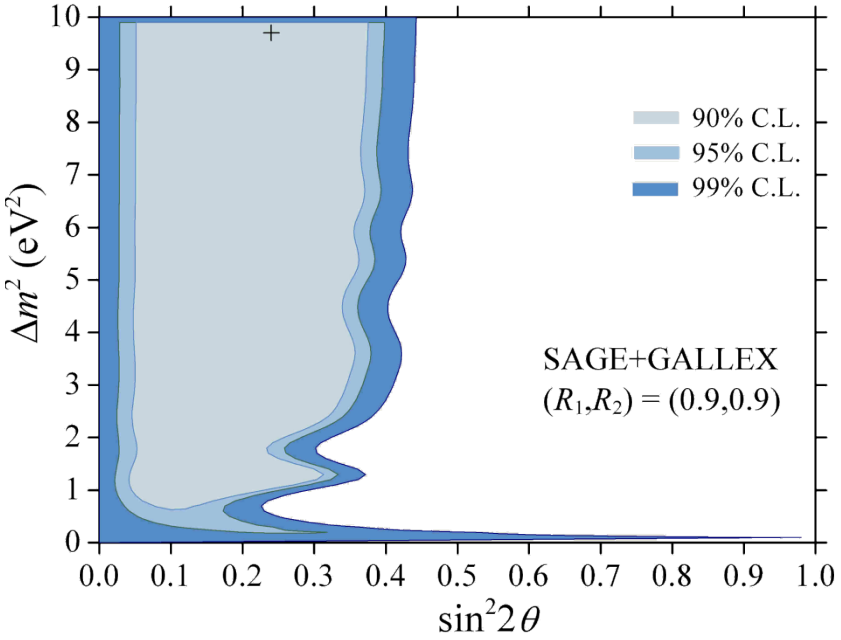


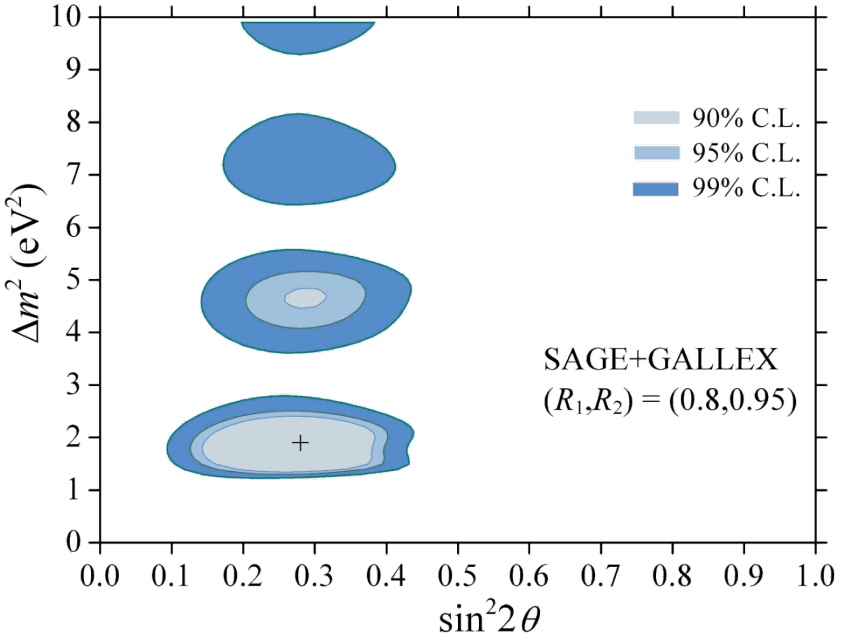


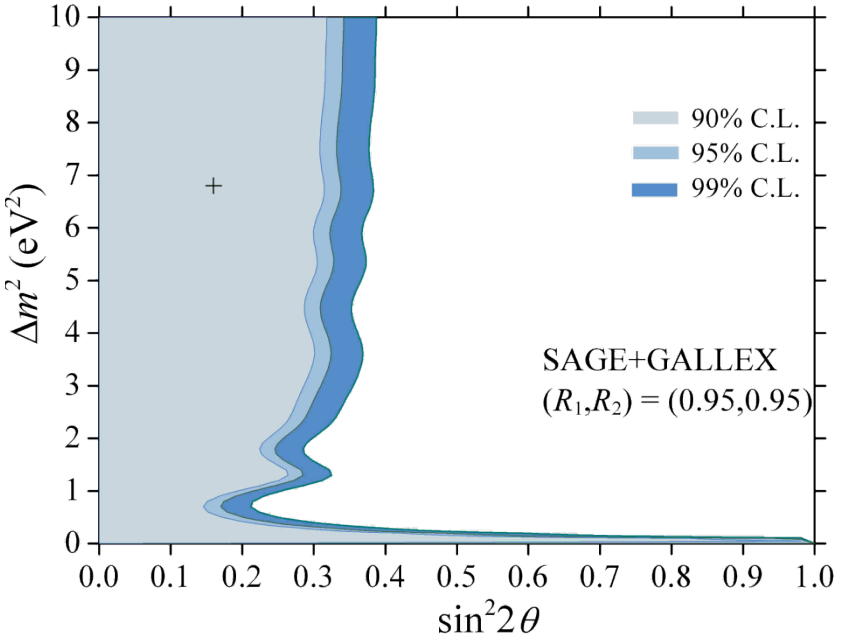


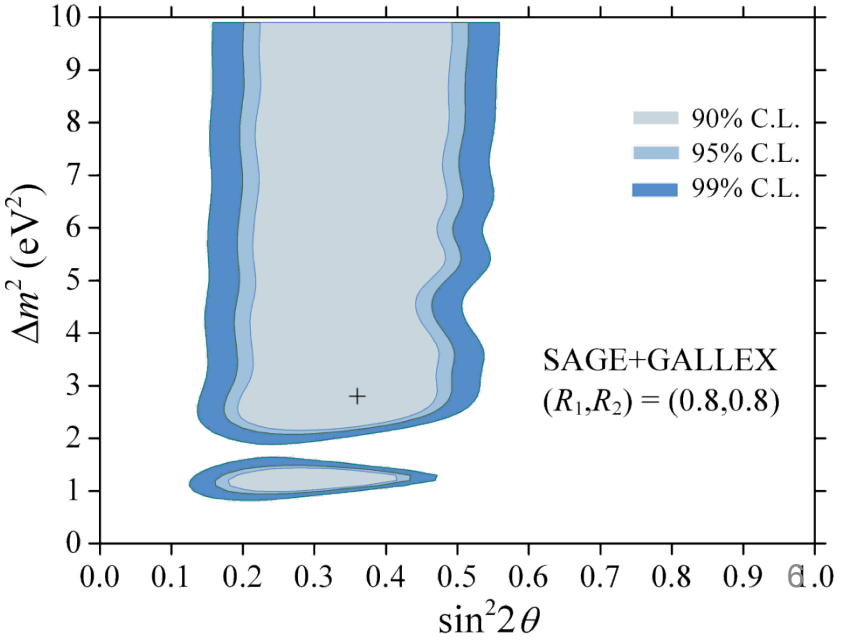


Examples of allowed oscillation parameters in the experiment BEST - 2









Possibilities for Borexino

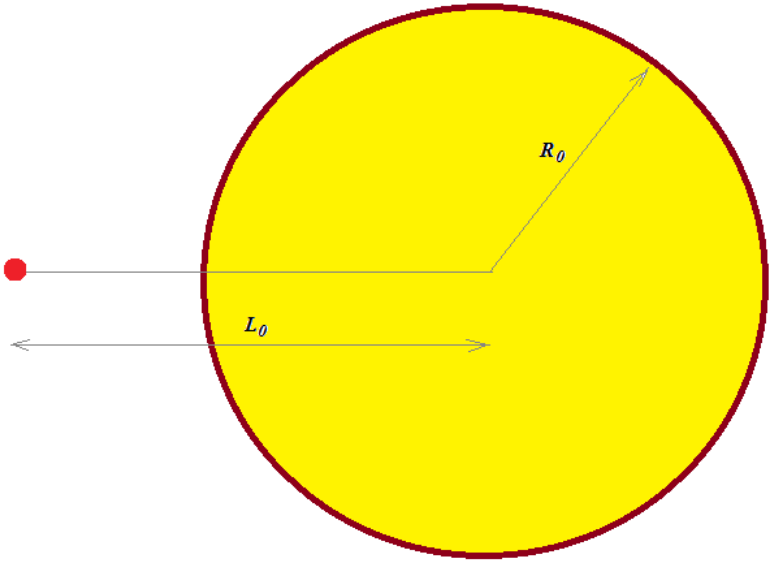
$R_0 = 8$ m (3.3 m Fid Vol)

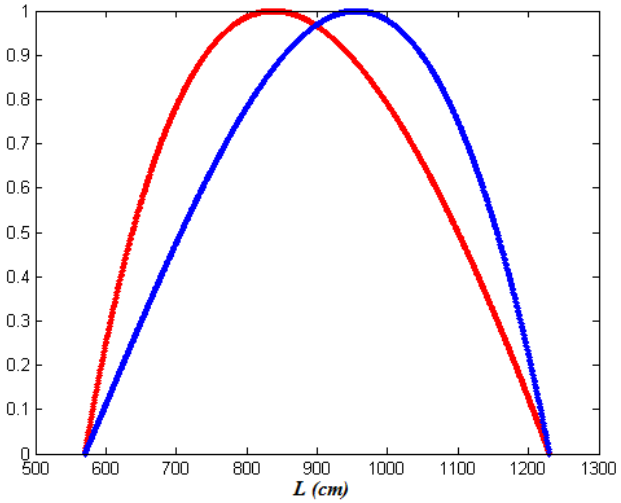
$L_0 = 9$ m

Point anti-neutrino source ^{144}Ce

$1.8 < E < 3.2$ MeV

$N = 10^4$ events





Dependence of counting rate from distance w/o oscillations (red)
(blue – for solar background)

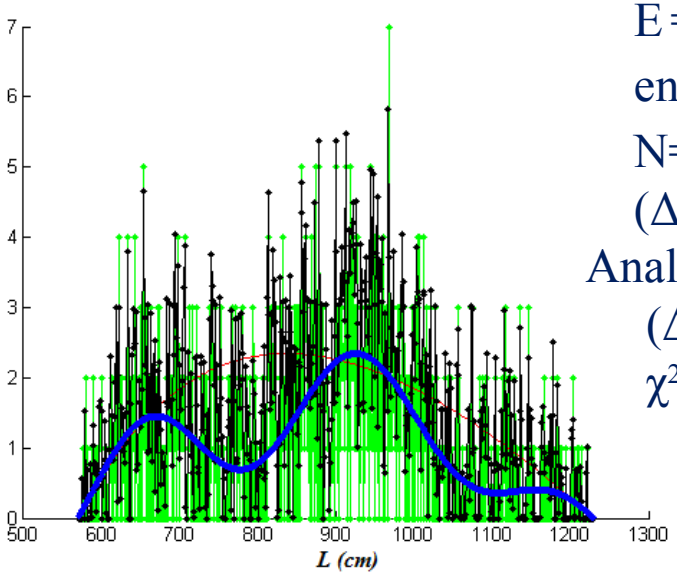
The amplitude of the oscillations ($\sin^2(2\theta)$) can be determined by the total counting rate

The parameter Δm^2 is associated with the distortion of the shape of this dependence

Consider the possibility of determining these distortions

Examples of distortion

Throw events in 1 energy bin in the spectrum of antineutrinos (Monte-Carlo)
The value of Δm^2 obtained in the analysis must be the same as specified



E = 2.5 MeV,

energy bin $\Delta E = 0.25$ MeV

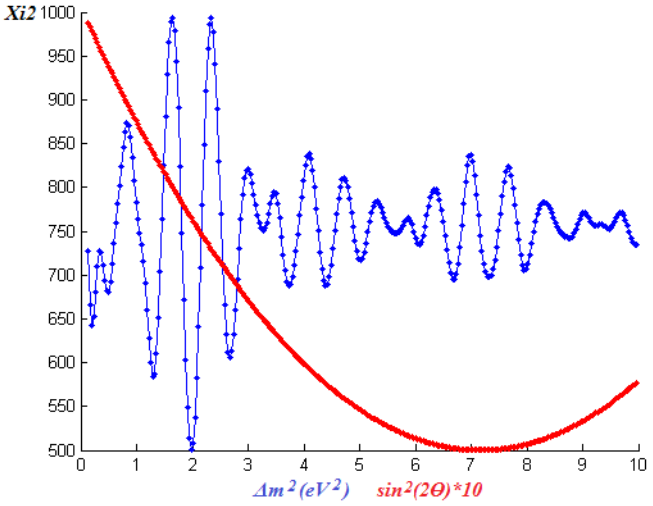
$N=10^3$ events evenly distributed

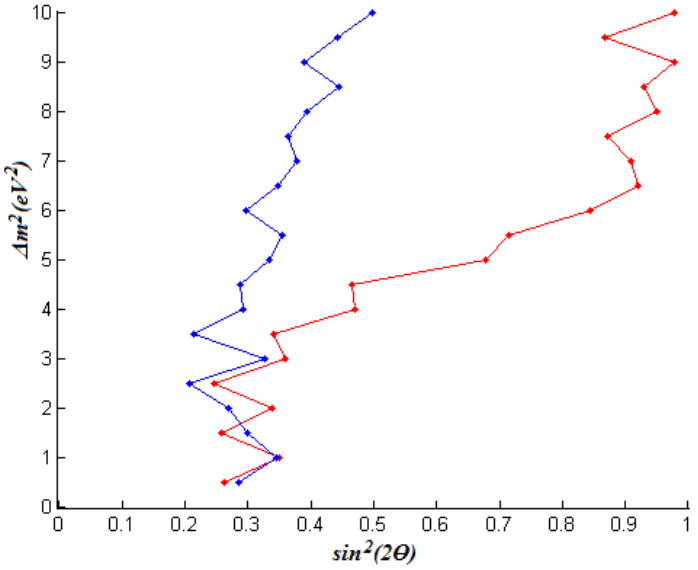
$(\Delta m^2, \sin^2 2\theta) = (2, 0.6)$

Analysis:

$(\Delta m^2, \sin^2 2\theta) = (1.98, 0.72)$

$\chi^2 = 500/550$





Area of possible determining of the parameters

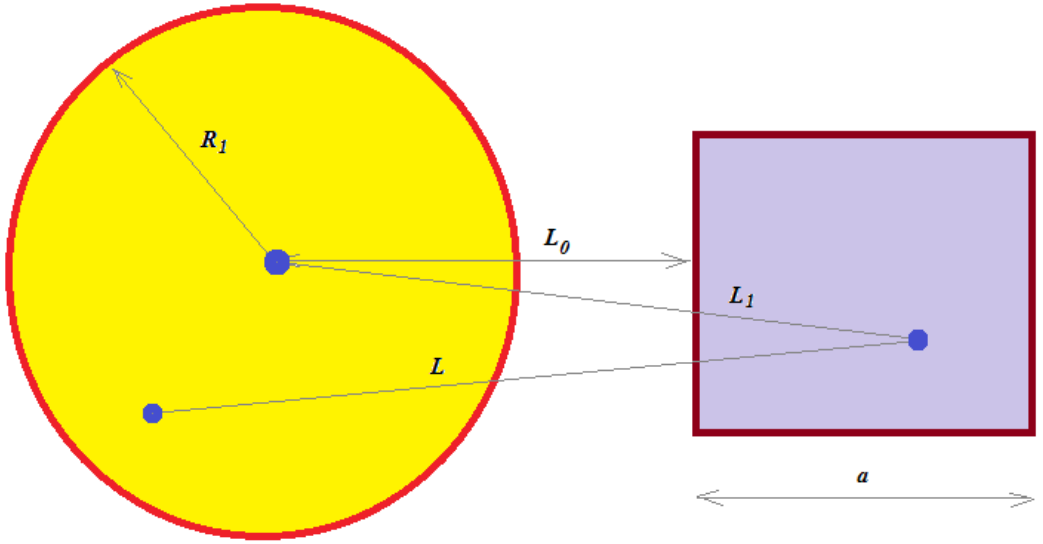
blue - $\Delta E = 0$

red - $\Delta E = 0.25$ MeV

Possibilities for DANSS

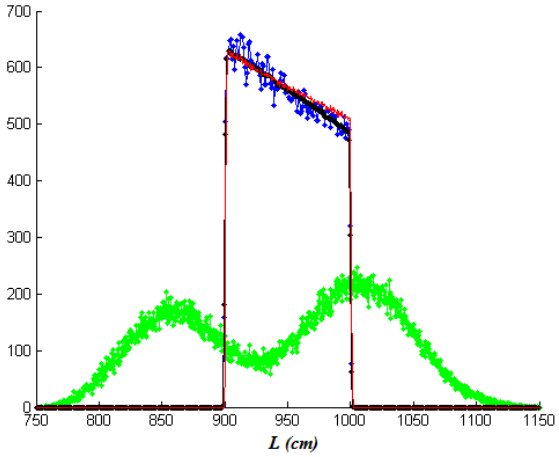
a = 1 m
Anti-neutrino source – Nuclear Reactor
R_1 = 1.5 m
L_0 = 10 m
1.8 < E < 8 MeV
N = 10^4 events / day

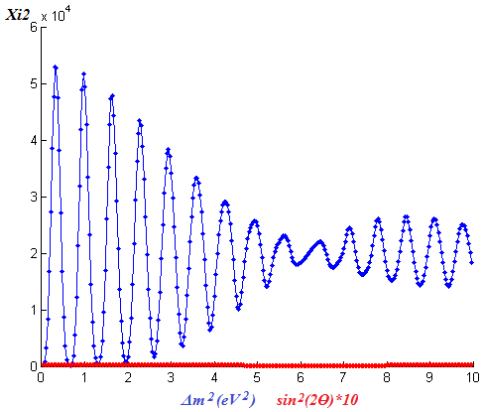
L – real distance
L_1 – "visible" distance



E = 2.5 MeV,
ΔE = 0.25 MeV
N=10^5 events evenly distributed
(Δm^2, $\sin^2 2\theta$) = (3, 0.9)

Analysis:
(Δm^2, $\sin^2 2\theta$) = (0.68, 0.55)
χ^2 = 135/100





Oscillations in DANSS

E = 2.5 MeV,

ΔE = 0.25 MeV

N=10^5 events evenly distributed

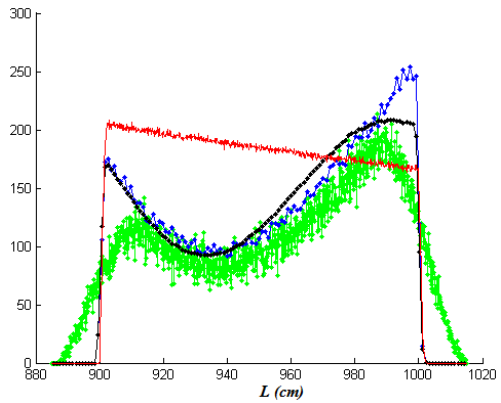
(Δm^2, $\sin^2 2\theta$) = (3, 0.9)

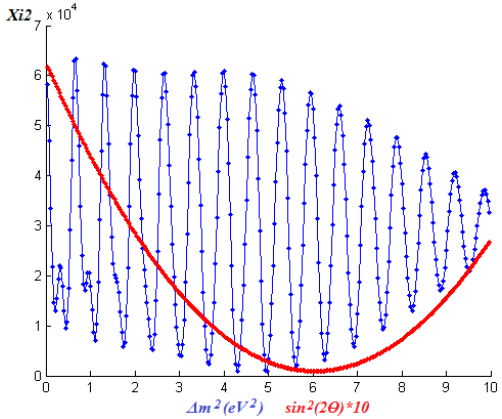
R_1 = 15 cm

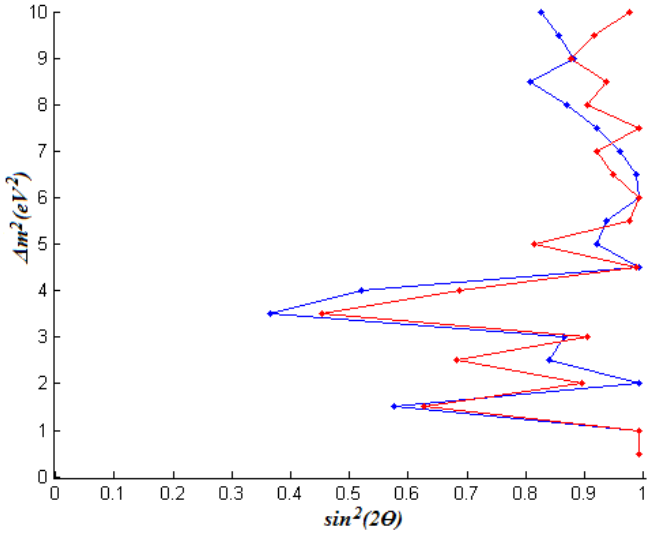
Analysis:

(Δm^2, $\sin^2 2\theta$) = (5, 0.61)

χ^2 = 877/100







Area of possible determining of the parameters

blue - ΔE = 0

red - ΔE = 0.25 MeV

The width of energy bin does not affect the form For a wide range of energies in a nuclear reactor (~1.8-8 MeV) for each value of dm2 (0÷10 eV2) one can choose energy bin with maximum sensitivity.

The combined analysis is not needed (unlike Borexino, where the total result for all bins gives an increase in sensitivity)

But here is not taken into account the transitions between bins (the error in determining E)

Conclusions

- Considered the possibility of three different experiments on determination of oscillation parameters
- Continuous neutrino spectrum has a different effect on the sensitivity of the experiments
- Reliable determination of the oscillation parameters can be combined analysis of all experiments
- It is interesting to compare the oscillation parameters of neutrino (BEST) and antineutrino (Borexino and DANSS) to test CPT in the neutrino sector