The Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences

The SUNLAB project

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The **S**ieroszowice **Un**derground **Lab**oratory in Poland, SUNLAB, had been discussed in a framework of the FP7 design study LAGUNA as an option for the realization of a next-generation large-volume neutrino observatory in Europe. The SUNLAB location is not under consideration in the LAGUNA-LBNO project, the follower of LAGUNA. However, the capability studies of the SUNLAB laboratory have been performed within the project UMO-2011/03/N/ST2/01971 of the Polish National Science Centre. They include sensitivity calculations, focused on the delta CP measurement and performed using the GLOBES package, for a large LArTPC detector at a distance of 950 km from CERN in a long baseline neutrino experiment. For this purpose we have simulated the neutrino beam based on the SPS proton accelerator at CERN and used the latest LAr data to simulate the detector response.

Apart from the anhydrite rock, considered in Laguna to locate the giant LAr detector, the geological structure in this region includes salt-rock characterized by extremely low level of natural radioactivity. This offers good conditions for a smaller very low background SUNLAB laboratory. Several detectors have been developed to be used in SUNLAB. For example, a low background Ge detector constructed at IFJ PAN in Kraków will be tested in the Sieroszowice mine in July this year.

Neutrino beam based on SPS:

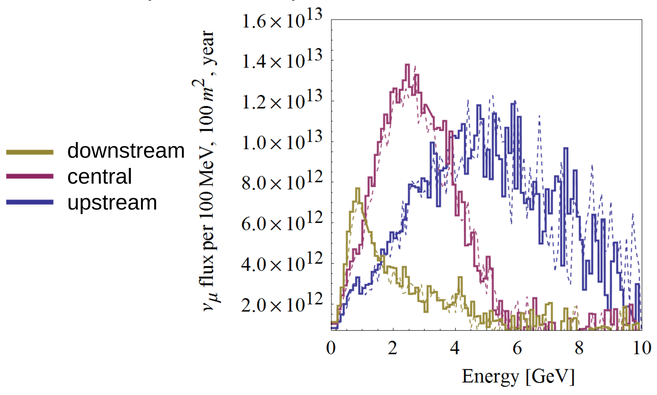
E_p = 400 GeV, 1.2 x 10^{20} p.o.t /year, 740 kW

Simulation based on GEANT4 and GENEBES [A.Longhin] simulation packages.

Goals:

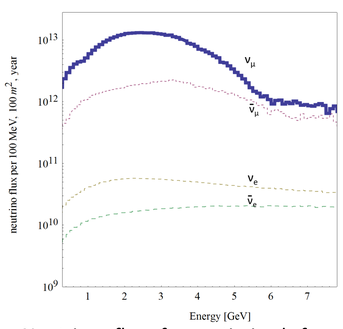
- maximal intensity in the 1st oscilation maximum region at **1.92 GeV** for ν and anti-ν modes.
- maximal purity

Changing target vs focusing horn position allows to optimize ν spectrum.



Simulation of the long baseline experiment at 950 km in SUNLAB

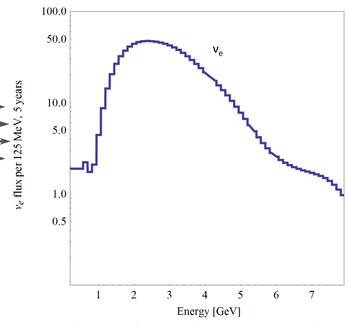
Before oscillations



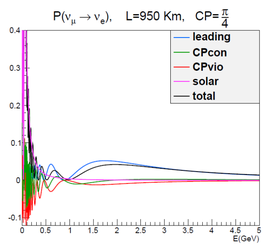
Neutrino flux for optimised focusing system, at 100 km distance for 100 m^2.

ν_μ - ν_e

After oscillations



Number of ν_eCC events after oscillations for 5 years of neutrino beam in 100 kton of LAr, 100% detector efficiency assumed.



Oscillation probability for a baseline of 950 km.
First oscillation maximum at 1.92 GeV

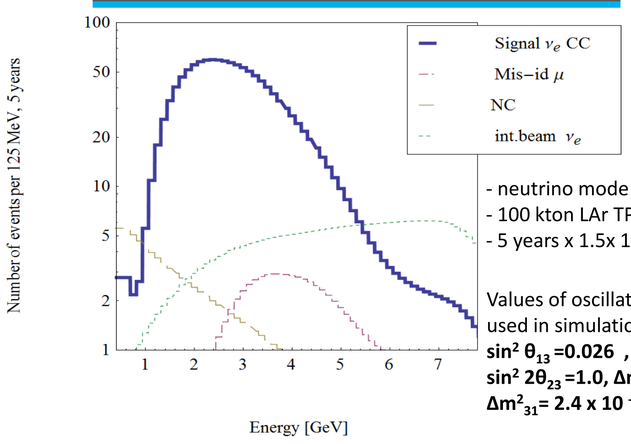
Detector parametrisation

100 kton LAr Time Projection Chamber

based on available LAr data and simulations in FLUKA MC generator.

E ν treshold	300 MeV
Detection efficiency	100 % μ and 100% e
Energy resolution	0.15 $\sqrt{E/GeV}$ ν_eCC 0.20 $\sqrt{E/GeV}$ ν_μCC
NC background	0.5%
Misidentified muons	0.5%
Beam contamination	80%
systematics	5%

Expected event rates



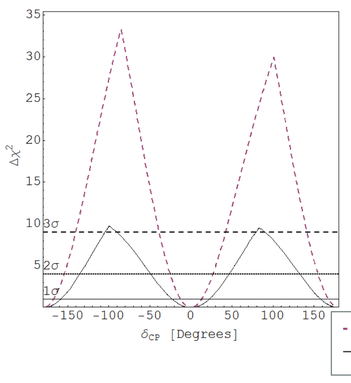
- neutrino mode
- 100 kton LAr TPC
- 5 years x 1.5x 10^{20} p.o.t.

Values of oscillation parameters used in simulation program:
$\sin^2 \theta_{13}$ =0.026 , $\sin^2 \theta_{12}$ =0.32 , $\sin^2 2\theta_{23}$ =1.0, Δm^2_{21}= 7.62 x 10^{-5}, Δm^2_{31}= 2.4 x 10^{-3}

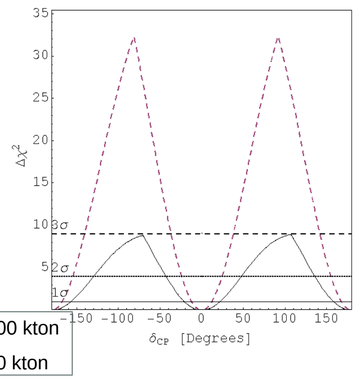
Signal ν_eCC , Normal Hierarchy, δ_{CP}=0	**1341**
Background total	559
Intrinsic beam contamination ν_e	365
Mis- identified μ	146
Neutral Current	57

CPV discovery potential

Normal Hierarchy

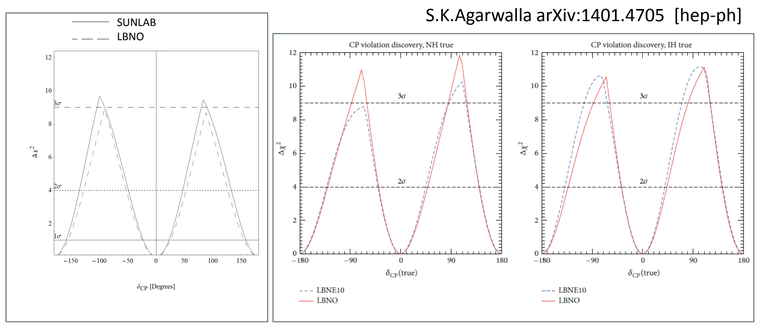


Inverted Hierarchy



Sensitivity for the CPV discovery presented as a function of the value of delta CP assuming the known mass hierarchy and standard set of oscillation parameters. Assumed 10 year of data taking - 5 years for both, neutrino and antineutrino beams. Calculations done using GLOBES package. The results are given for two detector masses: 20 kton and 100 kton.

For reference



S.K.Agarwalla arXiv:1401.4705 [hep-ph]

Sensitivity for the CPV discovery for two experiments:
LBNE in its first phase, 10 kton LAr, baseline 1300km, 6x10^{20} p.o.t.
LBNO in its first phase, 20 kton LAr, baseline 2290 km, 1.2x10^{20} p.o.t.

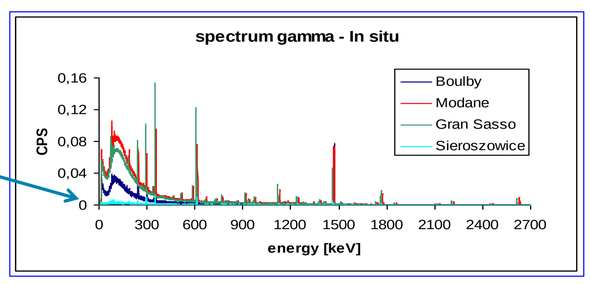
Low background SUNLAB laboratory

Extremely low level of natural radioactivity

❖ Gamma - *in situ*

J. Kisiel et al., Acta Phys. Pol. B 41, 1813 (2010)

Integral background counting rates 50 –2700 keV [CPS/keV*kg]	
Sieroszowice	**2.30 (0.02)**
Gran Sasso	57.68 (0.02)
Modane	66.06 (0.03)
Boulby	23.83 (0.05)

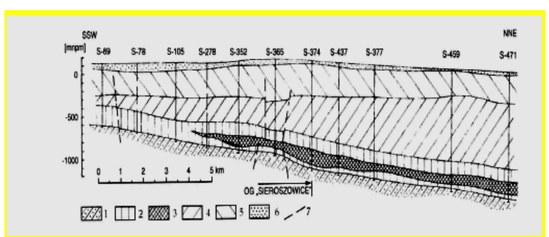


❖ Dose 8 months

1.8 nGy/h

❖ Alfa spectrometry

U-238: 0.0165+-0.0030 Bq/kg
U-234: 0.0225+-0.0030 Bq/kg
Th-232: 0.008+-0.001 Bq/kg
K-40: 4.0 +-0.9 Bq/kg



Geological profile of the Sieroszowice mine region (KGHM Polska Miedź S.A.). Thick layers of salt and anhydrite rock over coper deposit.

New measurements planned in SUNLAB

May 2014. Germanium low background detector - the test setup at IFJ PAN in Kraków.

Tests in the Sieroszowice salt chamber, 950 m undereground, foreseen in July this year.

Acknowledgements:
This work was supported by the Polish National Science Center grant 2011/03/N/ST2/01971.