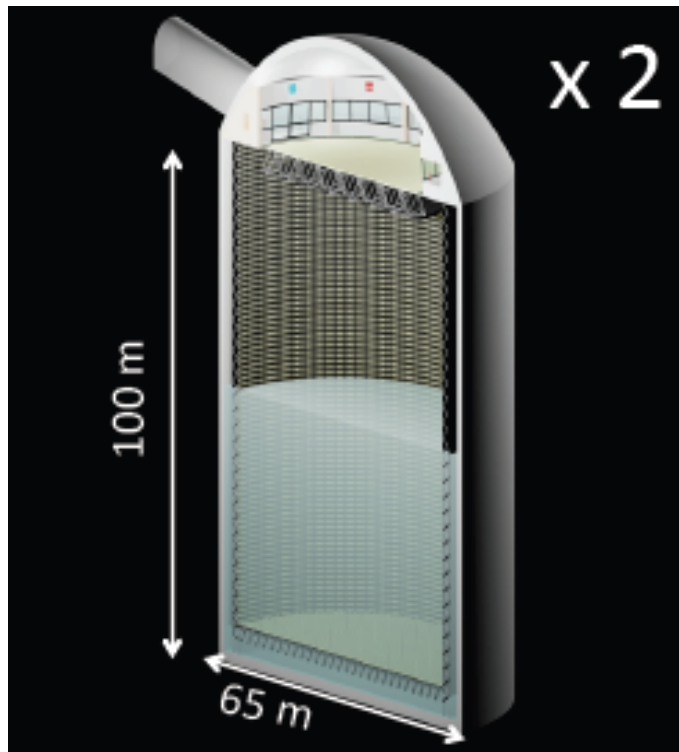




Potential Studies for the δ_{CP} Discovery with the MEMPHYS Water Cherenkov Detector

M. Buizza Avanzini,
APC Laboratory, Paris

MEMPHYS (MEgaton Mass PHYSics)



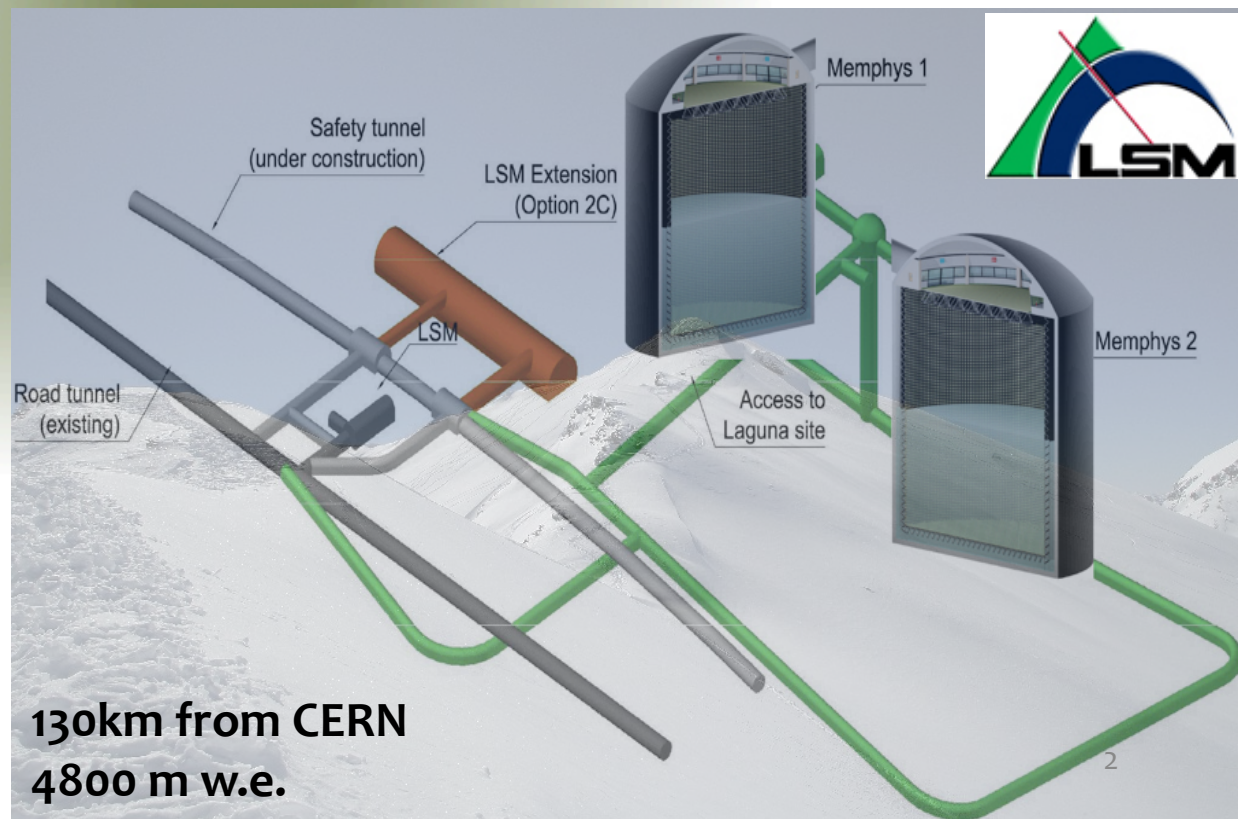
Detector design:

- 2 cylindrical modules **65m x 100m**
- Size limited by light attenuation length ($\lambda \sim 80\text{m}$) and pressure on PMTs
- Total fiducial mass: **540 kt**
- Readout: 200000, 12" PMTs, 30% geom. coverage (under study)

Water Cherenkov techniques is well proven technology

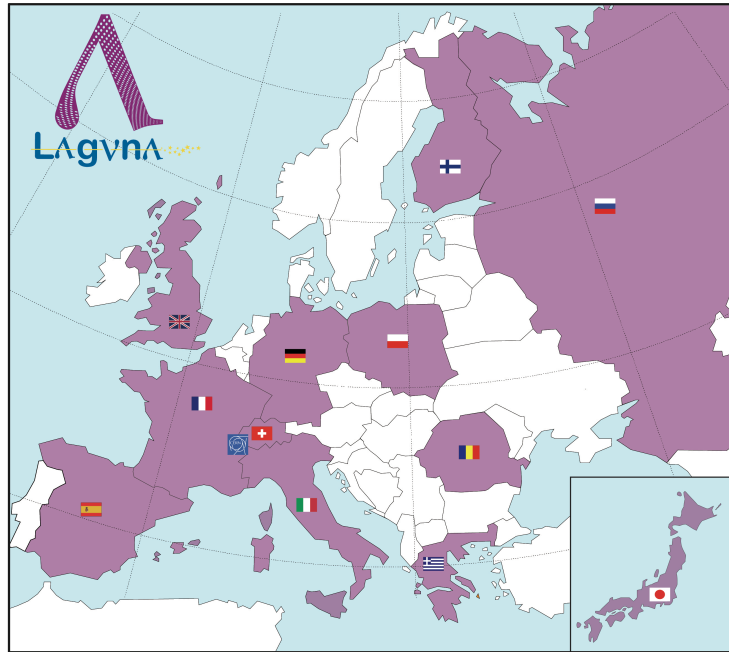
Laboratoire Souterrain de Modane - Frejus

31-10-2012



130km from CERN
4800 m w.e.

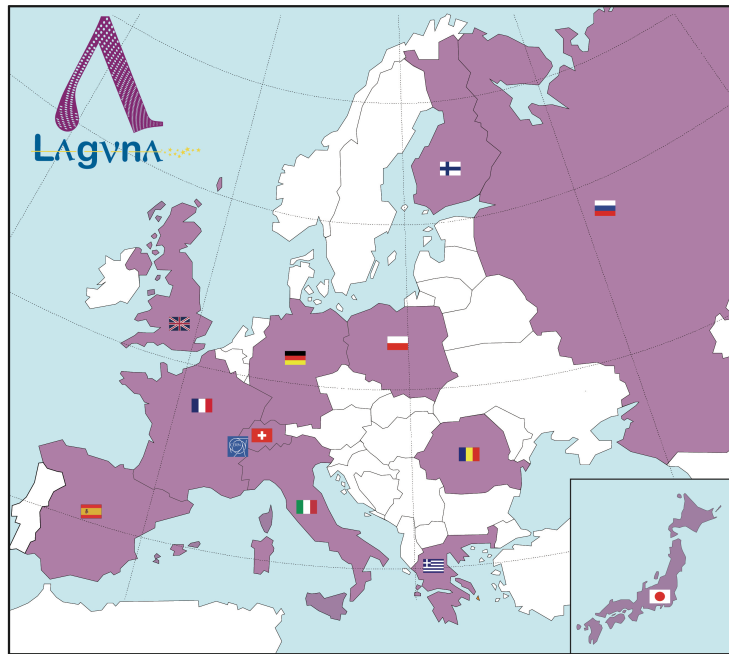
MEMPHYS and the EU FP7 DS LAGUNA-LBNO



Large **A**pparatus for **G**rand
Unification and **N**eutrino
Astrophysics - **L**ong **B**aseline
Neutrino **O**scillations

LAGUNA-LBNO consortium:
13 countries, 45 institutions,
~ 300 members, 2011 - 2014

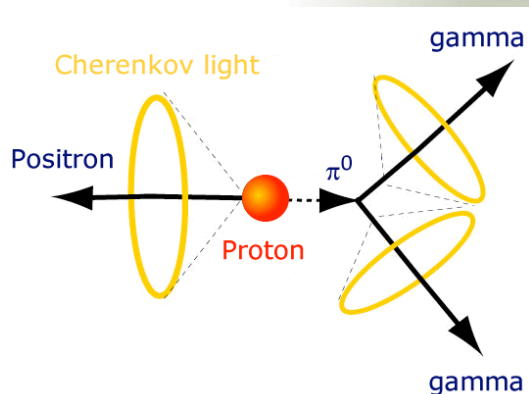
MEMPHYS and the EU FP7 DS LAGUNA-LBNO



Large Apparatus for Grand Unification and Neutrino Astrophysics - Long Baseline Neutrino Oscillations

LAGUNA-LBNO consortium:
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PROTON DECAY

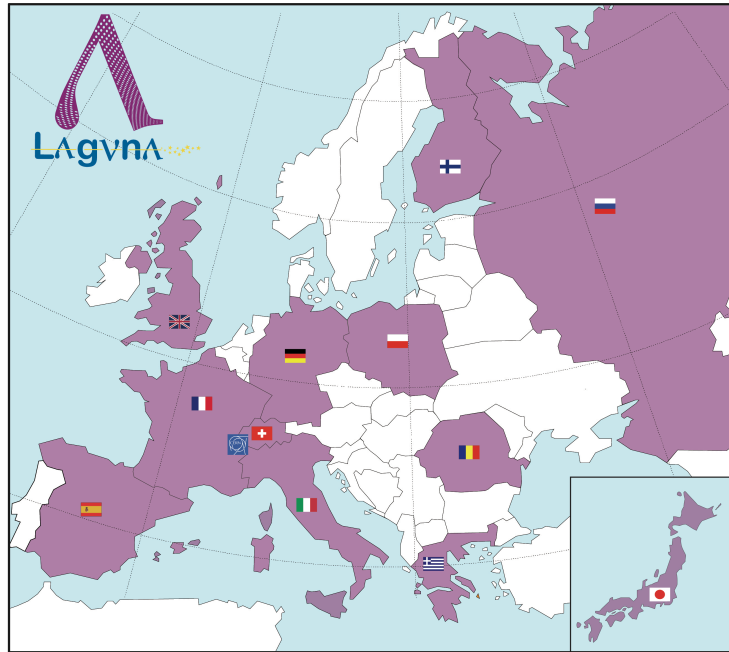


WCD 10 years, 500 kt active volume:

$p \rightarrow e^+ \pi^0$: $\sim 1.2 \times 10^{35}$ y @ 90% C.L.

$p \rightarrow \bar{\nu} K^+$: $\sim 2.4 \times 10^{34}$ y @ 90% C.L.

MEMPHYS and the EU FP7 DS LAGUNA-LBNO



Large Apparatus for Grand Unification and Neutrino Astrophysics - Long Baseline Neutrino Oscillations

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SUPERNOVA NEUTRINOS

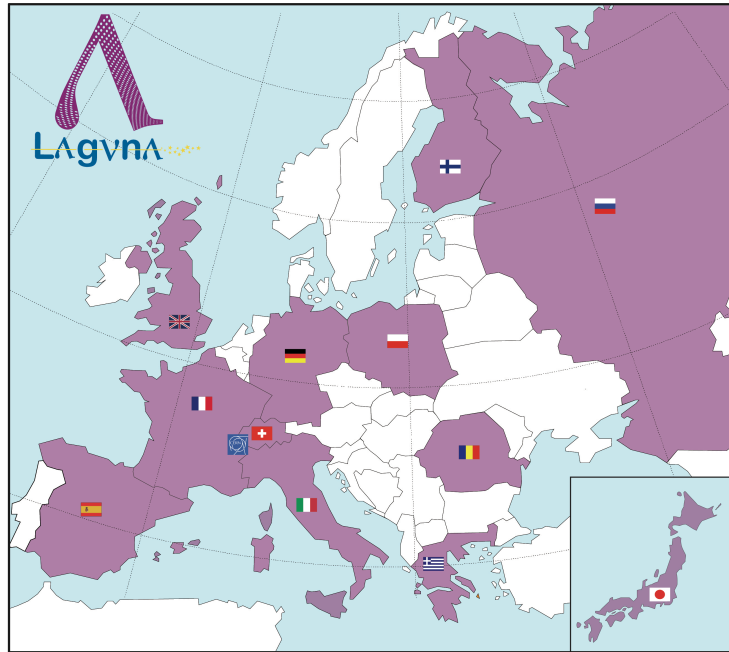


For a galactic Supernova @ 10 kpc:

CC: $\sim 2.5 \times 10^5 \nu_e$

ES: $\sim 1.2 \times 10^3 e^-$

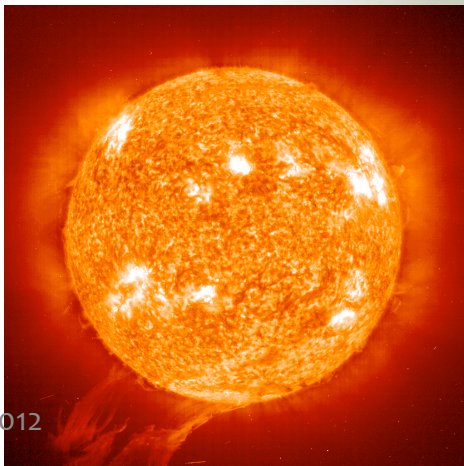
MEMPHYS and the EU FP7 DS LAGUNA-LBNO



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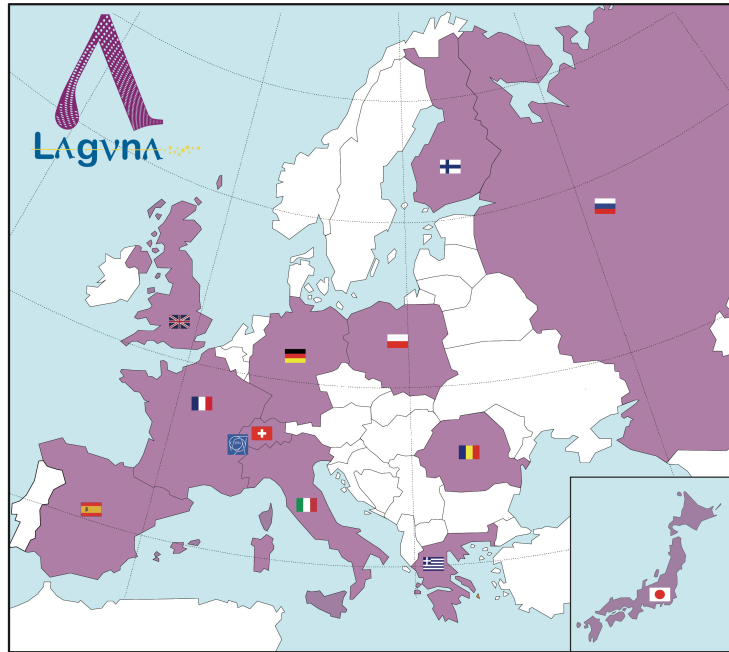
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SOLAR NEUTRINOS



ES $\nu_{8B} \sim 1.3 \times 10^6$ per year

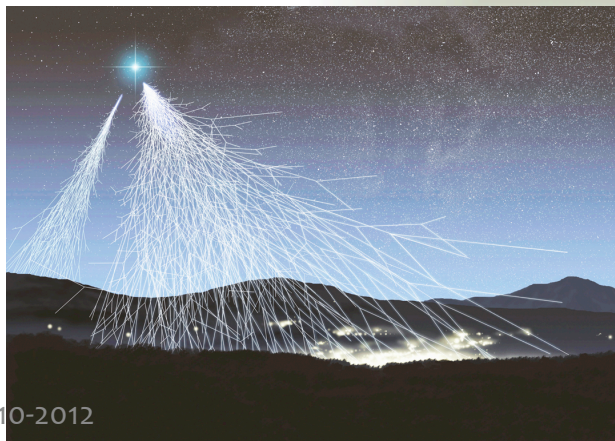
MEMPHYS and the EU FP7 DS LAGUNA-LBNO



Large Apparatus for Grand Unification and Neutrino Astrophysics - Long Baseline Neutrino Oscillations

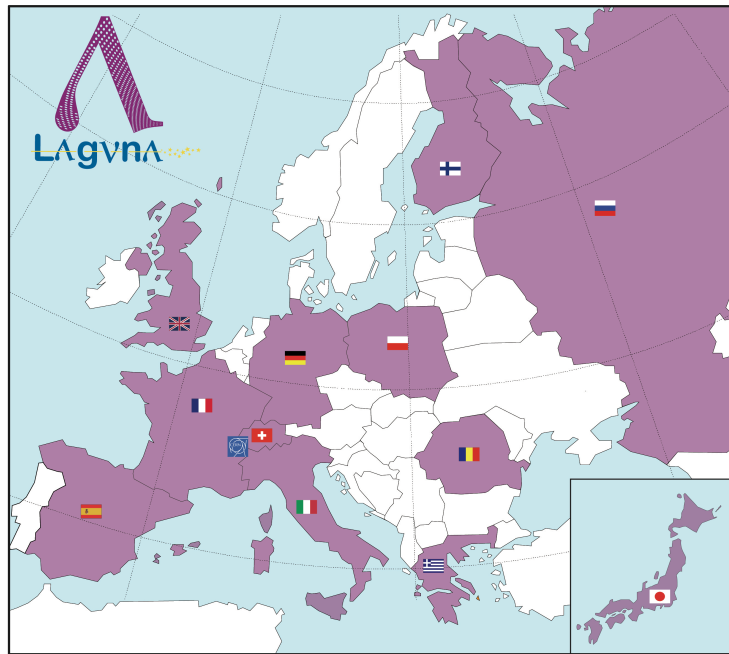
LAGUNA-LBNO consortium:
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ATHMOSPHERIC NEUTRINOS



$\sim 4.8 \times 10^4 \nu$ per year

MEMPHYS and the EU FP7 DS LAGUNA-LBNO



Large Apparatus for Grand Unification and Neutrino Astrophysics - Long Baseline Neutrino Oscillations

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REACTOR NEUTRINOS



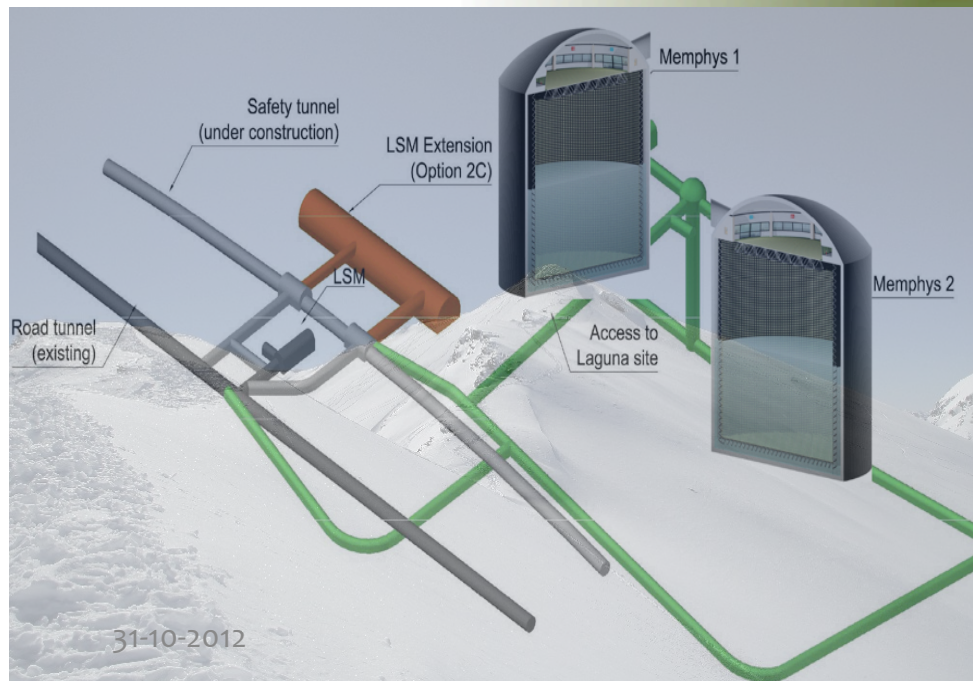
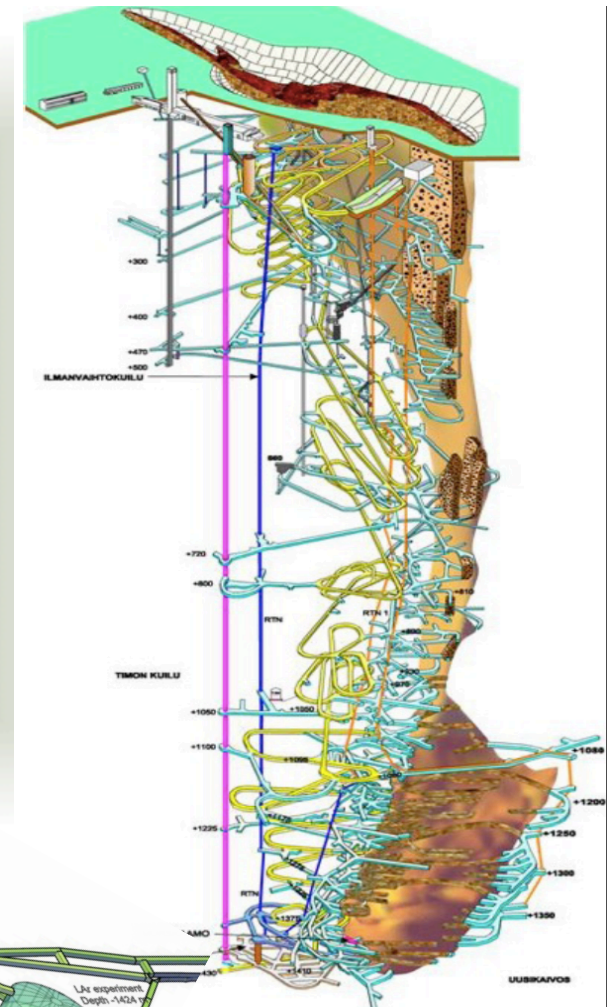
1 MEMPHYS tank with Gd
250 kt fiducial @ Fréjus:
~ 2.7×10^4 per year

LAGUNA-LBNO SITE INVESTIGATION

EOI for a very long baseline neutrino oscillation experiment

CERN-SPSC-2012-021; SPSC-EOI-007

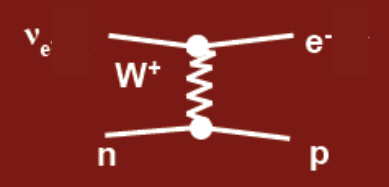
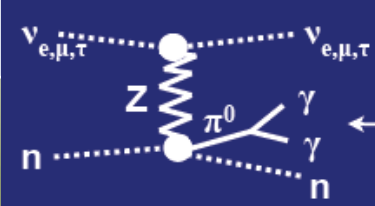
- 1st priority: CERN → Pyhäsalmi; LAr, LSc at the longest baseline (2300km), high energy wide band beam (neutrinos > 1 GeV)
- 2nd priority: CERN → Frejus; **WCD at the shortest long baseline** (130km), low energy beam (neutrinos < 1 GeV)



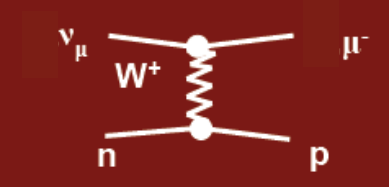
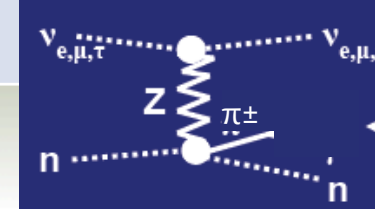
MEMPHYS MIGRATION MATRICES

MAIN SIGNALS AND BACKGROUNDS

- For super-beam

	Signal	Backgrounds
ν_e appearance		

- For beta-beam

	Signal	Backgrounds
ν_μ appearance		

⇒ **Need to identify particles !!**
 (μ^- , e^- or π^0 ??)

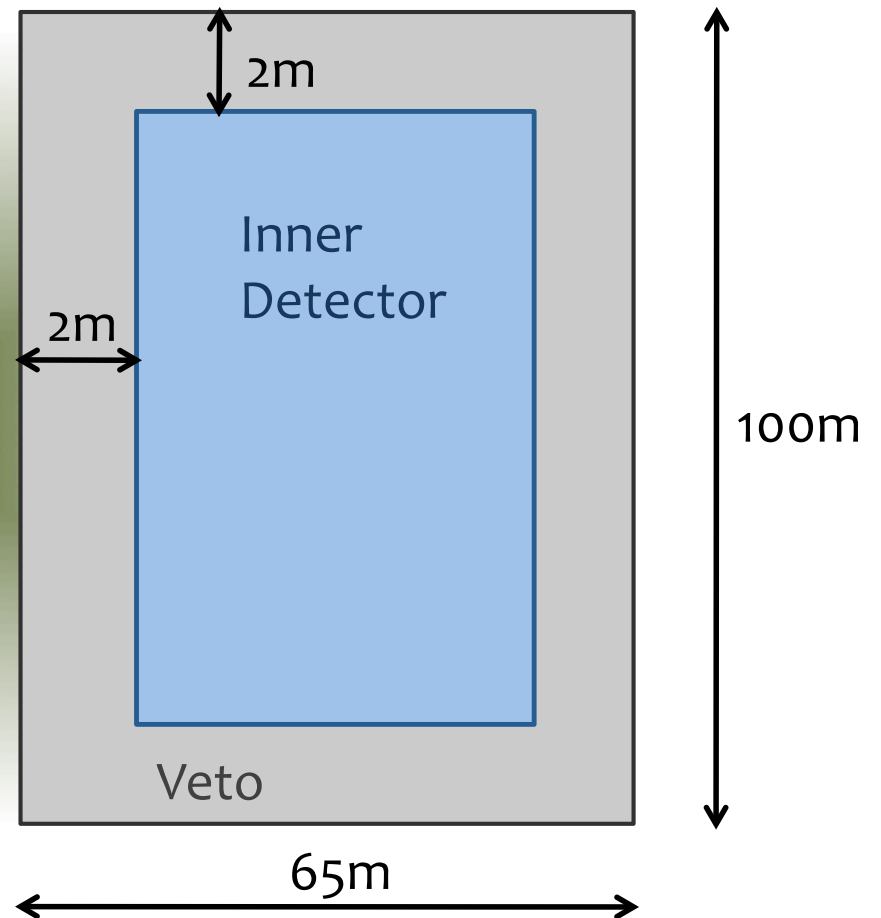
MIGRATION MATRIX CONCEPT

- Reconstructed vs true neutrino energy
 - Off-diagonality gives the resolution
- Projection gives efficiency on signal or background
- Summarize detector and analysis performance in one shot
- Used as standard input for GLOBES to parametrize detector performance

MEMPHYS SIMULATION

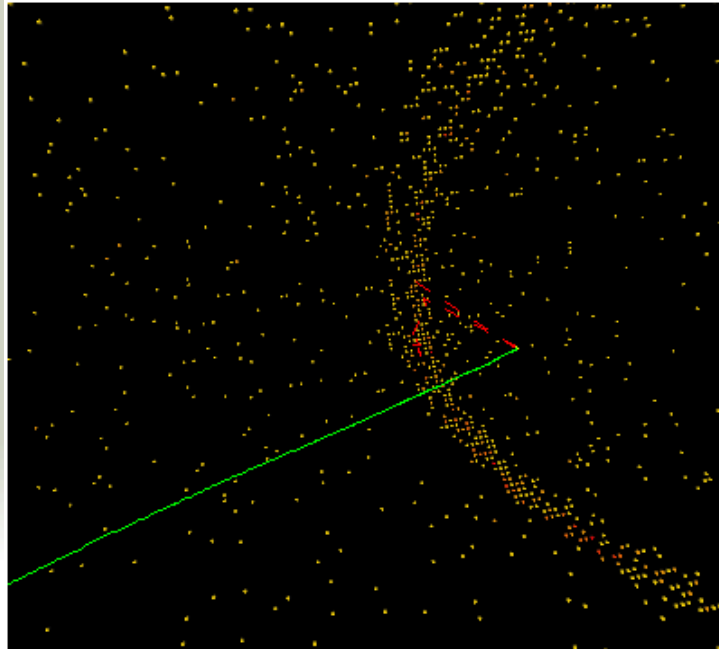
- Full simulation of the MEMPHYS detector
 - New implemented layout with 65m x 100m tank
 - Tests for the choice of the PMT dimensions
-
- Neutrino interactions in water simulated with GENIE
 - Geant4 detector simulation, with AIDA and OpenScientists used for ntuple production
 - Detailed detector description, easy to modify
 - The detailed simulation of light propagation in water is very slow: huge work of scripting for production of large samples

Present version in the MC



x 2 tanks!

THE RECONSTRUCTION CODE

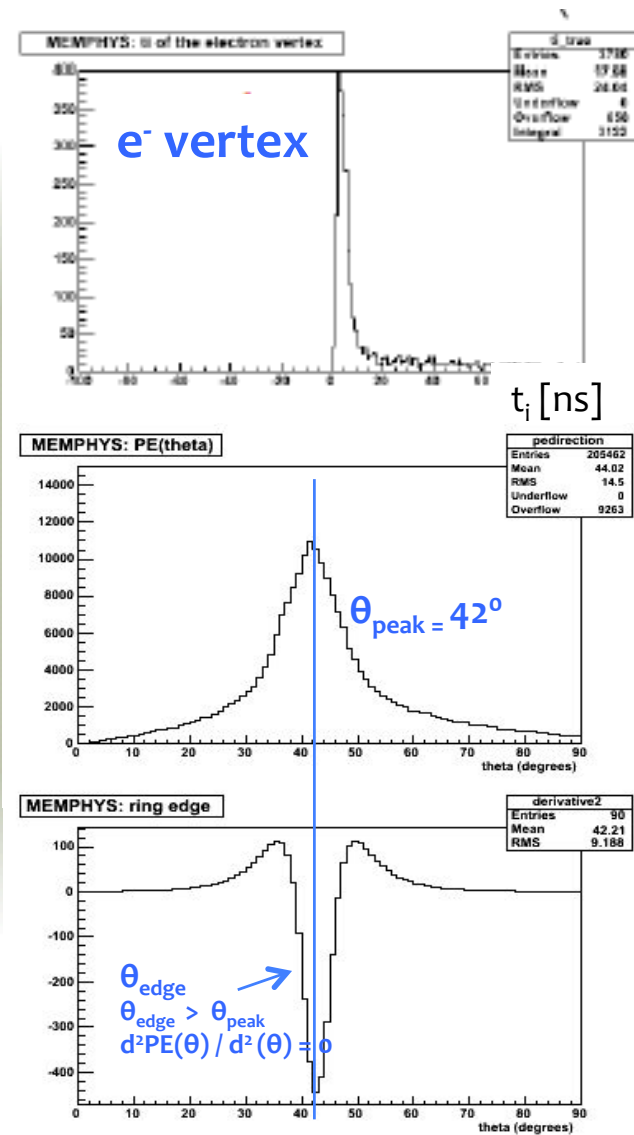


STEPS TOWARD MM

1. Reconstruction of interaction vertex and track direction
2. Ring edge finding
3. Particle identification (e vs μ) from ring “fuzziness”
4. Ring counting (to reject π^0 background) in electron sample
5. Lepton momentum reconstruction

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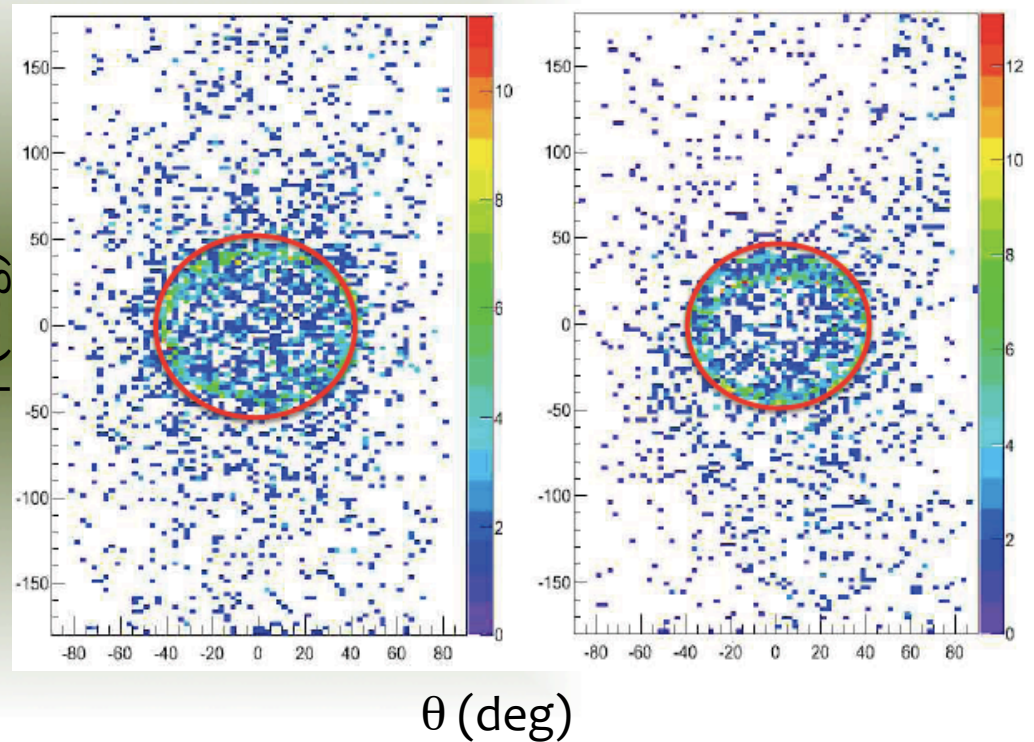


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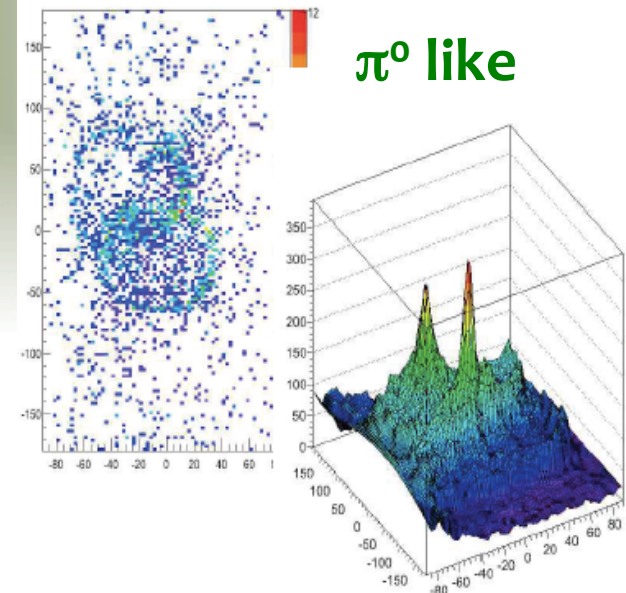
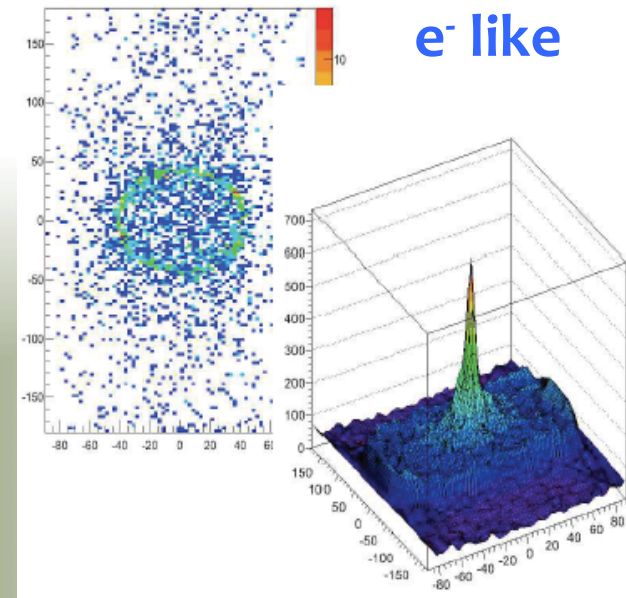
electron: fuzzy
ring edge

muon: sharp
ring edge



STEPS TOWARD MM

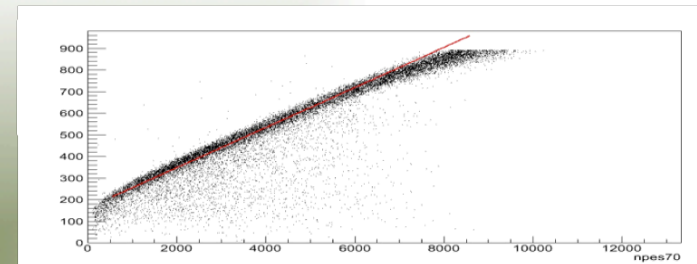
1. Reconstruction of interaction vertex and track direction
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4. Ring counting (to reject π^0 background) in electron sample
5. Lepton momentum reconstruction



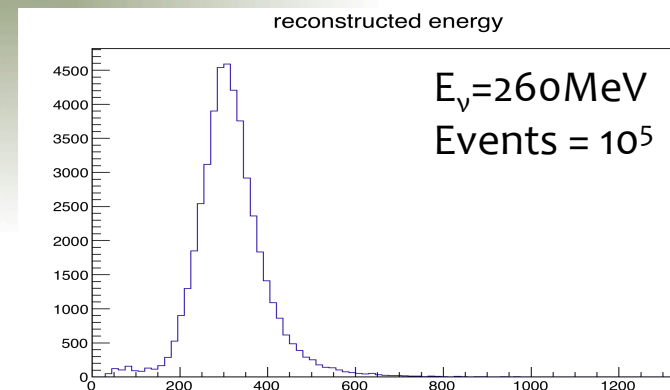
STEPS TOWARD MM

1. Reconstruction of interaction vertex and track direction
2. Ring edge finding
3. Particle identification (e vs μ) from ring “fuzziness”
4. Ring counting (to reject π^0 background) in electron sample
5. **Lepton momentum reconstruction**

$$E_{\mu}^{rec} = 160.0 + 0.0927npes70$$



$$E_{\nu} = \frac{m_n E_{\mu} - m_{\mu}^2 / 2}{m_n - E_{\mu} + p_{\mu} \cos \theta_{\mu}}$$

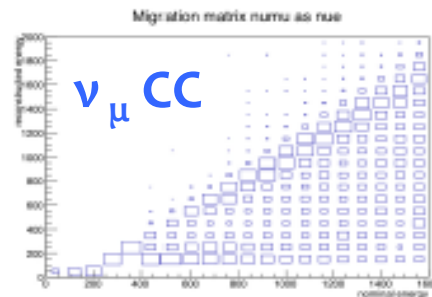
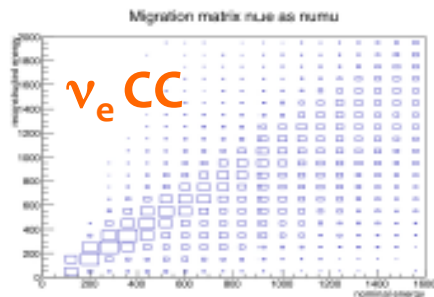
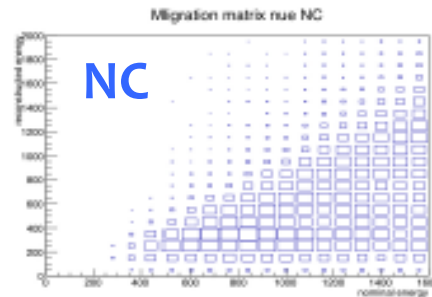
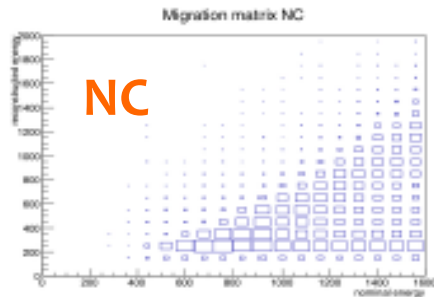
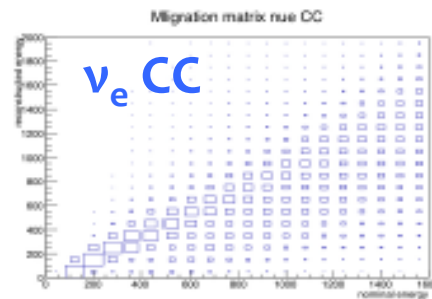
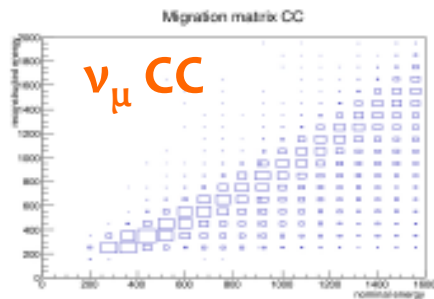


MEMPHYS MIGRATION MATRICES

ν_μ selection

ν_e selection

Reconstructed Energy



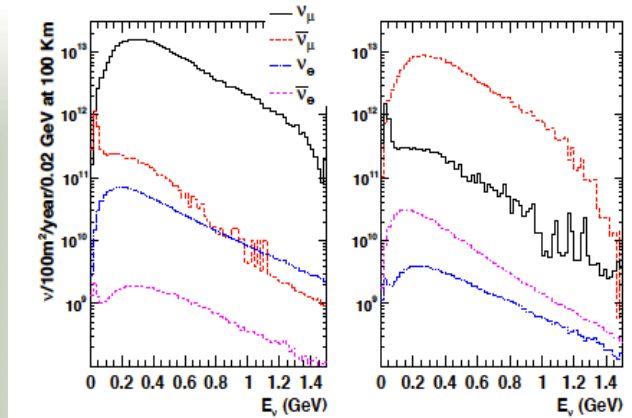
True Energy

PUBLISHED ON
[arXiv:1206.6665](https://arxiv.org/abs/1206.6665)

patzak@in2p3.fr
luca.agostino@apc.univ-paris7.fr
tonazzo@in2p3.fr
buizza@in2p3.fr

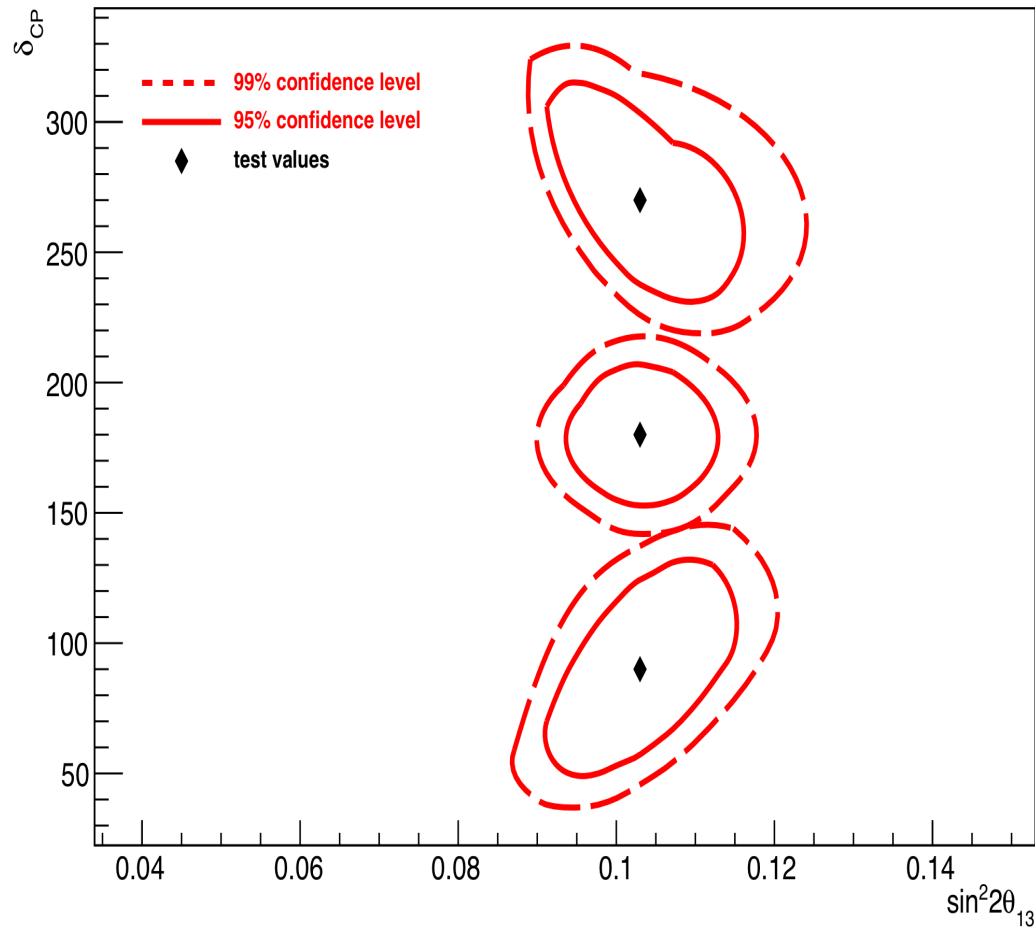
GLOBES INPUT

- BEAM FLUX 2-8 years neutrino antineutrinos (SPL by A. Longhin)
- Base Line 130 km
- Fiducial Volume 500 kt
- Efficiencies and Energy Smearing with new MMs
- Flat efficiency distribution as it is inside the MMs
- Cross Sections by NUANCE (will be soon updated to GENIE)
- Systematic errors: 5% signal 10% background



PHYSICS POTENTIAL (1)

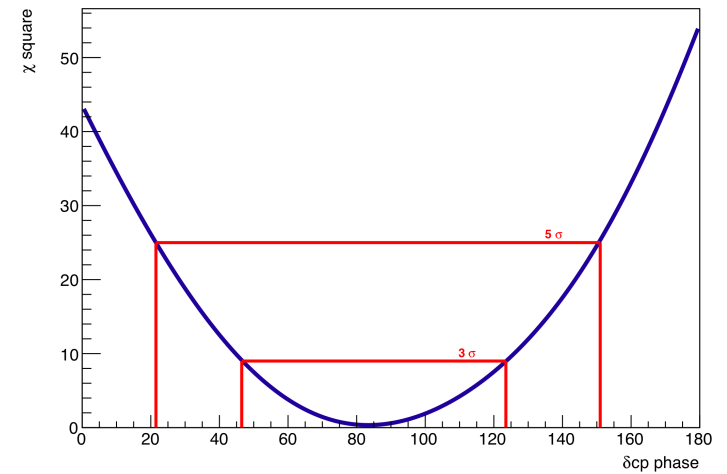
Confidence levels for δ_{CP}



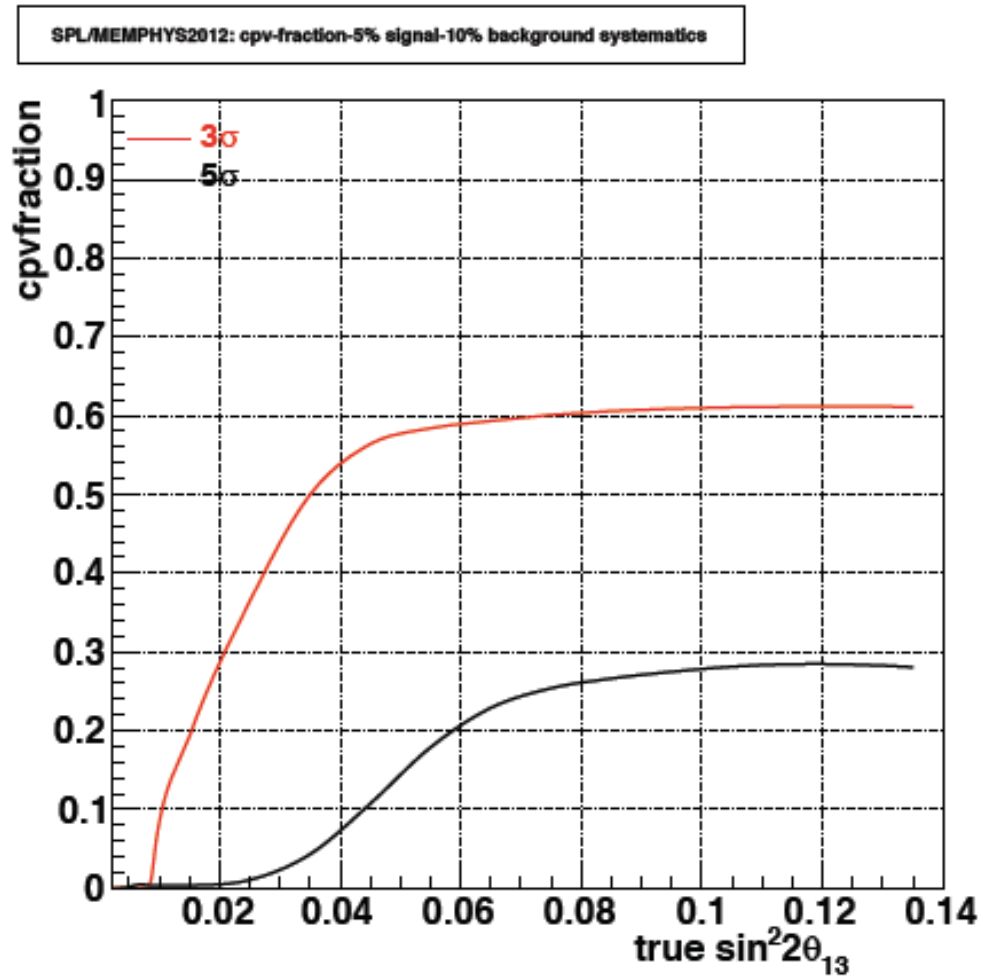
Confidences areas for the δ_{CP} discovery

Systematics:
5% signal
10% background

χ^2 projection onto dcp axe



PHYSICS POTENTIAL (2)



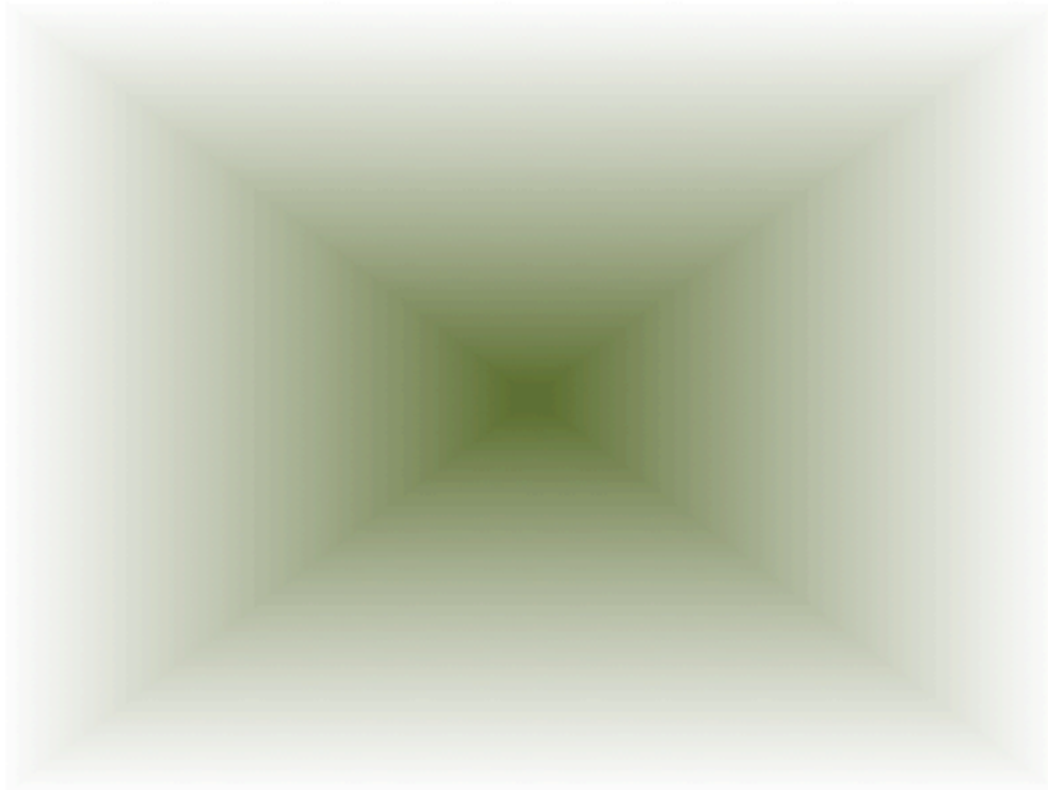
CP fraction coverage with
MEMPHYS at 3-5 σ

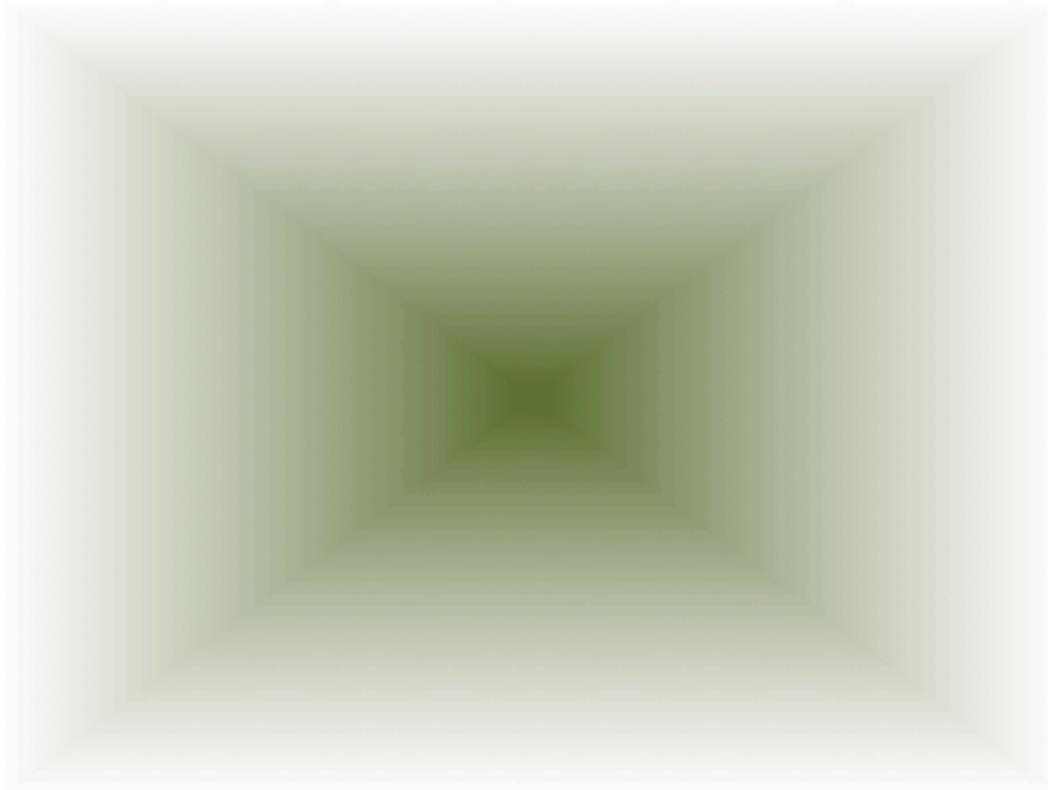
Systematics:
5% signal
10% background

arXiv:1206.6665

SUMMARY AND OUTLOOK

- A full Geant-4 simulation of MEMPHYS is available
 - Performances studies are in progress
- We have published the Migration Matrices for MEMPHYS
- First potential studies are done with GLOBES. Results confirm expectations
- Improvements on the MC code are in develop to reach better NC rejections, signal efficiency and detector performances





STEPS TOWARD MM

1. Reconstruction of interaction vertex and track direction
2. Ring edge finding
3. Particle identification (e vs μ) from ring “fuzziness”
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muon: sharp ring edge

