Double Chooz

A Reactor θ_{13} Experiment

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On behalf of the Double Chooz Collaboration

- Reactor $\theta 13$ measurement
- Description and Status of Double Chooz
- Expected schedule and sensitivities
- Summary

Reactor Neutrino Oscillations

$P(\overline{\nu}_e \rightarrow \overline{\nu}_e) \sim 1$

$- \cos^4\theta_{13} \sin^2 2\theta_{12} \sin^2(\Delta m^2_{12} L/4E)$

$- \sin^2 2\theta_{13} \sin^2(\Delta m^2_{13} L/4E)$

(Ignores tiny matter effect)

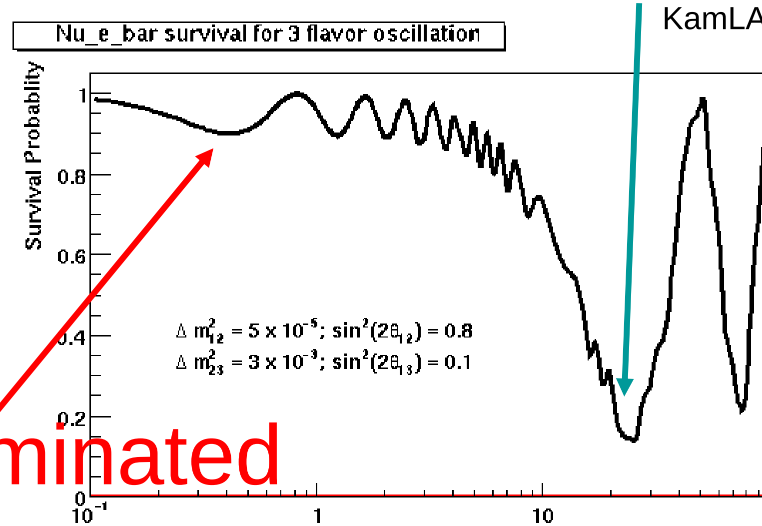
$L = \pi E/(2.54\ \Delta m^2)$

$\sim$ **<u>1-2 km</u>**

Δm^2_{12} dominated

KamLAND(180km)

P



Δm^2_{13} dominated

L/E(km/MeV)

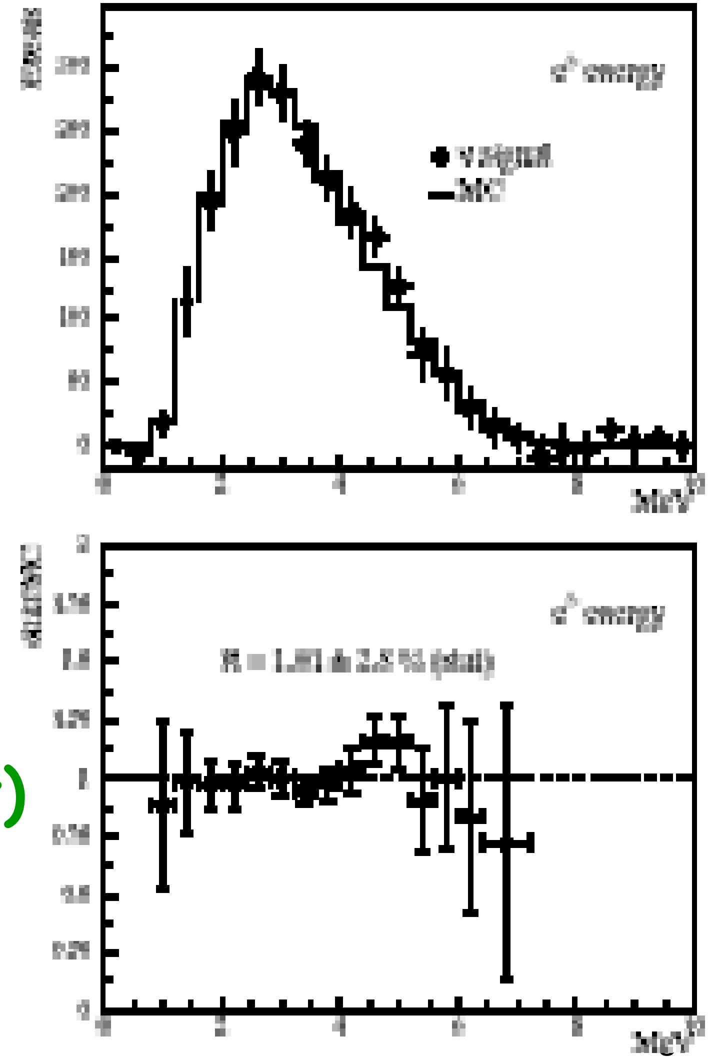
Best current limit is from CHOOZ

$\sin^2(2\theta)_{13} < 0.19$

Only ran 199 days

Total live time 341days

(Reactor off: 142days)

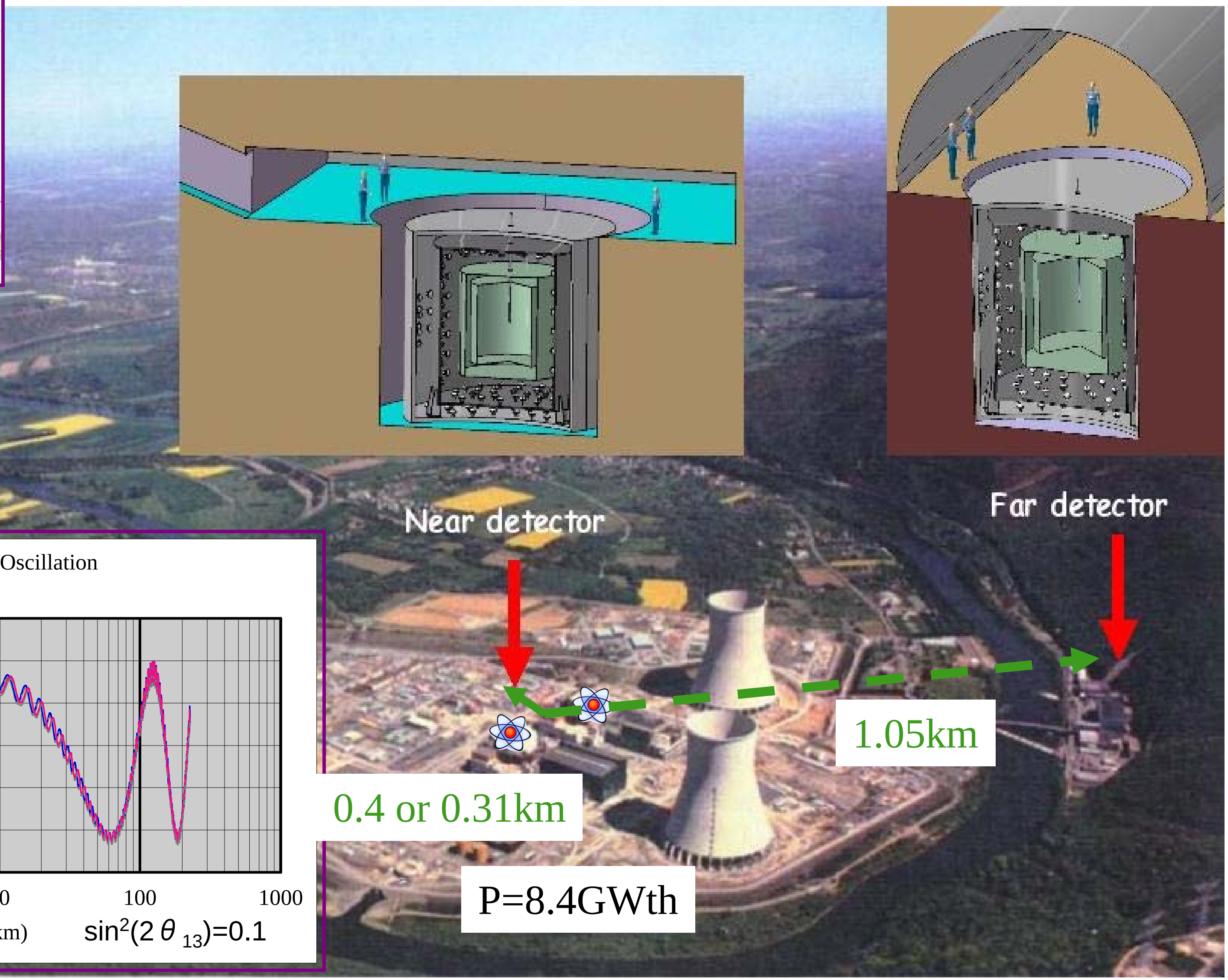


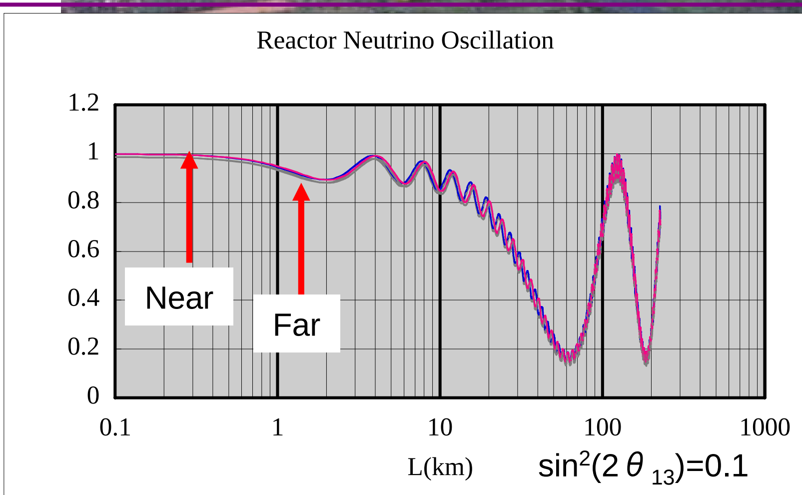
@CHOOZ:

R = 1.01 ± 2.8%(stat)±2.7%(syst)

Hep-ex/0301017

Double Chooz Experiment





Collaboration

- Japan
  - Tohoku U.
  - Tokyo Metropolitan U.
  - Niigata U.
  - Tokyo Institute of Technology
  - Kobe U.
  - Tohoku Gakuin U.
  - Miyagi University of Education
  - Hiroshima Inst. of Technology
- USA
  - Livermore nat lab
  - Argonne
  - Columbia U
  - Chicago U
  - Kansas U
  - Notre Dame U
  - Tennesse U
  - Alabama U
  - Drexel U
  - Illinois Inst Tech
- France
  - Saclay
  - APC Laboratory
  - Subatech Nantes
- Germany
  - MPI Heidelberg
  - TU Munich
  - Hamburg U
  - Tubingen U
  - Aachen U
- Spain
  - CIEMAT Madrid
- England
  - Oxford U
  - Sussex U
- Russia
  - Kurchatov Inst
  - Sc. Acad.
- Brasil
  - CBPF
  - UNICAMP

Why "Double"?

Reactor induced systematics

2 detectors →
cancellation of the reactor physical uncertainties

systematics	Error type	CHOOZ	2 identical detector Low background
Reactor	Flux, cross section	1.9%	O(0.1%)
	Thermal power	0.7%	O(0.1%)
	E/Fission	0.6%	O(0.1%)
	Σ	**2.1%**	O(0.1%)

Detector induced systematics

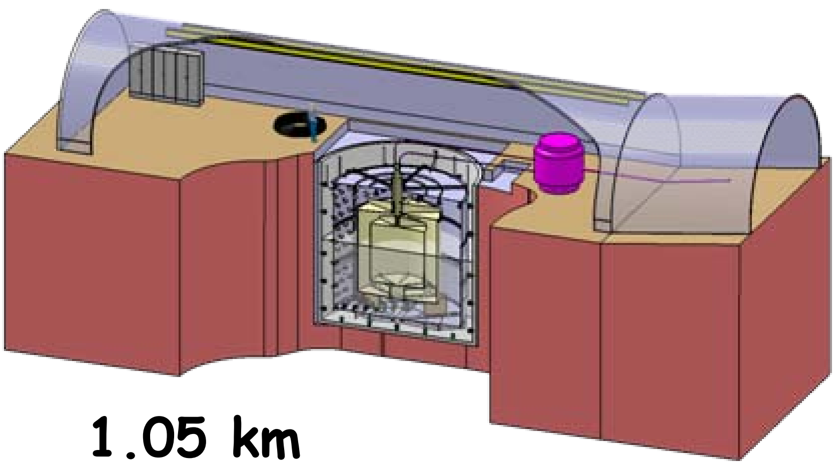
systematics	Error type	CHOOZ	2 identical detector Low backgrounds
Detector	Scintillator density	0.3%	O(0.1%)
	H/C ratio & Gd concentration	1.2%	O(0.1%)
	Target weight	**0.3%**	**0.2%**
	« Spill in/out » effect	1.0%	O(0.1%)

M. Apollonio et. al., Eur.Phys.J. C27 (2003) 331-374

A single scintillator batch will be prepared to fill both detectors with the same apparatus

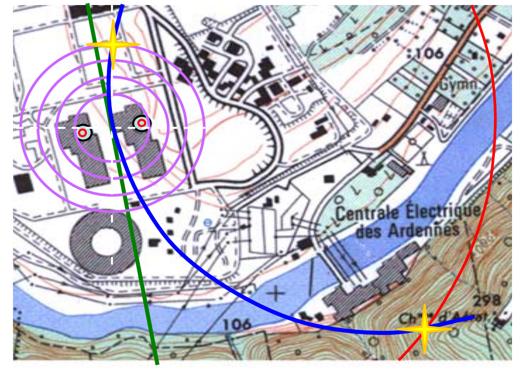
Far site

Integration to start early-2008



1.05 km
300 m.w.e
15 000 events/y

Near site



[Tunnel option]
400 m
120 m.w.e

[Pit option]
310 m
80 m.w.e

150 000 events/y

0.4% statistical error
(in 5 years)

Detector design

Calibration Glove-Box :

Outer Veto :
Scintillator panels

Target ν : 10,3 m^3
LS; 80% $C_{12}H_{26}$+ 20% PXE +0,1% Gd
+ PPO + Bis-MSB

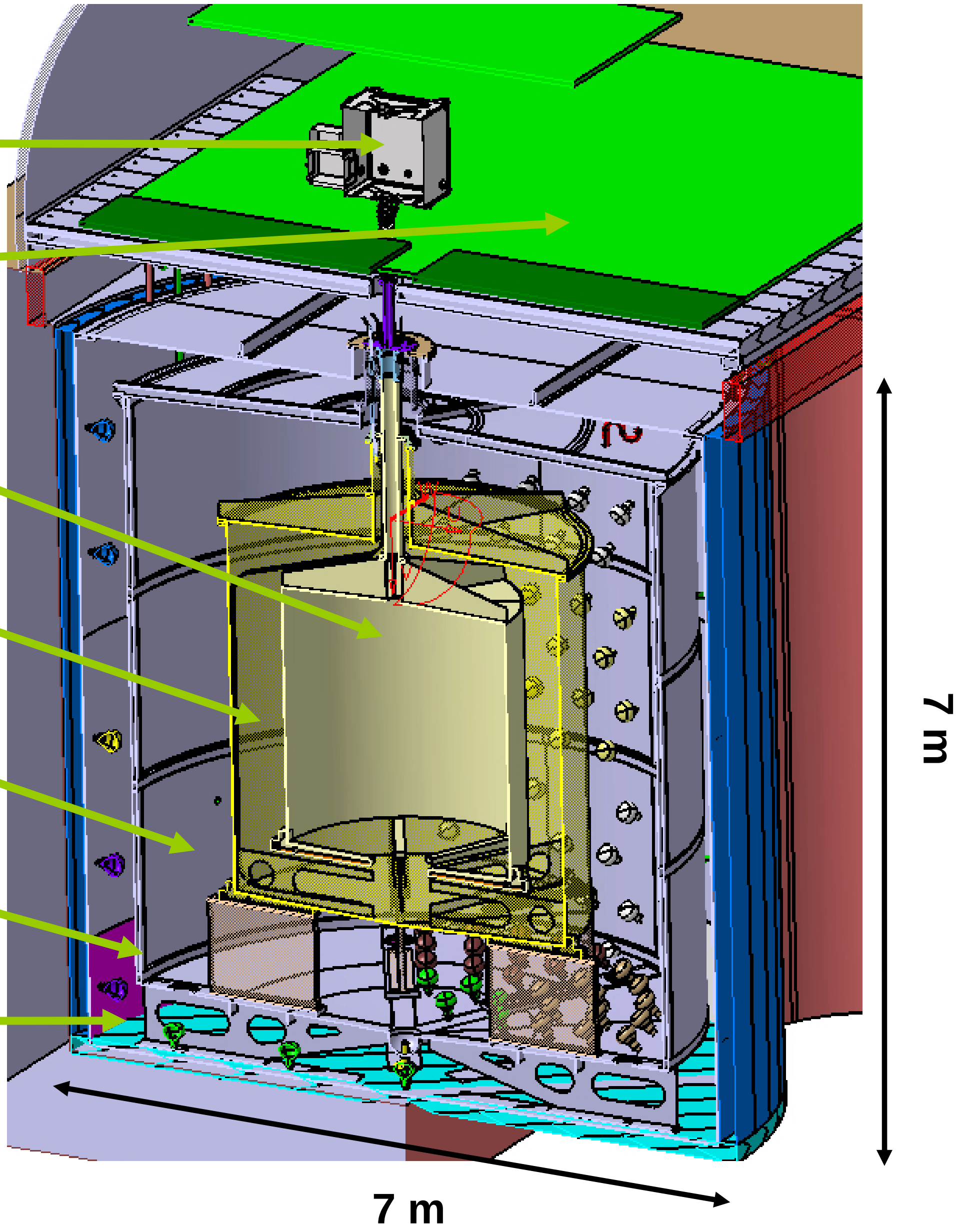
γ Catcher : 22,6 m^3
LS; 80% $C_{12}H_{26}$ + 20% PXE + PPO + Bis-MSB

Non scintillating Buffer : 114 m^3
mineral oil

Buffer vessel & 390 10'' PMTs :
Stainless steel 3 mm

Inner Muon Veto : 90 m^3
Scintillator + 70 8'' PMTs

Steel Shielding :
17 cm steel, All around



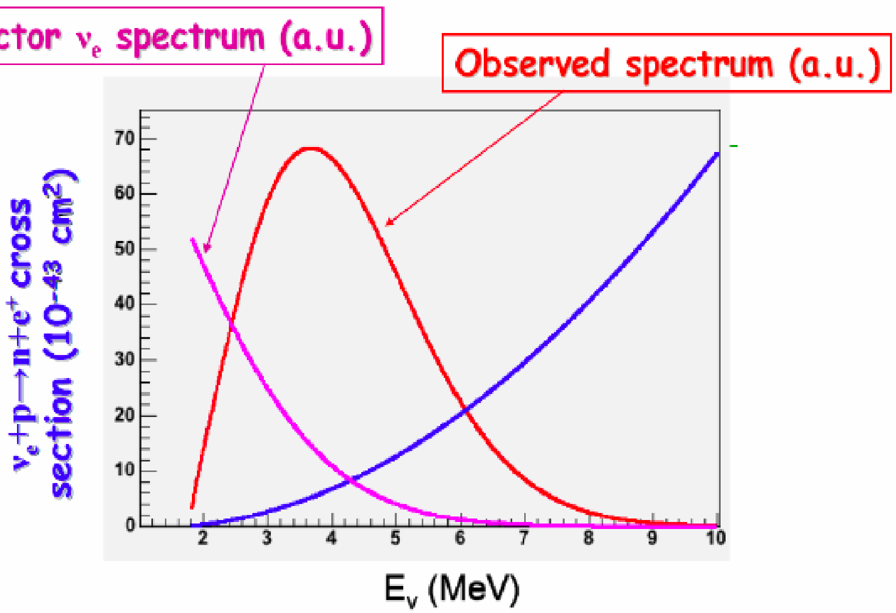
ν detection at reactor experiments

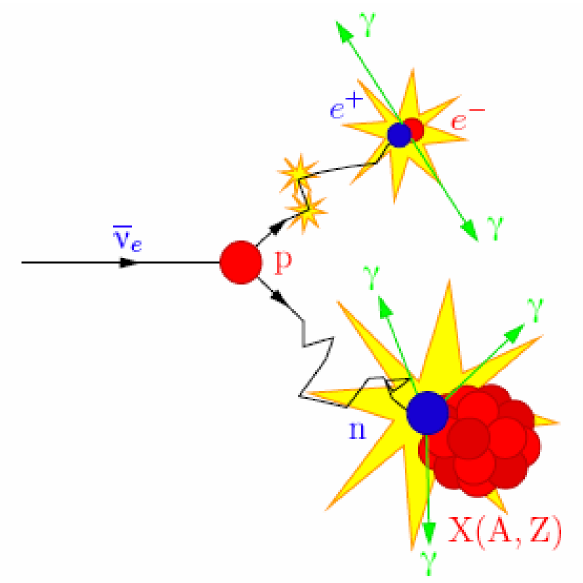
$$N_\nu\left(s^{-1}\right) = 6N_{Fiss}\left(s^{-1}\right) \approx 2\times10^{11} P\left(s^{-1}W^{-1}\right)$$

P=8GWth $\Rightarrow N_\nu \sim 10^{21} s^{-1}$ on all solid angle

Detection by "inverse beta decay"

$\bar{\nu}_e + p \rightarrow e^+ + n$





Prompt Energy(**e⁺** annihilation)

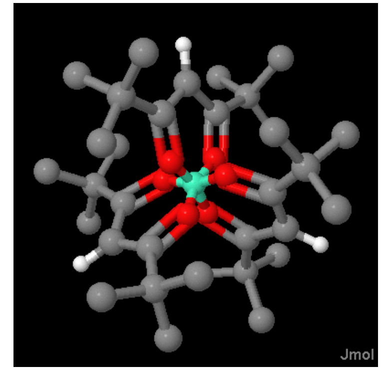
$E_{prompt} = E_\nu$ - 1.8 MeV(th.)+1.022MeV(an.)

Delayed photons from **n** capture on dedicated nuclei (Gd)

$\Delta t \sim 30\ \mu s$ $E \sim 8$ MeV

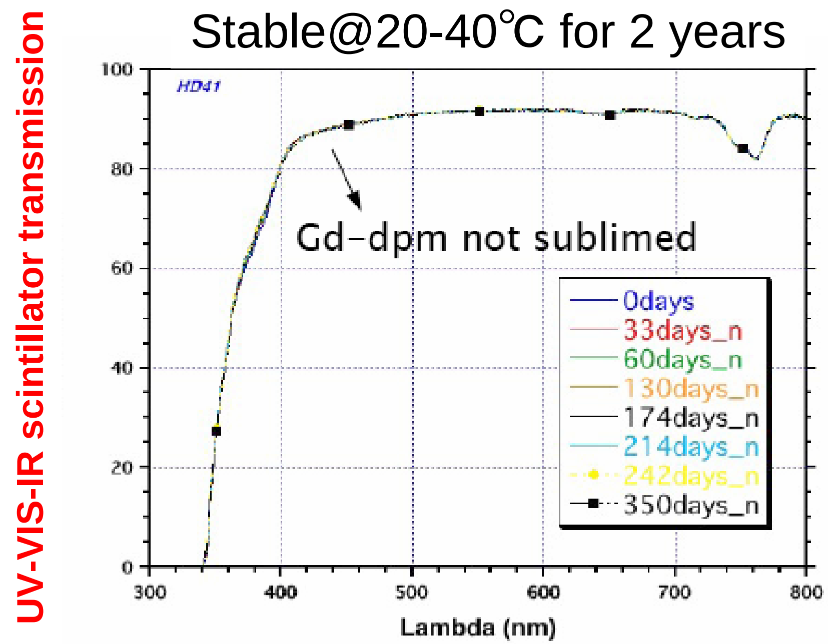
Gd doped scintillator

- **Solvent: 20% PXE(phenyl-xylyl ethane)– 80% Dodecane**
- **Gd loading: being developed @MPIK**
  - 0.1% Gd loading of Gd-BDK (Beta Diketonate)
  - Long term Stability promising
  - LY ~7000 ph/MeV: 6 g/l PPO + 50 mg/l Bis-MSB
  - Attenuation length: 5-10 m meters at 420 nm
  - Radiopurity → U: 10^{-12} g/g - Th: 10^{-12} g/g - K: 10^{-9} g/g



$Gd(dpm)_3$
dipivaloymethane

MPIK new building for storage and purification of scintillators

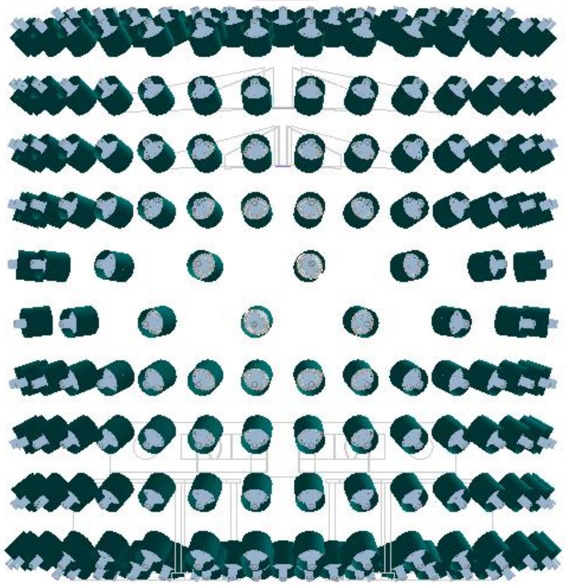


- Heidelberg MPIK →Transition to industrial production of 100 kg of Gd → Summer 2007
- On-site storage building *available* at Chooz → Upgrade will be done in 2007

PMT System

PMT configuration

a candidate



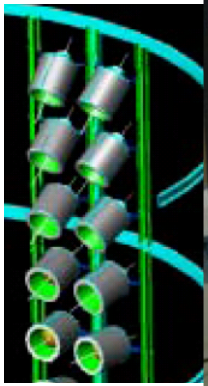
390   10“ PMTs at Buffer Vessel

(70   8“ PMTs for Inner Muon Veto)

13 % coverage

Energy resolution goal: 7 % at 1 MeV

(Option)
LC(Light concentrator)
[England]



Magnetic Shield
Support Structure
[Spain]

High performance
low background
10" PMT (Oil proof)
[Japan]

Backgrounds

CHOOZ OFF data & Simulation (represent CHOOZ results well)

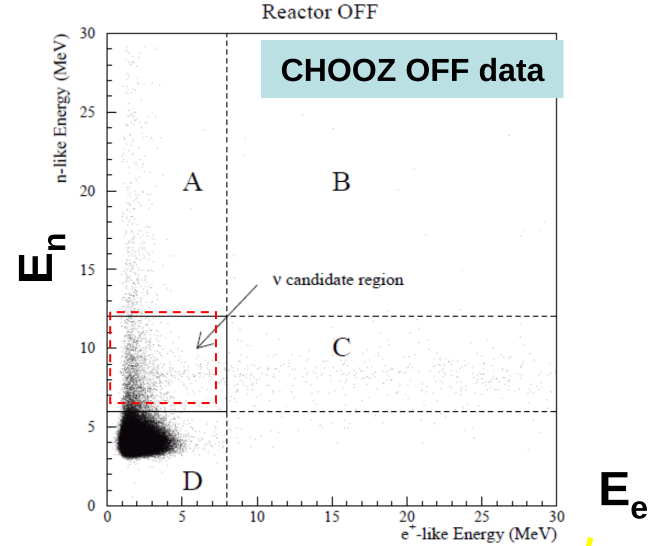
Accidental Background

✓**Prompt Signal**: radio activity dominated by PMTs **(Rate=Rp)**

✓**Delayed Signal: Neutrons** from cosmic μ spallation **(Rate=Rd)**

⇒ Accidental coincidence
Rate = Rp x Rd x Δt

N_{bkg} = ~1.6 evts/day (Far) 2.3% of ν signal
= ~17 evts/day (Near) 1.7% of ν signal



Correalated background

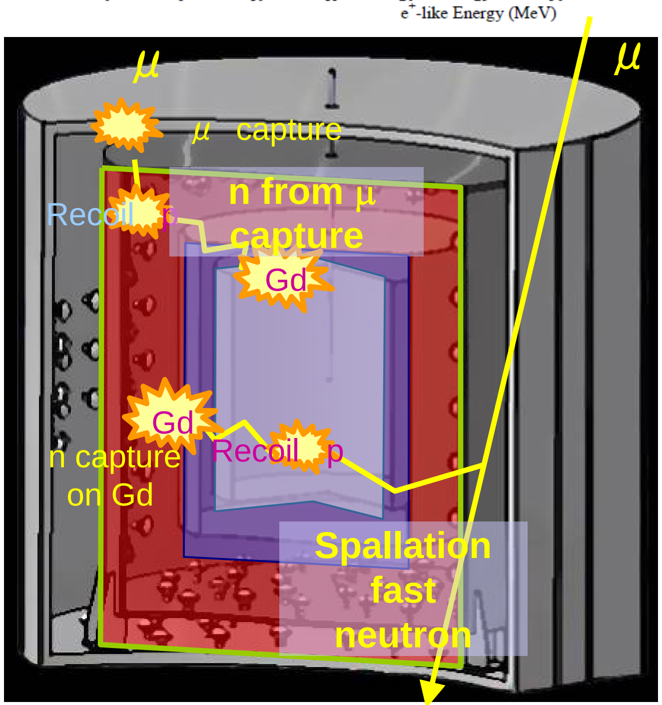
(cosmic μ induced)

✓ Fast Neutrons (recoil ***p*** and thermalized N)

✓ μ caputure

✓ Long-lived (9Li) β-(N)decaying isotopes

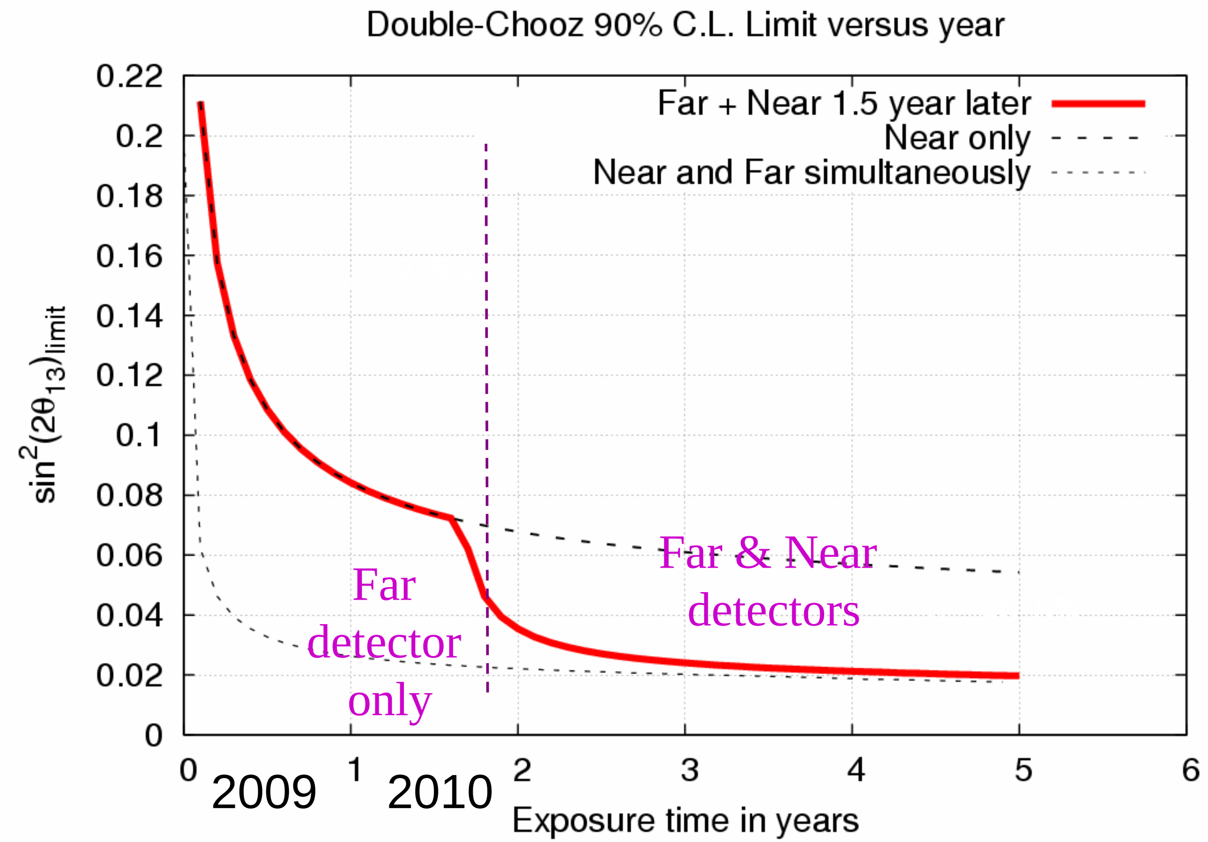
N_{bkg} = ~1.4 evts/day (Far) 2% of ν signal
= ~10 evts/day (Near) 0.9% of ν signal



Sensitivity

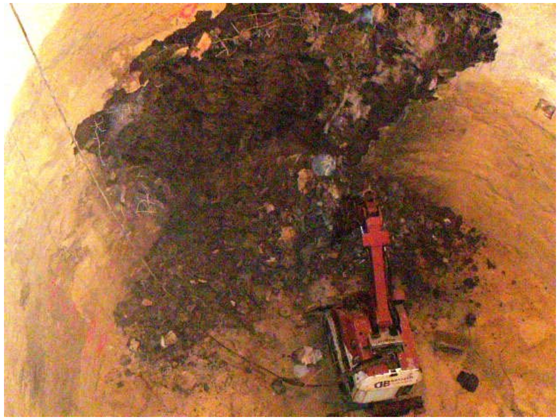
Double-Chooz Far Detector starts in 2008
Double-Chooz Near detector follows 16 months later

90% C.L. contour if $\sin^2(2\theta)=0$
Δm^2_{atm} = 2.8x10^{-3} eV^2 is supposed to be known at 20% by MINOS



Conclusions & outlook

Double Chooz R&D's are in final stages & Detector Construction just started.



civil engineering (pit cylinder)

First data taking expected to start in 2008 with far detector only

=> *$\sin^2(2\theta_{13}) < 0.06$ in 1,5 year*

In 2010 take data with both near and far detectors

=> *$\sin^2(2\theta_{13}) < 0.03$ in 3 years*

We will know or set a strong limit on the size of θ_{13} within a few years & the neutrino oscillation studies will go in a new phase.