Status of Double Chooz Reactor Neutrino Oscillation Experiment

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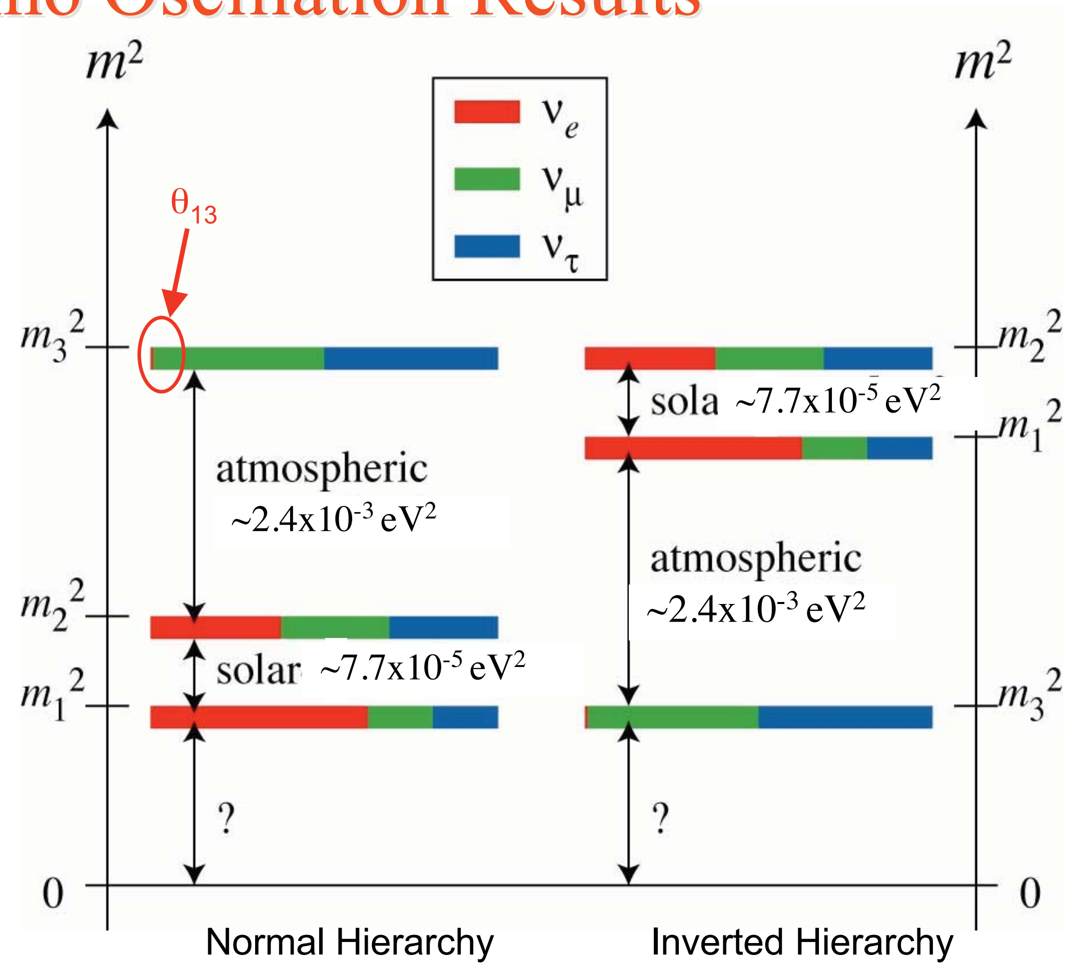
Implications of Neutrino Flavor Oscillations Workshop

6-10 July 2009, Santa Fe, USA

Neutrino Oscillation Results

Missing information:

1. What is ν_e component in the ν_3 mass eigenstate?
   - The size of the "little mixing angle", θ_{13} ?
   - Only know $\theta_{13}<13^0$
2. Is the μ - τ mixing maximal?
   - $35^0 < \theta_{23} < 55^0$
3. What is the mass hierarchy?
   - Is the solar pair the most massive or not?
4. What is the absolute mass scale for neutrinos?
   - We only know Δm^2 values
5. Do neutrinos exhibit CP violation, i.e. is $\delta \neq 0$?



Lot's of questions but the Big Question is
" How big is the the little mixing angle θ_{13} ?"

Experimental Methods to Measure Θ_{13}

- Long-Baseline Accelerators: Appearance ($\nu_\mu \rightarrow \nu_e$) at $\Delta m^2 \approx 2.4\times10^{-3}$ eV^2
  - Look for appearance of ν_e in a pure ν_μ beam vs. L and E
    - Use near detector to measure background ν_e's (beam and misid)

NOvA:
$\langle E_\nu \rangle = 2.3$ GeV
L = 810 km

T2K:
$\langle E_\nu \rangle = 0.7$ GeV
L = 295 km

- Reactors: Disappearance ($\bar{\nu}_e \rightarrow \bar{\nu}_e$) at $\Delta m^2 \approx 2.4\times10^{-3}$ eV^2
  - Look for a change in $\bar{\nu}_e$ flux as a function of L and E
    - Look for a non- $1/r^2$ behavior of the ν_e rate
    - Use near detector to measure the un-oscillated flux

Double Chooz:
$\langle E_\nu \rangle = 3.5$ MeV
L = 1100 m

Accelerator vs Reactor Experiment

Long-Baseline Accelerator Appearance Experiments

Θ_{13} probed by measuring electron neutrino appearance from accelerator produced muon neutrinos.
Need to have an L and E such that interference between solar and atmospheric scales can bee seen

Oscillation probability complicated and dependent not only on θ_{13} but also:

1. CP violation parameter (δ)
2. Mass hierarchy (sign of Δm_{31}^2)
3. Size of $\sin^2\theta_{23}$

$$
\begin{aligned}
P(\nu_\mu \to \nu_e) = {} & \sin^2\theta_{23}\sin^2 2\theta_{13}\frac{\sin^2(\Delta_{31}\mp aL)}{(\Delta_{31}\mp aL)^2}\Delta_{31}^{\ 2} \\
& + \cos^2\theta_{23}\sin^2 2\theta_{12}\frac{\sin^2(aL)}{(aL)^2}\Delta_{21}^{\ 2} \\
& + \cos\delta\sin 2\theta_{23}\sin 2\theta_{12}\sin 2\theta_{13}\cos\Delta_{32}\left(\frac{\sin(\Delta_{31}\mp aL)}{(\Delta_{31}\mp aL)}\Delta_{31}\right)\left(\frac{\sin(aL)}{(aL)}\Delta_{21}\right) \\
& + \sin\delta\sin 2\theta_{23}\sin 2\theta_{12}\sin 2\theta_{13}\sin\Delta_{32}\left(\frac{\sin(\Delta_{31}\mp aL)}{(\Delta_{31}\mp aL)}\Delta_{31}\right)\left(\frac{\sin(aL)}{(aL)}\Delta_{21}\right)
\end{aligned}
$$

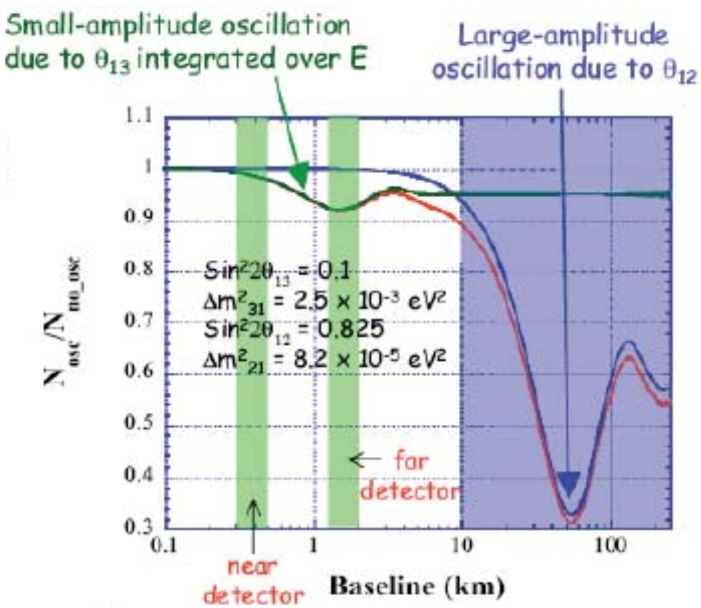
$\Rightarrow$ These extra dependencies are both a “curse” and a “blessing” since they will let us measure CP violation if θ_{13} is big enough.

Accelerator vs Reactor Experiment

Reactor Disappearance Experiments

Θ_{13} probed by measuring the disappearance of reactor produced electron anti-neutrinos.

Need to work at an L/E matched to the atmospheric Δm^2 (C.F. Kamland measurement at solar Δm^2)



$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) = 1 - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2\Delta_{21} - \sin^2 2\theta_{13}(\cos^2\theta_{12}\sin^2\Delta_{31} + \sin^2\theta_{12}\sin^2\Delta_{32})$$

$$\Delta_{ij} \equiv 1.27\Delta m^2_{ij} L/E$$

L(km), E(MeV), m(10^{-3}eV)

⇒ Reactor disappearance measurements provide a straight forward method to measure θ_{13} with no dependence on matter effects and CP violation

Reactors as Anti-neutrino Sources

Use very high flux of $\bar{\nu}_e$ from nuclear power reactors

- Need to know the $\bar{\nu}_e$ flux vs time

Use "inverse beta decay" process to detect $\bar{\nu}_e$ events

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

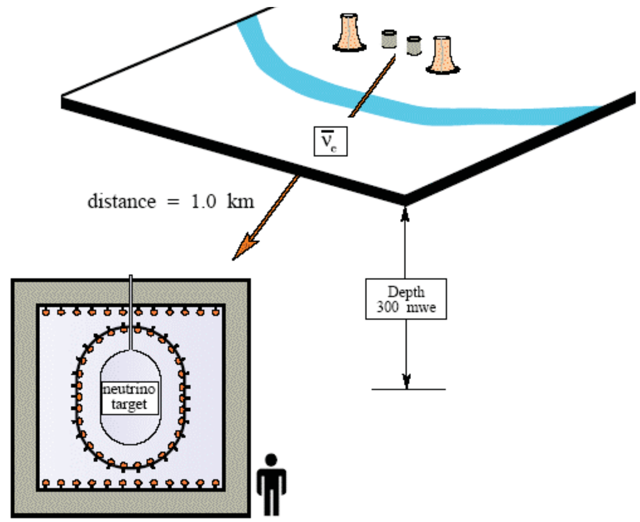
- Need to know the cross section vs neutrino energy

Detect the ν_e flux at two distances from the reactor

- Cancels many systematic uncertainties in flux and detection
- Need to know the exact position of cores and detectors

Minimize systematic uncertainties

- Use two "identical" detectors
- Go underground with well-designed veto system
  - $\Rightarrow$ Reduce cosmic muon backgrounds



Nuclear Reactors as a Source of $\bar{\nu}_e$'s

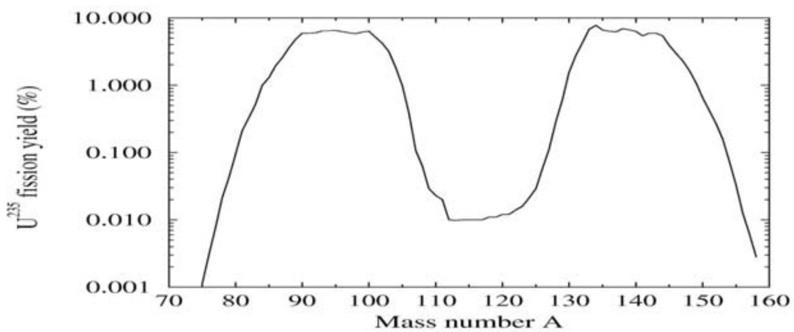
What creates the reactor $\bar{\nu}_e$'s ?

- Typical modern nuclear power reactor has a thermal power of: P_{therm} = 3.8 GW
  - About 200 MeV / fission of energy is released in fission of ^{235}U, ^{239}Pu, ^{238}U, and ^{241}Pu.
  - The resulting fission rate, f, is thus: f = 1.2 ×10^{20} fissions/s
  - At 6$\bar{\nu}_e$ / fission the resulting yield is: 7.1 ×10^{20} $\bar{\nu}_e$ / s.

Using e$^-$ spectra measurements for ^{235}U, ^{239}Pu, and ^{241}Pu
Can calculate the ν_e flux to ~1.5%.

Example: ^{235}U fission

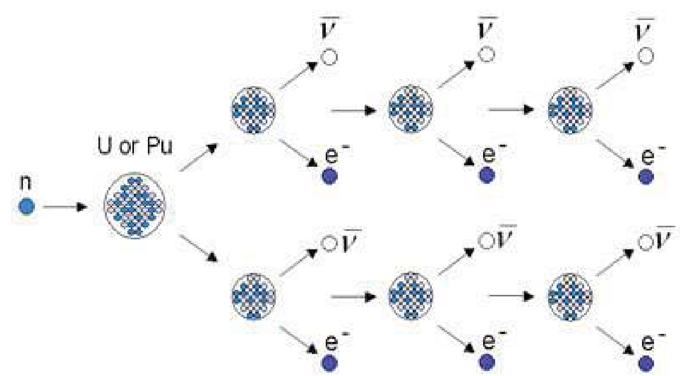
$$^{235}_{92}U + n \rightarrow X_1 + X_2 + 2n$$



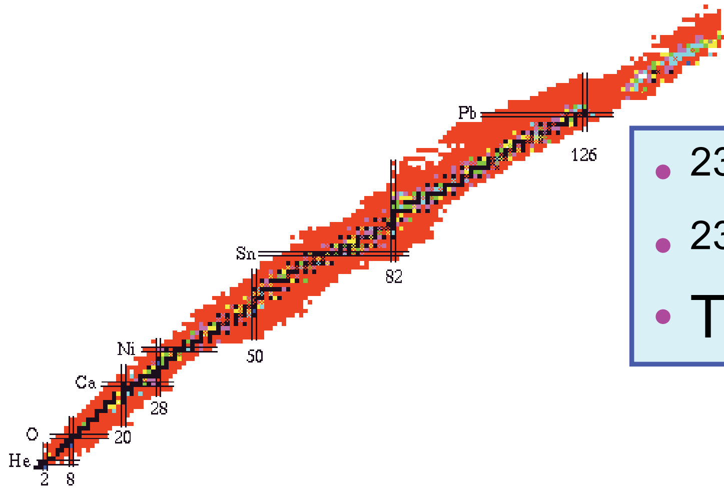
Most likely A from ^{235}U fission $\Rightarrow$ ^{94}Zr ^{140}Ce

→ on average 6 n have to β-decay to 6 p to reach stable matter: $^{94}_{40}Zr \; ^{140}_{58}Ce$

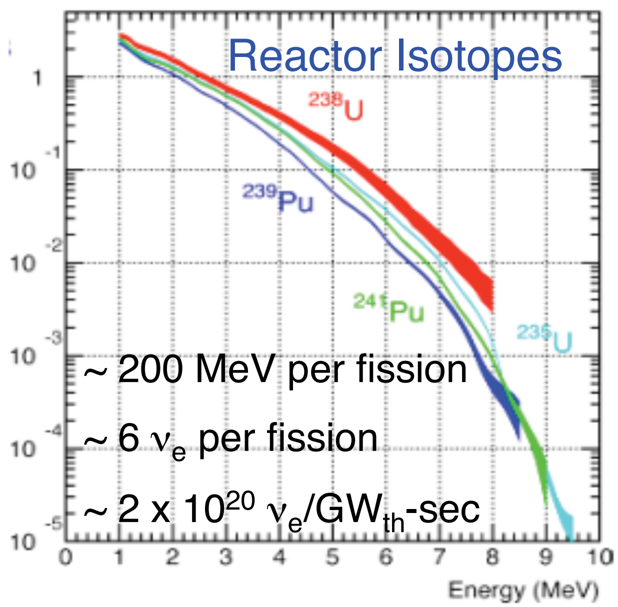
→ on average 1.5 ν_e are emitted with energy > 1.8 MeV

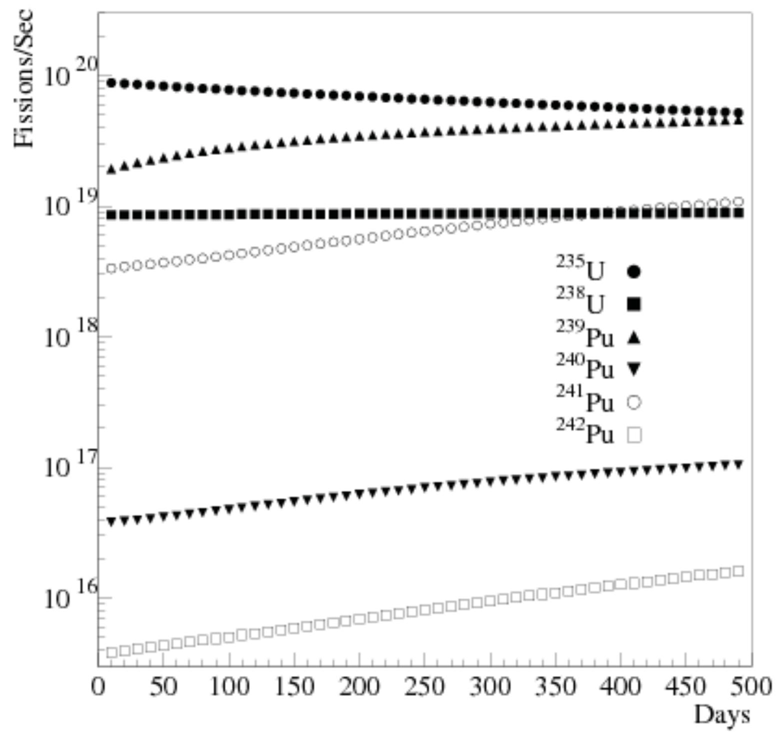


Reactor $\bar{\nu}_e$ Energy Spectrum



- ^{235}U, ^{239}Pu, ^{241}Pu from β measurements
- ^{238}U calculated
- Time dependence due to fuel cycle





Detection Technique

- The reaction process is inverse β-decay followed by neutron capture
  - Two part coincidence signal is crucial for background reduction.

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

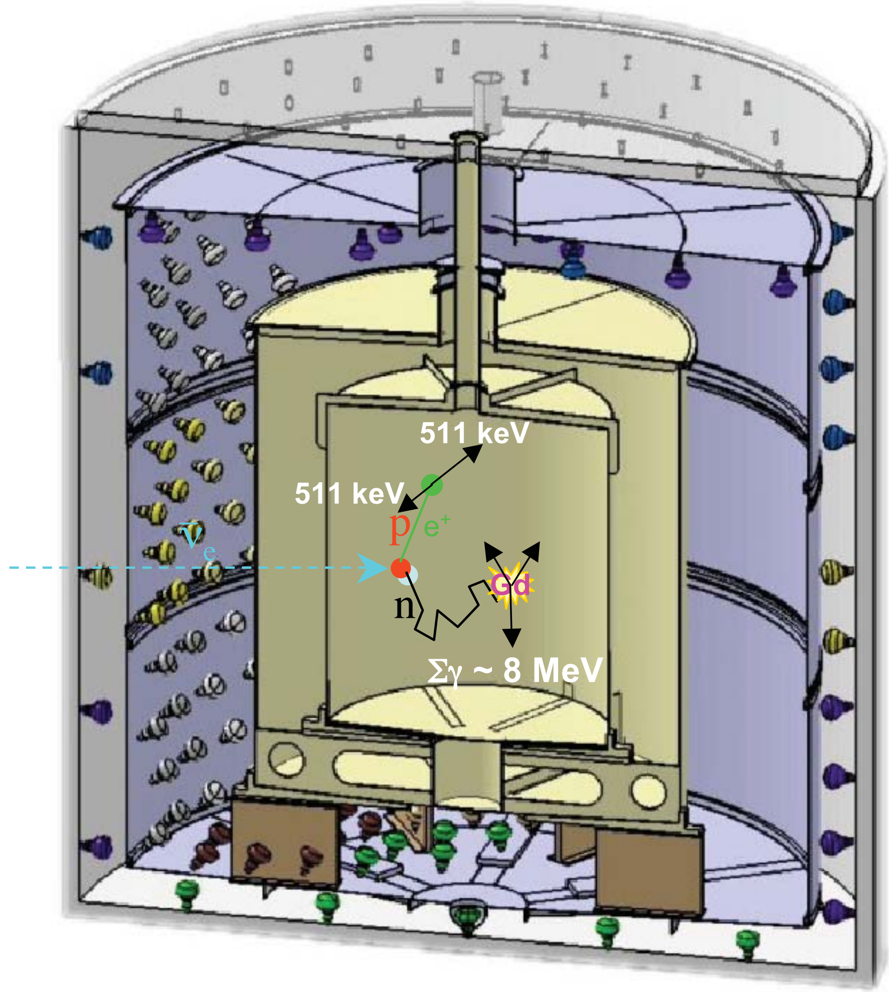
$$\hookrightarrow n \text{ capture}$$

- Positron energy spectrum implies the neutrino spectrum ($e^+e^- \rightarrow \gamma\gamma$)

$$E_\nu = E_{vis} + 1.8 \text{ MeV} - 2m_e$$

- The scintillator may be doped with gadolinium to enhance capture

$$n\ {}^{m}\text{Gd} \rightarrow {}^{m+1}\text{Gd}\ \gamma\text{'s (8 MeV)}$$



Signal = Positron signal + Neutron signal (within a few capture times)

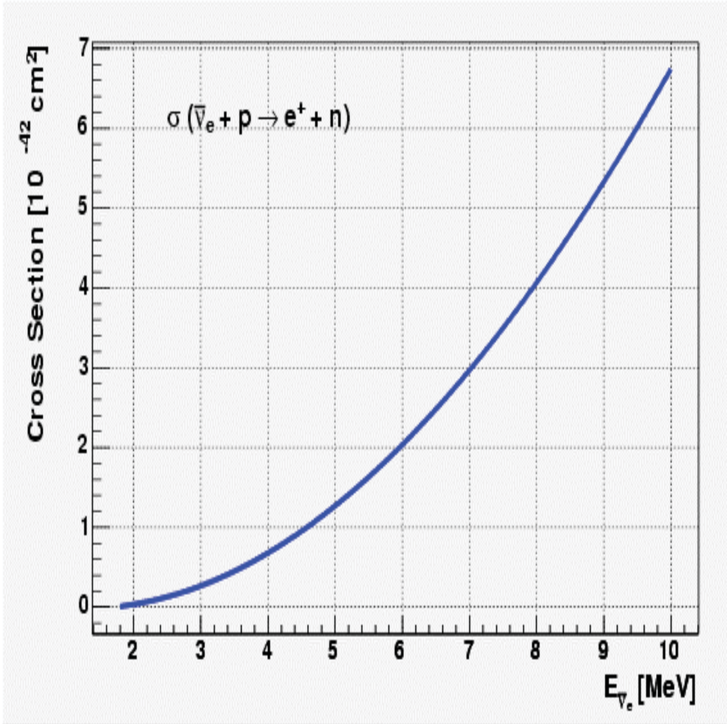
Detection cross section

$$\sigma_{tot}(E_e) \approx \frac{2\pi^2\hbar^3}{m_e^5 c^7 f\tau_n} \cdot p_e \cdot E_e \approx \frac{p_e \cdot E_e}{1\ MeV^2} \cdot 10^{-43}\ cm^2$$

In lowest order, assuming infinitely heavy neutron.

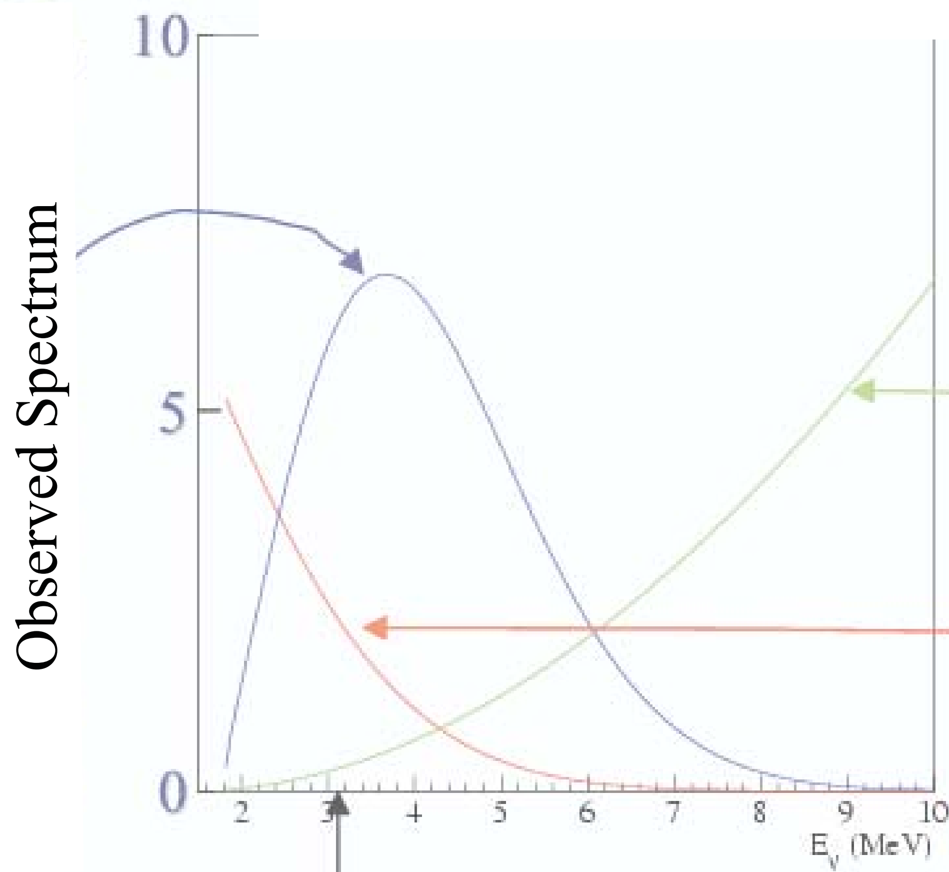
No nuclear matrix element involved.
Cross section directly linked to measured neutron life time and phase space.

Use cross section by Vogel & Beacom:
σ to order 1/M, radiative corrections, weak magnetism → few % correction



Cross section accurate to 0.2%

$\bar{\nu}_e$ Energy Spectrum



$\nu_e + p \rightarrow n + e^+$
cross-section

Calculated reactor
ν_e spectrum

Neutrinos with E<1.8 MeV
are not detected

Comparison of Prediction to Observation

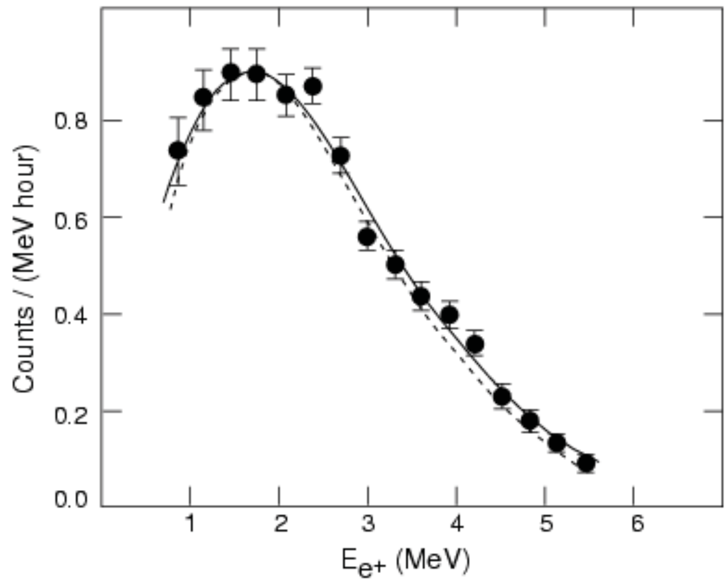


Figure 5: Positron spectrum measured at 45.9 m from the core of the Gösgen reactor [36]. Data points are obtained after background subtraction, errors are statistical only. The solid curve is a fit to the data assuming no oscillations. The dashed curve is derived independently by β-spectroscopy.

Goesgen Experiment

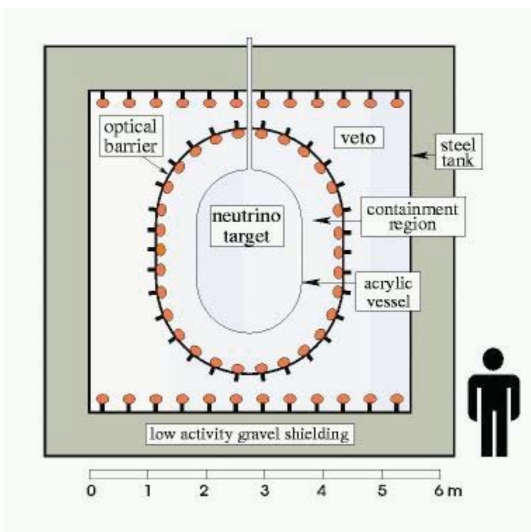
Solid: Fit to Data
Dashed: Prediction from β spectrum

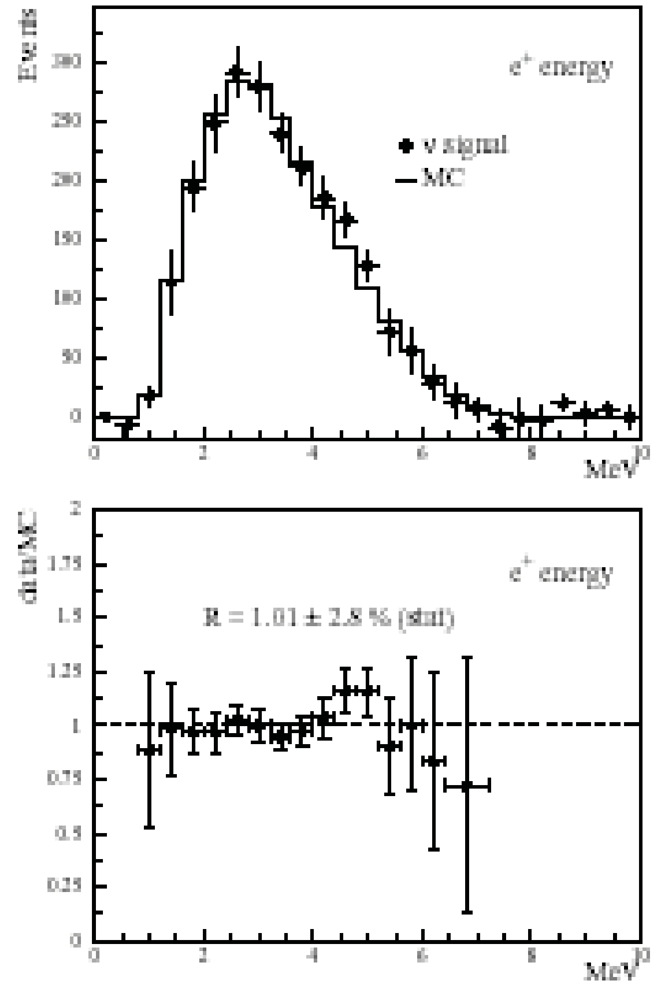
Flux and Energy Spectrum known at ~1-2 % level
→Reactors are calibrated sources of ν's

Previous Best Measurement: Chooz Experiment

The current best limit for $\sin^2 2\Theta_{13}$ is from the Chooz experiment.

Chooz ran for only 197 days at reduced reactor power.





CHOOZ : R_{osc} = 1.01 ± 2.8% (stat) ± 2.7% (syst)

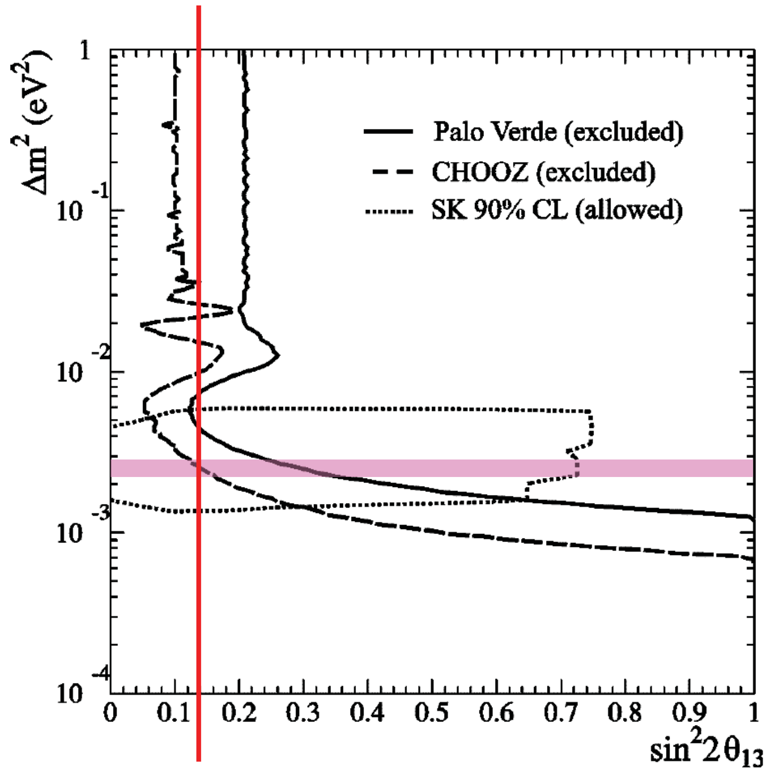
Previous Best Measurement: Chooz Experiment

- CHOOZ Experiment: current best limit on θ_{13}
  - One detector experiments
    - Major systematic was reactor flux
  - Large singles rate due to radioactivity of PMTs
    - scintillator out to tubes
  - Some troubles with reactors
    - only 200 days of data with either reactor on
  - Also, detector stability issues with scintillator
    - light output decreasing with τ=720 days
  - Small fiducial mass:
    - CHOOZ: 5 tons @ 1km, 5.7 GW
      - ~2.2 evts/day/ton with 0.2-0.4 bkgnd evts/day/ton
      - ~3600 ν events

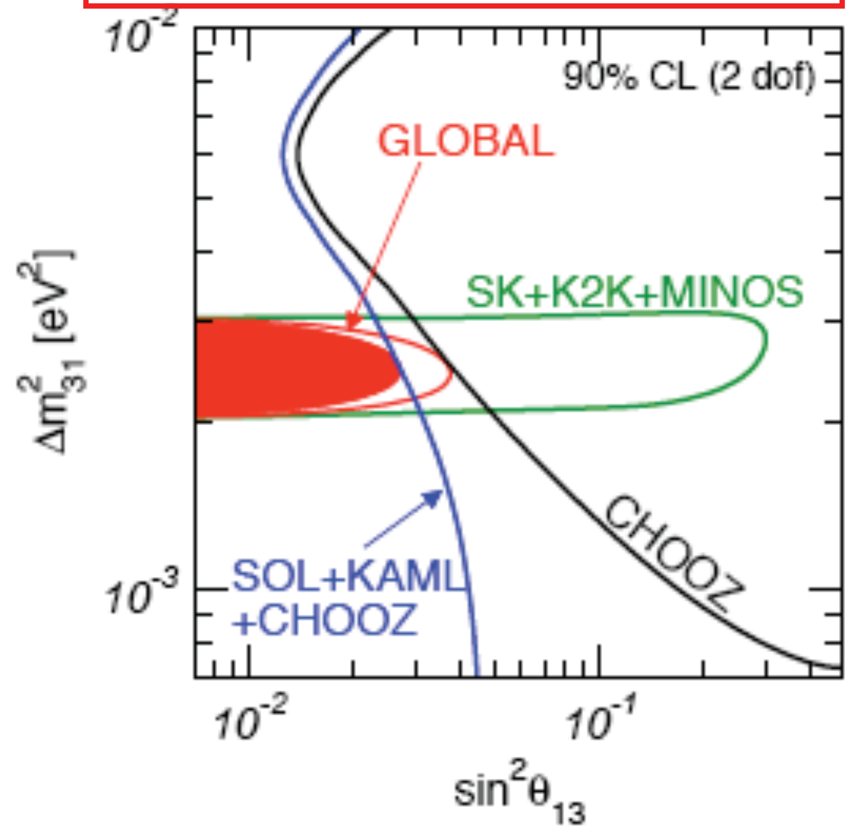
parameter	relative error (%)
reaction cross section & flux	1.9%
number of protons	0.8%
detection efficiency	1.5%
reactor power	0.7%
energy released per fission	0.6%
combined	2.7%

Previous Best Measurement: Chooz Experiment

$\sin^2 2\theta_{13} < 0.19$ at 90% CL
(or $\theta_{13} < 13°$)



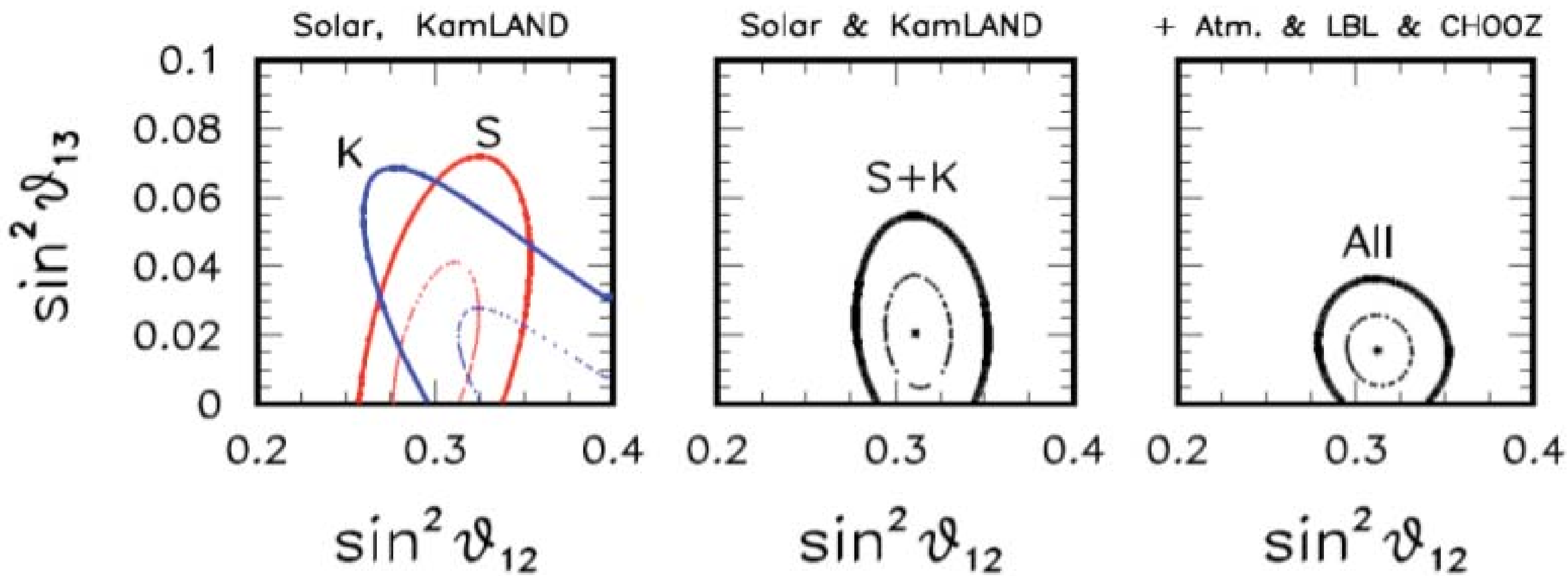
Best current limit from:
CHOOZ (single detector experiment)
$\sin^2(2\theta_{13})<0.2$
$(\sin^2(\theta_{13})<0.05)$



Non-zero Θ_{13} Hint

Recent global analysis fit for $\sin^2\theta_{13}$ vs $\sin^2\Theta_{12}$: Fogli et al.

PRL 101, 141801, 2008.



Best fit: $\sin^2 2\Theta_{13} = 0.06 \pm 0.04$

Is Θ_{13} non-zero and within a reach?

$\rightarrow$Need new sensitive experiments to tell

DOUBLE Chooz

The Double Chooz Collaboration

- **Brasil:** CBPF, UNICAMP
- **France:** APC - IN2P3, Dapnia CEA/Saclay, Subatech-IN2P3, IPHC-IN2P3, Strasbourg
- **Germany:** EKU Tübingen, MPIK Heidelberg, TU München, Aachen, Universität Hamburg
- **Japan:** Hiroshima IT, Kobe U, Niigata U, Tohoku U, Tohoku Gakuin U, Tokyo IT, Tokyo Metropoliten U
- **Russia:** RAS, Kurchatov Institute (Moscow)
- **Spain:** CIEMAT (Madrid)
- **UK:** Sussex
- **USA:** ANL, Barnard College, U Chicago, Columbia U, Drexel U, IIT, LLNL, MIT, Sandia Labs, U Alabama, UC Davis, U Notre Dame, U Tennessee

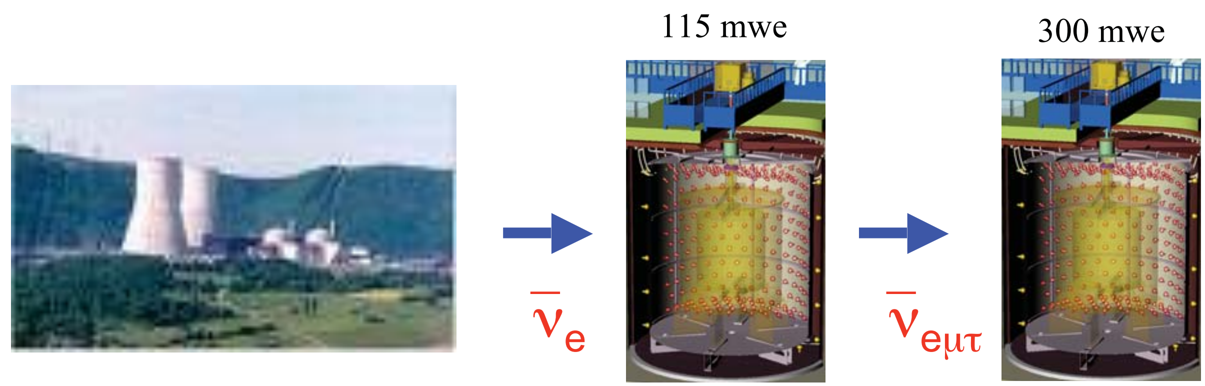
The Double Chooz Collaboration

Spokesperson: Herve de Kerret (APC)

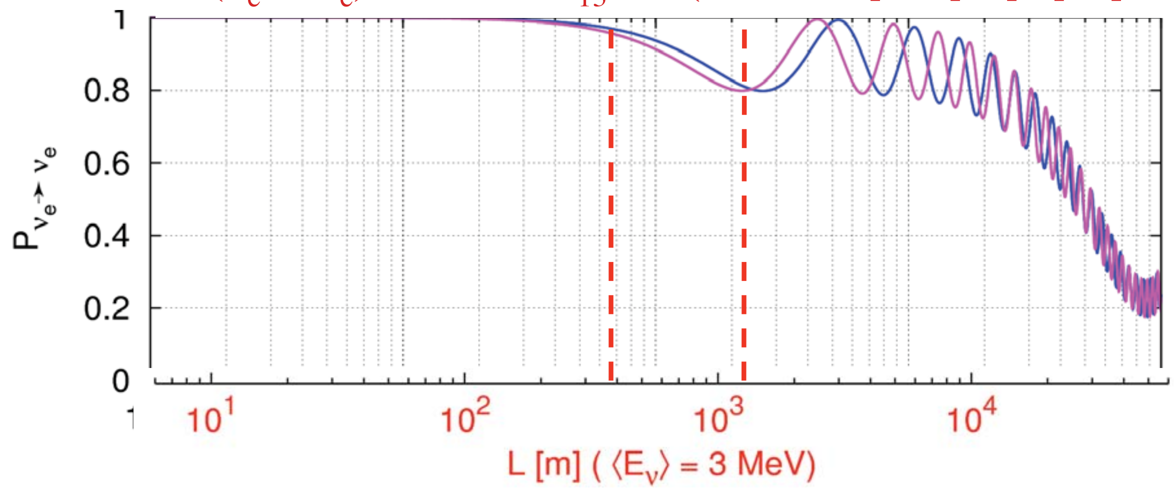
Double Chooz Strategy

-Use two identical detectors to remove the leading source of systematic error in CHOOZ: uncertainties on reactor neutrino spectrum

-Drastically reduce other systematic sources by relative measurement



$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) = 1 - \sin^2 2\theta_{13} \sin^2(1.27\ \Delta m^2[eV^2]\ L[m]/E[MeV])$



Double Chooz Improvement on Original Chooz

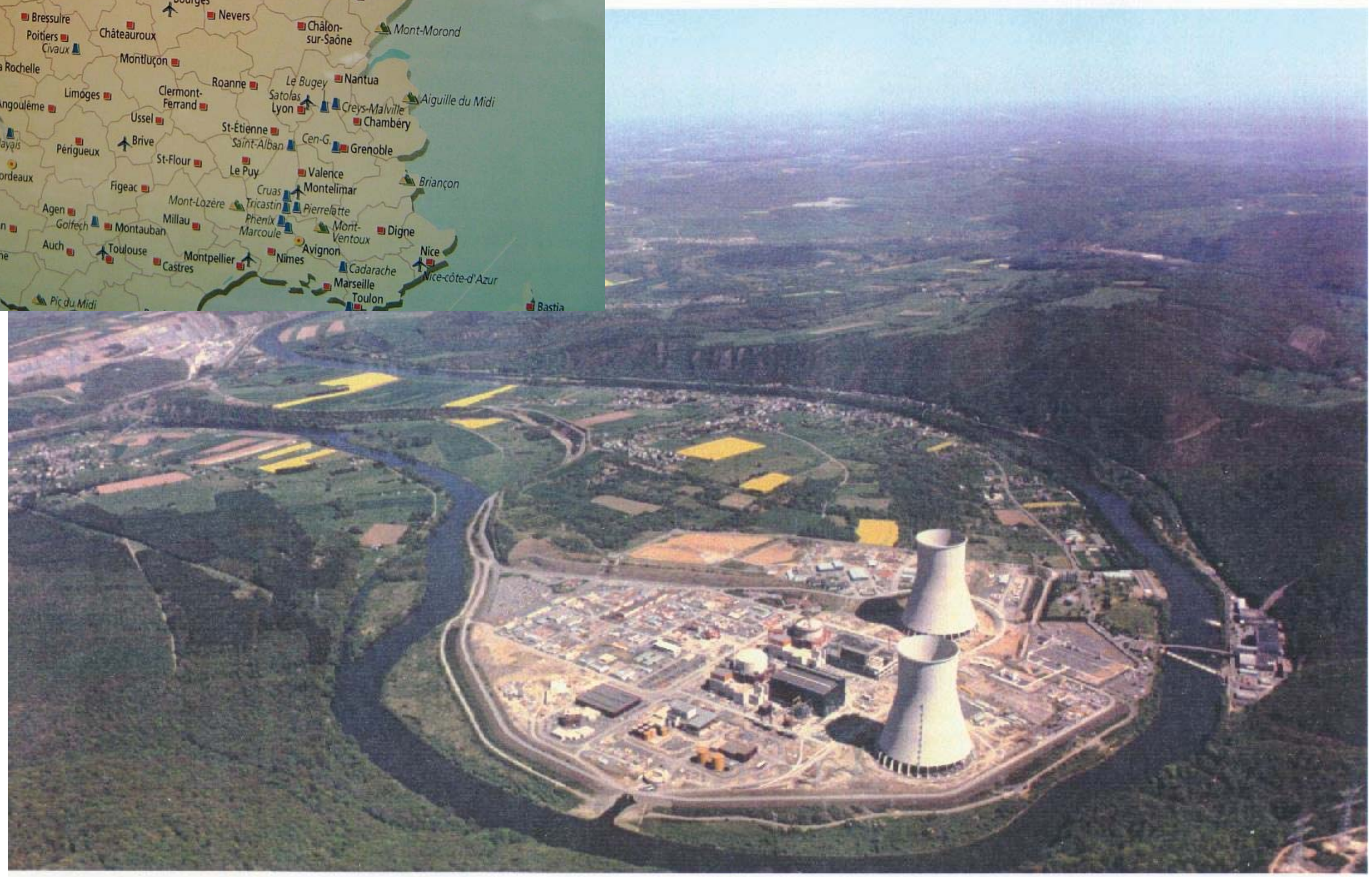
CHOOZ : $R_{osc} = 1.01 \pm 2.8\%$ (stat) $\pm 2.7\%$ (syst)

Double Chooz Goal: $\pm 0.4\%$ (stat.) $\pm 0.6\%$ (syst.)

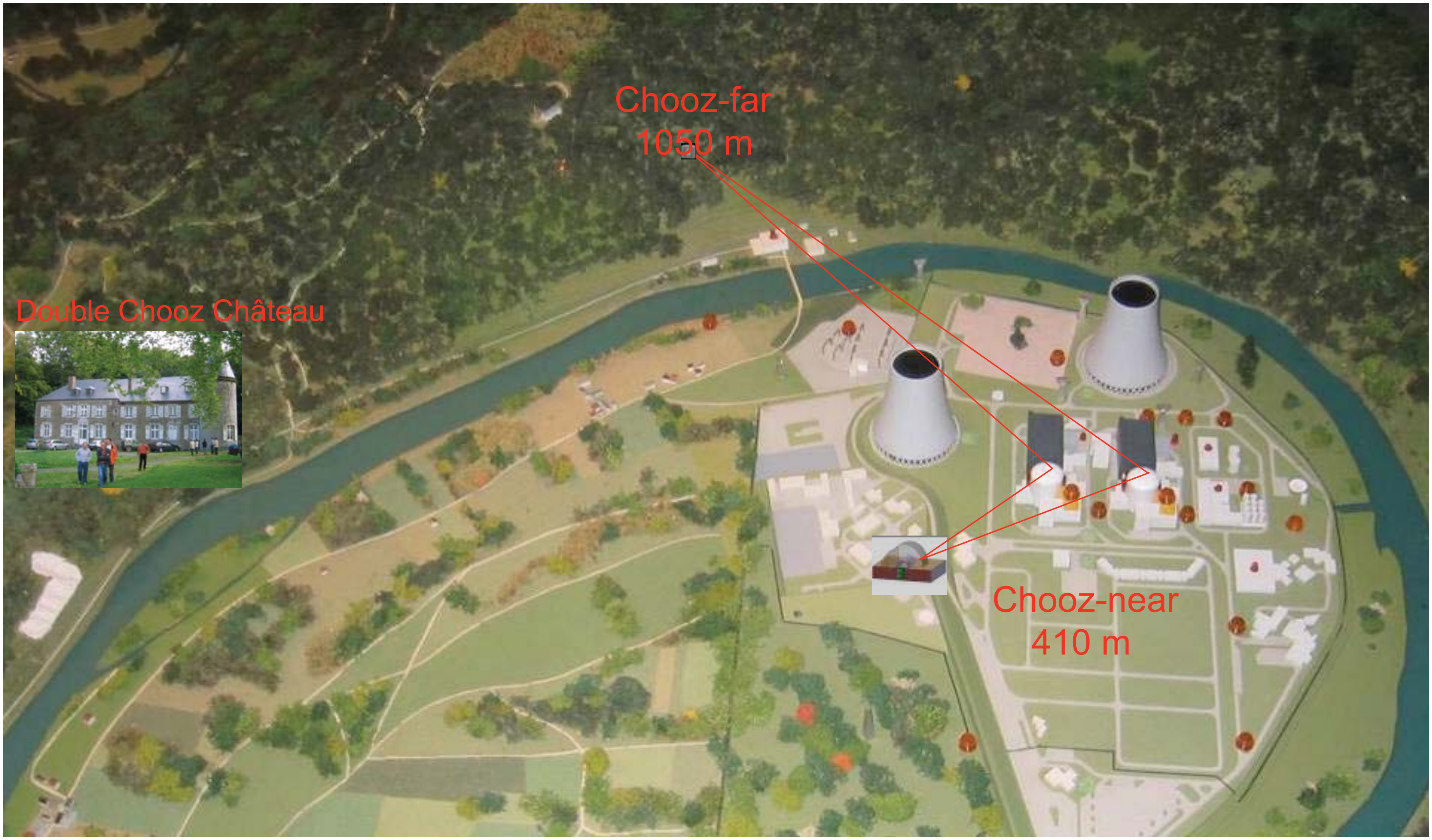
- Statistics
  - More powerful reactor (multi-core)
  - Larger detection volume → Double Chooz
  - Longer exposure → Double Chooz
- Experimental error: ν flux and cross-section uncertainty
  - Multi-detector → Double Chooz
  - Identical detectors to reduce inter-detector systematics (normalization, calibration …) → Double Chooz
- Background
  - Improve detector design → Double Chooz
  - Better cosmic muon veto system → Double Chooz
  - Improve background knowledge by direct measurement → Double Chooz

Chooz Power Plant

Two reactor cores:
4.27 GW_{th} / core

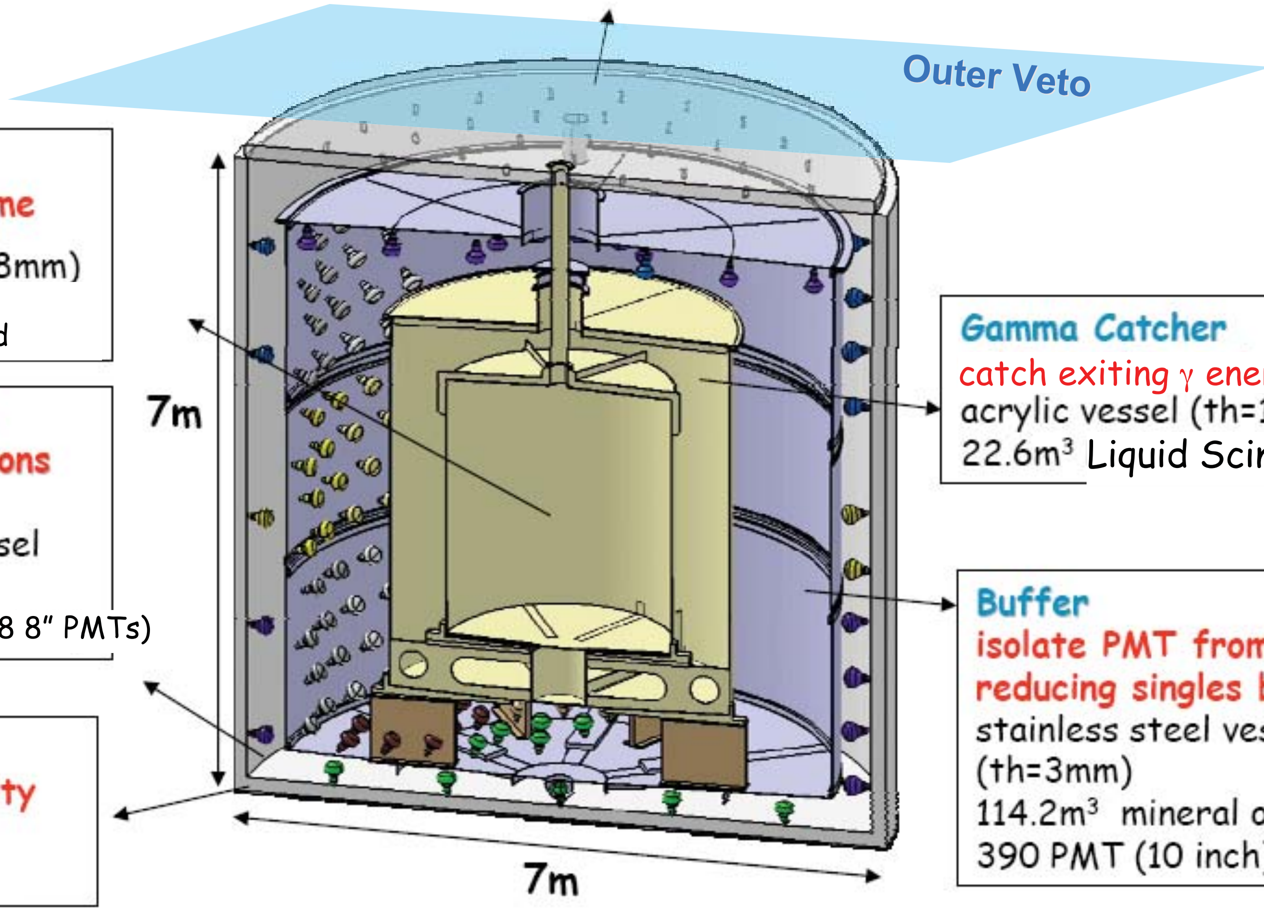


The Double Chooz Site in Ardennes (France)



Double Chooz Detector Components

Outer Muon Veto (panels of strips of coextruded plastic scintillator) **tag near passing muons causing fast-n**.



Target
ν interaction volume
acrylic vessel (th=8mm)
$10.1 m^3$ Liquid Scint. doped 0.1% Gd

Muon Inner Veto
tag traversing muons and fast-n
stainless steel vessel (th=10mm)
$80 m^3$ Liquid Scint. (78 8" PMTs)

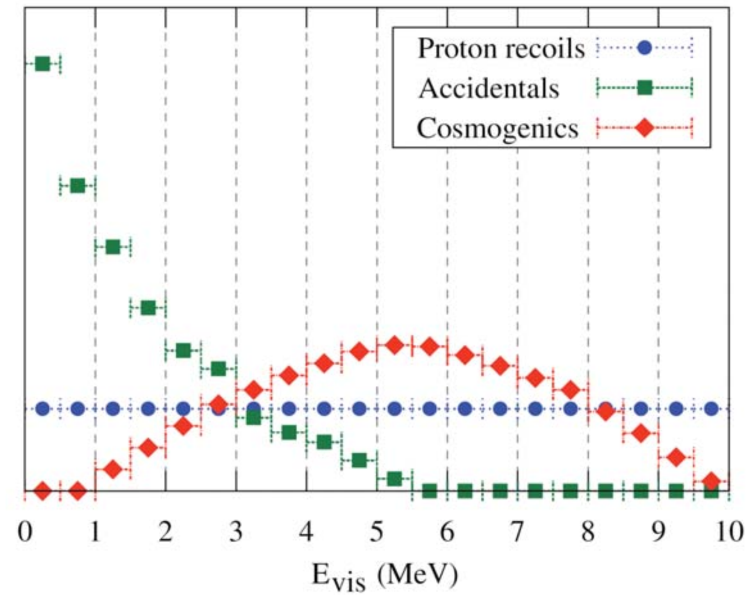
Shielding
reduce radioactivity from the rock
steel (th=150mm)

Gamma Catcher
catch exiting γ energy
acrylic vessel (th=12mm)
$22.6 m^3$ Liquid Scint.

Buffer
isolate PMT from target reducing singles bk.
stainless steel vessel (th=3mm)
$114.2 m^3$ mineral oil
390 PMT (10 inch)

Backgrounds

Backgrounds to the e^+ - n coincidence signal



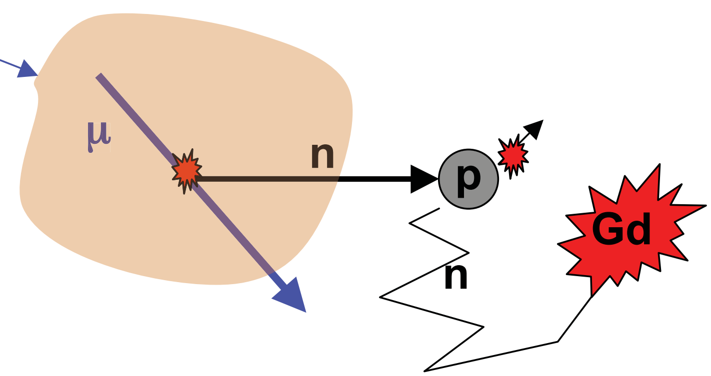
Uncorrelated Backgrounds

–accidentals

–cosmogenic neutrons

Correlated Backgrounds

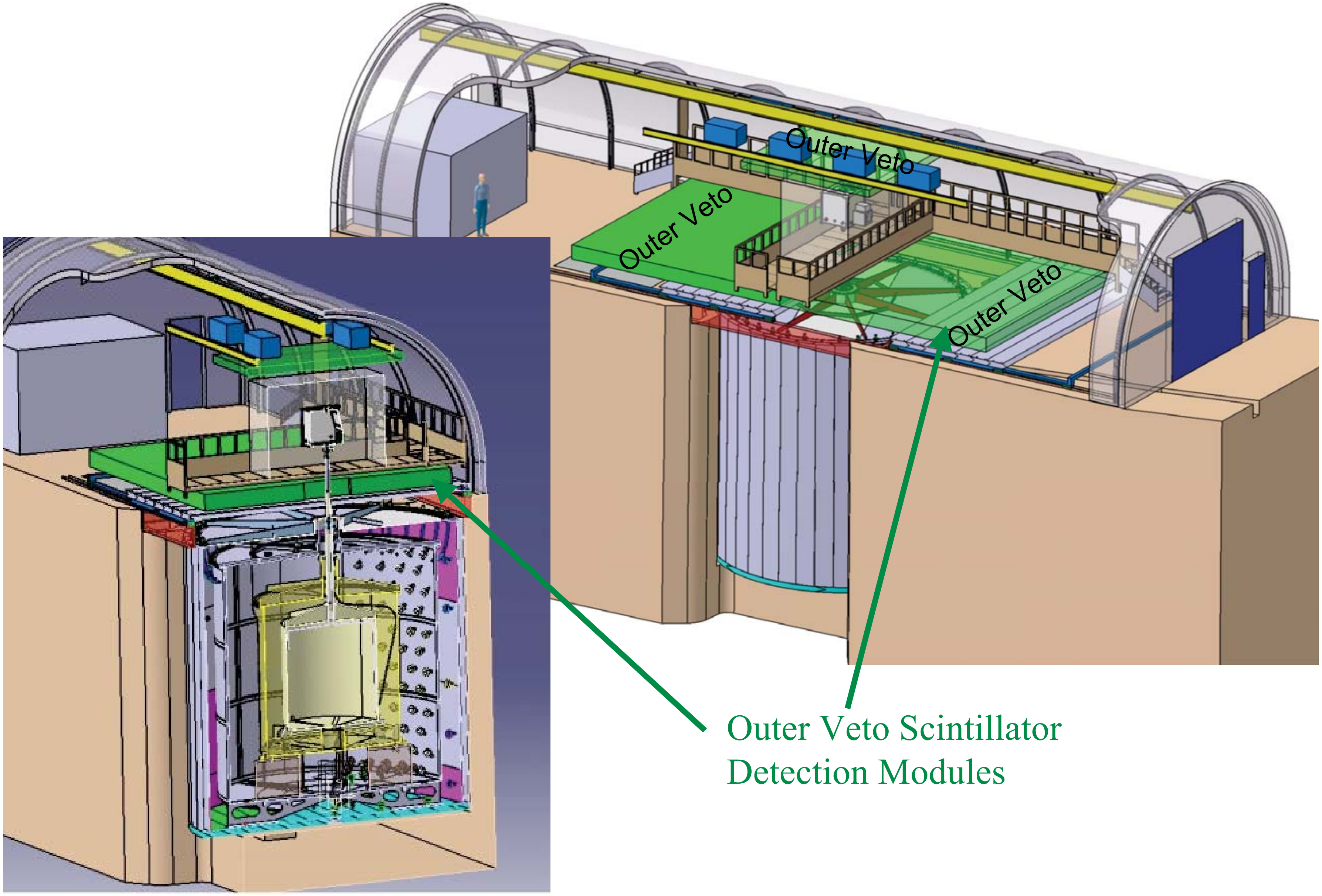
–muon produced fast neutrons in the surrounding rock and shielding



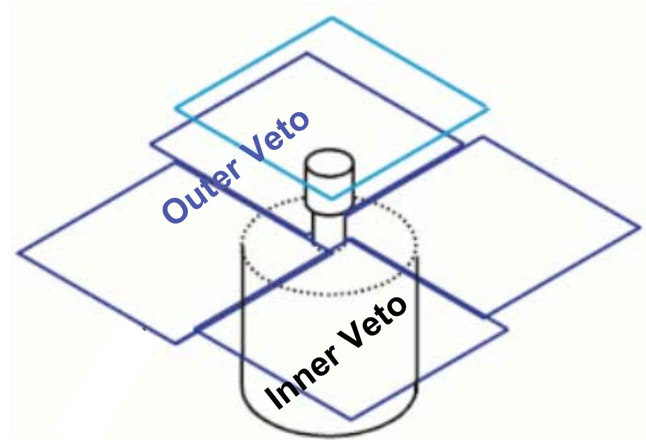
–muon produced radioactive nuclei that emit an electron and neutron

eg. ^{9}Li (T1/2=178ms)

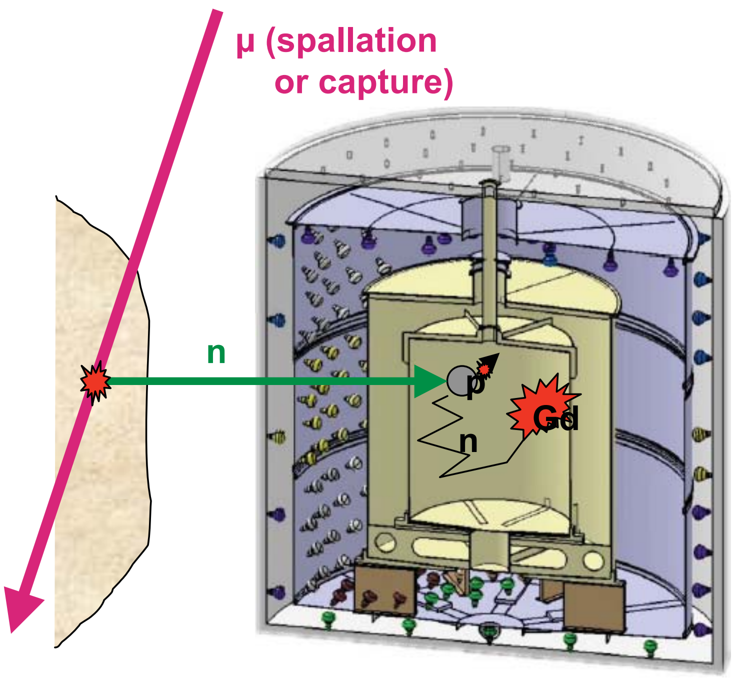
Outer Veto Layout

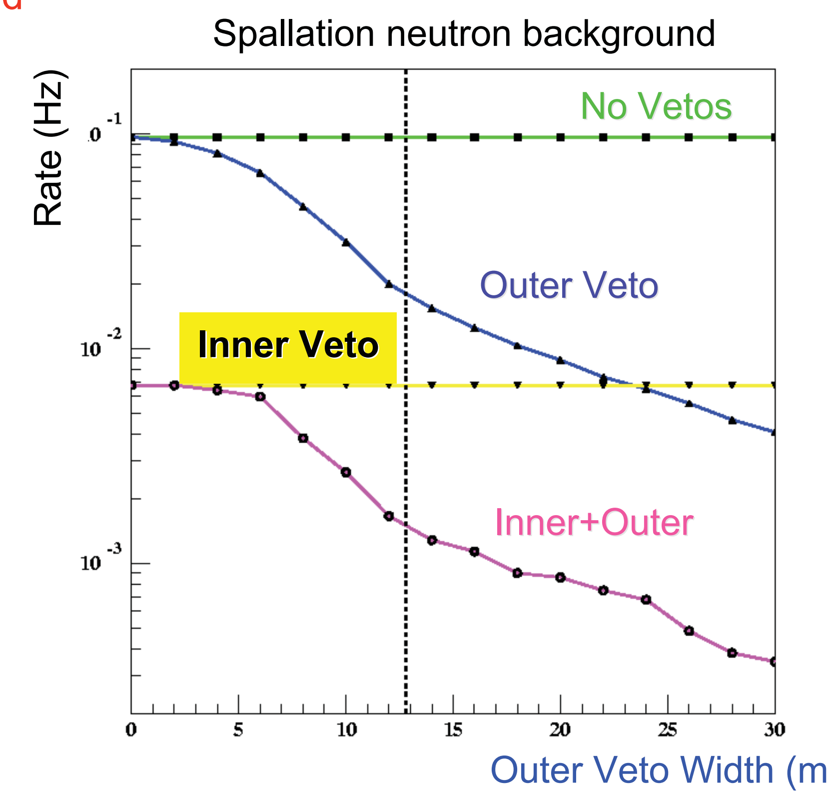


Outer Veto System

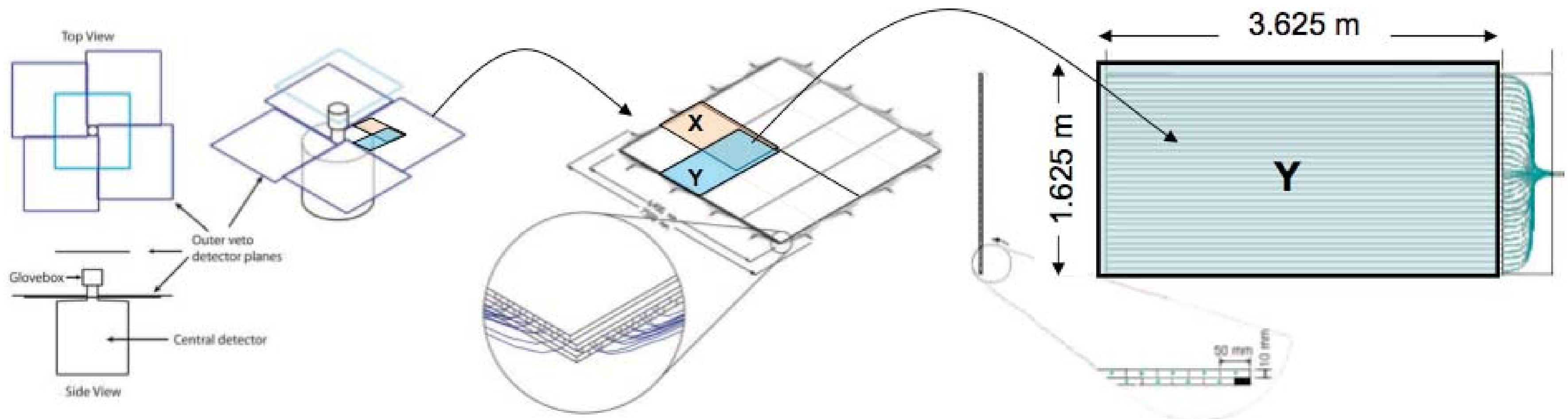


- Reduce muon produced spallation neutron rate (x5)
- Track muons that capture in dead material and produce neutrons
- Tag muons that can produce ^{9}Li background





Outer Veto System

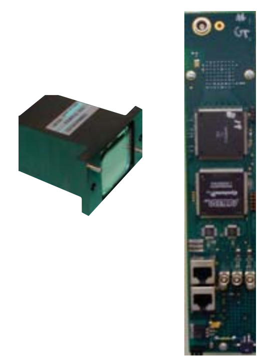


OV design for near detector consists of upper and lower tracking planes

Each plane is fully active and consists of modules oriented in both X and Y directions

OV modules consist of 2 layers of 64 scintillator strips with WLS fibers connected to a multi-anode PMT

Full-scale OV module prototype



Electronics

Effect of Veto on Observed Backgrounds

No Veto System

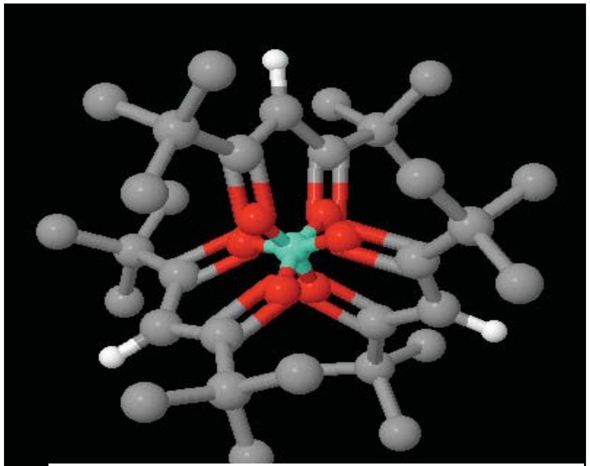
Detector	Site		Background				
			Accidental		Correlated		
			Materials	PMTs	Fast n	μ-Capture	^{9}Li
Double Chooz		Rate (d^{-1})	0.5 ± 0.3	1.5 ± 0.8	2.0 ± 2.0	28	1.0 ± 0.5
(69 ν/d)	Far	bkg/ν	0.7%	2.2%	2.9%	40%	1.4%
Double Chooz		Rate (d^{-1})	5 ± 3	17 ± 9	9.1 ± 9.1	266	9 ± 5
(1012 ν/d)	Near	bkg/ν	0.5%	1.7%	0.8%	26%	0.9%

With Inner and Outer Veto System

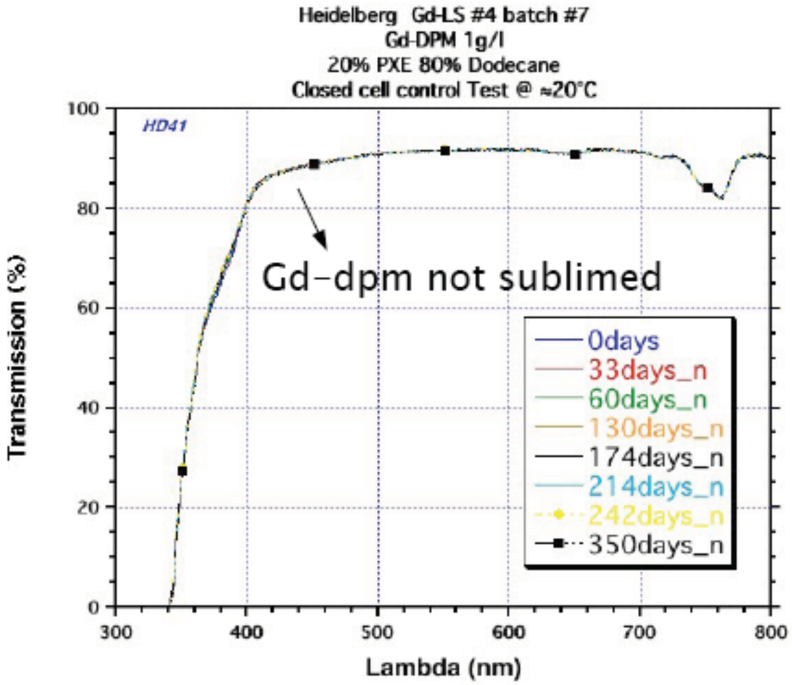
Detector	Site		Background				
			Accidental		Correlated		
			Materials	PMTs	Fast n	μ-Capture	^{9}Li
Double Chooz		Rate (d^{-1})	0.1 ± 0.1	0.3 ± 0.2	0.11 ± 0.11	< 0.1	1.0 ± 0.5
(69 ν/d)	Far	bkg/ν	0.1%	0.4%	0.2%	$< 0.1\%$	1.4%
		systematics	<0.1%	<0.1%	0.2%	<0.1%	0.7%
Double Chooz		Rate (d^{-1})	0.5 ± 0.3	1.7 ± 0.9	0.15 ± 0.15	0.4	9 ± 5
(1012 ν/d)	Near	bkg/ν	$< 0.1\%$	0.2%	$< 0.1\%$	$< 0.1\%$	0.9%
		systematics	<0.1%	<0.1%	<0.1%	<0.1%	0.5%

Liquid Scintillator

- Target scintillator composed of 20% PXE, 80% Dodecane, PPO, Bis-MSB, $Gd(dpm)_3$
  - Good stability tested over 3 years
  - Attenuation length >10m @ 430 nm
  - Materials exposed to the target are tested for compatability
  - 0.1% Gd loading
  - Light yield ~ 7000 ph/MeV



tris-(2,6-tetramethyl-3,5-heptanedione) Gd(III)

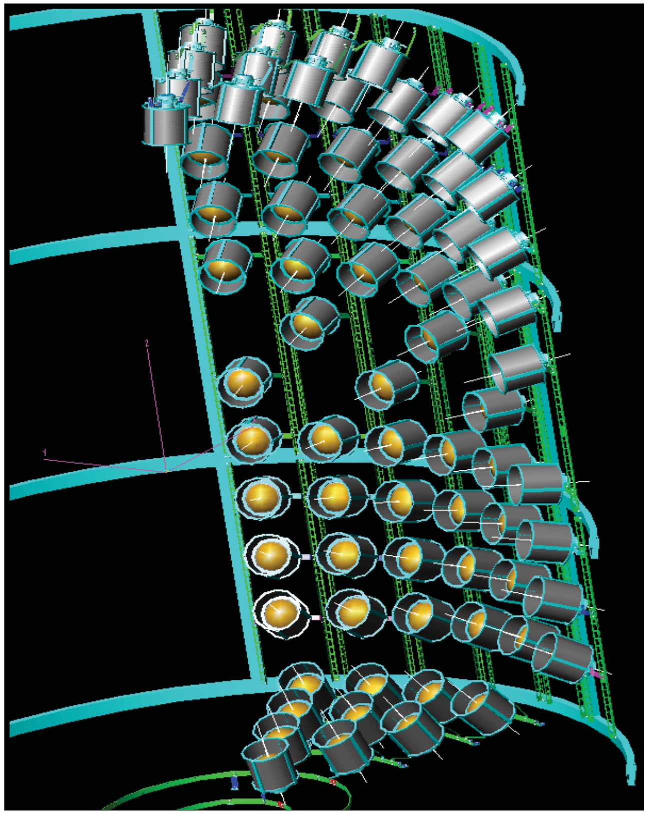


- Gamma Catcher Scintillator composed of 4% PXE, 46% Dodecane, 50% oil, PPO, Bis-MSB
  - Density and light yield matched to the target

- Inner Veto filled with scintillating LAB oil

Inner Detector Phototubes

- 10“ Ultra low background tubes
- 390 PMTs
  (270 side, 120 top + bottom)
- 13 % coverage
- Energy resolution goal:
  7% at 1 MeV

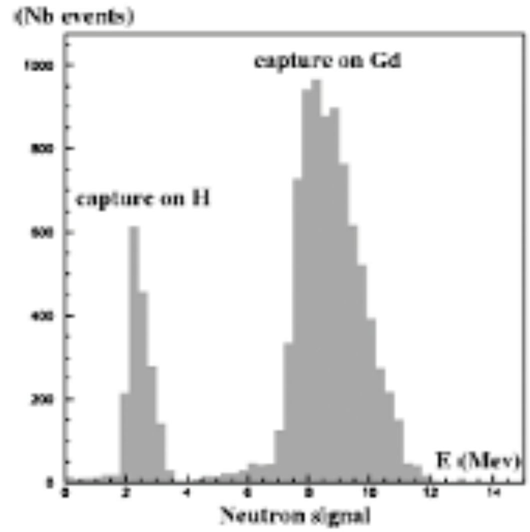


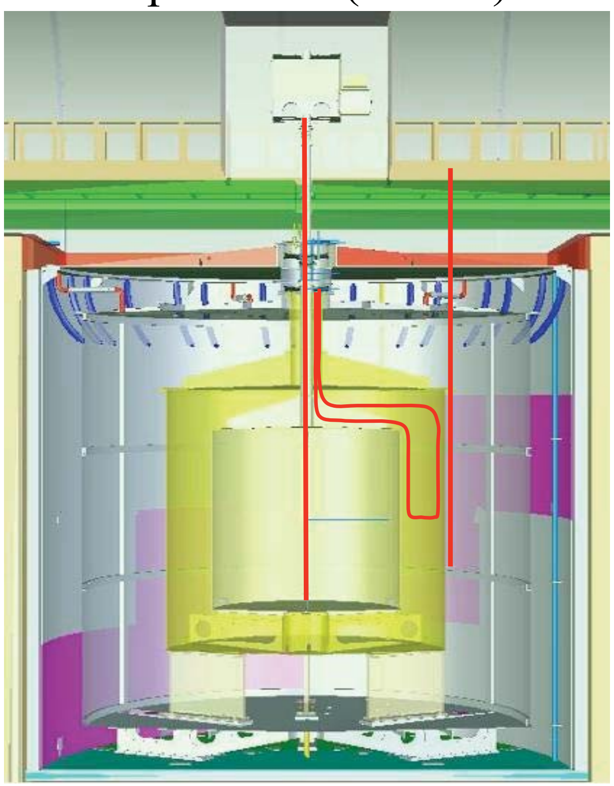
- Readout FEE: gain x15, pulse shape, trigger = analog sum>0.4MeV
- FADC, 500MHz, 8bit
- No deadtime
- Special muon showering electronics

Calibration

- **Relative** near/far detection uncertainty goal <0.6%
  - energy cut at threshold <0.1%
  - energy cut at 6 MeV for neutron capture <0.2%
  - neutron capture time distribution <0.1%
  - deadtime <0.1%
  - spatial cut (if used) <0.2%

Neutron Capture Peaks





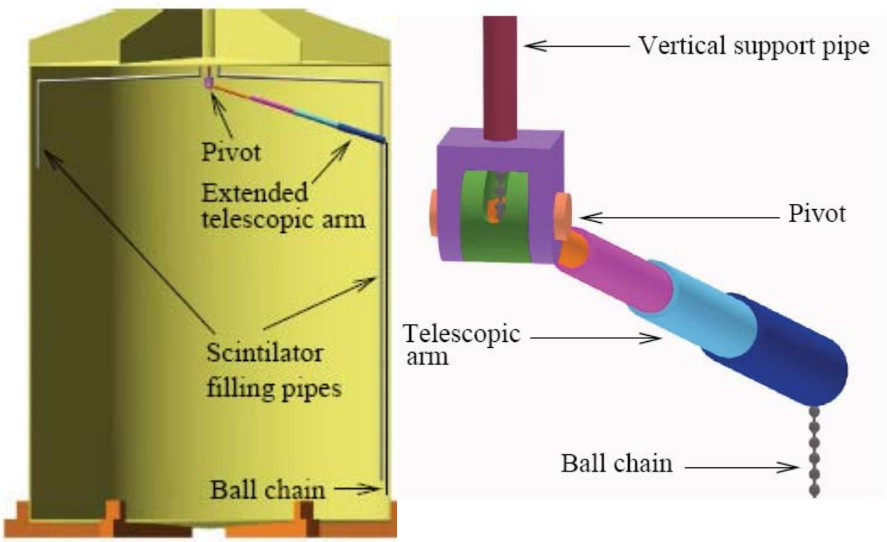
Calibration source deployment - γ, n, β

- Guide tubes inside detector
- z-axis system
- articulated arm
- Embedded LEDs

Calibration Sources

- Gamma Sources (^{203}Hg, ^{137}Cs, ^{68}Ge, ^{60}C, PoC).
  - Calibrates the energy scale, light transport, PMT QE, timing, deadtime, and detector stability
- Neutron Sources (PoC, ^{252}Cf, AmBe)
  - Calibrates the energy scale, n-detection efficiency and deadtime
- Light Flasher (multi-wavelength laser system, multi-wavelength LED system)
  - Calibrates the light transport, PMT gain and efficiency and detector stability
- Cosmics (muons, spallation neutrons, cosmogenics)
  - Calibrates the energy scale, PMT gain, and detector stability

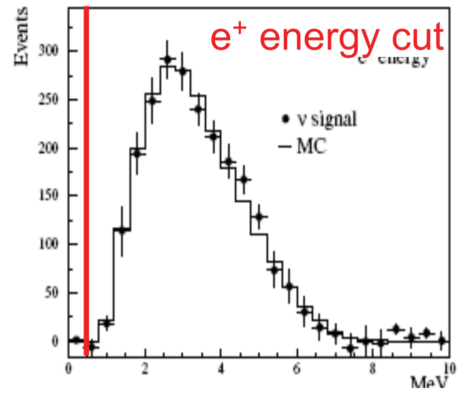
Articulated Arm

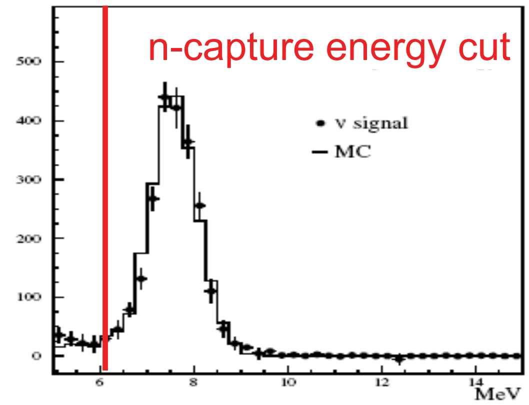


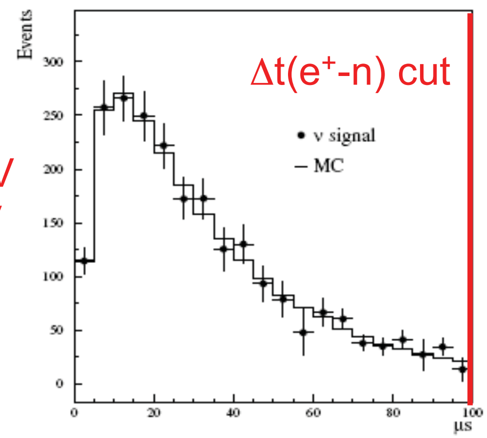
Analysis Cuts

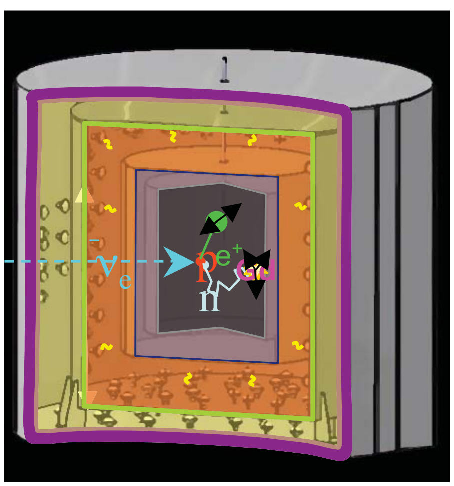
$$\overline{\nu}_e + p \rightarrow e^+ + n$$

- Previous Chooz: 1.5% syst. err.
  - 7 analysis cuts
- Goal Double-Chooz: ~0.3% syst.
  - 3 analysis cuts
  1. e+ annihilation energy > 0.4 MeV
  2. neutron capture energy > 6 MeV
  3. Δt (e^+ - n) < 100 μsec





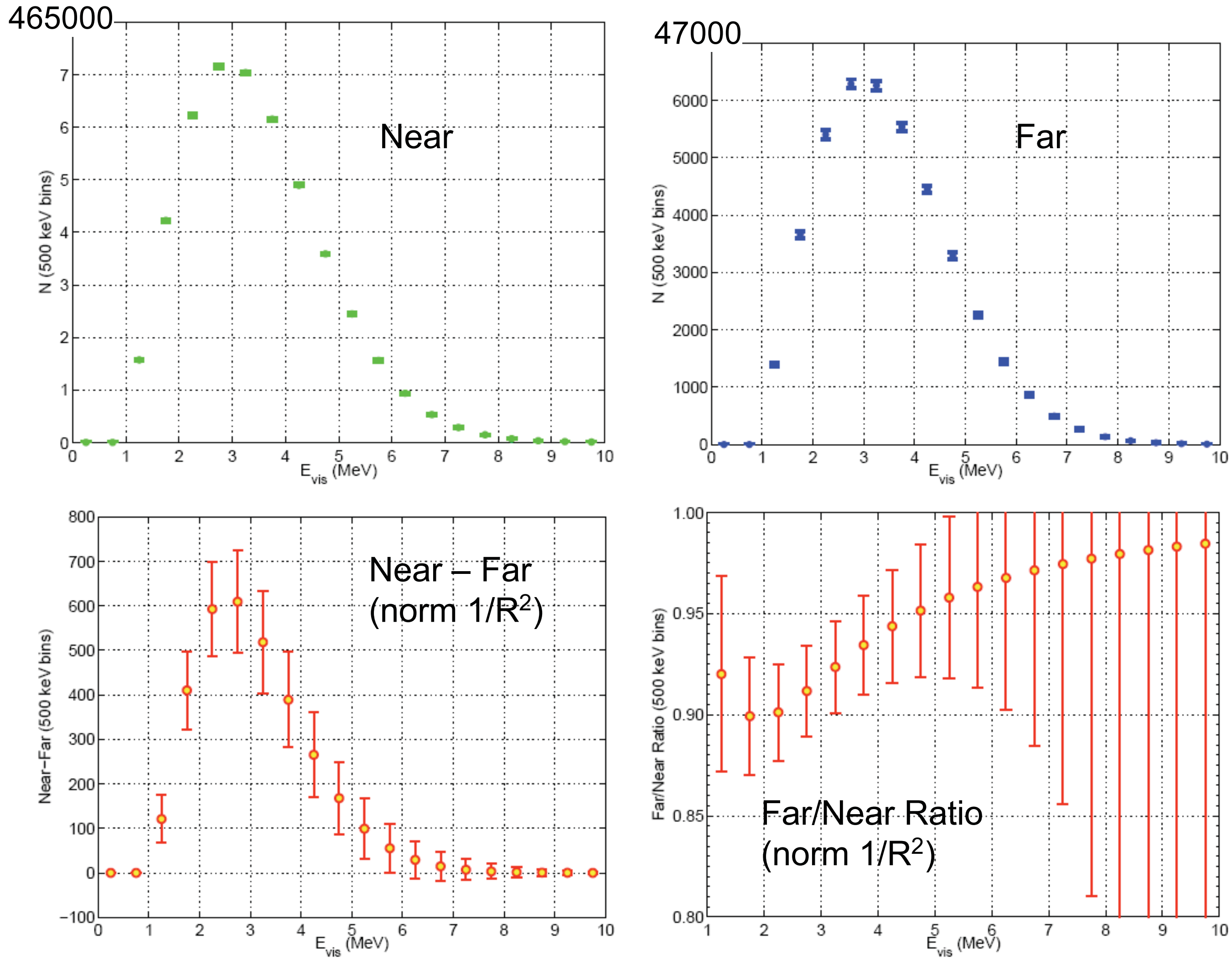




	CHOOZ	Double-CHOOZ	
selection cut	rel. error (%)	rel. error (%)	Comment
positron energy*	0.8	0	not used
positron-geode distance	0.1	0	not used
neutron capture	1.0	0.2	Cf calibration
capture energy containment	0.4	0.2	Energy calibration
neutron-geode distance	0.1	0	not used
neutron delay	0.4	0.1	—
positron-neutron distance	0.3	0 – 0.2	0 if not used
neutron multiplicity*	0.5	0	not used
combined*	1.5	0.2-0.3	—

*average values

Example Measurement (Double Chooz 3 Years)



$$\sin^2(2\theta_{13}) = 0.1 \text{ and } \Delta m^2_{31} = 2.5 \times 10^{-3}\ eV^2$$

Double Chooz Systematic Uncertainties

		Chooz	Double-Chooz	
Reactor-induced	ν flux and σ	1.9 %	<0.1 %	Two ''identical'' detectors, Low bkg
	Reactor power	0.7 %	<0.1 %	
	Energy per fission	0.6 %	<0.1 %	
Detector - induced	Solid angle	0.3 %	<0.1 %	Distance measured @ 10 cm + monitor core barycenter
	Volume	0.3 %	0.2 %	Precise control of detector filling
	Density	0.3 %	<0.1 %	Accurate T control (near/far)
	H/C ratio & Gd concentration	1.2 %	<0.1 %	Same scintillator batch + Stability
	Spatial effects	1.0 %	<0.1 %	Identical detectors and monitoring
	Live time	-----	0.1 %	Special electronic systems and monitoring
Analysis	From 7 to 3 cuts	1.5 %	0.2 - 0.3 %	Simplified cuts due to detector design
	Total	2.7 %	< 0.6 %	

DC improvements respect to CHOOZ

Increased statistics:

- Longer exposure
- Larger detector mass

	CHOOZ	DOUBLE CHOOZ
Target volume	5.55 m3	10.3 m3
Target composition	6.77 E28 H/m3	6.55 E28 H/m3
Data taking period	few months	3-5 years
Event rate near det.	/	~1 106 / 3 y
Event rate far det.	2700	40000/3years
Statistical error	2.8%	0.5%

Reduced systematic uncertainties

- Near/Far detectors comparison to minimize reactor errors
- Identical detector to do relative measurements
- Detailed calibration program

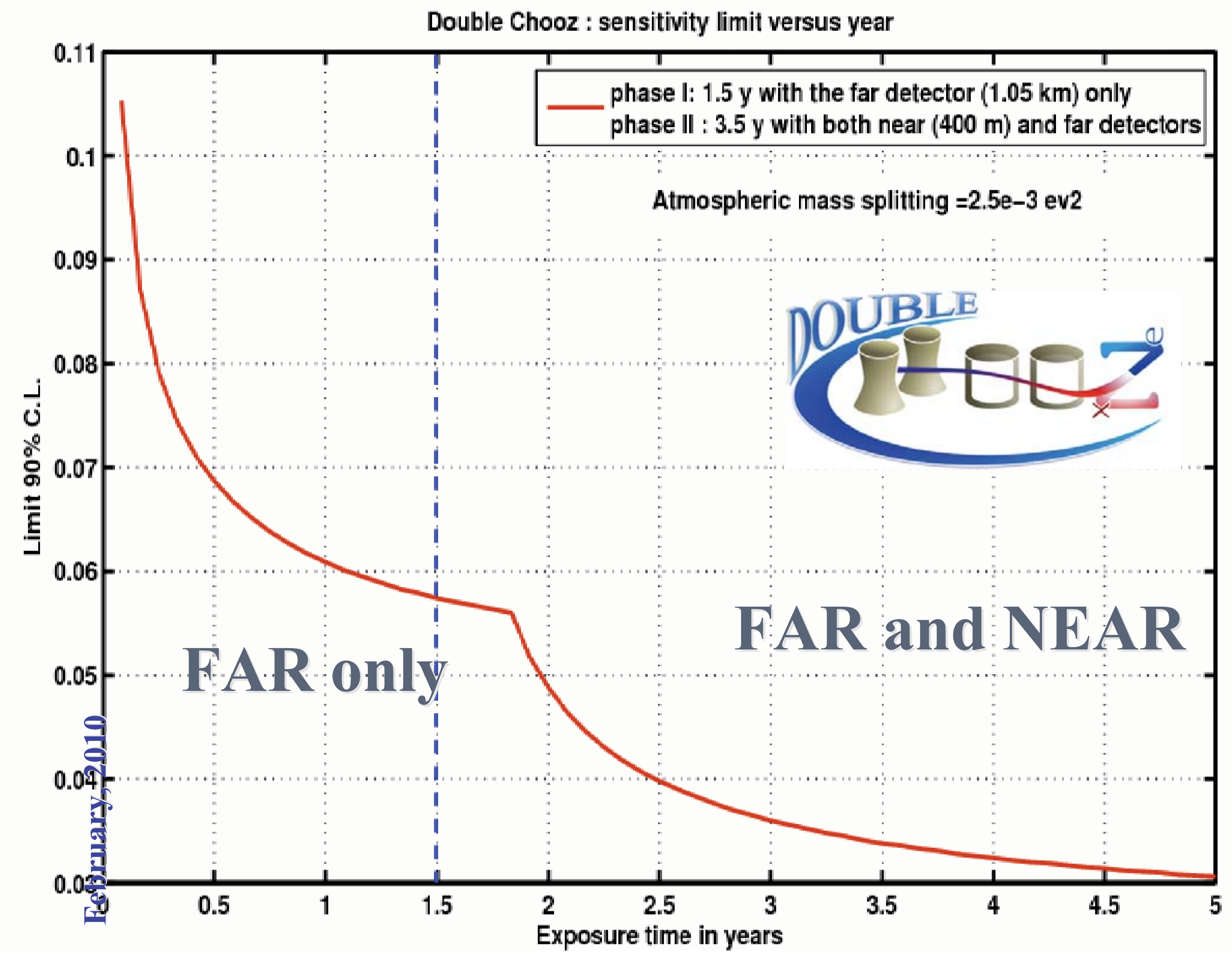
	CHOOZ	DOUBLE CHOOZ
Reactor Cross section	1.9%	/
Number of protons	0.8%	0.2%
Detector efficiency	1.5%	0.5%
Reactor power	0.7%	/
Energy per fission	0.6%	/

Suppressed background

- Improved detector design
- Better cosmic muon veto detectors
- Better external shielding

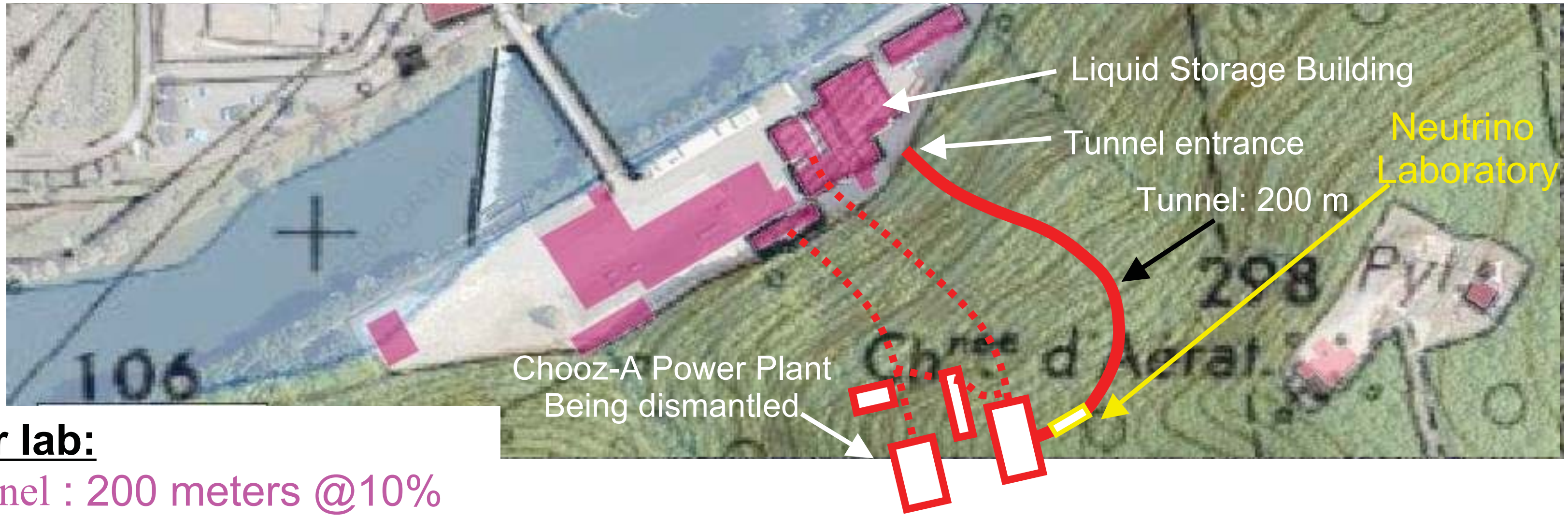
	signal	Corr. background	Acc. Background
Near detector	218 ev./d	11 ev./d	14 ev./d
Far detector	40 ev./d	2 ev./d	2 ev./d

Double Chooz Sensitivity to Θ_{13}



February, 2010

Far and Near Site Status



Far lab:

Tunnel : 200 meters @10%

-New ventilation, doors, safety, …

Liquid storage building

- Being upgraded
- First liquids in summer (Veto/Buffer)

Neutrino laboratory:

- 1 km baseline (15000 y^{-1})
- 300 m.w.e., μ-Rate: ~20 Hz
- Fire security, Pit refubrished
- Steel tank installed

- Lab cleaned and painted(Dec 2009)
- Muon Veto PMTs installed (February 2009)
- Buffer Vessel installed (April 2009)
- Thermalization system installed (April 2009)
- Inner PMT installation (June 2009)
- Future/Ongoing: Acrylic tanks, filling liquids, electronics…

$\boxed{\text{Neutrinos are close!}}$

Near lab: EDF committed to digging the near lab (November 2008)

Far Detector Construction

June 08: starting of the work

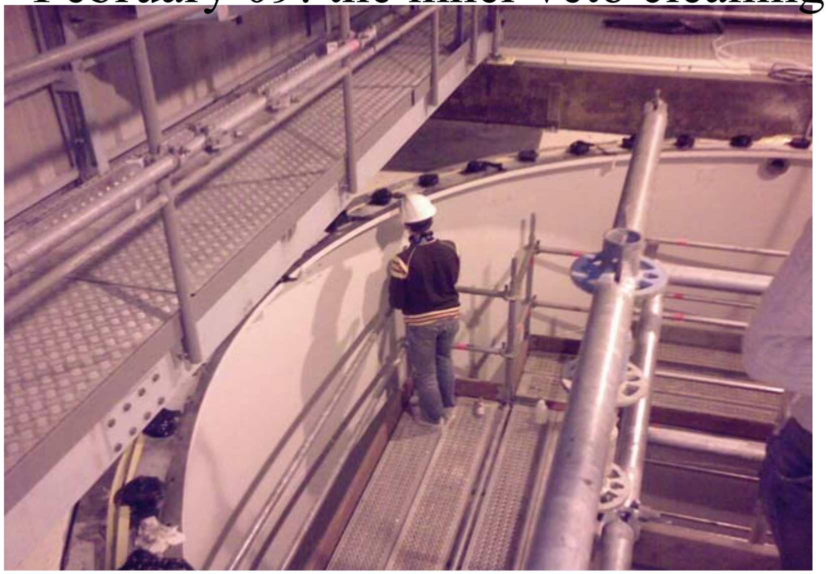
September 08: the steel shielding.

November 08: the inner veto tank

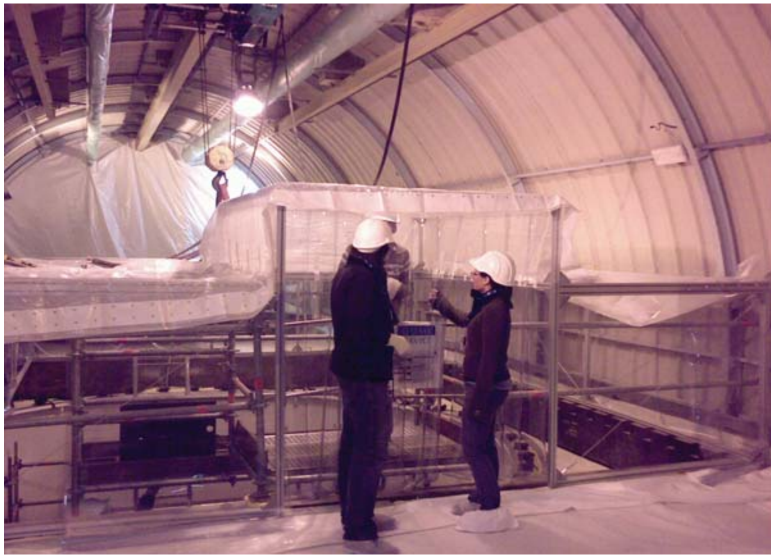
Dec 08 - Jan 09: painting and cleaning

Far Detector Construction

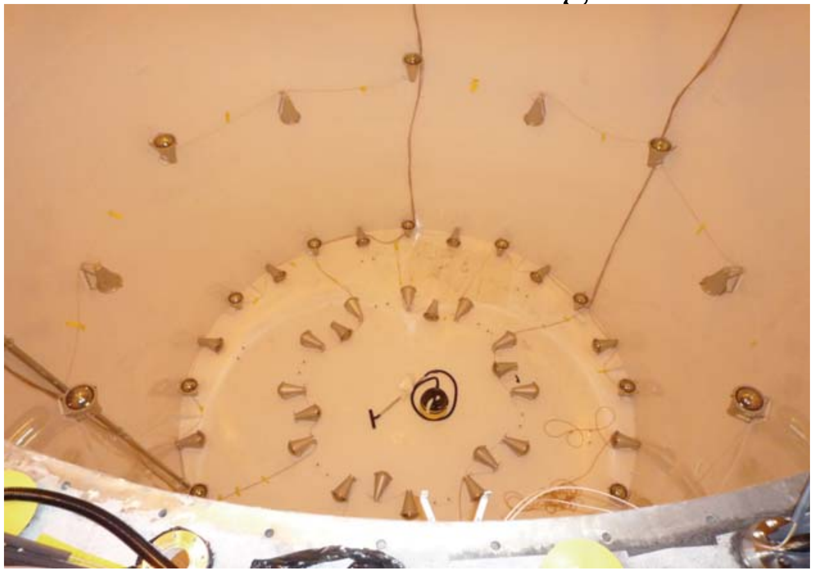
February 09: the inner veto cleaning



ISO6 tent mounting

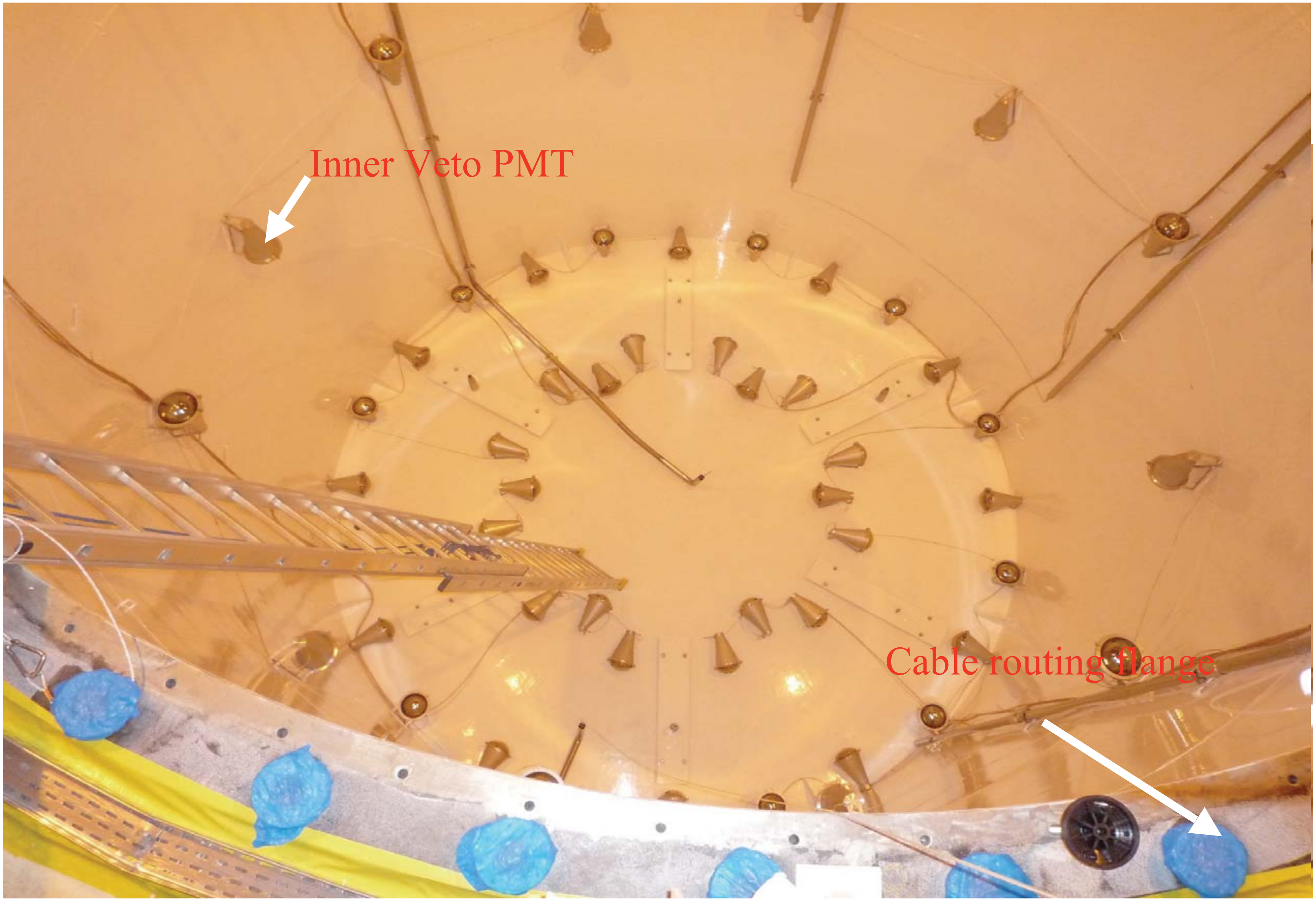


Inner veto PMT mounting

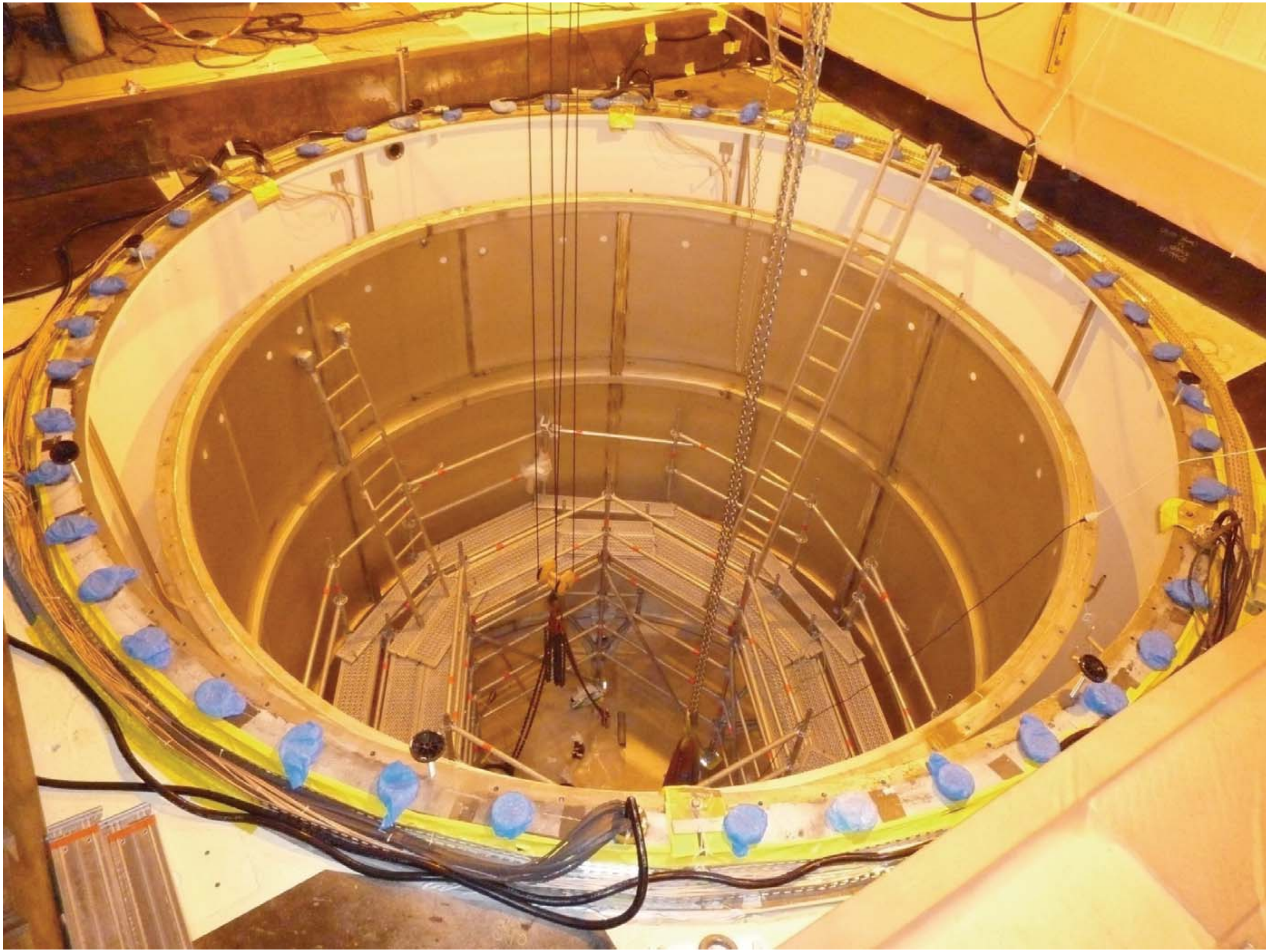


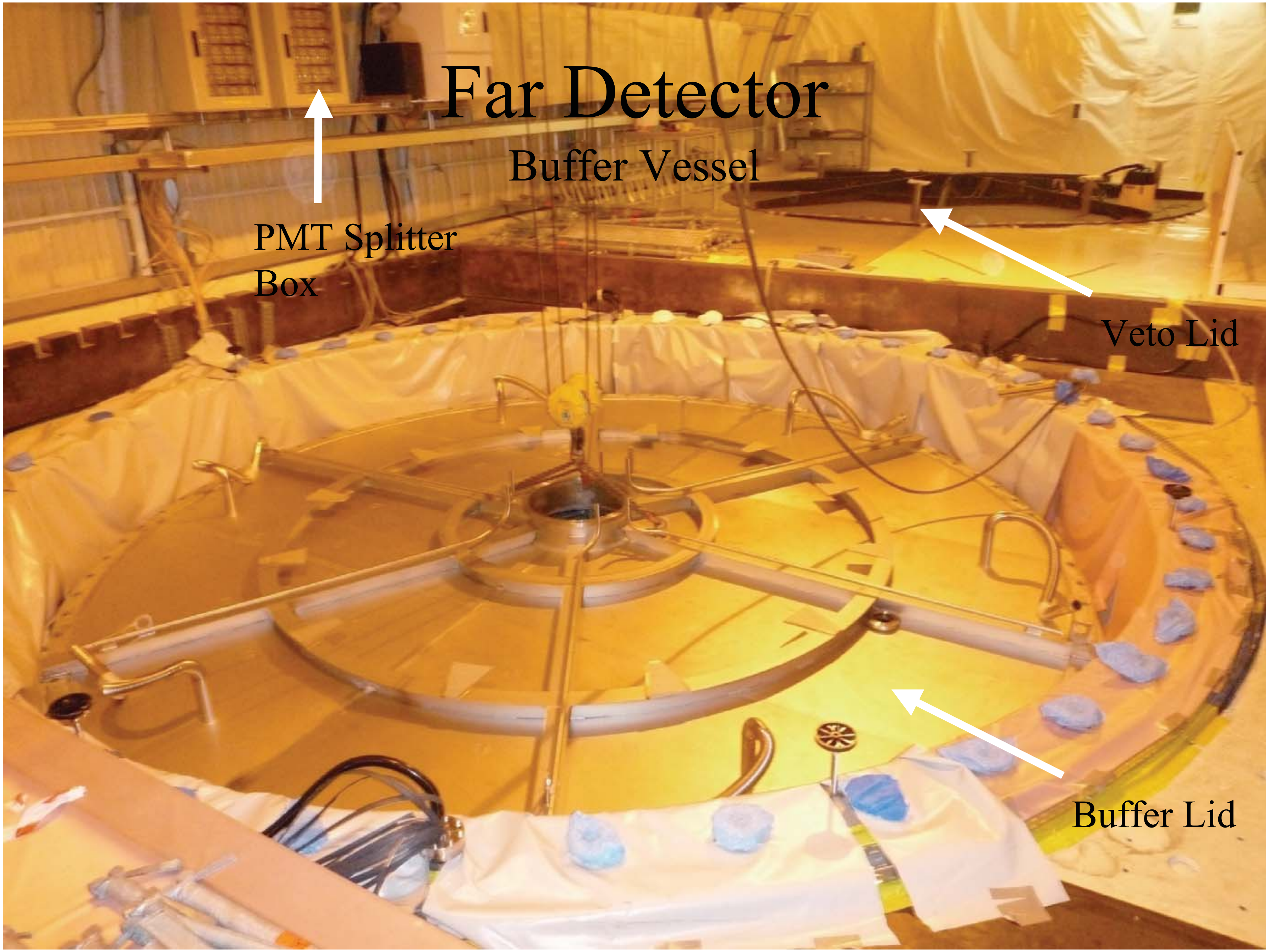
Buffer tank installation

Inner Veto PMTs



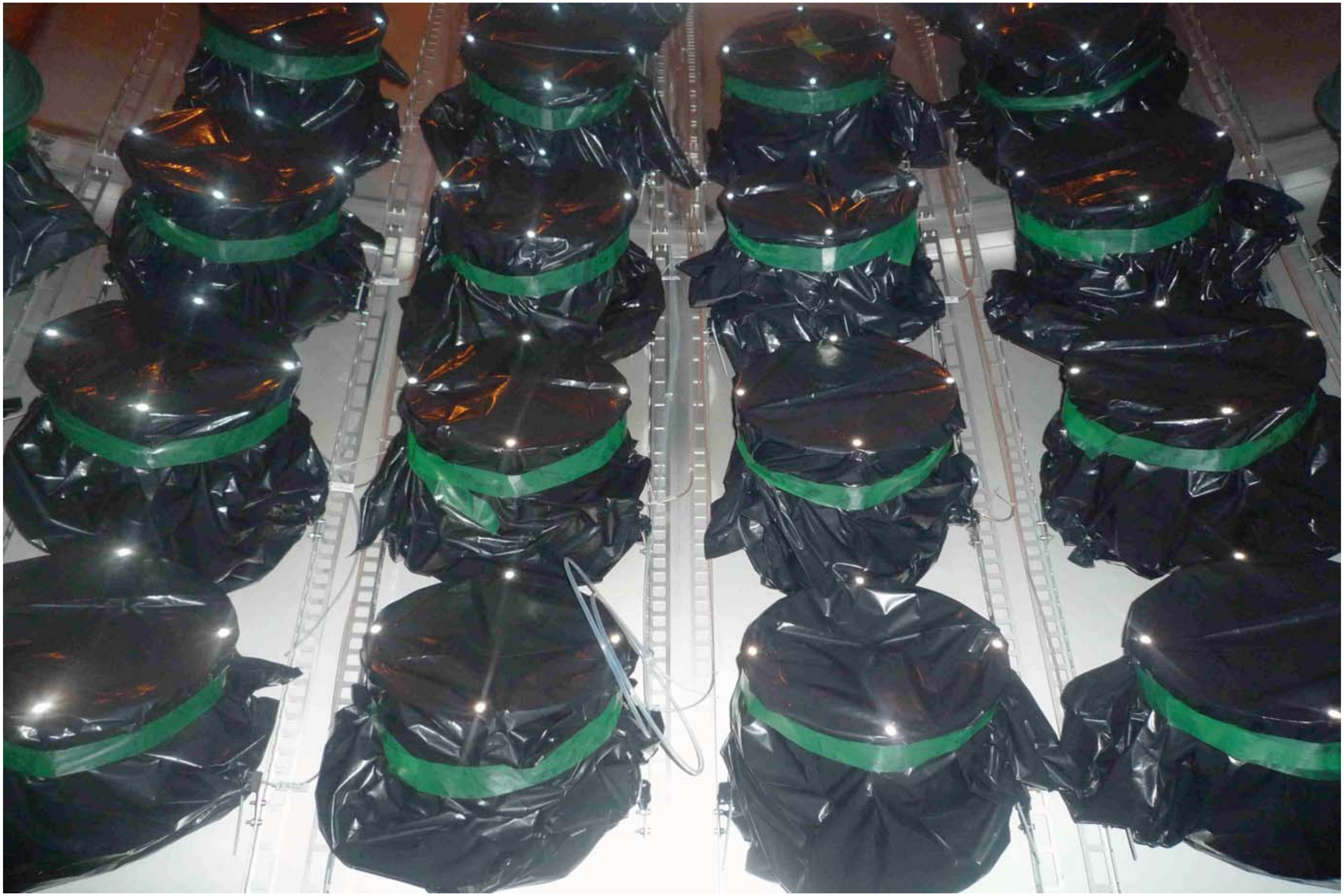
Buffer Tank Installation




Far Detector
Buffer Vessel
PMT Splitter
Box
Veto Lid
Buffer Lid

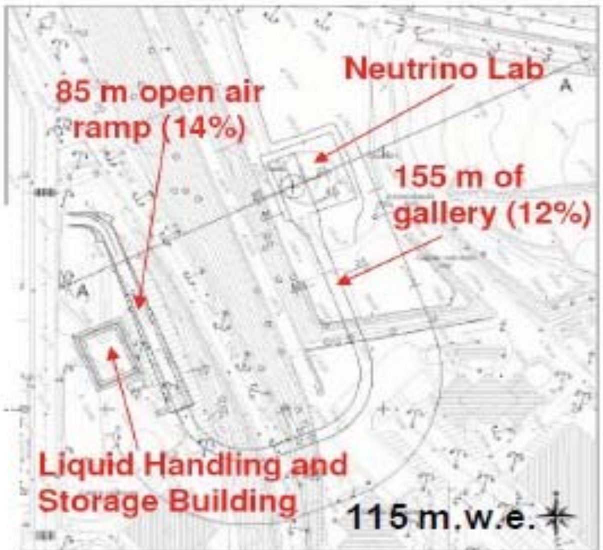
Inner PMTs, June 22

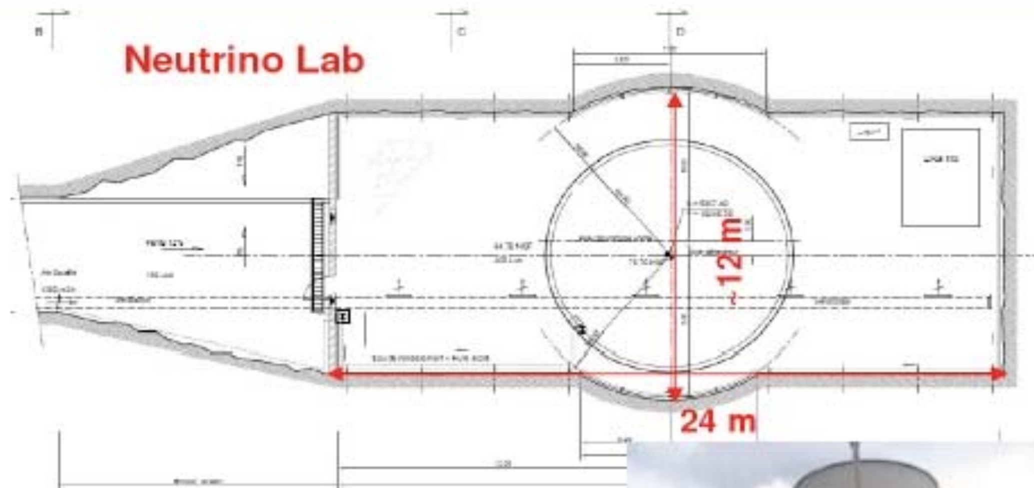
Inner PMTs



Near Detector Status

May 20: the agreement for the Near laboratory have been signed.
This was organized by the region Chanpagne Ardenne.
The agreement links this region, Edf, and French agencies.





Site has been chosen with >45m overburden, almost flat topology.

Geological site study completed.
Tender process for construction.
Schedule: lab available end of 2009.

Near Detector Status

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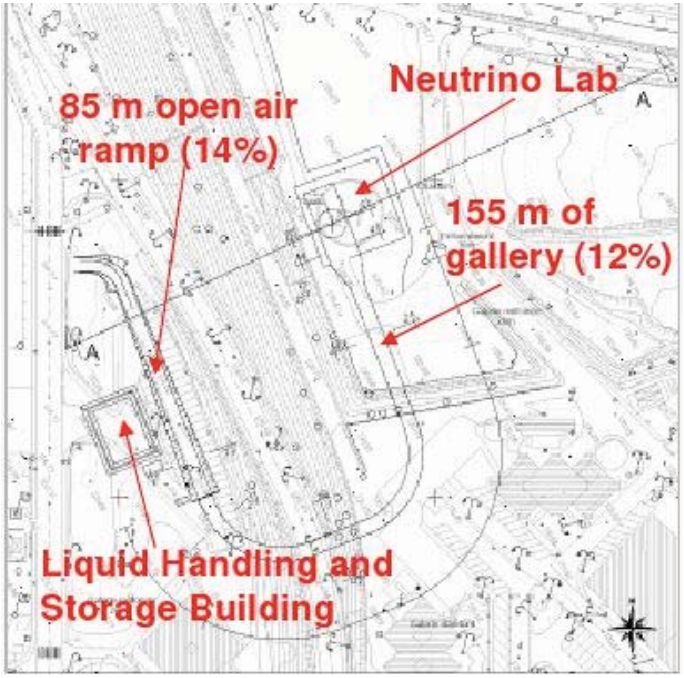

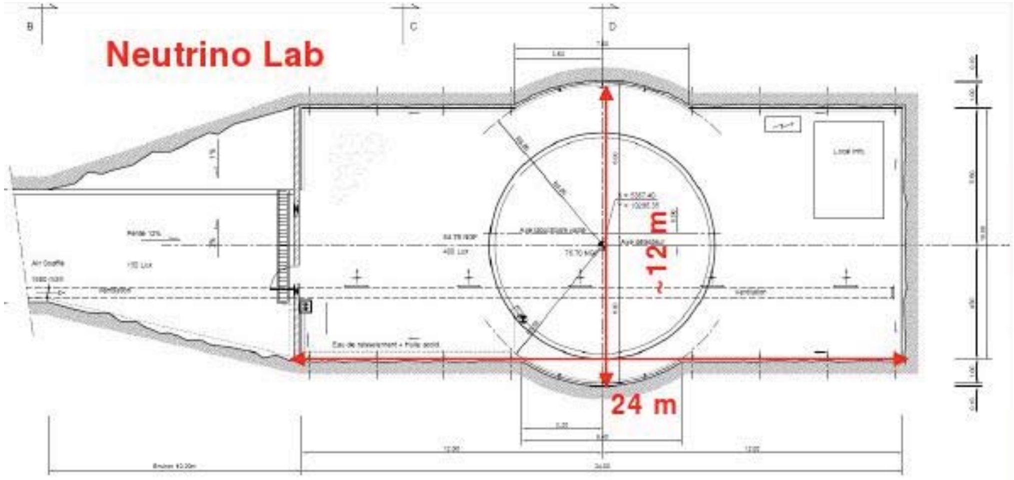

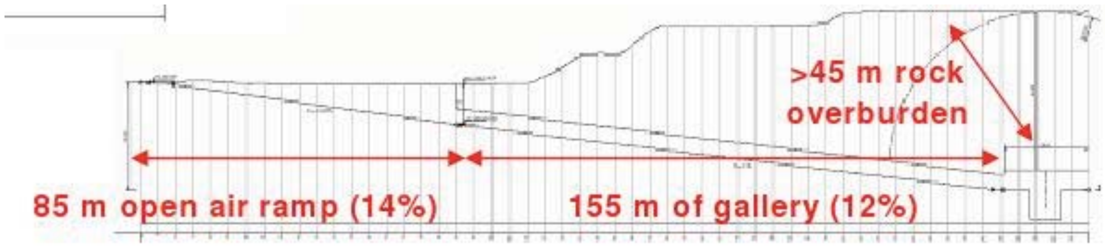

la dépêche du groupe EDF

n° 3117
25 mai 2009

DIFFUSION INTERNE

NUCLEAIRE

Chooz : coup double pour la recherche

Le 20 mai 2009, EDF a signé une convention avec le CEA et le CNRS pour engager l'expérience « Double Chooz ». Deux laboratoires souterrains de recherche sur la matière seront aménagés sur le site nucléaire de Chooz. La mise en place de ce dispositif constitue une première mondiale, dans un domaine où les précédentes découvertes ont déjà été couronnées par cinq prix Nobel.

Vue du futur détecteur Chooz B situé à 45 m sous terre et relié à la surface par un tunnel de 155 m de long

Ces deux laboratoires permettront de mieux comprendre le neutrino - une des quatre particules élémentaires – et sa faculté de changer d'état lors de sa propagation dans l'espace.

Une première expérience sur le site de Chooz A avait permis de lever en partie le voile sur ce phénomène énigmatique. Le programme «Double Chooz » prolonge l'expérimentation par la comparaison des flux de neutrinos à deux distances différentes des réacteurs de la centrale.

Lancé en partenariat avec le Conseil Régional de Champagne-Ardenne, le Conseil Général des Ardennes, le CEA et le CNRS, le programme nécessite la construction de deux détecteurs identiques, enterrés pour les protéger des rayonnements cosmiques et de la radioactivité naturelle. Le premier (détecteur proche) sera situé à proximité de Chooz B dans un nouveau laboratoire à 45 mètres sous terre. Le second (détecteur lointain) sera construit dans la colline de Chooz A, sur le site de la première expérience.

EDF, acteur majeur du projet

Outre la mise à disposition d'une partie de l'installation de Chooz A, EDF a fortement mobilisé son ingénierie : le Centre national d'équipement nucléaire pour l'étude de faisabilité du détecteur proche, le Centre d'ingénierie hydraulique pour la maîtrise d'œuvre du génie civil, le Centre d'ingénierie de déconstruction et environnement nucléaire pour la logistique journalière. La coordination générale est réalisée par les équipes de la centrale.

Une collaboration internationale à la hauteur des enjeux

Huit pays (Japon, Etats-Unis, Brésil, Russie, Grande-Bretagne, Allemagne, Espagne et France) coopèrent financièrement à la construction des détecteurs. 140 physiciens de 30 universités dans le monde participent à cette expérience. Le détecteur lointain sera opérationnel fin 2009, le détecteur proche fin 2011.

L'énigme neutrino

Très abondant dans l'univers, le neutrino est produit par les étoiles, le rayonnement cosmique ou encore par le cœur des centrales nucléaires. L'une des énigmes de cette particule réside dans sa faculté à se métamorphoser en trois états distincts : c'est le phénomène d'oscillation, dont seuls deux des trois paramètres ont pu être complètement mesurés à ce jour. Le neutrino est la baguette magique capable de changer un élément en un autre. Il pourrait expliquer la différence entre matière et anti-matière.

POUR EN SAVOIR +

• Olivier Lamarre, CNPE de Chooz, 03 24 36 30 01

RETROUVEZ LA DÉPÊCHE SUR e-toile ÉDITÉE PAR la direction de la Communication interne – Pauline Sergent

22-30, avenue de Wagram – 75382 Paris cedex 08 – www.edf.com
SA au capital de 911085545 euros – 552081317R.C.S.Paris – Le groupe EDF est certifié ISO 14001

May 27th:
EdF paper: quite friendly, with a good feeling about the Edf involvement in the experiment.

Schedule

- Conceptual Design Review October, 2006
- Technical Design Review, May 2007
- Far Lab start assembly, Fall 2007
- Far Lab: shielding installed, June 2008
- Far Lab: inner PMTs installed, June 2008
- Far Lab: ν target acrylic vessel gluing started
- Far Lab: LS filling to be completed Feb 2010
- Far Detector running Feb 2010
- Far Lab: Outer Veto to be installed April 2010
- Near Lab begin digging Mid 2009
- Near Lab finish digging End 2009
- Near Lab start assembly after digging
- Near Lab finish assembly 2010

Summary

- A new experimental concept to measure the mixing angle θ_{13}
  → use nuclear reactors with two identical detectors
  - Double Chooz will be the first of a new generation of neutrino experiments based on this concept

- Several detector improvements are being implemented
  - Stable Gd-loaded scintillators
  - Multi-layer detector design
  - Improved veto and calibration system to reduce systematic uncertainties

- It's all coming soon !
  - Early 2010: start data taking with far detector
  - 2011: start data taking with near+far
  - 2013: reach sensitivity $\sin^2 2\theta_{13} \sim 0.02$ to 0.03