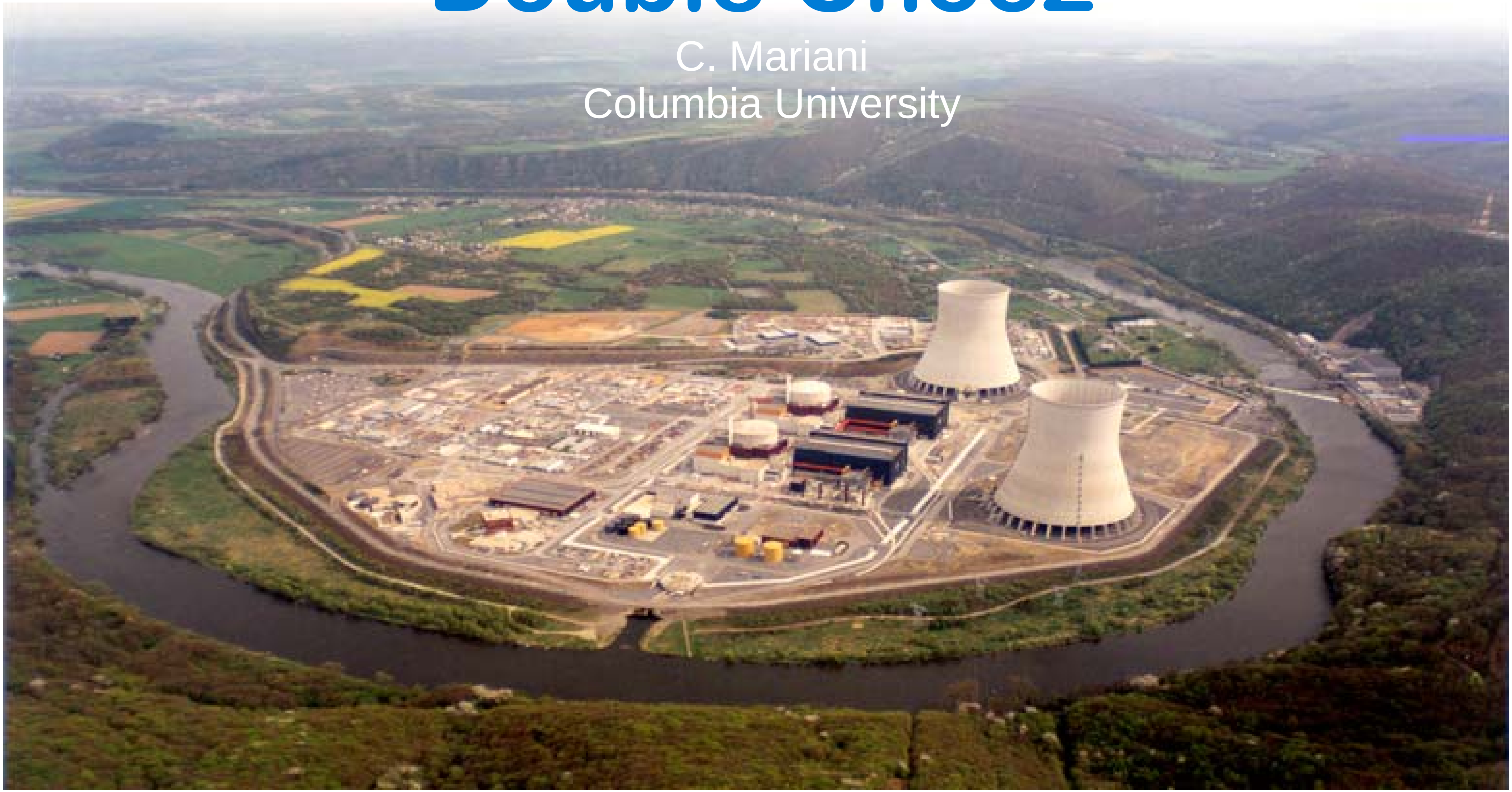
Double Chooz



C. Mariani
Columbia University

DC Collaboration

France: APC Paris, CEA/Dapnia Saclay, Subatech Nantes, IPHC Strasbourg

Germany: Aachen, MPIK Heidelberg, TU München, EKU Tübingen, Hamburg

Spain: CIEMAT Madrid

UK: Sussex

Spokesperson: Herve de Kerret (APC)

Japan: HIT, Kobe, MUE, Niigata, TGU, TIT, TMU, Tohoku

Russia: RAS, RRC Kurchatov Institute

USA: Alabama, ANL, Chicago, Columbia, Drexel, Illinois, Kansas, LLNL, LSU, MIT, Notre Dame, Sandia, Tennessee, UCD

Brazil: CBPF, UNICAMP

Contents

- θ_{13}:
  - Neutrino oscillation matrix;
  - current knowledge;
- Accelerator vs. reactor neutrino experiments;
- Reactor experiments:
  - Description;
  - ν spectrum;
- Chooz experiment;
- Double Chooz experiment:
  - far/near detector experimental concept;
  - improvements w.r.t. Chooz experiment;
  - far and near detectors;
  - Signal and background;
  - current status;
  - sensitivity;
- Conclusion.

θ_{13}: Neutrino mix matrix

Lepton: MNS Matrix

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\mu \end{pmatrix} \sim \begin{pmatrix} 0.8 & 0.6 & e^{i\delta}\sin\theta_{13} \\ -0.4 & 0.6 & 0.7 \\ 0.4 & -0.6 & 0.7 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

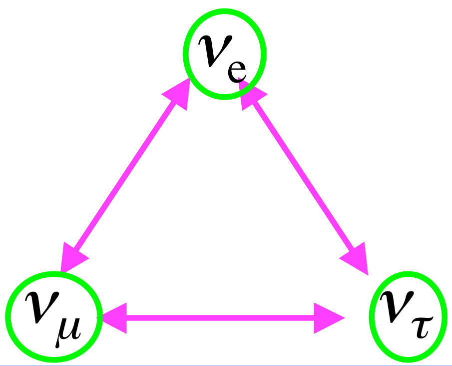
Quark: CKM Matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} 0.974 & 0.226 & 0.004 \\ 0.23 & 0.96 & 0.042 \\ 0.007 & 0.041 & 0.77 \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Unknown

Flavor eigenstate

Mass eigenstate



Flavor Transition
=Neutrino Oscillation

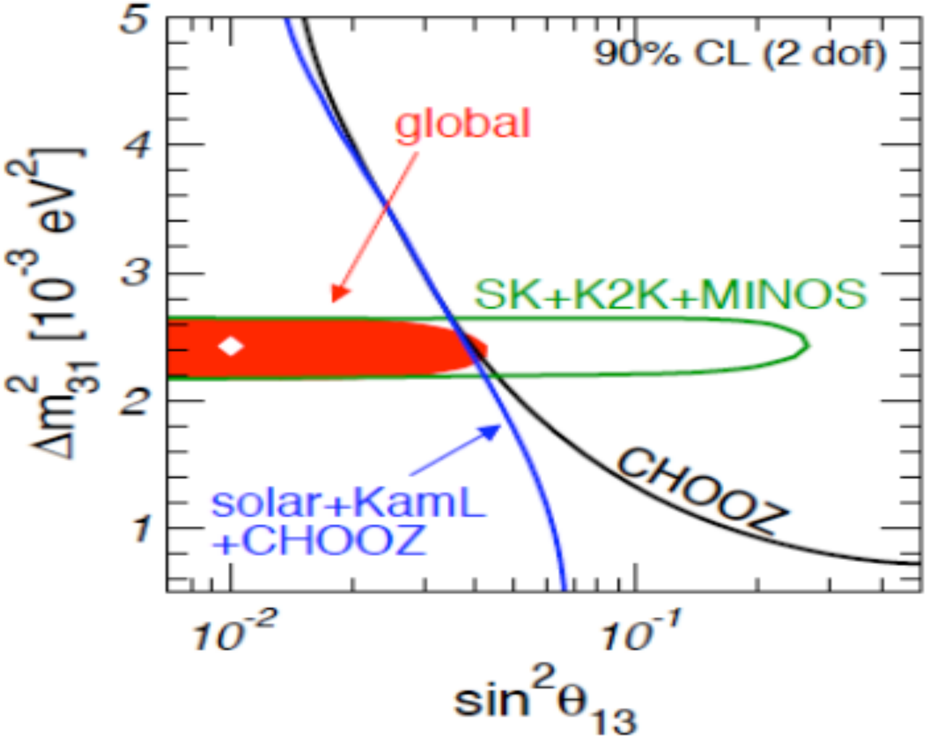
1st Oscillation measured by SK, K2K, MINOS
2nd Oscillation measured by KamLAND, Solar ν exps.

Measured by 3rd Neutrino Oscillation
=> to complete amplitude of MNS matrix

θ_{13} – current knowledge

- global: $\sin^2(2\theta_{13}) < 0.13$ (90%)
  - $\sin^2(\theta_{13}) < 0.035$ (90%)
- Dominated by Chooz [M.Apollonio et al, Eur. Phys. J. C27 (2003) 331]

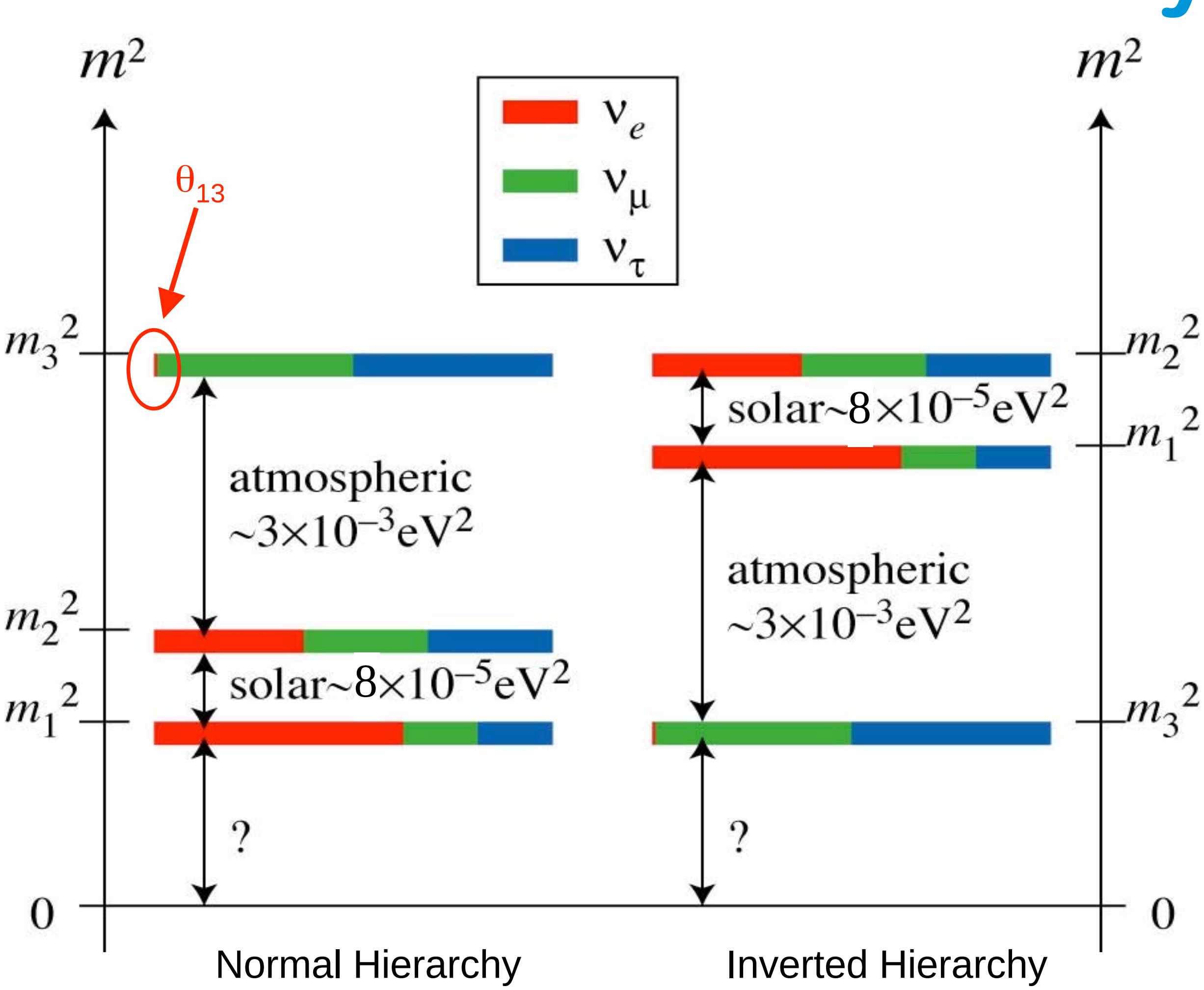
Maltoni and Schwetz, arXiv:0812.3161



Neutrino mass hierarchy

Missing information:

1. What is ν_e component in the ν_3 mass eigenstate?
   $\Rightarrow$ 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 $\delta \neq 0$?



There are many questions but the Big Question is " How big is the the little mixing angle θ_{13} ?"

Accelerator vs. Reactor exp.

- 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)

NOνA:
$\langle E_\nu \rangle = 2.3$ 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

Long-Baseline Accelerator Appearance Experiments

- 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 $\sin^2\theta_{23}$

$$
\begin{aligned}
P(\nu_\mu \to \nu_e) = {} & 4C_{13}^2 S_{13}^2 S_{23}^2 \sin^2 \frac{\Delta m_{31}^2 L}{4E} \times \left(1 + \frac{2a}{\Delta m_{31}^2} \left(1 - 2S_{13}^2\right)\right) \\
& + 8C_{13}^2 S_{12} S_{13} S_{23} (C_{12} C_{23} \cos\delta - S_{12} S_{13} S_{23}) \cos \frac{\Delta m_{32}^2 L}{4E} \sin \frac{\Delta m_{31}^2 L}{4E} \sin \frac{\Delta m_{21}^2 L}{4E} \\
& - 8C_{13}^2 C_{12} C_{23} S_{12} S_{13} S_{23} \sin\delta \sin \frac{\Delta m_{32}^2 L}{4E} \sin \frac{\Delta m_{31}^2 L}{4E} \sin \frac{\Delta m_{21}^2 L}{4E} \\
& + 4S_{12}^2 C_{13}^2 \left\{C_{12}^2 C_{23}^2 + S_{12}^2 S_{23}^2 S_{13}^2 - 2C_{12} C_{23} S_{12} S_{23} S_{13} \cos\delta\right\} \sin^2 \frac{\Delta m_{21}^2 L}{4E} \\
& - 8C_{13}^2 S_{13}^2 S_{23}^2 \cos \frac{\Delta m_{32}^2 L}{4E} \sin \frac{\Delta m_{31}^2 L}{4E} \frac{aL}{4E} \left(1 - 2S_{13}^2\right)
\end{aligned}
$$

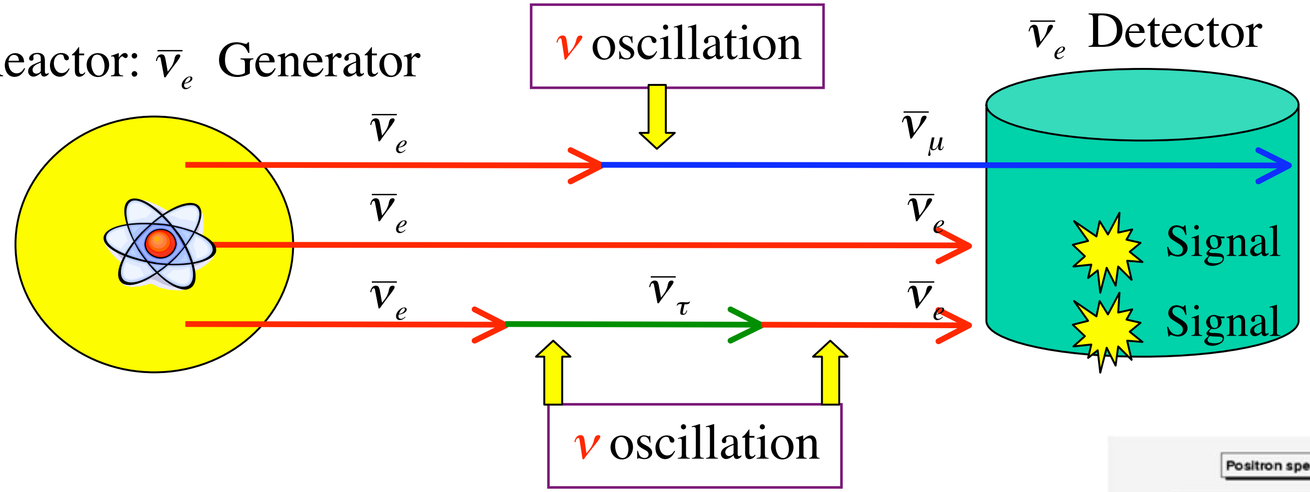
$\Rightarrow$ ***These extra dependencies are both a "curse" and a "blessing" since they will let us measure CP violation if θ_{13} is big enough***

Reactor Disappearance Experiments

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

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

Reactor experiment

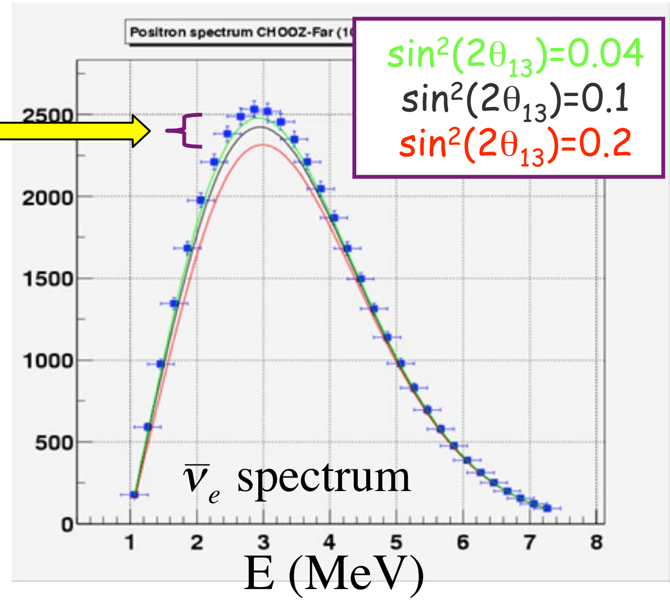


Looks deficit of ν

Deficit of $\bar{\nu}_e \propto \sin^2 2\theta_{13}$

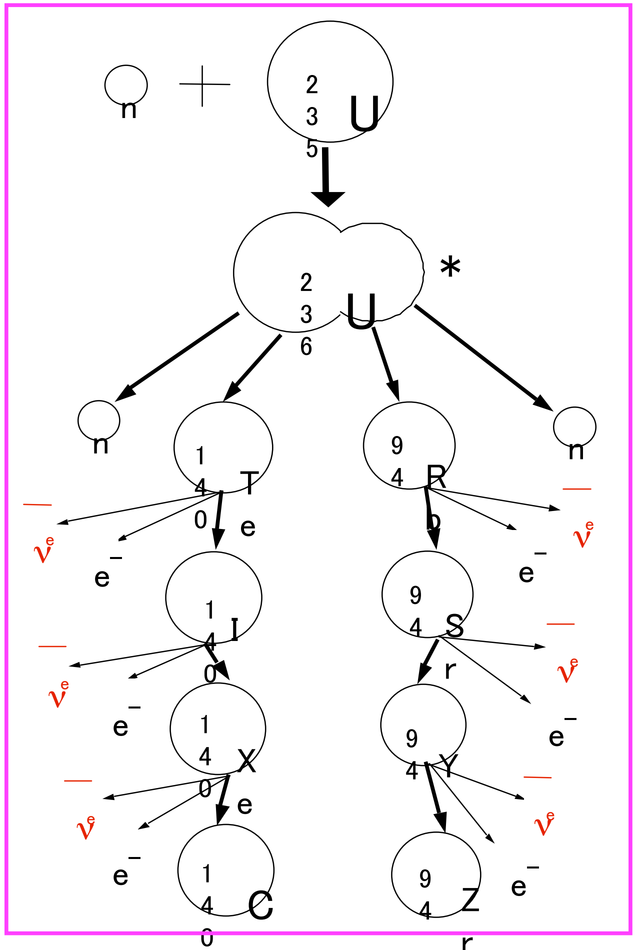
$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) = 1 - \sin^2 2\theta_{13}$$

The probability for $\bar{\nu}_e$ to remain $\bar{\nu}_e$



This deficit is small and we need <1% of accuracy.

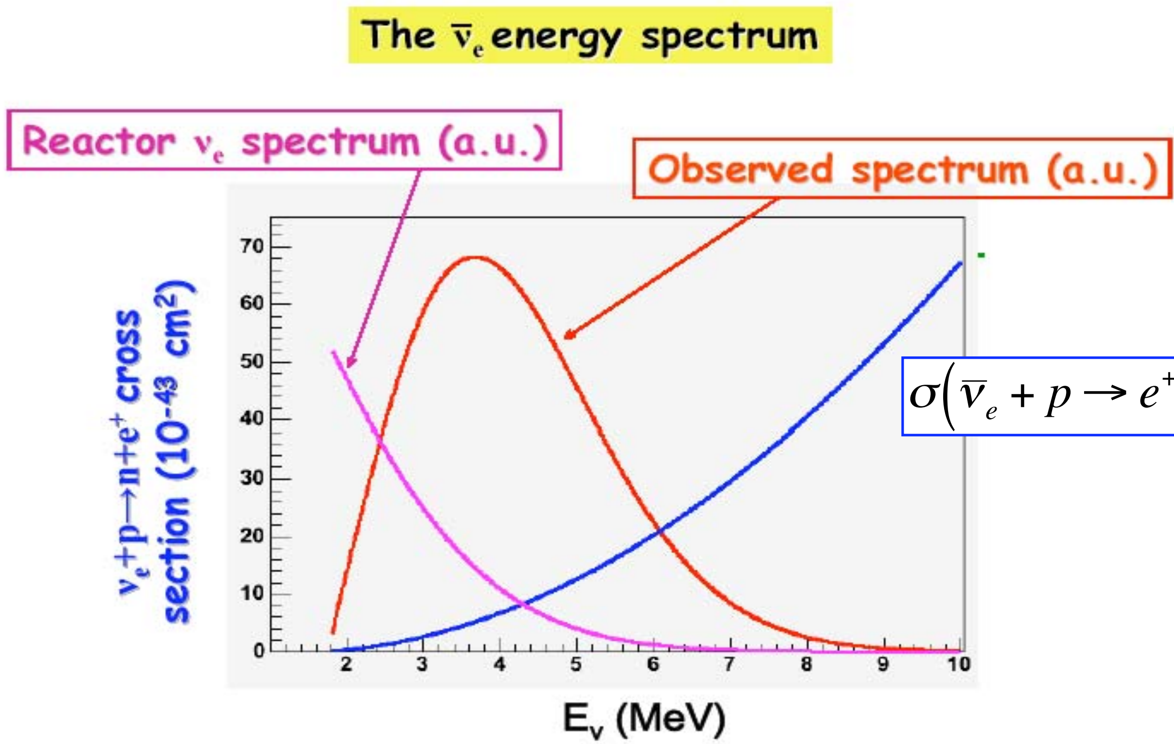
Reactor: ν spectrum



ν's are produced in β-decays of fission products.

$$\sim 6\times 10^{20}\,\overline{\nu}_e / s / reactor$$

Assuming 3 GWth

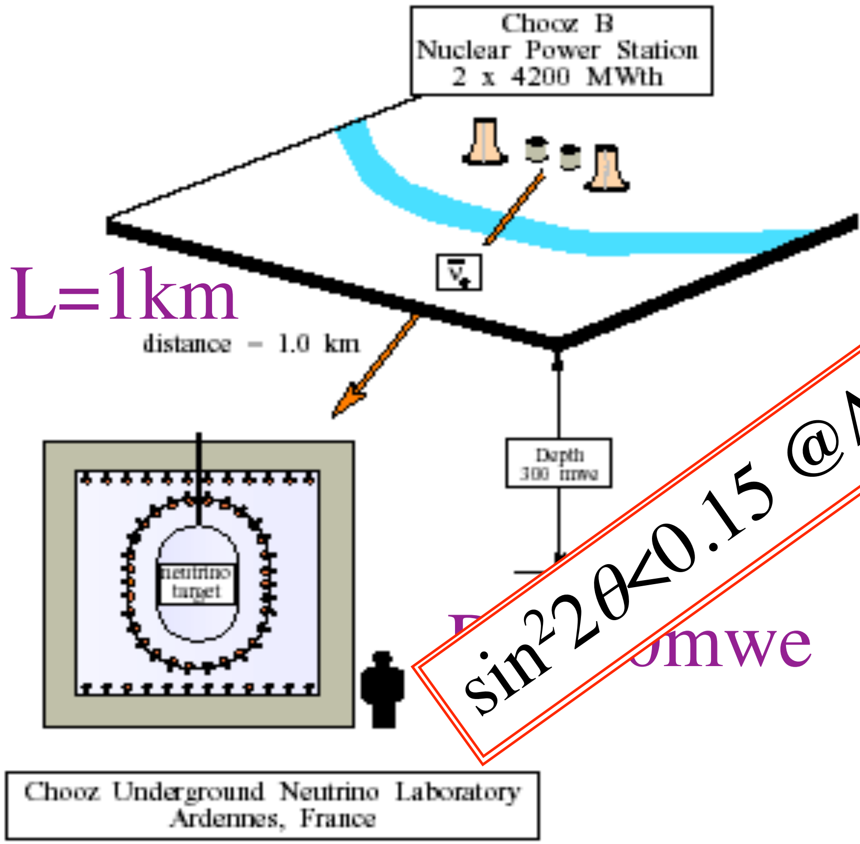


$$\sigma\left(\overline{\nu}_e + p \rightarrow e^+ + n\right)$$

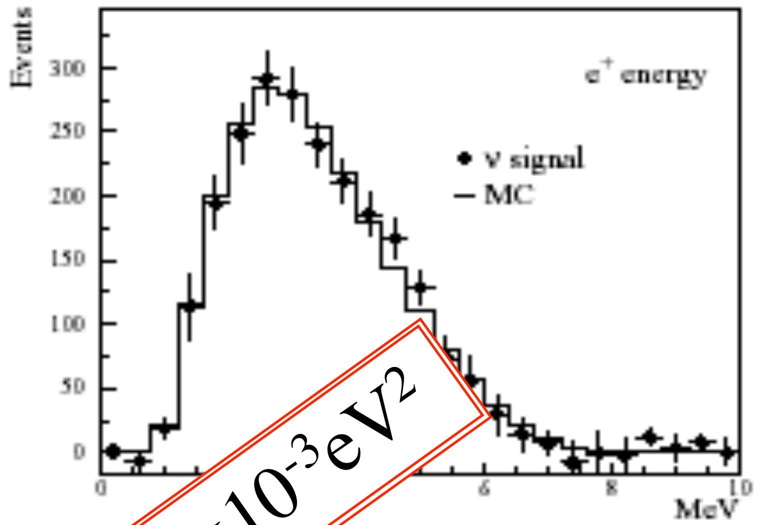
$$\boxed{E_\nu \sim 4\,^{+4}_{-2}\,MeV}$$

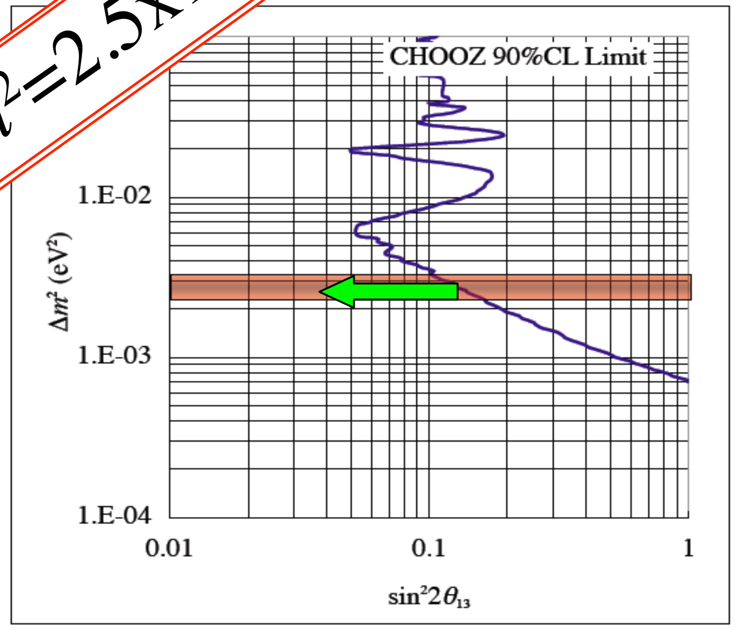
Chooz experiment

CHOOZ reactor ($\bar{\nu}_e$ --> $\bar{\nu}_e$) experiment



L=1km

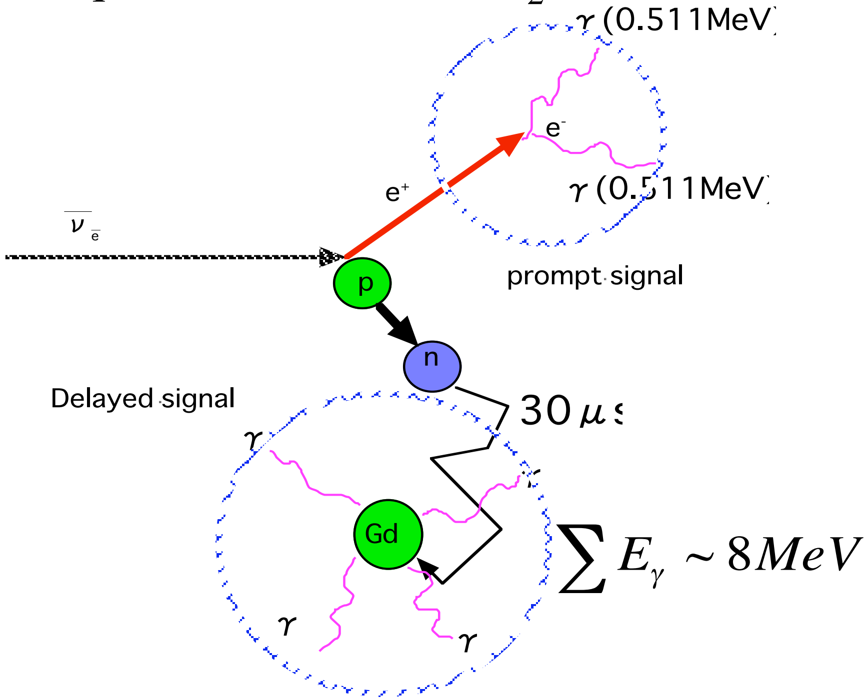


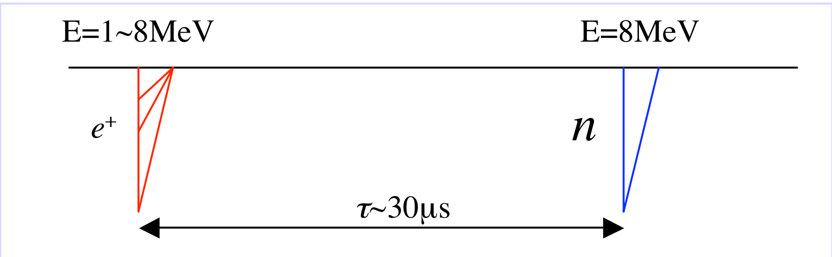


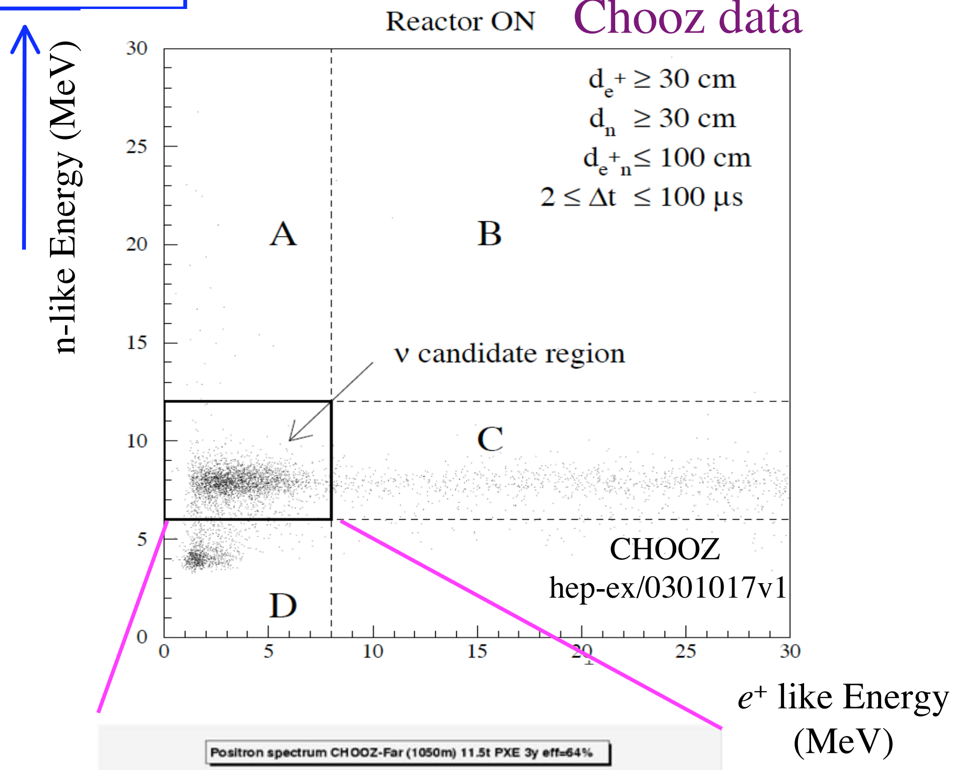
$\sin^2 2\theta < 0.15$ @ $\Delta m^2 = 2.5\text{x}10^{-3}\,\text{eV}^2$

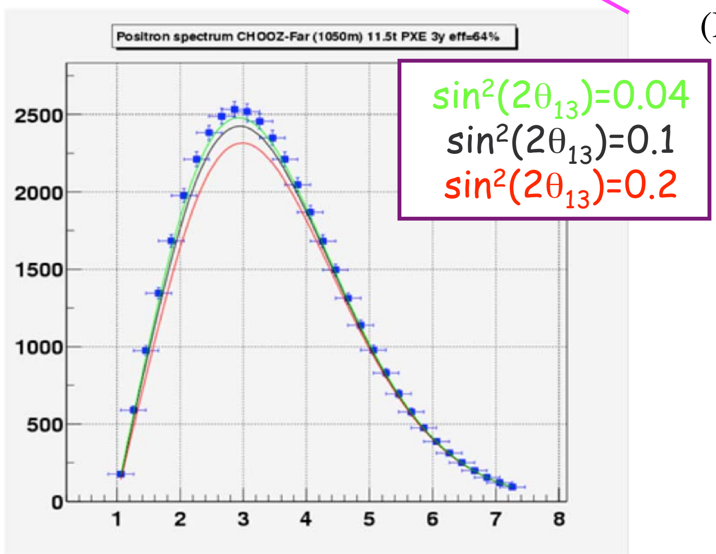
$\bar{\nu}_e$ Detection

Gd doped organic
liquid scintillator (~CH_2)

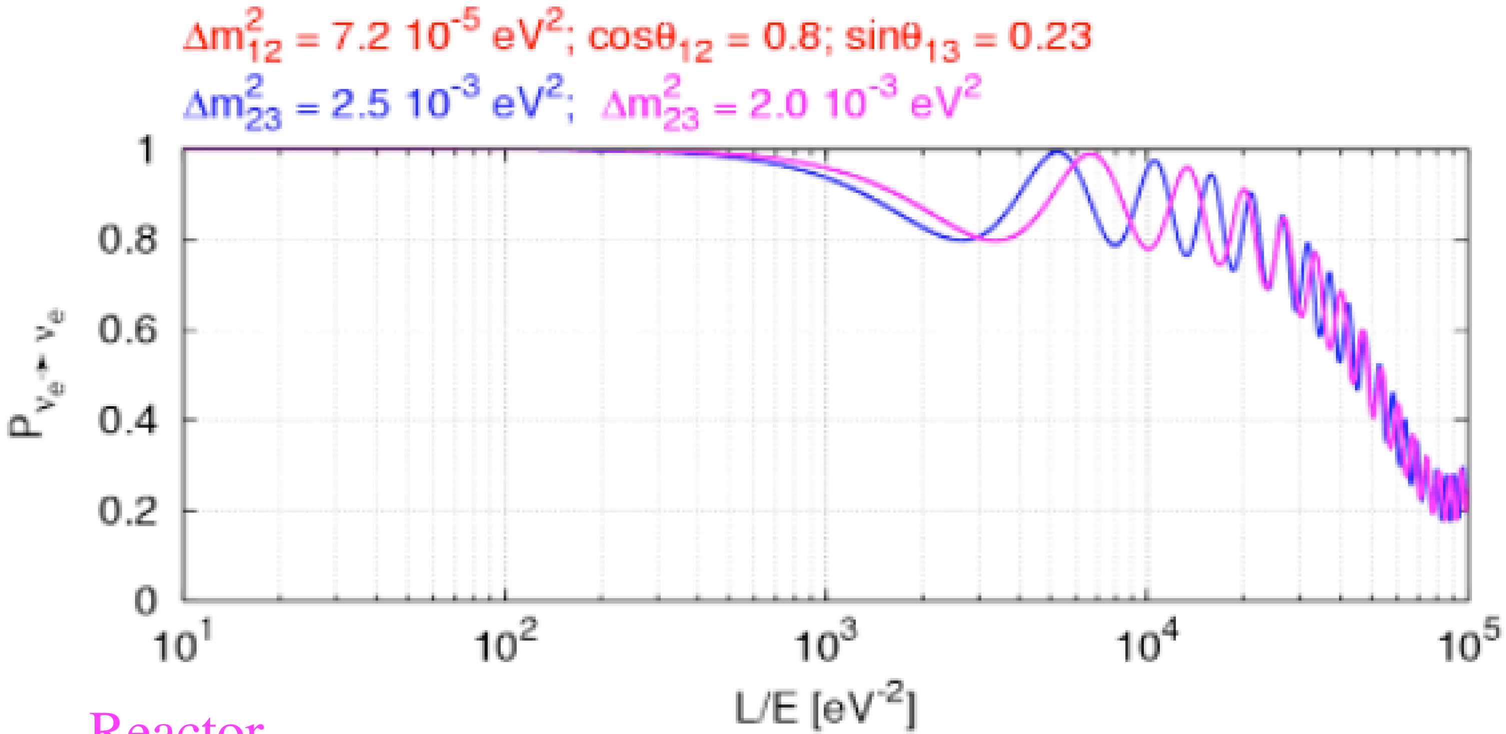


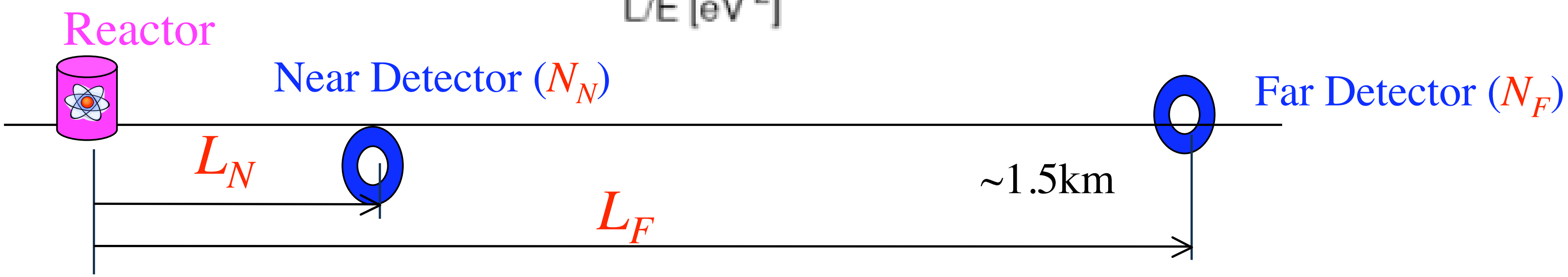






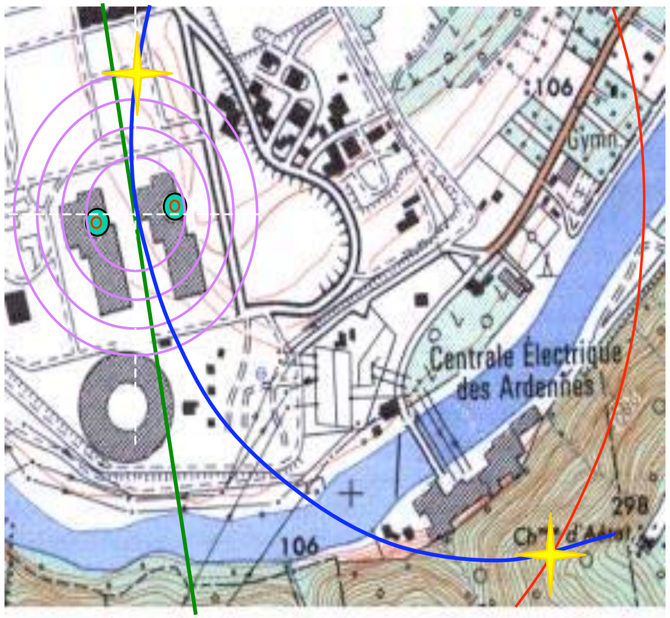
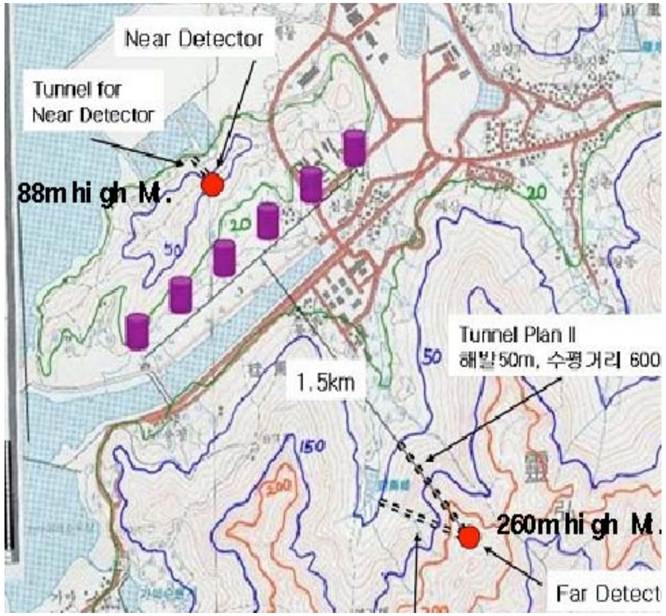
Far - Near: why use 2 detectors





Use near and far detector of identical structure to cancel systematic uncertainties of ν flux and detector response.

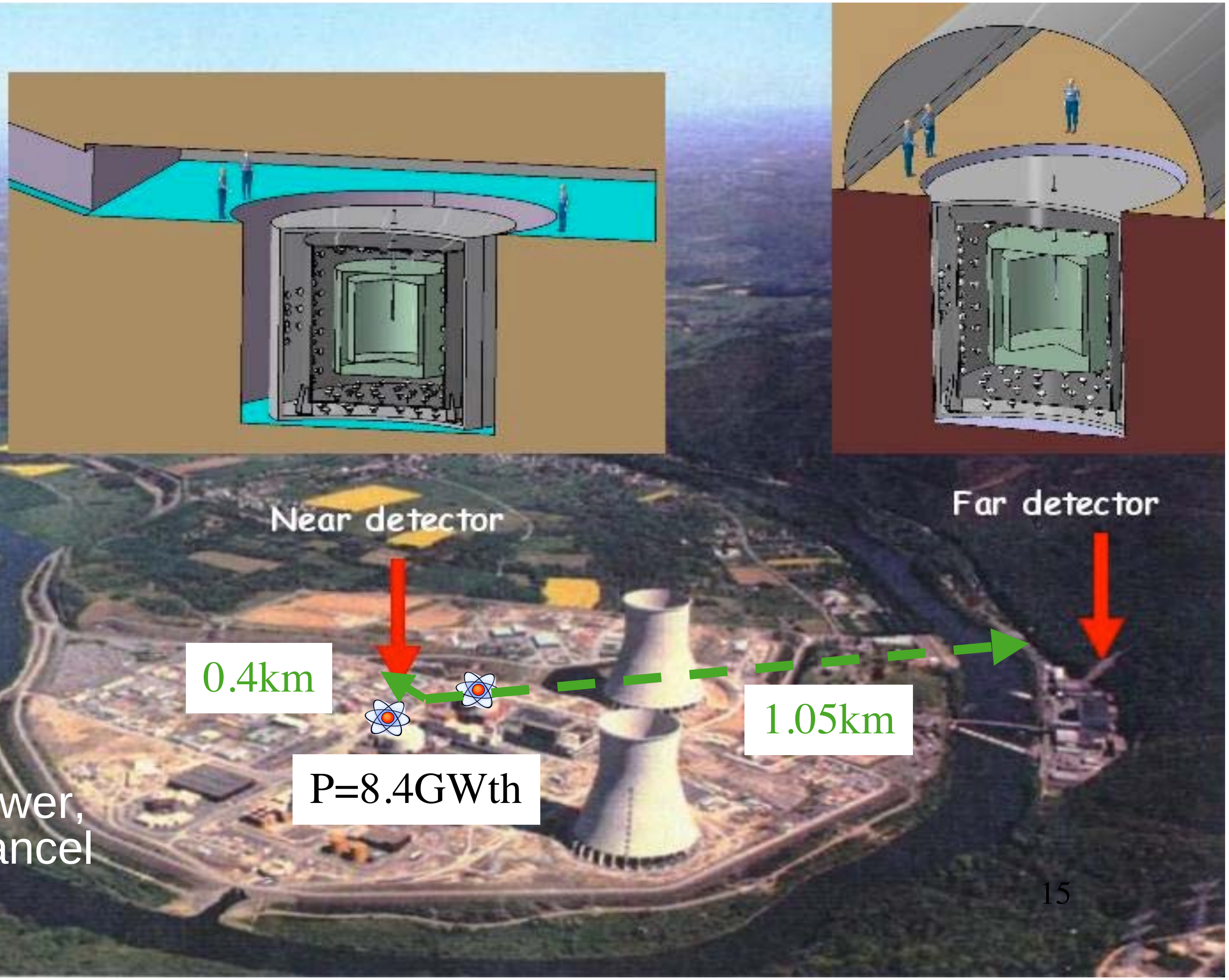
Reactor experiments

Double Chooz	Daya Bay	Reno
		

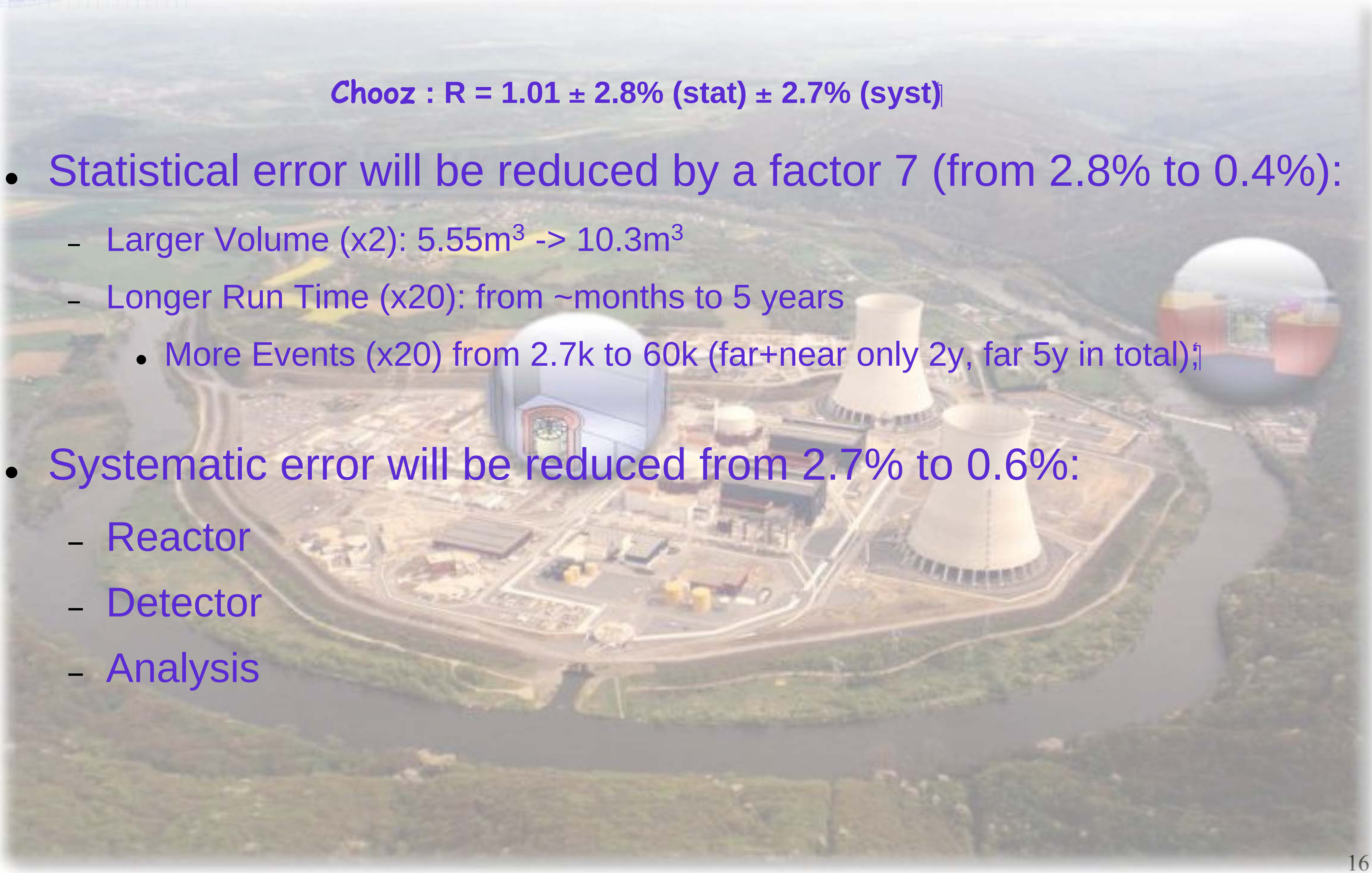
P = 8.2 GWth/2 L = 1.05(0.4)km	P = 11.6GWth/4 17.4 GWth/6 (2011~) L ~ 1.8km	P = 16.1 GWth/6 L ~ 1.4km

Double Chooz experiment

- 2 “identical” detectors:
  - **Near**
    - Distance: 410 m;
    - Deep: 115 m.w.e;
    - Rate: ~500 ν/day
  - **Far**
    - Distance: 1050 m;
    - Deep: 300 m.w.e;
    - Rate: ~70 ν/day
- Systematic on reactor power, neutrino spectrum, will cancel out when doing a relative measurement.



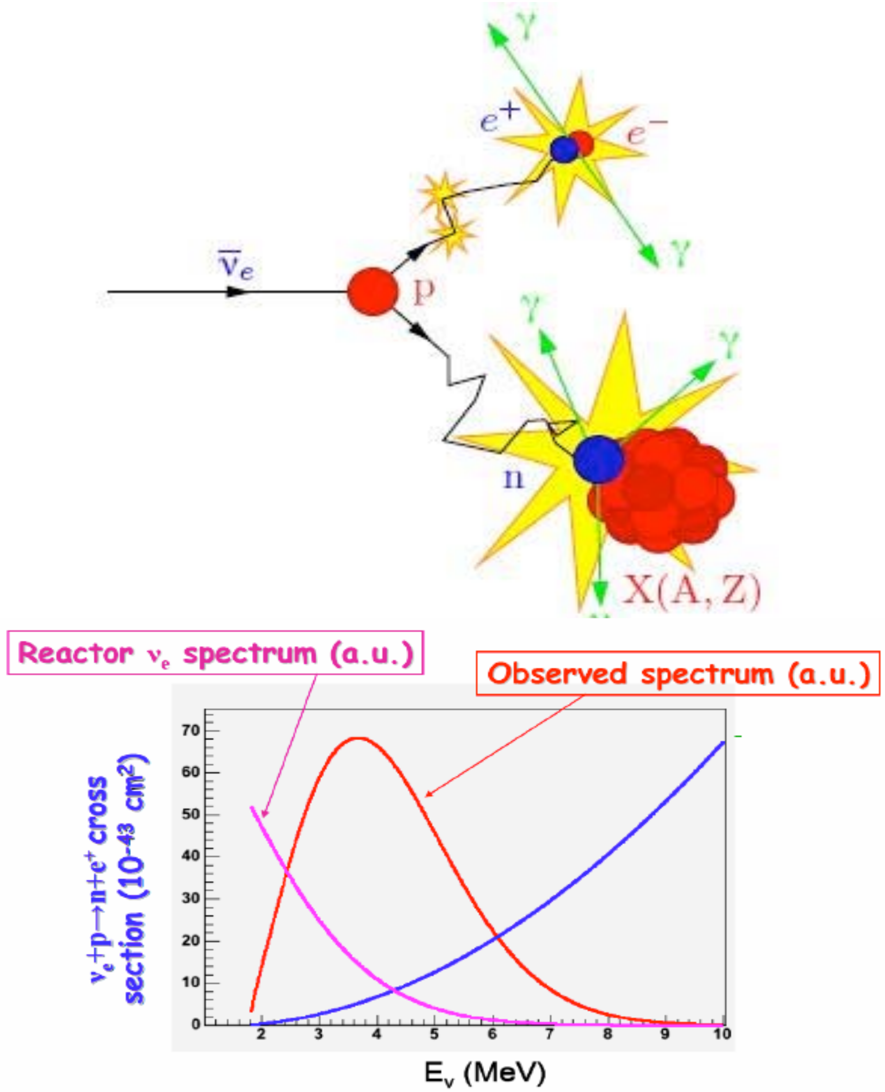
Improvements w.r.t. Chooz exp.



Chooz : R = 1.01 ± 2.8% (stat) ± 2.7% (syst)

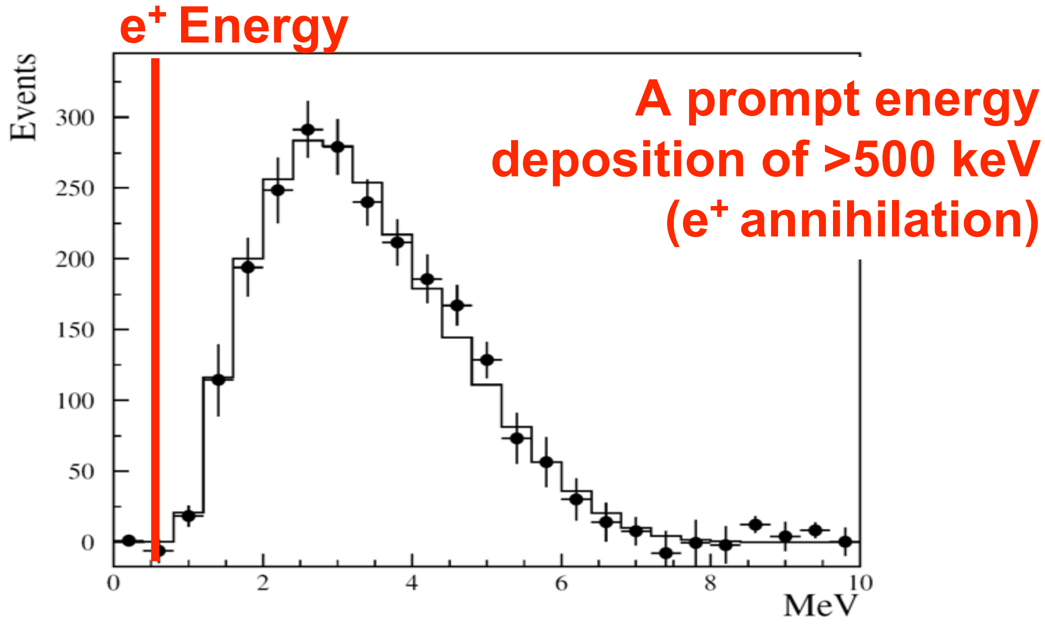
- Statistical error will be reduced by a factor 7 (from 2.8% to 0.4%):
  - Larger Volume (x2): $5.55m^3$ -> $10.3m^3$
  - Longer Run Time (x20): from ~months to 5 years
    - More Events (x20) from 2.7k to 60k (far+near only 2y, far 5y in total);
- Systematic error will be reduced from 2.7% to 0.6%:
  - Reactor
  - Detector
  - Analysis

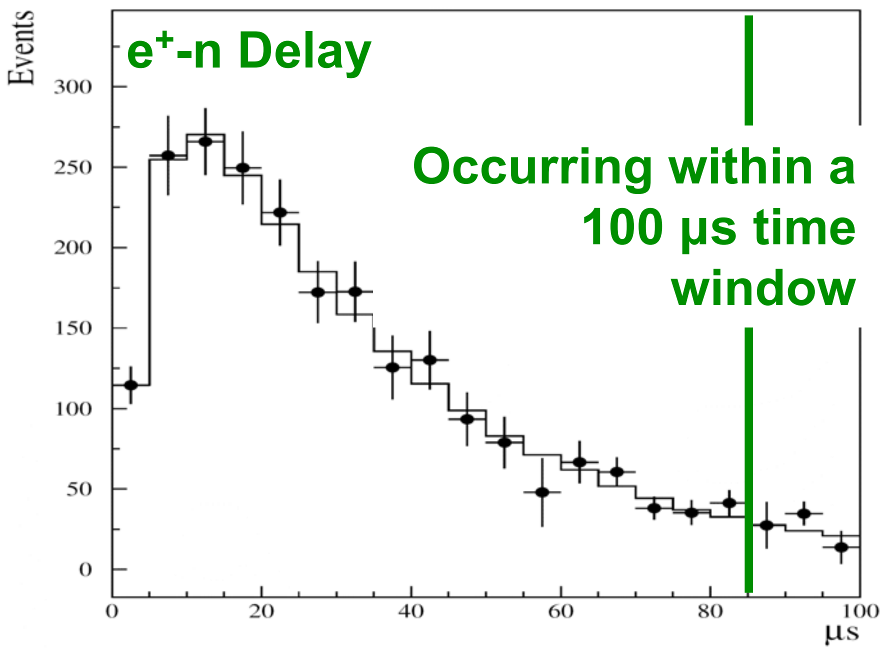
Signal: Inverse β Decay

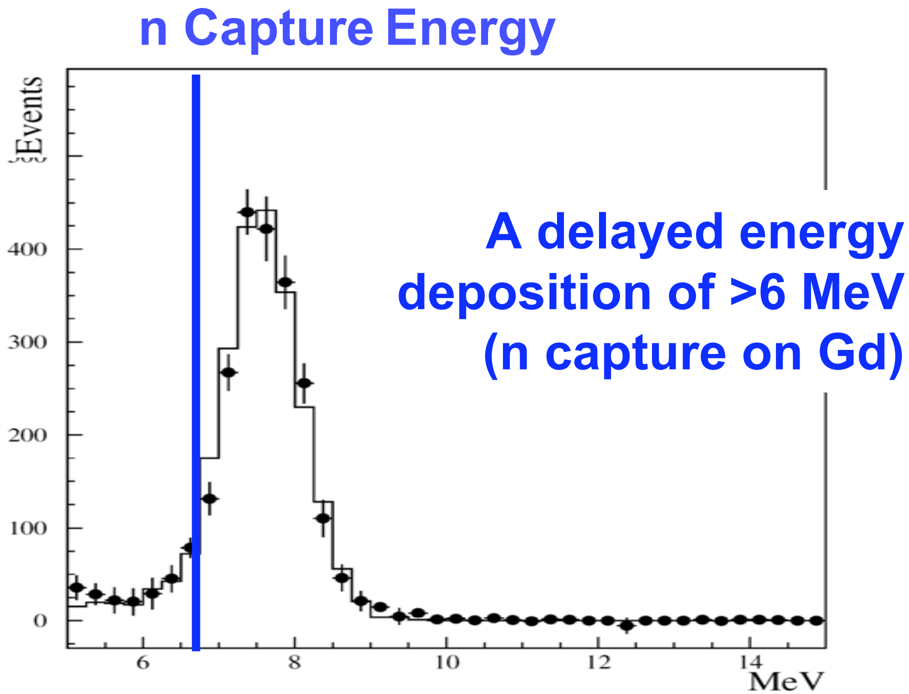


- Detect anti-neutrinos via inverse beta decay
  - $p + \overline{\nu} \rightarrow n + e^+$
- In Gd-loaded scintillator
  - e^+ signal 1-8MeV
  - e^+ e^- annihilation(2 x 511 keV)
    - $E_{vis} = E_\nu - (M_n - M_p) + m_e$
  - Delayed neutron capture on
    - Gd ~30 μs ~ 8 MeV (>80%)
    - H ~200 μs 2.2 MeV

Signal cont’d

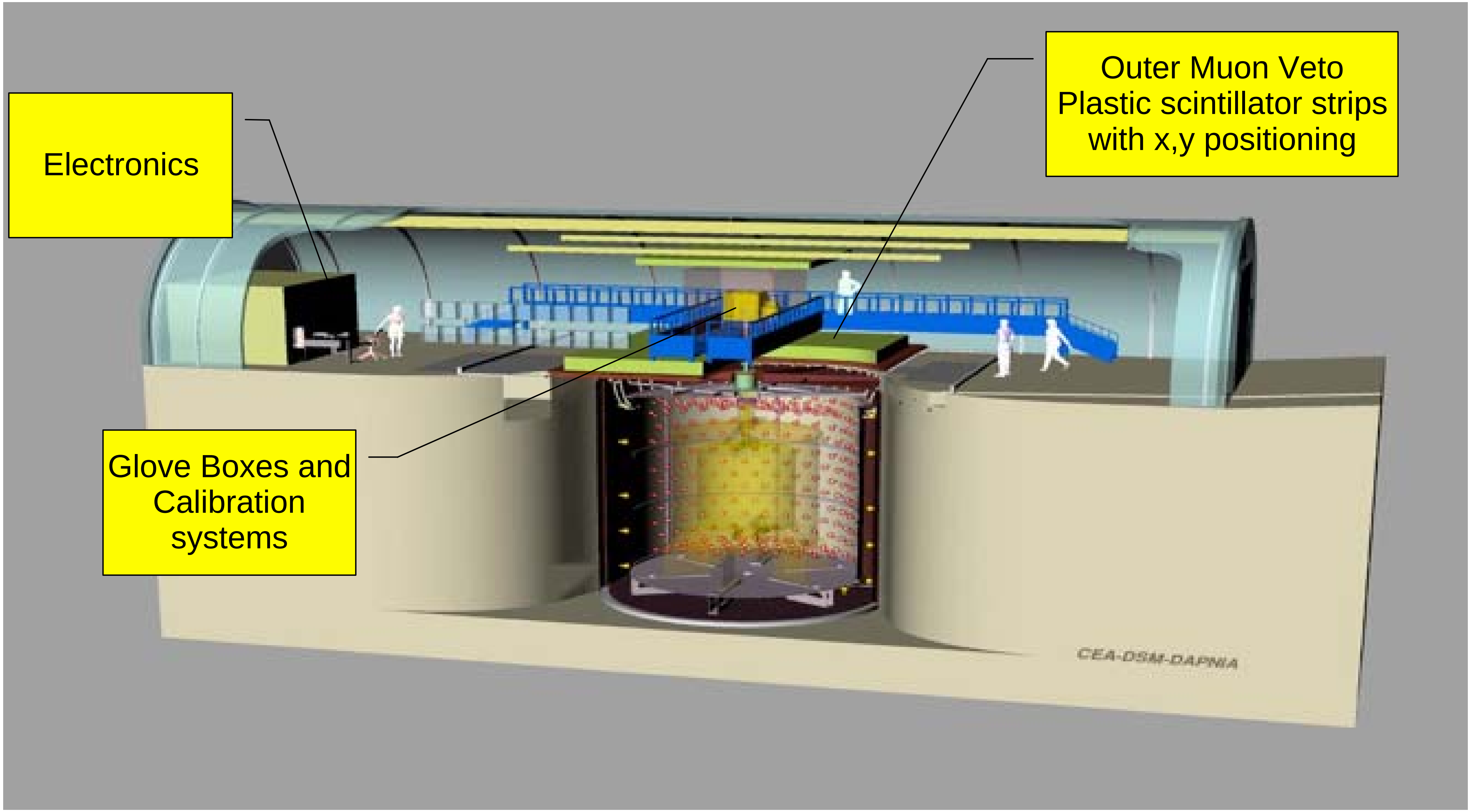






Apollonio, et al., Eur. Phys. J. C27 (331-374), 2003.

The Lab


Electronics
Outer Muon Veto
Plastic scintillator strips
with x,y positioning
Glove Boxes and
Calibration
systems
CEA-DSM-DAPNIA

Detector: far and near

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

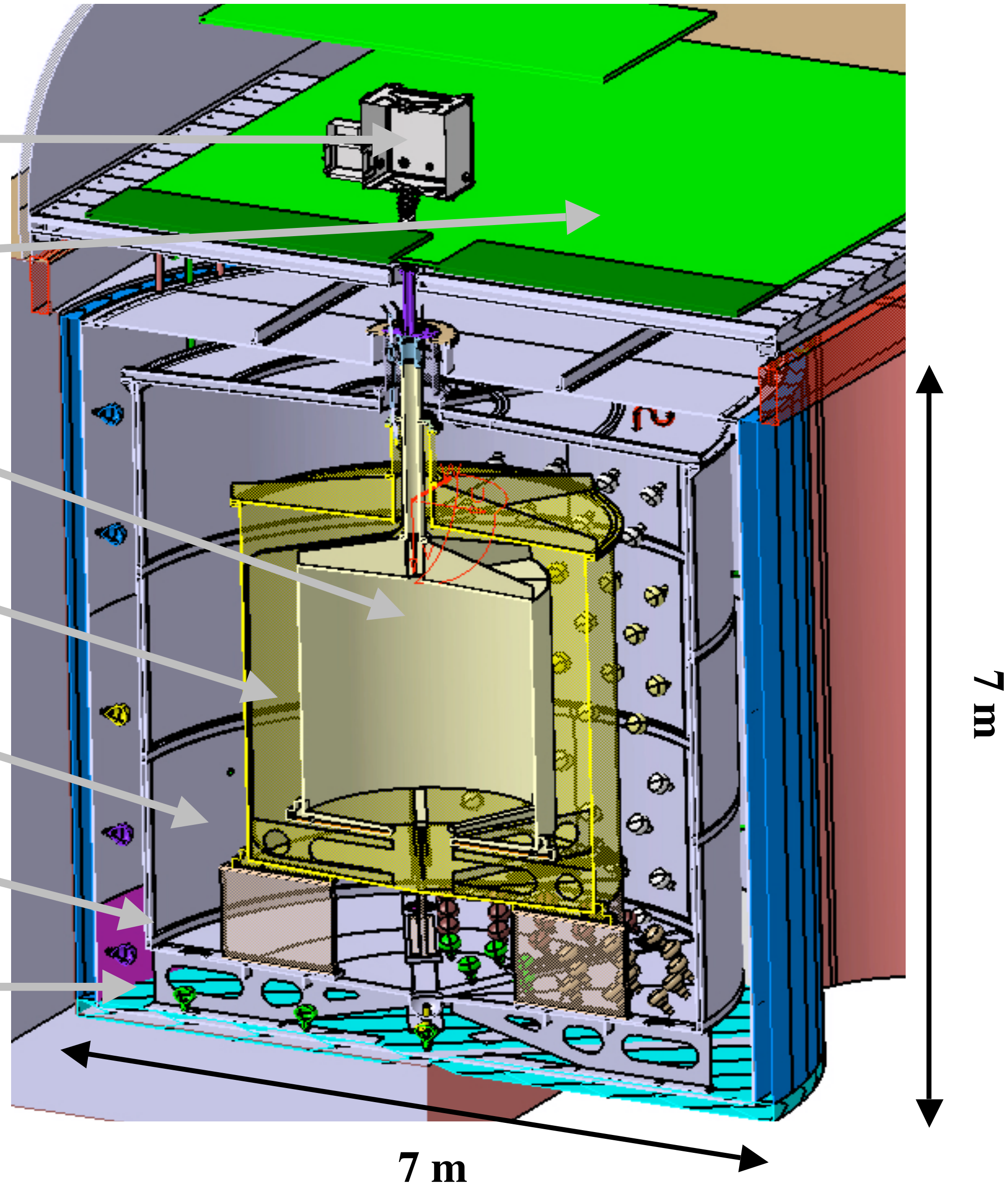
γ Catcher : 22,6 m^3
LS; 80% $C_{12}H_{26}$ + 20% PXE + PPO + Bis-MSB

Non scintillating Buffer : 114 m^3
mineral oil

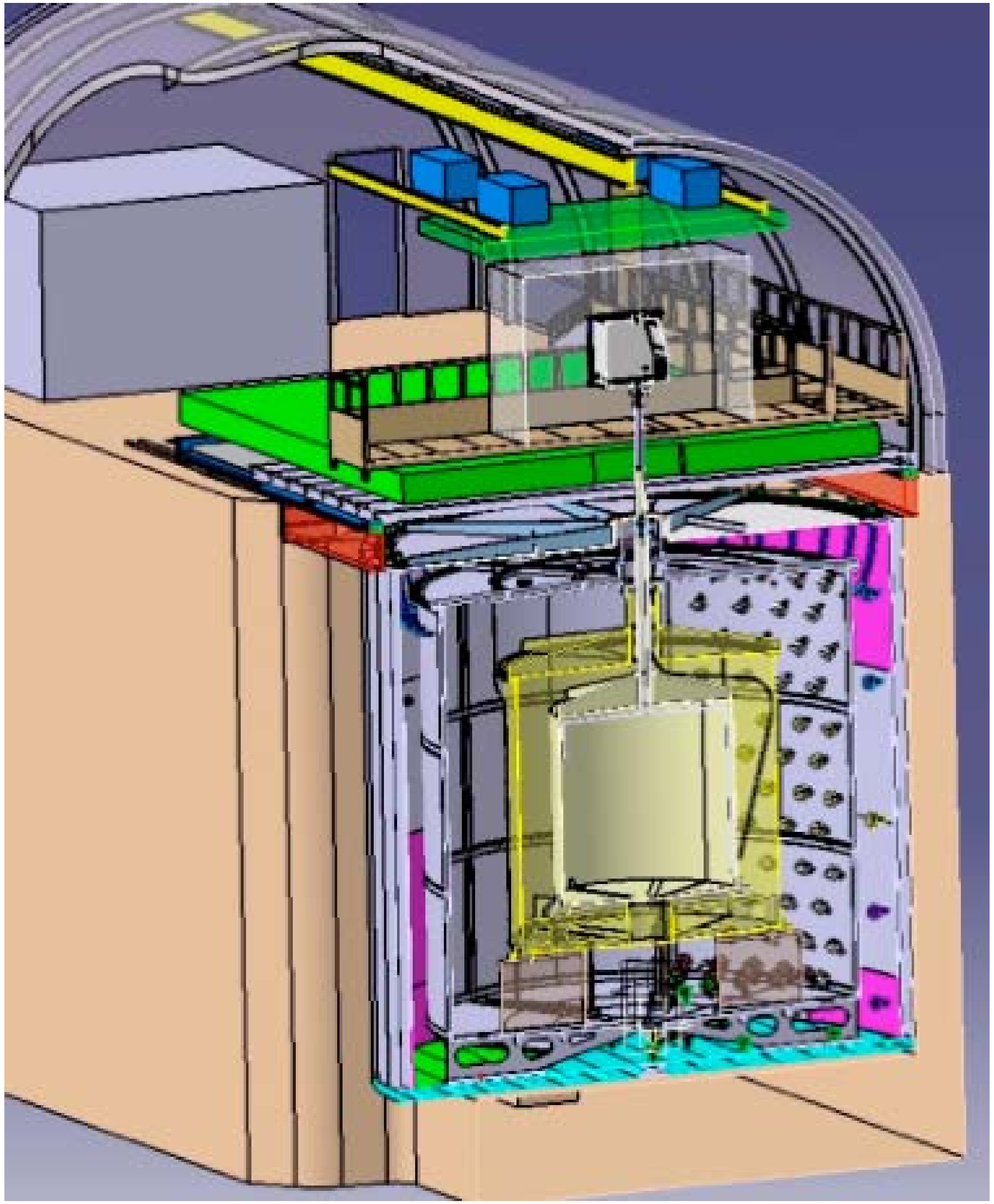
Buffer vessel & 390 10'' PMTs :
Stainless steel 3 mm

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

Steel Shielding :
17 cm steel, All around

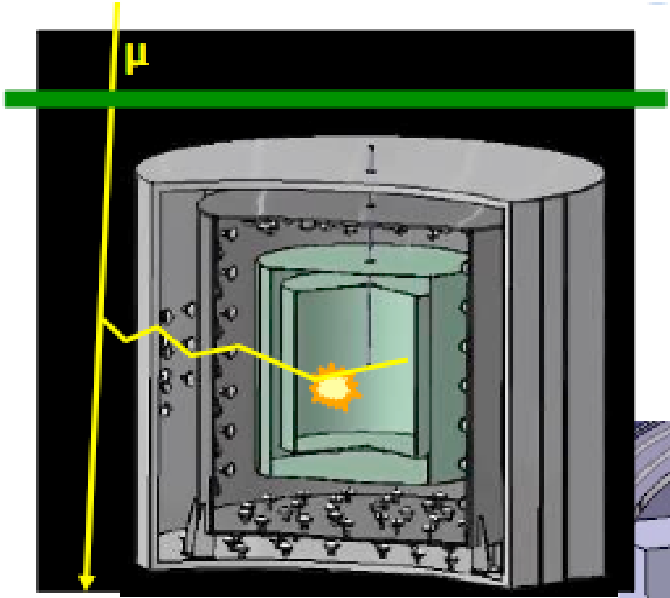


Muon Tracking



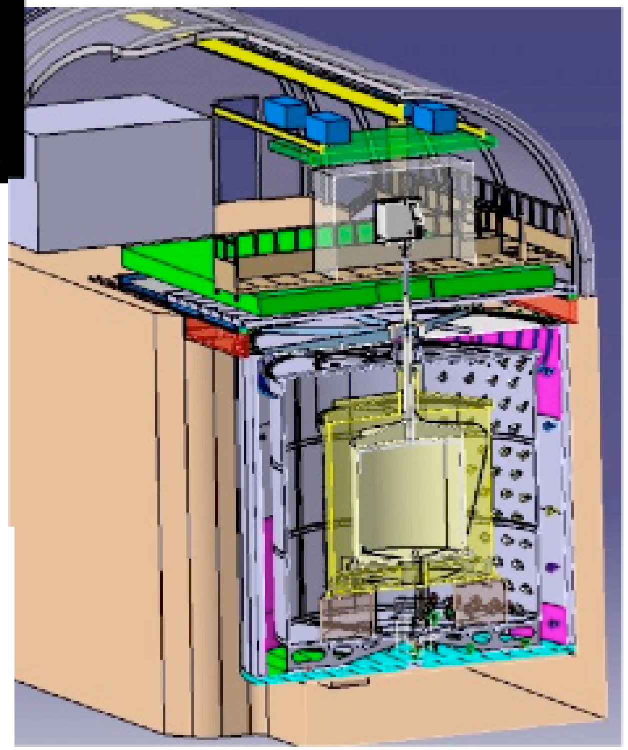
- Outer Veto
  - Tag near-miss muons
  - Entry point of any muon
- Inner Veto
  - Efficient tag of muons and secondaries
  - Track muon
- Muon Electronics
  - Attenuated output of Inner Detector PMTs
  - Track muon
- Use all 3 to reduce background systematic errors.

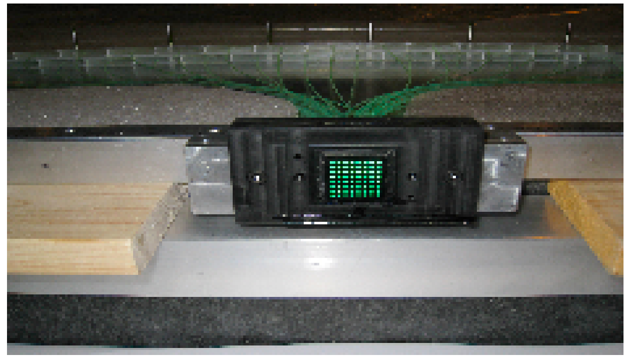
Outer Veto



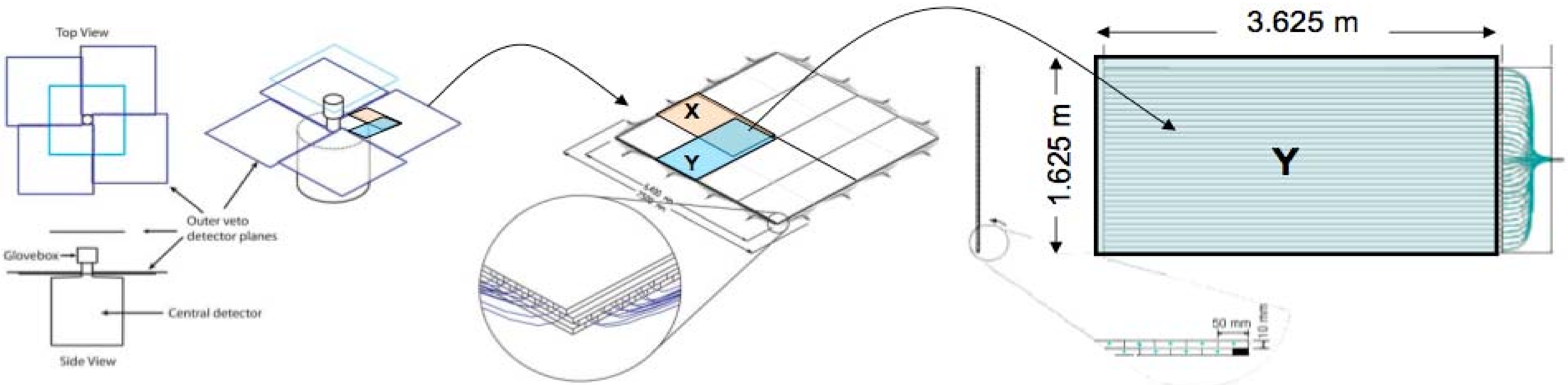
Tag near-miss muons, or missing deposit energy in the inner detector

- Chooz reactor off data gives ~1.5ν/day
- Strips of plastic scintillator and wavelength shifting fiber





Outer Veto cont'd



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

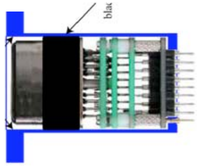
Full-scale OV module prototype built at U. Chicago

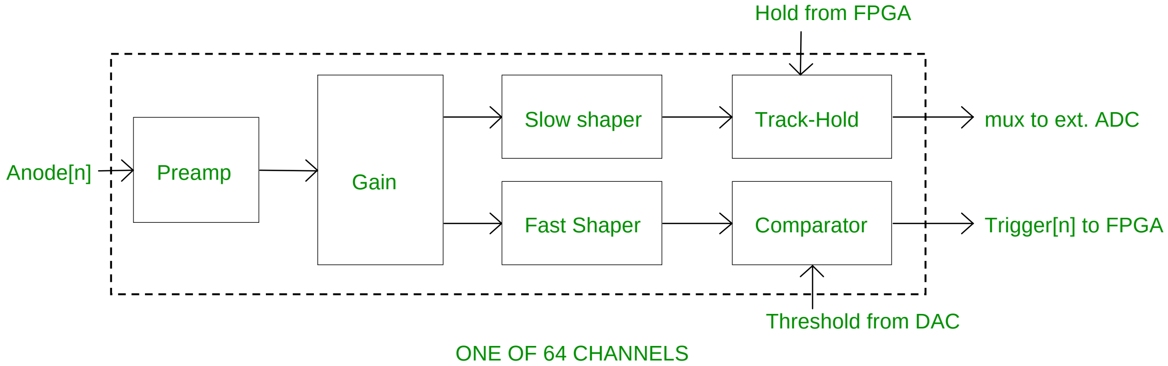
Electronics developed and tested at Columbia (Nevis)

Outer Veto: electronics

OV Readout Electronics

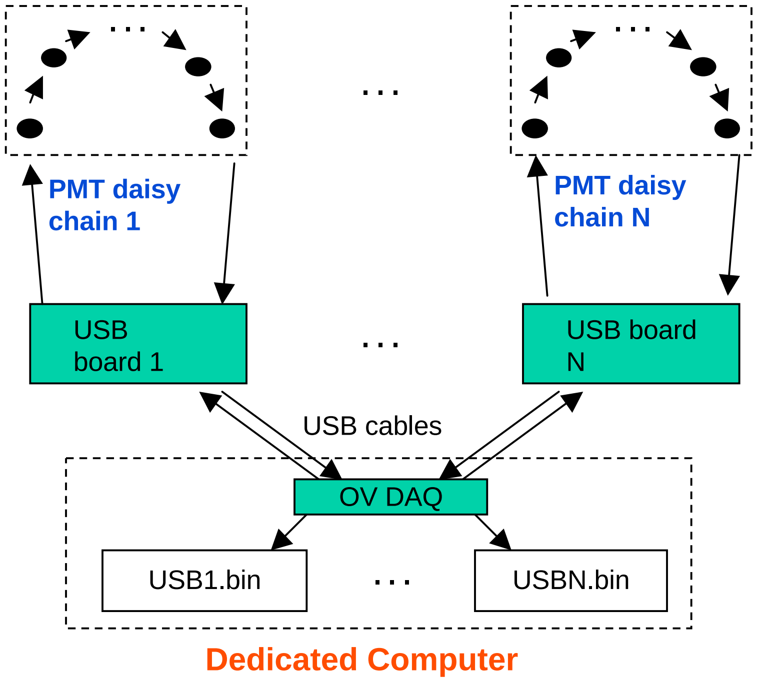
- Multi-anode PMT (M64)
- Multi-anode readout chip (Maroc2)
- Multi-anode readout card (custom-made at Columbia / Nevis labs)





OV High Voltage

- CAEN SY527 HV Mainframe
- 3-5 CAEN A734N HV cards
- HV Software developed at MIT

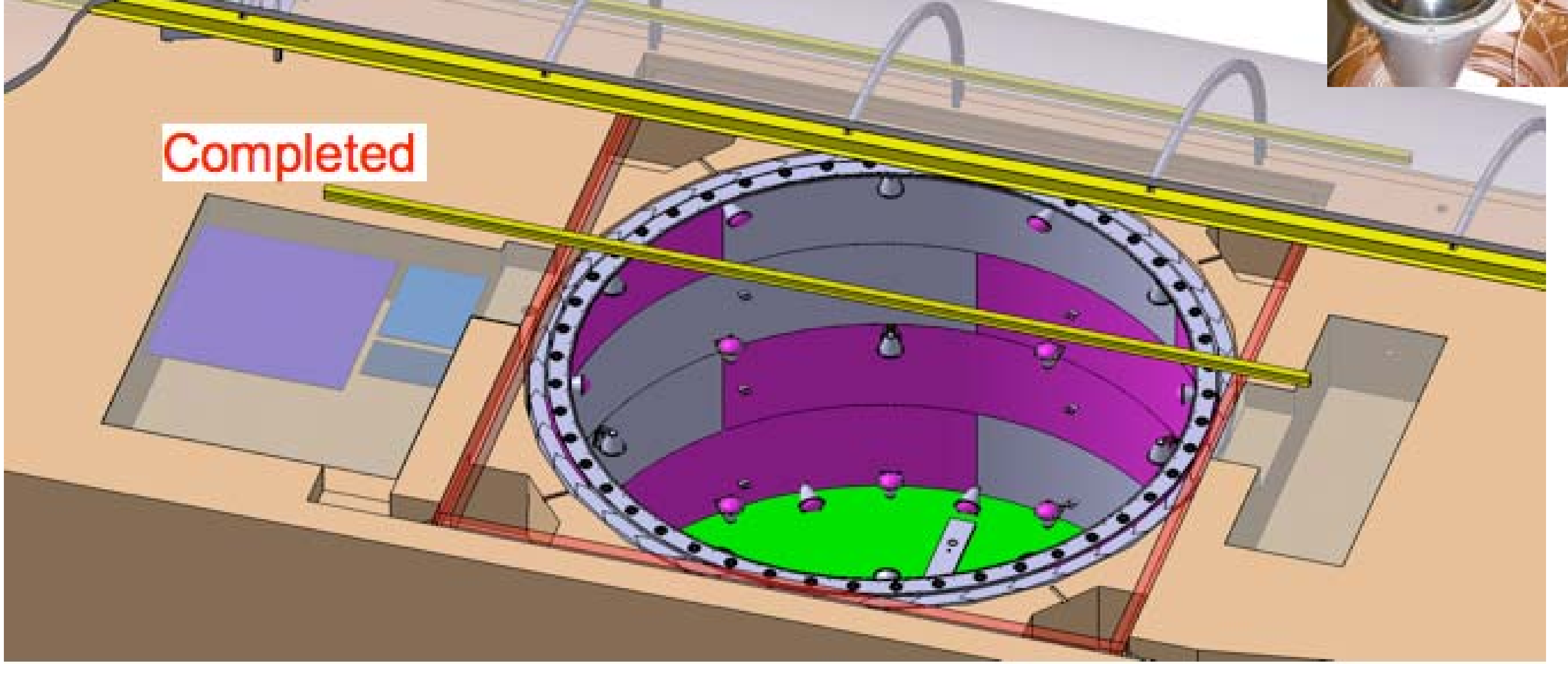


OV Readout Software

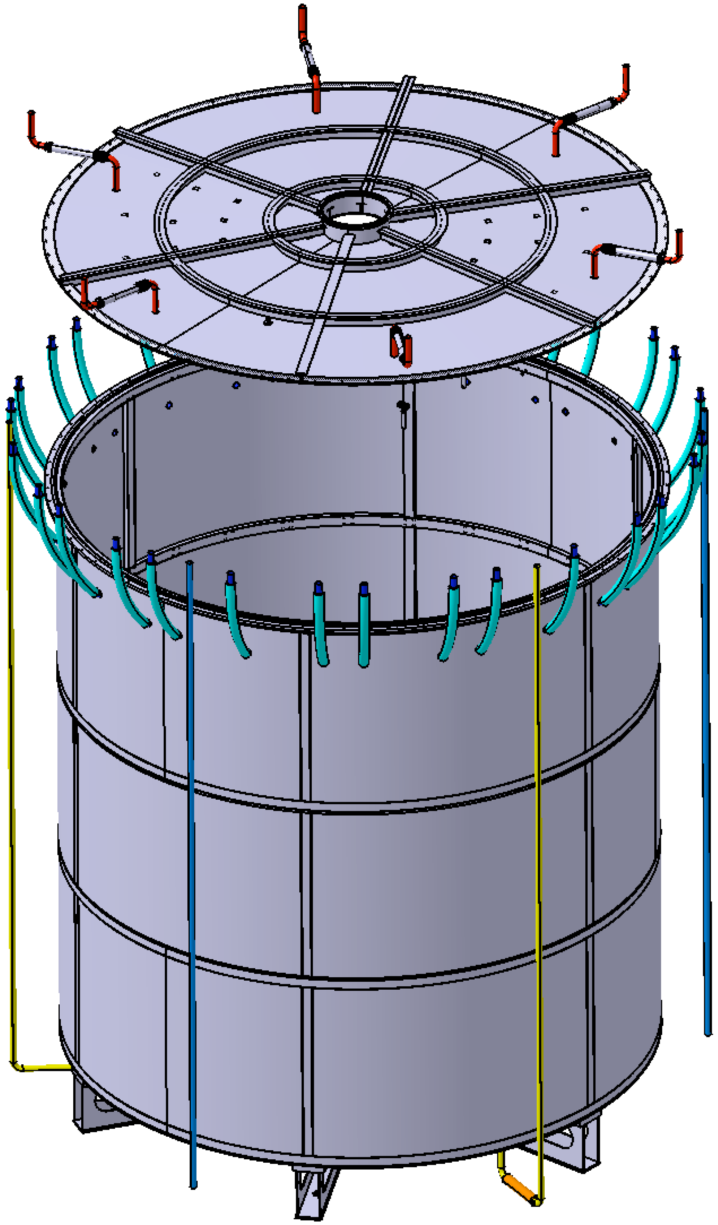
- USB-based readout system (developed at Columbia / Nevis Labs)
- PMTs connected via cat 6 cables in up to 6 different daisy-chains
- OV DAQ reads out each PMT daisy chain as a separate data stream via USB
- Data streams are combined and sorted to identify muons via event builder process running on raw data

Inner Veto

- Efficient tag of cosmic ray muons and fast neutrons
  - LAB and tetradecane, 50 cm thickness
  - 78 8“ PMTs (encapsulated IMB tubes)
  - Reflective walls (painted and foil)



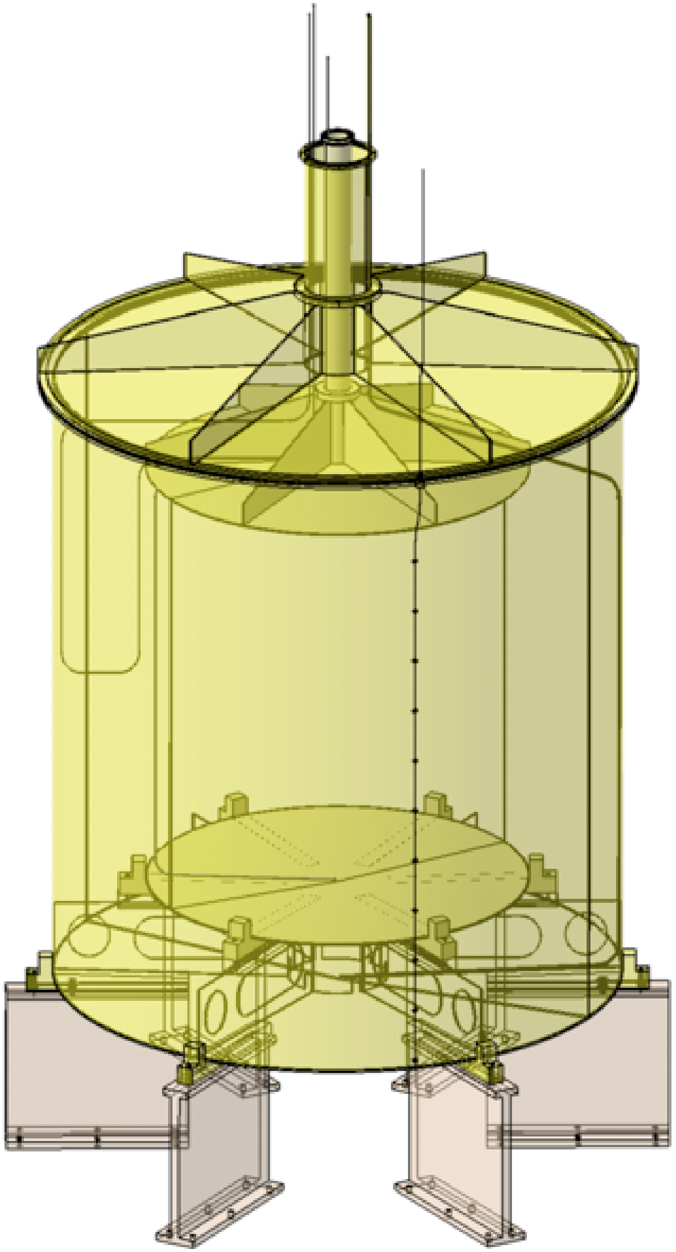
Buffer vessel



Installation already completed !

- Stainless steel 3mm thick
- Inner Height: 5674mm
- Inner Diameter: 5516mm
- Will contain 110m^3 of mineral oil
- 390 10'' PMTs to be attached to walls

Acrylic vessel

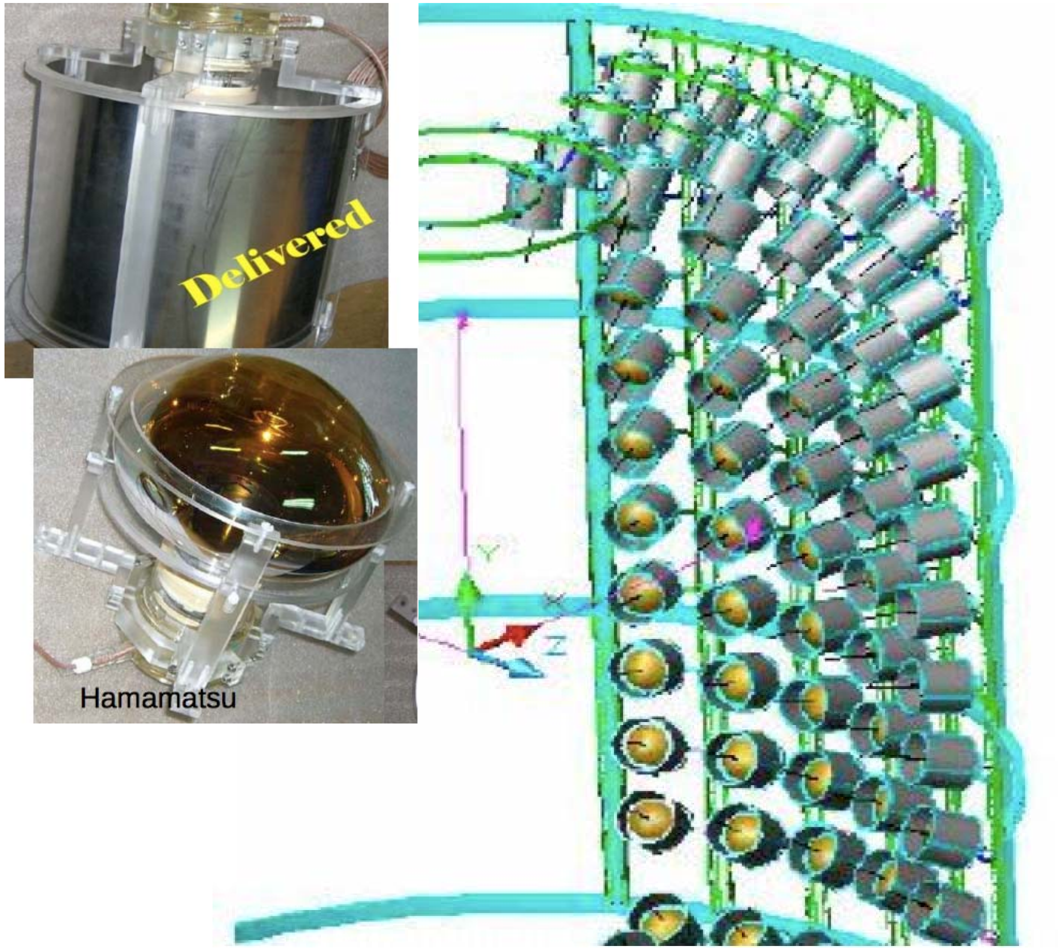


Gamma catcher
- 12 mm thick acrylic
- Inner Height: 3550 mm
- Inner Diameter: 3392 mm
- Will contain 22.3m^3 of scintillator (un-doped)

Target
- 8 mm thick acrylic
- Inner Height: 2458 mm
- Inner Diameter: 2300 mm
- Will contain 10.3m^3 of Gd-doped scintillator (1 g/l)

To be installed in June 2009!

Inner detector: photomultiplier

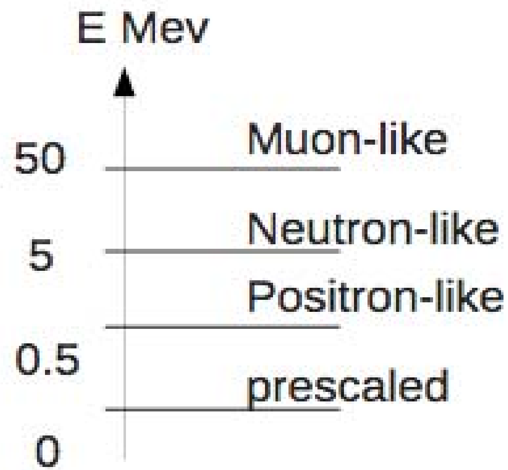


For Neutrino Signals

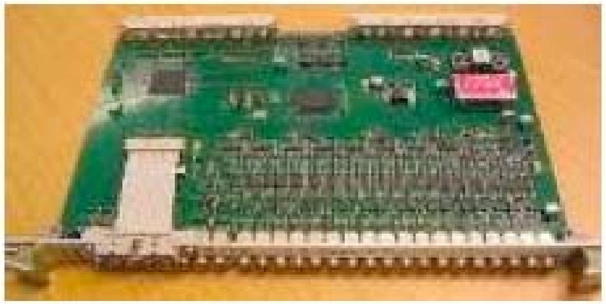
- Attenuated signals for muon electronics
- 15% coverage with 390 10" PMTs
- PMTs are angled to improve light collection uniformity
- Aim for 7% resolution at 1 MeV
- Low background version
- Extensive testing in Japan and Germany was performed.

Installation has started and is happening right now !

Trigger

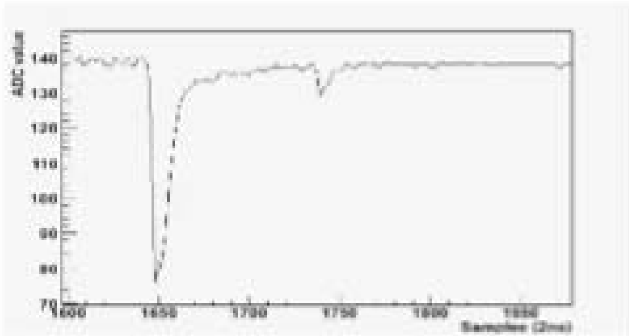


- Gives Info on type of event
  - Event ID (from energy of event)
  - Muon stops, crosses or passes ID?
- Information is passed to Waveform Digitizers



Waveform Digitizer

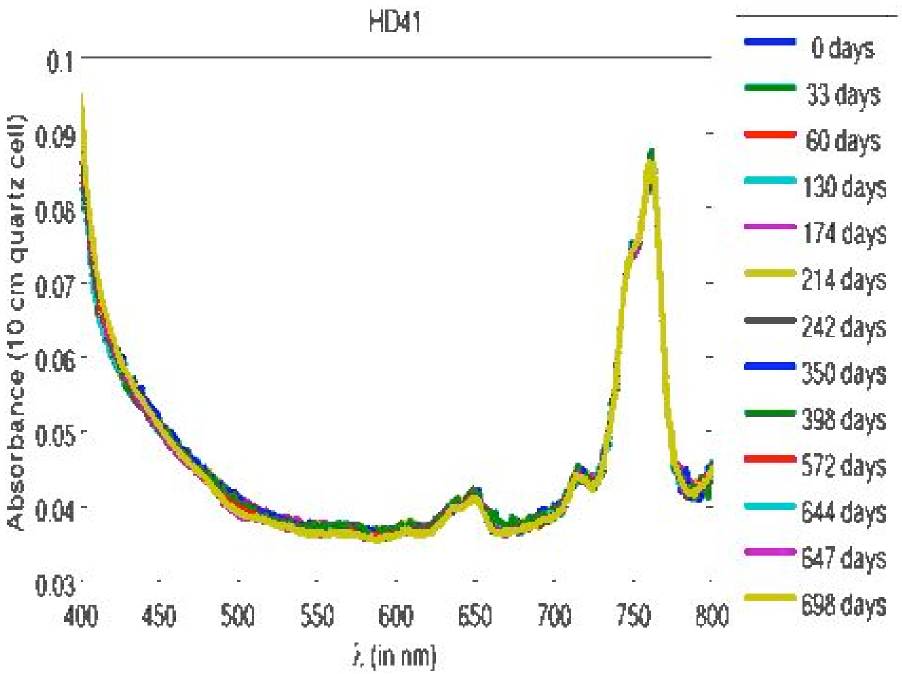
- 500 MHz 8-bit flash ADC (developed with Caen - V1721)
  - Less dead-time (for our expected event rate)
  - In-house firmware allows choice of event size based on
    - Info from trigger
    - Time between consecutive events
  - More data will be taken for the most interesting events



Gd - doped liquid scintillator

100kg Gd salt

- Stability tests reassuring;
- No change seen over ~700 days;
- Scintillator ingredients for both detectors ready to be mixed (MPIK);
- Mixing in one batch for both detectors;
- Exact proportions for both detectors (H, Gd);



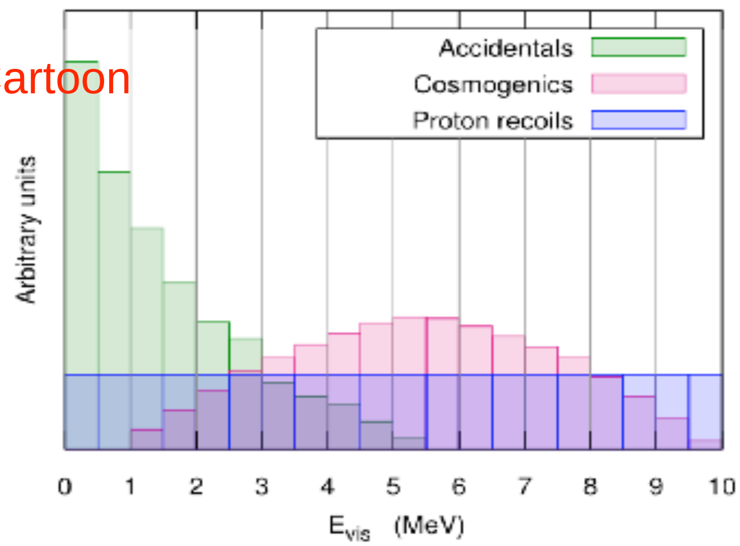
Backgrounds

Our signal is a positron followed by a neutron capture (2 triggers)

Accidental bkg

- Dominant source of accidentals - Radioactivity (from PMT)
- Solution - we aim for a singles rate of less than 5/s above 0.7 MeV
  - Stringent radio purity constraints

Cartoon



Correlated bkg

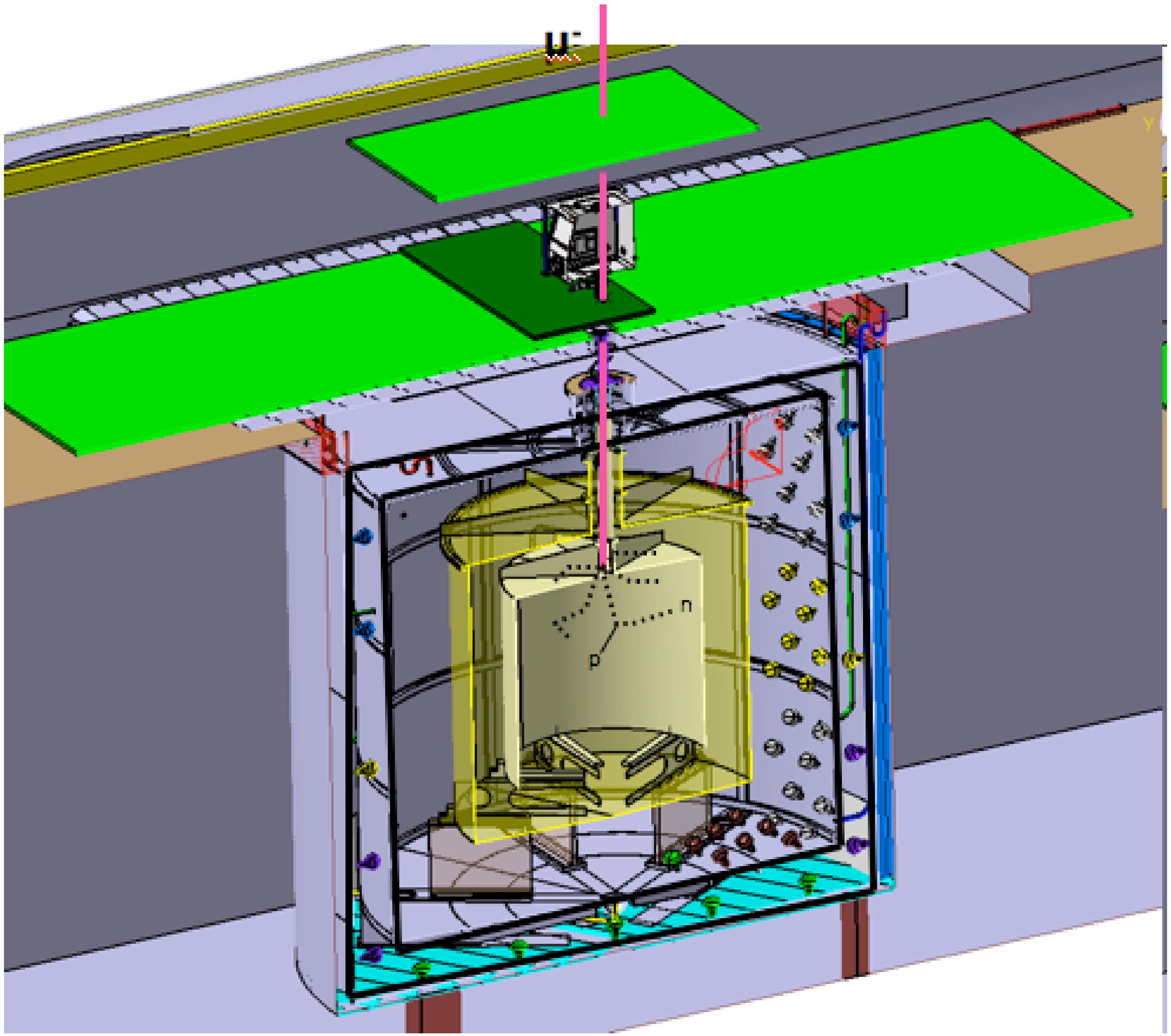
- Cosmogenics (β-neutron)
  - Li-9 and He-8 long lived
- Fast neutrons
  - Proton Recoil (positron-like signal) followed by neutron capture
- Caused by muons!
  - Crossing
  - Missing
  - Stopping

Want Signal/Background ratio > 50

Backgrounds: correlated

μ-Capture

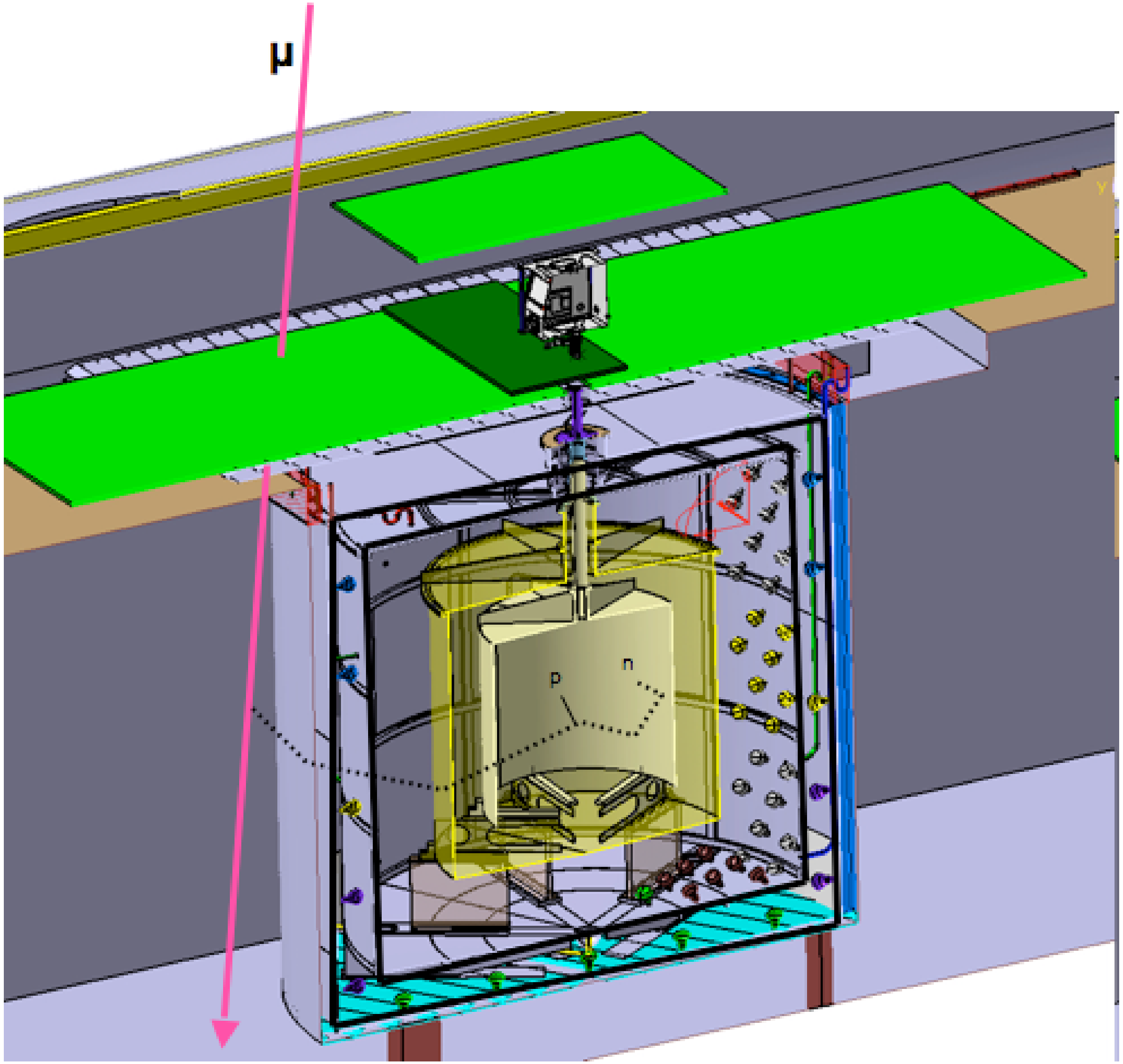
- Can cause nuclear break-up producing neutrons and cosmogenic nuclei
- Contributes to correlated backgrounds just as in previous 2 mechanisms
- Estimated from muon flux and μ^- capture rates in detector materials
- Expected to contribute <0.1% systematic error at both far and near detectors
- OV will be able to veto and track μ-capture on dead material in detector



Backgrounds: correlated

Fast n background

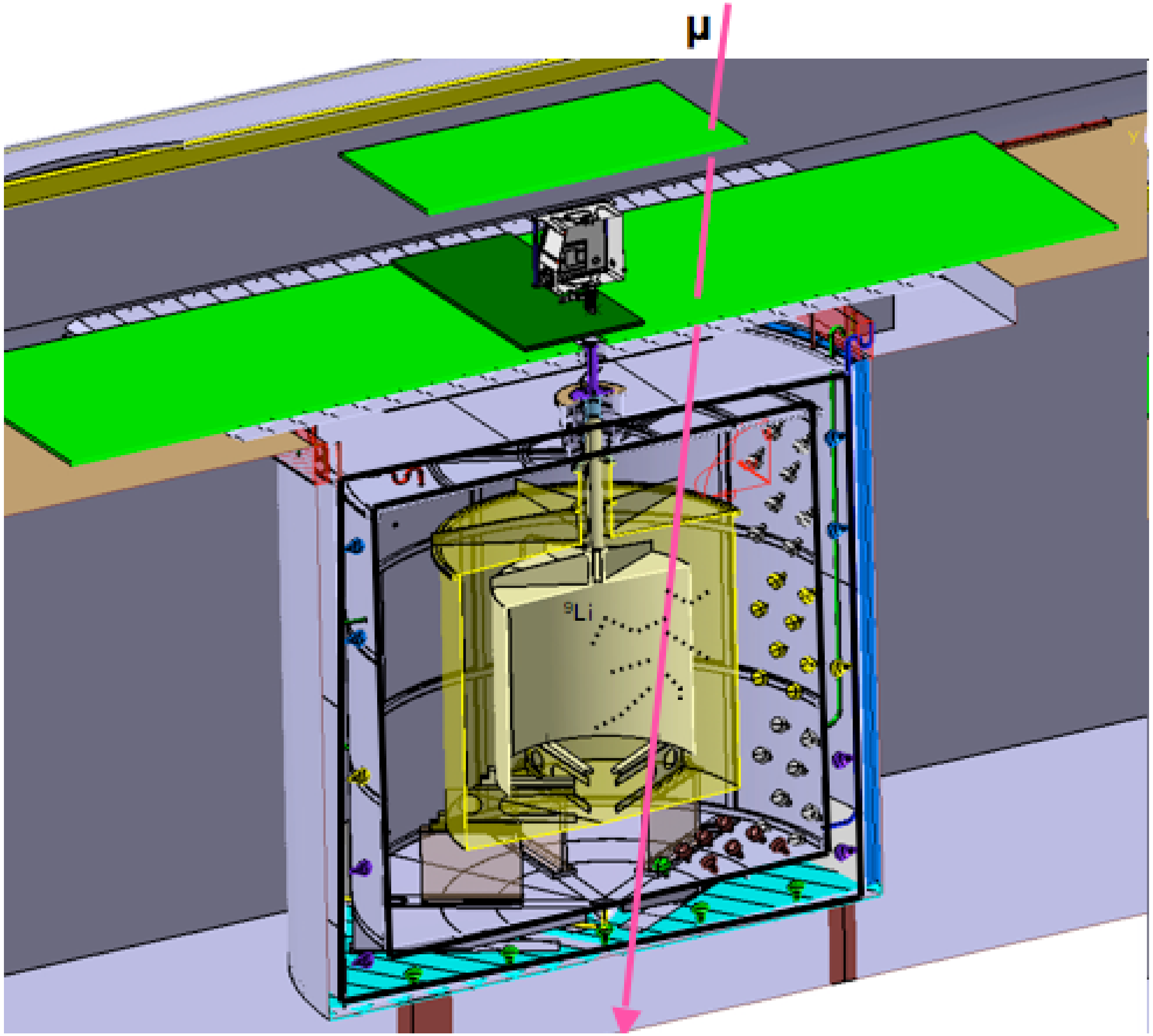
- Due to “near-miss” muons
- Neutrons created in the rock can propagate to target and scatter off a proton
- Proton recoil in target fakes positron signal
- Estimated using MC simulations benchmarked against CHOOZ data
- Expected to contribute a 0.2% systematic error in both far and near detectors
- OV will be able to veto the “near-miss” muons producing these neutrons



Backgrounds: correlated

Cosmogenics: ^{9}Li

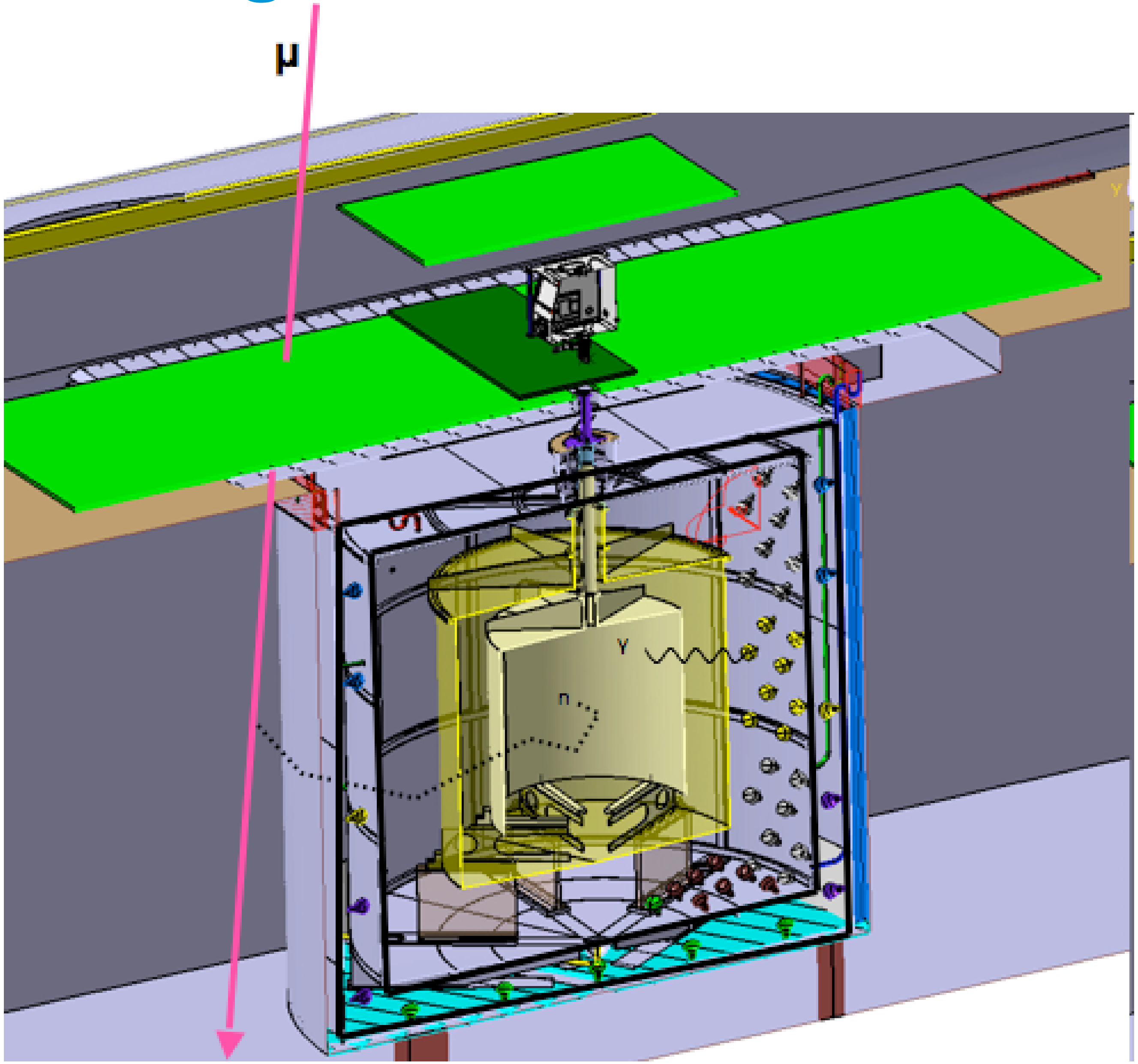
- Created by high-energy showering muons
- β-decay of ^{9}Li accompanied by neutron emission 50% of the time
- Has a lifetime of ~170 ms
- Estimated by fitting CHOOZ data and scaling to Double Chooz volume
- Expected to contribute a 0.7% (0.2%) systematic error in far (near) detector
- OV will be able to provide a tracked sample of muons to study this background



Backgrounds: uncorrelated

PMT radioactivity

- γ-rays from PMTs dominate the prompt signal event rate at 4-10 Hz
- Delayed signal event rate dominated by n capture on Gd (~83 h^{-1} in far detector)
- Can measure accidental coincidence rate to 10% by reversing coincidence cut
- Expected to contribute <0.1% systematic error in both far and near detectors
- OV will also veto “near-miss” muons associated with delayed signal



Background: summary

→ **All sources of background are <u>muon</u>-induced**

→ **OV especially important for far detector (worse signal-to-background ratio)**

Detector	Site		Background				
			Accidental		Correlated		
			Materials	PMTs	Fast n	μ-Capture	^{9}Li
CHOOZ		Rate (d^{-1})	—	—	—	—	0.6 ± 0.4
(24 ν/d)		Rate (d^{-1})	0.42 ± 0.05		$1.01 \pm 0.04(stat) \pm 0.1(sys)$		
	Far	bkg/ν	1.6%		4%		
		Systematics	0.2%		0.4%		
Double Chooz		Rate (d^{-1})	0.5 ± 0.3	1.5 ± 0.8	0.2 ± 0.2	< 0.1	1.4 ± 0.5
(69 ν/d)	Far	bkg/ν	0.7%	2.2%	0.2%	<0.1%	1.4%
		Systematics	<0.1%	<0.1%	0.2%	<0.1%	0.7%

Outer veto will help veto these background events

Outer veto will provide important handle for studying this background

Systematics

Systematic errors on the normalization of the detectors are kept low through:

- Improved detector design—fewer analysis cuts
- Two detector concept—relative normalization and efficiencies instead of absolute

			CHOOZ	Double Chooz
Reactor		Solid Angle	—	0.06%
Detector	H nuclei in Target	Volume	0.3%	0.2%
		Fiducial Volume	0.2%	0
		Density		0.1%
		H/C	0.8%	0
Detector	Electronics	Dead Time	—	0%
Particle Identification	Positron	Escape	0.1%	0
		Capture	0	0
		Energy Cut	0.8%	0.2%
Particle Identification	Neutron	Escape	1.0%	0
		Capture (% Gd)	0.85%	0.3%
		Identification Cut	0.4%	0.1%
Particle Identification	Antineutrino	Time Cut	0.4%	0.1%
		Distance Cut	0.3%	0
		Unicity	0.5%	0
Total			1.5%	$\boxed{0.5\%}$

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→ Critical to keep background contributions to systematics 0.1%

Systematic error: detector

		Chooz	Double Chooz	
Detector - induced	Solid angle	0.3 %	<0.1 %	
	Volume	0.3 %	0.2 %	Precise target mass measurement
	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 %	Spill in/out compensate to ~1%
	Live time	?	0.25 %	Difference near/far is relevant !

Systematic error: reactor

Chooz		Double Chooz
• Flux and cross-section 1.9%	->	<0.1%
• Reactor Power 0.7%	->	<0.1%
• Energy per fission 0.6%	->	<0.1%

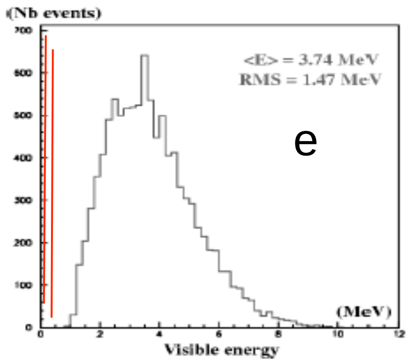
- Two 'identical' detectors (with low backgrounds)

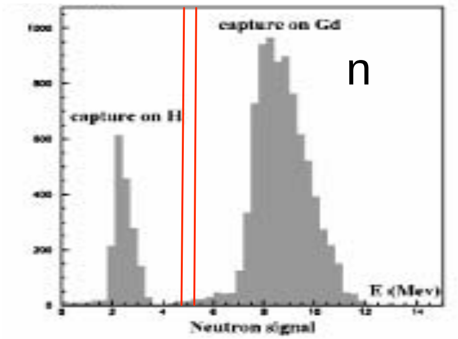
Systematic error: analysis

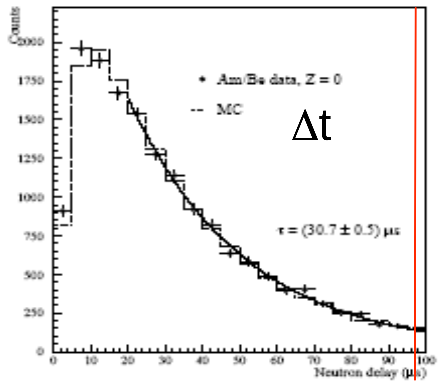
- Lower threshold (see all of positron spectrum)
- Target Acrylic vessel (no fiducial volume cut)

	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







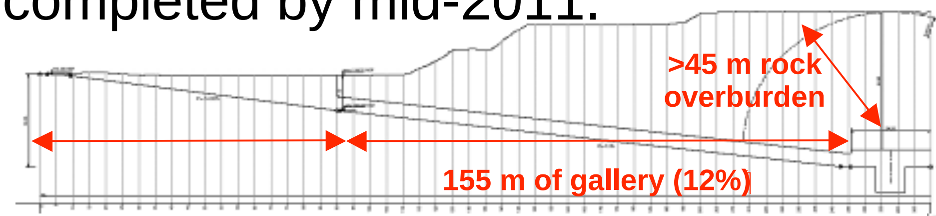
* Easier to control near vs far than absolute

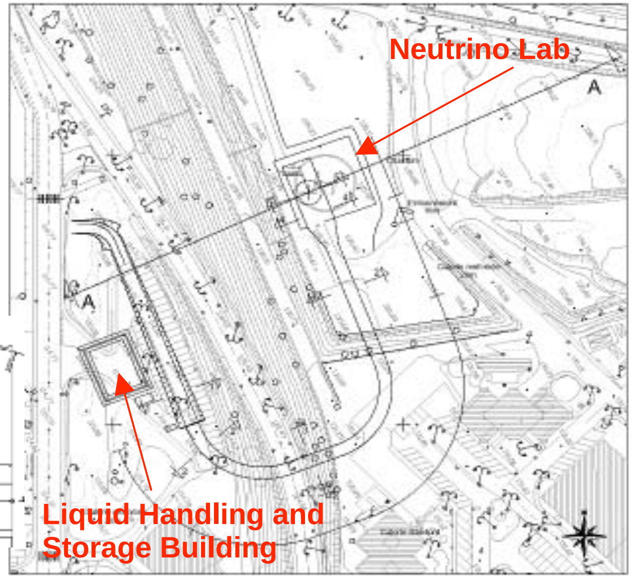
Status: Near Lab

Geological survey done

Finalization of access tunnel + lab excavation design

civil engineering to be completed by mid-2011.





Detector to be integrated by end of 2011.

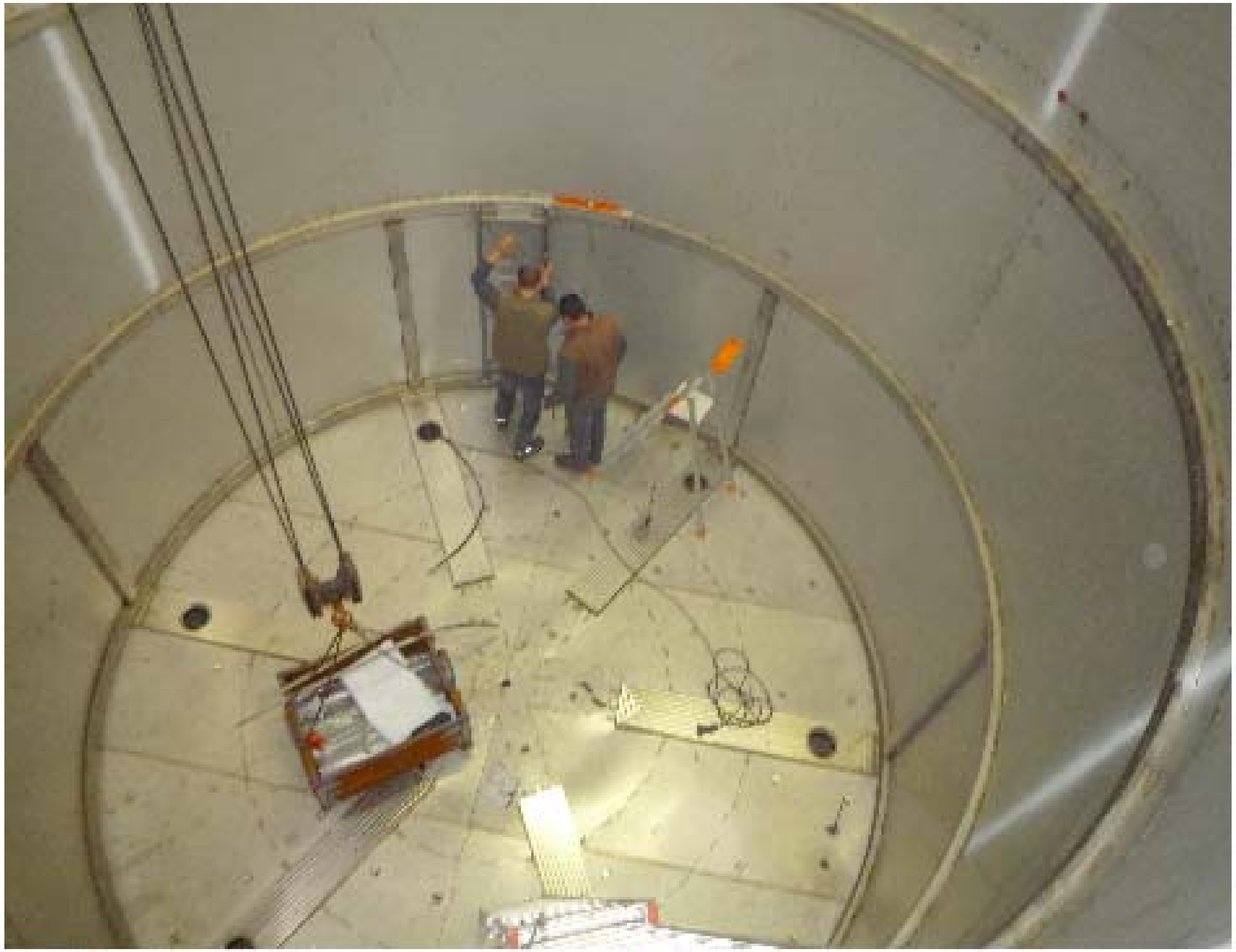
Status: Far Detector

Lab for the original Chooz experiment

Status: Far Detector

IV PMTs installed (Feb)

Status: Far Detector



Buffer Vessel during construction (at company).

Installation already completed.

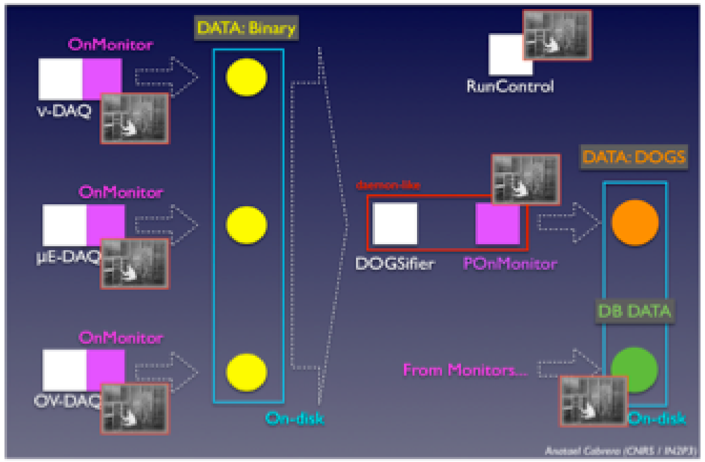
Status: PMT installation

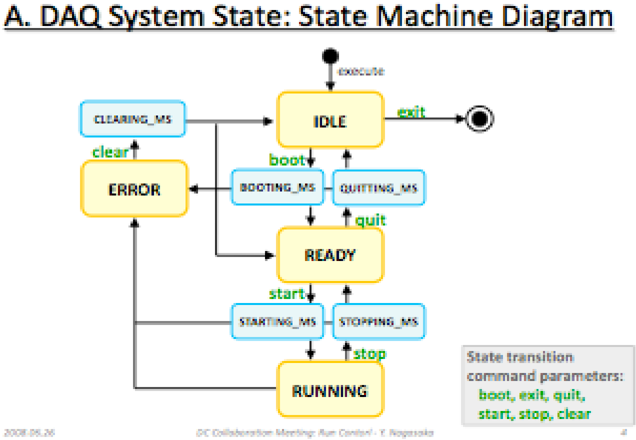
- PMT installation started this May;
- Will be completed by 29 of June for the bottom and wall PMTs;
- Lid PMTs installation in September

Status: Storage facility

Status: DAQ and online monitor

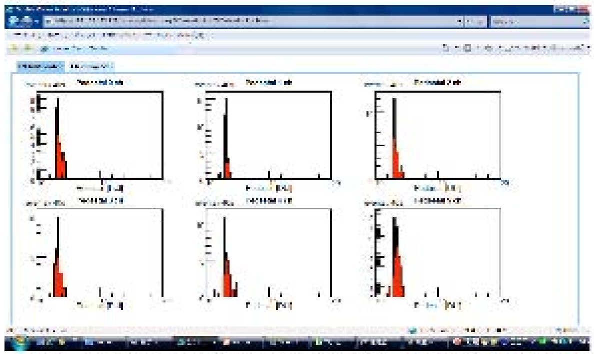
Online: data-wise



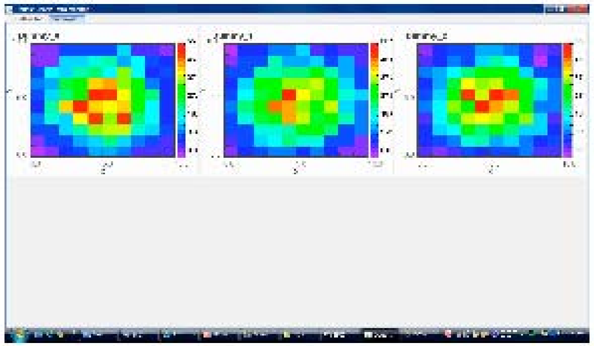


- Data quality monitoring (Pseudo-online Mon.) and histogram viewer graphical interface (Tokyo Tech, Tohoku-Gakuin)

DCMonitor on Web browsers
(1-D histogram, MC)

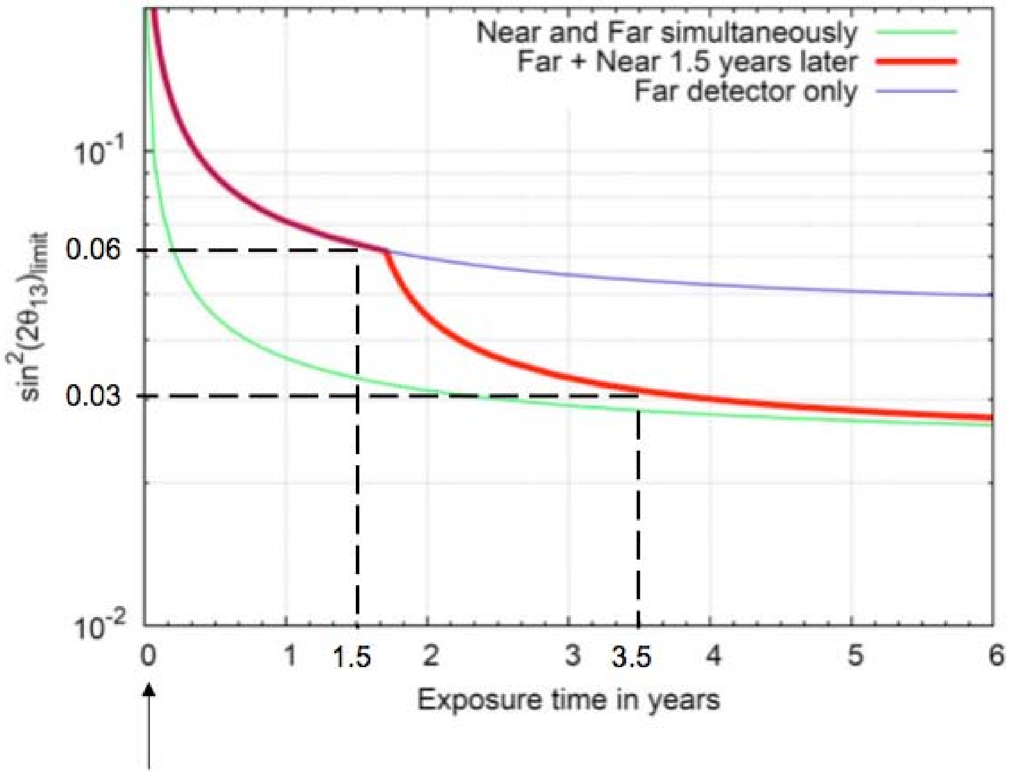


DCMonitor on Java Viewer
(2-D histogram, Dummy data)

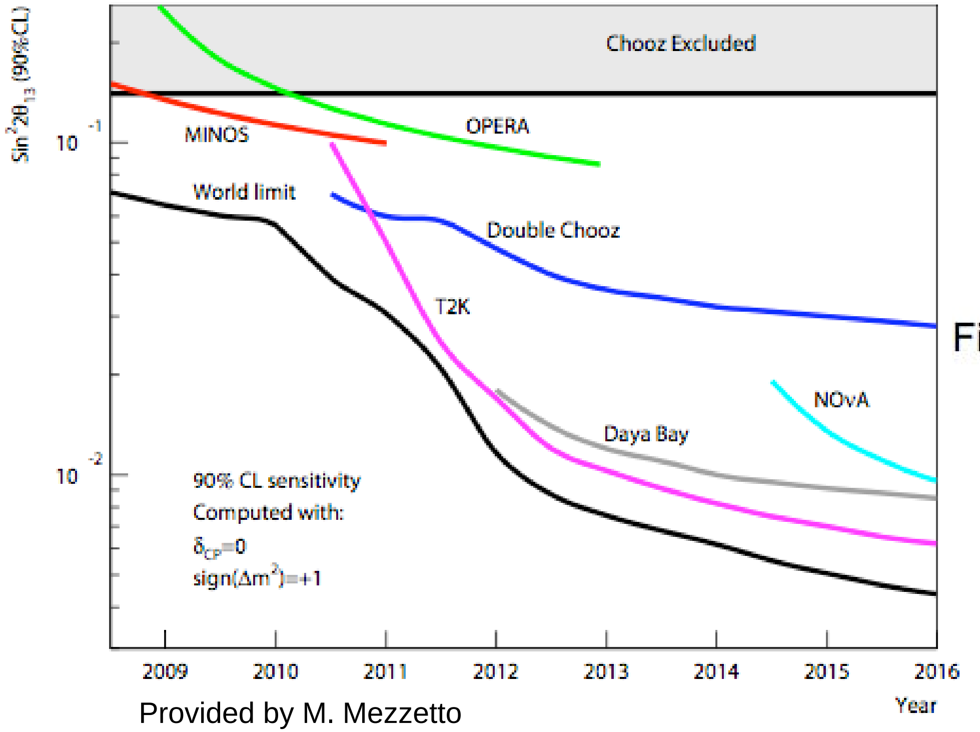


Sensitivity

- First phase – just far detector
- Second phase – both detectors

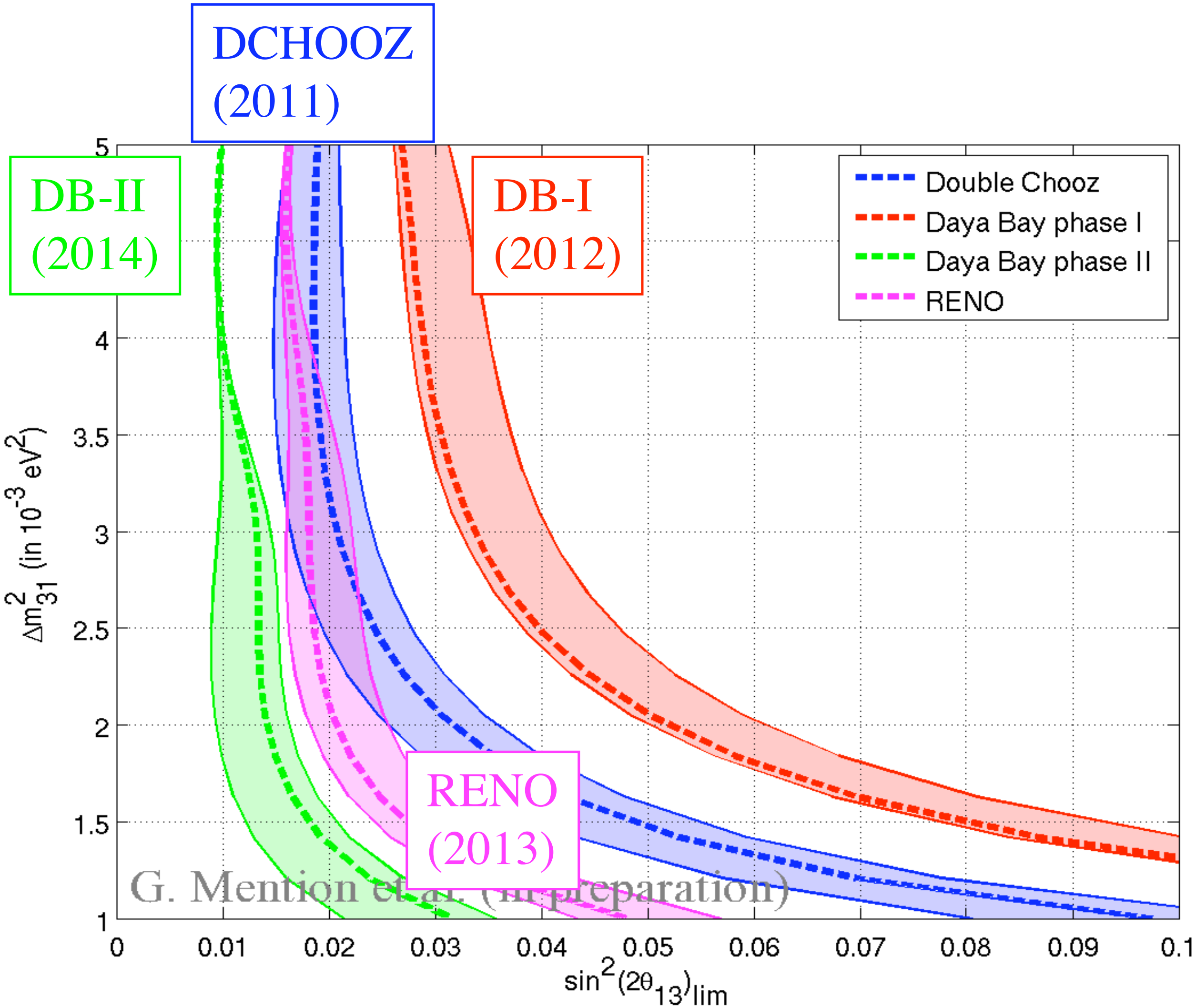


First data at the end of 2009



Provided by M. Mezzetto

Sensitivity cont'd



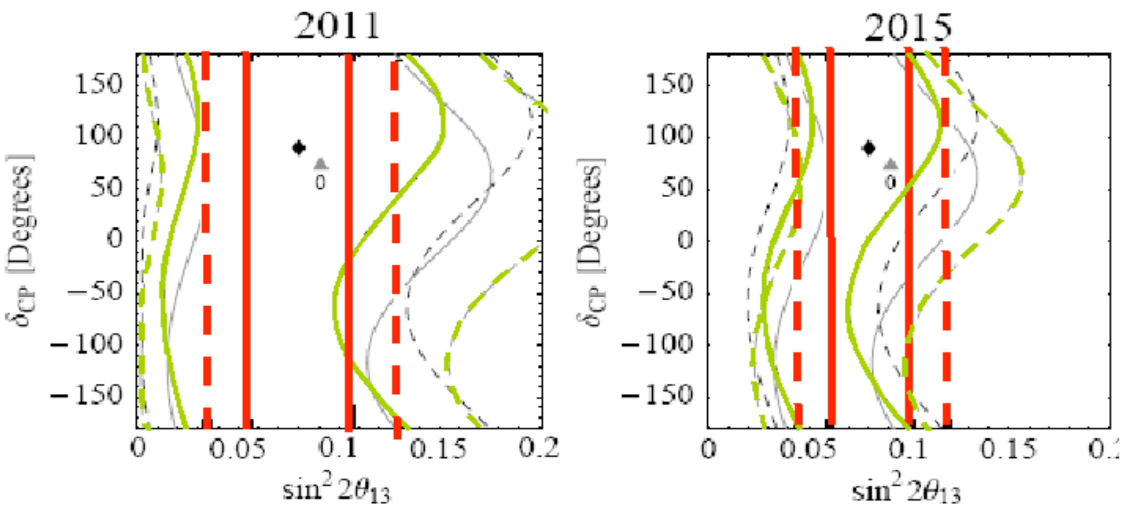
Conclusion

- NOW : far detector construction
- End of 2009 : far detector running
- 2011 : near detector installation
- 2013: reach target sensitivity $\sin^2 2\Theta_{13}$~0.03 (for Δm^2_{31}=2.5x10^{-3} eV^2)

Backup slides

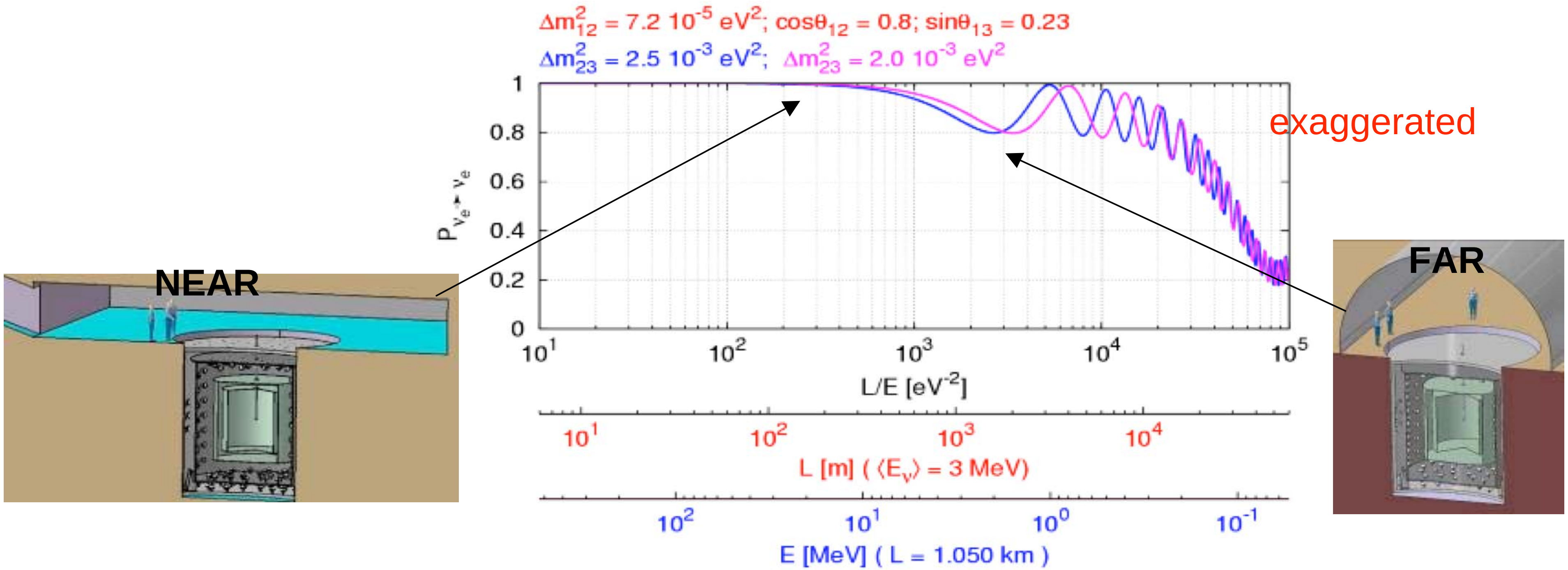
Complementary to Beam experiments

- Example of Double Chooz results compared to T2K
  - Assume full power for T2K
  - 2 years of 2 detector (DC)
  - Full =90%, dashed 3σ
- No dependence on δcp (reactor)



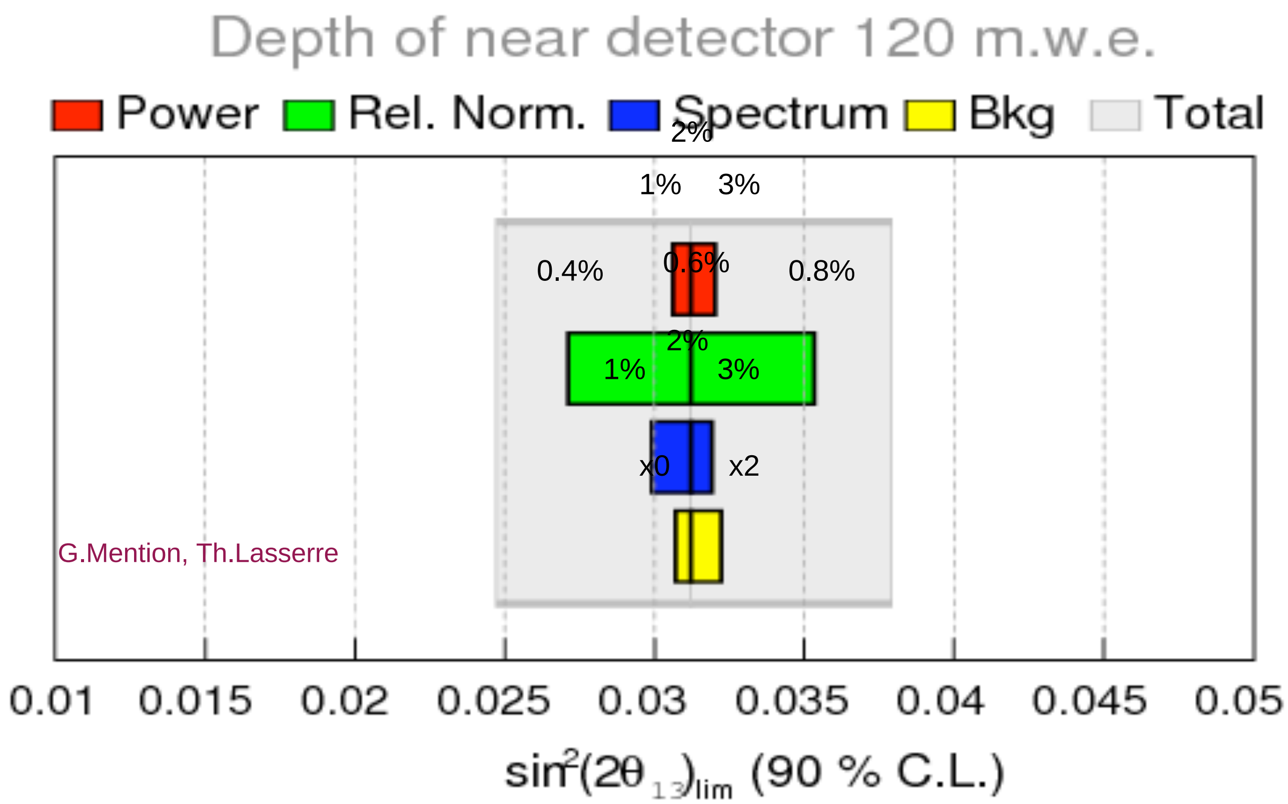
Reactor Experiments

- Disappearance of anti-neutrinos (independent of δ_{cp} and sign of Δm_{31}, weak dependence of Δm_{21})
- ~MeV energy signals, short distances (no matter effects);
- Independent from neutrino cross section and nuclear effect (FSI)
- But, limited by knowledge of processes inside reactor;



Radioactive Contamination Levels

	^{40}K g/g	^{238}U g/g	^{232}Th g/g	^{60}Co mBq/Kg
Target LS	10^{-10}	10^{-13}	10^{-13}	—
Target Acrylics	10^{-8}	10^{-11}	10^{-11}	—
GC LS	10^{-10}	10^{-13}	10^{-13}	—
GC Acrylics	10^{-8}	10^{-11}	10^{-11}	—
Buffer Oil	—	10^{-12}	10^{-12}	—
Buffer Vessel	—	10^{-9}	10^{-9}	15
Veto LS	—	10^{-10}	10^{-10}	—

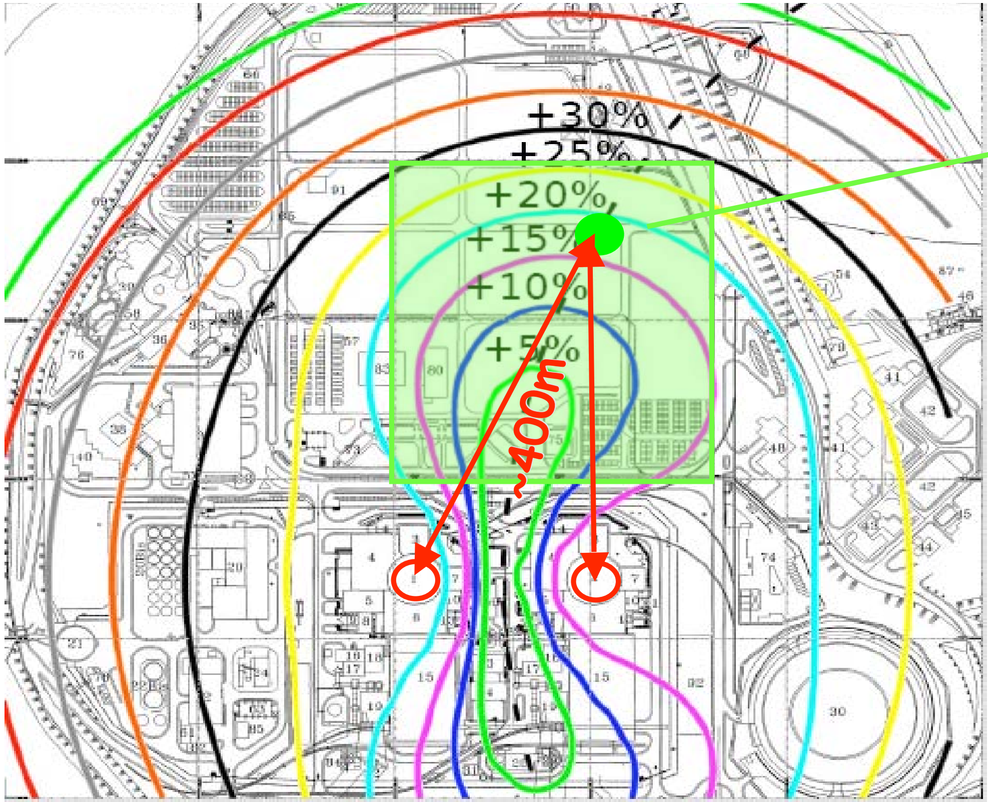


Total systematics: <~ 0.6%
Statistics: 60000 neutrino events @ Far Detector

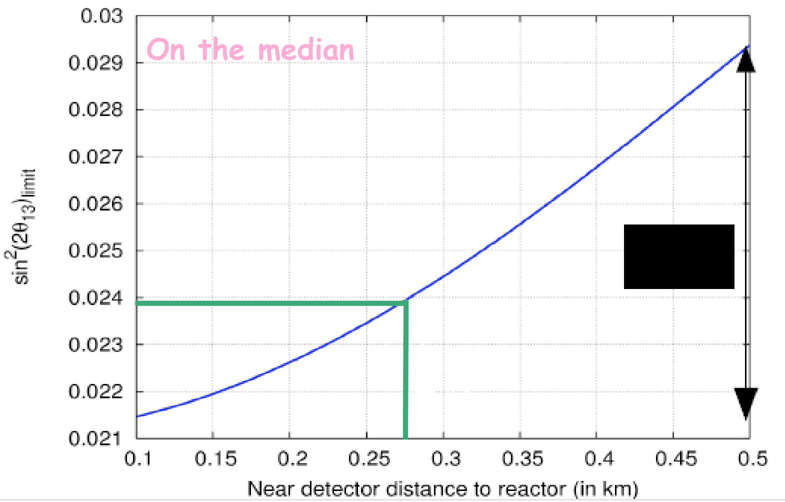
Near detector location

- Uncorrelated fluctuations included
- Relative Error : 0.6%
- Spectral shape uncertainty 2%
- Δm^2 known at 20%
- Power flucutation of each core: 3%

$$\chi^2 = \min_{\{\alpha_{i,k}^{D,R}\}} \left\{ \sum_{D=N,F} \sum_{i=1}^{NBins} \left[\left(\frac{\sum_{R=R_1,R_2} \left[O_i^{D,R} - T_i^{D,R} - \sum_{k=1}^{K} \alpha_{i,k}^{D,R} S_{i,k}^{D,R} \right]}{U_i^D} \right)^2 + \sum_{R=R_1,R_2} \sum_{k=1}^{K} c_{i,k}^{D,R} \left(\frac{\alpha_{i,k}^{D,R}}{\sigma_k^{D,R}} \right)^2 \right] \right\}$$



Spent fuel effect under study kopeikin and al.



3 years data taking

Background Comparison

Detector	Site		Accidental: Materials	Accidental: PMTs	Correlated: Fast n	Correlated: μ-Capture	^{9}Li
CHOOZ		Rate (d^{-1})	—	—	—	—	0.6 ± 0.4
(24 ν/d)		Rate (d^{-1})	0.42 ± 0.05		$1.01 \pm 0.04(stat) \pm 0.1(sys)$		
	Far	bkg/ν	1.6%		4%		
		Systematics	0.2%		0.4%		
Double Chooz		Rate (d^{-1})	0.5 ± 0.3	1.5 ± 0.8	0.2 ± 0.2	< 0.1	1.4 ± 0.5
(69 ν/d)	Far	bkg/ν	0.7%	2.2%	0.2%	<0.1%	1.4%
		Systematics	<0.1%	<0.1%	0.2%	<0.1%	0.7%
Double Chooz		Rate (d^{-1})	5 ± 3	17 ± 9	1.3 ± 1.3	0.4	9 ± 5
(1012 ν/d)	Near	bkg/ν	0.5%	1.7%	0.13%	<0.1%	1%
		Systematics	<0.1%	<0.1%	0.2%	<0.1%	0.2%

estimates with "old" near detector location
= conservative
(with new location: Nv/2 , N_μ/3)

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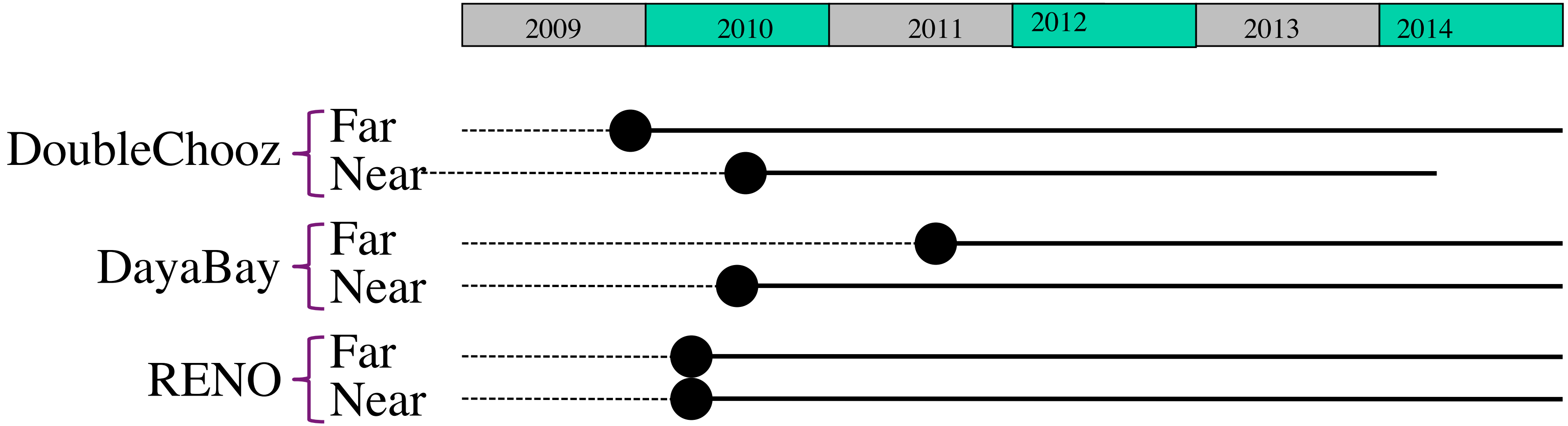
Signal/Bkg >50



DC, Dayabay and RENO finally start data taking within a year or two.

The neutrino study will go in the next phase a few years later.