Physics with a Super Neutrino beam and a large water Cherenkov detector.

Milind Diwan (diwan@bnl.gov) 9/15/2008
IPN-Orsay

- Brief Review
- Description of oscillations experimentation.
- New projects
- Ambitions for a new deep laboratory in the US

Many slides from others.

BROOKHAVEN NATIONAL LABORATORY

Standard Model of

FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

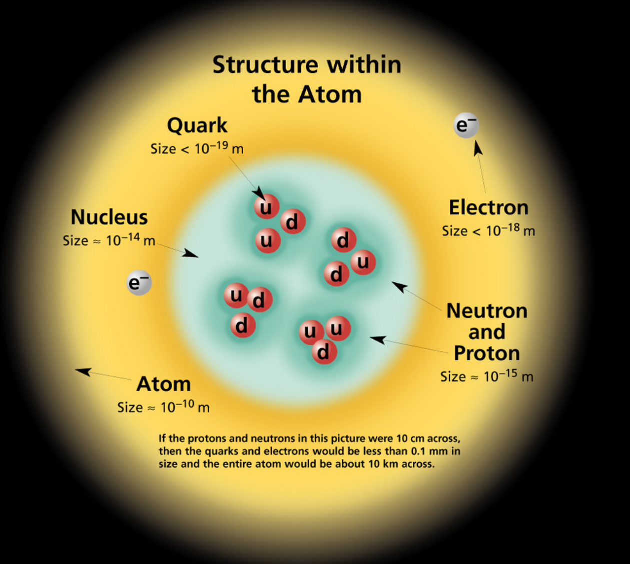
Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

Spin is the intrinsic angular momentum of particles. Spin is given in units of ħ, which is the quantum unit of angular momentum, where $\hbar = h/2\pi = 6.58\times10^{-25}$ GeV s = 1.05×10^{-34} J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The **energy** unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. **Masses** are given in GeV/c^2 (remember $E = mc^2$), where 1 GeV = 10^9 eV = 1.60×10^{-10} joule. The mass of the proton is 0.938 GeV/c^2 = 1.67×10^{-27} kg.



If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1

Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1

Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Color Charge

Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and ***W*** and ***Z*** bosons have no strong interactions and hence no color charge.

Quarks Confined in Mesons and Baryons

One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons** $q\bar{q}$ and **baryons** qqq.

Residual Strong Interaction

The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	Not applicable to quarks
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$

Baryons are fermionic hadrons. There are about 120 types of baryons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	–1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	–1	1.672	3/2

Mesons $q\bar{q}$

Mesons are bosonic hadrons. There are about 140 types of mesons.

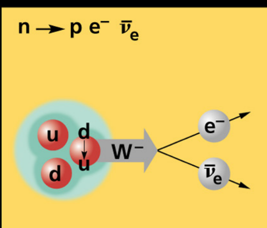
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	–1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2 .980	0

Matter and Antimatter

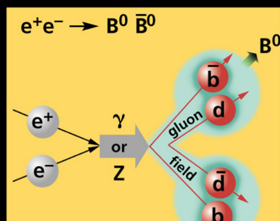
For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or – charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0, γ, and $\eta_c = c\bar{c}$, but not $K^0 = d\bar{s}$) are their own antiparticles.

Figures

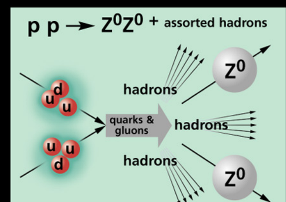
These diagrams are an artist's conception of physical processes. They are ***not*** exact and have ***no*** meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.



A neutron decays to a proton, an electron, and an antineutrino via a virtual (mediating) W boson. This is neutron β decay.



An electron and positron (antielectron) colliding at high energy can annihilate to produce B^0 and $\bar{B}^0$ mesons via a virtual Z boson or a virtual photon.



Two protons colliding at high energy can produce various hadrons plus very high mass particles such as Z bosons. Events such as this one are rare but can yield vital clues to the structure of matter.

The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at **http://ParticleAdventure.org**

This chart has been made possible by the generous support of:

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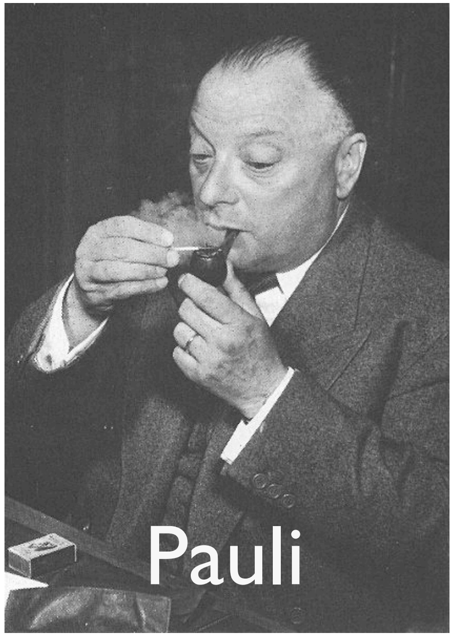
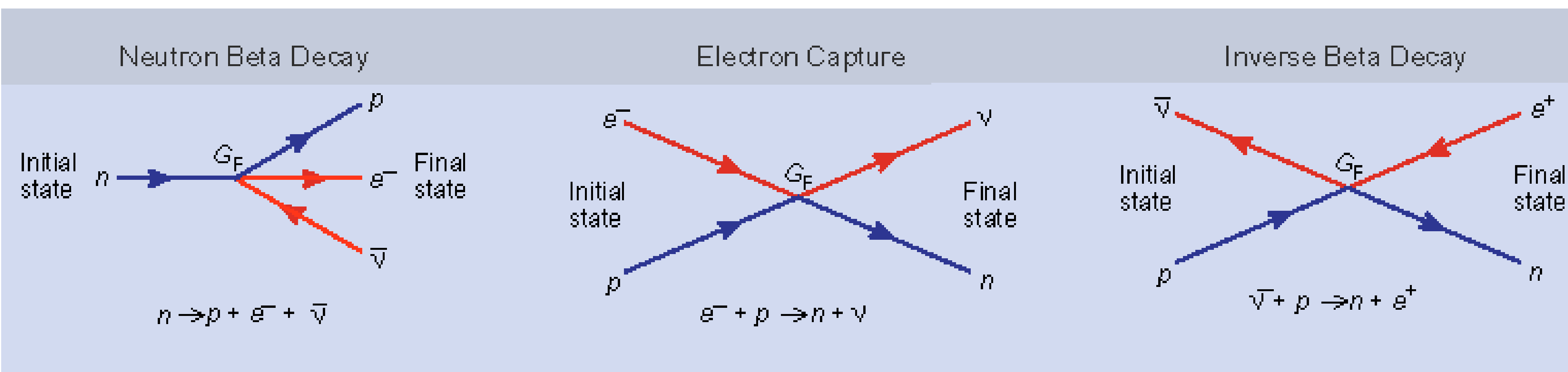


Inventor

Developer

Oscillator

small cross section: 10^{-38} cm² E/GeV



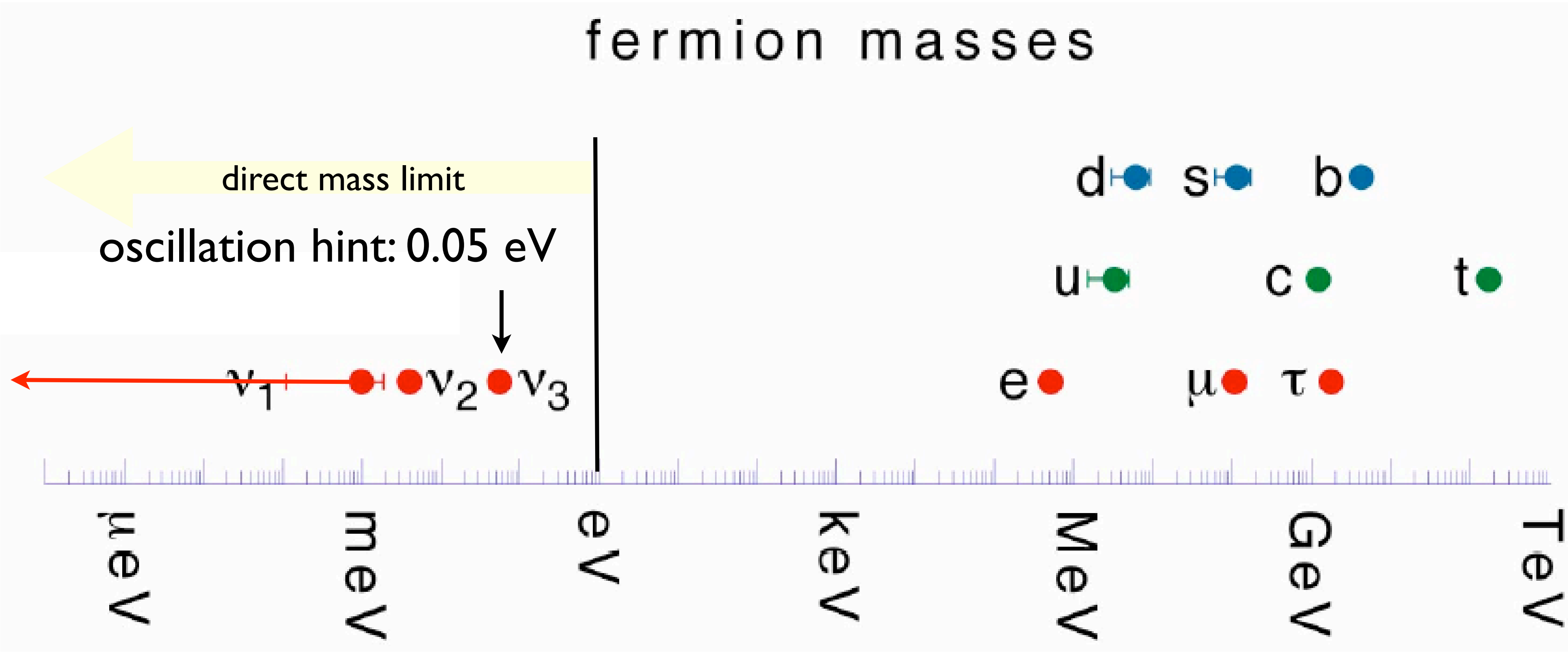
Additions afterwards

- Neutral currents:
  - neutrino +N -> neutrino +N
- 3 types of neutrinos: electron, muon, tau
  - Neutrino + N -> N' + lepton

Neutrino puzzles

- Do they have mass ? Why so small ?
- If they have mass what implications on left-right properties ?
- Can they turn into each other ?
- What implications for the structure of the universe ?
- What is the relationship to quarks ?

Current picture of masses from oscillations puzzling.



hierarchy

Why Mass could imply Lepton number violation

	Particle	Anti-particle
Left	$(e \quad \nu)_L$	$\overline{(e \quad \nu)_L}$
Right	$e_R \quad \nu_R$	$\bar{e}_R \quad \bar{\nu}_R$

- Standard model has only left handed leptons in isopin states. But if neutrino has mass it can become right handed.
- If $\bar{\nu}_L = \nu_R$ (Majorana) then neutrinos are their own antiparticles and can annihilate themselves.

Brief review of oscillations

Assume a 2×2 neutrino mixing matrix.

$$\begin{pmatrix} \nu_a \\ \nu_b \end{pmatrix} = \begin{pmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}$$

$$\begin{aligned} \nu_a(t) &= \cos(\theta)\nu_1(t) + \sin(\theta)\nu_2(t) \\ P(\nu_a \to \nu_b) &= |<\nu_b|\nu_a(t)>|^2 \\ &= \sin^2(\theta)\cos^2(\theta)|e^{-iE_2t} - e^{-iE_1t}|^2 \end{aligned}$$

Sufficient to understand most of the physics:

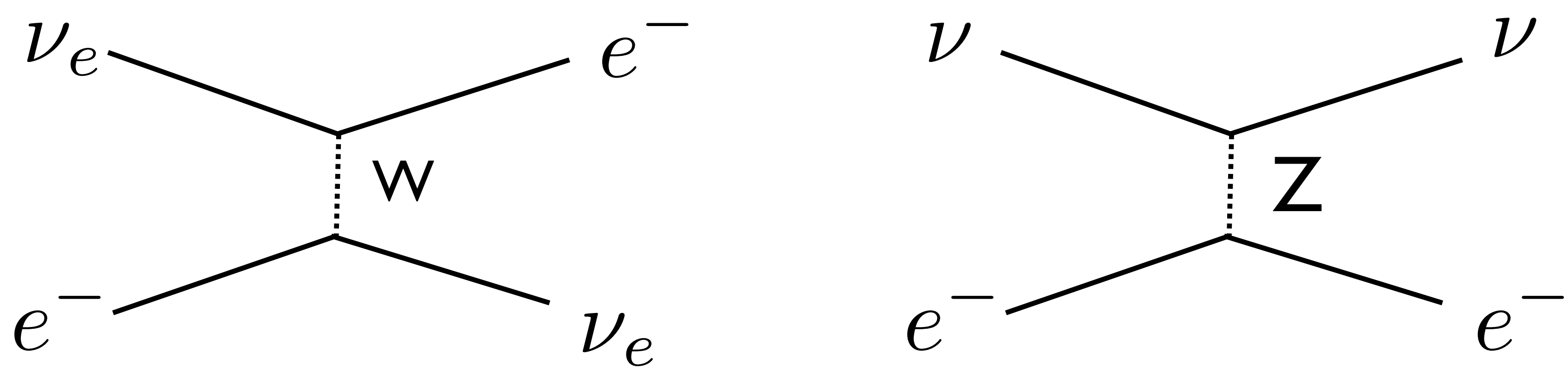
$$P(\nu_a \to \nu_b) = \sin^2 2\theta \sin^2 \frac{1.27((m_2^2 - m_1^2)/eV^2)(L/km)}{(E/GeV)}$$

$$P(\nu_a \to \nu_a) = 1 - \sin^2 2\theta \sin^2 \frac{1.27(\Delta m^2/eV^2)(L/km)}{(E/GeV)}$$

Oscillation nodes at $\pi/2, 3\pi/2, 5\pi/2, ...$ ($\pi/2$): $\Delta m^2 = 0.0025 eV^2$, $E = 1 GeV$, $L = 494 km$.

$$i\frac{d}{dx}\nu_f = HR_\theta\nu_m$$

L. Wolfenstein: Oscillations need to be modified in presence of matter.



Charged Current
for electron type only

Neutral Current
for all neutrino types

Additional potential for ν_e ($\bar{\nu}_e$): $\pm\sqrt{2}G_F N_e$

N_e is electron number density.

Oscillations in presence of matter

$$i\frac{d}{dx}\nu_f = R_\theta H(\nu_m) + H_{mat}(\nu_f)$$

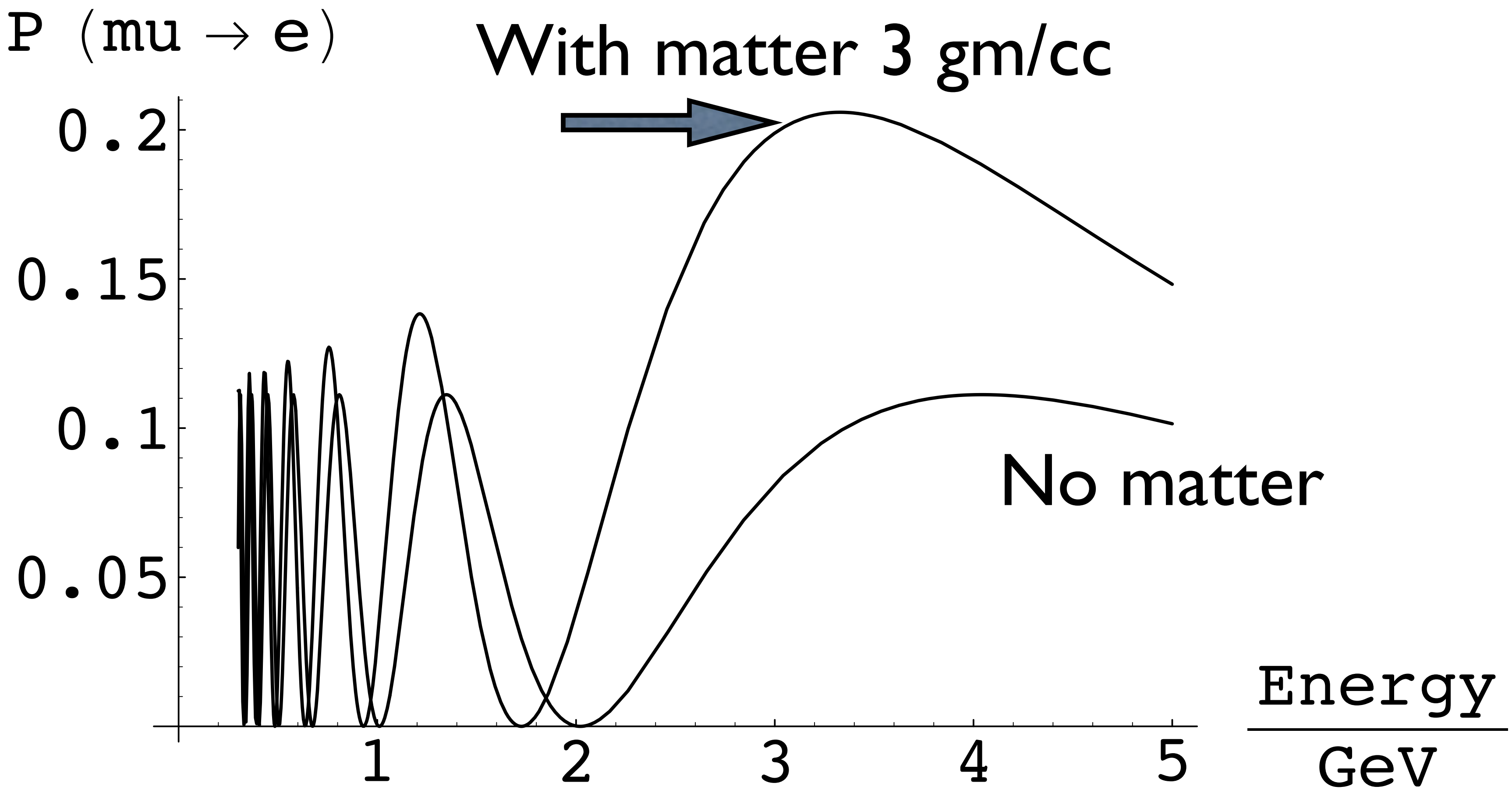
$$i\frac{d}{dx}\begin{pmatrix}\nu_e \\ \nu_\mu\end{pmatrix} = \frac{1}{4E}\left(R_\theta\begin{pmatrix}m_1^2 & 0 \\ 0 & m_2^2\end{pmatrix}R_\theta^T + 2E\begin{pmatrix}\sqrt{2}G_F N_e & 0 \\ 0 & -\sqrt{2}G_F N_e\end{pmatrix}\right)\begin{pmatrix}\nu_e \\ \nu_\mu\end{pmatrix} \quad (3)$$

$$P_{\mu\to e} = \frac{\sin^2 2\theta}{(\cos 2\theta - a)^2 + \sin^2 2\theta}\times\sin^2\frac{L\Delta m^2}{4E}\sqrt{(a-\cos 2\theta)^2 + \sin^2 2\theta}$$

$$\begin{aligned} a &= 2\sqrt{2}EG_F N_e/\Delta m^2 \\ &\approx 7.6\times 10^{-5}\times D/(gm/cc)\times E_\nu/GeV/(\Delta m^2/eV^2) \end{aligned} \quad (4)$$

Important only if electron neutrinos in the mix

2-neutrino picture

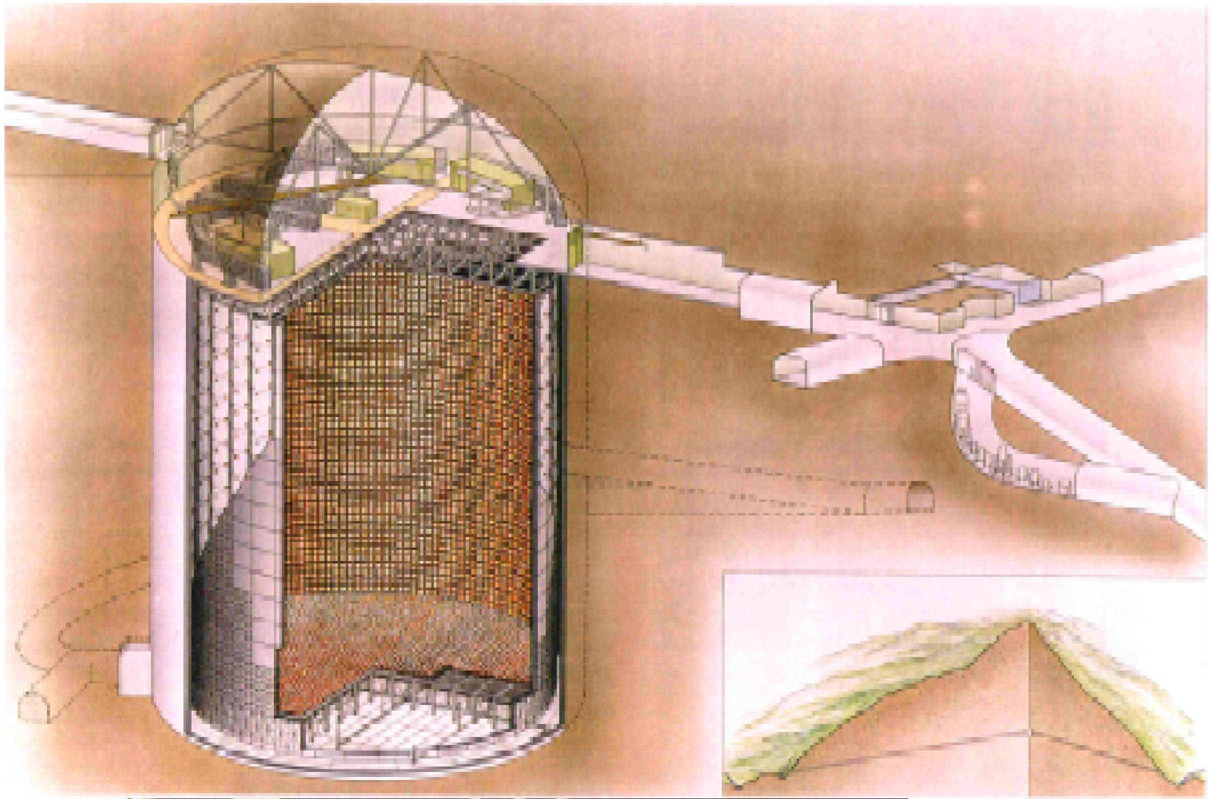


Osc. probability: 0.0025 eV^2, L= 2000 km, Theta=10deg

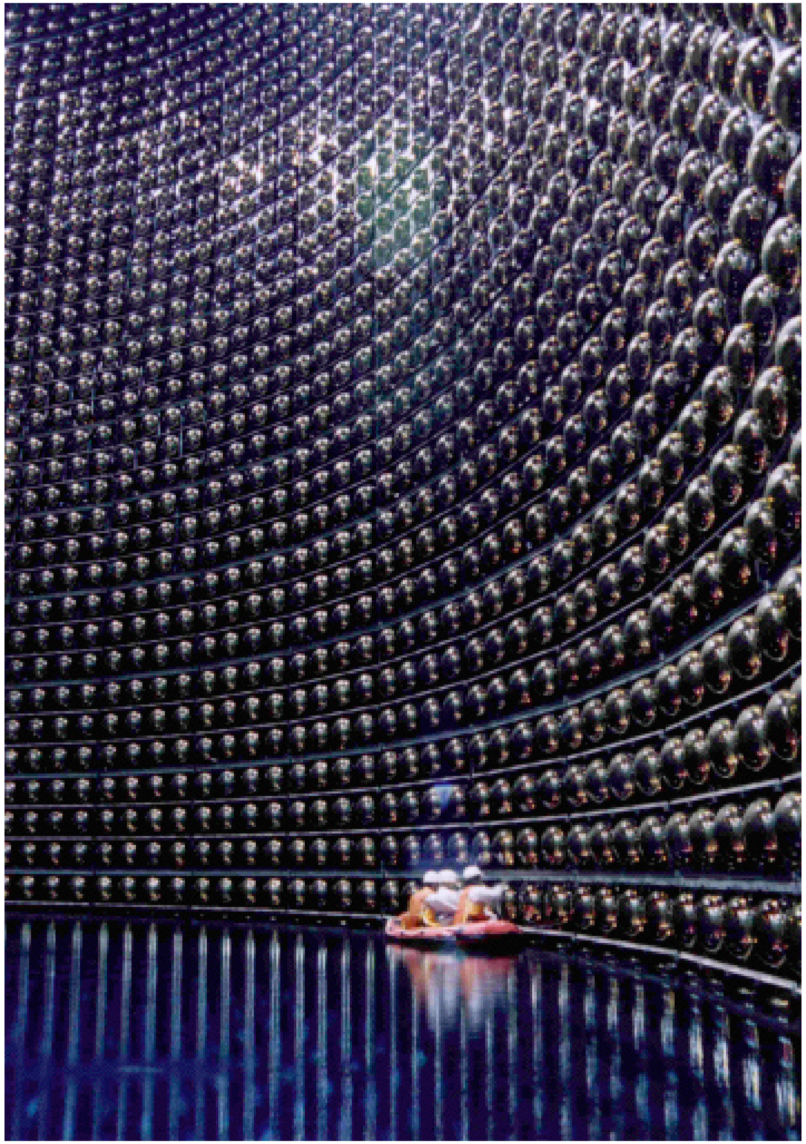
Key evidence

- Super KamiokaNDE (SK): observe atmospheric neutrinos.
- Sudbury Neutrino Observatory (SNO): observed solar neutrinos.
- KEK to SK accelerator beam
- MINOS accelerator beam
- KAMLAND reactor experiment

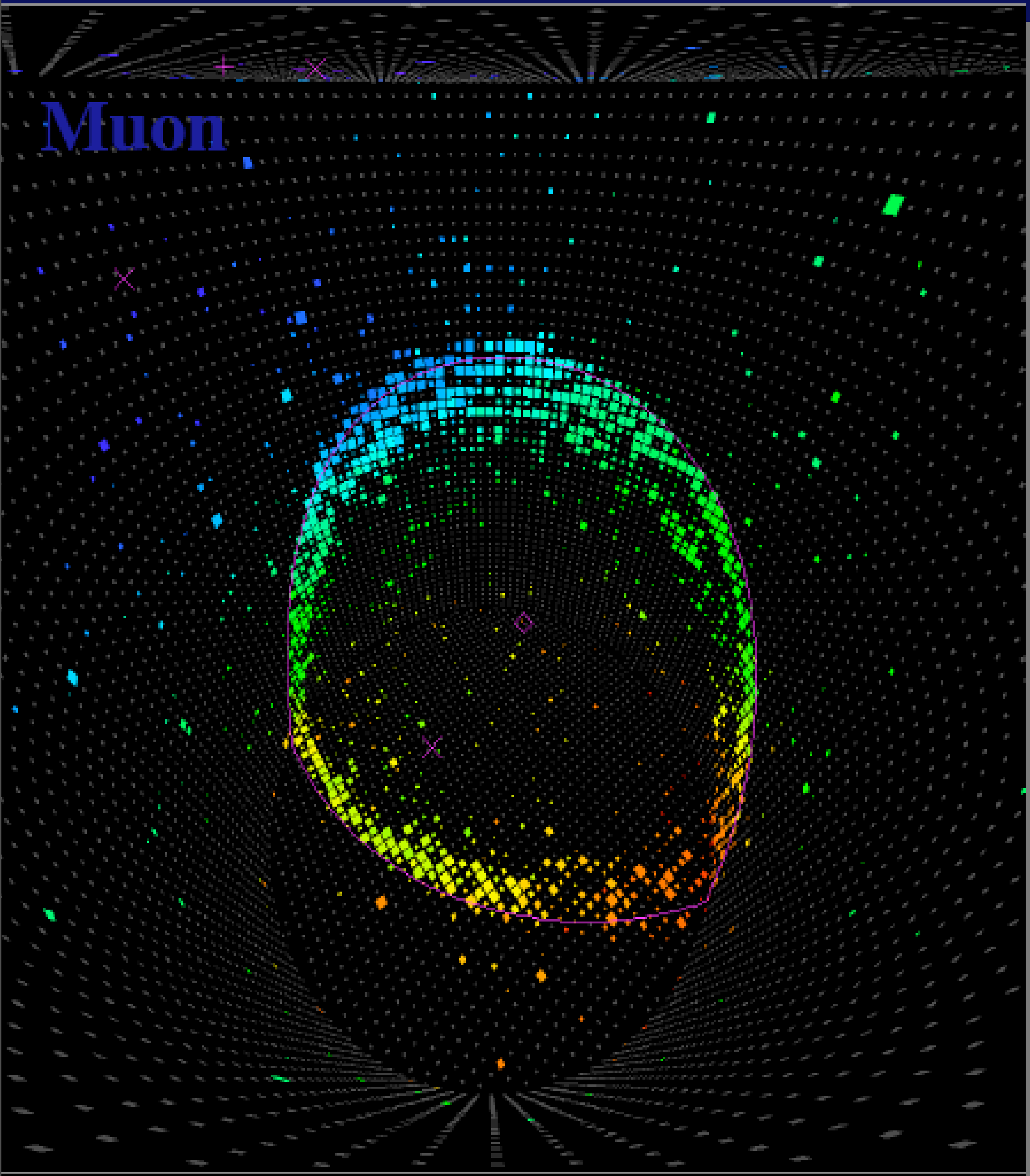
Apologies to many other pioneering experiments

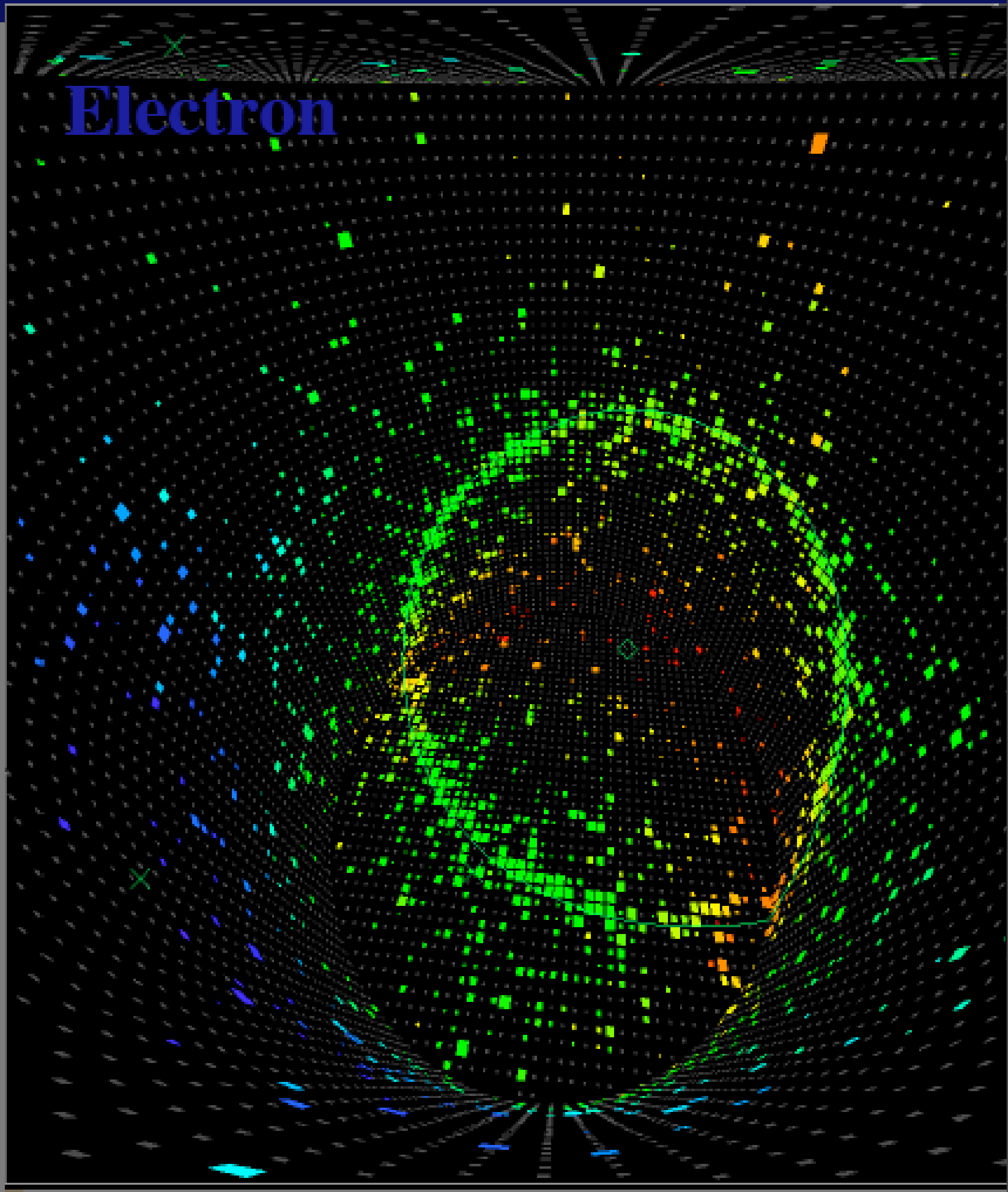


SuperKamiokaNDE



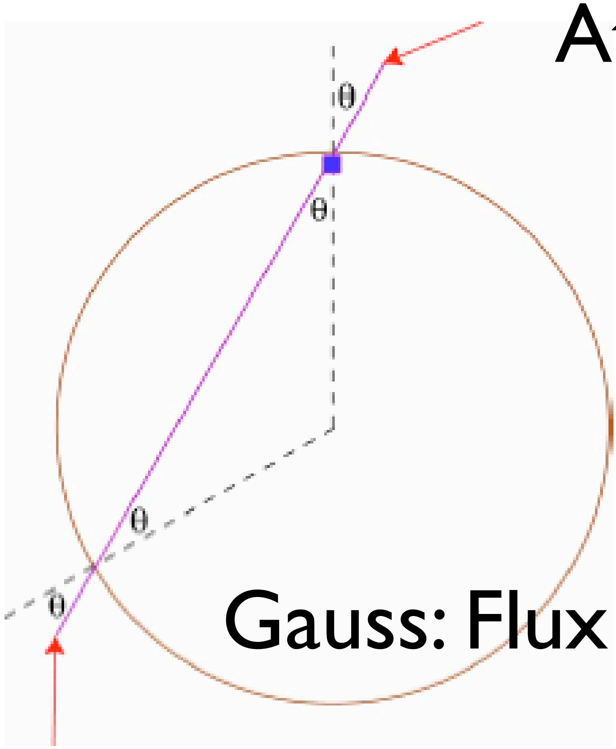
Particle Identification

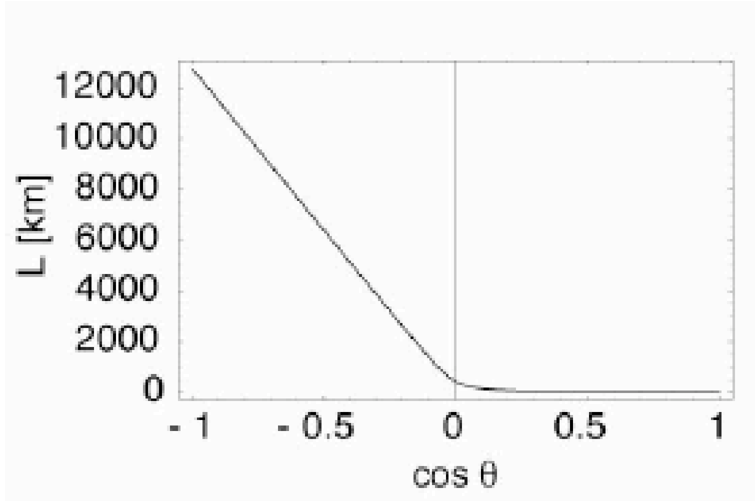


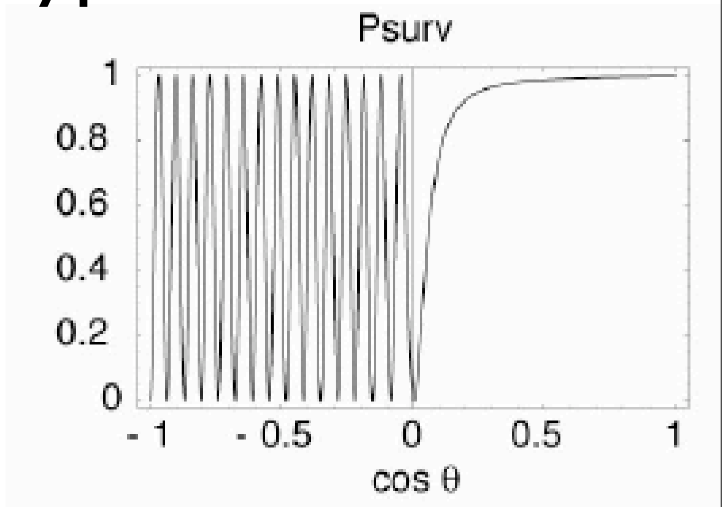


Atmospheric neutrinos as a source for oscillation experiments

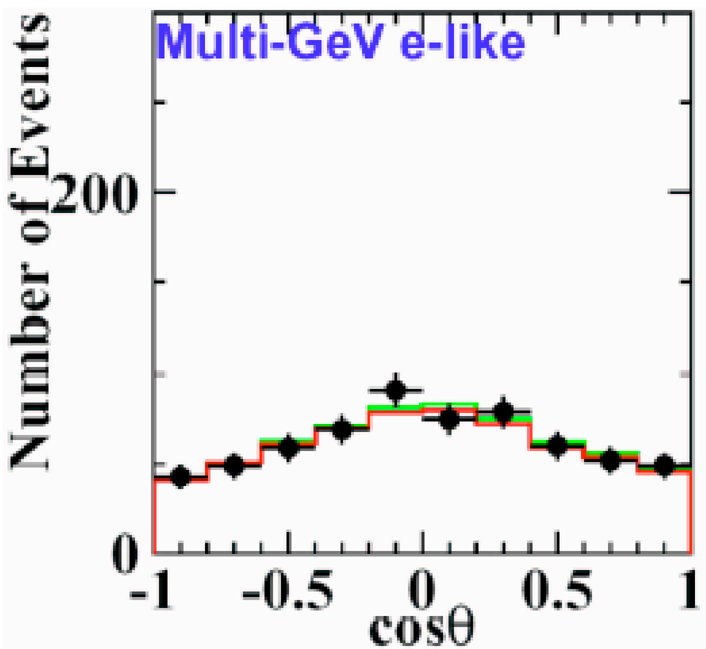
Atm. neutrinos 2:1 mu:e type

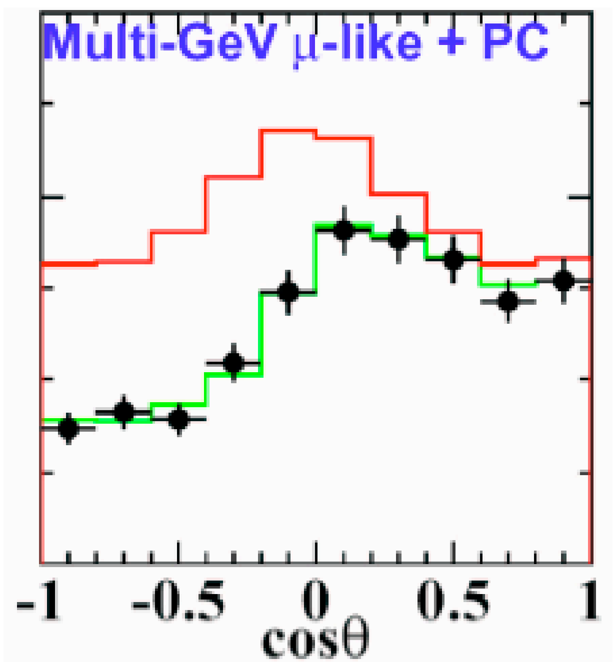






Gauss: Flux inside spherical shell isotropic

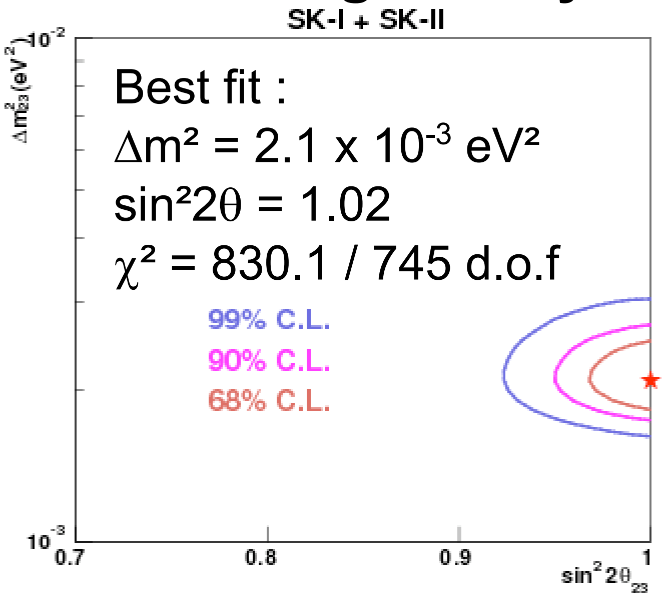




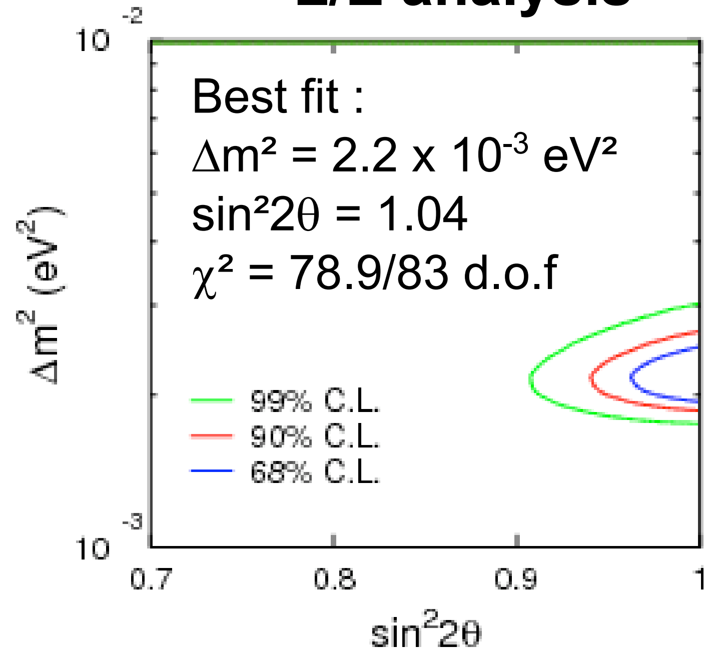
Evidence for neutrino oscillations from SuperK

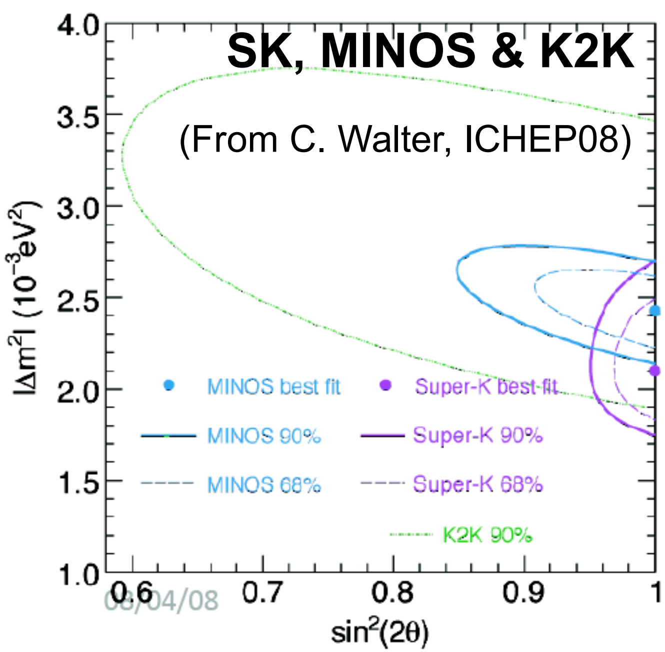
Allowed regions

Zenith angle analysis



L/E analysis

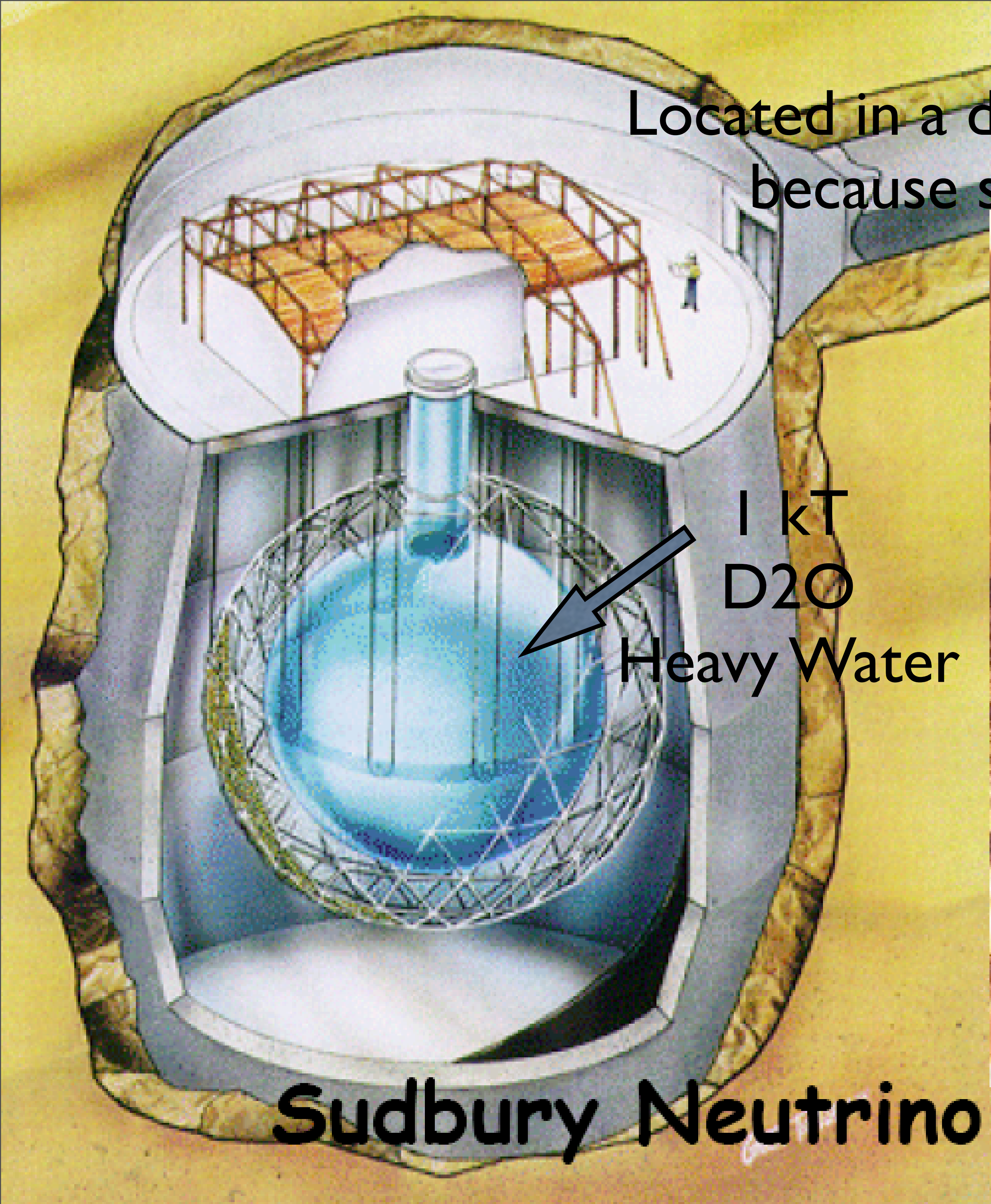




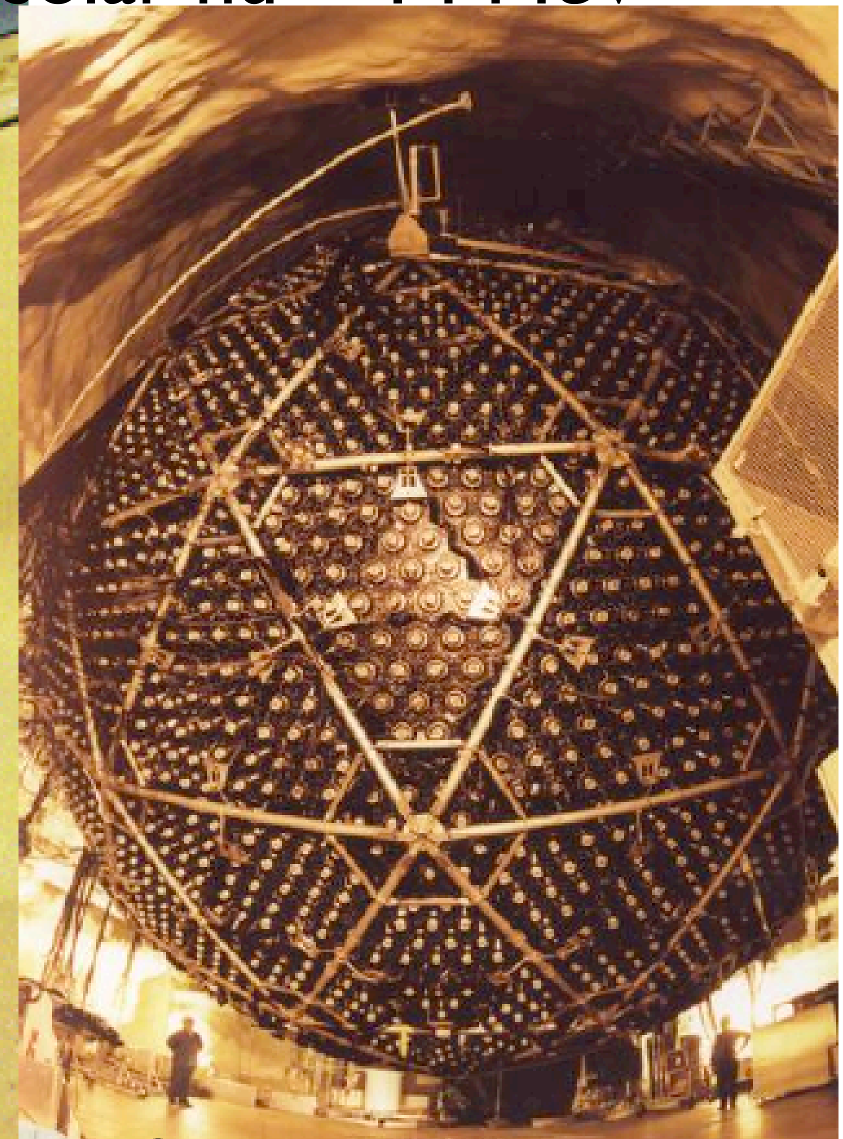
Current best measurement of θ_{23} :

~ 45±4° (10% accuracy)

Located in a deep mine ~ 6000 mwe
because solar nu < 14 MeV

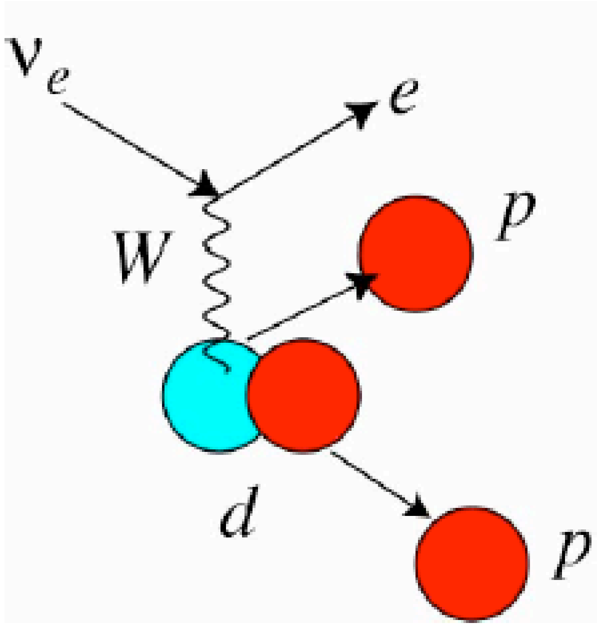


1 kT
D2O
Heavy Water

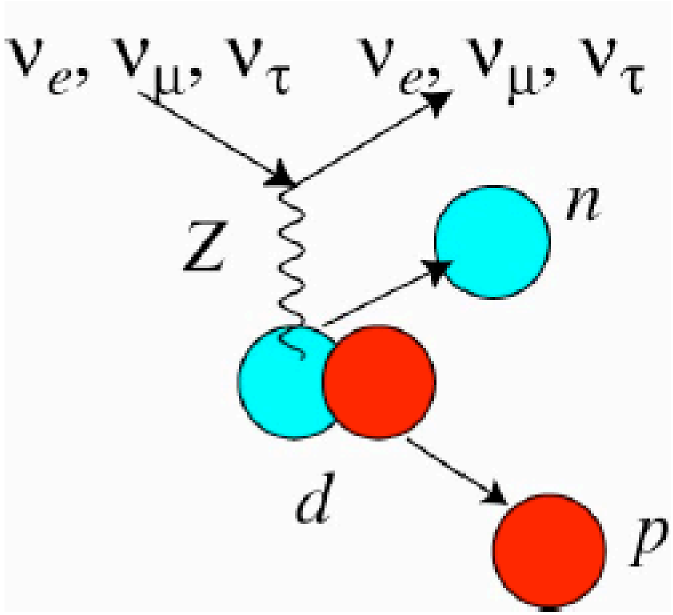


Sudbury Neutrino Observatory

Why does SNO use $300M worth of heavy water?



Charged Current

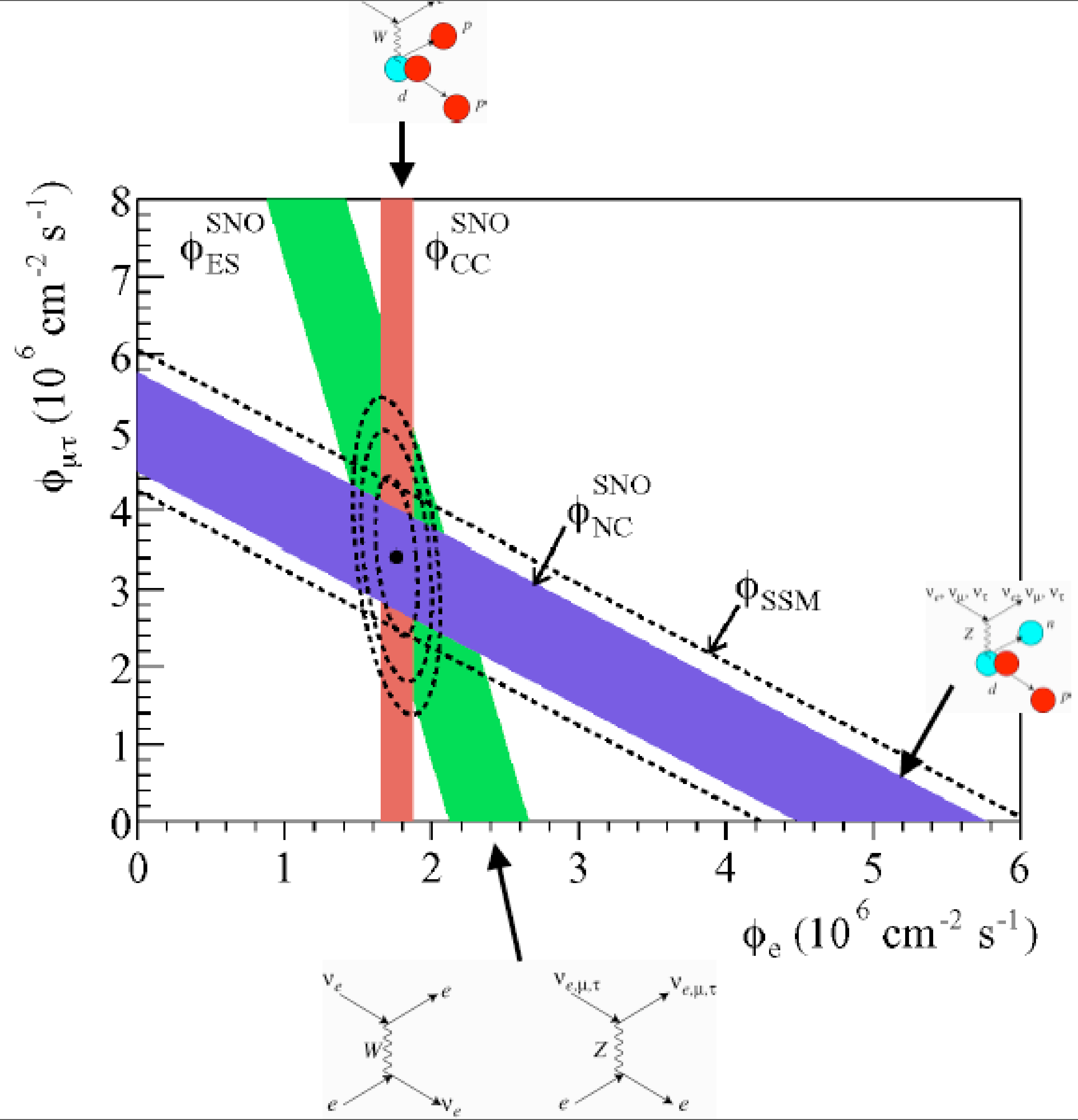


Neutral Current

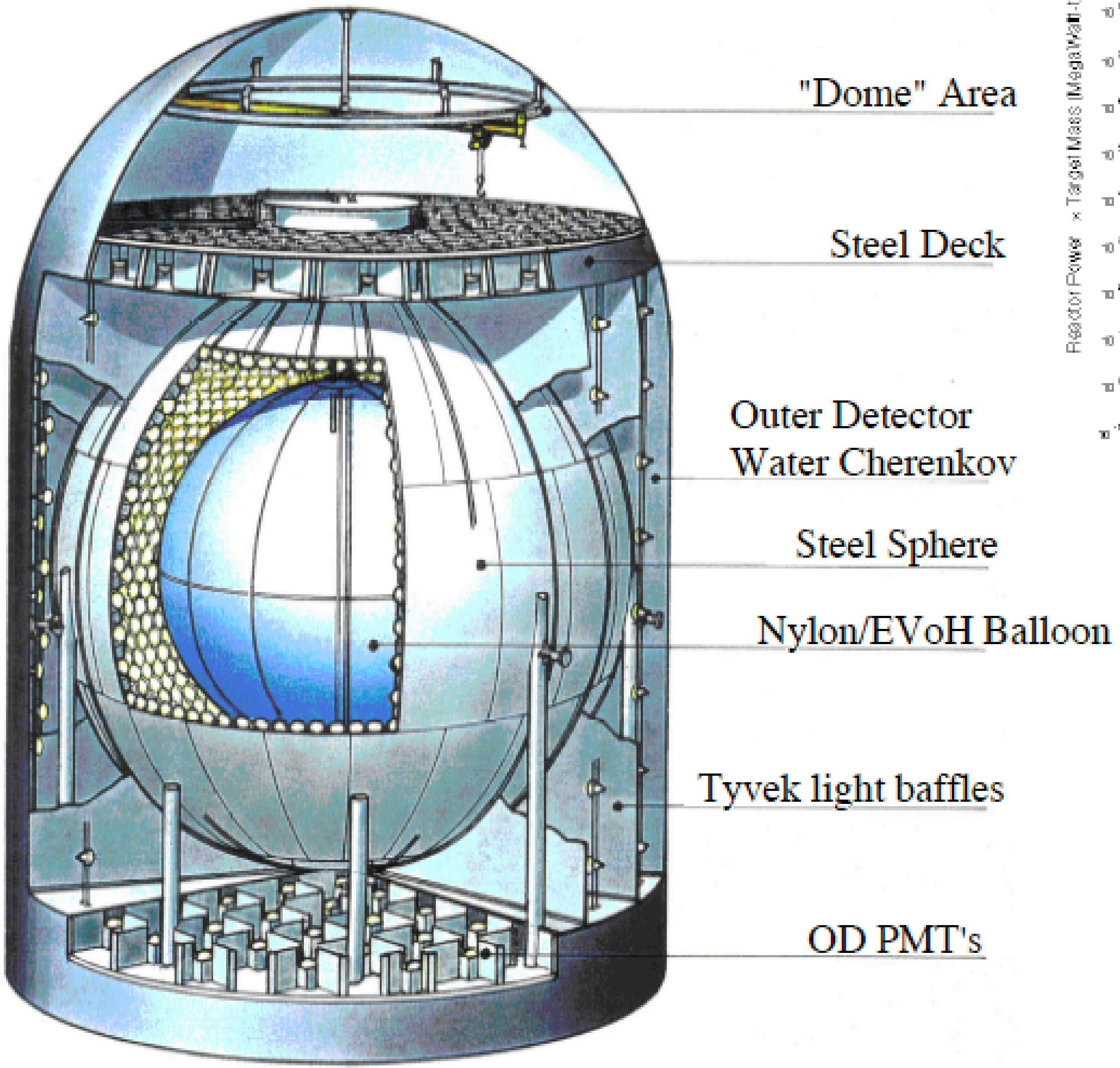
Fluxes

(10^6 cm^{-2} s^{-1})

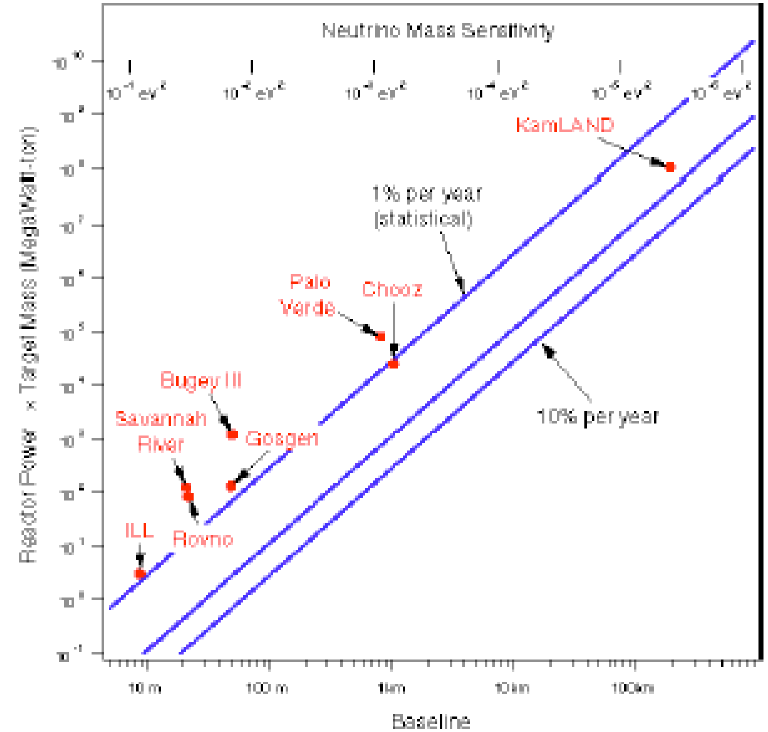
ν_e:	1.76(11)
$\nu_{\mu\tau}$:	3.41(66)
ν_{total}:	5.09(64)
ν_{SSM}:	5.05



KamLAND



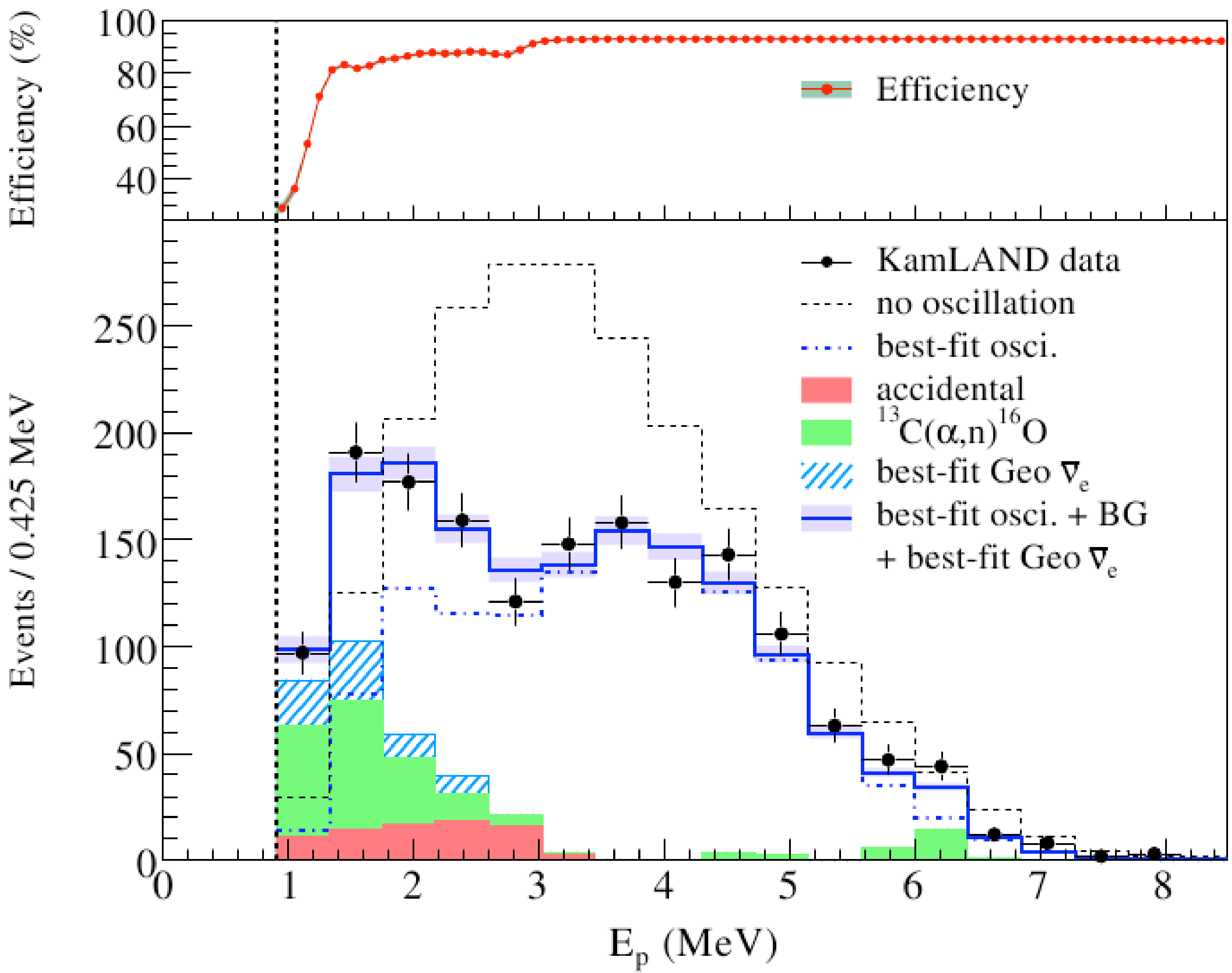
"Dome" Area
Steel Deck
Outer Detector
Water Cherenkov
Steel Sphere
Nylon/EVoH Balloon
Tyvek light baffles
OD PMT's



Neutrino Mass Sensitivity
10^{-1} eV^2
10^{-2} eV^2
10^{-3} eV^2
10^{-4} eV^2
10^{-5} eV^2
10^{-6} eV^2
KamLAND
1% per year
(statistical)
Palo
Verde
Chooz
Bugey III
Savannah
River
Gosgen
ILL
Rovno
10% per year
Reactor Power × Target Mass (MegaWatt-ton)
10 m
100 m
1km
10km
100km
Baseline

China
South Korea
KamLAND

The full anti-neutrino energy spectrum



Plot shows the Prompt event energy (e^+ kinetic energy + $2m_e$) which can be converted to

$E_\nu \approx E_{prompt} + 0.8MeV$

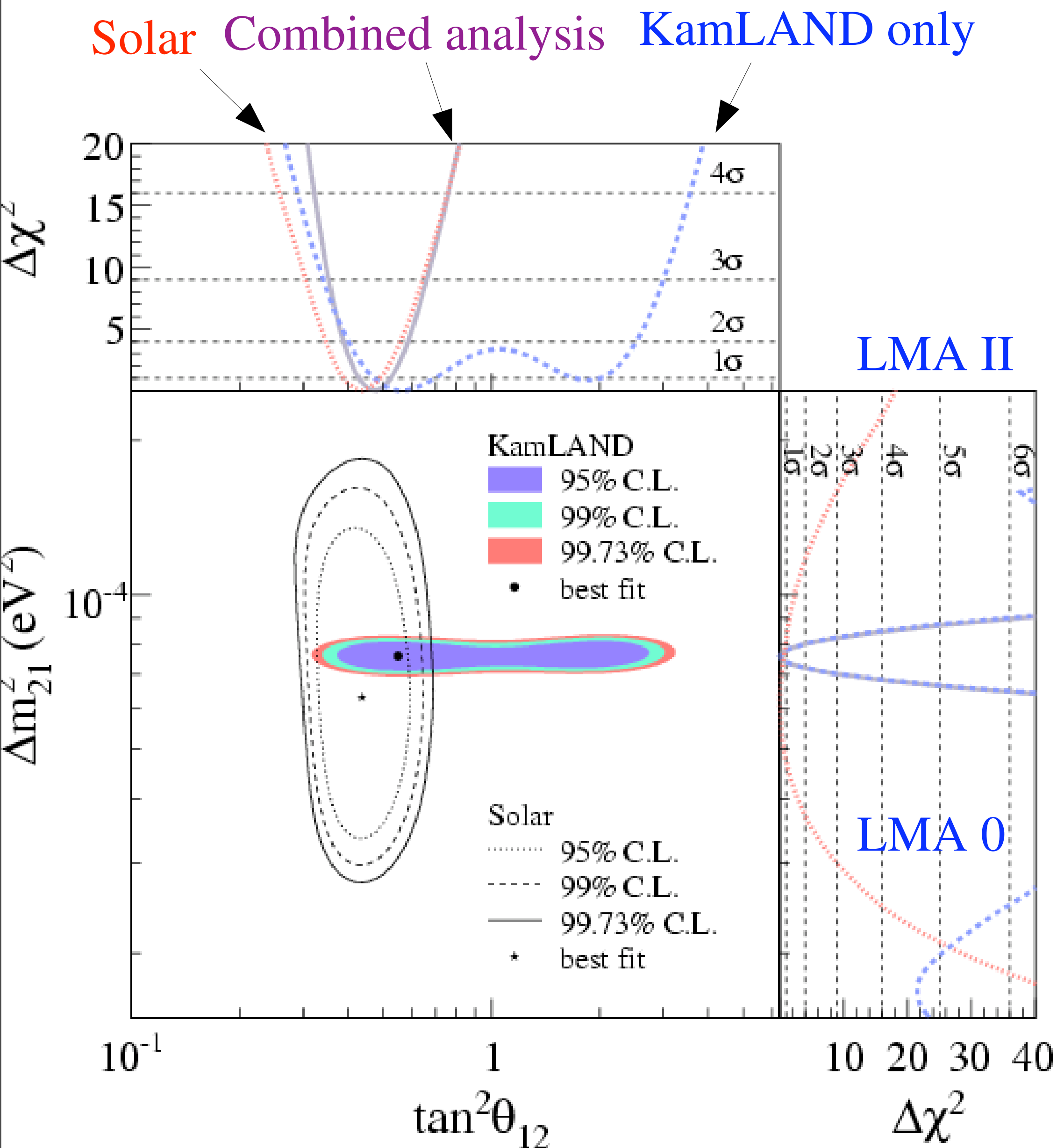
The best fit values:

$\Delta m_{21}^2 = 7.58 \times 10^{-5}(eV^2)$

$\tan^2\theta_{12} = 0.56$

Data taken between March 9, 2002 and May12, 2007, the 2.44×10^{32} proton-year exposure was used. This is the KamLAND only result (using $\theta_{13} = 0$ and taking into account reactor flux time variation). Scaled reactor spectrum (no oscillations included) was excluded at the 5.1σ level.

KamLAND + Solar oscillation analysis



KamLAND only:

$\Delta m^2 = 7.58^{+0.14}_{-0.13}(st) \pm 0.15(syst) \times 10^{-5}\ (eV^2)$

$\tan^2\theta = 0.56^{+0.10}_{-0.07}(st)^{+0.1}_{-0.06}(syst)$

KamLAND+solar:

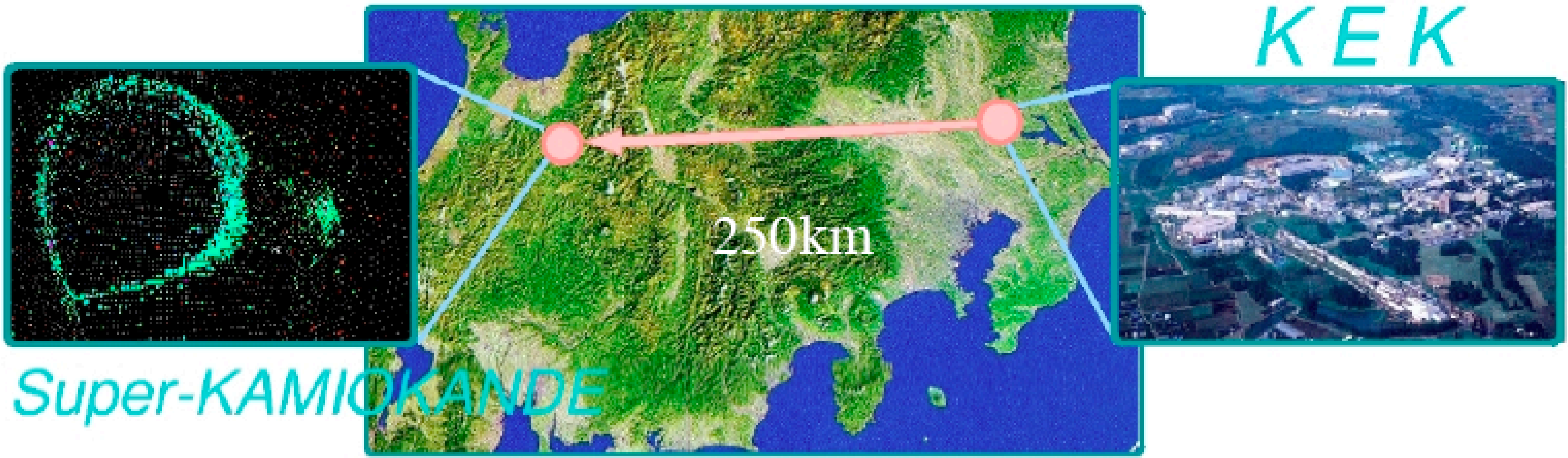
$\Delta m^2 = 7.59 \pm 0.21 \times 10^{-5} (eV^2)$

$\tan^2\theta = 0.47^{+0.06}_{-0.05}$

Only the LMA I solution remains

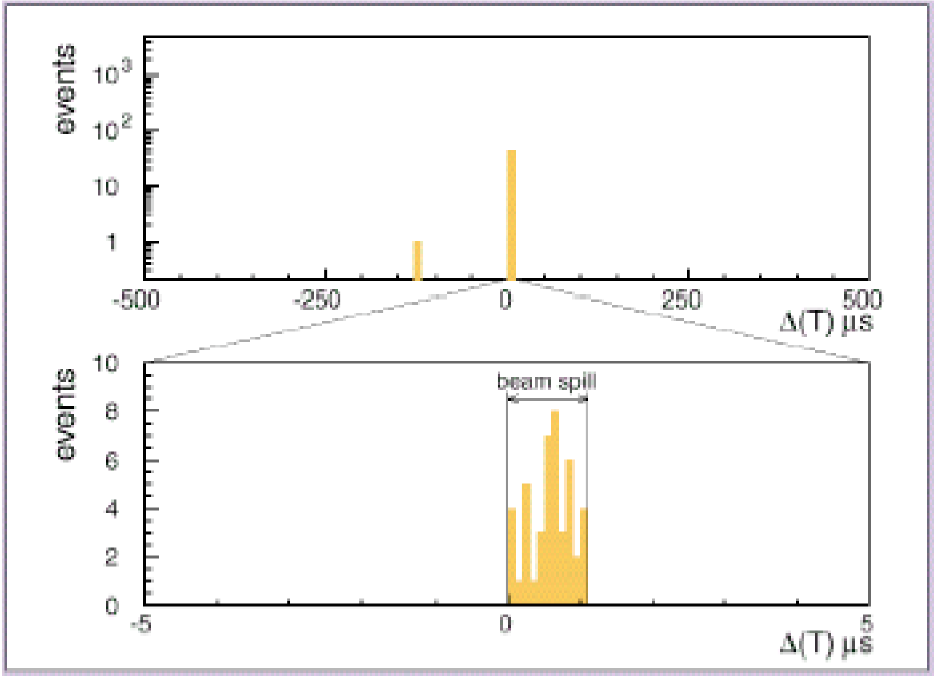
KamLAND improved result for mixing angle and Δm^2. Solar data have no effect on the Δm^2 measurement.

Long Baseline Experiments



First LBL exp. with positive result

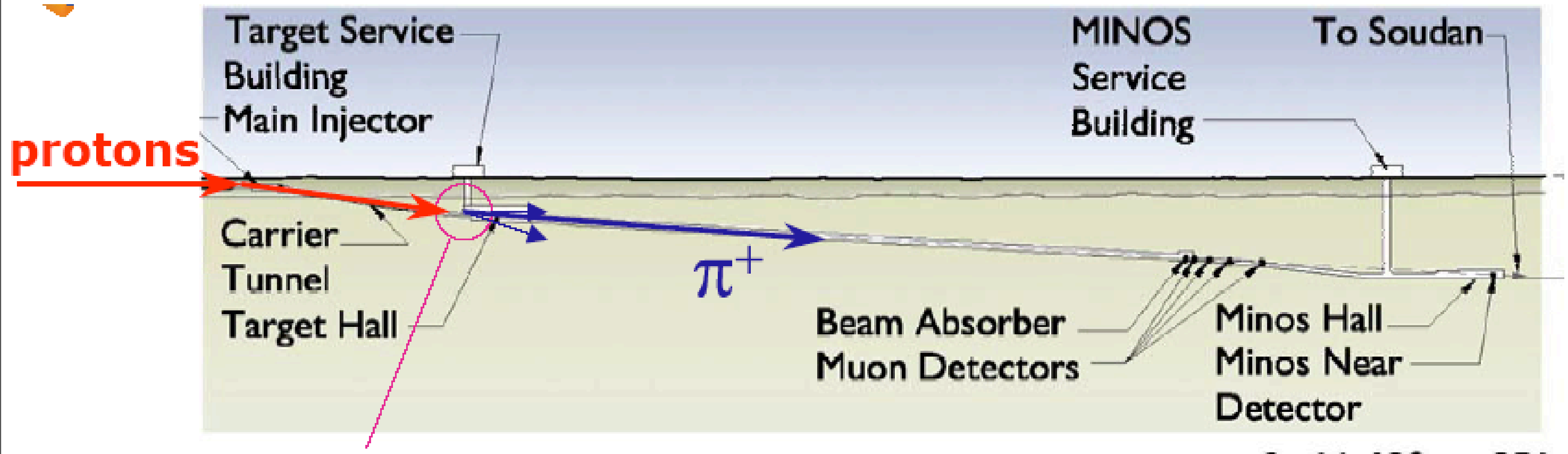
81±8 events no oscillation
56 events observed



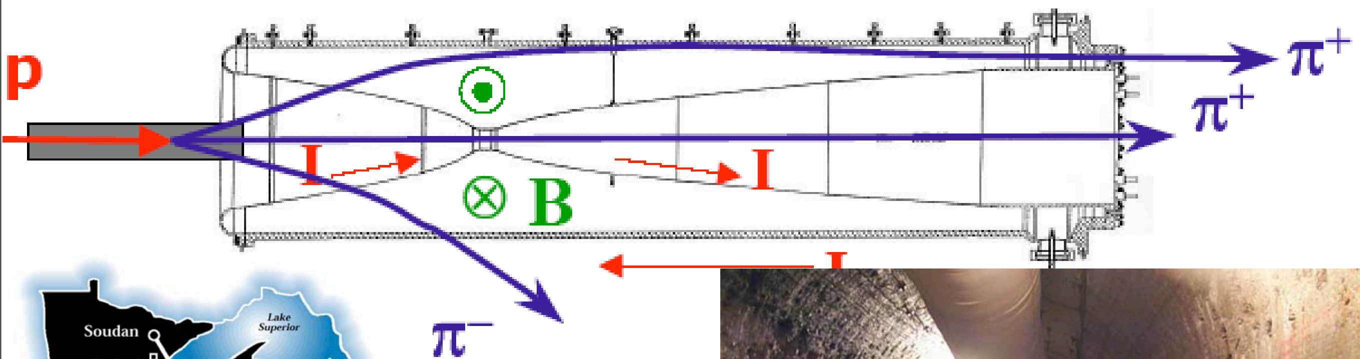
(Fermilab) Main Injector Neutrino Oscillation (MINOS) about to start running.

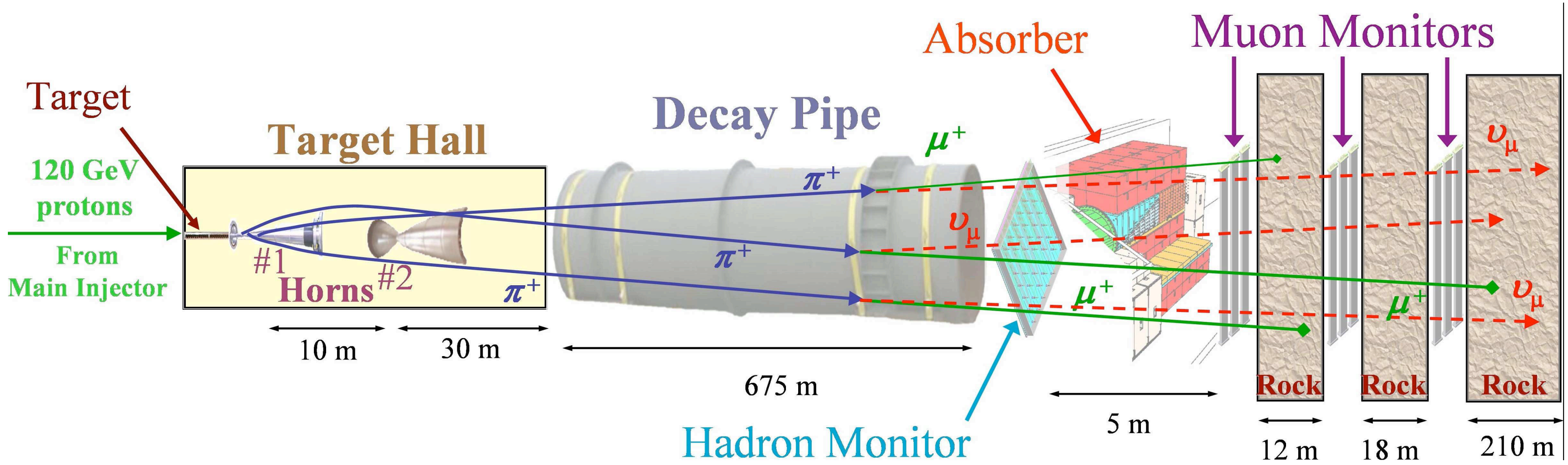
- ★ **120 GeV protons extracted from the MAIN INJECTOR in a single turn (8.7μs)**
- ★ **1.9 s cycle time**
- ★ ***i.e.* ν beam `on' for 8.7μs every 1.9 s**
- ★ **2.5×10^{13} protons/pulse**
- ★ **0.3 MW on target !**
- ★ **Initial intensity**

  2.5×10^{20} protons/year

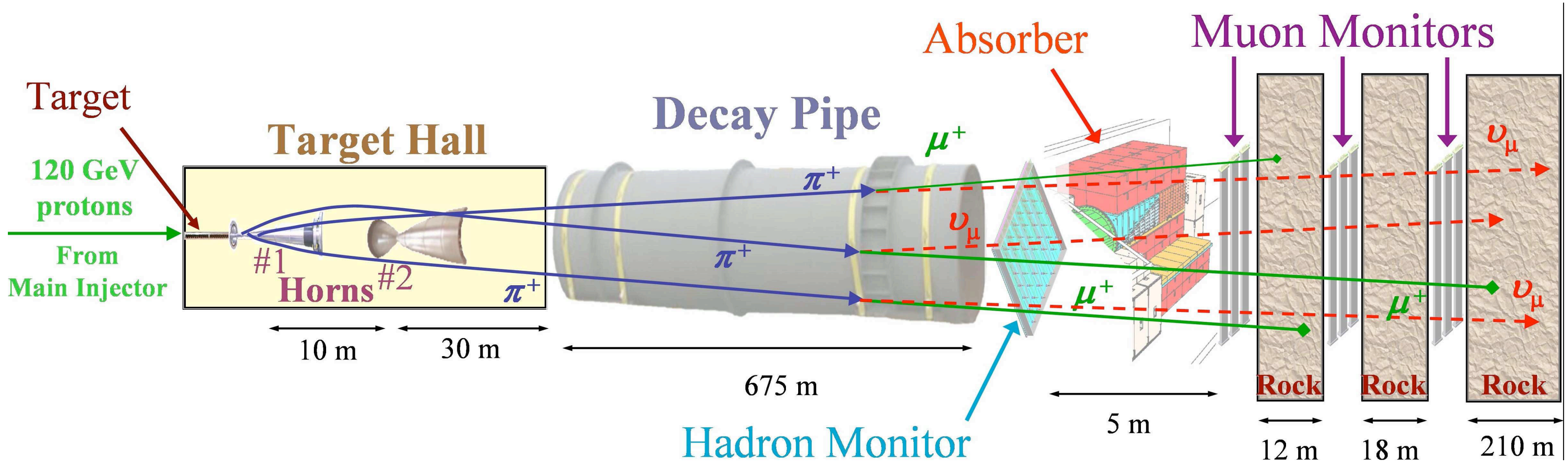


- **Horn pulsed with 200 kA**
- **Toroidal Magnetic field *B* ~ I/*r* between inner and outer conducters**

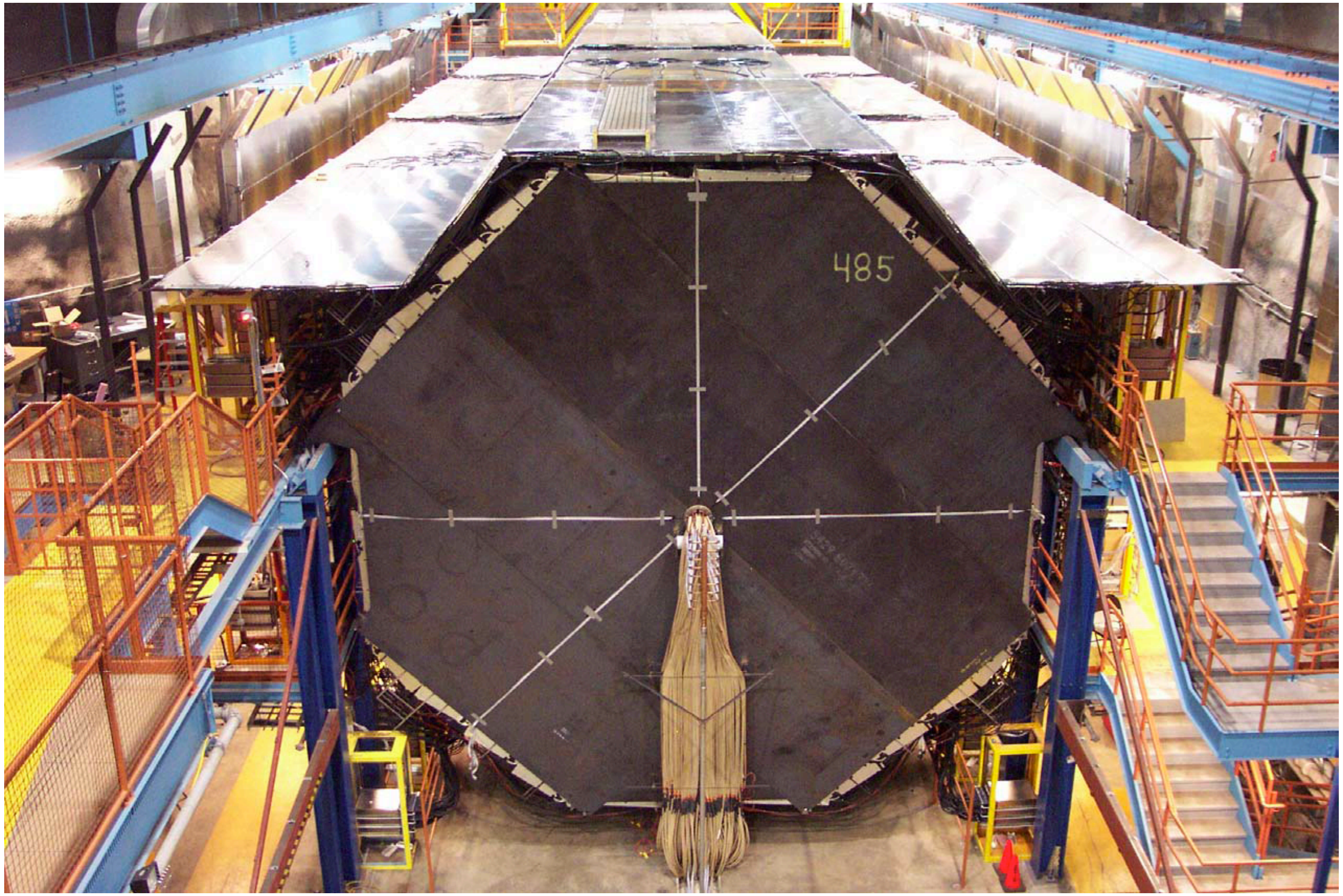




Minos detector: Iron/ scintillator 5kT



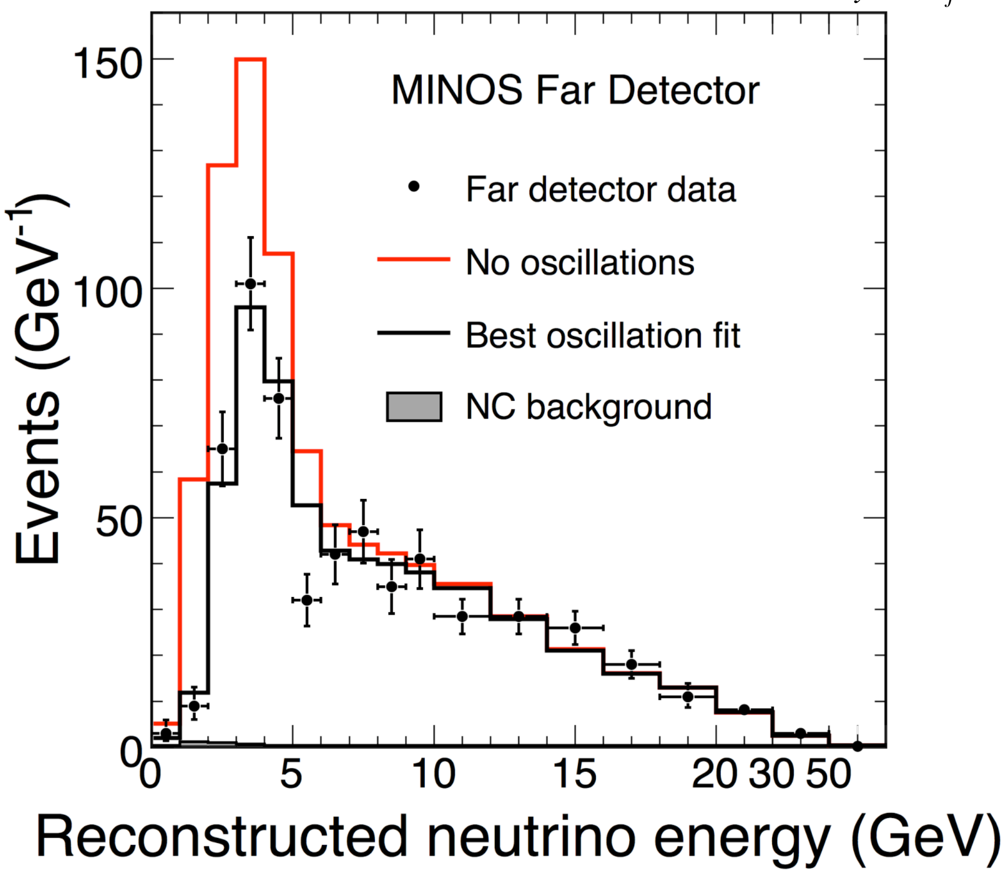
Minos detector: Iron/ scintillator 5kT



CC Energy Spectrum Fit

$$\chi^2 = \sum_{nbins}(2(e_i - o_i) + 2\, o_i \ln(o_i / e_i)) + \sum_{nsys} \frac{\Delta s_j^2}{\sigma_{s_j}^2}$$

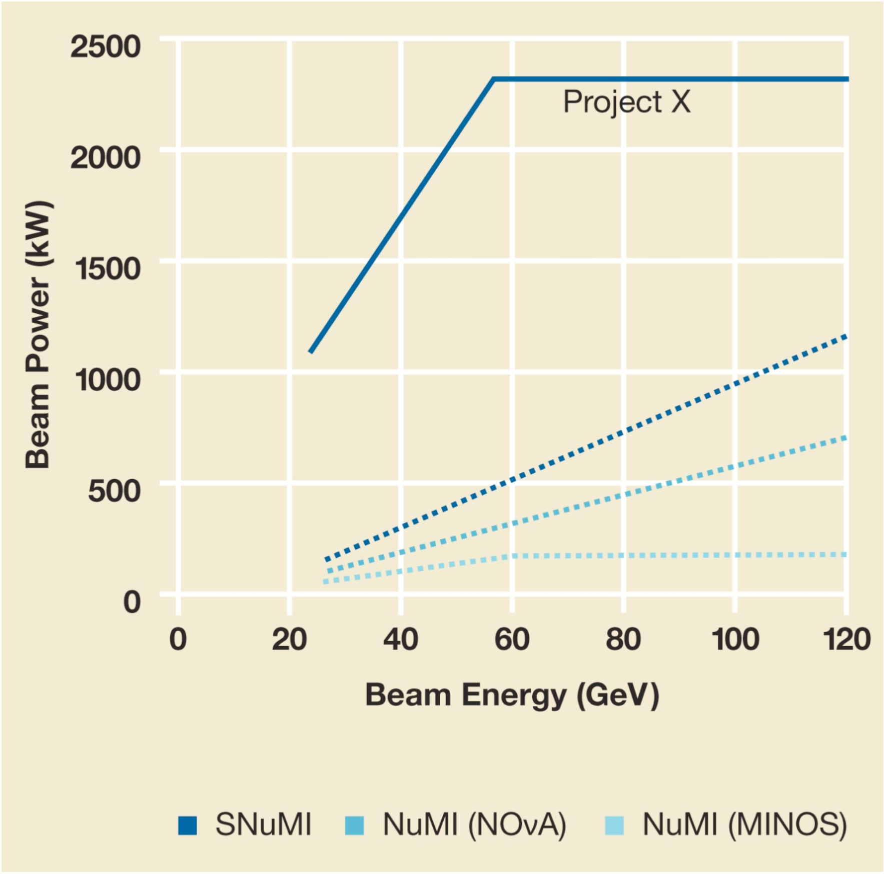
- Fit the energy distribution to the oscillation hypothesis:
- Including the three largest sources of systematic uncertainty as nuisance parameters
  - Absolute hadronic energy scale: 10.3%
  - Normalization: 4%
  - NC contamination: 50%



$3.6\ 10^{20}$ Protons on target

Best Fit:
$|\Delta m^2| = 2.43\times10^{-3}\ eV^2$
$\sin^2(2\theta) = 1.00$

- 60 -120 GeV protons from the Main Injector fed by Project X



20-40x10^{20} POT/yr

10x10^{20} POT/yr

6x10^{20} POT/yr

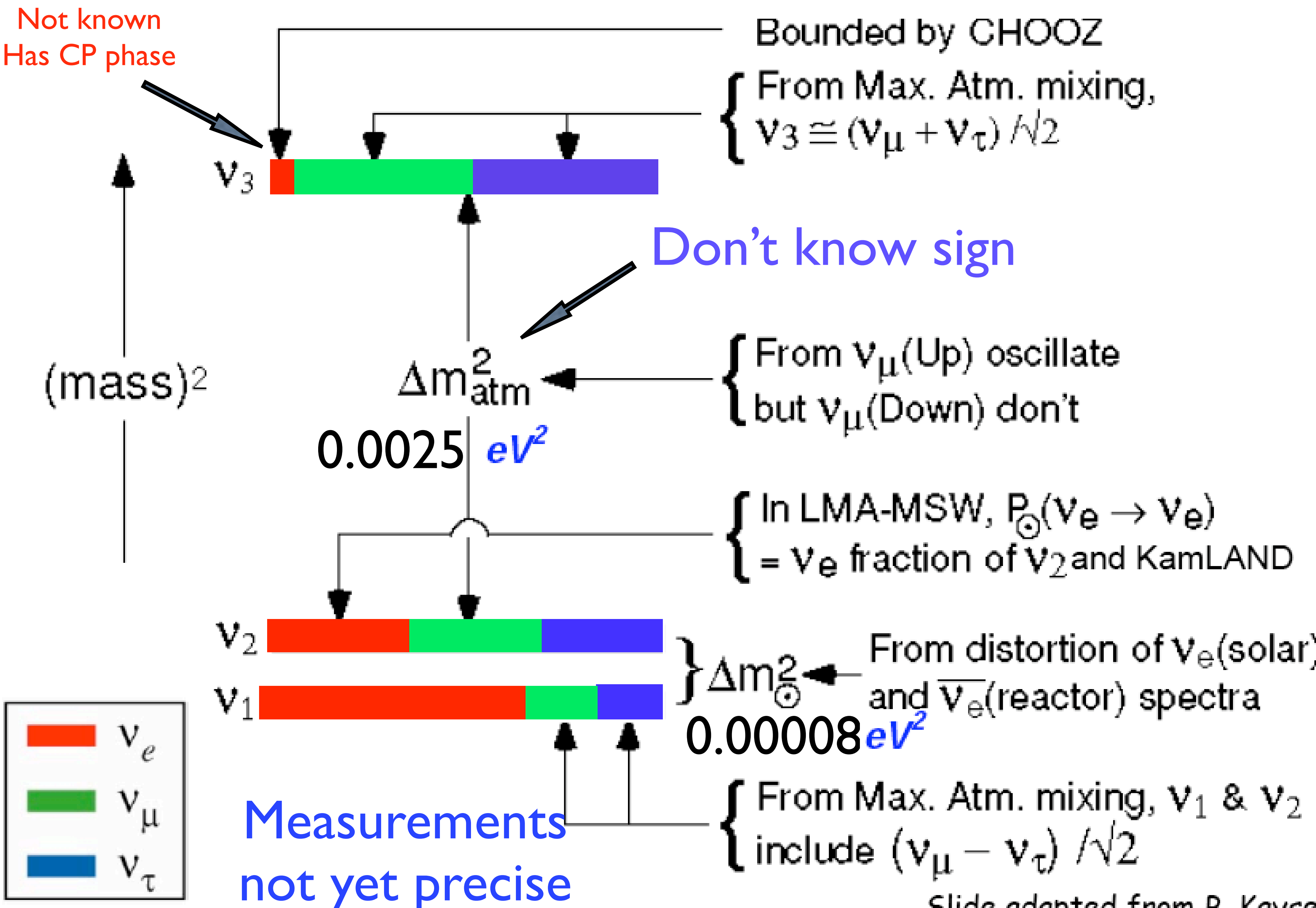
3x10^{20} POT/yr

Recent sensitivity studies are being done for 120x10^{20} POT each ν and $\bar{\nu}$ (120 GeV)

$$POT(10^{20}) = \frac{1000 \times BeamPower(MW) \times T(10^7 s)}{1.602 \times E_p(GeV)}$$

5.2 10^{20} POT for 1 MW and 10^7 sec

What do we know and how do we know it



Slide adapted from B. Kayser

Phenomenology of $\nu_\mu \rightarrow \nu_e$

The Mixing Matrix

Atmospheric, Cross-Mixing, Solar

$$U = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \times \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \times \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$c_{ij} \equiv \cos\theta_{ij}$
$s_{ij} \equiv \sin\theta_{ij}$

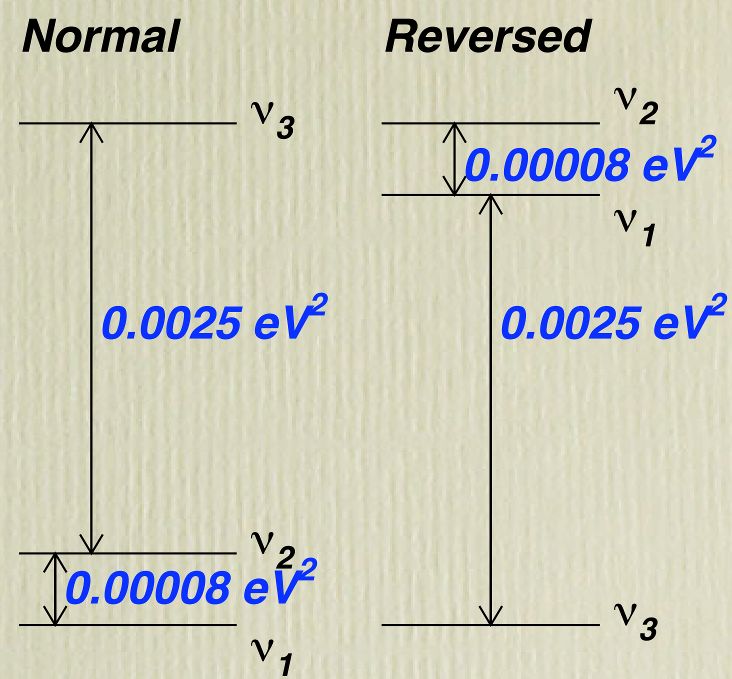
$$\times \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Majorana ~~CP~~ phases

$\theta_{12} \approx \theta_{sol} \approx 34°$, $\theta_{23} \approx \theta_{atm} \approx 37\text{-}53°$, $\theta_{13} \lesssim 10°$

δ would lead to $P(\overline{\nu}_\alpha \rightarrow \overline{\nu}_\beta) \neq P(\nu_\alpha \rightarrow \nu_\beta)$. ~~CP~~

mass-squares



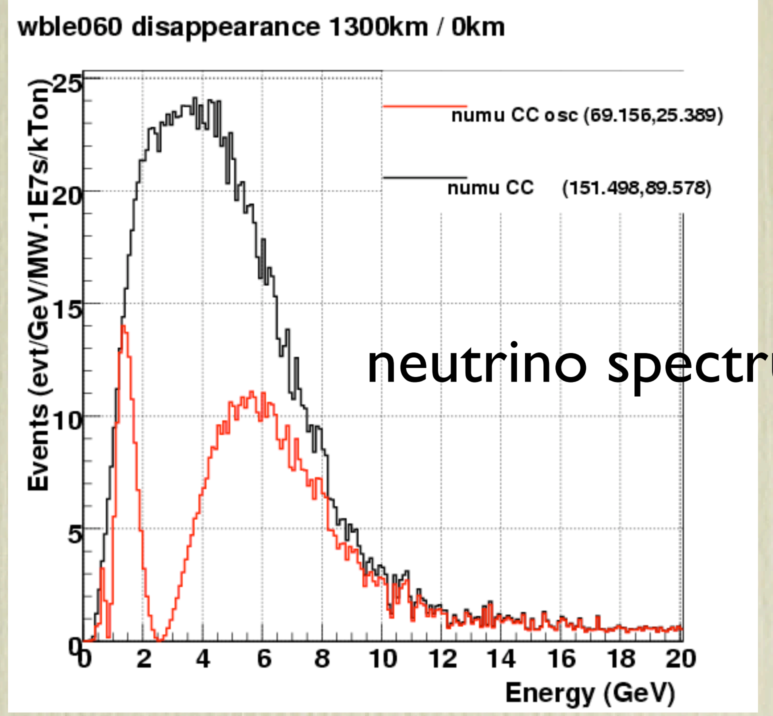
Difference in mass squares: $(m_2^2 - m_1^2)$

Oscillation nodes at $\pi/2, 3\pi/2, 5\pi/2, \ldots$ $(\pi/2)$: $\Delta m^2 = 0.0025 eV^2$, $E = 1GeV$, $L = 494km$.   Solar : L~15000*km*

Event rate

Evt rate: 1 MW for 3 yrs ★

Event type	300kT, 60 GeV 0 deg.
Numu CC no osc	272693
Numu CC with osc	124479



neutrino spectrum

High precision $\sin^2 2\theta_{23}$, Δm^2_{32}

- Important (esp. $\theta_{23} \sim 45$ deg.) with possibility of new physics.
- Either 120 GeV or 60 GeV beam can be used: two oscillation nodes.
- Measurement dominated by systematics (see hep/0407047) (~1%)

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★ yr~2x10^7 sec

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Key Event Rate in 100kT*MW*10^7

5.2e20 POT @ 120 GeV

$$\nu_\mu \longrightarrow \nu_e$$

$\Delta m^2_{21,31} = 8.6 \times 10^{-5}, 2.5 \times 10^{-3} eV^2$ $\sin^2 2\theta_{12,23} = 0.86, 1.0$ $\sin^2 2\theta_{13} = 0.02$

$$\delta_{CP}$$

	$sgn(\Delta m^2_{31})$	0 deg	+90 deg	180 deg	-90 deg	nue backg
WBLE NU (1300km)	+	87	48	95	134	47
WBLE NU (1300km)	-	39	19	51	72	
WBLE ANU (1300km)	+	20	27	15	7.2	17
WBLE ANU (1300km)	-	38	52	33	19	

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Science to be addressed with next detectors and the beam

- Neutrino Oscillations.
  - ★ What is the size of last mixing angle, θ_{13} ?
  - ★What is the ordering of Neutrino masses?
  - ★Do Neutrinos violate the CP symmetry?
  - ★What is the relationship of leptons and quarks ?

Detector needs to be similar size for both this physics and physics of nucleon decay. Can we do this important physics also ?

Neutrino CP violation

- Convergence of many profound theoretical ideas and observations:
  - ★ The see-saw mechanism
  - ★ Majorana nature of neutrinos
  - ★ Leptogenesis <=> Baryogenesis

Detector

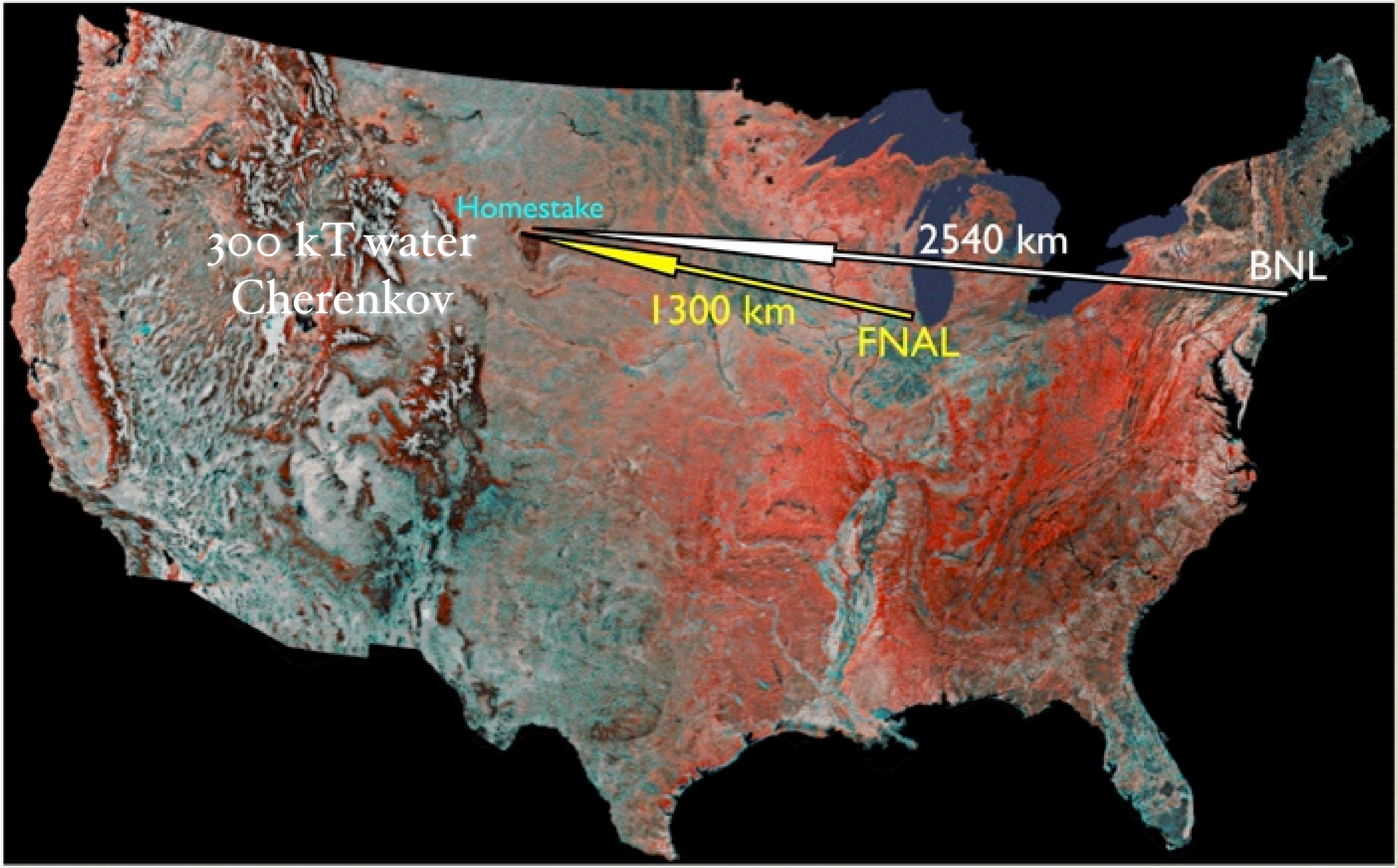
- Requirements: Very ambitious !
  - 500 kTons fiducial mass for both Proton decay and neutrino astro-physics and neutrino beam physics.
  - ~10 % energy resolution on quasielastic events
  - Muon/electron discrimination at <1%
  - 1, 2, 3 track event separation
  - Showering NC event rejection at factor of ~15
  - Low threshold (~10-15 MeV) for supernova search
  - Part of the detector could have lower threshold for solar neutrino detection.
  - Time resolution of ~few ns for pattern recognition and background reduction.

World wide ideas for such a detector

- MEMPHYS
- HYPER-KAMIOKANDE
- UNO at Henderson
- Multi-Modular detector at Homestake

FNAL to DUSEL long baseline experiment

Beam requirement: >1 MW, 1000 to 2000 km



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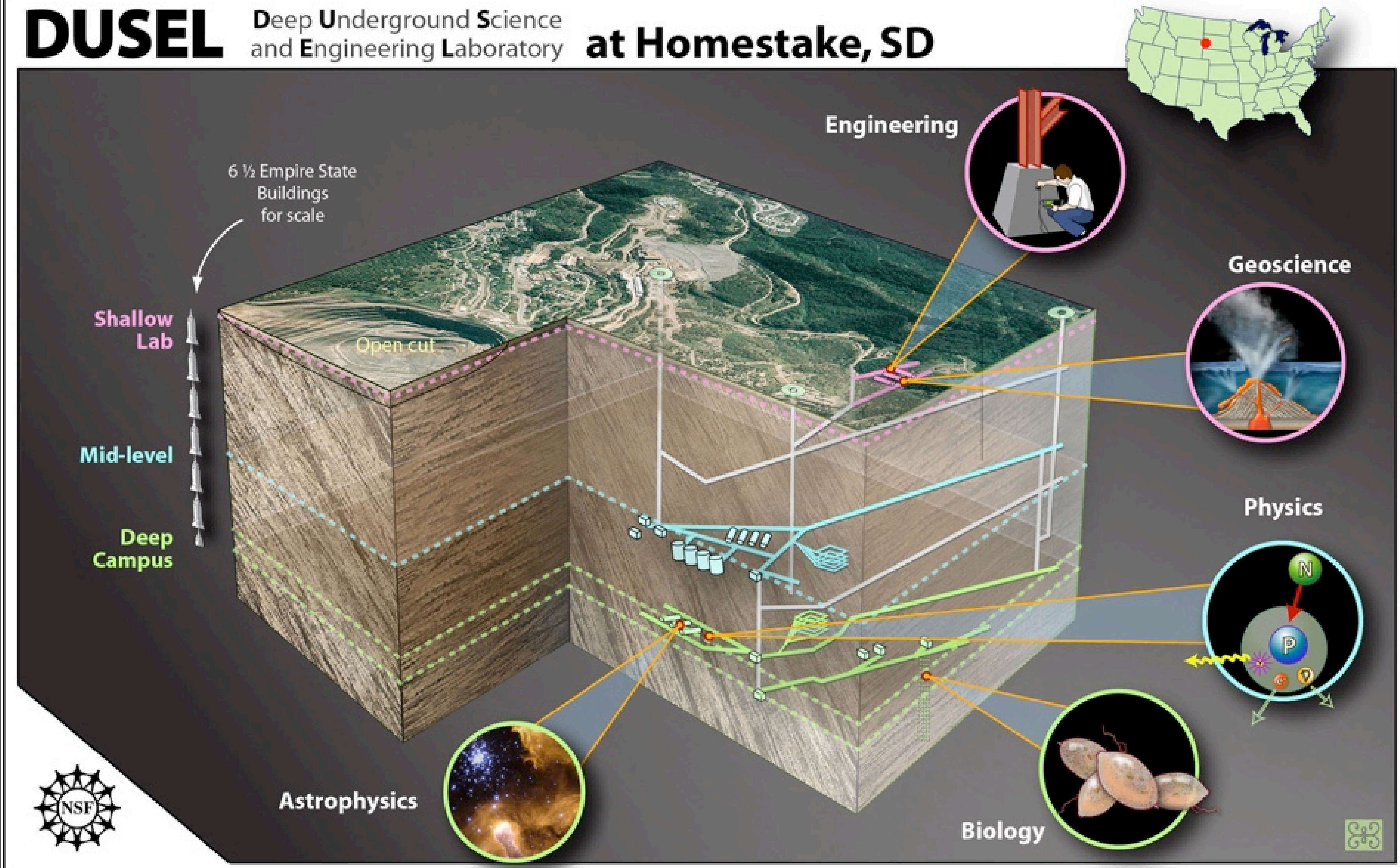


NSF site decision was HOMESTAKE on advice from a 22 member unanimous panel. Homestake and Henderson were finalists.

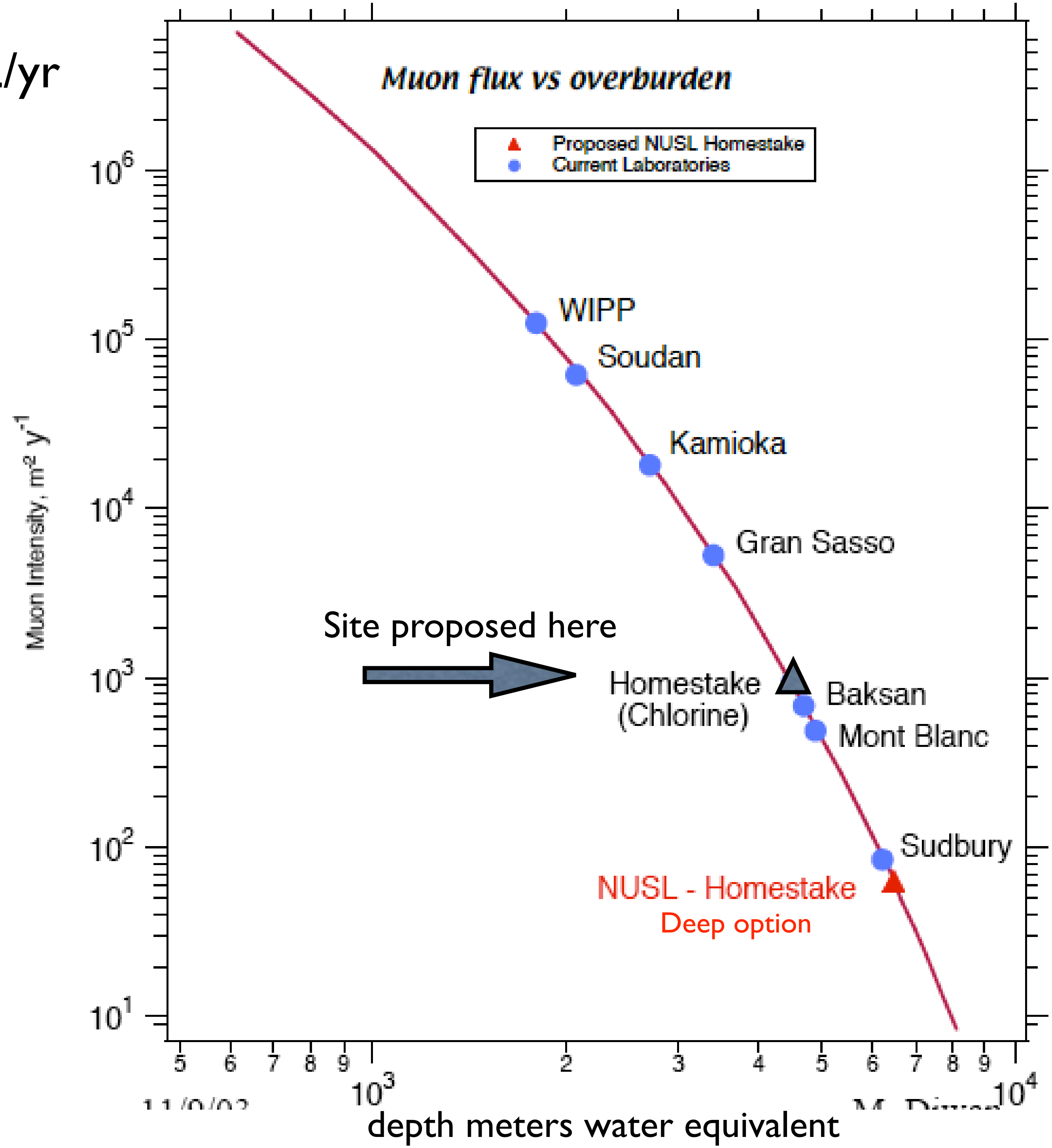
Surface: 3e9/m^2/yr

4850ft:
100kT
~3M mu/yr

with rate of 1 mu/10 sec/detector => may not need veto-counter

The Beam neutrinos will be obvious with a rate of 100-200/day in 10 mus spills.

No pattern recognition beyond time cut is needed.



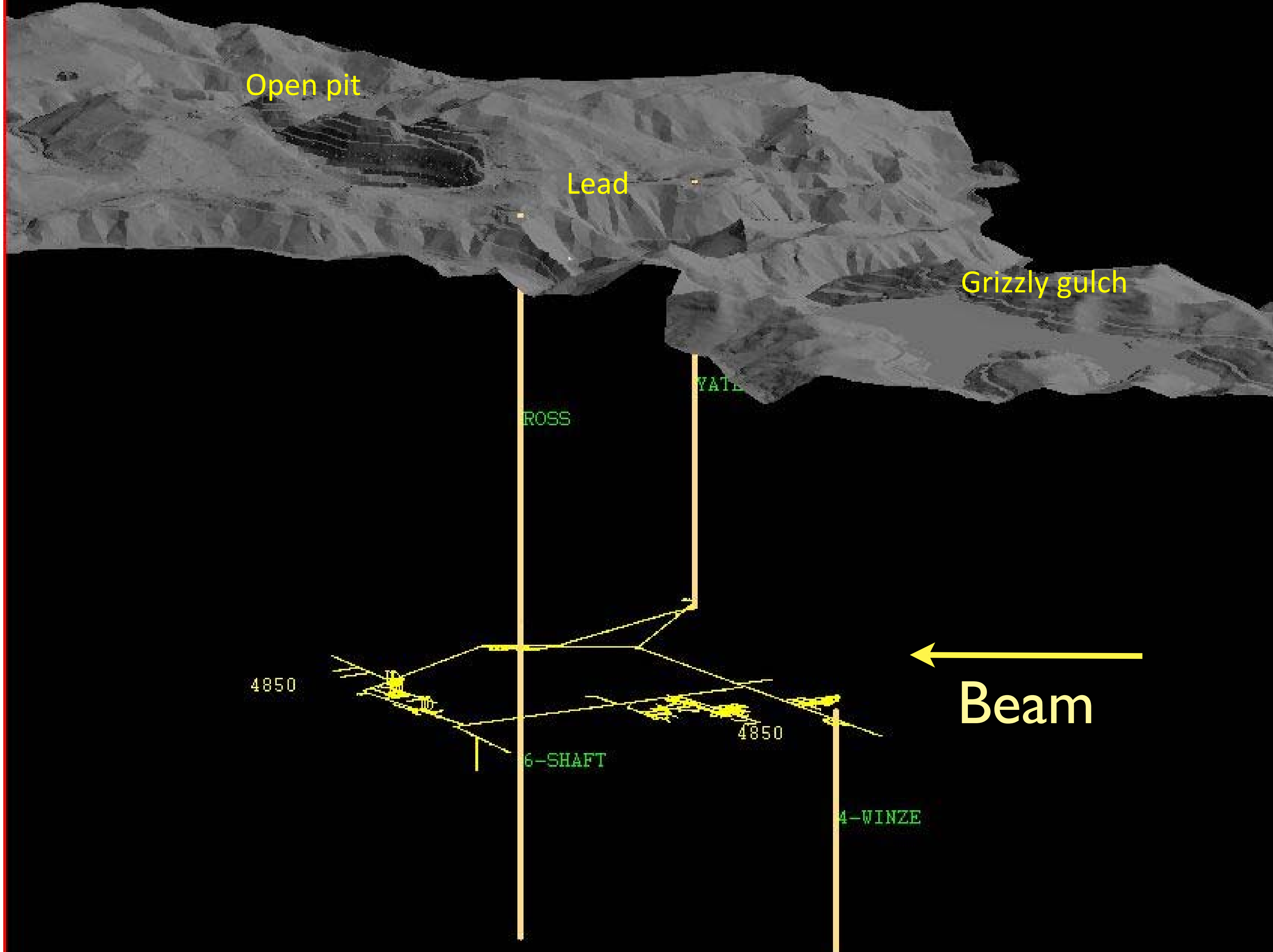
Where is S. Dakota ? What are black hills ?

SD has Tradition of mining

- South Dakota is West of Minnesota
- Black hills are very beautiful: bike trails, hiking, forests, small towns with Art galleries !

Where is the money?

- ~$40M from State and Federal resources.
- ~$70M from Sandford gift. DUSEL=>SUSEL.
- ~$15M/3yrs from NSF for preparation of TDR.
- ~$3M from NSF/DOE for R&D in next 3 yrs
- Promised ~$15M from NSF for engineering.



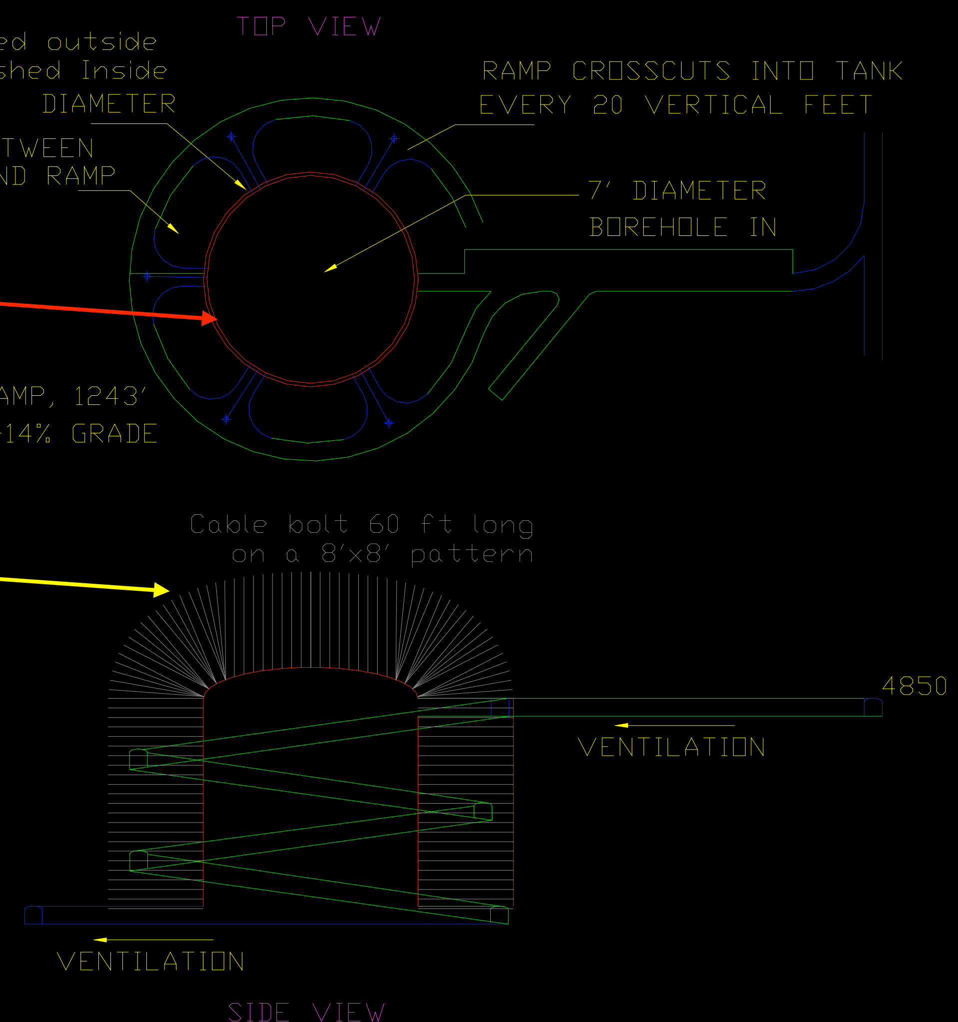
The Detector @ homestake

Megaton Modular Multi-Purpose Neutrino Detector

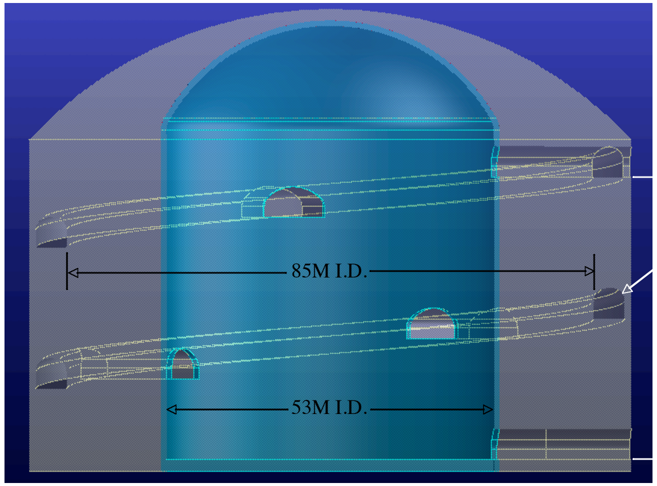
✓ Chamber Design

Controlled Blasting in Chamber

Could use Instrumented Cables for Engineering / Geotechnical Study



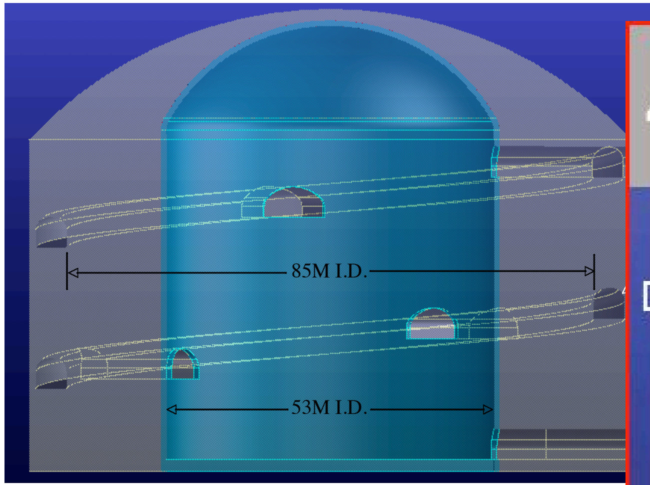
Water Cherenkov Detector



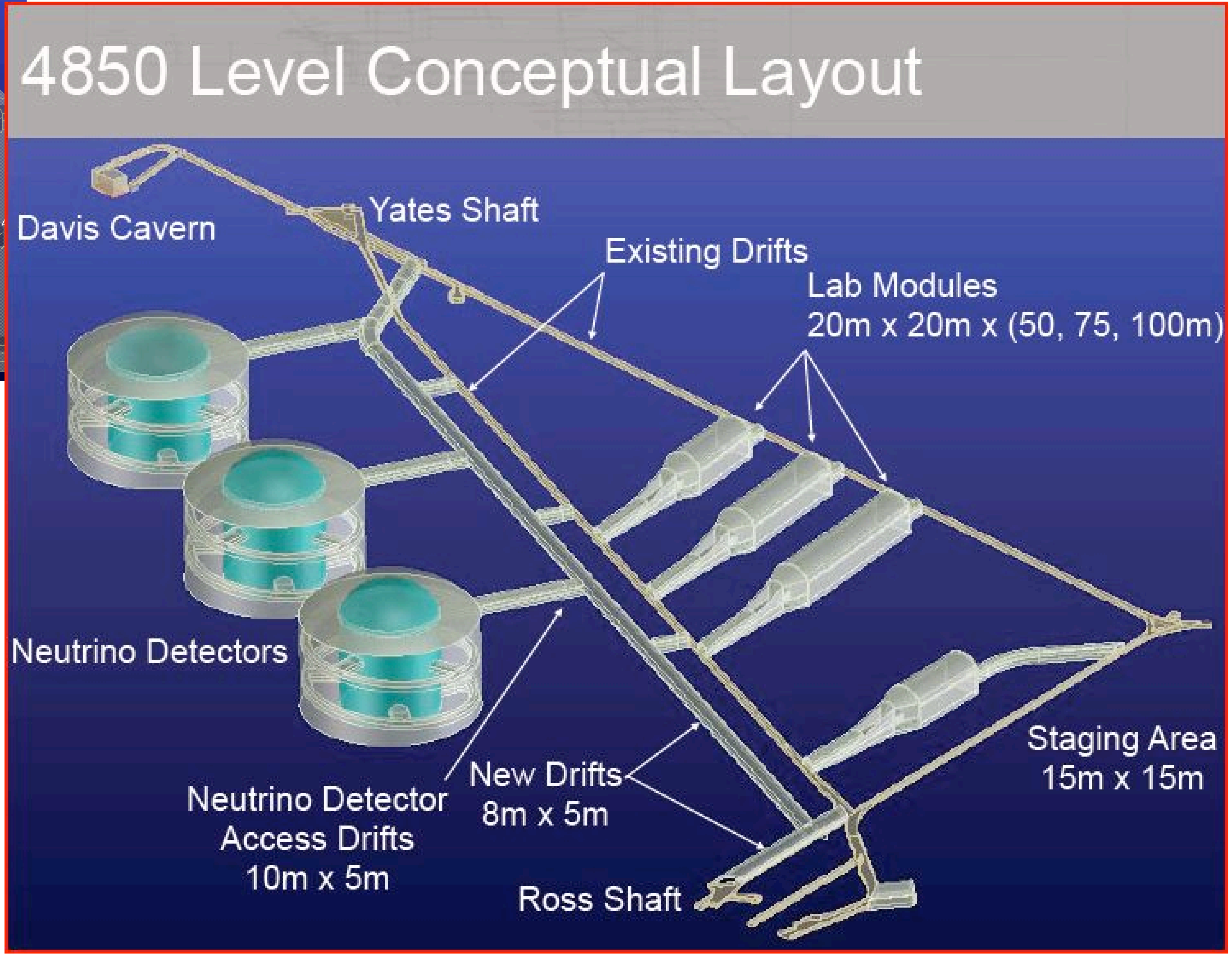
1 module fid:
100 kT

300 kT

Water Cherenkov Detector



1 module fid:
100 kT

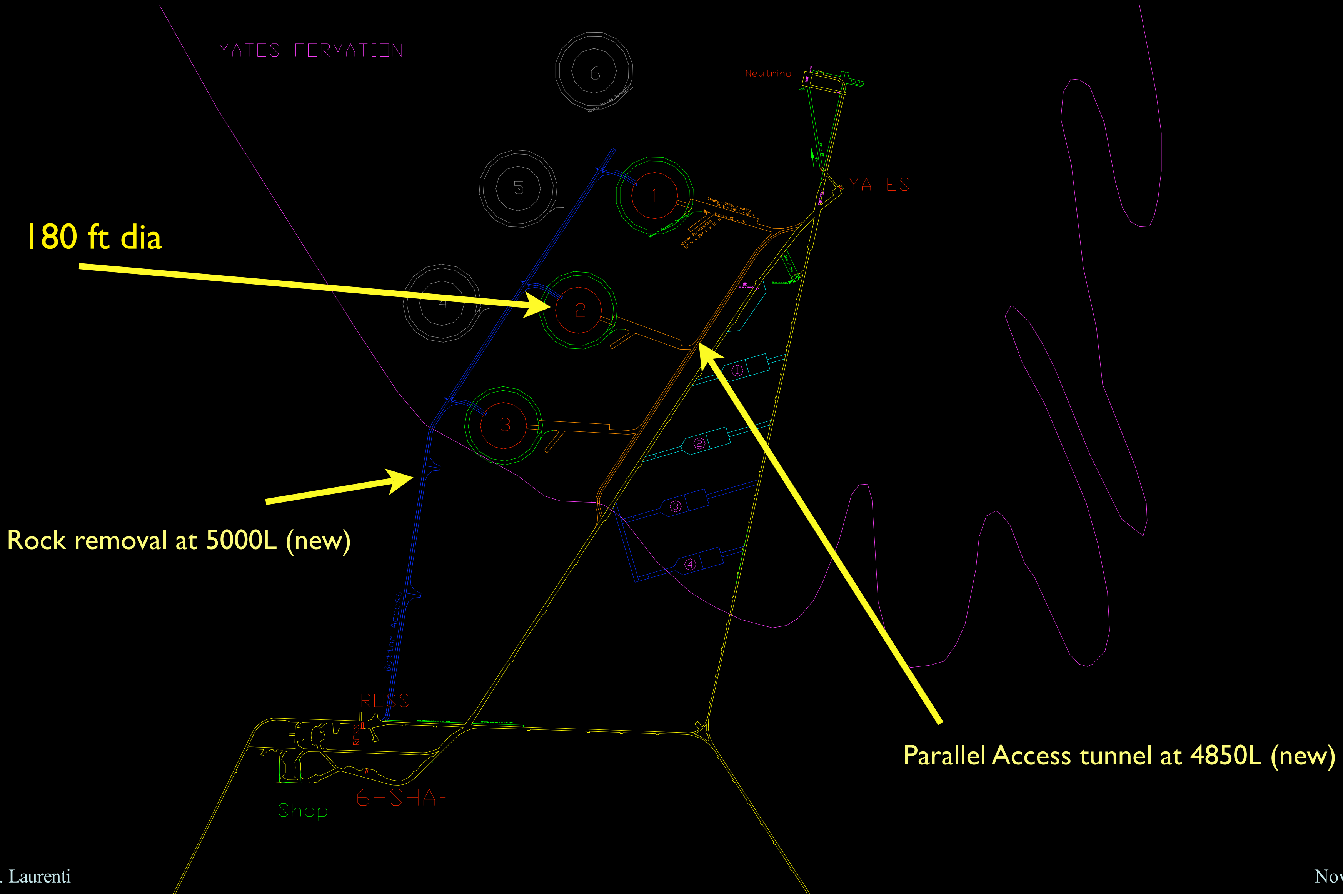


300 kT

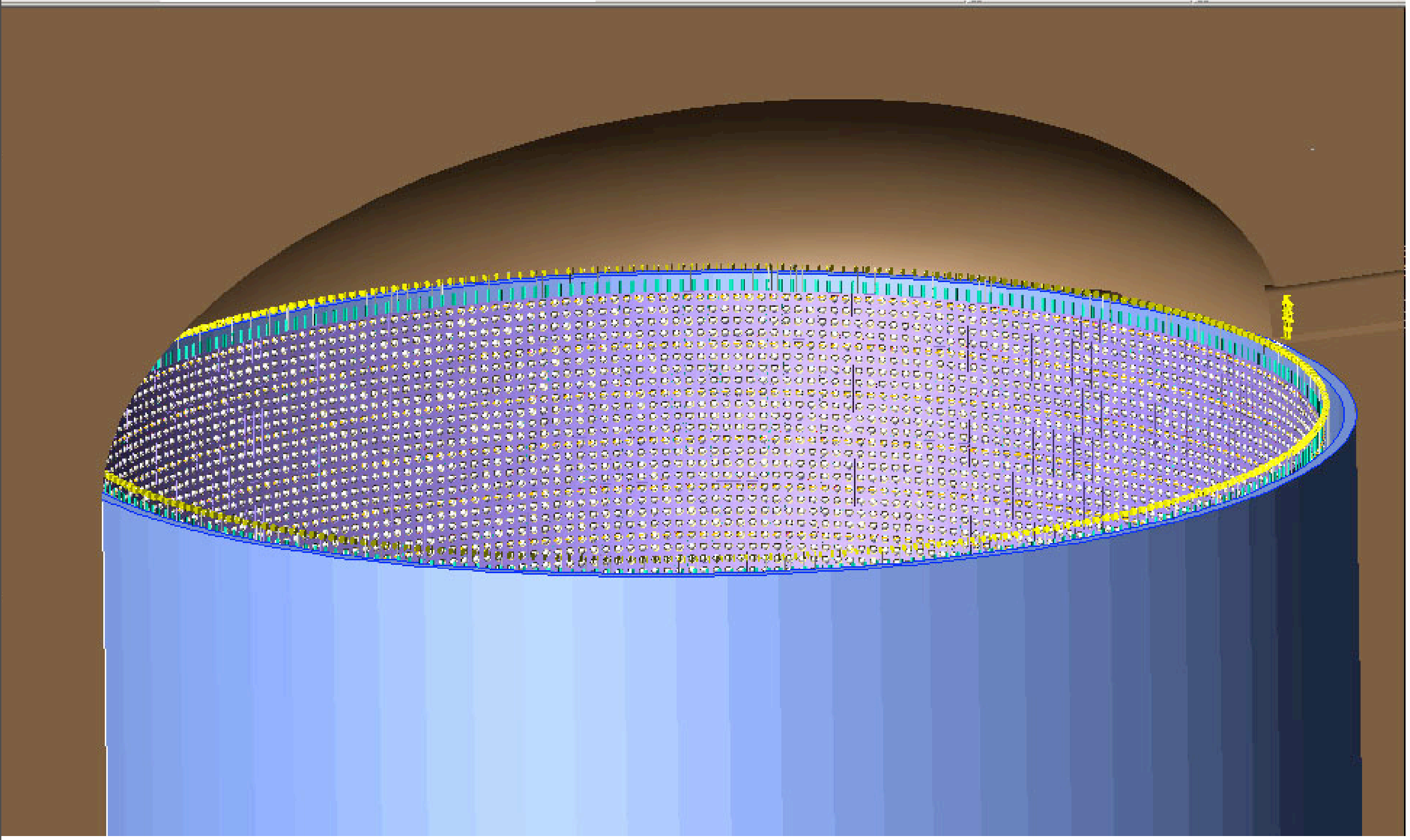
MEGATON MODULAR MULTI-PURPOSE NEUTRINO DETECTOR

✓ **Modular Configuration**

muon rate/cavern~1/10 Hz

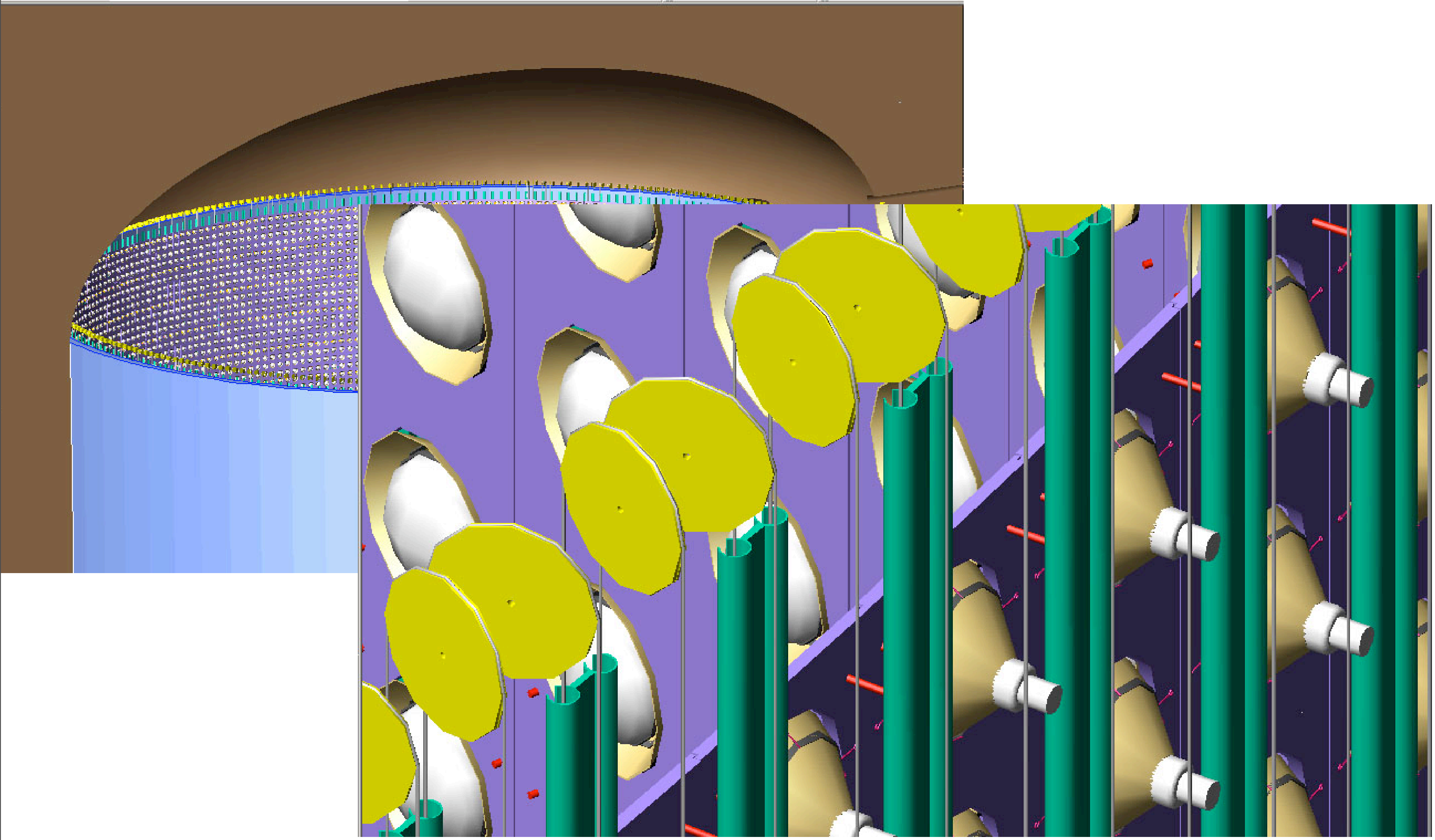


Installation



Conceptual design for installation

Installation



Conceptual design for installation

M.Diwan

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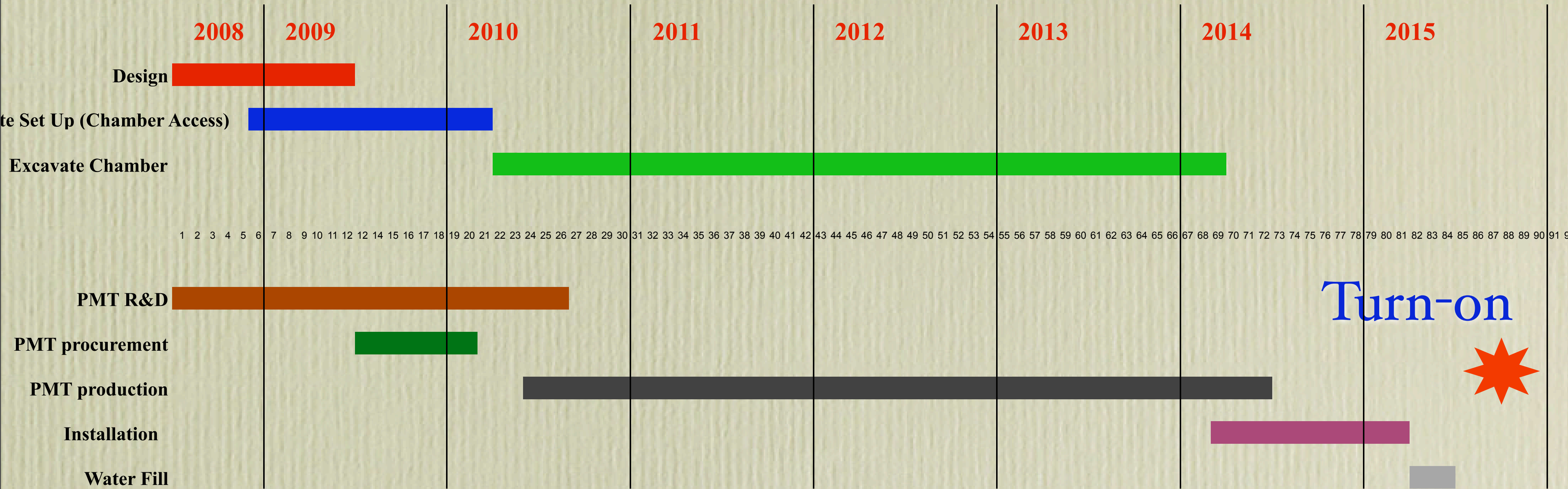
List of technical issues

- Cavern stability
- Cavern design: lining, water proofing, schedule.
- Material compatibility.
- PMT logistics and cost.
- PMT pressure capability and shock resistance.
- Electronics, cabling, etc.
- Installation design: < 1 year
- Water system (possibility of doping with Gadolinium)
- Integration.

Technically limited schedule for a single 100 kT fiducial detector



Comments: Phototube production is slowed down to match construction of 1 module only.
Schedule is strictly technical. Does not account for review process. See KTLesko talk
PMT testing facility, water system procurement and installation, and other items are not shown here.

- Tube production is slowed to match excavation. Tube production is NOT the limiting factor.
- For simplicity, water system, PMT testing, electronics, etc. are not shown.
- For 300 kT the time need not be tripled.

Organization

- The beam and the water Cherenkov detector are an exercise in organization and planning.
- There have been 4 meetings of an interim executive board (more about this later) since P5 committee rec.
- Two documents have been commissioned. (Depth paper and white paper)
- There have been several meetings at FNAL and Lead http://nwg.phy.bnl.gov/DDRD/cgi-bin/private/ListAllMeetings
- There is talk of forming an Institutional Board as quickly as possible so that the EB can be accountable

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Conclusion

- A 300kT detector at a good depth is well justified for accelerator neutrino physics.
- A conventional beam from FNAL to Homestake lab. is going through an examination by a technical working group.
- Excellent sensitivity for θ_{13} and mass ordering and CP violation. Non-accelerator physics additional.
- The caverns built could house different technology: better PMTs, Liquid Scintillator, Liquid Argon ...

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