Physics at the Intensity Frontier:

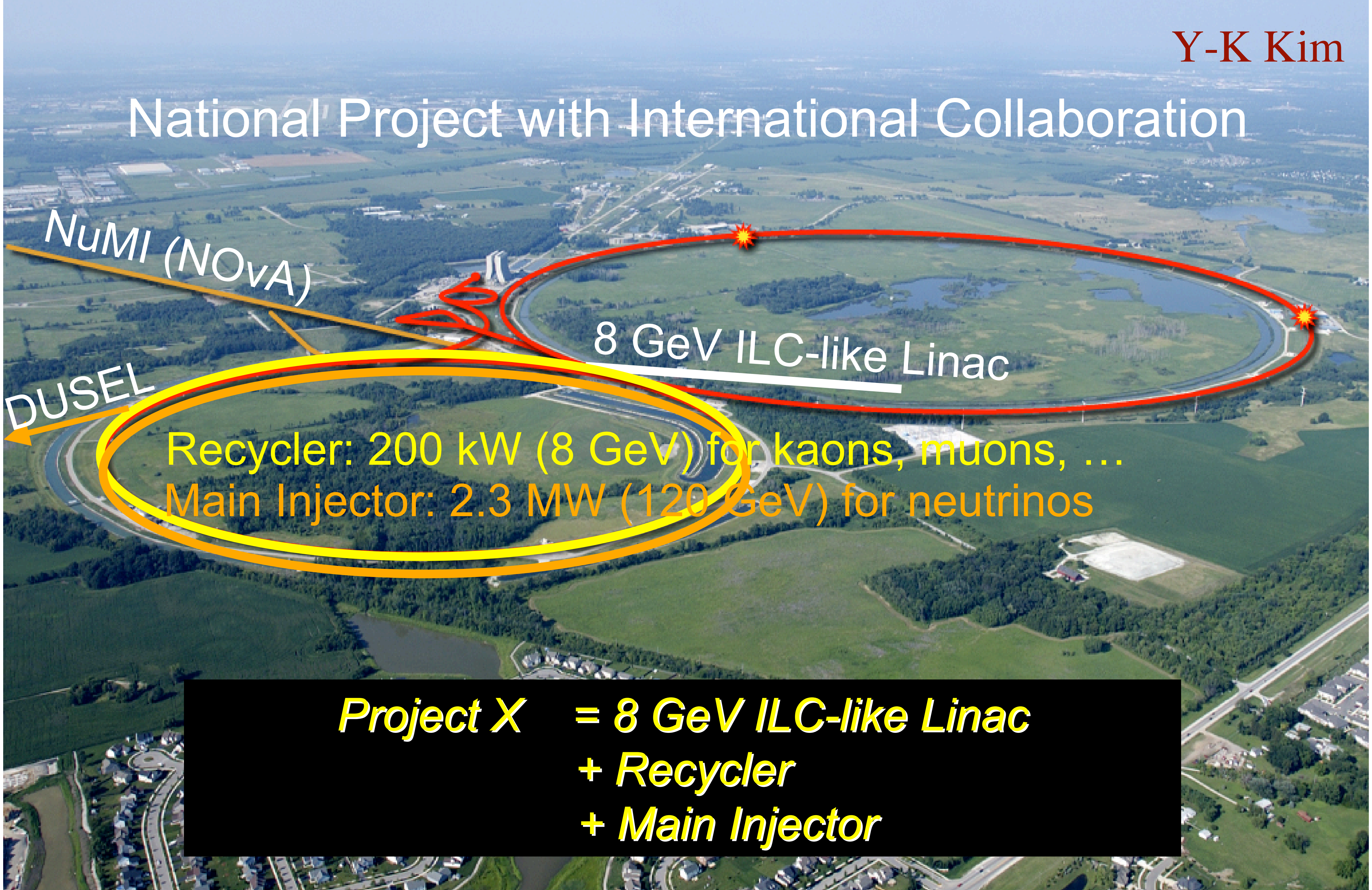
Stephen Parke, Fermilab, June 4 2009

- Neutrinos
- Muons
- Kaons, Anti-protons . . .

The Intensity Frontier With Project X

Y-K Kim

National Project with International Collaboration



Project X = 8 GeV ILC-like Linac
+ Recycler
+ Main Injector

- Neutrinos

"All the News
That's Fit to Print"

The New York

VOL. CXLVII . . . . No. 51,179 — FRIDAY, JUNE 5, 1998

Mass Found in Elusive Particle; Universe May Never Be the Same

Discovery on Neutrino Rattles Basic Theory About All Matter

By MALCOLM W. BROWNE

TAKAYAMA, Japan, June 5 — In what colleagues hailed as a historic landmark, 120 physicists from 23 research institutions in Japan and the United States announced today that they had found the existence of mass in a notoriously elusive subatomic particle called the neutrino.

The neutrino, a particle that carries no electric charge, is so light that it was assumed for many years to have no mass at all. After today's announcement, cosmologists will have to confront the possibility that much of the mass of the universe is in the form of neutrinos. The discovery will also compel scientists to revise a highly successful theory of the composition of matter known as the Standard Model.

Word of the discovery had drawn some 300 physicists here to discuss neutrino research. Among other things, they said, the finding of neutrino mass might affect theories about the formation and evolution of galaxies and the ultimate fate of the universe. If neutrinos have sufficient mass, their presence throughout the universe would increase the overall mass of the universe, possibly slowing its present expansion.

Others said the newly detected but as yet unmeasured mass of the neutrino must be too small to cause cosmological effects. But whatever the case, there was general agreement here that the discovery will have far-reaching consequences for the investigation of the nature of matter.

Speaking for the collaboration of scientists who discovered the existence of neutrino mass using a huge underground detector called Super-Kamiokande, Dr. Takaaki Kajita of the Institute for Cosmic Ray Research of Tokyo University said that all explanations for the data collected by the detector except the existence of neutrino mass had been essentially ruled out.

Dr. Yoji Totsuka, leader of the coalition and director of the Kamioka Neutrino Observatory where the underground detector is situated, 30 miles north of here in the Japan Alps, acknowledged that his group's announcement was "very strong," but said, "We have investigated all

Continued on Page A14

Detecting Neutrinos

1. Neutrinos pass through the Earth's surface to a tank filled with 12.5 million gallons of ultra-pure water . . .
2. . . . and collide with other particles . . .
3. . . . producing a cone-shaped flash of light.
4. The light is recorded by 11,200 20-inch light amplifiers that cover the inside of the tank.

And Detecting Their Mass

By analyzing the cones of light, physicists determine that some neutrinos have changed form on their journey. If they can change form, they must have mass.

Source: University of Hawaii

The New York Times

OKLAHOMA BLAST BRINGS LIFE TERM FOR TERRY NICHOLS

'ENEMY OF CONSTITUTION'

Judge Denounces Conspiracy and Hears From the Victims of a Terrifying Ordeal

By JO THOMAS

DENVER, June 4 — Calling him "an enemy of the Constitution," a Federal judge today sentenced Terry L. Nichols to life in prison without the possibility of parole for conspiring to bomb the Oklahoma City Federal Building, the deadliest terrorist attack ever on American soil.

In passing sentence after hearing from survivors of the blast and relatives of some of the 168 people who died in it, the judge, Richard P. Matsch of Federal District Court, said, "This was not a murder case."

He added: "It is a crime and the victims have spoken eloquently here. But it is not a crime as to them so much as it is a crime against the Constitution of the United States. That's the victim."

Last December, Mr. Nichols was convicted of conspiring with Timothy J. McVeigh to use a weapon of mass destruction in the April 19, 1995, bombing of the Alfred P. Murrah Federal Building, but was acquitted of Federal murder charges in the deaths of eight Federal agents who died. Mr. Nichols was found guilty of involuntary manslaughter in those deaths and today was given the maximum sentence of six years in prison for each, to run concurrently with his life sentence. He was also acquitted of actually committing the bombing.

While the conspiracy charge carried a possible death sentence, the jurors need to vote unanimously for such punishment, and they could not do so. The sentencing then fell to Judge Matsch.

Mr. McVeigh was convicted on all

Bajram Curri, in nc
Yugoslavia in three

Refugees
A Bitte

PADESH, Albania,
dent Slobodan Milose
via has unleashed th
tary operation in the
the end of the war in
thousands of ethnic A
the border area wit
reducing their village

At least 10,000
streamed through
passes and thousands

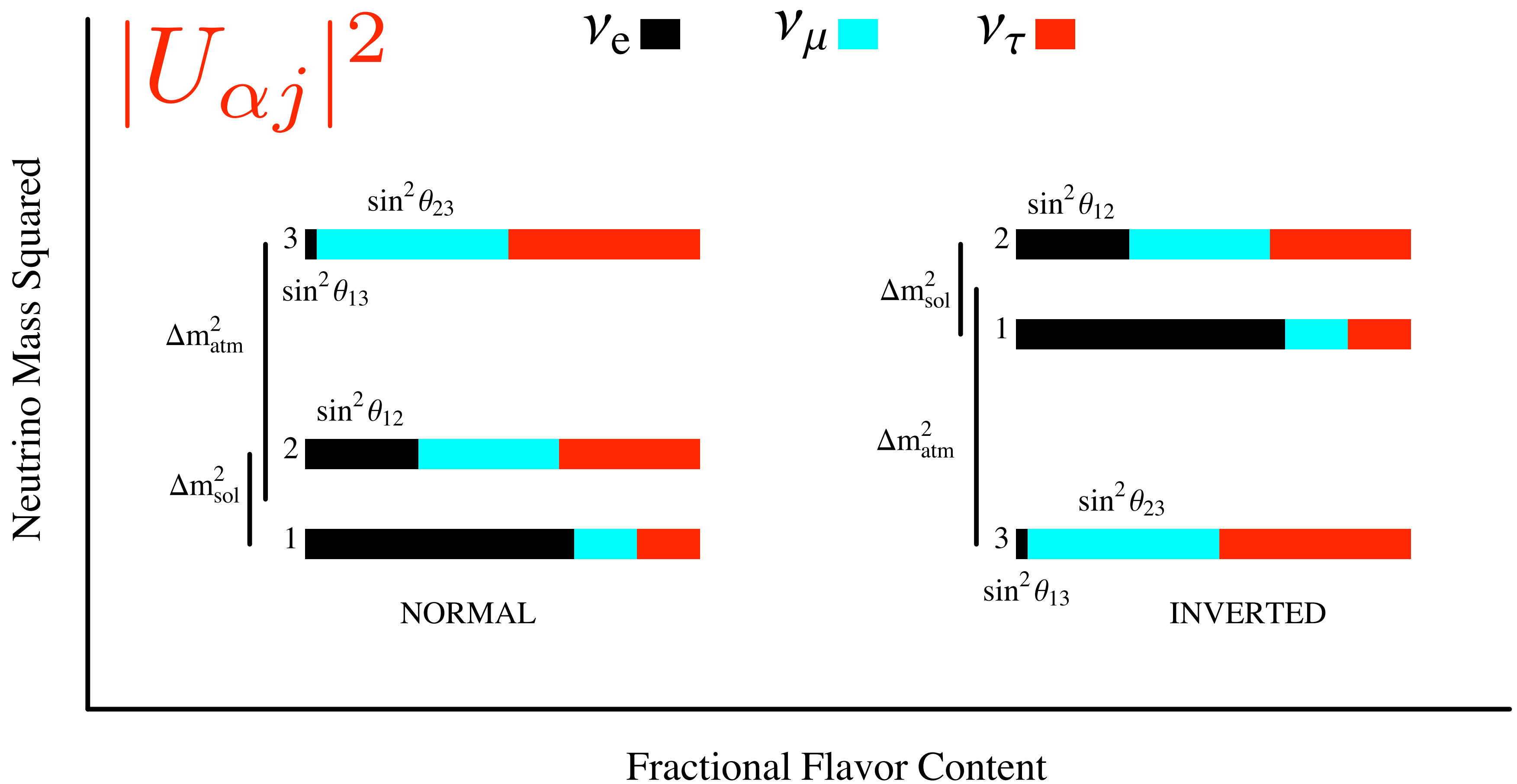
Mixing Matrix:

$$|\nu_e,\ \nu_\mu,\ \nu_\tau\rangle^T_{flavor} = U_{\alpha i}\ |\nu_1,\ \nu_2,\ \nu_3\rangle^T_{mass}$$

$$U_{\alpha i} = \begin{pmatrix} 1 & & \\ & c_{23} & s_{23} \\ & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & & s_{13}e^{-i\delta} \\ & 1 & \\ -s_{13}e^{i\delta} & & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & \\ -s_{12} & c_{12} & \\ & & 1 \end{pmatrix} \begin{pmatrix} 1 & & \\ & e^{i\alpha} & \\ & & e^{i\beta} \end{pmatrix}$$

Atmos. L/E $\mu \rightarrow \tau$ | Atmos. L/E $\mu \leftrightarrow e$ | Solar L/E $e \rightarrow \mu, \tau$ | $0\nu\beta\beta$ decay

500km/GeV | 15km/MeV



$$\sin^2\theta_{12} \sim 1/3$$

$$\sin^2\theta_{23} \sim 1/2$$

$$\sin^2\theta_{13} < 3\%$$

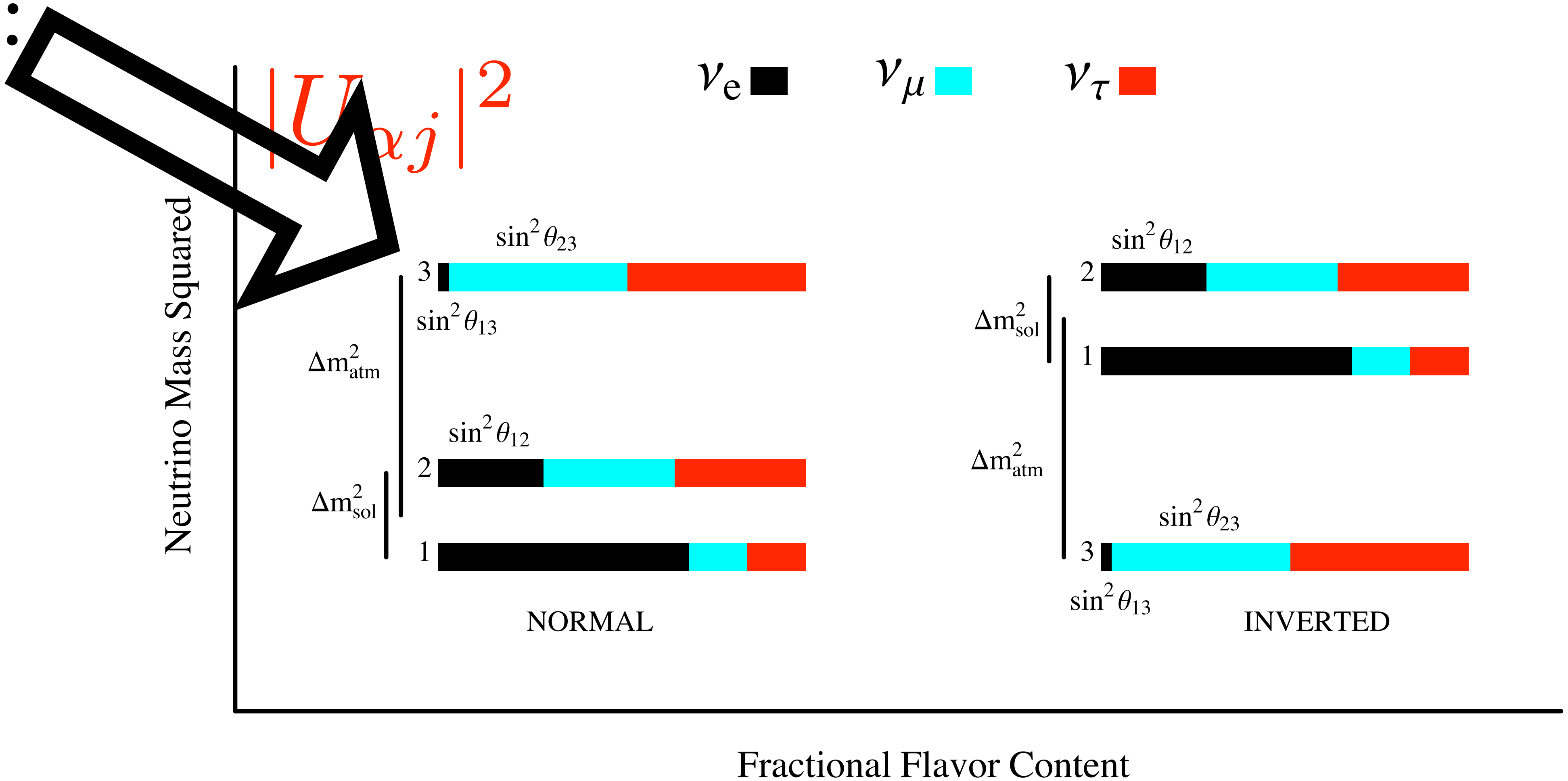
$$\delta m^2_{sol} = +7.6 \times 10^{-5}\ eV^2$$

$$|\delta m^2_{atm}| = 2.4 \times 10^{-3}\ eV^2$$

$$|\delta m^2_{sol}|/|\delta m^2_{atm}| \approx 0.03$$

$$\sqrt{\delta m^2_{atm}} = 0.05\ eV < \sum m_{\nu_i} < 0.5\ eV = 10^{-6} * m_e$$

KEY:



$$\sin^2\theta_{12} \sim 1/3$$

$$\delta m^2_{sol} = +7.6 \times 10^{-5}\ eV^2$$

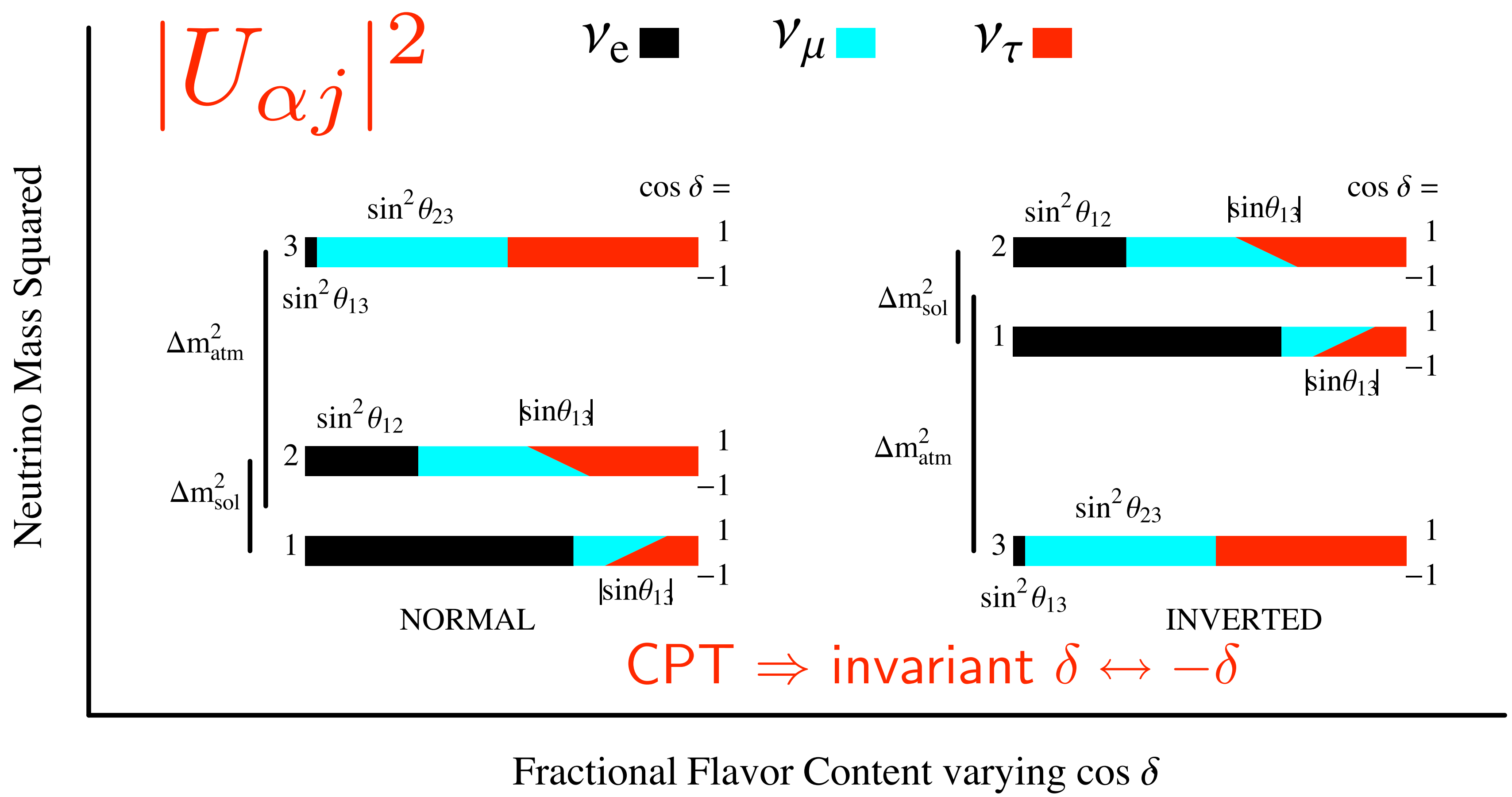
$$\sin^2\theta_{23} \sim 1/2$$

$$|\delta m^2_{atm}| = 2.4 \times 10^{-3}\ eV^2$$

$$\sin^2\theta_{13} < 3\%$$

$$|\delta m^2_{sol}|/|\delta m^2_{atm}| \approx 0.03$$

$$\sqrt{\delta m^2_{atm}} = 0.05\ eV < \sum m_{\nu_i} < 0.5\ eV = 10^{-6} * m_e$$



$$\sin^2\theta_{12} \sim 1/3$$

$$\sin^2\theta_{23} \sim 1/2$$

$$\sin^2\theta_{13} < 3\%$$

$$0 \leq \delta < 2\pi$$

$$\delta m^2_{sol} = +7.6 \times 10^{-5}\ eV^2$$

$$|\delta m^2_{atm}| = 2.4 \times 10^{-3}\ eV^2$$

$$|\delta m^2_{sol}|/|\delta m^2_{atm}| \approx 0.03$$

$$\sqrt{\delta m^2_{atm}} = 0.05\ eV < \sum m_{\nu_i} < 0.5\ eV = 10^{-6} * m_e$$

One Global Fit:

Dominated by

parameter	best fit	2σ	3σ	
Δm^2_{21} $[10^{-5}\text{eV}^2]$	$7.65^{+0.23}_{-0.20}$	7.25–8.11	7.05–8.34	KamLAND
$\lvert\Delta m^2_{31}\rvert$ $[10^{-3}\text{eV}^2]$	$2.40^{+0.12}_{-0.11}$	2.18–2.64	2.07–2.75	MINOS
$\sin^2\theta_{12}$	$0.304^{+0.022}_{-0.016}$	0.27–0.35	0.25–0.37	SNO
$\sin^2\theta_{23}$	$0.50^{+0.07}_{-0.06}$	0.39–0.63	0.36–0.67	SuperK
$\sin^2\theta_{13}$	$0.01^{+0.016}_{-0.011}$	≤ 0.040	≤ 0.056	Chooz

arXiv:0808.2016

Neutrino

Mass Spectrum:

- Quasi-Degenerate ?
- Hierarchical ?
- Normal or Inverted ?

Neutrino

Mass Spectrum:

- Quasi-Degenerate ?
- Hierarchical ?
- Normal or Inverted ?

Mixings:

- Deviations from $U_{Tri-Bi-Max}$

  $\boxed{\sin^2\theta_{13},}$ $(\sin^2\theta_{23} - 1/2)$, $(\sin^2\theta_{12} - 1/3)$
- Relationship between these deviations and

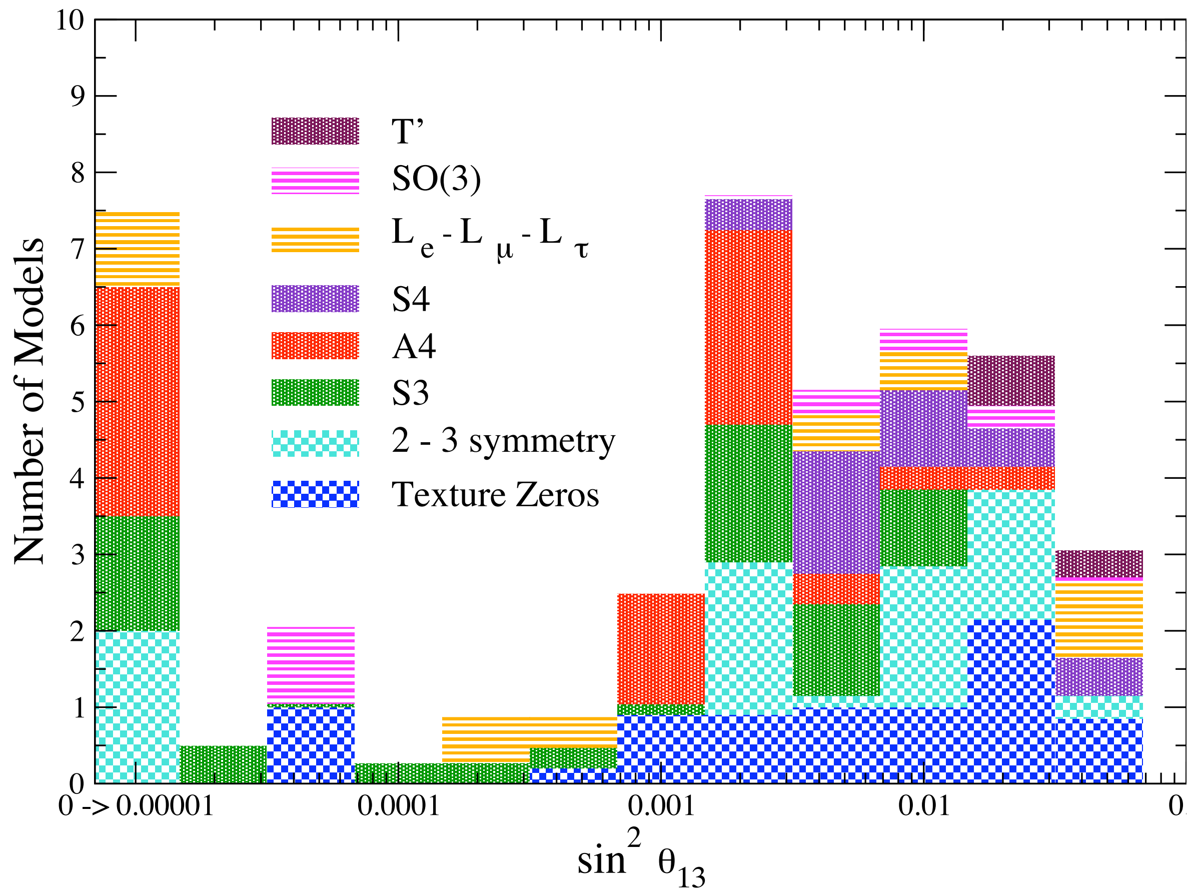
  $V_{CKM} - 1$

  if any ?
- Magnitude and sign of CPV:

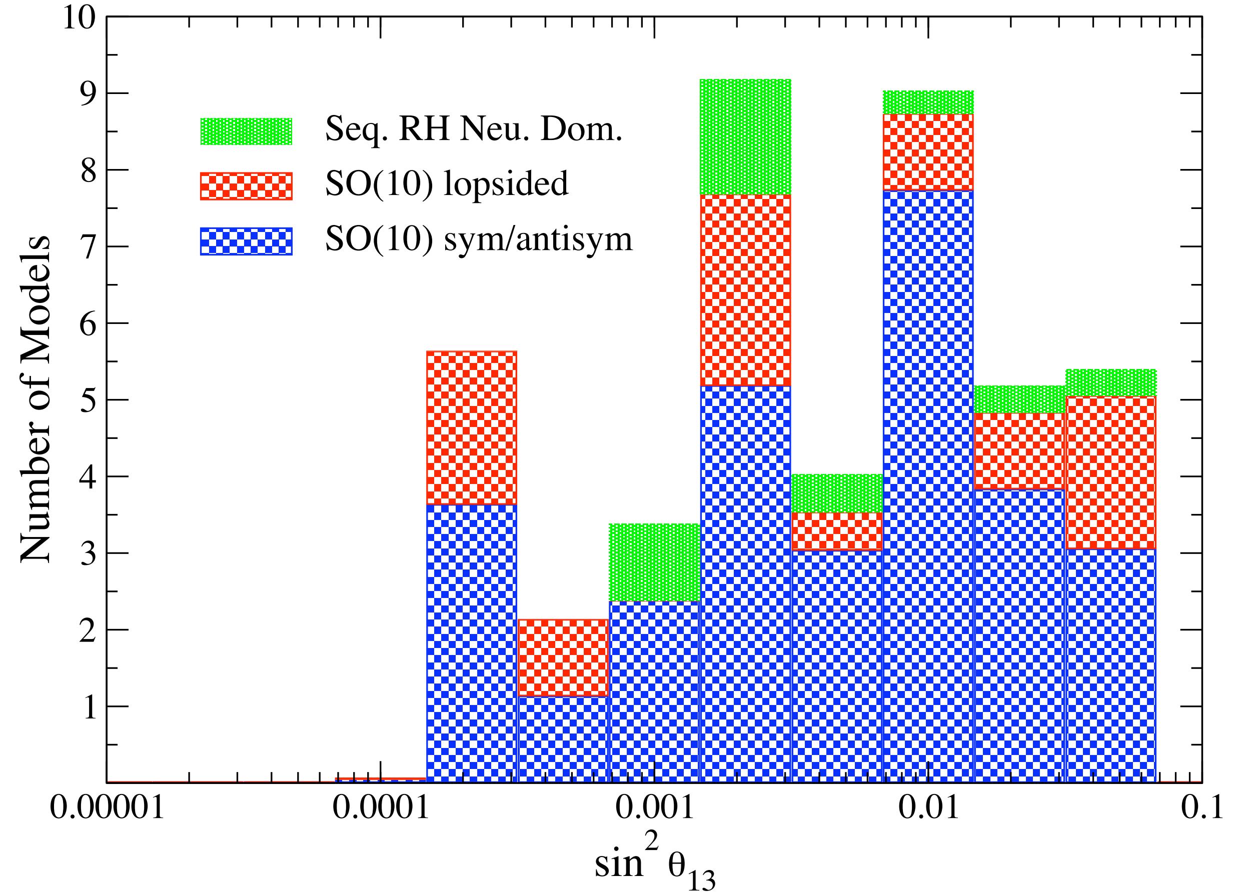
  $\propto \sin\theta_{13} \sin\delta$

MODELS:

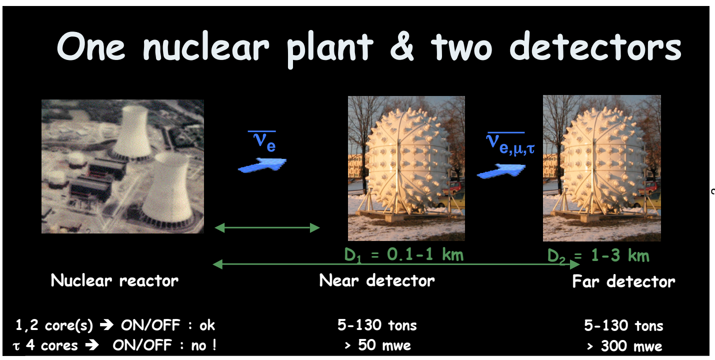
Predictions of Lepton Flavor Models

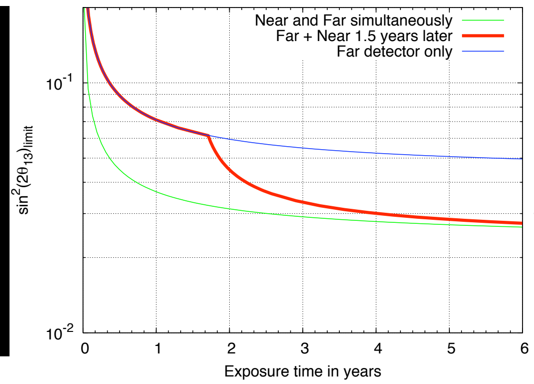


Predictions of Grand Unified Models



Double Chooz:

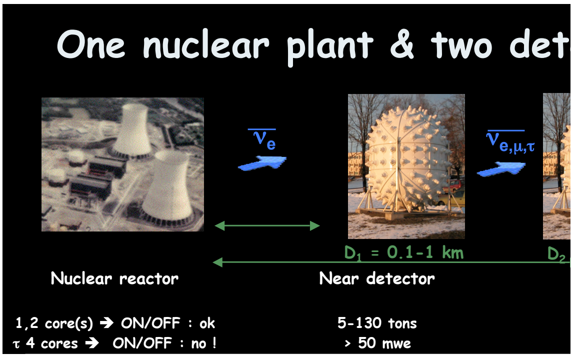




.03

Figure 18: $\sin^2(2\theta_{13})$ sensitivity limit for the detectors installation scheduled scenario

Double Chooz:

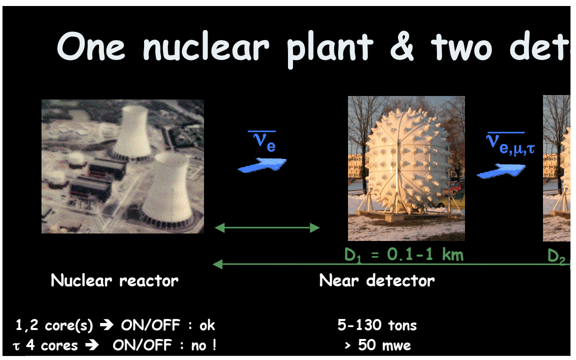


Daya Bay

push the limit on

$$\sin^2 2\theta_{13} < 0.01$$

Double Chooz:



Daya Bay

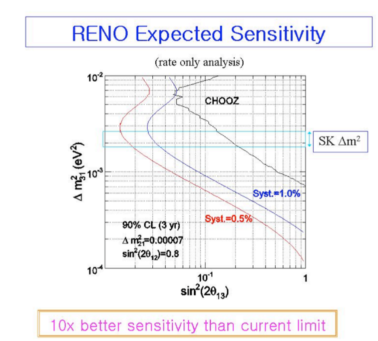
push the limi

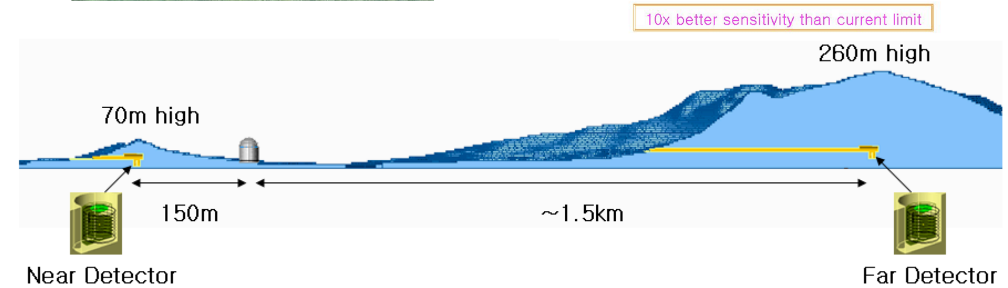
$\sin^2 2\theta_{13} < 0$

RENO

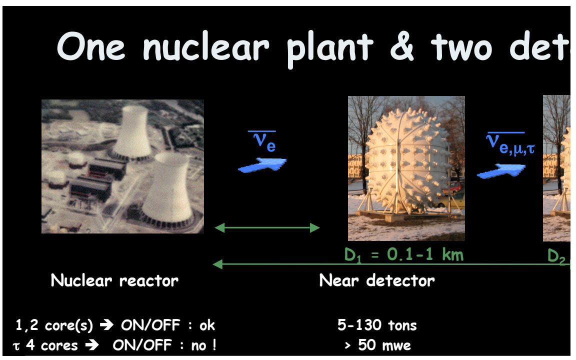
ν θ_{13}

(Reactor Experiment for Neutrino Oscillation)



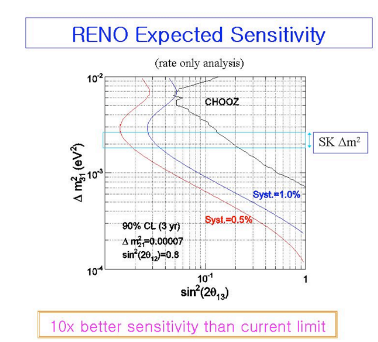


Double Chooz:



Daya Bay

(Reactor Experiment for Neutrino Oscillation)

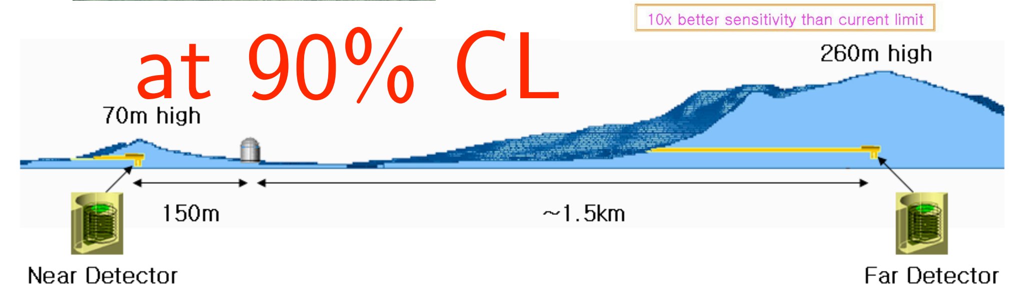


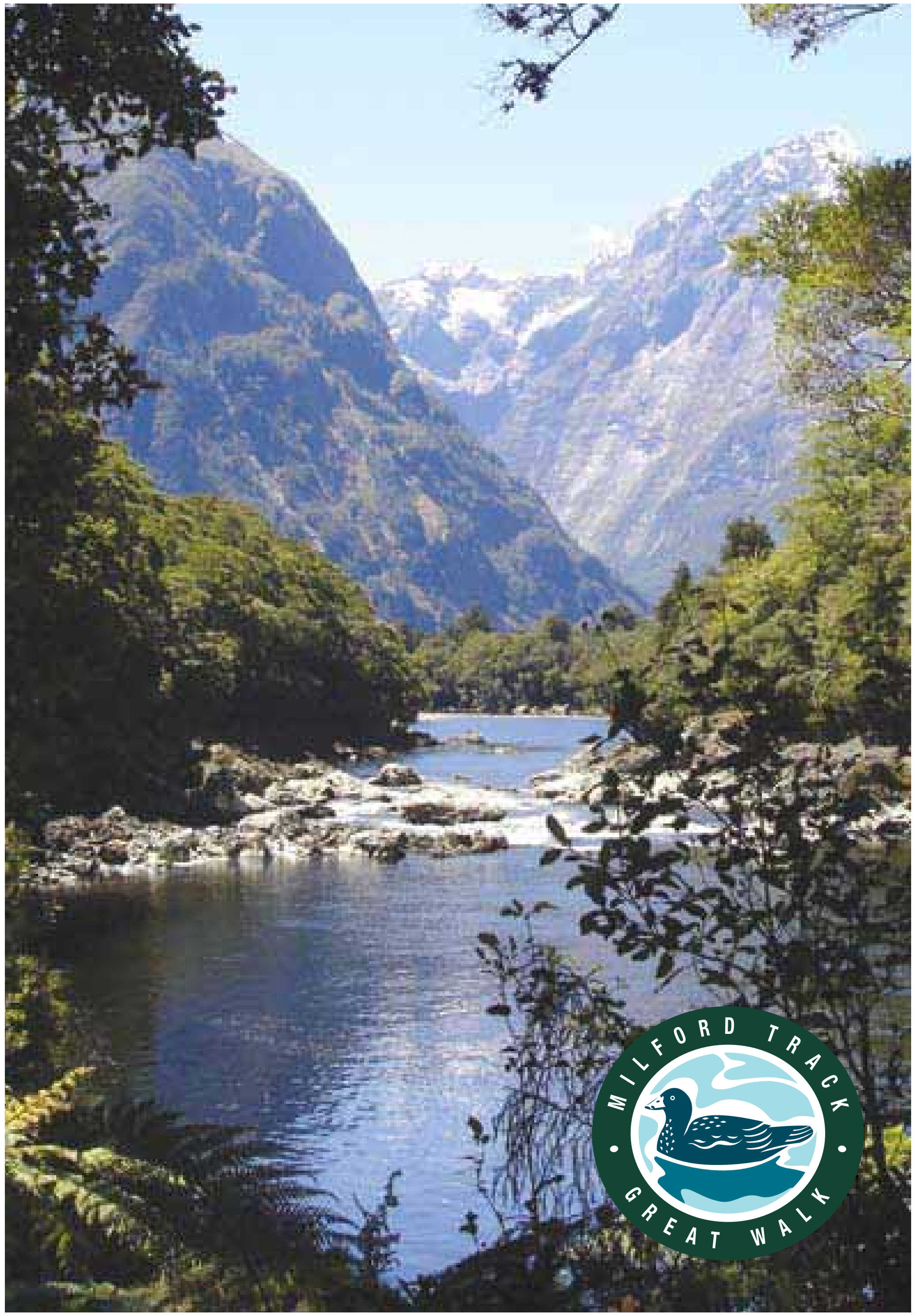
push the limi

$$\sin^2 2\theta_{13} < 0$$

$$1 - \langle P(\nu_e \to \nu_e) \rangle \sim 1.0 - 3.0\%$$

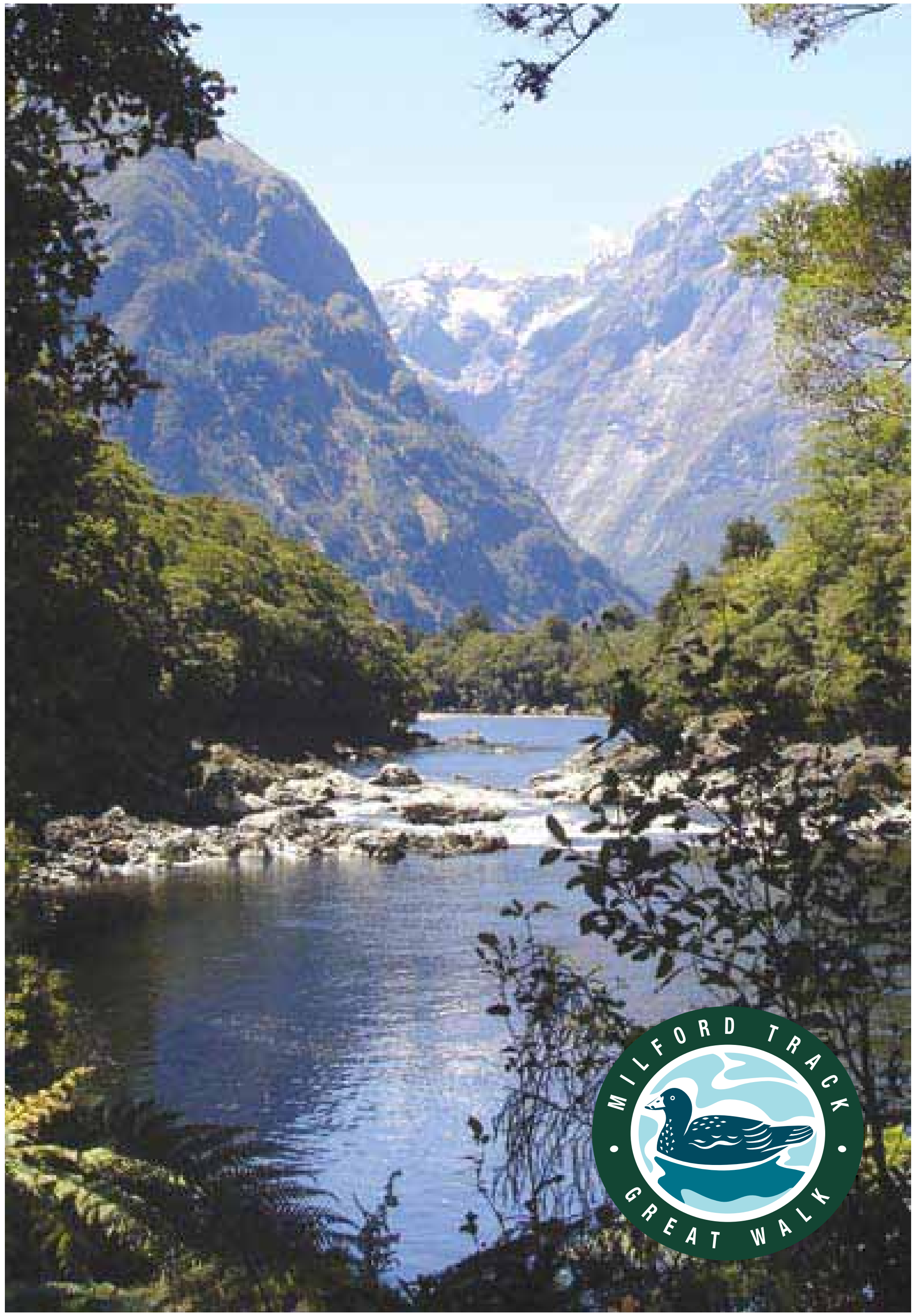
at 90% CL





Department of Conservation
Te Papa Atawhai

$\sin^2\theta_{13}$ from LBL:



Department of Conservation
Te Papa Atawhai

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

and related processes:

CP

$$\nu_\mu \longrightarrow \nu_e \qquad \Longleftrightarrow \qquad \bar{\nu}_\mu \longrightarrow \bar{\nu}_e$$

T $\Updownarrow$ CPT across diagonals $\Updownarrow$ T

$$\nu_e \longrightarrow \nu_\mu \qquad \Longleftrightarrow \qquad \bar{\nu}_e \longrightarrow \bar{\nu}_\mu$$

CP

- First Row: Superbeams where ν_e contamination $\sim$1 %
- Second Row: ν-Factory or β-Beams, no beam contamination

Vacuum LBL:

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

$$P_{\mu\rightarrow e} \approx |\ \sqrt{P_{atm}}e^{-i(\Delta_{32}\pm\delta)} + \sqrt{P_{sol}}\ |^2$$

$\updownarrow$ CP violation !!!

$\Delta_{ij} = \delta m^2_{ij} L/4E$

where $\sqrt{P_{atm}} = \sin\theta_{23}\sin 2\theta_{13}\ \sin\Delta_{31}$

and $\sqrt{P_{sol}} = \cos\theta_{23}\sin 2\theta_{12}\ \sin\Delta_{21}$

Vacuum LBL: $\nu_\mu \longrightarrow \nu_e$

$$P_{\mu\to e} \approx |\sqrt{P_{atm}}e^{-i(\Delta_{32}\pm\delta)} + \sqrt{P_{sol}}|^2$$

$\updownarrow$ CP violation !!!

$\Delta_{ij} = \delta m_{ij}^2 L/4E$

where $\sqrt{P_{atm}} = \sin\theta_{23}\sin 2\theta_{13}\ \sin\Delta_{31}$

and $\sqrt{P_{sol}} = \cos\theta_{23}\sin 2\theta_{12}\ \sin\Delta_{21}$

$$P_{\mu\to e} \approx P_{atm} + 2\sqrt{P_{atm}P_{sol}}\cos(\Delta_{32}\pm\delta) + P_{sol}$$

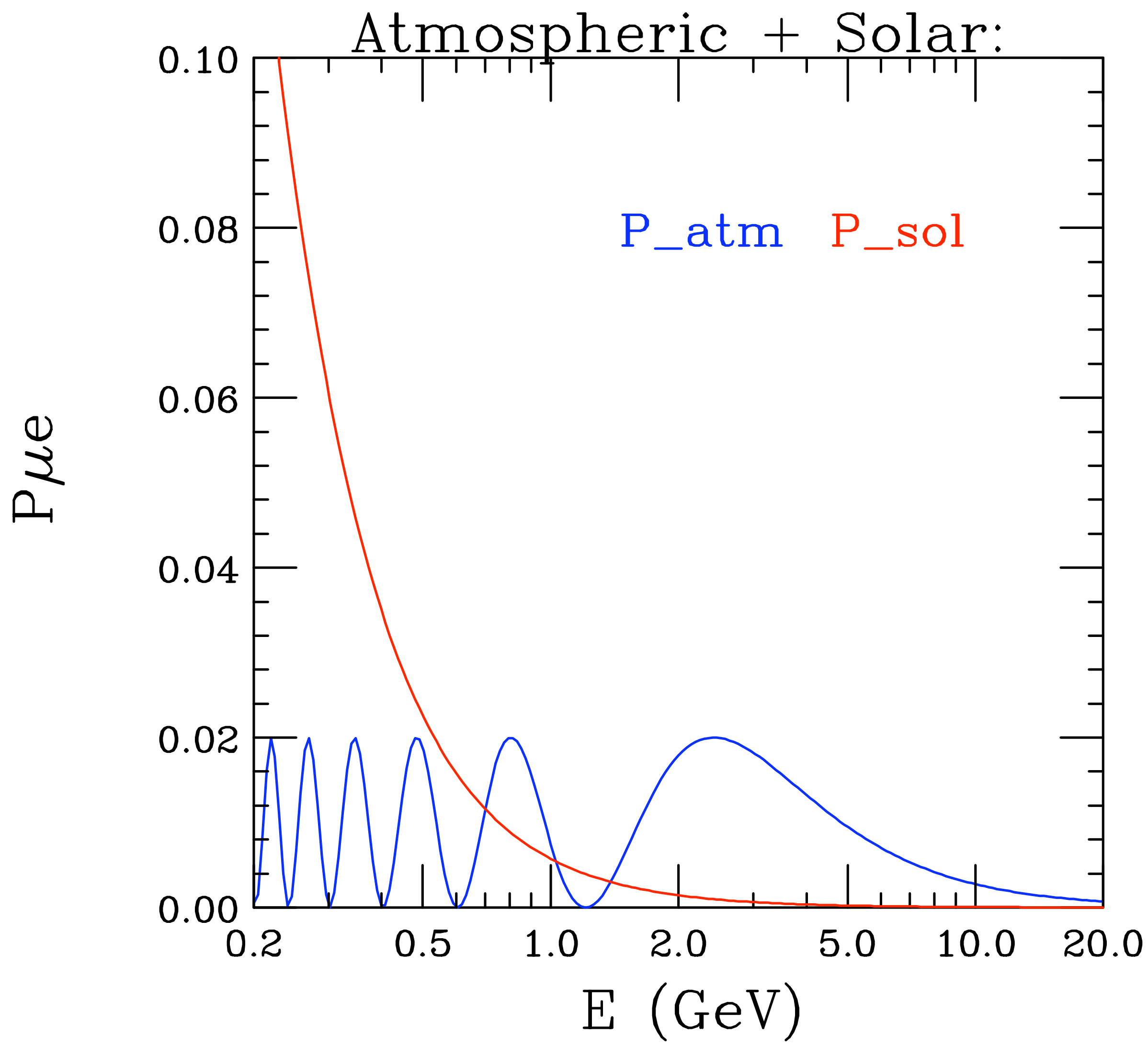
$\Updownarrow$

$$\cos(\Delta_{32}\pm\delta) = \cos\Delta_{32}\cos\delta \mp \sin\Delta_{32}\sin\delta$$

only CPV

$$P(\nu_\mu \rightarrow \nu_e) \approx |\sqrt{P_{atm}} e^{-i(\Delta_{32}+\delta)} + \sqrt{P_{sol}}|^2$$

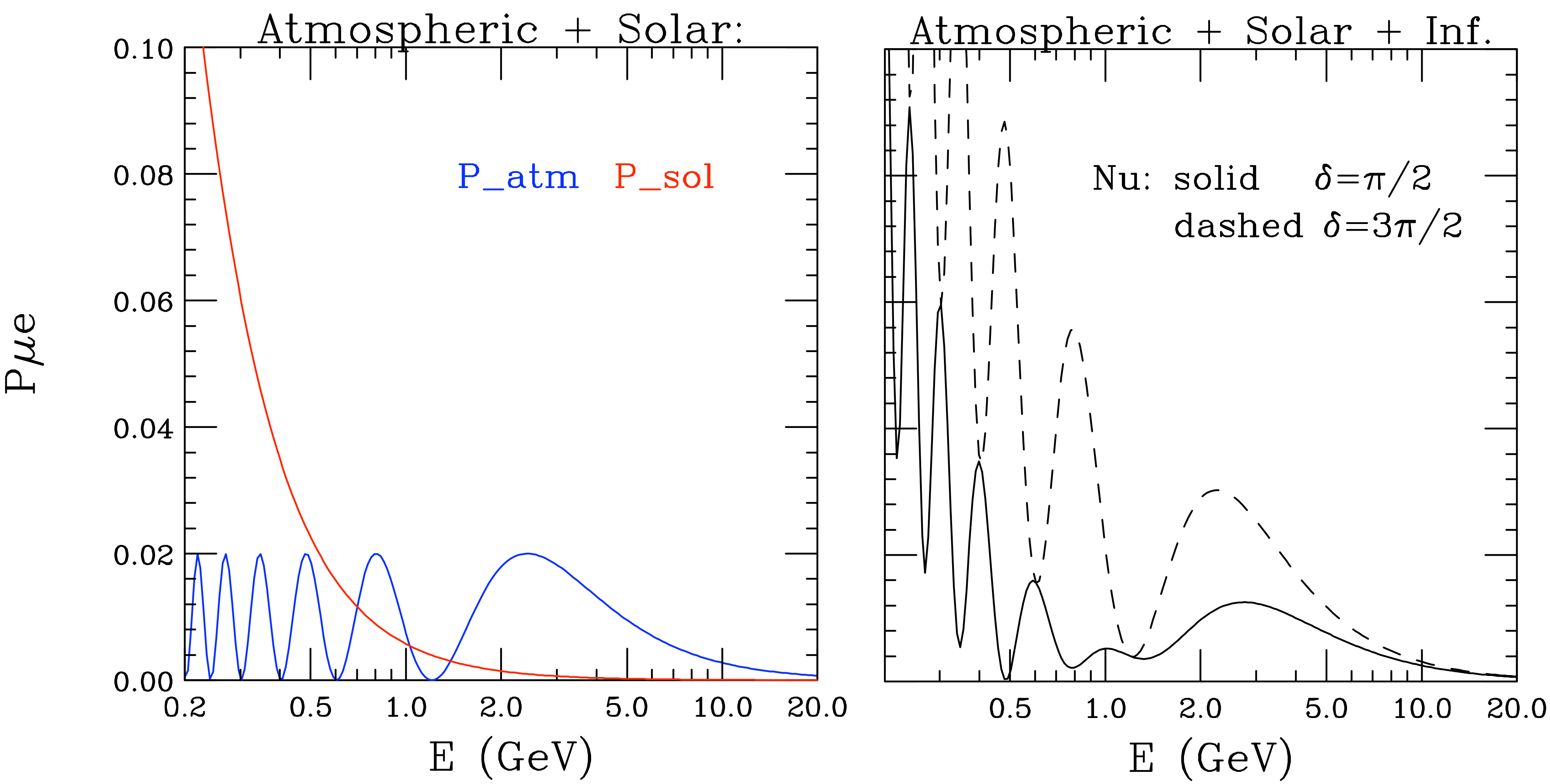
For $L = 1200\ km$
and $\sin^2 2\theta_{13} = 0.04$



x 3

$$P(\nu_\mu \rightarrow \nu_e) \approx |\sqrt{P_{atm}}e^{-i(\Delta_{32}+\delta)} + \sqrt{P_{sol}}|^2$$

For $L = 1200\ km$
and $\sin^2 2\theta_{13} = 0.04$



x 3

phase varies

In Matter:

$$P_{\mu\rightarrow e} \approx |\ \sqrt{P_{atm}} e^{-i(\Delta_{32} \pm \delta)} + \sqrt{P_{sol}}\ |^2$$

where $\sqrt{P_{atm}} = \sin\theta_{23}\sin 2\theta_{13}\ \frac{\sin(\Delta_{31} \mp aL)}{(\Delta_{31} \mp aL)}\ \Delta_{31}$

and $\sqrt{P_{sol}} = \cos\theta_{23}\sin 2\theta_{12}\ \frac{\sin(aL)}{(aL)}\ \Delta_{21}$

$$a\ =\ G_F N_e/\sqrt{2}\ =\ (4000\ \ km)^{-1},$$

In Matter:

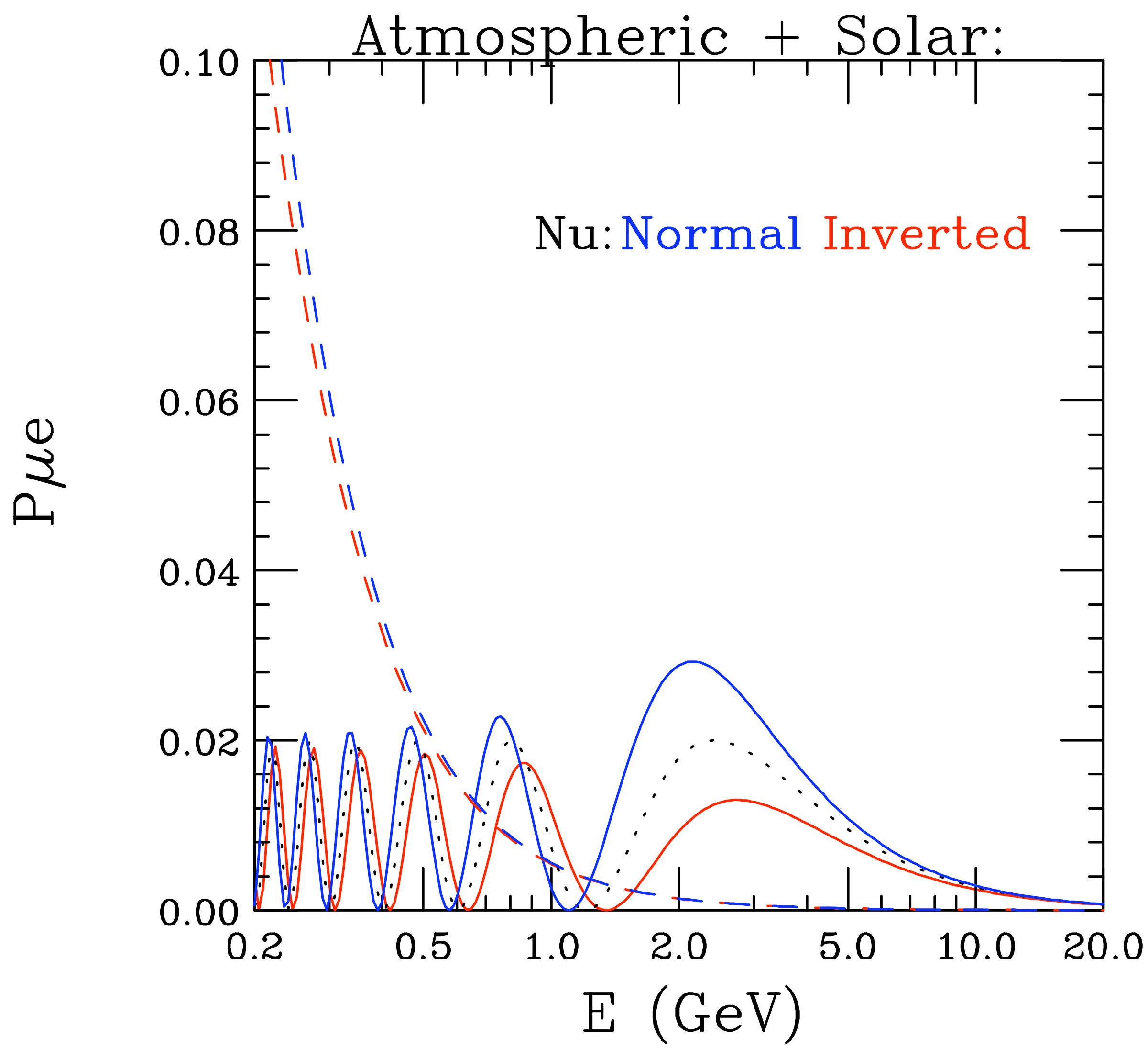
$$\boldsymbol{P_{\mu \to e} \approx |\, \sqrt{P_{atm}} e^{-i(\Delta_{32} \pm \delta)} + \sqrt{P_{sol}}\, |^2}$$

where $\sqrt{P_{atm}} = \sin\theta_{23} \sin 2\theta_{13} \, \frac{\sin(\Delta_{31} \mp aL)}{(\Delta_{31} \mp aL)} \, \Delta_{31}$

and $\sqrt{P_{sol}} = \cos\theta_{23} \sin 2\theta_{12} \, \frac{\sin(aL)}{(aL)} \, \Delta_{21}$

For $L = 1200 \; km$
and $\sin^2 2\theta_{13} = 0.04$

$$\boldsymbol{a = G_F N_e / \sqrt{2} = (4000 \;\; km)^{-1},}$$



In Matter:

$$\boldsymbol{P_{\mu\rightarrow e} \approx |\ \sqrt{P_{atm}}\, e^{-i(\Delta_{32}\pm\delta)} + \sqrt{P_{sol}}\ |^2}$$

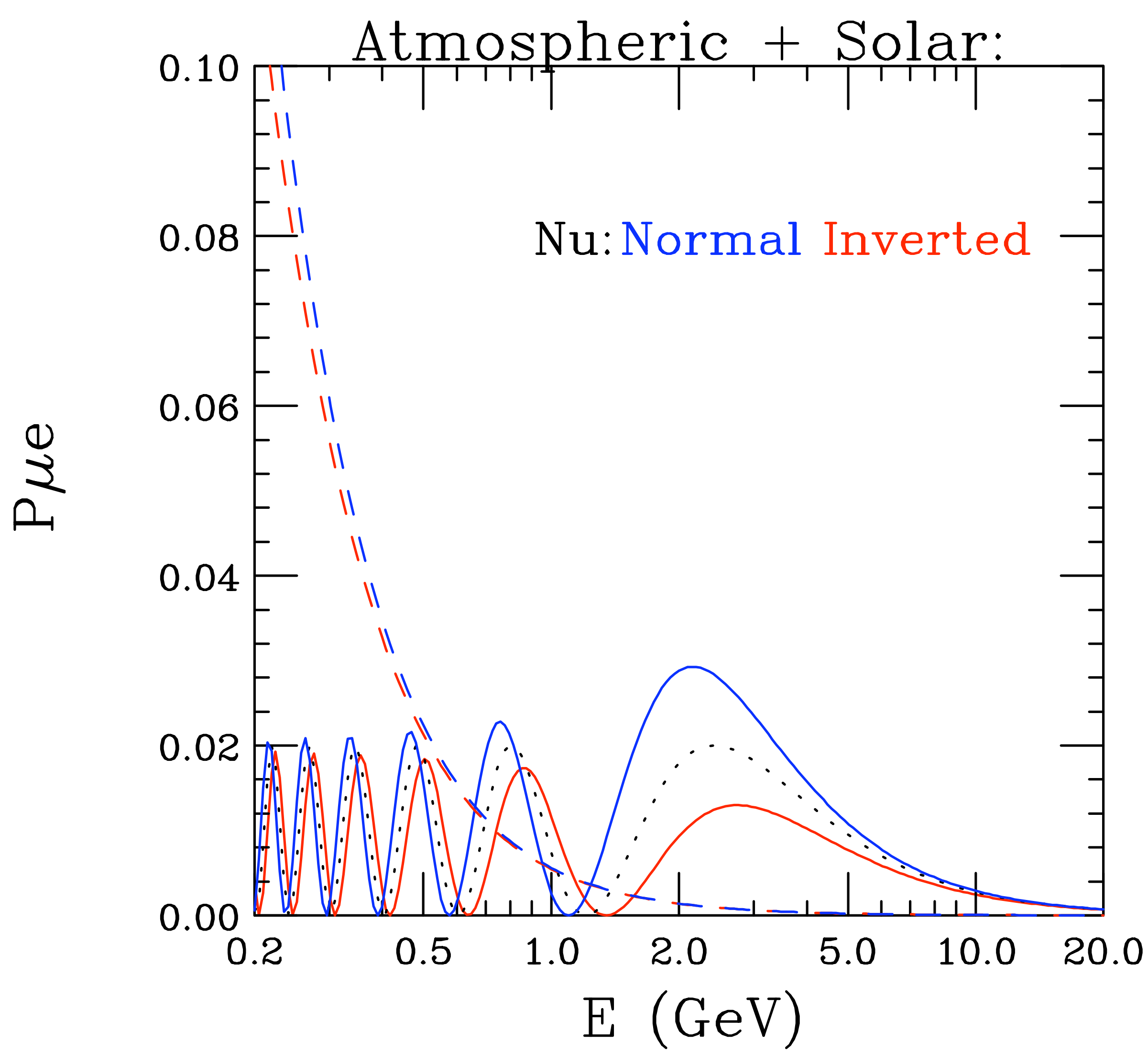
where $\sqrt{P_{atm}} = \sin\theta_{23}\sin 2\theta_{13}\ \frac{\sin(\Delta_{31}\mp aL)}{(\Delta_{31}\mp aL)}\ \Delta_{31}$

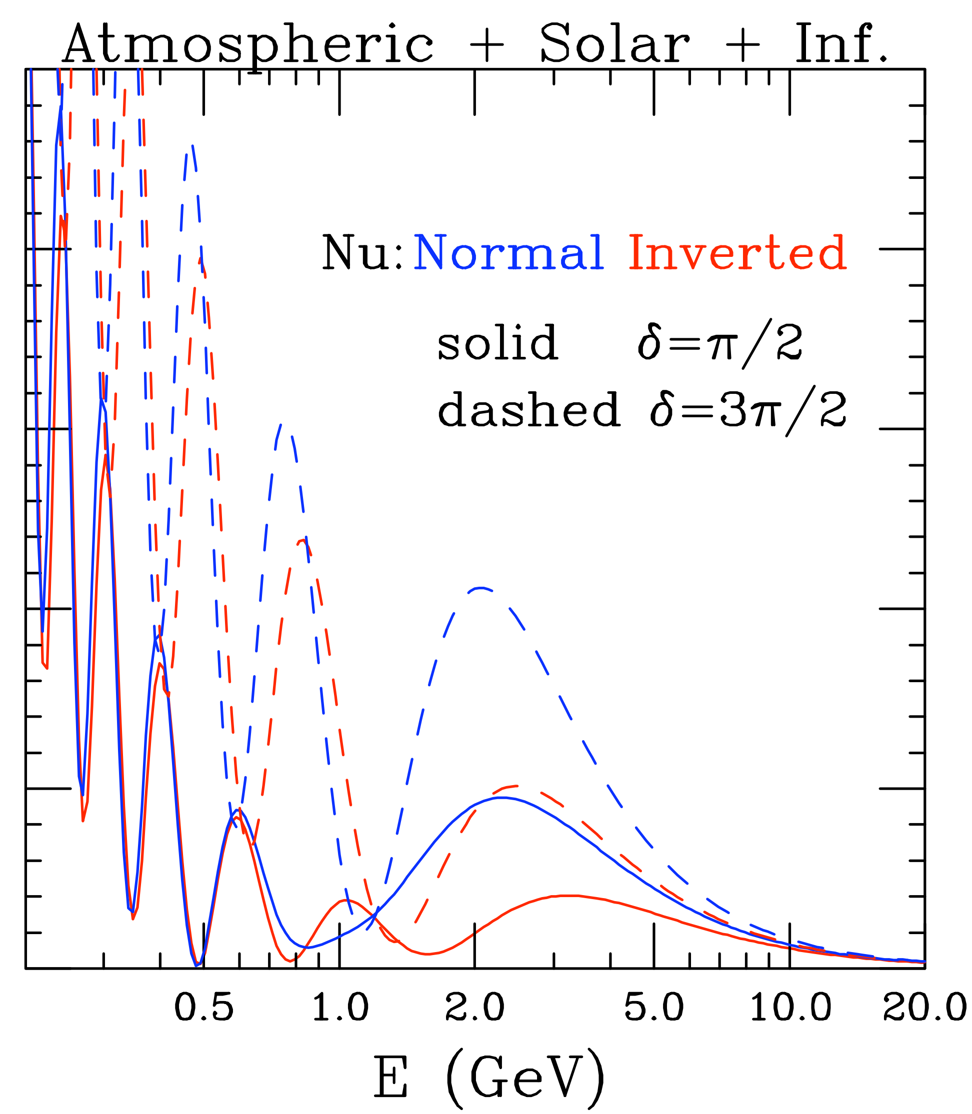
and $\sqrt{P_{sol}} = \cos\theta_{23}\sin 2\theta_{12}\ \frac{\sin(aL)}{(aL)}\ \Delta_{21}$

For $L = 1200\ km$
and $\sin^2 2\theta_{13} = 0.04$

$$\boldsymbol{a\ =\ G_F N_e/\sqrt{2}\ =\ (4000\ \ km)^{-1}},$$

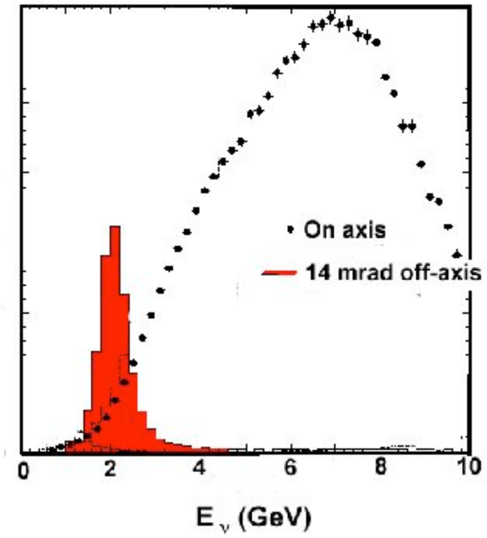
Anti-Nu: Normal Inverted
dashes $\boldsymbol{\delta = \pi/2}$
solid $\boldsymbol{\delta = 3\pi/2}$





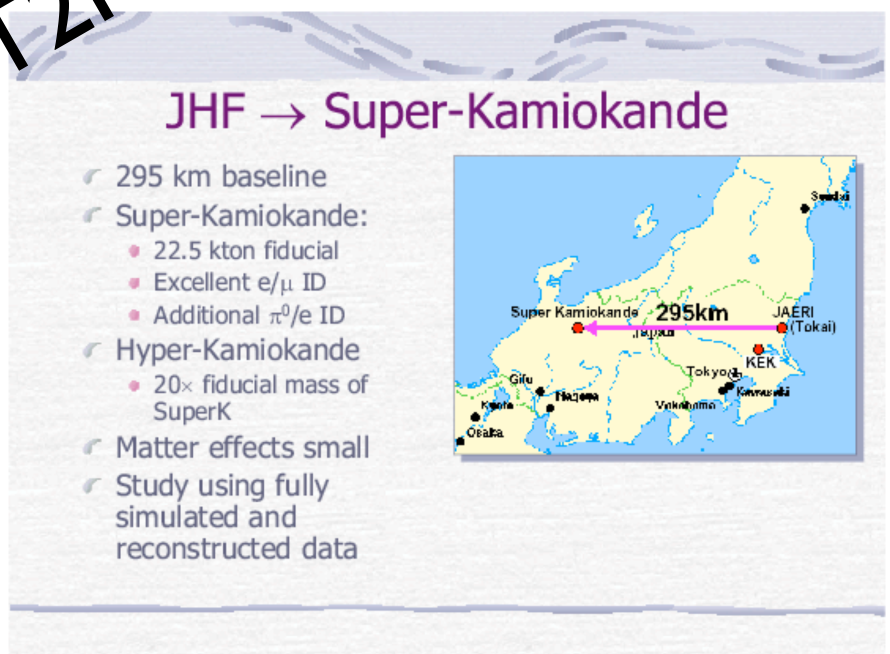
Off-Axis Beams:

BNL 1994



π^0 suppression

T2K



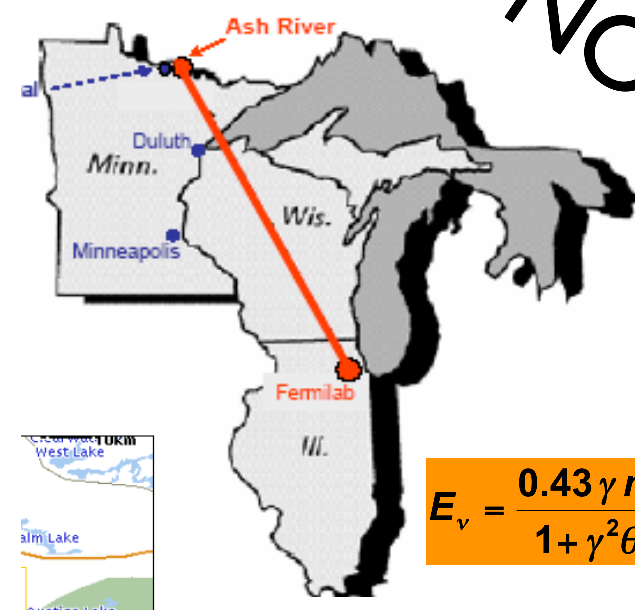
L=295 km and

Energy at Vac. Osc. Max. (vom)

$$E_{vom} = 0.6\ GeV \left\{ \frac{\delta m^2_{32}}{2.5\times10^{-3}\ eV^2} \right\}$$

0.75 upgrade to 4 MW

NOvA



$$E_\nu = \frac{0.43\,\gamma\, m_\pi}{1+\gamma^2\theta^2}$$

L=700 - 1000 km and

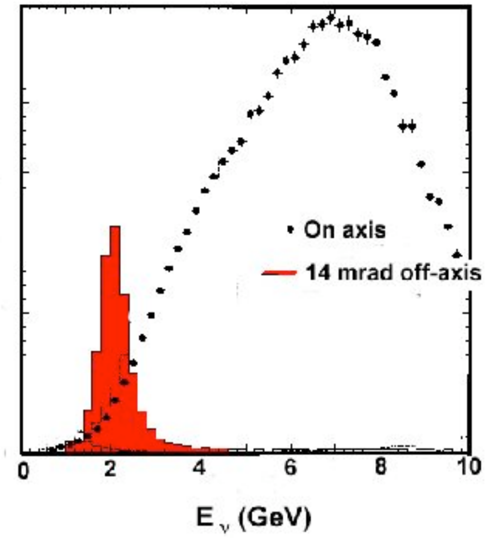
Energy near 2 GeV

$$E_{vom} = 1.8\ GeV \left\{ \frac{\delta m^2_{32}}{2.5\times10^{-3}\ eV^2} \right\} \times \left\{ \frac{L}{820\ km} \right\}$$

0.4 upgrade to 2 MW

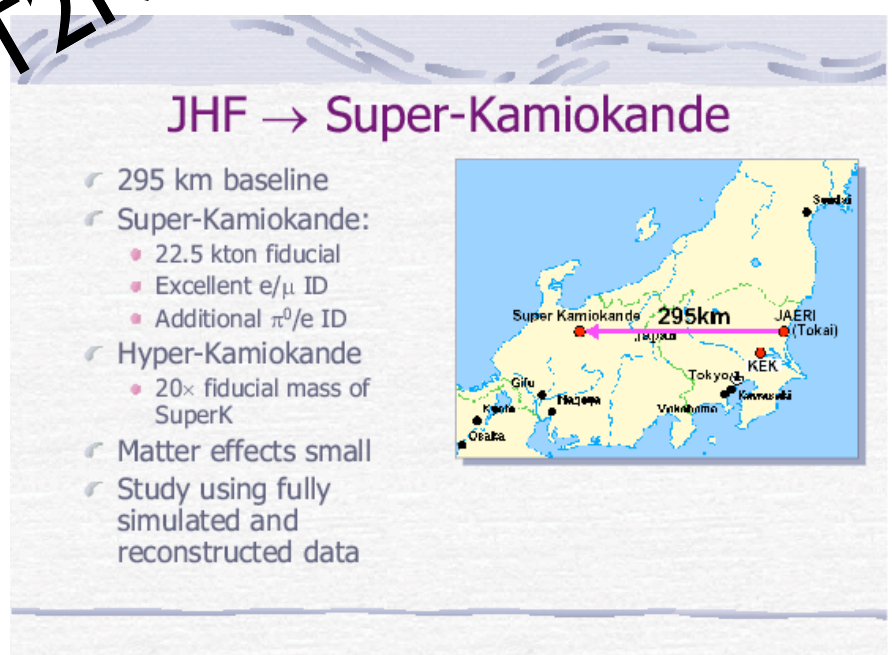
Off-Axis Beams:

BNL 1994



π^0 suppression

T2K



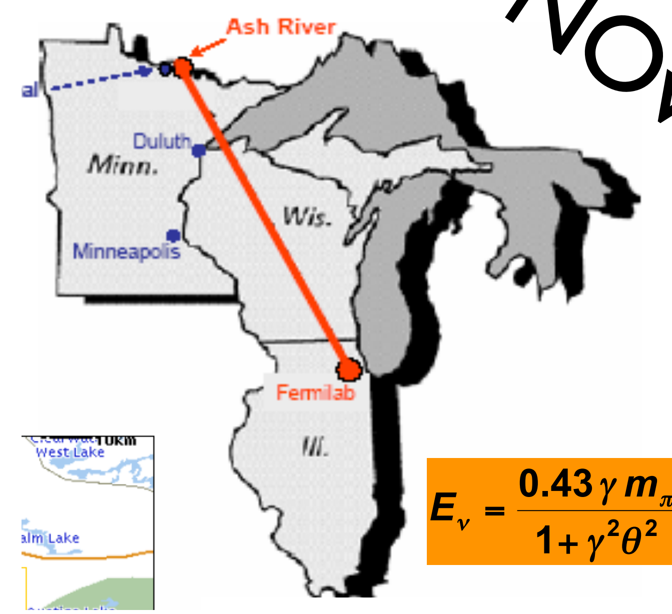
L=295 km and

Energy at Vac. Osc. Max. (vom)

$$E_{vom} = 0.6\ GeV \left\{ \frac{\delta m^2_{32}}{2.5\times10^{-3}\ eV^2} \right\}$$

0.75 upgrade to 4 MW

NOvA



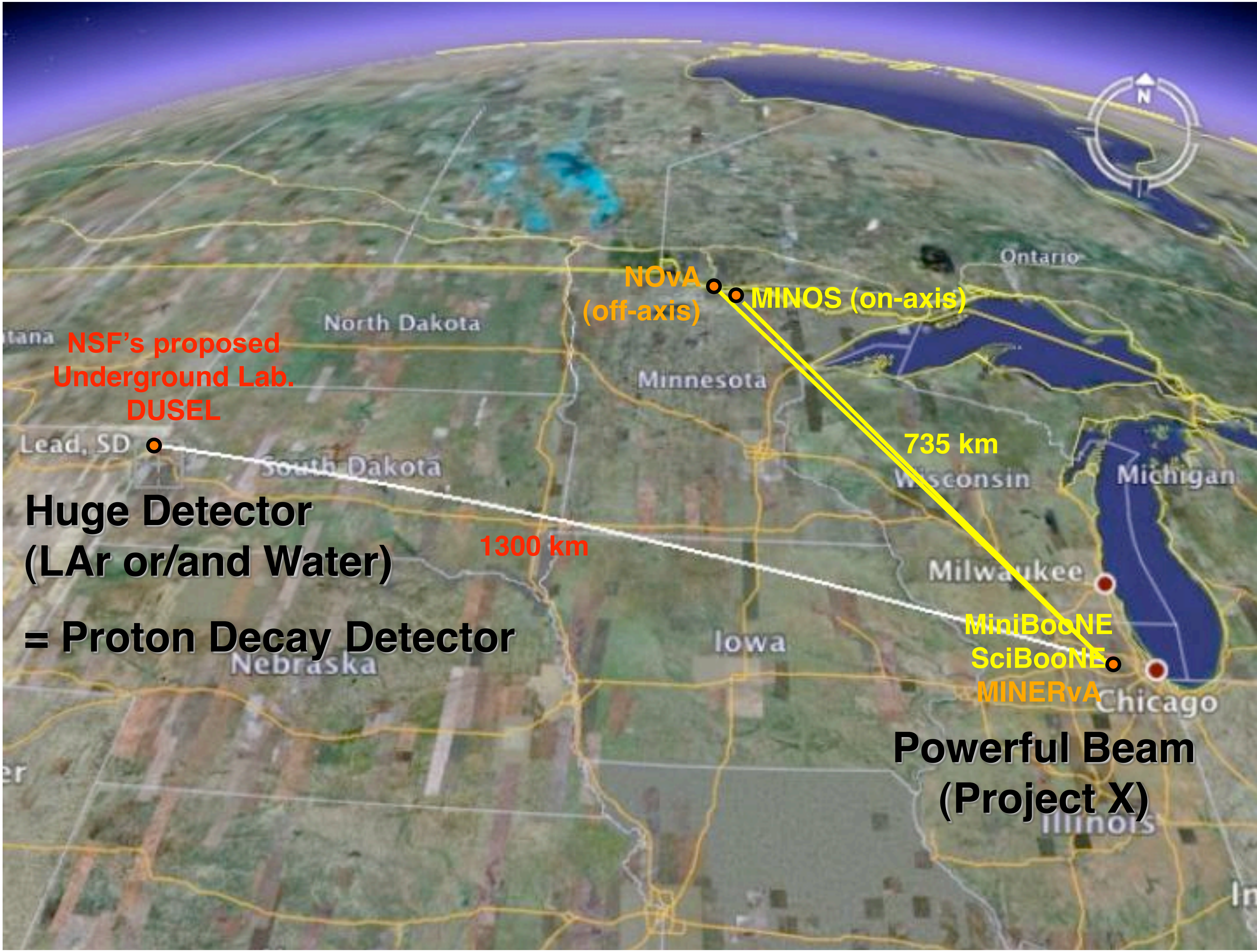
L=700 - 1000 km and

Energy near 2 GeV

$$E_{vom} = 1.8\ GeV \left\{ \frac{\delta m^2_{32}}{2.5\times10^{-3}\ eV^2} \right\} \times \left\{ \frac{L}{820\ km} \right\}$$

0.4 upgrade to 2 MW

$$\langle P(\nu_\mu \to \nu_e) \rangle \sim \mathbf{0.5 - 1.0\%}$$ at 90% CL



NOvA
(off-axis)
MINOS (on-axis)
Ontario
North Dakota
NSF's proposed
Underground Lab.
DUSEL
Minnesota
Lead, SD
South Dakota
735 km
Wisconsin
Michigan
Huge Detector
(LAr or/and Water)
1300 km
Milwaukee
= Proton Decay Detector
Nebraska
Iowa
MiniBooNE
SciBooNE
MINERvA
Chicago
Powerful Beam
(Project X)
Illinois

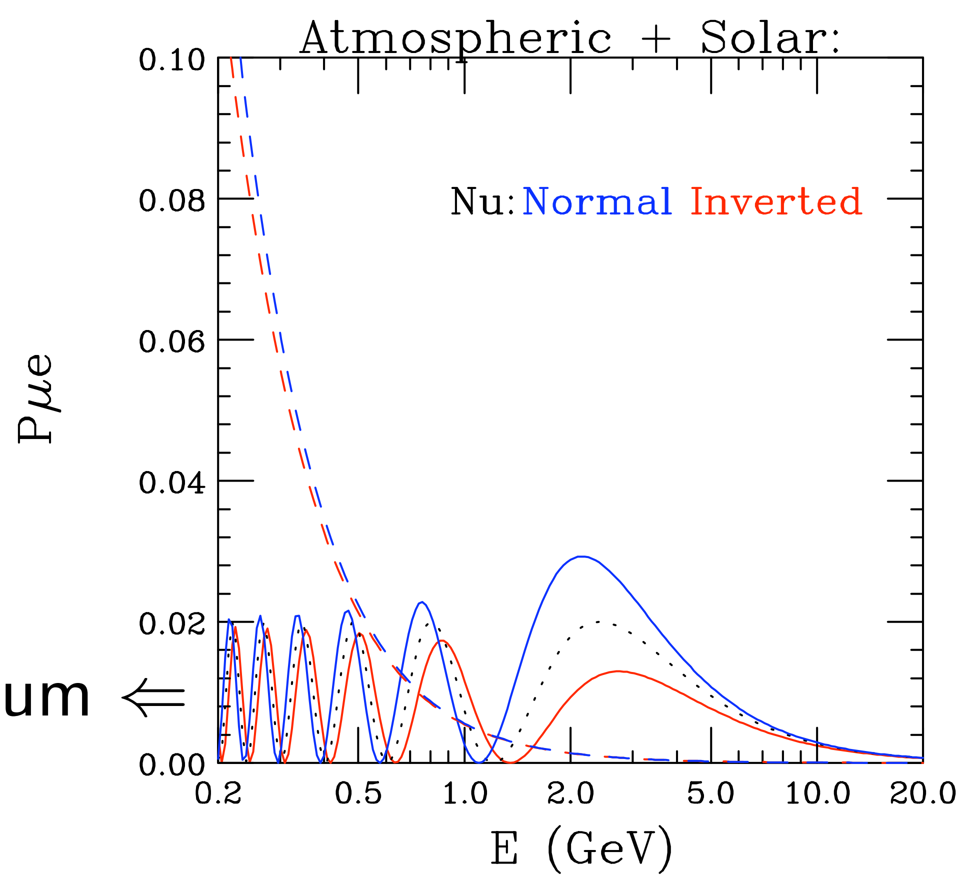
Narrow Band Beam: Same E, Longer L T2KK

Broadband Beam: Same L, Lower E Fermilab to DUSEL

In VACUUM the SAME but NOT in MATTER

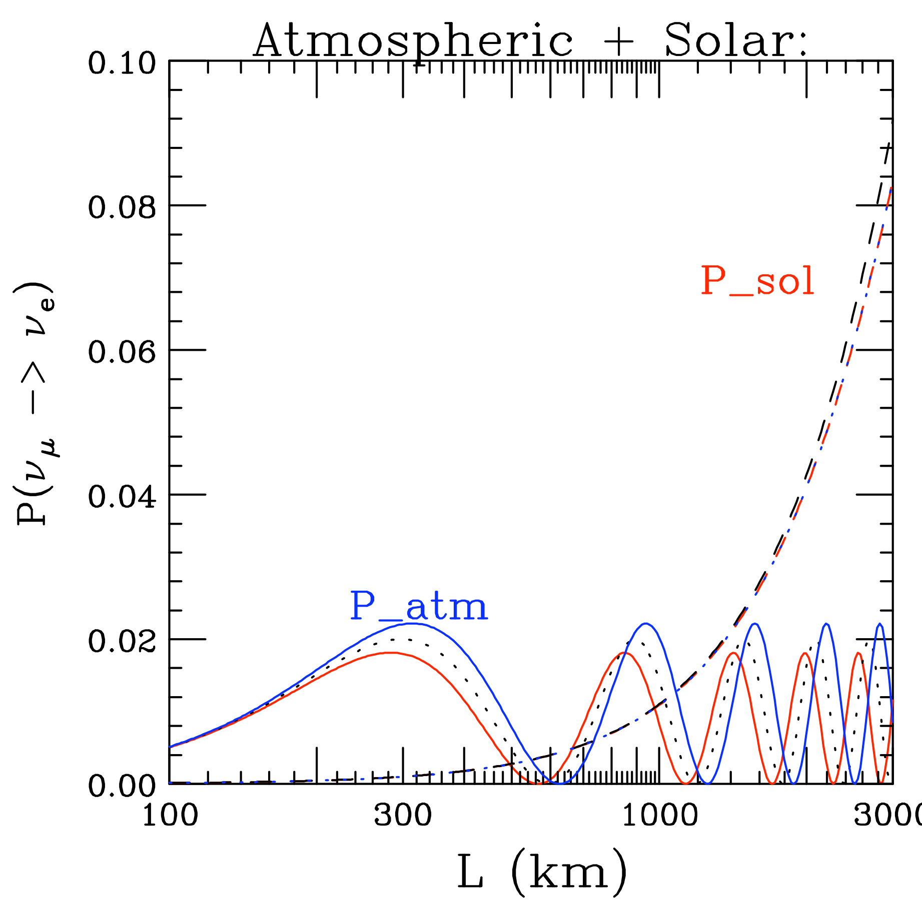
$$\sin^2 2\theta_{13} = 0.04$$

L=1200km



vacuum ⇐

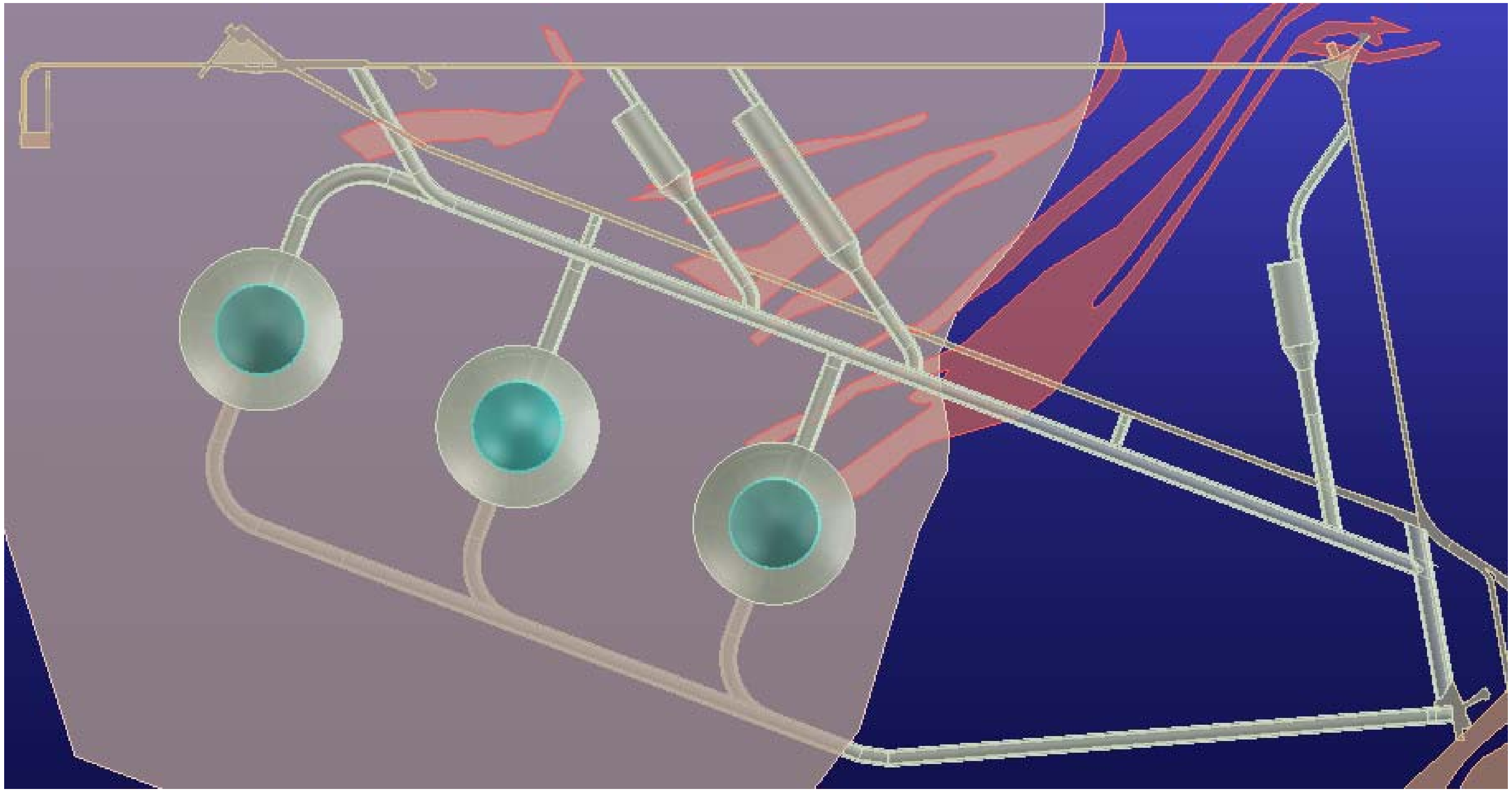
E=0.6 GeV

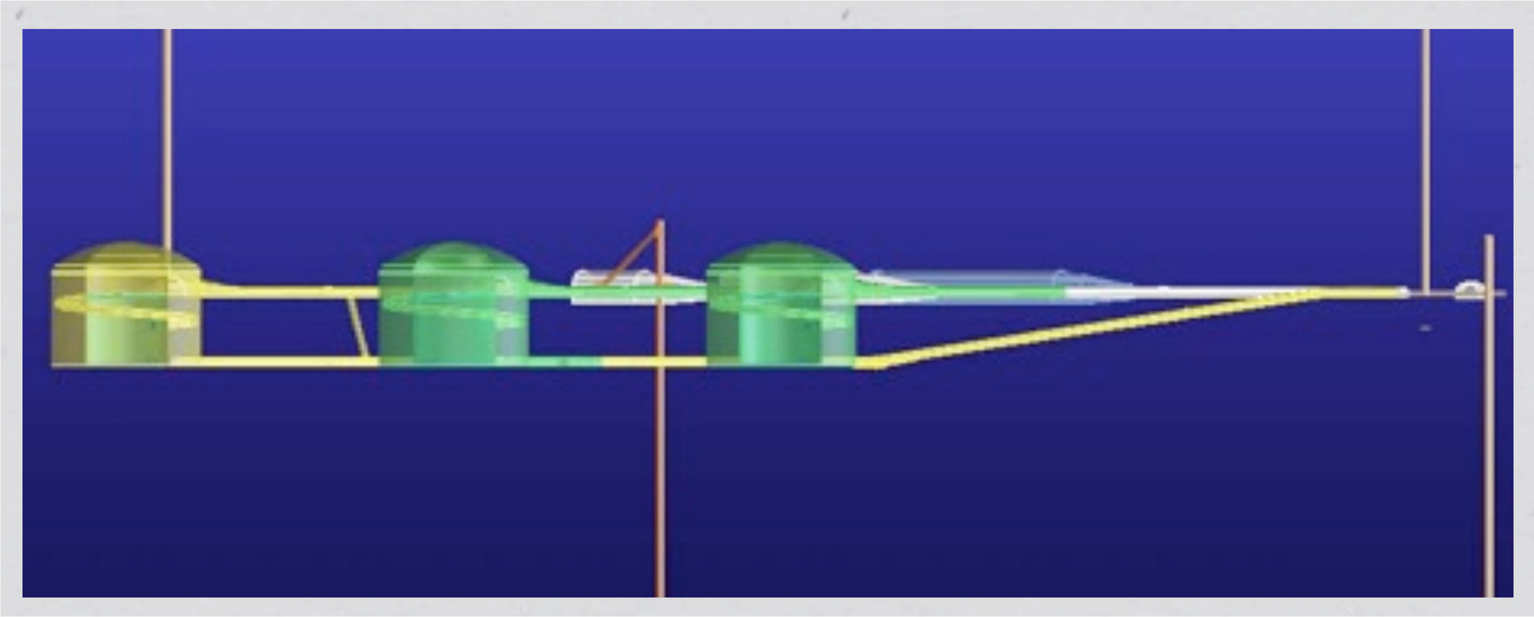


⇐ same height

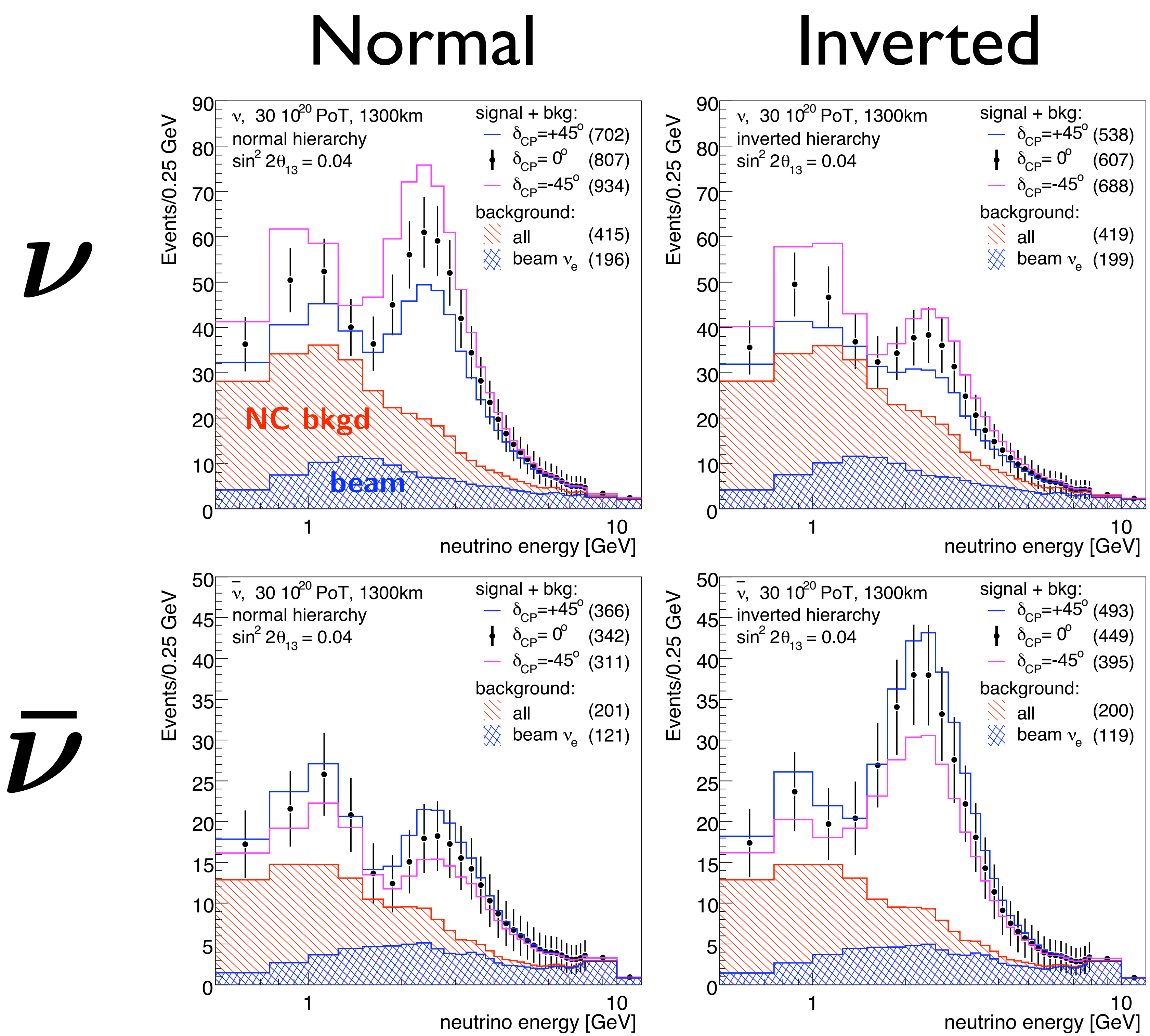
$$P_{\mu\rightarrow e} \approx |\ \sqrt{P_{atm}} e^{-i(\Delta_{32}\pm\delta)} + \sqrt{P_{sol}}\ |^2$$

layout of 4850 level





WATER CERENKOV: 300 KT



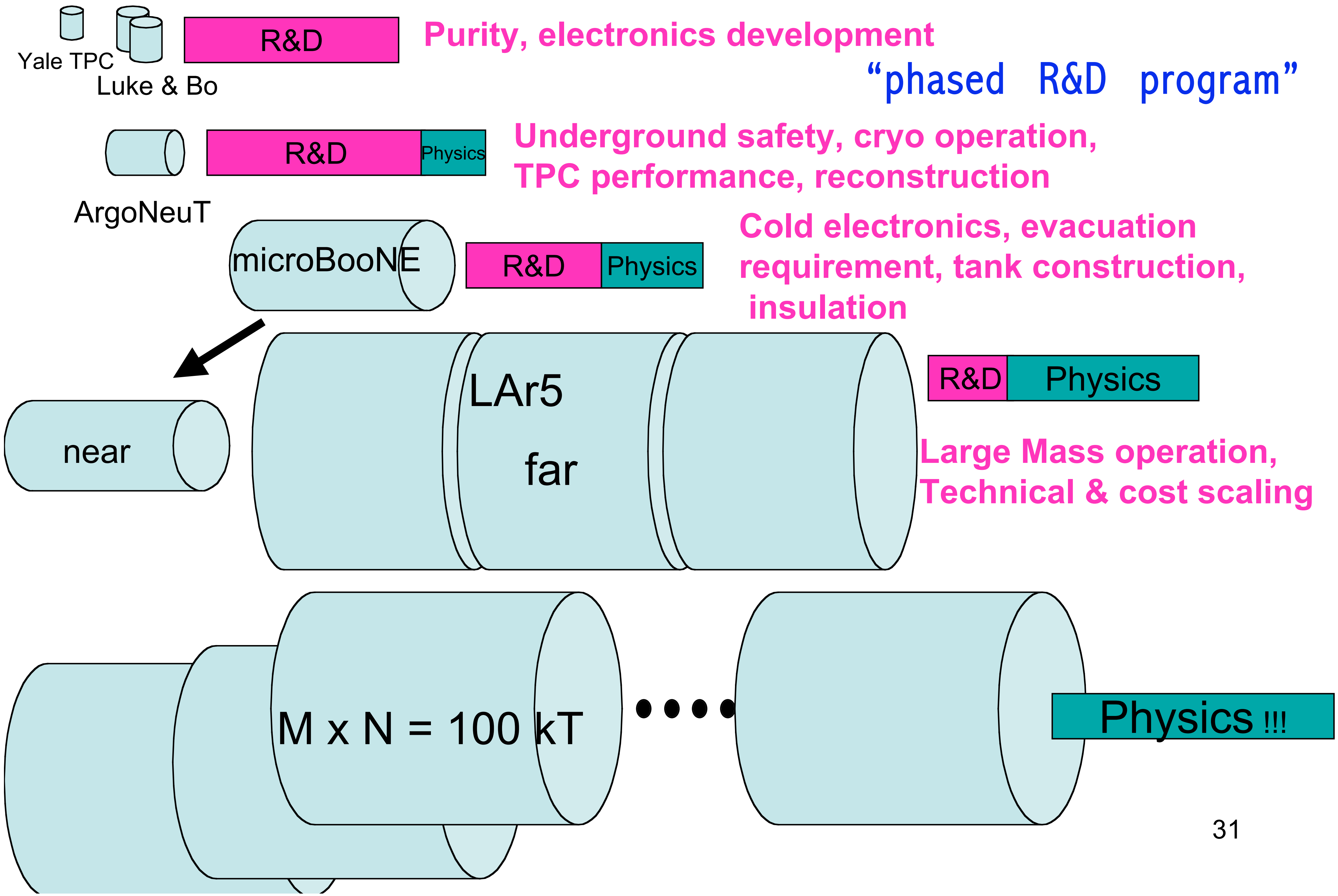
arXiv:0705.4396

Star Trek: The Next Generation

The visor "sees" Neutrinos!!!

Geordi La Forge: in "The Enemy"

Evolution of the Liquid Argon Physics Program

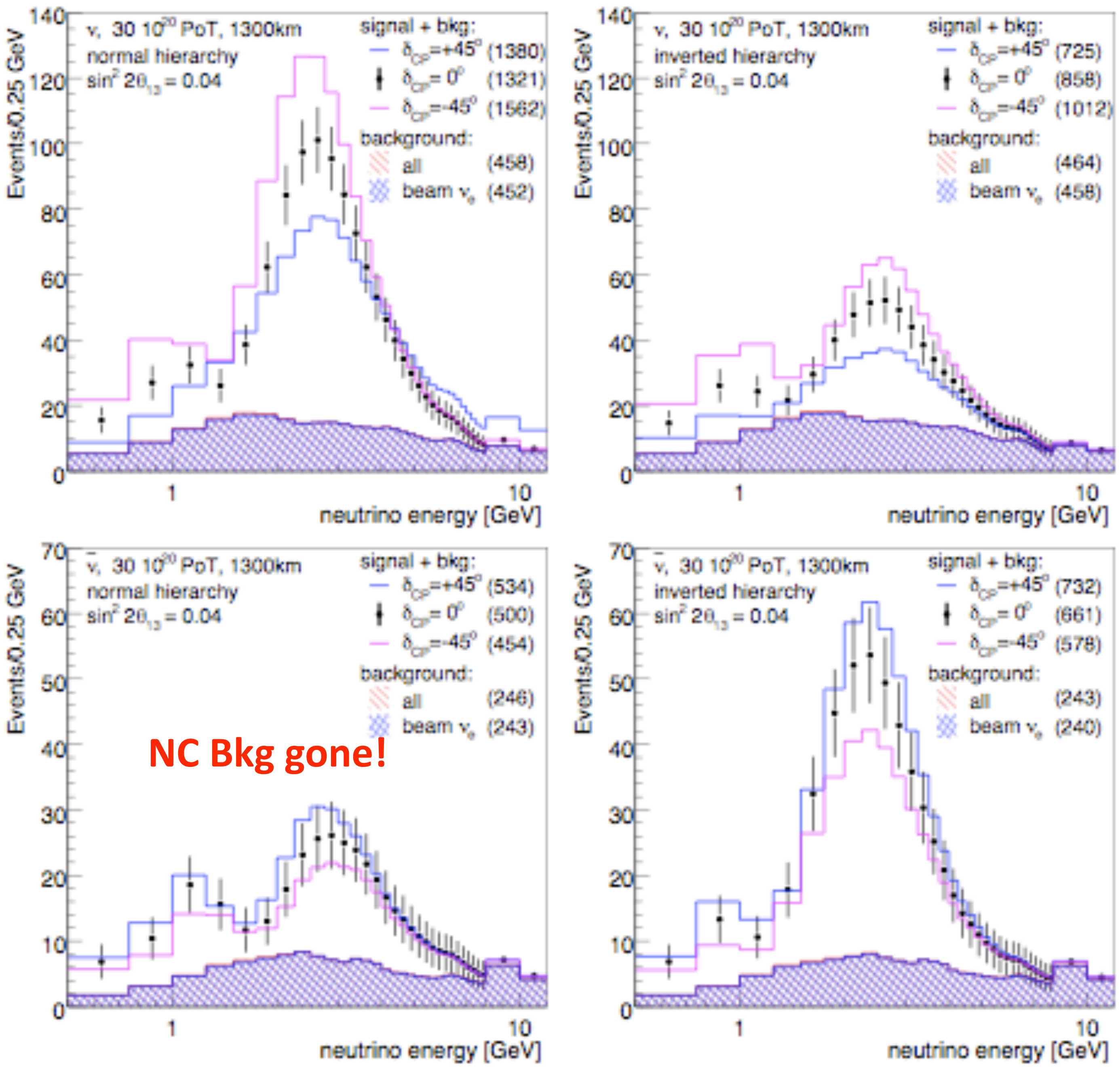


LIQUID ARGON: 100KT

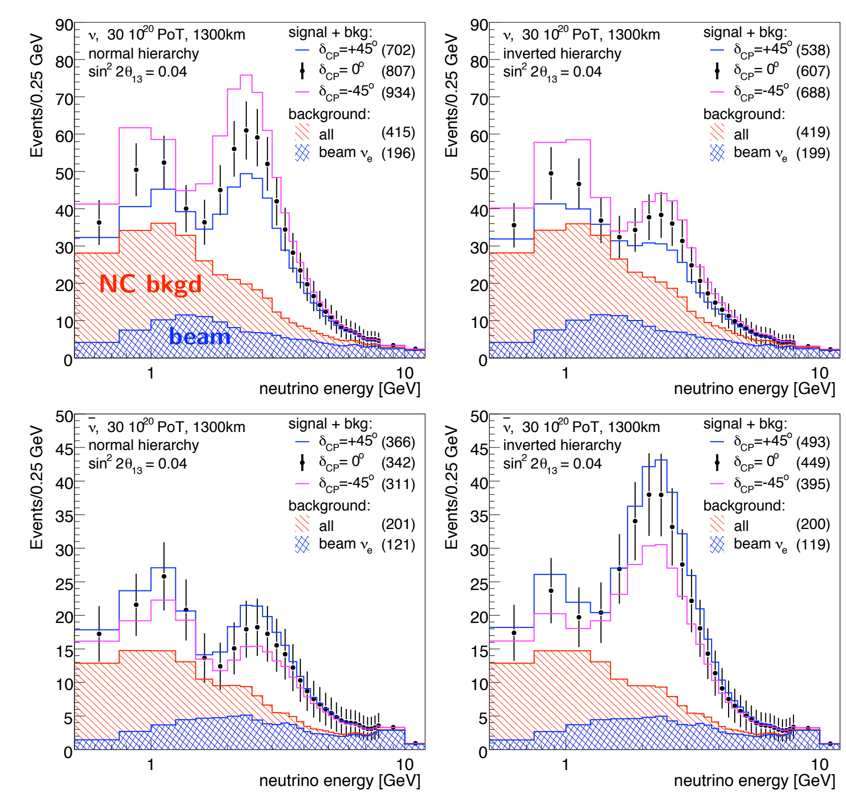
Normal Inverted

ν

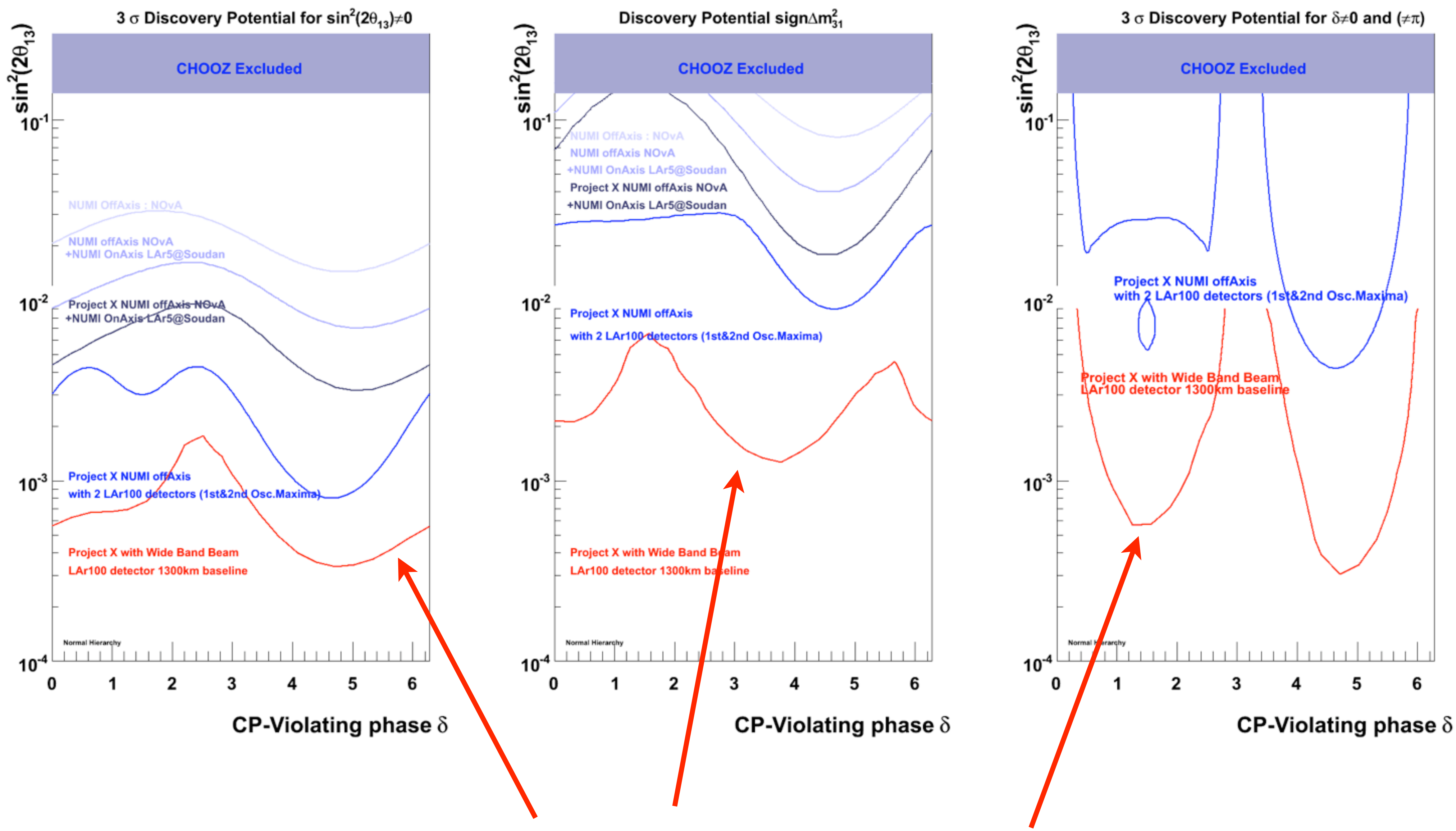
$\bar{\nu}$



Studies suggest 100 kt LAR = 300kt WC



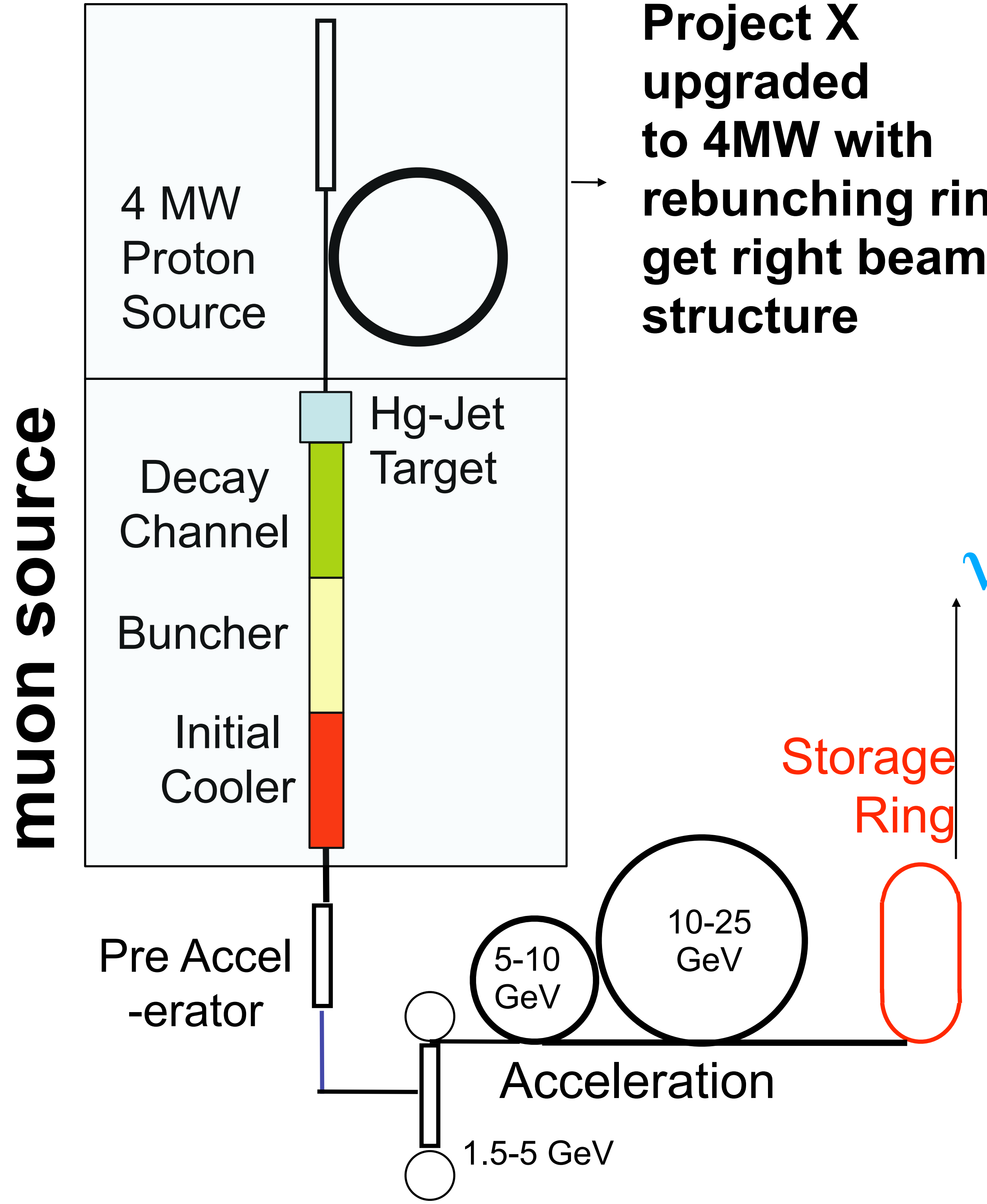
Sensitivity:



LAr 100kt 3+3 yrs 20e20 POT/yr

Neutrino Factory Schematic

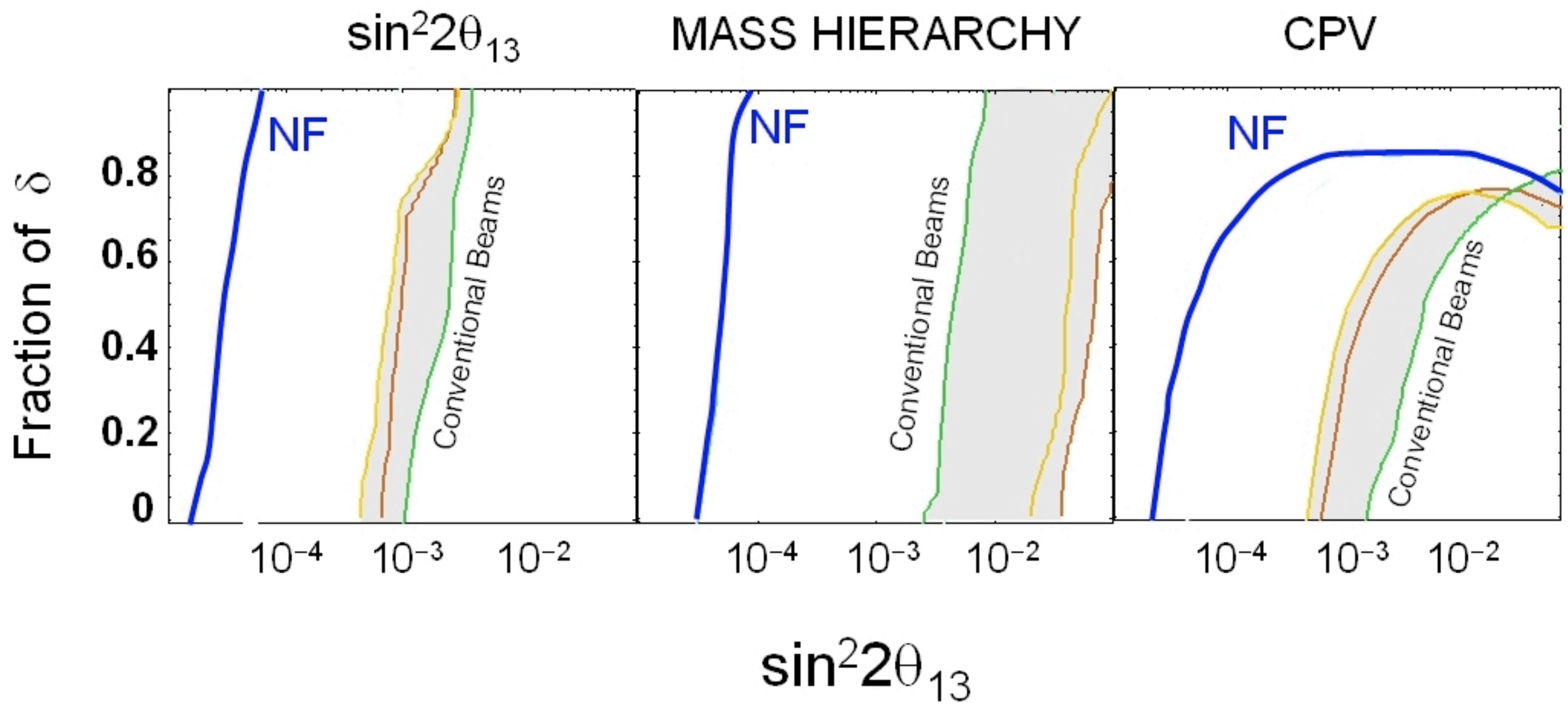
- Proton Source
  - primary beam on production target
- Target, Capture, and Decay
  - create π; decay into μ
- Bunching & Phase Rotation
  - reduce ΔE of bunch
- Cooling
  - reduce transverse emittance
- Acceleration
  - 130 MeV $\rightarrow E_{NF}$
- Storage Ring
  - store for 500 turns; long straight section



Project X upgraded to 4MW with rebunching ring to get right beam structure

If θ_{13} is Small

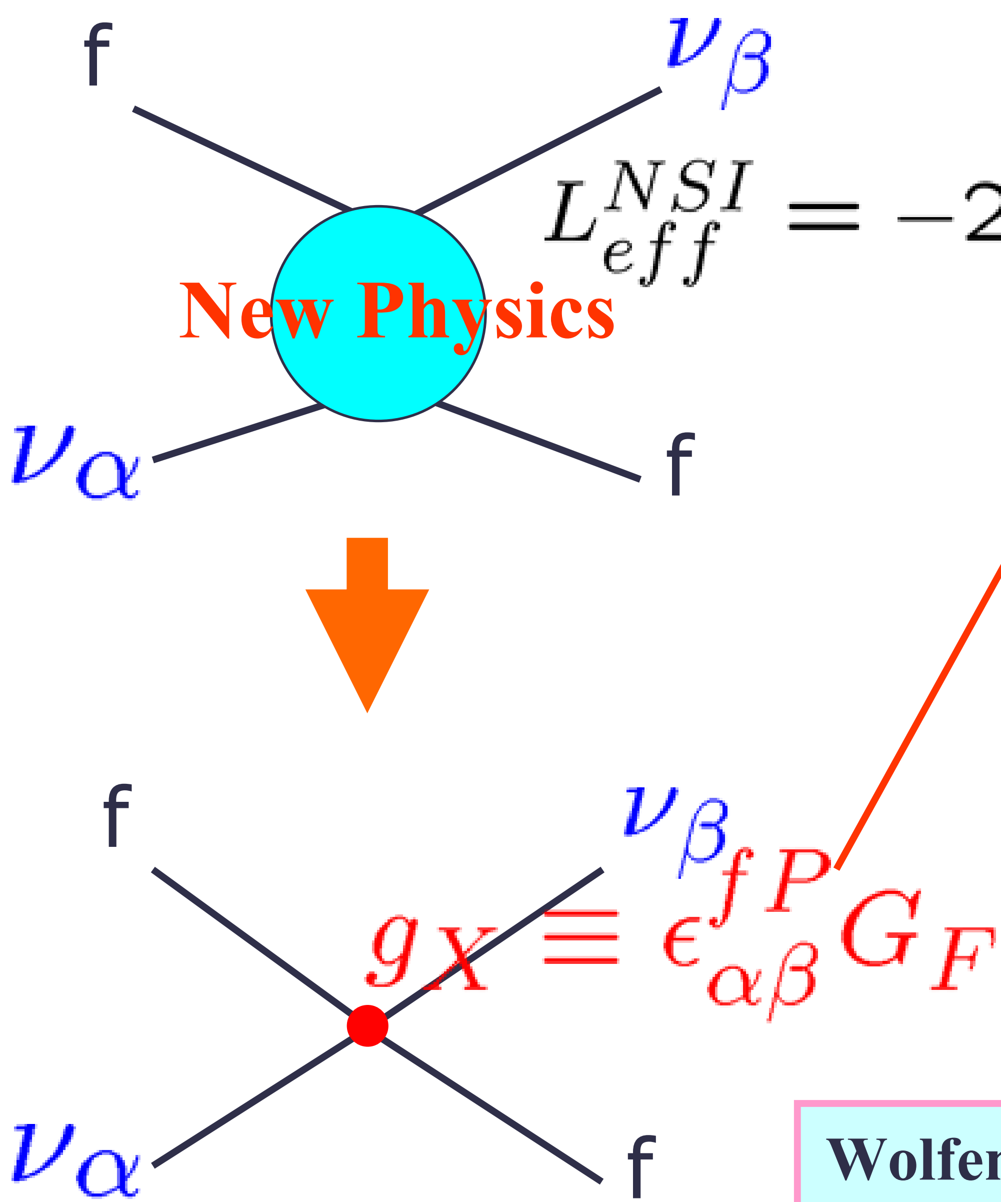
- Choose a NF energy of 25 GeV & a very long baseline (e.g. ~3000km)



- A NF would enable up to ~ x100 improvement in sensitivity c.f. a superbeam

Non-Standard neutrino Interaction

Non-Standard Interaction



$$L_{eff}^{NSI} = -2\sqrt{2}\epsilon_{\alpha\beta}^{fP} G_F (\bar{\nu}_\alpha \gamma_\mu P_L \nu_\beta)(\bar{f}\gamma^\mu P f)$$

$$P_L \equiv \frac{1}{2}(1-\gamma_5), P_R \equiv \frac{1}{2}(1+\gamma_5)$$

Naive Estimation $\epsilon_{\alpha\beta} \propto \frac{m_W^2}{m_X^2}$

If new physics scale ~ 1(10) TeV

$$\epsilon_{\alpha\beta} \sim 0.01(0.0001)$$

Wolfenstein '78, Grossman '95, Berezhiani-Rossi '02 and many people…

We concentrated on effects of NSI in ν propagation in matter

$$H = \frac{1}{2E}\left[U\begin{pmatrix} 0 & 0 & 0 \\ 0 & \Delta m^2_{21} & 0 \\ 0 & 0 & \Delta m^2_{31}\end{pmatrix}U^{-1} + \begin{pmatrix} 2\sqrt{2}G_F n_e E & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0\end{pmatrix}\right]$$

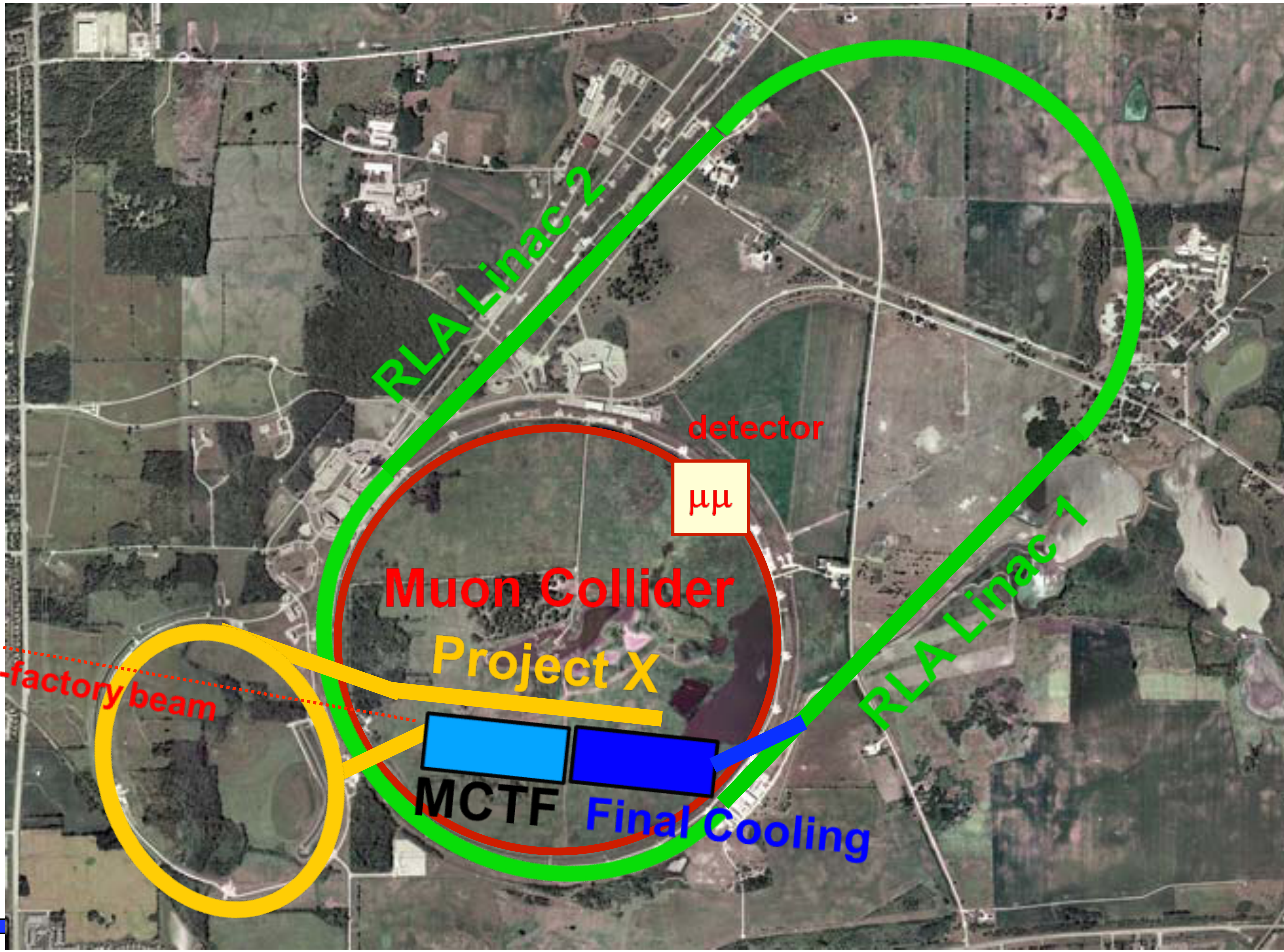
$$H = \frac{1}{2E}\left[U\begin{pmatrix} 0 & 0 & 0 \\ 0 & \Delta m^2_{21} & 0 \\ 0 & 0 & \Delta m^2_{31}\end{pmatrix}U^{-1} + 2Ea\begin{pmatrix} 1+\epsilon_{ee} & \epsilon_{e\mu} & \epsilon_{e\tau} \\ \epsilon^*_{e\mu} & \epsilon_{\mu\mu} & \epsilon_{\mu\tau} \\ \epsilon^*_{e\tau} & \epsilon^*_{\mu\tau} & \epsilon_{\tau\tau}\end{pmatrix}\right]$$

$$a \equiv \sqrt{2}G_F n_e$$

Valle, Gago-Guzzo-Nunokawa-Teves-Zukanovich Funchal

- $\epsilon_{\mu\tau}$ and $\epsilon_{e\tau}$ can be constrained by short baseline experiment.
- and/or a Neutrino Factory is needed all values of $\sin^2\theta_{13}$!

A Longer Term Muon Vision for Fermilab



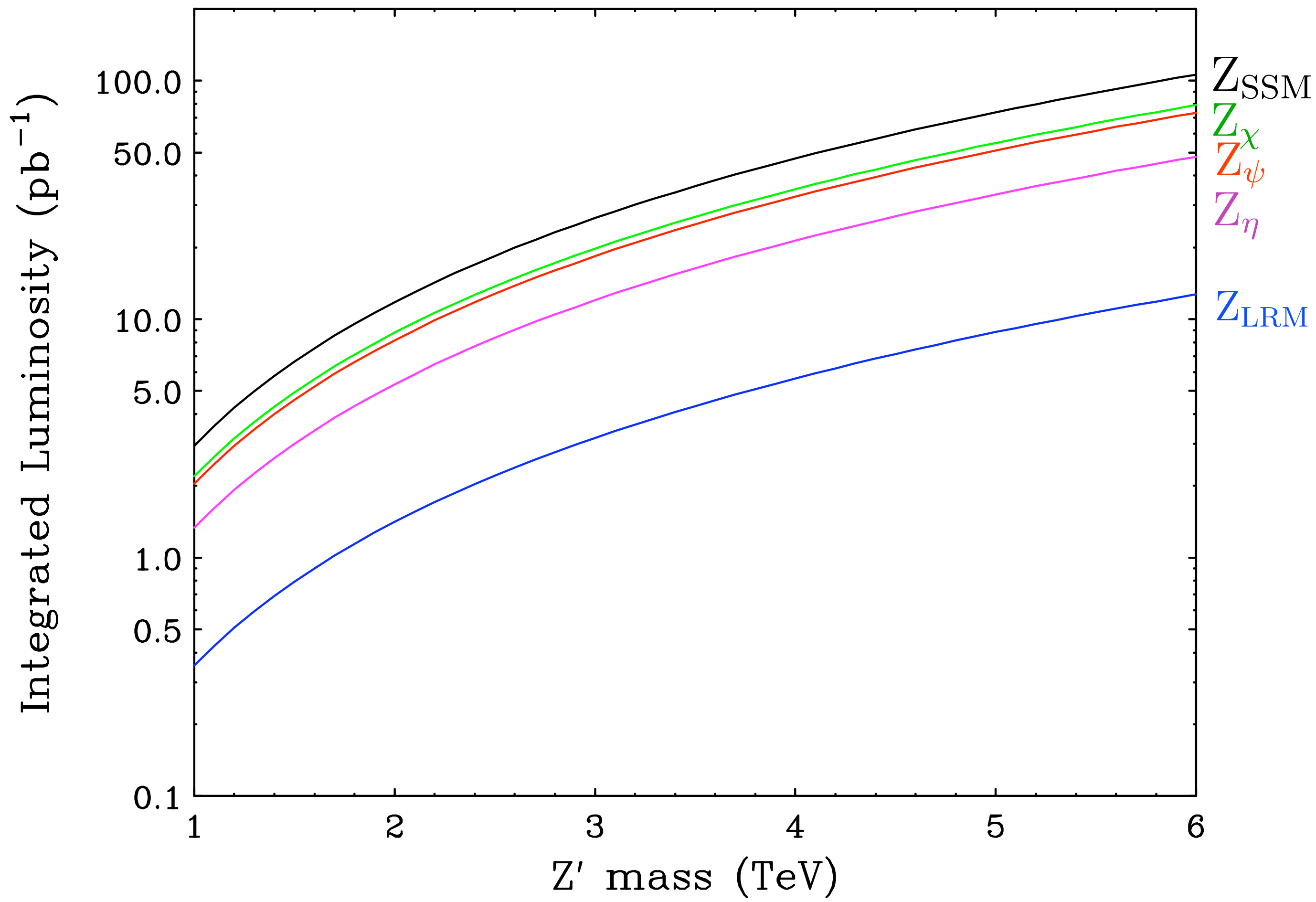
Minimum Luminosity for Physics:

- Assuming a new gauge boson: Z′
  - examples: SSM, E6, LRM
  - 5σ discovery limits: 4-5 TeV at LHC (@ 300 fb^{-1})

- For a narrow resonance with $2\Delta E_{beam} / \Gamma_{resonance} \ll 1$:

$$\rightarrow R_{\text{peak}} = (2J+1)3\frac{B(\mu^+\mu^-)B(visible)}{\alpha_{\text{EM}}^2}$$

The integrated luminosity required to produce 1000 $\mu^+\mu^-$ -> Z′ events on the peak



Hence minimum luminosity -> 0.5-5.0 x 10^{30} cm^{-2} sec^{-1}

for M(Z′) -> 1.5-5.0 TeV

E. Eichten, "The Basics of Muon Collider Physics" (Fermilab-Pub-09-225-T)

- Muons

$$\mu + N \rightarrow e + N$$

$$(g-2)_\mu$$

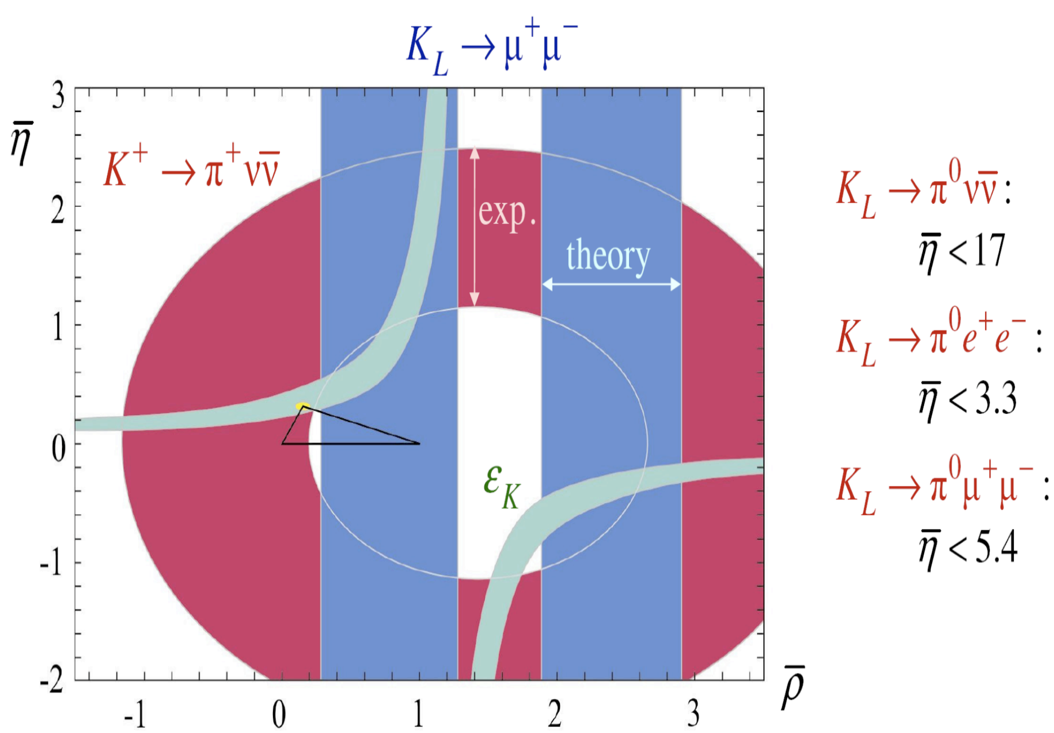
- Kaons

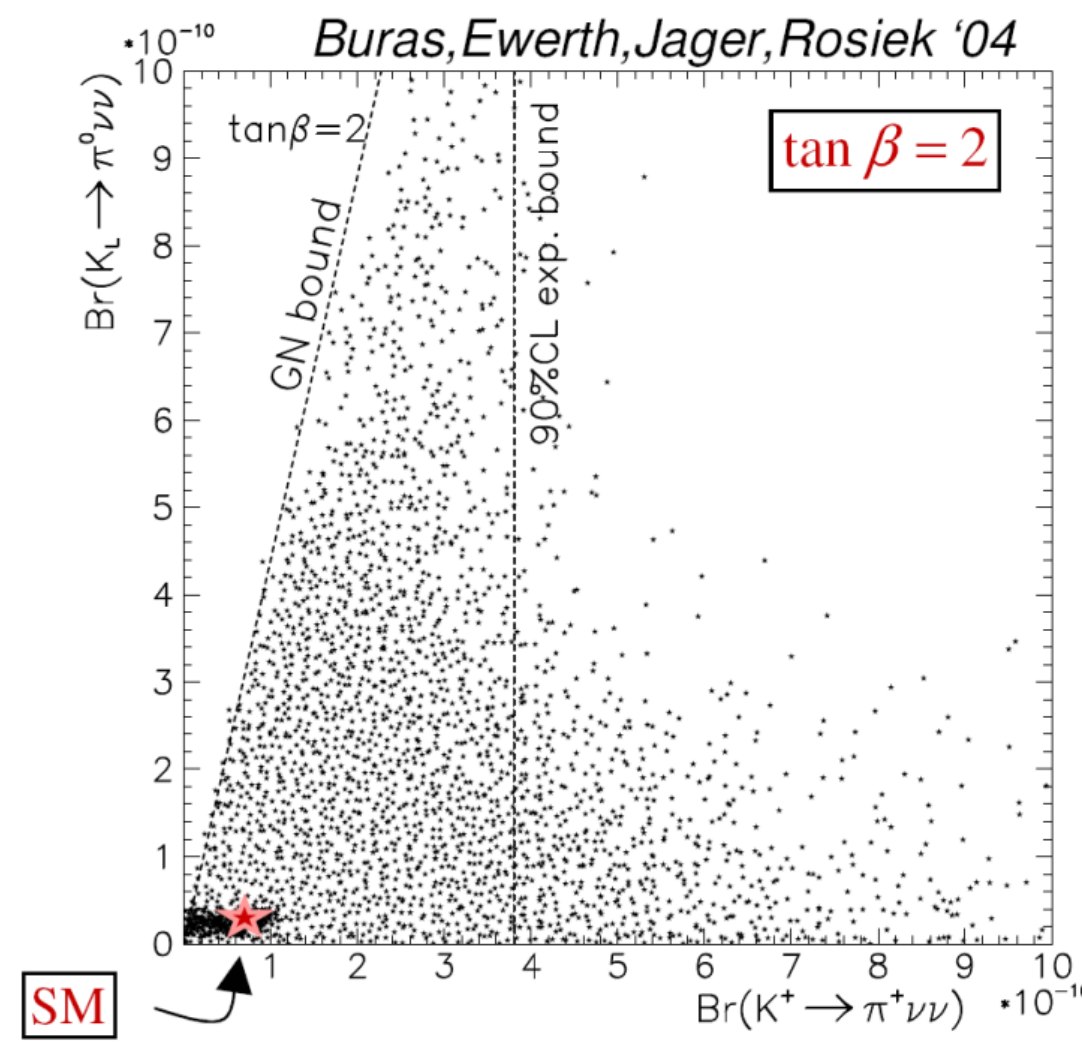
$$K^+ \to \pi^+ \nu \bar{\nu}$$

$$K_L \to \pi^0 \nu \bar{\nu}$$

Current Status:

	Theo(SM)$\times 10^{10}$	Exp.$\times 10^{10}$	Experiment
$K^+ \to \pi^+ \nu\bar{\nu}$	0.85 ± 0.07	$1.73^{+1.15}_{-1.05}$	BNL-E787/949
$K_L \to \pi^0 \nu\bar{\nu}$	0.28 ± 0.04	< 670	KEK-391





“Approved” Future Experiments:

	Experiment	Beam Power (kW)	# of Events 5 yrs @ SM
$K^+ \to \pi^+ \nu \bar{\nu}$	CERN-NA62	5-10 kW	100 - 200
$K_L \to \pi^0 \nu \bar{\nu}$	KEK-E14		phase I (II) $=$ few (10’s)

For Statistical Uncertainties $\approx$ Theoretical Uncertainties

$\sim$ 1000 events needed in K^+ and K_L !

with Project X 200$+$ kW at 8 GeV

Project-X: A blow-torch of protons...all the time!

Per year

Facility	Duty Factor	Clock hours	Beam hours	Projected # of K → $\pi\nu\bar{\nu}$
☆ CERN-SPS (450 GeV)	30%	1420	405	40 (charged)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	40 (charged)
Tevatron-Stretcher (120 GeV)	90%	5550	5000	200 (charged)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	250 (charged)
☆ JPARC-I (30 GeV)	21%	2780	580	~1 (neutral)
BNL AGS (24 GeV)	50%	1200	600	20 (neutral)
JPARC-II (30 GeV)	21%	2780	580	30 (neutral)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	30 (neutral)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	300 (neutral)

☆ Moving toward full approval.

J-PARC - Neutrino:Kaon = 50%:50%

Summary and Conclusions

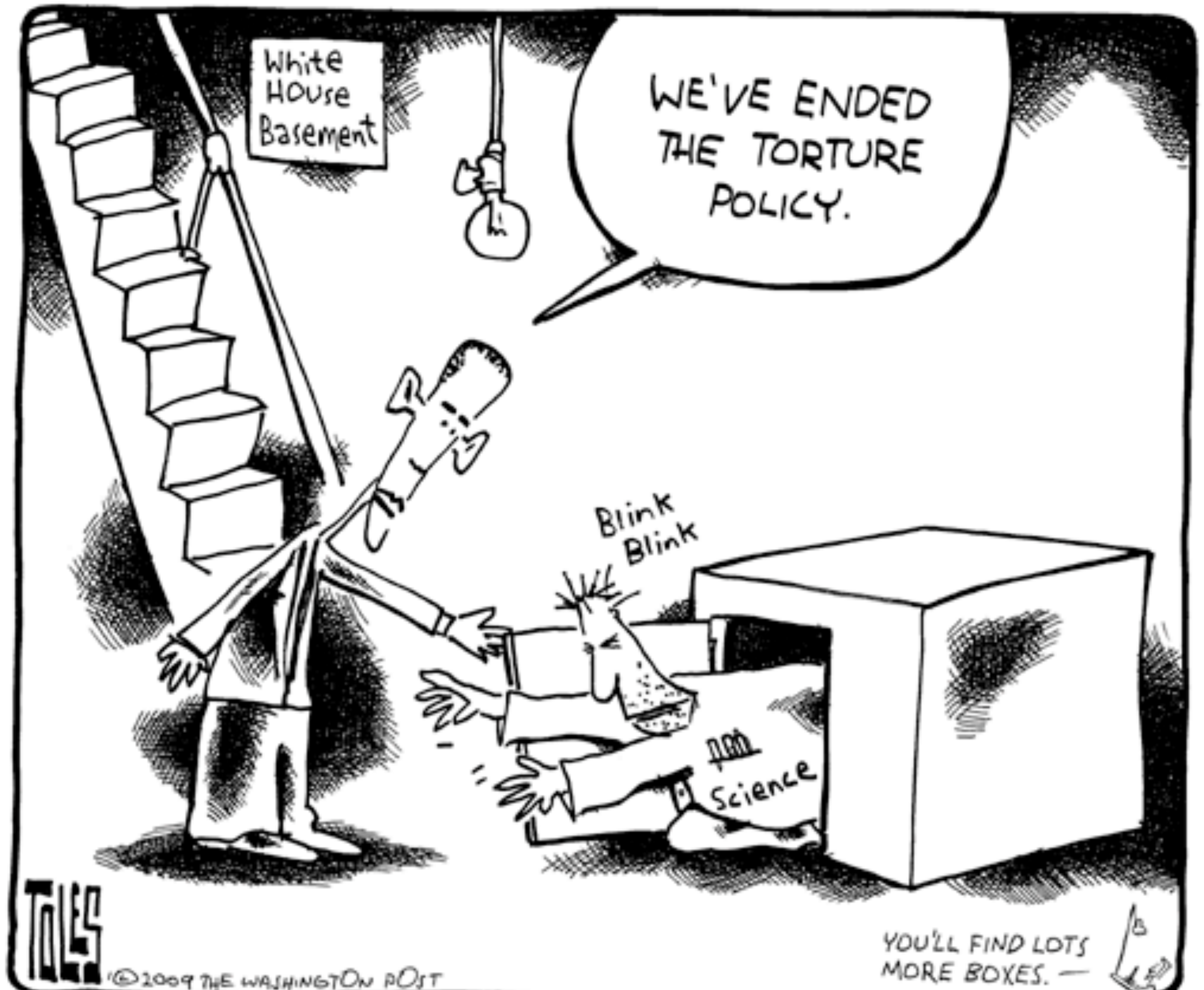
The Intensity Frontier has many exciting and compelling physics opportunities:

- Neutrinos:

Fraction of ν_e in 3^{rd} neutrino:	$\sin^2\theta_{13}$
Is atmospheric mixing maximal?:	$\sin^2\theta_{23} <,=,> 1/2$
Neutrino Mass Hierarchy:	sign δm^2_{31}
CP Violation:	$\sin\delta$
NSI,.....	surprises !!!

- Muons: $\mu + N \rightarrow e + N$ and $(g-2)_\mu$
- Kaons: $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ and $K_L \rightarrow \pi^0 \nu\bar{\nu}$
- Anti-Protons, ...

Washington Post 1/25/2009



http://www.washingtonpost.com/wp-dyn/content/opinions/tomtoles/?name=Toles&date=01252009