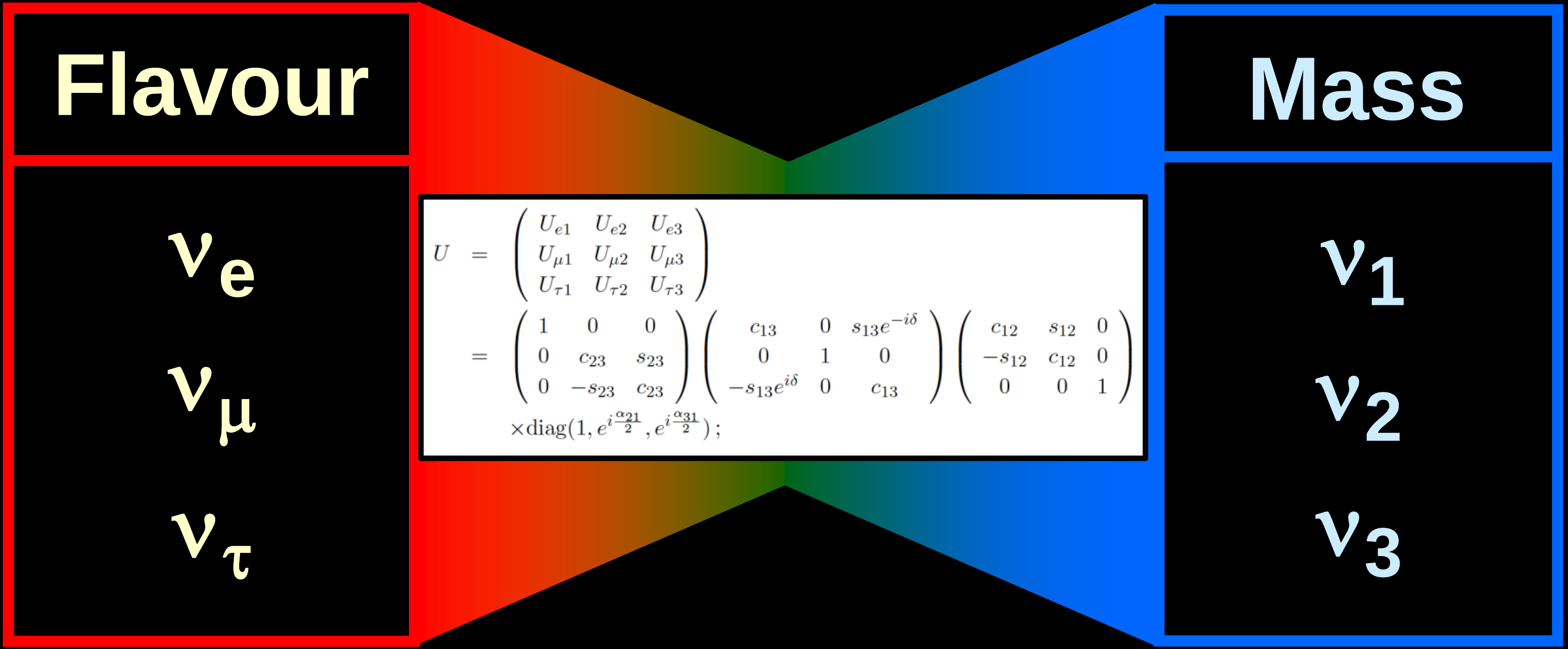
Future neutrino experiments

K. Long,
20 November,



Flavour

ν_e

ν_μ

ν_τ

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

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

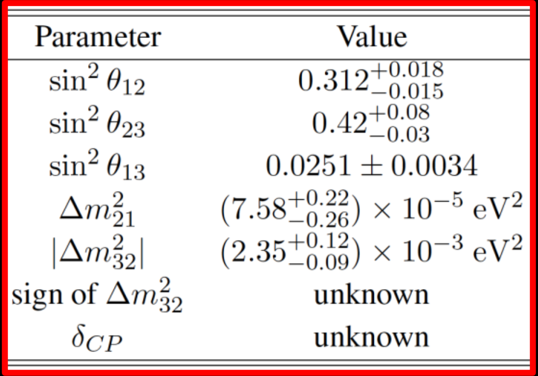
$$\times \mathrm{diag}(1, e^{i\frac{\alpha_{21}}{2}}, e^{i\frac{\alpha_{31}}{2}})\,;$$

Mass

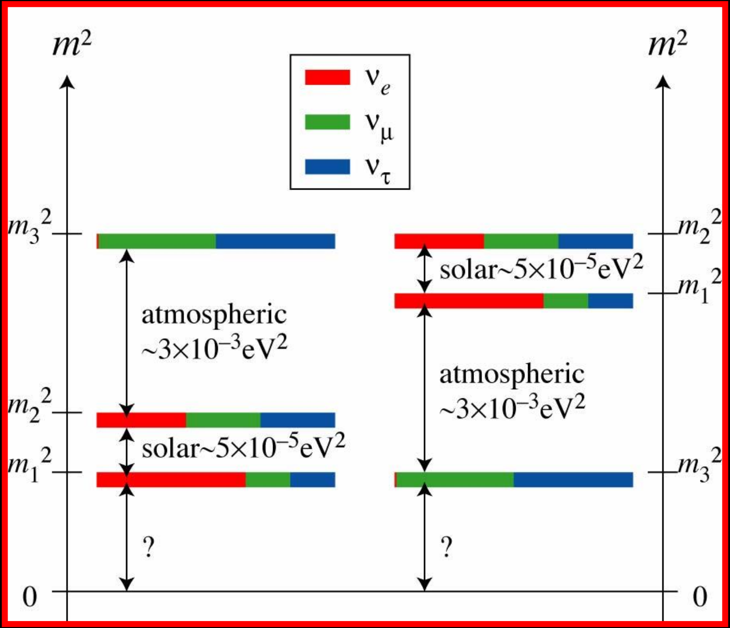
ν_1

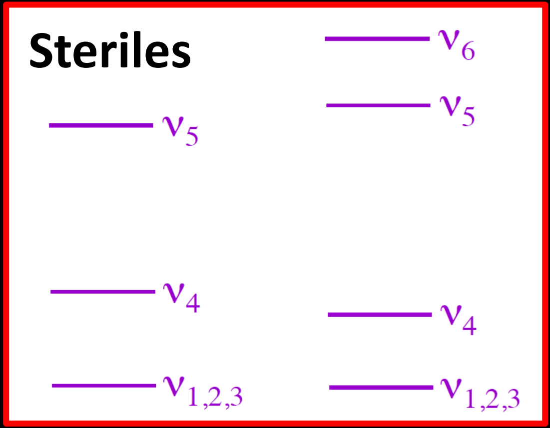
ν_2

ν_3



Parameter	Value
$\sin^2\theta_{12}$	$0.312^{+0.018}_{-0.015}$
$\sin^2\theta_{23}$	$0.42^{+0.08}_{-0.03}$
$\sin^2\theta_{13}$	0.0251 ± 0.0034
Δm^2_{21}	$(7.58^{+0.22}_{-0.26}) \times 10^{-5}$ eV^2
$\lvert\Delta m^2_{32}\rvert$	$(2.35^{+0.12}_{-0.09}) \times 10^{-3}$ eV^2
sign of Δm^2_{32}	unknown
δ_{CP}	unknown





Steriles

Contents:

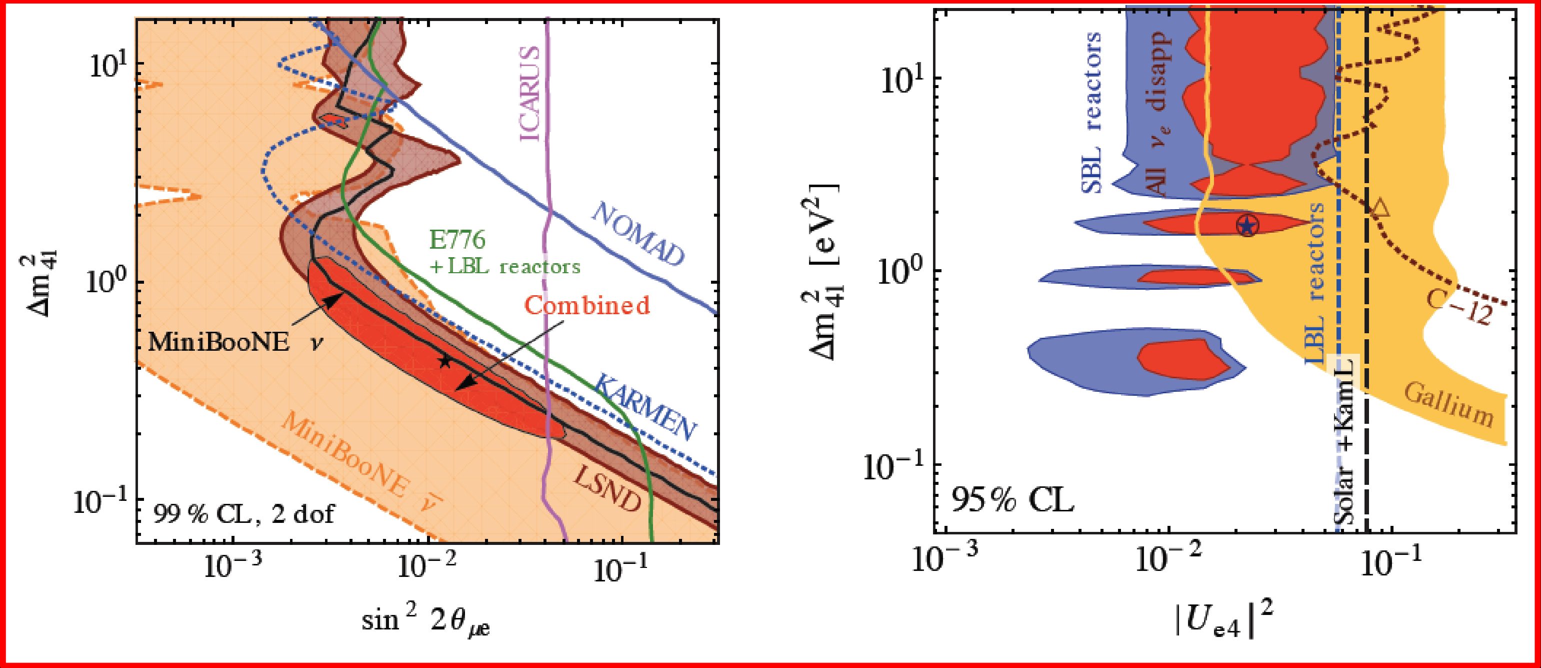
- Sterile neutrinos
- Neutrino oscillations
- CERN Neutrino Platform
- Epilogue and conclusions

Future neutrino experiments:

Sterile neutrinos

Global constraints [1]:

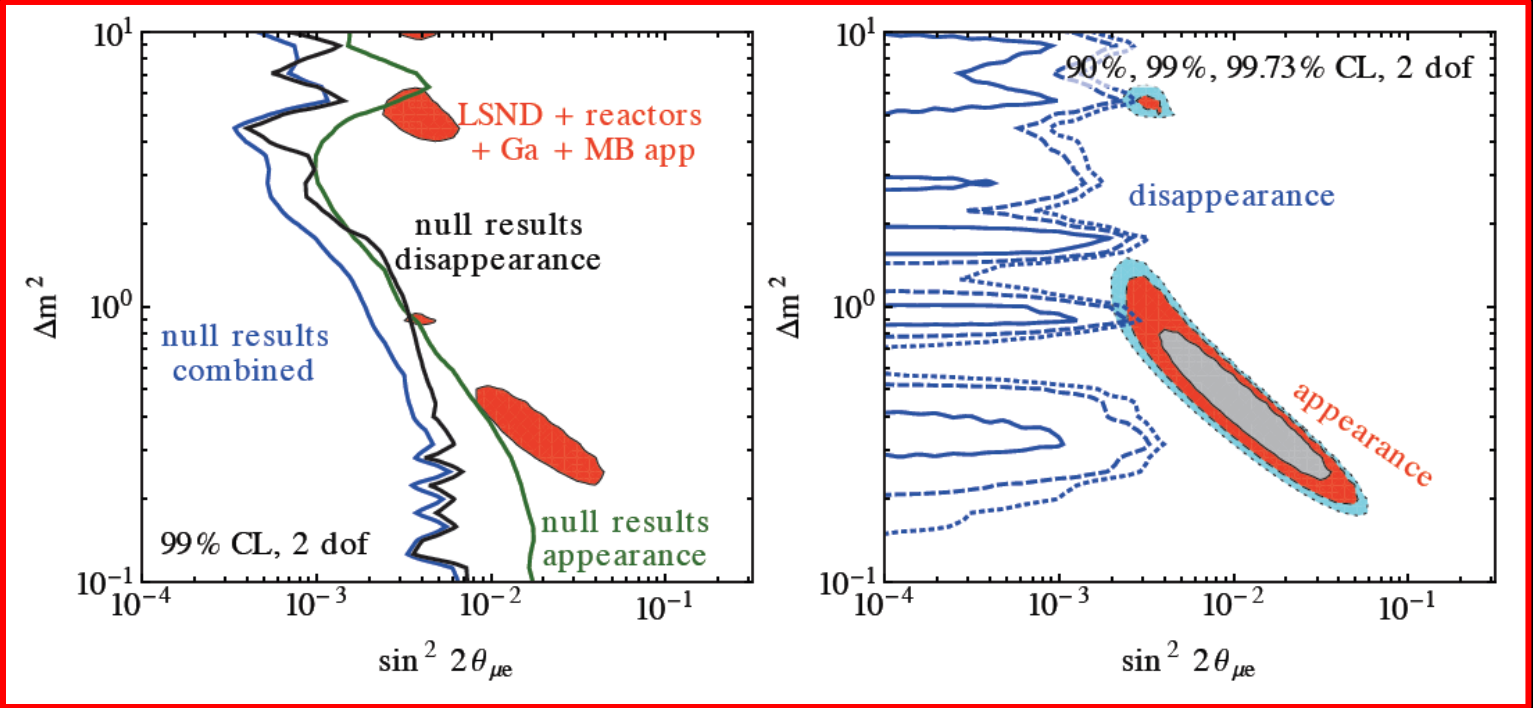
Sterile neutrino data		
	Appearance	**Disappearance**
Null hypothesis: SvM		
Inconsistent	LSND, MiniBOONE	Reactor flux, Gallium sources
Consistent	KARMEN, NOMAD, E776, ICARUS	Atmospheric, Solar, MiniBOONE, SciBOONE, MINOS, Reactor, CDHS, KARMEN, LSND, ^{12}C



- **Appearance and disappearance data sets self-consistent**

Global constraints [2]:

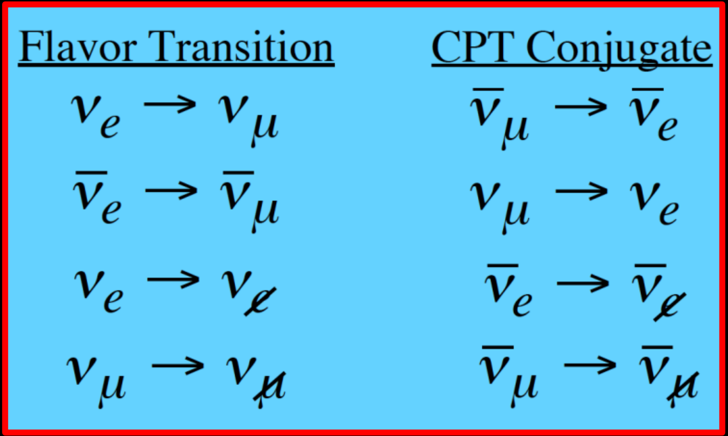
Sterile neutrino data		
Null hypothesis: SνM	Appearance	Disappearance
Inconsistent	LSND, MiniBOONE	Reactor flux, Gallium sources
Consistent	KARMEN, NOMAD, E776, ICARUS	Atmospheric, Solar, MiniBOONE, SciBOONE, MINOS, Reactor, CDHS, KARMEN, LSND, ^{12}C



- Appearance and disappearance data sets self-consistent
- Tension between parameter regions in measurements consistent with the null hypothesis and those which are inconsistent with it
- ν_e appearance data in tension with exclusion limits from disappearance searches

What we need to measure:

- Present, inconclusive, information from $\nu_e \rightarrow \swarrow_x$ and $\nu_\mu \rightarrow \swarrow_x$ transitions
- Ideally, study:

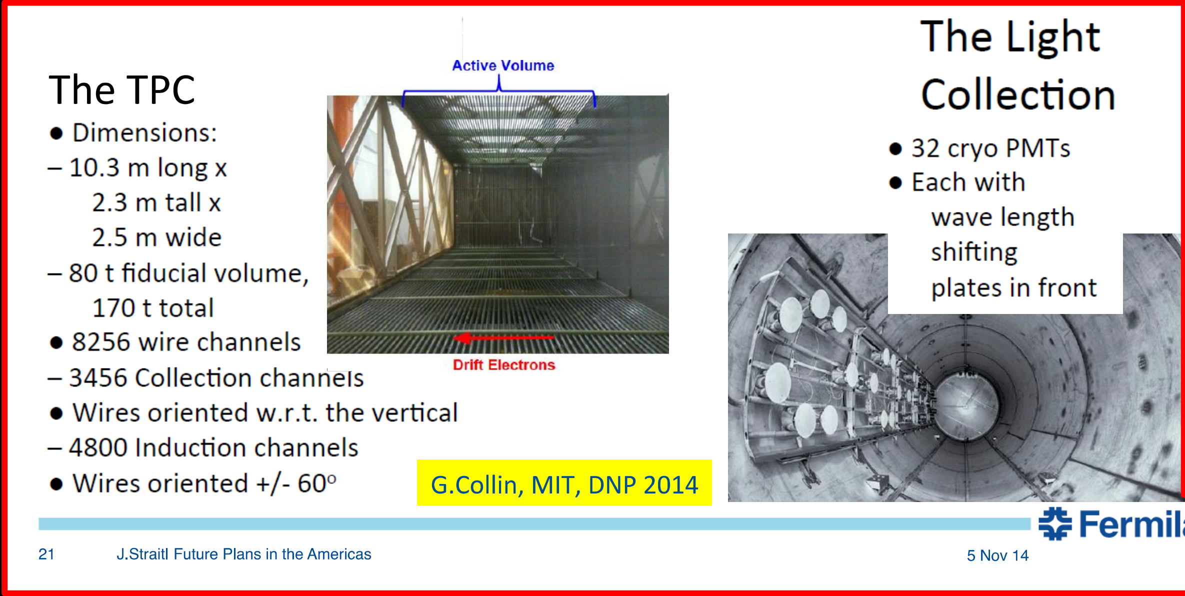


Flavor Transition	CPT Conjugate
$\nu_e \rightarrow \nu_\mu$	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$	$\nu_\mu \rightarrow \nu_e$
$\nu_e \rightarrow \nu_{\not e}$	$\bar{\nu}_e \rightarrow \bar{\nu}_{\not e}$
$\nu_\mu \rightarrow \nu_{\not \mu}$	$\bar{\nu}_\mu \rightarrow \bar{\nu}_{\not \mu}$

and

- – Determine neutral current rate
    - oscillation to steriles will change neutral current rate
- – Study $\nu_e N$ and $\nu_\mu N$ scattering
    - including hadronic final states to eliminate background uncertainties

Near future: MicroBooNE:



The TPC

- Dimensions:
  - 10.3 m long x
    2.3 m tall x
    2.5 m wide
  - 80 t fiducial volume,
    170 t total
- 8256 wire channels
  - 3456 Collection channels
- Wires oriented w.r.t. the vertical
  - 4800 Induction channels
- Wires oriented +/- 60°

The Light Collection

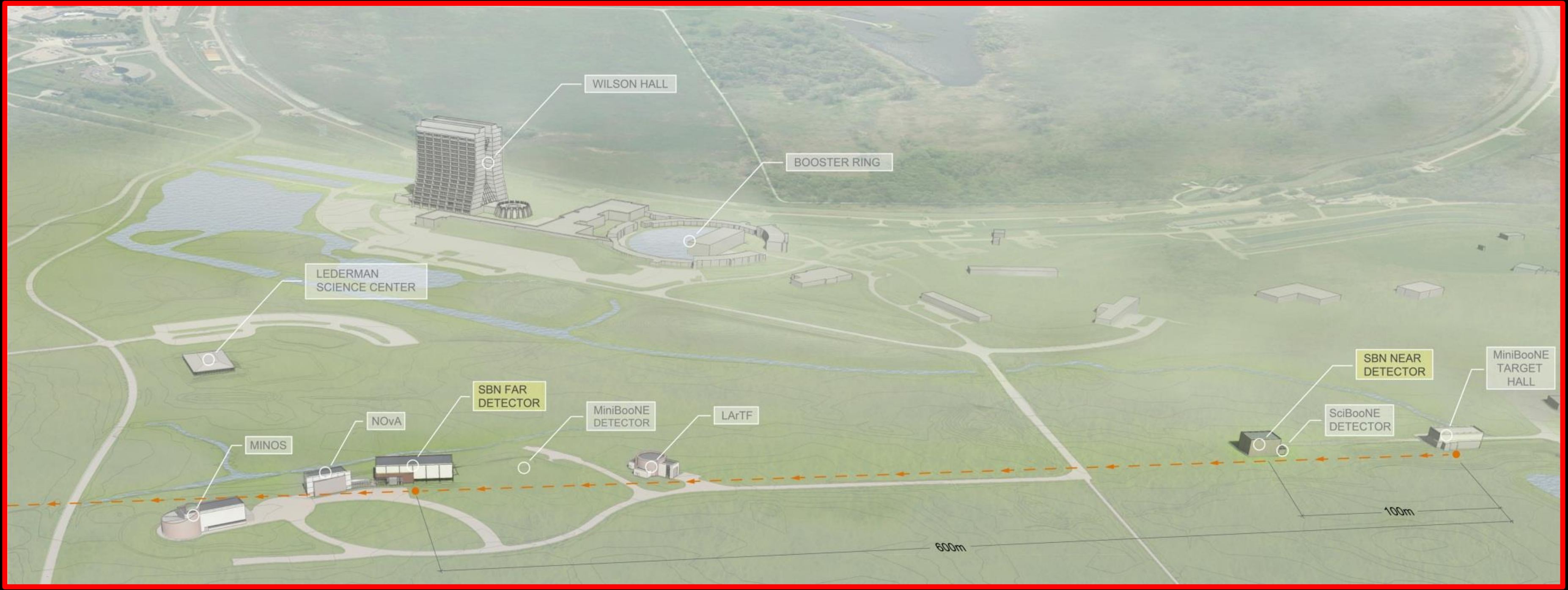
- 32 cryo PMTs
- Each with
  wave length
  shifting
  plates in front

G.Collin, MIT, DNP 2014

Fermilab

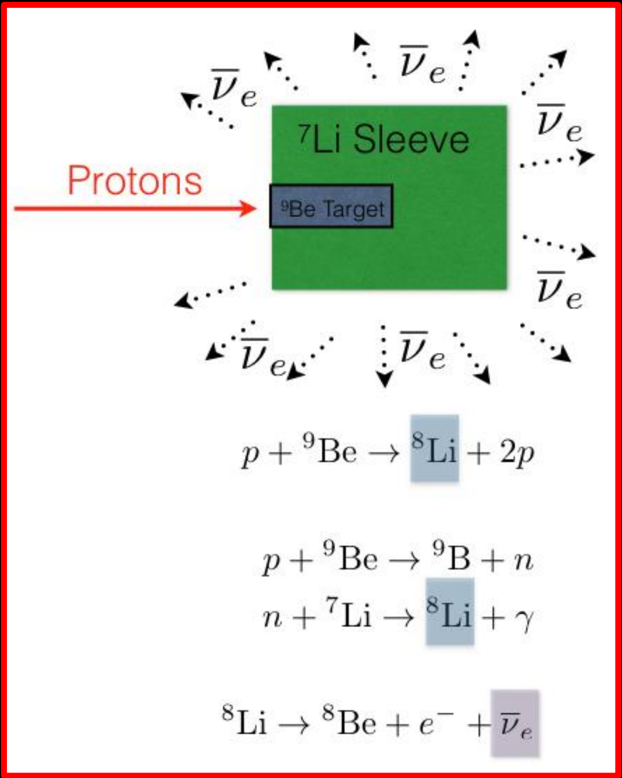
- **Goals:**
  - Resolve short-baseline anomalies in ν_μ ⍰ ν_e searches
  - Measure ν_μ-Ar cross sections
  - Develop LAr TPC technology
- **Timetable:**
  - Jan15: Fill with Lar
  - Spring/summer: commission and start data taking

Short baseline programme @ FNAL booster:



- **SBN based on Booster Neutrino Beam (BNB):**
  - 2015: MicroBooNE
  - 2018: Three-detector sterile neutrino programme:
    - Near detector @ 110m; LAr1ND
    - Middle detector @ 470m; MicroBooNE
    - Far detector @ 600m; ICARUS T600
      - Refurbished at CERN as part of CERN Neutrino Platform
  - Also under consideration for SBN @ BNB:
    - NESSiE (magnetic spectrometer); ANNIE (optical TPC); CAPTAIN (LAr for xSect)

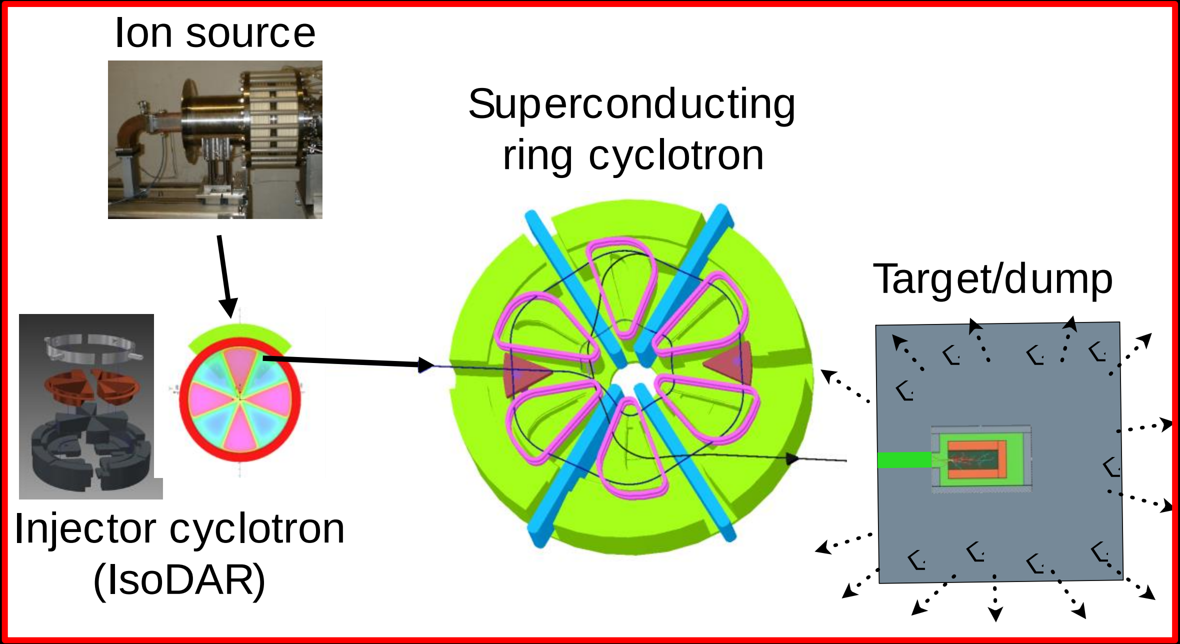
ISODAR:



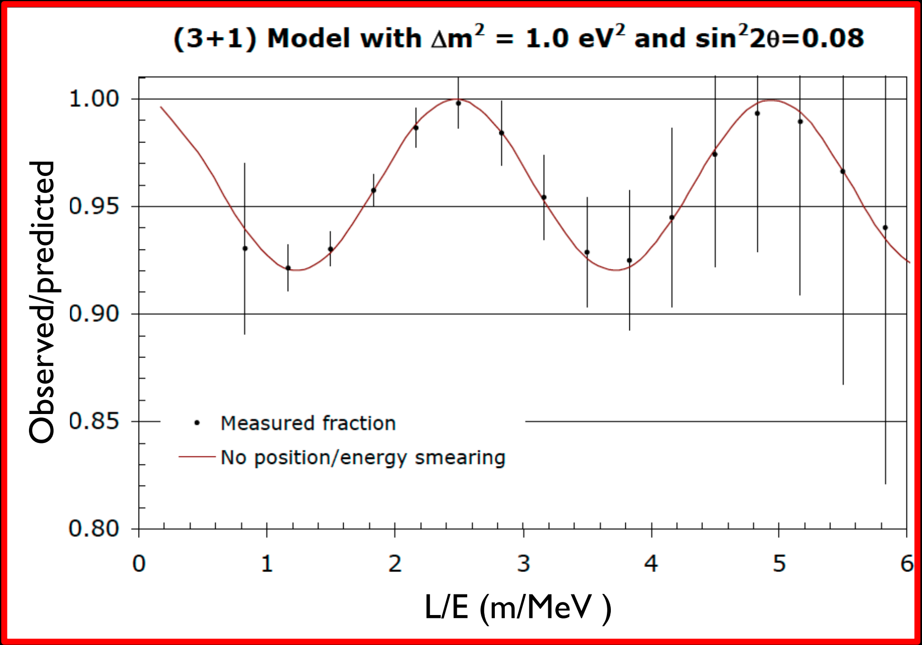
$$p + {}^{9}\mathrm{Be} \rightarrow {}^{8}\mathrm{Li} + 2p$$

$$p + {}^{9}\mathrm{Be} \rightarrow {}^{9}\mathrm{B} + n$$
$$n + {}^{7}\mathrm{Li} \rightarrow {}^{8}\mathrm{Li} + \gamma$$

$$^{8}\mathrm{Li} \rightarrow {}^{8}\mathrm{Be} + e^{-} + \overline{\nu}_e$$

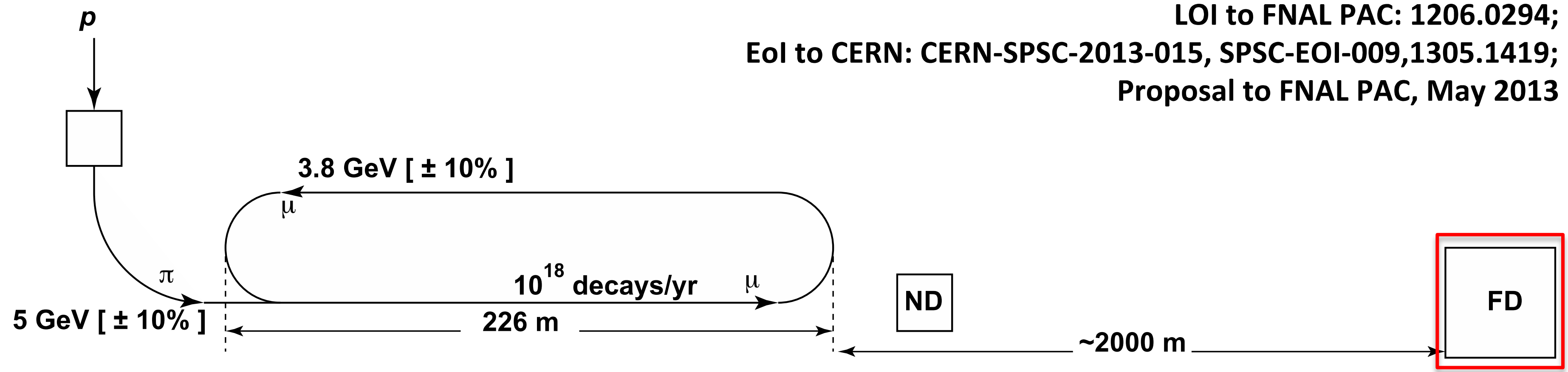


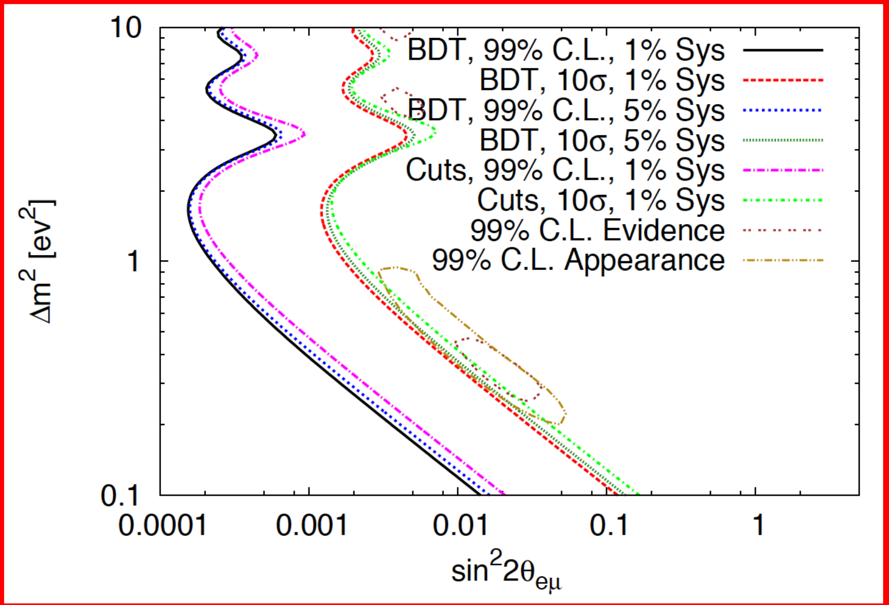
- **Example of sensitivity:**
  - **High-power cyclotron (MW class) illuminating Kamland;**
  - **Baseline 16m**
  - **Five years of running**

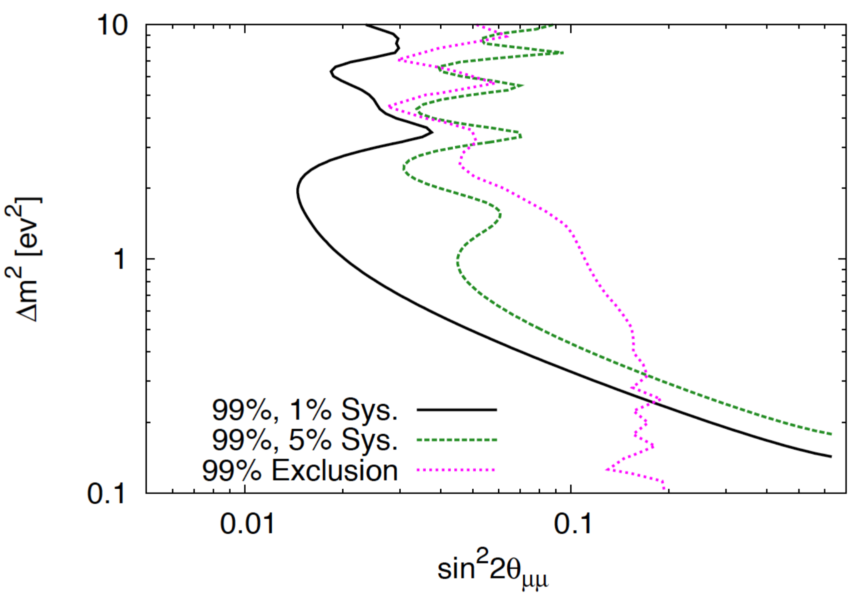


nuSTORM [1]:

LOI to FNAL PAC: 1206.0294;
EoI to CERN: CERN-SPSC-2013-015, SPSC-EOI-009,1305.1419;
Proposal to FNAL PAC, May 2013





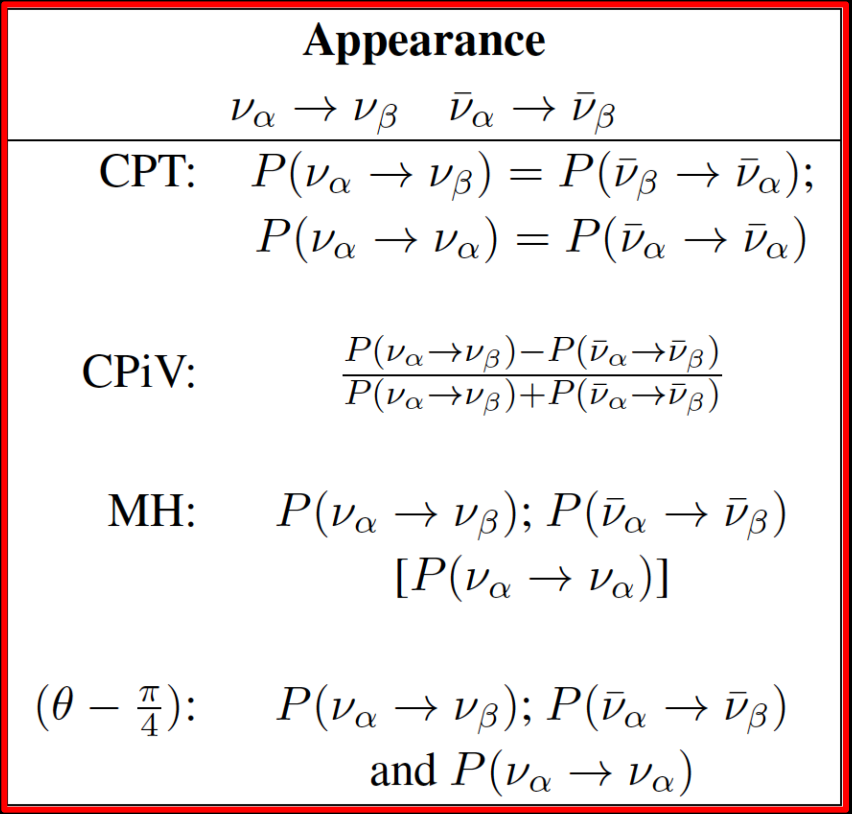


Future neutrino experiments:

Neutrino oscillations

The SvM measurement programme:

- Looking beyond MINOS, T2K, NOvA, DChooz, Daya Bay, Reno, …
  - θ_{13} will be very well known
- Therefore future programme must:
  - Complete the “Standard Neutrino Model” (SvM):
    - Determine the mass hierarchy
    - Search for (and discover?) leptonic CP-invariance violation
  - Establish the SvM as the correct description of nature:
    - Determine precisely the degree to which θ_{23} differs from $\pi/4$
    - Determine θ_{13} precisely
    - Determine θ_{12} precisely
  - Search for deviations from the SvM:
    - Test the unitarity of the neutrino mixing matrix
    - Search for sterile neutrinos, non-standard interactions, …

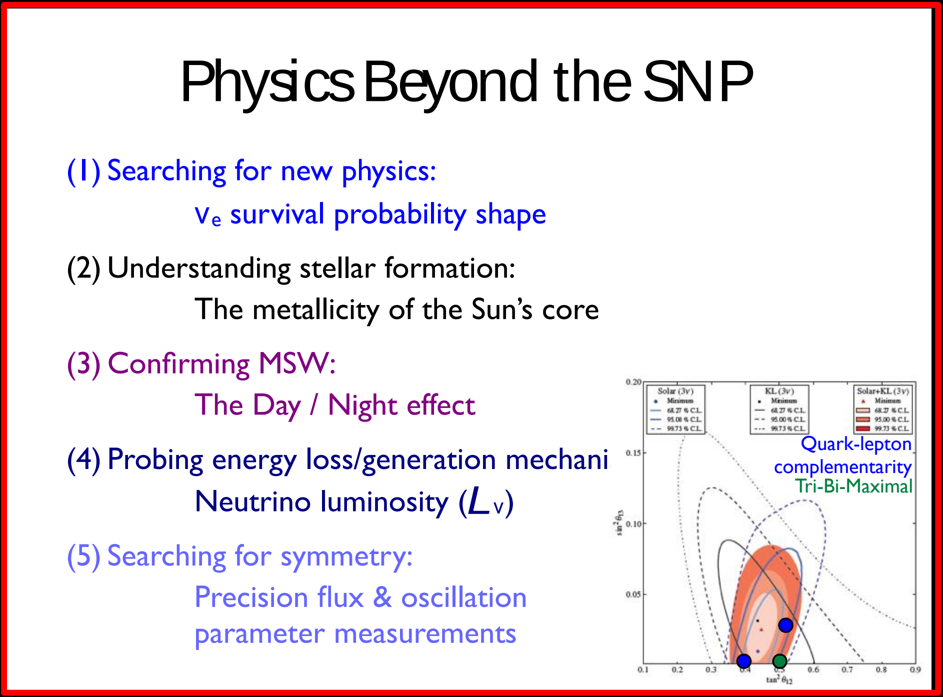


	Appearance $\nu_\alpha \to \nu_\beta \quad \bar{\nu}_\alpha \to \bar{\nu}_\beta$
CPT:	$P(\nu_\alpha \to \nu_\beta) = P(\bar{\nu}_\beta \to \bar{\nu}_\alpha)$; $P(\nu_\alpha \to \nu_\alpha) = P(\bar{\nu}_\alpha \to \bar{\nu}_\alpha)$
CPiV:	$\frac{P(\nu_\alpha \to \nu_\beta) - P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)}{P(\nu_\alpha \to \nu_\beta) + P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)}$
MH:	$P(\nu_\alpha \to \nu_\beta)$; $P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)$ $[P(\nu_\alpha \to \nu_\alpha)]$
$(\theta - \frac{\pi}{4})$:	$P(\nu_\alpha \to \nu_\beta)$; $P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)$ and $P(\nu_\alpha \to \nu_\alpha)$

Precision measurement: solar and reactor:

G. D. Orebi Gann; NNN’14

Solar:



Physics Beyond the SNP

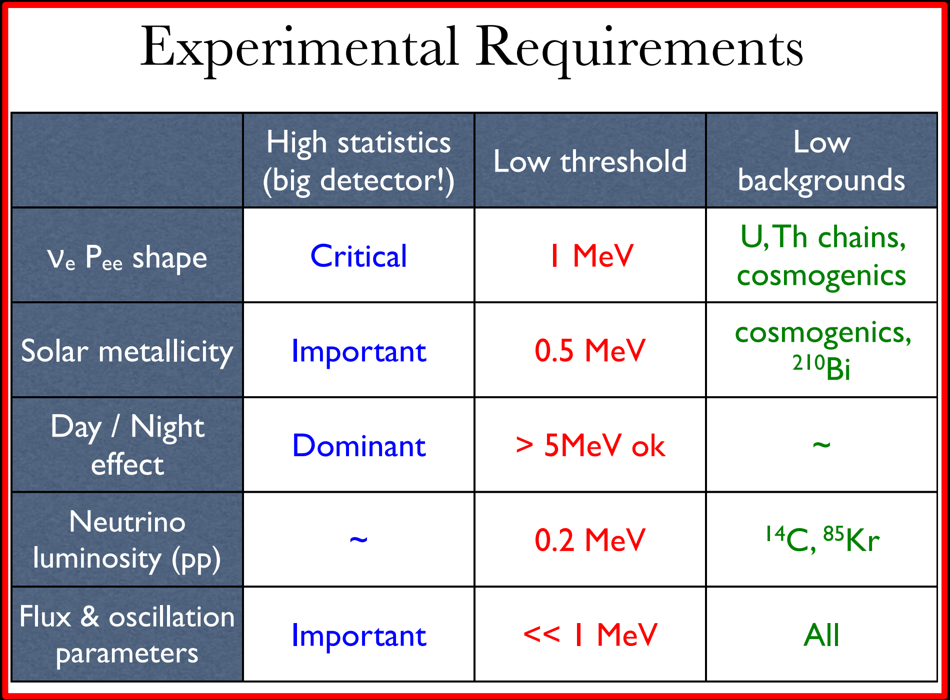
(1) Searching for new physics:
ν_e survival probability shape

(2) Understanding stellar formation:
The metallicity of the Sun’s core

(3) Confirming MSW:
The Day / Night effect

(4) Probing energy loss/generation mechani
Neutrino luminosity (L_ν)

(5) Searching for symmetry:
Precision flux & oscillation parameter measurements



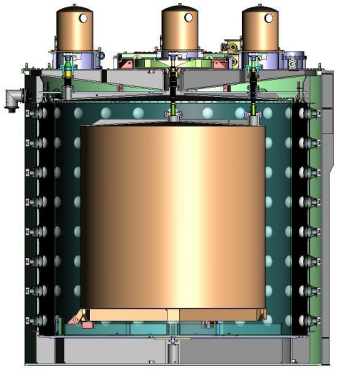
Experimental Requirements

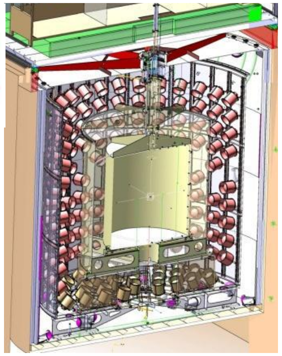
	High statistics (big detector!)	Low threshold	Low backgrounds
ν_e P_{ee} shape	Critical	1 MeV	U, Th chains, cosmogenics
Solar metallicity	Important	0.5 MeV	cosmogenics, ^{210}Bi
Day / Night effect	Dominant	> 5MeV ok	~
Neutrino luminosity (pp)	~	0.2 MeV	^{14}C, ^{85}Kr
Flux & oscillation parameters	Important	<< 1 MeV	All

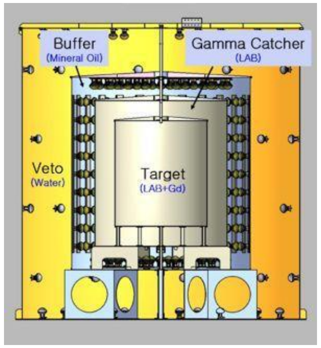
Solar neutrino experiments:

Elastic scattering:				
H2O Cherenkov	Super-K, Hyper-K			
Liquid scintillator	Borexino	SNO+	LENA	JUNO
Inorganic scintillator	CLEAN (Lne)	LBNF	XMASS, LZ (LXe)	
Charged-current detection				
Segmented detector	LENS			
Water-based liquid scintillator	ASDC (7Li loaded H2O C)			

Detector Configurations



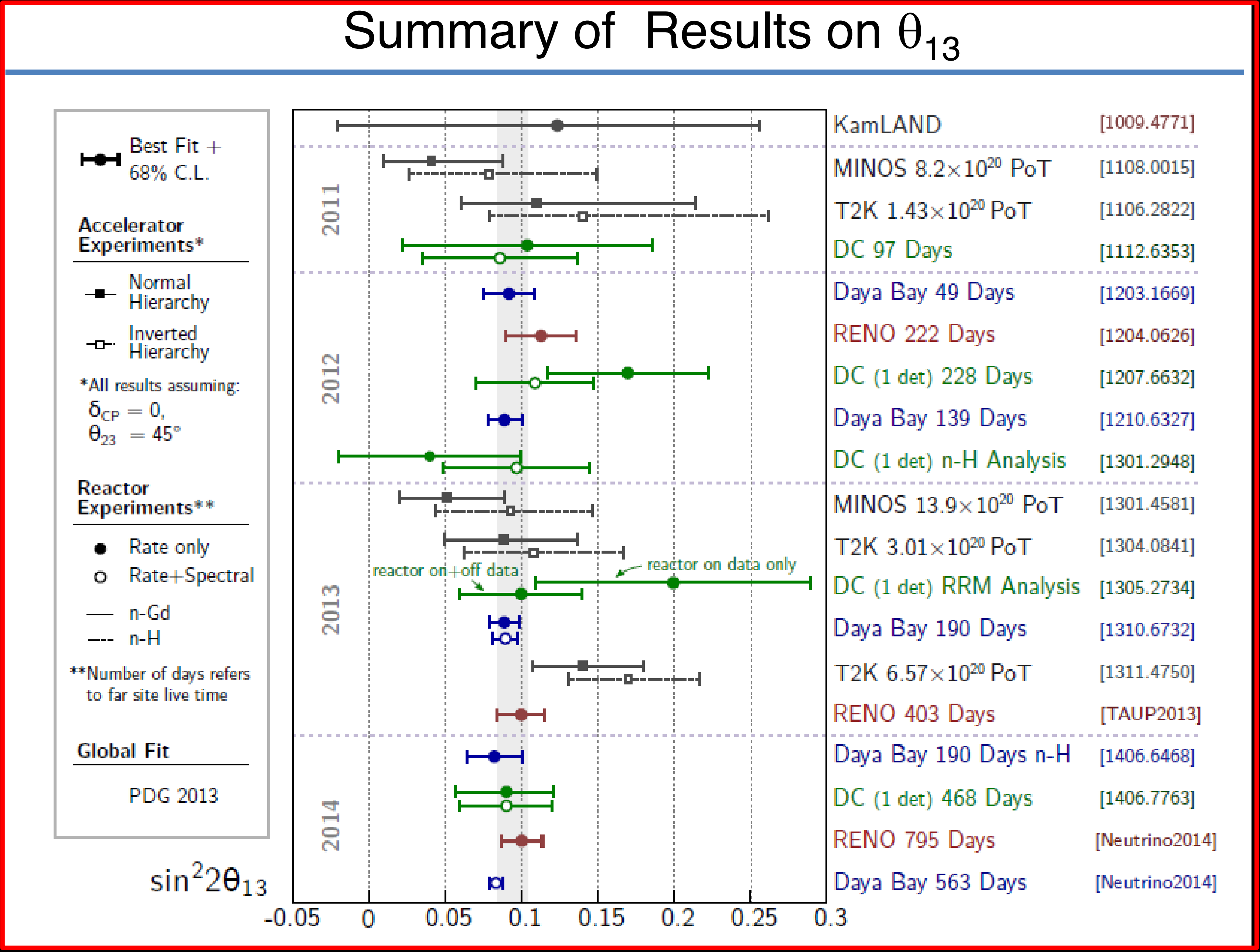




Experiment	**Daya Bay (China)**	**Double Chooz (France)**	**RENO (Korea)**
Reactor power (GW th)	17.3	8.6	16.4
Baseline near/far (m)	470 (570) / 1650	410 / 1050	410 / 1440
Target mass near/far (t)	2 x (2 x 20) / 4 x 20	8.3 / 8.3	16.5 / 16.5
Start date	12/2011 (6 AD) 10/2012 (8 AD)	04/2011 (far)	08/2011 (far + near)

M. Göger-Neff; NNN'14

Reactor:

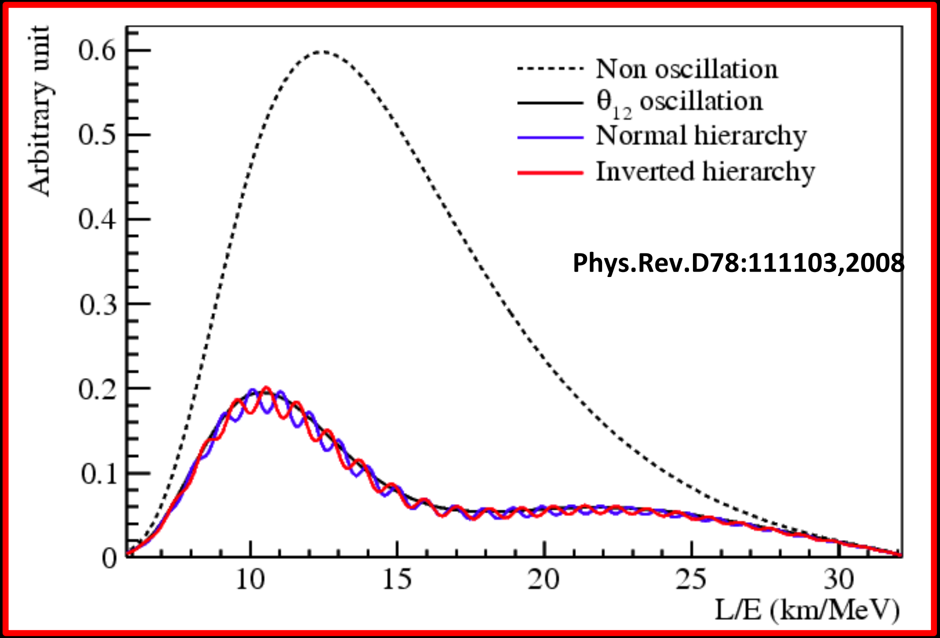


Summary of Results on θ_{13}

Mass hierarchy and CP-invariance violation:

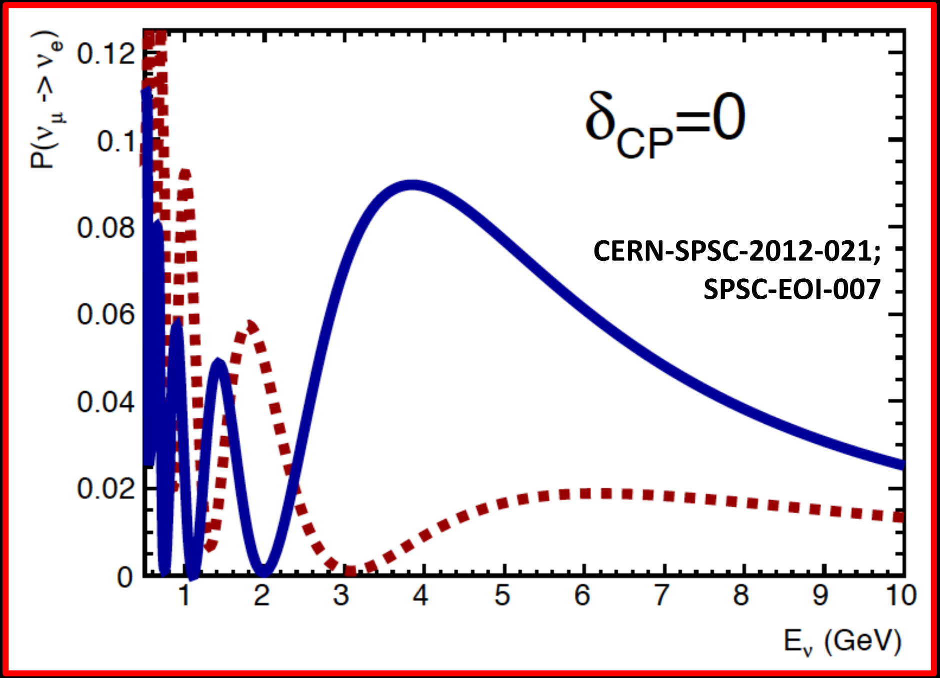
Mass hierarchy:

- Two options:
  - – Exploit *L*/*E* spectrum:



Phys.Rev.D78:111103,2008

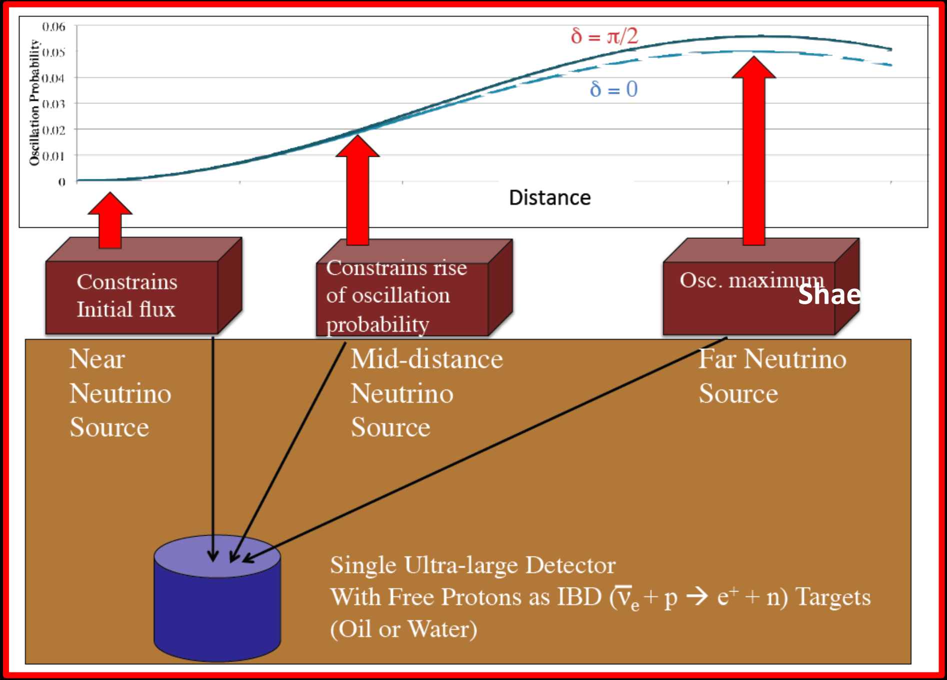
  - – Exploit matter effect:



CERN-SPSC-2012-021;
SPSC-EOI-007

CPiV:

- Two options:
  - Exploit *L*/*E* spectrum:
    - DAEδALUS



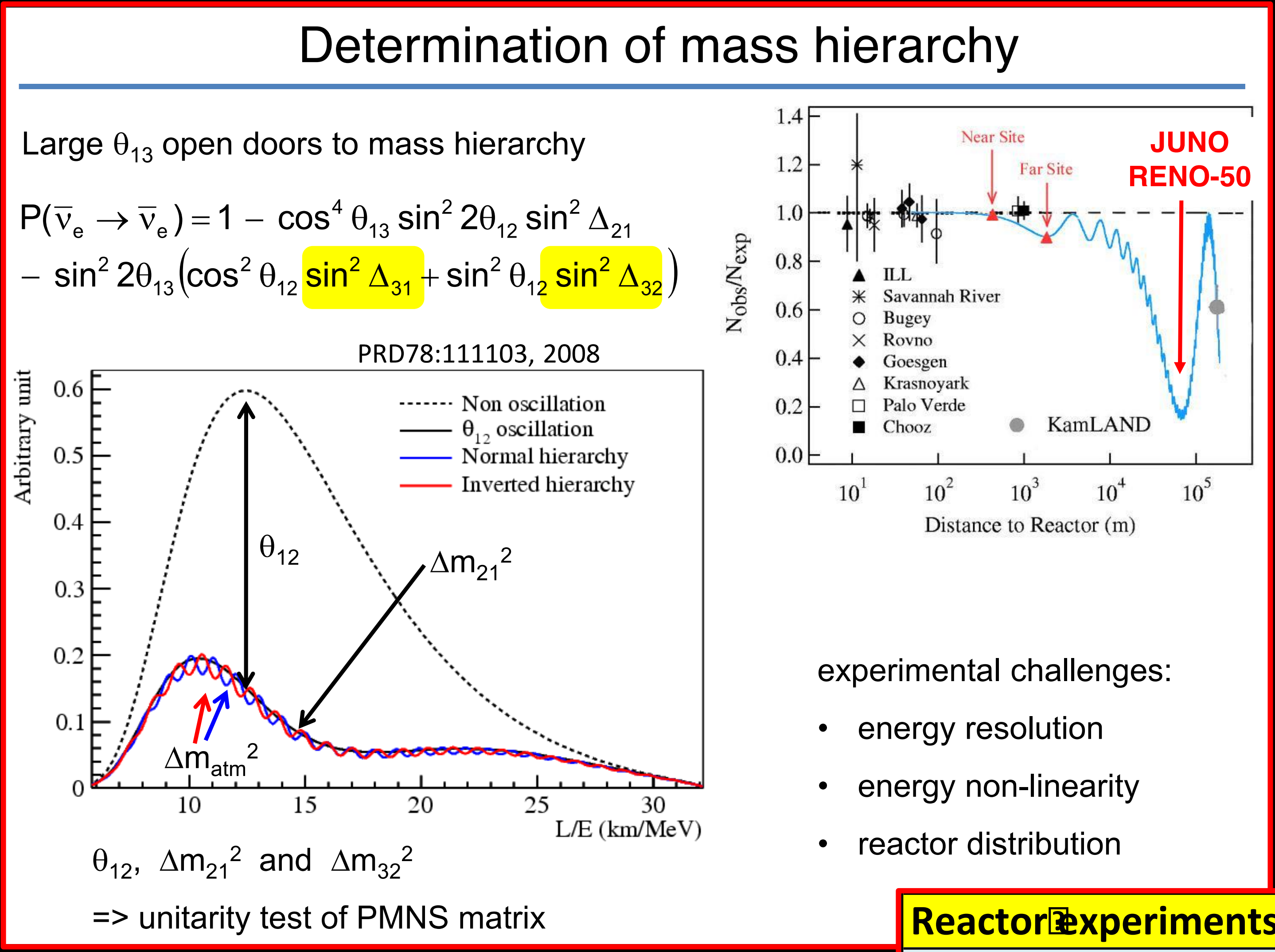
  - Measure asymmetry:
    - Large θ_{13} makes discovery conceivable, ***but***:
      - Places premium on the control of systematic uncertainties

$$\frac{P(\nu_\alpha \rightarrow \nu_\beta) - P(\bar{\nu}_\alpha \rightarrow \bar{\nu}_\beta)}{P(\nu_\alpha \rightarrow \nu_\beta) + P(\bar{\nu}_\alpha \rightarrow \bar{\nu}_\beta)} \propto \frac{1}{\sin 2\theta_{13}}$$

MH & CPiV: reactor and decay at rest:

M. Göger-Neff; NNN'14

Reactor:



Determination of mass hierarchy

Large θ_{13} open doors to mass hierarchy

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

PRD78:111103, 2008

θ_{12}, Δm_{21}^2 and Δm_{32}^2

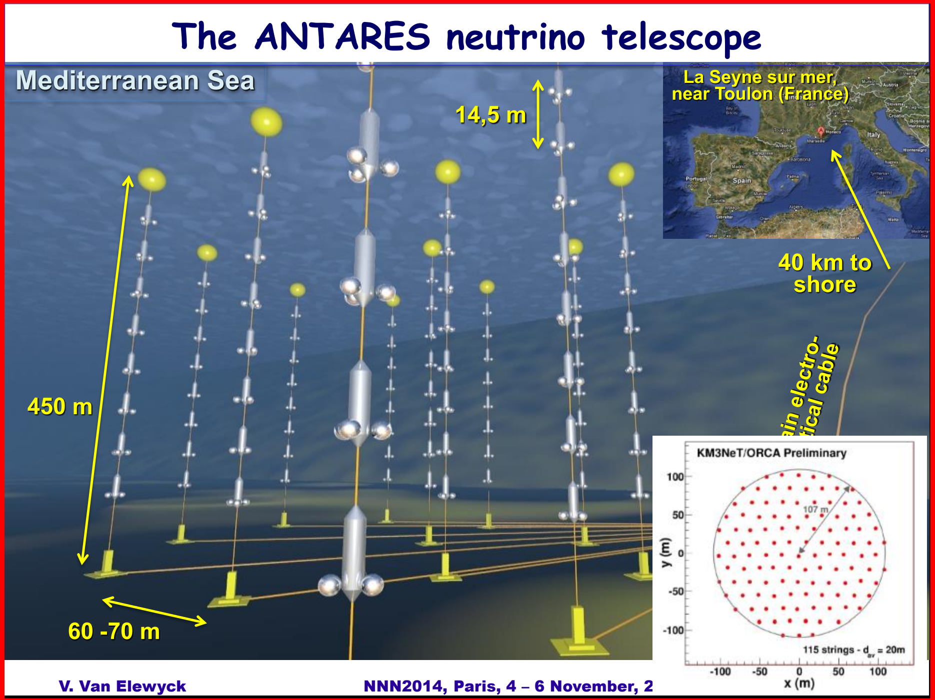
=> unitarity test of PMNS matrix

experimental challenges:

- energy resolution
- energy non-linearity
- reactor distribution

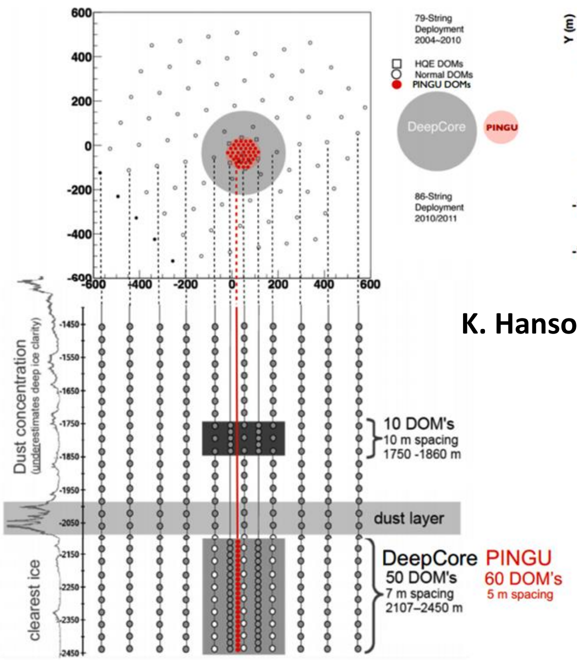
Reactor experiments:			
Jiangmen Underground Neutrino Observatory (JUNO)			
	Civil construction	**Detector installation**	**Operation**
	2014-2017	2018-2019	2020--
RENO-50			
	Civil construction	**Detector installation**	**Operation**
			2020--

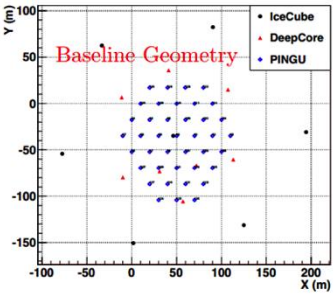
Atmospheric:



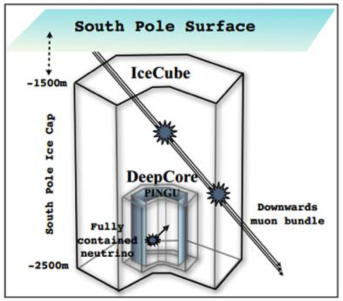
The ANTARES neutrino telescope

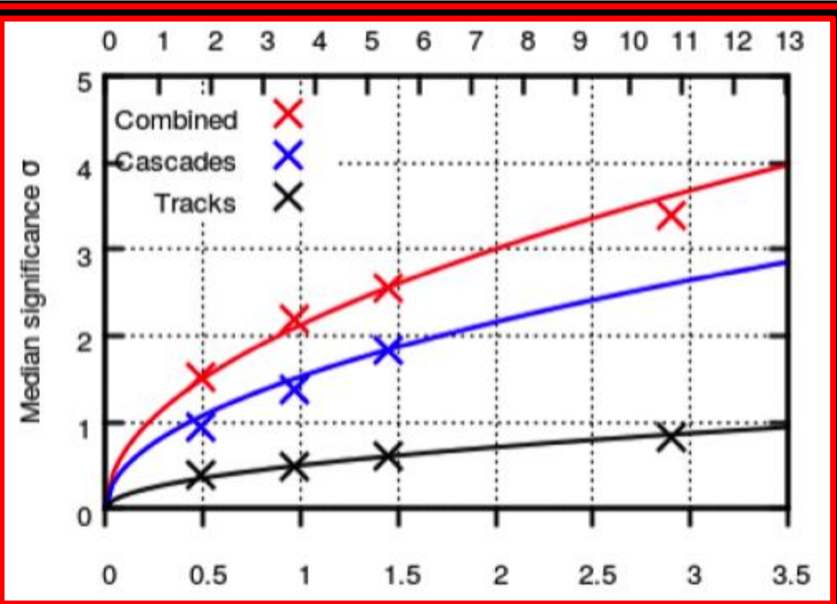
V. Van Elewyck   NNN2014, Paris, 4 – 6 November, 2

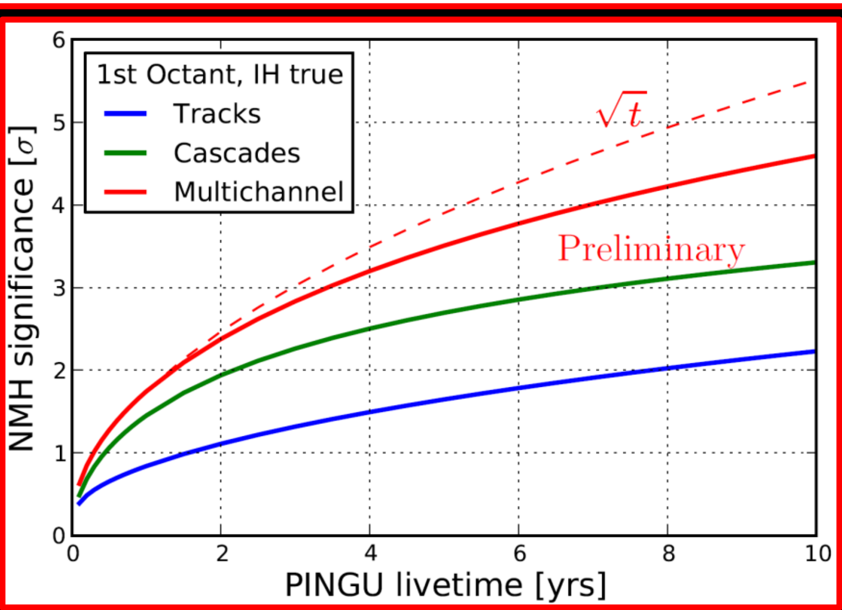




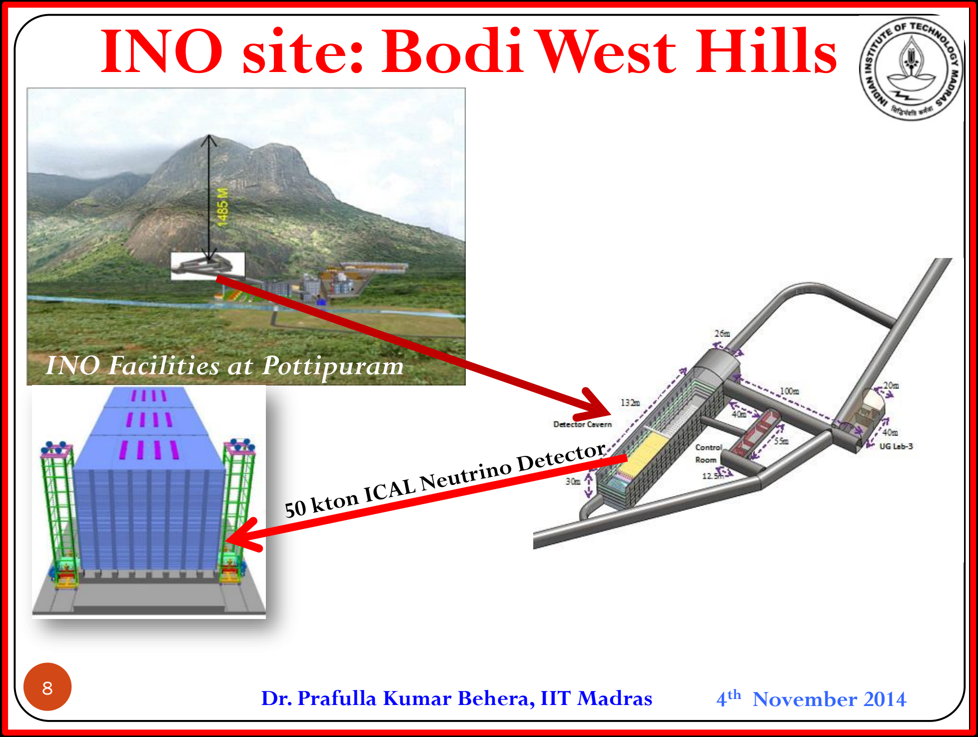
K. Hanson; NNN'14







Atmospheric:

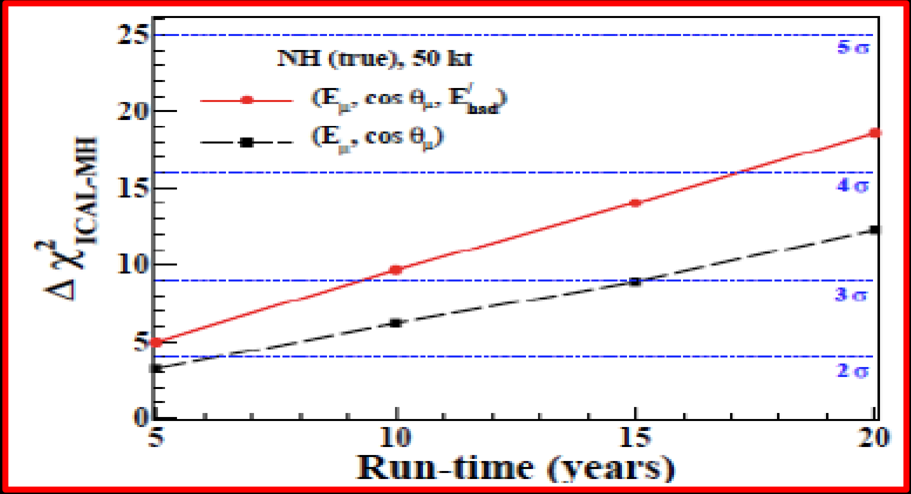


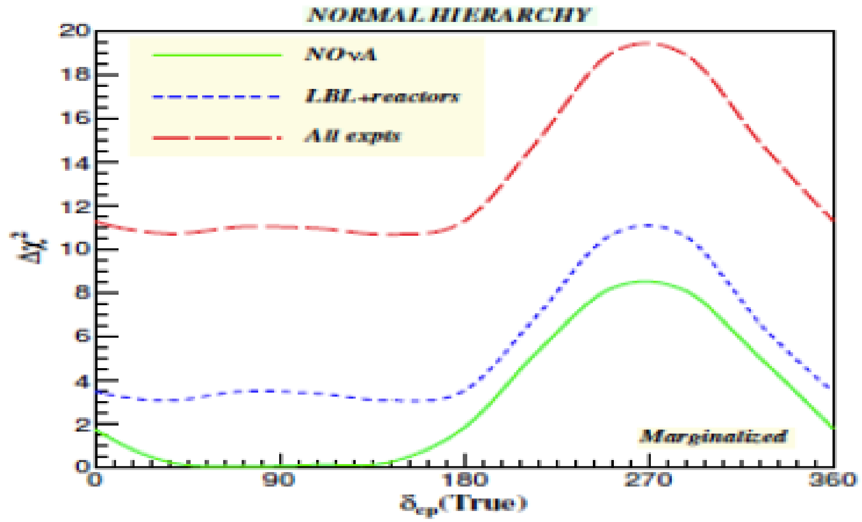
INO site: Bodi West Hills

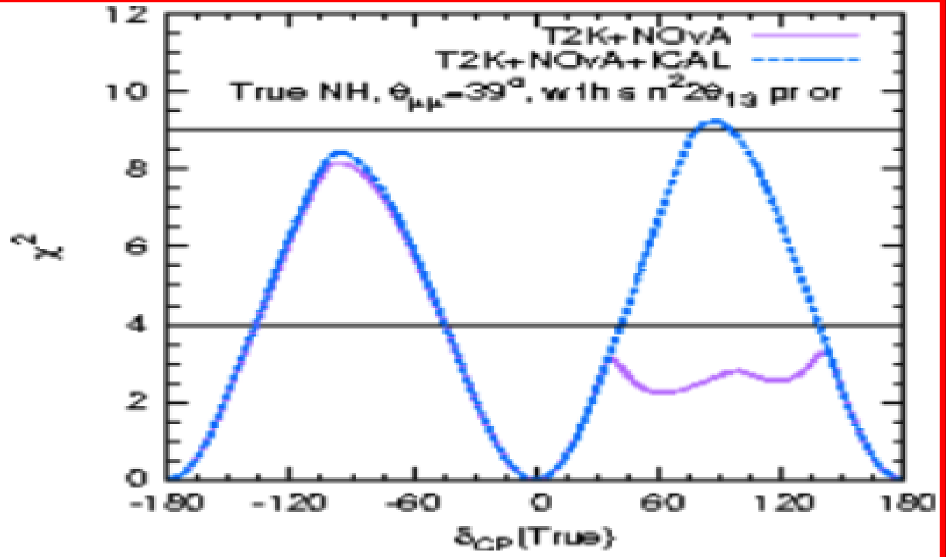
INO Facilities at Pottipuram

50 kton ICAL Neutrino Detector

Dr. Prafulla Kumar Behera, IIT Madras   4th November 2014





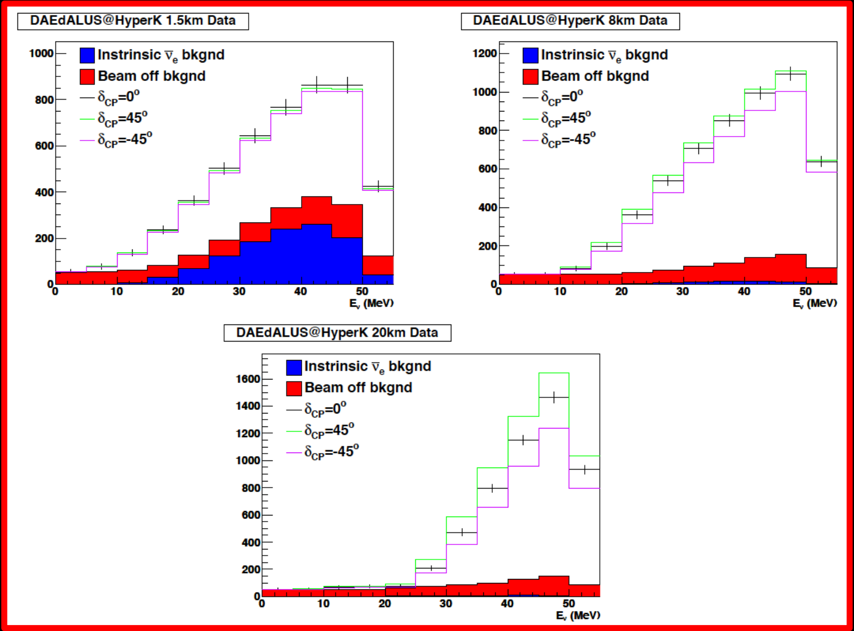


The DAEδALUS Neutrino Source

π^+ decay-at-rest (DAR) beam:

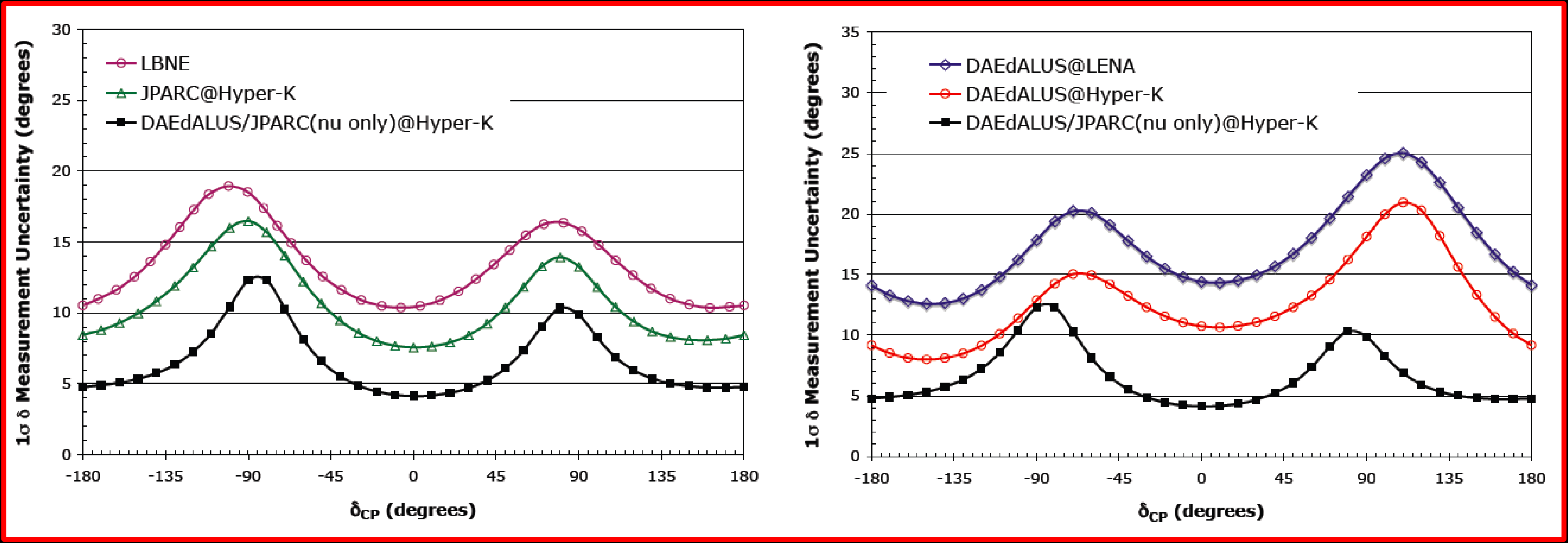
1307.6465
1307.2949
1006.0260v1

$$p + C \rightarrow \pi^+ \rightarrow \nu_\mu + \mu^+$$
$$\hookrightarrow e^+\bar{\nu}_\mu\nu_e,$$



Configuration Name	Source(s)	Average Long Baseline Beam Power	Detector	Fiducial Volume	Run Length
DAEδALUS@LENA	DAEδALUS only	N/A	LENA	50 kt	10 years
DAEδALUS@Hyper-K	DAEδALUS only	N/A	Hyper-K	560 kt	10 years
DAEδALUS/JPARC (nu only)@Hyper-K	DAEδALUS & JPARC	750 kW	Hyper-K	560 kt	10 years
JPARC@Hyper-K	JPARC	750 kW	Hyper-K	560 kt	3 years ν + 7 years $\bar{\nu}$
LBNE	FNAL	850 kW	LBNE	35 kt	5 years ν 5 years $\bar{\nu}$

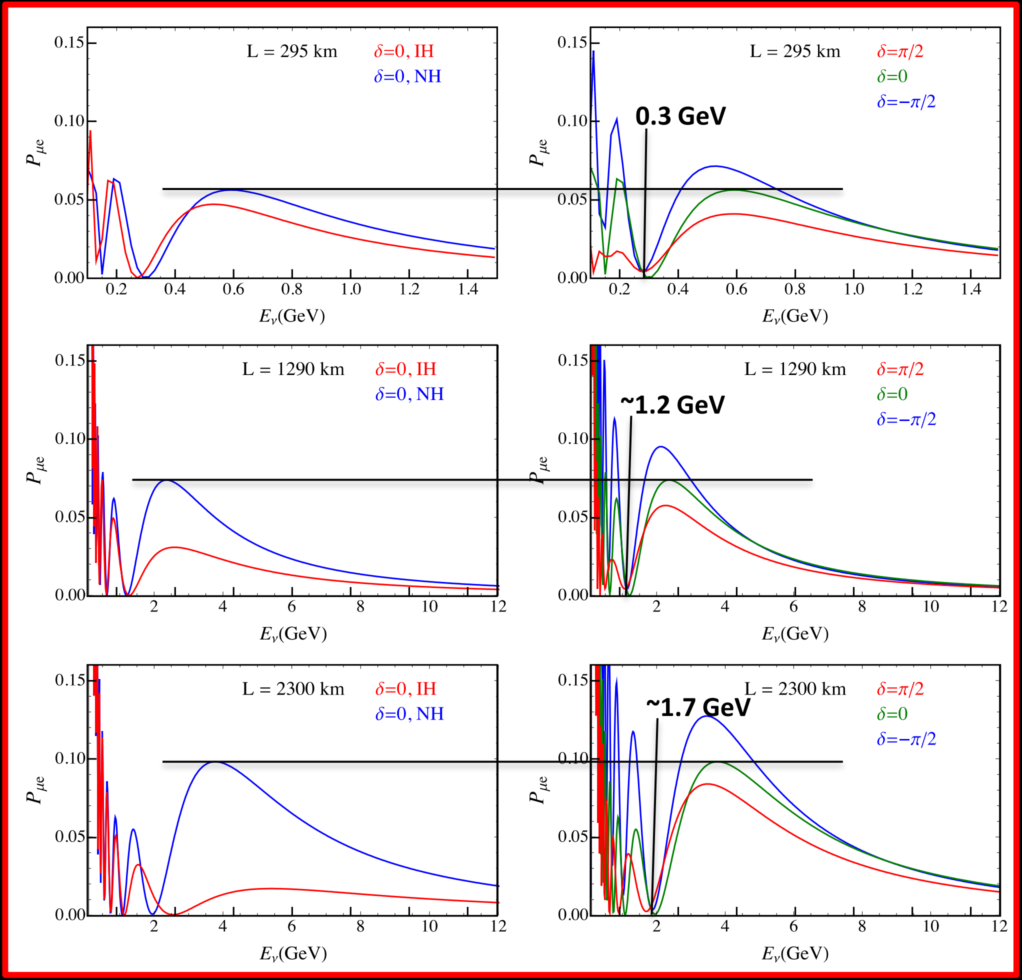
- **D^+ cyclotrons:**
  - 1 MW (1.5 km); 2 MW (8 km); 5 MW (20 km)



MH & CPiV: super-beams:

P. Coloma

MH and CPiV at LBL experiments:

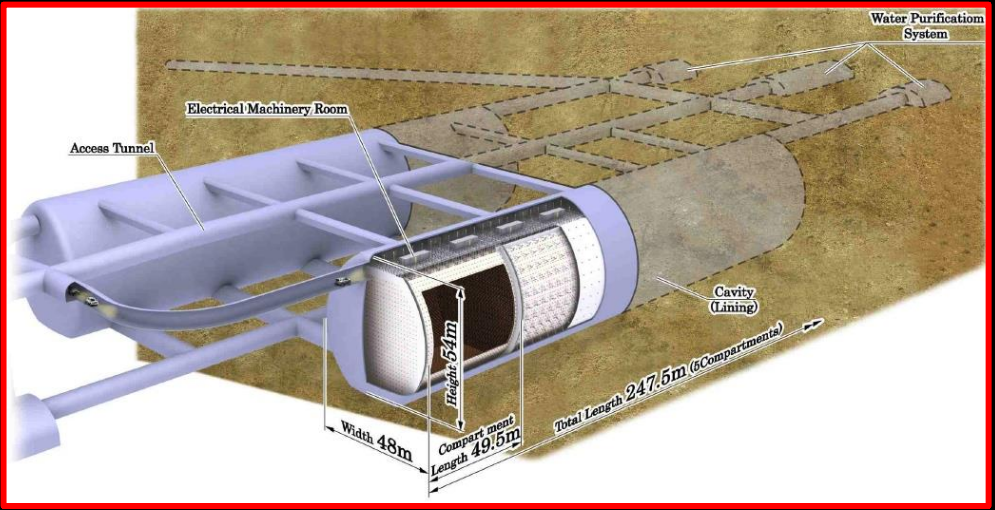


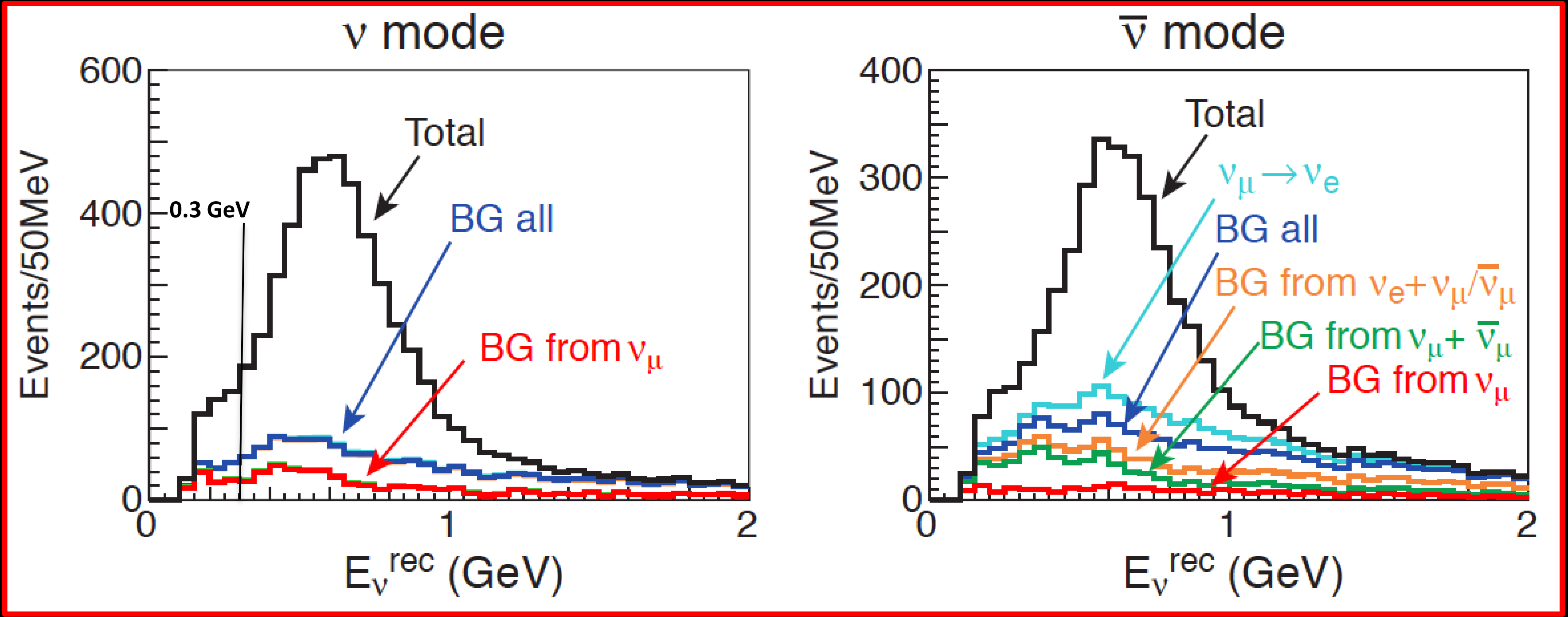
- Mass hierarchy and CPiV modulate oscillation probability:
  - Need to measure as a function of *L/E* [measure *E* spectrum]
- MH sensitivity grows with *L* [matter effect]
- CPiV modulation grows with *L/E* [but, measure *E* spectrum]

arXiv:1109.3262

T2 Hyper-Kamiokande:

- Source:
  - JPARC neutrino beam: upgrade path to 1.66 MW
- Detector: water Cherenkov
  - Fiducial mass: 560 kTonne
  - Site:
    - 2.5° off axis;
    - Baseline ~290 km

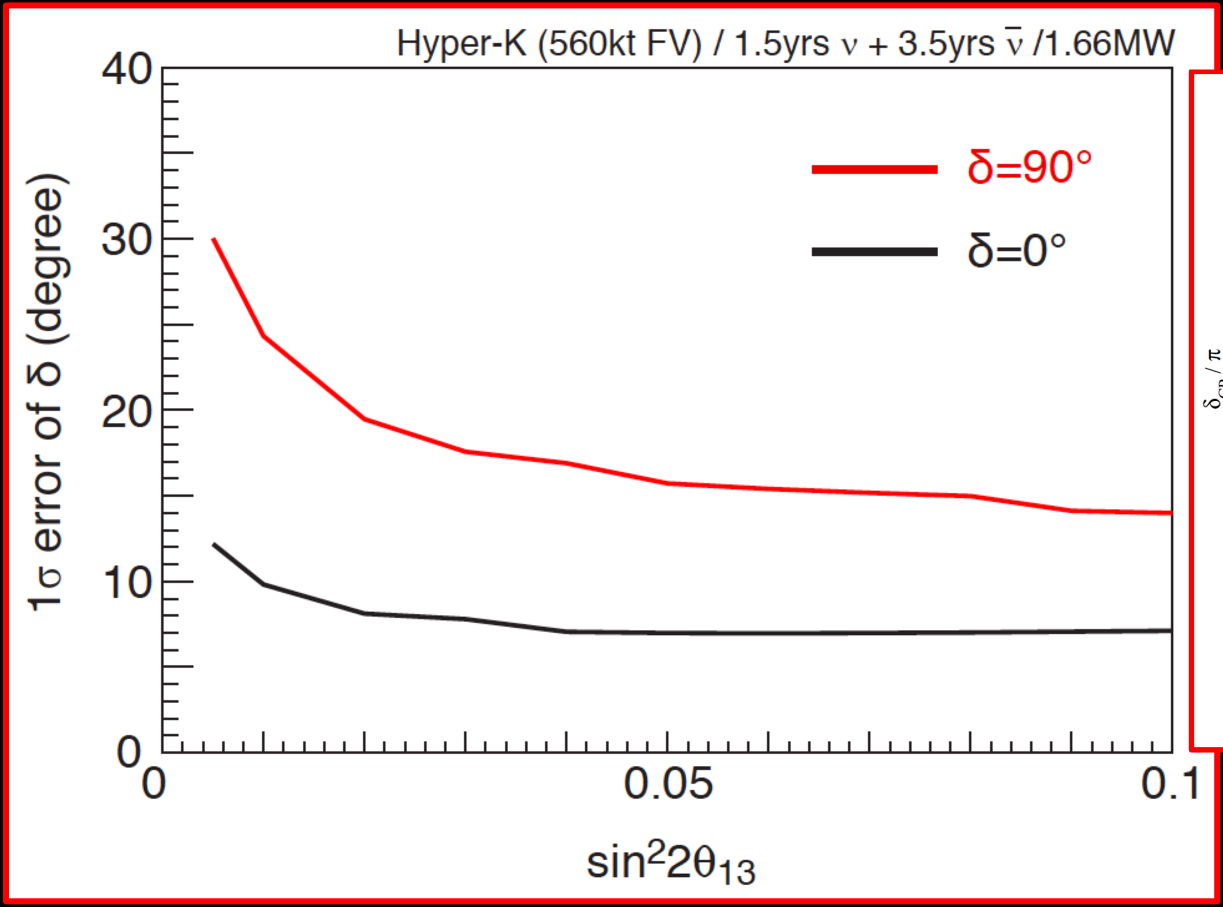


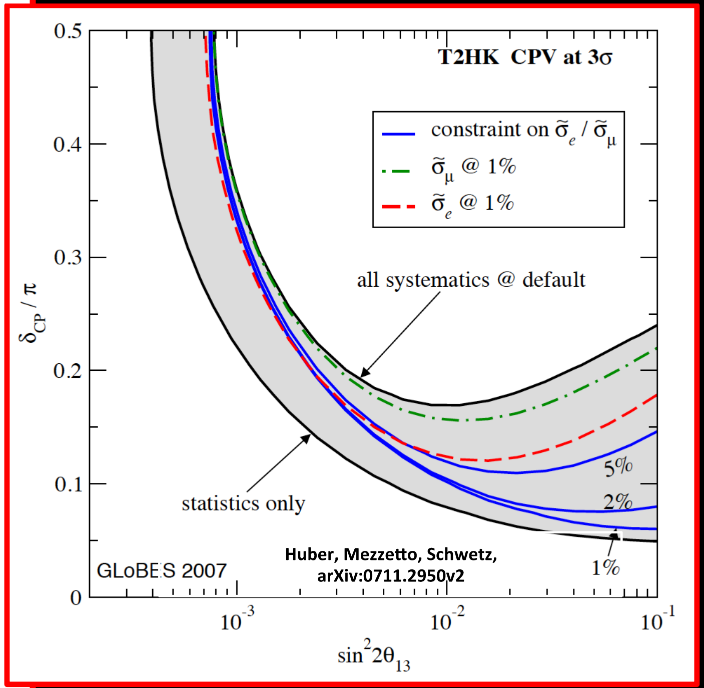


arXiv:1109.3262

T2 Hyper-Kamiokande:

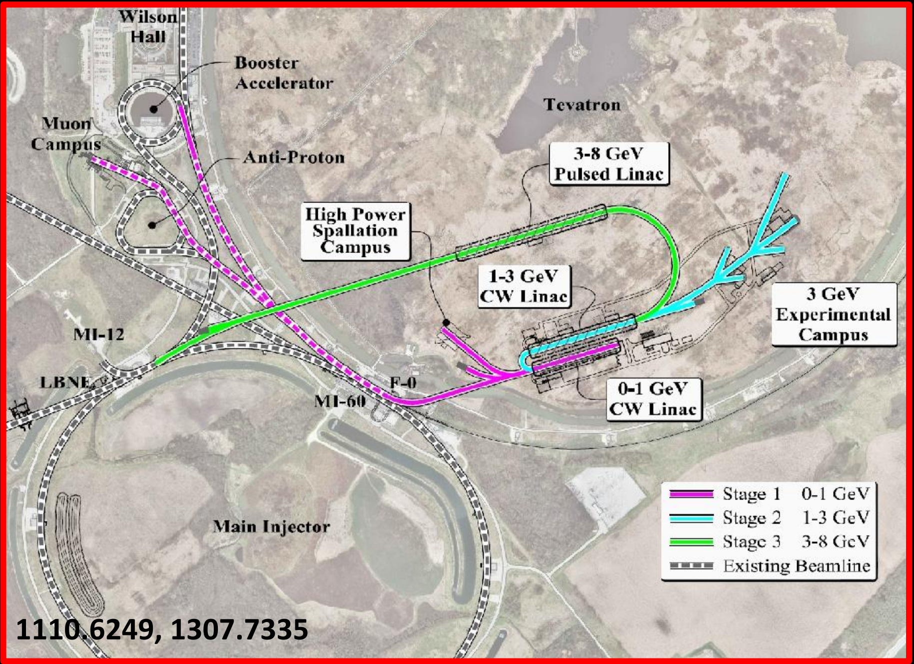
- Systematic uncertainties:
  - Signal: 5%
  - νμ induced background: 5%
  - νe induced background: 5%
  - Relative neutrino/anti-neutrino normalisation: 5%



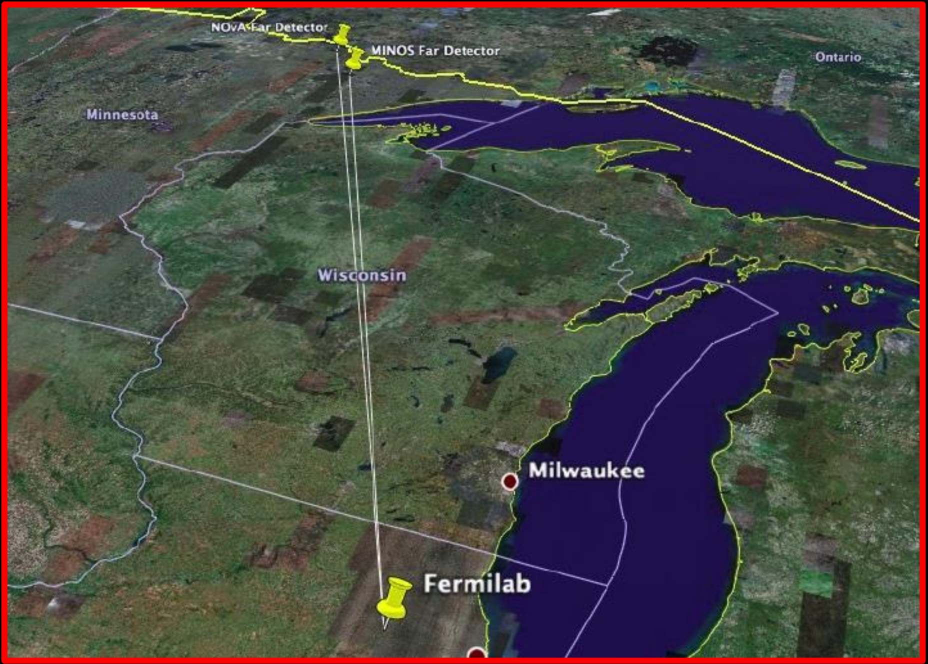


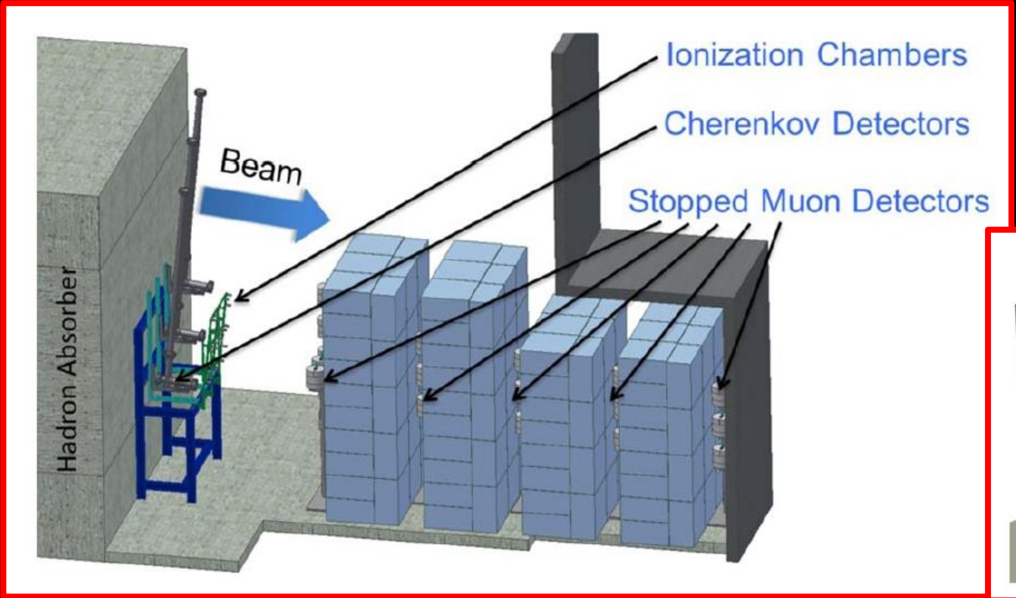
Huber, Mezzetto, Schwetz, arXiv:0711.2950v2

Long-Baseline Neutrino Experiment:

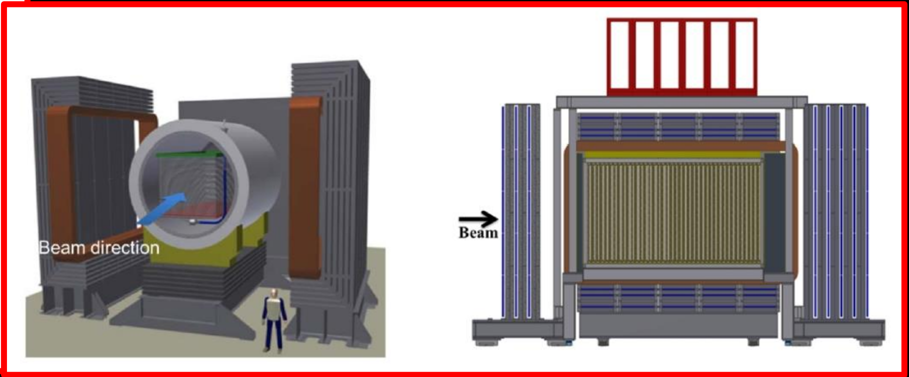


1110.6249, 1307.7335



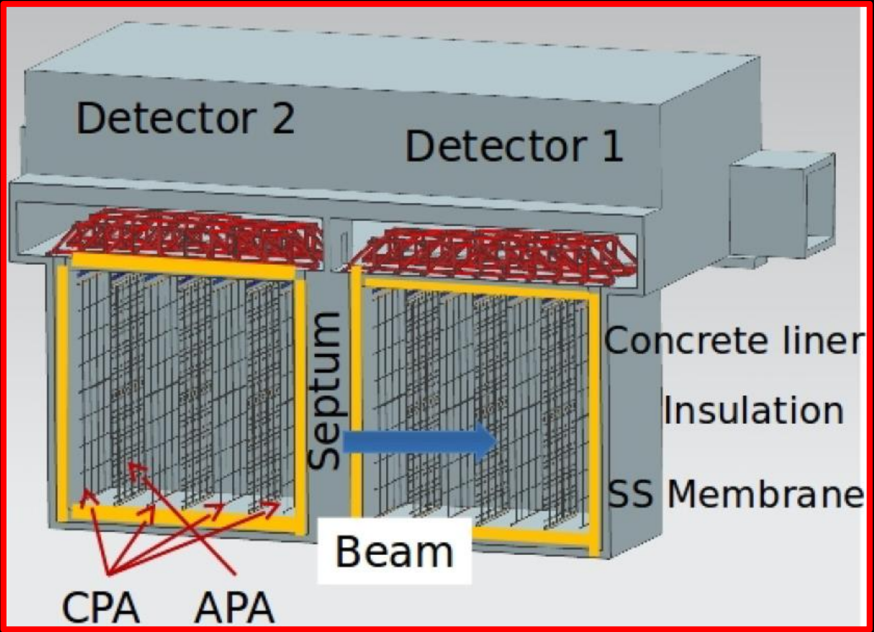


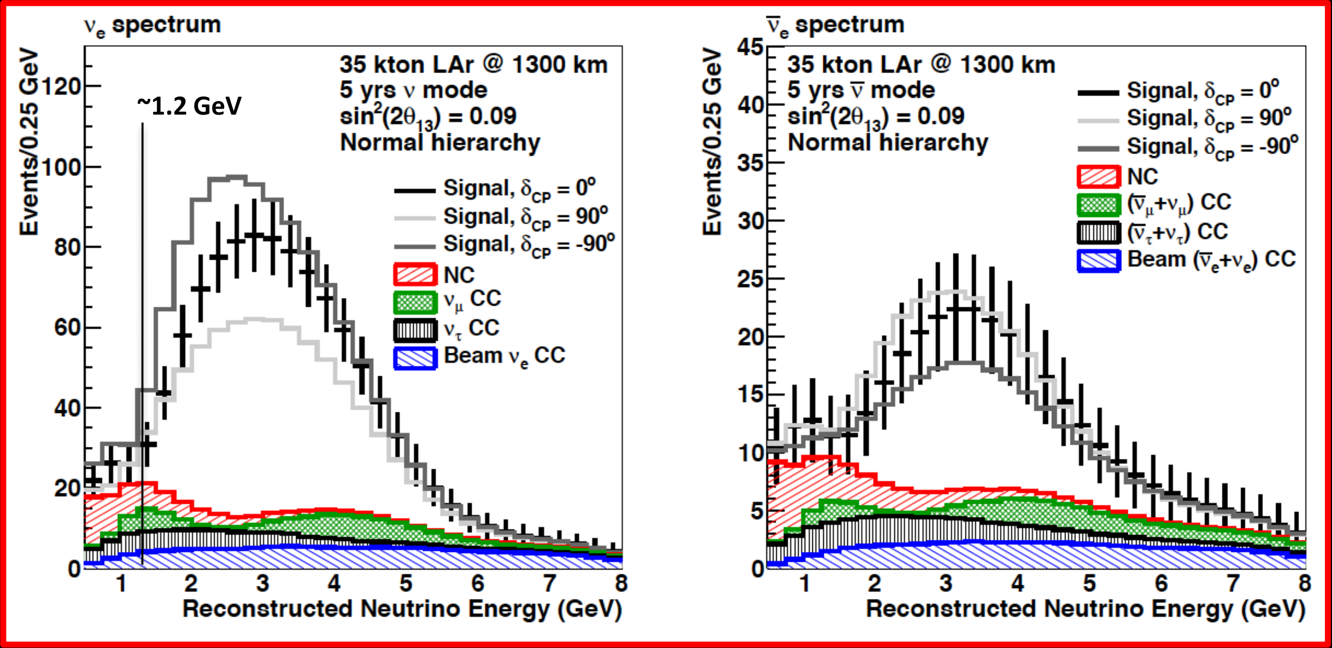
- **Near detector options:**
  - **HiResMnu**
  - **Lar TPC**



Long-Baseline Neutrino Experiment:

- **Source:**
  - FNAL MI: 700 kW
  - Project X: 2.3 MW [upgrade]
- **Detector: LAr TPC**
  - Fiducial mass: 10 kTonne
    - Upgrade to 34 kTonne
  - Site: SURF
    - On axis; upgrade u/g 4850 ft
    - Baseline 1300 km

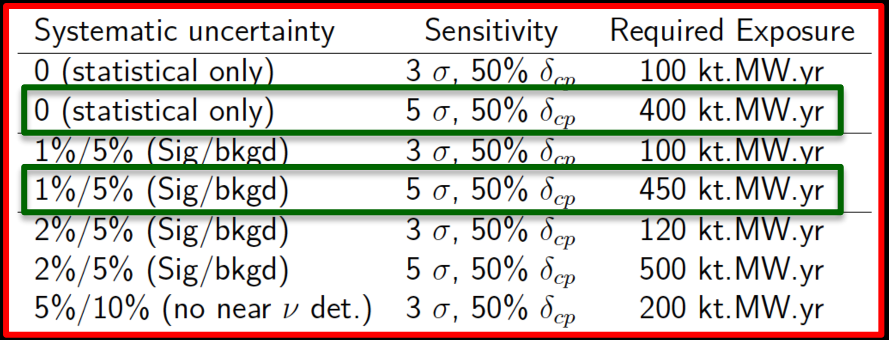




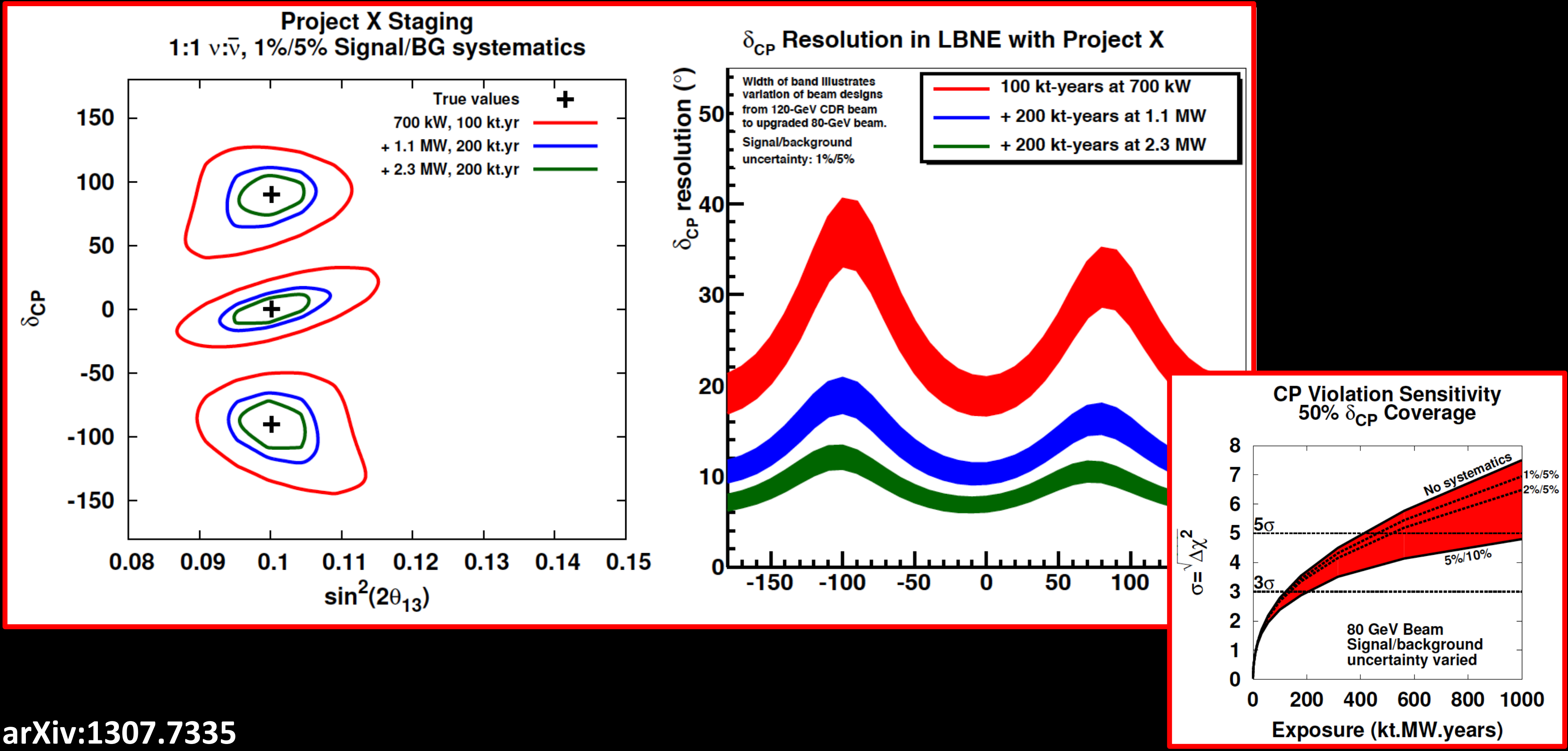
arXiv:1307.7335

Long-Baseline Neutrino Experiment:

- Systematic uncertainties:
  - – Signal: 1%
  - – Background: 5%



Systematic uncertainty	Sensitivity	Required Exposure
0 (statistical only)	3 σ, 50% δ_{cp}	100 kt.MW.yr
0 (statistical only)	5 σ, 50% δ_{cp}	400 kt.MW.yr
1%/5% (Sig/bkgd)	3 σ, 50% δ_{cp}	100 kt.MW.yr
1%/5% (Sig/bkgd)	5 σ, 50% δ_{cp}	450 kt.MW.yr
2%/5% (Sig/bkgd)	3 σ, 50% δ_{cp}	120 kt.MW.yr
2%/5% (Sig/bkgd)	5 σ, 50% δ_{cp}	500 kt.MW.yr
5%/10% (no near ν det.)	3 σ, 50% δ_{cp}	200 kt.MW.yr

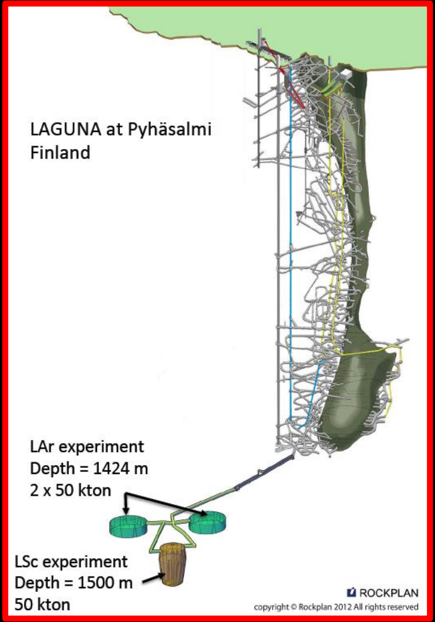


arXiv:1307.7335

CERN-SPSC-2012-021;
SPSC-EOI-007

Long-Baseline Neutrino Observatory:

- **Source:**
  - CERN SPS: 700 kW
  - PS 2: 2 MW [possible upgrade]
- **Detector: LAr TPC + MIND**
  - LAr fiducial mass: 20 kTonne
  - MIND fiducial mass: 25 kTonne
  - Site: Phyasalmi, Finland
    - On axis
    - Baseline 2300 km



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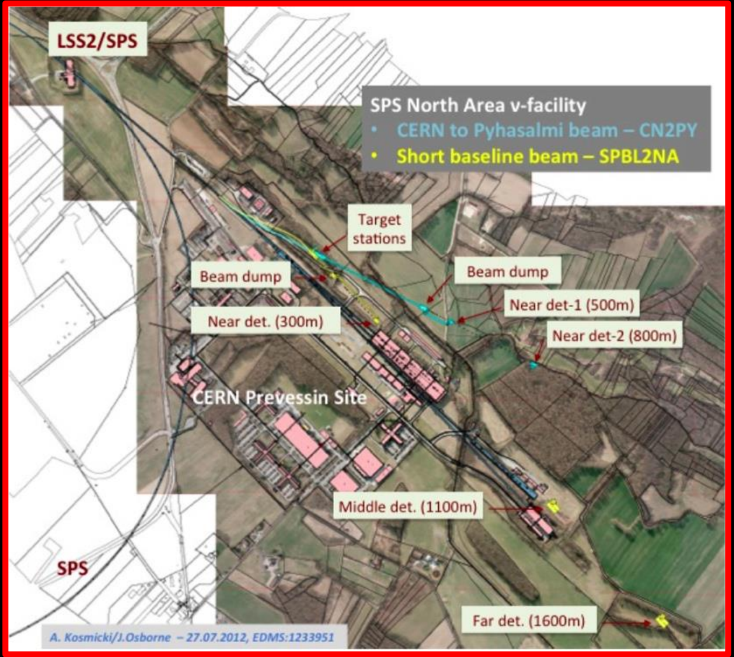
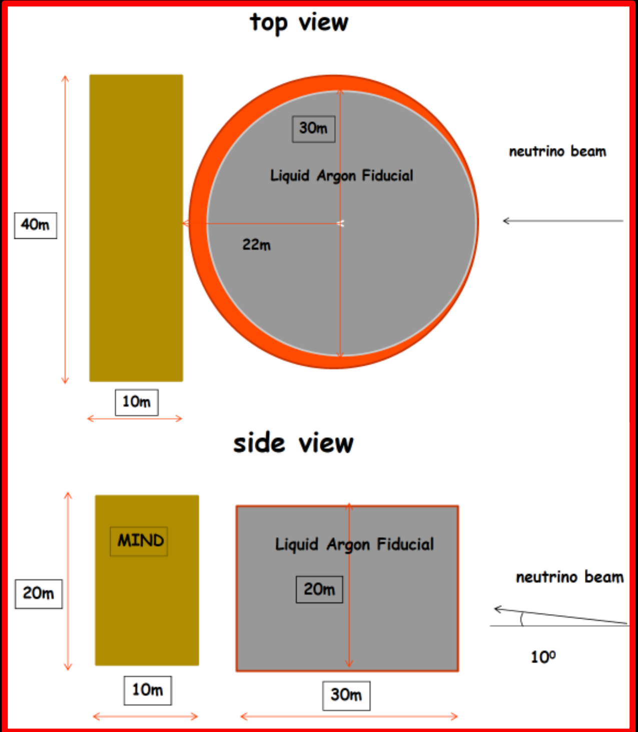
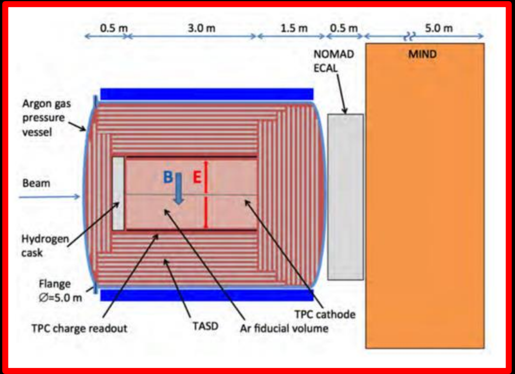


A. Kosmicki/J.Osborne – 27.07.2012, EDMS:1233951

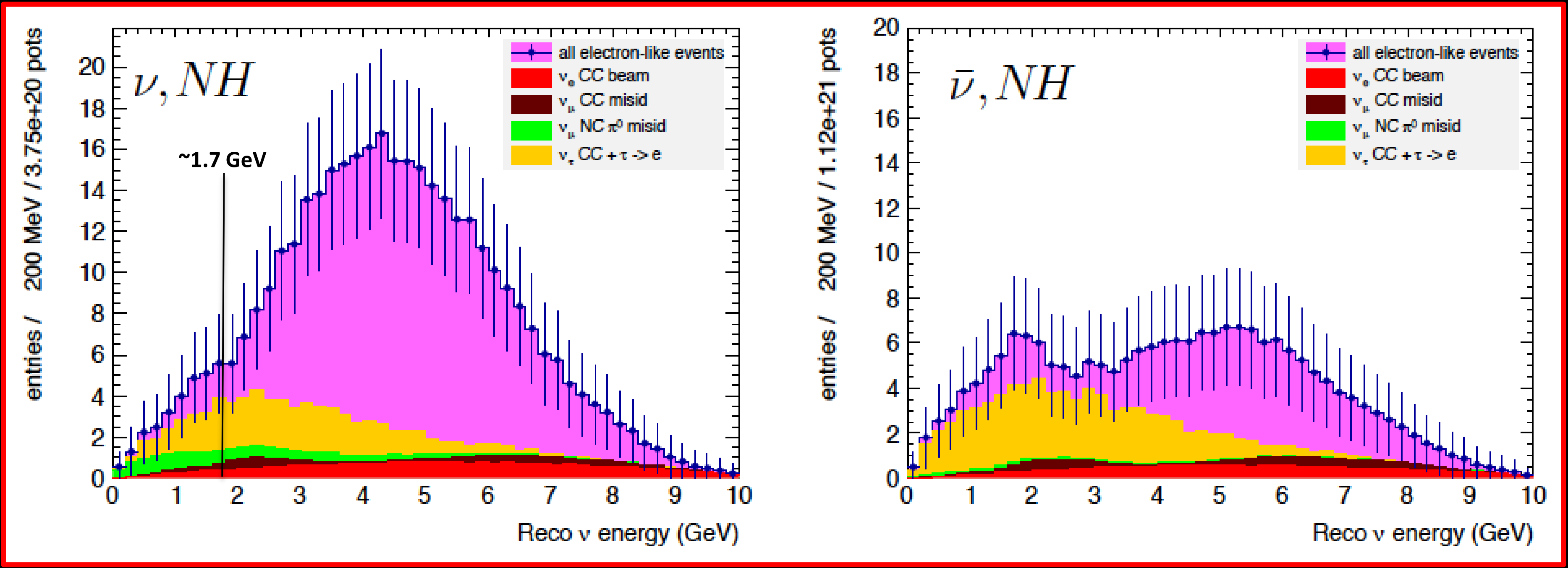


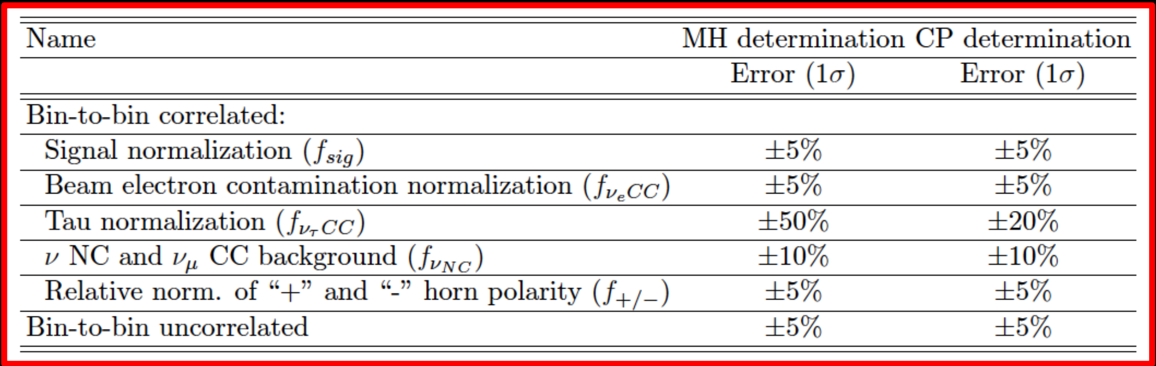
- **Suite of detectors:**
  - High-pressure Ar + MIND
  - L-scintillator



CERN-SPSC-2012-021;
SPSC-EOI-007

LBNO:





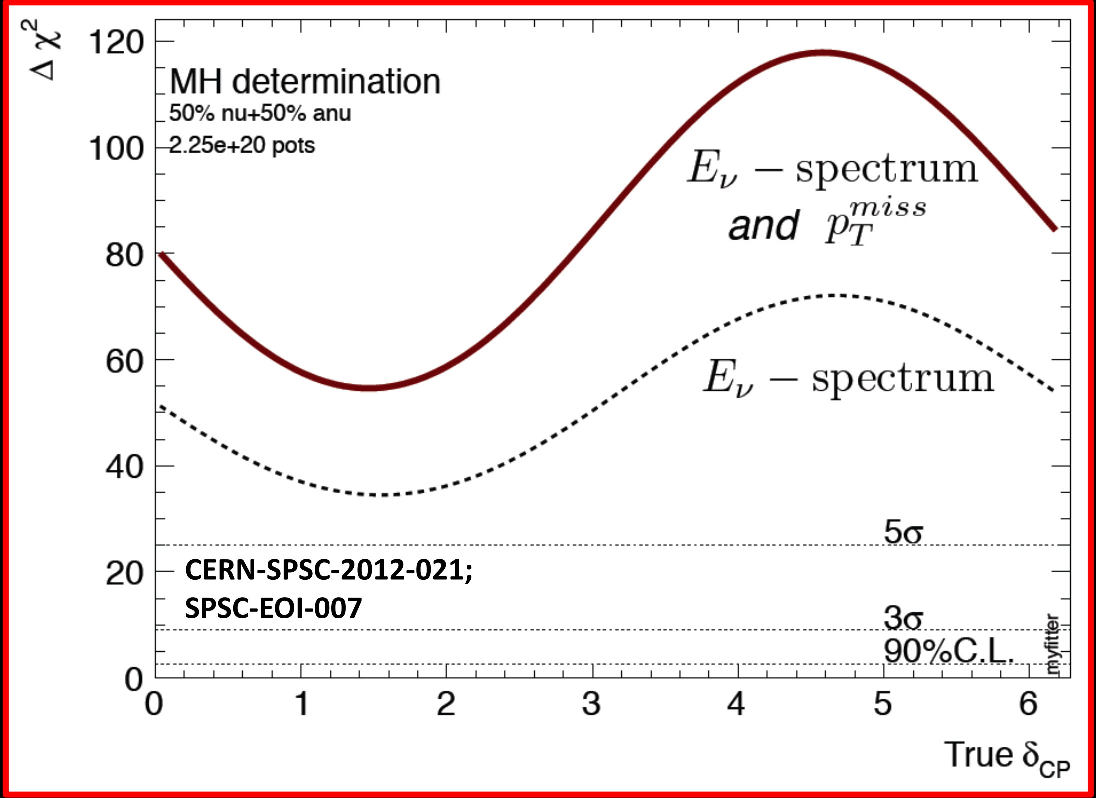
Name	MH determination Error (1σ)	CP determination Error (1σ)
Bin-to-bin correlated:		
Signal normalization (f_{sig})	±5%	±5%
Beam electron contamination normalization ($f_{\nu_e CC}$)	±5%	±5%
Tau normalization ($f_{\nu_\tau CC}$)	±50%	±20%
ν NC and ν_μ CC background ($f_{\nu NC}$)	±10%	±10%
Relative norm. of "+" and "-" horn polarity ($f_{+/-}$)	±5%	±5%
Bin-to-bin uncorrelated	±5%	±5%

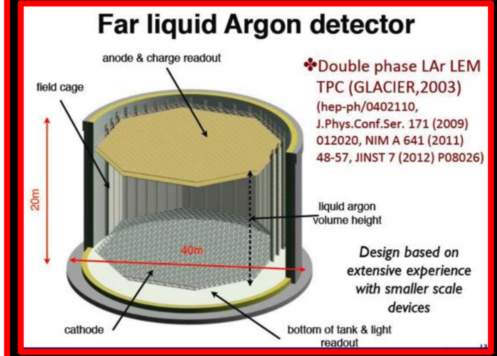
- **Limited sensitivity to second oscillation maximum**

- **Correlated and uncorrelated systematic uncertainties considered:**
  - **Signal: 5%**
  - **Background: 5% [but see table]**

LBNO:

CERN-SPSC-2012-021;
SPSC-EOI-007

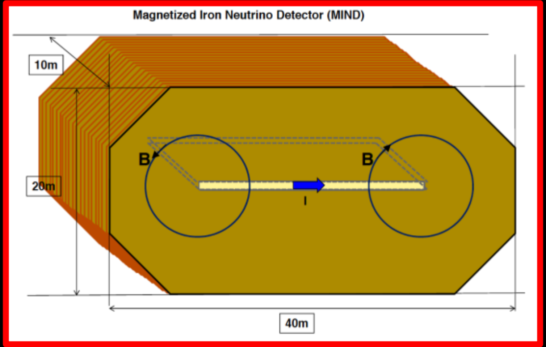




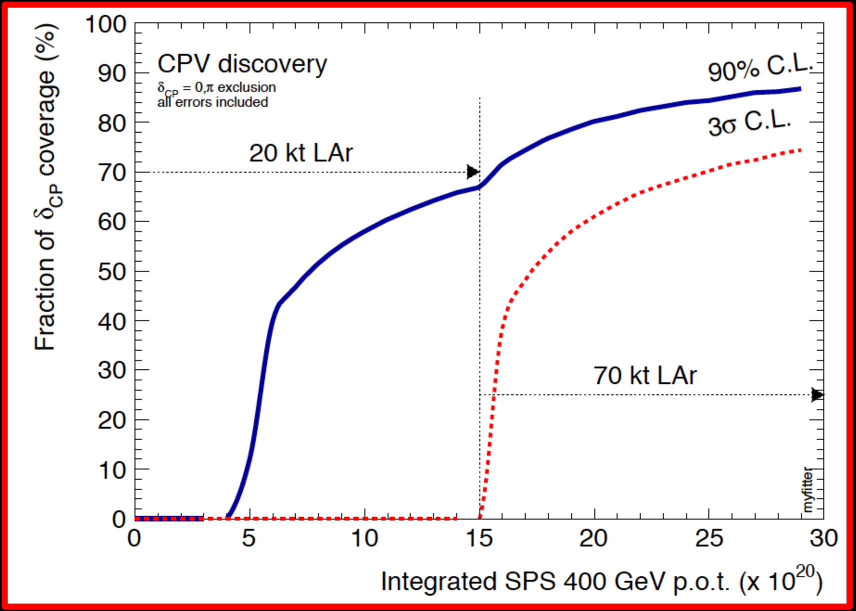
Far liquid Argon detector

✤Double phase LAr LEM TPC (GLACIER,2003) (hep-ph/0402110, J.Phys.Conf.Ser. 171 (2009) 012020, NIM A 641 (2011) 48-57, JINST 7 (2012) P08026)

Design based on extensive experience with smaller scale devices

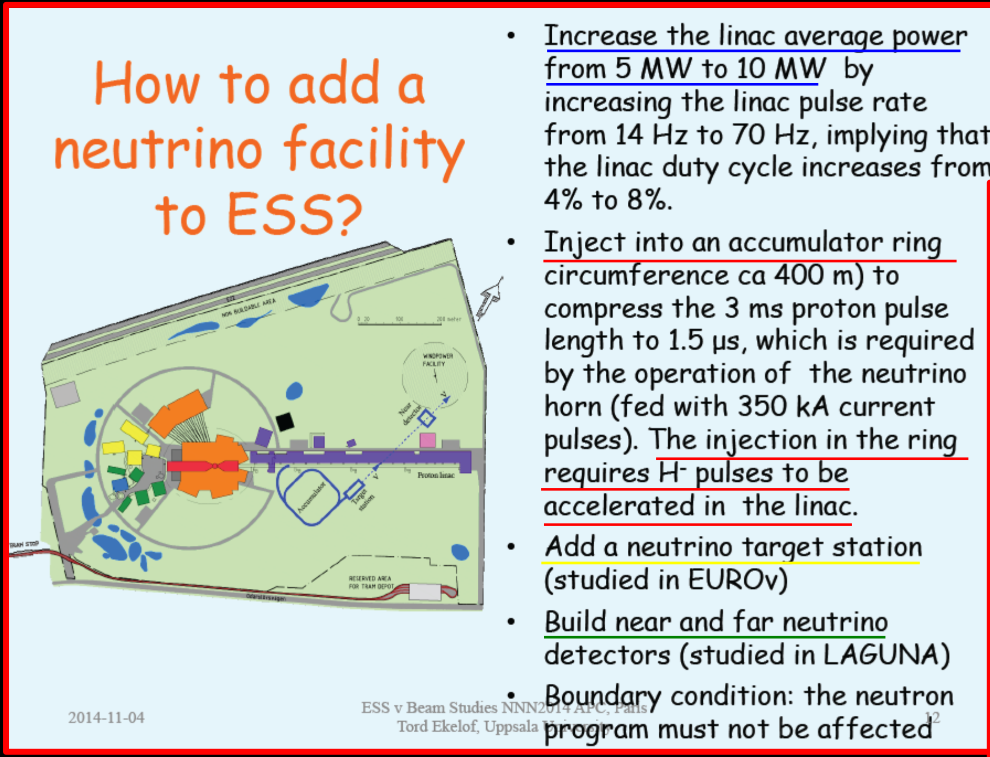


- **Benefit of long baseline clearly visible in excellent MH reach:**
  - **Study of matter effect in neutrino propagation**
- **CPiV reach competitive with LBNE**



ESSnuSB:

- **Exploit second oscillation maximum:**
  - Large CPiV effect;
  - Requires very high power and large detector mass
- **ESS:**
  - Double power (to 10MW) by adding H- acceleration and compressor/accumulator rings;
- **“MEMPHYS”:**
  - Can be hosted in one of the Nordic countries:
    - Various sites considered



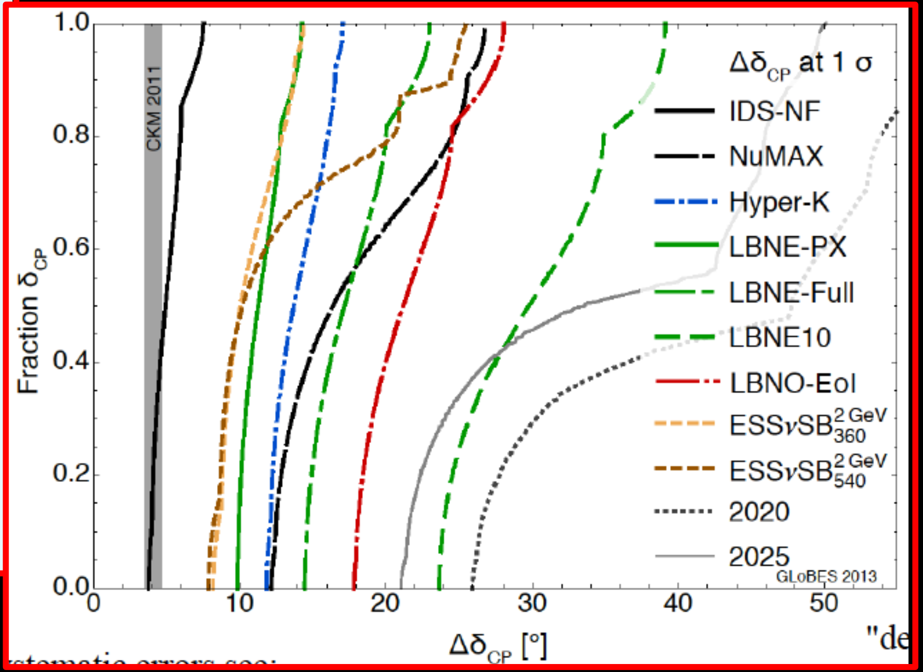
How to add a neutrino facility to ESS?

- Increase the linac average power from 5 MW to 10 MW by increasing the linac pulse rate from 14 Hz to 70 Hz, implying that the linac duty cycle increases from 4% to 8%.
- Inject into an accumulator ring circumference ca 400 m) to compress the 3 ms proton pulse length to 1.5 μs, which is required by the operation of the neutrino horn (fed with 350 kA current pulses). The injection in the ring requires H- pulses to be accelerated in the linac.
- Add a neutrino target station (studied in EUROν)
- Build near and far neutrino detectors (studied in LAGUNA)
- Boundary condition: the neutron program must not be affected

2014-11-04

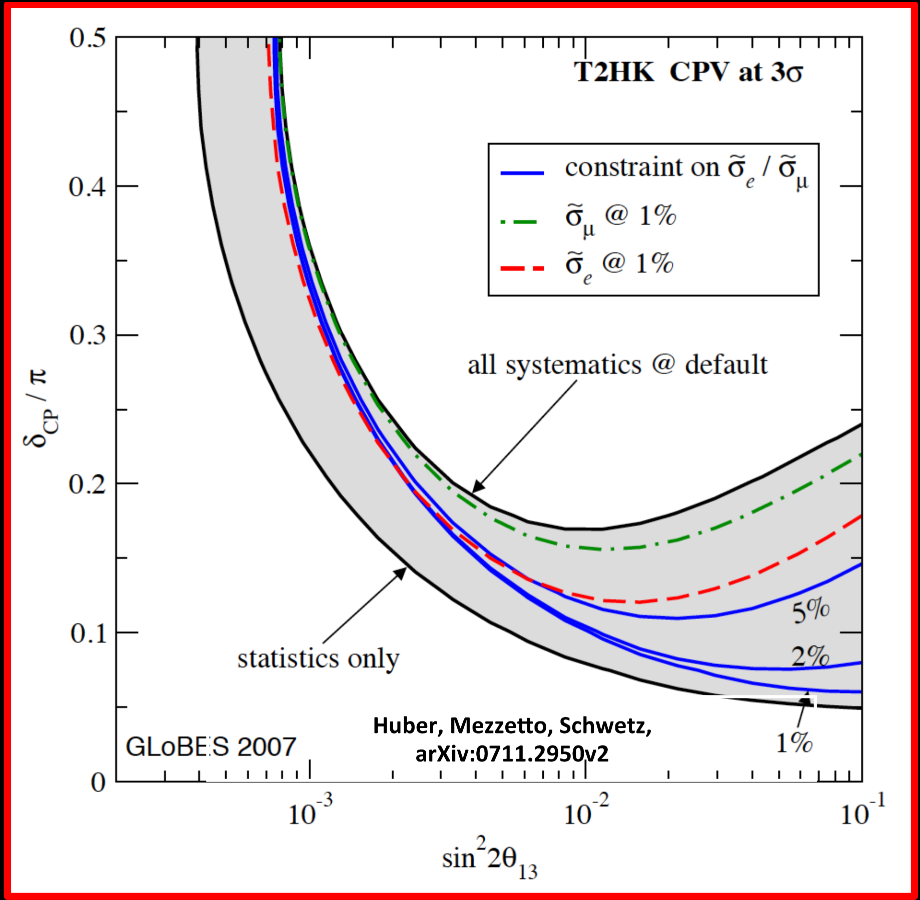
ESS ν Beam Studies NNN2014 APC, Paris
Tord Ekelof, Uppsala University

12

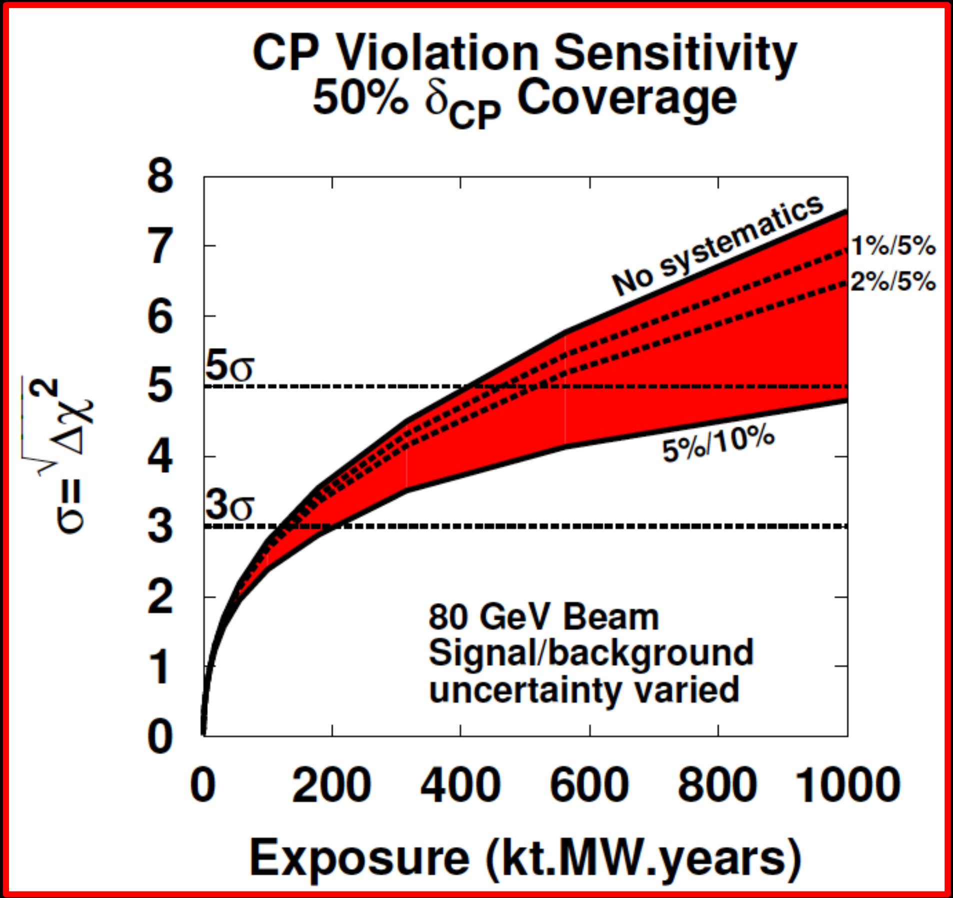


Neutrinos from stored muon beams

Effect of systematics:



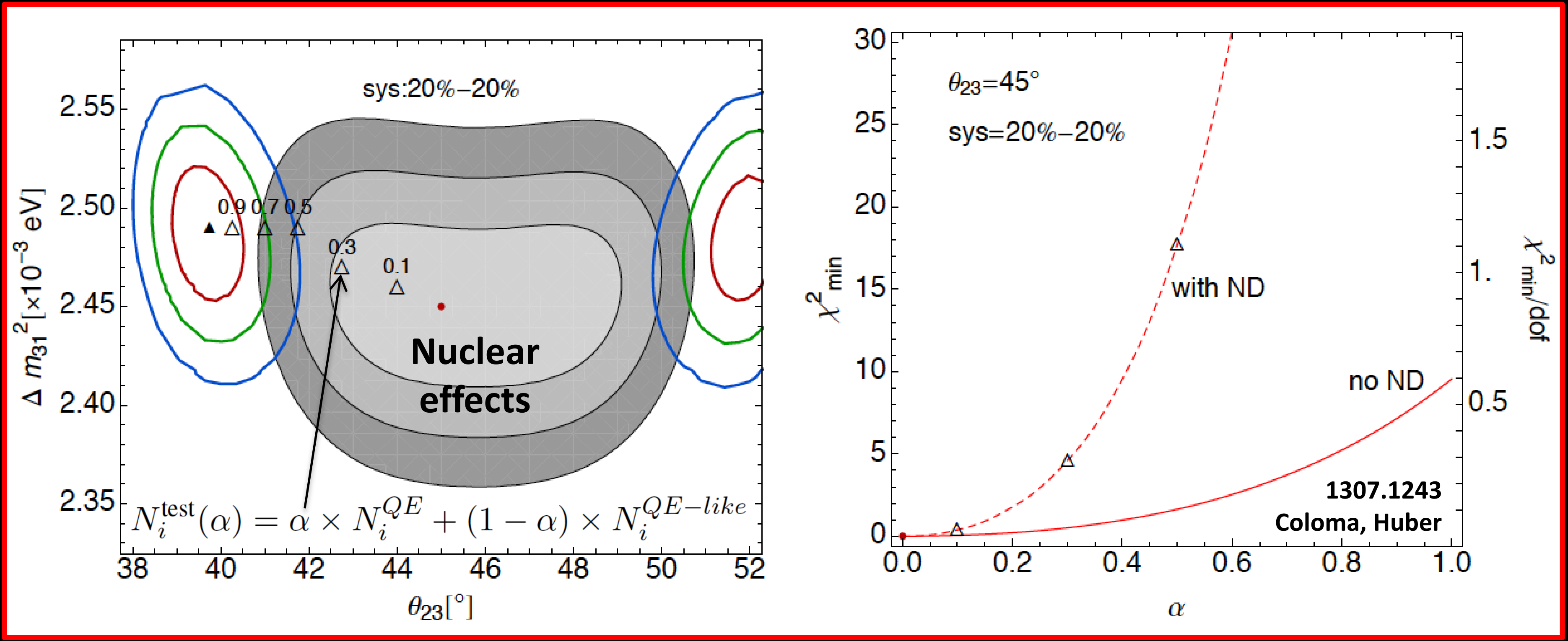
Huber, Mezzetto, Schwetz, arXiv:0711.2950v2



- Performance rapidly degrades if systematic error is not controlled at the several % level
  - Cross section error makes a critical contribution

Limiting systematics in the LBL programme:

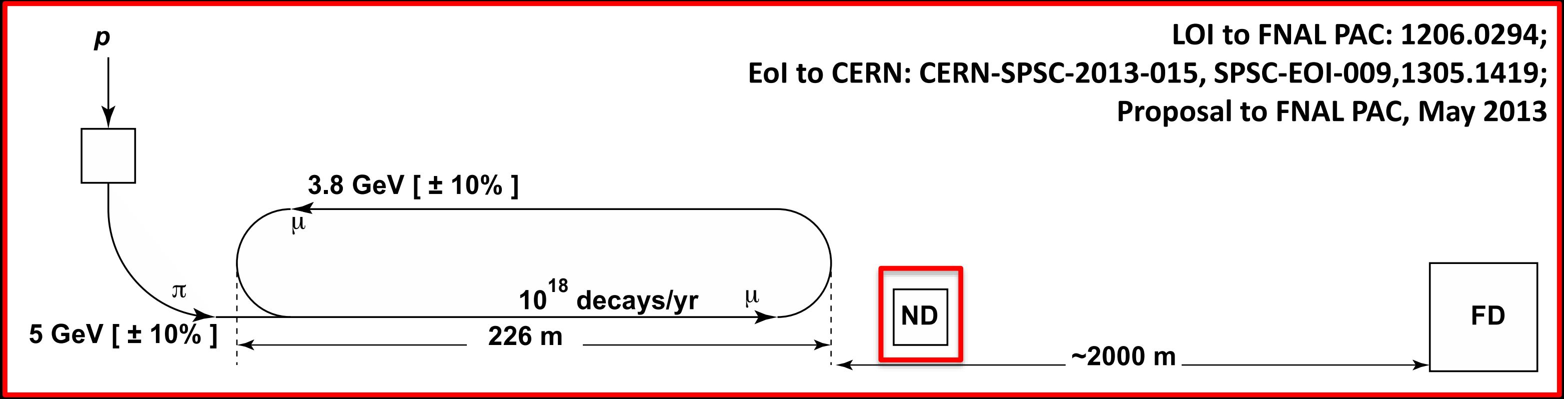
- Bias as well as uncertainty



Nuclear effects

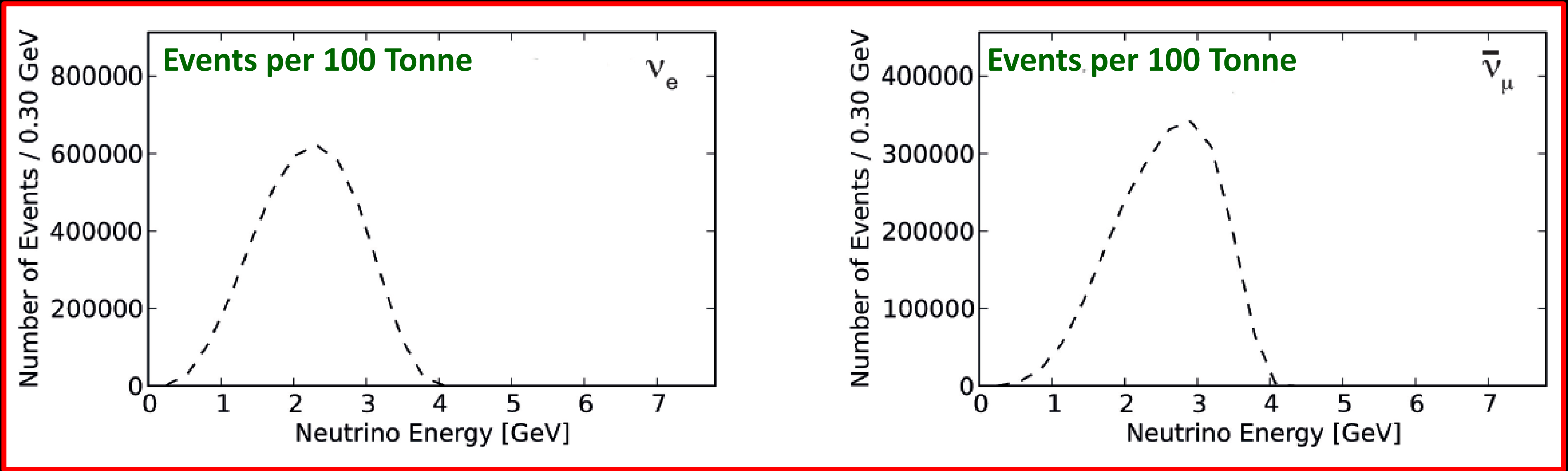
1307.1243
Coloma, Huber

nuSTORM and cross section measurement:



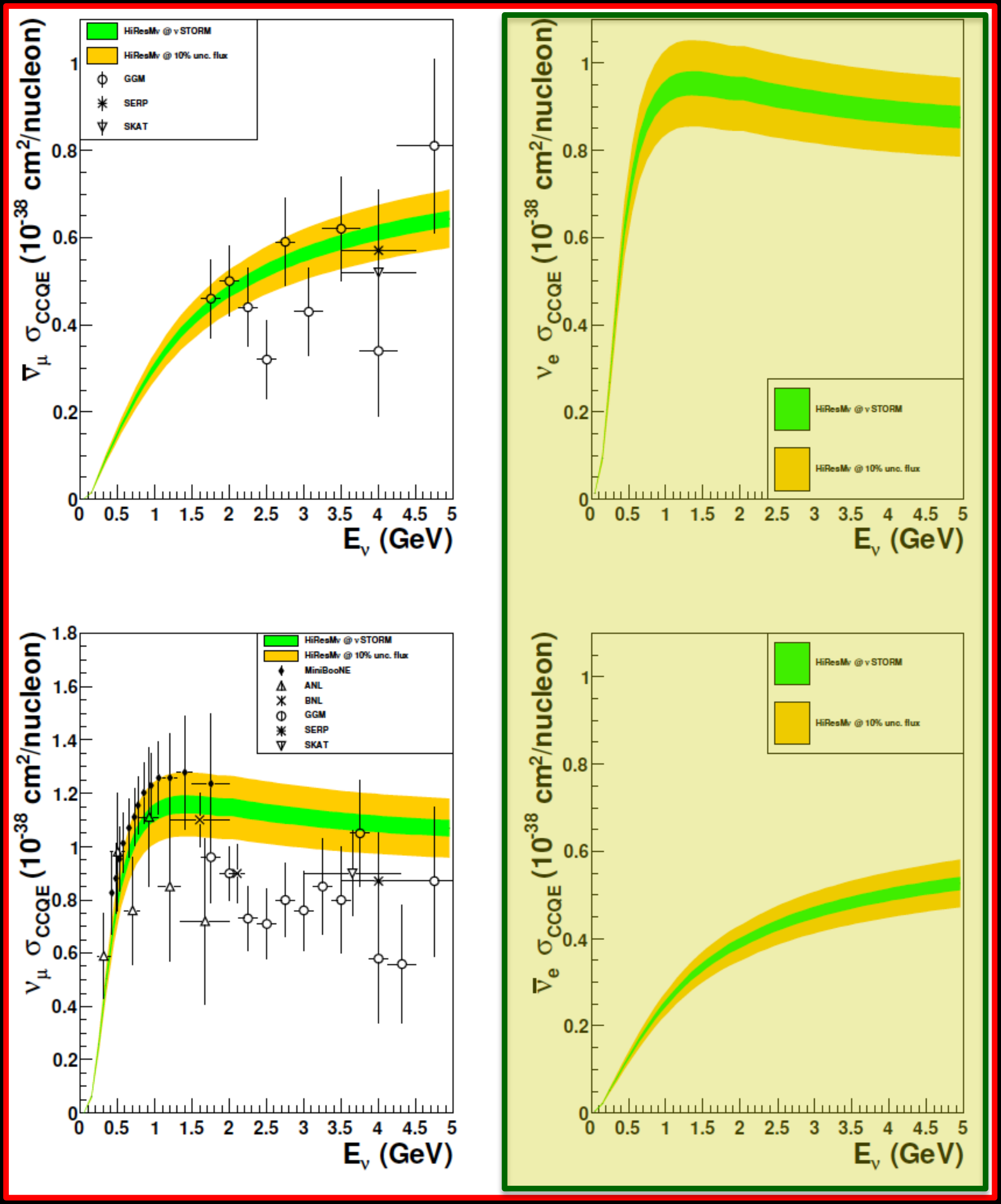
LOI to FNAL PAC: 1206.0294;
EoI to CERN: CERN-SPSC-2013-015, SPSC-EOI-009,1305.1419;
Proposal to FNAL PAC, May 2013

- **nuSTORM event rate is large:**
  - **Statistical precision high:**
    - **Can measure double-differential cross sections**



CCQE cross section measurement:

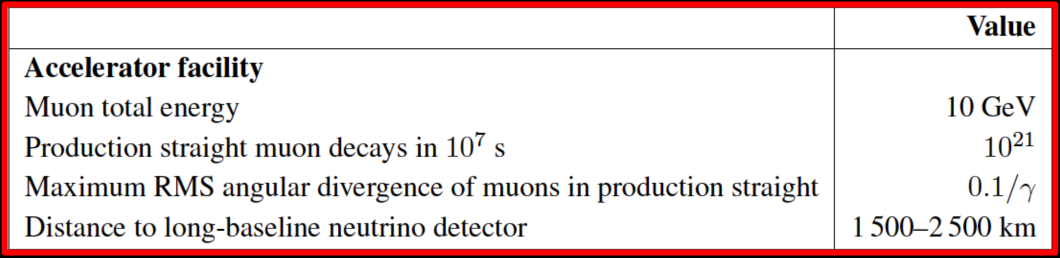
- Systematic uncertainties for CCQE measurement at nuSTORM:
  - Six-fold improvement in systematic uncertainty compared with “state of the art”
  - Electron-neutrino cross section measurement unique



arXiv:1112.2853; 1308.0494v1

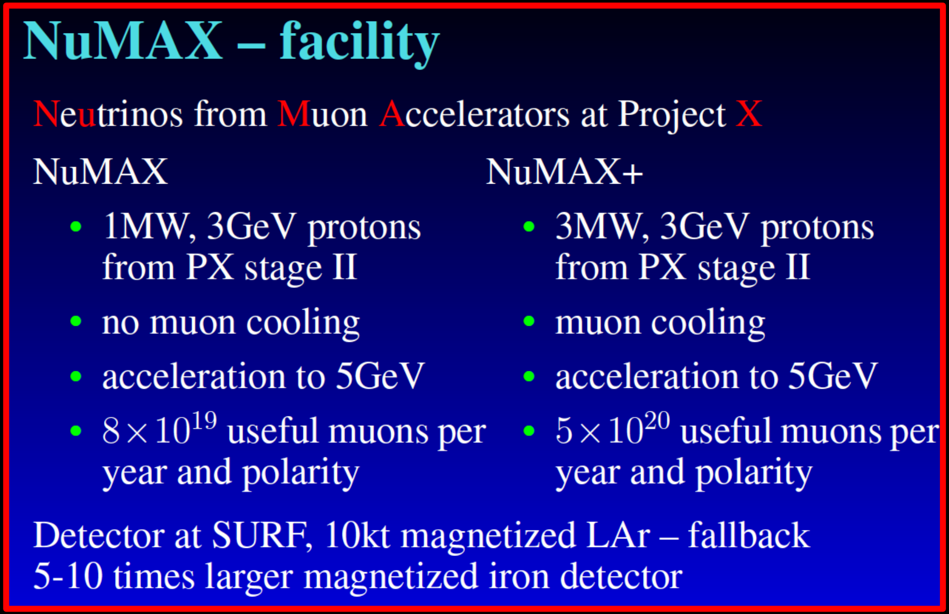
Neutrino Factory:

- Two approaches:
  - Optimise *L* and *E* to match detector threshold
    - IDS-NF approach:



	Value
Accelerator facility	
Muon total energy	10 GeV
Production straight muon decays in 10^7 s	10^{21}
Maximum RMS angular divergence of muons in production straight	$0.1/\gamma$
Distance to long-baseline neutrino detector	1 500–2 500 km

  - Exploit LAr detector sited 1300 km from FNAL
    - MAP/MASS approach:

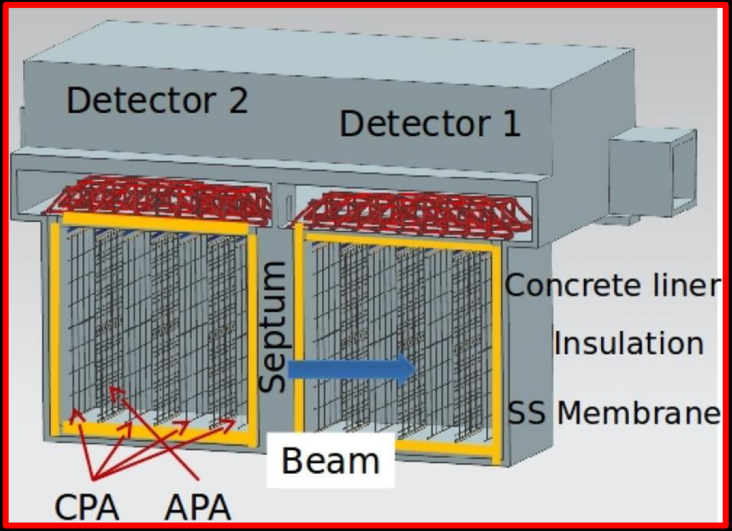


NuMAX – facility

Neutrinos from Muon Accelerators at Project X

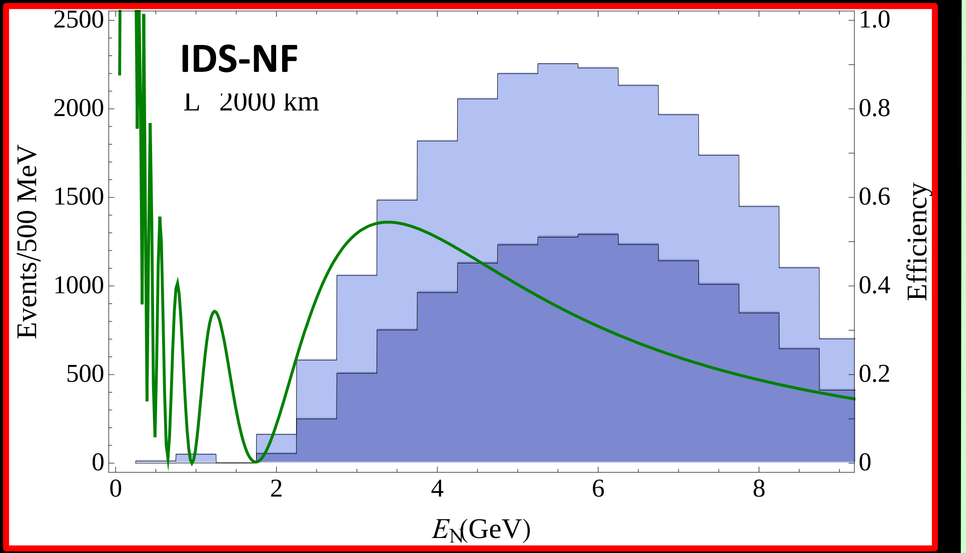
NuMAX	NuMAX+
1MW, 3GeV protons from PX stage II	3MW, 3GeV protons from PX stage II
no muon cooling	muon cooling
acceleration to 5GeV	acceleration to 5GeV
8×10^{19} useful muons per year and polarity	5×10^{20} useful muons per year and polarity

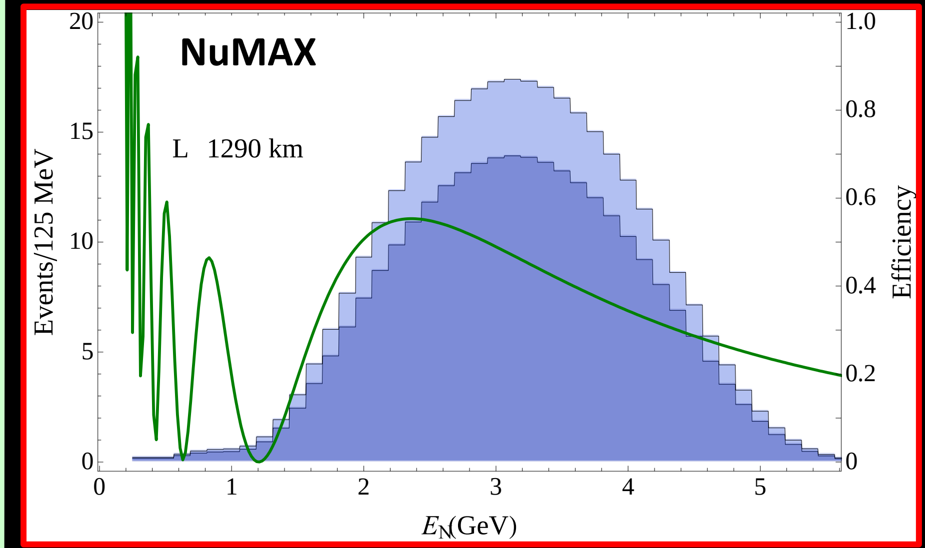
Detector at SURF, 10kt magnetized LAr – fallback
5-10 times larger magnetized iron detector

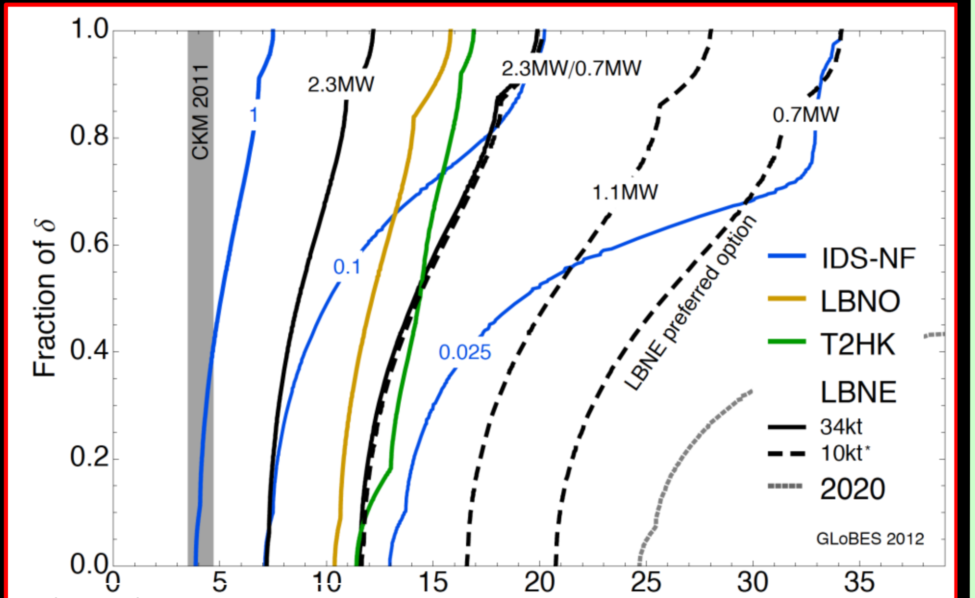


Bayes, Coloma

Neutrino Factory:

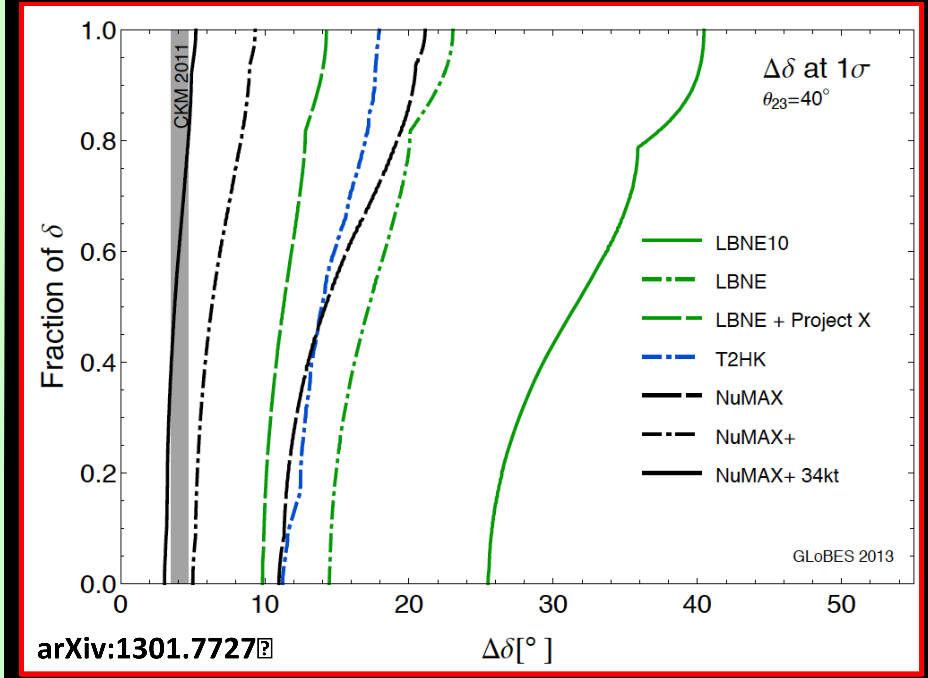






Coloma, Huber, Kopp, Winter
arXiv:1209.5973

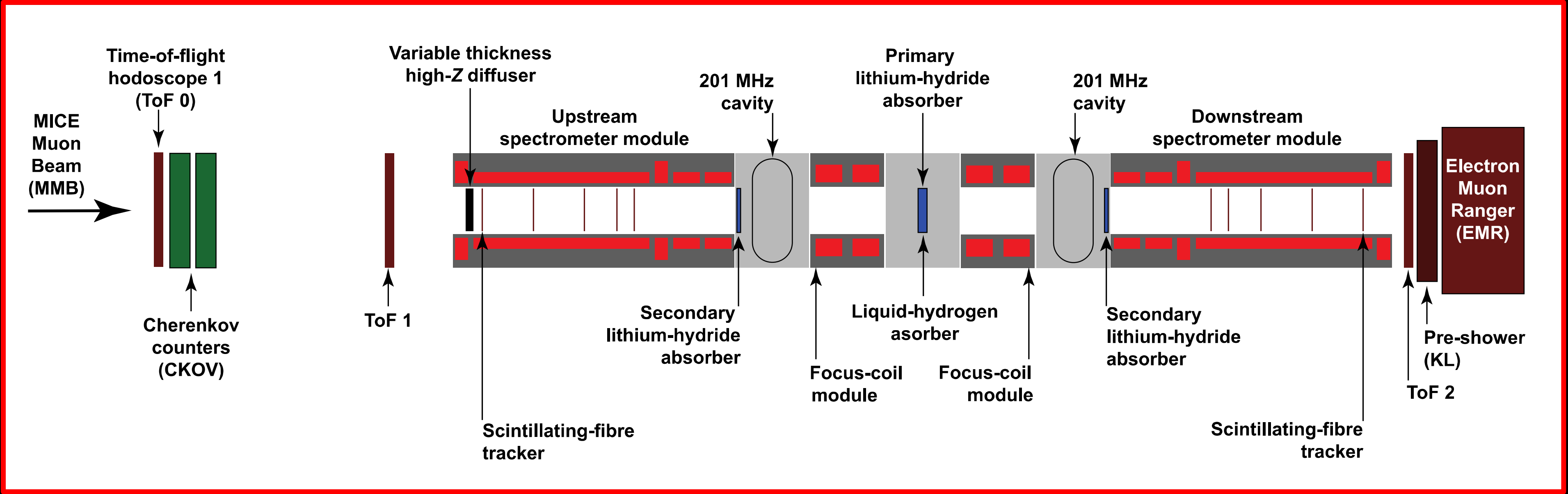
* Assumes surface operation to be equivalent to deep underground operation for beam physics



arXiv:1301.7727

MICE:

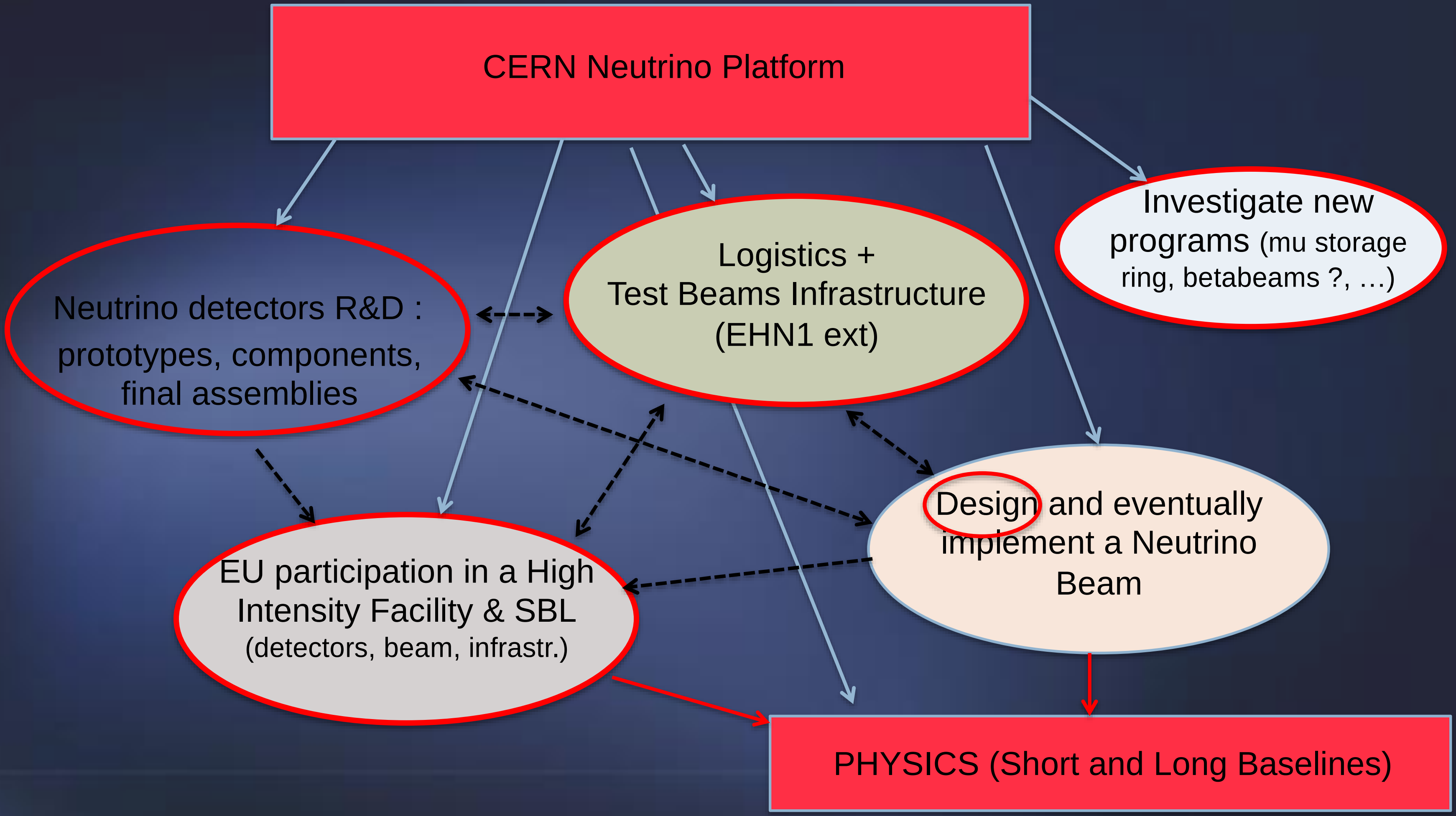
- Study of material, lattice, momentum and emittance (Step IV) will start Q2 2015;
- Ionization cooling demonstration:
  - Revised configuration developed in response to P5 recommendations;
  - Cooling demonstration configuration complete: summer 2017
    - All components fabricated
- Essential technology demonstration imminent



Future neutrino beams:

CERN Neutrino Platform

CERN Neutrino Platform



CERN Neutrino Platform

Neutrino detectors R&D : prototypes, components, final assemblies

Logistics + Test Beams Infrastructure (EHN1 ext)

Investigate new programs (mu storage ring, betabeams ?, …)

EU participation in a High Intensity Facility & SBL (detectors, beam, infrastr.)

Design and eventually implement a Neutrino Beam

PHYSICS (Short and Long Baselines)

WA104 : ICARUS detector overhauling

ICARUS Collaboration with INFN and CERN help

- *Move the detector from the GS Laboratory to CERN (2014)*
- *Prepare at CERN all the necessary infrastructure (clean rooms, cryogenics, …)*
- *Reshape the detector with new components*
- *Construct a new generation of cryostats*
- *Reshape, maintain and modernize the cryo plant*
- *Reassemble the 2 T300 detectors inside their cryostats*
- *Construct a new outer vessel*
- *Make it ready for shipment to FNAL*

WA105 : LAGUNA detector Demonstrator

LAGUNA Collaboration with CERN help

- *Prepare at CERN all the necessary infrastructure (clean rooms, cryogenics, …)*
- *Construct a new generation of cryostats based on membrane technology*
- *Provide all the necessary cryogenics*
- *Construct and test 2 prototypes of a 2-phases LAr TPC*
  - *3 x1 x 1 m^3*
  - *6 x 6 x 6 m^3*
- *Charged beam tests at the SPS with full readout capabilities*

WA104 : Magnetized Muon Spectrometer

NESSiE Collaboration with CERN help

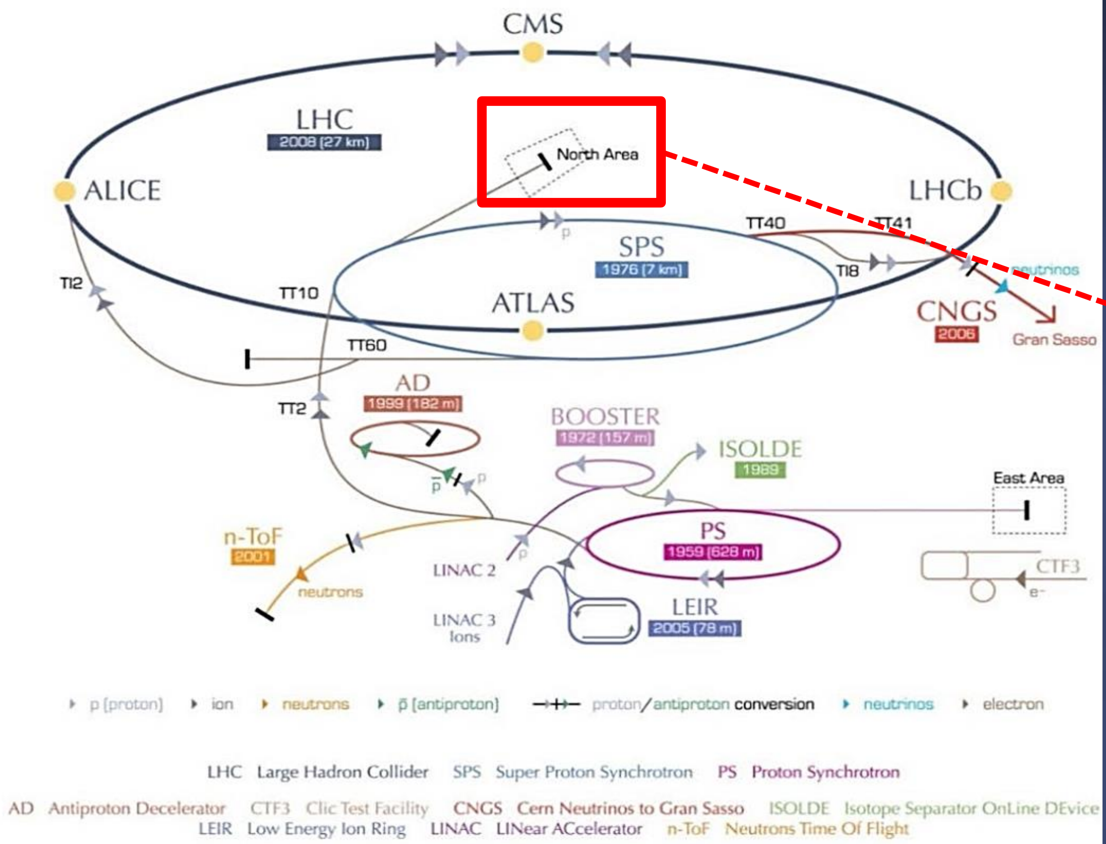
- *Prepare at CERN all the necessary infrastructure (space, logistics)*
- *R&D on a warm air core magnet*
- *R&D on a cold air core magnet*
- *Construct and test prototypes of a possible muon spectrometer*
- *Charged beam tests at the SPS with full readout capabilities*

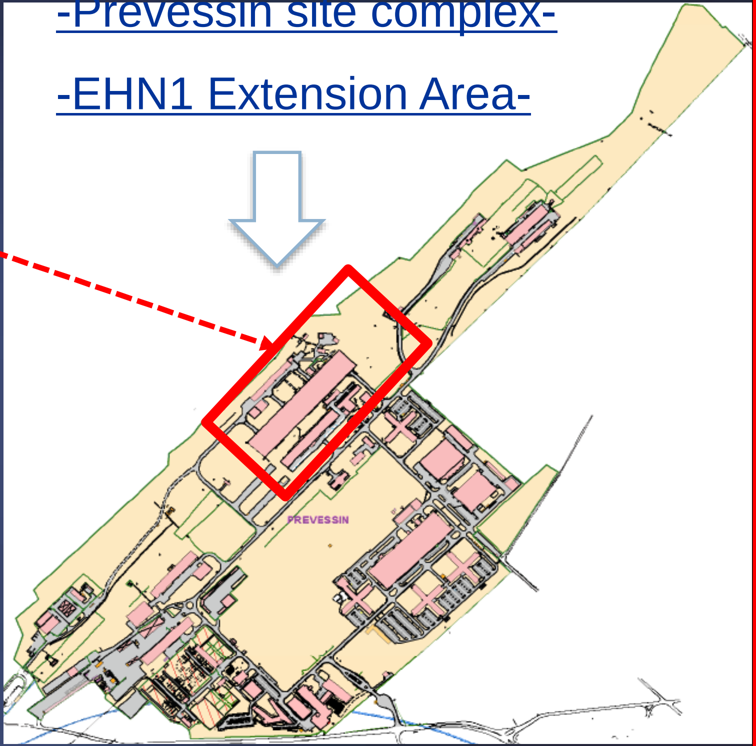
LBNF : Test of a large TPC module

LBNF Collaboration with CERN help

- *Prepare at CERN all the necessary infrastructure (space, logistics)*
- *Prepare a large cryostat for receiving this detector (new cap)*
- *Bring to CERN components assembled in the UK and USA*
- *Prepare/adapt the necessary cryogenics*
- *Charged beam tests at the SPS with full readout capabilities*

CENF – Civil Engineering Extension B887





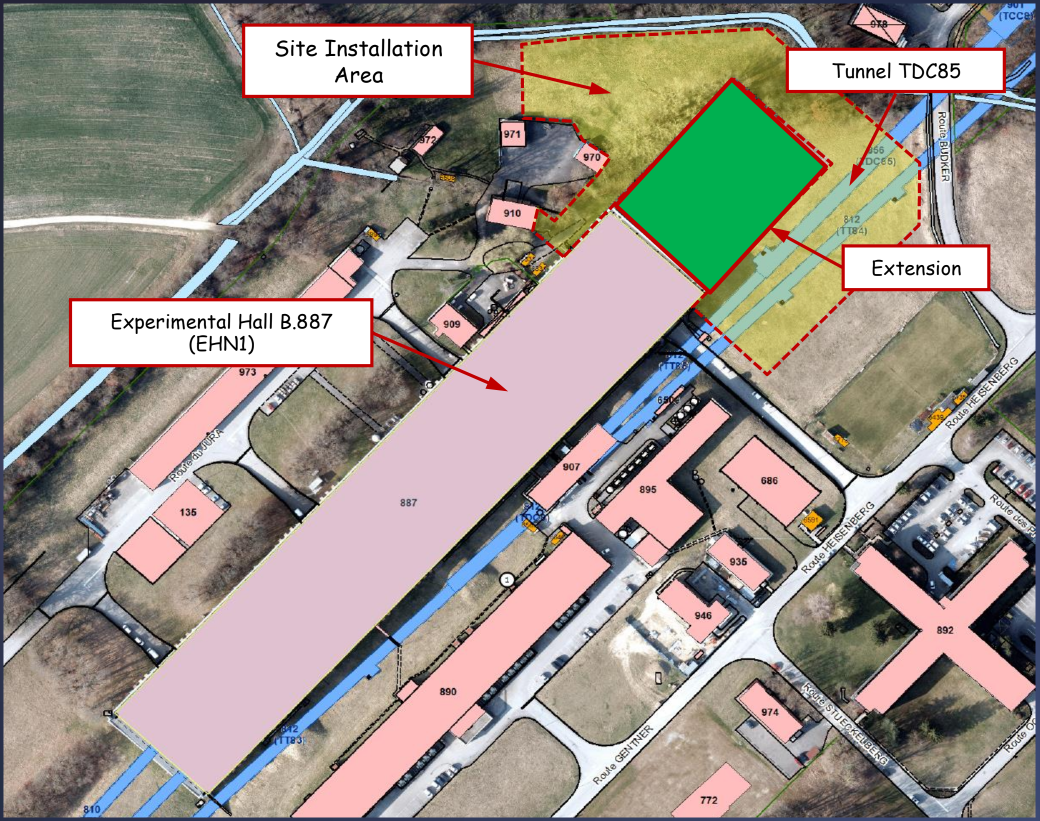
-Prevessin site complex-

-EHN1 Extension Area-

CERN Prototype Meeting – M.Nessi
N.Lopez, M.Manfredi (GS-SE)

CENF – Civil Engineering Extension B887

Technical Aspect: Location



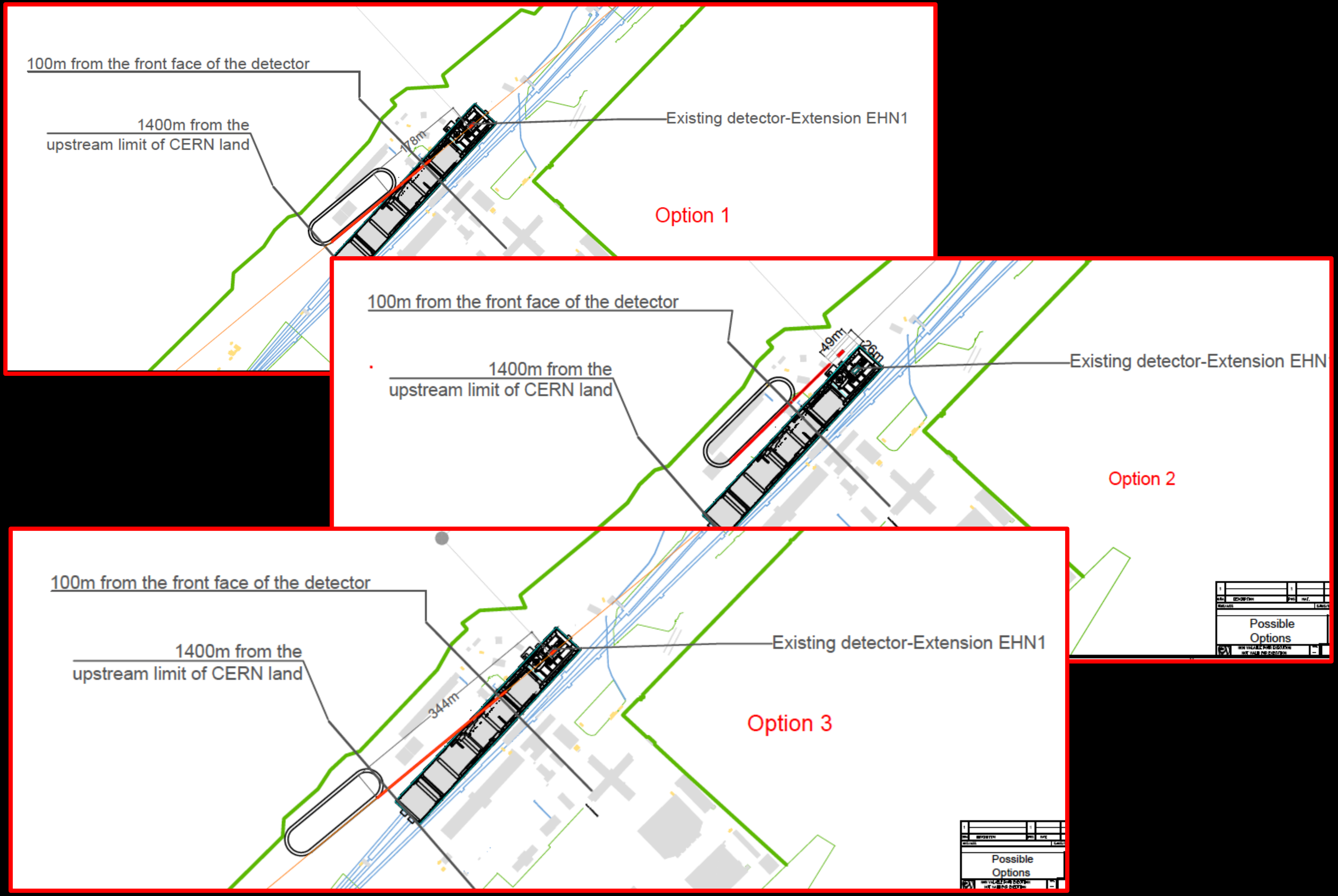
The EHN1 is a large industrial building situated on french territory, in Prévessin. The building has to be extended for the new generation of experiments on the neutrinos.

The Extension will extend northwards from the building for about 70 m in the direction of the beams.

Neutrino extension

nuSTORM serving the CERN Neutrino Platform

under study; M. Nessi et al



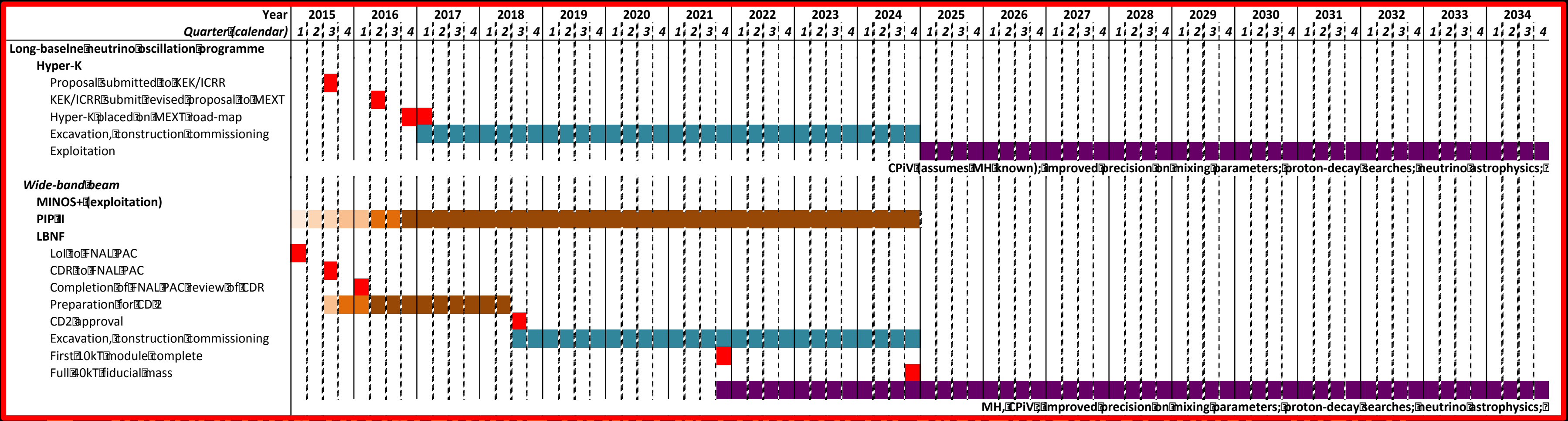
Future neutrino experiments:

Epilogue and conclusions

Epilogue:

- Long-baseline neutrino-oscillation programme:
  - Narrow-band and wide-band projects complementary:
    - Neutrino oscillations, proton-decay, neutrino astrophysics and cosmology, super-novae
- Following P5 in the US:
  - FNAL has established LBNF:
    - interim International Executive Board:
      - Deliver LOI; help establish collaboration;
    - LBNF international governance group:
      - Build on "CERN/LHC model" to see how best to organise LBNF as an international programme
- Possible evolution of the projects:

PI meetings:
CERN 05Dec14
FNAL 12Dec14



  - Supporting programme (R&D & control of systematics) must "match"

Conclusions:

- Combination of accelerator&non-accelerator-based programmes can:
  - Confirm or refute the existence of sterile neutrinos;
  - Determine the mass hierarchy; and
  - Make a first sweep of the CP parameter space

- Next generation of LBL experiments have the potential to:
  - To complete the Standard Neutrino Model (SνM)

- To establish the SνM as the correct description of nature requires:
  - Development of a capability to produce large, high-energy data sets; and
  - To control systematic uncertainties
    - This requires a dedicated programme

- An incremental programme can be (has been) articulated:
  - Scientific imperative: develop three-pronged programme:
    - Deliver critical oscillation measurements through super-beam programme;
    - Establish systematic-uncertainty control programme
      - Including measurement of $\nu_e N$ cross sections at nuSTORM
    - Develop capability required to implement the Neutrino Factory
      - Including MICE, the critical system demonstration for ionization cooling

- Realisation of fantastic programme requires international coordination