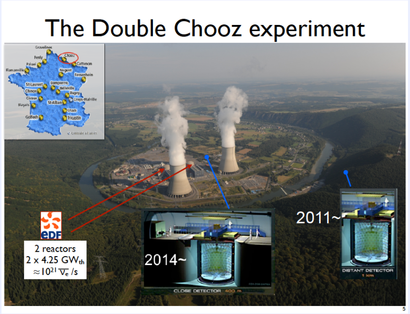
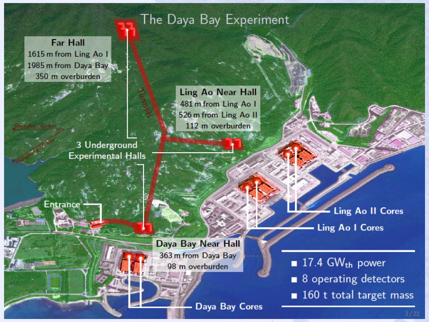
WG1 Summary

Many thanks to WG1 speakers and contributors.

Alexandre Sousa (University of Cincinati)
Enrique Fernandez-Martinez(Universidad Autónoma de Madrid/CSIC)
Takeshi Nakadaira(KEK)



News

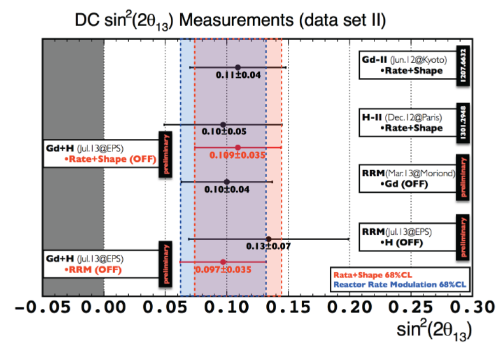


- Updated Reactor results:
  - Double Chooz

- All analyses showed consistent θ_{13}
  - Rate+Shape (combined): $\sin^2 2\theta_{13} = 0.109 \pm 0.035$
  - RRM (combined): $\sin^2 2\theta_{13} = 0.097 \pm 0.035$

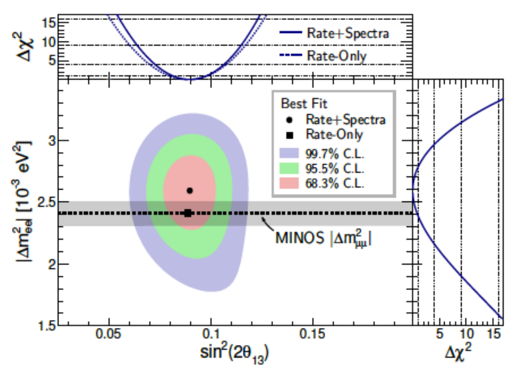
Ralitsa Sharankova

Summary of Double Chooz results



  - Daya Bay

Rate+Spectra Oscillation Results



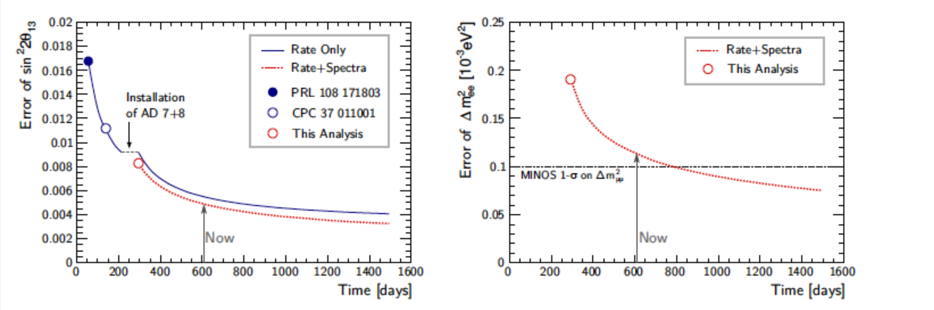
$$\sin^2 2\theta_{13} = 0.090^{+0.008}_{-0.009}$$

$$|\Delta m^2_{ee}| = 2.59^{+0.19}_{-0.20} \cdot 10^{-3}\mathrm{eV}^2$$

$$\chi^2/N_{\mathrm{DoF}} = 162.7/153$$

Soeren Jetter

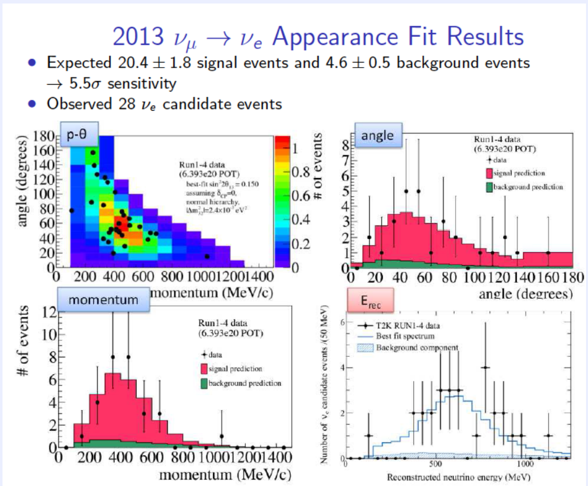
Sensitivity Projection

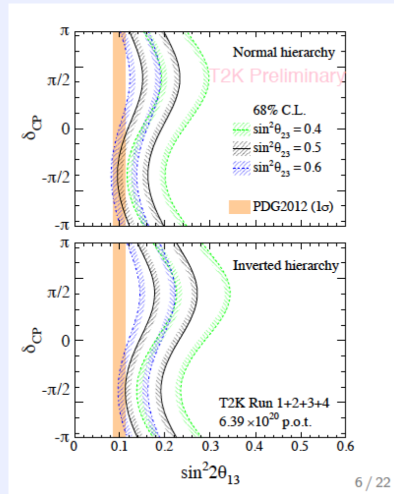


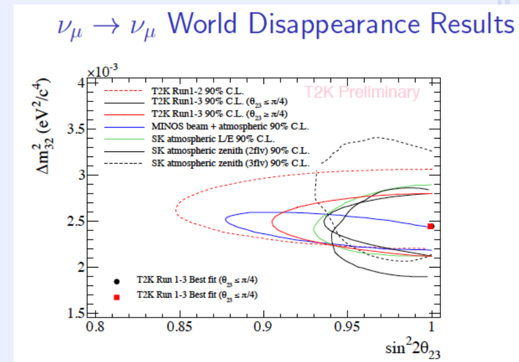
Sensitivity still dominated by statistics

Latest knowledge by LBL

- T2K observe ν_e appearance.

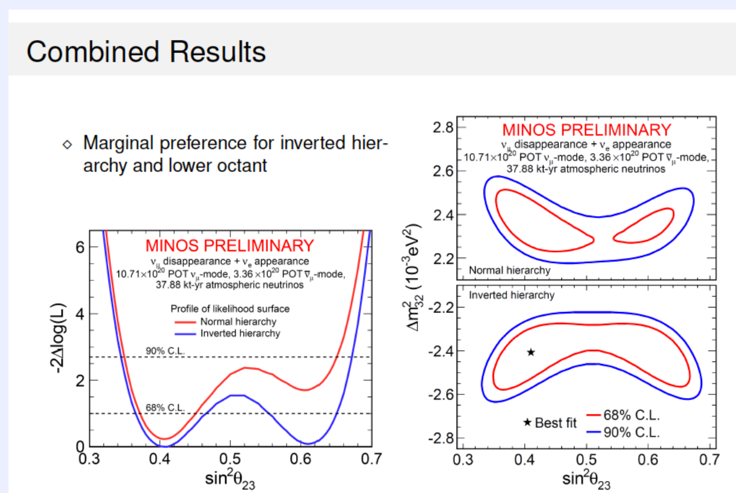






Megan Friend

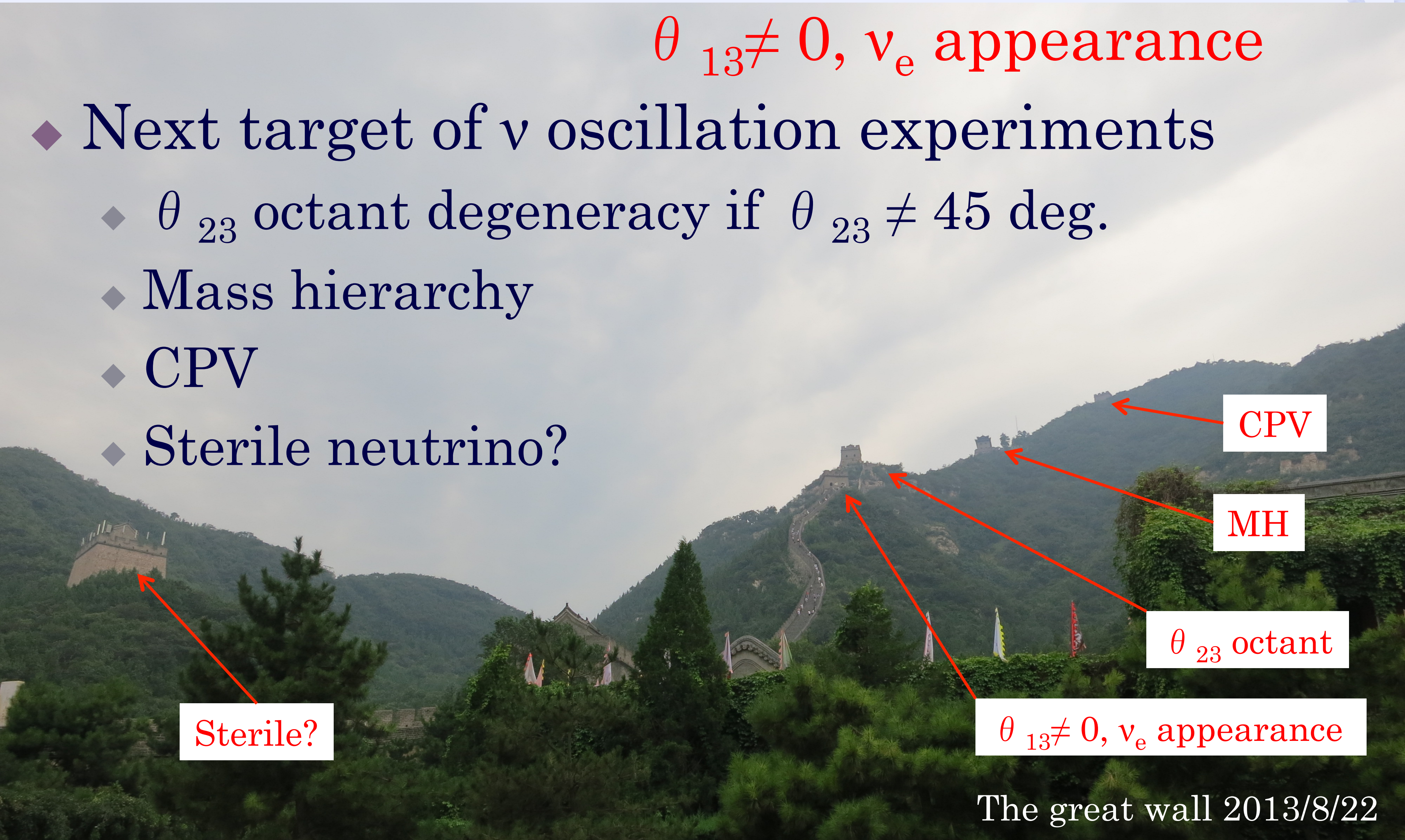
- MINOS latest results



Joao Coelho

What's next?

- Neutrino exp. reaches big milestone:
  $\theta_{13} \neq 0$, ν_e appearance
- Next target of ν oscillation experiments
  - θ_{23} octant degeneracy if $\theta_{23} \neq 45$ deg.
  - Mass hierarchy
  - CPV
  - Sterile neutrino?



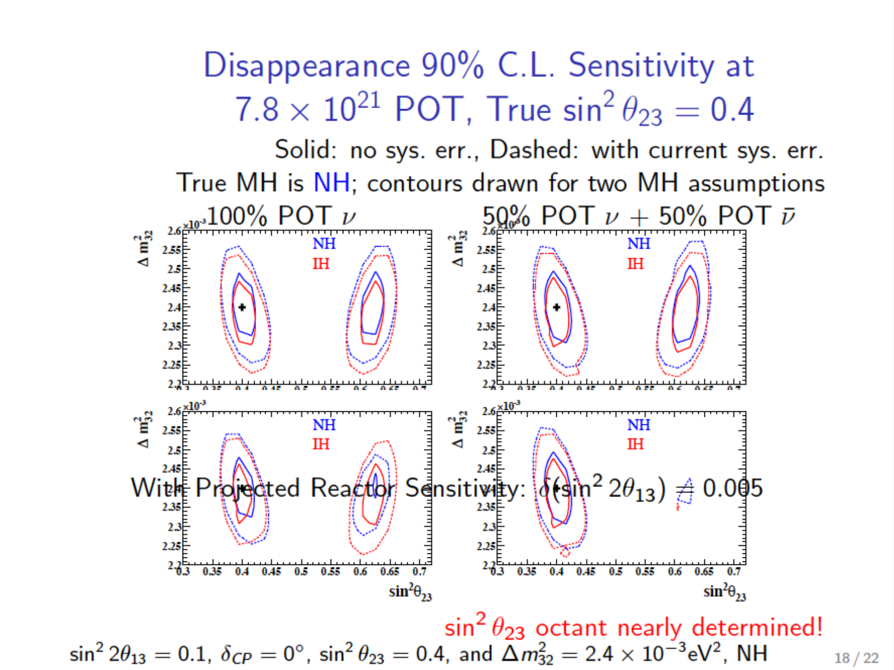
The great wall 2013/8/22

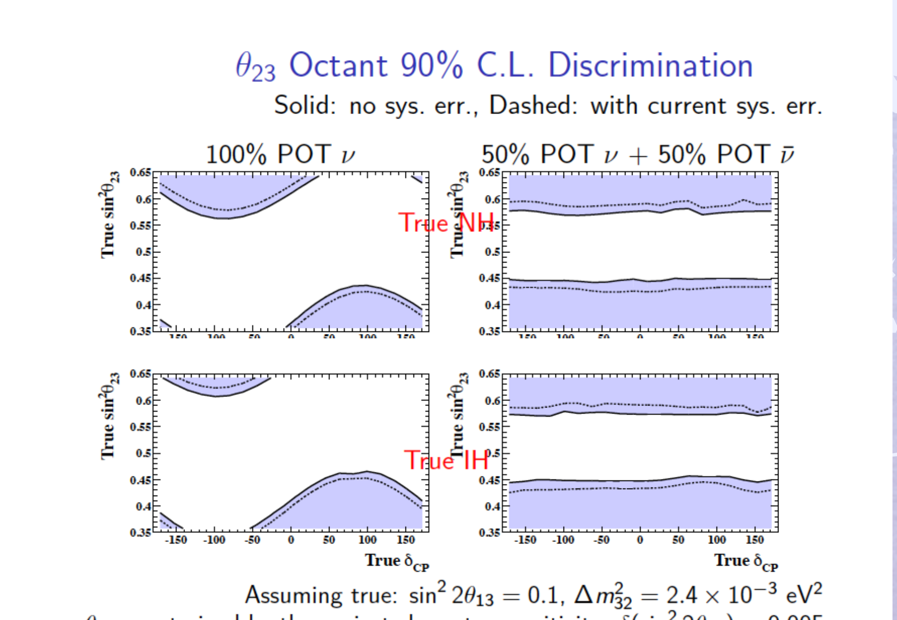
Approach for θ_{23} octant degeneracy

Questions from NuFact '12: *For how long do we need to run T2K + NOvA to reach the systematic/background limit? How much significance can they provide when they reach that limit? What is the expected sensitivity to deviations of θ_{23} from maximality and to its octant at different facilities.*

- The θ_{23} octant degeneracy can be addressed by T2K and NOνA by mixing ν-run and $\bar{\nu}$-run.

(Megan Friend, Sanjib Kumar Agarwalla)

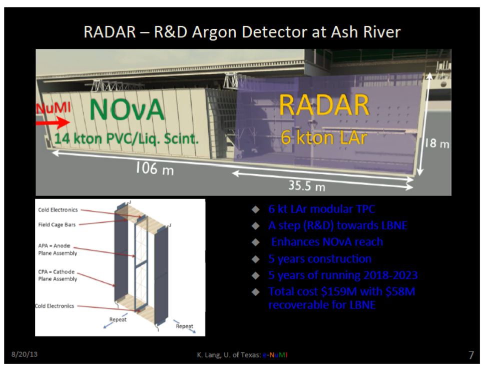


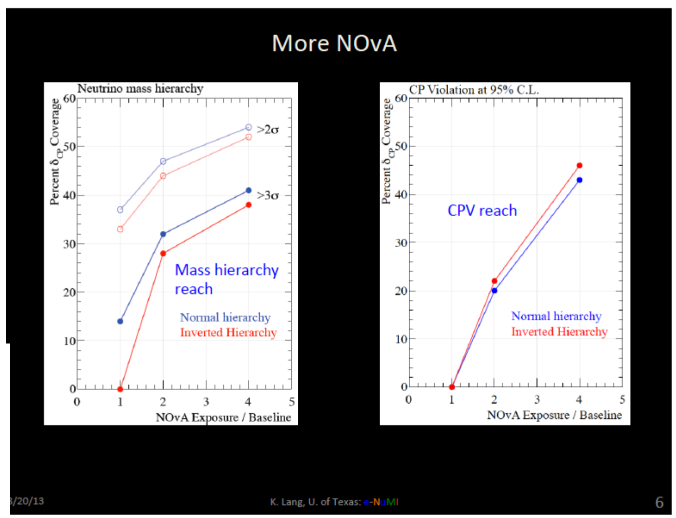


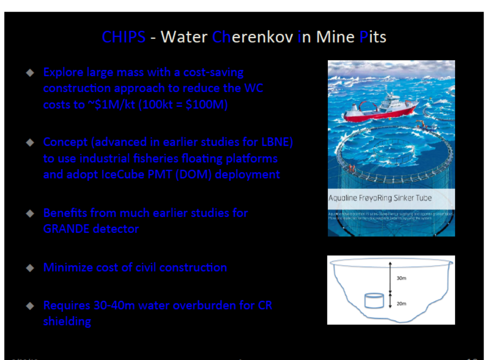
Megan Friend

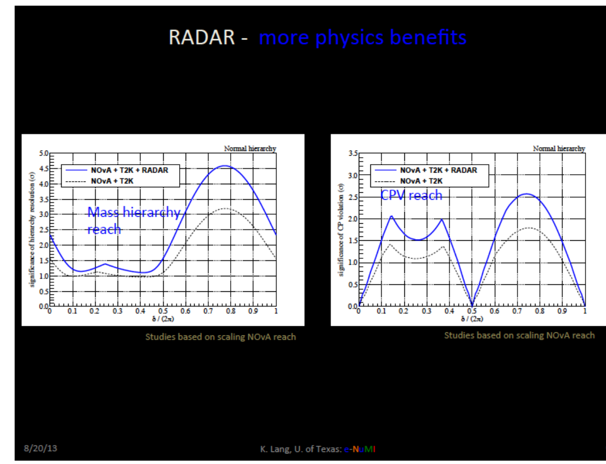
T2K & NOvA is still statistical limited.

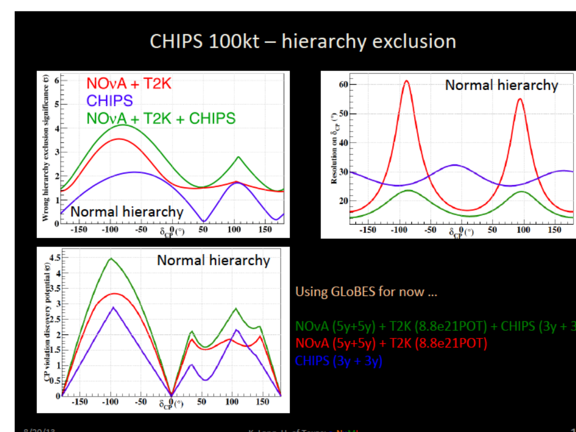
- e-NuMI: Upgrade/Extension of NOvA
  - +4kT LqS or +6kt LAr
  - CHIPS









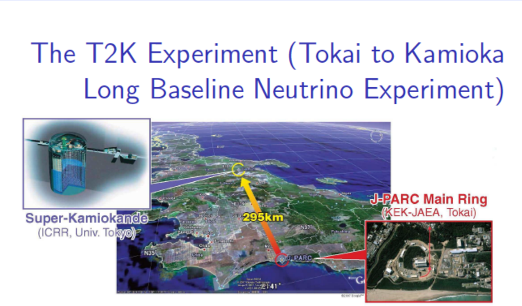


Karol Lang

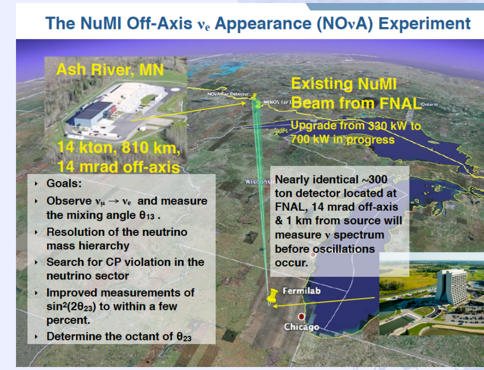
Towards Mass Hierarchy determination.

Questions from NuFact '12: *How much significance for the mass hierarchy can we expect from atmospheric neutrinos, reactor neutrinos, and cosmology? Do we need a dedicated accelerator experiment to reach the 5 sigma level for any value of delta?*

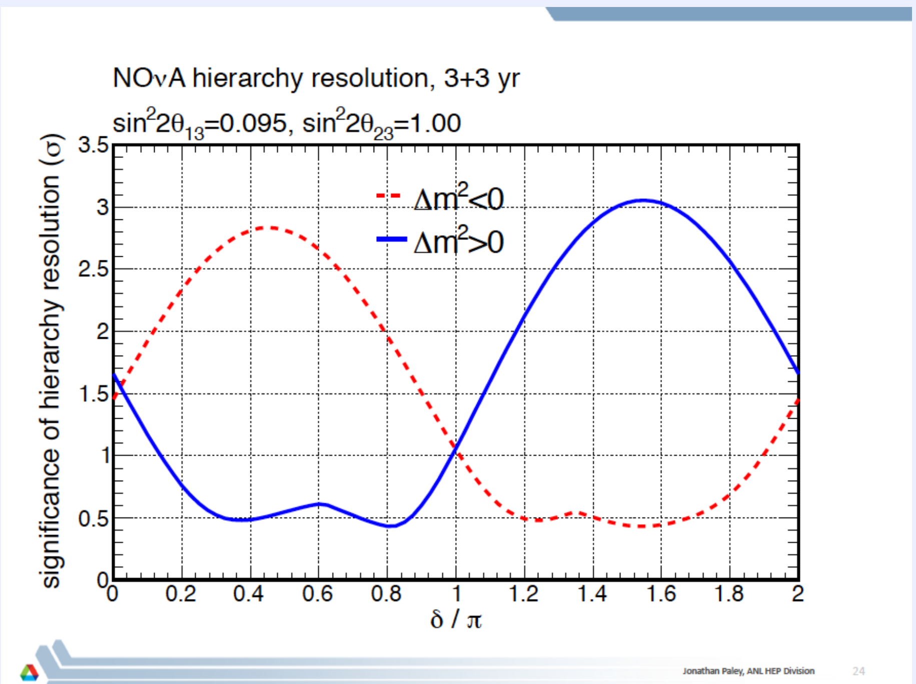
- Many approaches for MH determination
  - LBL accelerator neutrino
  - Atmospheric neutrino
  - Mid. Baseline reactor
  - Supernova neutrino
- Sum of neutrino mass can be constrained from cosmology.

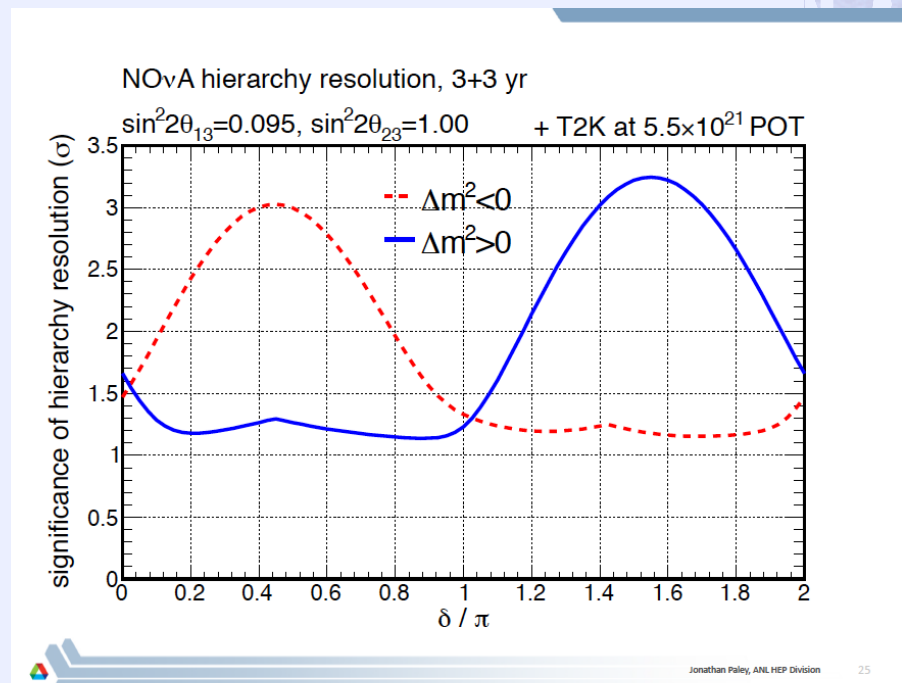


LBL



- Latest T2K & NOνA expectation.
  - Synergy among two base-line is significant!

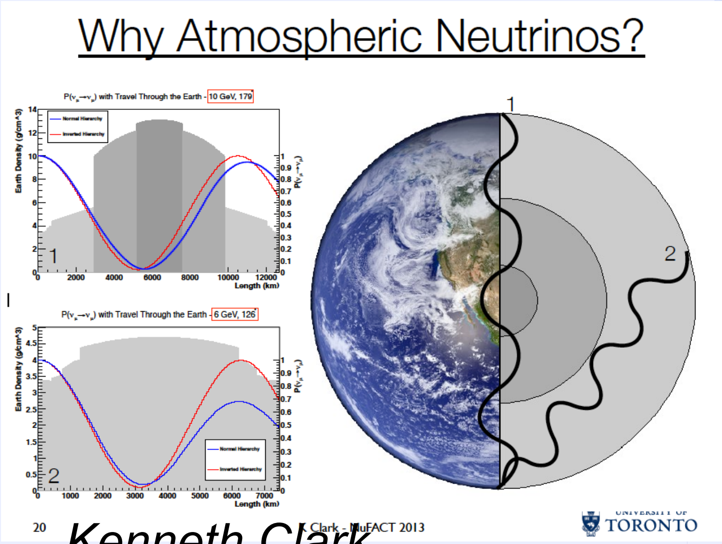




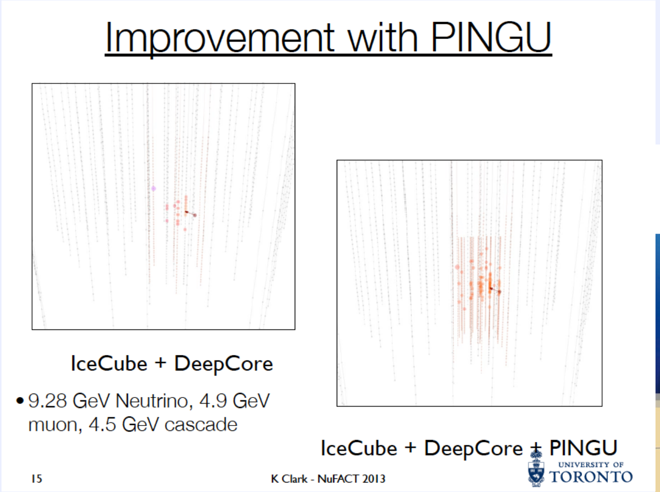
Jonathan Paley

Atmospheric neutrino

- LBNE
- Hyper-K
- PINGU
- ORCA/KM3Net
- INO

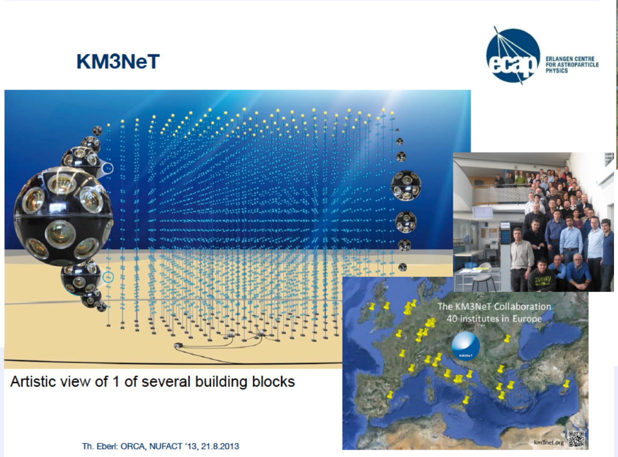


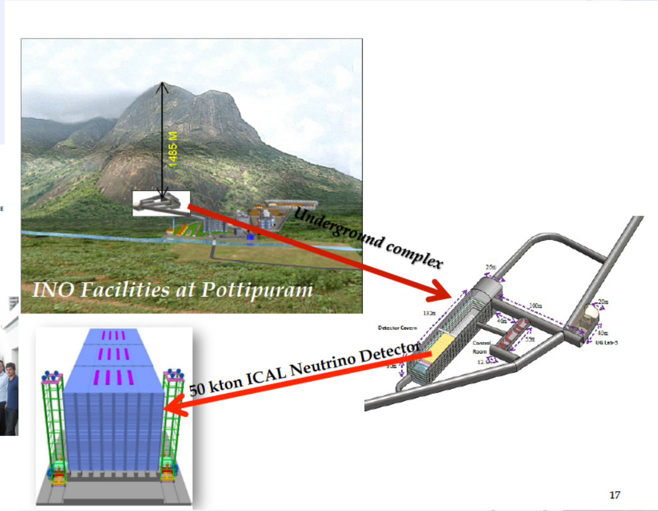
Kenneth Clark



Kenneth Clark

Thomas Eberl

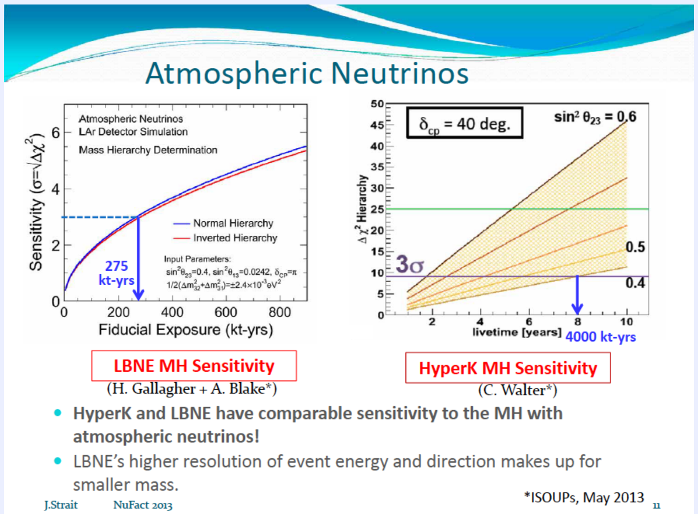




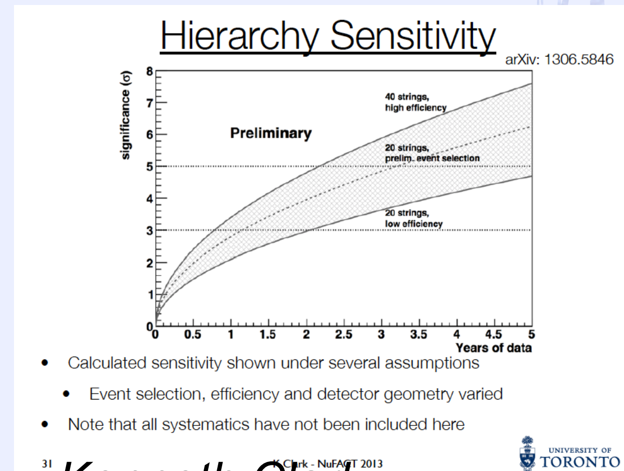
Naba Kumar Mondal

Atmospheric neutrino

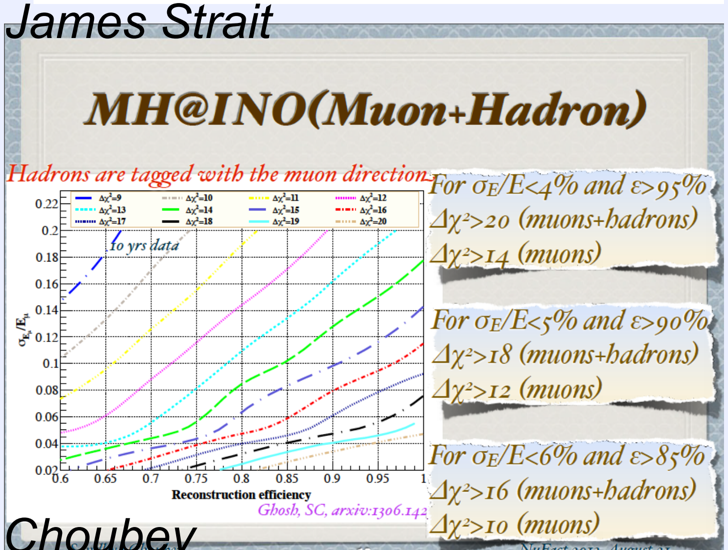
- Redundant measurements



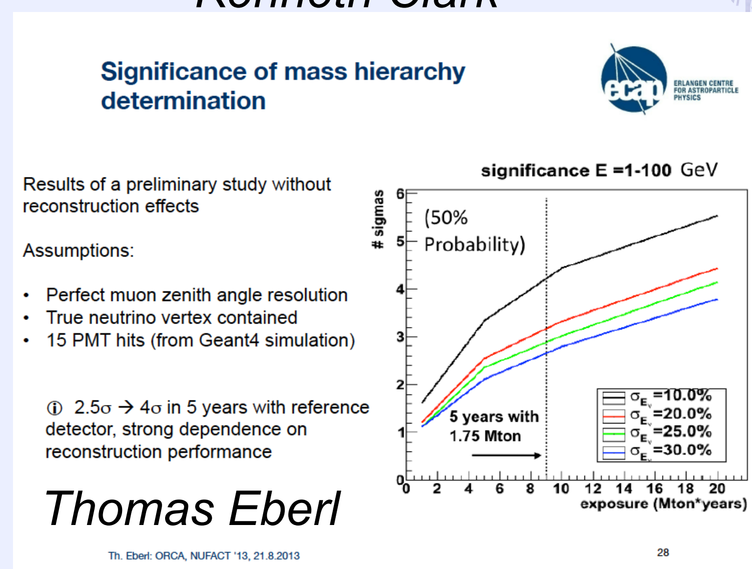
James Strait



Kenneth Clark



Sandhya Choubey

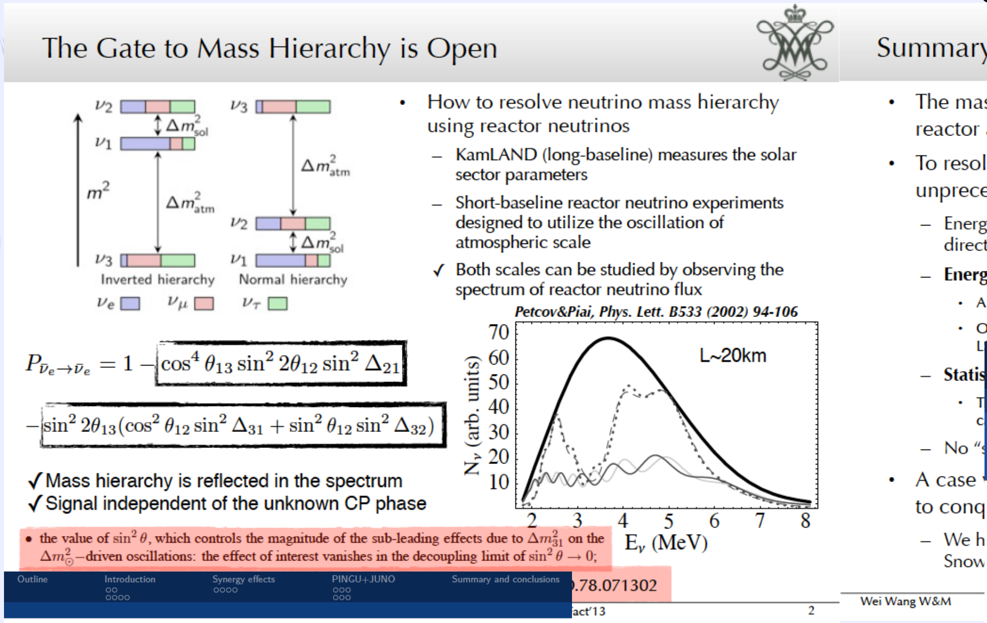


Thomas Eberl

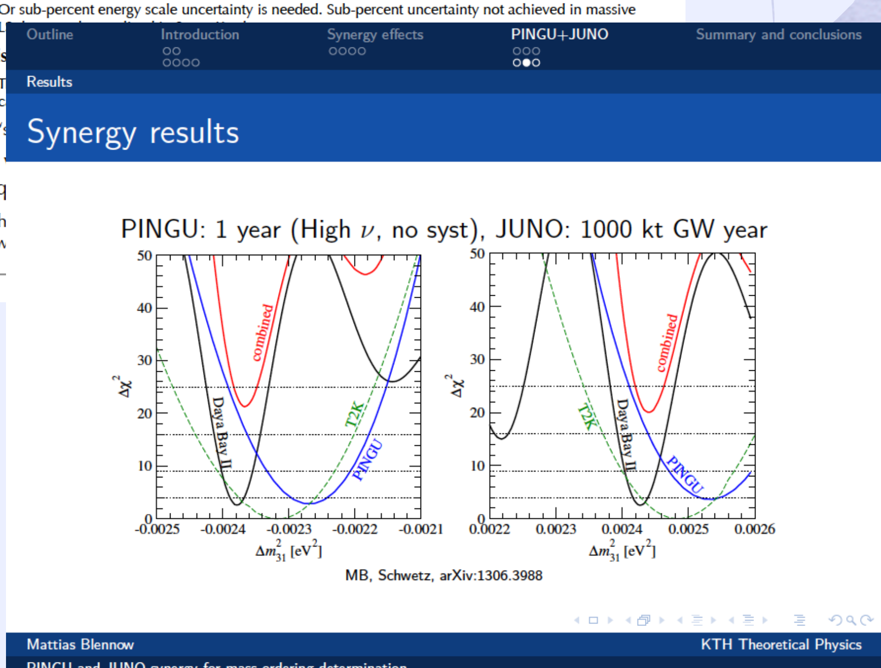
Mid. base-line reactor

- MH by Reactor exp. … Challenge for precise calibration.

Wei Wang

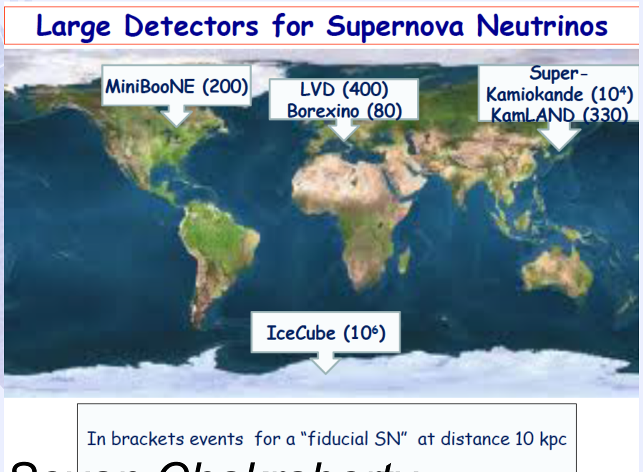


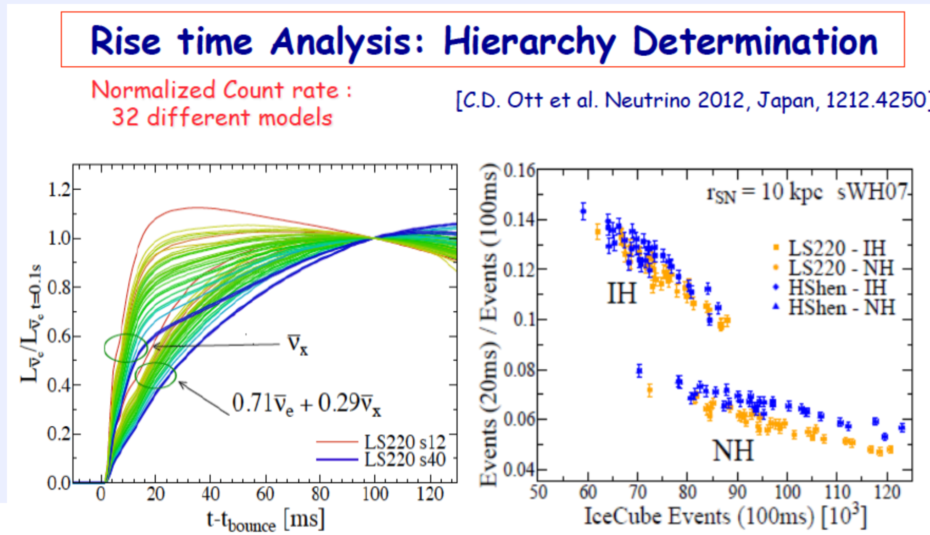
Mattias Blennow



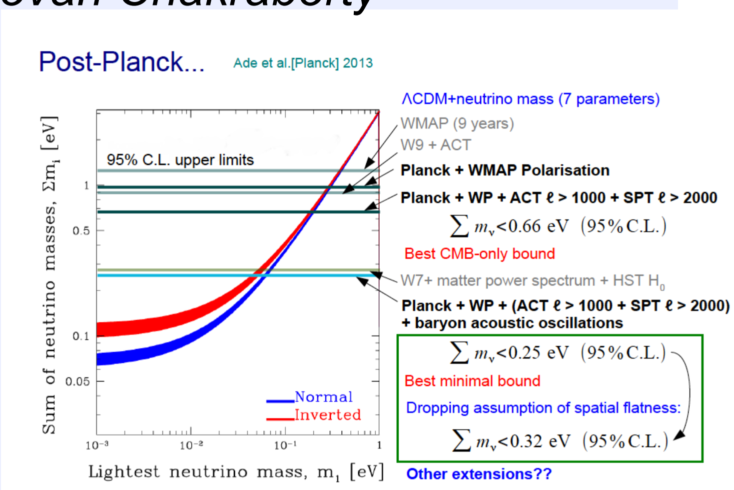
Super nova
& cosmology

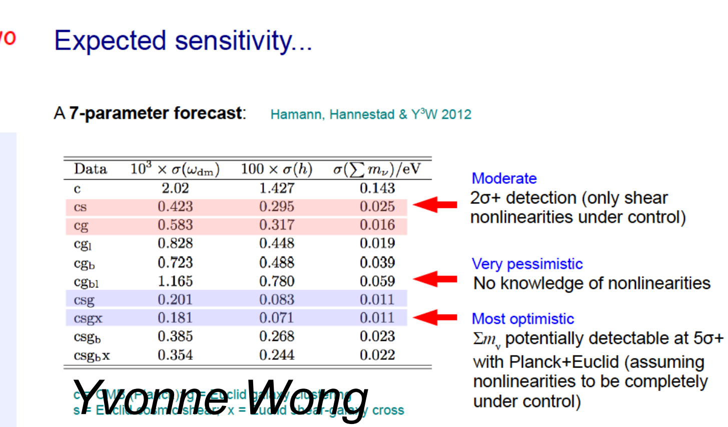
- SN: Timing distribution depends on MH.





Sovan Chakraborty





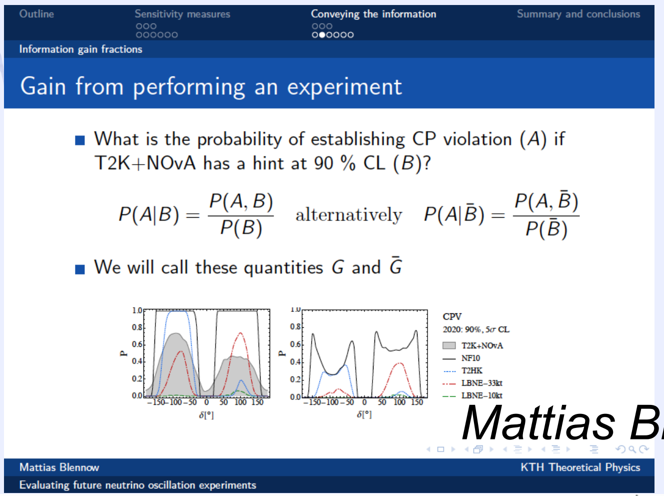
Data	$10^3 \times \sigma(\omega_{dm})$	$100 \times \sigma(h)$	$\sigma(\sum m_\nu)$/eV
c	2.02	1.427	0.143
cs	0.423	0.295	0.025
cg	0.583	0.317	0.016
cg_l	0.828	0.448	0.019
cg_b	0.723	0.488	0.039
cg_{bl}	1.165	0.780	0.059
csg	0.201	0.083	0.011
csgx	0.181	0.071	0.011
csg_b	0.385	0.268	0.023
csg_bx	0.354	0.244	0.022

Yvonne Wong

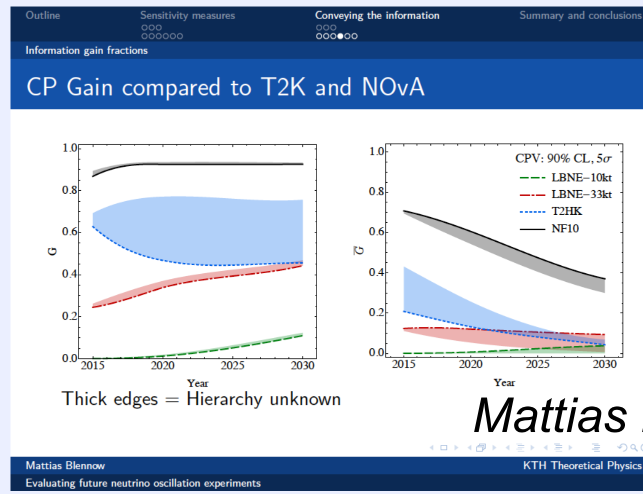
11~25meV

How to evaluate power of new experiments?

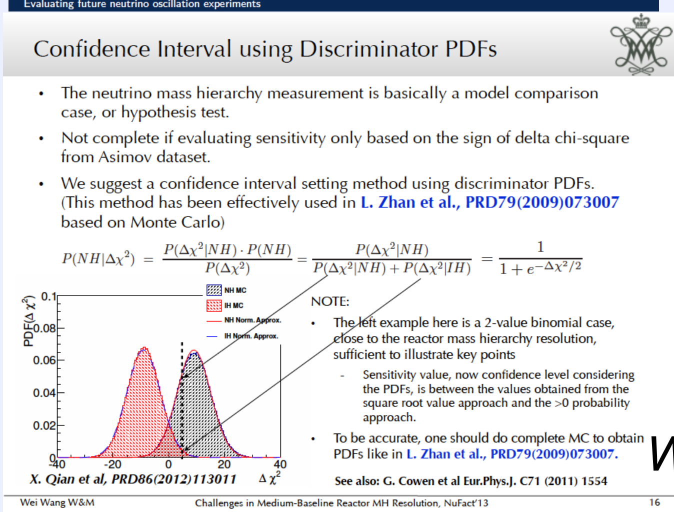
- Figure of merit of new experiment when the current experiment give a hint.
- MH … discrete quantity => More proper evaluator than $\sqrt{|\Delta\chi^2|}$ is exist?



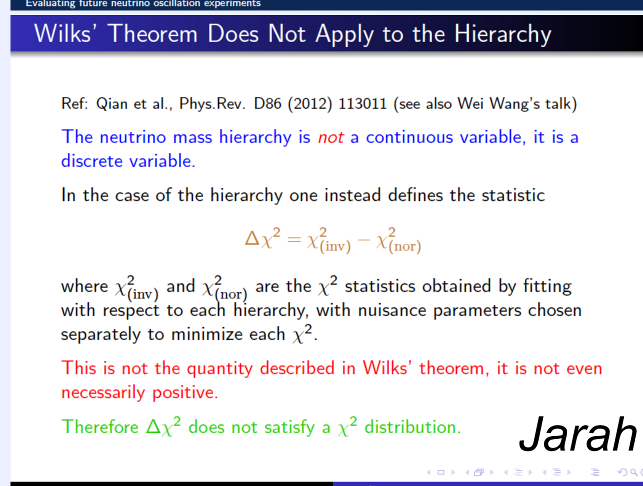
Mattias Blennow



Mattias Blennow



Wei Wang

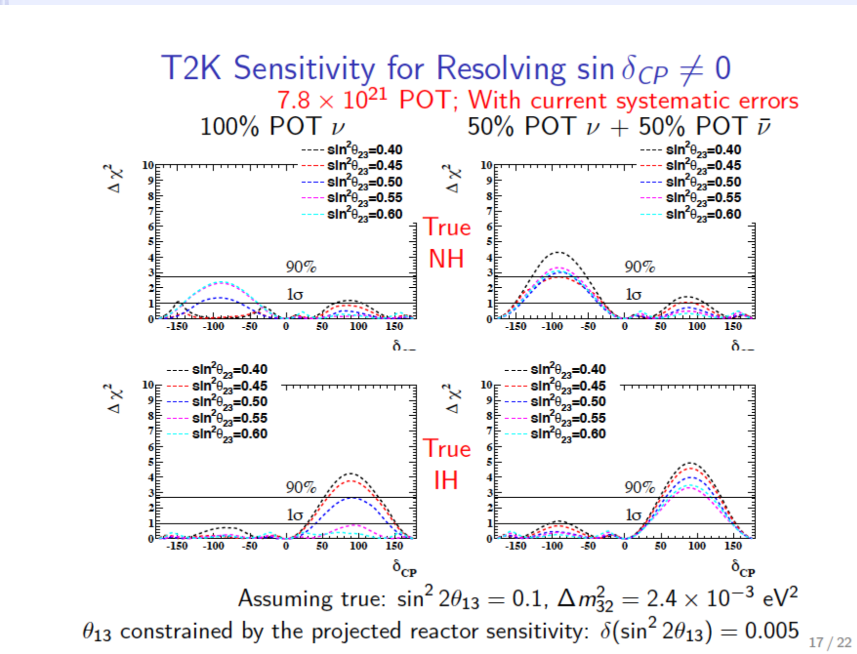


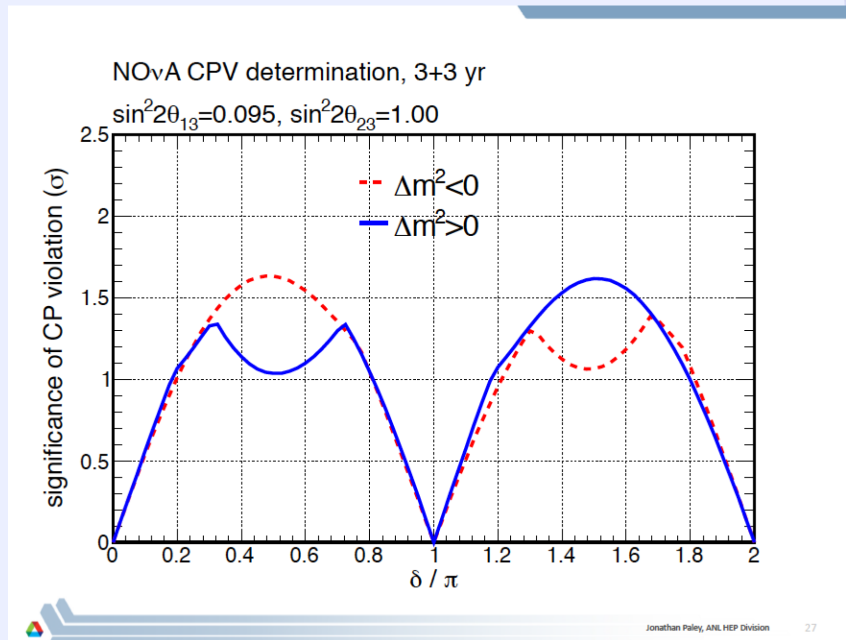
Jarah Evslin

Towards CP Violation search

Questions from NuFact '12: *Do we need to and can we re-optimize the design of future facilities for large θ13? Are off-axis beams still interesting for large θ13? Do we need a neutrino factory to confirm or rule out leptonic CP violation?*

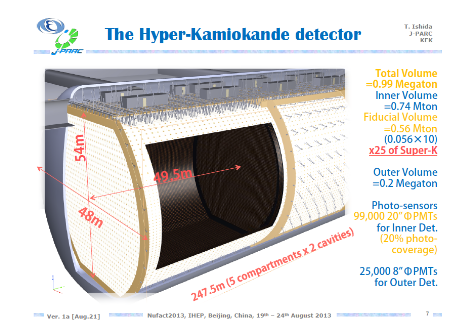
- Reach by T2K + NOνA is presented.





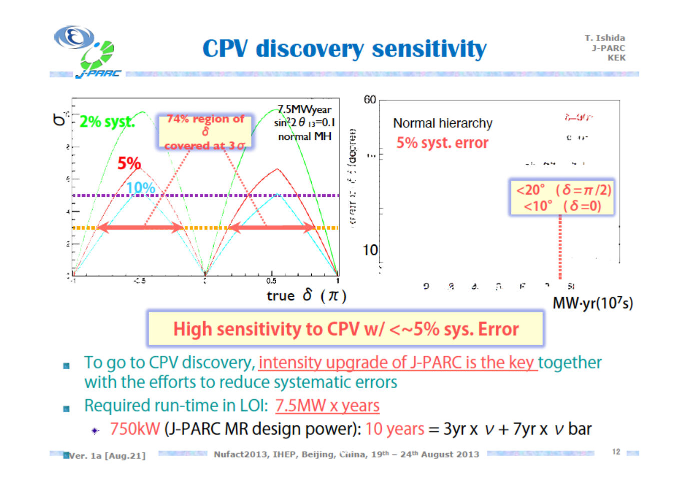
Megan Friend

Jonathan Paley

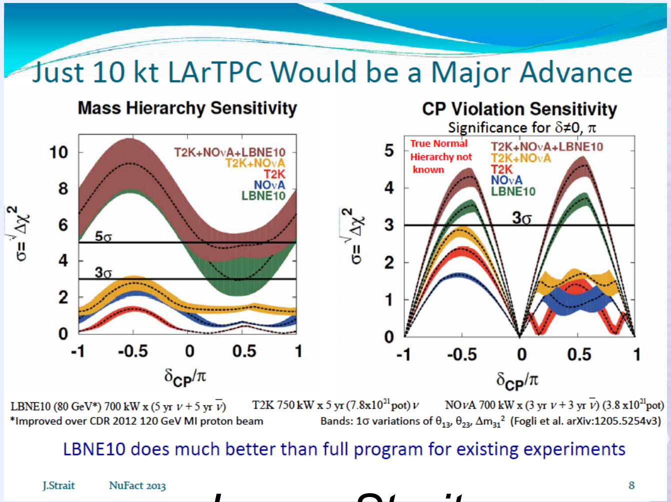


Future LBL

- Hyper-K
- LBNE
- LBNO
- ESS



Taku Ishida



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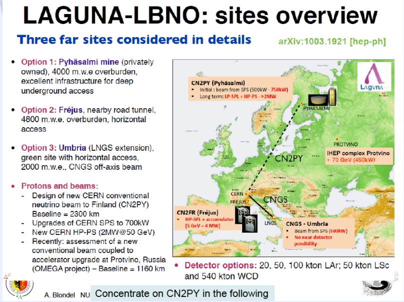
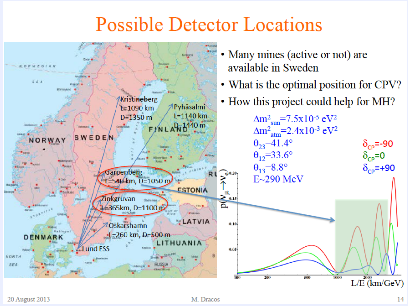
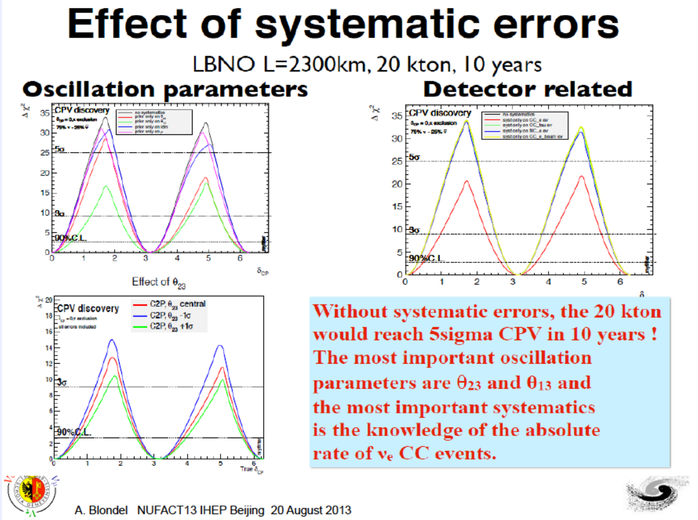
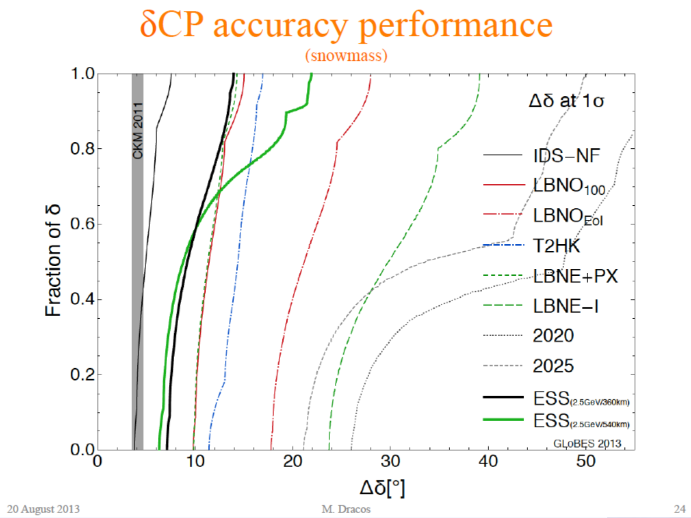






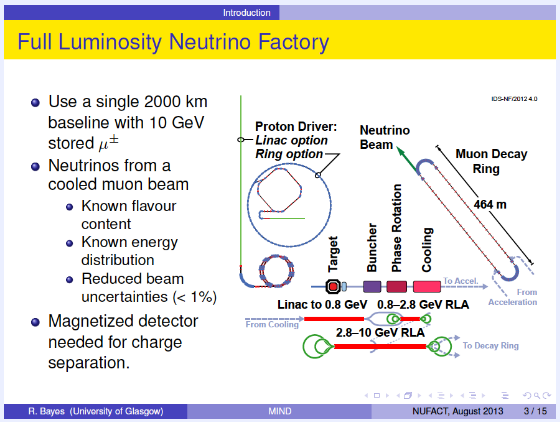
Alain Blondel

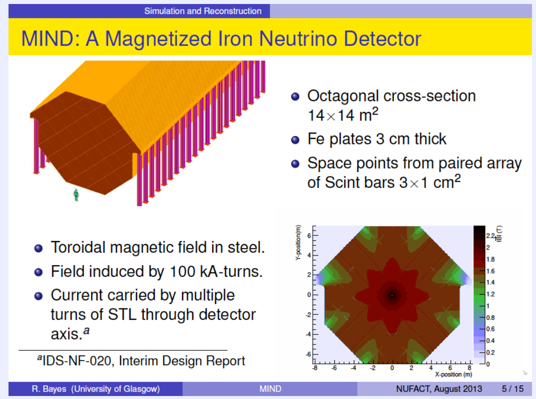


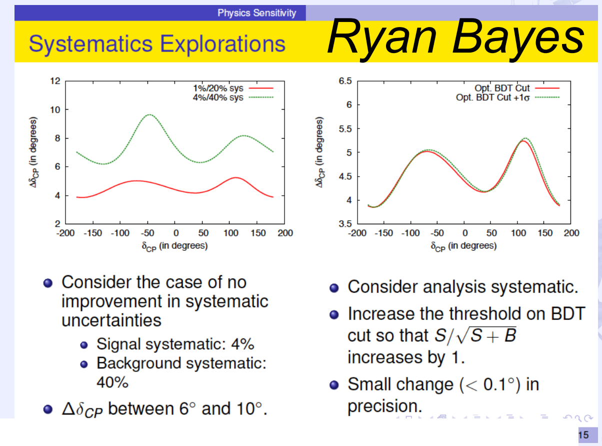
Marcos Dracos

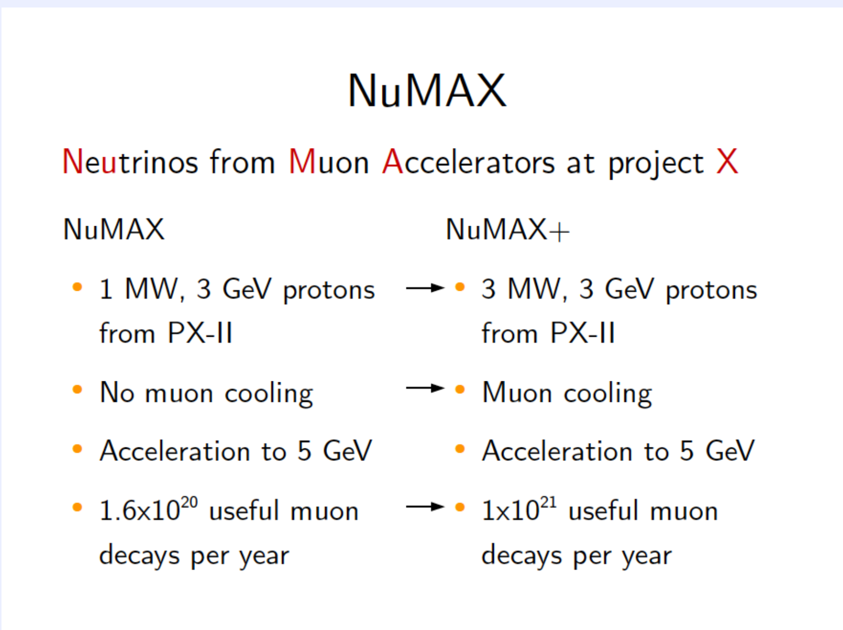
Neutrino Factory

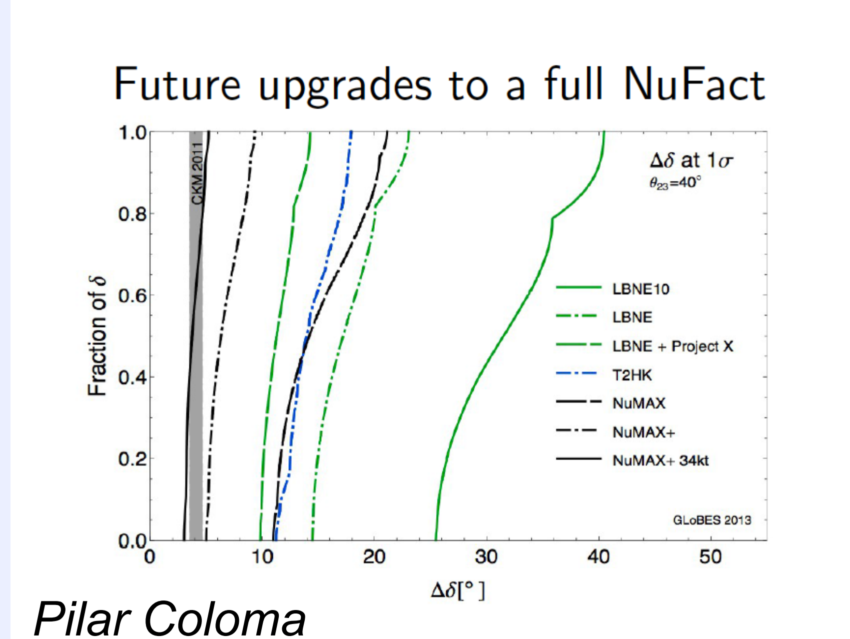
- Sensitivity reaches CKM level measurement.







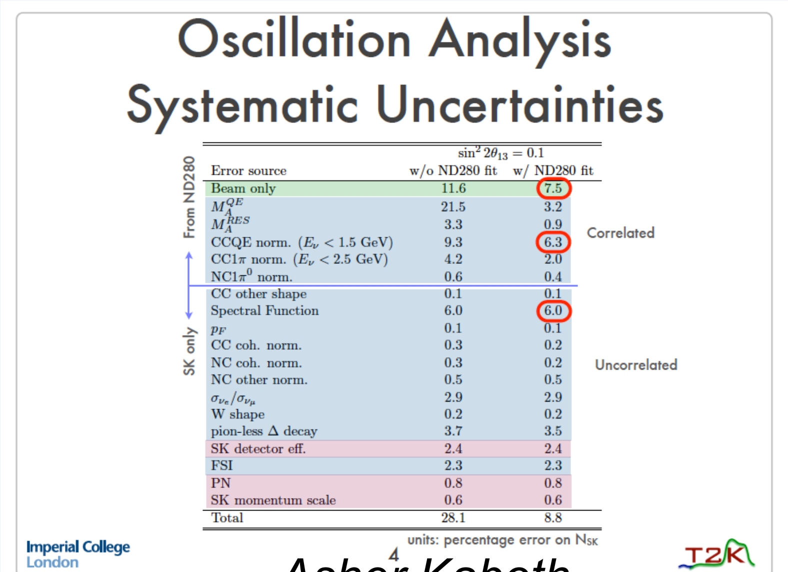




Systematic uncertainty: WG1+WG2

Questions from NuFact '12: *What is the sensitivity to the different sources of systematic errors at future facilities? Which of these sources are uncorrelated between neutrino and antineutrinos? Are these systematic errors reasonable assumptions? Can we do precision experiments without a Near Detector?*

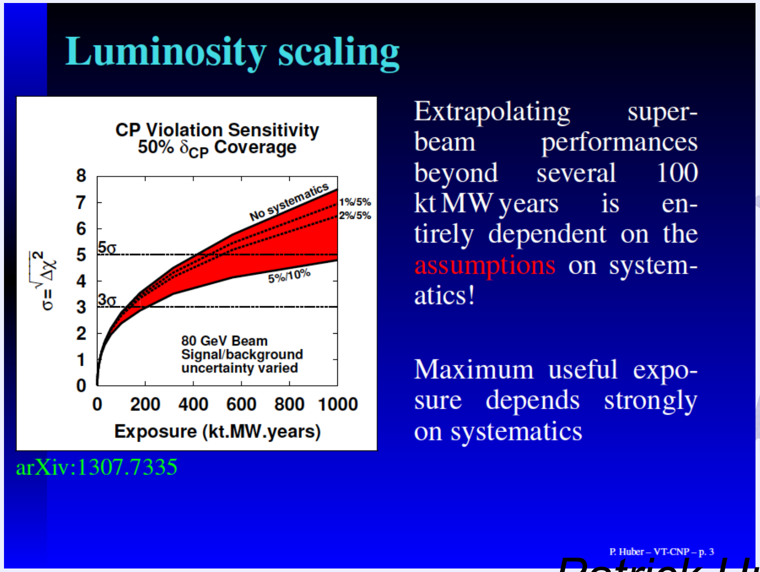
- State of arts: T2K ~8.8% w/ ND measurement.
- Active discussion was happened:
  The excellent Near Detector is necessary to reduce the uncertainty to much less than 10%.



Oscillation Analysis
Systematic Uncertainties

Error source	w/o ND280 fit ($\sin^2 2\theta_{13} = 0.1$)	w/ ND280 fit ($\sin^2 2\theta_{13} = 0.1$)
Beam only	11.6	7.5
M_A^{QE}	21.5	3.2
M_A^{RES}	3.3	0.9
CCQE norm. ($E_\nu < 1.5$ GeV)	9.3	6.3
CC1π norm. ($E_\nu < 2.5$ GeV)	4.2	2.0
NC1π^0 norm.	0.6	0.4
CC other shape	0.1	0.1
Spectral Function	6.0	6.0
p_F	0.1	0.1
CC coh. norm.	0.3	0.2
NC coh. norm.	0.3	0.2
NC other norm.	0.5	0.5
$\sigma_{\nu_e}/\sigma_{\nu_\mu}$	2.9	2.9
W shape	0.2	0.2
pion-less Δ decay	3.7	3.5
SK detector eff.	2.4	2.4
FSI	2.3	2.3
PN	0.8	0.8
SK momentum scale	0.6	0.6
Total	28.1	8.8

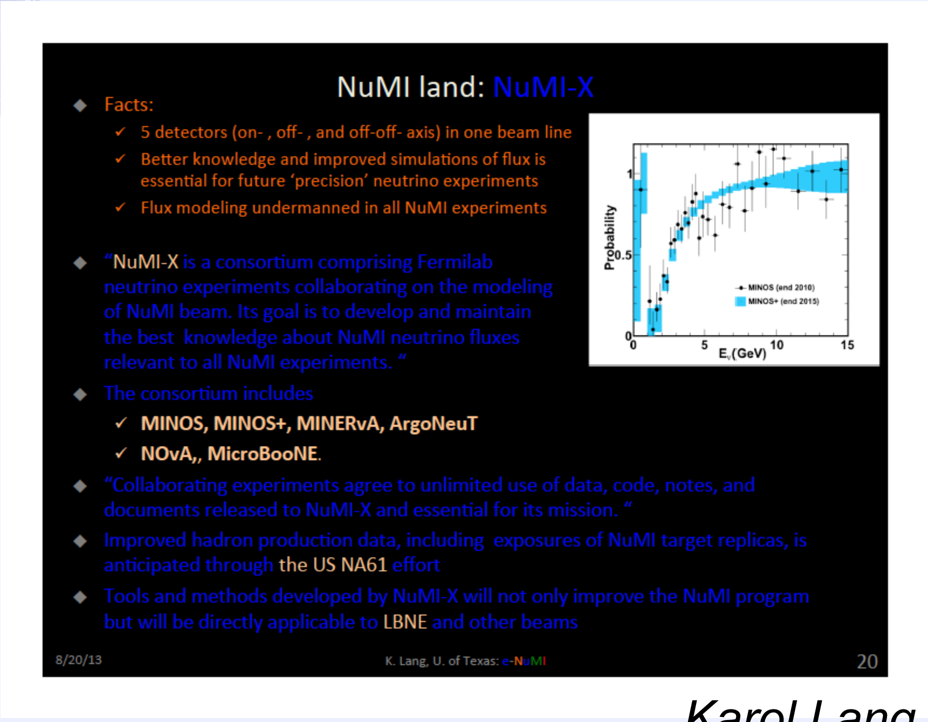
Asher Kaboth



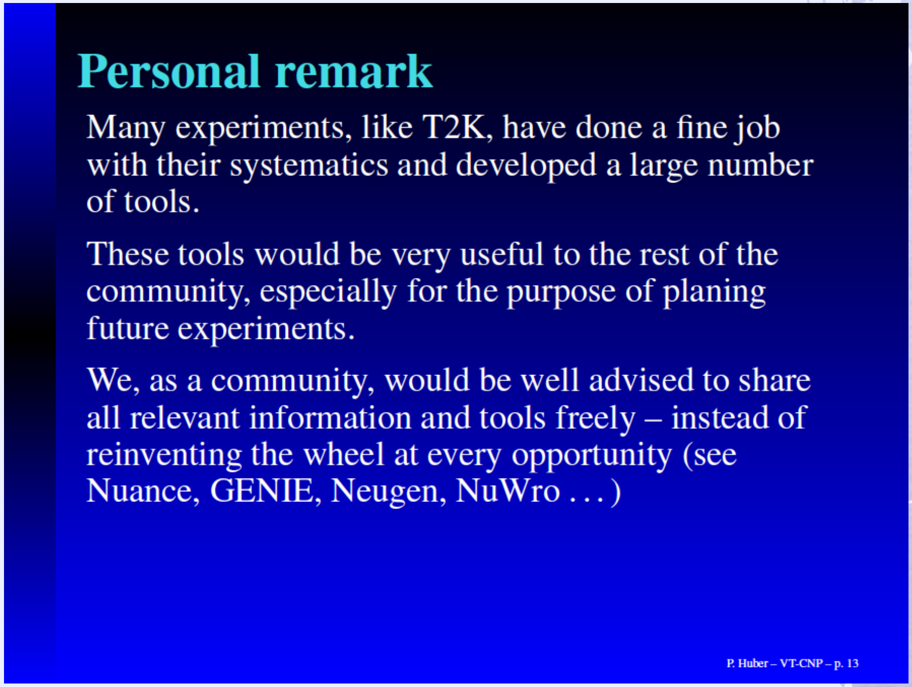
Patrick Huber

Systematic uncertainties

- NuMI-X: Synergy to understand the flux
- Common treatment on ν-interaction model is proposed for the consistent comparison among the experiments.



Karol Lang

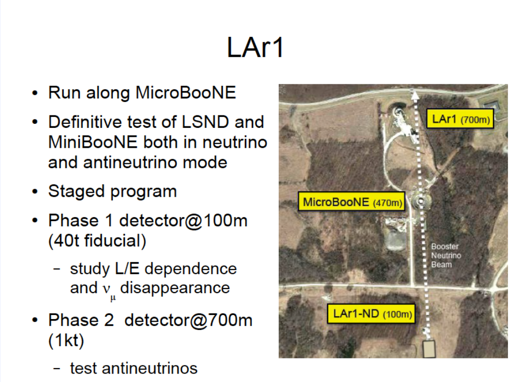


Patrick Huber

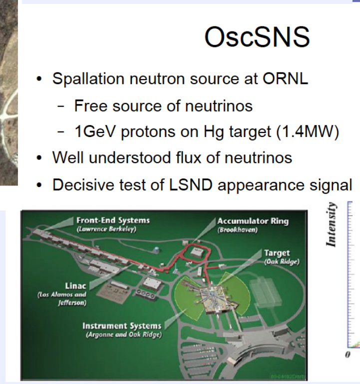
Sterile?

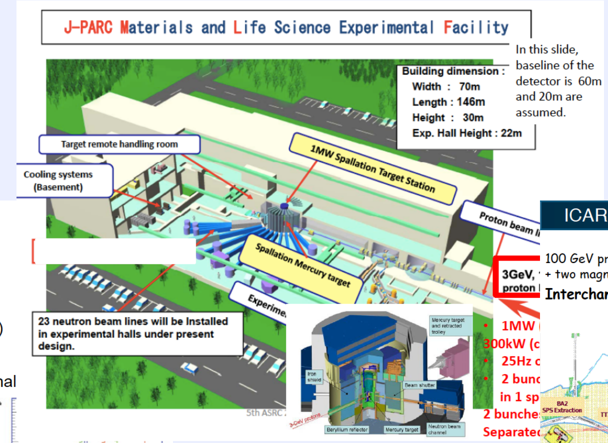
Standing questions: *Are there sterile neutrinos? Are LSND and MiniBooNE results evidence for light sterile neutrinos?*

- ICURUS, MicroBooNE, MINOS+
- Proposal/LOI:
  - US: LAr1, MiniBooNE+, MiniBooNE- II, OscSNS
  - JP: J-PARC MLF
  - EU: ICARUS @ CERN NA



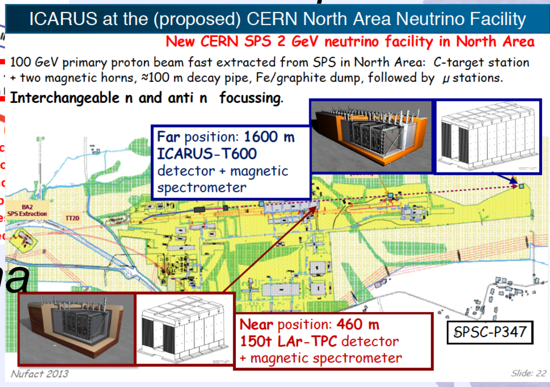
Pavlovic Zarko





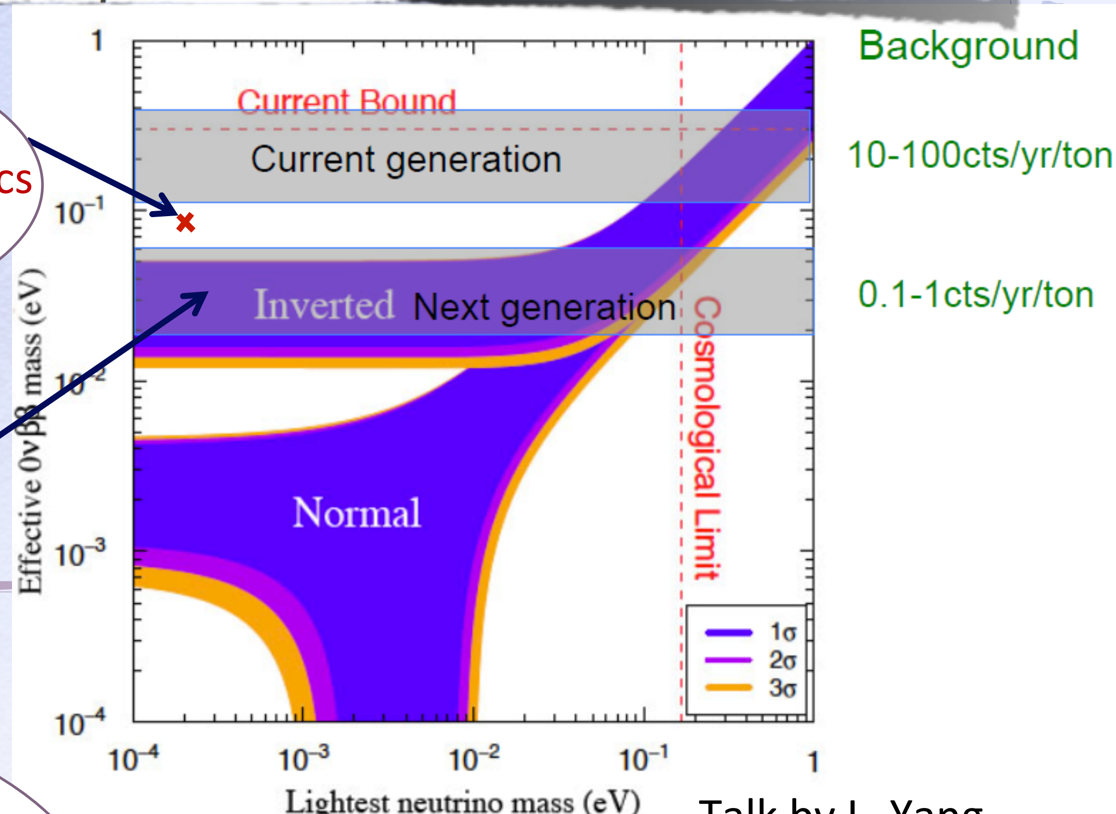
Takasumi Maruyama

paola sala



Questions from NuFact '12: *What can we learn about the Majorana nature of neutrinos from a measurement of the mass hierarchy combined with neutrinoless double beta decay probes? If the hierarchy is inverted and we don't find 0νββ decay, are neutrinos Dirac particles?*

If 0νββ measurement is larger than expected from oscillations new physics needed!! See talk by T. Ota



Talk by L. Yang

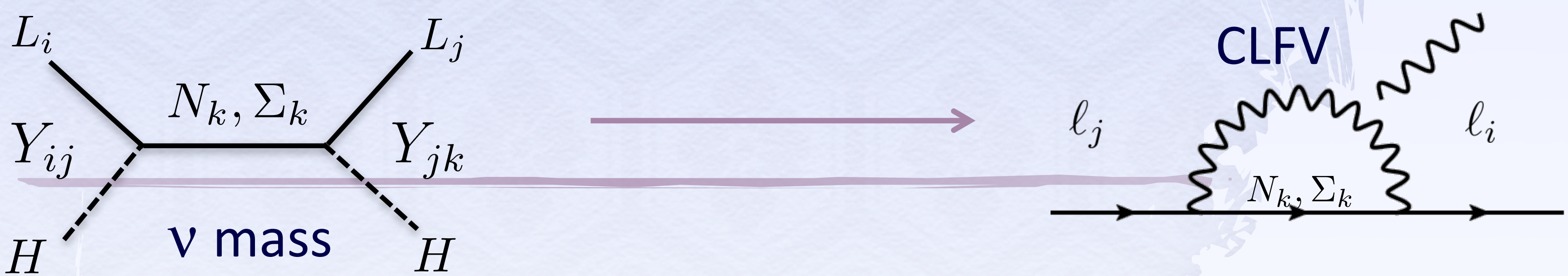
If hierarchy is inverted but we dont find 0νββ, neutrinos can be Dirac, but also Majorana with new physics at low scale. See talk by J. Lopez-Pavon

Combination of 0νββ searches with oscillations powerful test of new physics.

Question: *What can neutrino physics learn from charged lepton physics measurements?*

Most natural mechanisms behind neutrino mass generation imply new sates that mediate CLFV

TYPE I, III seesaws



From F. R. Joaquim talk (see also talks by B. Gavela and L. Calibbi)

To probe the model CLFV and oscillation data need to be combined

$$\mathbf{Y} = i\frac{\sqrt{2}}{v}\sqrt{\mathbf{M}_{\rm diag}}\,\mathbf{R}\,\sqrt{\mathbf{m}_{\rm diag}}\,\mathbf{U}^\dagger$$

What is next work?

Questions to Nufact2014

If improved precision in oscillation parameters results in tension between measurements, which new physics beyond the 3-flavor mixing paradigm would we be probing (NSI, steriles, unitarity, CPT, etc.)? And between oscillations and other searches (neutrinoless double beta decay, CLFV, cosmology…).

What symmetries can we identify from the PMNS matrix element relative sizes? What level of precision is required to rule out models like tribimaximal mixing?

Can we reach 1-2% level in systematic uncertainties for superbeam appearance experiments in order to measure leptonic CP violation? What level of optimization of the ND is required? To which level do we need to reduce the cross-section uncertainties on neutrino interactions in water, argon, carbon? Is NuStorm enough to achieve those reductions? Do we need a dedicated hadron production effort?

Questions to Nufact2014 (cont'd)

How do we account for differences in neutrino interaction generators used by each experiment to model their data when we compare or combine sensitivities or results from different experiments? For WG2?

When will the combined reach of all experiments resolve the mass hierarchy at more than 3σ for all δ? and 5σ? What impact would such measurement have on the design of future large facilities such as LBNE, T2HK, LBNO or ESS? Can we identify synergies between them?

What are the prospects for determining the θ_{23} octant over the next decade for current facilities? What is the sensitivity to the θ_{23} octant of medium-term atmospheric neutrino experiments such as INO, PINGU, KM3Net-ORCA?

Questions to Nufact2014 (cont'd)

Evidence for sterile neutrinos is dominated by the LSND result. What are the prospects for rejecting or confirming LSND at more than 5σ before NuStorm is built?

What is the effect of results from Daya Bay, RENO and Double Chooz on the reactor neutrino anomaly? Can we test the gallium anomaly with future projects?

What constraints can we place on light sterile neutrinos using direct mass measurements?

See you in NuFact2014.

THANK YOU.