

# Intro to Working Group 1

## - Neutrino Oscillations -



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# The Big Desert?

- The observation of a spin-0 boson at the LHC means that the Standard Model can be extended from the electroweak scale to (almost) arbitrarily high energy scales
- New phenomena are only guaranteed to occur at the Planck scale ( $10^{19}$  GeV) or perhaps at the GUT scale ( $\sim 10^{16}$  GeV)
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(Savas Dimopoulos, GGI, July 2013)

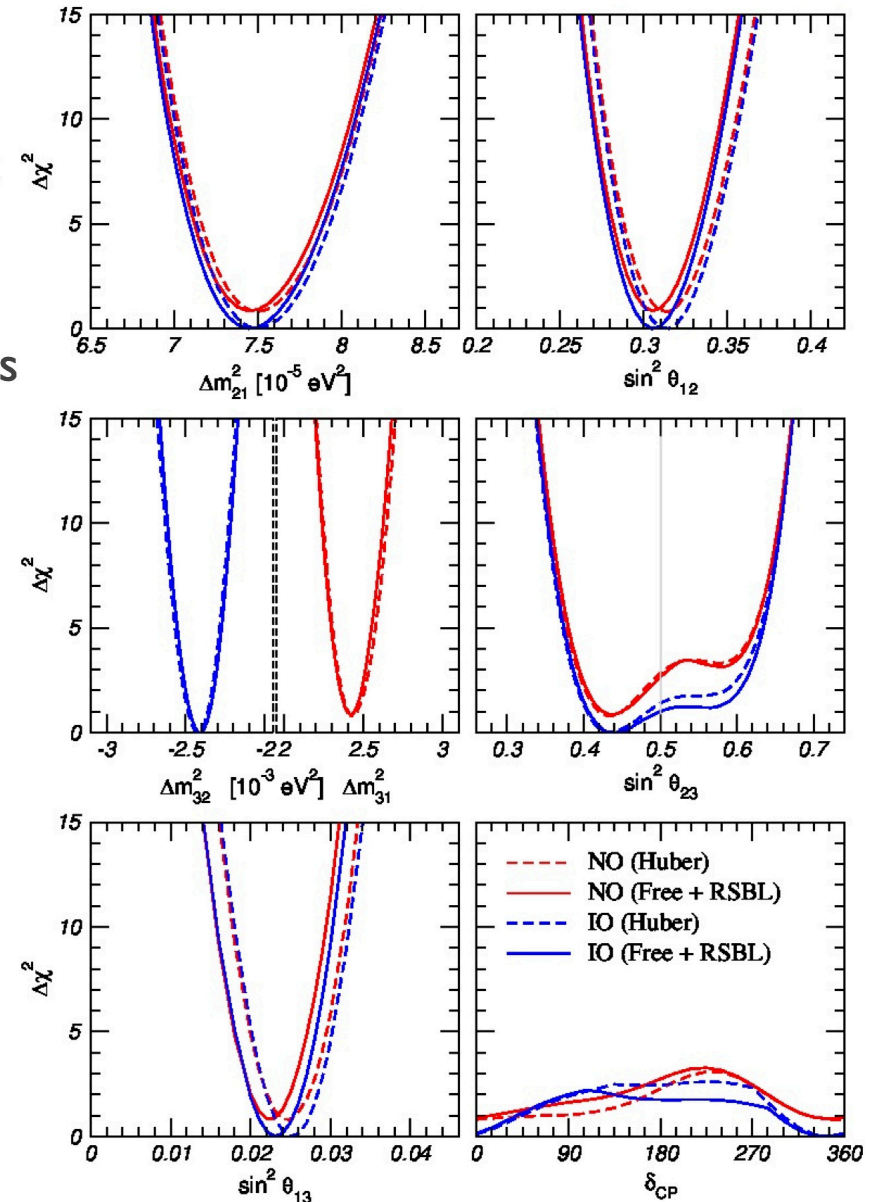
<http://resonaances.blogspot.com/>



# Neutrino Oscillations

NuFIT 1.1 (2013)

- However, we know the Standard Model is incomplete (neutrino oscillations, matter-antimatter asymmetry, dark matter indirect measurements, etc.)
- Neutrino oscillations  $\implies$  massive neutrinos
  - may provide guidance on where the next energy frontier lies
- If we establish neutrinos have Majorana masses, new particles would be expected at  $10^9$ - $10^{15}$  GeV through seesaw mechanism
- If we establish leptonic CP violation occurs, leptogenesis may explain matter-antimatter asymmetry
- Much progress since 1998 in measuring oscillation parameters, but much work remains!



[Gonzalez-Garcia, Maltoni, Salvado, Schwetz, JHEP12\(2012\)123](#)



# WG1 - Session 1

**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  $\theta_{23}$  from maximality and to its octant at different facilities.*

- **Latest results and predicted physics reach of current generation of long-baseline accelerator experiments**
- Tuesday, 10:30-12:30 @ Rm B326
- MINOS and MINOS+
- NOvA
- T2K
- Octant of  $\theta_{23}$  from T2K + NOvA



*National Center for the Performing Arts, 2007*

# WG1 - Session 2 - Joint with 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?*

- **Systematic uncertainties that current experiments are sensitive to**

- Tuesday, 13:30-15:30 @ **Rm A214**
- T2K
- MINERvA
- NOvA
- Discussion Leader: Patrick Huber



*Olympic Gardens, 2008*



# WG1 - Session 3

**Questions from NuFact '12:** Do we need to and can we re-optimize the design of future facilities for large  $\theta_{13}$ ? Are off-axis beams still interesting for large  $\theta_{13}$ ? Do we need a neutrino factory to confirm or rule out leptonic CP violation?

- **Proposals for next-generation accelerator facilities - Part I**
- Tuesday, 16:00-17:30 @ Rm B326
- eNuMI
- LBNE
- LBNO
- ESS



CCTV Headquarters, 2012



# WG1 - Session 4

**Questions from NuFact '12:** Do we need to and can we re-optimize the design of future facilities for large  $\theta_{13}$ ? Are off-axis beams still interesting for large  $\theta_{13}$ ? Do we need a neutrino factory to confirm or rule out leptonic CP violation?

- **Proposals for next-generation accelerator facilities - Part II**

- Wednesday, 8:30-10:00 @ Rm B326
- T2HK
- Low-Energy Neutrino Factory
- MIND
- Improvements of future facilities over T2K and NOvA



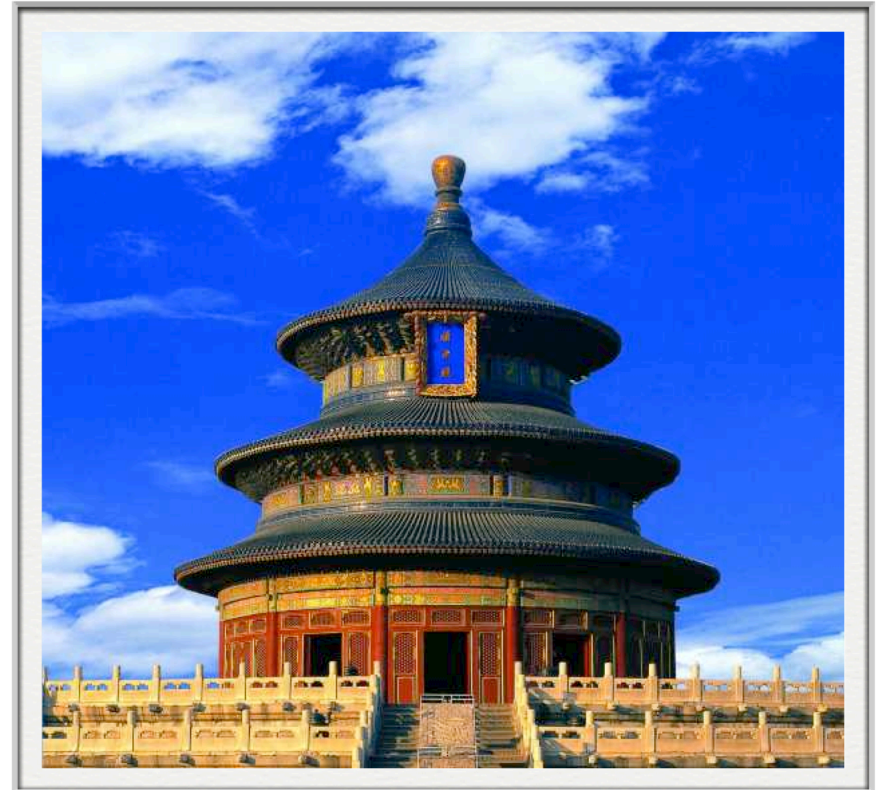
*National Art Museum of China (proposed)*

# WG1 - Session 5

**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?*

- **Mass Hierarchy Determination - Part I**

- Wednesday, 13:30-15:30 @ Rm B326
- Challenges in medium-baseline reactor experiments
- Confidence level in mass hierarchy determination
- PINGU
- Combined reach of PINGU + JUNO



*Temple of Heaven, 1420*



# WG1 - Session 6

**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?*

## • Mass Hierarchy Determination - Part II

- Wednesday, 16:00-17:30 @ Rm B326
- Mass hierarchy from Supernovae explosion
- kM3NeT - ORCA
- INO physics potential
- Neutrino masses from Cosmology



Temple of Heaven, 1420 (reflection)



# WG1 - Session 7

**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  $0\nu\beta\beta$  decay, are neutrinos Dirac particles?*

- **Neutrinoless double beta decay**
  - Thursday, 8:30-10:00 @ Rm B326
  - Status of experimental searches
  - Sterile neutrino contributions
  - Decomposition of the  $0\nu\beta\beta$  decay operator at the electroweak scale
  - Anarchy,  $0\nu\beta\beta$  decay and leptogenesis



*Golden Dragon, Forbidden City, 1771*

# WG1 - Session 8

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

- **Sterile neutrinos and reactor results**

- Friday, 10:30-12:30 @ Rm B326
- Sterile neutrino searches in the US
- Sterile neutrino searches in Japan
- ICARUS status
- Cosmological bounds on sterile  $\nu$ s
- Double Chooz results
- Daya Bay results



*Summer Palace, 1750*



# WG1 - Session 9 - Joint with WG4

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

- **Neutrino and charged lepton physics connections**

- Friday, 13:30-15:30 @ Rm B326
- Neutrino and Muon physics
- Results of  $\tau$  lepton flavor violation searches
- Muon Analysis in INO



*Institute for High Energy Physics, 1973*



# WG1 - Neutrino Oscillations

- We have entered a precision era in neutrino oscillation physics
- Looking forward to great advances in the measurement of the neutrino mixing angles, the determination of the mass hierarchy, and in charting out the parameter space for leptonic CP-violation
- Much, much work ahead to achieve these goals
- Please come to our sessions and contribute to make it happen!