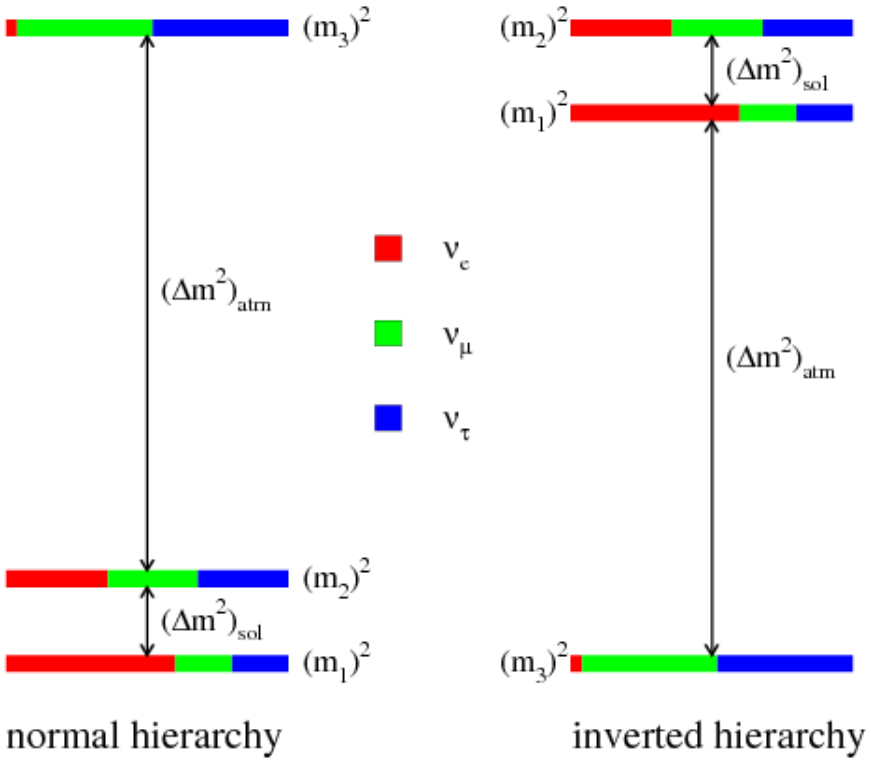
Journées Prospectives du LPSC
1 et 2 juin 2015

Réflexions sur
le futur des neutrinos et
de la détection directe
de matière noire

Neutrino, a still mysterious particle

Three flavors, oscillation between flavors, non-nul mass.

→ Oscillation parameters (Δm_{ij}, θ_{ij}) measured at few % level



Open questions:

- Nature ?
  → Dirac or Majorana ($\nu = \bar{\nu}$) ?
- Absolute scale mass ?
- Mass hierarchy ?
- CP violation ?
- Octant of θ_{23} ?
- Sterile neutrino ?
- Neutrino interaction with nuclei ?
- Non-standard interactions (beyond-the-Standard-Model) ?

Links with other fields

Cosmology

Neutrino mass constraint

Diffuse flux from past supernovae

Dark matter

DM candidate

Detector technology

Particle physics

Beyond-the-Standard-Model physics

Neutrinos

Ultra high energy neutrino sources

Cosmic rays

Neutrino emitters in nuclear reactor

Supernovae neutrino burst

Nuclear physics

Earth's radiated heat from radioactivity

Sun's energy from the CNO cycle

Geophysics

Astrophysics

Neutrino as a probe

Neutrino experiments: global picture

2015 2018 2021 2024

Sterile neutrino

Reactor **Stereo**, **Solid**, DANSS, NuLAT, Neutrino4, Prospect — Data taking ... ?

Source **SOX**

3 ν mixing

Reactor Daya Bay, **Double-Chooz**, **JUNO** ...

Accelerator MINOS, **T2K**, **DUNE** ...

Atmospheric SuperK, Icecube, MINOS ...

R&D ORCA/PINGU

ν properties

Mass KATRIN ...

Double beta **SuperNemo**, GERDA, EXO.... ... ?

R&D LUMINEU

Coherent elastic ν-nucleus scattering Ricochet, LZ, COHERENT

Sterile neutrinos: reactor experiments

	Source	Distance	Detector							
	P_{th} (MW)	L (m)	Depth (m.w.e.)	M_{target} (tons)	Gd	^{6}Li	^{10}B	Highly Segmented	Moving detector	First data
Nucifer (FRA)	70	7	13	0.8	■					2014
Poseidon (RU)	100	5-8	~15	~ 3	■					delayed
Stéréo (FRA)	57	8.8-12.4	18	1.75	■				■	2016
Neutrino 4 (RU)	100	6-12	~10	1.5	■				■	2015
Hanaro (KO)	2800	27	~15	0.5	◣	◥		■	■	2015
DANSS (RU)	3000	9.7-12.2	50	0.9	■			■		2015
Prospect (USA)	85	7-18	few	1 & 10	◣	◥		■	■	2017
SoLid (UK)	45-80	6-8	~10	2.9		■		■		2016
NuLat (USA)	85-1500	3-8	few	1		◣	◥	■	■	2017

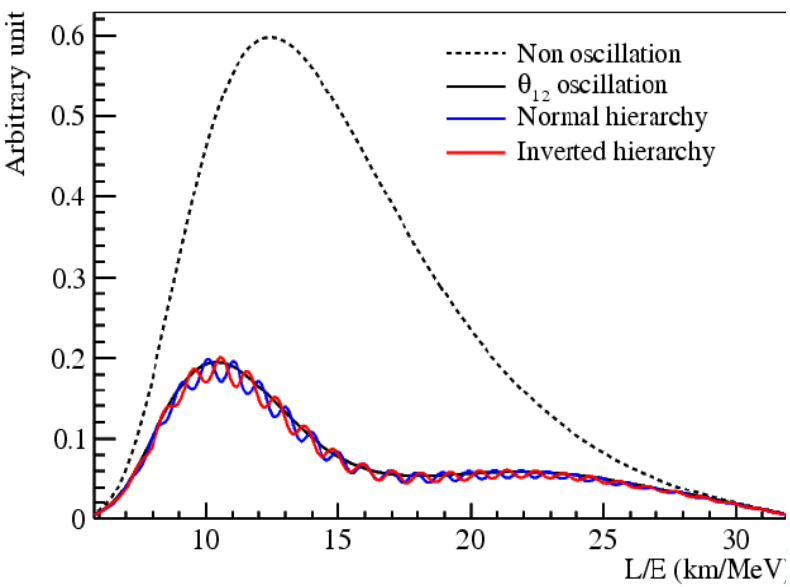
The JUNO experiment

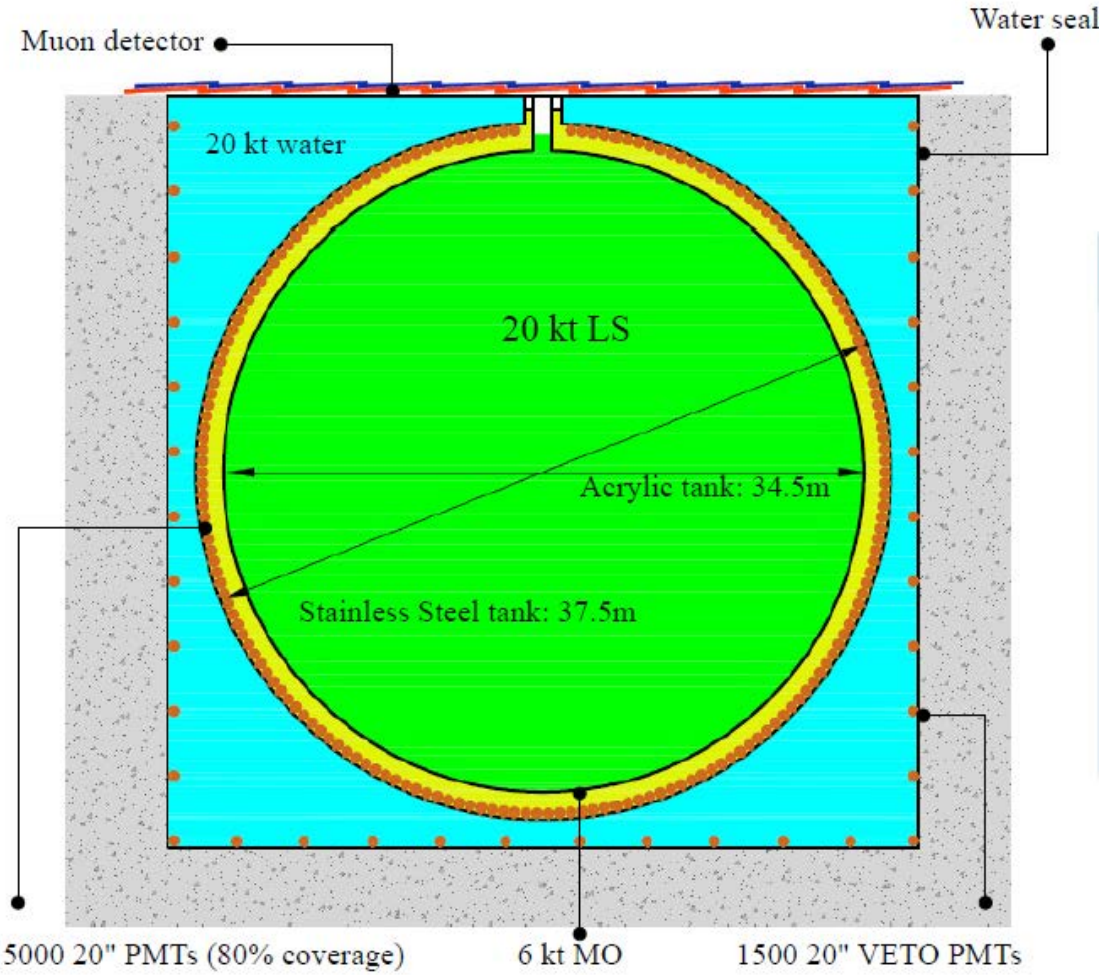
Main objective = mass hierarchy

"Side" measurements = precision measurements of oscillation parameters, Supernova, proton decay, geoneutrinos,...

Reactor neutrinos (China)

- Baseline : 53km-36GW.
- $\bar{\nu}_e$ energy : 2-8 MeV.
- 40 events / day.
- 3 to 4σ in 6 years.





The JUNO collaboration

⇒ 350 collaborators.

Europe : 20 labs (110 persons)

- France : VETO, electronics
  - APC : conception of electronics/online systems (3)
  - IPHC : Top Tracker from OPERA (10)
  - LLR : Detector response modelization / VETO optimization ? (4)
  - CPPM (2)
  - Subatech (1)
- Germany : Electronics → TUM, Hamburg, Mainz + Others.
- Italy : Scintillator + PMTs → 6 INFNs.
- Russia : PMT HV → JINR

Asia : 25 labs (235 persons)

- PMTs
- Calibration system.
- DAQ and Detector Monitoring.

US : not stated yet

Calibration system.

The DUNE experiment

Deep Underground Neutrino Experiment (DUNE) (former LBNE)

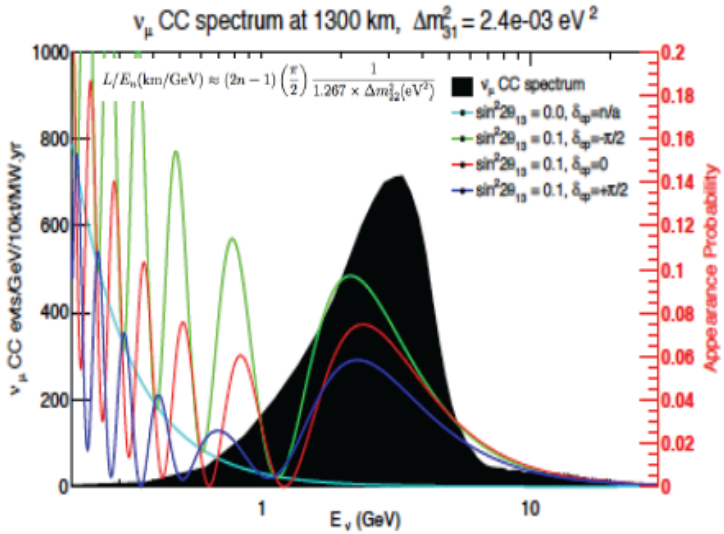
- Long-baseline neutrino experiment DUNE is proposed to consists of
  - -an intense neutrino beam originating at Fermilab
  - -near detector systems at Fermilab
  - -at least ~40 kt liquid argon time-projection chamber (TPC) at Sanford Laboratory at 4850 foot depth – 1300 km from Fermilab

Zelimir Djurcic, Maury Goodman
ANL HEP-PHY Neutrino Meeting, April 13, 2015.

The DUNE experiment

Experimental Technique

- Produce a pure muon-neutrino beam with energy spectrum matched to oscillation pattern at selected distance.
- Measure spectrum of ν_μ and ν_e at a distant detector.

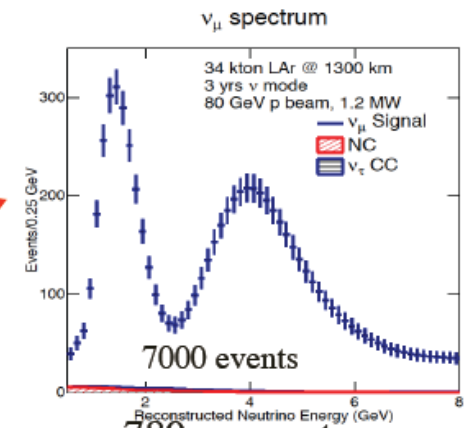


$$P(\nu_\mu \to \nu_e) \approx \sin^2 2\theta_{13} \sin^2\theta_{23} \frac{\sin^2(\Delta_{31} - aL)}{(\Delta_{31} - aL)^2}\Delta_{31}^2 + \alpha \sin 2\theta_{13} \cos\delta \frac{\sin(aL)}{(aL)} \frac{\sin(\Delta_{31} - aL)}{(\Delta_{31} - aL)} \cos\Delta_{32} - \alpha \sin 2\theta_{13} \sin\delta \frac{\sin(aL)}{(aL)} \frac{\sin(\Delta_{31} - aL)}{(\Delta_{31} - aL)} \sin\Delta_{32}$$

$$a = G_F N_e \sqrt{2}$$

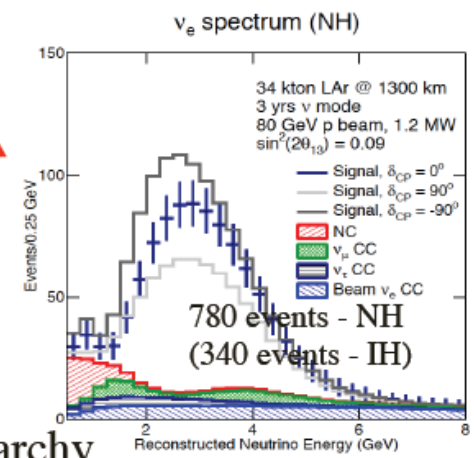
$$\Delta_{ij} = \frac{\Delta m_{ij}^2 L}{4E}$$

ν_μ disappearance



ν_e appearance

≈ 780 ν_e events



- LBNE is a good choice of beam and distance for sensitivity to CP-violation, CP-phase, neutrino mass hierarchy, and other oscillation parameters within the same experiment.

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Conclusions

- Still a lot of open questions in the neutrino field.
- Neutrino field has a lot of connections with other fields.
- For the future, identified french contributions concern mainly 3 ν mixing experiments (JUNO, DUNE).
- The LPSC group will work on STEREO at least until 2018 and later in case of positive signal.