L'esperimento JUNO e la gerarchia di massa

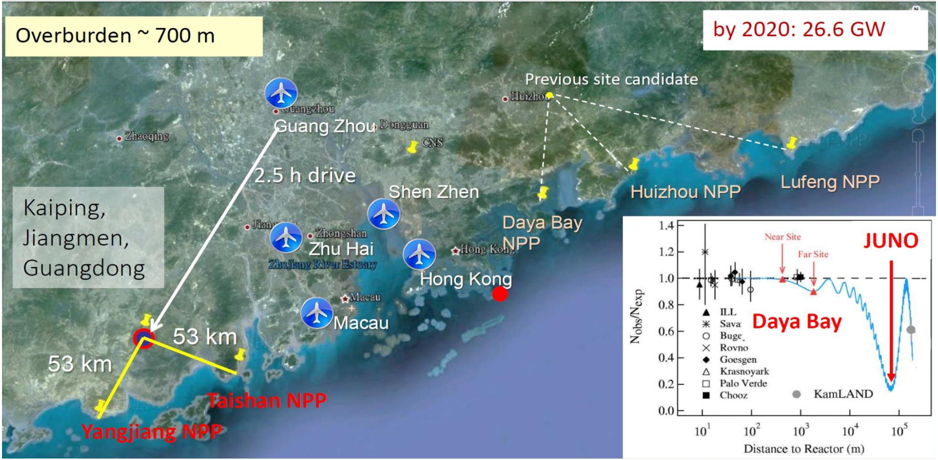
A. Garfagnini

Padova University and INFN

2 Dicembre 2014

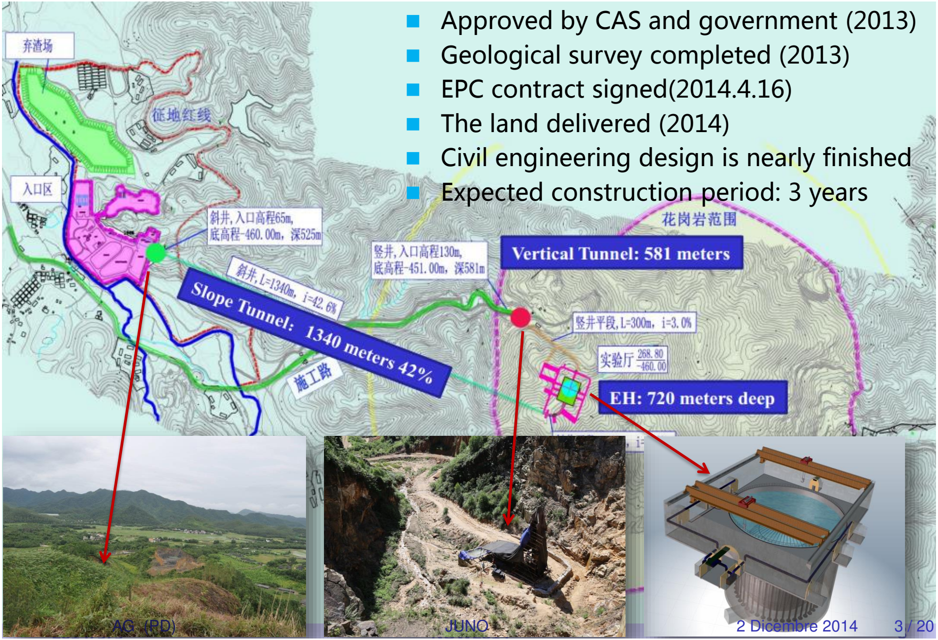
The experimental Site: Kaiping county, Jiangmeng

NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW

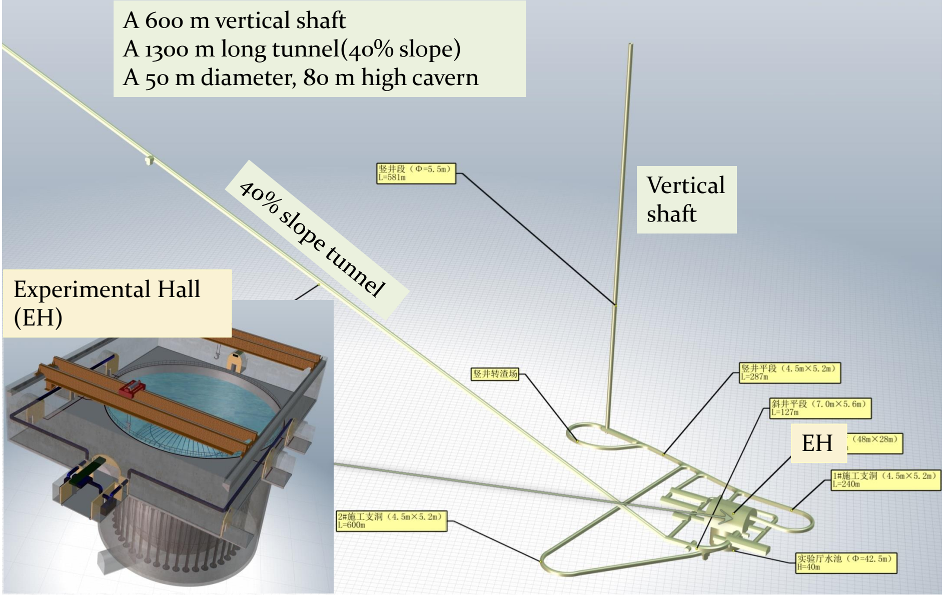


JUNO Civil Construction

- Approved by CAS and government (2013)
- Geological survey completed (2013)
- EPC contract signed(2014.4.16)
- The land delivered (2014)
- Civil engineering design is nearly finished
- Expected construction period: 3 years



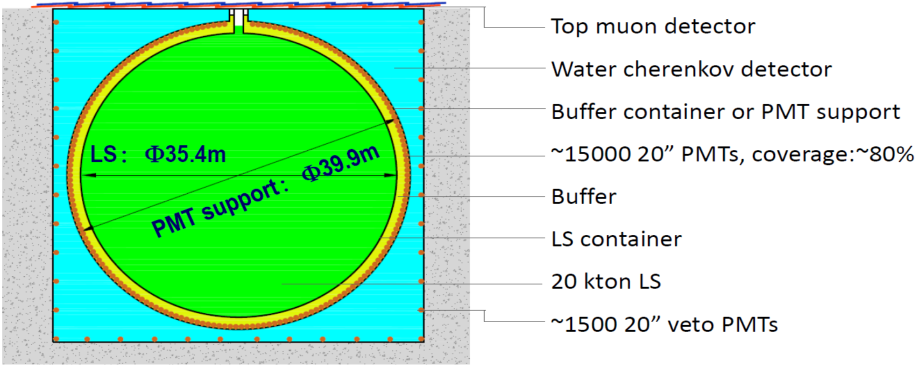
JUNO Underground



The JUNO detector concept

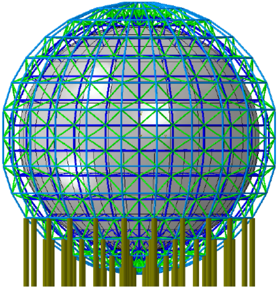
Requirements:
Large detector: **20 kt LS**
Energy resolution:
3%/√E → 1200 p.e./MeV

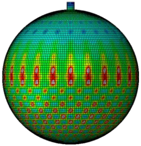
	KamLAND	JUNO
LS mass	**~1 kt**	**20 kt**
Energy Resolution	**6%/√E**	**3%/√E**
Light yield	**250 p.e./MeV**	**1200 p.e./MeV**



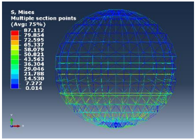
The JUNO Central Detector (baseline option)

- A large (D>35m) detector in the water pool
  - Mechanics, optics, chemistry, cleanness, assembly, …
- Default option: acrylic sphere + stainless steel truss
  - Independent designs from multiple groups
  - Acrylic performances research: strength, bonding, aging, creep
  - Connecting point R&D, making a part of sphere

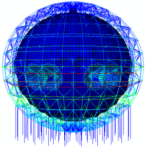




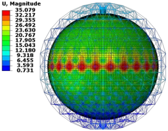
Stress analysis



0.1g seismic load

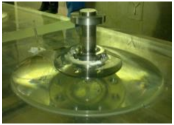


Double nonlinearity



Deflection analysis

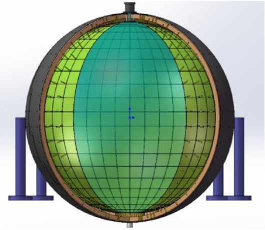
Aging test



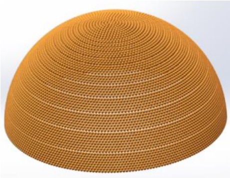
Connecting point test

The JUNO Central Detector (alternative option)

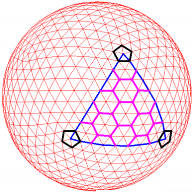
- Backup option : stainless steel tank + acrylic panel + balloon
  - Stainless steel tank design is in progress
  - Film material: ETFE/FEP/PEPA
  - Requirements to leakage and dust
  - 12 m prototype design is underway



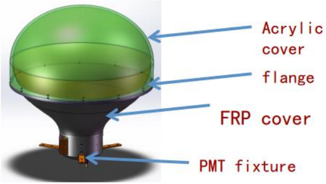
- PMT related
  - PMT coverage, implosion-proof, HV, sample test



Superlayer layout in latitude: >75%



Module layout: >75%

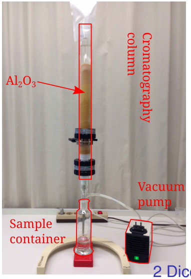


Possible implosion-proof structure

The JUNO Liquid Scintillator

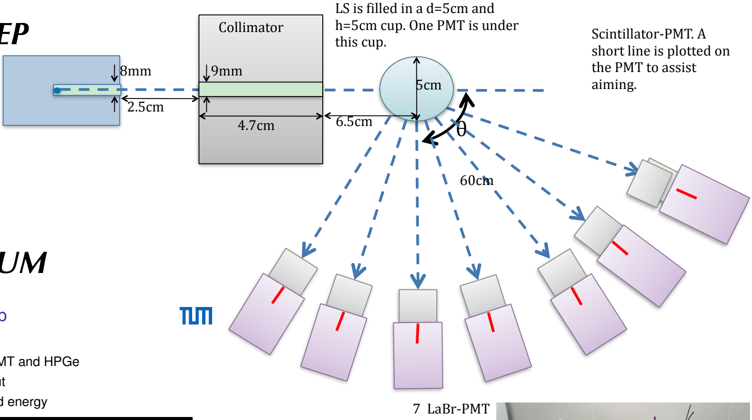
- JUNO LS: LAB + PPO + BisMSB :
  - ✓ no Gd doping: lower radioactivity
  - ✓ lower attenuation : 30 m (15 m in DYB)
- Important R&D effort :
  - ✓ improve raw materials
  - ✓ improve the production and the purification process:
  - ✓ colum purification (IHEP & TUM)
  - ✓ charcoal purification (IHEP & JINR)
  - ✓ vacuum distillation (IHEP & INFN)

Linear Alky Benzene (LAB)	Atte. L(m) @ 430 nm
RAW	14.2
Vacuum distillation	19.5
SiO_2 column	18.6
Al_2O_3 column	22.3
LAB from Nanjing, Raw	20
Al_2O_3 column	25



JUNO LAB Characterization measurements

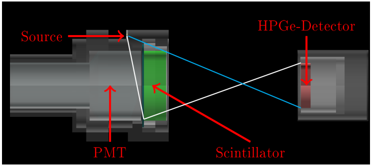
Setup I: IHEP

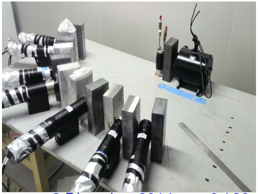


Setup II: TUM

Electron quenching: set-up

- Conincidence between PMT and HPGe
- PMT signal ⇒ Light output
- HPGe signal ⇒ Deposited energy



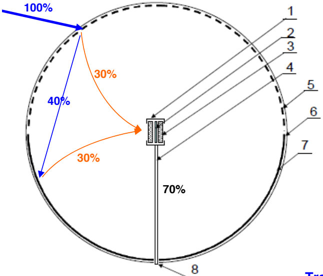


The JUNO PMT options

1) Using two sets of Microchannel plates (MCPs) to replace the dynode chain

2) Using transmission photocathode (front hemisphere) and reflection photocathode (back hemisphere) } **Fully active sphere surface**

JUNO PMT Plan A progressing well



1.Insulated trestle table

2.Anode

3.MCP dodule

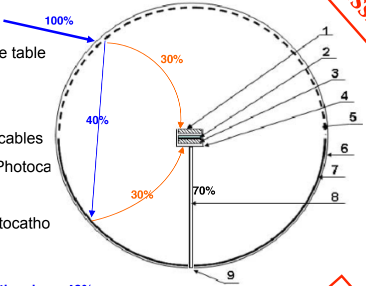
4.Bracket of the cables

5.Transmission Photoca

6.Glass shell

7.Reflection Photocatho

8.Glass joint



Transmission rate of the glass: 40%

Quantum Efficiency (QE) : of Transmission Photocathode 30% ; of Reflection Photocathode 30% ;

Collection Efficiency (CE) of MCP : 70%;

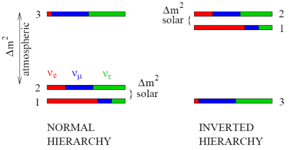
If nothing else changes, the detection efficiency (QE*CE) is nearly doubled by "saving" the ~40% transmitted photons.

3 Plans in Parallel by Collaborators

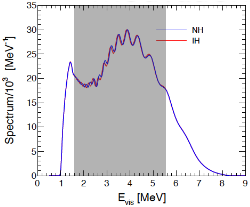
- **JUNO PMT plan B: Photonis China PMTs**
- **JUNO PMT plan C: new 20" Hamamatsu SBA high QE PMTs**

The energy resolution challenge

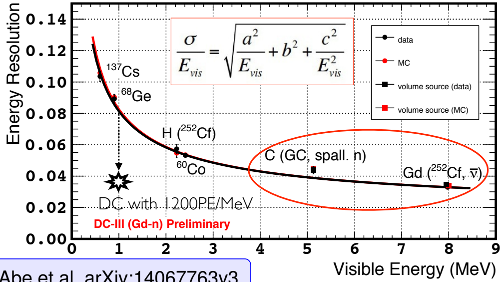
$\Delta m_{31}^2(IO) \neq \Delta m_{31}^2(NO) \Longrightarrow$ **δ~3%** (i.e. $\delta m^2/\Delta m^2$)



⊕



non-stochastic terms (b & c) have to be under control
and are very sensitive to the high energy level arm



a: statistical term
b: constant term
c: e.g. electric noise

Data
a=0.0773±0.0025
b=0.0182±0.0014
c=0.0174±0.0107

MC
a=0.0770±0.0018
b=0.0183±0.0011
c=0.0235±0.0061

Y. Abe et al, arXiv:14067763v3

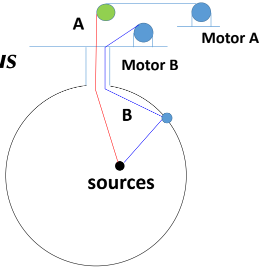
The Calibration system

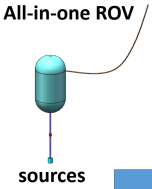
- Point radioactive source calibration systemx :
  - ✓ an automatic rope system is the primary source delivery system
  - ✓ a ROV is more versatile
  - ✓ a guide tube system covers the boundaries and near boundary regions

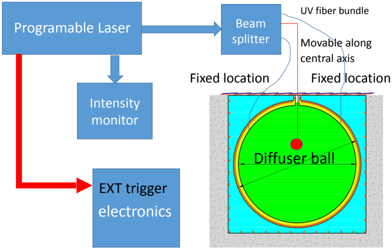
✓ considering short-lived diffuse radioactive sources to calibrate the detector response

✓ a UV laser system is being designed to calibrate the LS properties *in situ*

A-B rope synchronous motion







Pelletron as a positron beam calibration source

- Mature technology and commercially available:
  - ✓ is a positron gun to shoot positrons directly in the JUNO LS:
  - ✓ energy coverage: 0.5 – 6.5 MeV, uncertainty $< 10^{-4}$
  - ✓ can shoot both electrons and positrons and below 5 MeV cheaper than LINAC
  - ✓ energy can be calibrated with a dedicated system (Ge detector) to 0.1% level
  - ✓ excellent energy stability. Super-K LINAC e-beam calibration reached 0.6% absolute energy scale uncertainty

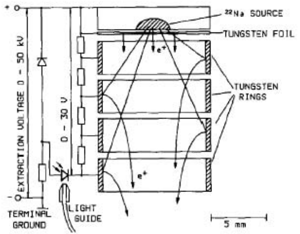
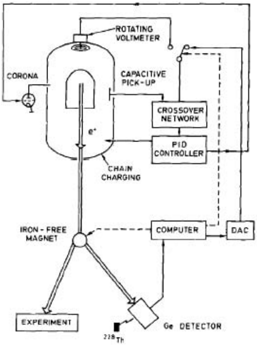
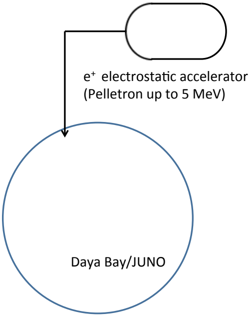


Fig. 1. Schematic of the slow-positron source with tungsten moderators.

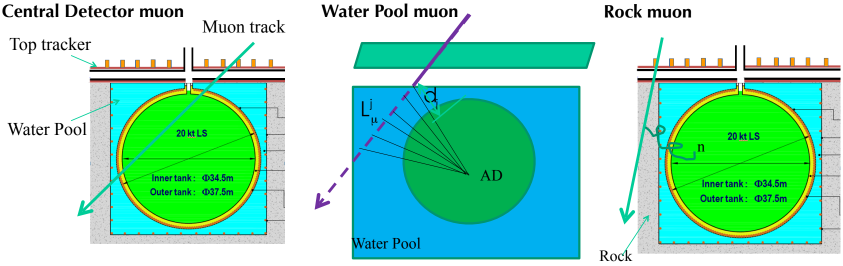
Bauer et al, The Stuttgart positron beam, its performance and recent experiments, NIM B50, 300 (1990)





The VETO system in JUNO

- the VETO system is an outer detector providing information to understand the cosmogenic background. It's made of:
  - ✓ a Water Cherenkov
  - ✓ a Top Tracker
- simulation and design studies are on going in order to optimize the design. Several options for the Top Tracker are being considered:
  - ✓ the OPERA Target Tracker (scintillator bars) will be moved to JUNO
  - ✓ other detectors technologies are under investigation



Backgrounds in JUNO

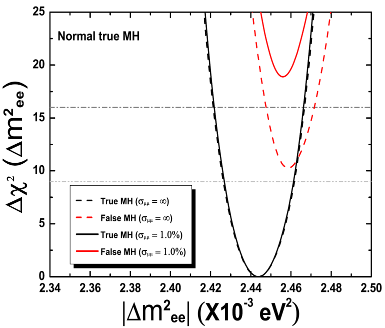
- expected IBD signal rate: $\sim$ 40 events/day
- expected backgrounds :
  - ✓ accidentals
  - ✓ fast neutrons
  - ✗ cosmogenic $^{9}Li/^{8}He$ production

Rock overburden: 700 m
$< E_\mu > \sim$ 200 GeV
$< R_\mu > \sim 3 - 4$ Hz

- ✓ accidentals will be reduced thanks to reduced PMT radioactivity and LS purification
- ✓ high muon detection efficiency is important for fast neutrons
- ✓ the biggest background contribution comes from cosmogenic $^{9}Li/^{8}He$

muon tracking in JUNO (Central Detector and Water Cherenkov + Top Tracker) is a key element

Expected Significance on Mass Hierarchy



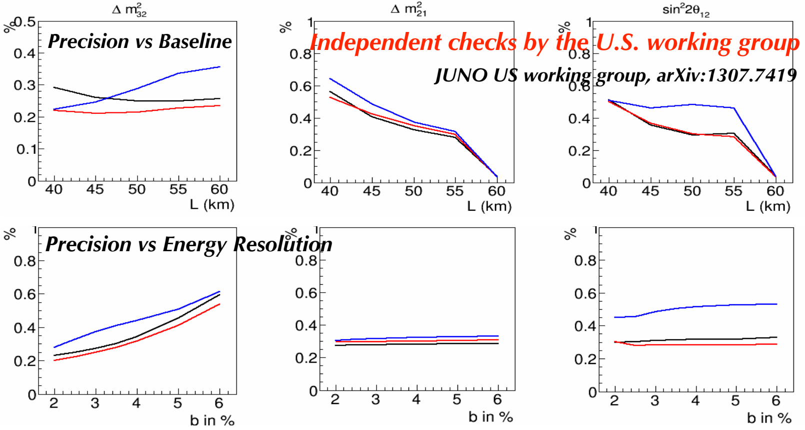
- ✓ 3σ if only a relative spectral measurement without external atmospheric mass-squared splitting inputs
- ✓ 4σ with an external Δm^2 measured to about 1% level in ν_μ beam oscillation experiments
- ✓ 1% in Δm^2 is based on combined T2K and NOvA analysis

  S.K. Agarwalla et al, arXiv:1312.1477

- ✓ realistic reactor distributions have been considered
- ✓ 20 kt target mass, 36 GW reactor power, 6-year running
- ✓ 3% energy resolution, 1% energy scale uncertainty assumed

Expected Precisions on Oscillation Parameters

	Nominal	+ B2B (1%)	+ BG	+ EL (1%)	+ NL (1%)
$\sin^2\theta_{12}$	0.54%	0.60%	0.62%	0.64%	0.67%
Δm^2_{21}	0.24%	0.27%	0.29%	0.44%	0.59%
$\lvert\Delta m^2_{ee}\rvert$	0.27%	0.31%	0.31%	0.35%	0.44%

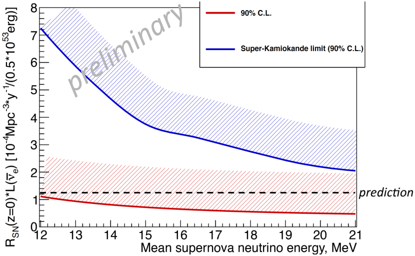


A Rich Physcis Program

- Supernova neutrinos
- Diffused supernova neutrinos
- Proton decay $P \rightarrow K^{+} + \bar{\nu}$

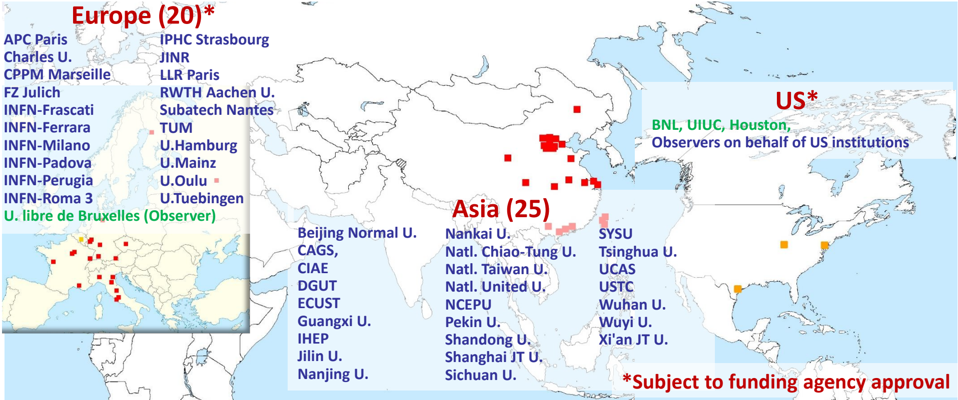
  $\tau > 1.9 \times 10^{34}$ yr (90% C.L.)
- Geoneutrinos
  - KamLAND: 30±7 TNU [PRD 88 (2013) 033001]
  - Borexino: 38.8±12.0 TNU [PLB 722 (2013) 295]
  - JUNO (preliminary): 37±10%(stat)±10%(syst)TNU

Channel	Type	Events for different $\langle E_\nu \rangle$ values		
		12 MeV	14 MeV	16 MeV
$\overline{\nu}_e + p \rightarrow e^+ + n$	CC	4.3×10^3	5.0×10^3	5.7×10^3
$\nu + p \rightarrow \nu + p$	NC	6.0×10^2	1.2×10^3	2.0×10^3
$\nu + e \rightarrow \nu + e$	NC	3.6×10^2	3.6×10^2	3.6×10^2
$\nu + {}^{12}\mathrm{C} \rightarrow \nu + {}^{12}\mathrm{C}^*$	NC	1.7×10^2	3.2×10^2	5.2×10^2
$\nu_e + {}^{12}\mathrm{C} \rightarrow e^- + {}^{12}\mathrm{N}$	CC	4.7×10^1	9.4×10^1	1.6×10^2
$\overline{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$	CC	6.0×10^1	1.1×10^2	1.6×10^2



- Solar neutrinos: high demand on the radioactive background purity. BOREXINO is the standard.
- Atmospheric neutrinos: not much value in redoing what Super-K has done. With JUNO's good energy resolution, atmospheric neutrinos could potentially aid the MH case (PINGU type signal)
- ......

The JUNO Collaboration



Europe (20)*

APC Paris
Charles U.
CPPM Marseille
FZ Julich
INFN-Frascati
INFN-Ferrara
INFN-Milano
INFN-Padova
INFN-Perugia
INFN-Roma 3
IPHC Strasbourg
JINR
LLR Paris
RWTH Aachen U.
Subatech Nantes
TUM
U.Hamburg
U.Mainz
U.Oulu
U.Tuebingen
U. libre de Bruxelles (Observer)

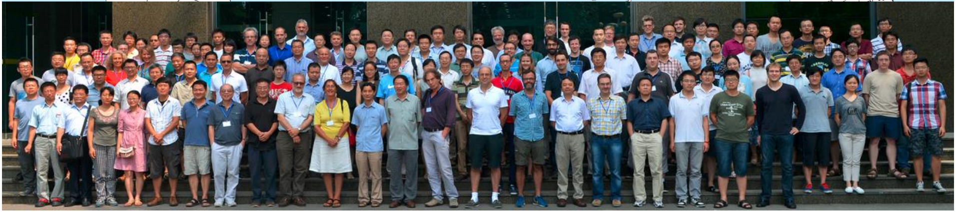
US*

BNL, UIUC, Houston,
Observers on behalf of US institutions

Asia (25)

Beijing Normal U.
CAGS,
CIAE
DGUT
ECUST
Guangxi U.
IHEP
Jilin U.
Nanjing U.
Nankai U.
Natl. Chiao-Tung U.
Natl. Taiwan U.
Natl. United U.
NCEPU
Pekin U.
Shandong U.
Shanghai JT U.
Sichuan U.
SYSU
Tsinghua U.
UCAS
USTC
Wuhan U.
Wuyi U.
Xi'an JT U.

*Subject to funding agency approval



The JUNO Schedule