The R&D progress of the Jinping Neutrino Experiment

Shaomin Chen (陈少敏)

(for the Jinping Neutrino Experiment research group)

Department of Engineering Physics

Tsinghua University

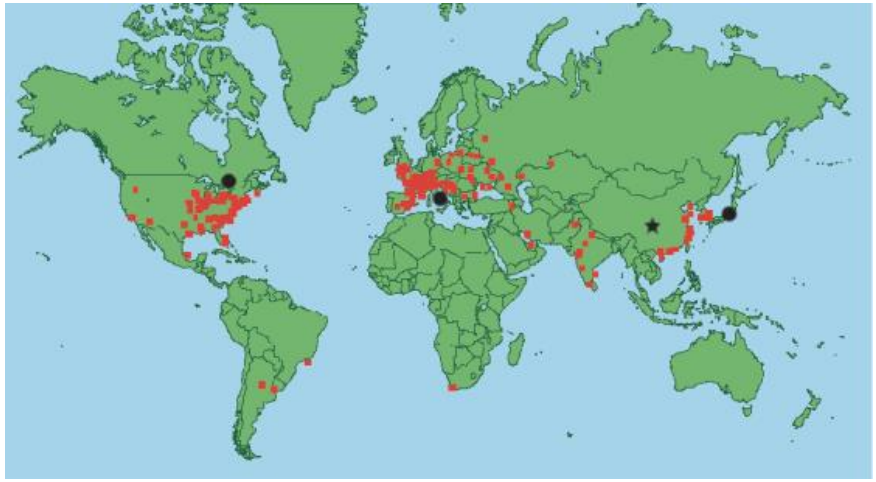
July 27, 2017@TAUP2017, Laurentian University

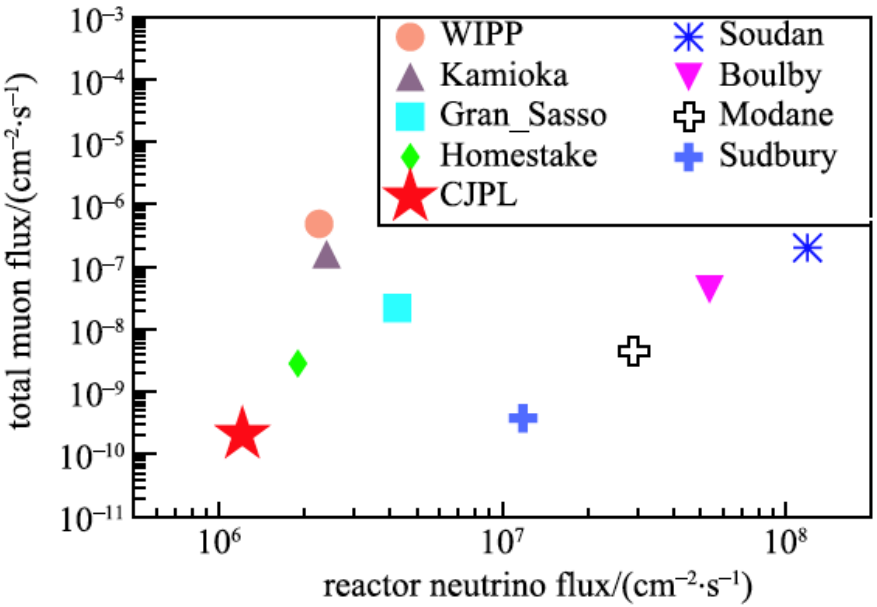
Outline

- **Jinping neutrino experiment proposal** (arXiv:1602.01733, arXiv:1607.01671, arXiv:1612.00133)
- **Detector concept: liquid scintillator Cherenkov** (arXiv:1511.09339)
- **Assay of stainless steel by smelting process** (arXiv:1706.04506)
- **Wide field-of-view and high-efficiency light concentrator** (arXiv:1703.07527)
- **One-ton prototype at Jinping** (NIMA 855 (2017) 81-87)

China JinPing underground Lab

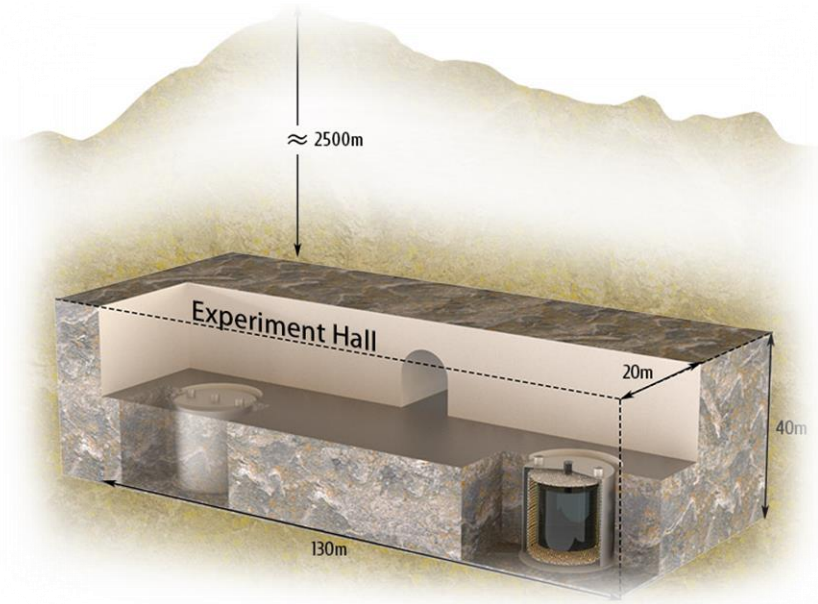
- Two 17-km long road tunnels below Jinping mountain with an overburden: ~2400 m.
- Totally evacuated space > 100k m^3 with possible expansion.
- Far away from nuclear power plants > 1000 km.
- Least radioactivity contamination.



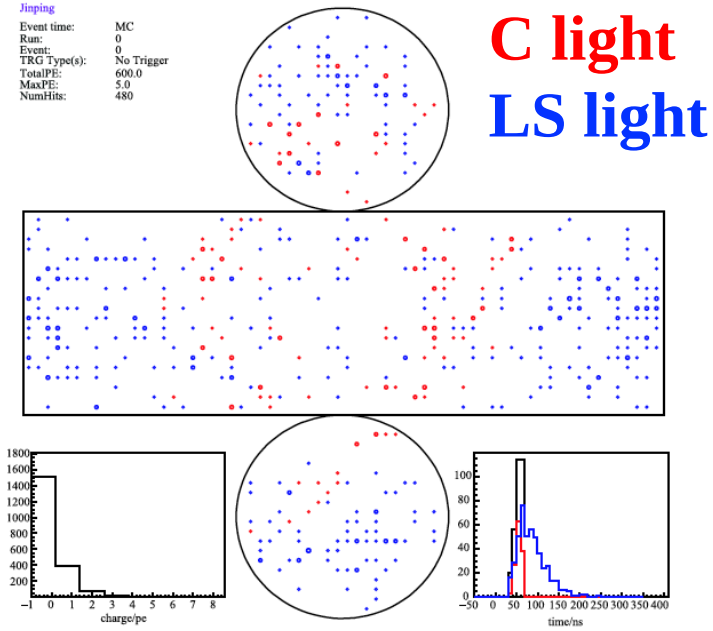


Detector concept

- ✓ **Two detectors with total fiducial mass 2000 tons (solar), 3000 tons (geo, supernova).**
- ✓ **LS or LSC (slow LS with directional info.).**
- ✓ **With similar low background level as Borexino.**
- ✓ **Light Yield > 500 pe/MeV.**



7 MeV electron



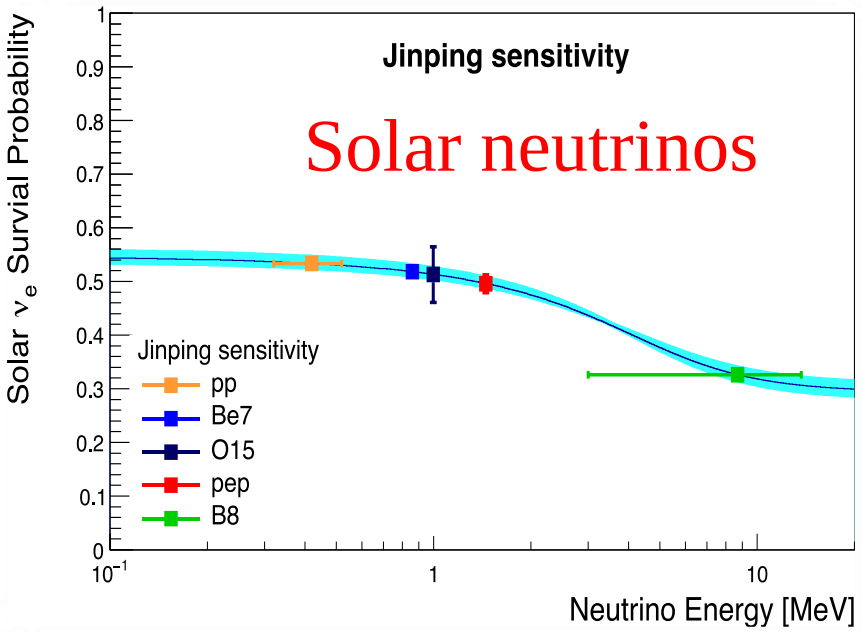
C light

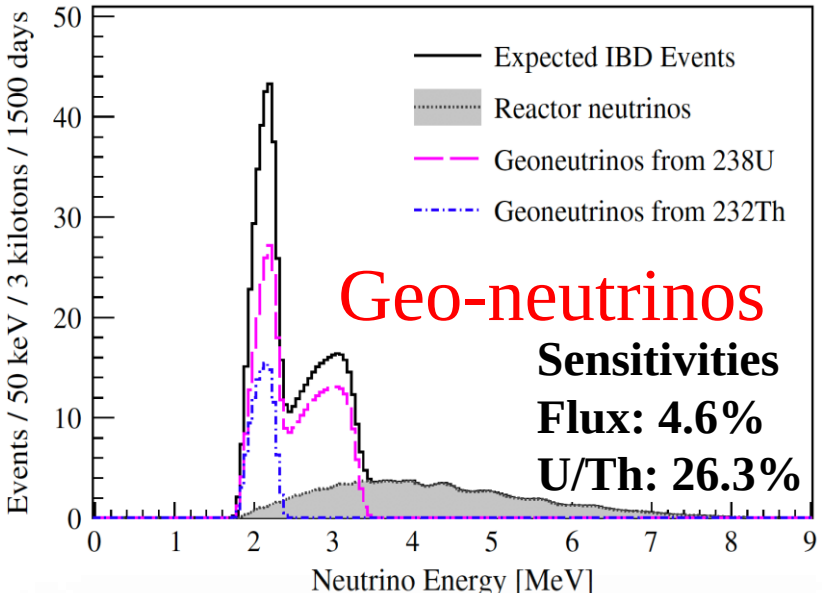
LS light

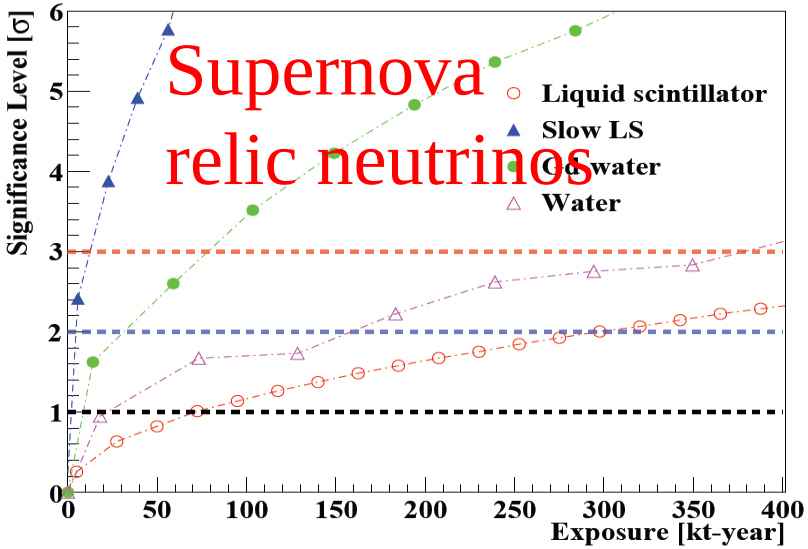
Jinping neutrino experiment

Physics motivations:

1. Geo-neutrinos
2. Solar neutrinos
3. Supernova neutrinos
4. Dark matter
5. …

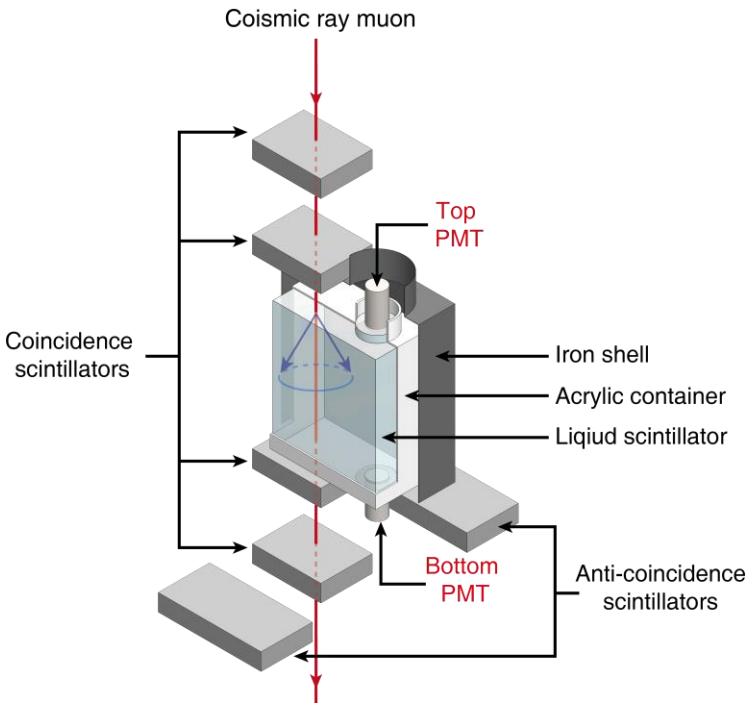


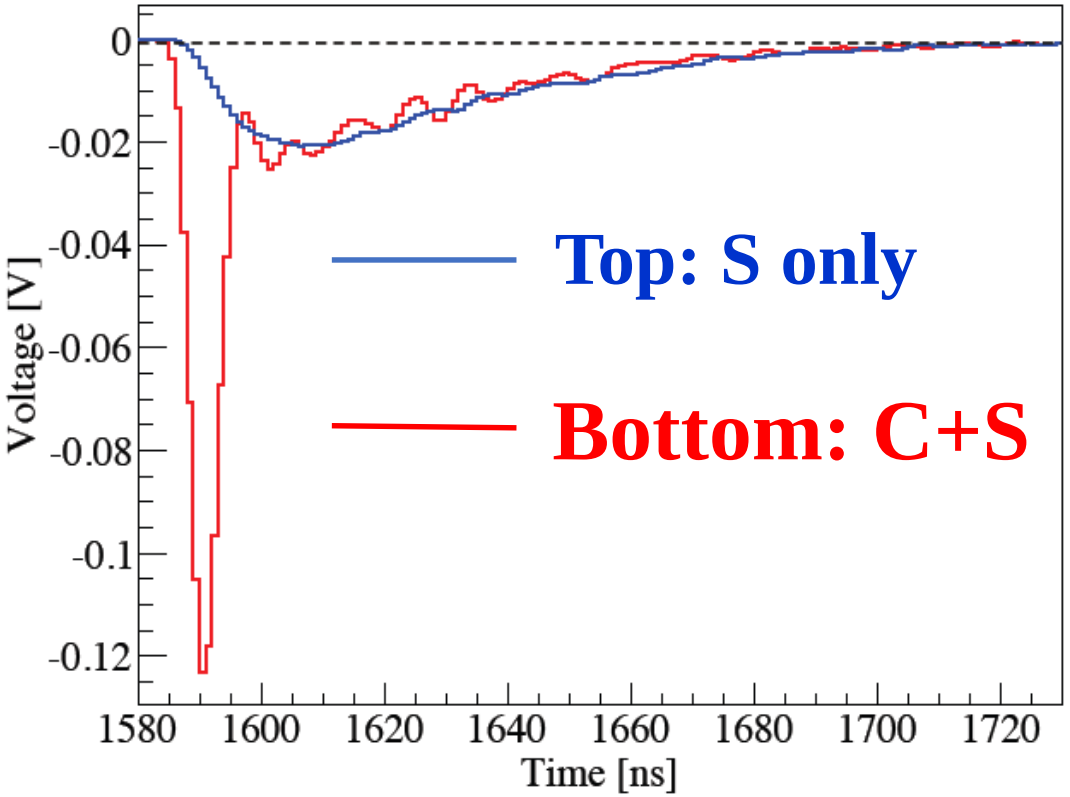




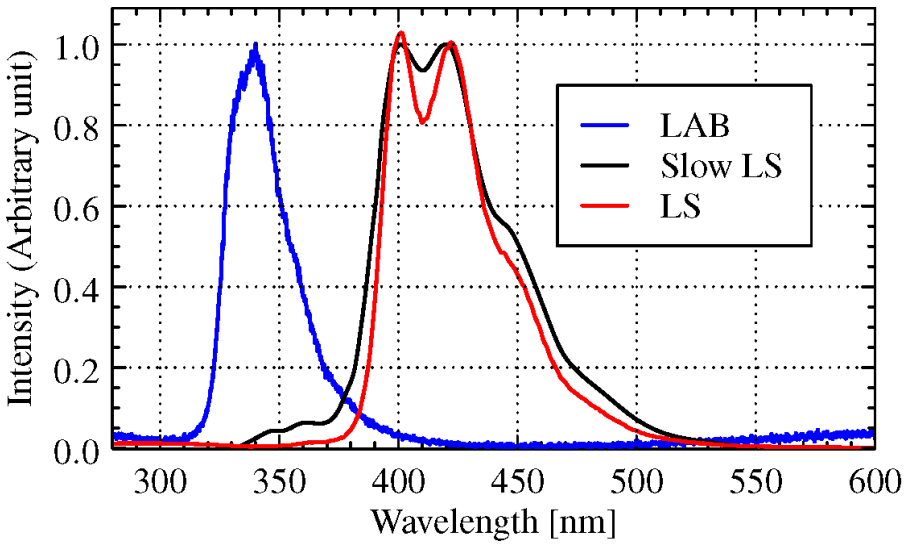
Liquid scintillator Cherenkov

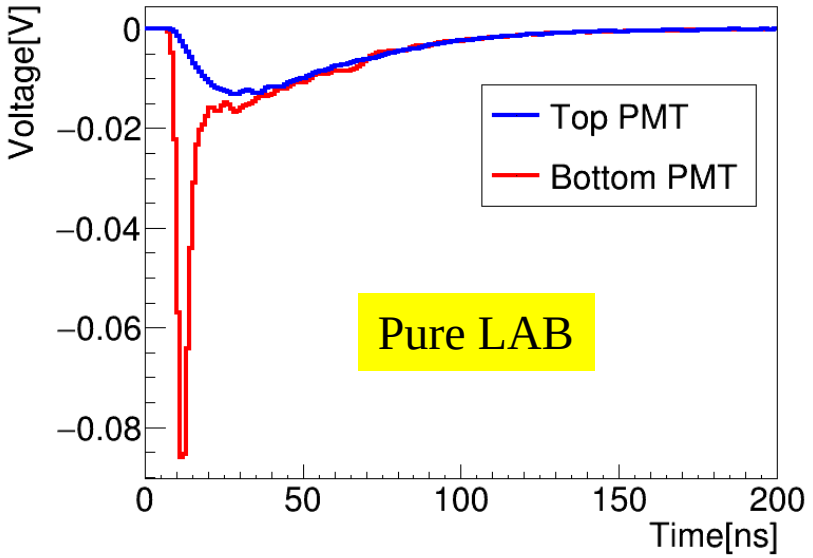
- ✓ **Test with down-going cosmic rays**
- ✓ **Check the waveforms of top and bottom PMTs in pure Linear Alkyl Benzene**

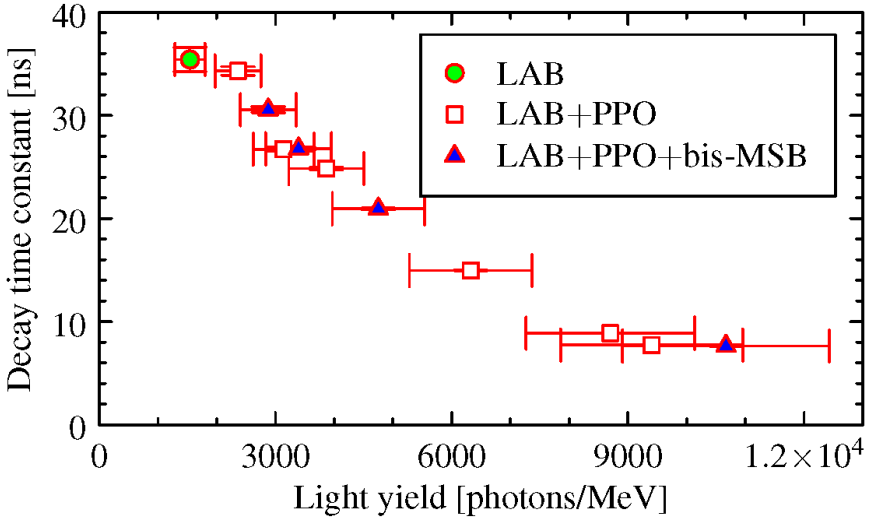


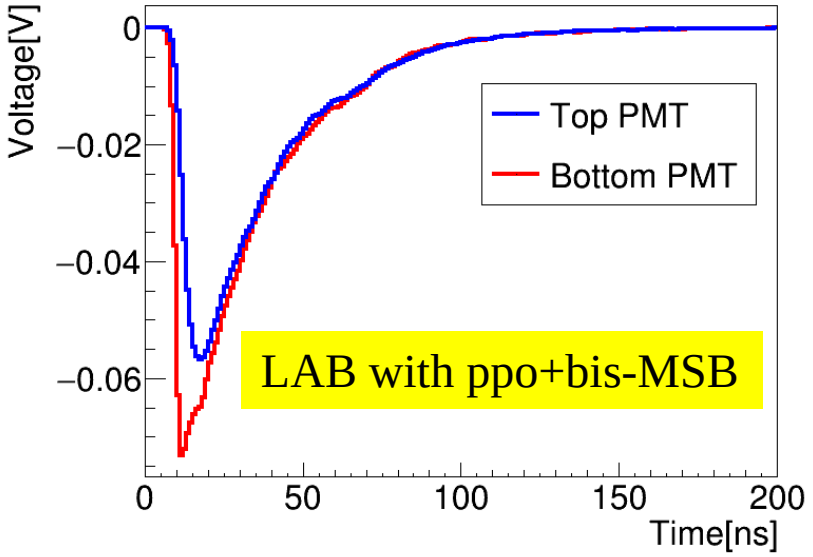


With PPO and bis-MSB









LSC parameters

1. Time constants

$$n(t) = \frac{\tau_r + \tau_d}{\tau_d^2}(1 - e^{t/\tau_r}) \cdot e^{t/t_d}$$

τ_r (ns) rise time

τ_d (ns) decay time

2. Light yield

$$L = \frac{D_{s,\exp}}{\varepsilon_{s,\mathrm{sim}} E_{\mathrm{vis}}}$$

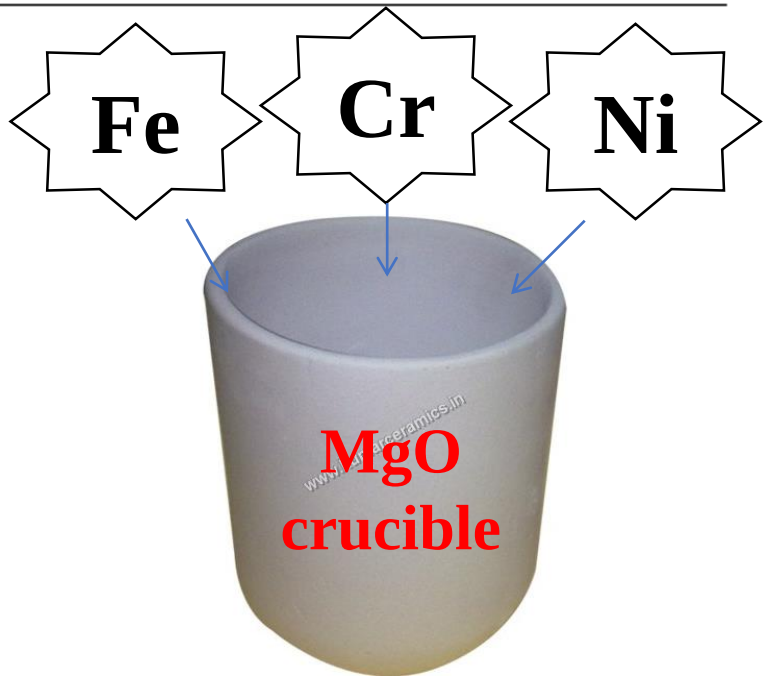
# of scintillation PEs

	τ_r (ns)	τ_d (ns)	L ($\times 10^3$ photon/MeV)	Attenuation length (m)
Pure LAB	7.7 ± 3.0	36.6 ± 2.4	1.01±0.12	19.52±0.39
LAB with ppo + bis-MSB	1.7 ± 0.1	26.6 ± 0.2	3.39±0.44	9.37±0.44

Assay of stainless steel by smelting process

The process uses 99.7% - 99.9% materials.

Element fraction (%)	Fe	Cr	Ni	C	Si	P	S	Mn	Mo
SST 304L	68	19.0	10.0	≤0.03	≤1.0	≤0.035	≤0.03	≤2.0	-
SST 316L	64	17	13.5	≤0.03	≤1.0	≤0.045	≤0.03	≤2.0	2.5



Samples and procedure test results

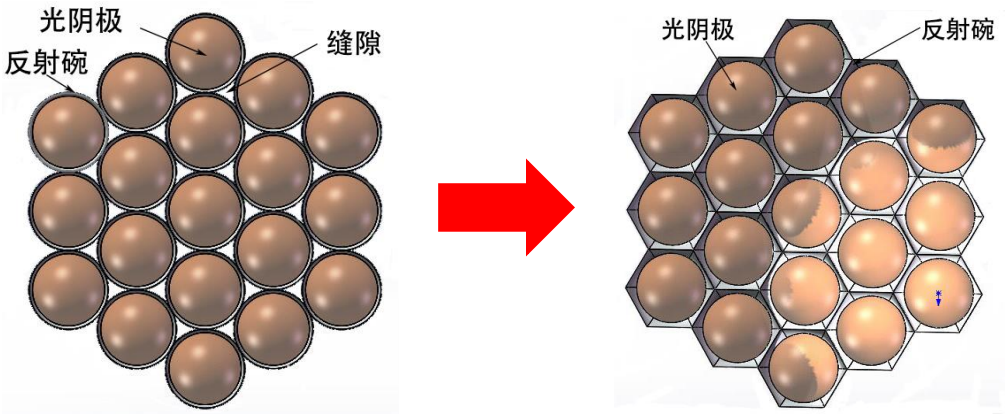
Analyzed by GDMS (1E-9 g/g), HPGe-groud (Bq/Kg), HPGe-Jinping (mBq/Kg)

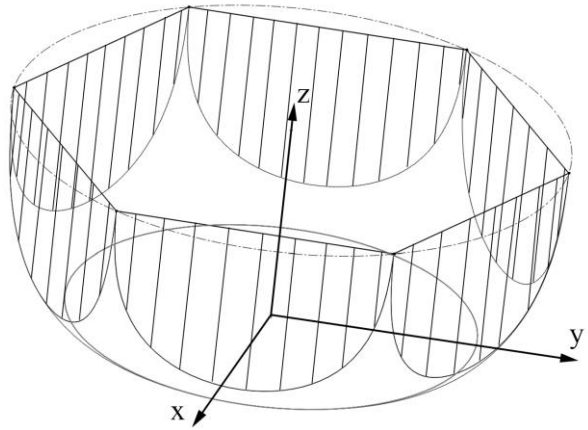
- ✓ C, Si, MgO sand: with significant radioactivity
- ✓ S, P: harmful to SST
- ✓ Mn is not 100% necessary
- ✓ Small impact from MgO crucible

mBq/kg	316-L	Borexino	NEXT
U-238	<5.4	4.6±0.9	32±9
Th-232	<2.0	11.4±1.2	1.9±0.2
K-40	<12.9	<14	3.2±0.7
Co-60	1.4±0.4	6±1	1.8±0.1

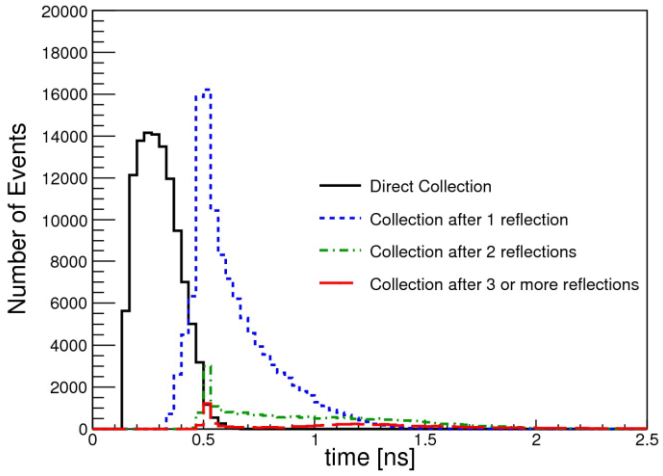
Light concentrator

Proposed a light concentrator with hexagonal opening to improve PMT coverage.

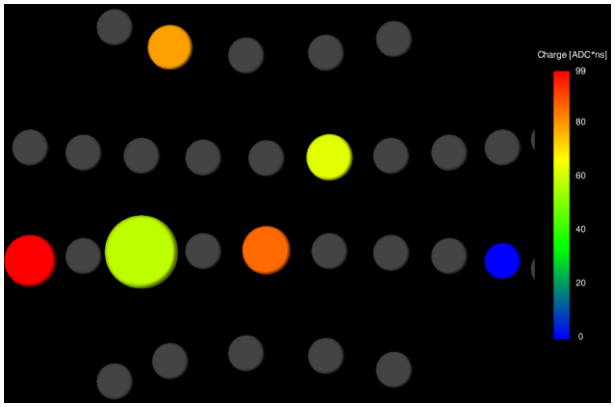




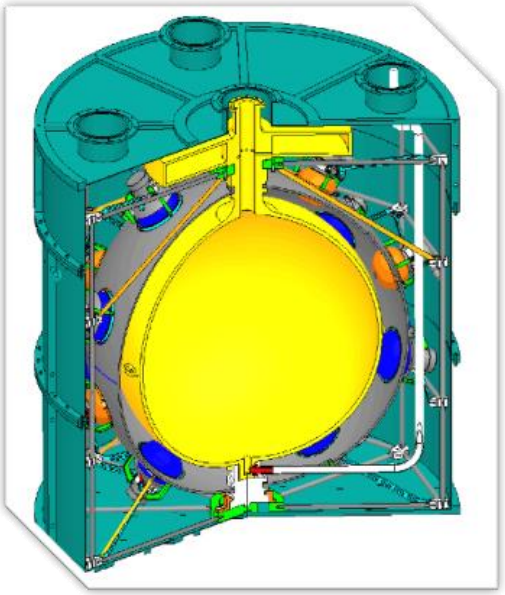
Coverage: ~100%.
Collection efficiency: > 97%.
Save nPMT: ~20%.
Time spread: ~ 2ns.



One-ton prototype at CJPL



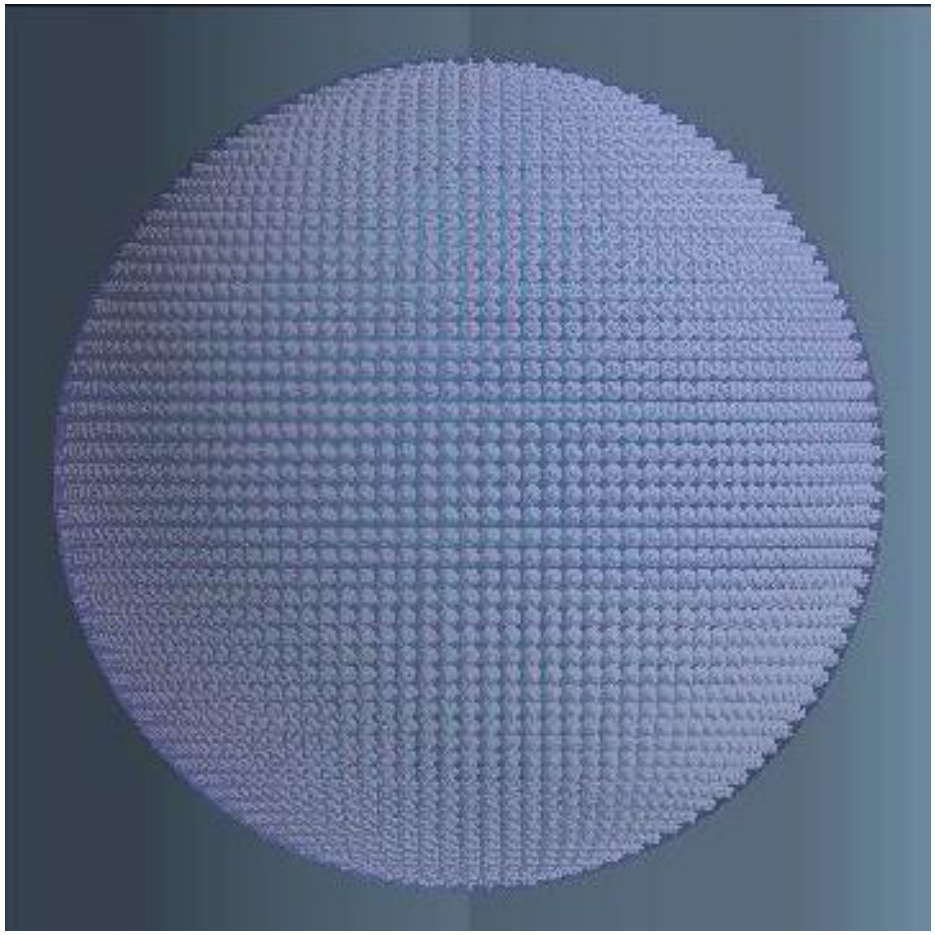
- **Motivations:**
  - Test the idea of LSC
  - Study PMT background
  - Measure neutron background
- **Status:**
  - Started with pure water mode in May
  - Will have a replacement of LSC this month



Jinping simulation & analysis package

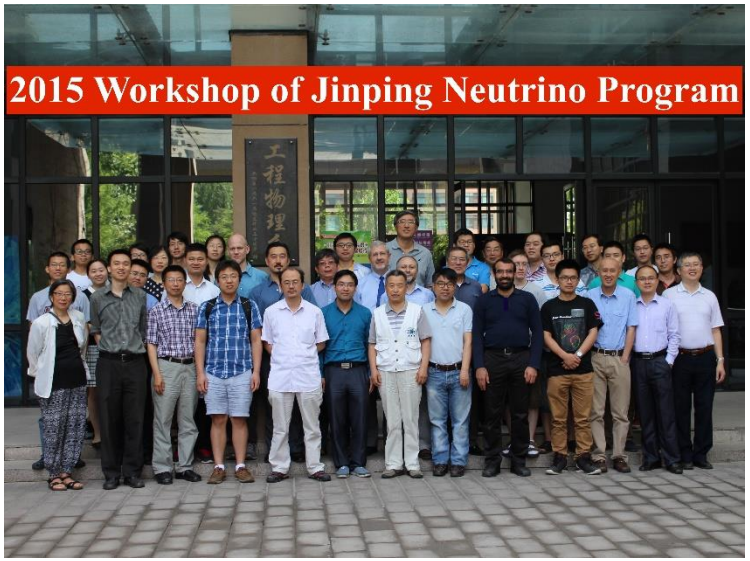
JSAP

1. **Comprehensive optical simulation**
2. **Flexible to different geometry setup**
3. **Waveform simulation**
4. **Flow style simulation G4->PMT->Elec-> Trigger**
5. **Doing Slow LS study**
6. **Doing Detector Optimization**

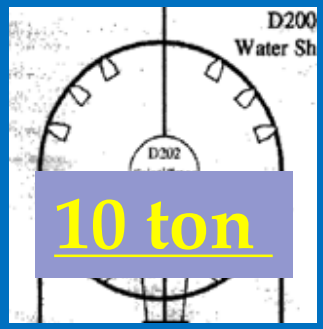


Workshop for Jinping ν experiment

1. **2015, 2017 two international workshops**
2. **Participants from:**
   Tsinghua, SYSU, Queen's University, UCAS, Guangxi University, Shandong University, BNL, University of Maryland, Technische Universität Dresden, Mainz University, Charles University, University of Michigan, Tohoku University, Nanjing University, Wuhan University



CJPL-II goes far ahead of us



2025, initial physics goals

18′-20′: TDR

20: kiloton detectors' construction

16′-18′: CDR

17-18: 10-ton Prototype, Slow LS and low bkg. Tech

14′-15′: LOI

16: 1 ton Prototype

14-15: 20 L Prototype

14-15: Physics Sensitivity, Baseline parameter

Summary

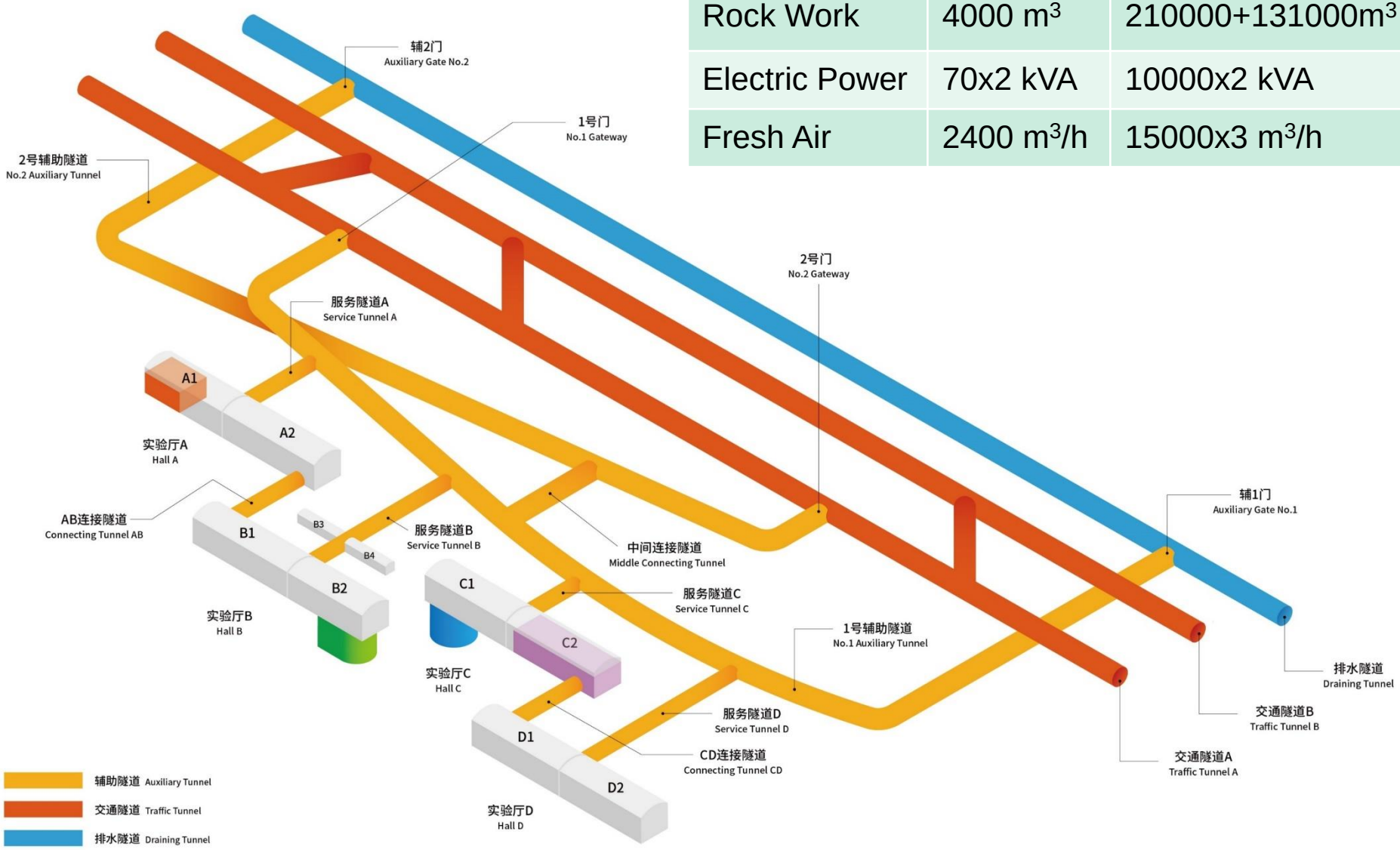
- **CJPL is ideal for the studies on geo, solar, and supernova relic neutrinos**
- **Significant progress of civic construction has been achieved.**
- **Many R&D efforts for Jinping neutrino experiment are on-going:**
  - ① **liquid scintillator Cherenkov**
  - ② **Assay of stainless steel by smelting process**
  - ③ **Light concentrator with hexagonal opening**
  - ④ **One-ton prototype is now running**
  - ⑤ **…**

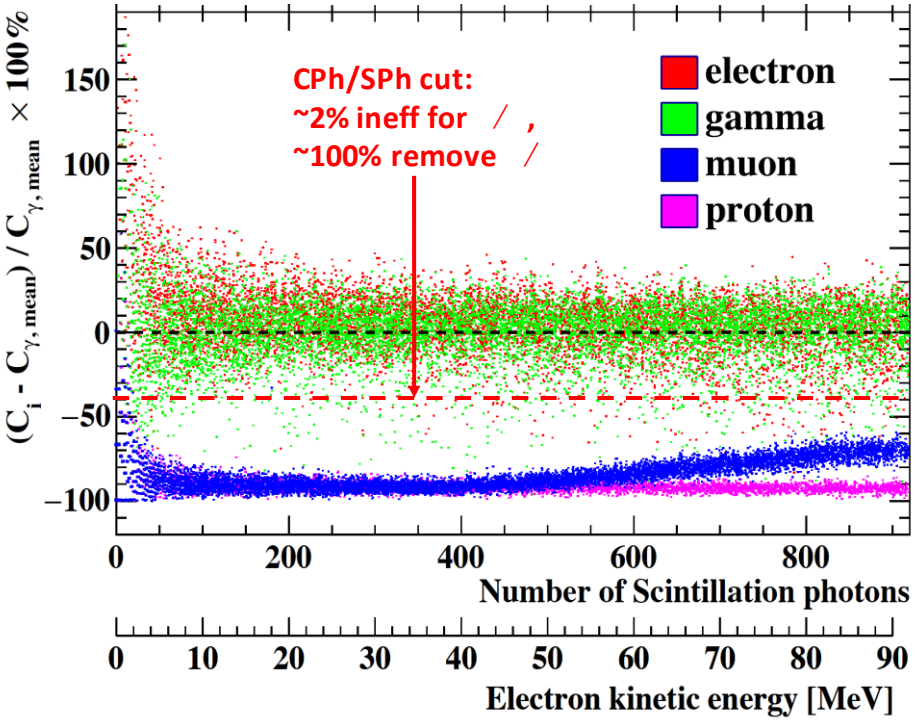
Thanks!

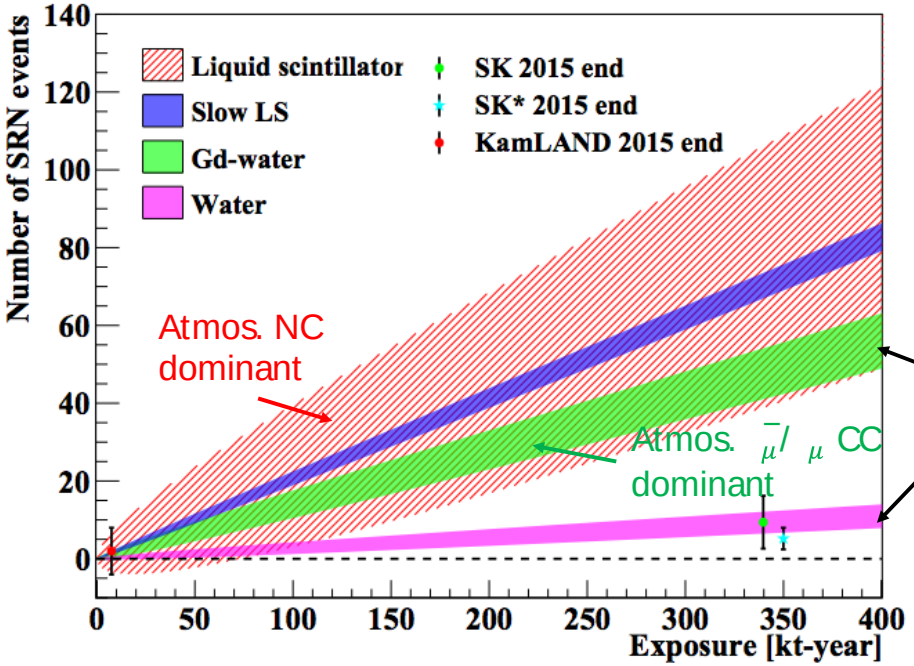
Backup slides

CJPL-II Layout

	CJPL-I	CJPL-II
Rock Work	4000 m^3	210000+131000m^3
Electric Power	70x2 kVA	10000x2 kVA
Fresh Air	2400 m^3/h	15000x3 m^3/h







Neutron tagging

Key issues in SRN detection

✓ Ignore the backgrounds induced by cosmic muons and reactor neutrinos, which are basically negligible at Jinping

	efficiency	Atmos. CC	Atmos. NC	Optical Photon to PMT
LS	~90%	**triple coin. from $\mu^{\pm}$, Michel $e^{\pm}$, and neutron capture** **$\mu^{\pm}$ visible in 10-30 MeV**	**Energetic neutrons (< 1GeV atmos. neutrinos considered due to strong quenching of neutron in LS)**	Scintillation
water w/o n-tag	~75%	**Michel $e^{\pm}$ from invisible $\mu^{\pm}$, reduced a lot by n-tag** **$\mu^{\pm}$ invisible in 10-30 MeV**	**Secondaries (decays) of n or $\pi^{\pm}/\pi^{0}$ (reduced by n-tag) below Cherenkov thresh or different hit pattern**	Cherenkov
water w/ n-tag	~10%			
Gd-water	~70%			

Green: advantage / Blue: disadvantage **Invisible muon: below Cherenkov threshold**

✓ **Solution: Cherenkov light + Scintillation light**

✓ **respective advantages + further suppress due to Cherenkov to Scintillation ratio**

Table 1. Radioactivity contamination in Bq/kg for some underground laboratories.

site	^{238}U	^{232}Th	^{40}K
Jinping	1.8±0.2 (^{226}Ra)	<0.27	<1.1
Sudbury	13.7±1.6	22.6±2.1	310±40
Gran Sasso hall A	116±12	12±0.4	307±8
Gran Sasso hall B	7.1±1.6	0.34±0.11	7±1.7
Gran Sasso hall C	11±2.3	0.37±0.13	4±1.9
Kamioka	∼12	∼10	∼520

	$coverage$ (%)	ε_{col} (%)	ε (%)	$nPMT(m^{-2})$
No reflectors	91	100	91	14.73
String method	91	86	78	7.97
Modified circular	91	90	82	8.73
String hexagon	100	94	94	10.64
Modified hexagon	100	97	97	11.65