The R&D progress of the Jinping Neutrino Experiment

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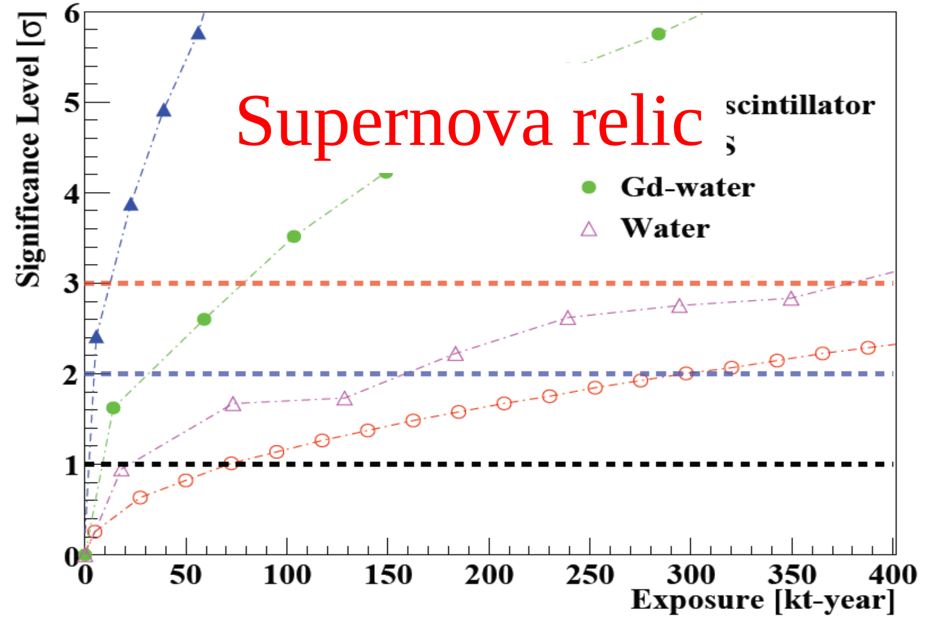
(for the Jinping Neutrino Experiment research group)

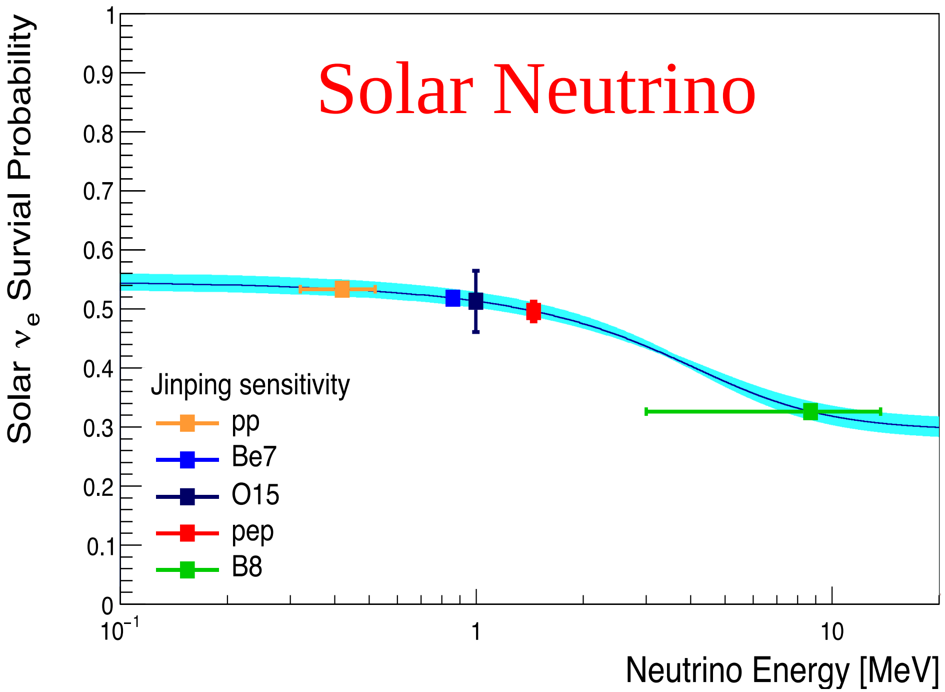
In this talk...

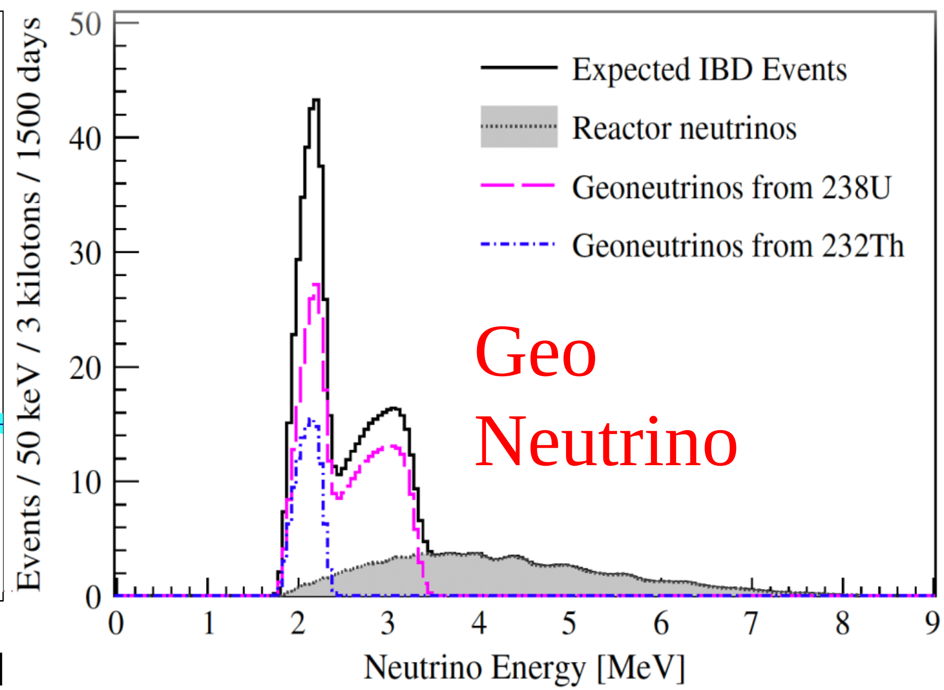
1. Jinping Neutrino Experiment proposal
2. Slow liquid scintillator
3. Assay of stainless steel by smelting process
4. Wide field-of-view and high-efficiency light concentrator
5. A 1-ton prototype at Jinping
6. Others

Jinping Neutrino Experiment

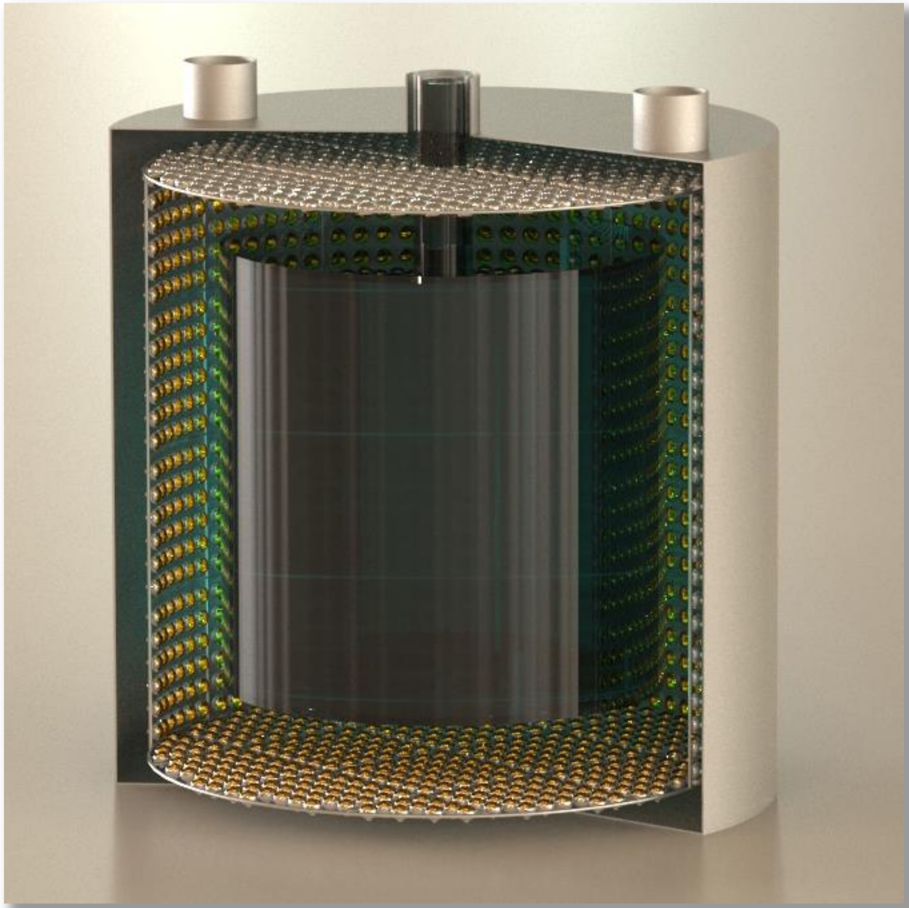
- Jinping underground laboratory
  1. 2400 m overburden
  2. 950 km from reactors
- Explore Solar, Geo, SRN neutrinos







Concept plot of the detector

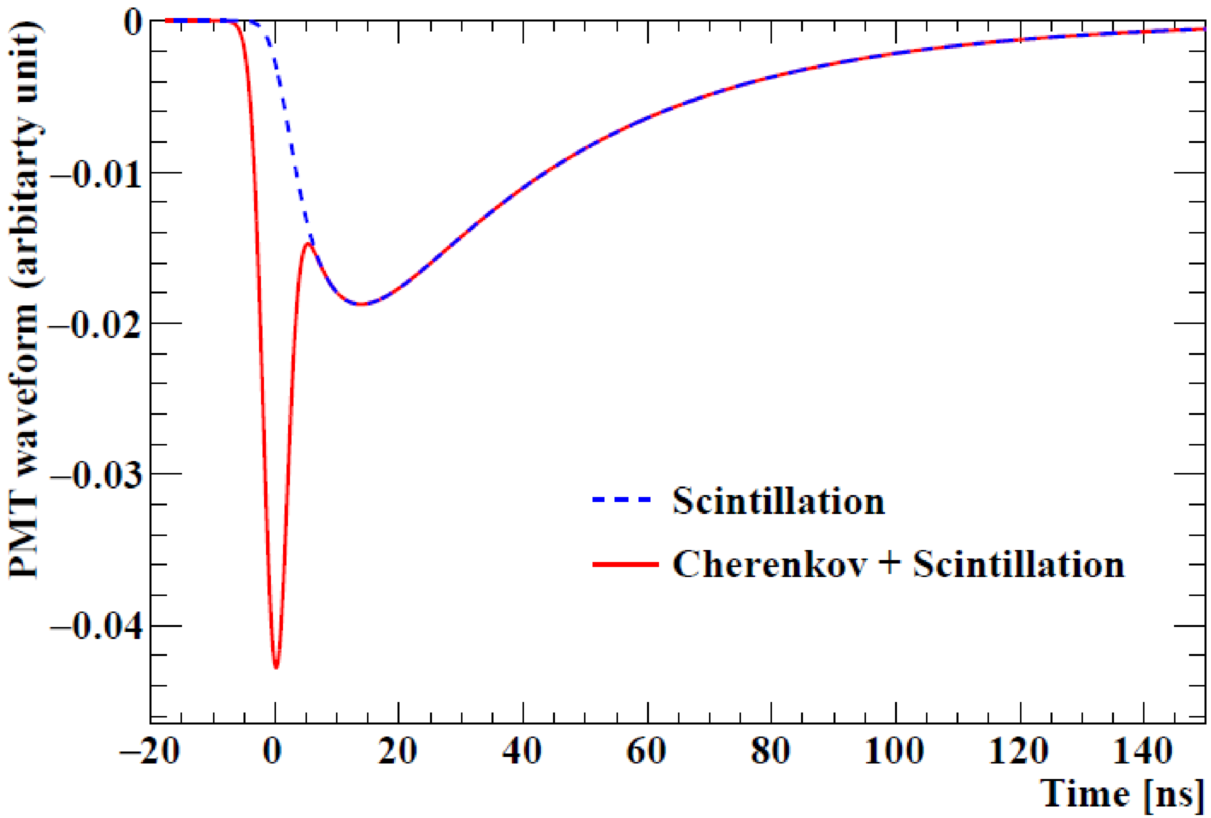


Or spherical detector

- TWO detectors
- Total fiducial mass 2000 tons (solar), 3000 tons (geo, supernova)
- Liquid scintillator or slow liquid scintillator
- ~20 m for height and diameter for each
- Light Yield>500 PE/MeV

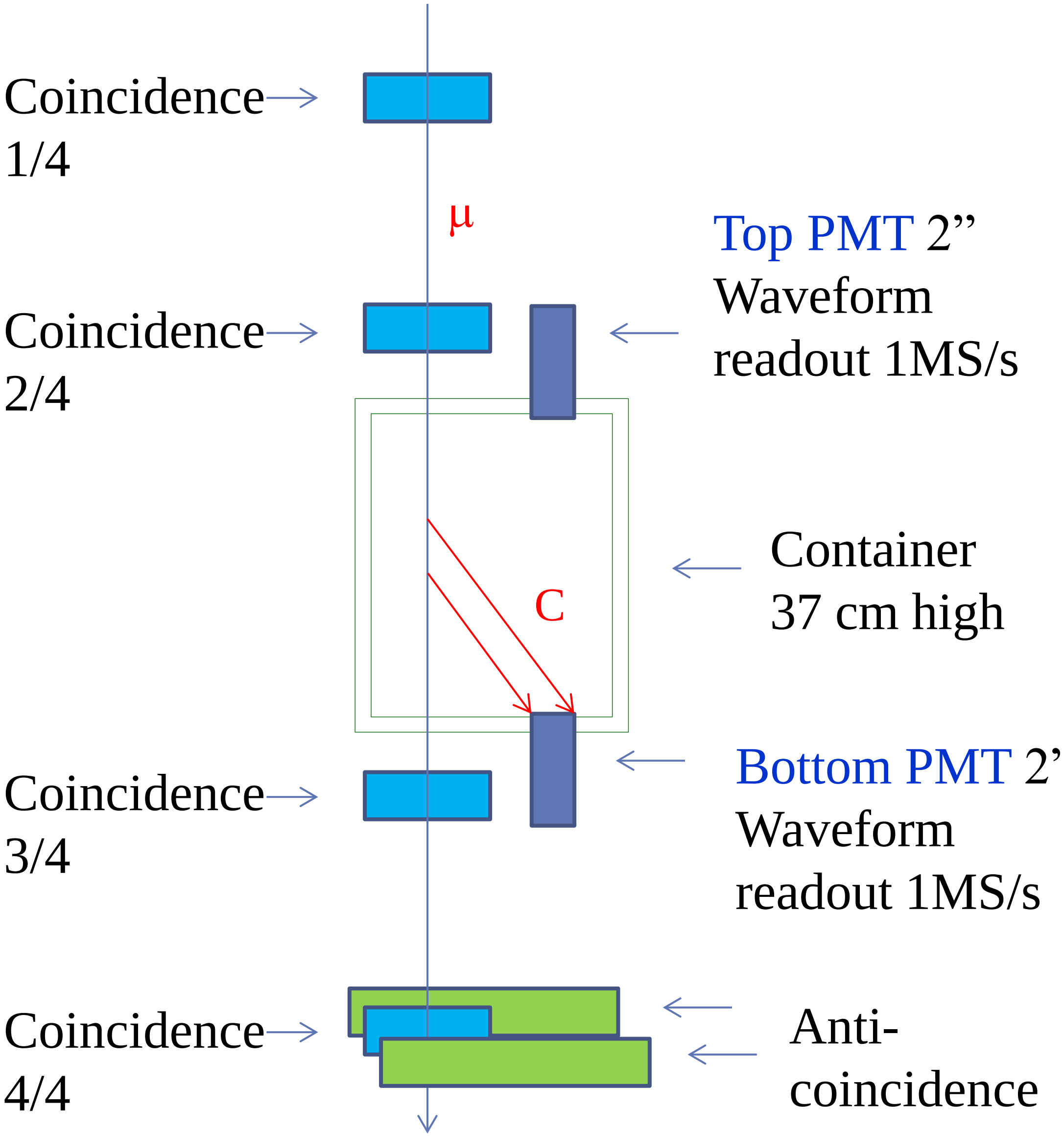
Slow liquid scintillator

1. With enough light yield
2. Scintillation emission time is slow
3. Distinguish Cherenkov and scintillation light



Impact on:
- SRN
- Proton decay
- $0\nu\beta\beta$
- neutrino beam usage

Apparatus

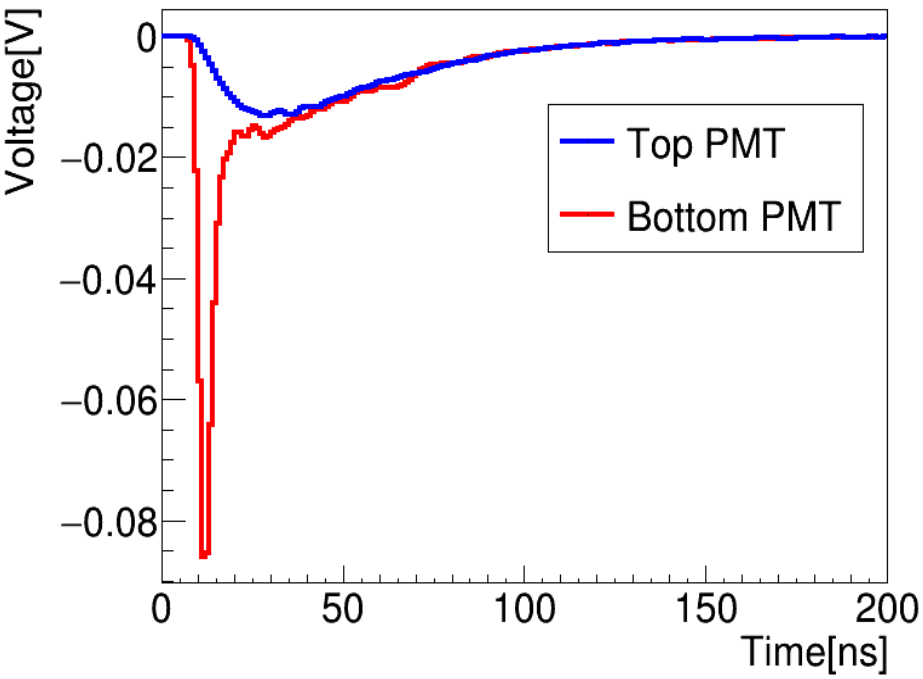


- Container with Low reflectivity inner surface
- Bottom PMT can see both Cherenkov light and scintillation light
- Top PMT can only see scintillation light
- Scintillation light is expected up-down symmetric

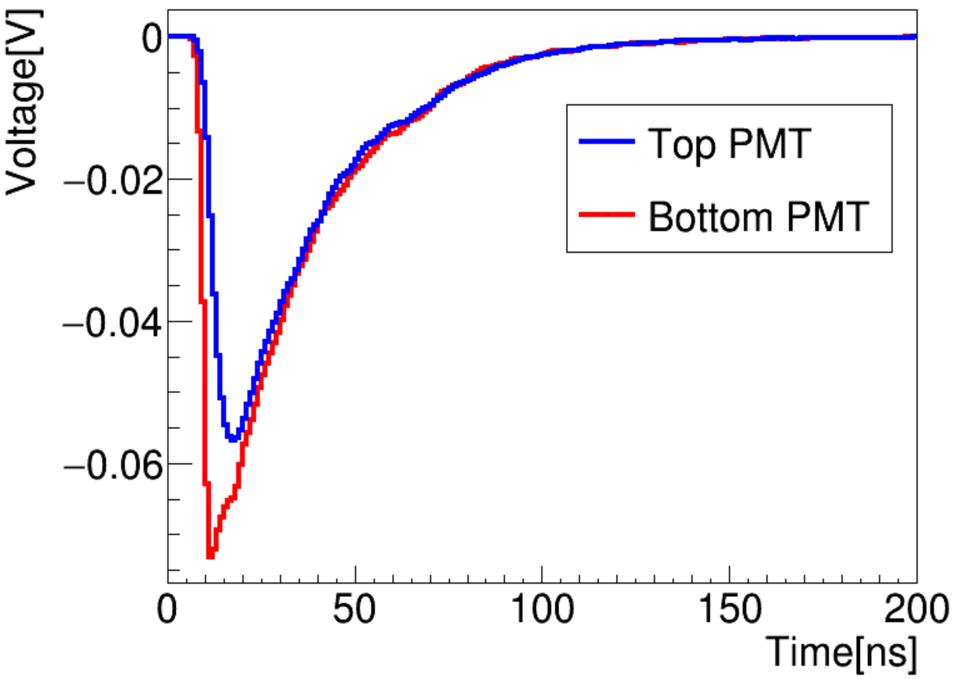
Slow liquid LS candidates

- Candidate A: Pure LAB
- Candidate B: LAB + PPO (0.07g/L) + Bis-MSB (13mg/L)

Candidate A:



Candidate B:



Slow LS Parameters

1. Time constants

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

2. Light yield

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

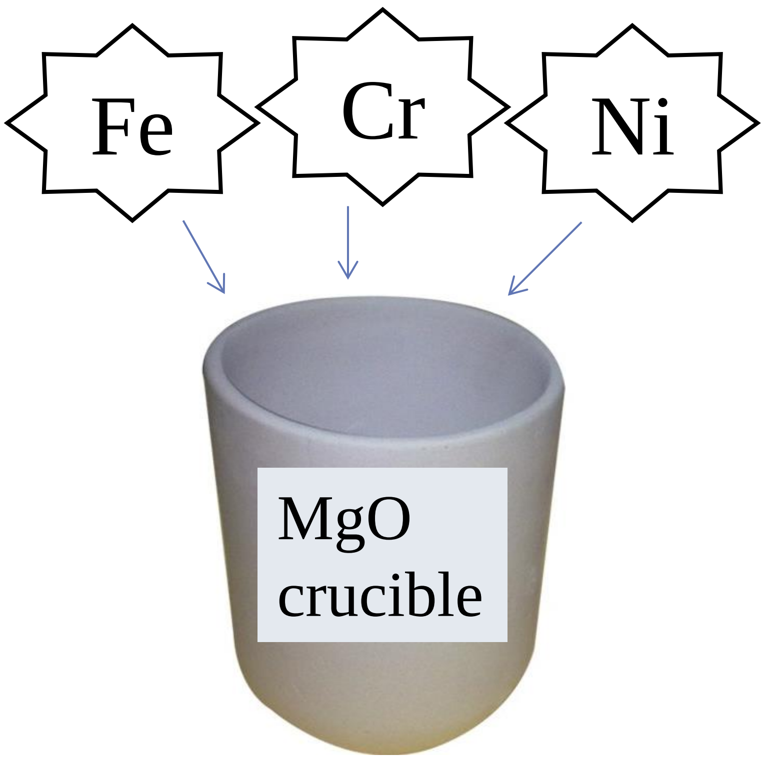
3. Attenuation length: 430nm in a 1-m long tube
4. Emission spectrum: A (<400 nm), B (>400 nm)

	Rising time constant (ns)	Decay time constant (ns)	Light yield (photons/MeV)	Attenuation length (m)
Candidate A	7.7 ± 3.0	36.6 ± 2.4	$(1.01 \pm 0.12) \times 10^3$	19.52 ± 0.39
Candidate B	1.7 ± 0.1	26.6 ± 0.2	$(3.39 \pm 0.44) \times 10^3$	9.37 ± 0.44

Stainless steel by smelting process

- The smelting process use 99.7% - 99.9% materials.

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



Sample and procedure test result

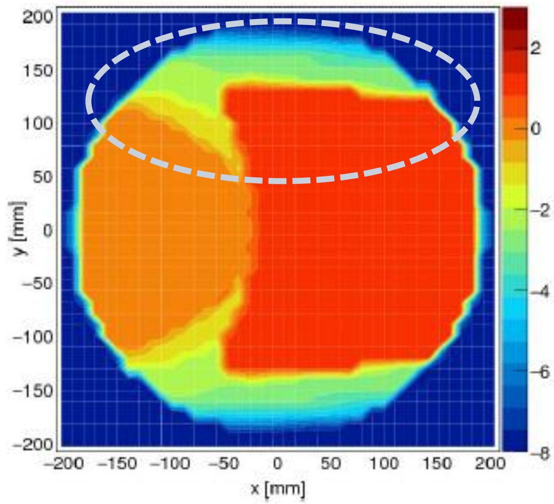
Analyzed by GDMS (1E-9 g/g), HPGe-groud (Bq/Kg), HPGe-Jinping (mBq/Kg)

1. C, Si, MgO sand: have a significant radioactivity
2. S, P: harmful to SST
3. Mn is not 100% necessary
4. Settle down on Fe, Cr, Ni (304L), Mo (316L)
5. Small impact from MgO crucible

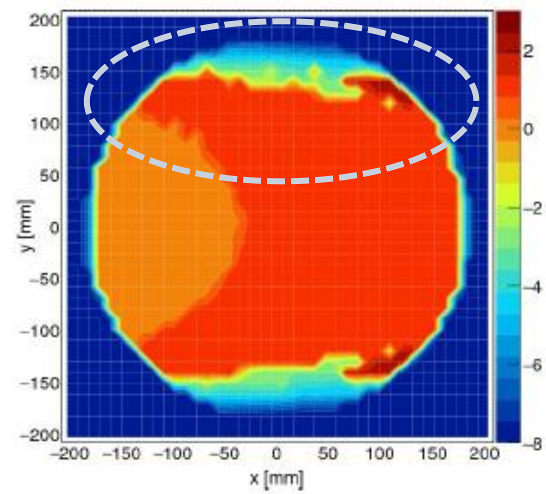
mBq/kg	316L	Borexino	NEXT
U-238	<5.4	4.6 ±0.9	32 ±9
Th-232	<2.0	11.4 ±1.2	1.9 ±0.2
K-40	<12.9	<14	3.2 ±0.7
Co-60	1.4 ±0.4	6 ±1	1.8 ±0.1

Wide field-of-view and high-efficiency light concentrator

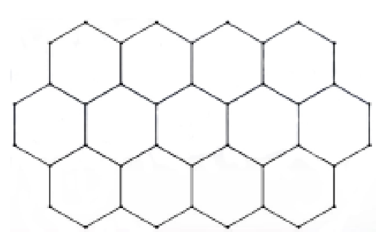
- Solar neutrino physics need high light yield.
- We add two more ideas to the String Method
  1. Consider the 3D geometry profile of PMT

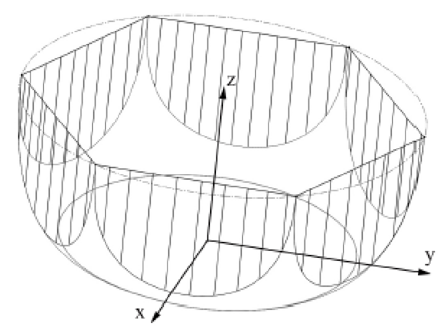


More light accepted

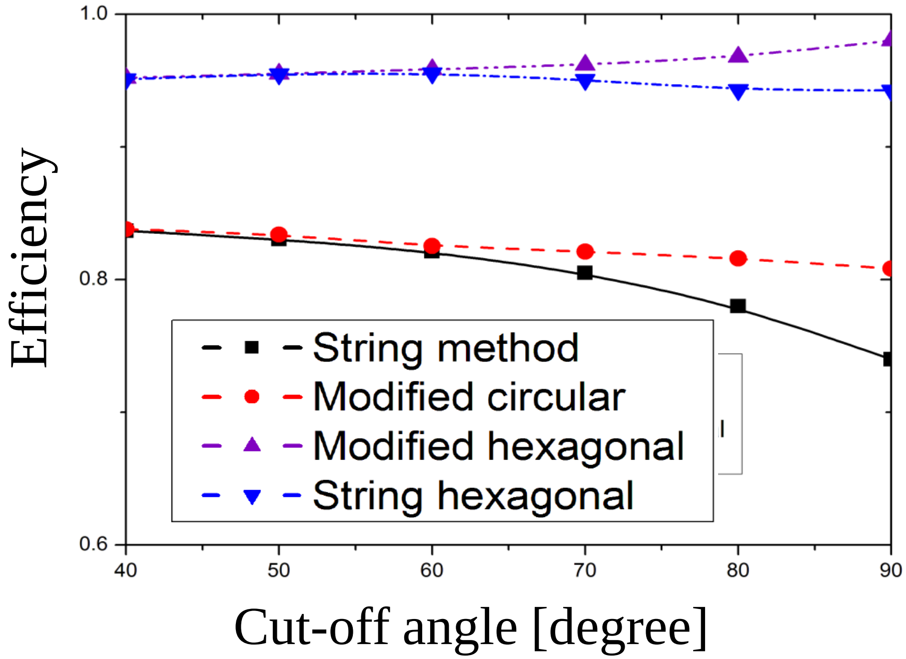


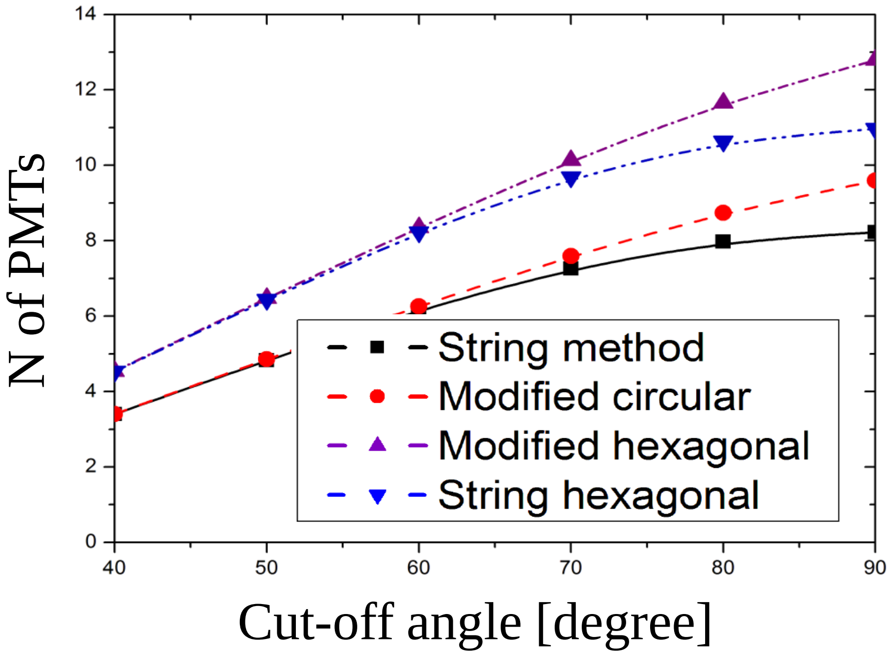
  2. Use hexagonal opening





Acceptance and numbers



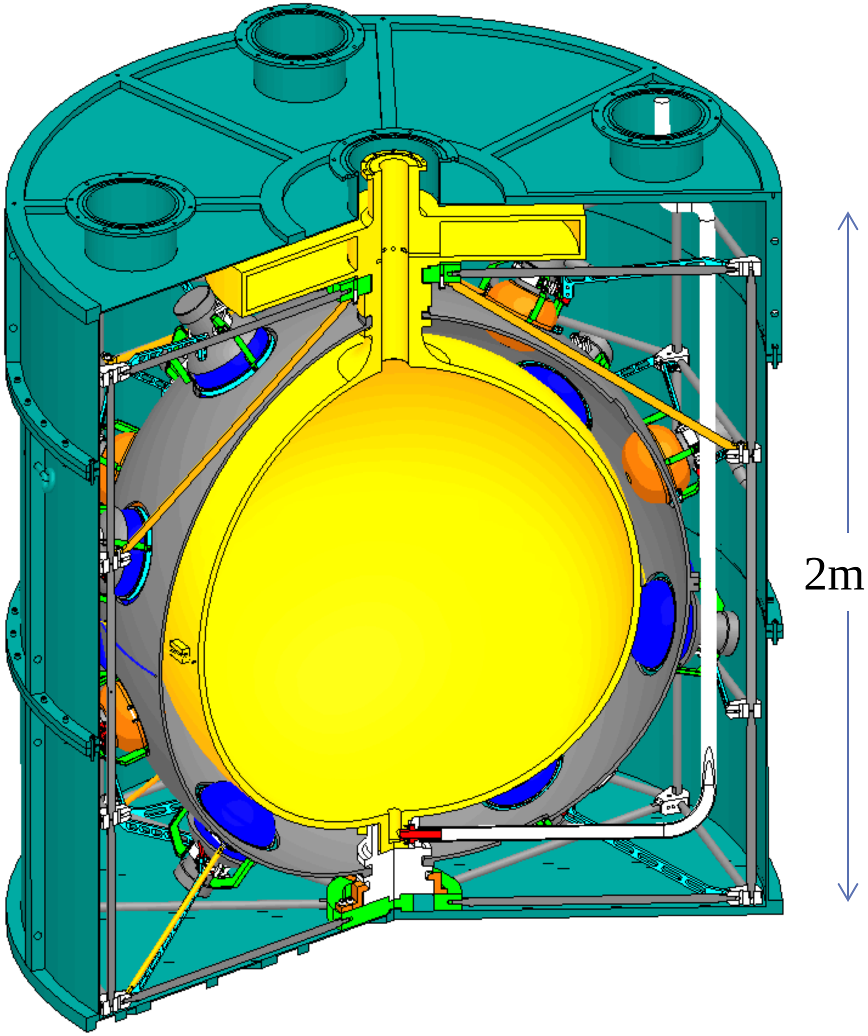


90º Cut-off	Photo cathode Coverage	Collection efficiency	N of PMT (m^{-2})
No reflector	91%	100%	14.73
Modified hexagonal	100%	97%	11.65

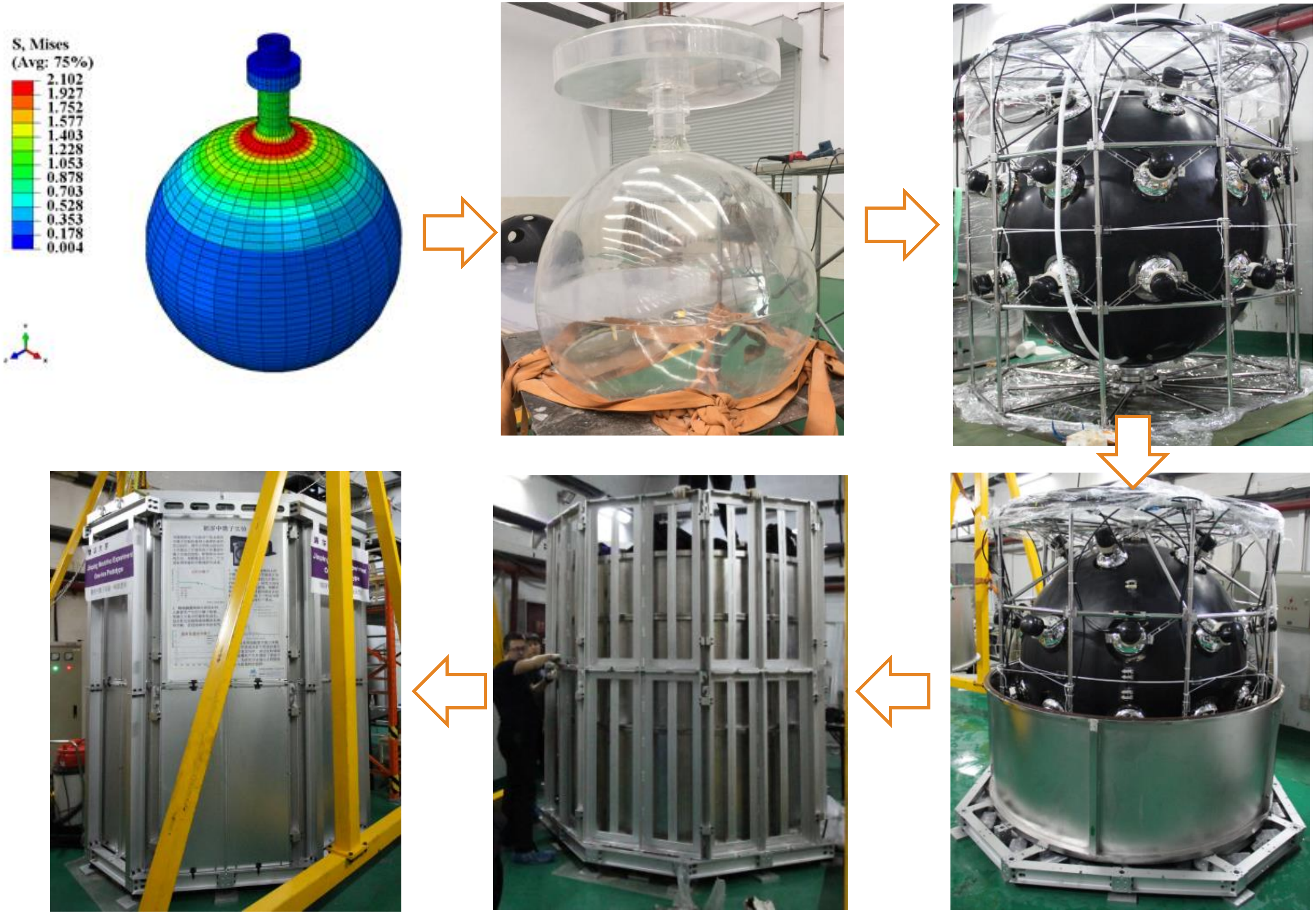
A 1-ton prototype at Jinping

1. **Measure fast neutron background**
2. **Test detection material: water, LS, and slow LS**
3. **A low bkg. facility**
4. **Reconstruction**

30 8" PMTs
FADC 10 bit 1GS/s
Transparent acrylic vessel
=> Inside: 1ton for LS
=> Water outside
Whole detector: lead shielding



Design and installation

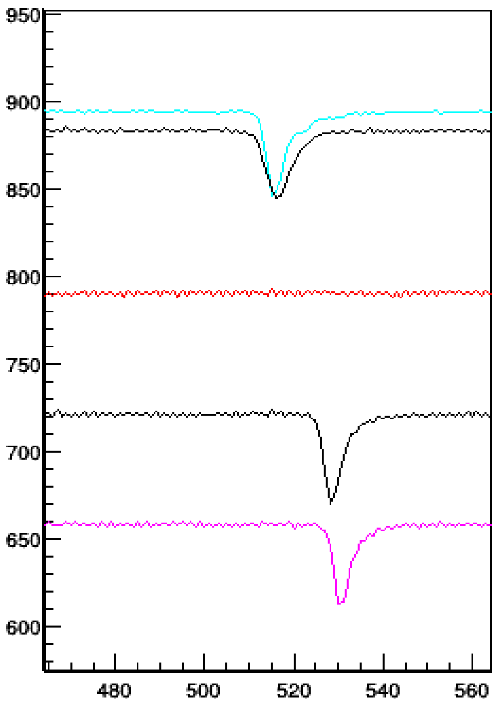


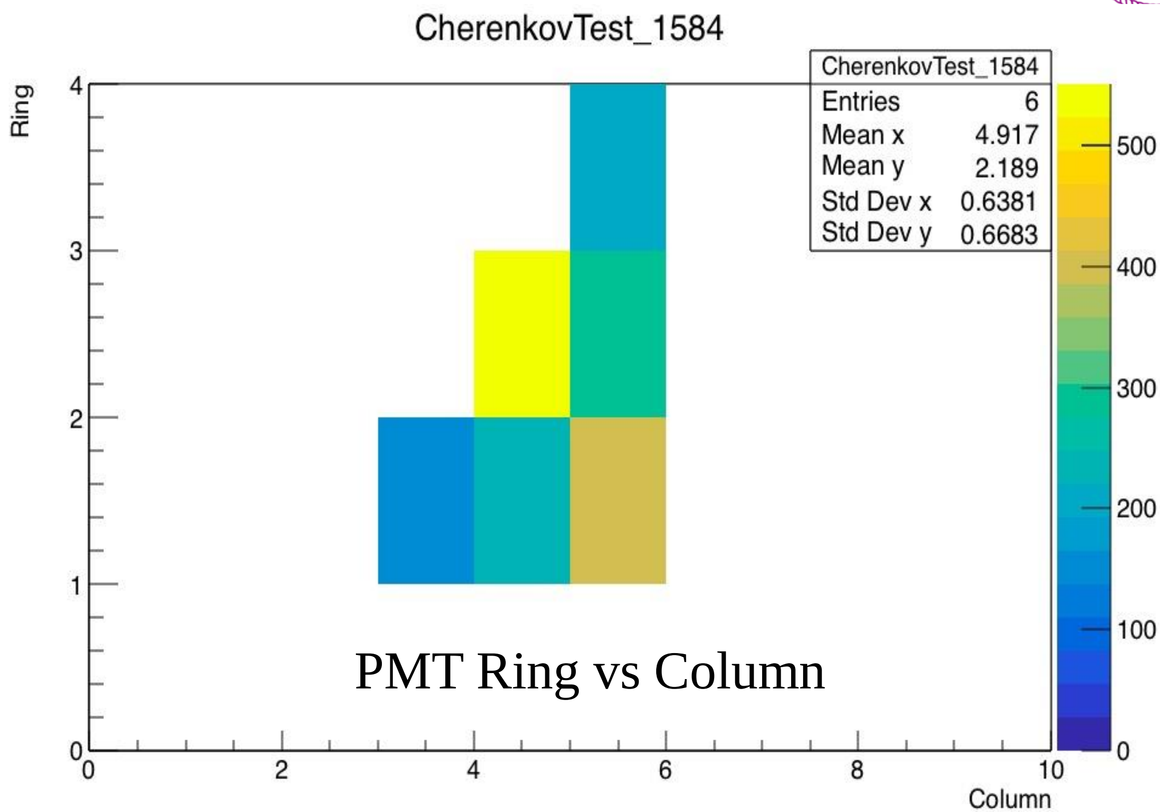
A 1-ton prototype at Jinping

Since May 10, 2017, taking data with pure water inside.
Will replace with LS soon.

Data taking status

Raw waveform



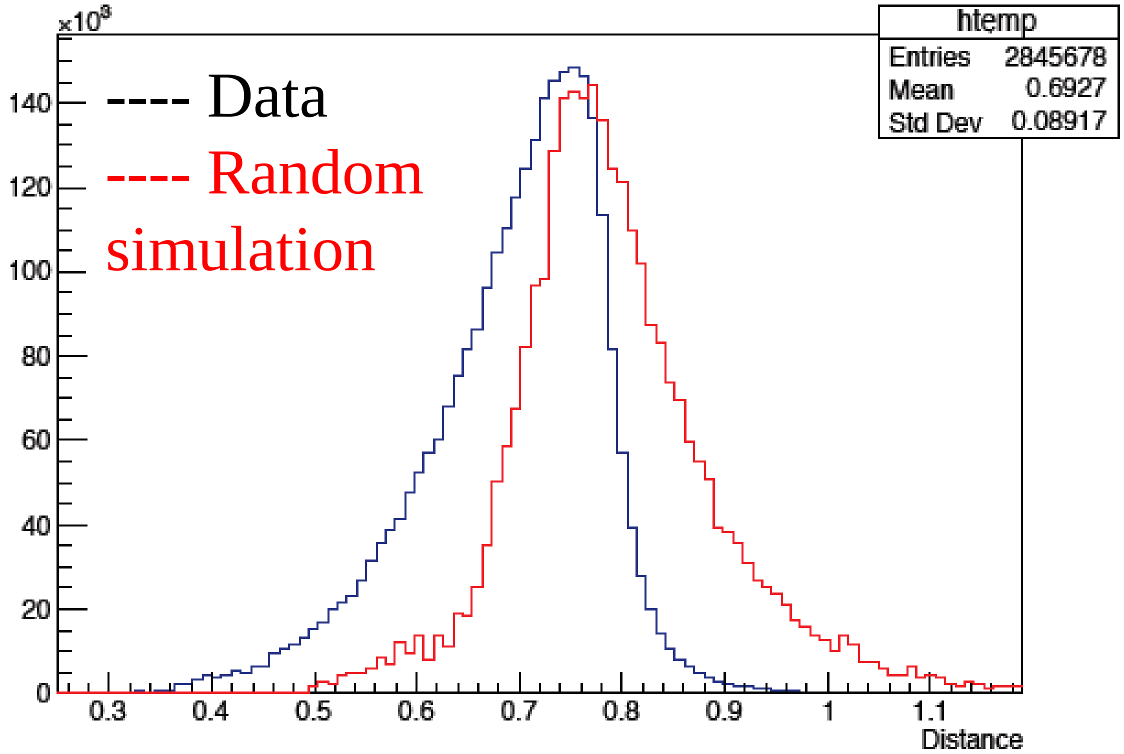


1. PMT gain calibration finished.
2. Cherenkov signal likely observed.

Further fine tuning about PMT HV and time calibration etc. will be done.

Cherenkov light signal search

Average distance to barycenter



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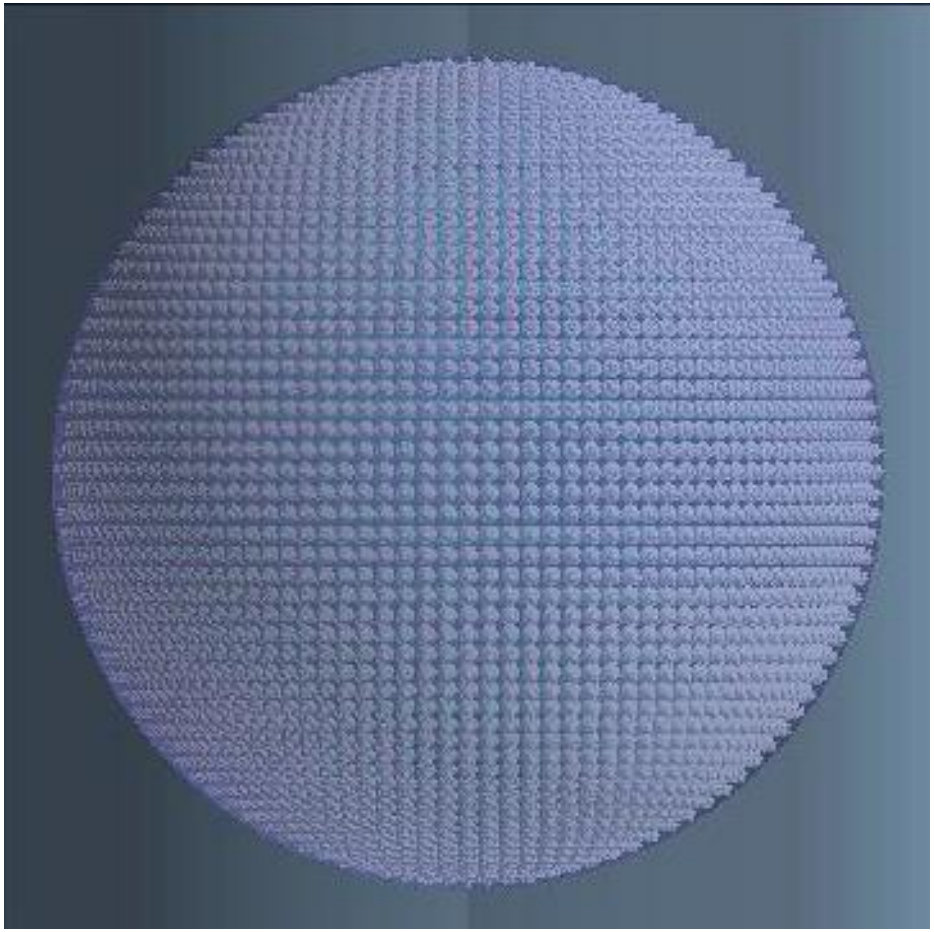
Jinping Simulation and Analysis Package

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**



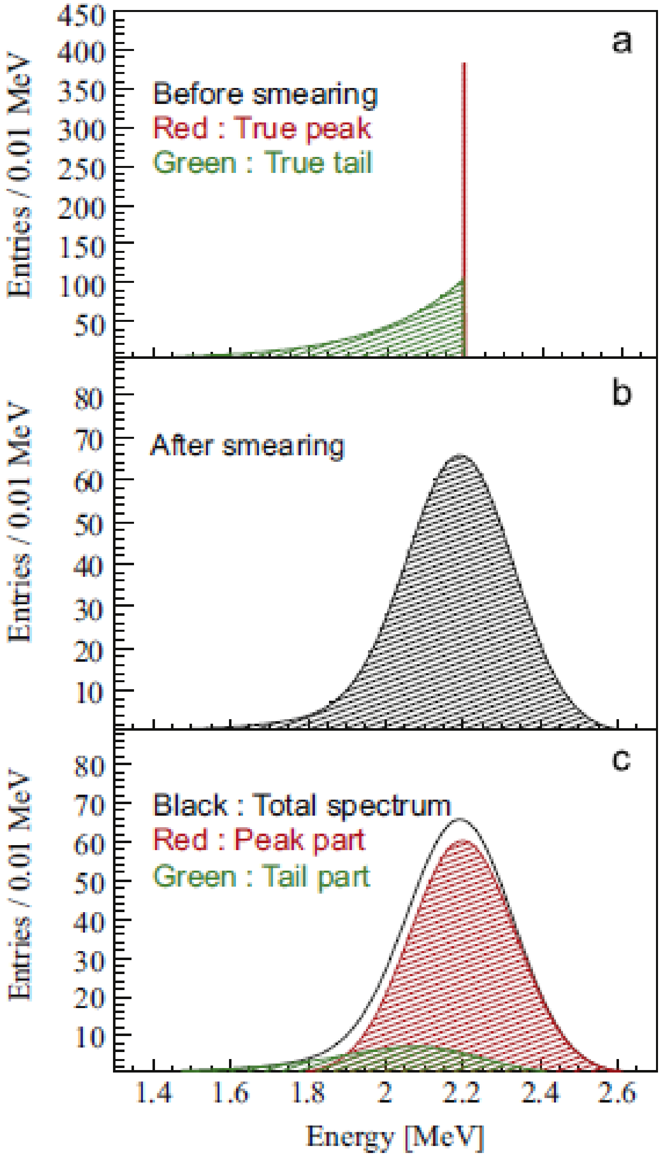
EM Calorimeter function

$$f_{\text{cal}} = (\alpha f_{\text{peak}} + (1 - \alpha) f_{\text{tail}}) \otimes f_{\text{resolution}}$$
$$= (\alpha\delta + (1 - \alpha) f_{\text{tail}}) \otimes \text{Gauss},$$

Parameters

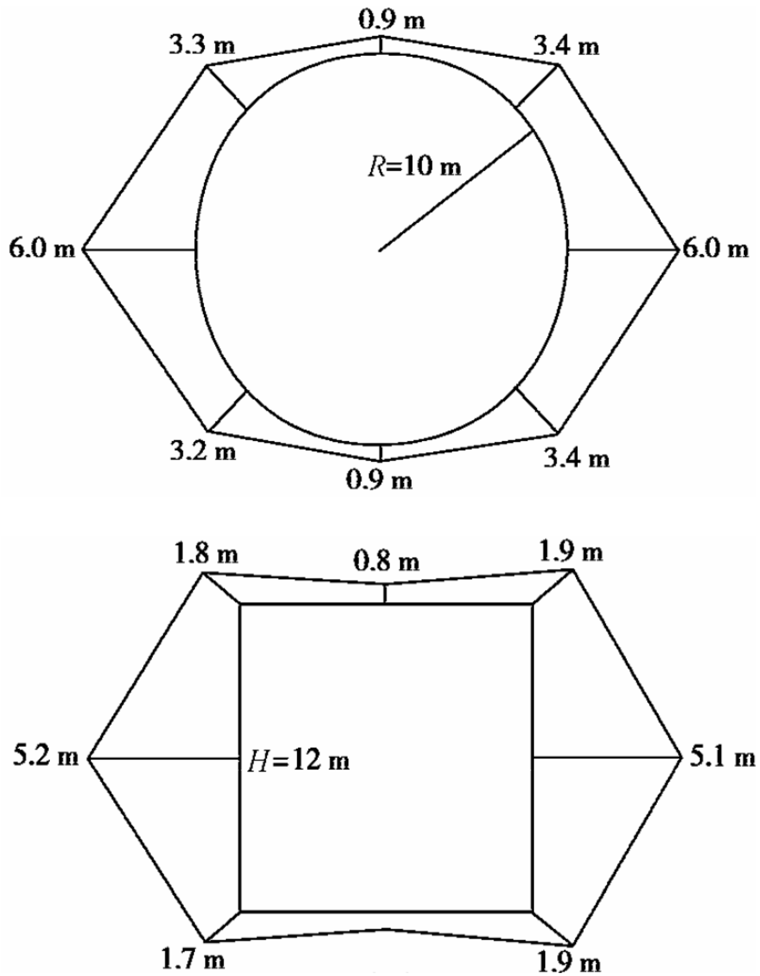
1. **Peak position**
2. **Resolution**
3. **Peak fraction**

With high statistics, the precisions of peak position, resolution are improved by an order of magnitude than crystal ball function, and peak fraction is physics-orientated.

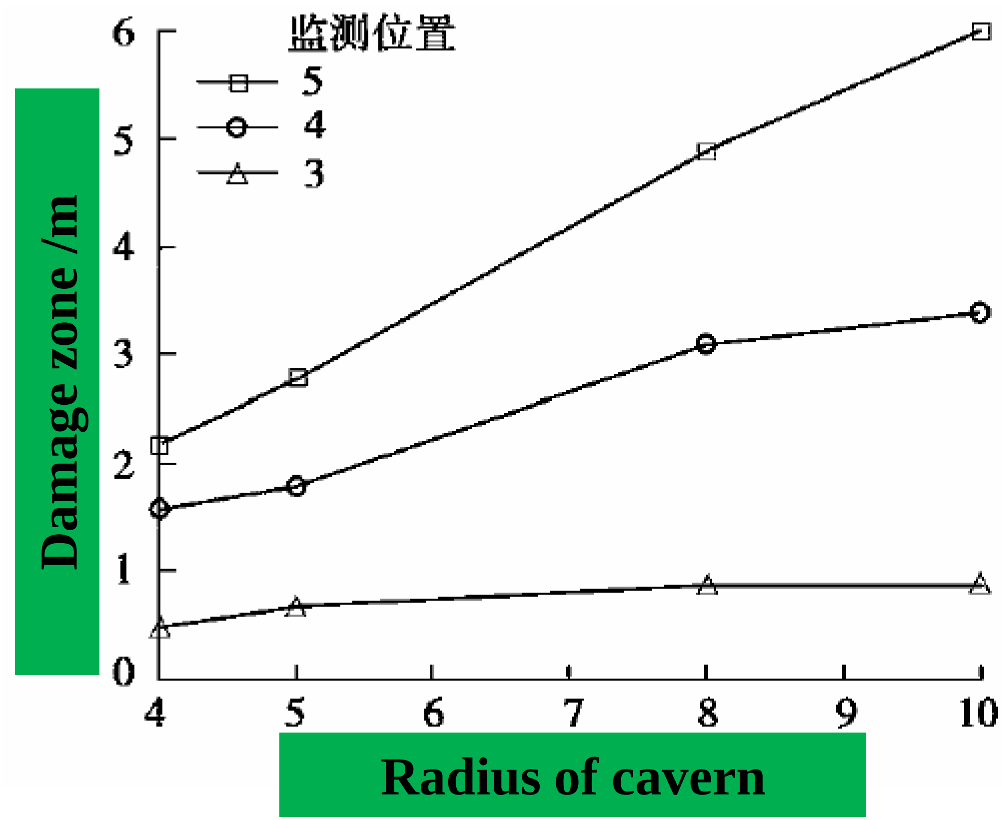


Rock Damage Zone

Damage zone shape



Rock simulation study under Jinping situation. Agree with Exp.



Summary

- Slow liquid scintillator candidates
- Low background SST
- A new light concentrator design
- One-ton prototype
- Others: Rock damage zone, JSAP, EM Calorimeter function

More details can be found at
http://jinping.hep.tsinghua.edu.cn/Publications.php

Thank you.

Especially we like to thank to all our funding agencies, CJPL IAC, and CJPL managing board.