The JUNO neutrino oscillation experiment

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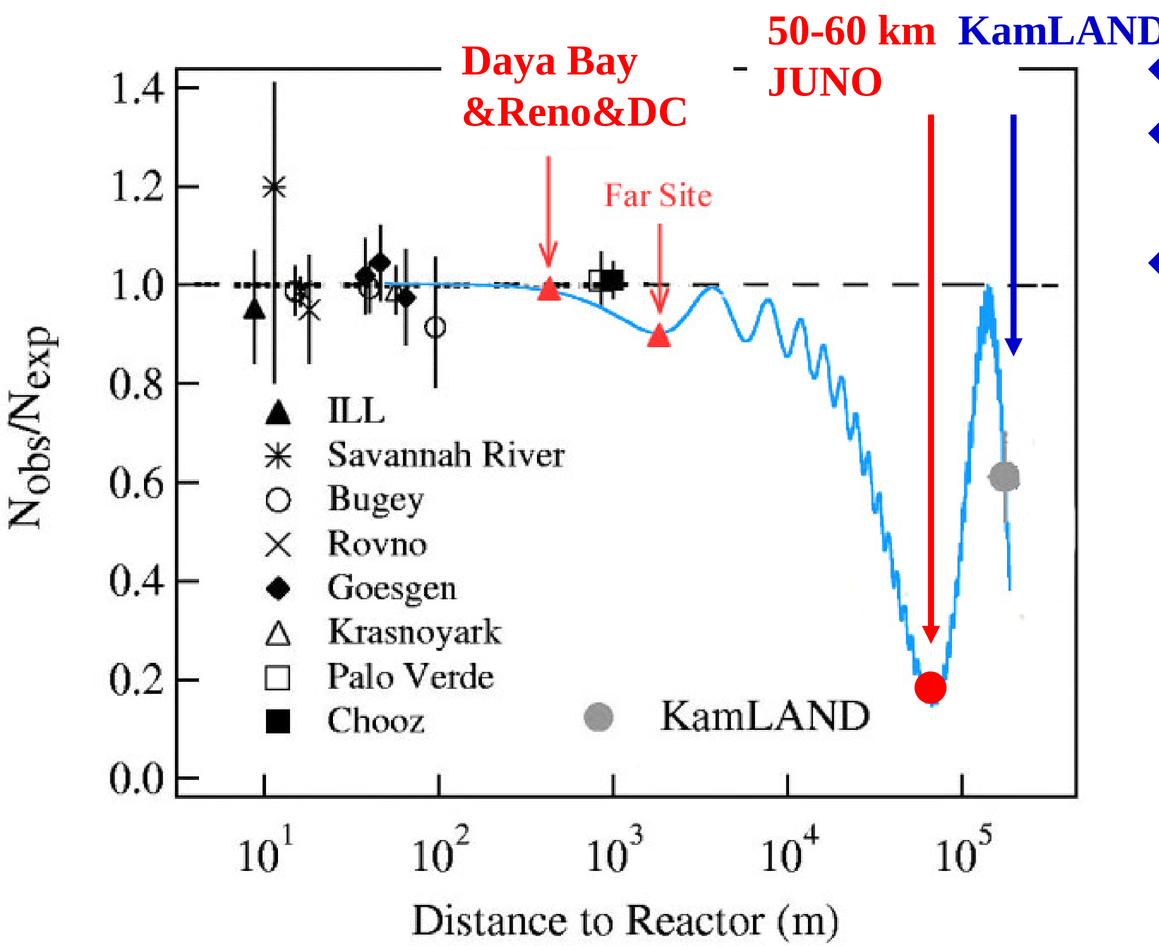
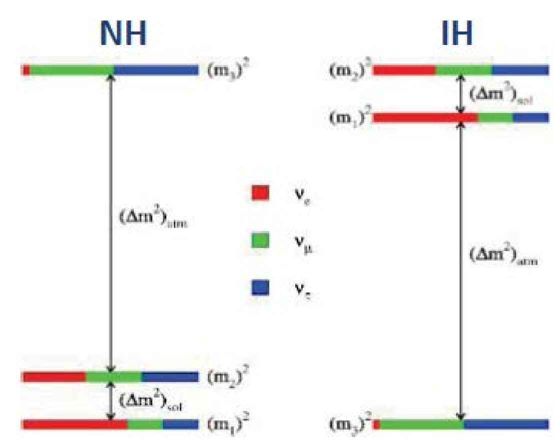
- Determination of the neutrino mass hierarchy with a large mass liquid scintillation detector located at medium distance – few tens of km – from a set of high power nuclear complexes
- Additional astroparticle program
- Requirement and technical features of the experiment

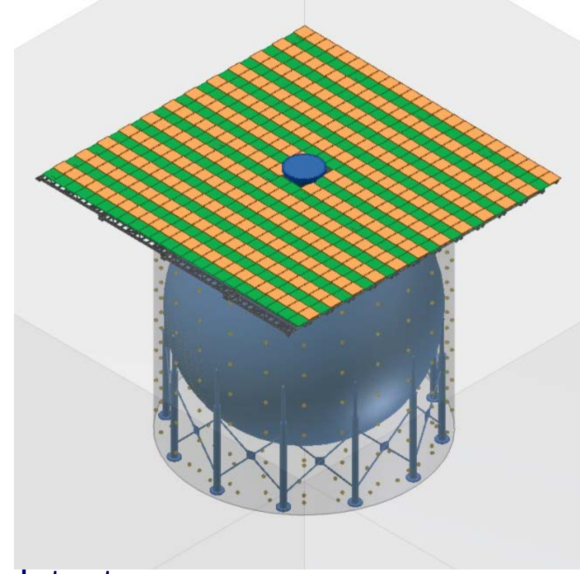
JUNO Experiment – physics summary



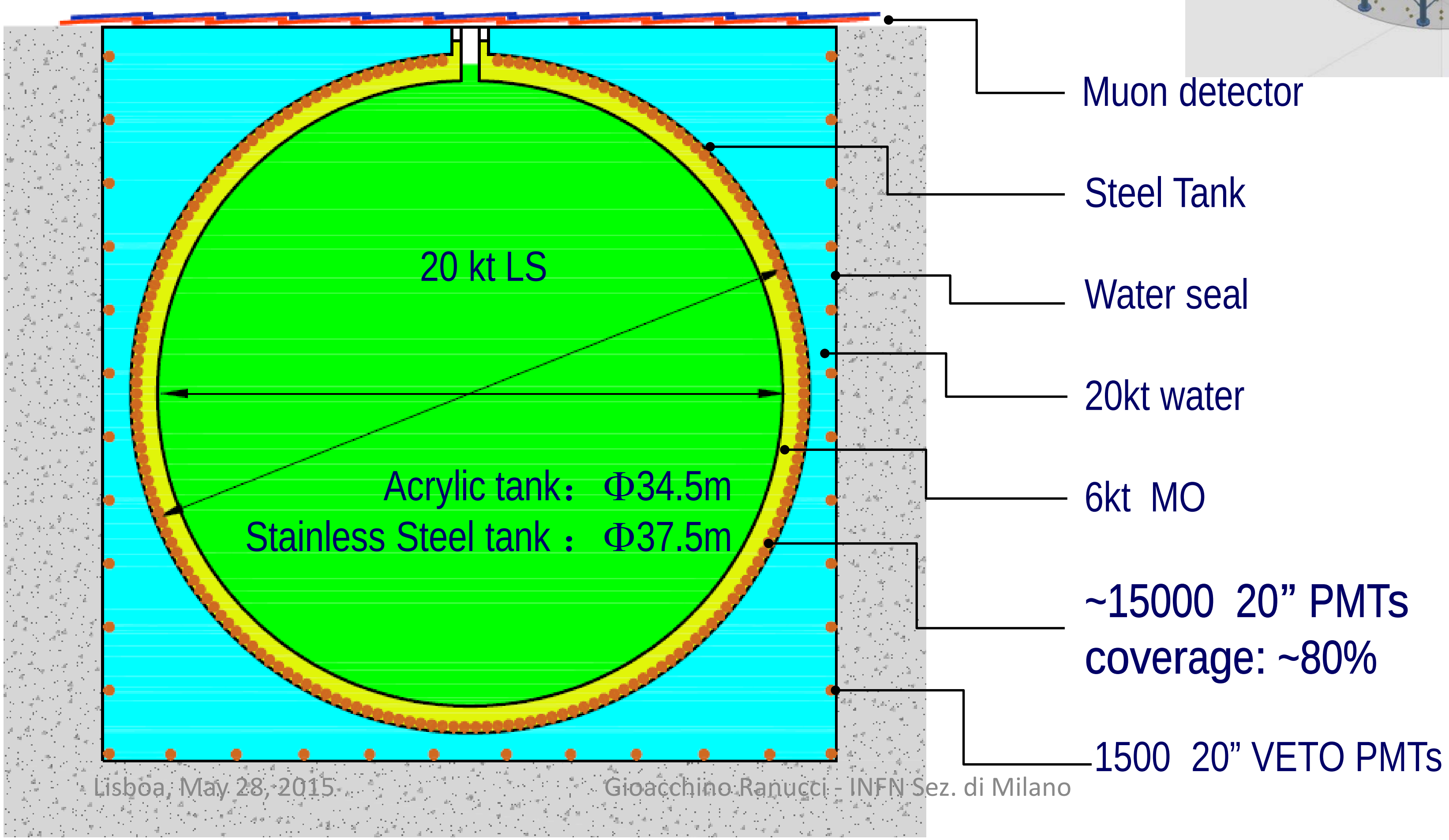
- **20 kton LS detector**
- **~3 % energy resolution-the greatest challenge**
- Rich physics possibilities
  - ⇨ **Mass hierarchy**
  - ⇨ **Precision measurement of 3 mixing parameters**
  - ⇨ **Supernovae neutrino**
  - ⇨ **Geoneutrino**
  - ⇨ **Sterile neutrino**
  - ⇨ **Atmospheric neutrinos**
  - ⇨ **Exotic searches**



The plan: a large LS detector



- LS large volume: ➔ for statistics
- High Light(PE) ➔ for energy resolution



Location of JUNO

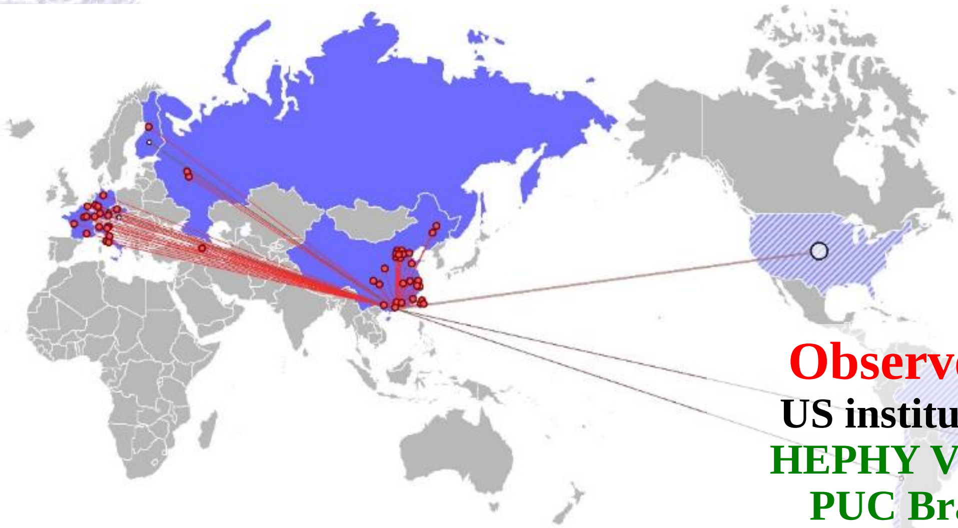
NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW

by 2020: 26.6 GW

Overburden ~ 700 m

Cores	YJ-C1	YJ-C2	YJ-C3	YJ-C4	YJ-C5	YJ-C6
Power (GW)	2.9	2.9	2.9	2.9	2.9	2.9
Baseline (km)	52.75	52.84	52.42	52.51	52.12	52.21
Cores	TS-C1	TS-C2	TS-C3	TS-C4	DYB	HZ
Power (GW)	4.6	4.6	4.6	4.6	17.4	17.4
Baseline (km)	52.76	52.63	52.32	52.20	215	265

JUNO Collaboration



Asia (28)

BNU
CAGS
CQ U
CIAE
DGUT
ECUST
Guangxi U
HIT
IHEP
Jilin U

Nanjing U
Nankai U
Natl. CT U
Natl. Taiwan U
Natl. United U
NCEPU
Pekin U
Shandong U
Shanghai JTU
Sichuan U

SYSU
Tsinghua
UCAS
USTC
Wuhan U
Wuyi U
Xiamen U
Xi'an JTU

Observers:

US institutions
HEPHY Vienna
PUC Brazil
PCUC Chile
Jyvaskyla U.

Europe (23)

France (5)
APC Paris
CPPM Marseille
IPHC Strasbourg
LLR Paris
Subatech Nantes
Finland (1)
U Oulu
Czech (1)
Charles U

Italy (6)
INFN-Frascati
INFN-Ferrara
INFN-Milano
INFN-Padova
INFN-Perugia
INFN-Roma 3
Russia (2)
JINR
INR Moscow

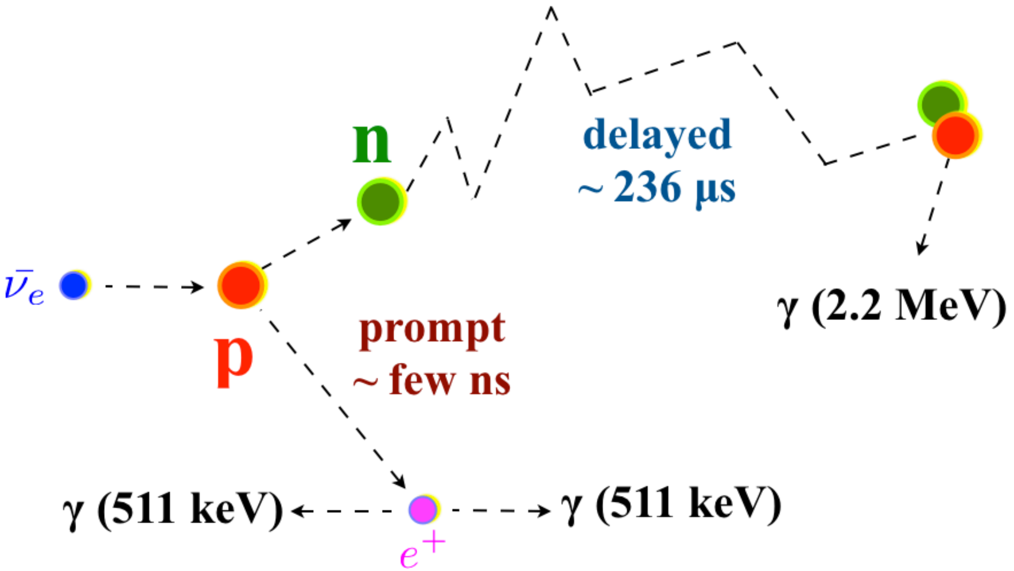
Germany (6)
FZ Julich
RWTH Aachen
TUM
U Hamburg
U Mainz
U Tuebingen
Belgium (1)
ULB
Amenia (1)
YPI

Method to infer the Mass Hierarchy

The determination of the mass hierarchy relies on the identification on the positron spectrum of the "imprinting" of the anti-ν_e survival probability

Detection through the classical inverse beta decay reaction (we use it in Borexino for the geo-neutrinos)

$$\bar{\nu} + p \rightarrow n + e^{+}$$ E_{ν}>1.8 MeV



The time coincidence between the positron and the γ from the capture rejects the uncorrelated background

The "observable" for the mass hierarchy determination is the positron spectrum
It results that $E_{vis}(e^+)=E(\bar{\nu})-0.8$ MeV

Method from Petcov and Piai, Physics Letters B 553, 94-106 (2002)

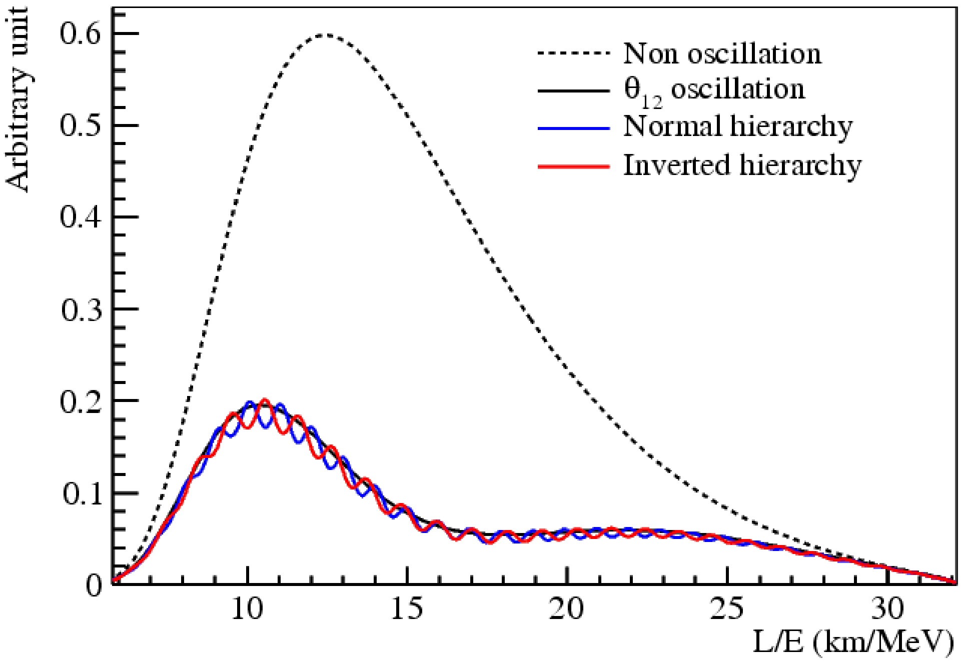
Survival probability

arXiv 1210.8141

$$P_{ee} = \left| \sum_{i=1}^{3} U_{ei} \exp\left(-i\frac{m_i^2}{2E_i}\right) U_{ei}^* \right|^2$$
$$= 1 - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2(\Delta_{21})$$
$$- \cos^2\theta_{12}\sin^2 2\theta_{13}\sin^2(\Delta_{31})$$
$$- \sin^2\theta_{12}\sin^2 2\theta_{13}\sin^2(\Delta_{32})$$

$$\Delta_{ij} \equiv \frac{\Delta m_{ij}^2 L}{4E_\nu}, \quad (\Delta m_{ij}^2 \equiv m_i^2 - m_j^2)$$

Or to make the effect of the mass hierarchy explicit, exploiting the approximation $\Delta m^2_{32} \approx \Delta m^2_{31}$:

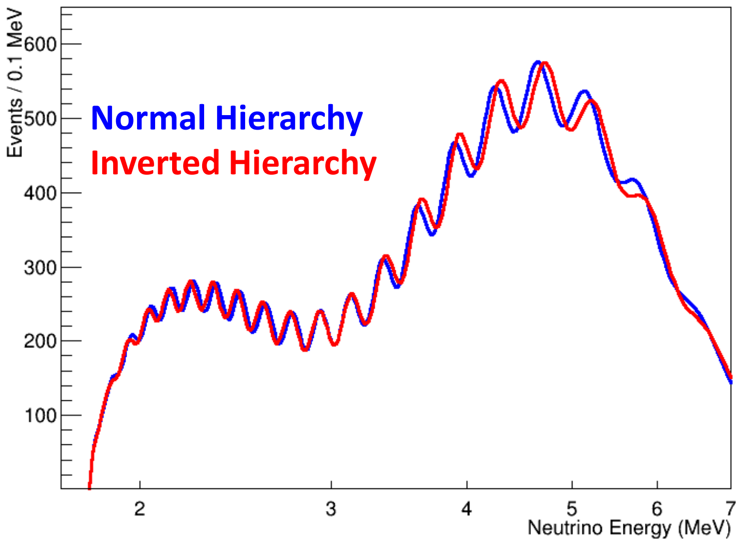


$$P_{ee} = 1 - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2(\Delta_{21})$$
$$- \sin^2 2\theta_{13}\sin^2(|\Delta_{31}|)$$
$$- \sin^2\theta_{12}\sin^2 2\theta_{13}\sin^2(\Delta_{21})\cos(2|\Delta_{31}|)$$
$$\pm \frac{\sin^2\theta_{12}}{2}\sin^2 2\theta_{13}\sin(2\Delta_{21})\sin(2|\Delta_{31}|),$$

+ NH
- IH

The big suppression is the "solar" oscillation → Δm^2_{21} , $\sin^2\theta_{12}$
The ripple is the "atmospheric" oscillation → Δm^2_{31} from frequency
MH encoded in the phase
"high" value of θ_{13} crucial

Neutrino & Positron Spectra



Spectrum in term of neutrino energy – no energy resolution

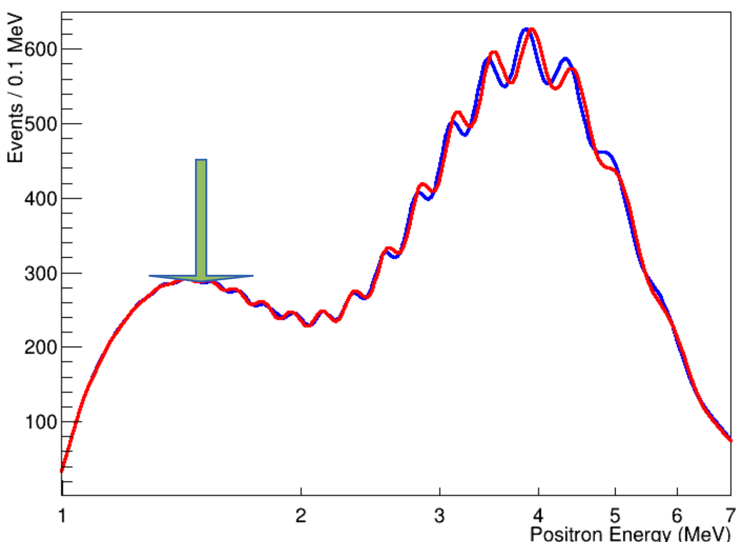
Exercise done by Marco Grassi post-doc INFN/IHEP at Beijing

Replicating sensitivity study in arXiv 1210.8141

- Three neutrino framework (no effective Δm_{ee} $\Delta m_{\mu\mu}$)
- Baseline: 50 km
- Fiducial Volume: 5 kt
- Thermal Power: 20 GW
- Exposure Time: 5 years
- more pessimistic than the JUNO values ▶ used to be in sync with paper

Visible energy due to inverse beta decay

- E(vis) ~ E(ν) – 0.8 MeV
- Assuming 3% / sqrt(E) resolution
- Assuming negligible constant term in resolution



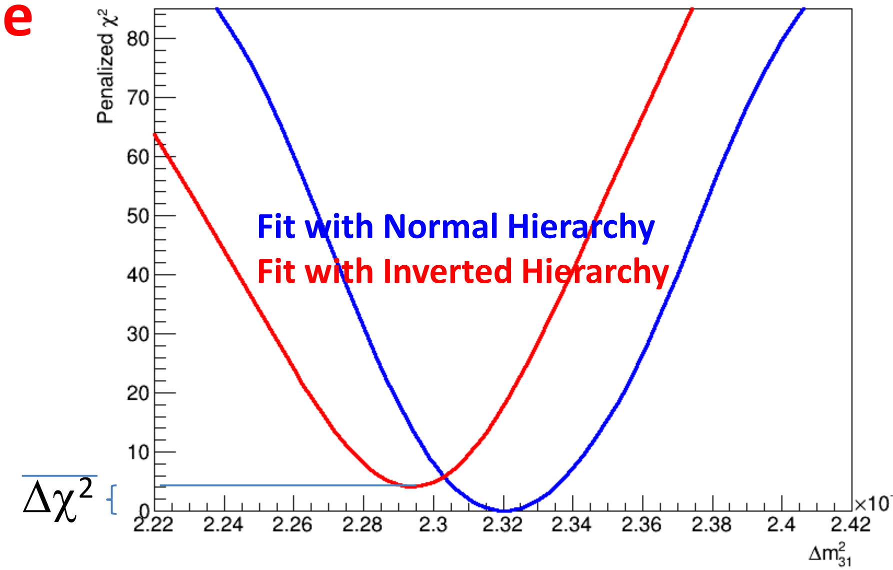
Spectrum in term of positron visible energy – with energy resolution

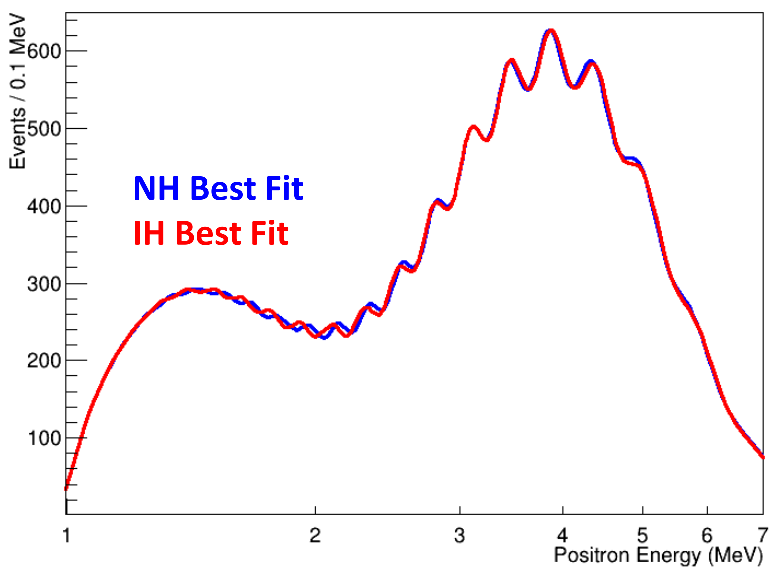
Example of χ^2 comparison – NH true

Numerical values as before
Scan of penalized (i.e. marginalized over the other minimization parameters) χ^2 vs. $|\Delta m^2_{31}|$

Case NH true- average spectrum
(no fluctuation –**Asimov data set**)
Test statistics → $\Delta\chi^2=\chi^2_{min}(NH) - \chi^2_{min}(IH)$

Fit NH minimum: $1.6\ 10^{-2}$ (practically 0)
FIT IH minimum: 4.0
$\overline{\Delta\chi^2}$ ~4.0



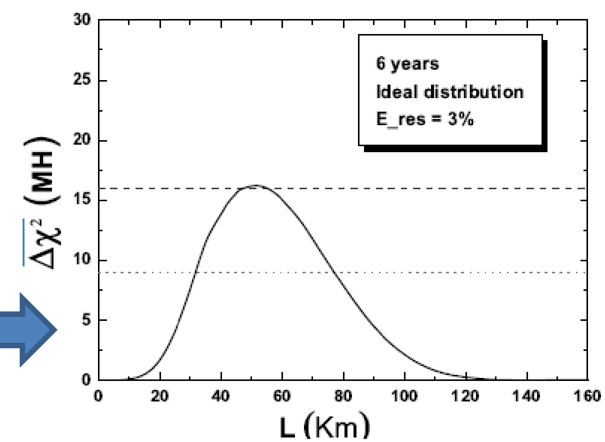


Comparison between IH/NH best fits
The best fit $|\Delta m_{31}|$ is different in the two cases

Fit almost succeeds in accommodating IH spectrum to NH data

The two solutions are fully degenerate but in a limited range of distances

Optimum distance to maximize $\overline{\Delta\chi^2}$



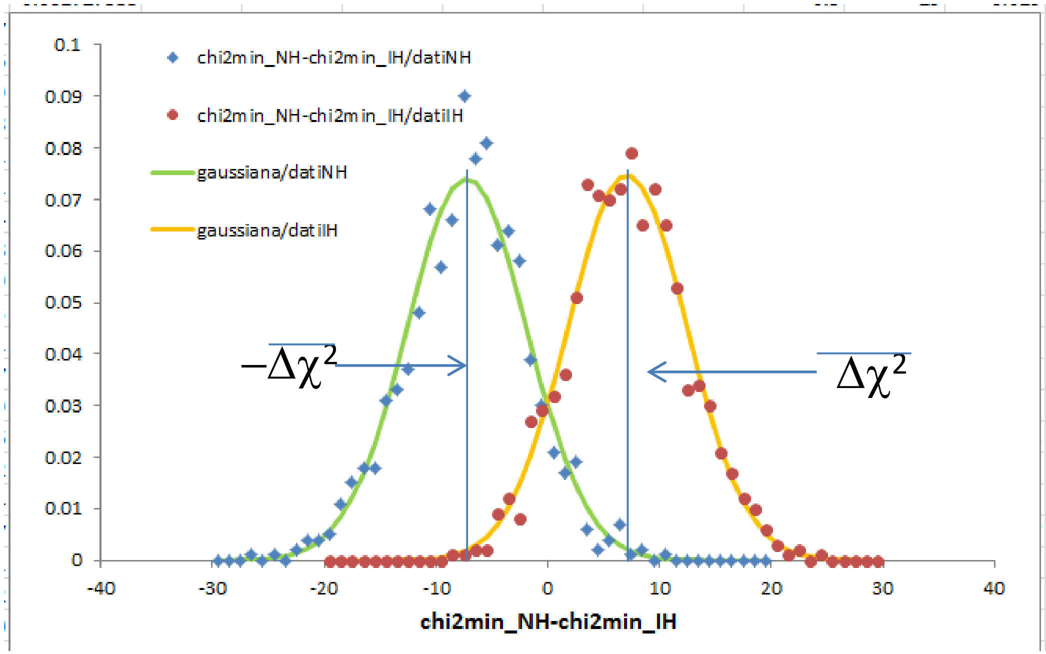
From arXiv:1303.6733v1 [hep-ex] JUNO
$\overline{\Delta\chi^2}$ can be as high as **16** @ 52 km

Distribution of the $\Delta\chi^2$ test statistics

So far only the mean value of the test statistics has been evaluated

Full distribution obtained taking into account the statistical fluctuations of the data

A Monte Carlo example



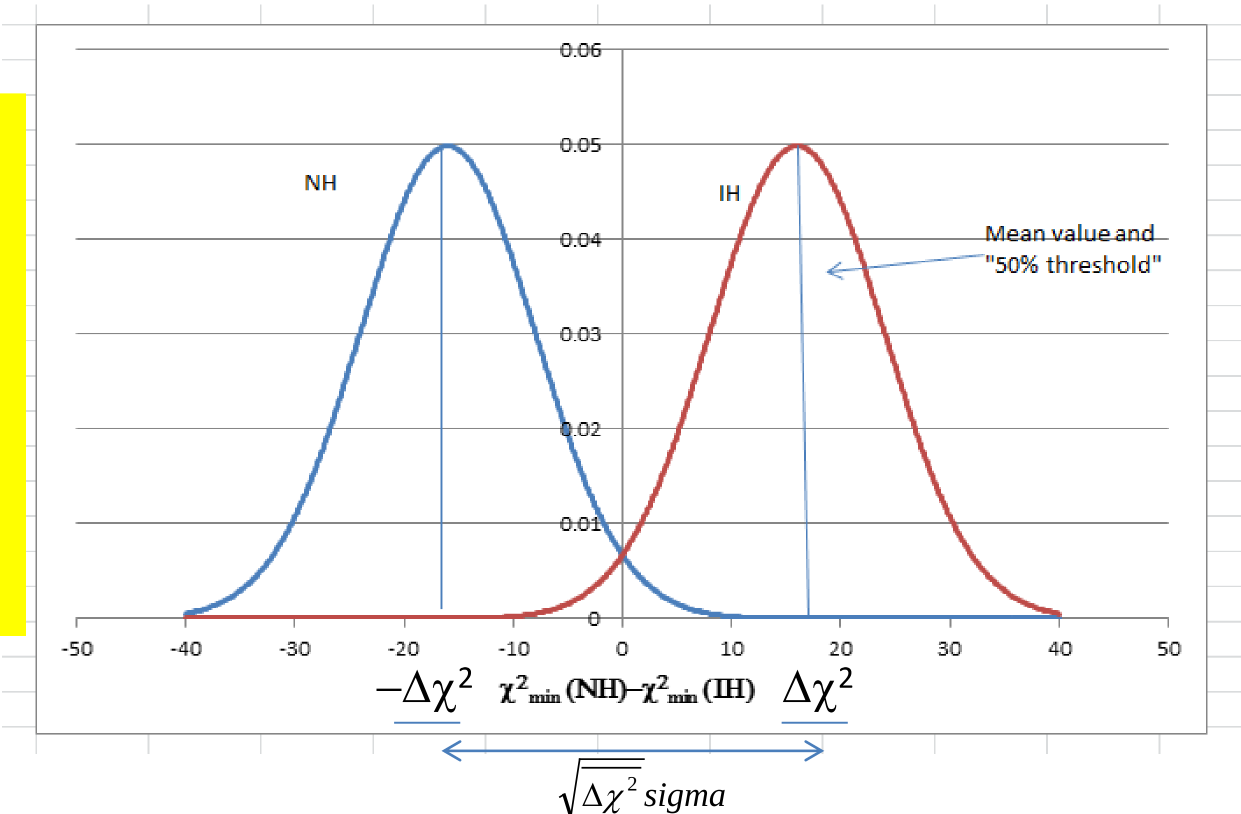
The actual distribution of the test statistics is a Gaussian centered on the absolute value of $\overline{\Delta\chi^2}$: yellow IH , green NH

The degree of overlap of the two Gaussian curves determines the "resolving" power of the experiment

How to quantify the discovery potential in term of number of sigma

- Not unique answer
- It depends upon the assumed framework (frequentist or Bayesian)
- However the actual information is fully encoded in the amount of overlap of the two Gaussian independently from how it is summarized as number of σ
- General result: sigma of each Gaussian = $2\sqrt{\Delta\chi^2}$ **arXiv: 1210.8141v2**

The mean value of the Gaussian curves is taken as representative of the **JUNO** capability at 52 Km arXiv:1303.673



The mean values of the two curves are displaced of exactly $\sqrt{\Delta\chi^2}$ *sigma*

Frequentist considerations for the number of σ

The special relation between sigma and mean value of the two distributions implies that the median sensitivity according to the frequentist framework is automatically equal to

$$\sqrt{\Delta\chi^2}\,\sigma$$

This means that if the actual outcome of the experiment is more extreme than the expected mean value one get a positive indication for one of the two hierarchies (IH if the outcome is positive or NH if the outcome is negative) with a CL better than $\sqrt{\Delta\chi^2}\,\sigma$ i.e. with a probability of making a mistake (type I error according to the statistical terminology) equal to the corresponding one tailed p-value on the Gaussian curve

3 σ → p-value (1-0.9973)/2 instead of the more common 1-0.9973

In summary for JUNO

- If the outcome is as typically expected, the MH will be determined rather unambiguously
- Even better if there will be an upward fluctuation
- A downward fluctuation will produce an ambiguous result

With these characteristics JUNO declare a **4 σ** sensitivity with the above meaning (spectrum with about 100000 events)

→

Baseline: 52 km

Fiducial Volume: 20 kt

Thermal Power: 36 GW

Exposure Time: 6 years

Proton content 12% in mass , en. res. 3%

Alternative way to define the sensitivity: Bayesian approach

Given the same overlapped Gaussian curves a Bayesian methodology leads to less σ
This is only an apparent effect of the way adopted to communicate the same fact, i.e. how much the two Gaussians are overlapped , it is not a real decrease of sensitivity, which is determined by the intrinsic overlap independently of the metric adopted as its measure
However, this has created huge misunderstandings, as well as a lot of papers on the arXiv
For a specific outcome $\Delta\chi^2$ of the test statistics define the two a-posteriori probabilities

- For IH

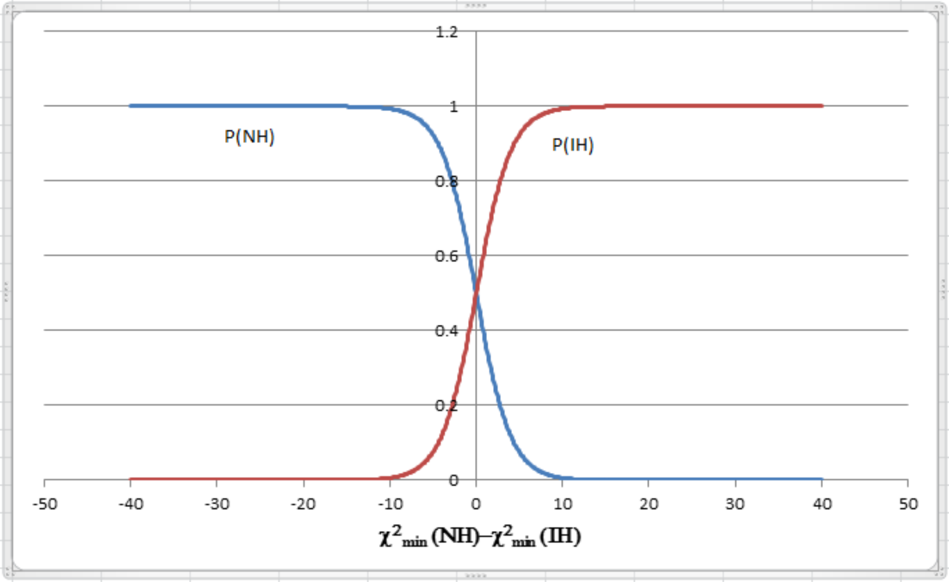
PIH=GIH($\Delta\chi^2$)/(GIH($\Delta\chi^2$)+GNH($\Delta\chi^2$))

- For NH

PNH=GNH($\Delta\chi^2$)/(GIH($\Delta\chi^2$)+GNH($\Delta\chi^2$))

Important result in **arXiv: 1210.8141v2**
they are invariant
Define

$$Paverage(IH) = \int_{-\infty}^{\infty} PIH(\Delta\chi^2)GIH(\Delta\chi^2)d\Delta\chi^2$$

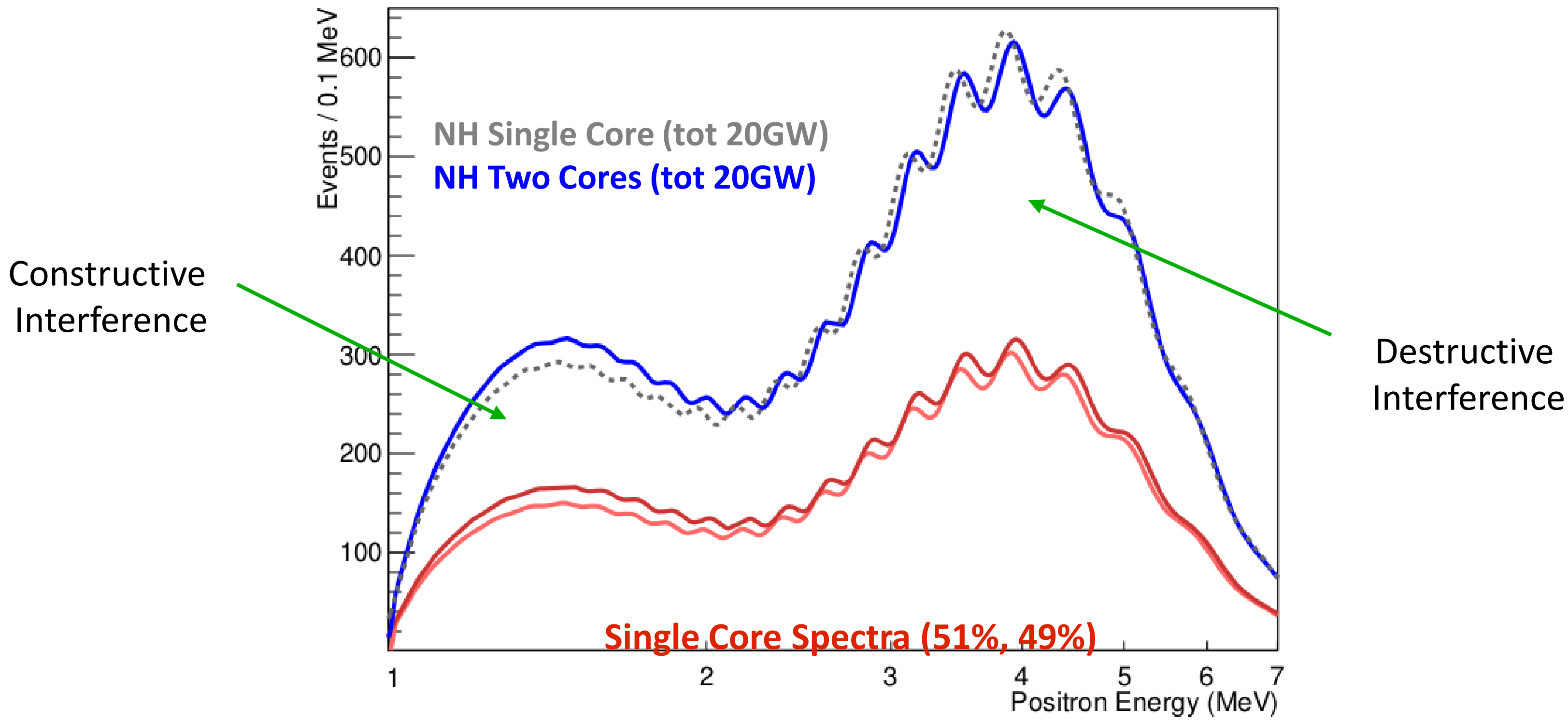


And similarly for *Paverage* (NH)
(practically equal)
The two *Paverage* are converted in two tailed Gaussian p-values and in the corresponding number of $\sigma \rightarrow$ for the same JUNO parameters this exercise leads to 2.1 σ

Caveat: Multiple Cores

Reduction in sensitivity might arise from actual spatial distribution of nuclear reactor cores

Eg. two cores with 51% (49%) of tot. power, placed at 50 km (50.5km) distance from detector

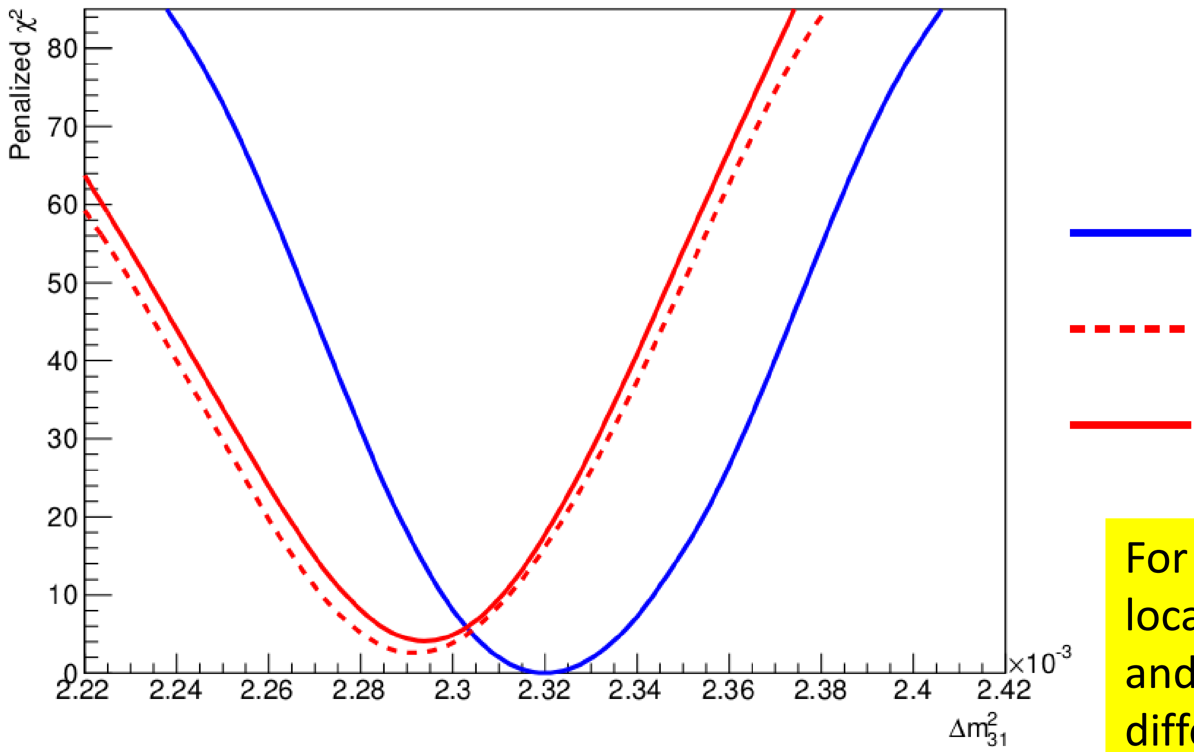


Baseline difference results in destructive interference in the most sensitive region of the spectrum

Important effect since JUNO will detect neutrinos from 10 cores

Multiple Cores: χ^2

Sensitivity loss is measured through the new χ^2 minimum



For JUNO this defines the location (only two reactors) and the maximum baseline difference : 500 m

$\Delta\chi^2$ between IH and NH in this numerical exercise is reduced from 4.0 to 2.6

In the JUNO set-up the spread of the cores is 500 m $\rightarrow$ $\Delta\chi^2$ reduction of about **5**

The other effects

❖ Adverse effect

Non linearity of the energy scale

This clearly impacts the ability to distinguish the true from false Hierarchy since distorts the experimental spectrum, therefore a very careful calibration is required better than 1% arXiv:1307.7419v3, as well as the long term stability of the detector (Borexino experience very promising, this is what we accomplished in the bulk of the FV , anyhow this is a challenge due to the large dimensions)

❖ Favorable element for analysis

Improved knowledge of $|\Delta m_{31}|$ by other experiments specifically T2K and NovA ~1%

Exploited by adding a pull in the χ^2 definition thus increasing $\overline{\Delta\chi^2}$

❖ In conclusion arXiv:1303.6733v1 demonstrates that JUNO can reach the value $\overline{\Delta\chi^2}$ in the range 15-20 ➡ **crucially dependent upon the resolution (this assumes 3%) which is by far the challenge of the experiment**

Beyond Mass Hierarchy

	Current	JUNO
Δm^2_{12}	3%	0.6%
Δm^2_{13}	5%	0.6%
$\sin^2\theta_{12}$	6%	0.7%
$\sin^2\theta_{23}$	20%	N/A
$\sin^2\theta_{13}$	14% → 4%	~ 15%

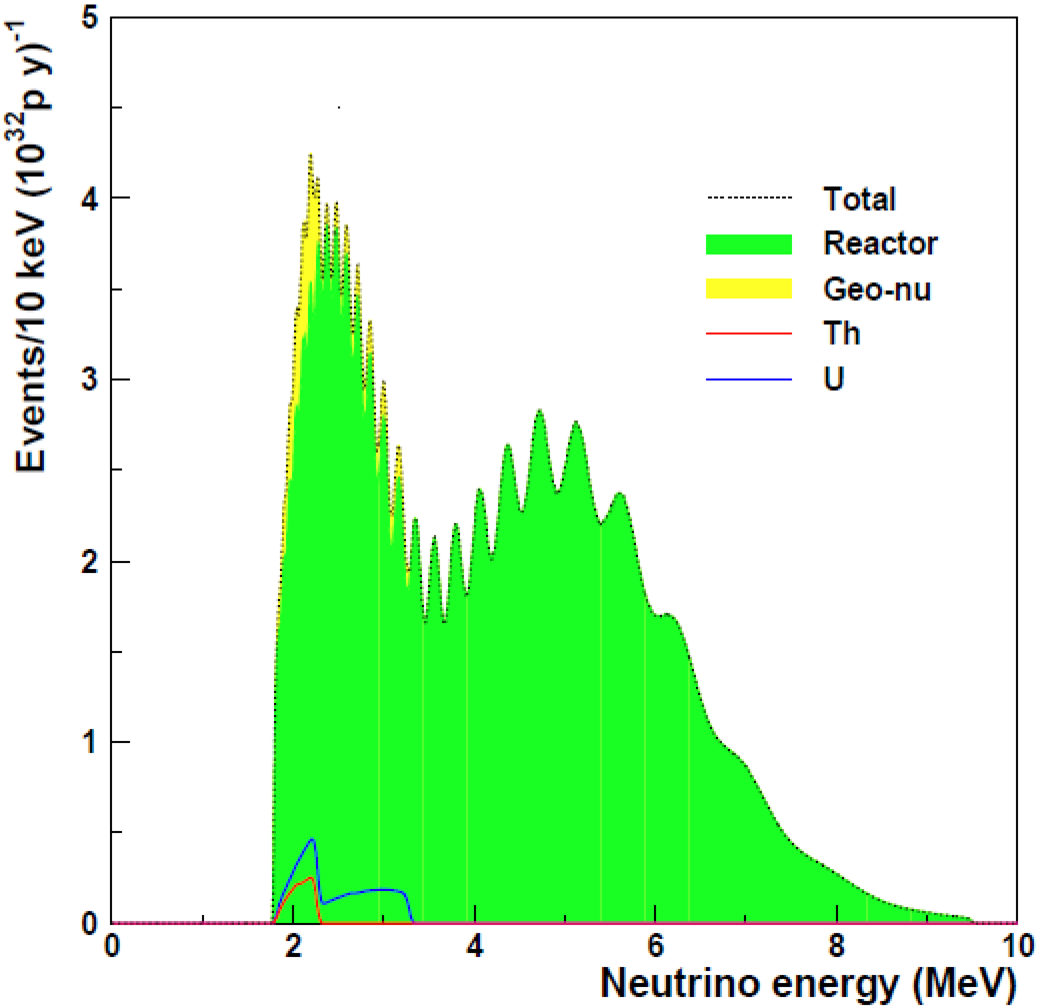
Daya Bay

- ⇨ Supernovae neutrinos
- ⇨ Relic neutrinos from past Supernovae
- ⇨ Geoneutrinos
- ⇨ Sterile neutrinos
- ⇨ Atmospheric neutrinos
- ⇨ Exotic searches
- ⇨ Solar neutrinos in principle possible but the radiopurity on large scale may be very challenging

Within the reach of a generic gigantic LS detector, see LENA paper Astroparticle Physics, Volume 35, Issue 11, p. 685-732 (2012)
Concern in JUNO : the background for the shallow depth and therefore the VETO efficiency

Geoneutrinos

- Current results:
  - **KamLAND:**
    40.0±10.5±11.5 TNU
  - **Borexino:**
    64±25±2 TNU
- Desire to reach an error of 3 TNU: statistically dominant
- JUNO: >×10 statistics, but difficult on systematics
- Background to reactor neutrinos



From Stephen Dye

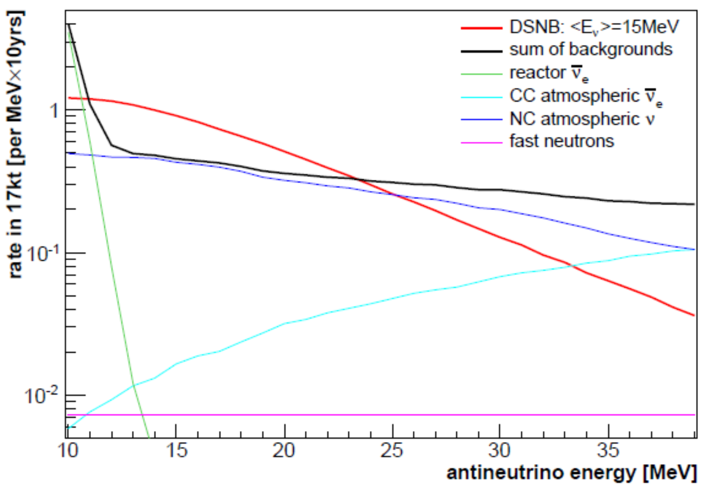
Supernova neutrinos

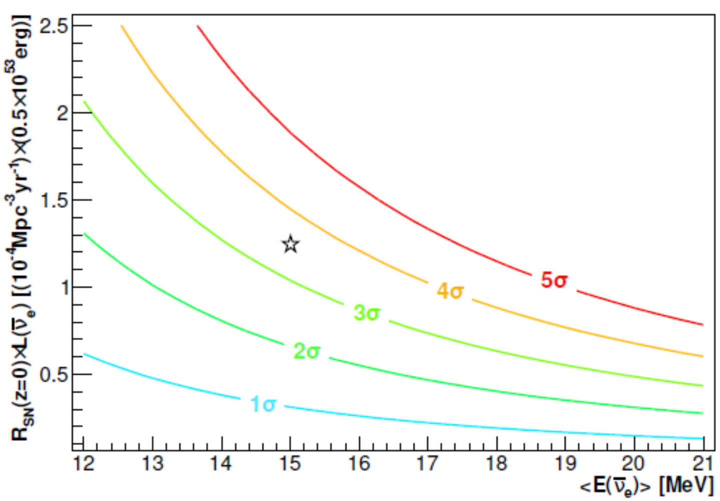
- Less than 20 events observed so far
- Assumptions:
  - Distance: 10 kpc (our Galaxy center)
  - Energy: 3×10^{53} erg
  - L_ν the same for all types
  - Tem. & energy
    - $T(\underline{\nu}_e) = 3.5$ MeV, $\langle E(\underline{\nu}_e)\rangle = 11$ MeV
    - $T(\nu_e) = 5$ MeV, $\langle E(\nu_e)\rangle = 16$ MeV
    - $T(\nu_x) = 8$ MeV, $\langle E(\nu_x)\rangle = 25$ MeV
- Many types of events:
  - $\bar{\nu}_e + p \rightarrow n + e^+$, ~ 3000 correlated events
  - $\bar{\nu}_e + {}^{12}C \rightarrow {}^{12}B^* + e^+$, ~ 10-100 correlated events
  - $\nu_e + {}^{12}C \rightarrow {}^{12}N^* + e^-$, ~ 10-100 correlated events
  - $\nu_x + {}^{12}C \rightarrow \nu_x + {}^{12}C^*$, ~ 600 correlated events
  - $\nu_x + p \rightarrow \nu_x + p$, single events
  - $\nu_e + e^- \rightarrow \nu_e + e^-$, single events
  - $\nu_x + e^- \rightarrow \nu_x + e^-$, single events

Water Cerenkov detectors can not see these correlated events

Energy spectra & fluxes of all types of neutrinos

Diffuse Supernova Neutrino





- DSNB: Past core-collapse events
  - ⇨ Cosmic star-formation rate
  - ⇨ Core-collapse neutrino spectrum
  - ⇨ Rate of failed SNe

Item		Rate (no PSD)	PSD efficiency	Rate (PSD)
Signal	$\langle E_{\bar{\nu}_e}\rangle = 12\,\mathrm{MeV}$	12.2	$\varepsilon_\nu = 50\,\%$	6.1
	$\langle E_{\bar{\nu}_e}\rangle = 15\,\mathrm{MeV}$	25.4		12.7
	$\langle E_{\bar{\nu}_e}\rangle = 18\,\mathrm{MeV}$	42.4		21.2
	$\langle E_{\bar{\nu}_e}\rangle = 21\,\mathrm{MeV}$	61.2		30.8
Background	reactor $\bar{\nu}_e$	1.6	$\varepsilon_\nu = 50\,\%$	0.8
	atm. CC	1.5	$\varepsilon_\nu = 50\,\%$	0.8
	atm. NC	716	$\varepsilon_{NC} = 1.1\,\%$	7.5
	fast neutrons	12	$\varepsilon_{FN} = 1.3\,\%$	0.15
	Σ			9.2

10 Years' sensitivity

Syst. uncertainty BG	5 %		20 %	
$\langle E_{\bar{\nu}_e}\rangle$	rate only	spectral fit	rate only	spectral fit
12 MeV	$1.7\,\sigma$	$1.9\,\sigma$	$1.5\,\sigma$	$1.7\,\sigma$
15 MeV	$3.3\,\sigma$	$3.5\,\sigma$	$3.0\,\sigma$	$3.2\,\sigma$
18 MeV	$5.1\,\sigma$	$5.4\,\sigma$	$4.6\,\sigma$	$4.7\,\sigma$
21 MeV	$6.9\,\sigma$	$7.3\,\sigma$	$6.2\,\sigma$	$6.4\,\sigma$

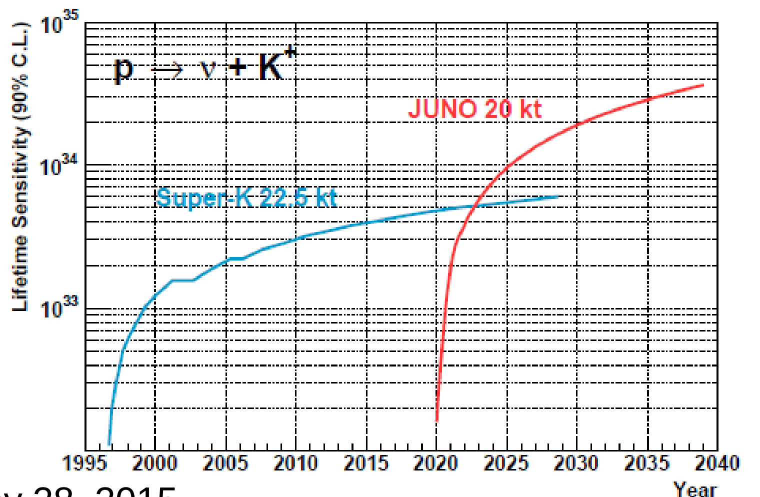
Solar and other Physics

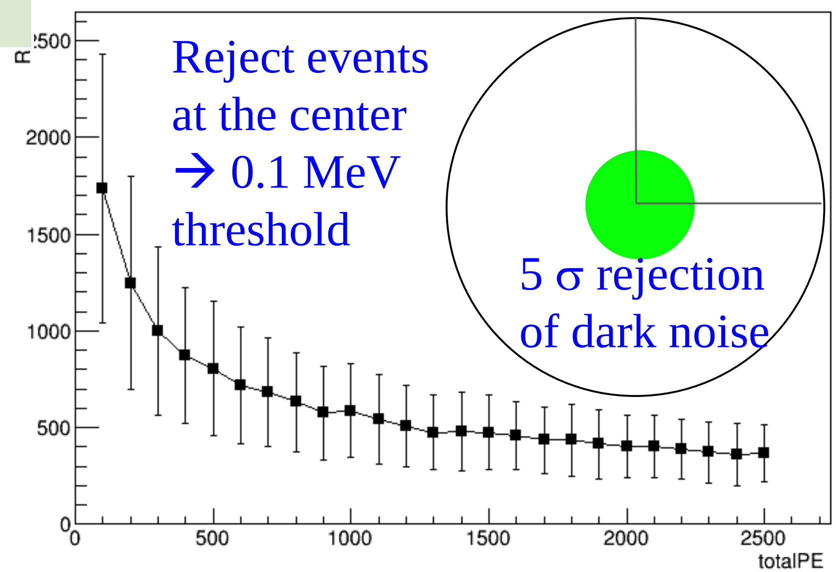
- **Solar neutrino**
  - Metallicity? Vacuum oscillation to MSW?
  - ^{7}Be and ^{8}B at JUNO

Liquid Scintillator	U238	Th232	K40	Pb210 (Rn222)	Ref.
No Distillation	10^{-15}	10^{-15}	10^{-16}	$1.4\cdot10^{-22}$	Borexino CTF, KamLAND
After Distillation	10^{-17}	10^{-17}	10^{-18}	10^{-24}	

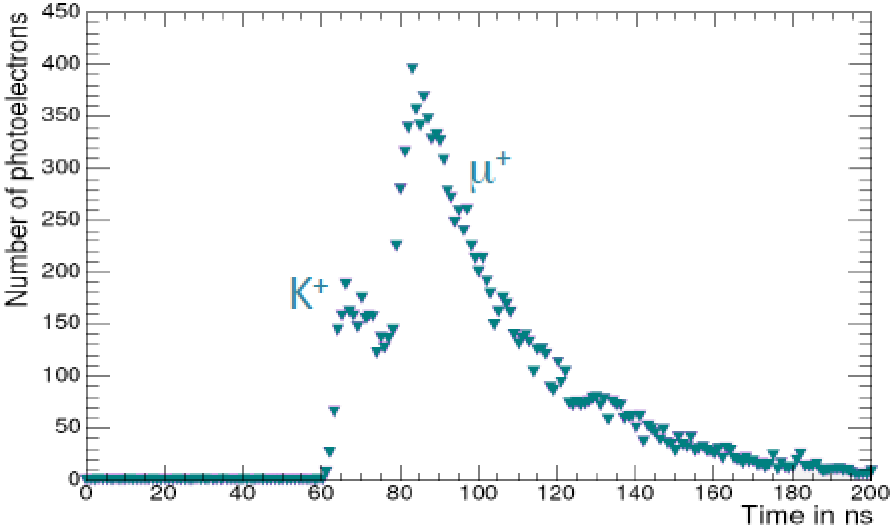
Source	Rate [cpd/1kt]
pp	1337
^{7}Be [line 0.384 MeV]	19
^{7}Be [line 0.862 MeV]	475
pep	28
^{8}B	4.5
^{13}N	25
^{15}O	28
^{17}F	0.7

- **Proton Decay, sterile, dark matter, etc.**





Proton decay into $K^+\bar{\nu}$



SUSY-favored decay mode

Signature $p \rightarrow K^+ \bar{\nu}$

$\hookrightarrow \mu^+\nu_\mu \,/\, \pi^0\pi^+$

→ kaon visible in liquid scintillator!

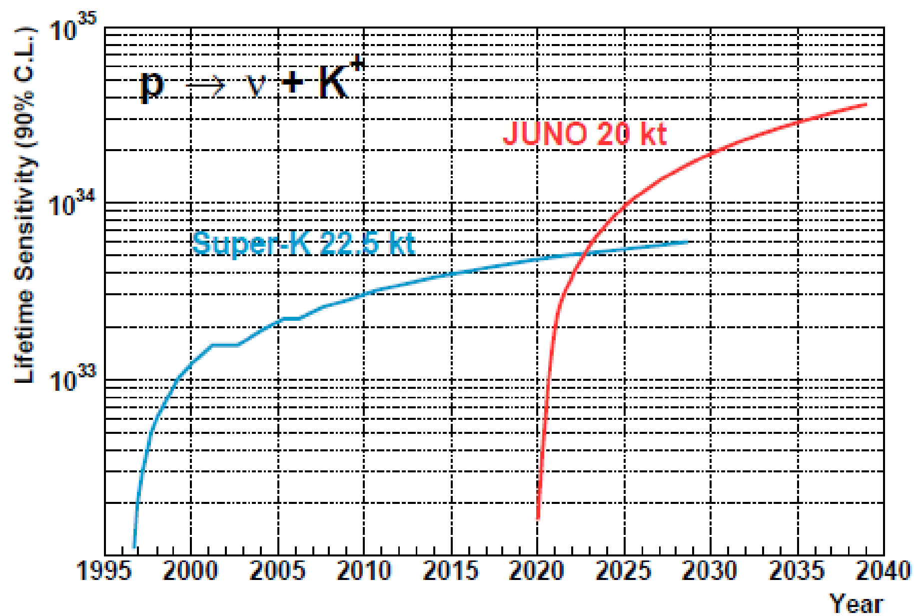
→ fast coincidence signature (τ_K = 13 ns)

→ signal efficiency: ~65% (atm. ν bg)

→ remaining background: <0.1 ev/yr

Limit if no event is observed in 10yrs (0.5 Mt·yrs):

$\tau_p >$ 2x10^{34} yrs (90%C.L.)

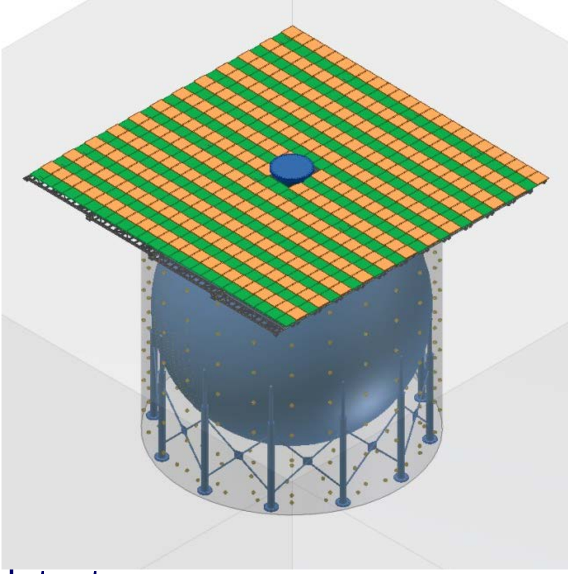


Physics at JUNO

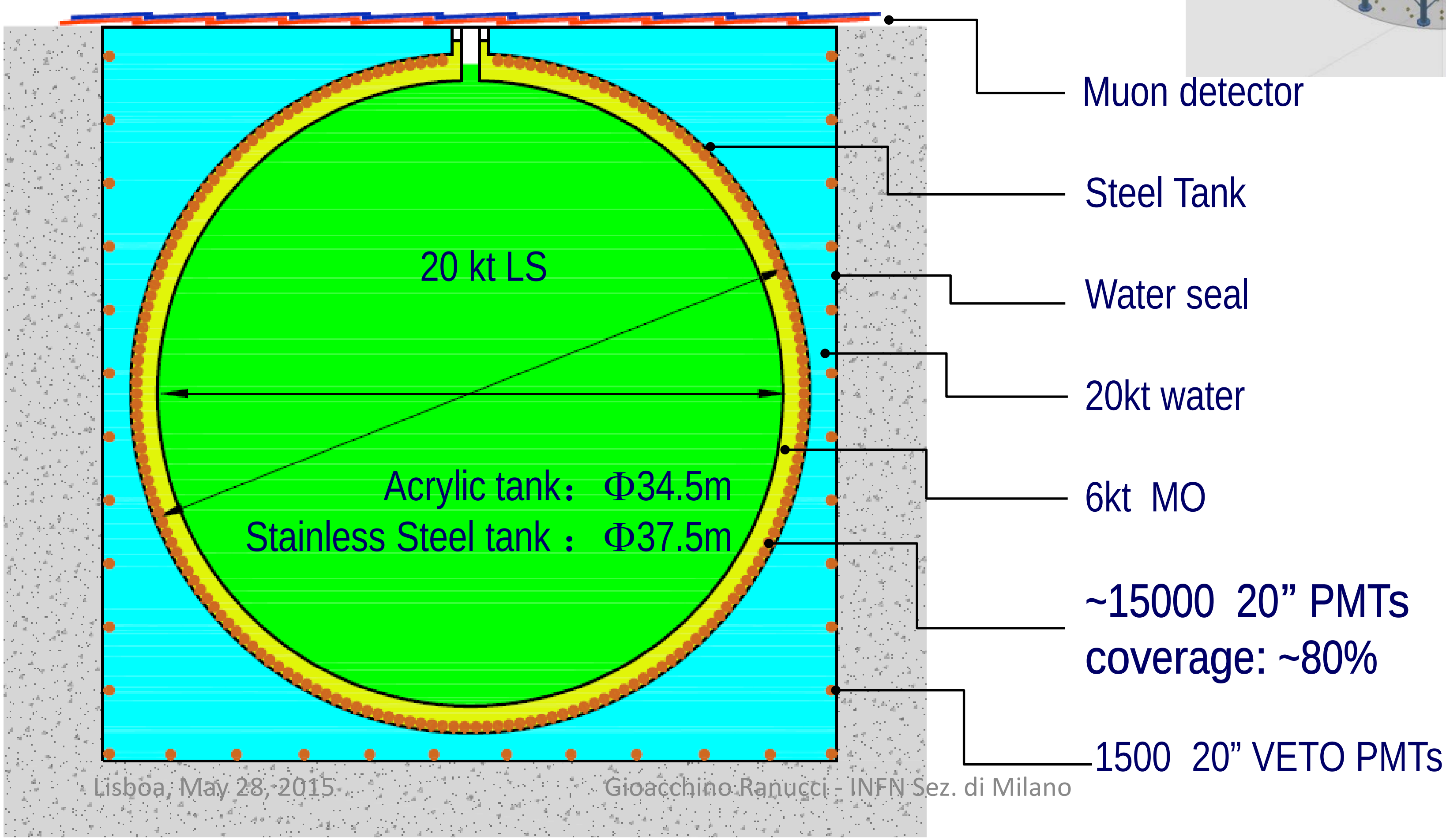
1. Introduction
2. Neutrino Mass Hierarchy
3. Precision Measurements of mixing parameters
4. Supernova burst neutrinos
5. Diffuse supernova neutrinos
6. Solar neutrinos
7. Atmospheric neutrinos
8. Geo-neutrinos
9. Sterile neutrinos
10. Nucleon decay
11. Indirect dark matter search
12. Other exotic searches
13. Appendix

Yellow book Almost Ready, ~200 pages

The plan: a large LS detector



- LS large volume: ➔ for statistics
- High Light(PE) ➔ for energy resolution
- CDR in preparation



Challenges

- Large detector: >10 kt LS
- Energy resolution: < 3%/√E ➔ ~1400 p.e./MeV

	Borexino	JUNO
LS mass	**~0.3 kt**	**20 kt**
Energy Resolution	**5%/√E**	**3%/√E**
Light yield	**500 p.e./MeV**	**~1400 p.e./MeV**

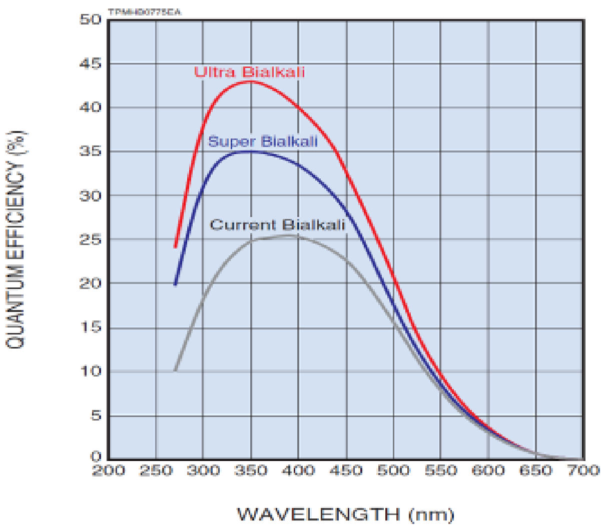
More photons, how and how many ?

- **Highly transparent LS:**
  - ⇨ **Target attenuation length: → 30m/34m (absorption-reemission helps a lot as shown by Borexino)**
- **High light yield LS:**
  - ⇨ **Borexino: 1.5g/l PPO → 5g/l PPO**
    about 30% more in the Light Yield
- **Photocathode coverage :**
  - ⇨ **Borexino: 33% → ~80%** **× 2.3**
- **High QE "PMT":**
  - ⇨ **20" SBA PMT QE: 25% → 35% (Hamamatsu option)**
    or New PMT QE: 25% → 40% (China option)

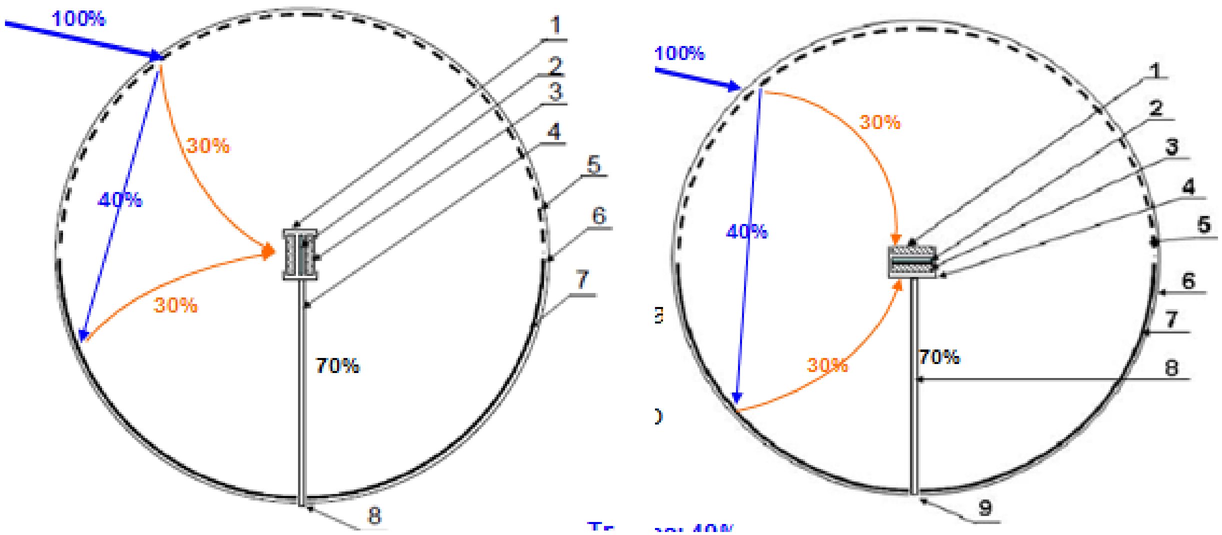
Alltogether these improvemente should ensure the desired LY and resolution - R&D ongoing to validate the various solutions

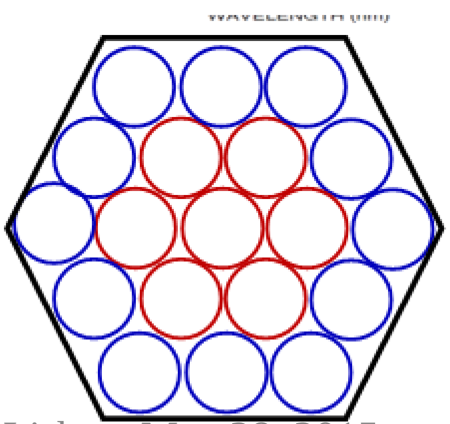
More Photoelectrons-- PMT

SBA photocatode



New type of PMT: MCP-PMT



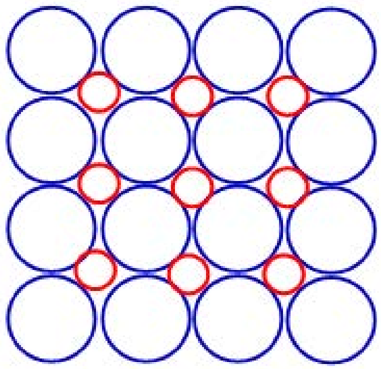


No clearance:

coverage 86.5%

1cm clearance:

coverage: 83%

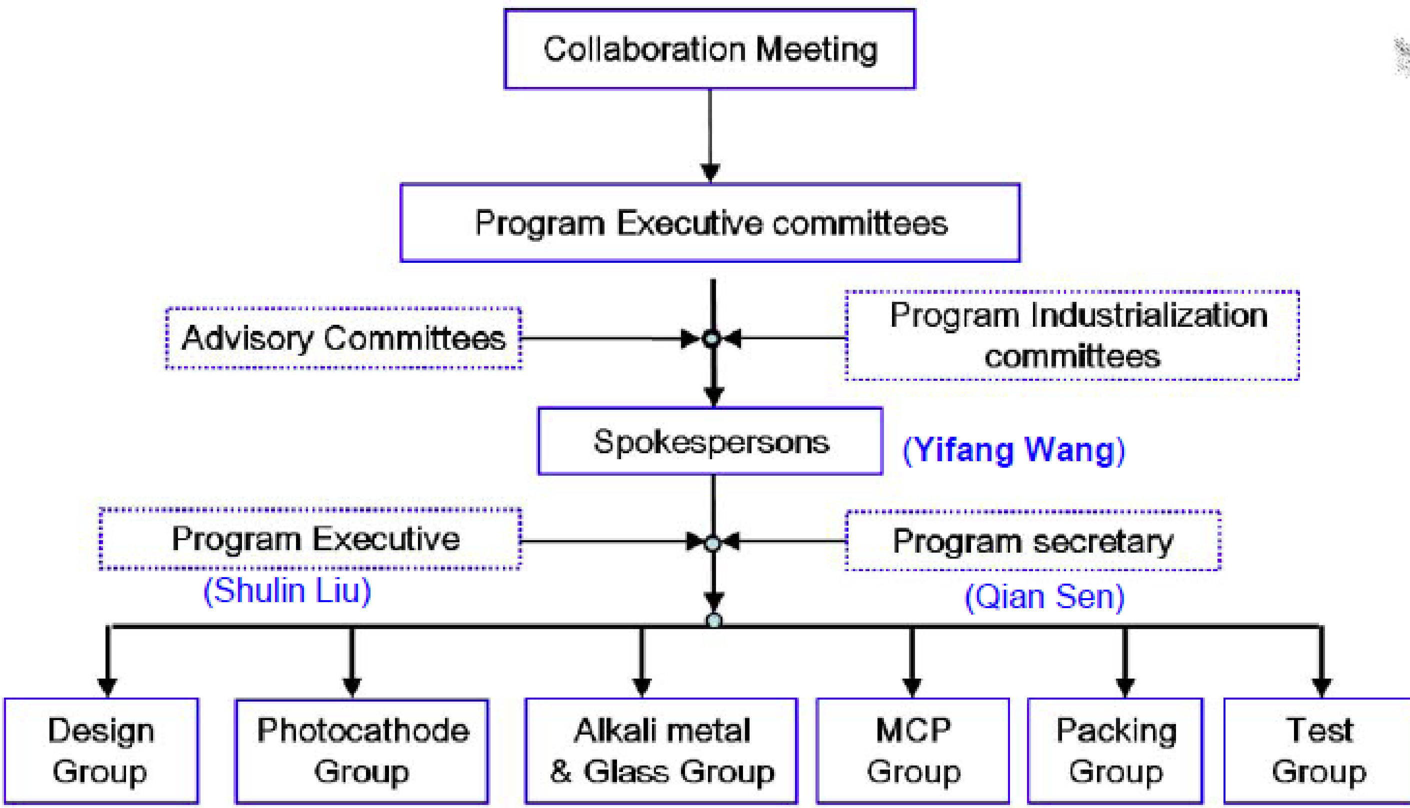


20" + 8" PMT

8" PMT for better timing(vertex)

A PMT R&D collaboration

Microchannel-Plate-Based Large Area Photomultiplier Collaboration (MLAPC)



A new PMT factory in China

- HZC bought Photonics PMT division three years ago. They have successfully produced first PMTs

PHOTONIS

- Production Equipment for PMT;
- Patents and Technique documents;
- Technique Trainings;
- Technique Support for R&D;
- User authentication & product certification

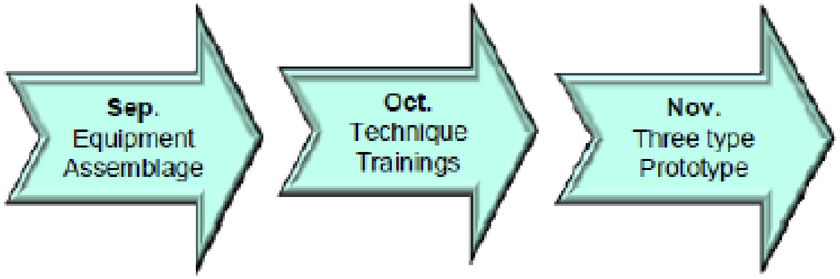
HZC PHOTONICS

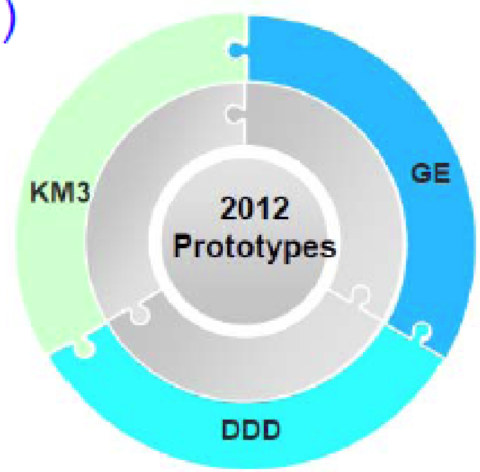
Office Building

Factory Building

HZC PMT plan

PMT Production Plan for the Market (2012)





PMT Prototype R&D Plan for the DayaBay II

3" QE= 38.4%

XP53B20

+

8" QE= 23.6%

XP1805

+

XP1807 12" QE= 24%

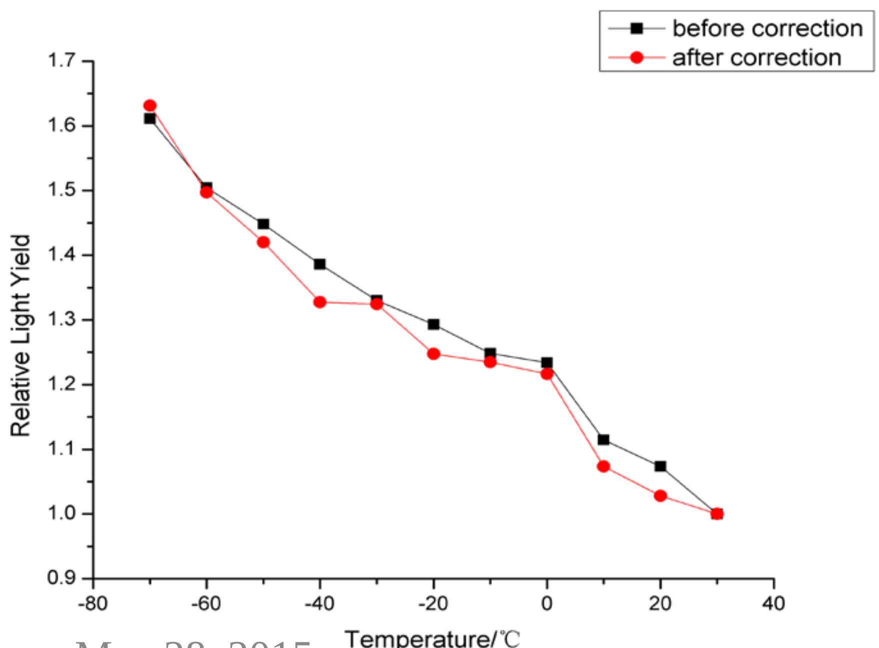
=

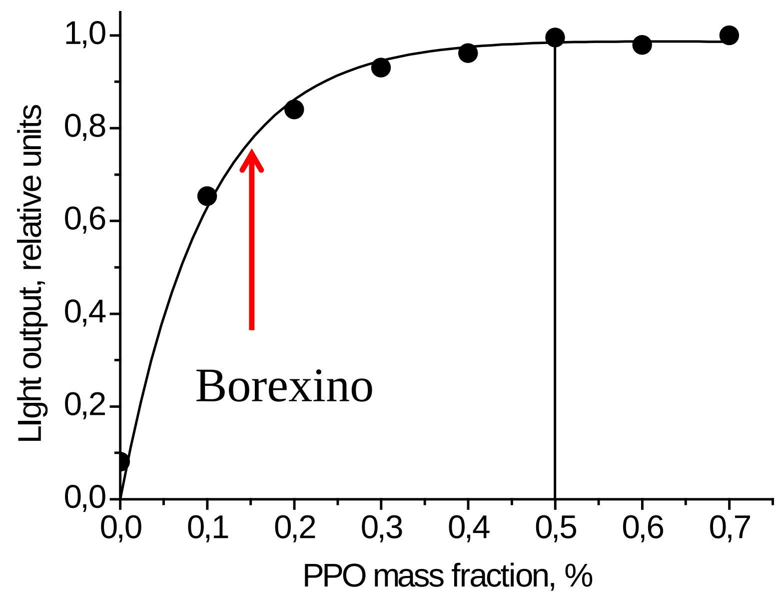
20" QE= 30%

More Photoelectrons-- LS

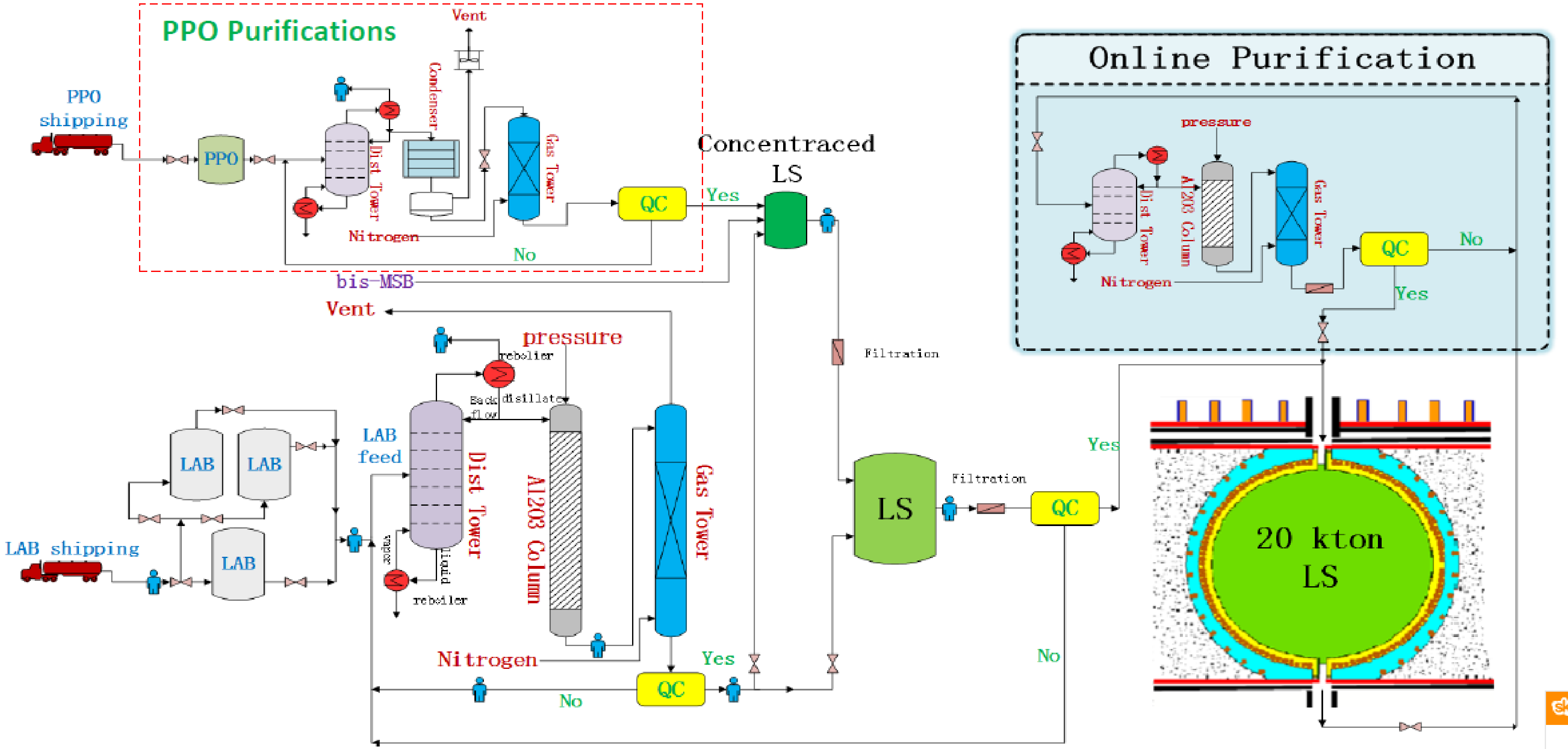
- **Longer attenuation length**
  - ⇨ Improve raw materials (using Dodecane instead of MO for LAB production）
  - ⇨ Improve the production process
  - ⇨ Purification
- **Higher light yield**
  - ⇨ Lower temperature
  - ⇨ fluor concentration optimization

Linear Alky Benzene	Atte. Length @ 430 nm
RAW	14.2 m
Vacuum distillation	19.5 m
SiO_2 coloum	18.6 m
Al_2O_3 coloum	22.3 m



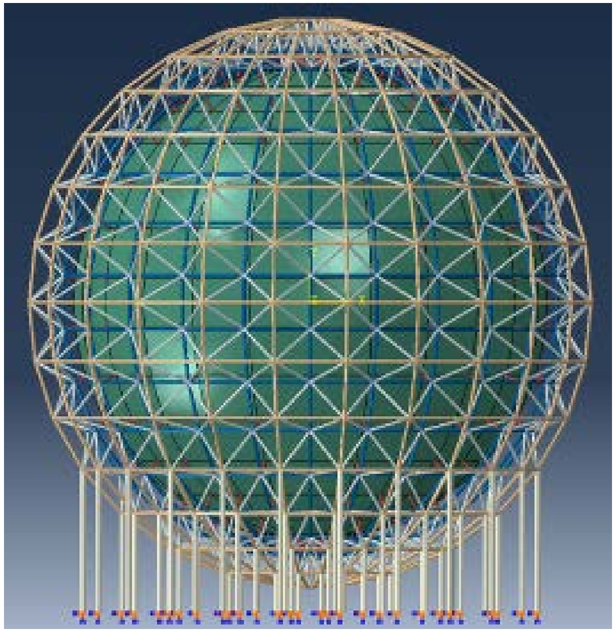


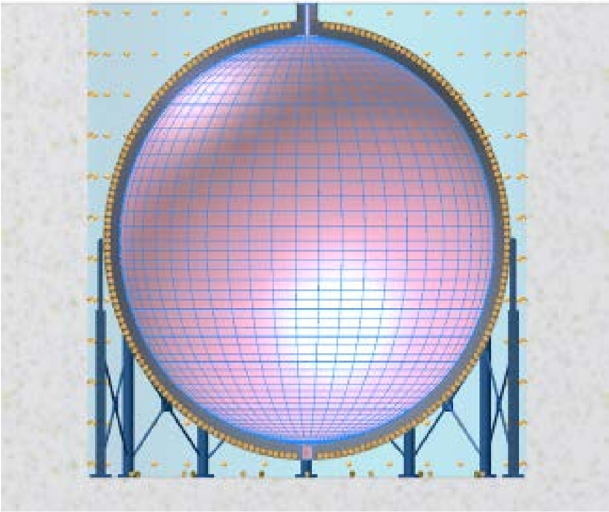
Jiangmen neutrino experiment
LS production-purification flow chart(primary)



Central Detector

- **Some basic numbers:**
  - **20 kt liquid scintillator as the target**
  - **Signal event rate: 40/day**
  - **Backgrounds with 700 m overburden:**
    - ✓ **Accidentals(~10%), $^{9}Li/^{8}He$(<1%), fast neutros(<1%)**
- **A huge detector in a water pool:**
  - **Default option: acrylic tank(D~35m) + SS structure**
  - **Backup option: SS tank(D~38m) + acrylic structure + balloon**
- **Issues:**
  - **Engineering: mechanics, safety, lifetime, …**
  - **Physics: cleanness, light collection, …**
  - **Assembly & installation**
- **Design & prototyping underway**





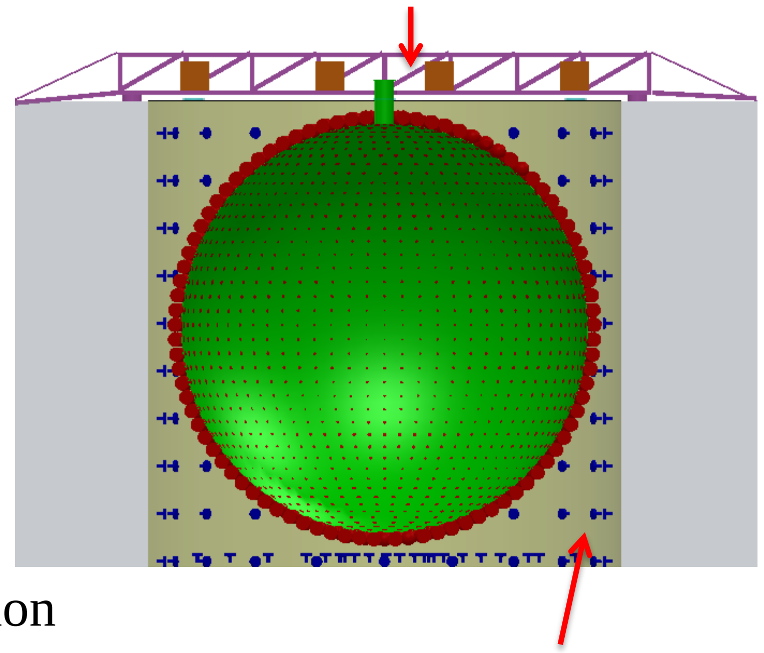
Veto Detectors

- Cosmic muon flux
  - Overburden：~700 m
  - Muon rate：**0.0031 Hz/m²**
  - Average energy：214 GeV
- Water Cherenkov Detector
  - At least 2 m water shielding
  - ~1500 20"PMTs
  - 20~30 kton pure water
  - Similar technology as Daya Bay (**99.8% efficiency**)
- Top muon tracker
  - Muon track for cosmogenic bkg rejection
  - Decommissioned OPERA plastic scintillator

Muon multiplicity at JUNO

Multiplicity	1	2	3	4	5	6
Fraction	89.6%	7.7%	1.8%	0.6%	0.3%	0.07%

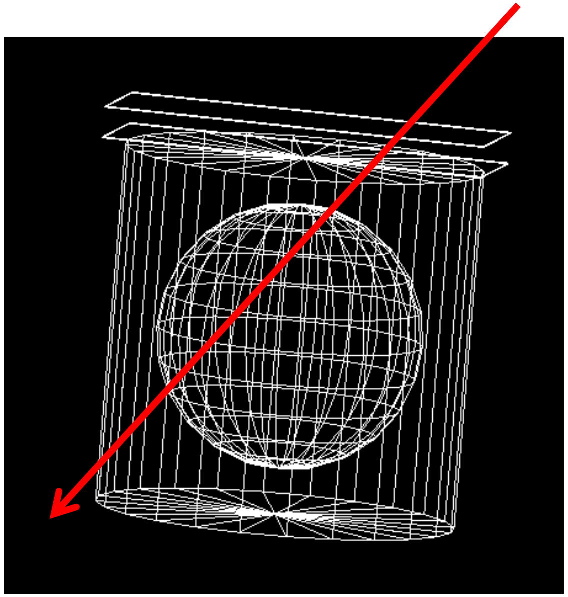
Top muon tracker



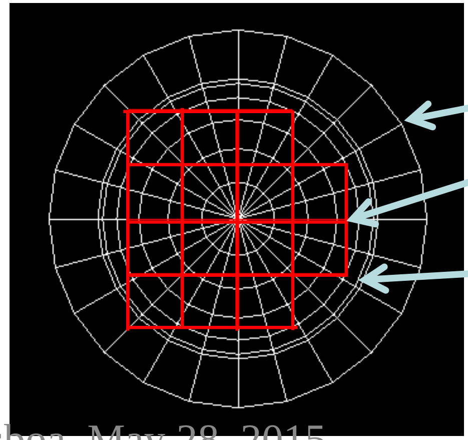
Water Cherenkov Detector

OPERA Target Tracker for the Top Tracker

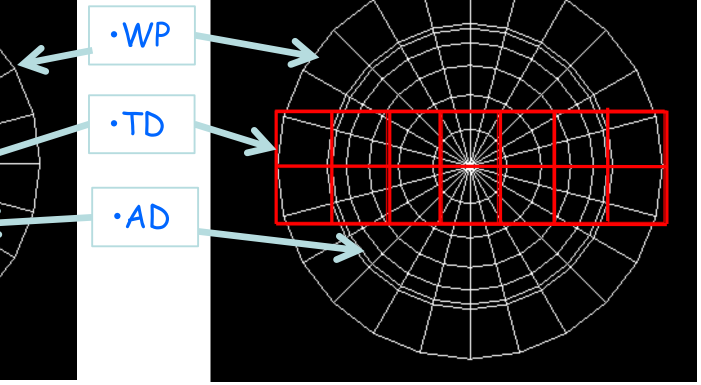
- 56 x-y walls (6.7m × 6.7m each)
- 14 TT stations, 4 walls each.
- each station is composed of 2 layers of 2 TT walls separated by 4 m distance.
- Distance of lowest and upper wall: 4 m
- Distance of lowest plane from water pool: 1 m.
- Different configurations (Middle, Rectangle, Around)
- Covered area is about 630m^2.



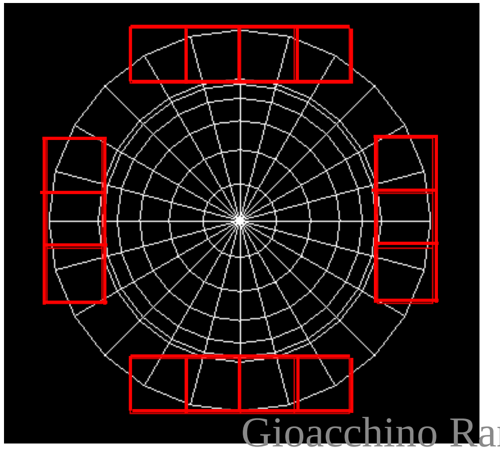
•4XY Middle (Mid)
•(3×4+2 modules)



•4XY Rectangle(Rtg)
•(2×7 modules)



•4XY Around("O")
•(2×4+2×3 modules)



Dismounting schedule

- Dismounting schedule:
  - mid-2015: first OPERA super module (31 TT walls, 248 modules)
  - beginning 2016: second OPERA super module (31 TT walls, 248 modules)
  - storage of all TT modules in Gran Sasso in containers up to the moment all dismounting is finished
  - send all TT containers (10) to Kaiping ~Spring 2016 if storage buildings already available
- Mounting in JUNO: ~2019

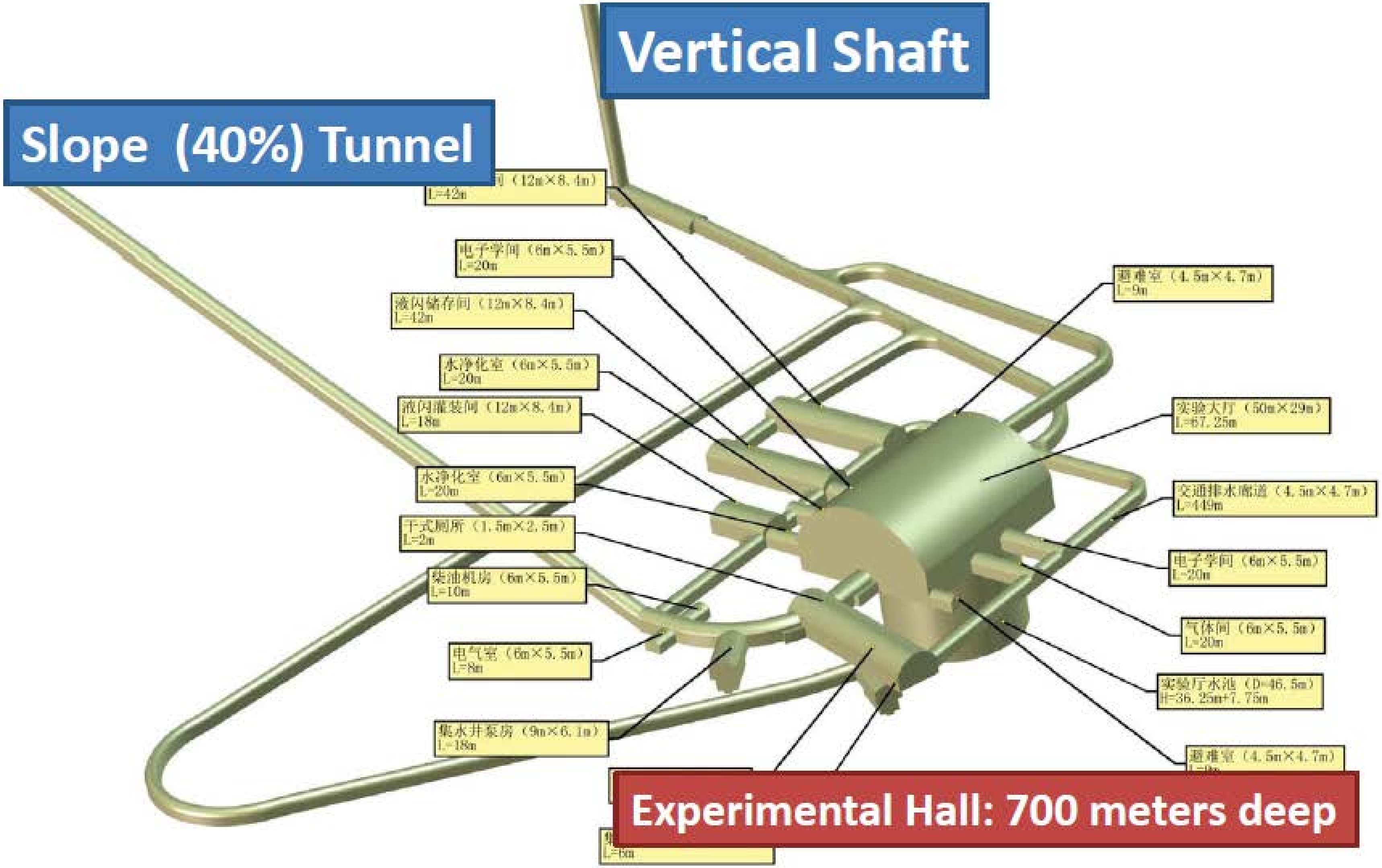
Electronics, trigger, DAQ…

- FADC at 1GHz sampling rate for pattern recognition, more information for event reconstruction, better event quality, …
- Complicated trigger schemes should be available
- Supernova is an additional burden
- A challenge to DAQ if FADC is used
- Possible a new software scheme for neutrino experiments
- Design to be finalized

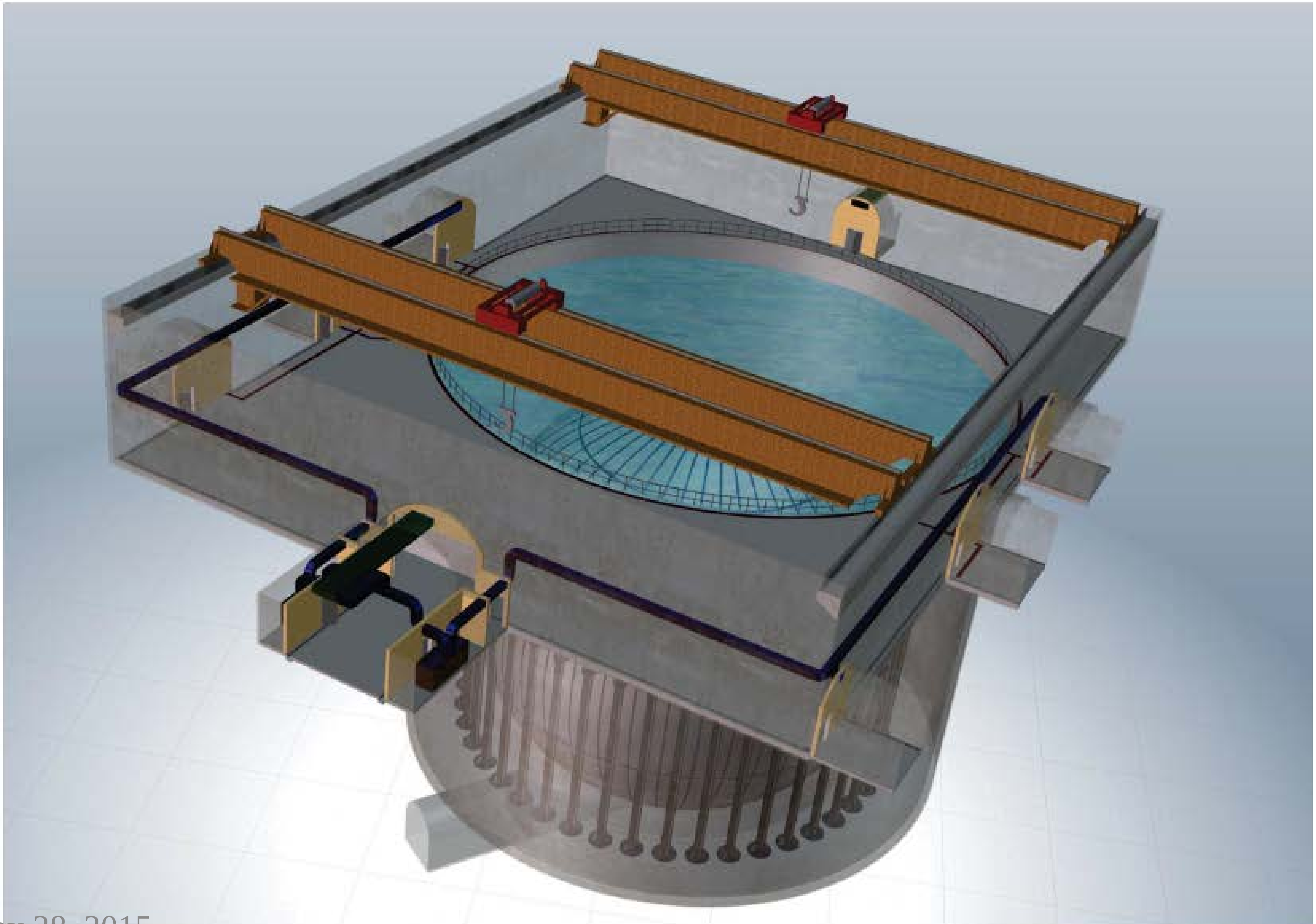
Calibration

- Of course we need it
- Precision of the energy scale, resolution, stability, uniformity all essential ingredients to ensure the success of the measure
- Which type ? Movable arms? Entire volume or only vertical?
- Sub-marine type ?
- Need ideas and R&D
- A working group recently established

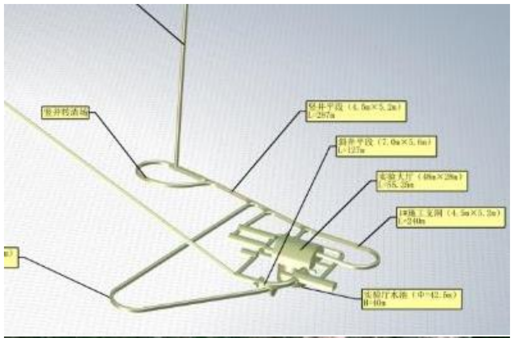
Underground Facility



Experimental Hall



Jan. 10, 2015



600 m vertical shaft
1300-m long tunnel(40% slope)
50-m diameter, 80-m high cavern


江门中微子实验建设启动会
Jiangmen Underground Neutrino Observatory

Project Plan and Progresses

First get-together meeting

Funding(2013-2014) review approved

Geological survey and preliminary civil design

1st 20" MCP-PMT

Collaboration formed

Groundbreaking Ceremony

2013

2014

Kaiping Neutrino Research Center established

Civil/infrastructure construction bidding

Funding from CAS: "Strategic Leading Science & Technology Programme" approved (~CD1)

Yangjiang NPP started to build the last two cores

Civil design approved

- Civil construction：2015-2017
- Detector component production：2016-2017
- PMT production：2016-2019
- Detector assembly & installation：2018-2019
- Filling & data taking：2020

Management Structure

Spokesperson
- Yifang Wang (IHEP)

Deputy Spokesperson
- Gioacchino Ranucci (INFN-Milano)
- Jun Cao (IHEP)

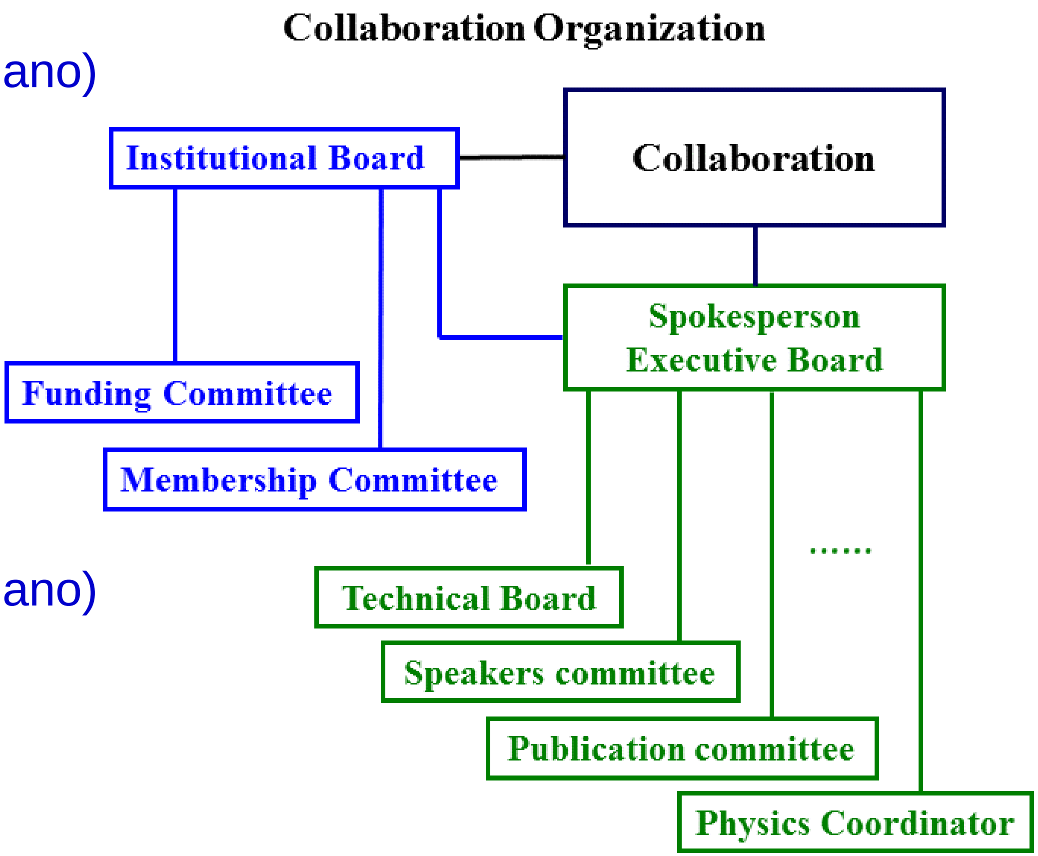
Chair of the Institutional Board (IB)
- Marcos Dracos (IPHC/IN2P3)

Executive Board (EB)
- Jun Cao (IHEP)
- Yee Hsiung (NTU)
- Steve Kettell (BNL)
- Jianglai Liu (STJU)
- Gioacchino Ranucci (INFN-Milano)
- Achim Stahl (Aachen)
- Yifang Wang (IHEP)
- Changgen Yang (IHEP)

Speaker's Committee (5)

Analysis Coordinator
- Liangjian Wen (IHEP)

Membership Committee (3)



Project Management Team

- Project manager: Y.F. Wang
- Deputy manager: J. Cao, S. Kettell
- Chief engineer: H.L. Zhuang, XXX
- Chief technical support：XXX, XXX
- Safety officer: XXX, XXXX
- L2 System manager (11):
  - Civil：X.N. Li
  - CD：Y.K. Heng，Y. Hsiung
  - VETO：M. Dracos，C.G. Yang
  - LS：L. Zhou，G. Rannucci
  - MCP-PMT: S.L. Liu
  - PMT(testing, potting, shielding, …): W. Wang, Z.H. Qin, Smirnov, XXXX
  - Electronics & Trigger & HV：X.S. Jiang，A. Stahl, D. Naumov
  - Calibration: J.L. Liu, S. Kettell
  - Integration: H.L. Zhuang, XXX
  - DAQ & Slow control：K.J. Zhu, A. Cabrera/S. Ducini
  - Offline & computing: W.D. Li，XXXX

Technical Board

- Managers
- Chief engineers/tech. support
- safety officer
- One of L2
- Z. Wang, W.G. Li, W. McKeown, P. Lombardi, L. Oberauer, Z. Krumstein

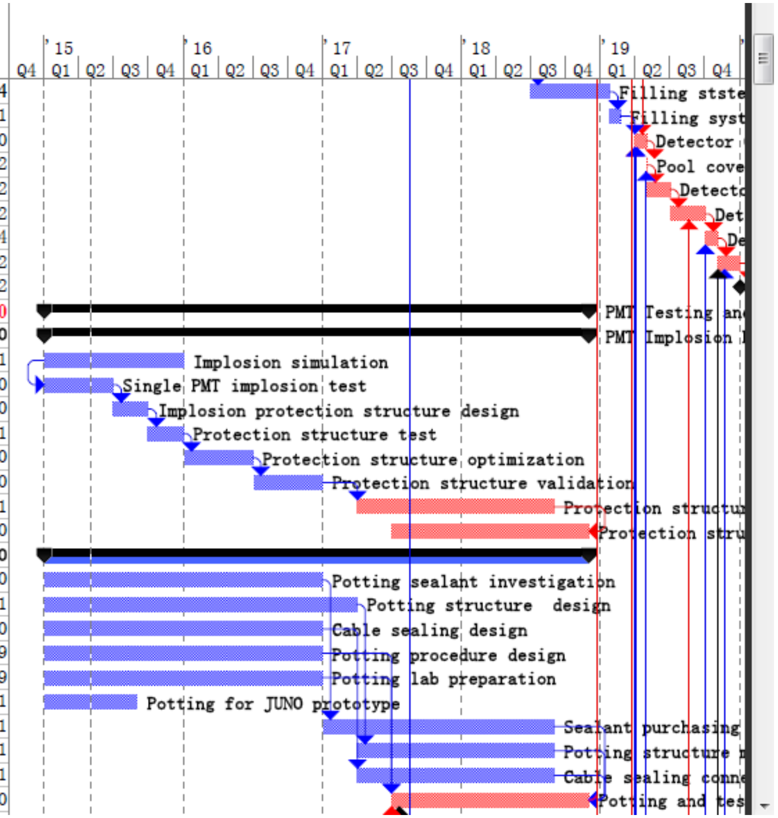
Task Sharing in progress

- China:
  - Civil, CD, VETO, LS, PMT, electronics, DAQ, calibration, …
- US:
  - Calibration: Pelletron, guided tube for sources
  - LS: QCQA,
- France:
  - VETO: TTS scintillator & electronics, shipping
- Italy
  - LS: distillation, gas striping,
  - TTS: DAQ
- Germany
  - electronics: FADC
  - LS: QCQA,
- Russia
  - PMT HV
  - TTS testing
  - TTS structure

A Preliminary Schedule

- CPM planning, under discussion
- Form an official schedule at July collaboration meeting
- Preliminary: JUNO Test Run on **Jan.2, 2020**

ID		任务名称	Duration	Start	Finish
34		Filling ststem production	150 days?	Fri 18/6/29	Thu 19/1/24
35		Filling system transport & installation	20 days?	Fri 19/1/25	Thu 19/2/21
36		Detector Cleaning	22 days?	Mon 19/4/1	Tue 19/4/30
37		Pool cover intallation	2 days	Wed 19/5/1	Thu 19/5/2
38		Detector Filling(water)	43 days?	Fri 19/5/3	Tue 19/7/2
39		Detector Filling (LS)	66 days?	Wed 19/7/3	Wed 19/10/2
40		Detector Sealing	23 days?	Thu 19/10/3	Mon 19/11/4
41		Test Run	43 days	Tue 19/11/5	Thu 20/1/2
42		Run	0 days	Thu 20/1/2	Thu 20/1/2
43		PMT Testing and Protection	1025 days?	Thu 15/1/1	Fri 18/11/30
44		**PMT Implosion Protection**	**1025 days?**	**Thu 15/1/1**	**Fri 18/11/30**
45		Implosion simulation	261 days?	Thu 15/1/1	Thu 15/12/31
46		Single PMT implosion test	129 days?	Thu 15/1/1	Tue 15/6/30
47		Implosion protection structure design	66 days?	Wed 15/7/1	Wed 15/9/30
48		Protection structure test	66 days?	Thu 15/10/1	Thu 15/12/31
49		Protection structure optimization	129 days?	Mon 16/1/4	Thu 16/6/30
50		Protection structure validation	131 days?	Mon 16/7/4	Fri 16/12/30
51		Protection structure mass production	372 days	Mon 17/4/3	Fri 18/8/31
52		Protection structure assembly	372 days?	Sat 17/7/1	Fri 18/11/30
53		**PMT Potting**	**1025 days**	**Thu 15/1/1**	**Fri 18/11/30**
54		Potting sealant investigation	522 days?	Fri 15/1/2	Fri 16/12/30
55		Potting structure design	587 days?	Fri 15/1/2	Fri 17/3/31
56		Cable sealing design	522 days?	Fri 15/1/2	Fri 16/12/30
57		Potting procedure design	522 days?	Thu 15/1/1	Thu 16/12/29
58		Potting lab preparation	522 days?	Thu 15/1/1	Thu 16/12/29
59		Potting for JUNO prototype	173 days?	Thu 15/1/1	Mon 15/8/31
60		Sealant purchasing	436 days?	Tue 17/1/3	Fri 18/8/31
61		Potting structure mass production	372 days?	Mon 17/4/3	Fri 18/8/31
62		Cable sealing connector purchasing	372 days?	Mon 17/4/3	Fri 18/8/31
63		Potting and testing	372 days	Sat 17/7/1	Fri 18/11/30



Conclusion

The vast potential physics reach of JUNO - MH determination and beyond - makes the experiment very attractive and one of he pillars of the next round of large liquid scintillator detectors worldwide

The perspectives for an Europen participation of significant impact are very promising, solidly grounded on previous expertise and well positioned in a larger Collaboration framework

New groups are eagerly needed and very welcomed