JUNO: info point

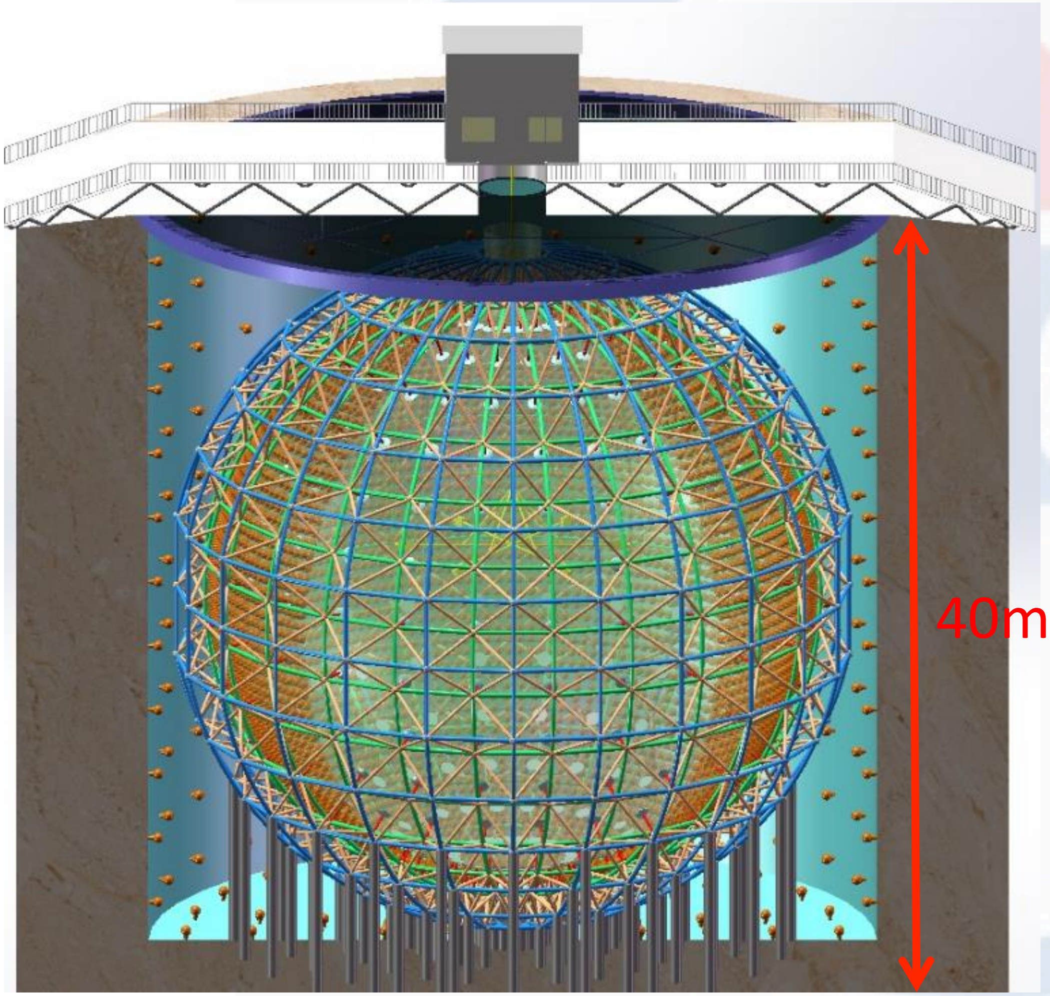
(**M. Buizza Avanzini**, O. Drapier, M. Gonin, Q. Huang)

Conseil Scientifique

LLR, 01/06/2017

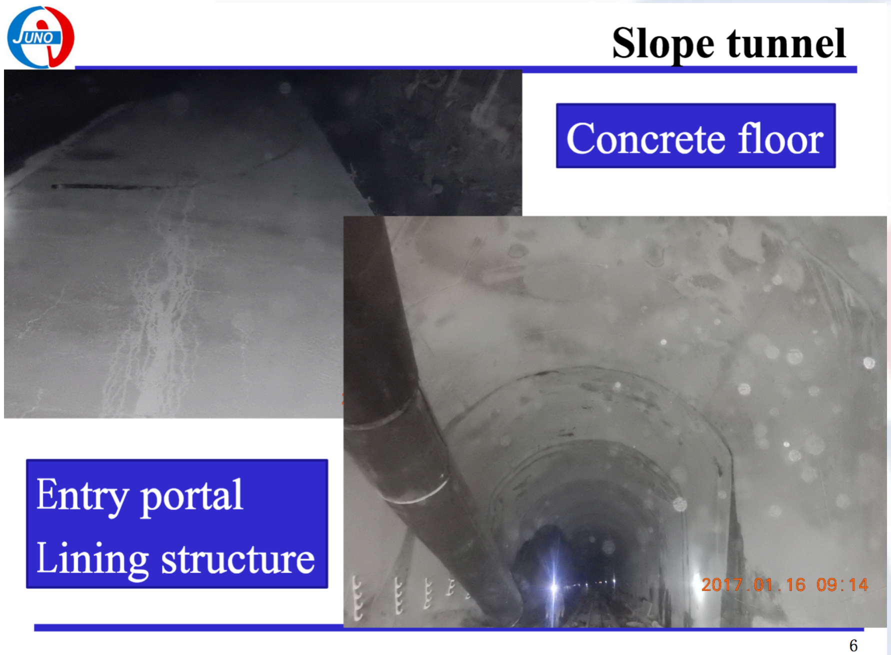
The JUNO Experiment

- Jiangmen Underground Neutrino Observatory, a multiple-purpose neutrino experiment, approved in Feb. 2013. ~ 300 M$.



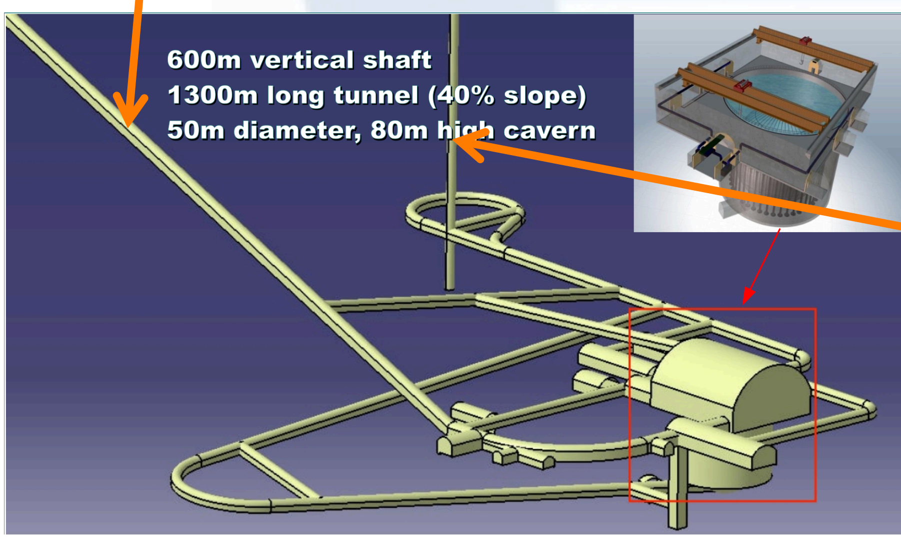
- 20 kton LS detector
- 3% energy resolution
- 700 m underground
- Rich physics possibilities
  - Reactor neutrino for Mass hierarchy and precision measurement of oscillation parameters
  - Supernovae neutrino
  - Geoneutrino
  - Solar neutrino
  - Atmospheric neutrino
  - Exotic searches

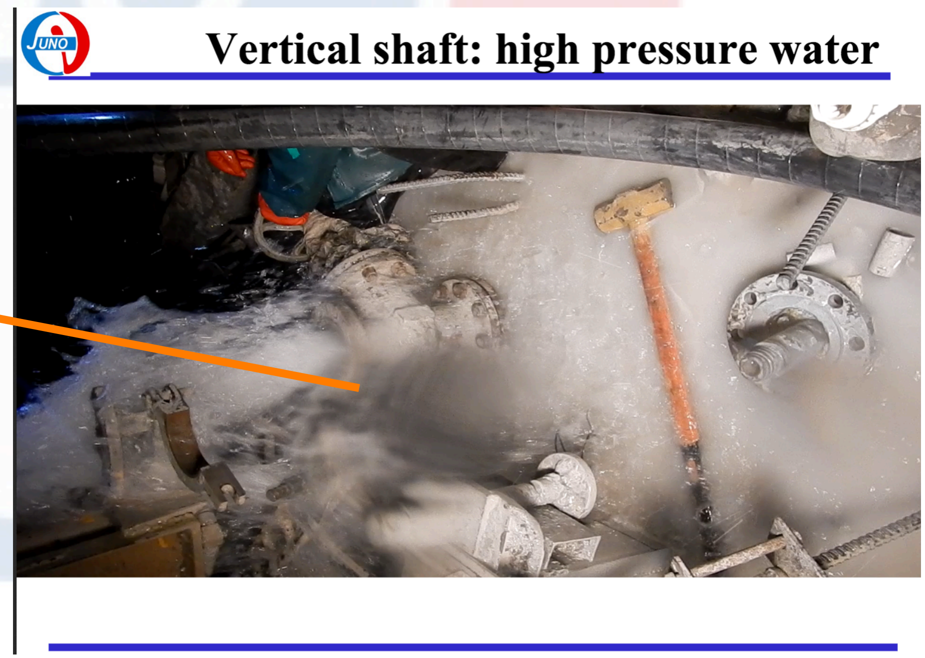
News from the experiment

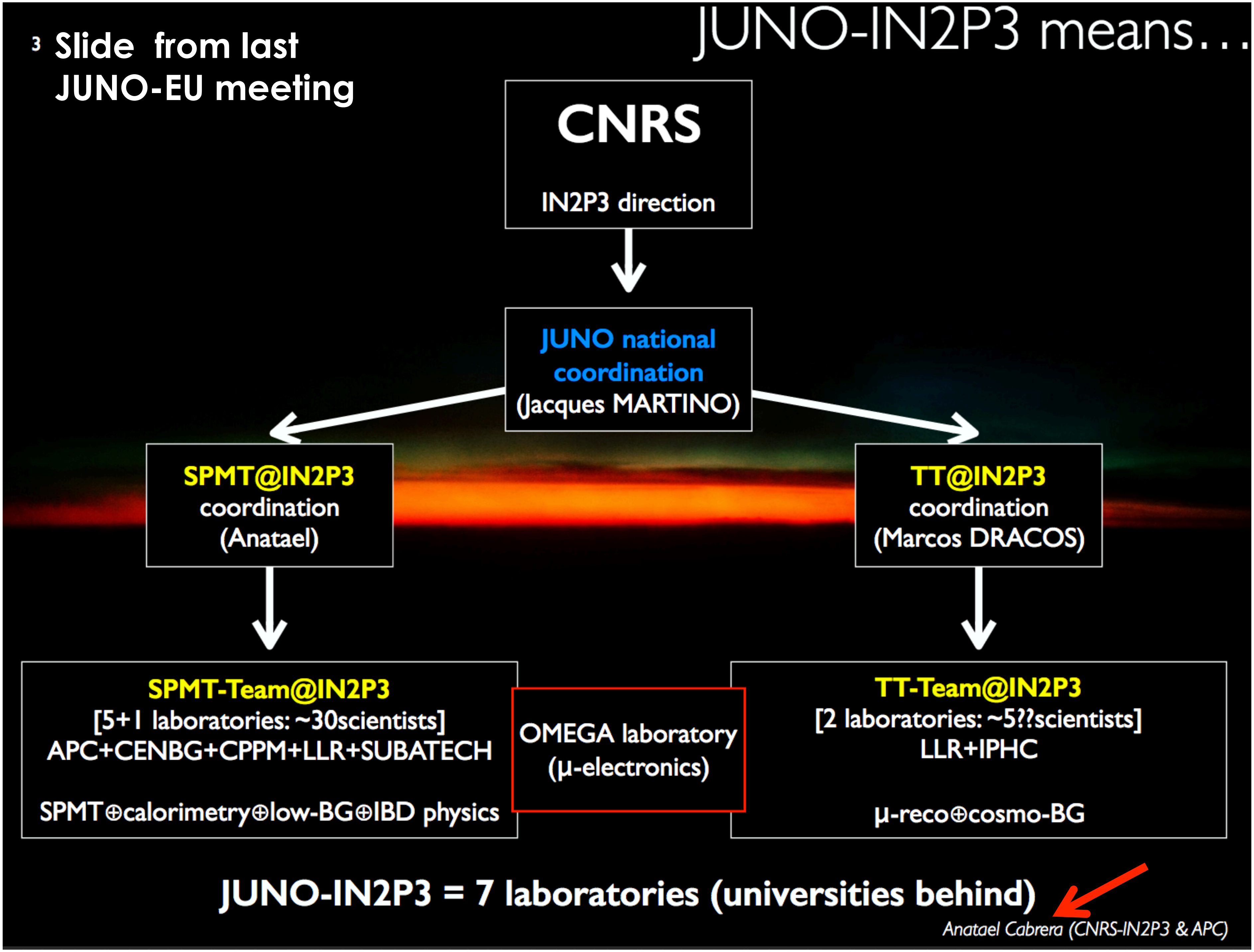


Vertical shaft drilling suffers of water inondation ➔ decided to stop vertical shaft 30m above the original design ➔ ~50m less rock coverage. Small impact on MH measurement, but less risky and shorter delay

6 months delay?
Start data taking 2021?





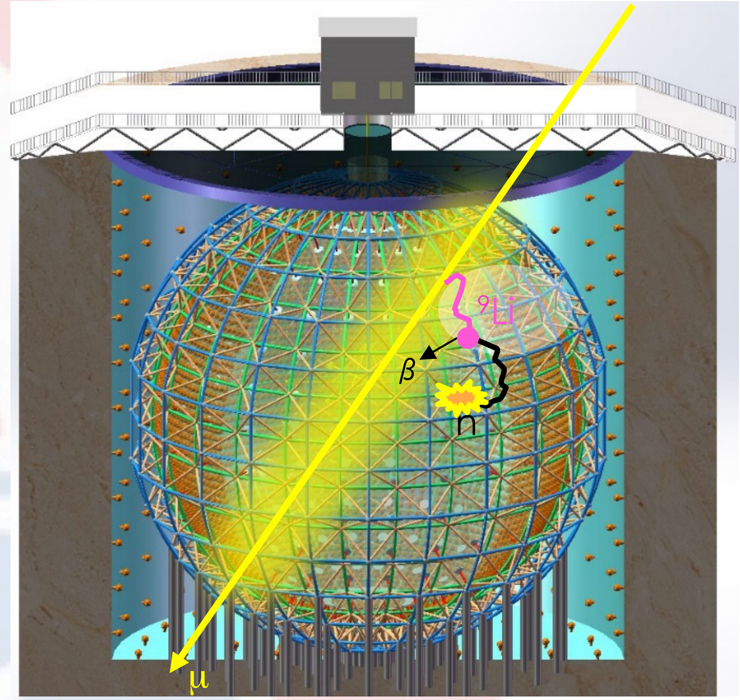

3 Slide from last JUNO-EU meeting
JUNO-IN2P3 means…
CNRS
IN2P3 direction
JUNO national coordination
(Jacques MARTINO)
SPMT@IN2P3
coordination
(Anatael)
TT@IN2P3
coordination
(Marcos DRACOS)
SPMT-Team@IN2P3
[5+1 laboratories: ~30scientists]
APC+CENBG+CPPM+LLR+SUBATECH
SPMT⊕calorimetry⊕low-BG⊕IBD physics
OMEGA laboratory
(μ-electronics)
TT-Team@IN2P3
[2 laboratories: ~5??scientists]
LLR+IPHC
μ-reco⊕cosmo-BG
JUNO-IN2P3 = 7 laboratories (universities behind)
Anatael Cabrera (CNRS-IN2P3 & APC)

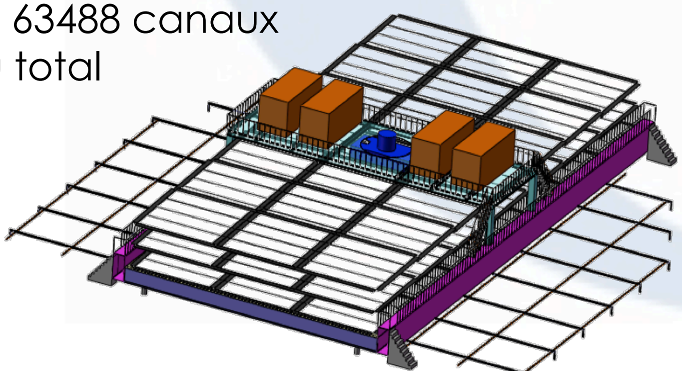
JUNO-LLR means

1. TT electronics (« concentrateurs »)
2. SPMT-Physics coordination
3. Simulation studies about the Light Concentrators option
4. PhD thesis since Oct 2016: Qinhua Huang working on SPMT simulations
5. JUNO-Software workshop organized @LLR in November 2016, ~ 40 participants (limited places!)

1. Électronique du Top Tracker de JUNO

- Rappel :
  - Important bruit de fond cosmogénique
    - ^{9}Li et ^{8}He créés par μ-spallation de ^{12}C
  - Veto μ impossible sur tout le détecteur :
    - Taux de μ cosmiques : ≈ 4 Hz ; Temps de veto : ≈ 1s
  - Solution : veto d'un tube (≈ m) autour des μ
    - Reconstruction des μ par
      - Détecteur veto (Cherenkov à eau) + Détecteur central
  - Top Tracker : échantillonnage des traces de muons pour améliorer la précision de la reconstruction des muons
  - 62 « Murs » répartis en 3 couches (3x20 + 2)
    - Chaque mur : 16 « modules » (4X + 4Y)
    - Chaque module a 64 canaux
    - Lus par 2 PMTs multi-anodes (H7546)
  - 63488 canaux au total





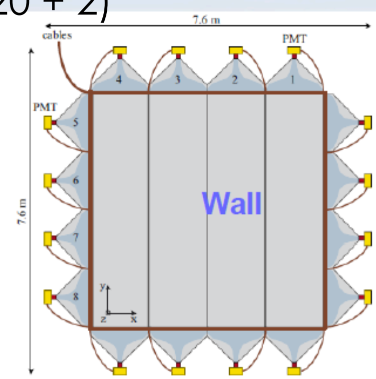
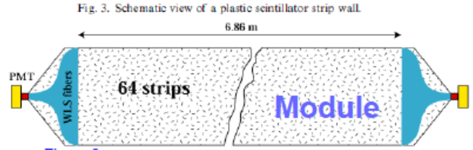


Fig. 3. Schematic view of a plastic scintillator strip wall.



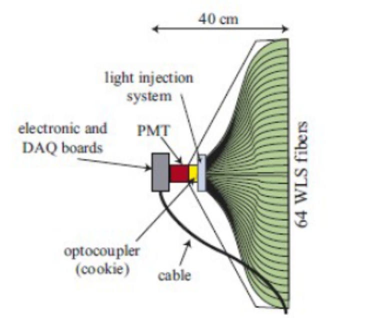
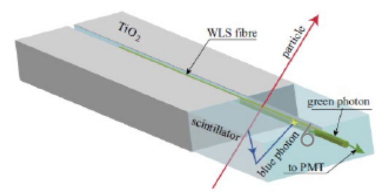
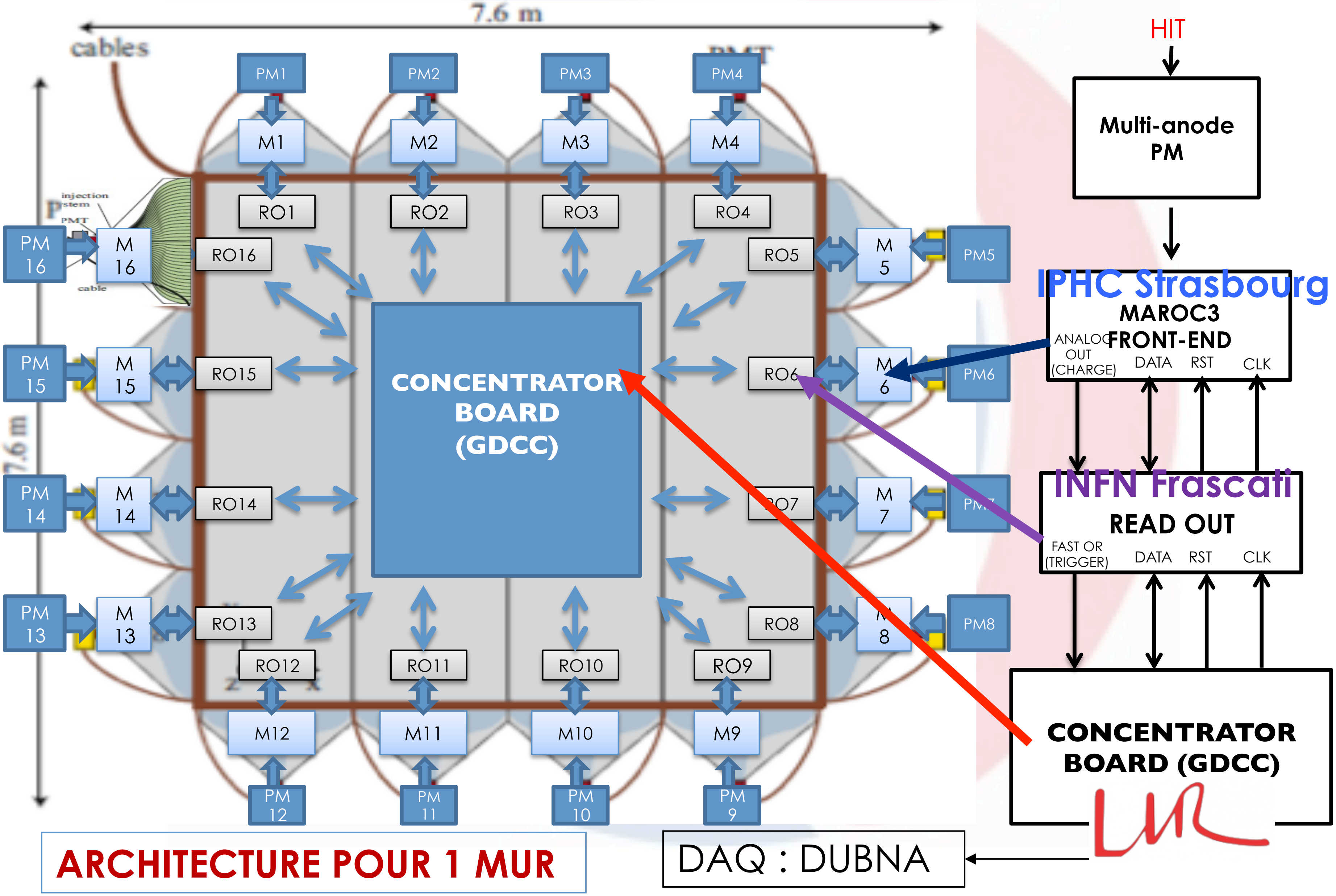


Fig. 2. Schematic view of an end-cap of a scintillator strip module.



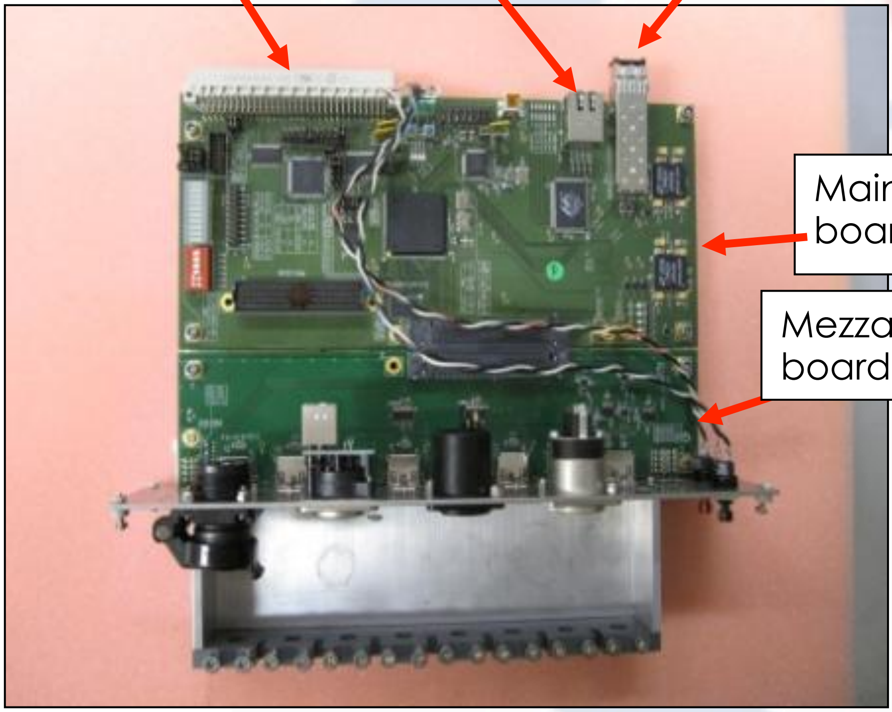
Carte GDCC développée pour CALICE au

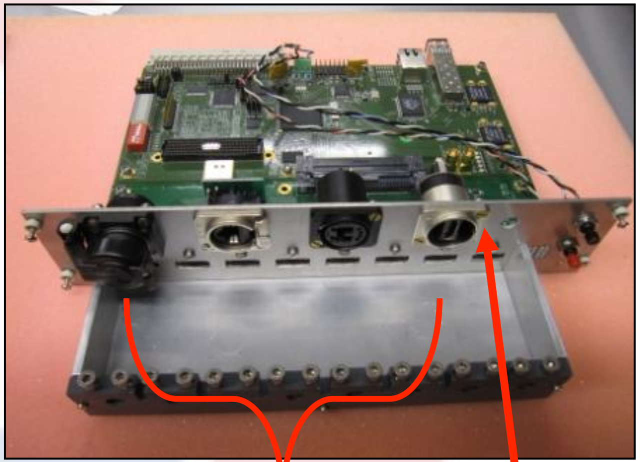
Utilisée par WAGASCI, proposée comme concentrateur JUNO TT (R. Cornat)



Rappel : La carte GDCC

- Format : VME 6U (connecteur J1 pour tensions)
- 1/3 mezzanine avec connections vers cartes Read-out
- 2/3 carte mère avec Xilinx Spartan XC6SLX75 + Marvell
- USB pour debug





A FAIRE

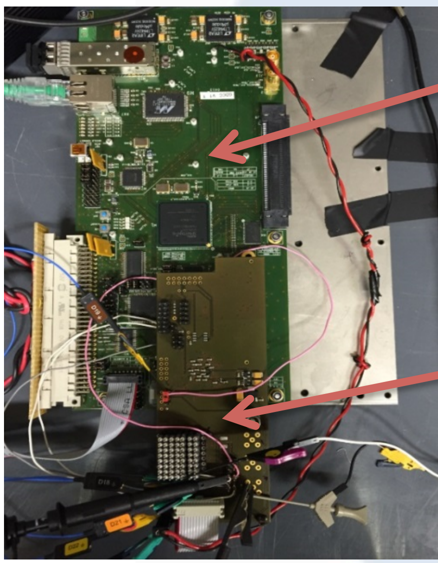
- **Adaptation principale : MEZZANINE pour 16 connections**
- **Révision du routage de la carte mère**
- **Upgrade du FPGA pour performances (et disponibilité)**

FAIT : tester GDCC avec carte d'évaluation MAROC3 (**Xuan L. + Franck G.**)
Utilise une GDCC / DIF (**Miguel R-R., Floris T.**)

En cours 1:
Tests carte MAROC3 (Strasbourg) avec GDCC

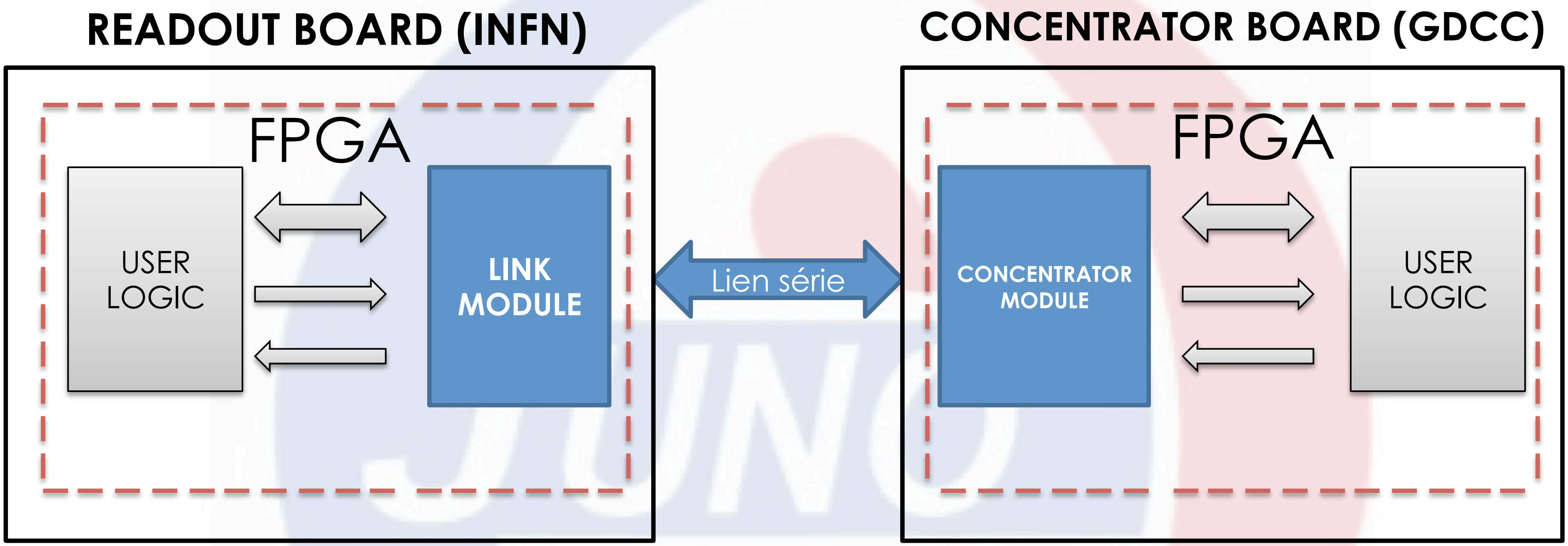
- Test avec une seule carte
  - <u>But</u>: Communication avec la carte Front-end (en attendant carte Read-out INFN)

  Mettre en place un trigger simple avec scintillateurs & PMs



- Configuration du MAROC3 à travers la carte Front-end
- Visualisation du signal à la sortie du MAROC3

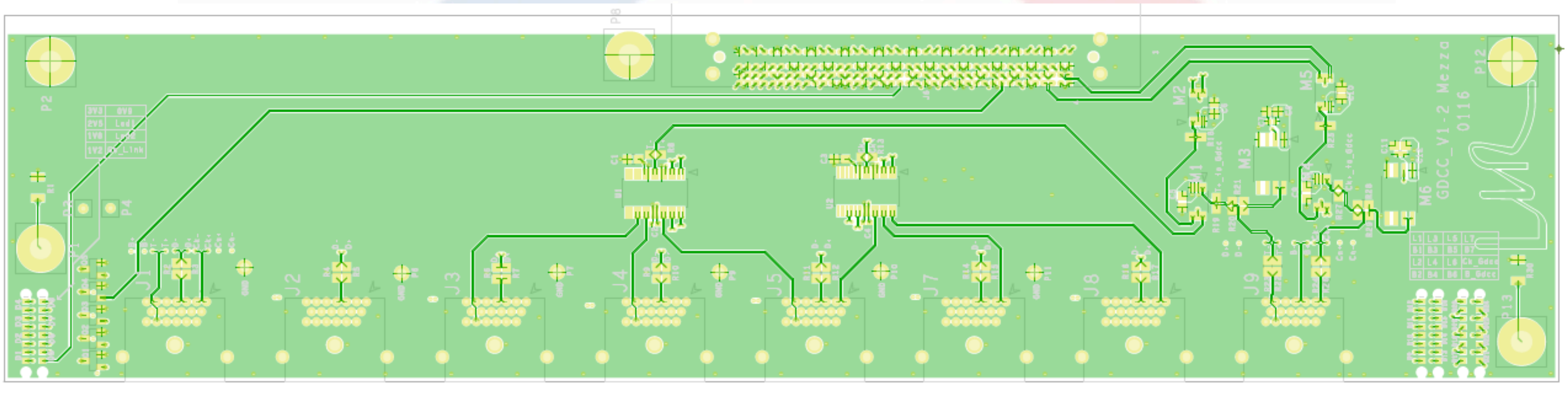
En cours 2: Protocole de communication GDCC/Read-out



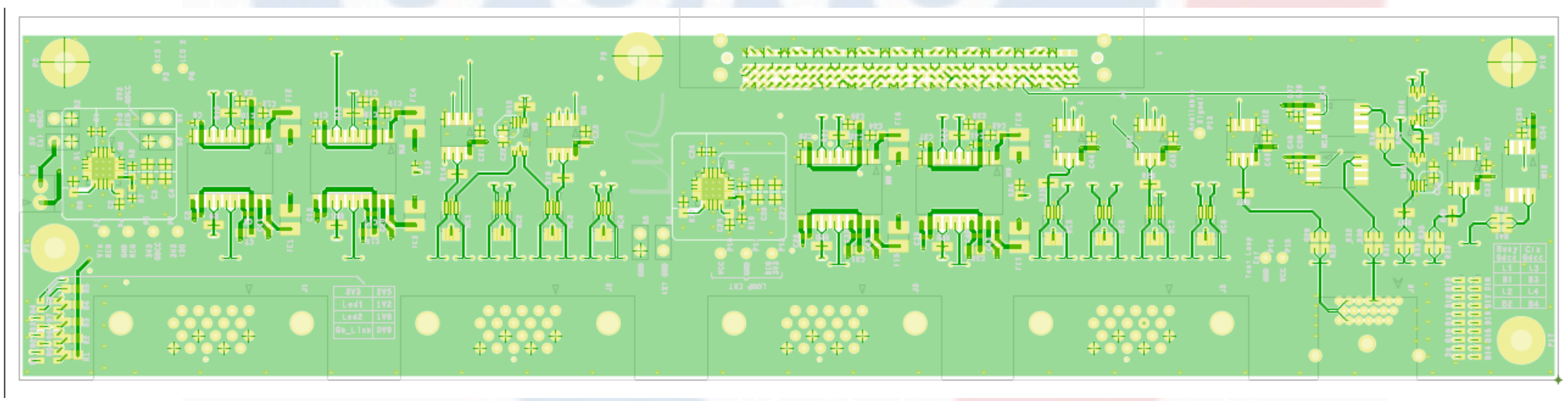
- Partager le code VHDL pour LINK & Concentrator module
  - **Link module** (contenu dans la "DIF"): doit être dans la carte readout
  - Nous donnerons aussi la partie "**module concentrateur**" pour tests à l'INFN
  - Etude et amelioration éventuelle du lien
- Pour cela :
  - preparation des modules VHDL et de la documentation
    - Travail en cours

En cours 3:
Design de la nouvelle mezzanine (Rémi G.)

- « Ancienne mezzanine » : (7 HDMI)



- « Nouvelle mezzanine » : (4 MDR)

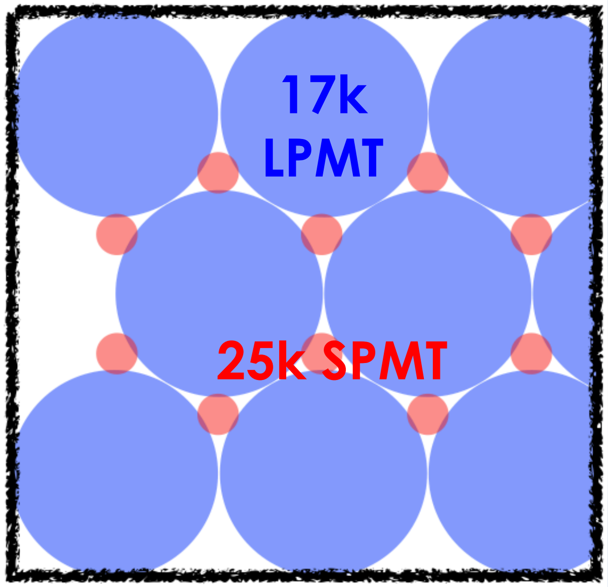


- C’est une version intermédiaire (interfacer 2/4 cartes, pas encore 16)
- La future version « finale » sera basée sur un nouveau design de la GDCC

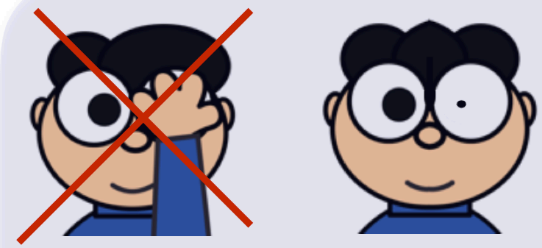
Feuille de route

- **OK** : tester GDCC avec carte d'évaluation MAROC3 (**Xuan L. + Franck G.**)
  - Utilise une GDCC / DIF (**Miguel R-R., Floris T.**)
- **En cours (Xuan L. + Franck G.) :**
  - Tester 1 carte Front-end (MAROC3-Strasbourg) avec mezzanine actuelle
  - Protocole de communication GDCC-cartes Read-out -> INFN
  - Nouveau design de mezzanine pour interfacer 2 (4 ?) cartes Read-out (INFN) et tester trigger (**Rémi G.**)
- Chaîne complète avec 2 Front-end + 2 Read-out : Fin 2017
- **Besoin développement ON-LINE !**
- **Etape suivante :**
  - Implémenter TDC et TRIGGER dans la GDCC
  - Nouveau design de GDCC (+ upgrade FPGA) pour interfacer 16 cartes Read-out
  - Avec mezzanine finale ou tout sur une carte ?
  - Nouveau banc de test
- **Besoin développement ON-LINE !!**
- D'ici fin 2018- mi 2019
- Production – installation : 2019 **+**

2. SPMT-Physics coordination



The main purpose of the sPMT system is thus to serve as an aid to the calibration of the LPMTs



Double-calorimetry: two independent sets of eyes with different systematics looking at the same events

The sPMT system also brings other advantages to JUNO, for free:
Independent physics (measurement of solar parameters), aid and redundancy in μ reconstruction, aid to supernova ν measurement,…

Work in the last few months has centered on better quantifying the sPMT physics performance in order to fine-tune the design and the requirements to **finalize the tender.**
About 1 meeting every 3-4 weeks, alternate woth SPMT-HW group

SPMT specifications

Evaluate the impact on physics results of the most important SPMT parameters.

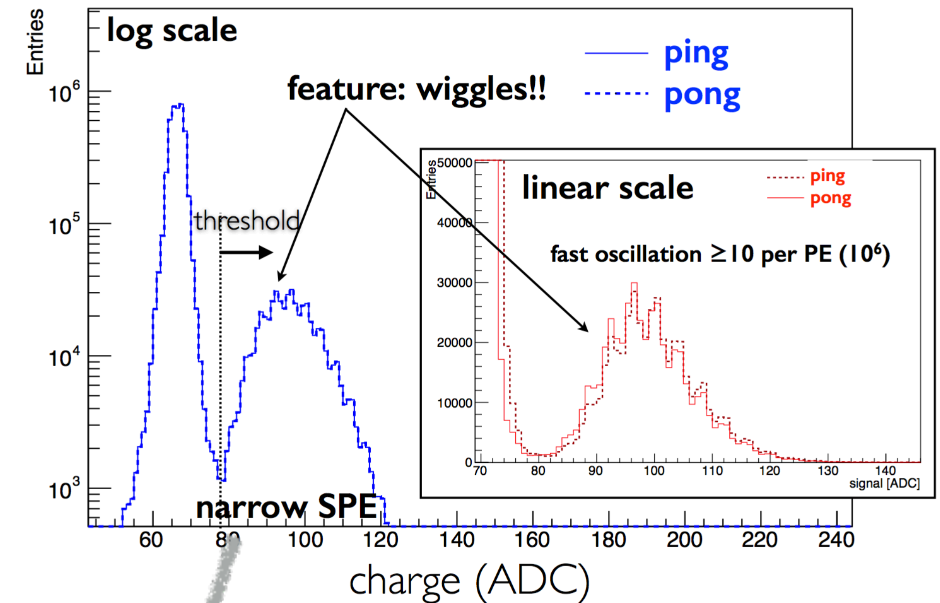
Goal: avoid too strong requirements which will blow up the price.

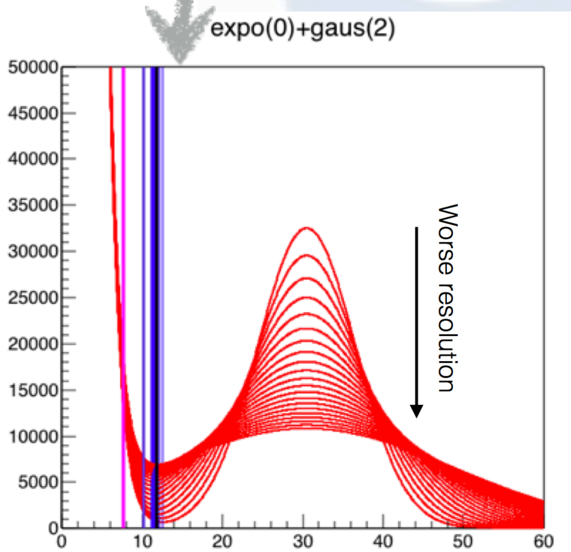
- **SPE resolution** : impact on light detection efficiency
- **Dark rate** : energy resolution, bandwidth occupation
- **After Pulse** : energy resolution (small impact is expected for PMT counting energy estimation)
- **TTS** : muon reconstruction
- **Number and installation**: impact on solar oscillation analysis, muon reco and detector response

TYPE	Requirement	HZC72B20 by IHEP	R12199 by IHEP	R12199 by Hamamatsu
QExCE @ 420 nm	minimum>22%, average>24%	23.9%@420nm 27.1%@380nm	~24%@420nm	minimum>25%, typical~28%
TTS(FWHM) of SPE	<5ns?	3-6ns	3.8ns	<3.4ns
Gain @ HV	3X10^6@<1300 V	3X10^6 @1189V	1110V	
P/V ratio of SPE	minimum>2, average>2.5	5.6@3X10^{6}gain 7.1@1X10^{7}gain		minimum>2, typical~3
SPE signal width (sigma)	<35%	35.2%@3X10^6 29.9%@1X10^7	42.7%@3X10^6 39.3%@1X10^7	<30%
Dark rate (@3X10^6+ preamp) @21℃	@ 1/4 SPE <1.5kHz	A few hundred Hz-2kHz	1.8kHz	Maximum<2kHz, typical~0.8kHz
	@ 1/3 SPE <1.0kHz		1.6kHz	
Cathode effective area	>80%	81%		81%
Non-uniformity	<15%			<15%
Glass radiation level	238U<400ppb 232Th<400ppb 40K<200ppb	238U<145ppb 232Th<272ppb 40K<162ppb		238U<400ppb 232Th<400ppb 40K<120ppb
Spectrum range	300-650nm	300-650nm		300-650nm
stability	Gain stability in one week：5% in one year：10%			Typical 2%, maximum 5% in one week
Water pressure resistant	>1MPa	>1.5Mpa		>1.5Mpa
Divider current	<10μA			
nonlinearity	<10% @1-100 P.E.			<10%

Single Photo Electron Resolution

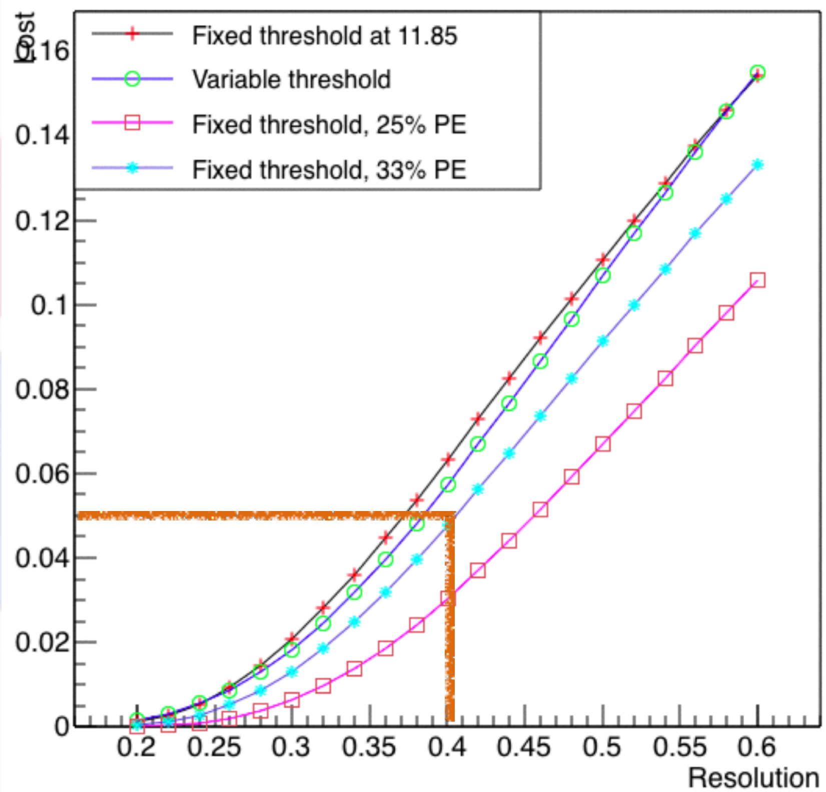
Dark Noise @ APC (not LED yet, but ready)





Evaluate the impact for the different resolutions (σ_{spe}/μ_{spe}) from 20% to 60% with a 2% step

Efficiency loss vs. Resolution



We require an efficiency loss < 5%

➔ **SPE res. < 40%**

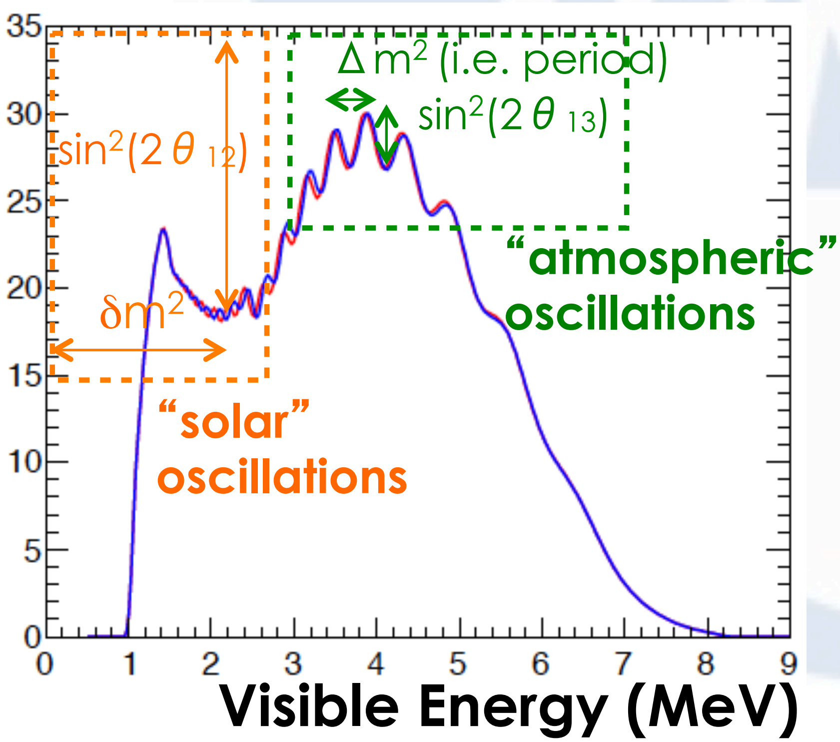
Qinhua

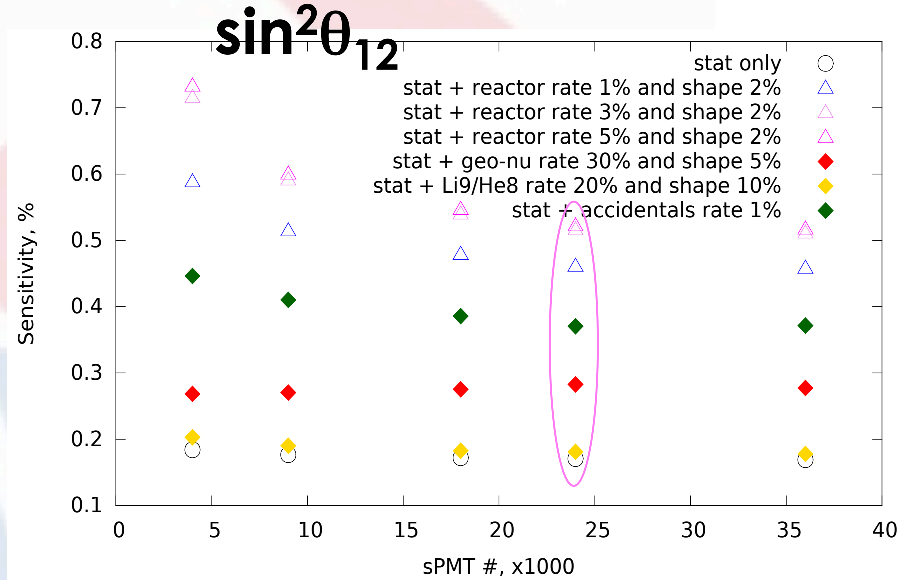
SPMT δm^2 and $\sin^2(2\theta_{12})$ measurements

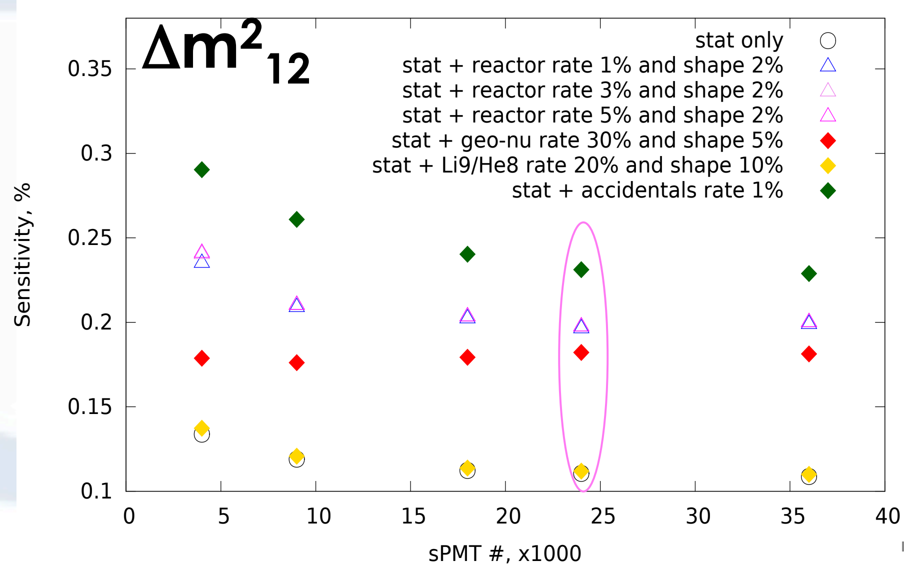
δm^2 & $\sin^2(2\theta_{12})$ measurement are rate+shape driven…

Use solar disappearance to cross-calibrate calorimetry for Mass Ordering precision & accuracy

[Possible if sensitivity on δm^2 are similar for SPMT and LPMT]







SPMT bidding… Done!

- An international bidding on May 8.
- HZC photonics have been choosen
- HZC will provide 25k (+1k spares) 3.1'' XP72B22 tubes in the next 2.5 years.
- HZC will produce HV divider and do potting for all PMTs.
- Contract signed last week.

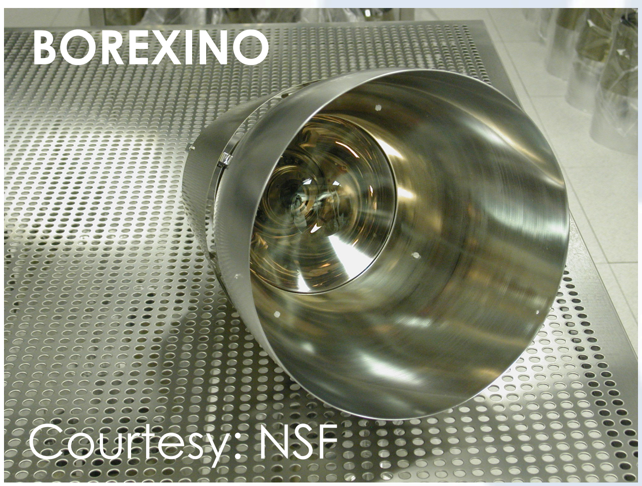
XP72B22

XP72B22 performances

Parameters	HZC's response
QE×CE @ 420 nm	24% (>22%)
TTS(FWHM) of SPE	<5ns
P/V ratio of SPE	3 (>2)
SPE signal width (sigma)	35% (<45%)
Dark rate @ ¼ PE	1kHz (<1.8kHz)
QE uniformity	<30% in Φ60mm
Pre/after pulse ratio	<5%, < 15%
Nonlinearity	<10%@1-100PE
Radioactivity	238U: <400ppb, 232Th: <400ppb, 40K: <200ppb

In 1 week: installation bidding
(check installation configuration -> Qinhua)

3. LPMT Light Concentrator Study



High reflectivity (~90%) inner faces

Usually adopted in liquid based neutrino detector to increase the effective light collection efficiency

Occulting Light Concentrator: motivations

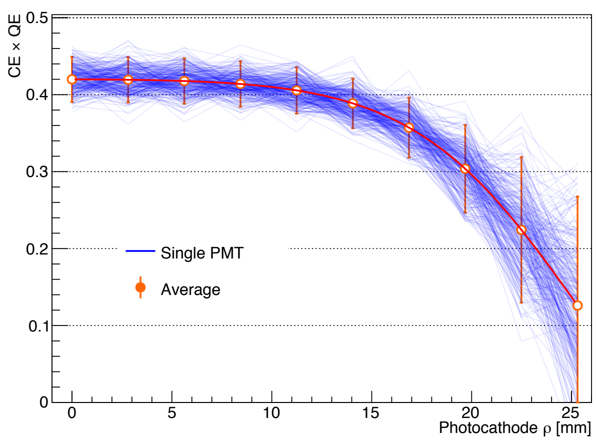
1. The JUNO PMT clearance is 25mm. Due to mechanical constraints, to the protection cover thinkness (8mm?), to the tolerance on LPMT diameter (5mm) -> maybe too optimistic. **Enlarge the clearance means decrease the number of LPMTs. OLC can help to recover the lost photo-coverage**

2. Fundamental parameter for JUNO is the energy resolution
   - The Detection Efficiency (DE) along the photocathode is not constant and this can affect the uniformity in the light collection
   - PMT-to-PMT differences in the DE profile can even worsen this effect

   Occulting LC help in **avoiding non uniformity effects due to photocathode**

3. Moreover **light collection** across the detector volume is **more uniform** when using LC

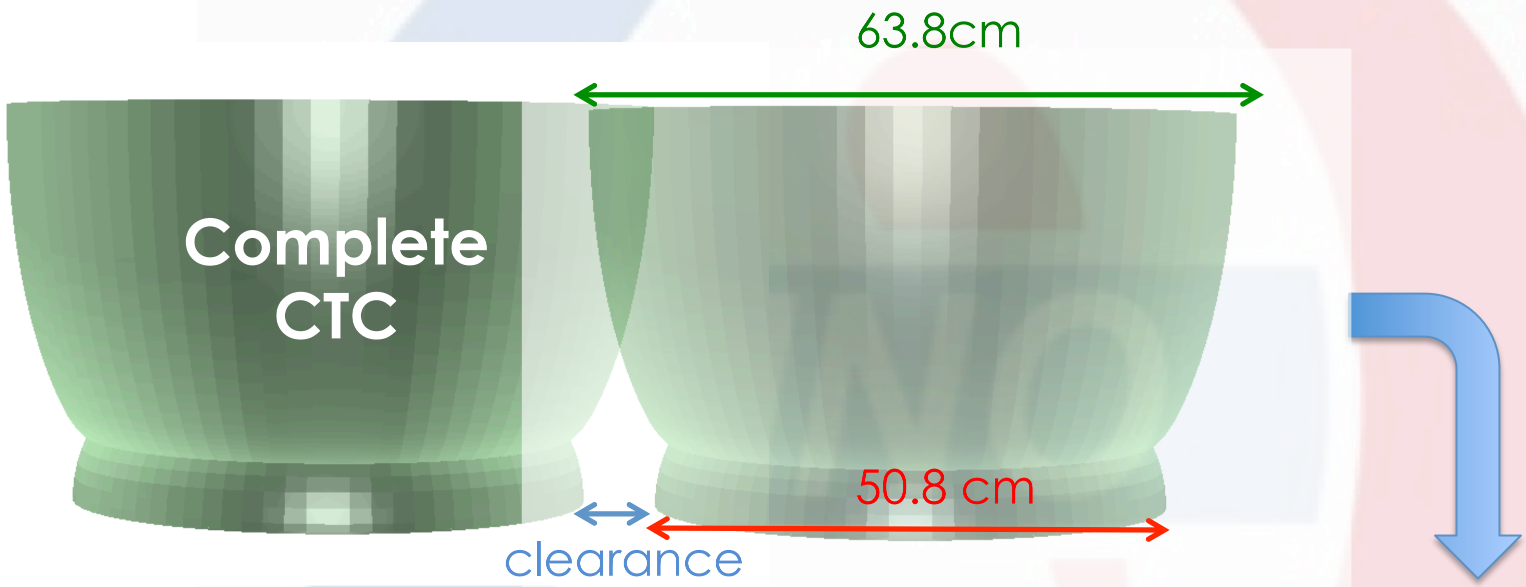
Exemple of DE profiles as derived from DoubleChooz



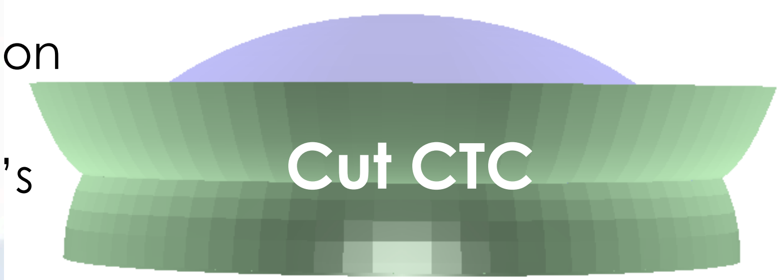
- ✓ Occulting Light Concentrator (OLC) for **precision calorimetry**.
- ✓ **Occulting** the worst performing part of the photocatode.
- ✓ Designed accounting for the PMT's **collection efficiency (CE)** profile.

Cut Compond Tangential Concentrator (CTC)

Due to clearance constraints, we cut the CTC, to avoid overlapping



- Designed with CTC (already used for SNO and Borexino) and optimized for JUNO geometry
- Exit aperture is optimized at r=240mm based on the measured CE
- The entrance aperture is constrained by PMT's clearance

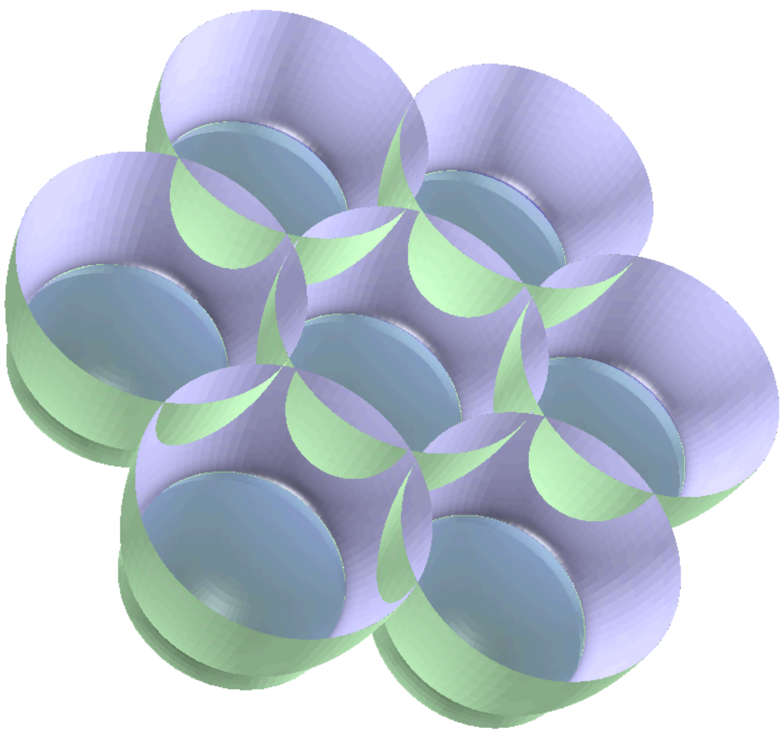


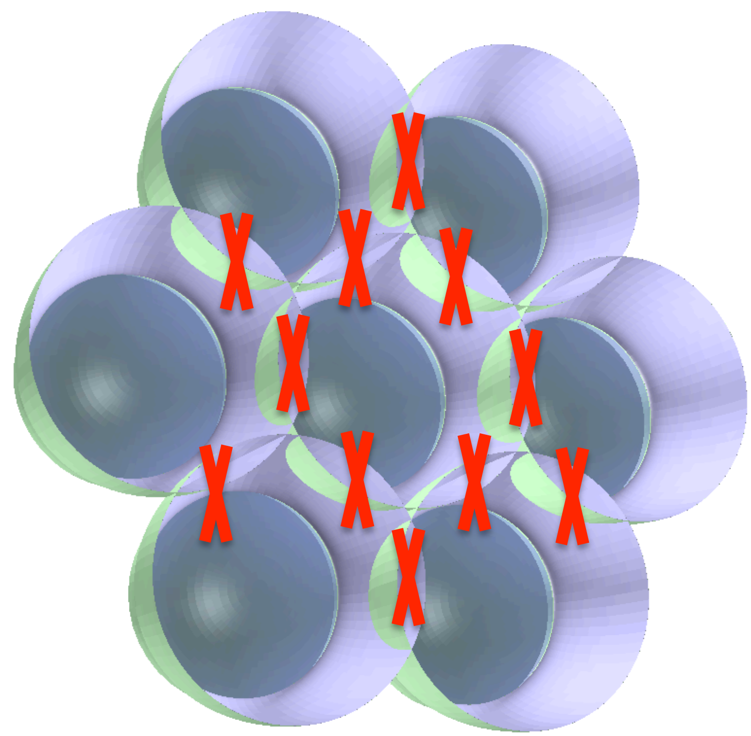
Images realized assuming a clearance of 60mm

JMC

« Crown » CTC

Use the standard CTC and only cut the overlapping part. In principle, performances of CTC are mantained and we should gain light w.r.t. standard cutCTC, **since we reach an almost 100% coverage**

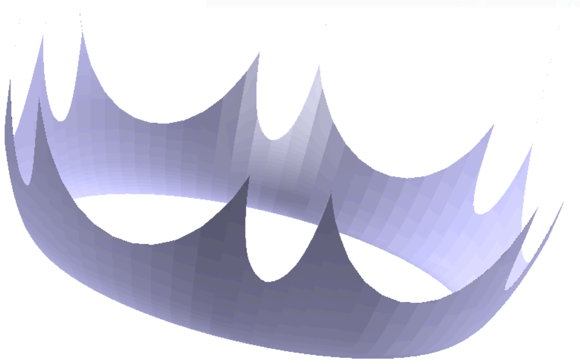


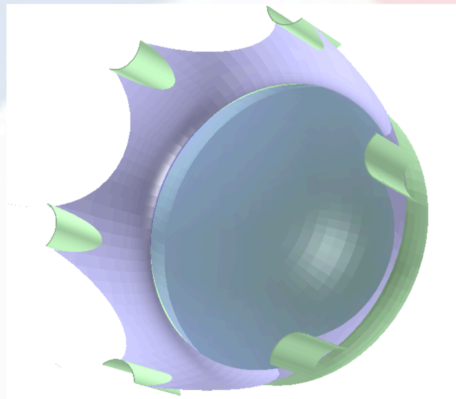


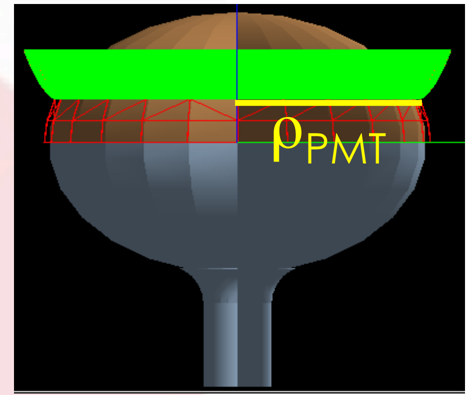
Images realized assuming a clearance of 60mm

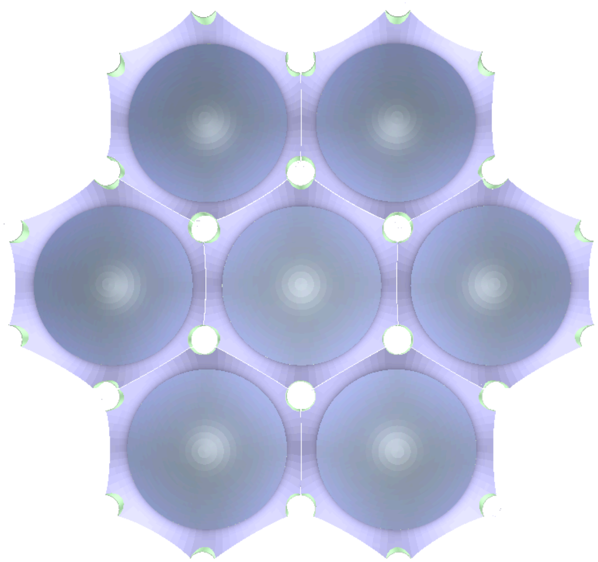
JMC

Crown CTC with SPMTs









PMT clearance_ρ_{PMT}	<Npe> Cut OLC	<Npe> Crown OLC	<Npe> No OLC
25mm_24cm	1770	1768	1768
35mm_24cm	1762	1742	1698
35mm_23cm	1721	1671	1698
60mm_24cm	1706	1736	1532

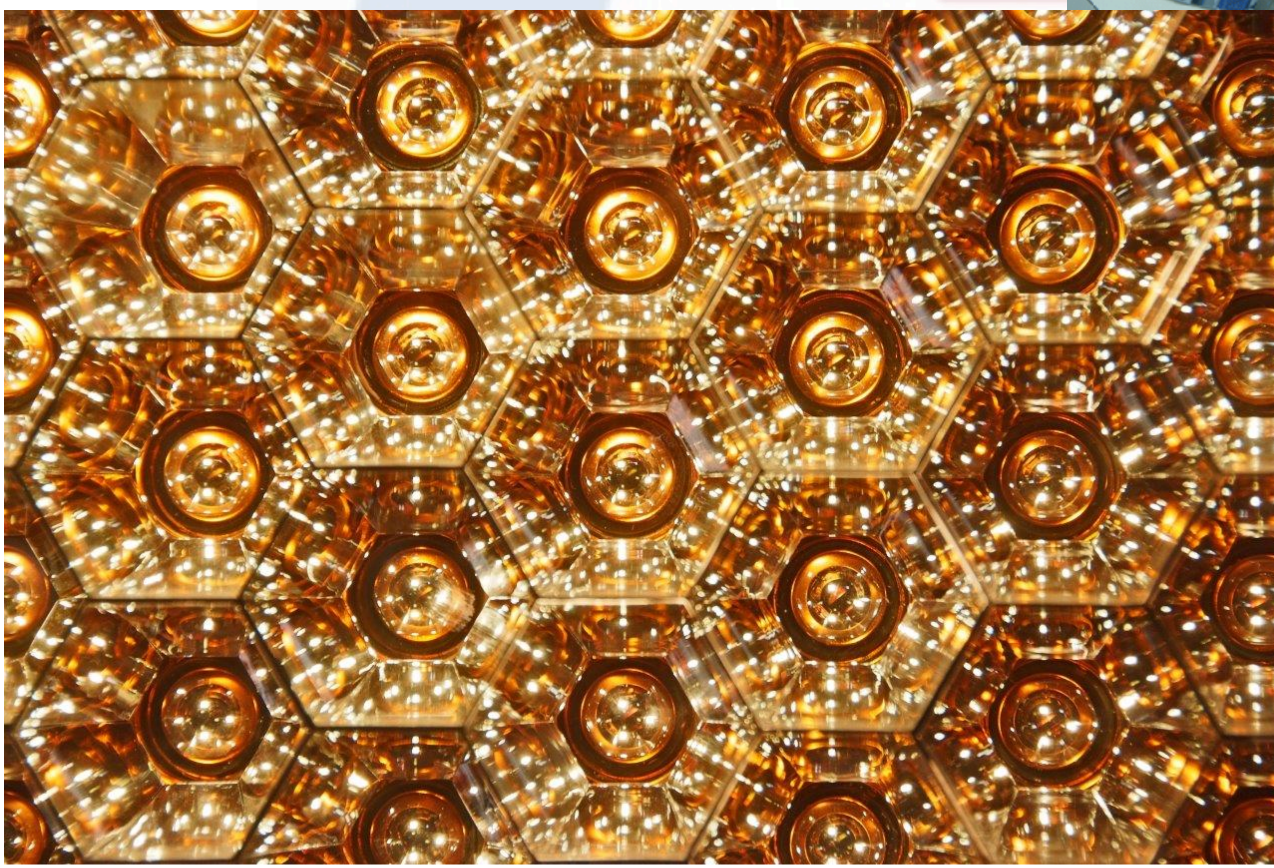
For small clearances, no evident improvement in using Crown OLCs (i.e. 100% coverage) w.r.t. Cut OLCs

Images realized assuming a clearance of 60mm

SAVIMEX
Vision in Future

http://www.savimex.fr/

Great experience in visor production



Already collaborated with LLR for HESS light concentrator (P. Manigot)

However, this time, difficult negotiation… we gave up also because…

@ last Coll. Meeting, JUNO Coll. guarantes

1. Almost constant Det. Efficiency along the LPMT photocathode
2. LPMT-to-LPMT clearance of 25mm
3. LPMT already bought (17k)

Summary

- LLR group active in JUNO: HW + SW + PhD thesis + workshop organization
- TT electronics proceeding as expected (as defined already in 2015)
- OLC studies done: not feasible in JUNO now, but pubblication in preparation
- SPMT-Physics coordination