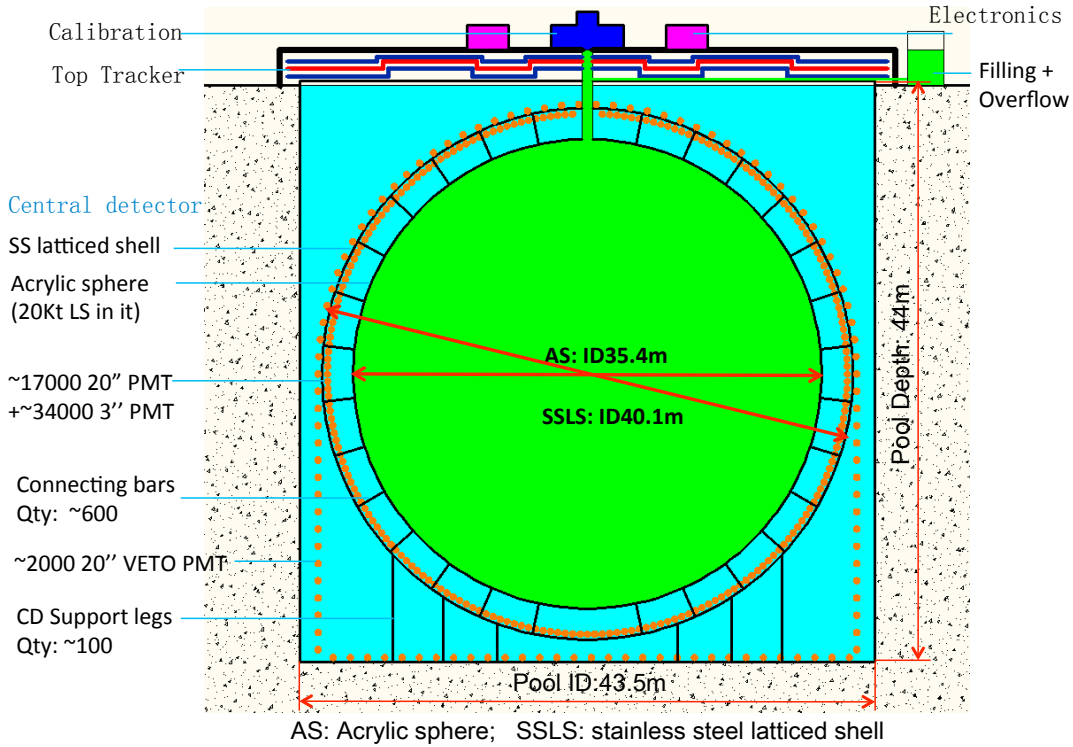
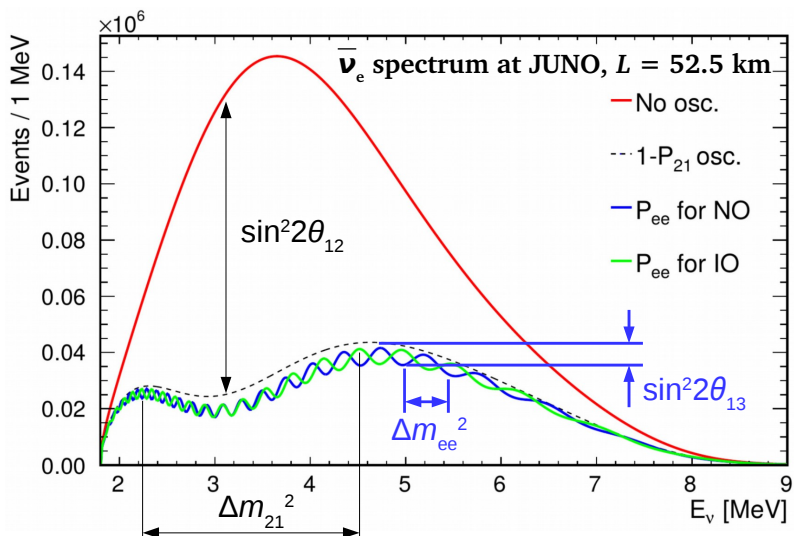
JUNO in a nutshell

- ν mass hierarchy and ν oscillation parameters measurement using reactor $\overline{\nu}_e$
- large scintillator mass (20 kton LAB) and high photo-coverage: 18 k (20") PMTs + 25 k (3") PMTs (double calorimetry)
- high statistics expected (O(10^5) events in 6 years), excellent energy resolution (3% at 1 MeV) and linearity required
- Several physics topics accessible : supernovae, solar, atmospheric and geo-neutrinos

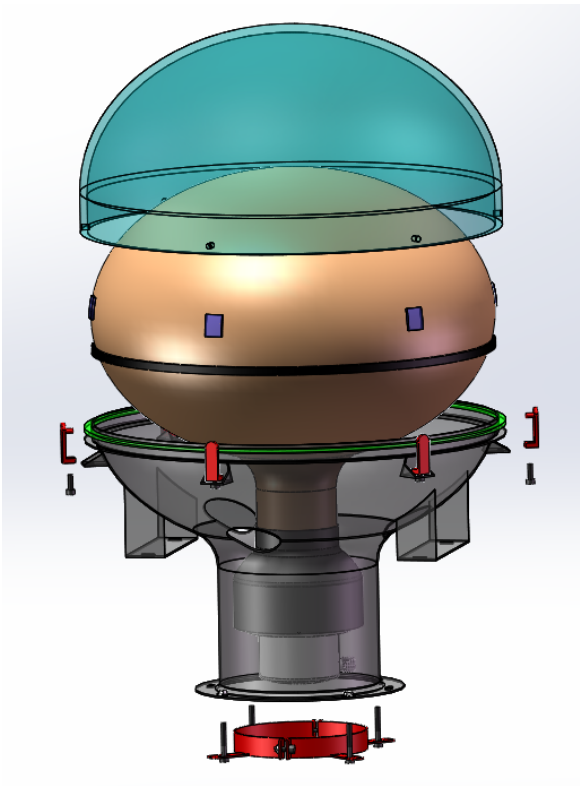




JUNO Large PMTs

- **15000 MCP-PMTs from NNVT** (Northern Night Vision Technology)
- **5000 dynode PMTs from Hamamatsu**
- **In production since 2016**
- **Already >9000 delivered**
- **More than 5000 tested**

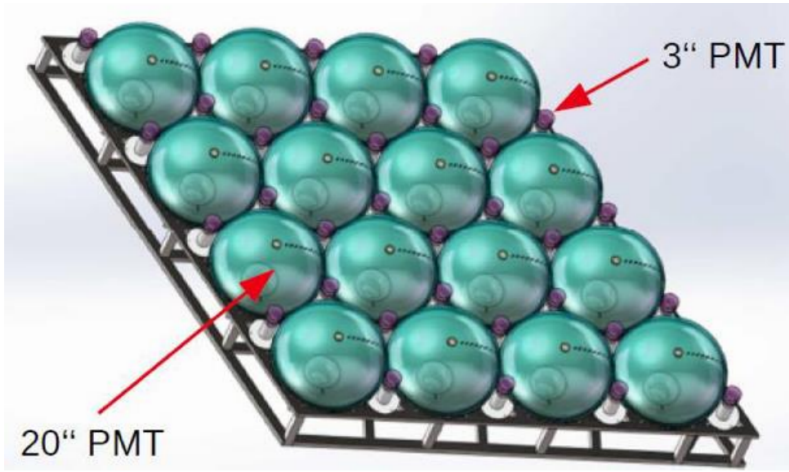
Characteristics	unit	MCP-PMT (NNVT)	R12860 (Hamamatsu)
Detection Efficiency (QE*CE)	%	27%	27%
P/V of SPE		3.5, > 2.8	3, > 2.5
TTS on the top point	ns	~12, < 15	2.7, < 3.5
Rise time/ Fall time	ns	R~2, F~12	R~5,F~9
Anode Dark Count	Hz	20K, < 30K	10K, < 50K
After Pulse Rate	%	1, <2	10, < 15
Radioactivity of glass	ppb	238U:50 232Th:50 40K: 20	238U:400 232Th:400 40K: 40



JUNO PMT with implosion protection cover

JUNO Small PMTs

- **Double calorimetry**
  - Always photon counting
    → Better control of systematics
    (Calibration of non-linear response of large PMTs)
  - Increased dynamic range
    → Helps with large signals
    (e.g. muons, supernova signal)

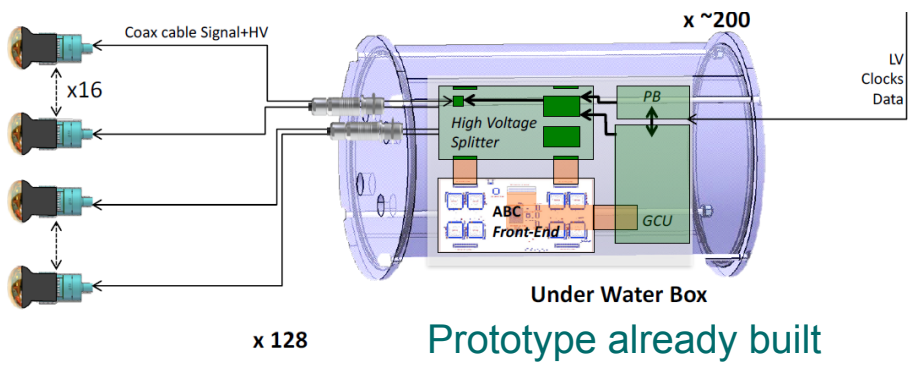


- **25000 PMTs contracted to HZC**
- **4000 produced, 3000 tested at HZC**

JUNO custom design:
XP72B22

QE 24% , P/V 3.0
SPE resolution 30%
TTS 2-5 ns

200 boxes × 128 PMTs



Prototype already built

A near detector for JUNO

- according to several studies, reactor spectrum might show micro-structure

  A. A. Sonzogni, et al. arXiv:1710.00092, D. A. Dwyer & T. J. Langford, Phys. Rev. Lett. 114,012502 (2015), D. V. Forero et al. arXiv:1710:07378

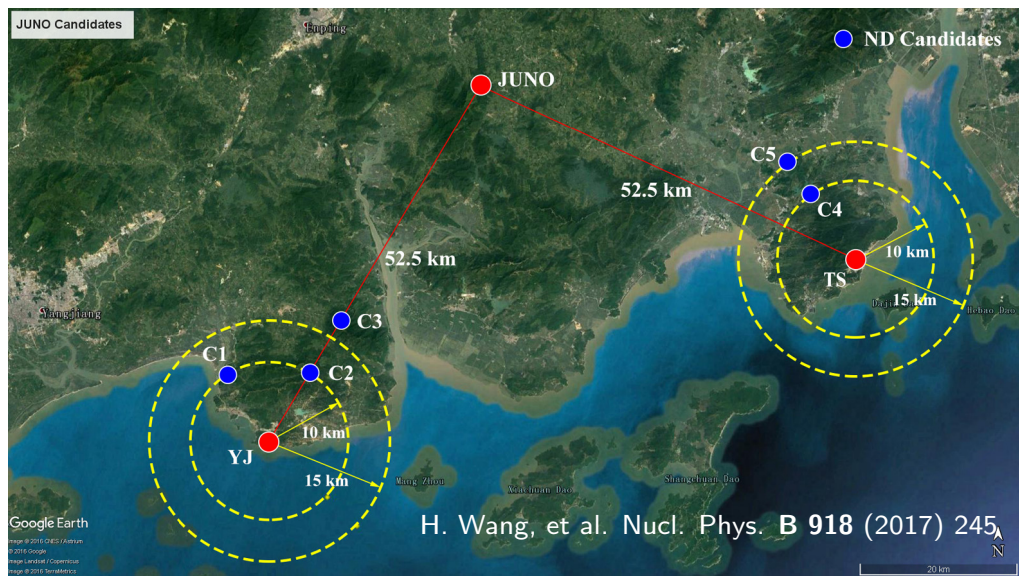
- during the last year the JUNO Collaboration has decided to design and build a 1 ton scale near detector. Possible options:

R&D started

- $\sim$ 3 ton Gd-LS in spherical vessel with outer buffer oil in stainless steel vessel
- central detector size: 2 m $\times$ 2 m $\times$ 2 m
- very close to ractors ($\sim$ 35m): after 1 year, 10$\times$ JUNO planned 6 years statistics

Readout sensors under evaluation

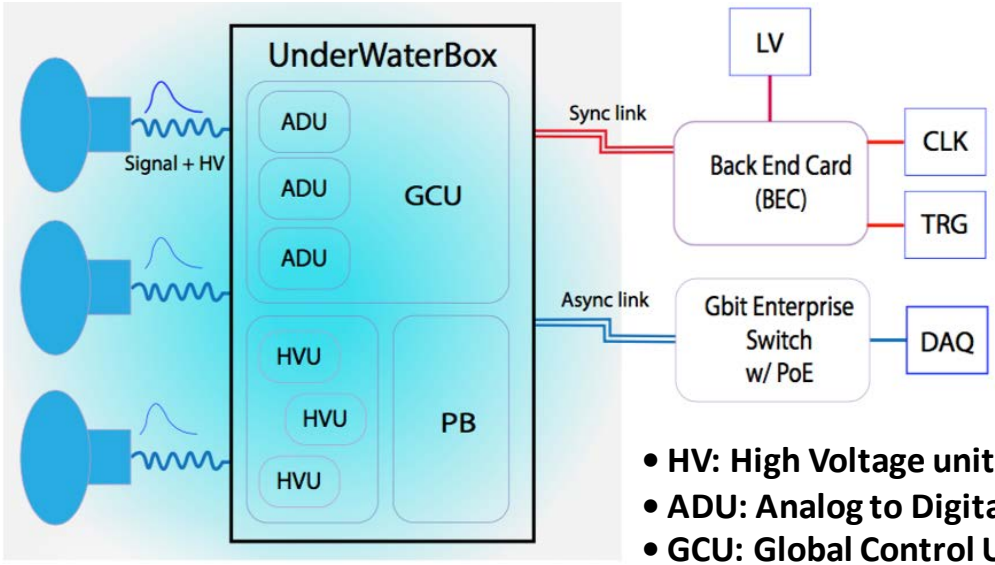
- SiPM (need $\sim 10\text{m}^2$),
  INFN interested to contribute
  ➜1.7% energy resolution goal (need to operate at -50°C)
- 3.5" PMTs (need 2300 PMTs)
  ➜2.5% energy resolution goal



JUNO PMT Readout Electronics

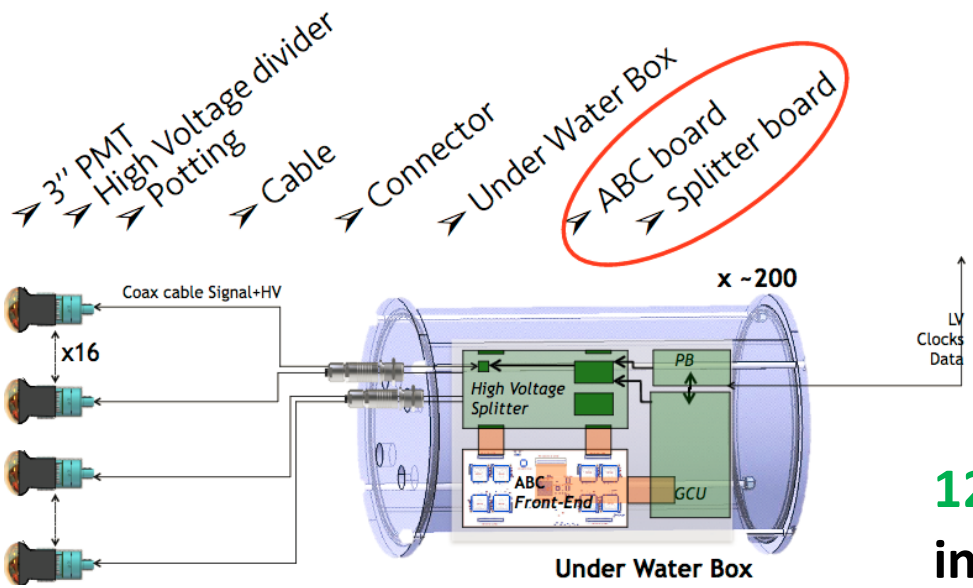
THREE 20” PMTs’ signals go into ONE underwater box.

1GHz 14bit-FADC in very front of each 20” PMT



- HV: High Voltage units
- ADU: Analog to Digital Unit
- GCU: Global Control Unit
- CAT cable: Category 5e cable
- High reliability needed

Severe constraints by power consumption

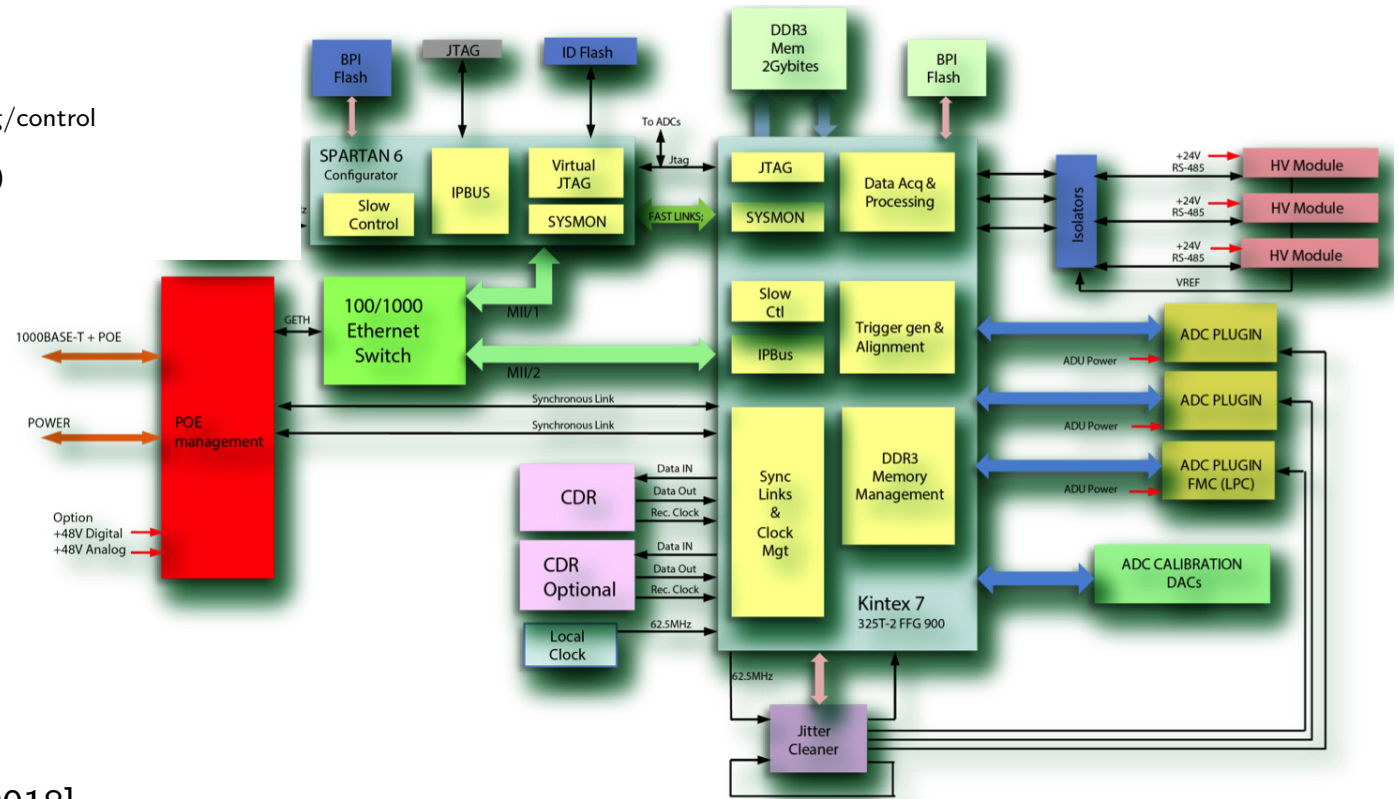


128 3” PMTs’ signals go into ONE underwater box

Global Control Unit - 1F3 Block Diagram

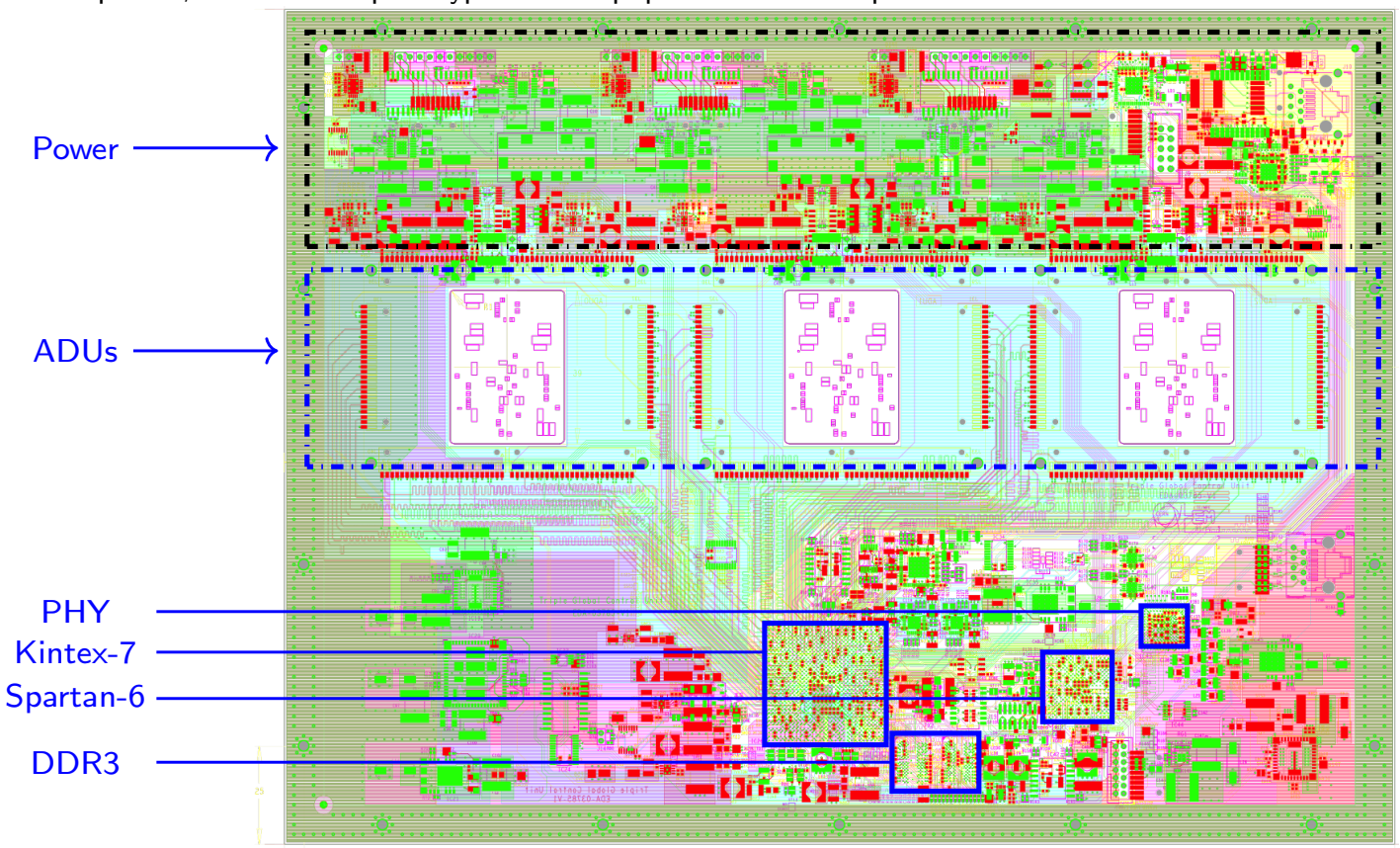
Major Design Specifications

- 3× 1 Gs/s 14 bit ADC readout
- 3× 50 kHz average trigger primitive generation
- 1000BASE-T Ethernet support for data readout
- Power-Over-Ethernet support
- Trigger modes: global trigger and auto trigger (supernova support)
- distributed clock alignment within 16 ns
- full remote reprogramming support
- standard FMC expansion support
- 3× RS485 support for HVU programming/control
- low power consumption (10 W / channel)
- high reliability

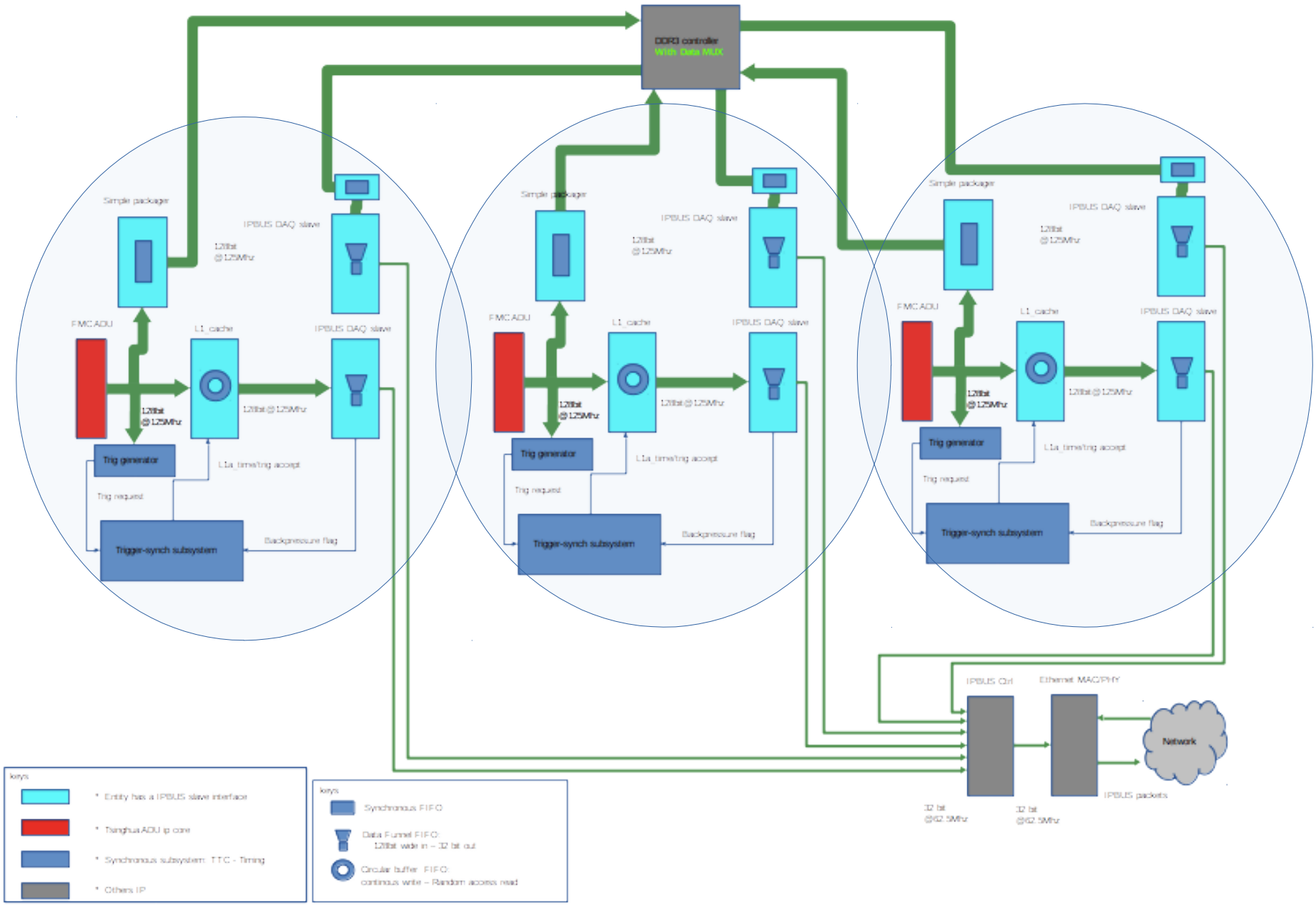


GCU : prototypes status

- design completed
- routing completed (at CERN)
- Signal Integrity simulation ongoing
- Thermal simulation ongoing
- a technical design review has been done in Padova at the end of April
- 20 prototypes PCBs have been ordered
- PCB production will be done in China at Dongguan Somacis Graphic
- 2-3 boards will be assembled and tested
- is tests passed, all the other prototypes will be populated with components



GCU: 1F3 Firmware Data Flow Block Diagram



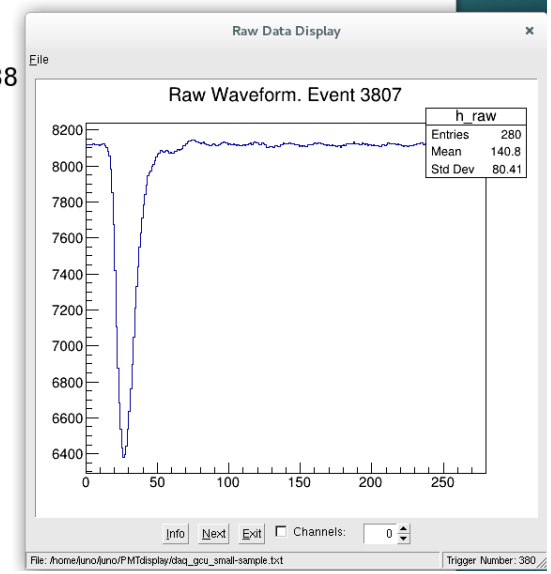
GCU: IPbus from software perspective

- few parameters for each channel can be set in a config file
- native C++ and python bindings are available
- a simple python library has been developed for testing the GCU
- 3 function calls needed to acquire data from GCU
- simple event display with ROOT developed

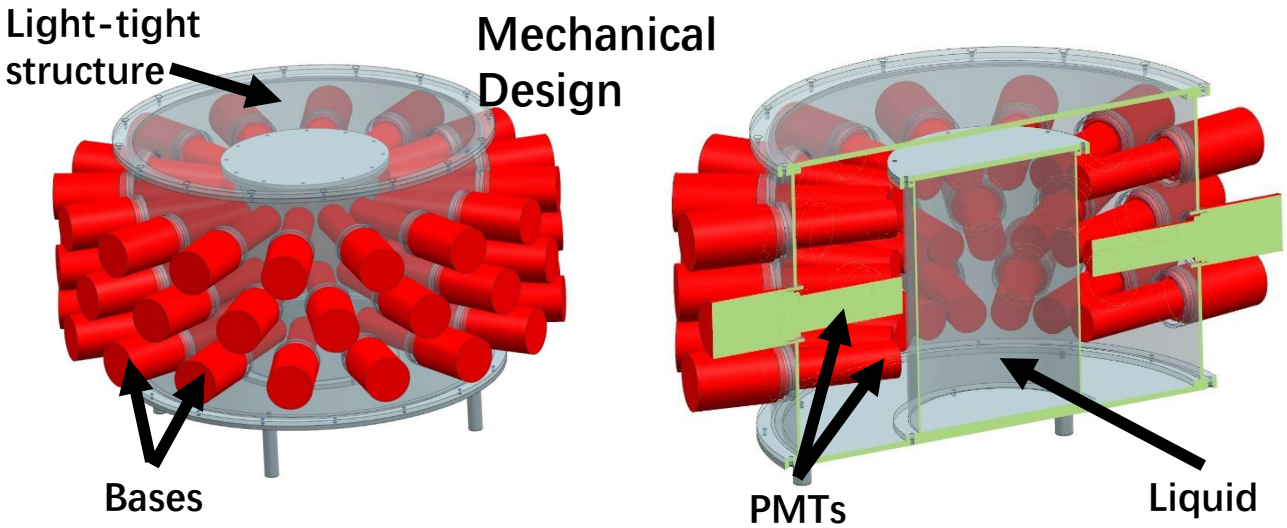
```
[IPBusParameters]
ConnectionFile=connections.xml
GCUNode=GCU
[DaqParameters]
#Threshold in ADC count: 0.07mV per count
Threshold=8000
# Pretrigger in sample numbers
PreTrigger=1
# Acquisition window in sample numbers
TriggerWindow=38
#Fifo Bandwidth balance Threshold
[ReadoutParameters]
#delay if Fifo
delay=0.0
initial_size=2048
granularity=10
FifoThreshold=1000
DumpFile=daq_gcu_fast.txt
#DumpFile=/dev/null
```

```
while True:
    time.sleep(delay)
    data = []
    # gain lock to the second stage fifo
    my_gcu.acquire_fifo_lock()
    # get 2nd stage Fifo occupation
    occupied = my_gcu.get_fifo_occupation()
    my_gcu.try_dispatch()
    occupied_current = occupied.value()
   # print "OCCUPATION FIfo", occupied_current
    fifo = my_gcu.read_from_daq_fifo(size)
    count = my_gcu.get_fifo_count()
    control = my_gcu.get_fifo_control()
    # release lock to the second stage Fifo
    my_gcu.release_fifo_lock()
    my_gcu.try_dispatch()
    data = fifo.value()  # incoming data from ipbus Fifo
```

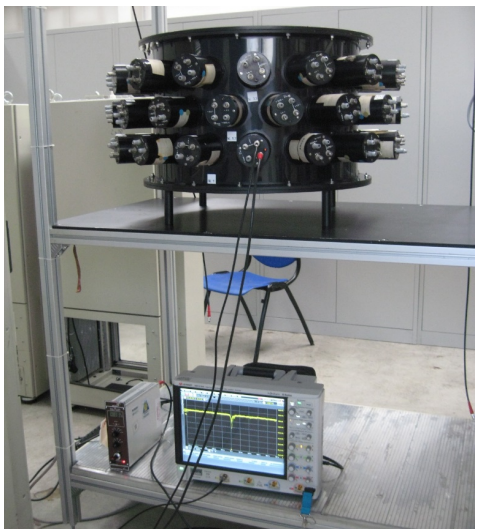
```
Line 0 : * GCU Daq readout: 2018-02-22 14:48:08
Line 1 : * Threshold: 7000
Line 2 : * PreTrigger: 8
Line 3 : * TriggerWindow: 38
Line 4 : * Begin Data *
word: 1f4f
word: 1f4c
word: 1f4a
word: 1f62
word: 55aa
word: 123
word: 4567
word: 89ab
word: cdef
word: ff00
word: 0
word: 8069
END of TRAILER found: 8069
Junk data discared.
```



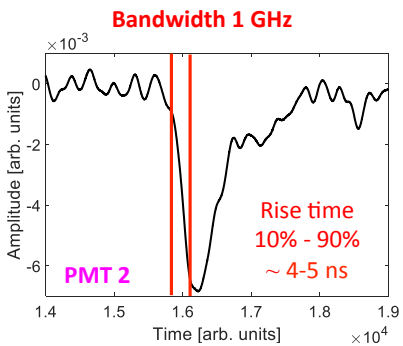
GCU System Test setup in Legnaro (Padova)



The PMTs were tested using the dark current noise. They were supplied at the nominal voltage. The signal was checked with an oscilloscope.

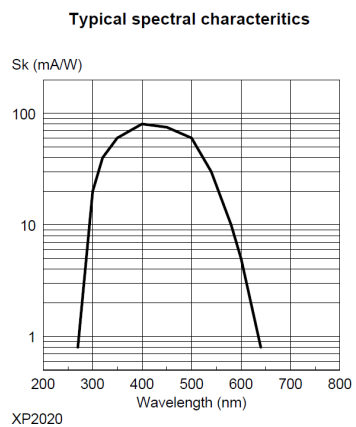


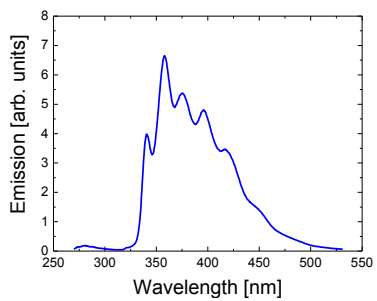
All PMTs provieds a signal.
Work has to be done to reduce the noise.



Thank to F. Ortica

The same concentration of Daya Bay was used:
LAB + PPO 3g/l + bisMSB 15 mg/l
in order to match the PMT response.





Attività JUNO elettronica a Padova

- in gruppo di Padova è coinvolto nello progettazione e produzione di una parte dell'elettronica dei fototubi (large and small PMTs)
- A. Garfagnini è coordinatore (L2) dell'elettronica di JUNO e coordinatore (L3) della Global Control Unit (GCU). Regolarmente organizziamo un workshop dell'eletronica a Padova (ultimo: aprile 2017). Prossimo workshop previsto per primavera 2019.
- nel 2018 abbiamo sviluppato il nuovo design della GCU, seguendo lo schema 1F3. Al momento i nuovi prototipi sono in produzione.
- 20 schede saranno prodotte e assemblate durante l'estate.
- da settembre partirà un importante test di integrazione di tutta l'elettronica con 48 canali (16 schede GCU). Si prevede di qualificare tutta la catena dell'elettronica (dal PMT al trigger e DAQ) e di avviare un test di lunga durata.

Attività previste nel 2019

Elettronica

- l'attività preponderante riguarda lo sviluppo dell'elettronica dei fototubi
- la gara di elettronica si effettuerà nel 2019, e l'investimento INFN da 2 M€ sarà ripartito su 2019 e 2020

e fisica

- S. Dusini è uno dei conveener del gruppo di fisica con gli small PMT
- L. Stanco, C. Sirignano e F. Sawy stanno sviluppando metodologie innovative per la determinazione della gerarchia di massa con i dati di JUNO

Dettaglio elettronica:

- test prototipi elettronica GCU
- test di integrazione con le altre componenti e caratterizzazione della catena completa
- finalizzazione disegno e scrittura capitolato per gara
- definizione e progettazione dei test di qualifica delle schede per la produzione

JUNO Preventivi 2018

Anagrafica : 6.3 FTE

R. Brugnera	30%	F. Chiarello	100%	S. Dusini	30%
A. Garfagnini	70%	A. Giaz	100%	I. Lippi	40%
M. Mezzetto	10%	F. H. Sawy	100%	C. Sirignano	30%
L. Stanco	30%				
M. Bellato	50%	F. Dal Corso	20%	C. Fanin	20%

Richieste 2019 - CSNII

Missioni	80 k	Consumo	60 k
Trasporti	10 k	Inventariabile	20 k
Costruzione Apparati	2 M		
[Gara GCU]			

Richieste 2019 - Servizi Sezione

U. Tecnico	0.4 mu	disegno test facility 48 PMT e sistema di test
O. Meccanica	0.4 mu	realizzazione test facility elettronica
S. Elettronica	24.0 mu	sviluppo elettronica e sistema di test