Testing PMTs R7600 and R10551

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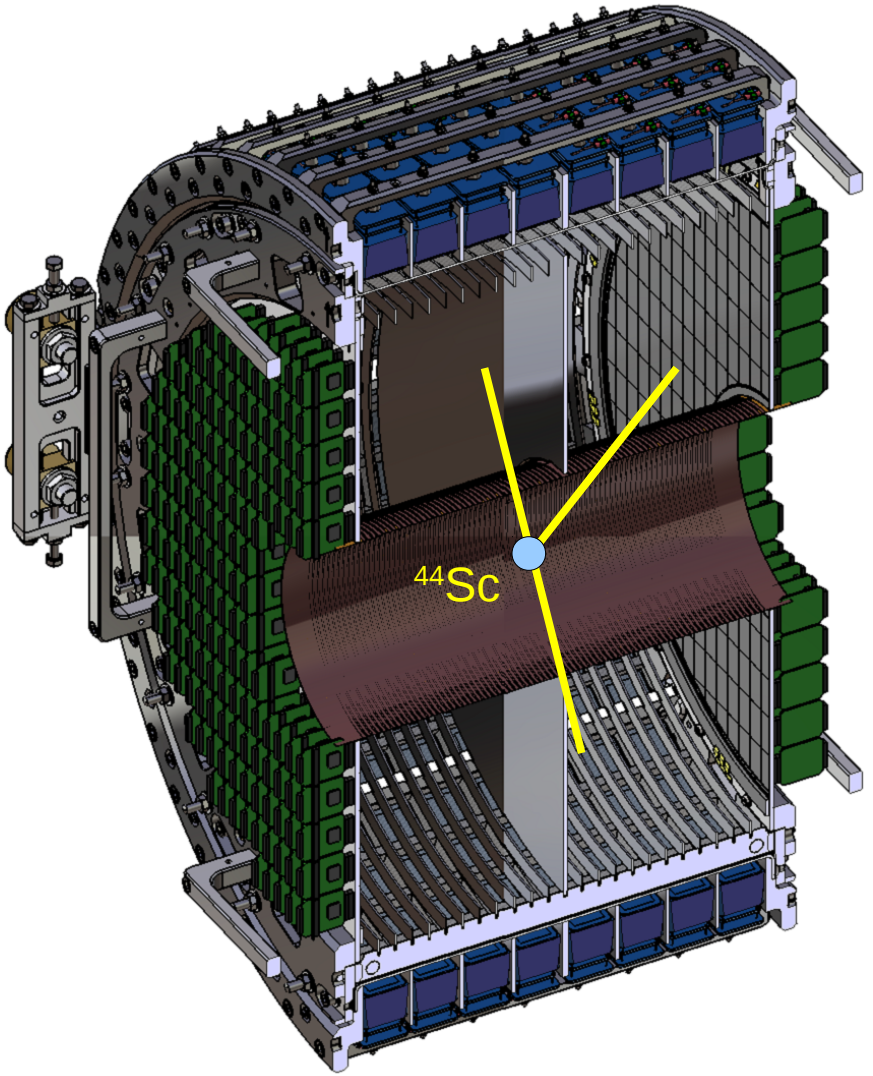
on behalf of the Subatech and KEK groups

Based on the work by Ryo Hamanishi (KEK) in Subatech

Why those tests? XEMIS2 for medical imaging

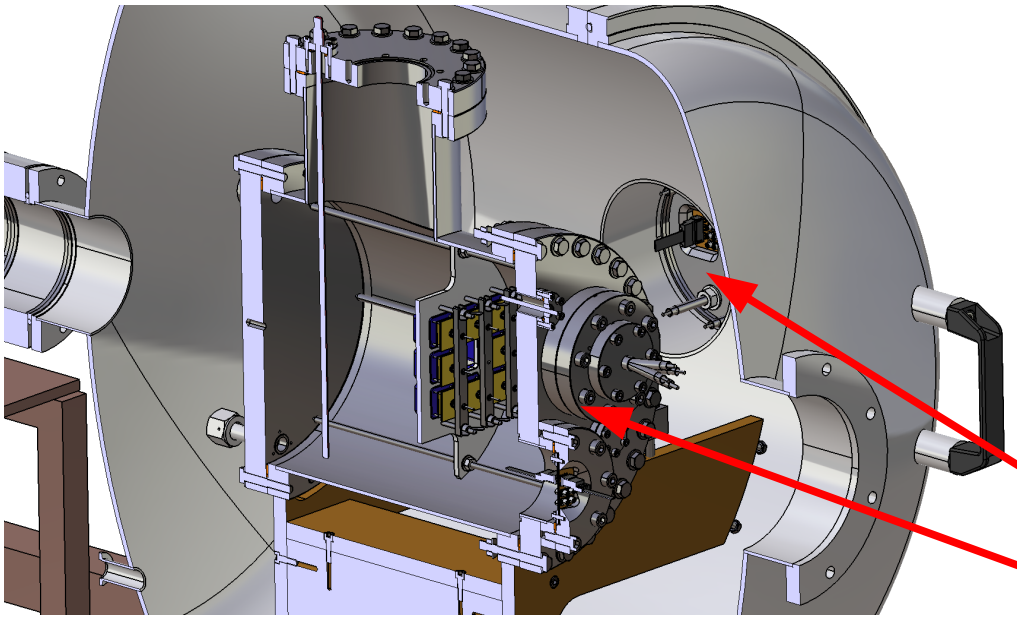
- An array of 35 x 8 PMTs
- Used as **trigger** for the charge signal readout
  (by determining the interaction volume)
- PMT that will be used :
  Hamamatsu R7600 1" PMT
- 50 PMTs purchased already
- PMTs must be **characterized**
  - Absence of defects
  - Gain calibration
  - Pulse shape
  - Linearity
  - Temperature dependency
  - ...

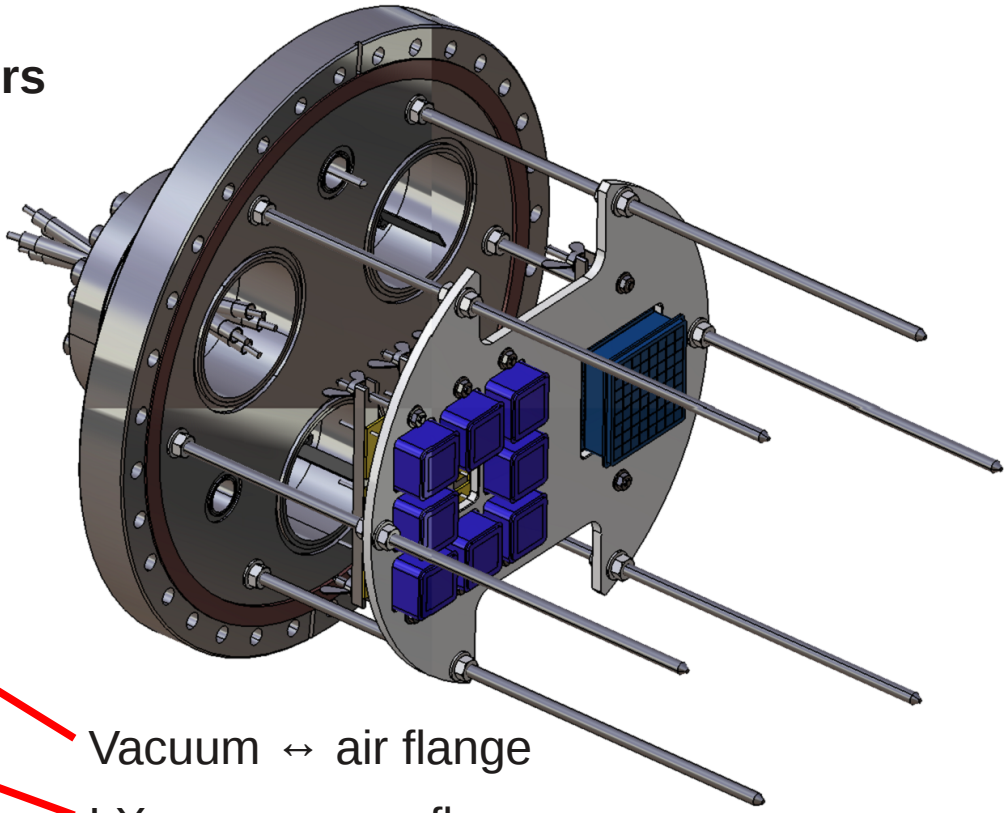
→ N**eed a PMT test station**



The new PMT test station in Subatech

- Built inside the **XEMIS1** cryostat
- **Very compact design** to store many PMTs (potentially up to 16 at same time)
- **LED** light generated outside (we can easily replace it)
- Light enters through 200 µm thick **optical fibers**



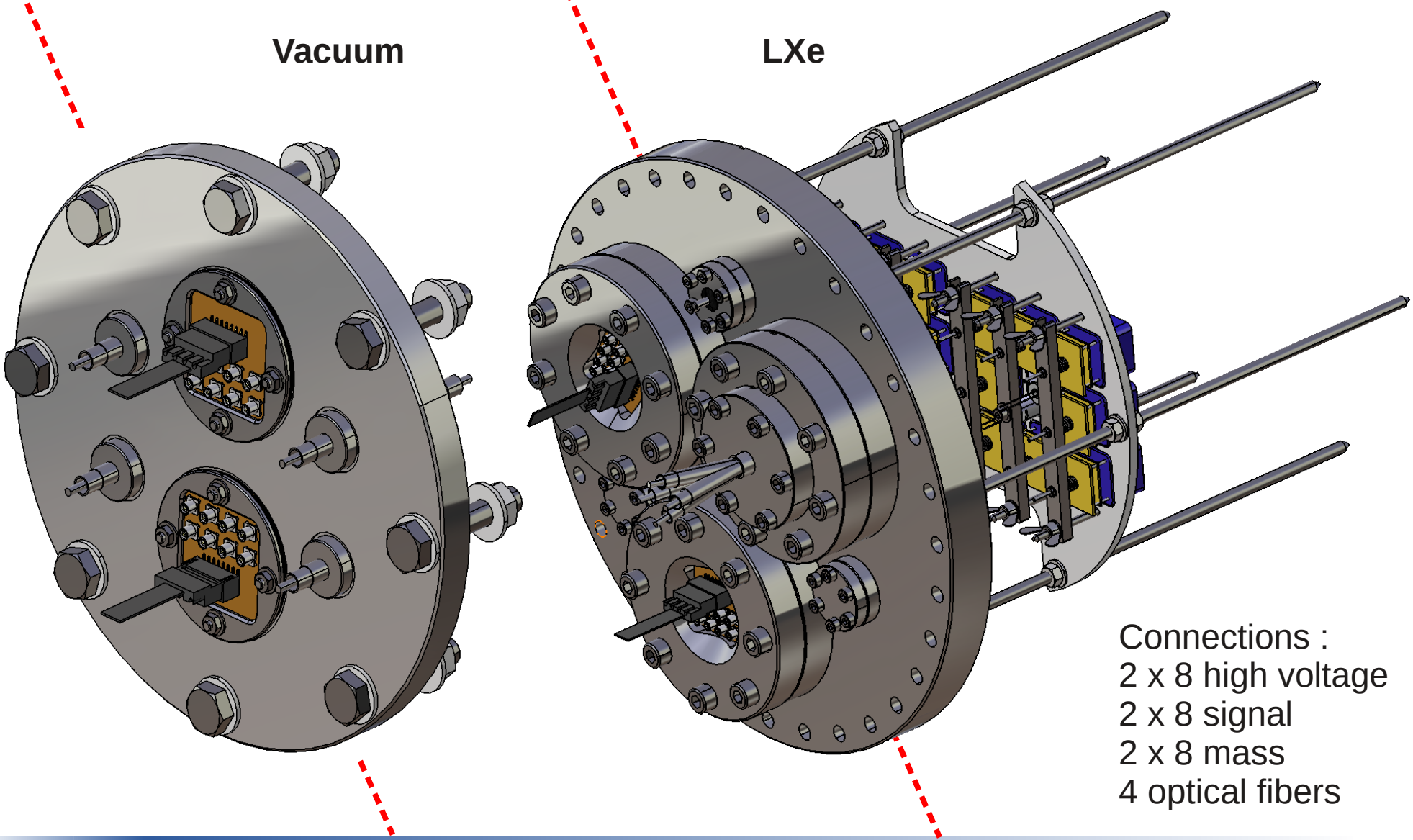


Vacuum ↔ air flange

LXe ↔ vacuum flange

Feedthrough

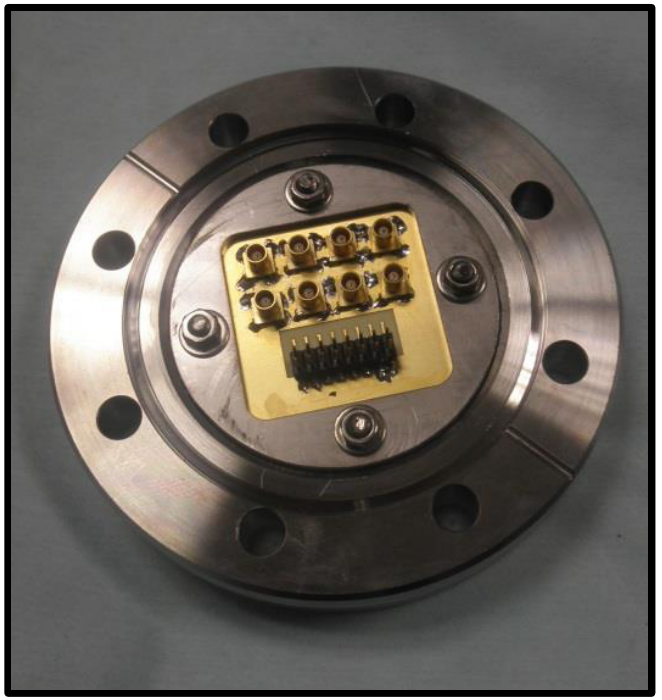
Air **Vacuum** **LXe**

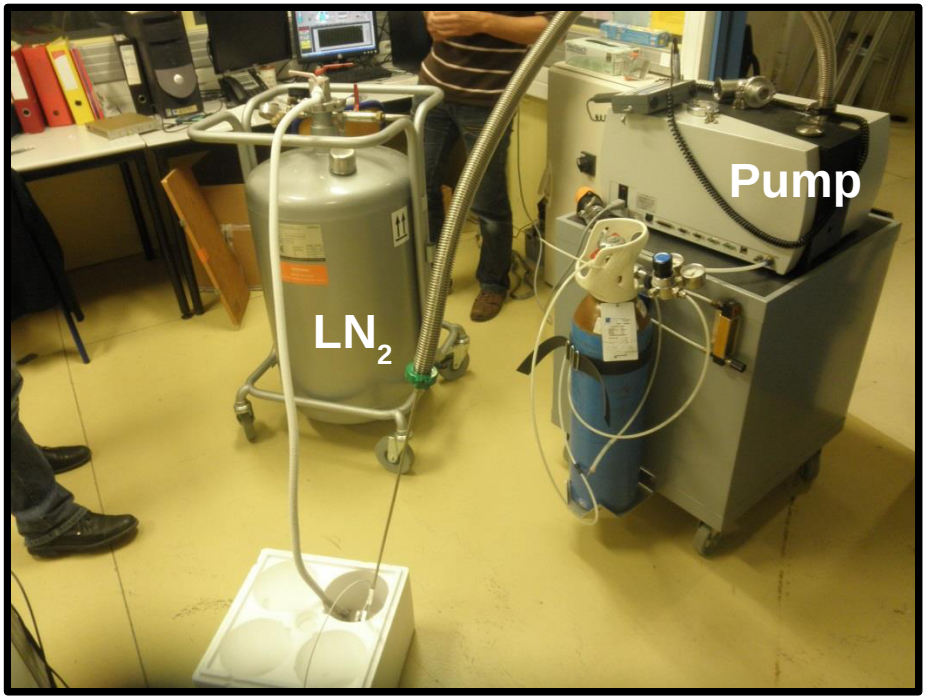


Connections :
2 x 8 high voltage
2 x 8 signal
2 x 8 mass
4 optical fibers

Feedthrough test

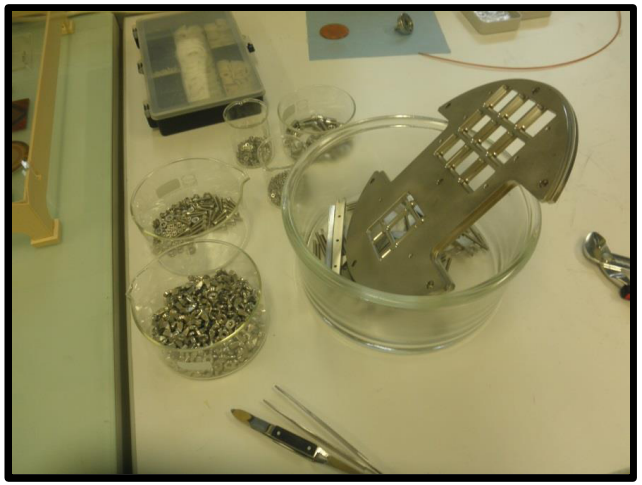
- Feedthrough test by using liquid nitrogen
- Put it into low temperature conditions and checked possible presence of vacuum leaks
- No issues found



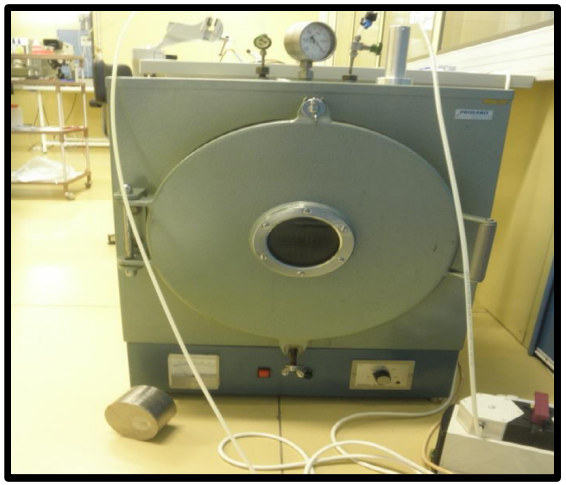


Components cleaning

- Before assembling, cleaned parts of PMT test station by using an ultrasonic cleaner and a drying oven



Ultrasonic cleaner



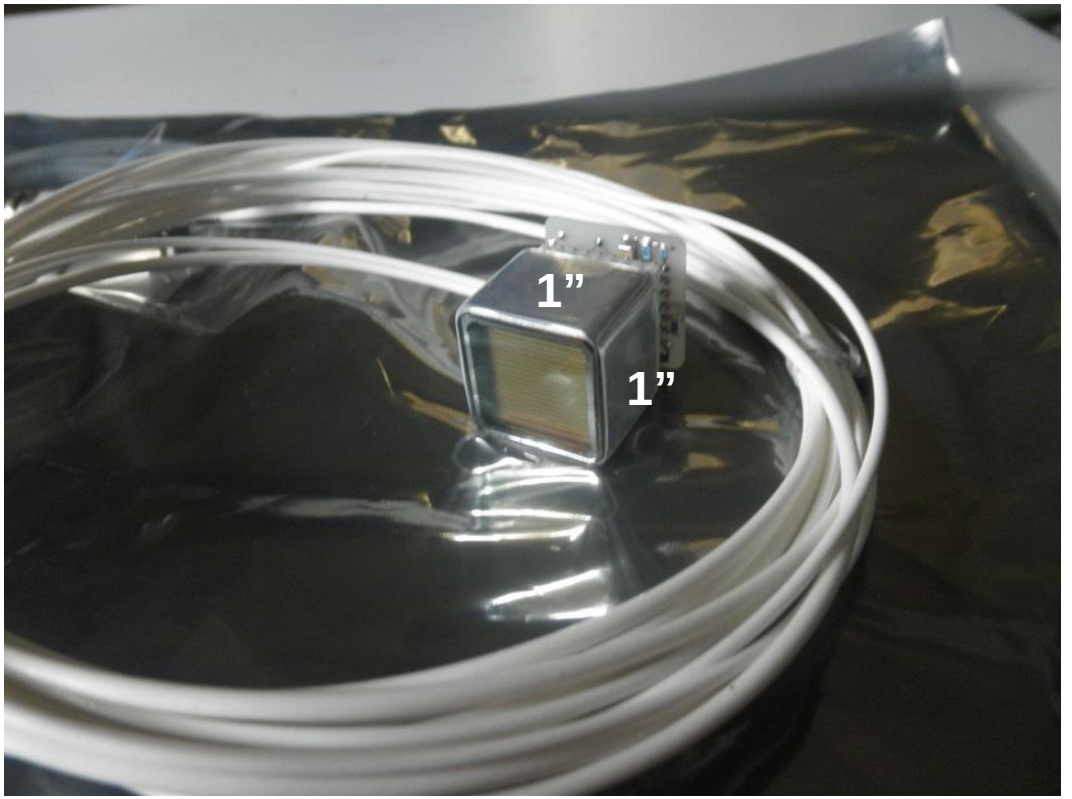
Drying oven

The PMTs used

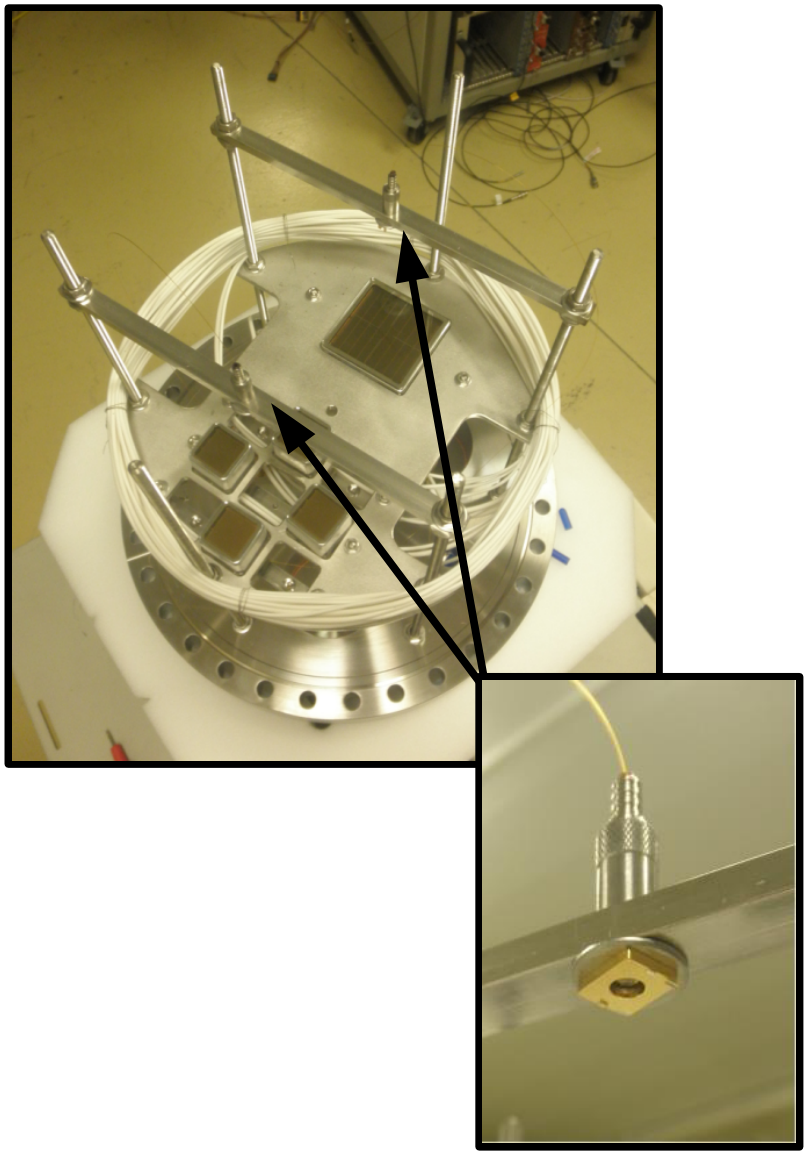
Hamamatsu R7600

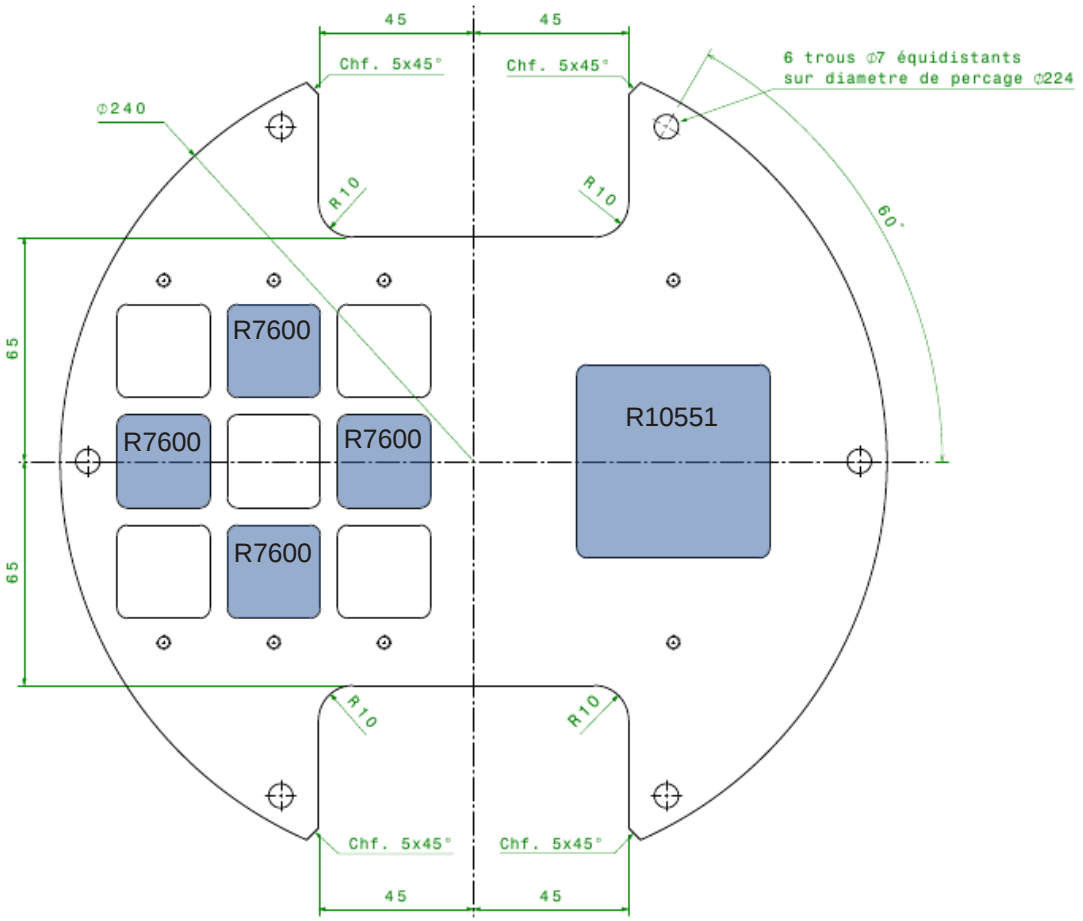
- Size : 1”

- Purchased 50 exemplars



PMT setup



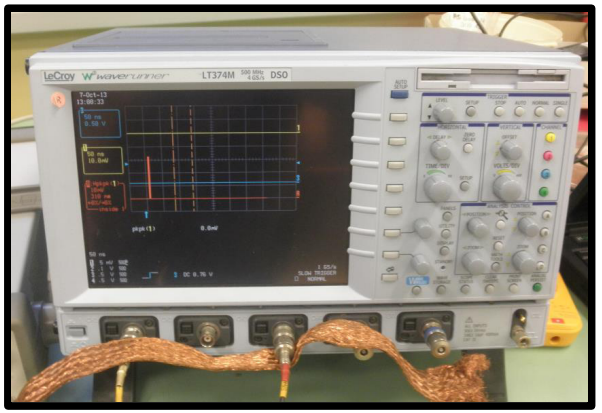

45
45
Chf. 5x45°
Chf. 5x45°
6 trous Φ7 équidistants
sur diametre de percage Φ224
Φ240
R10
R10
60°
65
65
R7600
R7600
R7600
R7600
R10551
R10
R10
Chf. 5x45°
Chf. 5x45°
45
45

Other equipment used

- Waveform generator :
  Agilent 33250A

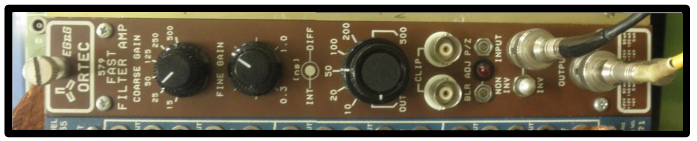
Characteristics	Values
High level	5.0 V
Low level	750 mV
Frequency	1.000 kHz
Pulse width	20.0 ns
Edge time	5.00 ns

- ADC :
  From oscilloscope
  LeCroy



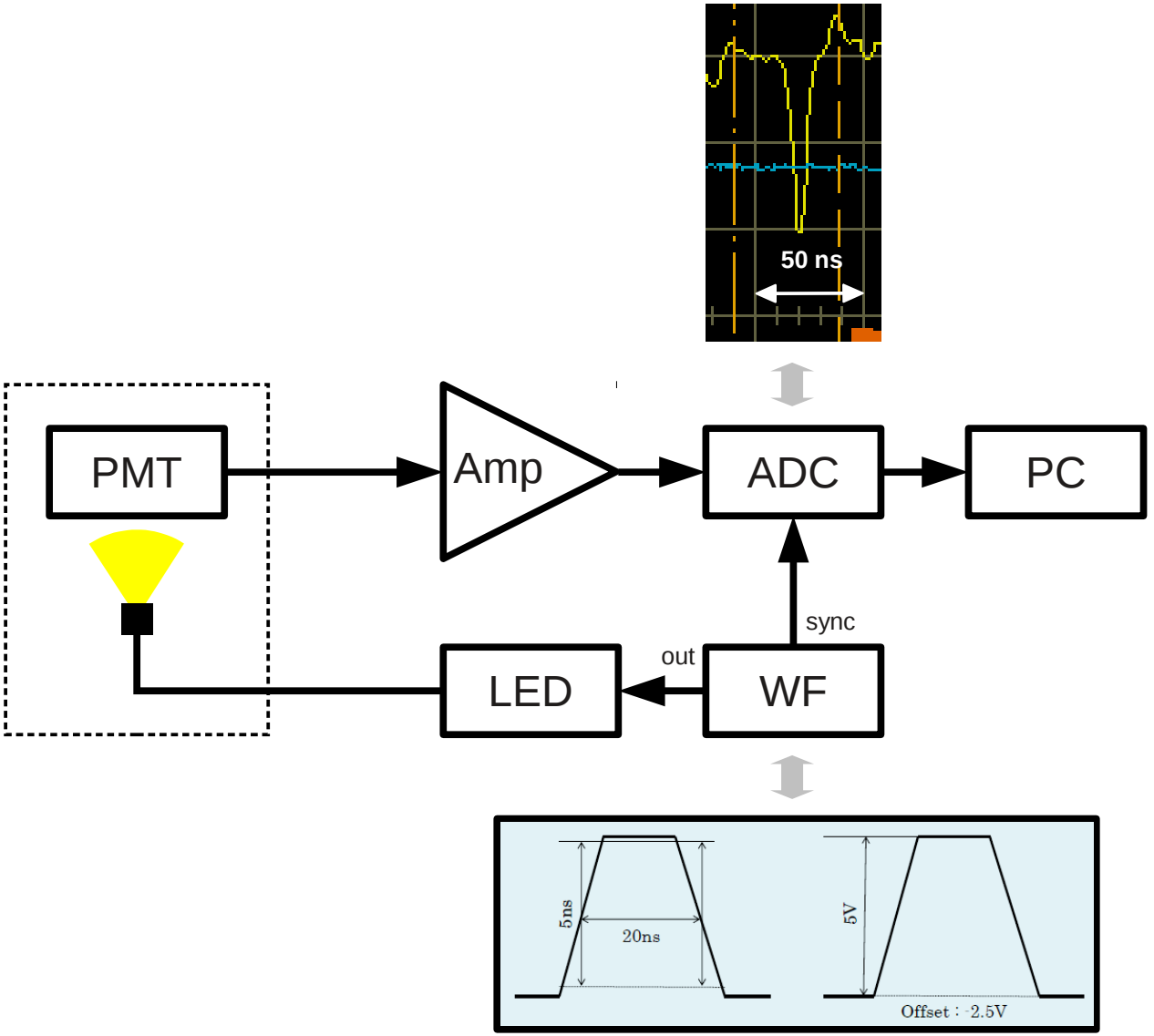
Characteristics	Values
Sampling frequency	2 GHz
Channels	4

- Amplifier :
  Ortec (not used with current setup)



Charasteristic	Value
Amplification	12 times

DAQ setup



Analyses performed

- Integrated pulse
  - With fixed integration interval
  - With variable integration interval (peak finding)

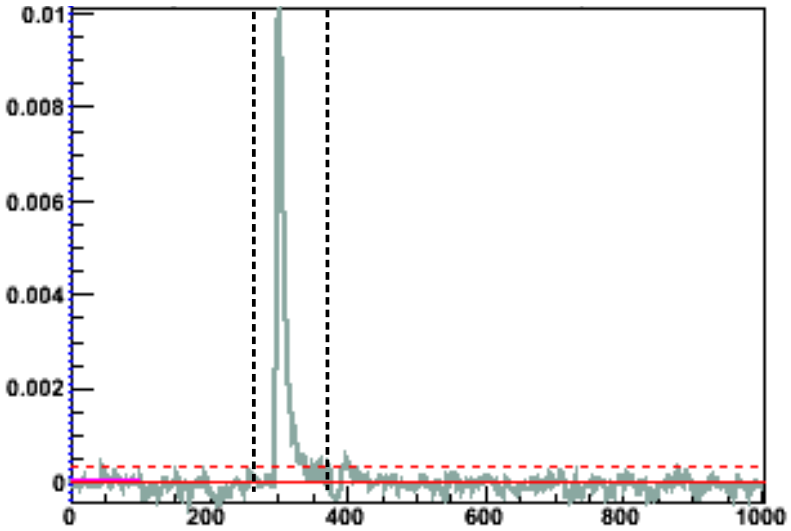
  → Choice on down and up time edges

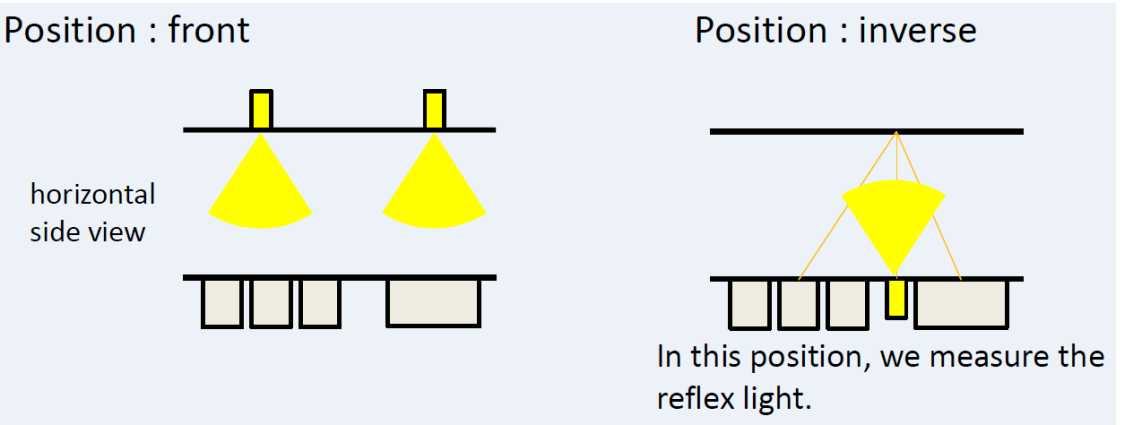
- Gain vs HV

- Stability studies. Checked dependency from:

  → Trigger rate

  → LXe temperature

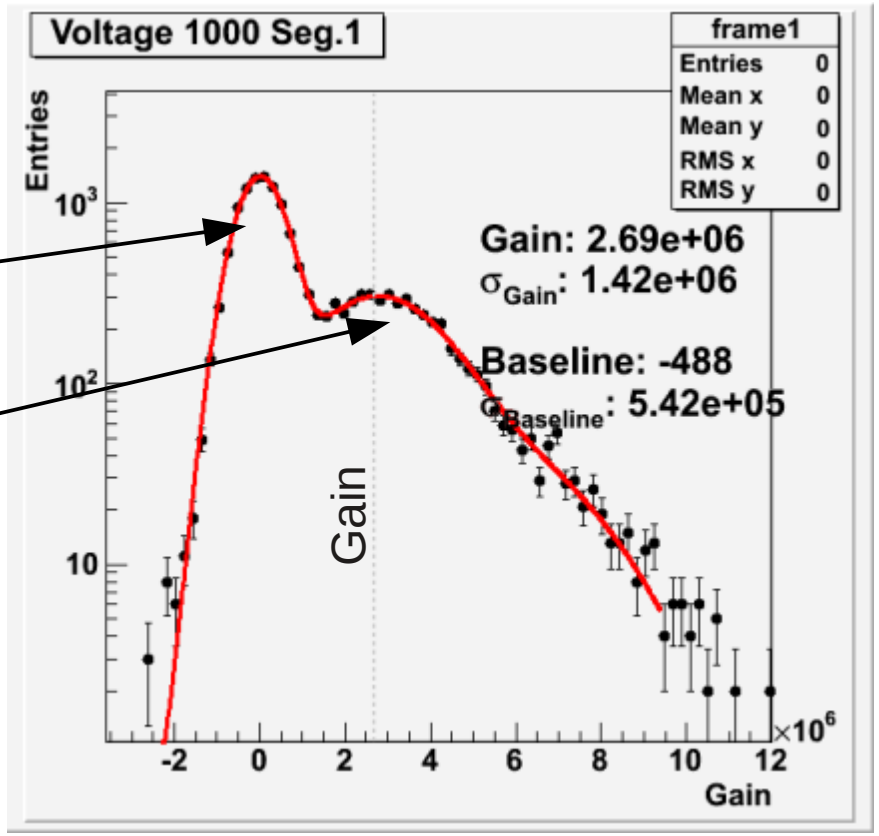




Gain measurement

Pedestal

Single Photo-electron signal



$$S_G = \underbrace{A_N exp\left(-\frac{(x-x_N)^2}{2{\sigma_N}^2}\right)}_{\text{Pedestal}} + \underbrace{A_1 exp\left(-\frac{(x-x_1)^2}{2{\sigma_1}^2}\right)}_{\text{Single photo electron}} + \underbrace{A_2\ exp\left(-\frac{(x-2x_1)^2}{4{\sigma_1}^2}\right)}_{\text{two photo electrons}}.$$

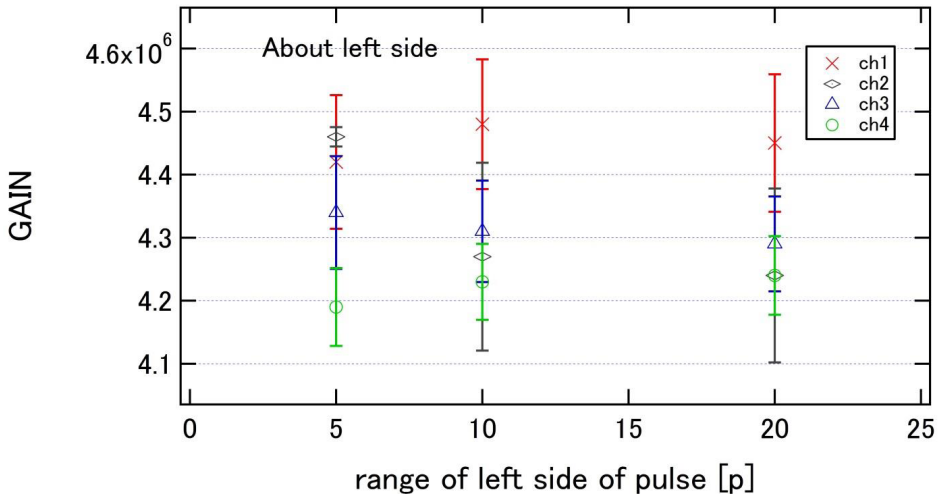
Dependency on integration interval

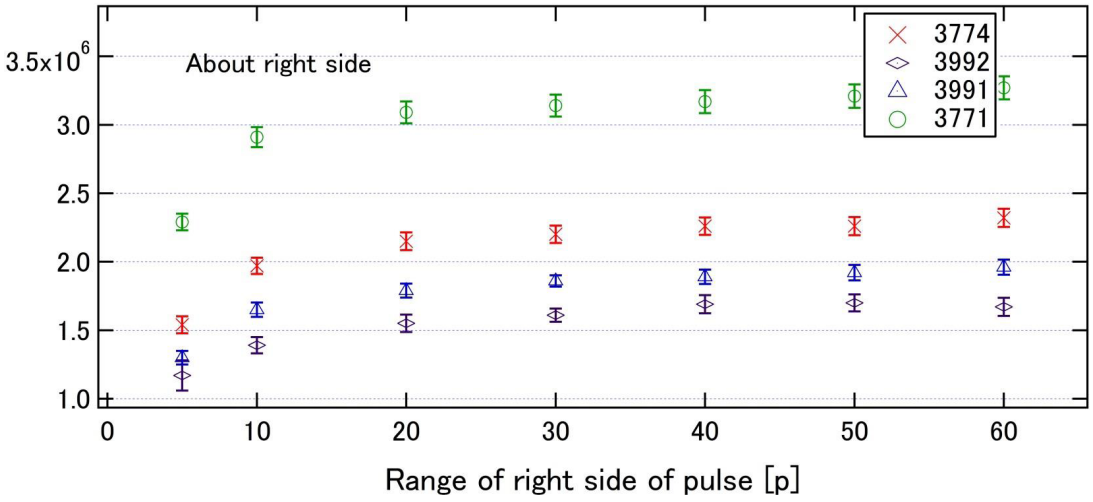
- **Integrated pulse**
  - With fixed integration interval
  - With variable integration interval (peak finding)

  → Choice on down and up time edges

- **Conclusion** : flat dependency
  - On the lower edge down to 2.5 ns
  - On the higher edge down to 10 ns

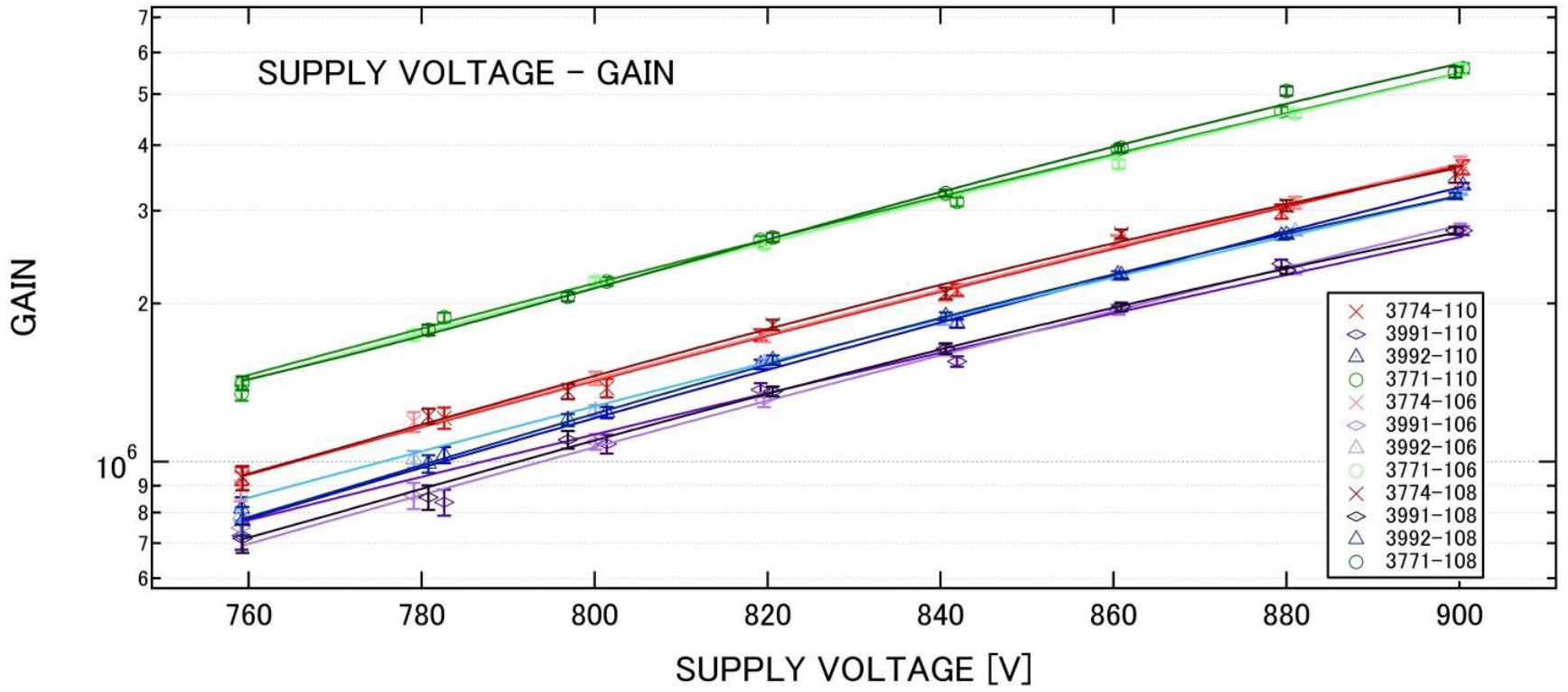
1p = 0.5ns





Gain vs HV

- **Gain vs HV**
- **Conclusion** : regular trend in the 760 – 900 V range

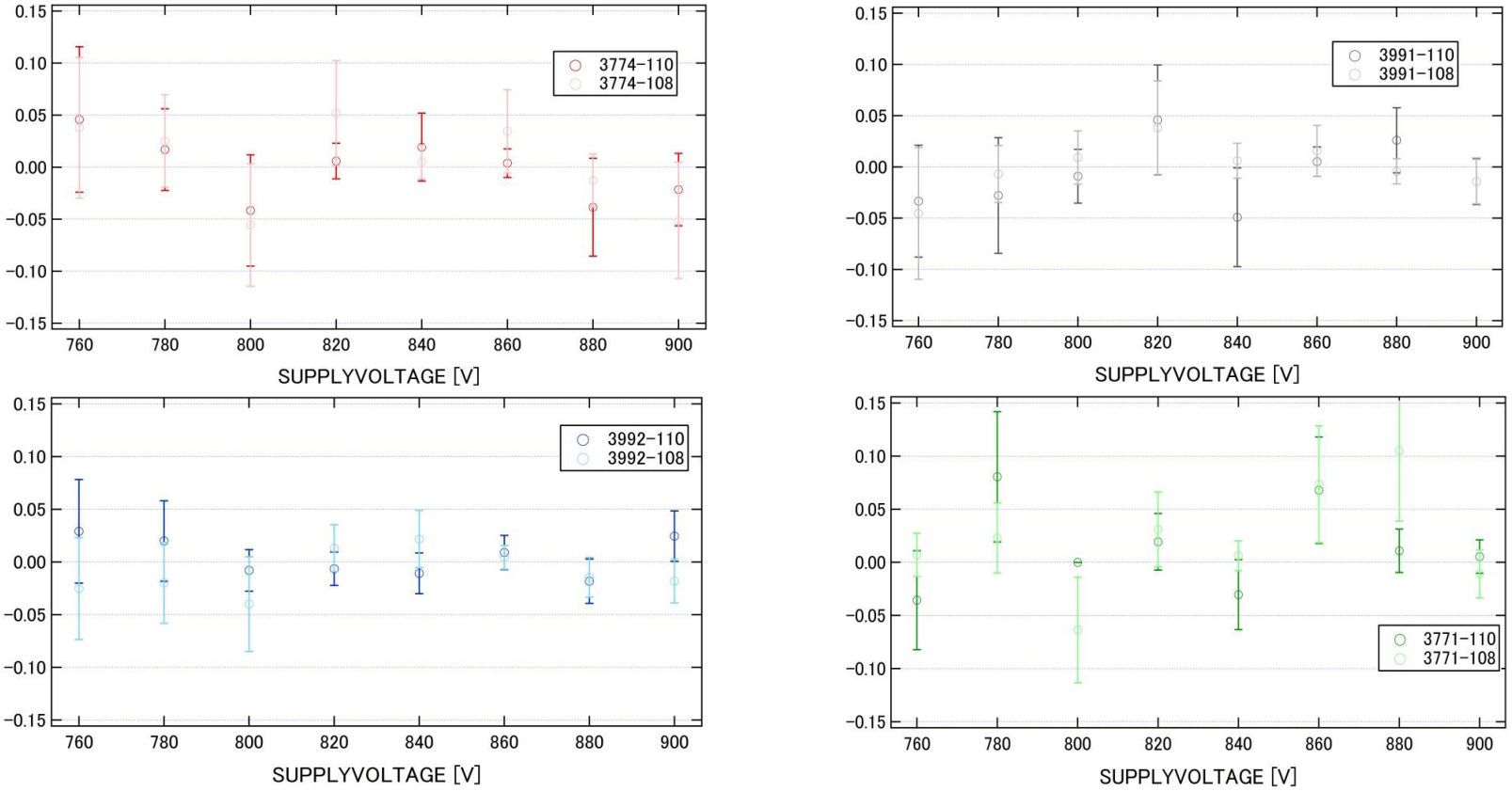


Dependency on temperature

- **Stability studies**. Checked dependency from:
  → **LXe temperature**

- **Conclusion** : Gain independent from temperature in the T = [-110, -106] °C range

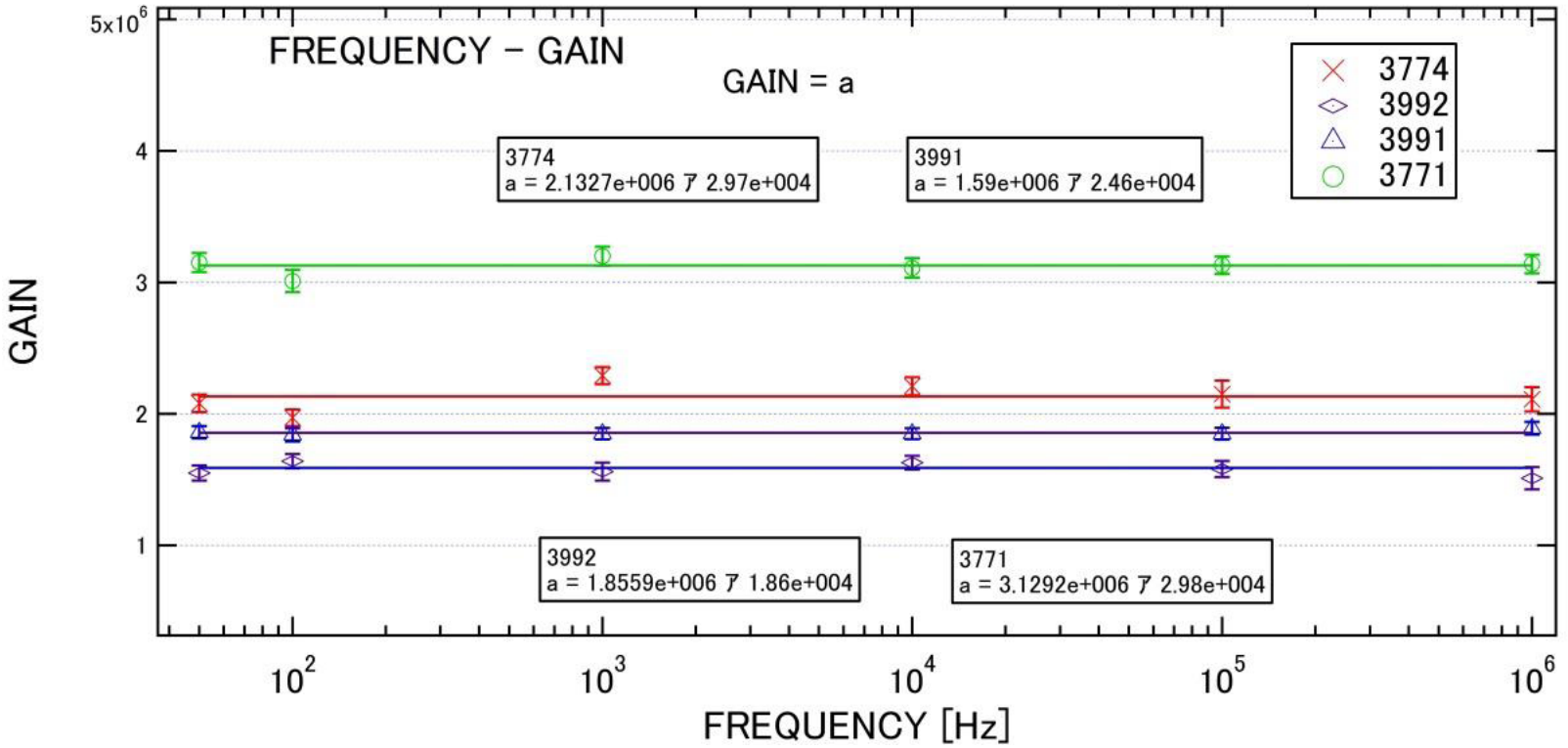
$(G_{-110 \text{ or } -108} - G_{-106}) / G_{-106}$



Dependency on trigger rate

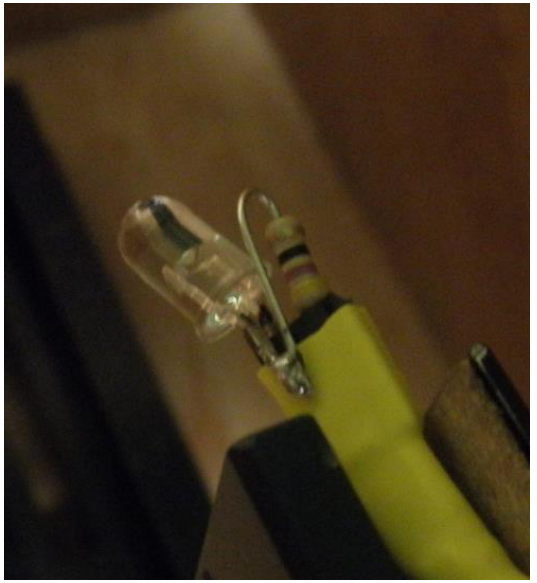
- **Stability studies**. Checked dependency from:
  → **Trigger rate**

- **Conclusion** : Gain independent from trigger rate in the 50 Hz – 1 MHz range



Next step : the light source

Simply a “yellow” light LED



Next step: using an high reliability gallium nitride (GaN) laser source

- UV at 406 nm (well inside the PMT spectral response range: 160-650 nm)

- Low output power (20 mW)

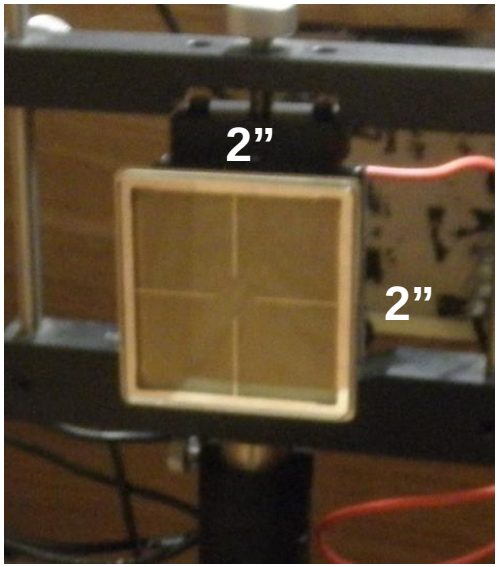
- Linear response

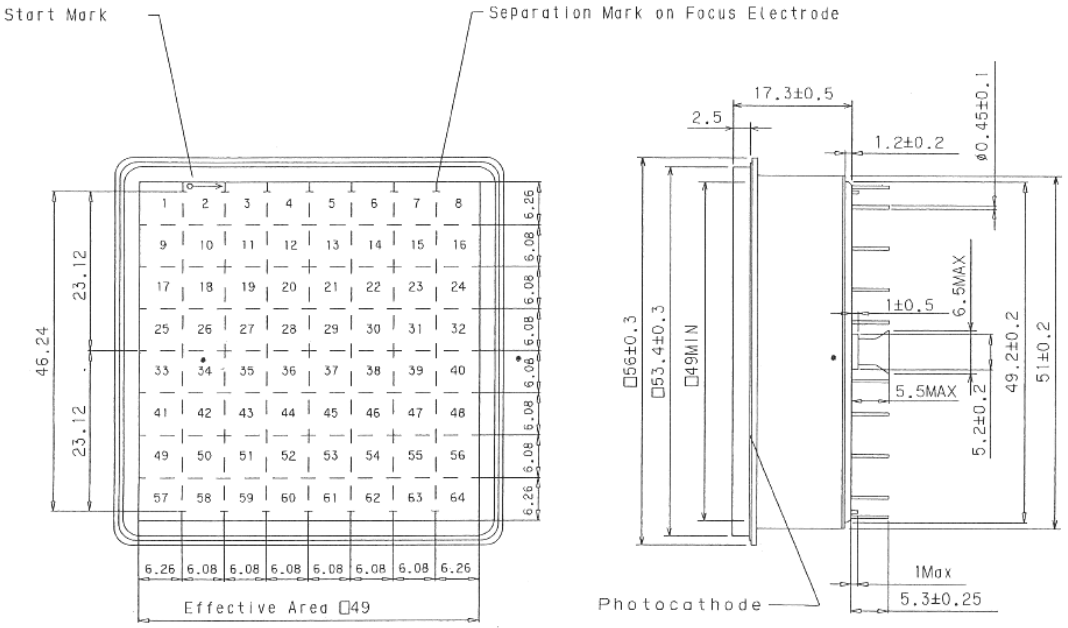
LASER COMPONENTS

Testing new PMT R10551

Hamamatsu R10551

- Size : 2” → covers area 4 times bigger
- Very compact
- 50% of quantum efficiency higher
- Made by 64 independent channels
  (fed by one unique HV source)

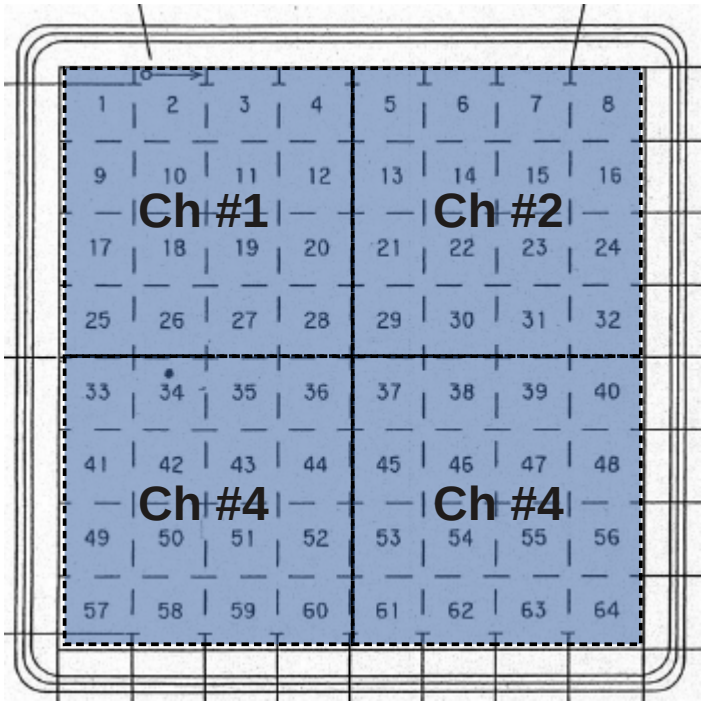


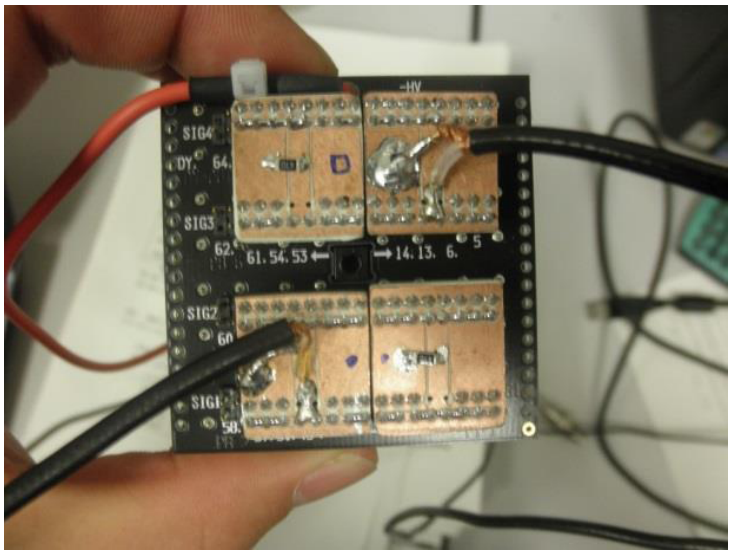


- Provided by the KEK group to Subatech
- **KEK** : R&D on flat 2” PMTs for Hamamatsu
- **Subatech** : interested for a future upgrade for XEMIS2

Measurements with PMT R10551

- We initially grouped the channels in 4 groups
- Each group is the sum of 16 independent channels





Measurements with PMT R10551

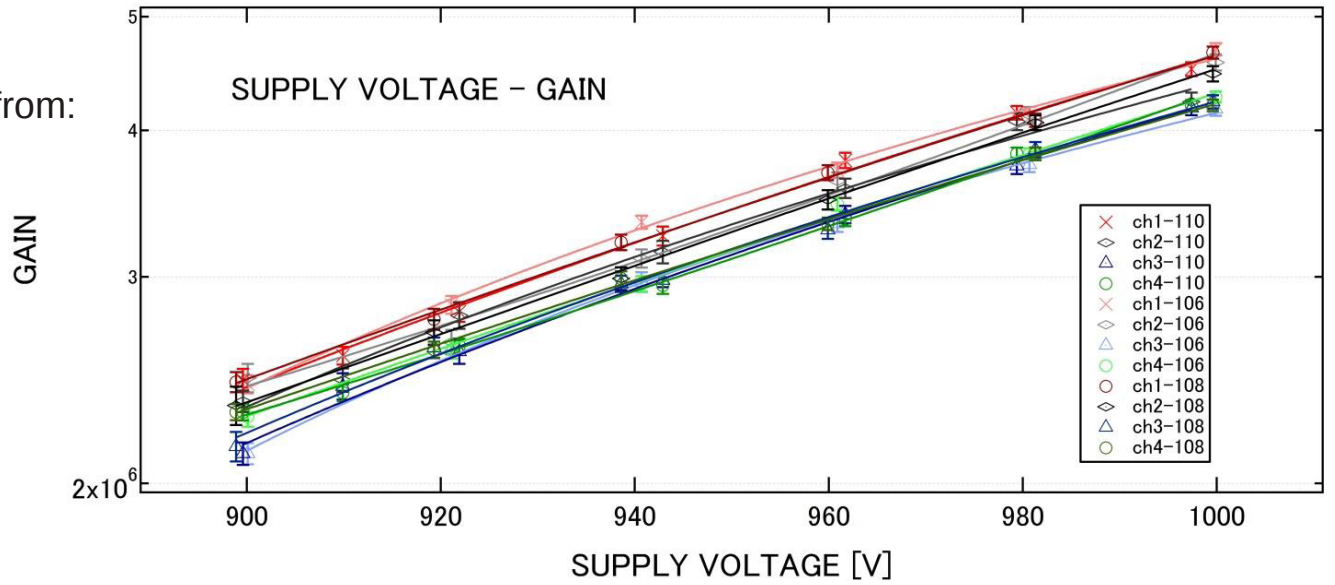
- Acquisition has been done in the same time with the 1” PMTs
- We repeated exactly the same analyses

- Integrated pulse
  - With fixed integration interval
  - With variable integration interval (peak finding)

  → Choice on down and up time edges

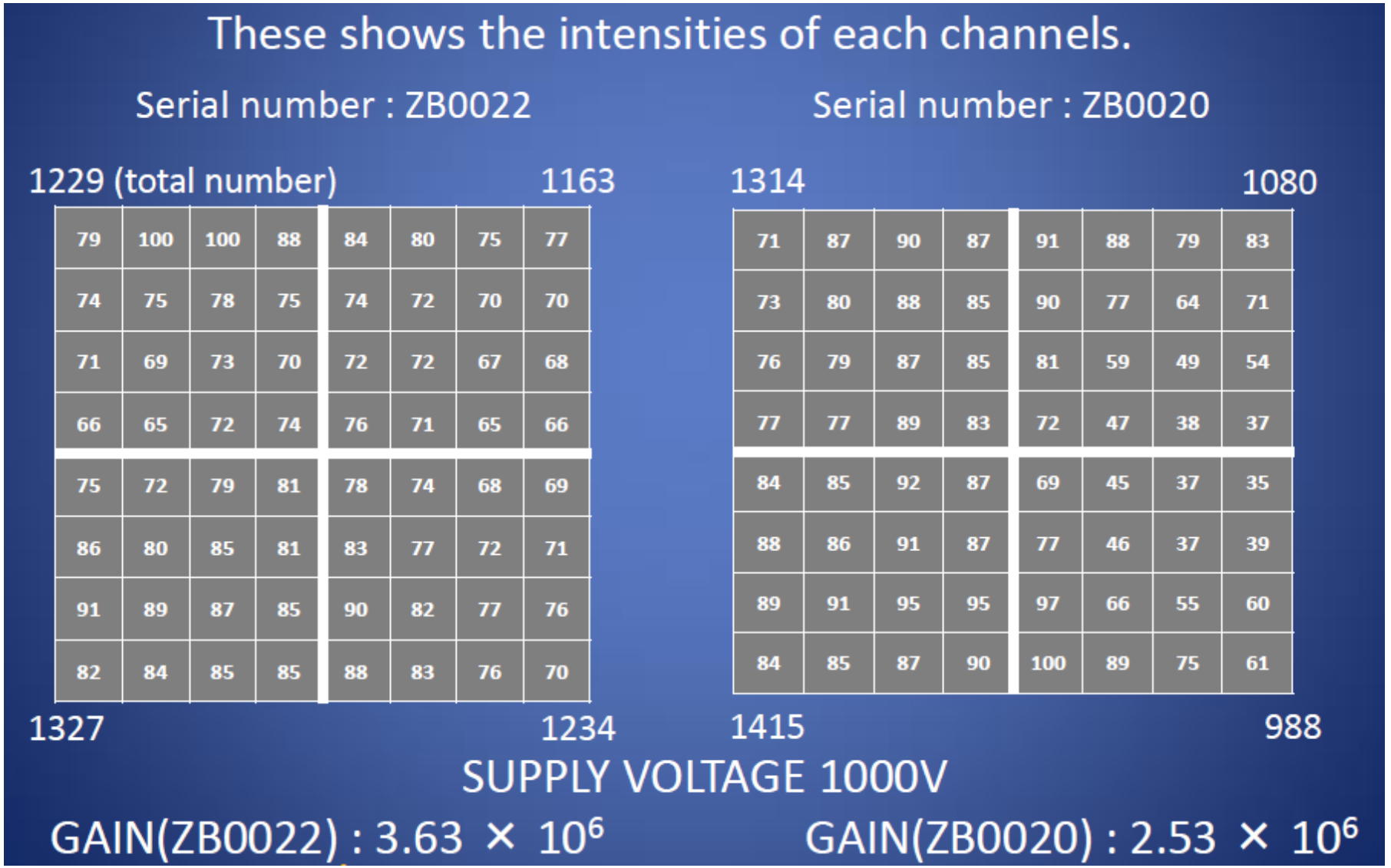
- Gain vs HV

- Stability studies. Checked dependency from:
  → Trigger rate
  → LXe temperature



- Conclusions :
  → Same level of stability
  → We measured so far 2 models, one with lower and one with higher gains (compatibly with what expected from Hamamatsu)

Specification from Hamamatsu



Advantages of the new PMT R10551

High potentiality for future detectors (Medical Imaging and Dark Matter)

- Size : 2”
  → covers area 4 times bigger at lower cost than 4 PMT 1”

- Very compact
  → we save a lot of LXe

- 50% of quantum efficiency higher
  → higher performances in the result

- Made by 64 independent channels fed by one unique HV source
  → less cabling inside the detector
  → If needed, higher position resolutions

- Hamamatsu interested for future collaborations for Dark Matter detectors
  → they are available to build a low-radioactivity version

Conclusions and outlook

Subatech, in a very fruitful collaboration with KEK, is proceeding very quickly in the characterization of the PMT for XEMIS2 :

- Good results compatible with expectations
- High stability on the performances
- Unique occasion to perform in parallel R&D on new experimental PMTs

Next :

- We will complete the characterization of all 50 PMTs R7600 1”
- New studies (noise, dark current rate, linearity, ...)
- We will study new models of the new PMT R10551 2”