MEG II実験のための液体キセノンガンマ線検出器のアップグレードの現状

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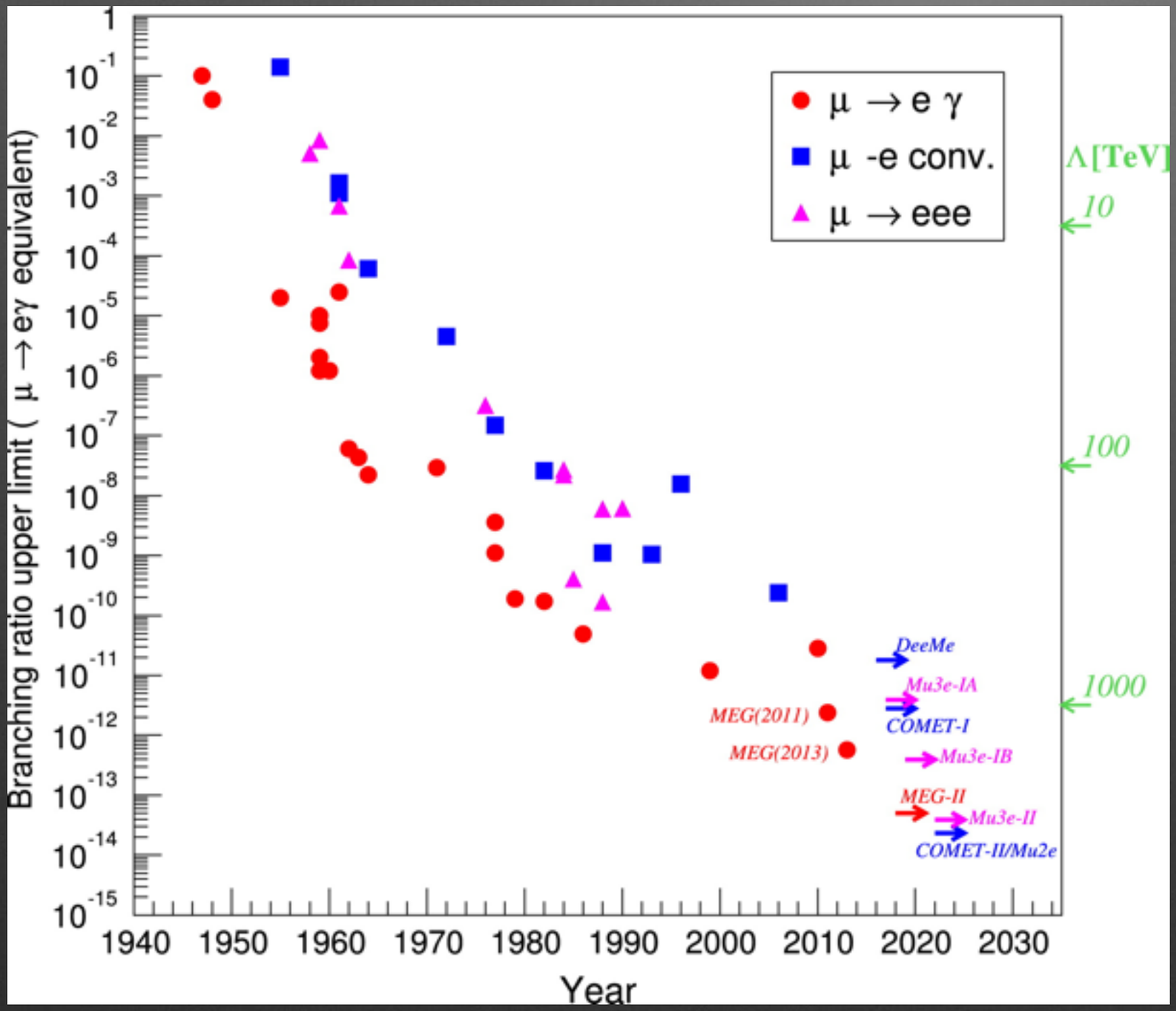
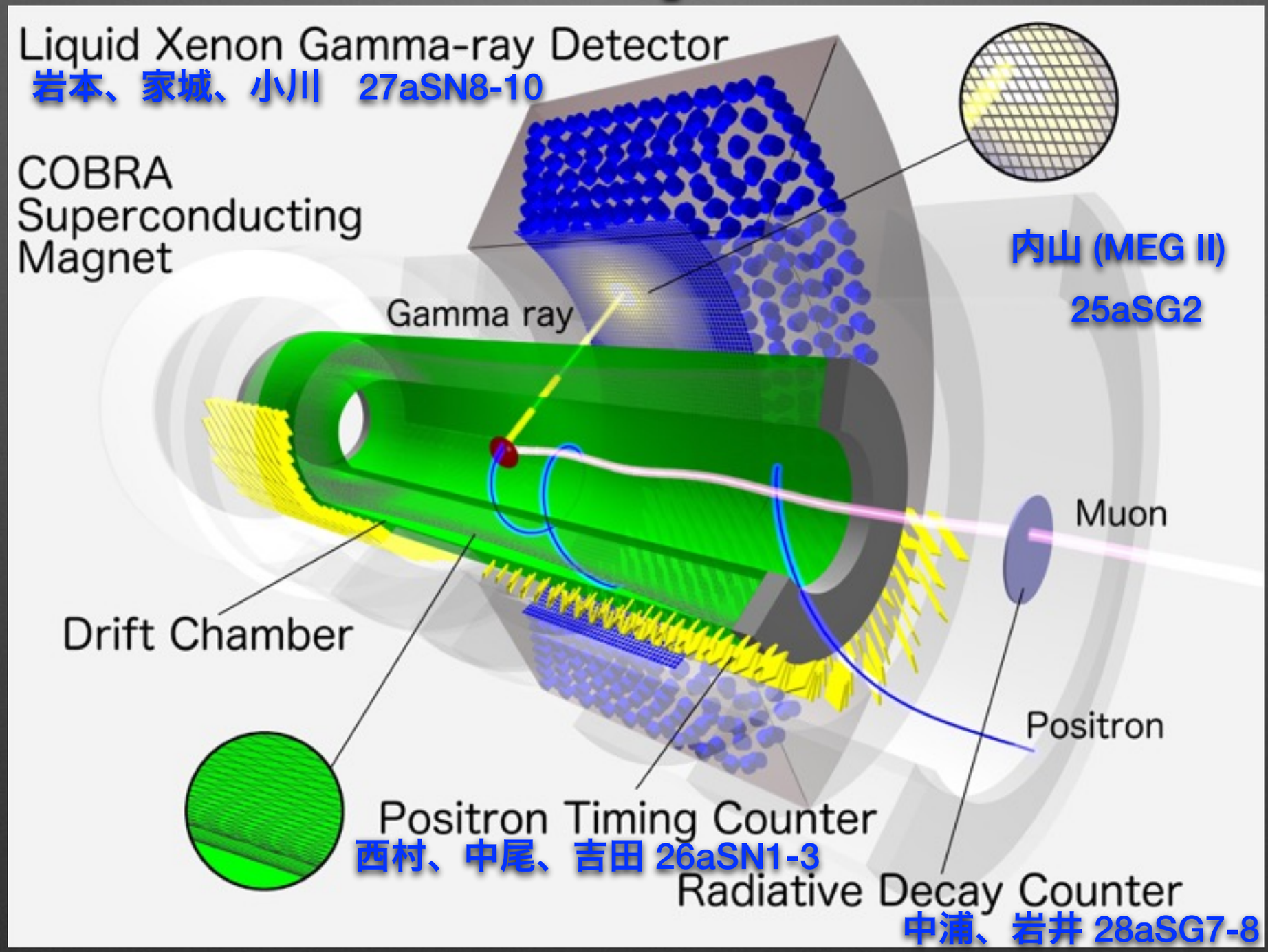
日本物理学会 2015年秋季大会
大阪市立大学　杉本キャンパス

$\mu^+ \rightarrow e^+\gamma$

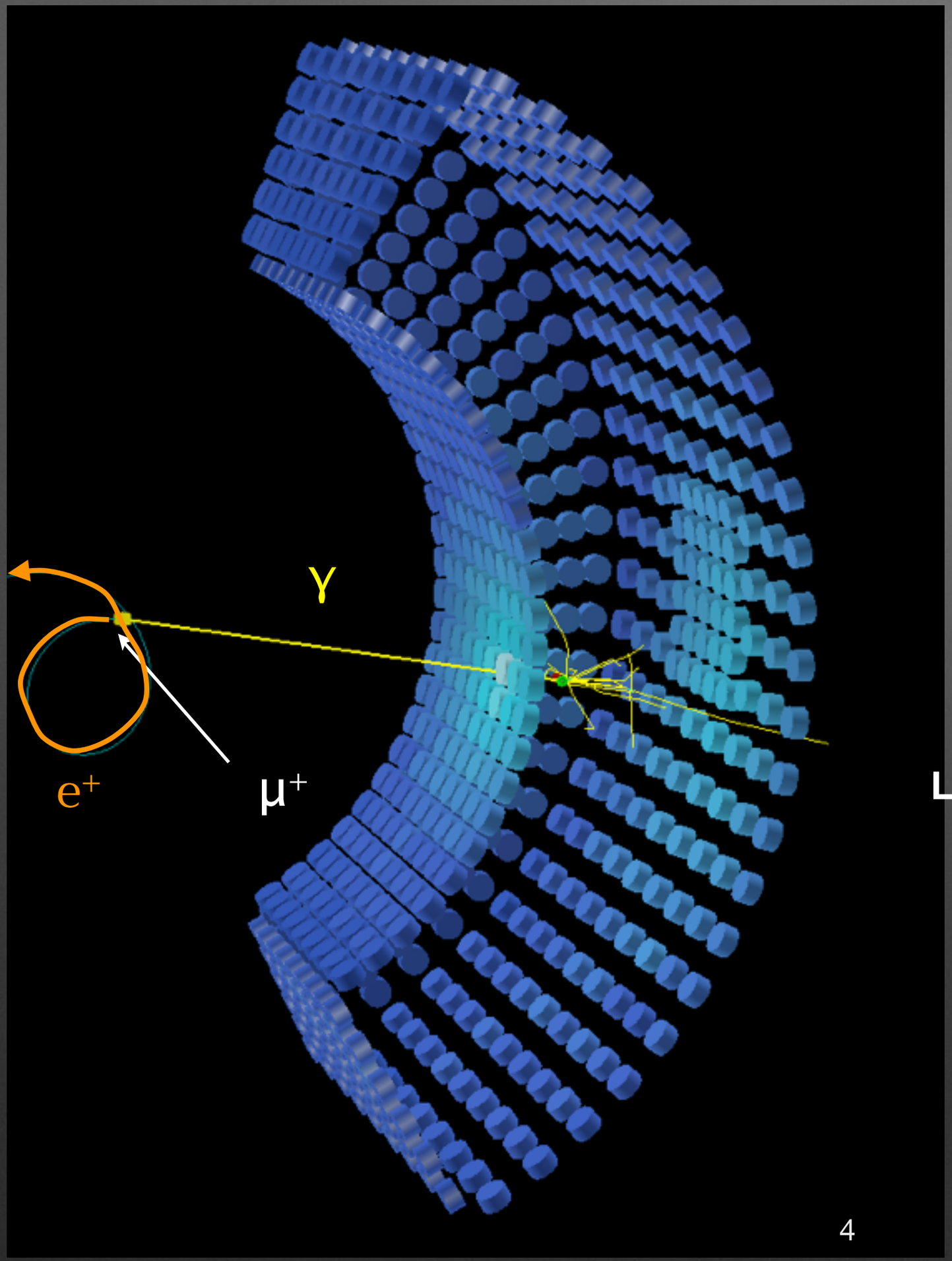


- Many parameters and issues are not explained by SM.
- No definitive discovery of new physics from any experiments yet.
- **Lepton flavor violation**
  - Neutrino oscillation is violating lepton flavor.
  - Long history in charged lepton ($\mu^+ \rightarrow e^+\gamma$, $\mu \rightarrow e$, $\mu \rightarrow 3e$, etc.) search, but no discovery yet
- BR($\mu \rightarrow e\gamma$)~10^{-54} in the SM with neutrino mass
- Observation of $\mu \rightarrow e\gamma$ decay is a clear signature of new physics
- Many new physics such as SUSY-GUT, SUSY-seesaw etc. predict large BR($\mu \rightarrow e\gamma$)
- MEG experiment set an upper limit of Br($\mu^+ \rightarrow e^+\gamma$) = 5.7×10^{-13} in 2013, and the final result will be published this year (金子 25aSG1)

MEG II Experiment



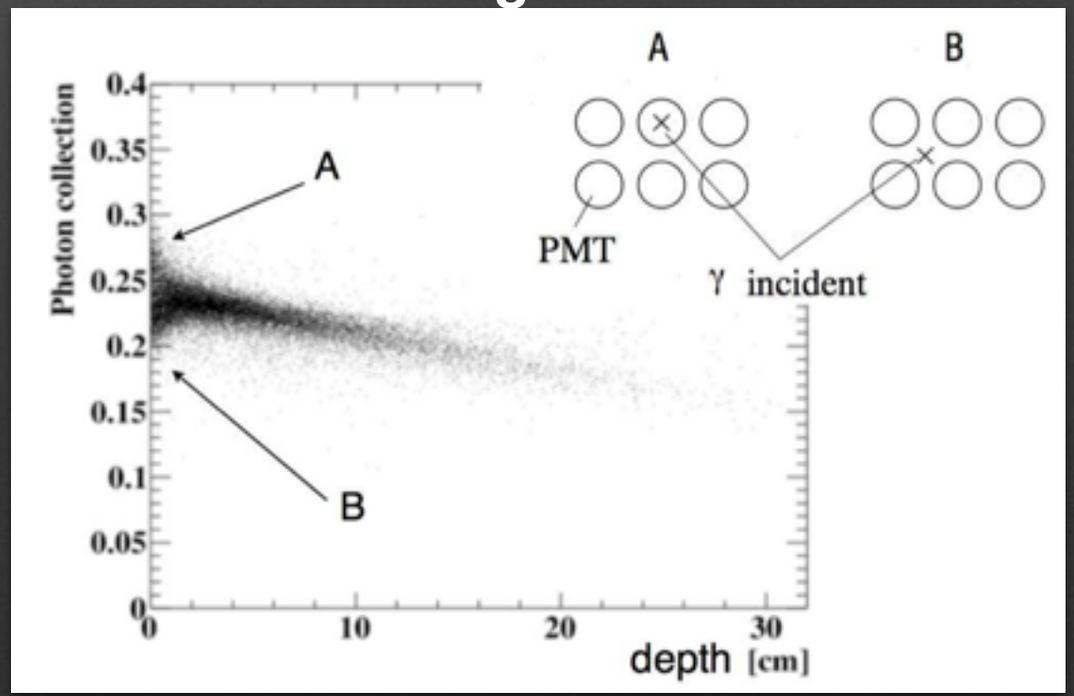
- Target sensitivity : 4×10^{-14}
  (one order of magnitude improvement from the MEG experiment)



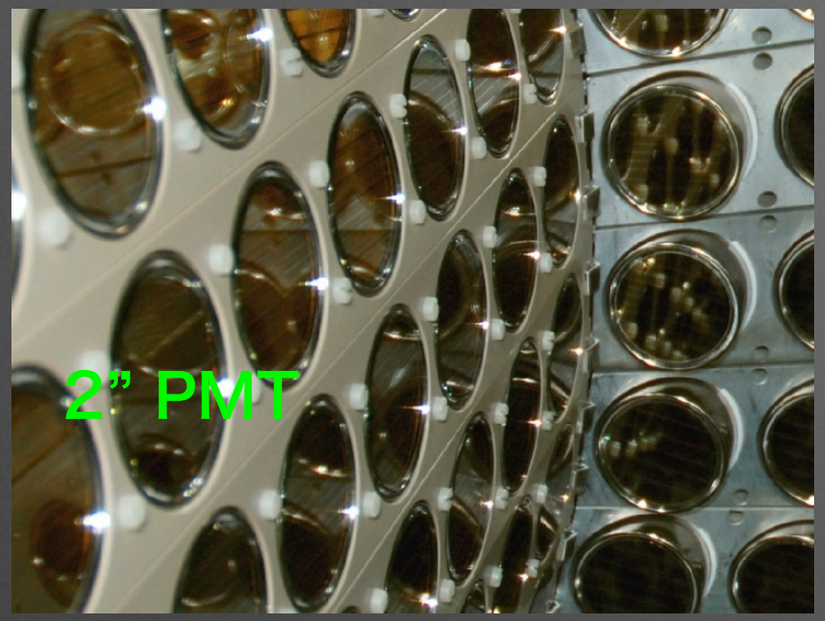
MEG Liquid Xenon Detector

- LXe 900L (2.7ton) homogeneous detector
  - High light yield, fast response, good uniformity
  - World largest LXe detector (still?)
- UV sensitive 846 2” PMTs directly in LXe
- Low T (165K), LXe scintillation λ=175nm
- Basically it was working well. However,

Limited resolution against shallow events

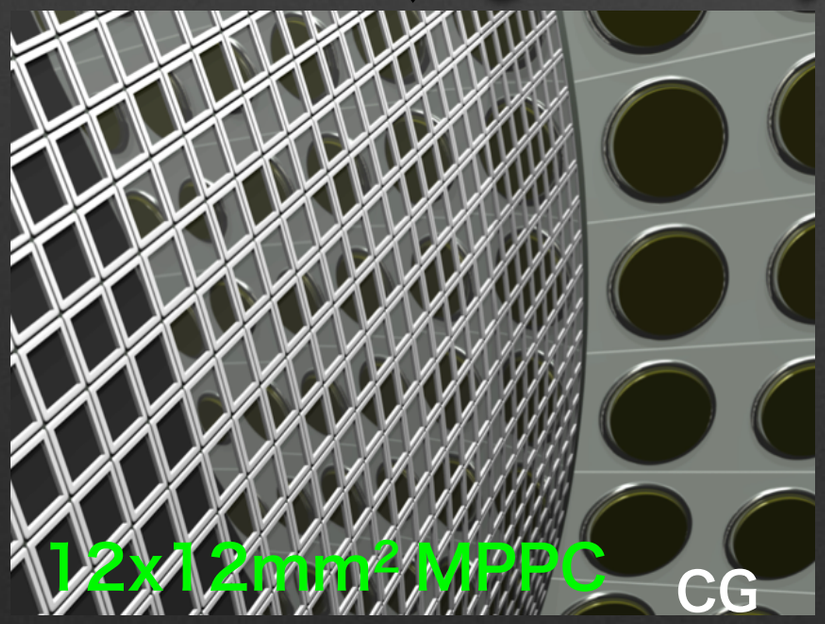


MEG II LXe detector



Smaller photo sensors for γ-ray incident face

Increase granularity

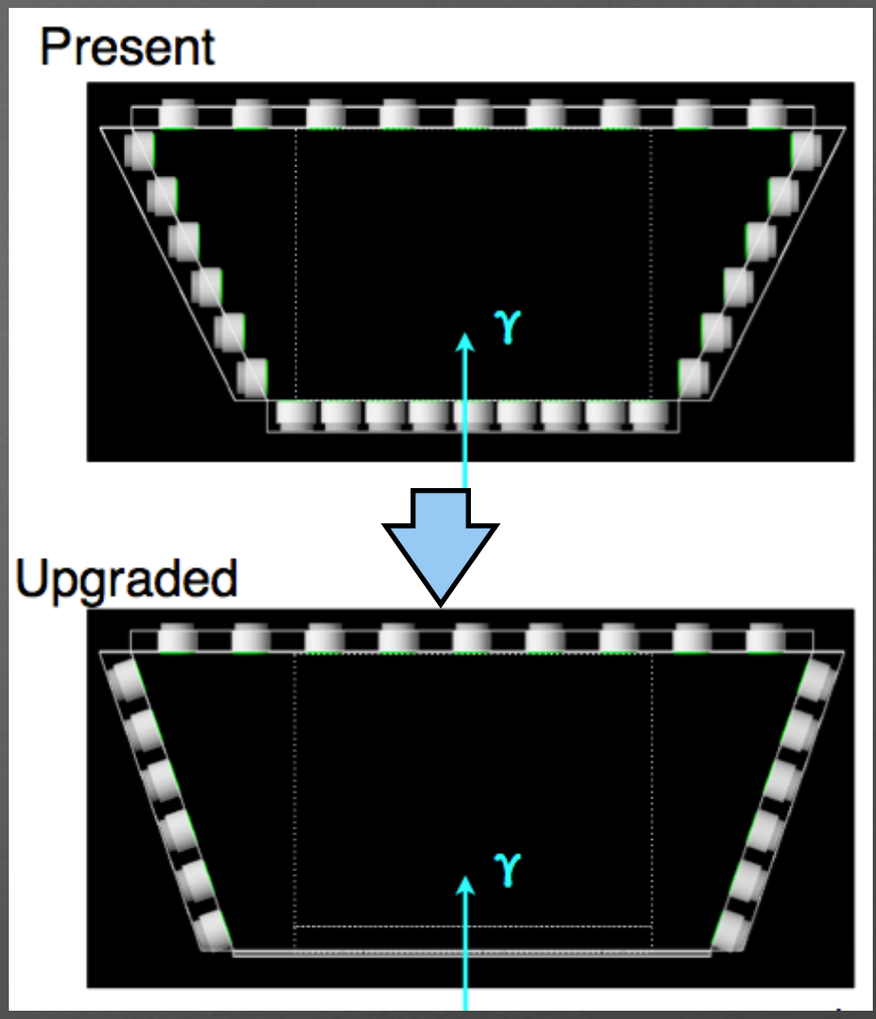


Different PMT angle of lateral face

Uniform response

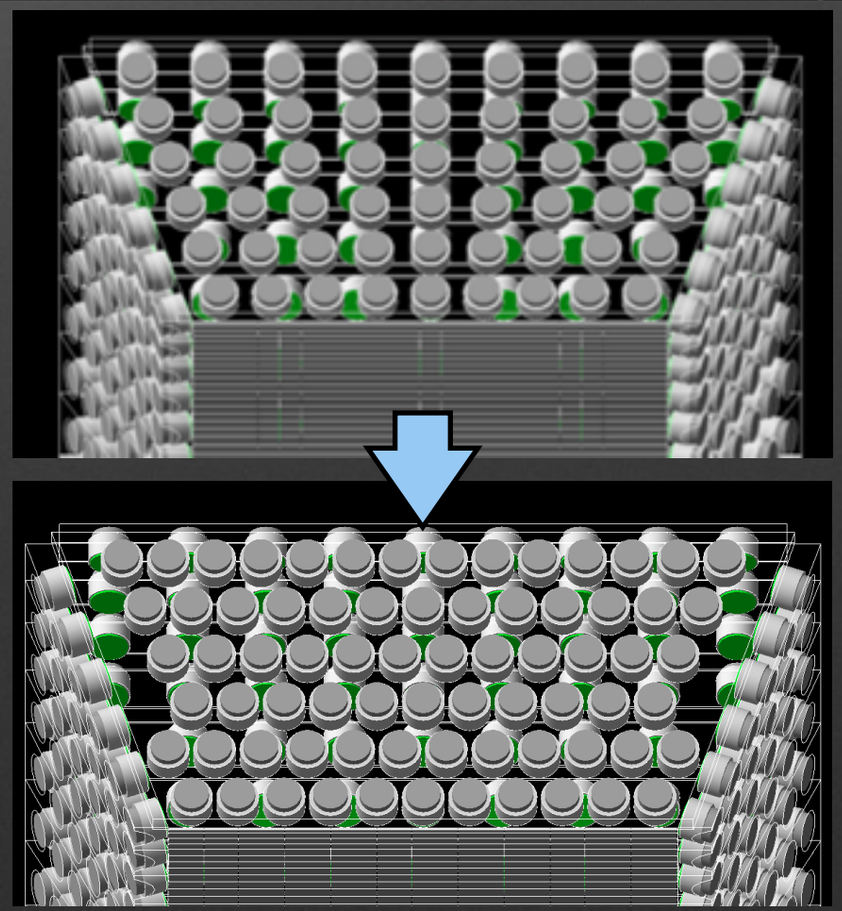
Wider incident face

Reduce shower leakage

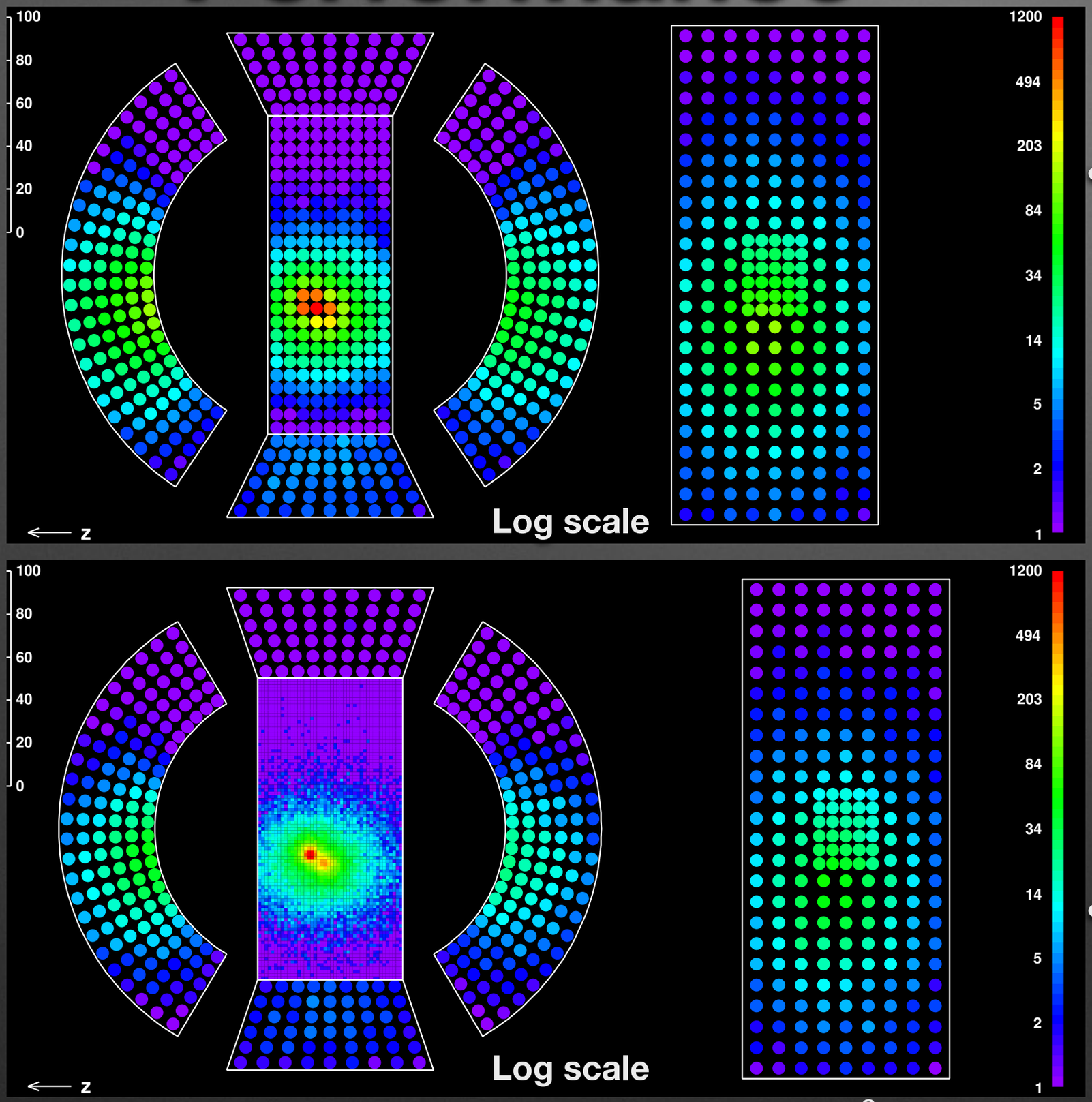


Increase #PMTs on top/bottom faces

Uniform response



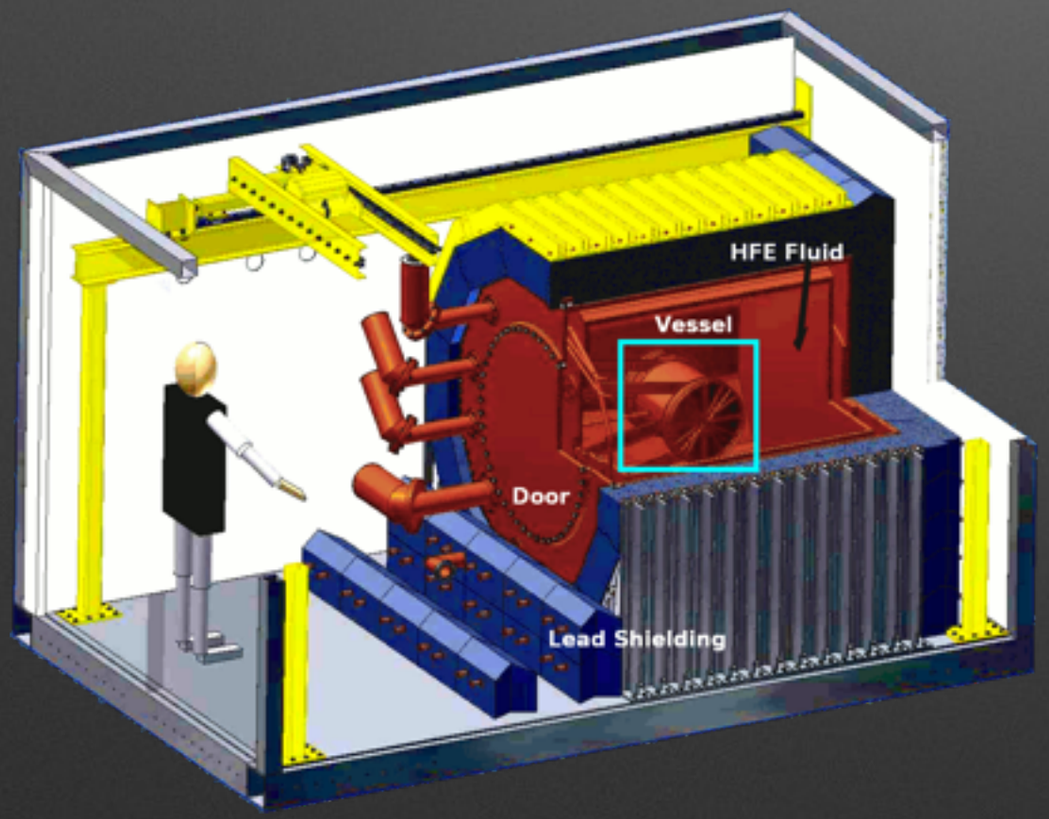
Performance

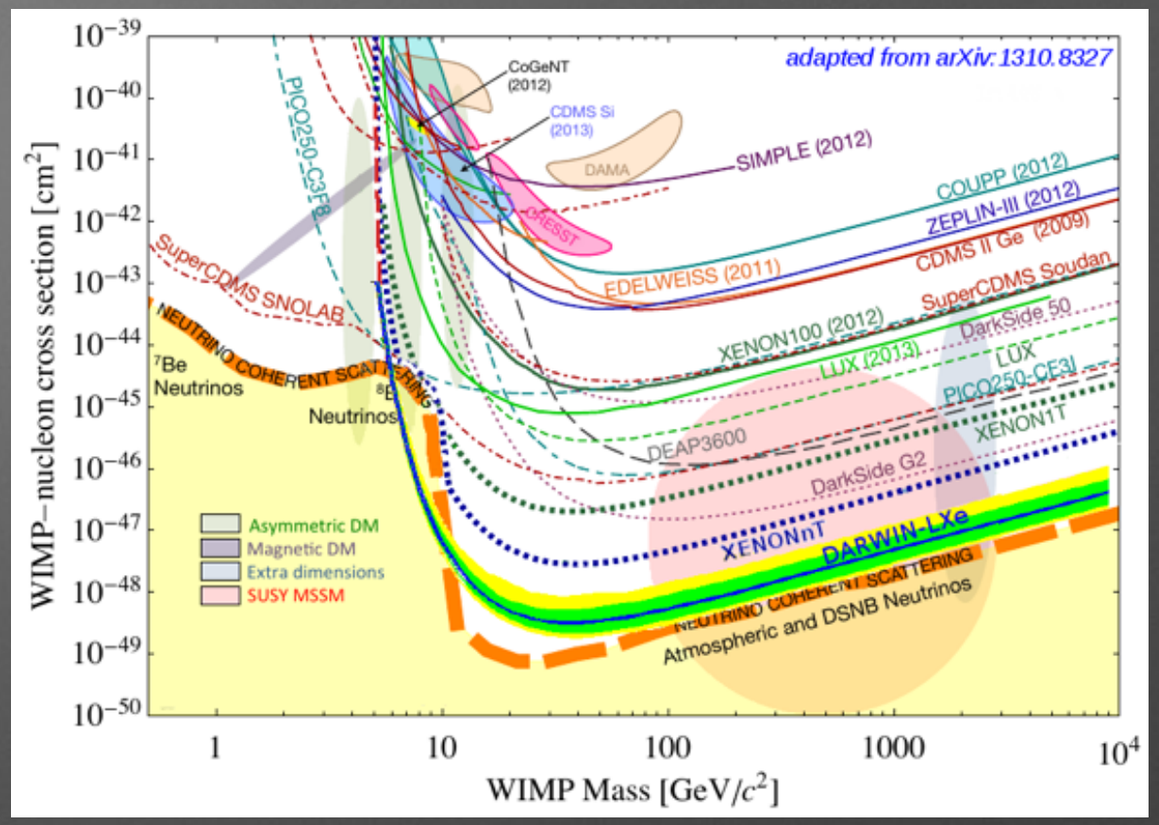


- Improvements
  - Better imaging power
  - Energy resolution
    <1% (2-3%)
  - Position resolution
    ~2mm (5-6mm)
  - Detection efficiency
    9% improvement
- Simulation study by S. Ogawa (27aSN-10)

LXe detectors in the world

- LFV
  - MEG (2008-2013), MEG II
- Double beta decay
  - EXO-200, nEXO
- Medical Imaging
  - LXe compton PET, TOF PET
- Gamma-ray Astrophysics
  - LXe Compton telescope, ionization calorimeter



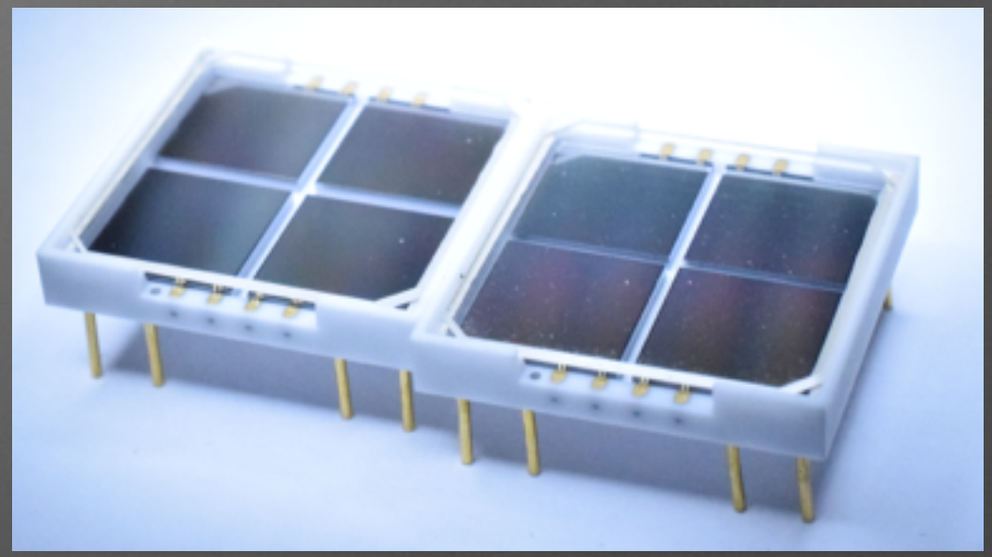


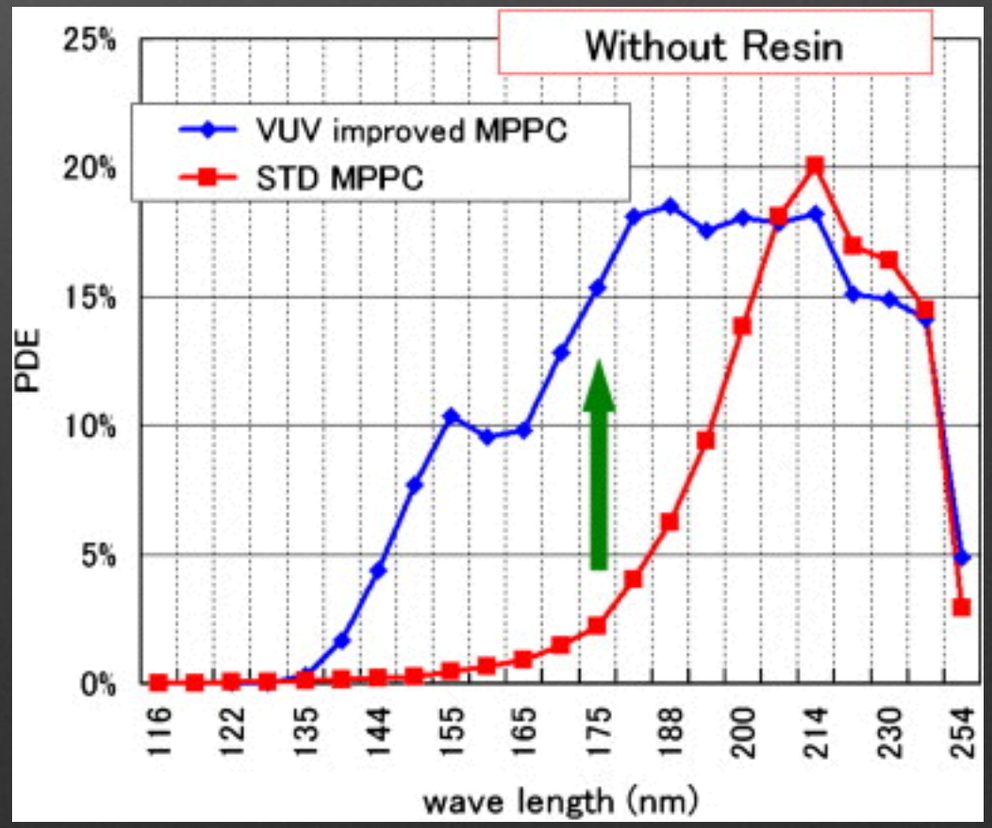
- Dark Matter search
  - Single-phase
    - XMASS
  - Dual-phase TPC
    - XENON1T (3.3ton LXe), start soon
    - XENONnT (7ton)
    - LZ (7ton) in 2016
    - DARWIN-LXe (30-50tons!) after 2020

LXe detectors play the leading part in many fields

VUV SiPM

- Silicon photomultiplier (SiPM)
  - already used in many other experiments
  - commercial ones were not sensitive to VUV light.
- HPK and MEG developed VUV sensitive MPPC (S10943-4186(X))
- Large area MPPC (12x12mm^2) is realized with four series connection on PCB.
- 4092 MPPCs will be used in the front face of the MEG II LXe detector (K. Ieki, 27aSN-9)
- Other experiments are also testing this model
  - EXO, XENON, mu2e (BaF2, 200nm), …
  - Application also for LAr scintillation light(128nm) detection (ANKOK). arXiv:1505.00091v1[physics.ins-det].
- Promising device for many applications



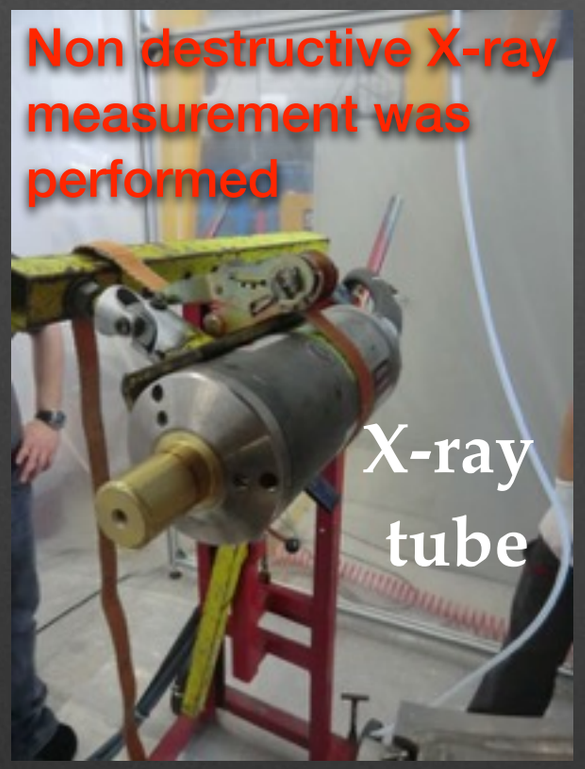


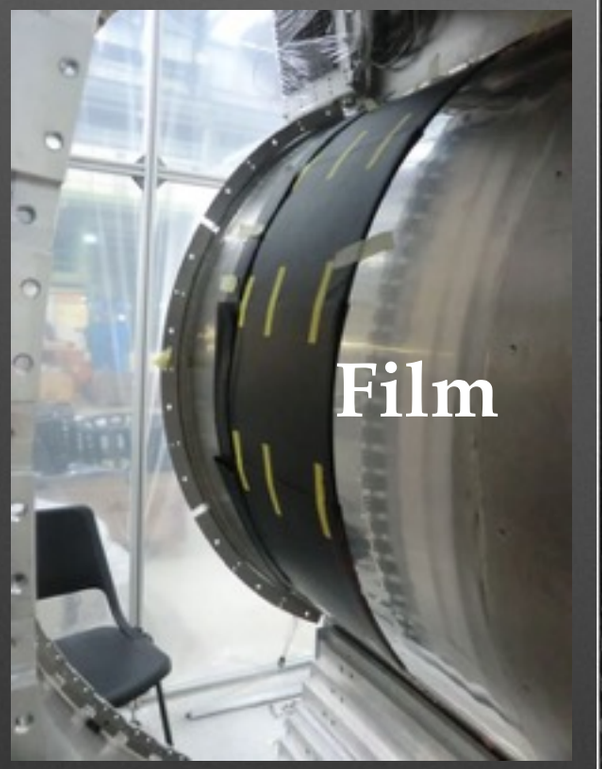
Upgrade status

- Detector cryostat check
- MPPC production, mass test
- Support structure production
- Alignment
- Calibration devices

X-ray test

- Detector cryostat has a thin entrance window to reduce gamma-ray interaction in front of the LXe detector
- Want to check the status, but direct access is limited.





- Whole region of the inner surface was scanned by X-ray, and the honeycomb structure is fine!
- Next, gas pressure test in October

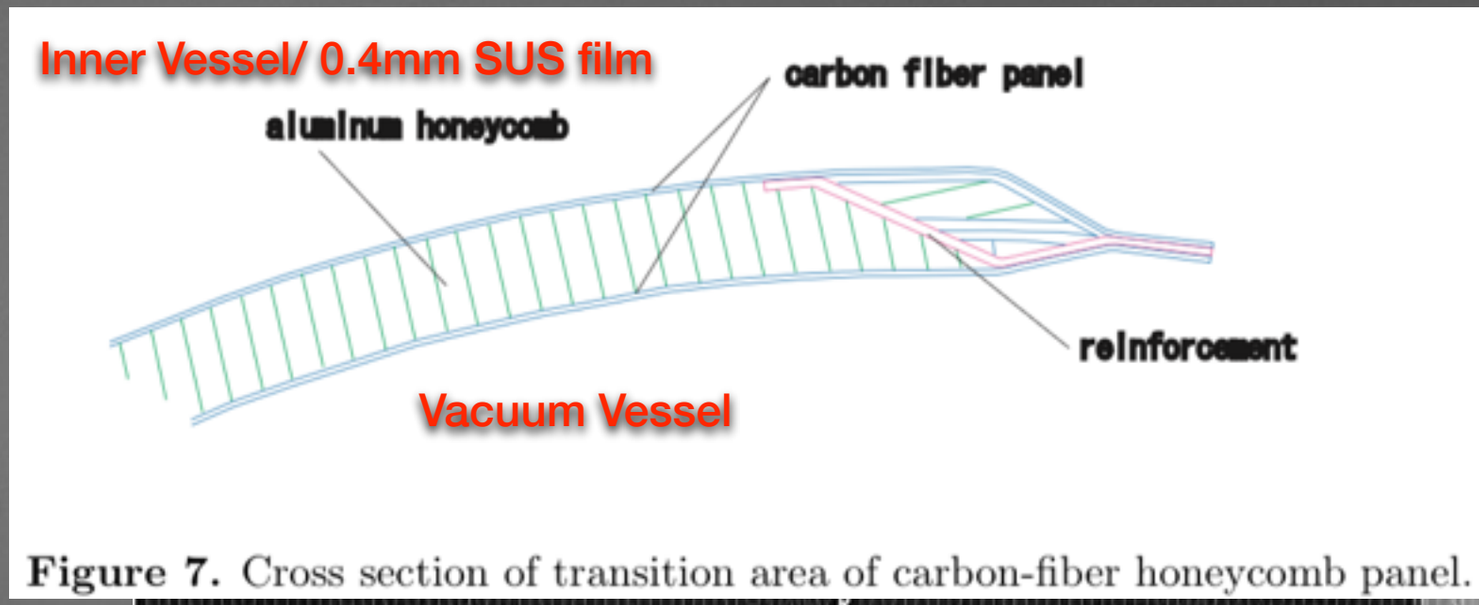
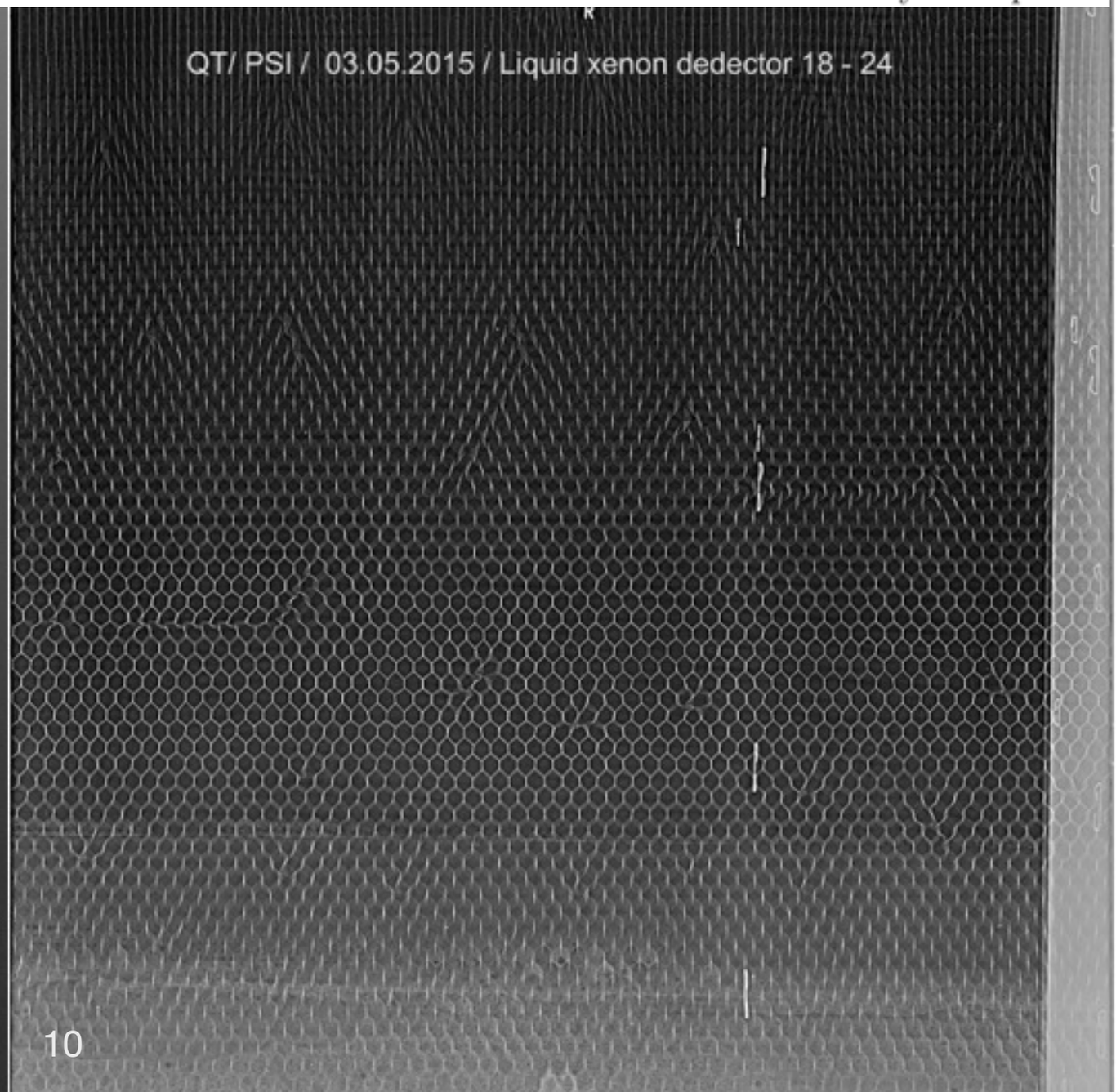
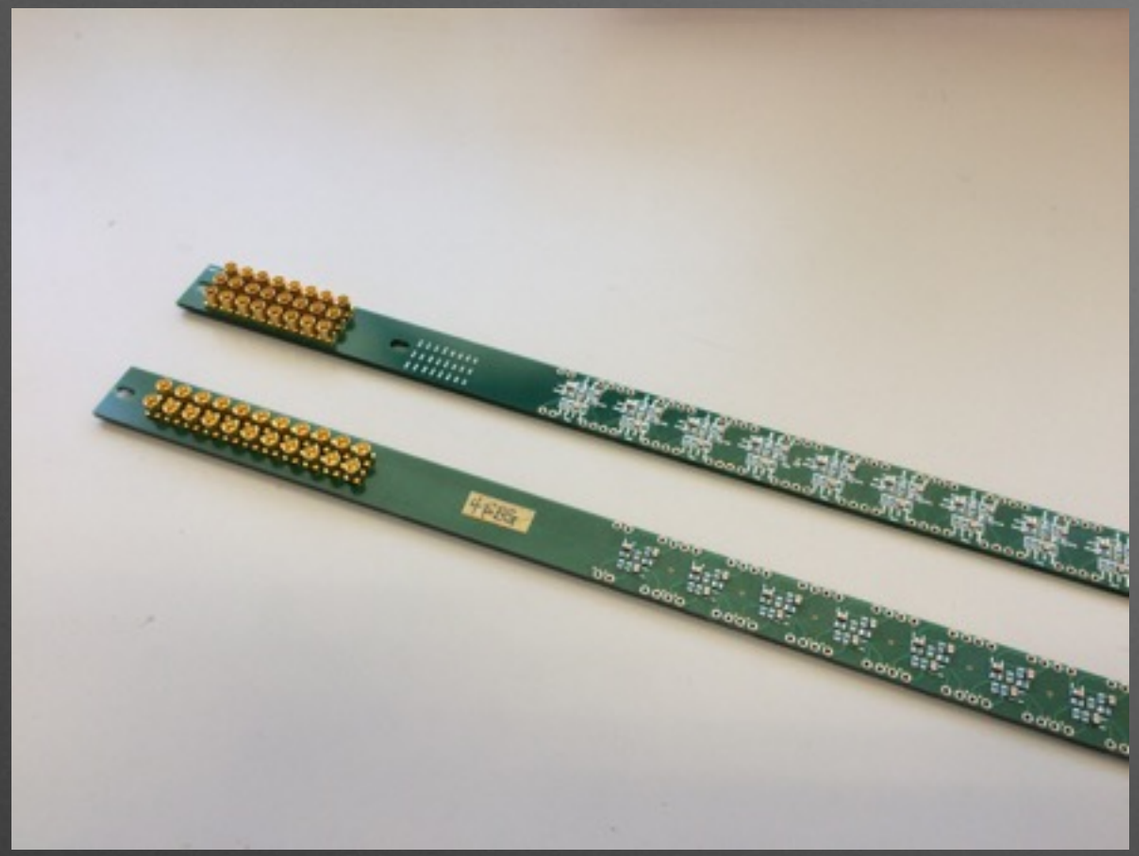
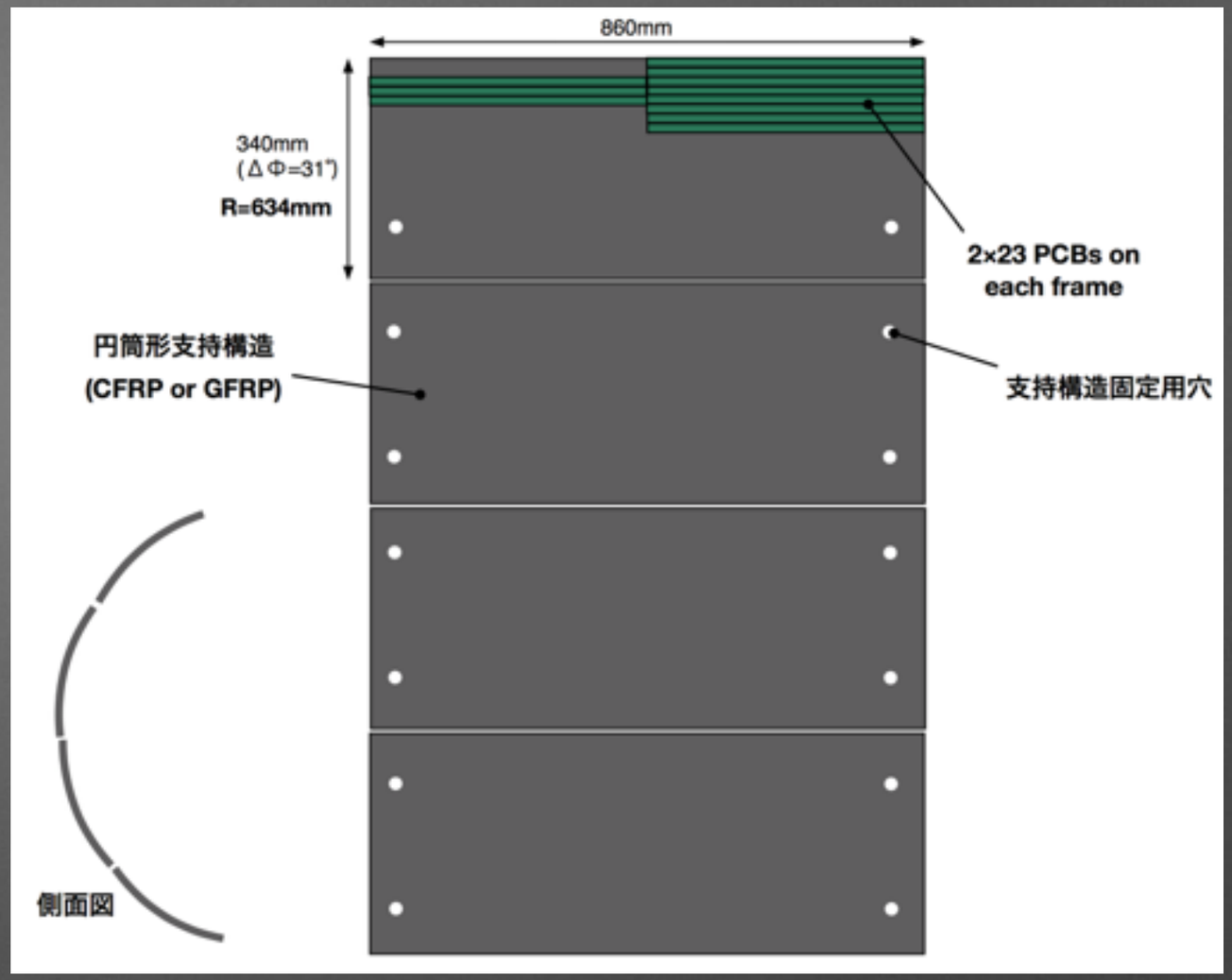


Figure 7. Cross section of transition area of carbon-fiber honeycomb panel.

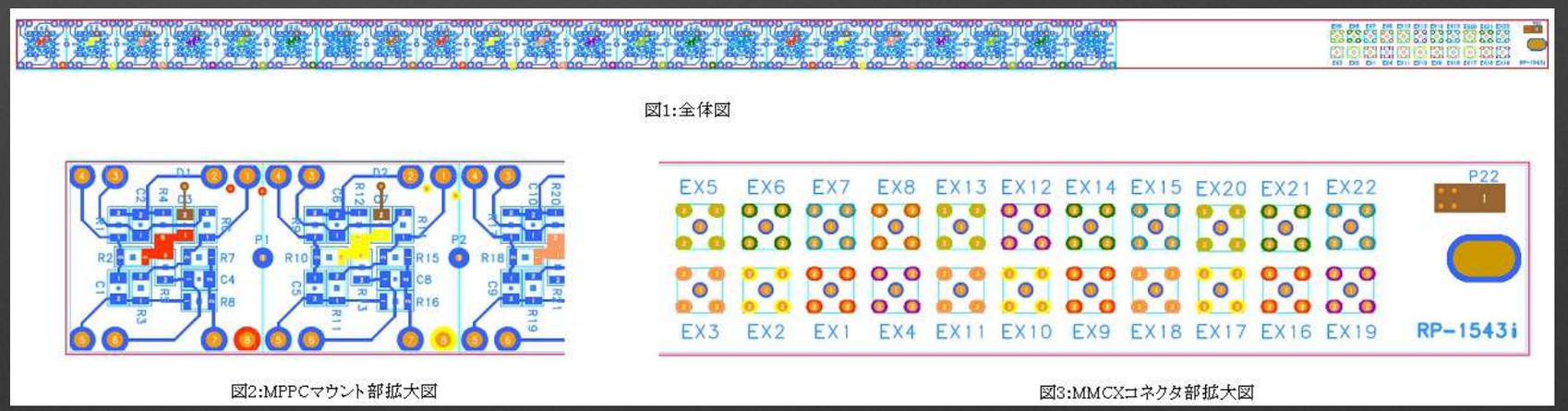


MPPC PCB



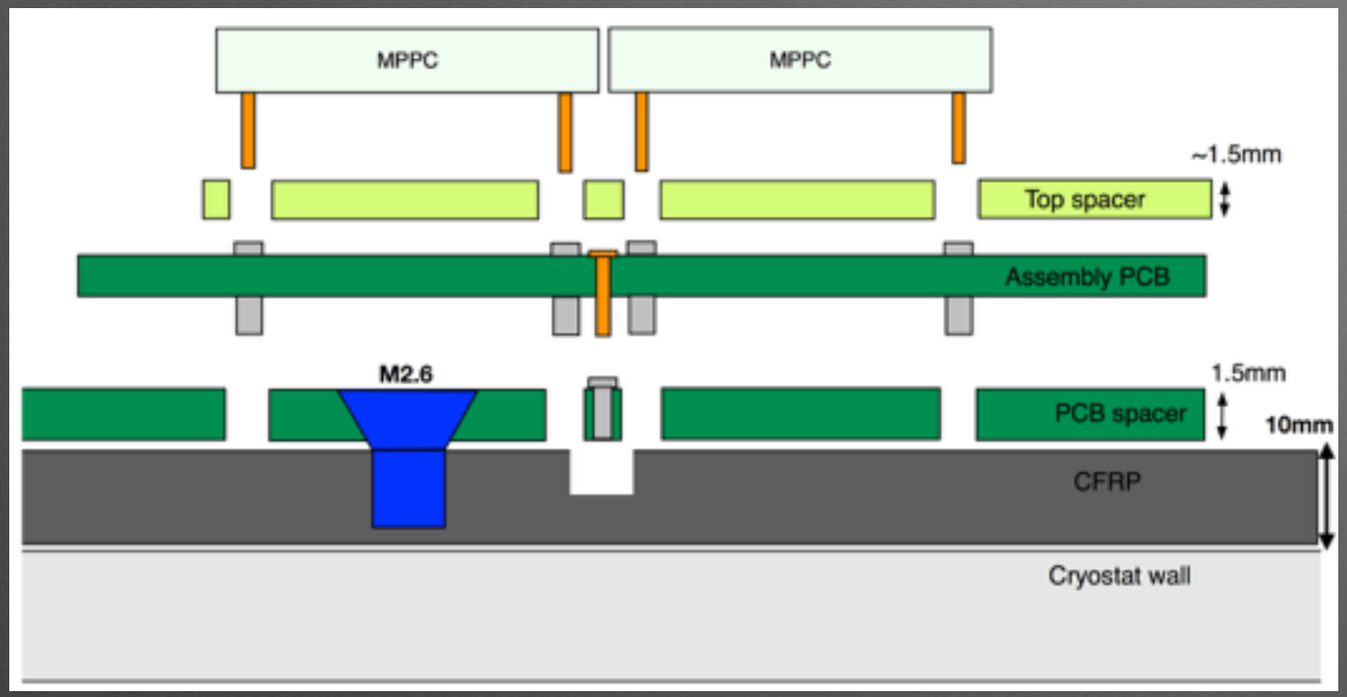


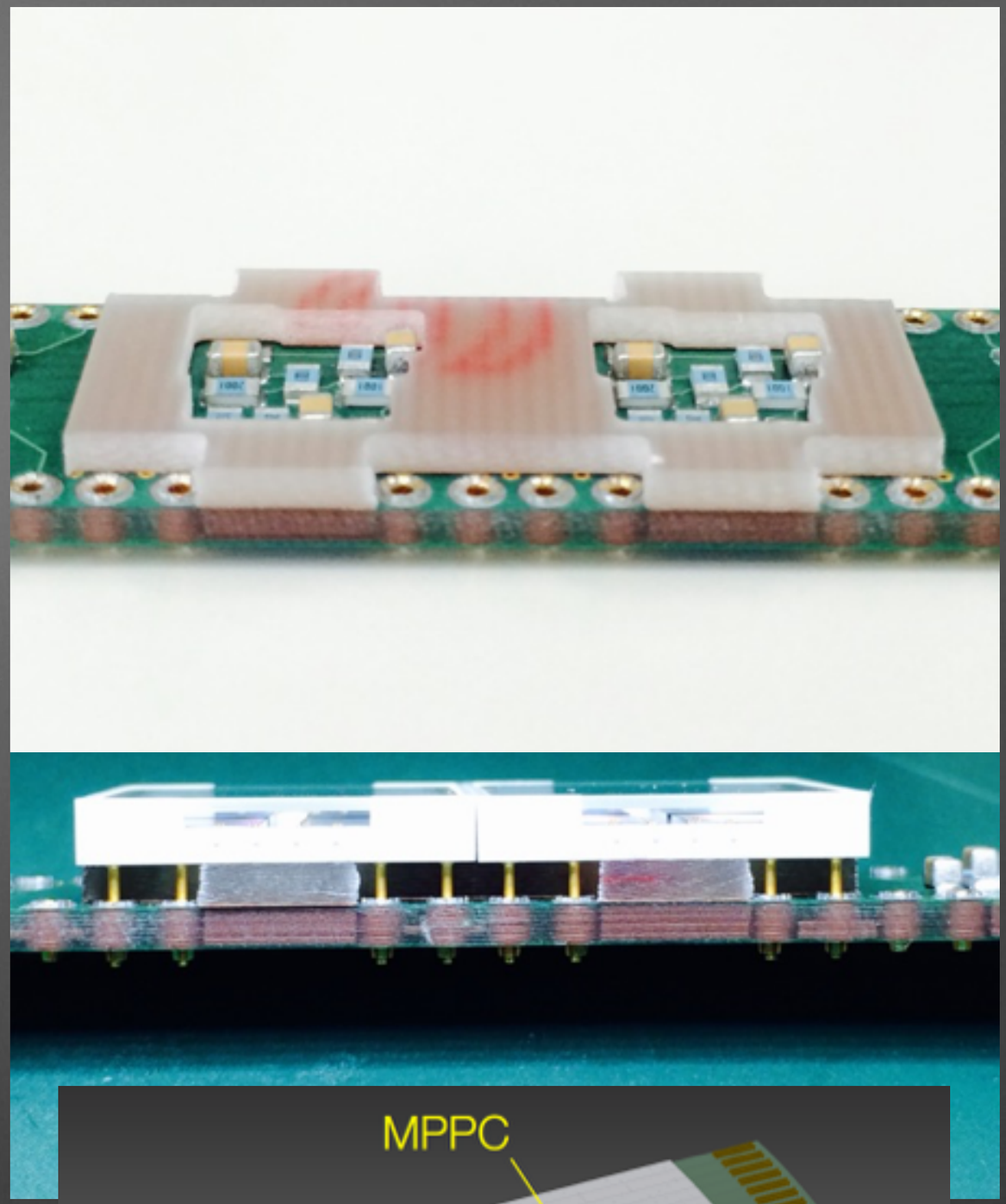
- MPPC mounting method
  - 22 MPPCs on a PCB
  - 93 PCBs at both US/DS
  - 4092 MPPCs on the inner face
- Series connection on the PCB

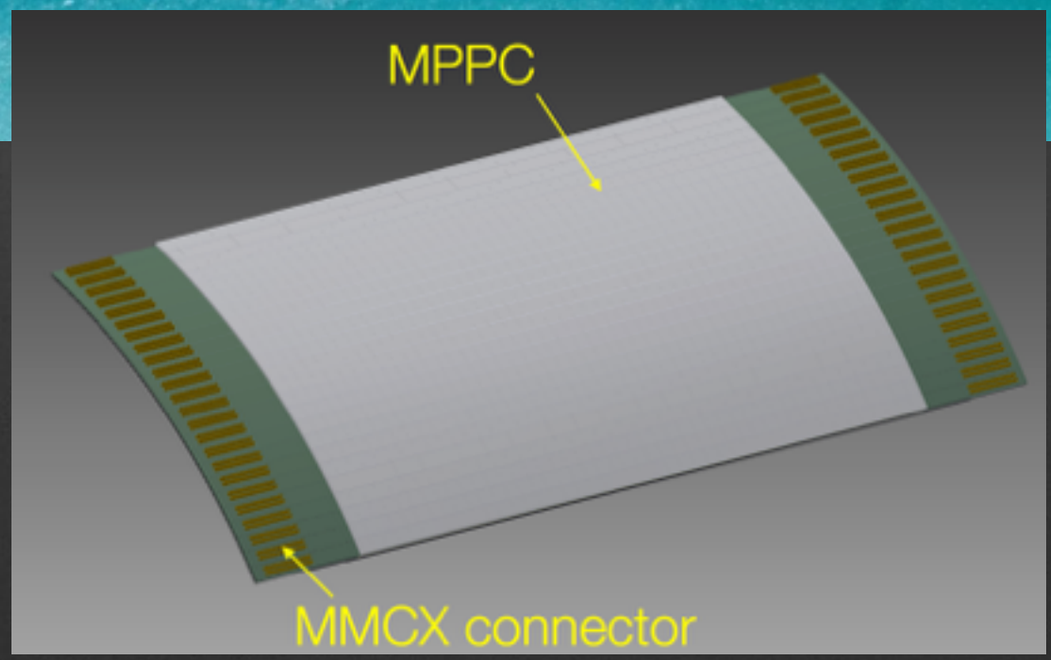


- PCB has multi-layers to realize coaxial like signal lines surrounded by separate ground lines and ground layers
- Signals are transmitted with RG178 thin cables from the PCB MMCX connectors to the feedthrough

MPPC Support structure



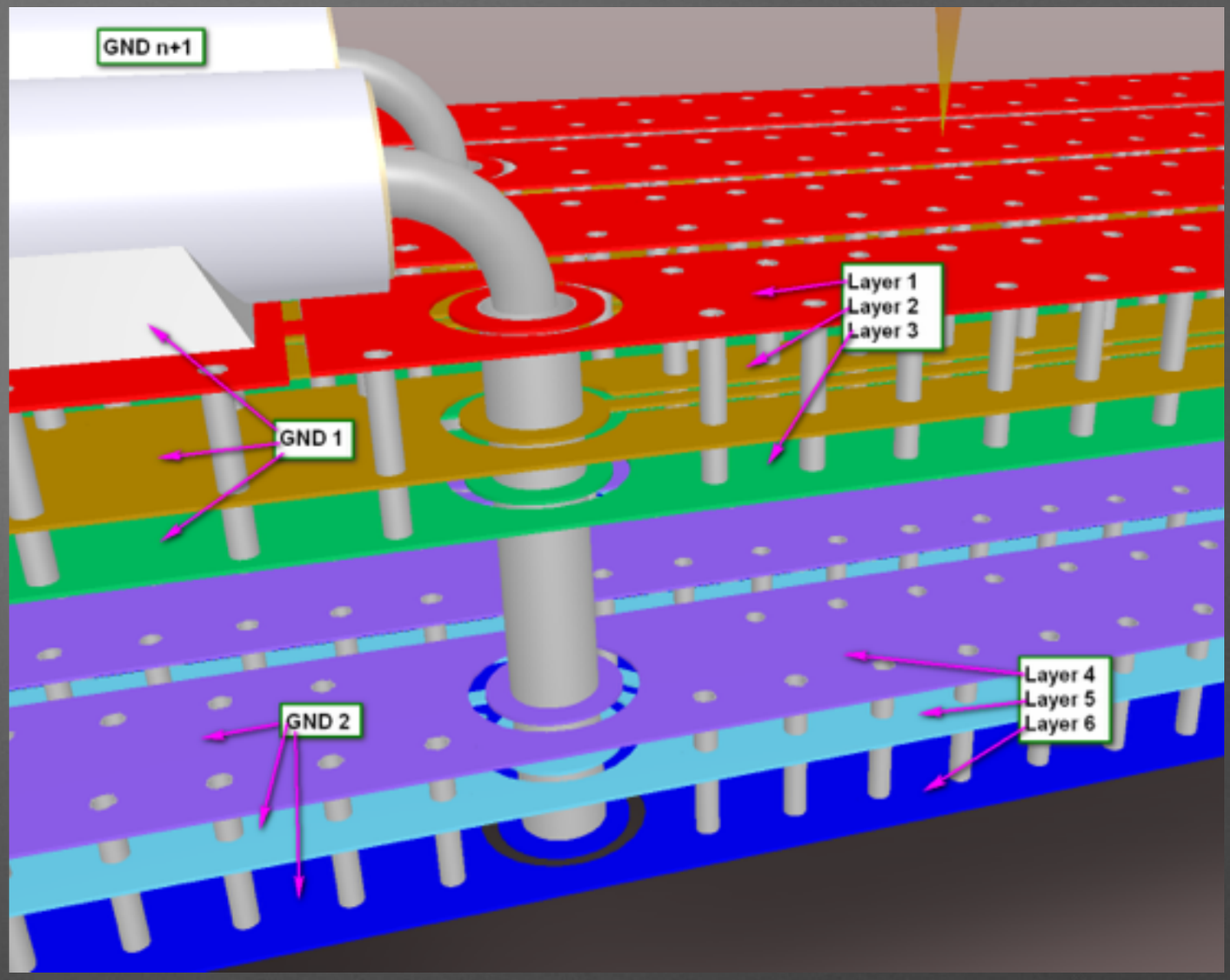


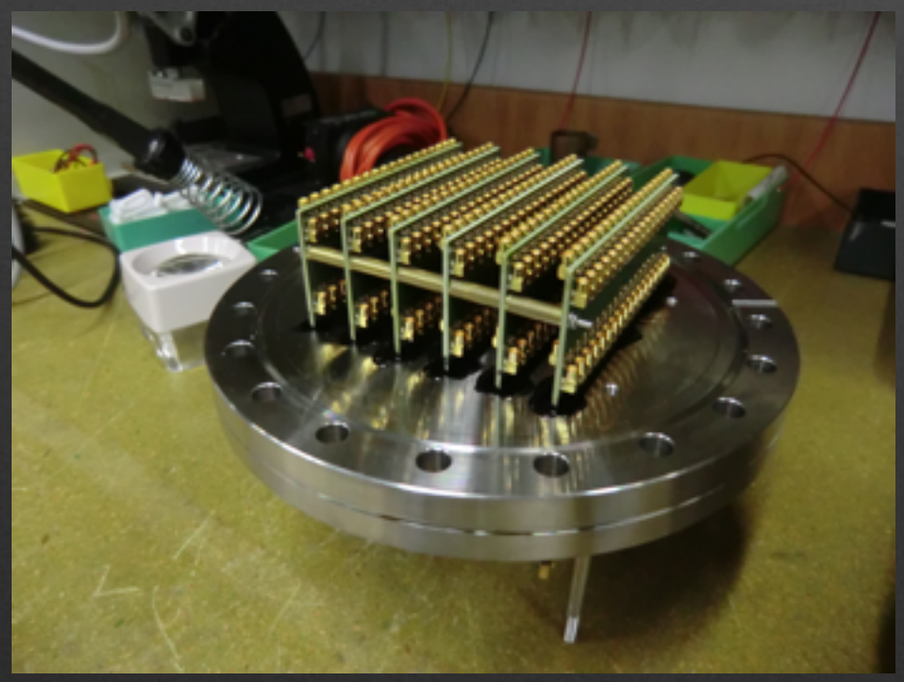


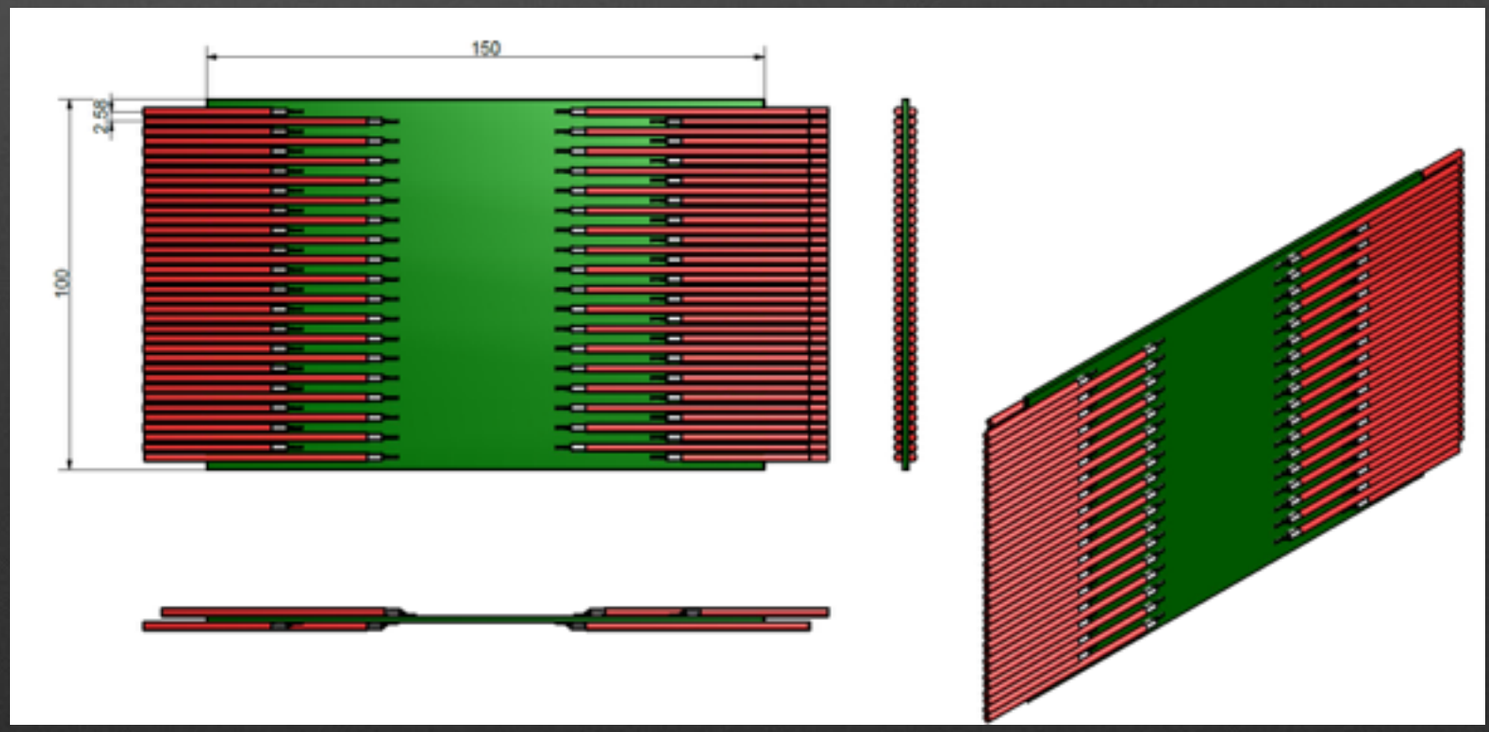
- Any space between MPPC and Cryostat wall cause detection inefficiency
- Need to fill the gap with light material

Feedthrough

- Coaxial like signal line surrounded by ground lines/ planes
- Separate ground lines inside PCB
- Cable soldering at both ends

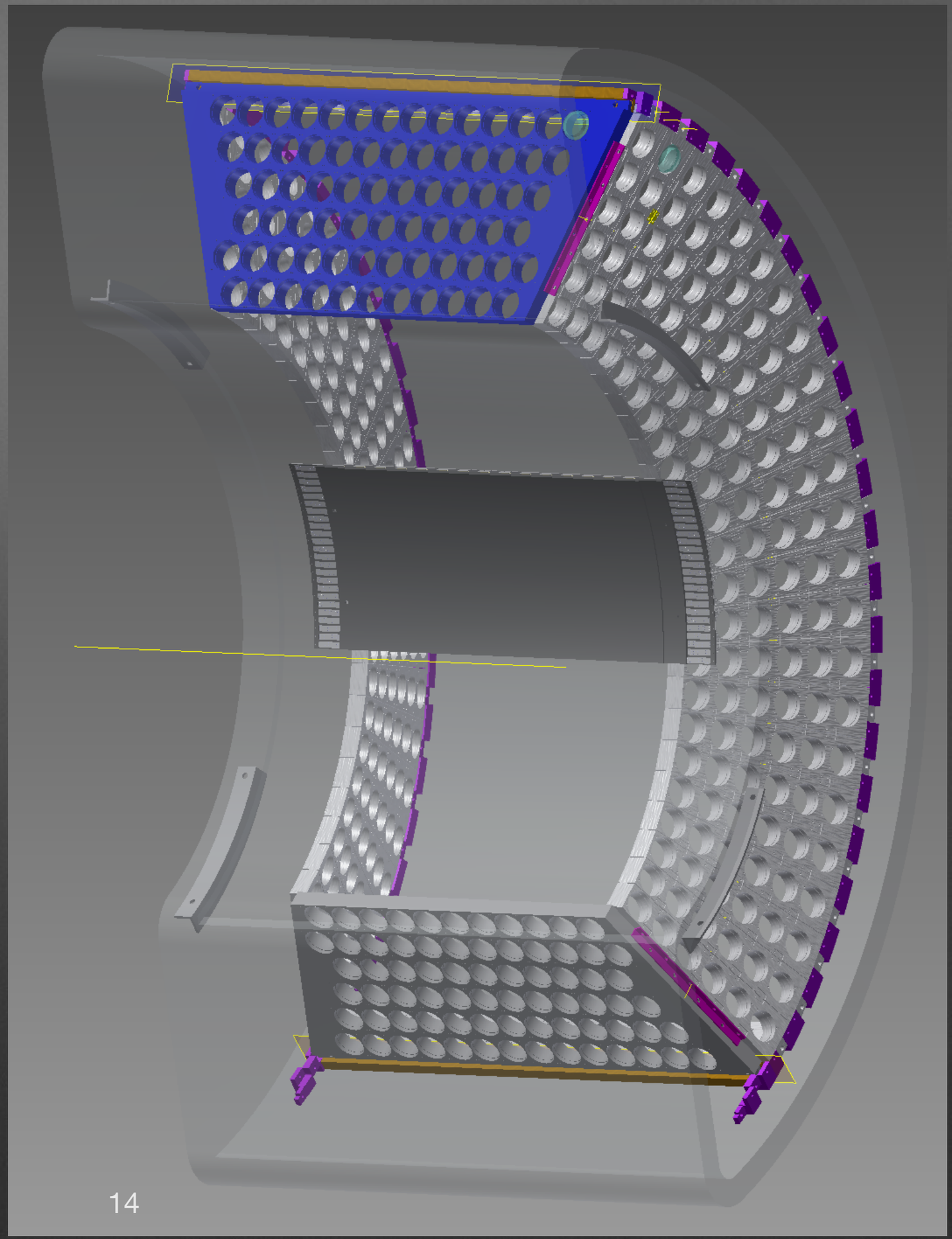






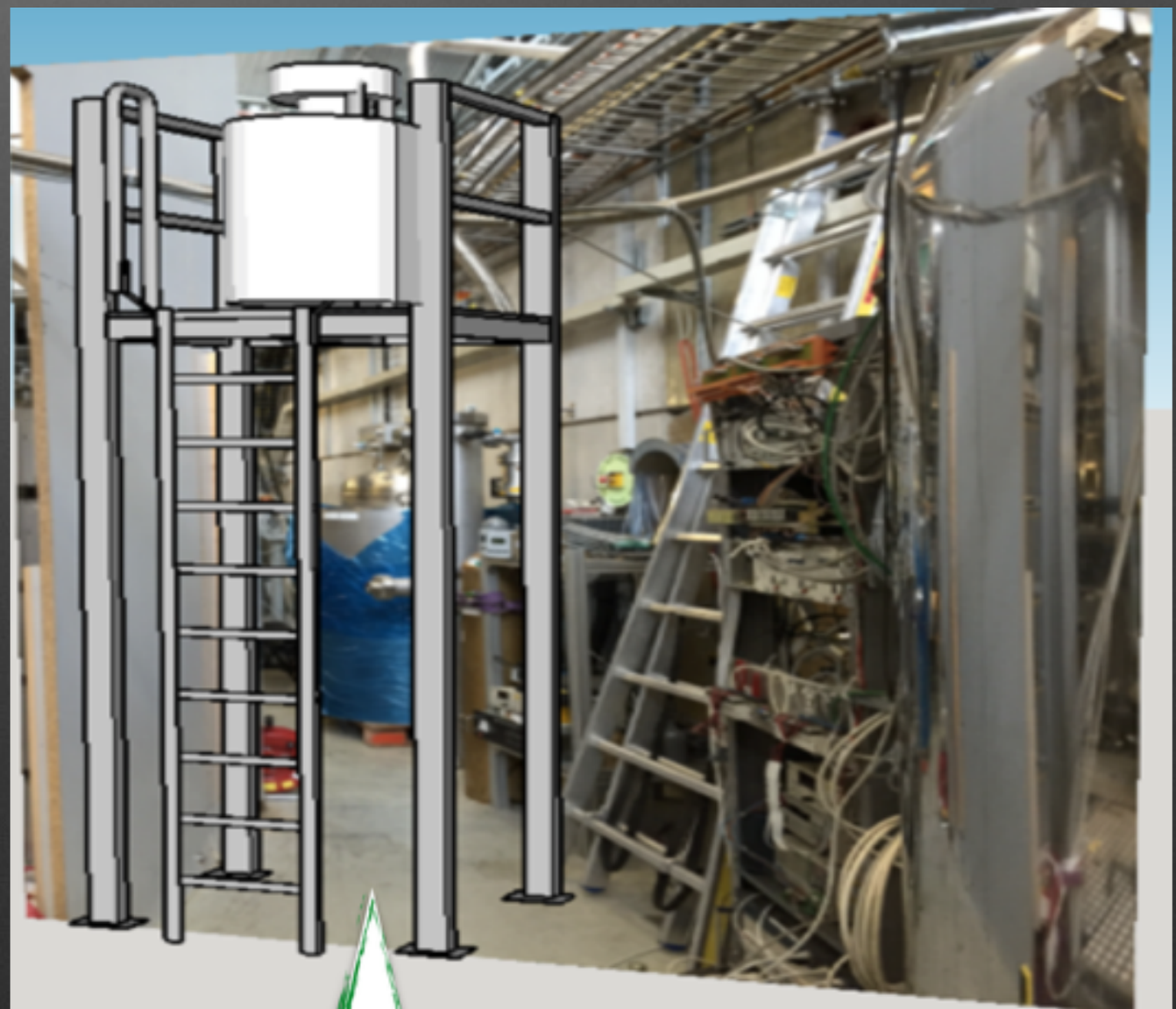
PMT support structure

- Modification
  - Wider inner face
  - PMT angle of lateral sides
- Top/bottom, and lateral PMT support structure will be modified
- To reduce the total volume of the cables, thinner cables (RG178 for signal cables, RG196 for HV) will be used
- Test assembly in November



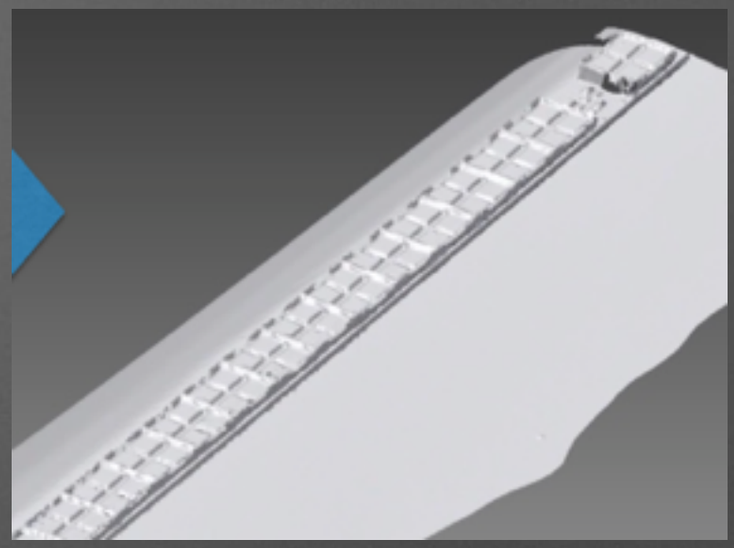
New refrigerator

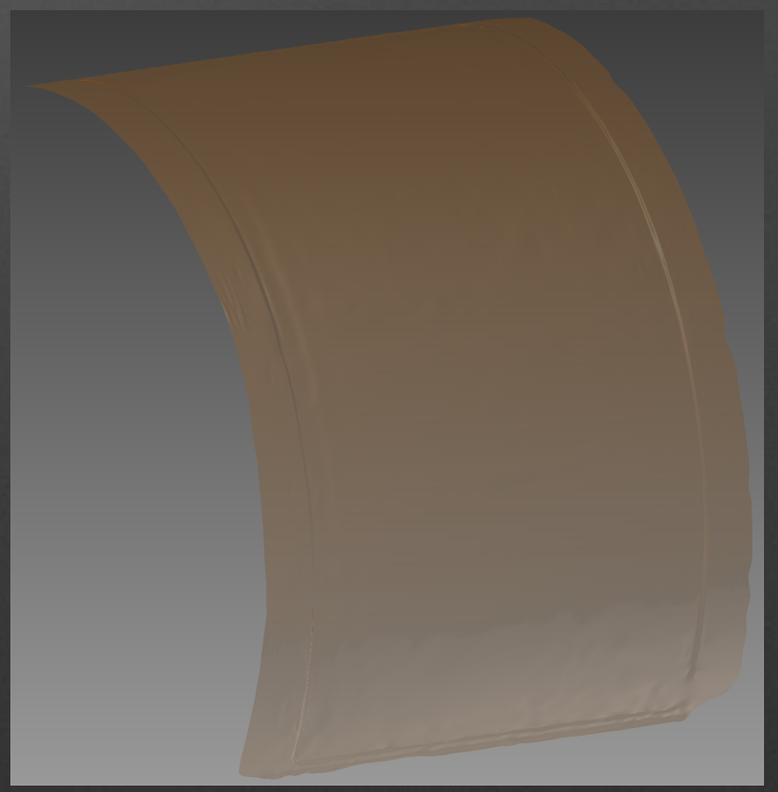
- Increased # MPPCs, cables
- More heat income
- More powerful refrigerator is necessary
- Pulse tube refrigerator (current system, 200W) + GM refrigerator (AL300, >300W) outside the detector hut
- Vacuum insulated tube is connected from the refrigerator to the detector
- The vessel is constructed now. Once the refrigerator is delivered, cooling power test will be done at PSI.



Detector Alignment

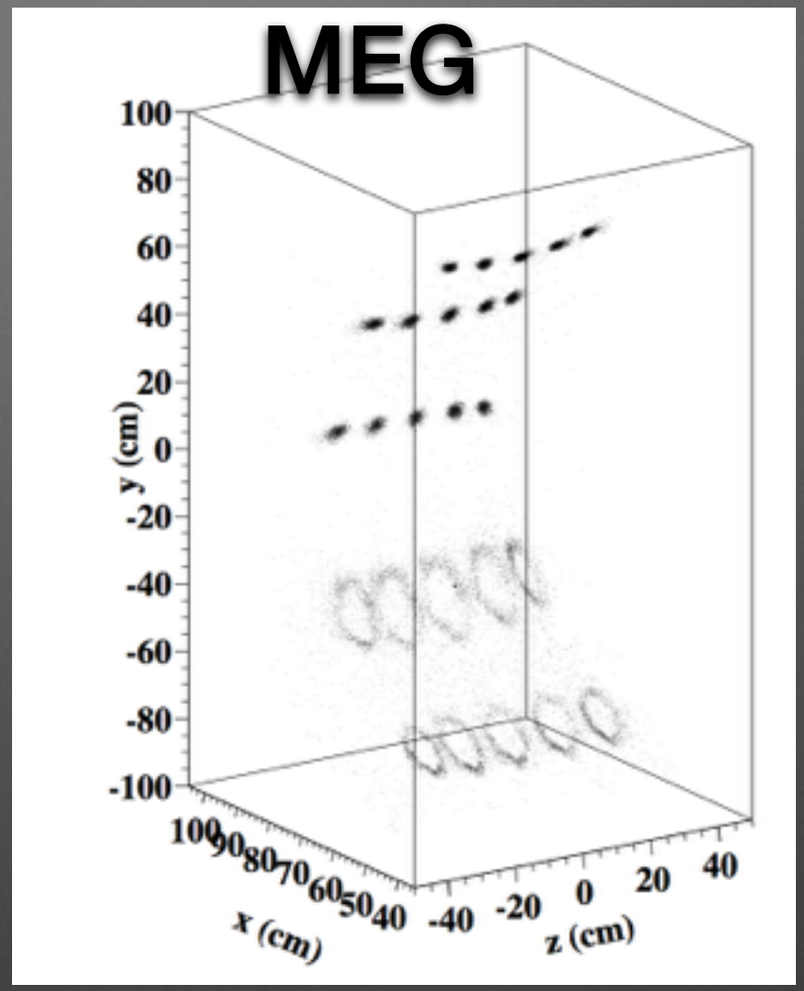
- Position resolution : **2mm**
- We want to know **the MPPC position within 0.5mm precision**
  - MPPC position scan by PSI 3D laser scan beforehand
    - Thin window was already scanned by PSI 3D laser, and MPPC scan will be done after all the MPPCs are mounted on the inner face
- Monitor the cryostat shape with LXe (SUS cryostat will shrink with the temperature)
- Later X-ray injection from the COBRA center with LXe?

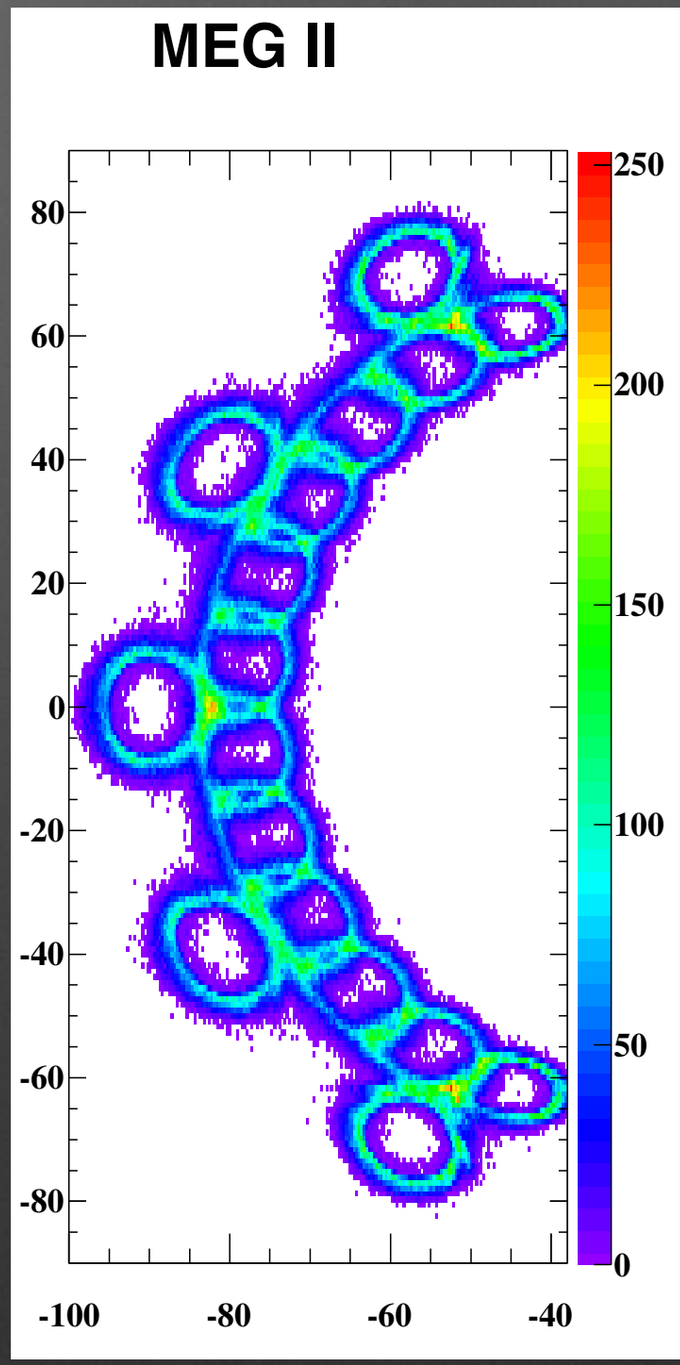


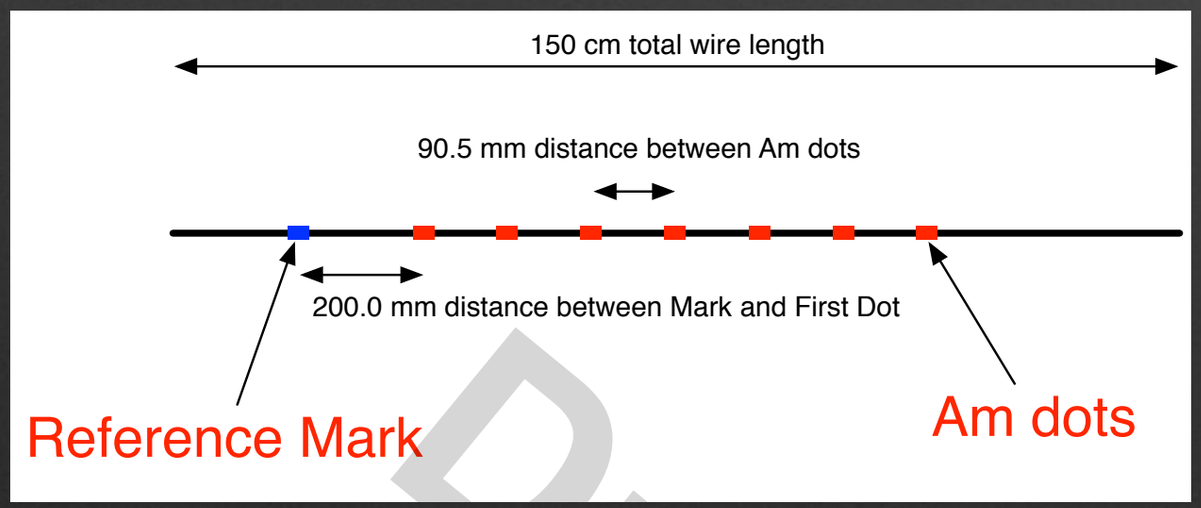


Calibration devices

- LED for gain, cross talk + after pulse etc.
- Alpha for PDE, QE estimate
- If we need #p.e. > 10, we need new alpha wire configurations
- Production for four months







Summary and schedule

- Summary
  - We will upgrade the LXe detector by replacing PMTs on the gamma-ray incident face with MPPCs, increasing the length of the inner face, modifying the lateral PMT angle, and the number of PMTs on top/bottom faces.
  - We are now in a construction phase, MPPC, support structure, feedthrough, a new refrigerator, etc.
- Schedule
  - Components will be ready in January-February in 2016
  - Assembly by April in 2016
  - Installation & liquefaction in the area in May
  - Calibration with LED, alpha, cosmics, Cockcroft-Walton, π0 calibration, together with purification in June - August, ready for engineering run

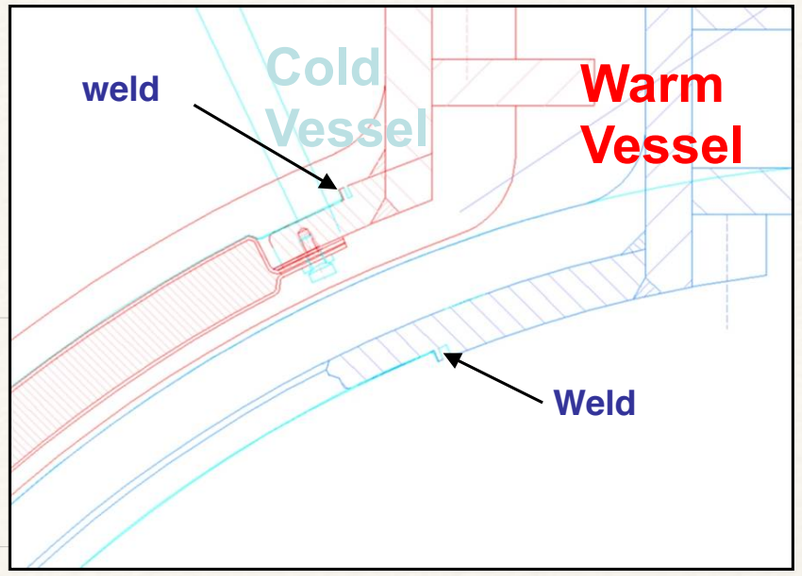
Structure of the inner window

- a thin metal sheet (0.4mm SUS)
- honeycomb-based structure combined with carbon fiber sheets
  - thickness of honeycomb 24mm(aluminum alloy), density 0.05g/cm3, HC5052 (hexcel)
  - The panel is fixed to the inner vessel with screws at the edges of the panel
- Outer vessel (0.7mm SUS)

Table 1. Specifications of honeycomb panel used in MEG liquid xenon detector.

Honeycomb material	Aluminum 5052
Hexagonal cell thickness	0.0254 mm
Hexagonal cell size	4.76 mm
Hexagonal cell height	19 mm
Carbon fiber sheet	T300 (Toray)
Carbon fiber sheet thickness	1.5 mm
Prepreg layers per sheet	0.13 mm × 8
Glue	EA 9361 (Hysol)

Measurement condition



Manufacturer: Philips
Type: MG 160 L
Voltage: max. 160 KV (for the actual examination we will use approx. 80-100 KV)
Tube Current Intensity: max 10 mA
Focal Spot Size: 1.6 mm

Objekt: Others
Aufnahmedatum: 07.03.2015 12:12:47
Röntgen: Strom [mA]=4 Spannung [kV]=90 Belichtungszeit [s]=20
Röntgenplatz:<??> Hersteller: Typ:
Bildgeber:CR-System / A212306005 / A212306005
Projekt: PSI liquid xenon dedector, PSI liquid xenon dedector, 07.03.2015, 15110253
Firma: Qualitech AG, 2883629035
DPI= 503 | 503

X-ray to measure MPPC position

- X-ray beam x=y=0, precisely known z, theta=pi/2, precisely known phi

- appropriate energy
  interaction length in LXe <1cm, compton electrons range<1mm

- Possible source
  Cobalt-57, 122/134keV or X-ray tube

- Alignment
  0.2mm, 0.2mrad required

- Collimated beam
  slit like 10cm, 0.1mm slit x 5mm thickness