

R&D on liquid xenon detector technology



Wan-Ting Chen, D. Chbib, J.-P. Cussonneau, J. Donnard, S. Duval, O. Lemaire, M. Le Calloch, P. Le Ray, A.-F. Mohamad-Hadi, E. Morteau, T. Oger, L. Scotto-Lavina, J.-S. Stutzmann, D. Thers



T. Haruyama, S. Mihara, T. Tauchi

History of LXe detectors



Application of liquid xenon detector – LXeTPC



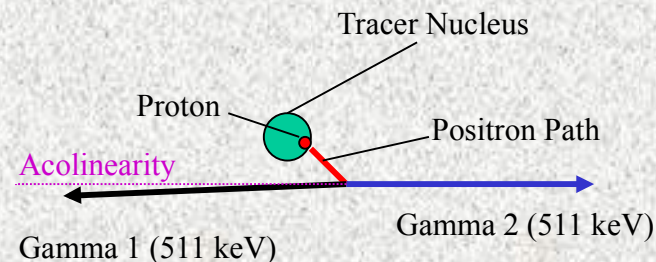
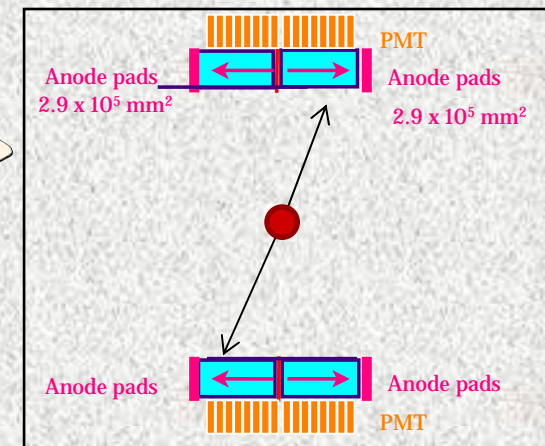
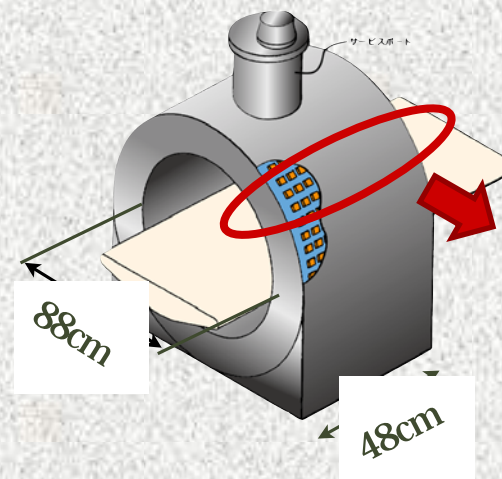
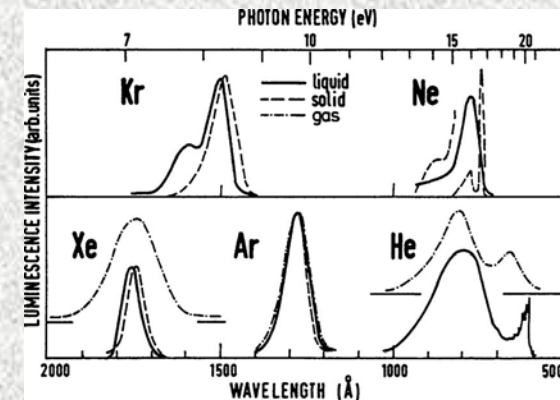
KEK expertise of cryogenic liquid (LAr, LXe)

- Cooling
- Purification
- Visualization etc

Photo sensor R&D history for the use in rare-gas liquid

Detector R&D in a view of application to PET

- Sci. light and charge
- Good energy resolutions of LXeTPC → Quality of Image!
- Future muon exp. as well

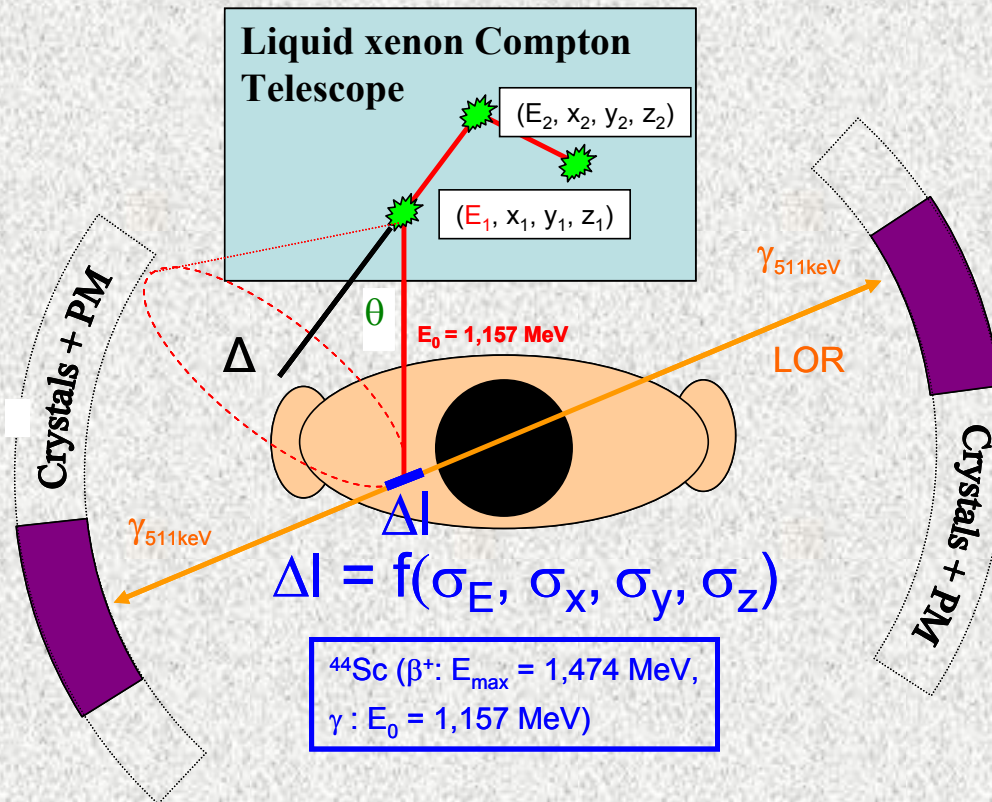


Application of liquid xenon detector – the 3γ imaging

$\beta^+ \gamma$ (^{44}Sc) nuclide + Compton Telescope + PET = 3D reconstruction

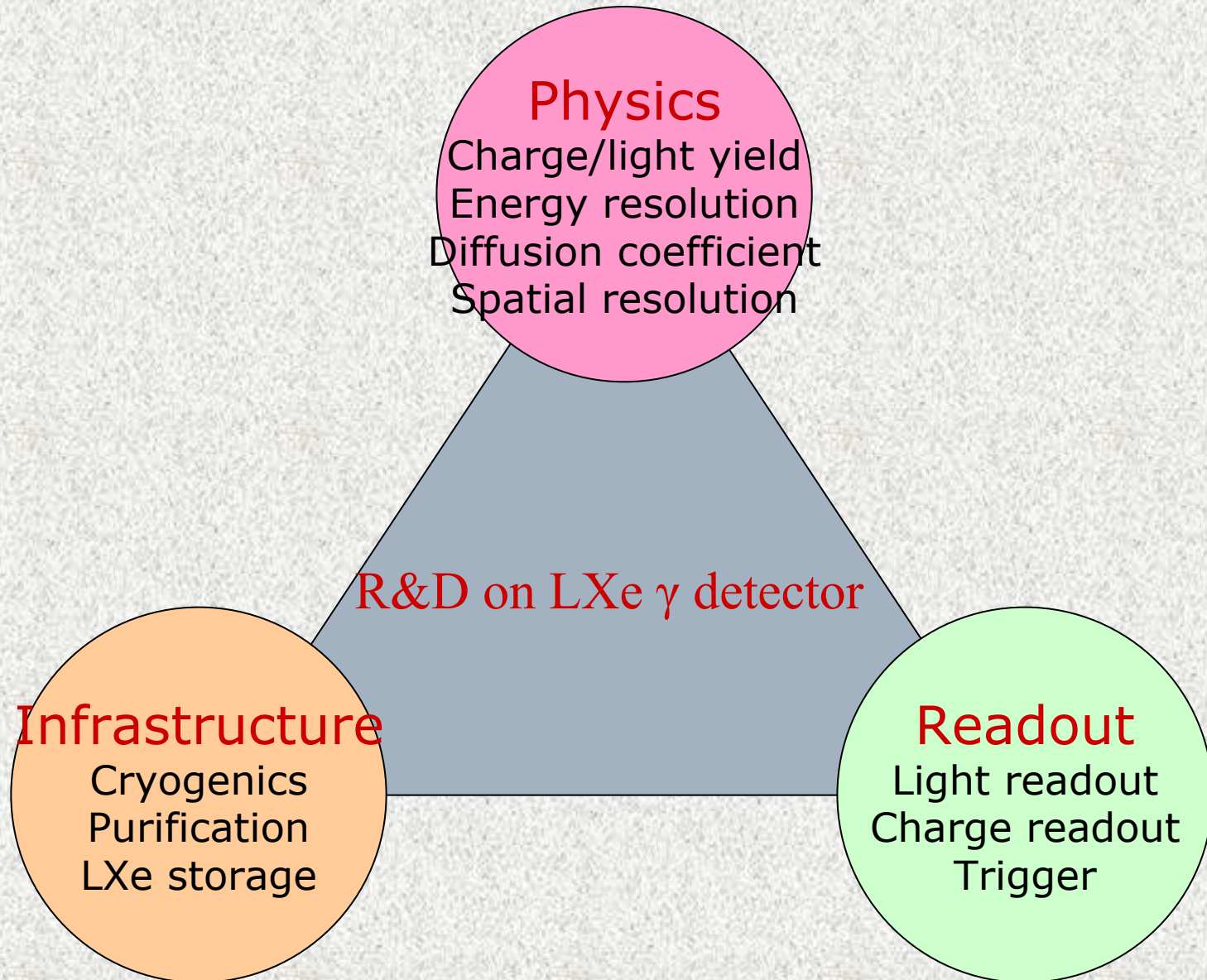


^{44}Sc produced @ ARRONAX



$\Rightarrow \Delta l \sim 1\text{-}2 \text{ cm}$ along the LOR targeted

R&D on liquid xenon detector for γ detection



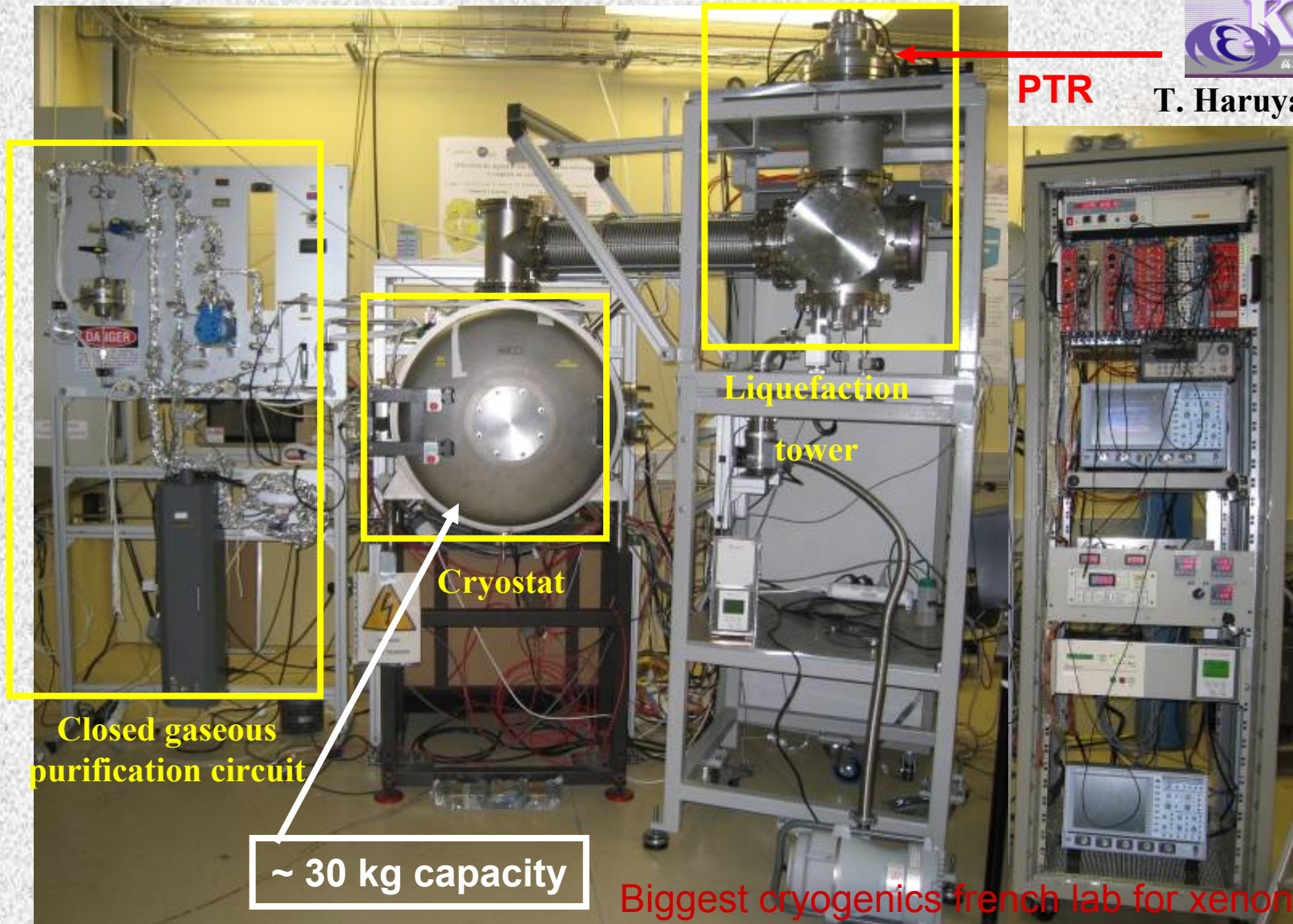
XEMIS1

Prototype for the “technical” prove of feasibility



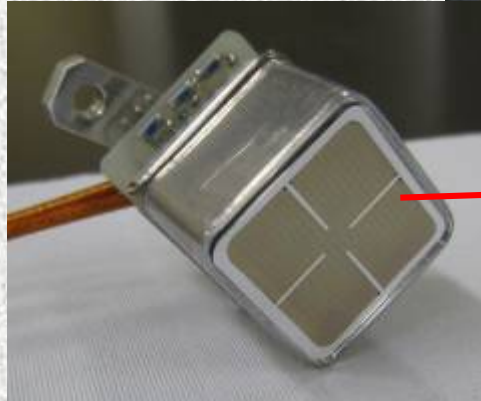
PTR

T. Haruyama team

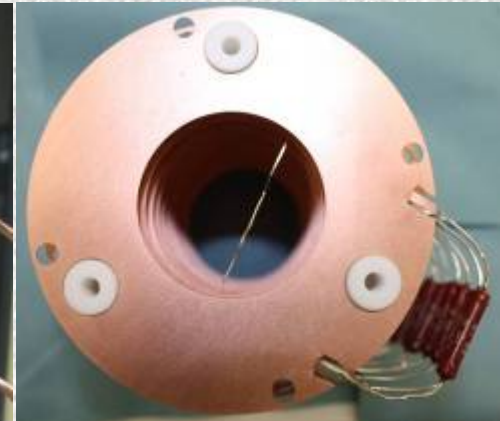
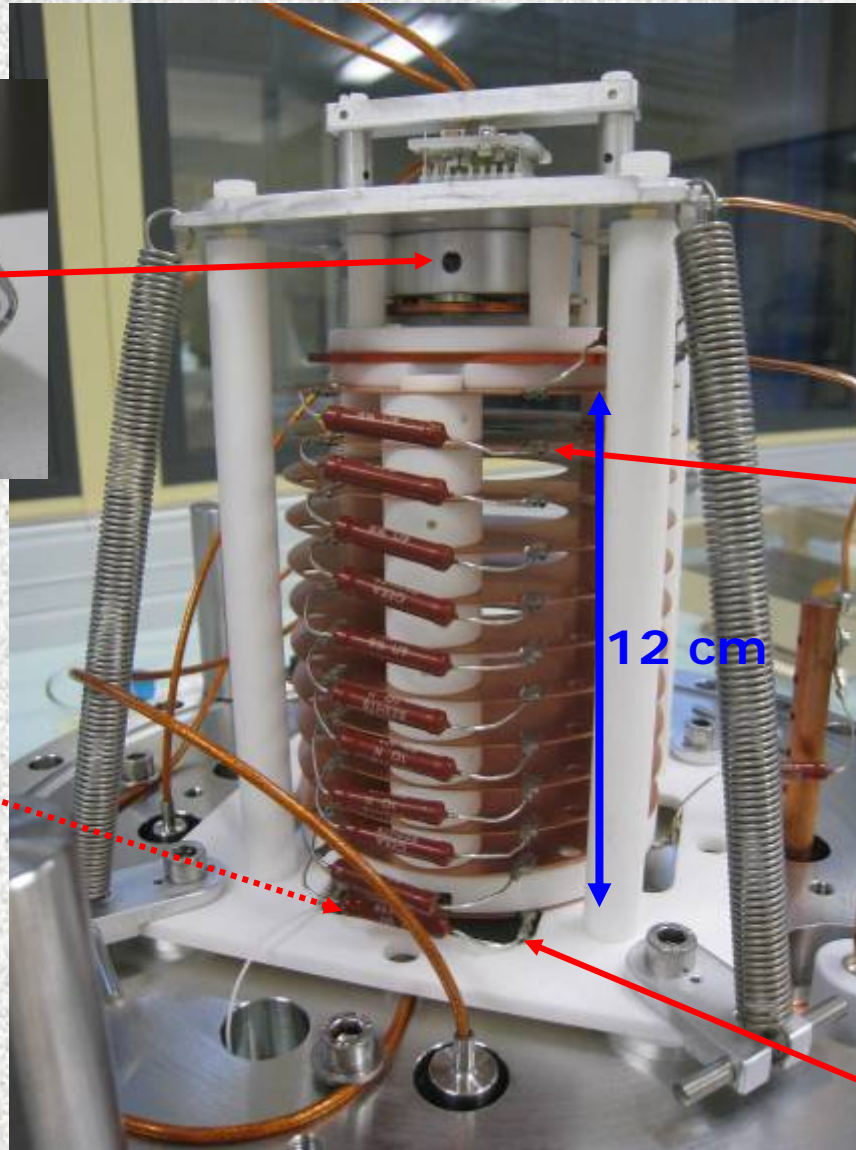


Biggest cryogenics french lab for xenon R&D

A TPC fully immersed in liquid xenon as a Compton telescope

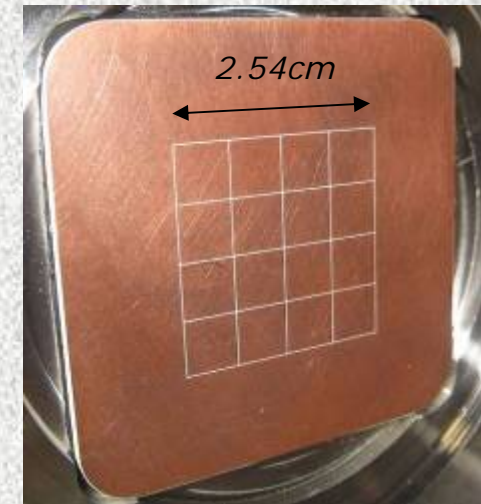
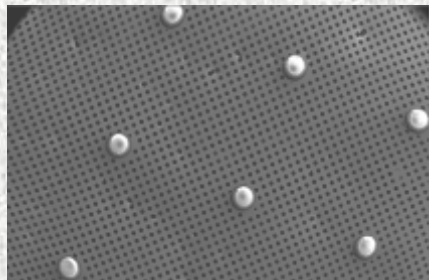


PMT



Field rings

**Micromegas Grid
(not viewable)**

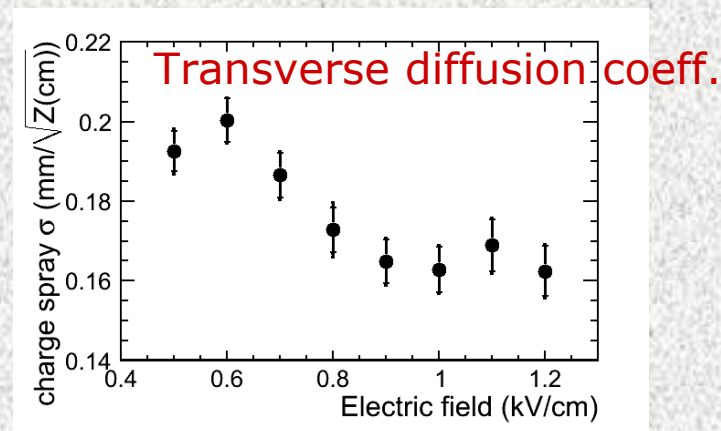
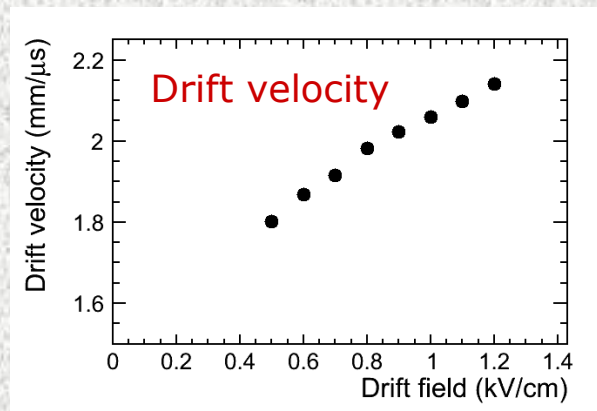
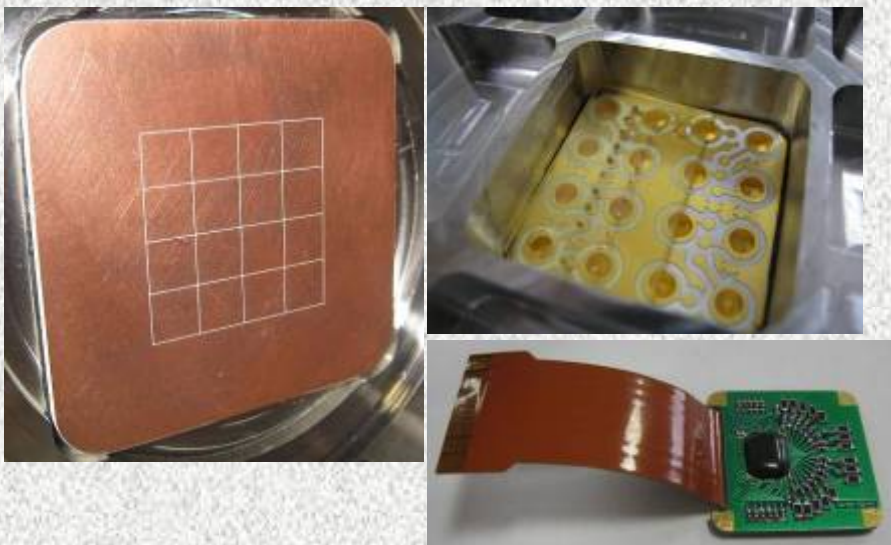


**Segmented anode
6.35 x 6.35 mm² pitch**

XEMIS: Ultra-low noise electronics

Anode: 16 channels pixels (6x6 mm²)

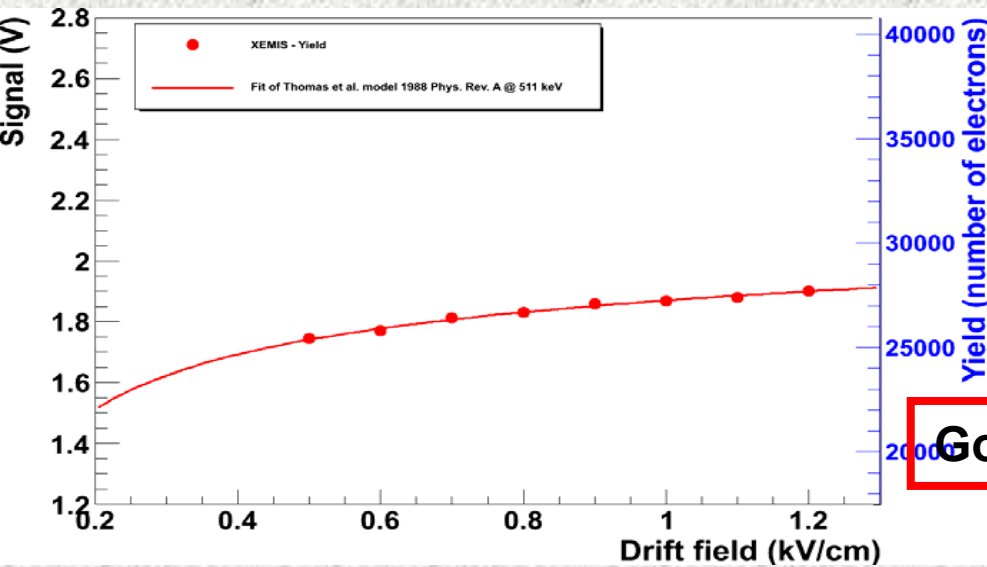
IdefX is a FEE developed by the CEA/IrFu for CdTe devices adapted by Subatech for LXe



Noise level $\sim 100 e^-$
→ Ok for measuring the electrons cloud size ...

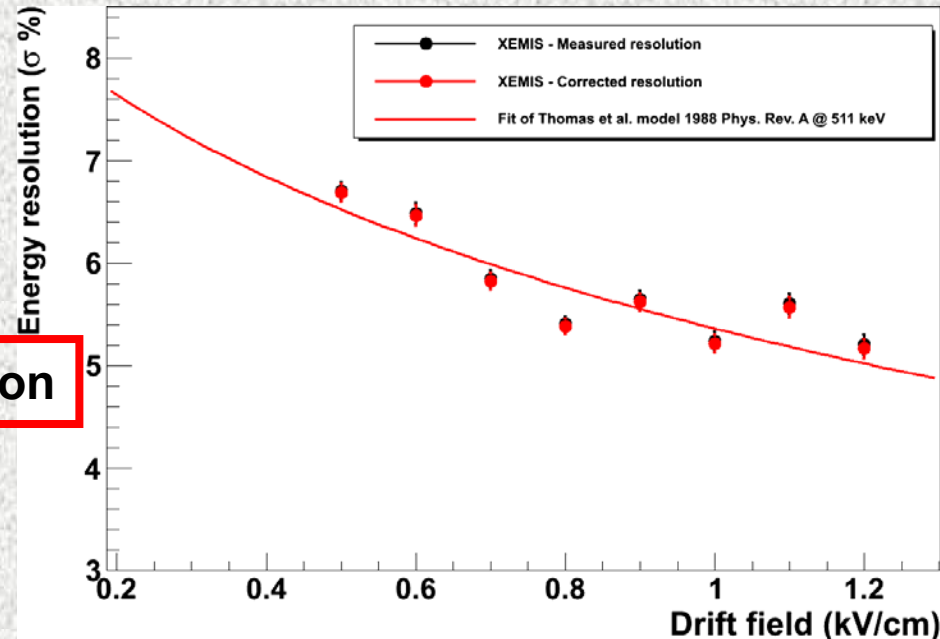
W-T. Chen *et al.* DSL 2011

Charge yield and energy resolution (511keV)



Good agreement with the Thomas model

Very promising measured energy resolution



T. Oger *et al.* NIM A (2011) for complements

Pure LXe station – ReStoX

Will be used by XENON1T, expected installation at the end of 2013



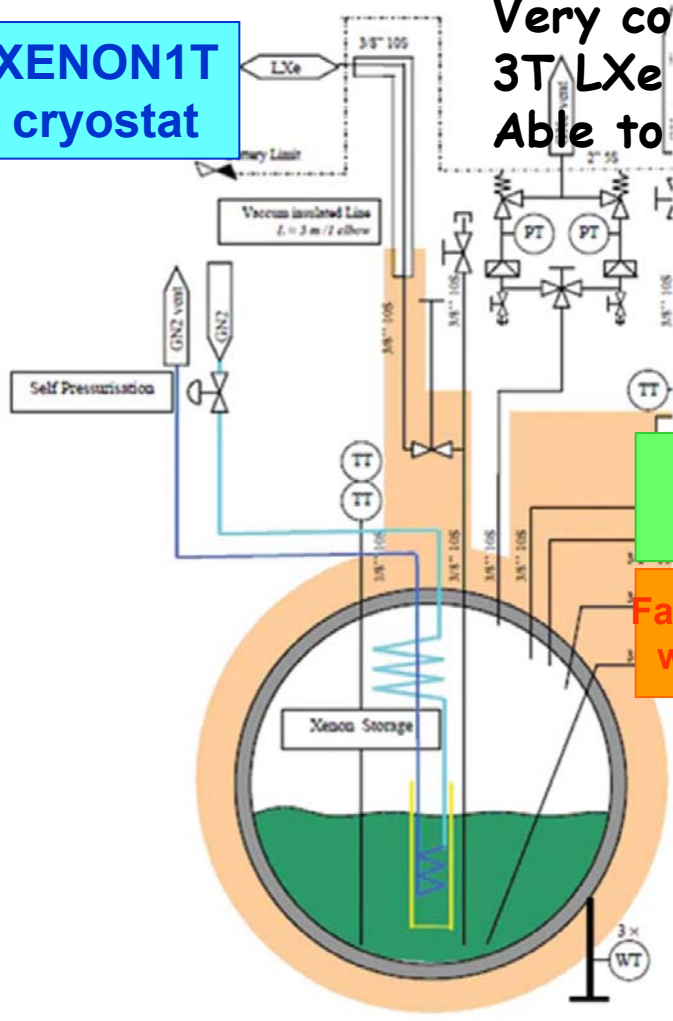
**XENON1T
cryostat**

Very compact station

3T LXe storage from 20° (65 atm) to -108°C (1.15 atm)

Able to keep high purity all the time

Can be easily scalable to larger sizes



**High power LN2
Cold head**

**Fast purification circuit
with heat exchanger**



Coaxial heat exchanger is much better (strong, easily cleanable) compared to plate heat exchanger

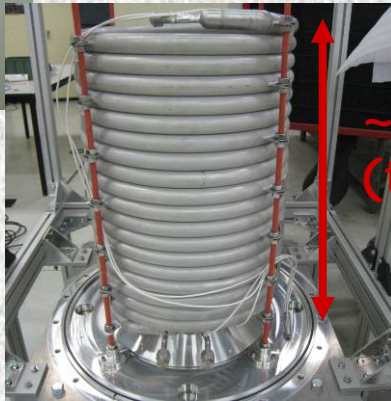
Poster presented by Wan-Ting Chen at ICEC24-ICMC2012, May 14-18 2012, Fukuoka, Japan



Experimental setup : XEMIS1.5

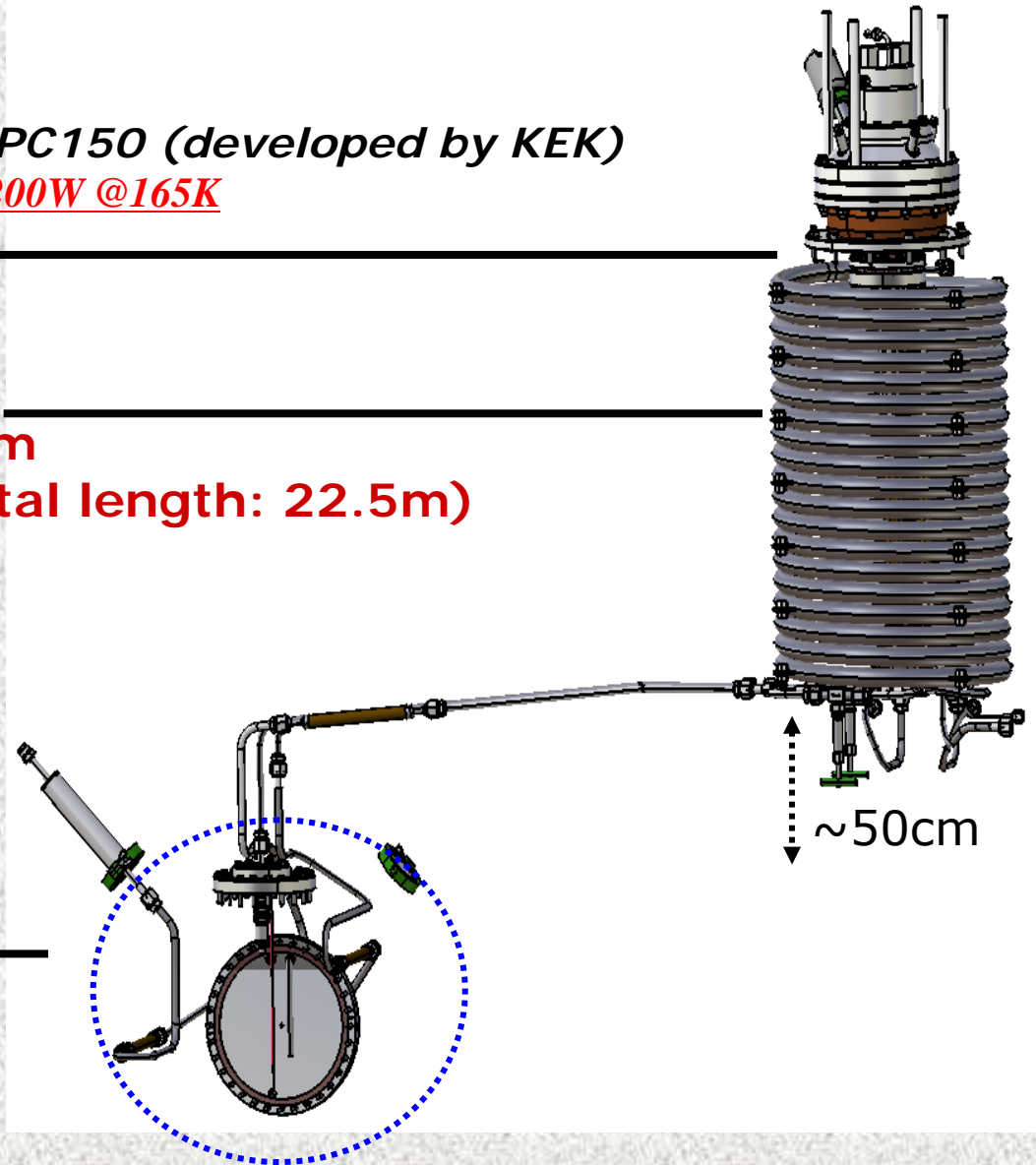


Model: Iwatani PC150 (developed by KEK)
Cooling power up to 200W @165K



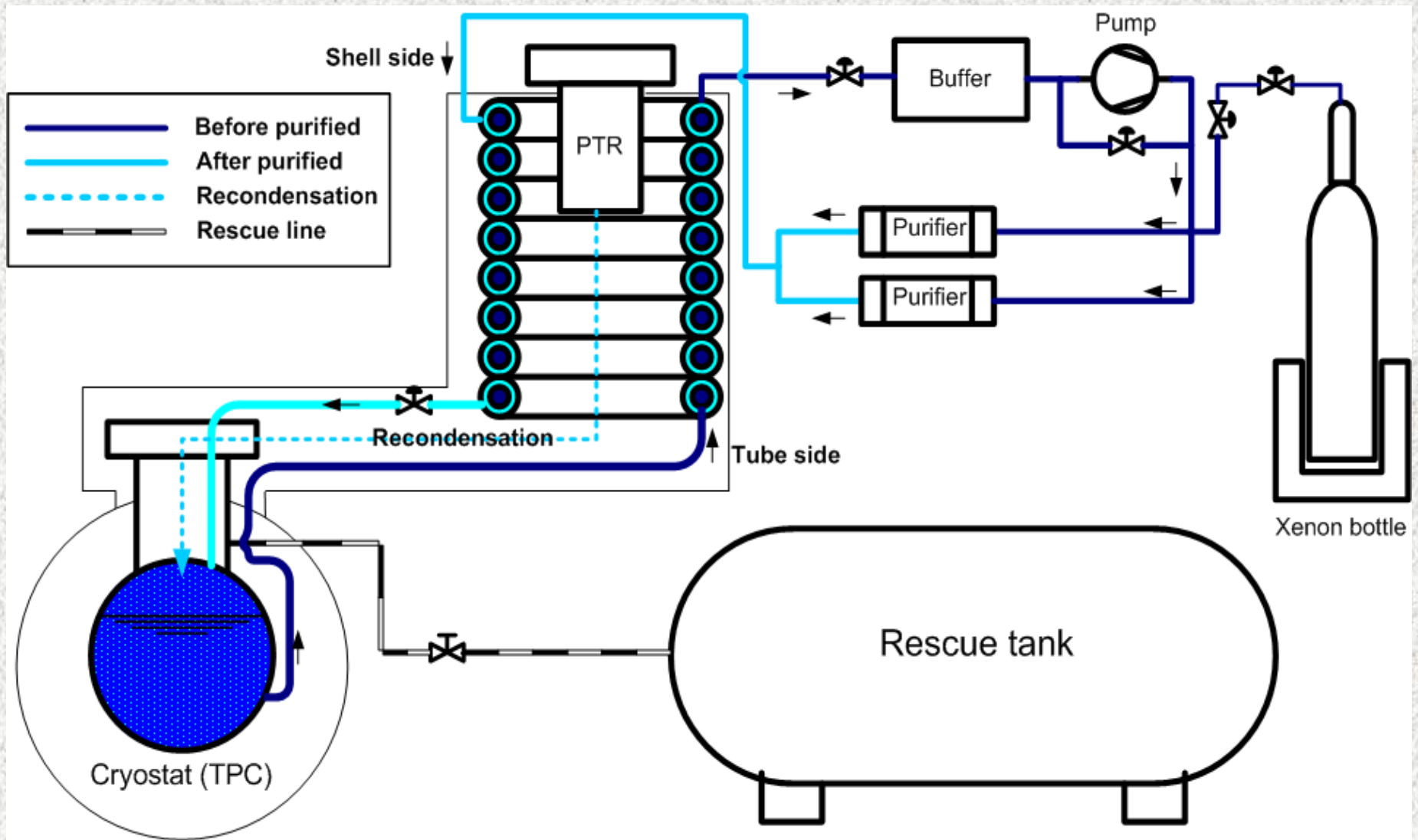
~ 1m
(total length: 22.5m)

Cryostat



~ 50cm

Apparatus and procedure

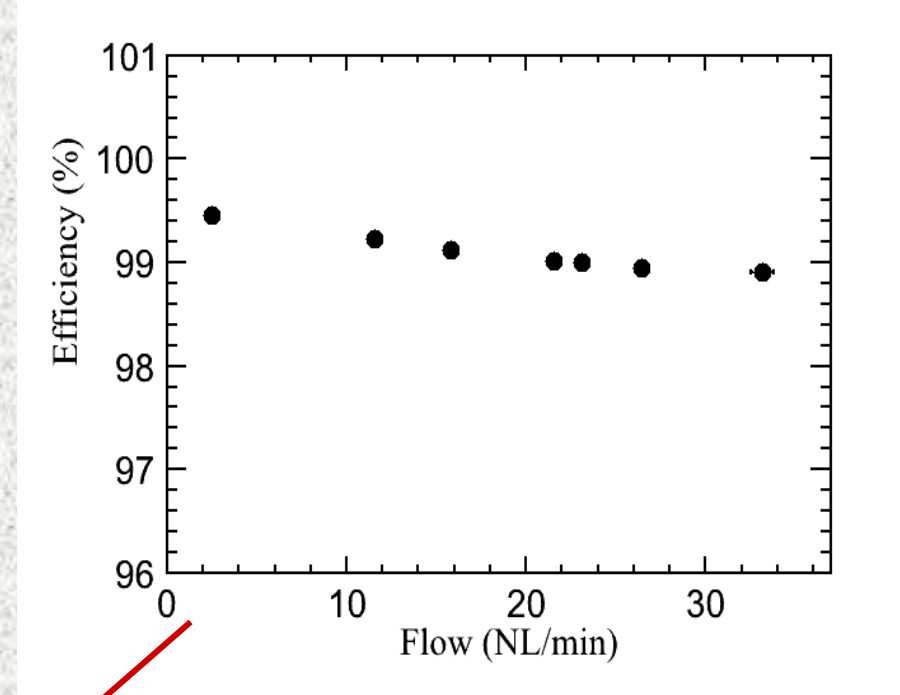
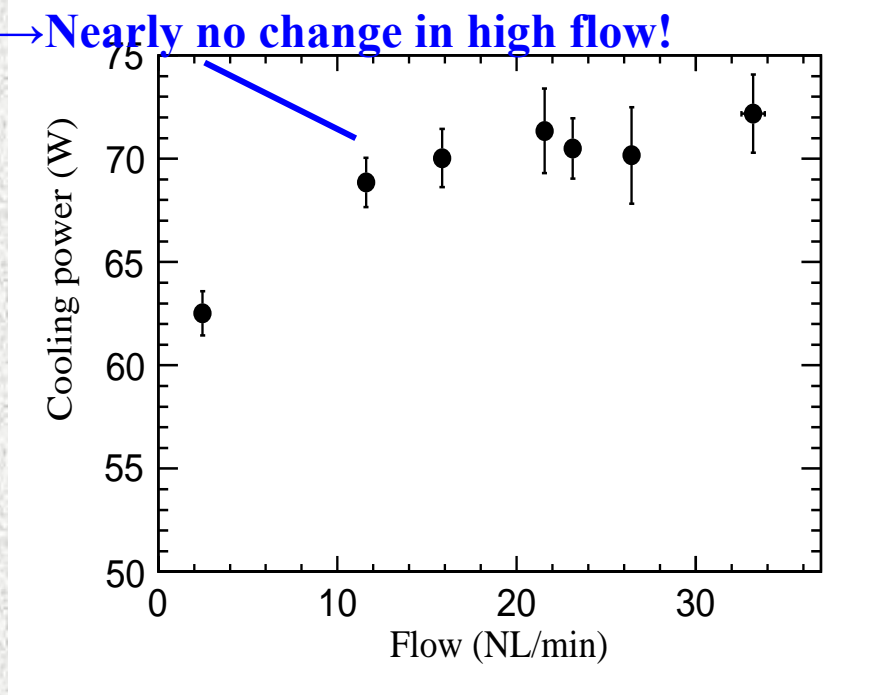


Efficiency of heat exchanger



Cooling power used to maintain the pressure of cryostat

→ Nearly no change in high flow!



99% @ 33NL/min is achieved!

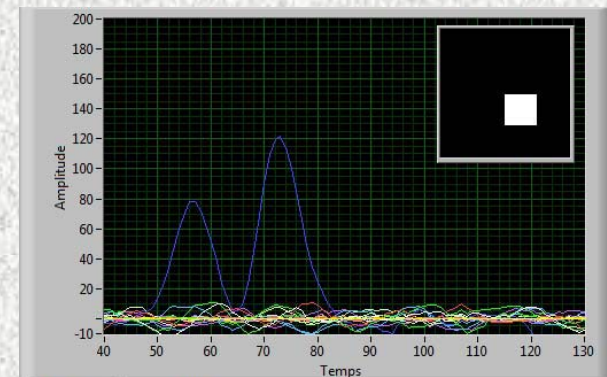
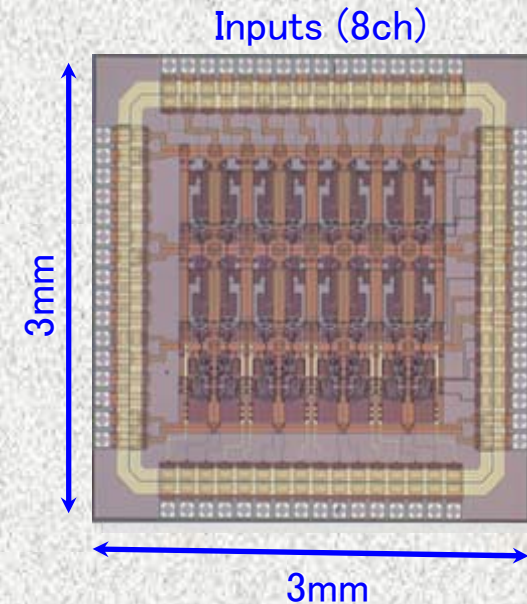
Presented by Wan-Ting Chen at ICEC24-ICMC2012, May 14-18 2012, Fukuoka, Japan

Wan-Ting CHEN, Annual FJPPL Workshop

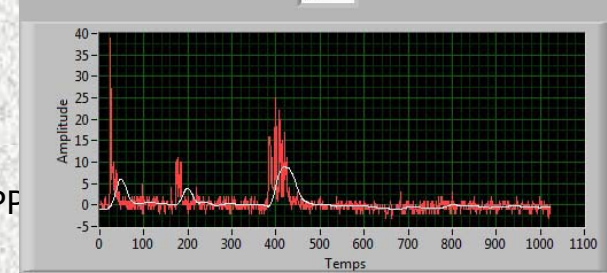


KEK LXeTPC Prototype and related studies

- LXeTPC Prototype
 - 5cm drift length
 - 16ch pad readout
- Readout electronics development
 - ASIC: Pre-amp. to PZC to shaper – output all analog channels
- Study of bubble formation in between the micromesh and anode
 - Confirmation of Subatech observation at KEK



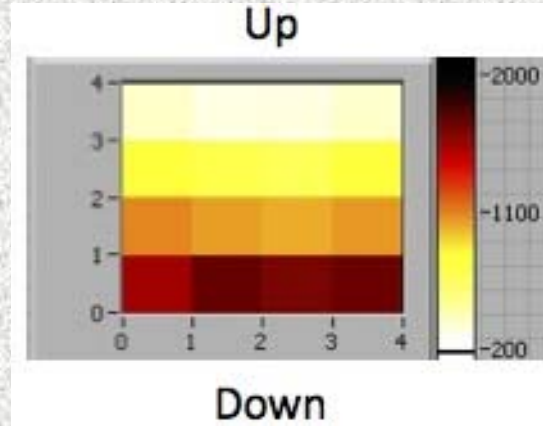
Ring 6 μ s threshold AN 25



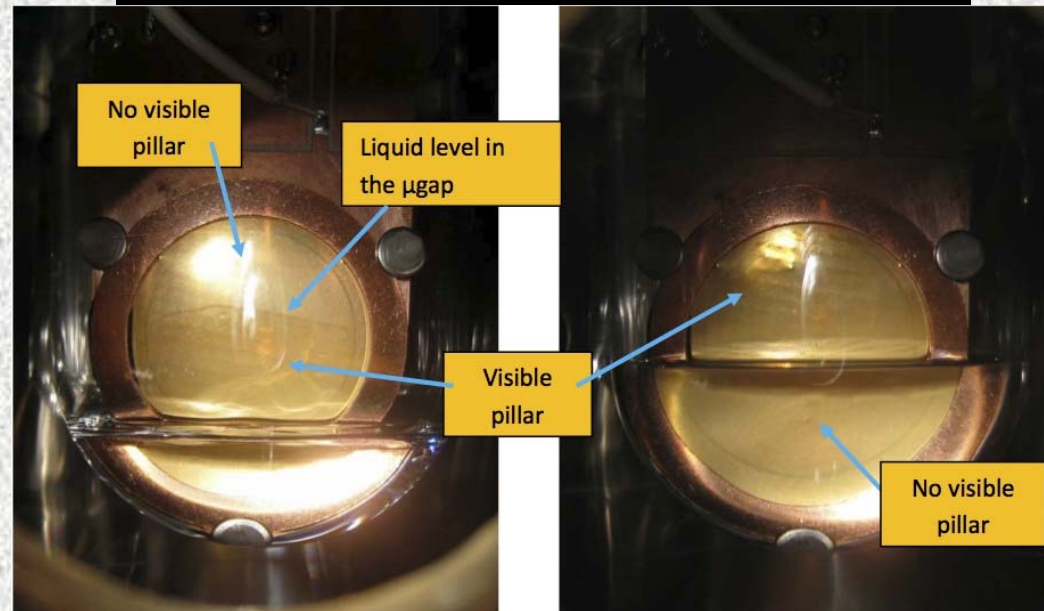
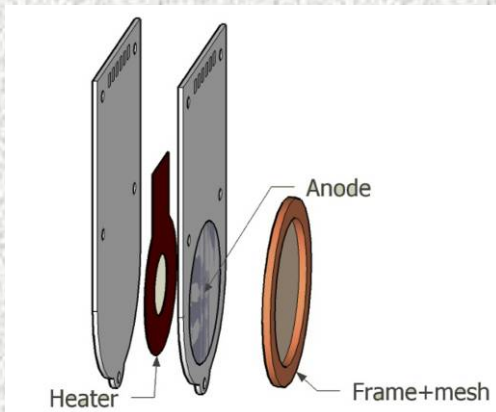
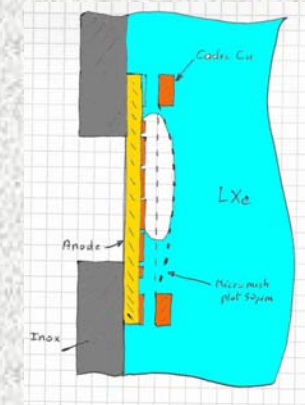
Xenon Bubble ?



- Confirm bubble formation observed at Subatech using a KEK glass cryostat
- Install a micro mesh and anode plate and fill the dewar with LXe
- Excite heater for bubble formation



Subatech 4x4
Charge RO data



Summary

- With quite limited budget supported by FJPPL, KEK and Subatech have performed several good work for the R&D of cryogenics
 - Installation and operation of cryocooler in Subatech (2007-2009)
 - Students exchange (2010)
 - Verification of coaxial heat exchanger efficiency (2011-2012) , presented in ICEC24-ICMC2012
 - Bubble test (2012)
- Base on the work of cryogenic system, the R&D concerning physics and readout is nearly finished.
- It's time to go to next stage!

Further steps

● Subatech activity

- New charge readout
 - Smaller pixels
(6x6 mm² → 3x3 mm²)
 - Spatial resolution will reach 500 μm
- New trigger design
- Small animal imaging – XEMIS2 !

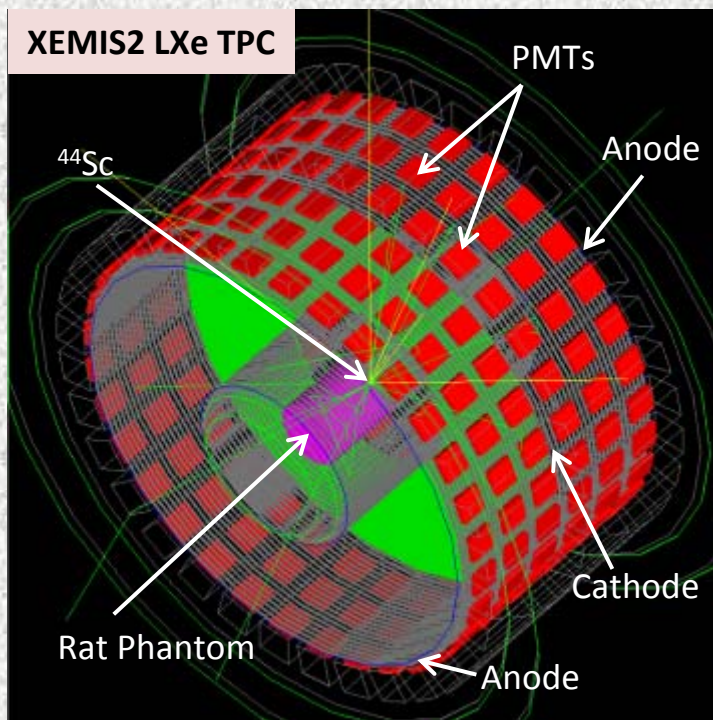
● KEK activity

- New photo sensor development
 - MPPC, Flat Panel PMT
- Low temperature electronics
- Ceramic plate feedthru
- Long-term stability of refrigerator



New proposal to FJPPL in 2013

XEMIS2 pre-design study for small animal imaging with GATE



Cylindrical camera XEMIS2 (~ 100 kg LXe)

- radial $8 < r < 20$ cm
- axial (z) Length = 2×12 cm
- Electric Field in z direction 2 kV/cm
- 192 PMTs
- Micromegas ionization read-out
- FEE Idef-X, pixels 3.175×3.175 mm² (~25k channels)

TPC characteristics

- Intrinsic energy resolution: 5% @ 511 keV
- Spatial resolution: 0.5 mm (X, Y and Z)

Performances (simulation in progress, *PhD student: A.F. Mohamad Hadi*)

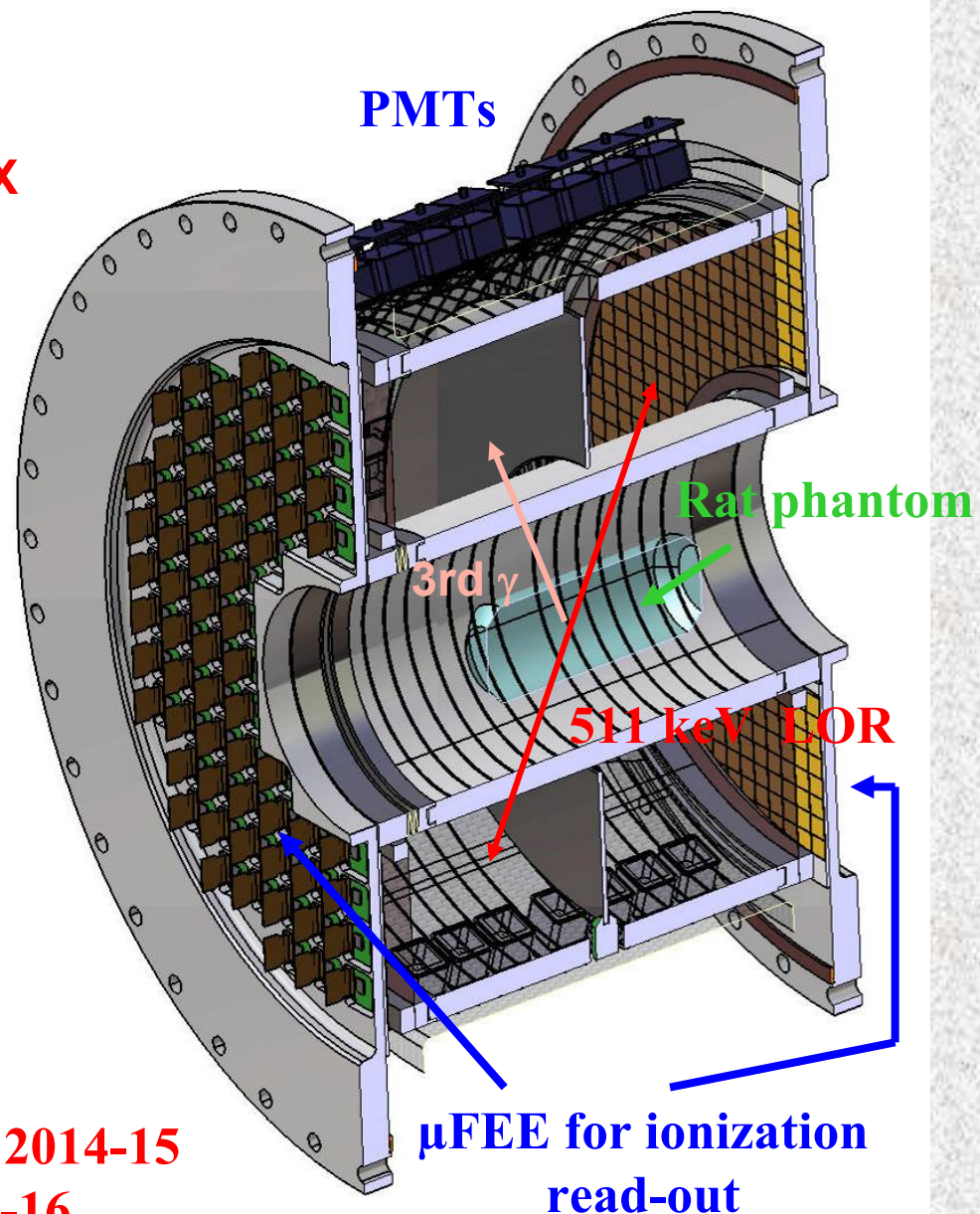
- Efficiency to measure LOR: 30%
- Efficiency to measure 1.157 MeV γ -rays: 43%
- 3 photons efficiency (after selection): ~5%
- Precision on localization along LOR ~ 1 cm (FWHM)

Simulation status:

- LXe Compton Telescope already implemented in GATE
- Future => Simulation of test Phantoms (NEMA, Derenzo...) with XEMIS2

**Funding issues almost addressed
with the ARRONAXPLUS EQUIPEX**

**Improved reliability and safety :
ReStoX (liquid xenon station)**



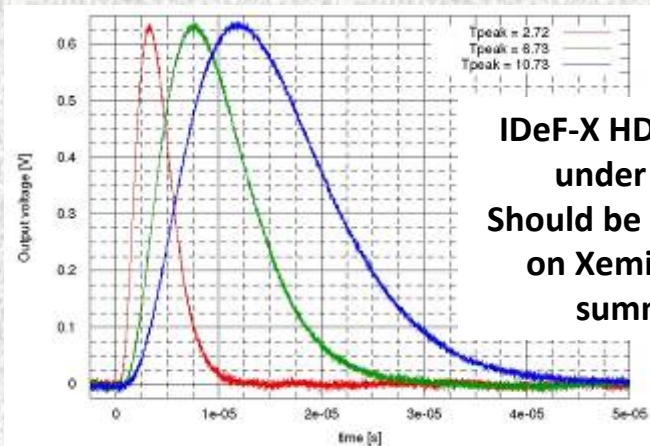
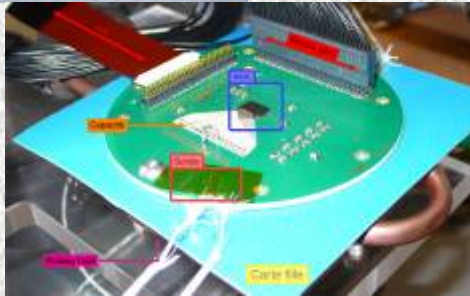
**Expected to run at Subatech in 2014-15
→ Nantes Hospital in 2015-16**

Thank you!

Backup

XEMIS1: Idef-X HD (64 channels per inch²)

64 channels pixels (3x3 mm²)



Idef-X HD already under test.
Should be mounted on Xemis1 this summer

Prove of concept should be addressed in 2012 with precise cones reconstructed

GATE Simulation for 511 keV electron recoil
Estimation of spatial resolution:

