Test of liquid xenon TPC for PET application

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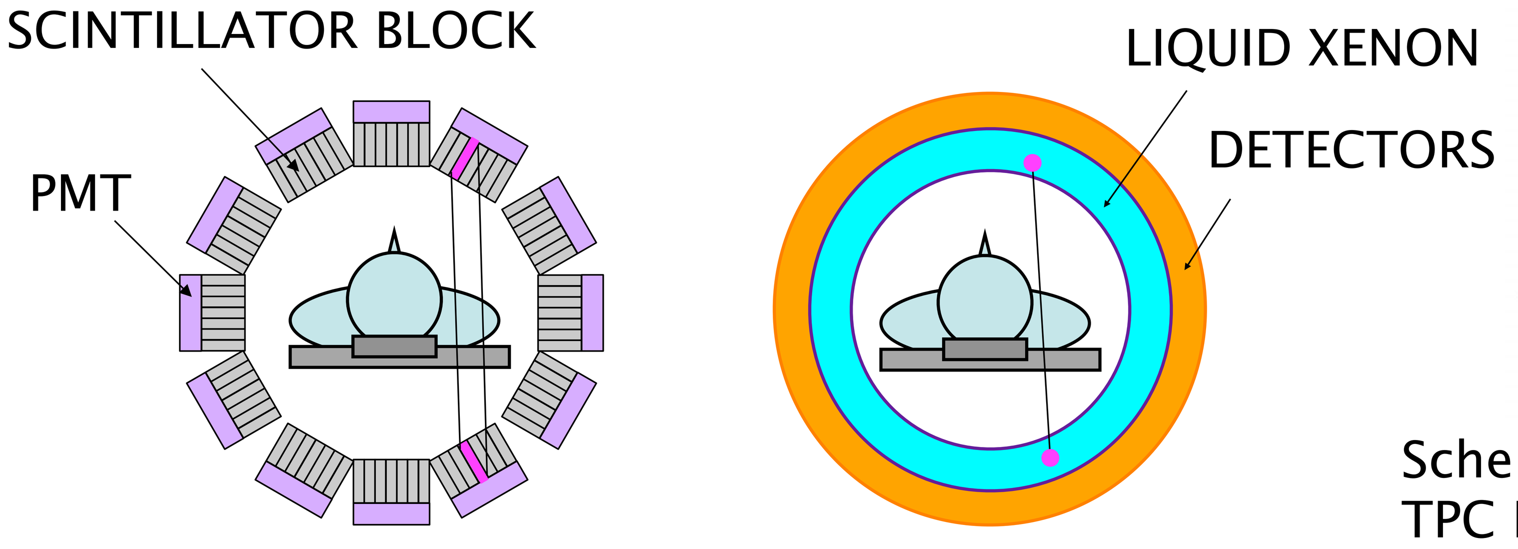
Liquid xenon Time Projection Chamber aiming at higher resolution of Position & Energy

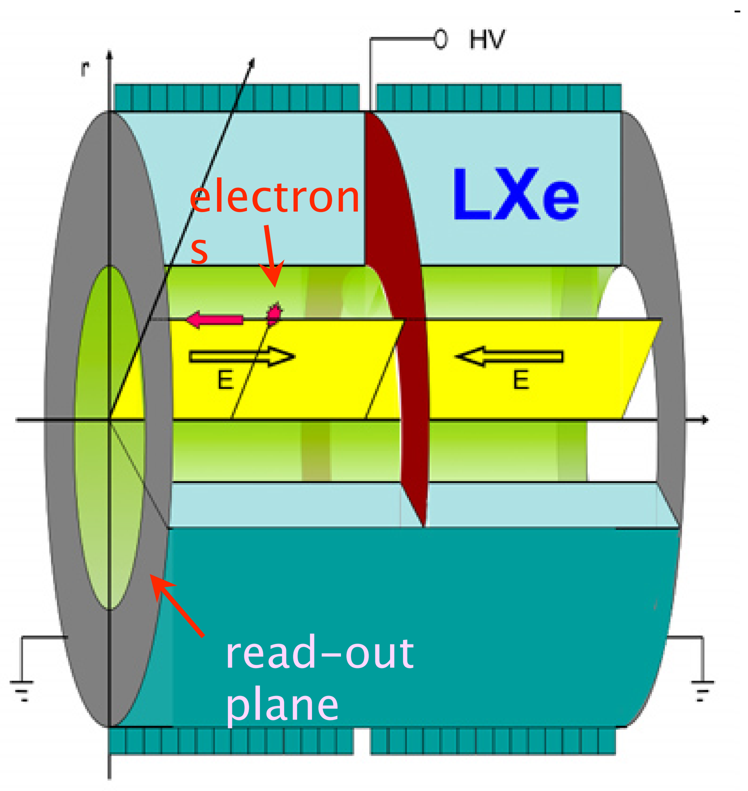
What is required for next generation PET ?

A) better position resolution (especially r direction, or DOI) DOI = Depth Of Interaction

B) higher sensitivity from larger acceptance



Conventional PET apparatus (left) have only 1 layer of scintillation crystal to radial direction, and size of crystal limits position resolution. On the other hand, LXeTPC type (right) PET is expected to give interaction point by <1mm (FWHM) uncertainty therefore coincidence event is given as line.



Schematic view of our proposing LXe TPC PET. In this coordinate, ionized electrons drift toward Z axis, while PMTs are set outer side of xenon. Using position & drift time information, 3-dimensional position can be derived. In addition, Time-of-Flight information from PMT efficiently remove accidental coincidences that cause noises to PET graphics.

Characteristics of Xenon

ionized electron & light are both available

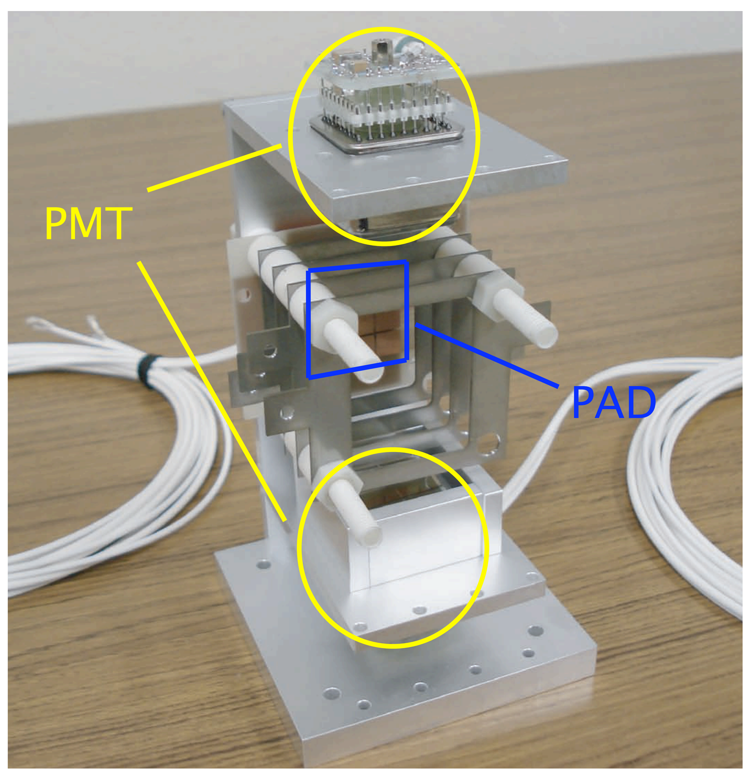
- Small W_e value (about 15 eV)
- High light yield (75% of NaI(Tl), W_γ ~ 23eV)
- Fast light response (τ= 4.2ns, 22ns, 45ns)
- Short radiation length (X_0 = 2.77cm)
- Homogeneity , Continuity
- …

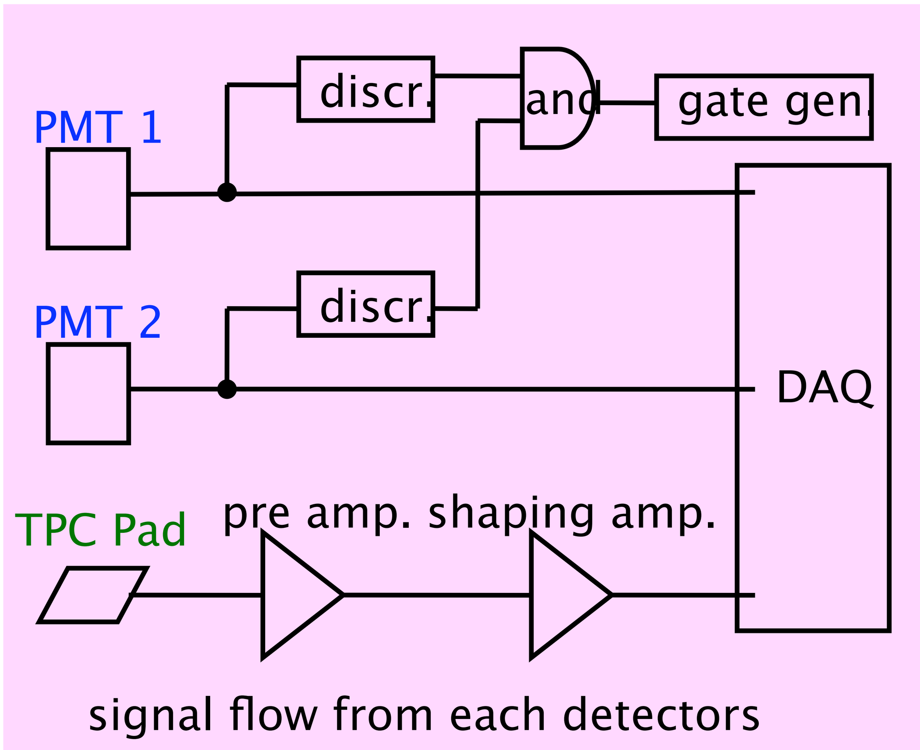
→ Suited to γ-ray detection !

Scintillator	BGO	GSO	LSO	LXe
Elements	Bi Ge O	Gd Si O	Lu Si O	Xe
Density[g/cm^3]	7.13	6.71	7.4	2.95
Photon Number per 1MeV	8200	9000	25000	43000
Wave length [nm]	480	440	420	178
Decay time [ns]	330	56	47	45

comparison with other scintillator materials for PET

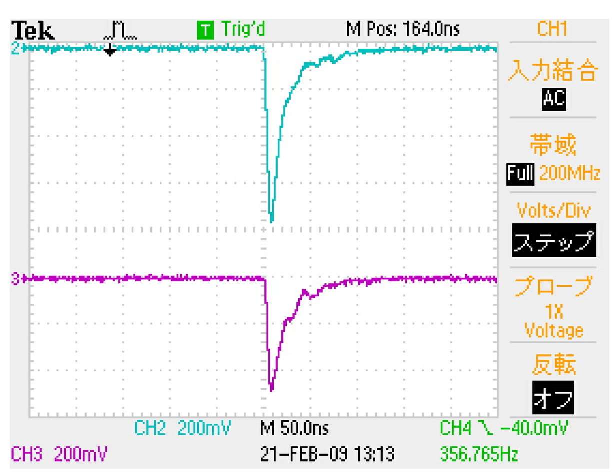
Basic design of our proto-type chamber





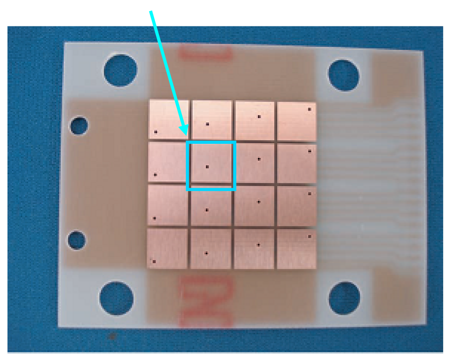
signal flow from each detectors

TPC electrodes are set on plastic screws (max 5cm gap), connected with potential divider resisters (100 MΩ glass resister). Two PMTs detect scintillation light to trigger event.



light signal from two PMTs

0.75×0.75 cm²



Read out pad printed on FR4 board

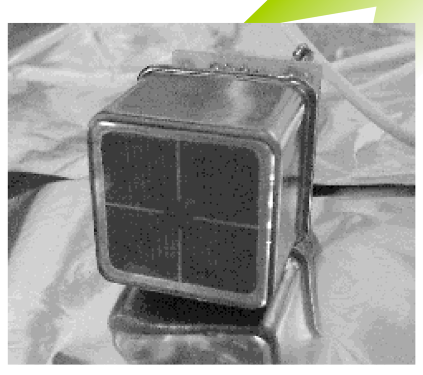
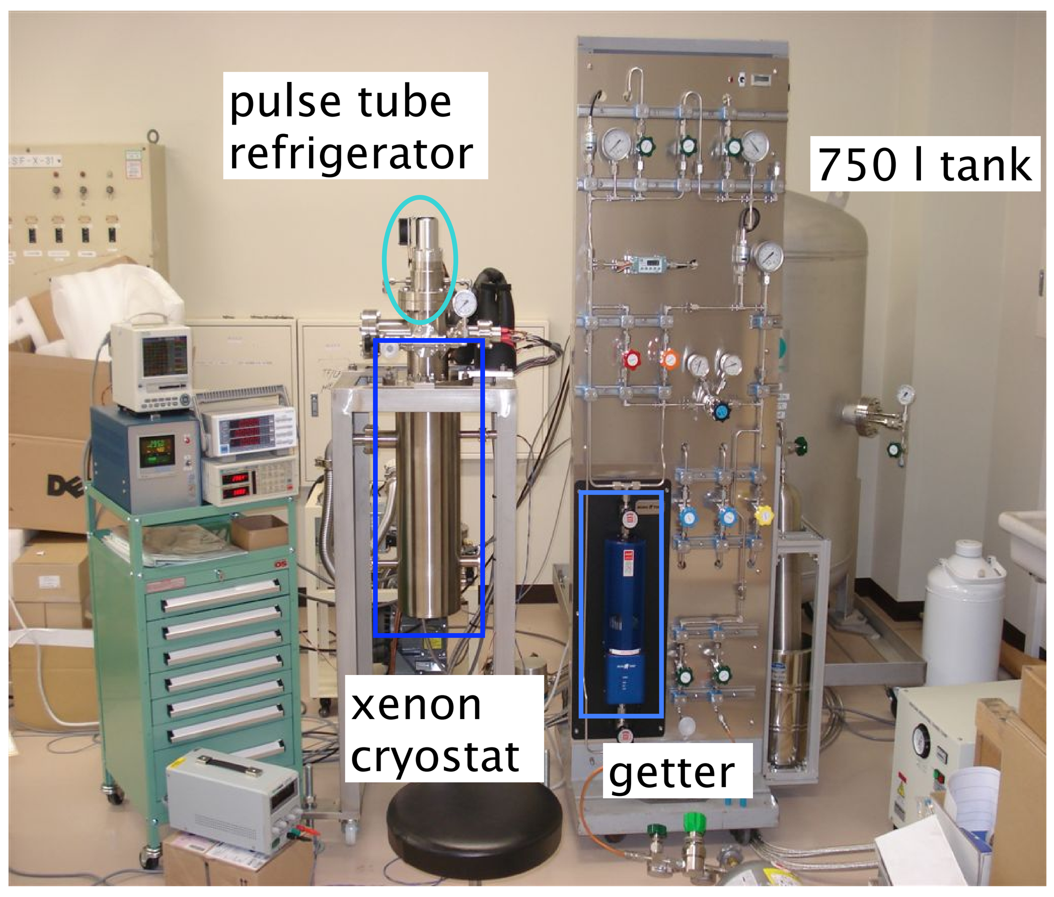


Photo-Multiplier Tube HAMAMATSU R5900 typical gain ~10^7 Q.E.~20% sensitive to VUV light

Xenon system



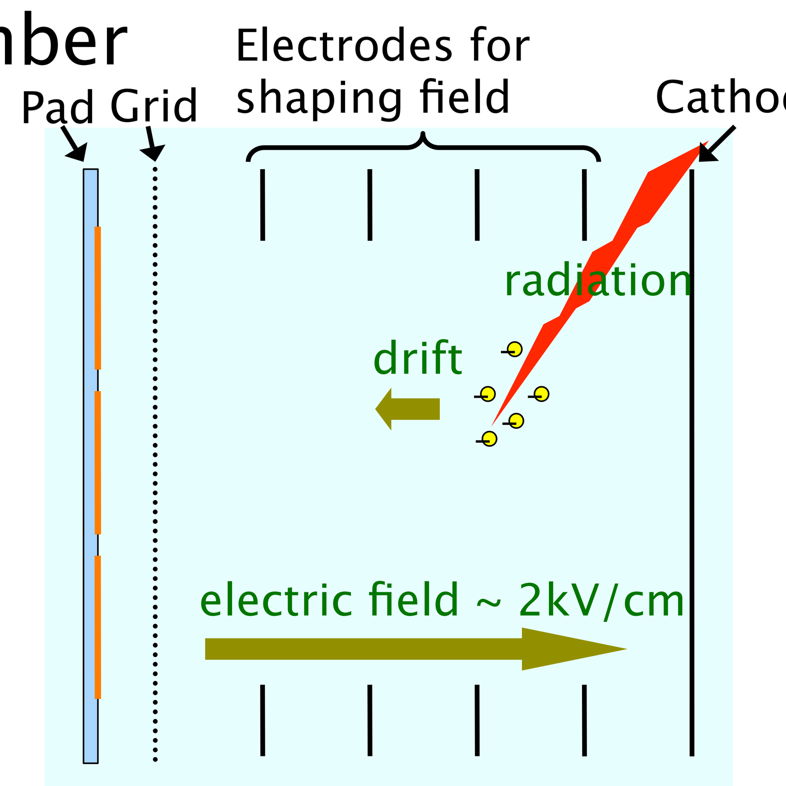
Xenon is cooled by pulse-tube refrigerator, developed for xenon system. This system can keep xenon very stable, within

$\Delta T < 0.1K$ $\Delta p < 0.001$ MPa .

With this system, we are planning to research electron drift properties depending on temperature and pressure of liquid xenon.

Xenon is purified through getter (SAES PS3) , circulating with diaphragm pump.

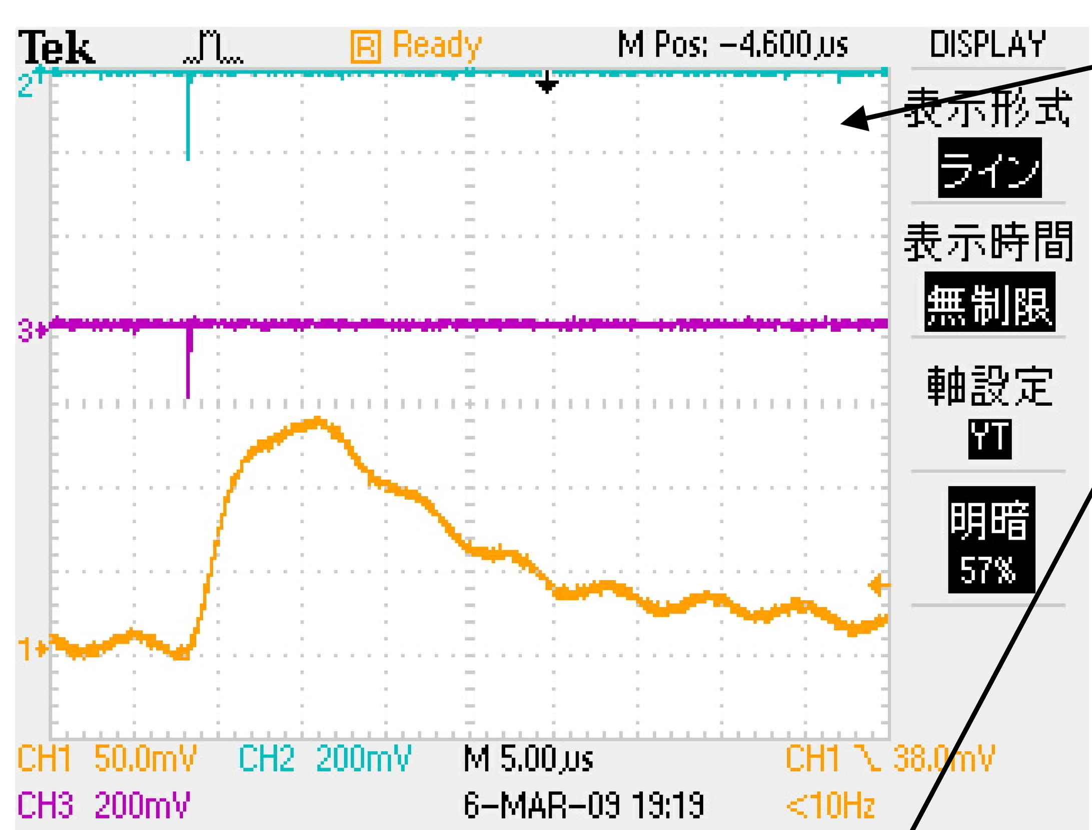
Mechanism of time projection chamber



drift velocity v_d ~ 2.2 [mm/μs] (at 2[kV/cm])

diffusion constant D ~ 50 [cm^2/s] (σ= 0.5mm after 5cm drift)

Recent Data



top left : measured wave forms of cosmic-ray events (yellow : TPC signal from shaper amp. blue PMT signal (upper). red PMT signal (lower))

bottom left : changing magnitude of light signal from ^{241}Am(5.5 MeV α) , xenon was being purified. (red : PMT upper, green PMT lower)

bottom right : electric field dependence of light yield. recombination ratio electron and xenon differs by electric field strength.