Liquid Xenon TPC for a gamma detector (LXeTPC)

T. Tauchi (KEK)

The 2nd JAAWS
29-30 November 2010
POSCO International Center, PAL, Korea

LXeTPC project

since 2007.4 as a KEKDTP project

Detection of KeV-MeV “gammas” with 3D positions and energy of high resolutions

Applications：Gamma ray astronomy; Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET)；Dark matter, Double β decay experiments

KEK : liquefaction & purification , PMT, TPC, DAQ

T.Tauchi, A.Maki, T.Haruyama, S.Tanaka, S.Mihara, T.Saeki

K.Kasami, S.Suzuki

Saga univ. : TPC, simulation, FE ASIC chip, test

A.Sugiyama, T.Higashi(D4)

Tokyo univ. : TPC, PMT, simulation, test

T.Mori, Y.Fujii(M2),T.Chiba(M1)

National Institute of Radiological Science : PET

M.Kumada, T.Tomitani, C.Toramatsu

Yokohama National univ. : APD test, Xe-property

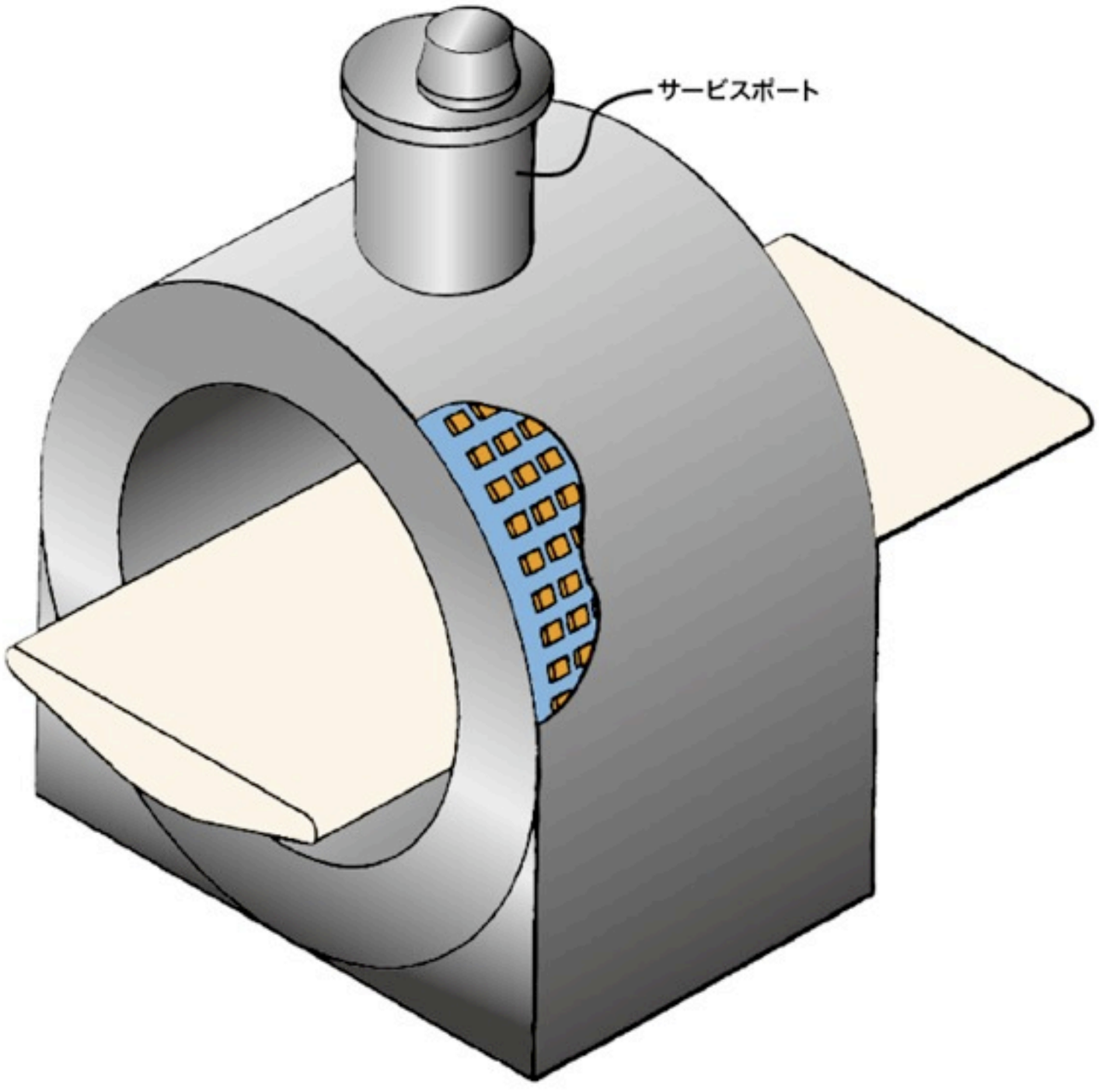
S.Nakamura, Y.Takagi (M1), Y.Endo(M1)

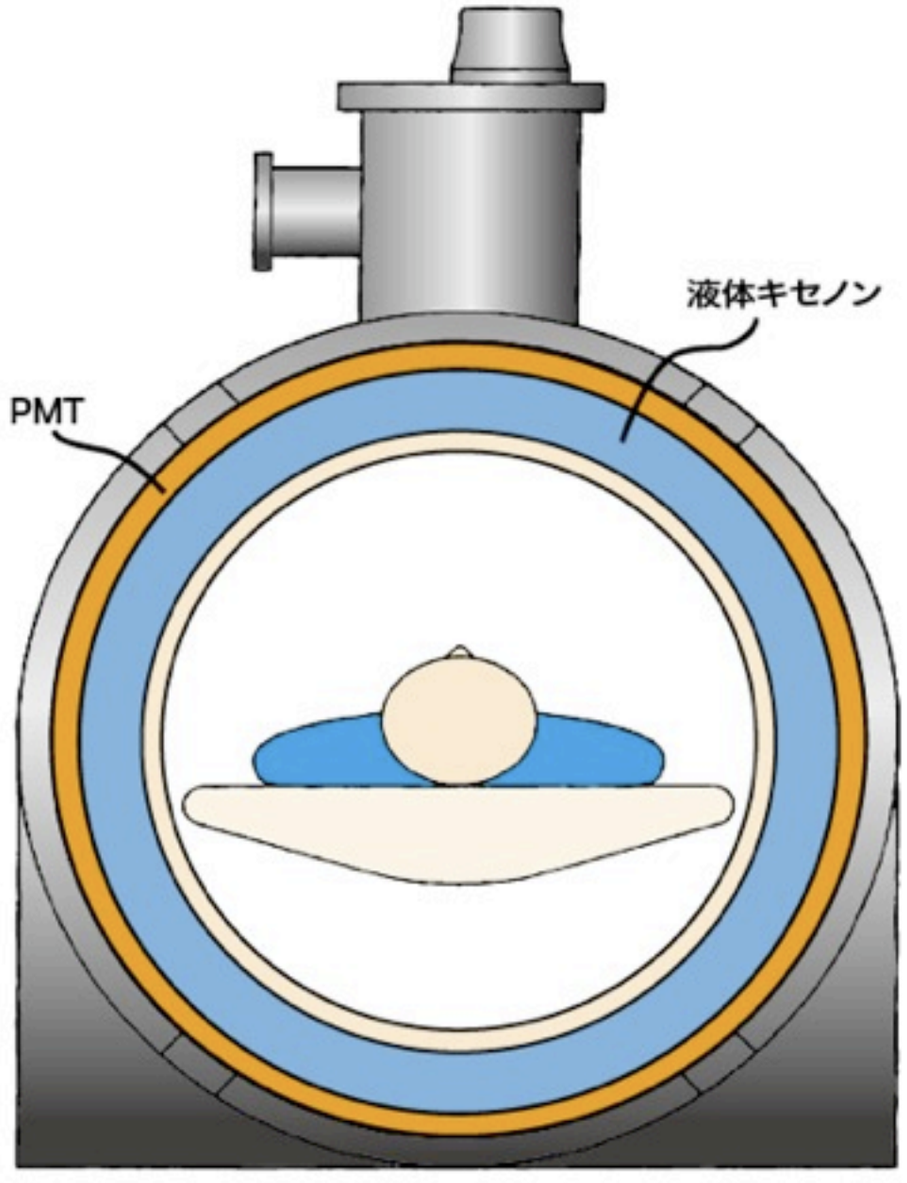
Cooperation : KEK electronics system group , DAQ

M.Tanaka et al.

Next-generation PET with LXeTPC

TXePET





LXe Cryogenic system at KEK , operation since May 2008

Gas handling panel

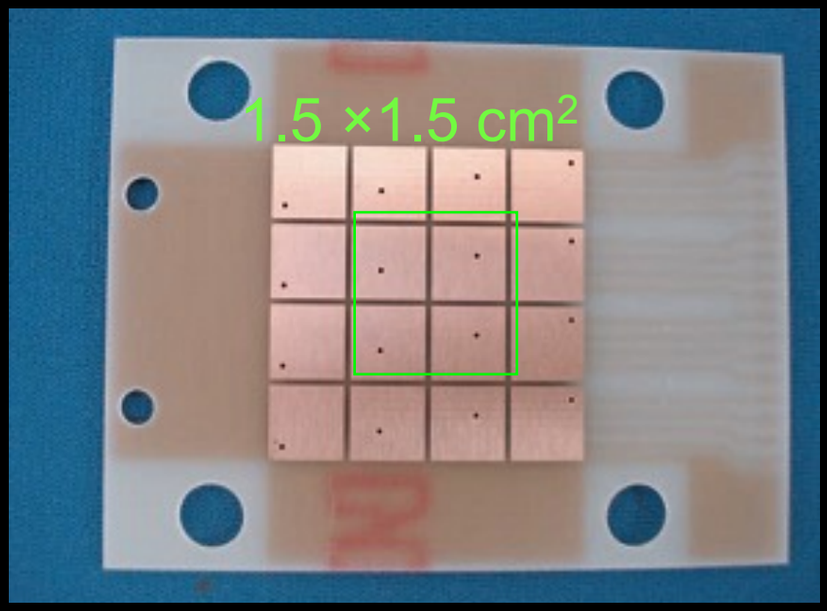
PTC (24W@165K)

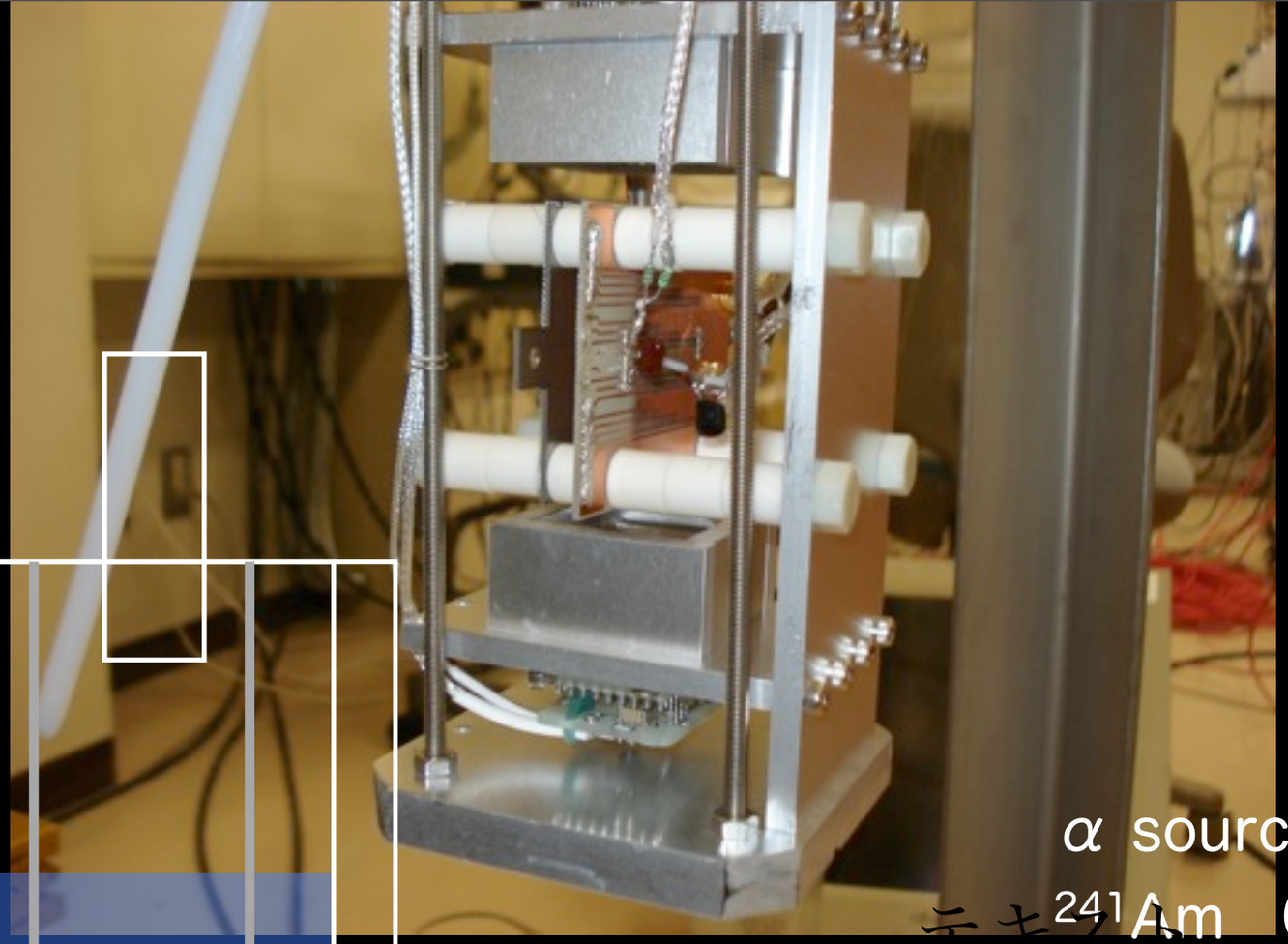
0.75m^3 Tank

700W compressor

Test chamber 1.5L-Xe

First Prototype, 2009





α source of
^{241}Am (200Bq)

PMT

TPC

Cathode

1cm

Pad

GND

50Ω

Test pulse

1KΩ

2pF

JFET

to Pre-amp IN

100MΩ

to Pre-amp
feedback

1pF

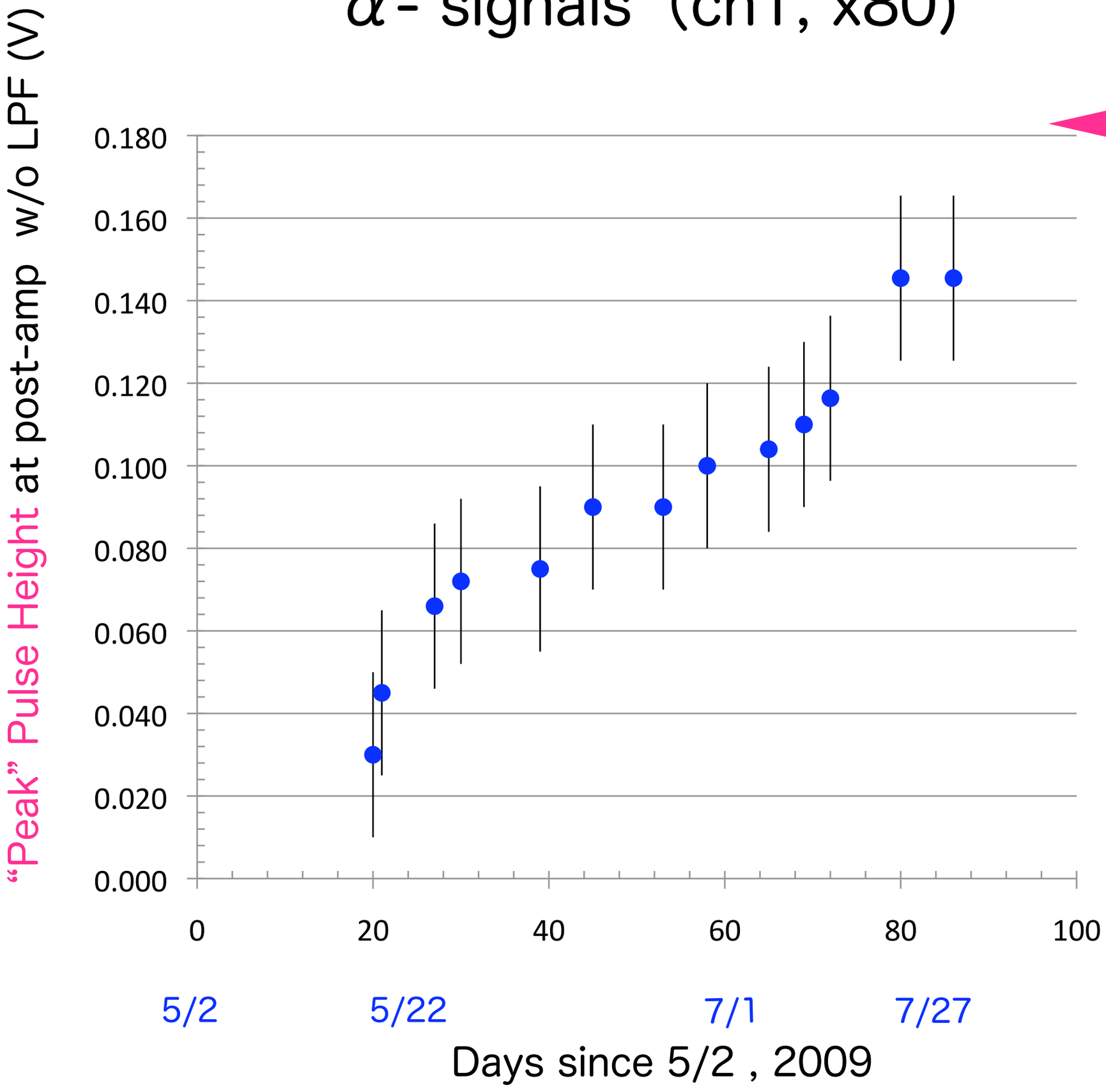
- H.V.

100MΩ

GND

Pre-amp :AMP-TEK
A250 (1V/pC)

α- signals （ch1, x80)



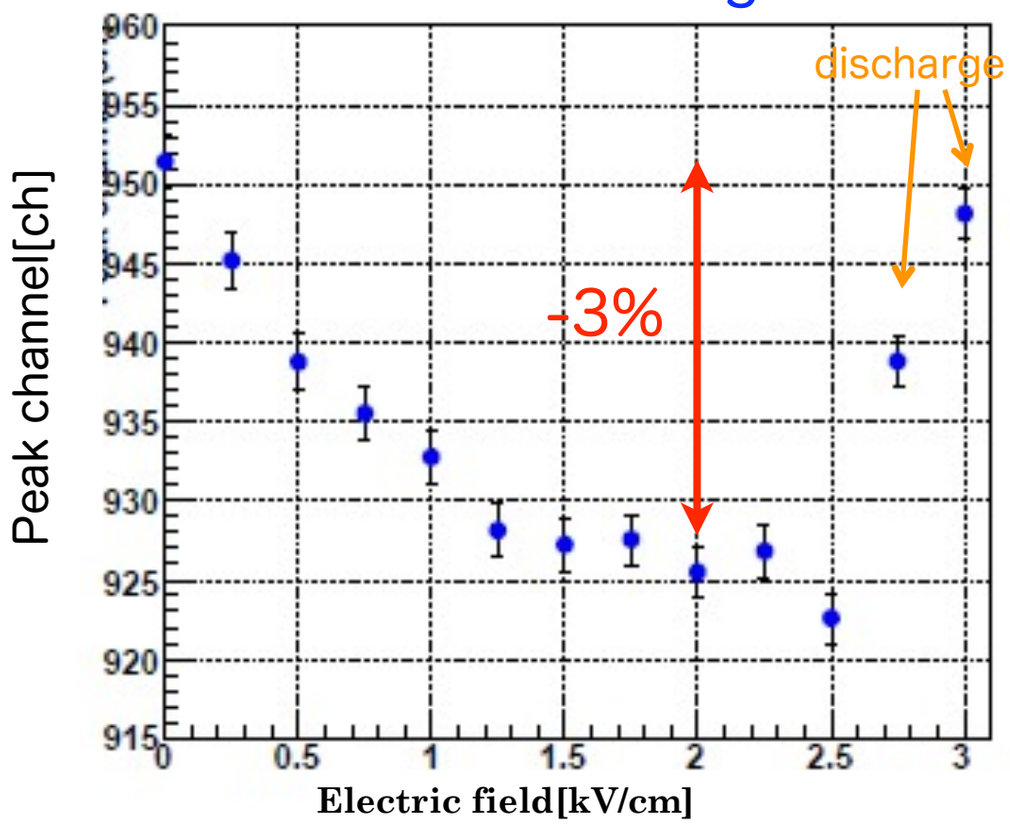
< expectation >
2.3fC
assume Q/Qo=4%
at E=-2kV/cm

note - pulse height : w/o : w LPF = 1.5 : 1

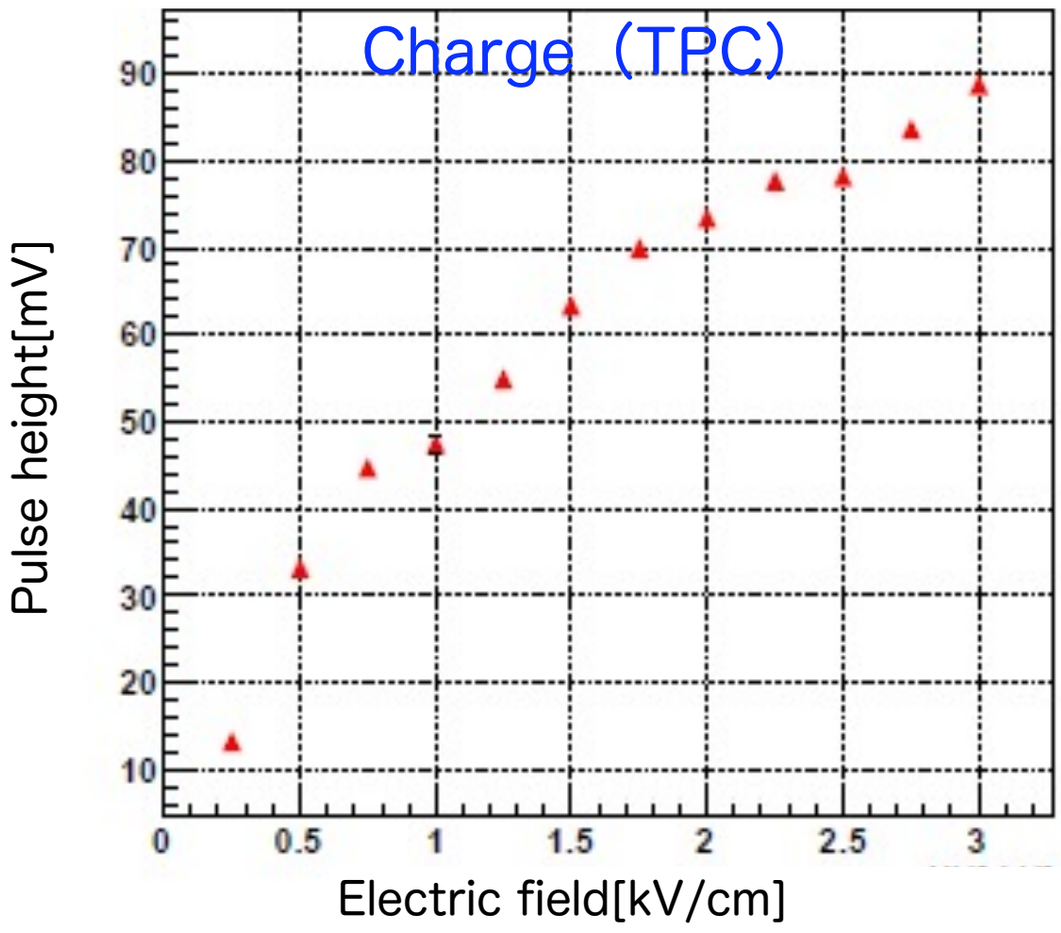
Electric field dependence (α)

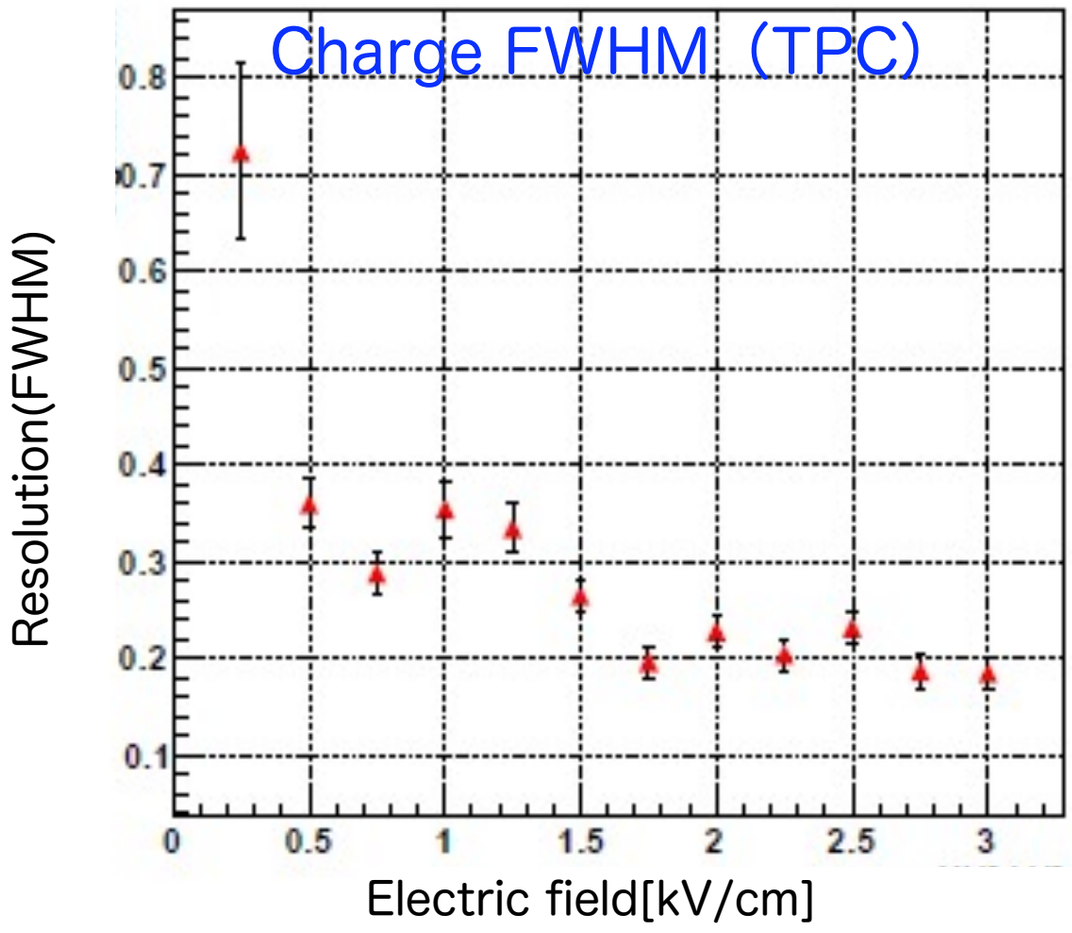
including attenuation due to impurity and drift time (E-field)

Electric field	2kV / 1kV
Scintillation lights	-3% / -2%
Charge	73mV / 46mV =1.6
Charge res. FWHM	0.22 / 0.35 = 0.6

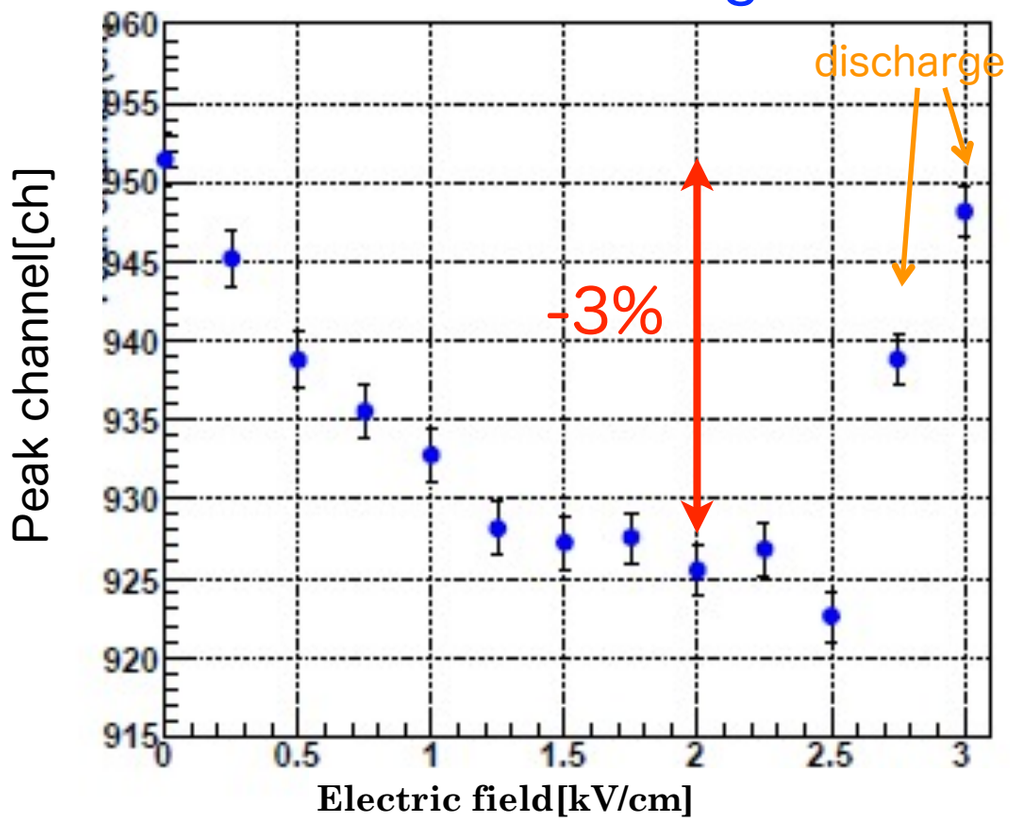


HV vs resolution





Scintillation Lights



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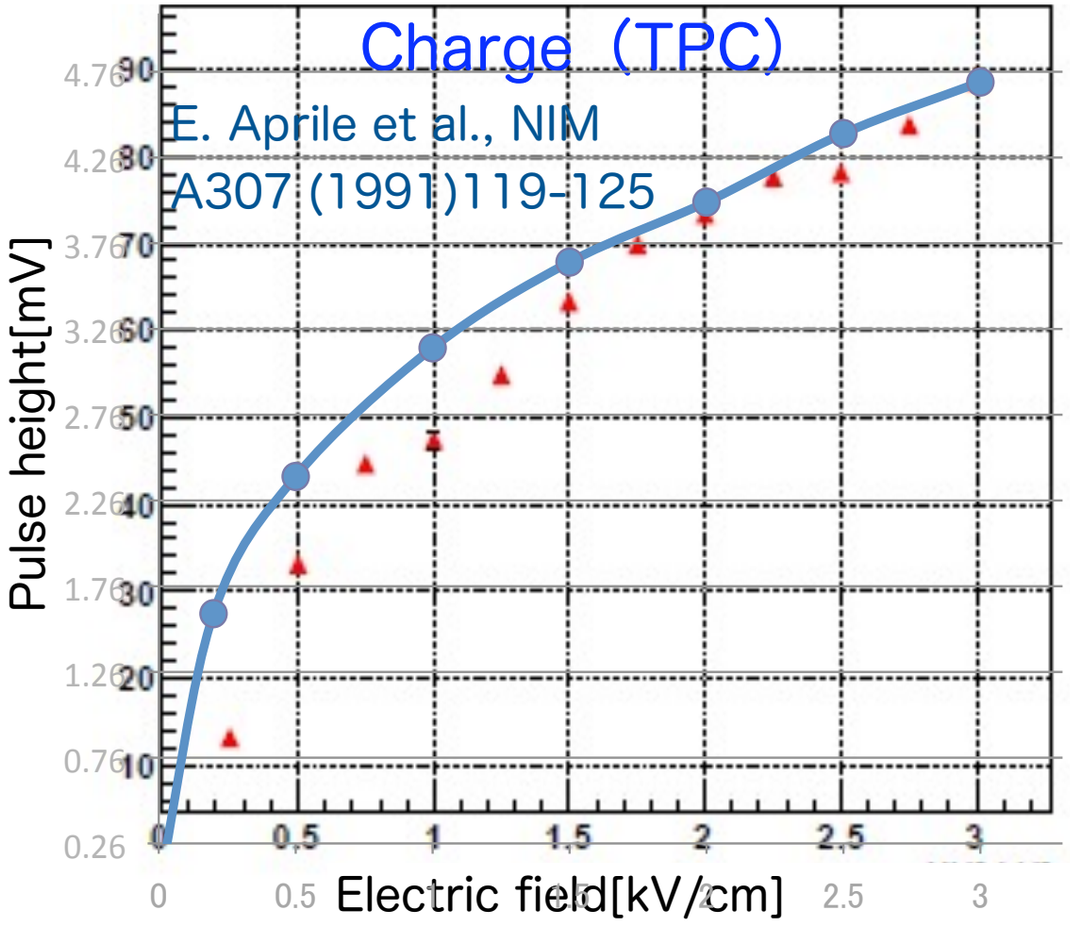
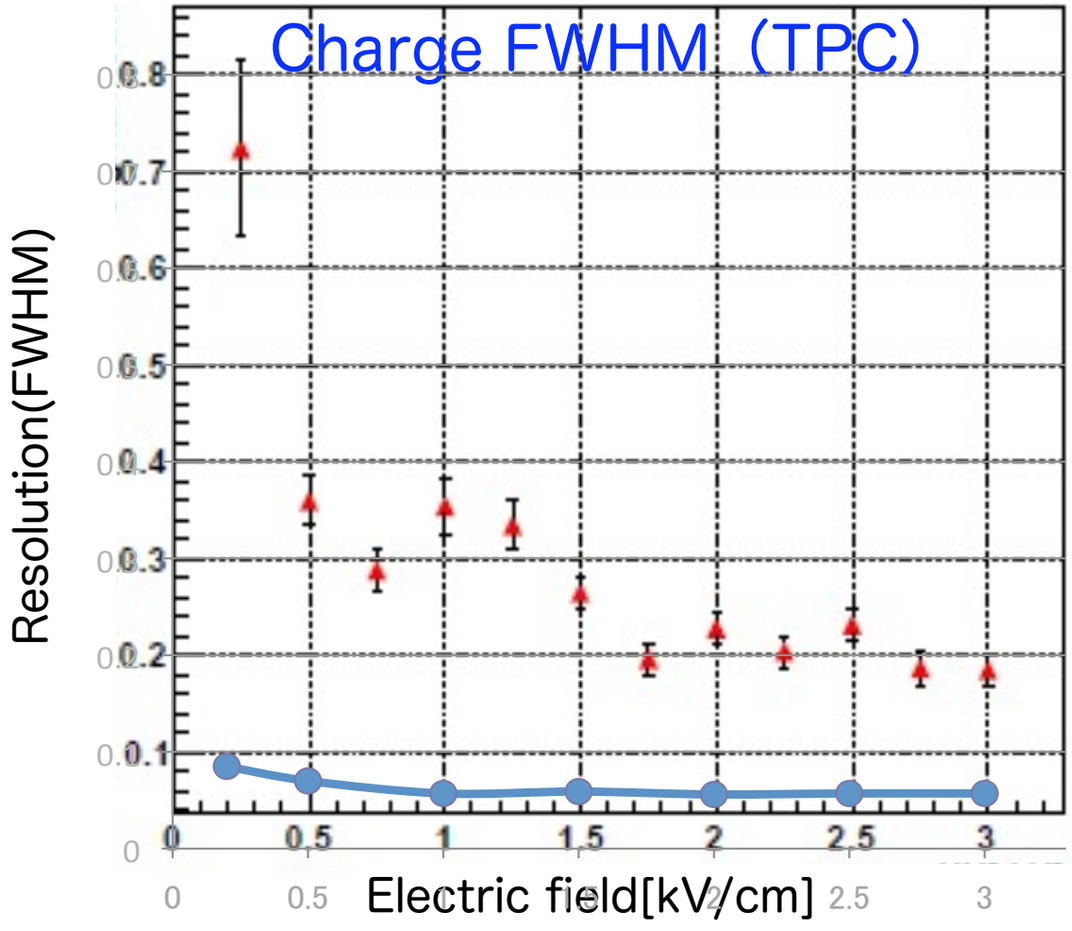
Scintillation lights	-3% / -2%
Charge	73mV / 46mV =1.6
	1.27
Charge res. FWHM	0.22 / 0.35 = 0.6

0.056/0.057= ~1

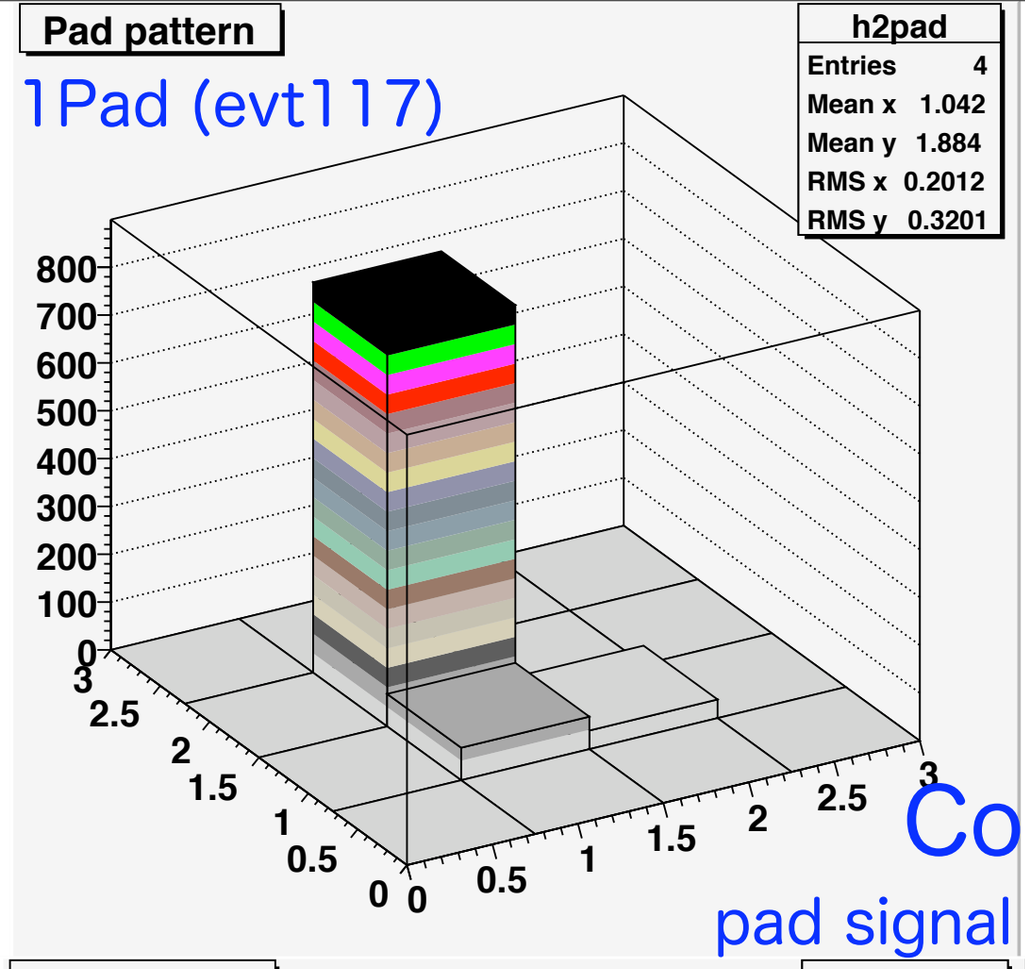
HV vs resolution

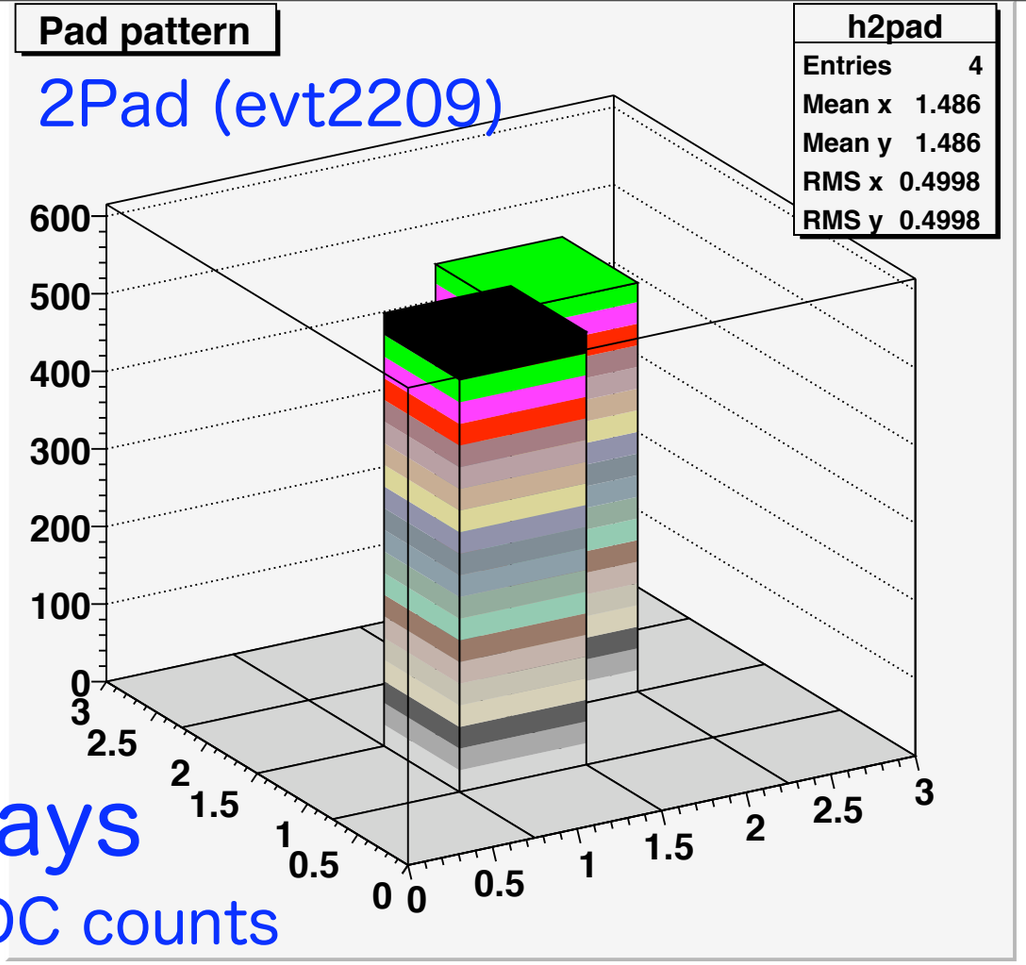


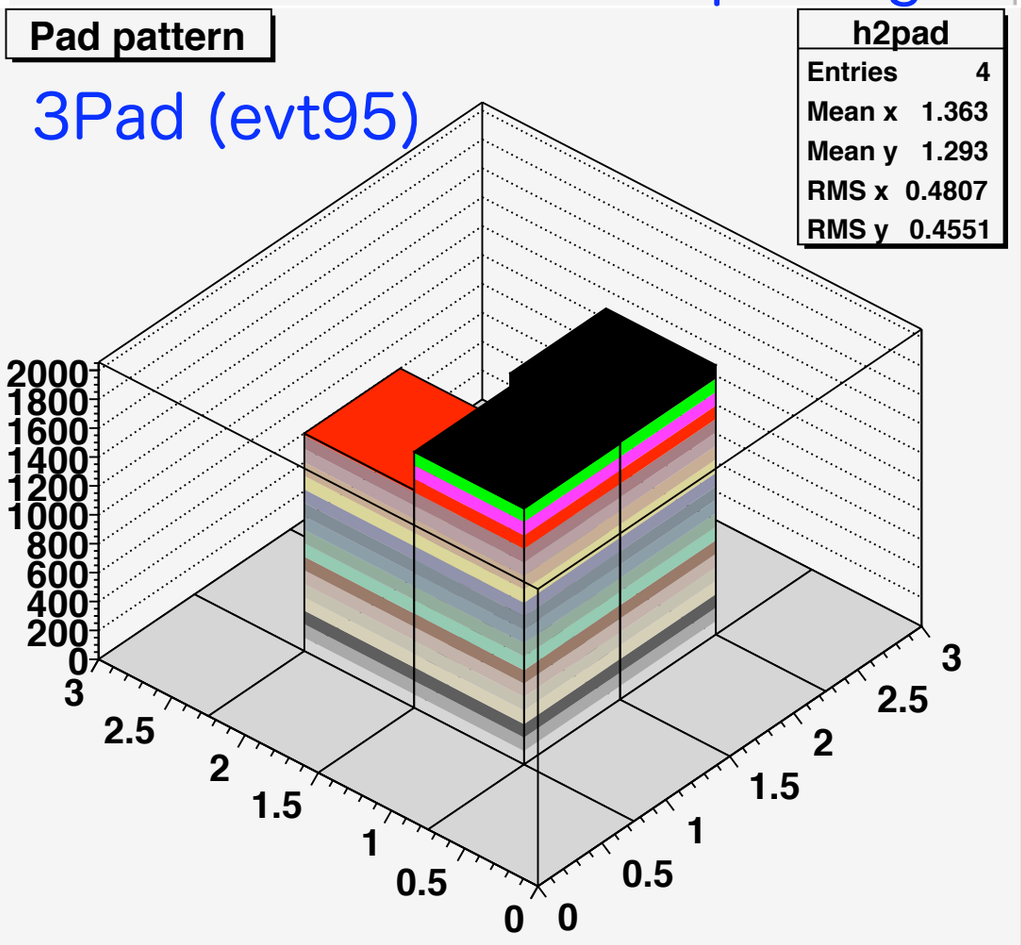


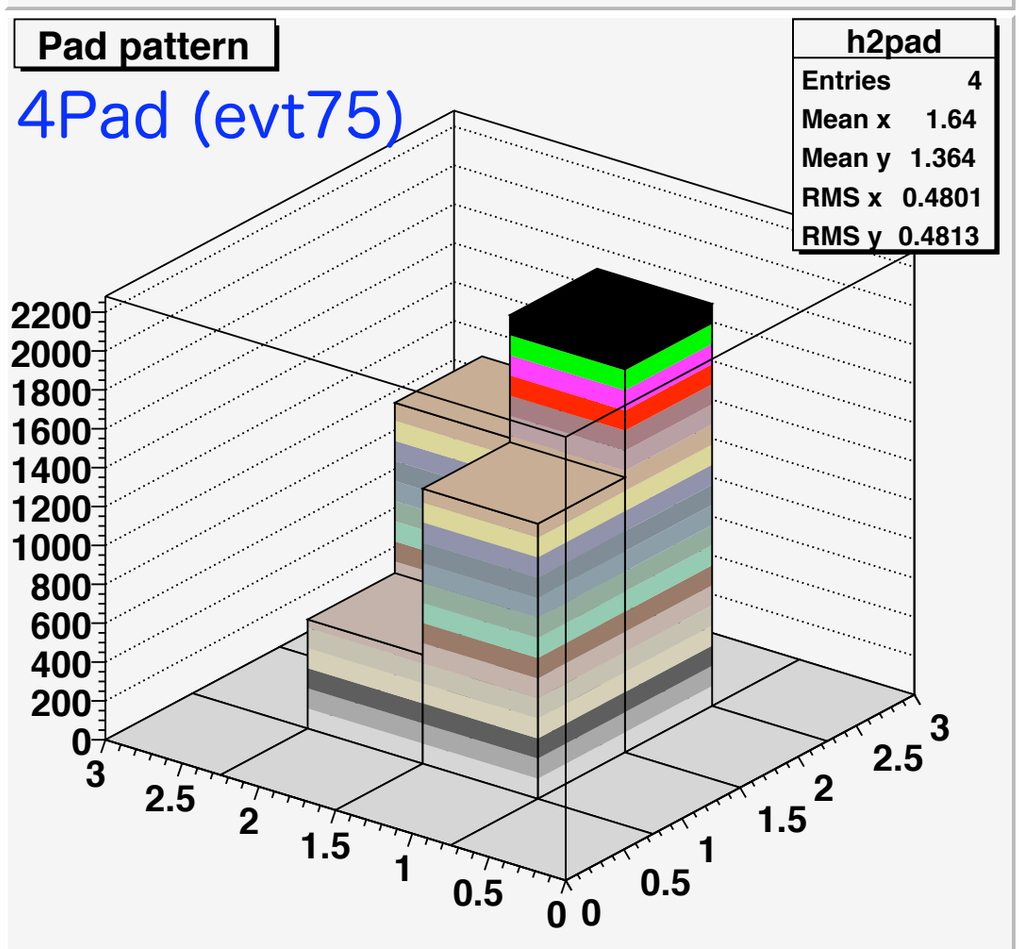
Cosmic rays

pad signal > 100 ADC counts



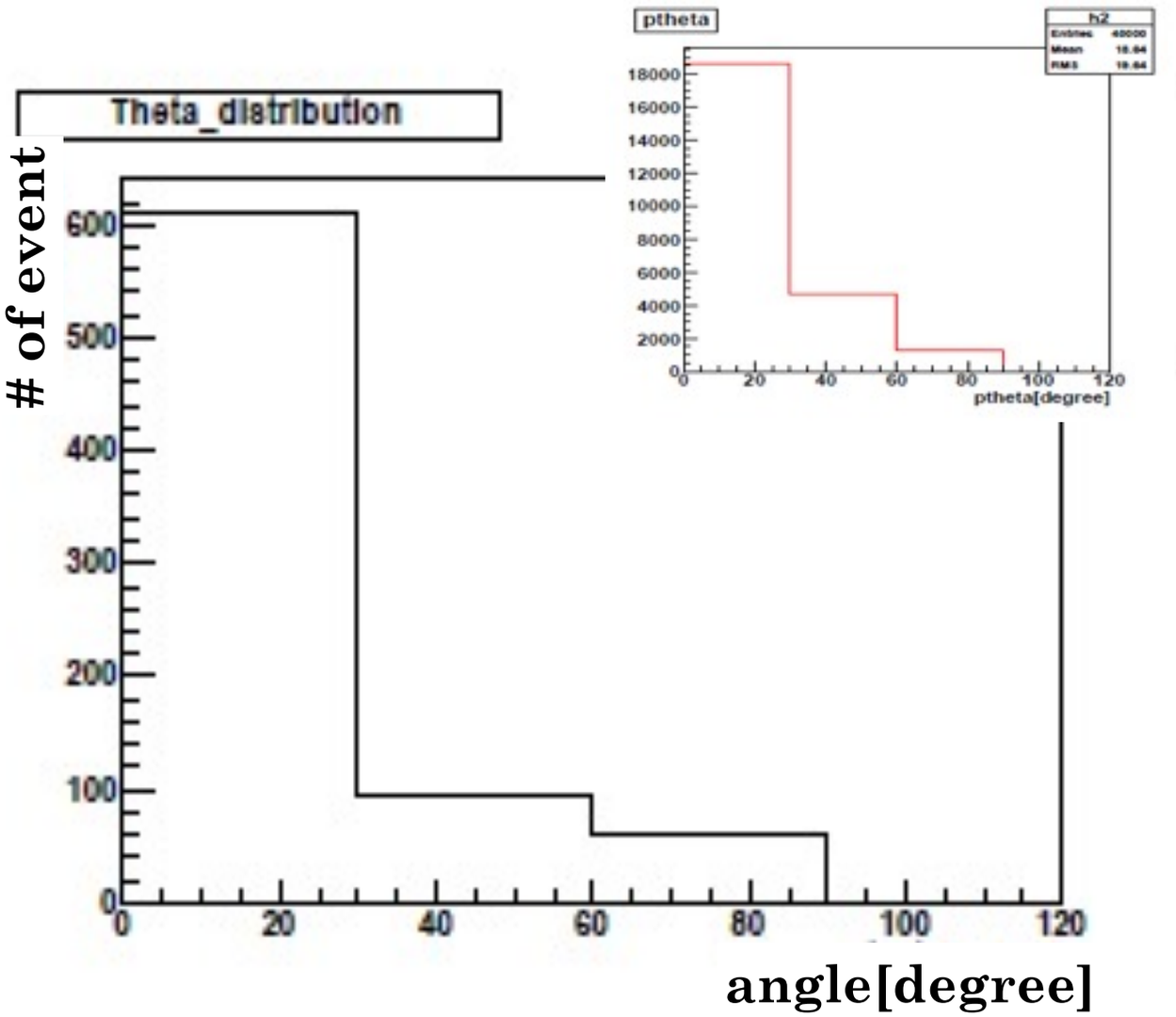






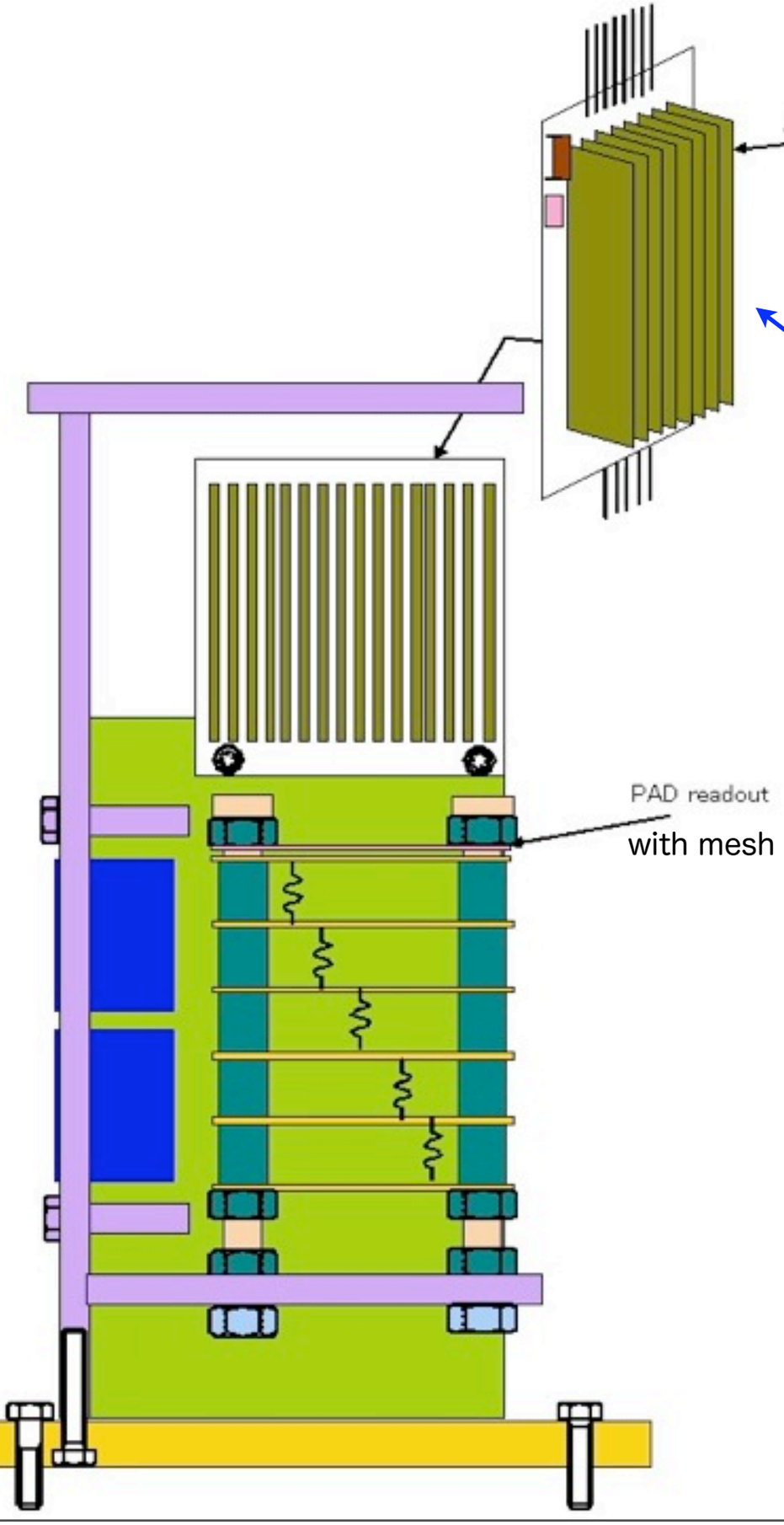
Zenith Angular Distribution of CRM

- Results
  - Sum of charges > 20fC
  - Cosmic ray muons have the zenith angular distribution as a function of $\cos^2\theta$
    - Red histogram shows the distribution with $\cos^2\theta$ (Monte Carlo), where the azimuthal angles are integrated.
  - Consistent distribution was obtained.



Y. Fujii, JPS fall meeting, Kohnann univ., 9 Oct. 2009

Present Experiment



5cm drift with grid(mesh)
&16 pad readout

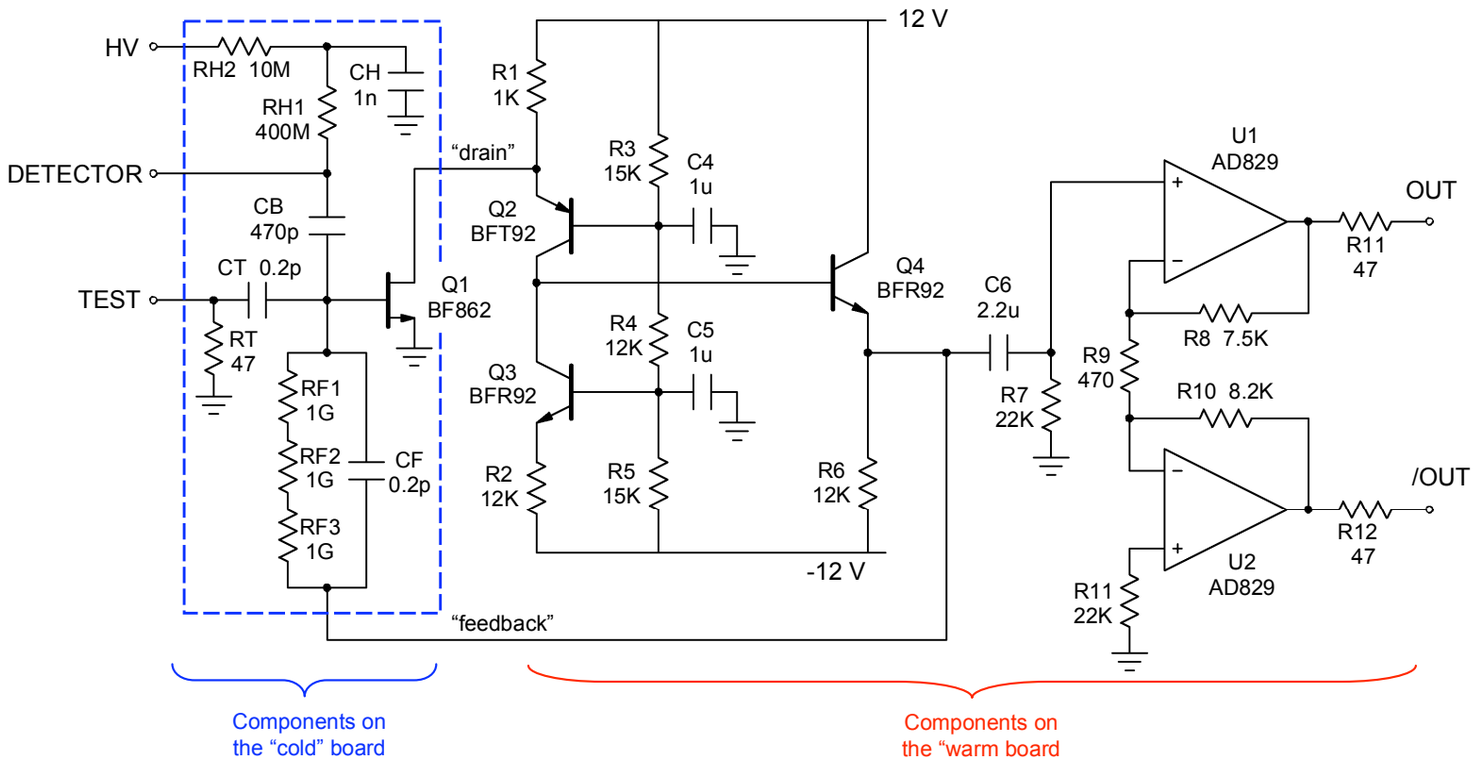
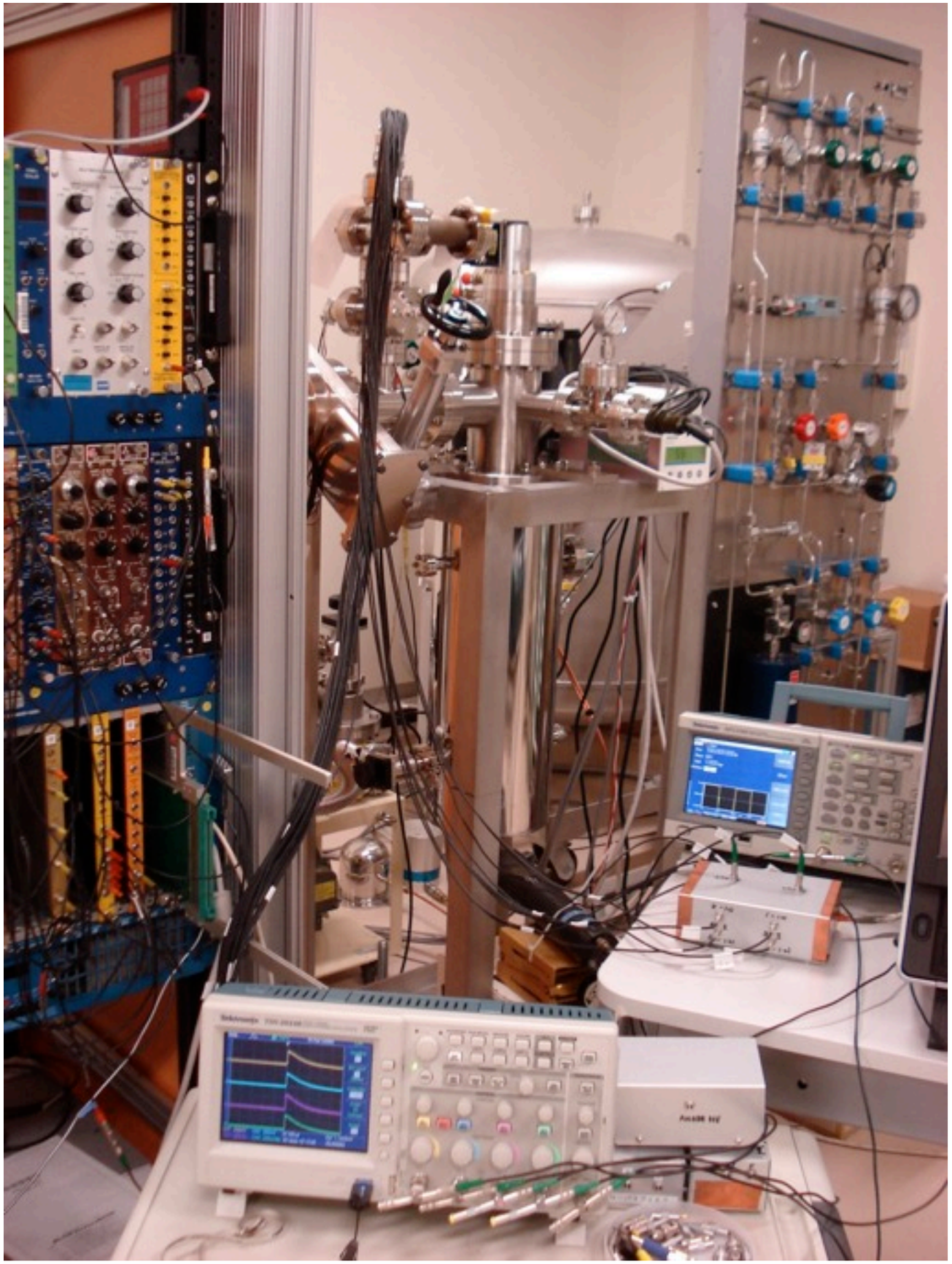


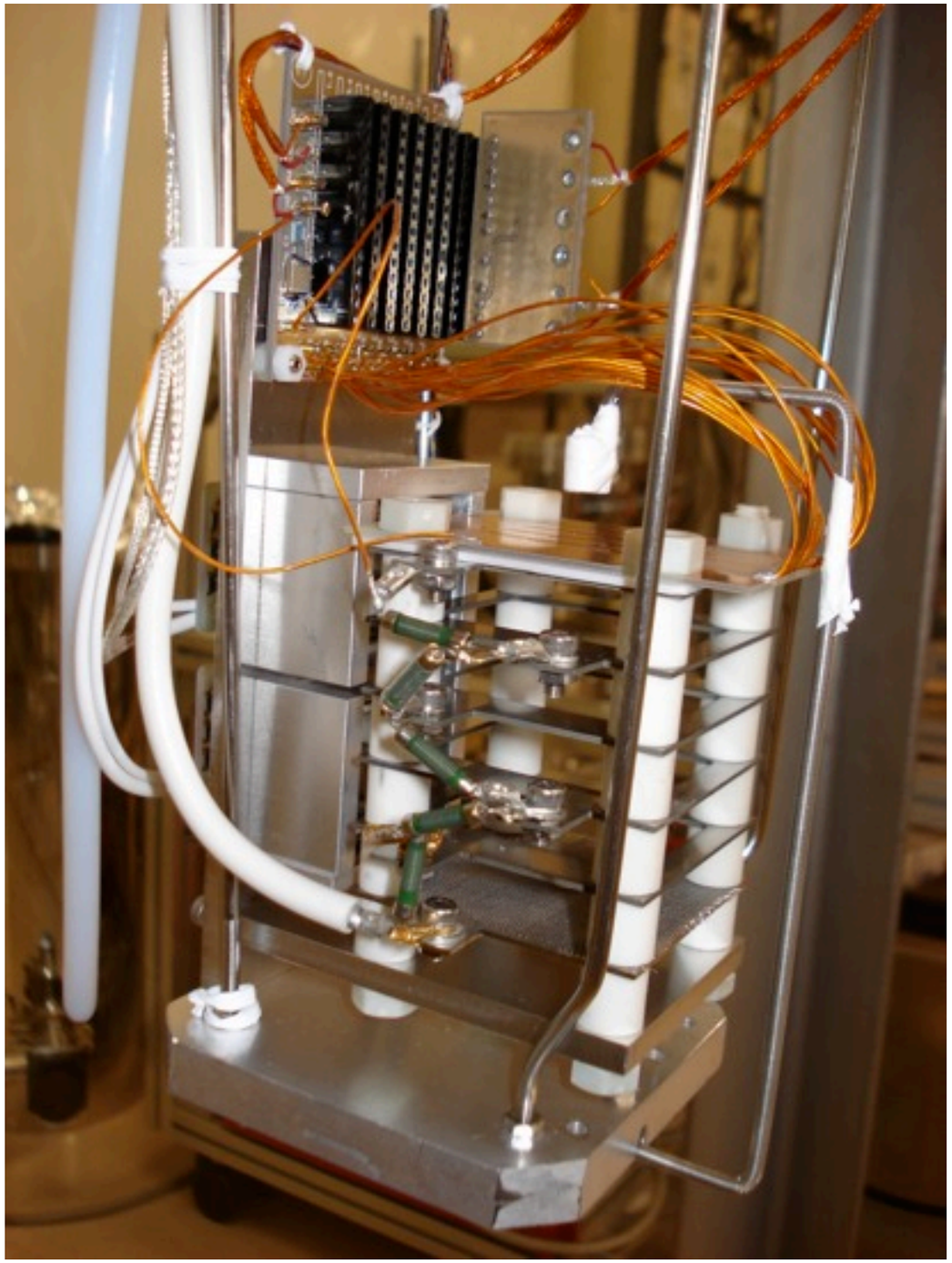
Fig. 3. Simplified schematic diagram of the charge sensitive preamplifier.

"A Cold Low Noise Preamplifier for Use in Liquid Xenon", A. Pullia et al.

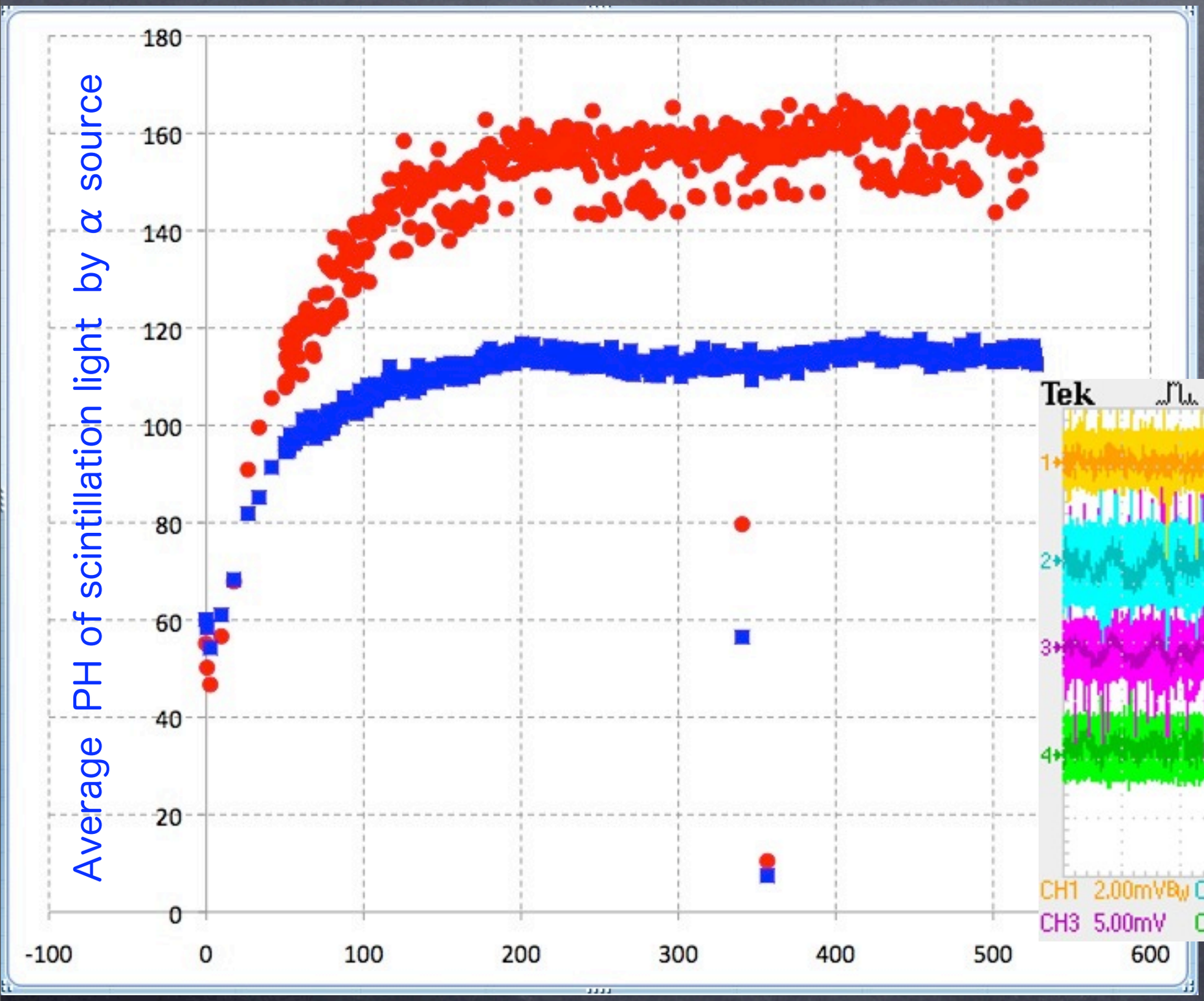
Experimental Setup



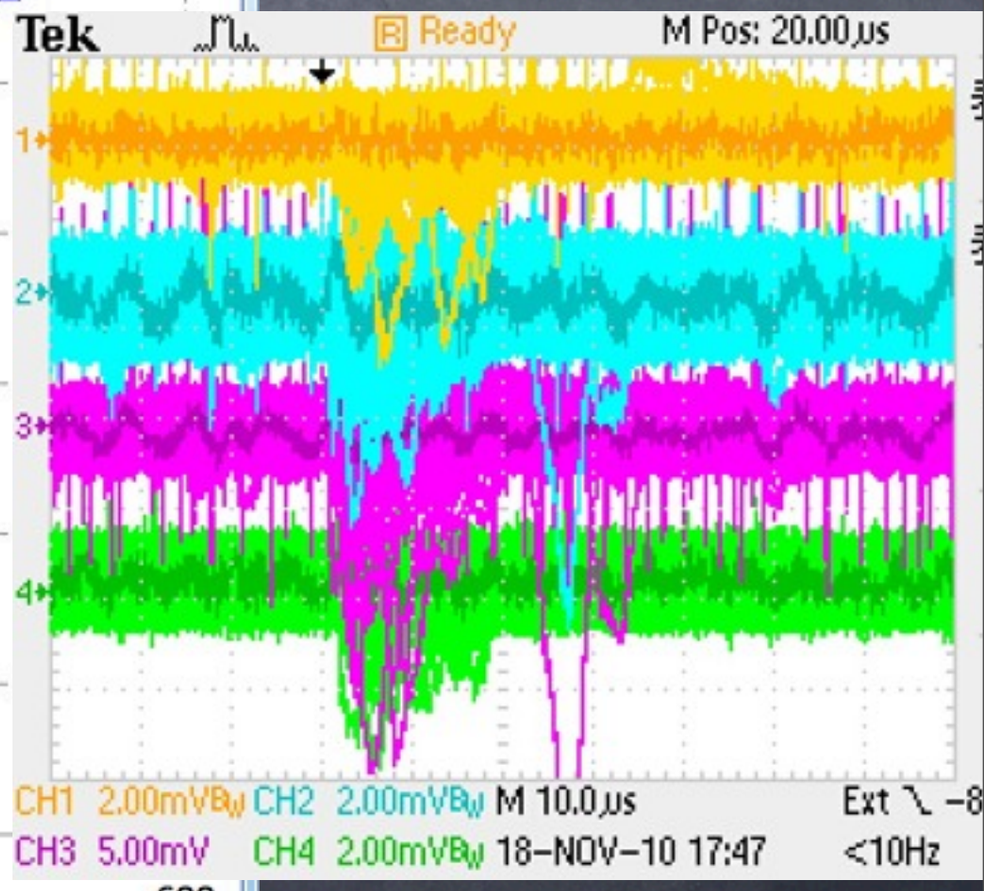
TPC prototype



Present Status ： Light and Charge Signals



4 pads in the center
w/ cosmic ray trigger



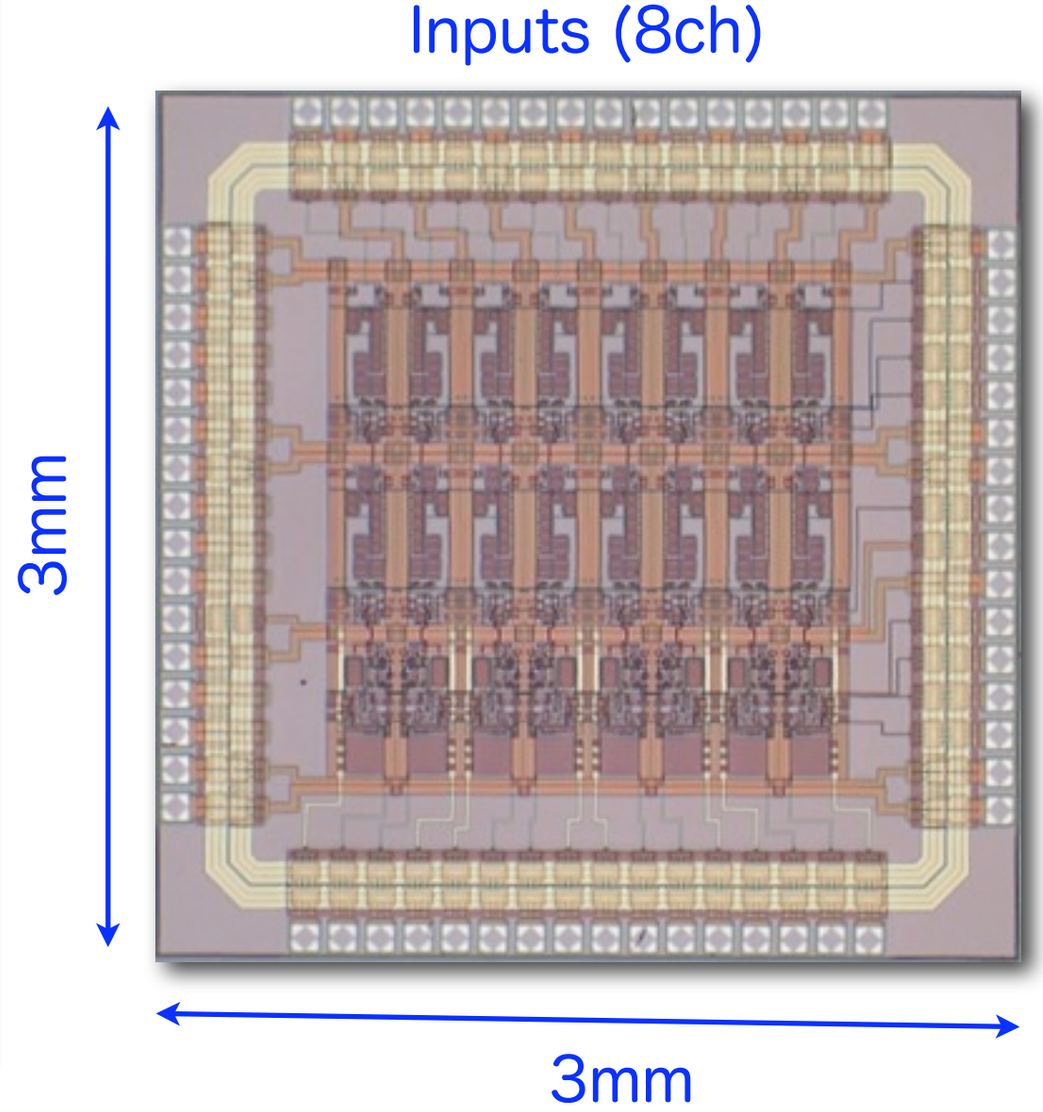
9/27 15:40 - purification started, unit in hour 10/20 17:00

Front-end ASIC chip R&D

First version : FEXE08

Pre-amp. to PZC to shaper - output all analog channels

PARAMETER	SPECIFICATION	Achieved in room temp.
chip size	3mm x 3mm	
channel number	8	
power supplies	±2.5V	
dissipation power	<10mW/ch	
gain	8.2V/pC	6.0±0.5V/pC
Input charge	±25fC	-60~100fC
peaking time	0.5, 1us, variable(>1us)	
prod. process	0.5um CMOS	
ENC	2,000e (C_d=1pF)	400e (C_d=1pF)



T. Higashi, JPS fall meeting, Kohnann univ., 9 Oct. 2009

Second version : FEXE08

Designed by Open-IT ;

Takatoshi Higashi (Saga univ.), Takahiro Fusayasu(NIAS) , Hirokazu Ikeda(JAXA) , Manobu Tanaka(IPNS)

Open-It (Open source consortium for detector instrumentation) collaboration

together with the neutron group

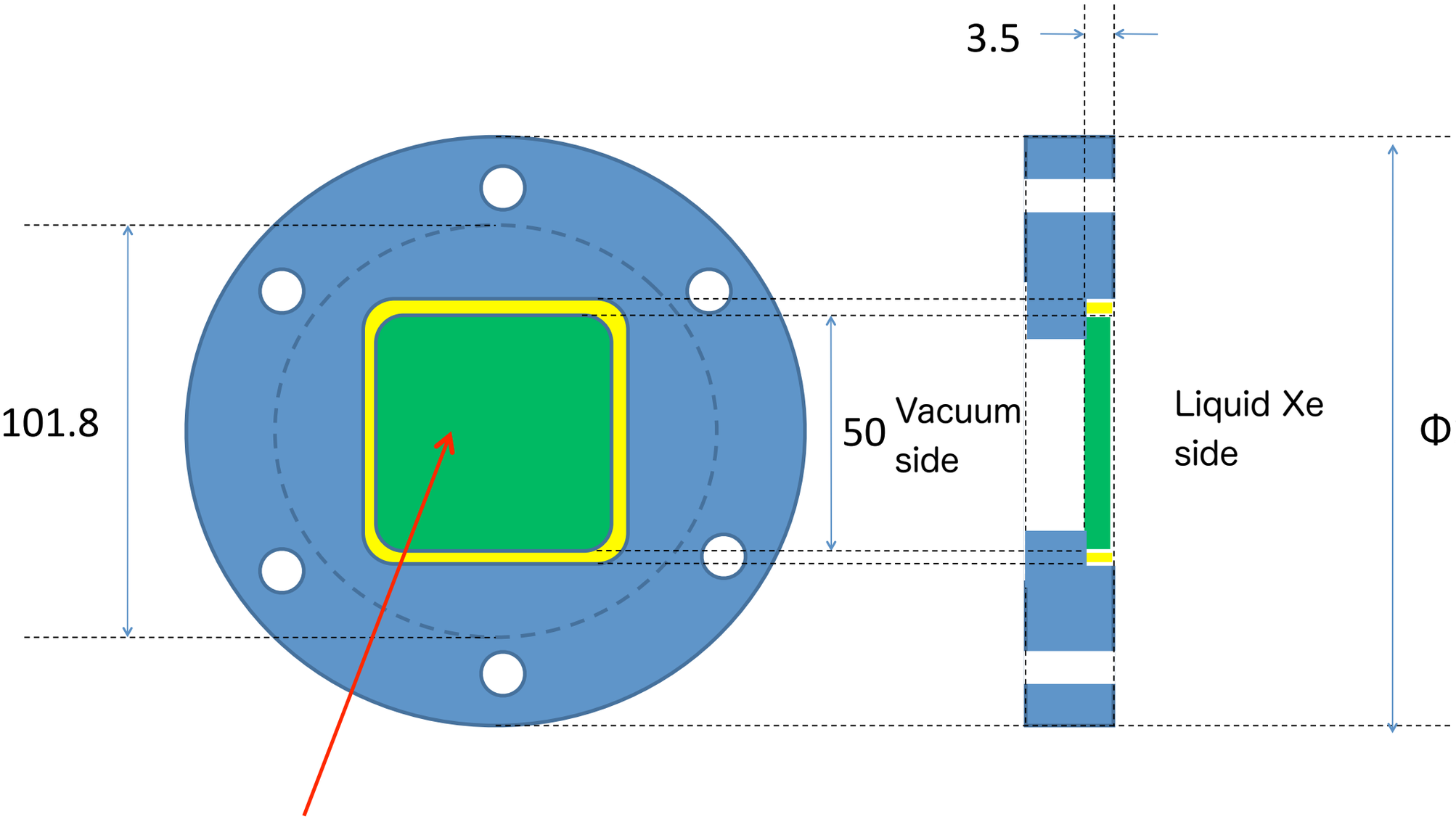
Parameters	TPCFE09(TPCFE1x)
dynamic range	-75fC~+25fC -500fC ~ -5fC
gain	2V/pC 10V/pC
gain tolerance	~1%
ENC	400+25/pF@0.5us
cross talk	~1%
peaking time	0.5, 1 and 2 us
power dissipation	<10mW/ch
Temperature range	-110 ~ + 25℃
# of channels	16ch
ADC	none (10bit/10MHz)

UMC 0.25um process

Schedule

1. Circuit design was completed
2. Simulation was completed
3. Layout design was passed to the company on 24 November
4. Tape out will be submitted by end of January 2011
5. Delivery in March 2011
6. Test in March 2011

Pressure Capacity Test on the Ceramic End Plate (vacuum - liquid xenon window)



Ceramic plate with
3.5mm thickness

at 3 ~4 bars and < -110 ℃

Summary

1. Charge signals of both cosmic ray and α sources
   were detected with a commercial pre-amplifier.
2. Purification process was monitored and
   understood by scintillation light and charge signals.
   The preliminary estimation is about 90 ppb
   (O_2 equiv.) with circulation in 2 months,
   which will be improved in next time.
3. Present R&D : TPC with 16ch-pads, 5cm drift.
   with improvement by a getter pump
4. Front end electronics ASIC (16ch) :TPCFE09
   The layout was just submitted and the test in JF2010
5. Ceramic end plate R&D
   The pressure capacity will be tested soon.