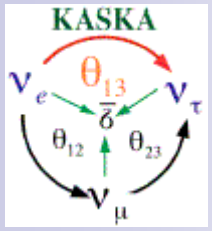


Present status of the KASKA experiment

Reactor θ_{13} measurement experiment

Yasunobu Sakamoto
RCNS, Tohoku University
for
KASKA collaboration

Collaborators

- Niigata Univ.
- Tohoku Univ.
- Tokyo Institute of Technology (TIT)
- Miyagi Univ. of Education
- KEK
- Okayama Univ.
- Kobe Univ.
- Tokyo Metropolitan Univ. (TMU)
- Hiroshima Institute of Technology

9 Institutes and 30 people

KASKA meeting inTohoku Univ.

Understanding of Neutrino Sector

- Maki-Nakagawa-Sakata mixing matrix

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \overbrace{\begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}}^{U_{MNS}} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

ν_e, ν_μ, ν_τ : flavor eigenstate

ν_1, ν_2, ν_3 : mass eigenstate

$$= \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix}}_{SK(atm),\, K2K} \begin{pmatrix} c_{13} & 0 & s_{13}e^{i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{-i\delta} & 0 & c_{13} \end{pmatrix} \underbrace{\begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{Solar,\, KamLAND} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$c_{23} = \cos\theta_{23}, s_{12} = \sin\theta_{12}, \quad etc.$

Unknown 1-3 sector

- Upper limit from CHOOZ reactor experiment:
  - $\sin^2 2\theta_{13} < 0.15$ @ $\Delta m^2_{13} = 2.5 \times 10^{-3} eV^2$

$$|U_{MNS}| \sim \begin{pmatrix} 0.7 & 0.7 & < 0.2 \\ 0.7 & 0.5 & 0.7 \\ 0.5 & 0.5 & 0.7 \end{pmatrix} \longleftarrow \sin\theta_{13} e^{i\delta_l}$$

$\sin\theta_{13} < 0.2$,
δ_l: totally unknown CPV phase

NOTE: $\Delta m^2_{13} = \Delta m^2_{12} + \Delta m^2_{23} \sim \Delta m^2_{23}$

Next important step is measuring θ_{13}

↓

ex) The finite value of $\sin^2 2\theta_{13}$ will indicate the possibility of CPV phase (δ_l) measurement.

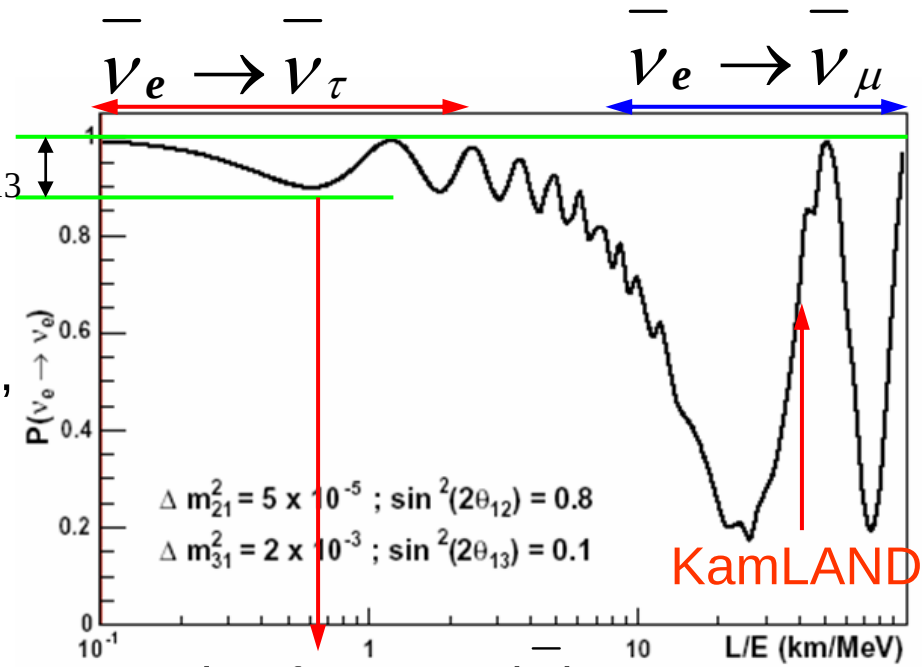
Measurement θ_{13} by reactor (1)

- Disappearance of reactor anti-ν_e(E~4MeV,L=1~2km)

$$P(\bar{\nu}_e \to \bar{\nu}_e) = 1 - \sin^2 2\theta_{13} \sin^2 \frac{\Delta m^2_{13} L}{4E} + O(10^{-3}) \text{ from } \Delta m^2_{12} \text{ oscillation}$$

Measure this small deficit.~ $\sin^2 2\theta_{13}$

Thanks to $\Delta m^2_{12} << \Delta m^2_{23(13)}$,
it is pure θ_{13} measurement.

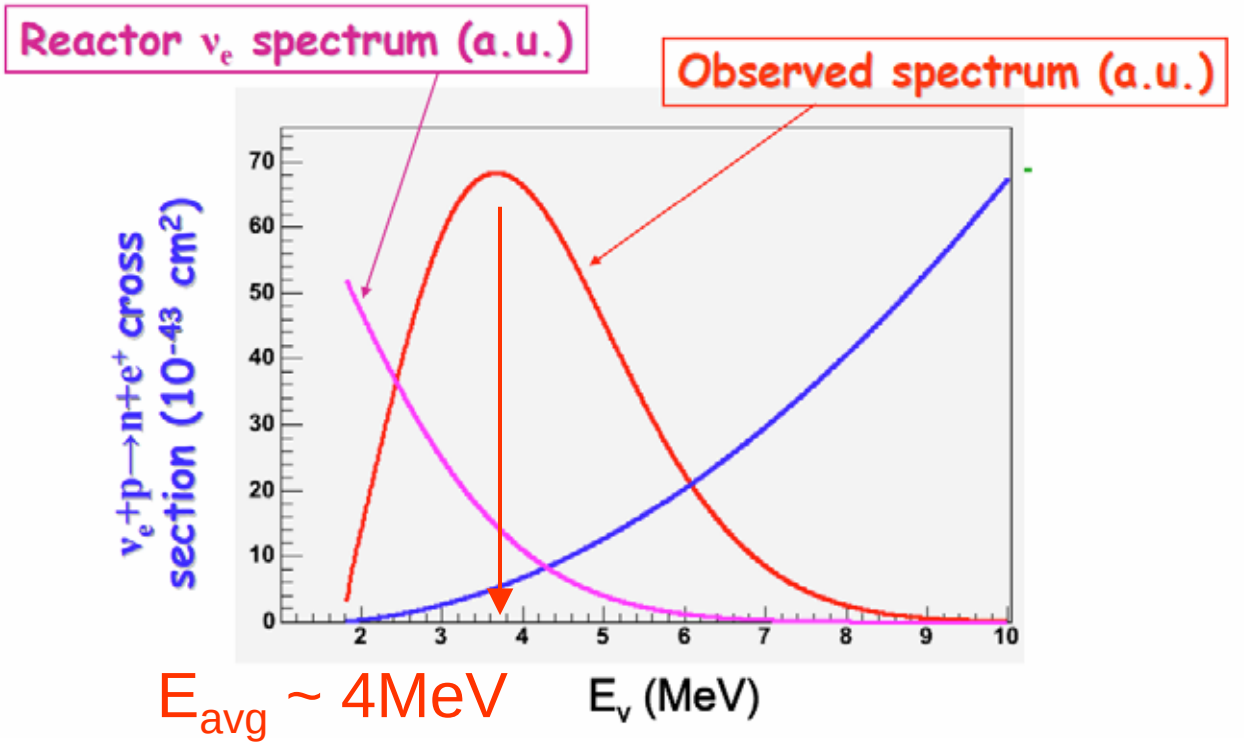


1~2km for 4MeV($\bar{\nu}_e$)

Measurement θ_{13} by reactor (2)

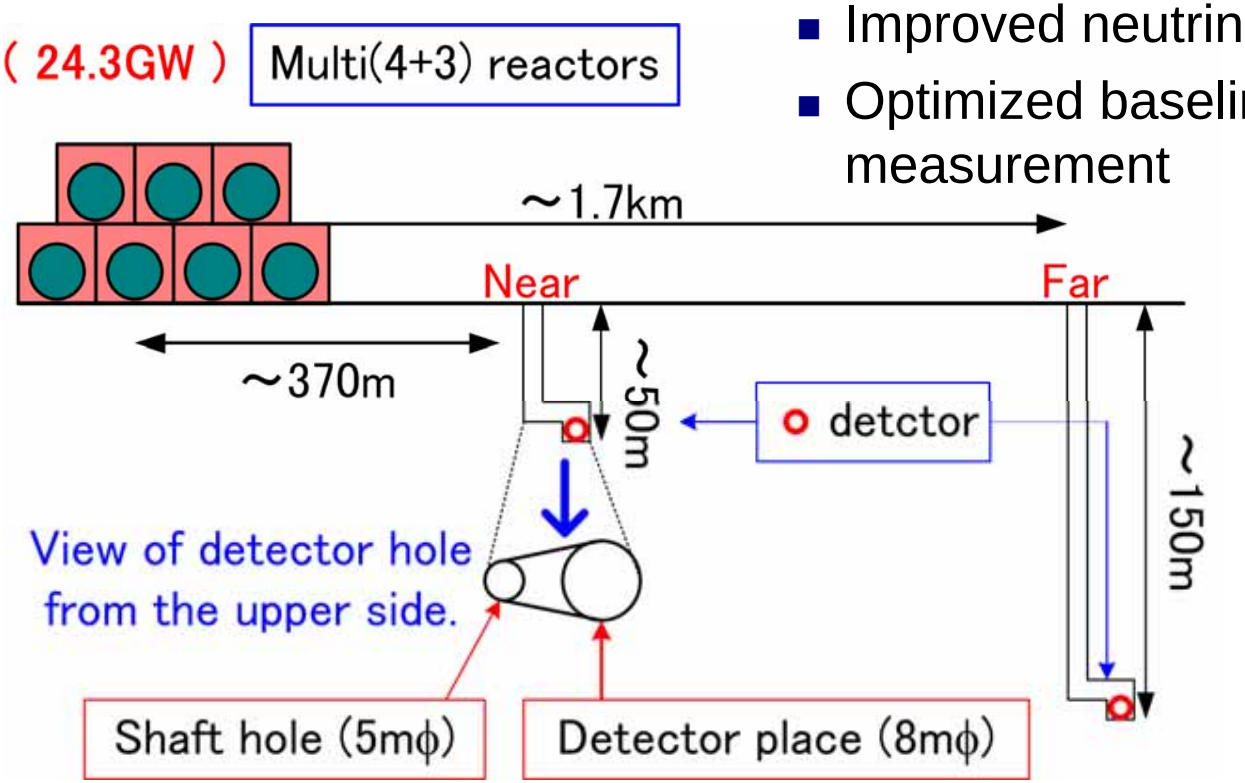
- Usual 1GW reactor emits 6x10^{20} $\bar{\nu}_e$ / sec
- Neutrino energy spectrum determined by spallation products data with 2.5% accuracy

Gratta/ν2004



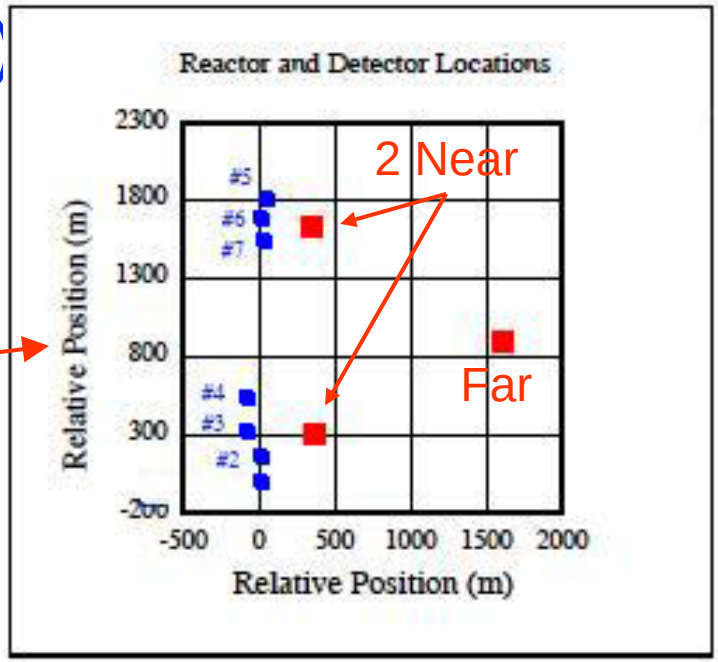
Concept of KASKA

- To improve from CHOOZ sensitivity
  - Cancel systematic errors between near and far detectors
  - “Higher luminosity” neutrino source
  - Improved neutrino detector
  - Optimized baseline for oscillation measurement



The neutrino source

- Kashiwazaki-Kariwa Nuclear Power Station
  - World's largest reactor complex: 24.3GWth (8.2GWe)
  - Tokyo Electric Power Co.
  - K-K supplies 20% of total consumption of Tokyo area.
- 7 reactors in two clusters (3+4)



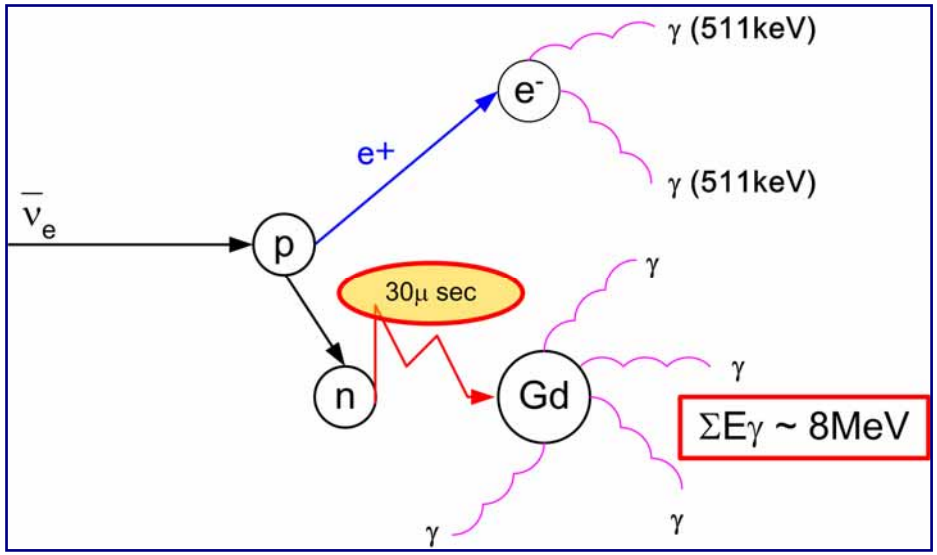
Detection of the neutrino event

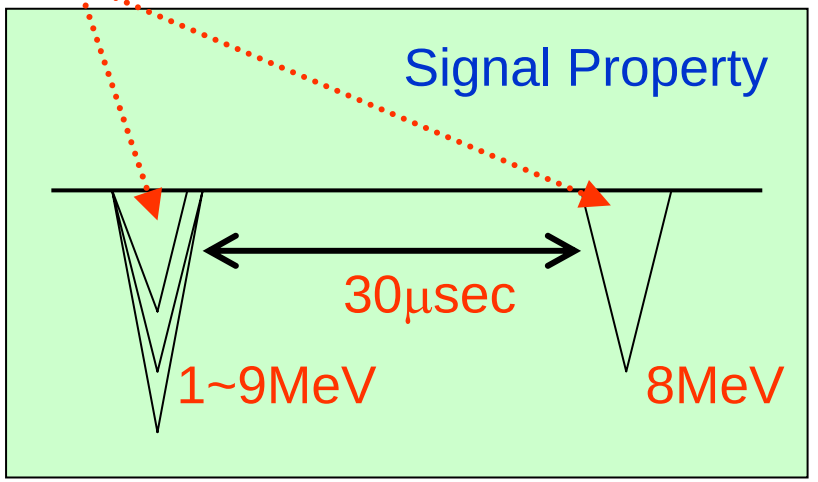
- Inverse beta decay ($E_{threshold}$ = 1.8MeV)

$$\bar{\nu}_e + p \rightarrow n + e^+$$

$$e^+ + e^- \rightarrow 2\gamma \quad (E_\nu - 0.8MeV)$$

$$n + Gd \rightarrow Gd' + \gamma s \left(\sum E = 8MeV\right)$$

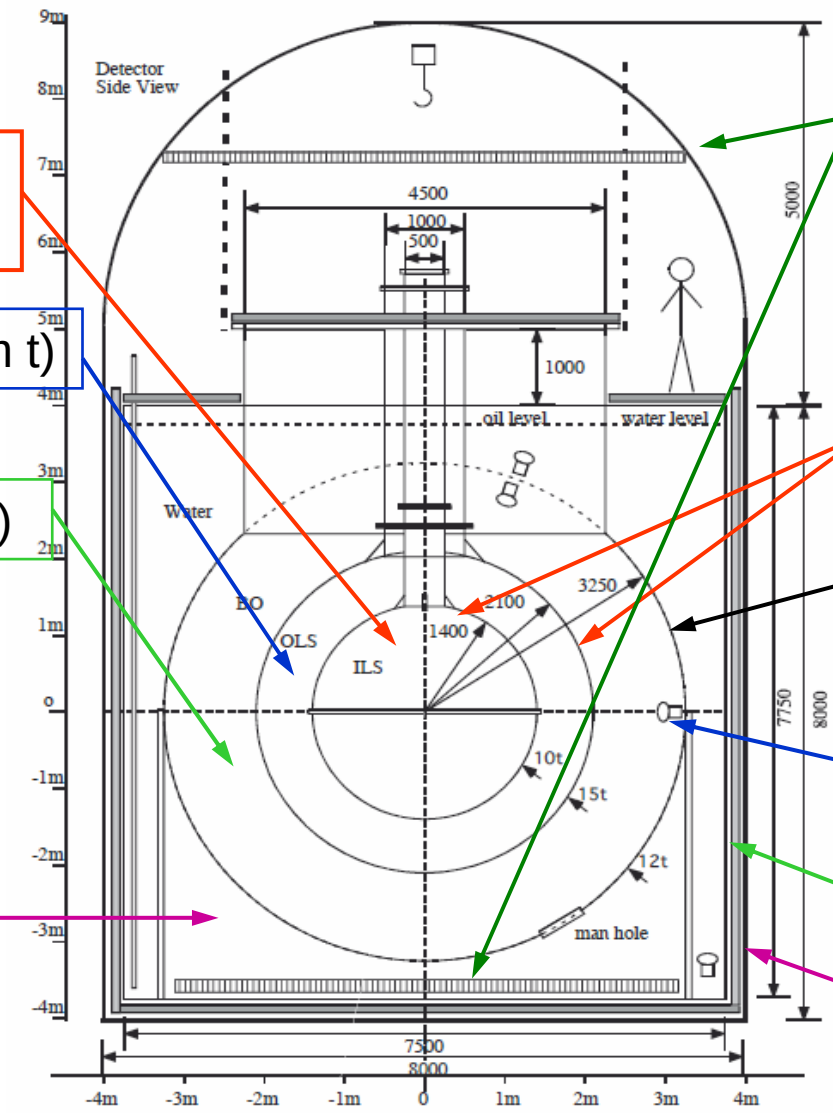




- "Delayed coincidence" drastically reduces the background.

The KASKA Detector

Design as of May 2005



ν detector Gd+LS
11.5m^3

LS γ catcher (70cm t)

Buffer Oil (115cm t)

Water

Cosmic ray tracker

Acrylic Vessels

Stainless Steel Tank

10''PMT x 300 (13'' x 150)
+
(2''PMT x 50)

Fe Tank (1cm t)

Fe Shield (10cm t)

Systematic errors

Detection efficiency related

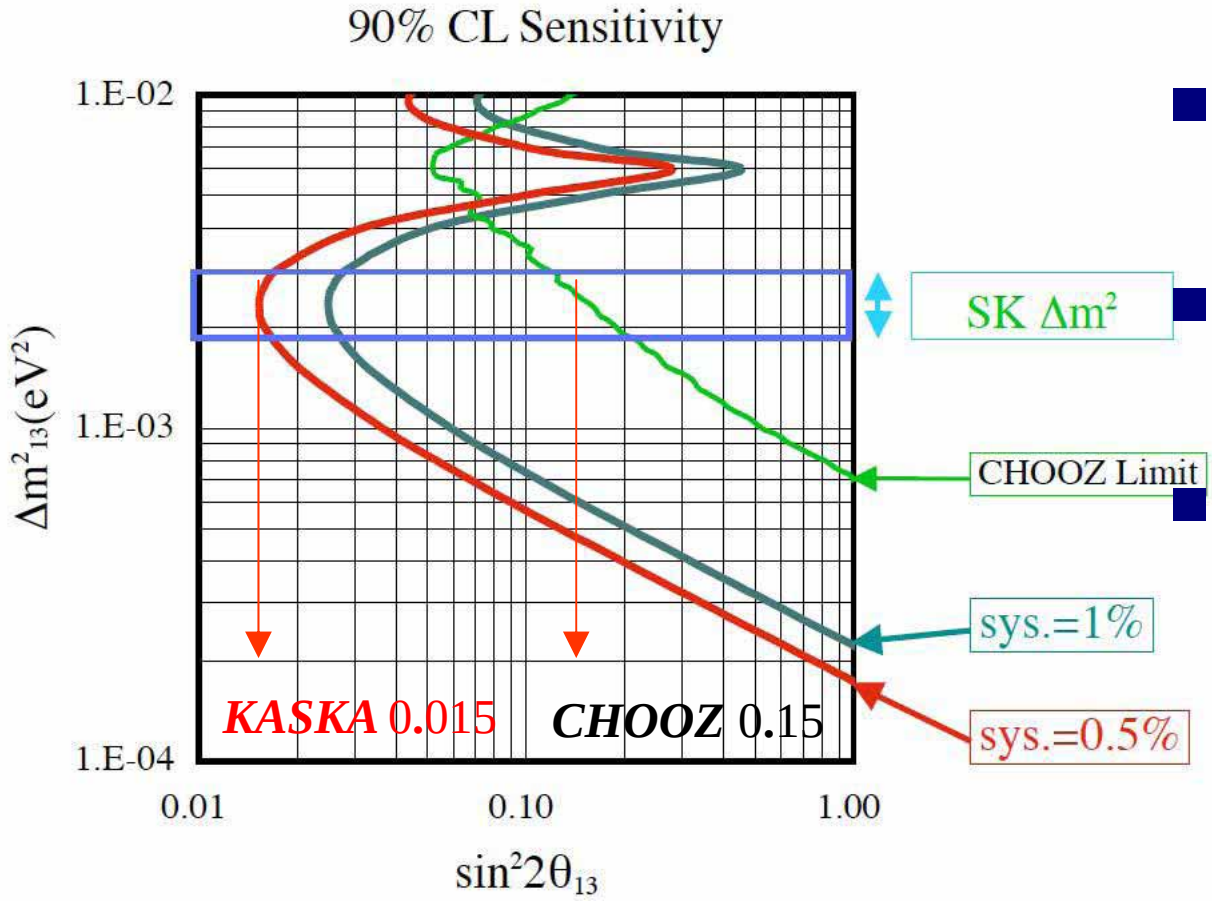
selection	CHOOZ	KASKA
positron energy	0.8%	<0.1%
positron position	0.1%	-
neutron capture	1.0%	<0.5%
capture energy containment	0.4%	<0.4%
neutron position	0.4%	-
neutron delay	0.4%	<0.2%
positron-neutron distance	0.3%	-
neutron multiplicity	0.5%	-
number of protons	0.8%	<0.5%
Combined	**1.76%**	**<0.85%**

+ neutrino flux, + BG

Parameter	CHOOZ	KASKA
Reaction Cross section	1.9%	-
Detection efficiency	1.76%	<0.85%
reactor power	0.7%	-
energy released per fission	0.6%	-
baseline difference	-	<0.2%
background	0%	<0.5%
Combined	**2.7%**	**<1.0%**

Expected sensitivity

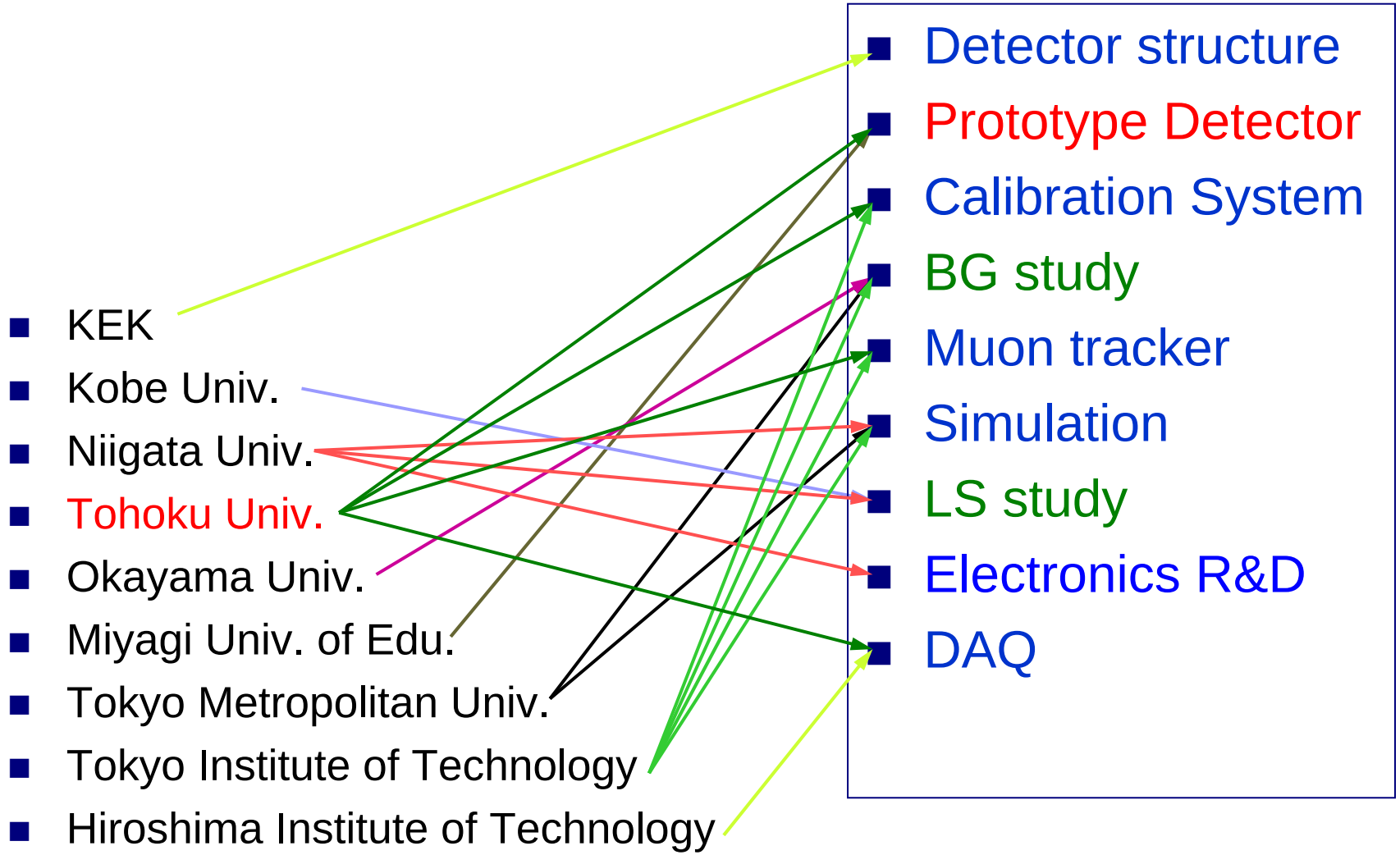
50,000 events / 3 years @ far detector
(1,200,000 events @ near detector)



- $\sigma_{stat} < 0.5\%$
  - CHOOZ 2.8%
- $\sigma_{sys} < 1\%$
  - CHOOZ 2.7%
- For $\sigma_{sys} = 0.5\%$
  - (aimed sensivity)

$\delta \sin^2 2\theta_{13} \sim 0.015$

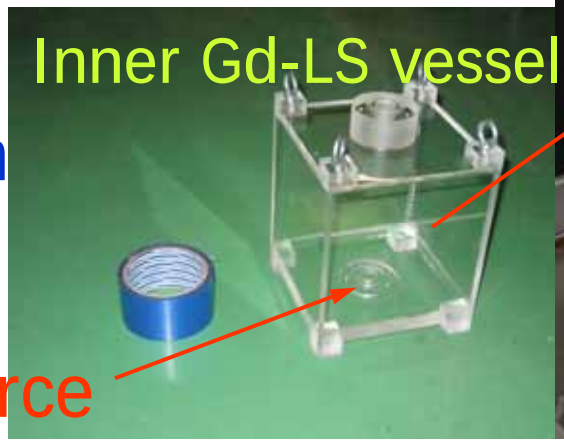
R&D

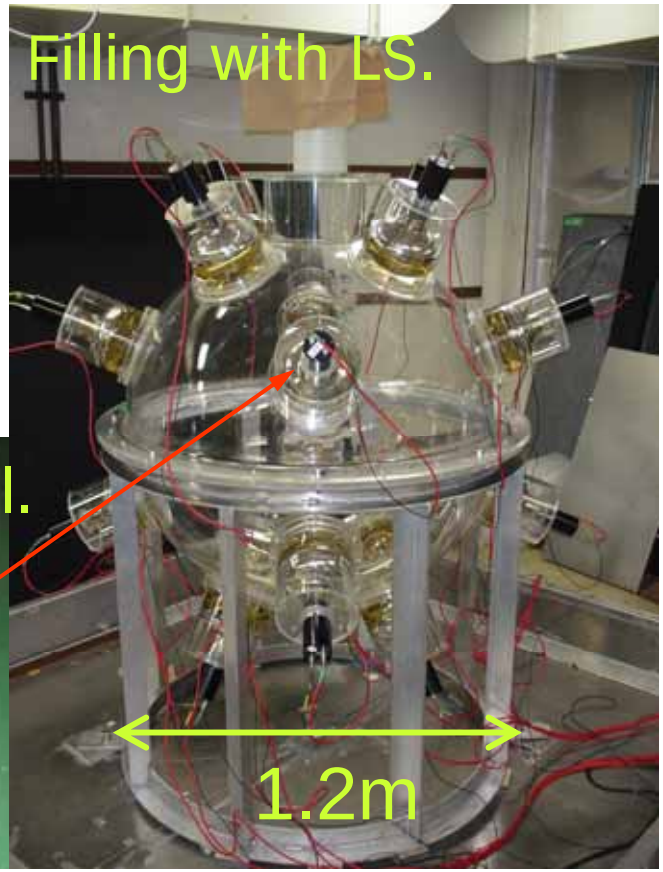

KEK
Kobe Univ.
Niigata Univ.
Tohoku Univ.
Okayama Univ.
Miyagi Univ. of Edu.
Tokyo Metropolitan Univ.
Tokyo Institute of Technology
Hiroshima Institute of Technology
Detector structure
Prototype Detector
Calibration System
BG study
Muon tracker
Simulation
LS study
Electronics R&D
DAQ

Prototype Detector Study

Main purpose: Testing of the 2nd layer of the KASKA detector. (LS γ Catcher)

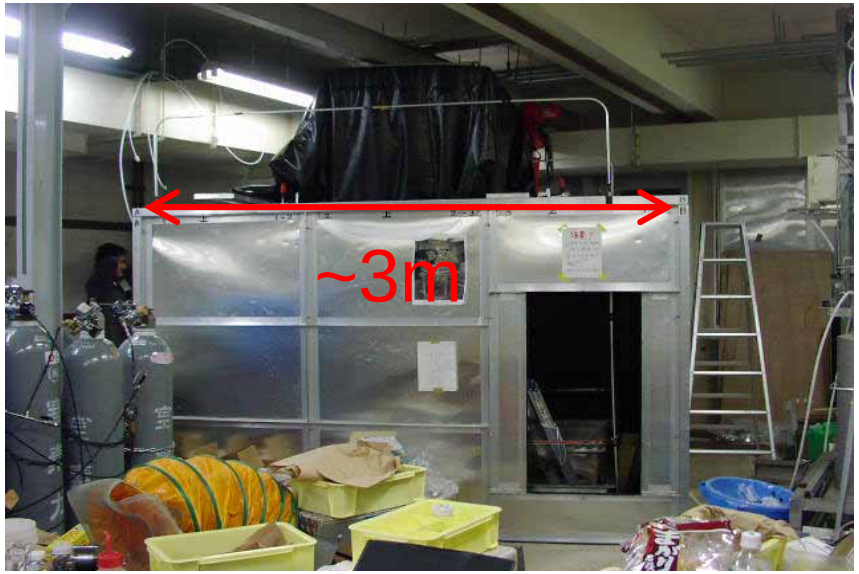
- Evaluation of γ ray containment
  - 8 MeV Neutron Energy spectrum
  - Evaluation of the 2nd layer thickness
- BG estimation from Gd spallation
- Neutrino observation @ JOYO reactor
- Test of calibration





Construction of the Prototype 1

Prototype Detector's Room



View from the inside (without roof)

Construction of the Prototype 2

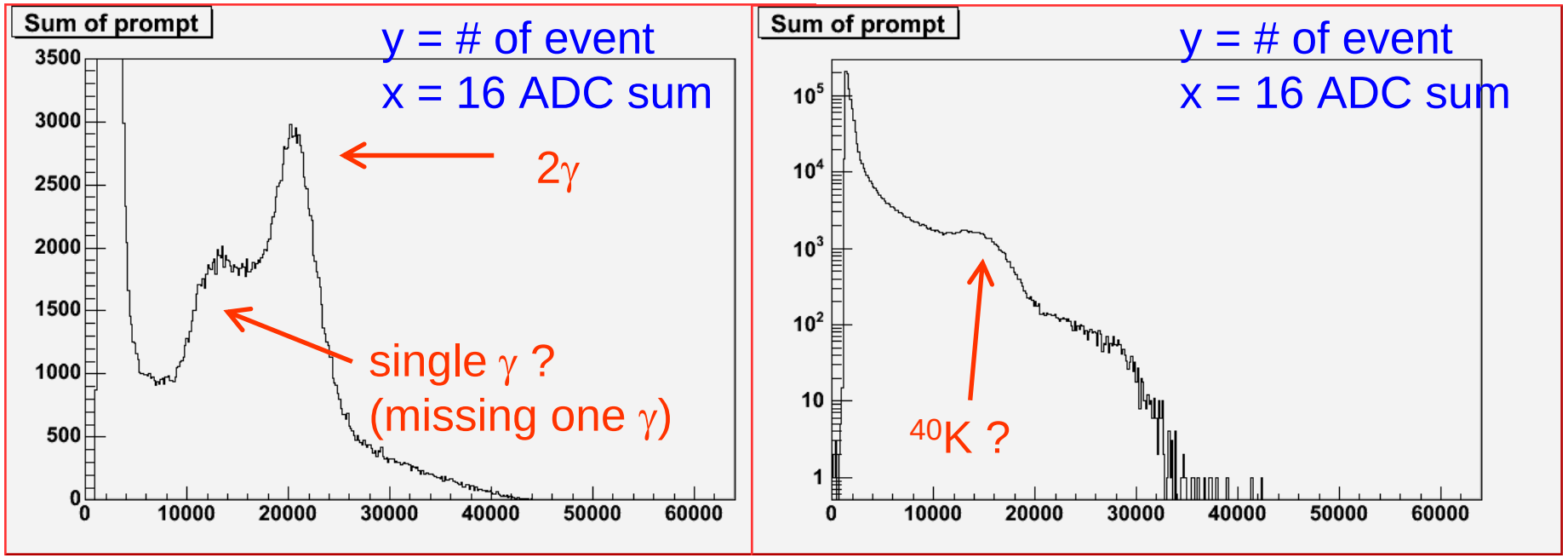
- Contents
  - Pseudocumene13.5%
  - Isoparaffin 86.5%
    - Paraol-850
  - PPO, BisMSB
- Light from the LS.
  - emission light from BisMSB

Present status of the prototype

2005/06/17 (The first data.)

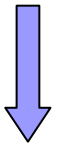
Preliminary

- ^{60}Co Source
- BG of Environment



Plan of the Prototype detectors

- PMT gain calibration has just started.
  - LED system and ^{60}Co source

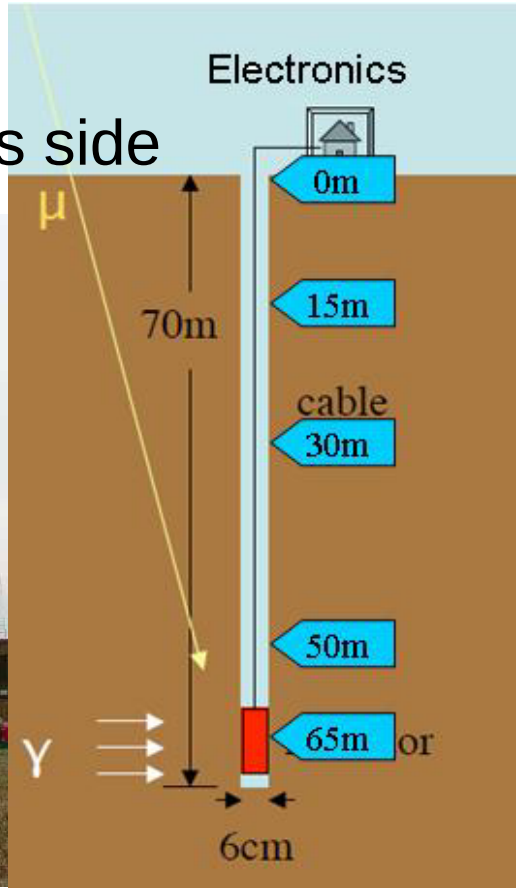


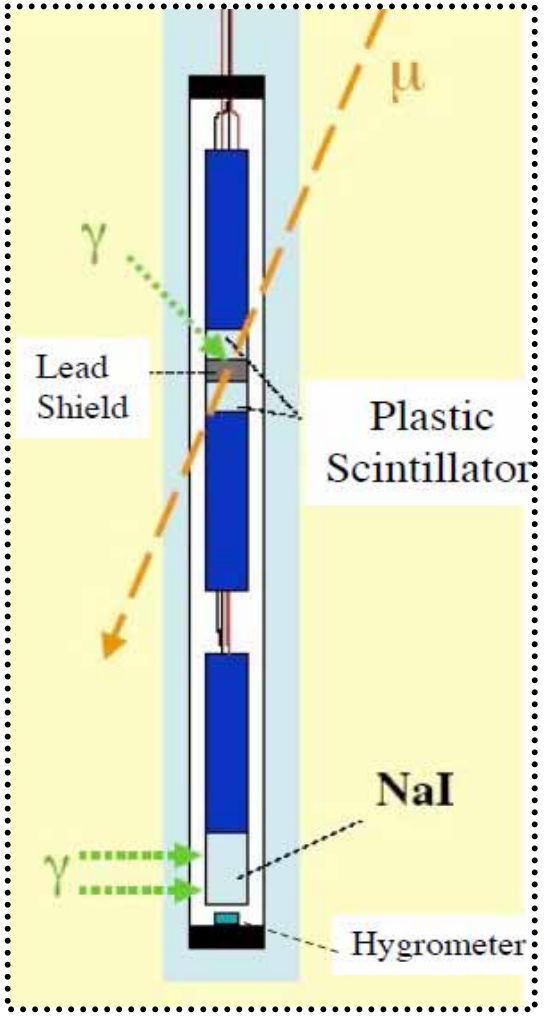
When all studies are finished. (this autumn)

- Prototype will be set near an Experimental Fast Reactor to detect real neutrino events.
  - Distance from the reactor, JOYO, is about 25-30m.
  - Contents of the detector will be Gd+LS. (Not LS)
  - It's challenging to detect reactor neutrino at the ground level.
- URL to JOYO (there is an English page)
  - http://www.jnc.go.jp/zooarai/joyo/indexs.htm

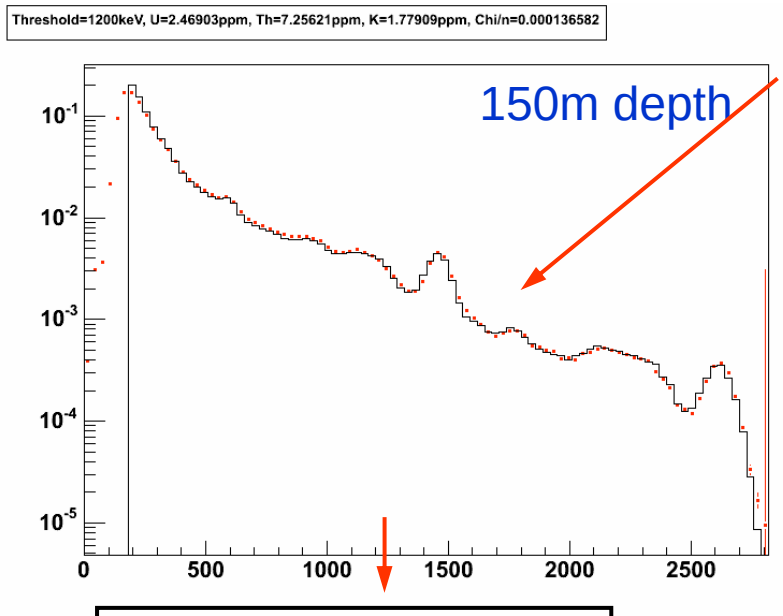
Cosmic ray and γ ray BG study

- Oct-Nov 2004
- Using boring hole @ near detector place
  - near #5-#7 reactors side





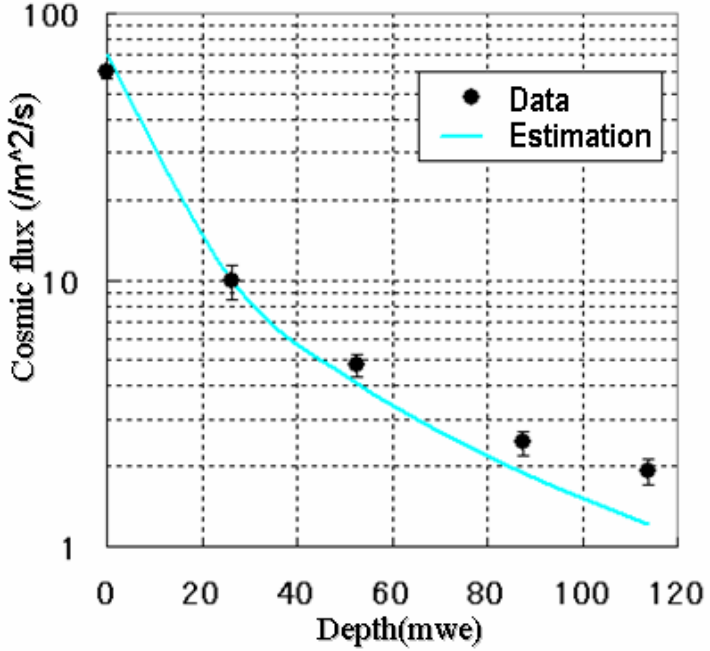
Results of BG study (TIT & TMU)



^{238}U 1.5~2.5 ppm
^{232}Th 6.8~7.3 ppm
^{40}K 1.8~2.2 ppm

Weight concentrations (ppm)

The γ spectrum is well reproduced by Geant4 with ~ 60 γ-ray energies.



Evaluation of neutron rate from cosmic ray simulation is going on.

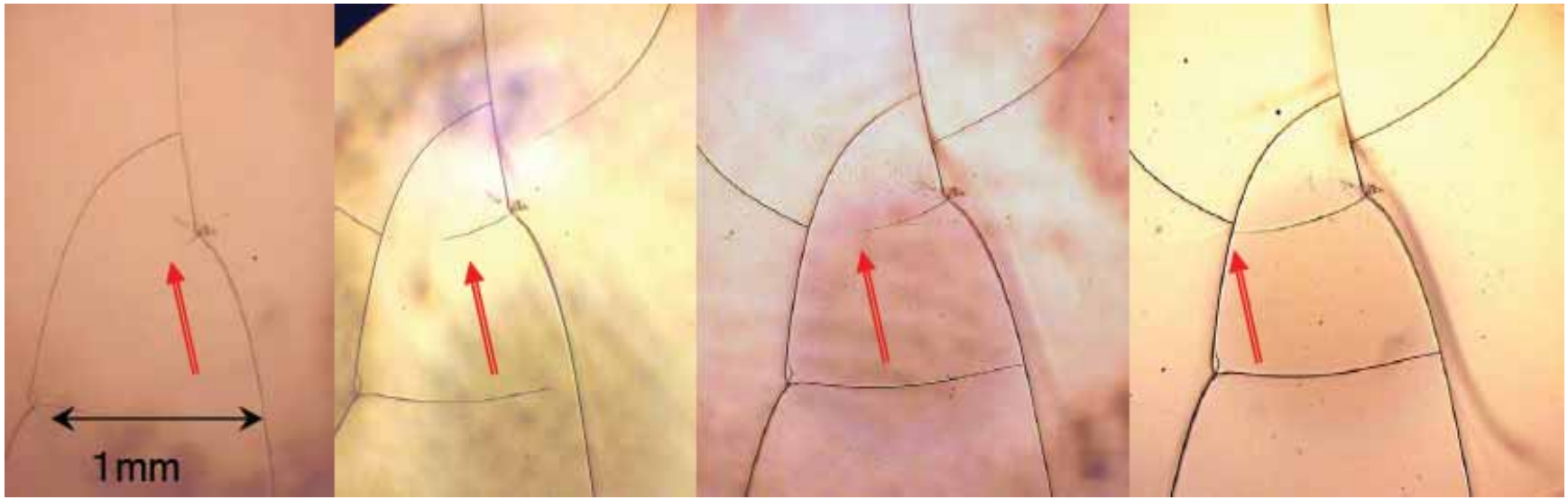
- BG@LS volume < 10Hz

(including other γ BG, from LS, Buffer Oil etc.)

Compatibility tests of acrylic (Niigata Univ.)

BAD example 100%PC @ 35 deg.

2 weeks 4 weeks 6 weeks 14 weeks



Our acrylic shows **no cracks** for actual PC concentration (40%).

Electronics & DAQ

- CAMAC based DAQ for prototype
- VMEbus or Compact PCI bus system for actual experiment

Acquisition rate 1.5kHz
(to be improved)

We started …

- Development of new 1GHz FADC board for actual experiment
- Network design at experimental site
- Software design

Conclusion

- KASKA project is proceeding steadily.
  - The collaboration is growing up.
- We got budgets for R&D.
  - Prototype detector study & Boring test
  - Cosmic ray tracker
  - Liquid scintillator
  - FADC development and others
- We apply for full budget in this year.
  - If we get it …
    - Starting the construction from 2006
    - Starting data taking from end of 2008