Position Sensitive Neutron Detector Development Programs in Japan

Neutron Science Laboratory (KENS),
High Energy Accelerator Research Organization (KEK)
and
Center for Proton Accelerator Facility
Japan Atomic Energy Research Institute (JAERI)

Michihiro Furusaka

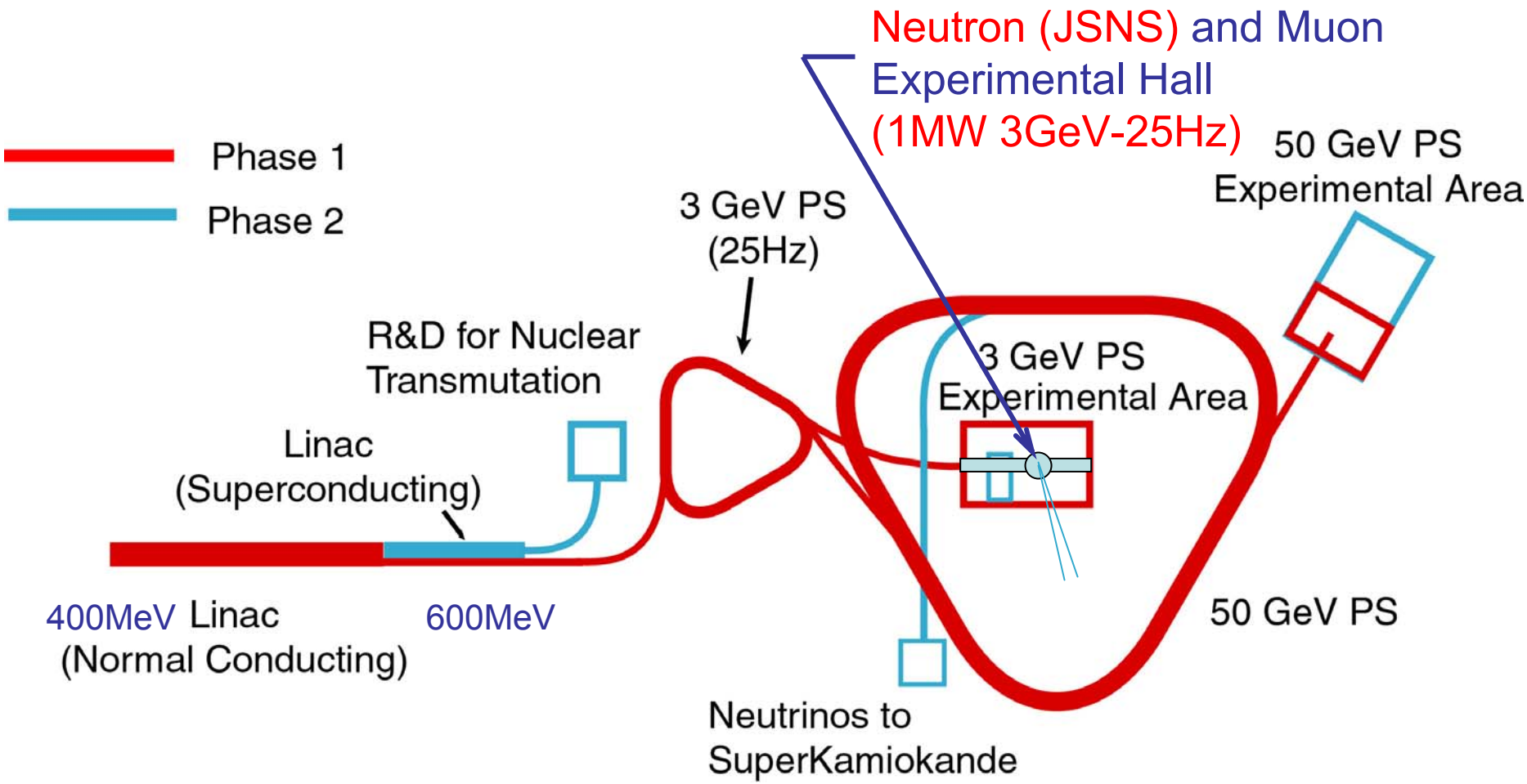
PSND2003

- The Third International Workshop on Position-Sensitive Neutron Detectors (PSND2003)
  - At KEK (High Energy Accelerator Research Organization), Tsukuba, Japan.
  - Co-organized by the J-PARC project, KEK and JAERI (Japan Atomic Energy Research Institute).
  - 1 st workshop: BNL, 1998
  - 2 nd workshop: HMI, 2001
- October 31- November 1, 2003. (PSND2003)

- International Symposium on Pulsed Neutron Science and Instruments (IPN2003)
- Oct. 27 - 30, 2003 (IPN2003)
- UK-Japan Neutron Science Workshop (UKJ2003) will be held. Oct. 31 - Nov 1, 2003 in Izura SPA (Pacific seaside), Japan

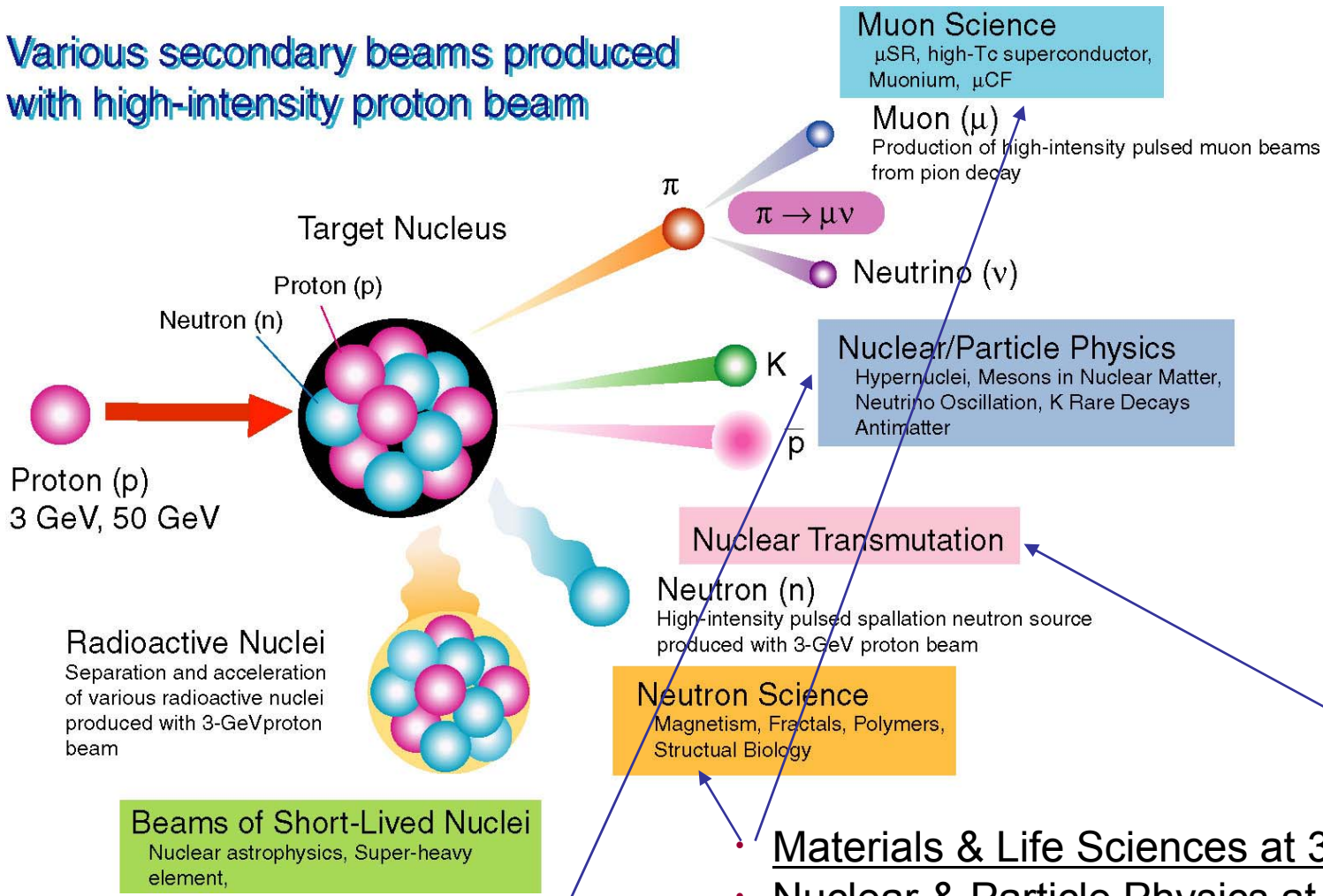
The J-PARC project

J-PARC Facilities Layout (Phase 1 & Phase 2)



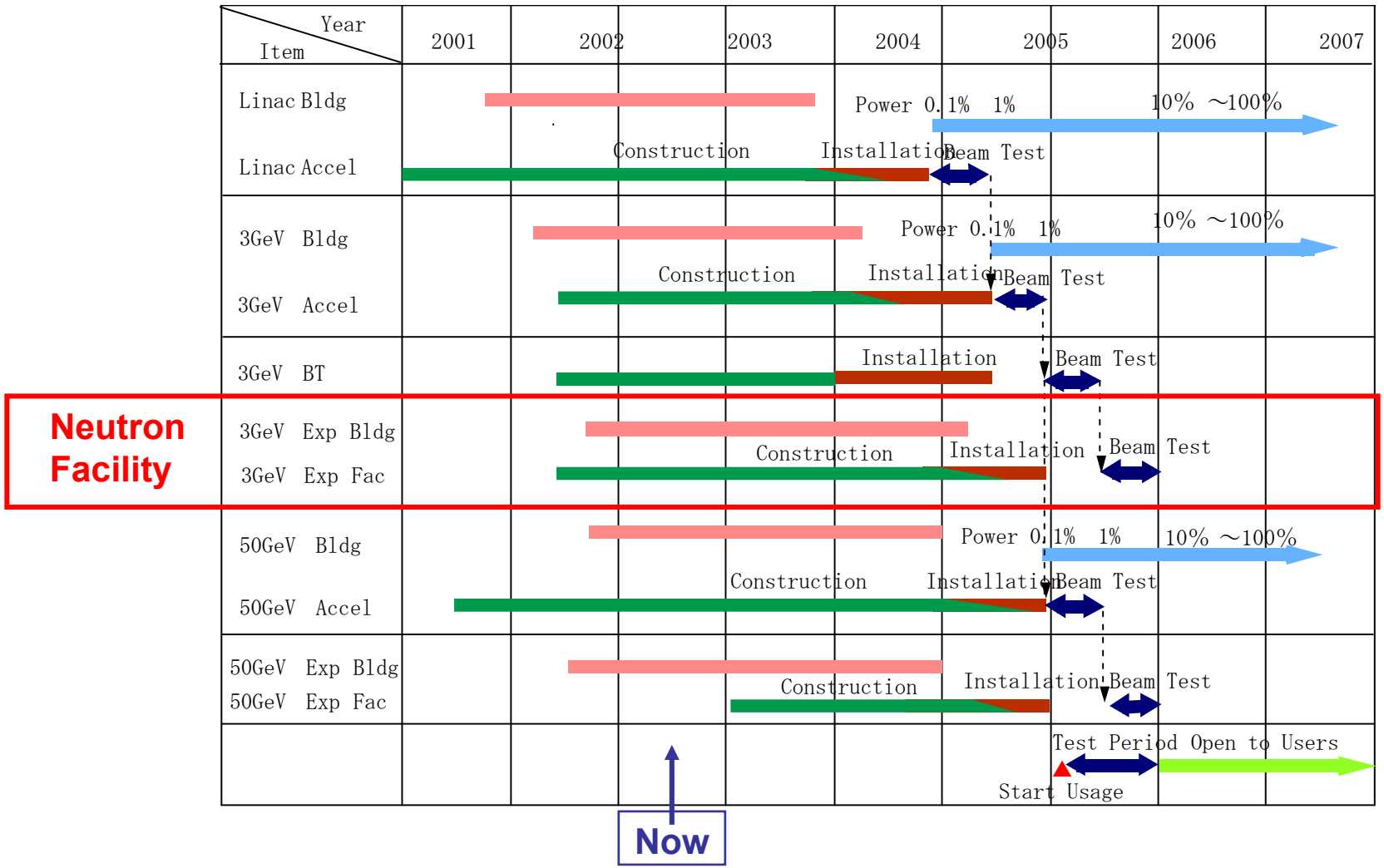
Expected View at the Completion

Three Goals at this Facility



- Materials & Life Sciences at 3 GeV
- Nuclear & Particle Physics at 50 GeV
- R&D toward Transmutation at 0.6 GeV

Construction Schedule & Commissioning



Two Big Phase 2 Projects • Neutrino (Budget request sent to MEXT) and Transmutation

Ground Breaking Ceremony

June, 2002

Construction site on May 2, 2003

Linac:

Front-end beam test at KEK

3MeV RFQ & chopper

Below: Linac construction site

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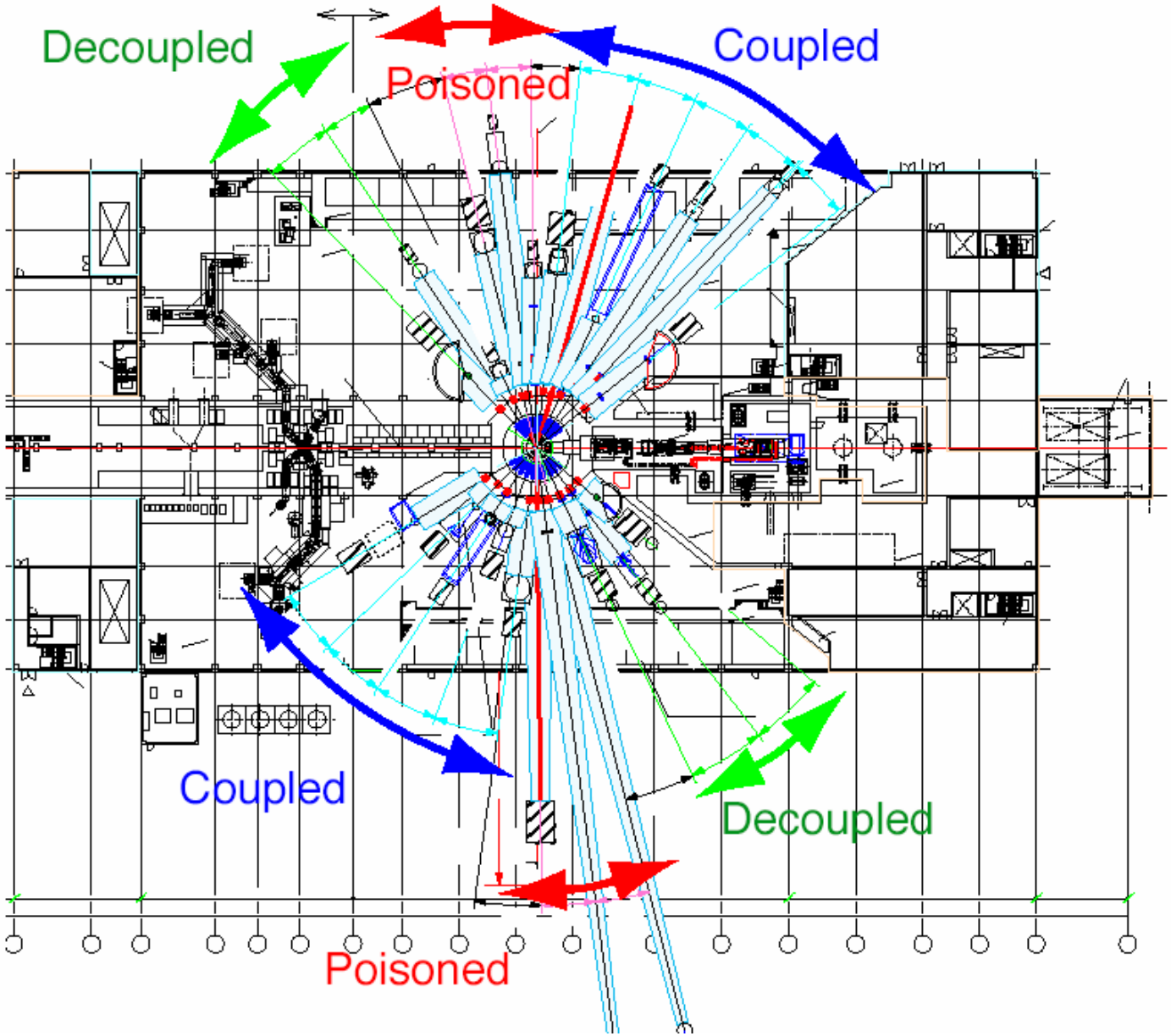
3 GeV Area

May 2, 2003

Preliminary instrument layout

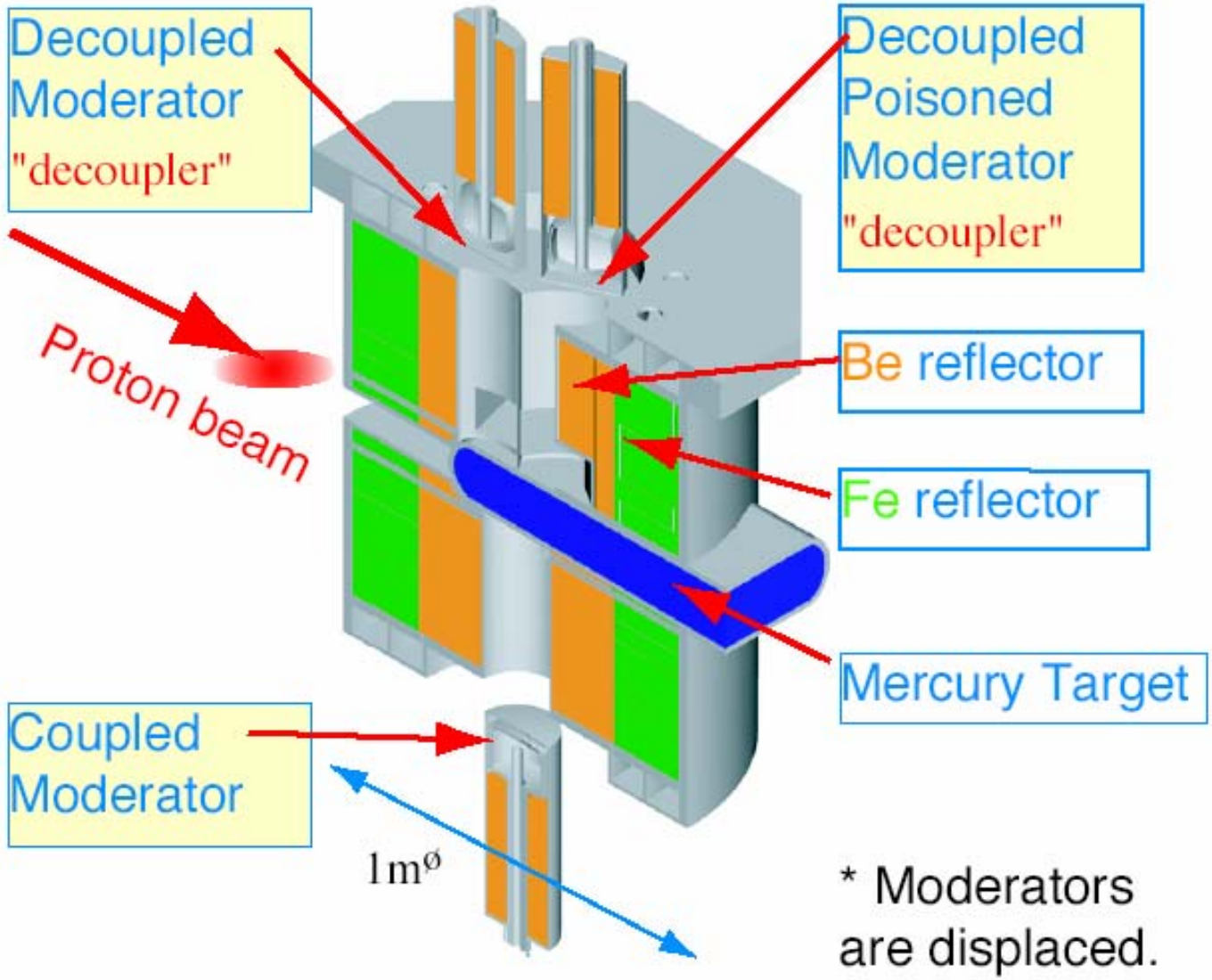
About half of the instruments are viewing at the coupled moderator.

23 + (6) beamlines with individual shutters.



Moderator-Reflector-Assembly

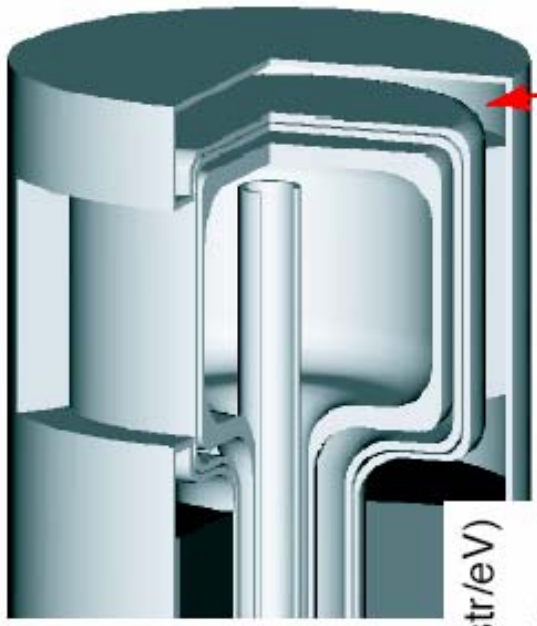
- Supercritical Hydrogen Moderators
  - Only three Moderators
  - No water moderator
- 100 % "Para" hydrogen assumed
  - AIC 1eV decoupler (Ag-In-Cd)
  - Nearly no absorber near coupled moderator



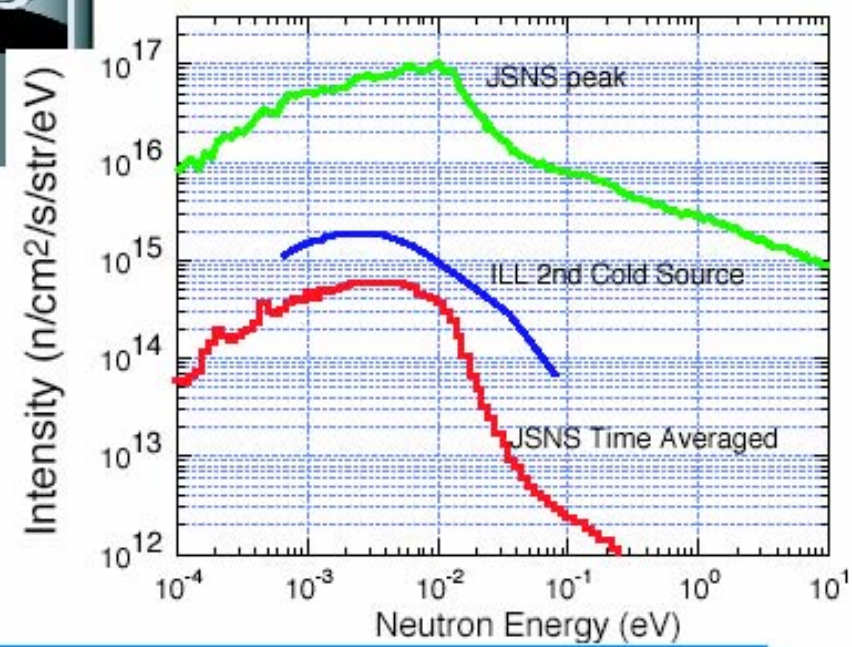
* Moderators are displaced.

High Performance Coupled Moderator

- "Para" hydrogen is transparent
  14 cm$^{\phi}$ × 10 cm^{H}
- Cylindrical shape
  – To minimise angular dependence.
- Avoide absorber near the moderator
  - e.g. No decoupler, SUS
- About 50% of the Instruments veiws Coupled moderator



premoderator
14 cm$^{\phi}$ × 10 cm^{H}
Usually ~5cm thick



Detector development

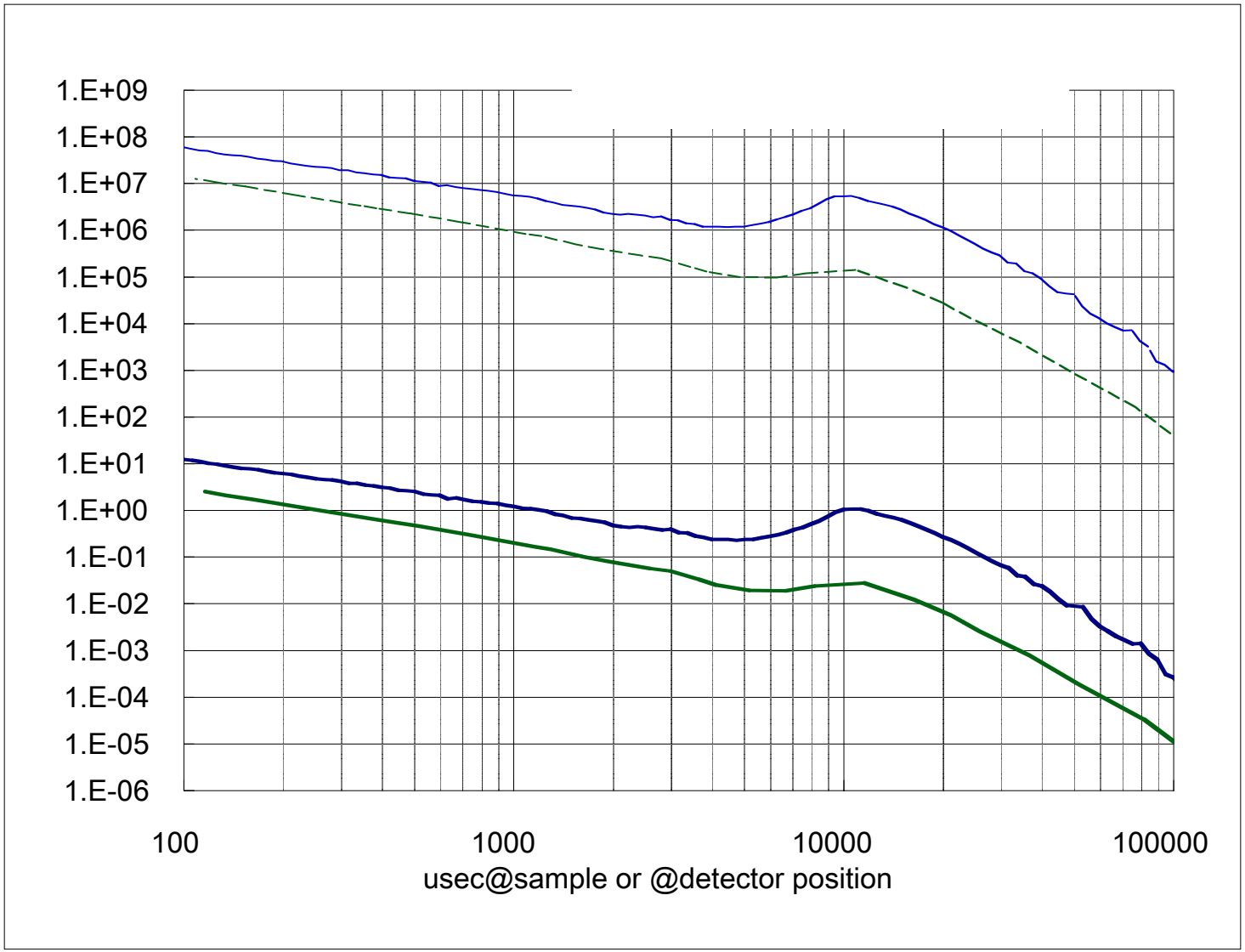
*Who are doing what?

- JSNS Detector development team
  - Core team: M. Furusaka (KEK),
    K. Sakai (TIT), H. Takahashi (Univ. Tokyo), Soyama (JAERI)
  - Scintillation detector: K. Sakai (TIT), Katagiri, Matsubara, OKU (JAERI)
  - MSGC, H. Takahashi(Univ. Tokyo), Ino, Satoh (KEK)
  - MPGC: Yamagishi, Nakamura (JAERI)
  - Readout electronics: Satoh (KEK), Yamagishi, Birumachi (JAERI)
  - ASIC: H. Takahashi(Univ. Tokyo), Satoh (KEK)
- Riken & JAERI-NOP group
  - WLSF development: H. M. Shimizu, Adachi, Oku
  - Multi-anode PMT: H. M. Shimizu
- Yamanashi univ. & Daiichi-Kiden
  - LBO glass & single crystal scintillation material: Hosoya, Ishii
- Hokkaido univ.
  - GSO scintillation detector (Kaneko)
  - Scintillation detector, Characterization (Y. Kiyanagi)
- Kyoto univ., Yamagata univ., Musashi IT, etc.

JSNS detector development strategy-1

- Requirements:
  - ~3-5 mm or worse resolution ≈ sample size (boring?)
    - In some cases ≤1mm
  - $\geq 10^6$ cps (10%deadtime)
  - Modular type detector with very little gaps.
  - Reasonable cost
    - <<$1M/m^2
    - $4.6k/2”PMT --> $1.8M/m^2
    - Cf: PSD tube system at KENS: $0.22M/m^2

Count-rate estimation on a detector pixel

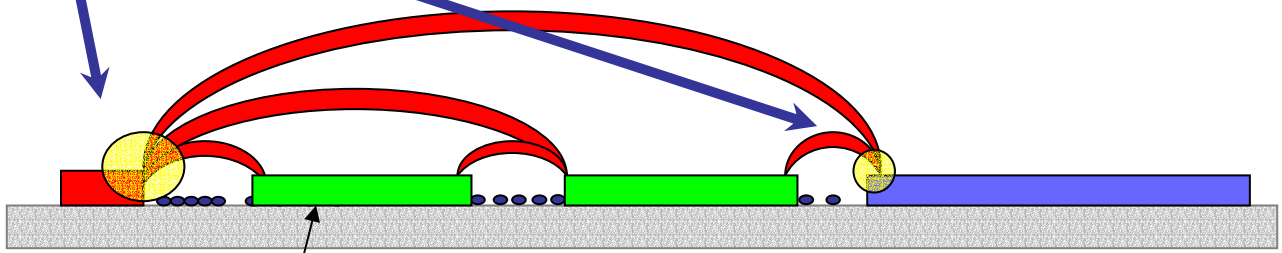


Detector candidates for JSNS

1. Micro-strip gas counter (MSGC)
   1. Multi-grid type MSGC (M-MSGC)
   2. Capillary plate + MSGC, Pin type (MPGC)
   3. Tube type MSGC
   - Long-time stability?
   - Radiation damage?
2. Scintillation detector
   1. WLSF-type for 0.3-0.5 mm resolution (achieved)
   2. Scintillator + Flat panel type PMT (2inch sq., 64ch)
   - Gamma sensitivity?

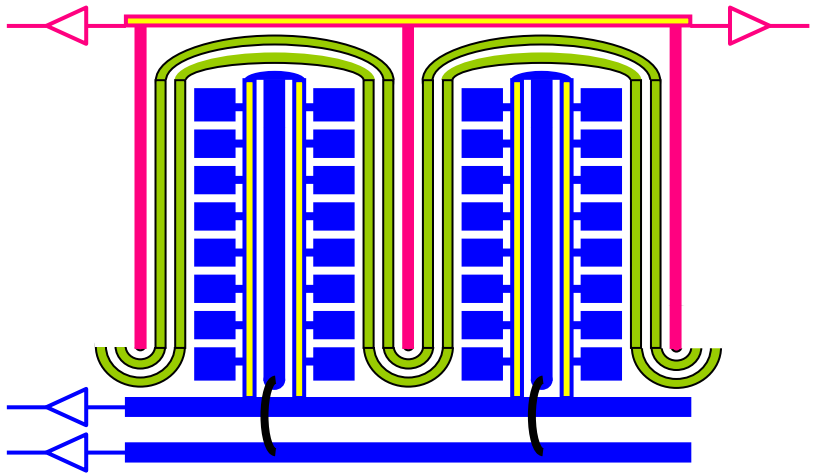
Multi-Grid Type MSGC (M-MSGC)

SEPARATE **Strong electric field** regions

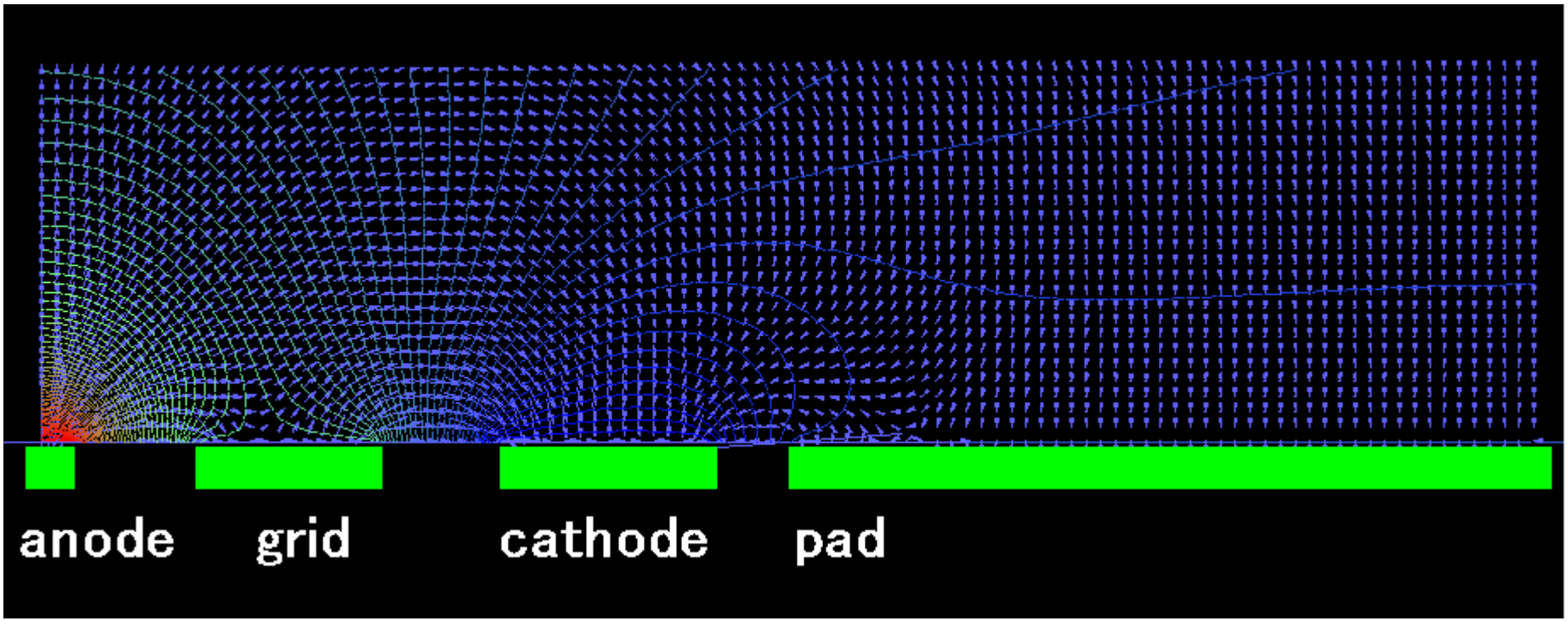


ANODE GRID#1 GRID#2 … CATHODE

Effectively REMOVE
surface charge



Electric field



200 um

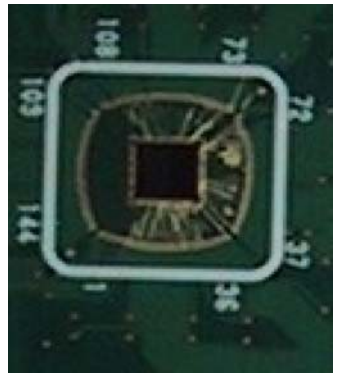
Calculated by ELFIN

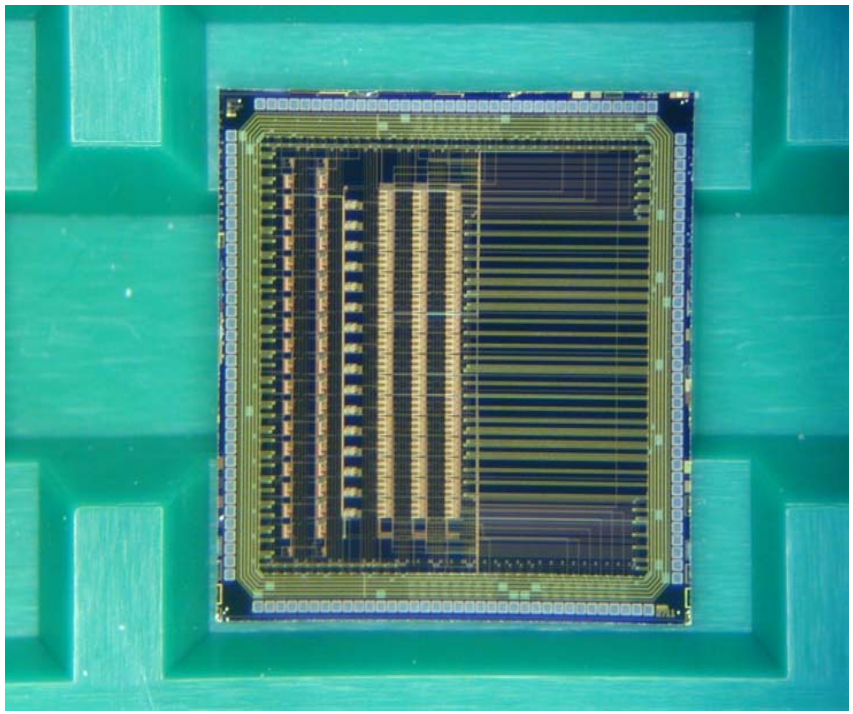
Enabling technologies

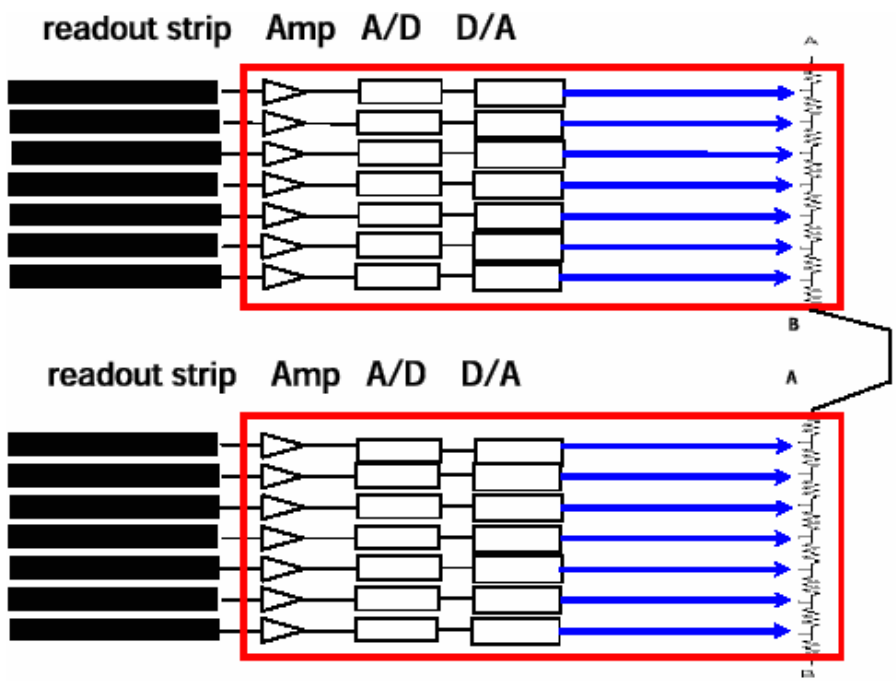
1. ASIC (Application Specific IC)
   - Encoding in a chamber
   - For MSGC & PMT
2. New Scintillation Materials
   - LBO glass
3. Flat-panel type
   Multi-anode Photomultiplier tube (MA-PMT)
   - High quantum efficiency PMT (GaAs)
     - Hamamatsu & RIKEN

Development of Readout Custom IC (ASIC)

- Reduce the number of interconnections through a high-pressure vessel.
- Accommodate bare chips inside a gas vessel.
- Development of new signal encoding methods.
- Also for photo-multiplier tube (MA-PMT)







- ROHM 0.35μm CMOS process

Micro-strip gas counter (MSGC)

~3-5mm resolution,

>10^6cps (10%deadtime),

Area detector, gas tube

Long-time stability?

Scintillation detector

~3-5 mm resolution,

>10^6cps (10%deadtime),

2 inch panel-type PMT

Gamma sensitivity?

Micro-pin gas counter +GEM (MPGC) JAERI+Kyoto

Full readout

Multi-grid type -MSGC U. Tokyo+KEK

Custom IC (ASIC) U. Tokyo

Scintillator Material (Yamanashi univ. JAERI, etc)

LiBO, Li-6, ZnS, etc.

Direct coupling

WLSF for high-resolution

0.2~0.3 mm resolution,

Multi-anode photo-multiplier tube

High quantum efficiency (RIKEN, Hamamatsu)

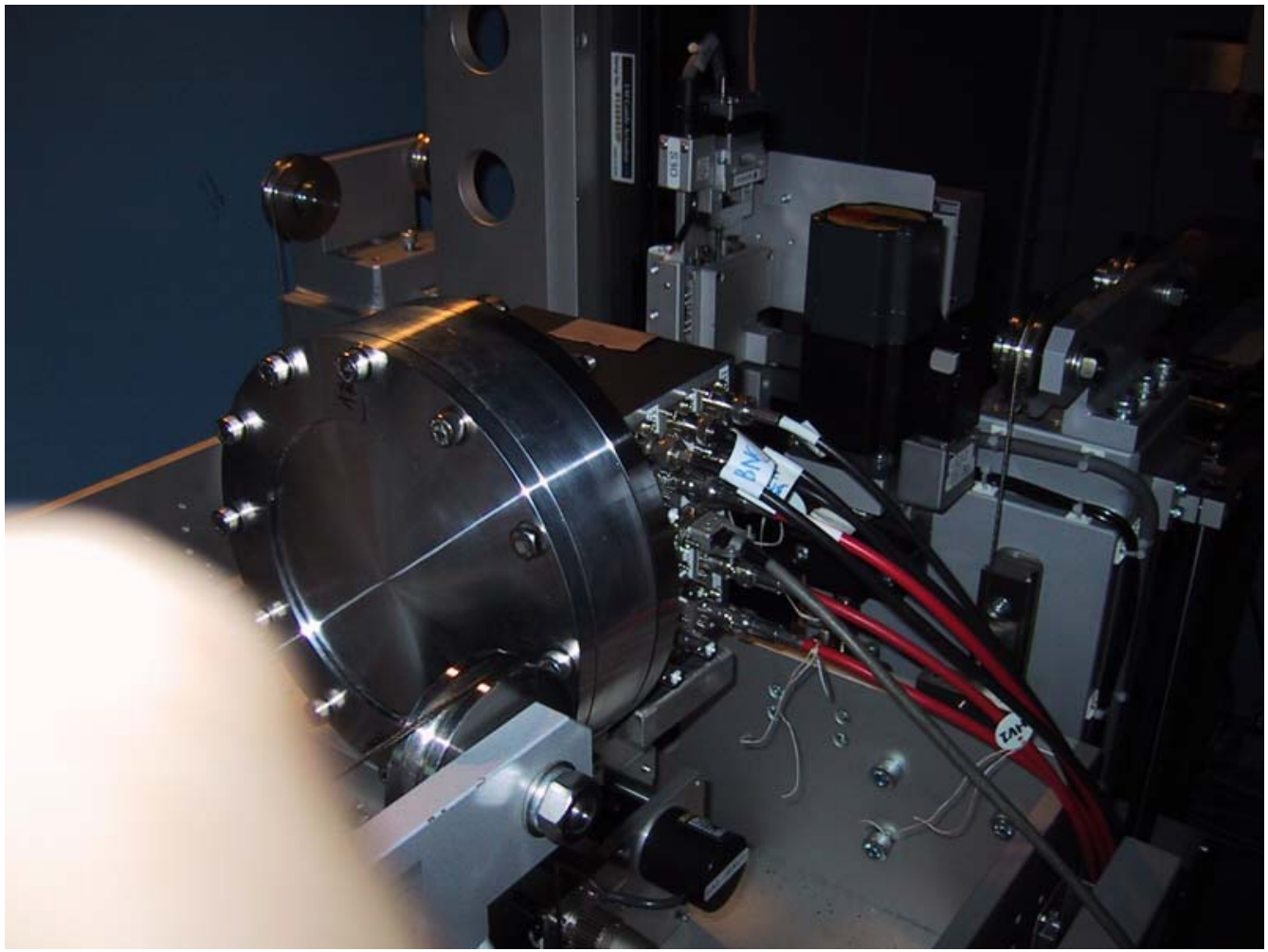
M. Furusaka

J-PARC: K. Sakai, H. Takahashi, K. Soyama, M. Katagiri H.M. Shimizu

T.I.Tech, U. Tokyo, JAERI RIKEN NOP etc.

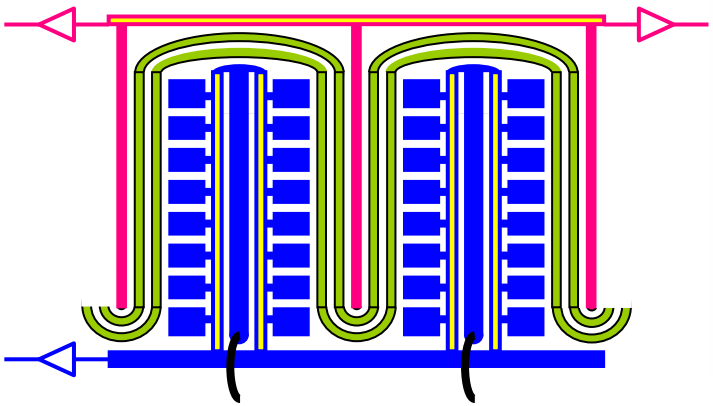
MSGC test chamber

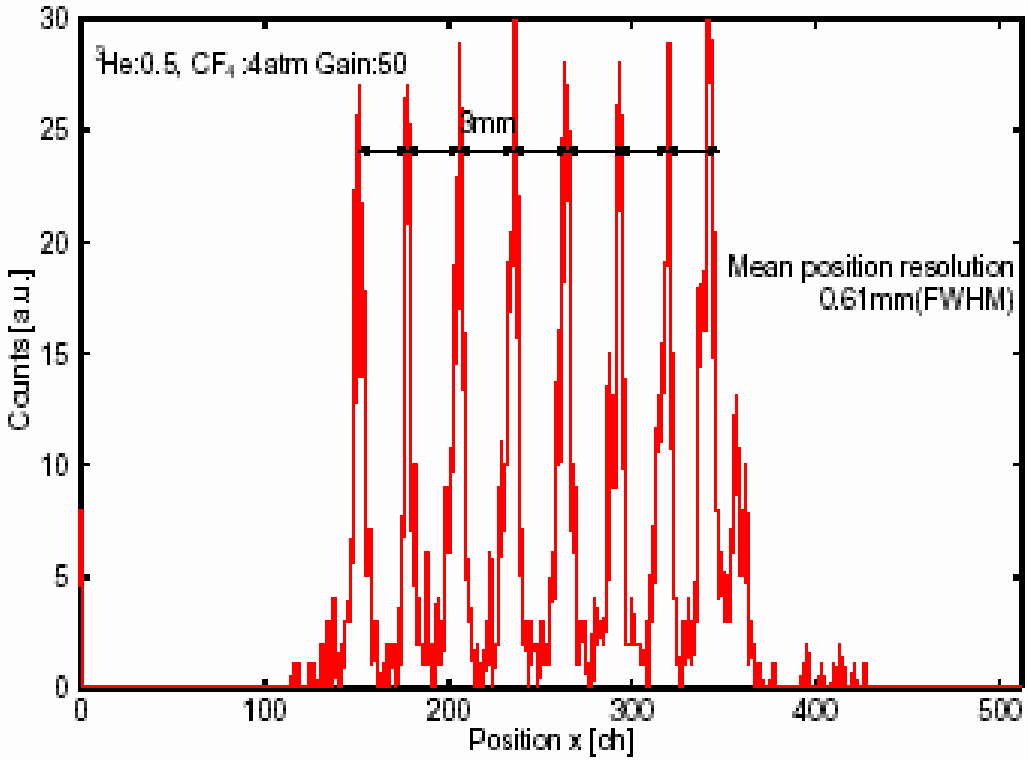
- Test of a ^{3}He sealed M-MSGC
  - ^{3}He 0.5 bar + CF_4 5 bar



Multi-grid type MSGC (M-MSGC)

- Prototype MSGC
  - 50mm*50mm plate
  - 200mm*200mm under development





•Multi-grid type Micro-strip pattern

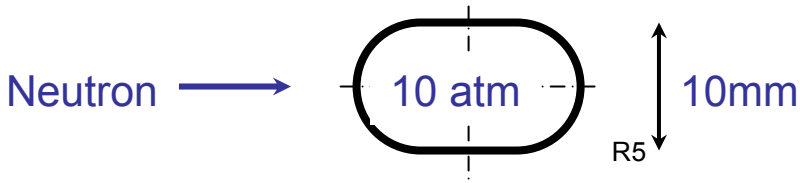
•Position resolution ~0.6mm
- •4atm CF_4 Stopping gas
- •He-3 0.5 atm

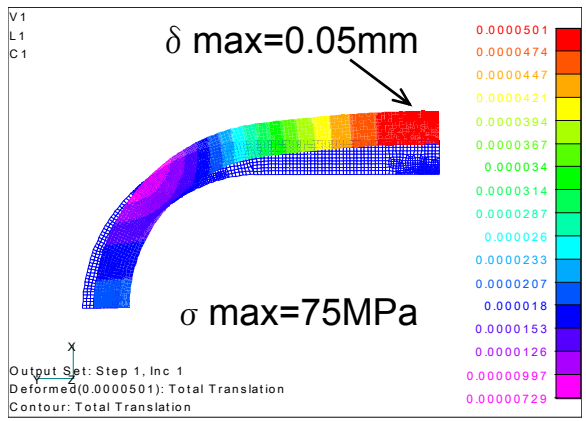
Modular Detector

- Tube type MSGC
  - Modular design
  - Minimize gaps between the detector tubes
- Under design
  - Prototype of single anode board just finished.
  - Binary encoding scheme along the tube using array of PAD.
  - Tube under design

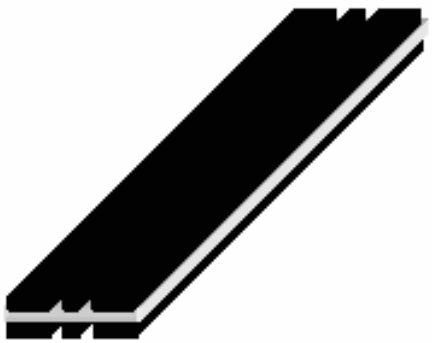
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

FEM analysis of the tube



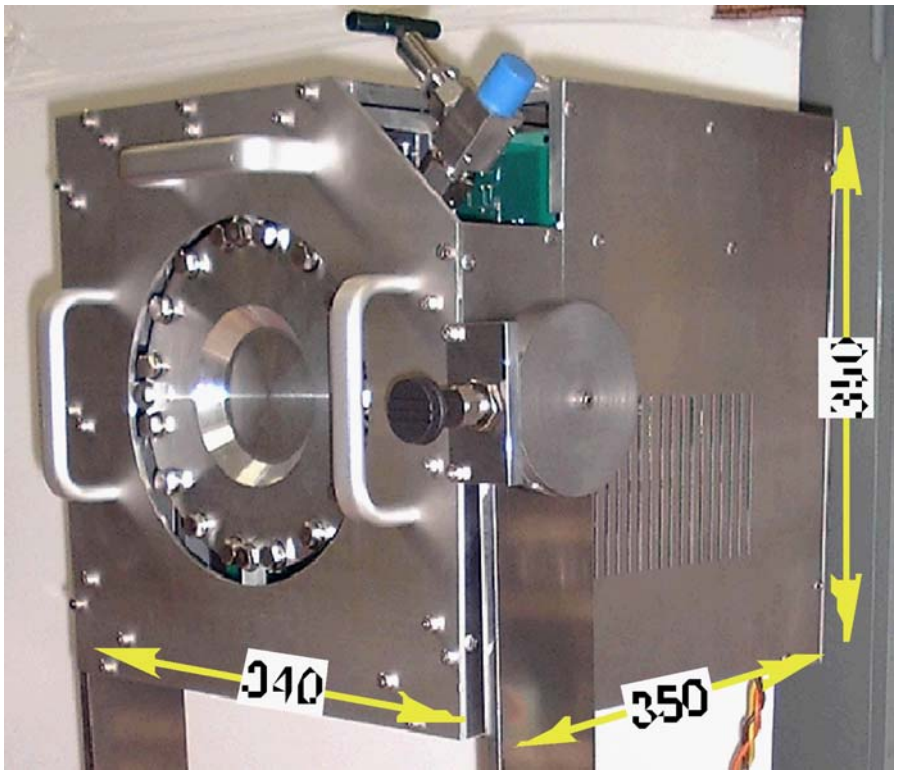


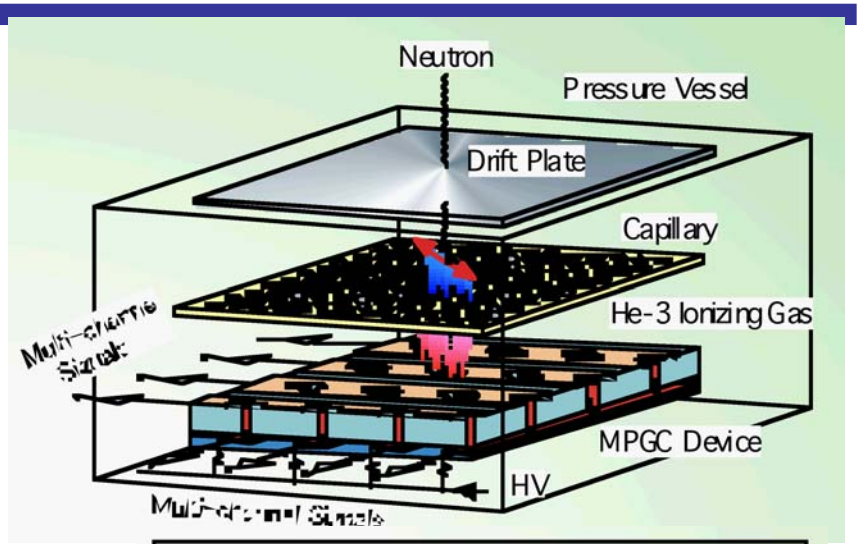
Single anode MSGC board

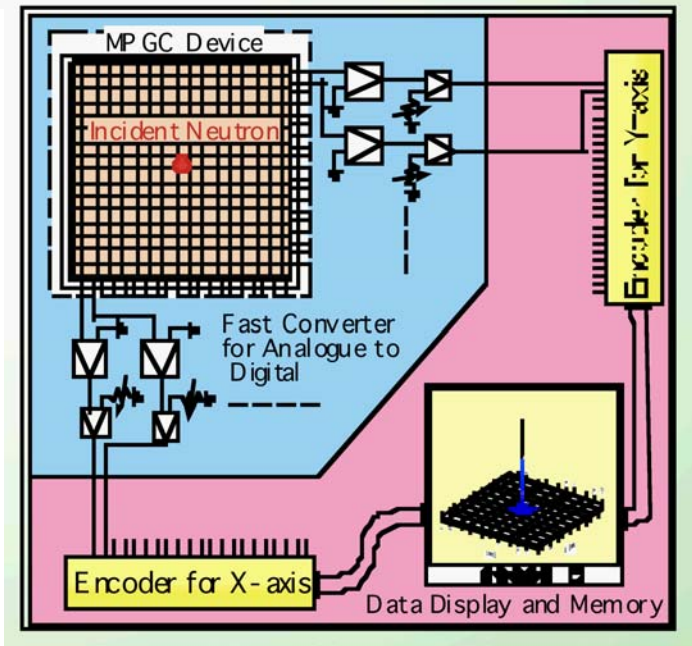


Micro-Strip/Pin Gas Counter

- He-3 gas
  + Capillary Plate + MSGC
  + Full readout electronics
- Micro-Pin Gas Counter



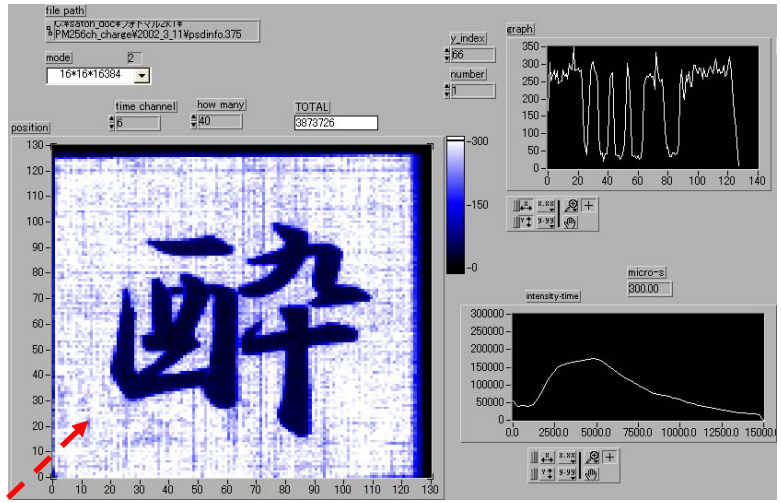




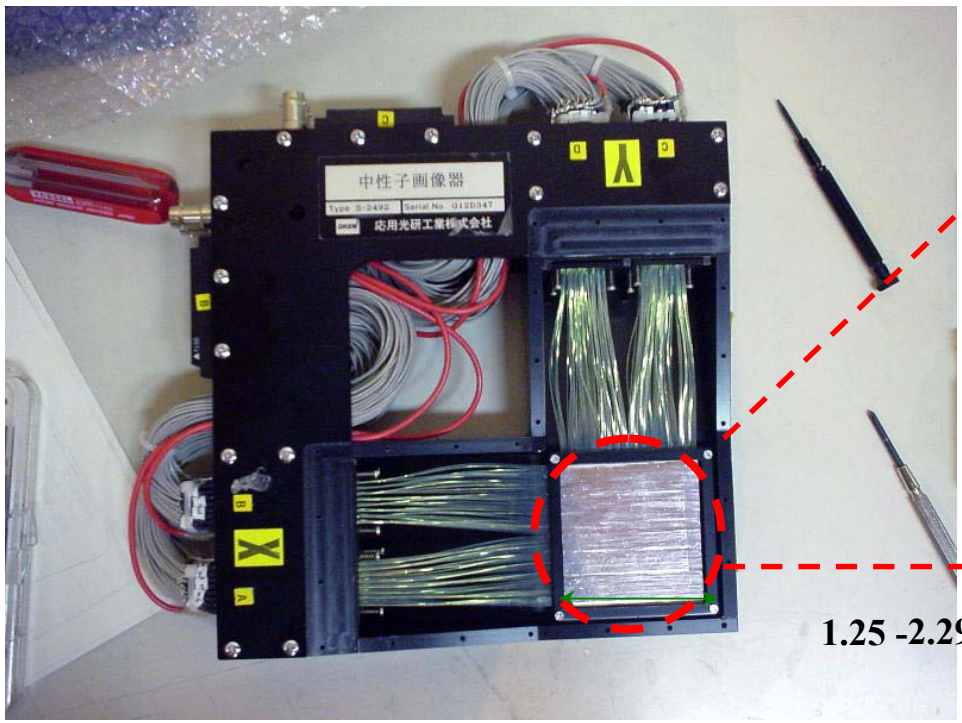
Yamagishi, Nakamura, Soyama (JAERI)

Wavelength-Shift Fiber Scintillation Counter

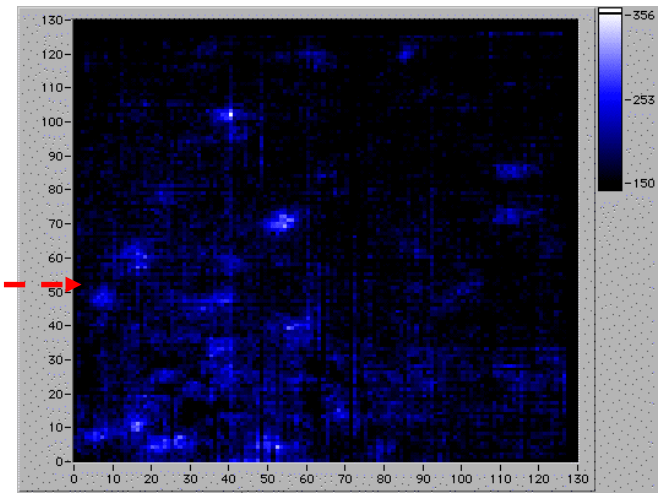
ZnS (^{6}Li)
Sensitive Area: 50×50mm^2
Detection efficiency: ~ 6% about 4Å
Position resolution: ~ 0.3×0.3mm^2



Neutron Image with a Cd mask



PM256-PSND (Cross fiber-arrays type)

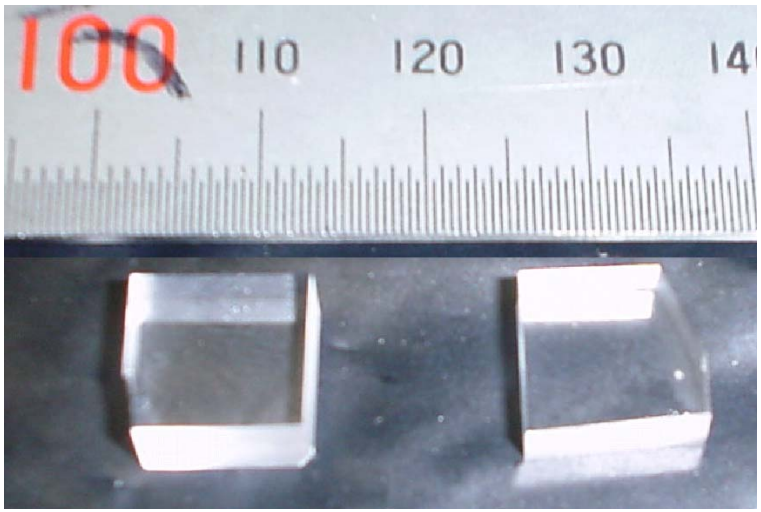


Single-Crystal Diffraction Pattern

Sakai (TIT), Adachi, Shimizu (RIKEN), Satoh (KEK) et al.

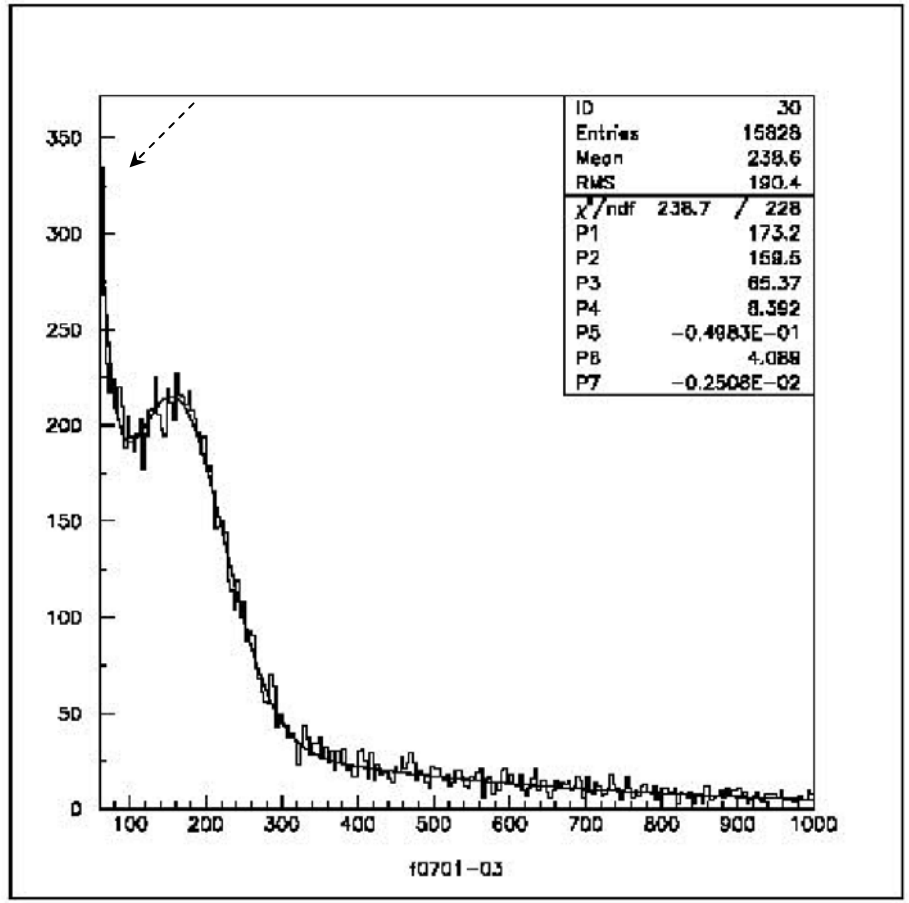
LBO-Glass Scintillator

- Parametric study of Li-glass scintillator



LBO glass (Yamanashi-Univ.)

- 2inch flat panel PMT
  - High quantum efficiency
  - 64/256 ch.



LBO-G9; neutron-H9 ; HV=2200;

PHA measurement with neutron

Direct coupling scintillation detector

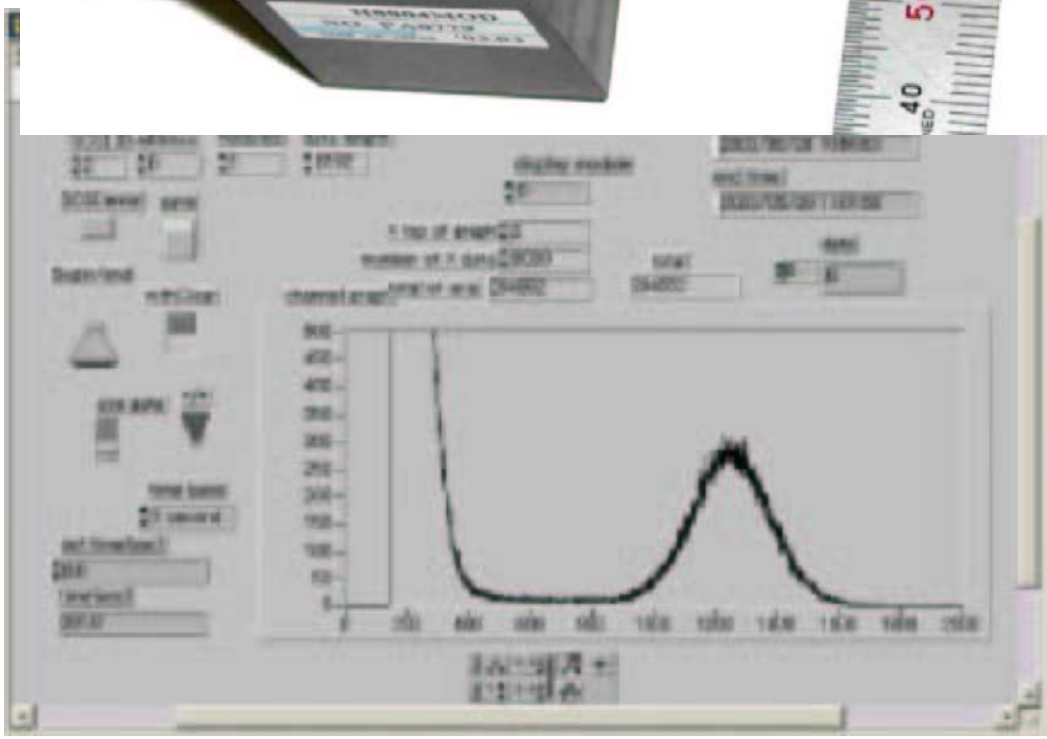
- Scintillator + Flat panel MA-PMT direct coupling
  - K. Sakai will talk about the current status.
- Li-6, LBO
- How to couple with MA-PMT
  - Conceptual design underway.
- Readout electronics prototype already exists
  - 32 ch. Time analyzer VME module developed.

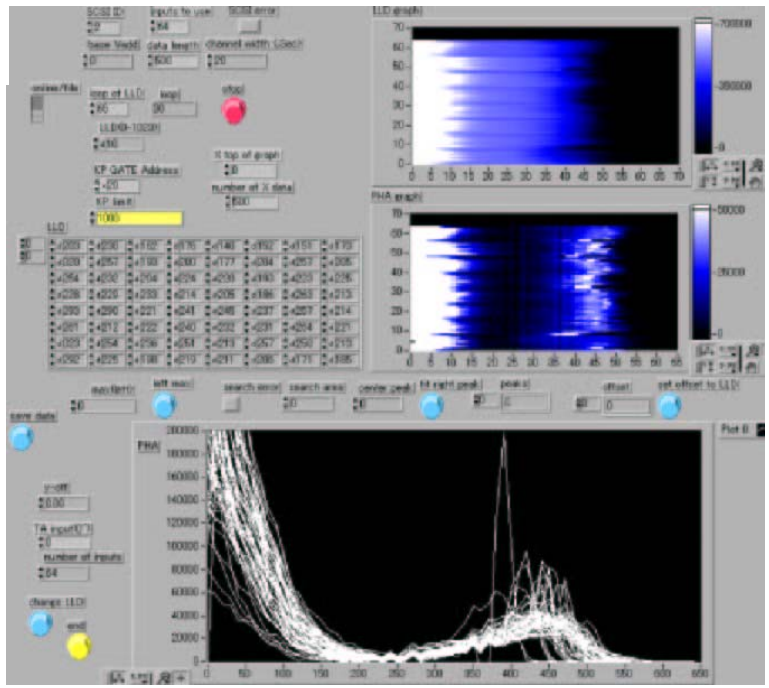
Flat Pannel type multianode photomultiplier tube assembly, H8500

Hamamatsu

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

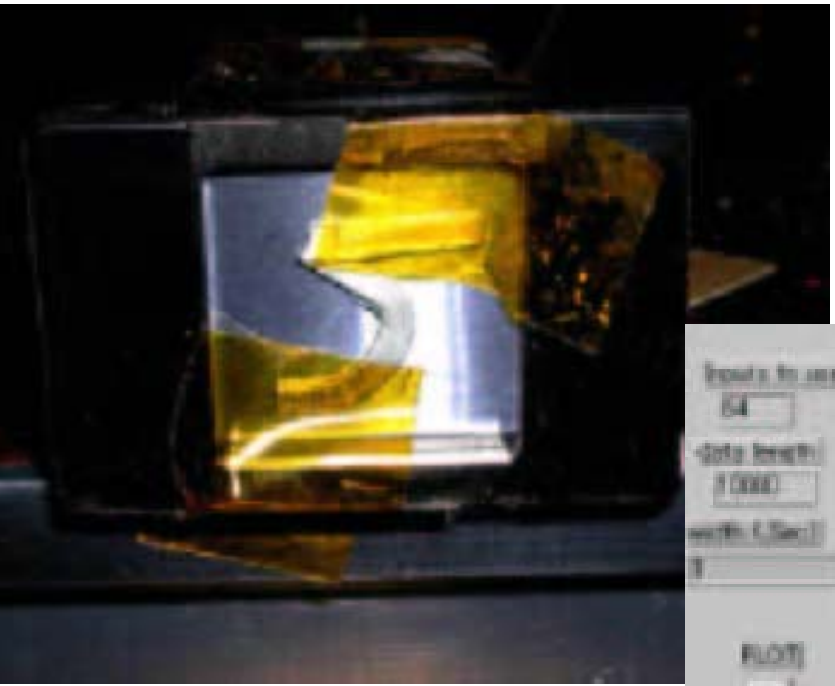
Just arrived this morning!

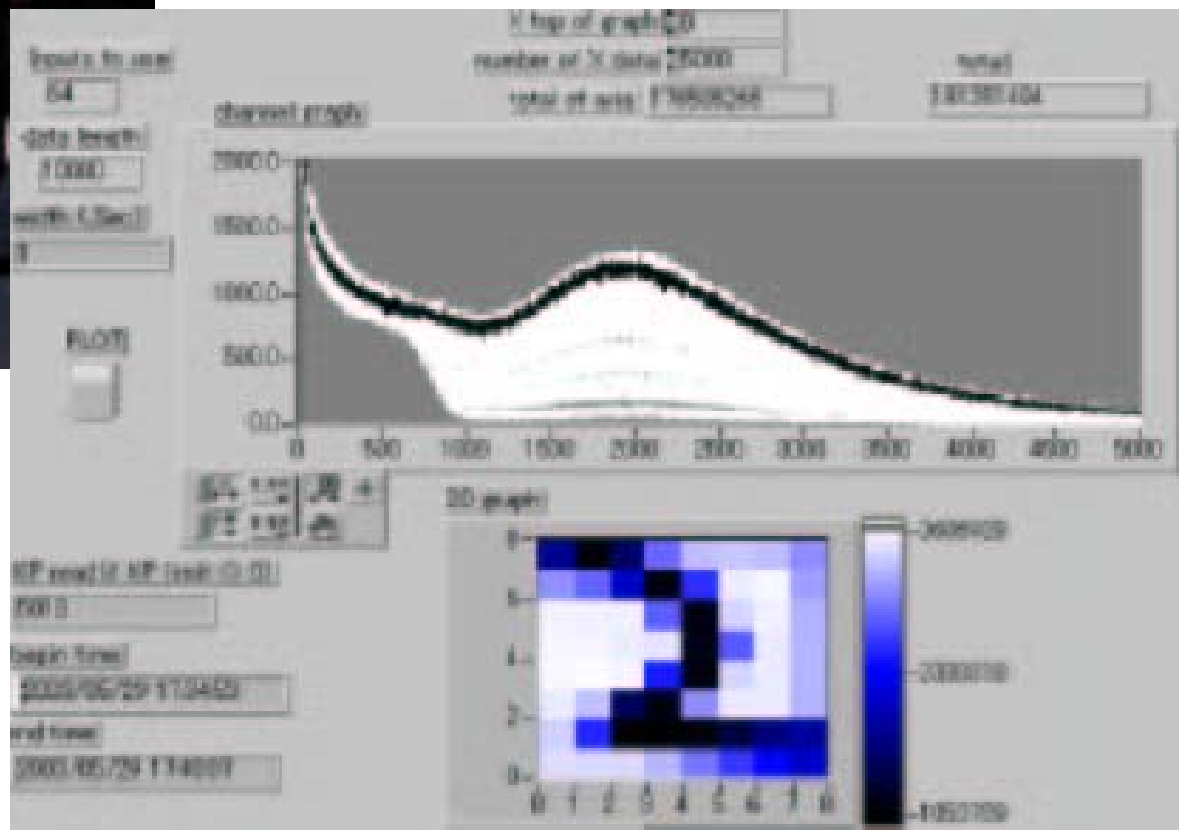




Kiyanagi (Hokkaido univ), Satoh (KEK)

Just arrived this morning!-2





Summary

- Current status of the J-PARC project
  - Site preparation underway
  - First beam in 2007
- M-MSGC
  - 0.6mm resolution obtained.
  - A working prototype in a few months time.
  - Tube type under design
- WLSF type scintillation detector
  - 256*256 channel prototype.
  - 0.3mm position resolution obtained
- Direct coupling scintillation detector R&D underway
  - LBO glass, etc.
  - High quantum efficiency MA-PMT under development.
  - Small scintillators coupled with MA-PMT under test.
  - Conceptual design of scintillator + flat-panel PMT underway.