A-RD-12
Scintillating fibers detection system for superconducting RF cavities

Y. Yamamoto *on collaboration behalf*

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Outline

- First results during cavity vertical tests
- Future tests
- Summary

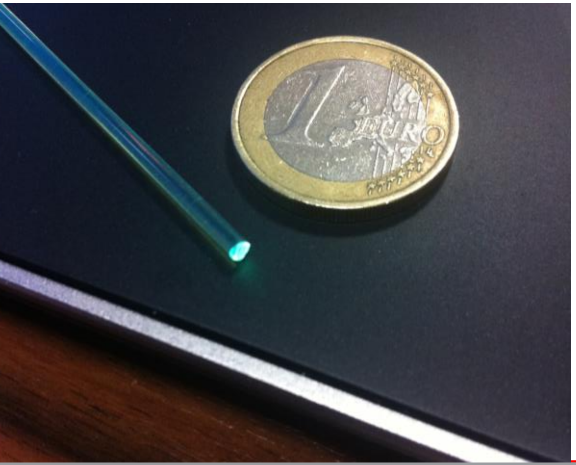
Experimental set-up

DE LA RECHERCHE À L'INDUSTRIE

cea

Test in CEA will be performed with:

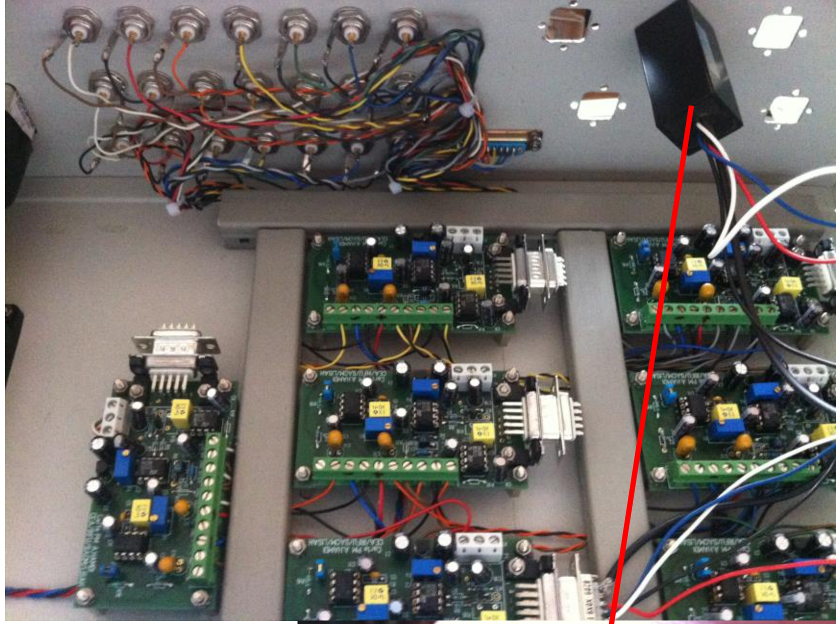
- Scintillating fibers: BCF-20 from Saint Gobain
- PM Hamamatsu H10721-110



Specific Properties of Standard Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	# of Photons per MeV**	Characteristics / Applications
BCF-10	blue	432	2.7	2.2	~8000	General purpose; optimized for diameters >250µm
BCF-12	blue	435	3.2	2.7	~8000	Improved transmission for use in long lengths
BCF-20	green	492	2.7	>3.5	~8000	Fast green scintillator
BCF-60	green	530	7	3.5	~7100	3HF formulation for increased hardness
BCF-91A	green	494	12	>3.5	n/a	Shifts blue to green
BCF-92	green	492	2.7	>3.5	n/a	Fast blue to green shifter
BCF-98	n/a	n/a	n/a	n/a	n/a	Clear waveguide

* For 1mm diameter fiber; measured with a bialkali cathode PMT
** For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity

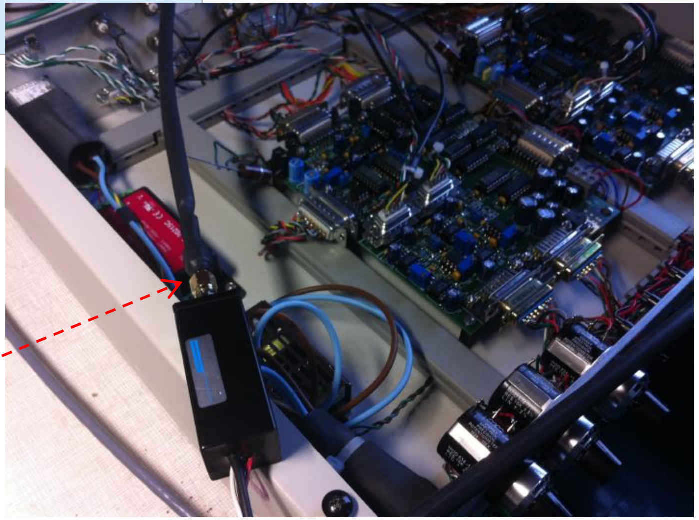


Common Properties of Single-clad Fibers –

Core material.................................Polystyrene
Core refractive index 1.60
Density...1.05
Cladding material..............................Acrylic
Cladding refractive index 1.49
Cladding thickness, round fibers ....3% of fiber diameter
Cladding thickness, square fibers ...4% of fiber size
No. of H atoms per cc (core)............4.82×10^{22}
No. of C atoms per cc (core) ....4.85×10^{22}
No. of electrons per cc (core) ....3.4×10^{23}
Operating temperature.....................-20°C to +50°C
Vacuum compatible..........................Yes

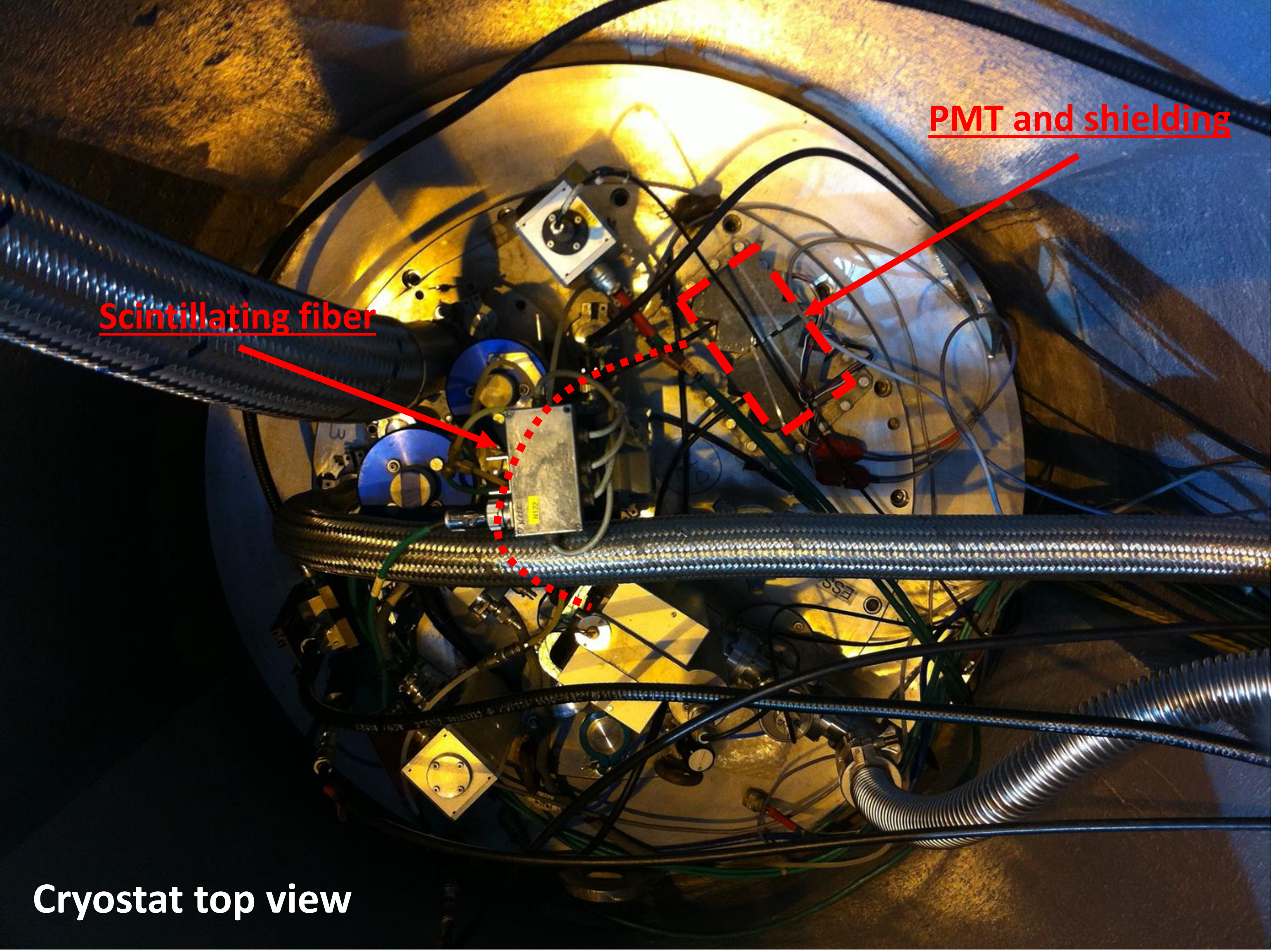
Common Properties of Multi-clad Fibers –

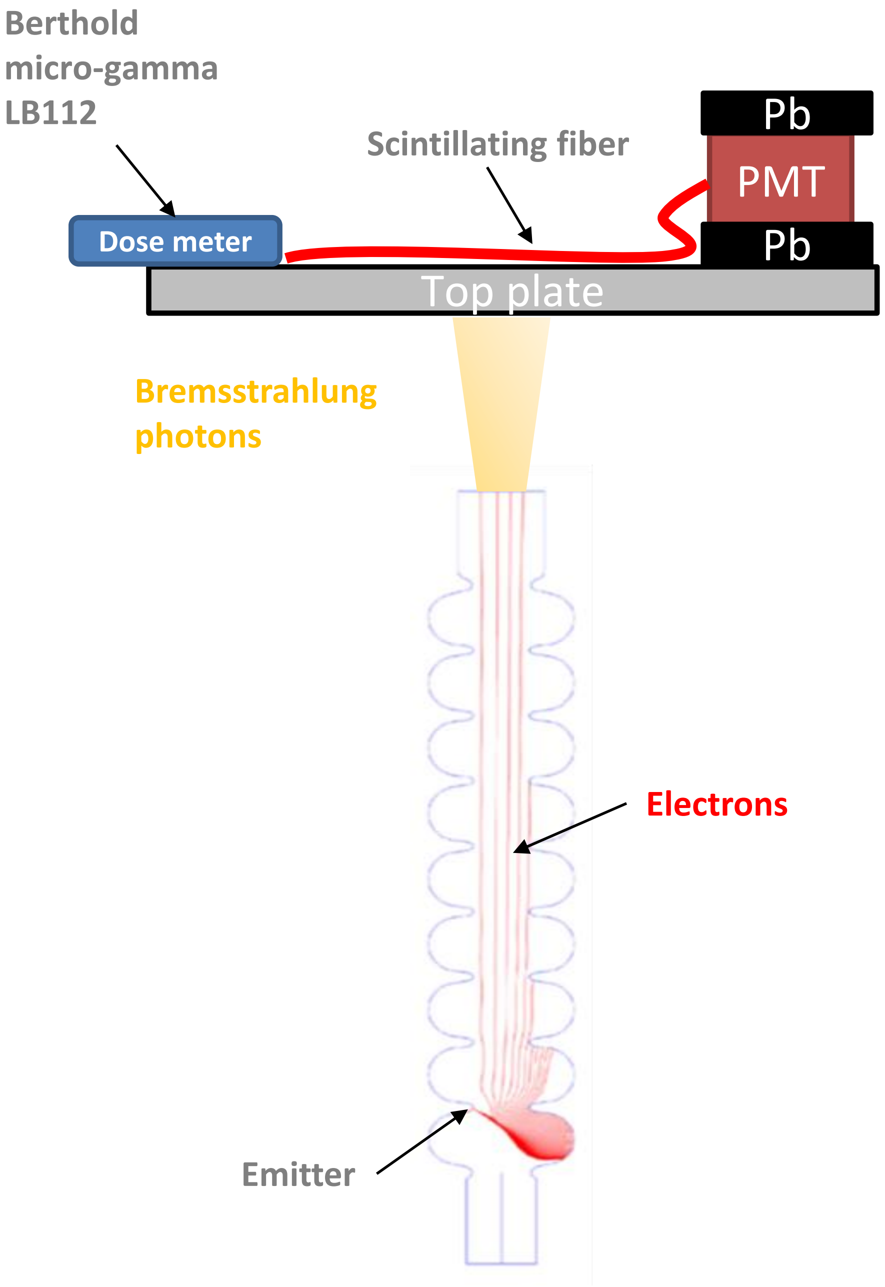
Second cladding material.................Fluor-acrylic
Refractive index 1.42
Thickness, round fibers ....1% of fiber diameter
Thickness, square fibers...................2% of fiber size
Numerical aperture 0.74
Trapping efficiency, round fibers .....5.6% minimum
Trapping efficiency, square fibers....7.3%



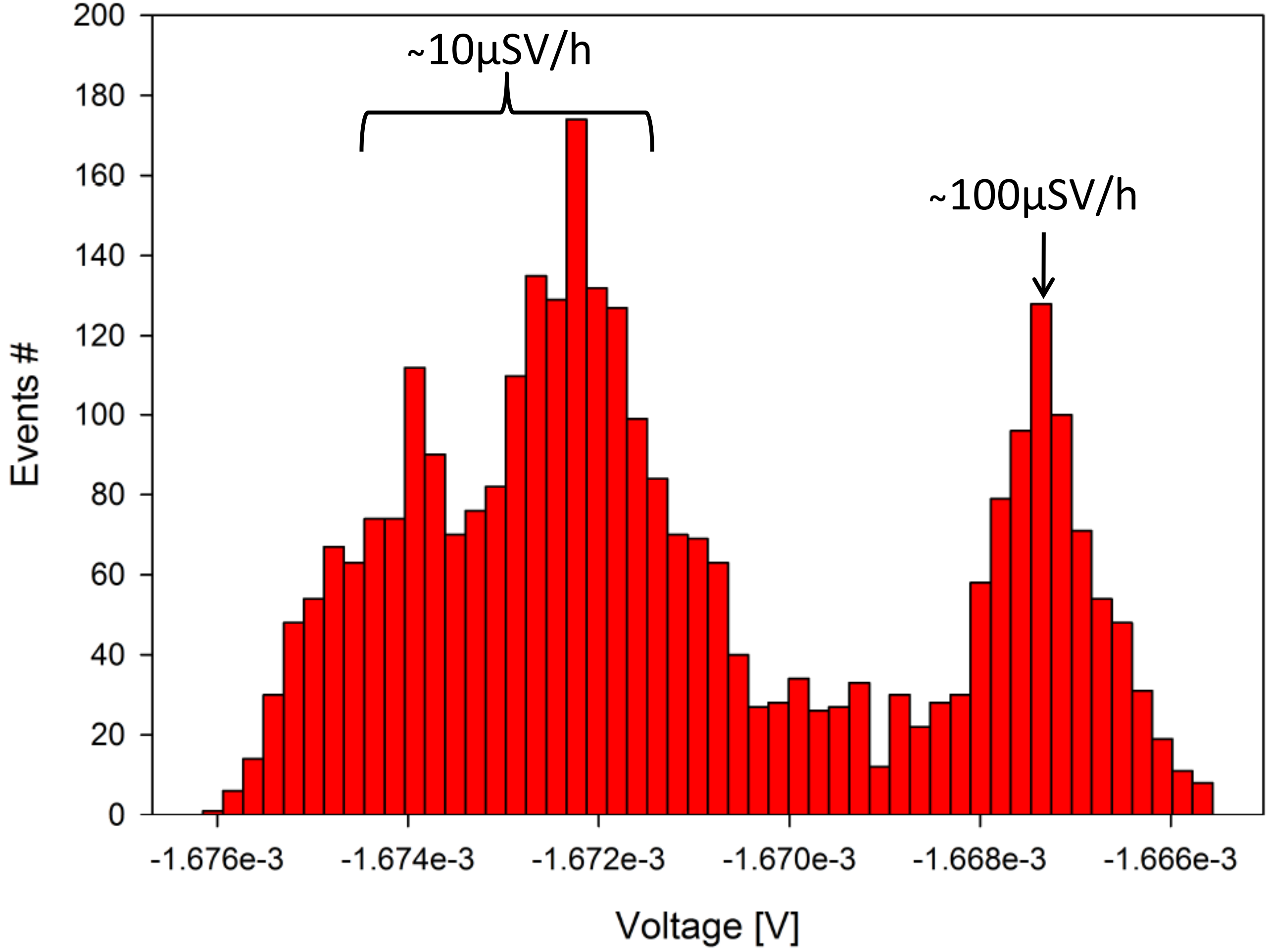
References:

- D. L. Chichester, S. M. Watson, and J. T. Johnson, Nucl. Sci. IEEE Trans. On **60**, 4015 (2013).
- Saint Gobain datasheet.
- S. Imai, S. Soramoto, K. Mochiki, T. Iguchi, and M. Nakazawa, Rev. Sci. Instrum. **62**, 1093 (1991

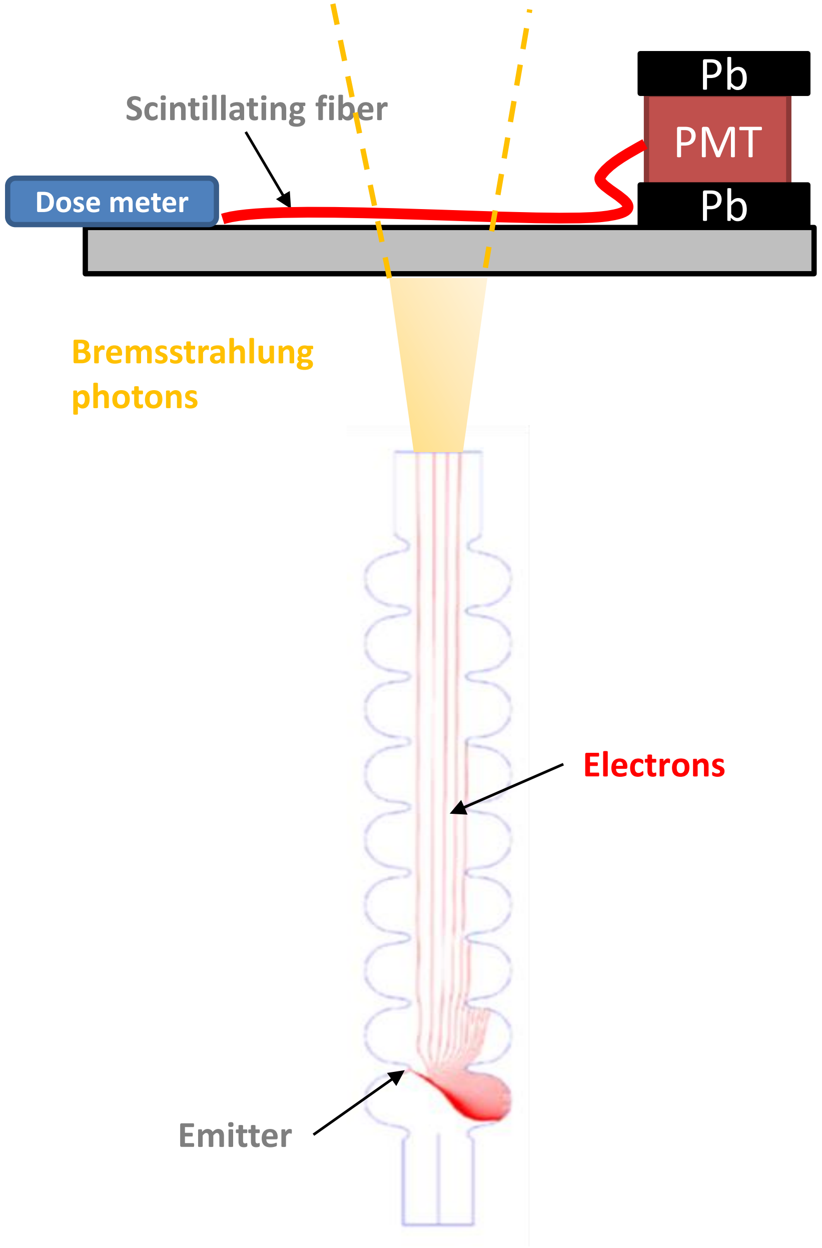


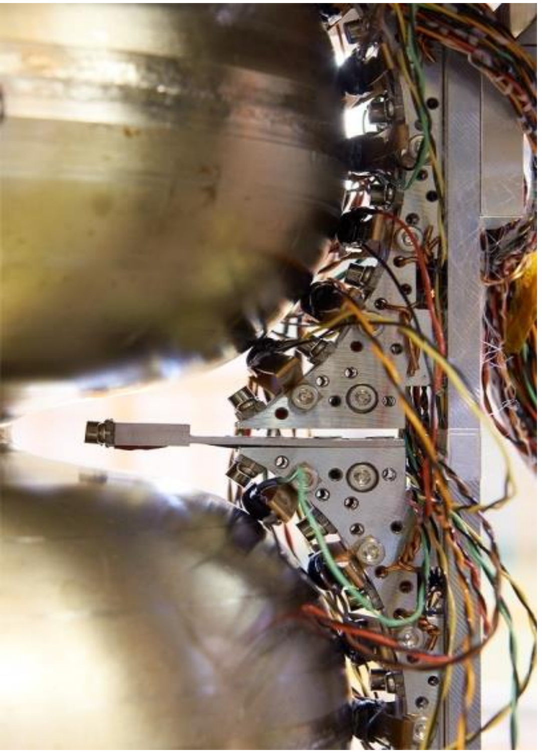


The fiber is positioned above the cover of the vertical cryostat.

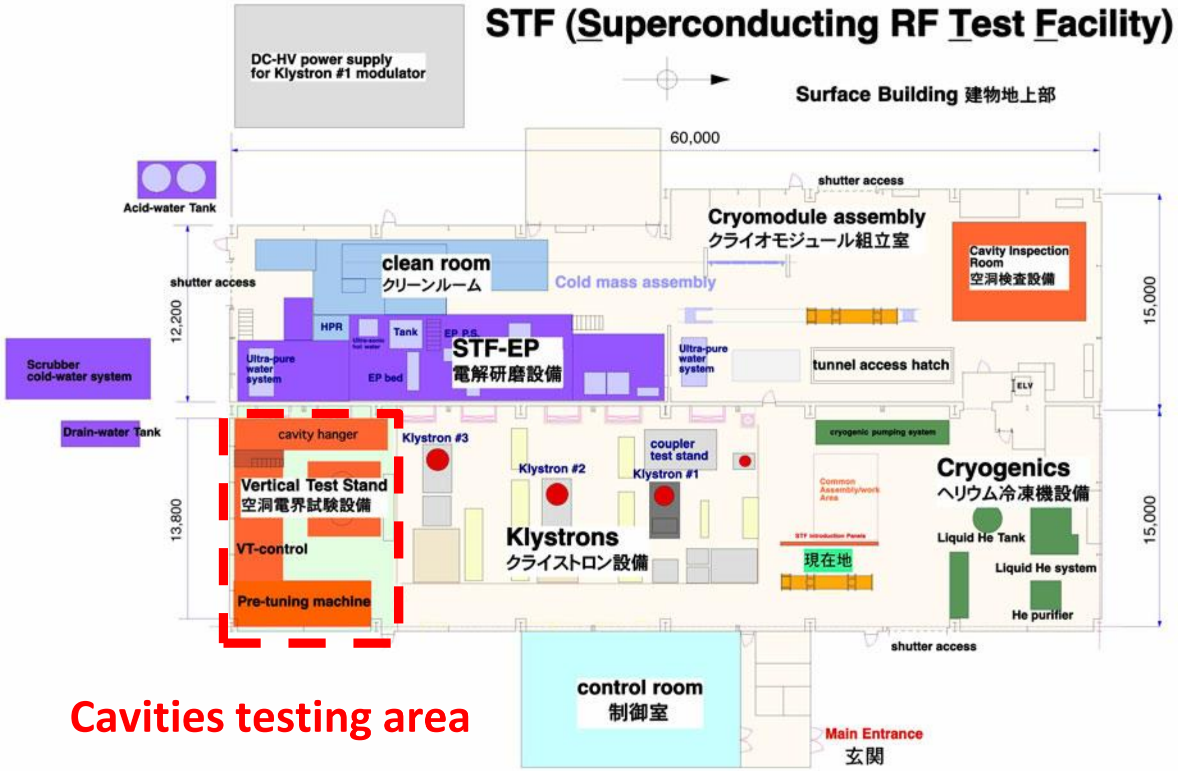


During cavity vertical test we experienced some processing, the radiation dose dropped from ~100μSV/h to ~10μSv/h, at the same time was observed a shift in the voltage.





Rotating mapping system



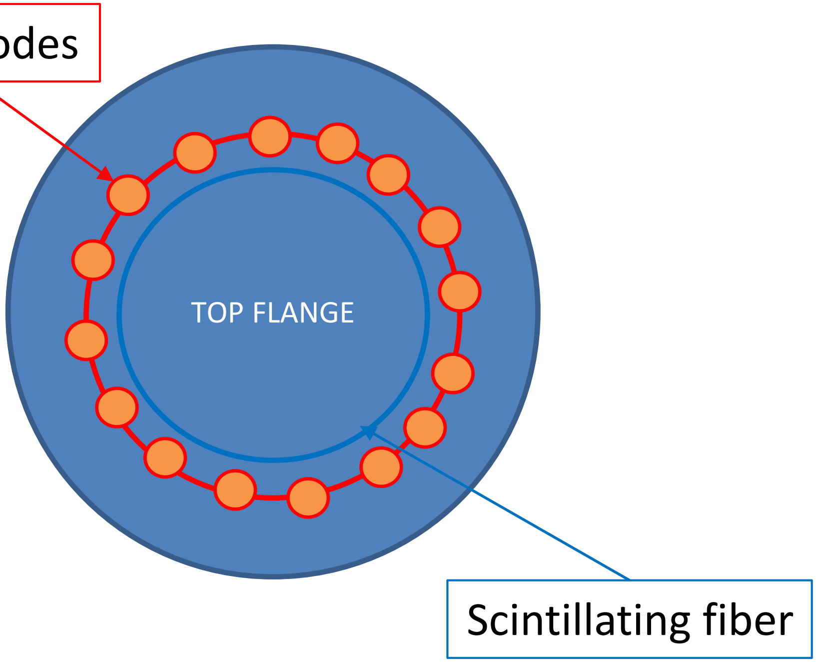
Cavities testing area

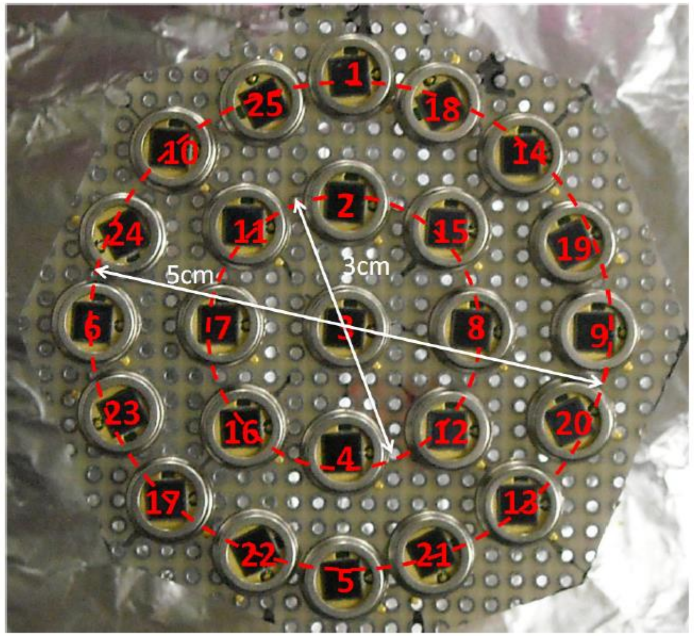
<u>We aim to compare PIN diodes measures with respect to scintillating fiber.</u>

Possible configuration for the first test with PIN diodes

1. Fiber loop on top flange with PIN diodes ring.

With a first test it will be possible to measure and compare the signal detected by the PIN diodes and the scintillating fiber placed on cavity flange.





PIN diodes on G10 board adapted for the cavity beam pipe flange.

A first test will be planned after summer in STF

Superconducting rf Test Facility

2017 plan

- We plan to perform a measure with scintillating fibers introduced in the vertical cryostat along with PIN diodes (at STF-KEK).

- We plan to measure scintillating response by means of standard radiation sources commonly use to calibrate scintillator detector.

Summary

- We have performed a first measure during cavity vertical test.
- We plan to continue tests during this year both in CEA and KEK

Thank you for your attention

ご清聴ありがとうございました

Back up slides

Motivation

Understanding the problem:

Different detection systems are currently used in order to measure x-ray produced by field emission electrons impacts.

Commonly PIN diodes are placed on the cavity profile and/or scintillator detectors are placed outside the cryostat during vertical tests.

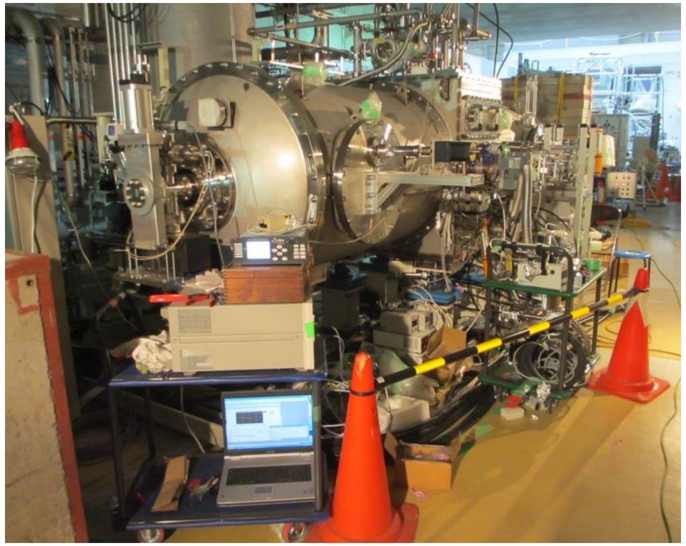
PIN diodes provides a high spatial resolution while scintillator can provide dose rate and photon energy spectrum .

Scintillating fibers offer benefit from both systems:

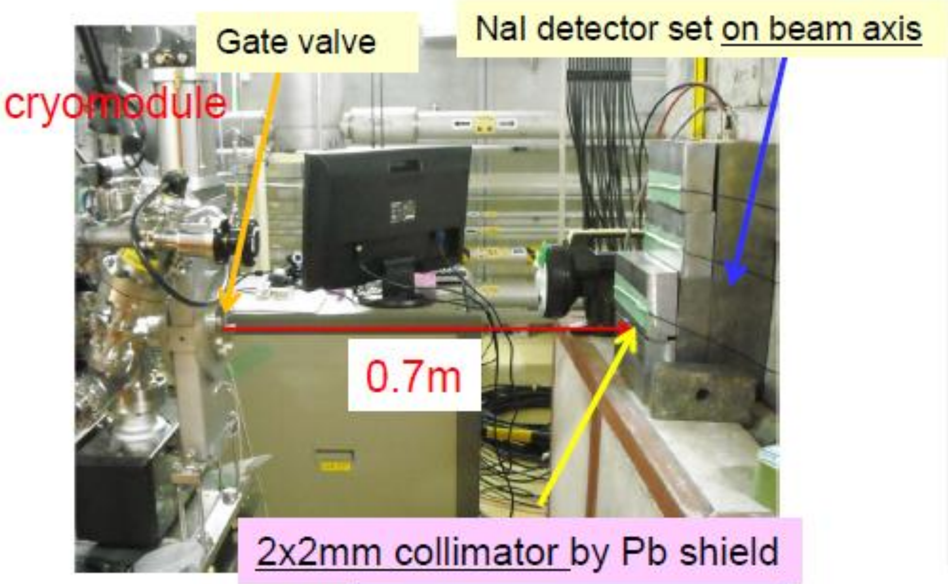
- They can be installed close to the cavity surface → High spatial resolution
- They are scintillators → Energy spectrum

1. With an x-ray map (location and energy) it is possible to determine the source position.
2. During the machine operation will be possible to monitor any change in x-ray pattern.

Case 2: energy spectrum measurement by NaI at cERL main linac cryomodule

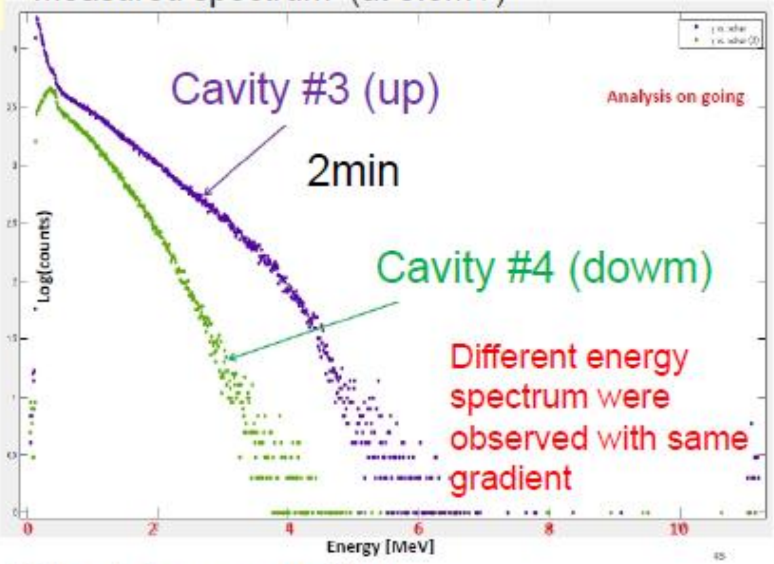


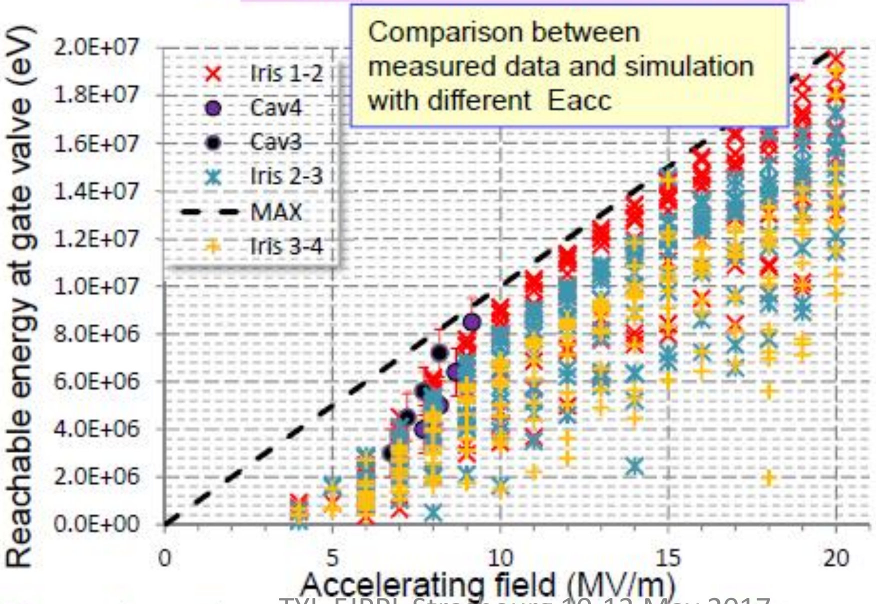
Survey location of field emission source by NaI



Enrico Cenni et al., TUP091 in SRF2013

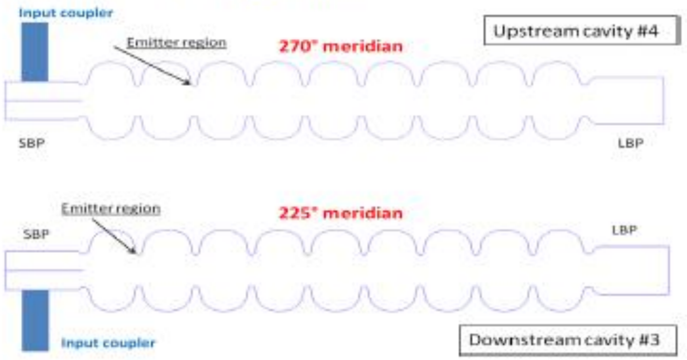
Measured spectrum (at 8.5MV)





Measured error is assumed end point of bremsstrulung effect

Estimated source position

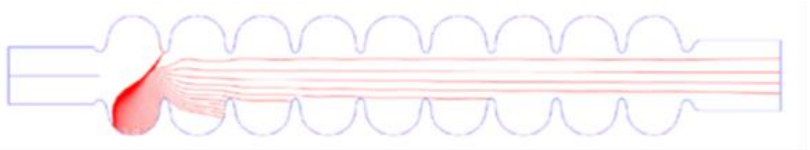


Position near SBP and input port is estimated as a radiation source. String assembly work was poor near SBP side ?? Coupler also caused the burst ??

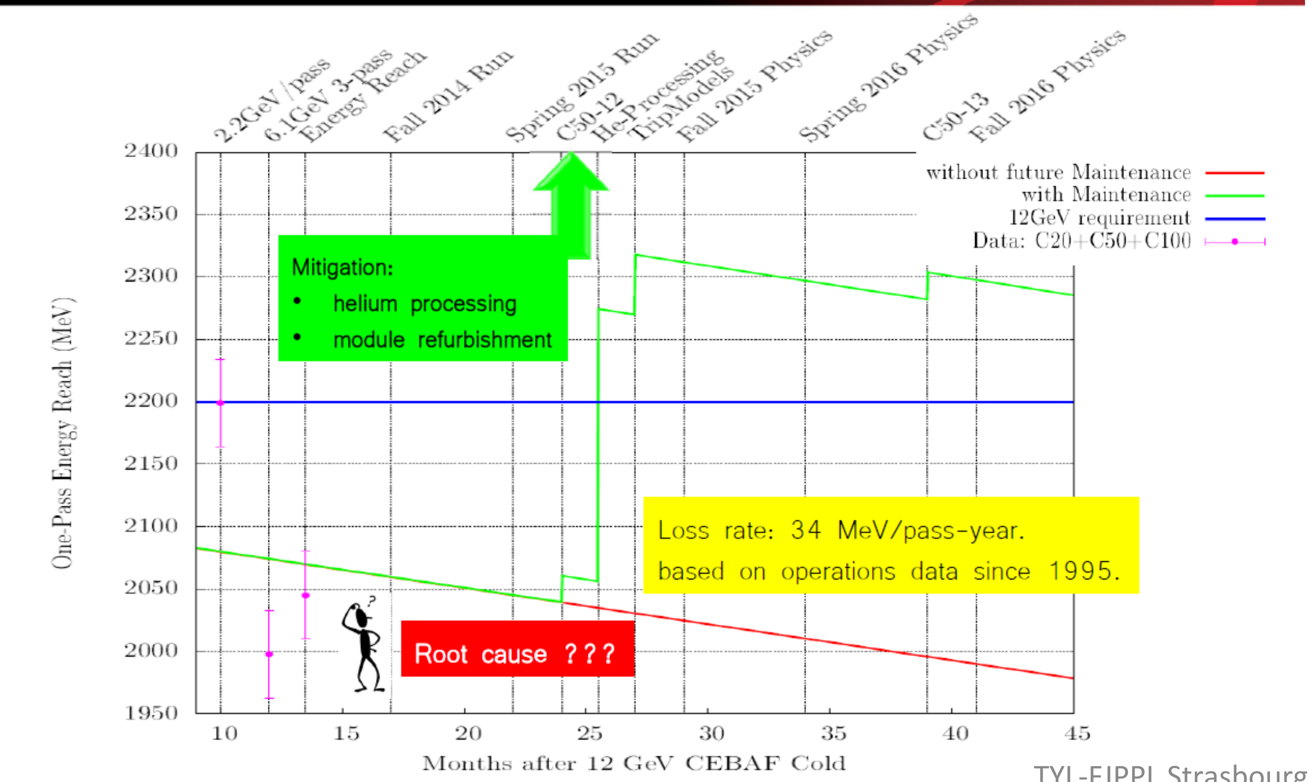
Motivation

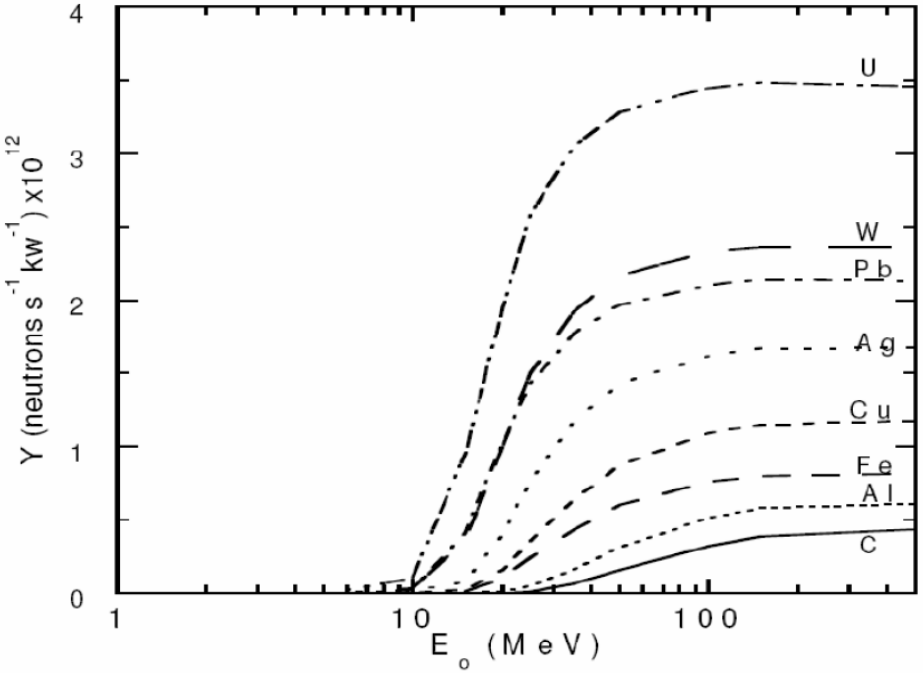
Field emission issues:

1. Field emission is one of the main issues for superconducting cavities quality factor degradation at high gradient operation.
2. Field emission electrons can induce material activation and damage accelerator components.



CEBAF Gradient Degradation





Neutron yield with respect to electron energy.

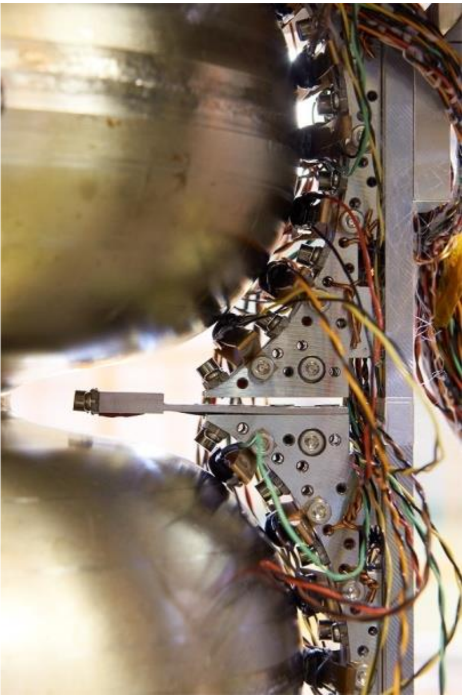
Cossairt, J. Donald. "Induced radioactivity at accelerators." FERMILAB-PUB-07-201-ESH. 2007.

R. Geng (JLAB) @IPAC16

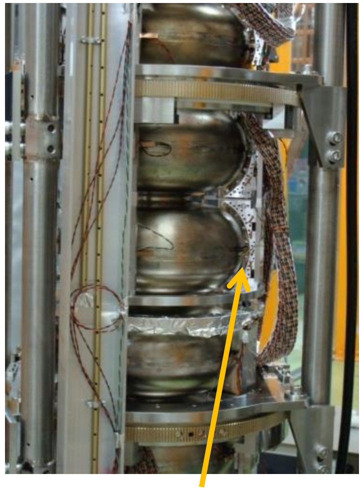
... SRF cavities 1995-2015", http://arxiv.org/abs/1502.06877

R. Bachimanchi, J. Benesch, M. Drury, A. Freyberger, R. Geng, J. Mammosser, "2014 Update: CEBAF Energy Reach and Gradient Maintenance Needs",JLAB-TN-14-024

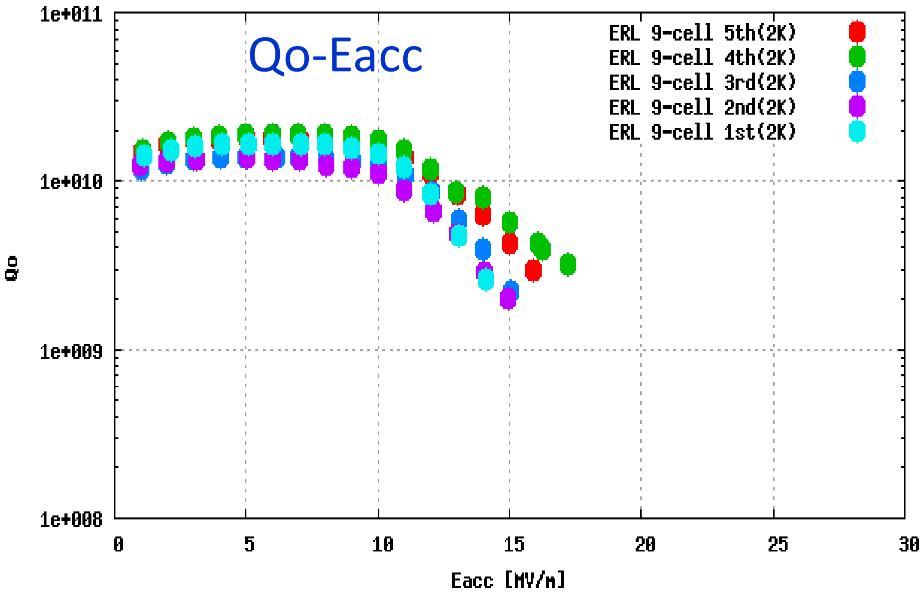
Case 1: field emission study during vertical test (cERL main linac cavity)

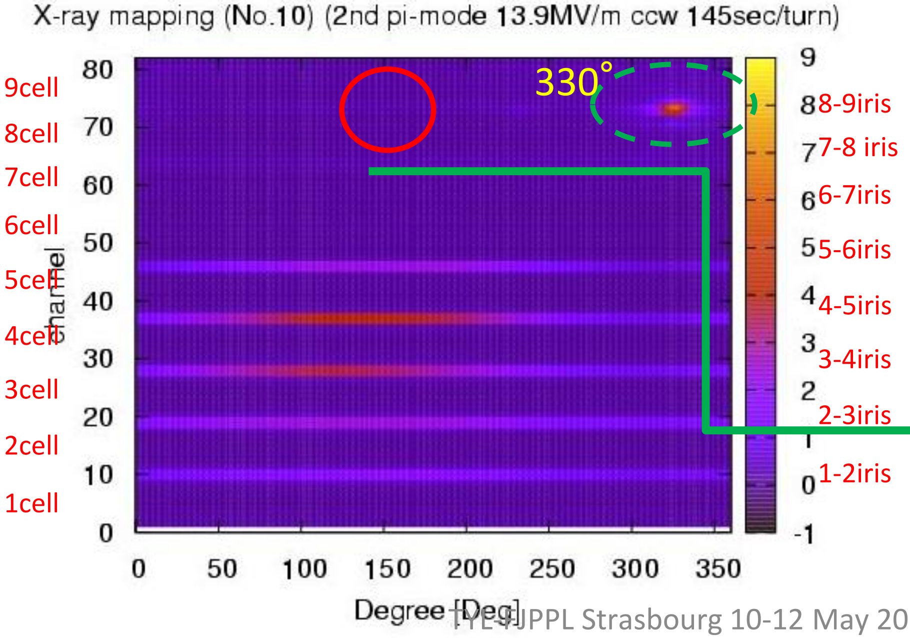


Rotating mapping system



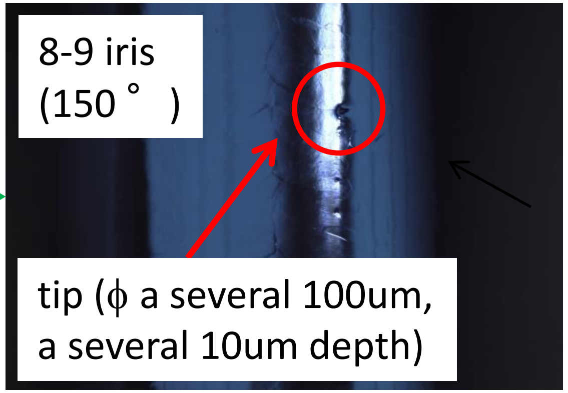
Array of Si PIN diode





Result of X-ray mapping

- Maximum Eacc = 15 ~ 17
- Eacc was limited by field emission
- Large X-ray signals were observed



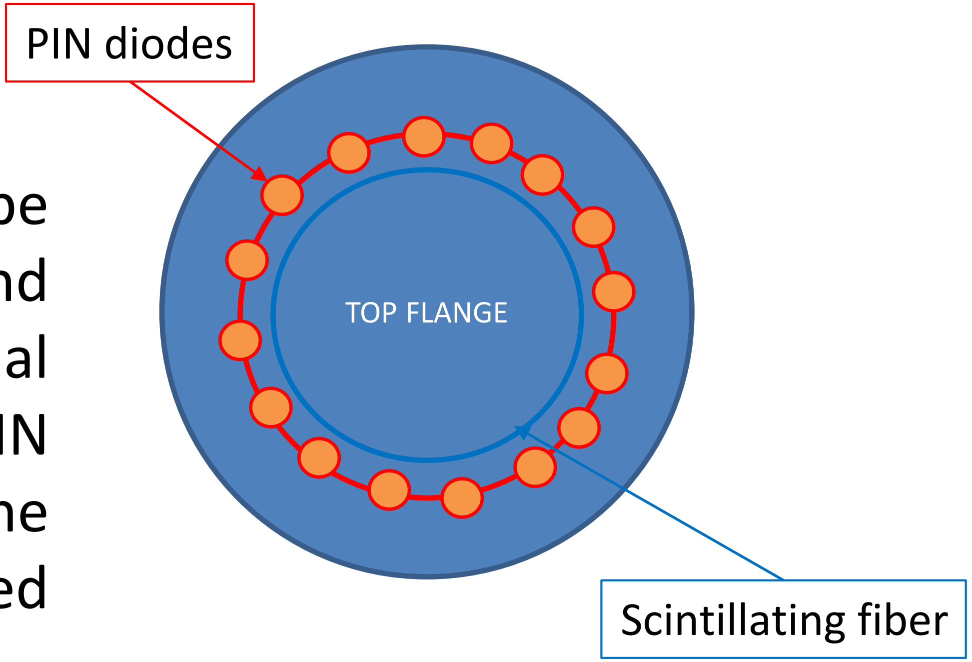
K. Umemori et al., IPAC10, WEPEC030, H. Sakai et al., IPAC10, WEPEC028

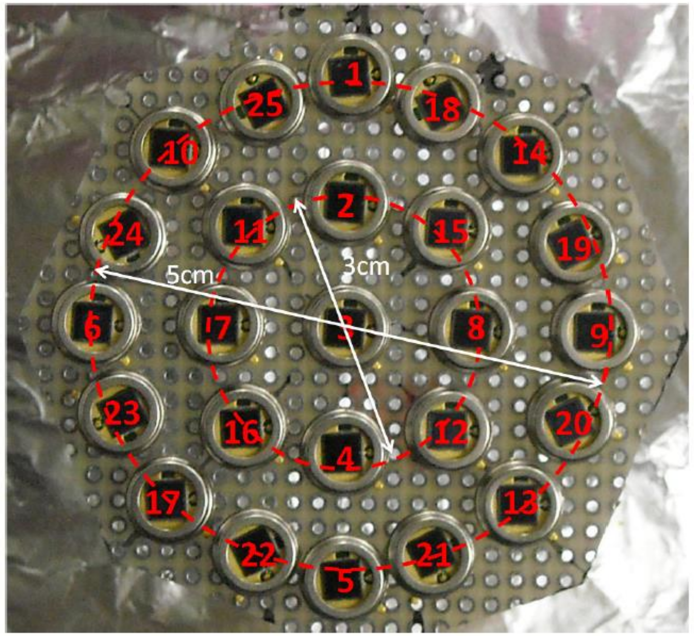
Possible configuration for the first test with PIN diodes

1. Fiber loop on top flange with PIN diodes ring.
2. Fiber along cavity profile or loop around an iris.

1st Test

With a first test it will be possible to measure and compare the signal detected by the PIN diodes and the scintillating fiber placed on cavity flange.





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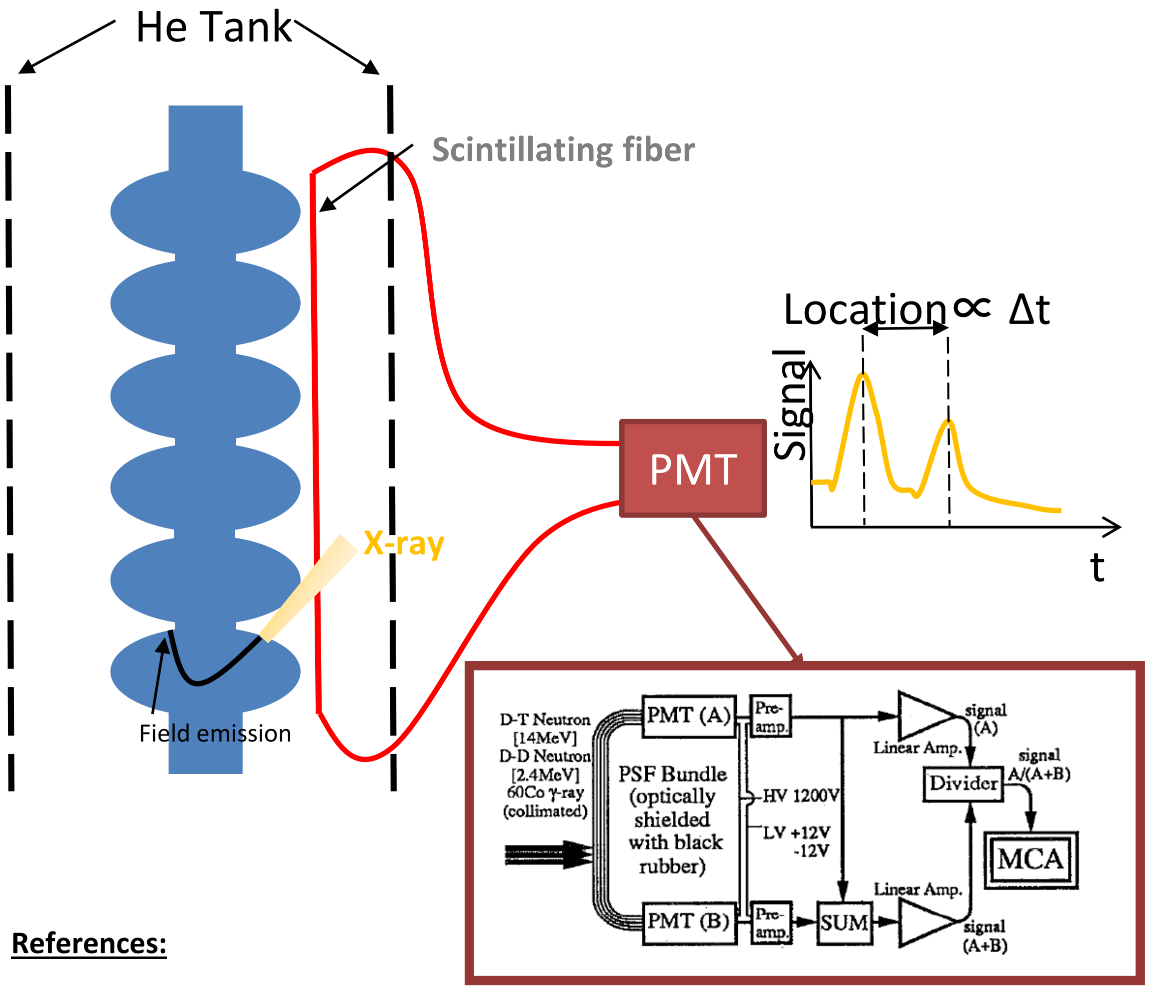

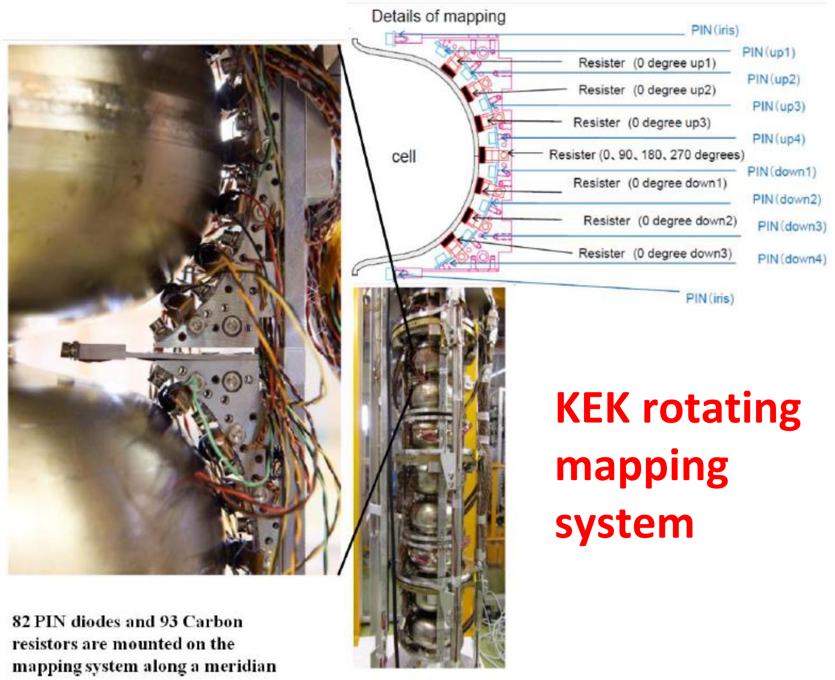

KEK rotating mapping system

2nd Test

Two options will be available:

1-Fiber loop on iris region (where signal is stronger)

2-Fiber bundle along the cavity profile (on the rotating mapping system)

In both case will be possible to compare the signal from the fibers and the rotating mapping system. A multichannel analyzer (MCA) will allow a measure of energy spectrum.

References:

- S. Imai, S. Soramoto, K. Mochiki, T. Iguchi, and M. Nakazawa, Rev. Sci. Instrum. **62**, 1093 (1991).