T2K beam profile monitor

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Univ. of Tokyo

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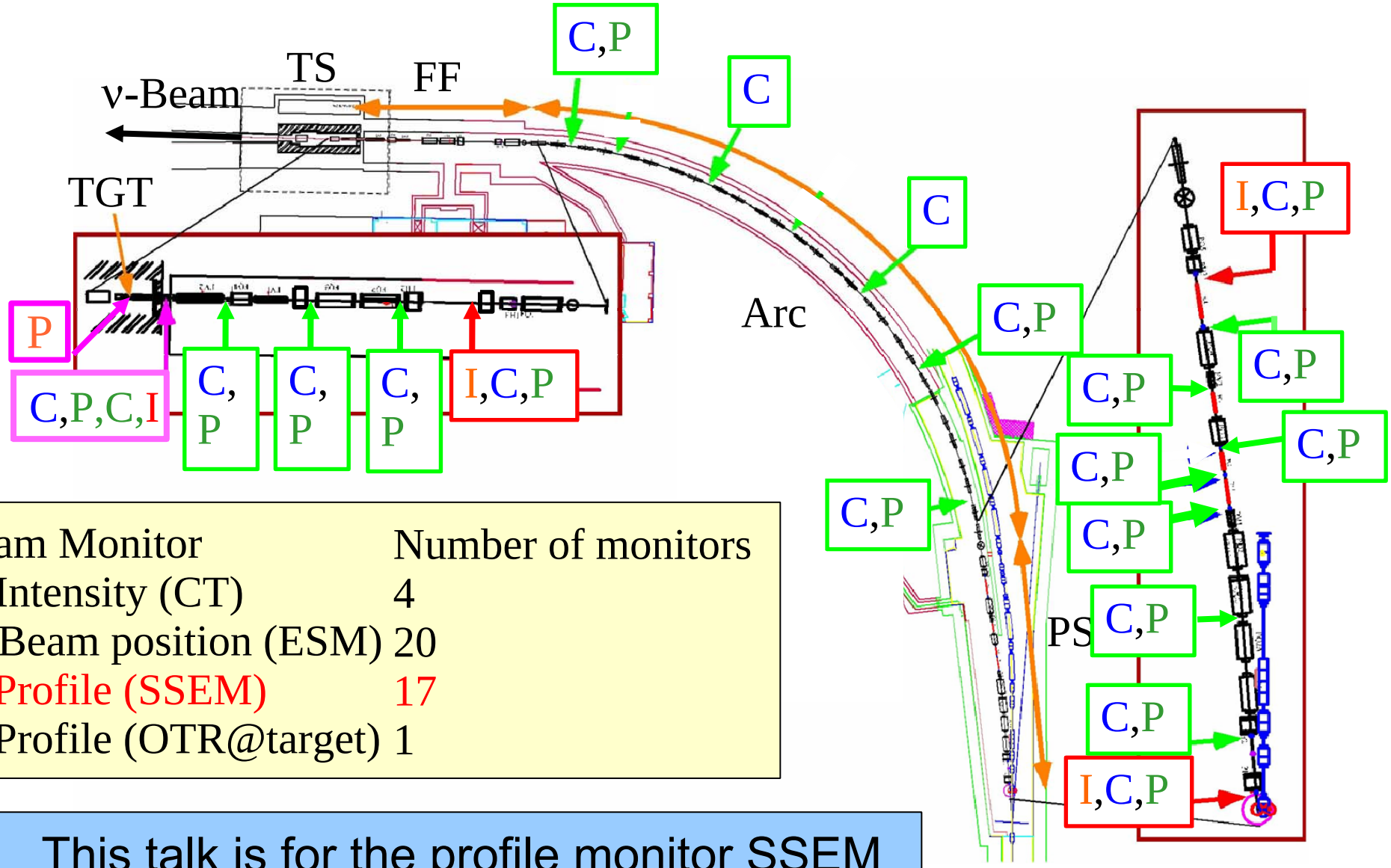
Neutrino Beams & Instrumentation 2006

Outline

1. Introduction
2. Beam test for the performance evaluation
3. Test of the movable structure
4. Irradiation test
5. Status of the readout electronics
6 Schedule
7. Summary

Primary beam line monitors



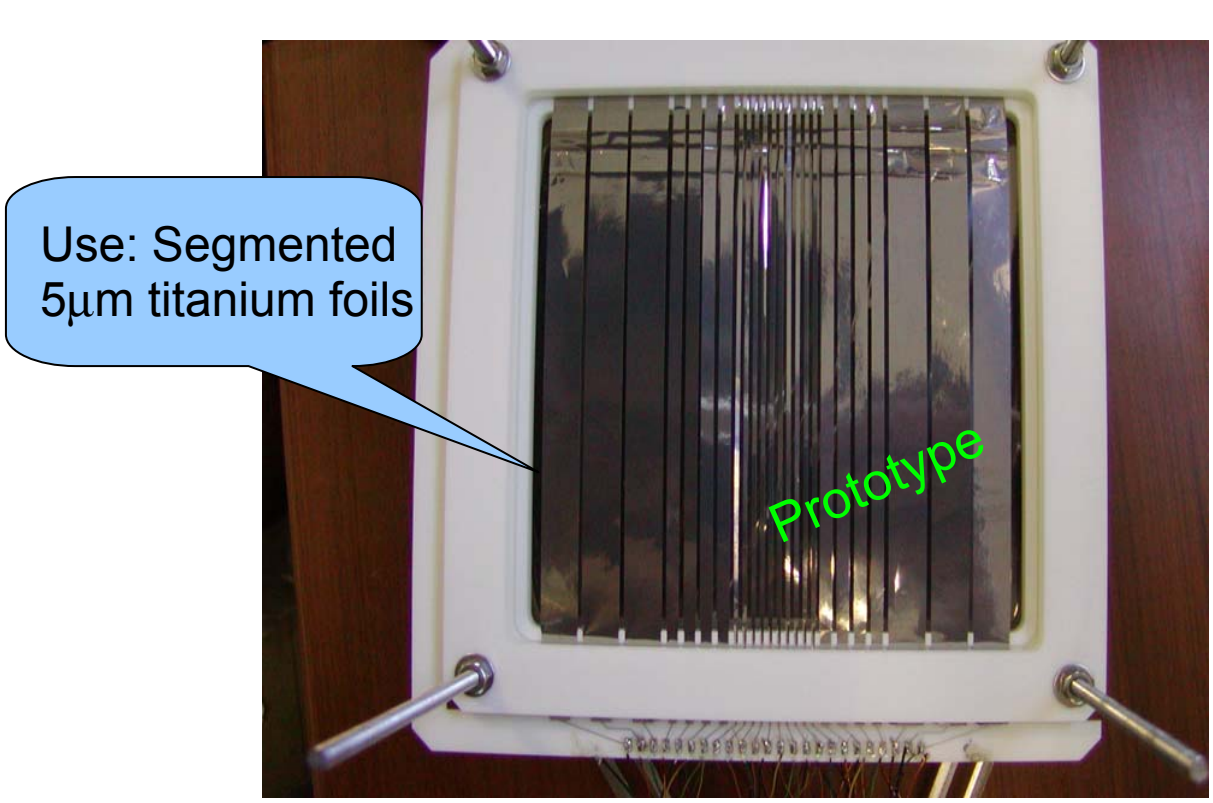
Beam Monitor	Number of monitors
I : Intensity (CT)	4
C: Beam position (ESM)	20
P: Profile (SSEM)	17
P: Profile (OTR@target)	1

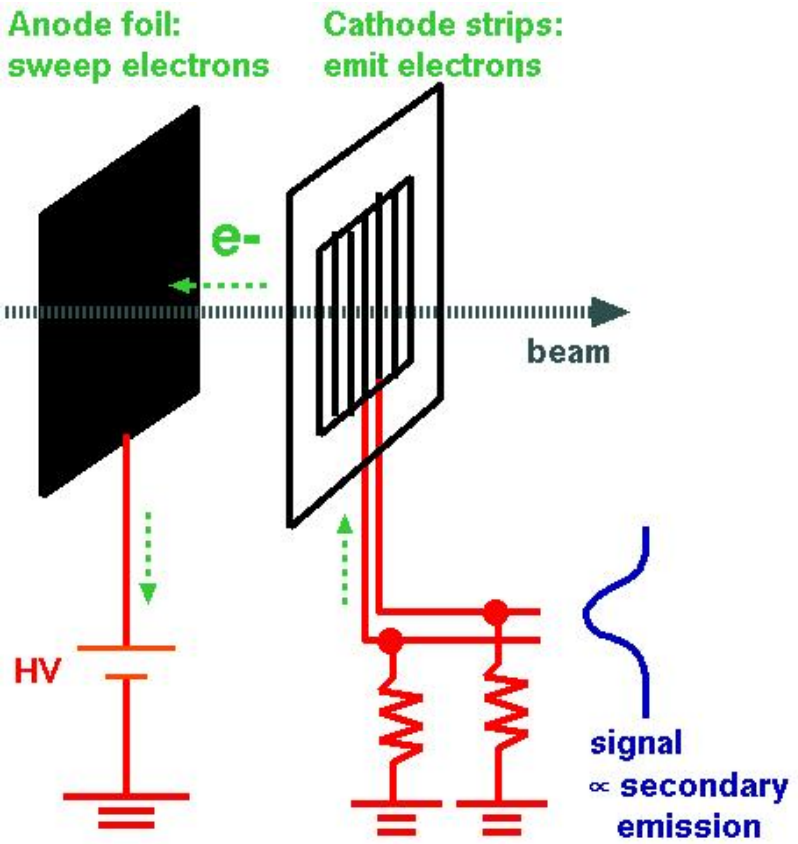
This talk is for the profile monitor SSEM

Beam profile monitor: SSEM

SSEM: Segmented Secondary Emission Monitor

- Measure x and y projection of the beam profile





SSEM in the monitoring scheme

Role of the SSEM:
1. beam monitoring device for the beam tuning
2. calibration device for the BPM

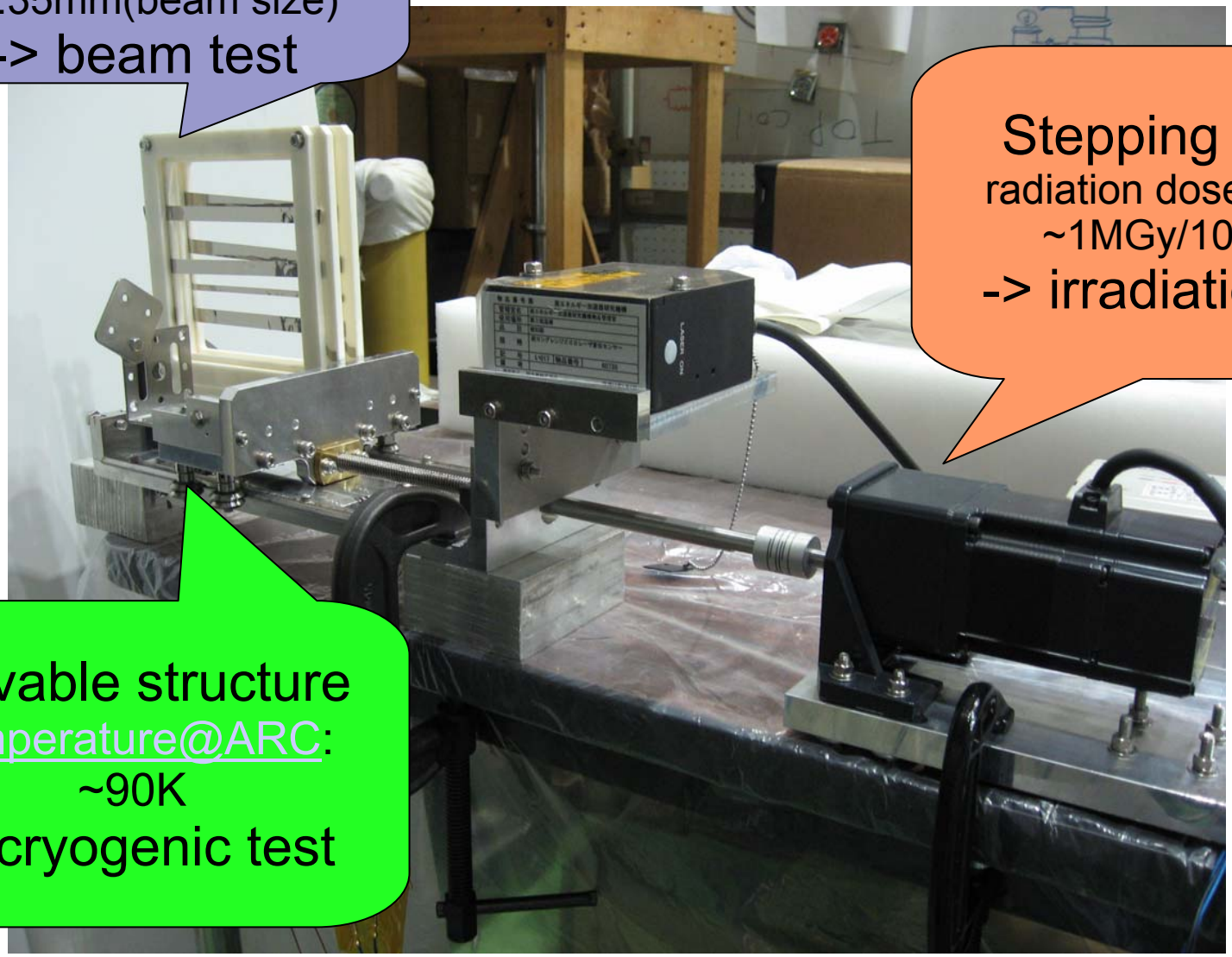
	Beam tuning	Physics run
Center position	BPM+SSEM	BPM
	calibrate	
Profile(prep,ARC)	SSEM	
Profile(FF)	OTR+SSEM	OTR
	calibrate	

Use of SSEM under beam cause:
beam loss & degradation of the secondary emission efficiency

Use SSEM only for the beam tuning
- use movable structure so that we can insert SSEM on demand
- use stepping motor to calibrate the SSEM strip gain

SSEM R&D items

SSEM
required resolution:
<0.5mm(center position)
<0.35mm(beam size)
-> beam test



Stepping motor
radiation dose @prep:
~1MGy/10years
-> irradiation test

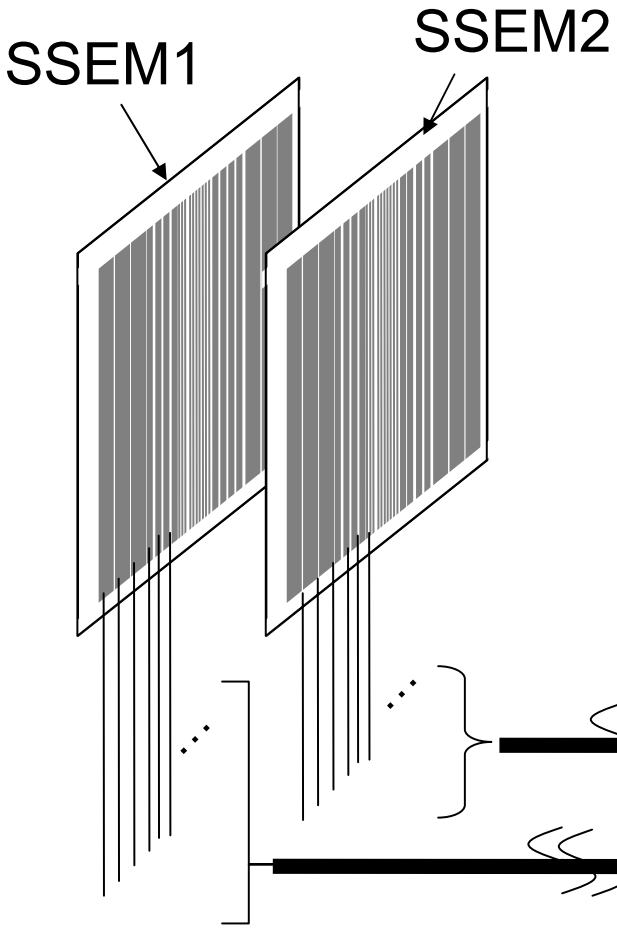
Movable structure
temperature@ARC:
~90K
-> cryogenic test

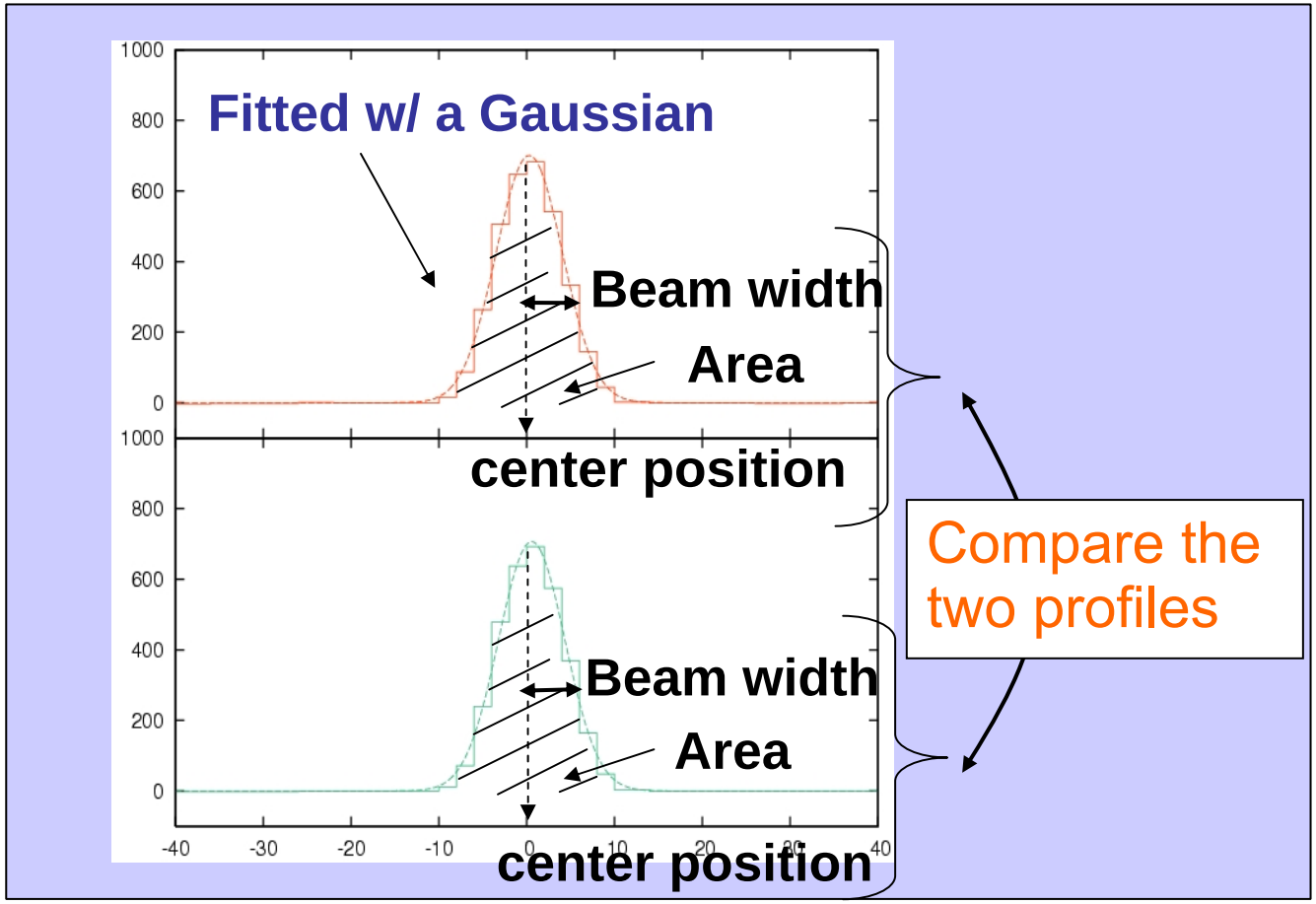
SSEM performance evaluation by a beam test

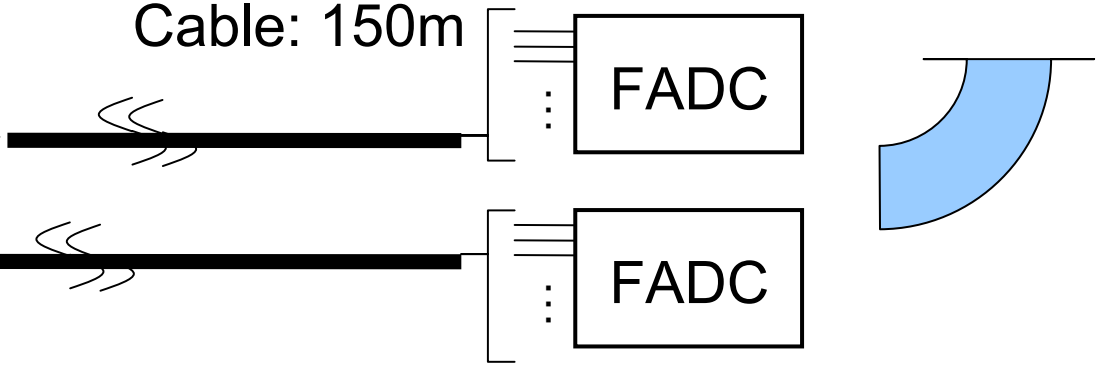
	Test beam line (Booster@KEK)	T2K beam line
# of bunches / spill	1	8
# of protons / bunch	2×10^{12}	3.7×10^{11} (1/100 intensity) 3.7×10^{13} (full intensity)
Beam size	3.8mm	~31mm (maximum)

Beam test

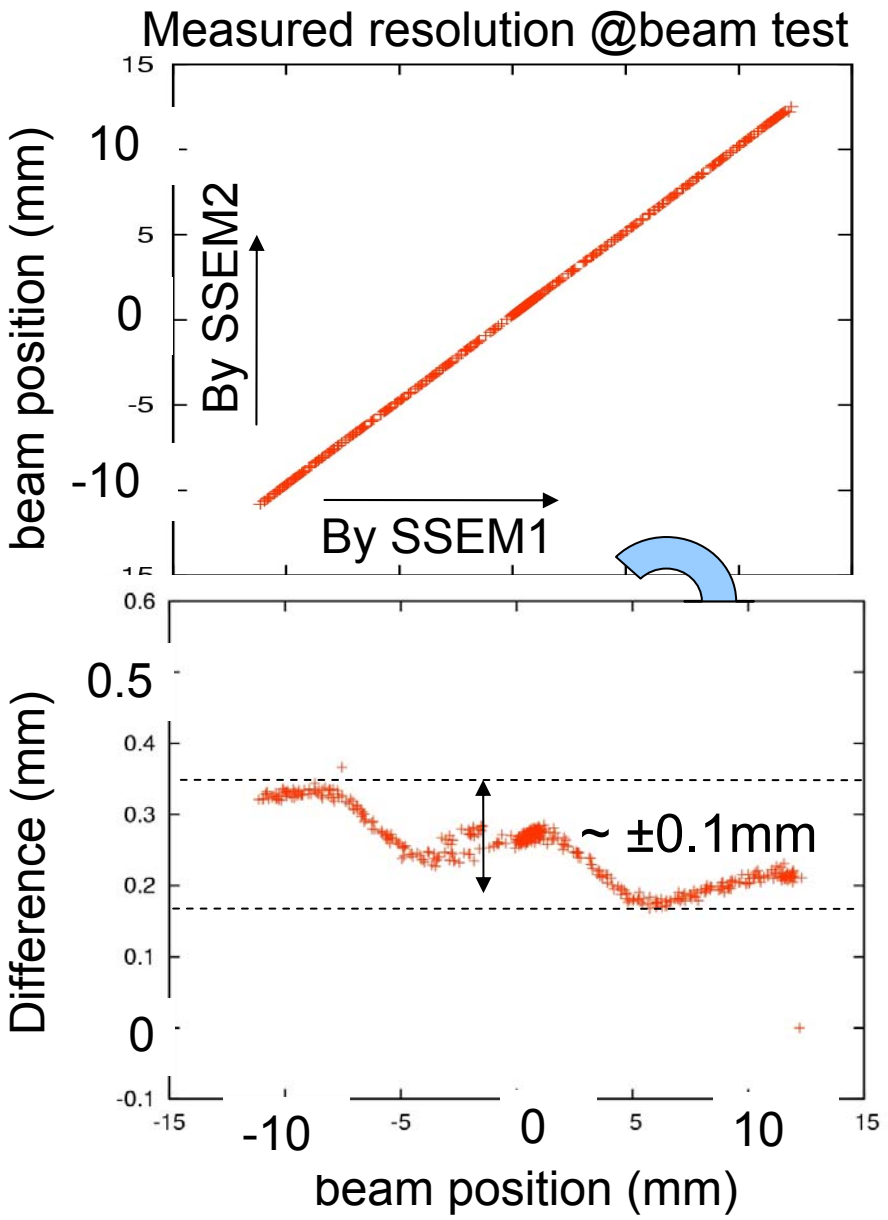
Use two SSEMs
to estimate their performance

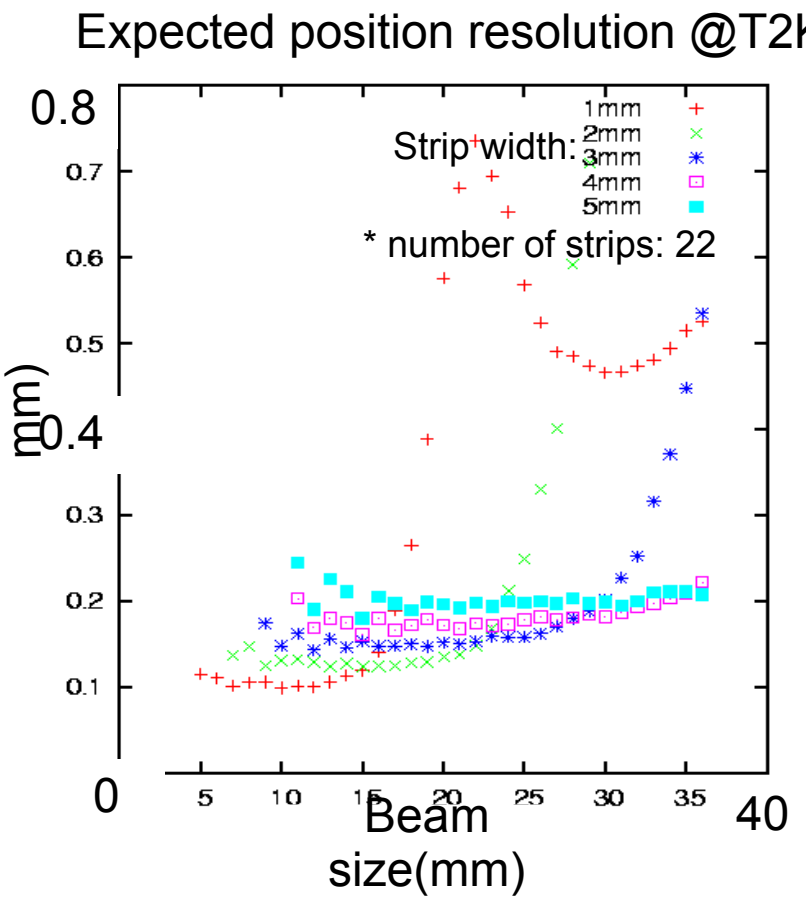






Beam position resolution

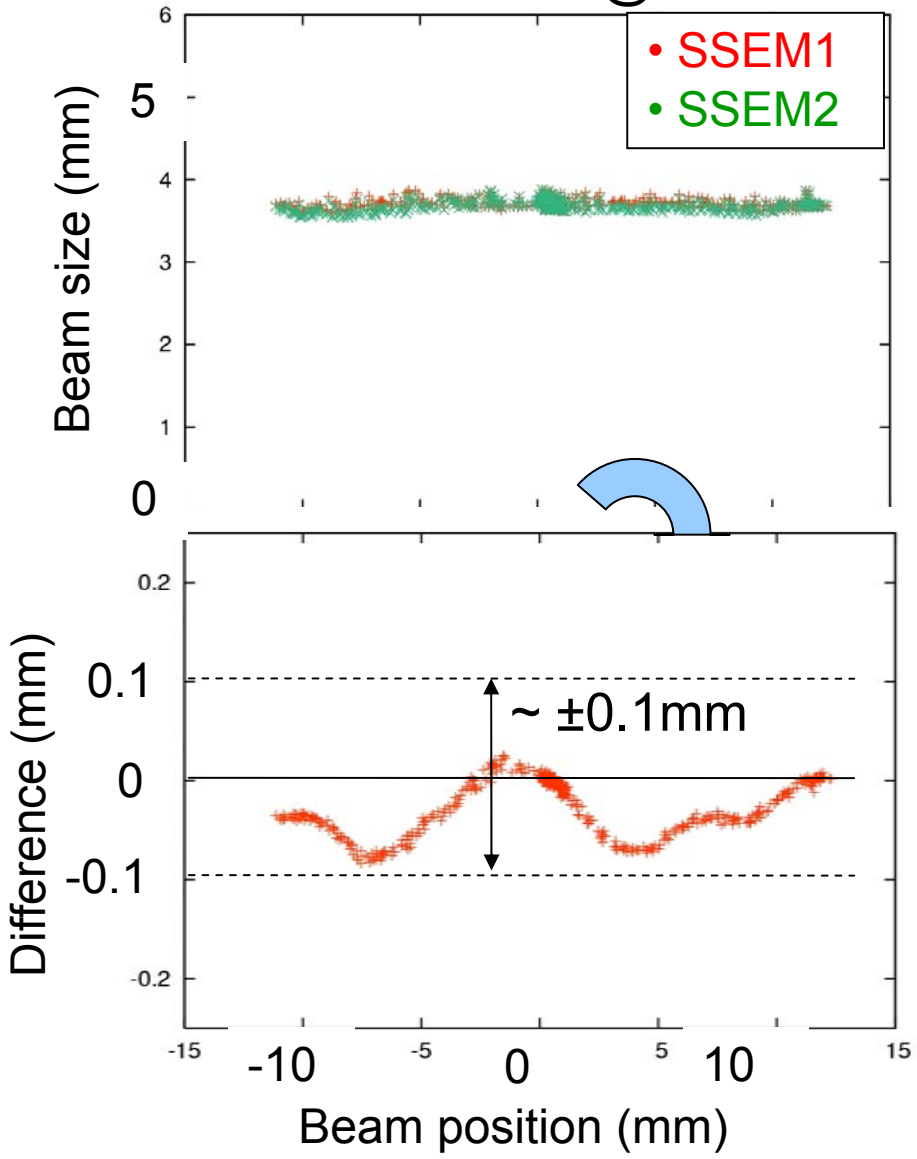




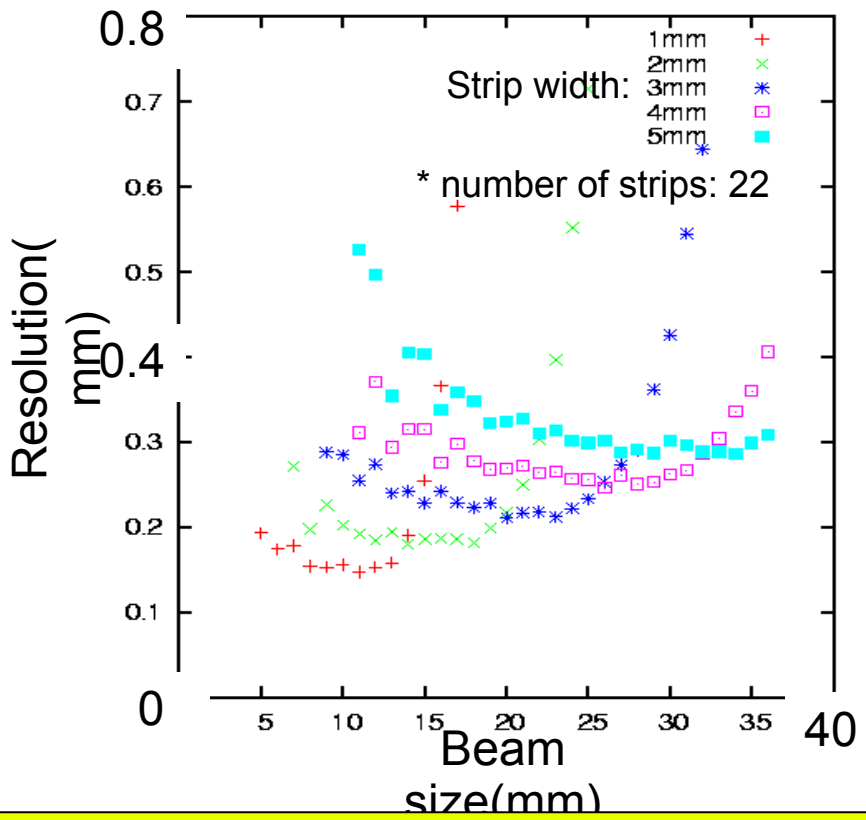
Position resolution at T2K is:
at most 0.19mm
(31mm beam size, 4mm strip width)
↔ requirement: < 0.5mm

Beam size resolution

Measured resolution @ beam test



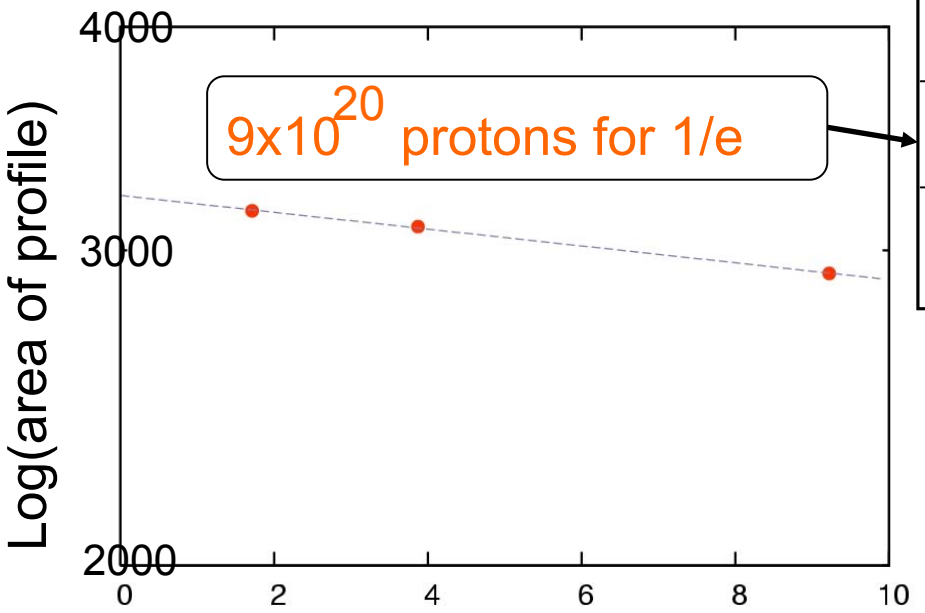
Expected resolution @T2K



Beam size resolution at T2K is:
at most 0.27mm
(31mm beam size, 4mm strip width)
↔ requirement: < 0.35mm

Gain stability

Long term stability of the secondary emission efficiency



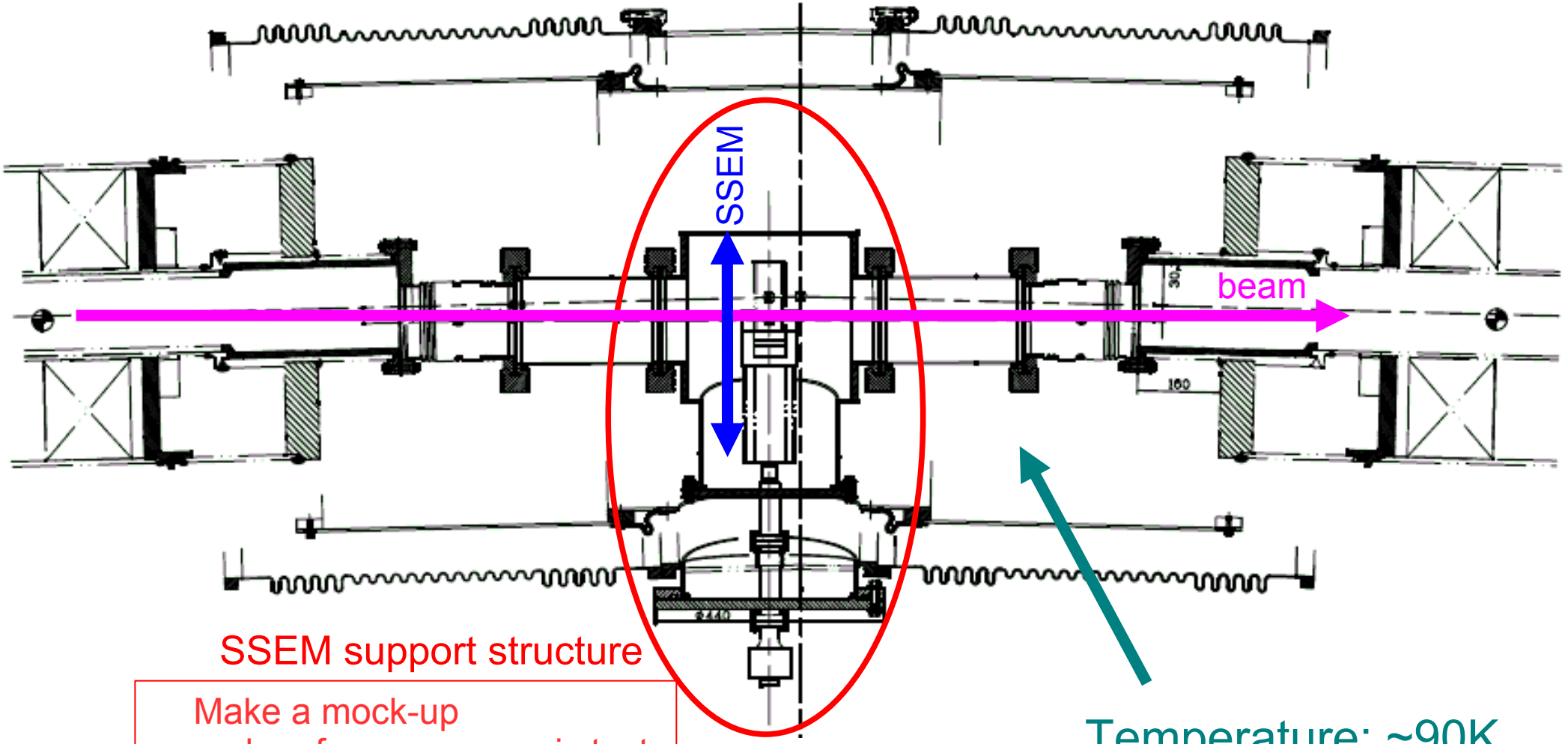
Number of pulses for 1/e at T2K	
1/100 intensity	2.7×10^6 pulses
Full intensity	27000 pulses

- Degradation of the secondary emission efficiency is observed
- We plan to have calibration mechanism:
  move SSEM position using a stepping motor

Test of the mechanical structure
- cryogenic test
- long term operation test

Cryogenic test for SSEM movable structure

SSEM in the ARC section



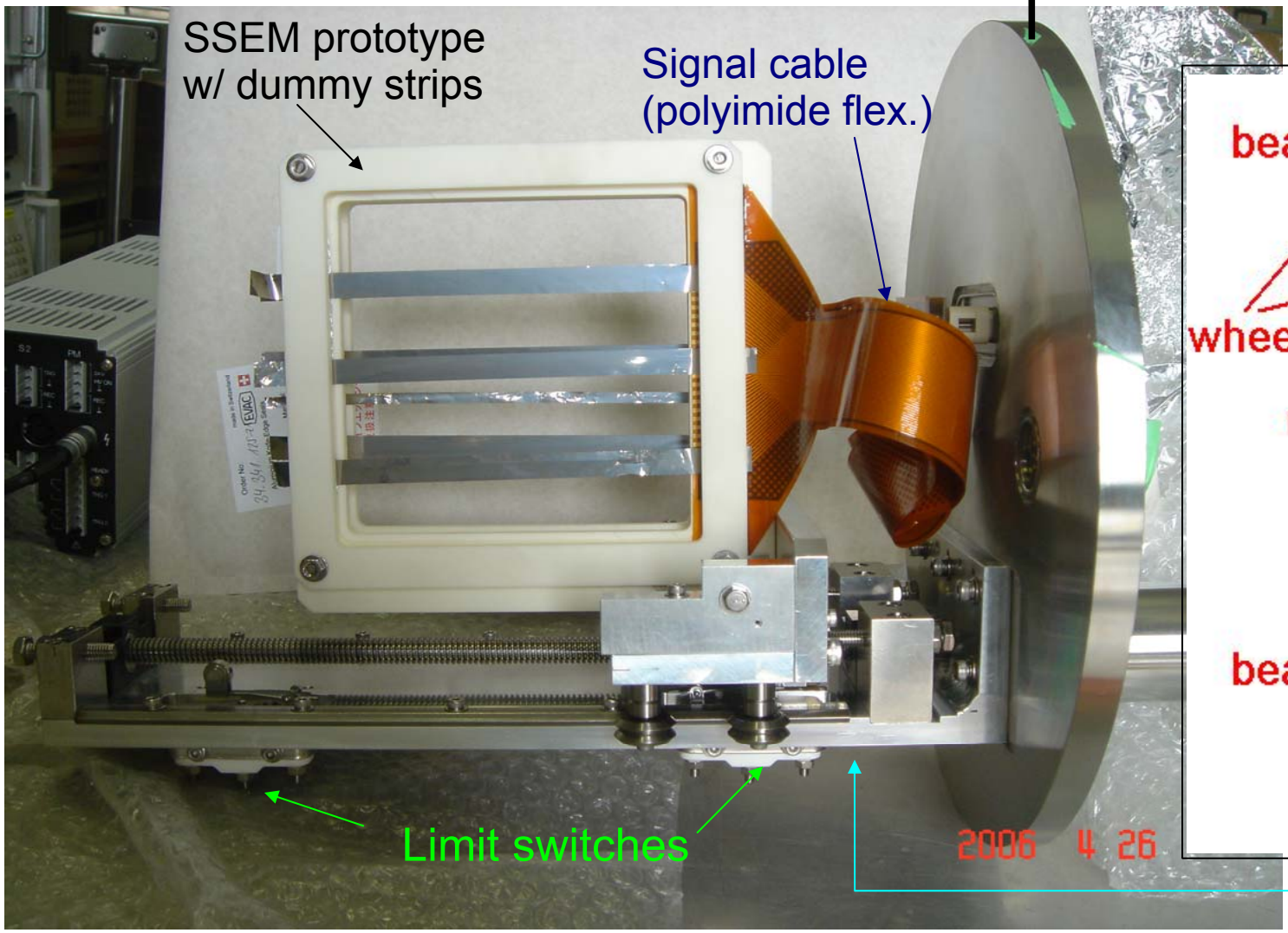
SSEM support structure

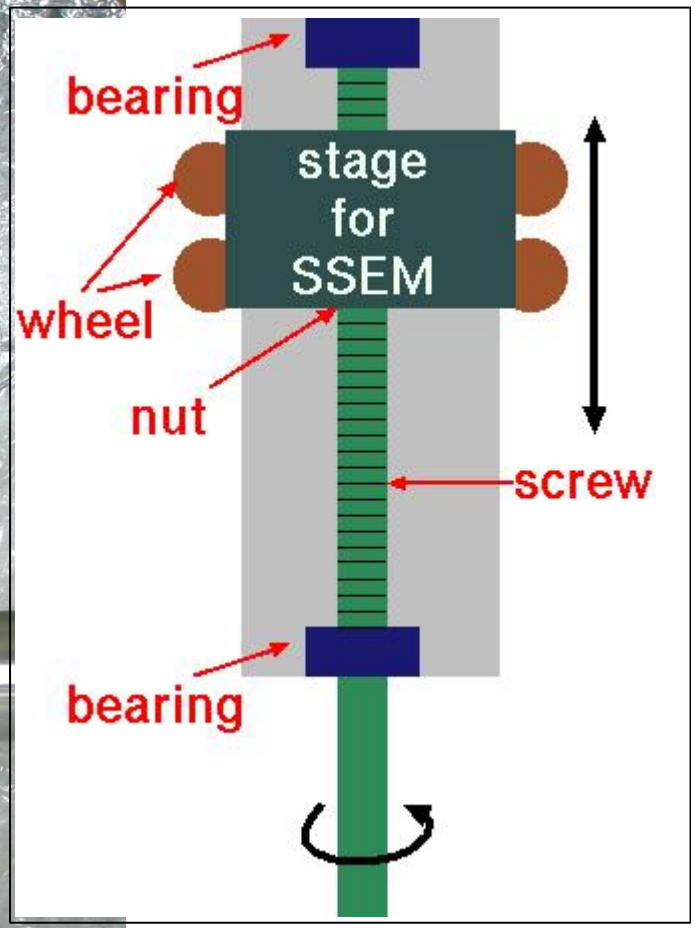
Make a mock-up
and perform a cryogenic test

Temperature: ~90K
(inside of the shield)

movable structure prototype

Temperature will be
~90 K for SSEMs at ARC section





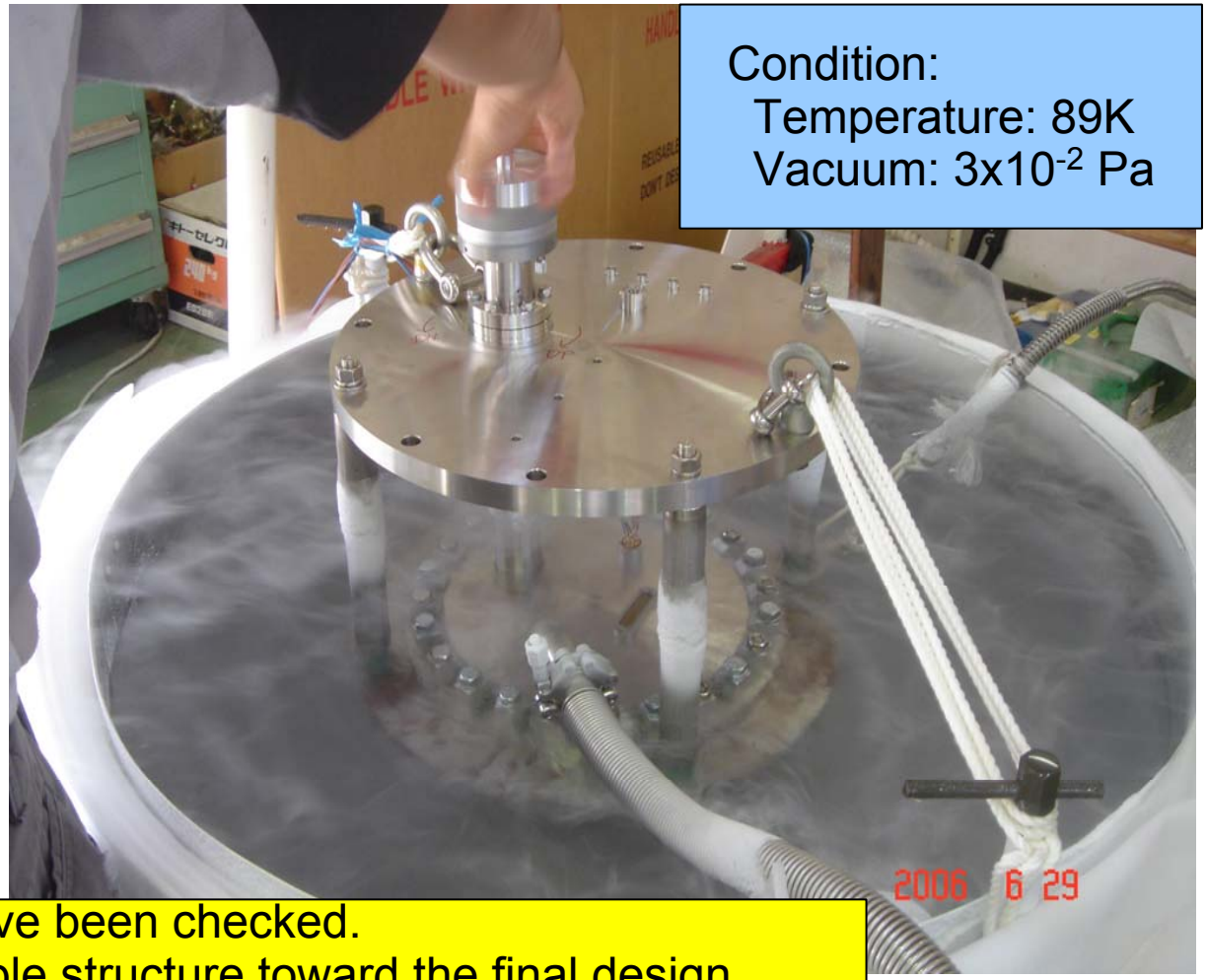
Linear guide

Cryogenic test

Both the linear guide
and the limit switches work

Maximum torque for the axis
of the movable guide: 0.5Nm

at room temp.: 0.2Nm
-> Sufficiently low torque
c.f.) maximum torque of
the stepping motor: 3Nm

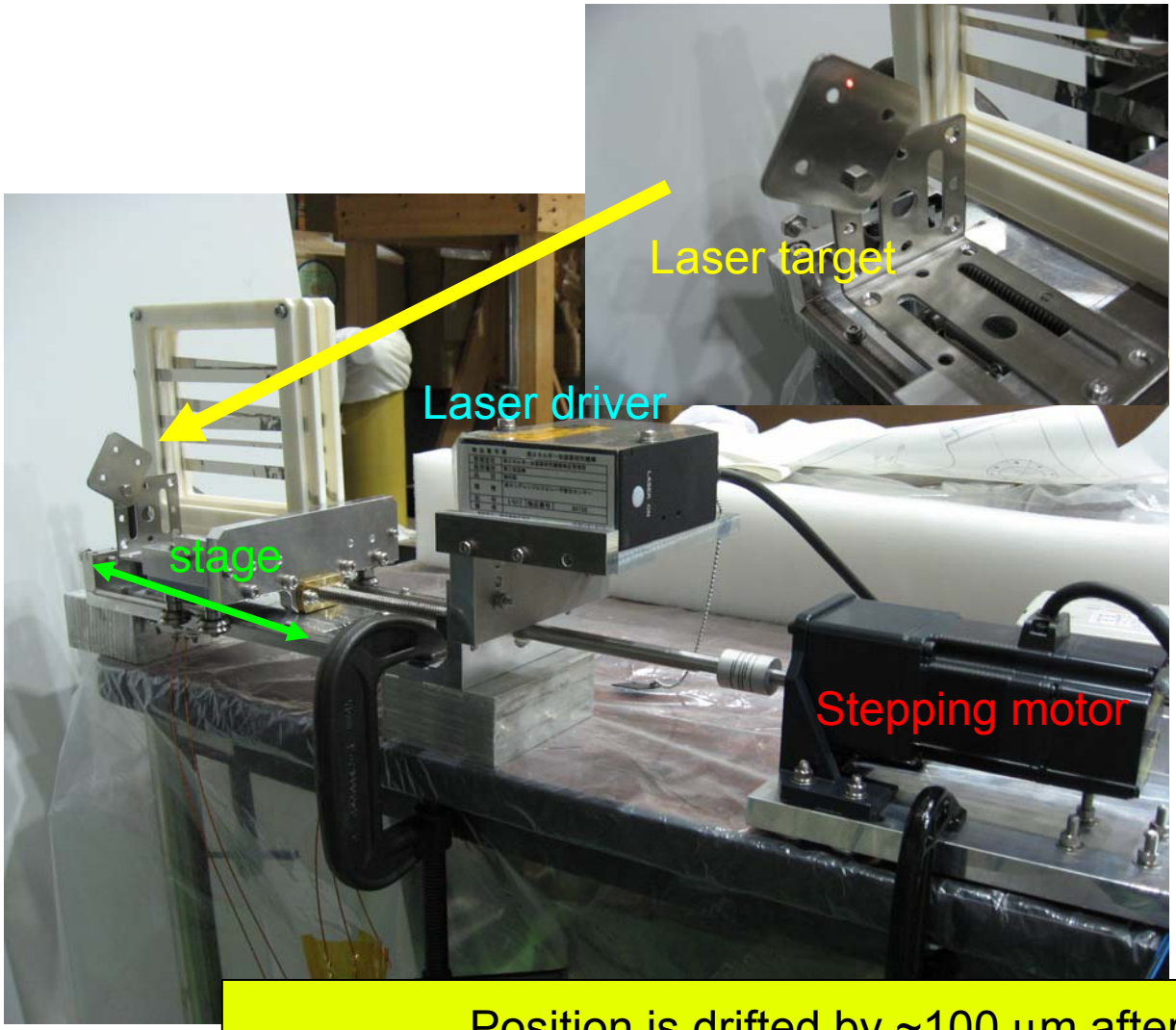


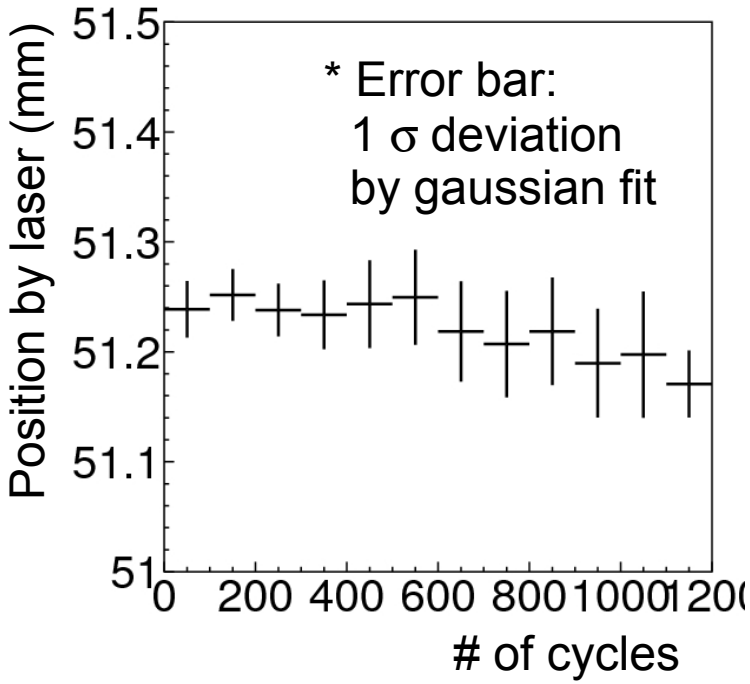
Condition:
Temperature: 89K
Vacuum: 3×10^{-2} Pa

- Basic functionality have been checked.
  -> make a new movable structure toward the final design

Long term structure test

Long term stability test of the movable structure





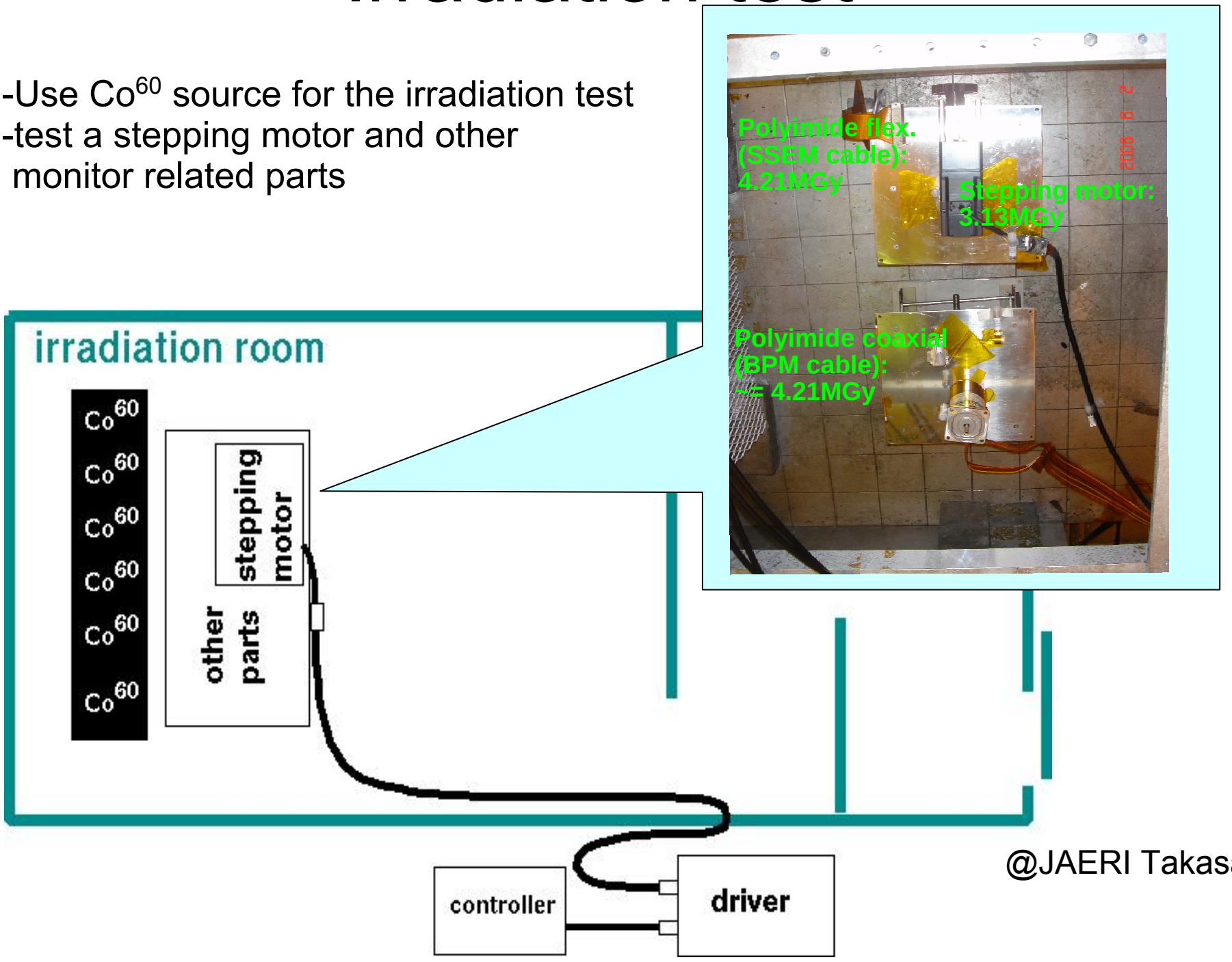
Full stroke between the limit switch

* error from the laser system: ~34μm

Position is drifted by ~100 μm after ~1000 cycles
test for further cycles is going on

Irradiation test

-Use Co^{60} source for the irradiation test
-test a stepping motor and other
monitor related parts



@JAERI Takasaki

Check of irradiated parts

1. Stepping motor

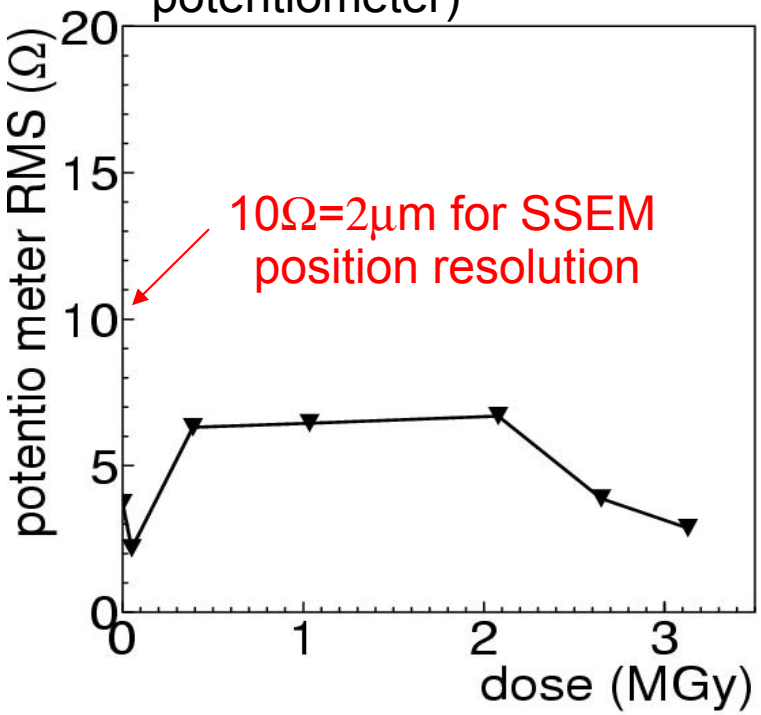
Motor itself works stably up to 3.1MGy

2. Cable

Insulation resistance

	Before irradiation	After irradiation
polyimide flex cable (SSEM cable)	>2000MΩ	5-20M Ω
polyimide coaxial cable (BPM cable)	>2000M Ω	>2000MΩ

Stability of the stepping motor (stability measured by a potentiometer)

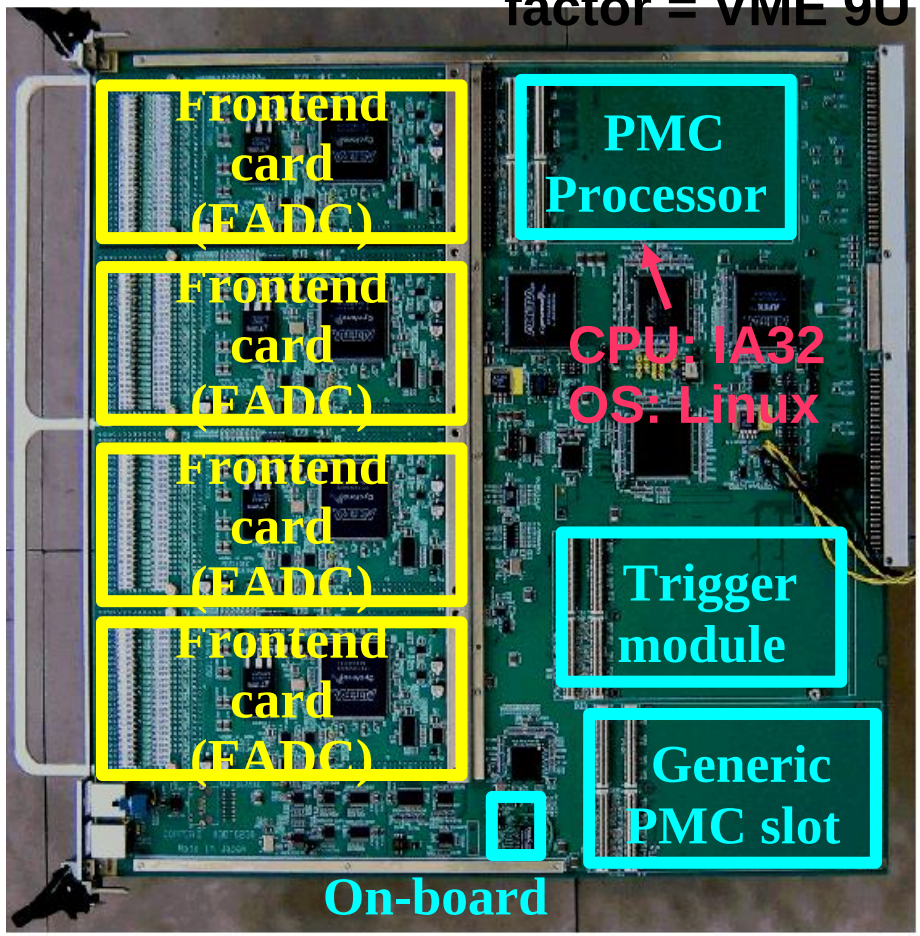


Stepping motor works at above 1MGy (~10 year operation @T2K line)
SSEM and ESM signal cables (polyimide flex. and polyimide coax.) are also OK

Status of the readout electronics

Use 65MHz FADC w/ shaper
← Copper based system developed at KEK
- Sample waveform so that we can extract bunch-by-bunch beam profile

Copper board: Form factor = VME 9U

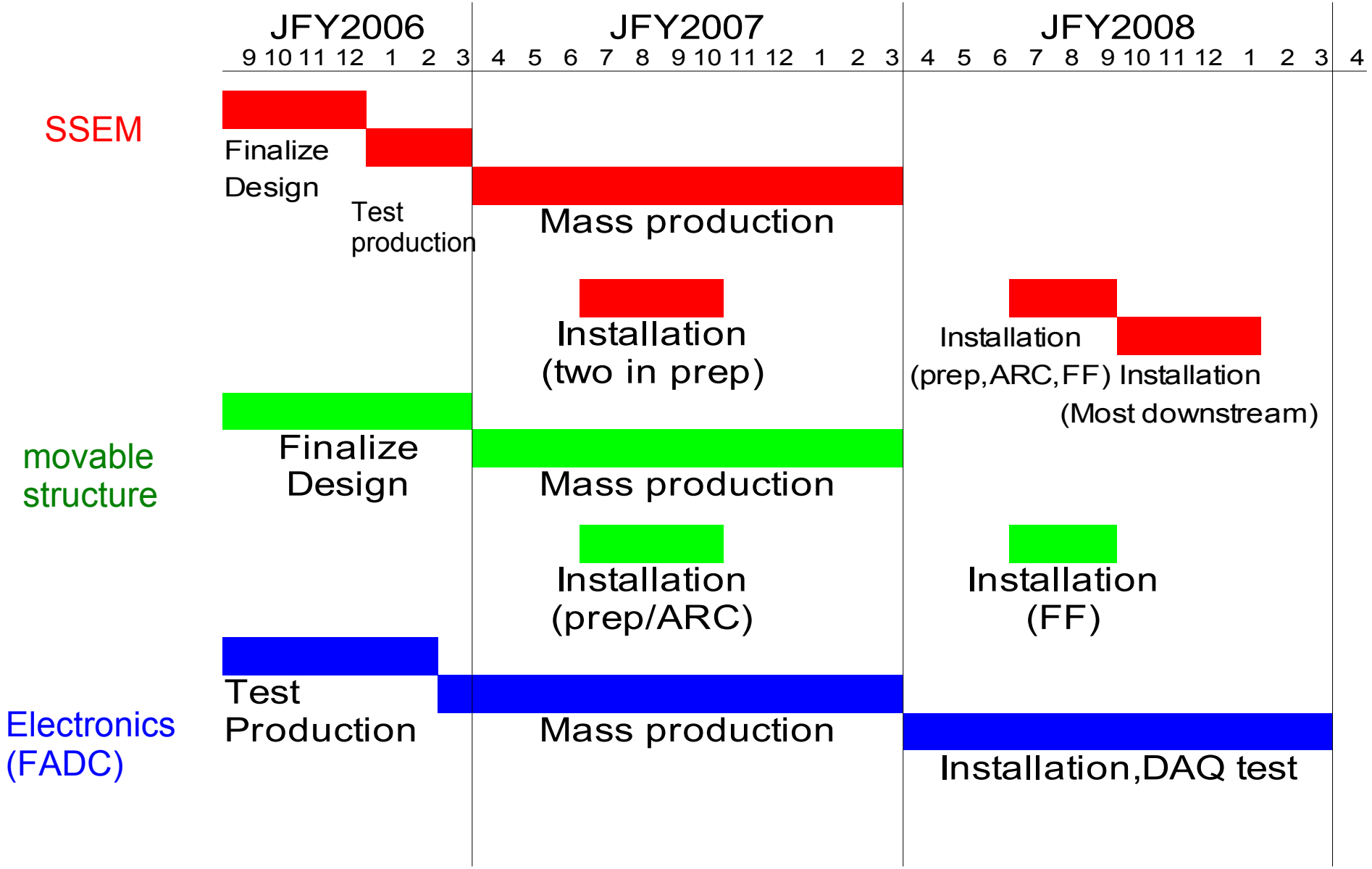


Performance is checked at the beam test
-optimized the shaping time (50ns)

-Copper boards are already ordered by Korean group
-Mass production of the FADC modules and its quality check will be also done by Korean group

-> Korean group is now preparing for the mass production of FADCs

Schedule


JFY2006
9 10 11 12 1 2 3
JFY2007
4 5 6 7 8 9 10 11 12 1 2 3
JFY2008
4 5 6 7 8 9 10 11 12 1 2 3 4
SSEM
Finalize Design
Test production
Mass production
Installation (two in prep)
Installation (prep,ARC,FF)
Installation (Most downstream)
movable structure
Finalize Design
Mass production
Installation (prep/ARC)
Installation (FF)
Electronics (FADC)
Test Production
Mass production
Installation,DAQ test

Summary

- SSEM performance evaluation
  SSEM satisfy the requirement for the beam tuning:
  resolution for the beam center position < 0.19mm
  resolution for the beam size < 0.27mm
- Status of SSEM structure
  First round of the Cryogenic test is done
  -> modify for the final design
- Electronics (FADC)
  Preparing for the mass production

- schedule is tight but we need to keep up with it:
  This year: Finalize all the design
  Next year: Mass production +
  Installation (structures for Prep./ARC)
  JFY2008: Installation

Gain calibration procedure

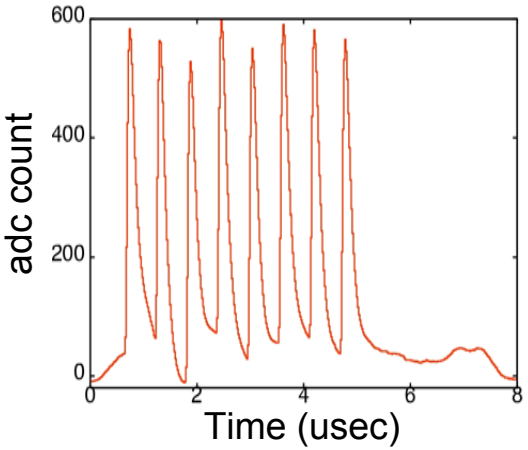
1. collect many pulse and average at beam center
2. move SSEM that corresponds to the strip pitch
3. collect many pulse and average at that position
4. For the strips that is parallel to the SSEM move,
   estimate the gain degradation from the above result

Gain of a certain strip: Gi
average intensity at that position: Ii
output signal Si = GiIi
-> move SSEM that corresponds to the strip pitch
output signal at that position: S'(i-1)=G(i-1)Ii
gain of the strip:
Gi = Si/S'(i-1) * G(i-1)
= Si/S'(i-1) * ... * S2/S'1 * G1
All the gain is written using one unknown gain G1

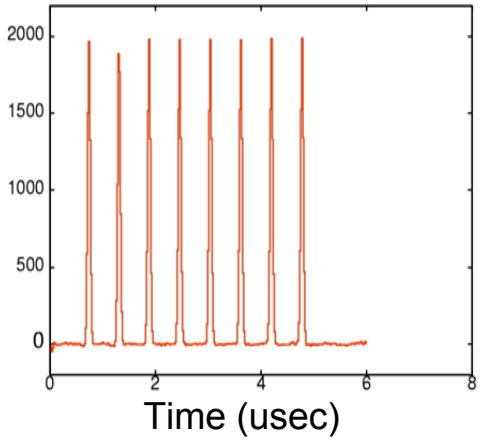
SSEM is required to have the uniform strip pitch

Degradation of the SSEM resolution in multi bunch environment

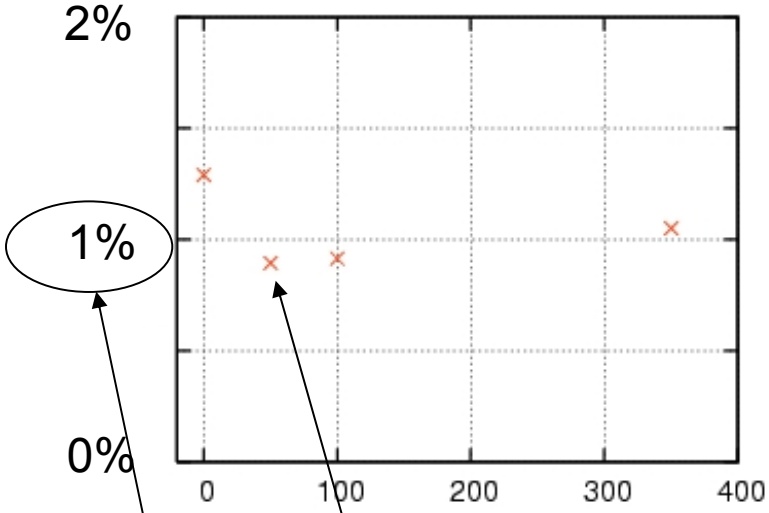
- Deviation of pulse height for each shaping time



Deconvolution
+
Baseline subtraction



Deviation of pulse height



50nsec is suitable for the T2K experiment

1% corresponds to

Beam position error	~0.06mm
Beam width error	~0.04mm

Structure test w/ motor

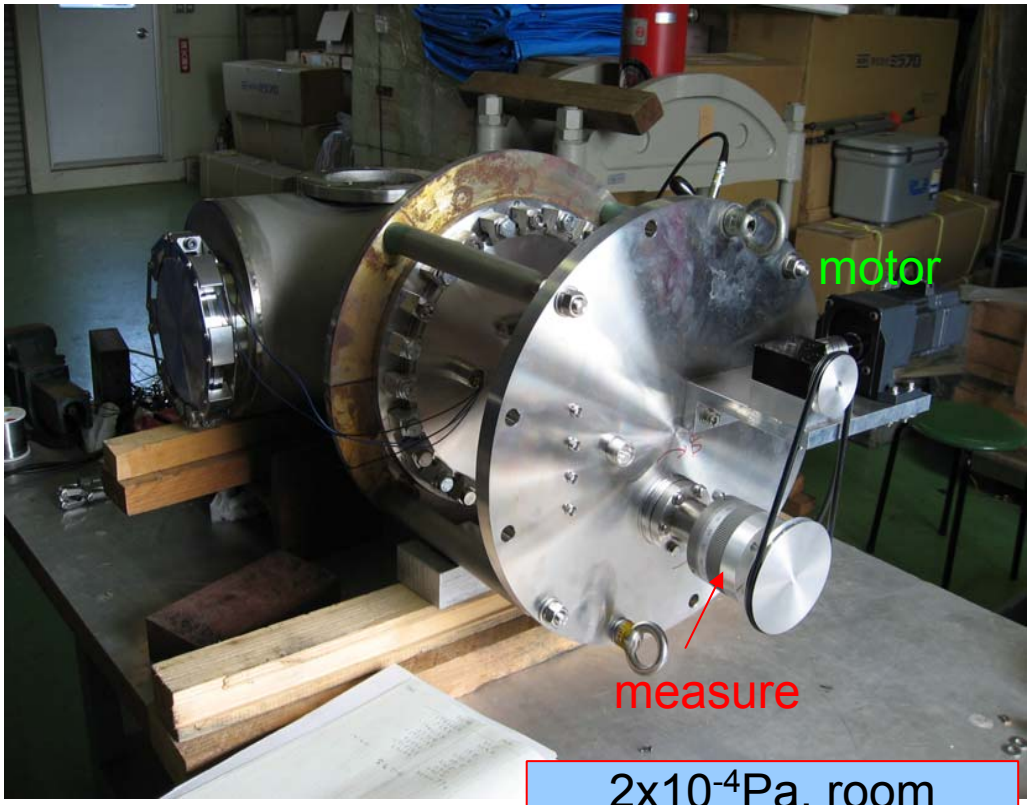
Test movable structure using stepping motor.

- 25 cycles full stroke between the limit switches

Stability of the position is OK (5-10 μm error) for 25 cycles

Stability of the number of steps is not stable (~0.1% deviation)

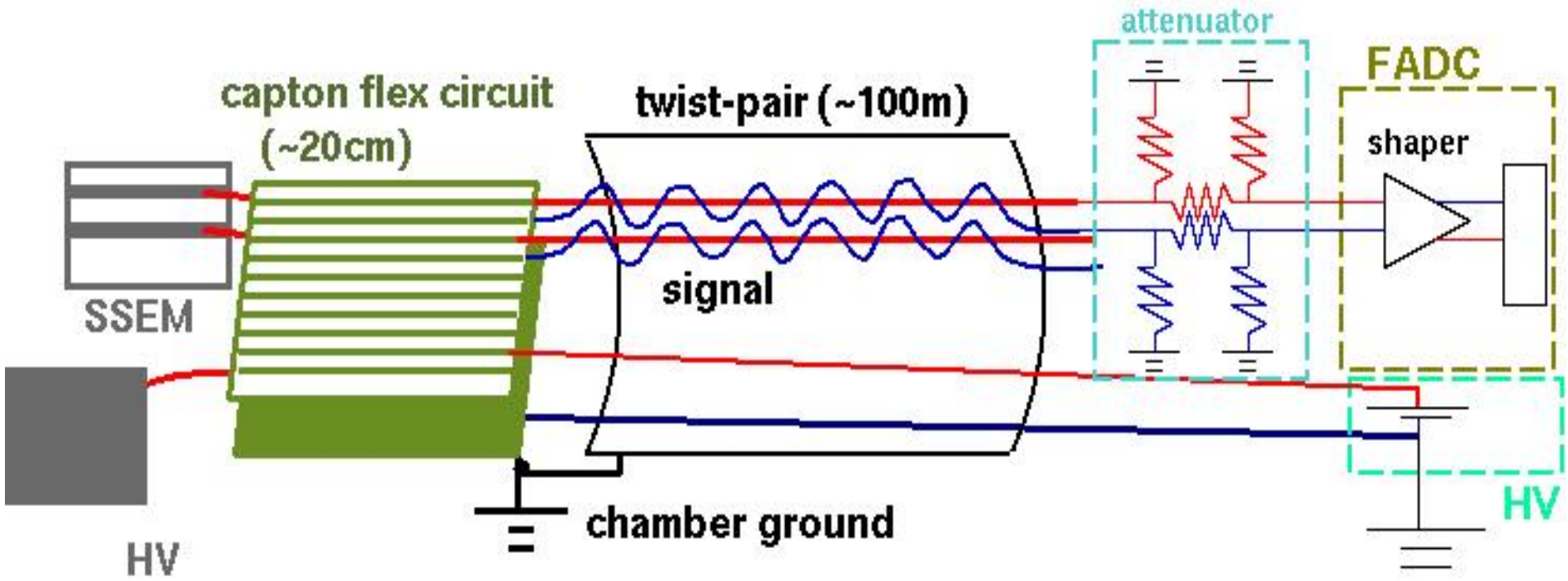
120m long cable did not work after 5 cycles



2×10^{-4}Pa, room temp.

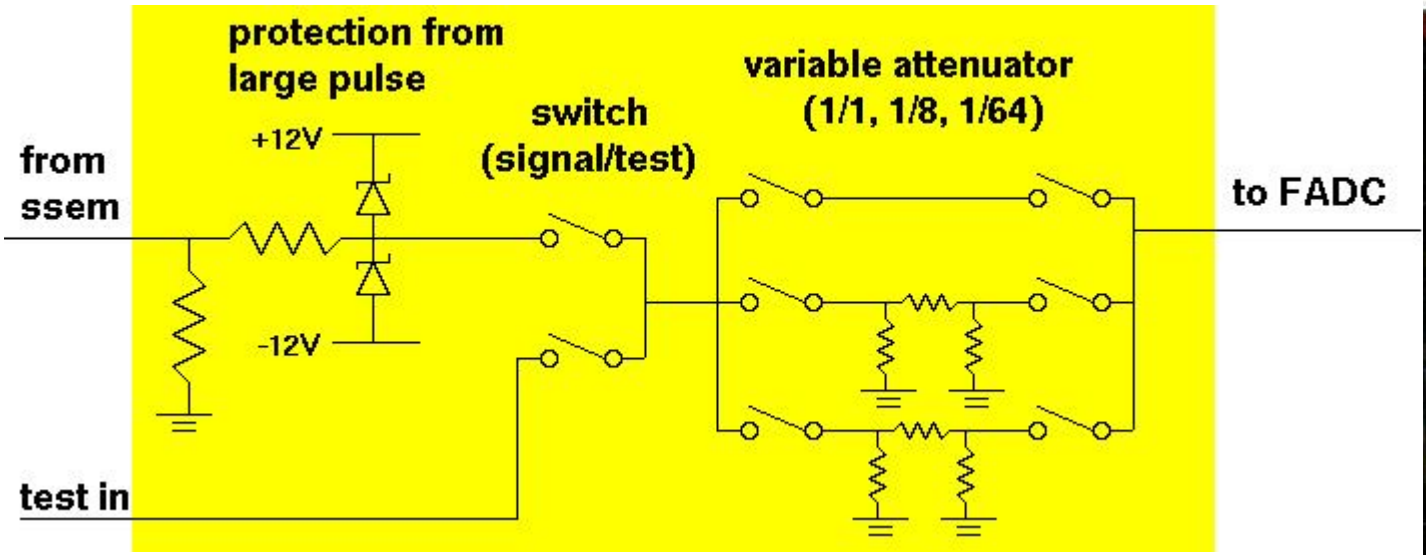
SSEM Electronics

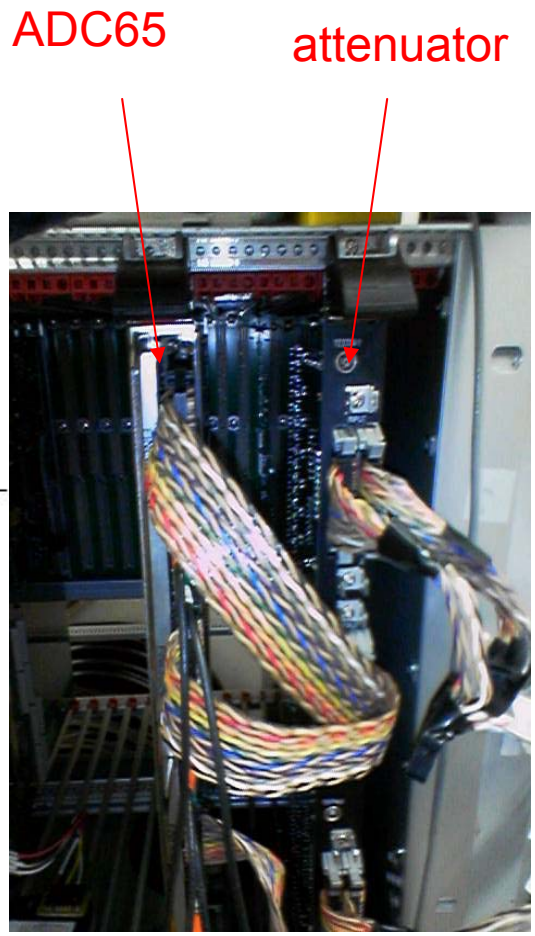
Test FADC65 module using the real proton beam at KEK
- Cables:
  capton flex circuit + ETFE twist-pair cable
- VME variable attenuator
- Readout module
  copper-base 65MHz FADC (ADC65)



Attenuator module

-Attenuation level (1/1, 1/8. 1/64) can be controlled via VME bus
-have test input for calibration purpose





Status:
The linearity of the signal turned to be bad
-> modify the design

FADC module

FADC w/ Default shaping time (1μs) work fine for the beam test (single bunch/pulse)

For T2K, we will have 8 bunches w/ 600ns spacing
-> optimized the shaping time to be 50ns

Default shaping time: 1μs