Beam Diffusers for Beam Loss Reduction

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J-PARC/KEK

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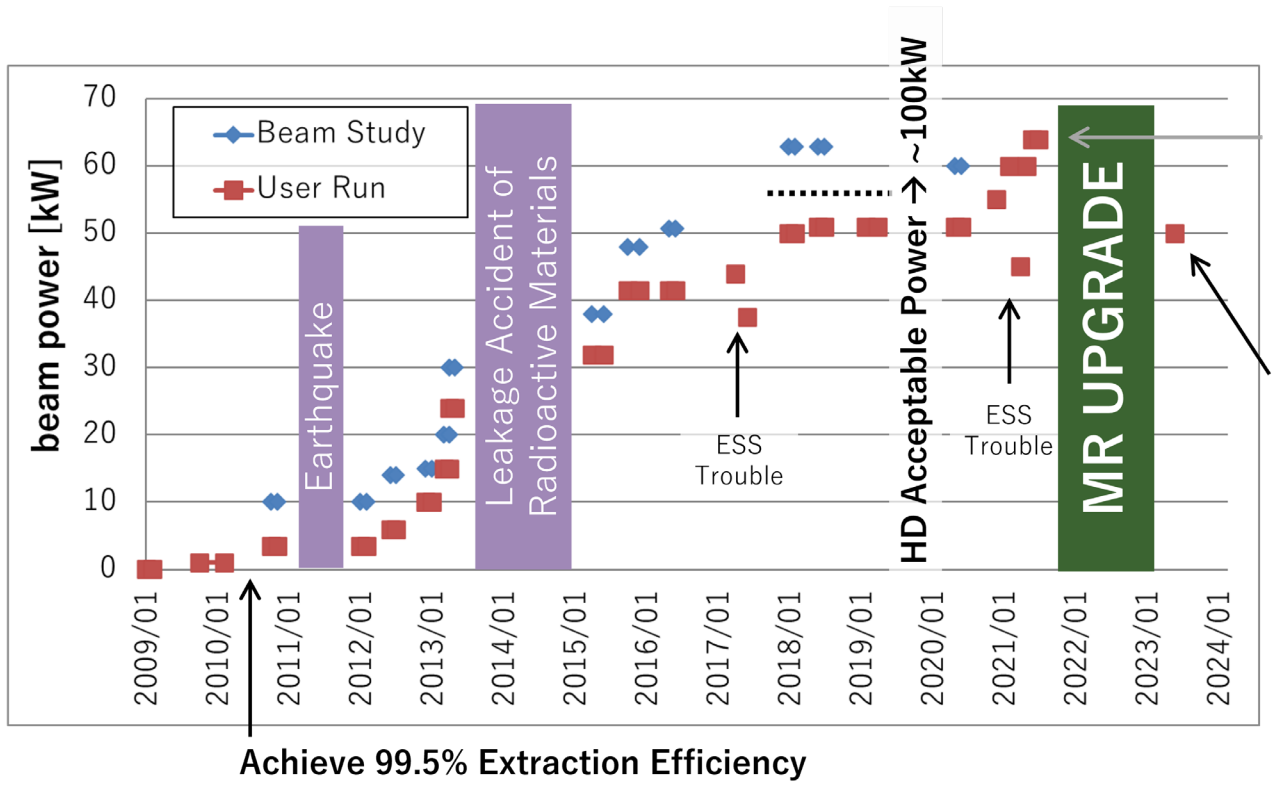
Slow Extraction Workshop 2024

Outline

- Motivation
- Concept of Beam Diffuser for Beam Loss Reduction
- Beam Test Result (from 2021 beam test)
- Estimation for Residual Radiation Dose Rate with Diffusers
- Future Plan
- Summary

Motivation

Slow Extraction Beam Power Trend



Before MR upgrade
Beam power: 64kW
(5.2 s repetition)
Ext. efficiency: 99.5%
Spill duty: ~60%
for user operation
(2021-Jun)

After MR upgrade
Beam power: 50kW
(5.2 s repetition)
Ext. efficiency: 99.5%
Spill duty: ~50%
for user operation
(2023-Jun)

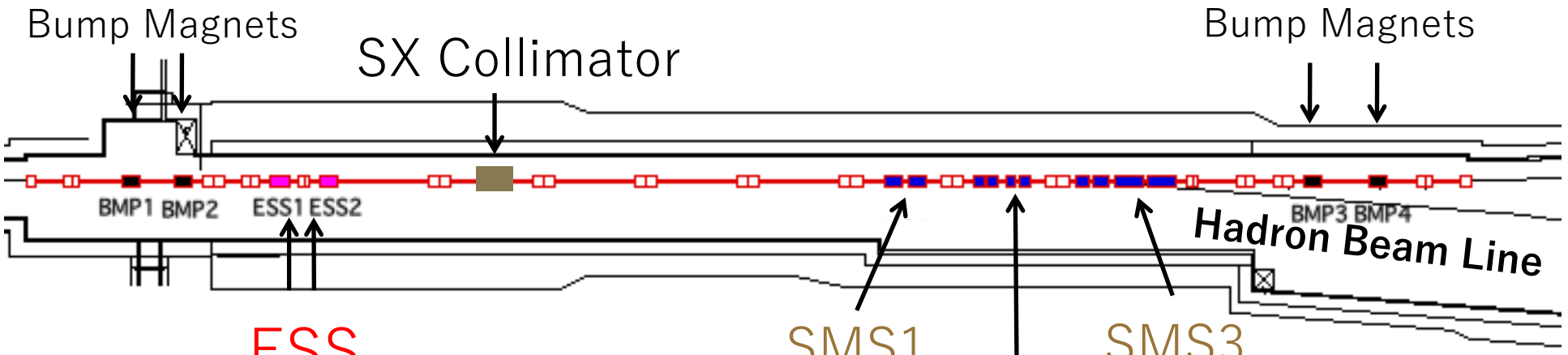
+COMET phase-α
(8 GeV, bunched SX)

8

It is highly desirable to further reduce the beam loss

- to suppress the residual radiation dose rate
- to reduce the frequency of ESS discharge during the beam operation

Residual Dose Rate in Slow Extraction Straight Section

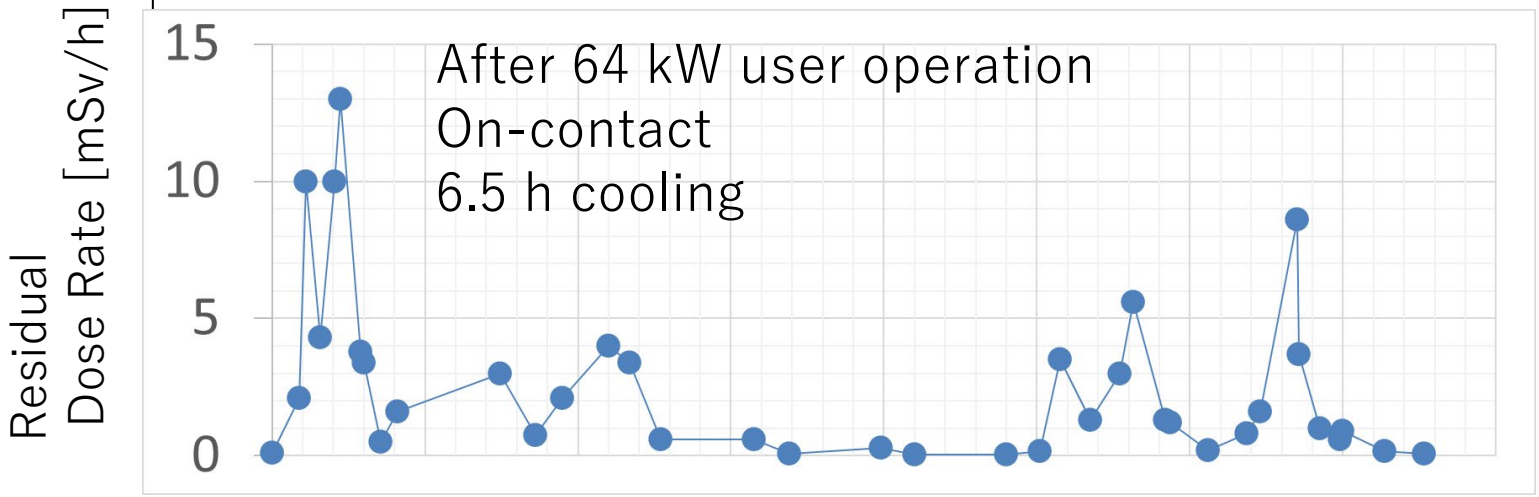


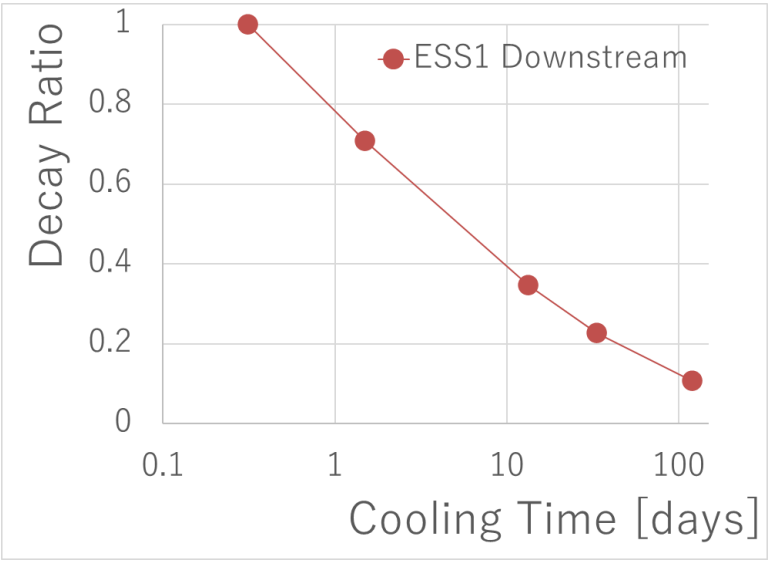
ESS
(Electrostatic Septum)

SMS1
SMS2
SMS3

Septum Magnets

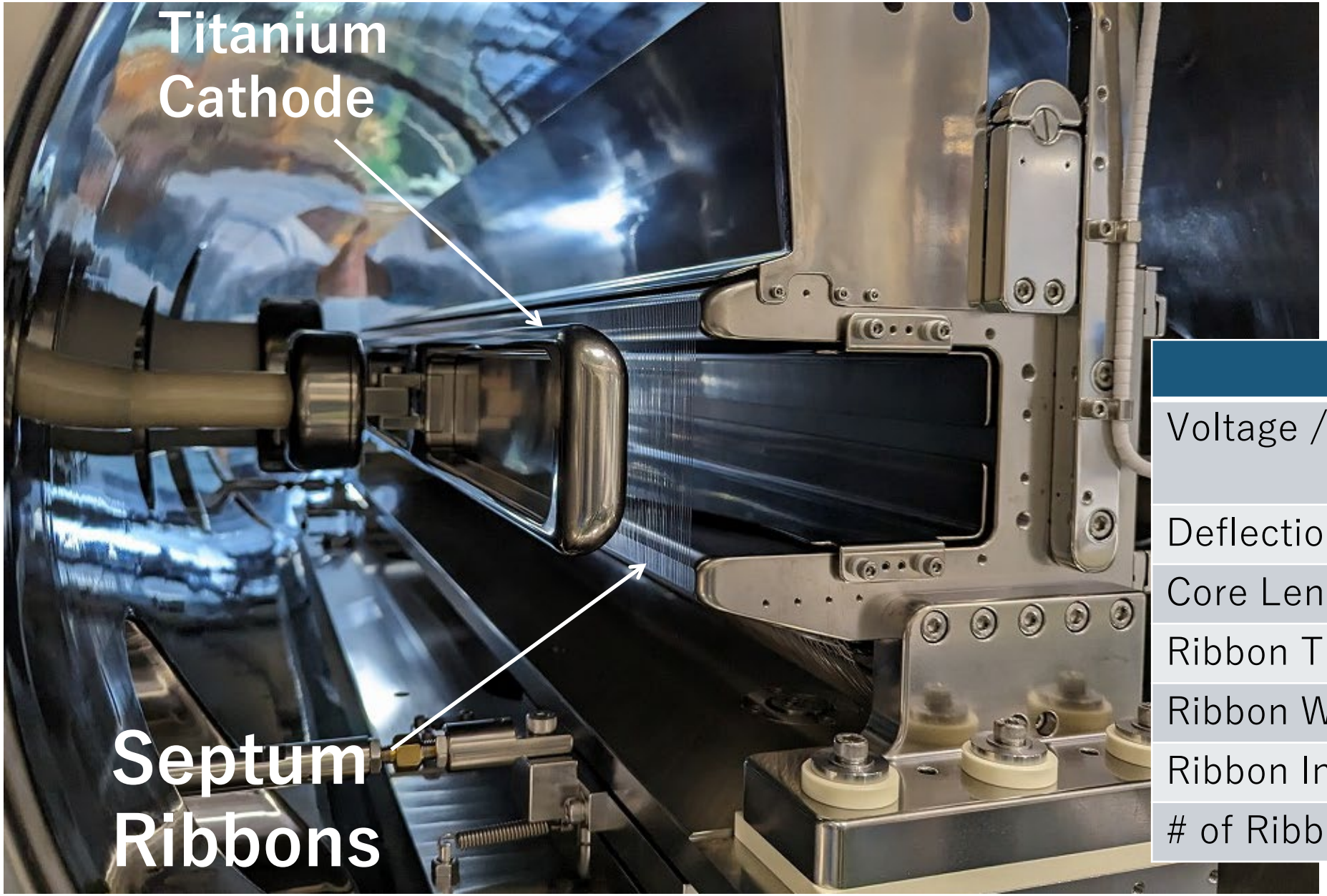
~100 m





Beam loss must be further reduced
to increase beam power
while keeping
the maintainability of devices.

Electrostatic Septum (ESS) in J-PARC MR



	ESS1,2
Voltage / Gap	**104 kV** / 25 mm = 4.2 MV/m
Deflection Angle	- 0.2 mrad
Core Length	1.5 m
Ribbon Thickness	30 μm
Ribbon Width	1 mm
Ribbon Interval	3 mm
# of Ribbons	495

Beam Loss Reduction Schemes

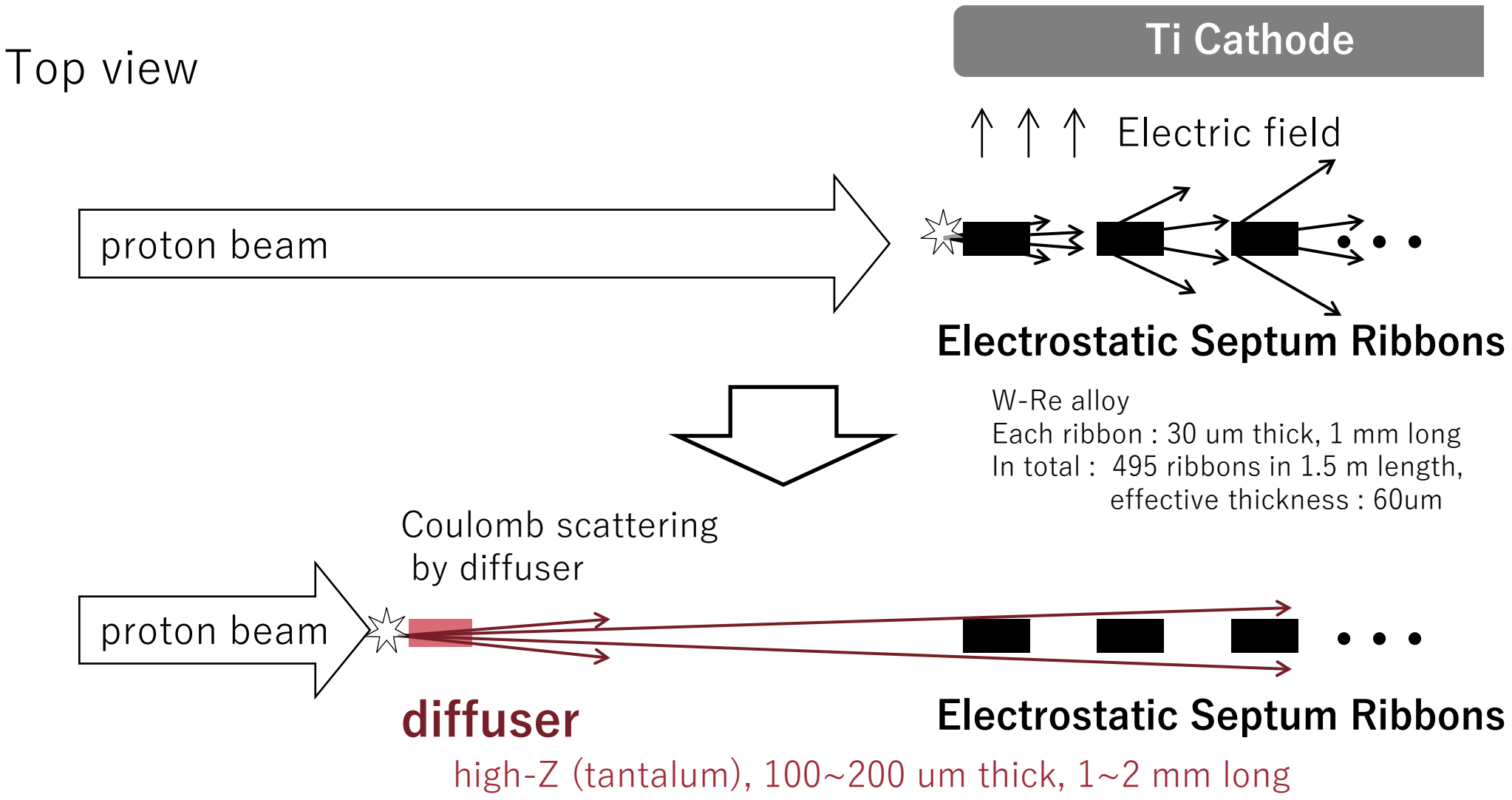
Beam loss mainly occurs at the most upstream ESS

→ Reduction of the proton hit rate on the septum is important

- Beam Diffusers

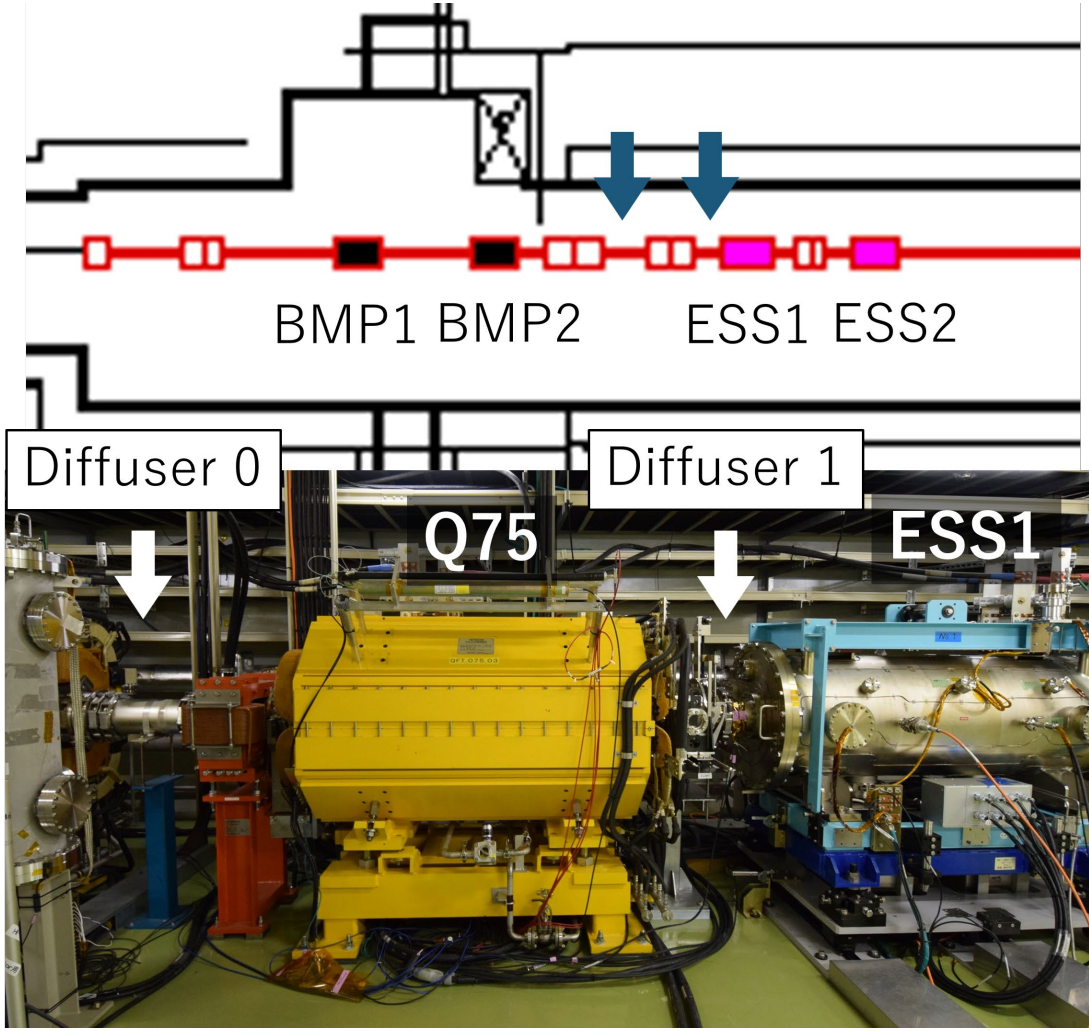
- Bent Silicon Crystal

Beam diffusers for loss reduction



The diffuser is easy to produce and needs only one insertion arm

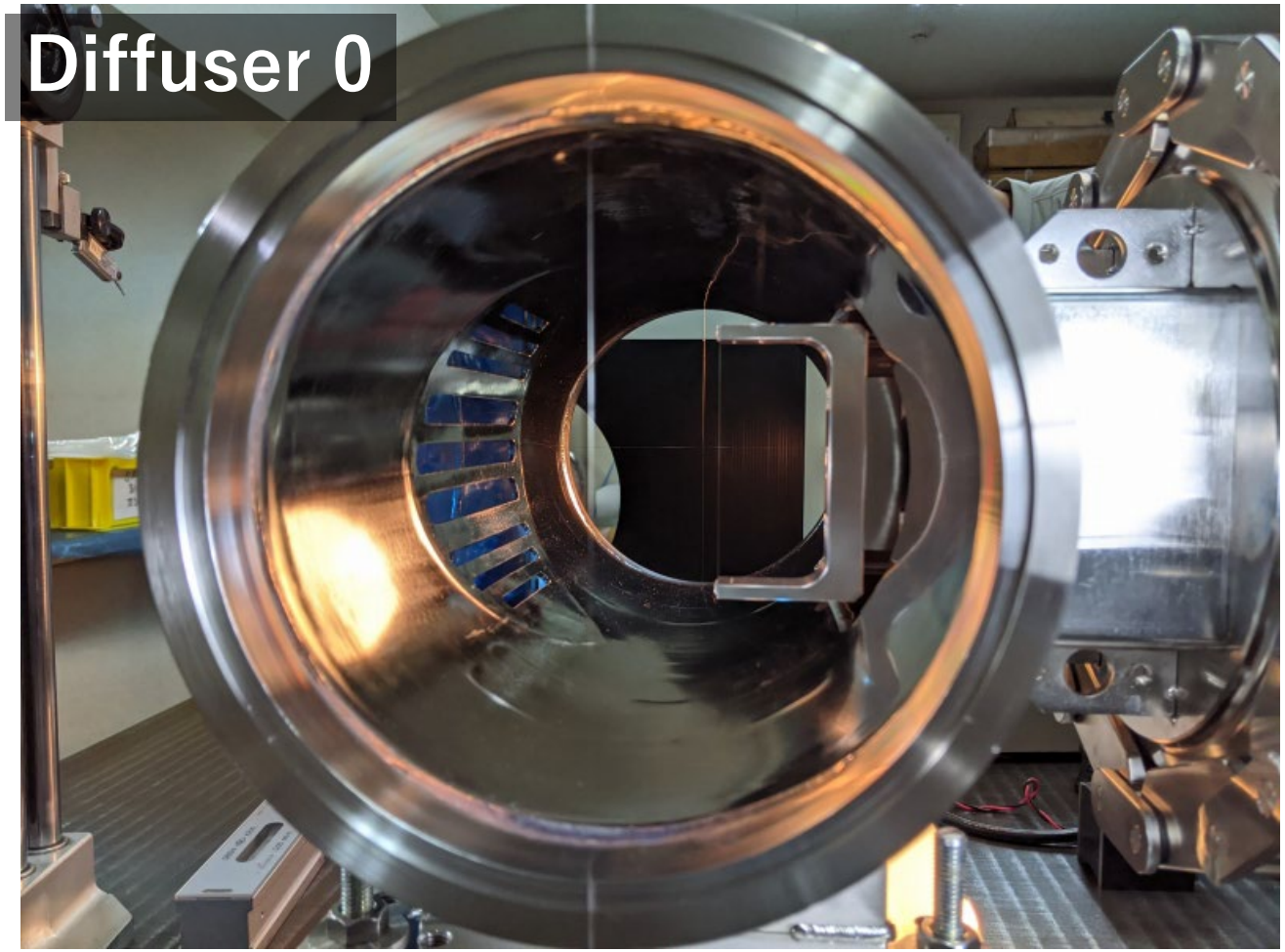
Places and Optimal Sizes of Diffusers



	Diffuser 0 phase ~5°		**Diffuser 1** phase ~0.7°		**beam loss**
	thickness [um]	length [mm]	thickness [um]	length [mm]	
No diffuser	-	-	-	-	1
diffuser 0 only	200	0.5	-	-	0.42
diffuser 1 only	-	-	100	2	0.47
diffuser 0 & 1	200	0.5	100	2	**0.35**

Diffuser at large phase advance
needs large thickness
but its length can be shortened

Installed Beam Diffusers



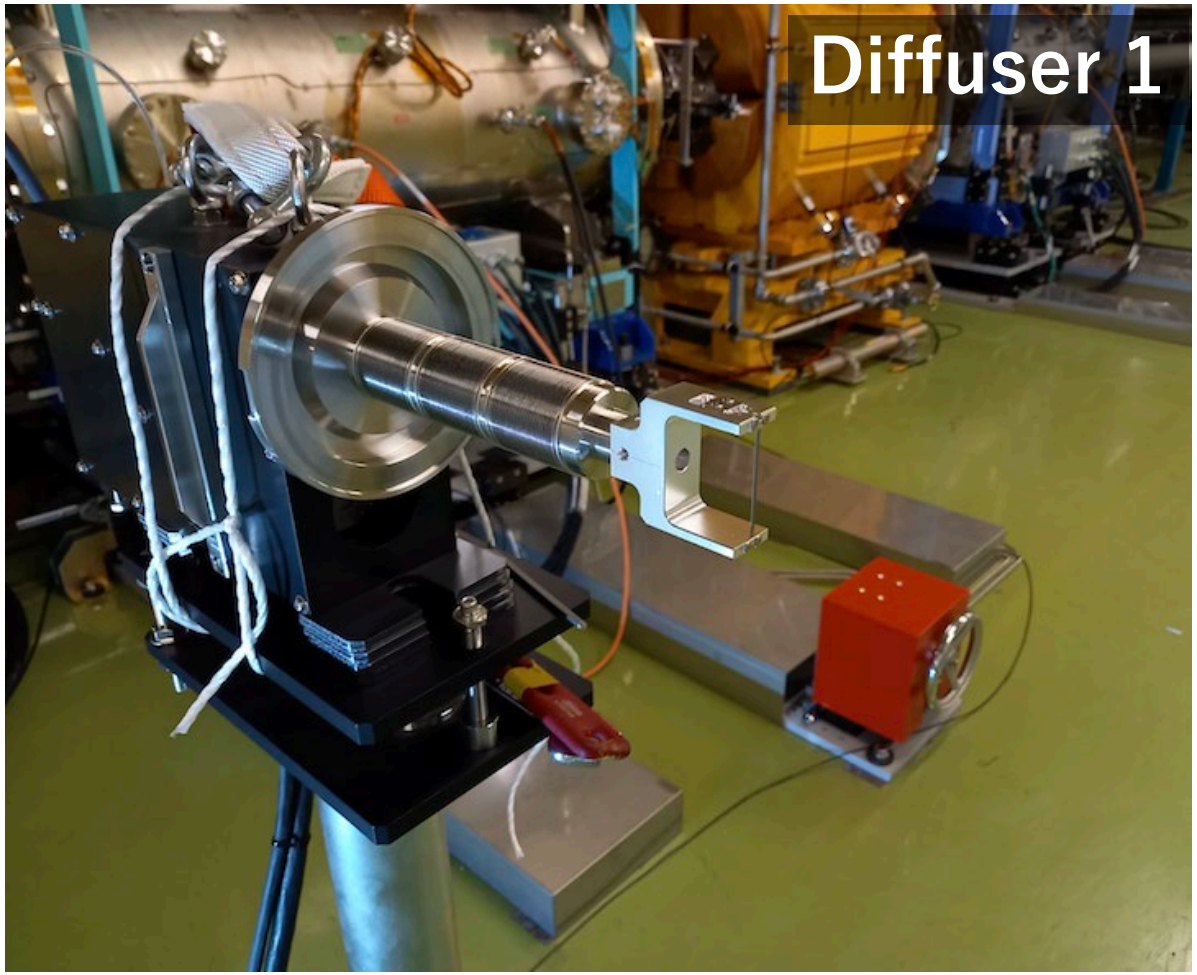
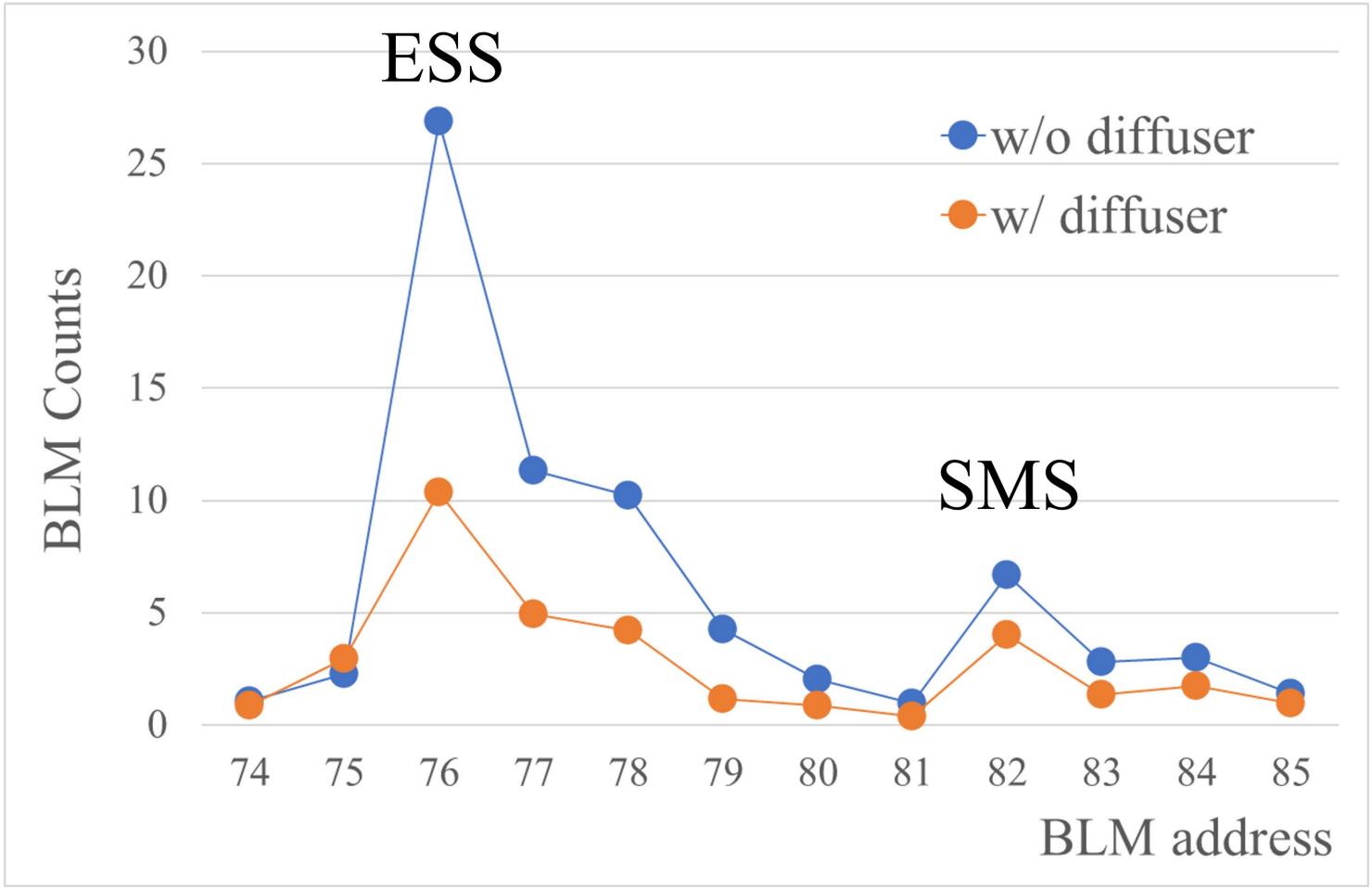


Photo from downstream

Beam Test for Diffuser 0

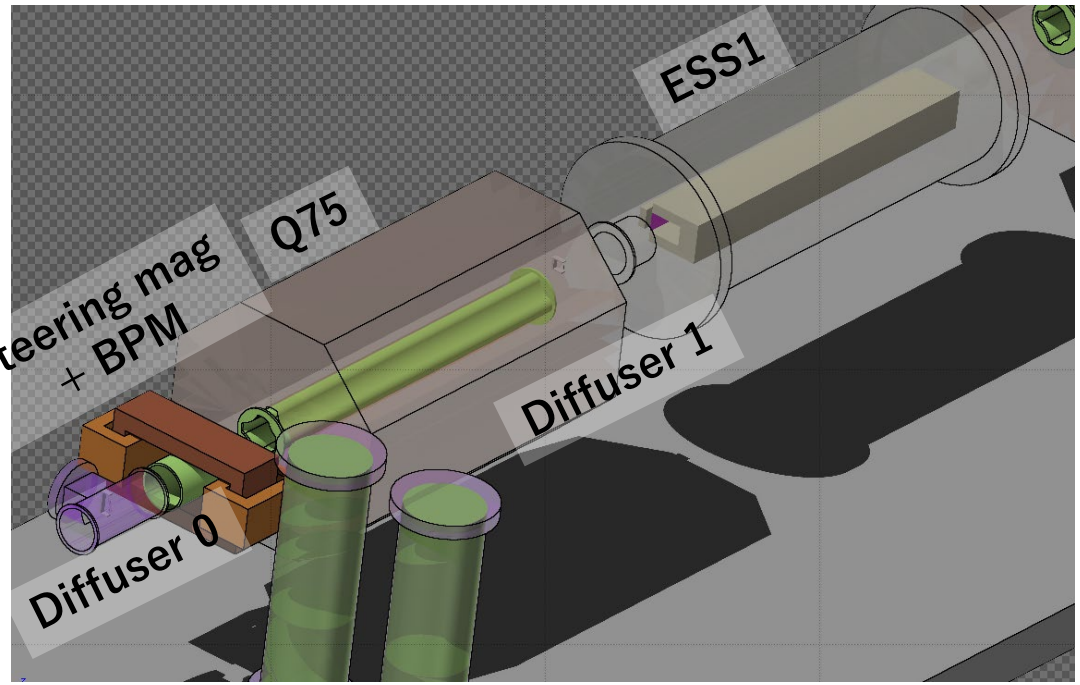
2021-Feb-18 16:00-17:00
Beam power: 10 kW



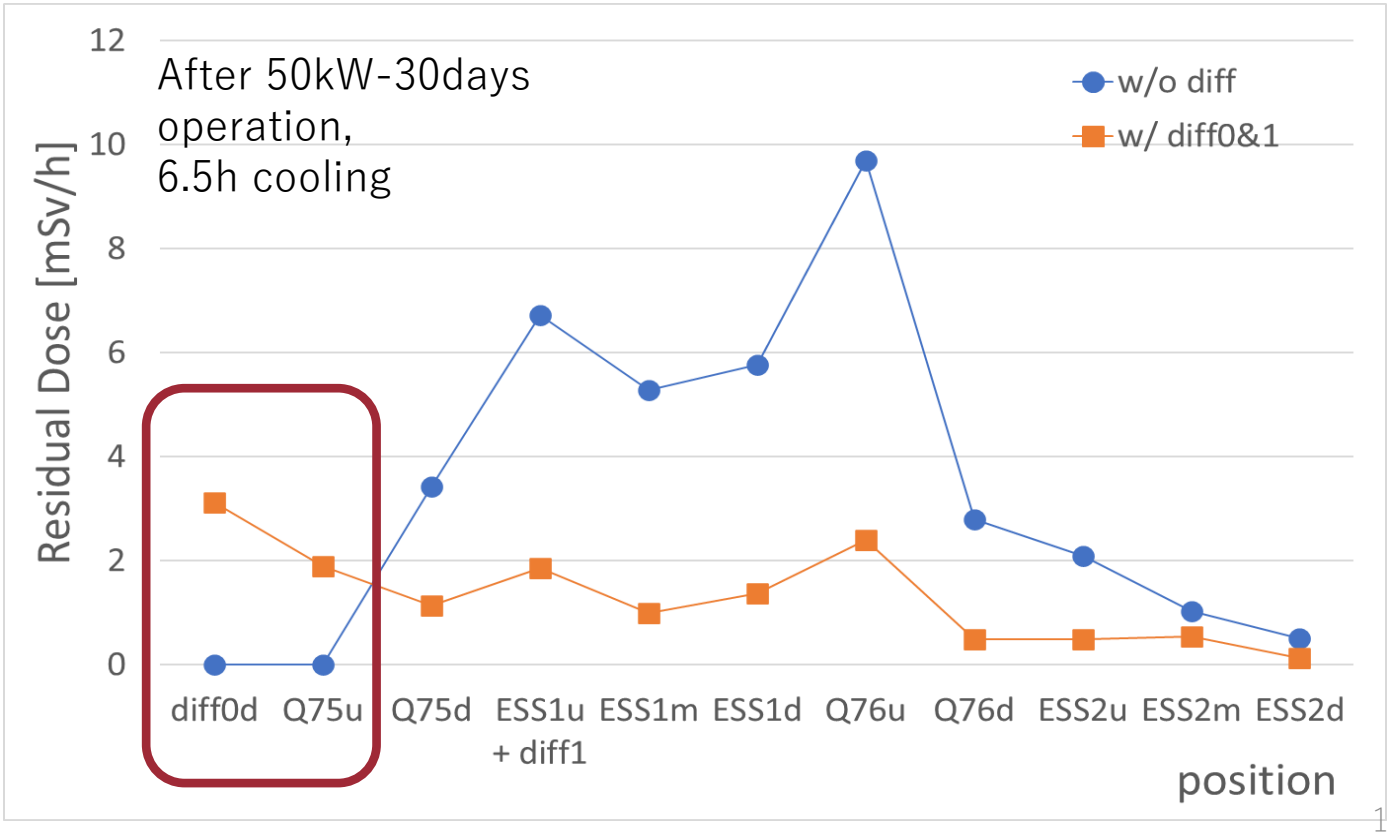
Beam loss was reduced to factor ~0.4 with diffuser 0 only (in good agreement with simulation)

- Diffuser 1 test
- Both Diffuser 0 & 1 in the beam
- Test with high-power beam will be done in the next beamtime

Estimation for Residual Radiation Dose Rate



Residual Radiation Dose Rate (FLUKA)



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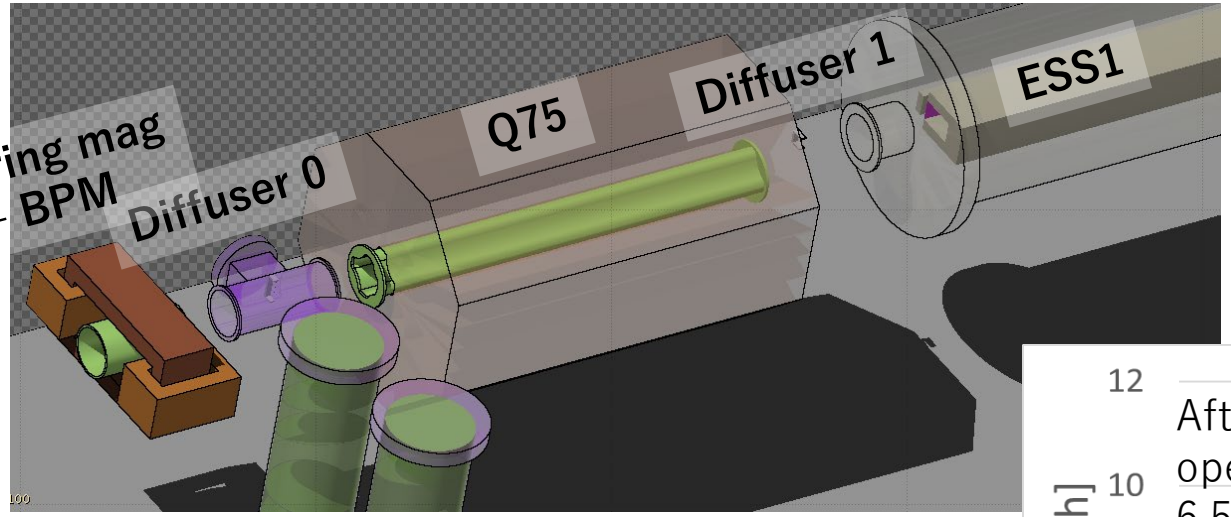

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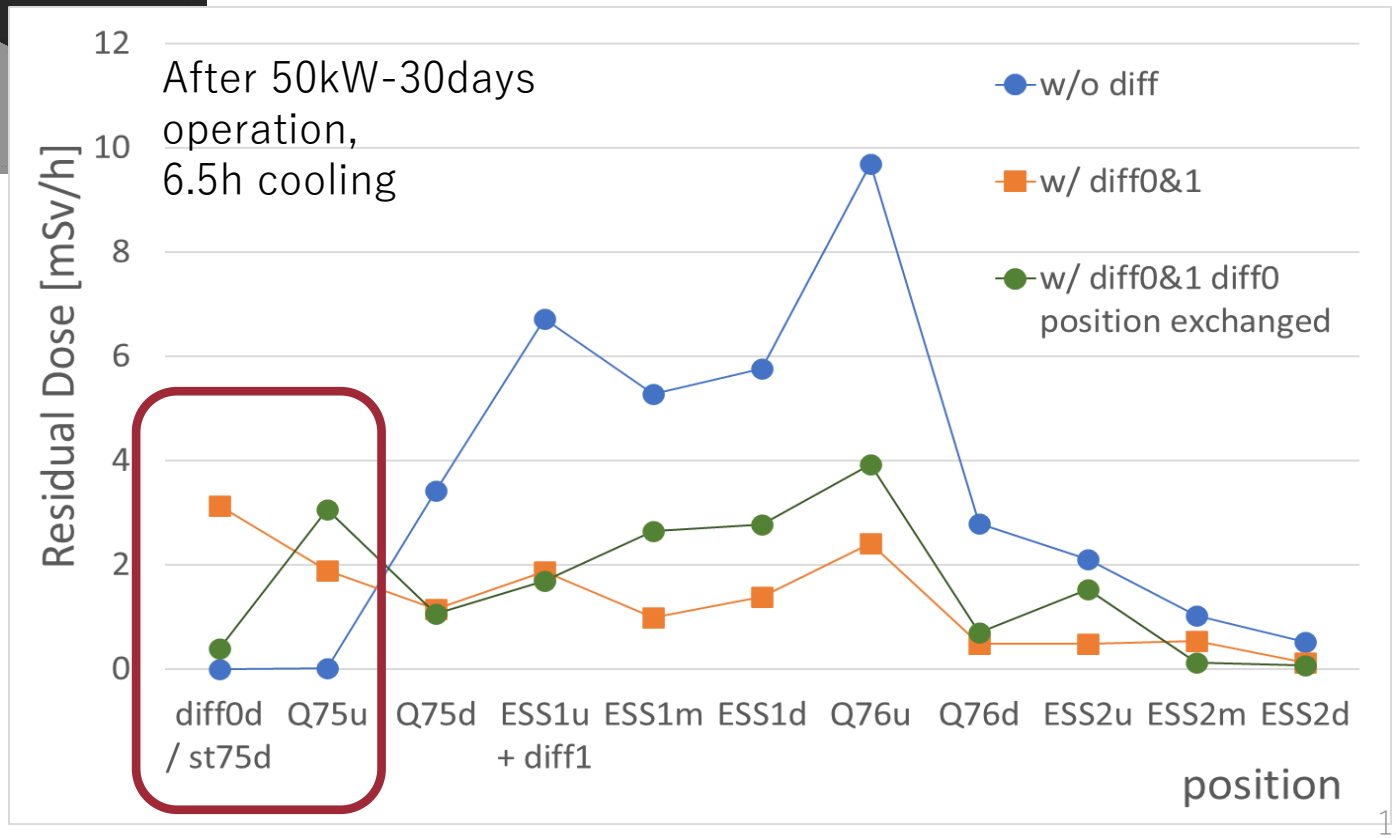
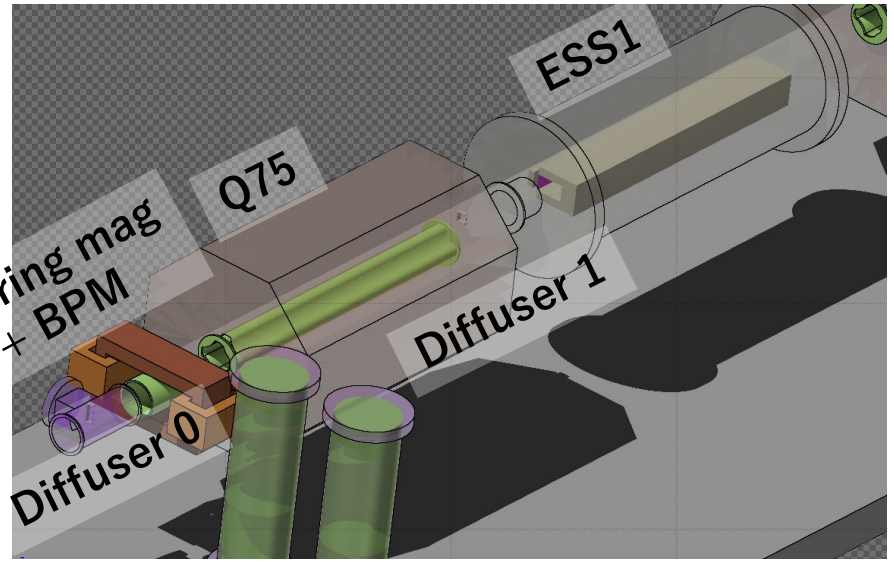
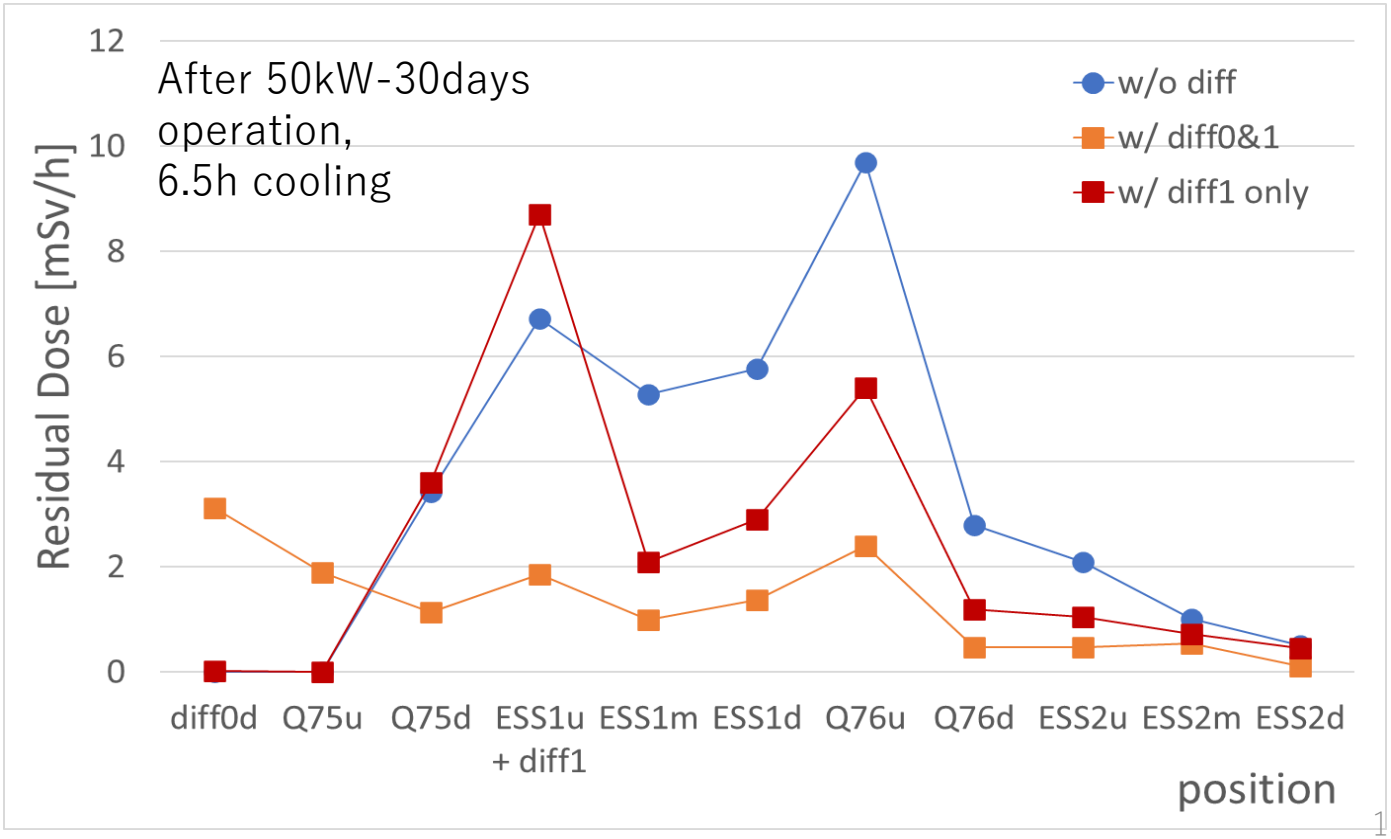


In case of exchanging the position of diffuser0 and steering mag + BPM

Estimation for Residual Radiation Dose Rate

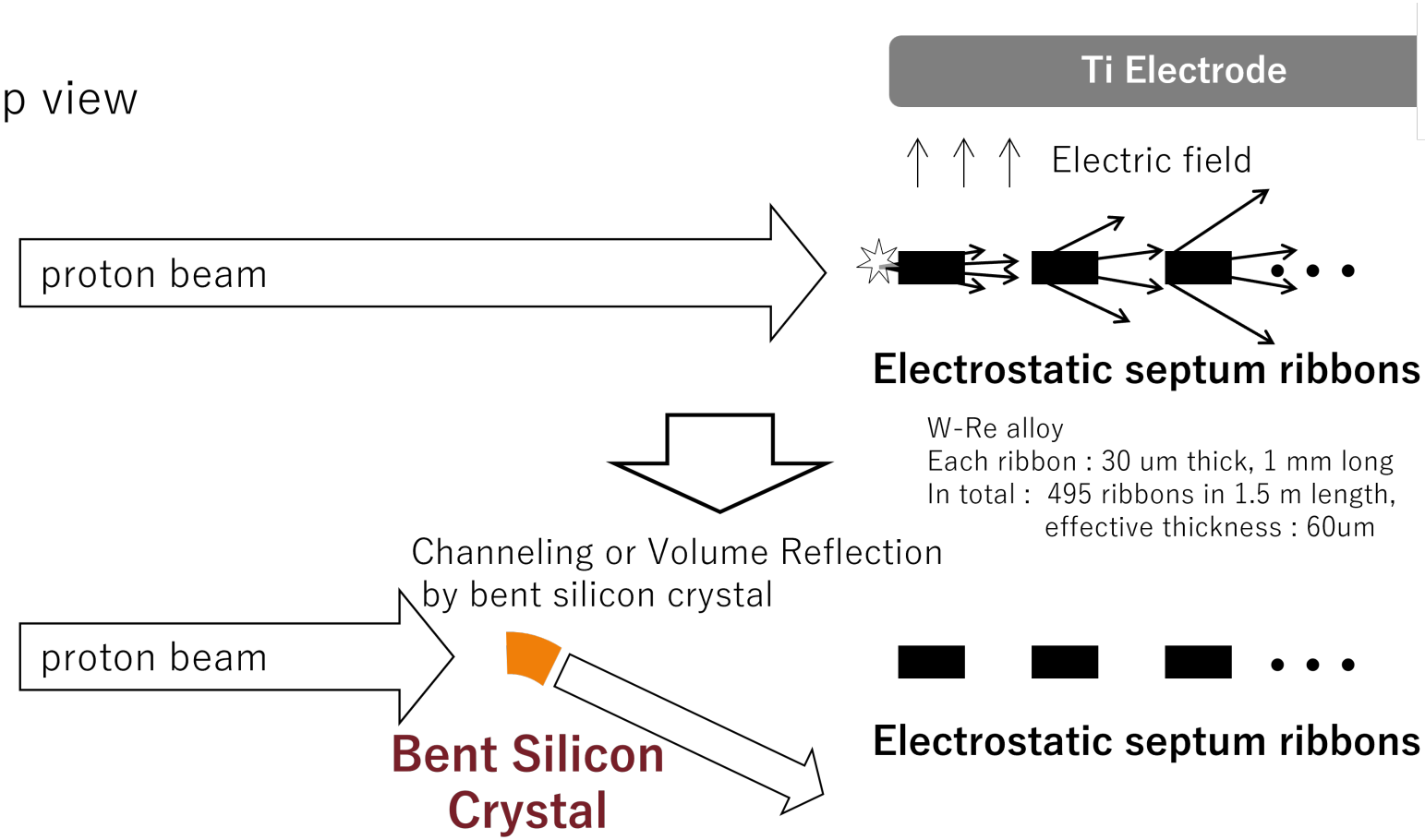


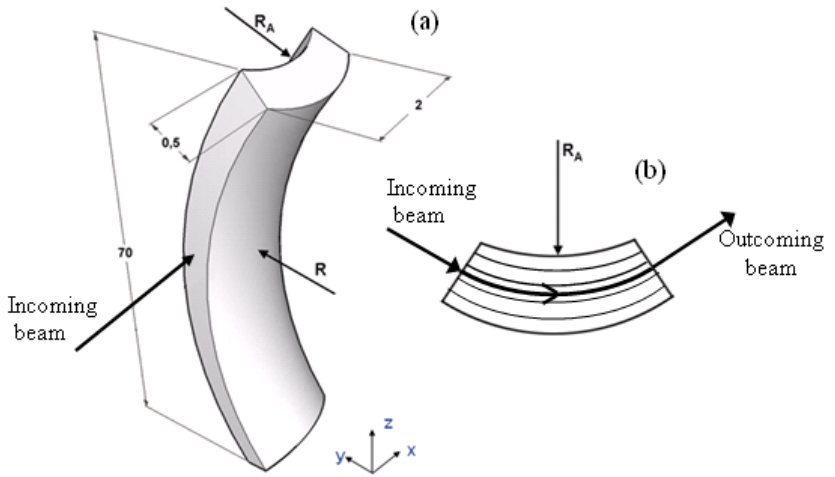
configuration	beam loss
No diffuser	1
Diff. 0 only	0.42
Diff. 1 only	**0.47**
Diff. 0 & 1	0.35



Silicon Bent Crystal for Loss Reduction

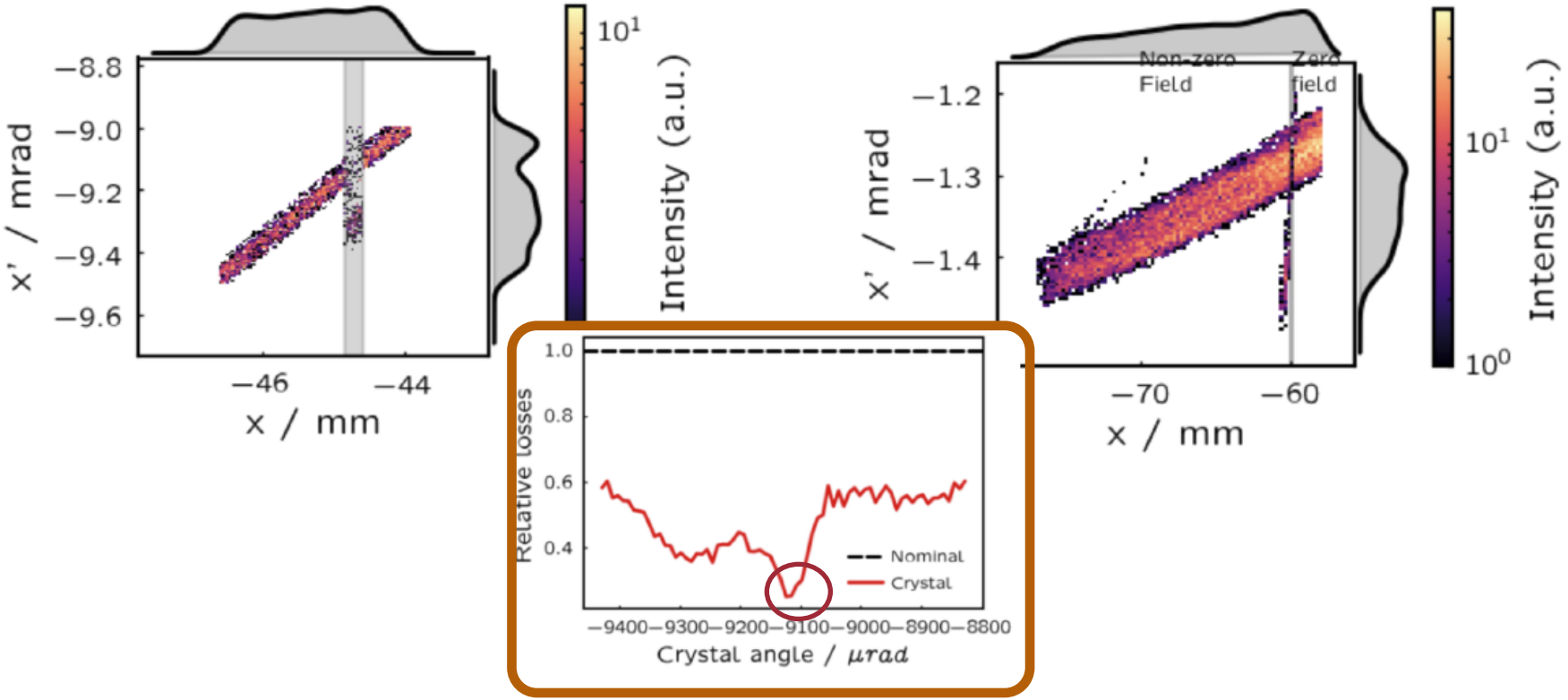
Top view





Simulation for Bent Silicon Crystal

Simulation studies for bent silicon crystal with 30 GeV proton
by F. M. Velotti et al. at CERN SPS



In simulation, beam loss can be reduced to **0.25** with bent silicon crystal with a thickness of 250 um.

The bent silicon crystal needs two arms for transverse position alignment and angle alignment.

Plan:
First, establish
the beam diffuser scheme
Next, exchange Diffuser 0
with bent silicon crystal
for further beam loss reduction

Summary

- To keep the current maintainability of the slow extraction devices with higher beam power, we need to further reduce the beam loss

- We installed two diffusers and tested the diffuser0 with a 10 kW beam and observed beam loss reduction by a factor of ~0.4

- We plan beam test with higher beam power for both diffuser0 and diffuser1 in April and May