WEP12

DEVELOPMENTS OF WIDE DYNAMIC-RANGE HALO MONITOR FOR 8 GeV PROTON BEAMS AT FNAL

Y. Hashimoto[†], C. Omori, Y. Sato, T. Toyama, T. Mitsuhashi,
M. Tejima, T. Sasaki, and M. Uota,
KEK/J-PARC, Japan
R. Ainsworth, FNAL, USA
H. Sakai, Mitsubishi Electric System & Service Co., Ltd., Japan

Abstract

The FNAL accelerator complex has been upgrading in increasing beam intensity and beam quality. A new beam halo diagnostic device is required in the beam transport line between booster and Recycler.

For this purpose, it was decided to introduce the wide dynamic range monitor technique that was developed in 2012 and has been in operation at the J-PARC beam transport line. The device is a two-dimensional beam profile monitor, and it has a dynamic range of approximately six digits of magnitude by using of Optical Transition Radiation and fluorescence screens. Eliminating harmful beam halos is the most important technique for high-intensity proton accelerators. Therefore, beam halo diagnosis is indispensable and becomes more and more important.

New FNAL device has been manufactured in a collaboration between J-PARC and FNAL as a part of U.S.-Japan Science and Technology Cooperation Program in High Energy Physics. The equipment will be manufactured at J-PARC and will be shipped to FNAL in 2025.

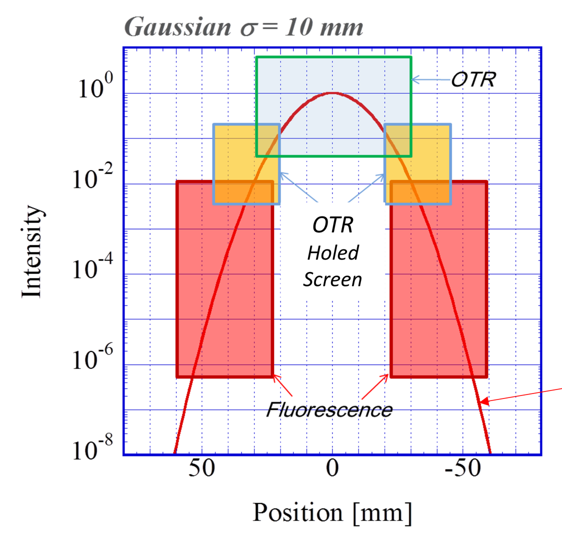
We designed the device to satisfy FNAL specifications: the beam energy, intensity, and size. Currently, most of the equipments are under construction. The large-aperture optical system has been completed and its optical characteristics are being evaluated at J-PARC. We have been also investigating measurement methods corresponding to FNAL bunch trains. This paper reports on the current status of these developments.

Concept (1): Dynamic range

Combination measurement with OTR and the fluorescence:

Beam core : Measure with OTR from 10 microns titanium foil with smaller beam loss
Beam Halo : Measure with Fluorescence from Chromium doped alumina screen

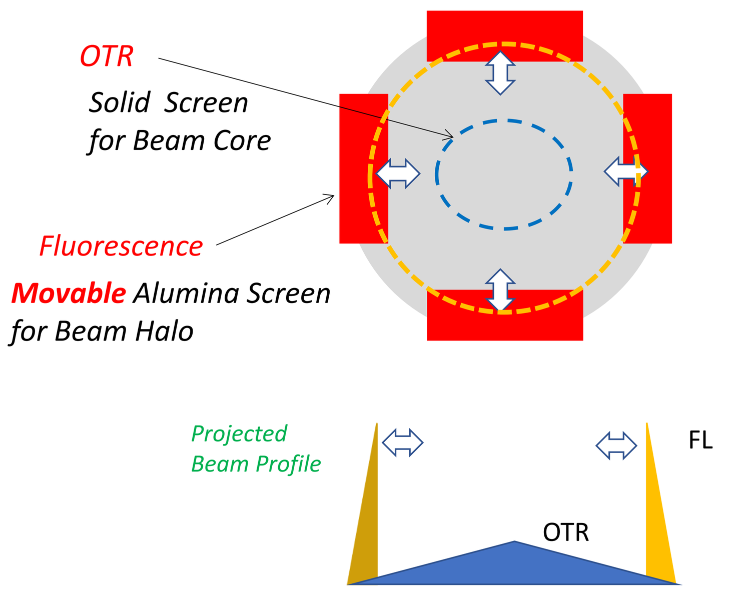
Adopting Suitable Gain of the Detector: Image Intensifier (II)



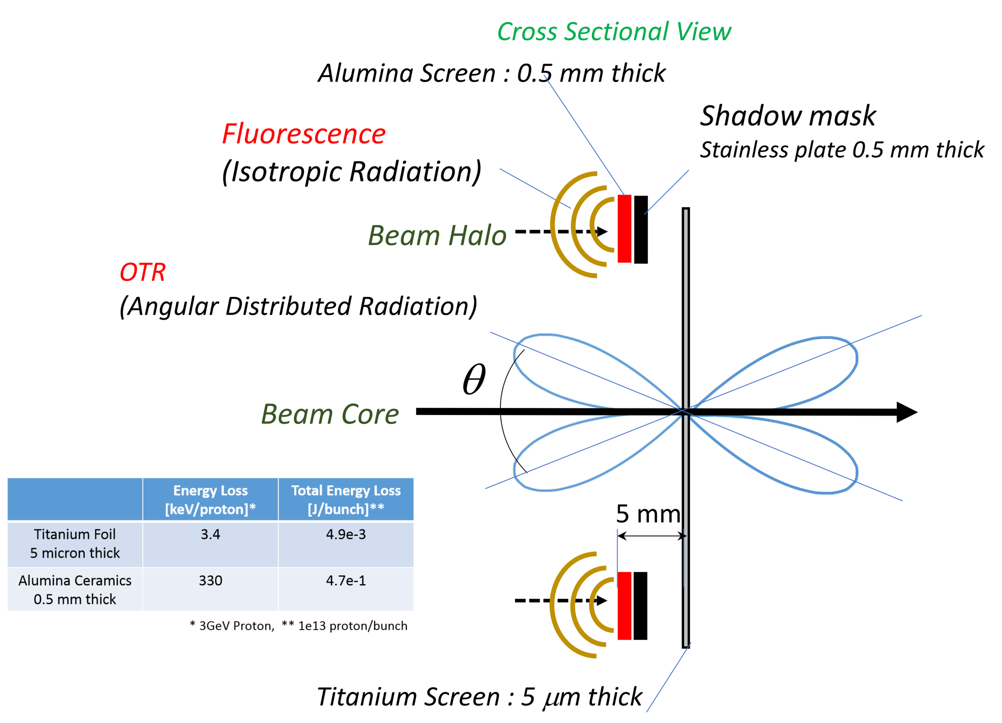
Gaussian Beam distribution
σ = 10 mm
Intensity: 10^{13} proton/bunch

Concept (2): Screen Configuration

Layout (Front View)



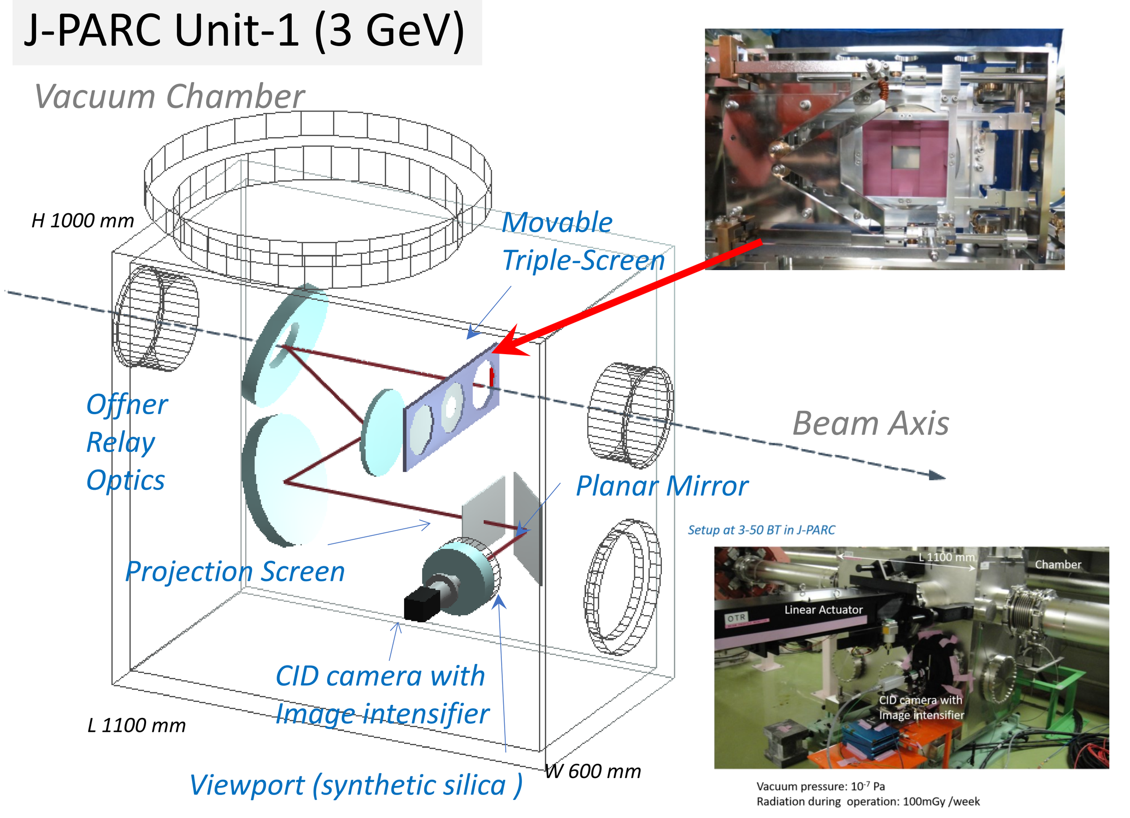
Concept (2): Target Cross-sectional View



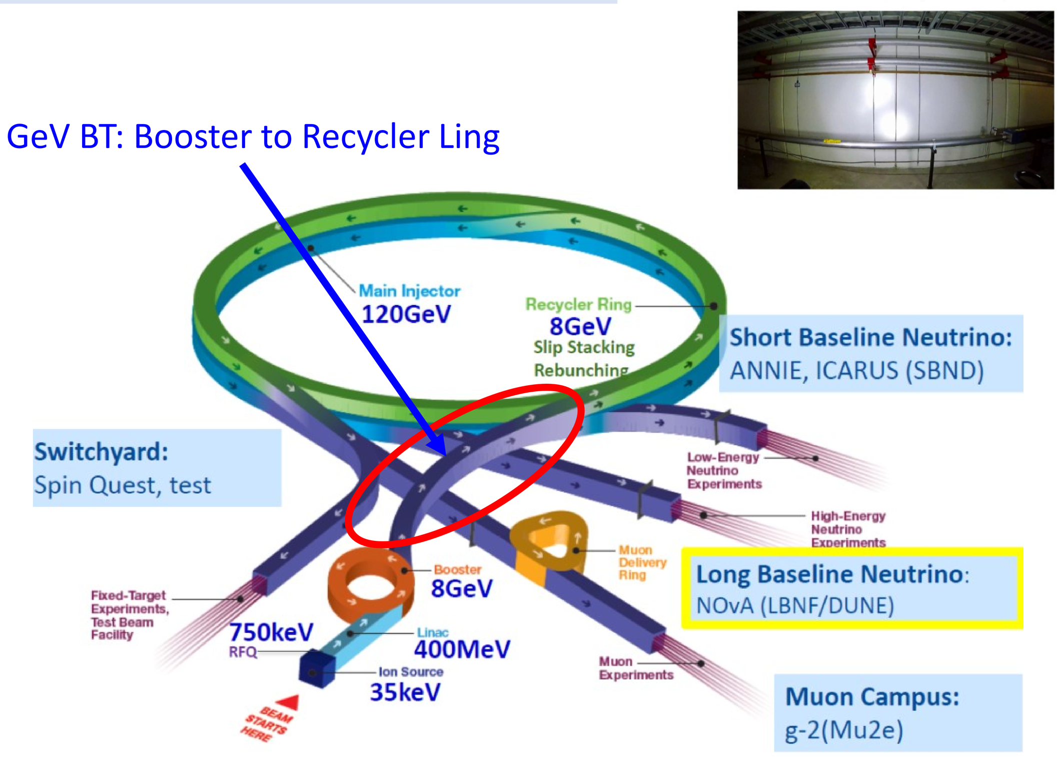
	Energy Loss [keV/proton]*	Total Energy Loss [J/bunch]**
Titanium Foil 5 micron thick	3.4	4.9e-3
Alumina Ceramics 0.5 mm thick	330	4.7e-1

* 3GeV Proton, ** 1e13 proton/bunch

J-PARC Unit-1 (3 GeV)



Location : FNAL design model

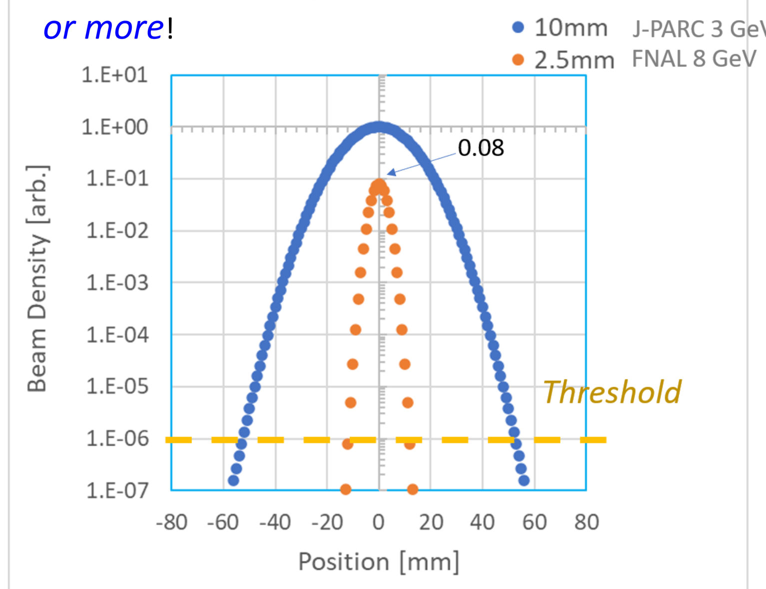


8 GeV Proton Beam : FNAL design model

Assuming the same set as J-PARC is used in FNAL, light limit is -5 digit.

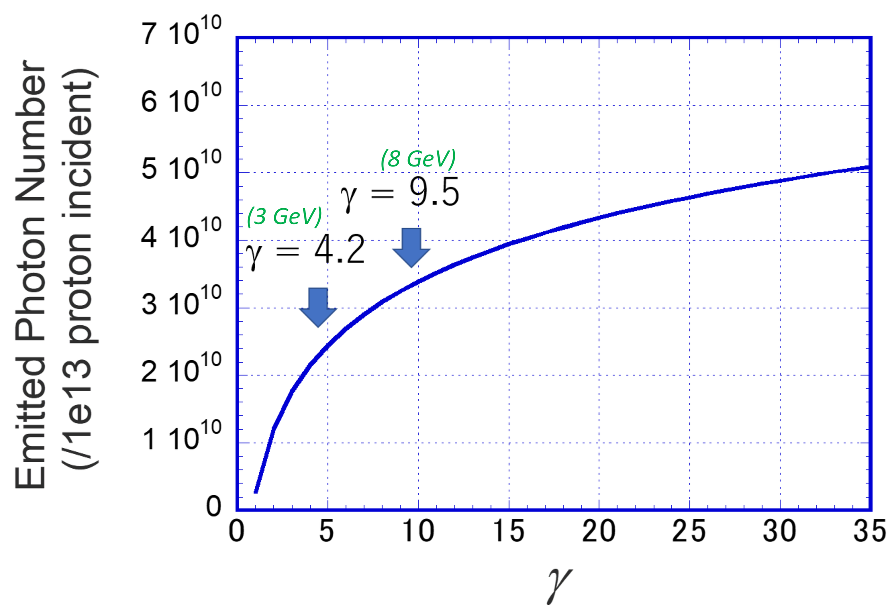
We want that value to reach -6 digit or more!

	Beam intensity [p/bunch]	Beam size (σ) [mm]
3 GeV (J-PARC)	1×10^{13}	10
8 GeV (FNAL)	5×10^{10}	2.5



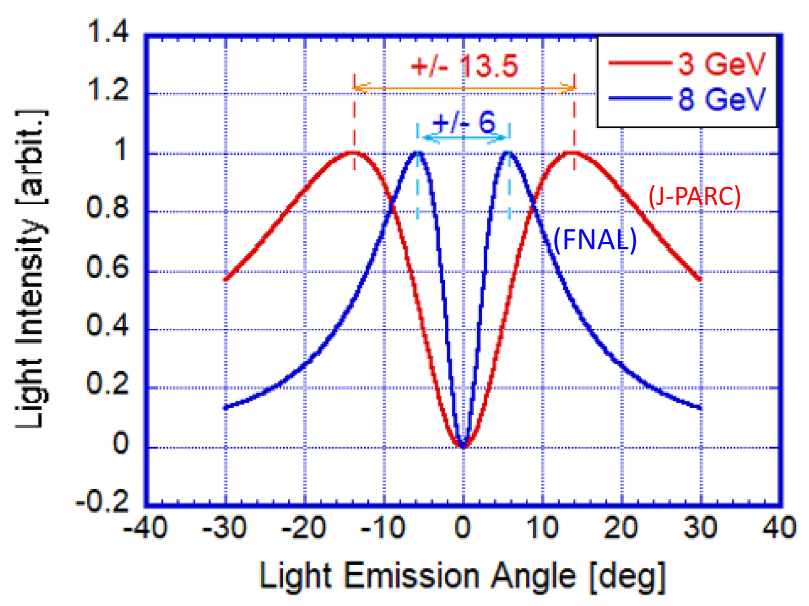
OTR from 8 GeV Proton Beam(1) : FNAL design model

J-PARC (3 GeV): 2.5×10^{10} [photon/ 1×10^{13}proton]
FNAL (8 GeV) : 3.3×10^{10} [photon/ 1×10^{13}proton]
FNAL is 1.32 times larger.



OTR from 8 GeV Proton Beam(2) : FNAL design model

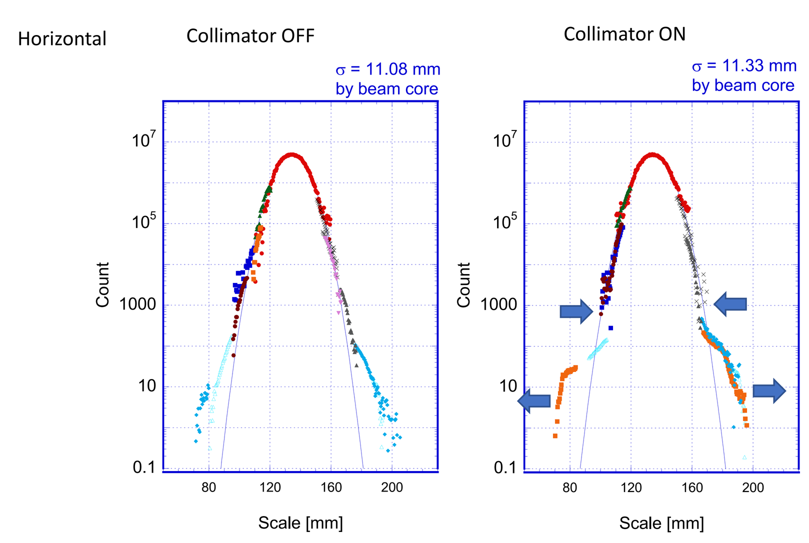
The divergence angle of the double peaks is ± 13.5 deg for 3 GeV and ± 6 deg for 8 GeV.
→As for OTR, FNAL can yield light with a smaller mirror aperture angle compared to J-PARC.



Typical Result (1): J-PARC Unit-1

Horizontal Projection

Dynamic Range :More than six order obtained
Beam Size: More than 120 mm at 10^{-6} order



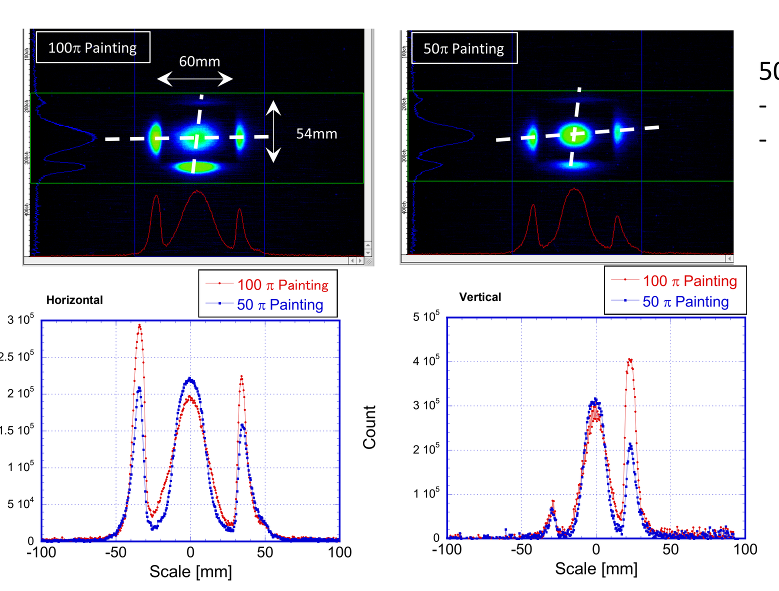
Collimator-ON
Waist appears at 10^{-4}
Expansion at 10^{-6}

Typical Result (2): J-PARC Unit-1

Simultaneous Measurement of Beam Core and Beam Halo (1)
Alumina Edge Position : Halo of 10^{-4} order

Difference by Painting Area of RCS Injection of 100 π and 50 π [mm.mrad]

Beam Intensity: 2.99e13/2bunch 5 times averaged



50 π Painting
- Smaller Beam Size
- Halo Rotation

Offner Optics : FNAL design model

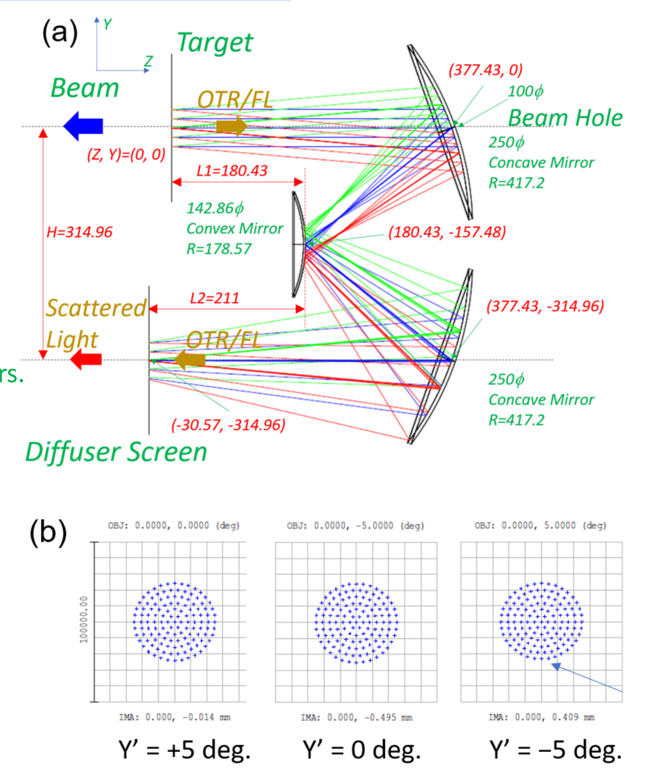
Scaled down from J-PARC Unit-1

- Concave Mirror Dia. 300 → 250 [mm]
- Spherical Radius 500 → 417.2 [mm]

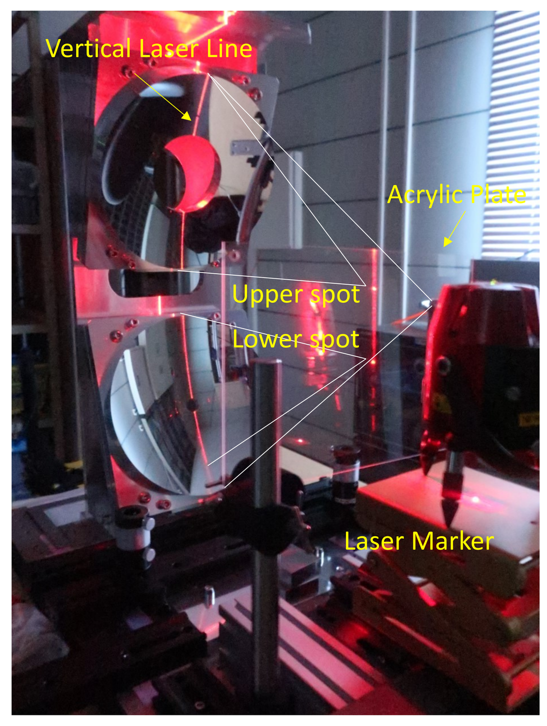
*Offner opt has concentric sphere mirrors.

Acceptance : ± 25 mm(H, V) with emit angle of ± 5 deg. (Cf. ± 2 deg J-PARC)

Ray traced map is a fairly uniform distribution.



Offner Optics : FNAL design model



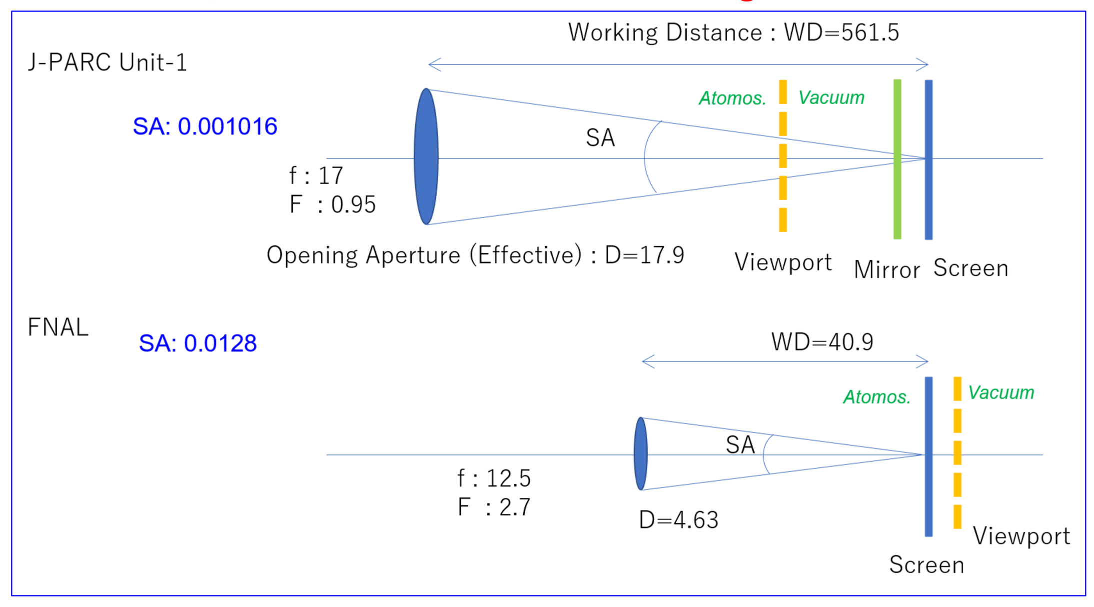
Tuning of the optical system in progress

Confirming the focal position of the concave mirror using a laser line marker and adjusting the mirror angle

Concave Mirror Pair
Material : A5052
Manufacturing : precision lathe Processing
Wavefront accuracy : below λ/4
Surface roughness : below 100 nm
Diameter: 250 mm
Curvature Radius : 417.2 mm

Secondary Optical System : FNAL design model

J-PARC Unit-1 has larger WD(561.5)
→ (FNAL) Decrease WD to increase light yield: WD(40.9)
*set the scattering screen on the atmosphere side
→ (FNAL) Light yield will be increased 12.5 times → 6 digits Beam Halo meas.

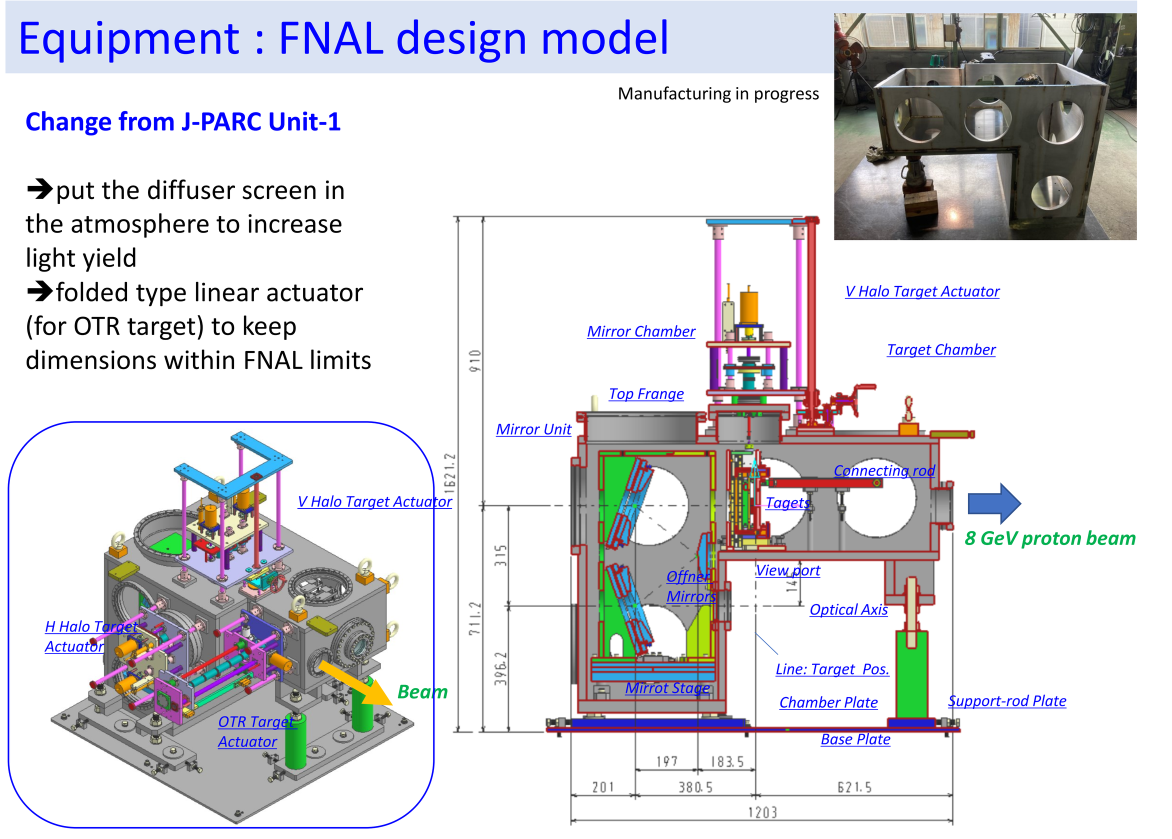


Equipment : FNAL design model

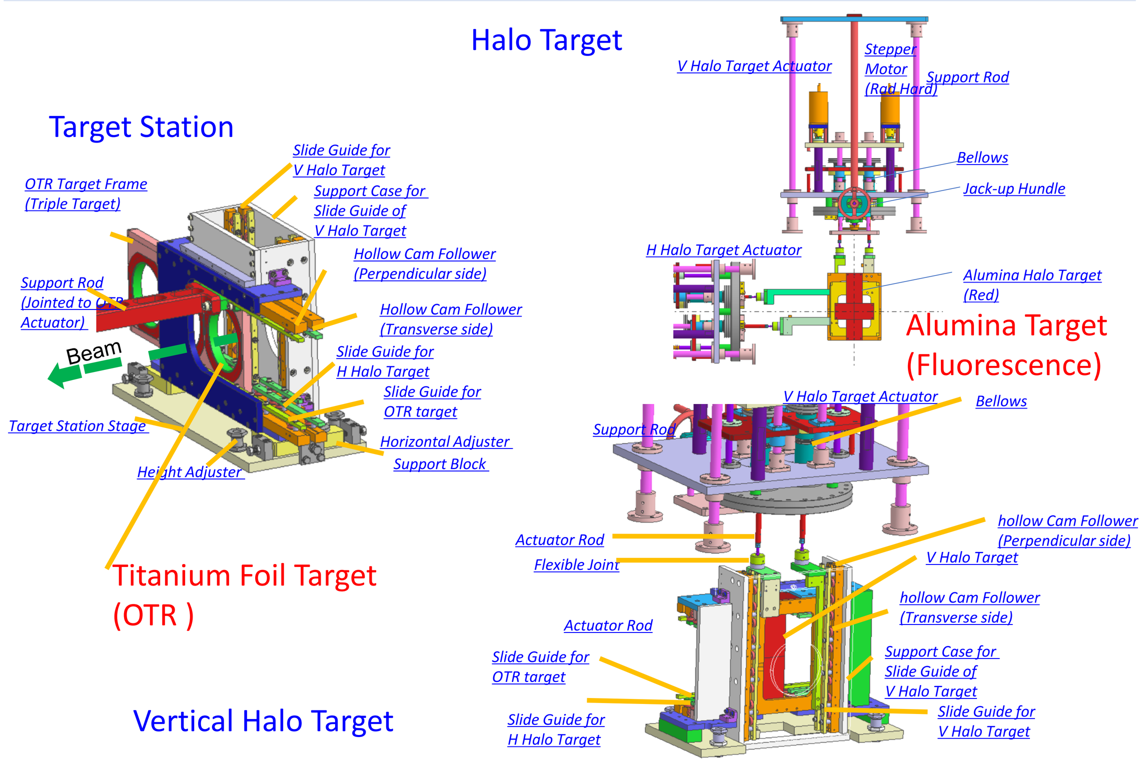
Manufacturing in progress

Change from J-PARC Unit-1

→put the diffuser screen in the atmosphere to increase light yield
→folded type linear actuator (for OTR target) to keep dimensions within FNAL limits



Target System : FNAL design model



SUMMARY AND PROSPECTS

- The profile monitor will be installed at FNAL based on J-PARC Unit-1 design and is estimated to have a dynamic range of 6 digits or more.
- Detailed evaluation experiments of the Offner optical system have begun.
- The equipment is currently being manufactured and adjusted. FNAL members are also scheduled to come to Japan to adjust the device. **The device will be installed in the FNAL tunnel next 2025 summer.**

ACKNOWLEDGEMENT

- This work is supported by U.S.-Japan Science and Technology Cooperation Program in High Energy Physics.

REFERENCES

J-PARC Halo monitor
[1] Y. Hashimoto, T. Toyama, T. M. Mitsuhashi, M. Tejima, and S. Otsu, "A Development of High Sensitive Beam Profile Monitor using Multi-Screen", Proc. IBIC'13, Oxford, UK, pp. 338-341.
[2] Y. Hashimoto, C. Omori, Y. Sato, T. Toyama, M. Tejima, T. Sasaki, M. Uota, R. Ainsworth, H. Sakai, "A WIDE DYNAMIC-RANGE HALO MONITOR FOR 8 GEV PROTON BEAMS AT FNAL", Proc. NaPAC'22, , Albuquerque, NM, USA, pp. 75-78.