A Development of High Sensitive Beam Profile Monitor Using Multi-Screen

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Contents

- Motivation
- Concept
- J-PARC and 3-50 Beam Transport Line
- OTR by Low γ : 3GeV Proton Beam
- Large Acceptance Optics
- Detector
- OTR profile with Intense Beam
- Combination Measurement with OTR and Fluorescence
- Simultaneous measurement of beam core and beam halo (Next step)
- Summary and Next Step

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Motivation

Basic Subject

- Diagnosing injection beam bound for Main Ring
  - Two dimensional beam profile measurement with OTR
- Beam halo/ collimated beam shape measurement
  - More sensitive measurement with fluorescence by chromium doped alumina screen
  - Beam halo ~10^{-6}

Advanced Subject

➔ Combination Measurement with OTR/Fluorescence

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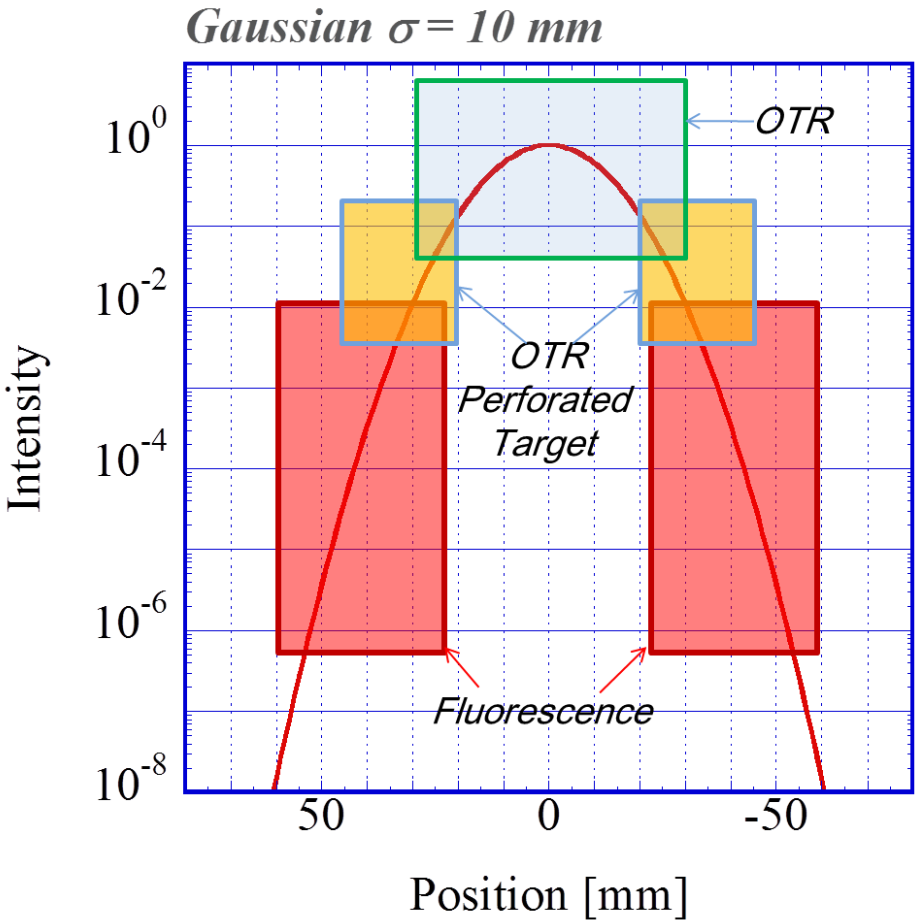
Concept (1)

Changing Triple Target (Multi-Screen):

OTR : Solid Foil for OTR/Perforated Foil with 50 mm diameter

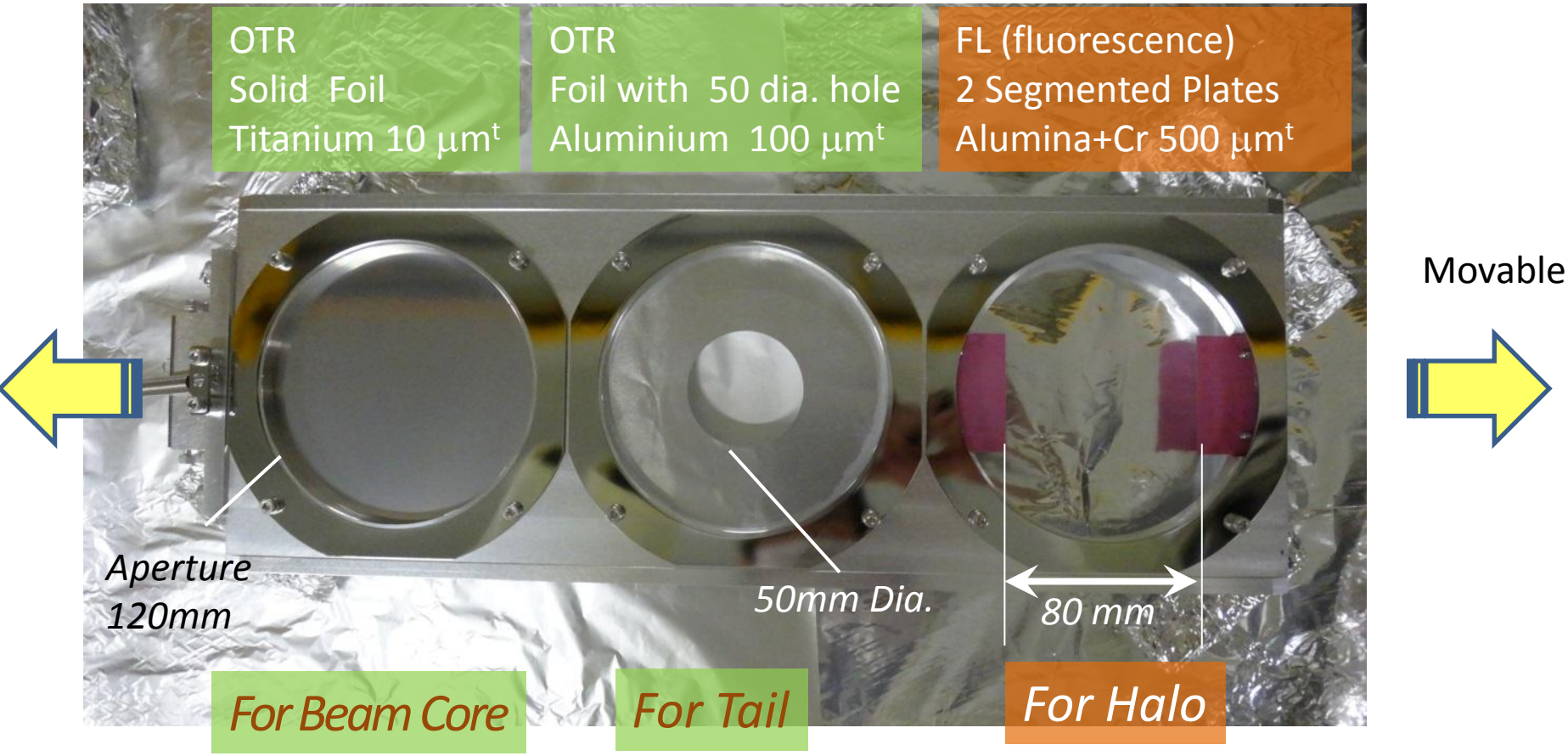
Fluorescence (FL): Chromium doped Alumina Screen

Adopting Suitable Gain of the Detector: Image Intensifier



Concept (2)
Multi-Screen : OTR/Fluorescence

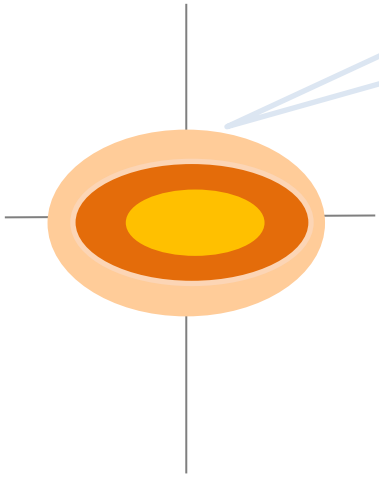
- *Linear Movable (H) Triple Screen Target to Demonstrate Sensitive Measurement with Wide Dynamic Range*



Concept (2)
Multi-Screen : OTR/Fluorescence

- *Linear Movable (H) Triple Screen Target to Demonstrate Sensitive Measurement with Wide Dynamic Range*

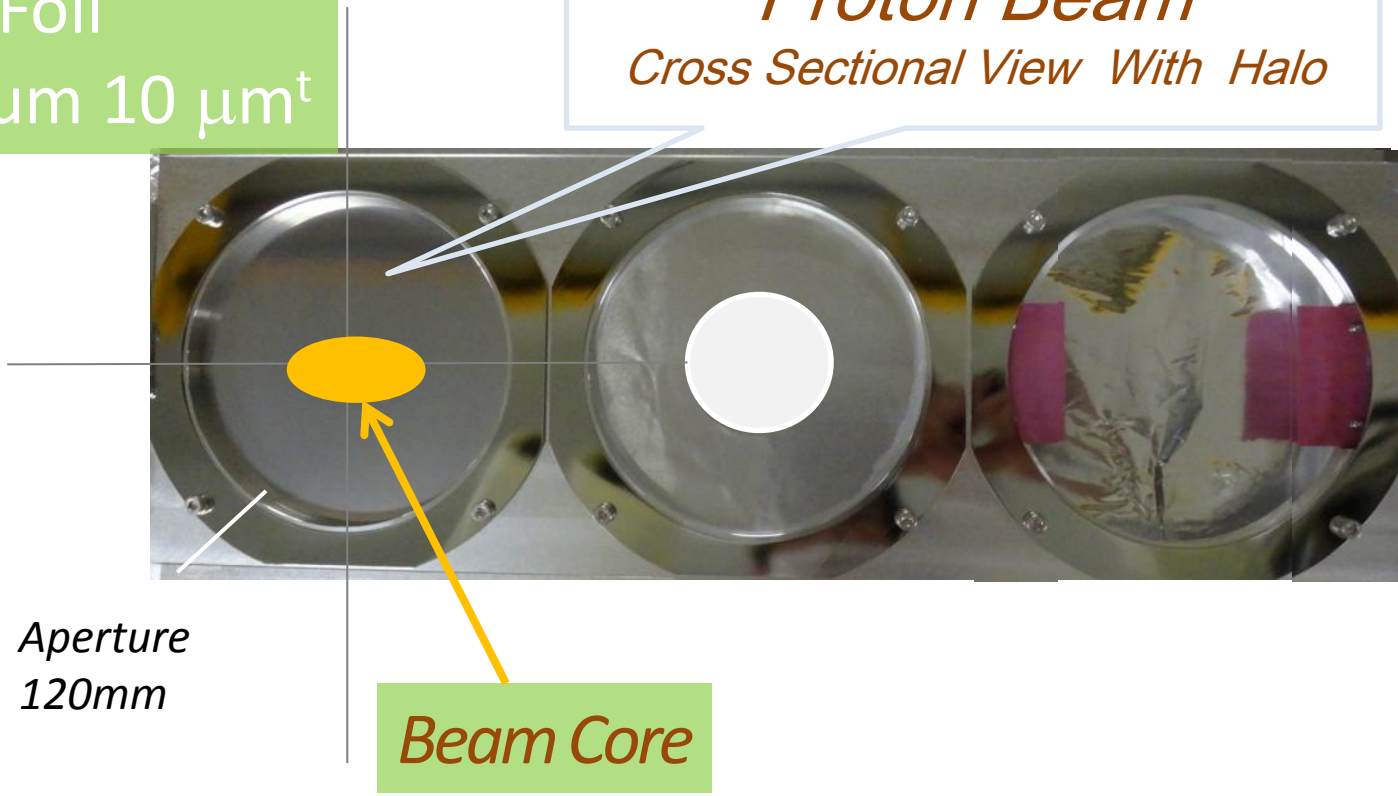
Target OFF



Concept (2)
Multi-Screen : OTR/Fluorescence

- *Linear Movable (H) Triple Screen Target to Demonstrate Sensitive Measurement with Wide Dynamic Range*

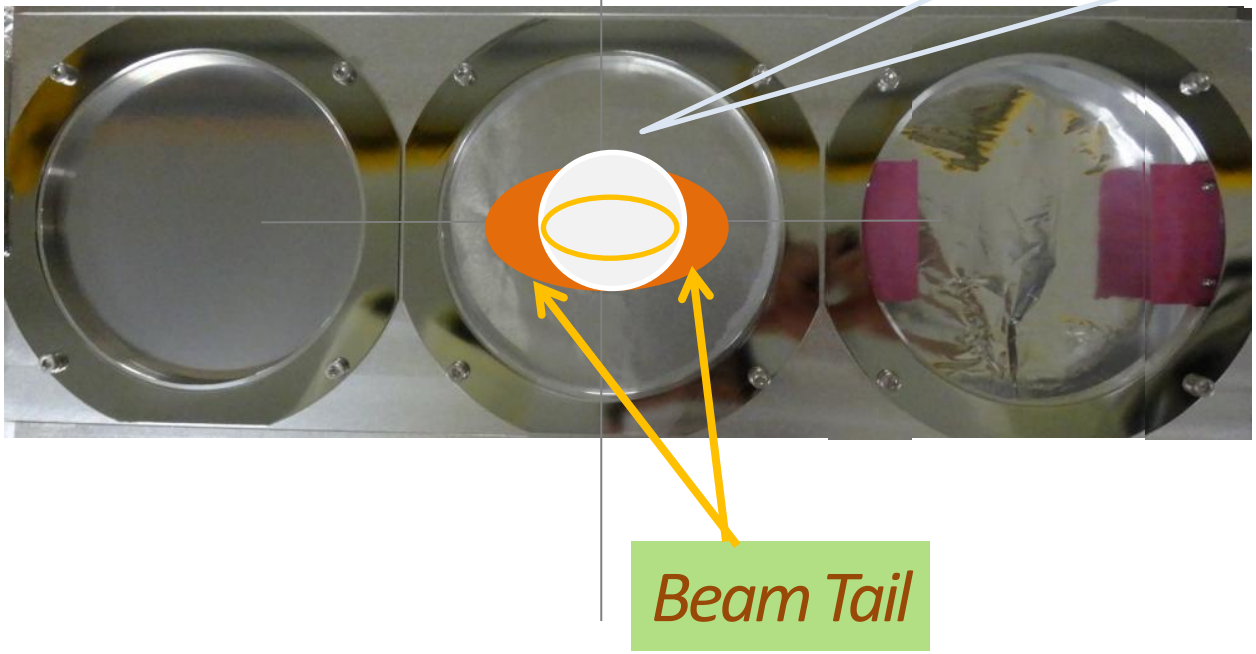
OTR
Solid Foil
Titanium 10 μm^t



Concept (2)
Multi-Screen : OTR/Fluorescence

- *Linear Movable (H) Triple Screen Target to Demonstrate Sensitive Measurement with Wide Dynamic Range*

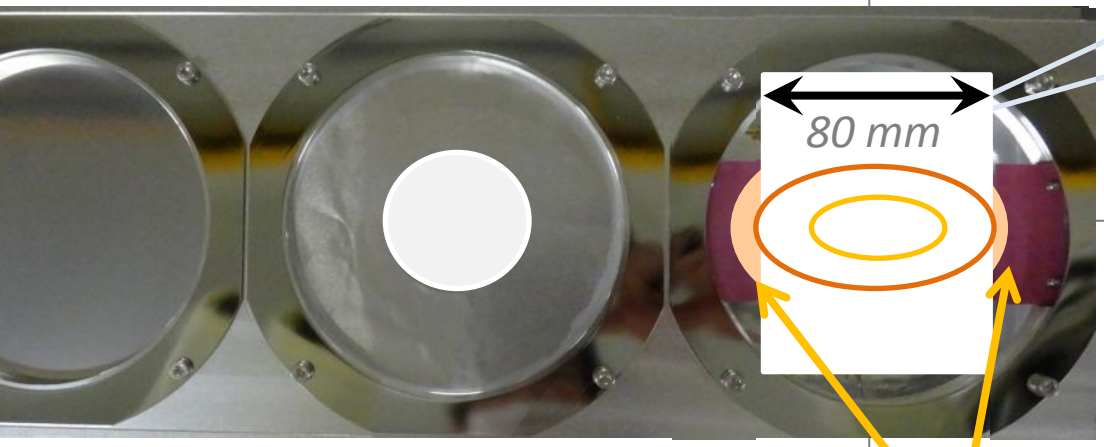
OTR
Foil with 50 dia. hole
Aluminium 100 μm^t



Concept (2)
Multi-Screen : OTR/Fluorescence

- *Linear Movable (H) Triple Screen Target to Demonstrate Sensitive Measurement with Wide Dynamic Range*

FL (fluorescence)
2 Segmented Plates
Alumina+Cr 500 μm^t



Proton Beam
Cross Sectional View With Halo

Edge Position:
Precise Movable

Beam Halo

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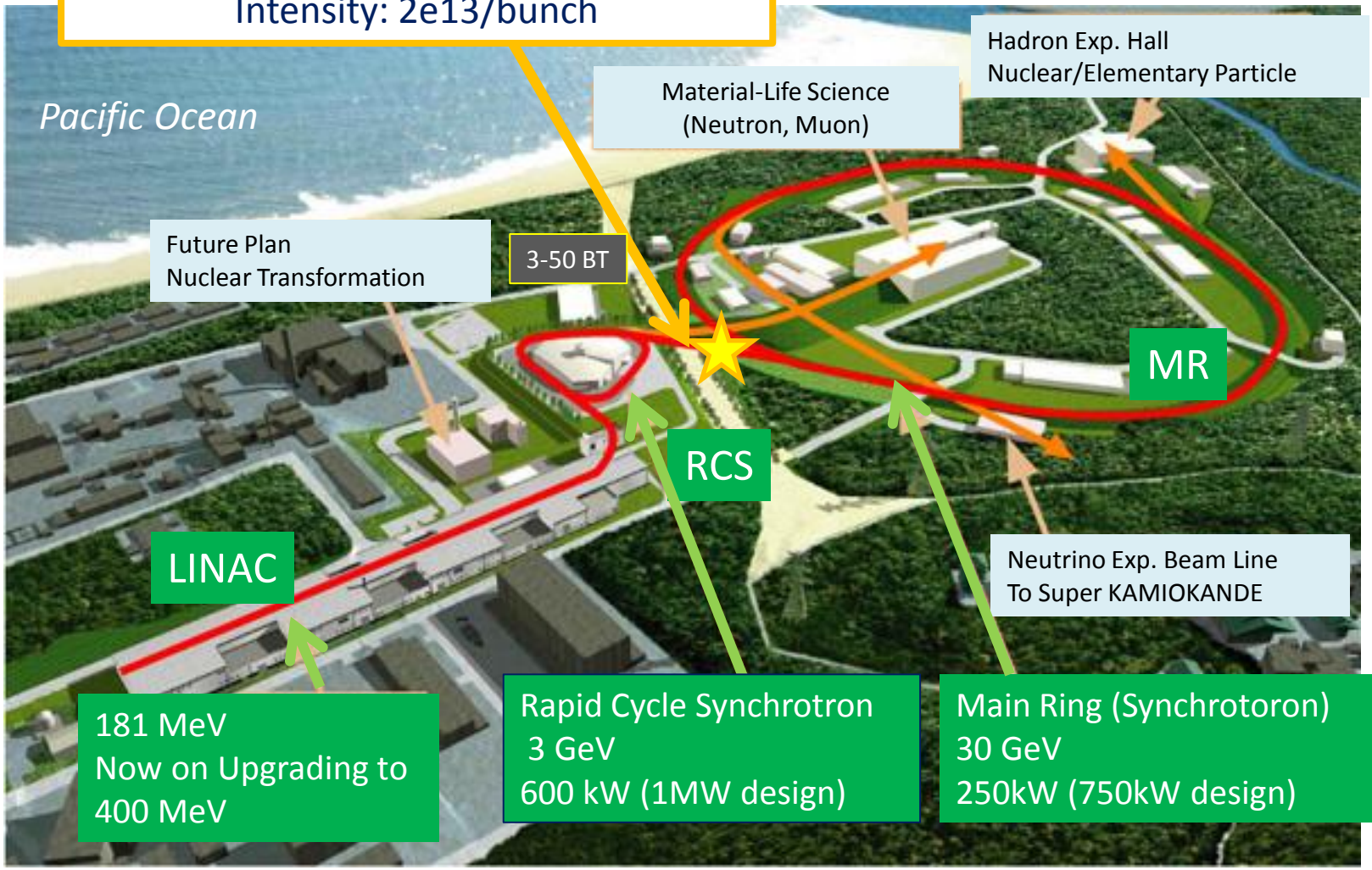
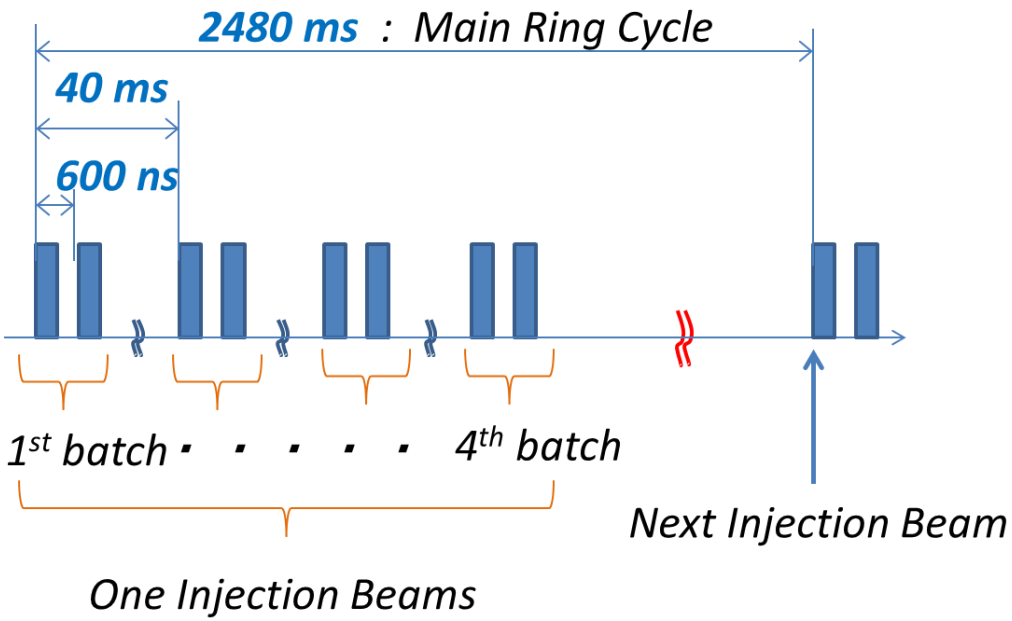
J-PARC and 3-50 BT Outline

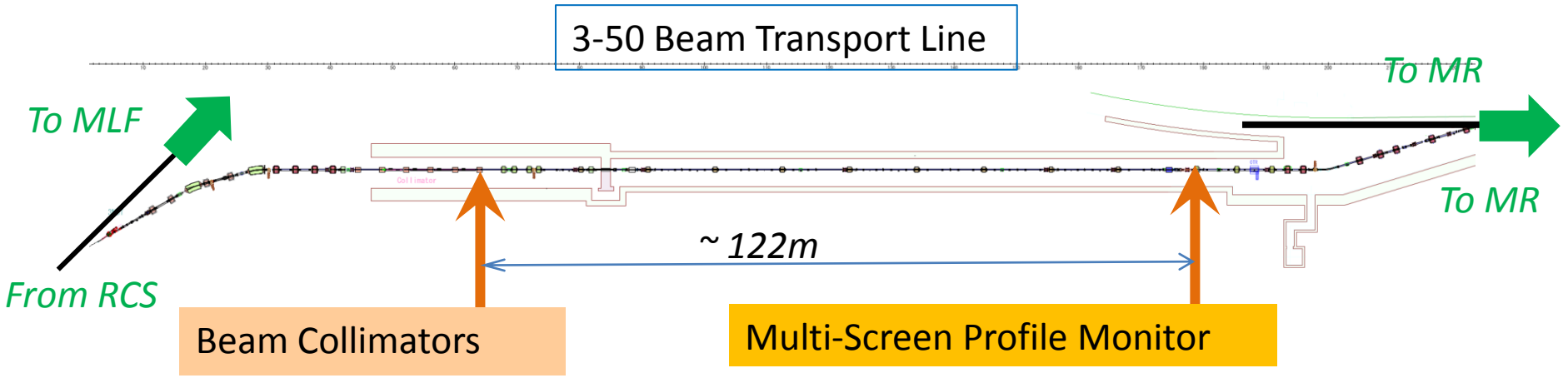


J-PARC and 3-50 BT

Beam Energy: 3 GeV
Beam Intensity :
1.6×10^{13} proton/bunch
Injection Beam:
2 bunch × 4 batch



- Our monitor usually measured 2bunch (1batch)
-Beam collimators located at 122m upper stream



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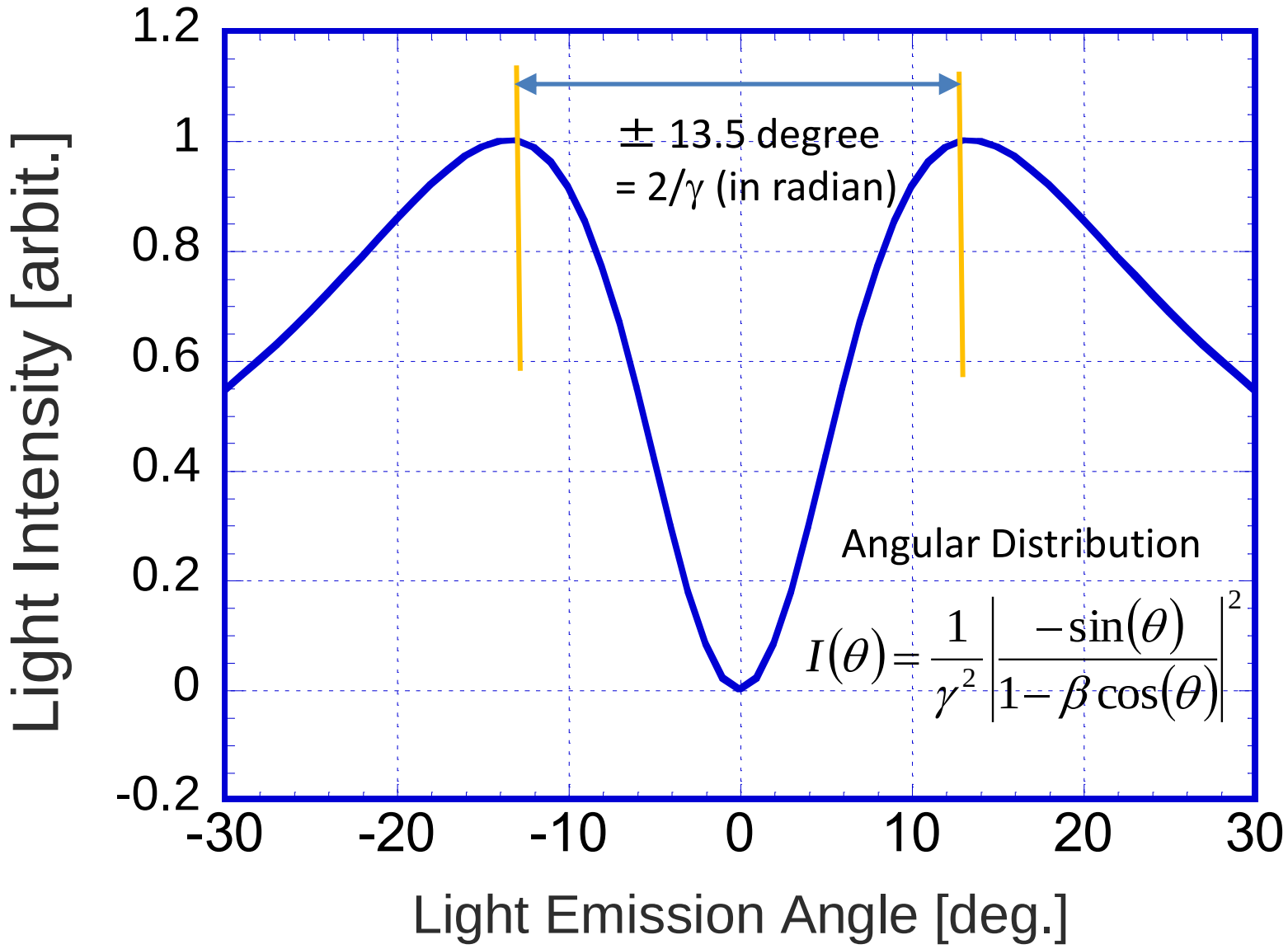
OTR by Low γ : 3GeV Proton Beam (1)

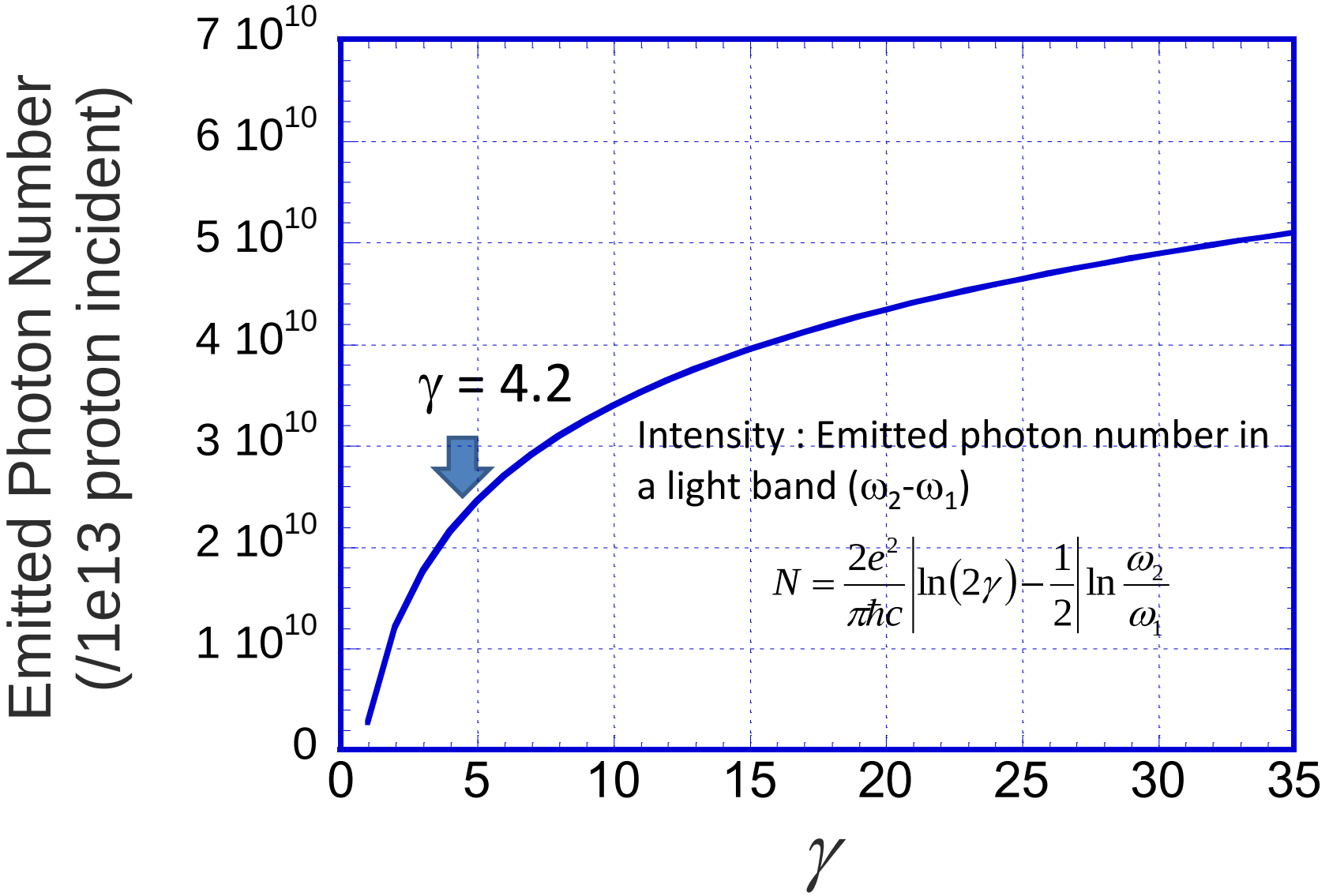
- Low γ : 4.2 ➔ Larger Angle Spread



OTR by Low γ : 3GeV Proton Beam (2)

MULTI-SCREEN BEAM PROFILE MONITOR

2.5×10^{10} photons/10^{13} protons



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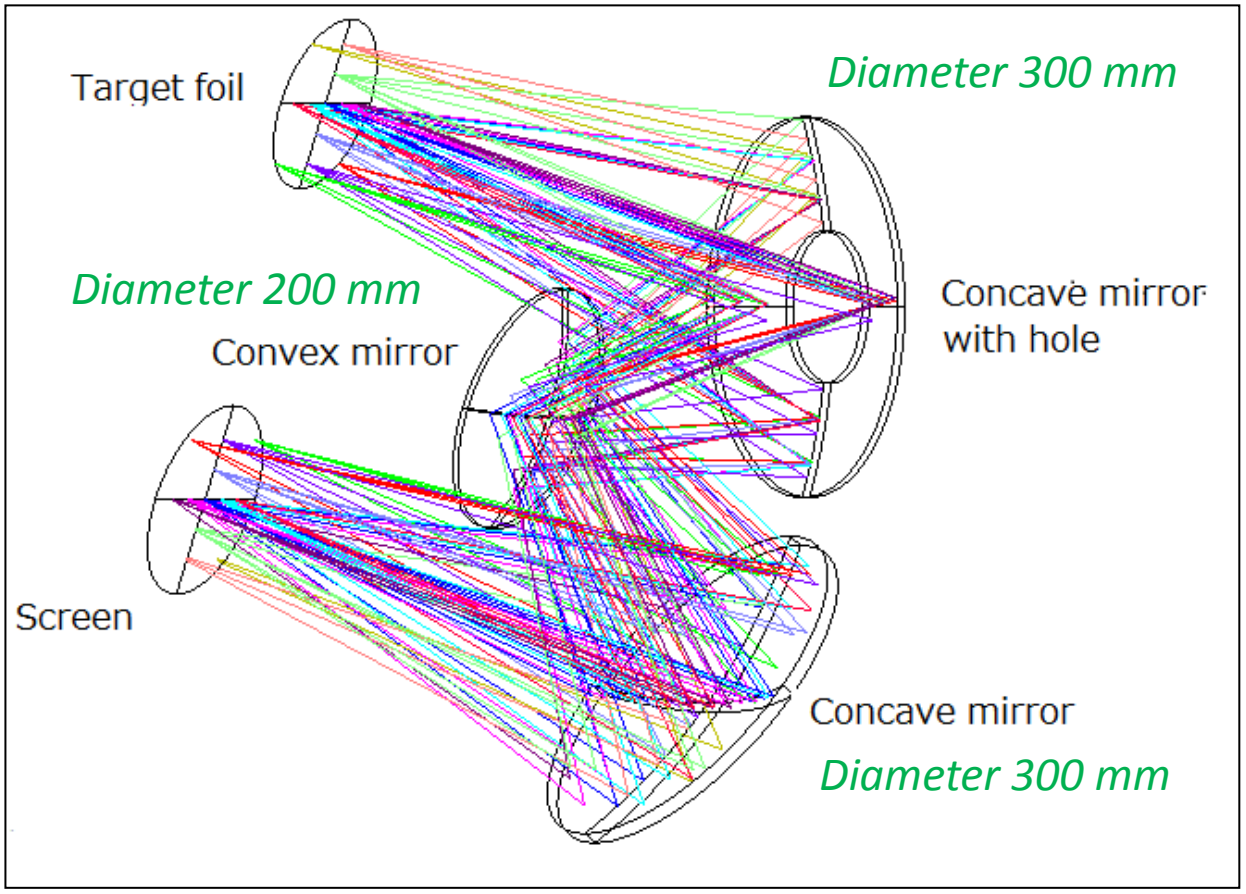
Large Acceptance Optics

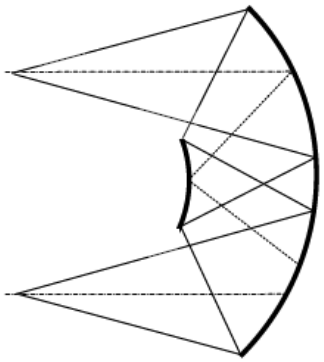
- Large Acceptance (±15 deg.)
- Larger Object Size ($100^{H} \times 80^{V}$ mm^2)
- In vacuum Off-axis Relay Optics

➡ *We employed Offner Optics.*

Our Scheme



Original Offner Scheme



Large Acceptance Optics

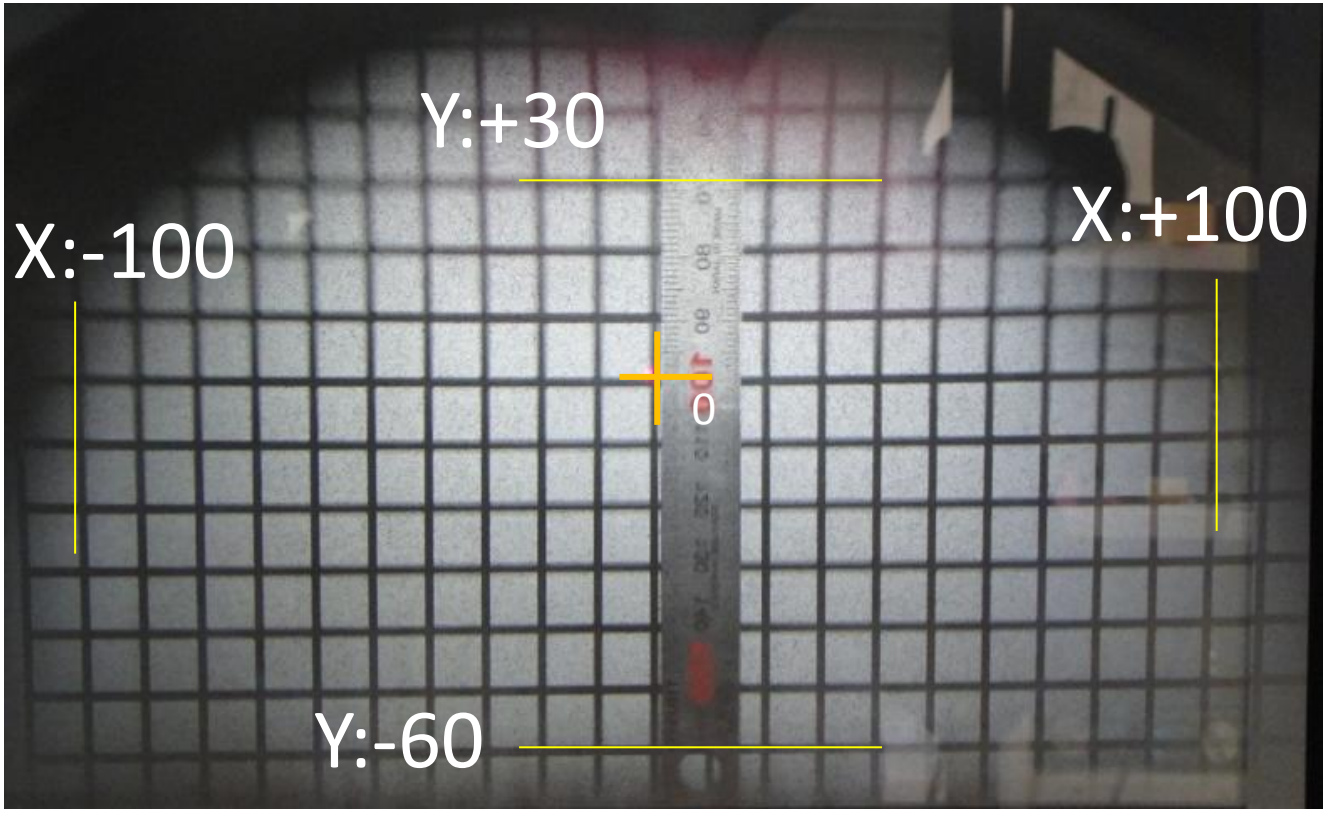
MULTI-SCREEN BEAM PROFILE MONITOR

Clear Aperture

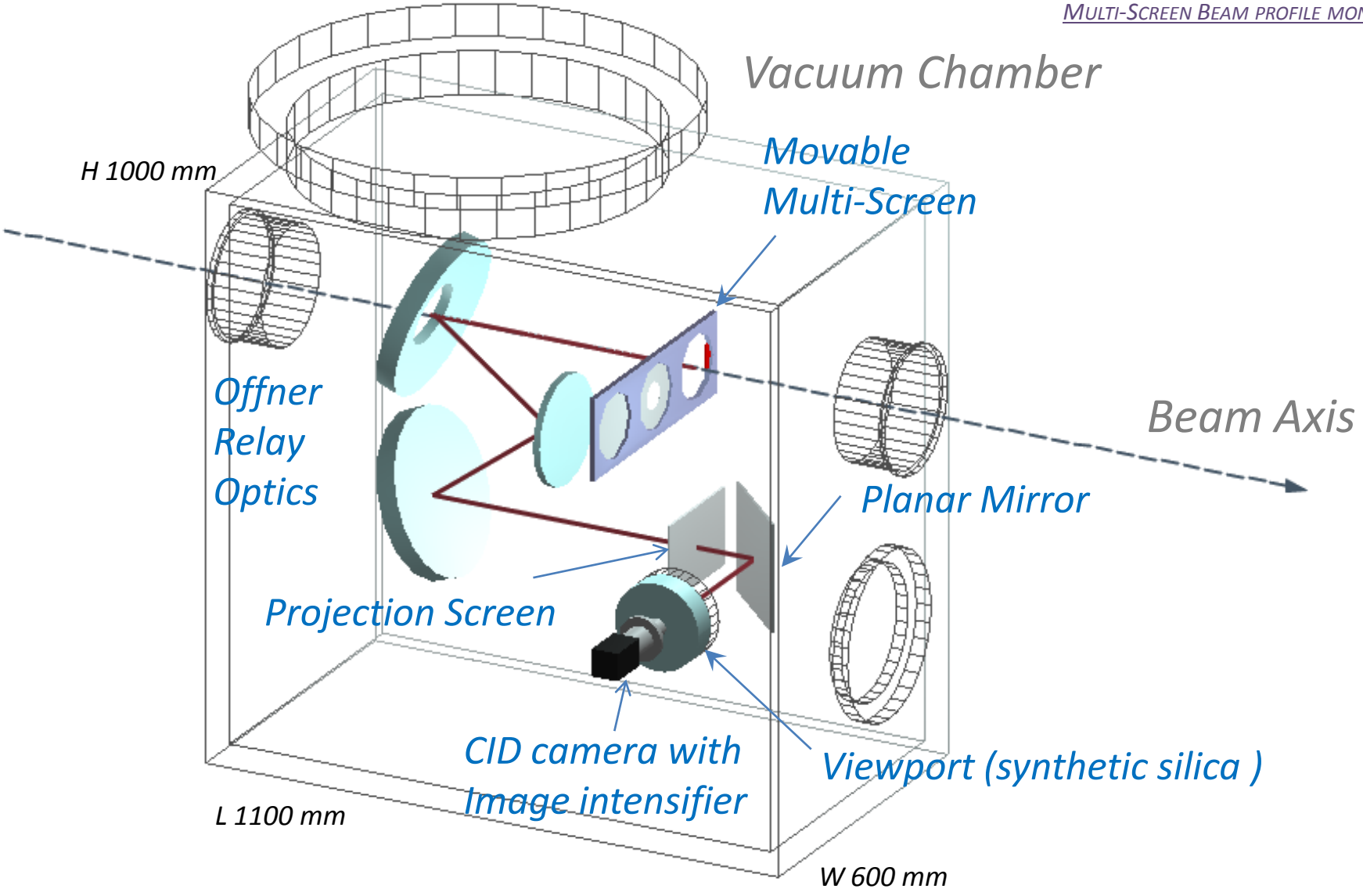
Horizontal: 200 mm

Vertical: 90 mm

Grid Pattern Test

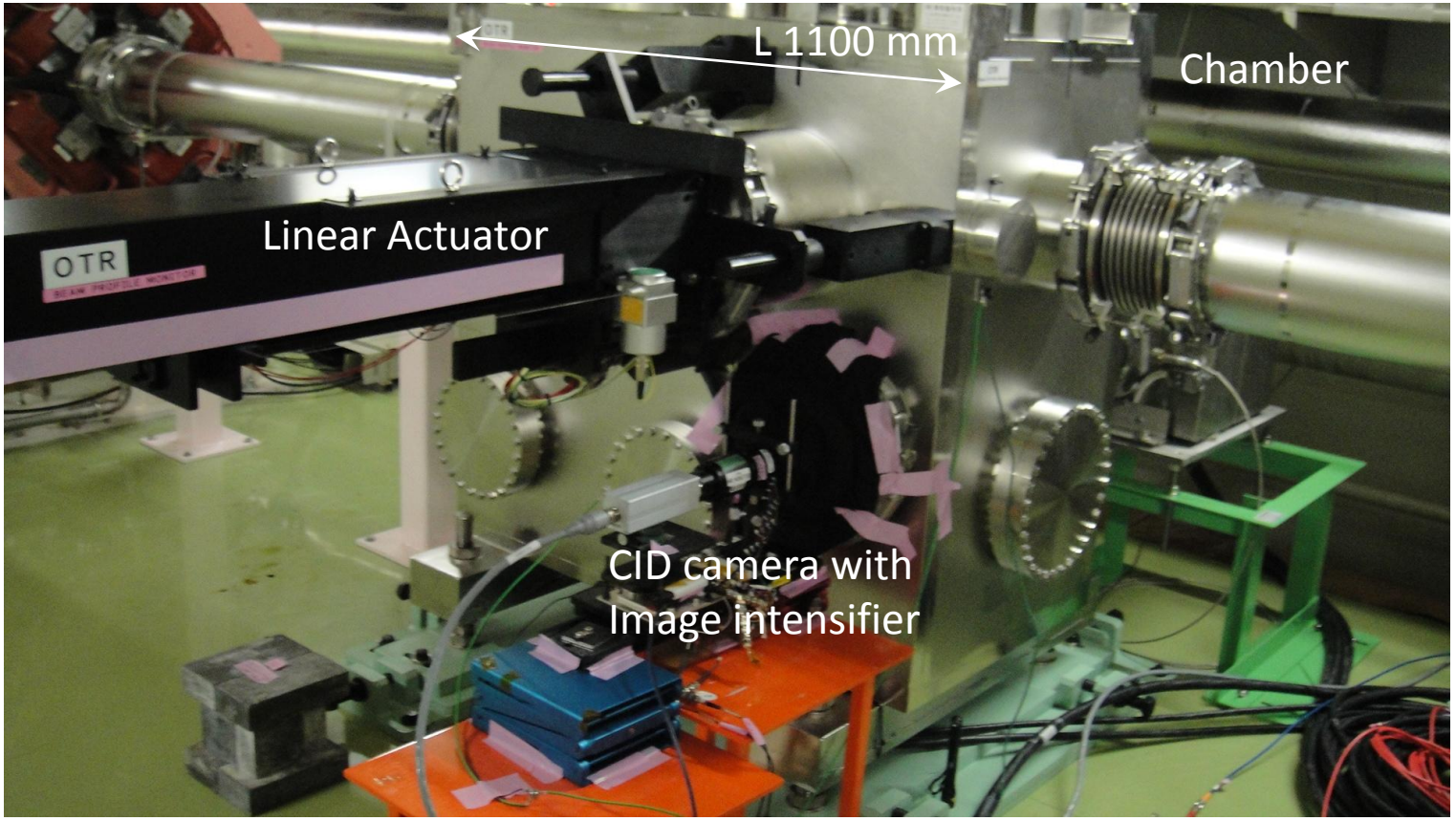


Large Acceptance Optics



Large Acceptance Optics

Setup at 3-50 BT in J-PARC



Vacuum pressure: 10^{-7} Pa

Radiation during operation: 100mGy /week

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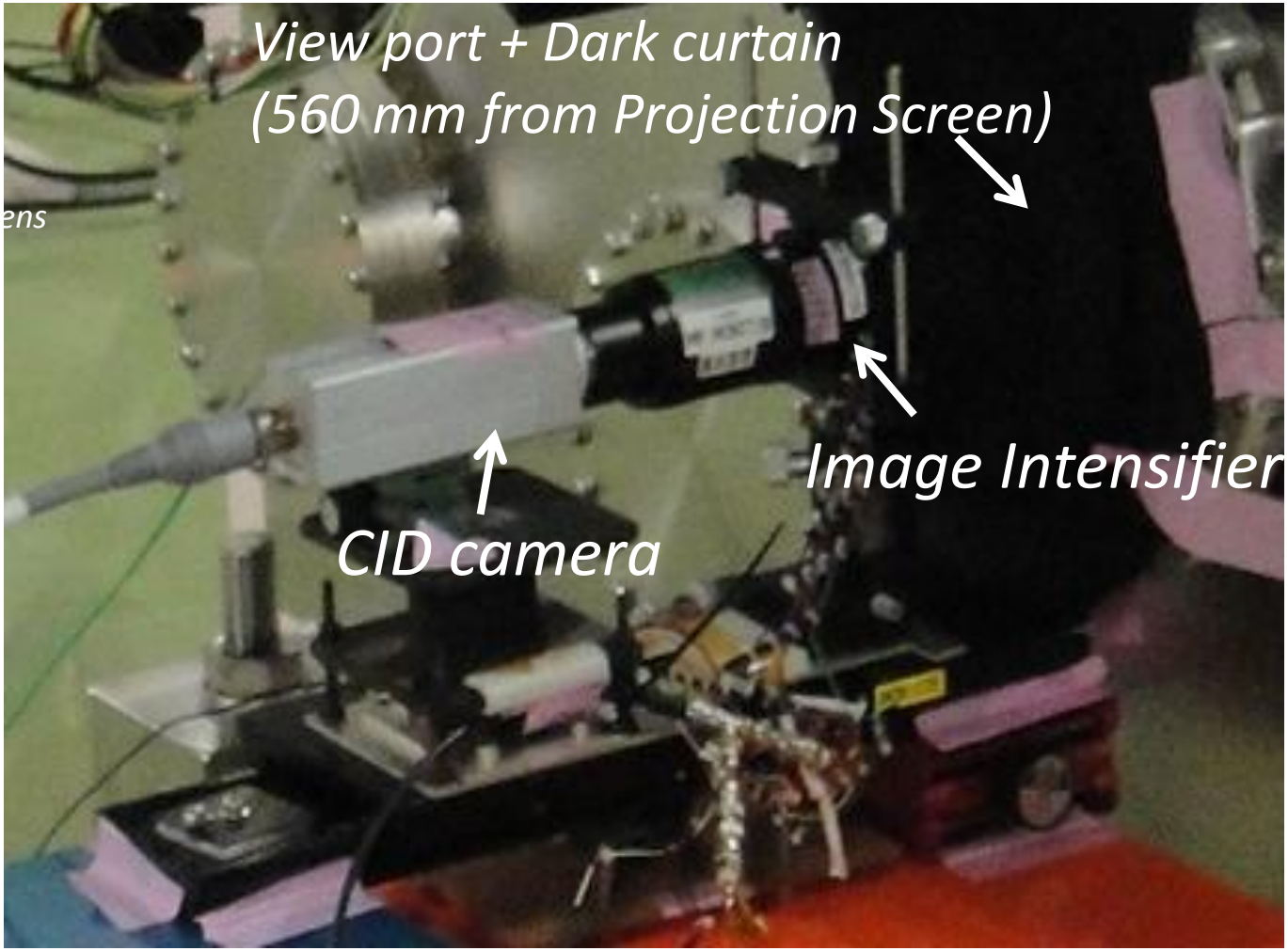
Detector

- **Image Intensifier with a Single Stage Micro Channel Plate**
- **Charge Injection Device (CID) Camera of Radiation Hard (300kGy)**

Setup



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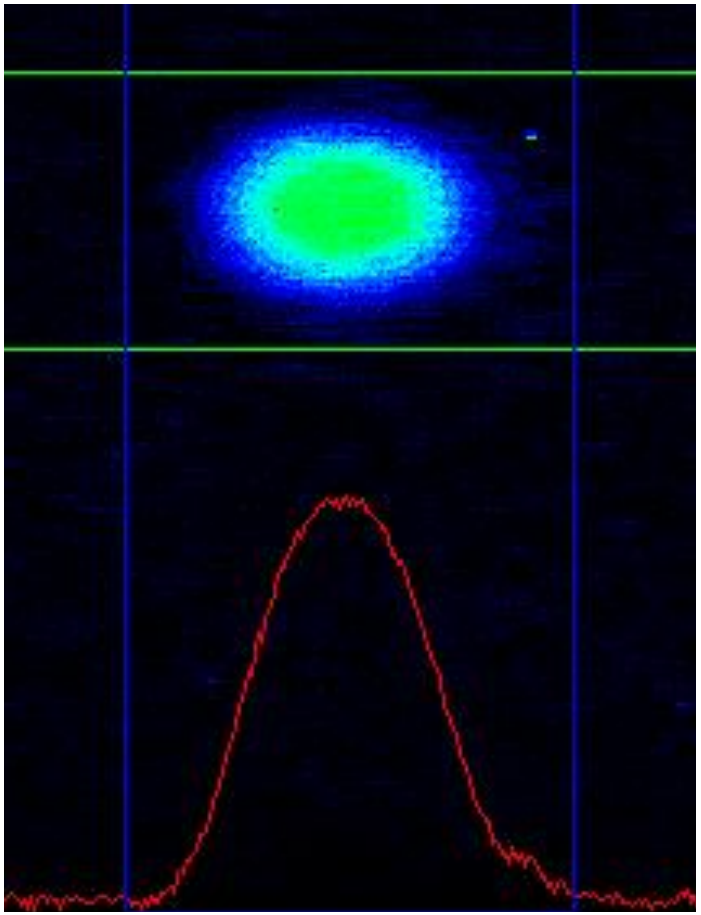
Profile of An Intense Beam with OTR

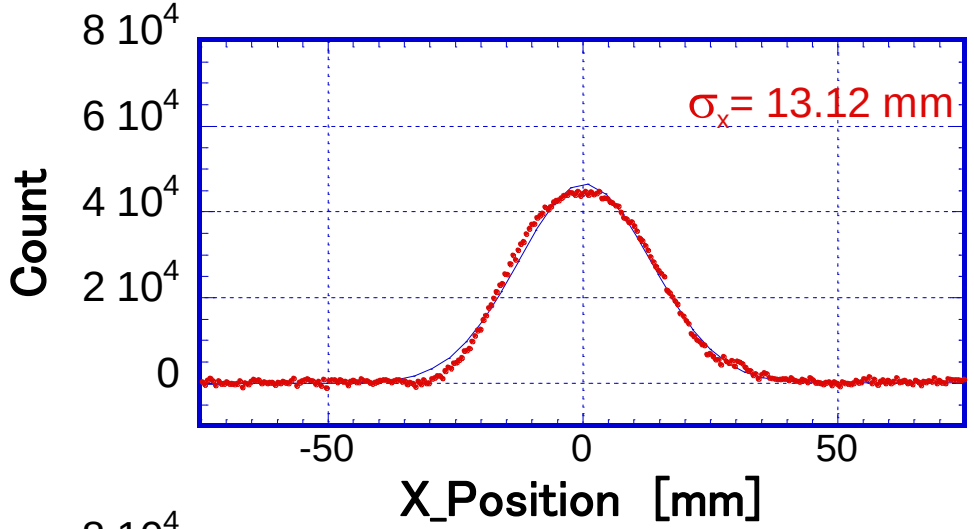
- High Intensity Study: 4.2e13/2bunch
- Single Shot
- Image Intensifier Gain : 7e3

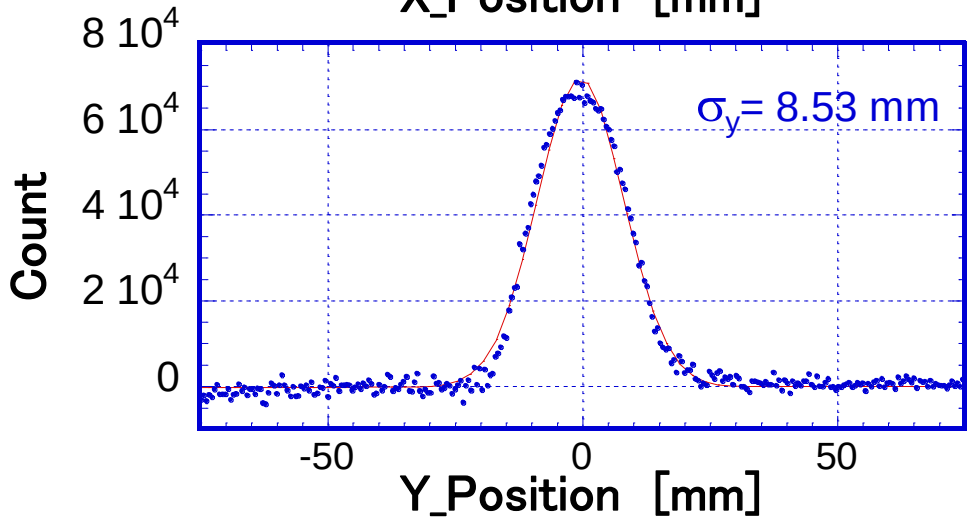
MULTI-SCREEN BEAM PROFILE MONITOR

Beam Image



Projection





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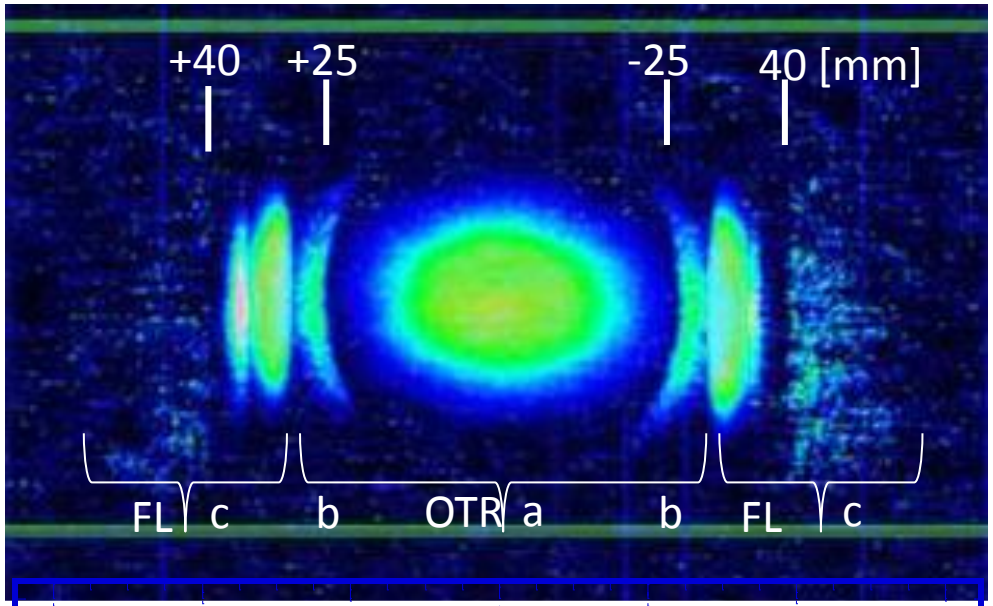
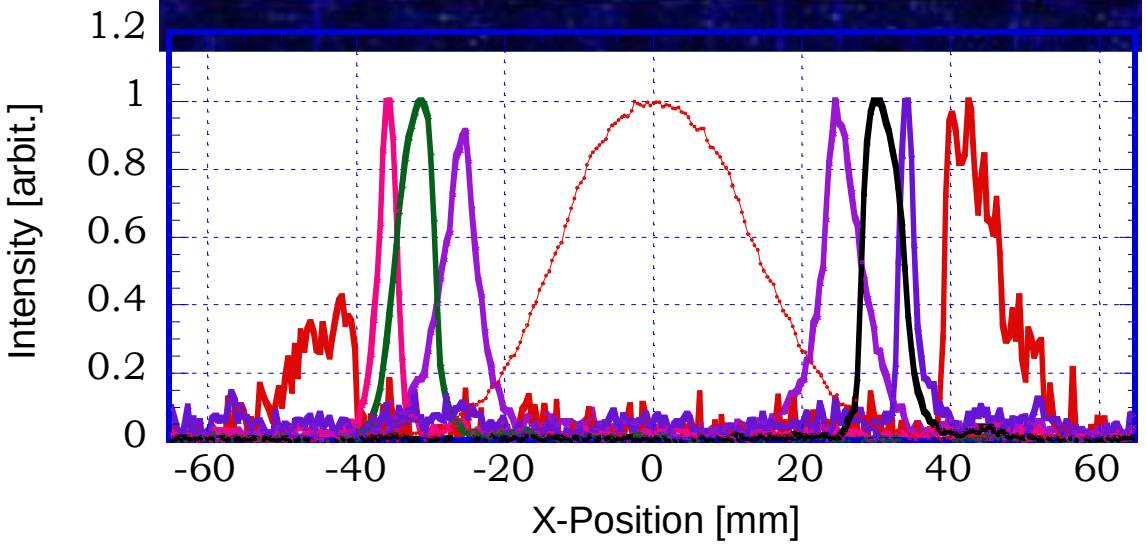
Combination Measurement with OTR and Fluorescence

- Intensity : 9.6 e 12 proton /2bunch
- 2 bunches × 5 Shots (AVG)
- Image Intensifier Gate: 10 μs

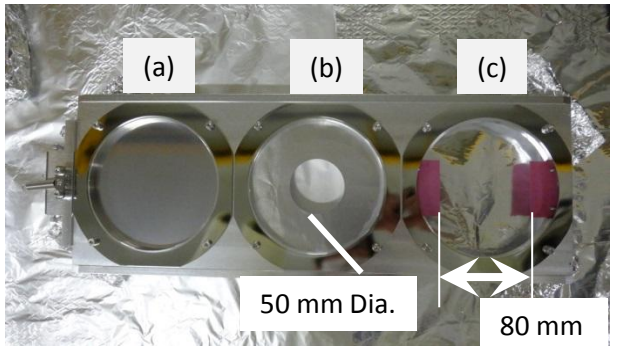




Superimposed Profile

Image

Multi-screen



Horizontal Projection (Normalized)

MULTI-SCREEN BEAM PROFILE MONITOR

- For obtaining an *UNIFIED* profile in Common Vertical Scale with next two ratio,

Gain ratio of the image intensifier: G_R

$G_R = G_{1000}/G_{SET}$ by Gain curve of the Image Intensifier

G_{1000} : Gain at MCP1000V (Maximum)

G_{SET} : Gain at MCP set voltage at Measurement

Yields ratio between Fluorescence/OTR: Y_R

OTR data → data/G_R

FL data → data/Y_R/G_R

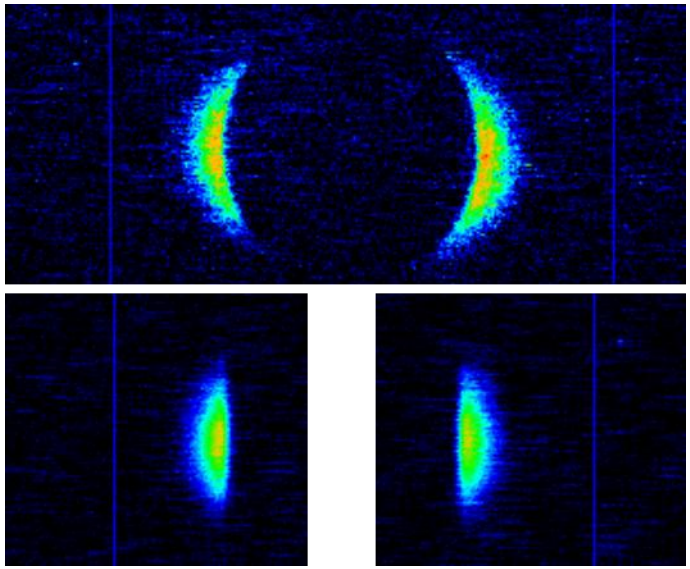
Combination Measurement with OTR and Fluorescence

Y_R : Yields ratio between Fluorescence/OTR (1)

MULTI-SCREEN BEAM PROFILE MONITOR

Measured Light Ratio :Y_{MR}
I.I. Gain at OTR meas.: G_{OTR}
I.I. Gain at FL meas.: G_{FL}

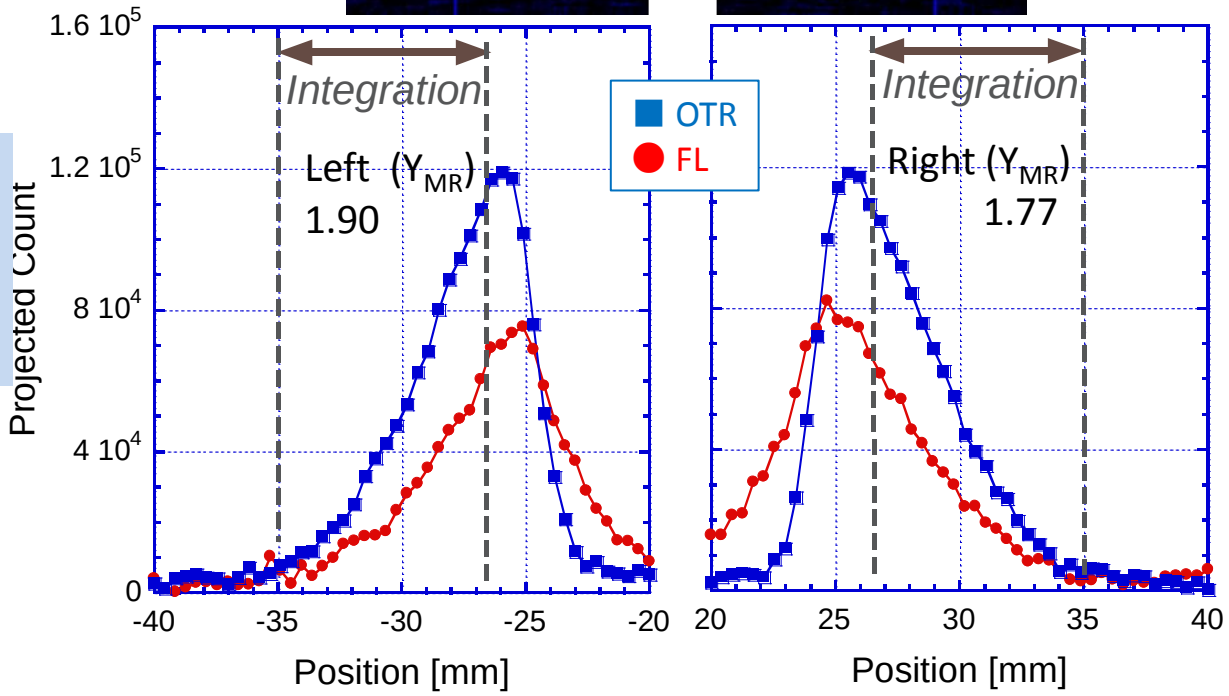
$$Y_R = Y_{MR} \times G_{OTR} / G_{FL}$$



OTR
50 mm dia. -Hole Target

Fluorescence
Alumina Target
Edge: ±25 mm

Integration Ratio (avg.)
$= Y_{MR}$
=1.84 ±0.07



Combination Measurement with OTR and Fluorescence

Y_R : Yields ratio between Fluorescence/OTR (2)

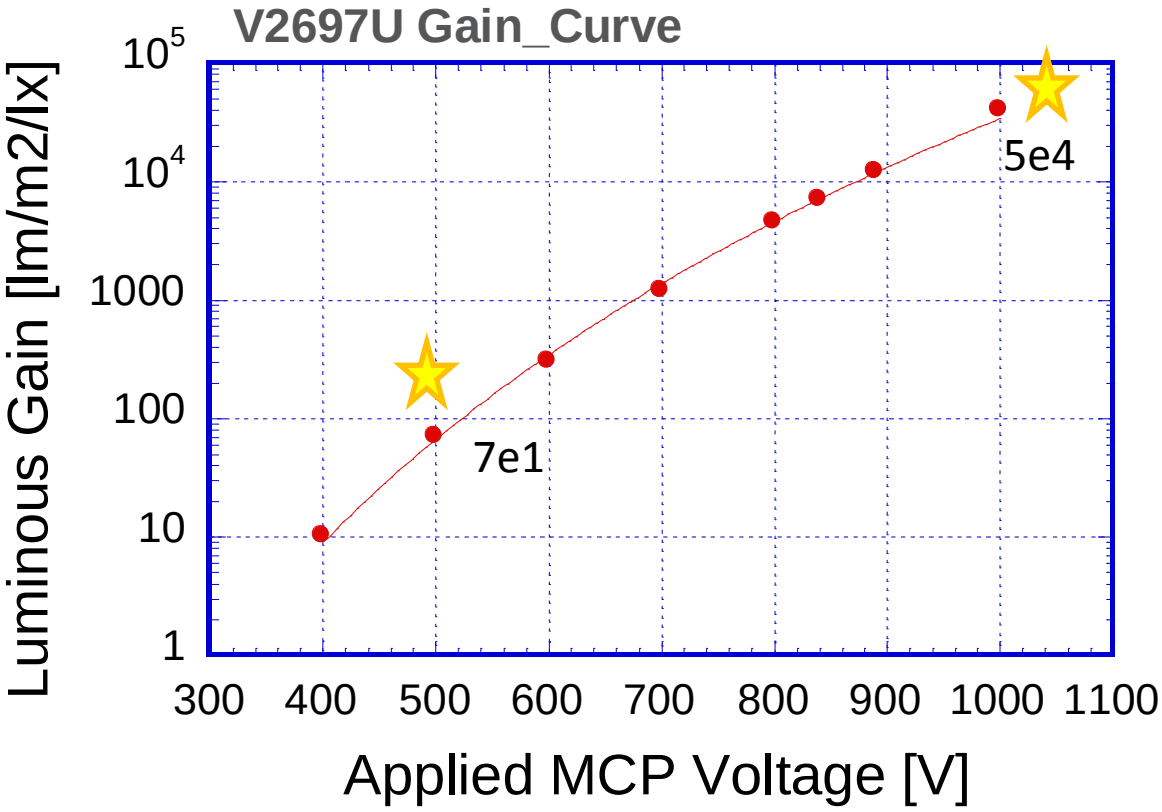
Measured Light Ratio :Y_{MR}
I.I. Gain at OTR meas.: G_{OTR}
I.I. Gain at FL meas.: G_{FL}

$$Y_R = Y_{MR} \times G_{OTR} / G_{FL}$$

Gain Ratio: G_{OTR} / G_{FL}
= MCP 1000V/MCP 500V
= 5e4/7e1
= 714.3

$$Y_R = Y_{MR} \times G_{OTR} / G_{FL}$$

$$= 1.84 \times 714.3$$
$$= 1314.6$$



Combination Measurement with OTR and Fluorescence

Results

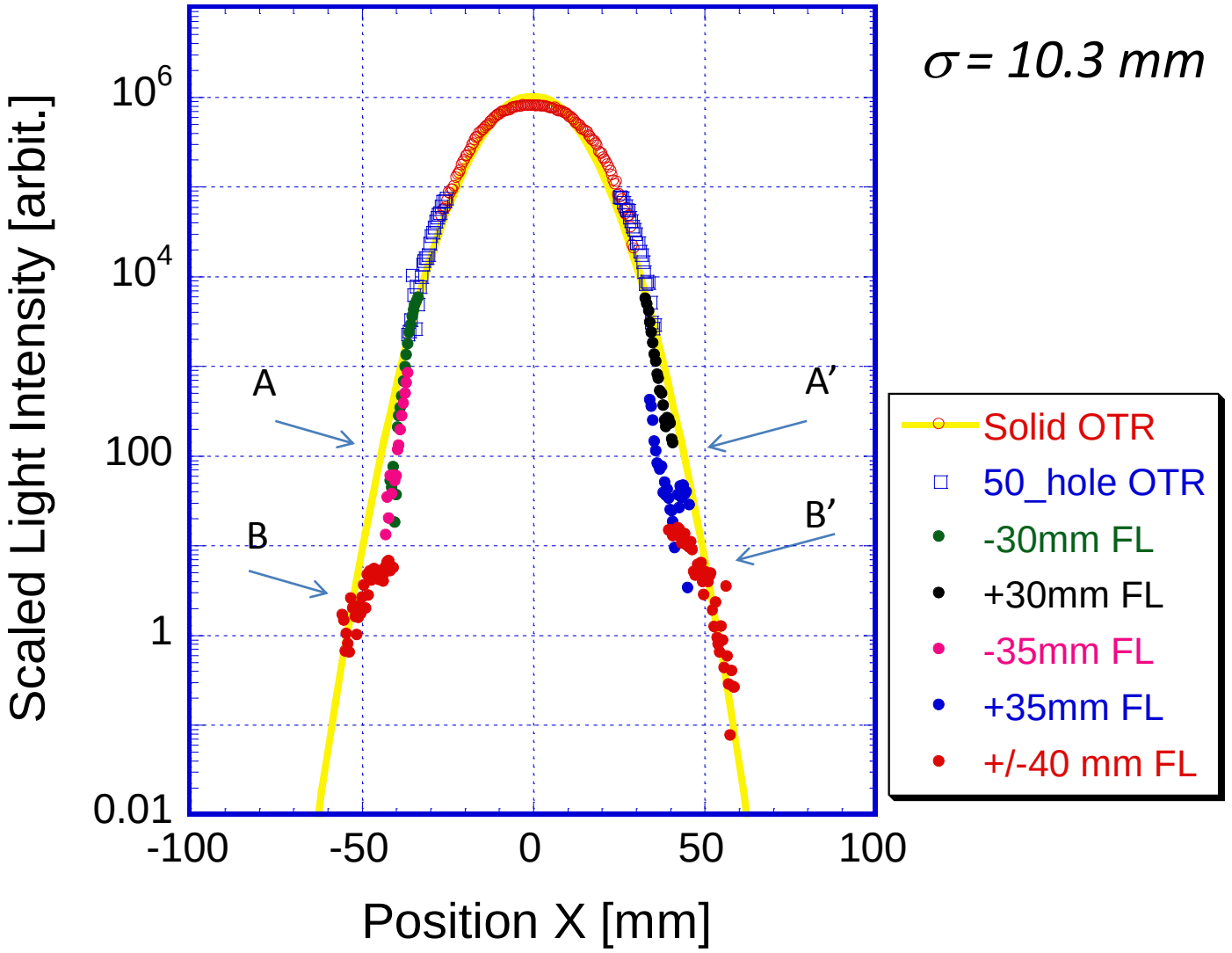
More than Six Order Obtained

More than 100 mm Spatially Distributed.

MULTI-SCREEN BEAM PROFILE MONITOR

A-A' : Collimating Effect?

B-B': New Halo produced by Collimation?



Combination Measurement with OTR and Fluorescence

Advantage of fluorescence by Cr doped alumina screen

☆Longer persistence: ≧ several 100 ms

➔ Integrated light (Gate of I.I. : 10 μs)

Compare to OTR

OTR emission ~ beam time (~ 200 ns x 2 bunch=400 ns)

➔ Integration time ratio FL/OTR~ 25

☆Larger transmission through the Offner Optics

➔ Isotropic in light emission

Compare to OTR

OTR: wide angle directionality by 3GeV proton beam

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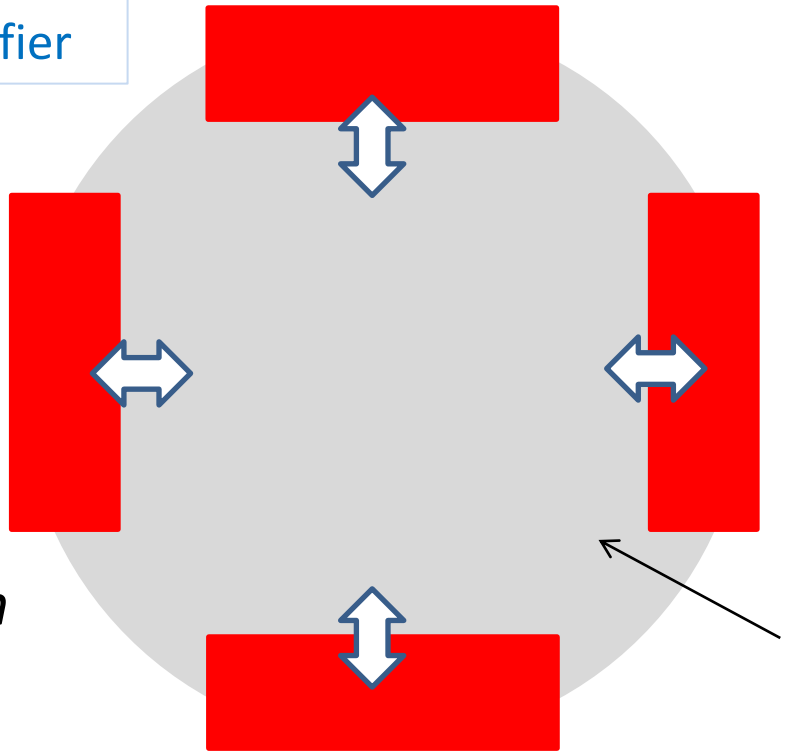
Simultaneous measurement of beam core and beam halo (Next step)

Knob for light yield control:
- Edge position of alumina screens
- Gate length of image intensifier



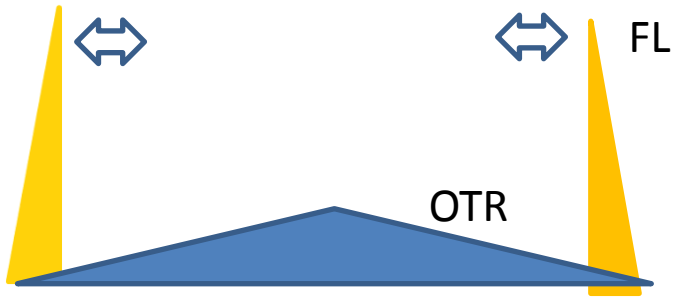
Fluorescence

Movable *Alumina Screen for Beam Halo*

OTR

Solid Screen for Beam Core

Projection



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Summary and Next Step

Summary:

Demonstration of High Sensitive Beam Profile Monitor Using Multi-Screen

***High dynamic range of six order*:**

We demonstrated a high sensitive measurement as horizontal spatial distribution of a beam by around six orders of light intensity ratio with using combination measurement by the OTR with the fluorescence from a chromium doped alumina screen.

***Simple Scaling*:**

To obtain a unified data , we used a simple scaling method by the image intensifier gain and by the light yield ratio between the fluorescence and the OTR.

Next Step:

➔**One shot measurement** for beam core and halo in the horizontal and the vertical direction simultaneously.

Thank you very much for your attention !

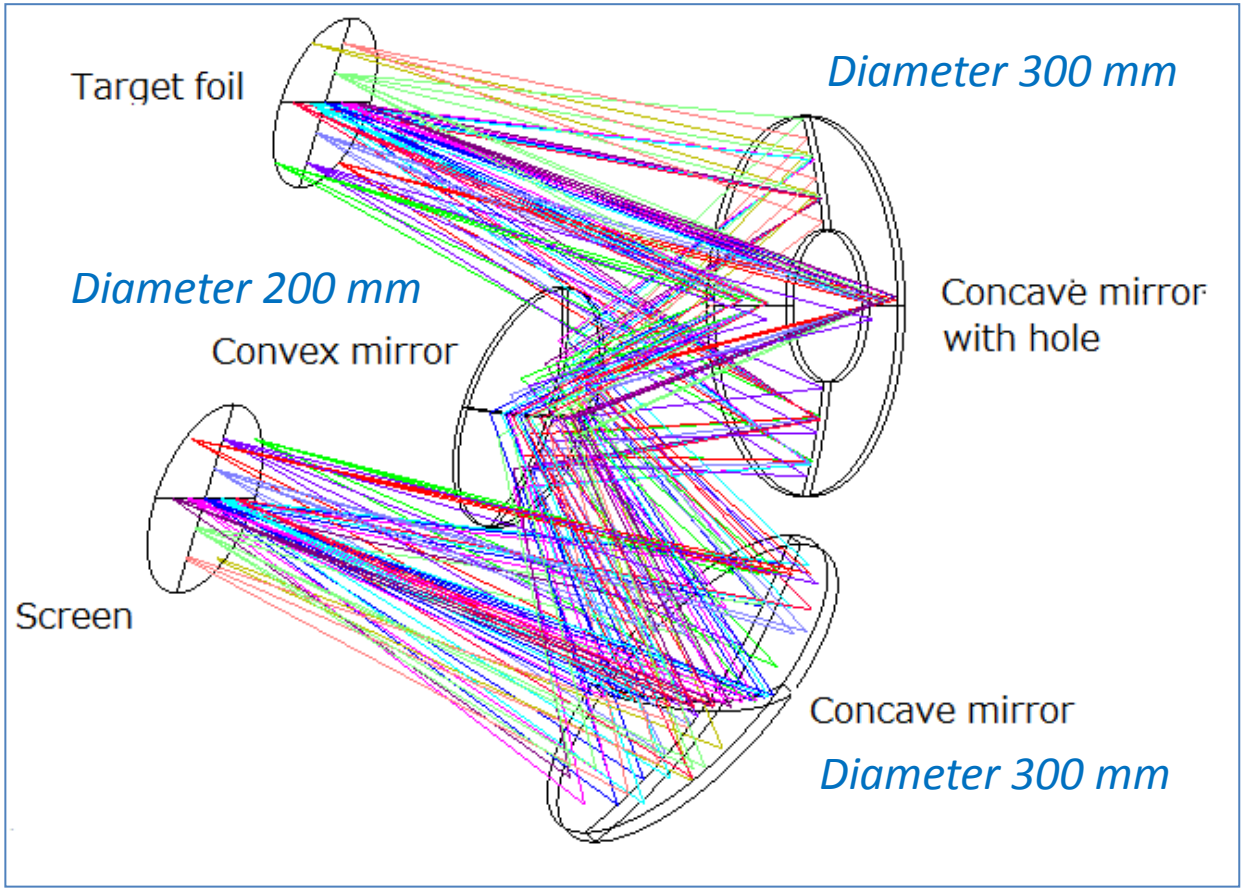
Backup

Large Acceptance Optics

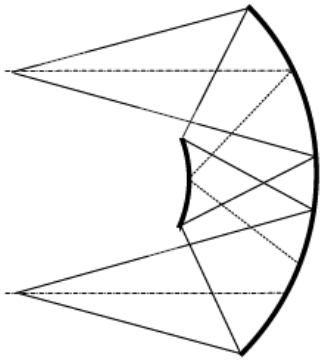
- Large Acceptance (±15 deg.)
- Larger Object Size ($100^{H} \times 80^{V}$ mm^2)
- In vacuum Off-axis Relay Optics
  - Cf. 45 deg. Tilted target : larger field depth and larger Object sizes → telecentric opticses but difficult
  - Cf. Elliptical and Parabolic Mirrors for off axis optics → difficult reason of aberration

We employed Offner Optics.

Our Scheme



Original Offner Scheme

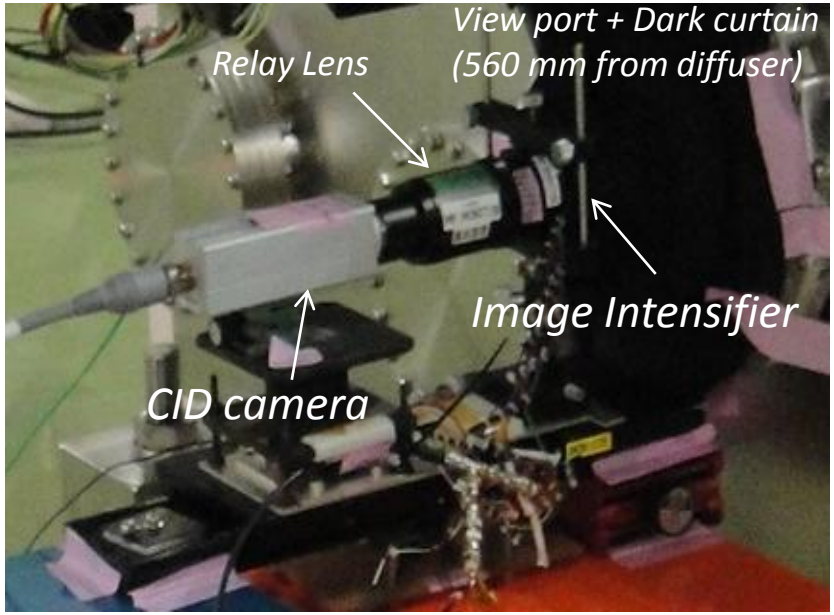


Backup

Detector

- **Image Intensifier**
- **Charge Injection Device Camera (Radiation Hard)**

Detector setup

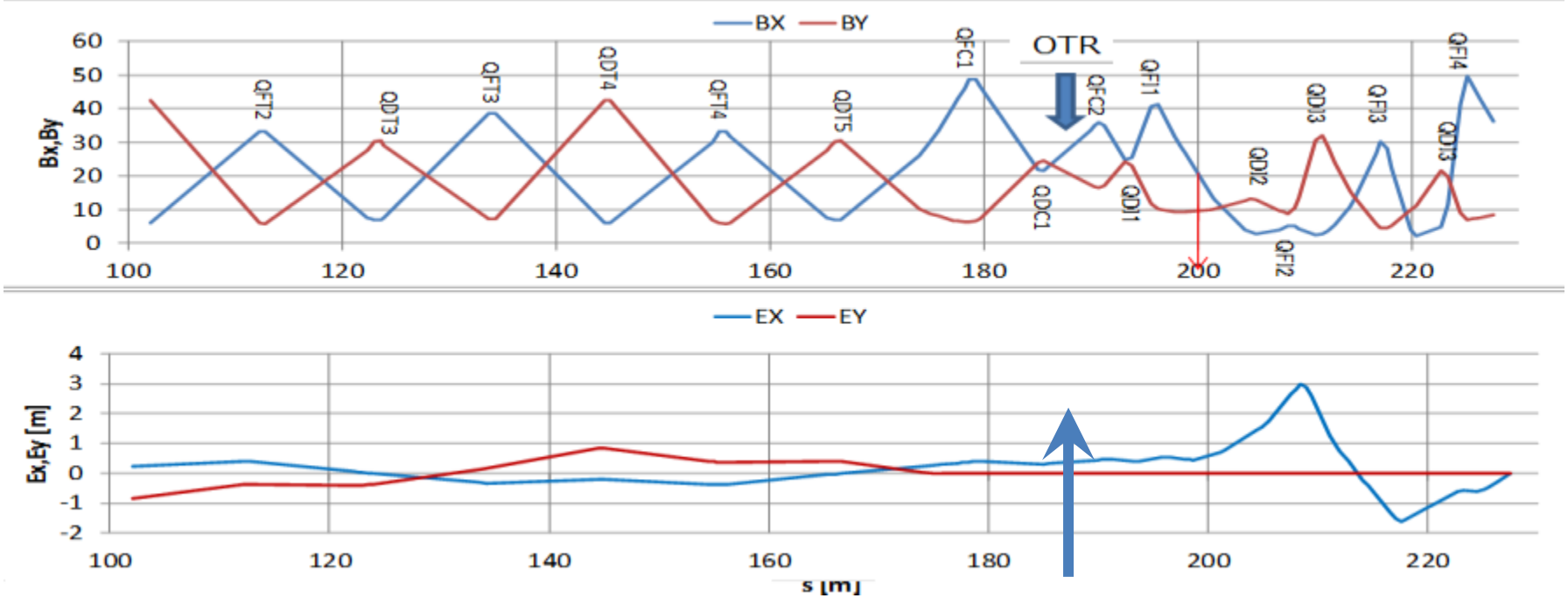


Device	Item	Specification
Focusing Lens	Focal Length	17 mm
[YakumoYMV2595N]	**F number**	**0.95**
	Image Format	1” (16 mm dia.) 12.8 × 9.6
	Front Aperture	26.8 mm
Image Intensifier	**MCP**	**Single Stage**
[HPK V2697U]	Luminous Gain	12000 [lm/m^2/lx]
	Resolution	30 [lp/mm]
	Phosphor Screen	Persistence: ~1ms
Relay Lens	Magnification	0.5
CID Camera	**Radiation Tolerance**	**300 kGy**
[ThermoFisher8725D]	Sensitivity	0.1 lx

Backup

J-PARC and 3-50 BT (3) Lattice Function

- Low dispersive
- βx: xx [m]



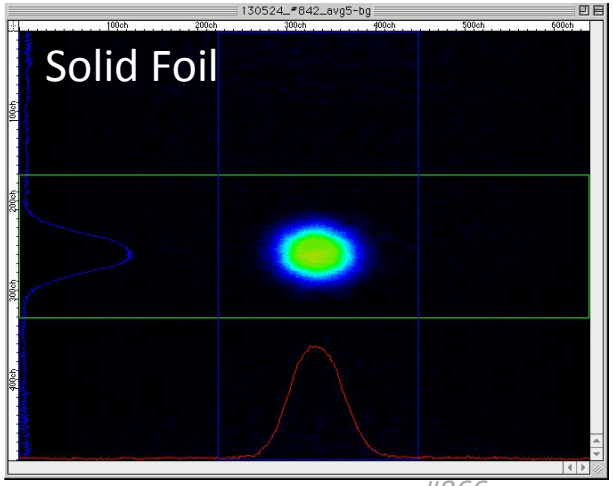
Multi-Screen Profile Monitor

Backup

(1) Beam core and tail maes. : Picture

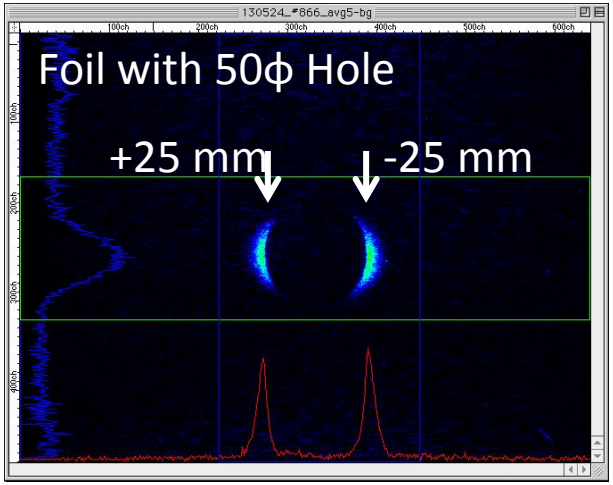
Beam core

#842_ MCP880V



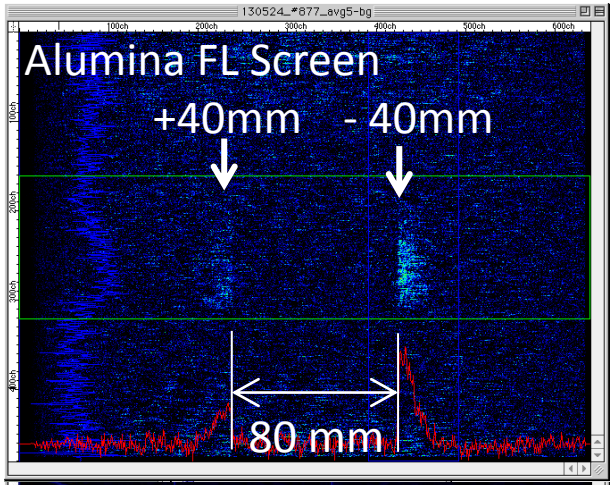
Near beam tail

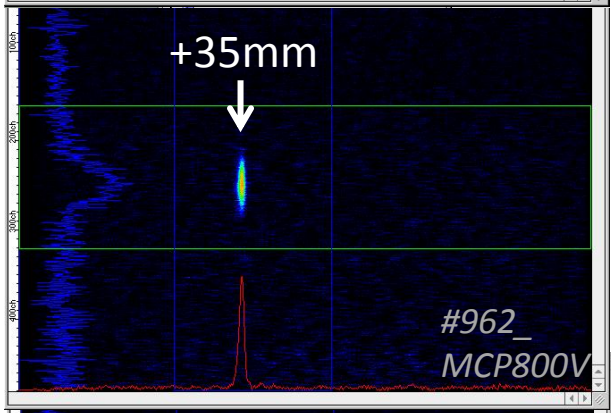
#866_ MCP1000V

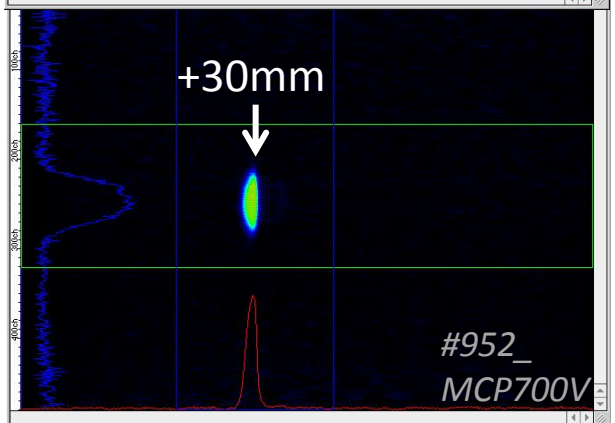


Far beam tail : Left

#877_ MCP1000V







Far beam tail : Right

#877_ MCP1000V