# *Multi-Ribbon Beam Profile Monitor Using Carbon Graphite Foil for the J-PARC*

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Contents:

# *Requirement for Target (One Passing Beam)*

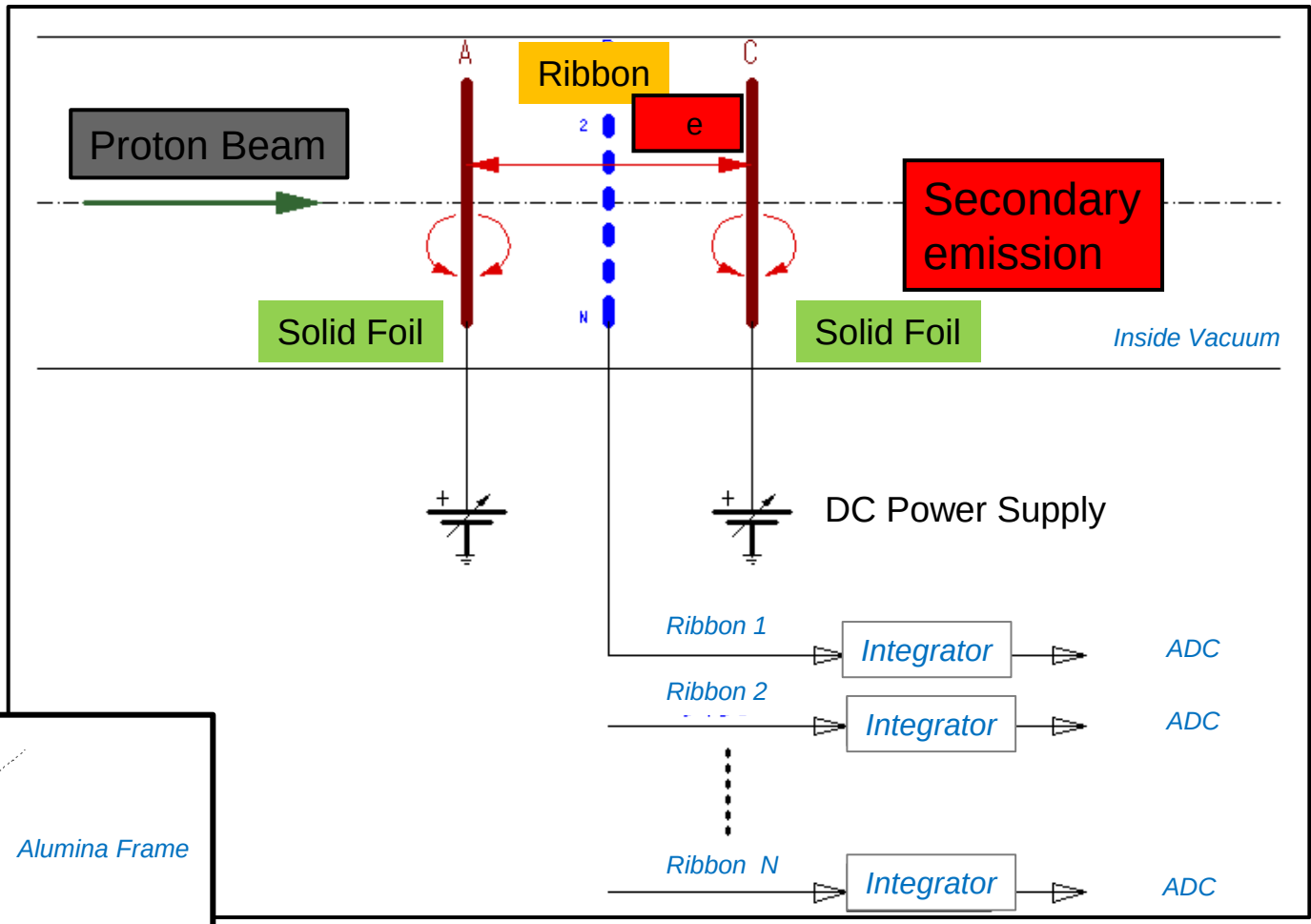
| Requirement | Solution |
|---|---|
| ***Low Beam Loss*** | ⇒*Low density Material* |
| | ⇒*Low Z Material* |
| | ⇒*Thin Foil* |
| *Large Detection Area (over 200×200 mm²)* | |
| ***Uniformity of Electron Emissivity*** | |
| ***High Sensitivity*** | ⇒ *Ribbon Type (segmented foil)* |
| *Heat Endurance* | |

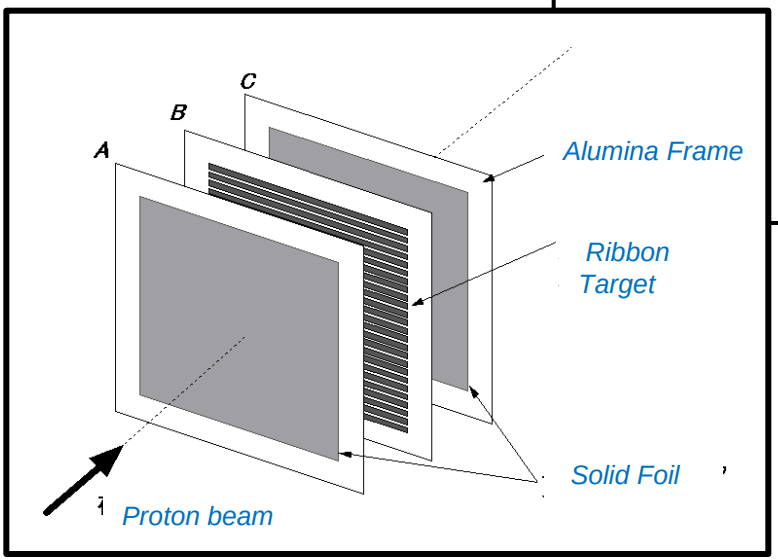
**For solving these requirements, a thin graphite foil was chosen.**

# Ribbon Type Detector

Distance 10 mm

Emissivity (secondary electron/proton) 2.1 % ($P_E$= 3 GeV)

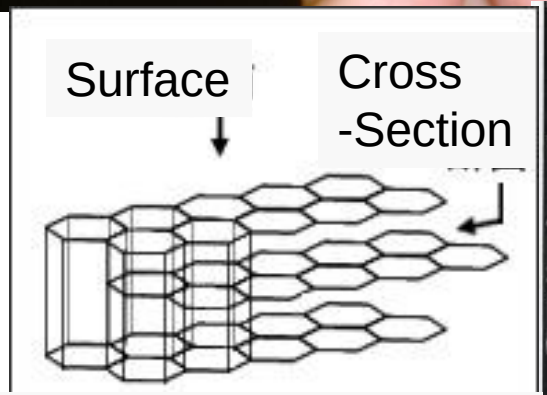


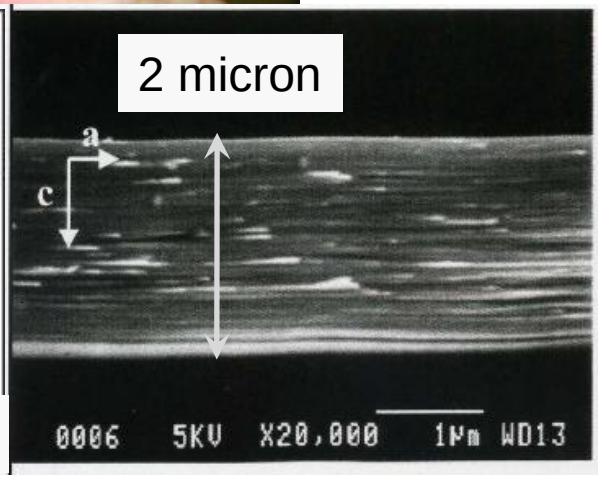
# Developed Target Material : Graphite (made by UBE)

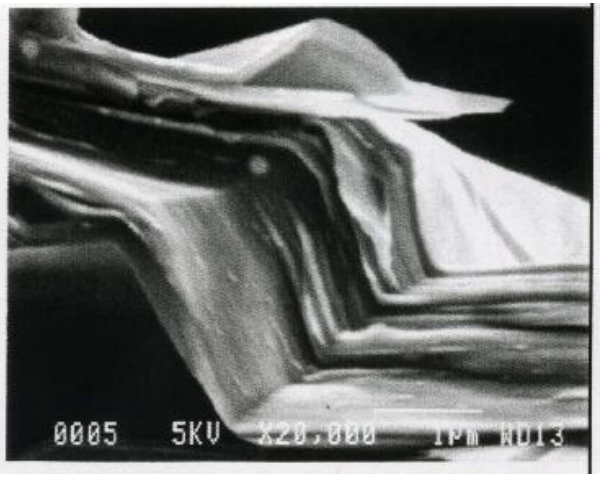
Thickness: 1.6 ~ 2 μm
Flexibility
Self-supporting
Large size :160 x 320 $mm^2$ max.
Firing temperature : 2600 degree C

UBE's Graphite has larger Crystallite
Adding toughness.




Layered oriented Benzene ring



## Beam Energy Loss: at Graphite Target by 3GeV Beam

| *Parameter* | *Value* |
|---|---|
| **Atomic Number Z** | **6** |
| **Material Energy Loss @ 3GeV proton** | **2.0 [MeV.cm2/g/proton]** |
| **Target Thickness** | **2 [micron]** |
| **Total Energy Loss** | **0.8 [keV/proton]** |

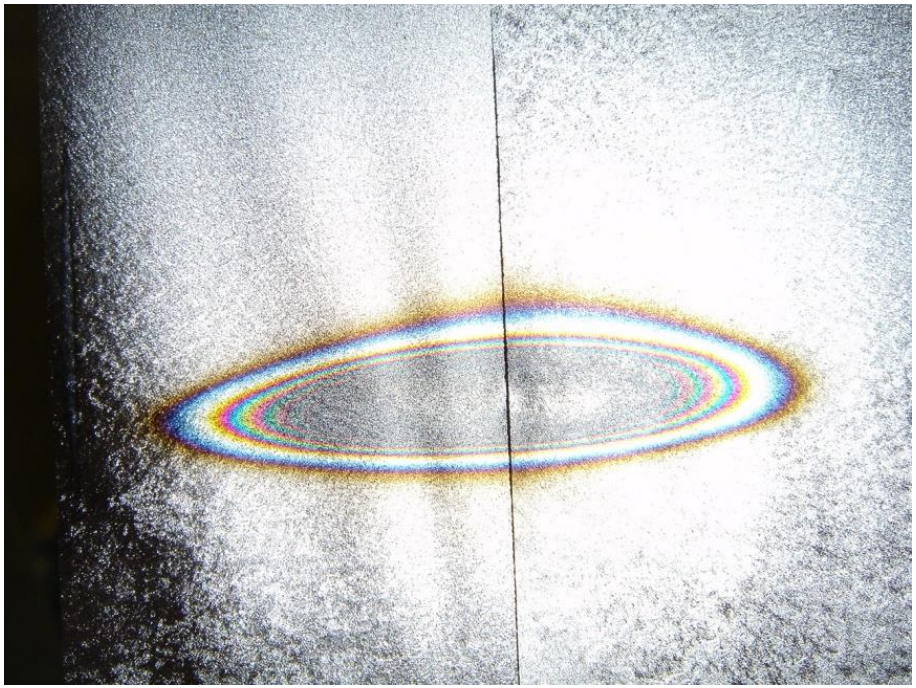
## Energy Deposition by 3-50 BT Beam at Graphite Target

| *Parameter* | *Value* |
|---|---|
| Design Beam Intensity | **4e13 [ppb]** |
| **Energy Deposition by bunch** | **5.1e-3 [J/bunch]** |
| **Energy Deposition by 8 bunch** | **4e-2 [J]** |
| **Estimated Temperature Raise** | **Several 10 ~ 200 [℃]** |

Endurance Test

## Long-Run Test (Net. 11 months)

Beam: Proton
Energy: 500 MeV
Intensity: 2e12 ppb, 20Hz
Beam Size : $45^{H} \times 15^{V}$ mm$^2$

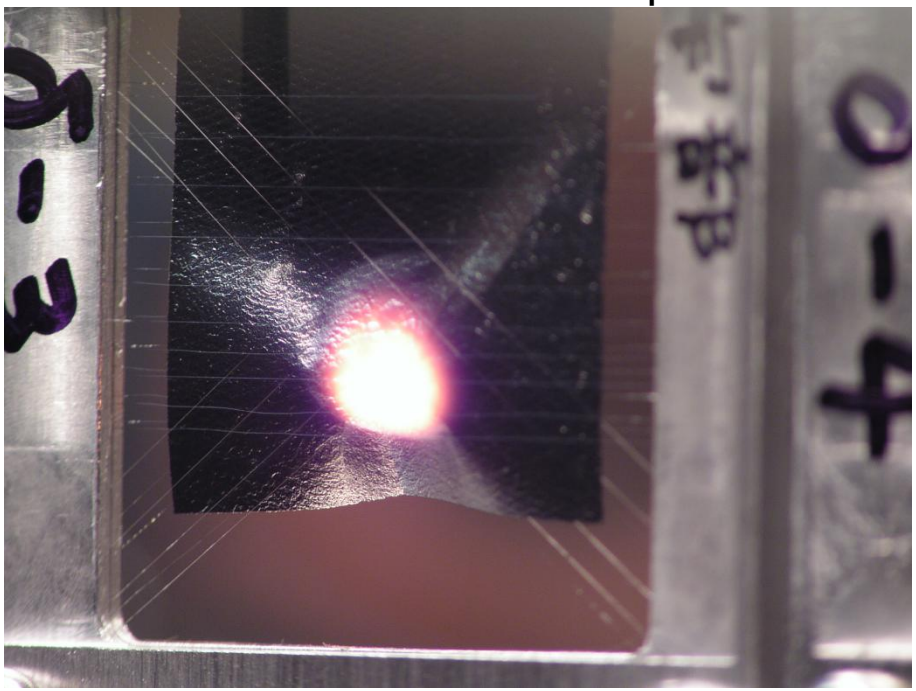


*Total Particle Number: ≧5×10$^{20}$*
*ALIVE*

* Electro-Conductive Binder remains
:sticked tightly.

## High Temperature Test

Beam: Ne+
Energy: 3,2MeV
Current: 3.0 μA
Beam Size 8 mmφ

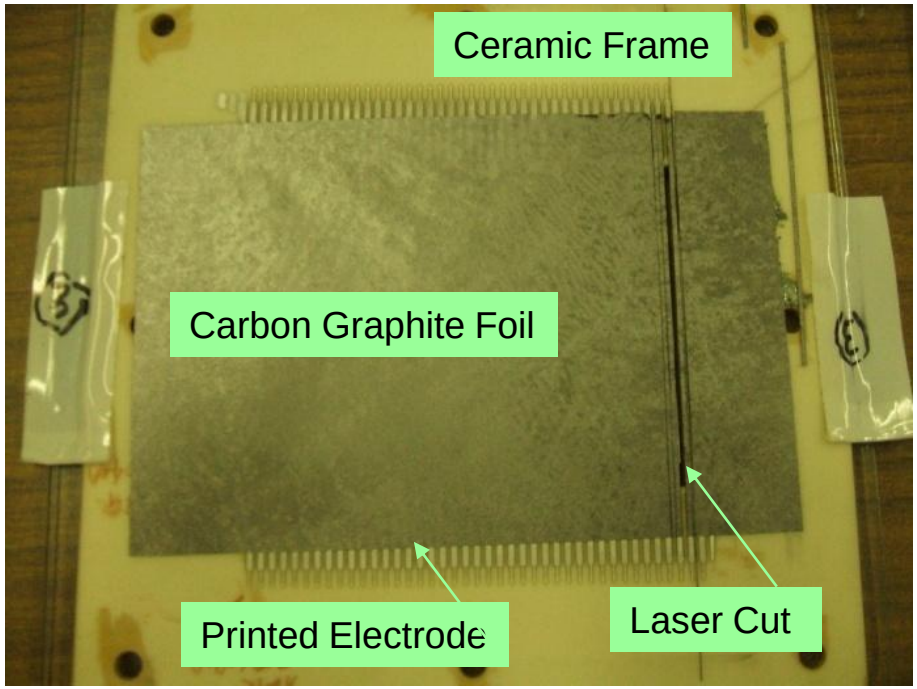


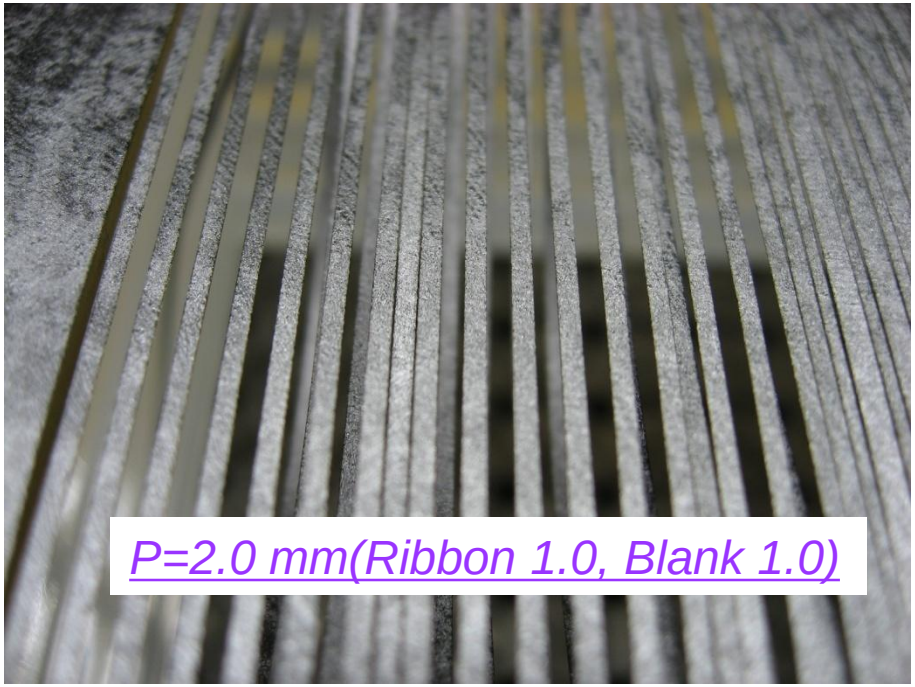
*Foil Temperature1400 ℃*
*after 67 min : BROKEN*

# Laser Cutting

- Preparation: A Foil was applied to electrode by the electro-conductive binder with any suitable tensions.
- Laser Cutting
  * Third harmonic of Excimer laser ~ 250 nm○
  * YAG ~ 1100 nm ◎
  * Laser Spot Size : 30 micron
  * Laser Position Accuracy: ~ 10 micron

*Cutting test*

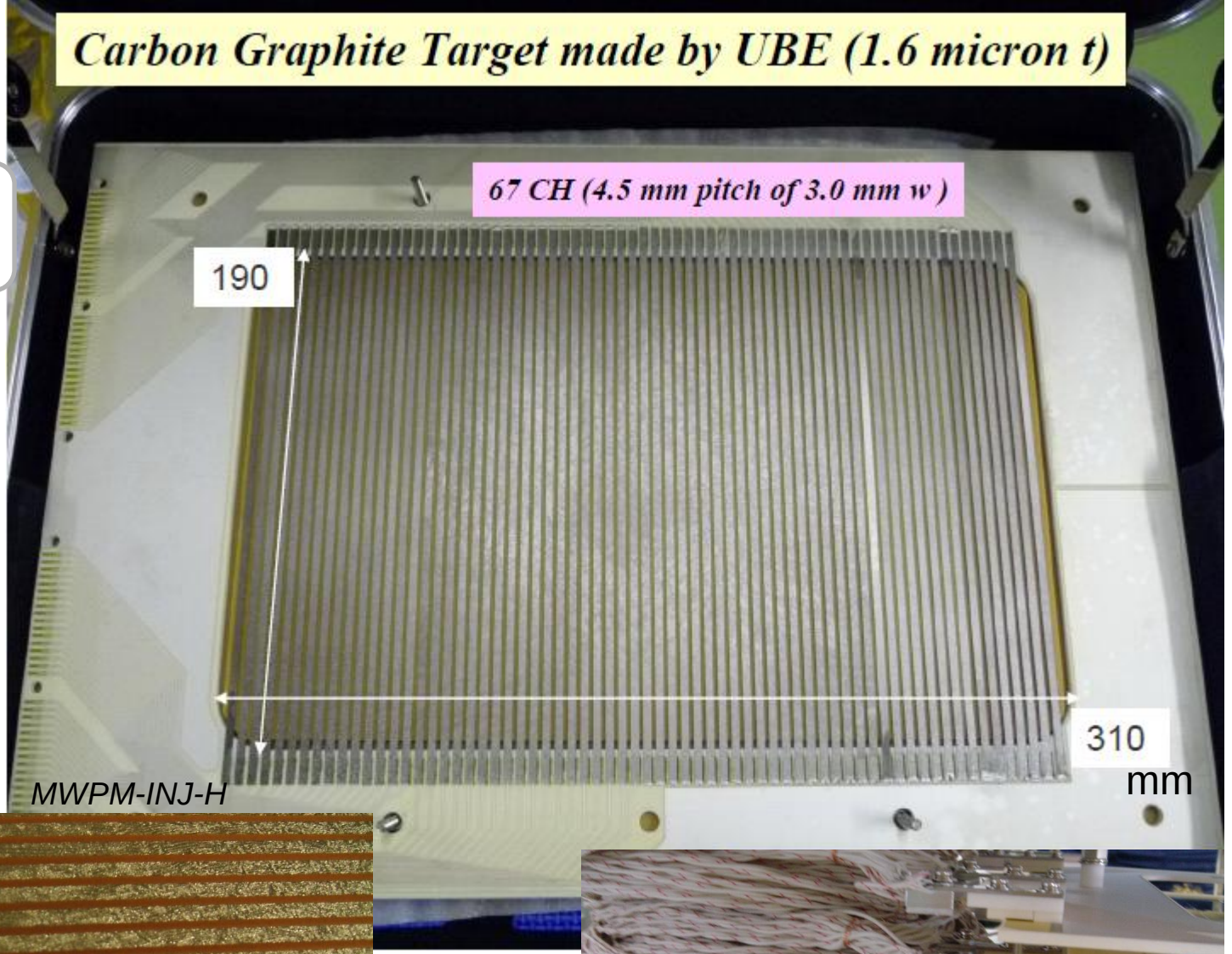


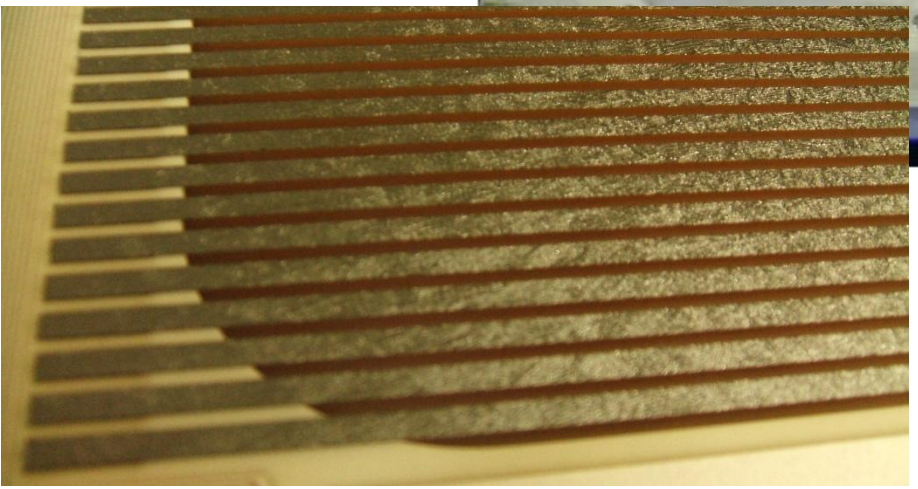



# Ribbon Target

*Alumina Frame:*
*410H×290V mm²*

Printed Pattern
Electrode :AgPt
Connector: Au



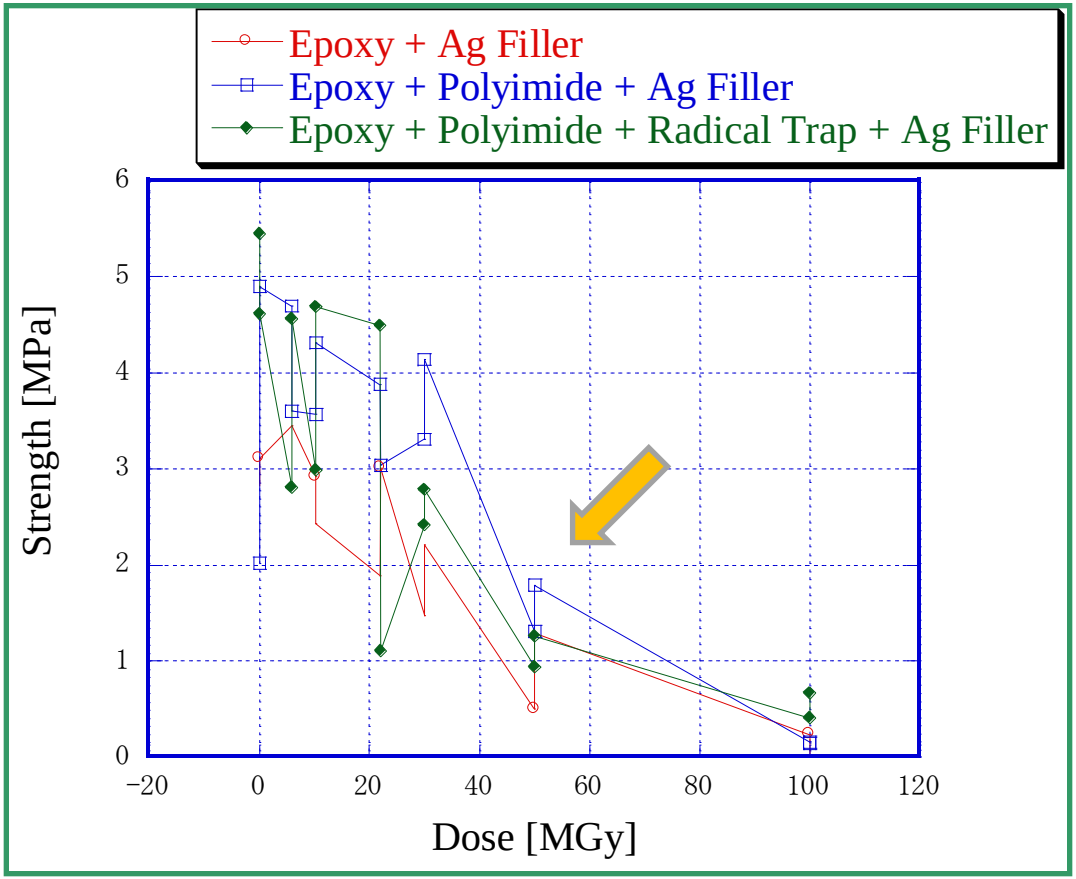
*Alumina Connector*

# Electro-Conductive Binder

- Radiation Resistance:
  Epoxy (Base) + Ag Filler (Hybrid Grain) + polyimide+ Radical Trap
- Low Outgassing: 1e-9 [Pa.m3/s/cm2])

Radiation Exposure Test by γ Ray ⇒After 50 MGy exposed, Pulling Strength was still remained about 1MPa

Exposure Sample
Cupper Plate(15×10 mm2)
⇒Pulling Test



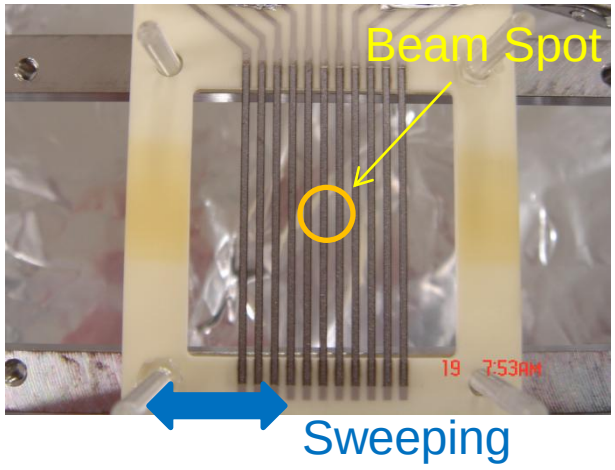
# Uniformity of Electron Emission from Carbon Graphite

## *Measurement Accuracy ⇔Uniform Emissivity*

Beam Test: HIMAC $C^{6+}$ 6MeV/u Beam

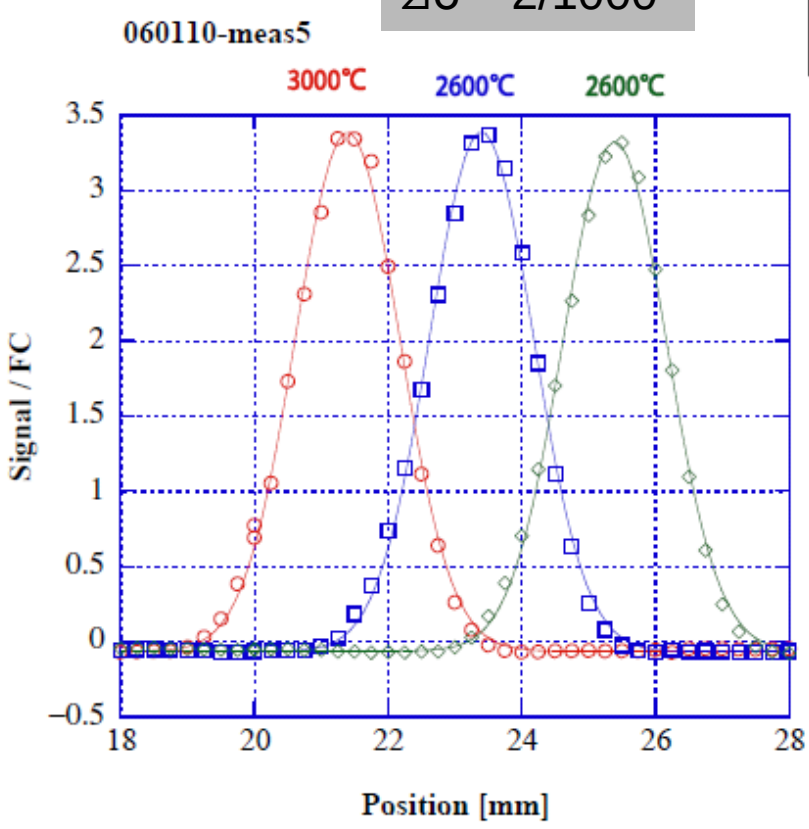
Un-uniformity≦1 %

Test Samples :Ribbon Array
Different Foil, Different Part




* Various Sample was tested.

⊿σ ~ 2/1000



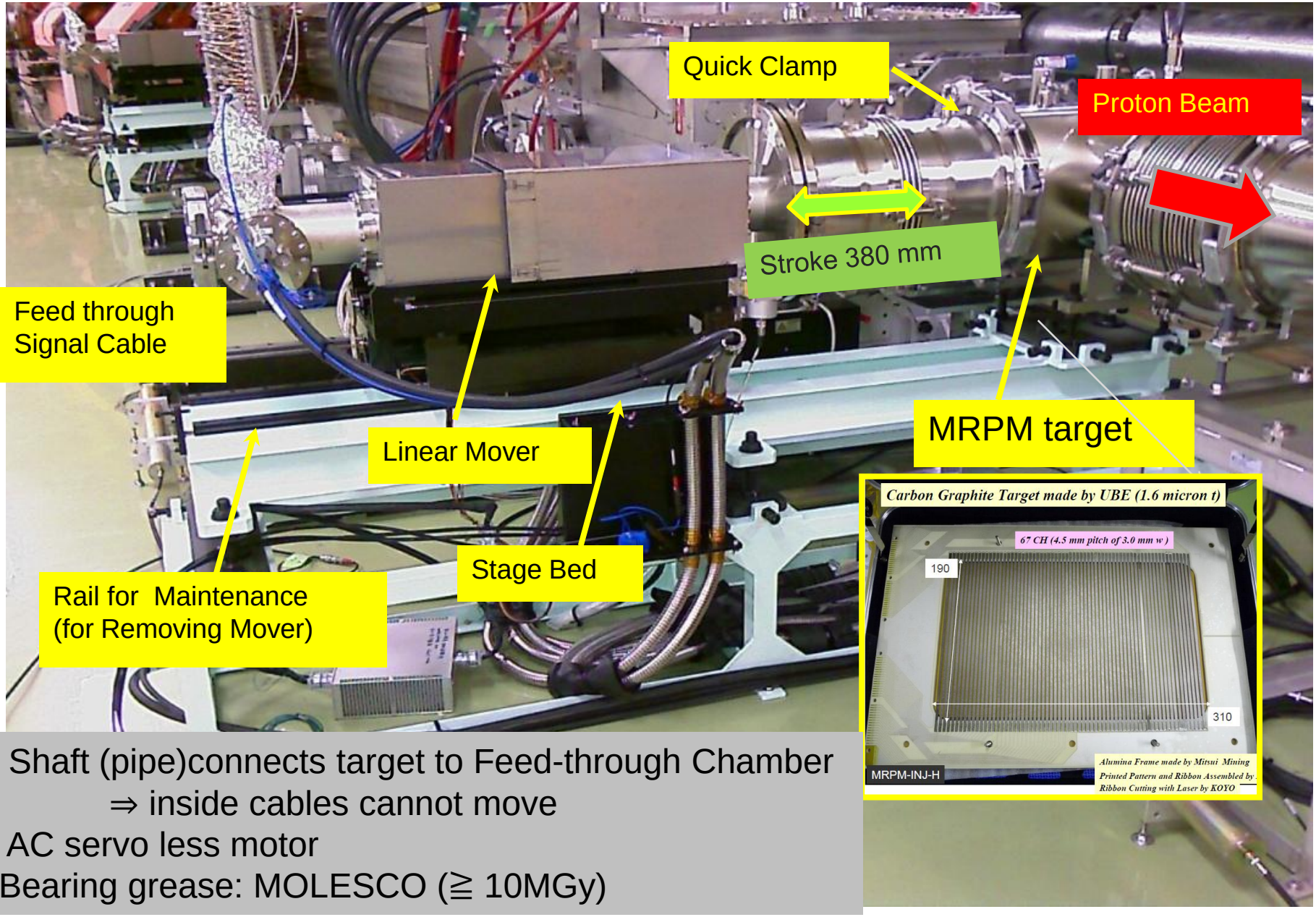

| y = n1+n2*exp(-(M0-n3)^2/(2... | 値 | エラー |
|---|---|---|
| n1 | -0.061198 | 0.010552 |
| n2 | 3.4515 | 0.028104 |
| n3 | 21.395 | 0.0069366 |
| n4 | 0.77616 | 0.0075221 |
| カイ２乗 | 0.10362 | NA |
| R | 0.99892 | NA |

| y = n1+n2*exp(-(M0-n3)^2/(2... | 値 | エラー |
|---|---|---|
| n1 | -0.063386 | 0.0097221 |
| n2 | 3.454 | 0.026524 |
| n3 | 23.399 | 0.0066493 |
| n4 | 0.77628 | 0.007333 |
| カイ２乗 | 0.09152 | NA |
| R | 0.99906 | NA |

| y = n1+n2*exp(-(M0-n3)^2/(2... | 値 | エラー |
|---|---|---|
| n1 | -0.060246 | 0.0091376 |
| n2 | 3.3855 | 0.024977 |
| n3 | 25.391 | 0.0063845 |
| n4 | 0.77604 | 0.0070318 |
| カイ２乗 | 0.081085 | NA |
| R | 0.99913 | NA |

# MRPM : Equipment

Vacuum : 5e-6 Pa




☆ Shaft (pipe)connects target to Feed-through Chamber
⇒ inside cables cannot move

☆ AC servo less motor

☆Bearing grease: MOLESCO (≧ 10MGy)

# 34 channels 1.5D coaxial cable assembly

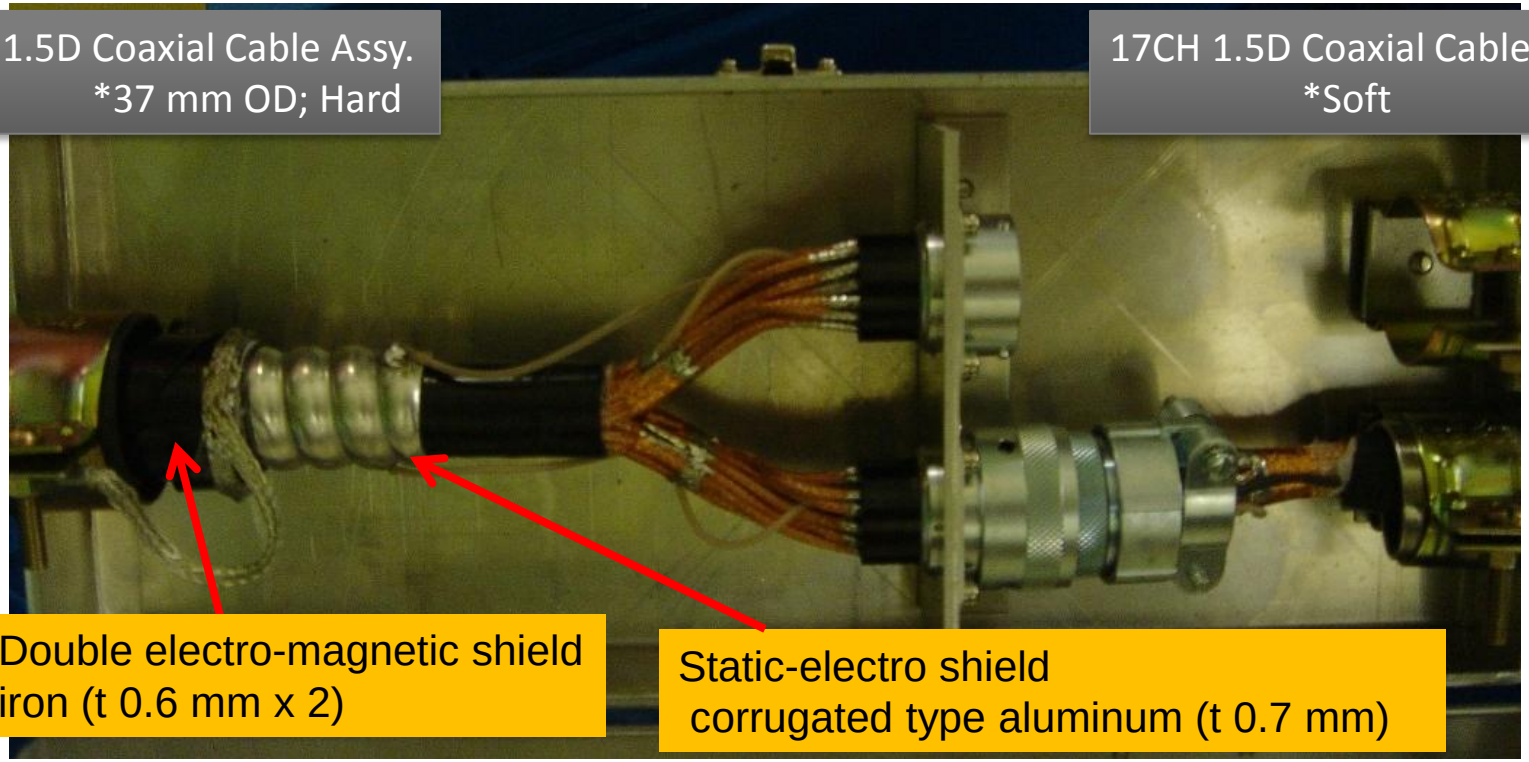
The charge signal was transmitted via this cable assembly without amplifier in length of around 400m from equipment to electronics situated in a MR local-control room.

Three layered Shield
Cross talk :≦- 60 dB or less (DC to 100 kHz)

Connector Box inside: Converted into head cable

34CH 1.5D Coaxial Cable Assy.
*37 mm OD; Hard

17CH 1.5D Coaxial Cable Assy. ×2
*Soft



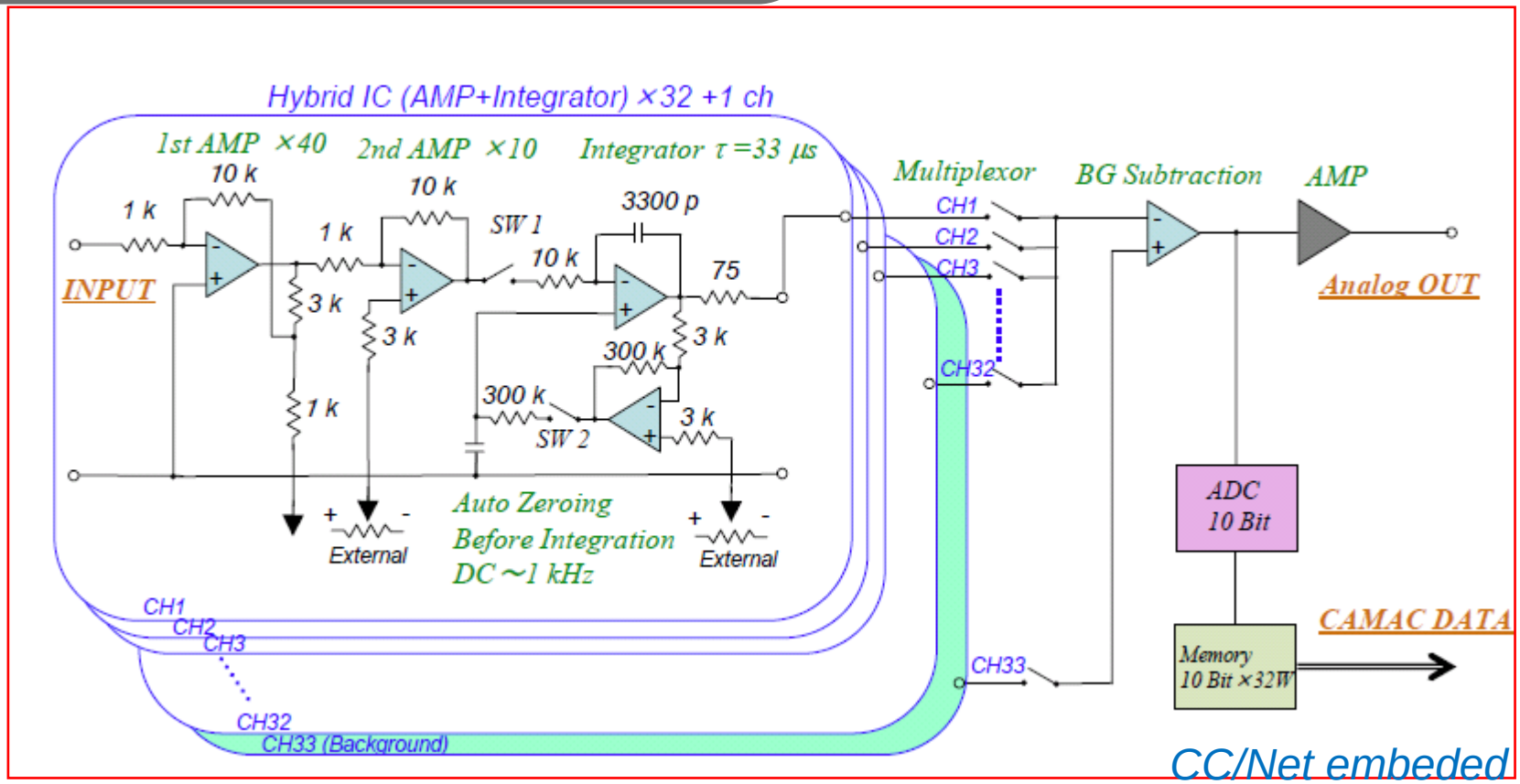
Double electro-magnetic shield
iron (t 0.6 mm x 2)

Static-electro shield
corrugated type aluminum (t 0.7 mm)

# Electronics : MWPM CAMAC Module

**diverting modules used at KEK-NML beam line*

Module: 32CH 10Bit ADC
HYBRID IC: AMP+INTEGRATION
INT.Const: 30μsec
INT.Gate: ~300μsec
Auto Zeroing: ~1kHz (except INT. Time)

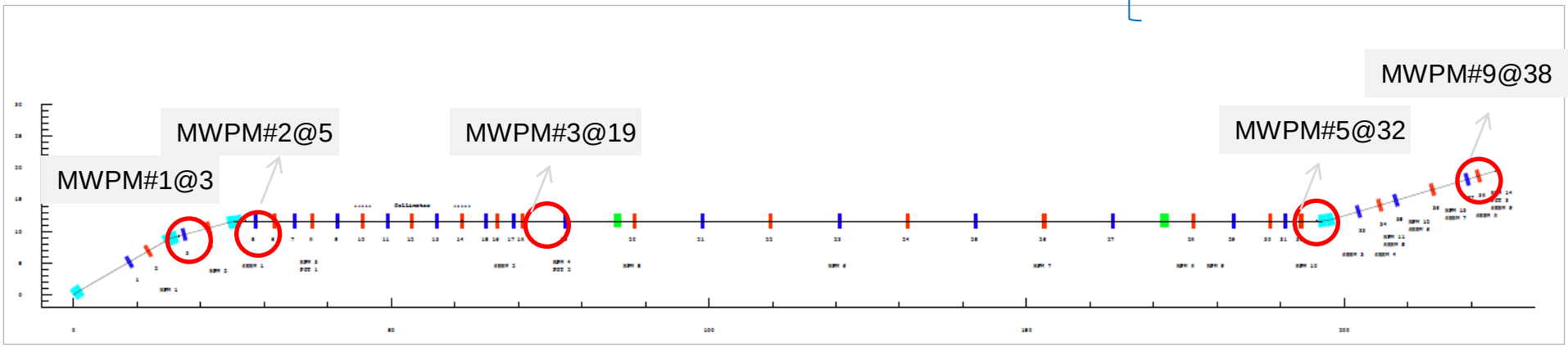




CC/Net embeded EPICS

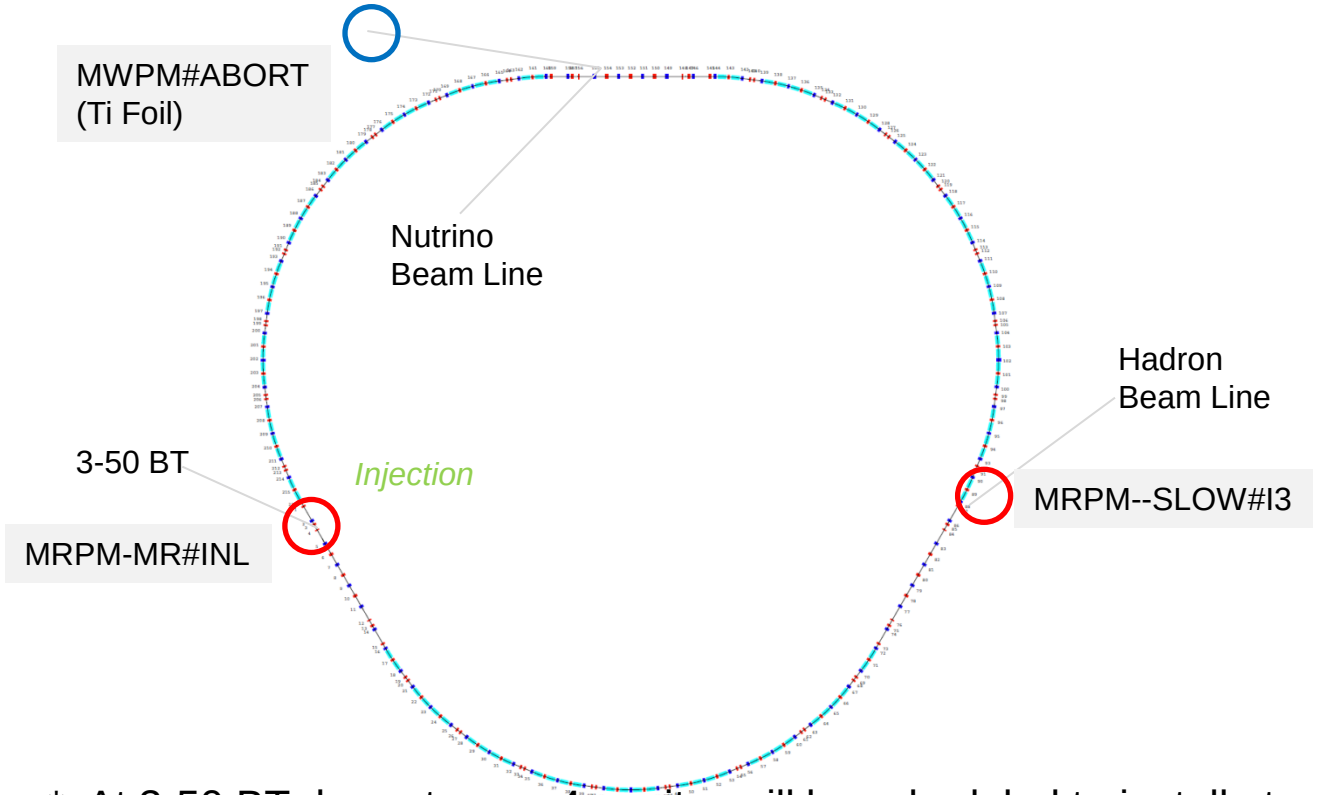
# MRPM in J-PARC

Seven monitors were installed
- 3-50 GeV: 5
- MR: 1
- SLOW EX: 1

350 BT MWPM MAP




MR MWPM MAP

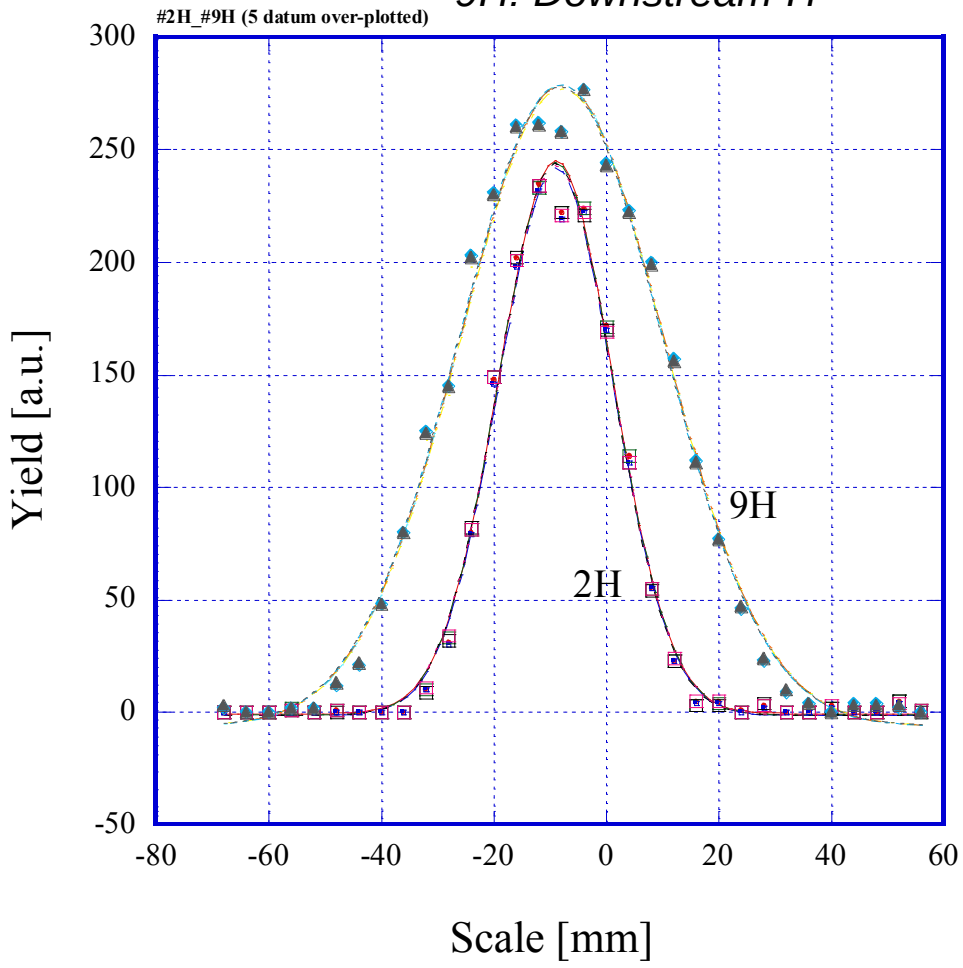



* At 3-50 BT downstream: 4monitor will be scheduled to install at next shutdown.

# Beam Measurements @ 3-50 BT

Beam intensity : 1 x $10^{13}$ ppb

*2H: Upstream-H*
*9H: Downstream-H*




*Both are over plotted and fitted by arbitral five another time's measurement*

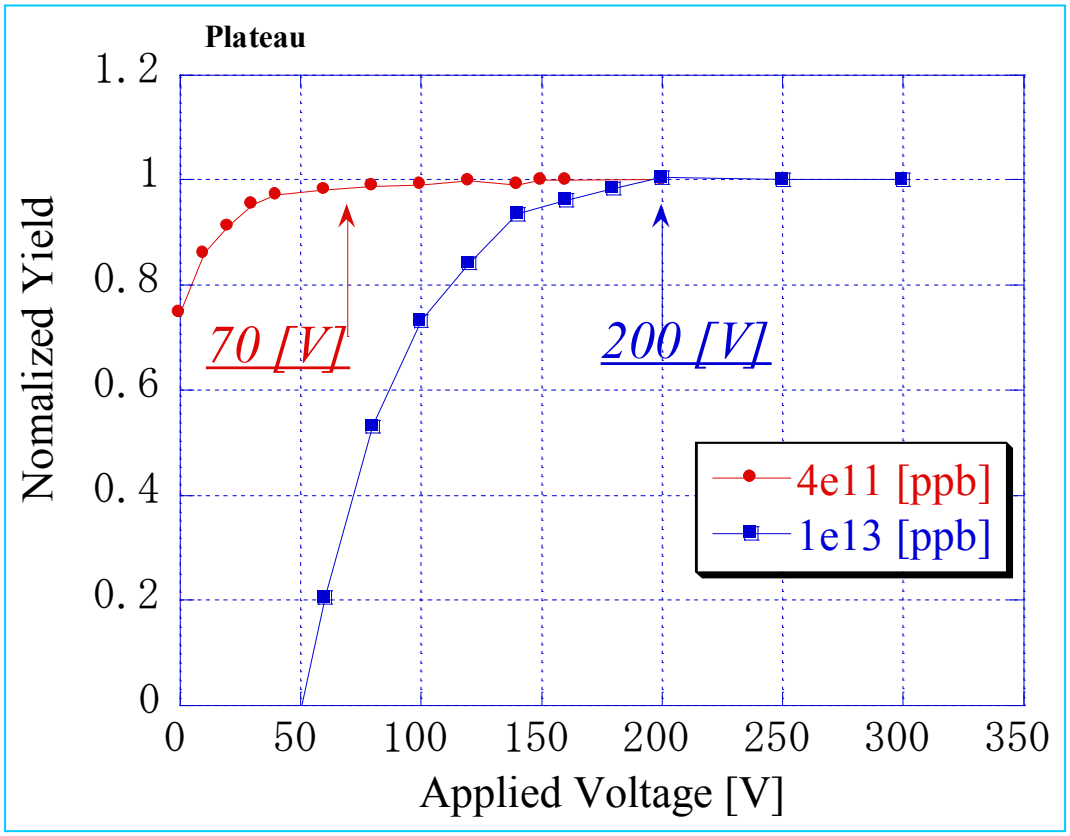
***Deviation was small***
***Good reproducibility.***

# Plateau Curve

Plateau Curve: Compared with two intensity's

4e11 [ppb] (bunch length:100ns, beam size: 35H x 16V mm2)

1e13 [ppb] (bunch length:100ns, beam size: 80H x 30V mm2)




*Space Charge Effect*

Electric potential reduced to negative or zero near ribbon surfaces.

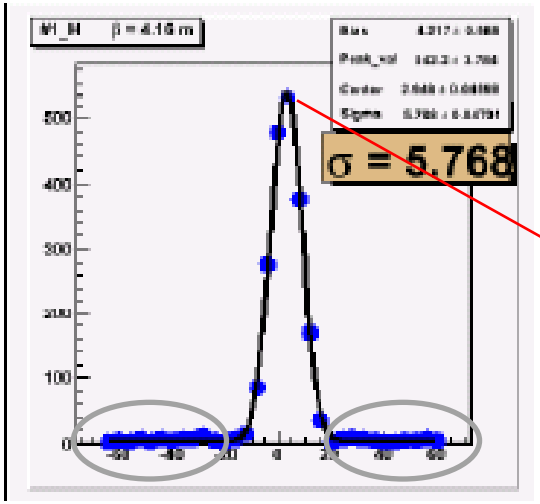
Electric potentialof Electron Correction Electrode must be raised.

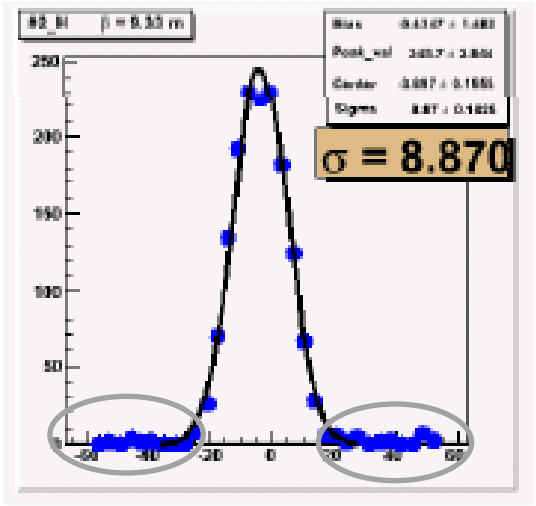
** Limitaion will be studied this Autumn.*

# [Preliminary ] Beam tail

1e13 ppb ×2bunch

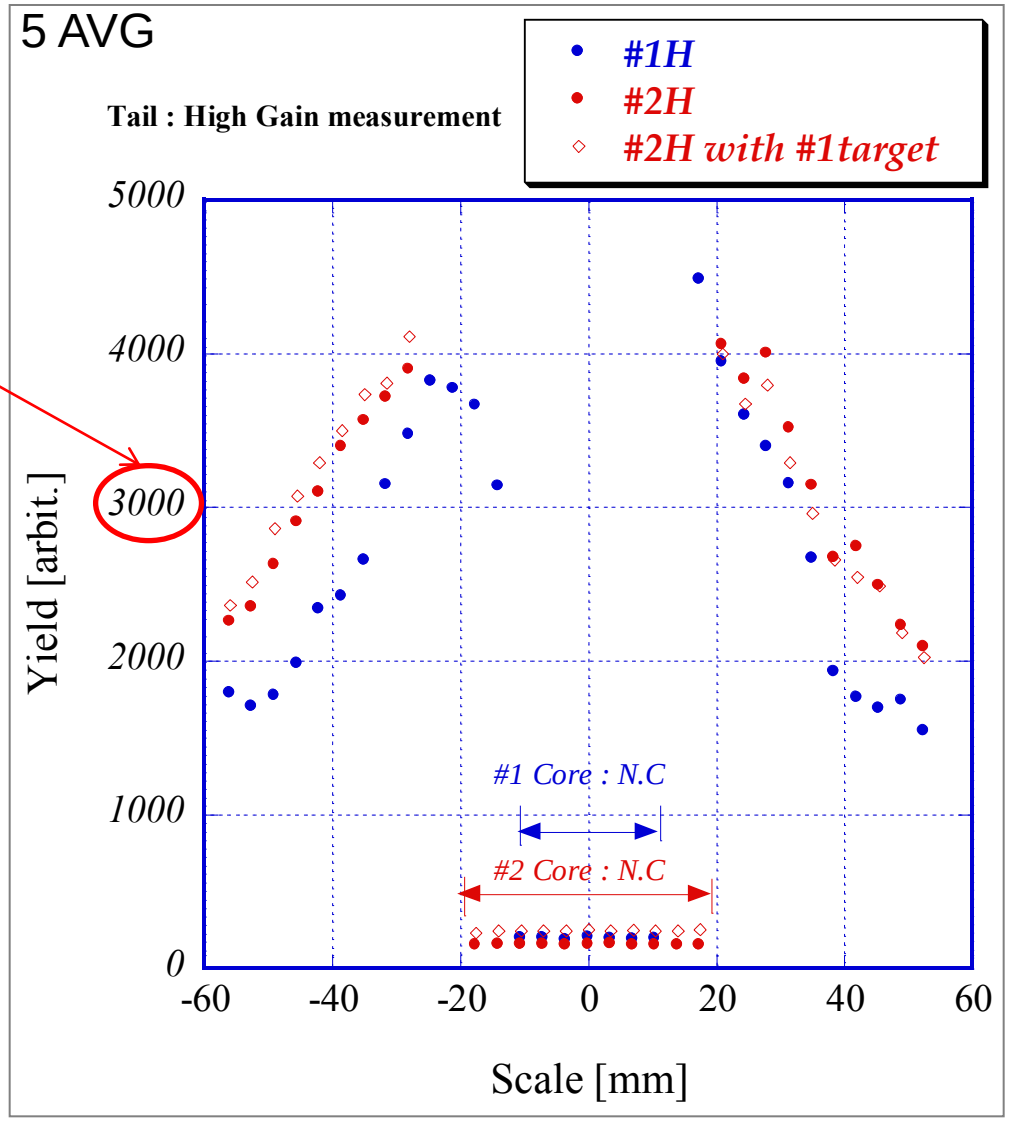
Beam Core Part was not measured. Effectively sensitivity of electronics was increased up to 2000 times than core measurement..



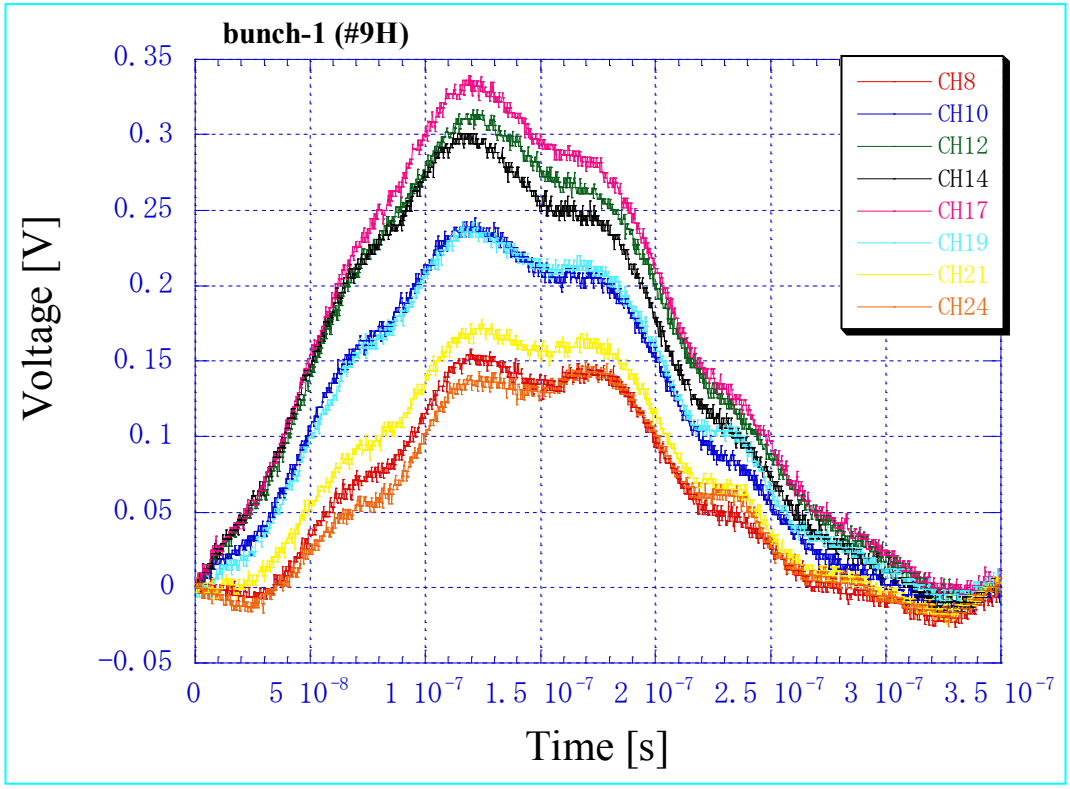

Single Shot

1/2000



# [Preliminary ] Time Transient Beam Profile

Beam Intensity: $1\times10^{13}$ [ppb]




Demonstration

☆Signal intensity is adequately high, signal detection could be possible by oscilloscope directory.

☆From MRPM 9H's signals, eight channels were selected and connected to two same type of 500 MHz scopes.

# Conclusion:

☆For high power beam as J-PARC, secondary-emission type beam-profile monitor using ***graphite ribbon*** was developed.

☆ It could be measured ***high intensity beam up to 1x10$^{13}$ ppb***.

☆The effective length of the ribbon was over 200mm, and ***un-uniformity of electron emission*** yield from its surface was ***1% or less.***

☆Since using thin as 2 micron of graphite thickness, ***beam energy loss*** per foil became smaller as ***0.8 keV*** at beam energy of 3 GeV. It amounts to only 4e-2 J loss per detector, in case of designed beam intensity of 4e13 ppb with 8 bunches.

☆Sensitivity became higher than ordinary wire target, beam tail test will be started soon.