Beam Profile Monitor at the 1MW Spallation Neutron Source

Shin-ichiro Meigo[1)], Motoki Ooi[1)], Kiyomi Ikezaki[1)], Tomoyuki Kawasaki[1)], Hidetaka Kinoshita[1)], Atsushi Akutsu[1)], Masaaki Nisikawa[1)], Shinpei Fukuta[1)] and Hiroshi Fujimori[2)]

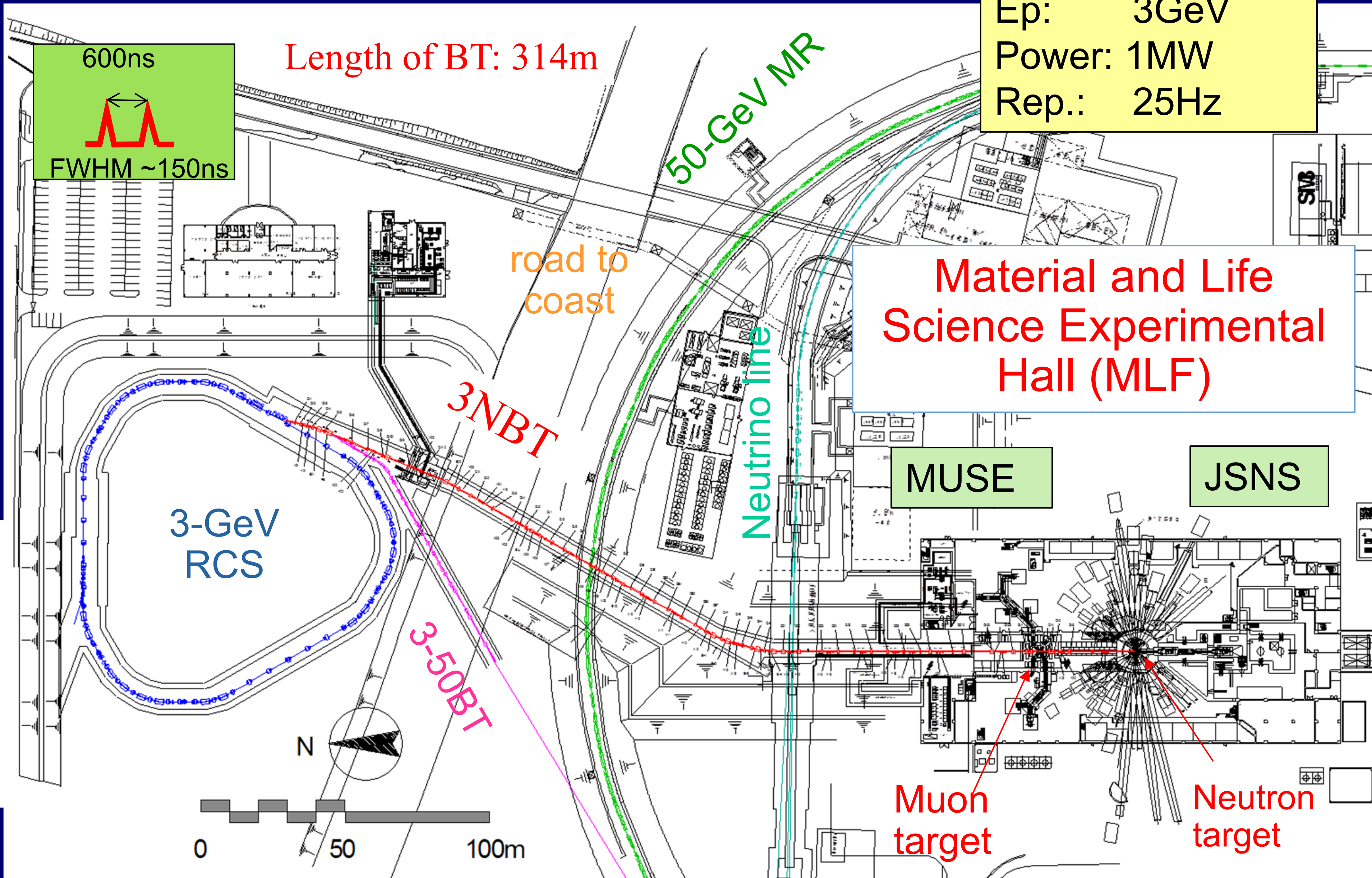
1) JAEA/J-PARC, 2) KEK/J-PARC

Outline

- Introduction of JSNS
- Beam monitor system at JSNS
  - Multi Wire Profile Monitor (MWPM)
  - Beam Halo Monitor
- Beam flattening system
- Development infrared and near-infrared camera system

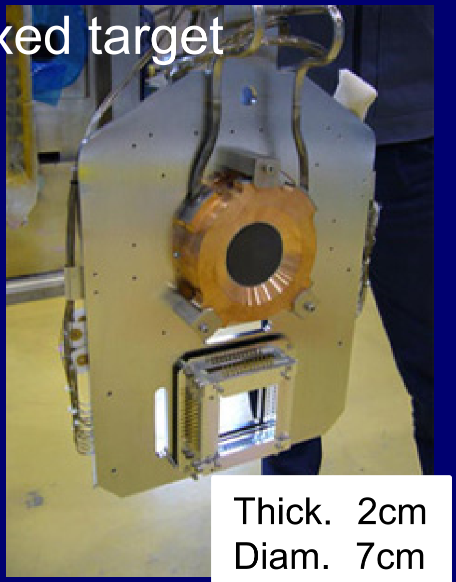
Beam transport to MLF

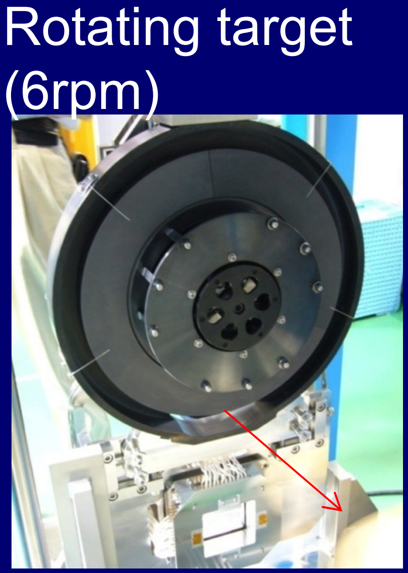
Ep: 3GeV
Power: 1MW
Rep.: 25Hz

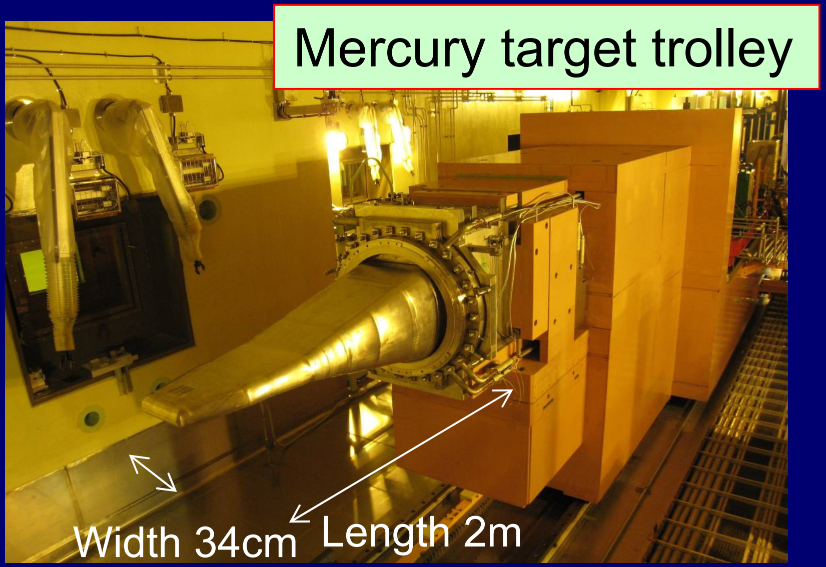


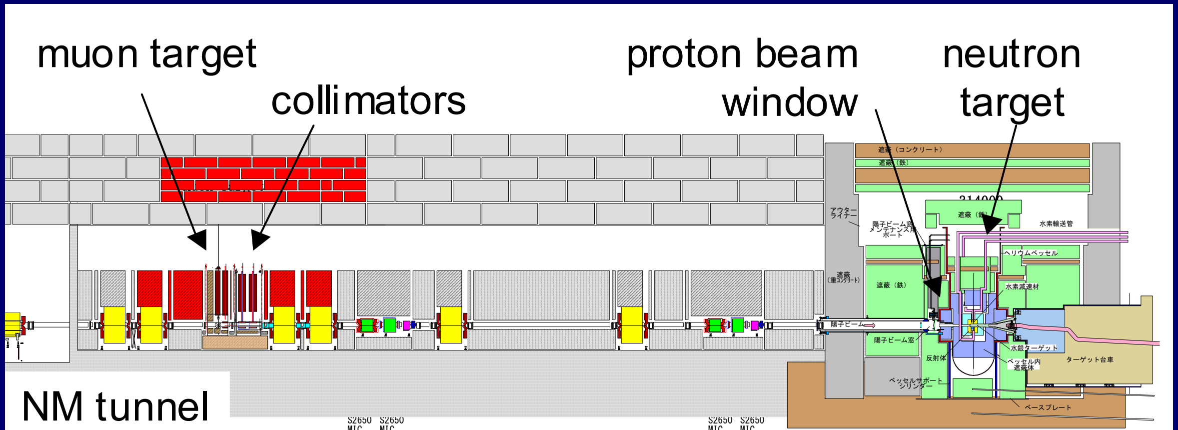
Targets located at MLF

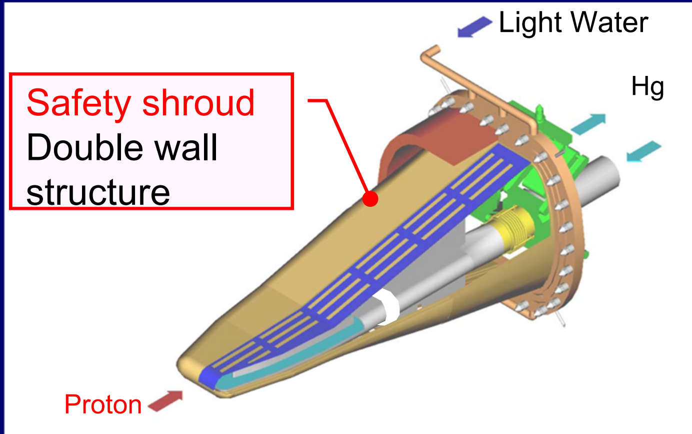
- Muon target
  - Carbon graphite (IG430)
  - Highest intensity in the world
- Neutron target
  - Mercury
  - Highest pulse intensity in the world









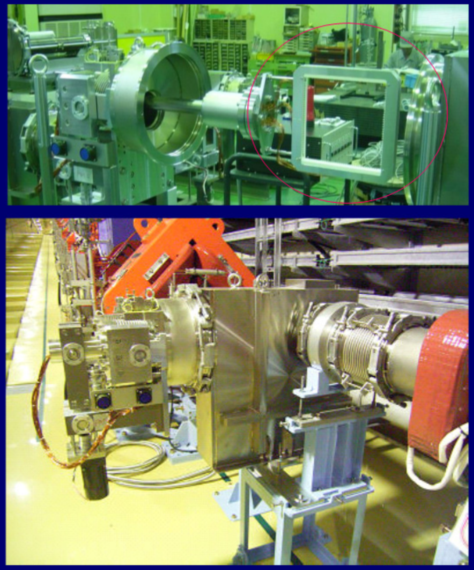


- Introduction of JSNS
- Beam monitor system at JSNS
  - Multi Wire Profile Monitor (MWPM)
  - Beam Halo Monitor
- Beam flattening system
- Development infrared and near infrared camera system

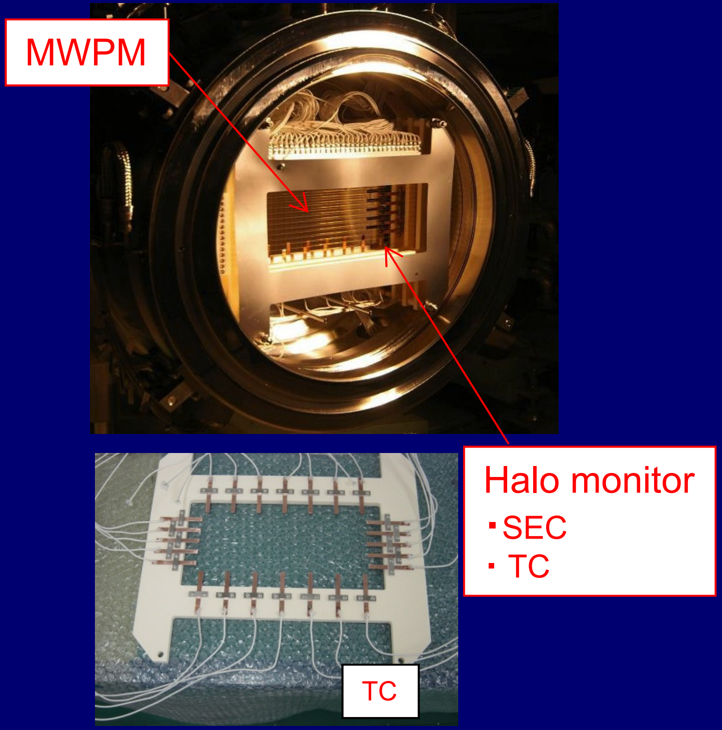
Beam diagnostics for profile and halo

- Profile monitor and halo monitor (online monitor)
  - Multi Wire Profile Monitors (MWPMs) (15 sets located) : SiC wires
  - Stationary MWPM at proton beam window (PBW) placed at 1.8 m upstream of the mercury target
- 2D profile： Residual radiation read by the IP (Offline type)

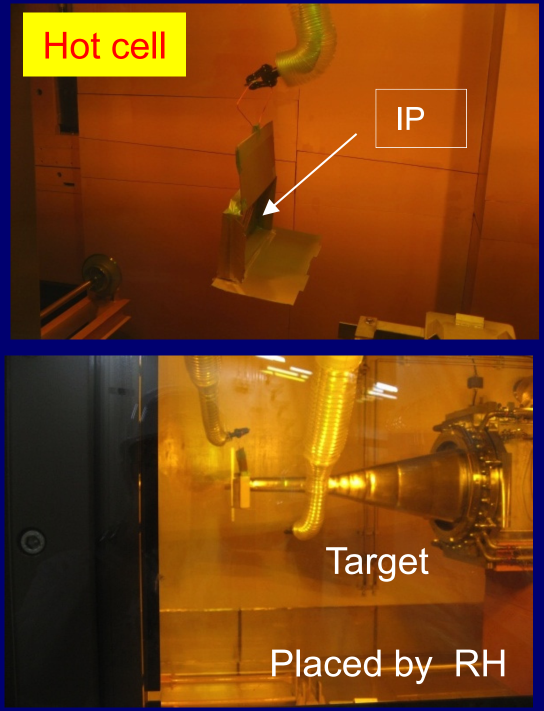
  After beam operation: IP was attached at the target by the remote handling



MWPM



Monitors at PBW

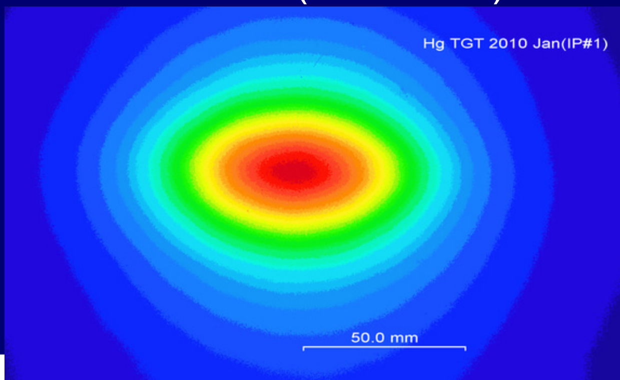


Imaging Plate(IP)

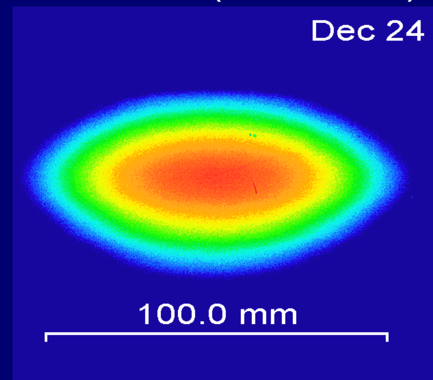
Beam profile at mercury target

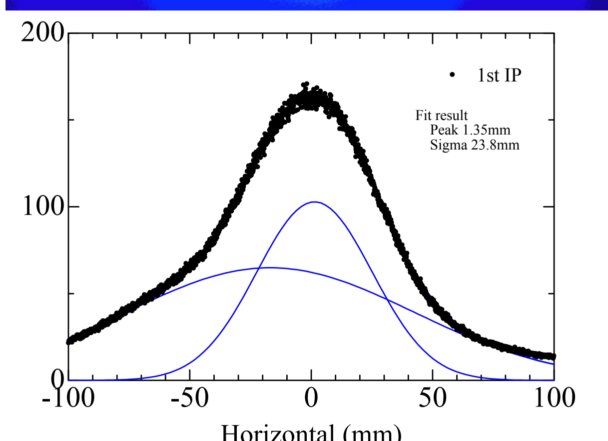
2-D measurement by IP

0.1 MW (2009 Dec)



0.2 MW (2010 Dec)



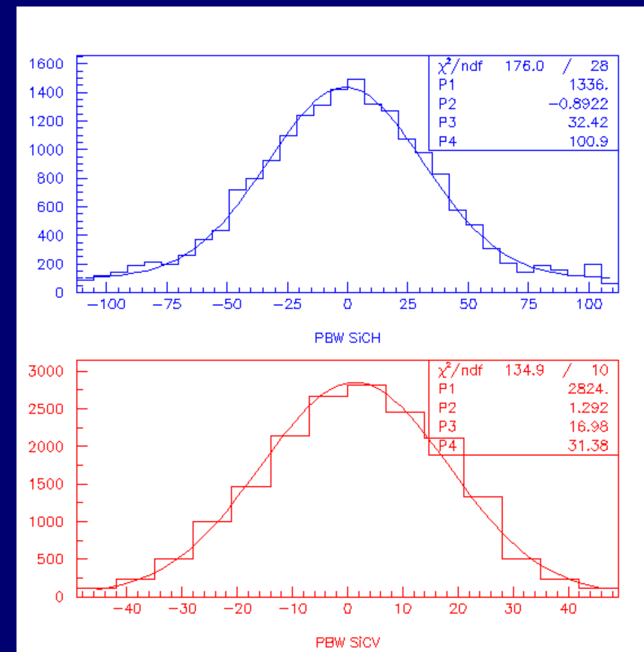


Obtained only 6 days of cooling duration after irradiation of 0.2 MW beam
⇒ Possible for 1MW with certain cooling time

Profile result by the IP

- Fitted by two Gaussian curves
  Contribution of primary protons and secondary particles (almost neutrons)

MWPM at PBW



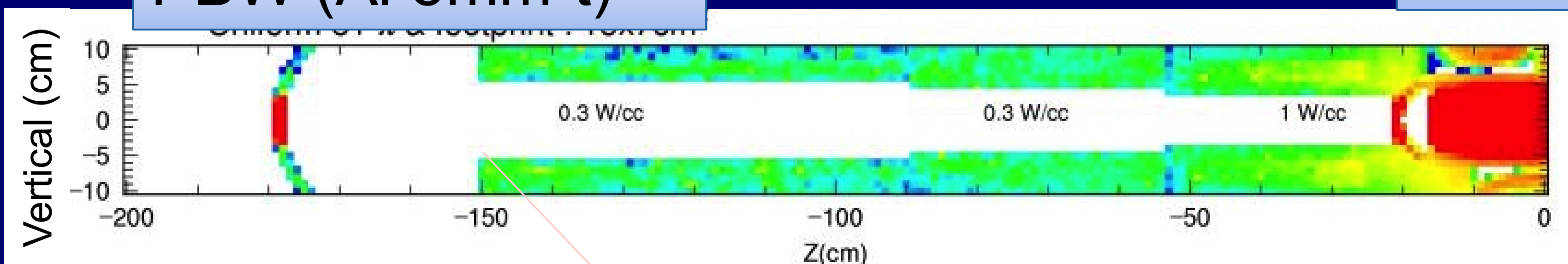
Result by MWPM
- Fitting by Gaussian
- Width and position for each pulse obtained
- Good agreement width result by IP

Beam halo measurements

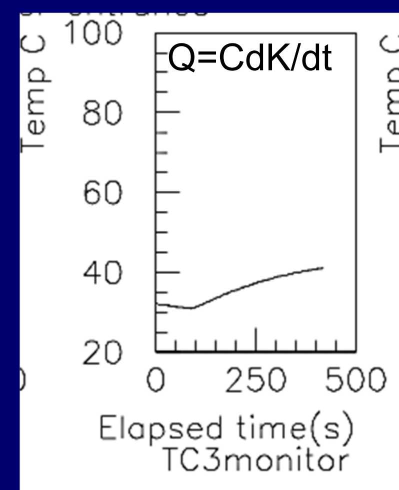
- Heat distribution at entrance of target station
  - Scattering beam at PBW producing heat at target vicinities (< 1W/cc i.e. 10^{-4} of peak), which is allowable level.

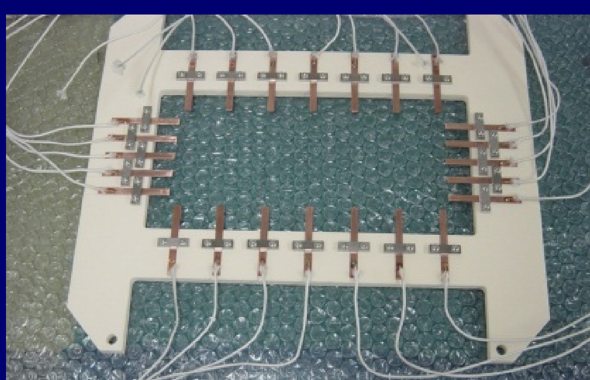
PBW (Al 5mm-t)

Hg target



Proton beam entrance at target station





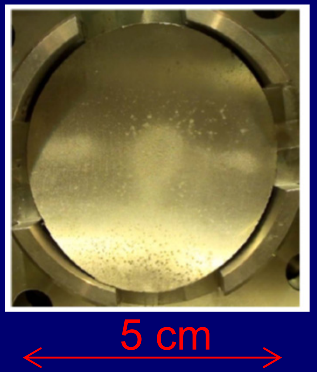
PBW Halo monitor TC-type

Thermocouples(TC)

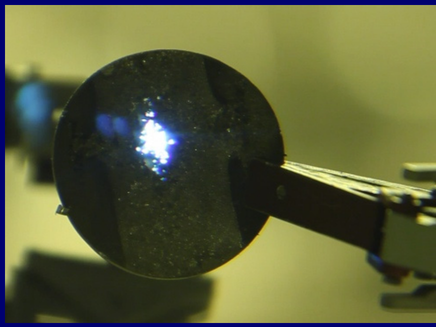
- Introduction of JSNS
- Beam monitor system at JSNS
  - Multi Wire Profile Monitor (MWPM)
  - Beam Halo Monitor
- Beam flattening system
- Development infrared and near infrared camera system

Proton beam at the target

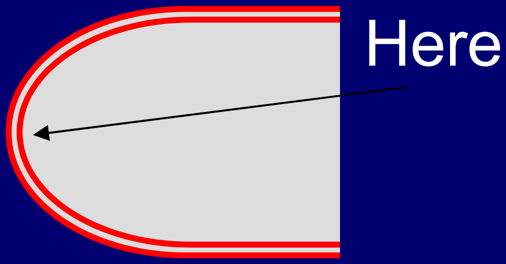
- Beam operational status
  - Study with 1 MW beam
  - User operation with 0.5MW
  - Getting narrow storage space
- Pitting damage is critical
  - Negative pressure attacks
  - Proportional to 4^{th} power of the peak current density at target
    - Useless beam rastering to mitigate
- JSNS harder condition than SNS
  - SNS: 60 Hz, Storage ring w/o muon target
  - JSNS: 25 Hz, RCS with muon target
- Although helium bubbling mitigates the pitting damage, peak reduction is essential.



Damage at JSNS target



Pin holes at target of SNS



Target vessel

Beam flattening system

- Beam edge folding by non-linear optics (octupole magnet)

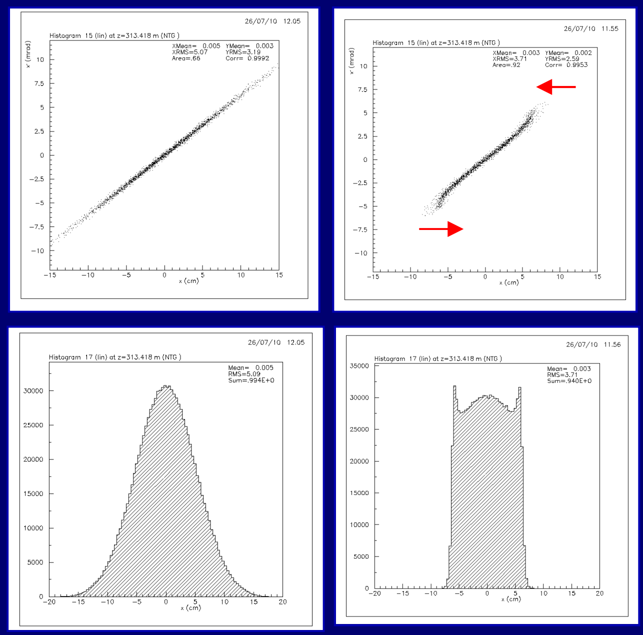
Linear / Non-linear

Phase space

Real space (Horizontal)

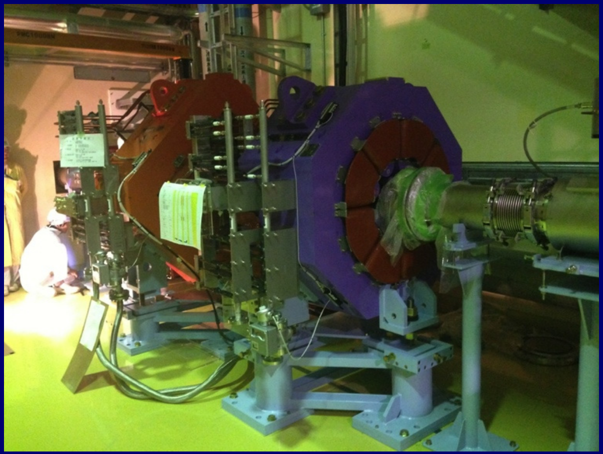
Divergence

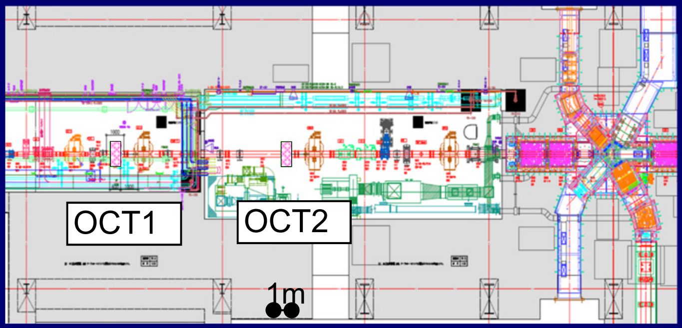
Intensity



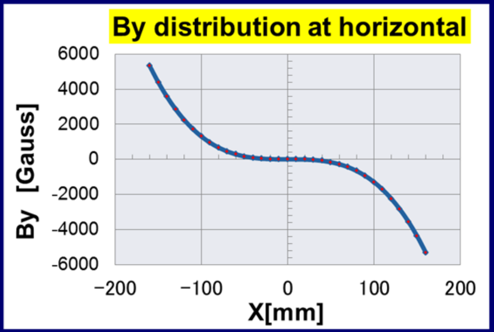
Position / Position

Octupole magnet: 800 T/m^3



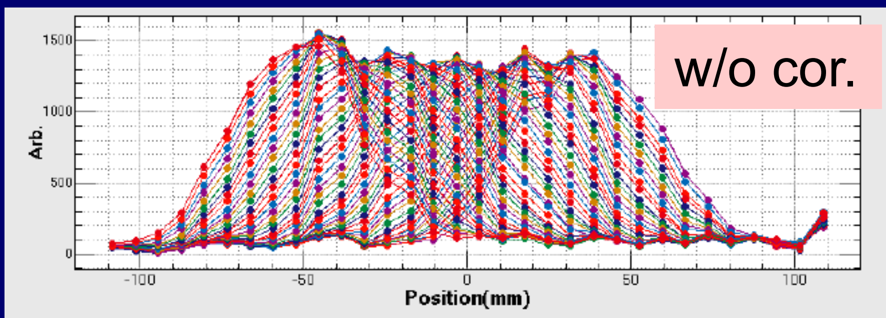


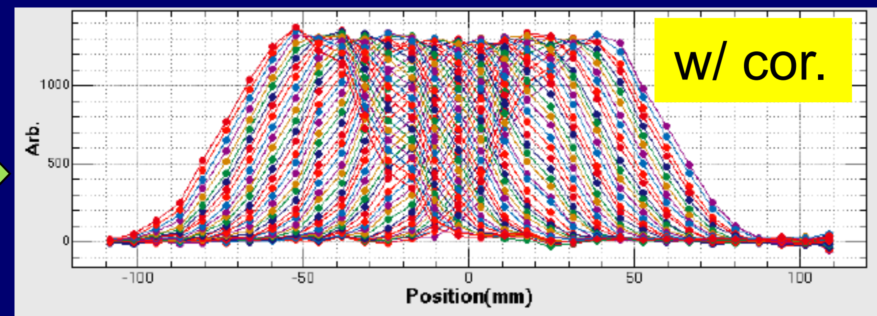
Horizontal plan



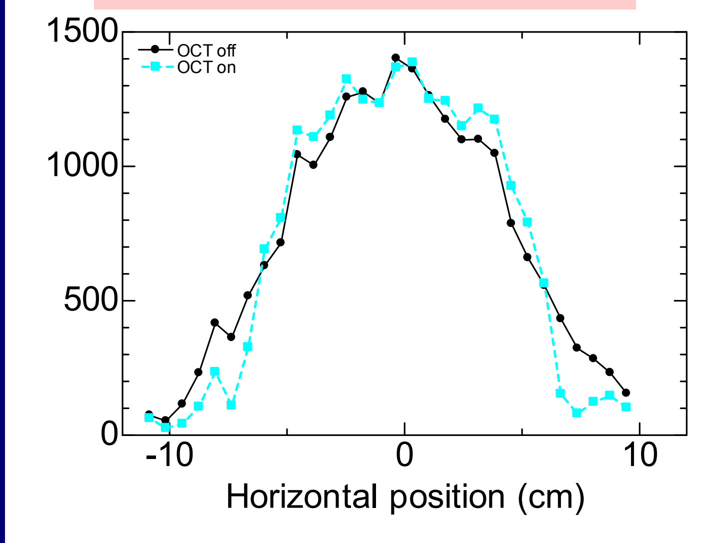
Calibration of MWPM

- By narrow beam scanning, sensitivity of wire was calibrated
  - Maximum correction ~6%

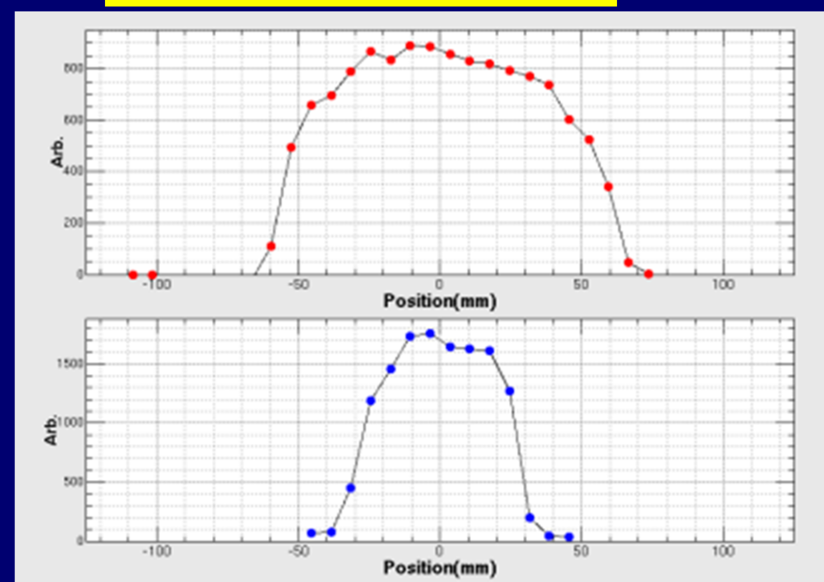




Profile w/o correction



Profile w/ correction

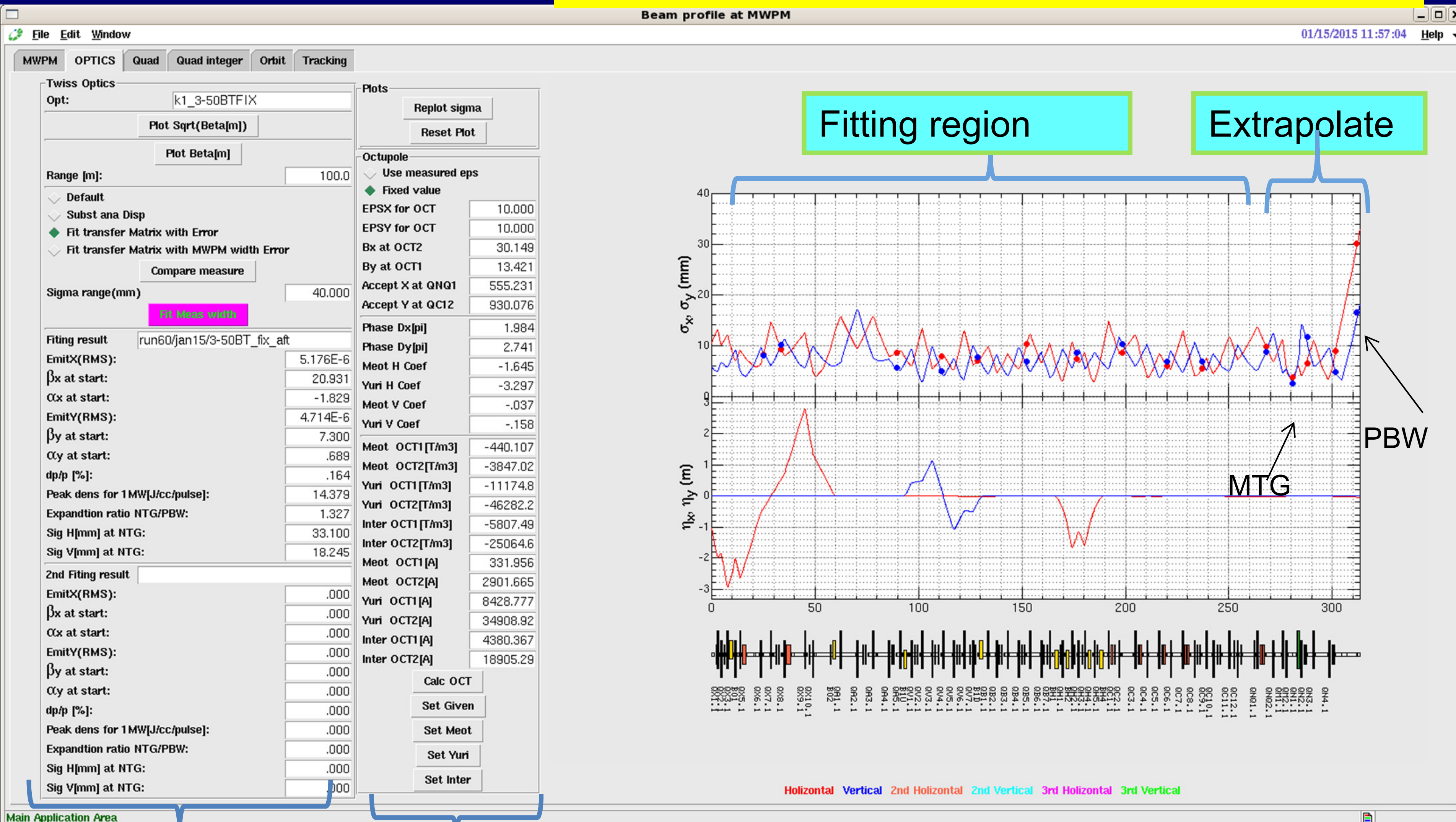


Beam tuning tool with SAD code

J-PARC

$T=M^{-1}S$

Fit by observed width and extrapolate to NTG



Initial condition

OCT tuning

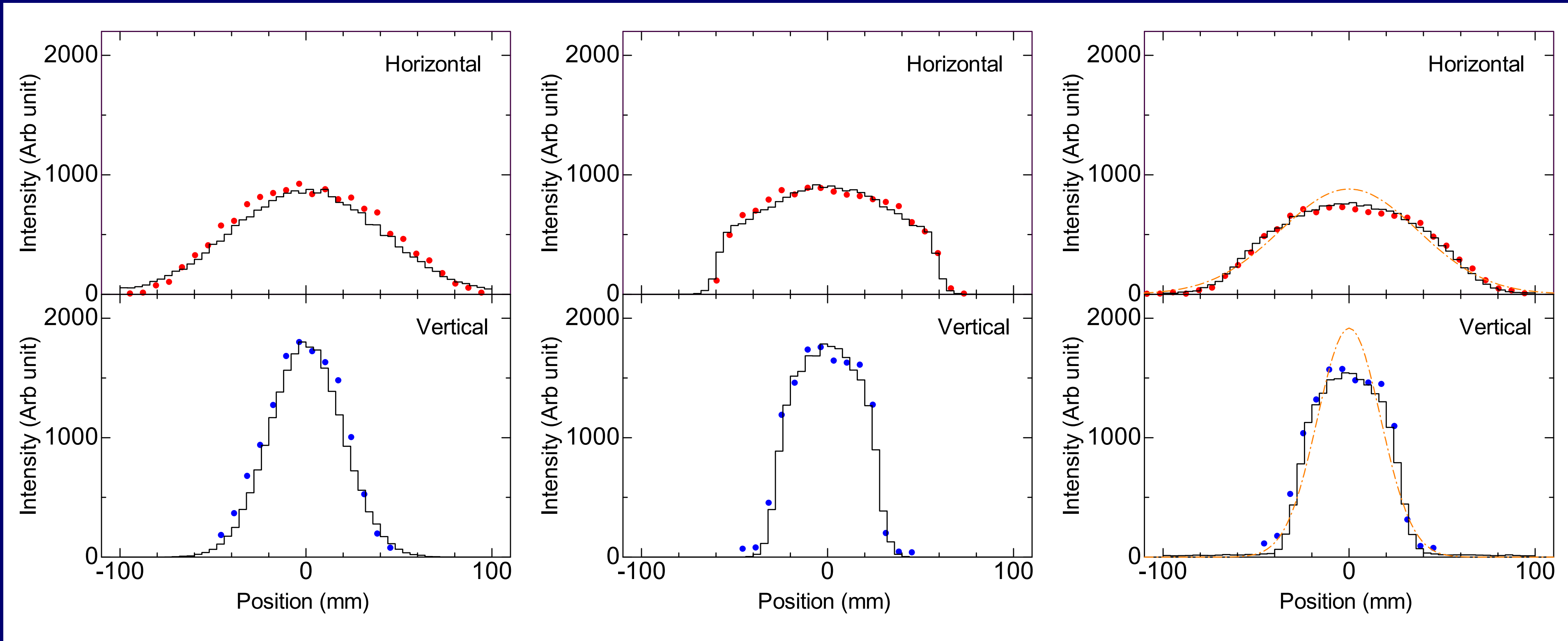
Acuracy of RMS emittance ~5 %

Obtained beam profile

OCT 0A

OCT 698A

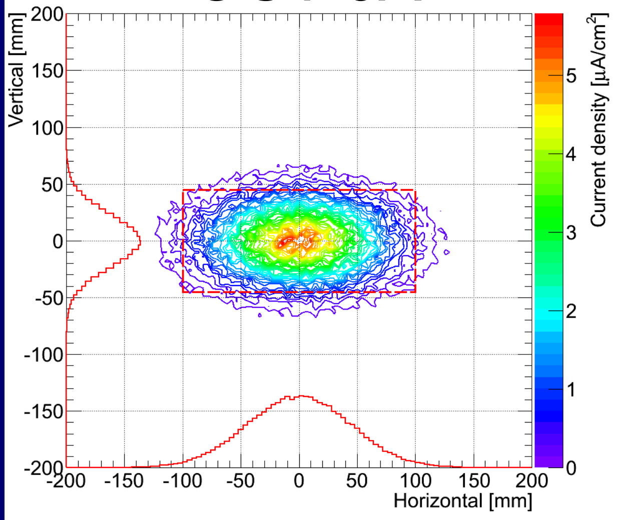
OCT 698A w/ muon target



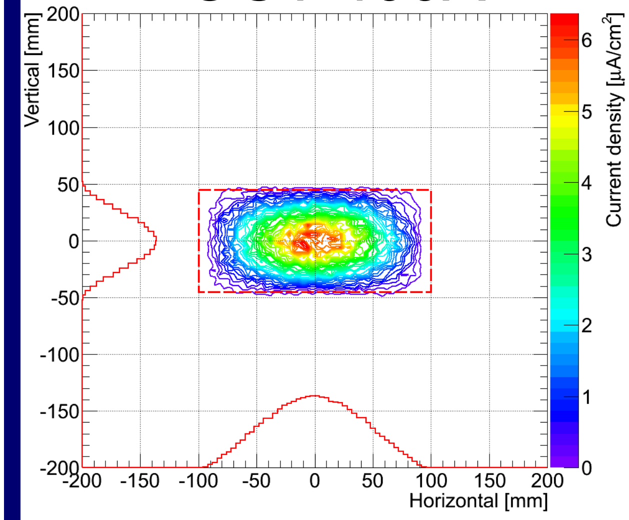
- Flat beam was obtained and lower intensity of beam halo was observed
- Good agreement of calculation shown even for w/ muon target
- Peak smaller by 14 % and 20 % at horizontal and vertical. Overall 40 % reduced.

Beam profile at neutron target (calculation)

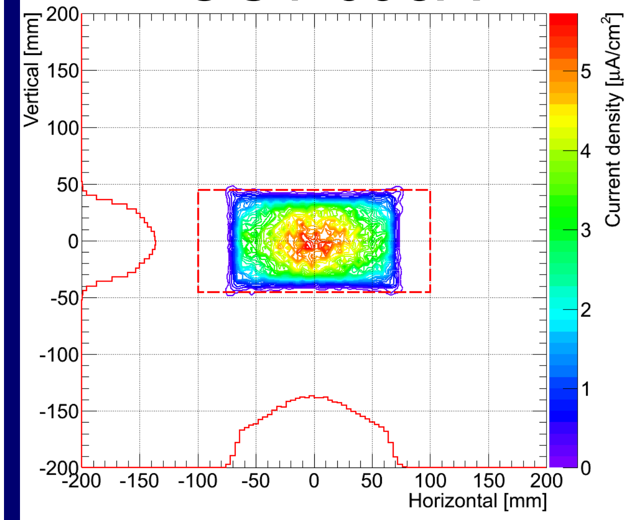
OCT 0A



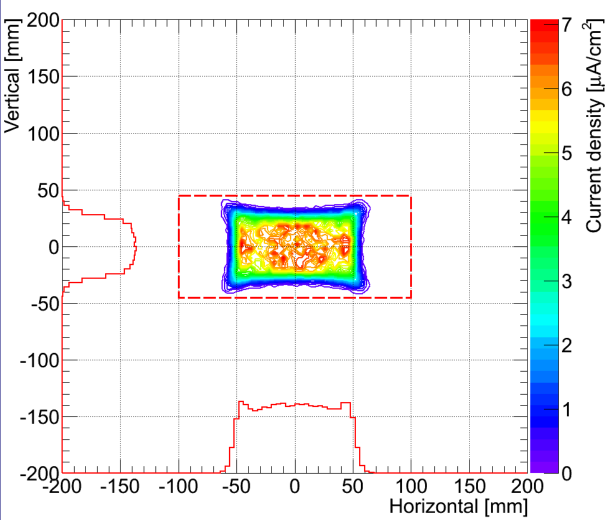
OCT 400A



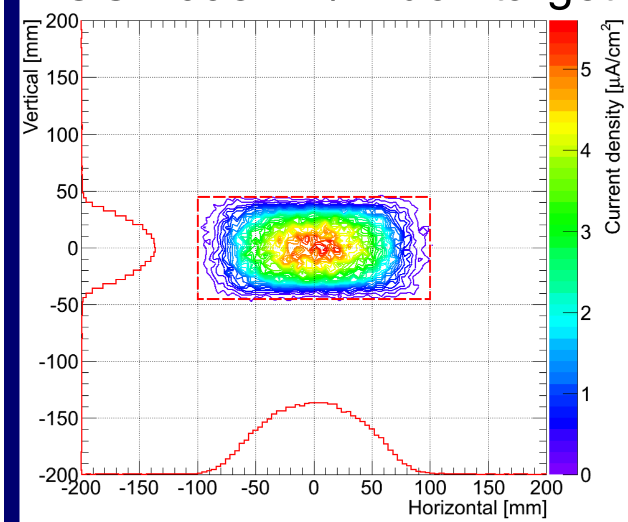
OCT 698A



OCT 1200A



OCT 698A w/ muon target



- Ideal shape however slight beam loss detected around octupole magnets which can be reduced by changing duct shape at Q mag
- Need develop profile monitor at the target

- Introduction
- Beam monitor system at JSNS
  - Multi Wire Profile Monitor (MWPM)
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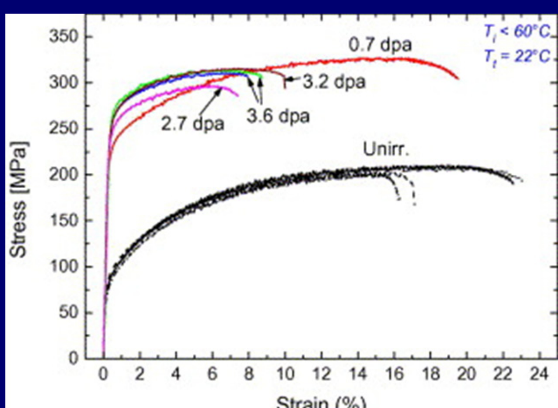
Development 2D profile monitor

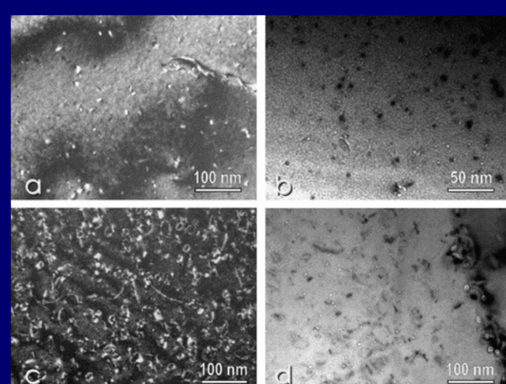
- Desirable 2D profile monitor at the target with long lifetime
- Unknown lifetime of MWPM

- Lifetime of proton beam window (PBW) ~2 years is determined by embrittlement due to helium gas production at the PBW
- Gas production rate will be carried out by using dump line and thin aluminum foil with Q-mass spectrometer

Result at SINQ/PSI for 0.6GeV

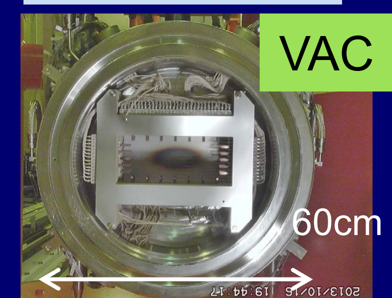
Y. Dai, et al, J. Nucl Mat. 343 184 (2005)

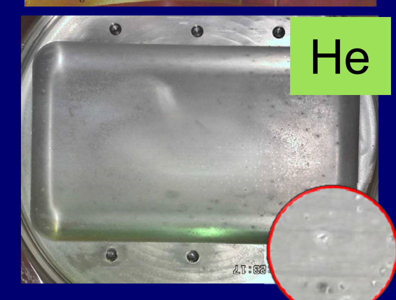




PBW

Spent PBW

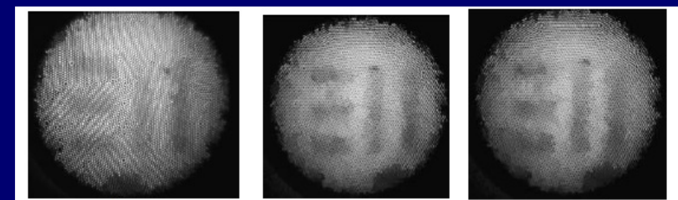




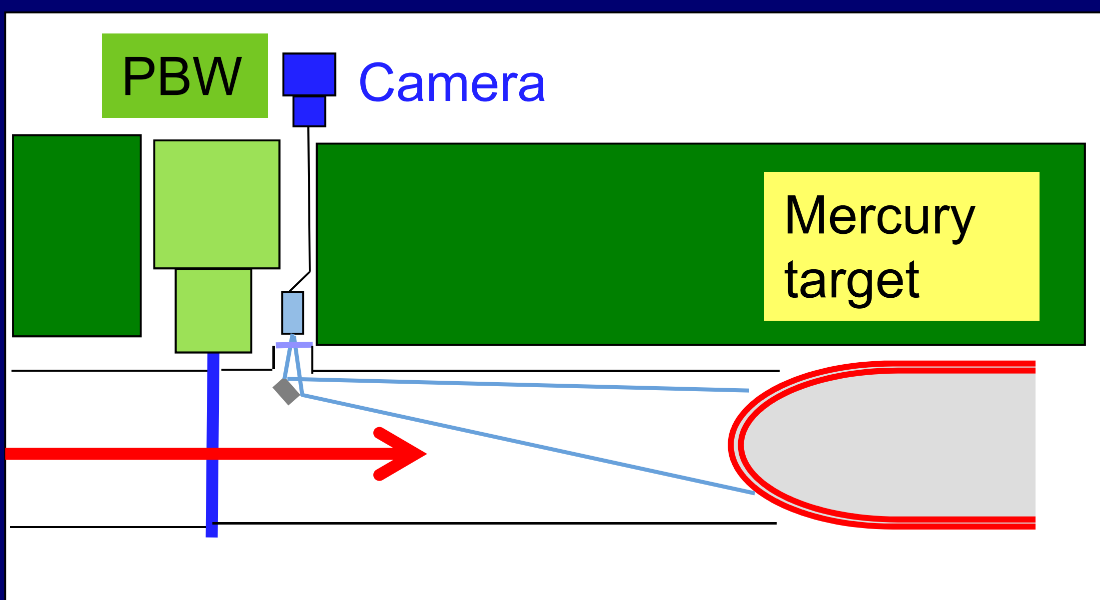
2D profile monitor by thermal

- Low temp(<100C)
  - For observation of spallation neutron target
  - Infrared with capillary tubes
- High temp(~1000C) :
  - For observation of rotating carbon target
  - Near-infrared with fiber scope
  - (Based on rad hard fiber to up 2 MGy)

Fujikura Fiber

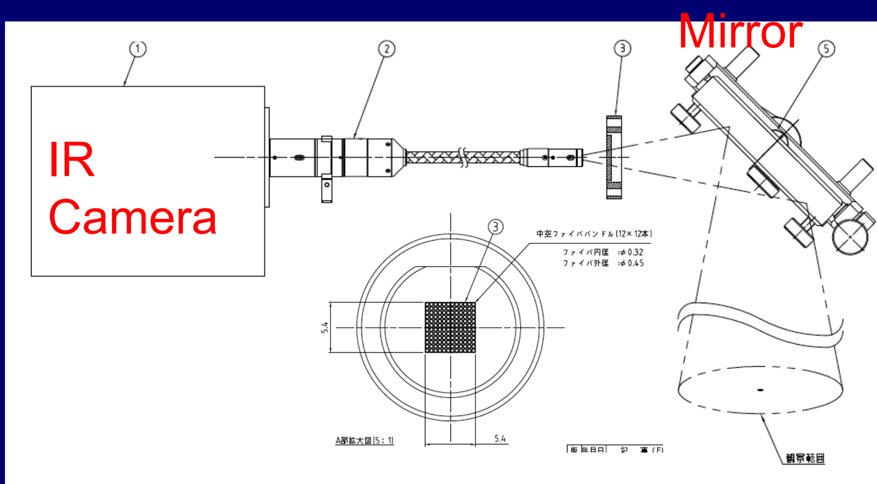


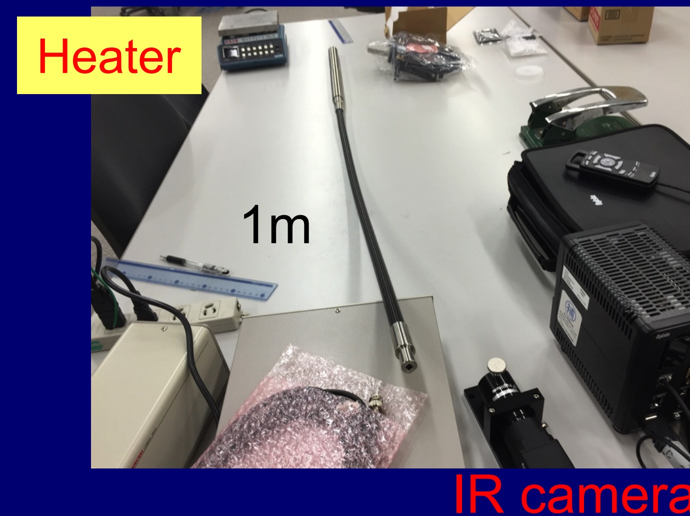
0 MGy 1 MGy 2 MGy



Infrared(IR) monitor

- Bundled hollow core fibers of quartz capillary tube coated by polyimide



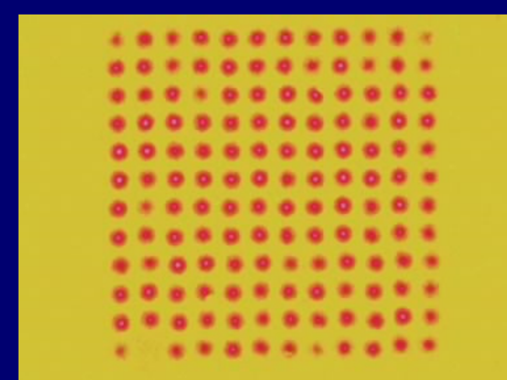


- Present system can be utilized as monitor for target-temp.

50 ° C

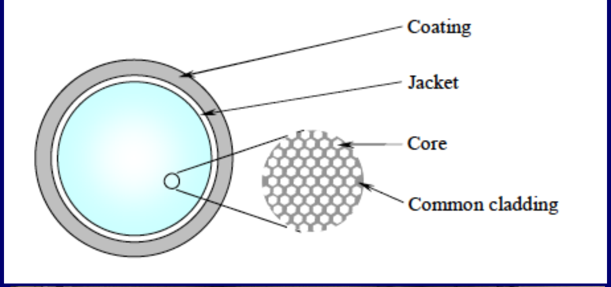
150 ° C

300 ° C



Near-IR system

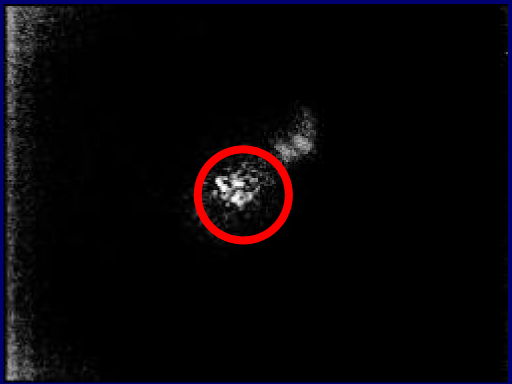
- Rad hard fiber scope (Fujikura FIGR-20, 20000 pixels) coupled with near-IR filter
- Profile at muon target with high temp can be observed.
- Utilize for temp anomaly detection of the target



650 ° C

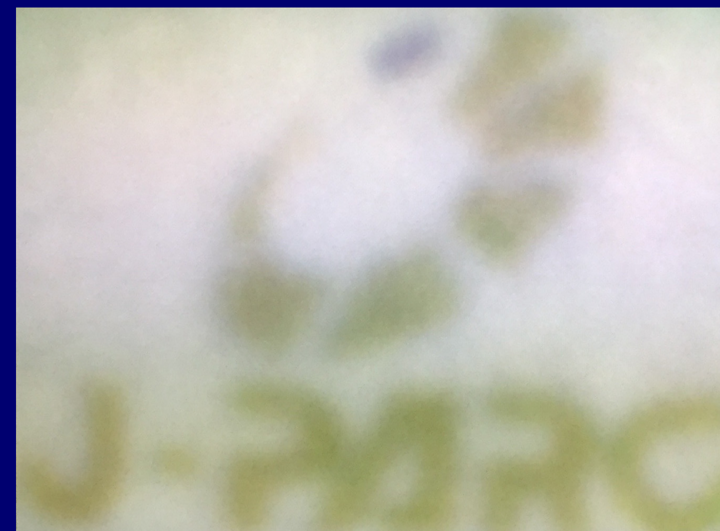
980 ° C

1300 ° C

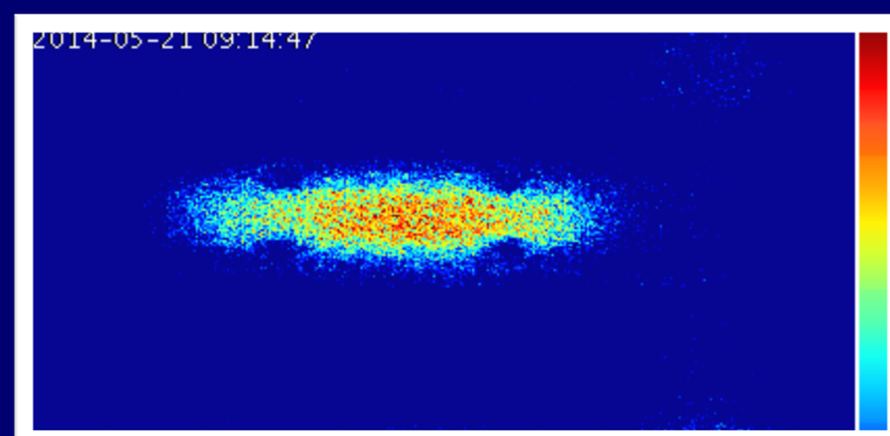


Visible light fiber scope system

Setup for visible light

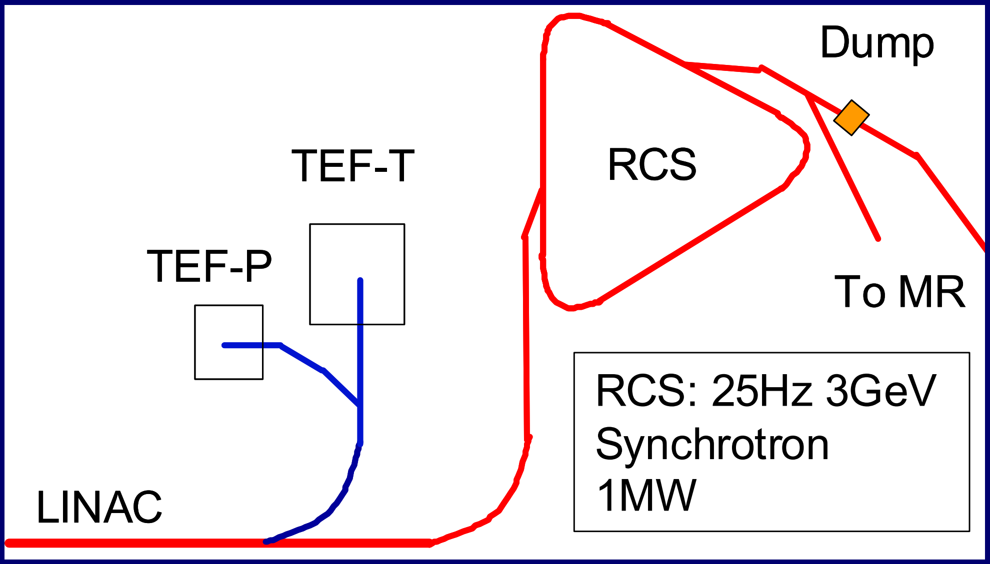


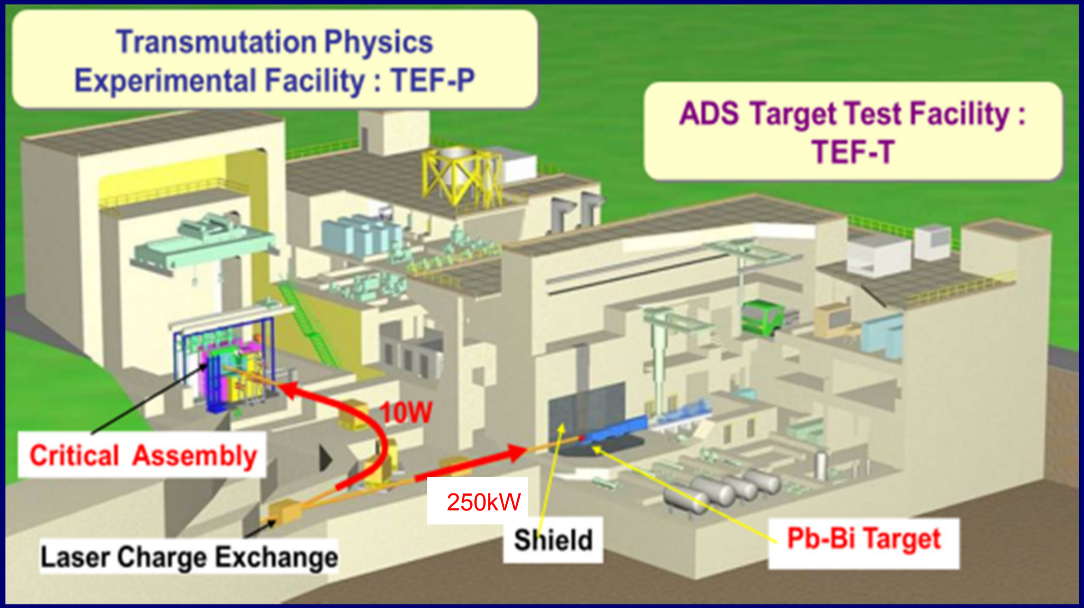
SNS monitor (SNS web page)



- Observation by luminescence with painting on target vessel is already established at SNS.

New facility at J-PARC for ADS development





- TEF-T: For Pb-Bi target test facility
  - H^-, 25Hz, 400 MeV, 250 kW beam
  - High current density (20 $\mu A/cm^2$) required
    - JSNS: 6 $\mu A/cm^2$
- Also long lifetime profile monitor required

Summary

- Using present beam monitor system, high power beam operation can be performed with highly confident.
- To mitigate pitting damage, beam flattening system has been developed. Peak intensity will be reduced by ~30 % intensity of linear optics.
- New profile monitor system developing by using fiber system

Acknowledgement:

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Thank you for your attention

Died on 2nd Sep 2015
R. I. P.