WEPF-17 Development of a Beam Profile Monitor using a Nitrogen-Molecular Jet for the J-PARC MR

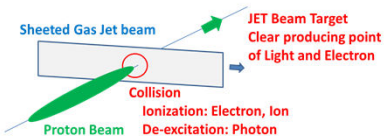
Y. Hashimoto#, Y. Hori, T. Toyama, M. Uota, T. Morimoto : KEK/J-PARC
T. Fujisawa, T. Murakami, K. Noda : NIRS, Chiba, Japan
D. Ohsawa, Kyoto Univ., Kyoto, Japan

Abstract
In order to measure a beam profile with a wide dynamic range covering the halo region around the core region of intense proton beams, a non-destructive beam profile monitor using a sheeted jet beam of nitrogen molecules as a target has been developed for the beam of the J-PARC main ring (MR). Two-dimensional detection of the beam core will be performed using de-excitation light of nitrogen molecule. On the other hand, beam halo will be detected using ionized electron. In the detection of the electron, a micro channel plate (MCP) will be used for charge multiplication. To achieve a sensitivity of about 10^-6, a phosphor screen will be employed for the anode of the MCP, and its light will be detected by photomultipliers array for position resolving. Thus beam core and halo will be detected simultaneously in this scheme.

Concept

Task:
Beam profile measurement for circulating beam in the Main Ring at J-PARC
- ★ Non-destructive
- ★ 2-dimentional
- ★ Short time as within the bunch separation

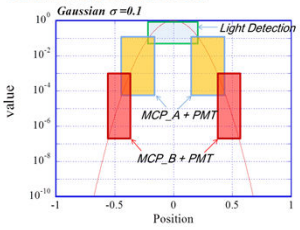
Requirement:
- ★Densor Gas Jet Beam : >1e11molecules/cc
- ★Thinner Jet Beam : 1 ~ 3 mm
- ★Without affection to vacuum of acceleration (1e-7～1e-8 Pa)



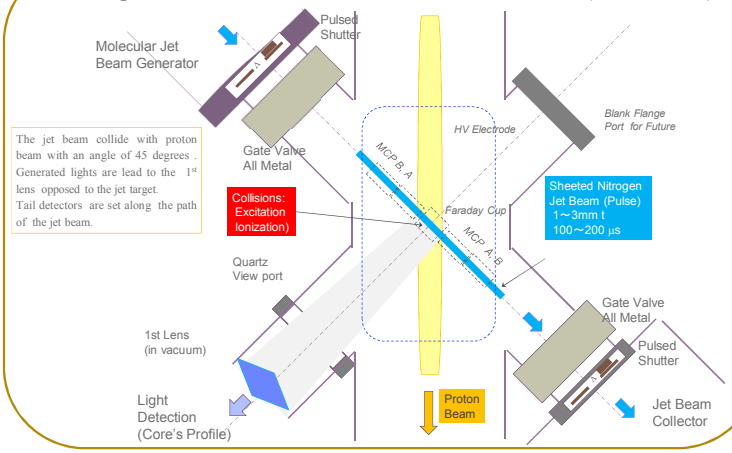
Collision with Nitrogen molecule
Ionization: production energy 35eV
⇒electron collection with parallel electric field: projected profile
⇒affected by beam induced electric-magnetic fields in case of high density beams

De-excitation : production energy 3.6 keV (in visible light region)
☆production number of photon is 1/100 equivalence to ionization
⇒free from beam induced electro-magnetic fields
⇒two dimensional beam profile

Combination Detection Method
Beam Core: Light Image of N_2 deexcitation
⇒Image, Image Intensifier (I.I)
Beam Tail: Ionized Electron
⇒ Projection, MCP+PMT 2range
Detection sensitivity and adopted detector

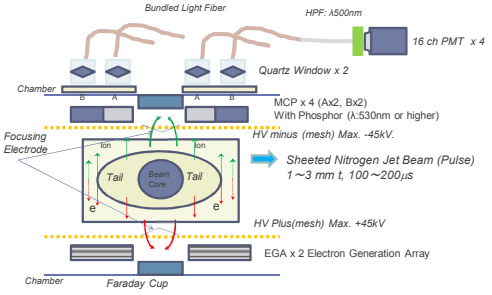


Configuration :Cross Sectional Schematic View (Horizontal)



The jet beam collide with proton beam with an angle of 45 degrees. Generated lights are lead to the 1st lens opposed to the jet target. Tail detectors are set along the path of the jet beam.

Configuration :Cross Sectional Schematic View (Vertical)



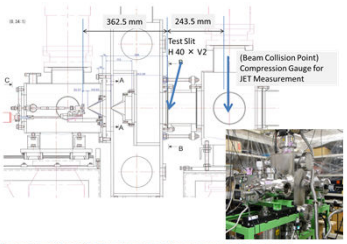
★Beam tails are detected using ionized nitrogen ion with four MCPs (double stage type) which is attached phosphor screen having wavelength of 530 nm or higher for reducing effect of cherenkov light in light fibers. The phosphor is also characteristics of fast decay time of almost 60 ns. The phosphor light (integrated beam profile of beam tail) is detected with PMT array via bundled light fibers.
★Beam core's nitrogen ions are not use for profile detection because of large beam induced field.
★The collection field is excited with parallel electric plates for only collection for beam tail's nitrogen ions.

Summary and Prospects

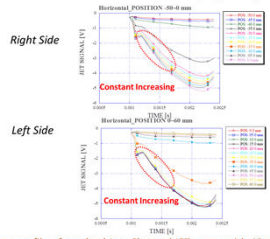
The development is under going. Basic consideration was almost finished.
A concrete structural designing is the subject just now. Actual equipment will be planed to installed in accelerator in next summer.

Sheeted JET beam study with JET density of 5e-4Pa

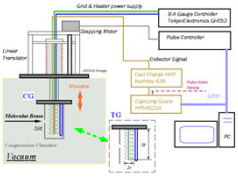
Gas Jet Generator (test stand)



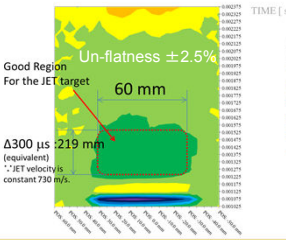
Beam profile of a pulsed Jet in horizontal direction
Time structure measured by a compression gauge: Integration molecules



Compression Gauge for Time Integrated Measurement for Molecular Jet



Beam profile of a pulsed Jet : Sheeted JET target with 40mm slit

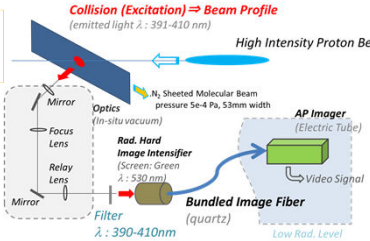


We obtained a sheeted JET of 60×219 mm² sizes by 40mm-width slit..
Next, 100mm-width slit will be tested.

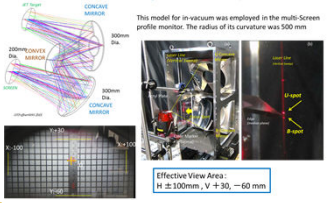
Detection Scheme for Beam core

Beam Core detection with Light by RH Image Intensifier + Camera

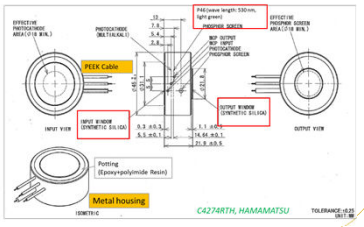
Requirement:
In-vacuum large acceptance optics
Radiation Hardness Image Intensifier



Beam Core detection with Light : A Plan Using an Offner Relay System
For weak light detection ⇒Large acceptance
In-vacuum optical system ⇒ Avoid nitrogen effect in atmosphere



Beam Core detection with Light by RH Image Intensifier + Camera

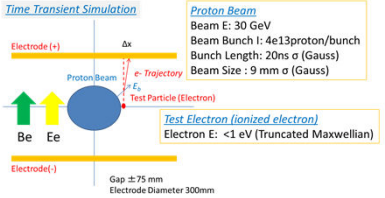


Beam Halo Detection: Position Error of Collected Electron

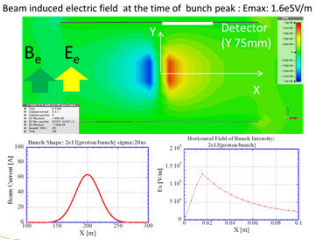
Optimum Collection Field
Ee = ±30 kV
Be = 0.05 T

Position error in electron collection
Error = 0.3 mm (at 10mm from beam center)

Collection error simulation of electrons produced at the halo region
The electrons produced at the median plane in the beam tail region moves toward to upper electrode by electric field E_e with guided magnetic field B_e.
⇒Transverse position error of collected electron?
⇒Optimum external field of E_e and B_e for intense J-PARC beams?

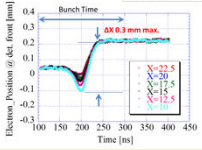


Beam induced electric field at the time of bunch peak : Emax: 1.6e5V/m



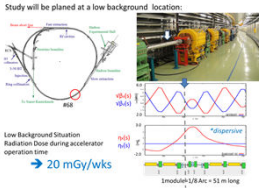
Optimum collection fields
B_e: 0.05 T
E_e: ±30kV (150mm gap)
Time dependency of transverse position error of collected electrons.
Electrons are produced at 10 to 22.5 mm apart from the beam center.

Error in time transient
Maximum Error : 0.3 mm



Background Study (Plan)

Study will be planed at a low background location:



Beam Halo Signal: Effect by BG-Light induced by beam loss
Theme: BG investigation
>MCP :e- emission
>Phosphor: light emission
>Fiber, Feeder: Cherenkov light