Flying Wire Beam Profile Monitors at the J-PARC main ring

US/Japan Beam Monitor Meeting

2015/3/25

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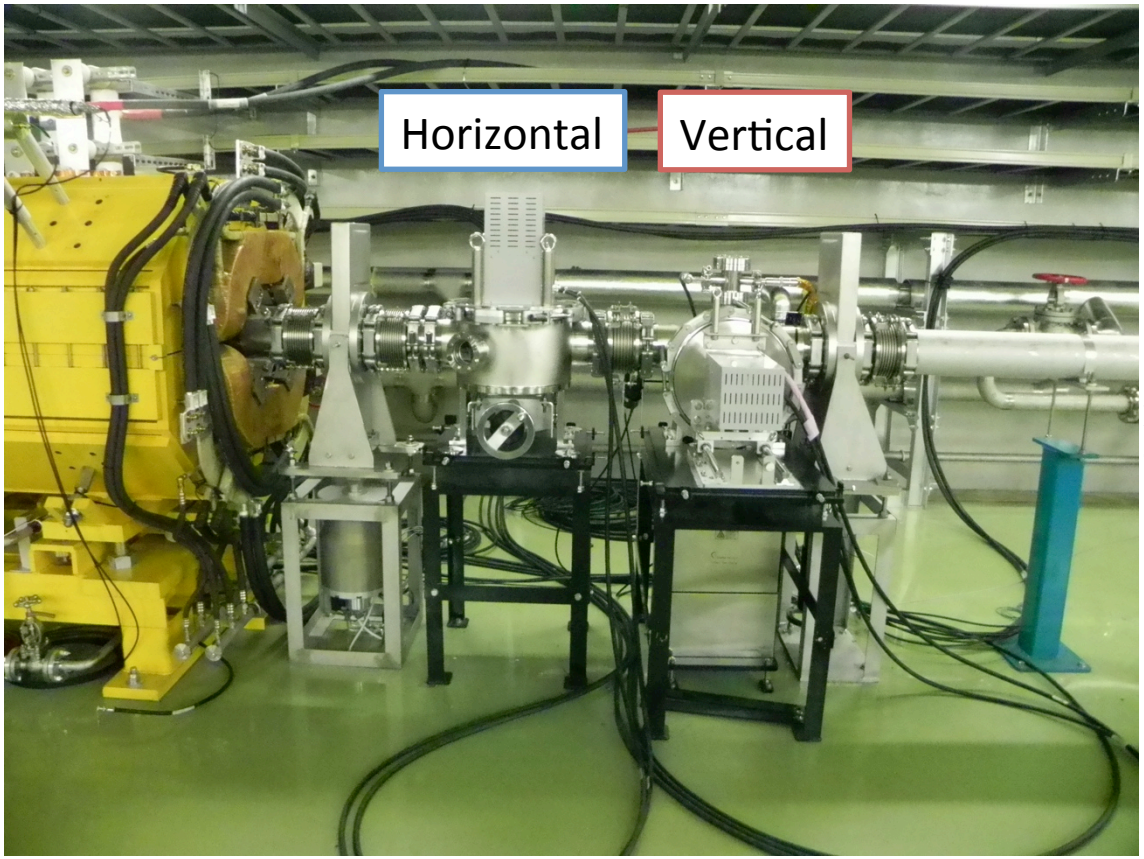
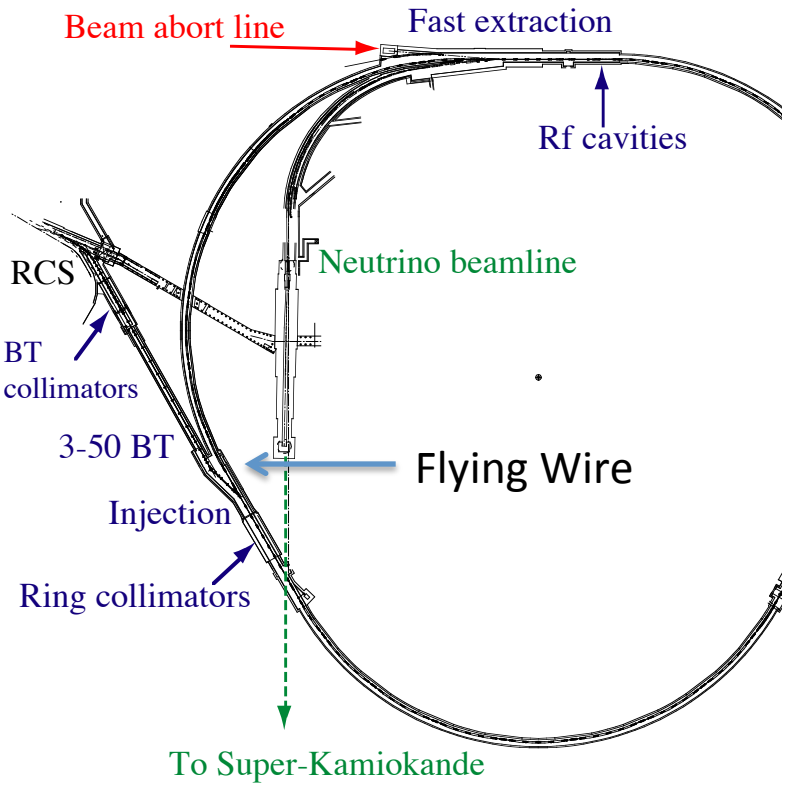
Flying Wire at the J-PARC main ring

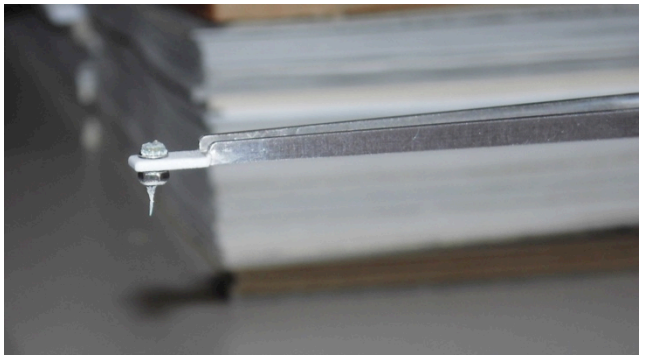
- Horizontal flying wire monitor was originally installed in the straight section downstream of the collimators in 2008.
- Beam background affected the profile measurement.
- Horizontal monitor was moved to the upstream of the collimator in 2010.
- Beam background is improved.
- Vertical monitor was installed next to the horizontal monitor in 2010.





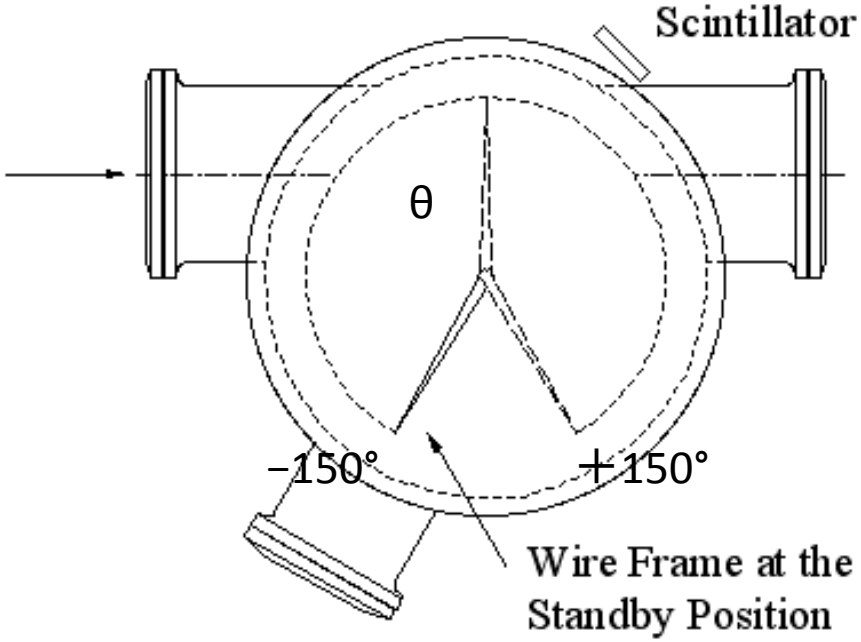
Wire Target

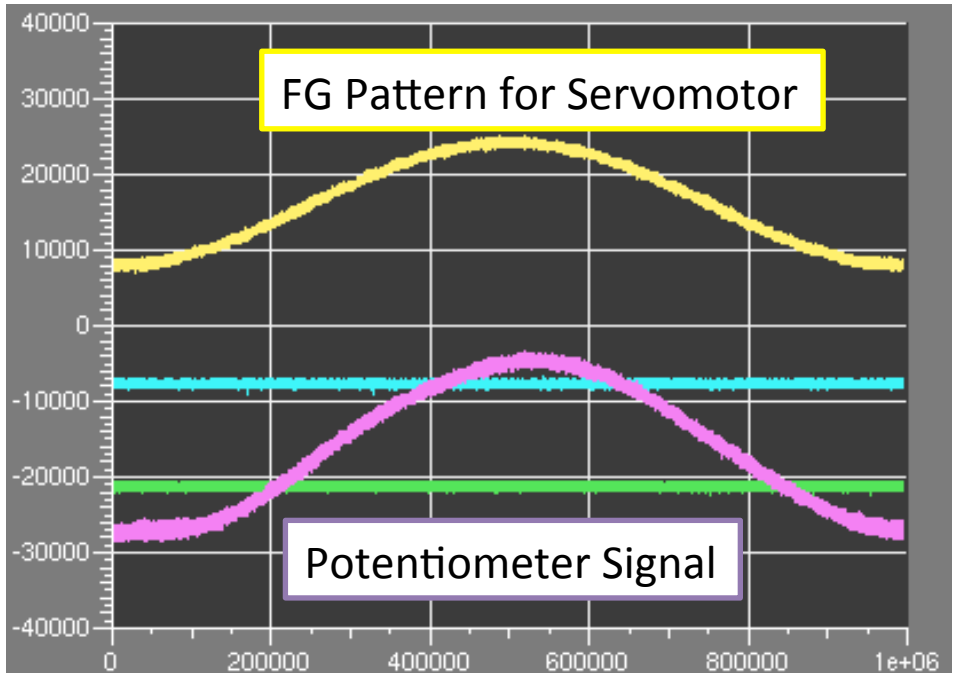
- Target : Carbon fiber of 7 μm in diameter.
- Copper wire of 200 μm ϕ is attached to the wire frame with glue “Electrodaq”
- An aluminum flame of 140 mm.
- The carbon fiber is glued with the copper wire.



Wire Scanning

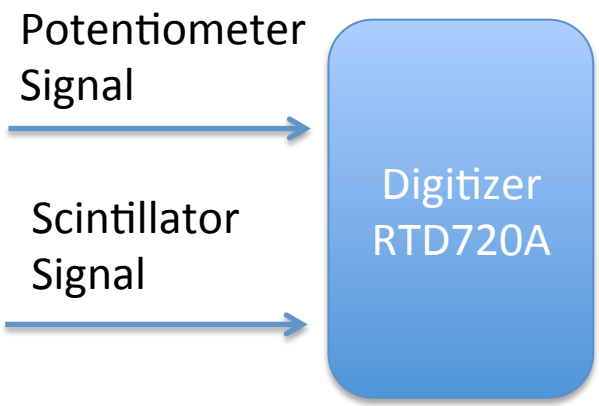
- Wire is scanned across the beam with the max speed of 5 m/s.
- An aluminum flame of 140 mm.
- Rotated with a DC servomotor.
- Potentiometer is attached to the wire flame for
  - the feedback of the servomotor
  - wire position measurement.
- Scintillator detects the secondary particles from the beam-wire scattering.

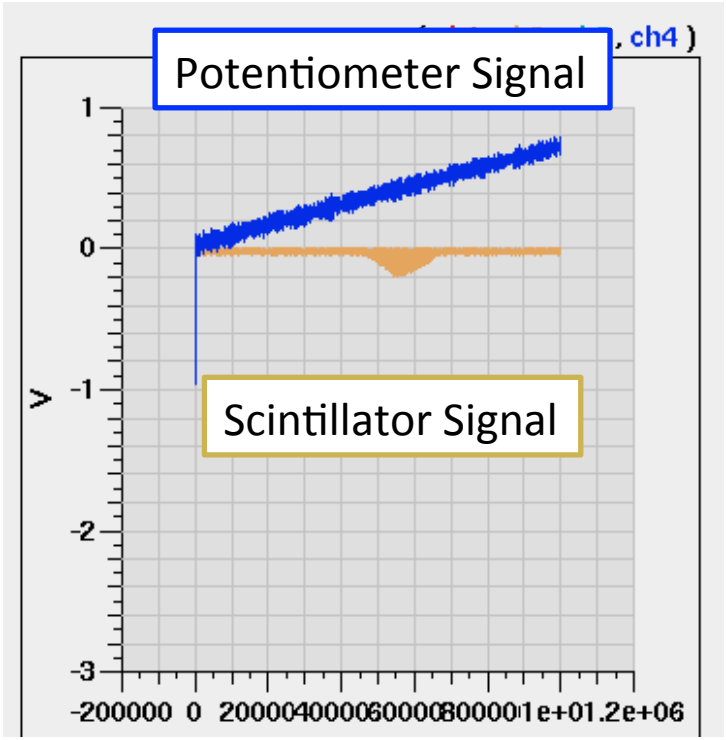


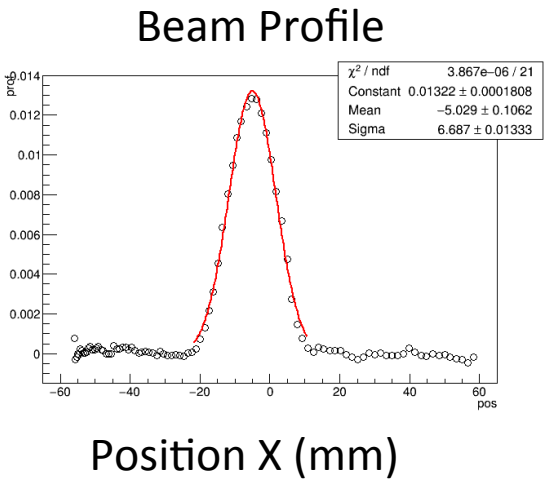


Data Acquisition

- Beam profile is reconstructed by making the scatter plot of
  - scintillator response
  - wire position.
- Wire scanning takes about 5 ms for a typical size of the beam.
- Scintillator signals and potentiometer output signals are digitized with a digitizer RTD720A with a 20 ns sampling for a 20 ms time range.
- The 1 M sample data are averaged over 10 k sample to make array of 100.
- Scattered plots are made for the scintillator data as a function of the wire position to make beam profiles.



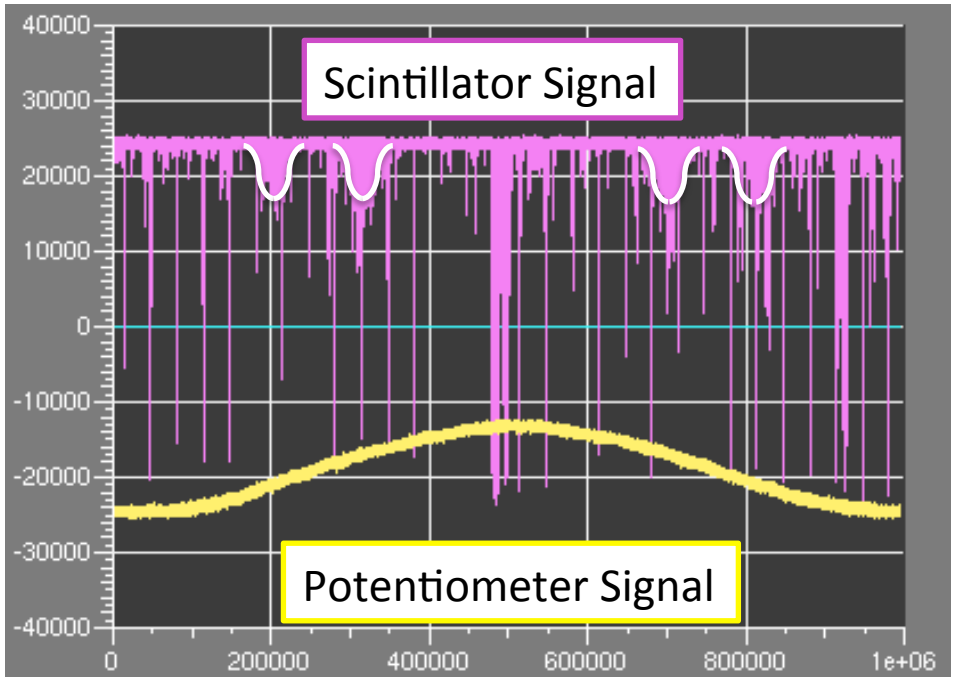




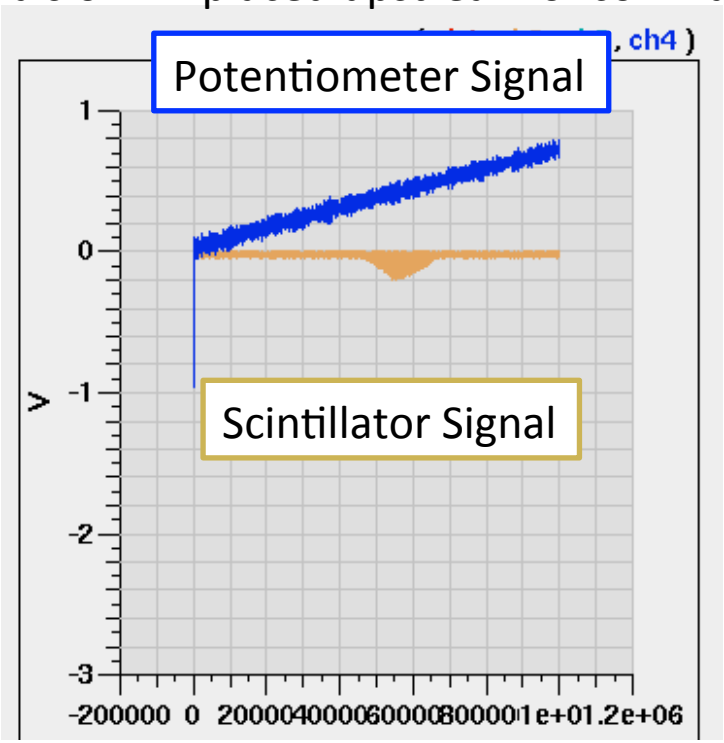
Beam Background

- Horizontal flying wire monitor was originally installed in the straight section downstream of the collimators.
- Beam background affected the profile measurements.
- Horizontal monitor was relocated to the upstream of the collimator in 2010.
- Beam background is improved.
- Vertical monitor was installed next to the horizontal monitor in 2010.

Signals of FW placed downstream of collimator

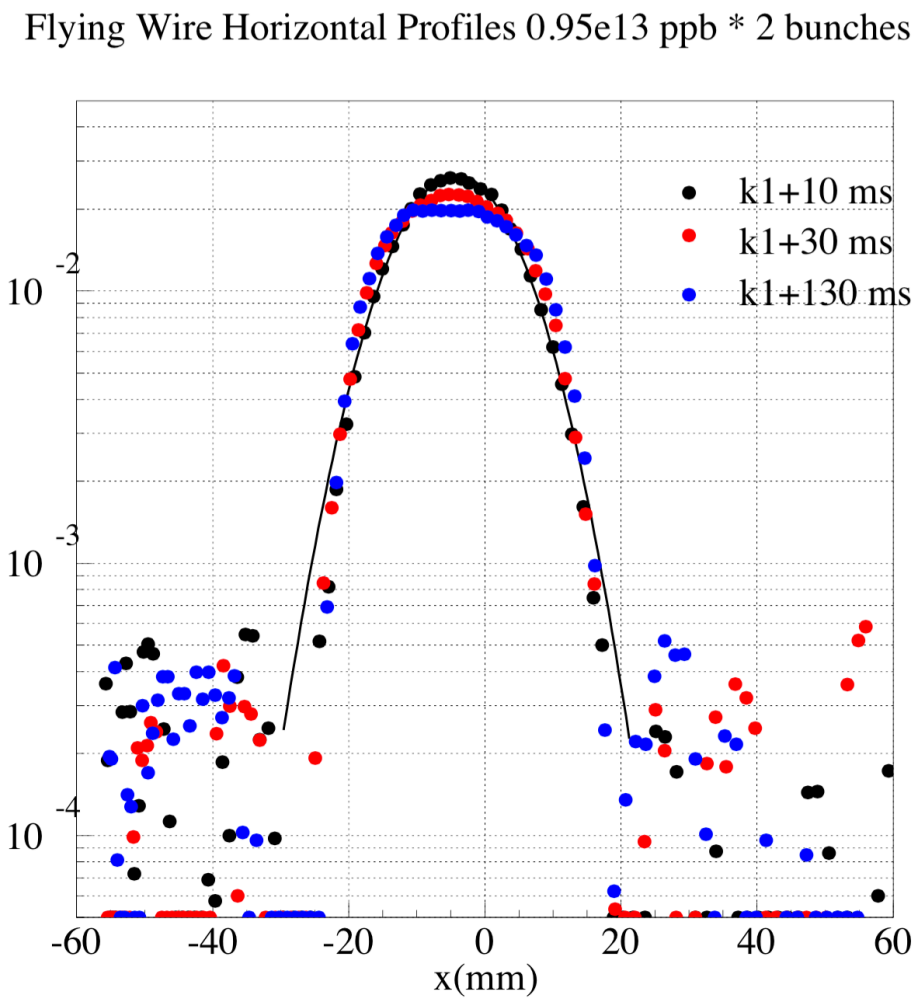


Signals of FW placed upstream of collimator



Beam Background

- The profile at k1 is well fitted with a Gaussian function.
- Beam background was ~ 2 % with respect to the profile peak.
- If the profile is in the Gaussian function, the profile of 2.8 σ should be at the background level.
- A part of 99.5 % is then observable and the rest of 0.5 % is not observable.
- For the high intensity beam operation we would like to maintain small beam losses, typically about 1 % or less.
- The beam halo of much less than 1 % level should be then measured in order to understand the beam loss mechanism.
- More detail studies of the beam halo and loss mechanism would be possible if we could improve the signal to noise ratio.
- Ideas such as a use of scintillator telescope, an optimization of wire thickness and wire movement should be explored.



Wire Breakage

- Wire breakage has been observed
  - once for the horizontal monitor of 6 year operation
  - once for the vertical monitor of 4 year operation.
- The horizontal wire breakage happened during measurement of the beam of 4.4×10^{13} ppp/2 bunches.
- The vertical wire breakage was not noticed.
  - We found recently that the vertical signal was not observed.
  - We will open the chamber for the wire replacement.
- The reason and remedy of the wire breakage are under investigation.

Wire breaking experiment by M. Sapinski CERN
CERN-ATS-2013-155

$$n_{ch} = N_{ch}\, d_W / v_w t_{rev} \sigma_{tr}$$

where:

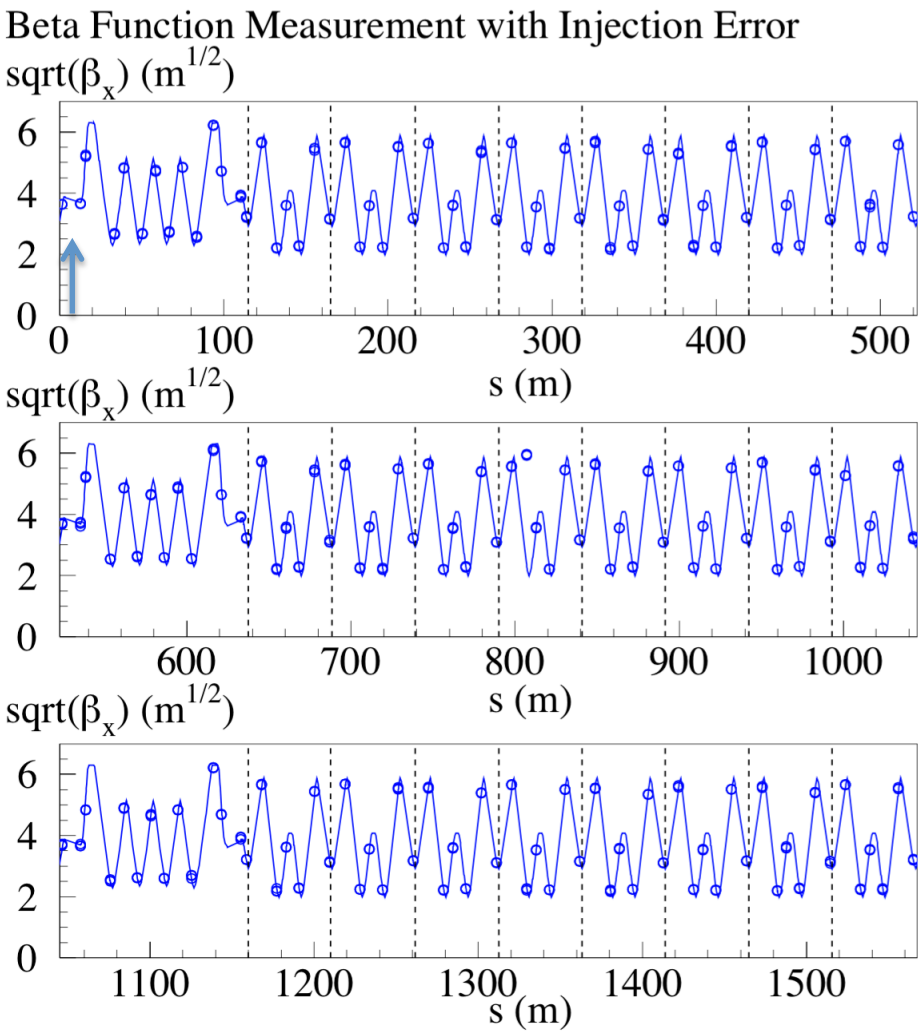
- N_{ch} - number of charges circulating in the beam
- d_W - wire diameter (30 microns) [m]
- v_w - speed of the wire [m/s]
- t_{rev} - revolution period [s]
- σ_{tr} - physical beam size [mm]

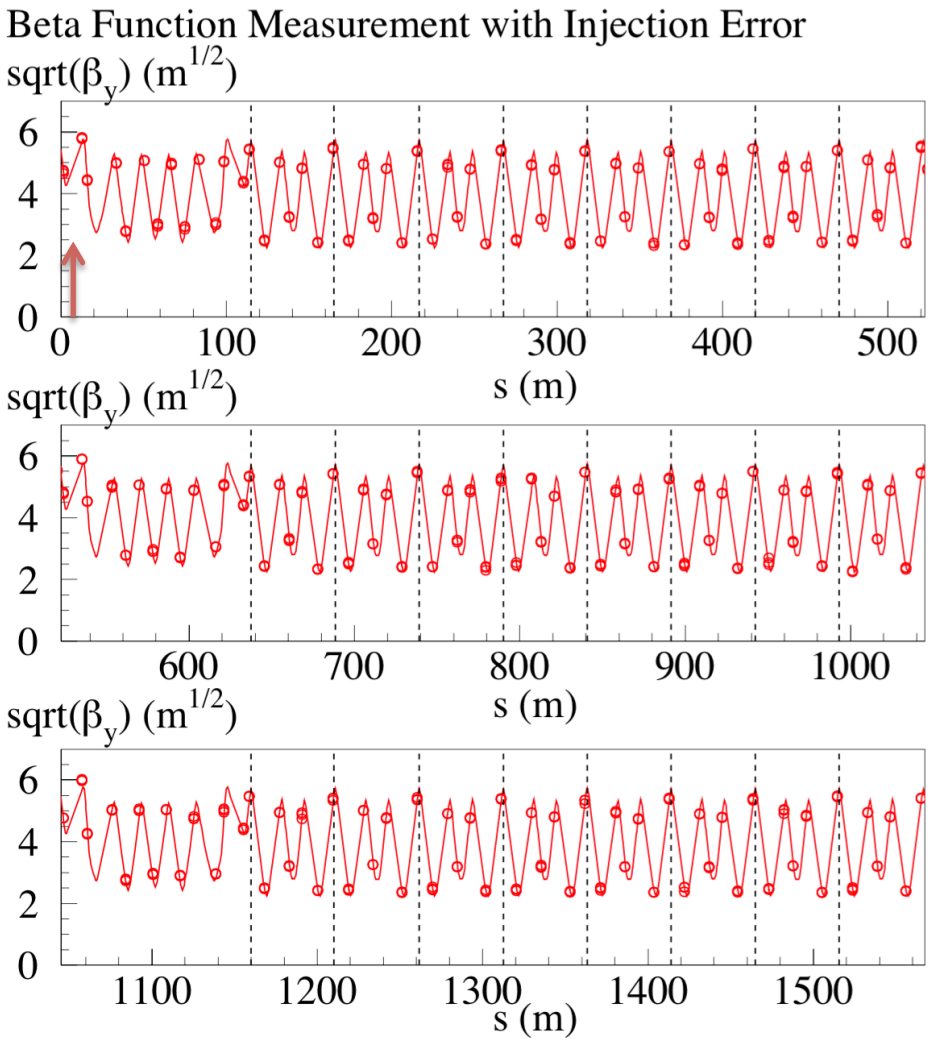
n_{ch}limit=5e12 charges/mm (?)

Applying this to J-PARC MR, the limit would be 1.8e14 protons per pulse.

β measurements (22.40, 20.75)

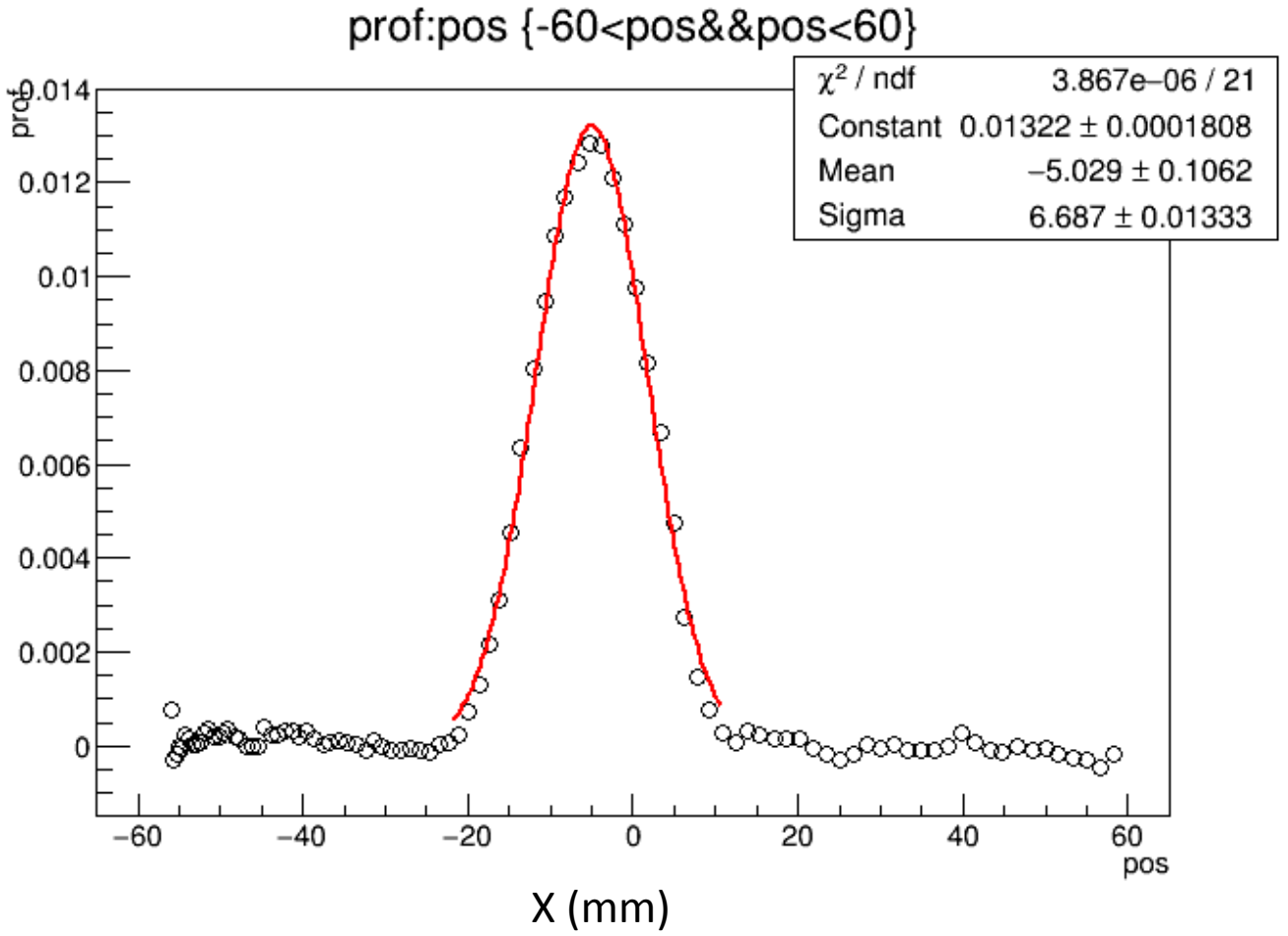
- βx = 15.4 m and βy = 18.5 m at Flying wire position





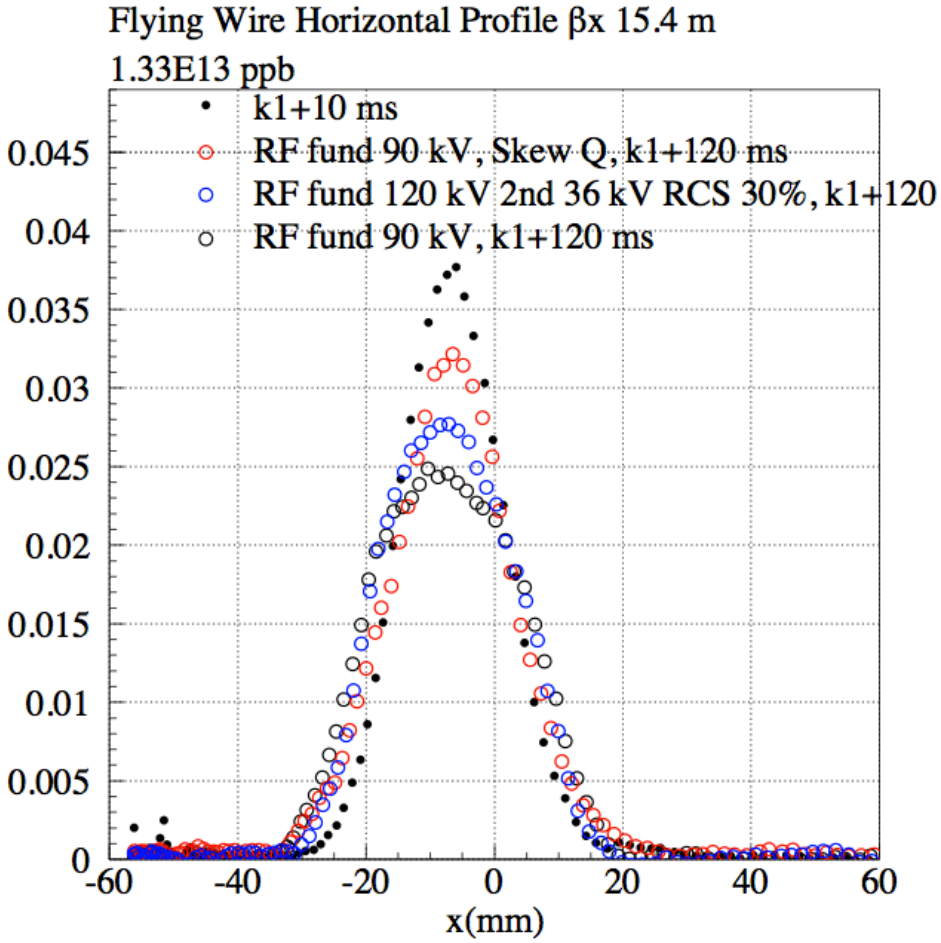
MR Horizontal Profile 2015/3/11

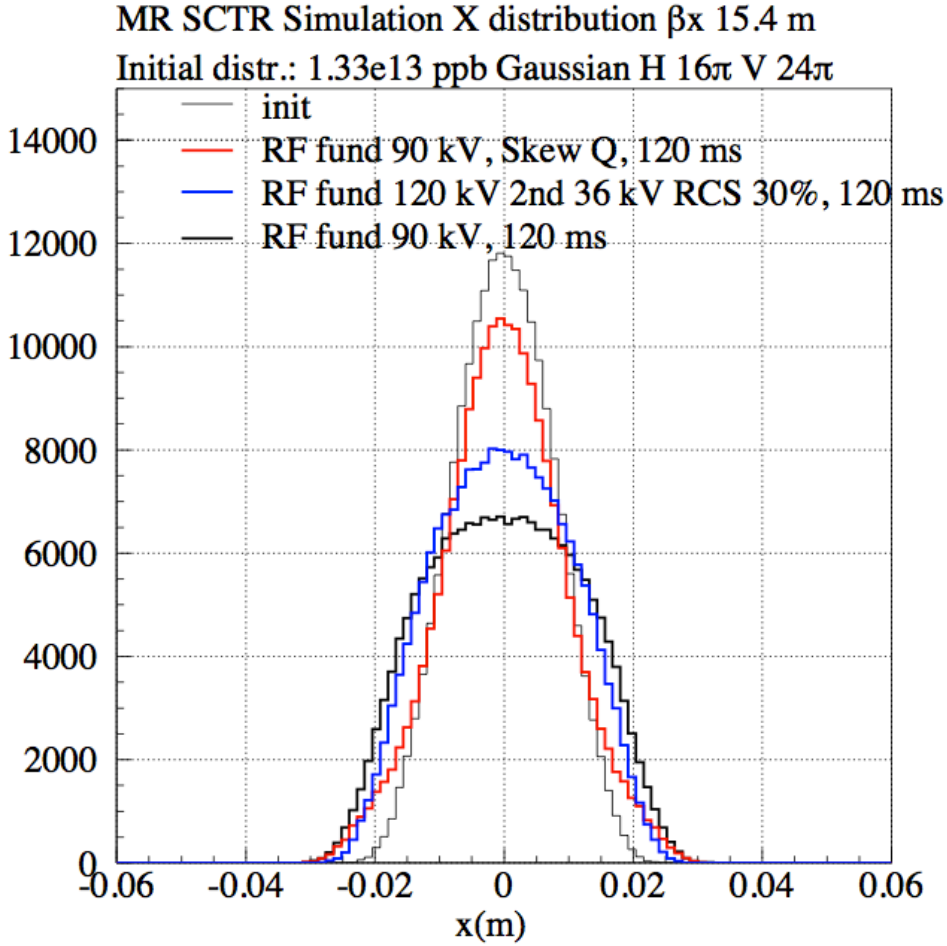
- K1 rear bunch 2.25e13 ppb
- K1 trigger
- 2σ emittance: 11.6π mmmrad



Horizontal Beam Profiles (Measurement and Simulation)

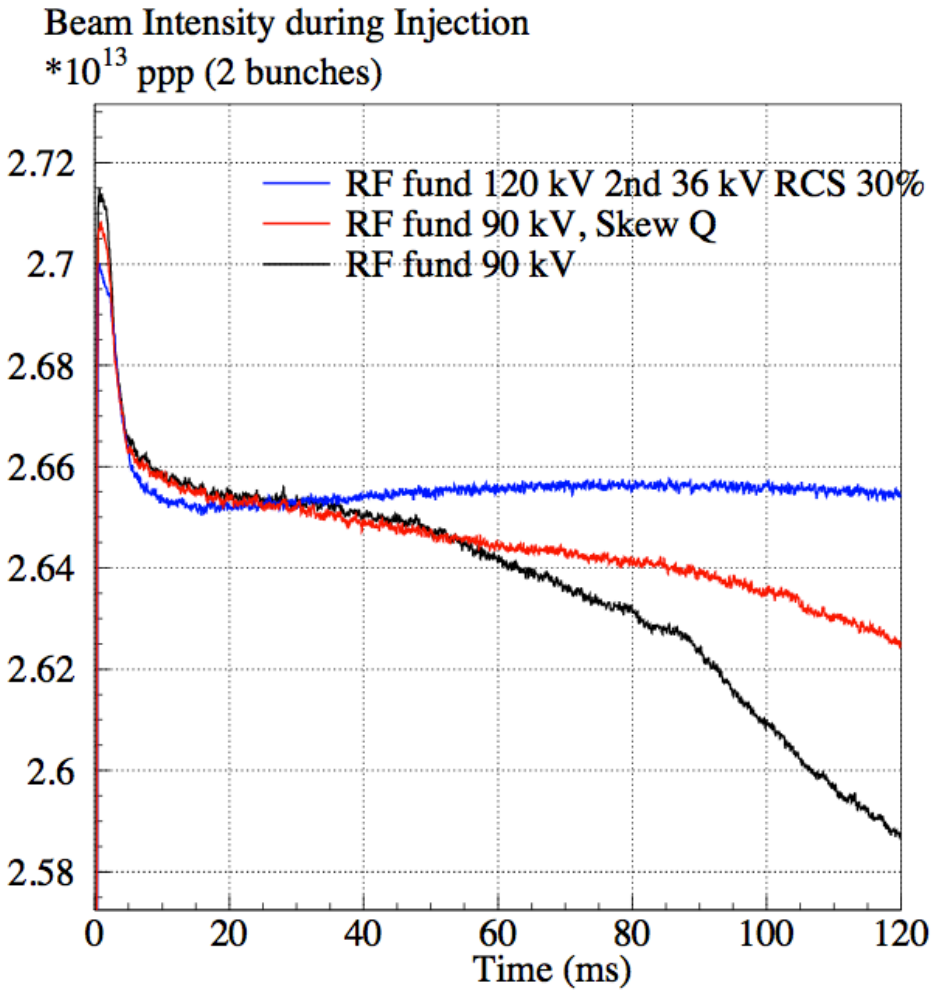
- 1.35e13 ppb × 2 bunch injection
- Flying Wire measurements at K1+10 ms and K1+120 ms.
- SCTR simulation with initial distribution of 16π mmmrad of Horizontal 2σ emittance and 24π for Vertical 2σ emittance.

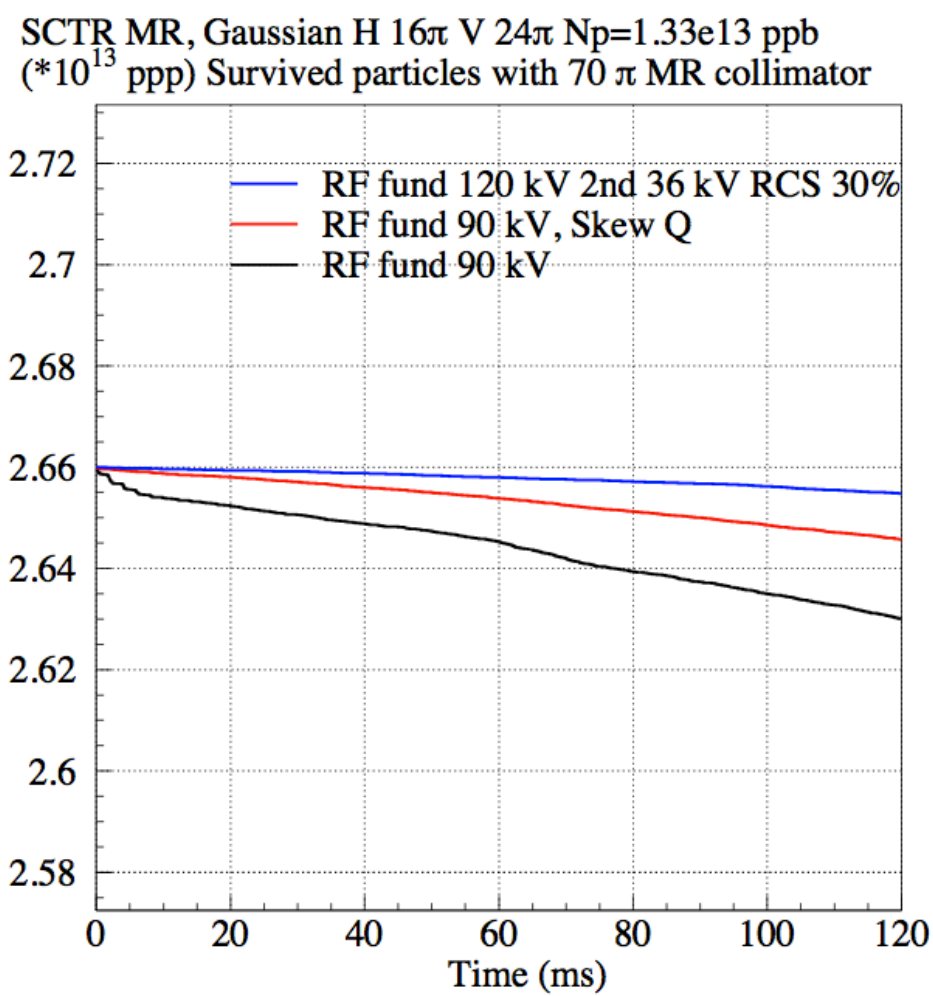




Beam Intensity (Measurement and Simulation)

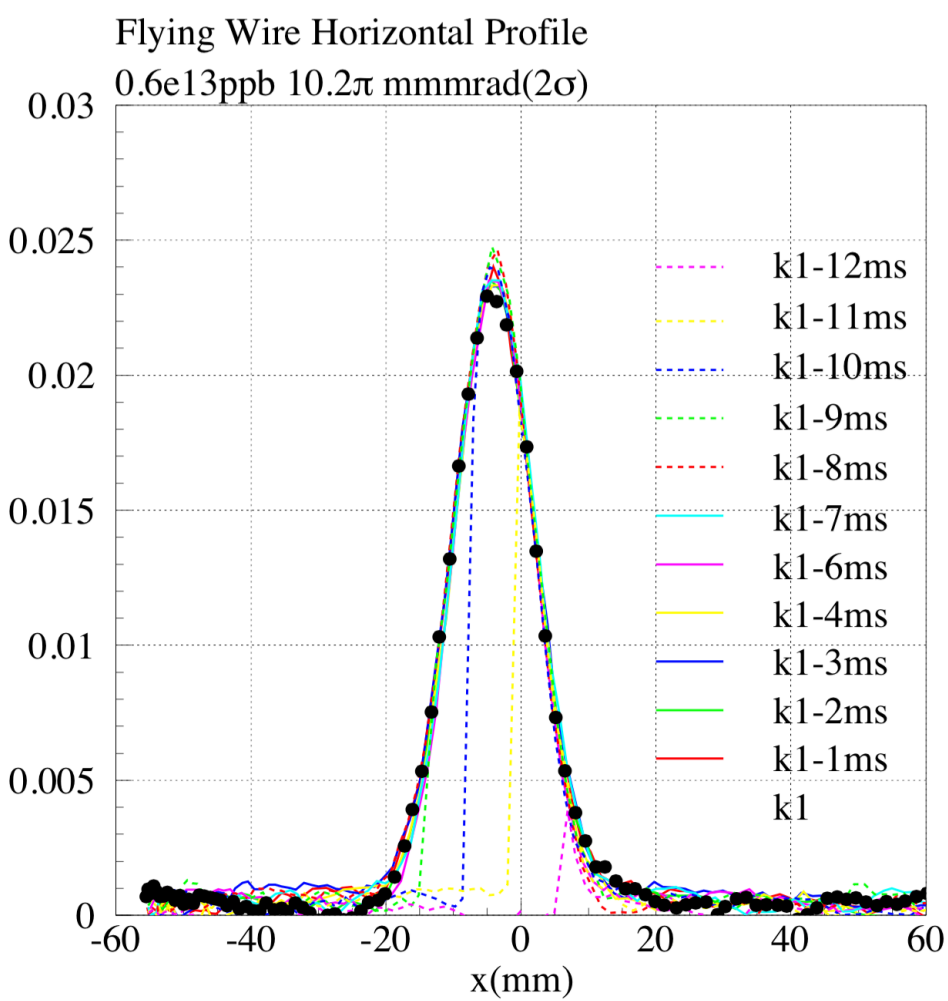
- DCCT measurement during the injection period of 130 ms
- 2 bunch injection
- SCTR simulation with initial distribution of 16π mmmrad of Horizontal 2σ emittance and 24π for Vertical 2σ emittance.

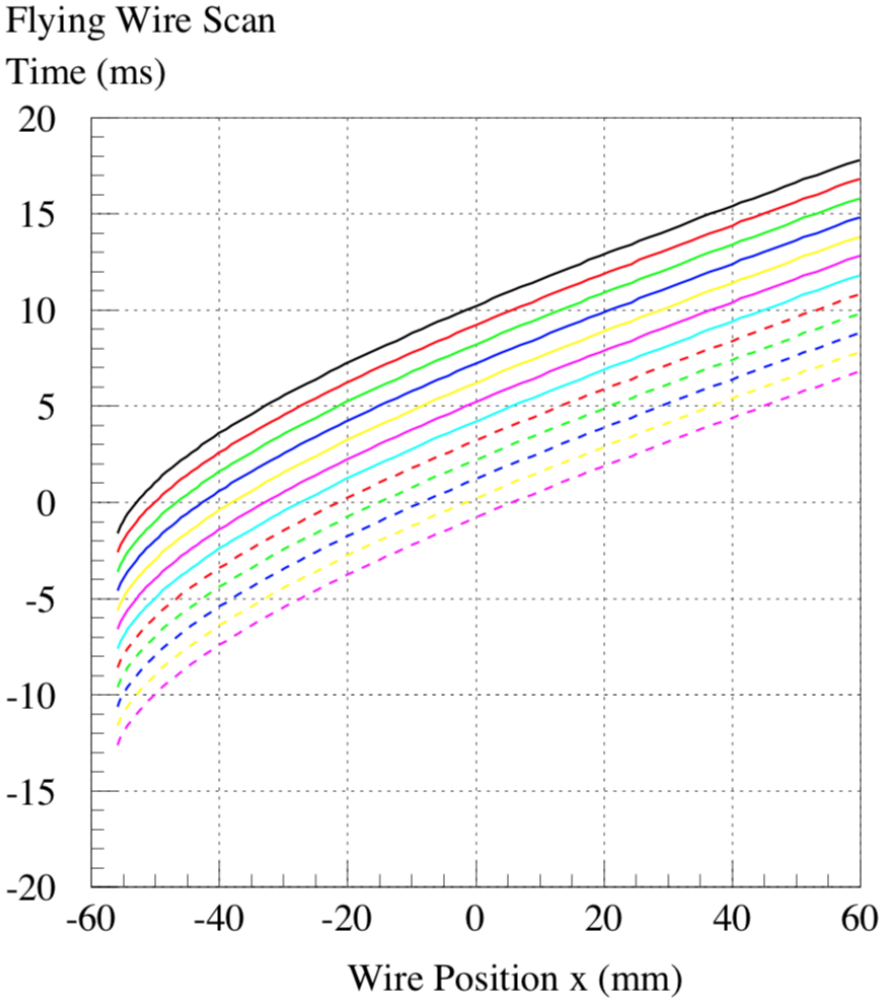




Profiles immediately after the Injection

- Profile data was acquired with changing the trigger by 1 ms step with respect to k1 for 0.6×10^{13} ppb.
- The profile peak was observed to be sharper immediately after the injection.





Summary

- Flying wire monitors have been used for the horizontal and vertical beam profiles at the J-PARC MR.
- The beam back ground is suppressed by installing the monitor upstream of the collimator.
- The profile data has been acquired up to the beam intensity of 2.2×10^{13} ppb.
- Wire breakage has occurred once in six years for the horizontal wire and once in four years for the vertical wire.
- We have successfully reconstructed beam profiles such as the profile immediately after the injection and profiles during the injection period.
- The monitors have been proven to be useful for the beam commissioning.