P-150 Studies

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The MINOS Collaboration Meeting

at Caltech

January 3-6, 2002

Characterization of Main Injector beam parameters

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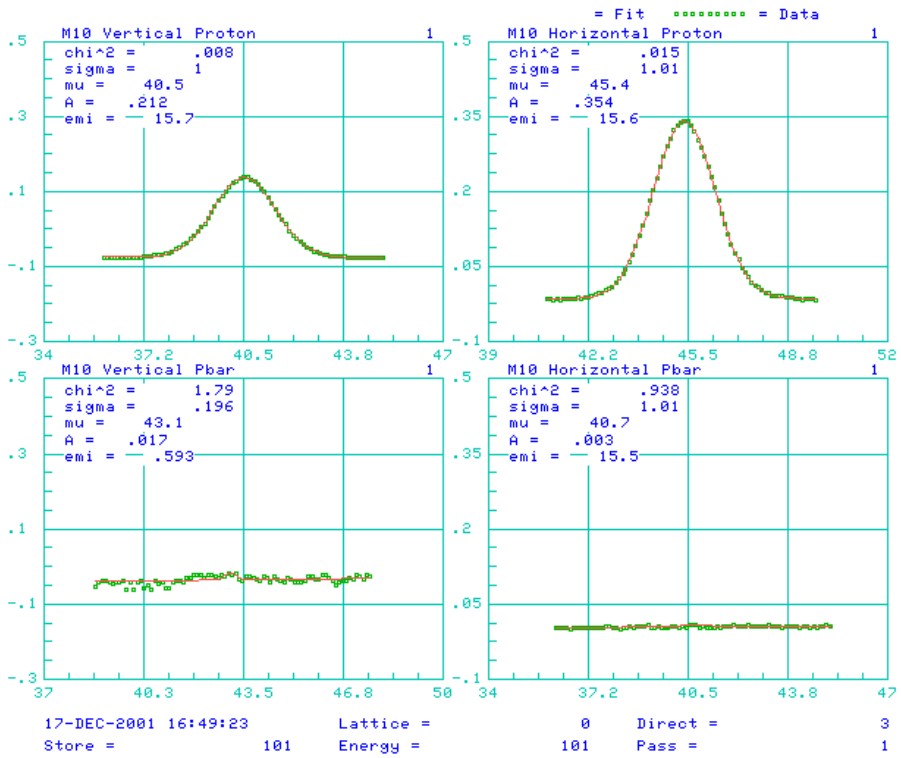
- Measurements of transverse and longitudinal beam profiles in MI as a function of beam intensity
- Additional measurements of momentum spread in P1
- Plan for the future

Flying wire in FMI

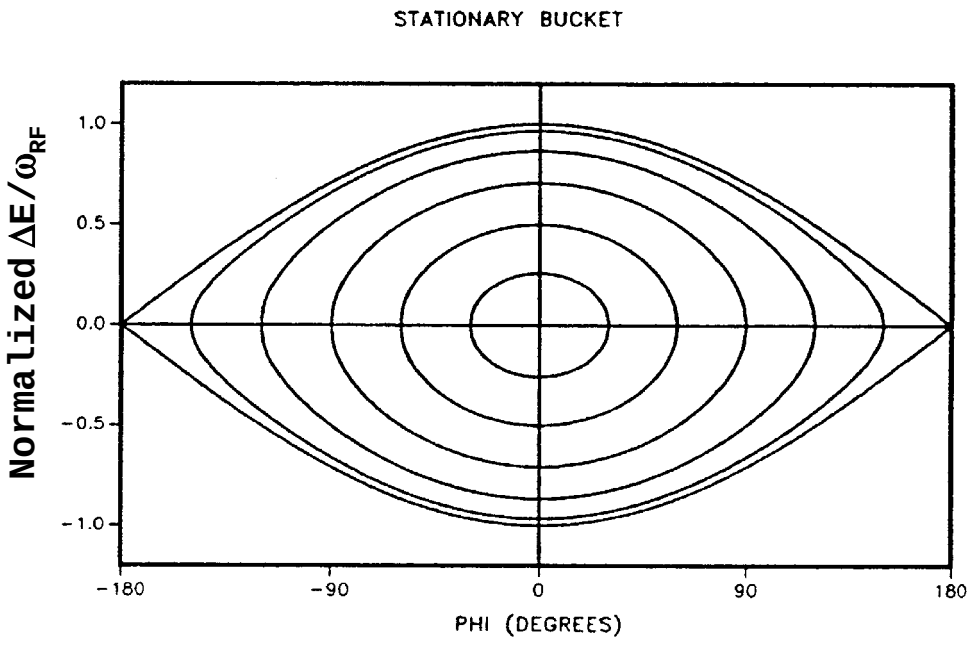
A measurement of transverse emittance

$$\varepsilon^* = \frac{6\sigma^2 \beta\gamma}{\beta_{Latt}}$$



Flattop, intensity ~ 4 10^{12}

Bunch in a stationary bucket



Δt = bunch half-length

$$\Delta\varphi = \omega_{RF}\Delta t$$

$$\Delta E = \left(\frac{2\beta^2 E_s V_{RF}}{\pi h \eta}\right)^{1/2} \sin\frac{\Delta\varphi}{2}$$

h = harmonic #

$$\eta = \frac{1}{\gamma_t^2} - \frac{1}{\gamma^2} \qquad \gamma_t = 21.8$$

Beam longitudinal emittance $\varepsilon_\ell \cong \pi\, \Delta E\, \Delta t$

$$\text{Bucket Area} = \frac{8}{\omega_{RF}}\left(\frac{2\beta^2 E_s V_{RF}}{\pi h \eta}\right)^{1/2} \qquad V_{RF} = 3MV \Rightarrow \text{Bucket Area} \cong 10\ \text{eVs}$$

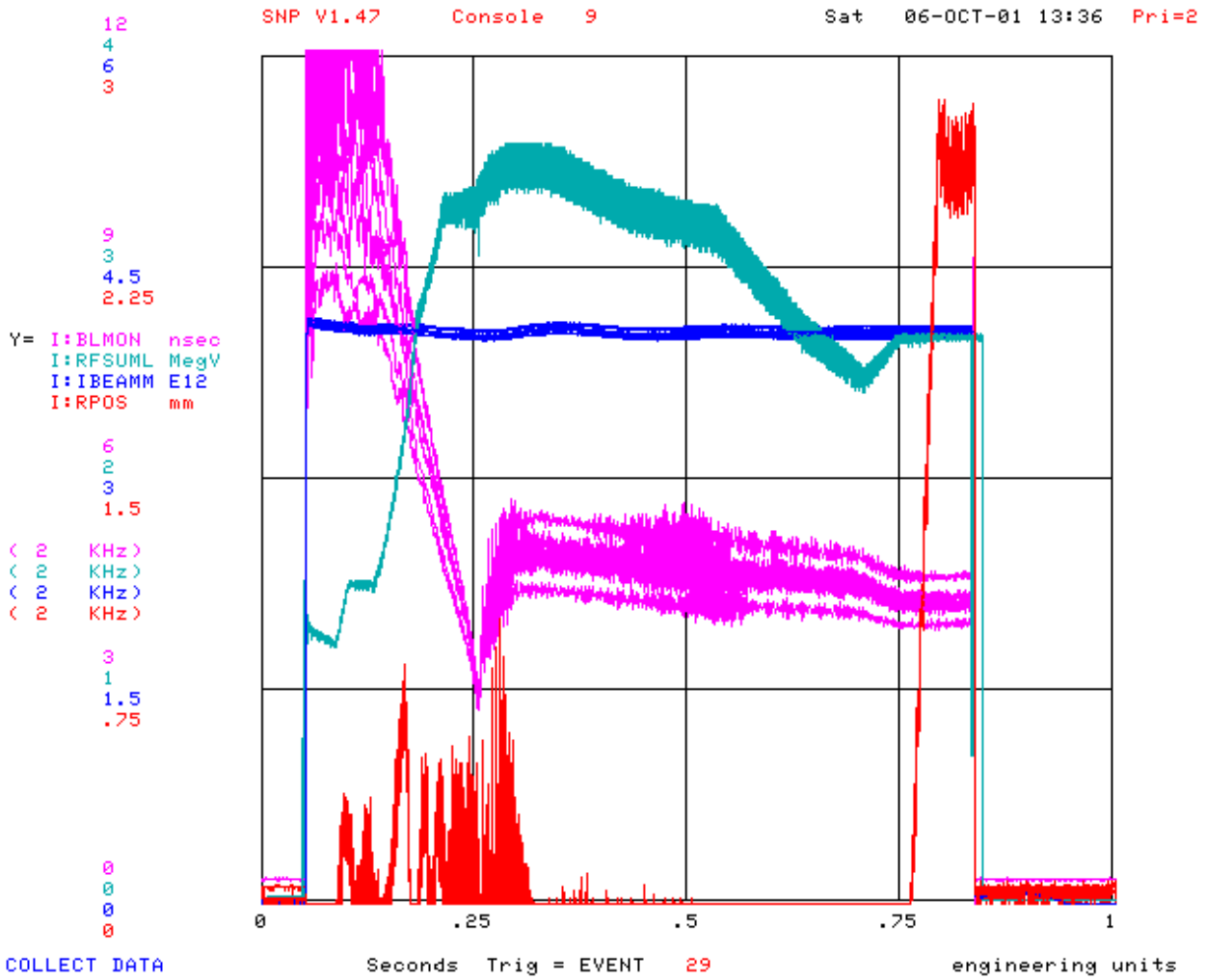
Bunch Length Monitor in FMI

The Bunch Length Monitor gives the average of the full bunch length (~ 4σ) over many bunches

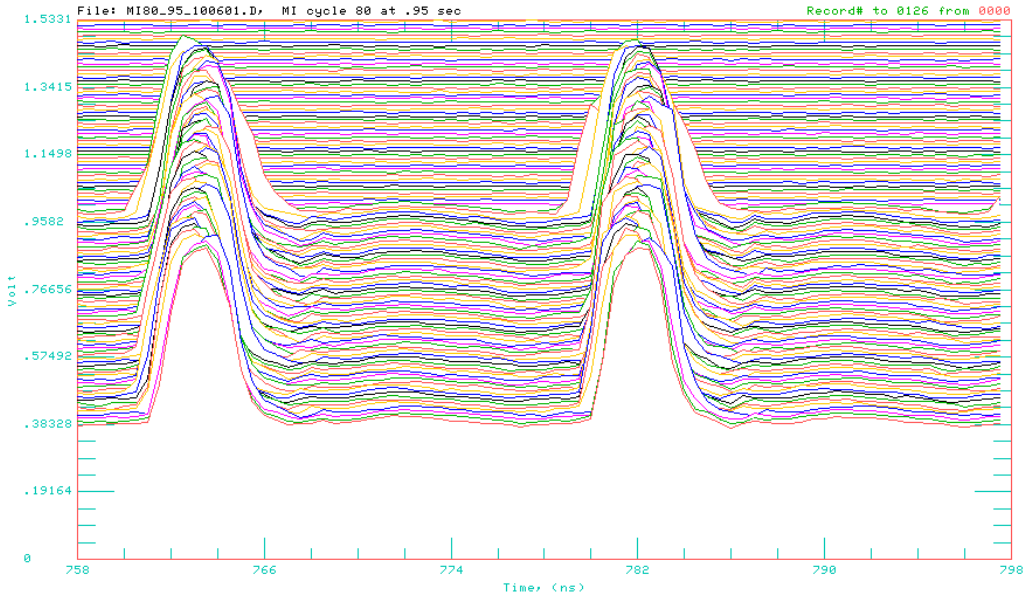
Bunch length

$$\sim \sqrt{\ln\left[\frac{V(\omega_0)}{V(3\omega_0)}\right]}$$

$\omega_0 = 2\pi f_{RF}$

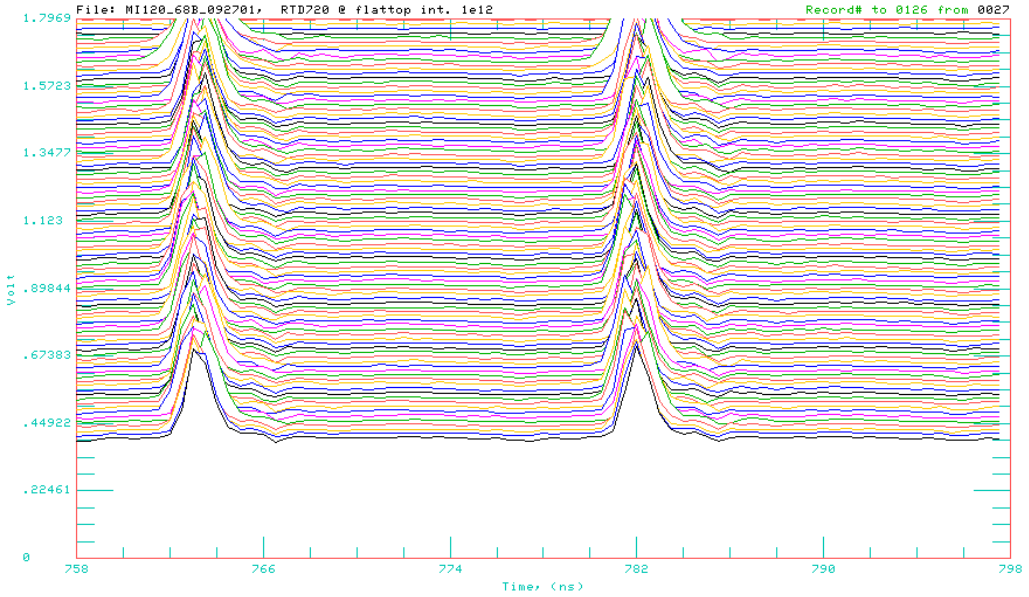


Resistive Wall Monitor in FMI (RTD720)



Flattop, intensity ~ 4 10^{12}

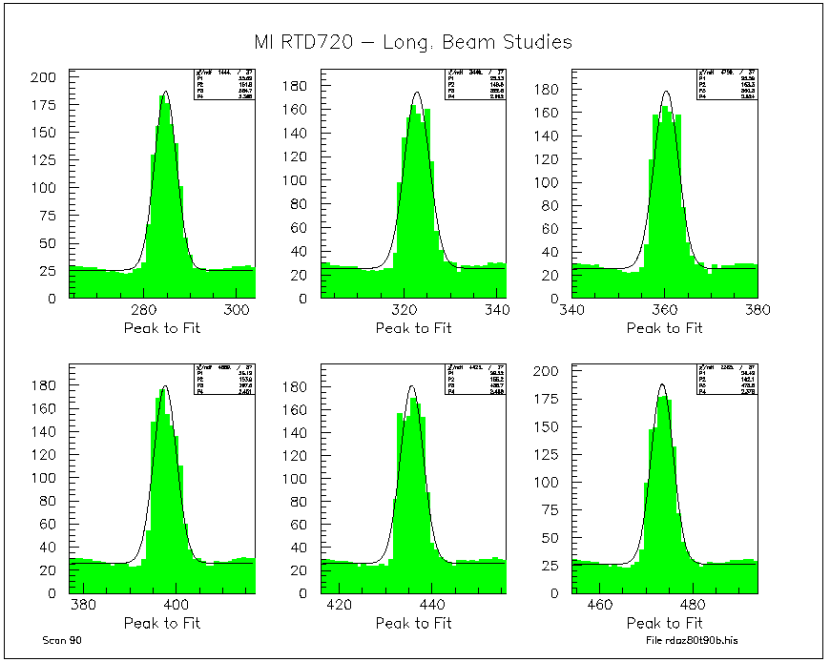
Flattop, intensity ~ 1 10^{12}



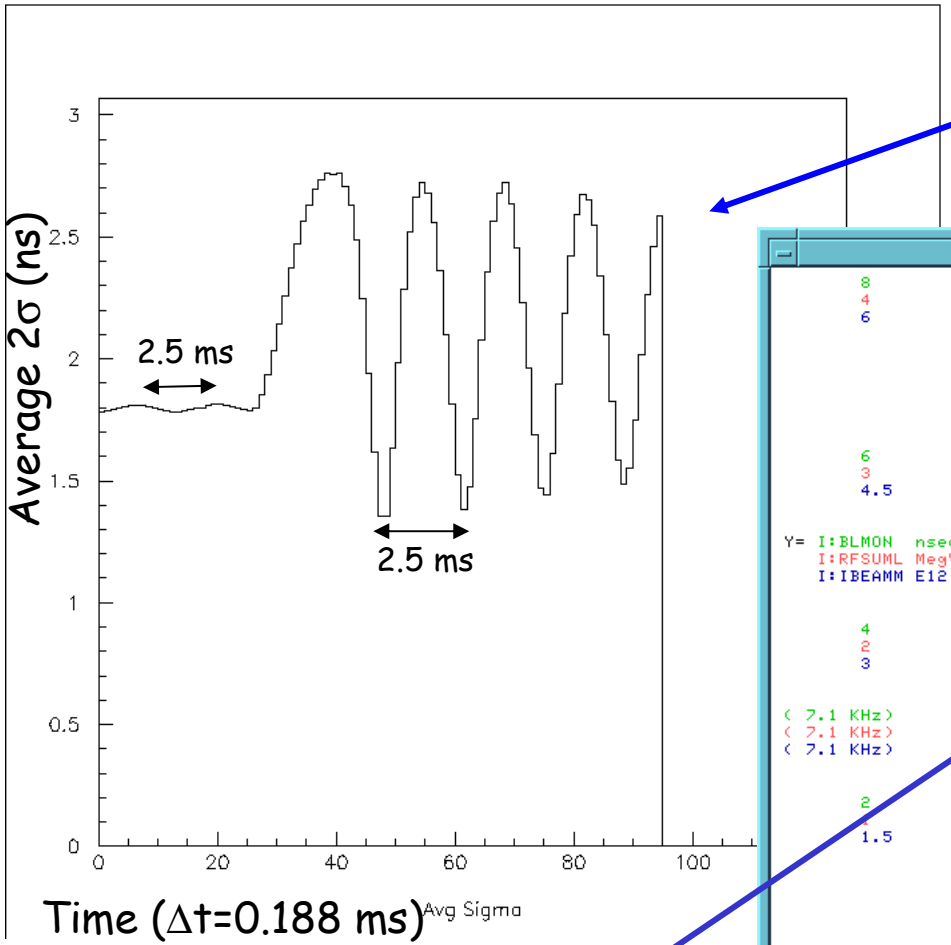
Bunch length from Resistive Wall Monitor @flattop before Bunch Rotation

Intensity	RF (MV)	Bunch half-length (2σ) (ns)	$\Delta p/p$	ε_l (eVs)
$1\ 10^{12}$	2.8	0.95	$5.6\ 10^{-4}$	0.20
$2\ 10^{12}$	2.8	1.15	$6.7\ 10^{-4}$	0.29
$4\ 10^{12}$	2.8	1.95	$1.1\ 10^{-3}$	0.83

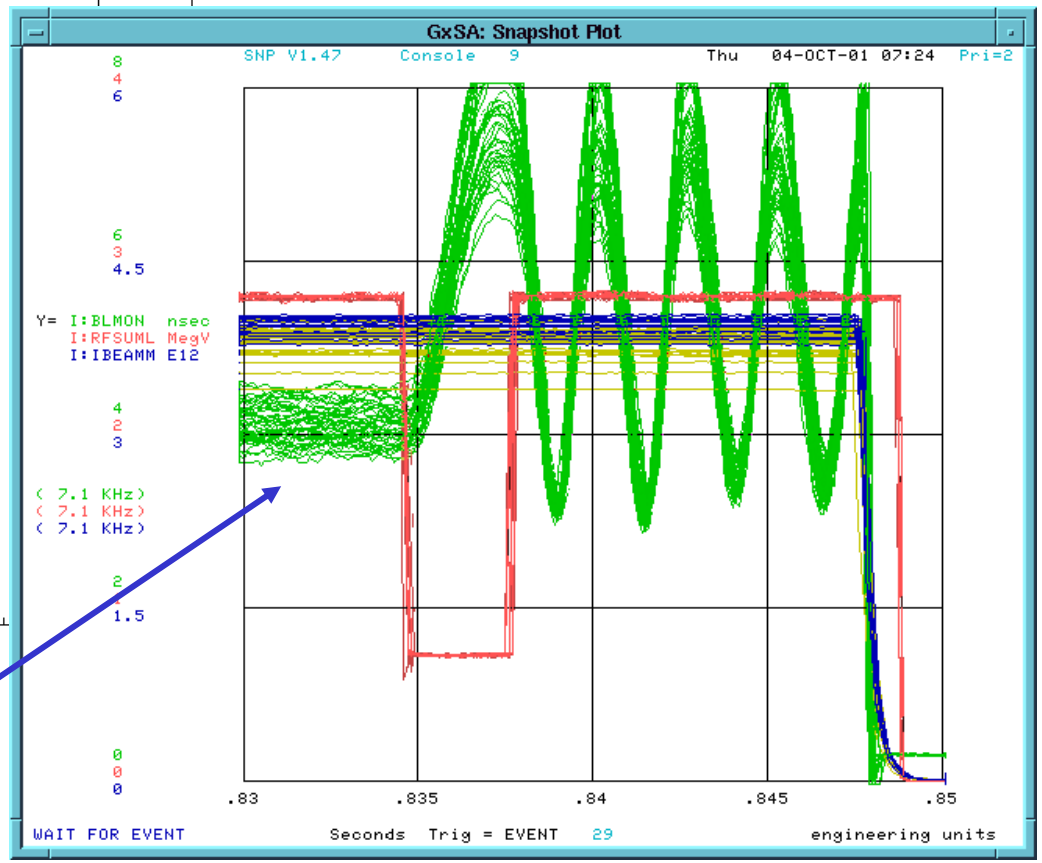
Observed variations of ~ 10%



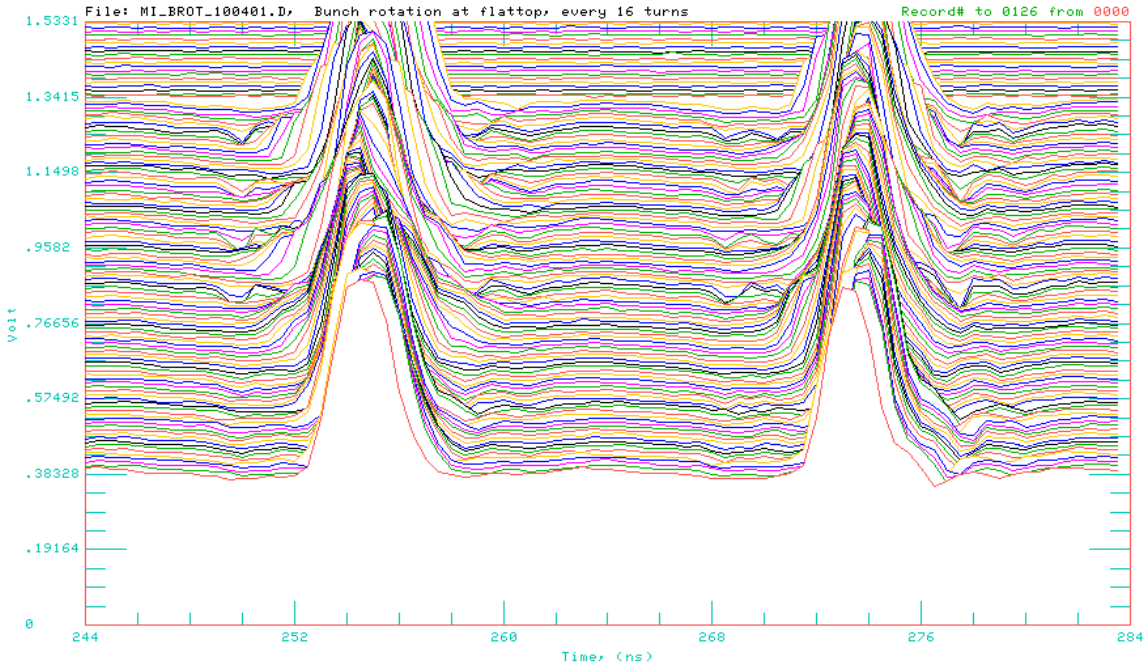
Bunch Length during Bunch Rotation



From RTD720



BLMON



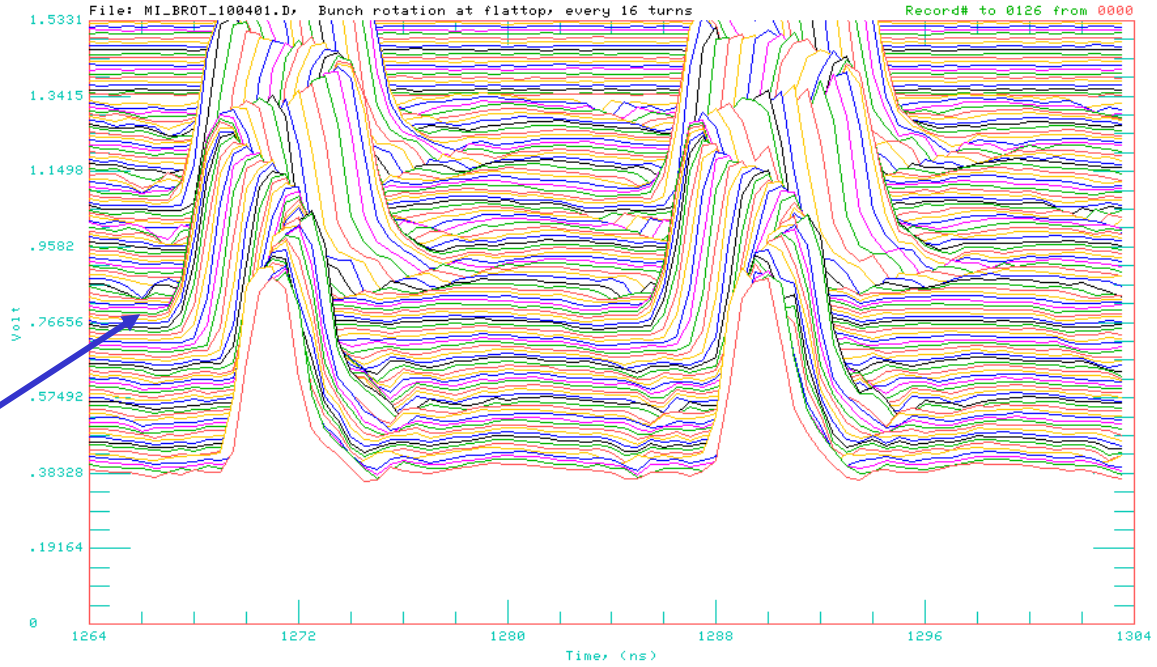
Bunch Rotation seen with the Resistive Wall Monitor

Intensity ~ 4 10^{12}

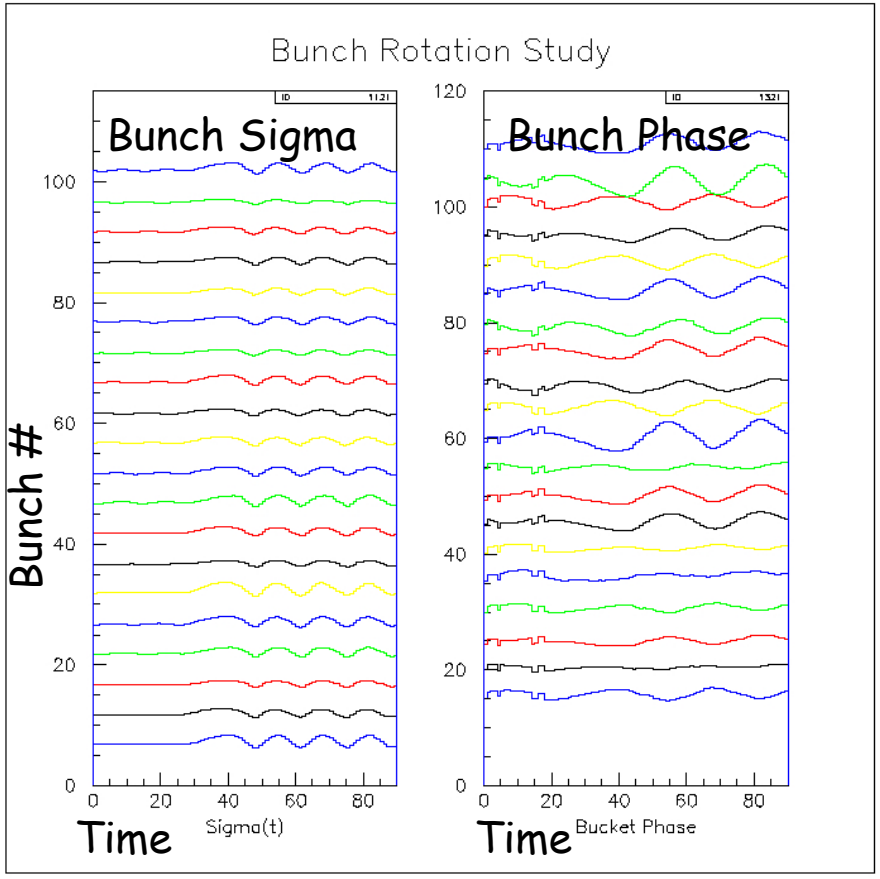
Different behaviours

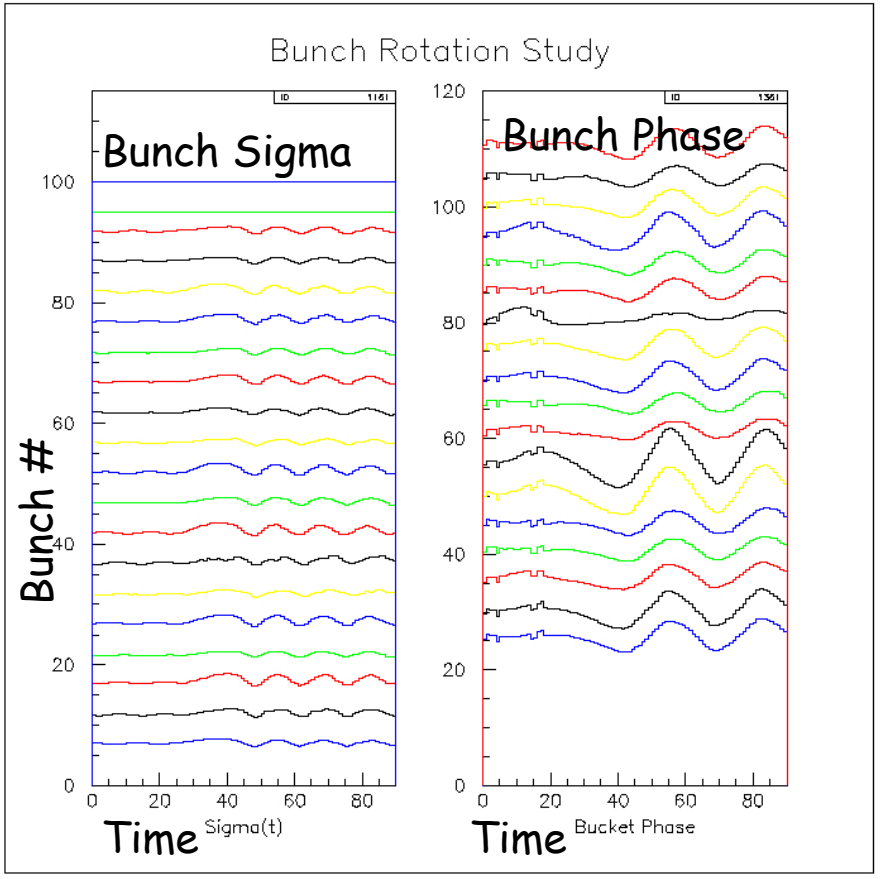
for different bunches

Phase oscillation with T=5 ms



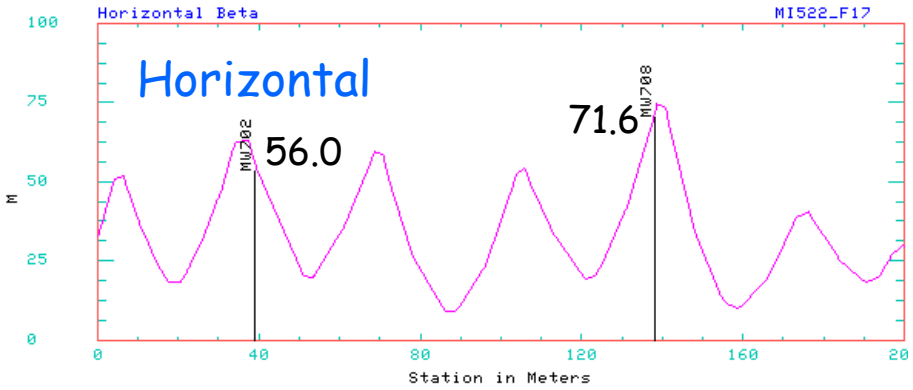
A closer look at bunch behaviours during Bunch Rotation

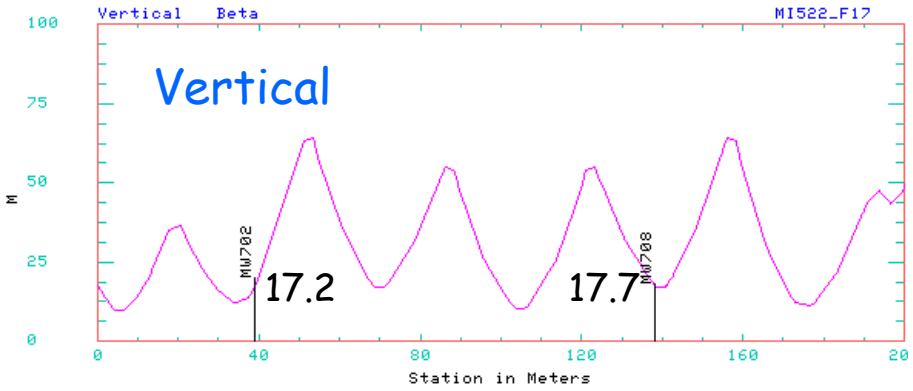




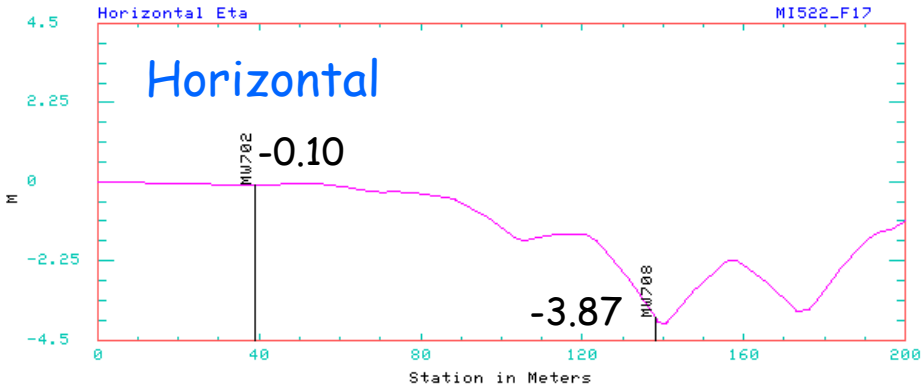
P1 lattice functions

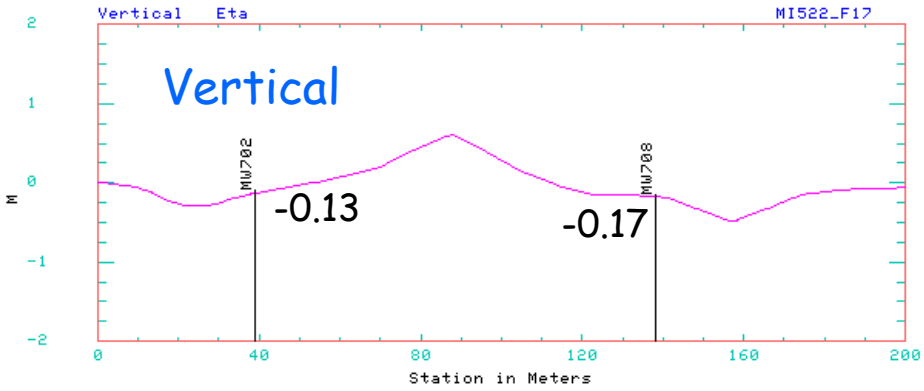
Beta functions





Eta functions

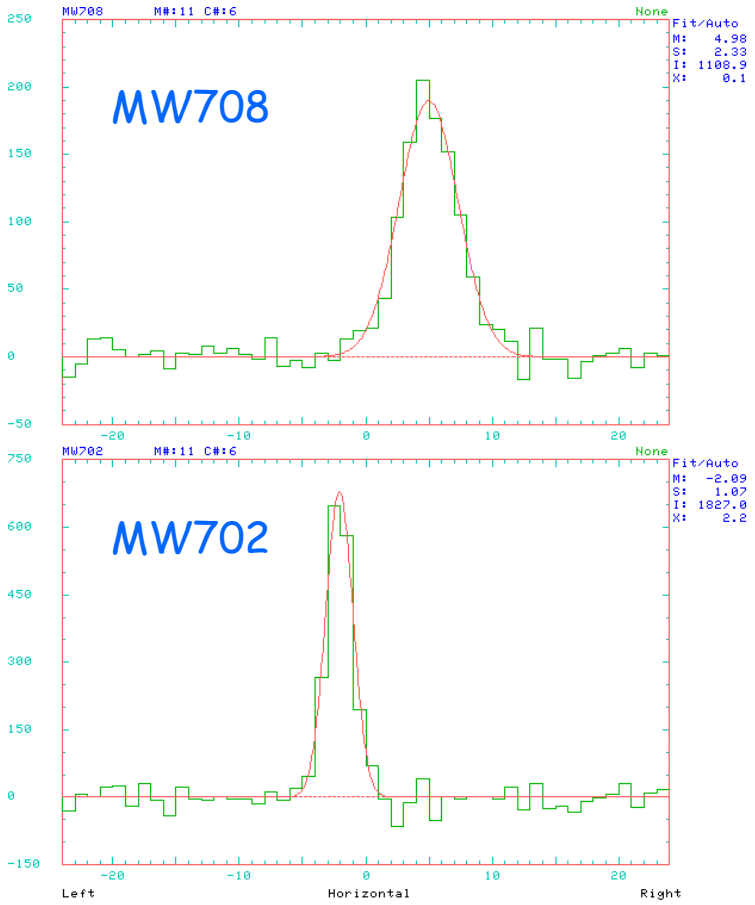




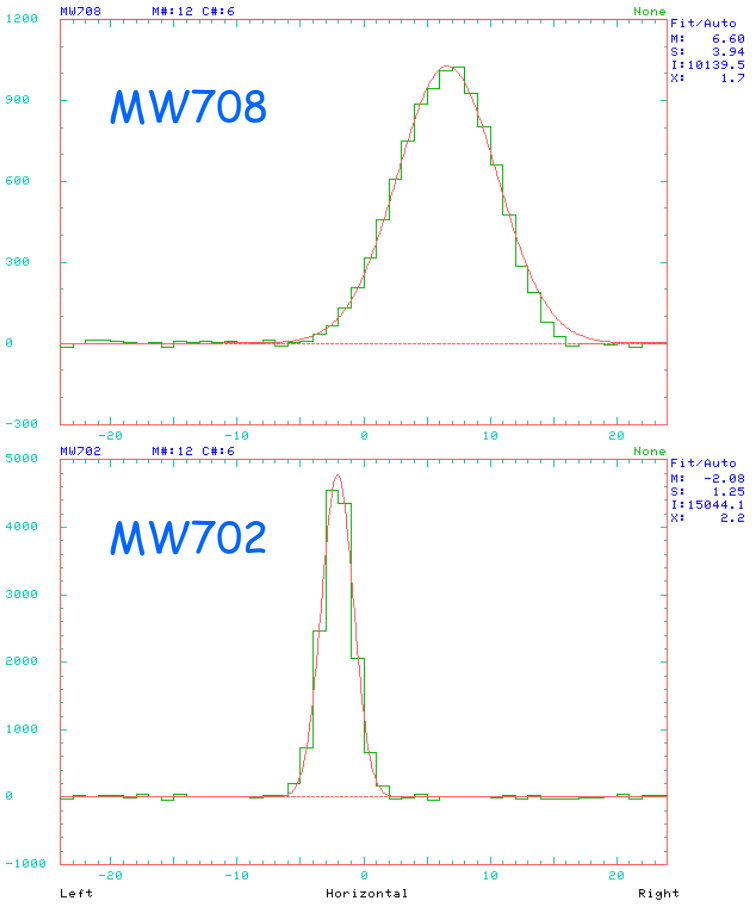
Measurement of Δp/p in P1 after Bunch Rotation (extracting beam @ minimum of Δt)

Horizontal MW profiles

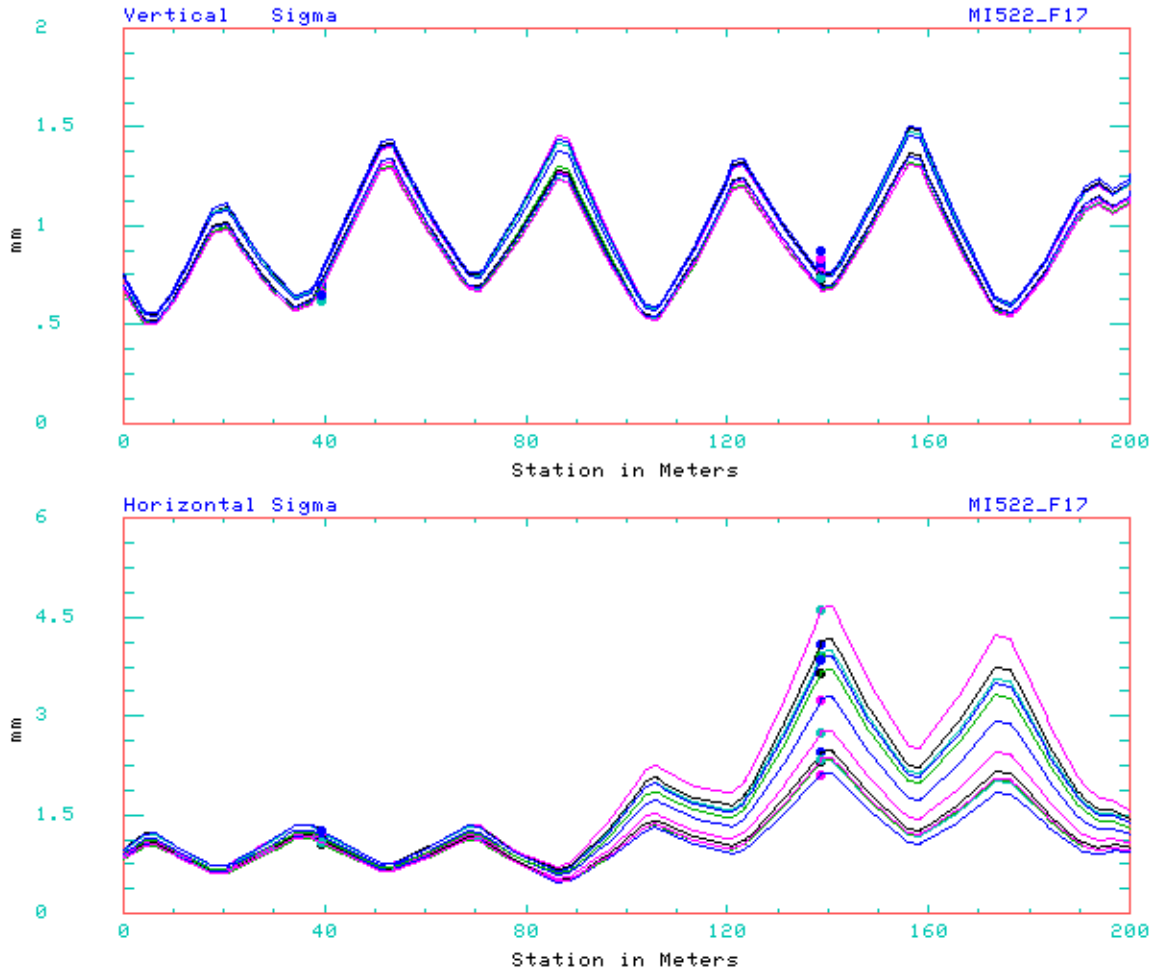
1 Booster turn



10 Booster turns



Fit results for transverse emittance and Δp/p



Fit results for transverse emittance and $\Delta p/p$

Intensity ($\times 10^{12}$)	Vert. Transv. Emittance (95%)	Hor. Transv. Emittance (95%)	$\Delta p/p$ ($\times 10^{-3}$) (95%)
0.48	20.0	16.3	1.00
0.91	20.2	15.9	1.00
1.3	21.5	16.6	0.86
1.8	20.3	16.8	0.98
2.2	15.5	17.2	1.06
2.6	20.1	17.9	1.22
3.1	19.9	18.6	1.72
3.4	23.9	19.7	1.48
3.6	23.8	21.7	1.86
3.8	24.1	22.3	1.94
3.9	23.6	22.4	2.22
4.1	24.9	22.2	1.82

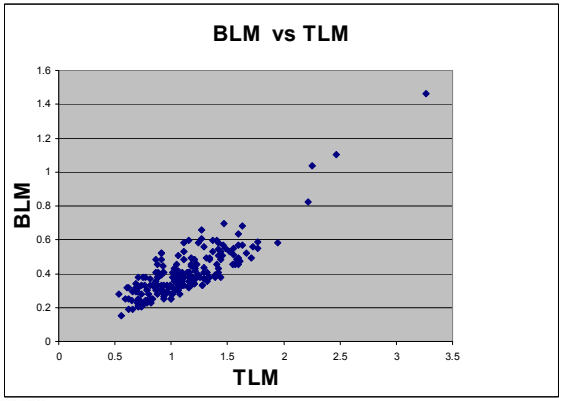
Plan for the future

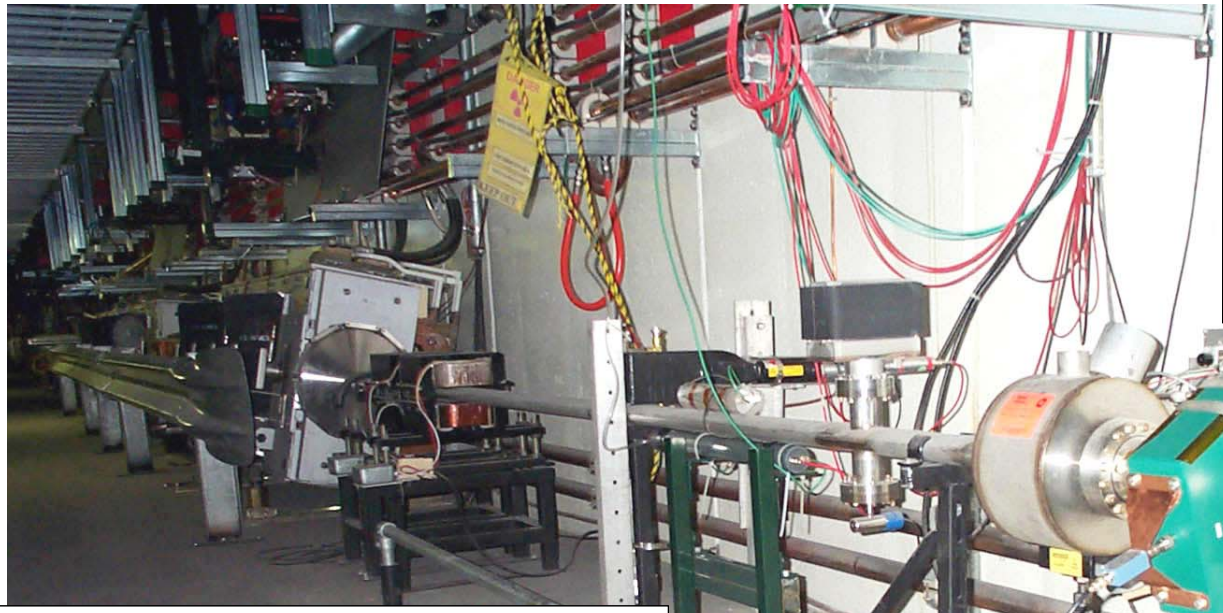
- Complete previous set of measurements
  - Measurement of momentum spread in P1 extracting beam at the maximum of Δt (as for NuMI)
- New studies
  - Study losses at Lambertson @ MI52
  - Measurement of beam tails with a crawling wire @ MI52

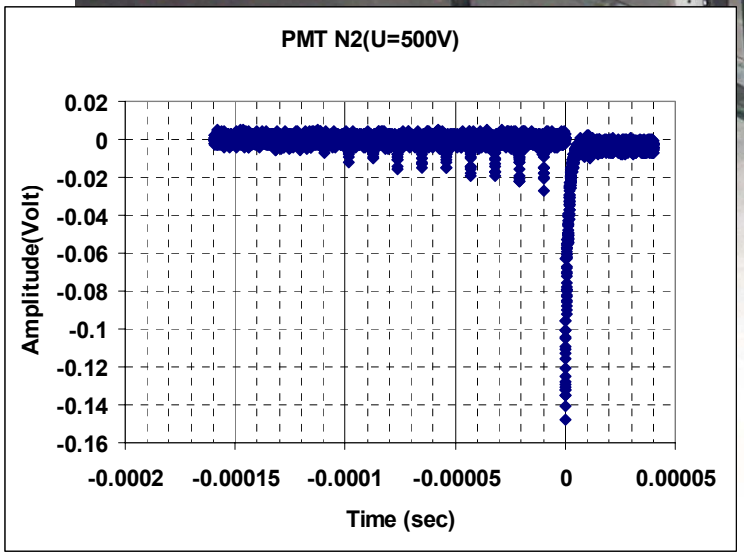
    and a scanning target @ Q702
  - Implement Data Logging of loss monitors, power supply stability in P1, beam stability in MI (BLMON, RPOS, …)

❖ Repeat the above measurements with MI in multi-batch mode

Crawling wire @ MI52







Scanning target

The target: tungsten, 100 μm thick,
1 cm long in the beam direction,
10 cm in the transverse direction

Conclusions

- Initial measurements indicate beam emittances growing with beam intensity
  - $\Delta p/p$ @ 4 10^{12} protons/batch before bunch rotation ≈ 1 10^{-3} (95%)
- Both quadrupole and dipole oscillations observed during bunch rotation
  - $\Delta p/p$ @ 4 10^{12} protons/batch with bunch rotation at the minimum of Δt ≈ 2 10^{-3} (95%)
- Next essential steps
  - measurement of beam tails
  - understanding of beam losses @ extraction
- A final characterization of the beam from MI requires to set up a test cycle in multi-batch mode