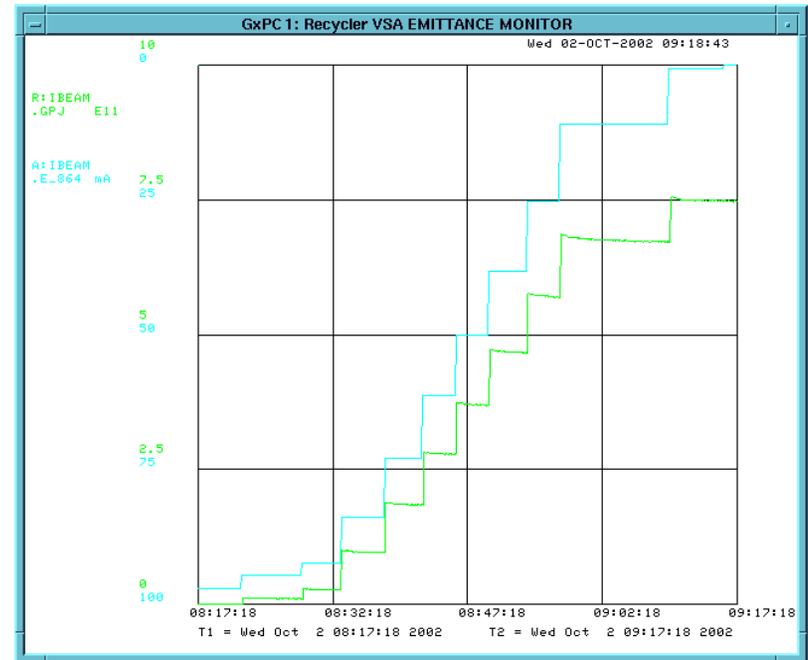
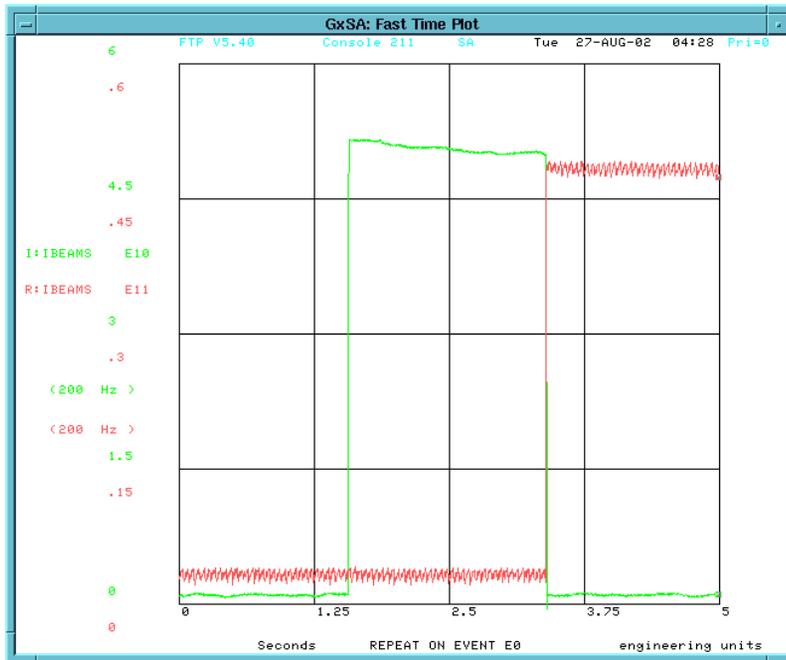

Recycler Instrumentation Status

John Marriner
DOE Review
July 22, 2003

Recycler Instrumentation & Integration Plan

- The plan is that we will make a plan in December 2003 for integration of the Recycler into operations.
- The plan will be comprehensive commissioning plan including a complete plan for instrumentation upgrades.
- This talk will concentrate on status of the current instrumentation and possible elements of the future plan.
- The Recycler BPM is being completely rebuilt and is the subject of another talk. I will not mention the BPM system further.
- The Recycler transverse feedback systems are under development, but are outside the scope of this talk.

DC Current Monitor



- DC current monitors provide the most accurate measurement of circulating beam in all the accelerators.
- They are commonly used to measure overall transfer efficiency.
- The Recycler DC current monitor has sufficient accuracy to measure a 100 hr lifetime over a time period of less than 1 hr.

Toroids (integrated pulse)

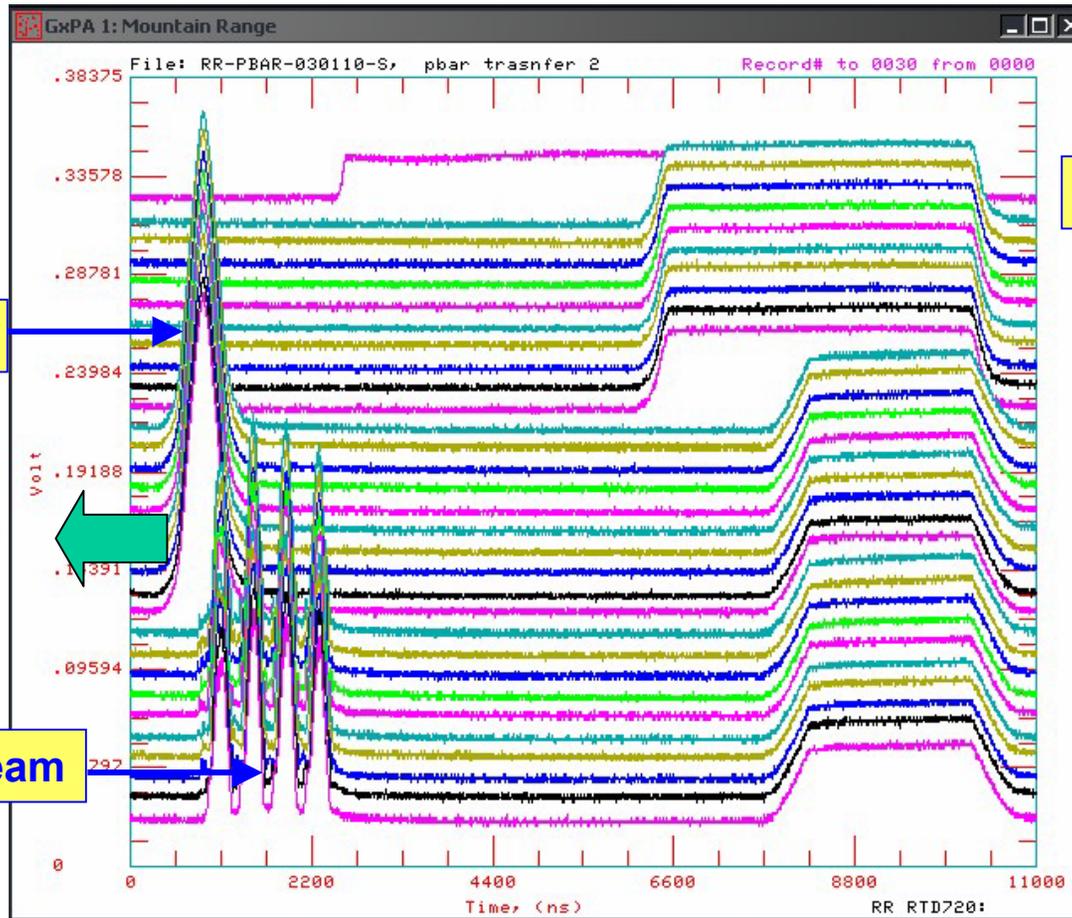
- A number of toroids are installed.
- These are conventional toroids with typical performance.
- Injection (pbar)
 - I:TOR303
 - R:TOR704
 - R:TOR214
- Extraction (pbar)
 - R:TOR330
 - R:TOR803
 - I:TOR303
- Abort line (R:TOR003)

Wideband Current Monitor

- This is a standard FNAL 1Ω pickup.
- It is used to measure all sorts of bunched beam structures.
- Improved software and automation is needed to be able to use this device in routine operations.
- A more sensitive (perhaps 50Ω) pickup would be useful for feedback loops and other applications requiring high sensitivity.

Wideband Current Monitor - Acquisition

RTD720 – A digitizing scope data



Squeezed Beam

Final Stack Beam

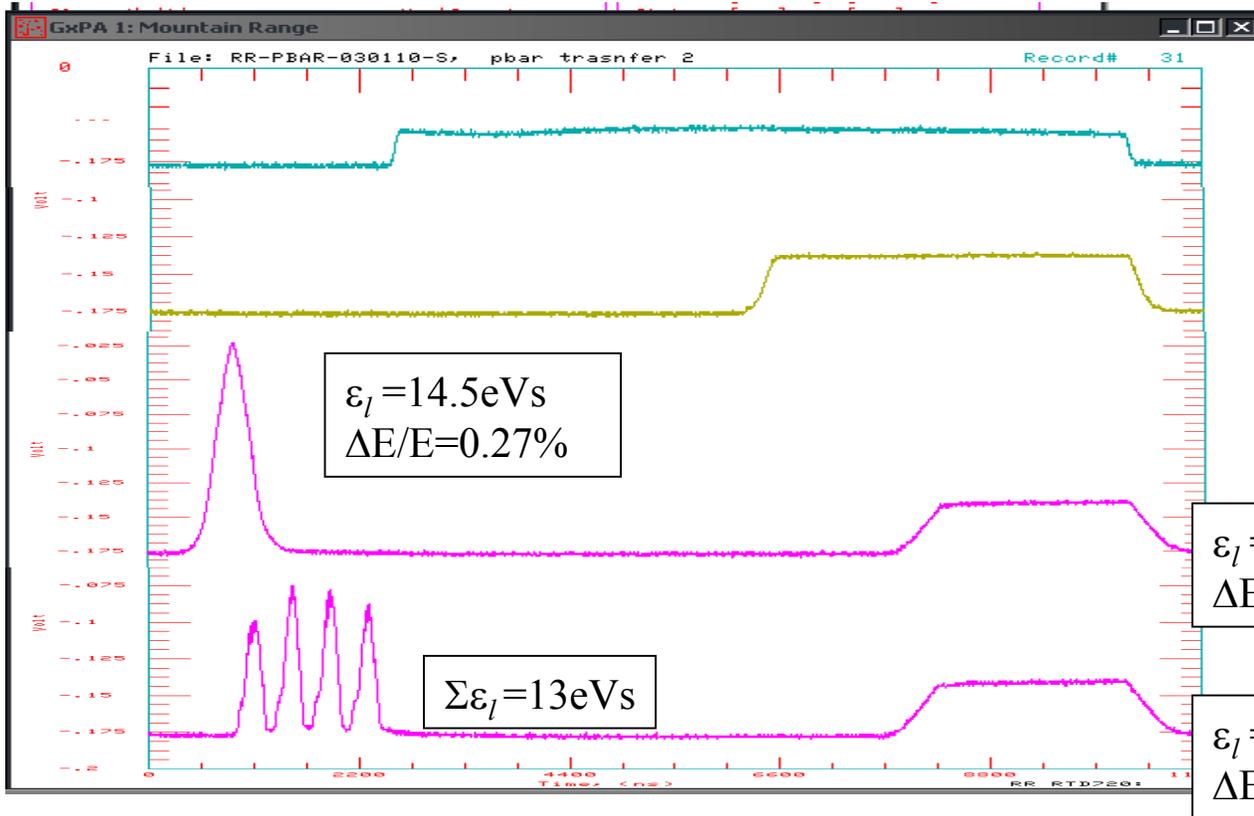
Beam coggling direction after squeeze

Newly arrived Beam

Stacked Beam

Wideband Current Monitor - Analysis

RTD720 – A digitizing scope data



Sum Emittance

$$\epsilon_l = 88\text{eVs}$$
$$\Delta E/E = 0.13\%$$

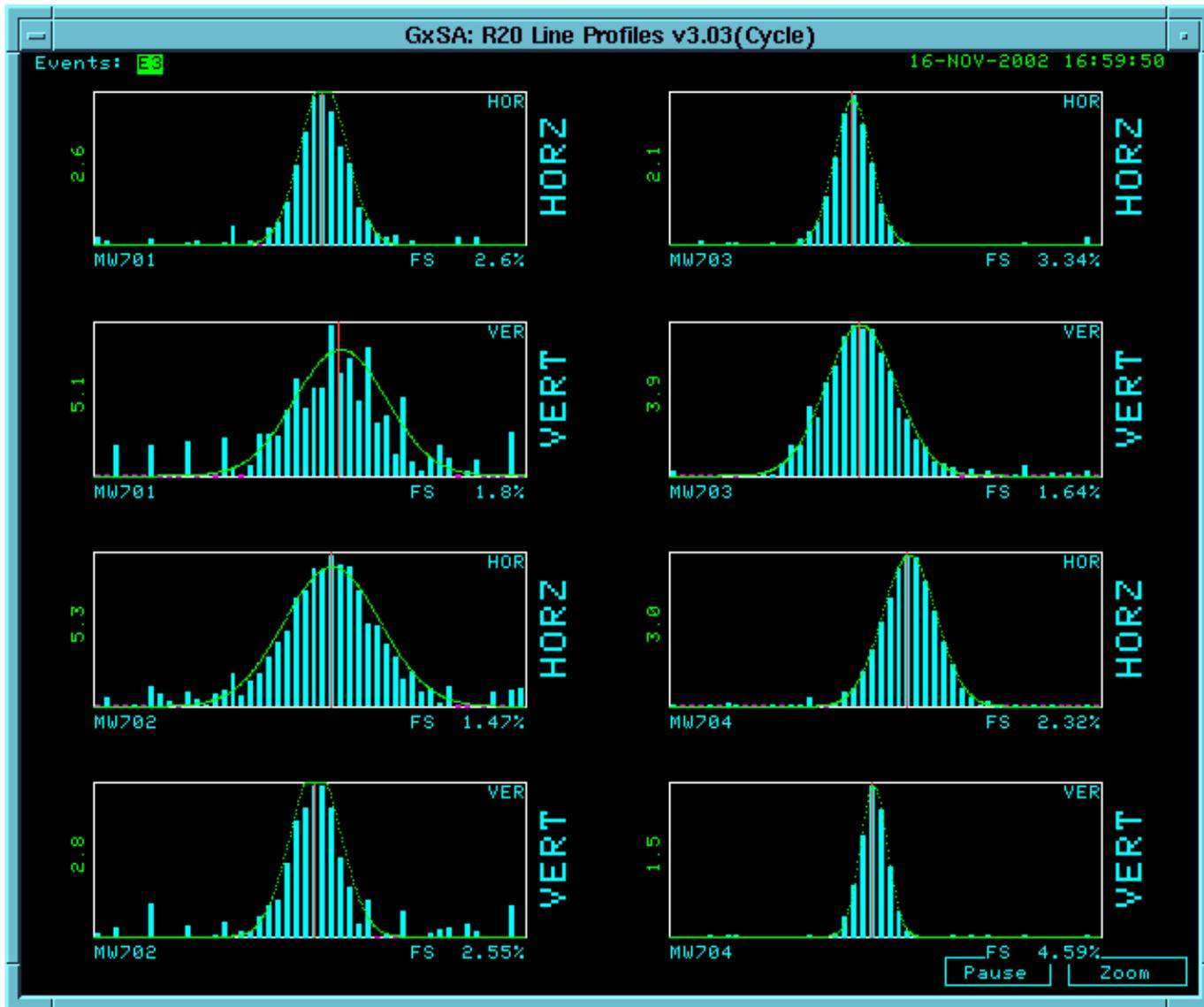
$$\epsilon_l = 81\text{eVs}$$
$$\Delta E/E = 0.23\%$$

$$\Sigma \epsilon_l = 78.5\text{eVs}$$

$$\Sigma \epsilon_l = 77\text{eVs}$$

The error in the measured longitudinal emittance $\cong 20\%$

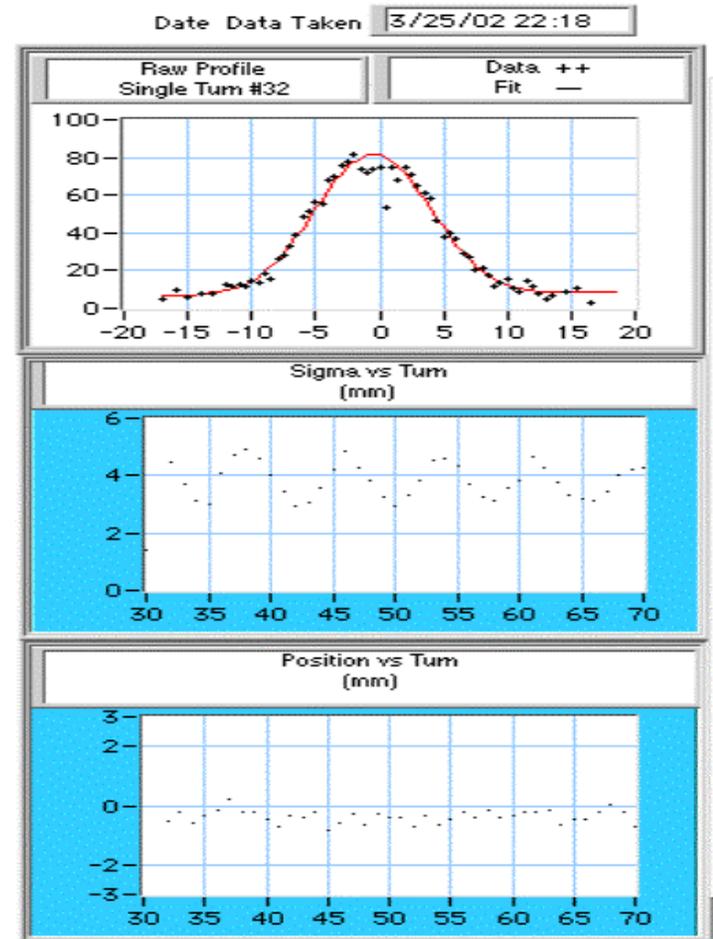
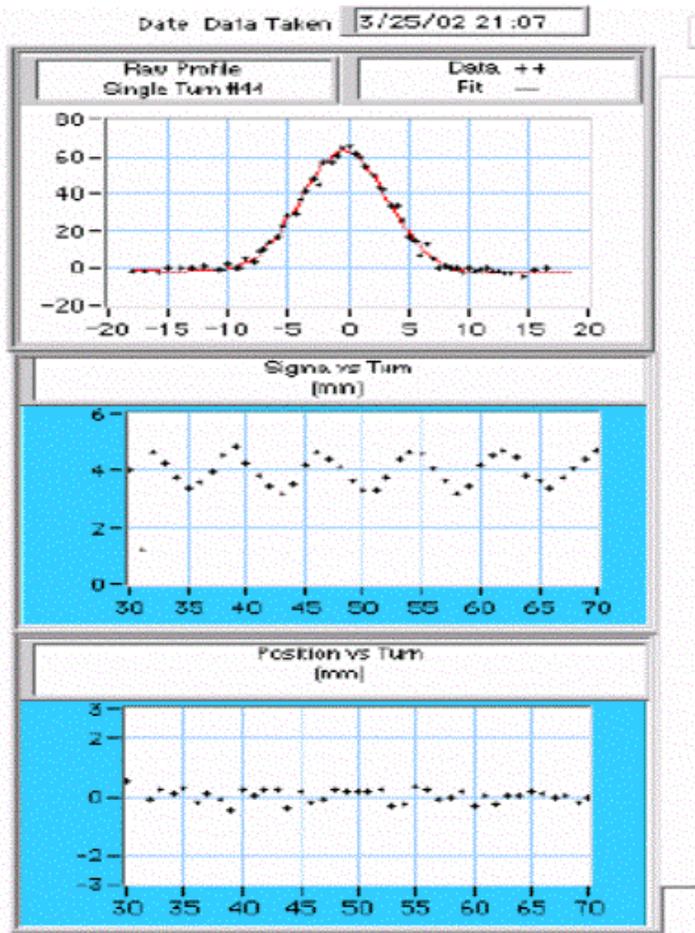
Transfer line Multiwire Chambers



Ion Profile Monitor (IPM)

- The ion profile monitor was part of the original Recycler instrumentation.
- It has recorded beam profiles, but the systematic errors have not been understood well enough for it to be used with confidence.
- The controls interface is through the program lab-view and it is usually operated via a dedicated Macintosh computer.
- The ion profile monitor will be removed in the August 2003 shutdown because it is not UHV compatible, particularly when the HV is on.
- The future utilization of the IPM is uncertain.

IPM Data



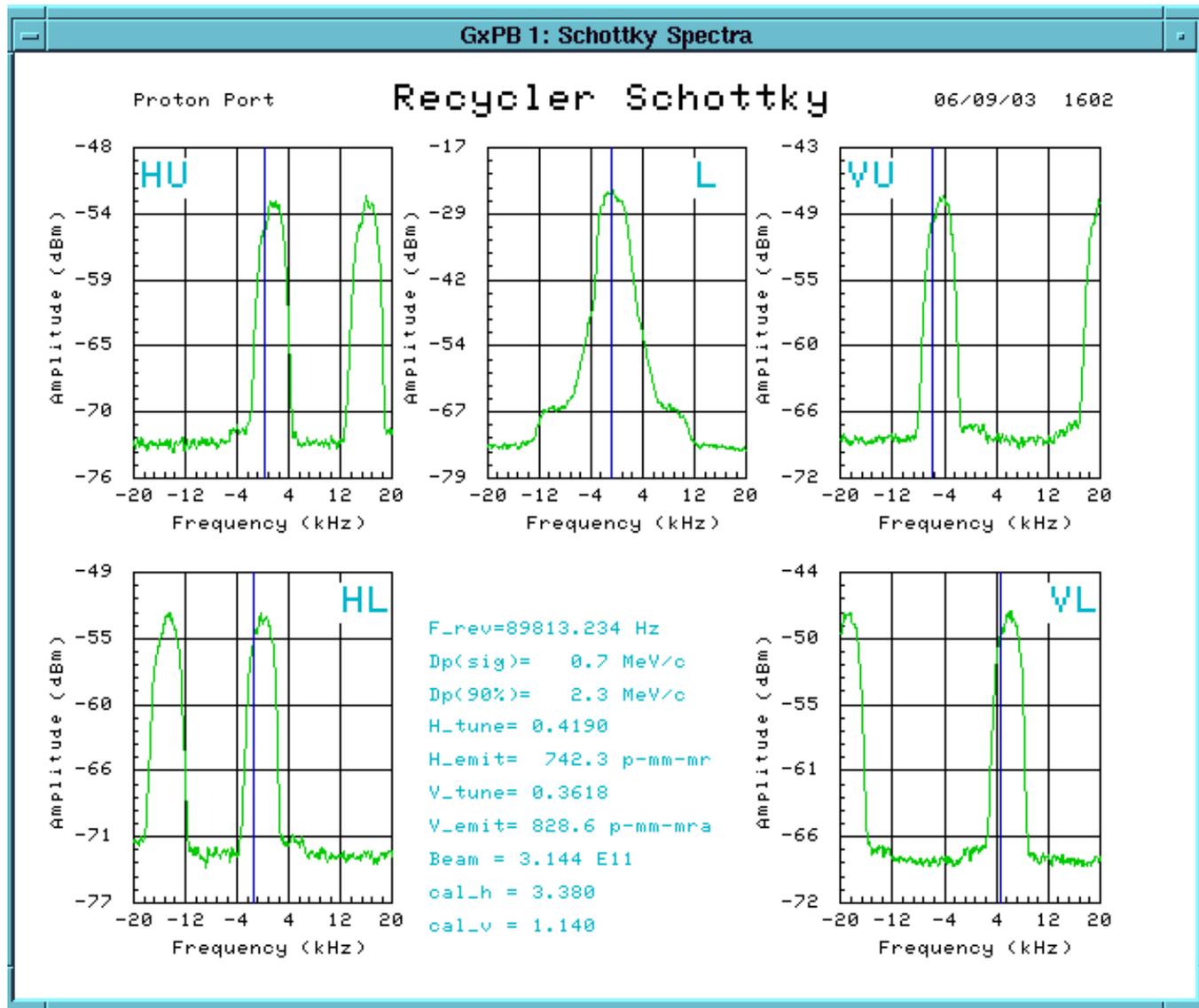
Flying Wire

- A flying wire system was built and installed in the Recycler.
- The system was not UHV because of errors in quality control.
- The flying wire is being prepared for reinstallation in August, but the installation schedule has not yet been determined.

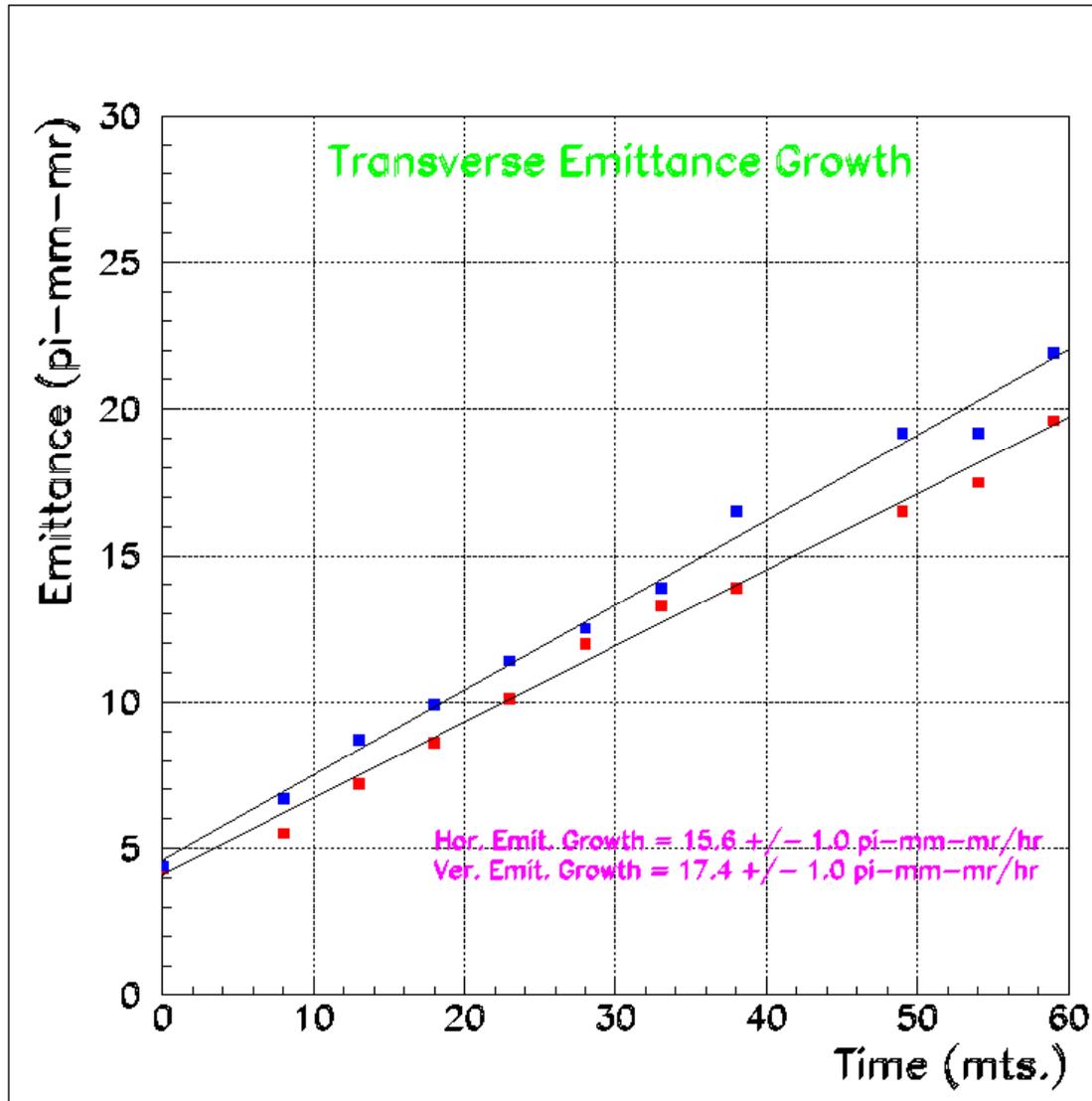
Schottky Signal Monitor

- A 1.7 GHz center frequency Schottky pickup was built and installed in the Recycler in January 2003.
- It measures revolution frequency, frequency spread (from which the emittance can be calculated), tune, and transverse emittance.
- This device is the primary non-destructive device for measuring emittance.
- The transverse emittance is calibrated with a scraped beam profile.
- The Schottky pickup measures only the rms beam size, not the full distribution.

Schottky Pickup Data



Transverse Emittance Growth



A subsequent recalibration of the Schottky PU leads to a more recent estimate of 10-12 π mm-mrad/hr.

Schottky Signal Monitor Issues

- The emittance of different segments of the beam can be measured when signal gating is implemented (imminent).
- Software to capture the beam emittance at appropriate times is under development.
- There is a modest coherent signal on the sum signal, but the difference signal seems to be a pure Schottky signal.

Scraper

- The Recycler has two scrapers (H and V). The scrapers are in regions with a nominal value of zero for the momentum dispersion.
- Each scraper has two jaws so that it is possible to scrape from either side or both.
- The ratio of $\alpha_p / \sqrt{\beta}$ in the Recycler is not favorable for a momentum scraper.
- The scraper position readback provides the standard for the Schottky emittance measurements.
 - A knowledge of the lattice beta-function at the Schottky pickup and the scraper is required.
 - A knowledge of the relationship between peak and rms oscillation amplitude is required (coupling matters).

Loss Monitor System

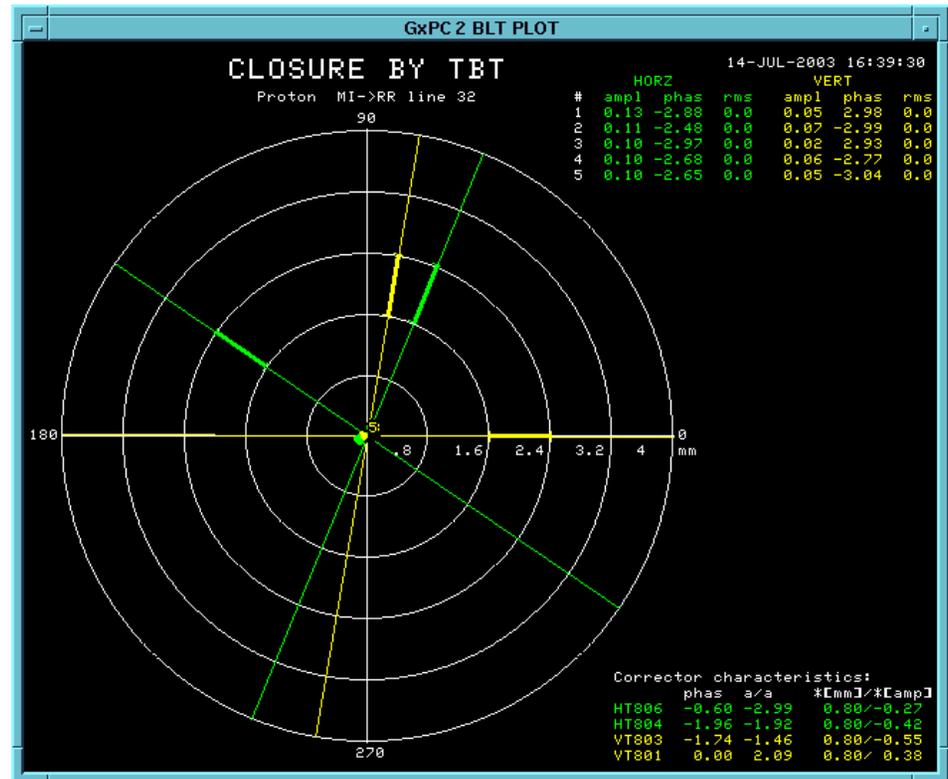
- The original Recycler design did not include a loss monitor system.
- The Recycler has "borrowed" some Main Injector loss monitors. Borrowing involves repositioning the device in the tunnel, but nothing more.
- The Main Injector loss monitors are designed to see fast, high intensity losses, and are useful in the Recycler only for injected beam.
- A more sensitive loss monitor system with a good dynamic range would be useful but is probably not critical.

Ion Clearing Current

- A system to apply ± 500 V to the BPM electrodes has been built to clear ions.
- An R&D project is underway to measure the ion clearing current accurately.
- It would be desirable to monitor the production and movement of ions operationally, but this need may not be critical.

Beam Line Tuner

- Used in routine operation for orbit closure.
- Works to close orbit to better than 0.5 mm (about $\frac{1}{4} \pi$ mm-mrad dilution).
- Works with 2.5 MHz bunch structure



Conclusion

- Many Recycler diagnostics working well (according to traditional performance levels and/or machine requirements).
- A formal plan to address the remaining issues will be developed by December 2003.
- Issues that will be resolved before or with the formulation of the Dec 2003 plan include:
 - Flying wire refurbishment and reinstallation
 - Development of IPM with regard to UHV compatibility, understanding systematic errors and calibration, and development of operational software.
 - New loss monitor system(?)
 - Other software to automate measurements, especially for beam transfers.

Multiwires for Recycler Proton Injection

