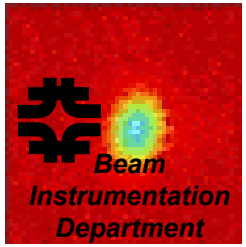

Accelerator Beam Instrumentation

Bob Webber

Beam Instrumentation Department

Definition

- Accelerator beam instrumentation --- the menagerie of devices, electronics, systems, methods, and analyses used to quantify particle beam parameters in the accelerators and transfer lines for the purposes of:
  - Knowing that information for its own sake
  - Applying that information for real-time beam feedback control
  - Using that information to understand the environment of the beam

Typical Quantities Measured and Devices

- Beam current or number of particles – Intensity
  - Current transformers
- Transverse position of beam in vacuum chamber – BPMs
  - Electromagnetic "antennae" inside chamber
- Transverse dimensions of the beam – Profile
  - Wires, IPMs, synchrotron light, OTR
- Longitudinal bunch position – Phase
  - Electromagnetic sensors of several types
- Beam losses – BLMs
  - Ion chambers, scintillation devices
- Many derived quantities from above measurements
  - Emittance, tune, chromaticity, luminosity, magnetic optics, …

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Current Customers

- Run II
  - Daily operational support
  - Major upgrade projects
    - New BPM systems for Tevatron, Pbar transfer beam lines, and Main Injector
    - New Tevatron IPM, BLM electronics, abort gap monitor
- SY120
  - Re-commissioning numerous old systems
- NUMI
  - New design and installation of BPMs, BLMs, profile monitors and intensity monitors
- MiniBooNE
  - Daily operational support and new profile monitor

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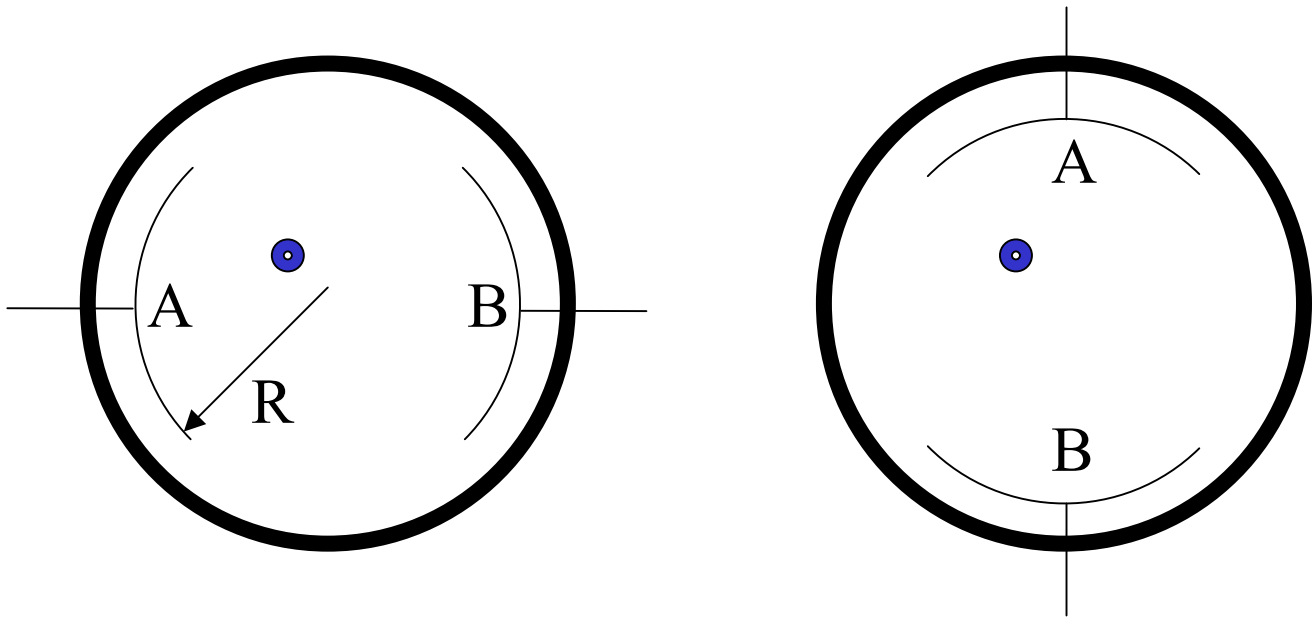
Instrumentation Priorities
My Perspective

- NUMI tasks (struggling to identify objectives and get going)
- TEV BPMs project (needs increased AD attention)
- Rapid Transfer Line BPMs (no one presently assigned)
- Tevatron BLMs
- Pbar Flying Wires (just to get it done)
- SY-120 (except BPM front-end)
- Flying Wire and Synch light front-end upgrades (for SDA)
- Flying Wire performance analysis (on-going)
- BLT standardization and robustification
- Toroid signal integration and readout upgrades
- TeV IPM
- Accumulator BPM MOOC/ACNET upgrade
- (MI BPMs hardly even make my list)

Beam Position Monitor (BPM) for Measuring Beam Centroid Position

A and B are electrodes that see the image charge of the beam



$X_{\odot} = R*(A-B)/(A+B)$ $\quad$ $Y_{\odot} = R*(A-B)/(A+B)$

Slide courtesy of Stephen Pordes

TeV BPM Positions in Store #3172 Old vs. New

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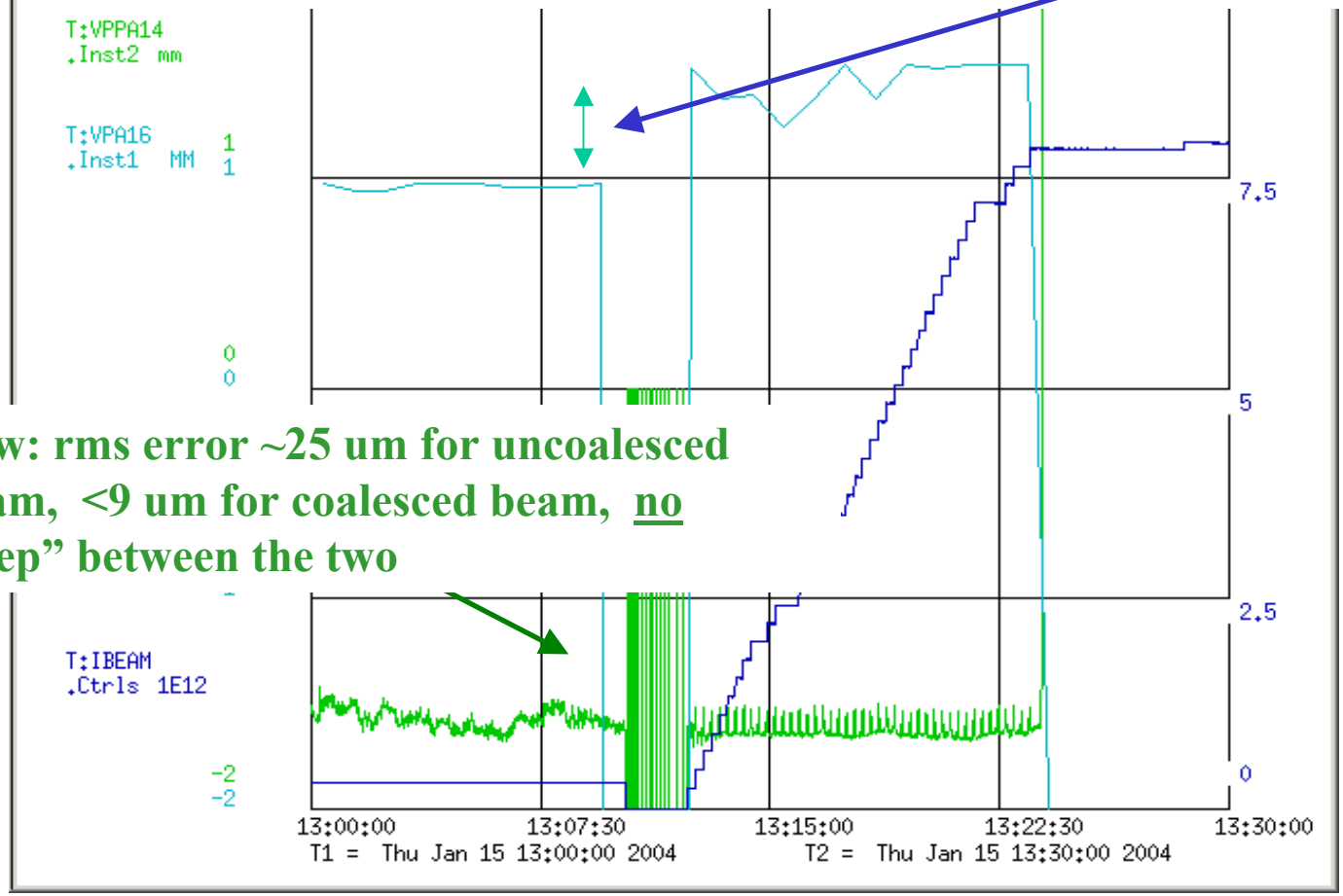
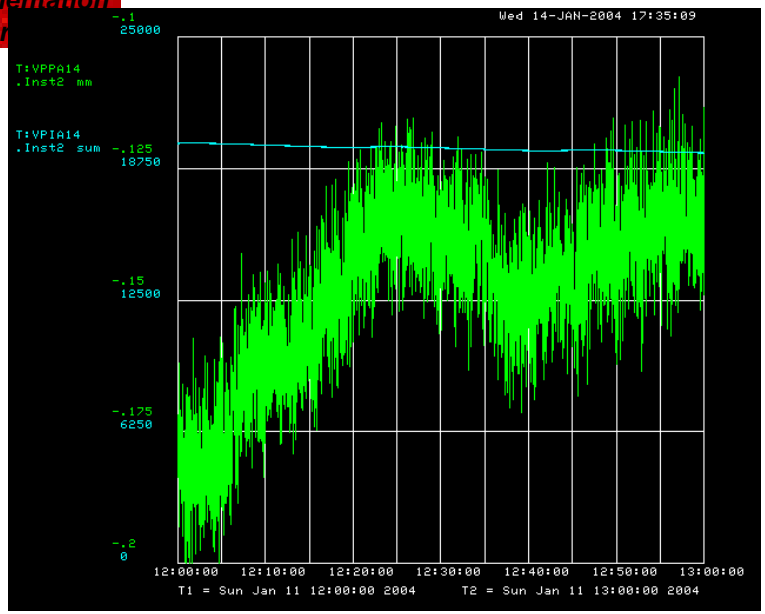
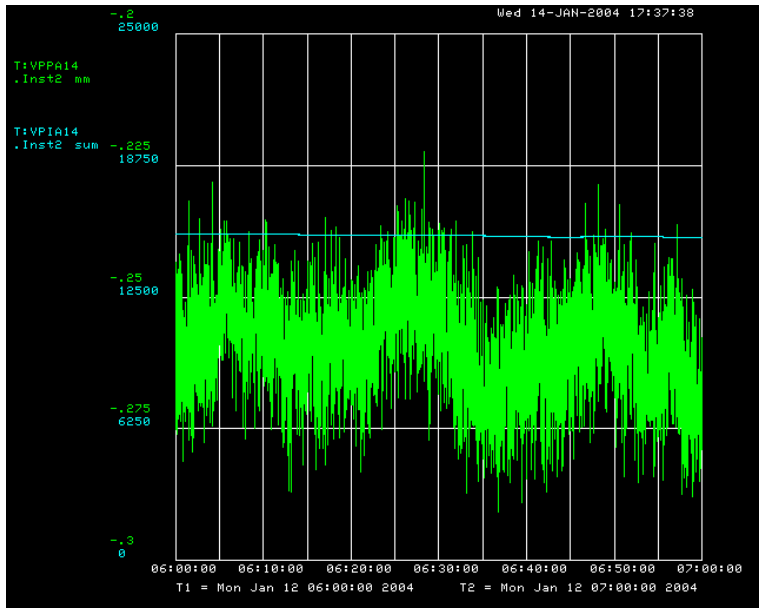
Old: rms error ~140 um for uncoalesced beam, ~70 um for coalesced beam, and 0.6 mm "step" between the two



New: rms error ~25 um for uncoalesced beam, <9 um for coalesced beam, no "step" between the two

Upper Limit of Closed Orbit Resolution



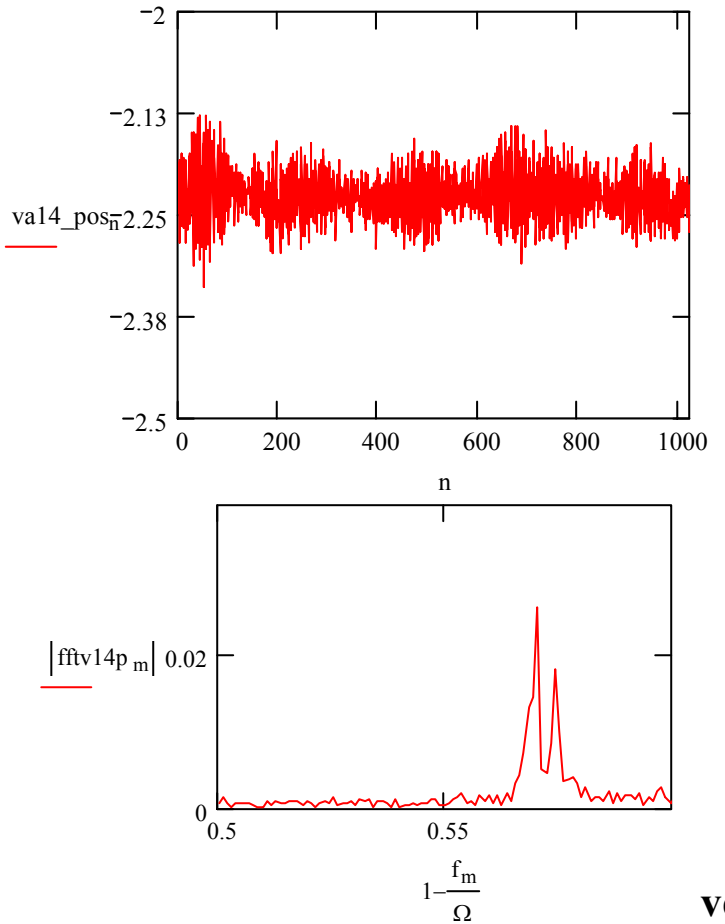


1 KHz bandwidth proton position measurement data from two one-hour periods, one early and one late, in store #3148. (data-logged at 1 Hz)
50 microns / vertical division

Average of standard deviations for twelve five-minute intervals	First one-hour interval	Second one-hour interval
	0.0085 ± 0.00061 mm	0.0090 ± 0.00072 mm

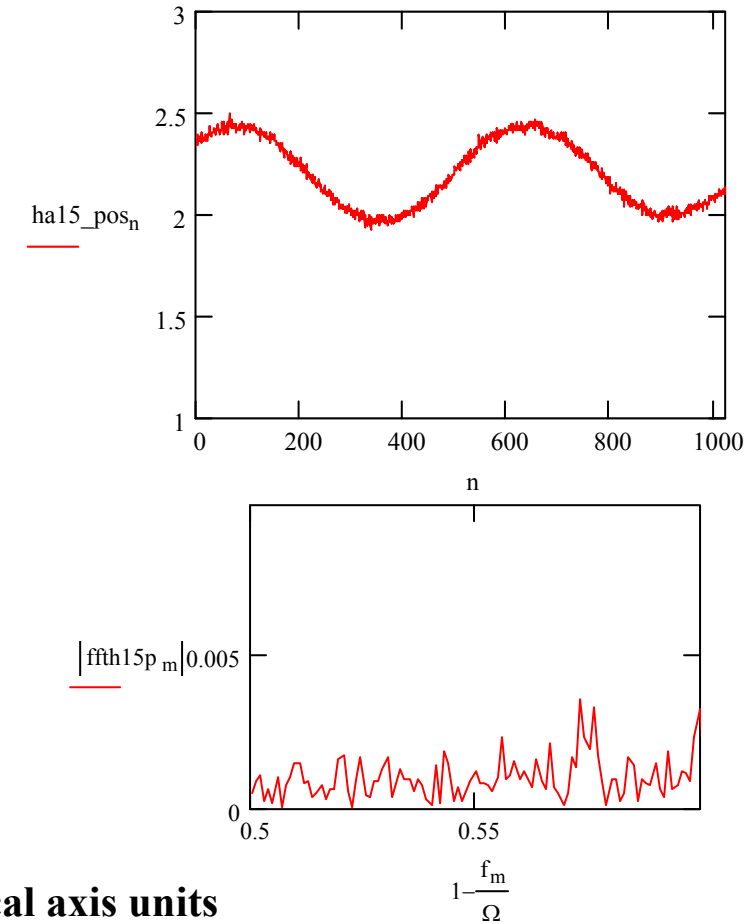
Demonstrates upper limit resolution of 9 microns rms in 1 Khz (any real beam motion not excluded) relative to spec of 7 micron 1 sigma in ~10Hz

Single Coalesced Bunch in TeV Seconds After Injection, No Kick



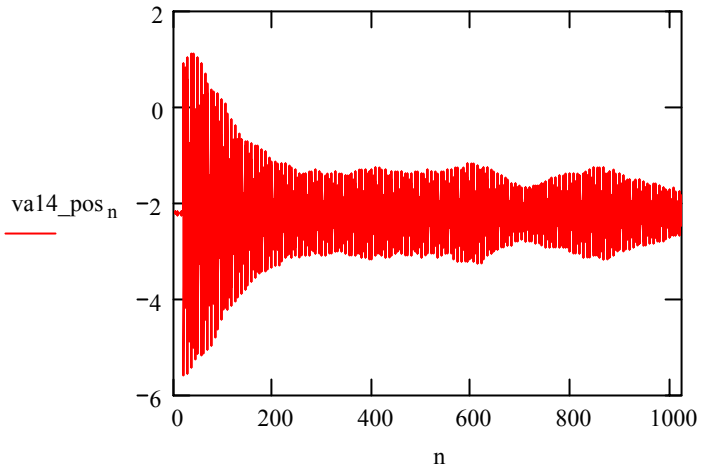
Vertical A14

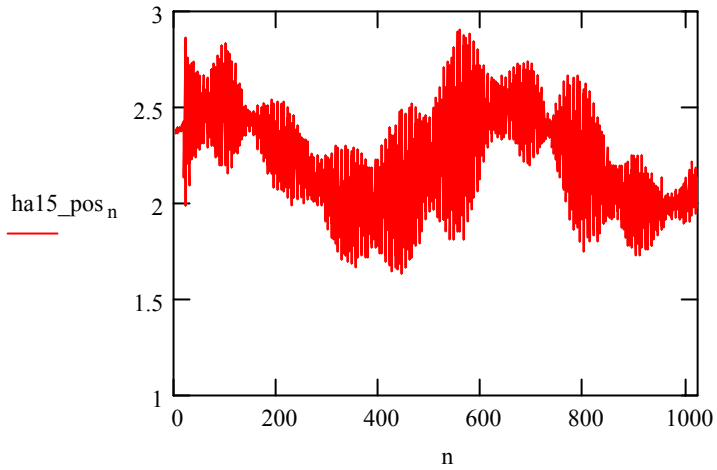
vertical axis units are millimeters in all plots

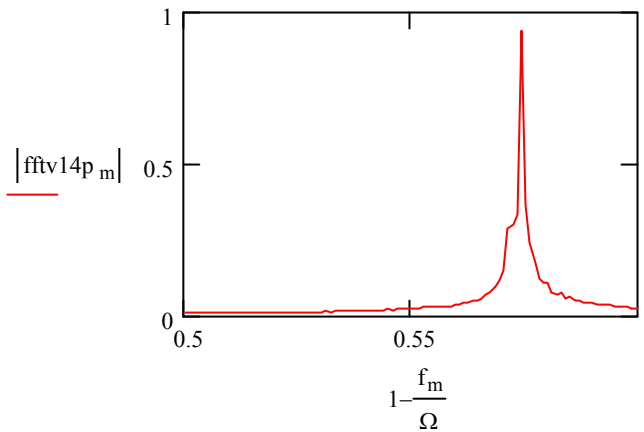


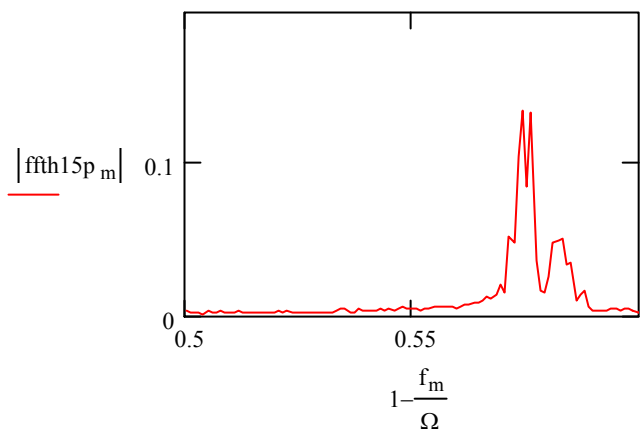
Horizontal A15

Same Coalesced Bunch Given Big Vertical Kick









Vertical A14

Horizontal A15

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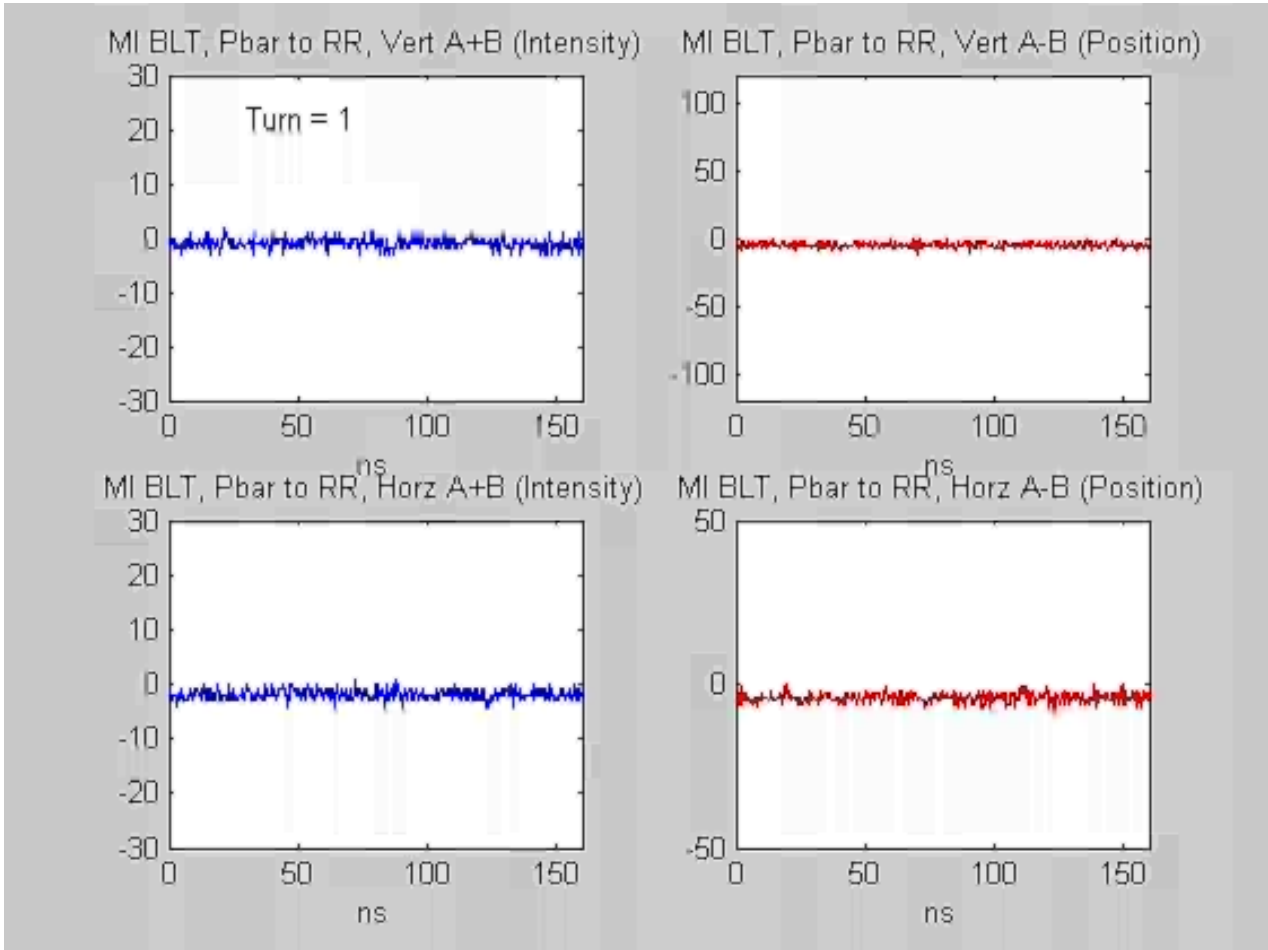
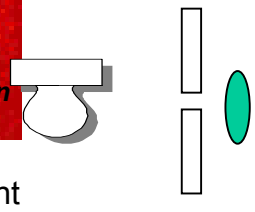
BLT: Pbars Injected into MI

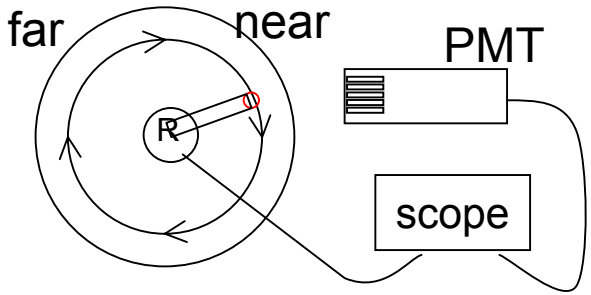
- Vertical and Horizontal BLT Sum and Difference Signals



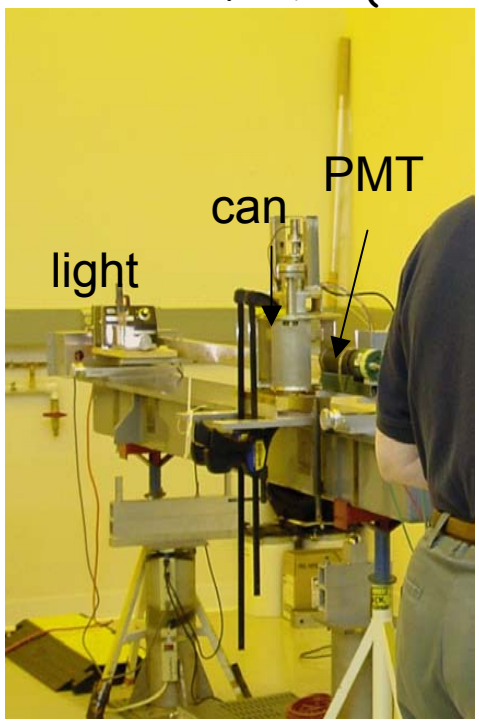
Courtesy of Vic Scarpine

Flying Wire Setup in Lab 3

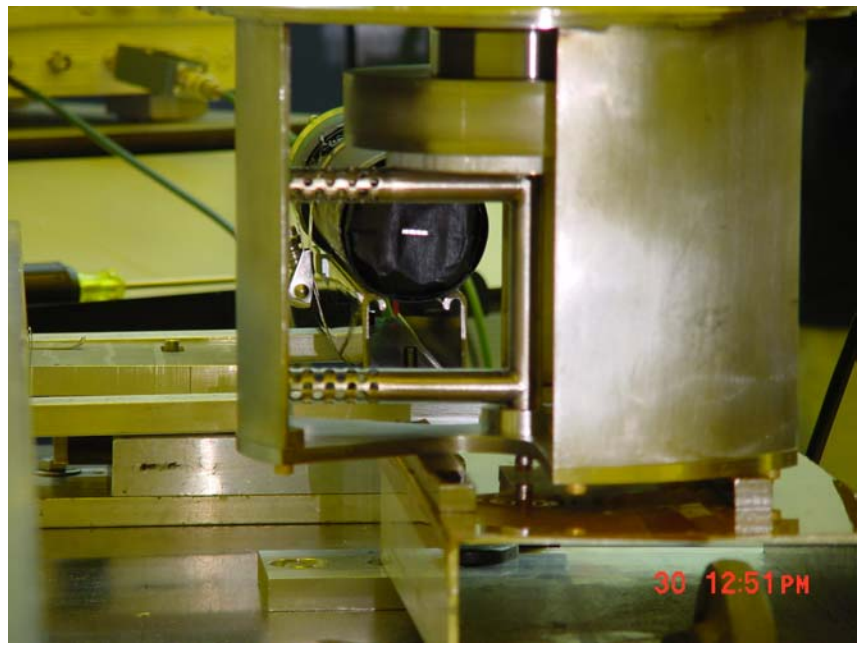




The face of the PMT is covered except for 5 slits of 25 microns spaced by 2225 microns. When the wire passes between the light and a particular slit, the PMT output is reduced. The R(esolver) gives 4096 pulses per turn.



general view



close up of PMT and fork

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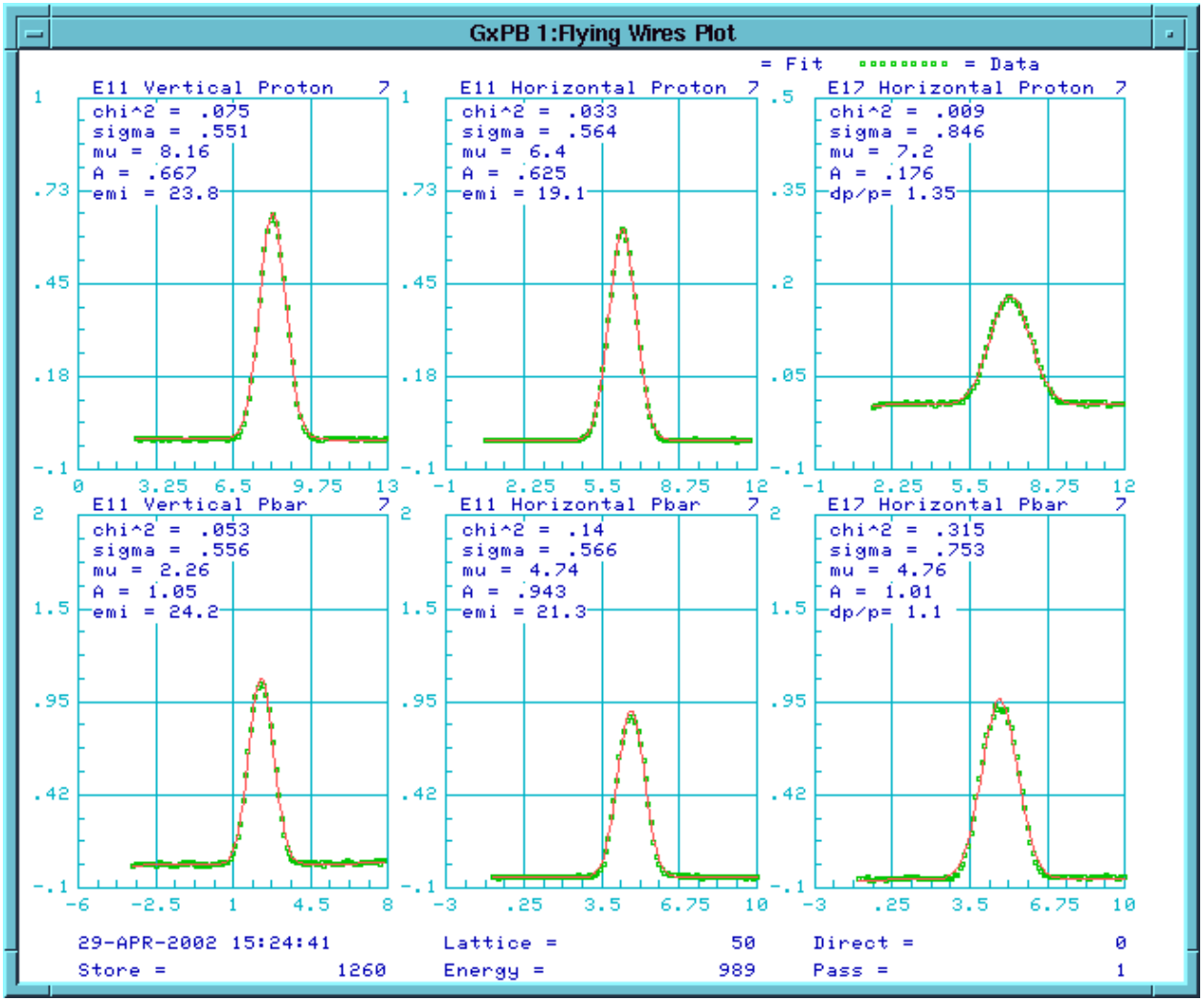
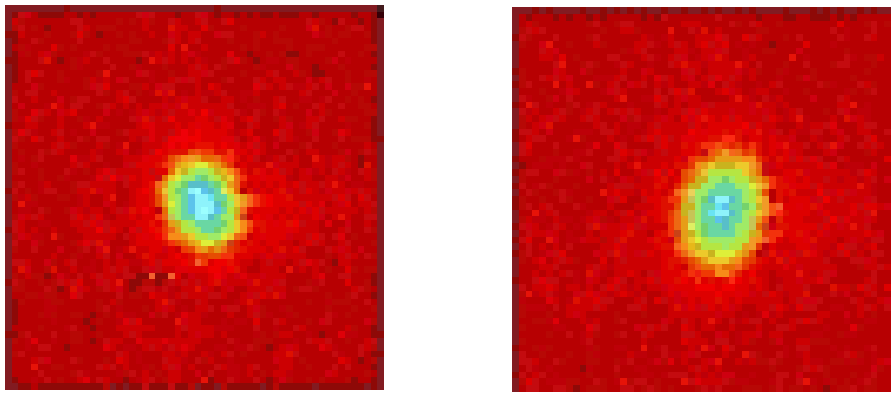
Beam Profiles from Flying Wires in Tevatron at 980 GeV



Courtesy of Stephen Pordes

Beam Instrumentation Department

Synchroton Light Images of Two Antiproton Bunches at 980 GeV

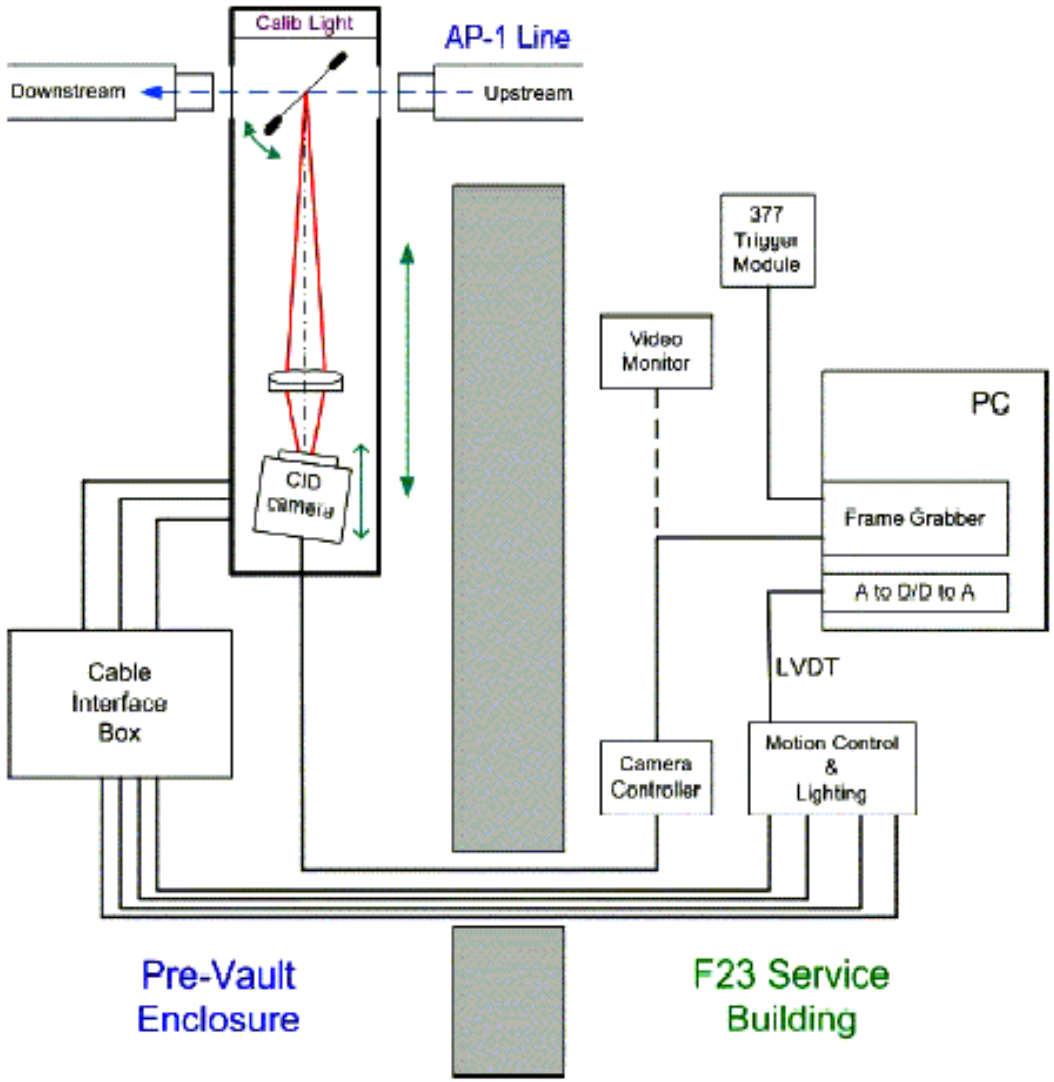


Courtesy of Stephen Pordes

Beam Instrumentation Department

Test of an Optical Transition Radiation Detector for High-Intensity Proton Beams at FNAL

Victor E. Scarpine, Alex H. Lumpkin, Warren Schappert, Gianni R. Tassotto



Beam Instrumentation Department

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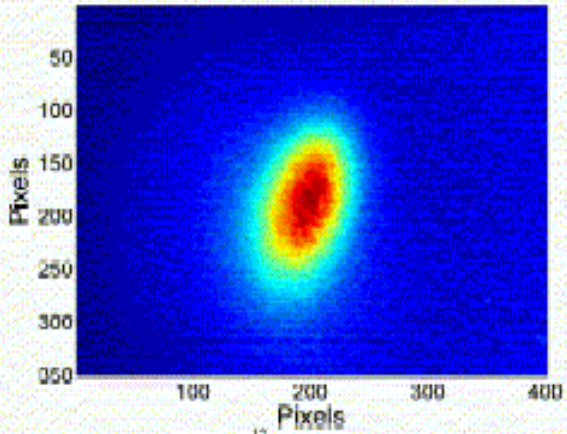


Fig. 3. OTR from 4.5×10^{12} 120 GeV protons through 12 μm titanium foil. Light intensity is attenuated by a factor of 200 to avoid camera saturation.

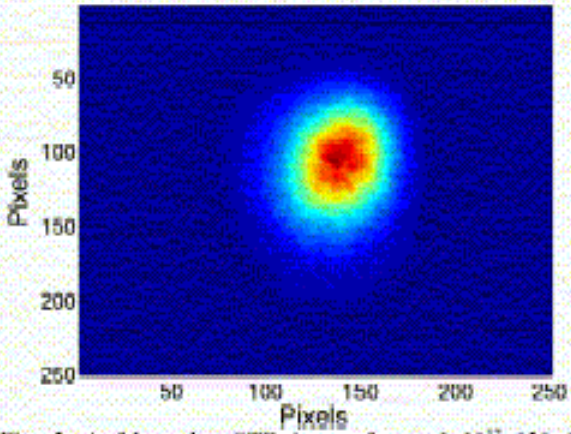


Fig. 5. A false-color OTR image from ~1×10^{12} 120 GeV protons through 12 μm titanium foil at nominal beam size.

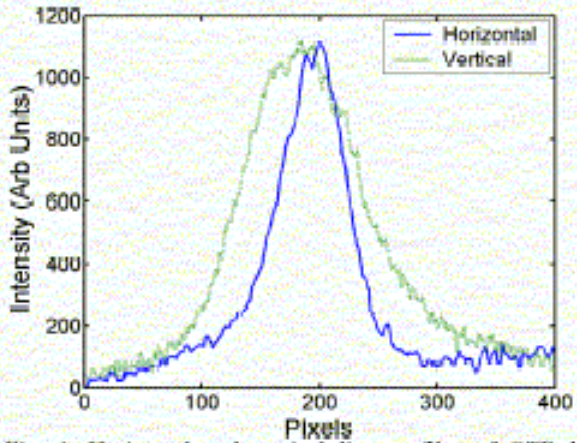


Fig. 4. Horizontal and vertical line profiles of OTR light intensity taken through the maximum of the OTR distribution.

B. OTR Shape Measurement

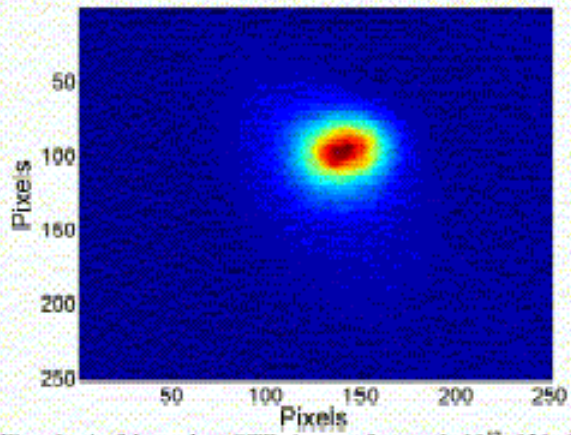
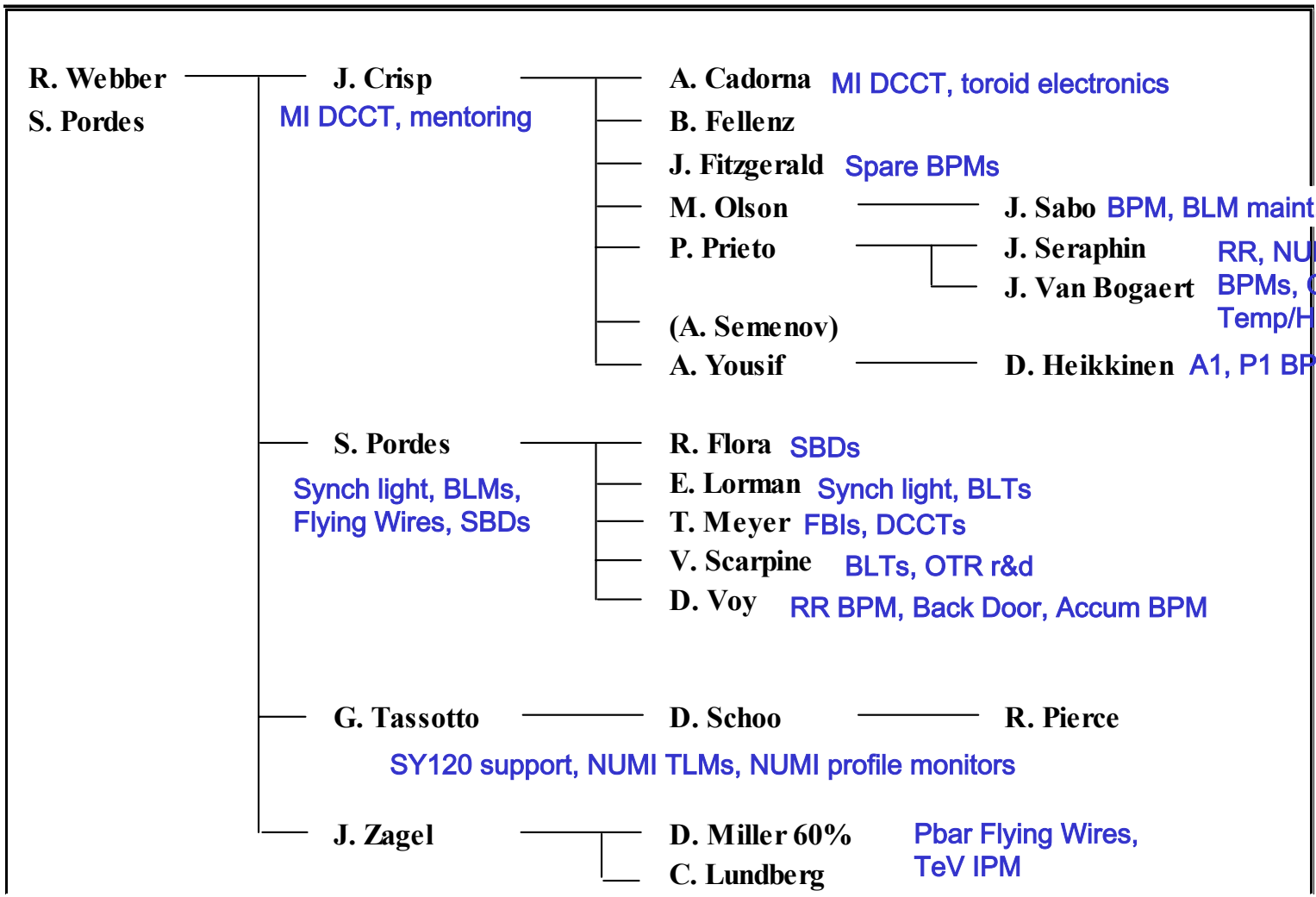


Fig. 6. A false-color OTR image from ~1×10^{12} 120 GeV protons through 12 μm titanium foil with a factor of ~2 reduction in vertical beam size.

X scale of 123 μm per pixel and Y scale of 106 μm per pixel

Current Activities



Beam Instrumentation Department

Department Efforts in February

Instrumentation Department Efforts in February

Tevatron ops	26%
SY120	21%
MI ops	11%
Default Beams	10%
Recycler ops	9%
NUMI	8%
Pbar source ops	7%
Proton source ops	5%
Tev BPM project	1%
Tev HeadTail project	0%

Beam Instrumentation Department

Collaborations/Outside Contributors

- PPD – Tev BLMs, flying wires, multiwires, electronics assembly, synch light, Flying Wire PMT and OTR mechanics
- CD – Tev BPM project, Recycler BPMs, Tev BLMs
- University of Texas – NUMI profile monitors
- And more