Overview of Electron Cooling Activities at FNAL

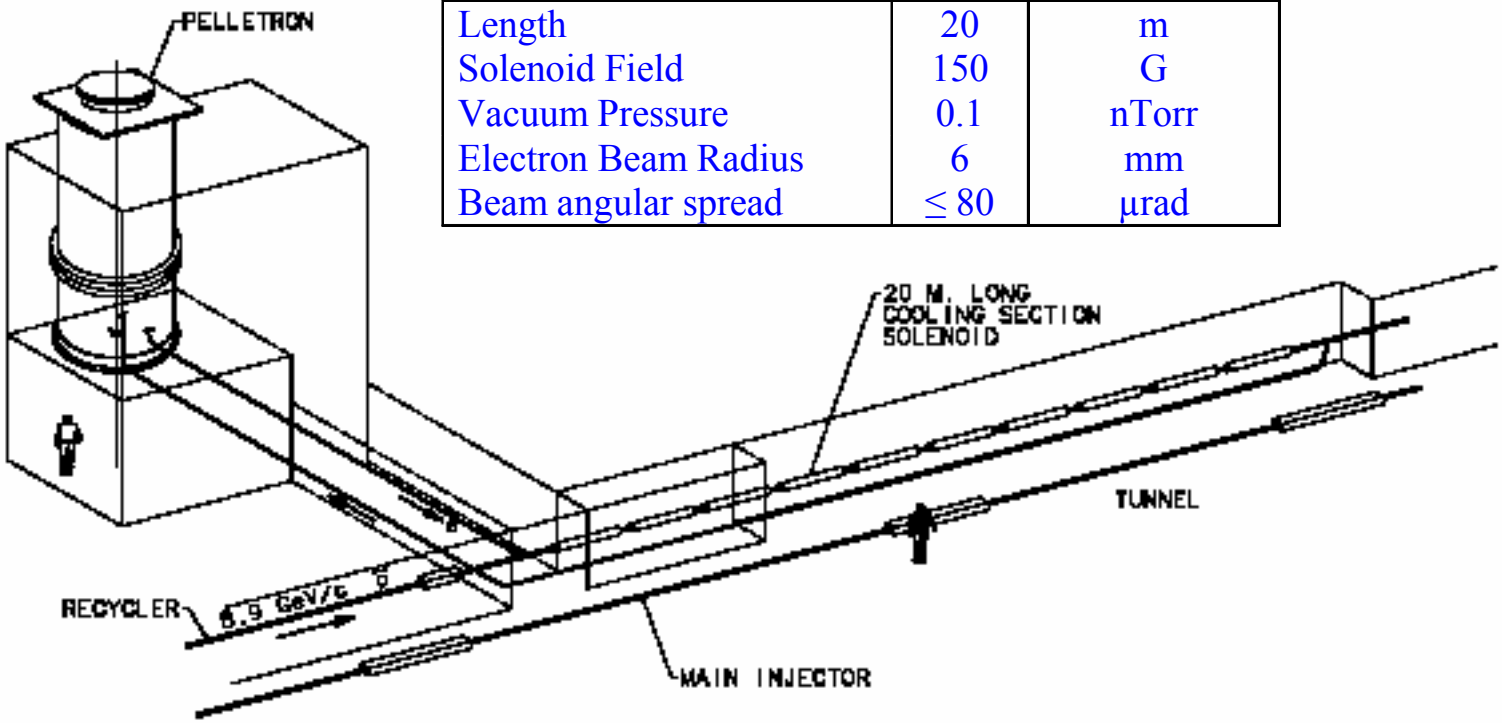
Thomas Kroc
Fermilab – Electron Cooling

EIC 2004
March 15-17, 2004
Jefferson Lab

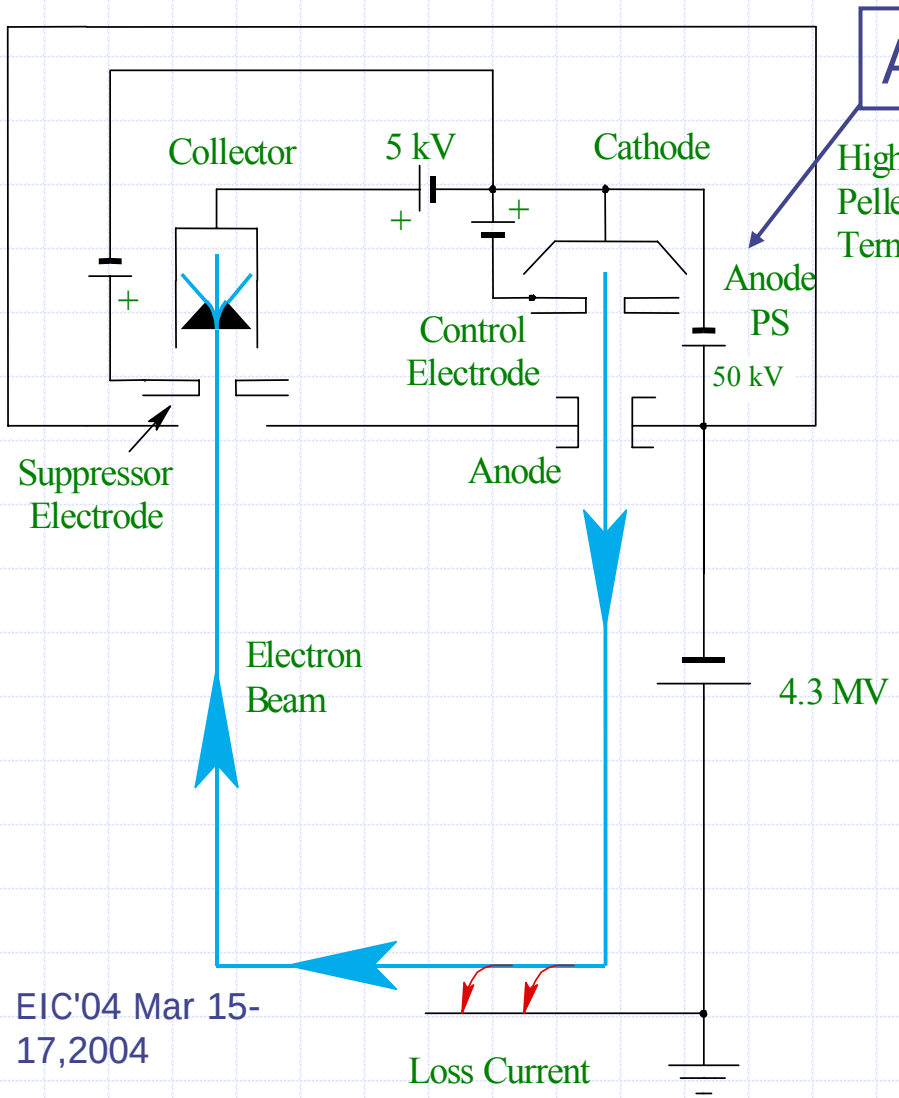
Schematic Layout of the Recycler Electron Cooling

Electron Cooling System Parameters

Parameter	Value	Units
Electrostatic Accelerator		
Terminal Voltage	4.3	MV
Electron Beam Current	0.5	A
Terminal Voltage Ripple	500	V (FWHM)
Cathode Radius	2.5	mm
Gun Solenoid Field	600	G
Cooling Section		
Length	20	m
Solenoid Field	150	G
Vacuum Pressure	0.1	nTorr
Electron Beam Radius	6	mm
Beam angular spread	≤ 80	μrad



Simplified Electrical Schematic of Recirculation

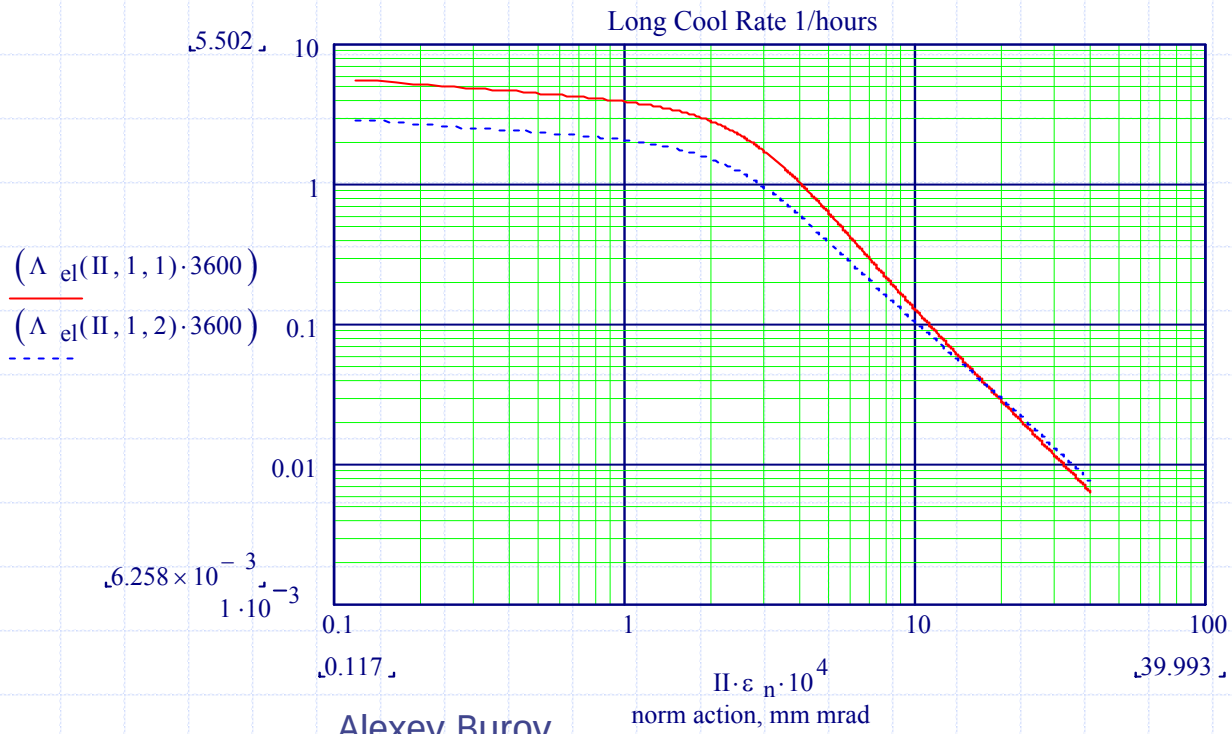


For I=.5A, ΔI=5μA

- Beam Power 2.15 MW
- Power in current loss 21.5 W
- Power dissipated in collector 2.5 kW

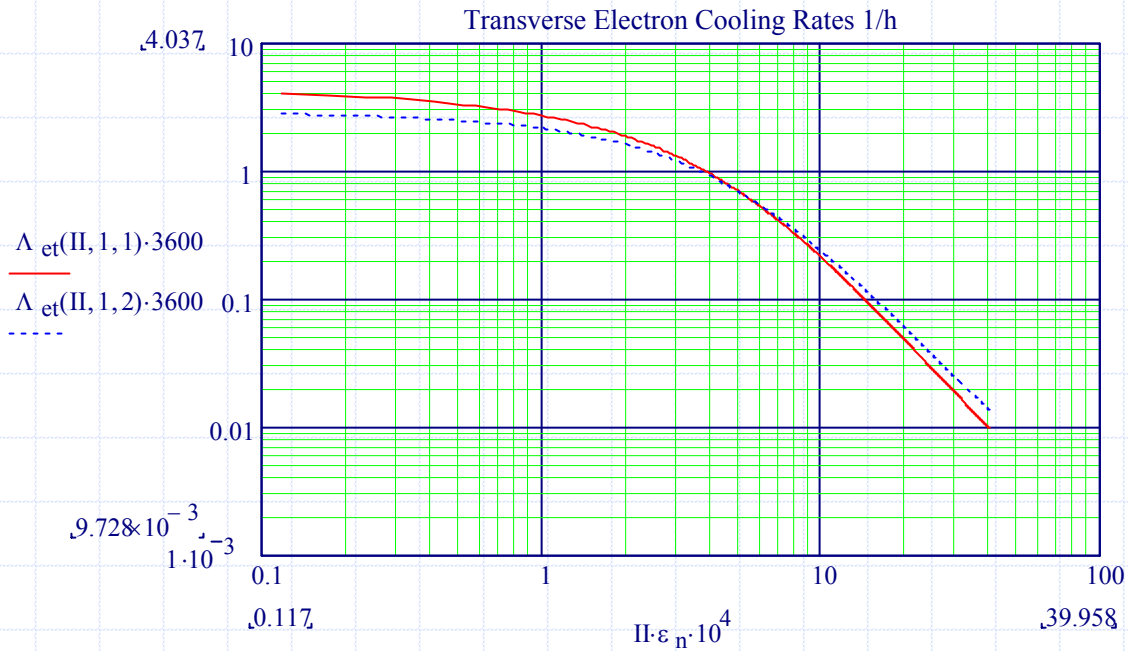
Longitudinal rates

- Both longitudinal and transverse electron cooling of pbars look attractive for the Recycler, especially with vacuum (1-3 pi mm mrad/h) improvements after the last summer shutdown. Figures below are calculated for 0.5 A of the electron current and 0.2 mrad of the effective 1D rms angle of the e-beam.

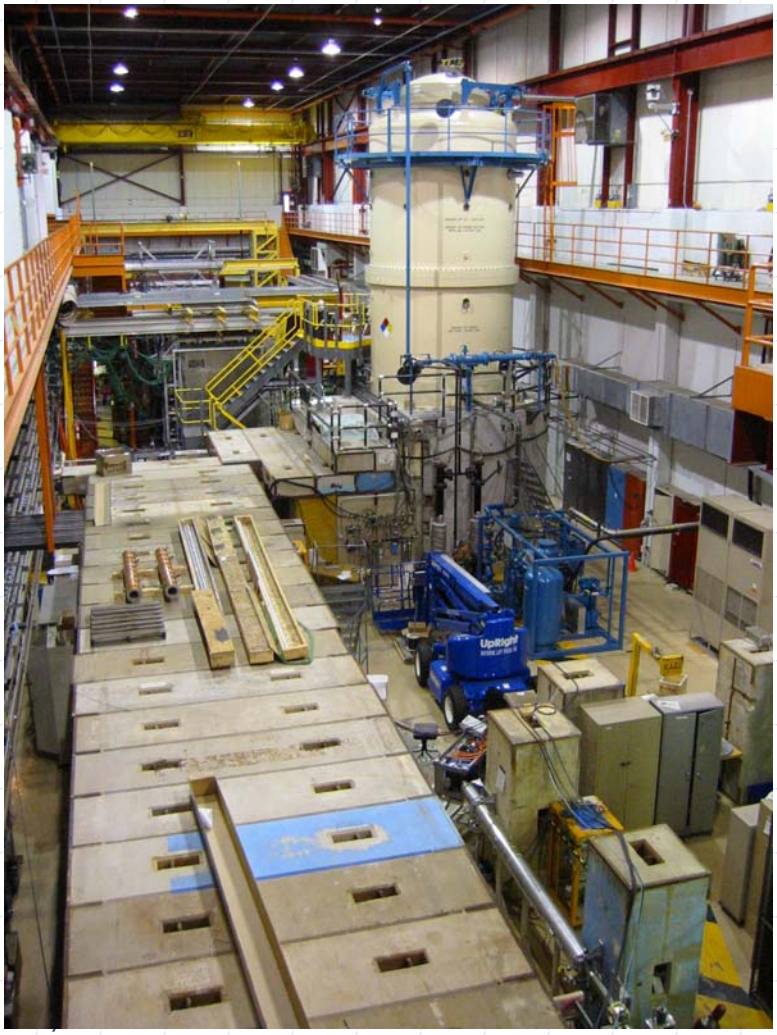


Transverse rates

- The transverse rate is shown here. Both curves are calculated for norm rms emittance of 1.2 mm mrad. The horizontal axis is the action in mm mrad (averaged action = norm rms emittance) for the longitudinal core (red) and tail (blue) particles. For the bulk of the beam, the e-folding time is 20 min or shorter. The rates are defined as action logarithmic derivatives.



Full Scale Beamline at Wideband

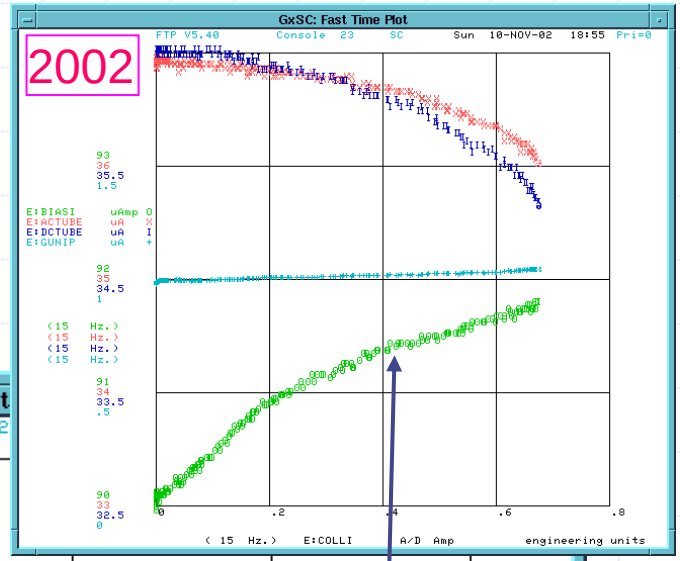


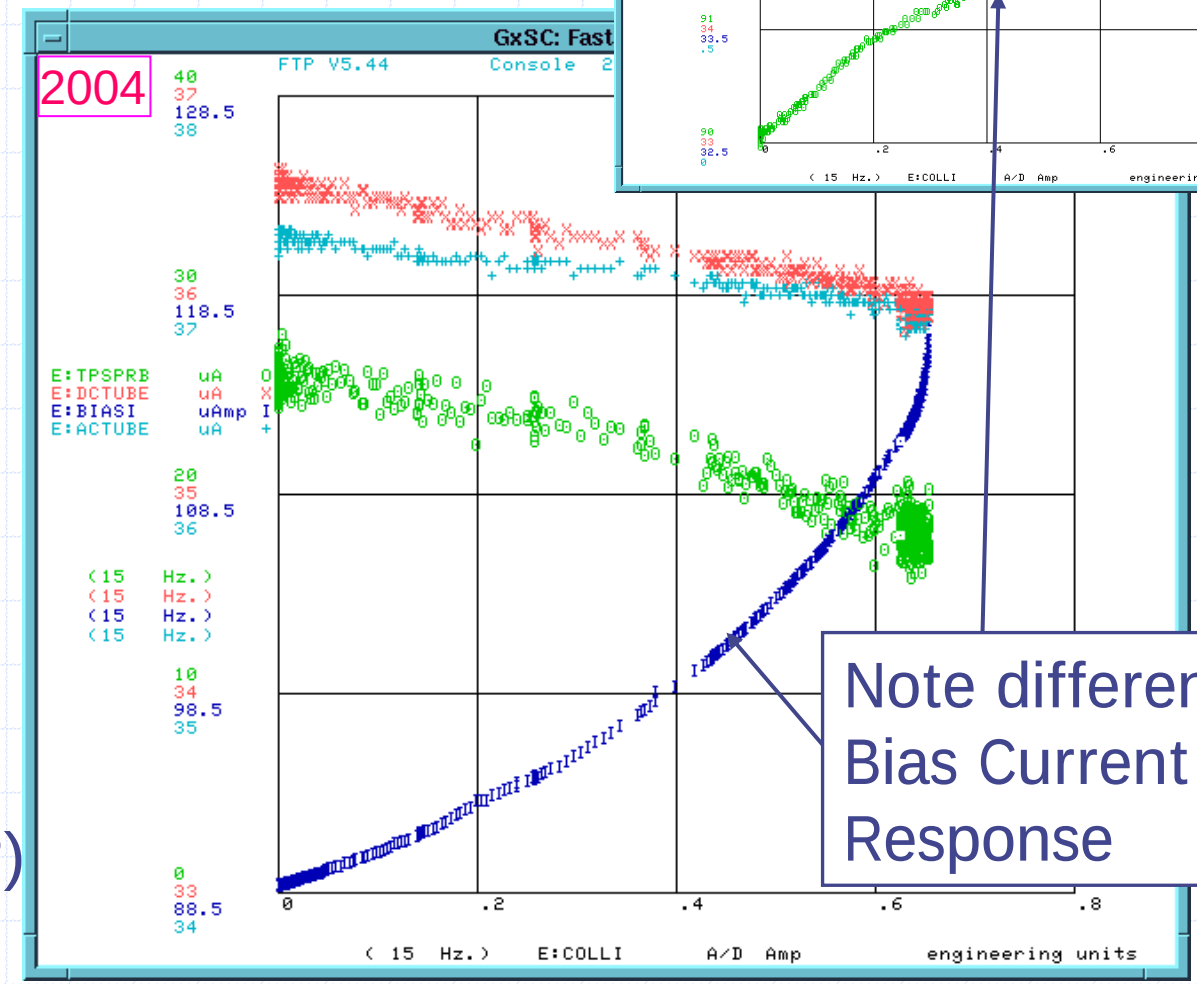
Milestones

- Low intensity DC beam in collector Jul 03 √
- Stable .5A at 3.5 MeV Dec 03 √
- Cold Beam at .5A, 3.5 MeV Mar 04

Recirculation

Comparison of 180 U-bend test with full beam line



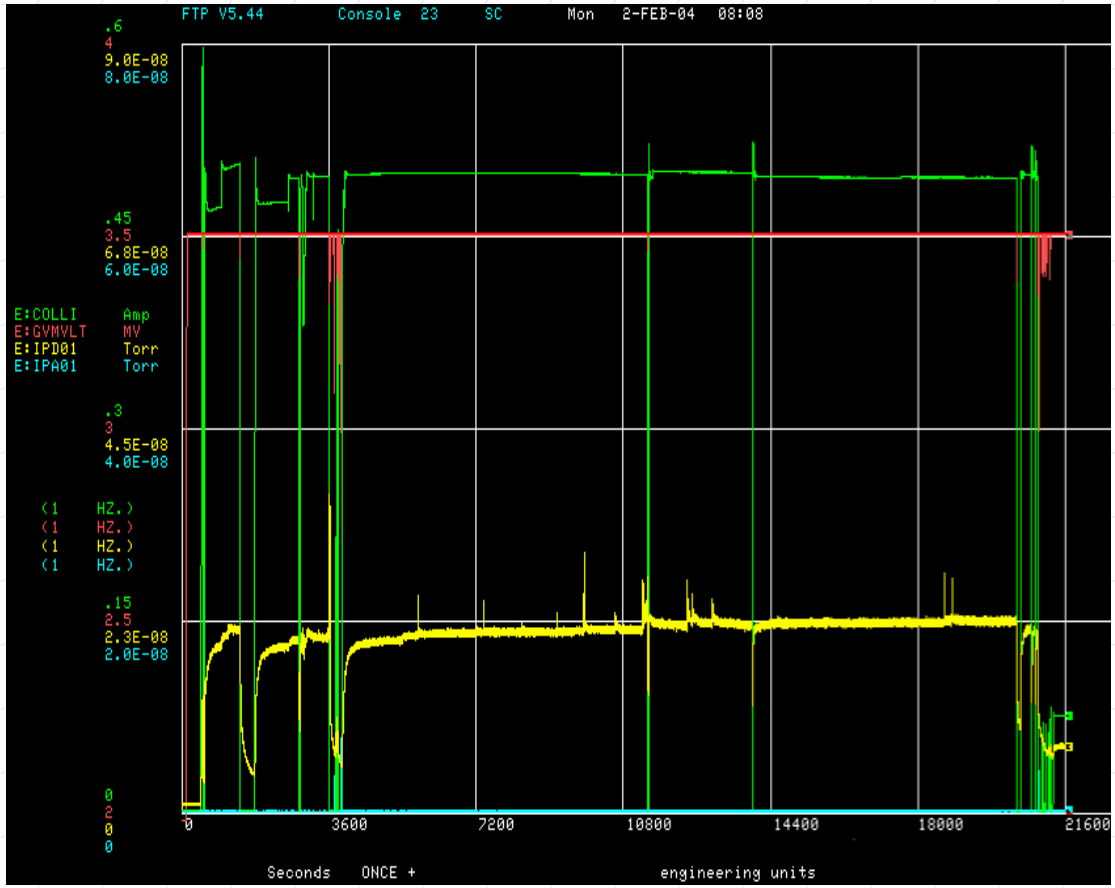


Difference in Bias current response due to different loss characteristics in line (affecting beam envelope ?)

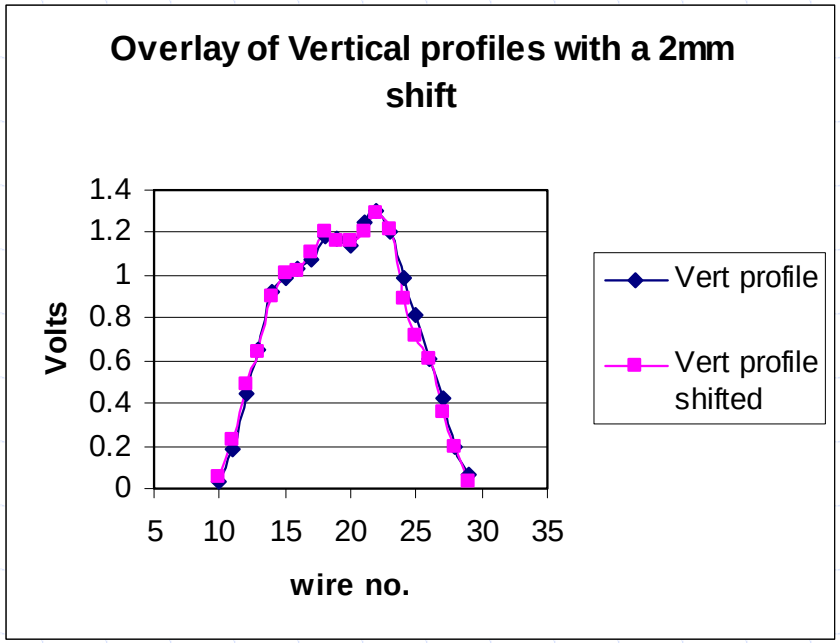
Note different Bias Current Response

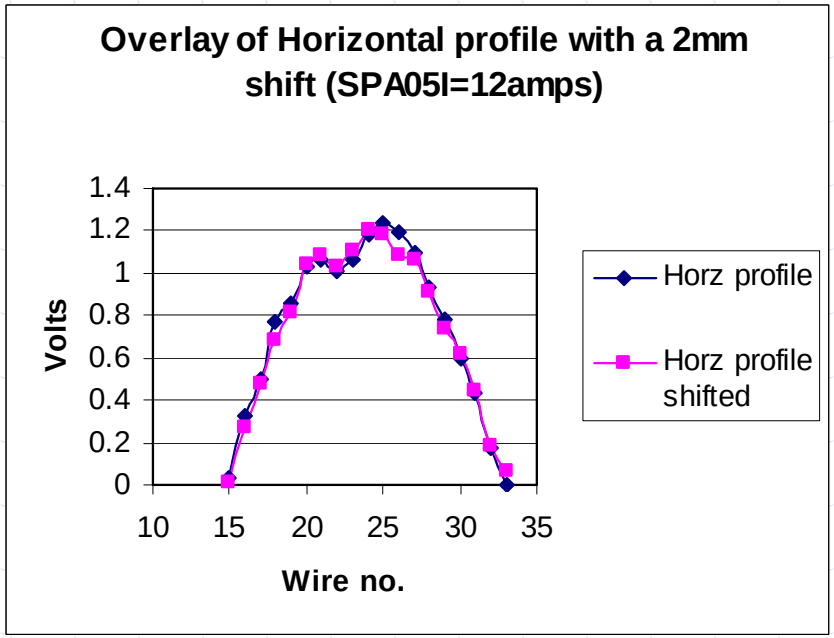
Stability

- 500 mA, 4.5 hour run
- 3 interuptions
- Restored within 12 seconds by FSM



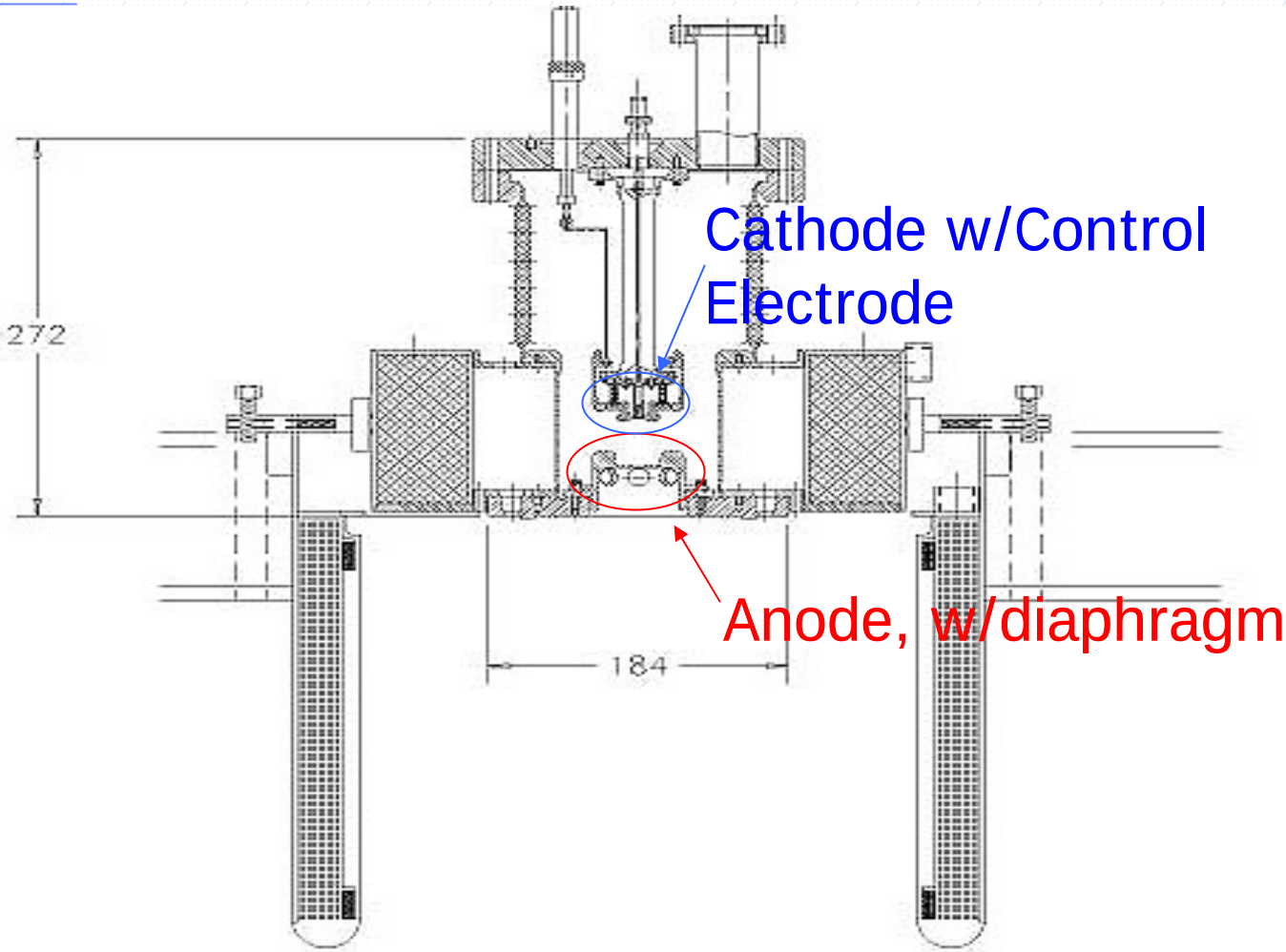
Multiwire Profile data





- Comparison of profiles that are shifted by 2mm
- ±2% relative variation

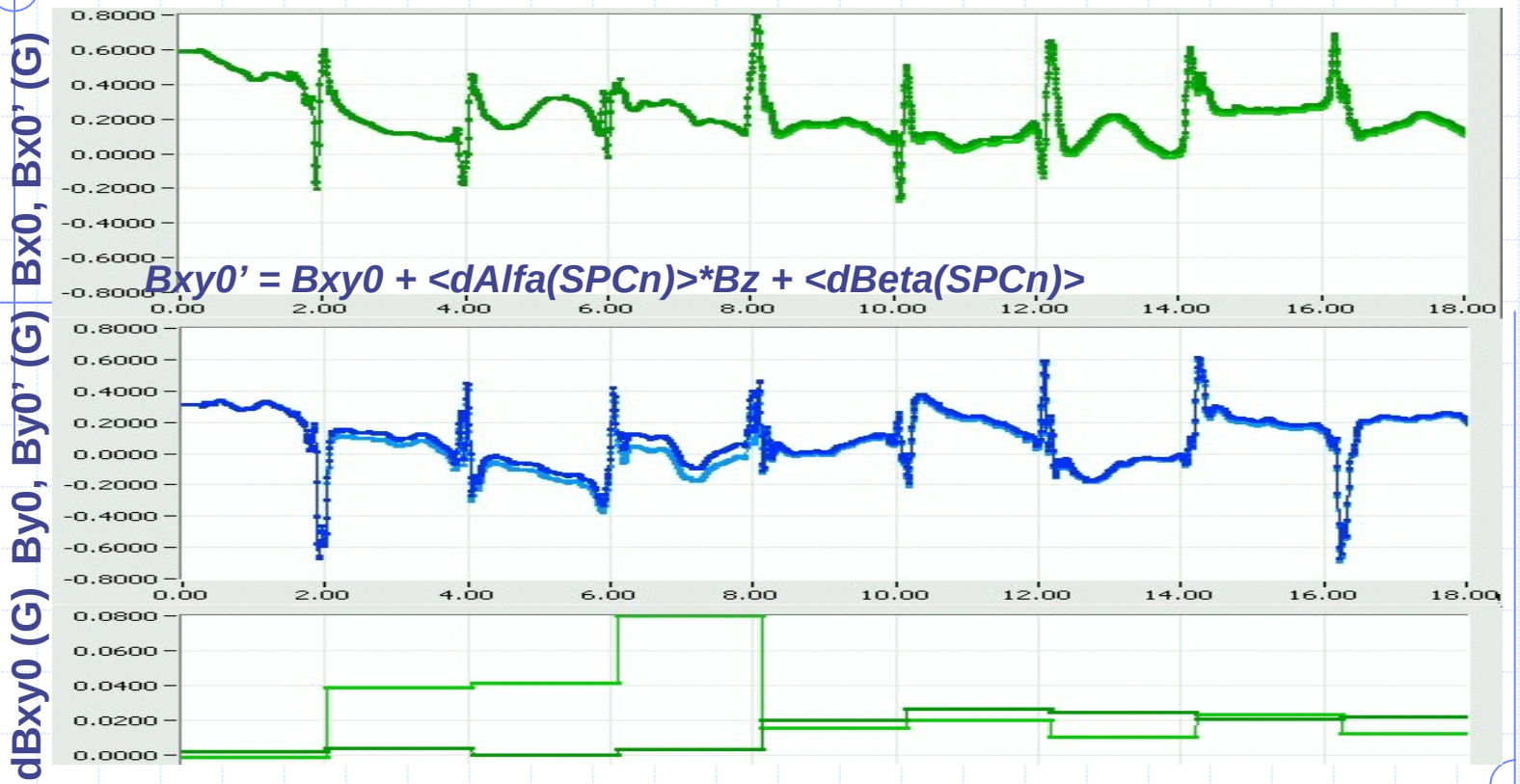
Gun Schematic



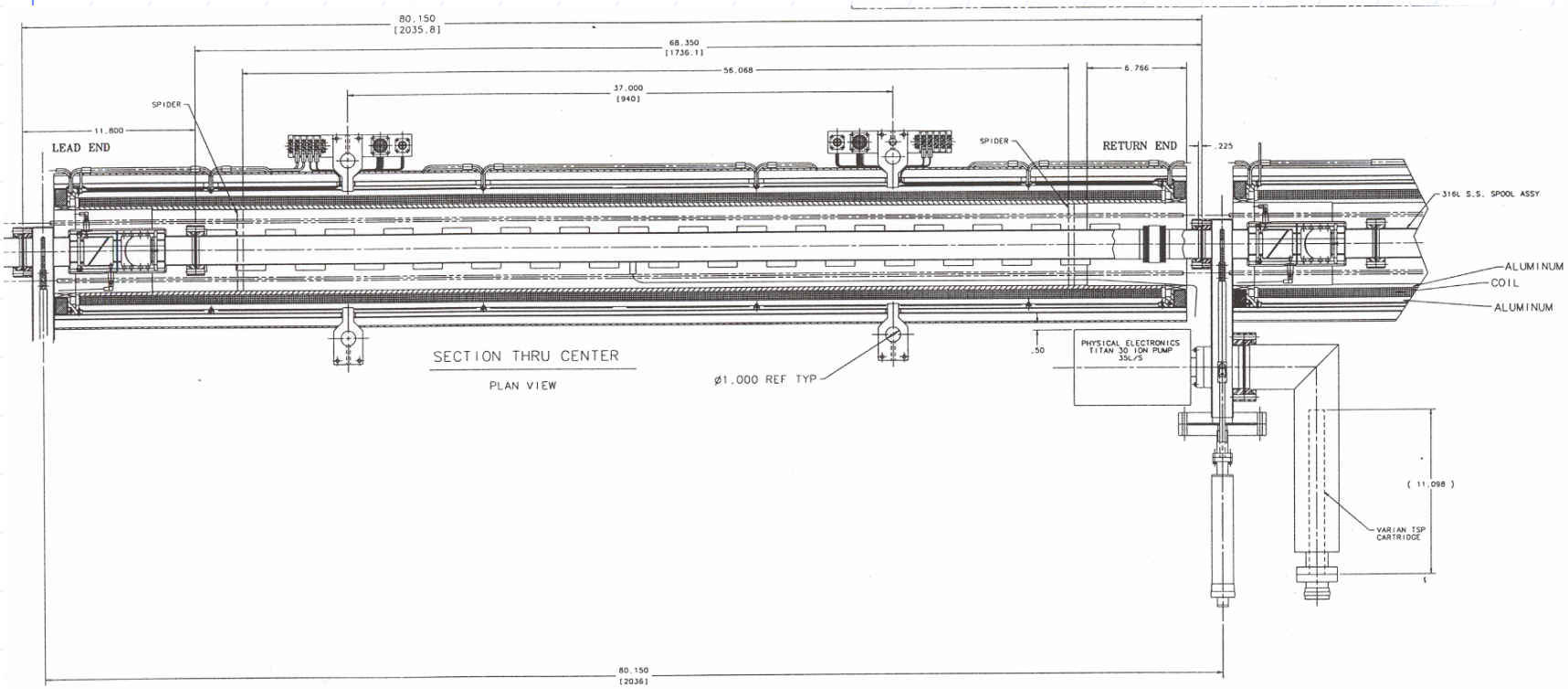
Gun assembly with solenoids

Field Maps of Cooling Section

-- based on August measurements for Bz=100G --



Drawing of a Cooling Module

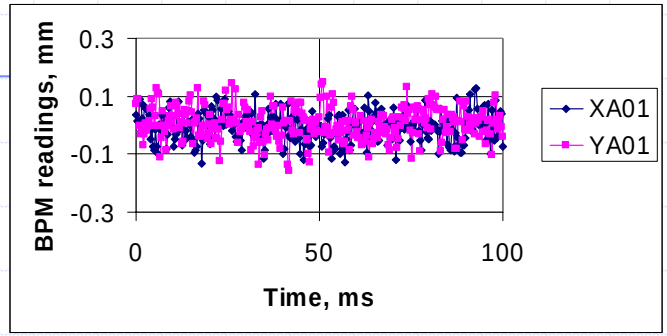


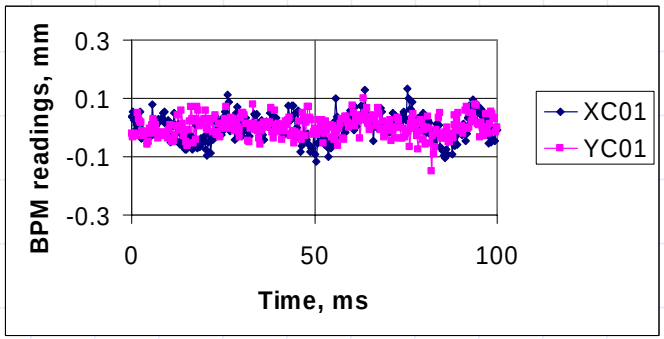
Angles in the Cooling Section

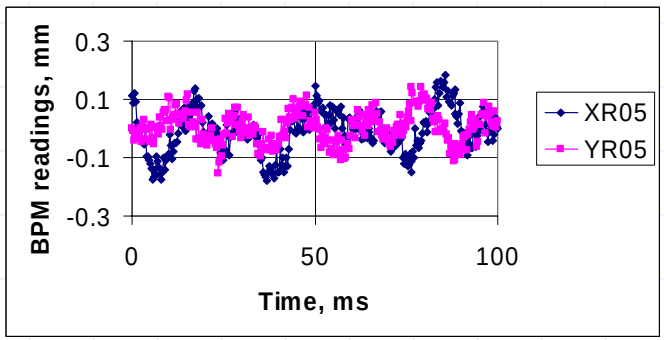
The best RMS values, in mrad. The goal is 0.08 mrad for each.

	Value	Comments
Central trajectory	0.3	Without CS field corrections
	0.2	With field corrections
Boundary electron with respect to the center	0.6	I = 0.35 A, Bcs=100G, beam diameter 9 mm
Trajectory oscillations and drift	0.1	I = 0.17 A, 3 Hz- 1 kHz
	0.2	In a shift
	?	> 1 kHz

Beam Oscillations







- A program records readings from a single BPM channel with 3 kHz rate
- The largest component in the most of signals is 30 Hz (29.6 Hz), and the next is 60 Hz
- 30 Hz component is the largest one in the CPO (Pelletron voltage) signal as well
- The beam oscillations may be originated by terminal mechanical motion, oscillations of HV, fields from motors and power grid, ...

Diagnostics

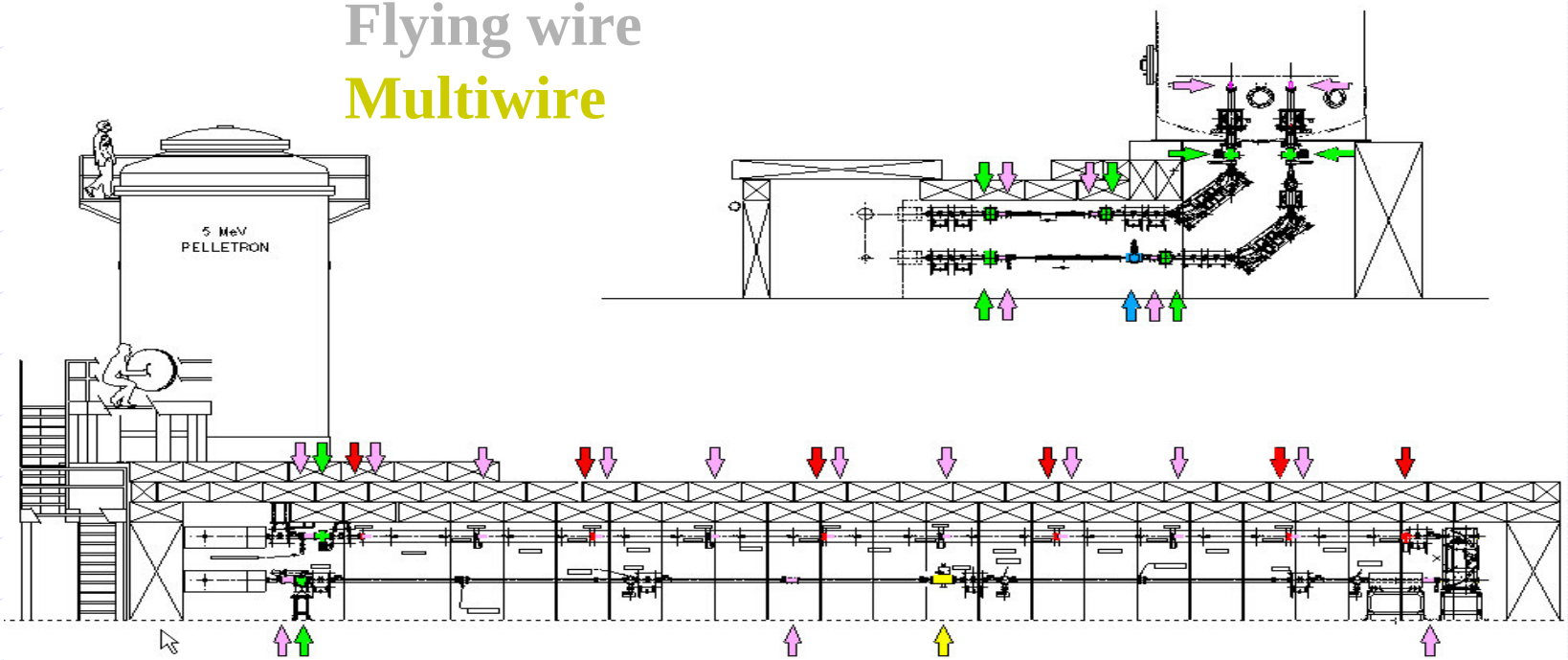
Wire scanner

BPM

Scraper

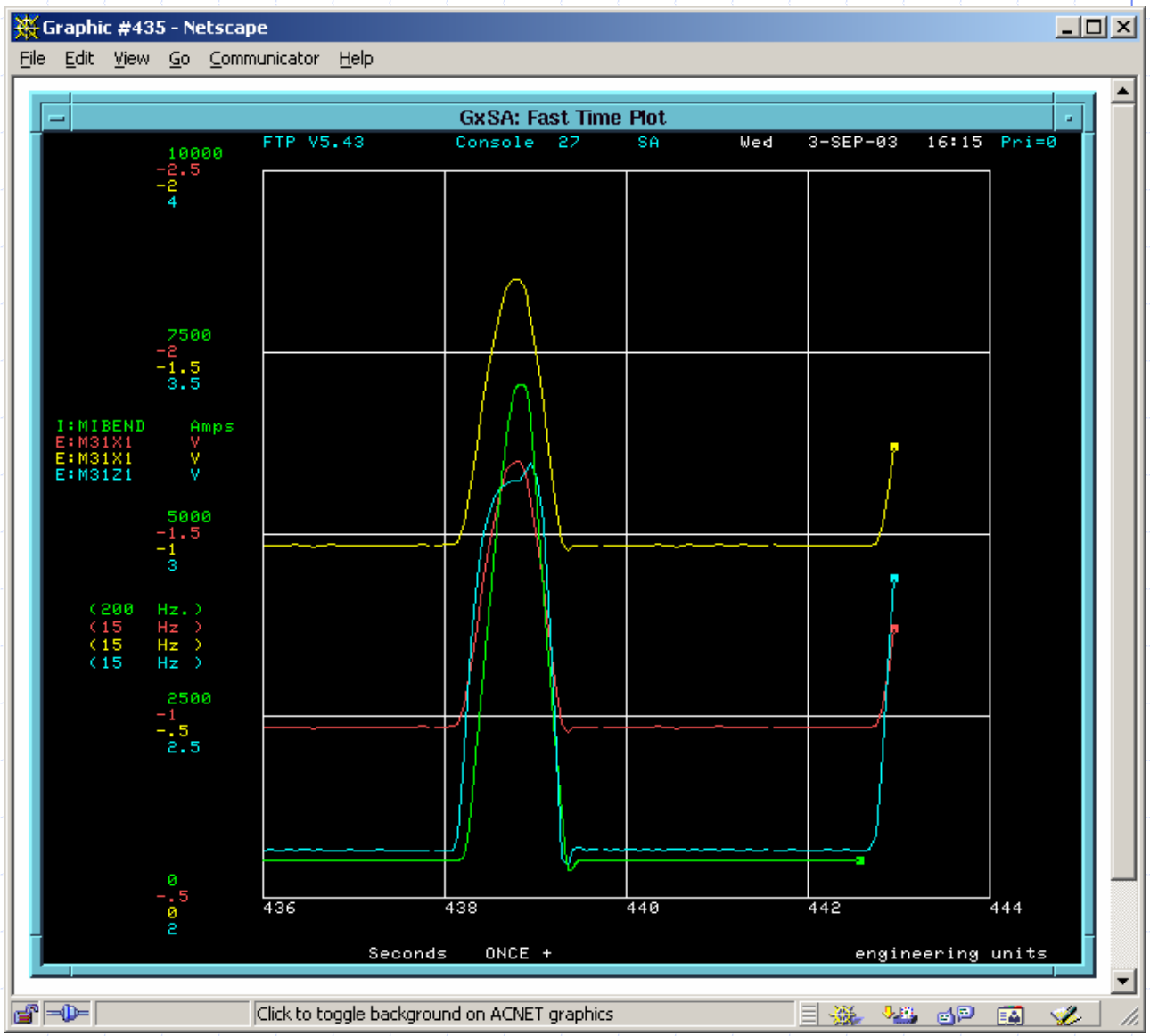
Flying wire

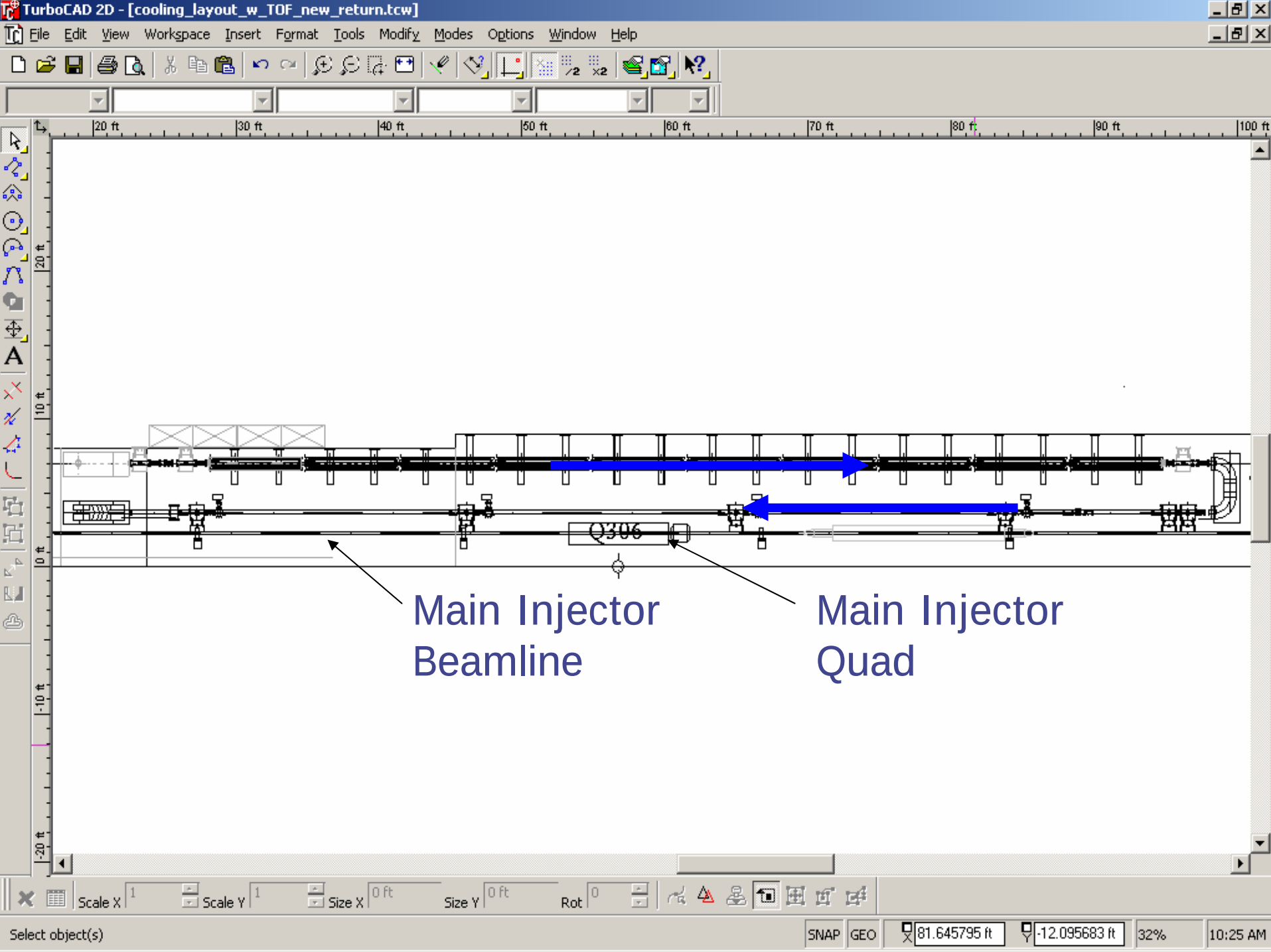
Multiwire



Magnetic Shielding

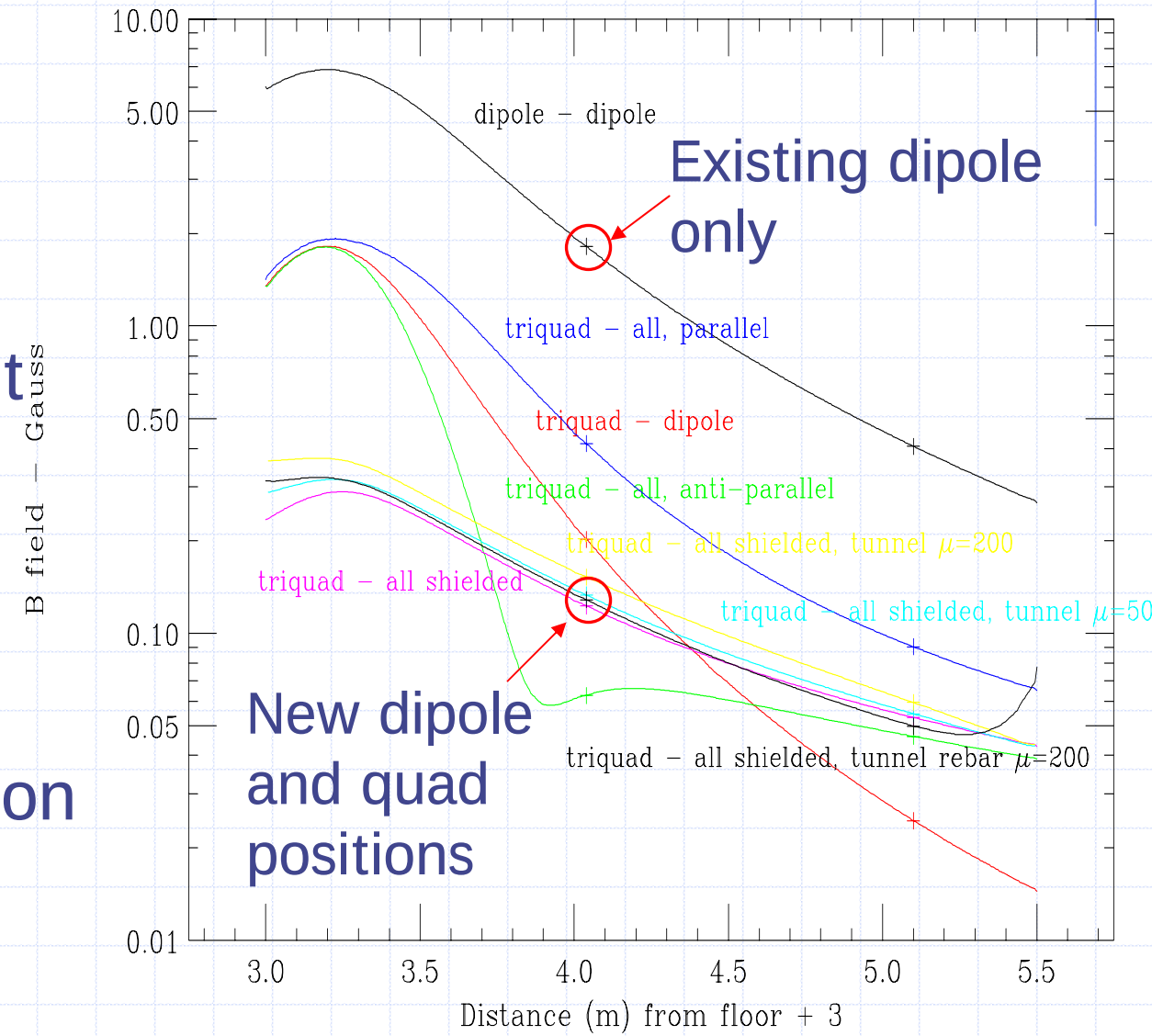
- MI Ramp ~ .5 Hz
- Fields due to busses, Q306




TurboCAD 2D - [cooling_layout_w_TOF_new_return.tcw]
File Edit View Workspace Insert Format Tools Modify Modes Options Window Help
20 ft 30 ft 40 ft 50 ft 60 ft 70 ft 80 ft 90 ft 100 ft
20 ft 10 ft 0 ft -10 ft -20 ft
Q306
Main Injector Beamline
Main Injector Quad
Scale X 1 Scale Y 1 Size X 0 ft Size Y 0 ft Rot 0
Select object(s)
SNAP GEO X 81.645795 ft Y -12.095683 ft 32% 10:25 AM

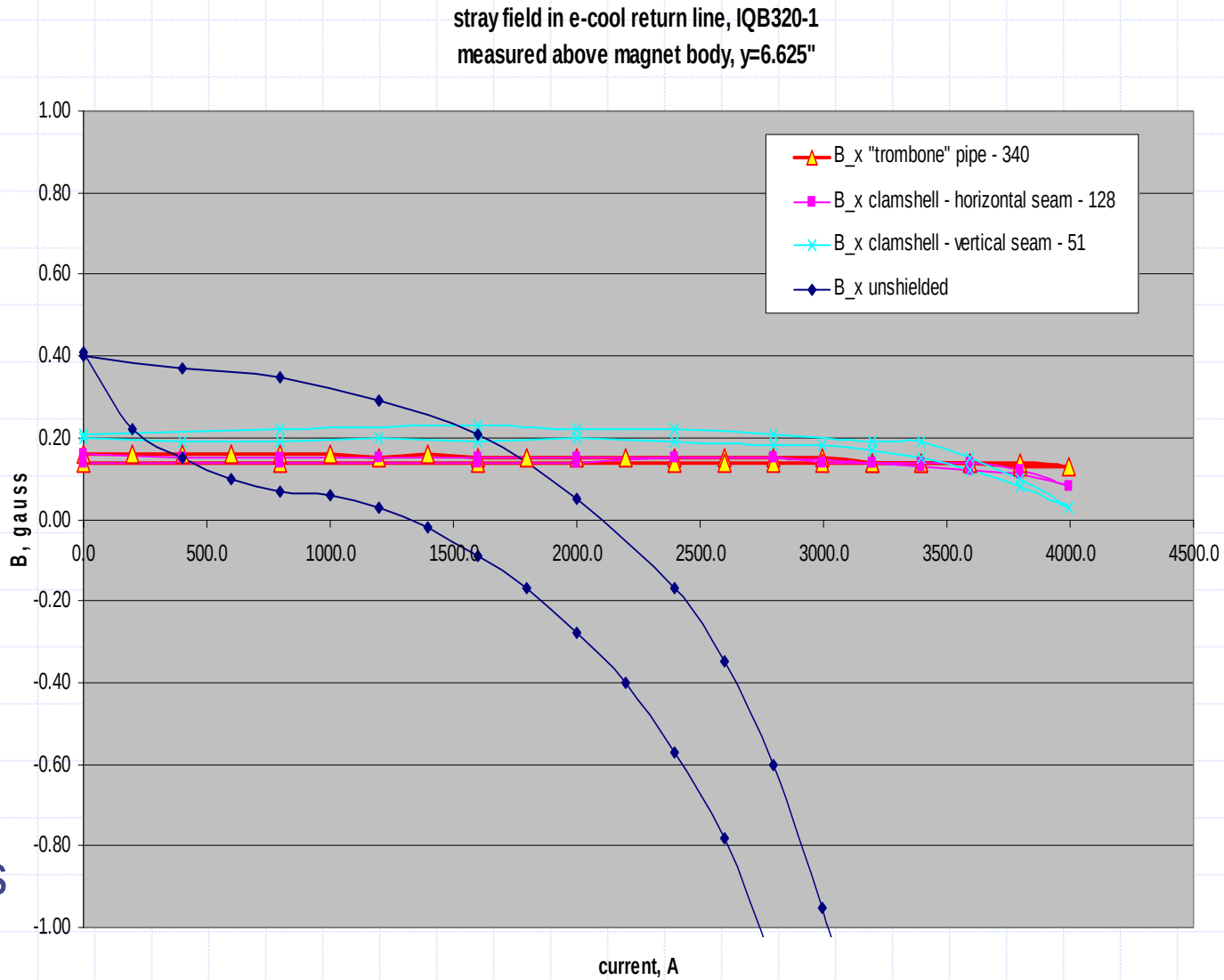
Bus Configuration

- Triquad bus
- 3 parallel busses
- Center full current
- 2 returns – half current
- Dipole and quad bus
- Quad compensation loop

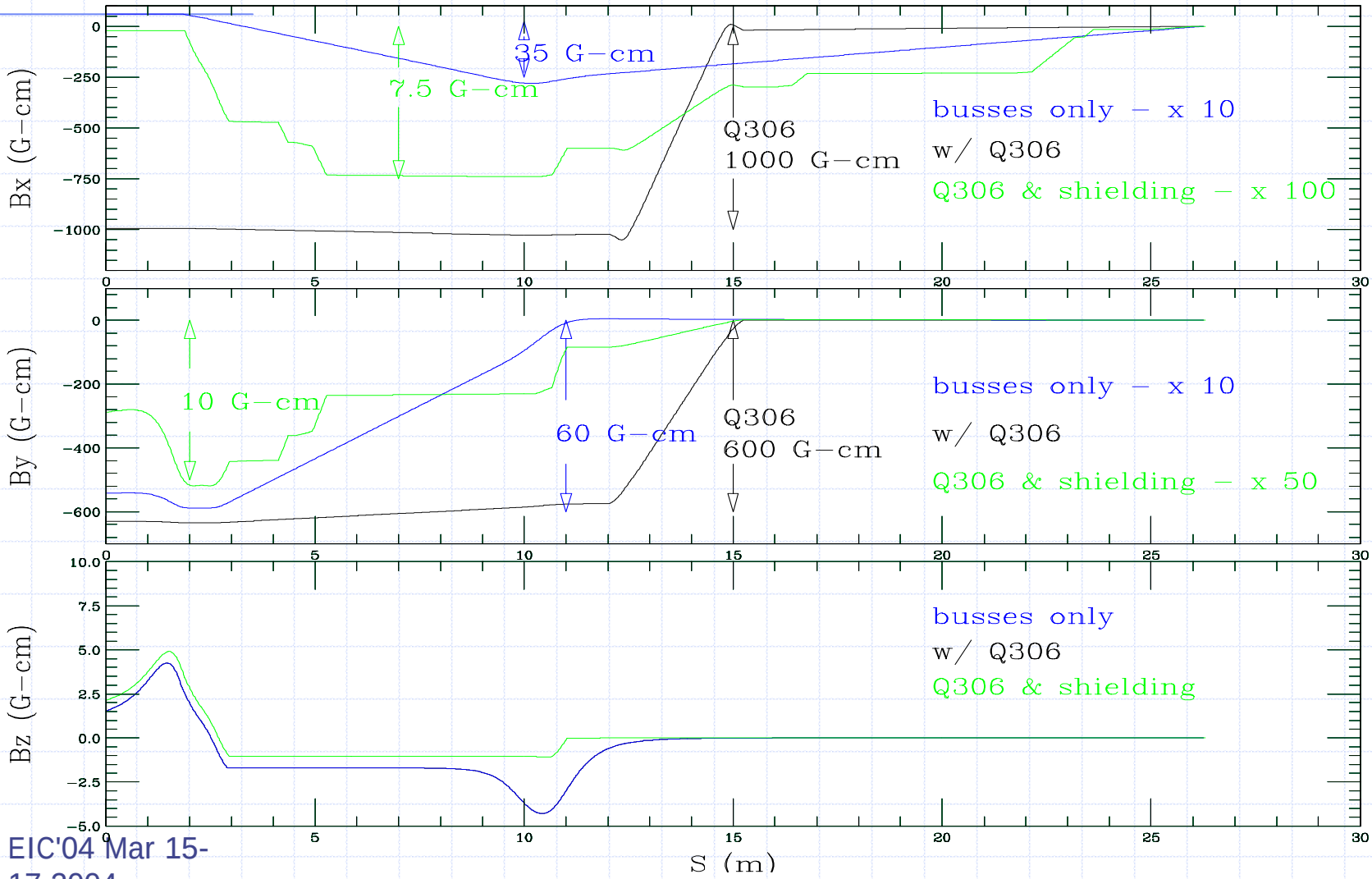


Magnetic Shielding

- Tested two shields
- Telescoping “trombone”
- 2 halves
- 2 orientations



Integrated Fields



To Do List:

- High Losses
- Gun lifetime
- Beam Motion
- Drifts
- Conditioning
- 4.3 MeV
- Magnetic Shielding
- Energy Cal.
- Detection of Cooling

Schedule

- Now – cold beam (not yet)
- 4/20/04 – new enclosure complete
- 6/1/04 – disassemble Pelletron, begin move
- 8/23 – 11/19 – shutdown for tunnel installation, resume reassembly
- 3/1/05 – commission Pelletron
- 5/1/05 – commission ecool
- 12/1/05 – Electron Cooling Operational

Commissioning stages

- HV commissioning of the Pelletron (1 month)
- U-bend recirculation (1 month)
- Full beam line (4 month)
  - Pulsed beam
  - DC beam
- Pbar – electron beam: position matching (1 month)
- Energy matching (1 month)
- Cooling rate measurements
- Electron beam optimization