# Electron Cooling Status

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February 24-25, 2004

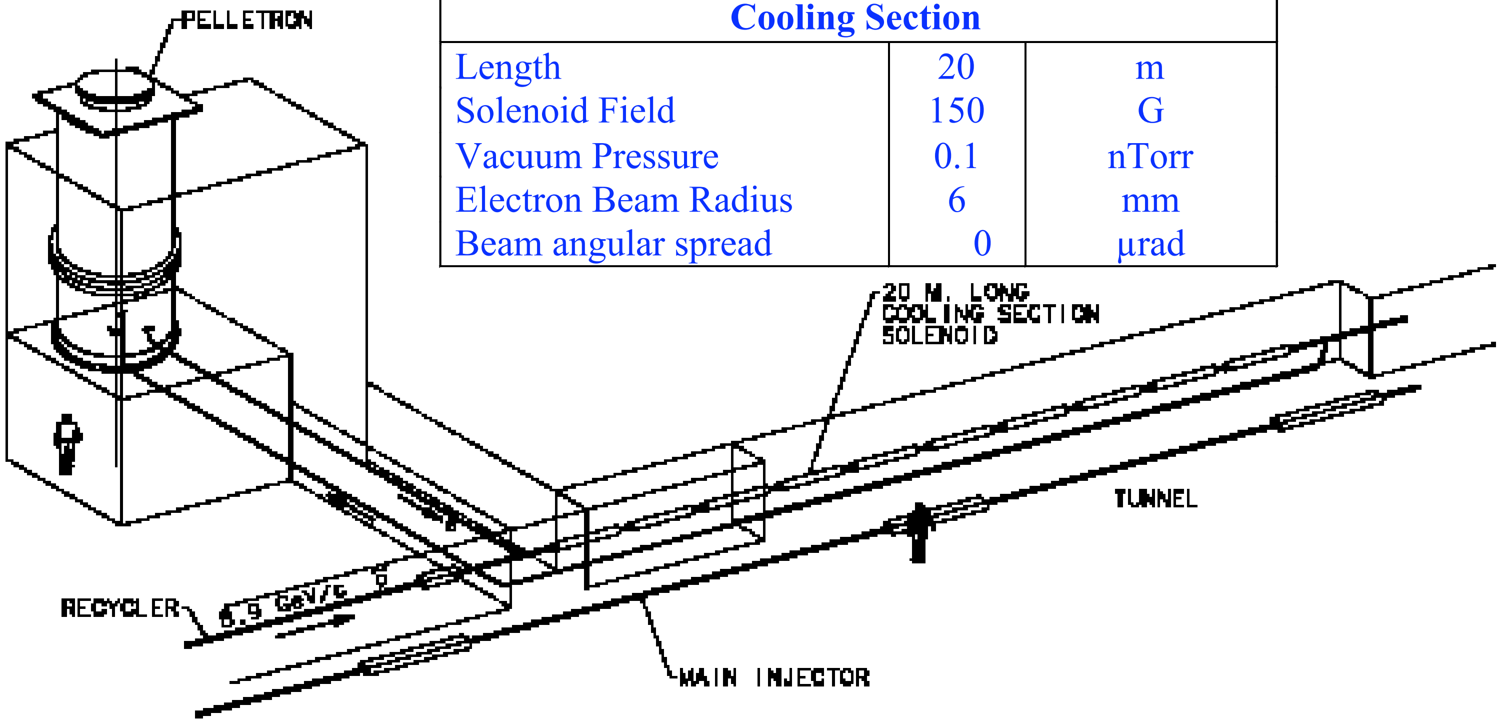
# Electron Cooling Status -- Summary

- The R&D project is on schedule
  - Milestone (500 mA) achieved on Dec 30, 2003
  - The beam current is reproducible but not very stable yet
  - Next and final milestone (beam properties) looks attainable
- The MI-31 building construction is on schedule and within budget
  - 82% complete at end of January
  - Tentative partial beneficial occupancy date 4/1/04
  - Tentative completion date 4/20/04
  - Currently on schedule and within budget
- Installation at MI-31 and in the tunnel
  - All Pelletron extension parts received
  - Misc. components ordered
  - Electrical racks for building and control room are due and T&M req. in-place to outfit them
  - Installation schedule developed

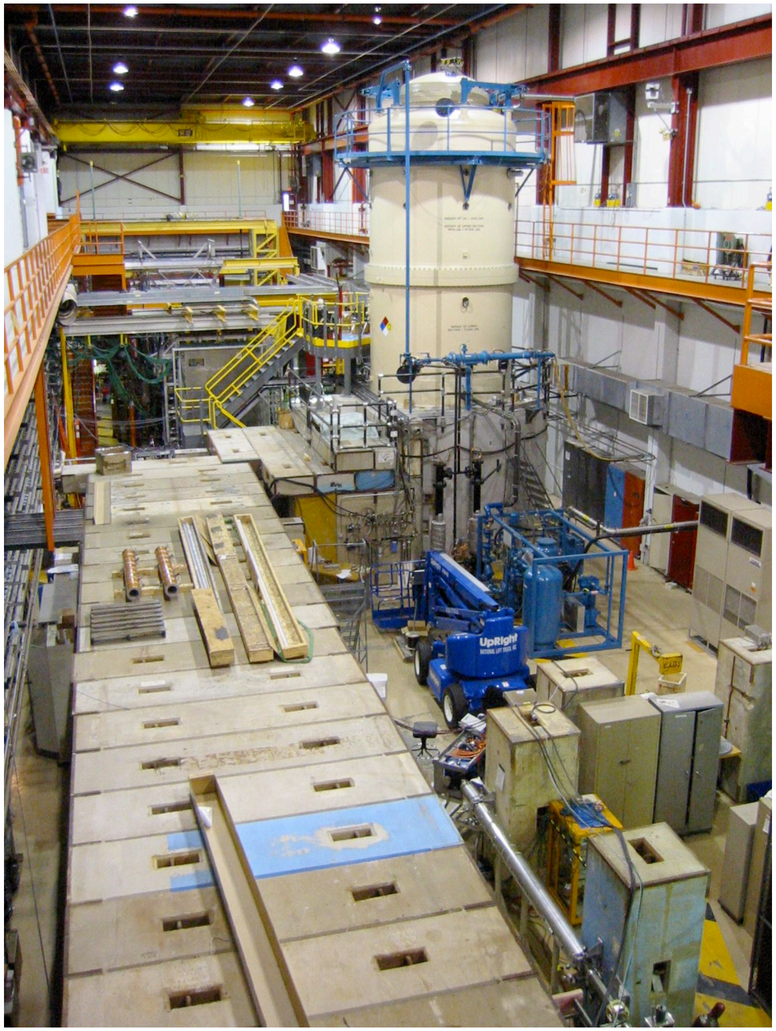
# Schematic Layout of the Recycler Electron Cooling

## 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 | 0 | µrad |



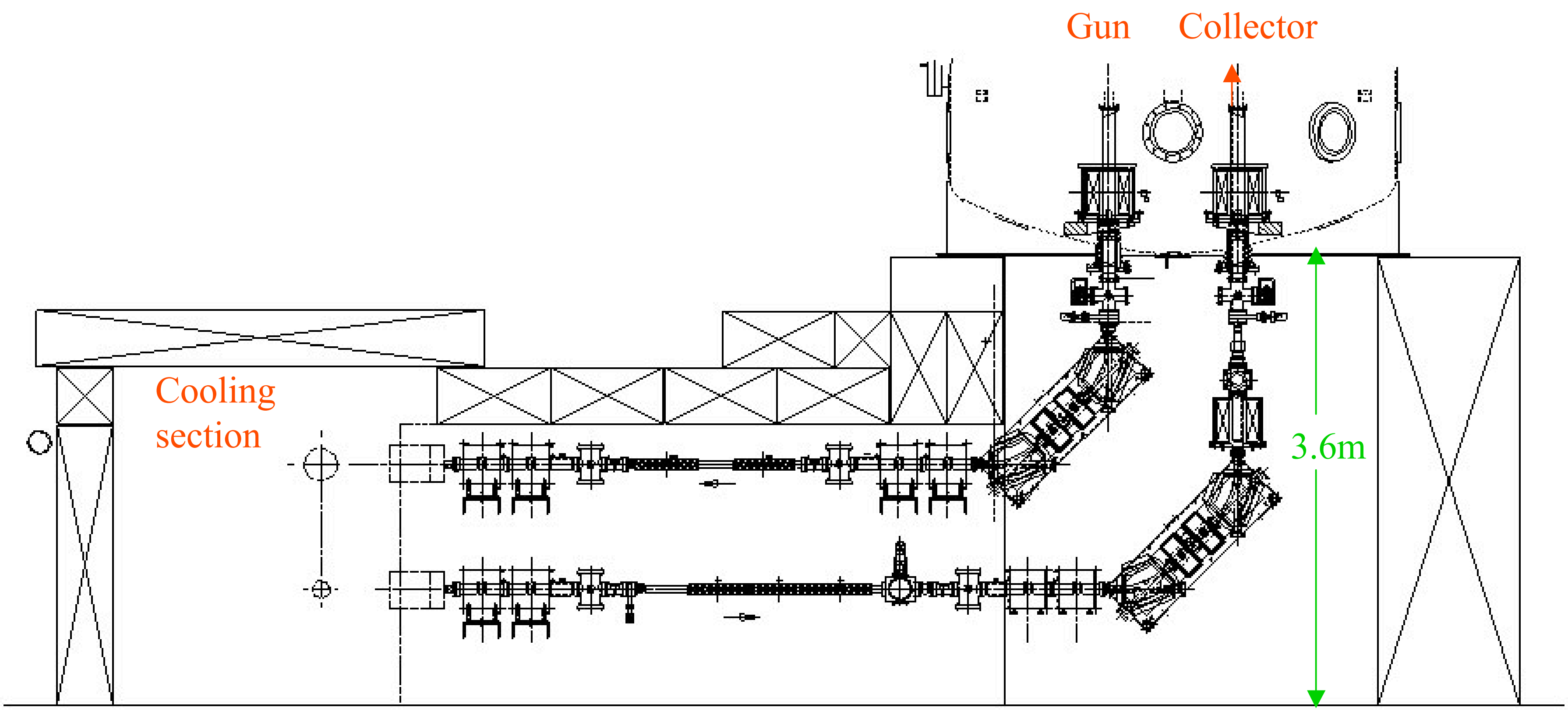
# Full scale beam line at WideBand



### Stages

| | | |
|---|---|---|
| Low-intensity DC beam in collector | Jul 03 | √ |
| Stable 0.5 A at 3.5 MeV | Dec 03 | √ |
| Cold beam at 0.5 A, 3.5 MeV | Mar 04 | |
| Low-intensity DC beam at 4.3 MeV | Apr 04 | |
| Disassemble the facility | May 04 | |

# Transfer line



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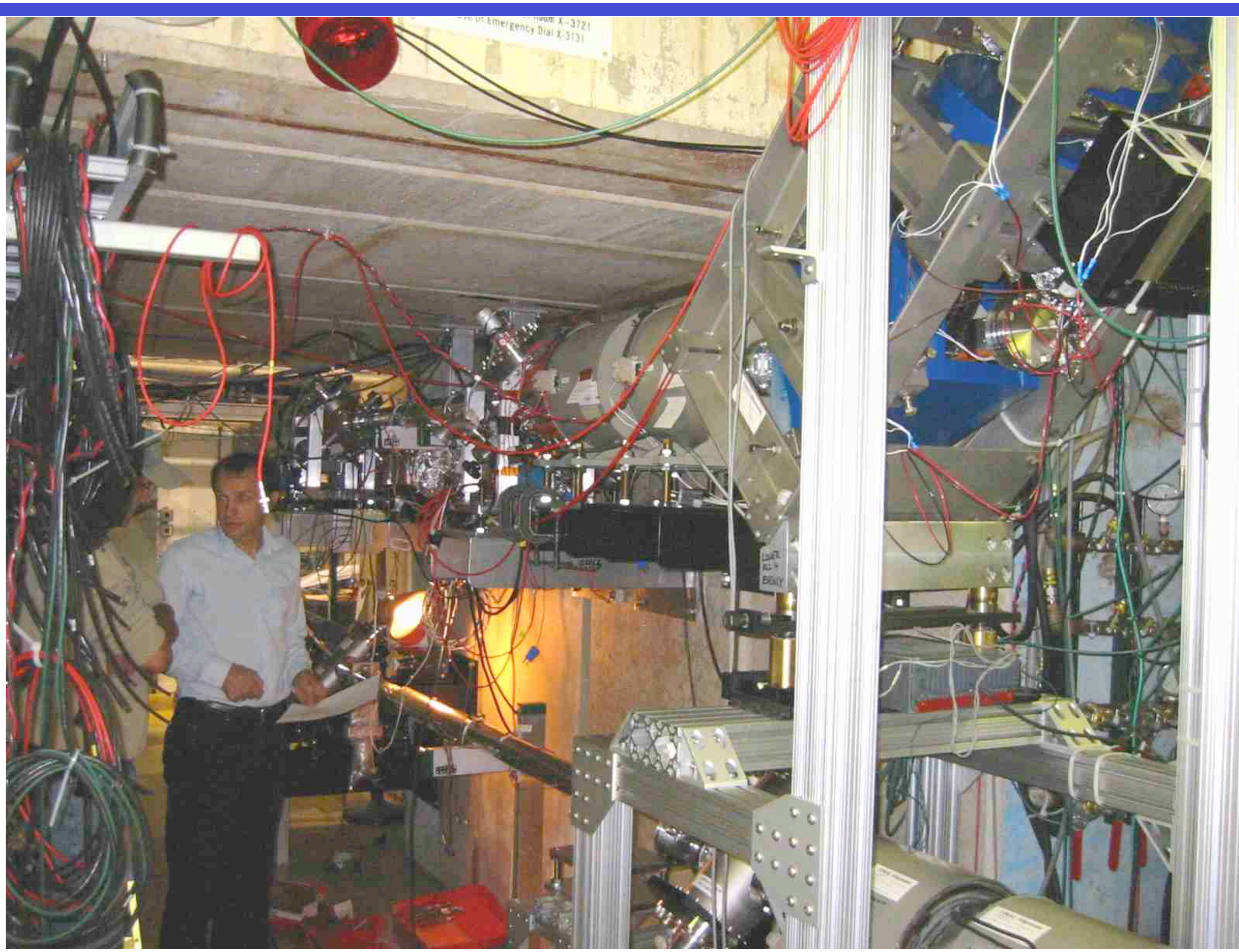
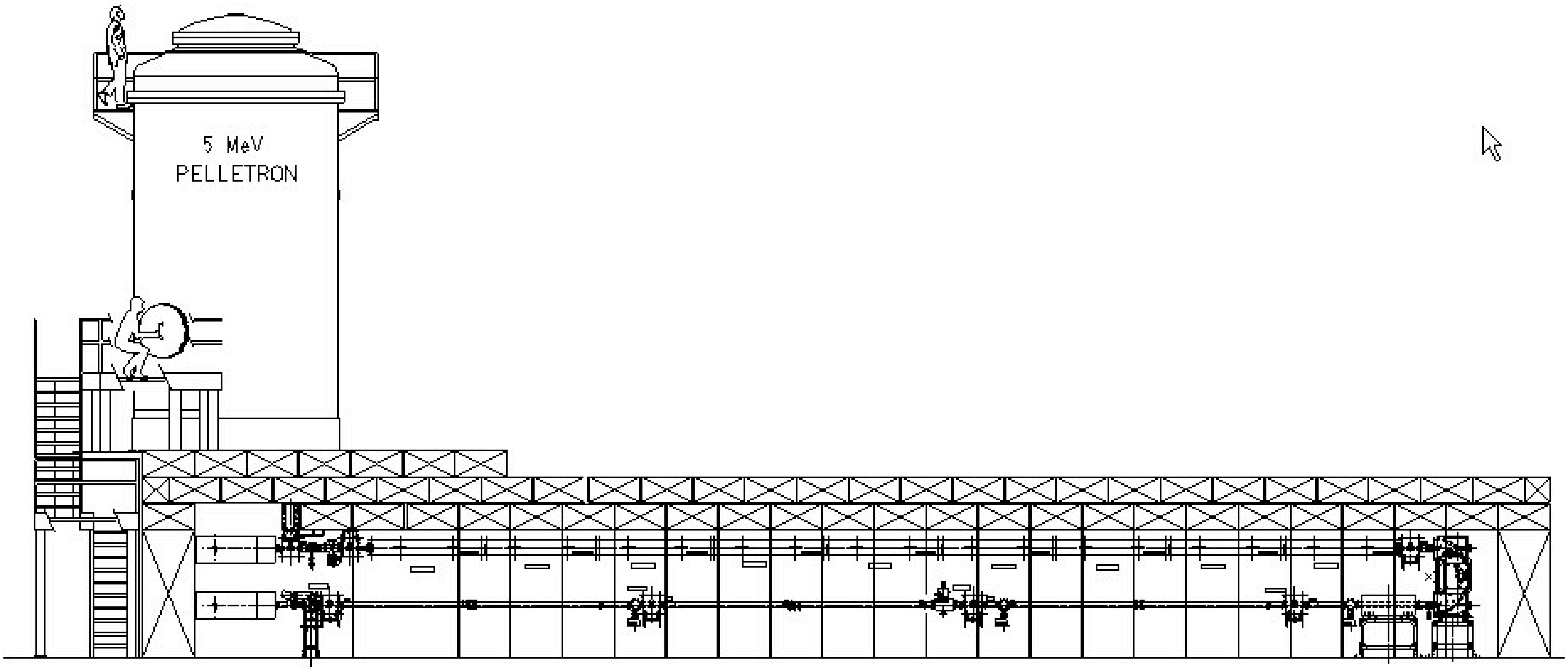


# Cooling section



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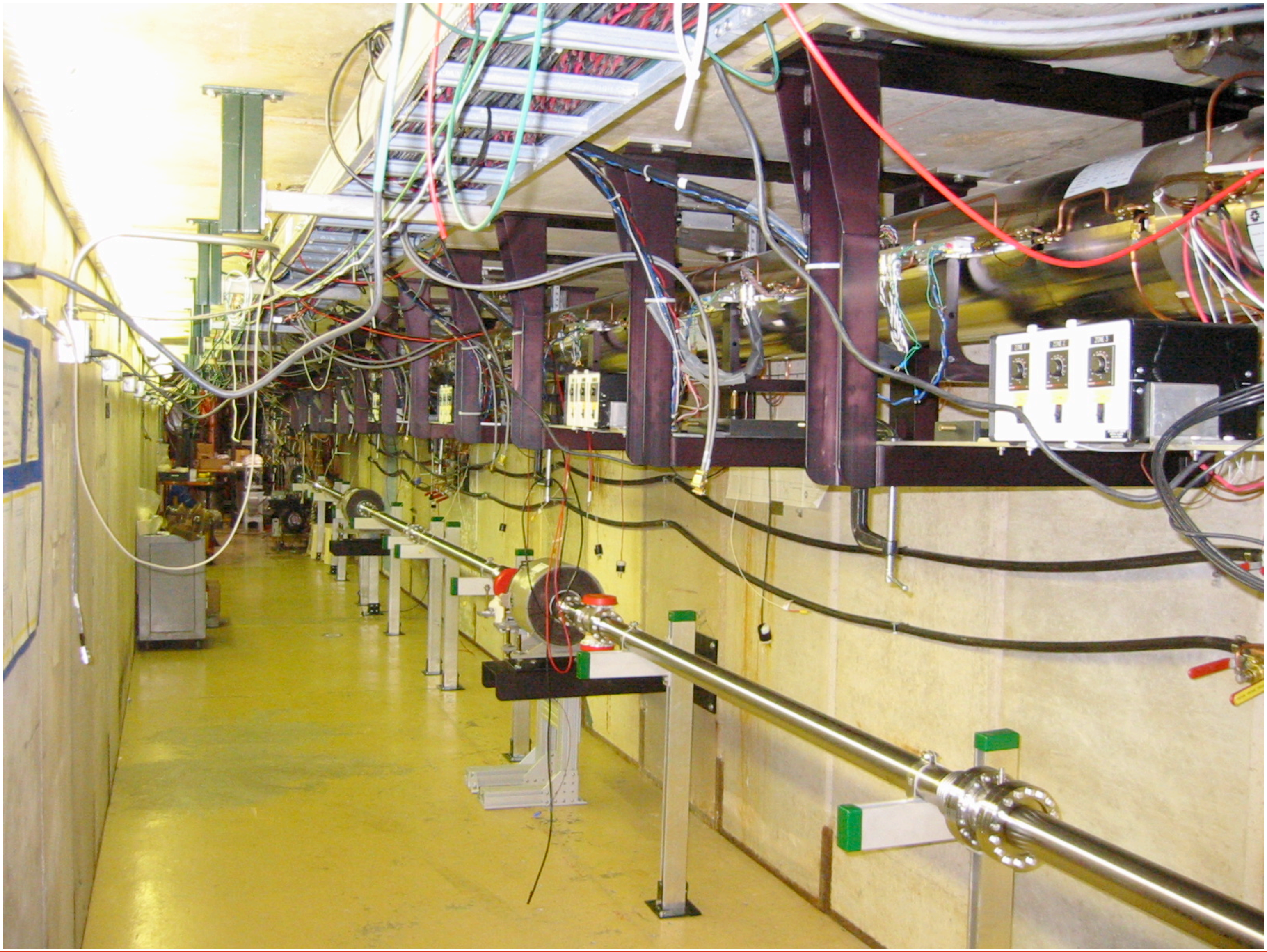

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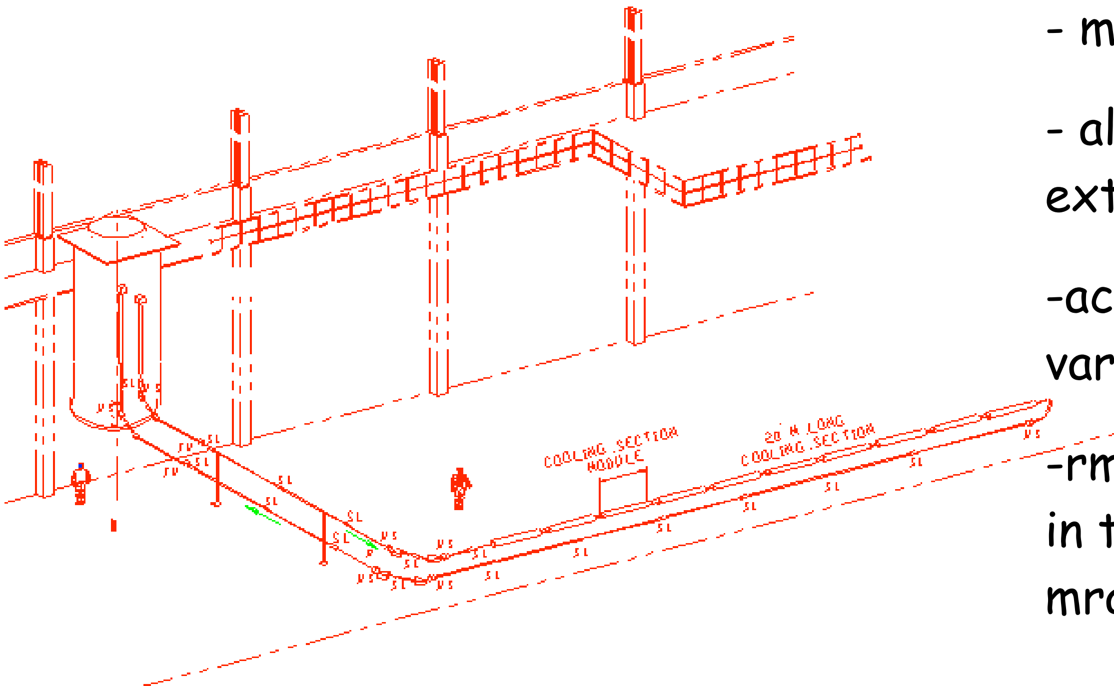



The facility almost replicates the future MI 31 (shorter transfer lines and 9 instead 10 modules in the cooling section).

## Current status

- max. DC current is 0.6 A;

- all diagnostics works to some extent;

-accuracy of optics simulation varies along beam line;

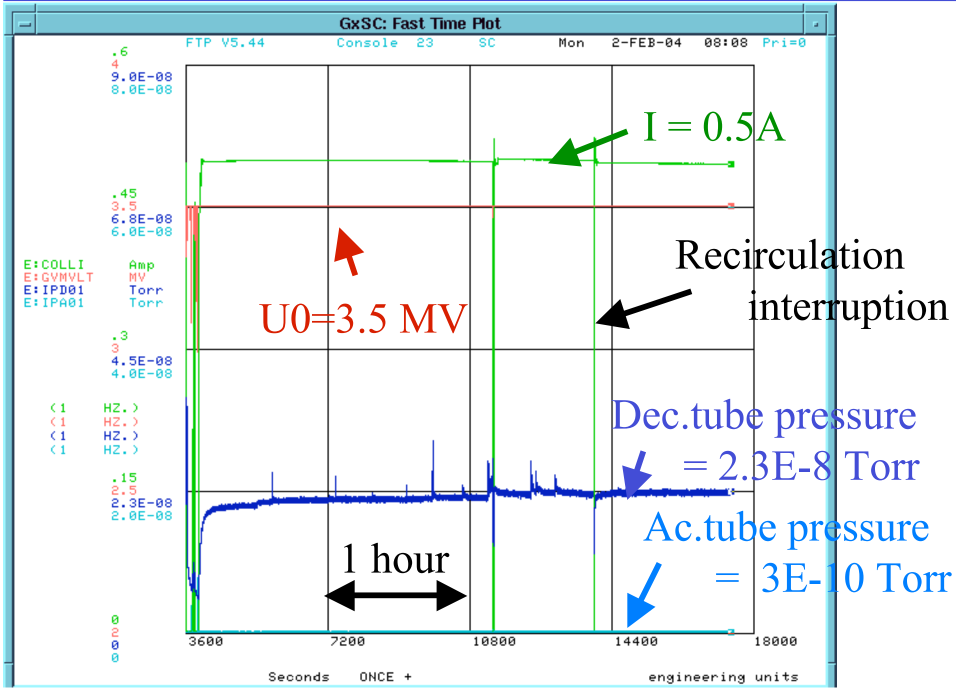
-rms angle of the beam center in the cooling section is 0.15 mrad;

-rms angle between axial and boundary electrons is 1 mrad;

- vac. pressure in the cooling section satisfies the Recycler requirements;

**-the main problem is a drift**

# DC beam recirculation




- I = 0.5 A is reasonably stable, 30- 80 min between recirculation interruptions in long runs.
- Slow drifts of the beam trajectory sometimes decrease the maximum current to 0.3-0.4 A
- Tube conditioning is needed once in a month; it takes ~ 4 hours.
- Current losses are much higher than they were in the recirculation test, $4\cdot10^{-5}$ vs $3\cdot10^{-6}$ . Losses grow nonlinearly with the beam current. The most probable reason is IBS.

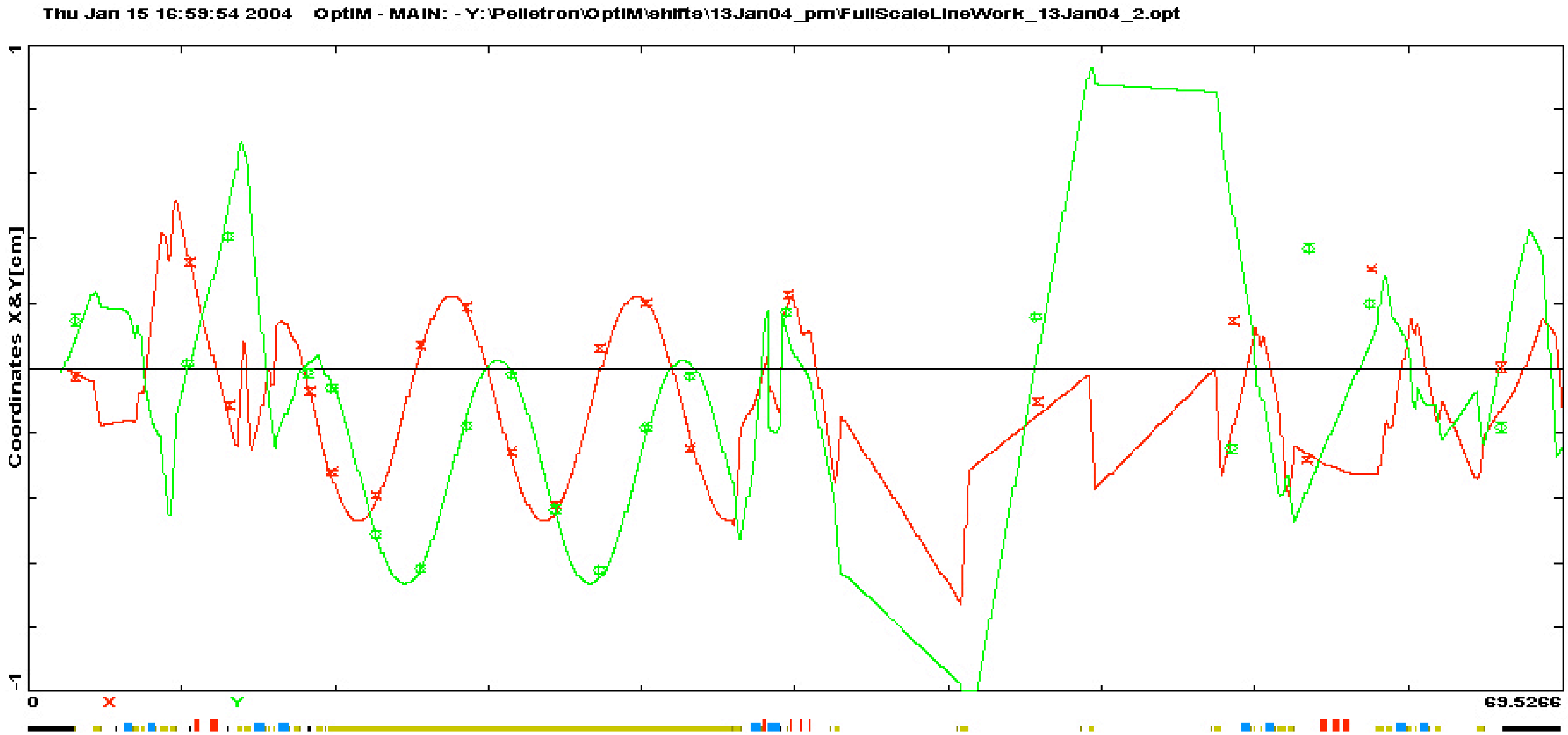
# Diagnostics

- BPMs work well and are used for both beam position and intensity monitoring. Resolution:
  - in a pulse (2-μs) mode is 100 μm for "fast" (1 Hz) readings and 30 μm for "slow" (with 10 averaging) readings
  - in a DC mode (32 kHz modulation) sometimes is as low as 3 μm, but typically is determined by beam motion due to Pelletron voltage variations
- Scrapers with 15 mm round openings have been used for first beam size measurements in the pulse and DC modes.
  - resolution is 1 mm in the pulse mode and ±0.1 mm in DC
  - an automated procedure is being developed

# Diagnostics (cont.)

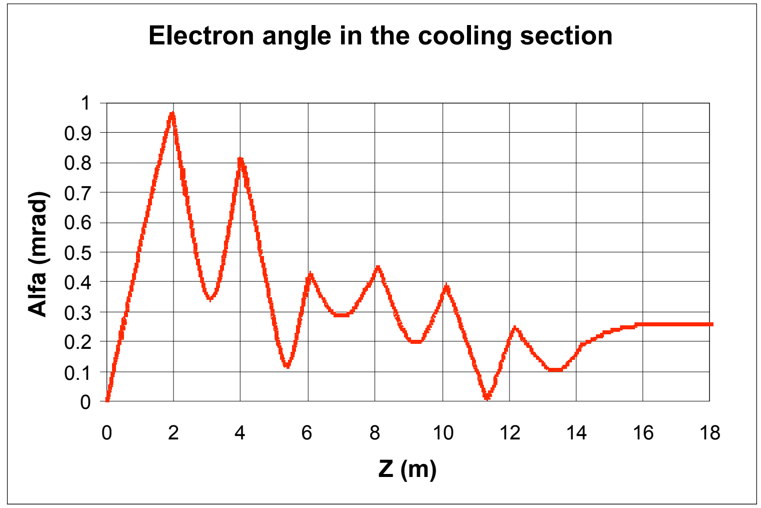
- A multi-wire harp works. Improvements to software are necessary.
- Flying wire works but is not very practical because the beam doesn't survive the fly at I > 50 mA
- Loss monitors work.
- Number of diagnostic tools in the straight return line is too low and will be increased in the MI-31 design.

# Beam simulations




- Simulations are made with Optim code
  - agreement with measurements is good in the first half of the trajectory and poor toward the end
  - envelope simulations – work in progress

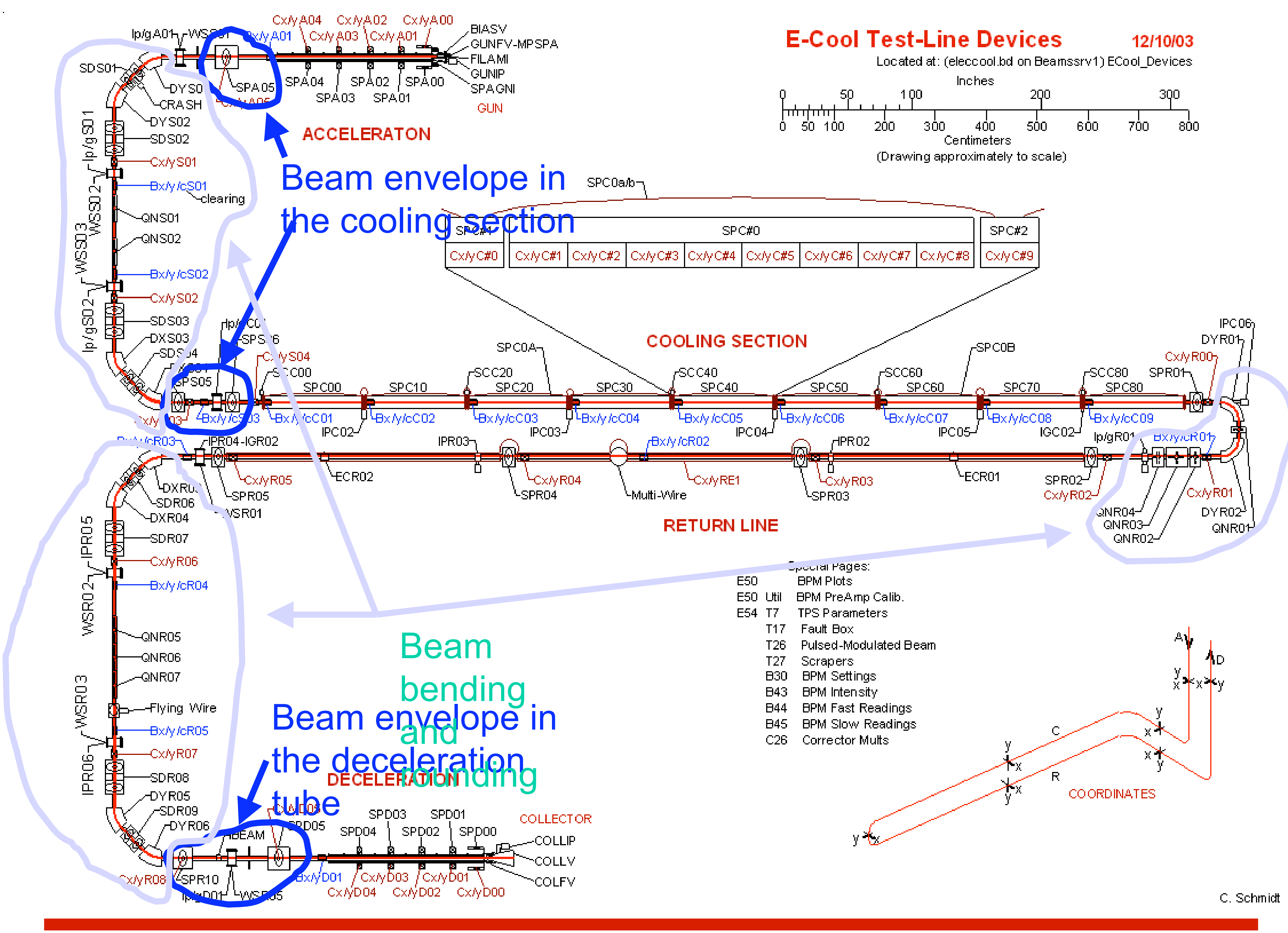
# Beam center in the cooling section




- The rms angle estimated from BPM readings and magnetic measurements is 0.15 mrad.
- Initial goal for the total rms angle was 0.08 mrad. According to A.Burov, the restriction may be relaxed to 0.2 mrad.
- The present limitation for improving the angle is the instability of the beam trajectory.

# Beam envelope

- "Cold" envelope in the cooling section : round and non-scalloping beam
- "Roundness" of matrices is checked by conservation of angles in trajectory measurements.
- Preliminary tuning of beam scalloping is being done with a pencil beam; final measurements employ scrapers.
- The best measured beam ellipticity in the cooling section is Rmax/Rmin~1.05.
- Achieved minimum amplitude of the beam size variations, ± 1 mm, is determined by our knowledge of optics, by quality of measurements, and by stability of the trajectory.



E-Cool Test-Line Devices
12/10/03
Located at: (eleccool.bd on Beamssrv1) ECool_Devices
Inches
0 50 100 200 300
0 50 100 200 300 400 500 600 700 800
Centimeters
(Drawing approximately to scale)
ACCELERATON
GUN
BIASV
GUNFV-MPSPA
FILAMI
GUNIP
SPAGNI
Beam envelope in the cooling section
COOLING SECTION
SPC#1
SPC#0
SPC#2
Cx/yC#0
Cx/yC#1
Cx/yC#2
Cx/yC#3
Cx/yC#4
Cx/yC#5
Cx/yC#6
Cx/yC#7
Cx/yC#8
Cx/yC#9
RETURN LINE
Multi-Wire
Beam bending and rounding
Beam envelope in the deceleration tube
DECELERATION
COLLECTOR
COLLIP
COLLV
COLFV
Special Pages:
E50 BPM Plots
E50 Util BPM PreAmp Calib.
E54 T7 TPS Parameters
T17 Fault Box
T26 Pulsed-Modulated Beam
T27 Scrapers
B30 BPM Settings
B43 BPM Intensity
B44 BPM Fast Readings
B45 BPM Slow Readings
C26 Corrector Mults
COORDINATES
C. Schmidt

# Beam position stability

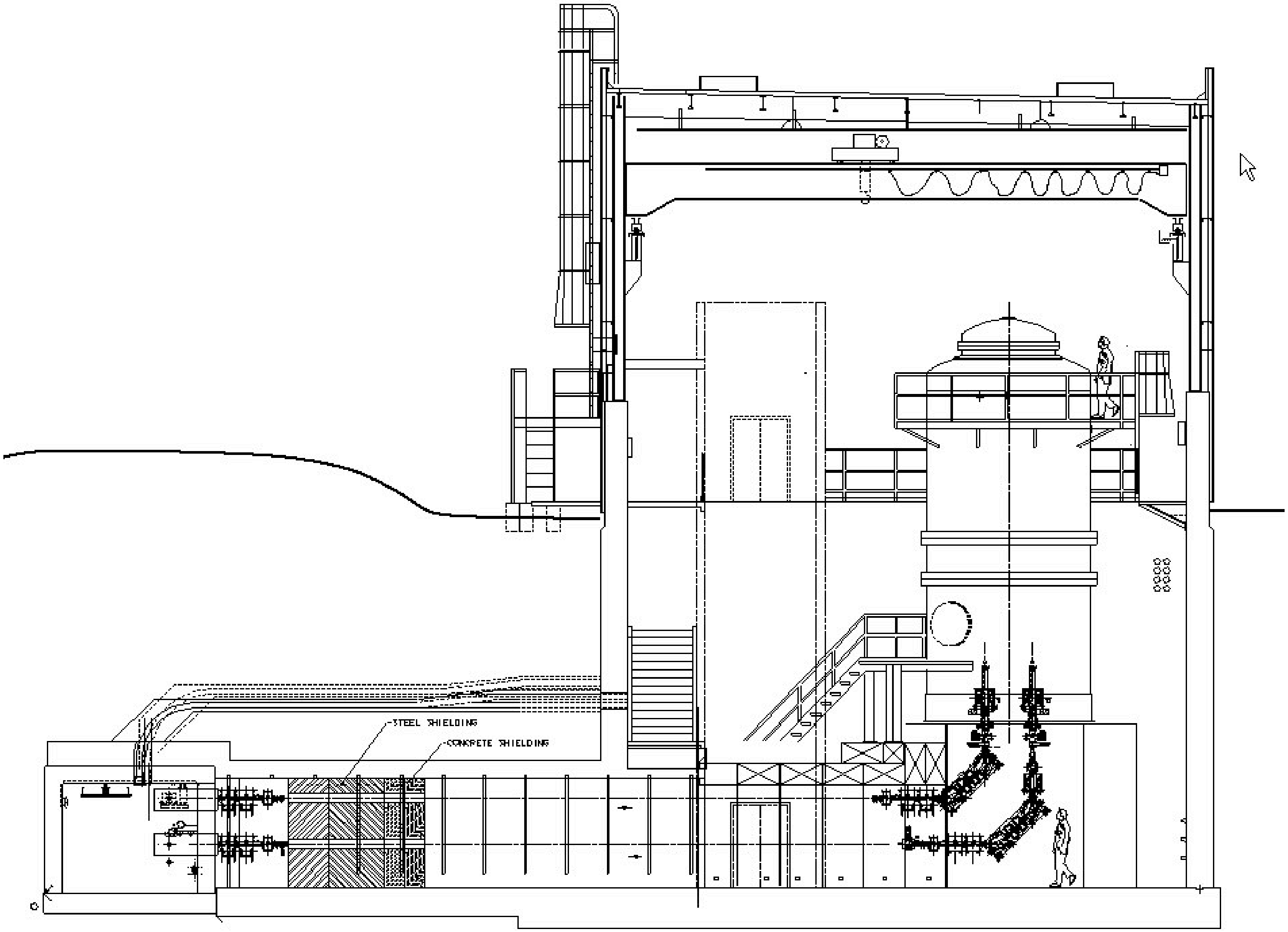
- Beam positions may change from day to day up to 0.3 mm in the cooling section and up to 2 mm in the return line.
- Attempts to stabilizing the beam position inside the section with a feedback loop have been only partly successful.
- ♣ Bend fields are stabilized to $3 \cdot 10^{-5}$ by an NMR-based feedback loop. Recently a correction for DC beam-induced field was implemented.
- ♣ Work to understand sources of the position drifts is under way (data collection + optical analysis).

# Energy calibration

- Electron energy was calibrated by measuring the wave length of the electron Larmor spiral in the cooling section. Precision of the calibration is ~1%.

- To commission the electron cooling system, we will need to match electron and pbar energies to within the energy acceptance of the Recycler, ±0.3%.

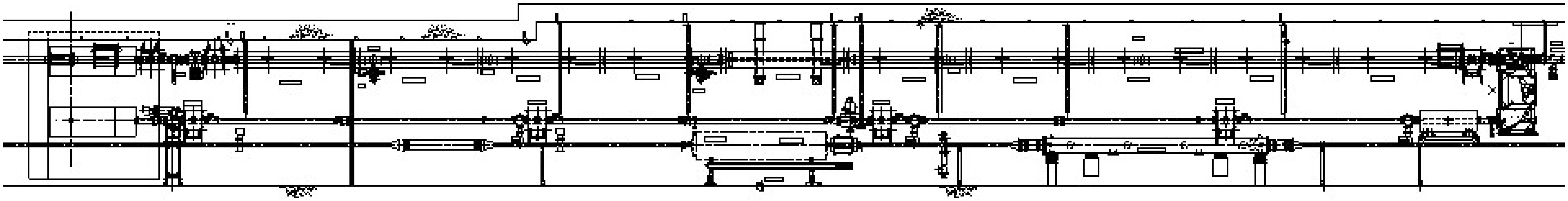
# MI-31 building




TRANSFER LINE AT MI-31

# MI-31 building

# Cooling section in the Recycler tunnel

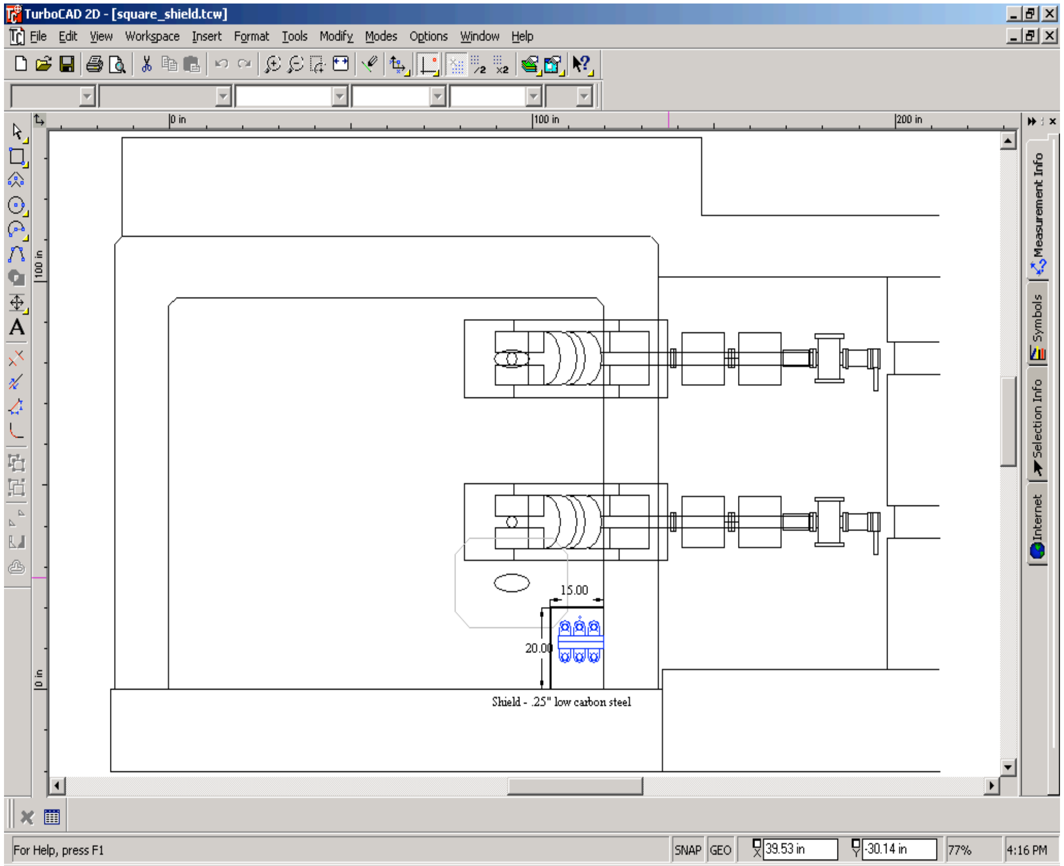


# Magnetic shielding for the return line

- Simulations give a maximum B•dl of 50 G-cm over the 500-600 cm span between focusing solenoids.
- Or
- 250 G-cm over the full length of the return beam line.

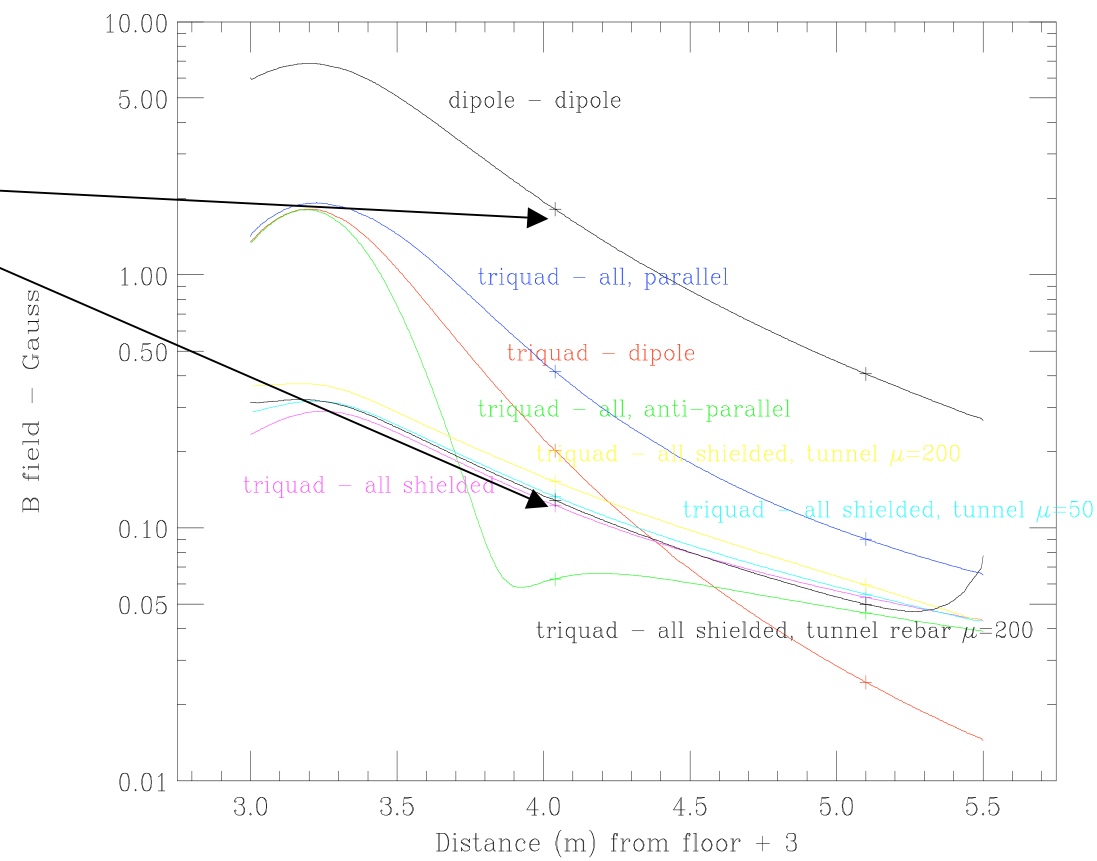
# MI Bus Field Reduction

- Bus location and orientation
- _ positive current outside
- Full negative current center
- _" low carbon shield



# Expected field reduction

Factor of 10 reduction at return line and cooling line due to shielding and bus orientation



# Work in progress

- Test beamline shield configurations in March
- Combination of bus layout, bus shielding, and beamline shielding will reduce magnetic fields to acceptable levels

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