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# Electron Beam Commissioning Plan

## Outline

Set-up and parameters

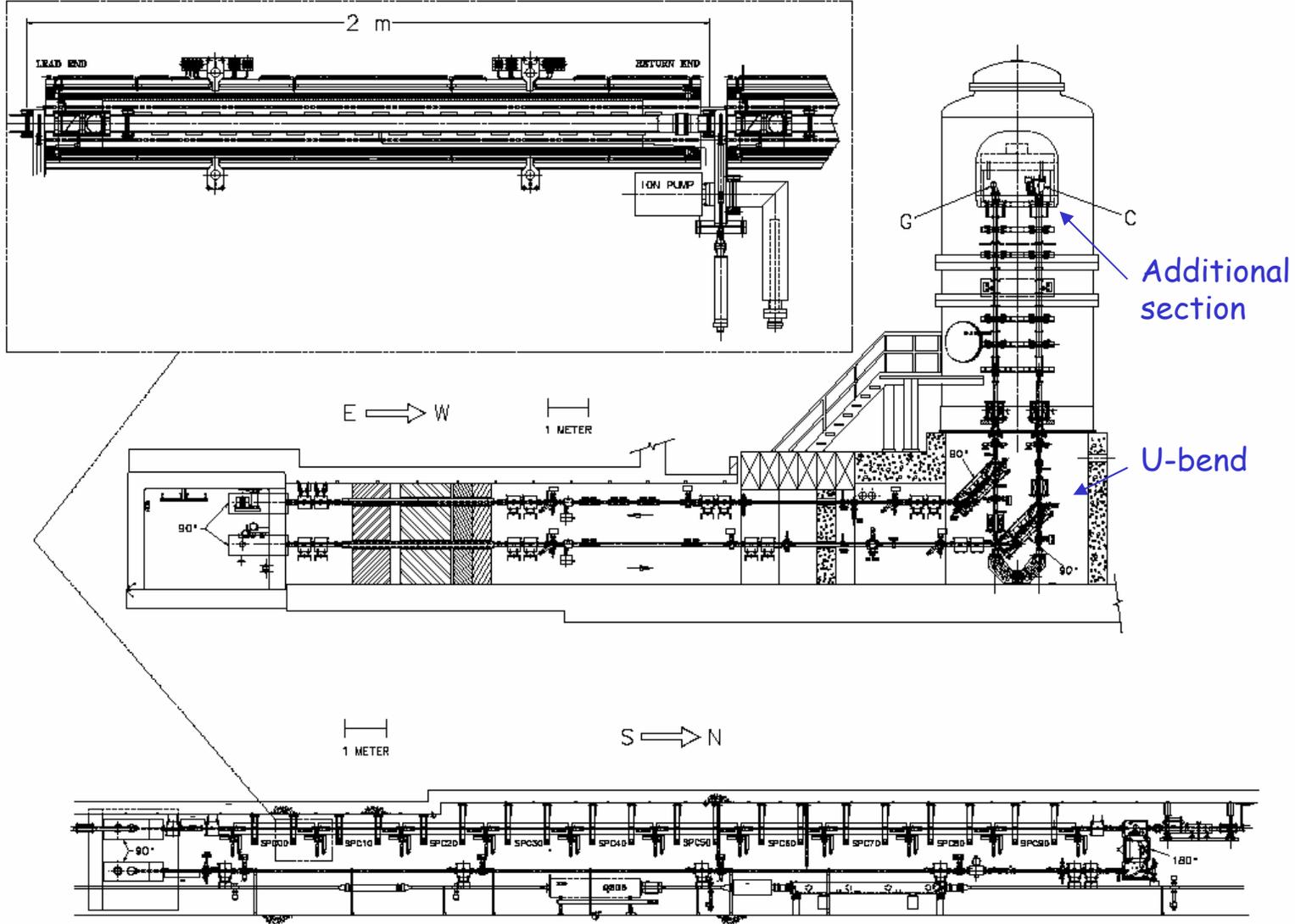
Initial conditions

The Plan

Assumptions

Milestones

# Electron cooling setup in MI-30



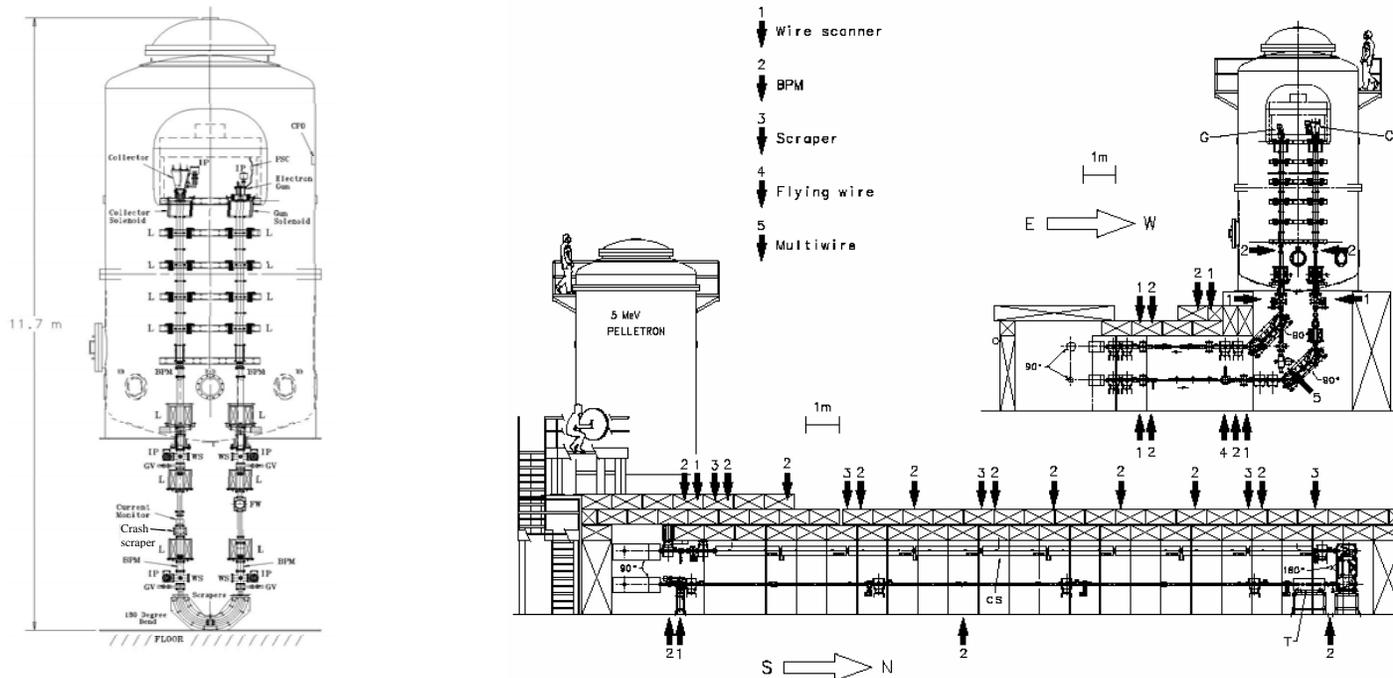
# Electron beam parameters

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- Electron kinetic energy 4.34 MeV
- Absolute precision of energy  $\leq 0.3 \%$
- Energy ripple  $\leq 10^{-4}$
- Beam current 0.5 A DC
- Duty factor (averaged over 8 h) 95 %
- Electron angles in the cooling section (averaged over time, beam cross section, and cooling section length), rms  $\leq 0.2$  mrad

# The Wide Band run

- 20-Mar-01- First time HV on both tubes
- 28-Dec-01 - 0.6 A in the short beam line
- 18-Nov-02 -  $I_{max}=1.7$  A; beginning of a shutdown
- 17-Jul-03 - DC beam recirculated through the full-scale line
- 30-Dec-03- 0.5 A DC beam
- 29-May-04- 0.1 A beam with no scalloping in the cooling section



## Issues not resolved in WB

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- Reliability of operation at 4.3 MV
  - Acceleration tubes are extended by 1/5
  - A new fast gun shut-off system will be installed
- Quality of the cooling section magnetic field
  - Quality of magnetic measurements in MI-31 is about two times better than in WB
  - The BPM system has a low offset between 32 and 89 kHz modes, that allows to use the pbar beam as a reference line
  - 4-rod system for beam tilting in the entire cooling section is installed
  - A procedure for a beam-based field adjustment is being developed
- High current losses in a full-scale beam line
  - An explanation and a cure have been found in test bench measurements

## Issues not resolved in WB (cont.)

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- **Protection system**
  - Loss monitors are installed
  - A new protection hardware and software is under development
- **Beam size/density distribution diagnostics**
  - A YAG and 3 OTR screens are installed (in collaboration with Argonne)
- **Beam motion in the cooling section**
  - A feedback system is under development
- **Software for beam tuning**
  - Programs to tune the beam Larmor helix and envelope scalloping in the cooling section are under consideration

# The Plan- stage 1

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- Pelletron and U-bend commissioning - 1.5 month
  - All electronics in Pelletron is operational with HV on
  - Tubes conditioning
- Each section is conditioned to 1.1 MV. The total voltage of 5 MV is stable with all lenses on.
  - Optics measurements in U-bend
- A pulsed beam is transported with low losses ( $< 2\%$ ).
- The OTR monitor under the acceleration tube and the pepper pot are commissioned. Data to restore the beam parameters at the acceleration tube exit are taken.
- DC beam in U-bend
  - BPMs in the U-bend are commissioned.
  - **Spark diagnostics and the protection system are tested.**
  - 0.2 A beam stays at 4.34 MeV in a shift-long run with 95% duty factor.

## The Plan- stage 2

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- Full beam line commissioning - 3 weeks
- A pulsed beam is transported through the entire beam line with low losses ( $< 2\%$ ).
- All BPMs (in the pulse mode) and the YAG/OTR at the end of the cooling section are commissioned.
- Trajectory responses are measured in the entire line, are analyzed, and major discrepancies are resolved.

# The Plan - stage 3

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- DC beam commissioning - 3 months
  - Establish a 5-mA DC beam.
  - Effects of e-beam aborts on pbars
- Effects of e-beam aborts on pbars are measured, including recording of pressure in MI-30 region and of pbar positions.
  - Beam line optics
- All elements are measured with a DC beam. A simulated differential trajectory in the cooling section fits measurements within 0.05 mm.
  - Energy
- The absolute value of the electron energy is measured with precision of 0.3 % by using the results of the longitudinal field measurements and the wave length of the electron trajectory in the cooling section.

## The Plan - stage 3 (cont.)

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### ➤ Beam position

- Drifts and oscillations of the electron beam position in the cooling section and in the entire line are measured, and contributions of major sources of the motion, including MI ramp effects, are determined.
- A feedback loop stabilizing the beam position in the cooling section is commissioned.

### ➤ Establish 0.5 A DC beam

# The Plan- stage 4

- Pbar cooling - 2 months

- Low electron beam temperature in the cooling section

Component	Upper limit, $\mu\text{rad}$	WB result, $\mu\text{rad}$	Measured by	Required resolution of diagnostics
Temperature	90	No meas.	Pepper pot image at OTR monitor	50 $\mu\text{m}$ in the OTR image
Aberration	90	< 100	Pepper pot image at OTR monitor; BPMs	150 $\mu\text{m}$ in OTR image; 50 $\mu\text{m}$ in BPMs
Envelope scalloping	100	100	Movable orifices	500 $\mu\text{m}$ in beam dimension measurements
Dipole motion caused by magnetic field imperfections	100	~ 200	BPMs	30 $\mu\text{m}$ in "DC" BPM resolution; 50 $\mu\text{m}$ in BPMs' offsets measured wrt pbar beam
Beam motion	50	30	BPMs	50 $\mu\text{m}$ in BPM signal in 100 Hz bandwidth
Drift velocity	20	No meas.	Calculated	
<b>Total</b>	<b>200</b>	<b>~ 300</b>		

## The Plan- stage 4 (cont.)

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### ➤ Match the beams

- Beam positions are aligned
- The energies are aligned within 0.3 % using absolute calibrations for both beams.

### ➤ Observe electron cooling

- Effect of electron cooling is observed by a longitudinal Shottky monitor.

# Assumptions

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- The commissioning **team** is identical to WB's as of May '04 or expanded.
- **Ten** 6-hour **shifts** a week.
- By the beginning of commissioning (Feb. 1, 05), all **equipment** is installed and is ready to go.
- Interruptions caused by the Recycler's **work for luminosity** have a small effect on commissioning. An interference with the Recycler begins in stage 3 (Full beam line commissioning).
- We are very lucky, and no major **repairs** are necessary in the time of commissioning.
- No interruptions caused by lab-wide **shutdowns** are included.

# Interference with the Recycler's work for luminosity

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- Effects of ECool bends and cooling section field on the pbar dynamics in RR- should be corrected anyway
- Effects of the e - beam space charge on the pbar dynamics in RR- supposed to be negligible
- Changes in the pbar lifetime caused by a pressure rise in the cooling section- is negligible according to measurements in WB
- Drag force- many e- beam measurements can be done either at low electron currents or at the electron energy shifted by 1%
- Measurements of DC beam dimensions in CS and measurements with the YAG/OTR downstream of the cooling section- no pbars in RR
- If the above is correct, the electron cooling tune-up may be done with the Recycler using 80% of time for luminosity

# Milestones

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- All e-cool systems are ready for commissioning 02/01/05
- U-bend commissioned 03/14/05
- Full beamline commissioned 04/04/05
- A 0.5 A DC beam 07/08/05
- Cooling of antiprotons 09/08/05