SNS IPM

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1. Overview of RHIC IPM: Performance, Lessons learned, Rebuild
2. SNS requirements
3. Mechanical design
4. Signals and operating modes
5. Electron energy nonlinearity of amplifier
6. Signal processing

RHIC IPM

Electrons from ionization give accurate profiles.

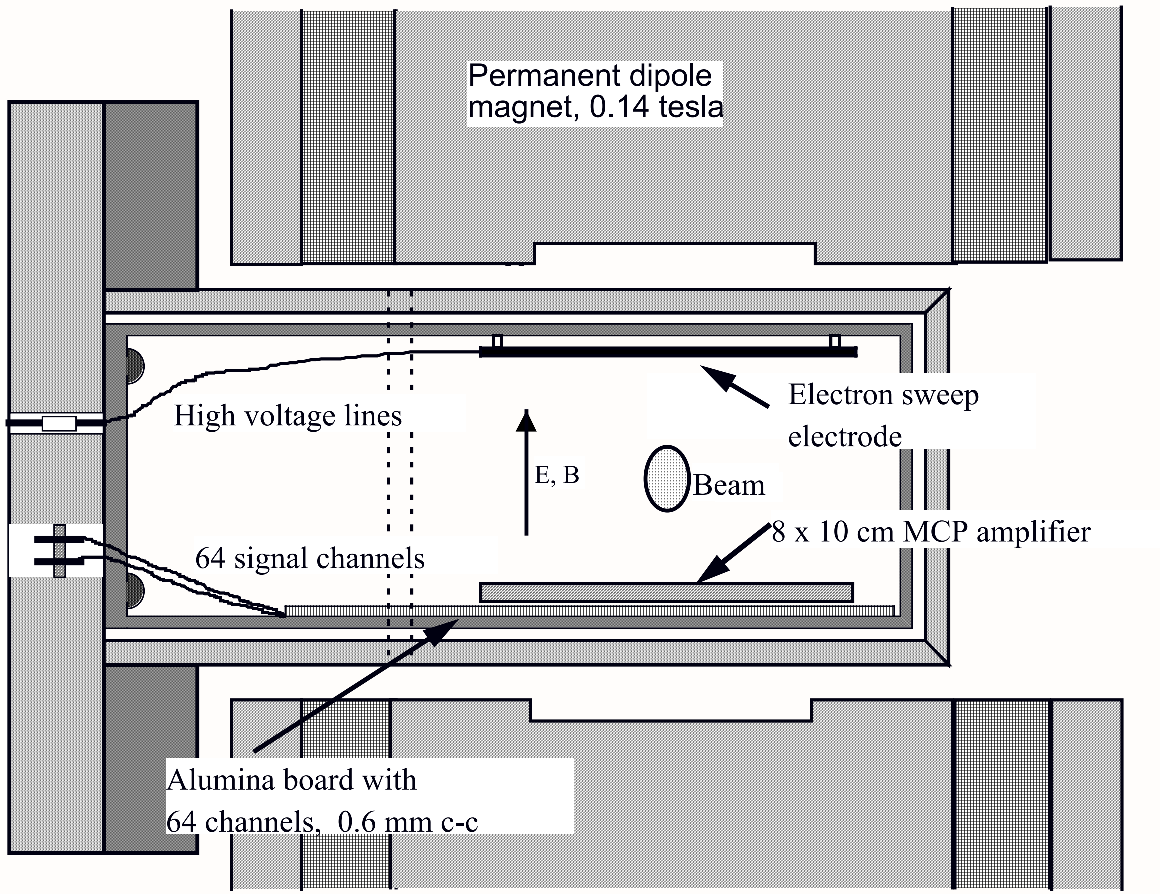
We have demonstrated single-bunch profiles.

The detector is sensitive to noise sources.

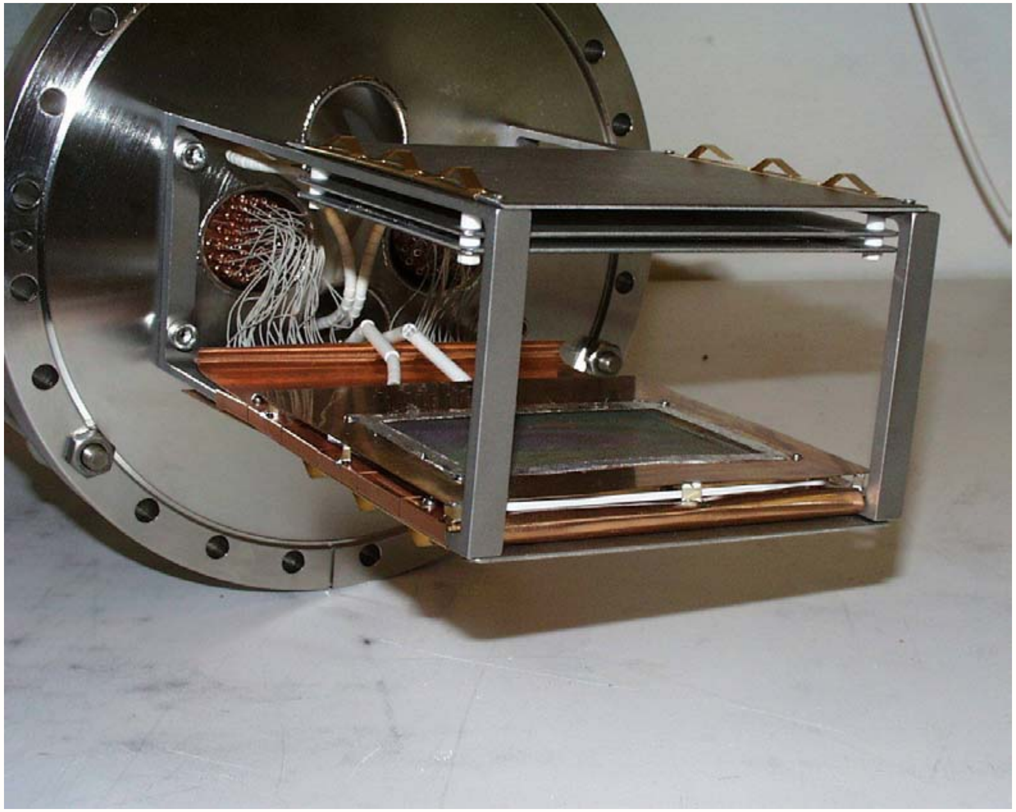
1. Rf coupling to beam
2. Radiation spray from beam loss
3. Secondary electrons

Lessons learned from RHIC IPM rebuild will be applied to SNS.

Cross section of RHIC IPM



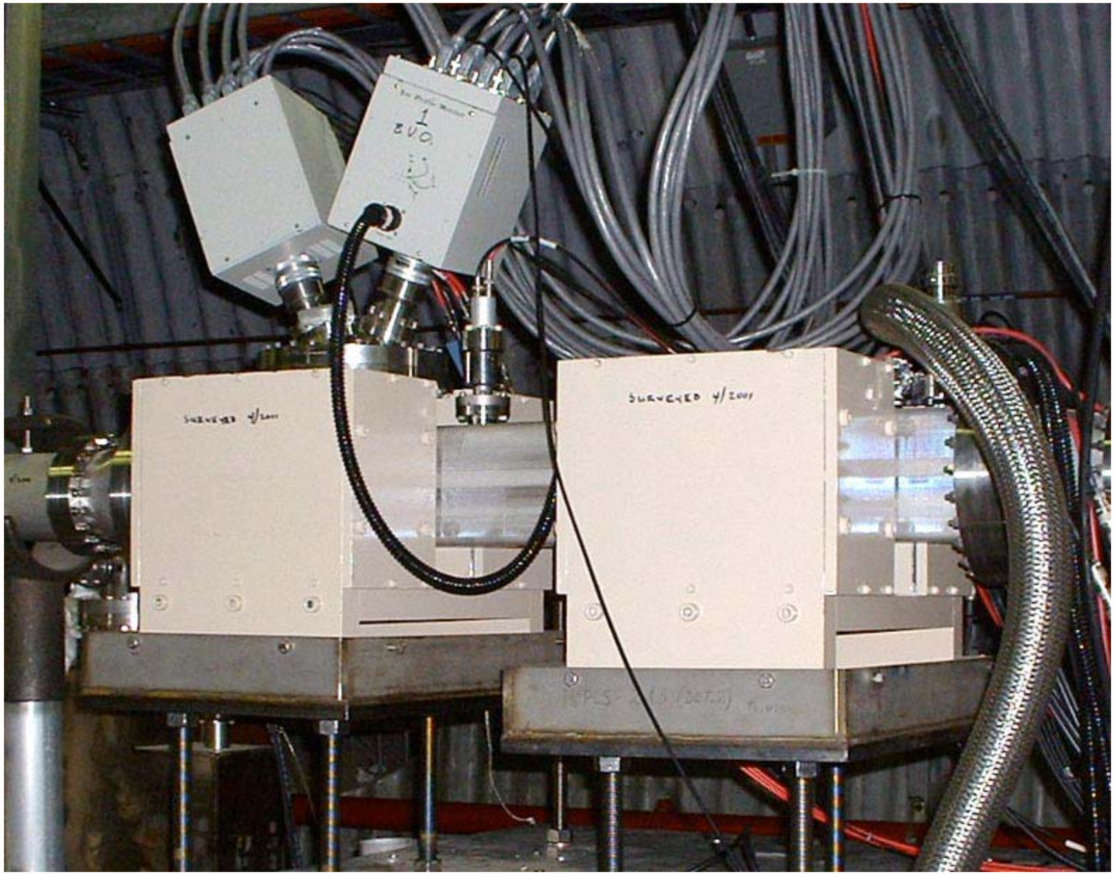
Photograph of original detector head



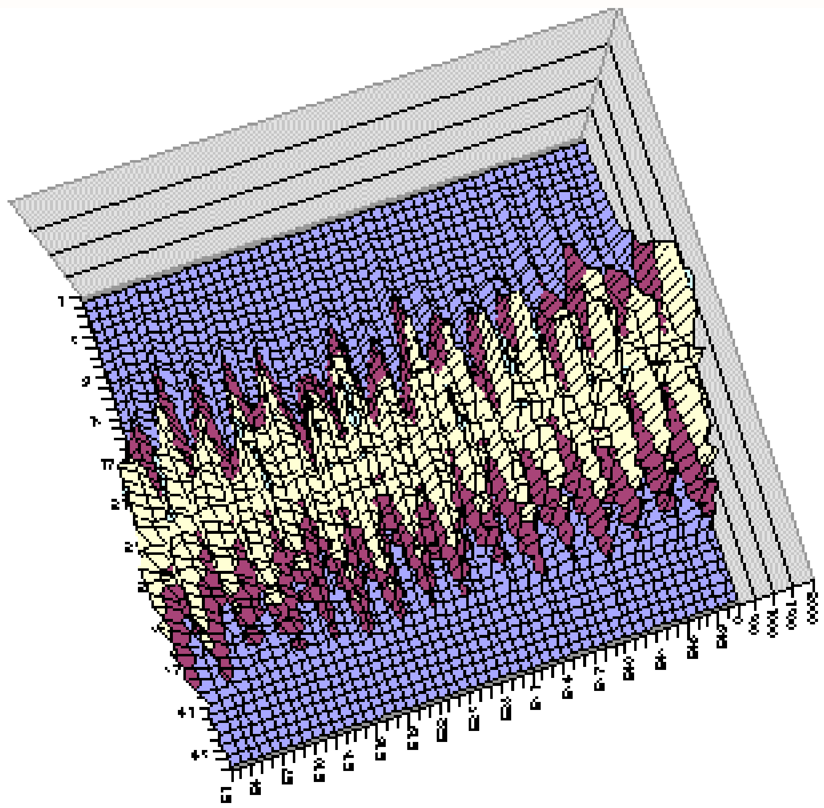
Attached to the top of the brackets are the electrodes which sweep electrons toward the collector. At the bottom is the anode-MCP assembly. The rectangular brackets have been replaced by open ended brackets and a continuous EMI shield has been placed over the entire anode-MCP-feedthrough assembly.

Blue vertical IPM

In RHIC there is one detector magnet and an identical corrector magnet. SNS will use two half-strength correctors for full orbit correction.



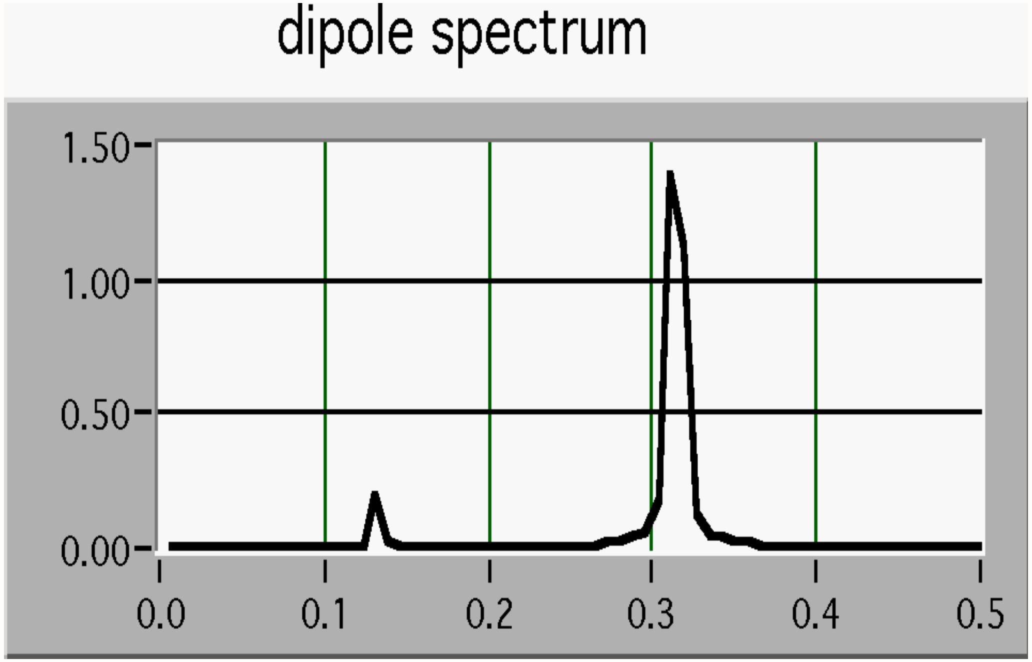
Mountain-range of one bunch at injection



Detector channels are plotted on the vertical axis and turn number is on the horizontal axis. Data contains both tune frequencies and quadrupole oscillation.

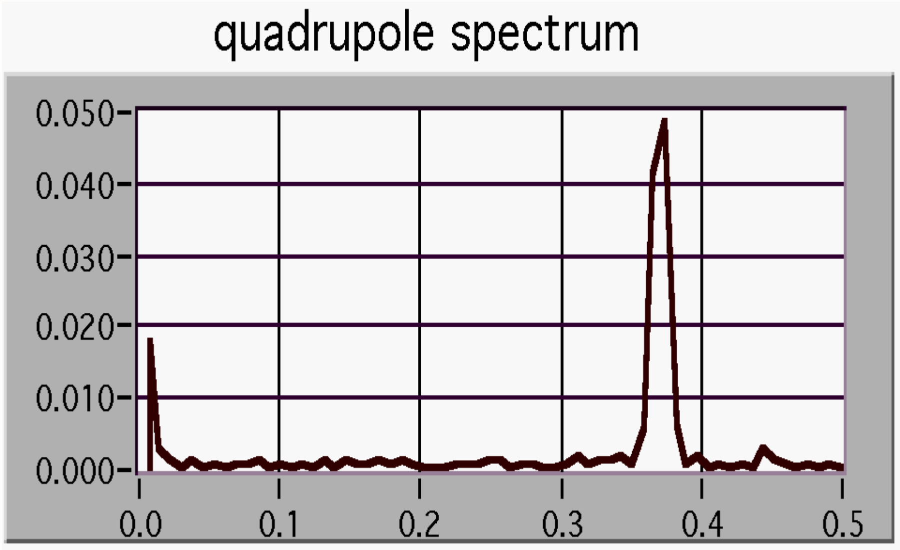
SNS will measure 5-7 profiles on each turn so mountain-range plots of each bunch will be available.

Dipole oscillations at injection



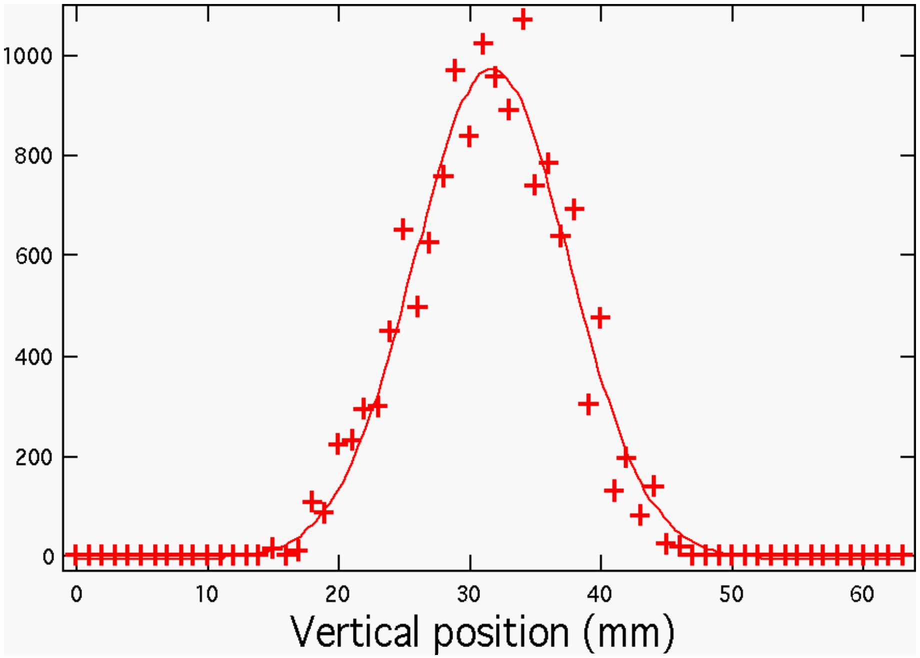
The centers of the bunch for 128 turns after injection were calculated by fitting Gaussian curves to data from each turn. This sequence was Fourier transformed to give a power spectrum. Data show the vertical tune of 0.32 and the horizontal tune of 0.13.

Quadrupole oscillations at injection.



The rms widths of the bunch for 128 turns after injection were measured. This sequence was Fourier transformed to give a power spectrum. The betatron frequency was measured to be 0.32 so the quadrupole frequency is 0.64. Since sampling is done at the rotation frequency the quadrupole frequency appears at the aliased frequency of 0.36.

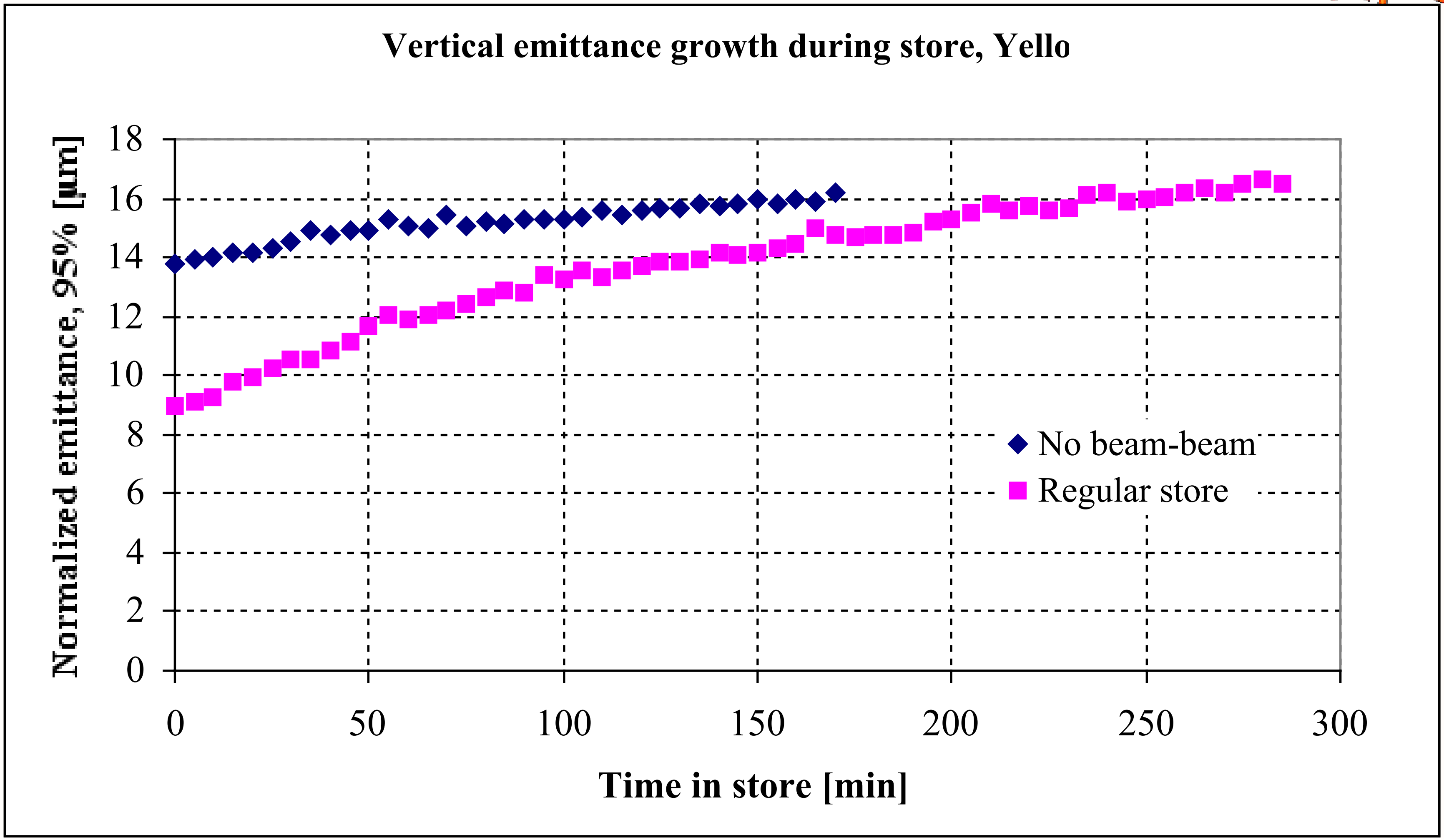
Single-bunch profile



One profile from the mountain-range data set. This is a measurement of a single bunch passing once through the detector. The fitted curve has a width of σ=5.9±0.2 mm.

This is from one bunch equivalent to 3 x 10^{12} protons. The individual profiles (6/turn) in SNS should be of this quality after first 100 turns.

Emittance growth from beam-beam



SNS IPM parameters

Beam parameters used in design

One bunch, 645ns long and one gap, 300ns long.
Each injected bunch, 1.5 x 10^{11} protons.
Total bunch intensity at end of cycle, 1.5 x 10^{14} protons.
Full beam diameter 100mm. ($E=\pi\ 240\times10^{-6}$ m, $\beta=12$ m)
Clear aperture 200mm.

Detector parameters

64 collector channels covering 140mm.
Channels 74mm long spaced 2.2mm apart.
Single extended-dynamic-range MCP.
Collimating magnetic field strength > 0.1 T.
Two magnets to give corrected beam angle (maybe 3).
Electric sweep field adjustable to 100kV/m.

Collection of electrons

1. Immunity to space charge

   Maximum space-charge field ~50kV/m. Assume 0.1T dipole field.

   $R_e = E\ m/qB^2 = 30\ \mu m$.

2. Collection time

   $t_e = \mathrm{sqrt}\ \{2dm/qE\} = 3.4ns$ starting at center of pipe

   $t_{H2} = 0.2\ \mu s$ $t_{CO} = 0.7\ \mu s$

3. The CO ions from the front of the bunch will be collected at the same time as the H_2 ions from the back of the bunch.

4. During the drift time from the pipe an H_2 ion can move transversely by more than two collection channels.

5. Magnet field requirement:

   98% of electrons have recoil energies < 1 keV.

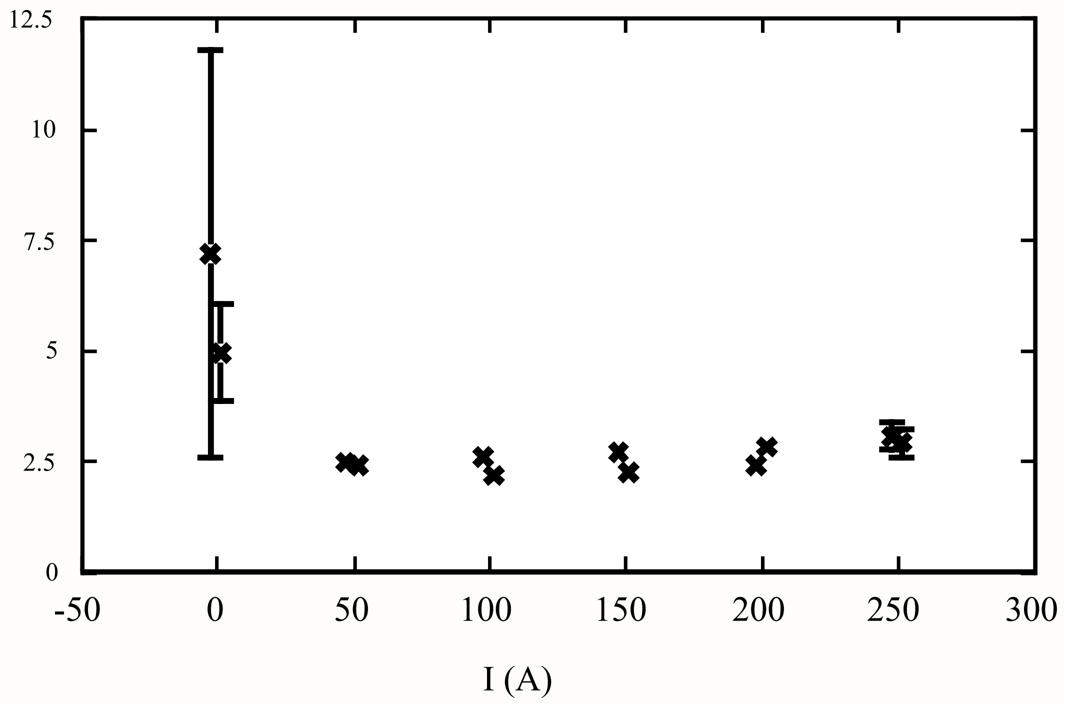
   For 1 keV electrons, $R = mv/qB = 10^{-4}/B$ ----> 0.1 T field gives R < 1mm.

Measured width vs. magnetic field strength

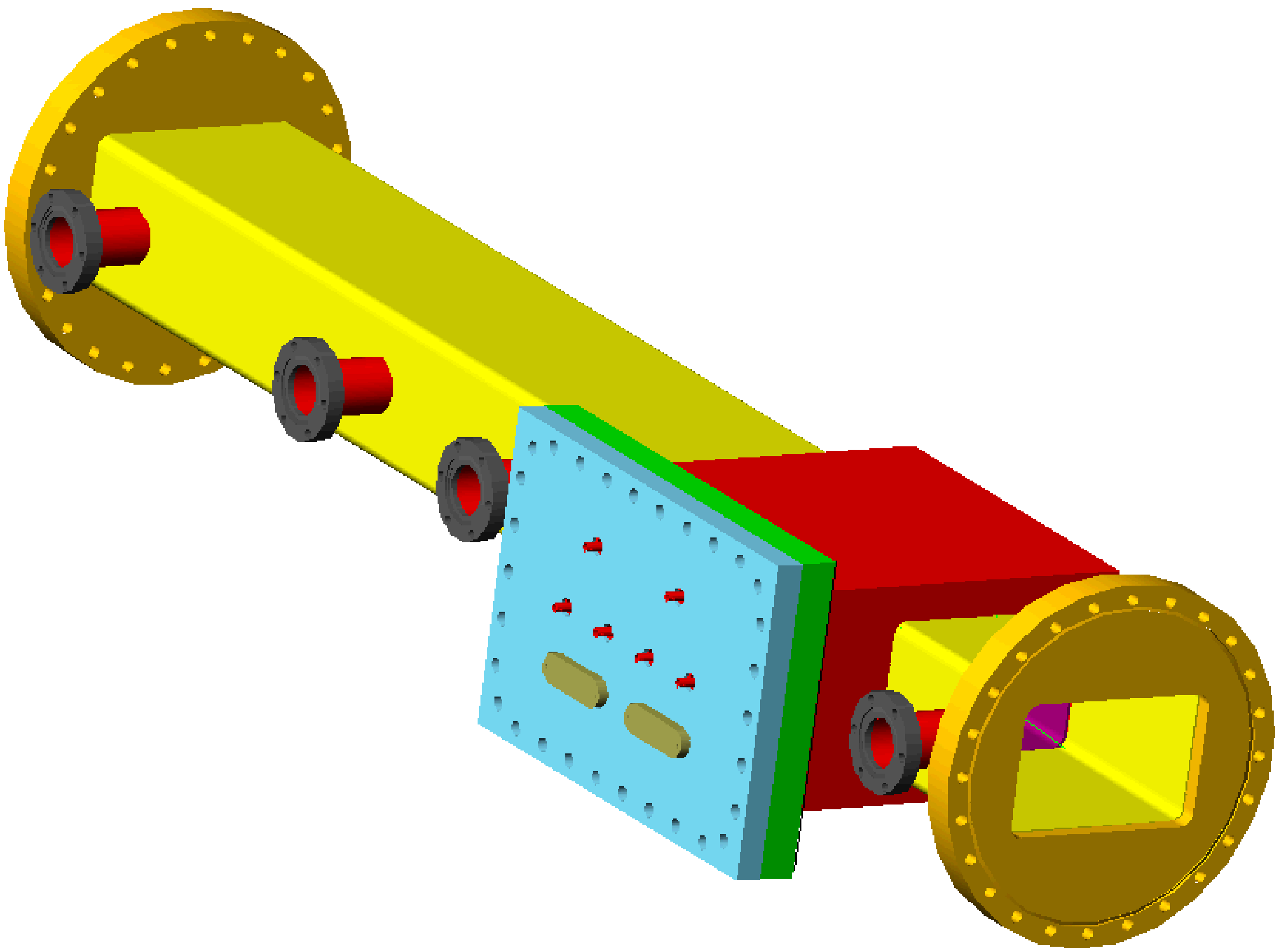
During test of RHIC prototype we measured a beam with six different values of the magnetic field.

The calibration is 50A=1 kG.

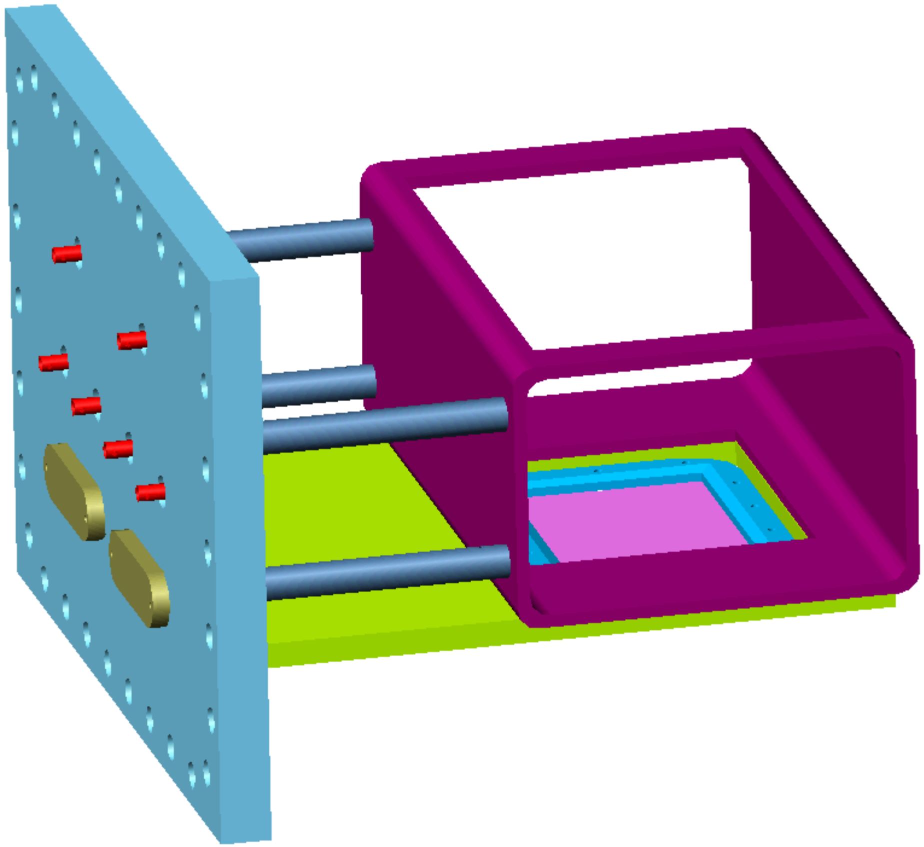
Data show no further narrowing of measured width above 1kG.



New RHIC IPM vacuum chamber



Transducer head



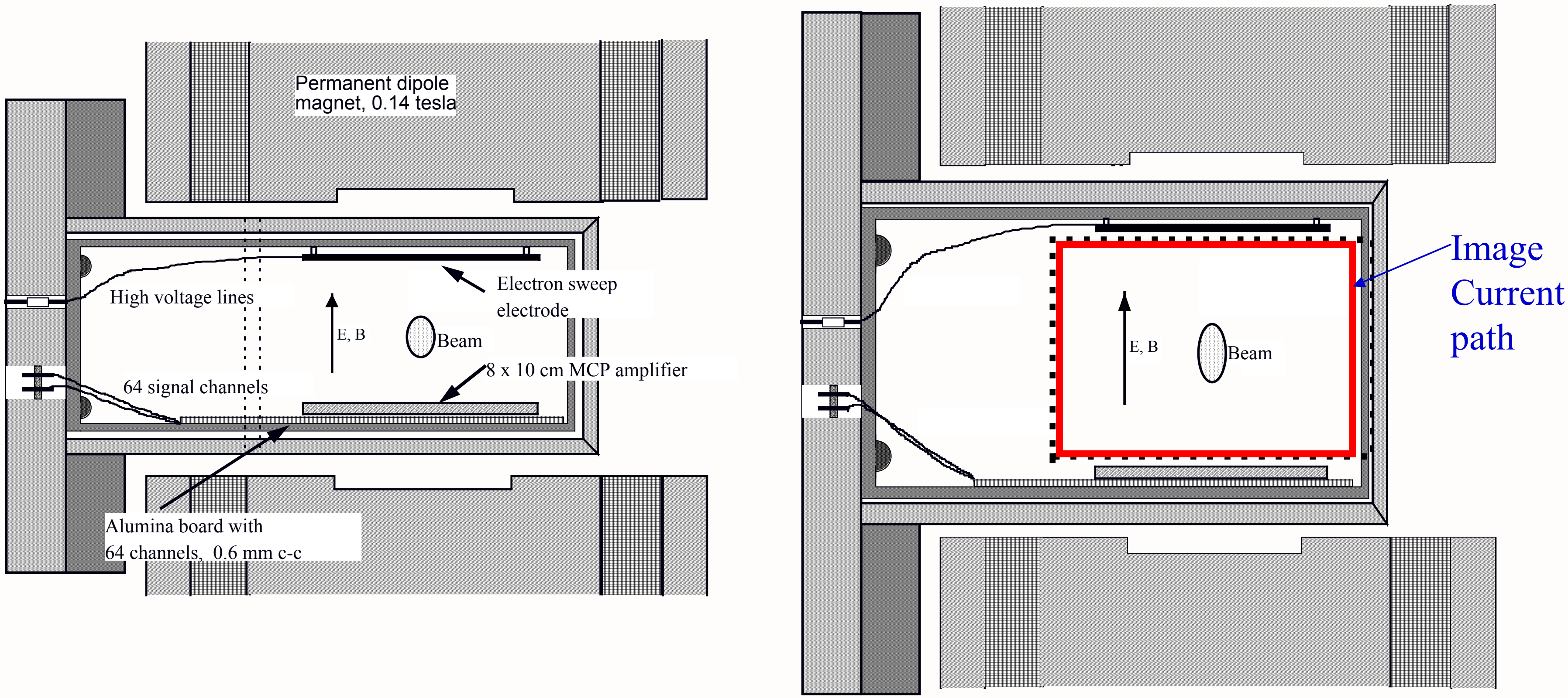
Top opening will contain sweep electrode. For RHIC bottom opening is rf screen grounded to pipe. In SNS rf screen over MCP will float at acceleration potential.

MCP is located out of the beamline, in a hole in a stainless steel mounting plate. The channel plate is shielded from radiation spray by several centimeters of steel.

Impedance bump is greatly reduced.

No projections for secondary electron production.

Modification of transducer



Now the detector components are inserted inside the beamline. This restricts aperture and makes detector components vulnerable to stray beam. A new detector chamber will allow the detector components to be outside of the cross section of the pipe.

Notes

All collector electronics will be outside of an image current path which is exactly the beam line cross section. This will eliminate secondaries in chamber and reduce vulnerability to radiation spray.

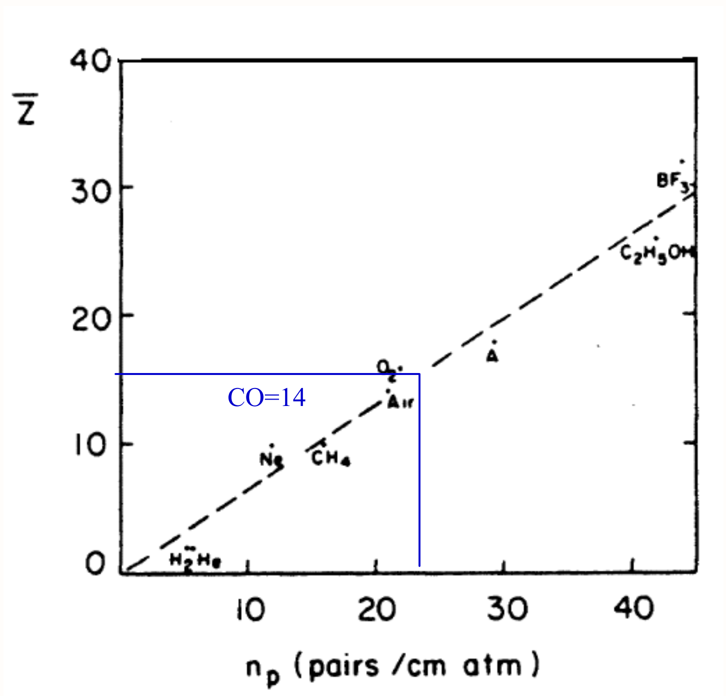
A uniform cross-section image current path will reduce amount of energy left behind in detector chamber.

Magnet will be about 0.1 Tm and will deflect the beam by 18 mrad. This will cause a 2cm displacement in the beam position with a two-magnet detector. A three bump is needed.

SNS Signal Estimate

Background gas expected to be 2/3 H_2 and 1/3 CO. At STP a 1 GeV proton produces 5.2 ionization events/cm in H2 (measured) and 22/cm in CO (estimated from graph). The SNS mixture will give 10.7 electrons/cm/proton. At 10-9 torr expect from one injected turn:

$(10.7 \times 1.5 \times 10^{11}$ electrons/cm$) \times (10^{-9}/760) \times (8$ cm$) = 15$ electrons

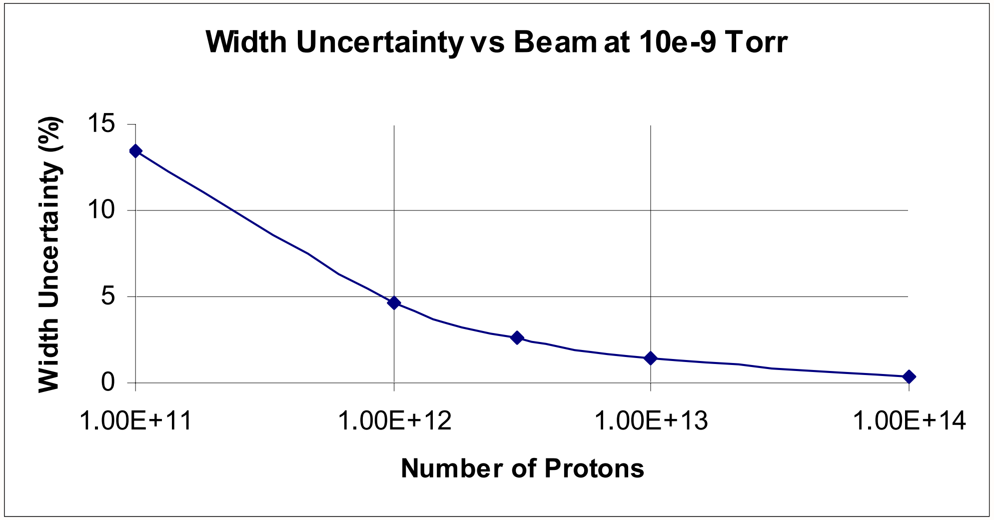


Graph from:
F. Sauli, Principles of Operation of Multiwire Proportional and Drift Chambers, CERN 77-09, Geneva, May 1977

A pressure bump is needed for early in cycle.

From measurement statistics need about 500 electrons for 3% measurement.
At 10-9 torr need about 50 turns in machine to get good measurement (see graph).

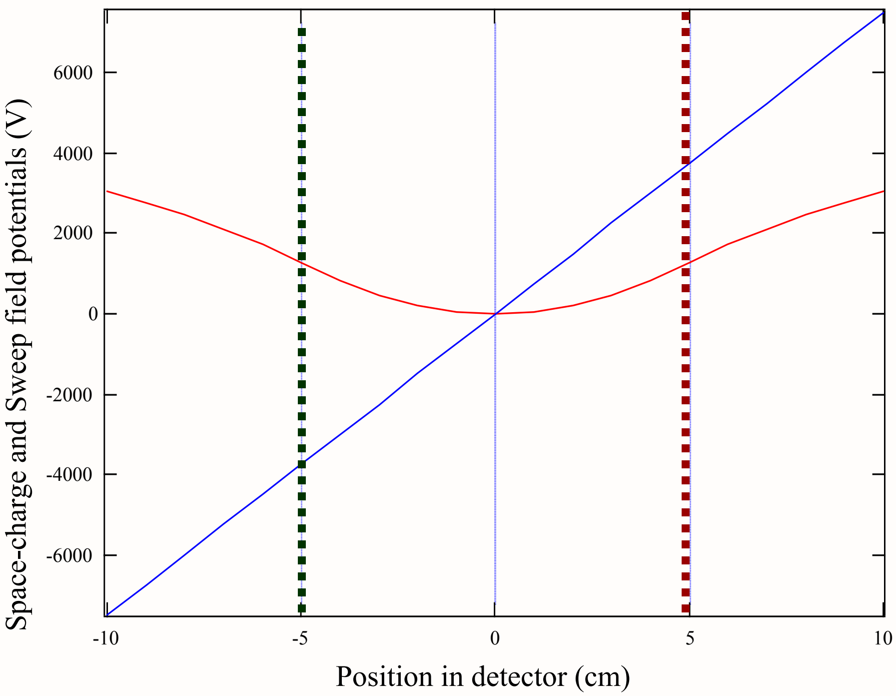
To study early part of machine cycle we will have to introduce a pressure bump.

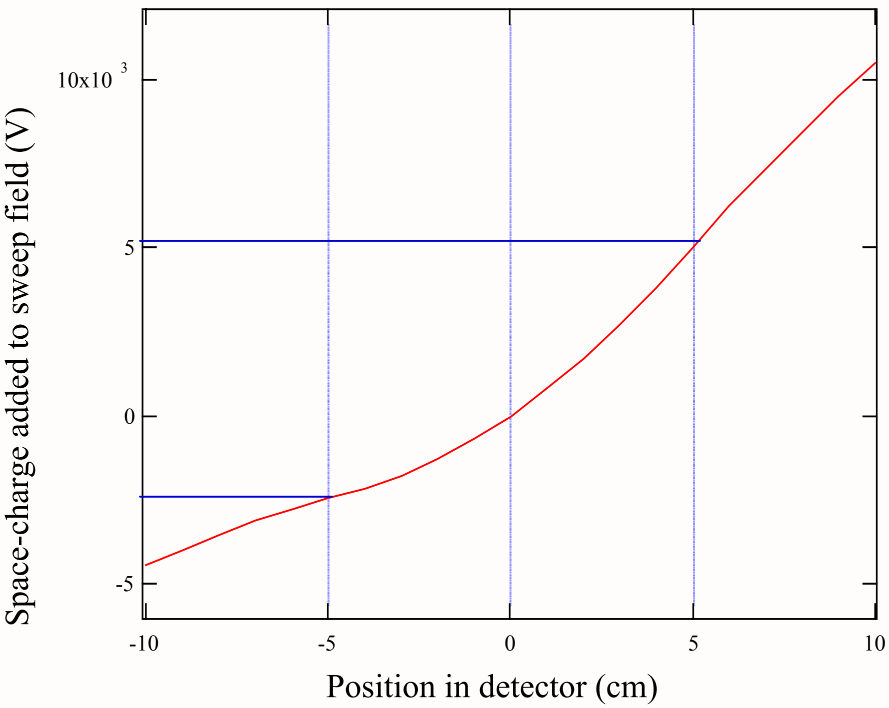


IPM Gas System Installed in RHIC

Potential Distribution

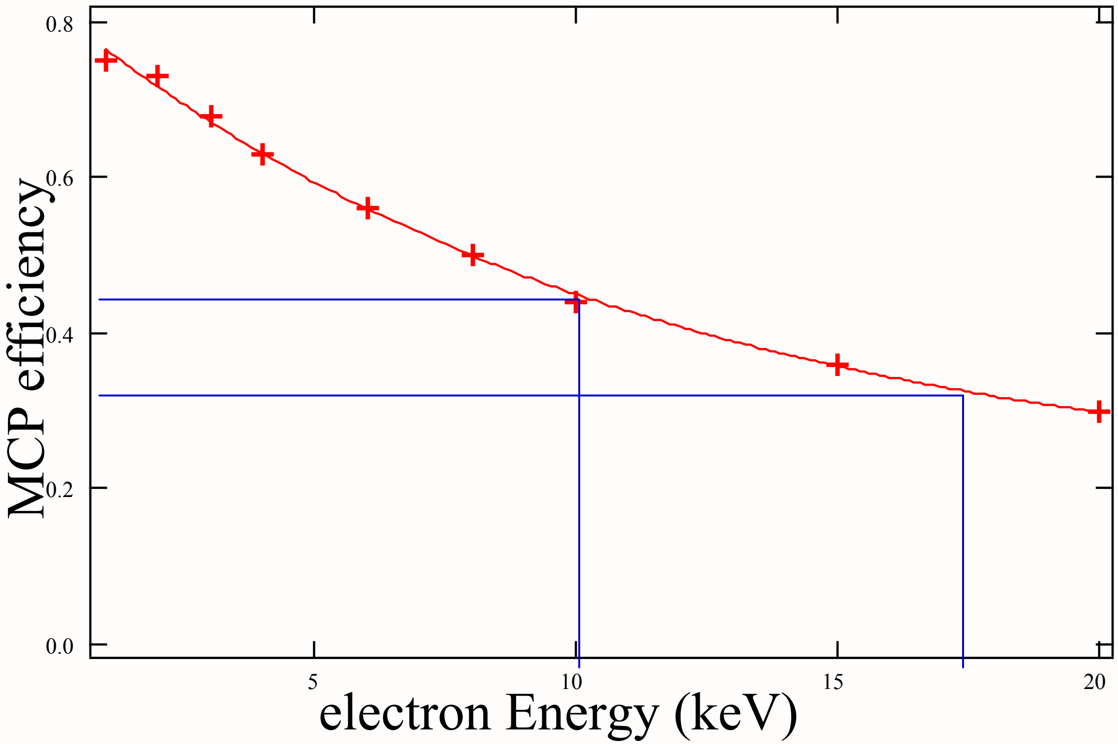
- Beam Space charge potential (Red) and 15 kVApplied Potental (Blue)
- Net potential distribution. Vertical lines are detector extent





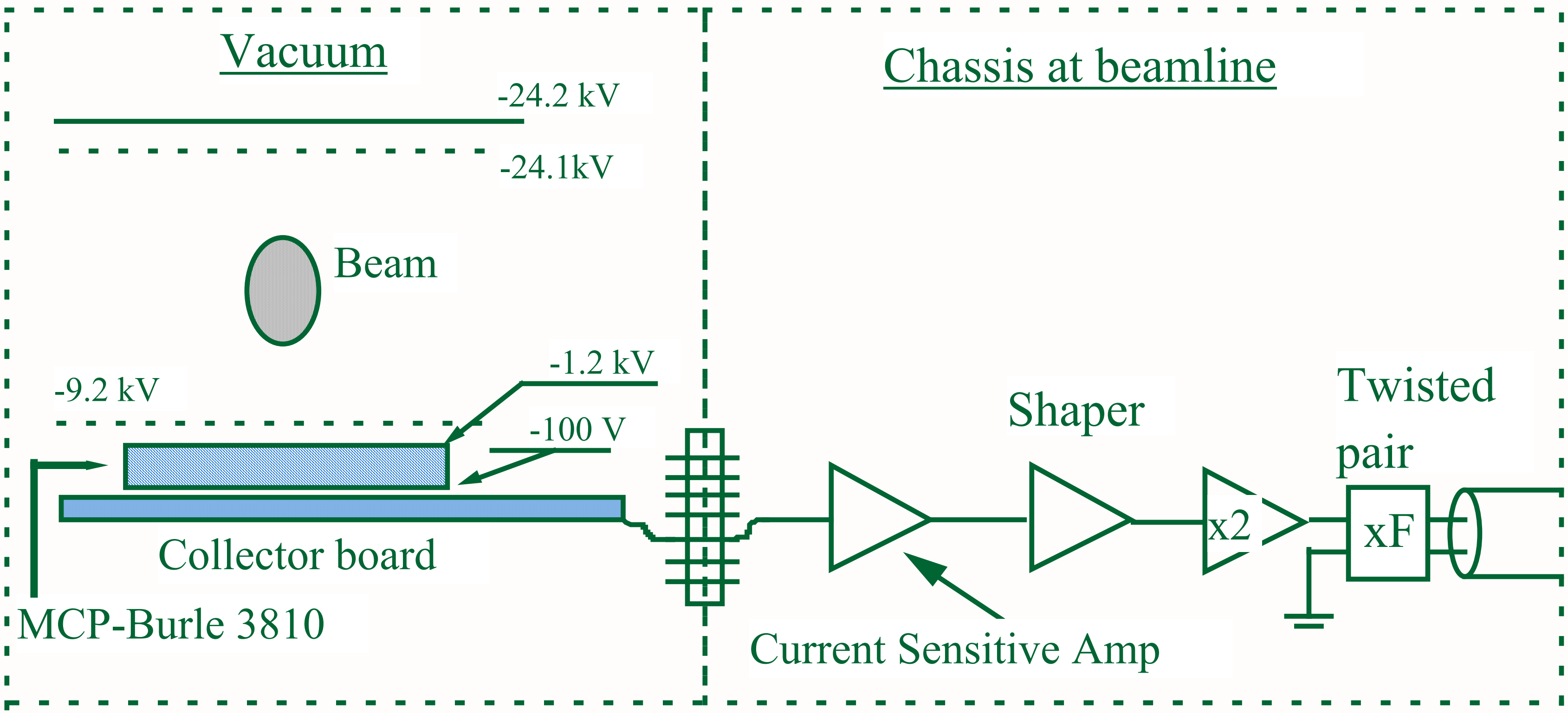
To tilt the space-charge potential well enough for the electrons to spill out will require a sweep potential of 15kV across 20 cm aperture. This will result in a spread of electron energies of 7.5 kV.

MCP Efficiency Dependence on Electron Energy



The variation of detection efficiency with electron energy decreases with electron energy. To reduce this effect the average electron energy will be increased with an 8kV step between the rf screen and the MCP input.

Electrical schematic of transducer head



Three voltage knobs: 1. MCP bias
2. Input of MCP-Near rf screen
3. Sweep voltage across pipe

These three voltages added on top of each other. All track any change in one.

Electrical notes

A section of an MCP can deliver continuously a current density of 10% of the strip current density.

With 40 channels/plate, maximum current/channel is,

$$(300\mu A)(0.10)/(40 \text{ channels}) = 750 \text{ nA/channel}$$

Noise floor at <10nA/channel output equivalent.

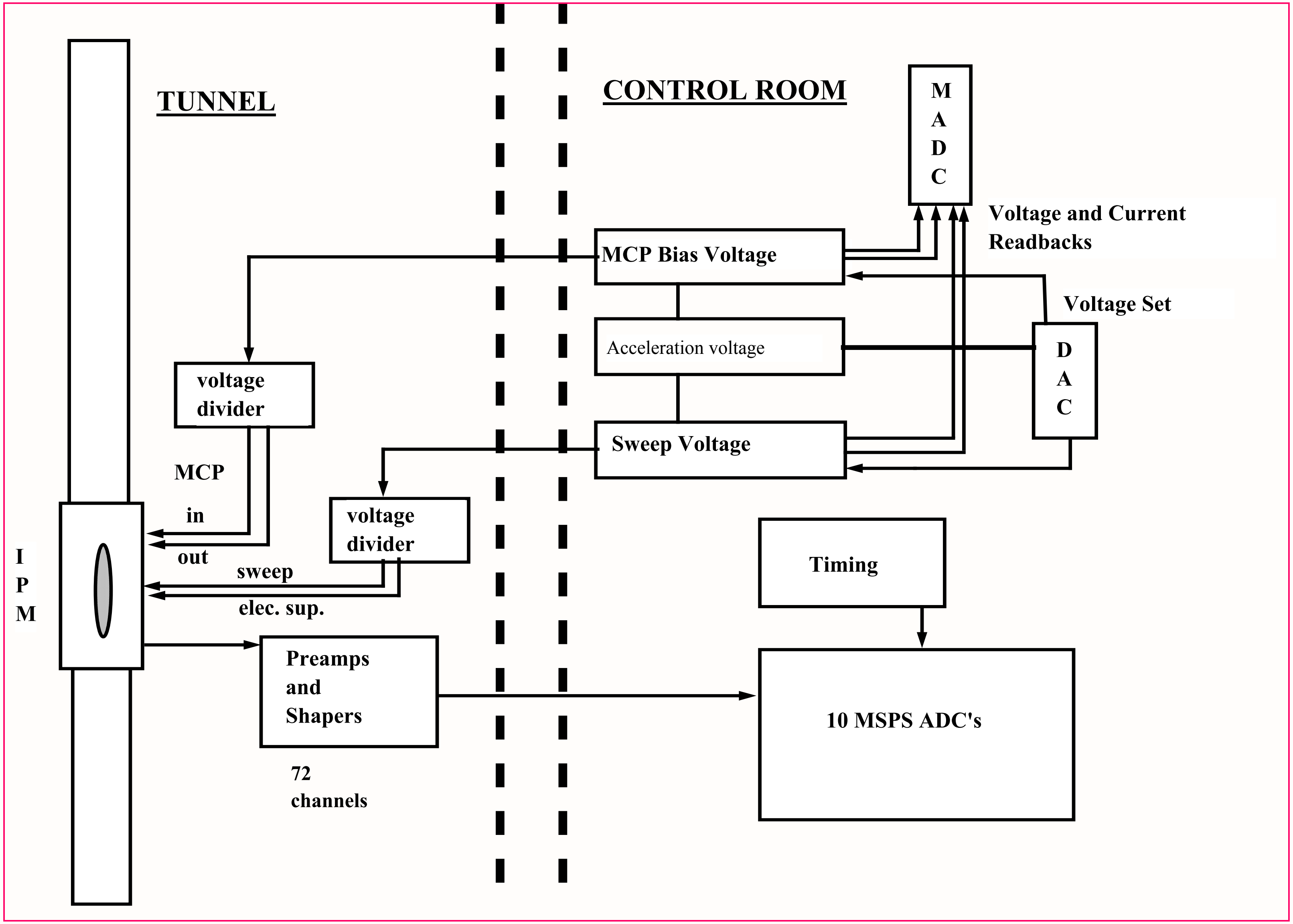
Preamps, shapers and output drivers will be located at detector to get the signal/noise and bandwidth needed.

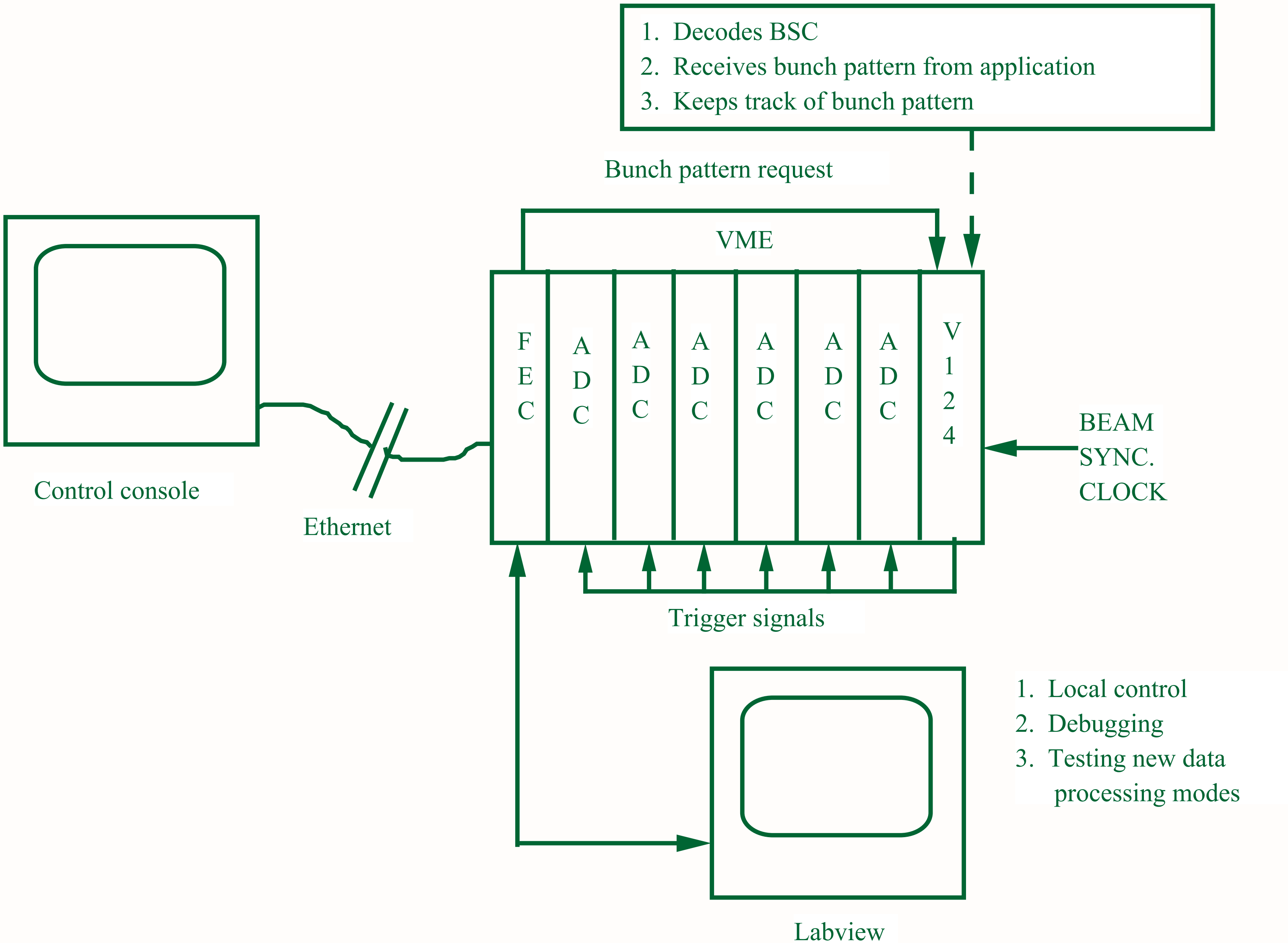
14-bit ADC's will be triggered at 100ns intervals to give 5-7 profiles/turn.

First 100 turns will require a pressure bump. It may be possible to feedback peak channel signal to control bias voltage to follow all of last 90% of fill.

A preamplifier at the beamline should have a lifetime of >1 year. All parts will be replaceable (sockets).

Block diagram





1. Decodes BSC
2. Receives bunch pattern from application
3. Keeps track of bunch pattern
Bunch pattern request
VME
FEC
ADC
ADC
ADC
ADC
ADC
ADC
V124
BEAM SYNC. CLOCK
Control console
Ethernet
Trigger signals
1. Local control
2. Debugging
3. Testing new data processing modes
Labview

IPM status

First RHIC IPM was susceptible to noise from radiation spray, rf, and electrons.

A new RHIC design will be tested this fall. Lessons learned will be applied to SNS.

A first physics design for a magnet is finished. No problems are anticipated.

A prototype collector board is finished.

Instrumentation Division is developing rad hard electronics for Atlas. Preamps and shapers will be in tunnel with anticipated lifetimes of >1 year.

5-7 profiles will be measured in each revolution.