Position Monitors for 3 TeV High Energy Booster

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Propose 1 bpm per half cell, 350 bpm's and 350 blm's for each beam. Provides about 350/(2*33) = 5.3 bpm's per betatron wavelength. Main Injector has 3.8, Main Ring and TeV have 6.4 bpm's per betatron period. MI note 75 indicates for Main Injector, measuring both planes would improve the rms closed orbit distortion correction by only 10%. The ratio of beta max to beta min makes it less important to measure the orthogonal plane.

With 132 nsec between bunches it's tempting to measure each bunch using a log amp processor. Both logA/B and logAB would be digitized to determine position and intensity.

The main ring AM to PM rf module cost about $5k to reproduce, however, a log amp module costs $1k per channel. The 4 plate detector cost $1000 but the split tube detector is about $500. In comparison, Main Injector tunnel cost about $2400 per foot.

Linearity is much better for split tube detectors as can be seen in the following figures.

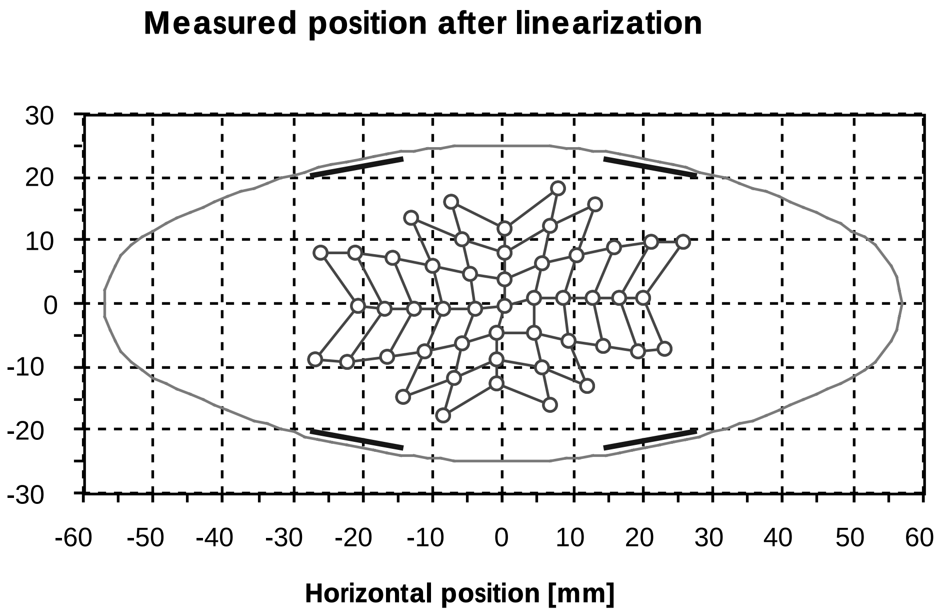


Figure 1. Main Injector 4 plate detector.

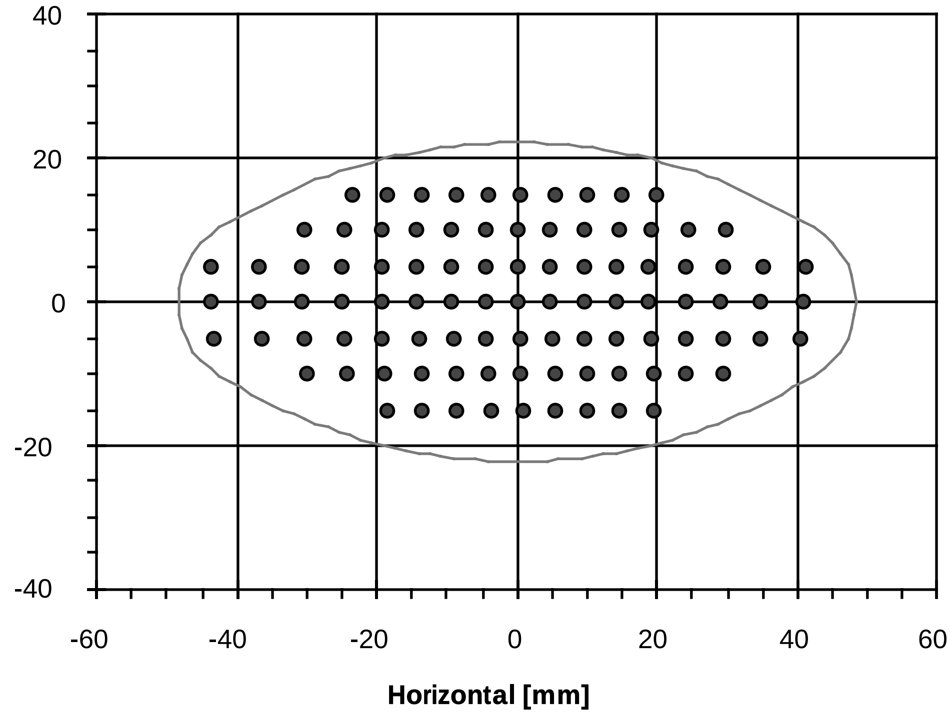
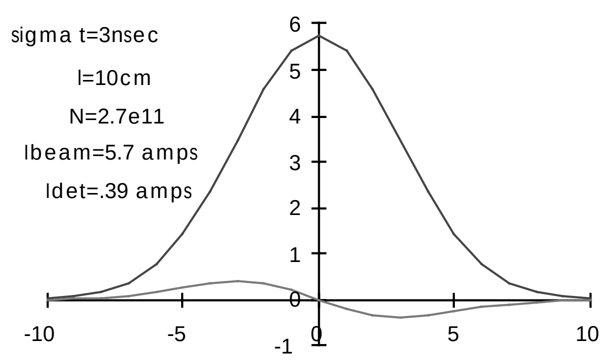


Figure 2. Recycler ring horizontal split tube detector.

The detector plate acts like a differentiator as beam current is induced onto the plate and then removed. The signal induced on a 10 cm detector is estimated below.

$$I = \frac{Ne}{\sigma_t \sqrt{2\pi}} \exp^{-\frac{1}{2}\left(\frac{t}{\sigma_t}\right)^2}$$



Measured beam position is proportional to the log of the ratio of the two bpm signals.

$$pos = \frac{mm}{db} 20 \log_{10} \frac{A}{B}$$

The effects of thermal noise limit how small the electrodes can be. The equivalent position noise is estimated below.

$$\frac{A}{B} = \frac{V_{out} + V_{noise}}{V_{out} - V_{noise}} = \frac{1 + V_{out}/V_{noise}}{1 - V_{out}/V_{noise}}$$

$$\ln\frac{1+x}{1-x} = 2x + \frac{2}{3}x^2 + \frac{2}{5}x^3 + \cdots \quad \approx 2x$$

(use $\sqrt{2}x$ since x represents uncorrelated noise)

$$\log_{10}\frac{A}{B} = \log_{10} e \quad \ln\frac{A}{B}$$

$$pos \quad noise = \frac{mm}{db} 20 \log_{10} e \ \sqrt{2}\frac{V_{noise}}{V_{out}}$$

$$V_{out} = Z_{plate}\ I_{\det} \quad \text{and} \quad V_{noise} = \sqrt{4kTBZ} \quad \text{(thermal kTB noise)}$$

$$\boxed{pos \quad noise = \frac{mm}{db} 20 \log_{10} e \ \sqrt{2}\frac{\sqrt{4kTB}}{I_{\det}\sqrt{Z_{plate}}}}$$

10cm split tube detector
I det = .2 amps, 2.7E11/bunch
sigma t = 3 nsec
4 MHz bandwidth
50 ohm impedance, (higher requires cables < 2ft)
1 db/mm, (scaled from RR 5x12cm pipe)

Thermal noise 2.4 um RMS

In order not to waste signal, plate capacitance should provide an impedance greater than the amplifier at frequencies less than 50 MHz. To satisfy this, the detector housing should be at least 20% larger than plates. This may require the bpm not be placed within the magnet. If the cables between the bpm and the log amplifiers is longer than two feet the amplifier input impedance should match the characteristic impedance of the cable. Split tube detector with log amp $1500/BPM

Loss Monitors

Ion chambers with 116 cc of Argon at 725 mm of Hg is currently used in the TeV, MR, and MI. At 1 or 2 KV, they provide about 1 uamp for 14.3 Rads/second. The amplifier response is shown in the figure below. They cost about $200 for the detector and $300 for the supporting electronics.

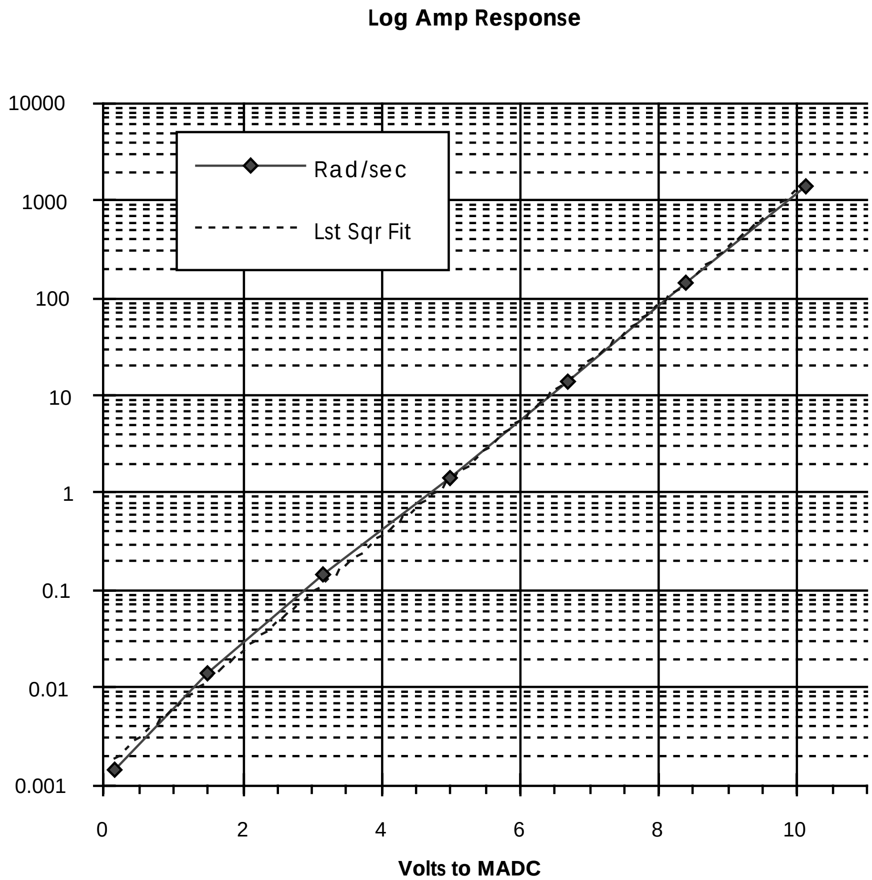


Figure 3. BLM amplifier response.

The Ion chamber could be made from air dielectric coaxial cable which runs the length of each half cell. If more position resolution is desired, each half cell could be subdivided with loss monitor cables which run up and downstream of the controls node.

1/4" Andrew coaxial air dielectric cable
- $5.91/m
- 1.6 KV
- 26 cc/m

Since the half cell is about 100m, the cost of 1/4" cable is comparable to the present ion chamber. It would contain about 22 times the volume of gas, however, the type of gas, pressure, and voltage could be selected to provide the desired sensitivity.

Air dielectric CATV cable may provide a less expensive alternative, however, the types I could find would not work. One used plastic disks to support the center conductor but each disk is water tight making it impossible to flow gas through the cable. The other used splines to support the center conductor but the center conductor was completely surrounded by dielectric making it impossible to collect ions.

Commercial diode loss monitors cost about $500 in small quantities. They have a hundred nsec time constant and large dynamic range but very small volume sensitive to radiation. They are interesting for specific applications but may not be desirable everywhere.