Fermilab

$\bar{p}$ Note # 425

# ION TRAPPING IN THE ACCUMULATOR

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# ION TRAPPING IN THE ACCUMULATOR

The beam space charge (- for $\bar{p}$'s) will attract positive ions. In the absence of additional fields (clearing electrodes, e.g.) these ions will be trapped in the beam potential well. The depth of this potential well has been calculated for some geometries relevant for the accumulator.

## Elliptical beam in a circular chamber

The Green's function for ~~the~~ the potential at the center of a grounded circular pipe of radius b is $\ln \frac{r}{b}$. The potential is:

$$\Phi = -\frac{1}{2\pi\epsilon_0} \int_0^a \int_0^{2\pi} \ln \frac{r}{b}\, \rho(r,\phi)\, d\phi\, r\,dr$$

where $\rho(r,\phi)$ is the charge density. For an ellipse with a uniform charge density:

$$\Phi = \frac{Q}{4\pi^2\epsilon_0}\int_0^{2\pi}\frac{d\phi}{(1+\epsilon\cos\phi)^2}\left[\ln a/b - \tfrac{1}{2} - \ln(1+\epsilon\cos\phi)\right]$$

where the major and minor axes of the ellipse are $a\sqrt{1-\epsilon^2}/(1-\epsilon)$ and $a\sqrt{1-\epsilon^2}/(1+\epsilon)$. The integral was evaluated by expanding ln in powers of $\epsilon$ and integrating term by term (using residues). The resulting power series gave accurate results for $\epsilon < .8$ (using 20 terms).

## Application to the Accumulator

The potential (at the center of the beam) is plotted for the accumulator in figure 1. A beam intensity of $10^{12}$ $\bar{p}$'s in an emittance of $1\pi$ mm-mrad was assumed. Beta functions were obtained from SYNCH output. Displacement of the centroid (dispersion) was ignored. A 10 cm. id. pipe was assumed. Positions of the quads and clearing electrodes (CE) are shown in figure 1. From this calculation one sees a pocket of ionization exists in the long straight sections (low $\beta$).

### Star Chamber

The star chamber (in all small quads) has parts of the wall substantially closer to the beam than the circular pipe. Calculations with POISSON show that the star chamber acts approximately like a circular pipe of a 1.44" diameter. The geometry and equipotentials are shown in figure 2. This calculation shows that the potential in the star chamber will be about 1.5 volt less and will therefore trap ions in the shaded areas shown in figure 1 (the clearing electrode can not clear ions through the quad until the beam potential is partially neutralized.

## Other traps

1. Between Q9 and B9 there is ~1 meter of circular pipe between a star chamber and a rectangular chamber. At a neutralization of ~10% ions will flow through the quad to the clearing electrode on the far side of Q9.
2. The high dispersion long straight sections (between Q14's) are ion traps just like the zero dispersion straight sections.
3. The stochastic cooling kicker electrodes have different potentials at the transitions. The 3cm x 15cm beam tubes have about 1 volt deeper potential than the 3cm x 3cm transitions.

## Bellows

The id. of the bellows is well matched to beam pipe and there does not appear any ion trapping in the bellows.

# Recommendations to reduce ion trapping*

(In order of effectiveness)

1. Add clearing electrodes to the centers of all long straight sections

2. Add a clearing electrode to Q4 (side opposite the BPM)

3. Add a clearing electrode between B7 and S7.

4. Add a clearing electrode ~~on~~ ~~the~~ to Q6 (opposite BPM)

5. Add a clearing electrode between Q9 and B9 ~~to~~ ~~a~~ (it appears the electrode would have to go inside the sextupole).

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* It should not be concluded that ~~this~~ ~~not~~ ~~necessary~~ implementation of these recommendations is necessary for any specific performance — only that these are steps which could be taken to reduce ion trapping.

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# Accumulator Potential

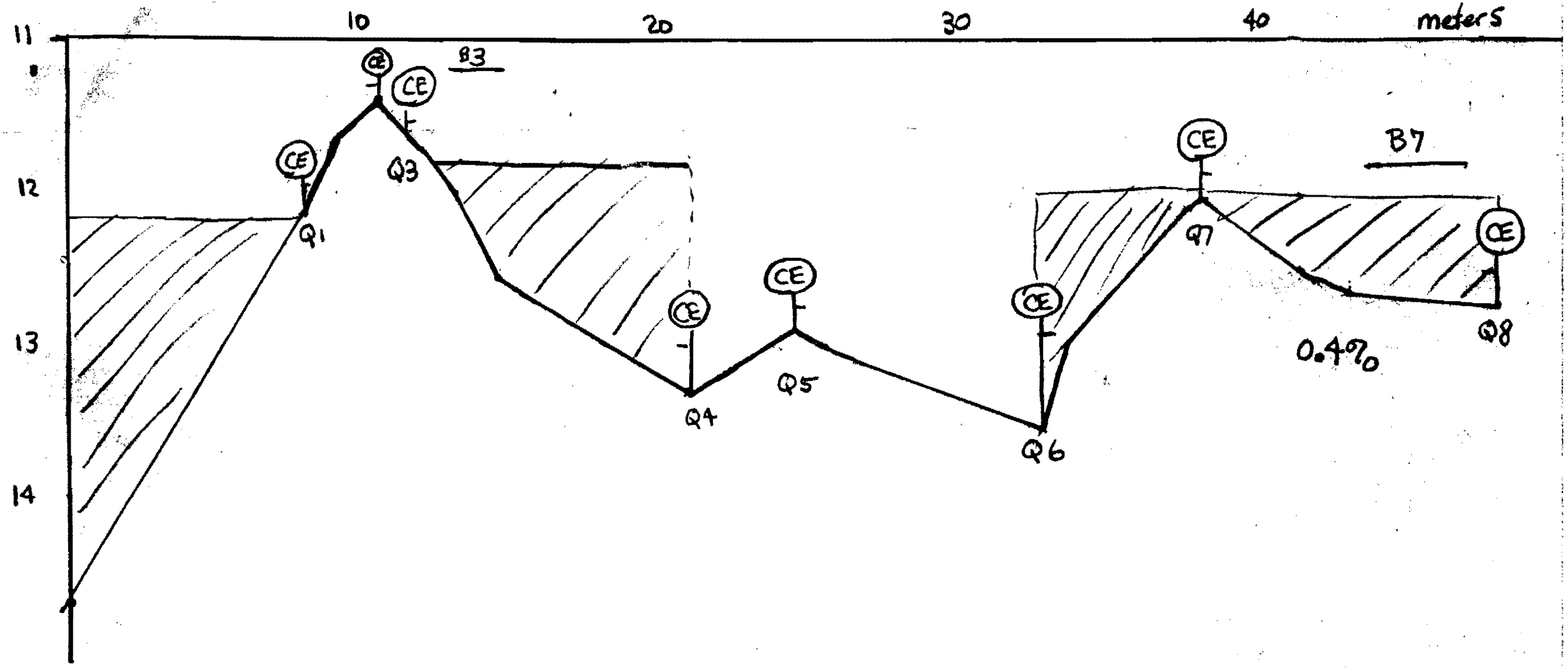

Figure 1

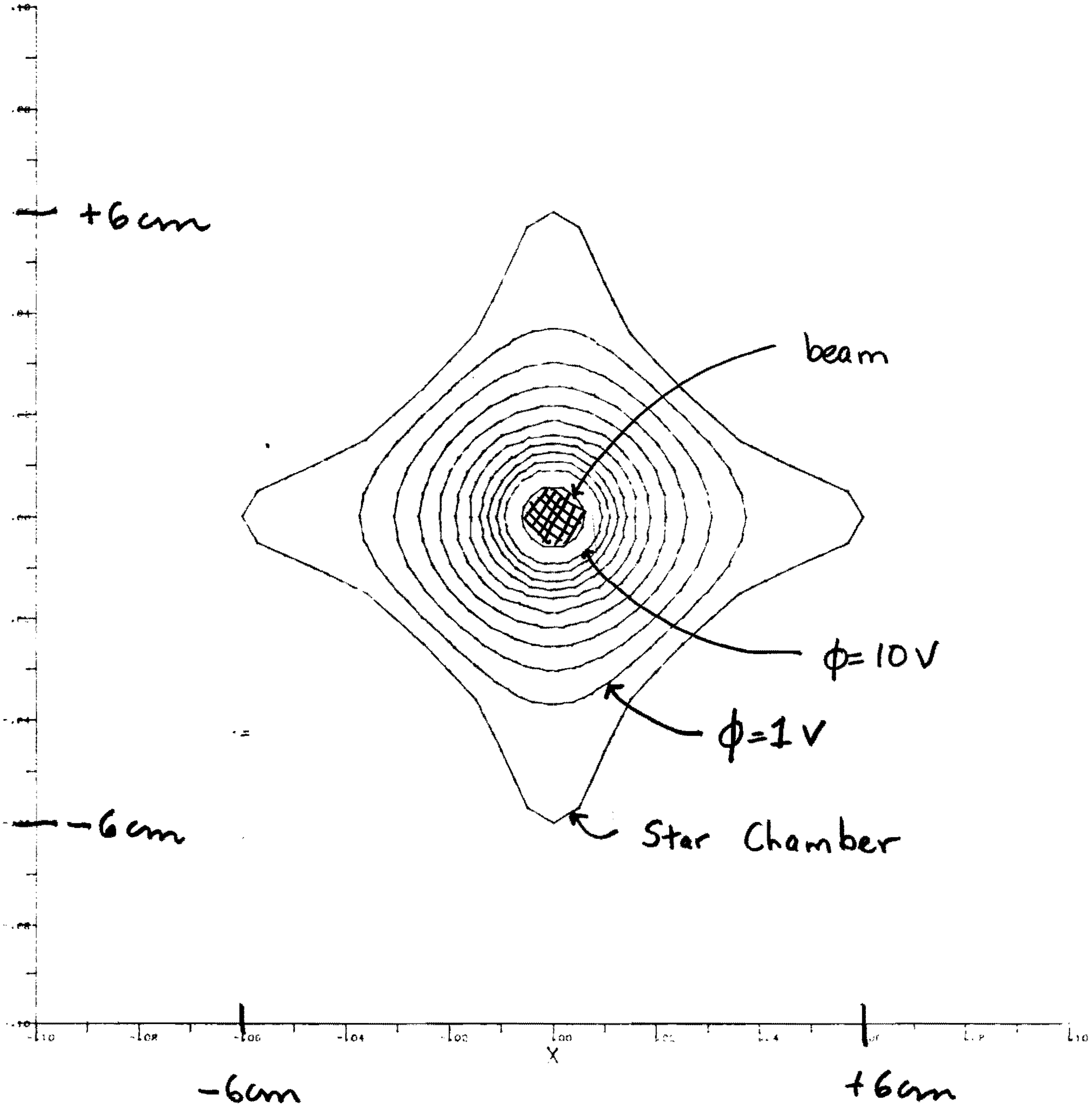

Figure 2

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# SUMMARY OF SURVEY DATA FOR ACCUMULATOR TRIM DIPOLES†

| VAX NAME | LOCATED BETWEEN | NEAREST QUAD | SERIAL NUMBER | DISTANCE TO NEAREST MAGNET* | | |
|---|---|---|---|---|---|---|
| A:V102 | A1Q2-A1Q3 | A1Q2 | NDA016 | $8\frac{7}{16}$" | to | NSA037 |
| A:V104 | A1Q4-A1Q5 | A1Q5 | NDA020 | $18\frac{5}{16}$" | to | A1Q5 |
| A:H105 | A1Q5-A1Q6 | A1Q6 | NDA009 | $17\frac{5}{8}$" | to | A1Q6 |
| A:V106 | A1Q6-A1Q7 | A1Q7 | NDA006 | $17\frac{3}{16}$" | to | A1Q7 |
| A:V109 | A1Q9-A1B9 | A1Q9 | NDA012 | $11\frac{9}{16}$" | to | A1Q9 |
| A:V209 | A2B9-A2Q9 | A2Q9 | NDA013 | $12\frac{3}{16}$" | to | A2Q9 |
| A:V206 | A2Q7-A2Q6 | A2Q7 | NDA008 | $18\frac{3}{4}$" | to | A2Q7 |
| A:H205A | A2Q6-A2Q5 | A2Q6 | NDA010 | $17\frac{13}{16}$" | to | A2Q6 |
| A:V204 | A2Q5-A2Q4 | A2Q5 | NDA003 | $18\frac{1}{4}$" | to | A2Q5 |
| A:V202 | A2Q3-A2Q2 | A2Q2 | NDA030 | $8\frac{3}{4}$" | to | NSA085 |
| A:V302 | A3Q2-A3Q3 | A3Q2 | NDA027 | $6\frac{15}{16}$" | to | NSA095 |
| A:V304 | A3Q4-A3Q5 | A3Q5 | NDA019 | $18\frac{3}{16}$" | to | A3Q5 |
| A:H305 | A3Q5-A3Q6 | A3Q6 | NDA021 | $17\frac{5}{16}$" | to | A3Q6 |
| A:V306 | A3Q6-A3Q7 | A3Q7 | NDA001 | $18\frac{1}{8}$" | to | A3Q7 |
| A:V309 | A3Q9-A3B9 | A3Q9 | NDA029 | $12\frac{1}{16}$" | to | A3Q9 |
| A:V409 | A4B9-A4Q9 | A4Q9 | NDA011 | $12\frac{1}{8}$" | to | A4Q9 |
| A:V406 | A4Q7-A4Q6 | A4Q7 | NDA032 | $18\frac{3}{16}$" | to | A4Q7 |
| A:H405 | A4Q6-A4Q5 | A4Q6 | NDA018 | $18\frac{3}{8}$" | to | A4Q6 |
| A:V404 | A4Q5-A4Q4 | A4Q5 | NDB017 | 20 5/32" | to | A4Q5 |
| A:V402 | A4Q3-A4Q2 | A4Q2 | NDA031 | $15\frac{13}{16}$" | to | A4Q2 |
| A:V502 | A5Q2-A5Q3 | A5Q2 | NDA014 | $14\frac{9}{32}$" | to | A5Q2 |
| A:V504 | A5Q4-A5Q5 | A5Q5 | NDB038 | $19\frac{15}{16}$" | to | A5Q5 |
| A:H505 | A5Q5-A5Q6 | A5Q6 | NDA024 | 18 1/4" | to | A5Q6 |
| A:V506 | A5Q6-A5Q7 | A5Q7 | NDA004 | $17\frac{3}{4}$" | to | A5Q7 |
| A:V509 | A5Q9-A5B9 | A5Q9 | NDA025 | 11 3/4" | to | A5Q9 |
| A:V609 | A6B9-A6Q9 | A6Q9 | NDA005 | 12 5/8" | to | A6Q9 |
| A:V606 | A6Q7-A6Q6 | A6Q7 | NDA026 | $18\frac{3}{8}$" | to | A6Q7 |
| A:H605 | A6Q6-A6Q5 | A6Q6 | NDA022 | $18\frac{1}{8}$" | to | A6Q6 |
| A:V604 | A6Q5-A6Q4 | A6Q5 | NDA007 | $18\frac{3}{8}$" | to | A6Q5 |
| A:V602 | A6Q3-A6Q2 | A6Q2 | NDA028 | $7\frac{15}{16}$" | to | NSA092 |

† Data taken by O'Boyle + Howat May 22-23, 1985, except A:V504 + A:V404 which were done by Lennox 7-11-85.

* Measured from dipole center to steel of nearest magnet.