

BNL-105088-2014-TECH

Booster Technical Note No. 41;BNL-105088-2014-IR

Space charge effect in the AGS Booster for high intensity proton operation

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May 1986

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U.S. Department of Energy

USDOE Office of Science (SC)

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SPACE CHARGE EFFECT IN THE AGS BOOSTER FOR HIGH INTENSITY PROTON OPERATION

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> > G. PARZEN May 22, 1986

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SPACE CHARGE EFFECT IN THE AGS BOOSTER FOR HIGH INTENSITY PROTON OPERATION

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This note briefly summarizes the results of a tracking study of the effects of space charge for a high intensity proton beam in the AGS Booster.

This study is being continued. The results so far indicate that the essential space charge limit, which is the space charge limit due to the non linear space charge forces in the absence of resonances due to non-space charge forces, plays an important role. Assuming that the first few resonances due to non-space charge forces, that are crossed by the beam, can be corrected, then the space charge limit is determined by the essential space charge limit, defined above. This is reached at about .5 x 10^{13} protons/bunch in the booster, corresponding to a space charge v-shift of about $\Delta v \approx .6$.

The above results are based on looking for self-consistent solutions in which the beam does not grow. It may be that the results are on the pessimistic side. Solutions in which the beam is allowed to grow have so far not been studied. This may be done in the future.

Looking for self-consistent solutions with a tracking program is an improvement in the computation of space charge effects. However, one should keep in mind that the approach shows that certain beam intensities are achievable, and it suggests that higher beam intensities may cause unacceptable beam growth but it does not conclusively demonstrate this.

Model for Space Charge Effects

Two Models for limit on intensity

- 1) Limit due to Veronances driven by hon-Space Charge forces. Space Charge forces move V-Values on to resonance. This is the traditional model. It indicates that the larger 1/3-boosten may have lower space charge limit than the 1/4-boosten. This limit will be called the <u>resonance limit</u>.
 - 2) The Alimit arises from the non-linear Space charge forces them selves; even when no resumances are present due to other forces than space charge. If this limit is reached before

the v-values have reached the damaging resonance, then this limit dominates and provides the basis for comparing two accelerators.

This limit will be called the <u>essential</u> space charge force limit. Computing the Space Charge Force Limit

This can be done with a tracking program - One difficulty is computing the force on a particle due to the fields of all the other particles. If this is done correctly , this approach is exact. Jn the following the fields due to all the other particles is approximated by the field of of a beam with a continuous distribution which does not change during the tracking run. One then louks for Self-Consistent soutions. The results sufound suggest values for the Space charge limit. The results are not rigorous.

Space Charge Effects in tracking Studies

At each element, magnet or drift space, the particle is given the Kicks, $\delta x' \sim E_x L/BP$, $\delta y' \sim E_y L/BP$.

By Narying the initial X y and DP/p, and by fourier analyzing the orbitmotion, one can find DVC, DV(A), DV(P). These results include octupate and higer orden multipole effects. By including the magnet errors, bic and ar, one can observe the instabilities due to imperfection resonances, or systematic resonances.

Running time of the tracking program is considerably in creased. studies are possible for a small accelerator like the booster, where space charge is particularly important. Actual Process for Space Charge effects For a Given NBNCH injected, Beam grows in size until it stabilizes or XBM. Final XBM and NBNCH are related. XBM = XBM(MBNCH)

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XBM~ Aperture gives largest NBNCH.

For given XBM, increase NBNCH To find largest NBNCH for no growth growth. This gives result for XBM NS. N BNCH relation (Beam dimensions do not changen in this seaved)

For XBM = Aperture, the gives largest NBNCH.







Raka, Ahrens, Frey, Gill, Glenn, Sandens, Weng TEEE Trans, Nuclisci. NS-32, Nois, P.3110. (1985) All resonance lines shown can be Corrected in AGS.

BNy, sc = -. 58, BNx, s, c = -.16

No space charge limit has been demonstrated - More curvent injected gives more current in AGS.

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Possible Con clusions

- 1. The Resonance limit can effectively be removed with correction magnets in the range of interest.
- 2. The intensity limit is determined primarily by the Space charge force limit.
 - 3. Proposed experiment for the A6sreduce the aperture and measure the limit due to apace charge.
 - 4. other factors that may change results 9. Non-round beams
 - b. Image Fields