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Effect of injection energy spread in multiturn injection on AGS Booster

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U.S. Department of Energy

USDOE Office of Science (SC)

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Abstract

The beam of protons coming from the ASG LINAC has a finite kinetic energy spread. Computer simulation is done to explore its effects on the R.F. capture efficiency of the multiturn injection on the AGS Booster.

The beam of protons coming from the AGS LINAC has a full width kinetic energy spread [1] of 0.8 MeV. When the beam is multiturn injected into the AGS Booster at the energy of 200 MeV, this initial energy spread influences the capture efficiency.

We consider the problem in the longitudinal phase space $(\phi, \frac{\Delta p}{p})$. Suppose we devide the d.c. beam of finite energy spread as a series of horizontal beam "lines", each consists of particles of a certain energy $\frac{\Delta p}{p}_i$ but negligible energy spread, and of random R.F. phase ϕ. Without considering the space charge effect, beam "line" injected at $\frac{\Delta p}{p}_i = 0$ level has the highest capture rate. The larger the absolute value of $\frac{\Delta p}{p}_i$, the less the efficiency. Therefore large initial energy spread decreases the achievable capture efficiency.

Initial beam energy spread also changes the beam distribution in the longitudinal phase space. Particles which initially belong to the d.c. "line" of a certain $\frac{\Delta p}{p}_i$ can never get into the elliptic contour of $|\frac{\Delta p}{p}_{max}| < |\frac{\Delta p}{p}_i|$. Therefore a large initial energy spread results less particles near the certer of the bucket. The distribution is thus more uniform.

Things become less obvious when the space charge effect is included. In Ref. 2 we discussed the R.F. capture efficiency of $100\mu s$ multiturn injection of proton beam of initial kinetic energy spread of $\Delta T_i = 0.2 MeV$, or $\frac{\Delta T_i}{T_i} = 10^{-3}$. Here in Fig.1 we show the capture efficiency as a function of the injection energy spread under the same condition as in Ref. 2. Fig.2 and Fig.3 show the $1ms$ programmed R.F. capture of protons of $\Delta T_i = 0.8 MeV$, without and with considering the beam space charge effect respectively. With the R.F. programming, the R.F. capture efficiency is about 93% under the proton intensity of $5 \cdot 10^{12}$ per bunch.

Fig.4 and Fig.5 show the corresponding diagrams for the other scenario of having a constant $\dot{B}_0 = 1.5\ T/s$ during the capturing process. Note that due to the non-zero $\dot{B}_0$, the injection energy relative to the center of the bucket is shifted by $\frac{\Delta p}{p} = 0.001$ during the $100\mu s$ injection time. From the same argument above we conclude that the beam should be injected "symmetrically" with respact to the bucket center to achieve the highest capture efficiency, *i.e.* $|\frac{\Delta p}{p}_{C,first\ turn}| = |\frac{\Delta p}{p}_{C,last\ turn}| = 0.0005$. With the constant $\dot{B}_0 = 1.5\ T/s$ the R.F. capture efficiency is 81%.

Acknowledgment

We would like to thank Dr. *M. Brennan* very much for pointing out the problem for us.

REFERENCES

1) E. Raka *et. al.*, IEEE 1985 PAC. pp.3110

2) J. Wei, S.Y. Lee and A.G. Ruggiero, Booster Tech. Notes No.115 (1988)

FIGURE CAPTIONS

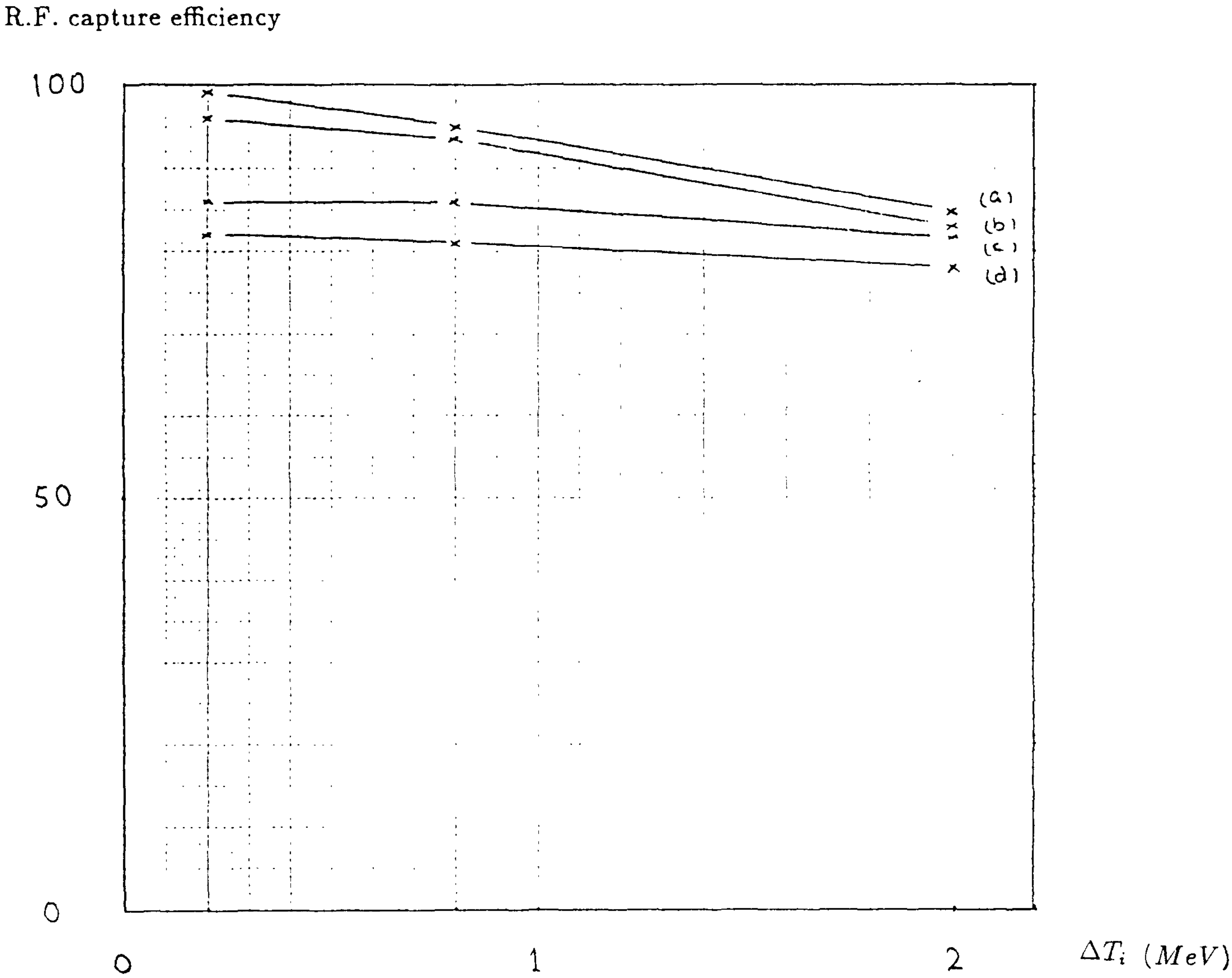
Fig. 1. The R.F. capture efficiency as a function of the injection beam full width kinetic energy spread.

Fig. 2. The longitudinal phase space diagrams of proton beam of $\Delta T_i = 0.8MeV$ at different moments during R.F. capture. The space charge effect is not considered. The survival rate is 95.1%. The R.F. system is programmed in $1ms$, as discussed in Ref.2.

Fig. 3. The longitudinal phase space diagrams of proton beam $\Delta T_i = 0.8MeV$ at different moments. The space charge effect is considered. 200 bins, 20000 representative particles are used in the simulation. The survival rate is 93.4%. The R.F. system is programmed in $1ms$, as discussed in Ref.2.

Fig. 4. The longitudinal phase space diagrams of proton beam of $\Delta T_i = 0.8MeV$. The space charge effect is not considered. The survival rate is 86.0%. $\dot{B}_0 = 1.5\ T/s$.

Fig. 5. The longitudinal phase space diagrams of proton beam of $\Delta T_i = 0.8MeV$. The space charge effect is considered. 200 bins, 20000 representative particles are used in the simulation. The survival rate is 81.1%. $\dot{B}_0 = 1.5\ T/s$.



a. 1 ms programmed R.F., without considering space charge effect

1 ms programmed R.F., space charge effect considered. $g_o = 2$

c) $\dot{B}_o = 1.5$ T/s, without considering space charge effect

d) $\dot{B}_o = 1.5$ T/s, space charge effect considered. $g_o = 2$

Fig. 1.

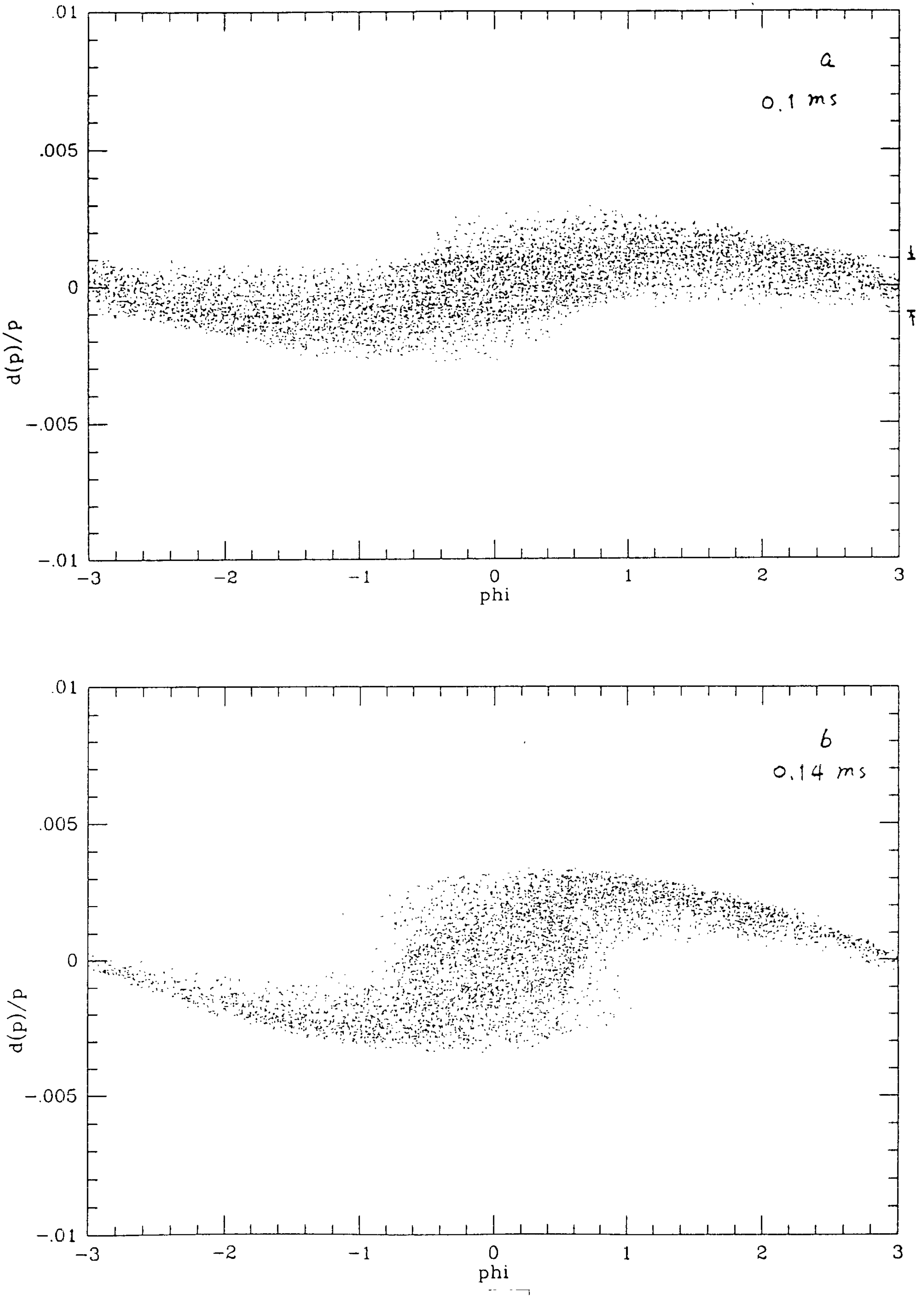
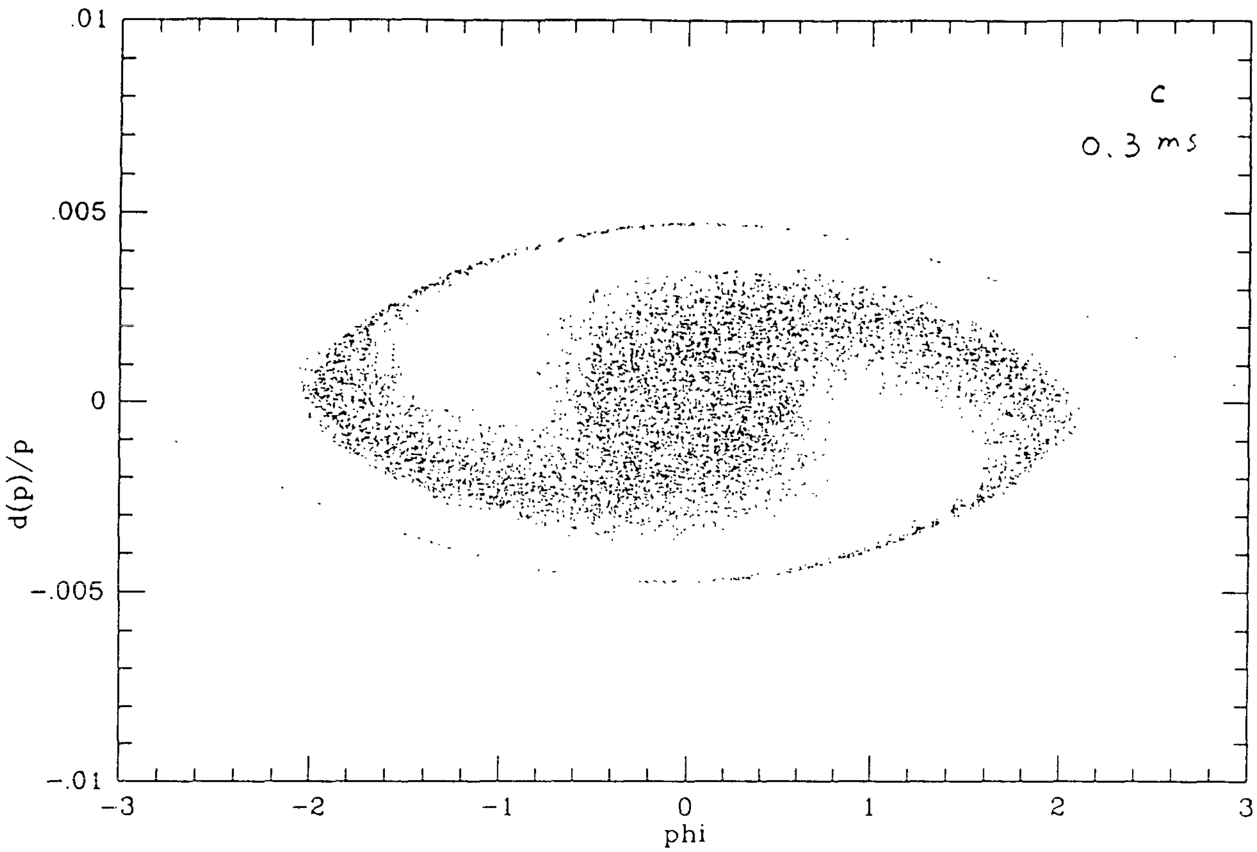


Fig. 2.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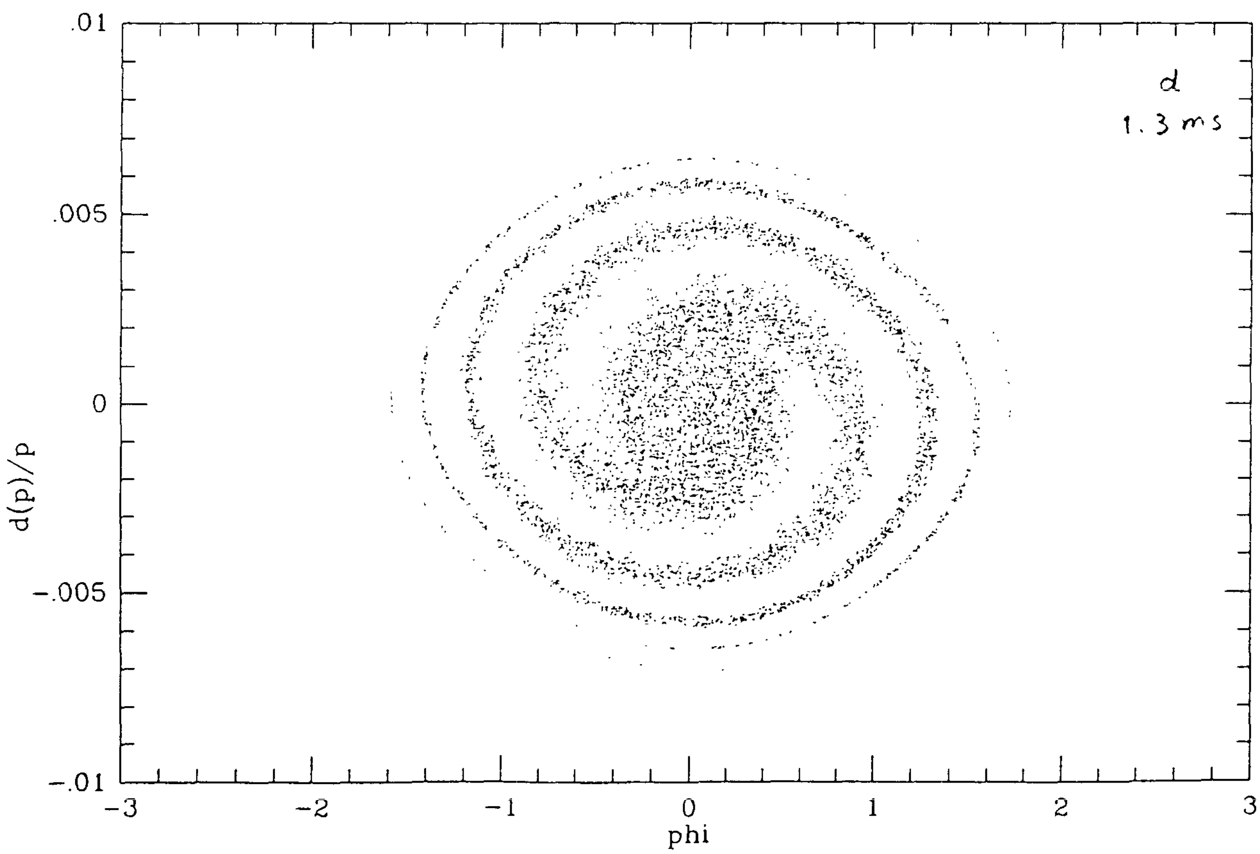
.005
0
-.005
-.01
d(p)/p
-3
-2
-1
0
1
2
3
phi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.005
0
-.005
-.01
d(p)/p
-3
-2
-1
0
1
2
3
phi

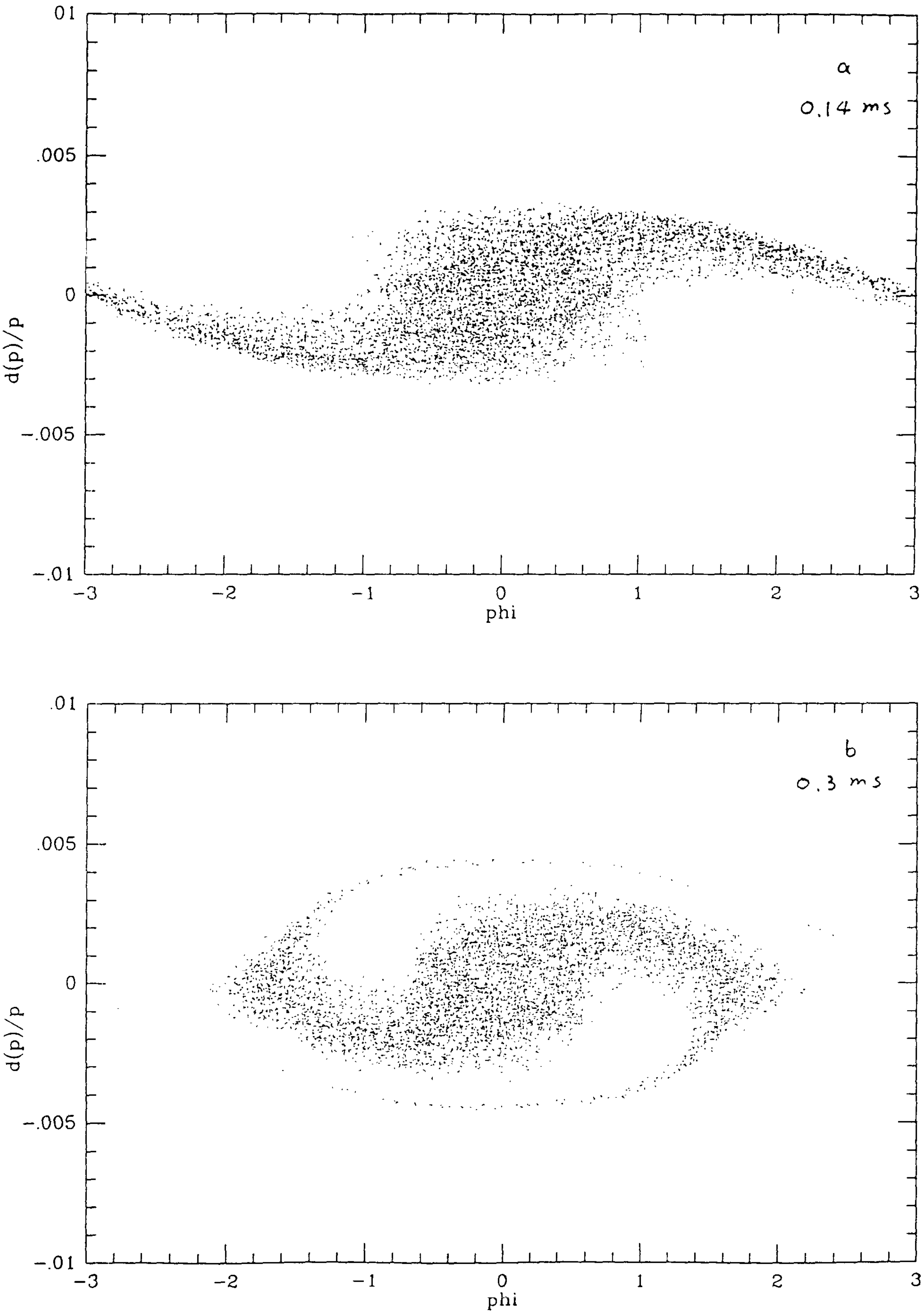


Fig. 3.

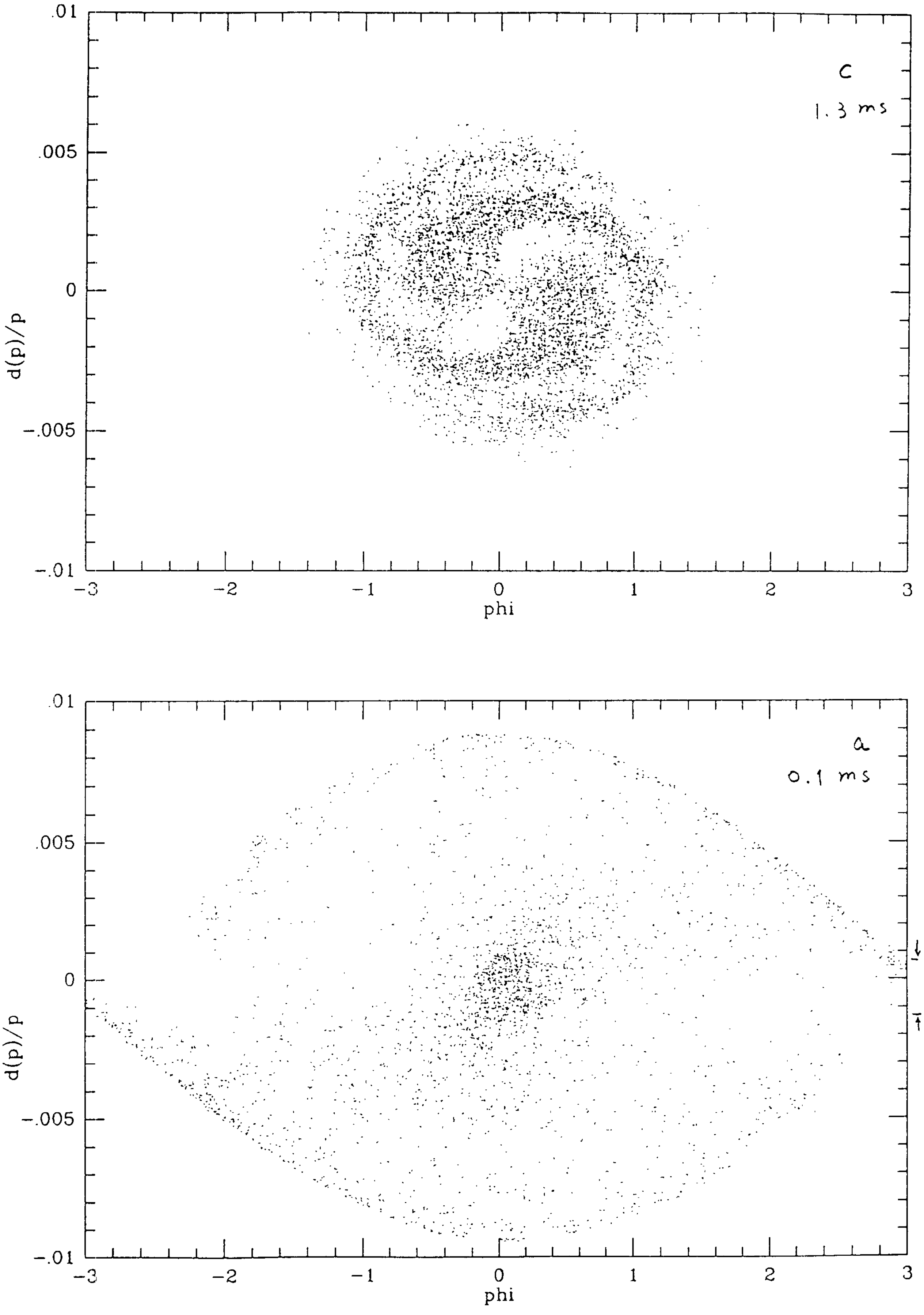
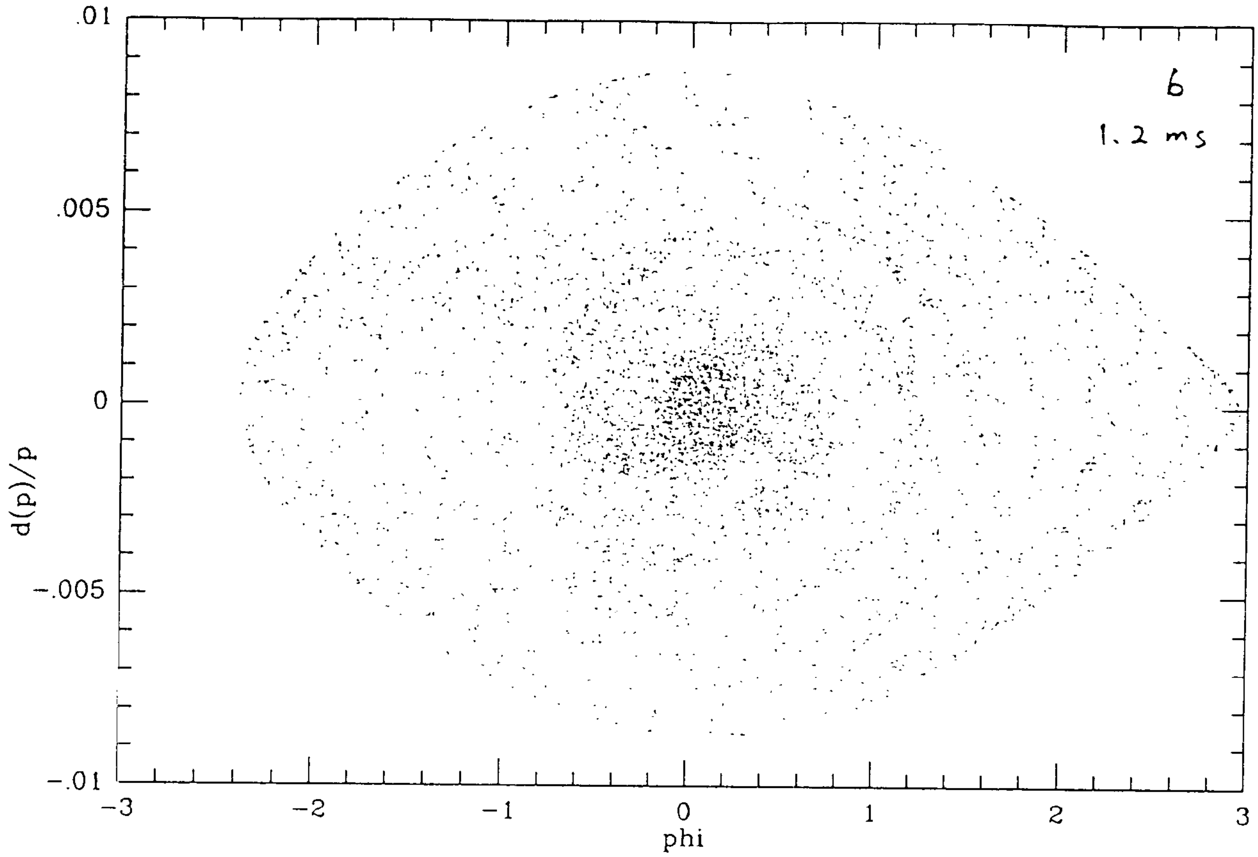


Fig. 4.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.005
0
-.005
-.01
d(p)/p
-3
-2
-1
0
1
2
3
phi

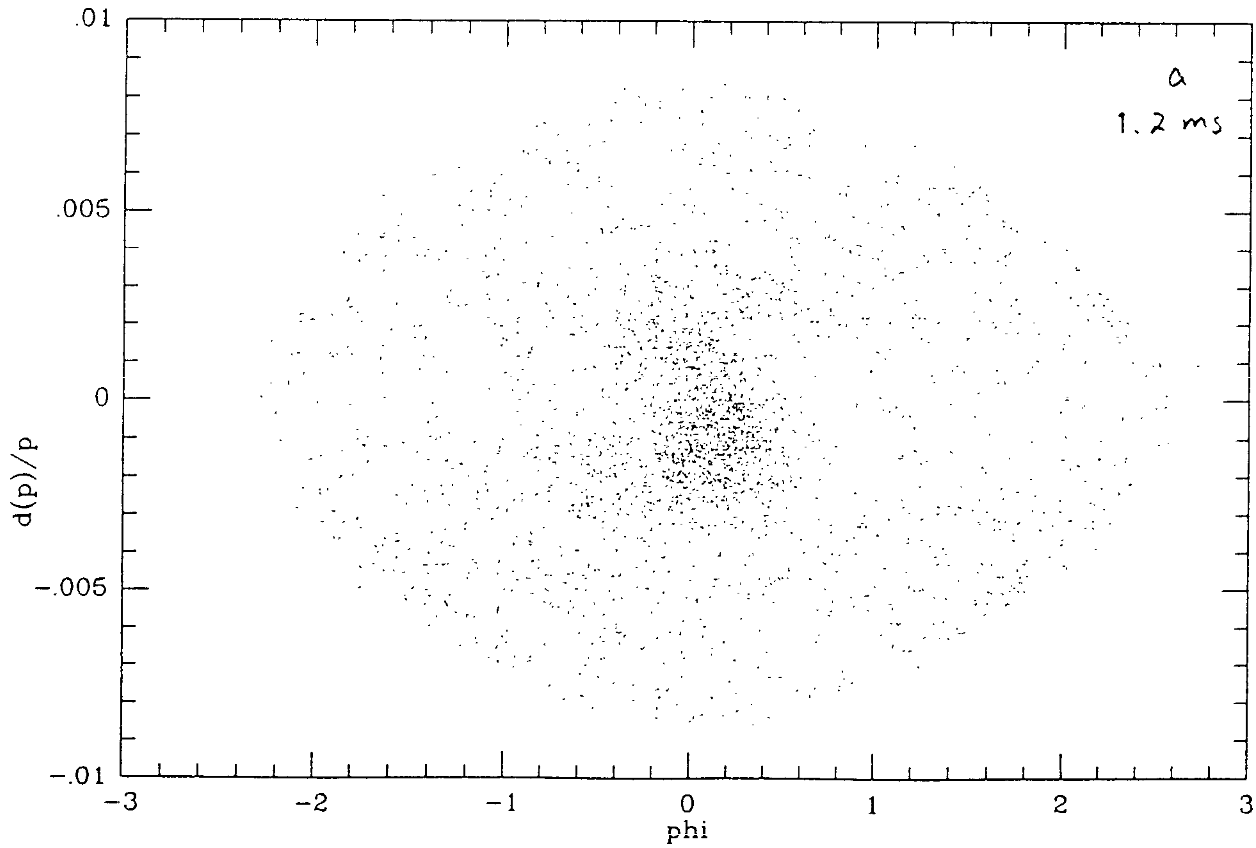
a
1.2 ms
.01
.005
0
-.005
-.01
d(p)/p
-3
-2
-1
0
1
2
3
phi

Fig. 5.