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A Proposed Simple Modification of the AtR Line to Optimize the Polarization Transfer of a Polarized Proton Beam from AGS to RHIC

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Spin Note

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Intoduction

The stable spin direction of a polarized proton beam at the RHIC injection point depends on the proton beam energy as well as the stable spin direction of the polarized beam at AGS[1]. A detailed study of this dependance over the energy range in which a polarized proton beam will most likely be injected into the RHIC machine, has been done, and the results appear in (Ref.1). Currently most of the depolarized resonances at AGS have been overcome[2] and a polarized proton beam can be extracted from AGS with momentum p=22.03 GeV/c (γ=23.5,Gγ=42.13) with the beam maintaining an appreciable polarization. In addition an effort is under way at AGS to go over the depolarization resonances which appear at beam momentum higher than p=22.03 GeV/c, and push the energy of a polarized proton beam at the maximum available energy of AGS. The study of Ref. 1, has shown that the optimum polarization transfer from AGS to the RHIC injection point is energy dependent and occurs in a rather narrow energy range of the injected proton beam. In order to optimize the polarization transfer to a wider energy range, and specifically from 22.0 GeV/c to 29.5 GeV/c, a simple modification of the AtR line is proposed. This modification will provide the AtR line with "tunability" for optimum polarization transfer at any proton momentum between 22.0 GeV/c and 29.5 GeV/c.
In this technical note a description of the modification will be presented, and results of the stable spin direction at the RHIC injection point for a given "tune" of the AtR line will be presented for two cases:
a) Partial Snake at AGS off.
b) Partial Snake at AGS on.

Description of the Proposed Modification of the AtR Line

The dependance of the stable beam direction at the RHIC injection point on the beam energy and the stable spin direction at AGS, stems from the geometry of the AtR line, and in particular of the "12.5 mrad vertical bend" Fig. 1. A description of the 12.5 mrad vertical bend as it appears in Fig. 1 is given in Ref.1. The proposed modification consists in the insertion of three horizontally bending dipoles arranged symmetrically with respect to the bending center of the second dipole (Fig. 2), and placed in the 12.5 mrad vertical bend section of the AtR line as shown in Fig. 3. In this technical note the combination of the

three dipoles as it appears in Fig. 2, will be referred to as "AtR snake". The insertion of the AtR snake in the AtR line (Fig. 3) will effect neither the chromaticity, nor the beam parameters and direction of the beam at the exit of the AtR snake. It is only the components of the stable spin direction that will be affected by the AtR snake; the rest of the beam parameters will remain practically unchanged outside the AtR snake.

Results of the Stable Spin Direction at the RHIC Injection Point for a Particular "tune" of the AtR Snake

The procedure to calculate the stable spin direction at the RHIC injection point has been described in details in Ref. 1. In this section only the results of the stable spin direction at the RHIC injection point in the proton momentum range of 21.96 GeV/c to 25.1 GeV/c ($G\gamma$=42 to $G\gamma$=48) are presented. The calculations include the effect of the AtR snake which has been tuned so that the field of the first dipole magnet (see Fig. 2) bends the central trajectory by 2^0 to the right. This tune of the AtR snake is equivalent to optimizing the polarization transfer at a proton beam energy corresponding to a value for $G\gamma$=42.4. The results are summarized in Fig. 4 (partial snake in AGS off) and Fig. 5. (partial snake in AGS on) where the directional cosine of the stable spin direction with the vertical, at the RHIC injection point, is shown as a function of $G\gamma$. In particular in Fig. 4, the filled squares correspond to the directional cosines (at RHIC injection point) of the central trajectory with the AtR snake off, and the filled circles, to those with the AtR snake on. The lines joining the points in Fig. 4 are to guide the eye. Also in Fig. 4 the non-filled squares correspond to the directional cosines of a non-central trajectory which has been chosen just outside the 95% population of the beam distribution at AGS[1] and with the AtR snake off. Similarly the non-filled circles in Fig. 4 correspond to the noncentral trajectories at AGS with th AtR snake on. This particular tune of the AtR snake permits optimum transfer of polarized beam from AGS to RHIC in the energy range corresponding to $G\gamma$=42 and $G\gamma$=45.5. When the AtR snake if off, optimum polarization transfer occurs in the range of $G\gamma$=45.5 to $G\gamma$=48 at least.

When the partial snake in AGS is turned on, the results of the stable spin direction at the RHIC injection point are shown in Fig. 5. The filled squares in figure 5 are the values of the directional cosines of the stable spin direction with the vertical at the RHIC injection point as a function of $G\gamma$, when the AtR snake is on. For each central momentum trajectory p_0, four more trajectories with momenta $(1\mp0.0005)p_0$ and $(1\mp0.001)p_0$ were also traced down the AtR line and a set of five directional cosines at the RHIC injection point were generated. This set of the five directional cosines appears in Fig. 5, and shows how the stable spin direction at the RHIC injection point, depends on the

momentum spread of the beam.
The corresponding directional cosines, with the AtR snake off, are shown in the same figure (non-filled squares). The lines between the points are to guide the eye. Comparison between the data with AtR snake on and off, shows that the energy region for optimum polarization transfer can be controlled with the AtR snake.

Conclusions

A simple modification of the AtR line provides tunability for optimum polarization transfer of a polarized proton beam in the proton momentum range from 21.96 GeV/c to 29.5 GeV/c

References

1. N.Tsoupas, T. Roser, A. Lace "Stable Spin Direction of a Polarized Proton Beam at the RHIC Injection Point." AGS/RHIC/SN No.021

2. H. Huang et. al. "Preservation of Proton Polarization by a Partial Snake" Phys. Rev. Let. V. 73 No. 22 p. 2982 (1994)

Figure Captions

1. Schematic diagram of the 12.5 mrad vertical bend of the AtR transfer line.

2. Schematic diagram of the proposed AtR snake.

3. Schematic diagram of the 12.5 mrad vertical bent of the AtR line as modified with the insertion of the AtR snake.

4. Directional cosine of the stable spin direction with the vertical, as a function of $G\gamma$, at the RHIC injection point. The AGS partial snake is off.
   Solid squares: Central trajectory, AtR snake off.
   Non-solid squares: Non-central trajectory, AtR snake off.
   Solid circles: Central trajectory, AtR snake on.
   Non-solid circles: Non-central trajectory, AtR snake on.

5. Directional cosine of the stable spin direction with the vertical, as a function of $G\gamma$, at the RHIC injection point. The AGS partial snake is on. Each central momentum trajectory is accompanied by four off-central momentum particles thus generating a set of five directional cosines at the RHIC injection point. The set of these five points provides a measure of the stable spin direction spread.
   Solid squares: AtR snake off.
   Non-solid squares: AtR snake on.

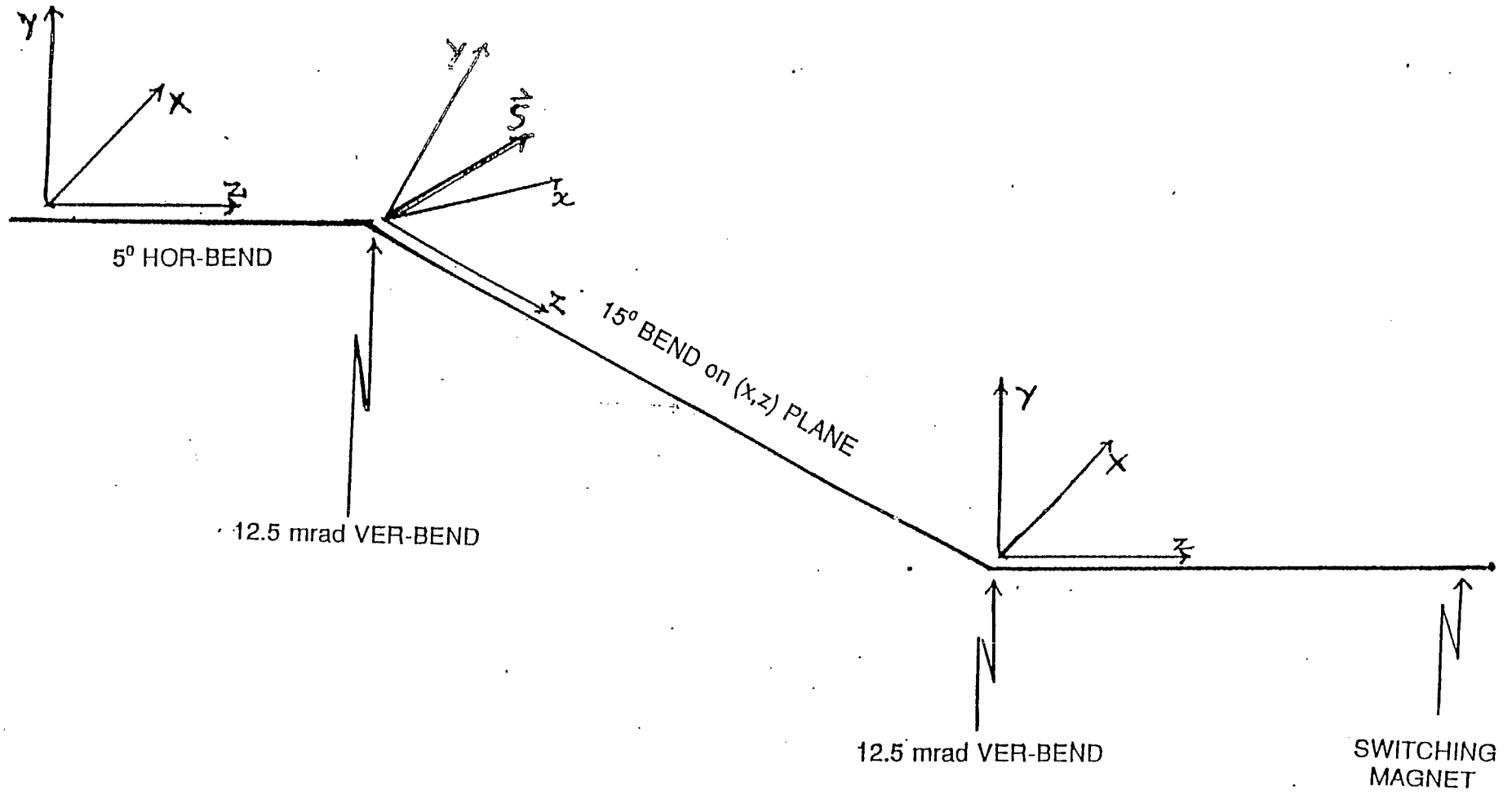
y
x
z
y
x
z
5° HOR-BEND
12.5 mrad VER-BEND
15° BEND on (x,z) PLANE
y
x
z
12.5 mrad VER-BEND
SWITCHING
MAGNET

Figure 1.

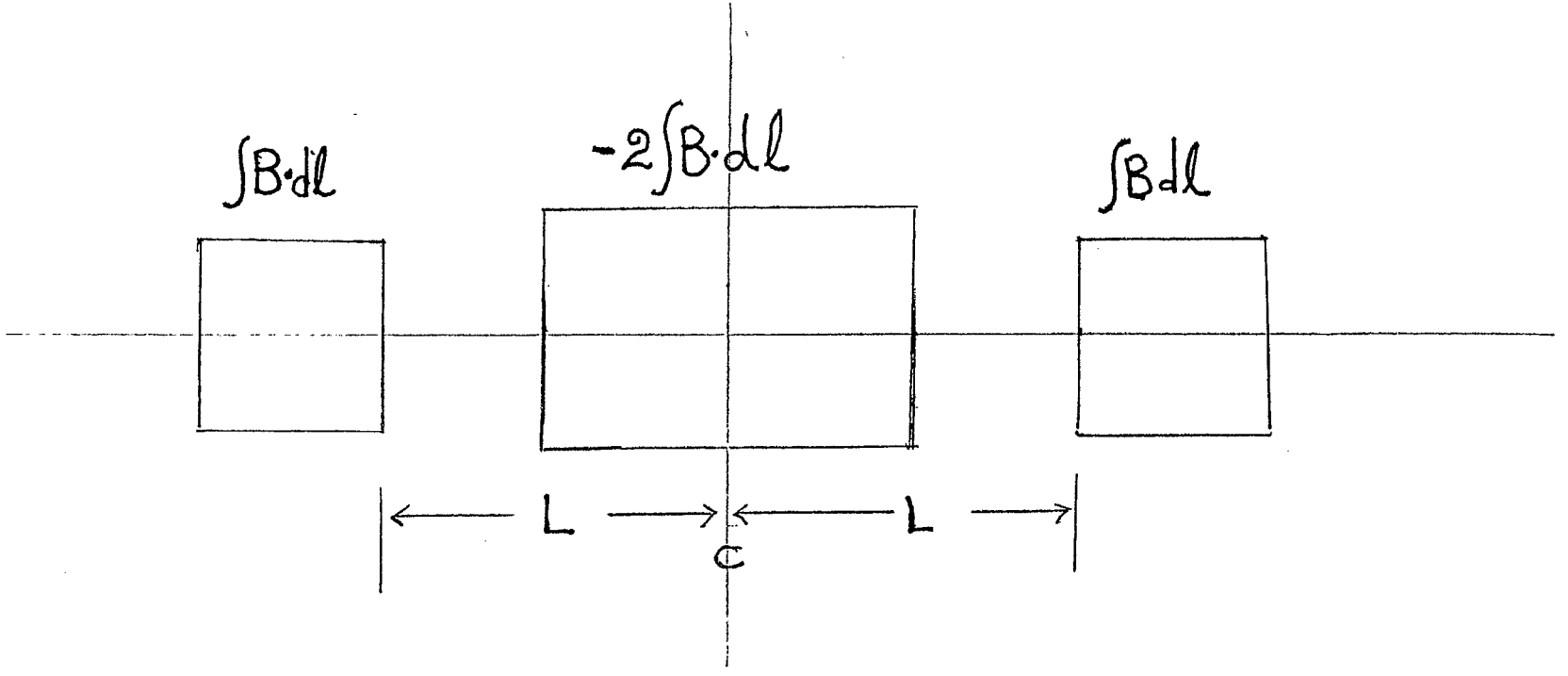

Figure 2.

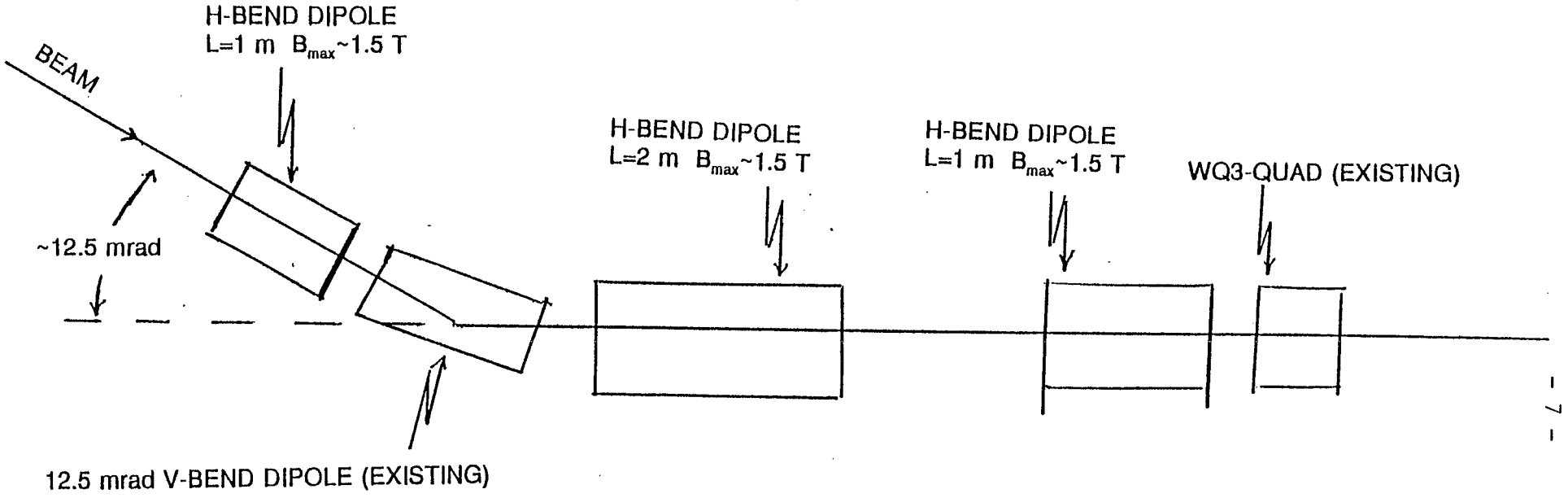
H-BEND DIPOLE
L=1 m B_{max}~1.5 T
BEAM
~12.5 mrad
H-BEND DIPOLE
L=2 m B_{max}~1.5 T
H-BEND DIPOLE
L=1 m B_{max}~1.5 T
WQ3-QUAD (EXISTING)
12.5 mrad V-BEND DIPOLE (EXISTING)

Figure 3.

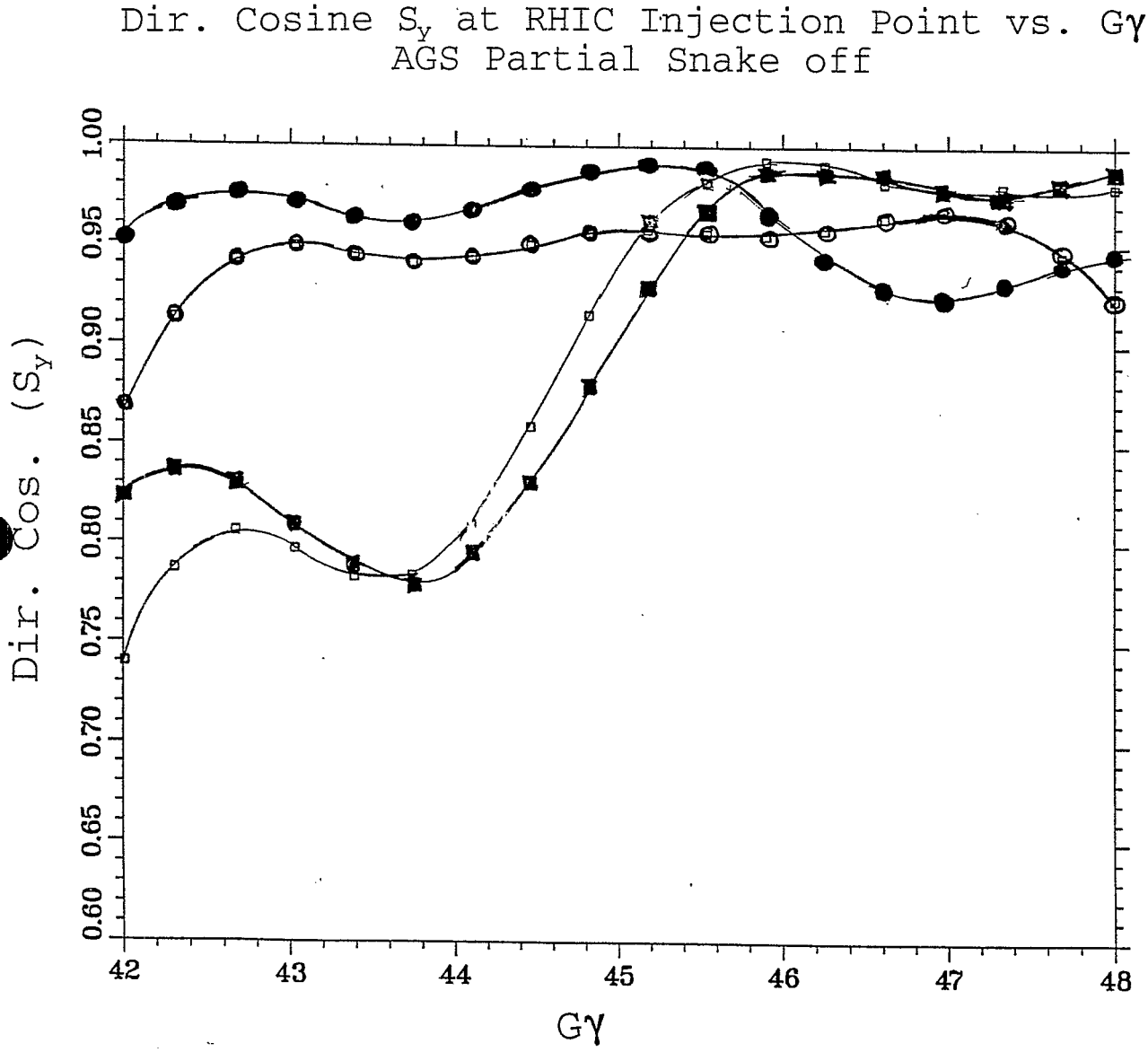
Dir. Cosine S_y at RHIC Injection Point vs. Gγ
AGS Partial Snake off
Dir. Cos. (S_y)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
42
43
44
45
46
47
48
Gγ

Figure 4.

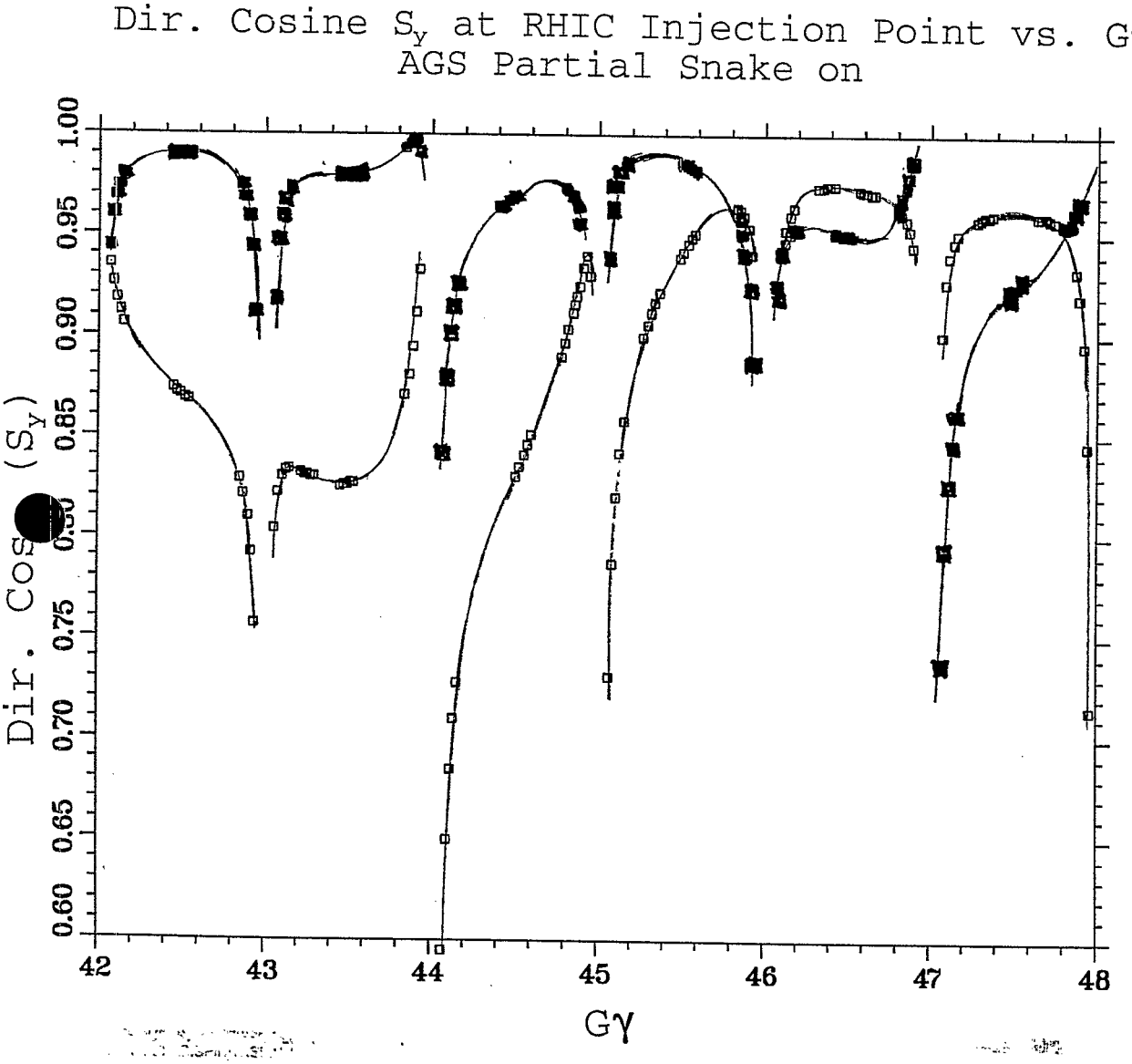
Dir. Cosine S_y at RHIC Injection Point vs. Gγ
AGS Partial Snake on
Dir. Cos (S_y)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
42
43
44
45
46
47
48
Gγ

Figure 5.