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THE PARAMETERS OF THE BARE AGS

E. J. Bleser

March 1996

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

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Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Accelerator Division
Technical Note

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Summary

This note briefly recapitulates the properties of the bare AGS as calculated by MAD using a revised set of input parameters. It slightly changes the previously standard tune values and offers a parameterization of the tunes and chromaticities as functions of the momentum.

Modeling and Calculations

Technical Note No. 429 parameterized the quadrupole and sextupole fields of the main AGS magnets as functions of momentum. This note uses these parameterizations in MAD to calculate the tune and chromaticity of the AGS. It then parameterizes these results as a function of momentum, resulting in a set of simple formulas which give the tune and chromaticity for any value of the momentum of the AGS. The contributions of this note are 1.) the formulas just discussed, and 2.) new calculated values for the tunes, presumably better than what we have been using. This change in the calculated tunes is discussed in Appendix I.

These calculations are for the "Bare AGS", that is for the AGS with just the main magnets powered. These calculations are also for the "DC AGS", that is for the case where the magnetic field is not changing and there are no eddy currents. They provide a baseline set of numbers which can be adjusted to take account of low field and high field correction magnet systems and which can be adjusted for eddy current effects. The accuracy of these calculations should be about one part in a thousand. Careful tune measurements may have an accuracy better than this and experiment may dictate modifying the results presented here.

The file used to input the AGS to MAD has been greatly elaborated to make modeling the AGS easier for the user. It now includes the standard geometry as before, all the high field correction systems, and parameterized momentum and current inputs. The user must simply specify his operating momentum and the currents at which he wants to operate his correction systems. Running MAD is somewhat analogous to operating the AGS.

Tune and Chromaticity Results

Table 1 gives the horizontal and vertical tunes, Q_x and Q_y, the normalized horizontal and vertical chromaticities, Q'_x/Q_x and Q'_y/Q_y, and the mean of the chromaticities. These values were calculated by MAD for input values of the momentum, P, from 1 to 32 GeV/c. Also given in the table are the values of the main magnet current, I, calculated from the formula in Tech Note No. 424. The tune results are plotted in Figures 1, 2, and 3, the chromaticity results in Figure 4.

Note that in Figures 1 and 2 the tune droops significantly at high field due to the saturation of the AGS magnets. The curves drawn in these figures are calculated from the formulas given in Table 2, resulting from a fit over the range from 1 to 32 GeV/c. Figure 3 shows the tunes over our operating range. Around 2 GeV/c the fit is not perfect but it is within our measurement accuracy. As discussed in Appendix I, the old results for Q_y were around 8.75 rather than 8.76 as calculated now.

Figure 4 shows that the mean of the normalized horizontal and vertical chromaticities is close to -1, as we should expect for a nearly round accelerator. The sextupole component in the main magnets splits the horizontal and vertical chromaticities. At high fields a large saturation sextupole component increases this splitting. Below 20 GeV/c eddy currents in the vacuum chamber produce an additional large sextupole field which will make any non-DC measurements differ significantly from these calculations. Table 3 contains the parameters for the curves fitted to these data.

The fitted results must be checked against experiment , but in principle the is no further need to run "bare AGS" tune calculations in MAD.

Twiss Results

In Tech Note No. 297 Auerbach presented extensive results for the Twiss parameters. The present calculations may be slightly different as discussed in the Appendix, but not significantly so. This note presents a calculation at 15 GeV/c. Table 4 lists the various parameters for one superperiod, A, which starts at the entrance to magnet A1. The high field correction magnets are specified in the element column but are not powered. In other superperiods the correction magnets may be different, but as long as they are not powered, all the superperiod Twiss parameters will be identical to the results given here. These results are plotted in Figures 5, 6, and 7.

APPENDIX I. COMPARISON OF THE OLD AND NEW CALCULATIONS

Until the present calculations, the quadrupole gradients used in MAD assumed that the gradients in the open magnets were the same for both the long, A, magnets and the short, B, magnets. In actuality since the end fields are a larger effect in the short magnets than in the long magnets, the gradient in B should be slightly lower than the gradient in A. Detailed integrations by Thern have confirmed this assumption and his more correct values have been used for this note and installed in MAD. Using the old gradients reproduces the earlier calculations, using the new gradients reduces the calculated tunes by about 0.01 units as shown in Figure A1.

TABLE 1

THE BARE AGS

WITH NO EDDY CURRENTS

P	I	Qx	Qy	Qx'/Qx	Qy'/Qy	MEAN of
GeV/c	Amperes			m^{-1}	m^{-1}	Qx'/Qx & Qy'/Qy
1	169.4	8.706	8.758	-2.466	0.250	-1.108
2	343.5	8.711	8.764	-2.400	0.187	-1.106
3	516.5	8.711	8.765	-2.368	0.159	-1.105
4	689.4	8.710	8.764	-2.343	0.136	-1.103
5	862.1	8.708	8.763	-2.320	0.116	-1.102
6	1034.7	8.707	8.762	-2.301	0.099	-1.101
7	1207.3	8.706	8.761	-2.287	0.085	-1.101
8	1379.7	8.706	8.760	-2.277	0.076	-1.100
9	1552.0	8.706	8.760	-2.273	0.072	-1.100
10	1724.2	8.706	8.760	-2.274	0.073	-1.101
11	1896.5	8.706	8.760	-2.280	0.077	-1.101
12	2068.8	8.706	8.761	-2.289	0.086	-1.102
13	2241.3	8.706	8.761	-2.302	0.097	-1.103
14	2414.0	8.706	8.760	-2.317	0.111	-1.103
15	2587.0	8.705	8.760	-2.333	0.126	-1.104
16	2760.4	8.705	8.759	-2.350	0.141	-1.104
17	2934.1	8.703	8.757	-2.368	0.158	-1.105
18	3108.1	8.702	8.755	-2.388	0.177	-1.105
19	3282.4	8.700	8.753	-2.410	0.198	-1.106
20	3456.9	8.698	8.750	-2.438	0.225	-1.107
21	3631.7	8.696	8.747	-2.476	0.261	-1.108
22	3806.7	8.693	8.743	-2.527	0.309	-1.109
23	3982.2	8.690	8.738	-2.600	0.377	-1.111
24	4158.7	8.686	8.733	-2.703	0.473	-1.115
25	4336.8	8.680	8.725	-2.847	0.606	-1.120
26	4517.7	8.672	8.716	-3.046	0.790	-1.128
27	4703.2	8.661	8.703	-3.317	1.040	-1.139
28	4895.6	8.645	8.686	-3.683	1.376	-1.153
29	5098.3	8.622	8.662	-4.170	1.824	-1.173
30	5315.8	8.589	8.629	-4.814	2.416	-1.199
31	5553.9	8.545	8.585	-5.663	3.197	-1.233
32	5819.9	8.484	8.527	-6.784	4.228	-1.278

TABLE 2

THE TUNE of the BARE AGS as a FUNCTION of the MOMENTUM in GeV/c

$$Q = q_0 + q_1 P + q_2 P^2 + q_3 P^3 + q_4 P^4 + q_5 P^5 + q_6 P^6$$

	Q_x	Q_y
q_0	8.7005	8.7497
q_1	9.0027E-03	1.1705E-02
q_2	-2.7937E-03	-3.2926E-03
q_3	3.6114E-04	4.0215E-04
q_4	-2.2733E-05	-2.4222E-05
q_5	6.8948E-07	7.0669E-07
q_6	-8.1737E-09	-8.1188E-09

TABLE 3

THE CHROMATICITY of the BARE AGS as a FUNCTION of the MOMENTUM in GeV/c

$$Q'/Q = r_0 + r_1 P + r_2 P^2 + r_3 P^3 + r_4 P^4 + r_5 P^5 + r_6 P^6$$

	Q'_x/Q_x	Q'_y/Q_y
r_0	-2.5374	0.3159
r_1	8.4661E-02	-8.1296E-02
r_2	-1.3439E-02	1.3069E-03
r_3	1.4142E-03	-1.4019E-03
r_4	-9.8939E-05	9.7259E-05
r_5	3.6948E-06	-3.5710E-06
r_6	-5.5707E-08	5.2981E-08

TABLE 4. SUPERPERIOD A OF THE AGS

	ELE-MENT	MAGNET TYPE	S meters	BETAX meters	ALFAX	MUX 2 PI	DX meters	DPX	BETAY meters	ALFAY	MUY 2 PI
0	BEGIN SUPER A		0	19.753	-1.569	0	2.054	0.148	11.741	1.028	0
1	A1	BF	2.007	22.305	0.381	0.015	2.167	-0.037	10.251	-0.238	0.03
2			2.616	21.86	0.35	0.019	2.144	-0.037	10.579	-0.301	0.04
3	A2	BF	4.623	16.824	1.994	0.035	1.888	-0.213	14.591	-1.827	0.066
4			4.91	15.704	1.909	0.038	1.827	-0.213	15.664	-1.912	0.069
5	PUE A02		4.91	15.704	1.909	0.038	1.827	-0.213	15.664	-1.912	0.069
6			5.232	14.503	1.814	0.041	1.758	-0.213	16.928	-2.008	0.072
7	A3	CD	7.62	10.395	0.063	0.074	1.508	-0.001	22.11	0.042	0.091
8			7.991	10.362	0.027	0.08	1.508	-0.001	22.085	0.025	0.094
9	QHFV		8.382	10.356	-0.011	0.086	1.507	-0.001	22.073	0.008	0.097
10	QPOL		8.773	10.379	-0.049	0.092	1.507	-0.001	22.073	-0.01	0.1
11			9.144	10.429	-0.085	0.097	1.507	-0.001	22.087	-0.027	0.102
12	A4	CD	11.531	14.673	-1.854	0.13	1.751	0.211	16.851	2.013	0.121
13			11.818	15.762	-1.941	0.133	1.812	0.211	15.72	1.927	0.124
14	PUE A04		11.818	15.762	-1.941	0.133	1.812	0.211	15.72	1.927	0.124
15			12.141	17.045	-2.038	0.136	1.88	0.211	14.508	1.831	0.127
16	A5	AF	14.528	22.329	0.034	0.155	2.137	0	10.338	0.074	0.16
17			15.29	22.303	0	0.16	2.137	0	10.282	0	0.172
18			16.052	22.329	-0.034	0.165	2.137	0	10.338	-0.074	0.184
19	A6	AF	18.44	17.045	2.038	0.184	1.88	-0.211	14.508	-1.831	0.216
20			19.049	14.673	1.854	0.19	1.751	-0.211	16.851	-2.013	0.222
21	A7	CD	21.437	10.429	0.085	0.223	1.507	0.001	22.087	0.027	0.241
22			21.871	10.373	0.043	0.229	1.507	0.001	22.072	0.007	0.244
23	SXV		22.526	10.359	-0.021	0.239	1.508	0.001	22.082	-0.022	0.249
24			22.961	10.395	-0.063	0.246	1.508	0.001	22.11	-0.042	0.252
25	A8	CD	25.348	14.503	-1.814	0.279	1.758	0.213	16.928	2.008	0.271
26			25.635	15.569	-1.899	0.282	1.819	0.213	15.8	1.923	0.274
27	PUE A08		25.635	15.569	-1.899	0.282	1.819	0.213	15.8	1.923	0.274
28			25.958	16.824	-1.994	0.285	1.888	0.213	14.591	1.827	0.277
29	A9	BF	27.964	21.86	-0.35	0.301	2.144	0.037	10.579	0.301	0.304
30			28.574	22.305	-0.381	0.305	2.167	0.037	10.251	0.238	0.313
31	A10	BF	30.58	19.753	1.569	0.32	2.054	-0.148	11.741	-1.028	0.343
32			32.104	15.377	1.302	0.334	1.829	-0.148	15.282	-1.295	0.362

TABLE 4. continued

	ELE-MENT	MAGNET TYPE	S meters	BETAX meters	ALFAX	MUX 2 PI	DX meters	DPX	BETAY meters	ALFAY	MUY 2 PI
33			33.628	11.816	1.035	0.352	1.604	-0.148	19.637	-1.562	0.376
34	A11	BD	35.635	10.315	-0.239	0.382	1.481	0.023	22.18	0.379	0.39
35			36.244	10.644	-0.301	0.391	1.495	0.023	21.737	0.348	0.395
36	A12	BD	38.251	14.674	-1.836	0.418	1.716	0.2	16.725	1.985	0.411
37			38.538	15.753	-1.922	0.421	1.773	0.2	15.611	1.9	0.414
38	PUE A12		38.538	15.753	-1.922	0.421	1.773	0.2	15.611	1.9	0.414
39			38.86	17.024	-2.018	0.424	1.838	0.2	14.416	1.805	0.417
40	A13	CF	41.248	22.231	0.042	0.443	2.078	-0.004	10.325	0.063	0.45
41			41.682	22.202	0.022	0.446	2.076	-0.004	10.289	0.021	0.457
42	SXH		42.337	22.192	-0.007	0.451	2.074	-0.004	10.303	-0.043	0.467
43			42.772	22.207	-0.027	0.454	2.072	-0.004	10.358	-0.085	0.474
44	A14	CF	45.159	16.945	2.024	0.472	1.816	-0.206	14.582	-1.844	0.506
45			45.446	15.808	1.937	0.475	1.757	-0.206	15.666	-1.931	0.509
46	PUE A14		45.446	15.808	1.937	0.475	1.757	-0.206	15.666	-1.931	0.509
47			45.769	14.59	1.84	0.479	1.691	-0.206	16.942	-2.028	0.513
48	A15	AD	48.156	10.402	0.074	0.511	1.451	0	22.199	0.034	0.531
49			48.918	10.345	0	0.523	1.451	0	22.173	0	0.537
50			49.68	10.402	-0.074	0.534	1.451	0	22.199	-0.034	0.542
51	A16	AD	52.068	14.59	-1.84	0.567	1.691	0.206	16.942	2.028	0.561
52			52.677	16.945	-2.024	0.573	1.816	0.206	14.582	1.844	0.567
53	A17	CF	55.065	22.207	0.027	0.592	2.072	0.004	10.358	0.085	0.6
54			55.436	22.193	0.01	0.595	2.074	0.004	10.309	0.049	0.605
55	QHFH		55.827	22.193	-0.008	0.597	2.075	0.004	10.285	0.011	0.611
56	QGTR1		56.218	22.205	-0.025	0.6	2.077	0.004	10.292	-0.027	0.618
57			56.589	22.231	-0.042	0.603	2.078	0.004	10.325	-0.063	0.623
58	A18	CF	58.976	17.024	2.018	0.622	1.838	-0.2	14.416	-1.805	0.656
59			59.263	15.89	1.933	0.624	1.78	-0.2	15.476	-1.889	0.659
60	PUE A18		59.263	15.89	1.933	0.624	1.78	-0.2	15.476	-1.889	0.659
61			59.586	14.674	1.836	0.628	1.716	-0.2	16.725	-1.985	0.662
62	A19	BD	61.593	10.644	0.301	0.654	1.495	-0.023	21.737	-0.348	0.679
63			62.202	10.315	0.239	0.663	1.481	-0.023	22.18	-0.379	0.683
64	A20	BD	64.209	11.816	-1.035	0.693	1.604	0.148	19.637	1.562	0.698
65			65.732	15.377	-1.302	0.712	1.829	0.148	15.282	1.295	0.712
66	END SUPERA		67.256	19.753	-1.569	0.725	2.054	0.148	11.741	1.028	0.73

FIGURE 1

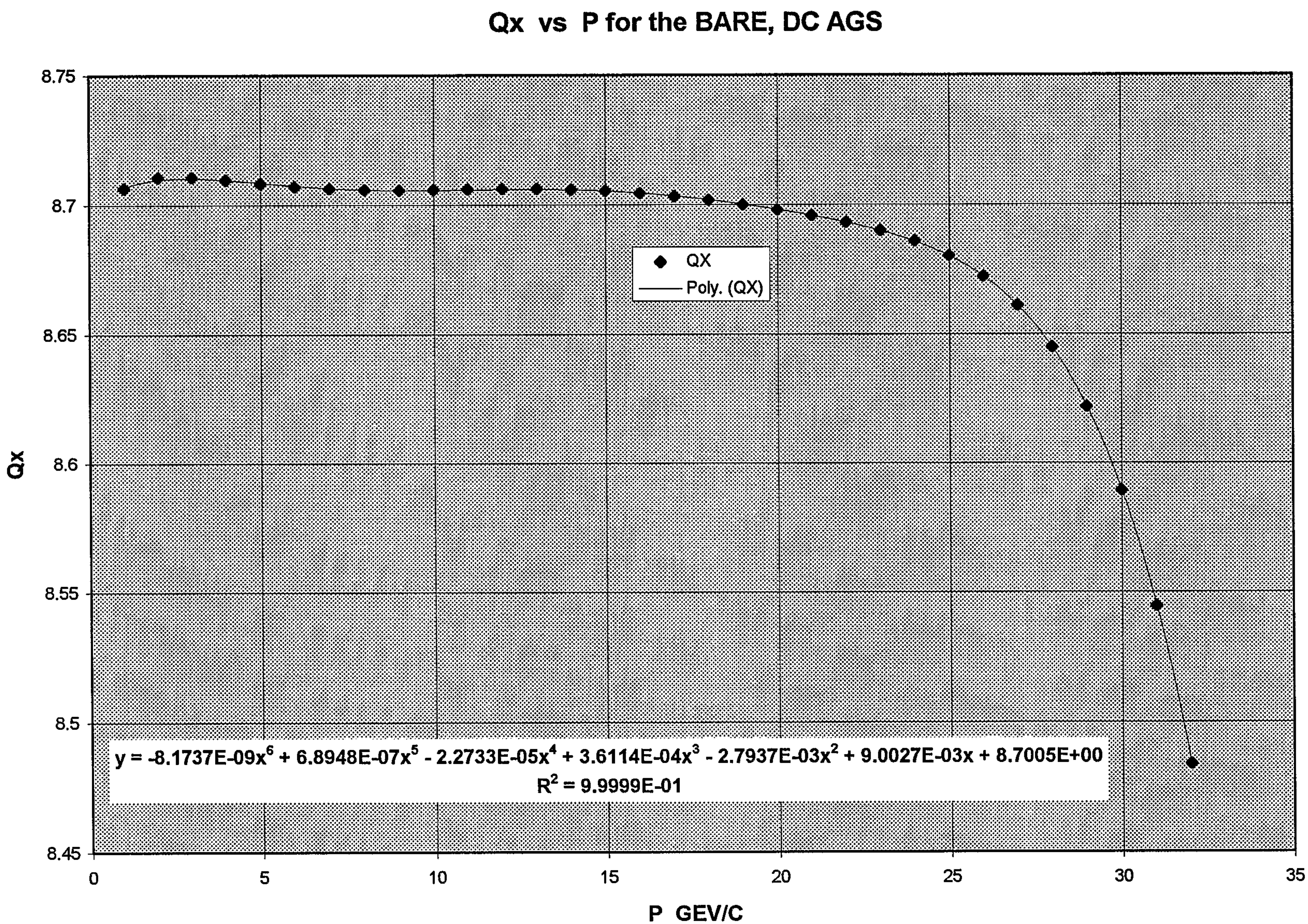
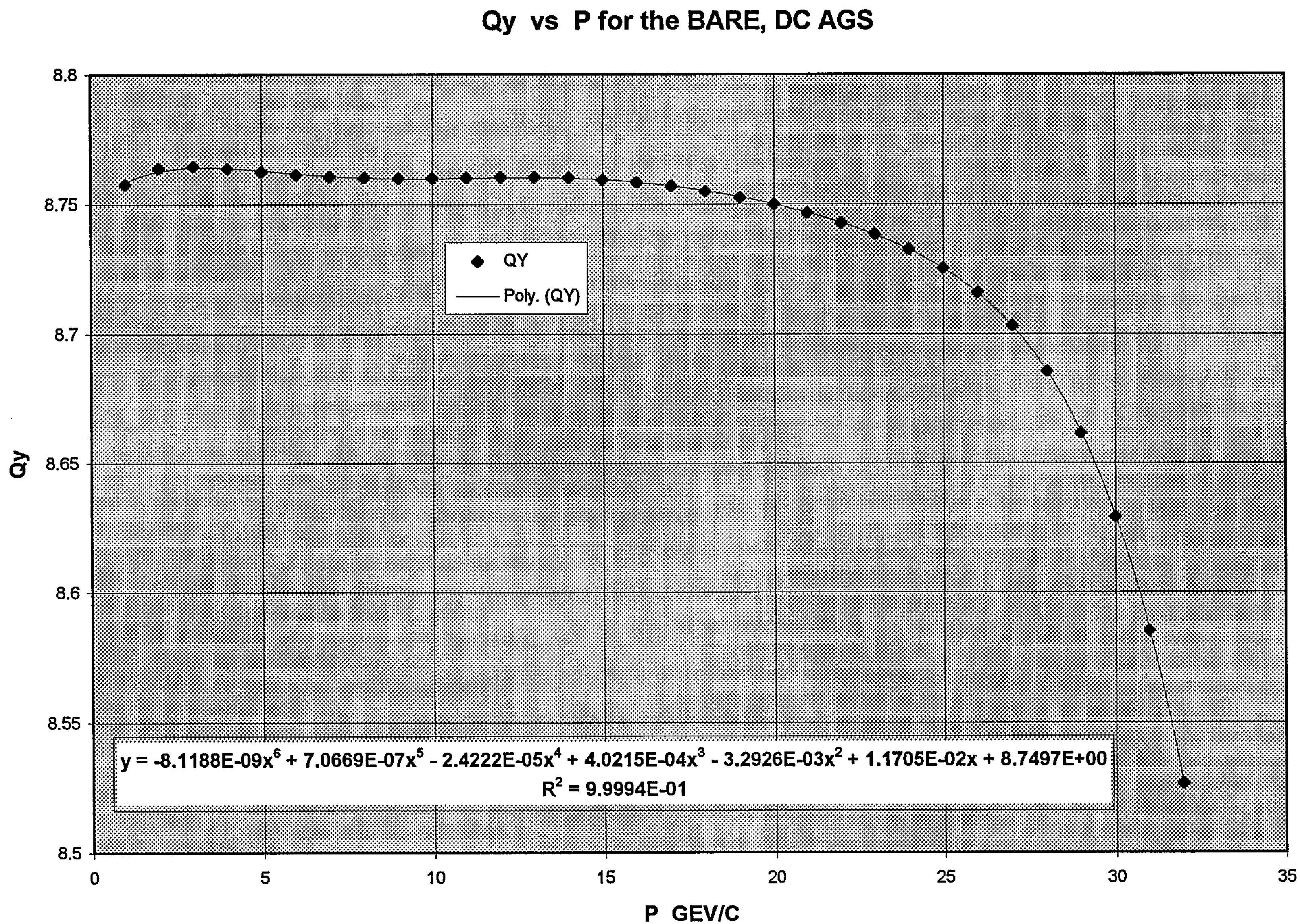
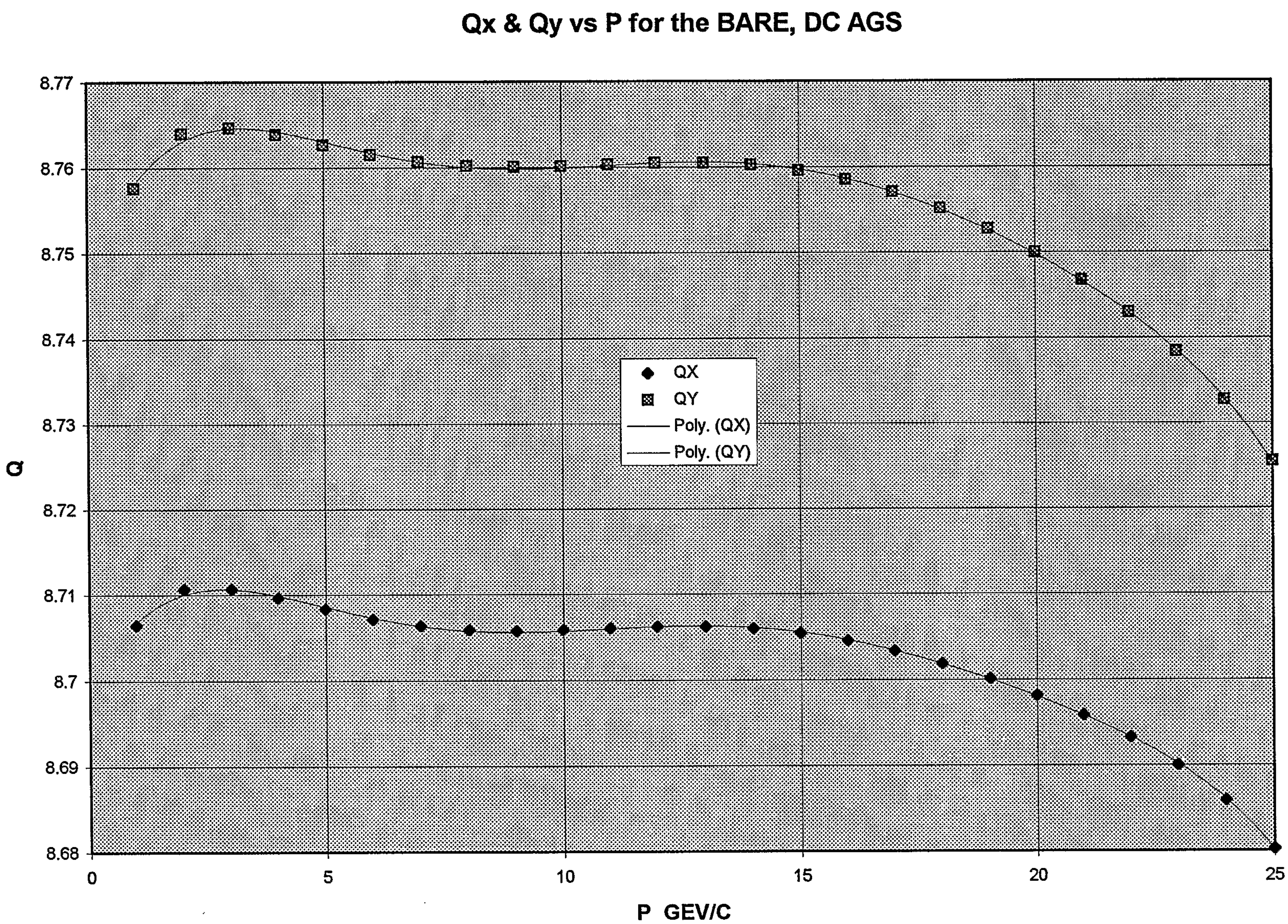

Qx vs P for the BARE, DC AGS
Qx
8.75
8.7
8.65
8.6
8.55
8.5
8.45
0
5
10
15
20
25
30
35
P GEV/C
QX
Poly. (QX)
$y = -8.1737E\text{-}09x^6 + 6.8948E\text{-}07x^5 - 2.2733E\text{-}05x^4 + 3.6114E\text{-}04x^3 - 2.7937E\text{-}03x^2 + 9.0027E\text{-}03x + 8.7005E{+}00$
$R^2 = 9.9999E\text{-}01$

FIGURE 2



Qy vs P for the BARE, DC AGS
8.8
8.75
8.7
8.65
8.6
8.55
8.5
Qy
0
5
10
15
20
25
30
35
P GEV/C
QY
Poly. (QY)
y = -8.1188E-09x6 + 7.0669E-07x5 - 2.4222E-05x4 + 4.0215E-04x3 - 3.2926E-03x2 + 1.1705E-02x + 8.7497E+00
R2 = 9.9994E-01

FIGURE 3



Qx & Qy vs P for the BARE, DC AGS
8.77
8.76
8.75
8.74
8.73
8.72
8.71
8.7
8.69
8.68
Q
0
5
10
15
20
25
P GEV/C
QX
QY
Poly. (QX)
Poly. (QY)

FIGURE 4

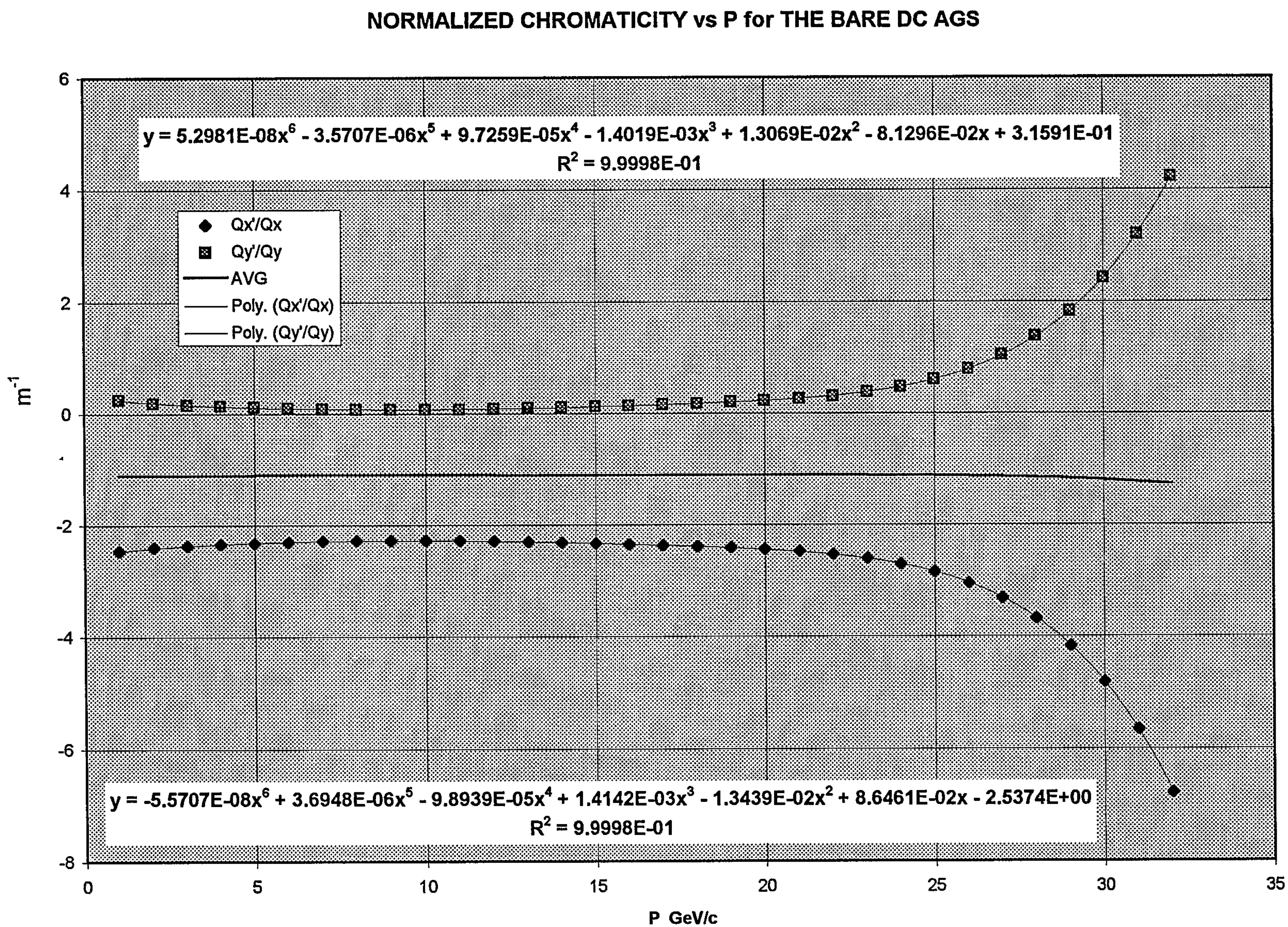
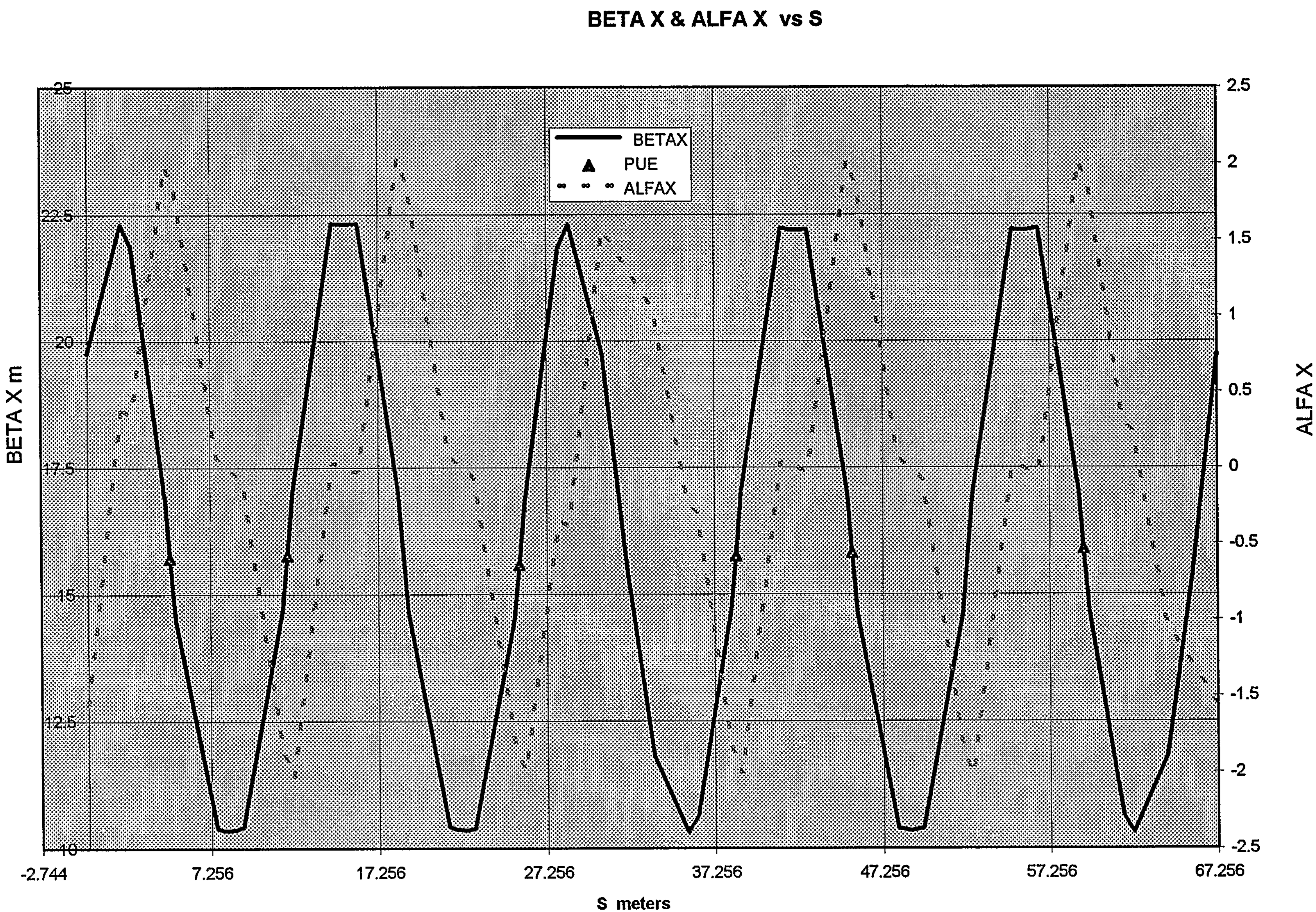

NORMALIZED CHROMATICITY vs P for THE BARE DC AGS
y = 5.2981E-08x^6 - 3.5707E-06x^5 + 9.7259E-05x^4 - 1.4019E-03x^3 + 1.3069E-02x^2 - 8.1296E-02x + 3.1591E-01
R^2 = 9.9998E-01
Qx'/Qx
Qy'/Qy
AVG
Poly. (Qx'/Qx)
Poly. (Qy'/Qy)
y = -5.5707E-08x^6 + 3.6948E-06x^5 - 9.8939E-05x^4 + 1.4142E-03x^3 - 1.3439E-02x^2 + 8.6461E-02x - 2.5374E+00
R^2 = 9.9998E-01
m^-1
P GeV/c
6
4
2
0
-2
-4
-6
-8
0
5
10
15
20
25
30
35

FIGURE 5



BETA X & ALFA X vs S
BETAX
PUE
ALFAX
BETA X m
ALFA X
S meters
25
22.5
20
17.5
15
12.5
10
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2.744
7.256
17.256
27.256
37.256
47.256
57.256
67.256

FIGURE 6

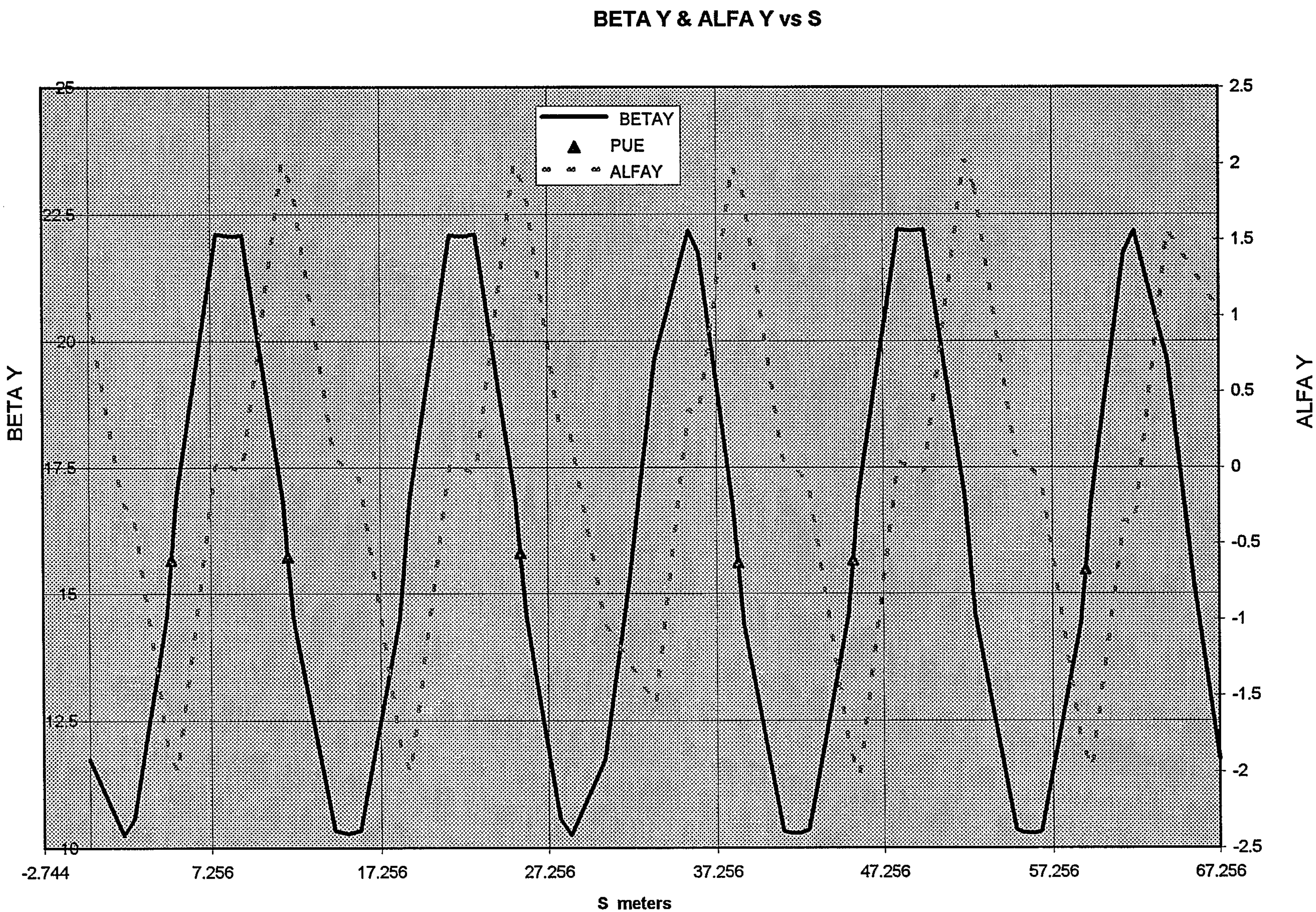

BETA Y & ALFA Y vs S
BETAY
PUE
ALFAY
BETA Y
ALFA Y
S meters
25
22.5
20
17.5
15
12.5
10
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2.744
7.256
17.256
27.256
37.256
47.256
57.256
67.256

FIGURE 7

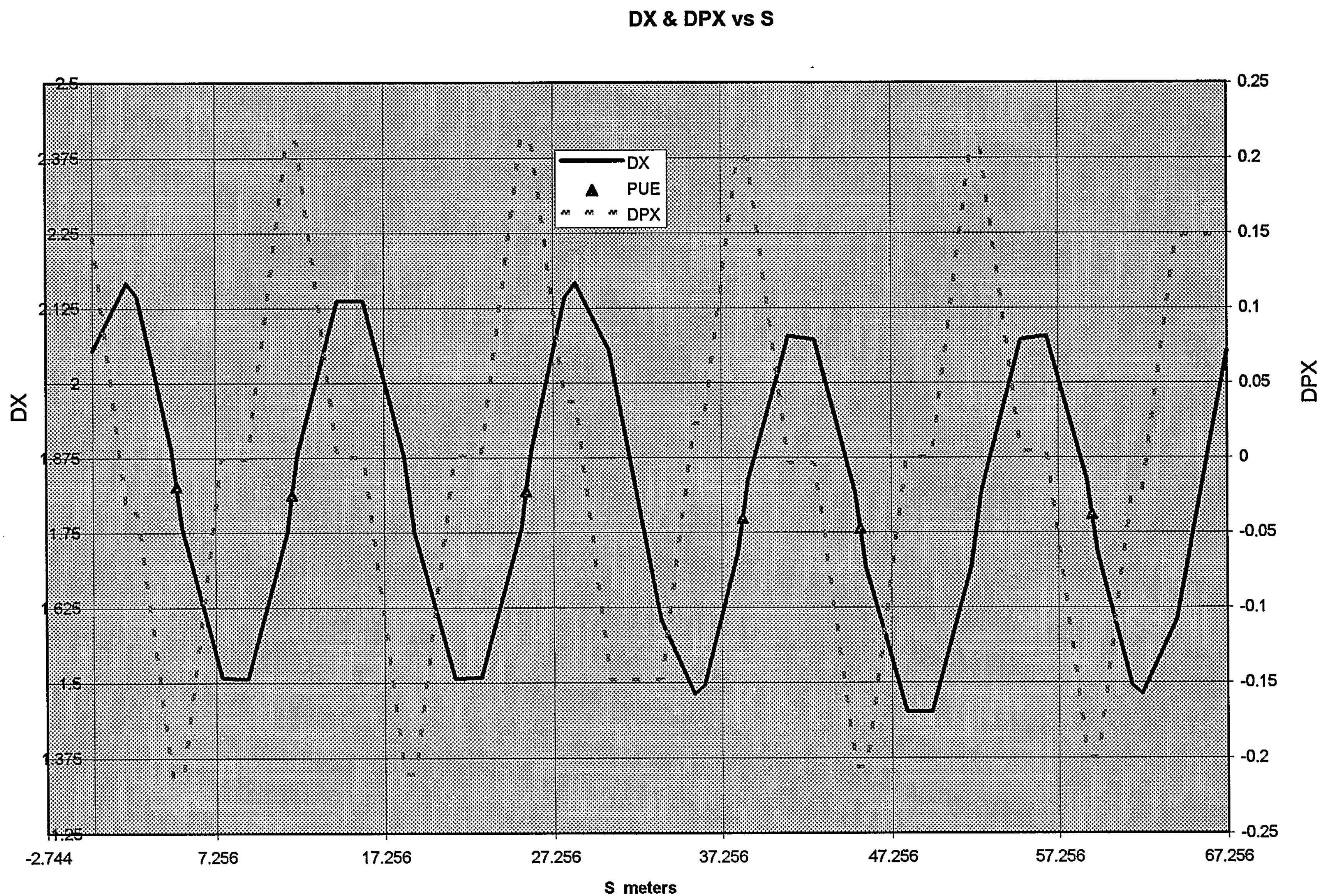
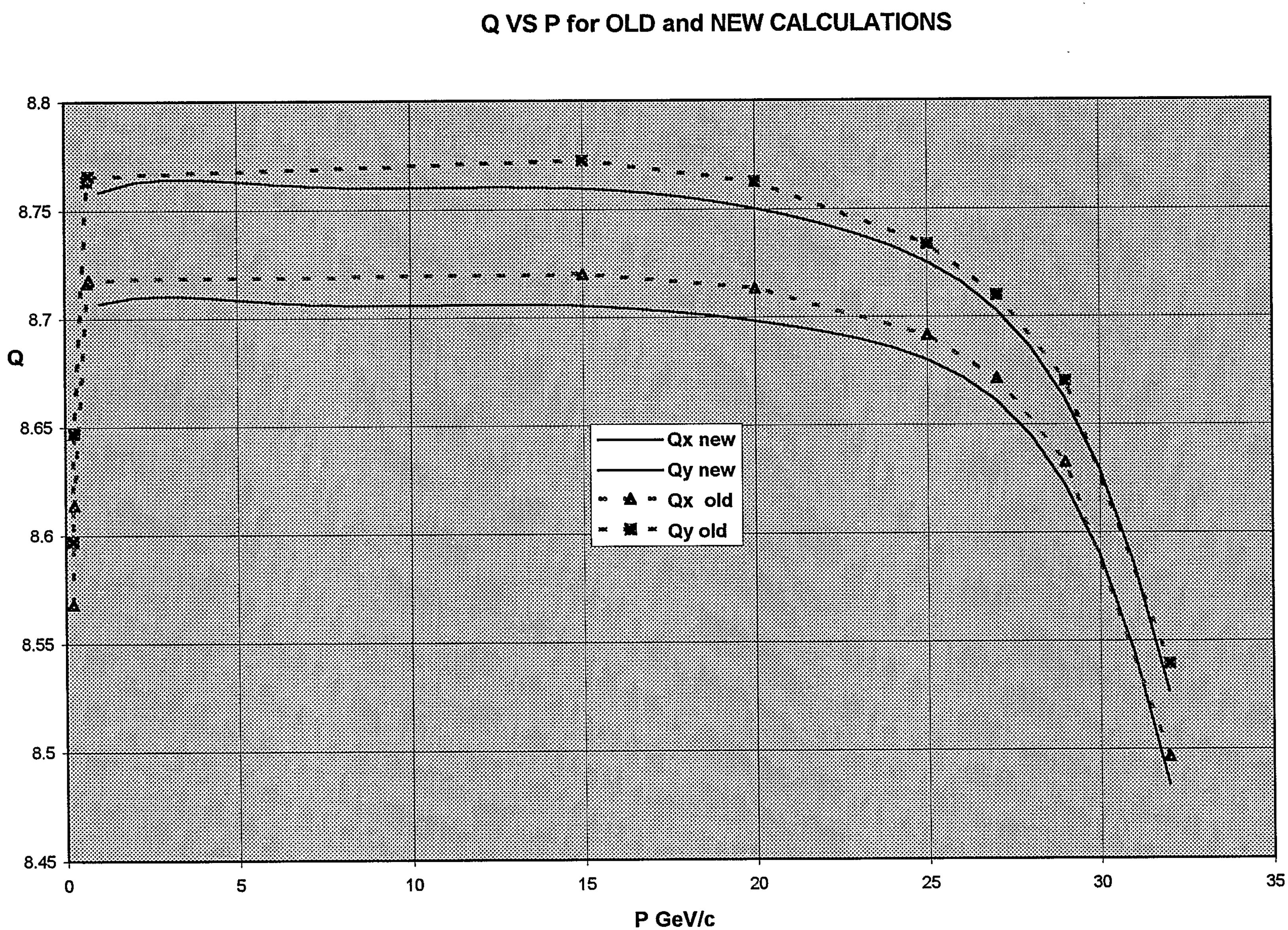

DX & DPX vs S
DX
PUE
DPX
2.5
2.375
2.25
2.125
2
1.875
1.75
1.625
1.5
1.375
1.25
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-2.744
7.256
17.256
27.256
37.256
47.256
57.256
67.256
S meters

FIGURE A1



Q VS P for OLD and NEW CALCULATIONS
8.8
8.75
8.7
8.65
8.6
8.55
8.5
8.45
Q
0
5
10
15
20
25
30
35
P GeV/c
Qx new
Qy new
Qx old
Qy old

- 15 -