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CALCULATION OF THE POLARIZATION STATE OF THE X-RAY BEAM AT THE SAMPLE ON THE SRS WIGGLER PROTEIN CRYSTALLOGRAPHY STATION (9.6)

by

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ABSTRACT

Calculations of the polarization state of the x-ray beam at the sample on the SRS wiggler protein crystallography station (9.6) have been made and tabulated. All options of the instrument are catered for (ideal geometry and perfect materials are assumed). The relevant background theory needed for using the information on the beam polarization for protein crystal data reduction (from film or electronic area detectors) is given.

INTRODUCTION

The protein crystallography station (9.6) on the wiggler beam line, is capable of being operated in a number of different experimental arrangements. These usually affect the polarization state of the beam, at the protein crystal sample. The list below indicates the conditions affecting beam polarization at the sample:

(a) Machine energy
(b) Wiggler magnetic field
(c) X-radiation wavelength
(d) Mirror aperture
(e) Monochromtor crystal type and design
  (i) single crystal (horizontally dispersing)
  (ii) double crystal (vertically dispersing)
  (iii) monochromator 2d(hkℓ) spacing)
(f) Mode of operation
  (i) monochromatic
  (ii) Laue (white beam)
(g) Crystal sample or collimator size

For the purposes of the calculations here the machine energies and wiggler magnetic fields, at which the SRS has been operating 2.0 GeV, 5 Tesla and 1.8 GeV, 4.5 Tesla, are relevant. There is not a particular standard monochromator wavelength setting for the station owing to the variety of project requirements; monochromatic data have been collected over the wave-

length range 0.6 Å < λ < 1.73 Å and Laue data using 0.2 < λ < 3.0 Å.

A pre-monochromator focusing mirror was commissioned in December 1984 for the rejection of monochromator harmonics and to provide a higher intensity at the sample; the design figure of a 10-fold intensity improvement has been achieved in practice. An effect of this was to cause a significant change in the polarization factor. A bent Si(111) monochromator has been used for the majority of monochromatic experiments on 9.6, however there are plans to use a Ge(111) single crystal and Si(220) channel cut monochromators.

The aim here is to calculate polarization factors for all likely conditions on station 9.6.

BASIC THEORY

1. Angular aperture

(a) Without pre-mirror

The vertical angle subtended (γ_V) at the protein crystal or collimator (C), whichever is smaller, from a synchrotron source of vertical size (S) is:

$$\gamma_V = \frac{(S + C)}{D} \qquad (1)$$

where D is the distance from S to C.

(b) With pre-mirror

A focusing pre-mirror collects a large angular aperture of radiation and images the source at the sample. In so doing, a larger percentage of vertically polarized light is brought to the sample (ie the beam is less polarized overall).

Equation (1) becomes:

$$\gamma_V = \frac{(A + C)}{D_C} \qquad (2)$$

where A is the spatial aperture of the mirror and D_C the distance from the mirror to the collimator.

2. Polarization Factor

(a) Without monochromator (Laue mode)

If the parallel (horizontal) and perpendicular (vertical) intensities, integrated over the angle γ_V (equations (1) and (2)), are $I_\parallel$ and $I_\perp$ respectively, then a quantity τ specifying the polarization content of the beam can be defined as:

$$\tau = \frac{I_\parallel - I_\perp}{I_\parallel + I_\perp} \qquad (3)$$

This is the quantity needed for Laue work.

(b) Single crystal monochromator (horizontally dispersing)

The polarization ratio, after reflection from a single crystal monochromator, is, for a specific wavelength λ:

$$\tau' = \frac{\alpha\, I_\parallel - I_\perp}{\alpha\, I_\parallel + I_\perp} \qquad (4)$$

where $\alpha = \cos 2\theta m$ and $2\theta m$ is the Bragg angle of the cylindrically bent, perfect, single crystal.

(c) Double crystal monochromator (vertically dispersing)

In the case of a vertically dispersing parallel double crystal monochromator the polarization ratio is, for a specific wavelength λ:

$$\tau'' = \frac{I_\parallel - \alpha^2\, I_\perp}{I_\parallel + \alpha^2\, I_\perp} \qquad (5)$$

where α is defined as in 2(b).

(d) Polarization factor

The polarization factor P[2] working from Azaroff[1] is then:

$$P = \frac{(1 + \cos^2 2\theta)}{2} - \frac{\tau'}{2} \cos 2\rho \sin^2 2\theta \qquad (6)$$

where 2θ is the protein crystal Bragg angle and ρ the azimuthal angle in the plane of the film or electronic detector, which is placed normal to the X-ray beam. ($\rho = 0°$ is the axis mutually perpendicular to the beam and protein crystal rotation axis at normal diffraction geometry). In equation (6) for Laue work τ' is replaced by τ, and for the double crystal monochromator τ' is replaced by τ''.

CALCULATION OF τ, τ' AND τ''

On station 9.6 the 5σ source size is S = 1.0 mm and the source to collimator distance is D = 22000 mm. In addition the mirror aperture A is 2mm, ie the 75 cm long mirror is set at a critical angle of 3 mrad. Finally the distance of the collimator to the mirror is 11 m.

Calculations of $I_\parallel$ and $I_\perp$ were made with a program based on that of Poole[3] as a function of machine energy, wiggler magnetic field, wavelength and collimator size (table 1).

Tables 1-8 give the values of τ (for Laue), τ' (single crystal monochromator) and τ'' (double crystal monochromator) for without and with mirror options at 2 GeV, 5T or 1.8 GeV, 4.5 T combinations.

DISCUSSION

The calculations for Ge as well as Si monochromators has been made for the sake of completeness. The differences between these calculations are small as would be expected from their similar 2d spacings. The values of τ' for a single crystal monochromator decrease monotonically in going from short to long wavelengths. However τ (white beam) and τ^{*} for a double crystal monochromator case pass through a minimum. The beam is over 99% polarized, in the case of a double crystal monochromator, at wavelengths $\gtrsim$ 1.8 Å (without mirror) and $\gtrsim$ 2.3 Å (with mirror) and is least polarized at long wavelengths with a single crystal monochromator because of the increased geometric attenuation of the $I_{\parallel}$ component compared with the unimpaired transmission of $I_{\perp}$.

Several assumptions have been made in these calculations to do with ideal geometry of the SRS with respect to the instrument optics; eg 1) the optic axis of the instrument intersects the SRS source, 2) any mirror-monochromator (vertical-horizontal) focusing is orthogonal and set true with respect to the orbit plane, 3) the monochromators used are based on perfect crystals.

ACKNOWLEDGEMENTS

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TABLE 1

Polarization calculation at 1.8 GeV 4.5 Tesla with a focusing pre-mirror and germanium single or double crystal monochromators.

λ(Å)	(1) τ	(1) τ'	(1) τ"	(2) τ	(2) τ'	(2) τ"	(3) τ	(3) τ'	(3) τ"
0.10	0.957	0.957	0.957	0.957	0.957	0.957	0.957	0.957	0.957
0.20	0.924	0.924	0.924	0.923	0.923	0.924	0.923	0.923	0.924
0.30	0.900	0.900	0.902	0.898	0.897	0.900	0.896	0.896	0.899
0.40	0.887	0.887	0.892	0.882	0.881	0.886	0.879	0.878	0.883
0.50	0.877	0.876	0.885	0.869	0.868	0.877	0.864	0.862	0.872
0.60	0.871	0.869	0.882	0.861	0.858	0.872	0.853	0.851	0.865
0.70	0.867	0.864	0.882	0.855	0.851	0.871	0.845	0.842	0.862
0.80	0.864	0.860	0.884	0.850	0.846	0.872	0.839	0.834	0.862
0.90	0.862	0.857	0.887	0.847	0.842	0.875	0.835	0.829	0.864
1.00	0.861	0.855	0.892	0.846	0.839	0.880	0.832	0.824	0.869
1.10	0.861	0.853	0.898	0.844	0.836	0.885	0.830	0.820	0.874
1.20	0.861	0.852	0.904	0.844	0.033	0.892	0.828	0.817	0.881
1.30	0.861	0.850	0.911	0.844	0.831	0.900	0.827	0.814	0.889
1.40	0.862	0.849	0.919	0.844	0.829	0.908	0.827	0.811	0.897
1.50	0.863	0.848	0.927	0.844	0.827	0.916	0.827	0.808	0.907
1.60	0.863	0.846	0.934	0.844	0.825	0.925	0.827	0.805	0.916
1.70	0.864	0.844	0.942	0.845	0.823	0.934	0.827	0.803	0.926
1.80	0.865	0.843	0.950	0.846	0.821	0.943	0.827	0.800	0.935
1.90	0.866	0.841	0.958	0.847	0.818	0.951	0.828	0.797	0.945
2.00	0.867	0.839	0.965	0.847	0.815	0.960	0.829	0.793	0.954
2.10	0.868	0.836	0.972	0.848	0.813	0.967	0.830	0.790	0.963
2.20	0.869	0.834	0.978	0.849	0.809	0.975	0.830	0.786	0.971
2.30	0.870	0.831	0.984	0.850	0.806	0.982	0.831	0.782	0.979
2.40	0.871	0.828	0.989	0.851	0.802	0.987	0.832	0.777	0.986
2.50	0.872	0.824	0.993	0.852	0.797	0.992	0.833	0.772	0.991
2.60	0.873	0.820	0.997	0.853	0.792	0.996	0.834	0.766	0.996
2.70	0.874	0.815	0.999	0.854	0.787	0.999	0.835	0.760	0.999
2.80	0.875	0.810	1.000	0.855	0.781	1.000	0.836	0.752	1.000
2.90	0.876	0.804	1.000	0.856	0.774	1.000	0.837	0.744	1.000

Ge(111) Single monochromator 2d(h,k,l) = 6.532 A

Ge(220) Double monochromator 2d(h,k,l) = 4.000 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0115 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0125 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0135 deg.

TABLE 2

Polarization calculation at 2.0 GeV 5.0 Tesla with a focusing pre-mirror and germanium single or double crystal monochromators.

λ(Å)	(1) τ	(1) τ'	(1) τ"	(2) τ	(2) τ'	(2) τ"	(3) τ	(3) τ'	(3) τ"
0.10	0.944	0.944	0.944	0.944	0.944	0.944	0.944	0.944	0.944
0.20	0.904	0.903	0.904	0.903	0.903	0.904	0.902	0.902	0.903
0.30	0.877	0.877	0.880	0.874	0.873	0.876	0.872	0.871	0.875
0.40	0.865	0.864	0.870	0.858	0.857	0.863	0.853	0.852	0.858
0.50	0.855	0.853	0.863	0.845	0.843	0.854	0.838	0.836	0.847
0.60	0.849	0.847	0.861	0.837	0.834	0.850	0.827	0.824	0.841
0.70	0.846	0.842	0.863	0.831	0.827	0.850	0.820	0.816	0.839
0.80	0.844	0.839	0.866	0.828	0.823	0.852	0.814	0.809	0.841
0.90	0.843	0.837	0.871	0.826	0.819	0.857	0.811	0.804	0.844
1.00	0.843	0.835	0.877	0.824	0.817	0.863	0.809	0.800	0.850
1.10	0.843	0.834	0.884	0.824	0.814	0.870	0.807	0.797	0.857
1.20	0.844	0.833	0.892	0.824	0.813	0.878	0.807	0.794	0.866
1.30	0.845	0.832	0.900	0.824	0.811	0.887	0.806	0.791	0.875
1.40	0.846	0.831	0.909	0.825	0.809	0.896	0.807	0.789	0.885
1.50	0.847	0.830	0.918	0.826	0.808	0.906	0.807	0.787	0.895
1.60	0.848	0.829	0.927	0.827	0.806	0.916	0.808	0.784	0.906
1.70	0.849	0.828	0.936	0.828	0.804	0.926	0.809	0.782	0.917
1.80	0.851	0.826	0.945	0.830	0.802	0.936	0.809	0.779	0.928
1.90	0.852	0.825	0.953	0.831	0.800	0.946	0.810	0.776	0.939
2.00	0.854	0.823	0.961	0.832	0.797	0.955	0.812	0.773	0.949
2.10	0.855	0.820	0.969	0.833	0.795	0.964	0.813	0.770	0.959
2.20	0.856	0.818	0.976	0.835	0.792	0.972	0.814	0.766	0.969
2.30	0.858	0.815	0.983	0.836	0.788	0.980	0.815	0.762	0.977
2.40	0.859	0.812	0.988	0.838	0.784	0.986	0.817	0.757	0.984
2.50	0.860	0.808	0.993	0.839	0.780	0.992	0.818	0.752	0.990
2.60	0.862	0.804	0.996	0.840	0.774	0.996	0.819	0.746	0.995
2.70	0.863	0.799	0.999	0.842	0.769	0.999	0.821	0.740	0.998
2.80	0.864	0.794	1.000	0.843	0.763	1.000	0.822	0.732	1.000
2.90	0.866	0.787	1.000	0.844	0.755	1.000	0.823	0.724	0.999

Ge(111) Single monochromator 2d(h,k,l) = 6.532 A

Ge(220) Double monochromator 2d(h,k,l) = 4.000 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0115 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0125 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0135 deg.

TABLE 3

Polarization calculation at 1.8 GeV 4.5 Tesla with a focusing pre-mirror and silicon single or double crystal monochromators.

		(1)			(2)			(3)	
λ(Å)	τ	τ'	τ"	τ	τ'	τ"	τ	τ'	τ"
0.10	0.957	0.957	0.957	0.957	0.957	0.957	0.957	0.957	0.957
0.20	0.924	0.924	0.924	0.923	0.923	0.924	0.923	0.923	0.924
0.30	0.900	0.900	0.902	0.898	0.897	0.900	0.896	0.896	0.899
0.40	0.887	0.886	0.892	0.882	0.881	0.887	0.879	0.878	0.883
0.50	0.877	0.876	0.885	0.869	0.868	0.878	0.864	0.862	0.872
0.60	0.871	0.869	0.883	0.861	0.858	0.873	0.853	0.850	0.866
0.70	0.867	0.864	0.883	0.855	0.851	0.872	0.845	0.841	0.863
0.80	0.864	0.860	0.885	0.850	0.846	0.874	0.839	0.834	0.864
0.90	0.862	0.857	0.889	0.847	0.841	0.877	0.835	0.828	0.867
1.00	0.861	0.855	0.895	0.846	0.838	0.882	0.832	0.824	0.872
1.10	0.861	0.853	0.901	0.844	0.835	0.889	0.830	0.820	0.878
1.20	0.861	0.851	0.908	0.844	0.832	0.896	0.828	0.816	0.885
1.30	0.861	0.849	0.915	0.844	0.830	0.904	0.827	0.813	0.894
1.40	0.862	0.848	0.923	0.844	0.828	0.913	0.827	0.810	0.903
1.50	0.863	0.846	0.931	0.844	0.826	0.921	0.827	0.806	0.912
1.60	0.863	0.844	0.939	0.844	0.823	0.931	0.827	0.803	0.922
1.70	0.864	0.843	0.948	0.845	0.821	0.940	0.827	0.800	0.932
1.80	0.865	0.841	0.956	0.846	0.818	0.949	0.827	0.797	0.942
1.90	0.866	0.838	0.963	0.847	0.815	0.958	0.828	0.793	0.952
2.00	0.867	0.836	0.971	0.847	0.812	0.966	0.829	0.790	0.962
2.10	0.868	0.833	0.977	0.848	0.809	0.974	0.830	0.786	0.970
2.20	0.869	0.830	0.984	0.849	0.805	0.981	0.830	0.781	0.978
2.30	0.870	0.826	0.989	0.850	0.801	0.987	0.831	0.776	0.985
2.40	0.871	0.822	0.993	0.851	0.796	0.792	0.832	0.771	0.991
2.50	0.872	0.818	0.997	0.852	0.791	0.996	0.833	0.764	0.996
2.60	0.873	0.813	0.999	0.853	0.785	0.999	0.834	0.758	0.999
2.70	0.874	0.807	1.000	0.854	0.778	1.000	0.835	0.750	1.000
2.80	0.875	0.801	0.999	0.855	0.770	0.999	0.836	0.741	0.999
2.90	0.876	0.793	0.997	0.856	0.762	0.997	0.837	0.731	0.996

Si(111) Single monochromator 2d(h,k,l) = 6.271 A

Si(220) Double monochromator 2d(h,k,l) = 3.840 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0115 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0125 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0135 deg.

TABLE 4

Polarization calculation at 2.0 GeV 5.0 Tesla with a focusing pre-mirror and silicon single or double crystal monochromators.

		(1)			(2)			(3)	
λ(Å)	τ	τ'	τ"	τ	τ'	τ"	τ	τ'	τ"
0.10	0.944	0.944	0.944	0.944	0.944	0.944	0.944	0.944	0.944
0.20	0.904	0.903	0.905	0.903	0.903	0.904	0.902	0.902	0.903
0.30	0.877	0.877	0.880	0.874	0.873	0.877	0.872	0.871	0.875
0.40	0.865	0.864	0.870	0.858	0.856	0.863	0.853	0.852	0.859
0.50	0.855	0.853	0.864	0.845	0.843	0.855	0.838	0.836	0.848
0.60	0.849	0.846	0.862	0.837	0.834	0.851	0.827	0.824	0.842
0.70	0.846	0.842	0.864	0.831	0.827	0.851	0.820	0.815	0.841
0.80	0.844	0.839	0.868	0.828	0.822	0.854	0.814	0.809	0.843
0.90	0.843	0.836	0.873	0.826	0.819	0.859	0.811	0.804	0.847
1.00	0.843	0.835	0.880	0.824	0.815	0.866	0.809	0.799	0.853
1.10	0.843	0.833	0.888	0.824	0.814	0.874	0.807	0.796	0.861
1.20	0.844	0.832	0.896	0.824	0.811	0.882	0.807	0.793	0.870
1.30	0.845	0.831	0.905	0.824	0.810	0.892	0.806	0.790	0.880
1.40	0.846	0.830	0.914	0.825	0.808	0.902	0.807	0.787	0.891
1.50	0.847	0.829	0.923	0.826	0.806	0.912	0.807	0.785	0.902
1.60	0.848	0.827	0.932	0.027	0.804	0.922	0.808	0.782	0.913
1.70	0.849	0.826	0.942	0.828	0.802	0.933	0.809	0.779	0.925
1.80	0.851	0.824	0.951	0.830	0.799	0.943	0.809	0.776	0.936
1.90	0.852	0.822	0.959	0.831	0.797	0.953	0.810	0.773	0.947
2.00	0.854	0.819	0.967	0.832	0.794	0.962	0.812	0.769	0.957
2.10	0.855	0.817	0.975	0.833	0.790	0.971	0.813	0.765	0.967
2.20	0.856	0.814	0.982	0.835	0.787	0.979	0.814	0.761	0.976
2.30	0.858	0.810	0.988	0.836	0.782	0.986	0.815	0.756	0.984
2.40	0.859	0.806	0.993	0.838	0.778	0.992	0.817	0.750	0.990
2.50	0.860	0.802	0.997	0.839	0.773	0.996	0.818	0.744	0.995
2.60	0.862	0.797	0.999	0.840	0.766	0.999	0.819	0.737	0.999
2.70	0.863	0.791	1.000	0.842	0.760	1.000	0.821	0.729	1.000
2.80	0.864	0.784	0.999	0.843	0.752	0.999	0.822	0.720	0.999
2.90	0.866	0.776	0.997	0.844	0.743	0.997	0.823	0.710	0.996

Si(111) Single monochromator 2d(h,k,l) = 6.271 A

Si(220) Double monochromator 2d(h,k,l) = 3.840 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0115 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0125 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0135 deg.

TABLE 5

Polarization calculation at 1.8 GeV 4.5 Tesla without a mirror and germanium monochromators.

	(1)			(2)			(3)		
λ(Å)	τ	τ'	τ"	τ	τ'	τ"	τ	τ'	τ"
0.10	0.983	0.983	0.983	0.978	0.978	0.978	0.973	0.973	0.973
0.20	0.982	0.982	0.983	0.976	0.976	0.976	0.969	0.969	0.969
0.30	0.982	0.982	0.983	0.976	0.976	0.976	0.968	0.968	0.969
0.40	0.982	0.982	0.983	0.975	0.975	0.976	0.968	0.968	0.969
0.50	0.982	0.982	0.984	0.976	0.975	0.977	0.968	0.968	0.970
0.60	0.983	0.983	0.984	0.976	0.976	0.978	0.969	0.968	0.972
0.70	0.983	0.983	0.985	0.977	0.976	0.979	0.969	0.969	0.973
0.80	0.984	0.983	0.986	0.977	0.977	0.981	0.970	0.969	0.975
0.90	0.984	0.983	0.987	0.978	0.977	0.982	0.970	0.969	0.976
1.00	0.984	0.984	0.988	0.978	0.977	0.983	0.971	0.970	0.978
1.10	0.985	0.984	0.989	0.979	0.977	0.985	0.972	0.970	0.979
1.20	0.905	0.984	0.990	0.979	0.977	0.986	0.972	0.970	0.981
1.30	0.985	0.984	0.991	0.979	0.978	0.987	0.973	0.970	0.983
1.40	0.986	0.984	0.992	0.980	0.978	0.988	0.973	0.970	0.985
1.50	0.986	0.984	0.993	0.980	0.978	0.990	0.974	0.971	0.986
1.60	0.986	0.984	0.994	0.980	0.978	0.991	0.974	0.971	0.988
1.70	0.986	0.984	0.994	0.981	0.978	0.992	0.974	0.971	0.989
1.80	0.986	0.984	0.995	0.981	0.978	0.993	0.975	0.970	0.991
1.90	0.987	0.984	0.996	0.981	0.978	0.994	0.975	0.970	0.992
2.00	0.987	0.984	0.997	0.982	0.977	0.995	0.976	0.970	0.994
2.10	0.987	0.984	0.997	0.982	0.977	0.996	0.976	0.970	0.995
2.20	0.987	0.984	0.998	0.982	0.977	0.997	0.976	0.969	0.996
2.30	0.988	0.983	0.999	0.982	0.977	0.998	0.977	0.969	0.997
2.40	0.988	0.983	0.999	0.983	0.976	0.999	0.977	0.969	0.998
2.50	0.988	0.983	0.999	0.983	0.976	0.999	0.977	0.968	0.999
2.60	0.988	0.982	1.000	0.983	0.975	1.000	0.978	0.967	0.999
2.70	0.988	0.982	1.000	0.983	0.975	1.000	0.978	0.966	1.000
2.80	0.988	0.982	1.000	0.984	0.974	1.000	0.978	0.966	1.000
2.90	0.988	0.981	1.000	0.984	0.973	1.000	0.978	0.965	1.000

Ge(111) Single monochromator 2d(h,k,l) = 6.532 A

Ge(220) Double monochromator 2d(h,k,l) = 4.000 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0031 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0036 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0042 deg.

TABLE 6

Polarization calculation at 2.0 GeV 5.0 Tesla without a mirror and silicon monochromators.

	(1)			(2)			(3)		
λ(Å)	τ	τ'	τ"	τ	τ'	τ"	τ	τ'	τ"
0.10	0.979	0.979	0.979	0.973	0.973	0.973	0.966	0.966	0.966
0.20	0.979	0.979	0.979	0.971	0.971	0.971	0.963	0.963	0.963
0.30	0.979	0.979	0.980	0.971	0.971	0.972	0.962	0.962	0.963
0.40	0.979	0.979	0.980	0.971	0.971	0.972	0.962	0.962	0.964
0.50	0.980	0.979	0.981	0.972	0.971	0.974	0.963	0.962	0.965
0.60	0.980	0.980	0.982	0.972	0.972	0.975	0.964	0.963	0.967
0.70	0.981	0.980	0.983	0.973	0.972	0.977	0.965	0.964	0.969
0.80	0.981	0.981	0.984	0.974	0.973	0.978	0.966	0.964	0.971
0.90	0.982	0.981	0.985	0.974	0.973	0.980	0.966	0.965	0.973
1.00	0.982	0.981	0.987	0.975	0.974	0.981	0.967	0.965	0.975
1.10	0.983	0.981	0.988	0.976	0.974	0.983	0.968	0.966	0.977
1.20	0.983	0.982	0.989	0.976	0.974	0.985	0.969	0.966	0.980
1.30	0.983	0.982	0.990	0.977	0.975	0.986	0.969	0.966	0.982
1.40	0.984	0.982	0.991	0.977	0.975	0.988	0.970	0.967	0.984
1.50	0.984	0.982	0.992	0.978	0.975	0.989	0.970	0.967	0.986
1.60	0.984	0.982	0.993	0.978	0.975	0.991	0.971	0.967	0.988
1.70	0.985	0.982	0.994	0.979	0.975	0.992	0.972	0.967	0.989
1.80	0.985	0.982	0.995	0.979	0.975	0.993	0.972	0.967	0.991
1.90	0.985	0.982	0.996	0.979	0.975	0.995	0.973	0.966	0.993
2.00	0.986	0.982	0.997	0.980	0.975	0.996	0.973	0.966	0.994
2.10	0.986	0.982	0.998	0.980	0.974	0.997	0.973	0.966	0.996
2.20	0.986	0.981	0.998	0.980	0.974	0.998	0.974	0.966	0.997
2.30	0.986	0.981	0.999	0.981	0.974	0.998	0.974	0.965	0.998
2.40	0.986	0.981	0.999	0.981	0.973	0.999	0.975	0.964	0.999
2.50	0.987	0.981	1.000	0.981	0.973	1.000	0.975	0.964	0.999
2.60	0.987	0.980	1.000	0.982	0.972	1.000	0.975	0.963	1.000
2.70	0.987	0.980	1.000	0.982	0.971	1.000	0.976	0.962	1.000
2.80	0.987	0.979	1.000	0.982	0.970	1.000	0.976	0.961	1.000
2.90	0.987	0.978	1.000	0.982	0.969	1.000	0.976	0.959	1.000

Si(111) Single monochromator 2d(h,k,l) = 6.271 A

Si(220) Double monochromator 2d(h,k,l) = 3.840 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0031 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0036 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0042 deg.

TABLE 7

Polarization calculation at 2.0 GeV 5.0 Tesla without a mirror and germanium monochromators.

λ(Å)	τ	(1) τ'	τ"	τ	(2) τ'	τ"	τ	(3) τ'	τ"
0.10	0.979	0.979	0.979	0.973	0.973	0.973	0.966	0.966	0.966
0.20	0.979	0.979	0.979	0.971	0.971	0.971	0.963	0.963	0.963
0.30	0.979	0.979	0.980	0.971	0.971	0.972	0.962	0.962	0.963
0.40	0.979	0.979	0.980	0.971	0.971	0.972	0.962	0.962	0.964
0.50	0.980	0.979	0.981	0.972	0.971	0.973	0.963	0.963	0.965
0.60	0.980	0.980	0.982	0.972	0.972	0.975	0.964	0.963	0.967
0.70	0.981	0.980	0.983	0.973	0.973	0.976	0.965	0.964	0.969
0.80	0.981	0.981	0.984	0.974	0.973	0.978	0.966	0.965	0.971
0.90	0.982	0.981	0.985	0.974	0.973	0.979	0.966	0.965	0.973
1.00	0.982	0.981	0.986	0.975	0.974	0.981	0.967	0.966	0.975
1.10	0.983	0.982	0.987	0.976	0.974	0.982	0.968	0.966	0.977
1.20	0.983	0.982	0.989	0.976	0.975	0.984	0.969	0.966	0.979
1.30	0.983	0.982	0.990	0.977	0.975	0.986	0.969	0.967	0.981
1.40	0.984	0.982	0.991	0.977	0.975	0.987	0.970	0.967	0.983
1.50	0.984	0.982	0.992	0.978	0.975	0.988	0.970	0.967	0.985
1.60	0.984	0.982	0.993	0.978	0.975	0.990	0.971	0.967	0.987
1.70	0.985	0.982	0.994	0.979	0.975	0.991	0.972	0.967	0.988
1.80	0.985	0.982	0.995	0.979	0.975	0.992	0.972	0.967	0.990
1.90	0.985	0.982	0.996	0.979	0.975	0.994	0.973	0.967	0.992
2.00	0.986	0.982	0.996	0.900	0.975	0.995	0.973	0.967	0.993
2.10	0.986	0.982	0.997	0.980	0.975	0.996	0.973	0.967	0.995
2.20	0.986	0.982	0.998	0.980	0.975	0.997	0.974	0.966	0.996
2.30	0.986	0.982	0.998	0.981	0.974	0.998	0.974	0.966	0.997
2.40	0.986	0.981	0.999	0.981	0.974	0.998	0.975	0.965	0.998
2.50	0.987	0.981	0.999	0.981	0.974	0.999	0.975	0.965	0.999
2.60	0.987	0.981	1.000	0.982	0.973	1.000	0.975	0.964	0.999
2.70	0.987	0.980	1.000	0.982	0.973	1.000	0.976	0.963	1.000
2.80	0.987	0.980	1.000	0.982	0.972	1.000	0.976	0.962	1.000
2.90	0.987	0.979	1.000	0.982	0.971	1.000	0.976	0.961	1.000

Ge(111) Single monochromator 2d(h,k,l) = 6.532 A

Ge(220) Double monochromator 2d(h,k,l) = 4.000 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0031 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0036 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0042 deg.

TABLE 8

Polarization calculation at 1.8 GeV 4.5 Tesla without a mirror and silicon monochromators.

λ(Å)	τ	(1) τ'	τ"	τ	(2) τ'	τ"	τ	(3) τ'	τ"
0.10	0.983	0.983	0.983	0.978	0.978	0.978	0.973	0.973	0.973
0.20	0.982	0.982	0.983	0.976	0.976	0.976	0.969	0.969	0.969
0.30	0.982	0.982	0.983	0.975	0.975	0.976	0.968	0.968	0.969
0.40	0.982	0.982	0.984	0.976	0.975	0.977	0.968	0.968	0.969
0.50	0.983	0.983	0.984	0.976	0.976	0.978	0.969	0.968	0.970
0.60	0.983	0.983	0.984	0.976	0.976	0.978	0.969	0.968	0.972
0.70	0.983	0.983	0.985	0.977	0.976	0.980	0.969	0.969	0.973
0.80	0.984	0.983	0.986	0.977	0.976	0.981	0.970	0.969	0.975
0.90	0.984	0.983	0.987	0.978	0.977	0.982	0.970	0.969	0.977
1.00	0.984	0.984	0.988	0.978	0.977	0.984	0.971	0.970	0.978
1.10	0.985	0.984	0.989	0.979	0.977	0.985	0.972	0.970	0.980
1.20	0.985	0.984	0.990	0.979	0.977	0.986	0.972	0.970	0.982
1.30	0.985	0.984	0.991	0.979	0.977	0.988	0.973	0.970	0.984
1.40	0.986	0.984	0.992	0.980	0.978	0.989	0.973	0.970	0.985
1.50	0.986	0.984	0.993	0.980	0.978	0.990	0.974	0.970	0.987
1.60	0.986	0.984	0.994	0.980	0.978	0.992	0.974	0.970	0.989
1.70	0.986	0.984	0.995	0.981	0.978	0.993	0.974	0.970	0.990
1.80	0.986	0.984	0.996	0.981	0.977	0.994	0.975	0.970	0.992
1.90	0.987	0.984	0.997	0.981	0.977	0.995	0.975	0.970	0.993
2.00	0.987	0.984	0.997	0.982	0.977	0.996	0.976	0.969	0.995
2.10	0.987	0.983	0.998	0.982	0.977	0.997	0.976	0.969	0.996
2.20	0.987	0.983	0.998	0.982	0.976	0.998	0.976	0.969	0.997
2.30	0.988	0.983	0.999	0.982	0.976	0.999	0.977	0.968	0.998
2.40	0.988	0.983	0.999	0.983	0.976	0.999	0.977	0.968	0.999
2.50	0.988	0.982	1.000	0.983	0.975	1.000	0.977	0.967	0.999
2.60	0.988	0.982	1.000	0.983	0.974	1.000	0.978	0.966	1.000
2.70	0.988	0.981	1.000	0.983	0.974	1.000	0.978	0.965	1.000
2.80	0.988	0.981	1.000	0.984	0.973	1.000	0.978	0.964	1.000
2.90	0.988	0.980	1.000	0.984	0.972	1.000	0.978	0.962	1.000

Si(111) Single monochromator 2d(h,k,l) = 6.271 A

Si(220) Double monochromator 2d(h,k,l) = 3.840 A

(1) Collimator 0.2 mm, gamma(ver) = 0.0031 deg.
(2) Collimator 0.4 mm, gamma(ver) = 0.0036 deg.
(3) Collimator 0.6 mm, gamma(ver) = 0.0042 deg.