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PROPOSAL: PROCEDURE FOR OPTICS TEST OF 8- AND 20- BEV/C SPECTROMETERS

INTRODUCTION

The designed optical properties of the 8- and 20- BeV/c spectrometers are given in detail in earlier SLAC technical reports[1,2]. A procedure is proposed here to measure parameters pertinent to use of the spectrometers. Measurements may then be compared to predicted values. The test can be accomplished by directing a discrete ray of high energy primary electrons of low intensity and very small phase space into a spectrometer. The apparent source position is located within the target region. Prior to spectrometer incidence, the ray's spacial orientation is controlled by a bending magnet triplet and is measured with position monitors. Momentum of the incident beam relative to spectrometer momentum setting can be varied. Optical transformation coefficients at critical locations of the spectrometer then may be determined.

Also schemes are considered for the absolute calibration of primary beam energy, and methods for interpreting the optics test data are suggested.

OBJECTIVE

We are interested, among other things, to learn empirical values of the following parameters:

1. Position of the focal planes (φ, θ, p)
2. Tilt angle of the p focal plane.
3. First order dispersion coefficients D_{φ}, D_{θ}, D_{p}.
4. Solid angle of acceptance.

These first order optical parameters can be measured in a straightforward way. Second order optics and the depth-of-field effect of the target can also be explored.

EQUIPMENT TO CONTROL INCIDENT RAY

Equipment for calibrating the 20 BeV/c spectrometer is shown schematically in figure 1. The ray entering end station A may have been collimated about 70 feet upstream by a variable-jaw device (C10). Or collimation may be done

by a simpler instrument in the end station alcove. The alcove collimator is simply swung into the beam line or removed. The primary ray is located by the position monitors P_{in1} and P_{in2}. When the testing magnets are not excited the ray acts as the spectrometer "central ray", and passes precisely through the simulated hydrogen target center line at zero degrees with respect to the spectrometer magnetic axis.

The testing magnets (BI, BII, BIII)were selected[3] to manipulate the ray over the entire spectrometer acceptance region. Horizontal displacement at the simulated target region is induced by BI, and measured with P_{in2}. Since displacements of interest exceed the beam tube apertures at BII and BIII, these magnets may be driven laterally on a table with remote readout available from a decitrak encoder. BII provides the ray with simulated horizontal (production) angle, while BIII operates independently on the ray to supply vertical (azimuthal) angle. In this way our discrete ray may be manuvered to explore more than the entire spectrometer acceptance.

It is possible to calculate the incident ray orientation by measuring currents of the testing magnets, ray location on the position monitors already mentioned, and distances involved. In addition, ray orientation incident to the spectrometer may be measured more directly with the large aperture position monitors, P_{incl} and P_{inc2}. The first is located immediately after BIII and tracks laterally with the magnets. The second monitor (only used with 20 BeV/c spectrometer) is bolted directly to the vacuum chamber at spectrometer entrance. Of course, all the position monitors mentioned so far may be removed and inserted remotely.

To simulate momentum dispersion with a discrete ray, it is necessary only to create a known percentage relationship between the incident ray and the spectrometer momentum setting. To test the spectrometer optics it is unnecessary to know the exact ray momentum. Hence, either a small increase in beam momentum can be requested, or spectrometer momentum setting could be decreased. The testing is perhaps less ambiguous if BSY momentum is varied, and this method is preferred. However, practicability at the time of testing may influence the choice.

Quadrupoles within the calibration configuration might be useful, although they may not be available. Since azimuthal angle is focussed at the p plane, it may be useful to input a real vertical divergence after

BI while also minimizing vertical beam height at the simulated target center and requesting a small momentum dispersion from the beam switchyard. If detector sensitivity in the spectrometer focal region is adequate it would be feasible to search for minimum beam size near the momentum focussing plane by moving a detector in that vicinity.

POSITION MONITORS FOR THE SPECTROMETERS.

Three screens are prepared for the focal region; all are always perpendicular to the central ray axis. P_{f1} and P_{f3} are located at either end of the focal region. P_{f2} can be driven along the central axis line over a distance of roughly ten feet, with remote readout available. They will be located as appropriate for the focussing characteristics of each spectrometer. In addition it will be interesting to view ray position occasionally midway in each spectrometer.

20 BeV/c SPECTROMETER

Nominal input specifications are:

x_o	projected target length	$\pm$ 3 cm
θ_o	horizontal angle	$\pm$ 4.5 mr
y_o	vertical displacement	$\pm$ 0.15 cm
φ_o	vertical angle	$\pm$ 8 mr

The spectrometer focuses φ at 1.395 meters, and θ at 6.48 meters from the exit of the last bending magnet. Momentum focus occurs at a plane 0.5 meters downstream from the θ focus with a calculated tilt angle of 47.8° from the vertical.

Momentum focussing occurs at the middle of the central sextupole and a number of other measurements on the spectrometer can be made there. Therefore, two removeable position monitors are located in the vacuum boxes at either ends of the central sextupole.

8 BeV/C SPECTROMETER

Nominal input specifications are:

$x_o = \pm$ 10 cm
$\theta_o = \pm$ 8 mr
$y_o = \pm$ .15 cm
$\varphi_o = \pm$ 30 mr

The 8 BeV/c spectrometer focusses θ at 4.25 meters from the end of the last quadrupole, and p at 0.5 meters farther downstream. The p focus is tilted at 13.7° from the central axis, while the central axis itself is oriented 30° upward from the horizontal.

While no azimuthal focussing occurs, it may at times be interesting to check ray position between the two bending magnets. A removeable screen might be located there, but space for the screen is a problem.

COMMENTS ON POSITION MONITORS.

These monitors will probably be the conventional ZnS screens. In any event, such screens are available. If more suitable position monitors exist at the time of optics testing, they could be substituted.

Considerations influencing the choice of monitors are as follows:

1. Simplicity and reliability. No one seems available to carry out the development of a sophisticated system. Engineering support and funding is limited. Since any equipment specially developed for the optic tests would only be used a few weeks, we are constrained to build only rather standard and perhaps expendable equipment.
2. Low required beam current and high sensitivity. Radiation could be annoying. The choice should waiver between maximizing available information, and minimizing radiation, heating problems, etc.
3. Borrowing someone's sophisticated system is encouraged.
4. Precise beam position information is important. If one chooses a positional error of 1 mm, it has been shown[3] that even by adding maximum possible errors, the calibration magnets will supply an incident beam well within the spectrometer resolution. Unhappily however, an error in position of 1 mm can result in rather large errors at the focal region. For instance, one might expect an error of two centimeters in determination of the p focal plane.

Hence, while we are free to use ZnS screens for incident beam monitoring, one welcomes a more clever technique to locate the exiting ray's orientation in space over the spectrometer focal region.

Scintillating gas, Cerenkov light, a moveable one-dimensional hodoscope of plastic scintillators, a simple spark chamber – all have been discussed and present their own problems. Perhaps one of the most useful devices would be a series of "wire spark chambers"[4] with magnetostrictive readout, but this seems prohibitively complex. Accuracy to about .1 mm is obtainable with the wire spark chamber, but only about 10 electrons/pulse could be accepted and readout electronics is not trivial.

The most practicable replacement for visual screens appears to be a hodoscope-like array of SEMs developed by the BSY group.[5] Measurements show outputs roughly 1% of incident beam current. Positional accuracy to 1 mm seems feasible. Even these items require some development however.

INTENSITY MEASUREMENTS

Particularly for determination of solid angle of acceptance, knowledge of the relative number of electrons entering and leaving the spectrometer will become interesting. When the ray scrapes the magnet pole faces, this becomes evident by a loss in exiting beam relative to incident beam.

One large ion chamber near BI and another after the last spectrometer magnet should be available for use as intensity monitors. The latter should be large enough to cover the entire exiting aperture. Both are used for current measurement only. The first is remotely removeable from the beam line.

Twenty ionization chambers for use as general radiation monitors should be available with analogue outputs. These are to be placed at critical locations along the spectrometer to determine where pole face scattering occurs.

PROCEDURE

It should be noted that this description is in no sense inflexible. Below the reader finds an approach at least similar to the one which will evolve before and during the actual optics testing.

The test sequence described is written for the 20 BeV/c spectrometer. For the 8 BeV/c spectrometer, one should simply remember that no φ focus exists and no central cross-over occurs. Hence, comments related to those characteristics should be neglected. When it is interesting to observe ray position between the two 8 BeV/c bending magnets, this is found in parenthesis.

PROCEDURE

CENTRAL RAY ALIGNMENT

After the testing magnets have been degaussed and de-energized, spectrometer bending magnets only are brought to design excitation. Screens in the focal region will have been previously aligned and centered about the central axis. Incident ray positions are measured on screens and the center line is defined. The exiting ray is located in the spectrometer focal region. Then spectrometer bending magnet excitations and spectrometer angle with respect to the primary beam line are each adjusted until the ray is centered on focal region screens. Ray position at the middle of sextupole (S2) is centered by making any adjustments necessary. (Similarly the ray position between the 8 BeV/c bending magnets should be checked if possible.)

Bending magnet currents are then measured, and each quadrupole is excited to corresponding currents as determined by spectrometer design. First Q1 in the spectrometer is brought to design current and the ray is observed to assure that no beam displacement results. This is repeated for Q2, and so on. If the quadrupoles do affect the central ray, mechanical adjustment of some kind will be necessary. This procedure, assuring that multipole elements are properly aligned, is repeated for the sextupole magnets.

INITIAL TESTS FOR GROSS MALADJUSTMENT

Initially it is informative to test the spectrometer by varying independently each of the three variables, φ_o, θ_o, and Δp. Gross maladjustment of the spectrometer would become evident, and a knowledge of spectrometer optics should allow appropriate corrective action to be taken. A great deal of information will become available very quickly.

Firstly, φ_o is varied at discrete values until pole face scattering occurs. D_φ, the first order dispersion coefficient at designed φ focus position will be available. Azimuthal acceptance, neglecting target length effects, will result.

Secondly, θ_o is varied at discrete values until pole face scattering occurs. D_θ is determined and the θ focus is established. Production angle acceptance will also result.

Thirdly, BSY momentum setting is varied roughly over the spectrometer momentum acceptance ($\sim \pm 2\%$). The momentum dispersion, D_p, at designed momentum focus will be available, and momentum acceptance information will result.

Since the absolute beam energy is not calibrated yet, measured momentum dispersion will not be precise. Techniques for absolute energy calibration are discussed later.

ROUGH MEASUREMENT OF SOLID ANGLE OF ACCEPTANCE

Experimentally the next most likely measurement of interest is the solid angle of acceptance. The boundary of the Φ_o-θ_o plot would be measured by setting Φ_o (or θ_o) at discrete values and varying θ_o (or Φ_o) until pole face scattering occurs. These measurements would be repeated for different values of Δp, providing values for $\Omega(\delta)$. Direct measurement of transmission can also be made with large ionization chambers placed before and after the spectrometers.

NECESSARY JUDGEMENTS

Physicists may wish to make adjustments to the spectrometer as a result of the data above, and then repeat the measurements; or the whole spectrometer may need readjustment.

It is conceivable that the measurements of dispersions at the predicted focal planes are both linear and within tolerance. In this case, the optics test could proceed promptly to a more detailed study of dispersions, solid angle of acceptance, and depth-of-field effects.

On the other hand, it may be decided that a rigorous attempt should be made to locate the focal planes by experiment. If this becomes necessary, techniques are described generally below. Available beam time would affect these decisions.

LOCATING THE P FOCUS

An azimuthally dispersed beam of well defined momentum will focus to a point only at the p focus, and this property of the spectrometers is basic to the test. One could proceed in two ways:

A. The first method involves using a discrete ray and two fixed screens subtending the focal region. First, discrete $\pm \varphi_o$ are input to the central ray. The calculated intersection is the center in space of the p focal plane. The intersection of the p focal plane and a vertical plane though the central axis is found by repeating the procedure above, but for discrete $\pm \Delta p$.

Finally, the p focal plane can be found by repeating the procedures above, but for discrete $\pm \theta_o$.

B. The second method involves using a vertically divergent ray and a single screen which moves along the central axis remotely. A real vertical divergence will have been induced by quadrupoles after BI in the testing magnet configuration. A tall narrow beam is requested from the BSY. The quadrupoles would minimize beam height at the simulated target center, while also inducing a real vertical divergence.

The spectrometer is designed to focus such a beam to a point (for small θ) at the momentum plane. Hence, the screen is moved along the central axis until minimum beam size is established. This is the center of the momentum focal plane.

To find the line which intersects the p focal plane and a vertical plane through the central axis, the procedure is repeated, but for discrete values of $\pm \Delta p$.

Finally, the whole plane is determined with a vertically divergent beam by first inducing discrete $\pm \theta_o$ and then proceeding as above.

The second method, that of using quadrupoles, may be difficult in practice. Horizontal blow-up would occur and the beam might become so diffuse in the focal region that it could not be easily located. An array of horizontally oriented long-scintillators and photomultiplier tubes might be the appropriate moving detector if the quadrupole technique is used.

The procedure for locating the p focus is explained by the formula for the tilt angle, Ψ_δ, which is the angle of the momentum focal plane with respect to a plane perpendicular to the central ray. The formula is:

$$\tan \Psi_{\delta} = - \frac{(y|\delta)(\Phi|\Phi_o)}{(y|\Phi_o\ \delta)}$$

LOCATING THE φ FOCUS

A beam of large momentum dispersion, but discrete azimuthal angle will focus to a point (for small θ) only at the φ focus, and this property of the spectrometers is basic to the test. Again, it is possible to accomplish the test either with two fixed screens or with a single screen which moves along the central axis near the design φ focus.

A. If two screens are used, the beam switchyard supplies the usual discrete ray. The central ray is again established, and the BSY supplies each of $\pm \Delta p$. The intersection of the rays is the center of the φ focus.

   The intersection of the φ plane and a vertical plane through the central axis is found by repeating the procedure above, but for discrete $\pm \varphi_o$.

   Finally, the φ focal plane can be found by repeating the procedures above, but for discrete $\pm \theta_o$.

   D_{φ} is determined also by this procedure because φ, the azimuthal angle of the incident ray, is measured as well as the ray's position in the focal region.

B. If a single moving screen is used, the beam switchyard supplies a beam of small φ but opens the slits (SL-10) to provide large δ. The spectrometer is designed to focus such a beam to a point (for small θ) only at the φ focus. Hence, the screen is moved along the central axis until minimum beam size (height) is established. This is the center of the φ focus. To find the line which intersects the φ focal plane and a vertical plane through the central axis, the procedure is repeated but for discrete $\pm \varphi_o$. Finally, the φ focal plane can be found by repeating the procedures above, but for discrete $\pm \theta_o$.

ESTABLISH θ FOCAL PLANE; STUDY θ DISPERSION

The spectrometers are designed for horizontal line (at the target) to point (at the focus) production angle focussing. In principle, it would be possible to input rays of discrete production angle (θ_o), but different displacements (x_o) at the target, and then to measure the intersections over the focal region. Unfortunately, this method is not practical since these rays would intersect at very small angles in the focal region. Detector sensitivity is likely to be inadequate.

A feasible approach is simply to locate a screen upstream from the measured p focus position according to design. Then θ dispersion is actually measured. Dispersion measurements would be repeated for various φ_o and Δp values. Finally, discrete lateral displacements, x_o, would be input to verify that line-to-point θ focussing does occur to within designed spectrometer resolution. The screen might be moved if measurements indicate.

LOCATE SCREENS TO MEASURED POSITIONS; STUDY φ AND p DISPERSIONS.

Physicists may wish to move screens to their measured positions, and then double check dispersions as was done with the θ focus in the paragraph above.

DEPTH-OF-FIELD EFFECTS

In a real experiment when the spectrometer operates at angles other than 90^o, target length introduces depth-of-field effects to the spectrometer optics. These effects change momentum and angular resolutions in a complicated way.[6]

Calculations of the effects based on the earlier first order optics measurements should be reliable.

However, part of the effects can be simulated with a discrete ray. For example, a large y_o at the projected target position, x_o , can be introduced to the ray, simulating a particle leaving the end of a target. For the effect on momentum resolution, this method should be fairly sensitive since momentum resolution is mainly affected by the first order term $(y|y_o)\, y_o$. A few checks could be made by introducing sensible x_o and y_o values and then measuring dispersions at the foci.

However, sensitivity for determining the depth-of-field effect on angular resolution is poor, since angular resolution is determined only by second order optics terms.

SOLID ANGLE ACCEPTANCE

Since first order spectrometer optics will have been rather thoroughly investigated, the remaining task is to measure the solid angle of acceptance. Screens for measuring the incident ray would continue to be used, and also an SEM or ionization chamber would measure incident beam intensity. The intensity monitor could be inserted or retracted from the beam line remotely.

In addition, a fixed intensity monitor of the same type would be permanently located after the last spectrometer magnet. The monitor would cover the entire aperture.

Employing the intensity monitors, one can determine spectrometer transmission, the relative beam intensity through the spectrometer. For large incident angle and displacement, pole face scattering will occur and this will be evidenced by a drop in relative beam intensity at the focal region. Also radiation monitors will be placed at critical regions of the spectrometer in an effort to determine where in the spectrometer the beam scraping occurs.

As beam time is limited, a reasonable order of data collection is as follows:

A. $\theta_o(x_o)$: For fixed x_o values, find the limits of θ.

B. $\varphi_o(\delta)$: Vary φ_o for discrete values of Δp.

C. Ω: This should be repeated at this time. Find the boundary of $(\Phi_o - \theta_o)$ plot.

D. Ω_δ

E. $\Omega_\delta(x_o)$

F. $\Omega_\delta(y_o)$

G. $\Omega_\delta(x_o, y_o)$

ABSOLUTE BEAM ENERGY CALIBRATION

To determine spectrometer momentum dispersion, spectrometer momentum setting and primary beam energy must be precisely calibrated. Three methods are mentioned here.

1. The most straightforward and unambiguous technique discussed often. The spectrometer bending magnets can be used alone to analyze primary beam momentum. Accuracy depends only on how well the $\int B \cdot dl$ and the

radius of curvature in a magnet are known. At the time of optics test the experimental configuration is most easily adapted to perform the energy calibration by this technique.

During experimentation it will not be easy to set up the spectrometer to allow primary beam to pass through the spectrometer. Then more interest can be expected about other possible methods based on the kinematice of electron scattering from a hydrogen target.

2. Primary beam energy can be calculated by locating the elastic scattering peaks for two primary energy beams. Relative field measurements are made in the BSY for two primary energies, E_{O_1} and E_{O_2}. A spectrometer observes the elastic scattering peak in each case, which are E_1' and E_2'. Relative field measurements of the spectrometer bending magnets are made at the elastic scattering peak in the two runs. Then:

$$E_1' = \frac{E_{O_1}}{1 + \frac{2E_{O_1}}{M} \sin^2 \frac{\theta}{2}} \tag{1}$$

and

$$E_2' = \frac{E_{O_2}}{1 + \frac{2E_{O_2}}{M} \sin^2 \frac{\theta}{2}} \tag{2}$$

Experience with the BSY magnets indicates that direct current measurements are accurate to $1/10^4$. NMR measurements may also be useful. It seems evident that a ratio of two fields can be found to at least $1/10^4$. That is,

$$E_{O_2} = (N_{BSY})\, E_{O_1} \tag{3}$$

$$E_2' = (N_{SPEC})\, E_1' \tag{4}$$

Equations (3) and (4) can be substituted into Eq. (2). Then Eqs. (1) and (2) each involve only E_{o_1} and E_1', from which E_1' is eliminated. One solution is:

$$E_{o_1} = \frac{M}{2 \sin^2 \frac{\theta}{2}} \times \frac{(N_{SPEC}/N_{BSY}) - 1}{1 - N_{SPEC}} \qquad (5)$$

Hence, primary beam energy is calibrated in terms of the well known proton mass, M, and two pairs of reliable relative measurements. The method is even more general; in the same way the two kinematics equations could be solved for E_1' or E_2', thus providing a method for energy calibrating the spectrometers.

For simplicity the equations are shown to assume that the spectrometer is not moved, and that the measured production angles, θ, are equal. Of course this needn't be true in general. The production angles must be measured precisely for each run.

It should be possible to optimize the accuracy of the energy calibration by careful choice of primary energies, scattered energies, production angles, beam intensity, and target length. The two primary energies would hopefully be not far separated to assure that large magnet field changes do not change the BSY optics, and the same consideration is true of the spectrometers. From the appearance of Eq. (5), it is evident that terms of the sort, (N_{SPEC}/N_{BSY}) and N_{SPEC}, must be sufficiently different from the number, one (1).

Also, error results from field measurements, resolution of the elastic peaks and the θ measurements. Careful consideration must be given to whether Eqs. (3) and (4) are in fact valid to the required accuracy. Available data[7] suggests it is possible to resolve the elastic peak to better than 10 MeV. Of course, more attention should be given to the propogation or error. Typical count rates should be estimated, etc.

(3) An alternative kinematic method of establishing absolute incident energy presumes confidence in the N^* mass measurements made by other means, confidence in the straightforward interpretation of the inelastic spectra, and confidence in the absolute momentum calibration of the spectrometer. No knowledge of the beam switchyard system is required. Taking absolute field measurements of the spectrometers at two inelastic nucleon isobar peaks, the equations are:

$$E'_1 = \frac{E_o - ([M^*_1]^2 - M^2)/2M}{1 + \frac{2E_o}{M} \sin^2 \frac{\theta_1}{2}} \qquad (1)$$

$$E'_2 = \frac{E_o - ([M^*_2]^2 - M^2)/2M}{1 + \frac{2E_o}{M} \sin^2 \frac{\theta_2}{2}} \qquad (2)$$

E'_1 and E'_2 are measured absolutely with the spectrometers. Then Eq. (2) is subtracted from Eq. (1) to yield E_o since all other parameters are known. Because of background from the radiative tail, the broad width of the nucleon resonances, and large magnetic field changes, sources of error associated with this method are a bit frightening.

More thought should be given to the potential usefulness of these techniques. If further investigations make the kinematic methods look hopeful, then it seems sensible to calibrate the BSY with a spectrometer at the time of optics test by the straightforward $\int B \cdot dl$ method and then to compare results with the kinematic methods as soon as a hydrogen target is used.

DATA ANALYSIS

The optics testing procedure as written should allow for adjustments to a spectrometer, result in determination of the dispersion coefficients, and provide some information on solid angle of acceptance. The order in which measurements are made results primarily from the interpretation an experimenter can apply to data as it becomes available. In fact, for a given spectrometer set-up, every time a measurement is made, more information becomes available that is immediately used.

How the data could be treated completely is suggested below:

USING SCREENS

When screens are used, one gathers information on the incident ray's orientation and relative momentum:

$$x_o,\ y_o,\ \theta_o,\ \varphi_o,\ \Delta p$$

and also on the exiting ray's orientation over the focal region

$$x_f,\ y_f,\ \theta_f,\ \varphi_f\ .$$

When x_o and y_o are zero, data is necessarily being gathered which leads to information on the position of the φ and p foci,

$$F_p,\ F_\varphi\ .$$

When only y_o is zero, data is being gathered (if detector sensitivity is adequate) which also leads to location of the θ focus,

$$F_\theta\ .$$

When x_o and y_o are zero, information is being gathered from which the dispersion coefficients and spectrometer resolutions can be calculated. These are:

$$D_p,\ D_\theta,\ D_\varphi$$

$$P_r,\ \theta_r,\ \varphi_r\ .$$

For values of x_o and y_o, information relating to spectrometer angle and target length effect on dispersion and resolution are gathered,

$$(D_p, D_\theta, D_\varphi)_{x_o, y_o}$$

$$(P_r, \theta_r, \varphi_r)_{x_o, y_o} \quad .$$

These can be related directly to a real experiment when spectrometer production angle setting (θ_s) and target length (l_t) are involved.

$$(D_p, D_\theta, D_\varphi)_{\theta_s, \ell_t}$$

$$(P_r, \theta_r, \varphi_r)_{\theta_s, \ell_t}$$

USING INTENSITY MONITORS

Whenever screens or intensity monitors provide ray transmission through the spectrometer information about the spectrometer solid angle of acceptance is being gathered. These are:

$$(\varphi_o - \theta_o)\text{plot}$$

$$\theta_o(x_o) \quad \theta_o(y_o) \quad \theta_o(\delta)$$

$$\varphi_o(x_o) \quad \varphi_o(y_o) \quad \varphi_o(\delta)$$

$$\Omega_{x_o} \qquad \Omega_{y_o} \qquad \Omega_\delta$$

$$\Omega_{x_o\delta} \qquad \Omega_{y_o\delta}$$

$$\Omega_{x_o y_o \delta}$$

Again whenever x_o and y_o are involved, the data can be related to a real experiment when spectrometer production angle setting (θ_s) and target length effects (ℓ_t) occur, that is,

$$\theta_o(\theta_s, \ell_t), \varphi_o(\theta_s, \ell_t)$$
$$\theta_o(\theta_s, \ell_t, \delta), \varphi_o(\theta_s, \ell_t, \delta)$$

and finally

$$\Omega(\theta_s, \ell_t, \delta) \ .$$

COMPUTER ASSISTANCE

An attractive notion is to utilize the SDS 9300 to assist with interpretation of the optics testing data. Some work is proceeding in this direction; but how much help will result from use of the computer is still uncertain, and depends on both the state of computer operability and the programming effort available.

How, ideally, the computer might be used is suggested below.

1. A series of plot or CRT routines could be prepared to illustrate in sequence what data points mean in terms of dispersion, resolution and acceptance. That is, from knowledge of the incident and exiting orientations or transmission, a point would appear on the CRT or X-Y plotter of any of the optics characteristics mentioned above.

Ordinary transport runs on the 7090 could be done to learn the predicted exiting ray orientation for each incident ray planned.

These predicted incident and exiting ray orientations would be used as data points for the optics plot routines, providing predicted optical performance. At the time of optics test then, one would simply input experimental incident and exiting ray orientations. The real spectrometer optics characteristics would become immediately evident.

2. A first order TRANSPORT program could be written in FORTRAN and prepared on the 9300. This would make no fits. It would, however, trace a ray through the spectrometer as currents (only) are varied. CRT plots would illustrate effects, by showing the ray trace and magnet apertures. Then physicists would have at hand graphic illustration of how the spectrometer should affect the ray being used as spectrometer magnet currents are varied.

3. Simple routines could be written to provide incident and exiting ray orientations from the measured position on screens, testing magnet currents, and BII, BIII displacement. Conversely confusion during the optics test will be reduced if, following central ray alignment, a physicist is simply able to punch in x_o, y_o, θ_o, φ_o and the computer assists in setting up the testing magnets. Computer control of the spectrometer magnets is planned to be available at the time of the optics test. Encoders are available for the testing magnets as well.

SPECTROMETER DIAGNOSIS

Mechanical misalignment or error in the magnetic field setting of elements could be diagnosed more readily during the optics test with the aid of a table for the purpose. Such errors in spectrometer set-up may have substantial effects on the ray positions at the screens in the spectrometer and over the focal region. A method similar to that used for calculating spectrometer tolerances[1,2] could be applied to this situation. With the appropriate table, an experimenter could quickly relate certain patterns of deviation from predicted ray positions to errors in spectrometer element set-up. Then the element could be adjusted and the measurements repeated.

ACKNOWLEDGEMENTS

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FIGURES

1. Optics Test Equipment with 20 BeV/c Spectrometer.

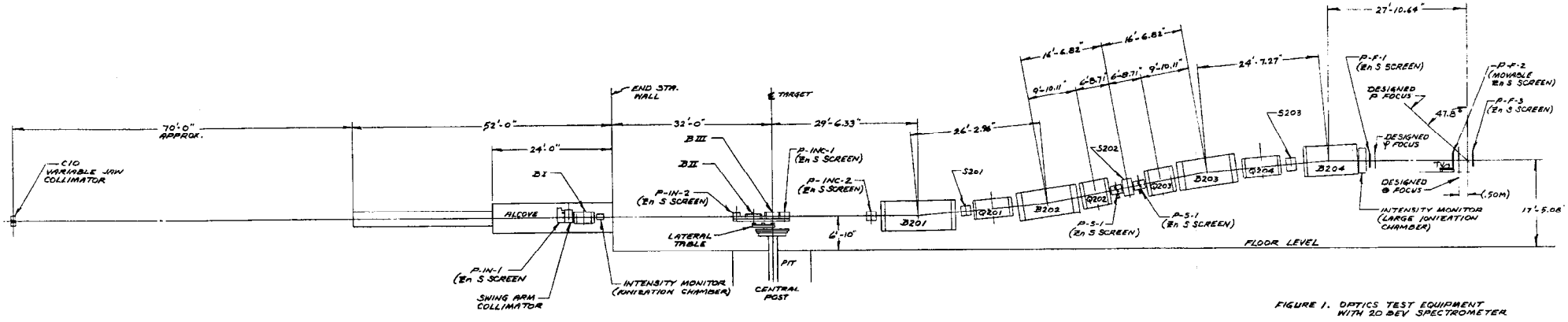

FIGURE 1. OPTICS TEST EQUIPMENT WITH 20 BEV SPECTROMETER