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P. Spillantini: AZIMUTHAL DISTORTION AND SPIRALLING OF CHARGED PARTICLES IN A SOLENOID AT LEP.

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If a longitudinal solenoid is used as Jet Detector at LEP, spiralling of low momentum particles and azimuthal distortion of particles escaping the magnetic field will be among the most difficult problems to be faced to understand the foreseen complex final states. In fact many particles per event will spiral inside the solenoid(1) blinding a large part of the track detector, while the other charged particles will not escape the magnetic field radially in azimuth but with a showy deflection, which will set serious limits on the granularity and on the performance of any detection system external to the solenoid; moreover the actual coil thickness crossed by the particles will be considerably increased.

In this short note curl-up limit and azimuthal distortion trends are given as a function of the radial bending power of the solenoid. Figures will be given for the solenoid studied at the "Les Houches LEP Summer Study"(2) and for a solenoid 'equivalent' to a (conservative) toroid of small external radius ($r < 1.25$ m; see ref. (3)).

For the transverse component of the momentum ($p_\perp$) the distortion in azimuth is expressed by the angular deviation δ of the particle from the radial direction at the exit from the magnetic field ($\delta = 1/2\ \alpha$, where α is the azimuthal deflection of the particle in the solenoid; see Fig. 1).

Particles with $p_\perp = p_{\perp s} = 0.15\ B \times r$ ($B \times r$ = radial bending power, in Tesla x m) come out from the magnetic field tangent to the coil surface, with $\delta = 90^o$. Particles with $p_\perp < p_{\perp s}$ spiral inside the solenoid, while for $p_\perp > p_{\perp s}$ the azimuthal distortion angle δ is a simple function of $p_\perp$: $\delta = \arcsin(0.15\ \frac{B \times r}{p_\perp})$.

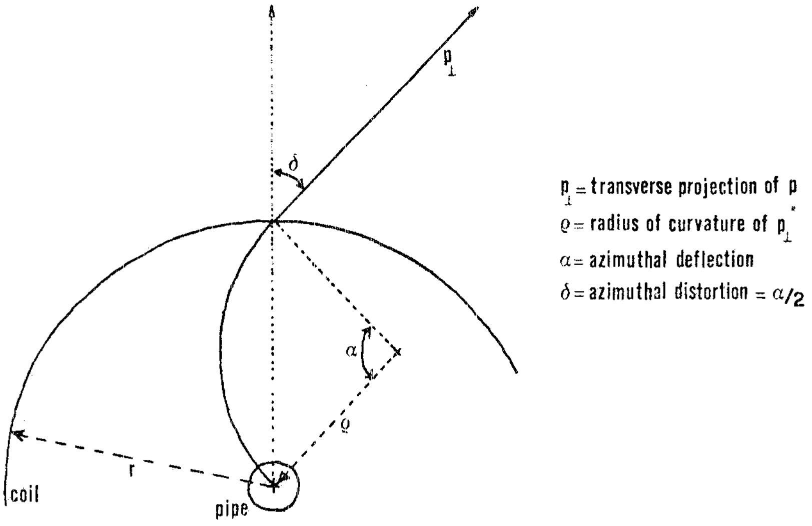

FIG. 1 - Geometrical conventions.

In Fig. 2 δ is plotted as a function of p for different values of $B \times r$ and for various emission angles ϑ. Values at different ϑ's are obtained simply by reducing p to $p_\perp = p \sin\vartheta$. The abscissa is not linear in p, but in the foreseen integral charged particle production $\int_0^p (dN_{ch}/dp)\, dp$, normalized to 1 at 70 GeV/c[3]; corresponding values of p are also reported for convenience.

The trend of δ versus this abscissa shows in a direct way the fraction of charged particles (and their corresponding momenta) captured by the magnetic field, or escaping it with a fixed limit in δ.

The fraction of charged particles spiralling in the solenoid are summarized in Fig. 3, while in Fig. 4 are collected the values of the azimuthal distortion δ^* corresponding to half of the foreseen integral charged particle production (i. e. to $\int_0^p (dN_{ch}/dp)\, dp/\text{total} = 0.5$).

The fraction of charged particles spiralling in the solenoid[4] and the values of δ^* are reported in Table I for the solenoid proposed at

TABLE I

	Solenoid studies at the "Les Houches LEP Summer Study" ($B \times r = 4.1$ Tesla x m)				Solenoid 'equivalent' to a toroid of small external radius ($B \times r = 1.475$ Tesla x m)			
ϑ	30°	45°	90°	30°-90°	30°	45°	90°	30°-90°
Fraction of particles spiralling in the solenoid	0.46	0.35	0.26	0.30	0.20	0.14	0.10	0.12
Azimuthal distortion corresponding to half of the charged particle production (δ^*)	52°	36°	24°	31°	17°	12°	8.5°	10°

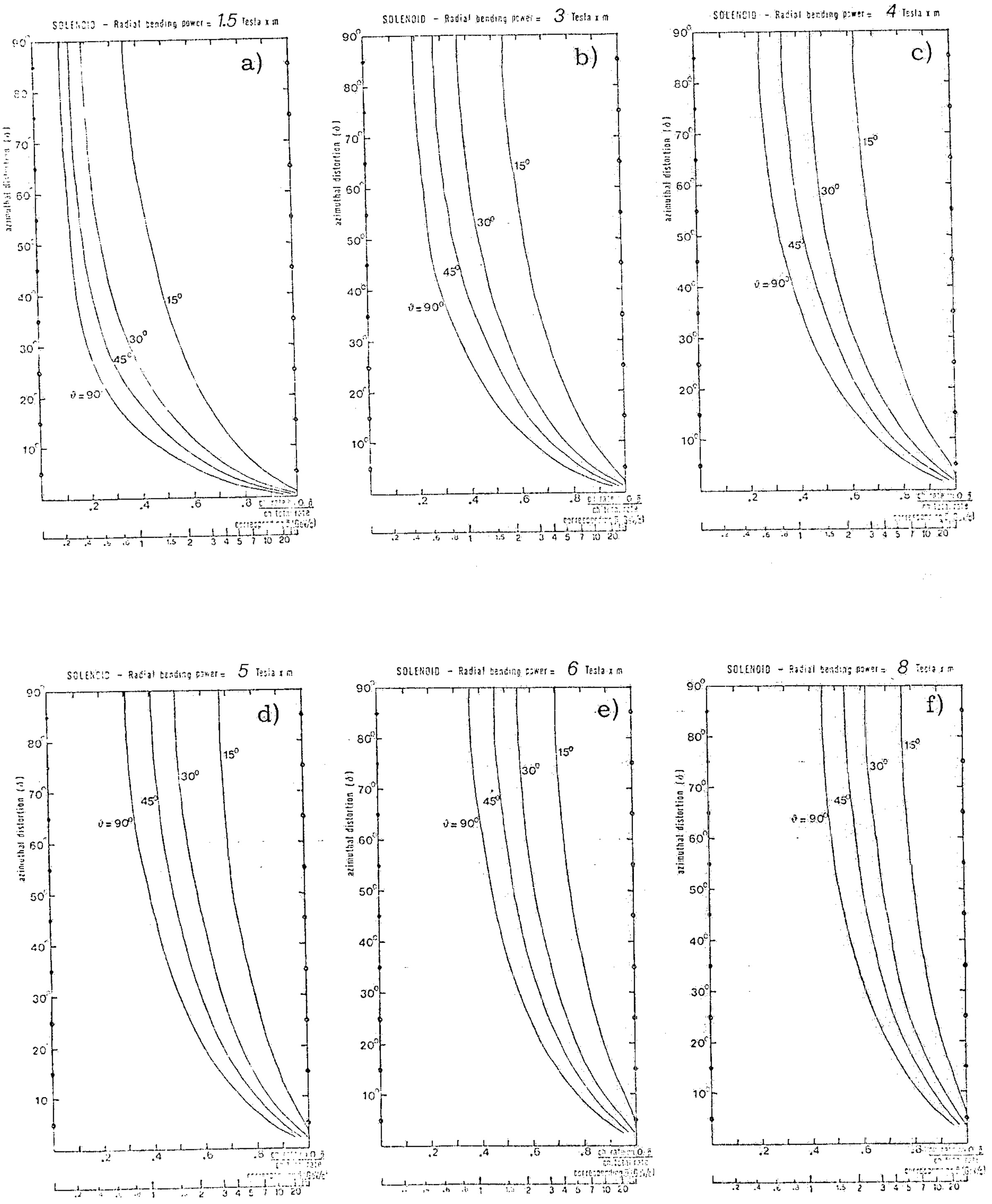

FIG. 2 - Azimuthal distortion as a function of the momentum for different values of the radial bending power of the solenoid and for various emission angles ϑ. The abscissa is linear in the foreseen integral charged particle production $\int_0^p (dN_{ch}/dp)\,dp$ normalized to 1 at 70 GeV/c, and gives directly the fraction of charged particles corresponding to a fixed δ. Corresponding values of p are also reported for convenience.

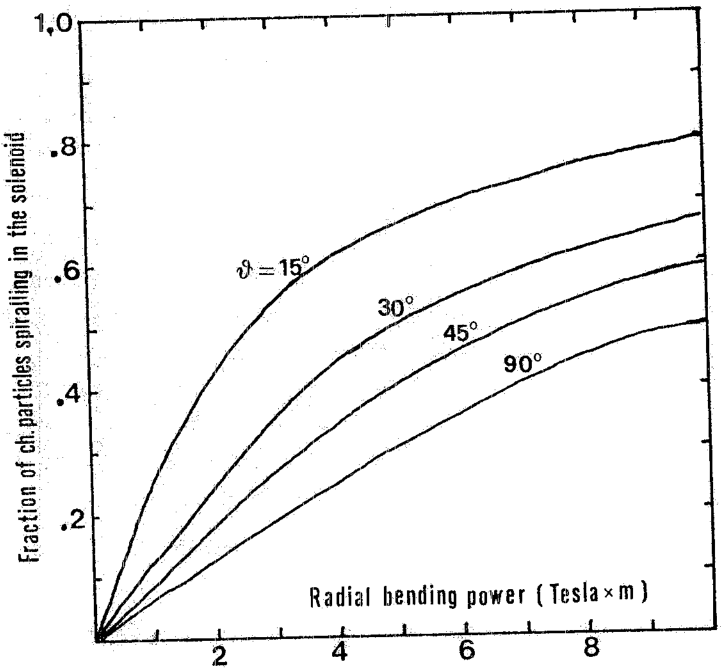

FIG. 3 - Fraction of the charged particles spiralling in a solenoid as a function of its radial bending power(4).

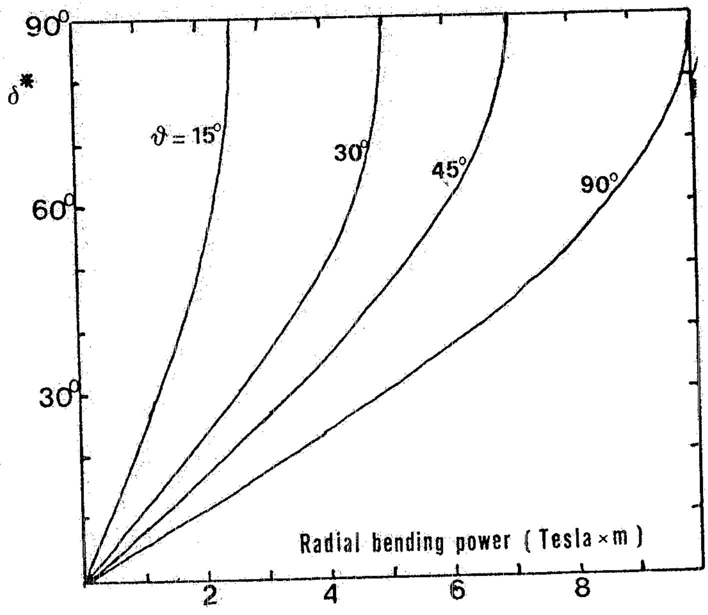

FIG. 4 - Azimuthal distortion δ^* corresponding to half of the foreseen integral charged particle production (i. e. to $\int_0^p (dN_{ch}/dp)\, dp/\text{Total} = 0.5$).

the "Les Houches LEP Summer Study"(2) ($B \times r$ = 4.1 Tesla x m) and for the 'equivalent' solenoid(3) ($B \times r$ = 1.475 Tesla x m) mentioned above.

Some conclusive remarks can be made:

- For $\vartheta \ll 30^{\circ}$ azimuthal distortion is not manageable already at low values of $B \times r$ ($\sim$ 1 Tesla x m) (see in Fig. 2a curves for $\vartheta = 15^{\circ}$ and $\vartheta = 30^{\circ}$). This is a further argument to limit the zenithal coverage of a solenoid down to no more than $\sim 30^{\circ}$.
- In the central region (i.e. $\vartheta \gtrsim 30^{\circ}$) values of the radial bending power greater than 3 Tesla x m prevent the use of external devices for most of the produced particles and can also give problems in disentangling the leading particles. Moreover already at 3 Tesla x x m more than 1/3 of the charged particles (i.e. an average of nearly 6 particles per event) spiral inside the solenoid, and this value rises to more than 1/2 at $B \times r \simeq 7$ Tesla x m.
- Anyway even in the central region the azimuthal distortion is spectacular already for modest values of the radial bending power. For example the 'equivalent' solenoid(3) is relatively weak, but still gives strong limitations to the granularity and to the performance of thick external devices (say 50-60 cm or more) since at least 1/3 of all the charged particles escape the magnetic field with $\delta > 15^{\circ}$ (see Fig. 2a). One should remember, in addition, that in general $p_{\parallel} \neq 0$, so that the trajectories in real space are even more skew than in the transverse projection.

I wish to thank T. Taylor of CERN for the useful discussions which stimulated this work.

REFERENCES AND NOTES.

(1) - The degradation in energy due to the gas and to the chambers is very slow. The insertion of two or more radial vanes inside the solenoid does not help much to stop the spirals (T. Taylor, ECFA/LEP-SSG/13/5/June 1979).

(2) - D. Drijard, H. Grote and P. G. Innocenti, The LEP Jet Detector: event simulations and particle tracking, ECFA/LEP 78-15 (1978).

(3) - H. Grote and P. Spillantini, Solenoid and toroid momentum resolution: a comparative simulation for 2-jet events, ECFA/LEP--SSG/13/1, March 1979.

(4) - In this note the coil was always supposed to be ideally thin. To evaluate the fraction of particles actually measurable outside the solenoid multiple scattering and nuclear interactions in the coil material have to be added.