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Correction of possible inaccuracy of magnetic field map

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Abstract

Magnetic field map of the DIRAC spectrometer magnet was measured and used for data analysis. Possible difference of "true" magnetic field distribution from measured one is considered in this note.

Introduction

Investigation of Q_L-distribution of $\pi^+\pi^-$ pairs shows that position of Coulomb peak depends on pair laboratory momentum (see Table 1). This fact contradicts to expected position of Coulomb peak at 0.

Table 1: Dependence of Coulomb peak position of Q_L-distribution as a function of $\pi^+\pi^-$ pair laboratory momentum

$P_{\rm lab}$ GeV/c	Q_L MeV/c
$3.0 \div 4.0$	-0.003
$4.0 \div 5.0$	-0.091
$5.0 \div 6.0$	-0.102
$6.0 \div 7.0$	-0.306
$7.0 \div 10.$	-0.494

There was attempt to explain this deviation with inaccuracy in the setup geometry measurement. But changes of arm axis angles and shifts of arms relatively to the spectrometer magnet center provide shift in the first range ($3.0 \div 4.0$ GeV/c) in 2 times less then in the last ranges ($6.0 \div 7.0$ GeV/c and $7.0 \div 10.$ GeV/c) it is easy to see that it is impossible to put peaks to 0 in all momentum ranges simultaneously.

Additional correction could be rotation of the first (big) DC chamber around Y-axis in the secondary channel reference system (Z-axis is along an axis of secondary beam channel). In this case a peak shift is more or less uniform for all momentum ranges. Therefore it is possible to put all Coulomb peaks to 0 using rotation of spectrometer arm (right or left) axes by angle about 0.5 mrad and rotation of the first big chamber by angle 6 mrad. Difference of real and measured angle of one arm axis 0.5 mrad or 0.25 mrad for both arm is possible because this values are compatible with accuracy of measurements of the DIRAC setup geometry ($0.2 \div 0.3$ mm). But angle of the first DC chamber rotation can not be 6 mrad because it provides shifts of the left and right chamber edges by ~ 6 mm in Z-direction.

Therefore it is need to use any another hypothesis about the reason of Coulomb peak shift. It seems that most probable reason is difference between measured and "true" distribution of magnetic field in the spectrometer magnet of DIRAC setup.

1 Magnetic field correction

Magnetic field map was measured in absence of surrounding radiation protection which includes iron blocks. It could be possible reason of difference between "true" and measured magnetic field map.

For correction of this inaccuracy the simplest model was used:

$$B'(X,Y,Z) = (1+aX)B(X,Y,Z)\,. \tag{1}$$

Here $B'(X,Y,Z)$ is "true" magnetic field and $B(X,Y,Z)$ is measured one, a is a asymmetry parameter. This correction depends only on X-coordinate because only difference of field in the left part of magnet relative to the right part could provide shift in Q_L. Especially if particles of pair have very close value of Y-coordinate as it is for DIRAC. Linear dependence was selected because an effect is a result of influence of magnetic field inaccuracy and various geometrical inaccuracies. In this situation it is very difficult to provide reliable definition of quadratic term. And for simplicity it is reasonable to use box-like approximation of magnetic field:

$$\sin\gamma = \sin\alpha + \frac{0.3BL}{P}\,, \tag{2}$$

$$R = \frac{P}{0.3B} = \frac{L}{\sin\gamma - \sin\alpha}\,,$$

$$X_{\mathrm{Out}} = X_{\mathrm{In}} + L\frac{\cos\alpha - \cos\gamma}{\sin\gamma - \sin\alpha} = X_{\mathrm{In}} + R(\cos\alpha - \cos\gamma)\,,$$

$$\gamma = \alpha + \int_0^l \frac{0.3B}{P}\,ds\,.$$

Here B is an effective magnetic field in Tesla, L - a length of field in meters (along Z-axis in our case), α is an angle of upstream track with normal to "magnetic field box", γ is an angle of downstream track with normal to "magnetic field box", R is a curvature radius of particle trajectory in a magnetic field and l is a length of trajectory in a magnetic field, X_{In} is a coordinate of entrance point to magnetic field and X_{Out} is a coordinate of exit point and P is a laboratory momentum of a particle in GeV/c.

Variation of exit angle γ due to magnetic field inaccuracy (1) could be estimated as:

$$\delta_\gamma = \gamma'_B - \gamma_B \simeq \int_0^l \frac{0.3(B'-B)}{P}\,ds = \int_0^l \frac{0.3BaX(s)}{P}\,ds \tag{3}$$

Taking into account Eq. 2 and relation for arch of a circle $\Delta s = R\Delta\alpha$ one obtains:

$$\delta_\gamma = \int_\alpha^\gamma \frac{0.3BaX(t)}{P} R\,dt = \int_\alpha^\gamma aX(t)\,dt = \int_\alpha^\gamma a(X_{\mathrm{In}} - R\cos t)\,dt = a(X_{\mathrm{In}}(\gamma - \alpha) - L) \tag{4}$$

Variation of X-coordinate X_{Out} could be estimated in the next way:

$$\Delta X_{\mathrm{Out}} = \frac{\int_\alpha^\gamma R(\gamma - t)\frac{d\delta_\gamma(t)}{dt}\,dt}{\cos\gamma}\,, \tag{5}$$

$$\delta_\gamma(t) = a(X_{\mathrm{In}}(t-\alpha) - L(t)) = a(X_{\mathrm{In}}(t-\alpha) - R(\sin t - \sin\alpha))\,,$$

$$\frac{d\delta_\gamma(t)}{dt} = a(X_{\mathrm{In}} - R\cos t)\,,$$

$$\delta_\gamma(t) = \frac{aR(0.5X_{\mathrm{In}}(\gamma-\alpha)^2 + R((\gamma-\alpha)\sin\alpha + \cos\gamma - \cos\alpha))}{\cos\gamma}\,. \tag{6}$$

Hear $d\delta_\gamma(t)/dt$ is a derivative which defines change of an angle variation for $ds = Rdt$ path. After multiplication by path length $R(\gamma - t)$ up to the exit from a magnet field one obtains deflection from trajectory in uniform magnetic field. Dividing of integral in Eq. 5 by $\cos\gamma$ allows to take into account an angle between particle trajectory and a normal to the magnetic field.

2 Implementation to ARIANE

Tracking procedure of ARIANE provides track parameters on the exit of the spectrometric magnet and in the entrance to the magnet (in assumption that particle is generated at the target). Measured X-coordinate X_{meas} and angle of downstream track in X-projection γ_{meas} could be presented as:

$$X_{\mathrm{meas}} = X_{\mathrm{Out}} + \Delta X_{\mathrm{Out}}\,,$$

$$\gamma_{\mathrm{meas}} = \gamma + \delta_\gamma\,. \tag{7}$$

Hear X_{Out} and γ are track parameters for a magnetic field which corresponds to magnetic field map. Corrections δ_γ and X_{Out} are defined by Eqs. 4,5 and describes difference between "true" and measure magnetic fields. In ARIANE these corrections are calculated by subroutine ClcCorrMapMF and are subtracted from measured X-parameters of downstream tracks at calculation upstream track parameters with polynomials based on the magnetic field map. Correction are controlled by parameters read from FFreadInput:

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CorrMapMF  1.  0.  135.
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CorrMapMF(1) is a scale factor for momentum, CorrMapMF(2) is parameter a (Eq.1), and CorrMapMF(3) is a field length in a box-like approximation.

Conclusion

This procedure allows to estimate influence of an asymmetry of difference between “true” and measured magnetic field. For this purpose it is needed to investigate dependence of Coulomb peak position on a (Eq. 1). The results will be reported in one of the next DIRAC note.