esipap
European School of Instrumentation in Particle & Astroparticle Physics

ESIPAP 2019 - Module 1

Physics of particle and astroparticle detectors

Tracking

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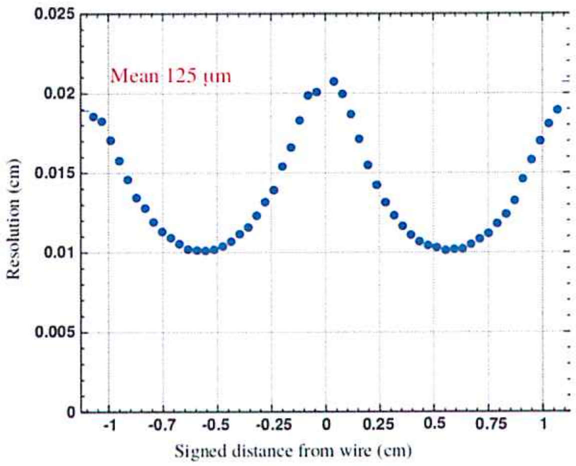
Documents authorised: PDG booklet, lecture notes.
Whenever an explanation is required, try to support your answer with a formula and explain the various terms present.

1

We consider the BABAR experiment which exploits a drift chamber as its main tracking device.

1 1.1 Figure 1 depicts the spatial resolution on the track obtained in the drift chamber with respect to the distance of the track to the wire. Explain the shape of the distribution.



→ resolut ∝ √drift time
→ if split charge sharing better resol.

Figure 1: Track position resolution in the drift chamber of the BABAR experiment.

3 1.2 The evolution of the momentum resolution with the momentum is given by figure 2. Where does the linear behaviour comes from? In general, would you expect a rise of the momentum resolution at low momentum and why? Explain why it is not observed here. $\frac{\sigma_p}{p} \propto p$, mult. scatt @ low p, large gas vol → no mult scatt

2 1.3 The inner cylinder of the drift chamber is made of two different metals of similar thickness. The middle part crossed by particles uses beryllium, while aluminium builds the external part. Knowing that the radiation length of the beryllium and aluminium are respectively: $X_0(Be) = 35.28$ cm and $X_0(Be) = 8.9$ cm.
Justify the reason for this choice. → minimize mult scatt to match inward. $\sigma_{ms} \propto \sqrt{\frac{thic}{X^0}}$

2 1.4 BABAR conducted a very successful program, the next generation of this kind of experiment tries to

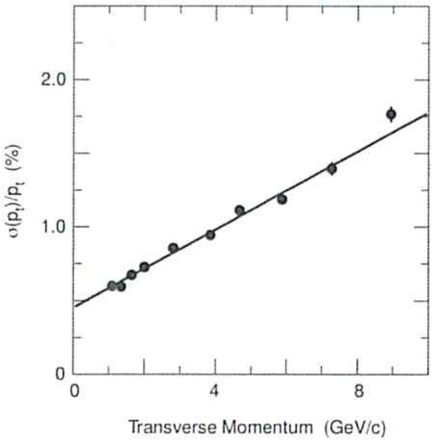


Figure 2: Momentum resolution from the BABAR drift chamber.

improve detection performances. A key aspect is the addition of detection layers close to the interaction point. The closest measurement point moved from a radius of 32 mm to a radius of 12 mm.
Explain for which measurement this modification is beneficial and the amplitude of the expected gain. You can consider that the detection layers have equal thickness and resolution, and that the external layers are located at the same radii.

Impact param, vertex, $\sigma_{IP} \propto \frac{1}{R_{1st}}$

2

We consider the problem of associating new measurement points to an existing track. In a collider experiment, we assume that the parameter of a particle track are known to a given precision from measurements at large radii. The track is extrapolated inward to a new detection layer, where several hits have been detected in the vicinity of the track extrapolation. The question is: which hit do we associate to the track?

2.1 To decide how to associate measured hits on a given layer with a track crossing this layer, the following cost function is computed.

2

$$\chi^2(x_p, z_p) = \frac{(x_t - x_p)^2}{\sigma^2_{\mathrm{eff,R\phi}}} + \frac{(z_t - z_p)^2}{\sigma^2_{\mathrm{eff},z}}. \quad (1)$$

In this formula, x_p is the measured hit position with uncertainty σ_p, x_t is the extrapolated position of the track on the layer associated with an uncertainty σ_t. The indexes $R\phi$ or z indicate whether the position is taken in transverse or longitudinal (with respect to the beam) direction.
Explain the meaning and find the expression of σ_{eff} in this formula. What does this χ^2 represent in terms of hypothesis testing?

$\sigma_{eff} = \sigma_{s.p.} \oplus \sigma_{extrapol}$, chi2 to test matching hit-track

2.2 One can compute from the previous formula that the probability to associate the correct hit is given by:

2

$$P = \frac{1}{1 + 2\pi\sigma_{\mathrm{effR\phi}}\sigma_{\mathrm{effz}}\rho}. \quad (2)$$

What is the parameter ρ? Explain the behaviour of the probability with σ_{eff} and ρ.

ρ = hit density, P rises if smaller σ_{eff} & ρ ⇒ easier to match correct hit

2 2.3 This problem typically arises at the step of track finding with a local method. From the previous formula, propose three possible improvements on the detector side to increase the probability.

faster t integrat° / better $\sigma_{s.p.}$ / better geom for σ_{extra}

2 2.4 To start the local track finder method, track seeds are needed. How many points are required to start an helix? In a typical collider experiment (looking like a cylinder with many layers) which detection layers would you choose to build a track seed?

3 , either most precise either with lowest density.

3

An important aspect of tracker is their alignment, which we discuss briefly here.

2 3.1 The following figure 3 shows a situation with a single misaligned layer. Explain how the track fitting procedure can help recognize that a layer position is wrong and how to correct it.

fit χ^2 depends on true position

Δ residues

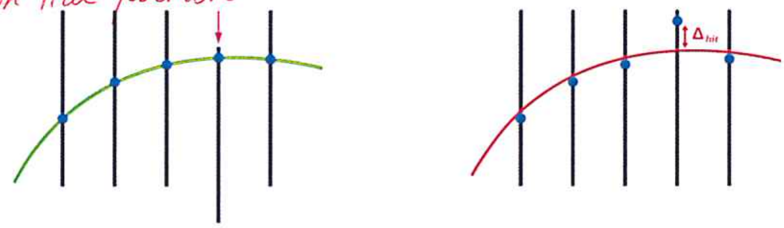


Figure 3: A single misaligned layer among other tracking layers. On the left: the real situation. On the right: the situation with perfect positions assumed (before alignment).

2 3.2 Sometimes, a bunch of layers can be altogether misaligned. For instance, three layers suffer from an unknown rotation $\Delta\Phi$ in figure 4. Can the strategy using track fit output be useful in this case and why? Could you propose a complementary strategy?

+ No, p is changed but χ^2 still good.

+ mass measurements

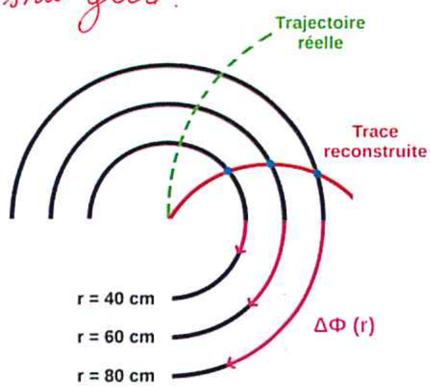


Figure 4: Three layers of a tracker suffering from a global rotation.