Event Time from Tracks

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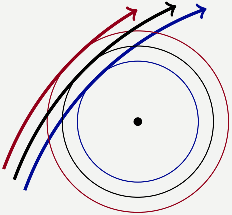
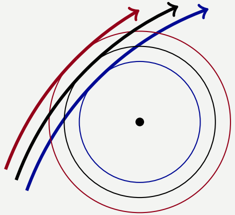


What Does a Drift Chamber Measure?



Measurement Procedure

- passing charged particle ionizes gas
- gas cloud collapses on wire
- difference
  T(passage of particle) – T(collapse)
  gives distance of passage

How do we know the passage time?

Usually:

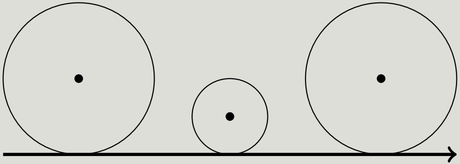
- Starting time of the track is evaluated
- T(Passage) =Track Length / Velocity

A drift chamber is a device that measures time, positions are inferred.

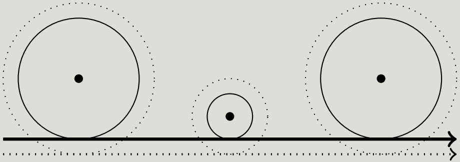
What Happens if the Time is Badly Known?

The simplest case, straight lines, all hits on one side.

Correct Timing



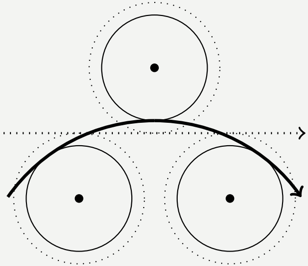
Passage Time Underestimated



- position measurement depends on the evaluated drift time
- In this simple case a bias in time leads to bias in position.

With Wires on Both Sides

Let's misadjust the passage time estimate …and fit



- the track fit can be very sensitive to correct starting times
- thus we can find an optimal time for each event or track

Time Alignment

Tracking problem:

$$\chi^2 = \sum_{\text{hits i}} (m_i - H_i s)^T R_i^{-1} (m_i - H_i s) = \min$$

Minimize the distance between the measurements m_i and the projections H_i of the track parameters s, i.e. the residuals r, weighted by the residual covariances

$$R_i = V_i - H_i C H_i^T$$

(V_i measurement covariance, C covariance of track params)
Alignment problem:

$$\chi^2 = \sum_{\text{tracks } k} \sum_{\text{hits } i} (m_{ik}(a) - H_{ik} s_k)^T R_{ik}^{-1} (m_{ik}(a) - H_{ik} s_k) = \min$$

Find the track parameters s_k and the set of alignement parameters a that simultaneously minimize this χ^2.

Solution of Alignment Problem

Once everything is linear, the χ^2 minimization separates in two parts (very convenient!):

1. find track parameters (i.e. fit the tracks)
2. find the optimal alignment parameters (i.e. align)

Solution

$$a - a_0 = -\left(\sum_{ik} \frac{\mathrm{d}}{\mathrm{d}a} r_i(s_k, a)\bigg|_{a=a_0} \cdot R_{ik}^{-1} \cdot \frac{\mathrm{d}}{\mathrm{d}a} r_i(s_k, a)\bigg|_{a=a_0} \right)^{-1} \left(\sum_{ik} \frac{\mathrm{d}}{\mathrm{d}a} r_i(s_k, a)\bigg|_{a=a_0} \cdot R_{ik}^{-1} \cdot r_i(s_k, a_0) \right)$$

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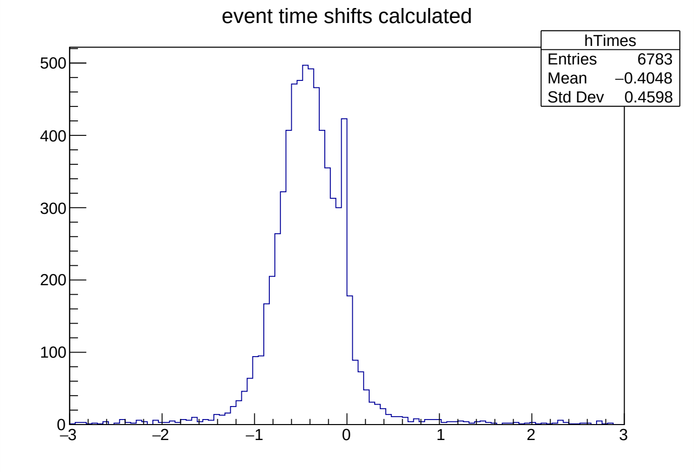
We can do this for the *event time* (just take only tracks from one event, and think of a shift in time like you would about a shift in space):

$$t - t_0 = -\frac{\sum_{ik} \frac{\mathrm{d}}{\mathrm{d}t} r_i(s_k, t)\Big|_{t=t_0} \cdot R_{ik}^{-1} \cdot r_i(s_k, t_0)}{\sum_{ik} \frac{\mathrm{d}}{\mathrm{d}t} r_i(s_k, t)\Big|_{t=t_0} \cdot R_{ik}^{-1} \cdot \frac{\mathrm{d}}{\mathrm{d}t} r_i(s_k, t)\Big|_{t=t_0}}$$

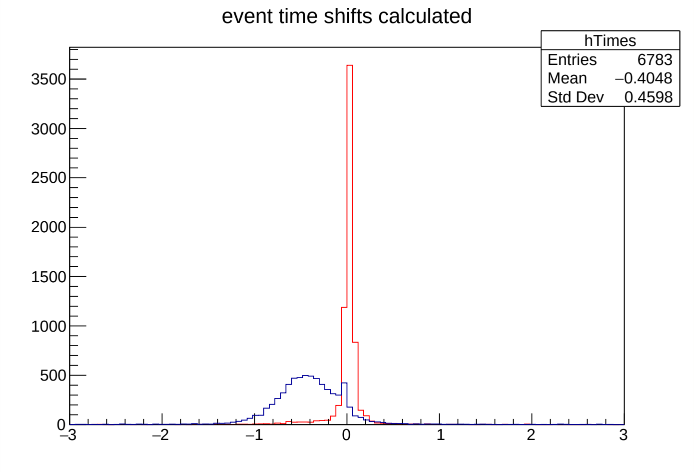
Implemented after some preparatory work: this works best with the full covariance matrix for the track (usual Kalman only gives local covariances), need derivatives of the x-t relation.

Very Preliminary Results



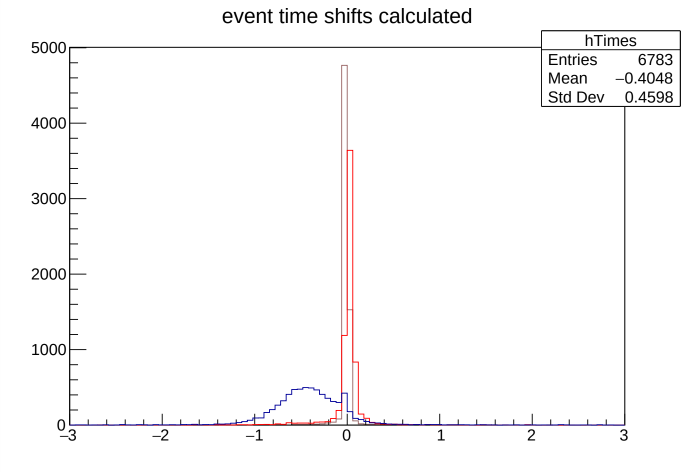
Initial calculation: $\approx 0.5\,\text{ns}$ wide distribution, not centered at zero, weird peak at zero (reasons not yet investigated, probably initial calculation in `GenFitterModule` not precise, weird peak from numerically bad cases)

Very Preliminary Results



After one iteration: peak becomes sharper, moves beyond center.

Very Preliminary Results



After two iterations: peak even sharper, nicely centered (visible in finer binning)

A Few More Topical Items

1. distribution for individual tracks is broader than what was shown (as expected), also moves to center (as expected)
2. P-value distribution shows no discernible improvement (which is a bit weird, but maybe it's a really small improvement)
3. very promising
4. of course this could be grown into a complete alignment ;-)

On Different Particles

At our low momenta, propagation speed depends considerably on the particle species ($m_\pi : m_K : m_p = 1 : 4 : 7$)

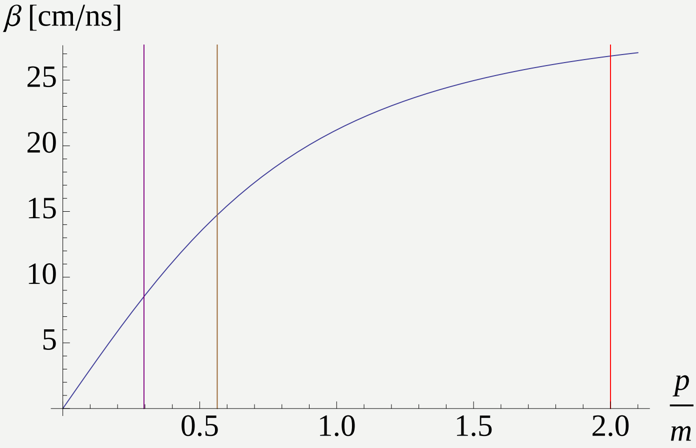


Figure: Velocity as function of p/m. Same momentum ($p = 2m_\pi = 280\,\text{MeV}$) is indicated for protons, kaons and pions

x-t Relation

The main issue will be the separation of the errors from the drift and from the time measurement. For this, we need to invert the x-t relations which give the distance as function of the drift time. Here is a typical x-t relation for one cell, depending on various track impact angles. (Linear relation in red.)