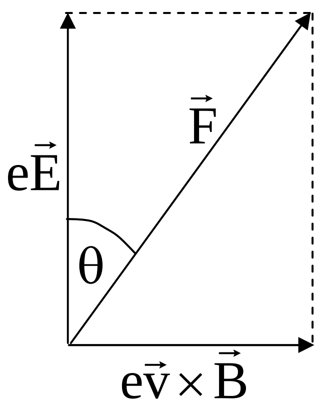
Lorentz angle effects in the CPCCD

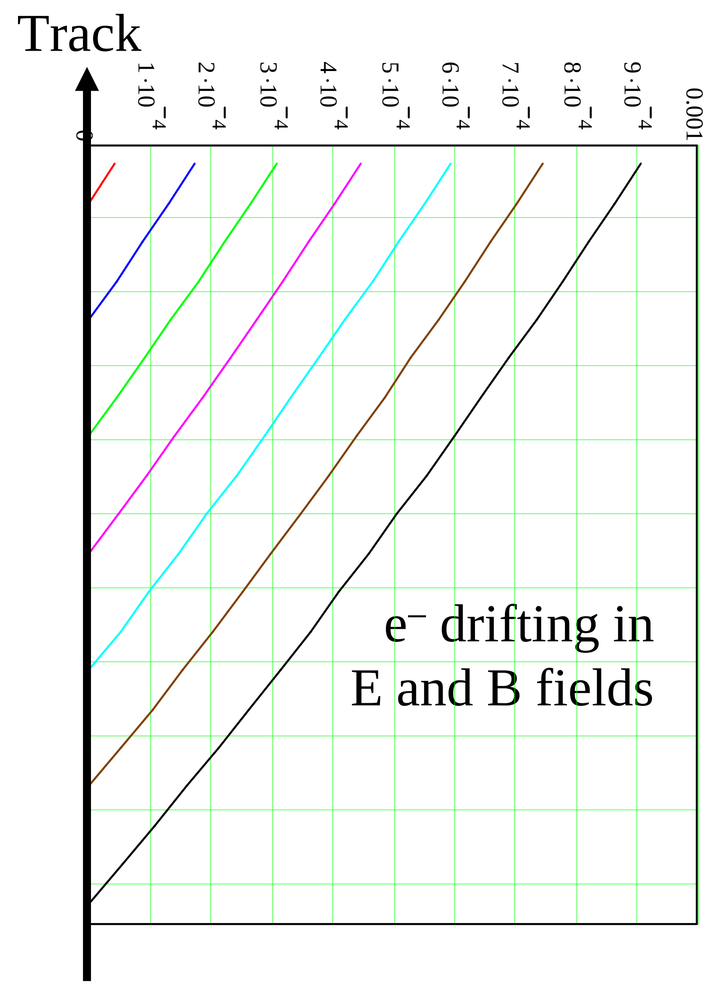
- Electrons drifting in depletion region of CCD experience Lorentz force in magnetic field, $\vec{F} = e\vec{E} + e\vec{v} \times \vec{B}$.
- For normal E and B fields, direction of net force on moving e is at Lorentz angle θ to E field.



$$\tan\theta = \frac{e\vec{v} \times \vec{B}}{e\vec{E}} = \frac{vB}{E} = r_H \mu B$$

- Here μ is mobility, with correction r_H due to effects of B field.

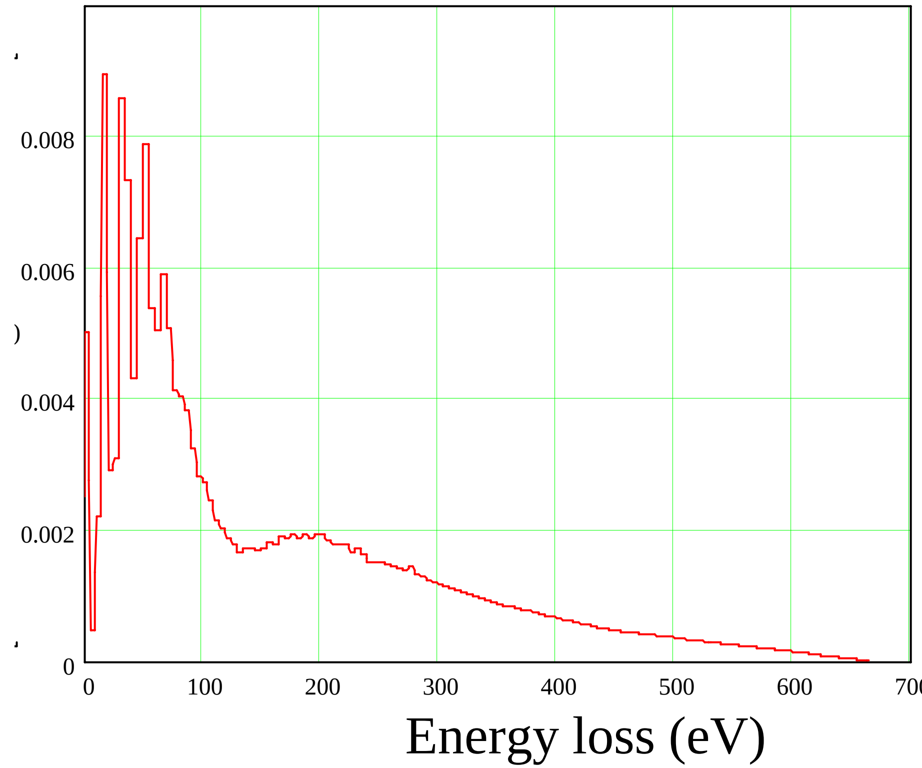
- This causes displacement of hits:



Lorentz angle effects in the CPCCD

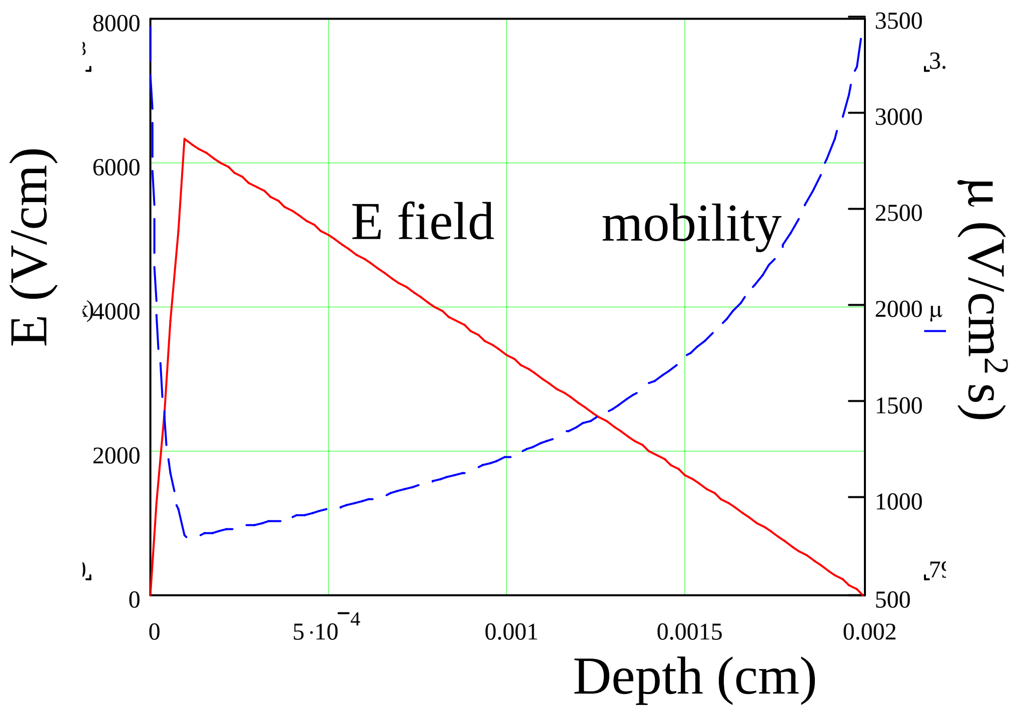
- Lorentz force induced hit displacement is not a problem if its size is known.
- Problem arises due to fluctuations in energy deposition and hence numbers of electrons released along track.
- The charge weighted hit position then also fluctuates.
- Correcting for the mean displacement removes any bias, but results in a poorer space-point resolution in the coordinate normal to the B field.
- There are possible secondary effects on the resolution due to increased drift distance, charge spreading...

- Energy lost by 1 GeV π traversing 1 μm of Si:



Lorentz angle effects in the CPCCD

- Estimate size of these effects for 20 μm depletion depth, B = 5T.
- Assume potential 12V at depth of 1 μm below buried channel, gives E field and mobility:



- Mobility dependent on E field and temperature.
- According to CMS model:

$$\mu(x) = \frac{\mu_{sat}}{\left(1+\left(\frac{\mu_{low} E(x)}{v_{sat}}\right)^{\beta}\right)^{\frac{1}{\beta}}} \mathrm{V\,cm^{-2}\,s^{-1}}$$

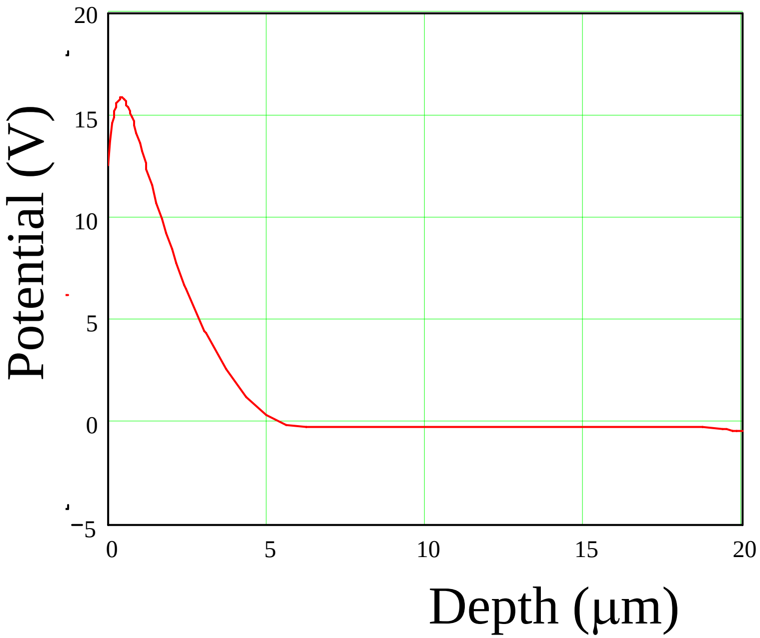
$$\mu_{low} = 1417\left(\frac{T}{300}\right)^{-2.2} \mathrm{V\,cm^{-2}\,s^{-1}}$$

$$v_{sat} = 1.07\times10^{7}\left(\frac{T}{300}\right)^{0.87} \mathrm{cm\,s^{-1}}$$

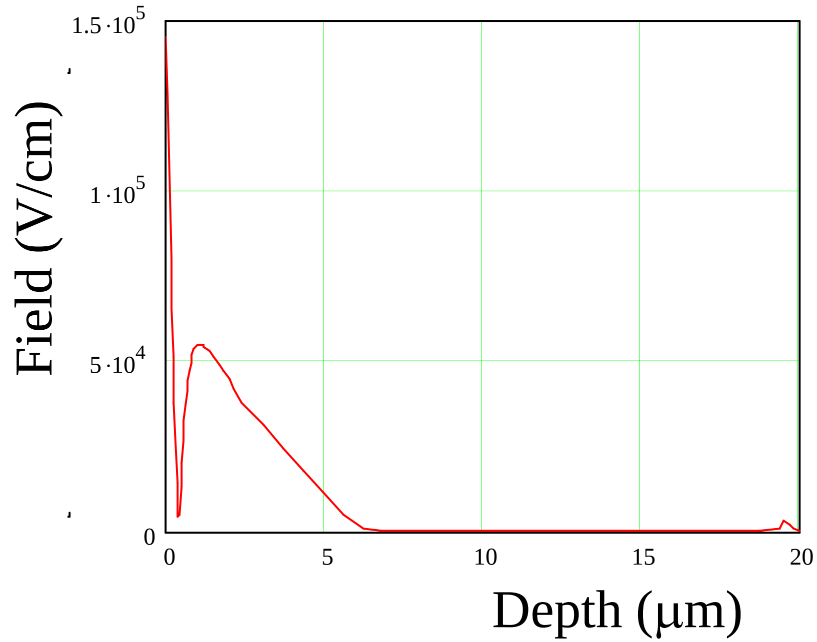
$$\beta = 1.109\left(\frac{T}{300}\right)^{0.66}$$

Field in CCD32 (as used in VXD3 at SLD)

- Gate +6V, potential distribution:

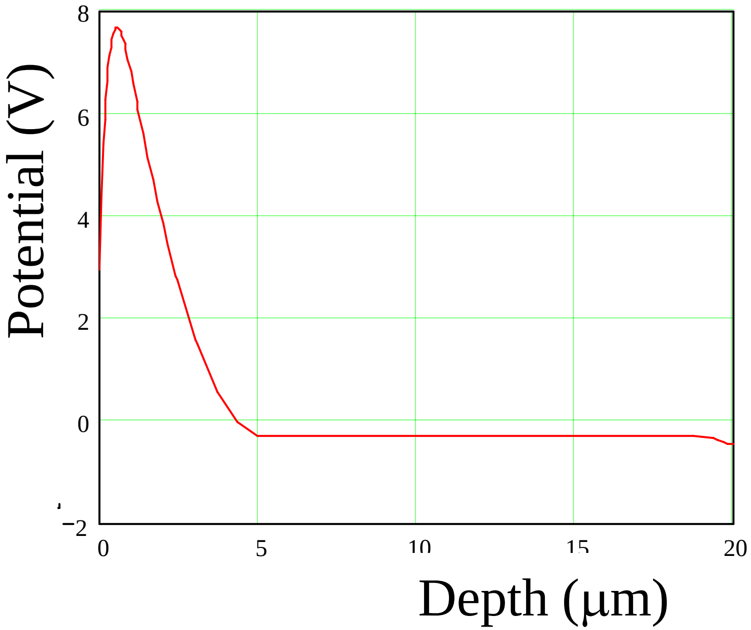


- Field:

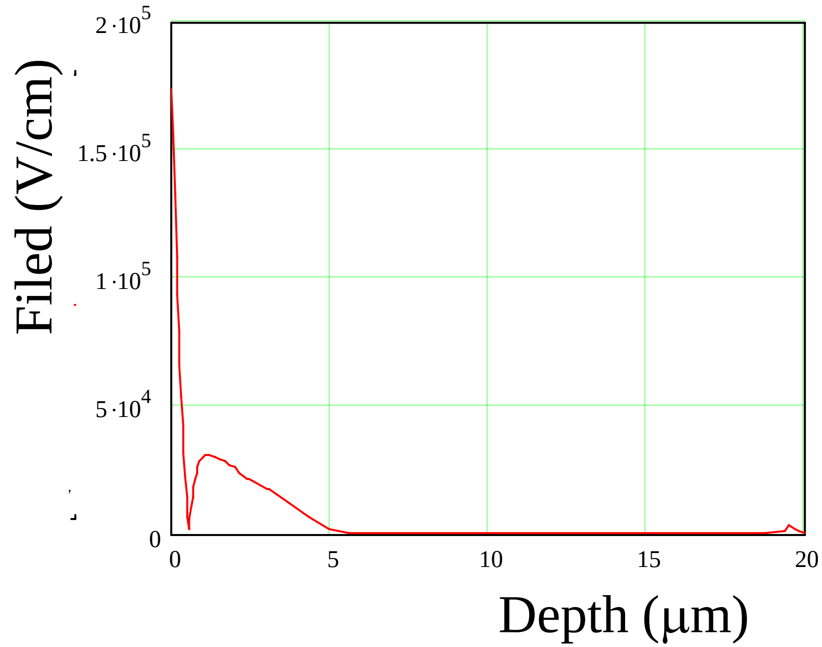


Field in CCD32 (as used in VXD3 at SLD)

- Gate -5V, potential distribution:

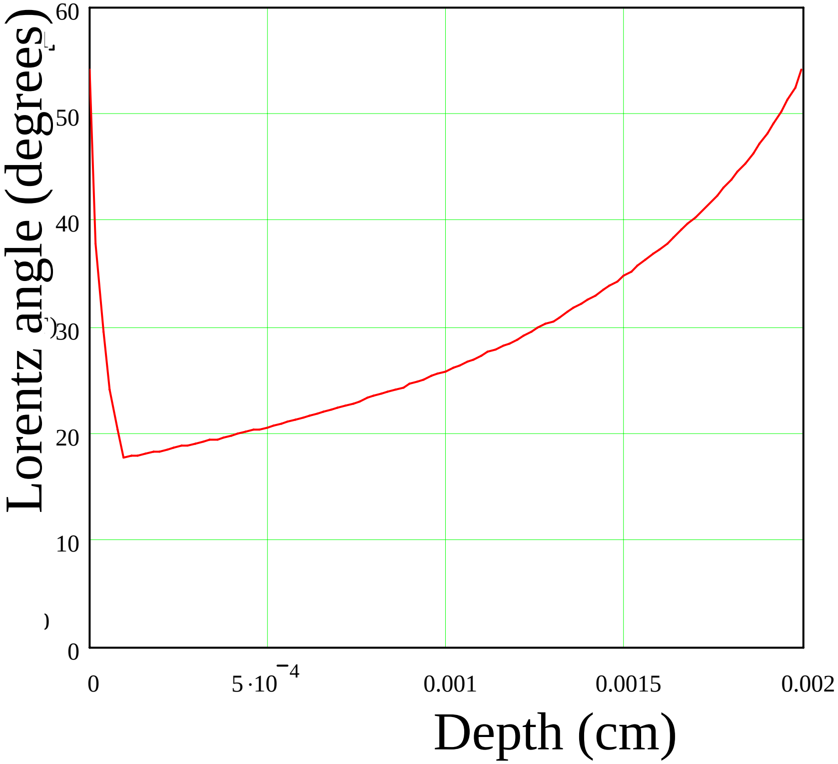


- Field

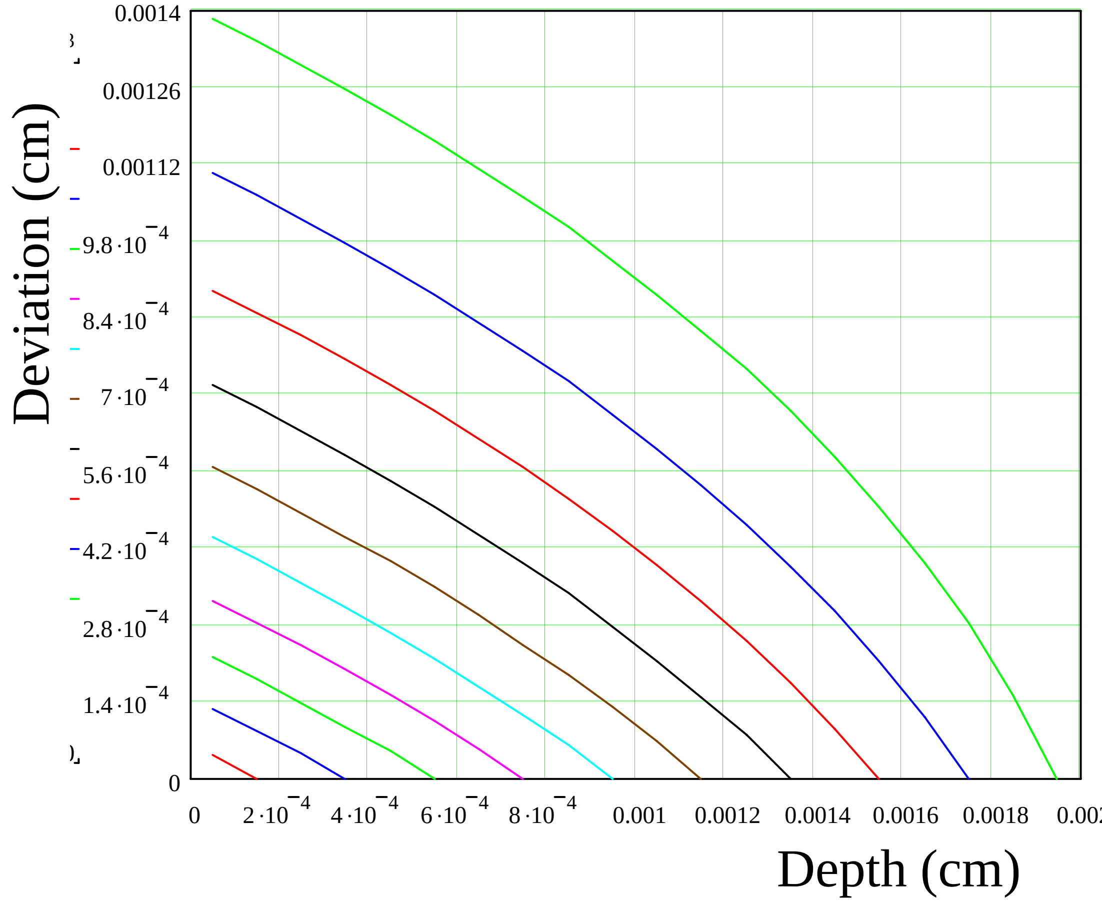


Lorentz angle effects in the CPCCD

- Resulting Lorentz angle:



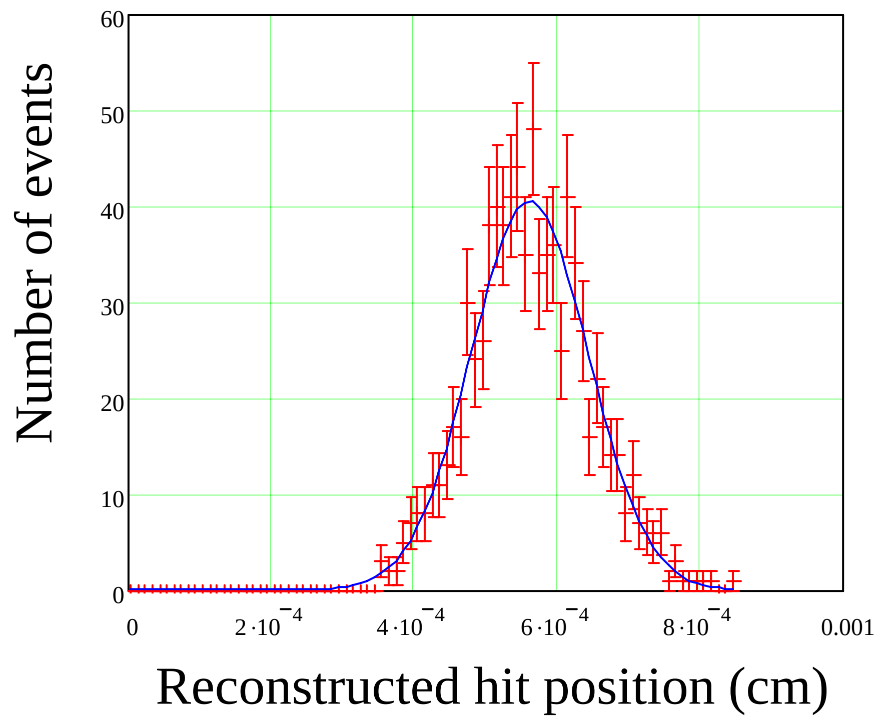
- Electron drift paths from various depths:



Change in position and spread of detected charge due to Lorentz angle

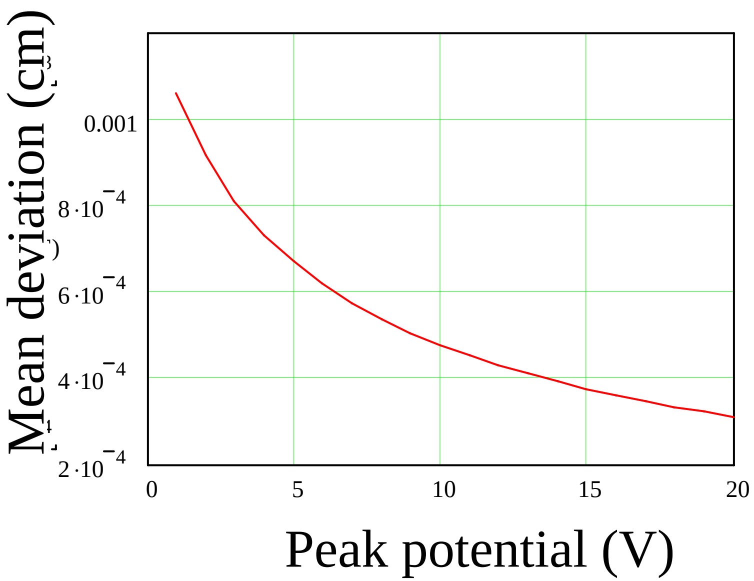
- Look first at tracks that are normal to the sensors.
- Track crosses sensor at origin.
- Reconstruct hit position using centre-of-gravity.
- See track position is displaced on average by 5.6 μm here.
- Width of distribution, σ = 0.8 μm here, represents additional spread due to Lorentz angle effects.

- Mean reconstructed hit position for track at origin:

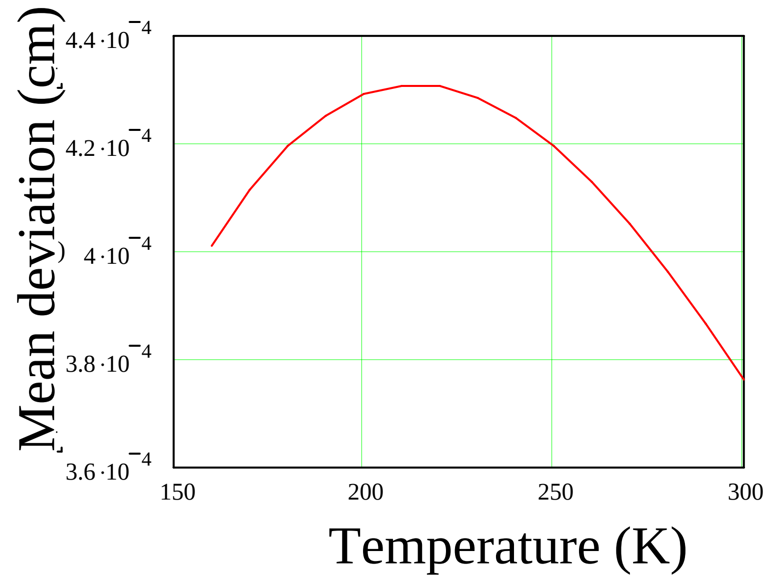


Lorentz angle effects in the CPCCD

- Mean deviation of charge weighted position depends on E field (for temperature of 200 K)...

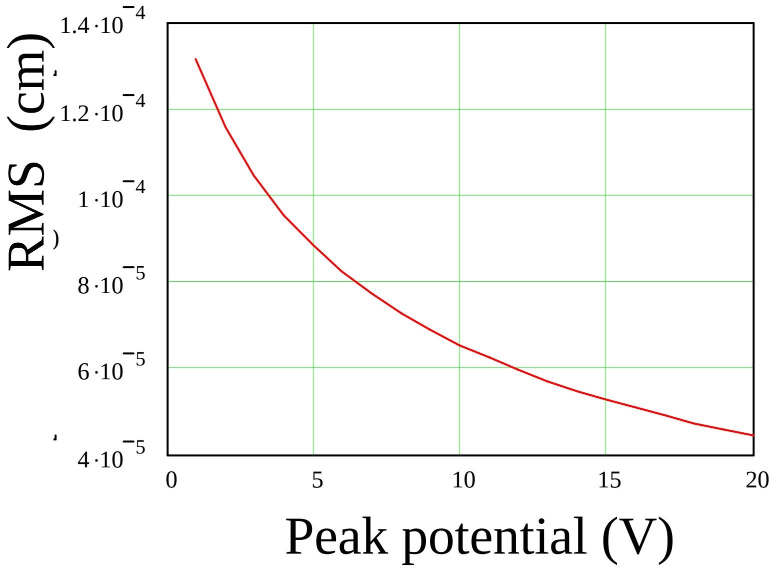


- ...and on temperature (here for peak potential of 12 V):

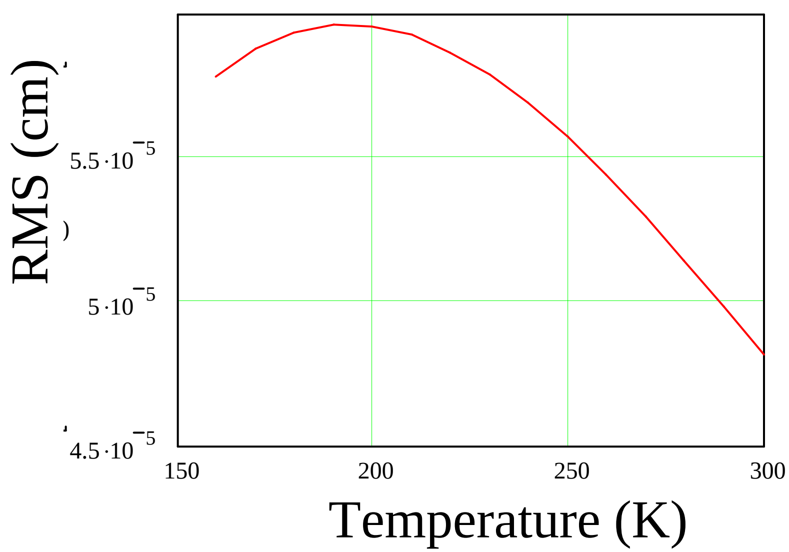


Lorentz angle effects in the CPCCD

- Standard deviation of charge weighted position depends on E field (for temperature of 200 K)...



- ...and on temperature (here for peak potential of 12 V):



Summary

- Lorentz angle effects in the CPCCD will cause the reconstructed positions of hits in the sensors to be displaced from the track positions.
- This displacement can be several microns, depending on the B-field strength and the parameters of the CCD.
- There is a small additional contribution to the error on the position of the reconstructed hits due to Lorentz angle effects.
- This additional contribution is likely to be around 0.5 μm, negligible compared to the expected hit resolution.