SCT Test Beam August 2000

- Setup/modules/programme
- Alignment and Offline
- Analysis status
- Results
  - efficiency and noise vs B, α, V_{bias}
  - forward common mode noise?
  - spatial resolution
  - ballistic deficit
  - charge collection in irradiated detectors
- Conclusion

http://ific.uv.es/sct/tb00/tb00.html, http://ific.uv.es/ vos

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Thanks to: Alan Barr, Lars Eklund, John Hill, Peter Kodys, Gareth Moorhead and others

Modules

- 3 irradiated detectors: RLT9$< 111 >$, K3113$< 100 >$, RLT10$< 100 >$
- 1 fully irradiated module: $RLT4 < 111 >_{325}$
- 3 non-irradiated modules: K3112$< 100 >$,$RLT5 < 111 >_{325}$, SCAND1
- 3 forward K-III modules, VAL1$< 111 >$, FRK152(CIS), FRK153(CIS)

Programme

- An (irradiated) detector test beam
- 1.56 T magnetic field
- incidence angle [-20,20]
- bias voltage [80,250]/[150,500]

TB2000: Offline & Analysis

- All 2000 data processed into new format DSTs
- DSTs available on /hpss/cern.ch/atlas/testbeam/sct/2000/dst/
- Alignment parameters and run lists at http://ific.uv.es/sct/tb00/tb00.html
- Summary Ntuple available at http://ific.uv.es/sct/tb00/summary.html
- Analysis results from Valencia at http://ific.uv.es/ vos/tb2000/aug2000/aug2000.html
- Further results expected from Cambridge, Melbourne, Freiburg and KEK
- Final results to be joined into an ATLAS internal note

TB2000: Alignment

Tracks reconstructed using the telescope information.

Precision depends on number of points: the fit χ^2 is stored with the track.

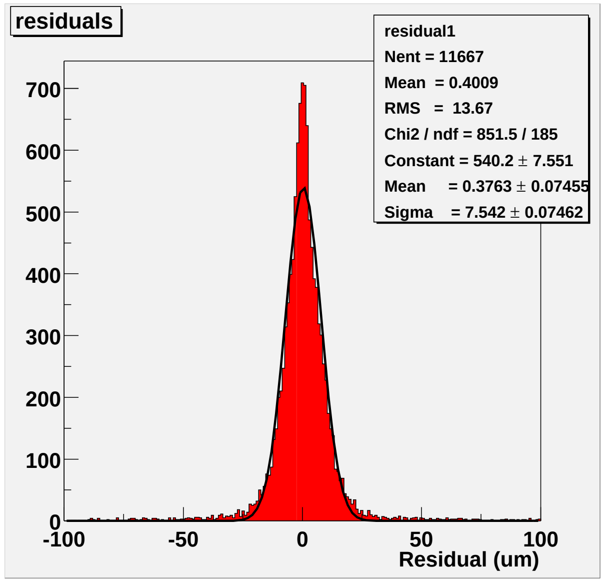


Figure 1: Residuals telescope plane 0-0, all tracks accepted

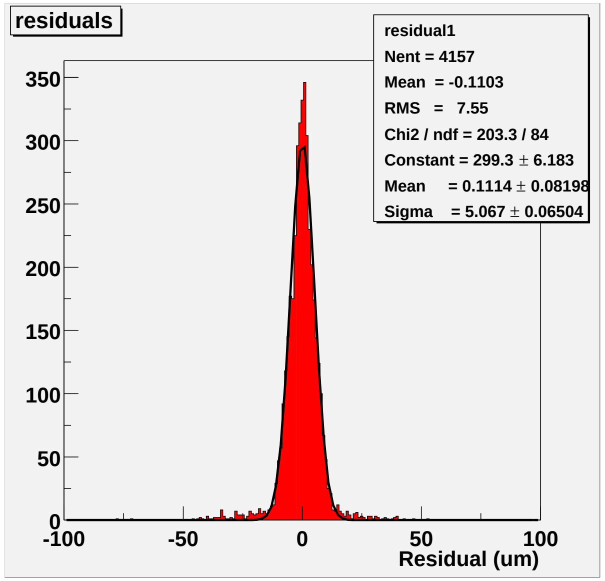


Figure 2: Residuals telescope plane 0-0, cut as in analysis

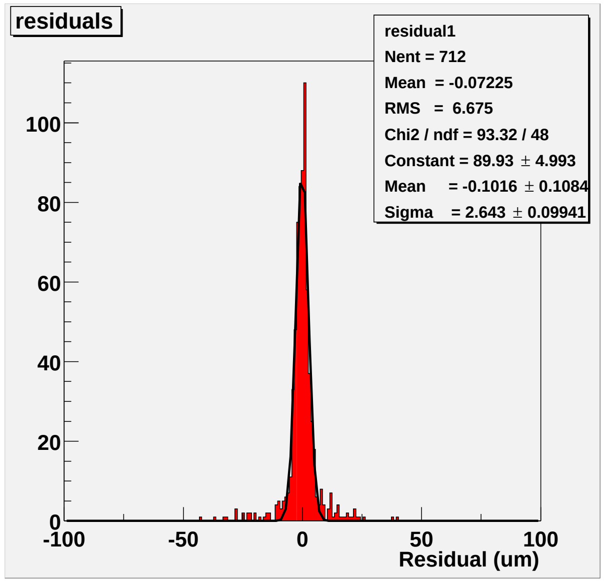


Figure 3: Residuals telescope plane 0-0, with a strict cut

Track precision of the order of 10 μm allows to resolve effects below the strip pitch level.

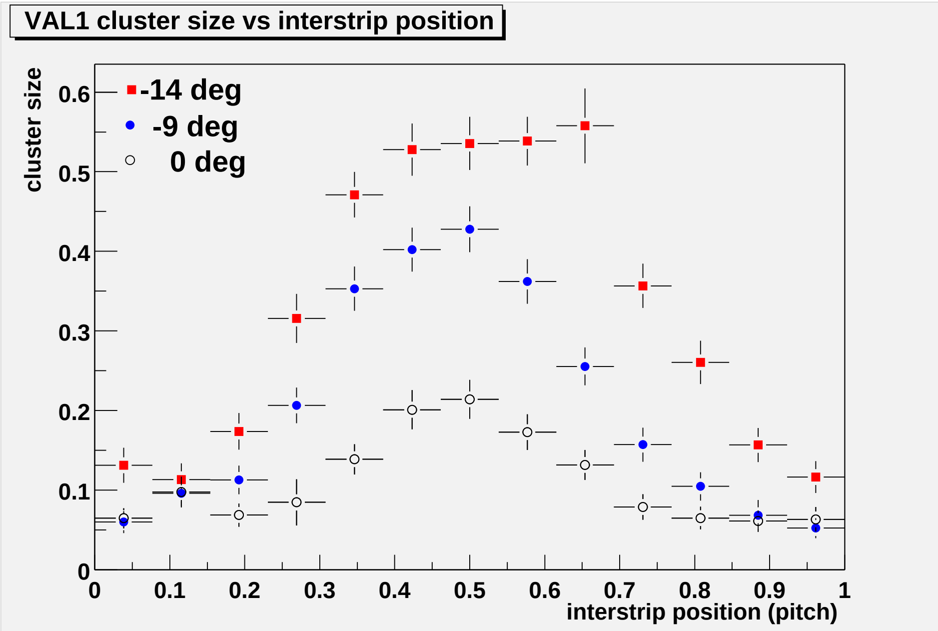


Figure 4: Av. cluster size versus interstrip position, 1 fC, no field, 250 V

perpendicular incidence: spatial distribution of the charge from diffusion.

non-zero incidence angle: charge deposited along $dsin(\alpha)$: $43\mu m$ for 8.8 degrees, $64\mu m$ for 13.8 degrees

Threshold scans taken at 5 bias voltages $\times$ 5 angles with a 1.56 T magnetic field and without.

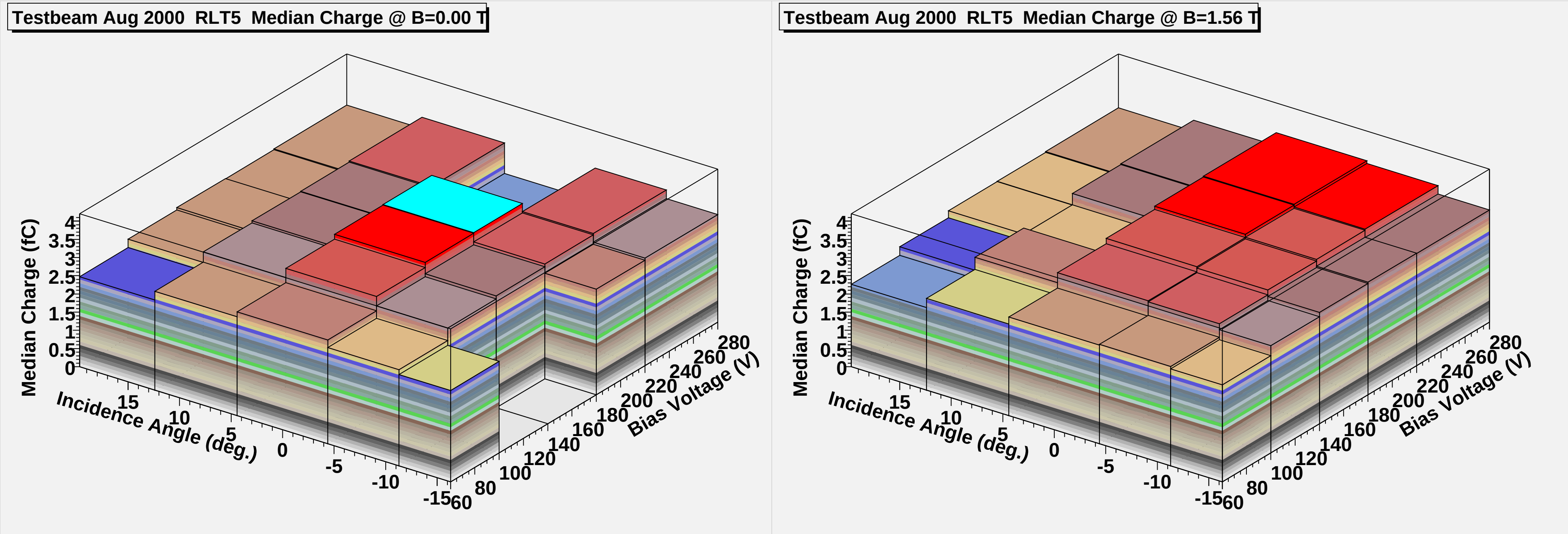
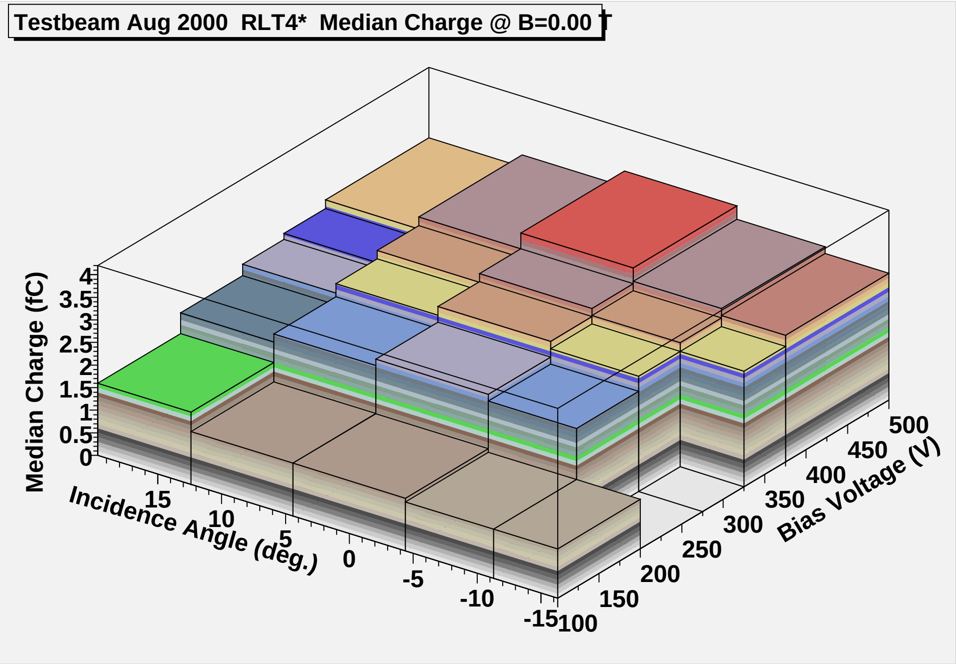


Figure 5: Median charge vs. bias voltage and incidence angle, RLT5, no magnetic field

Figure 6: Median charge vs. bias voltage and incidence angle, RLT5, in a 1.56 T field

The magnet causes the carriers to drift at an angle (Lorentz angle): the median charge is asymmetric in angle for the 1.56 T run.

The irradiated module shows a very strong dependence on bias voltage.



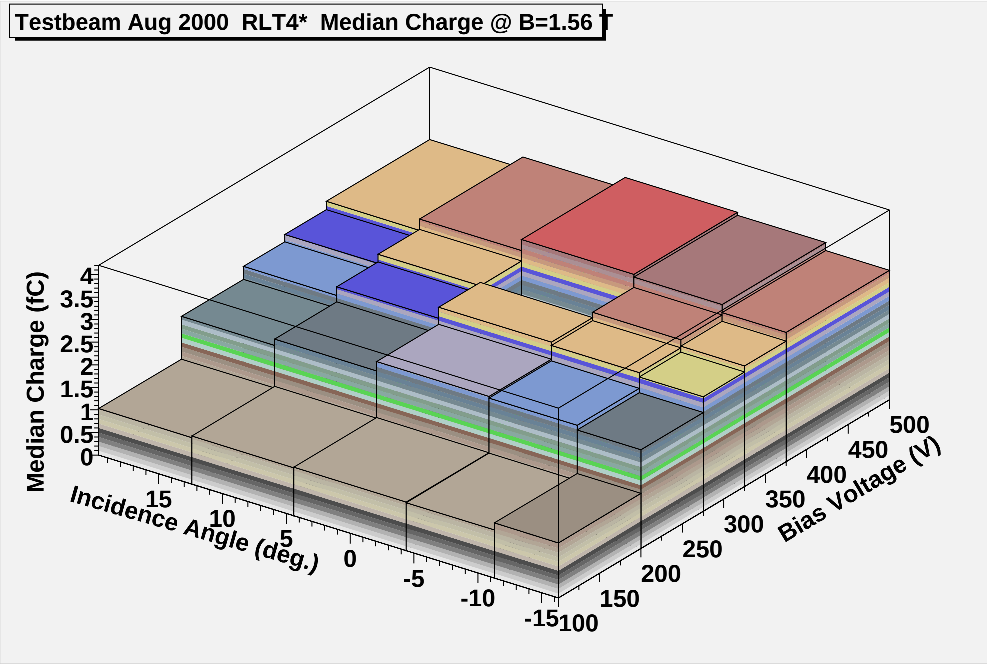


Figure 7: Median charge vs. bias voltage and incidence angle, RLT4, no magnetic field

Figure 8: Median charge vs. bias voltage and incidence angle, RLT4, in a 1.56 T field

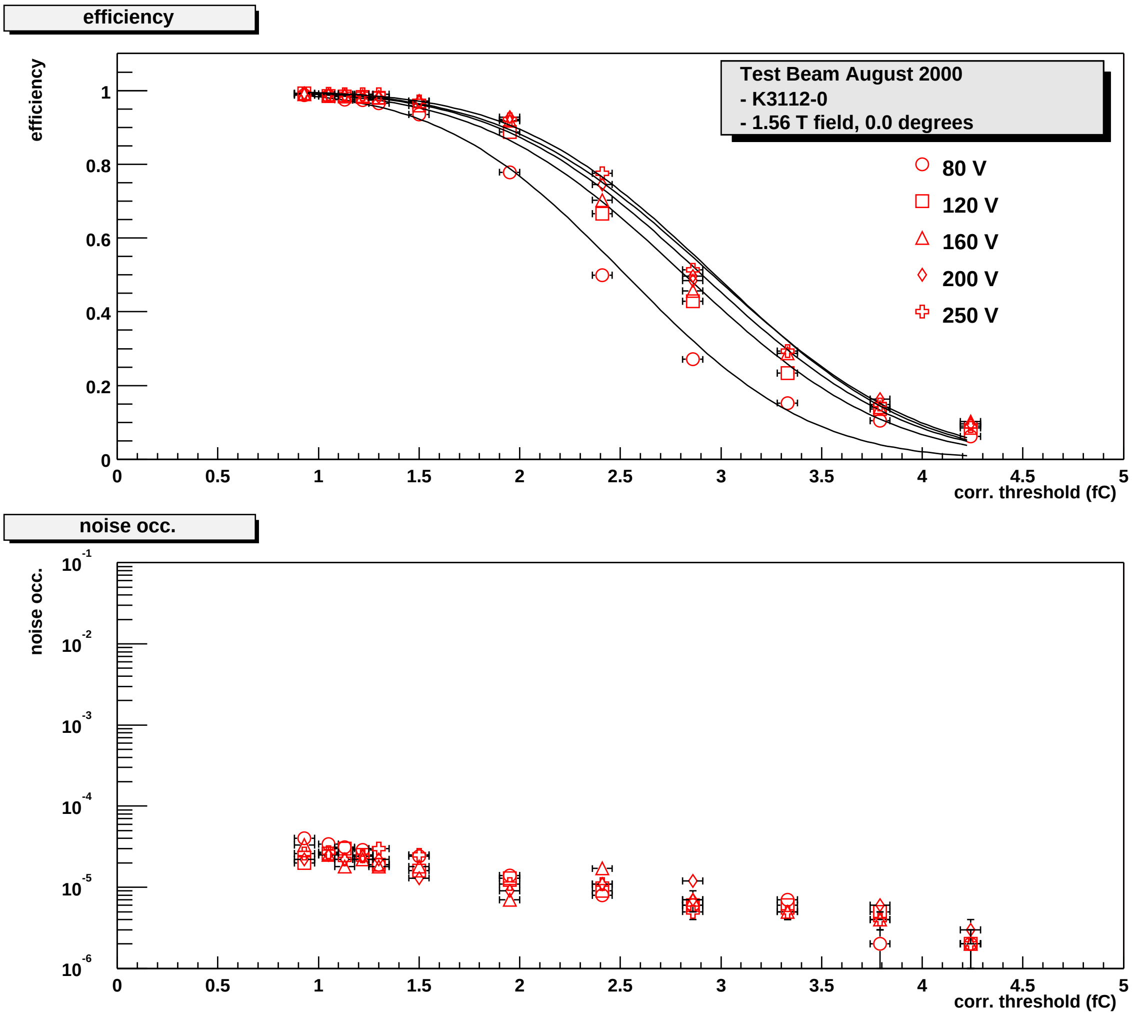


Figure 9: K3112: S-curves at normal incidence, 1.56 T field

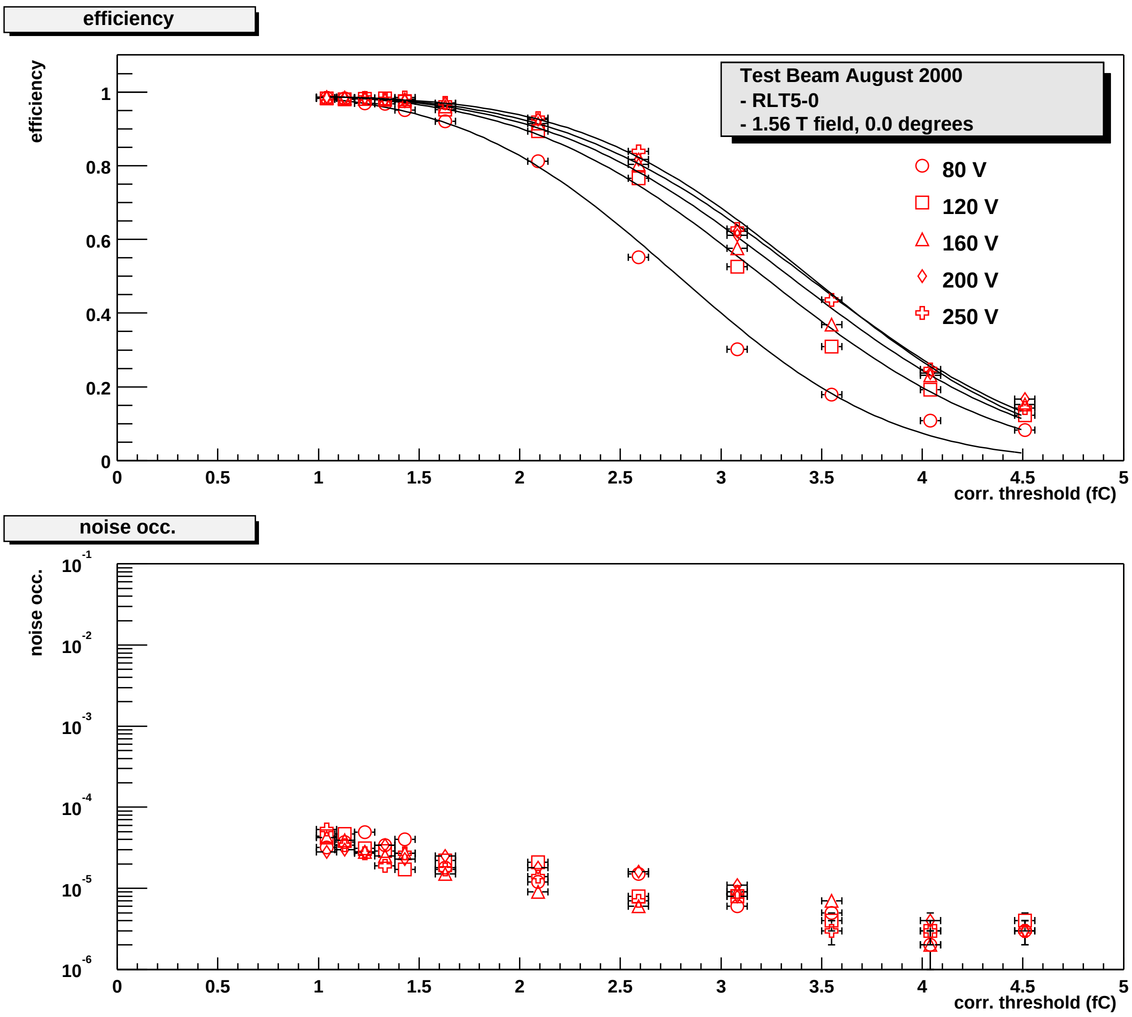


Figure 10: RLT5: S-curves at normal incidence, 1.56 T field

TB2000 Results - S-curves

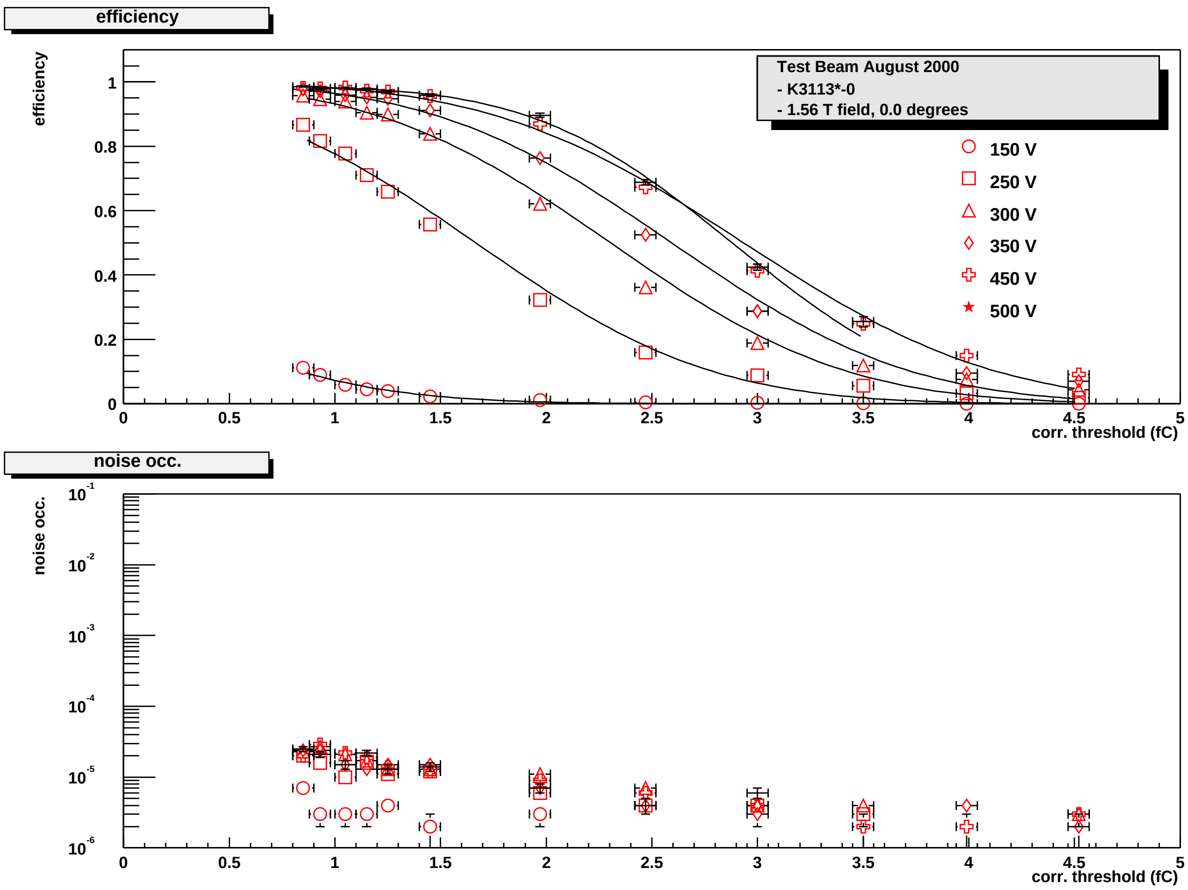


Figure 11: K3113: S-curves at normal incidence, 1.56 T field

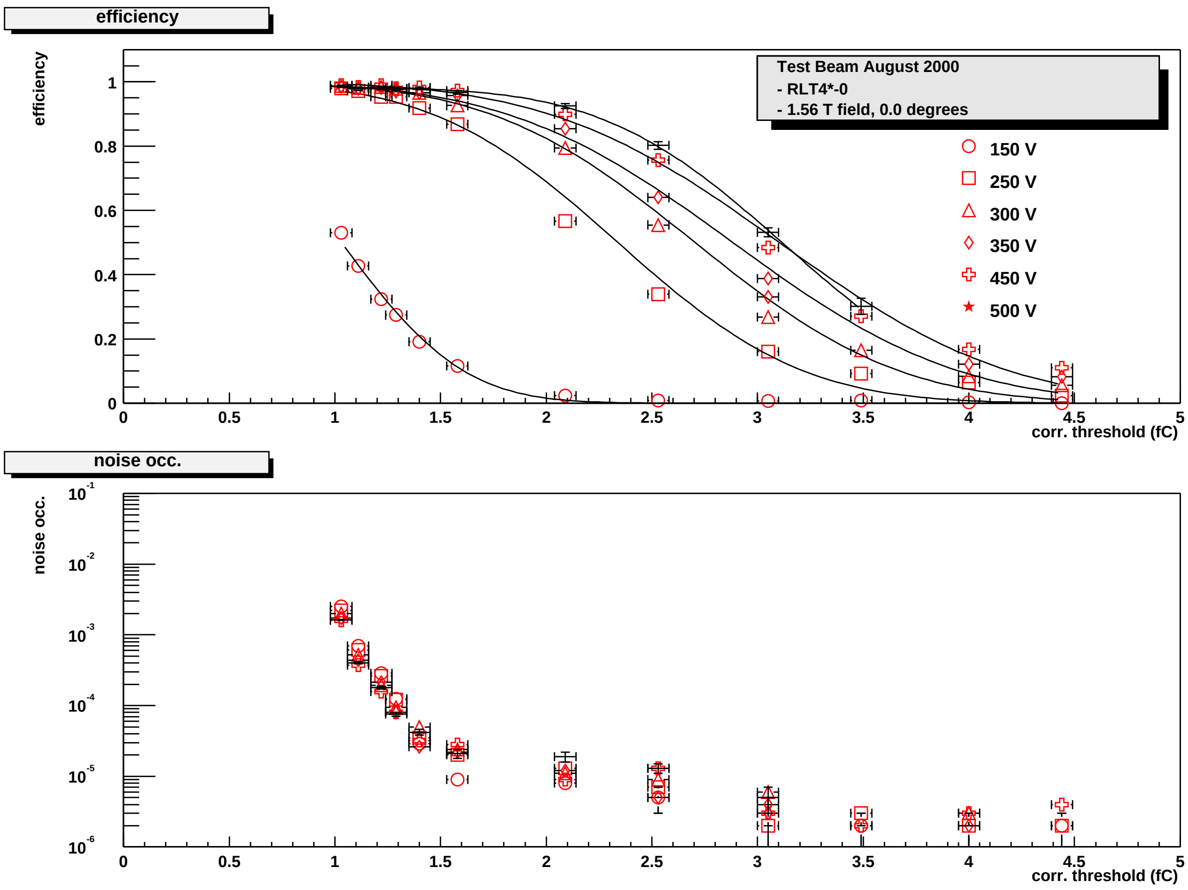


Figure 12: RLT4: S-curves at normal incidence, 1.56 T field

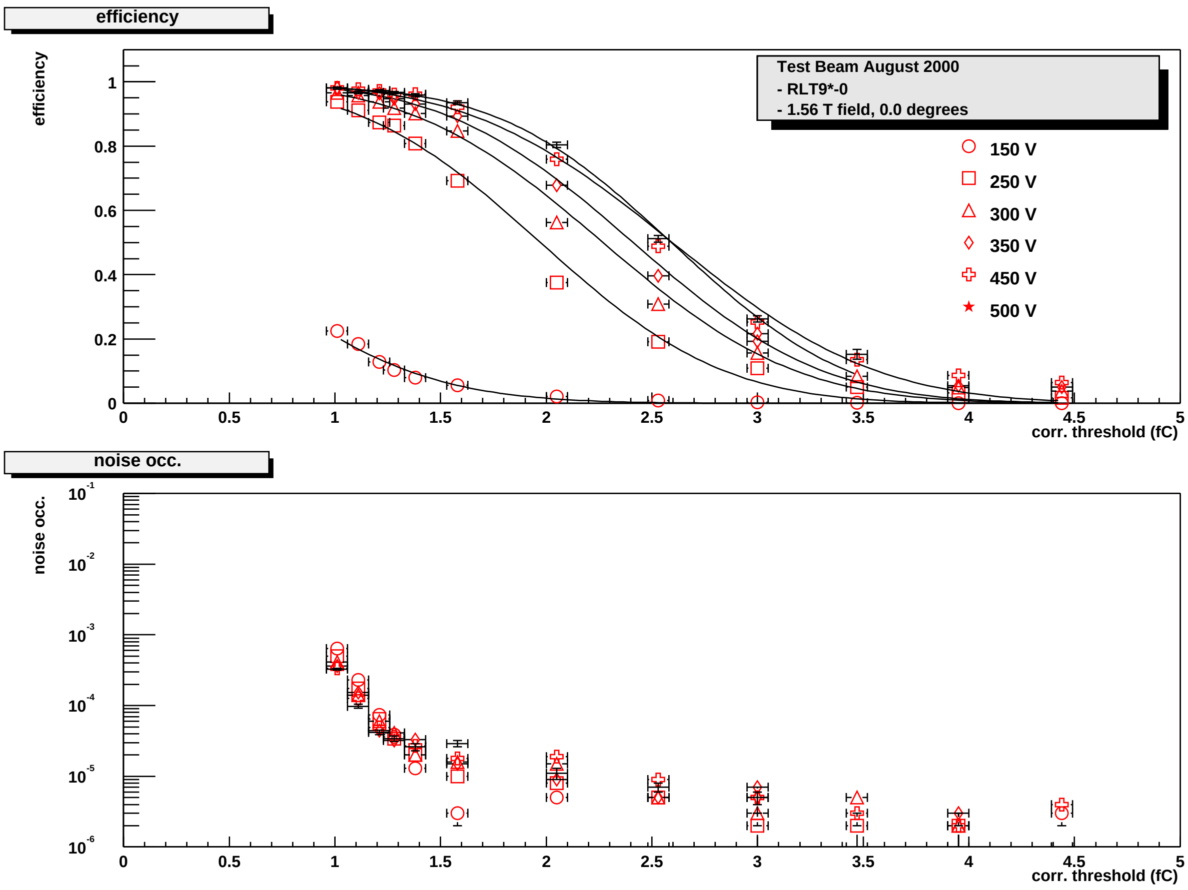


Figure 13: RLT9: S-curves at normal incidence, 1.56 T field

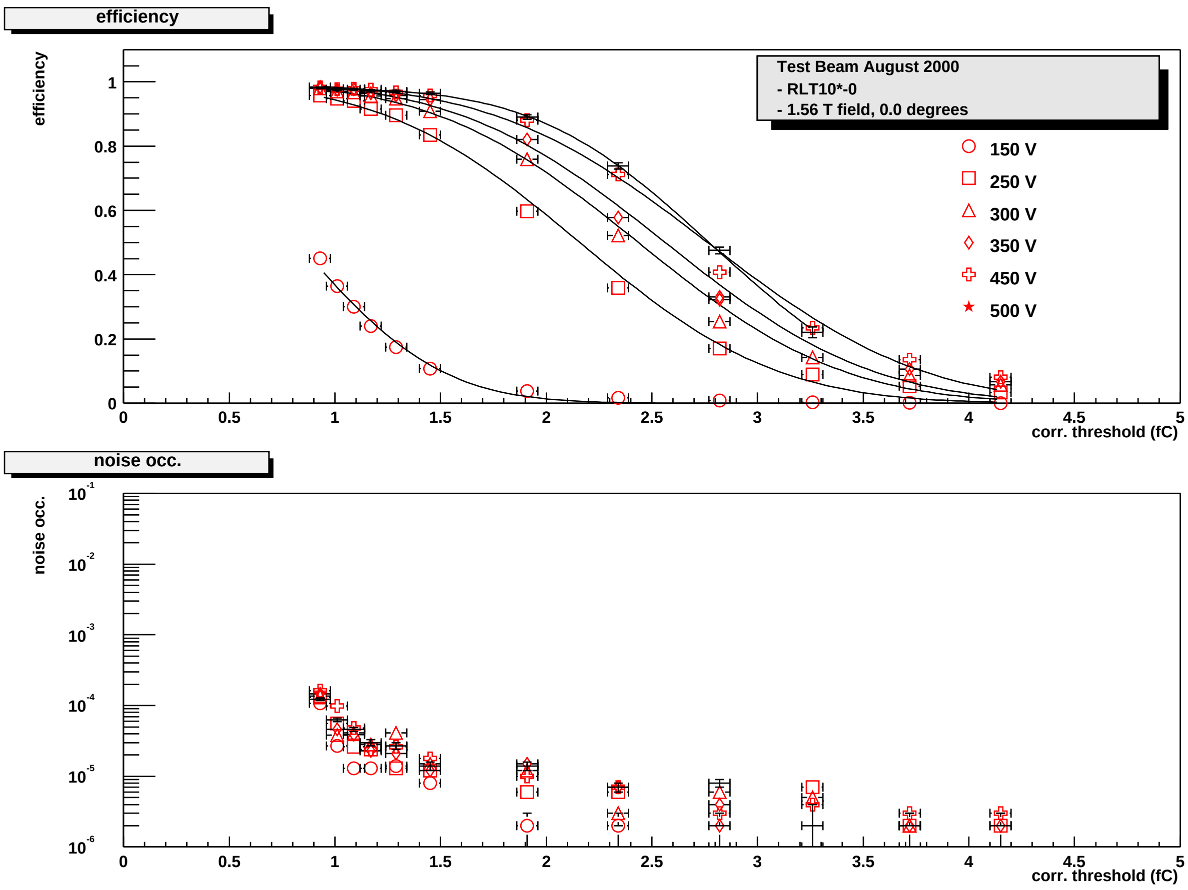


Figure 14: RLT10: S-curves at normal incidence, 1.56 T field

TB2000 Results - S-curves

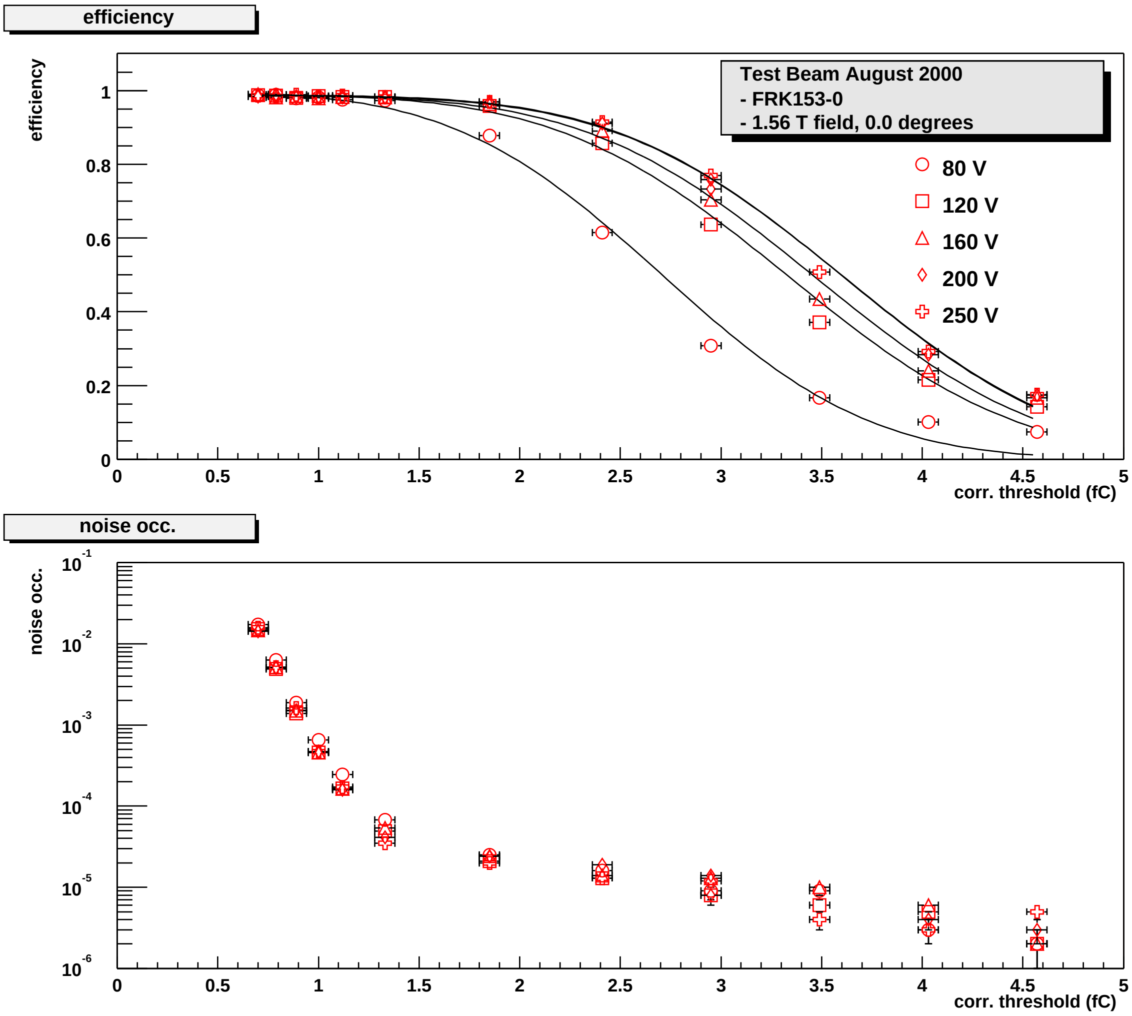
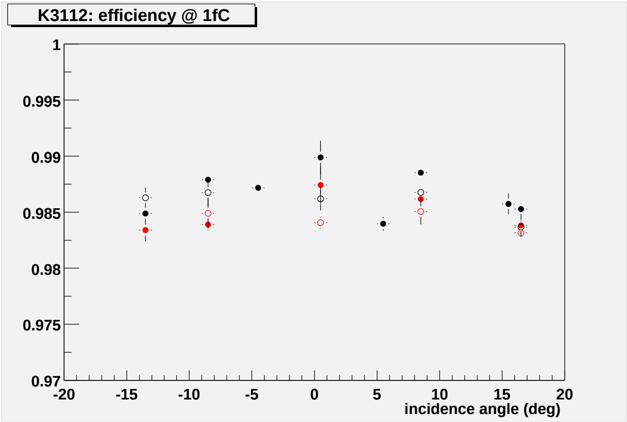
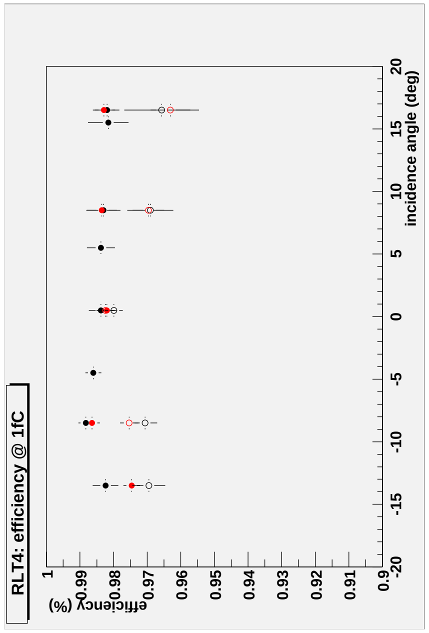
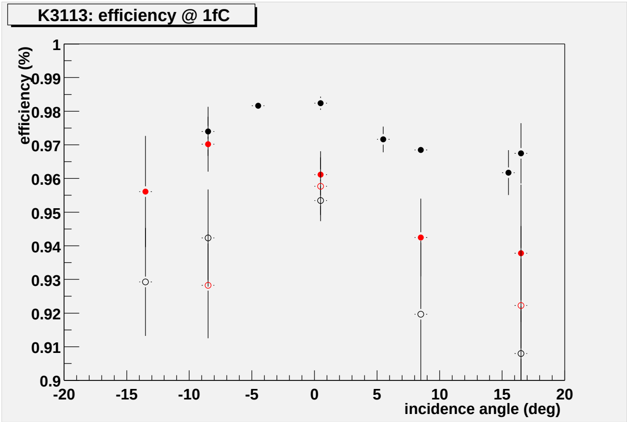


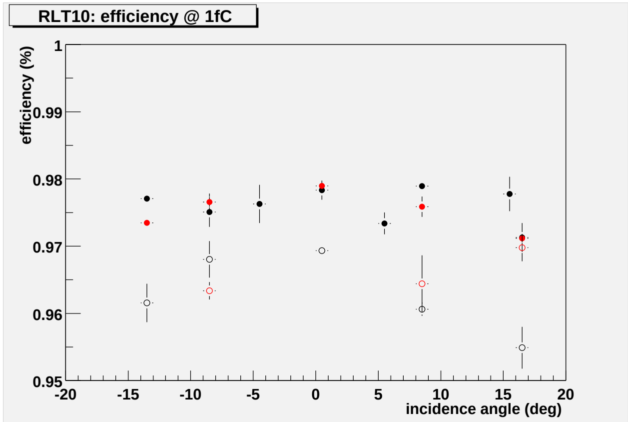
Figure 15: FRK153: S-curves at normal incidence, 1.56 T field

TB2000 - non-perpendicular incidence









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TB2000 Results - spatial resolution

$$\sigma_x = \sigma_{u,v}/\sqrt(2)\ (16\ \mu m)$$
$$\sigma_y = \sqrt(2)\sigma_{u,v}/\alpha\ (\sim 800 \mu m)$$

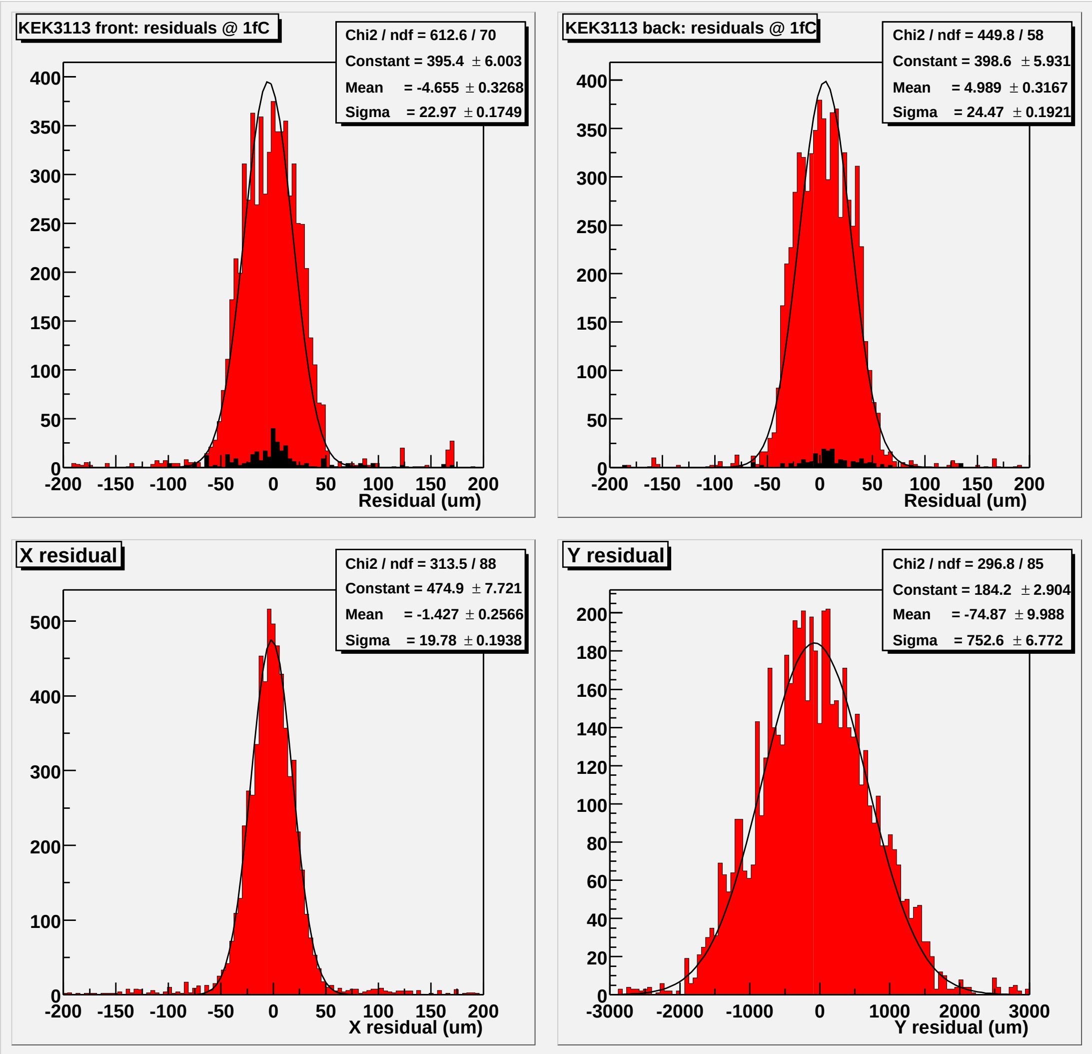


Figure 16: K3113: Spatial resolution in u, v, x and y

$$\sigma_x = \sigma_{u,v}/\sqrt(2) \text{ (16 } \mu m)$$
$$\sigma_y = \sqrt(2)\sigma_{u,v}/\alpha \ (\sim 800\mu m)$$

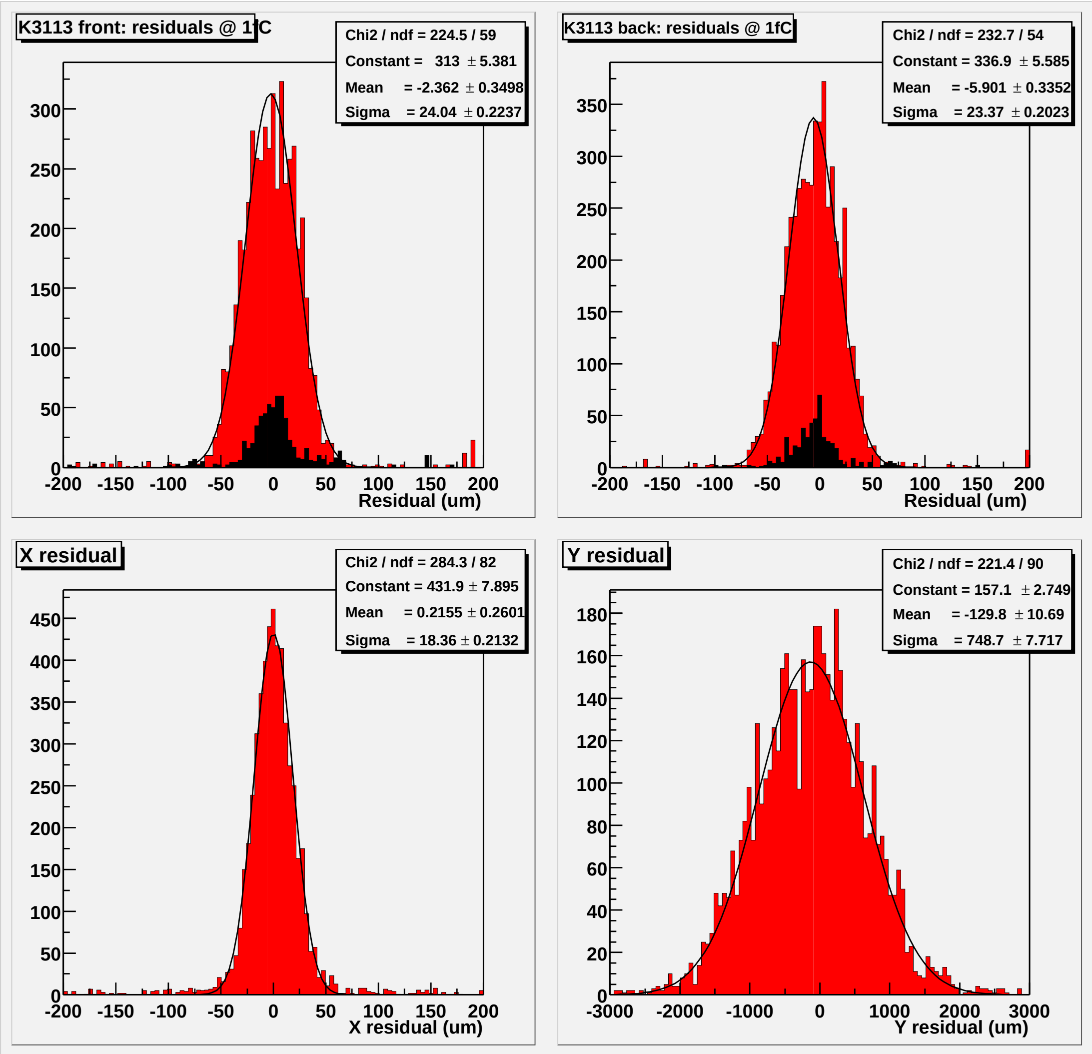


Figure 17: K3113: Spatial resolution in u, v, x and y

$$\sigma_x = \sigma_{u,v}/\sqrt{(2)}\ (16\ \mu m)$$
$$\sigma_y = \sqrt{(2)}\sigma_{u,v}/\alpha\ (\sim 800\mu m)$$

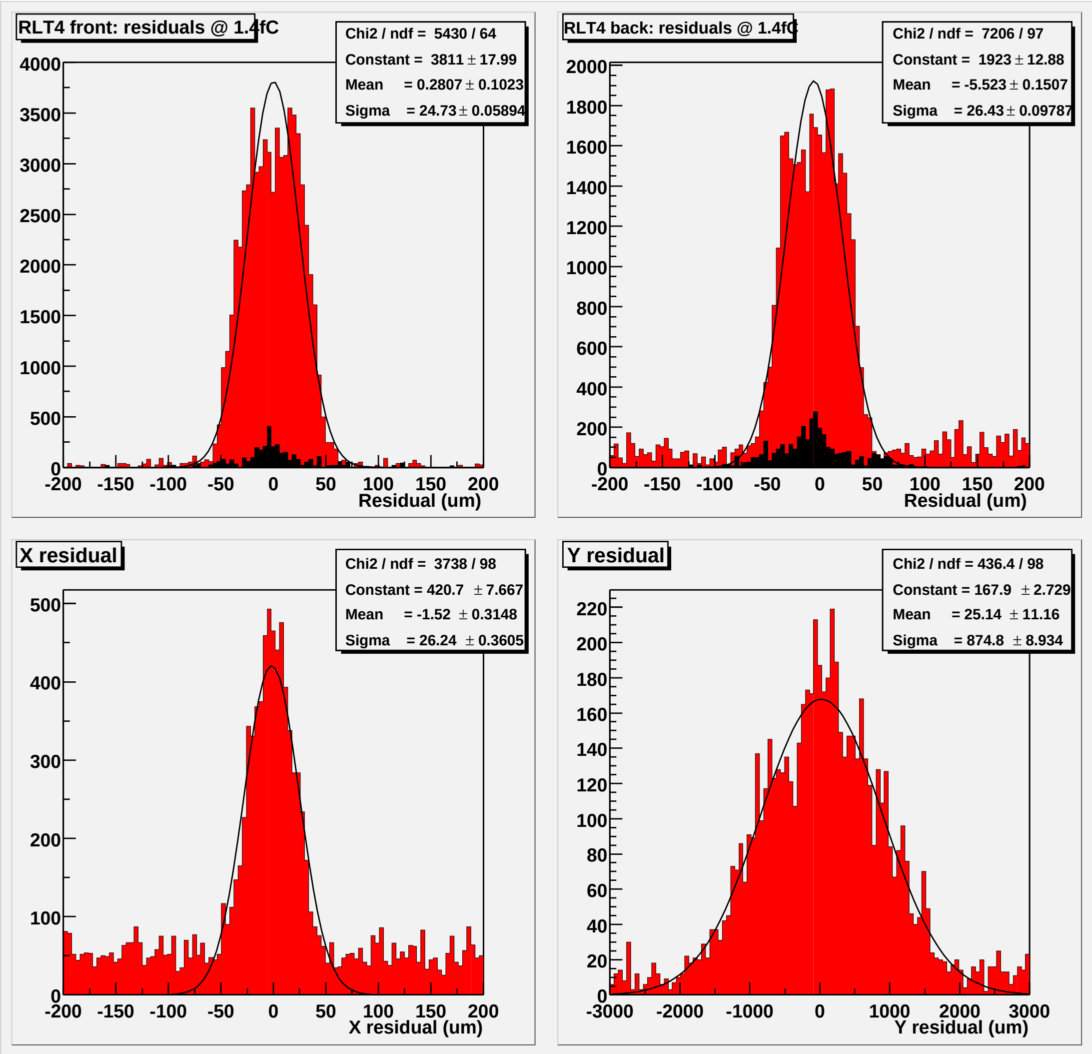


Figure 18: RLT4: Spatial resolution in u, v, x and y

$$\sigma_x = \sigma_{u,v}/\sqrt(2) \text{ (16.3 } \mu m)$$
$$\sigma_y = \sqrt(2)\sigma_{u,v}/\alpha \ (\sim 800 \mu m)$$

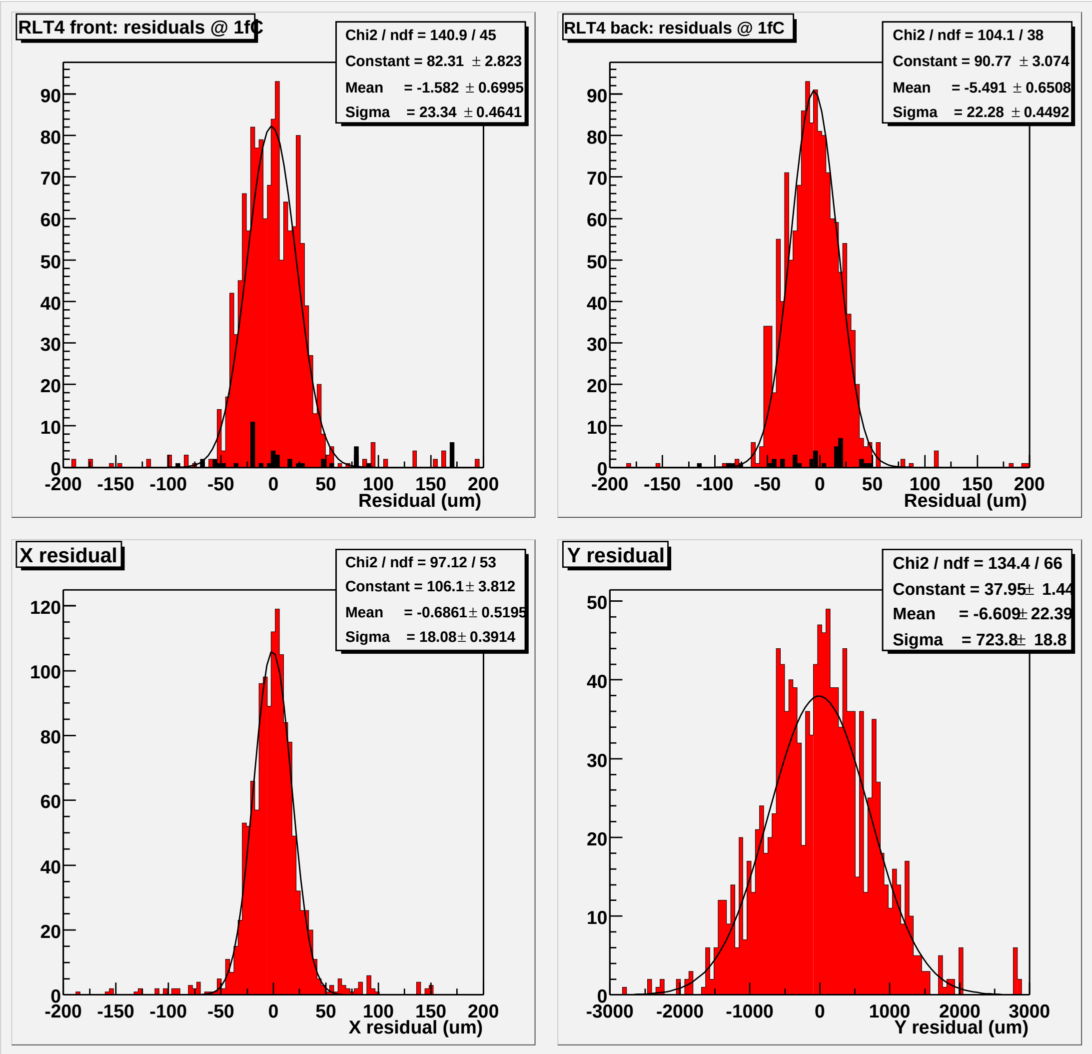


Figure 19: RLT4: Spatial resolution in u, v, x and y

The magnetic field causes the charge carriers in the Silicon to drift at an angle to the electrical field. The Lorentz angle for p^+n material in a 1.56 T field is 2.7 degrees.

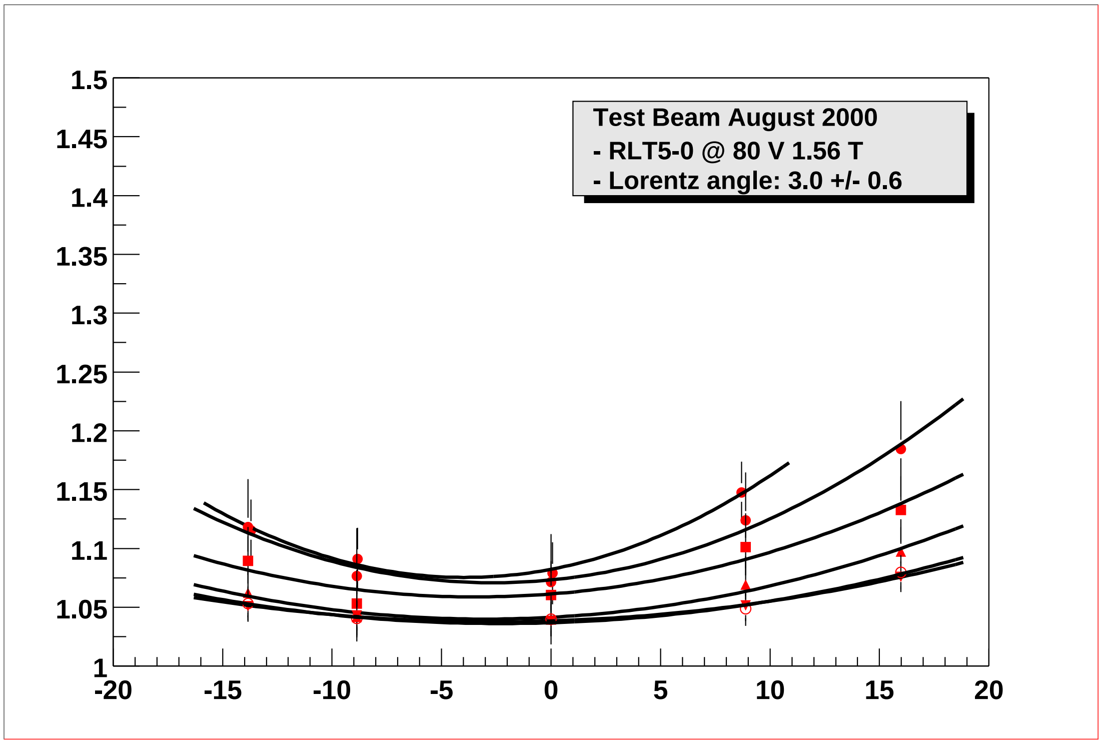


Figure 20: RLT5: Cluster width vs incidence angle

TB2000 - Lorentz angle

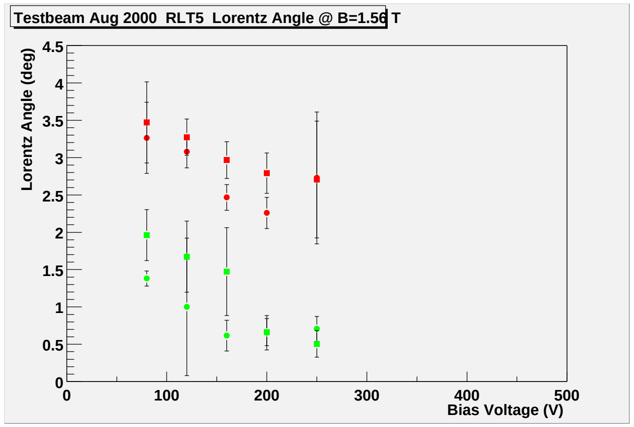


Figure 21: RLT5: lorentz angle

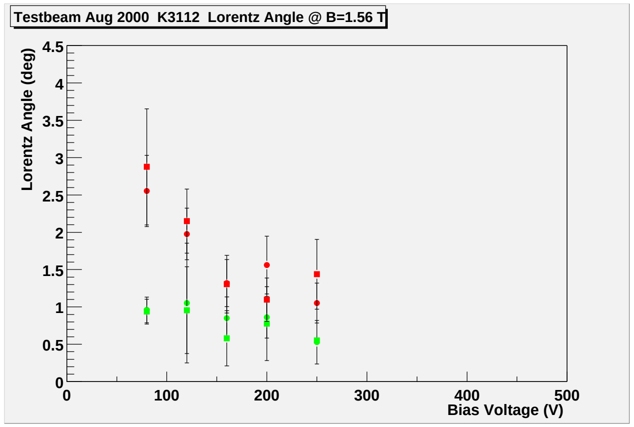


Figure 23: K3112: lorentz angle

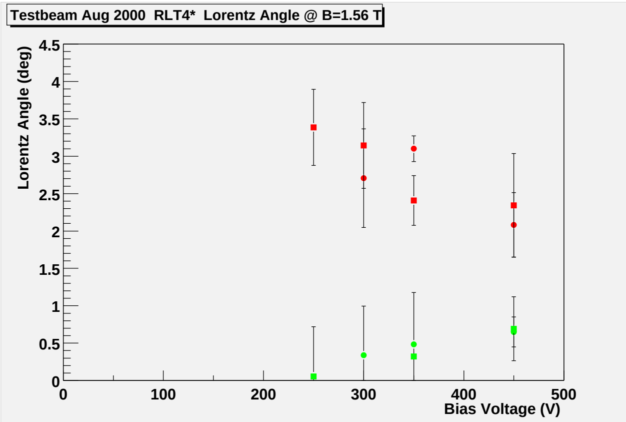


Figure 22: RLT4: lorentz angle

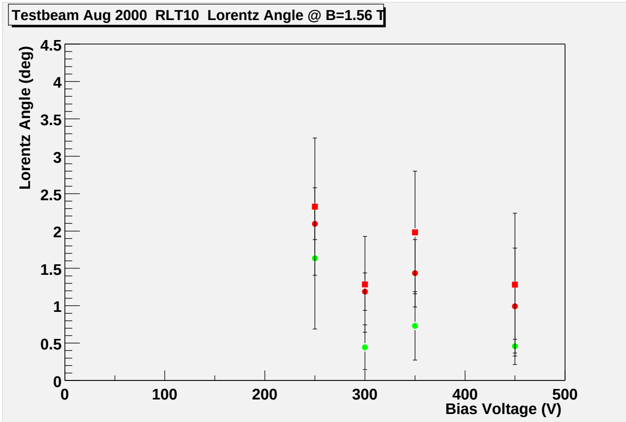


Figure 24: RLT10: lorentz angle

TB2000 - Forward Common Mode?

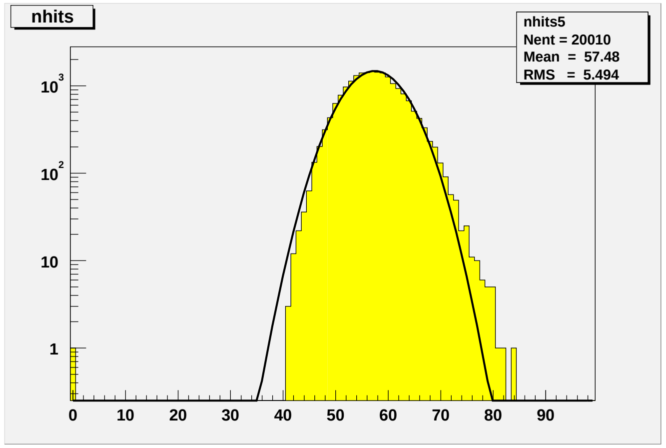


Figure 25: #hits/event RLT5 (barrel module)

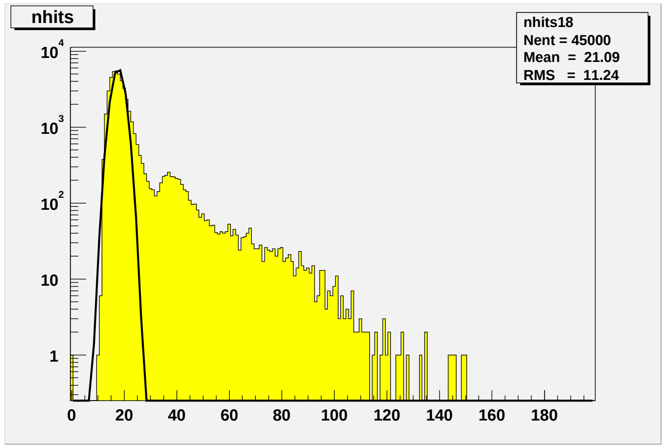


Figure 27: #hits/event FRK153 at 1.0 fC

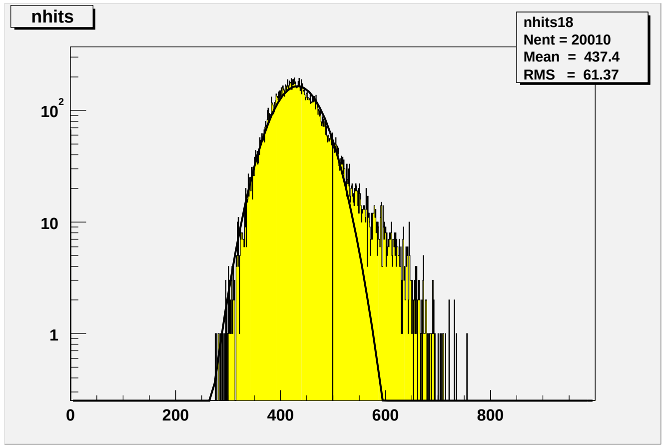


Figure 26: #hits/event FRK153 at 0.7 fC

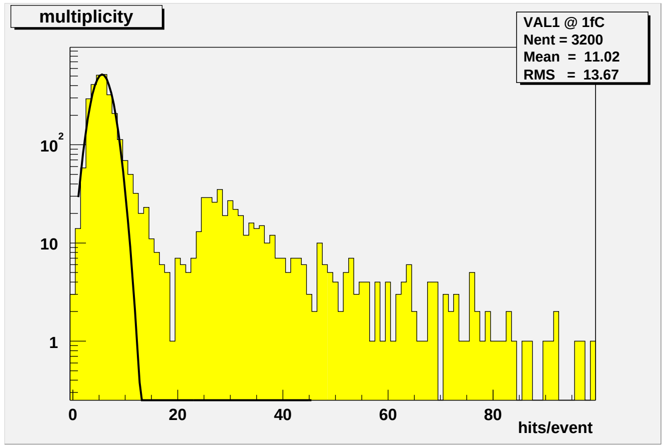


Figure 28: VAL1 at 1.0 fC, beam run

Relative Ballistic Deficit approximately given by:

$$RBD \sim \frac{1}{8}\left(\frac{d^2}{\mu\tau V_{bias}}\right)^2 \tag{1}$$

,where μ is the majority carrier mobility, and τ the design peaking time of the shaper

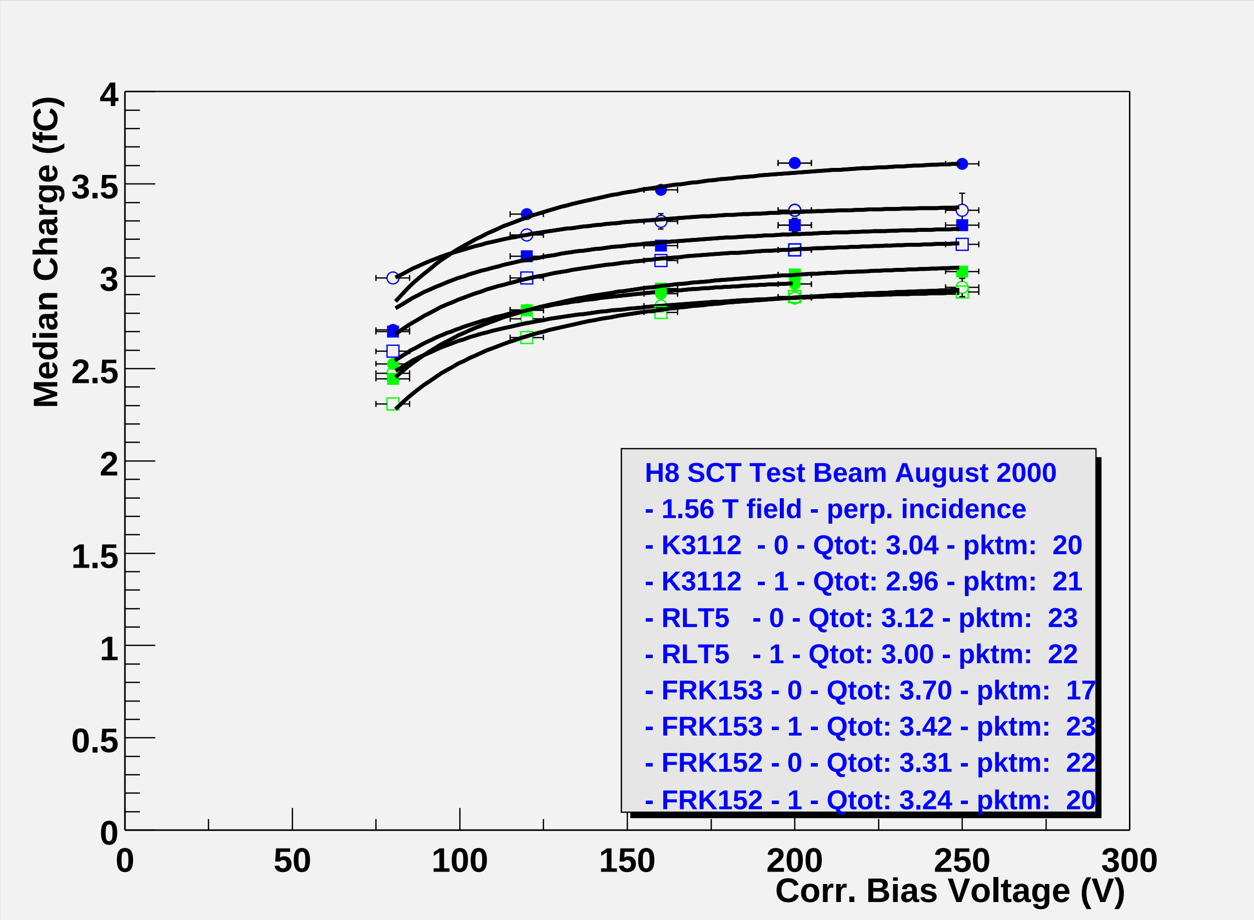


Figure 29: Scaled median charge versus bias voltage forward (blue) and barrel modules (green)

The ballistic deficit stretches the shaper pulse. The effective peaking time becomes:

$$t_m = \frac{T}{1 - exp{-}T/\tau} \qquad (2)$$

,where T is the input pulse length and τ the design peaking time of the shaper

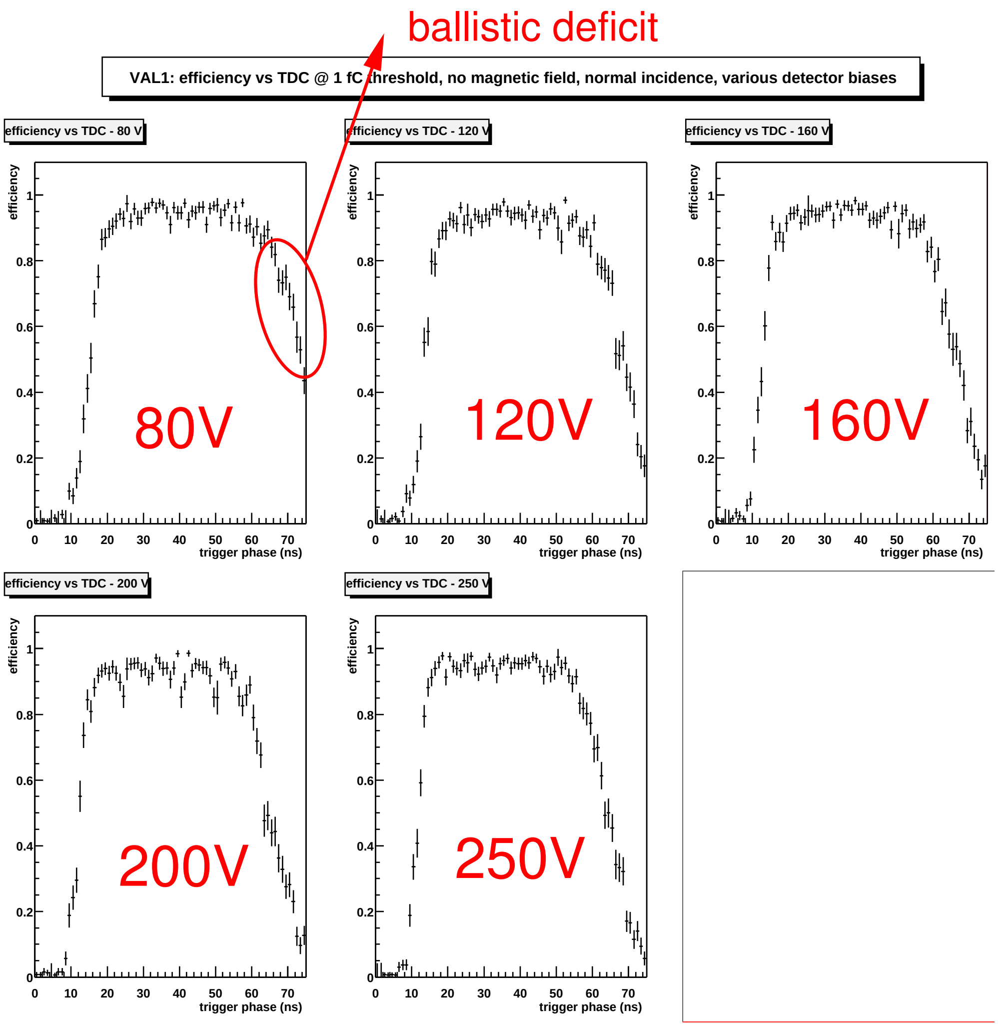


Figure 30: VAL1: Efficiency versus trigger phase distribution

The efficiency versus TDC distributions for the modules with irradiated sensors do not show any sign of ballistic deficit.

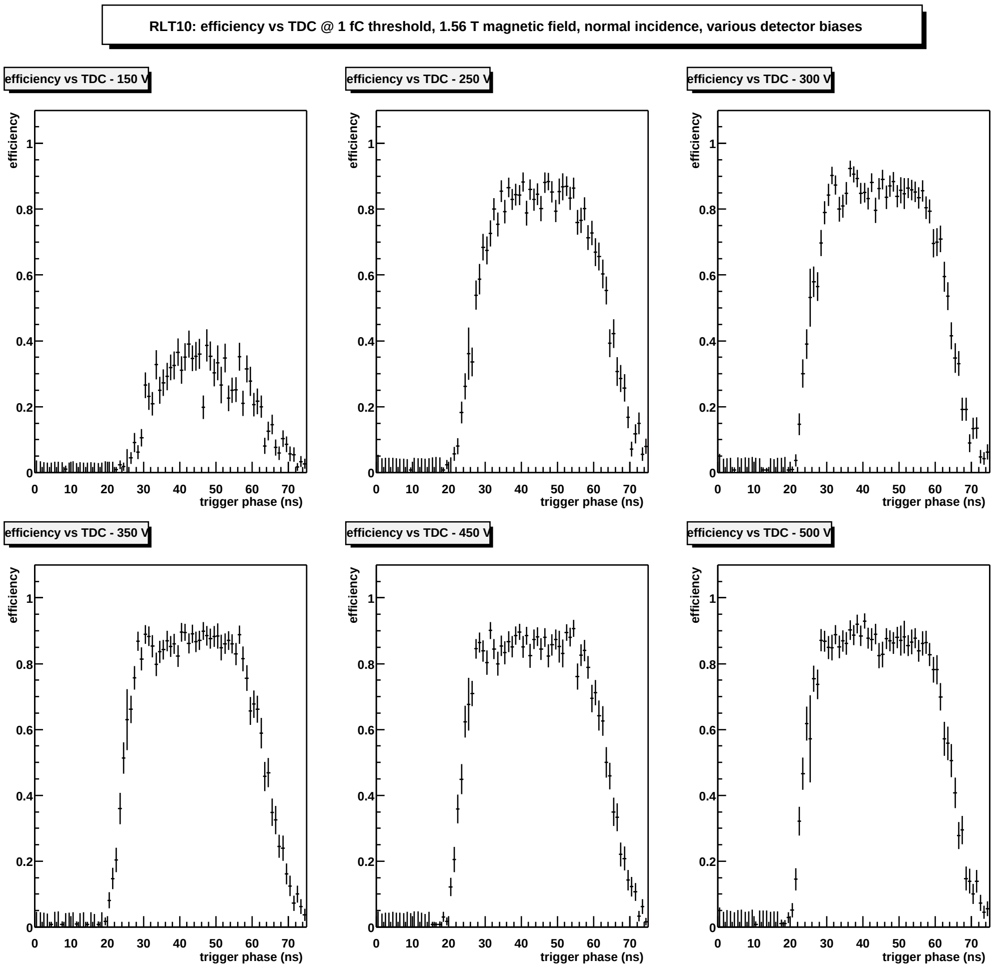


Figure 31: RLT10: Efficiency versus trigger phase distribution

The width of the efficiency versus trigger phase distribution at a (corrected) threshold of 1 fC for all modules.

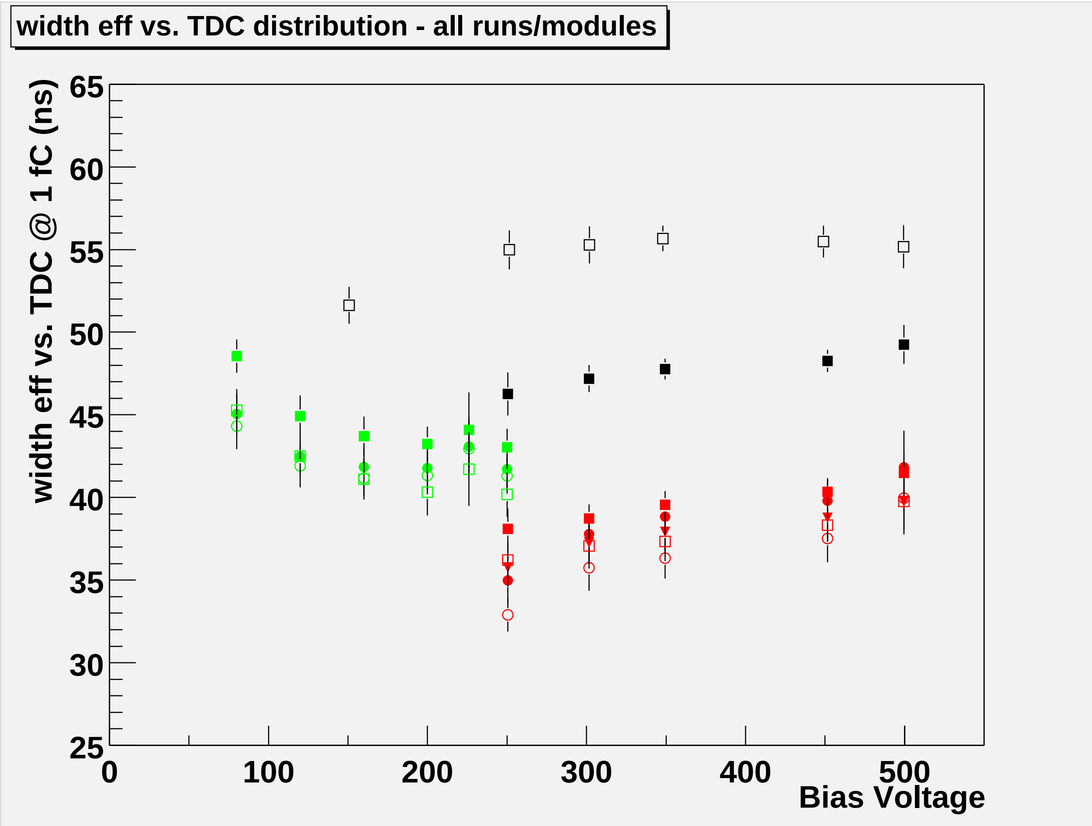


Figure 32: Width (at half maximum) of efficiency vs TDC at 1 fC. K3112(green circles) and RLT5(green squares). K3113(red circles), RLT9(red triangles) and RLT10(red squares). RLT4 (black squares).

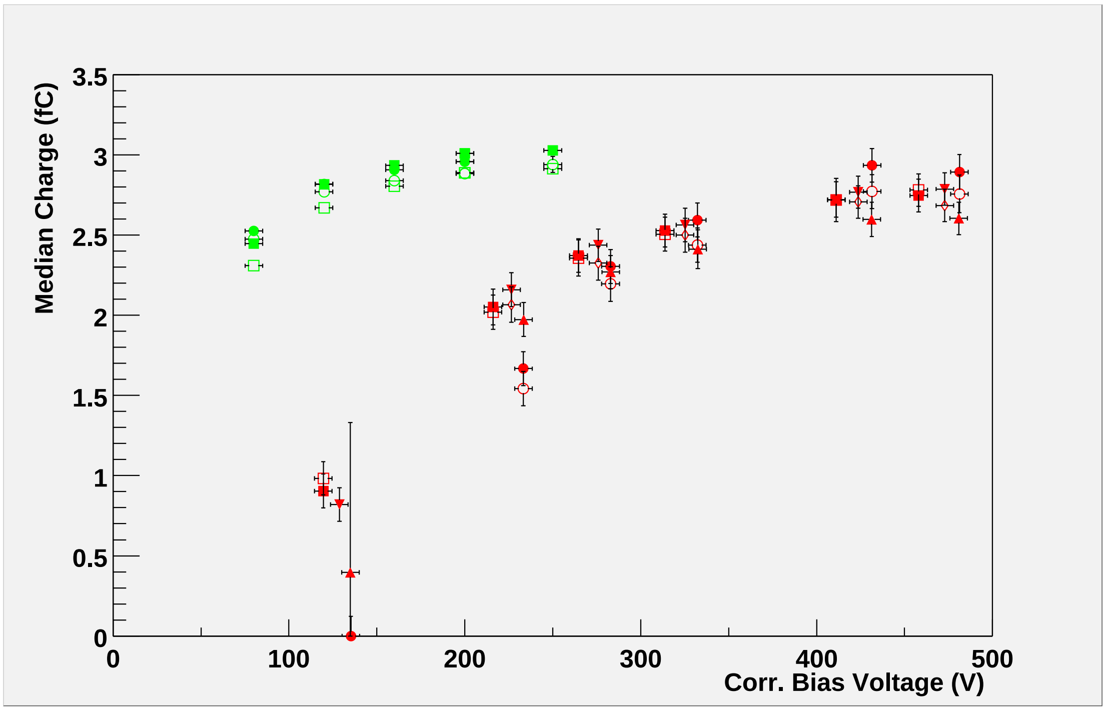
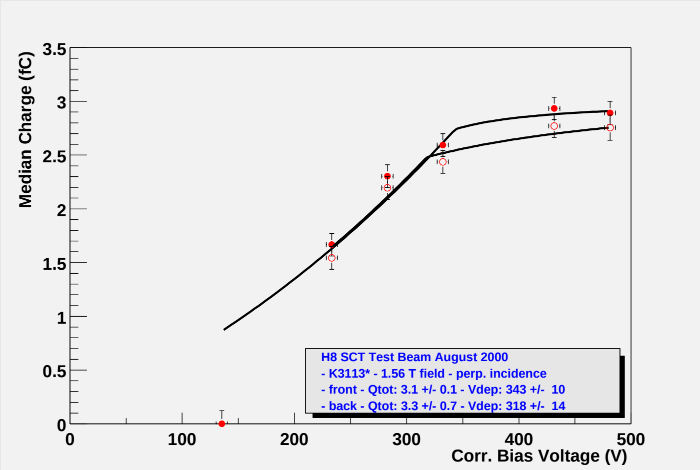
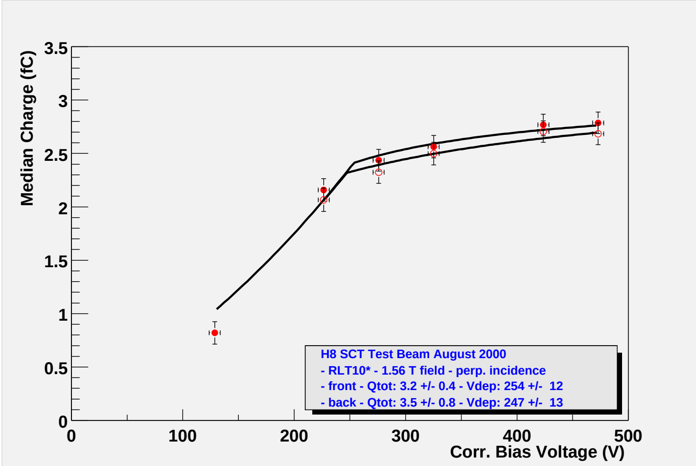


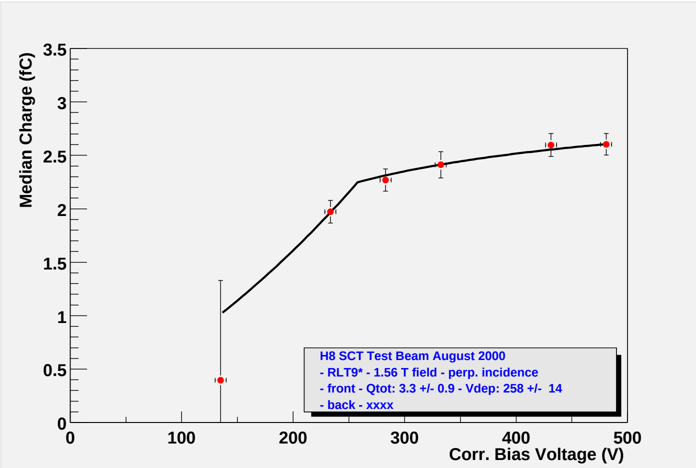
Figure 33: Median charge versus bias voltage. K3112(green circles) and RLT5(green squares). K3113(red circles), RLT4 (red squares), RLT9(red triangles) and RLT10(upward triangle). Bias voltages have been corrected for the voltage drop in the bias resistor. Charges have been scaled with detector thickness.

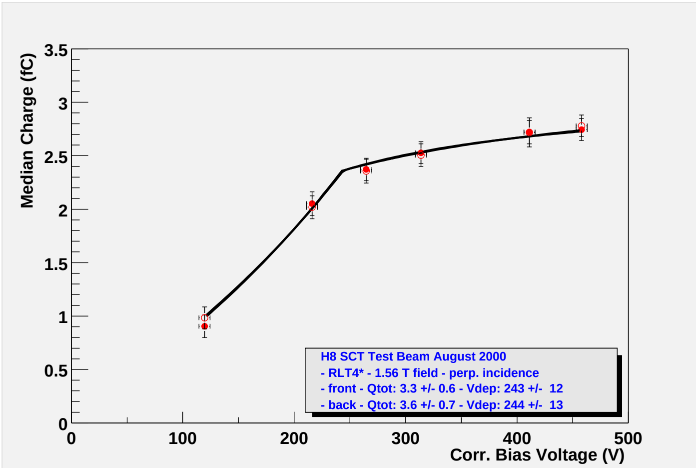
TB2000 - Charge Collection

Fit of charge collection as a function of bias voltage with a model by G. Casse and S Marti i Garcia. The model accounts for underdepleted operation (moving carriers induce a signal on the strips) and charge trapping in lattice vacancies.









In underdepleted operation signal is induced on the strips. This will lead to different spatial properties (governed by attenuation instead of diffusion).

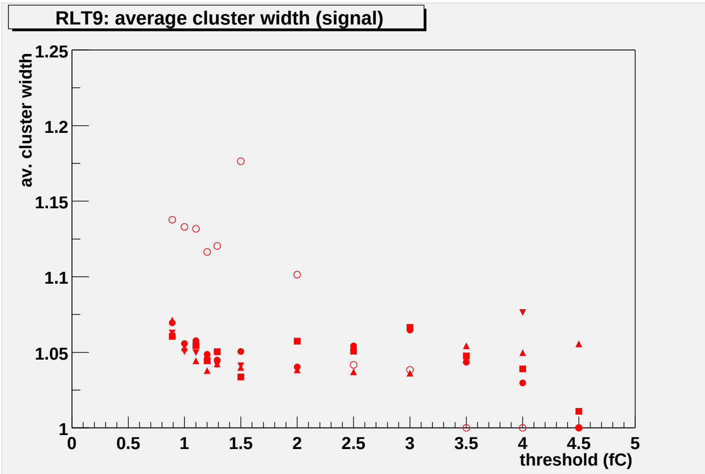


Figure 34: RLT9: Cluster width vs. threshold for 150 V (open circles), 250 V (full circles), 300 V, 350 V and 450 V

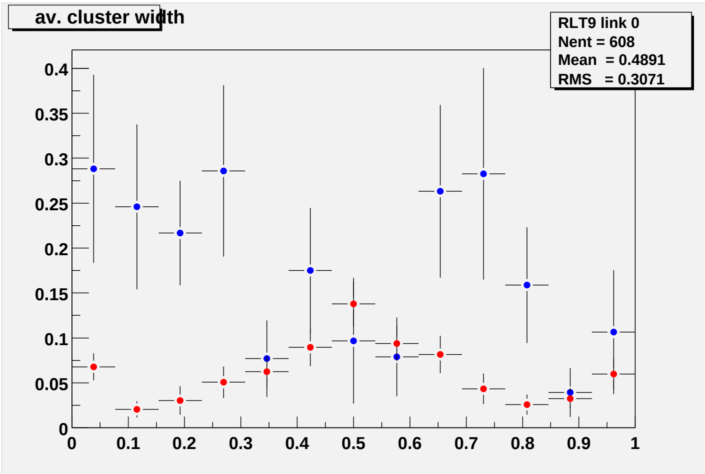


Figure 35: RLT9: Cluster width @ 1fC vs. interstrip position for 150 V (blue circles), and 500 V (red)

The 150 data have clearly higher average cluster width at low threshold. There is also no well-defined peak in the cluster width vs. interstrip position.

Results from TB2000:

- The incidence angle reduces the charge collected per strip to 90% at 14 degrees in a magnetic field (12 degrees without field).
- The effect of the magnetic field on the collected charge is marginal
- Unirradiated modules suffer some charge loss due to ballistic deficit of the shaper below 120 V
- Modules with irradiated sensors are capable of retrieving a similar charge, but at a high bias voltage. At 300 V the collected charge is 0.5 fC less than in the unirradiated sensors
- No evidence is found for a ballistic deficit in the modules with irradiated sensors (down to 150 V). Charge loss is probably due to trapping.
- Unirradiated barrel modules have unprecented low noise
- Barrel modules with irradiated sensors have higher noise (except for K3113), but within specifications

TB2000: Conclusions

- The irradiated module shows significantly higher noise and deviating timing. The threshold has to be raised to 1.2 fC in order to reach the specified 5×10^{-4} noise occupancy.
- Forward modules were very noisy in the test beam. The noise has a significant common mode component
- The spatial resolution in u,v,x and y is as expected provided the noise is below the specification value.
- The Lorentz angle measured is close to the theoretical value for p^+n material (2.7 degrees), but seems to decrease with increasing bias voltage. Not yet understood.
- No significant difference is found between $< 100 >$ and $< 111 >$ sensors.