KEK Beam Test

Modules:

$\Downarrow$ BEAM

- K3103 (ABCD2T, reference).
- KEK11 (Thinned &Metalized).
- Telescope A.
- KEK22 (Extra capacitor in V_{dd} and V_{cc}).
- KEK (Irradiated, Only in run II).
- Telescope B.
- VAL K3-166 (Irradiated).
- VAL K3-165.
- Telescope C.
- CG K3-170.

$\Downarrow$ BEAM

run I

Conditions:

- KEK irradiated module not present.
- All modules:

  FEB = 220 μA.

  (Valencia irrad FEB = 128 μA).

  FES = 30 μA.

- Bias Scan.

  Each voltage $\Rightarrow$ Threshold Scan.

run II

Conditions:

- 7 modules present.
- All modules:

  FEB = 220 μA.

  (Irrads FEB = 128 μA).

  FES = 30 μA.

  (Irrads FES = 24 μA).

Problems in the irradiated module

TrimDAC Range:

- The trim DAC range is set in the config register (2 bits).

  optimisation of the range before and after irradiation

- After irradiation some chips had problems in the transfer of the range bits to the trim DACs.

- Depends on the temperature.

  Explains the difference barrel-forward.

- Depends on Vcc.

Vdd:

- $> 4V$ needed to operate all chips (without protocol violations).

- SCT-LV2 cannot provide sufficient power.

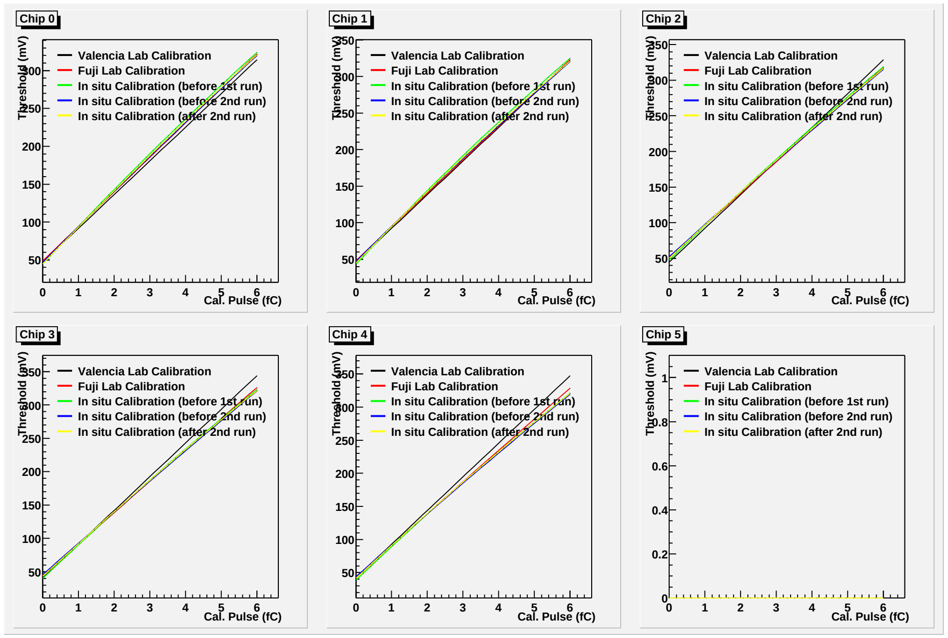
  Use external power supplies (no sensing).

- Val irradiated $\sim$ 5.1 V. KEK irradiated $\sim$ 4.8 V.

VAL166 Link 1 does not respond in the cold box $\Rightarrow$ bypass M8

Calibration

- 20-point response curve at optimum strobe delay.
- Same procedure for all modules.
- Finds a slightly lower gain for the forward modules.

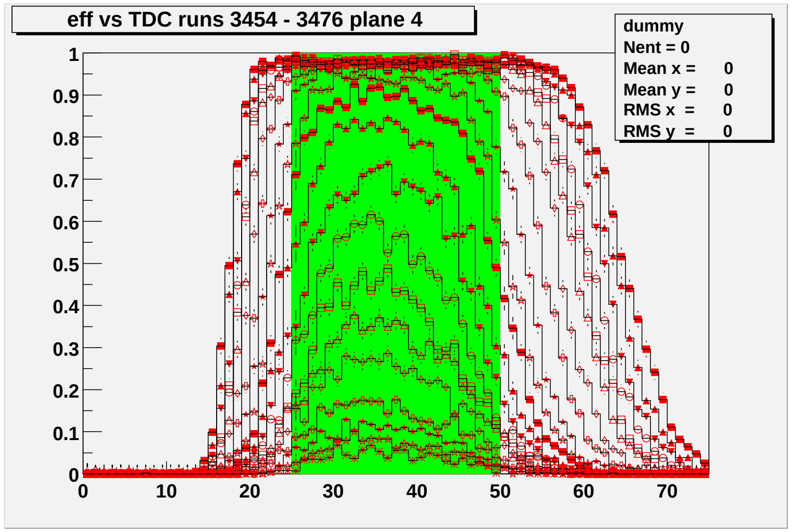


module	Kek3	Kek11	Kek22
Gain run II (mV/fC)	33.7	50.9	53.9
Gain run I (mV/fC)	-	52.4	55.5
module	Val166	Val165	CG170
Gain run II (mV/fC)	27.9	46.3	44.3
Gain run I (mV/fC)	31.8	48.2	48.5

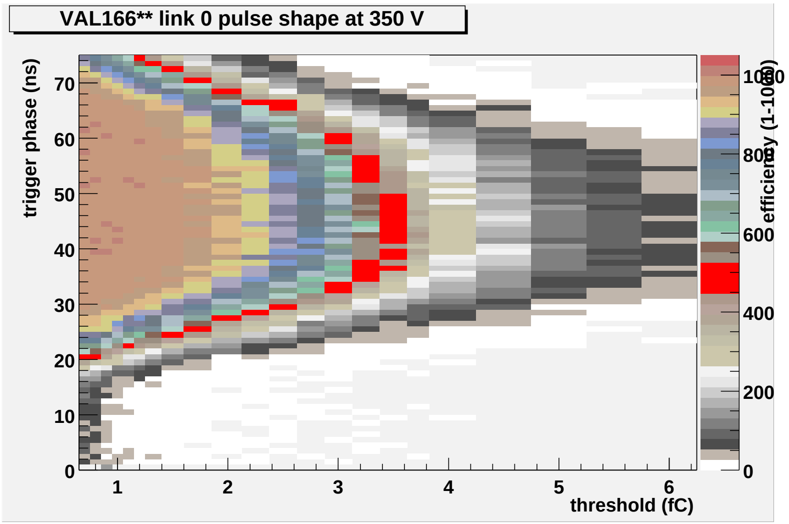
In run II the I_{sh} of the irradiated modules was $24\mu A$, in all other cases the shaper current was $30\mu A$.

Analysis

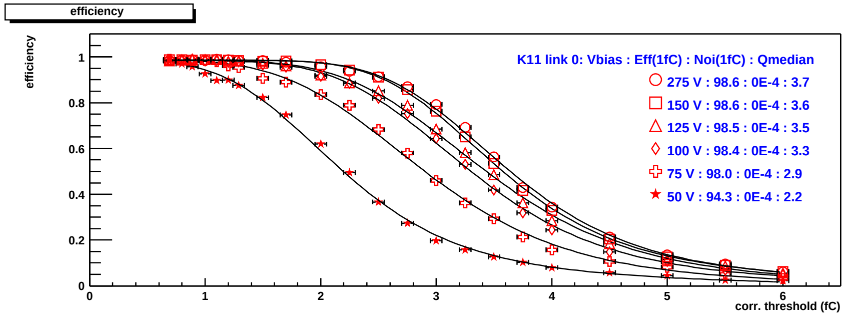
Traditional analysis chooses a rather wide TDC window, leading to an underestimation of the median charge.

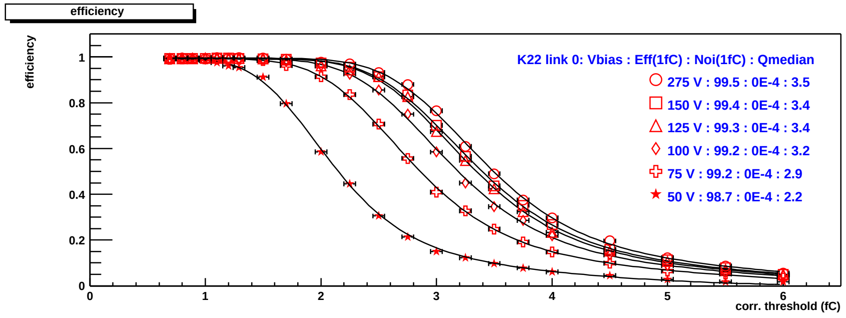


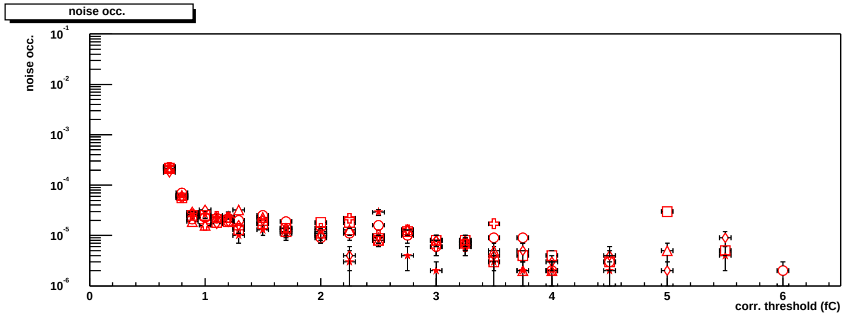
Alternative: explicitly find median charge dependence on TDC (i.e. reconstruct the pulse shape).

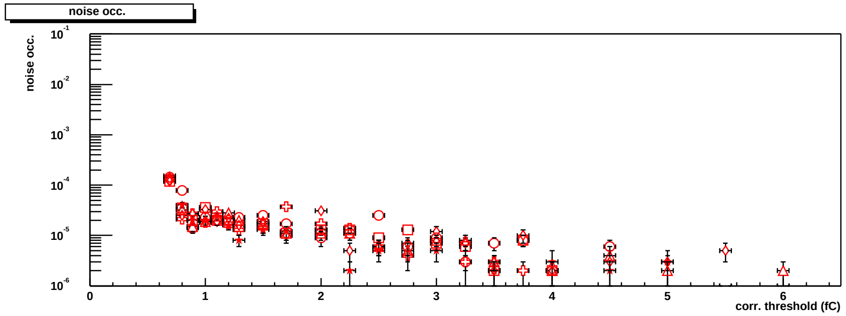


Results: traditional

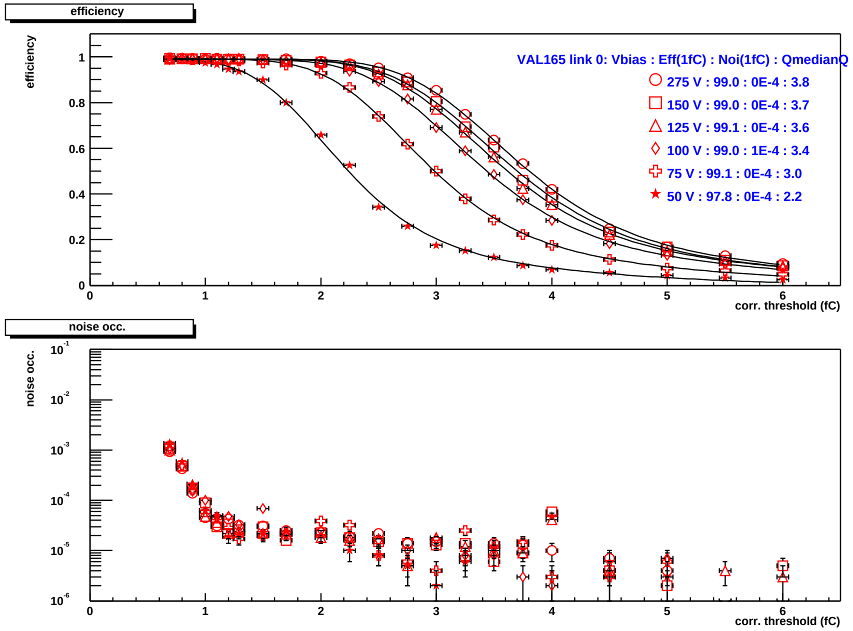


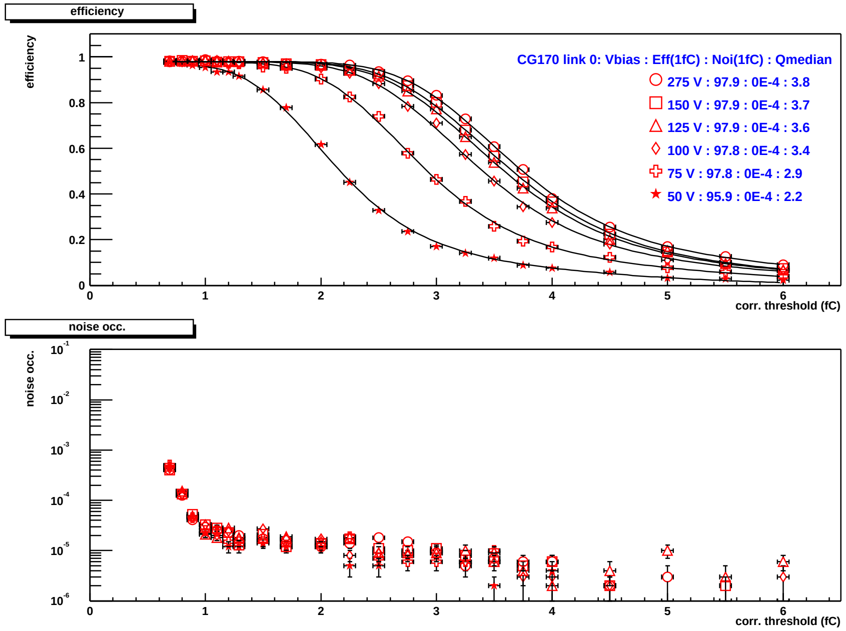




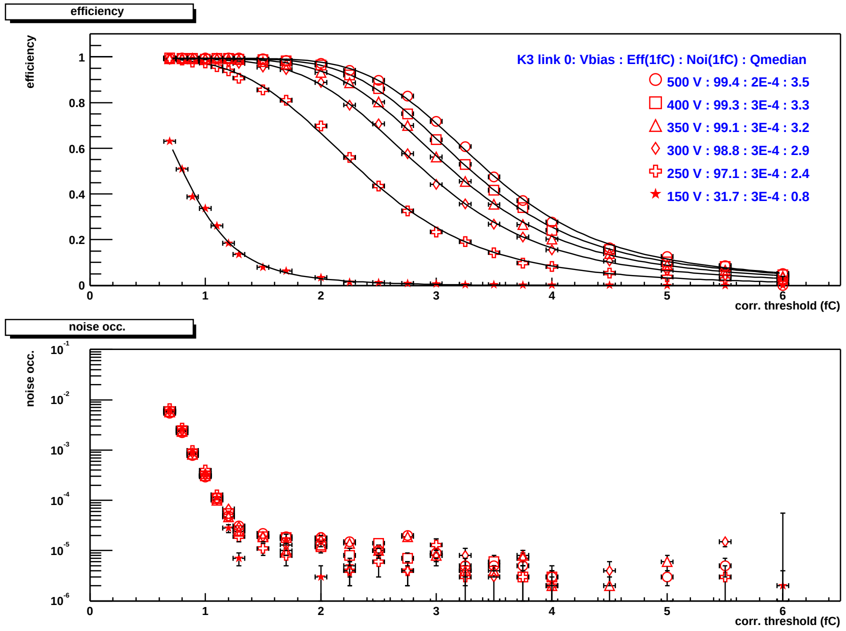


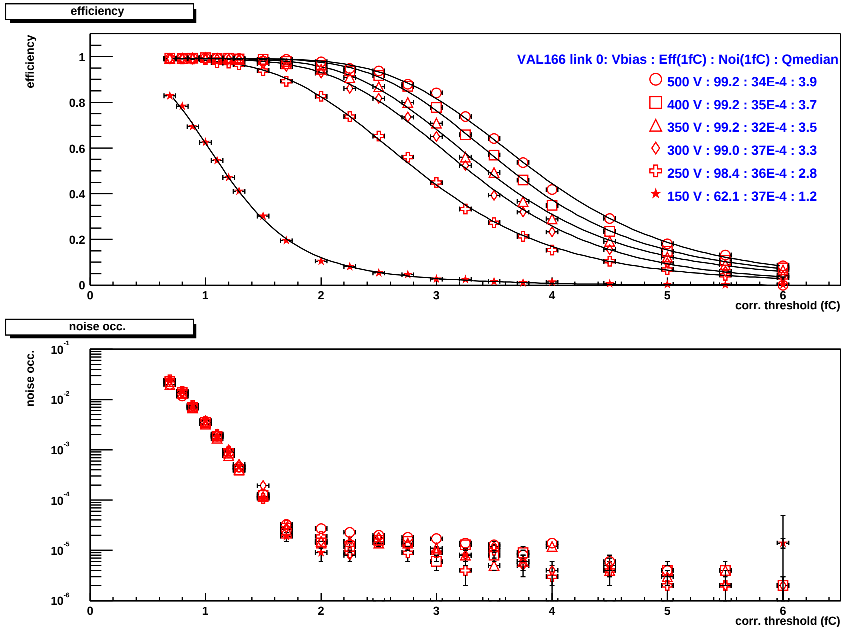
Results: traditional



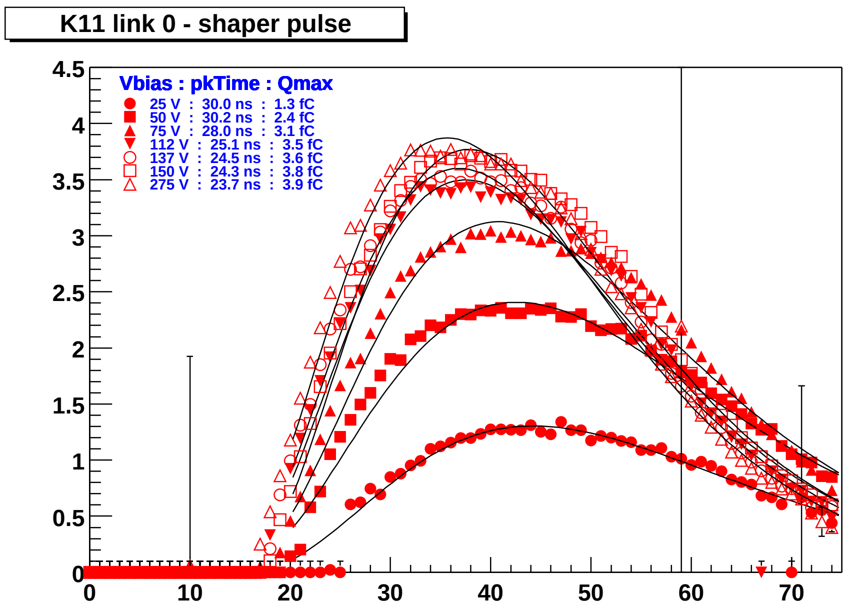


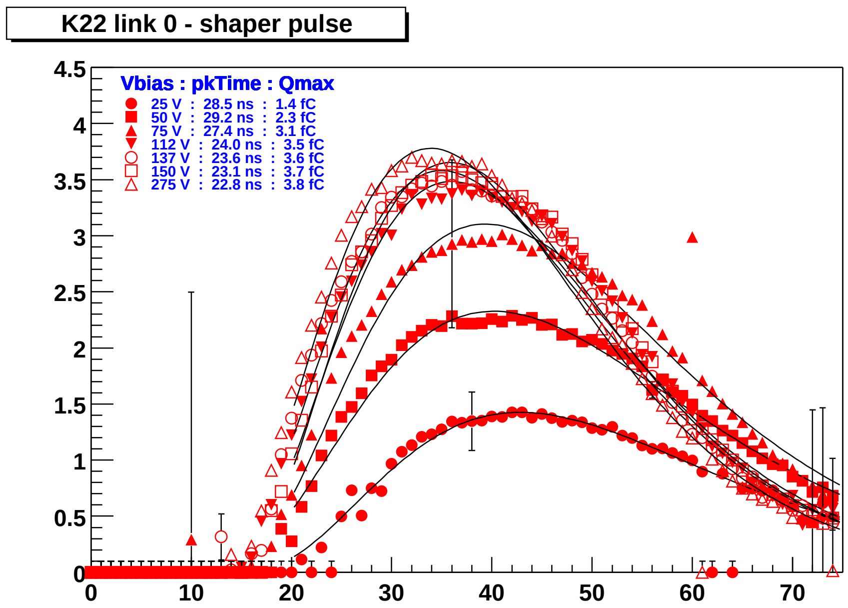
Results: traditional



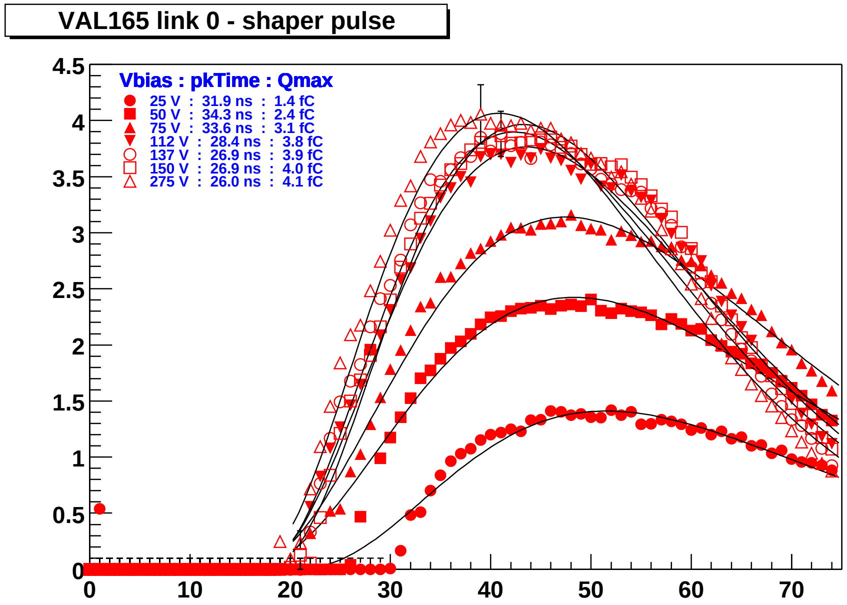


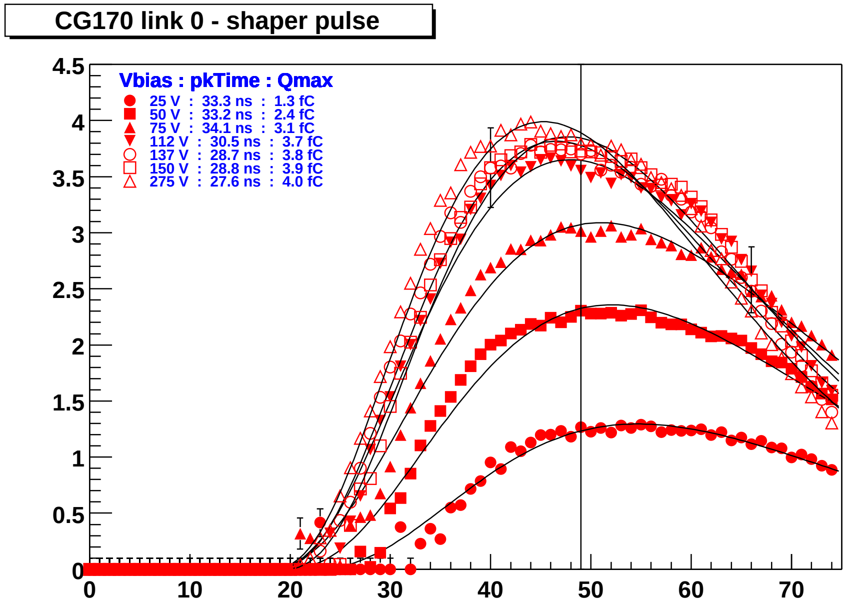
Results: pulse shape reconstruction



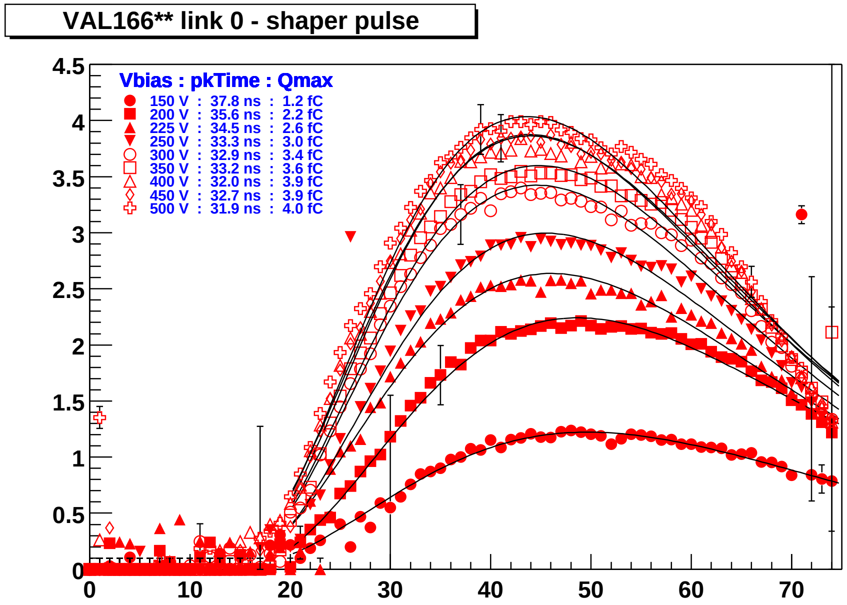


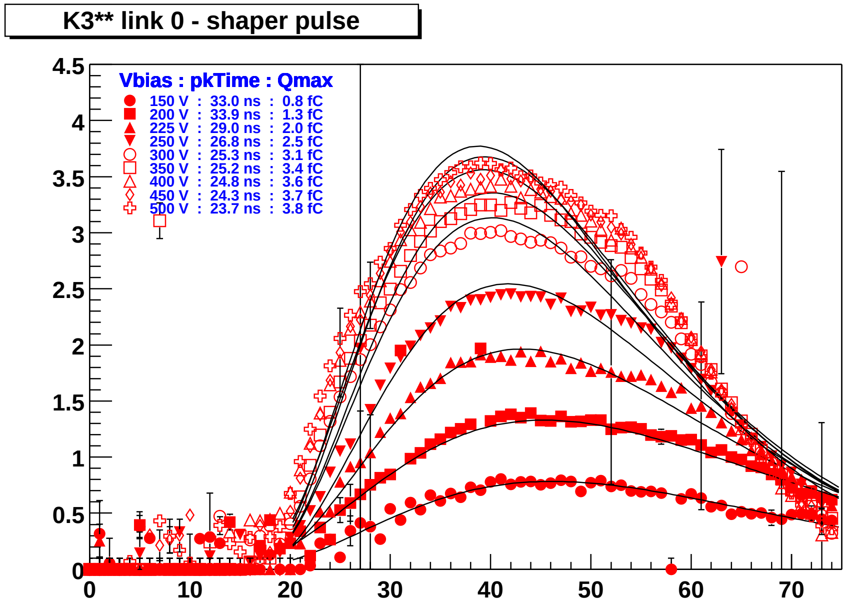
Results: pulse shape reconstruction





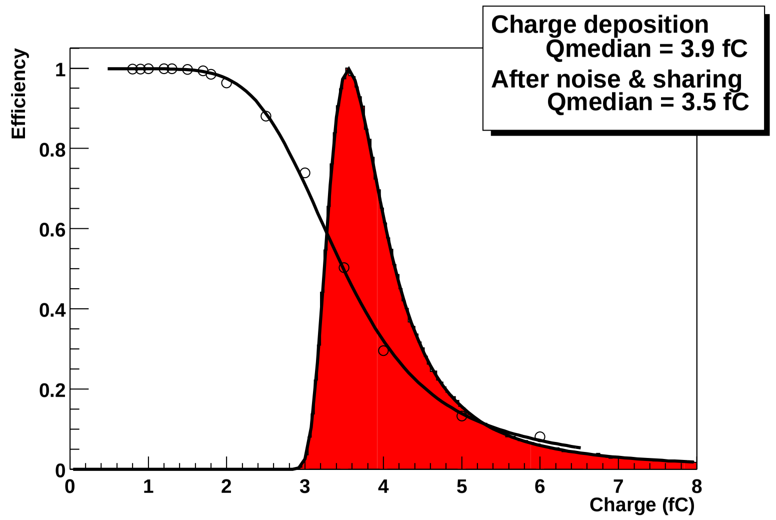
Results: pulse shape reconstruction





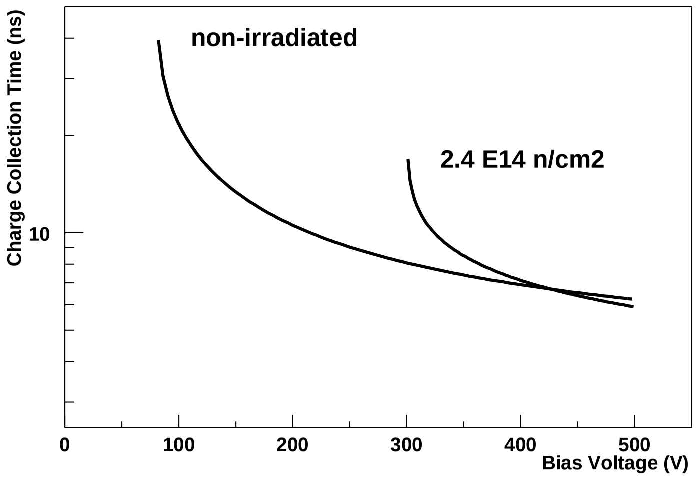
Theory

- In the ideal case, the charge is deposited according to a Landau distribution. The S-curve is a simulation of the effect of charge sharing and noise on the initial distribution.



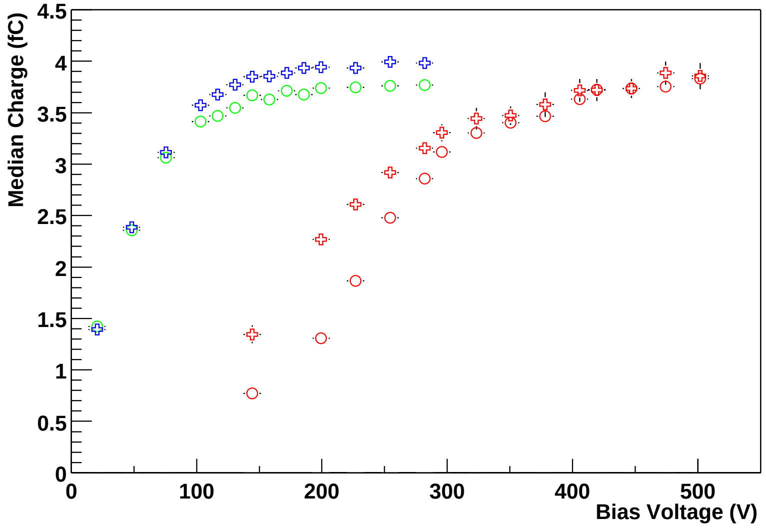
- Only carriers formed in the depleted region contribute to the signal: $w = d\sqrt{V/V_{fd}}$.
- After type inversion the depleted region grows from the back plane. Partially depleted operation is possible thanks to induction through the non-depleted bulk. Attenuation by $e^{-(d-w)/\lambda_0}$, with w the thickness of the depleted bulk and λ_0 the attenuation lenght (measured to be $\sim 180\mu m$, independent of irradiation history, see [S. Marti i Garcia et al, Charge collection for irradiated p^+n detectors])
- In irradiated Silicon, lattice defects may act as trapping sites. Detrapping times for holes are comparable to or longer than the shaping time (see for example [Michael Moll, Radiation damage in Silicon particle detectors, Doctoral thesis, Hamburg 1999.])

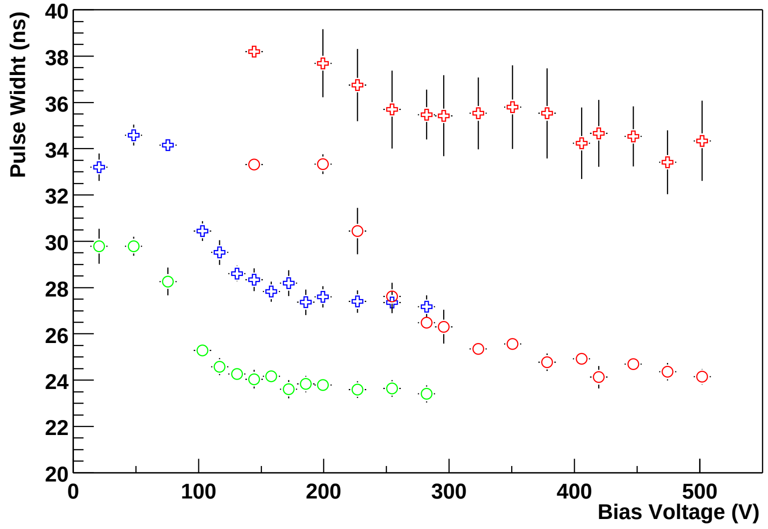
- The trapping probability may depend on the carrier velocity, leading to dependence on the bias voltage (until the saturation field of $\sim 1 - 2V/\mu m$ is reached).
- When the charge collection time becomes comparable to the shaper peaking time, ballistic deficit of the shaper reduces the charge collection efficiency.



- Charge collection time according to a model/measurements by T.J. Brodbeck et al, Carrier mobilities in irradiated Silicon, ROSE/TN/2000/09.
- In partially depleted operation one might expect long charge collection times, because of the low field region?

Results: pulse shape reconstruction

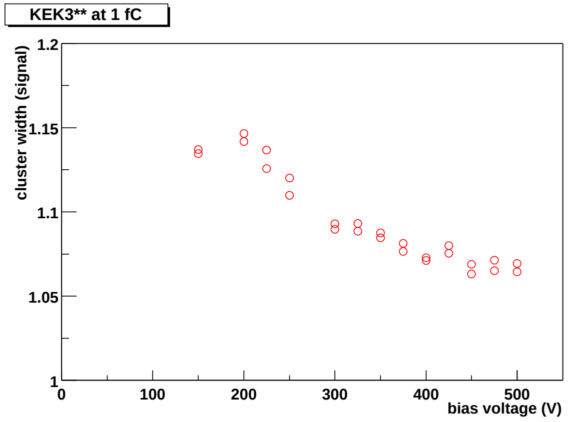


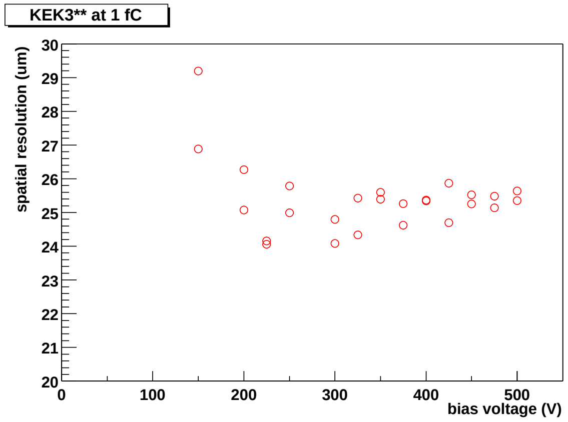


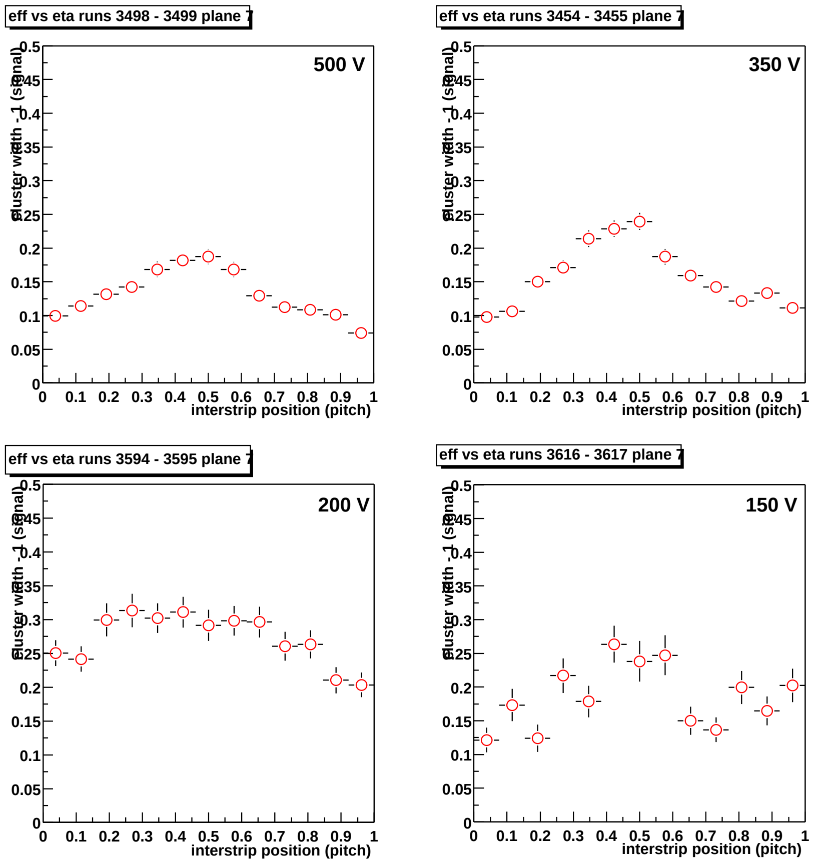
Results are shown separately for unirradiated barrel (green) and forward (blue) modules and VAL166* (red crosses) and KEK3* (red circles).

Error bars represent the variation between modules and links.

Results: spatial distribution of the charge







Below the depletion voltage, the average cluster width increases and becomes nearly independent on the inter-strip position of the track.

Results: median charge measurement

module	*Kek11.0*	*Kek11.1*	*Kek22.0*	*Kek22.1*	*Kek3.0*	*Kek3.1*
Qm (fC) TDC cut @ 500/275 V	3.66	3.60	3.50	3.39	3.46	3.58
Qm (fC) CRRC fit @ 500/275 V	3.9	3.8	3.8	3.6	3.8	3.9
Qm (fC) parabolic fit @ 500/275 V	3.77	3.72	3.77	3.60	3.61	3.76
Qm (fC) TDC cut @ 450/200 V	3.68	3.57	3.48	3.42	3.40	3.52
Qm (fC) KEK @ 450/200 V	3.45	3.37	3.27	3.23	3.27	3.38

module	*V166.0*	*V166.1*	*V165.0*	*V165.1*	*CG170.0*	*CG170.1*
Qm (fC) TDC cut @ 500/275 V	3.86	3.64	3.82	3.64	3.77	3.81
Qm (fC) CRRC fit @ 500/275 V	4.0	3.7	4.1	3.9	4.0	4.0
Qm (fC) parabolic fit @ 500/275 V	4.00	3.64	4.03	3.86	3.96	3.95
Qm (fC) TDC cut @ 450/200 V	3.73	3.54	3.82	3.61	3.75	3.81
Qm (fC) KEK @ 450/200 V	3.45	3.52	3.67	3.45	3.61	3.66

Results: charge, efficiency and noise

module	*V166.0*	*V166.1*	*V165.0*	*V165.1*	*CG170.0*	*CG170.1*
Qm (fC) @ 500/275 V	3.86	3.64	3.82	3.64	3.77	3.81
V(efficiency spec) (V)	300	300*	75	75*	75*	75*
Noise at 1 fC	36.8×10^{-4}	30.7×10^{-4}	0.66×10^{-4}	0.62×10^{-4}	0.26×10^{-4}	0.43×10^{-4}

module	*Kek3.0*	*Kek3.1*	*Kek11.0*	*Kek11.1*	*Kek22.0*	*Kek22.0*
Qm (fC) @ 500/275 V	3.46	3.58	3.66	3.60	3.50	3.39
V(efficiency spec) (V)	300	300	75*	75*	75	75
Noise at 1 fC	3.38×10^{-4}	4.29×10^{-4}	0.23×10^{-4}	0.22×10^{-4}	0.25×10^{-4}	0.24×10^{-4}

Conclusions:

- Non-irradiated modules satisfy noise specification.
- Non-irradiated modules satisfy efficiency specification when $V_{bias} > 75V$.
- Irradiated modules satisfy efficiency specification when $V_{bias} > 300V$.
- After irradiation the noise occupancy increases by one (barrel) or two (forward) orders of magnitude.

* If 99 % efficiency is not reached, the voltage at which maximum efficiency is reached is quoted.

Questions:

- Median charge measurement depends on methodology.
- The forward modules find ~ 0.3 fC more charge.

Results Unirradiated modules:

- Ballistic deficit affects median charge in unirradiated modules up to 137 Volts.
- Forward K3 modules seem to have a higher (0.3 fC) and longer (4 ns) pulse than barrel modules with the same chips.
- Around the depletion voltage ($\sim 80V$) the length of the shaper pulse increases rapidly.

Results Irradiated modules:

- Partially depleted operation results in long pulses.
- The pulse length has increased for barrel and forward module, when compared to unirradiated modules.
- Below depletion the spatial distribution of the charge changes.