Results from the 1999 ATLAS-SCT beam tests

- LHC - ATLAS - SCT
- Introduction test beam
- Efficiency/noise results
- Detector bias - ballistic deficit
- Conclusions

H8 results published as ATL-INDET-2000-004

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KEK results presently being analyzed

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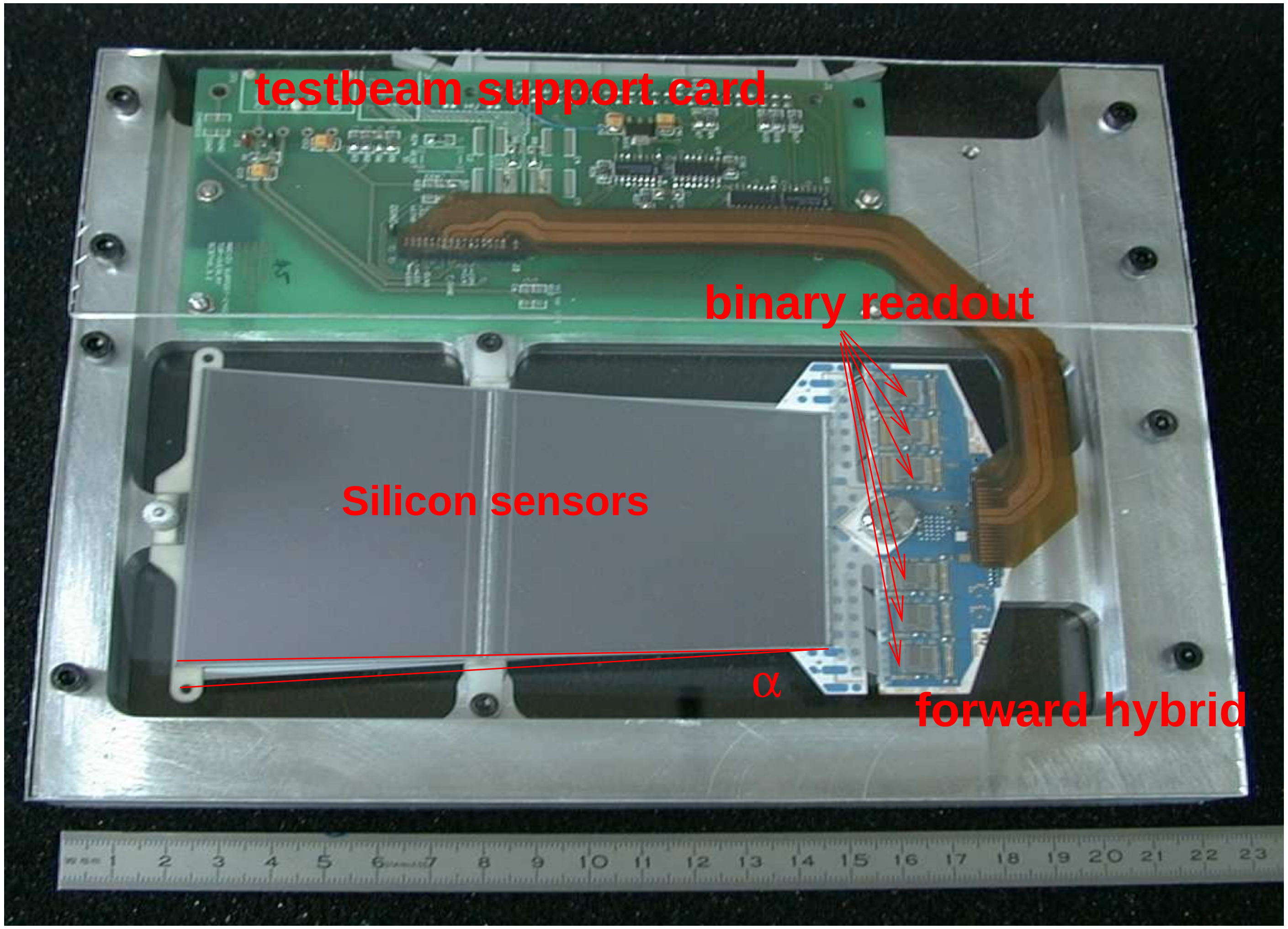
IFIC

A forward SCT module: VAL-2



BiCMOS:

ABCD

OR

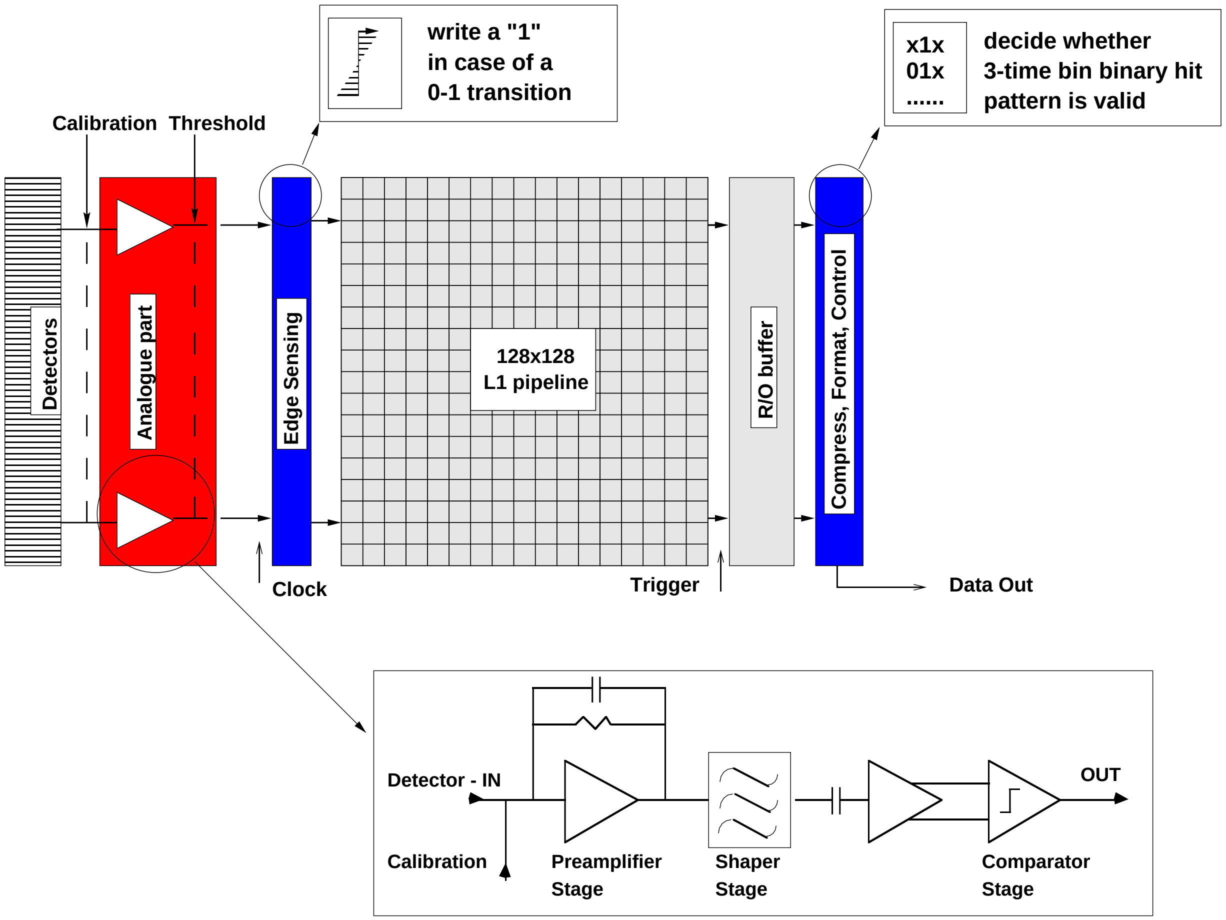
bipolar:

CAFE/P

&

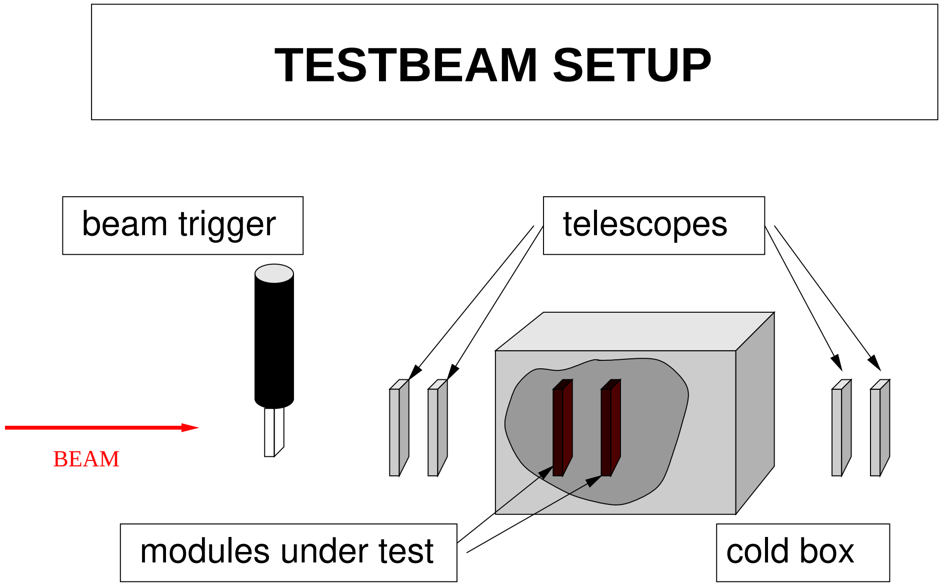
CMOS:

ABC



SCT binary Front End electronics

SCT "standard" test beam setup



DUT performance is compared to information from:

- Beam triggers (scintillators $\rightarrow$ TDC)
- Analog telescopes (Silicon stripts $\rightarrow$ VIKING $\rightarrow$ IRAMs)
- An anchor module

H8 test beam August 99

180 GeV pions in H8 beamline, SPS, CERN

- ABC1[a] : 325 μm, 6 CAFE/P + ABC
- CGNT1[b] : 325 μm, 6 ABCD2NT
- CGT1[b] : 325 μm, 6 ABCD2T

KEK test beam December 99

4 GeV π^- in $\pi 2$ beamline, 12 GeV PS, KEK

- KEK-ABCD1[c] : 285 μm, 12 ABCD2T
- KEK-ABCD2[c] : 325 μm, 12 untrimmed ABCD2T
- KEK-CAFE1[c] : 285 μm, 12 CAFE/P-ABC
- FR-ABCD[d] : 285 μm, 12 ABCD2T
- FR-IRRAD1[d] : Irradiated detector, 2 ABCD2T

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[a] built at LBNL, Berkeley
[b] built at the University of Geneva
[c] built at KEK, Tsukuba
[d] built at Freiburg University

Data

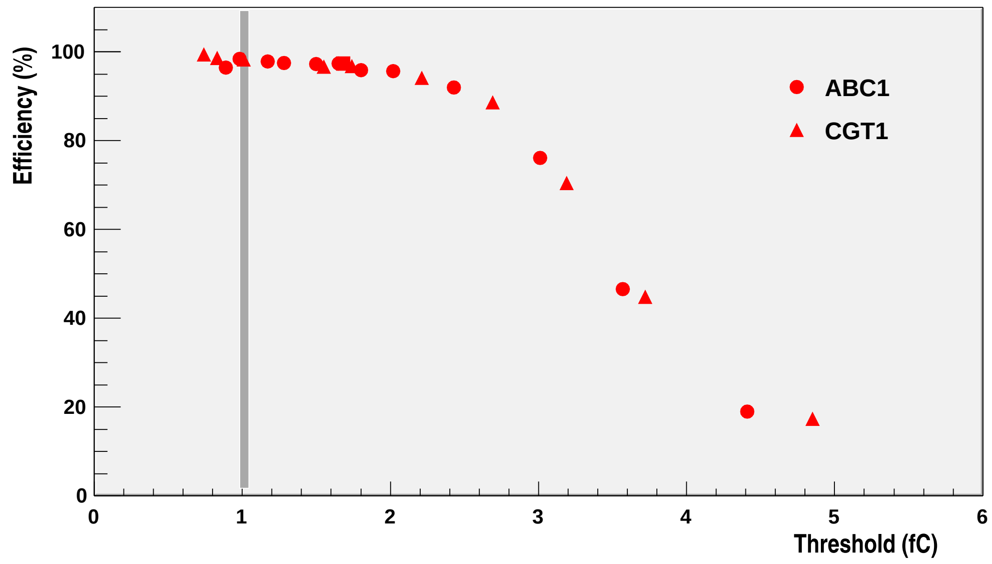
- Threshold Scans with Edge Sensing Circuit **ON/OFF** and 80 and 240 V bias voltage (**H8**)
- Threshold Scans with Edge Sensing Circuit **ON** at 60, 80, 100, 120, 140, 160, 180, 200 V bias **KEK**)
- Online, all hits are read out, in order to maximize timing information
- Offline, when calculating efficiency and noise, only hits in central time bin are accepted
- $\rightarrow$ Bias voltage affects the charge collection time in the Silicon:

$$T \sim \frac{d^2}{\mu V_{bias}}$$

80 Volt: 27 ns

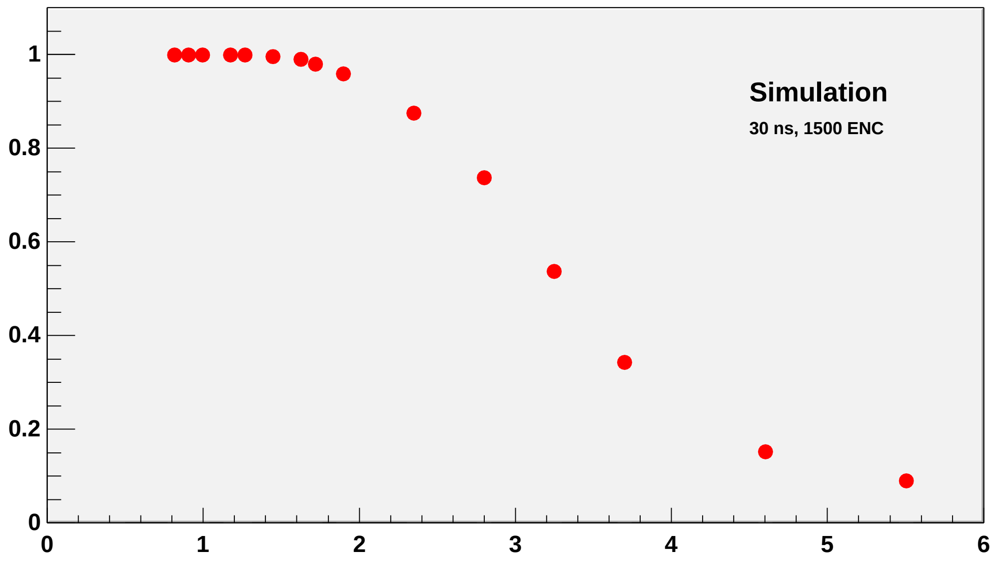
240 Volt: 9 ns

Efficiency versus threshold, edge ON, 240 V



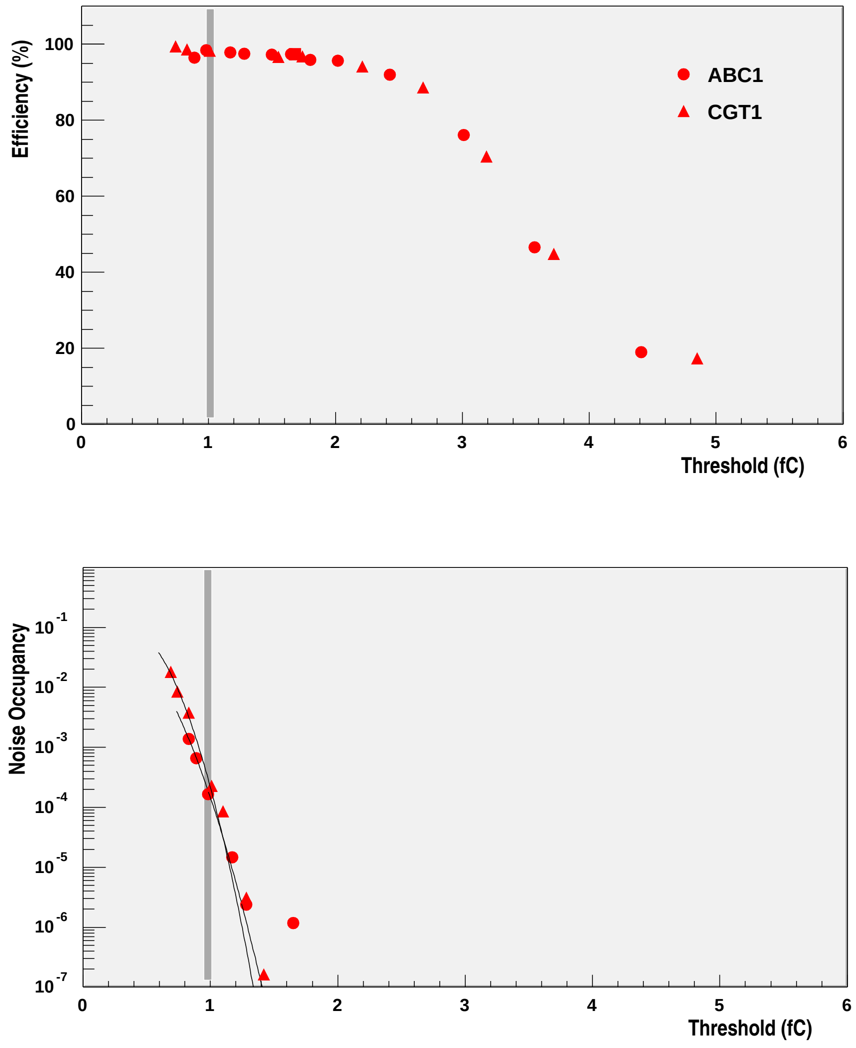
- Compare binary information to telescope prediction
- Only central time bin considered
- Narrow TDC interval for each threshold

Efficiency versus threshold, edge ON, 240 V



- Landau charge distribution + noise
- Inefficiency due to timing taken into account
- No ballistic deficit

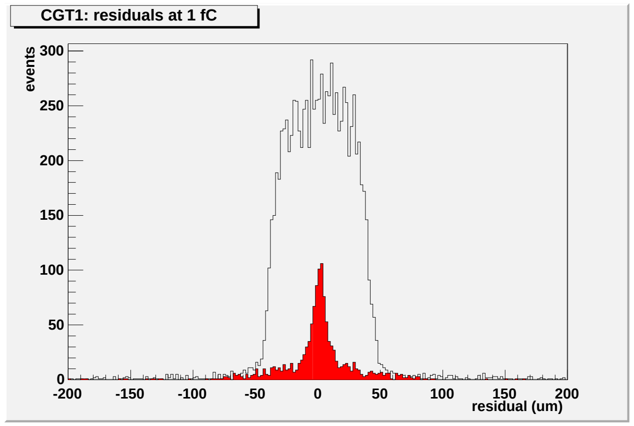
Efficiency vs. Noise



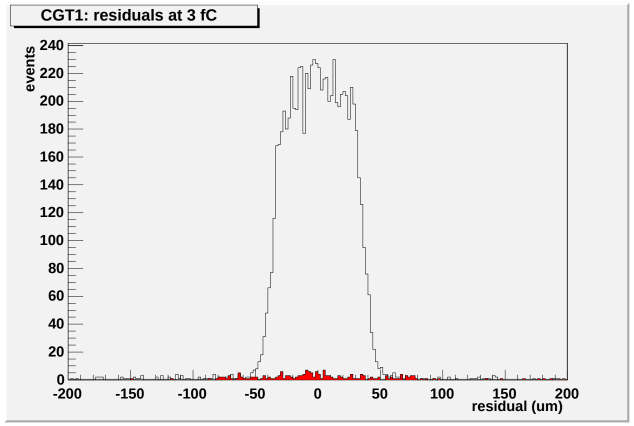
- **Efficiency** at 1 fC (for a narrow TDC interval) $> 99\%$
- **Noise occupancy** (from events taken between spills) $< 10^{-4}$
- 240V, edge ON, bad channels rejected

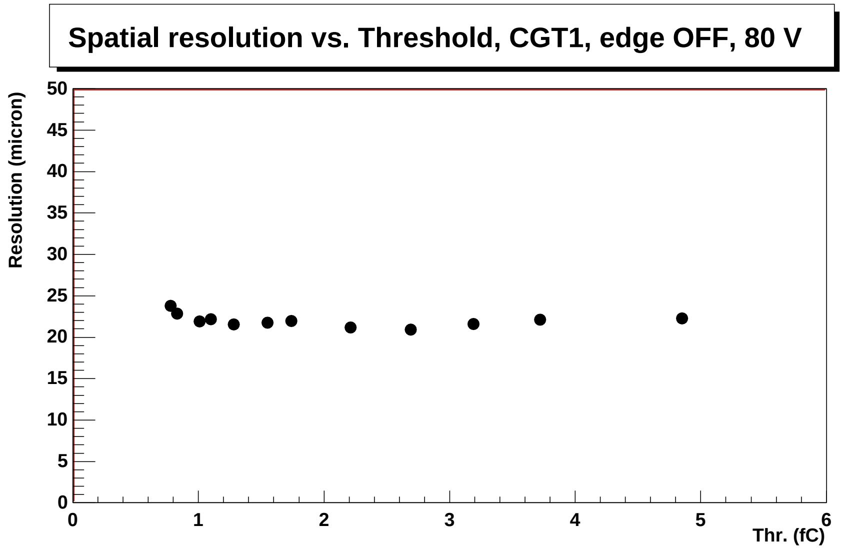
SCT requierements are met by both FE types

Residuals at 1 fC ...



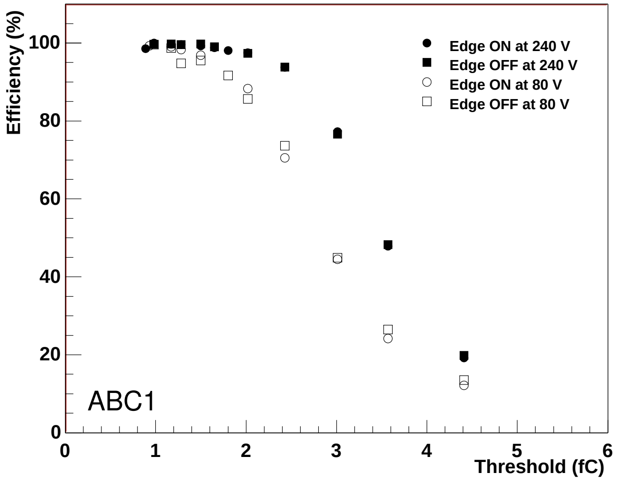
and 3 fC (CGT1)

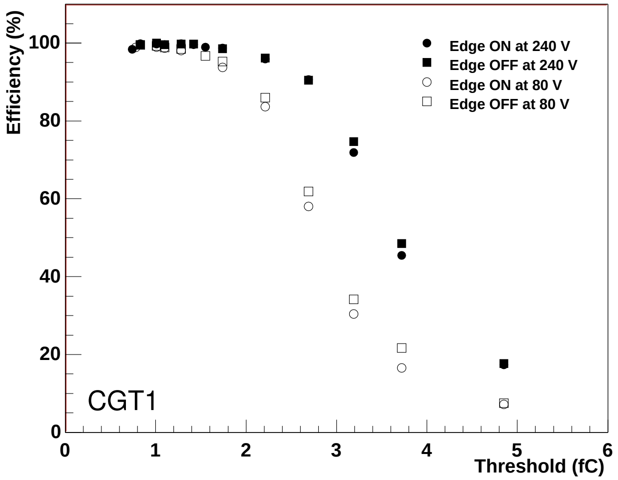




Spatial resolution $\sim$ 23 μm, nearly independent of discrimination threshold

Bias voltage affects tracking efficiency

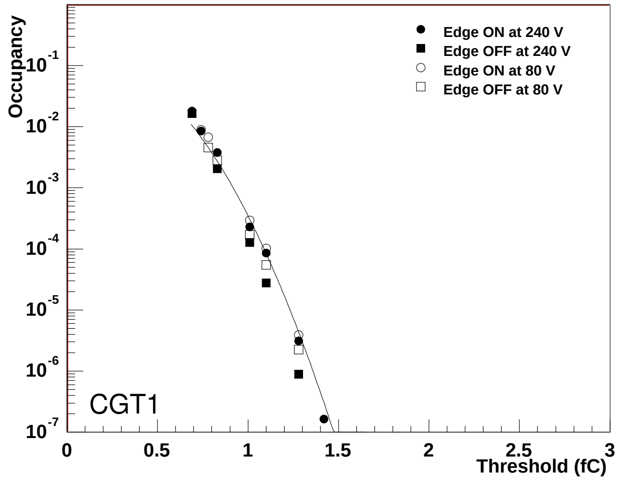




Ballistic deficit

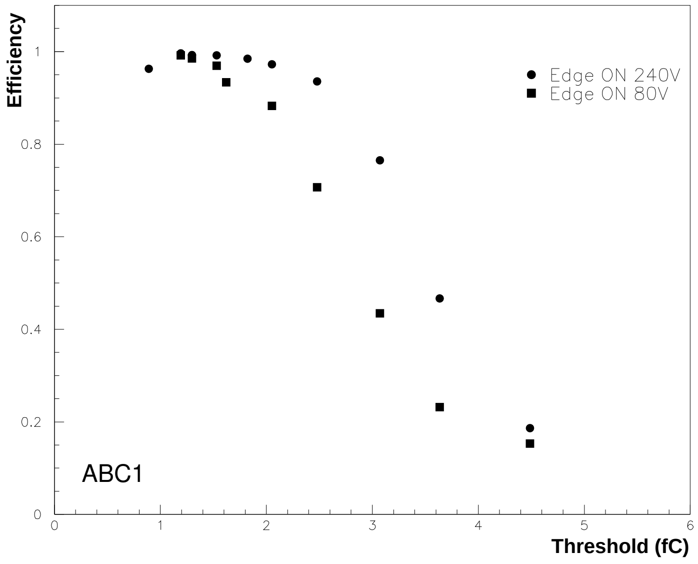
$\rightarrow$ Slow charge collection with respect to shaper peaking time causes charge loss

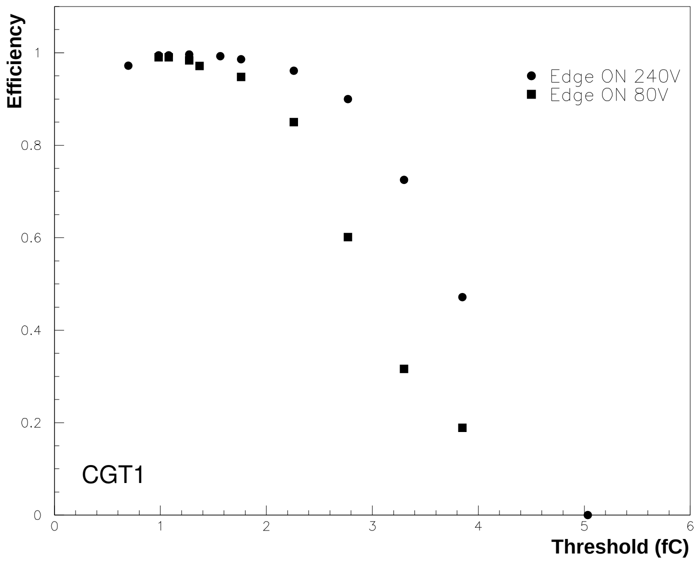
No effect on noise



Binary only analysis

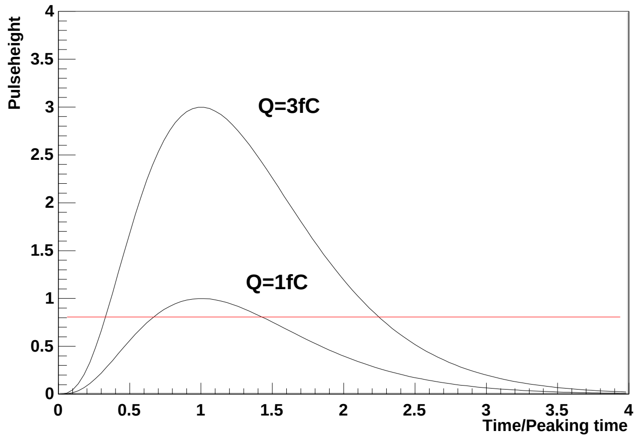
- Information from telescopes and TDC not used
- Tracks reconstructed from other binary modules + reference
- Inherently less sensitive to residual inefficiencies
- Fast $\rightarrow$ high intensity beams

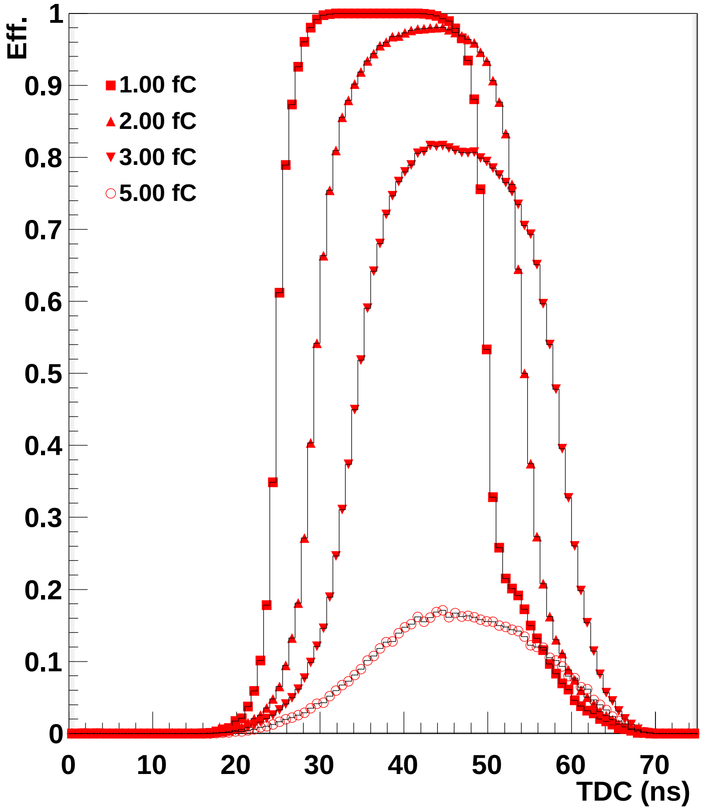




Monte Carlo Simulation

- Landau charge distribution
- Analysis equivalent to real data
- Shaper described as ideal third order CRRC
- Assuming δ function input pulse !!





Timing Results: efficiency versus TDC - CGT1

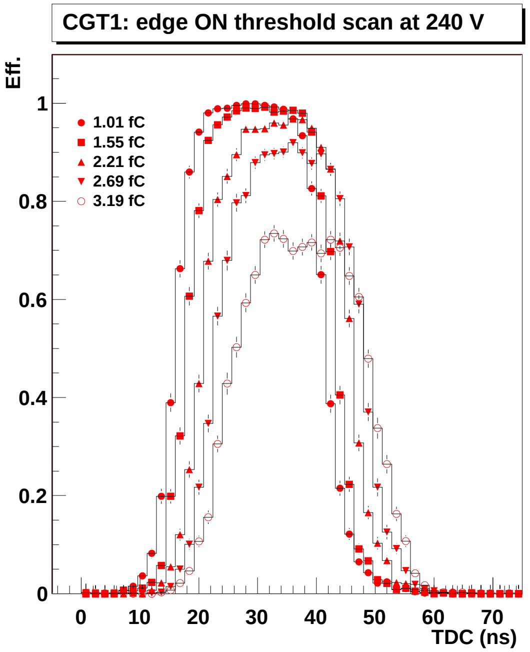


Figure 1: Edge ON, 240 V: edge sensing effectively limits shaper pulse length to 25 ns

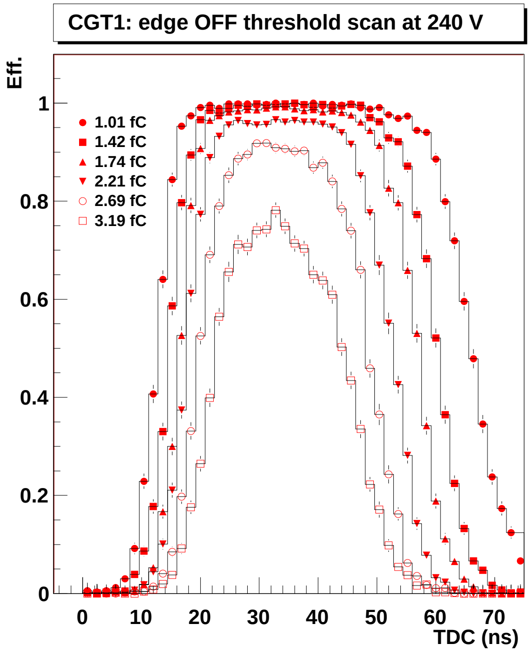


Figure 2: Edge OFF, 240 V: tail of pulse shape visible → semi-Gaussian

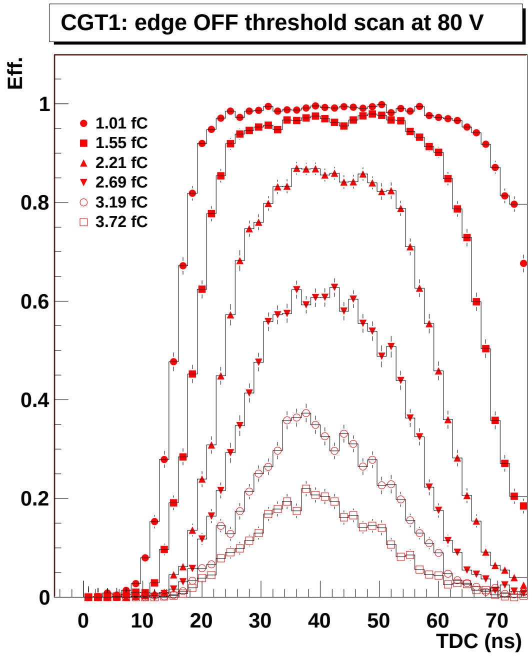


Figure 3: Edge OFF, 80 V: similar but stretched shaper pulse w.r.t. 240 V

Timing Results: efficiency versus TDC - ABC1

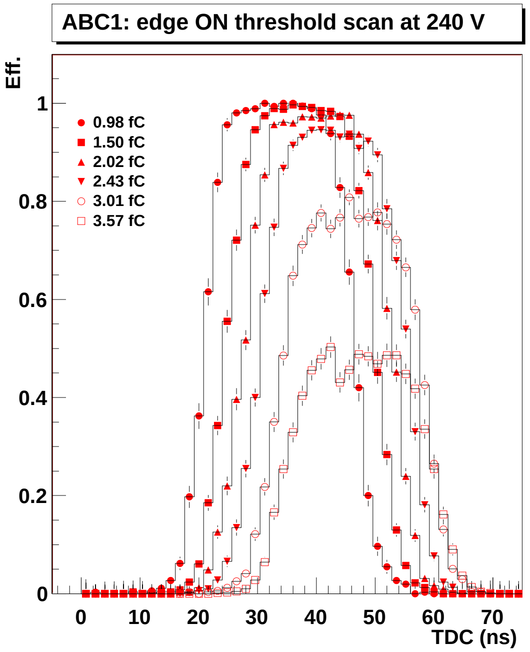


Figure 4: Edge ON, 240 V: edge sensing effectively limits shaper pulse to 25 ns

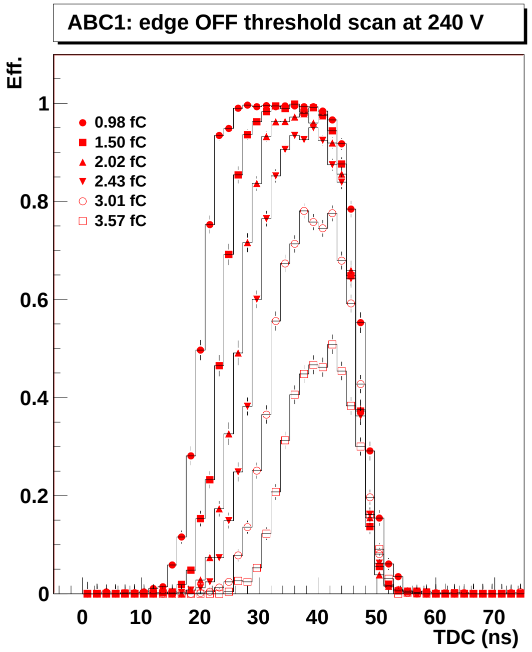


Figure 5: Edge OFF, 240 V: entire pulse shape visible, fast fall-off not well understood

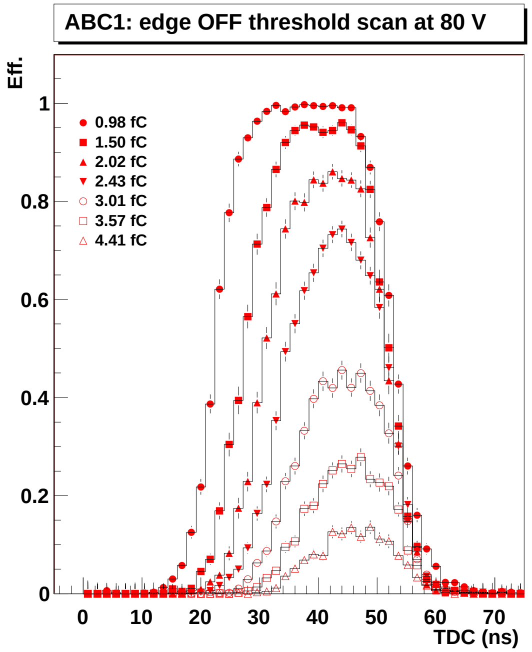
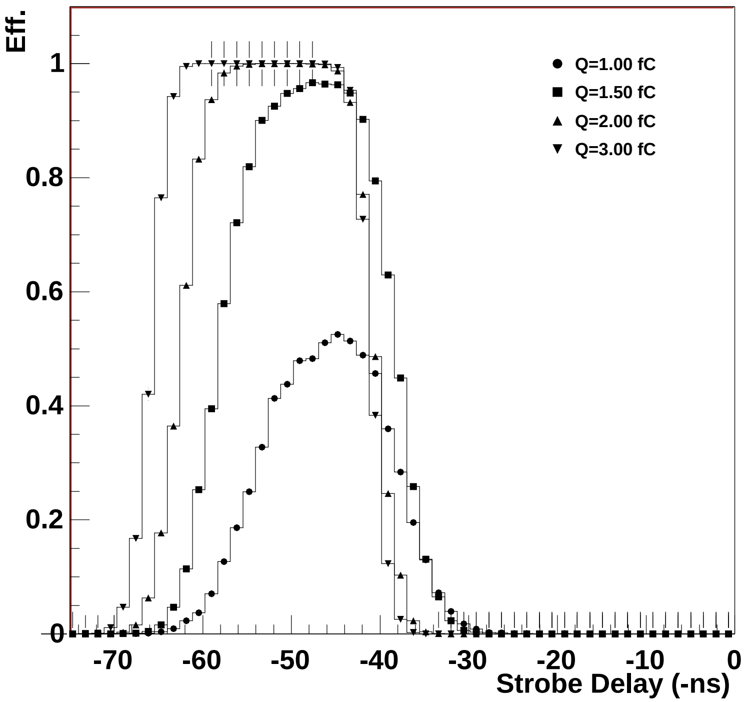


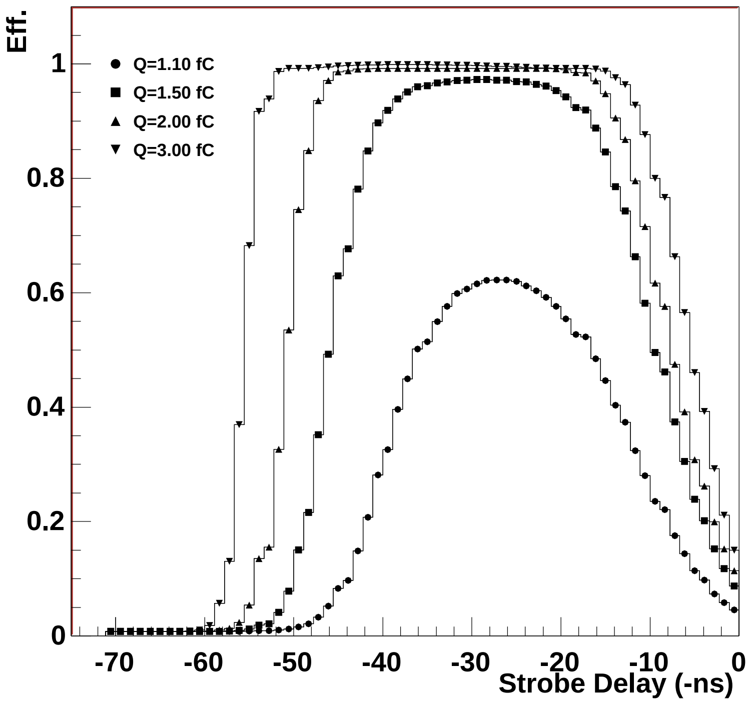
Figure 6: Edge OFF: shaper pulse stretched in 80 V data w.r.t. 240 V

Laboratory: efficiency versus strobe delay

CAFE/P+ABC

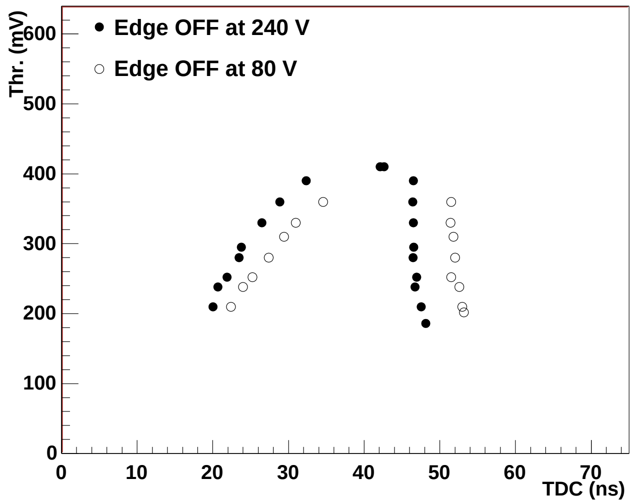


ABCD2T

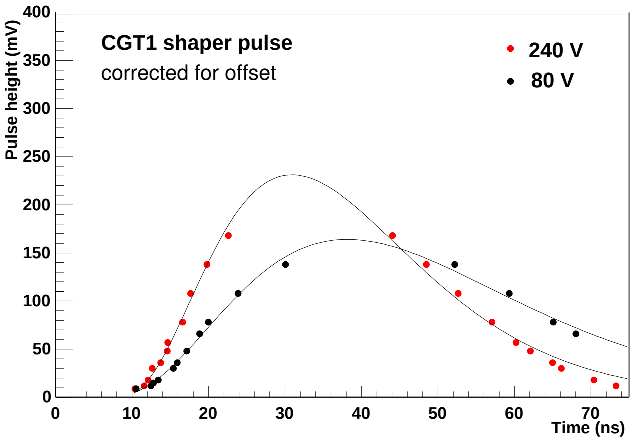


- Varying charge at fixed threshold of 1 fC
- Negative strobe delay plotted

ABC1



CGT1



Ballistic deficit in $CRRC^3$ shapers:

Effective peaking time[a]

$$t_m = \frac{T}{1 - e^{-T/\tau}}$$

240 V: t_m = 30 ns

80 V: t_m = 41 ns

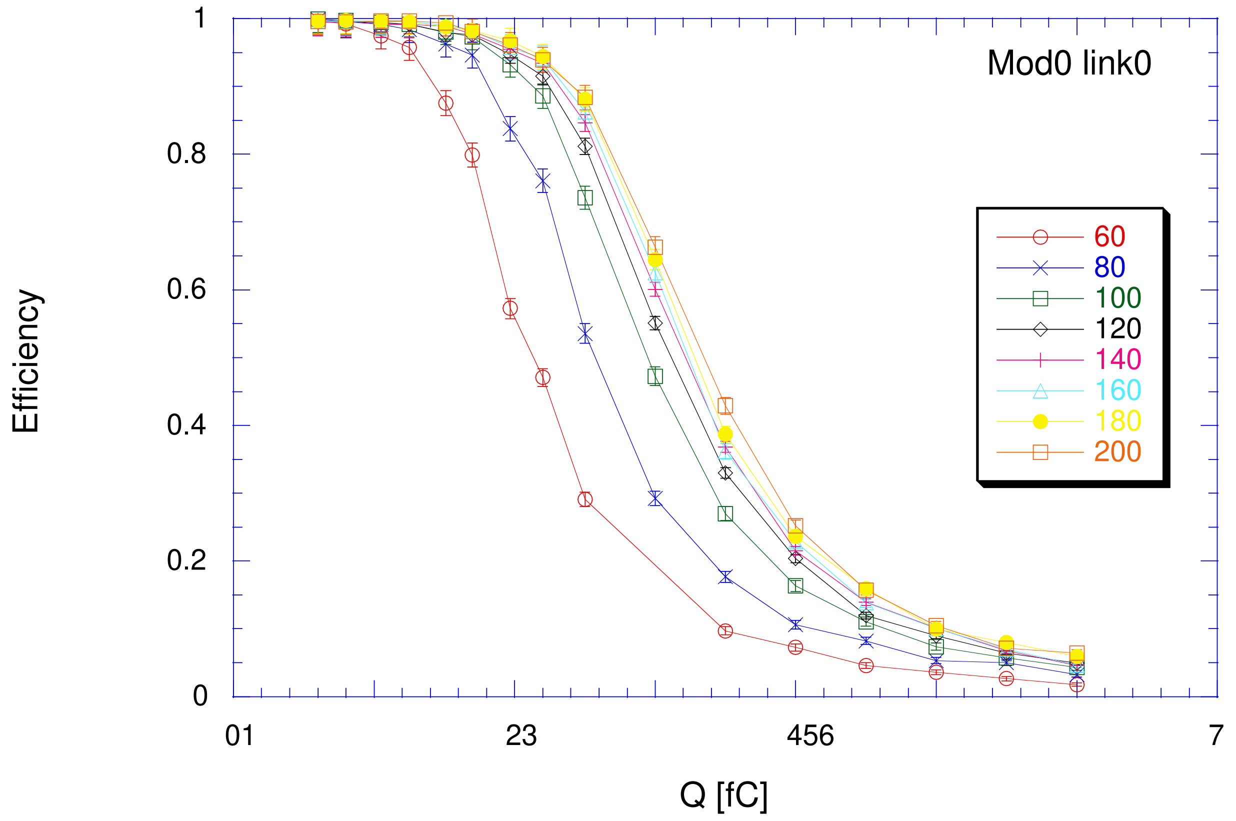
Amplitude loss (relative ballistic deficit):

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

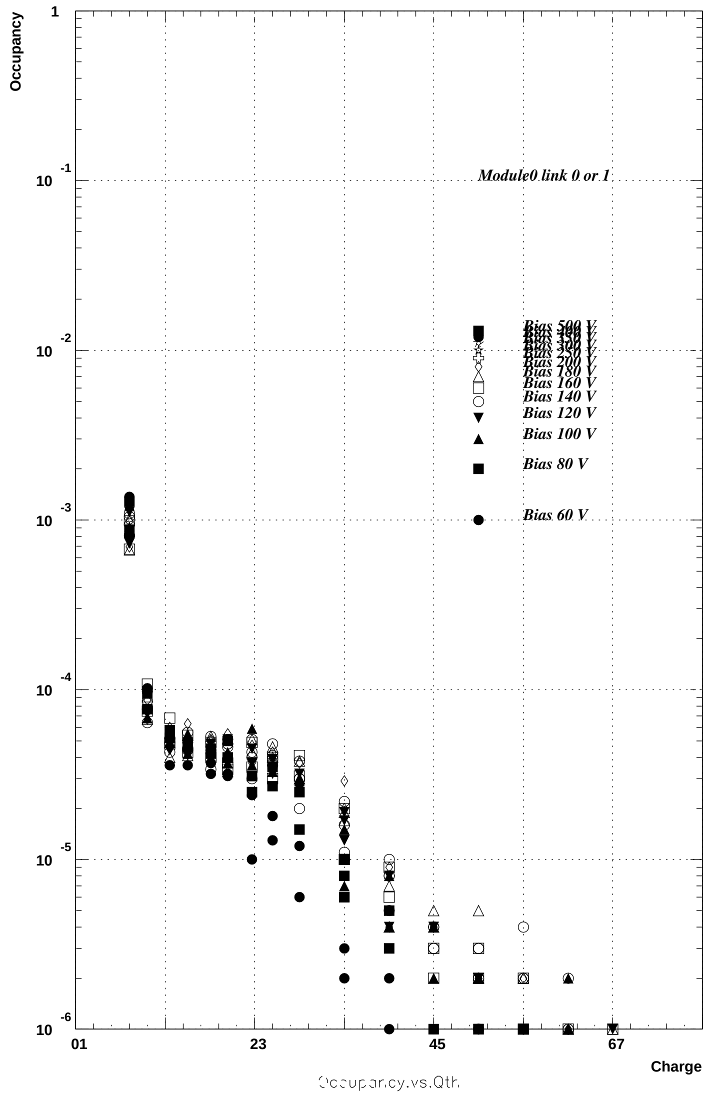
240 V: RBD = 1.6 %

80 V: RBD = 15 %

Efficiency dependence on bias voltage

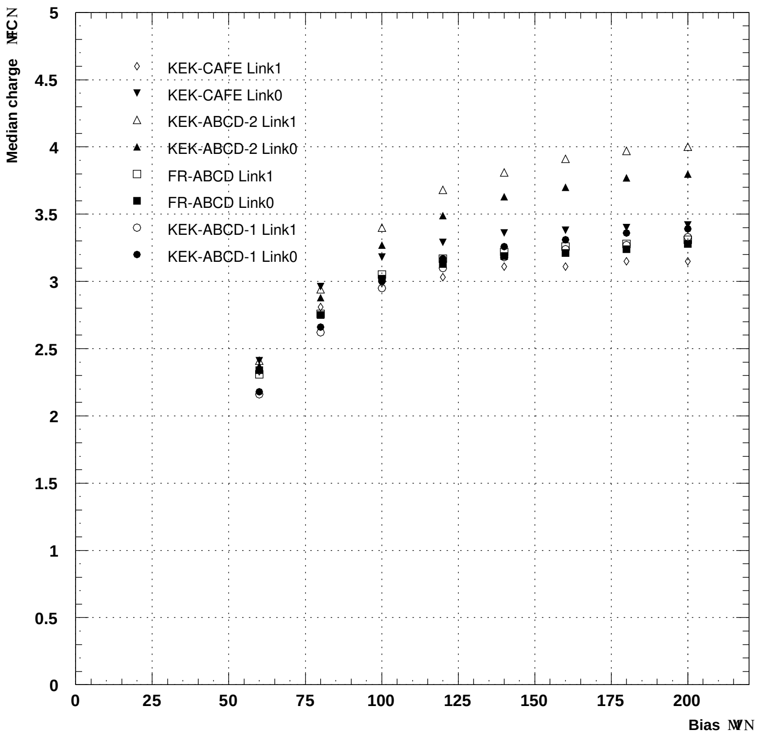


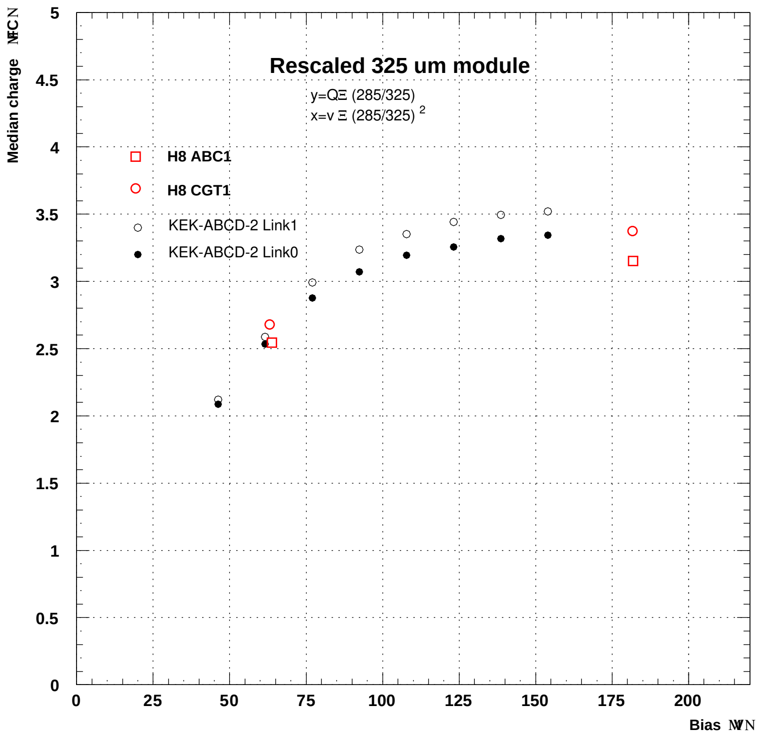
KEK-ABCD1 module



KEK-ABCD1 module

Median pulse height versus bias voltage





- Median pulse heights were extracted from S-curves 50% points
- Charge and Voltage were corrected for 325 μm thick detector
- All points are consistent to within (calibration uncertainty)
- Saturation (unirradiated) for $\sim$ 120 V

Summary of Results

- Two beam tests find all SCT prototype (half) modules, equipped with two kinds of FE electronics, to provide the required efficiency $> 99\%$ and noise occupancy $< 10^{-4}$, at sufficiently high detector bias voltage
- Noise figures consistent with laboratory measurements, typically around 1400-1500 ENC
- Ballistic deficit effect observed at low detector bias voltage in efficiency and confirmed by shaper pulse reconstruction
- Preliminary: Approximately 50 V over depletion needed for full charge integration