Non-standard geometry scaling effects

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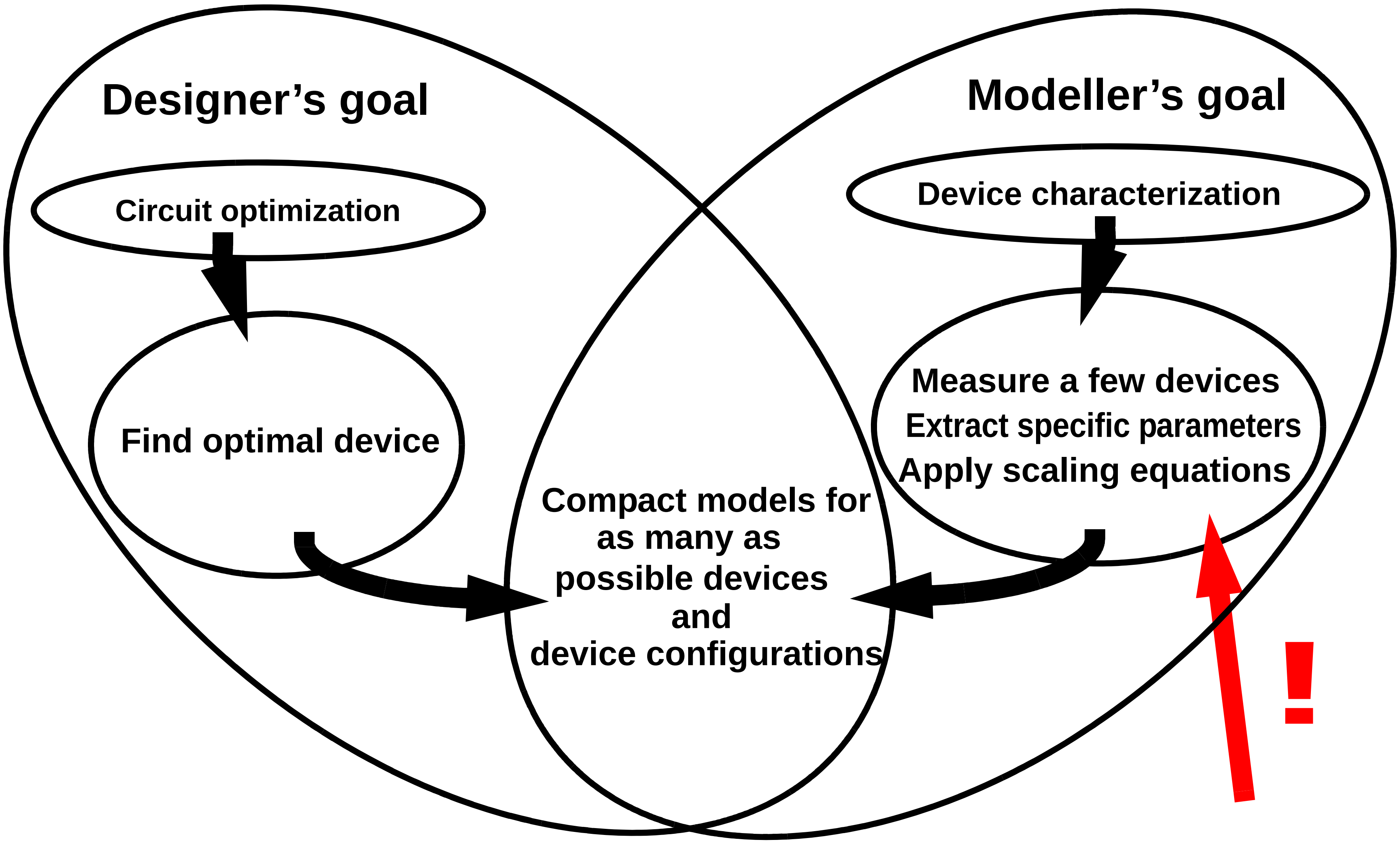
Outline

- Motivation for investigations
- Reference profile
- Variations of the reference profile
- Results for electrical characteristics and FOMs (f_T, I-V, ...)
- Summary

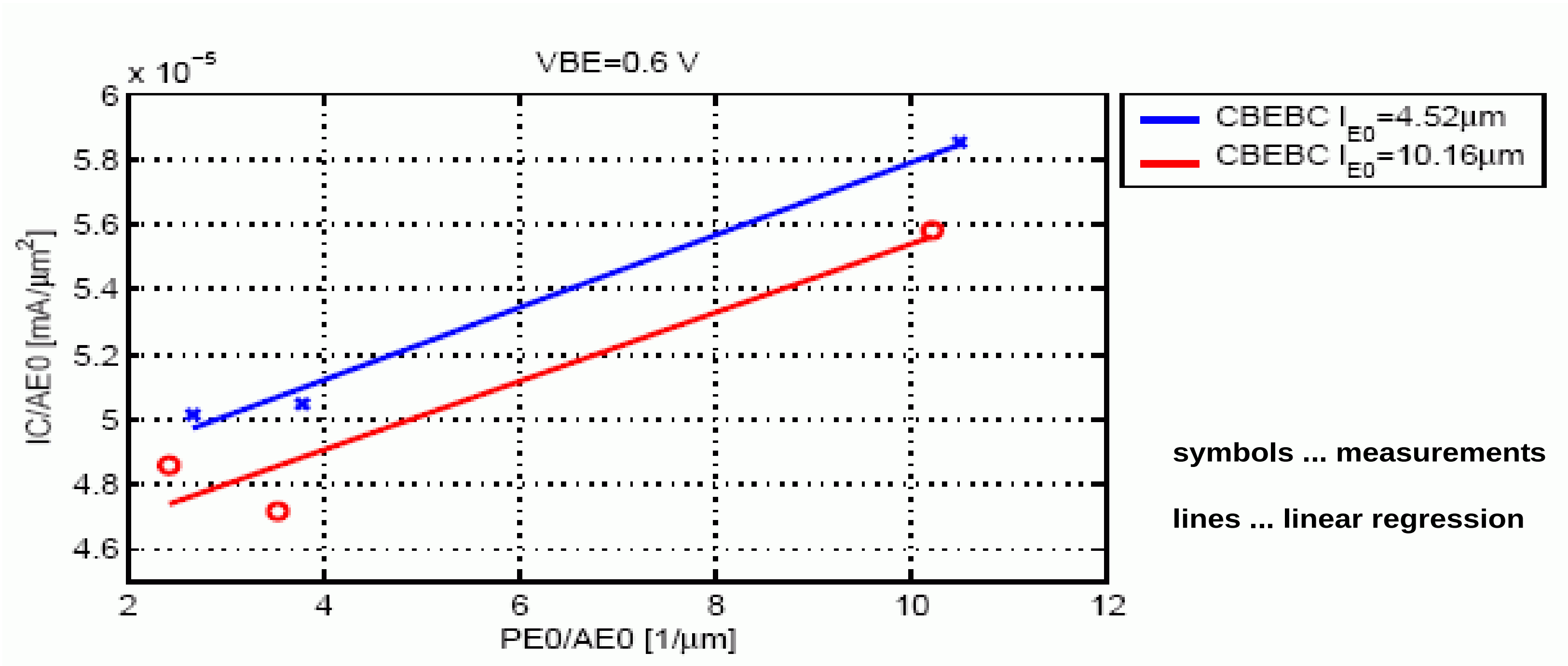
Motivation for investigation



Measurements of some advanced process technologies show deviations w.r.t. conventional scaling equations.

Motivation for investigation

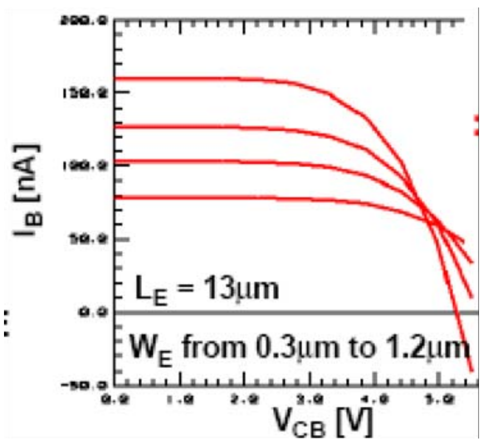
measurements of scaling of collector current

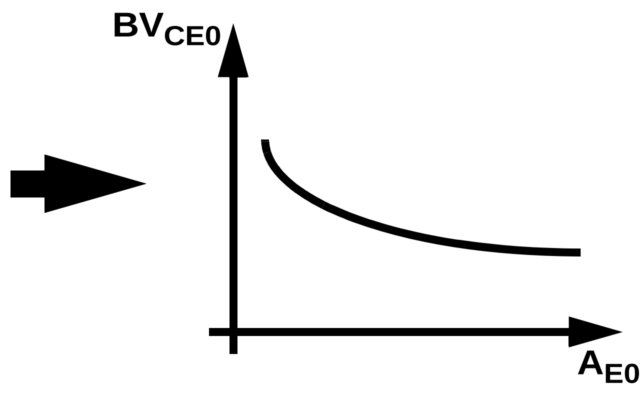


symbols ... measurements

lines ... linear regression

measurements of scaling of breakdown voltage

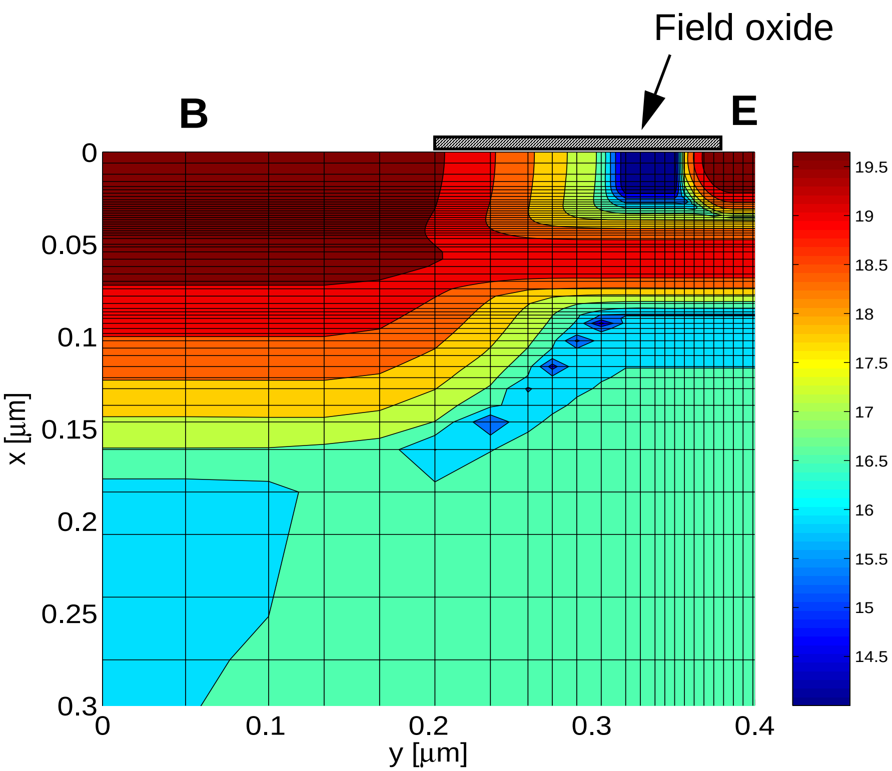


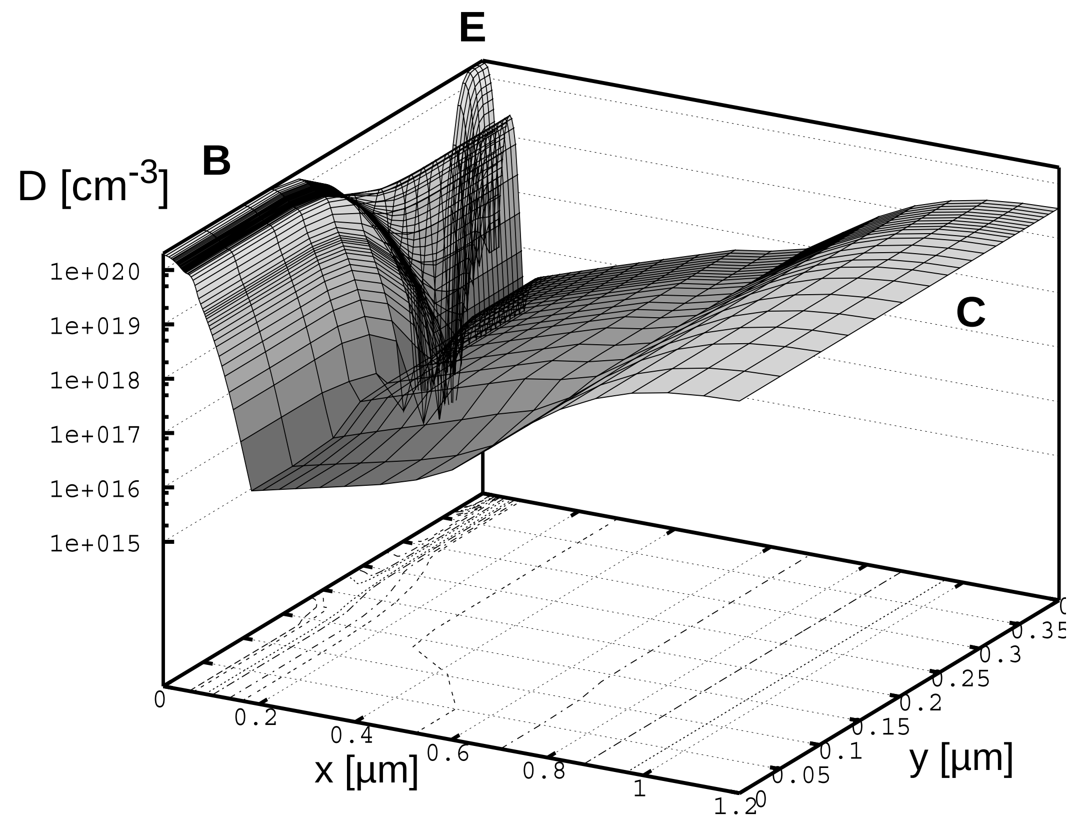


Reference profile

Reference profile based on SIMS measurements (in the following => Standard):

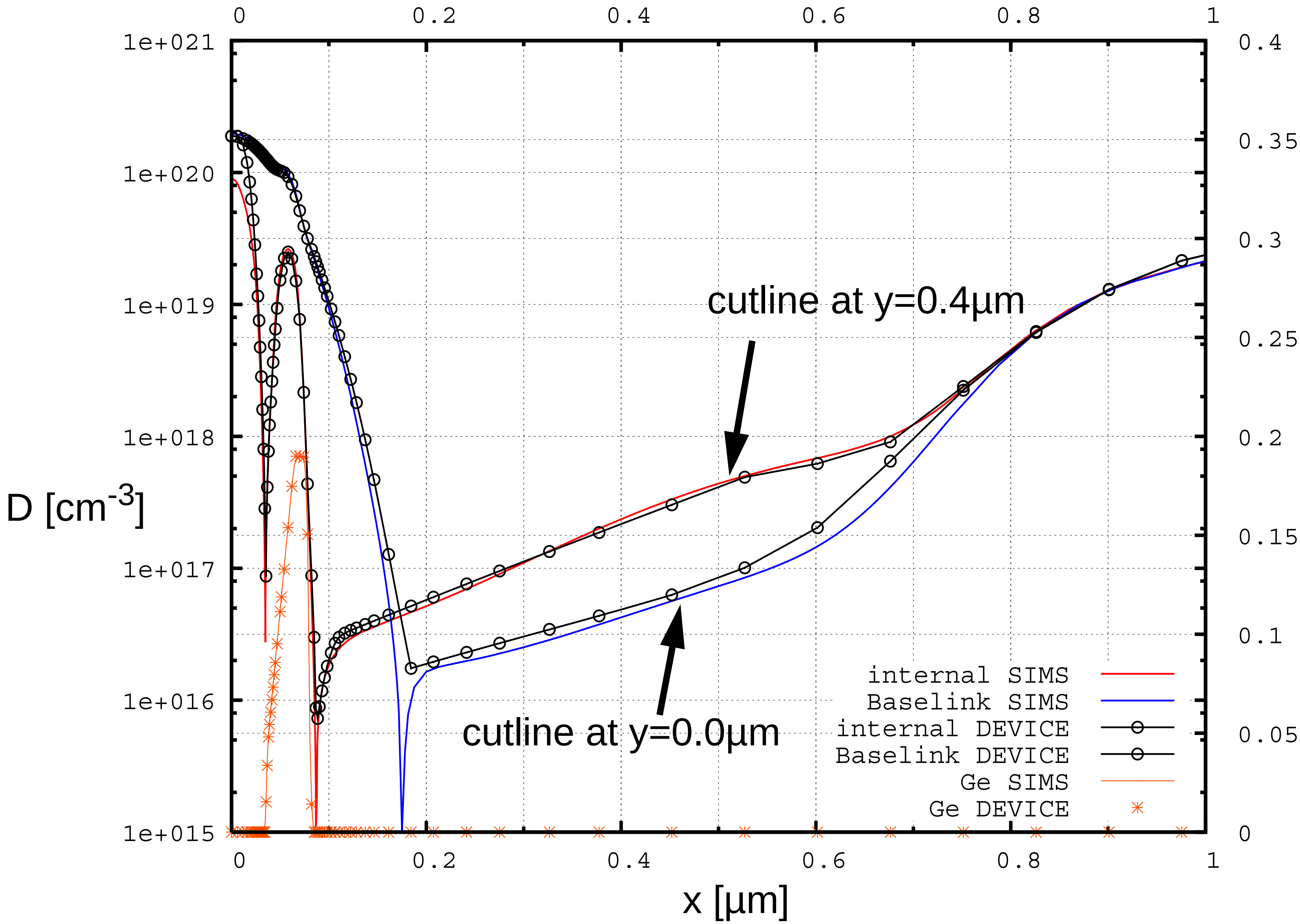
- Non-selective epitaxy (Ge-profile lateral constant)
- Doping of the internal transistor is laterally constant
- Simulated emitter widths: b_{E0}=[0.25 0.45 0.65 1.05 1.45]µm



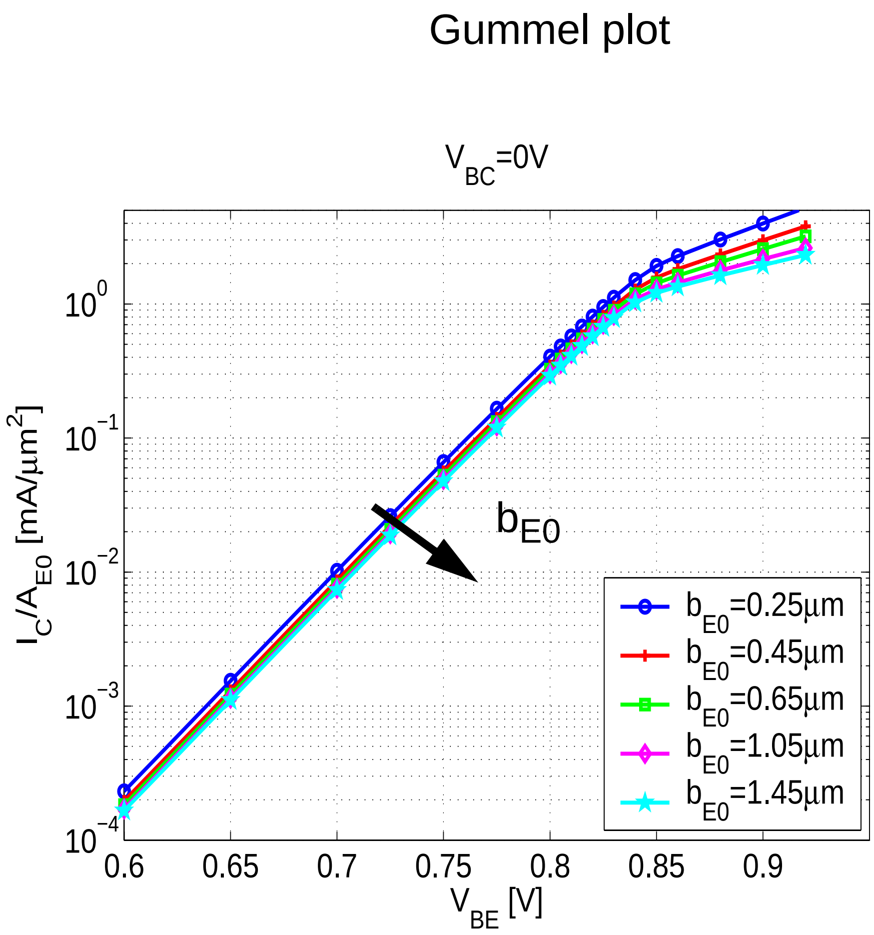


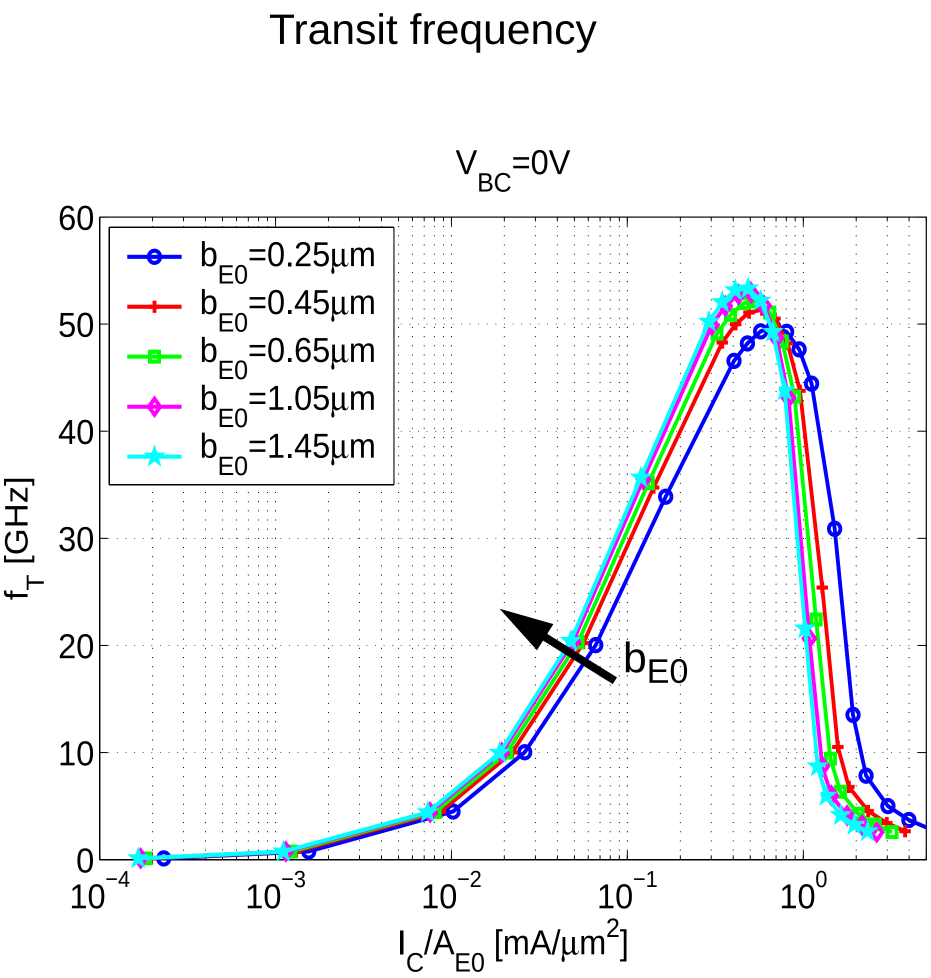
=> obeys standard scaling rules

Reference profile



Reference profile





Variations of the reference profile/1

Variations of doping with emitter width ($b_{E0,nom}$=0.65µm):

Base-emitter junction depth increases/decreases with emitter width (Depthvar1/Depthvar2)

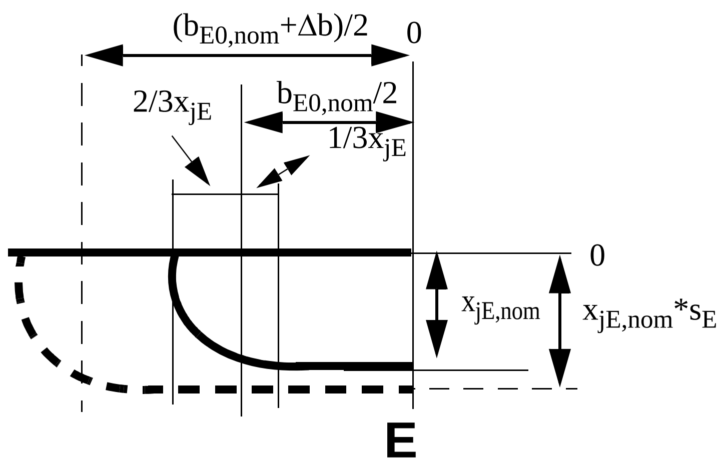
SIC width increases with emitter width (SICvar1)

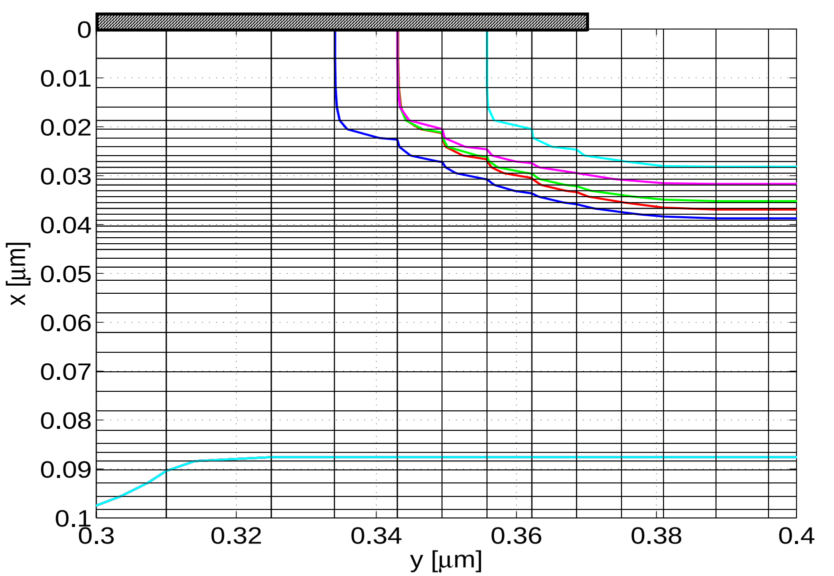
Depthvar1:

$$s_E = \frac{0.05}{0.2}\Delta b$$

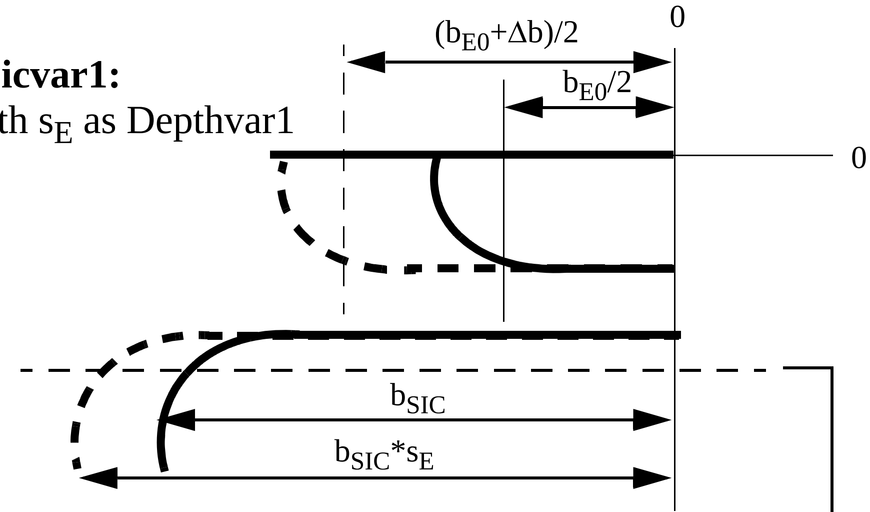
Depthvar2:

$$s_E = -\frac{0.05}{0.2}\Delta b$$

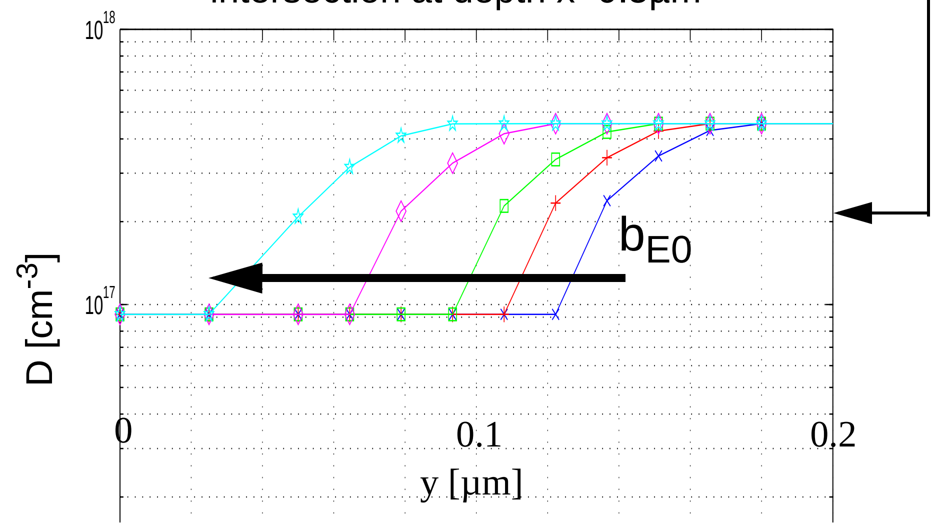




Sicvar1:
with s_E as Depthvar1



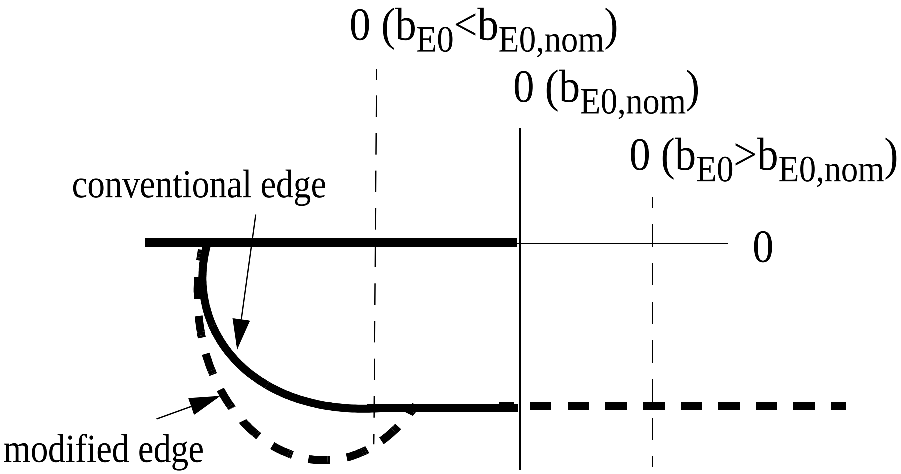
intersection at depth x=0.5µm

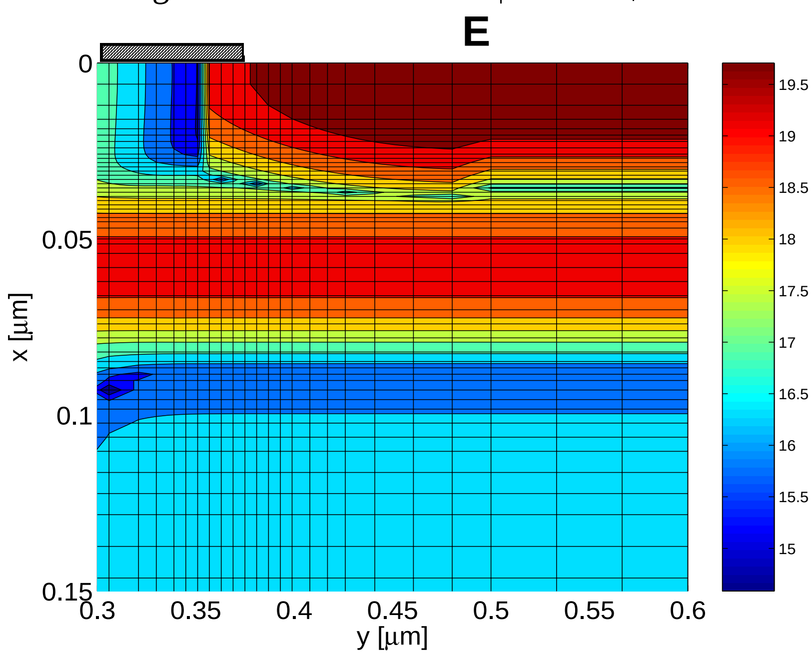


Variations of the reference profile/2

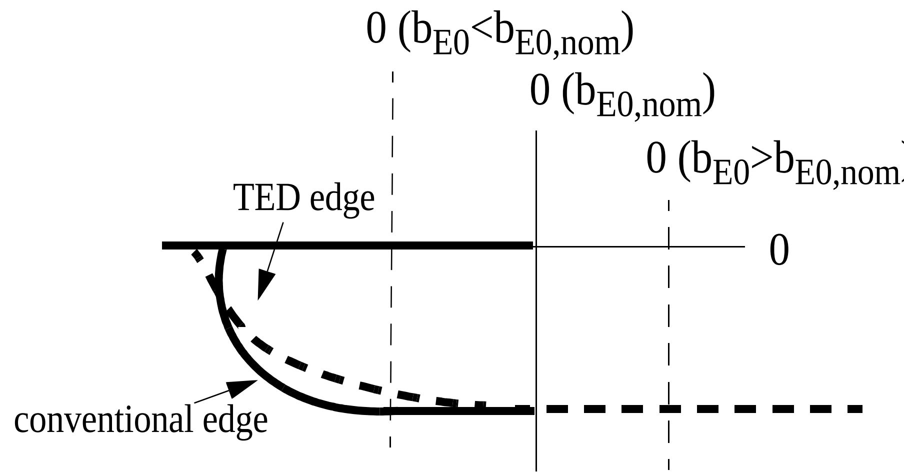
Non-standard lateral doping

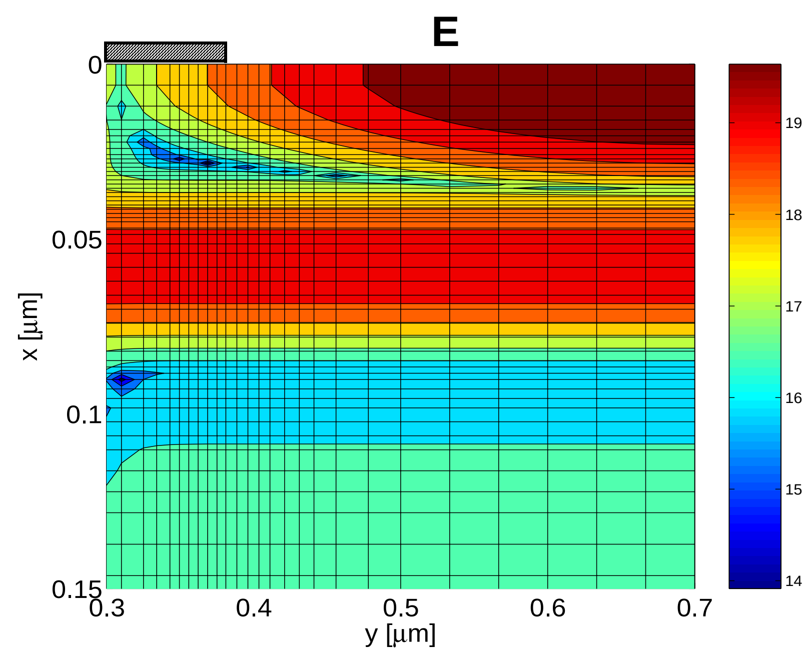
Increased edge doping due to fast poly edge diffusion (Polyvar)





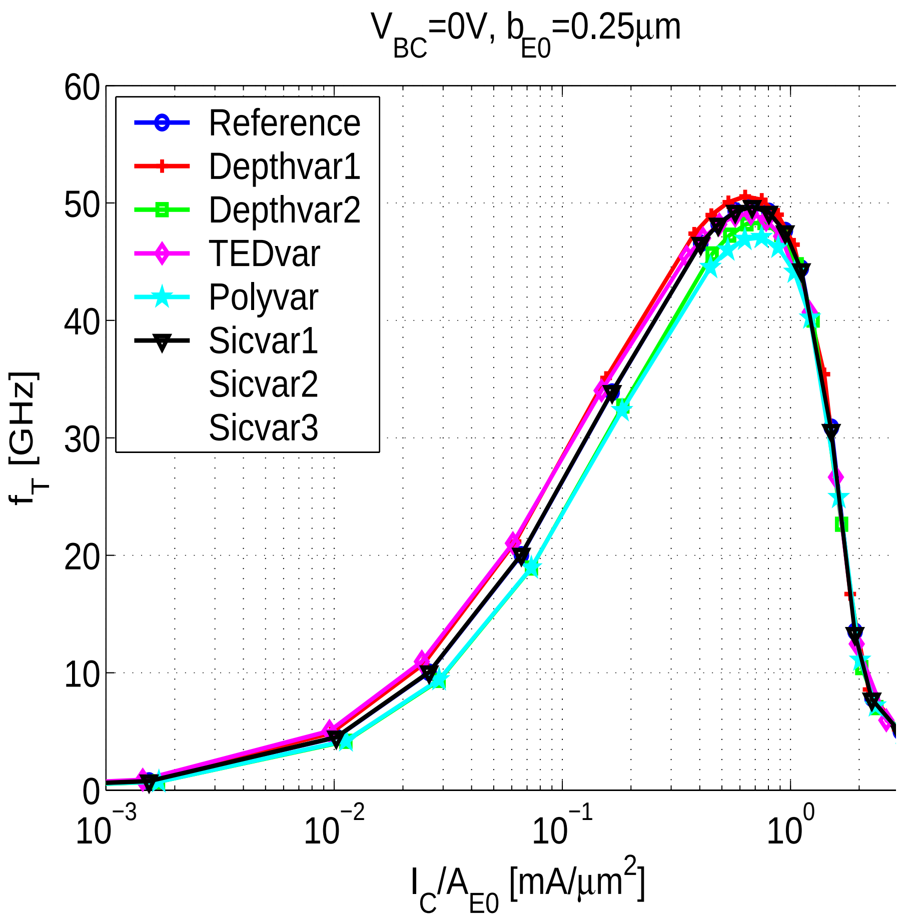
Transient enhanced diffusion (TEDvar)

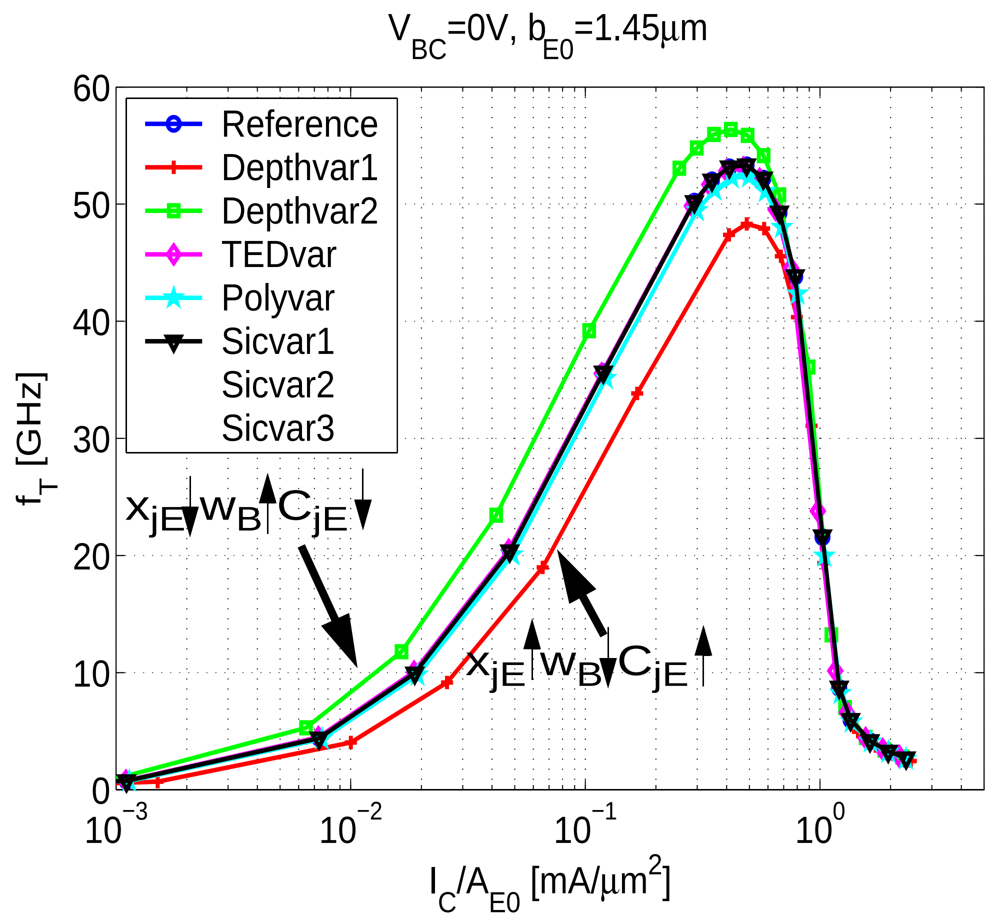




Results - Transit frequencies

- Large influence on transit frequencies for Depthvar1 and Depthvar2
- For small emitter width Polyvar shows the same behavior as Depthvar2 (smaller neutral base width, higher doping at BE junction => larger BE junction capacitance)
- For small emitter width TEDvar shows the reverse effect as Polyvar (wider neutral base width, lower doping at BE junction => smaller BE junction capacitance)
- For larger emitter width the variations of the edge doping (Polyvar, TEDvar) show decreased deviations w.r.t. reference profile

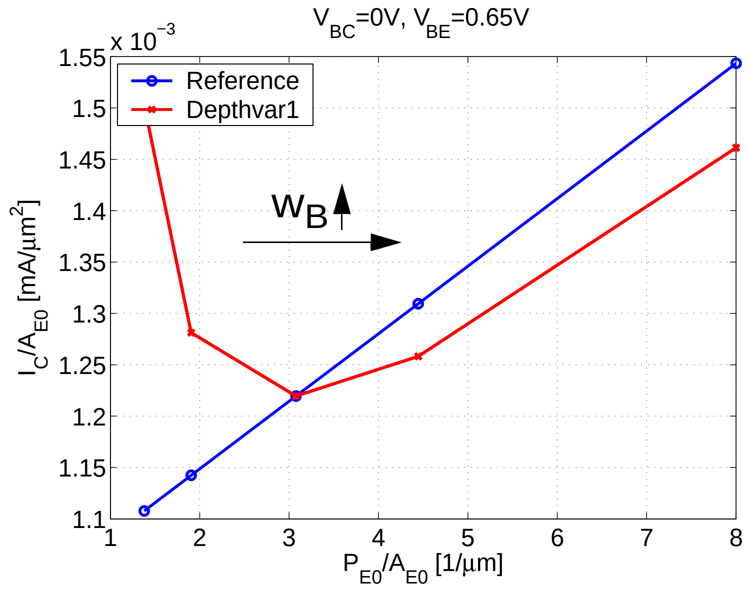


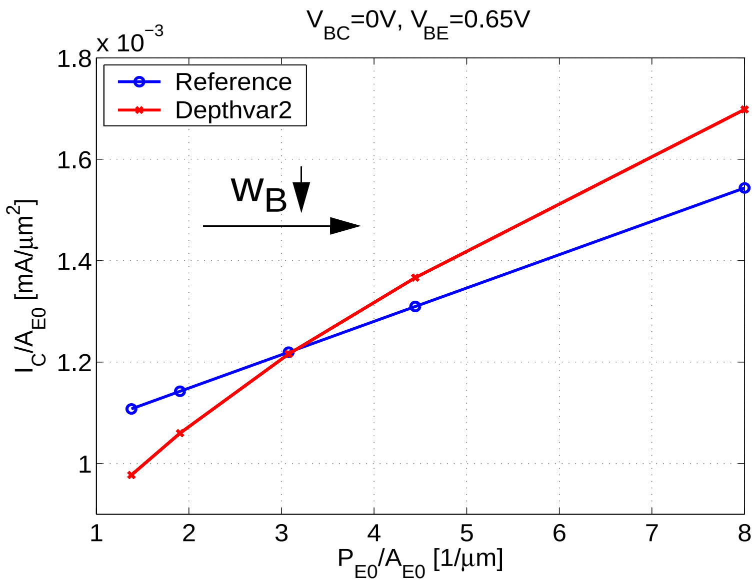


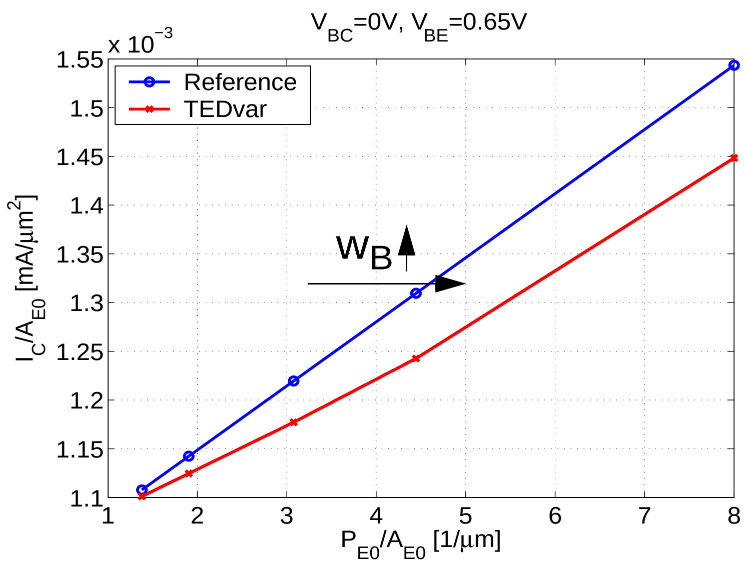
Results - Collector current

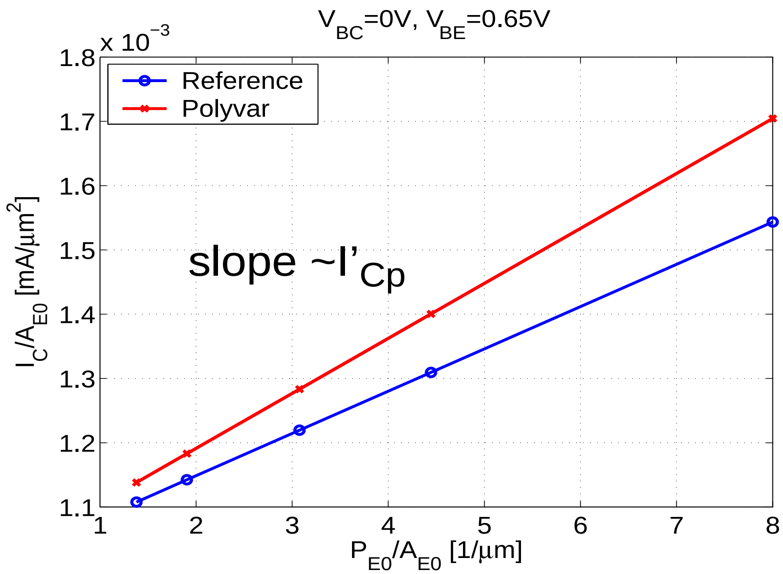
Standard method for perimeter-area separation

- Polyvar and Sicvar1 still show linear scaling behavior





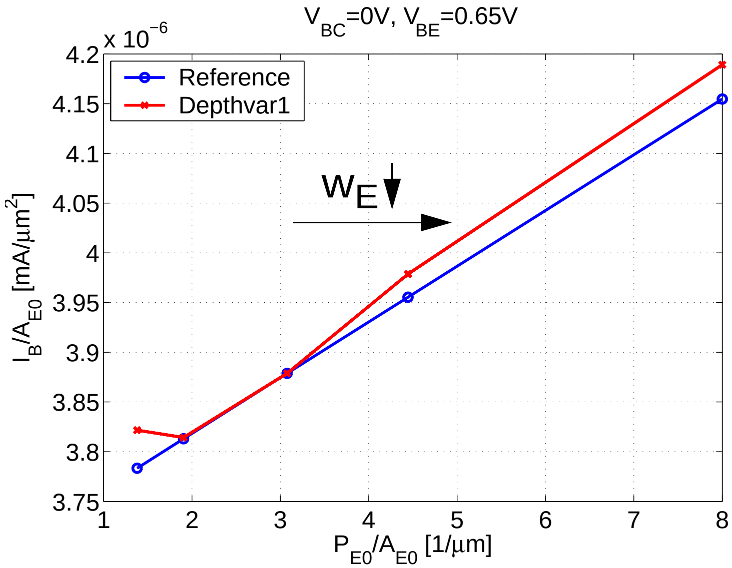


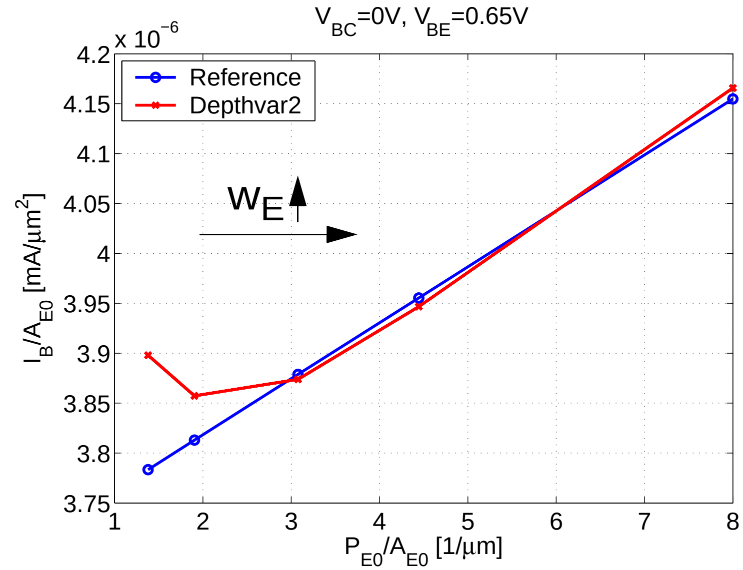


Results - Base current

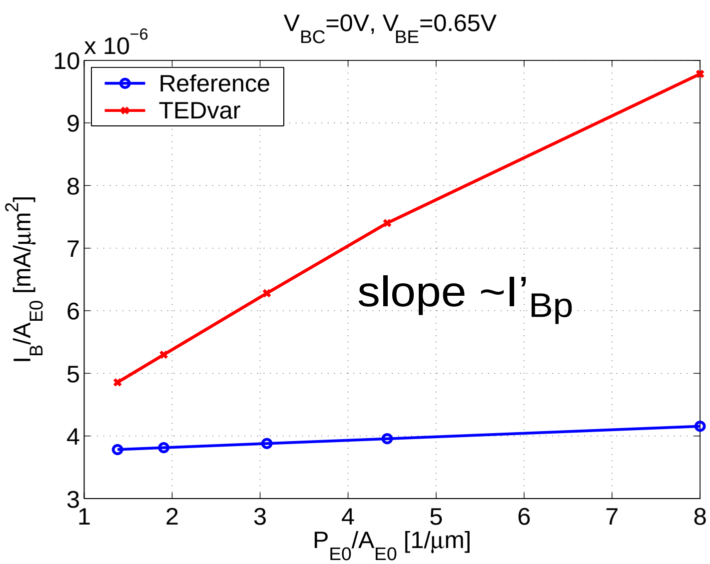
Standard method for perimeter-area component separation

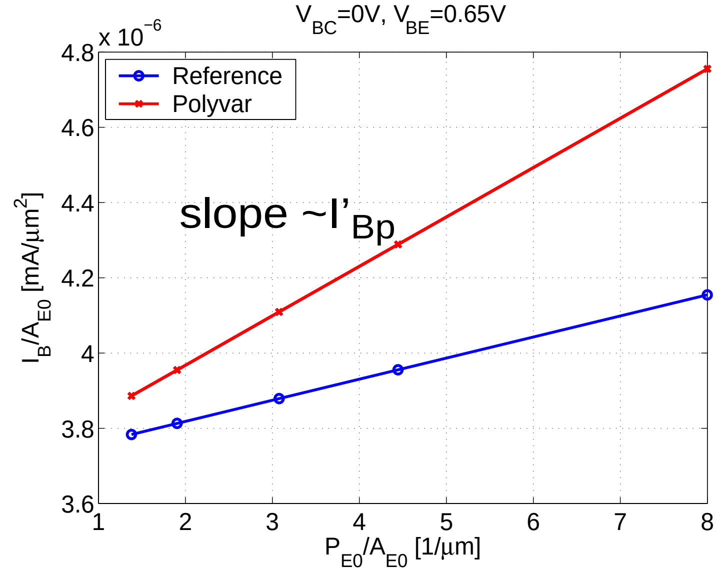
- Sicvar1, Polyvar and TEDvar show linear behavior (with varying peripheral component)



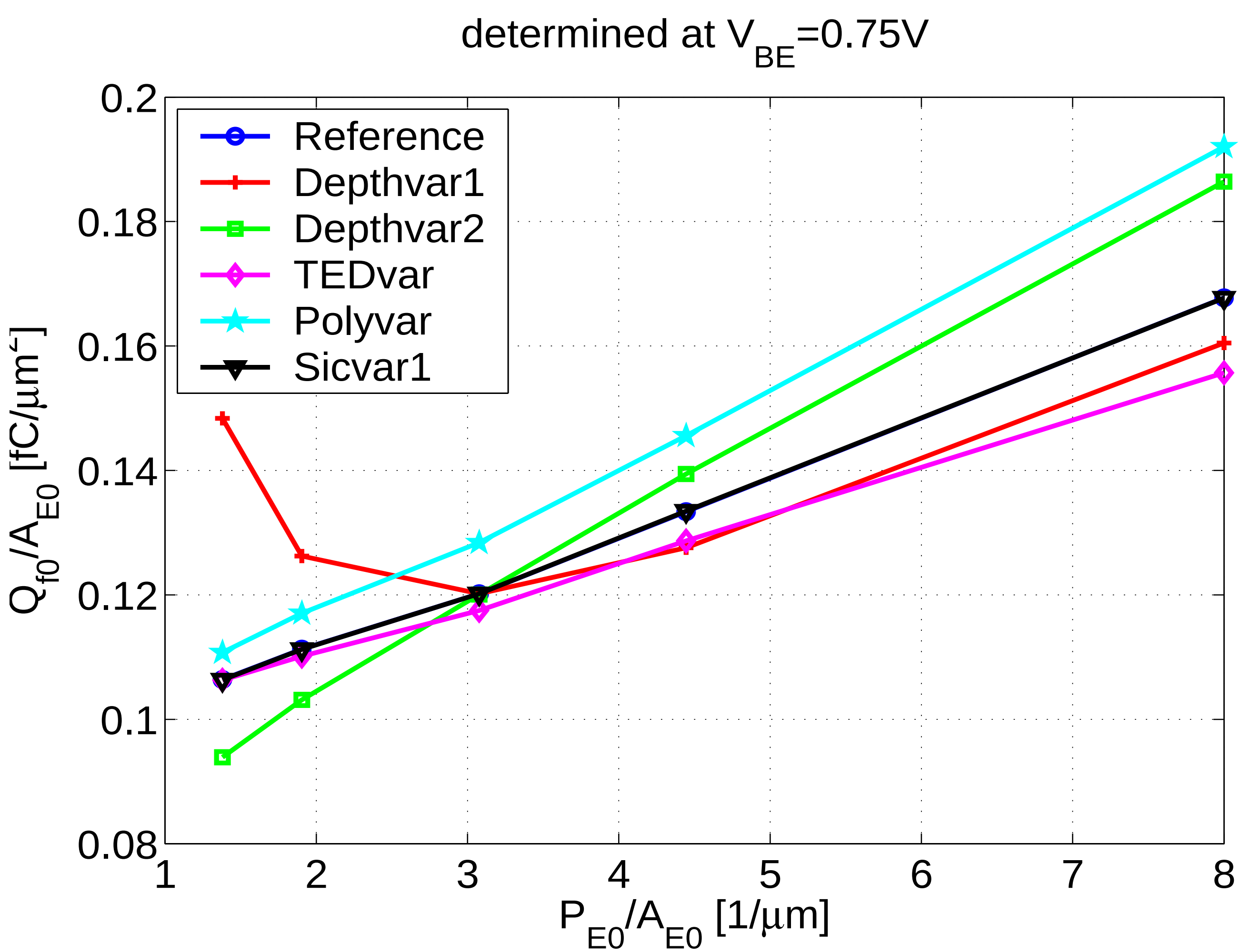


$v_{cE}=3*10^5$cm/s



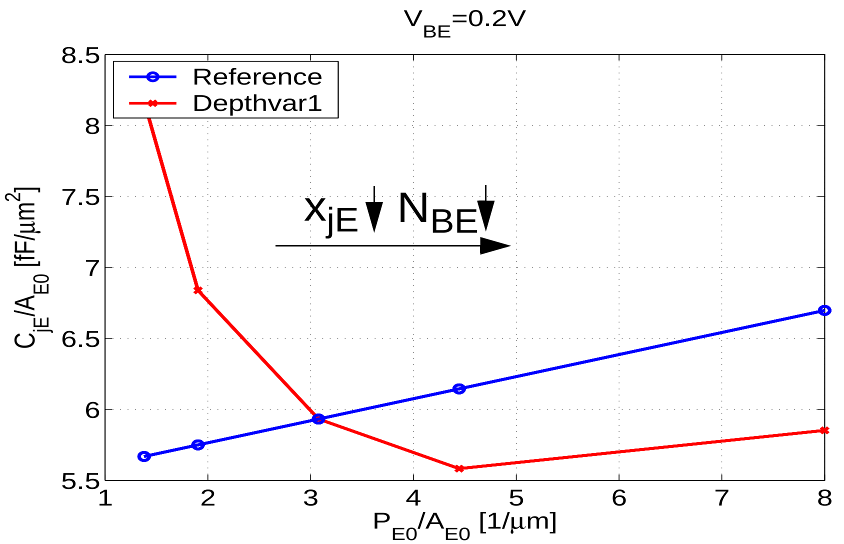


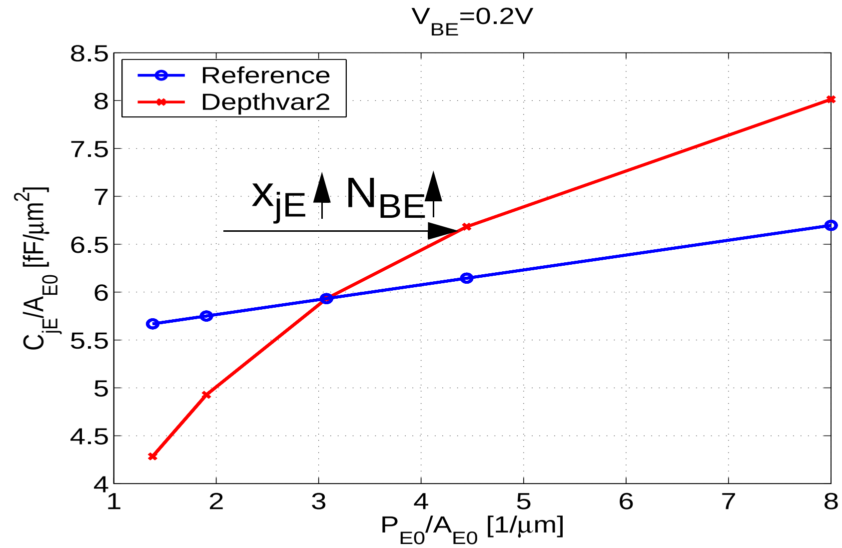
Results - Low-current forward charge

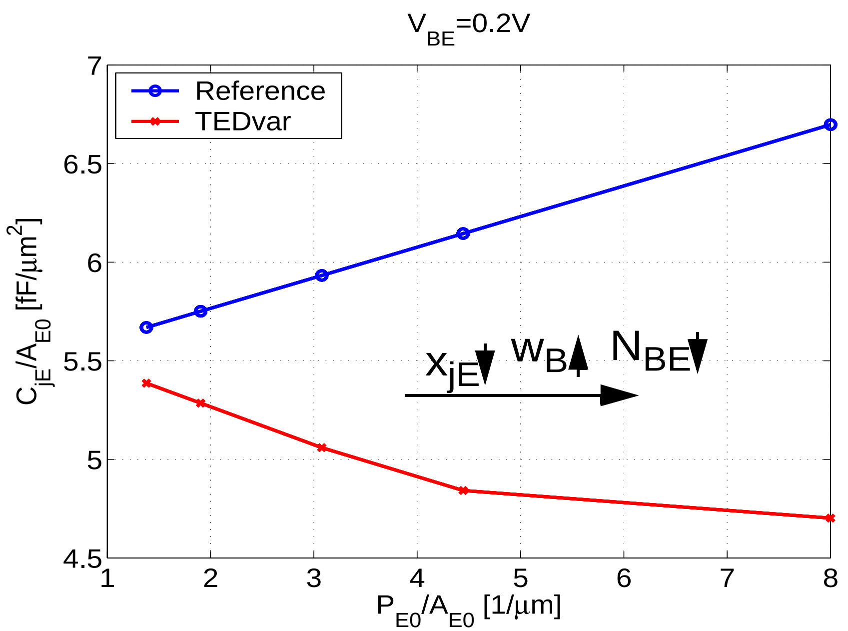


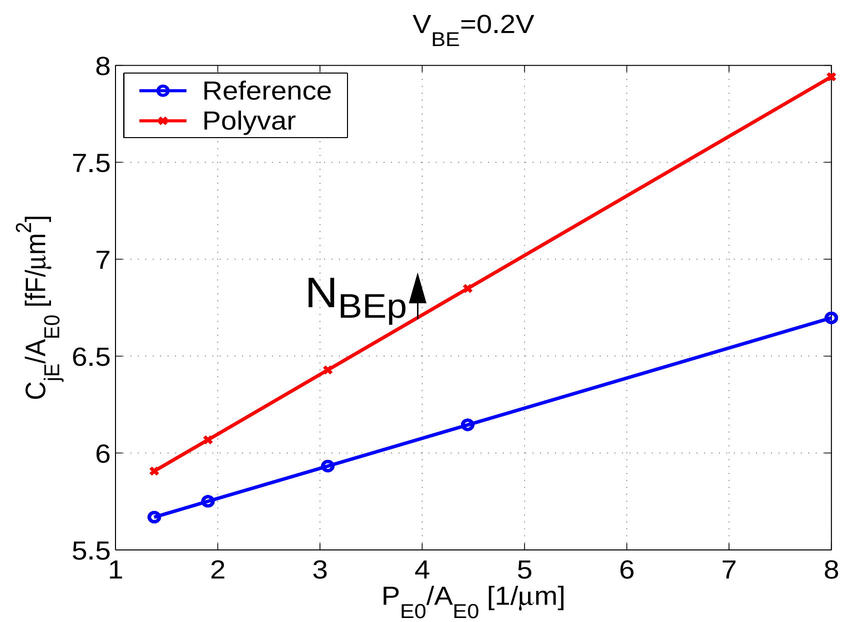
- $Q_{f0} = \tau_{f0} I_C$
- Reference, Sicvar as well as Polyvar, TEDvar: the larger devices deviate from linear scaling slightly
- Depthvar1 (increasing junction depth with regard to emitter width) shows significantly more nonlinear scaling behavior than Depthvar2

Results - Junction capacitances



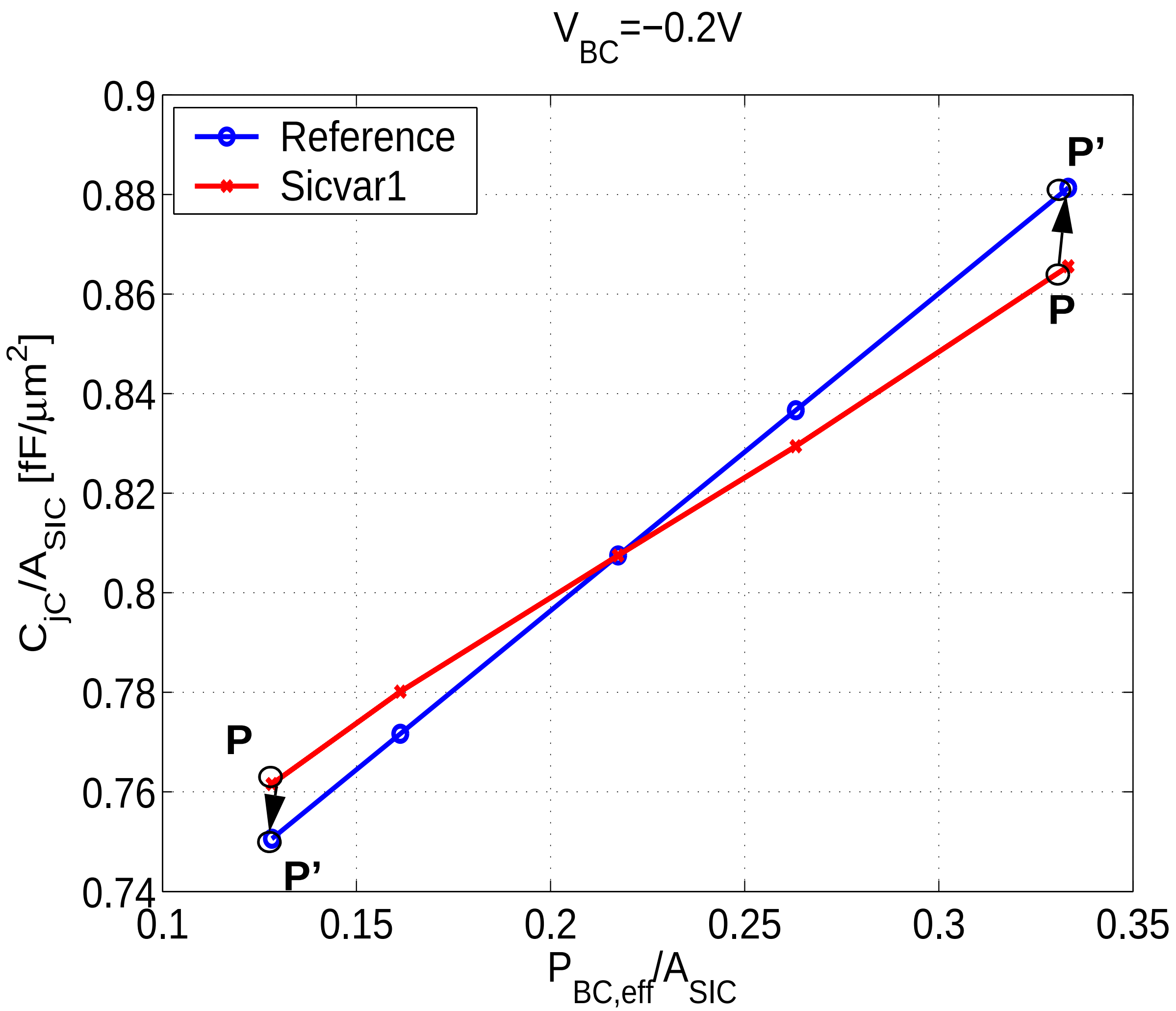


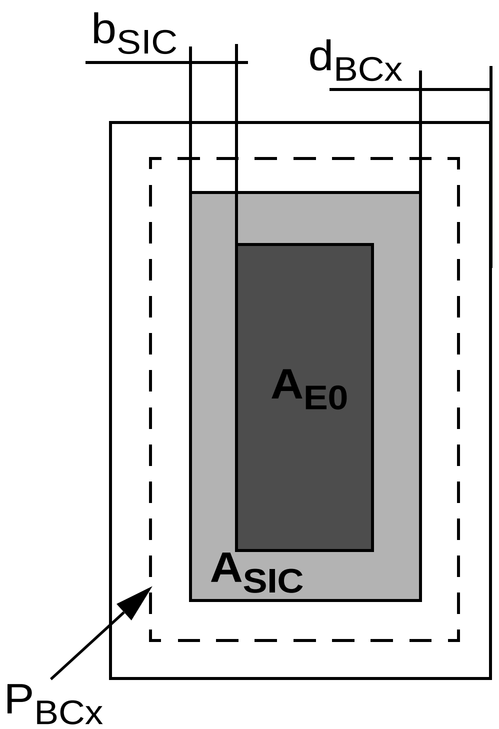




Results - Junction capacitances

- $C_{jC} = \overline{C_{jCi}} A_{SIC} + C'_{jCx} A_{BCx} = \overline{C_{jCi}} A_{SIC} + C'_{jCx} d_{BCx} P_{BCx}$
- Use of the correct dimensions for A_{SIC} and A_{BCx} would shift P=>P'

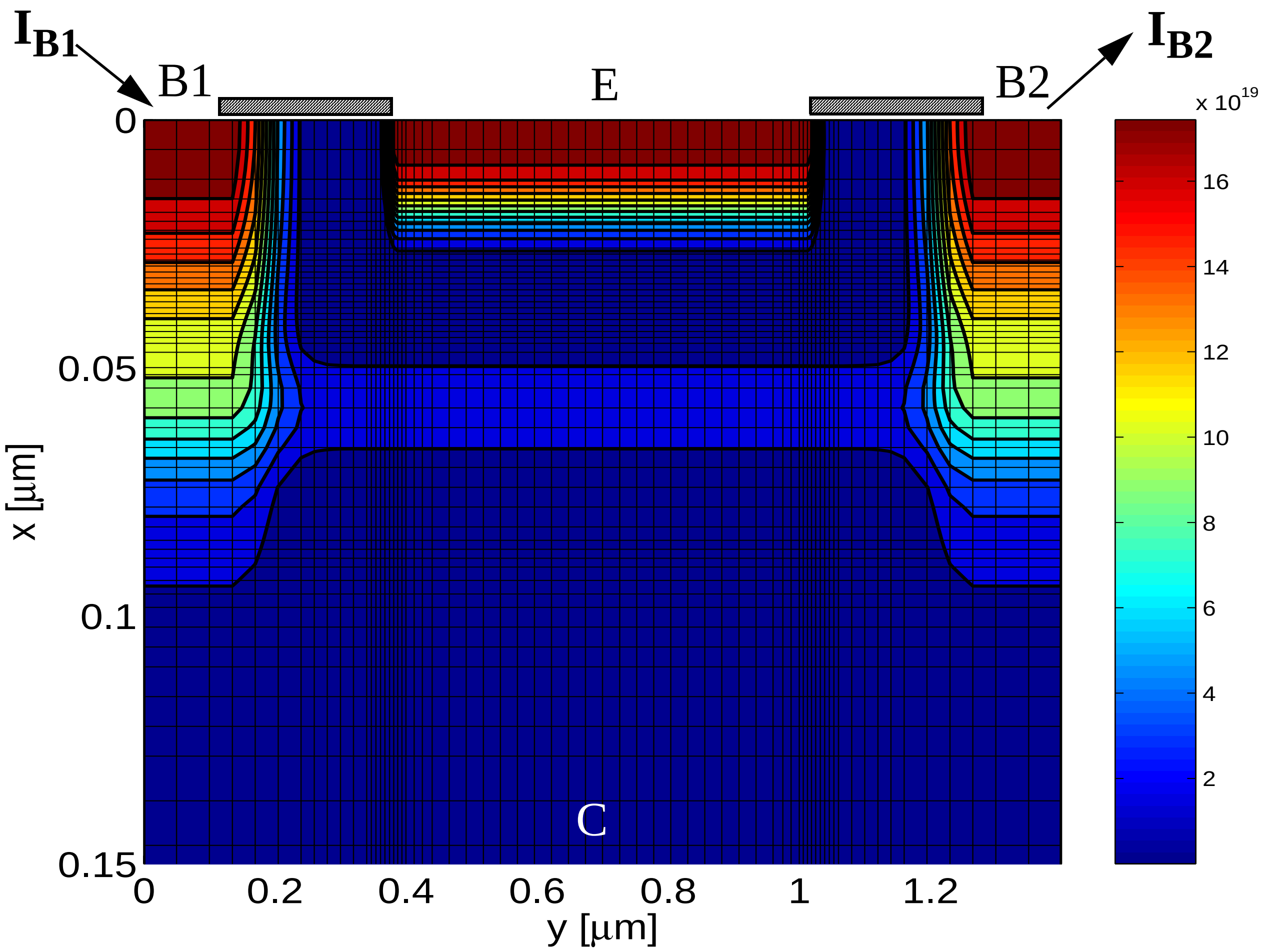




Tetrode simulations

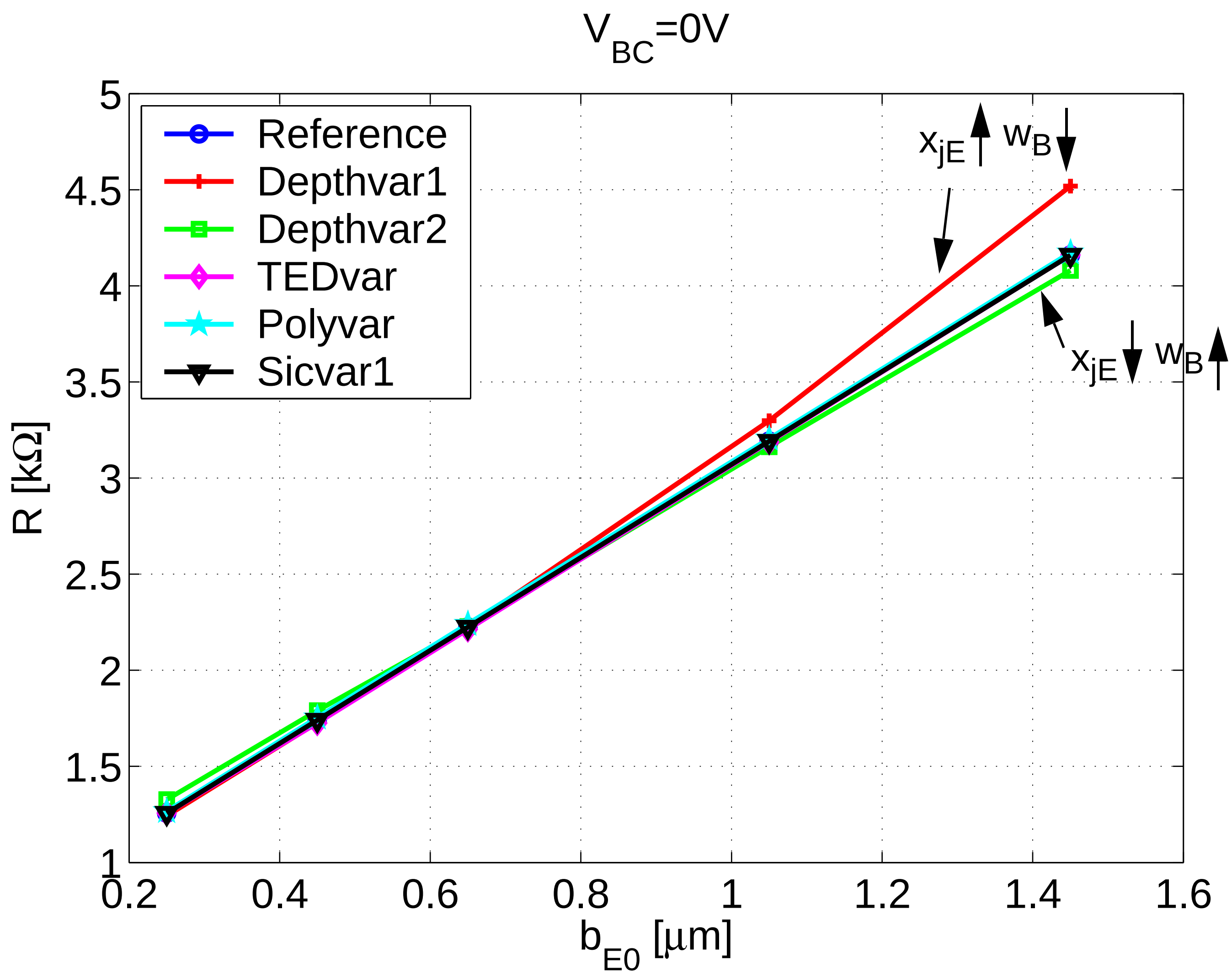
Symmetric structure as shown below has been simulated

- Voltage difference of +10mV between base contact B1 and B2.
- $R = \dfrac{V_{B2} - V_{B1}}{(I_{B1} + I_{B2})/2} = 2r_{Bx} + r_{SBi}\dfrac{b_{E0}}{l_{E0}}$ with $l_{E0} = 1\mu m$.



Results - Tetrode simulations

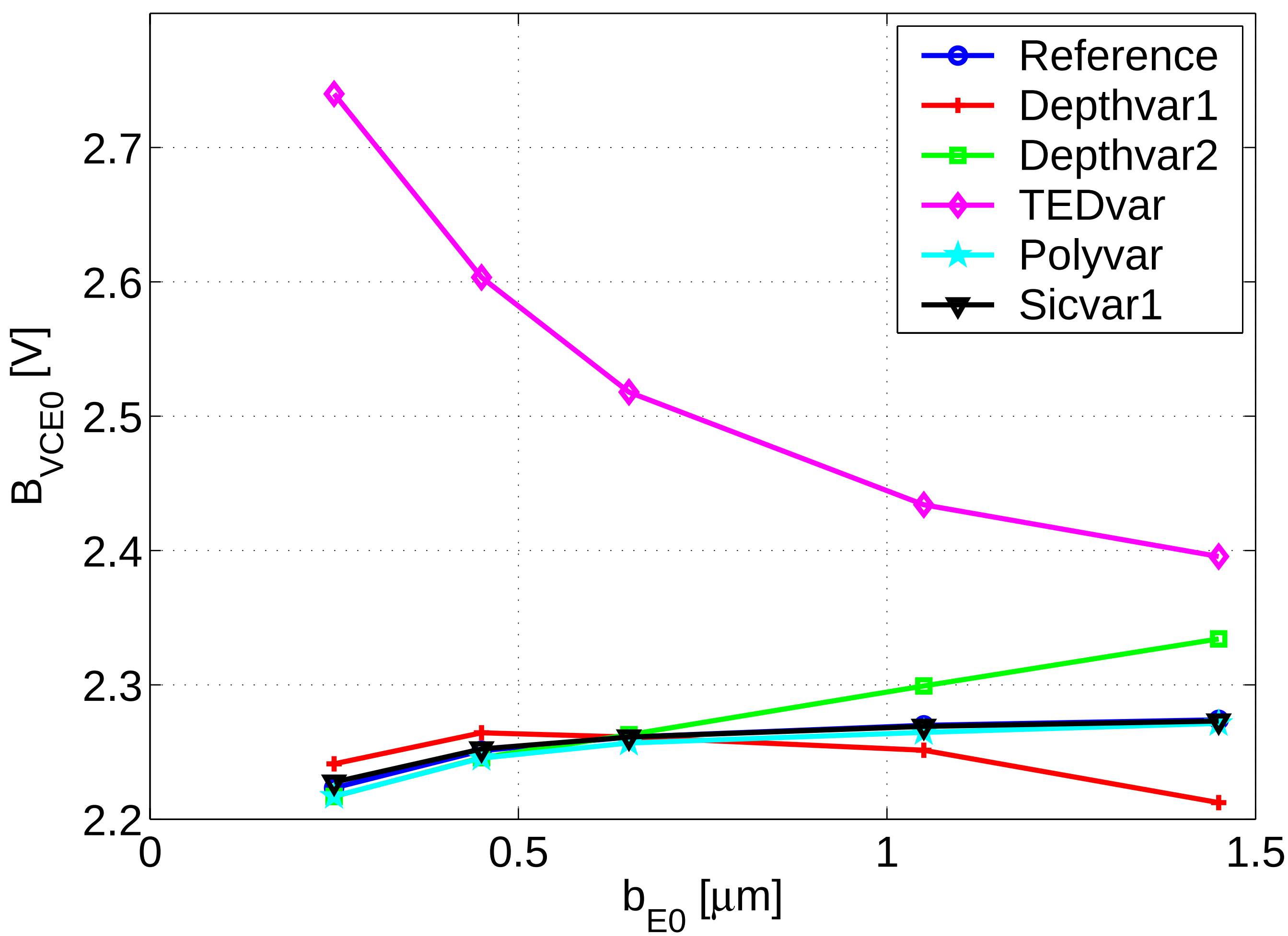
- Relevant deviations with respect to linear scaling are found only for Depthvar
  => direct influence of the varying neutral base width
- For very small emitter width a deviation of Polyvar is expected due to the same reason

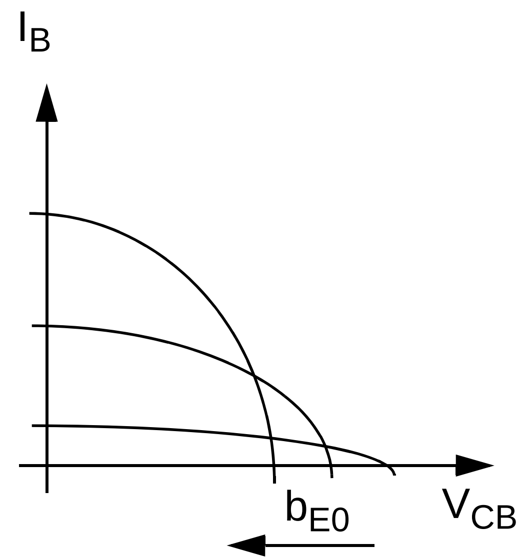


Results - BV_{CE0}

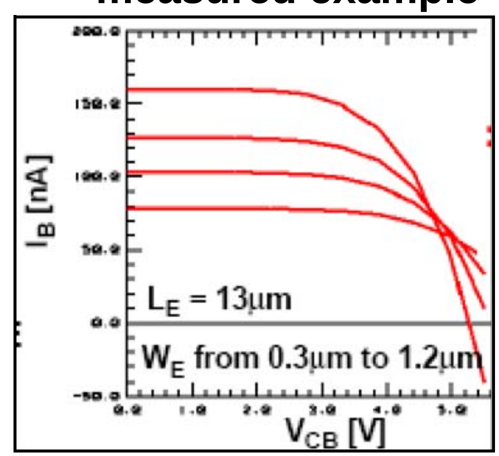
- For Depthvar, Sicvar, Polyvar only slight deviations in BV_{CE0} are observed
- TEDvar shows a significant higher BV_{CE0} and a dependence on emitter width

determined at V_{BE}=0.55V





measured example



Summary

- Variation of base-emitter junction depth with emitter width shows a large deviation with respect to conventional scaling
  => in dependence of occurence of similar measurements a modification of existing scaling equations has to be considered depending on observed measurement trends

- Some deviations with respect to conventional scaling occur only at small emitter width or or influence but even the peripheral components (e.g. Polyvar, in parts TEDvar)

- Evaluation of measured curves can allow conclusions regarding lateral doping profile (e.g. BV_{CE0} => TEDvar)

- Reason for deviation from conventional scaling for the forward charge Q_{f0} for large devices has to be investigated

- Develop preprocessor to include non-standard scaling behavior in “scalable” model parameter generation