

# Simulation of SiGe Bipolar Devices



**SILVACO**



## Introduction

- Construction of SiGe HBT using ATHENA
- Mesh Refinement using DevEdit
- Device Characterization using ATLAS
- Conclusion

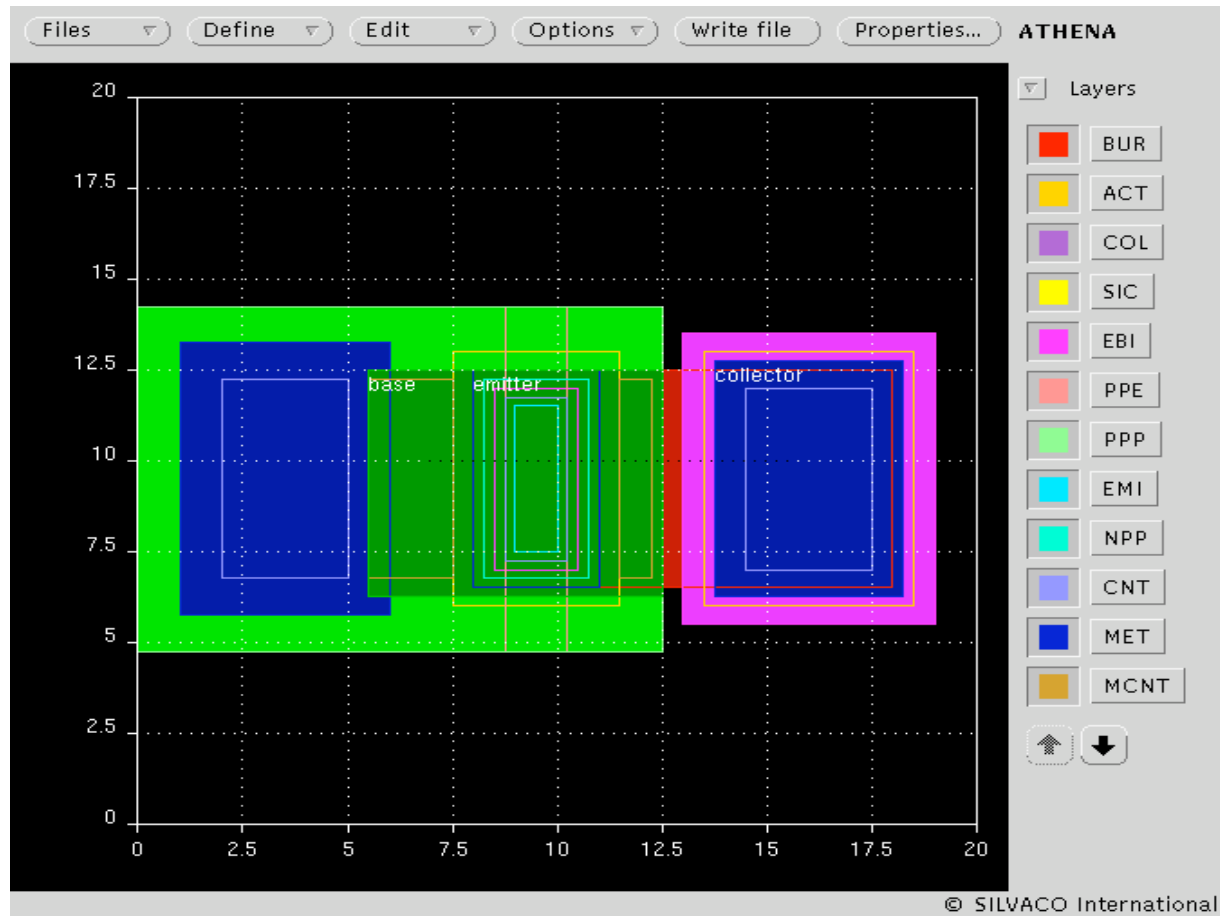


## Construction of SiGe HBT using ATHENA

- Layout
- Structure cross-section
- Surface Details
- Doping Profiles
- Mesh

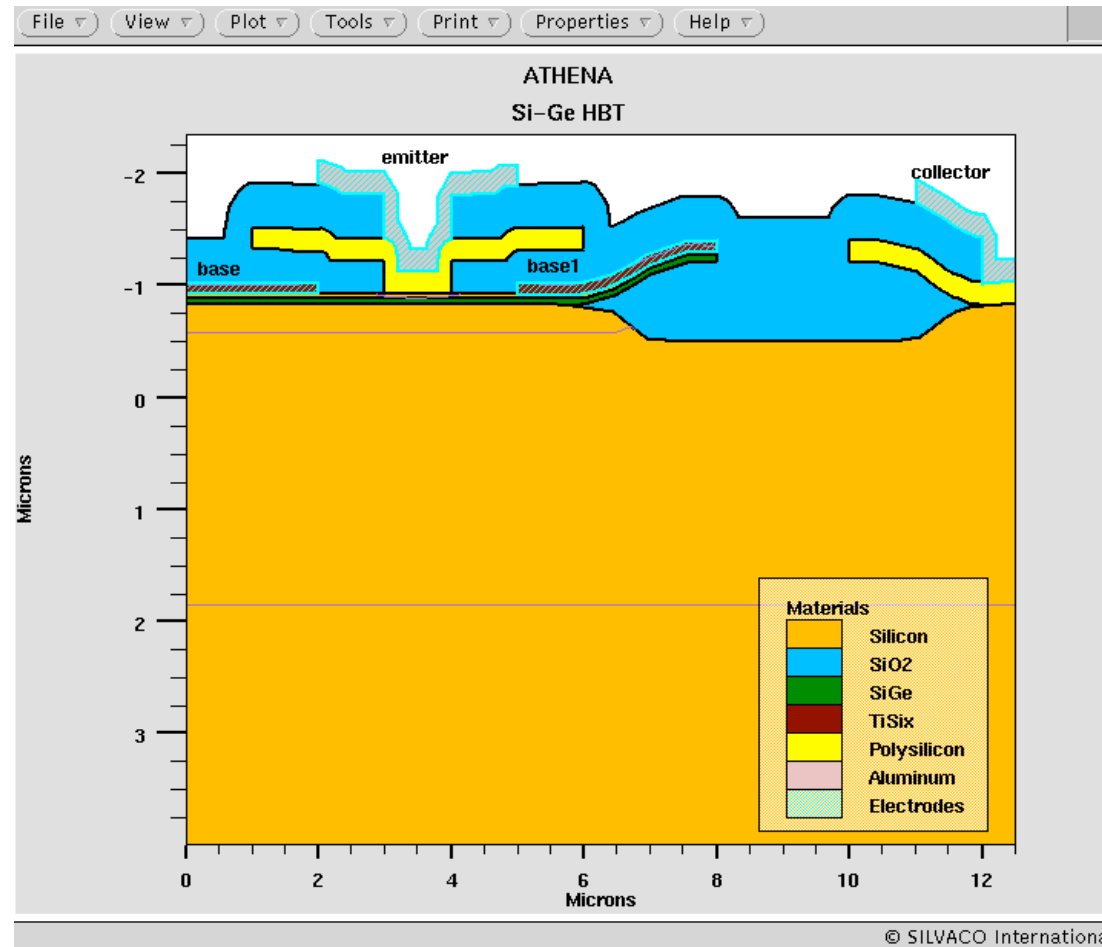


# SiGe HBT Layout



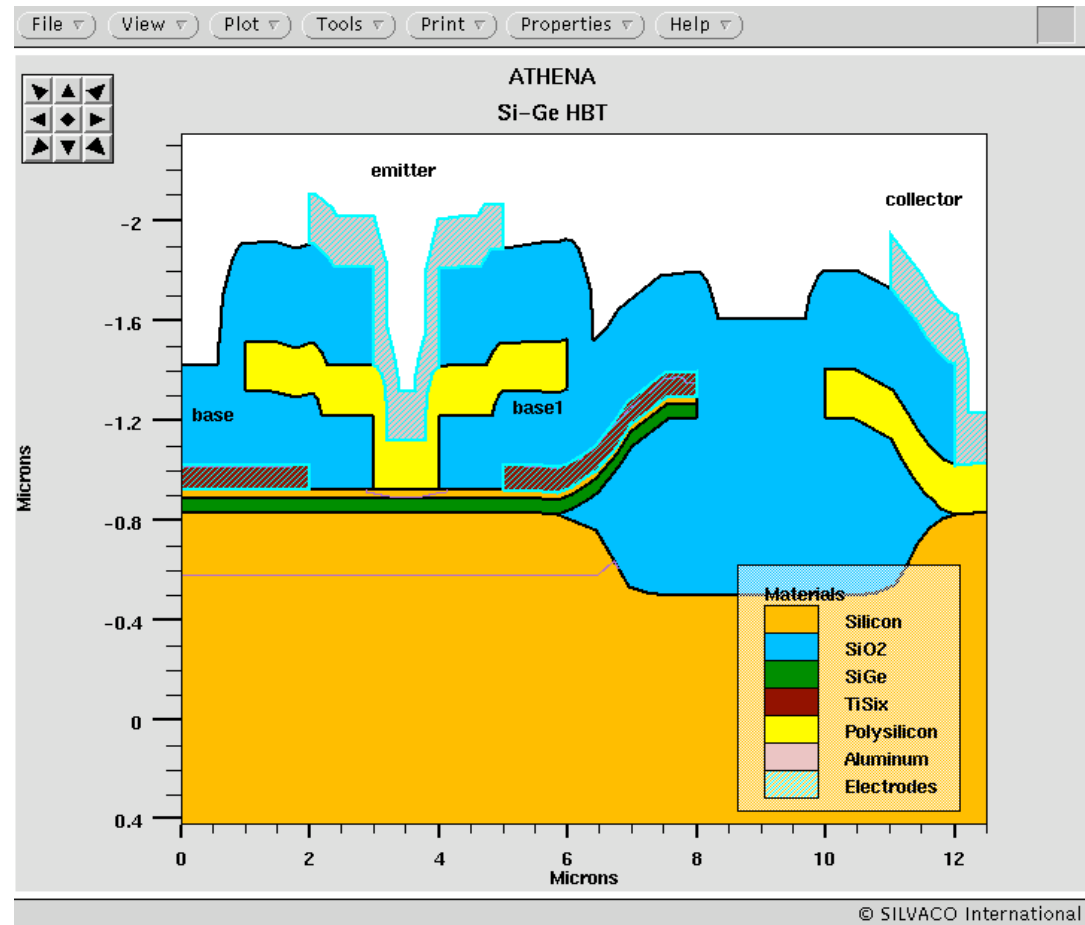


# SiGe HBT Generated by ATHENA



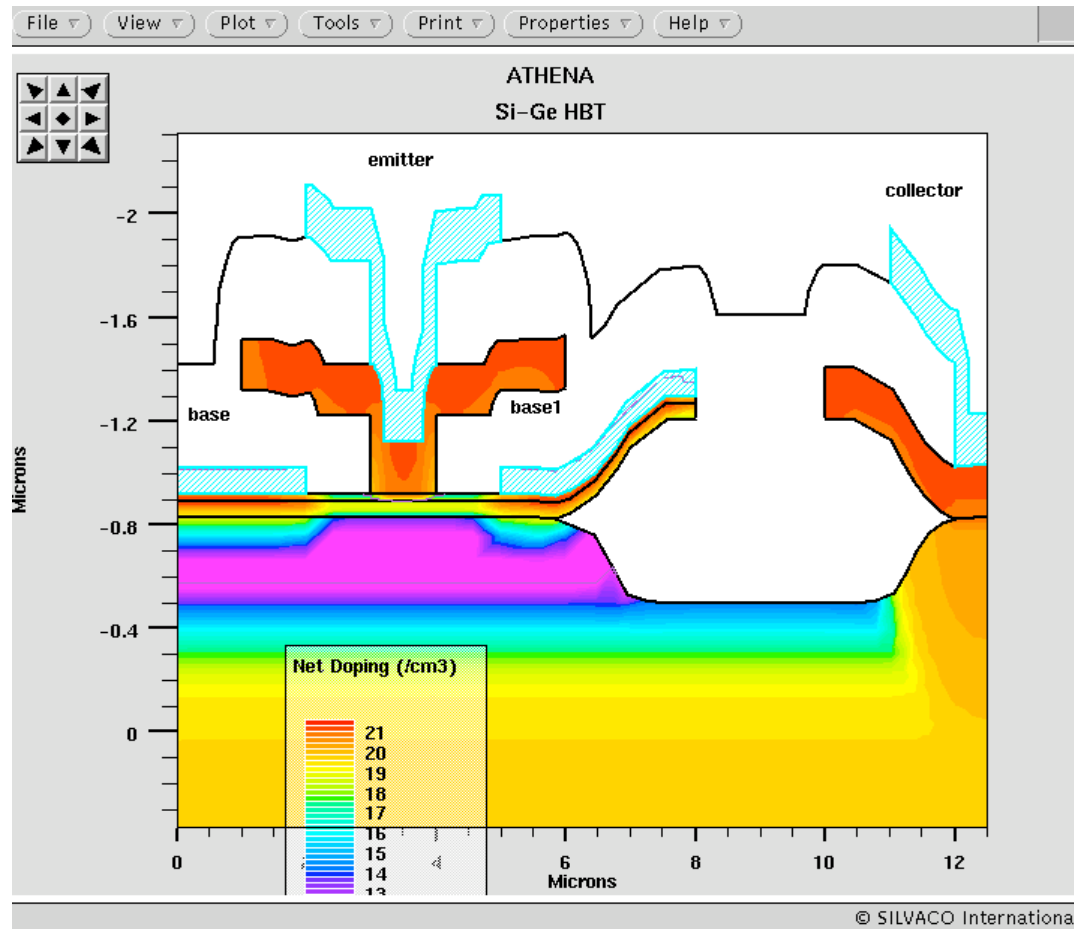


# SiGe HBT



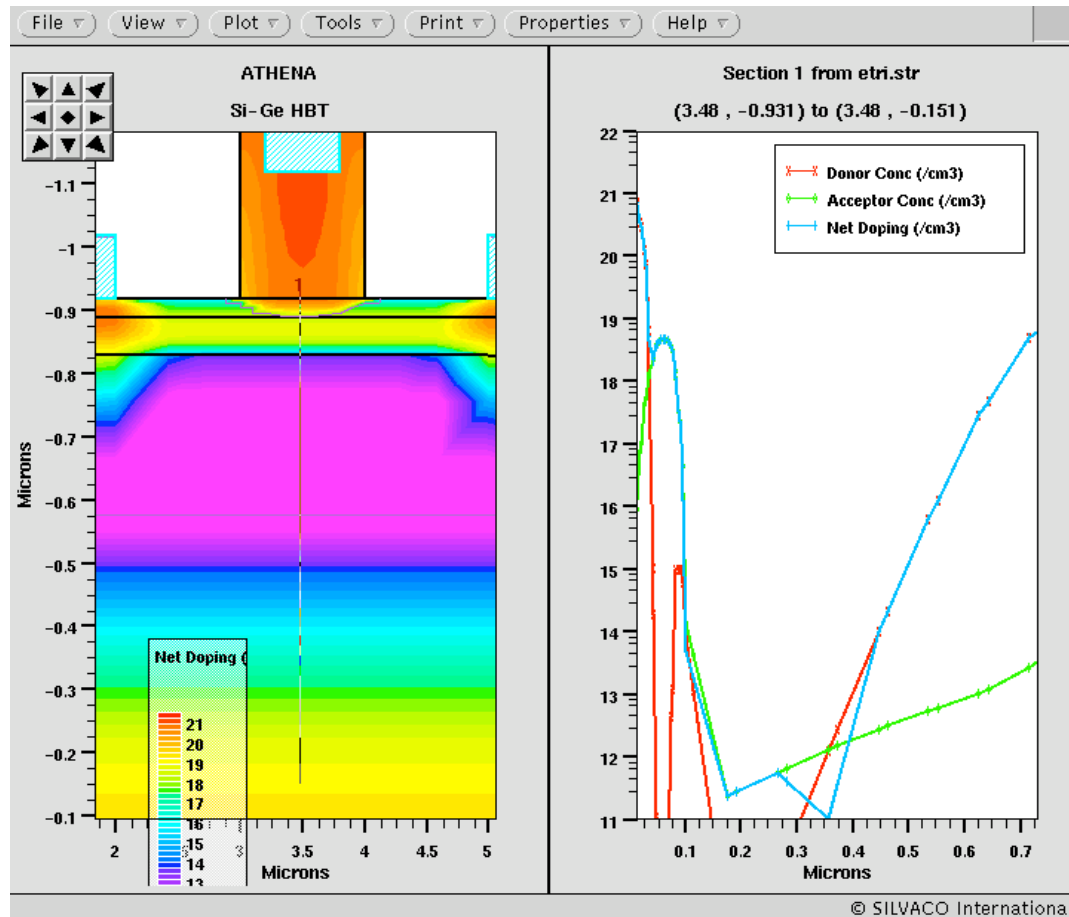


# SiGe HBT Doping



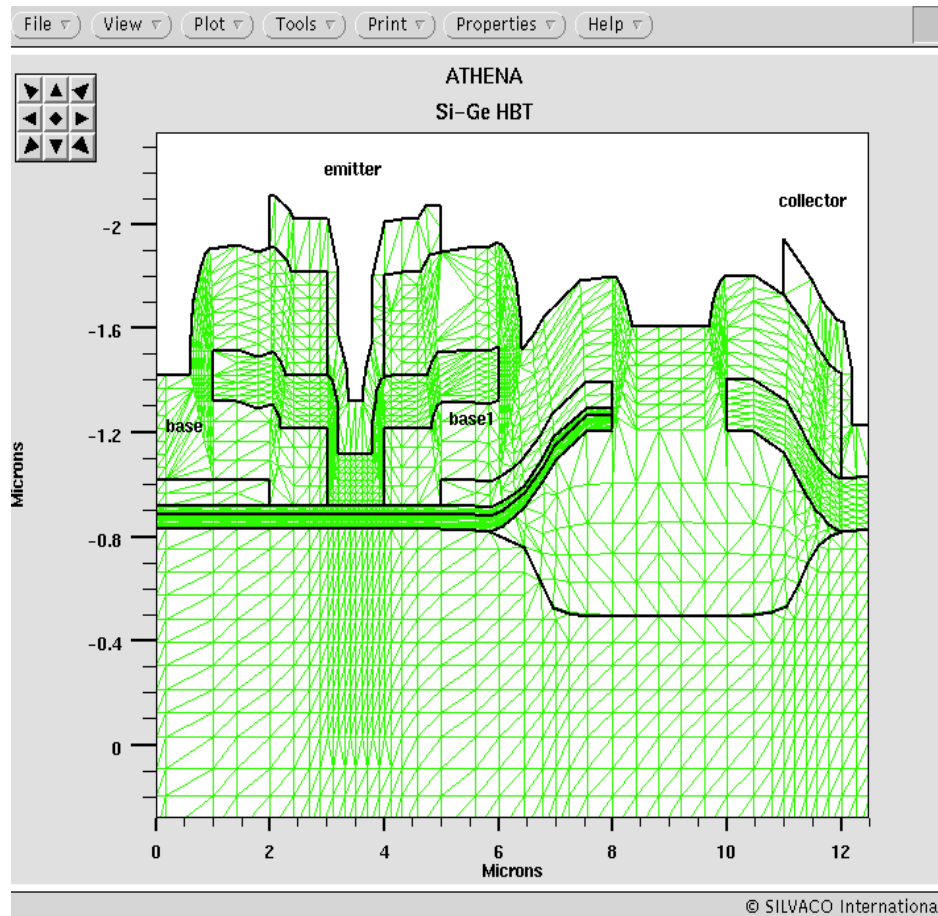


# Vertical Doping Profile Under the Base Electrode





# ATHENA Generated Mesh





## Mesh Refinement Using DevEdit

- ATHENA process mesh is not Ideal for device simulation using ATLAS
- DevEdit can provide the correct Interface



# Mesh Refinement Using DevEdit

DevEdit 2.3.0.R sige.str

File Regions Impurities Mesh Help

Refinement On Quantities

Min. Mesh Spacing: 0.0200 Microns

Refinement Quantities

Add

Delete

Refinement Weighting Default

None Selected

Scale: Linear

Sensitivity 1.00 Exp: 0

0.01 100000

Transition value:  $10^{1.00}$

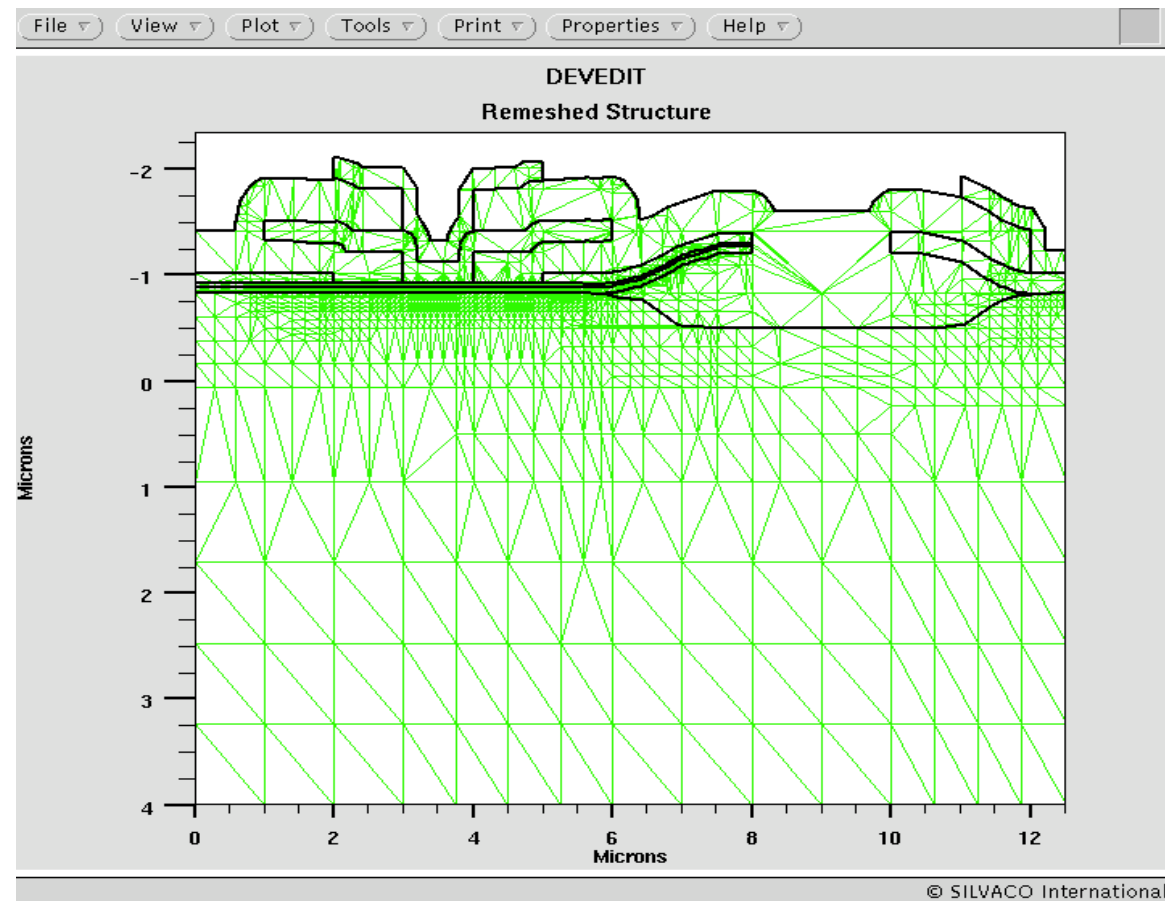
-30 300

Done

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# Refined Mesh Generated by DevEdit



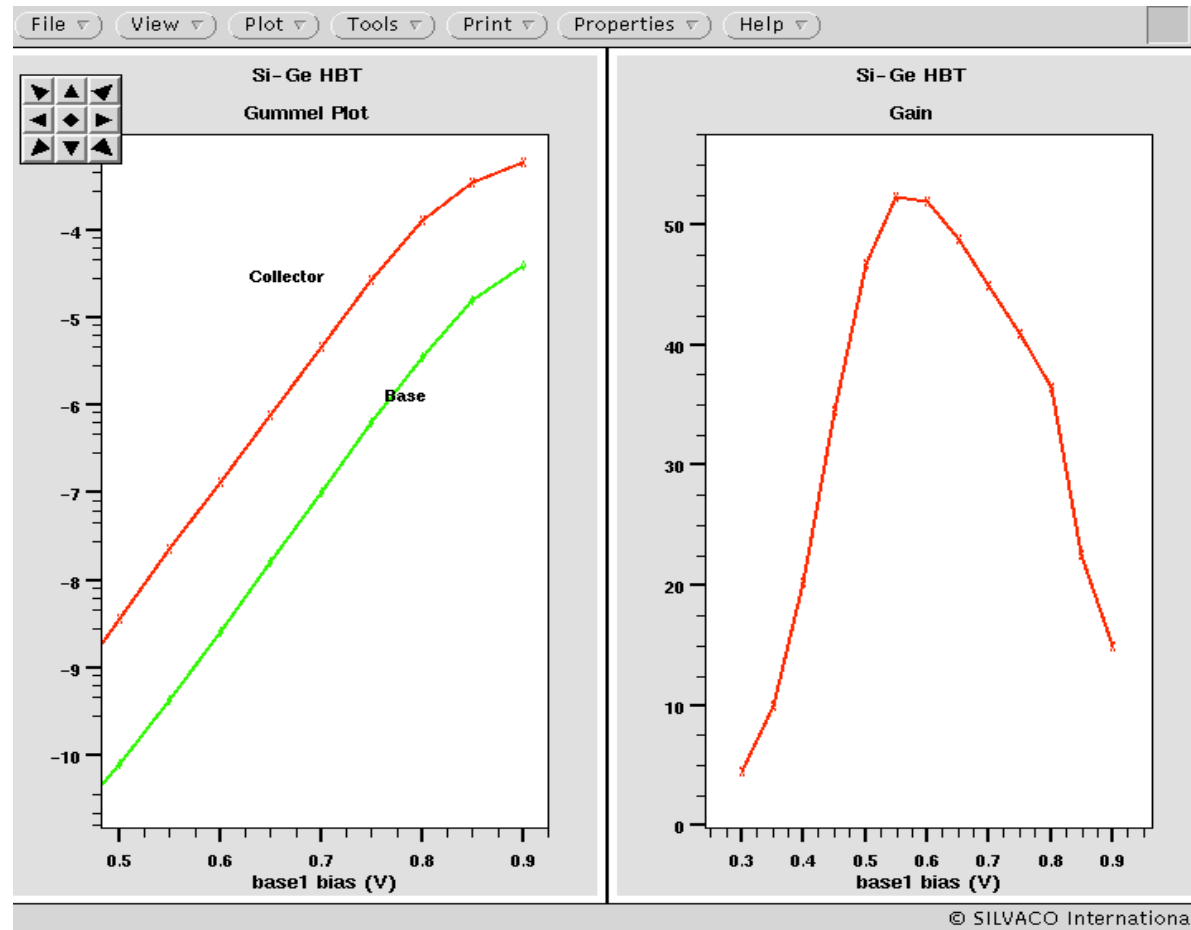


## Device Characterization Using ATLAS

- Gummel plot
- Small signal frequency response
- Energy bands
- Example deck

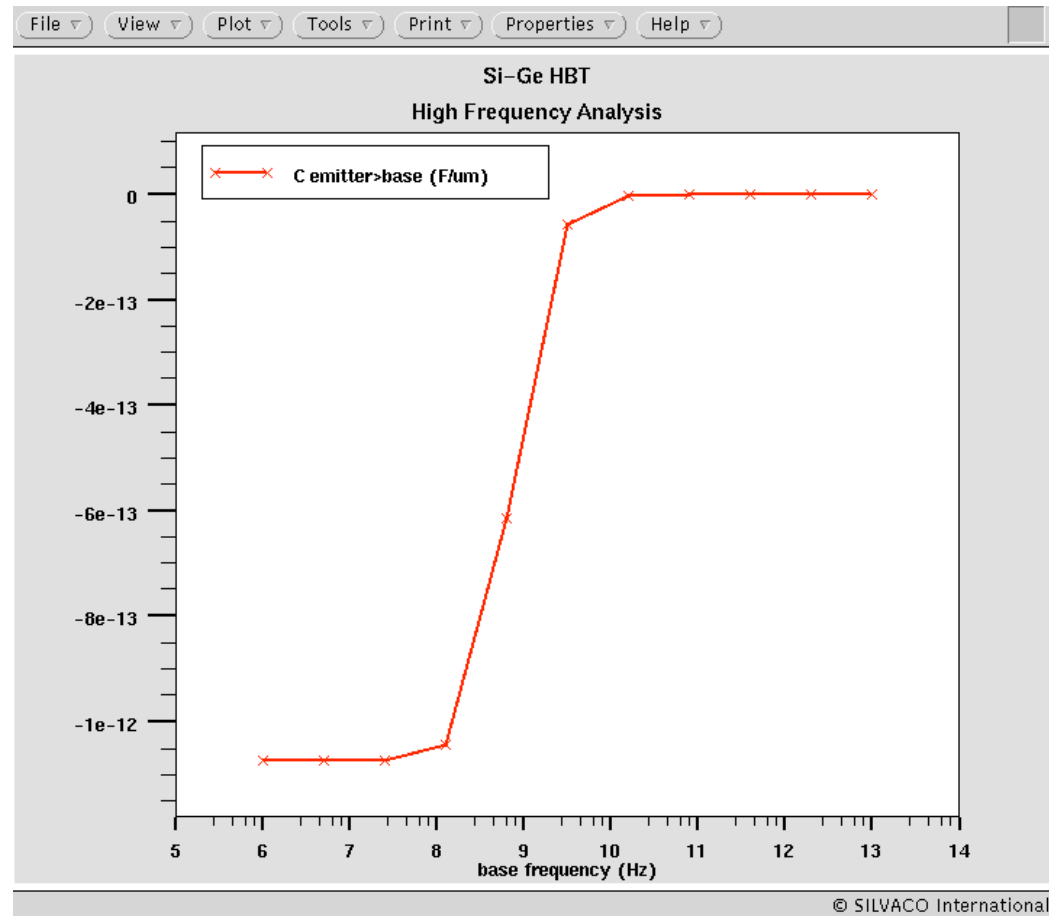


# SiGe HBT Gummel Plot and Gain Curve



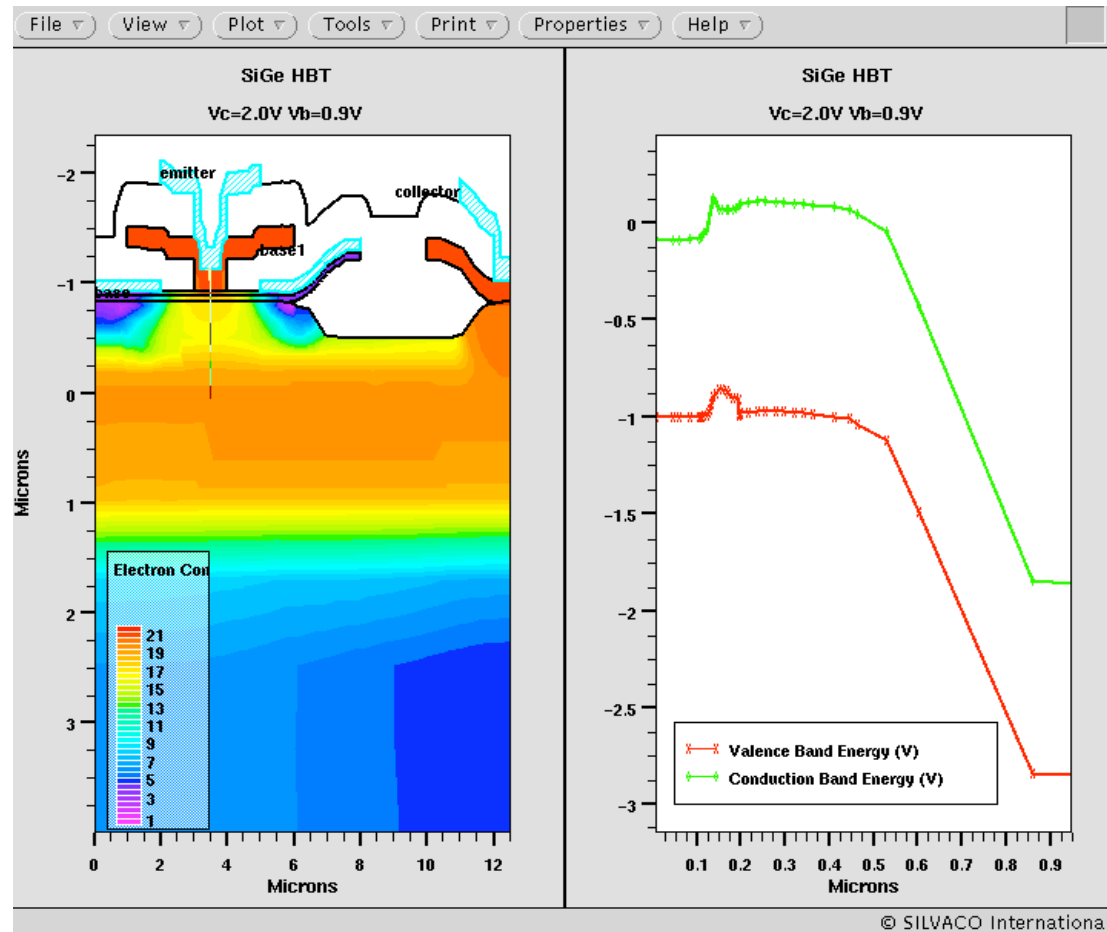


# Capacitance Versus Frequency





# Electron Concentration and Energy Band Diagram





## SiGe HBT Worked Example

```
go athena
# SiGe HBT simulation (c) Silvaco International 2004
#
# Establish initial grid and substrate material
#
line x location=0.0 spacing=0.1
line x location=0.5 spacing=0.05
line x location=0.7 spacing=0.05
line x location=1.2 spacing=0.1
line x location=2.2 spacing=0.25
#
line y location=0.0 spacing=0.01
line y location=0.1 spacing=0.02
line y location=0.5 spacing=0.05
line y location=0.8 spacing=0.15
#
```



## SiGe HBT Worked Example (con't)

```
init silicon c.phos=2e16
#
structure outf=tmp1.str
#
init inf=tmp1.str flip.y
implant phos energy=60 dose=3e15
#
diffuse time=5 temp=1000
struct outf=temp
init inf=temp flip.y
#
# Deposit Silicon germanium with composition fraction 0.2 for base
#
deposit sige      thick=.1 divis=12 ydy=0.05 dy=0.02 c.frac=0.2
c.boron=1e15
#
```



## SiGe HBT Worked Example (con't)

```
moments i.boron sige dose=1e13 energy=10 range=0.033
std.dev=0.018 gamma=0.04 kurt=3.2
implant boron energy=10 dose=1.0e13
#
# Deposit silicon for the emitter
deposit silicon thick=0.2 divis=10 ydy=0.08 dy=0.04
c.phos=1.e15
#
moments i.boron sige dose=3e14 energy=12 range=0.033
std.dev=0.018 gamma=0.04 kurt=3.2
implant boron energy=12 dose=3e14
#
diffuse time=0.5 temp=920
#
# Mask and implant the emitter
```



## SiGe HBT Worked Example (con't)

```
deposit photo thick=.5 divis=5
etch photo left p1.x=0.5
#
moments i.phos sige dose=6e15 energy=38 range=0.0534
std.dev=0.0236 gamma=0.401 kurt=3.1630
implant phos energy=38 dose=6e15#diffuse time=5 temp=920strip
#
# Deposit and pattern the contact metal
deposit aluminum thick=.05
etch aluminum start x=0.5 y=10.
etch          cont  x=0.5 y=-10.
etch          cont  x=1.2 y=-10.
etch          done  x=1.2 y=10.
#
```



## SiGe HBT Worked Example (con't)

```
# Define the electrodes
electrode    name=emitter x=0.0
electrode    name=base    x=2.0
electrode    name=collector backside
#
# Define impurity characteristics in each material
impurity i.boron acceptor sigc
impurity i.phos  donor    sigc
#
structure outfile=example.str

go atlas
#
# Material parameter and model specification
#
```



## SiGe HBT Worked Example (con't)

```
material material=Si    taun0=1e-7 taup0=1e-7
material material=SiGe taun0=1.e-8 taup0=1.e-8
model      bgn  consrh  auger fldmob conmob
#
# Bias collector to 2 volts
output con.band val.band
method gummel newton
solve local vcollector=2.0
#
# Bias base for Gummel plot
output con.band val.band
method  newton  trap
solve vbase=0.01
solve vbase=0.05
```



## SiGe HBT Worked Example (con't)

```
solve vbase=0.2
```

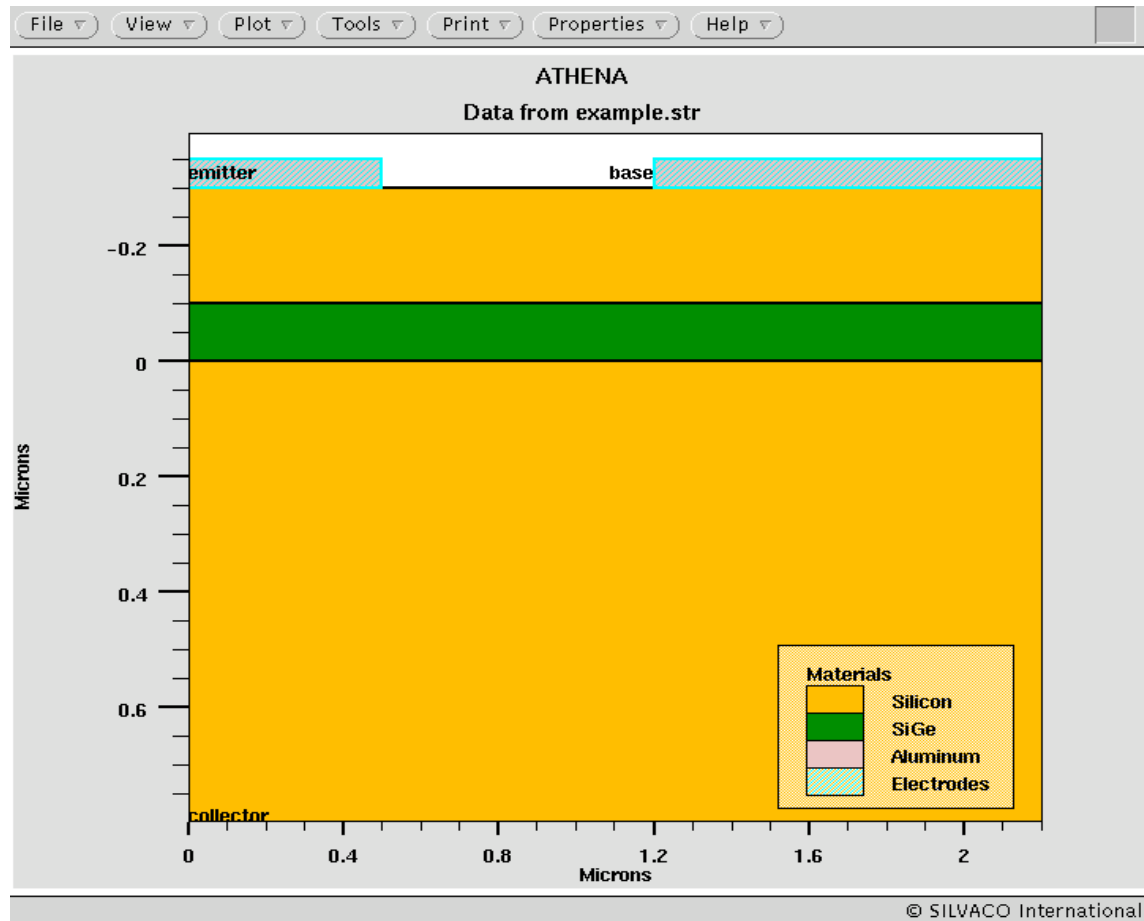
```
log outfile=ex_gum.log master
```

```
solve vbase=0.3 vstep=0.05 name=base vfinal=0.9
```

```
save outfile=ex_str.str
```

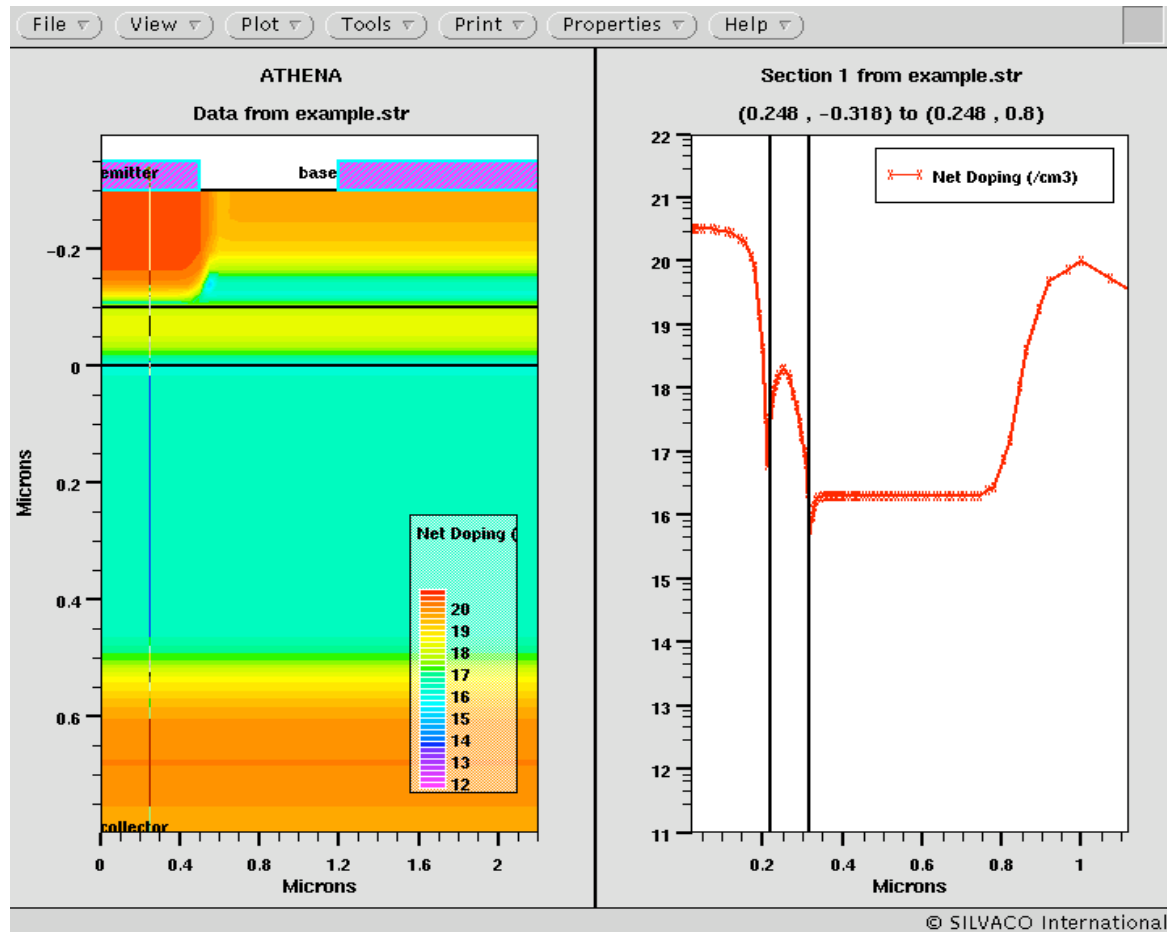


# Worked Example HBT



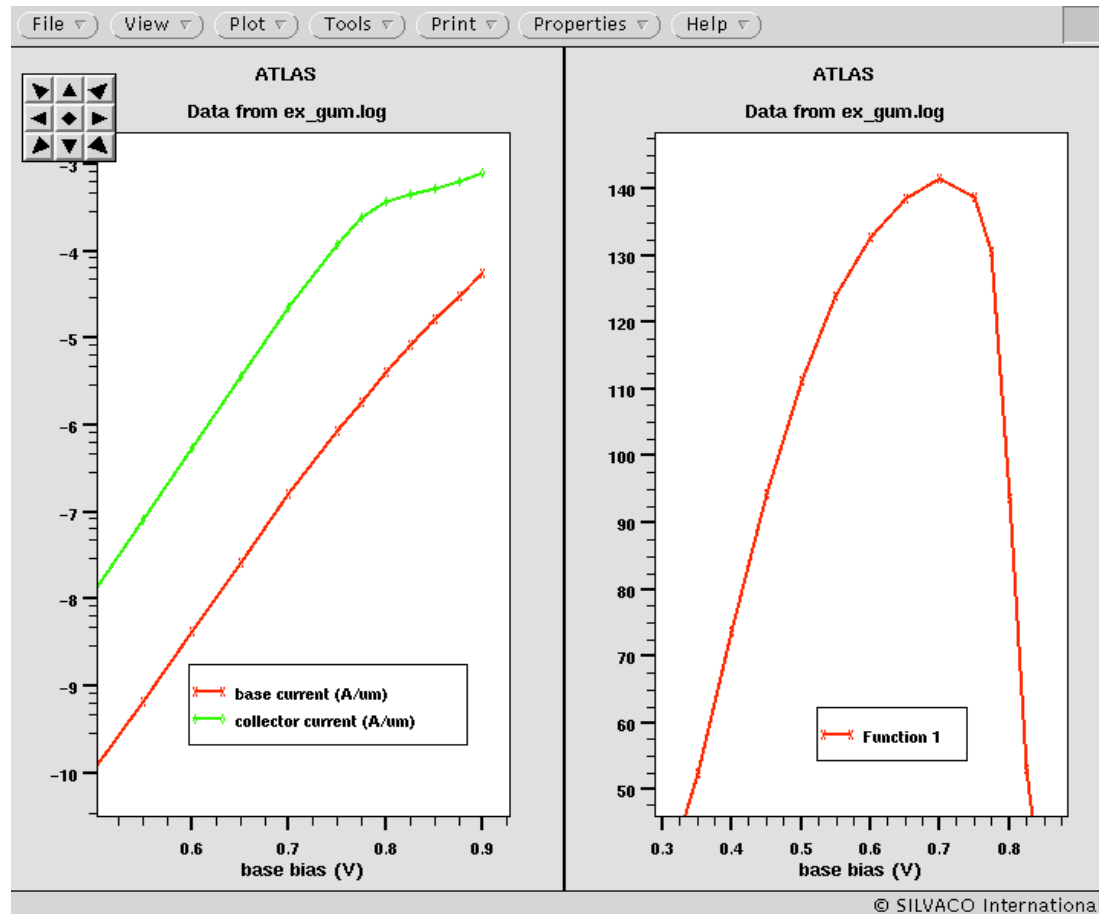


# Doping Concentration



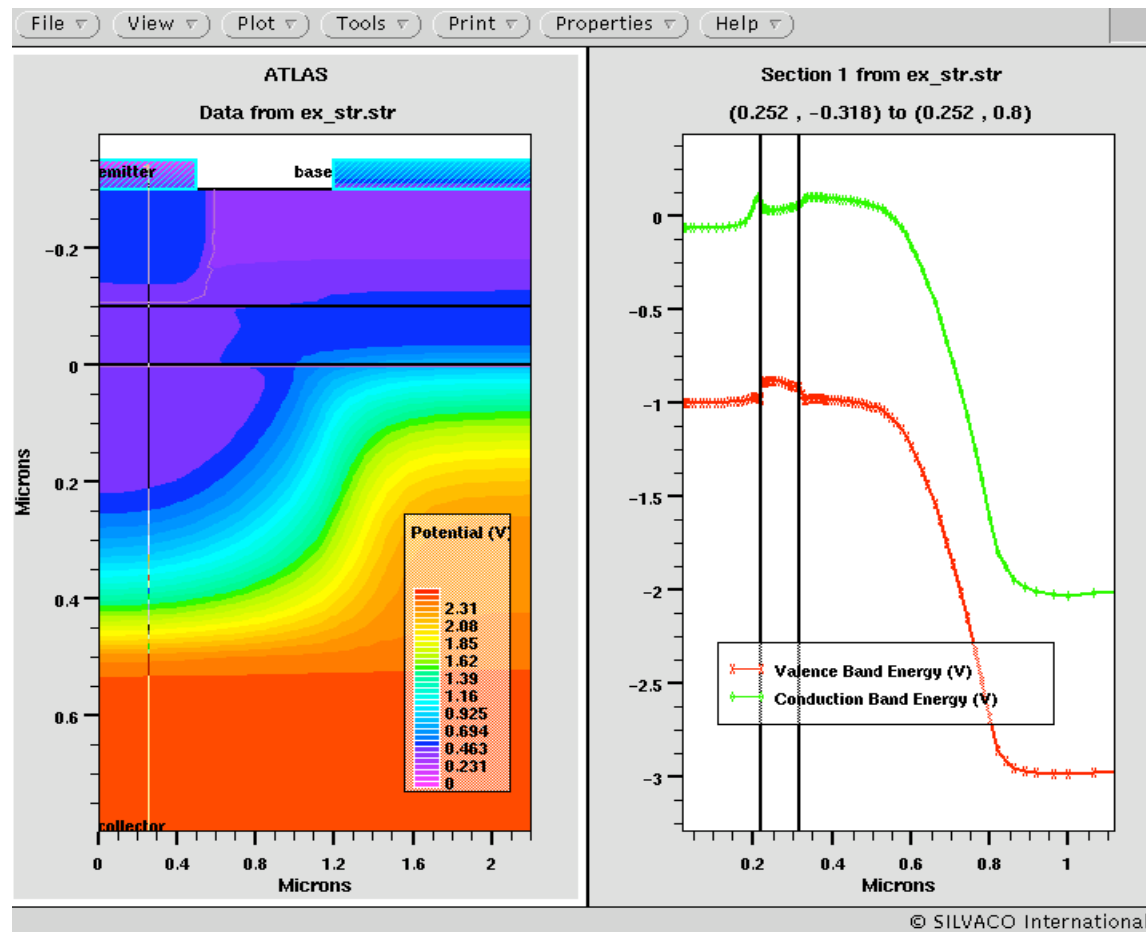


# Gummel Plot and Gain Curve





# Electrostatic Potential and Energy Band Diagram





## Conclusion

- ATHENA provides a complete simulation of SiGe processing for HBT devices
- DevEdit provides the necessary bridge from process simulations to device characterization
- ATLAS provides accurate characterization of device performance