Update of XMOD Activities

HICUM WORKSHOP - Dresden, June 2007

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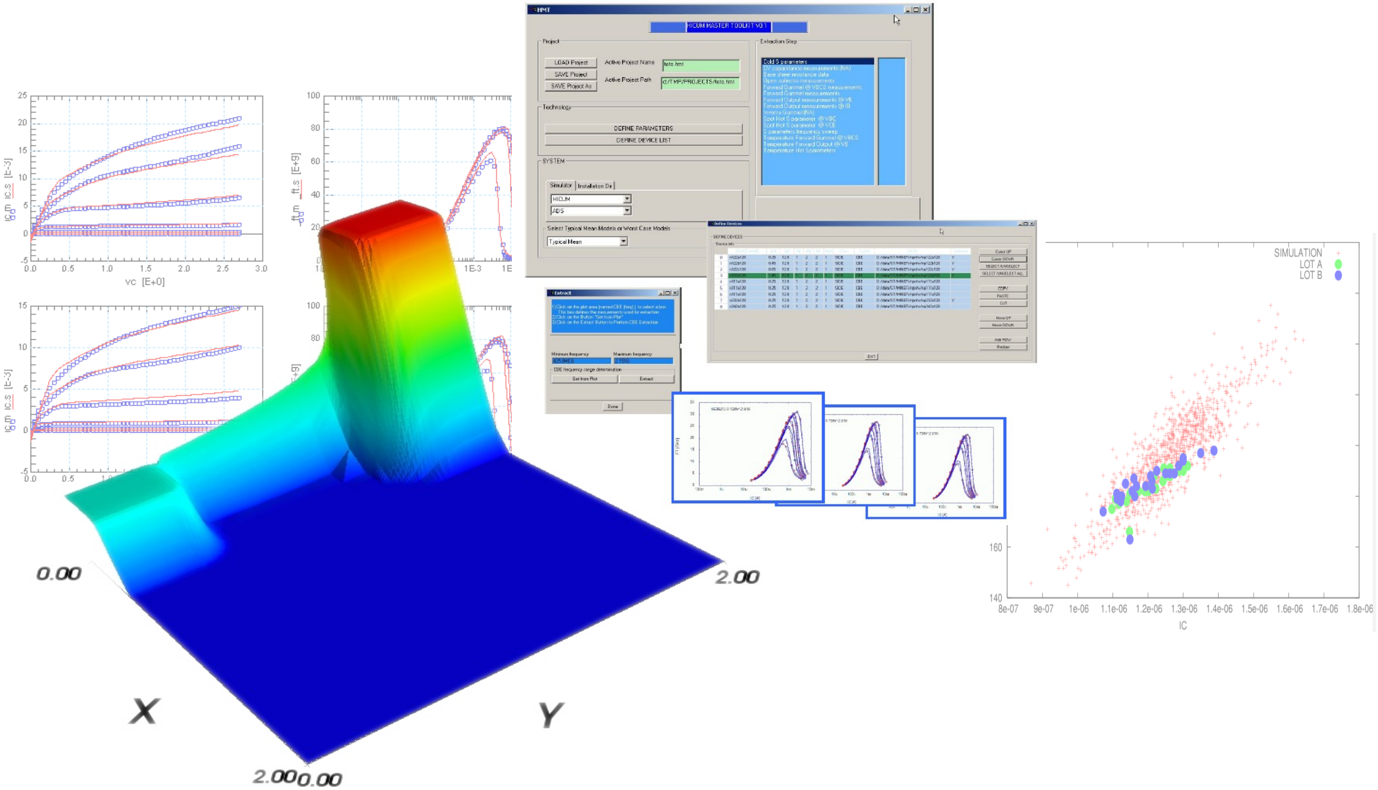
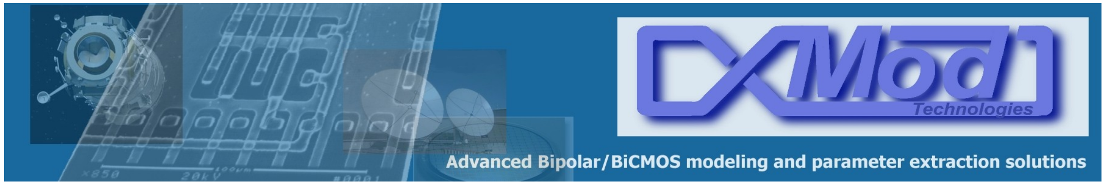




Current Status: HMT

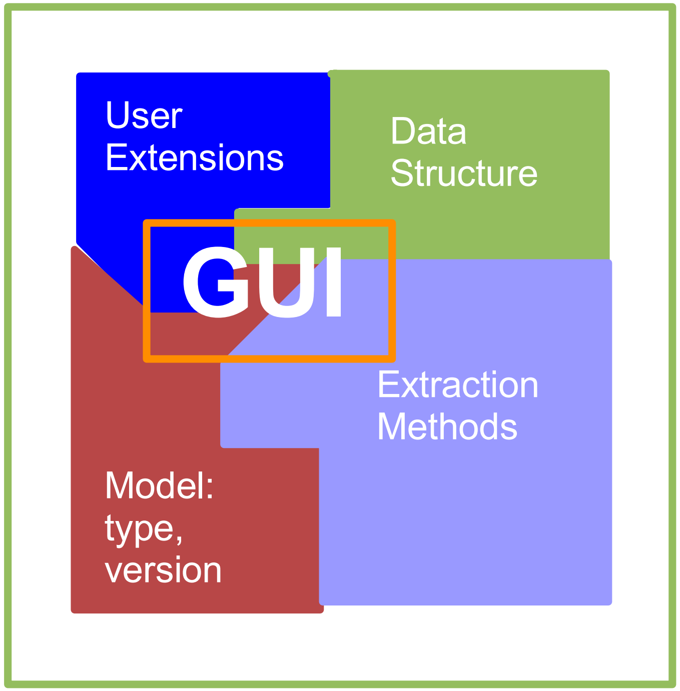
- HMT (HiCUM Master Toolkit)/TRADICA:
  - Mature Solution
  - Benefit from TRADICA being the HiCUM development tool
  - HMT can be used as a complete flow (generates model cards)
  - Standalone TRADICA GUI version can be further used with inputs generated from HMT
    - Statistics
    - Other active and passive devices
    - Transistor sizing (for designers)
    - Plotting, ...

SMACH

- SMACH: what's this ?
    - SMACH a scalable and statisical parameter extraction platform fully integrated in ICCAP (no external tool - without TRADICA)
    - SMACH has been designed for flexibility
        - Targets multi-models (HiCUM, VBIC, PSP, MM20), multi-devices (Bipolar, RFCMOS, LDMOS)
    - SMACH has been designed for maintenability AND user extensions
    - Extraction Plugin concept

How typical extraction tools are built?

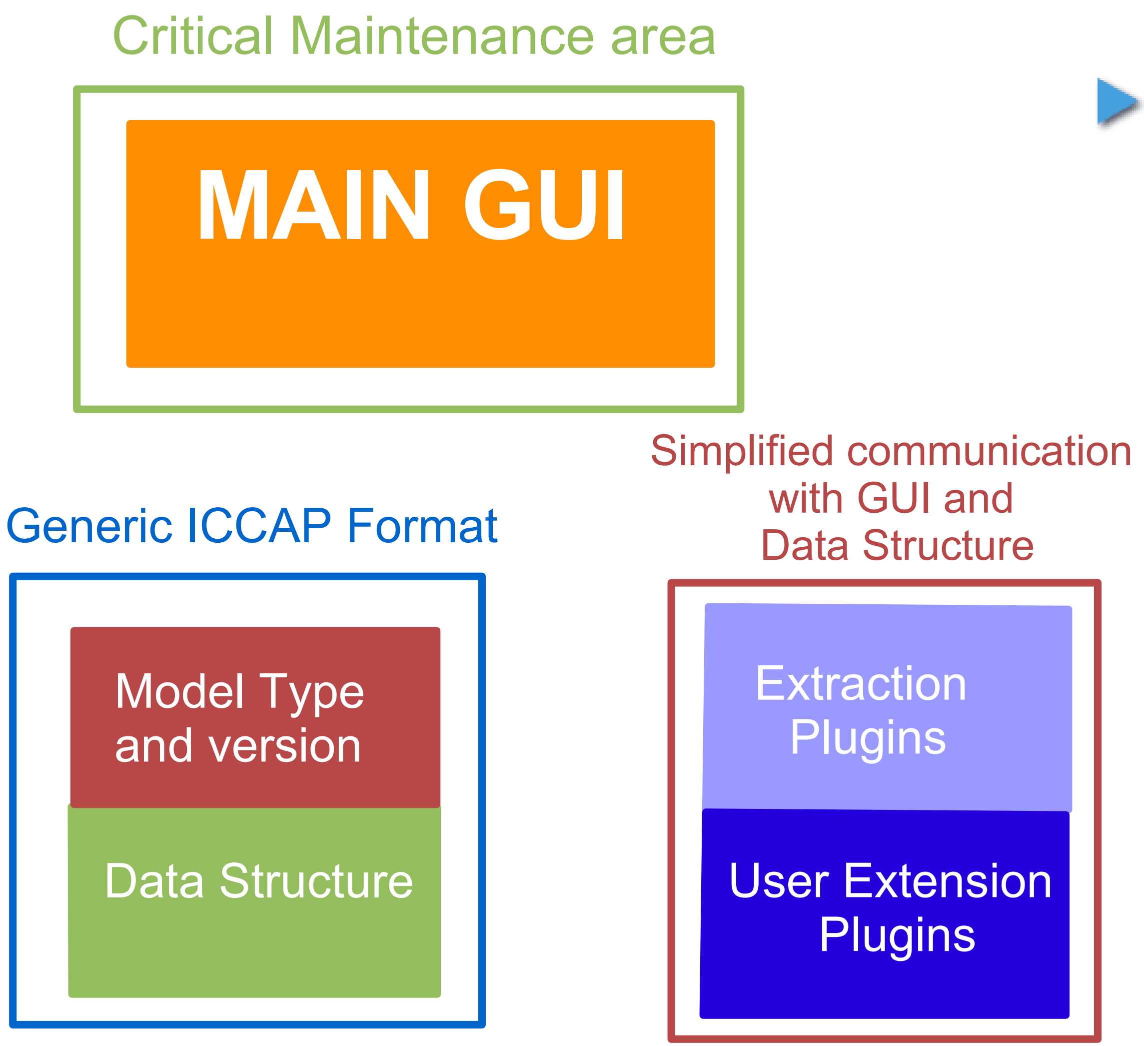
Critical Maintenance area



- **Changing model type or version:**
  - New extractions
  - New Data Structure
  - User extensions incompatibilities
  - Re-check complete architecture
- **Flexibility needs (GUI) interacting with tool core**
  - Complex code mixed with extraction code
  - Difficulty to upgrade or modify

→ Maintenance is difficult
Usability is reduced

SMACH concept



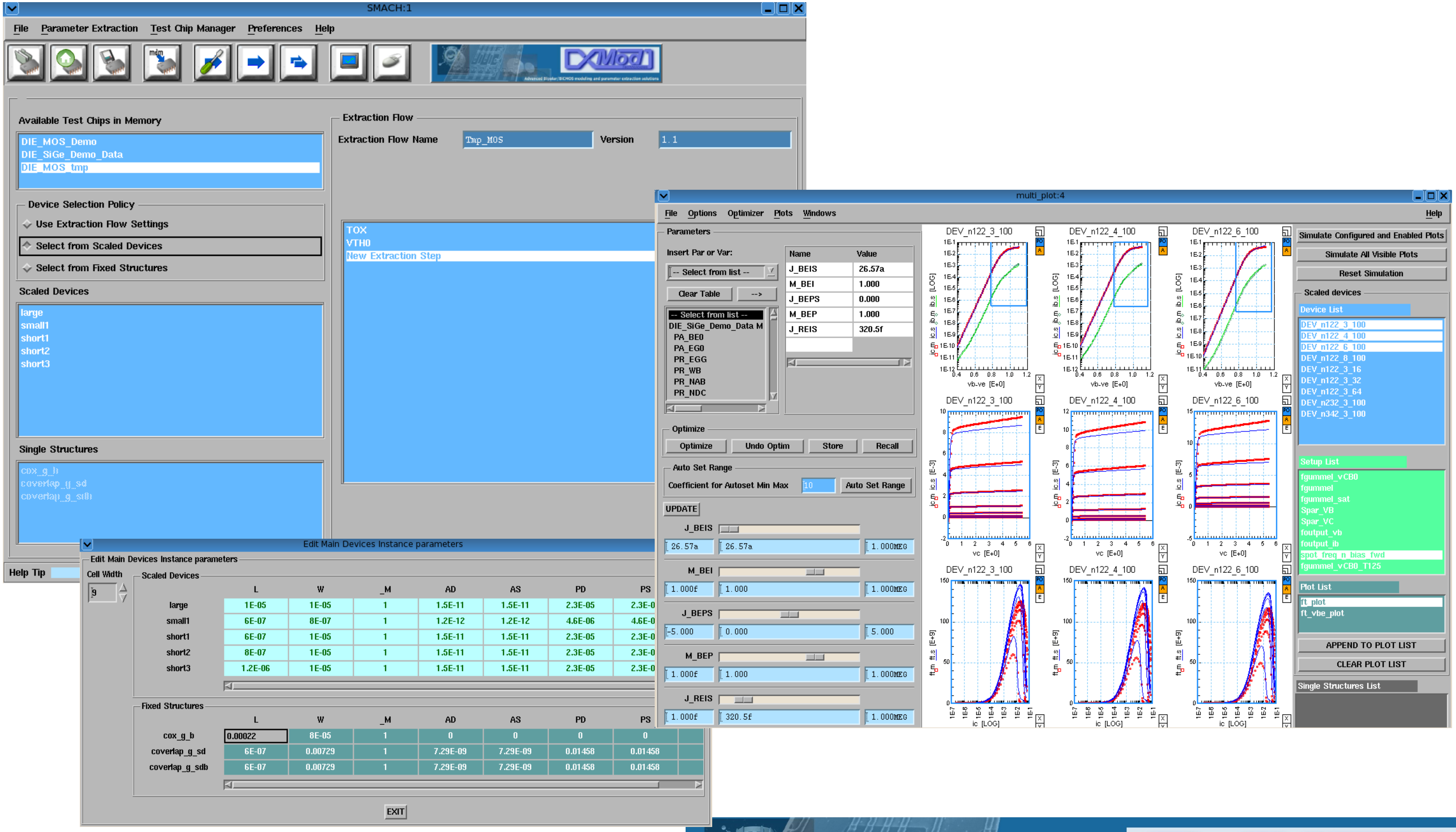
- Each module can be modified without affecting others
  - MAIN GUI can manage different models, different data structures and different Extraction Plugins
  - Simple RULES used for communication between modules
  - Modules can be modified and upgarded without the need to touch the critical maintenance area
  - Modules are simple

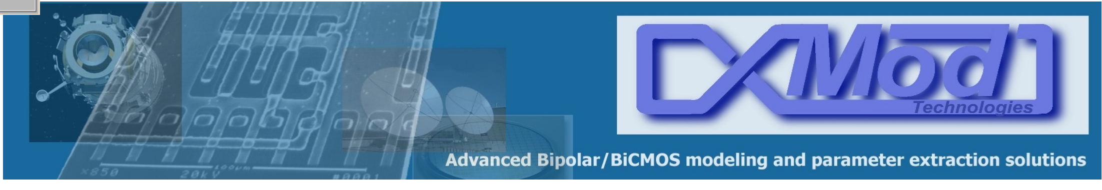
SMACH benefits

- Plugin based architecture (attach new plugins from the GUI)
- Simplified parameter extraction flow (via optimizer plugin) done in minutes
- Optimization, Extraction or mix of both
- Can maintain top level even in case of user extensions
- User extension easy (no need to know the architecture)
- Full scalable and statistical model (in simulator language)
- Efficient use of new ICCAP ploting capabilities
- Data gathered in self-contained entities (Test Chips) seperate from any code
- Switch models from the GUI (MOS, Bipolar)

→ Ideal Tool for evaluation of models before CMC standardization

SMACH: cf Demo





Statistical Plugin

- Theory Presented at HiCUM WS 2006
- Let us see Practical implementation

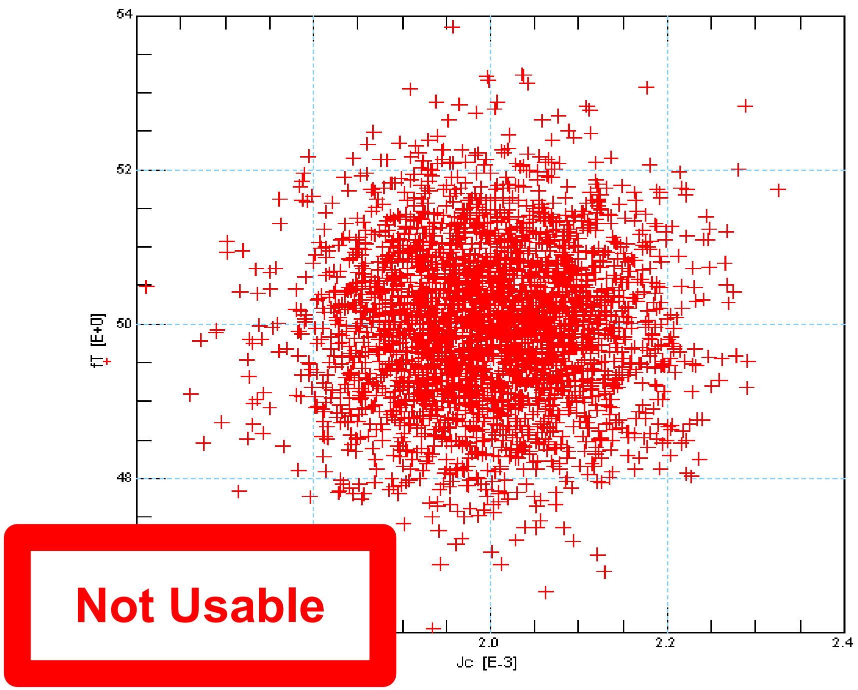
What is the principle of Statistical modeling?

- Simplest Case: Resistor
  - Measured Statistical variation R is also a model parameter --> Easy
  - This is the basis of most EDA Monte Carlo tools

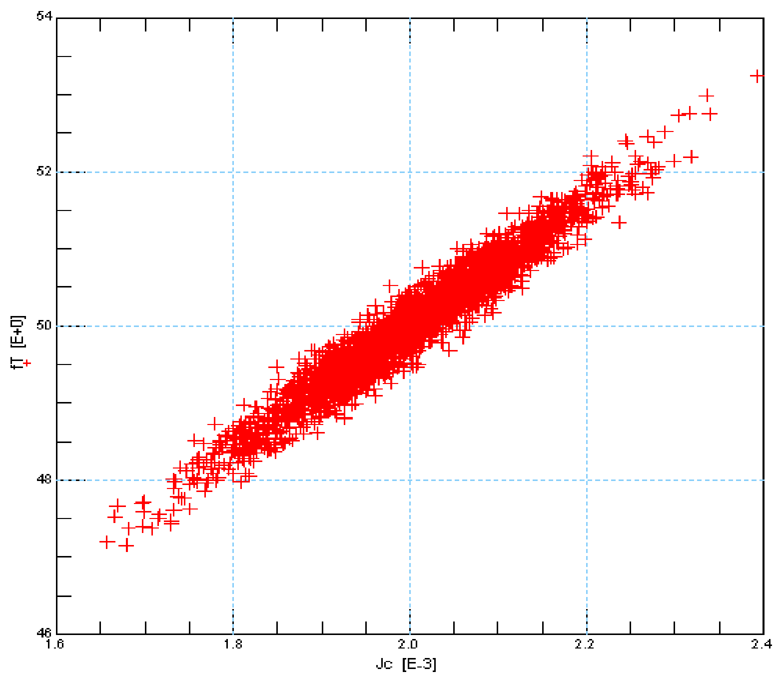
Statistical Plugin

- For Active devices: OPTION 1: use model parameters as inputs
  - No idea of model parameters statistical variation (or requires massive parameter extraction + PCA analysis)
  - Model parameters are correlated!

Monte Carlo Applied to Model parameters



Real Behavior



Statistical Plugin

- For Active devices: OPTION 2: use PCM as inputs
  - One could find relationships between model parameters and PCM
  - Reduces measurement and extraction effort
  - Automatically in Accordance with PCM measurements
  - But PCM are correlated

Not Usable

Statistical Plugin

- For Active devices: OPTION 3: use TP as inputs
  - One can find relationships between model parameters and TP
  - TP are uncorrelated
  - Reduces measurement and extraction effort
  - But TP statistical variations are unknow!

⇒ Re-Simulate PCMs, and adjust TPs variations until fit is obtained
Once Optimization is finished, TPs are KNOWN

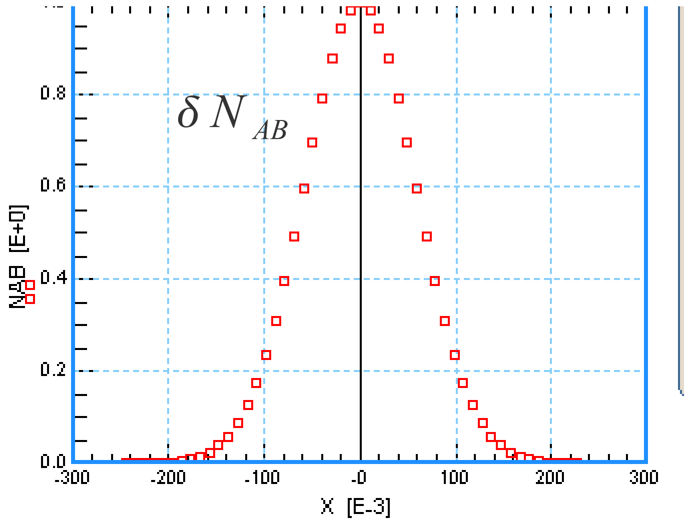
- Other Problem: we need to evaluate the statistical spread: this requires several thousand simulation runs
- The above simulations need to be ran again many time (eg, compute Jacobian matrix for the optimizer)

⇒ **It would require days to be completed (or simply may crash)**

Our Implementation Solves this issue by using tricky practical implementation

Definitions

Normalized base doping (NAB)
Statistical distribution.



For a given wafer run, TPs can beexpressed as:

$$\frac{N_{AB}^{*}}{\overline{N_{AB}}} = 1 + \delta N_{AB}$$

$$\frac{N_{AB}^{*}}{\overline{N_{AB}}} = 1 + SIG_{NAB} * PR_{NAB}$$

Ratio of deviation at 1σ (can also be expressed in %)
This value is fixed for a given process

Actual deviation of a given wafer run, in number of σ
This becomes an instance parameter: random number between [-3;+3]

Statistical Plugin

Example of (ADS based) HiCUM scalable & statistical macro model

```
define                SMACH     (C B E S)
parameters            DRAWN_BE0=0.42 DRAWN_LE0=0.84 NE=1 MULT=1 \
\
A_BE0=0.01 A_EG0=0.01  R_EGG=0.01  R_WB=0.01  R_NAB=0.01   R_NDC=0.01  R_WC=0.01  R_NCX=0.01 R_WE=0.01  \
R_NDE=0.01   R_GAIB=0.05  FAC_T0=0.6 FAC_SIC=1.5 \
\
SIG_BE0=0 SIG_EG0=0 SIG_EGG=0 SIG_WB=0 SIG_NAB=0 SIG_NDC=0 SIG_WC=0 \
SIG_NCX=0 SIG_WE=0 SIG_NDE=0 SIG_GAIB=0

;———— PROCESS GEOMETRY ————
 b_ov=0.12
w_s=0.1
b_pm=0.1
l_pm=0.1
...
;———— ELECTRICAL specific parameters ———
 C_JEI0=4.3
C_JCI0=4.2
C_JEP0=0.85
C_JCB0=0.1274
...
C_10=3.467E-014
Q_P0=1.5
 ...
;———— Internal Calculations ————
 PBC=(MULT*NE*2*(BBC+LBC))
ASIC=(MULT*NE*(BE0+2*b_sic)*(LE0+2*b_sic))
PSIC=(2*MULT*NE*((BE0+2*b_sic)+(LE0+2*b_sic)))
...

model MAIN HICUM Tnom= 27  \
C10 = (C_10*AE*AE*1e-18*r_AE0*r_AE0* (1+R_EGG*SIG_EGG)*(exp(A_EG0*SIG_EG0)) )  \
Qp0 = (Q_P0*AE*1e-15*r_AE0*(1+R_WB*SIG_WB)*(1+R_NAB*SIG_NAB))  \
...
Rci0 = ((R_CI0/(AE*fcs))*(1+R_WC*SIG_WC)/((1+R_NDC*SIG_NDC)))  \
...
end SMACH
```

Instance Parameters

1 σ TP variations (% from nominal) R_x's

deviation from nominal (number of σ) SIG_x's

geometrical information

geometry independent parameters

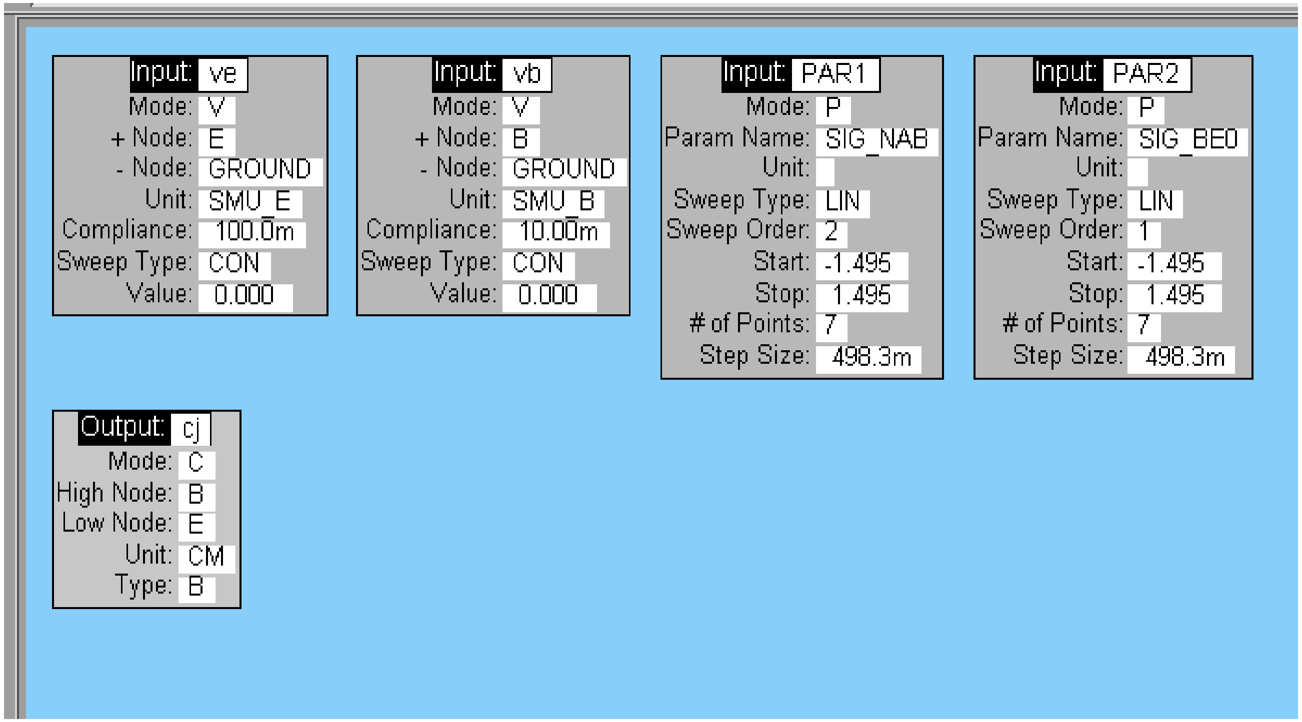
Intermediate calculations

Satistical equation

Scaling equation

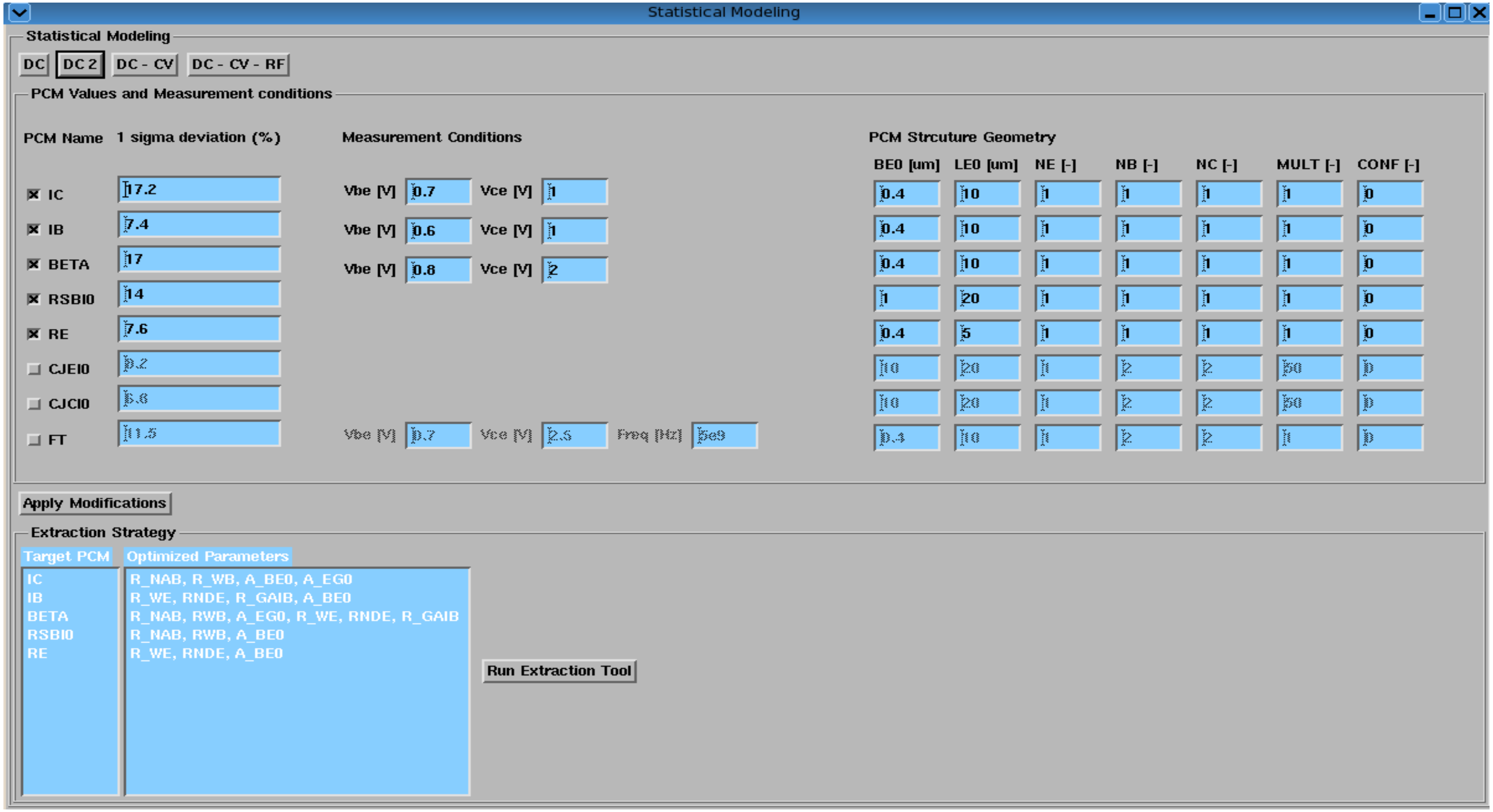
Implementation

- Simulator Linear User Sweeps PAR1 and PAR2 emulates random values for SIG_NAB and SIG_BE0 with Gaussian distributions -> speed up by a factor of 100 to 1000
- This aproximation is justified by real MC simulation once the TP optimization is achieved



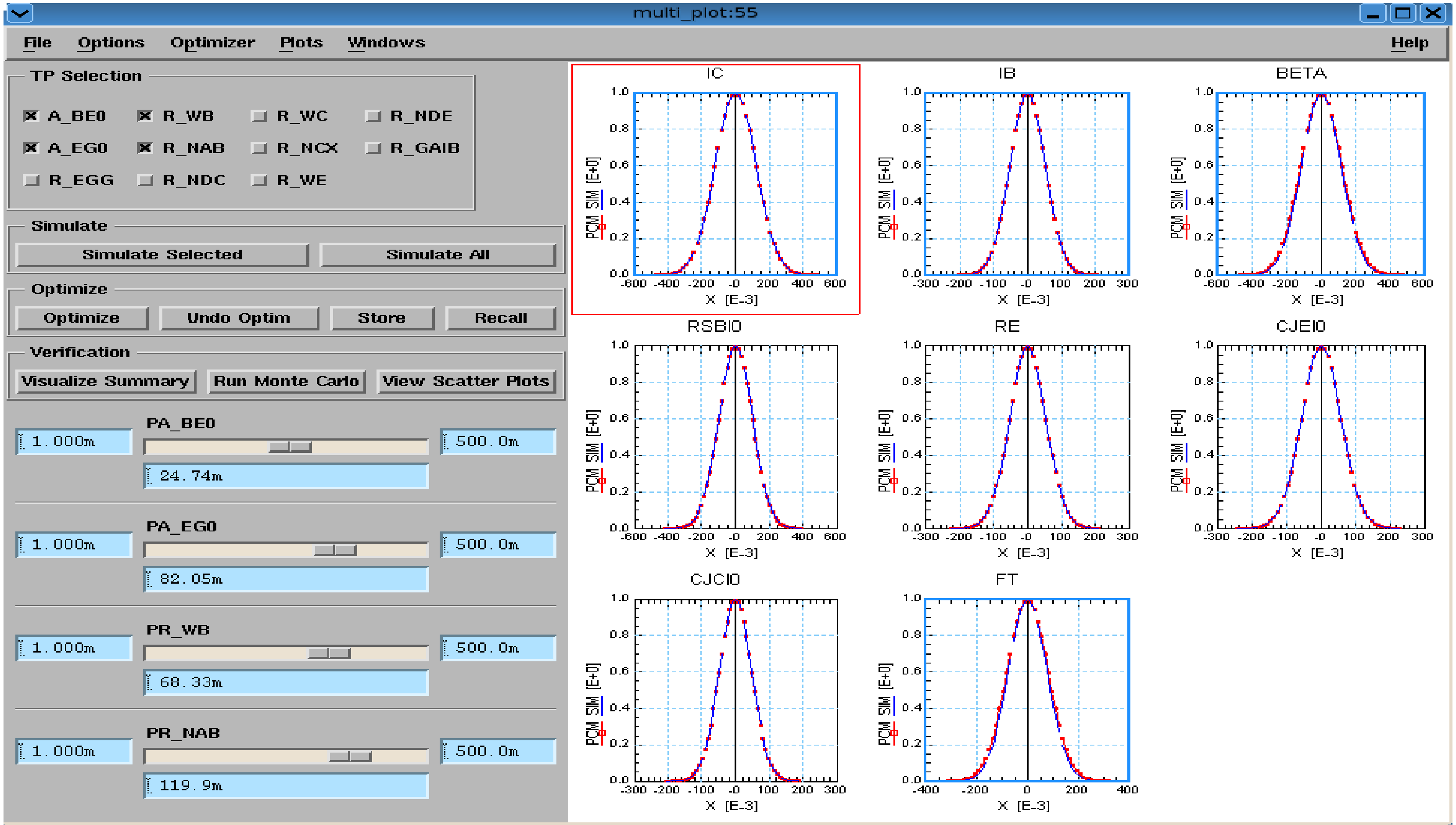
Statistical Plugin

- PCM selection, Bias points and geometry definition

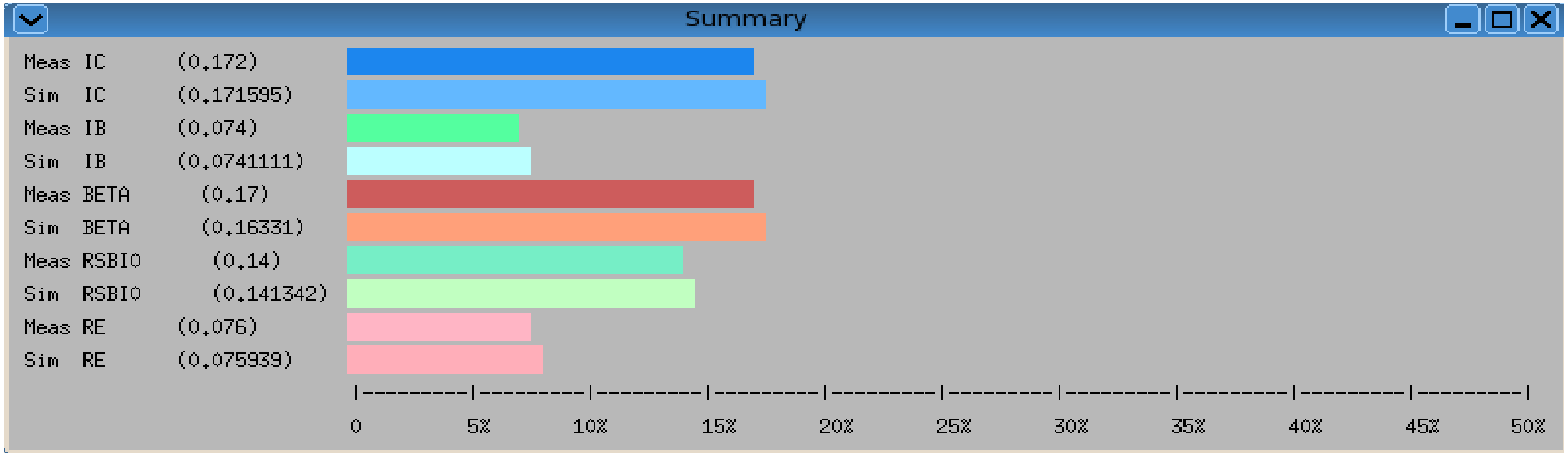


Statistical Plugin

- Extraction: TPs are parameters, measured PCMs spread are targets, PCM simulated spread are simulations
- Done in a few minutes



Statistical Plugin

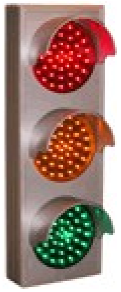


cf SMACH Demo

HMT Roadmap

HMT	1H 2007	2H 2007	1H 2008	2H 2008
HiCUM v2.1				
HiCUM v2.21/2.22				
HiCUM L0 v1.11				
VBIC			*	

*depends on customer priorities



= High Delay risk

= Medium Delay risk

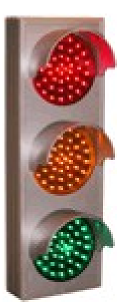
= Low Delay risk

Already available

SMACH Roadmap

SMACH	1H 2007	2H 2007	1H 2008	2H 2008
HiCUM v2.1				
HiCUM v2.21/2.22				
HiCUM L0 v1.11				
VBIC				
MM20				
Other models (HVEKV, varactors, Inductors)				

*depends on customer priorities



= Simplified Extraction

= Full set of extraction plugins