Radiation-induced Single Event Transients Modeling on Ultra-Nanometric Technologies

Boyang Du, Luca Sterpone
Politecnico di Torino
Torino, Italy

Sarah Azimi
Noshirvani University of Technology
Babol, Iran

Goal

To propose a new methodology combining an analytical and a pattern-oriented simulative model for analyzing the sensitivity of SET on ultra-nanometric technologies

Collaboration

The radiation experiment has been carried out with collaborations of:

- Université Catholique de Louvain (UCL)
- European Space Agency
- Microsemi

Outline

- Introduction
- Radiation Experiment
- The analytical model
- The pattern-oriented simulative model
- Conclusion

Introduction

- Increasing susceptible to Single Event Effects
  - Technology scaling
  - Aging
  - Radiation particles (even at sea level)
- Single Event Upset (SEU)
  - ECC
  - TMR
  - Configuration memory scrubbing (SRAM-based FPGA)
- **Single Event Transients (SET)**
  - TMR (Higher Level)
  - Broadening and Filtering effects of gate itself

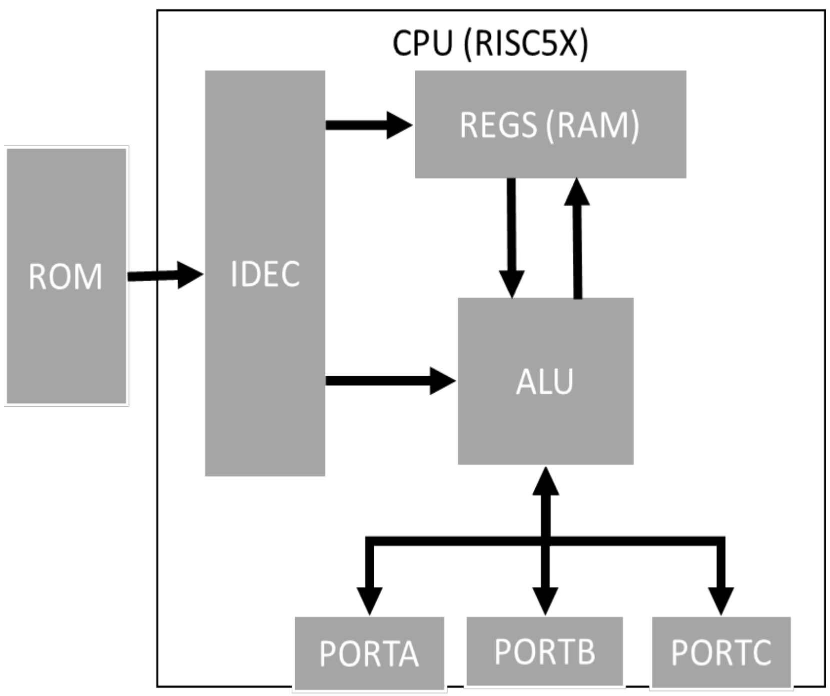
Introduction

Analysis of SEEs

- SEUs
  - Simulation (RTL even behavioral level, cycle-accurate)
  - FPGA emulation
- SETs
  - Simulation (discrete simulation interval)
  - FPGA emulation (difficult to inject)
  - Electric pulse injection
  - Radiation experiment (need to separate from SEUs)

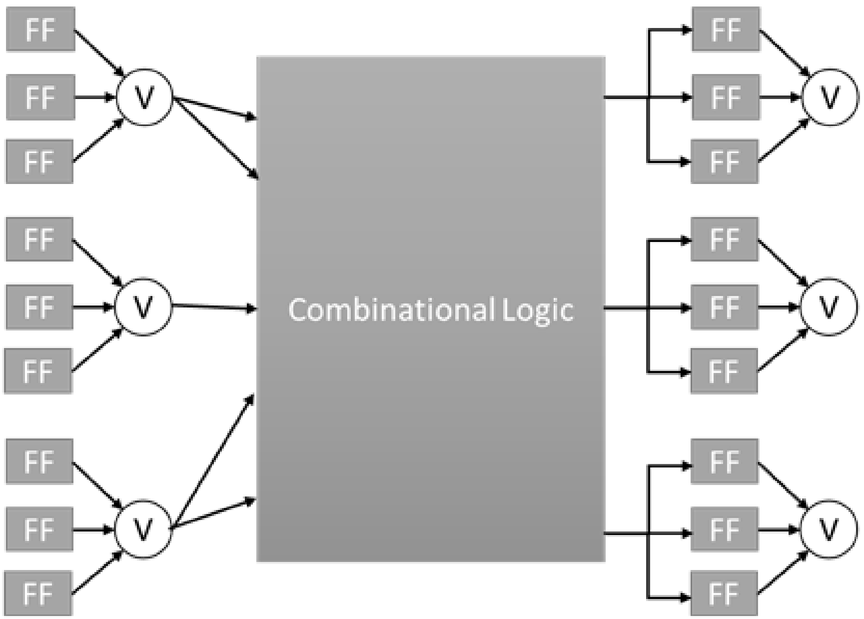
The Radiation Experiment

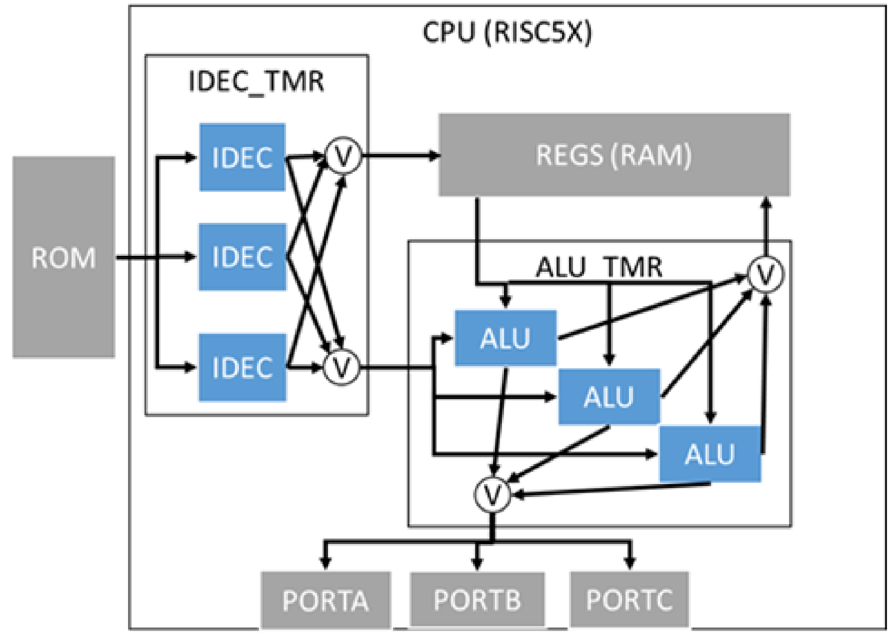
- Heavy-ion experiment at the Cyclotron of the Université Catholique de Louvain (UCL)
- Microsemi ProASIC3 Flash-based FPGA (130-nm)
- A RISC micro-processor (RISC5X from OpenCores)

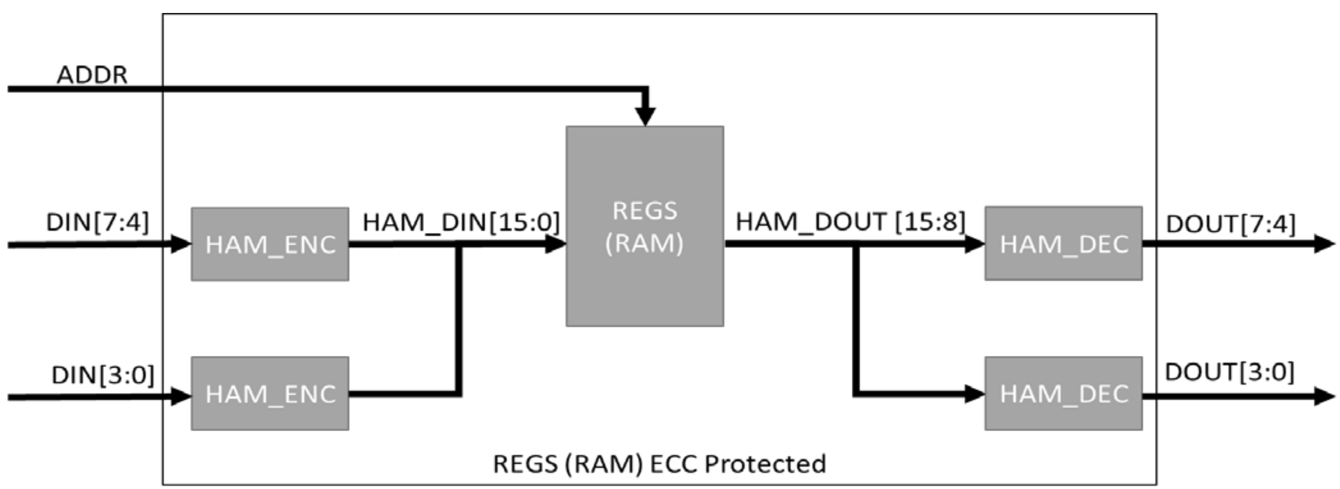


- RISC5X : 20MHz
- Kripton ion
- Fluence = 3.04E8 (particles)
- Avg Flux =1E4 (particles/sec)

The Design under Test



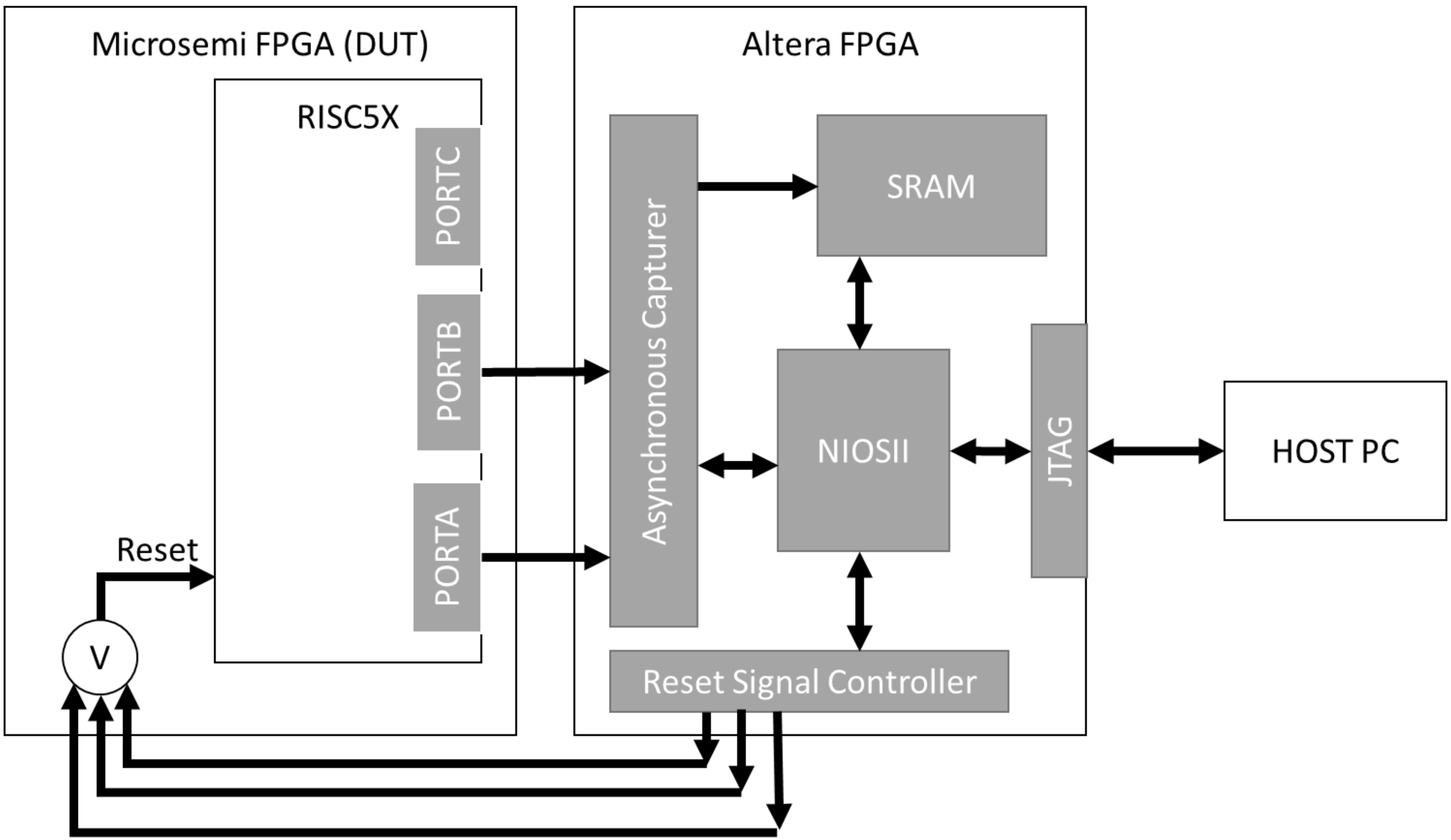




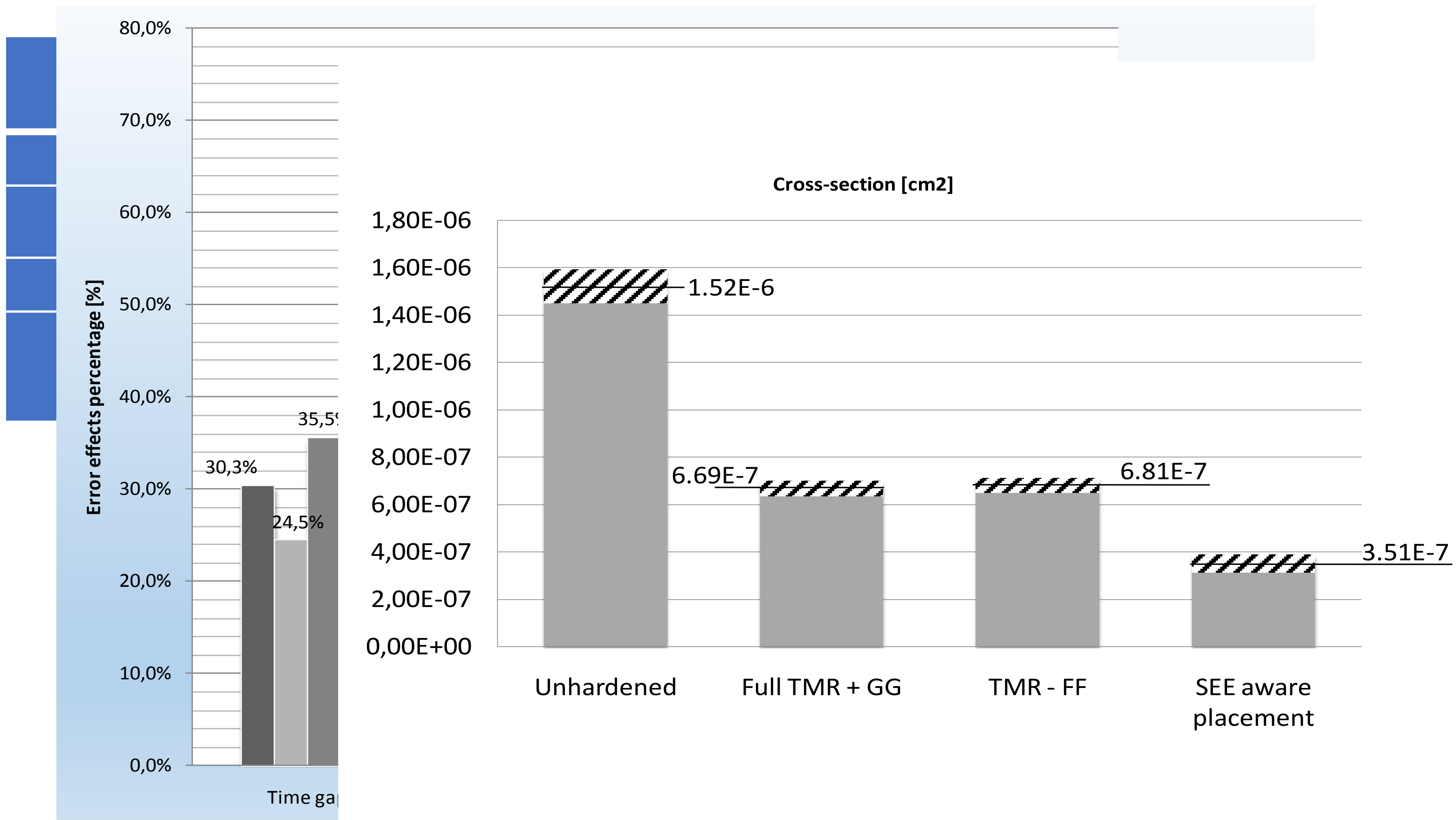
The Software Benchmark

```
// Loop through each element of RAM
for each ram element re in RAM:
    for i in [0, 8) : {
        re = 0x01 << i
        for j in [0, 500): // Add 0 to the RAM element for 500 times
            re += 0x00
        output_to_PORTA(re)
    }
```

The Hardware Setup

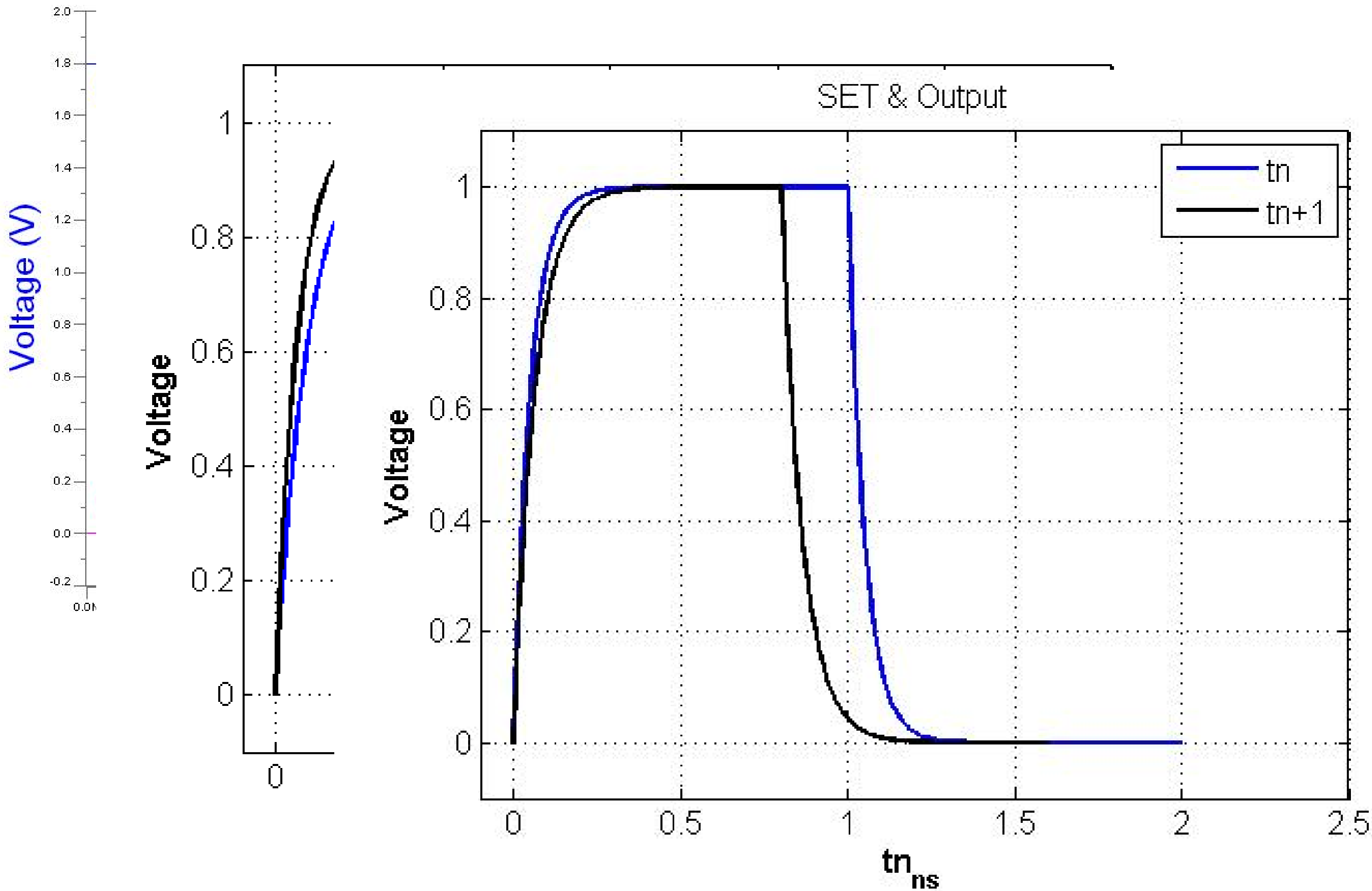


The Experimental Results

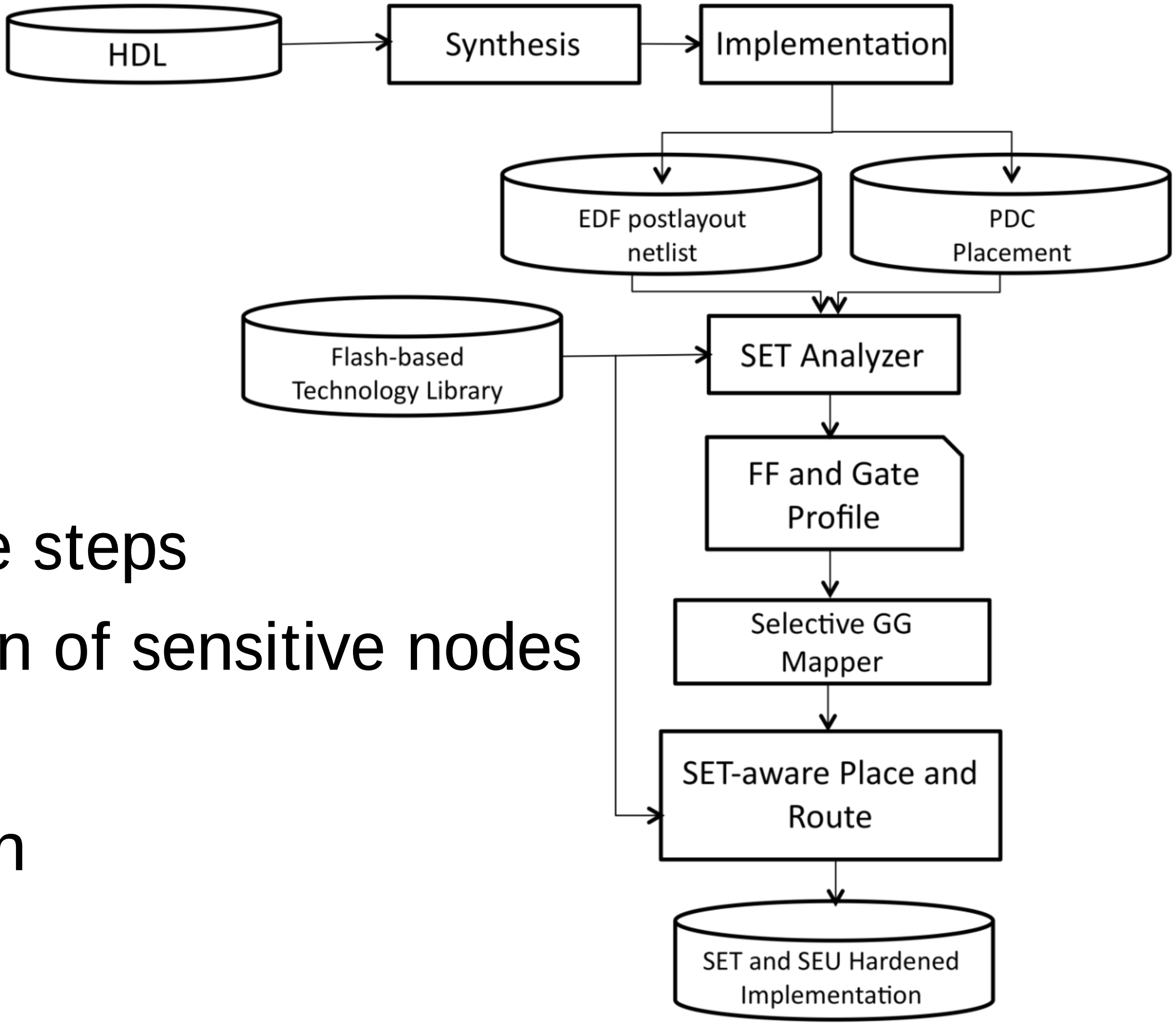


The experimental result is the starting point of more effective and realistic analysis of SETs

The analytical model

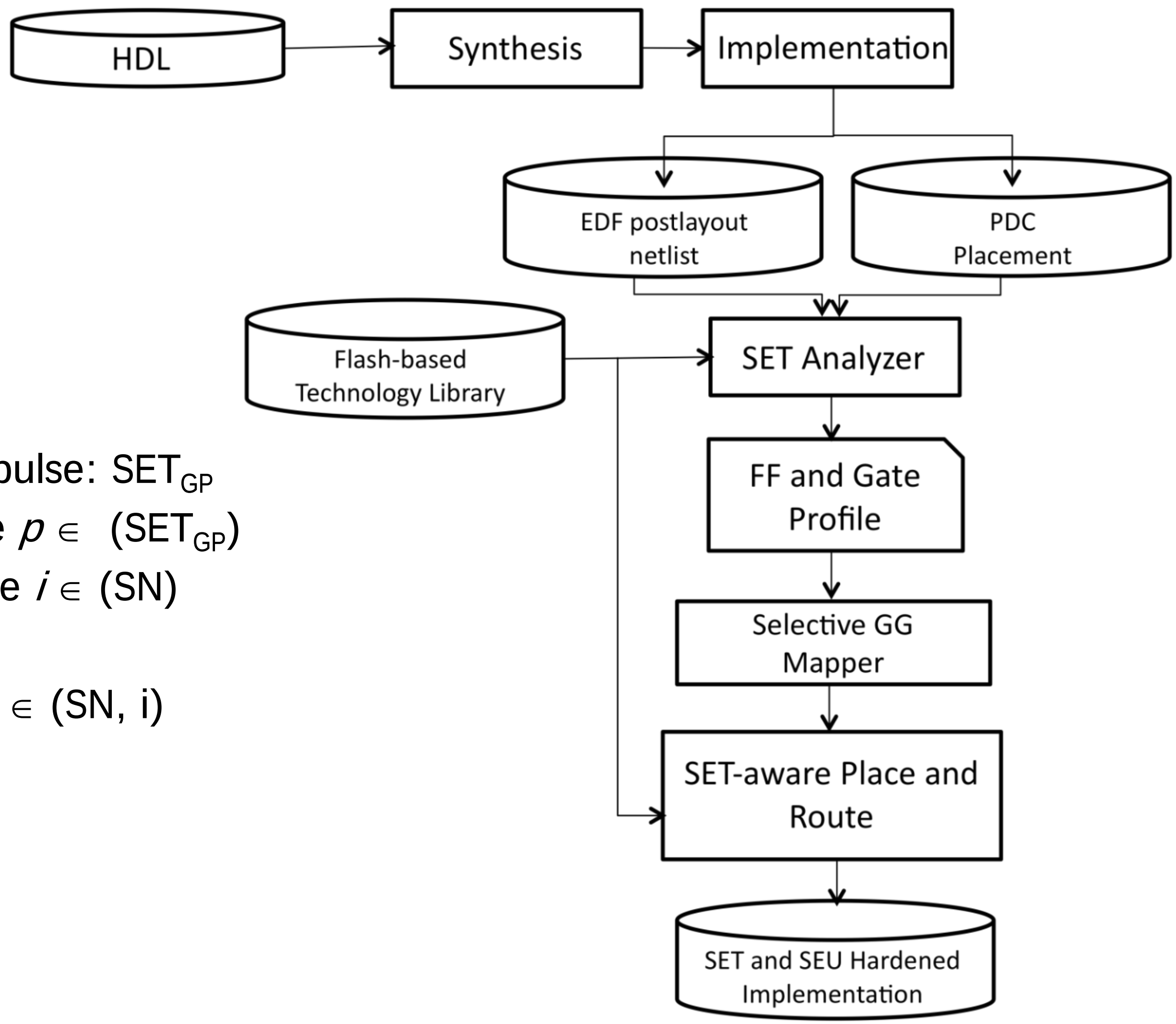


The pattern-oriented simulative model



- Executed in three steps
  - Identification of sensitive nodes
  - Propagation
  - Classification

The pattern-oriented simulative model



1. Generate the list of SET pulse: SET_{GP}
2. For each generated pulse $p \in (SET_{GP})$

   2. For each sensitive node $i \in$ (SN)

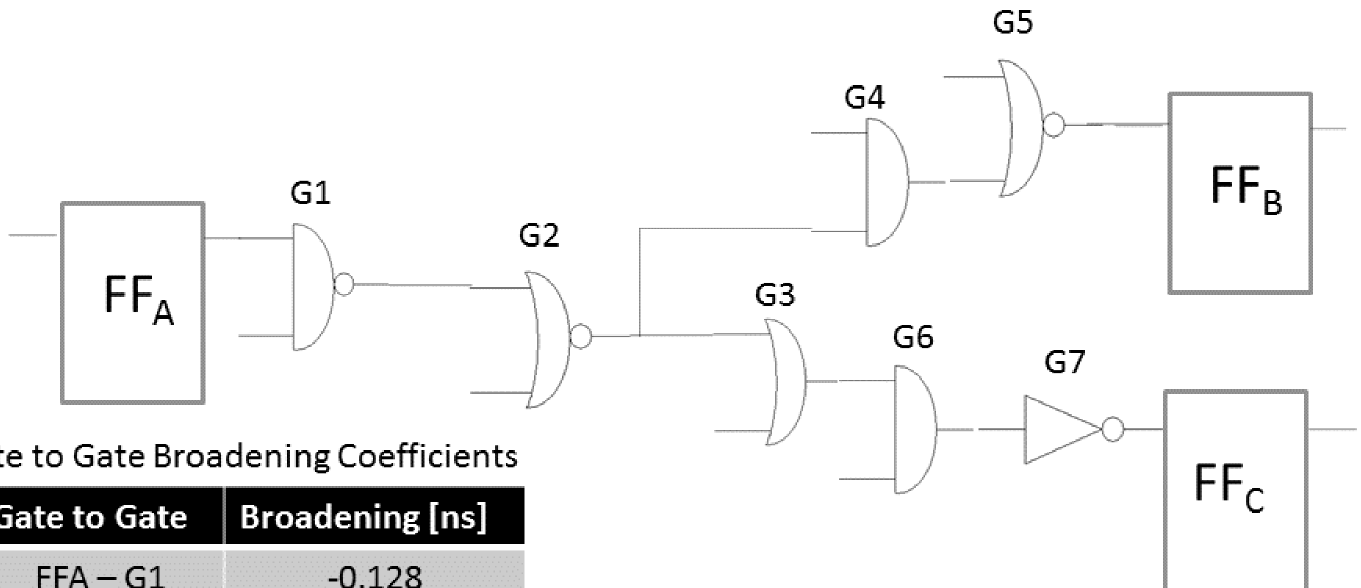
   Apply pulse p to i

   Find destination node $dn \in$ (SN, i)

      3. For each dn

      Propagate p on (i, dn)

The pattern-oriented simulative model



Gate to Gate Broadening Coefficients

Gate to Gate	Broadening [ns]
FFA – G1	-0.128
G1 – G2	0.458
G2 – G4	0.070
G2 – G3	-0.090
G3 – G6	0.480
G6 – G7	0.092
G7 - FFC	0.140
G4 – G5	-0.094
G5 - FFB	0.130

FFs maximal broadening pulses

Flip-Flop	Maximal Pulse [ns]
FFB	0.436
FFC	0.952

Conclusion

- The analytical model is able to provide SET pulse broadening/filtering profile per gate and can be extended to different cell library (e.g. opencell-15nm)
- The pattern-oriented simulative model can use the results coming from the analytical model to analyze a circuit providing information such as Gate-to-Gate broadening effect and FF profiles
- With the results coming from two models, further actions can be made:
  - SEE-aware place & route
  - Simulation-based fault injection

Thanks for your attention

Questions?