EM Injection : fault model and locality

S. Ordas[1] , L. Guillaume–Sage[1], P. Maurine[1,2]

[1] LIRMM

[2] CEA-TECH

State of the Art

2002

J.J. Quisquater, D. Samyde :
Eddy current for Magnetic Analysis with Active Sensor

2007

J.-M. Schmidt, M. Hutter :
Optical and EM Fault-Attacks on CRT-based RSA: Concrete Results

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- Harmonic EM Injection modifies the behavior or RO based TRNG **(phase locking)**
- EM pulse Injection produces **timing faults** during the course of hardware cryptographic modules
- EM pulse Injection produces **timing faults** during the course of hardware and software …

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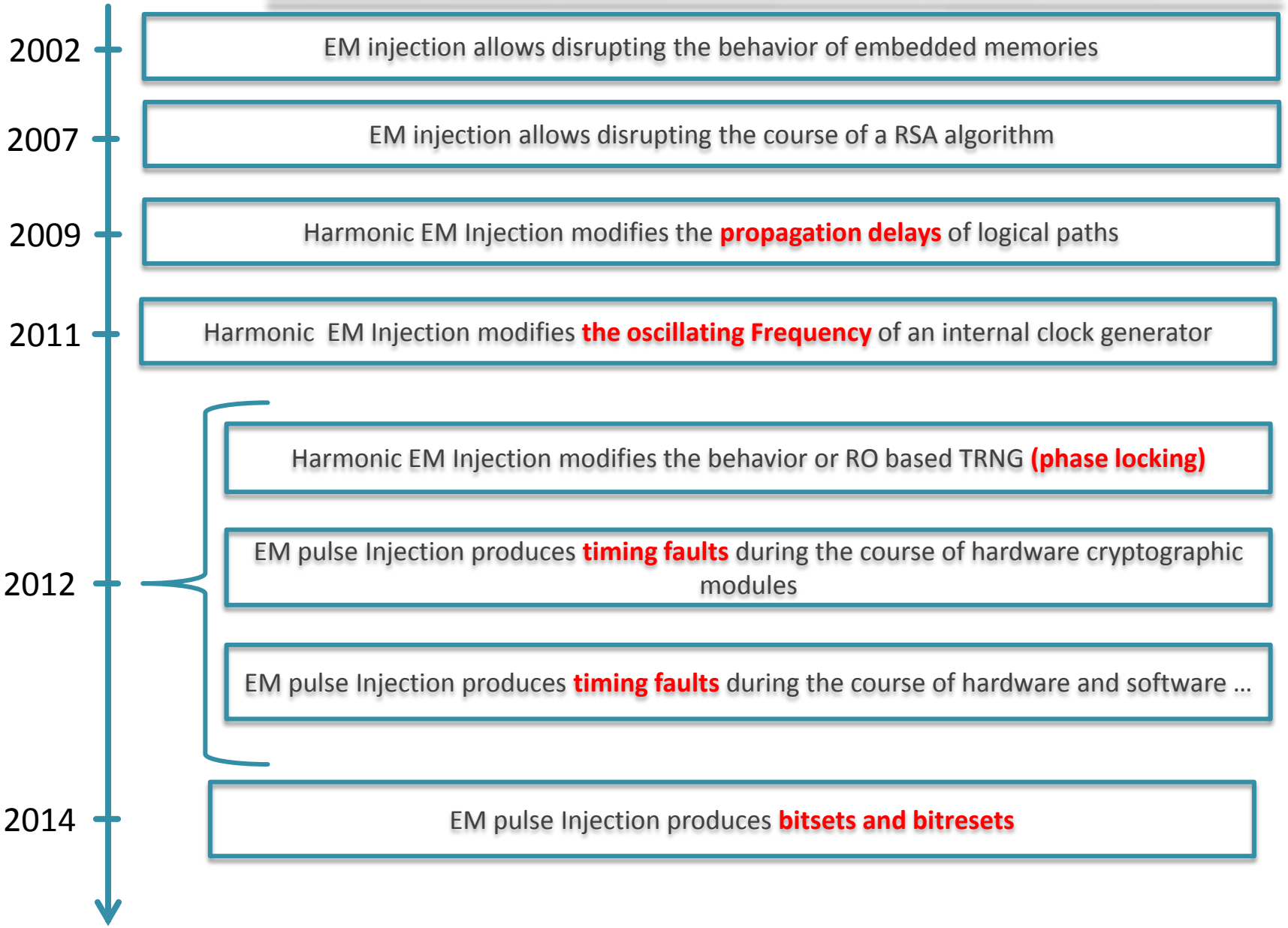
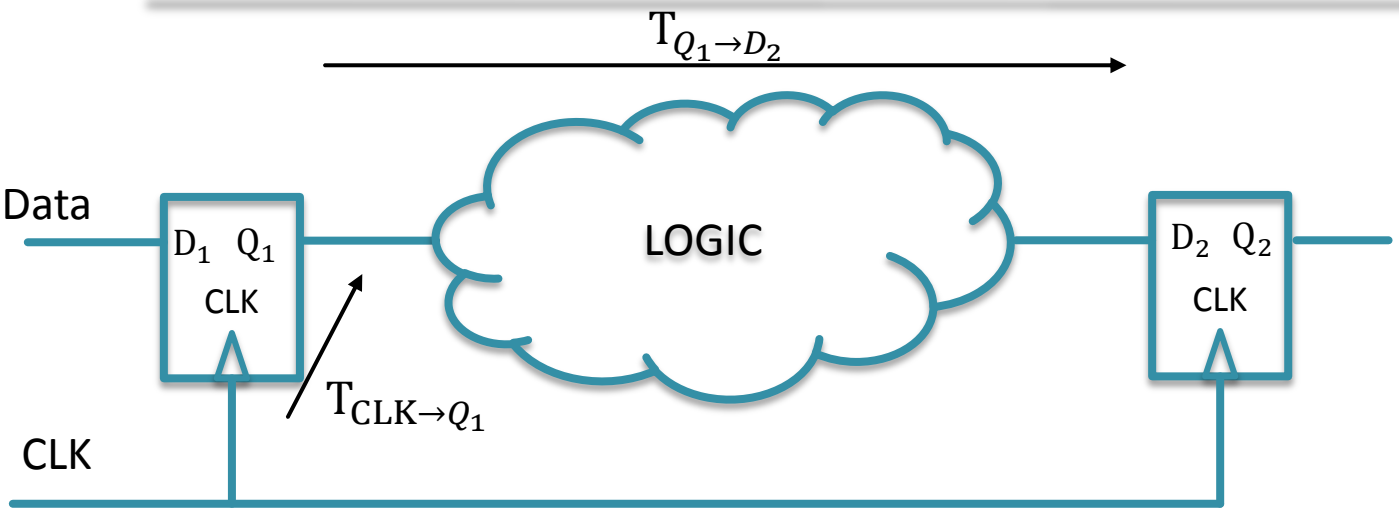


CONCLUSION OF OUR PREVIOUS PAPER

1. Polarity of EM injection is important
2. EM injection has a local effect
3. EM injection induce bitsets and bitresets
4. Pulse must have a high voltage to produce bitset and bitreset

What kind of faults appears on an operating circuit?

TIMING FAULTS MODEL

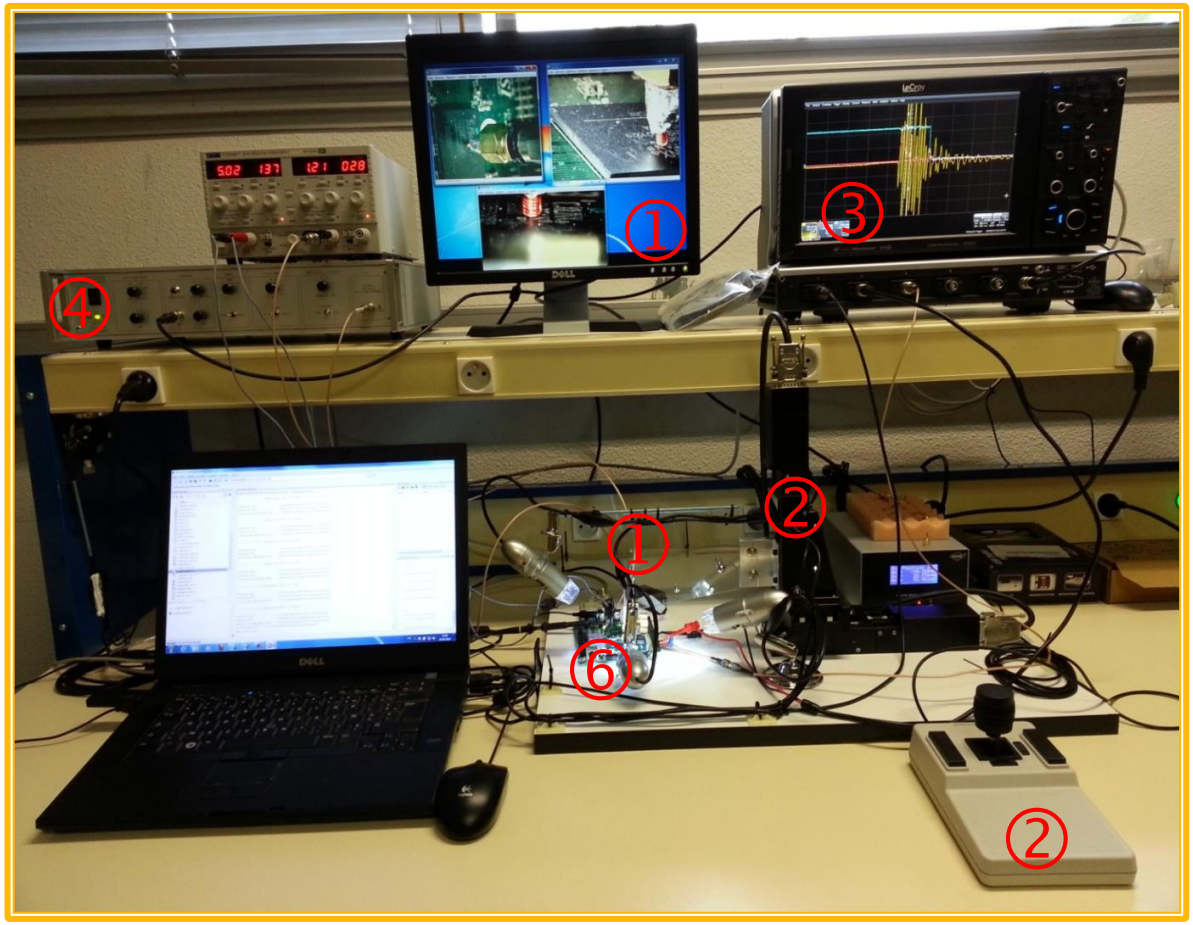


Timing constraint :

$$T_{CLK \rightarrow Q_1} + T_{Q_1 \rightarrow D_2} < T_{CLK} - T_{skew} - T_{Setup}$$

EM Injection induces Setup time constraint violations

EM Injection Platform: overview



① 3-axes vision system

② 3-axes positioning system

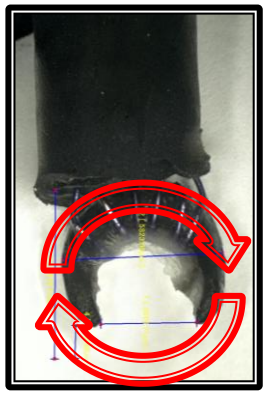
③ Oscilloscope

④ Pulse generator

⑥ Hand made injection probes

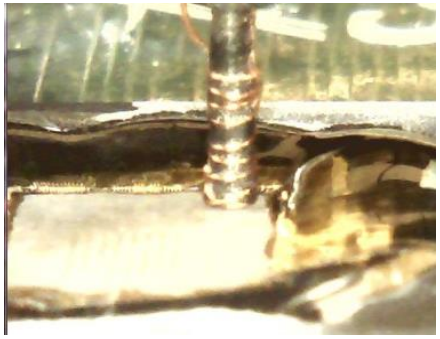
⑦ a laptop

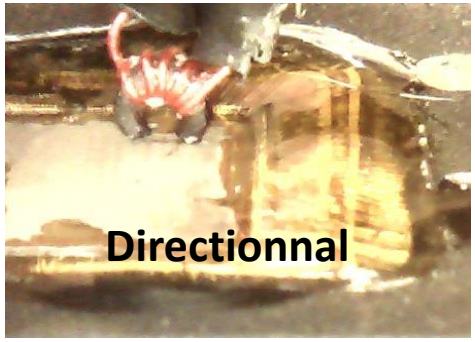
HAND MADE INJECTION PROBES



Magnetic flux is spread over a large surface

Concentrate the magnetic flux on a reduced area of the IC surface using concentric field lines

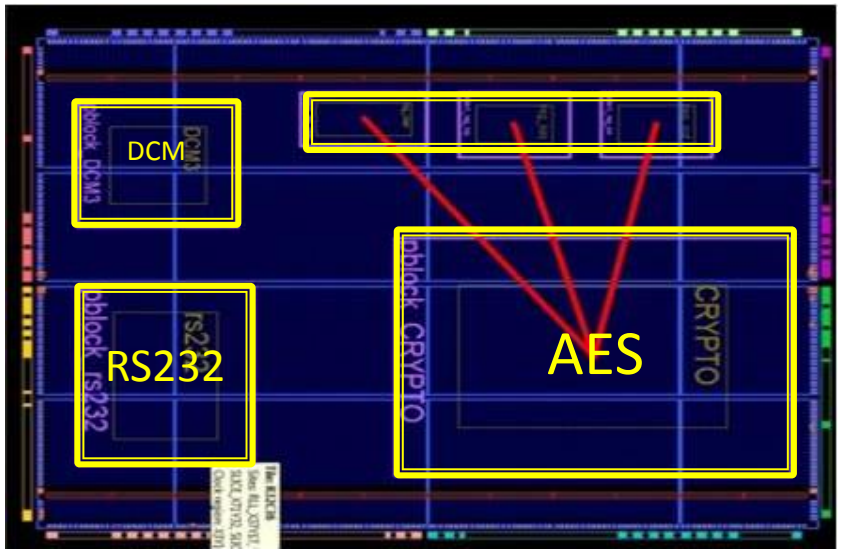




EXPERIMENTATION ON AN OPERATING CIRCUIT

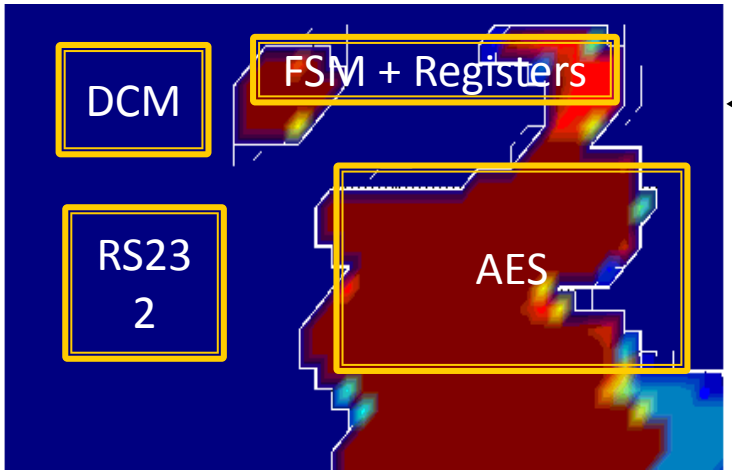
To evaluate if some areas of the system are more sensitive to EM pulsed than others

- Fpga Xilinx Spartan 3
- Vdd= 1.2V
- Frequency : 100MHz (generated by DCM)
- Cartography step : 200µm
- Vpulse = 44V << 110V
- Hand made probe
- 100 shoots per position

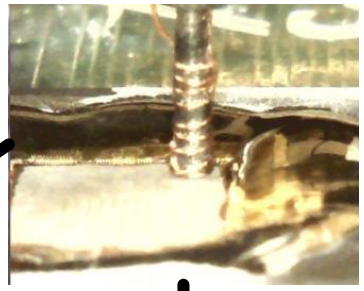


LOCALITY OF THE EM INJECTION

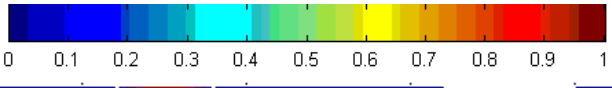
bad ciphering

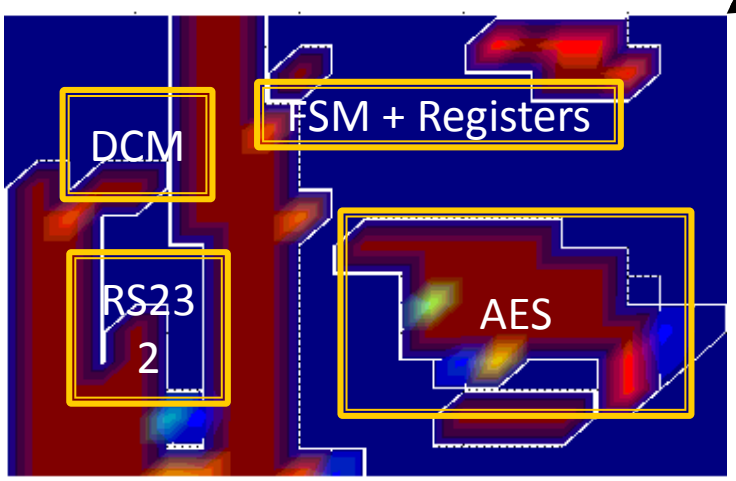


Crescent injector



flathead injector





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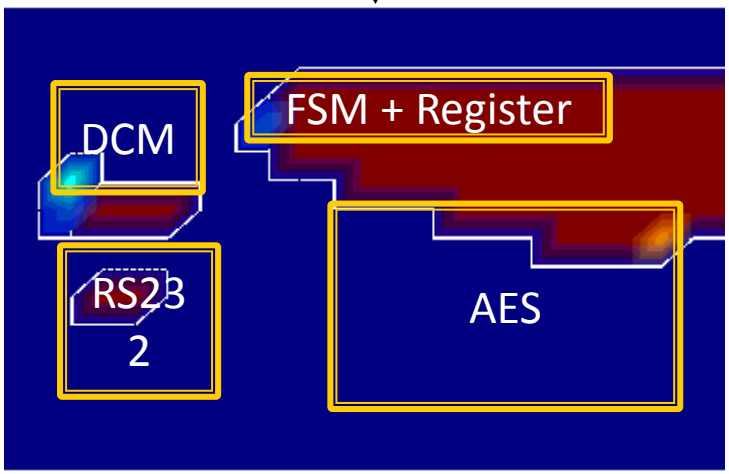
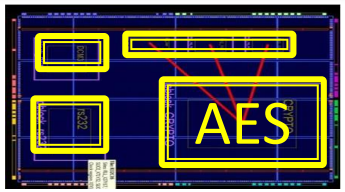
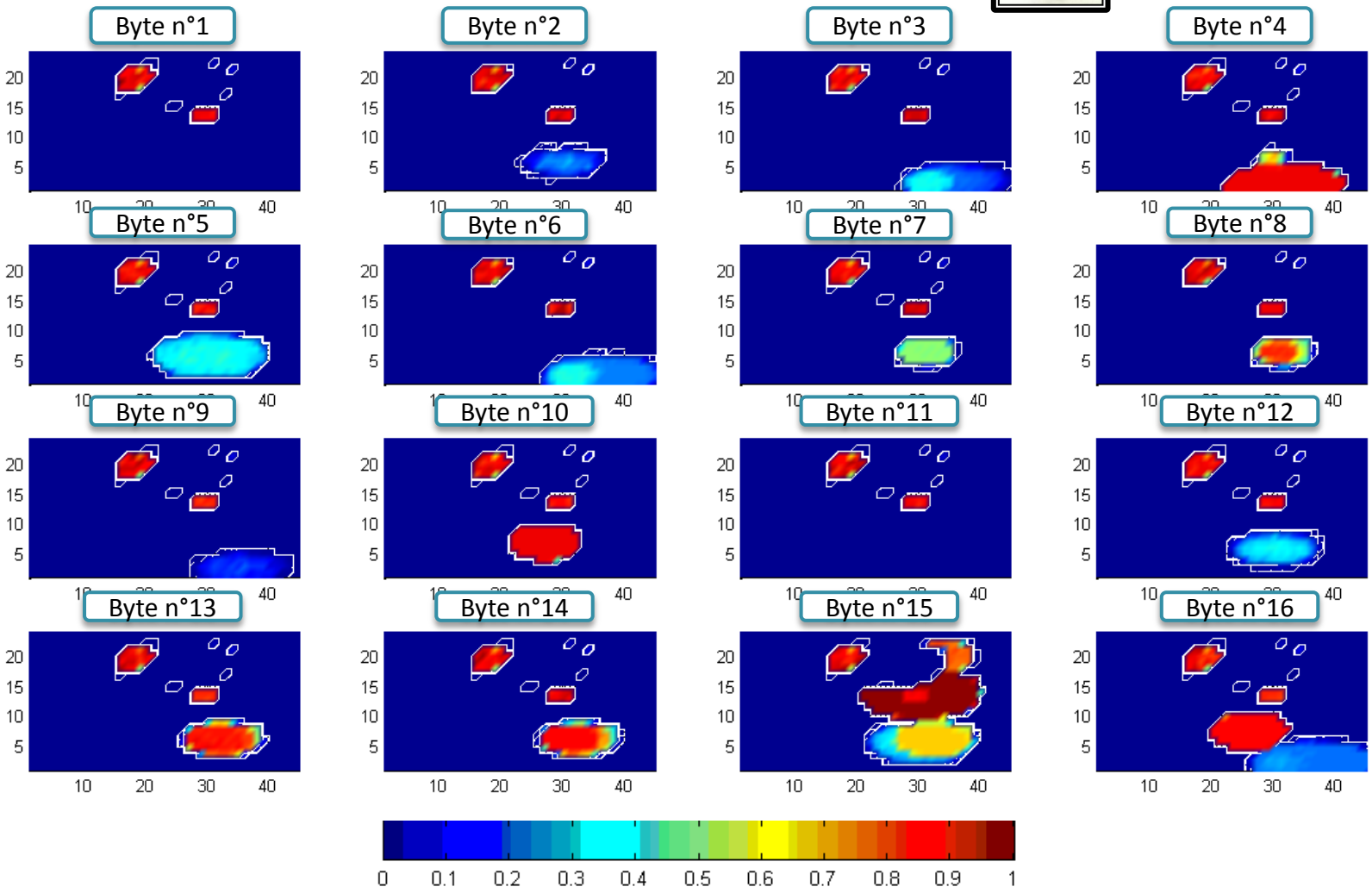


no-response

LOCALITY OF EACH BYTE FAULTED





EXPERIMENTATION ON AN OPERATING CIRCUIT

To evaluate if some moments of the AES calculus are more sensitive to EM pulsed than others

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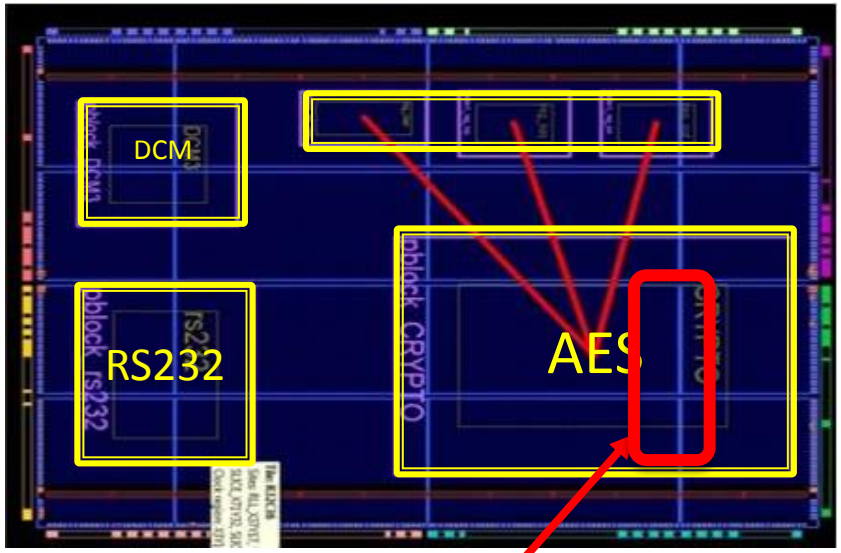
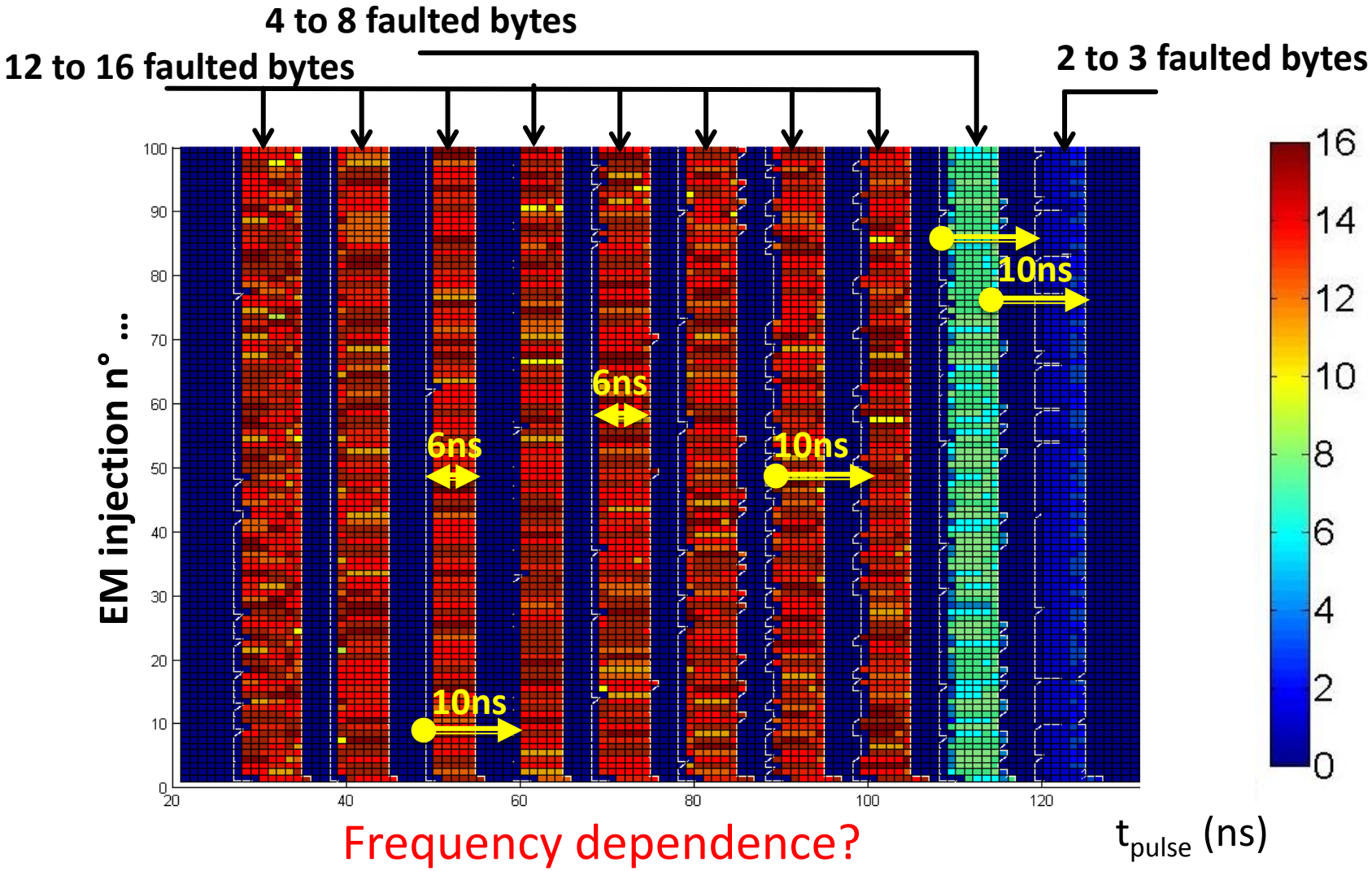
- Hand made probe



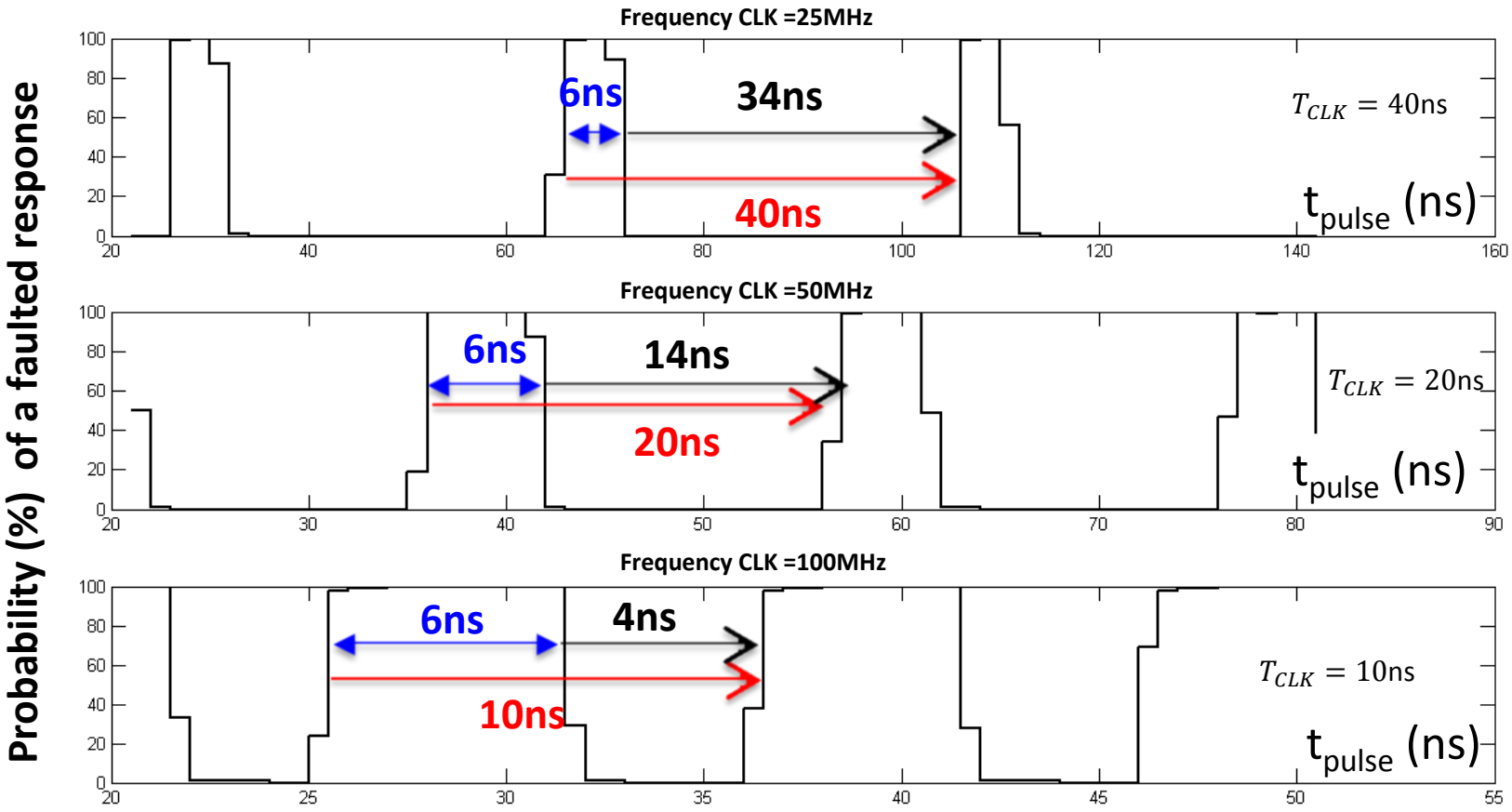
- Moment of the injection varies for covering all the ciphering

LOCALIZATION IN TIME OF THE FAULTS

$F_{CLK} = 100MHz \quad T_{CLK} = 10\text{ns}$



FREQUENCY DEPENDENCE?

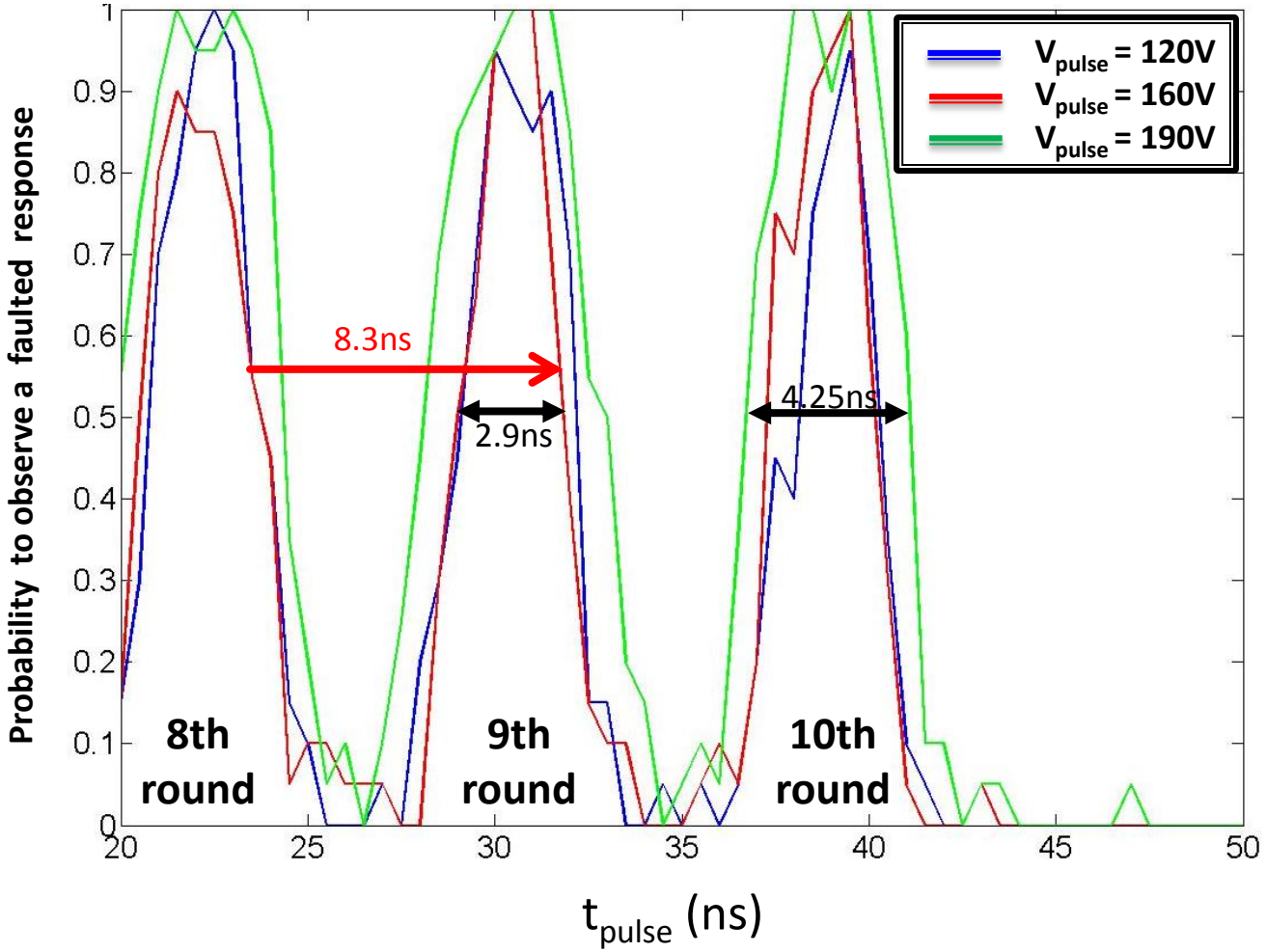


No frequency dependence

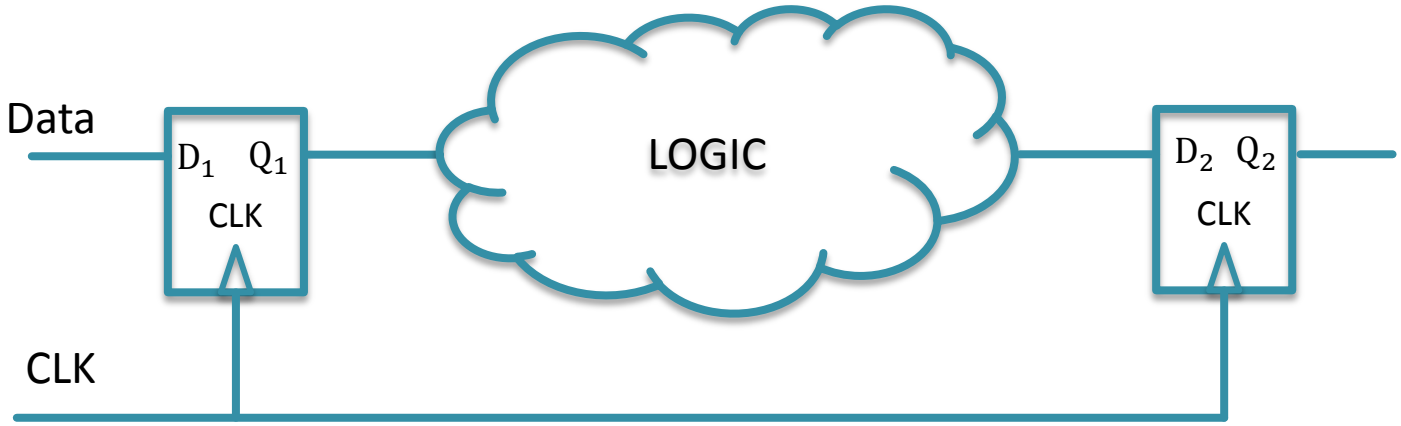
Faults are not timing faults

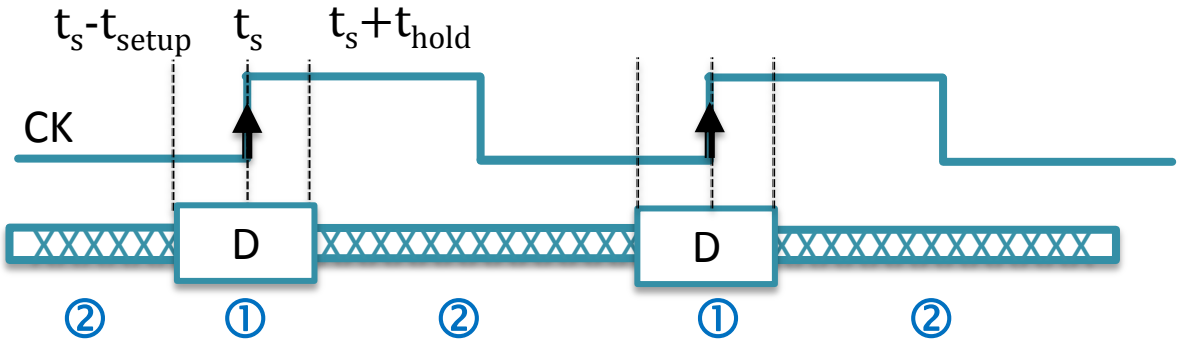
EXPERIMENT VALIDATION ON MICRO-CONTROLLER

- Experiment realized on an AES hardware
- Frequency of the CLK : 120MHz



OPERATING CIRCUIT



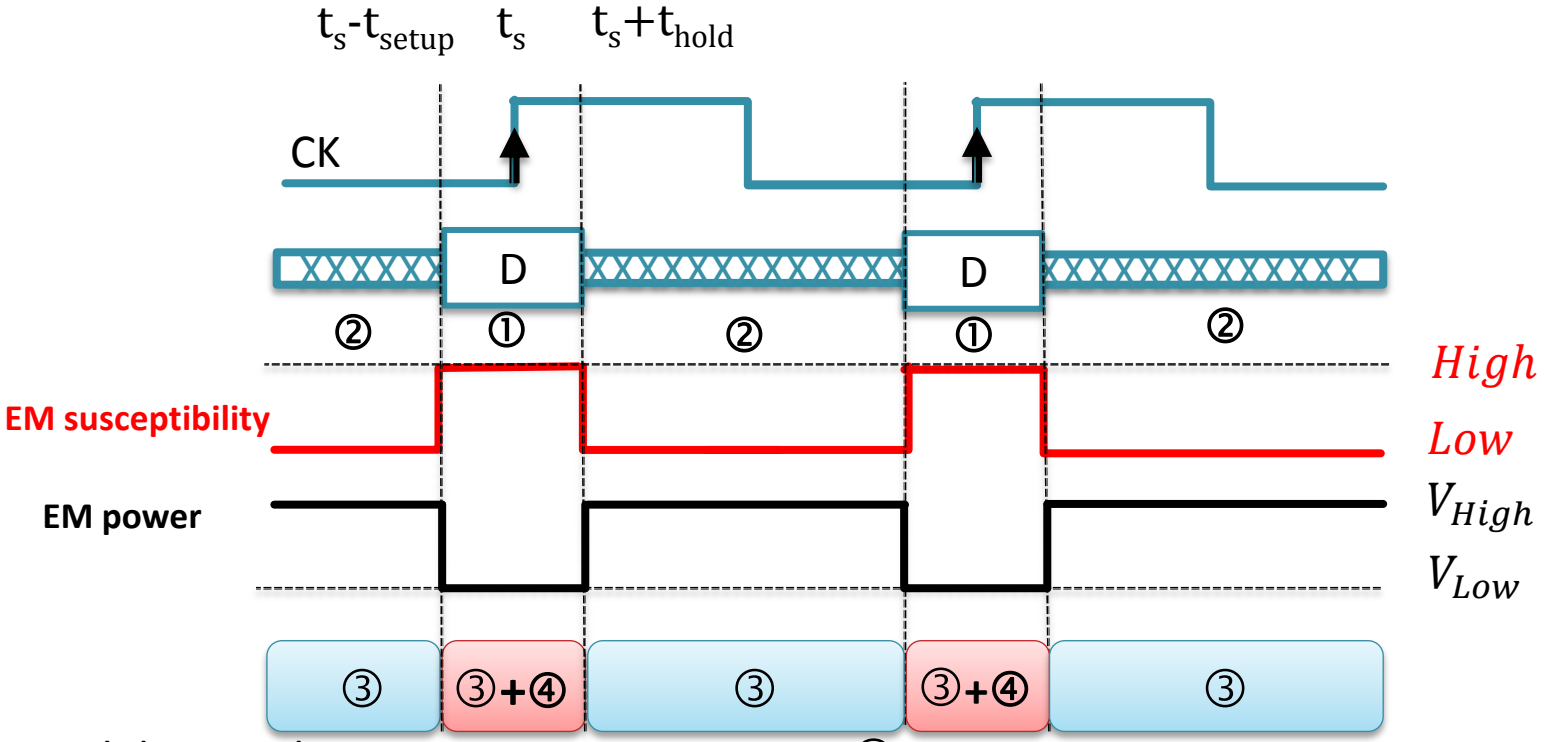


① : Stability window

② : Processing window

FAULT MODEL

- Sampling faults
  - Disrupt an input signal of the DFF (CLK, Data ,Reset, Set)
  - Disrupt during the stability window (t_{setup}+t_{hold} around rising clock edges)



① : Stability window

② : Processing window

③ : Bitset or bitreset produced

④ : Sampling fault produced

CONCLUSION

1. EM injection has a local effect
2. EM injection may induces bitsets and bitresets
3. EM injection do not produce timing faults
4. EM injection easily disrupts the switching of DFF
5. Define a fault model for EM Injection (the sampling fault model)

Thank you for your attention

Questions?