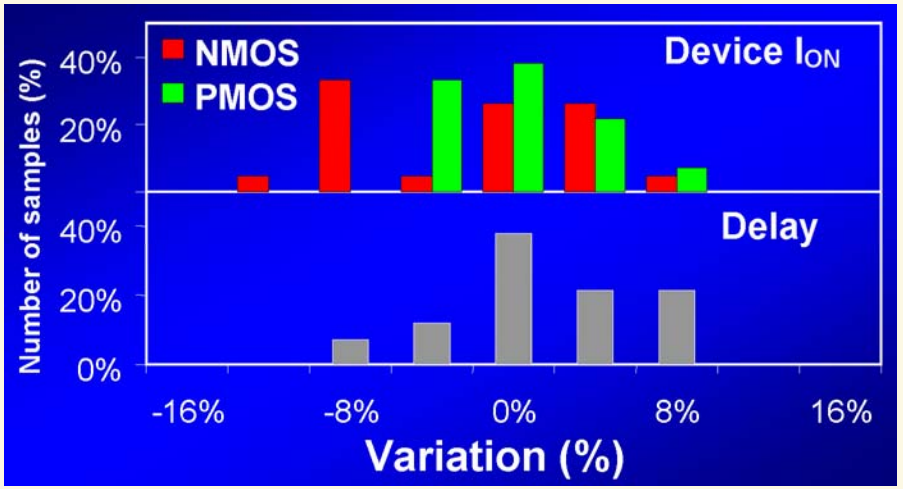
Modeling of Total Parameter Variations

Frank Sill, Claas Cornelius, Dirk Timmermann

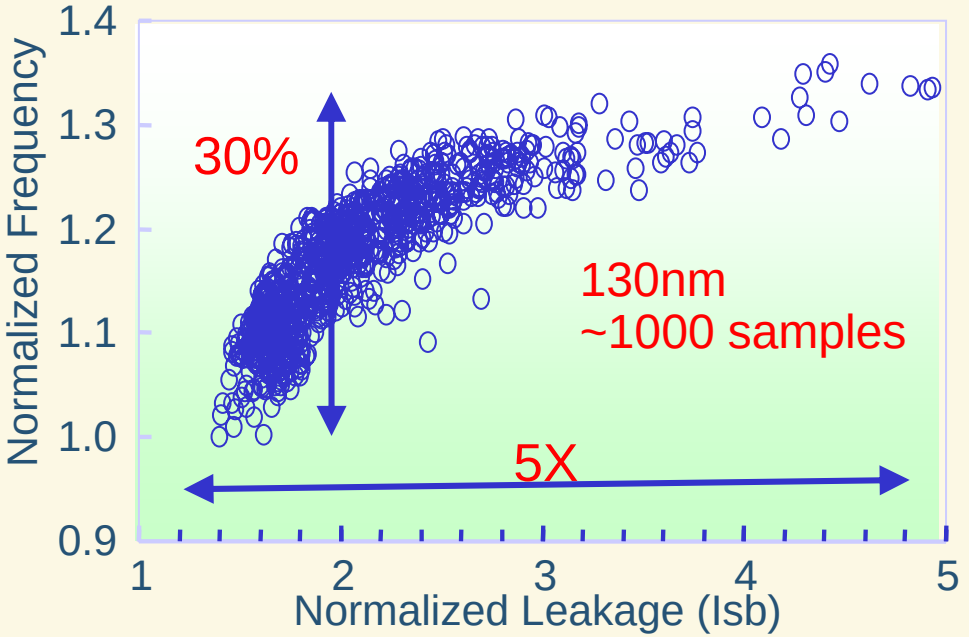
2nd September 2005

8th Euromicro Conference on **Digital System Design**

Parameter Variations Increase



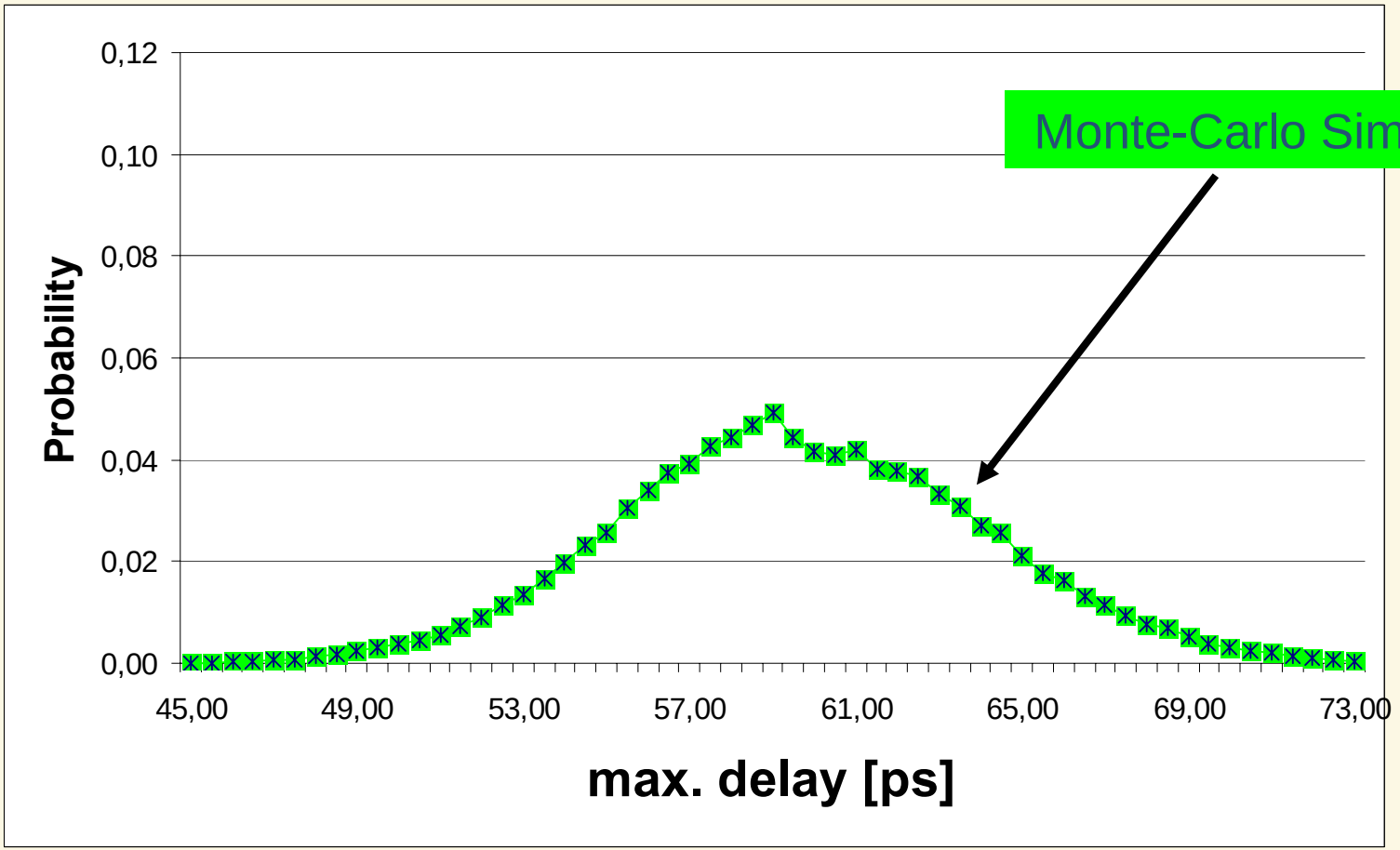
from: S. Borkar, VLSI'05



L (nm)	250	180	130	90	65	45
Vt (mV)	450	400	330	300	280	200
σ-Vt (mV)	21	23	27	28	30	32
σ-Vt/Vt	4.7%	5.8%	8.2%	9.3%	10.7%	16%

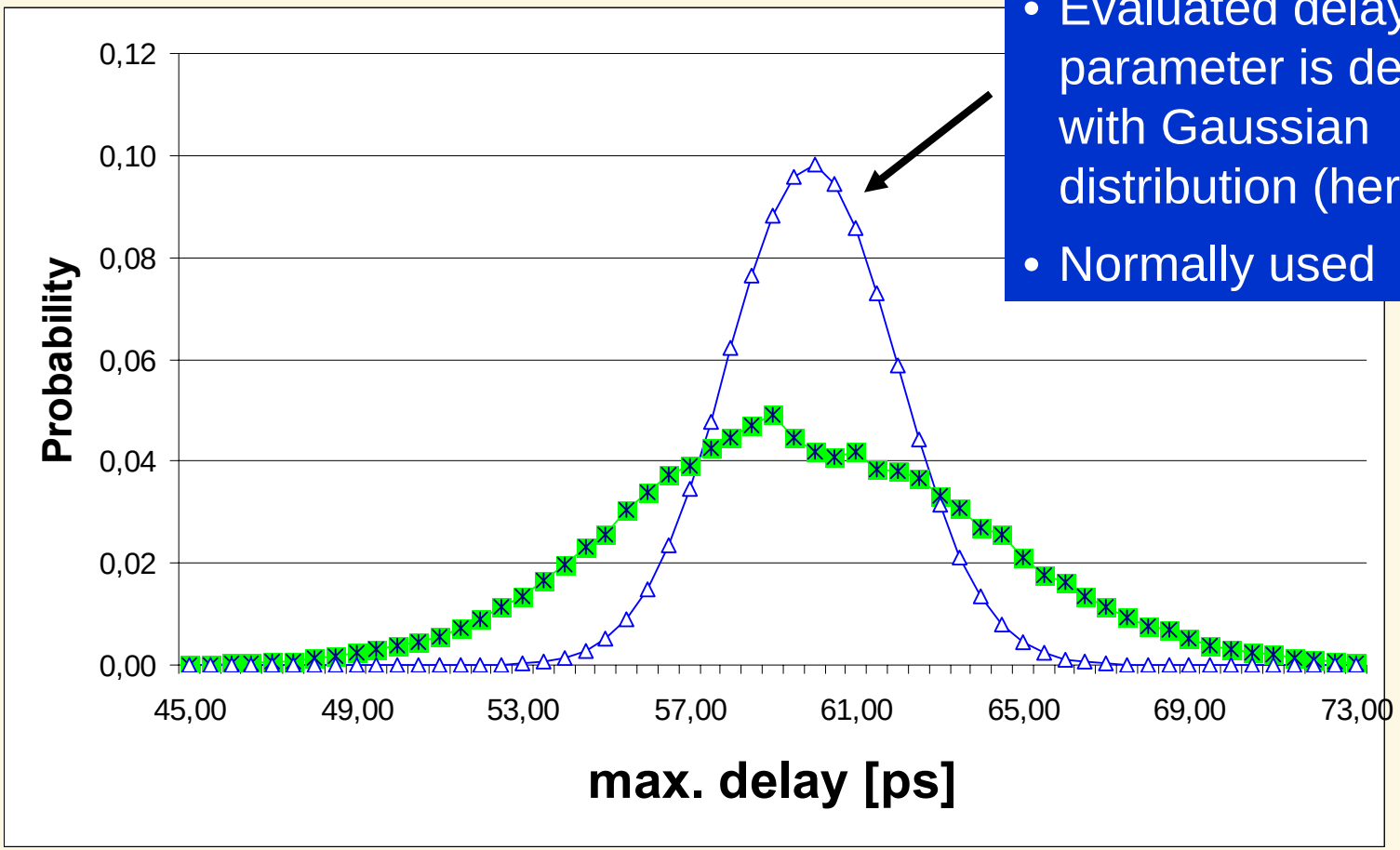
from: ITRS'03

Delay - Extraction



NAND2 in predictive 65 nm BPTM technology

Delay - Extraction



- Evaluated delay, if one parameter is described with Gaussian distribution (here L_{eff})
- Normally used

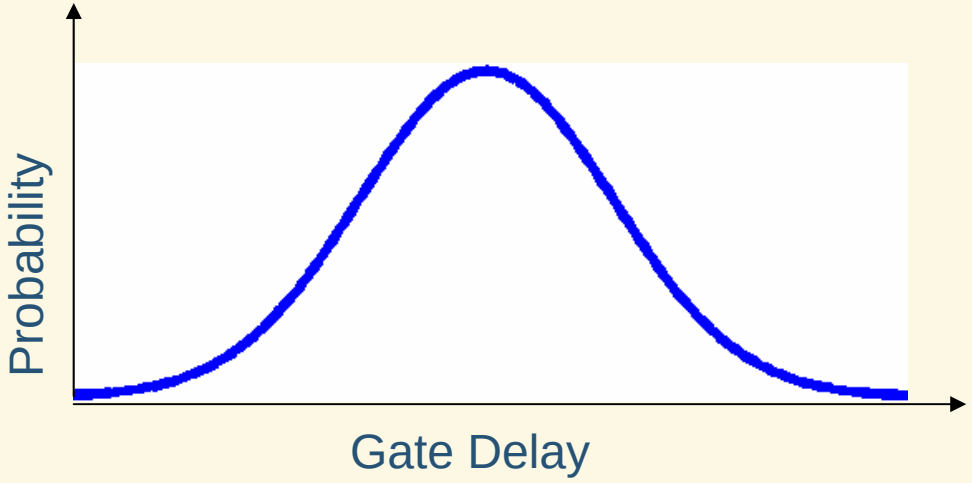
NAND2 in predictive 65 nm BPTM technology

Modeling of Gate Delay

Probability Density Function (PDF)

Probability that the gate delay has the value x

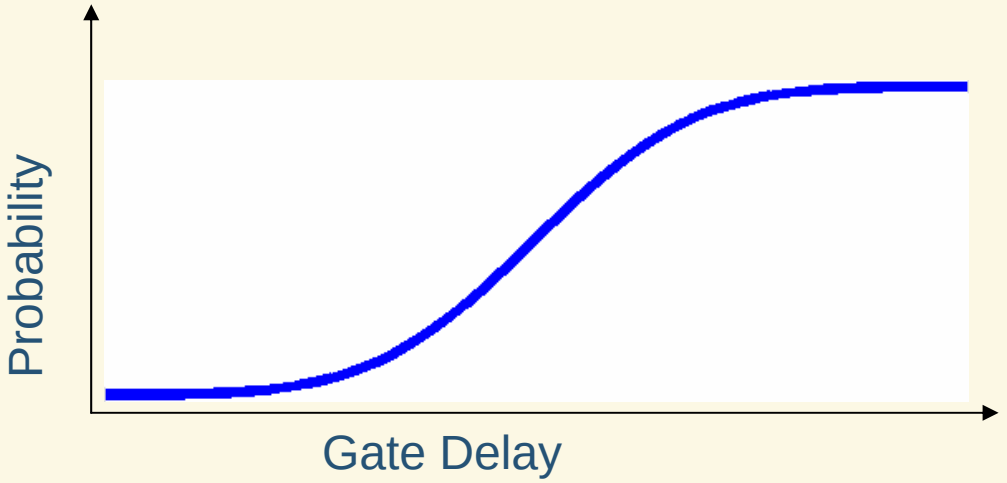
$$PDF(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$



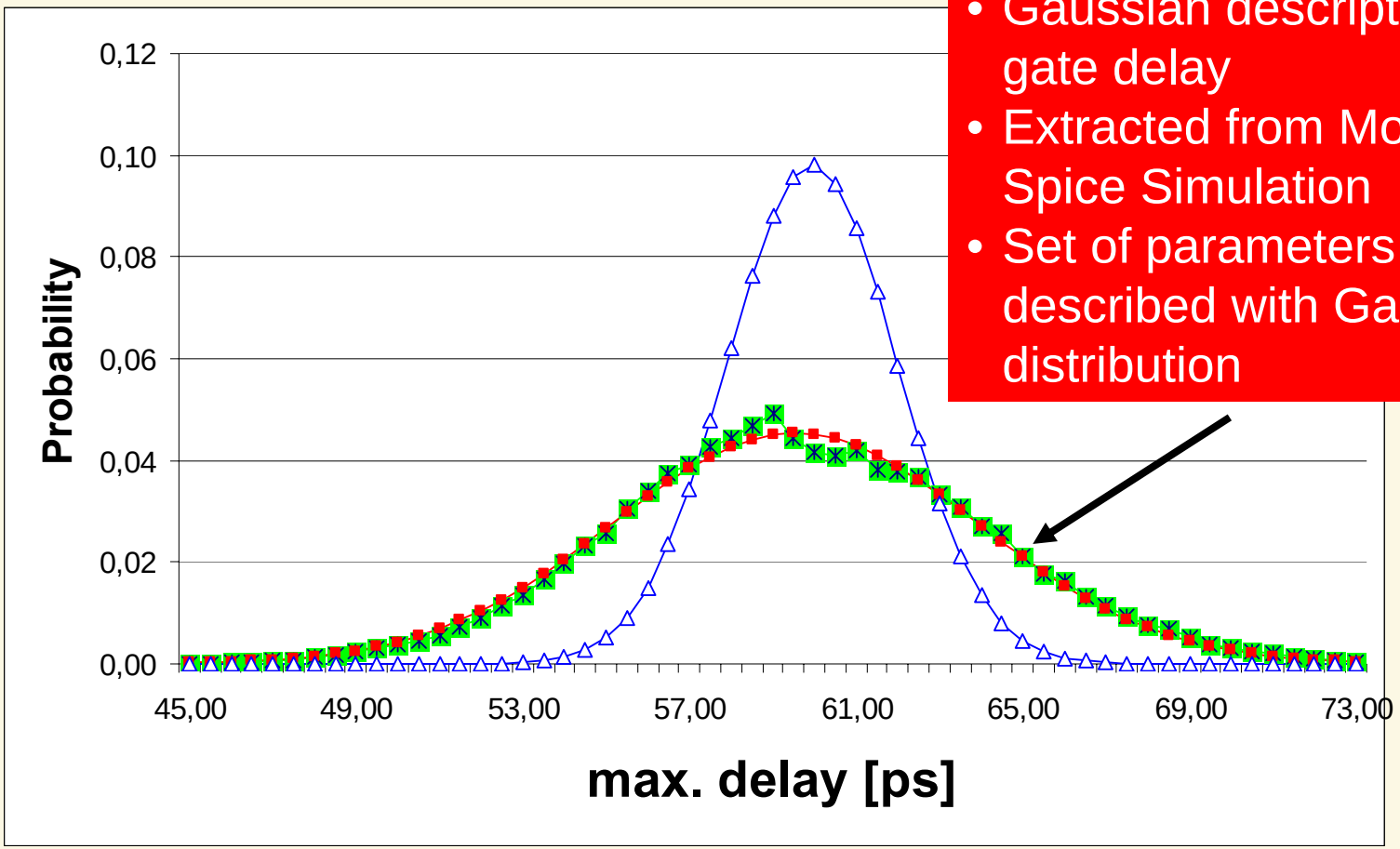
Cumulative probability Distribution Function (CDF)

Probability that the gate delay is smaller than x

$$CDF(x) = \int_0^x PDF(t)dt = \int_0^x \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp\left(-\frac{(t-\mu)^2}{2\sigma^2}\right)dt$$



Delay - Extraction

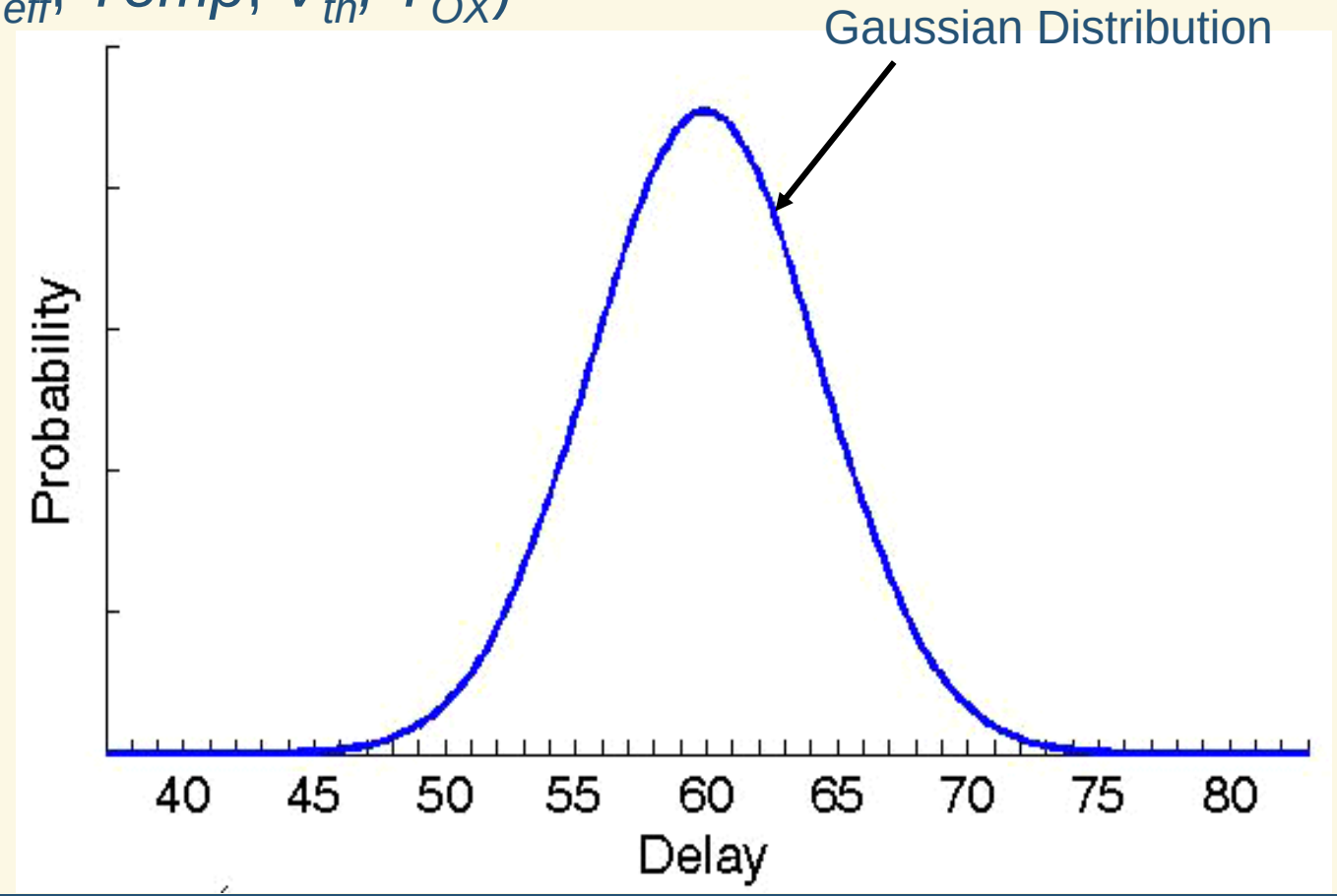


- Gaussian description of gate delay
- Extracted from Monte-Carlo Spice Simulation
- Set of parameters described with Gaussian distribution

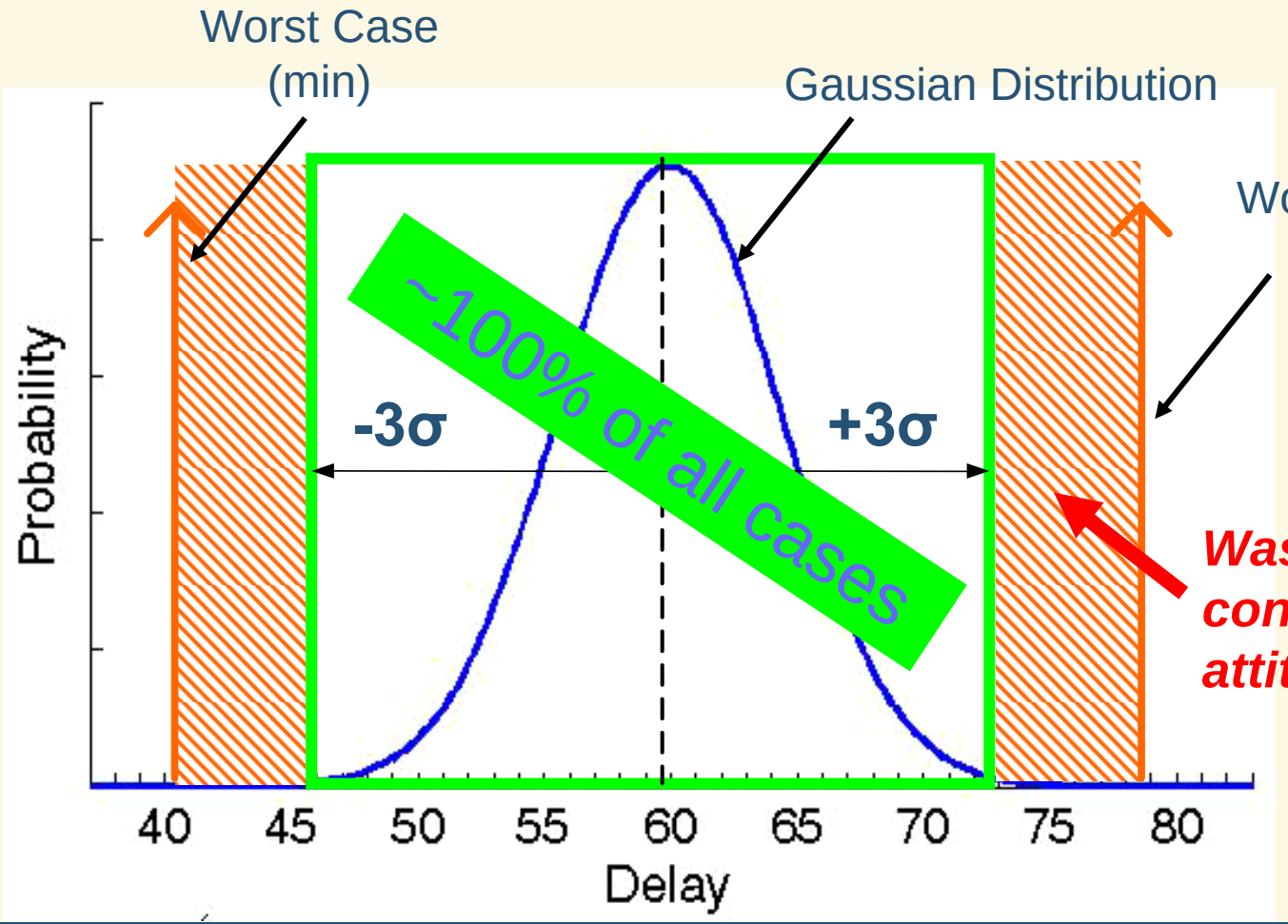
NAND2 in predictive 65 nm BPTM technology

Deterministic vs. Statistical STA

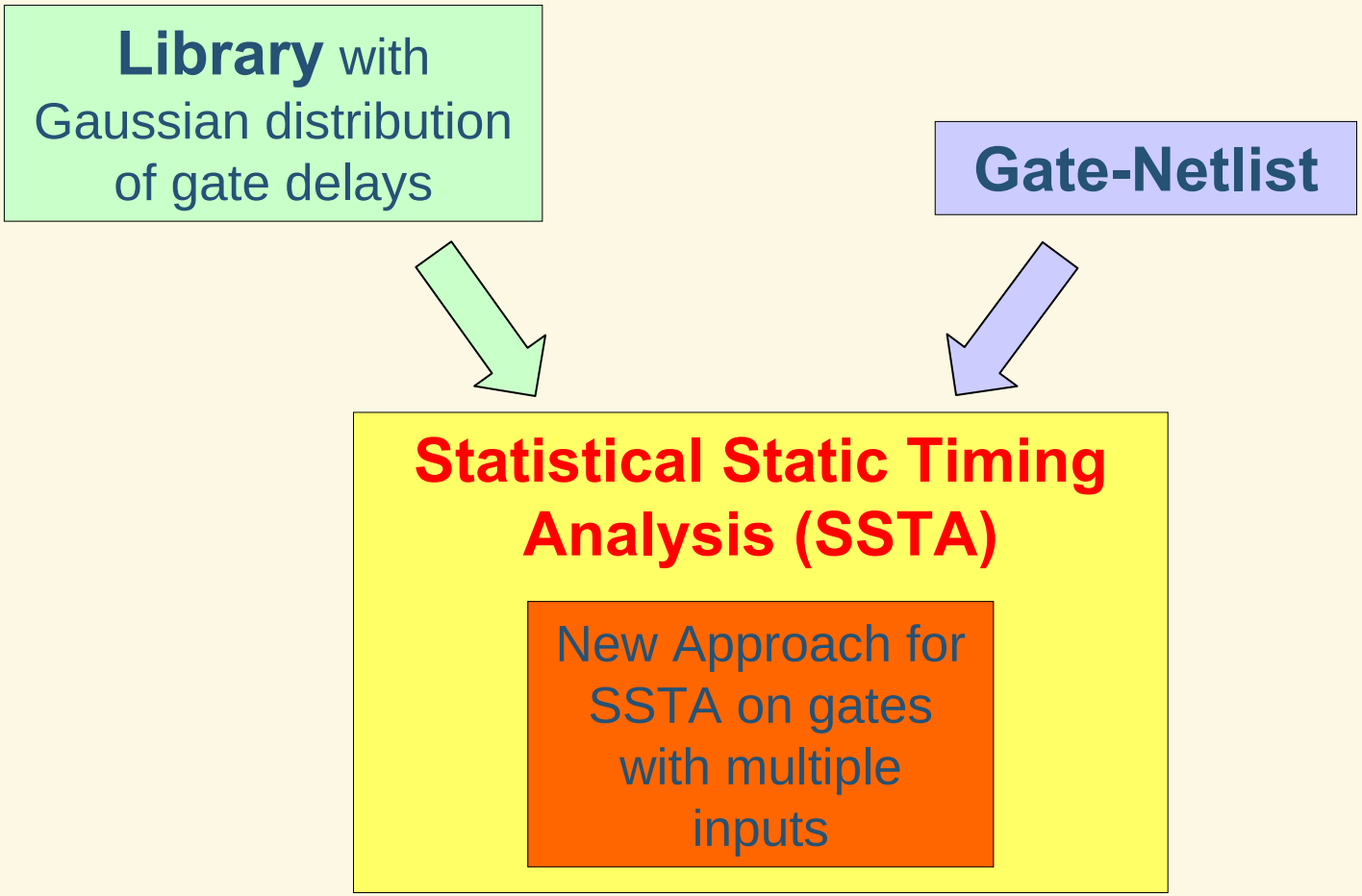
#10k Monte-Carlo simulations of NAND2 (Variation of NDEP, L_{eff}, W_{eff}, *Temp*, V_{th}, T_{OX})



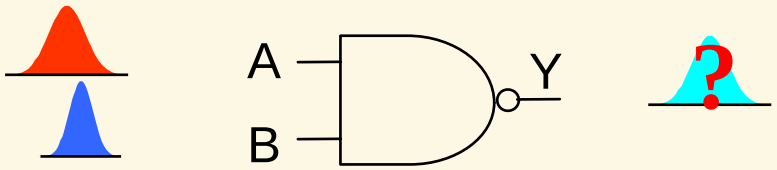
Deterministic vs. Statistical STA

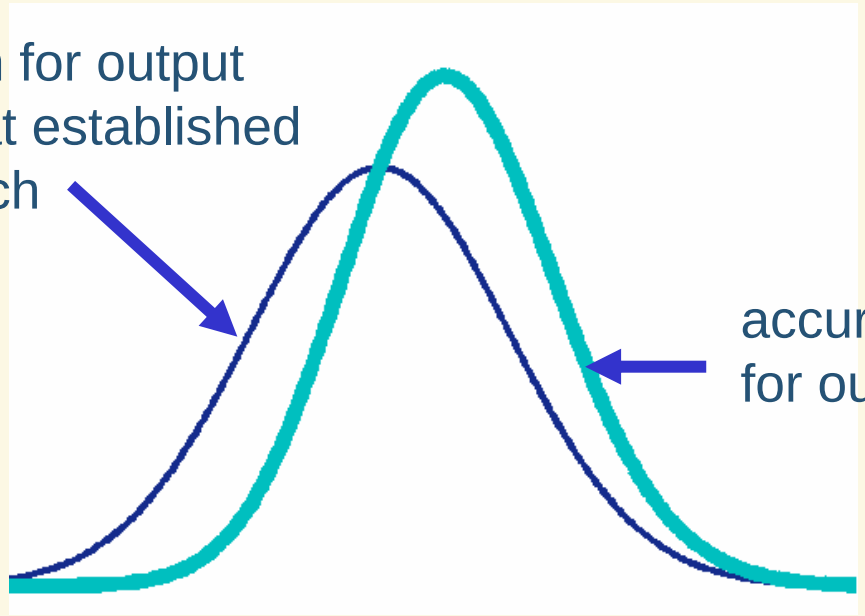


Concept


Library with Gaussian distribution of gate delays
Gate-Netlist
Statistical Static Timing Analysis (SSTA)
New Approach for SSTA on gates with multiple inputs

SSTA on Multi-Input Gates

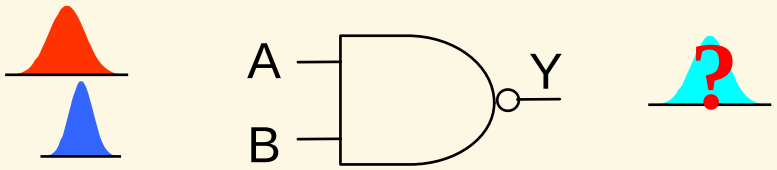


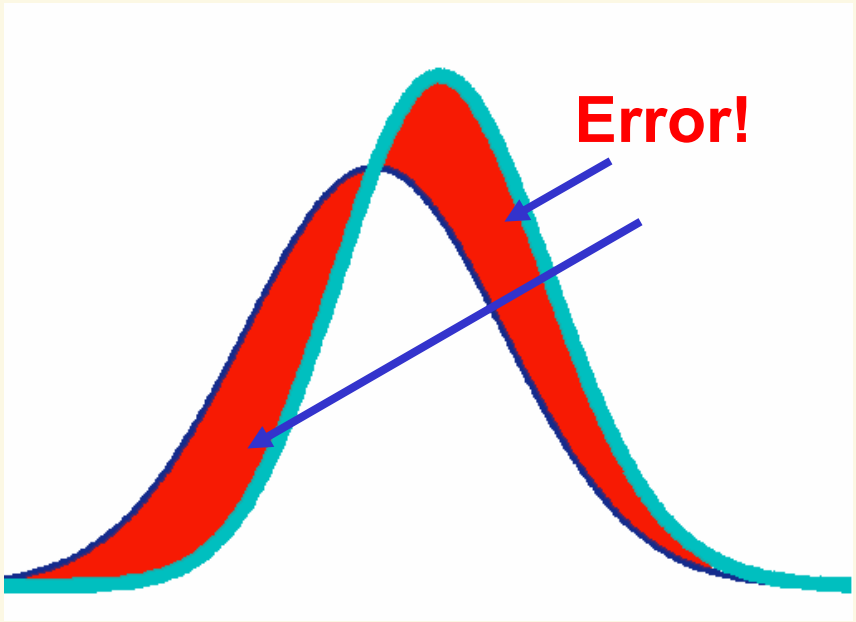


Established Approach:

all but one input are ignored

SSTA on Multi-Input Gates





Established Approach:

all but one input are ignored

SSTA on Multi-Input Gates cont'd

New Approach:

Function of output signal results from multiplication of all input CDFs

⇒ CDF is approximated as straight line

⇒ new CDF results from multiplication of all approximated straight lines of input signals