

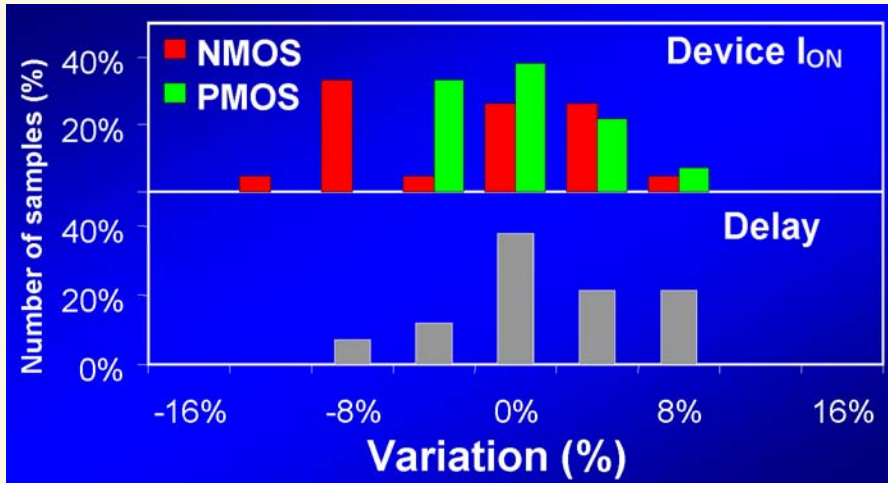
# Modeling of Total Parameter Variations

Frank Sill, Claas Cornelius, Dirk Timmermann  
2<sup>nd</sup> September 2005

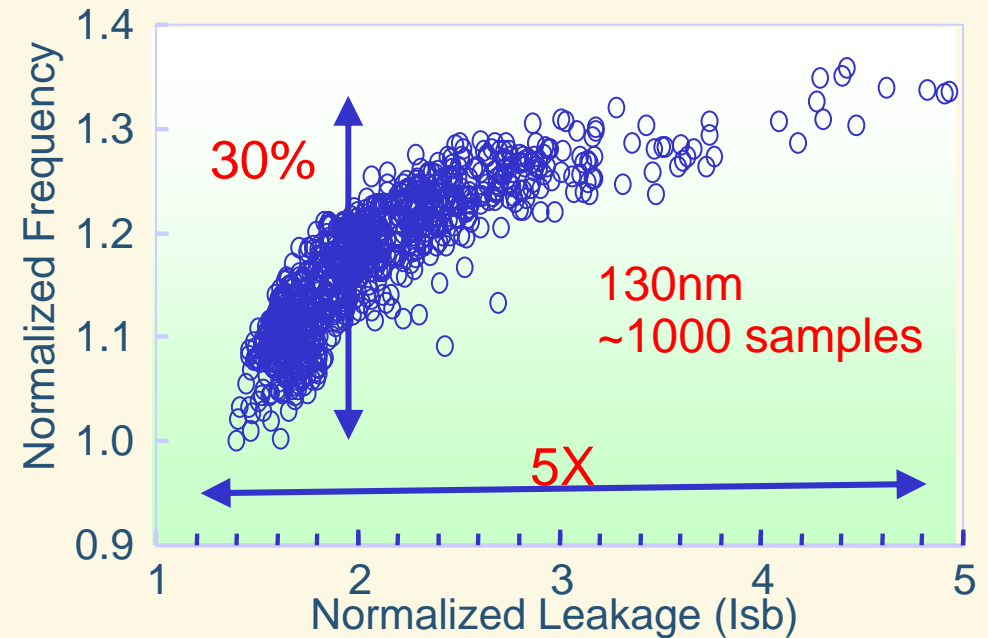
8<sup>th</sup> Euromicro Conference on **Digital System Design**



# Parameter Variations Increase



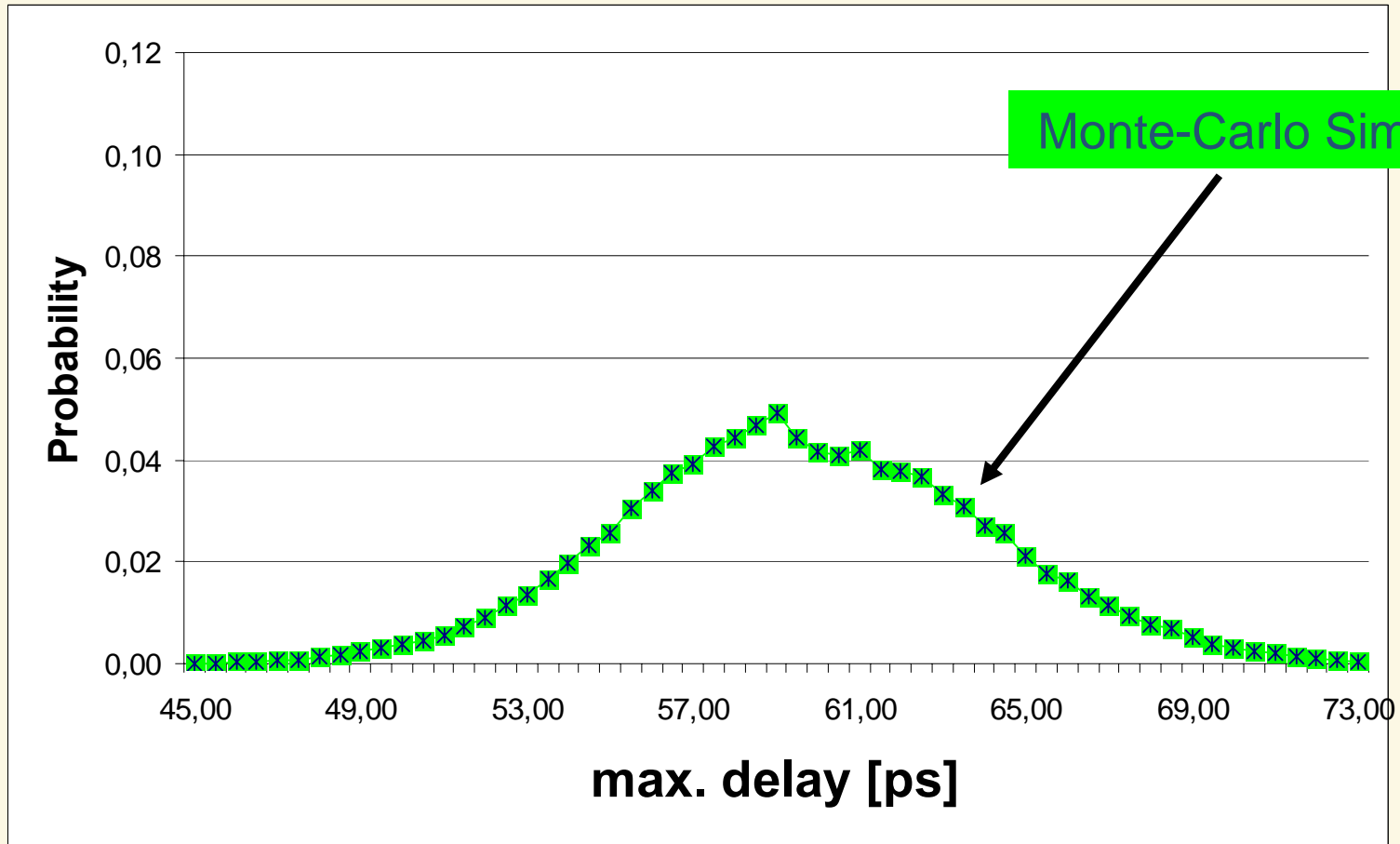
from: S. Borkar, VLSI'05



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

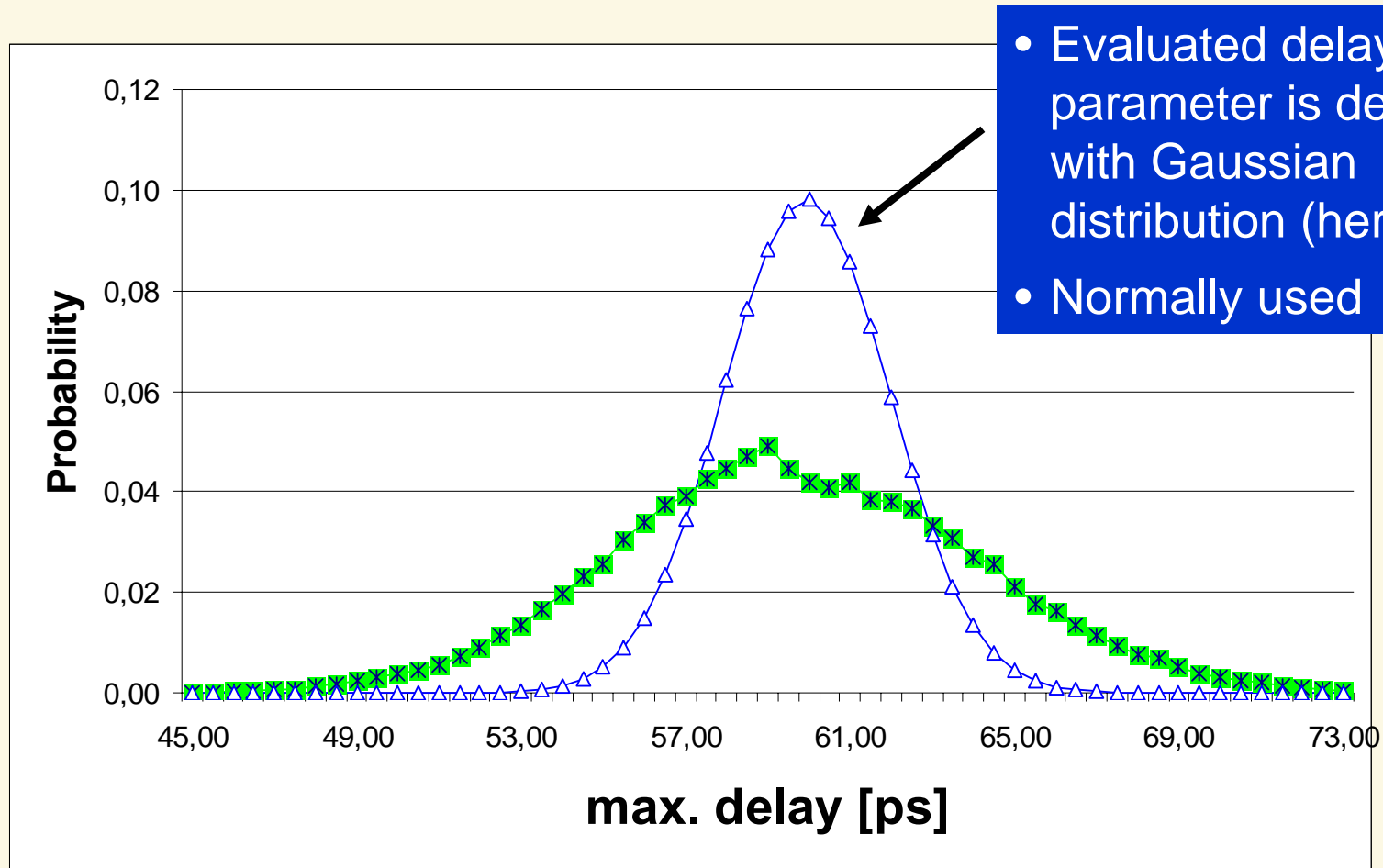
from: ITRS'03

# Delay - Extraction



*NAND2 in predictive 65 nm BPTM technology*

# Delay - Extraction



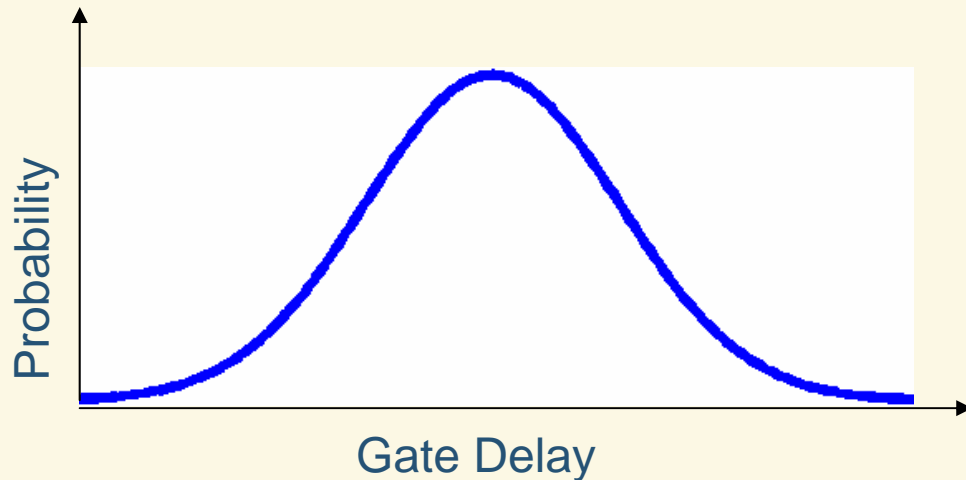
*NAND2 in predictive 65 nm BPTM technology*

# Modeling of Gate Delay

## Probability Density Function (PDF)

Probability that the gate delay has the value  $x$

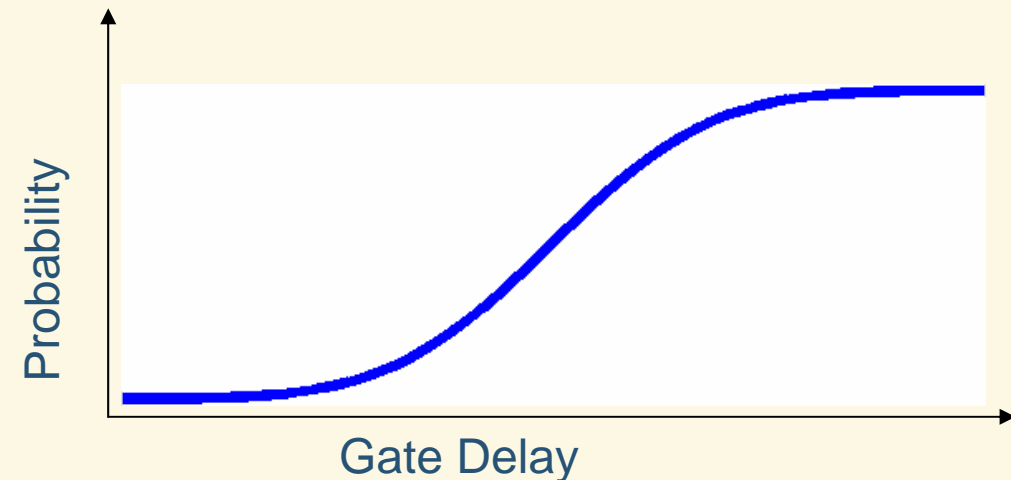
$$PDF(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$



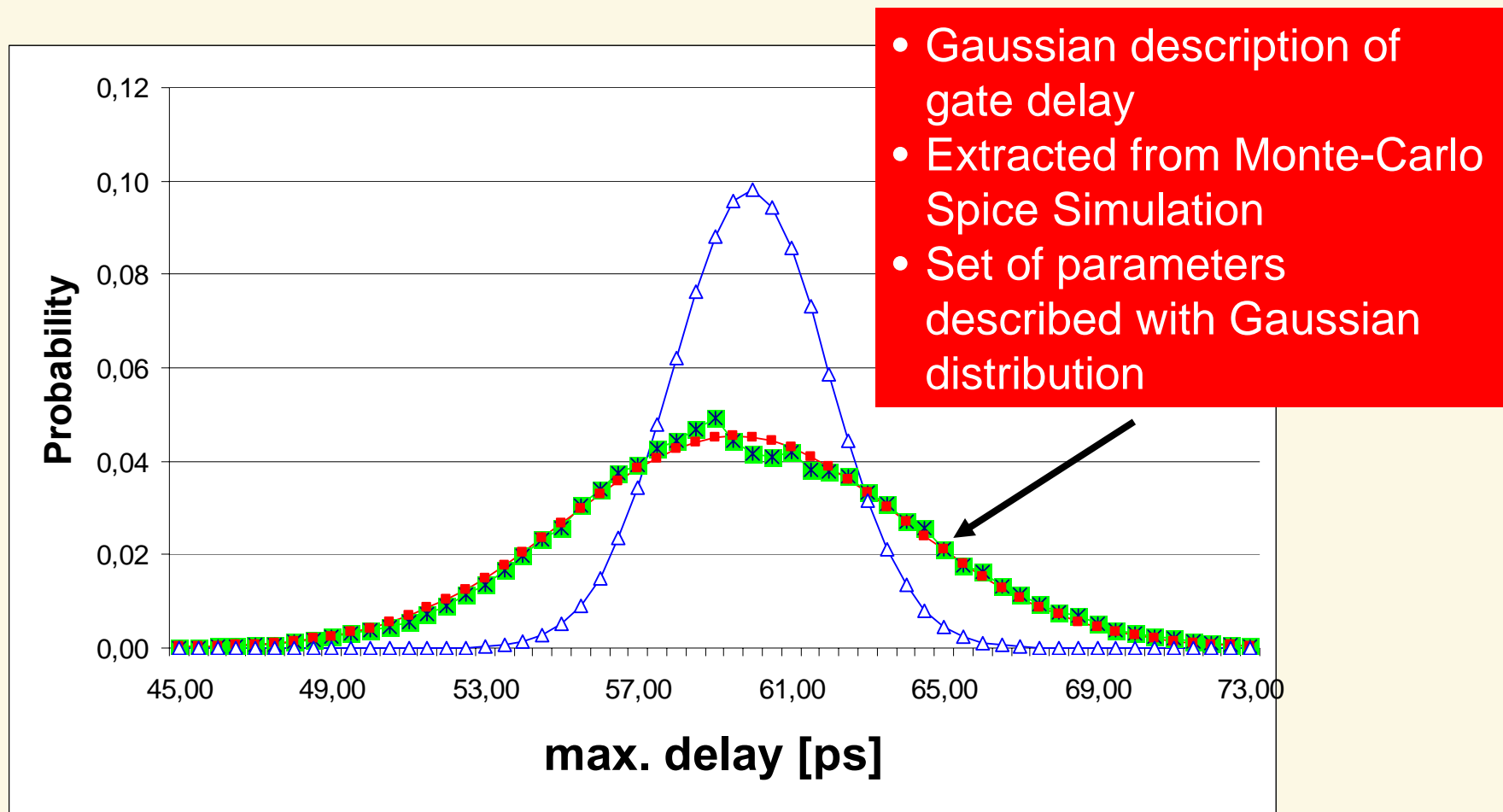
## Cumulative probability Distribution Function (CDF)

Probability that the gate delay is smaller than  $x$

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



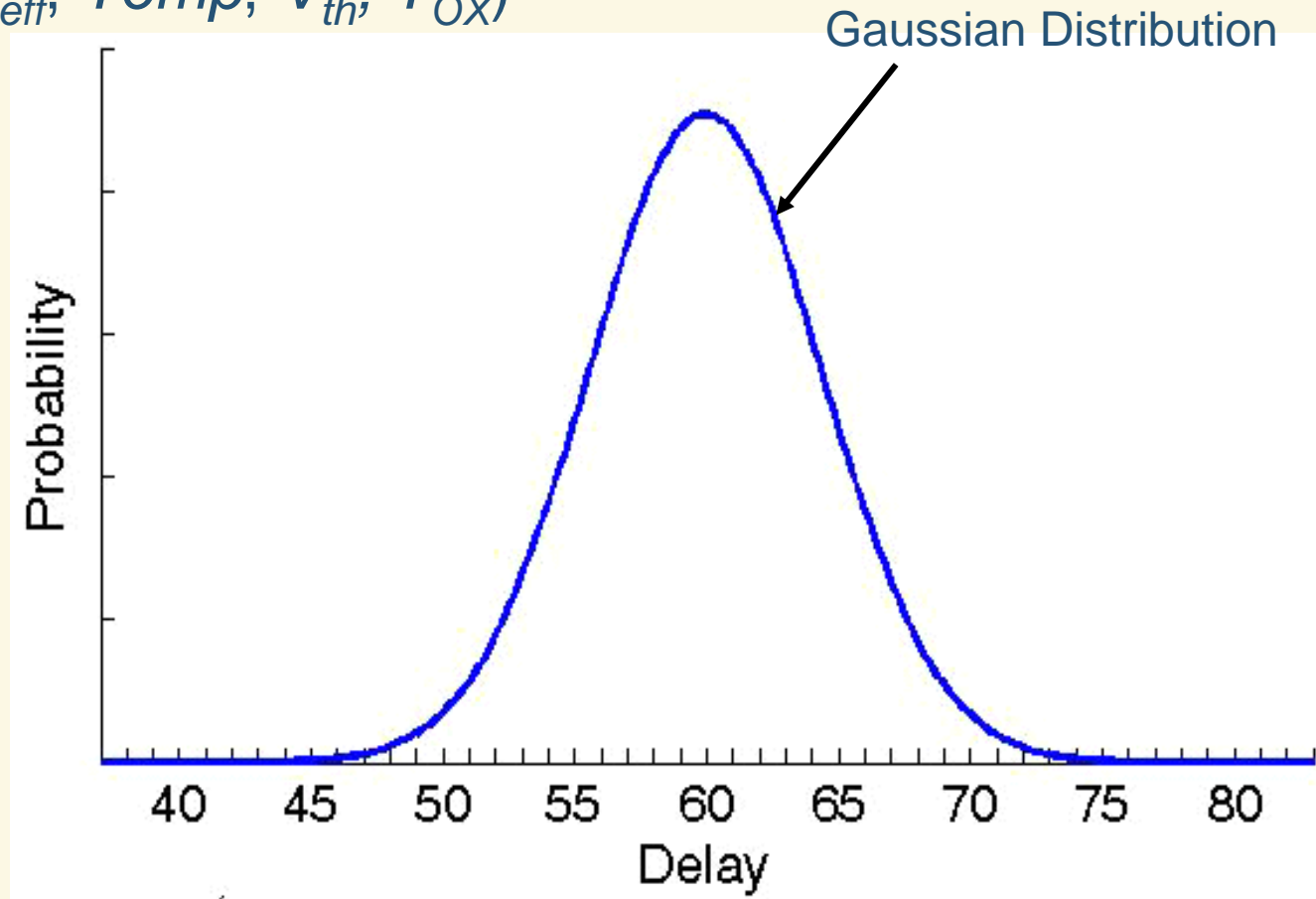
# Delay - Extraction



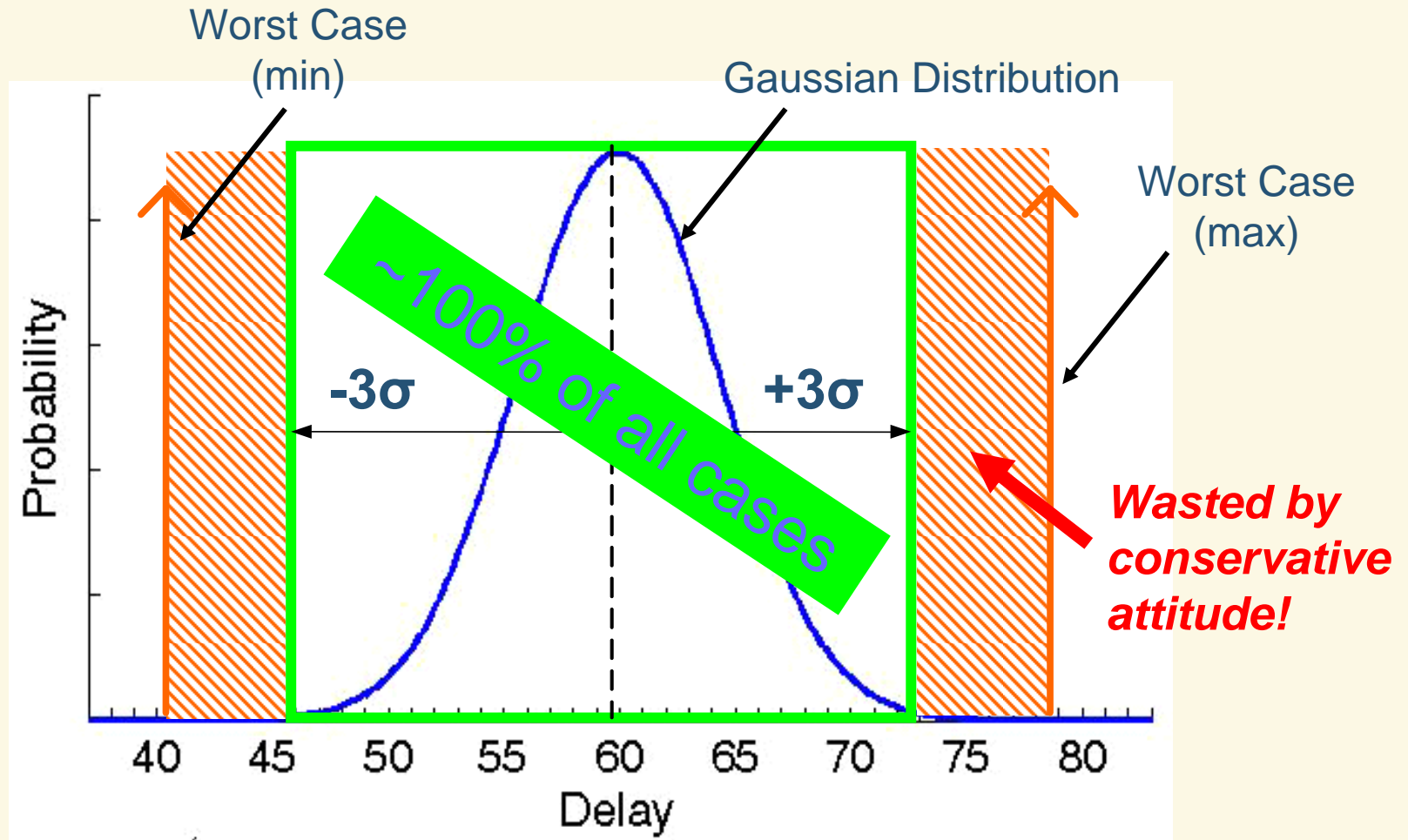
*NAND2 in predictive 65 nm BPTM technology*

# Deterministic vs. Statistical STA

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

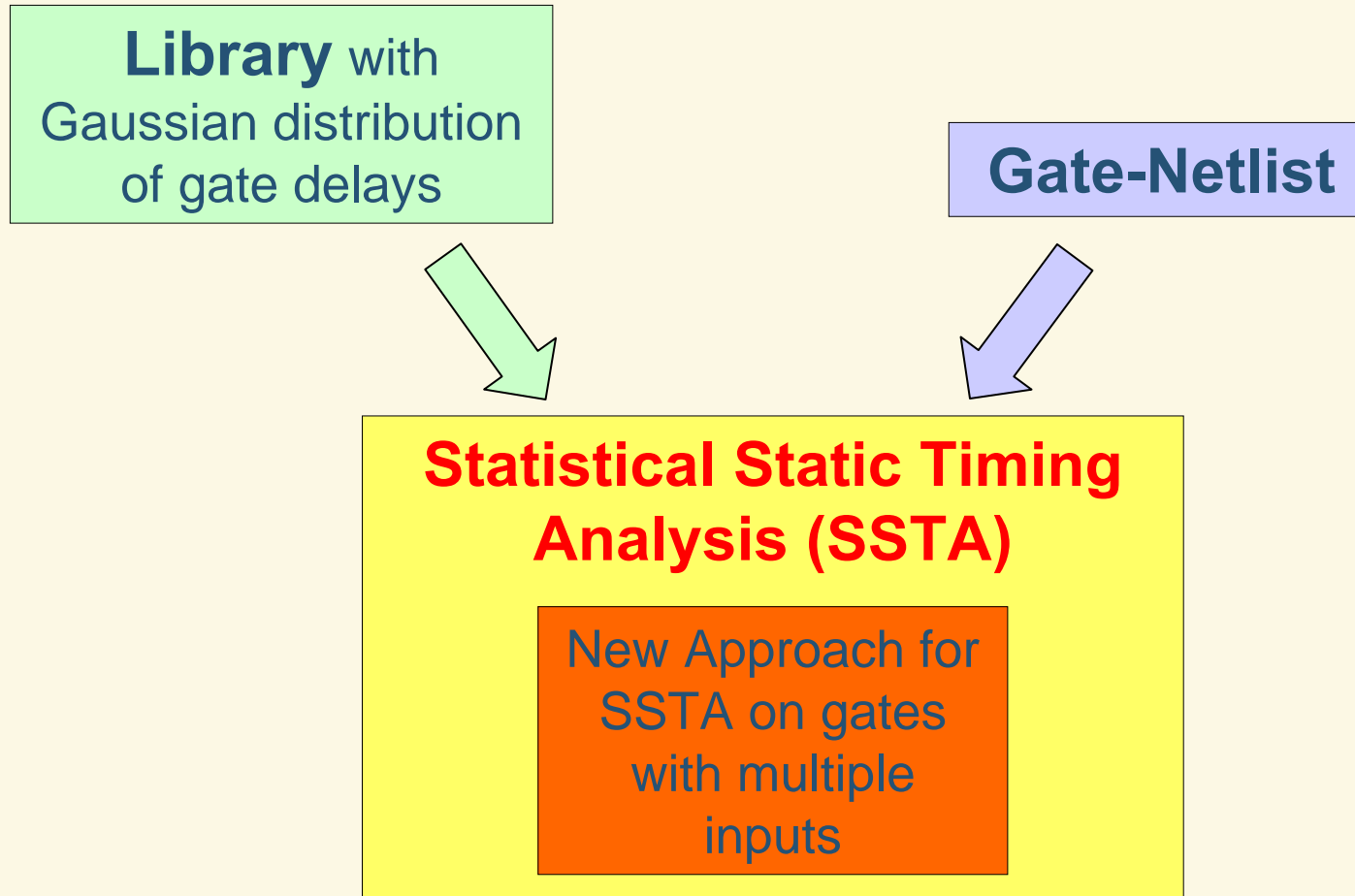


# Deterministic vs. Statistical STA

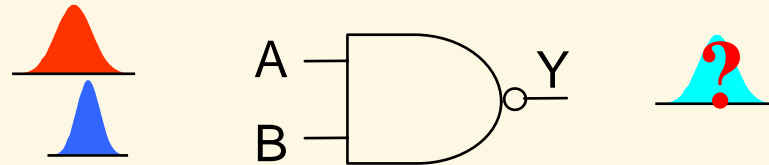




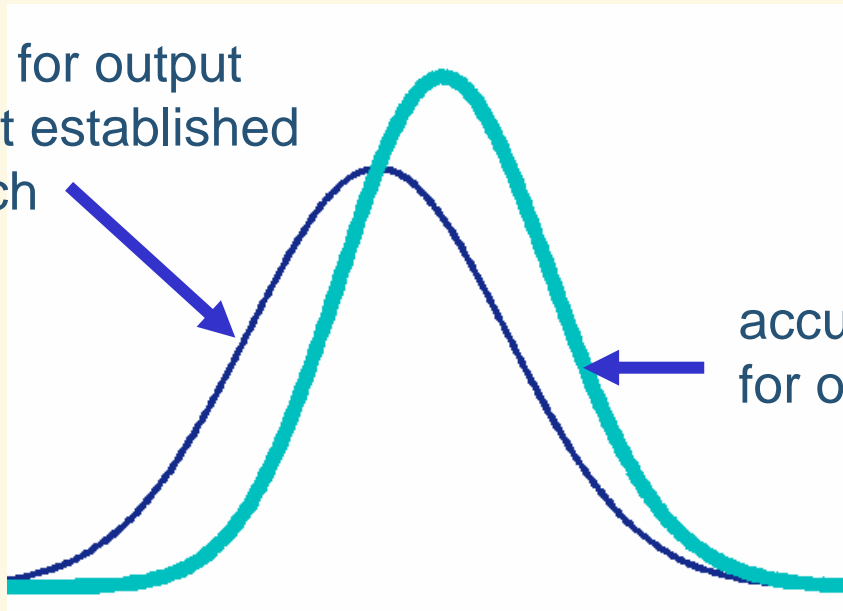
# Concept



# SSTA on Multi-Input Gates



function for output signal at established approach

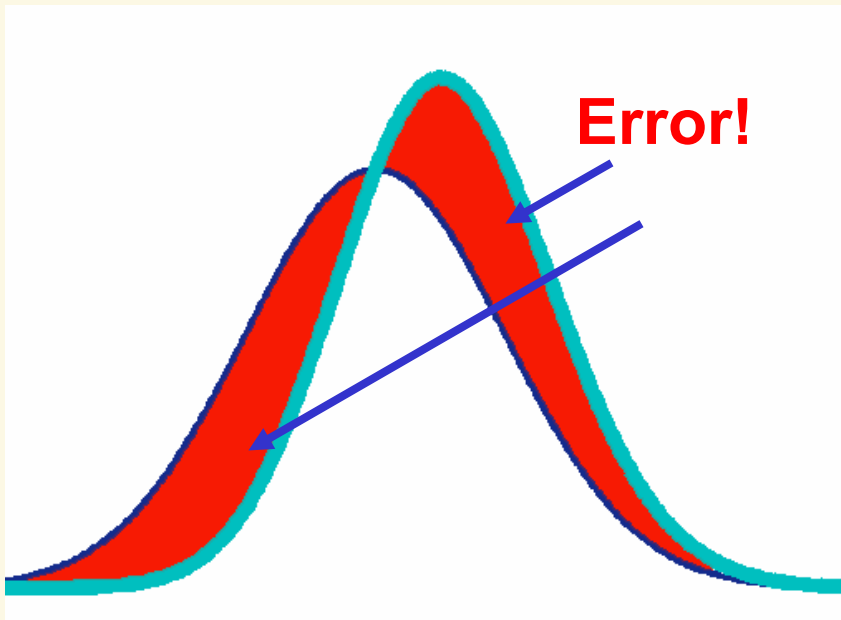
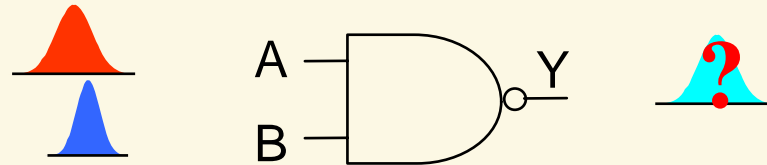


## Established Approach:

all but one input are ignored

accurate function for output signal

# 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

