Supporting Statistical Semiconductor Device Analysis Using EGEE and OMII-UK Middleware

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EGEE 3rd User Forum

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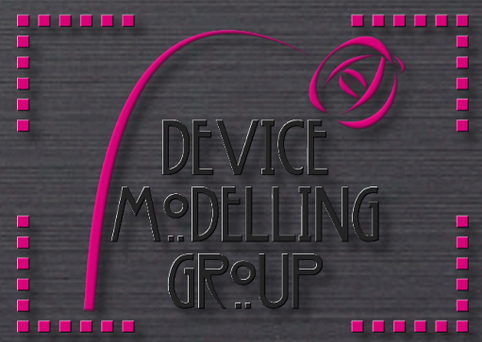
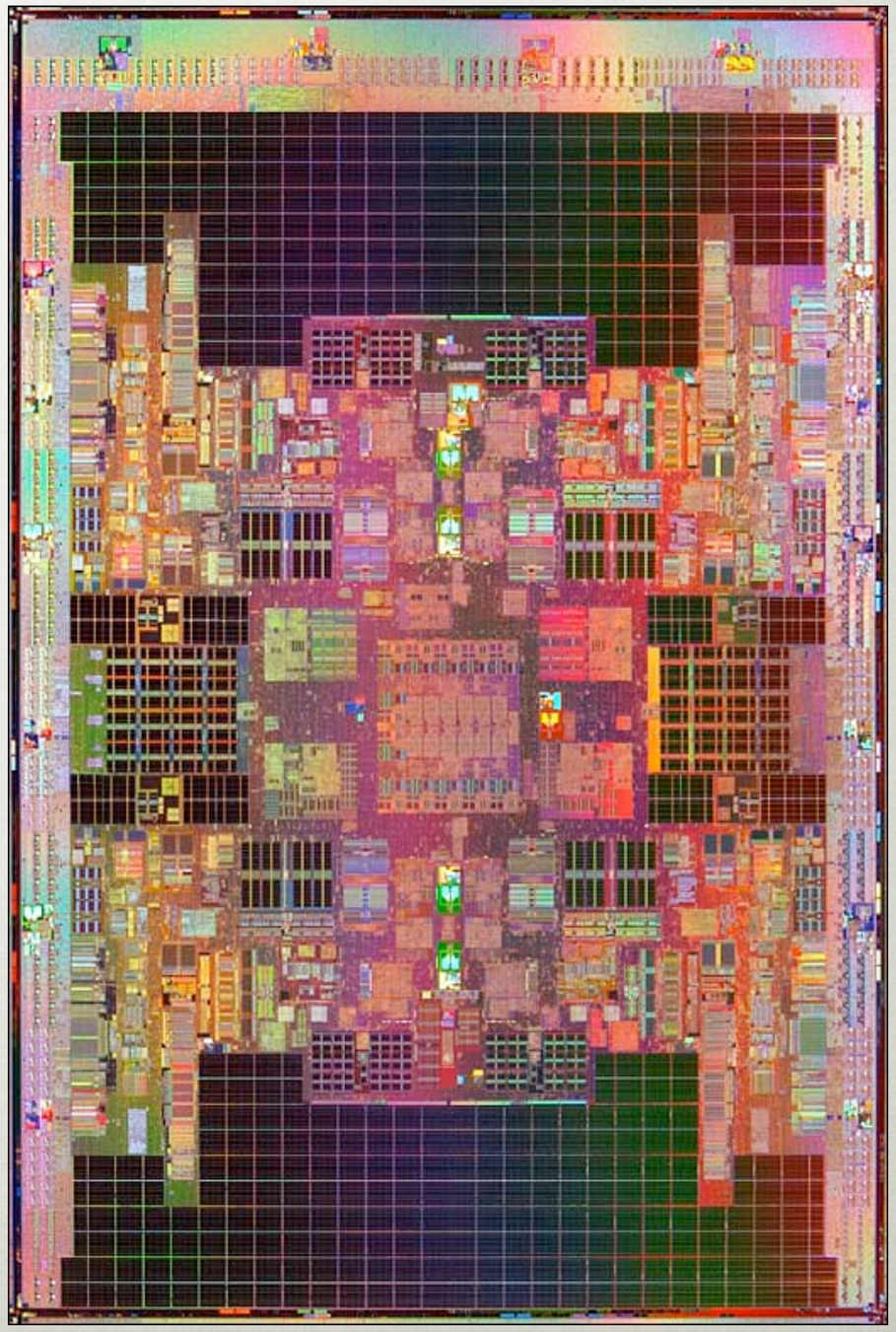
University of Glasgow



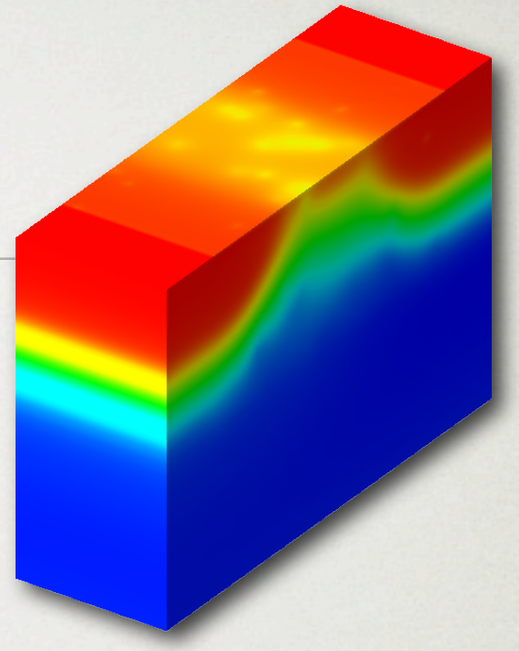
DEVICE MODELLING GROUP

Overview

- Motivation
- eScience & Grid
- Results & Analysis
- Conclusions



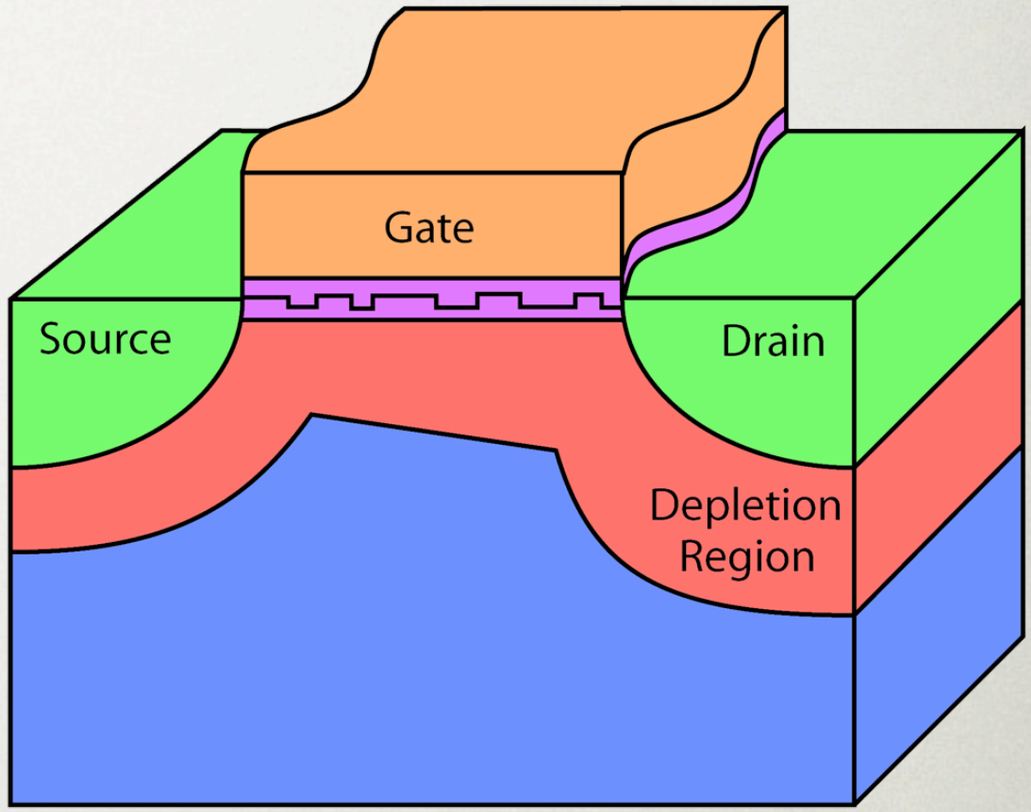
Motivation



- CMOS scaling drives the semiconductor industry
- Variability of device parameters is becoming increasingly important
  - Prediction of parameter fluctuations allow designs to be improved
  - These predictions can be made through simulation
- Design predictions are made based on the assumption of Gaussian statistics

What are Mosfets?

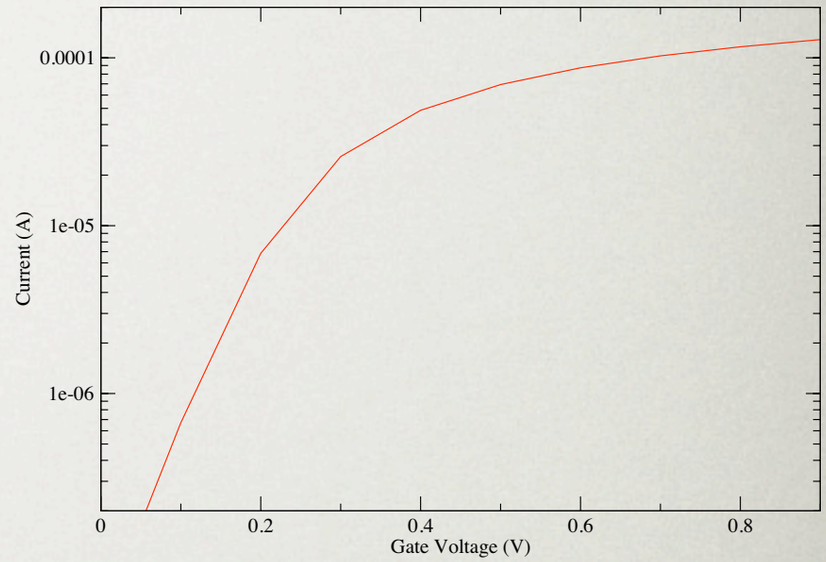
- MOSFETs are essentially switches
- When a voltage is applied to the drain, the current flow can be controlled by the gate



- MOSFETs are used to build standard cells, which are used to build up more complex systems

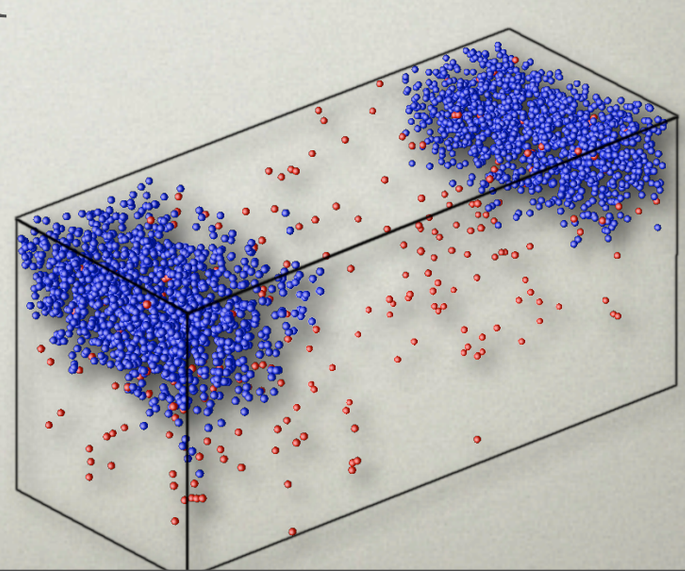
Device Simulation

- What are we simulating?
  - Threshold voltage search
  - Also storing off current
    - Simulations done at low drain: V_d=100mV
- Simulating 35nm Toshiba device and 13nm scaled device
- Will be simulating $I_D V_G$ curves in future too



How Do Random Dopants Affect V_{TH}?

- Compared to a uniformly doped device, V_{th} will be lower
- It is possible for early turn-on to occur due to “valleys” in the potential landscape
- This leads to a lower threshold voltage



What is ScotGrid?

- ScotGrid is a compute grid based at NeSC at the University of Glasgow
- Consists of 140 worker nodes running Scientific Linux 4.5 on:
  - 2 Dual Core Opteron 280, 2.4 Ghz
  - 8 GiB RAM, 80GB IDE Disc
  - Dual 1Gbs NICs
- 10 Storage Nodes providing 10TB to the cluster

Job Submission

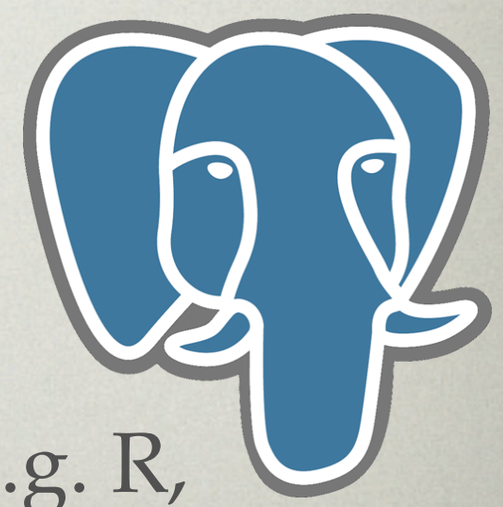
- Problem: Need to submit lots of jobs in parallel
- Globus is completely unuseable for large scale job submission and monitoring
- Used ganga as a frontend
  - Jobs submitted 500 at a time
  - Automates monitoring

Job submission with Ganga

- Ganga simplifies job submission, but has problems since Globus is still the underlying mechanism
  - Don't forget your grid proxy!
- In some cases Ganga lost track of jobs
  - NFS bug in Ganga
  - Timeouts to the RB
- Job monitoring is better, but not great
- Jobs largely successful after submission

Data Management

- Tracking 2 files per device quickly becomes problematic for huge ensembles
- 35nm devices were done by dividing things up on the file system
  - Better, but still problematic for tracking
- Switched to a Postgres DB for 13nm device
  - Allows job completion monitoring
  - SQL queries allow powerful filtering
  - Easy to interface with other programs, e.g. R, python

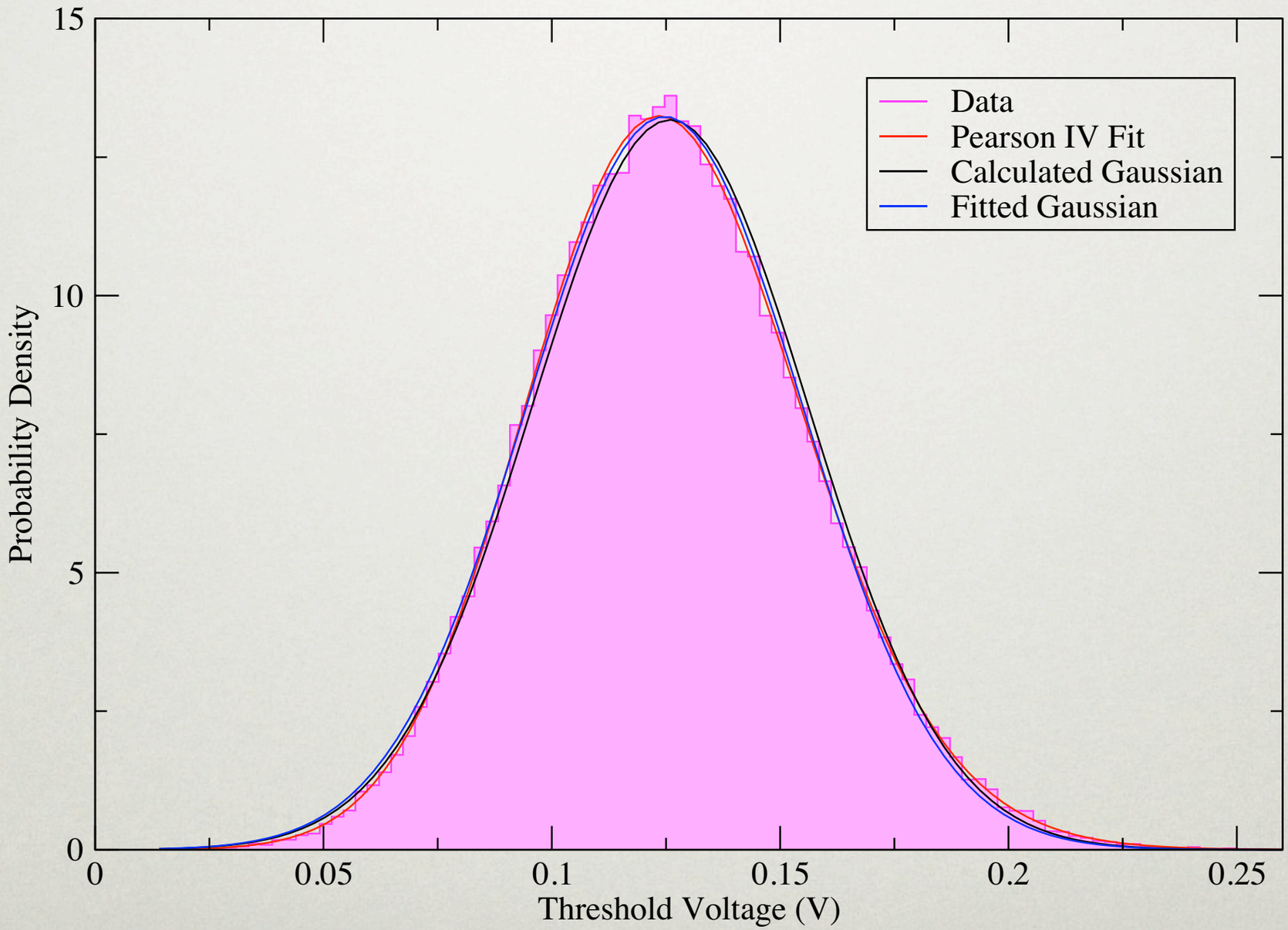


Threshold Voltage

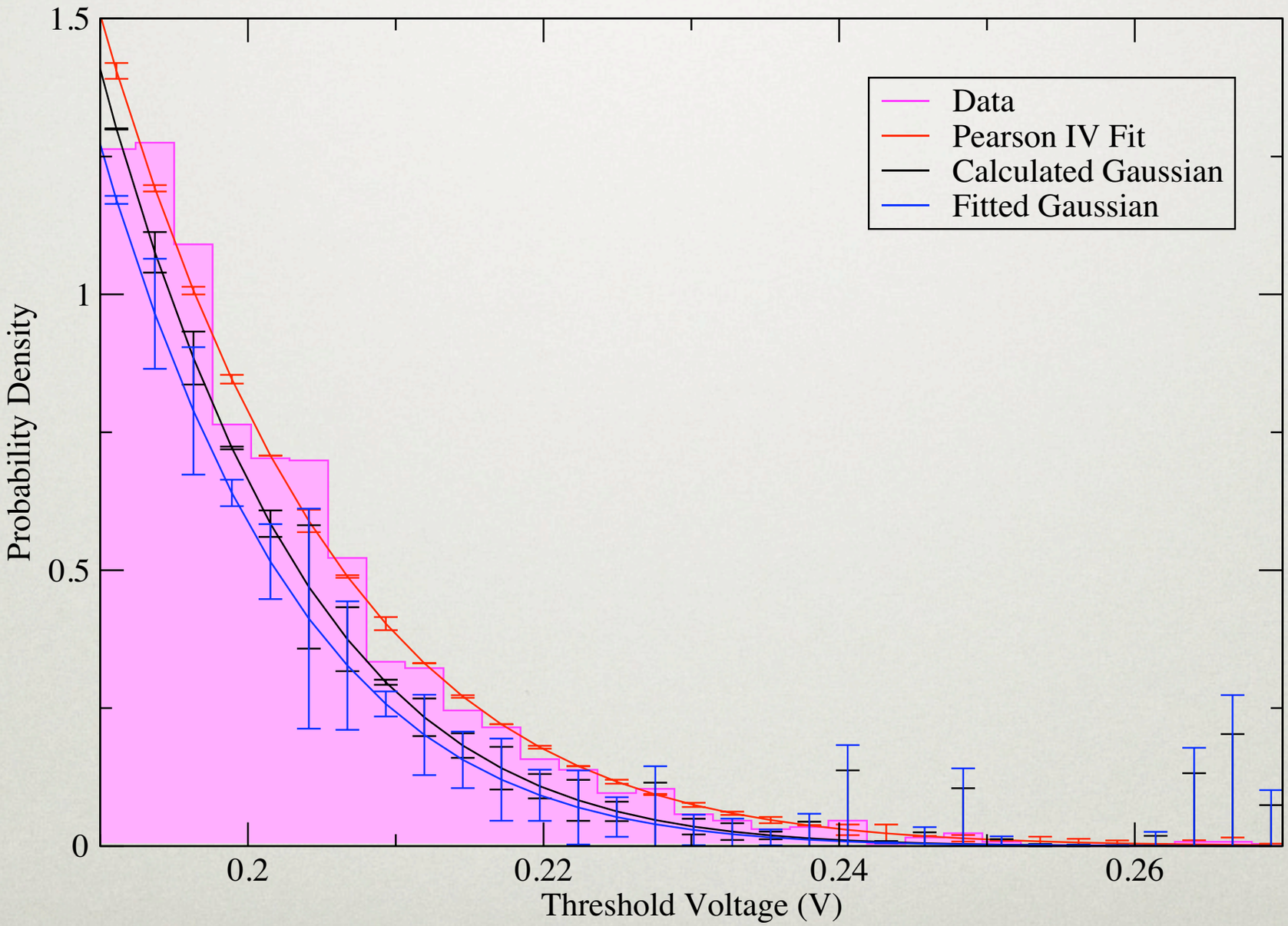
- We suspect that the distribution of threshold voltage is non-gaussian
- Fitted the histogram of the results with a Pearson IV distribution

$$k[1+\left(\frac{x-\lambda}{a}\right)^2]^{-m}\ \exp[-\nu\ \arctan(\frac{x-\lambda}{a})]$$

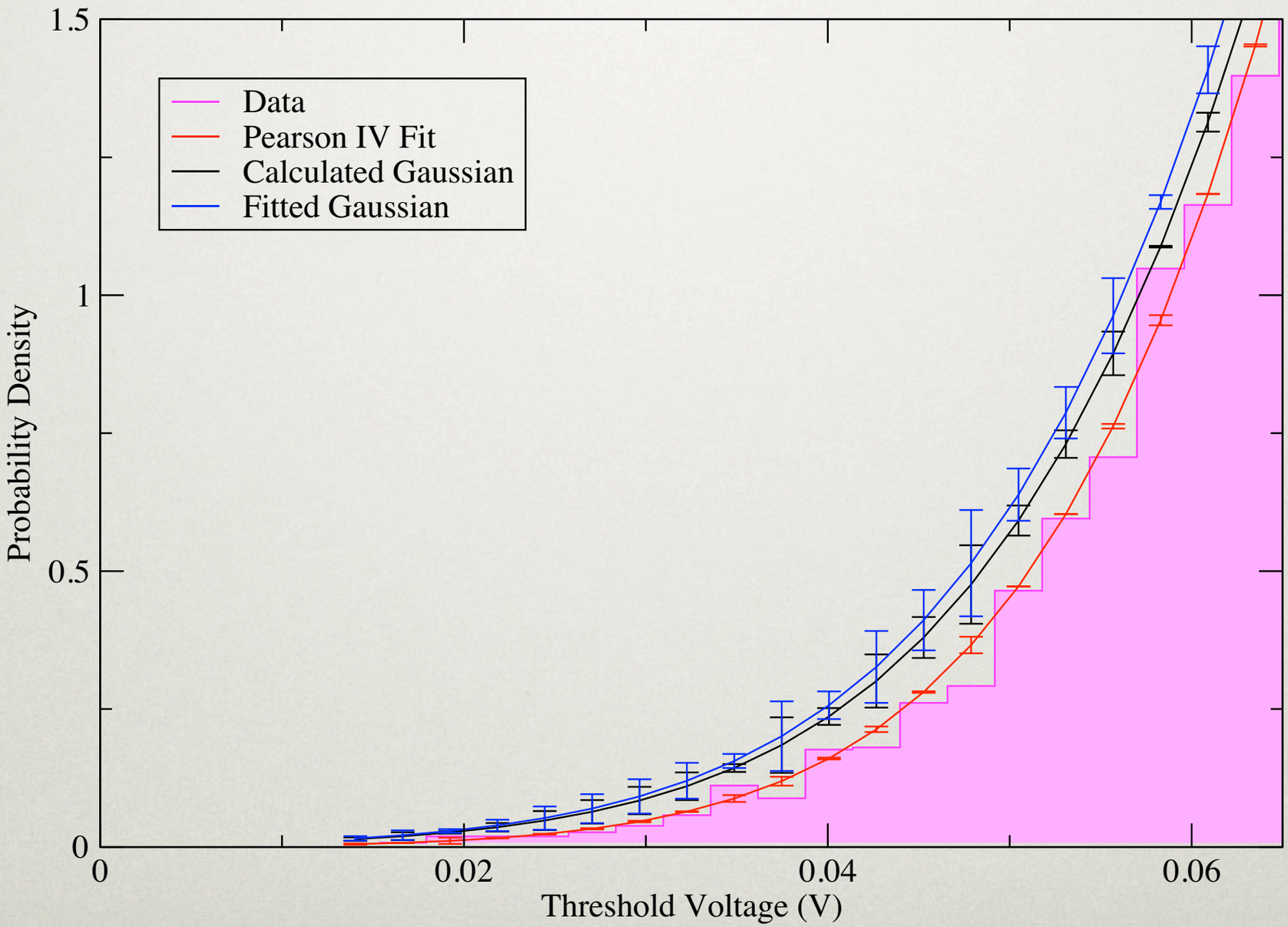
V_{TH} Distribution for 35nm



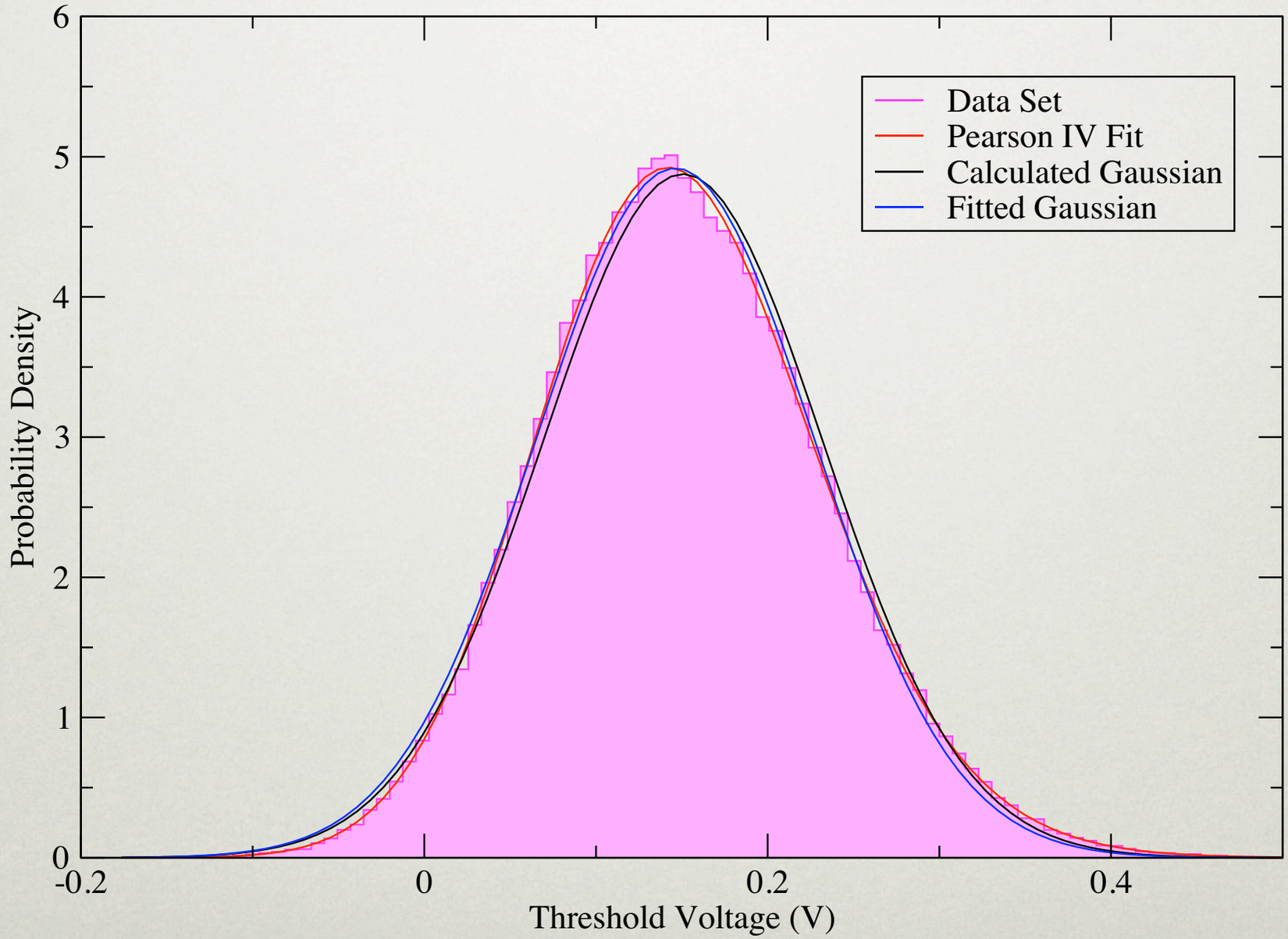
V_{TH} Distribution for 35nm



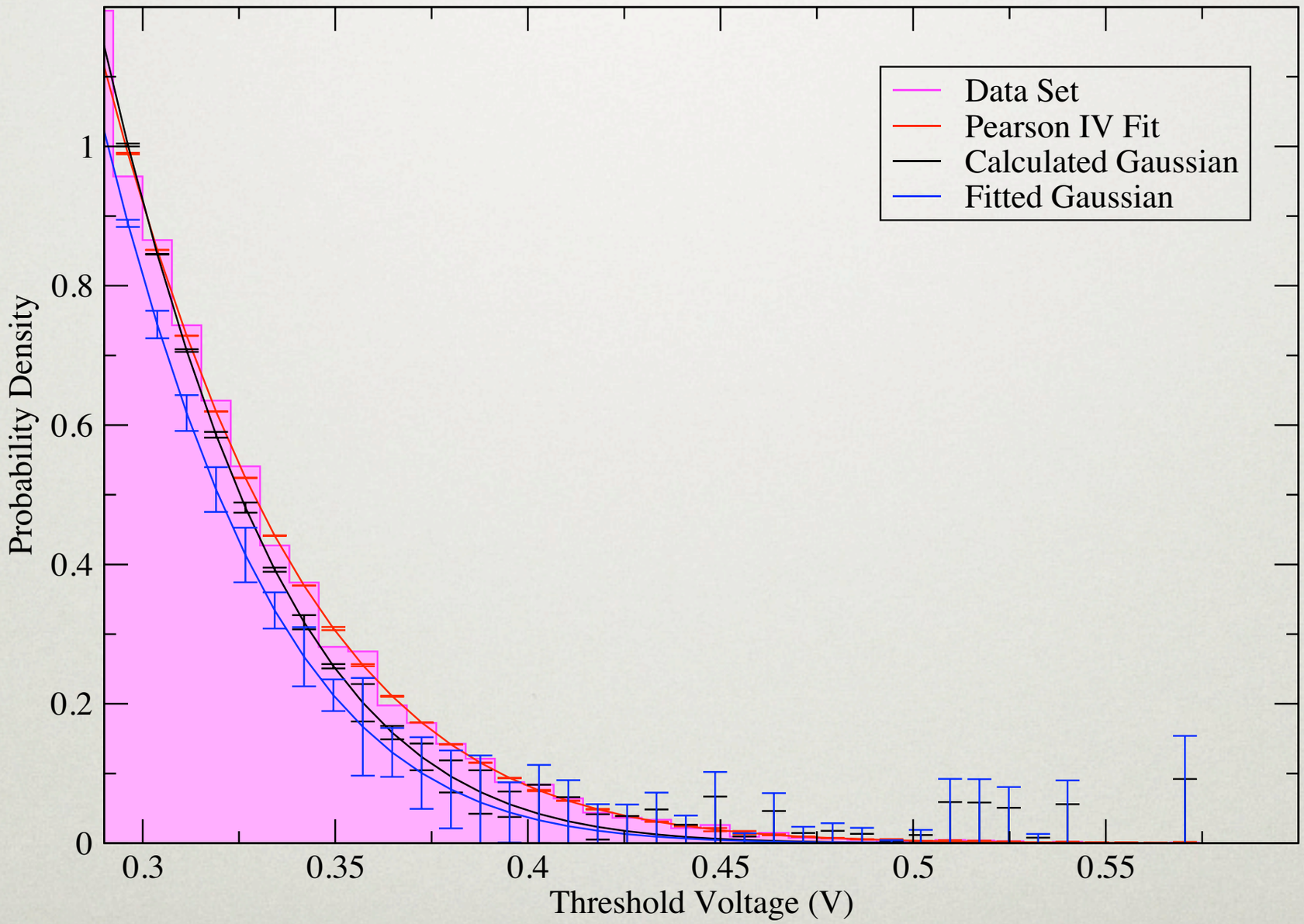
V_{TH} Distribution for 35nm



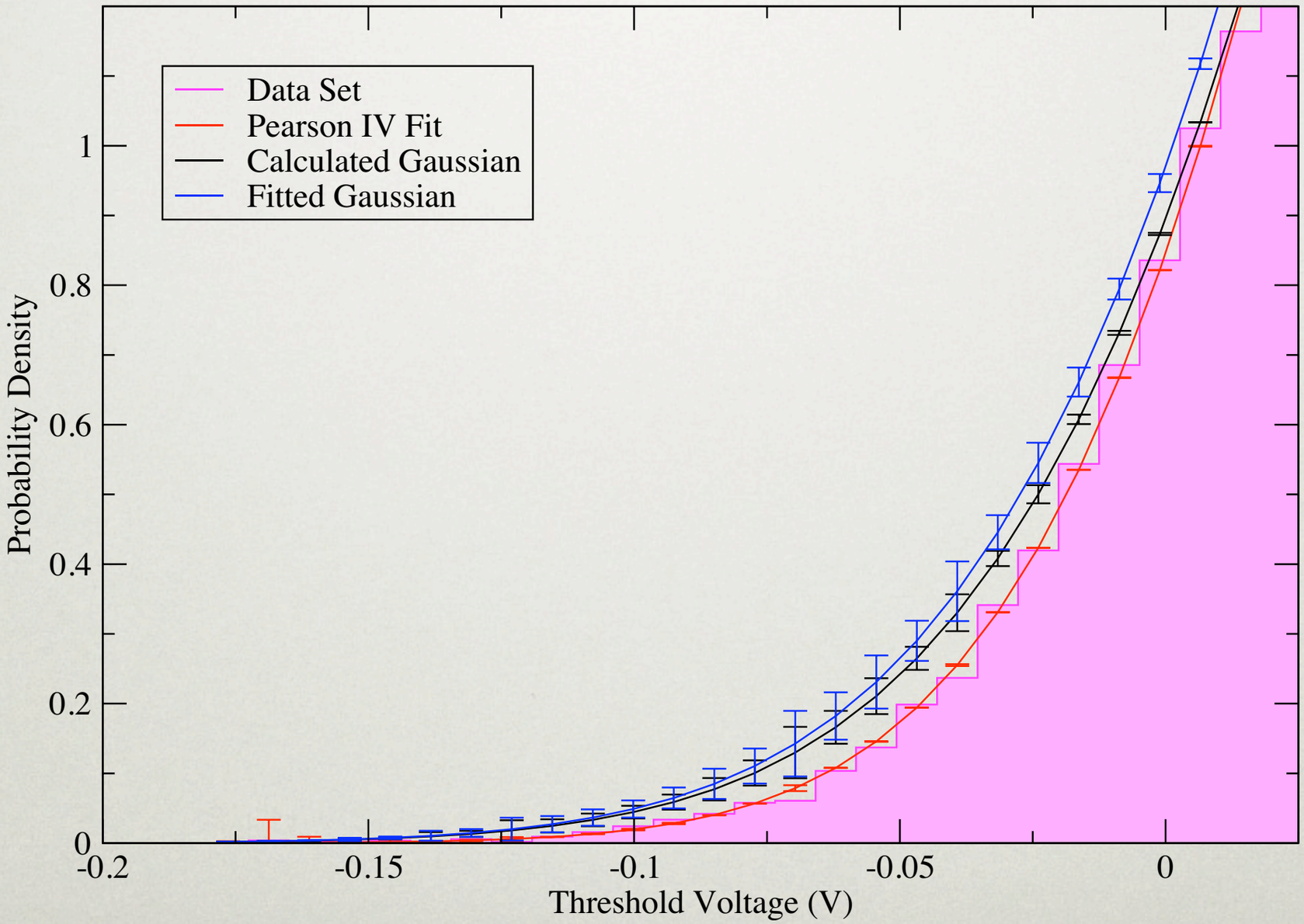
V_{TH} Distribution for 13nm



Vth Distribution for 13nm



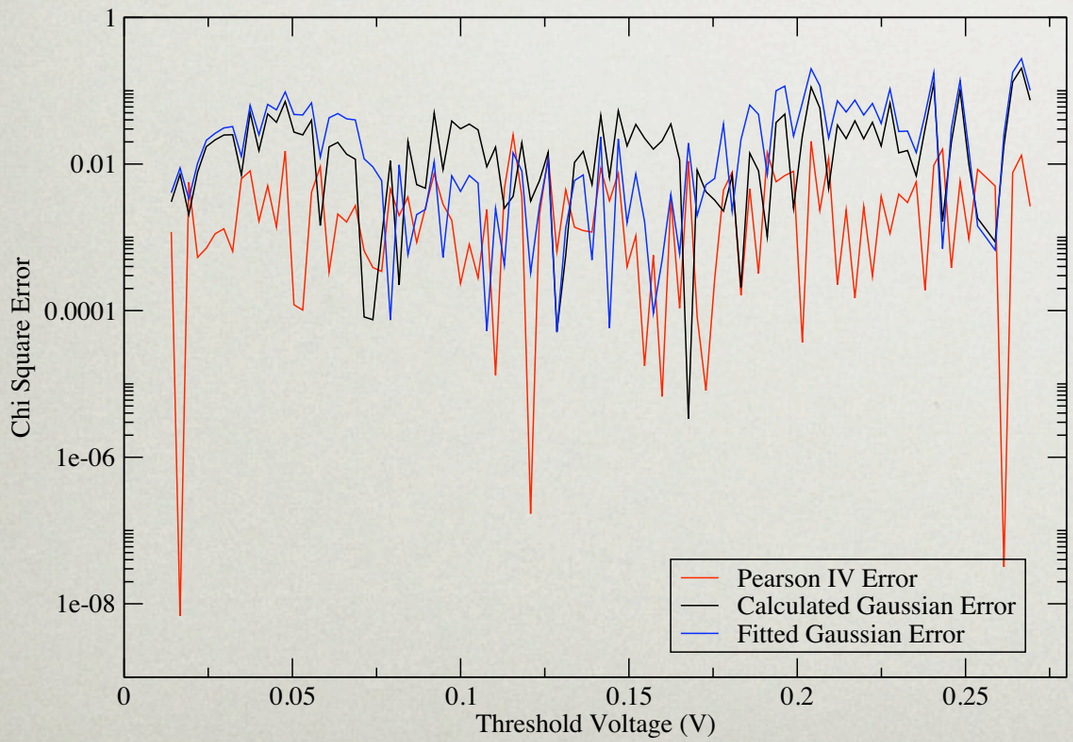
V_{TH} Distribution for 13nm



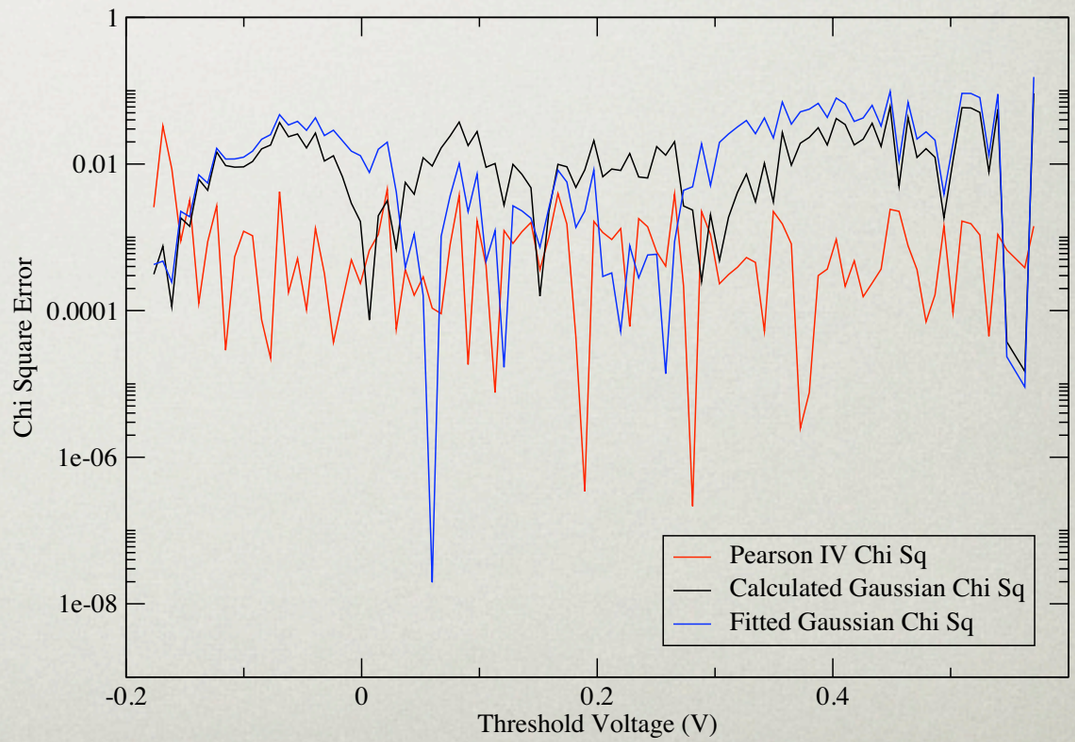
Fitting Parameters

Pearson IV Curve Fit

Device	Mean	St Dev	Skew	Kurtosis
35nm	125.9mV	30.4mV	0.162	0.081
13nm	150.6mV	81.8mV	0.218	0.121



35nm Device



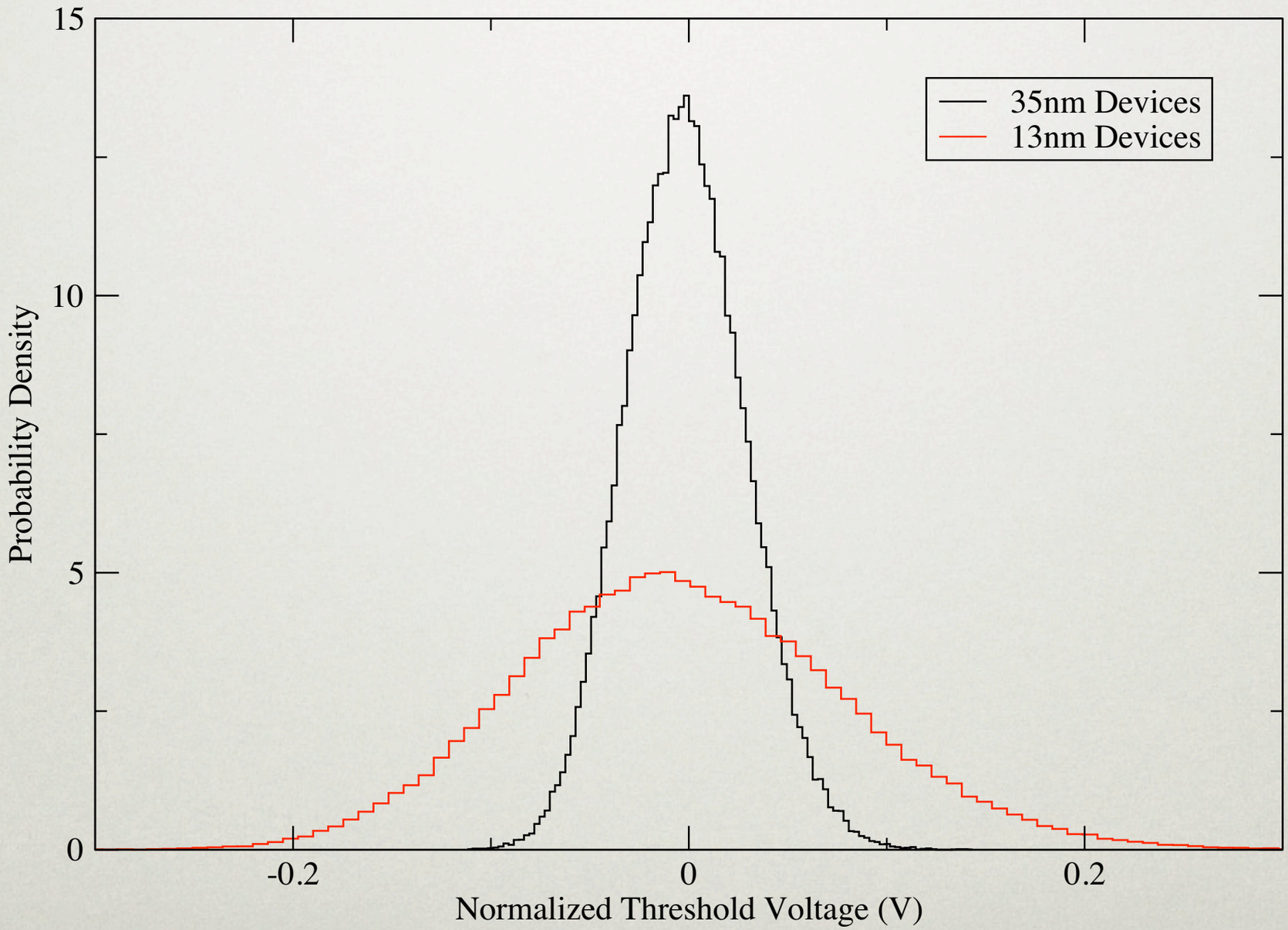
13nm Device

Design Margins (35nm)

- Deviations from gaussian parameter distributions will affect design margins, and hence yields

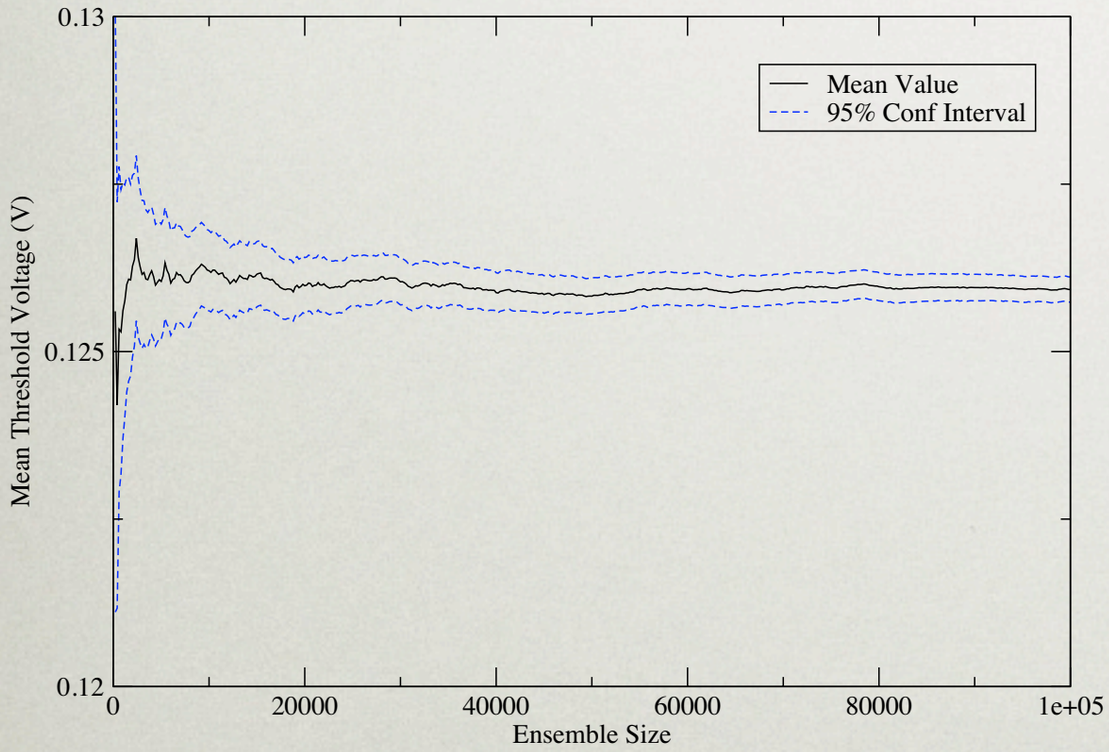
-4σ	-3σ	Distribution	+3σ	+4σ
N/A	-0.08785	Data	0.09322	0.12513
-0.12113	-0.09085	Calc. Gaussian	0.09085	0.12113
-0.12303	-0.09292	Fitted Gaussian	0.08791	0.11802
-0.11415	-0.08793	Pearson IV	0.09498	0.13274

V_{TH} 35nm vs 13nm

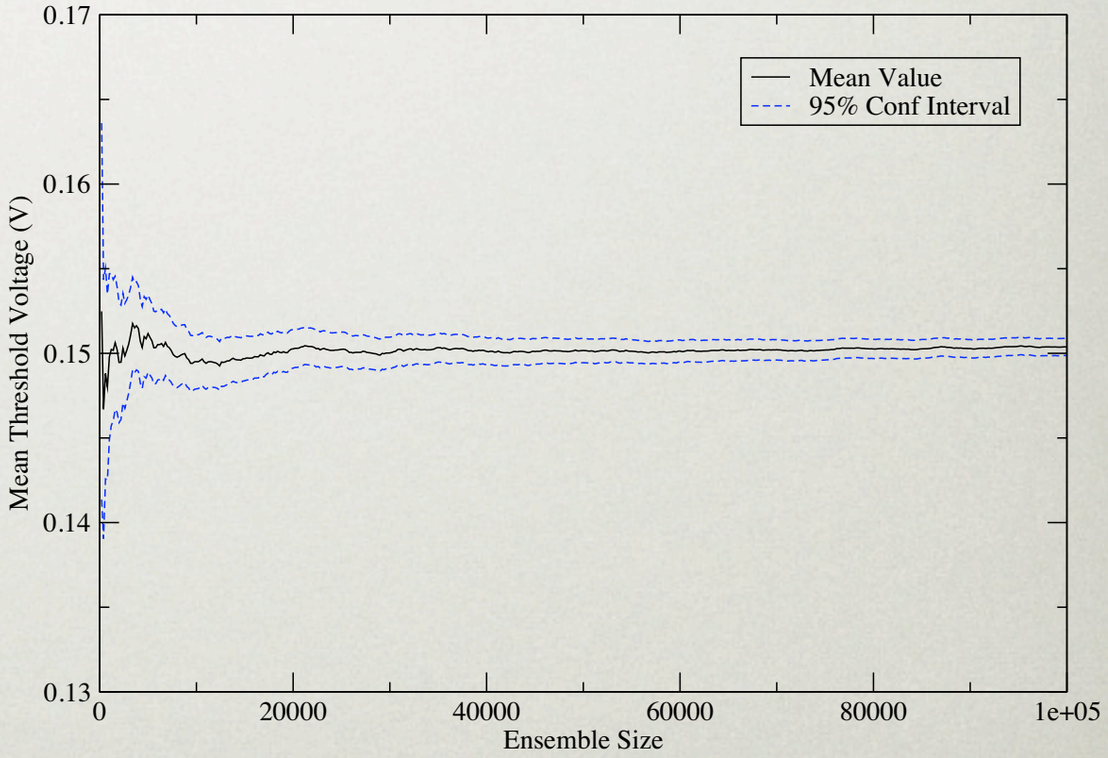


How Much is too much?

- How many devices do we actually need to simulate?



35nm Device



13nm Device

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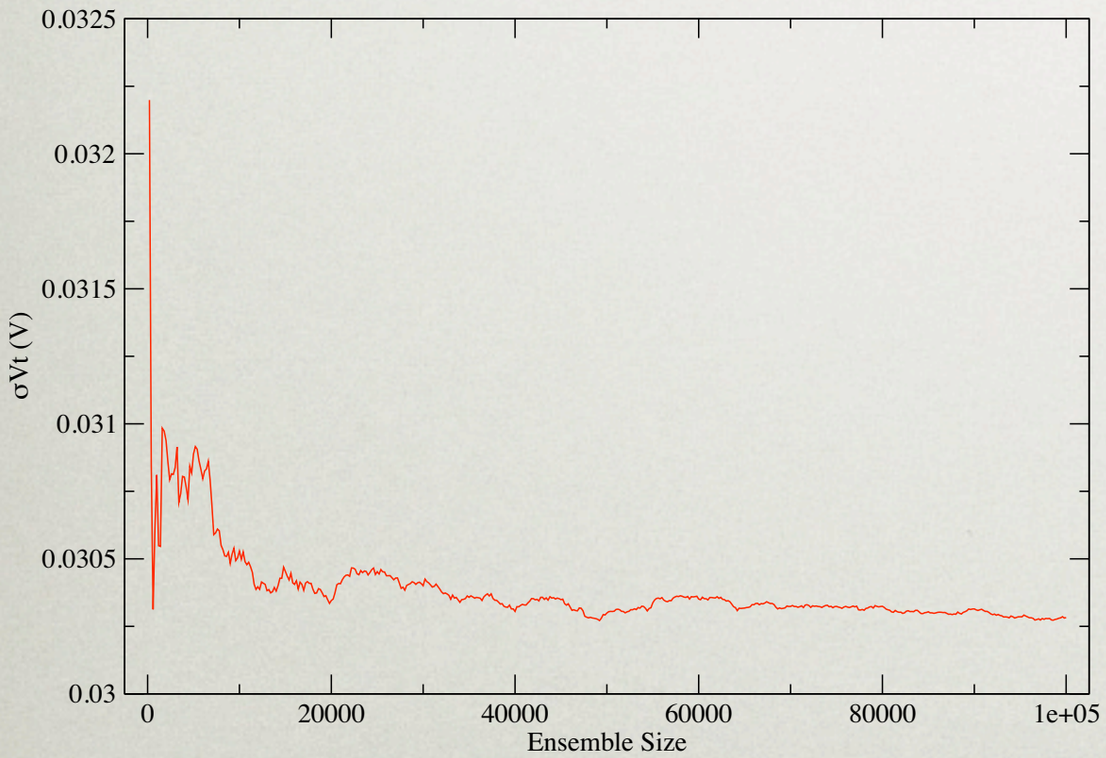
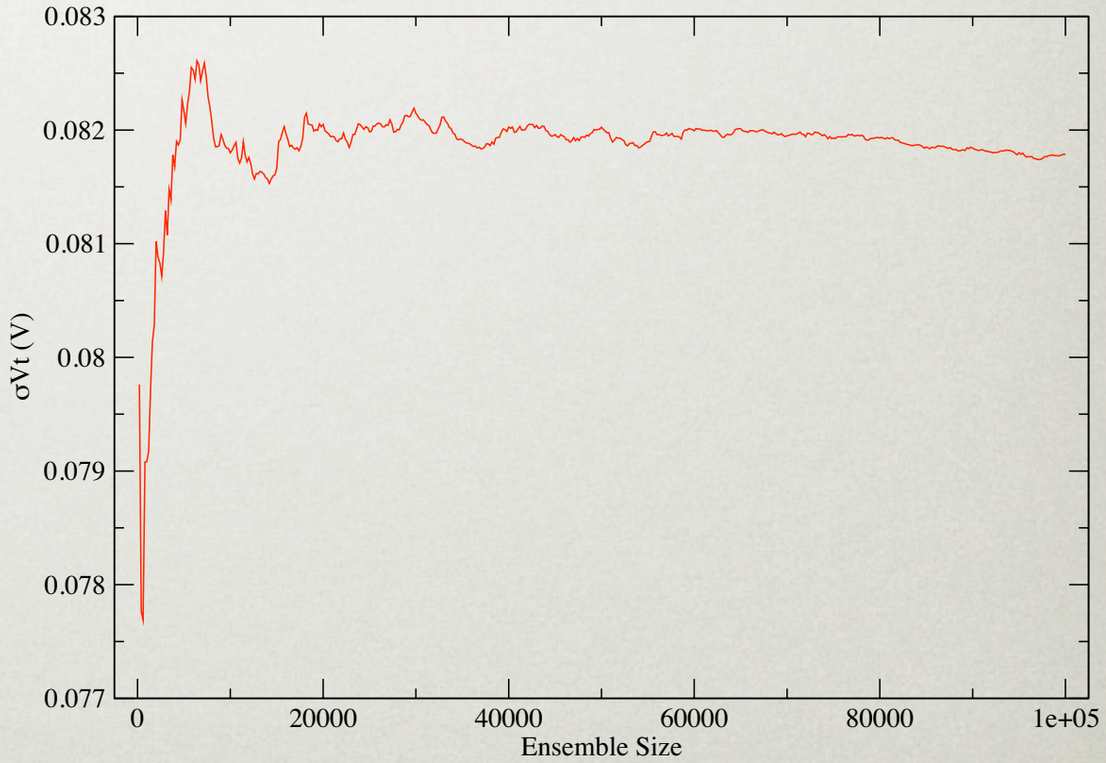


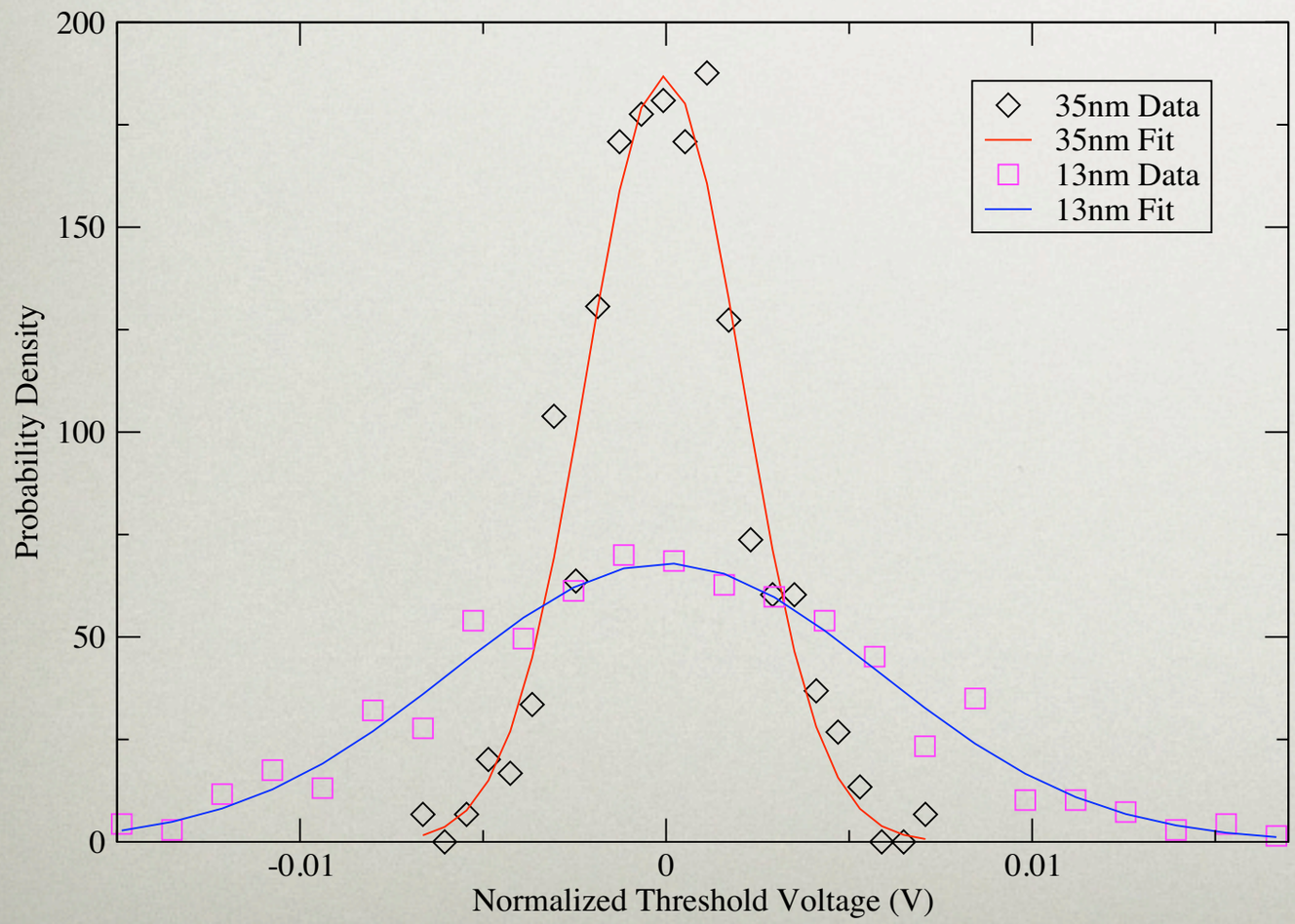
35nm Device



13nm Device

Variation of small ensembles

- Traditionally ensembles of 200 used
  - Assume ~5% error in the resulting distribution



- Results show a bigger error on the smaller device
  - ~11% for 35nm
  - ~22% for 13nm

Conclusions

- True distributions need to be understood to design around variability
- ScotGrid has enabled us to generate the large datasets we need to investigate parameter fluctuations
- Distribution of V_{th} deviates from normally distributed enough to be significant for design
- 200 device ensembles are far too small for valid analysis