Data Retention in MLC NAND Flash Memory

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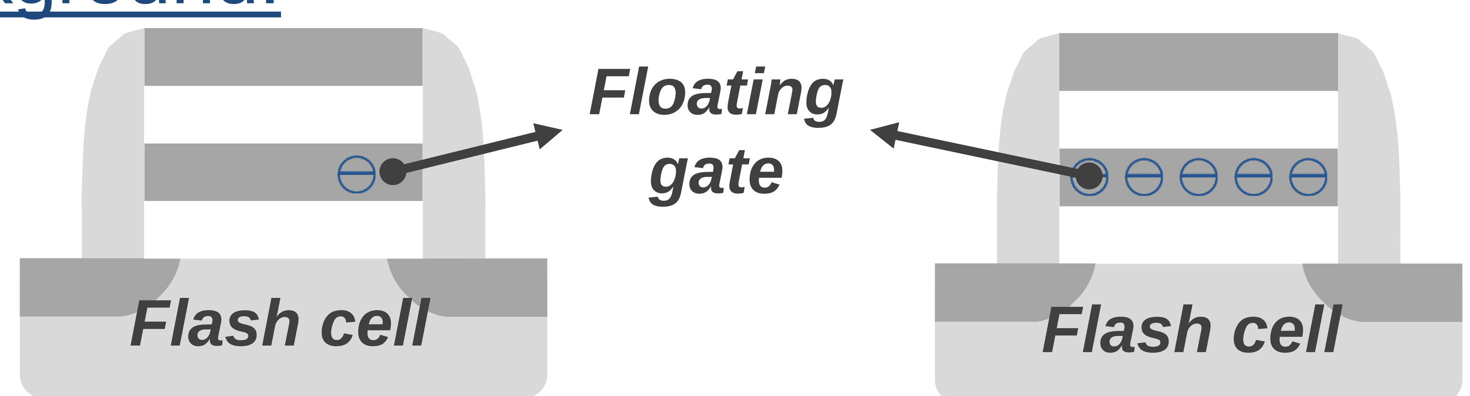
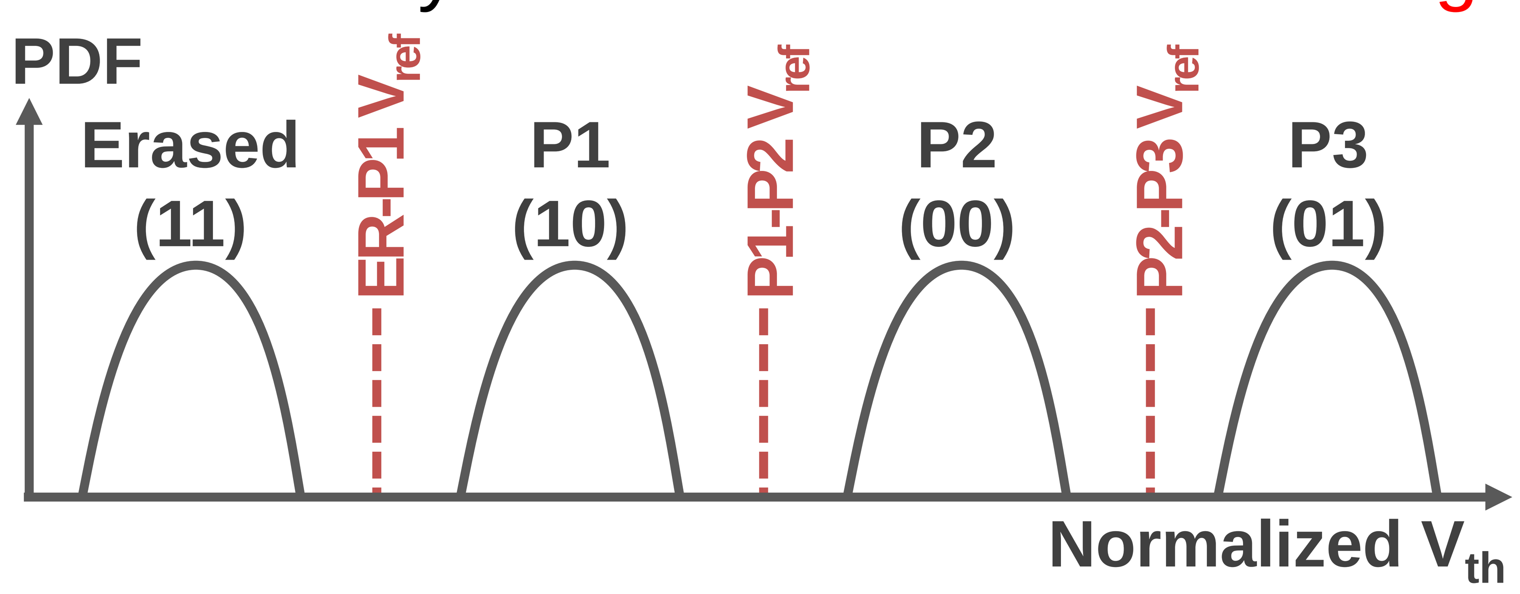
MLC NAND Flash Data Retention

Background:

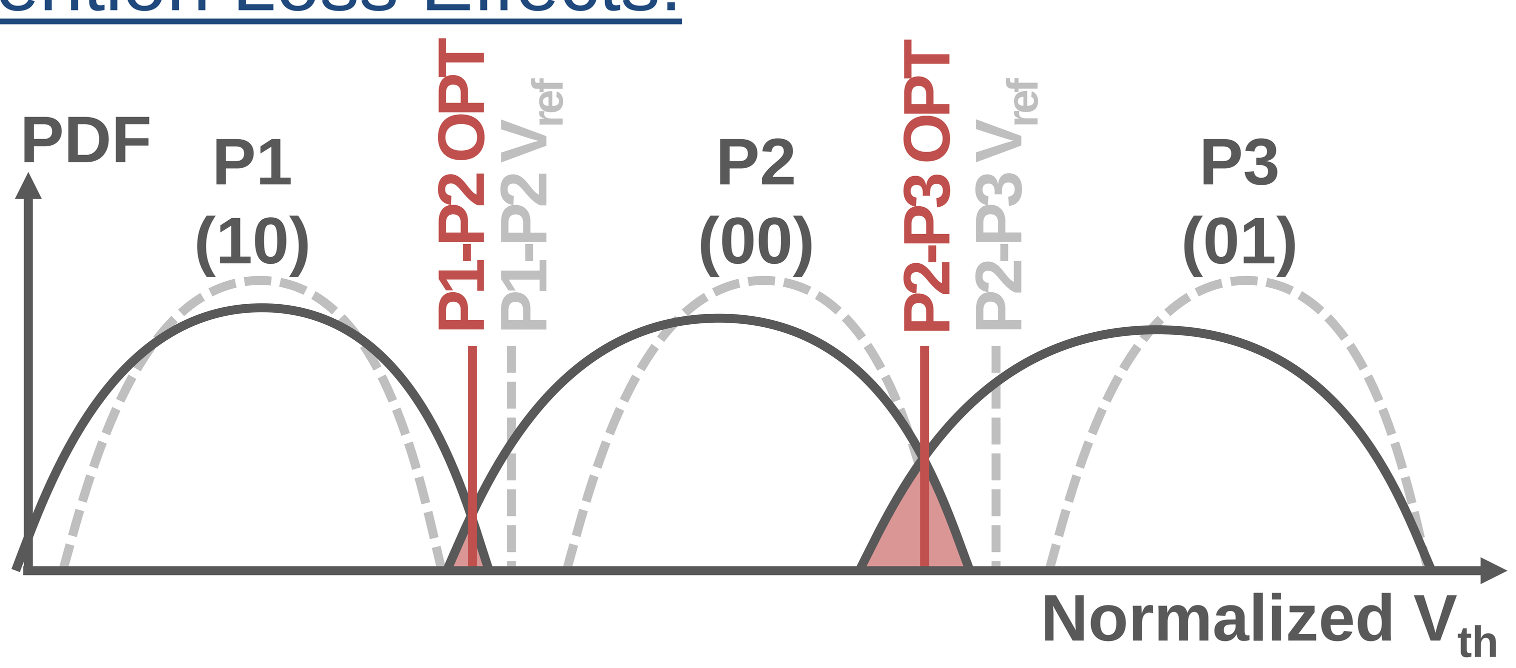


- Flash memory stores data in forms of charge



- The amount of charge determines the *threshold voltage (V_{th})* state of each cell, which is defined by V_{th} ranges separated by *read reference voltages (V_{ref})*

Retention Loss Effects:

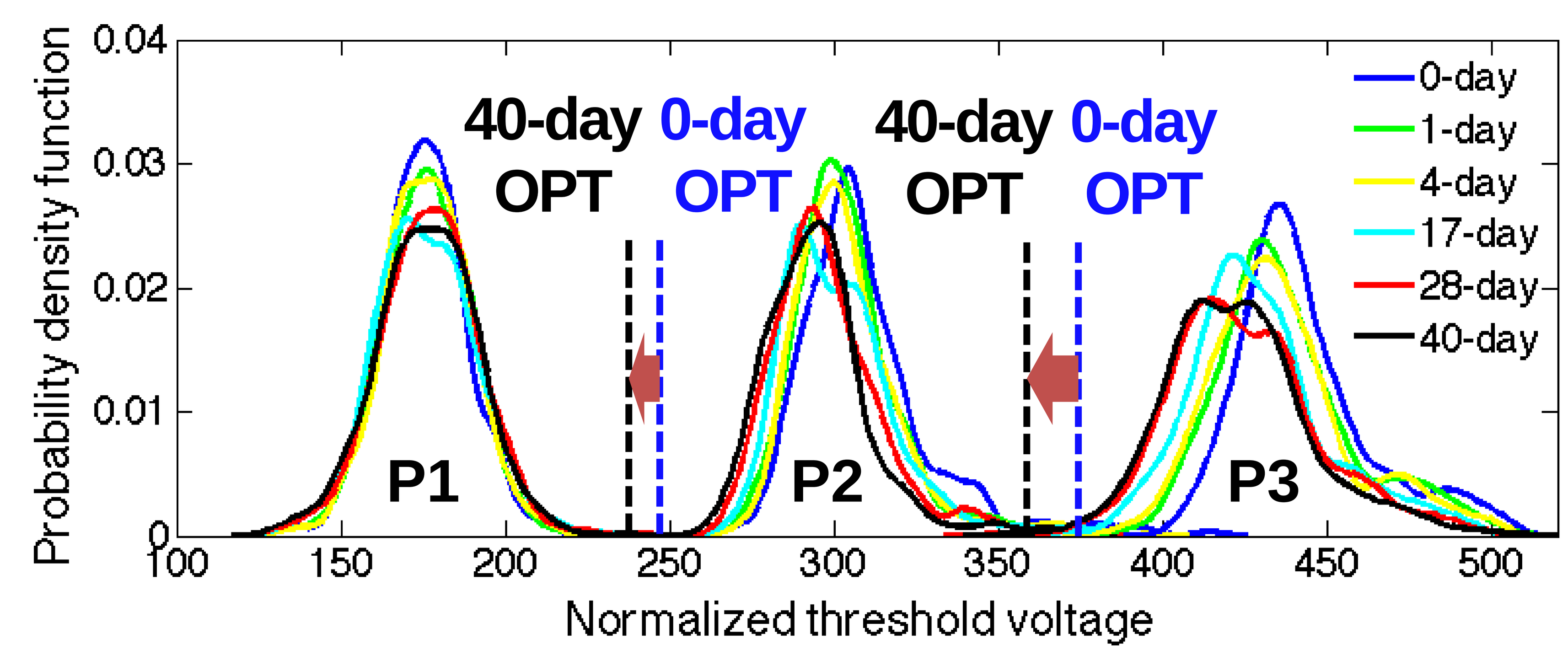


- Charge leaks over time such that V_{th} is changed

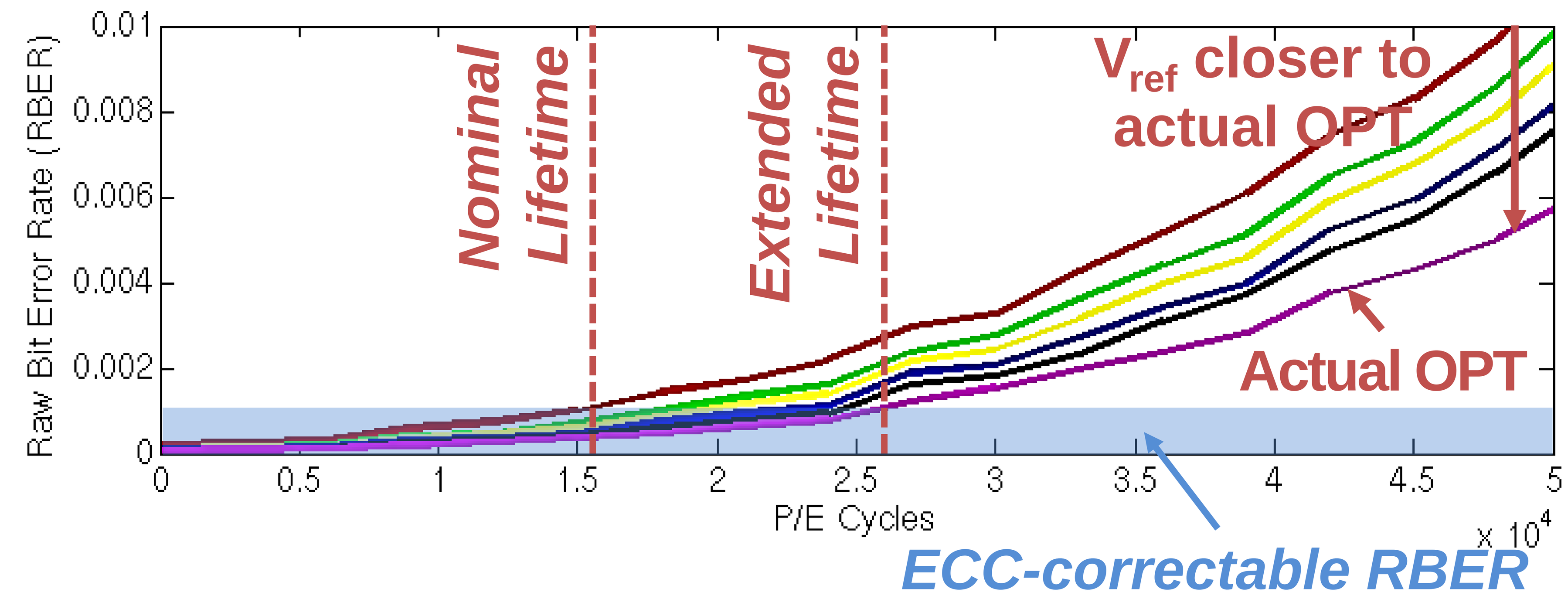
Characterize Retention Loss Effects

Key findings:

- P2 and P3 state distributions *shift to lower* voltages
- Each state's distribution becomes *wider*
- Higher-voltage state distribution shifts *faster*
- Optimal read reference voltage (OPT) shifts *lower*
- Higher OPT shifts *faster*



- A closer estimate of the OPT achieves *lower* RBER and *longer* lifetime

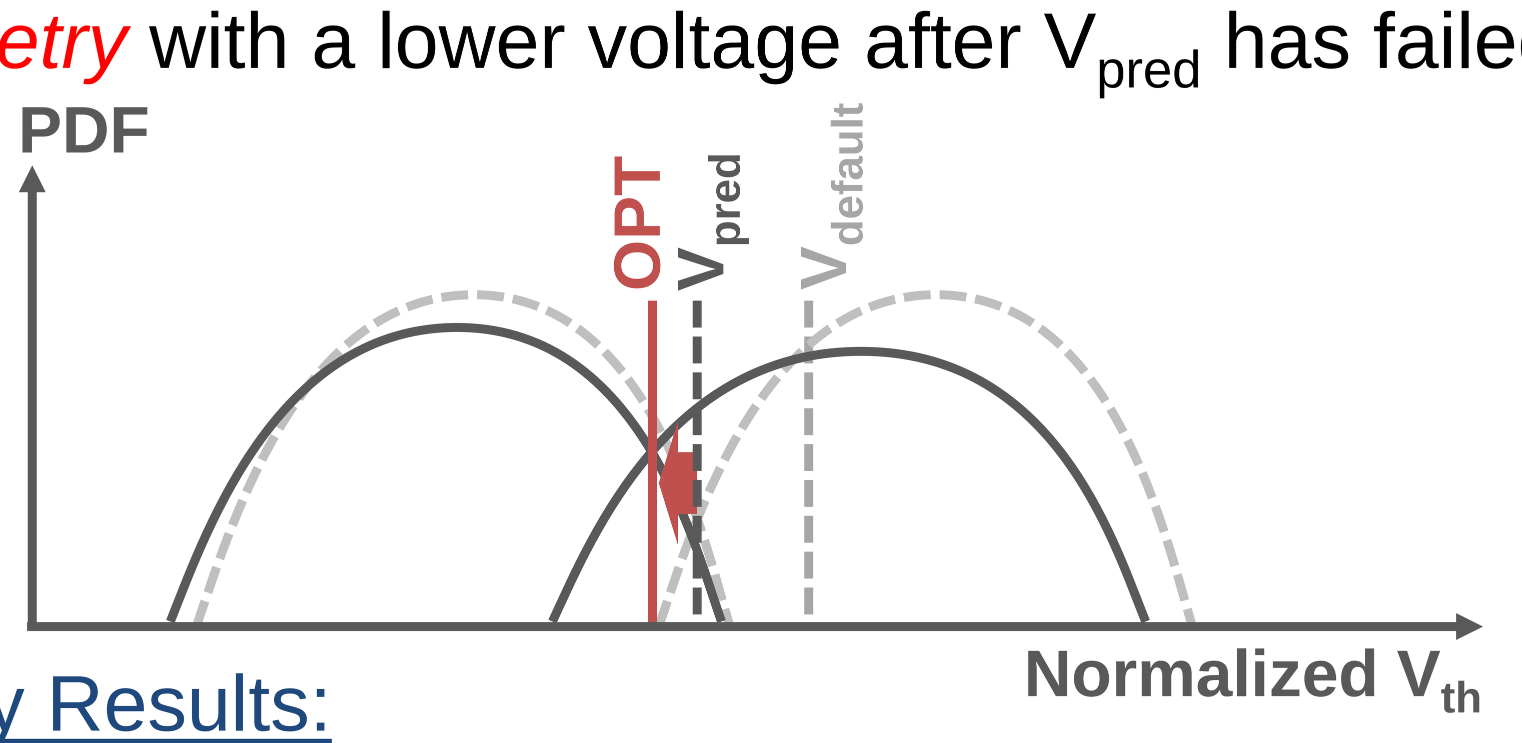


Retention Optimized Reading (ROR)

- Optimal read reference voltage (OPT) gradually changes over time due to data retention
- When the default read reference voltage ($V_{default}$) fails, read-retry is required, which is slow

Idea: *Dynamically* find and apply the actual OPT

- Periodically learn a per-block prediction (V_{pred}) of the actual OPT
- If the actual OPT shifts lower due to retention, *retry* with a lower voltage after V_{pred} has failed



Key Results:

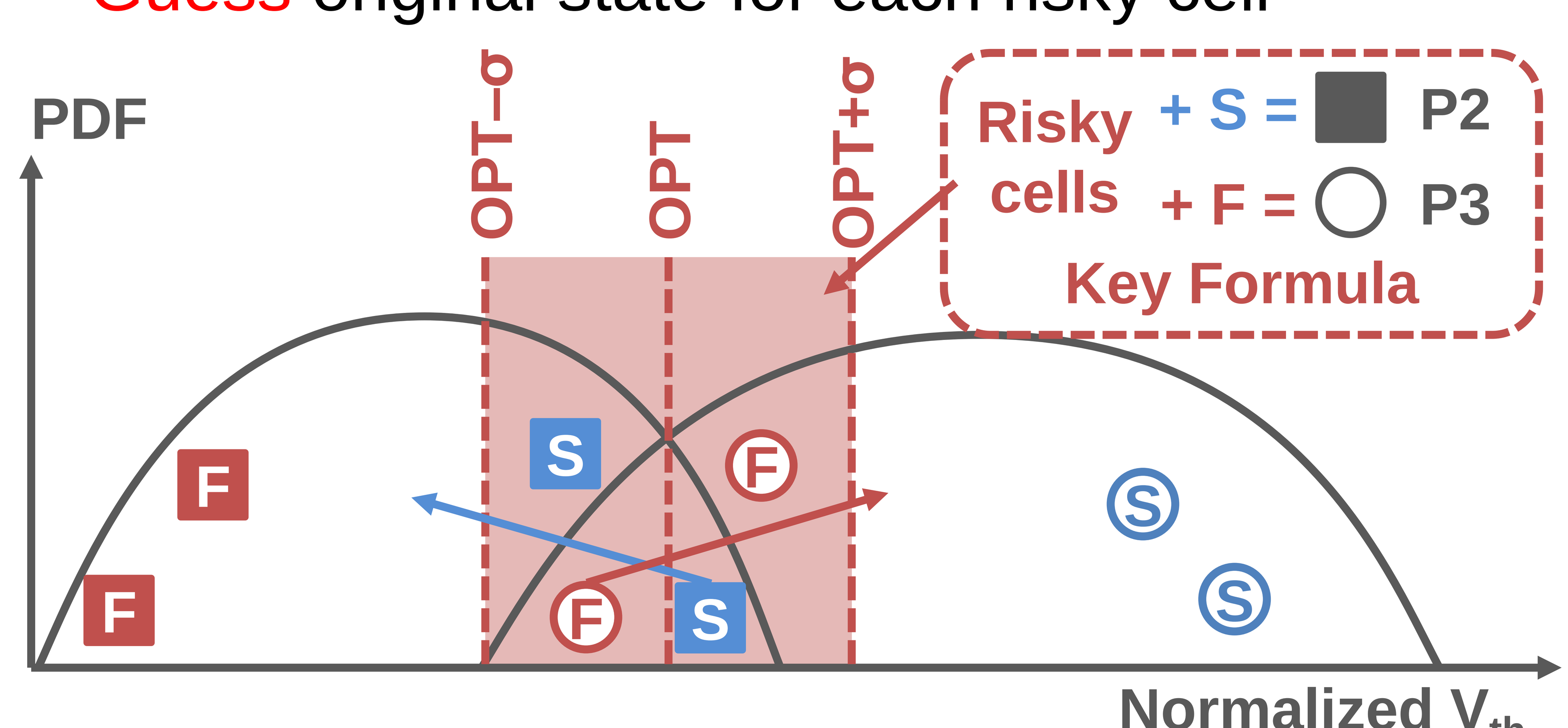
- 64% lifetime improvements
- 10.1% ECC decoding latency reduction
- 70.4% read latency reduction in ext. lifetime

Retention Failure Recovery (RFR)

- Some cells leak charge extremely fast/slow
- High temperature can accelerate this process and quickly generate an uncorrectable error *(retention failure)*

Idea: Correct retention errors after failure happens by "turning back retention time"

- Identify *(risky)* cells susceptible to retention errors
- Identify fast- and slow-leaking cells
- Guess original state for each risky cell



Result: 50% RBER reduction

Y. Cai et al. *Data Retention in MLC NAND Flash Memory: Characterization, Optimization and Recovery*. HPCA 2015.

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