

# Bit Error Analysis on Drives for Data Recovery

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Kroll Ontrack, Inc.

# Agenda

- » Introduction and Parameters
- » Overview and high level analysis
- » Specific Patterns
  - Routine
  - Less Frequent
- » Summary

# Introduction

» Why is this research important?

- Determine ECC effectiveness
- Improve data recovery success

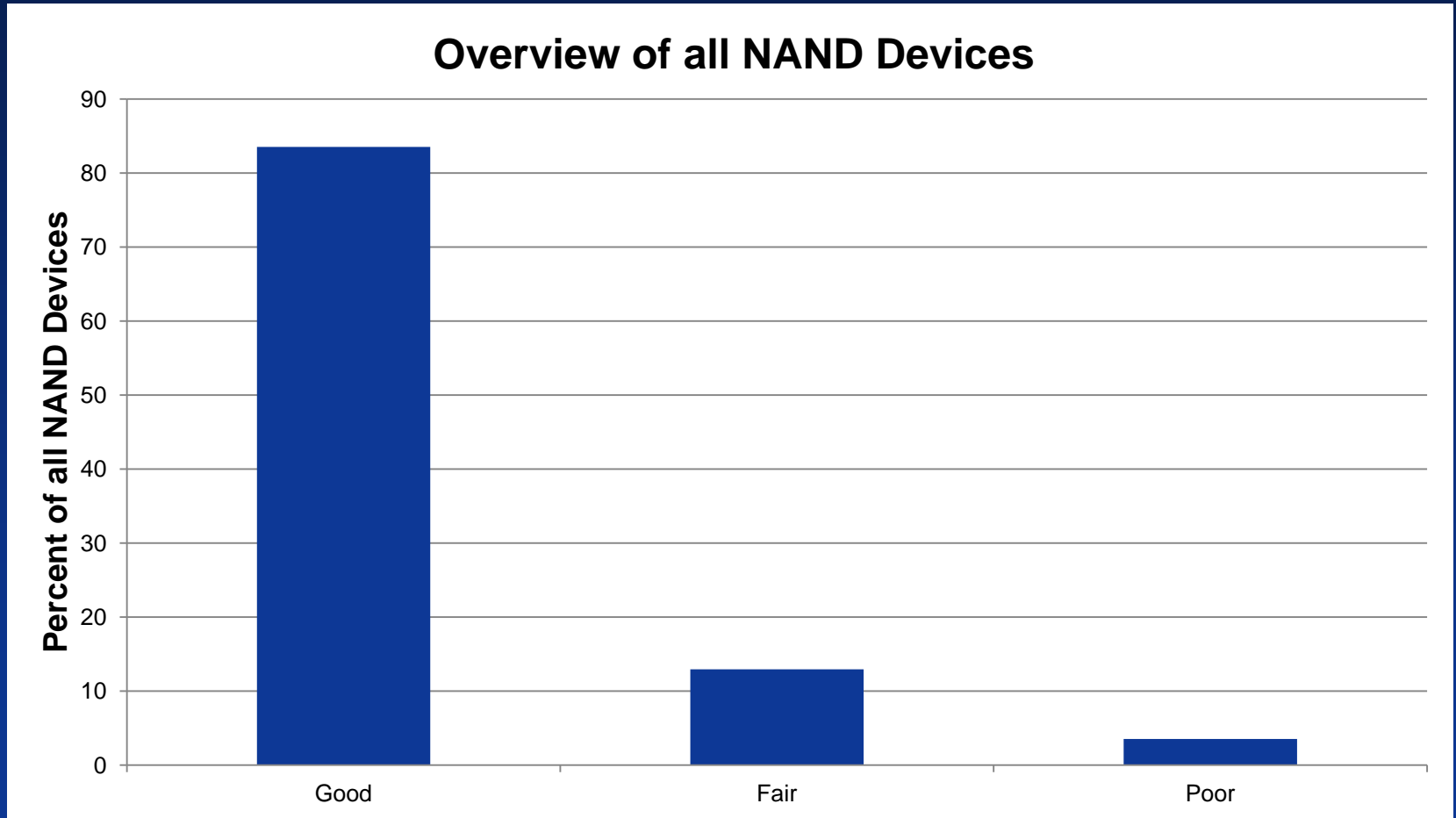
# Parameters of Analysis

- » Customer drives submitted for data recovery
  - Over past 18 months
  - Required raw extraction
- » One NAND device from each drive (not all NAND devices)
- » All based on BCH Codewords (CW's) processed
- » Most are:
  - Two bit-per-cell (MLC) (94%)
  - Removable (USB Stick, SD, etc.)

# Category Criteria

Chart Categories (Kroll Ontrack specific)	
Good	<ul style="list-style-type: none"><li>• &gt;80% Perfect CWs</li><li>• &lt;1% CWs that were uncorrectable (UNC) or had bit errors &gt; half correction capability</li></ul>
Fair	Neither Good nor Poor
Poor	>25% UNC CW's

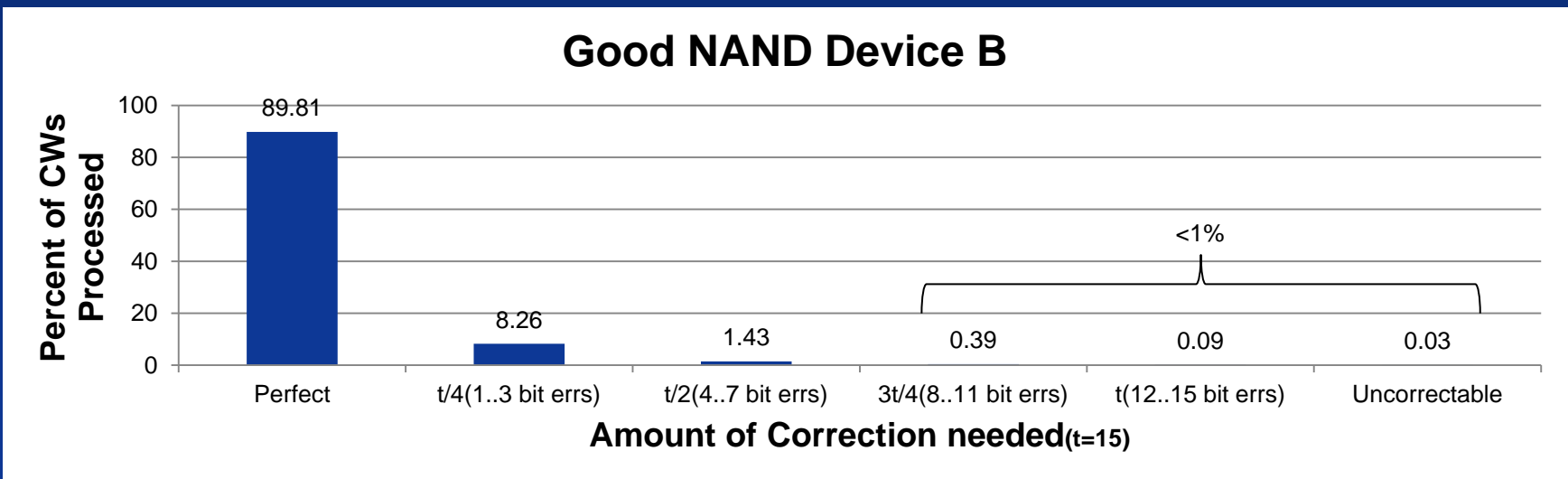
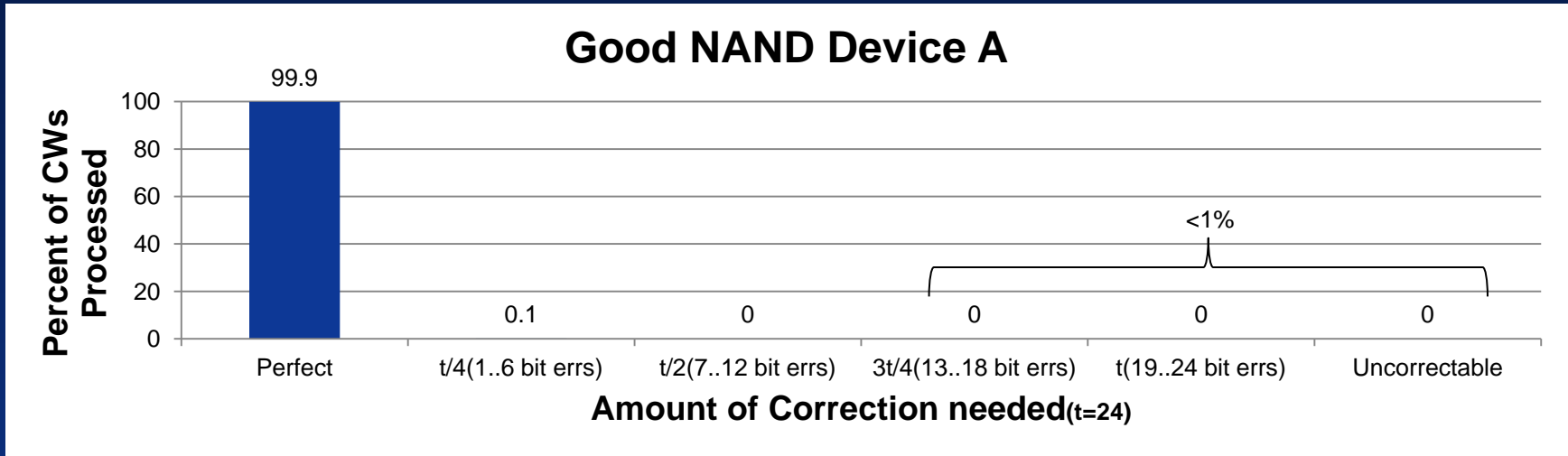
# Overview Chart



# Definitions for Charts

- »  $t$  = number of bits code can correct
- » Split into four sections to normalize data ( $t$  ranges from 2 to 48)
  - $t/4$ ,  $t/2$ ,  $3t/4$ , and  $t$
- » Two additional categories
  - Perfect (no errors)
  - Uncorrectable (too many errors)

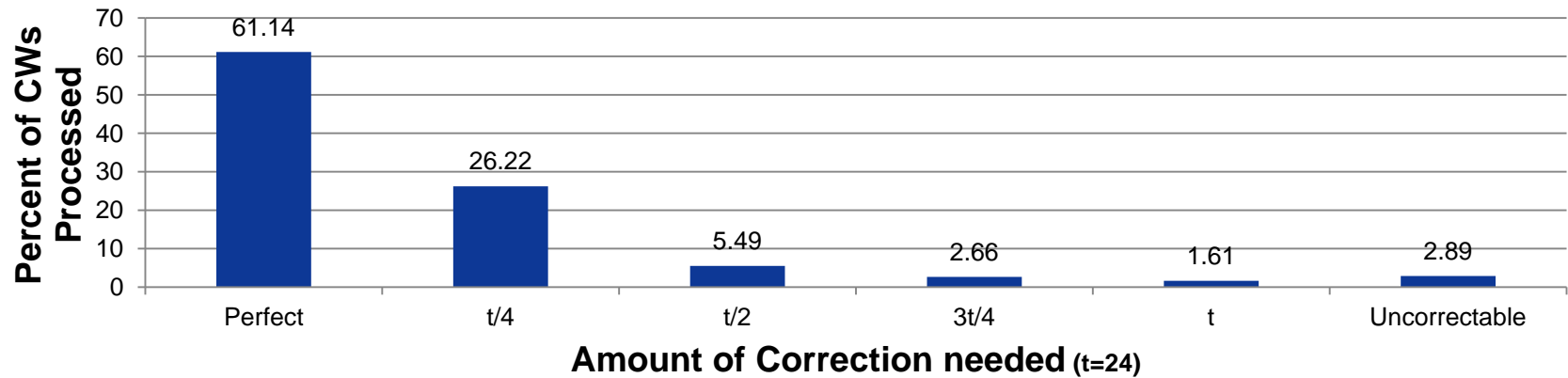
# Example Good NAND Devices



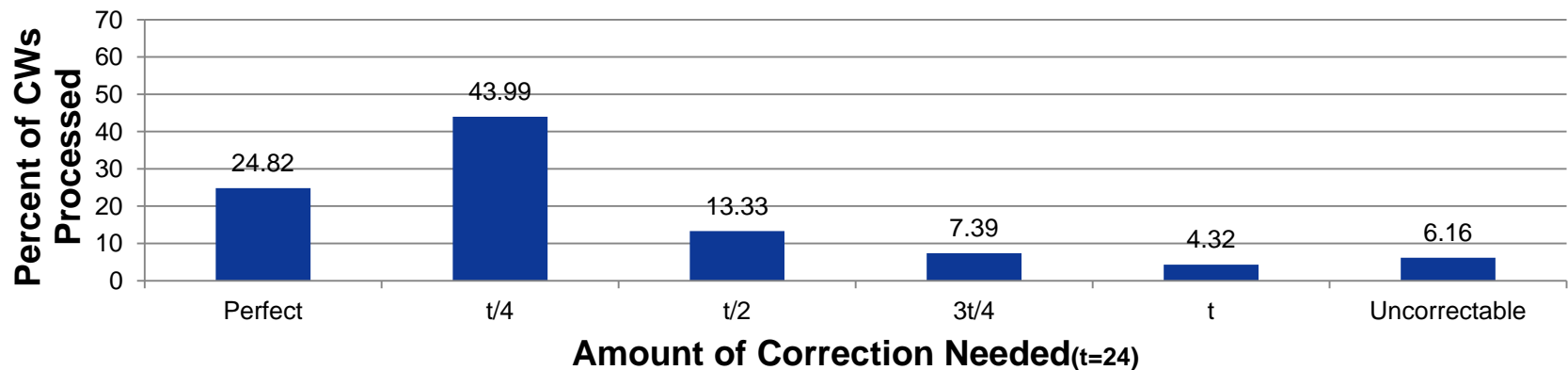


# Example Fair NAND Devices

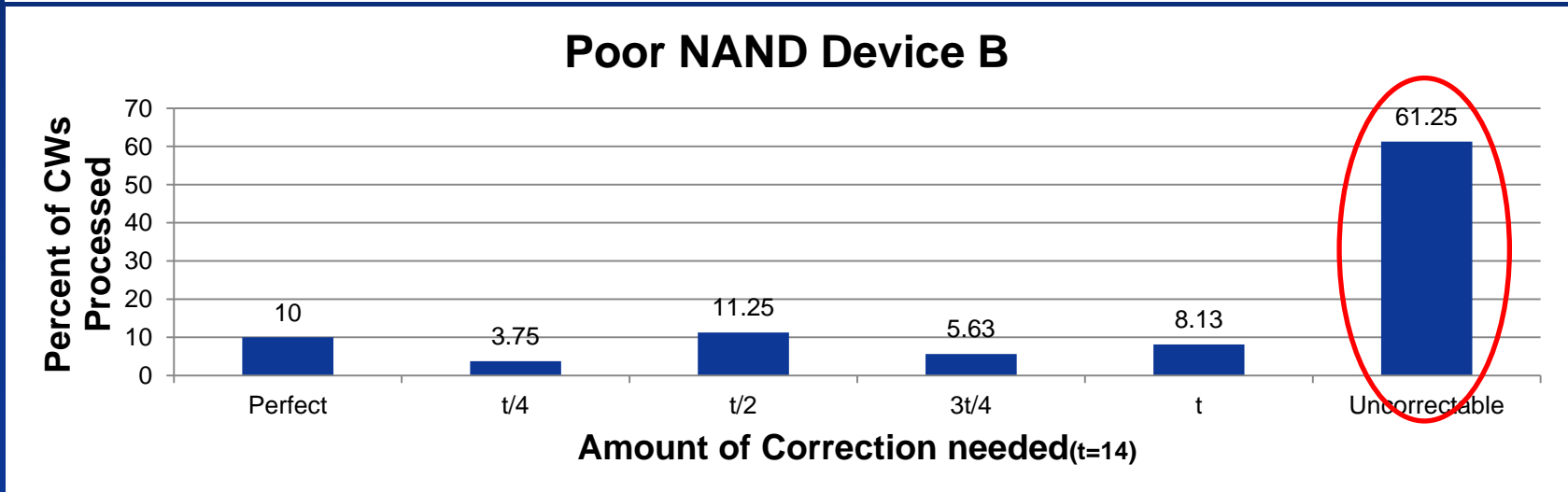
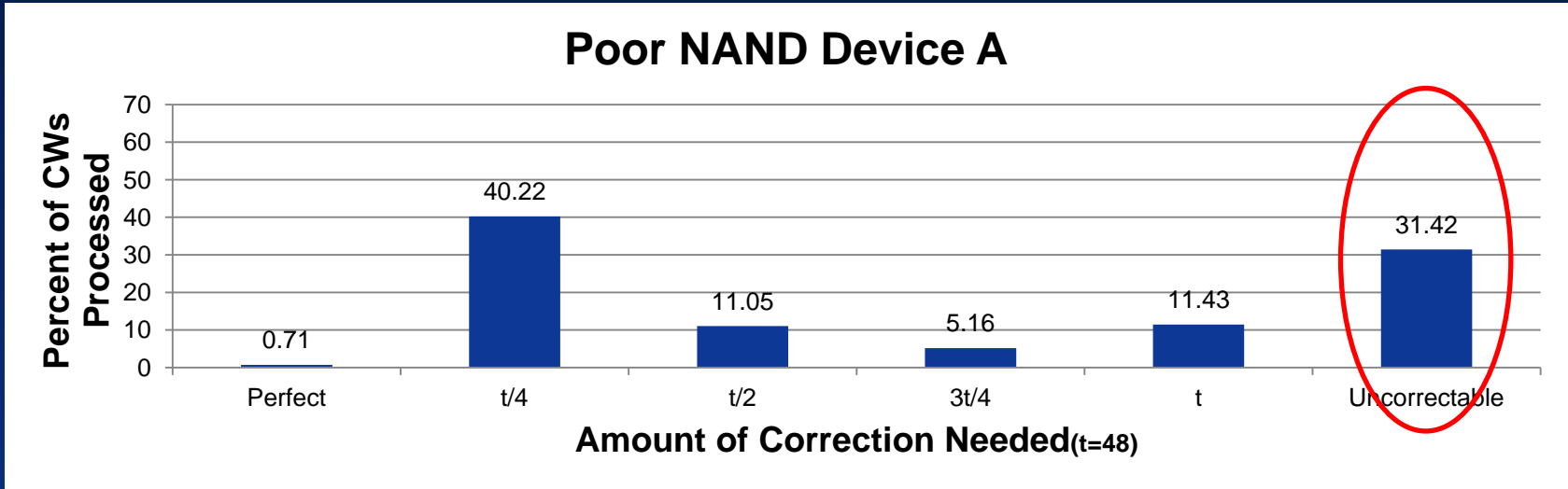
## Fair NAND Device A



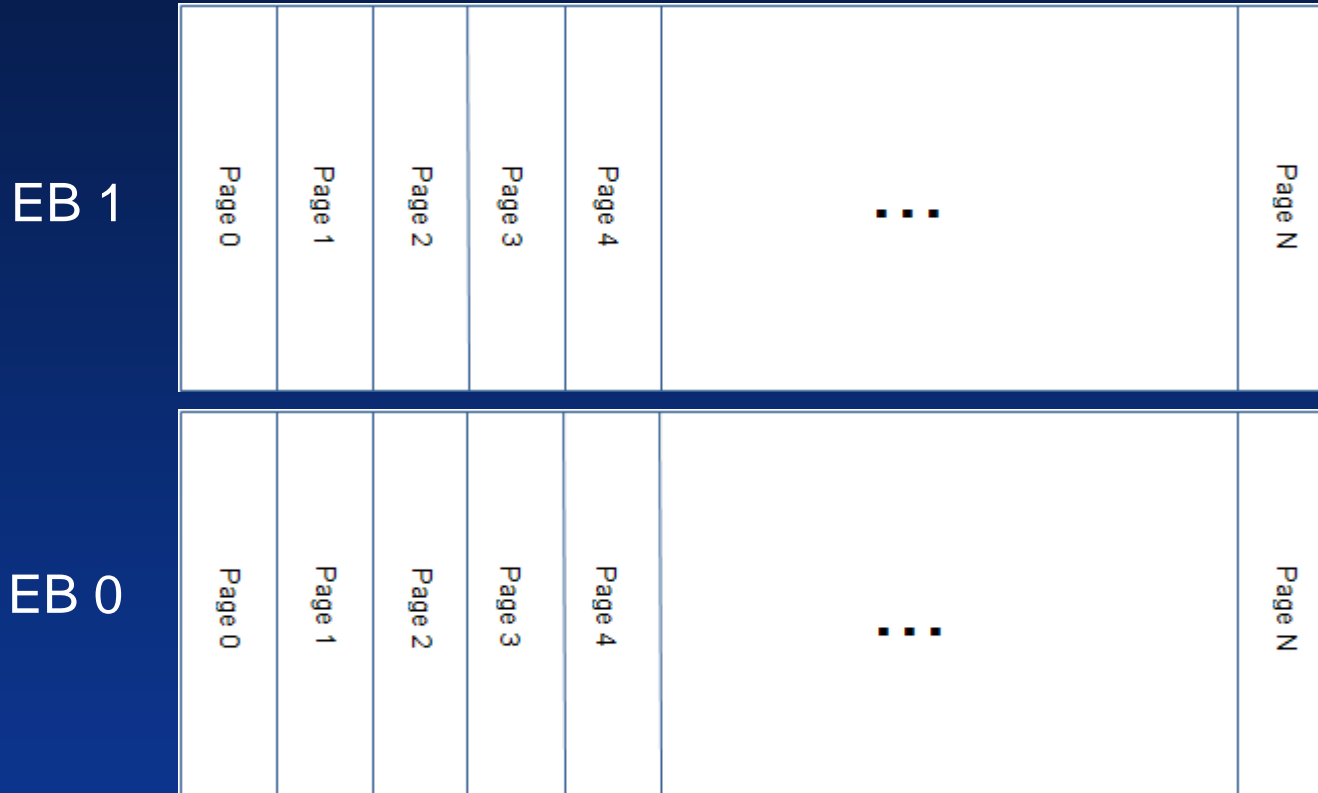
## Fair NAND Device B



# Example Poor NAND Devices



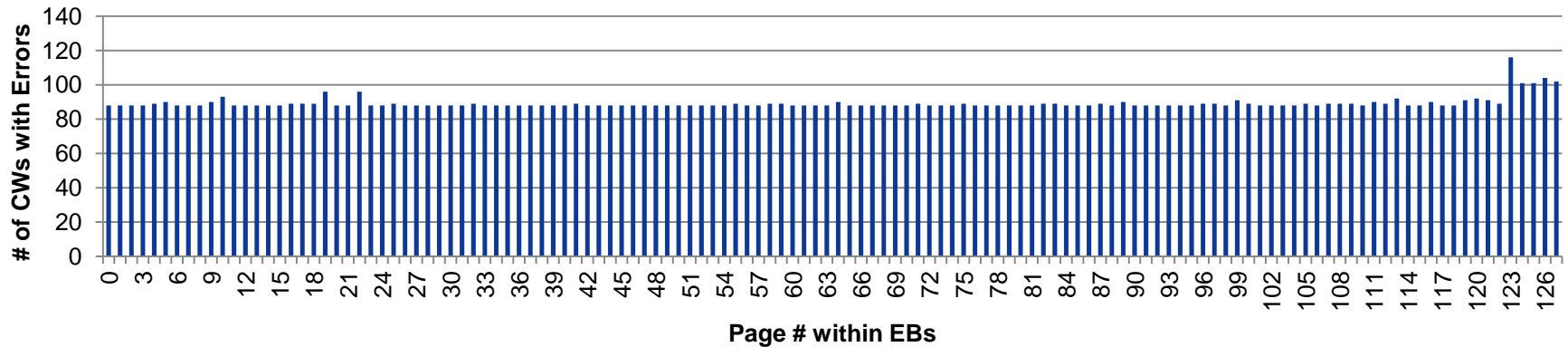
# Patterns Across Pages



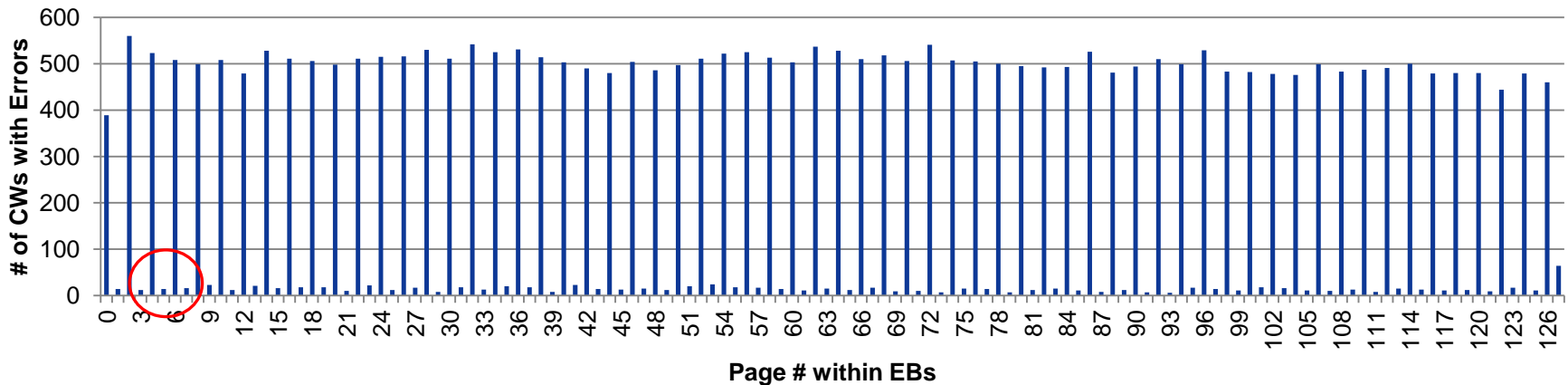
- » Comparison of all Pages at same position in Erasure Blocks (EB's)
- » Similar to stacking each EB on top of each other to line up the Pages

# Patterns Across Pages (Consistent and Alternating)

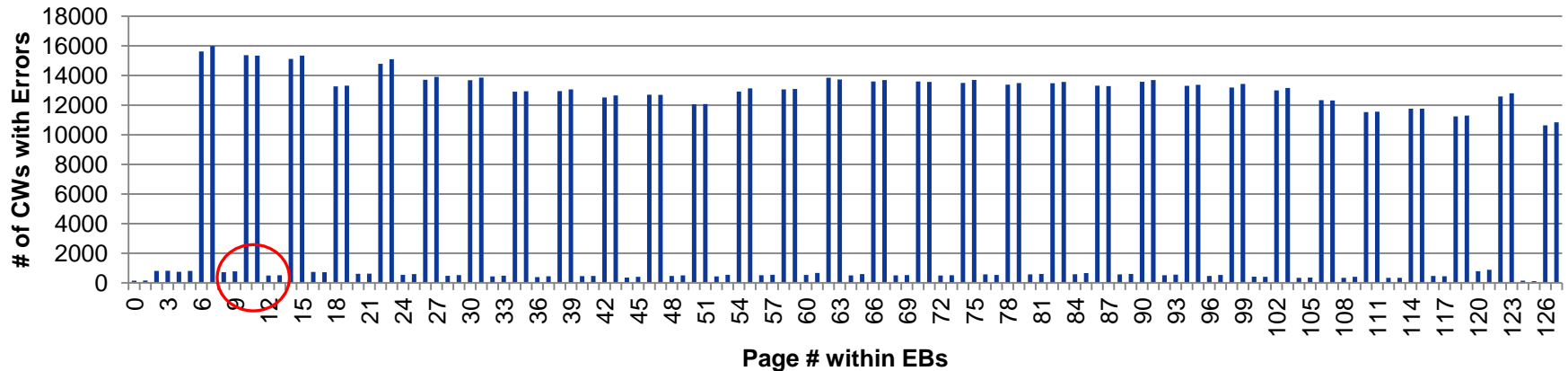
Magnitude of Codeword errors (per page) across all EBs



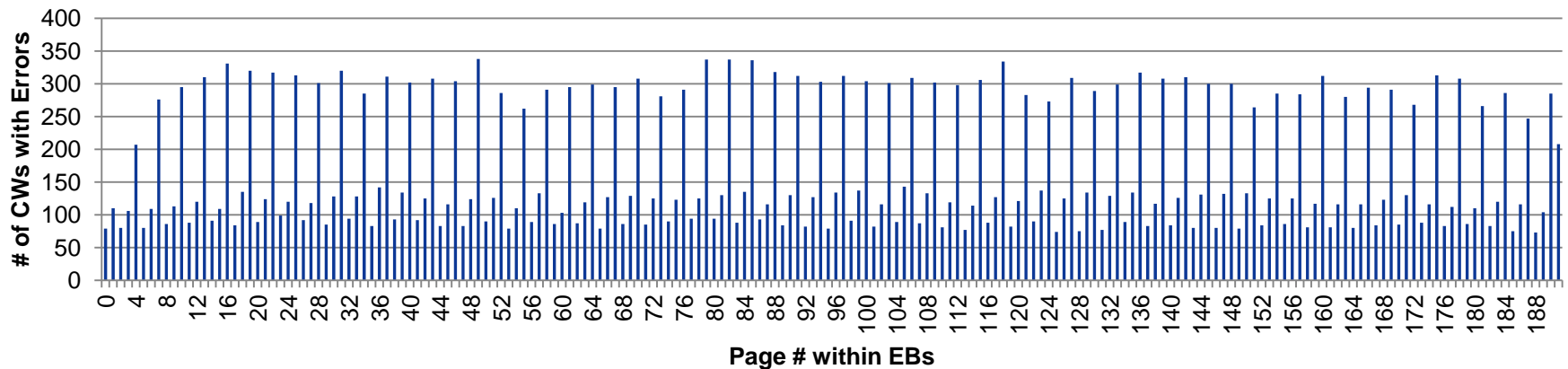
Magnitude of Codeword errors (per page) across all EBs



Magnitude of Codeword errors (per page) across all EBs

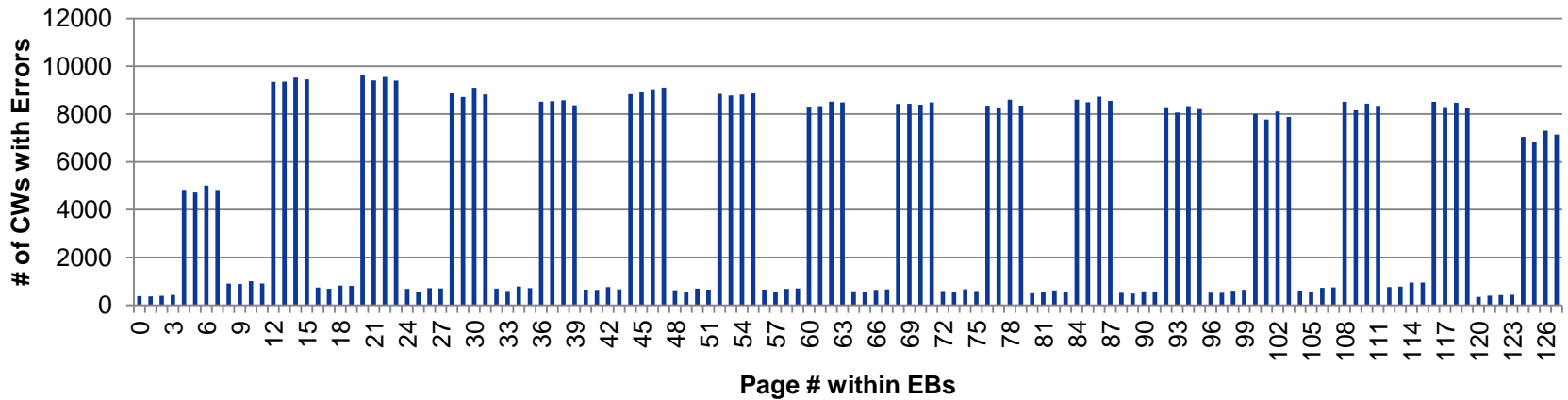


Magnitude of Codeword errors (per page) across all EBs

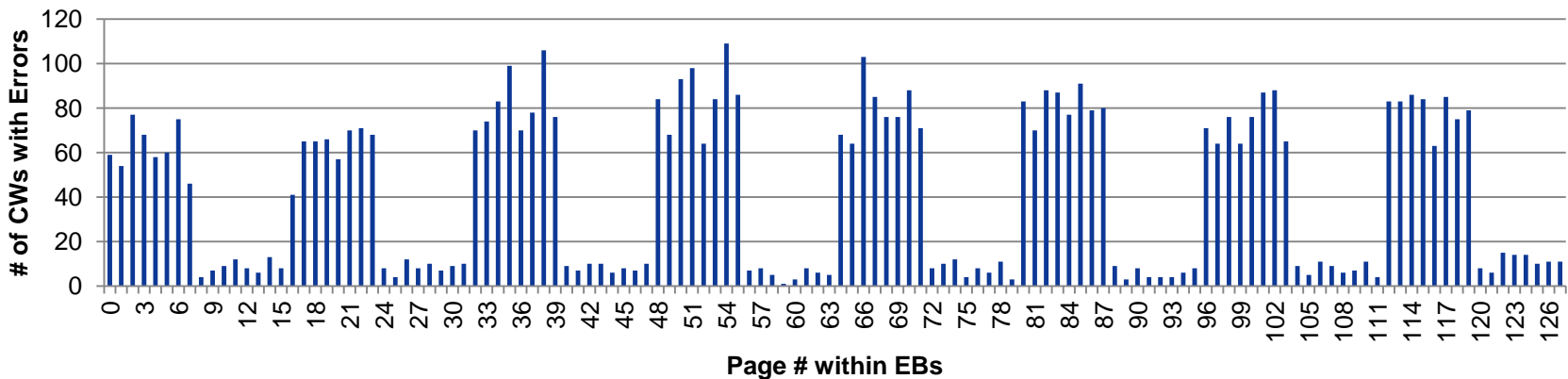


# Patterns Across Pages (By four and by eight)

Magnitude of Codeword errors (per page) across all EBs

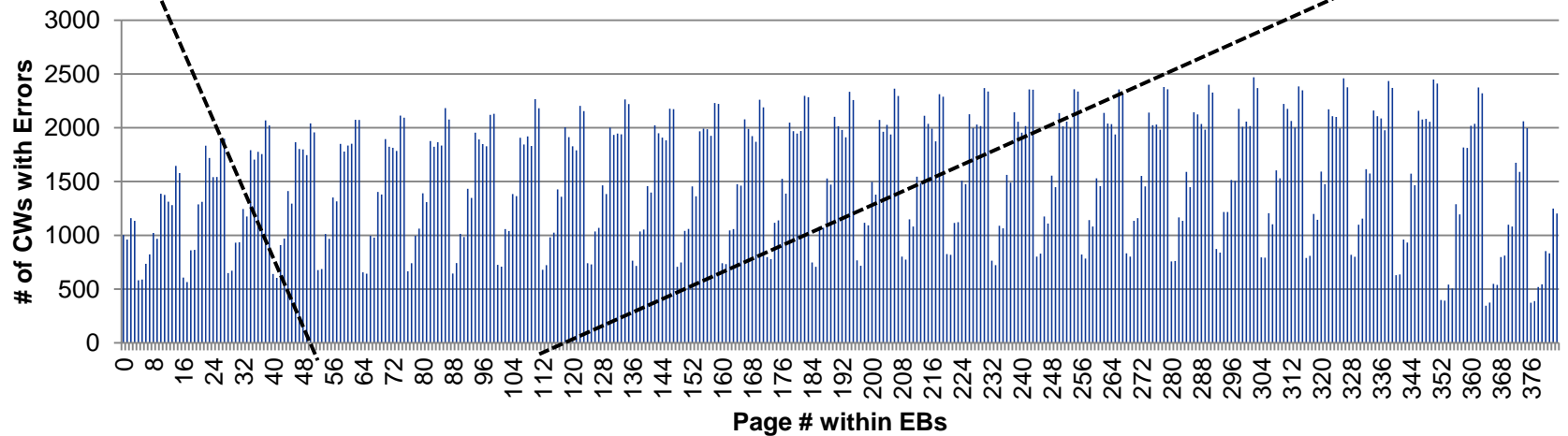
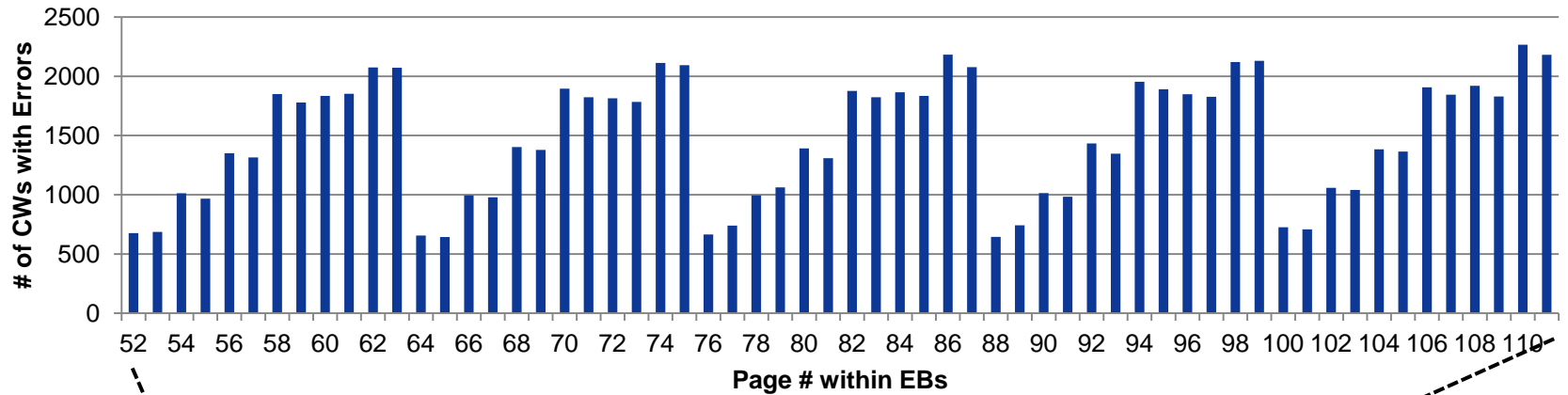


Magnitude of Codeword errors (per page) across all EBs



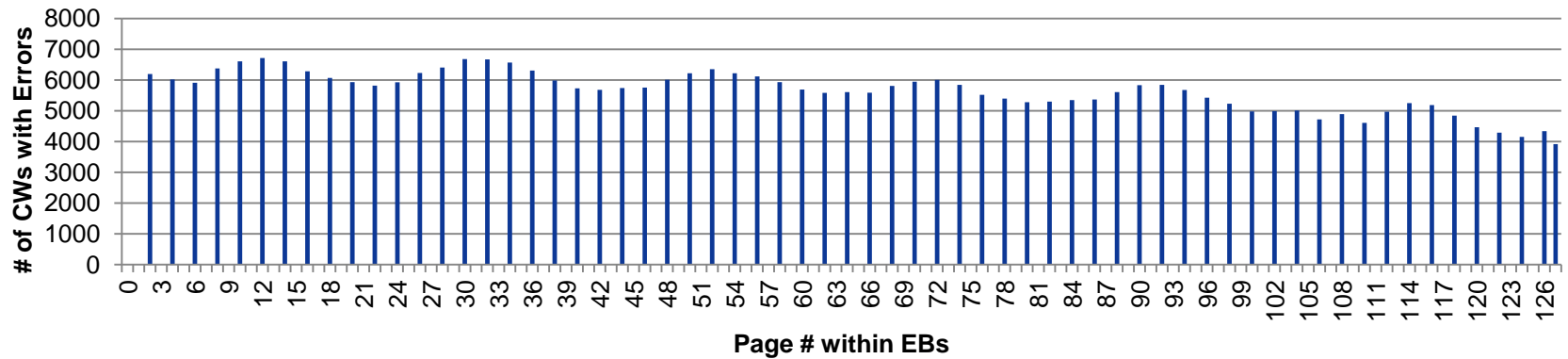
# Patterns Across Pages (By 12 (3bpc))

Magnitude of Codeword errors (per page) across all EBs

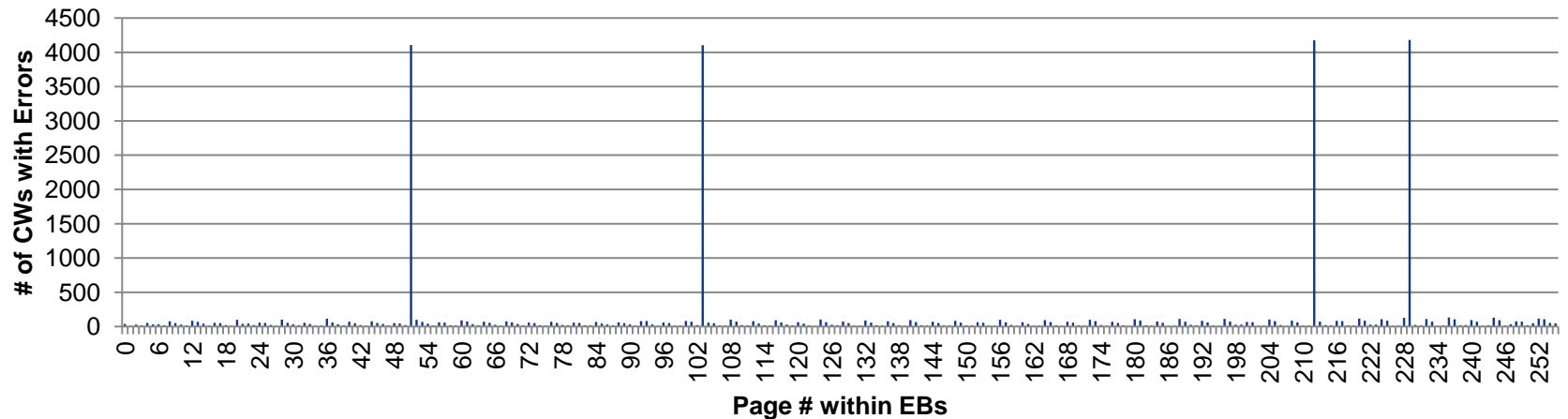


# Non-Frequent Patterns

Magnitude of Codeword errors (per page) across all EBs



Magnitude of Codeword errors (per page) across all EBs



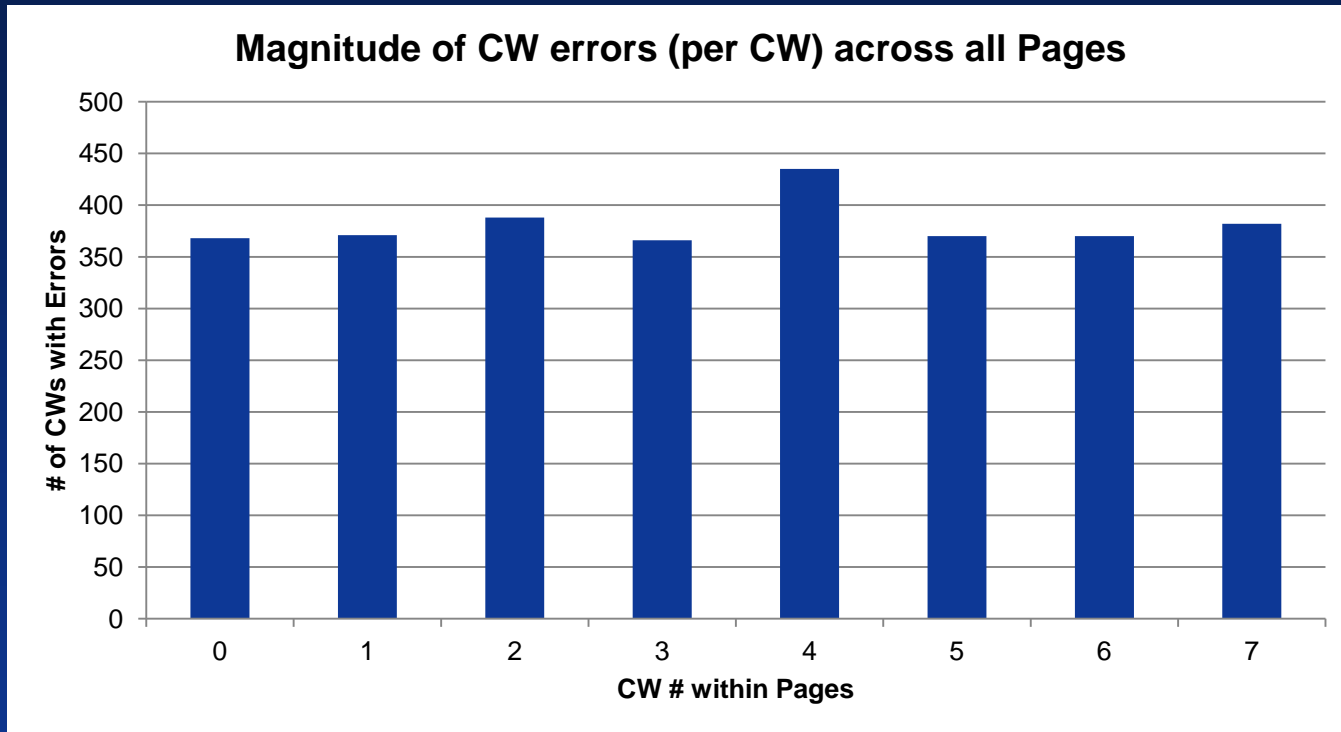


# Patterns Across CWs

Page 1	CW/0	CW/1	CW/2	CW/3	CW/4	...	CW/N
Page 0	CW/0	CW/1	CW/2	CW/3	CW/4	...	CW/N

- » Comparison of all CW's at same position in pages
- » Similar to stacking each page on top of each other to line up the CW's

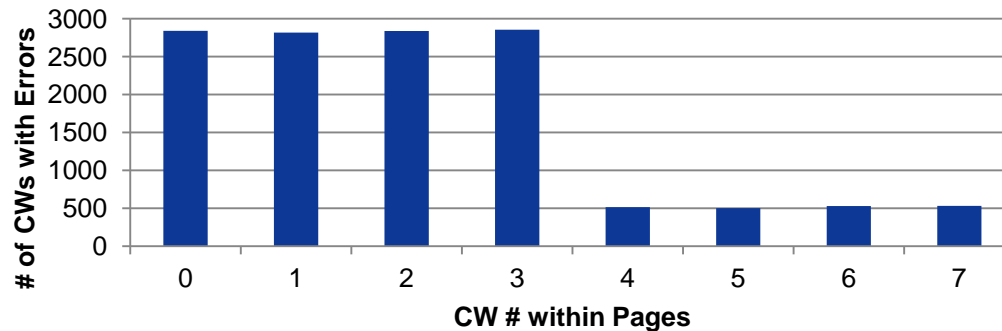
# Patterns Across CWs



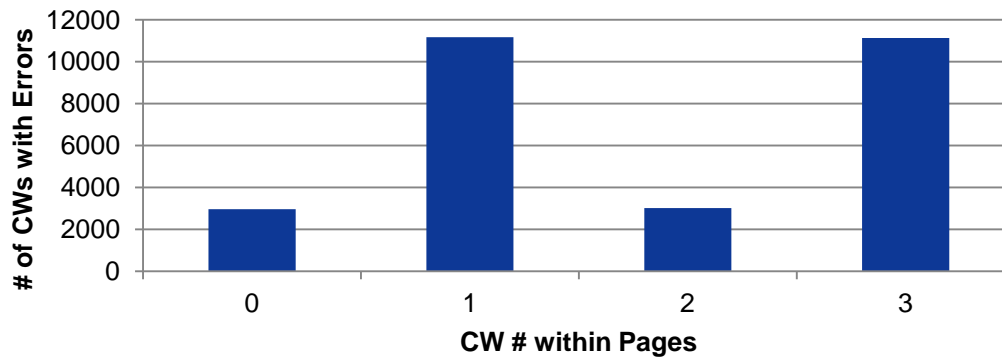
- » More than 75% are consistent such as the one above
- » Some NAND devices do show other patterns

# Patterns Across CWs

Magnitude of CW errors (per CW)  
across all Pages



Magnitude of CW errors(per CW)  
across all Pages



# Other Findings

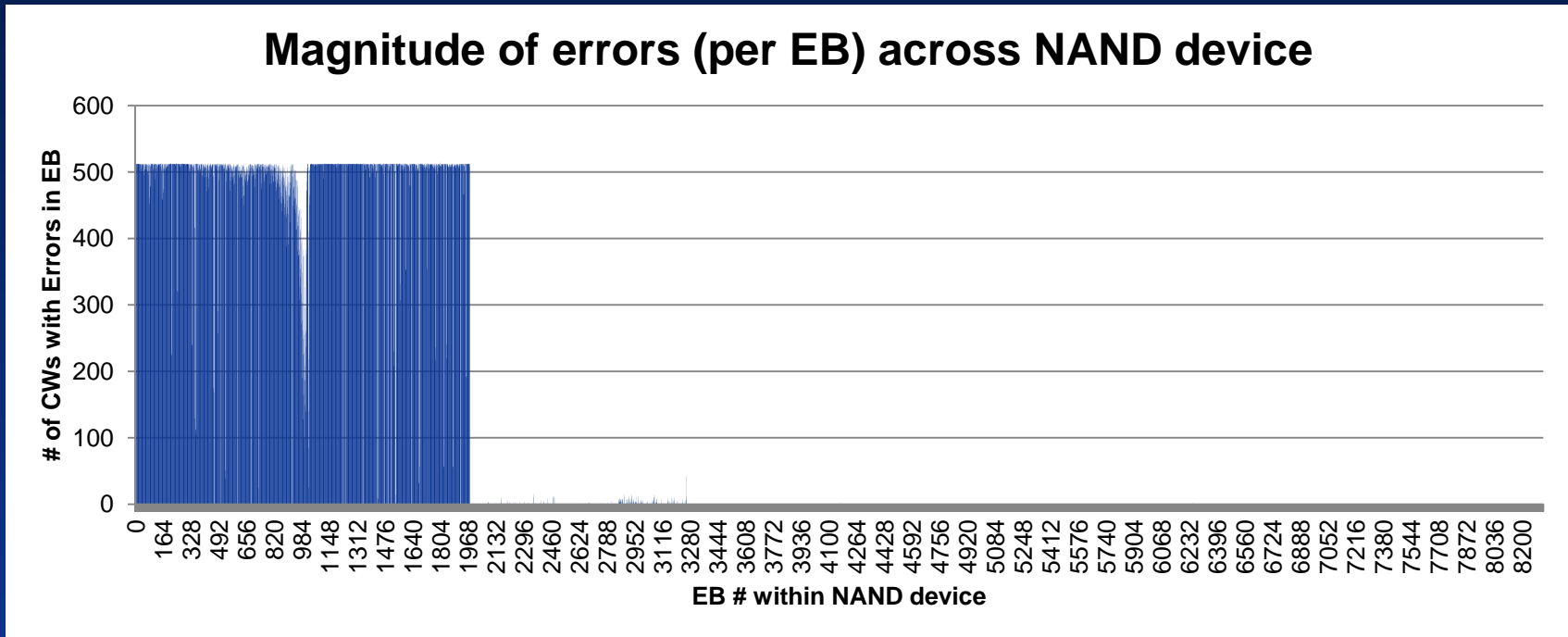
- » Patterns across EB's could be further analyzed as not all EB's written
- » No significant difference among NAND devices with:
  - Randomization pattern on Parity only
  - Randomization pattern across pages
  - No randomization pattern

# Summary

- » Current ECC codes adequate as 95+% NAND devices from drives considered Good or Fair
- » Many different error patterns exist and with ECC evolving, further research could lead to better performing devices
- » Kroll Ontrack is willing to partner with companies for further investigation.
- » Stop by our booth (#721)



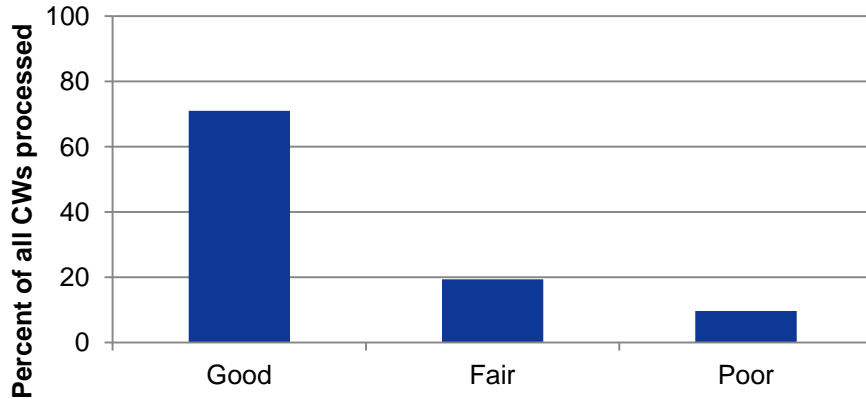
# Supporting Slides



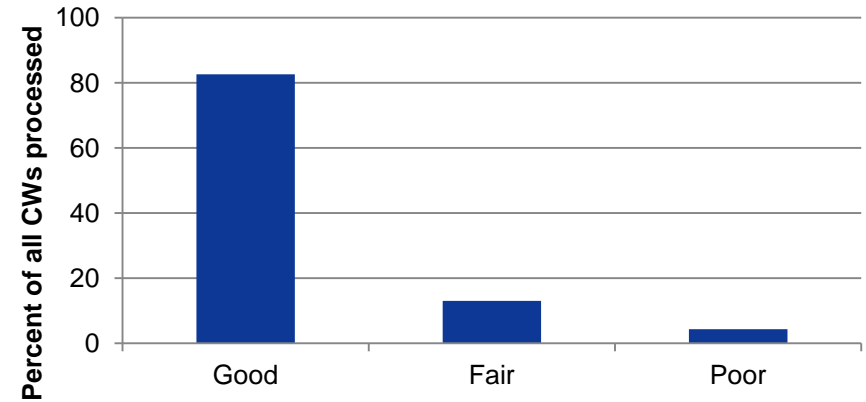
- » Additional research could be done into EB's in latter part of NAND device
  - Written but no errors
  - Not written to

# Supporting Slides

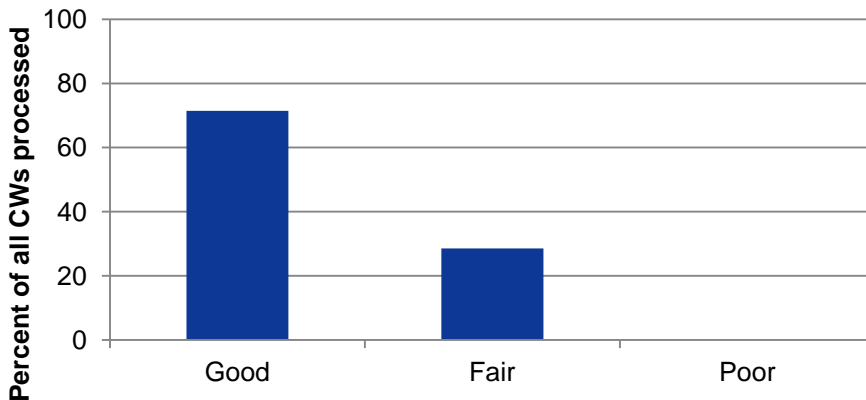
## Randomization: Both



## Randomization: Parity only



## Randomization: Across Pages



## Randomization: None

