Crossover in TD efficiency – When brick wall is not the best.

FormFactor

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IEEE SW Test Workshop

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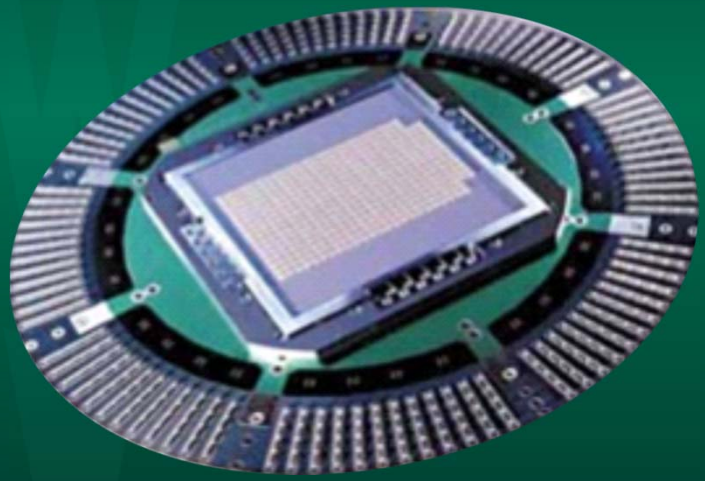
Overview

- Background
- Method of Analysis – FFI TDO Tool
- Analysis of thirteen 300mm wafers
- The Crossover Formula
- What about skip row or skip row & column?
- Summary
- Does it really work?

When does it make sense to use a Full Wafer Contactor??

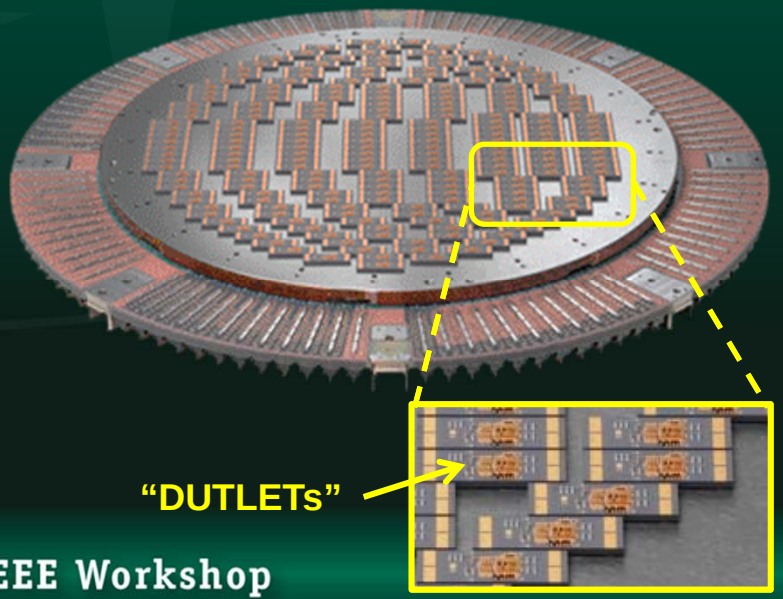
Probe Head

- Multiple sizes from 50mm to 150mm.
- Depending on the die can do:
  - Brick wall (no gaps between tested die)
  - Skip R or C (a 1 die gap in one direction)
  - Skip R & C (a 1 die gap in both directions)



Full Wafer Contactor (FWC)

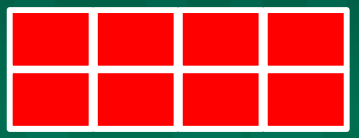
- Touches the entire wafer at once (200mm or 300mm)
- DUTlet based system uses the same routing on all sites
- Initial cost is higher than PH, but ROI is worth it when parallelism is high enough.



But when is the parallelism high enough??

Terminology & Method of Analysis

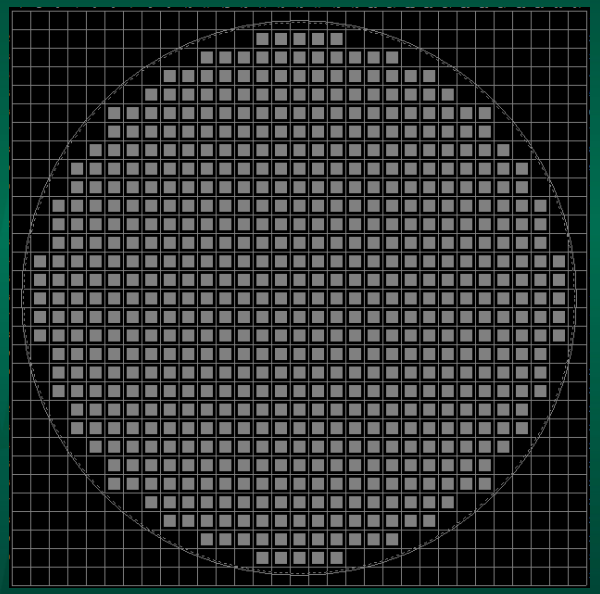
- **Brickwall**



- **Skip Row**

- **Skip Column**

- **Skip R & C**



300mm wafer,
2mm edge exclusion.

For each die size from:
4mm x 4mm to 12mm x 12mm:
Run 4 analyses

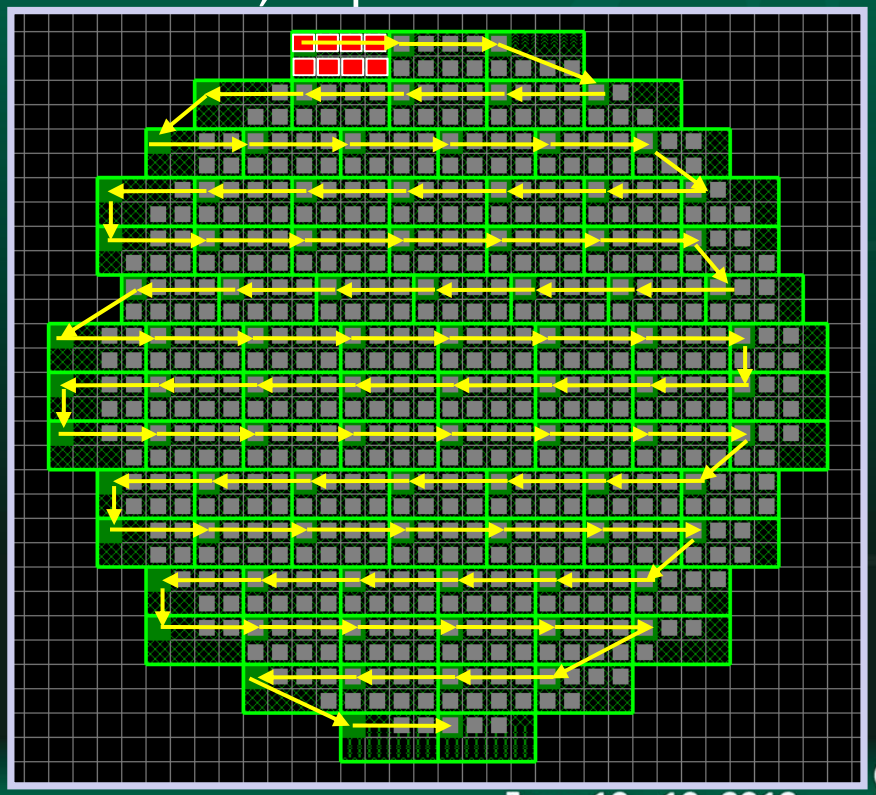
1) PH Brickwall,
2) PH Skip R and PH Skip C
3) PH Skip R & C
4) Full Wafer Contactor

Analysis #1 – 8 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

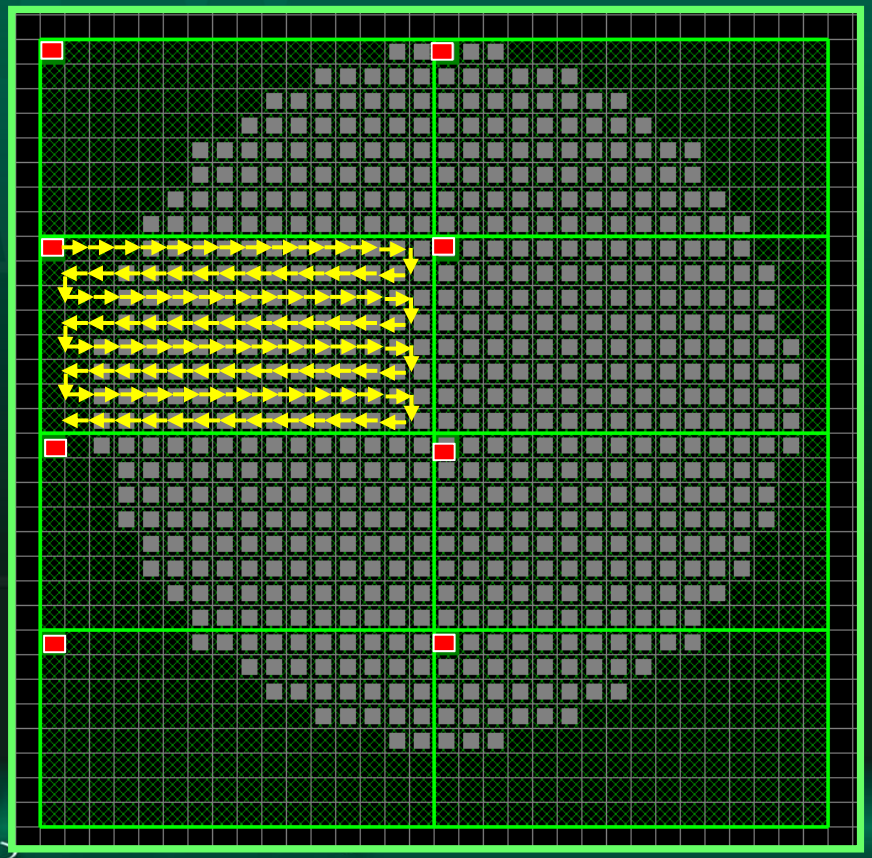
Probe Head

- 2x4, brickwall = 91 TDs
- 2x4, skip R = 93 TDs
- 2x4, skip R&C = 97 TDs



Full Wafer Contactor

- 7 skip R x 14 skip C
  = 120 TDs

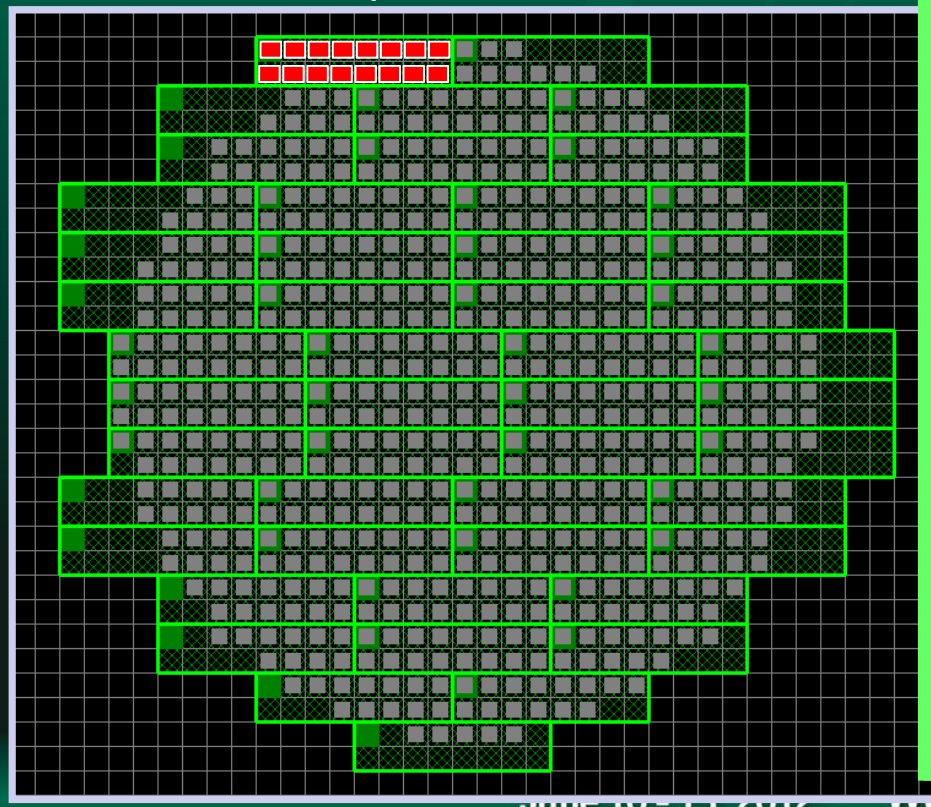


Analysis #1 – 16 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

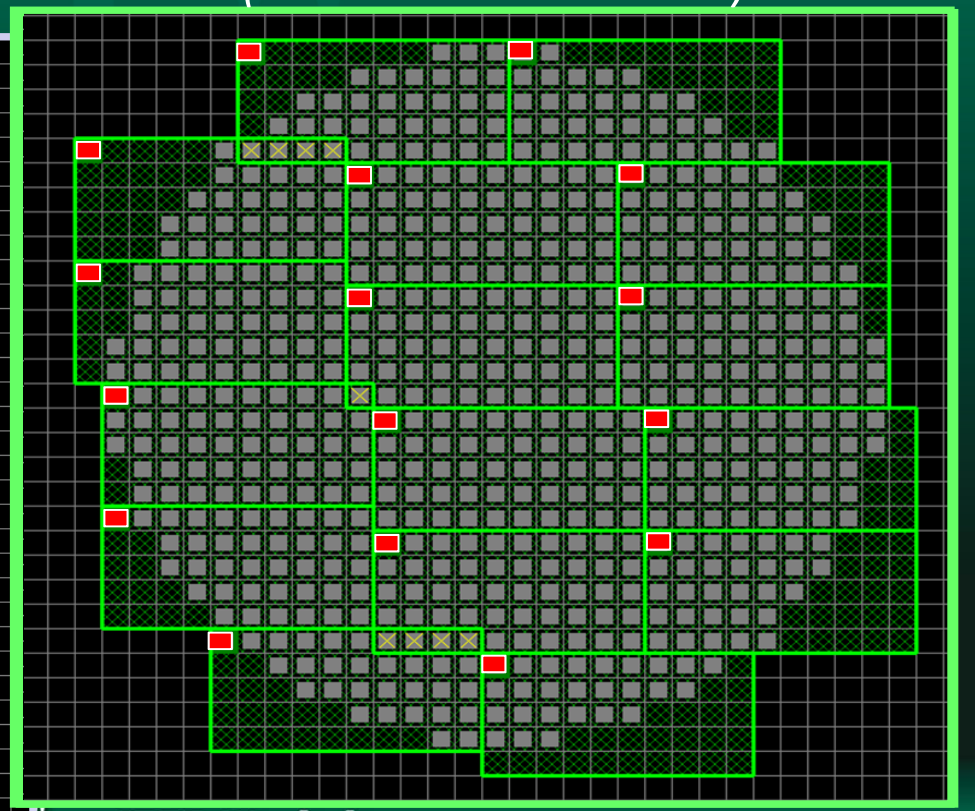
Probe Head

- 2x8, brickwall = 49 TDs
- 2x8, skip R = 51 TDs
- 2x8, skip R&C = 54 TDs



Full Wafer Contactor

- 4 skip R x 10 skip C = 55 TDs
- 4 skip R x 9 skip C = 50 TDs
  (with 9 double touches)

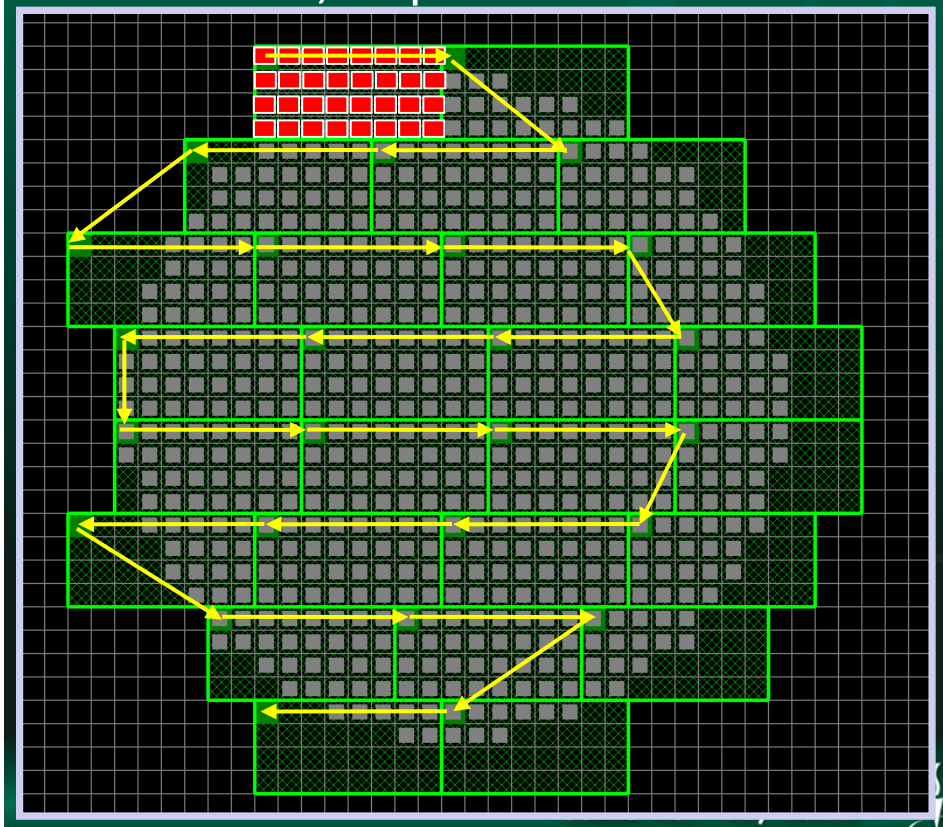


Analysis #1 – 32 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

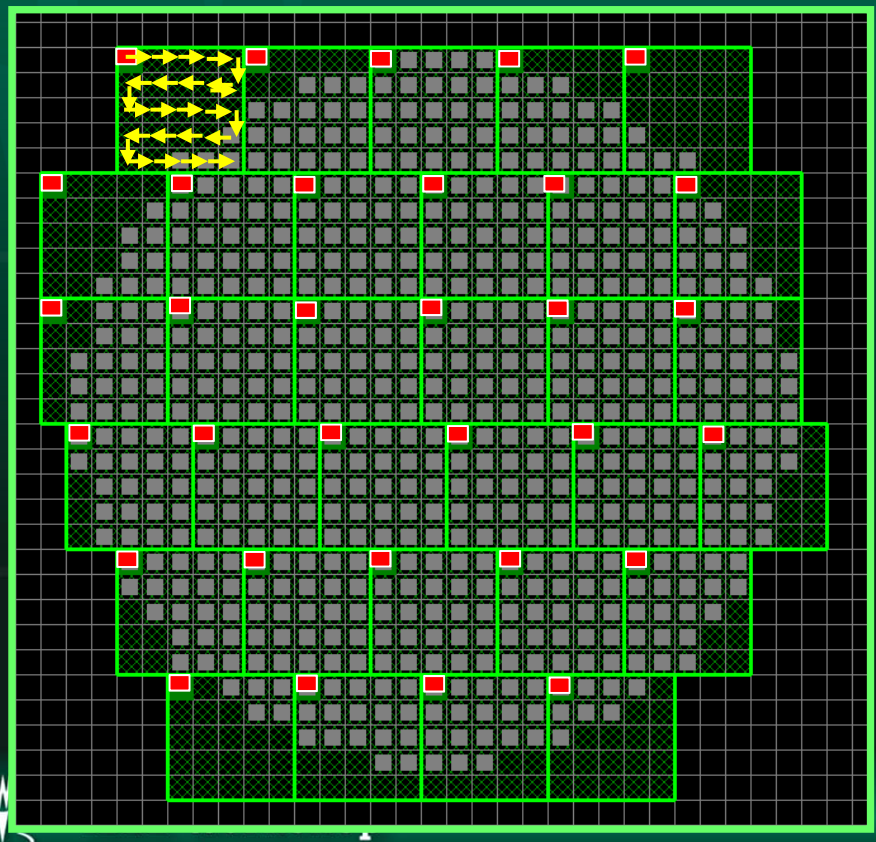
Probe Head

- 4x8, brickwall = 26 TDs
- 4x8, skip R = 28 TDs
- 4x8, skip R&C = 31 TDs



Full Wafer Contactor

- 4 skip R x 4 skip C = 25 TDs

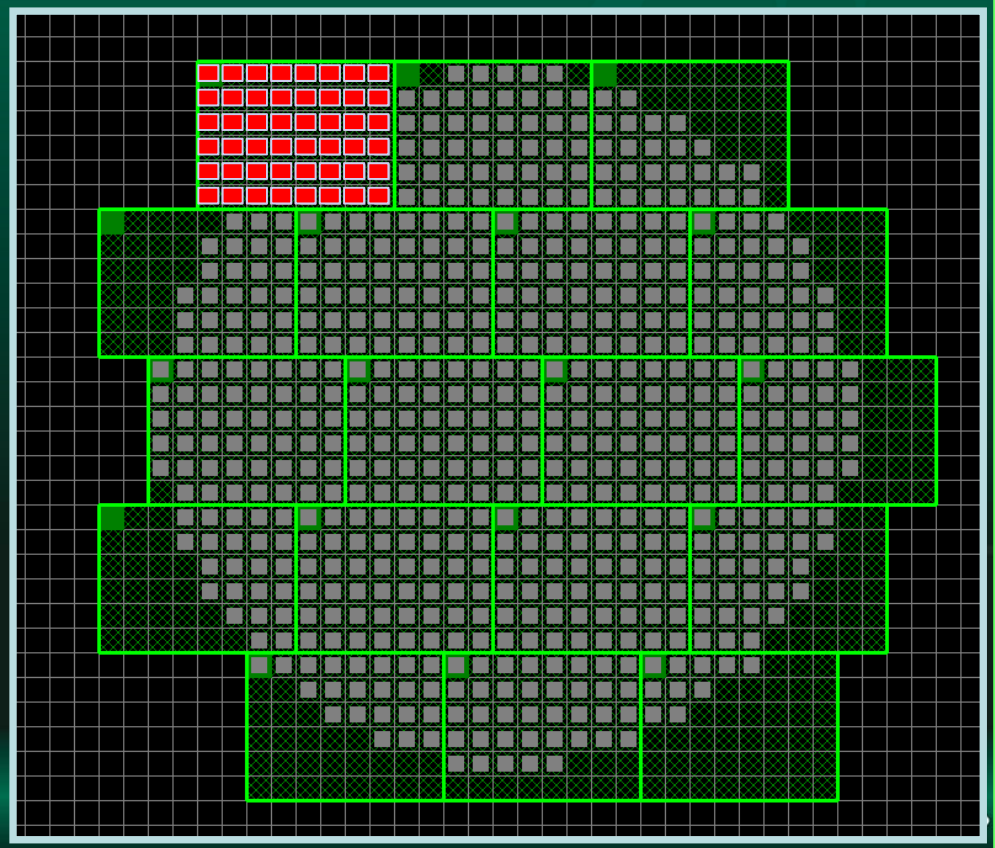


Analysis #1 – 48 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

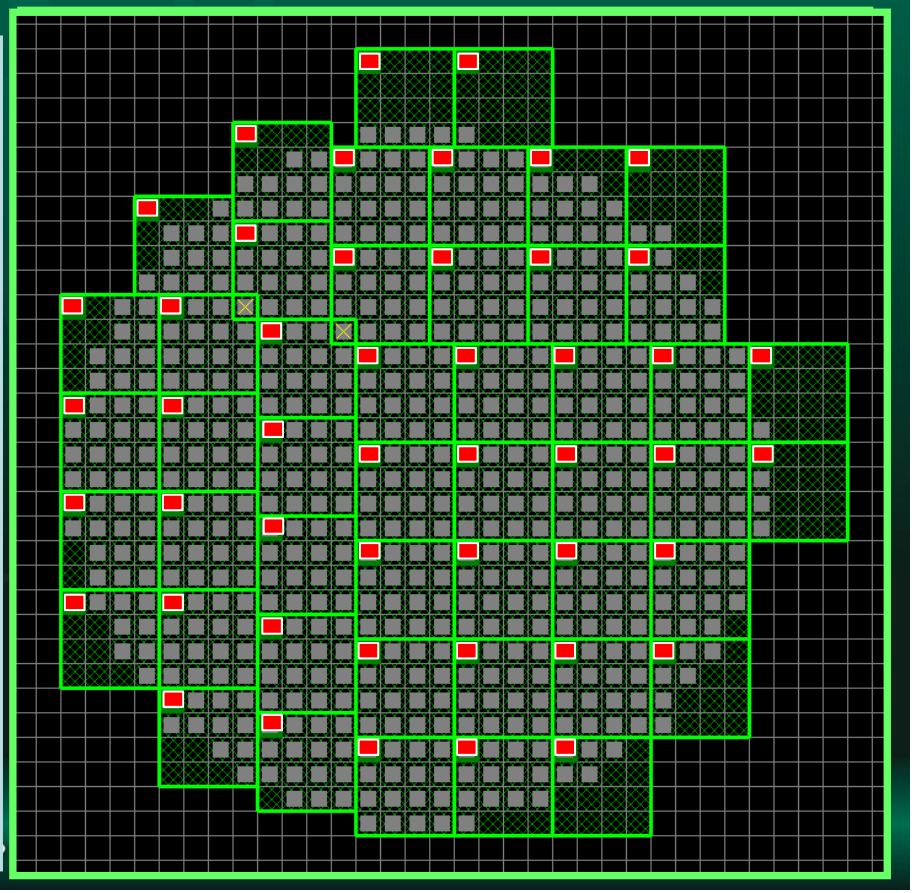
Probe Head

- 6x8, brickwall = 18 TDs
- 6x8, skip R = 20 TDs
- 6x8, skip R&C = 23 TDs



Full Wafer Contactor

- 2 skip R x 5 skip C = 18 TDs
  (and uses only 42 DUTs)
- Or 16 TDs *(with 2 double touches)*

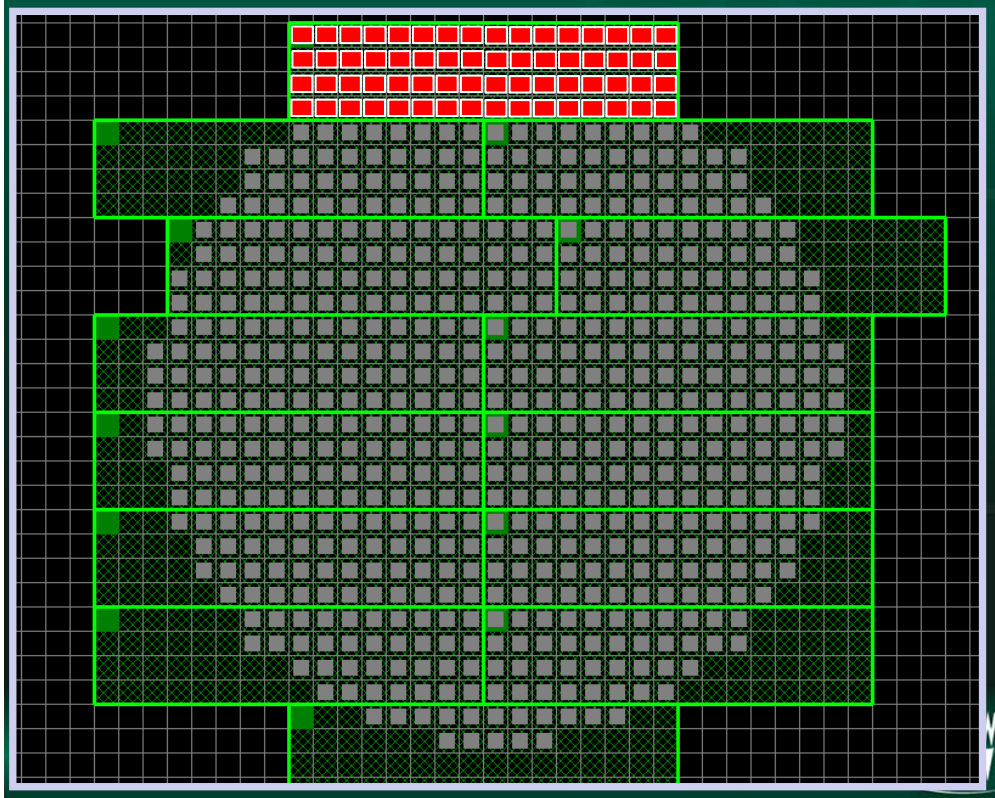


Analysis #1 – 64 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

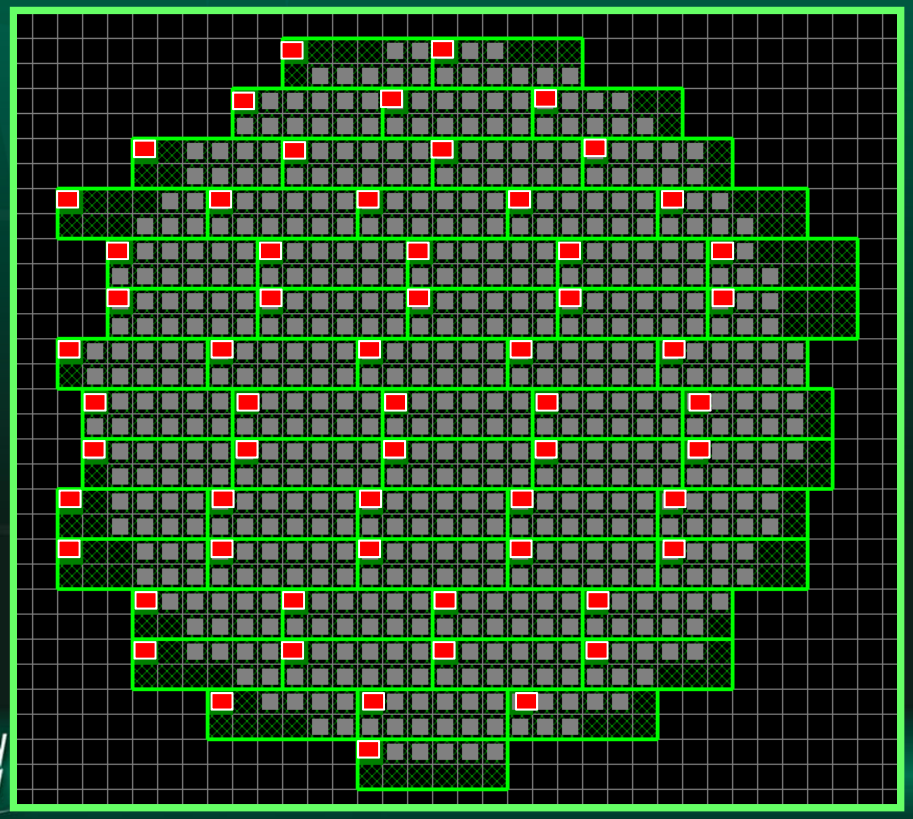
Probe Head

- 4x16, brickwall = 14 TDs
- 4x16, skip R = 16 TDs
- 4x16, skip R&C = 16 TDs



Full Wafer Contactor

- 1 skip R x 5 skip C
  = 12 TDs
  (and only uses 61 DUTs)



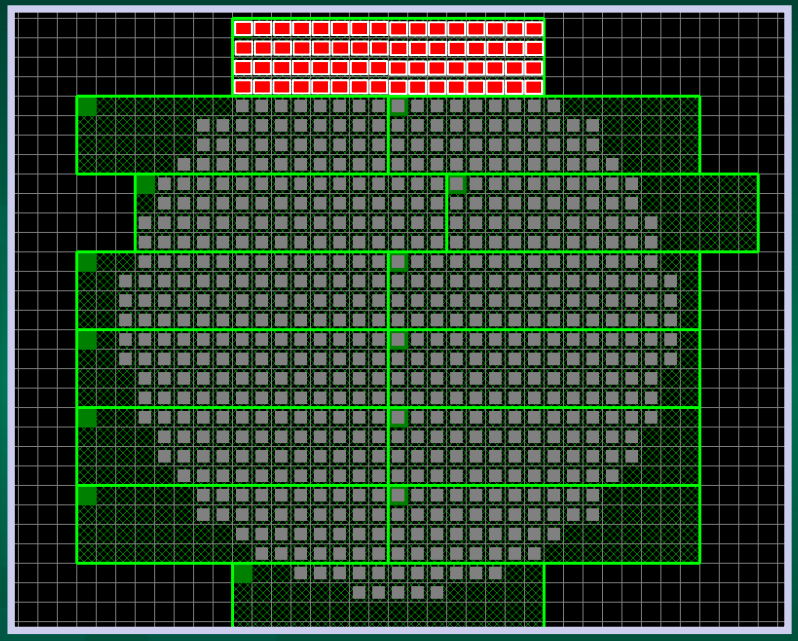
Sidenote:

300mm wafer, 10x10 die, 633 DPW

- **64 DUTs in Parallel**

Probe Head

  - 4x16, brickwall = 14 TDs



#	TD Count	Probe Card Array	Probe Card DUTs
1	14	15 x 4	60
2	14	4 x 15	60
3	14	9 x 7	63
4	14	7 x 9	63
7	14	8 x 8	64
5	14	16 x 4	64
6	14	4 x 16	64

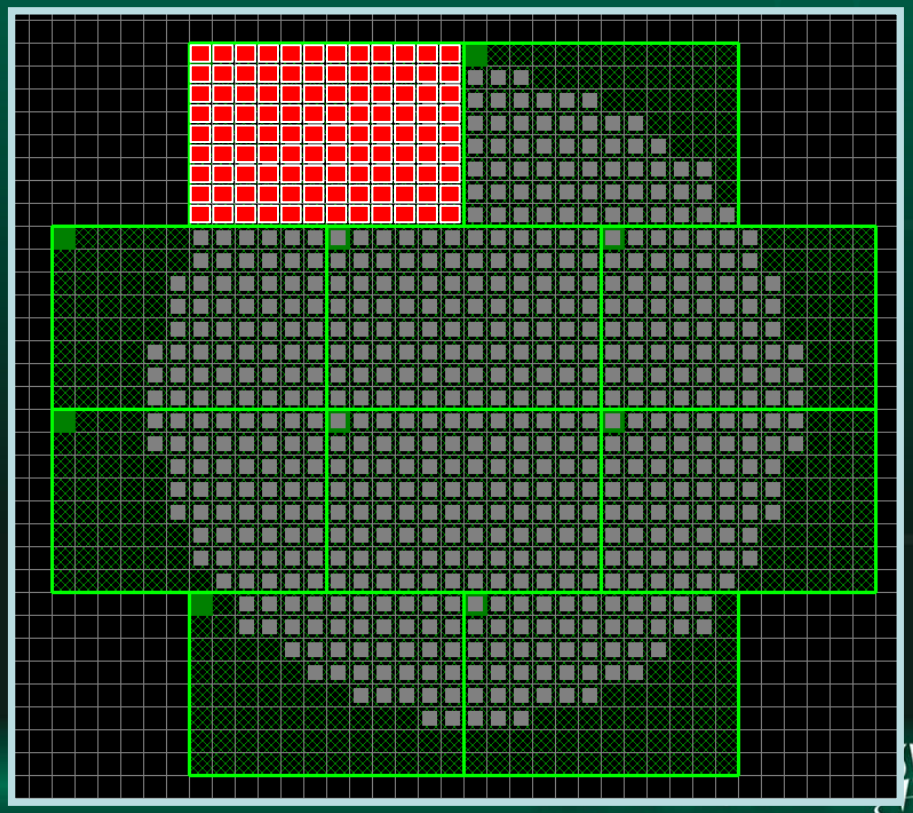
- **For each and every analysis – I run all possible rectangular combinations. For example – in this case – 15x4, 4x15, 9x7, 8x8, etc. – all yield a 14TD design. In all cases I try to minimize the TD count with the maximum resources allocated (64 in this case).**

Analysis #1 – 96 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

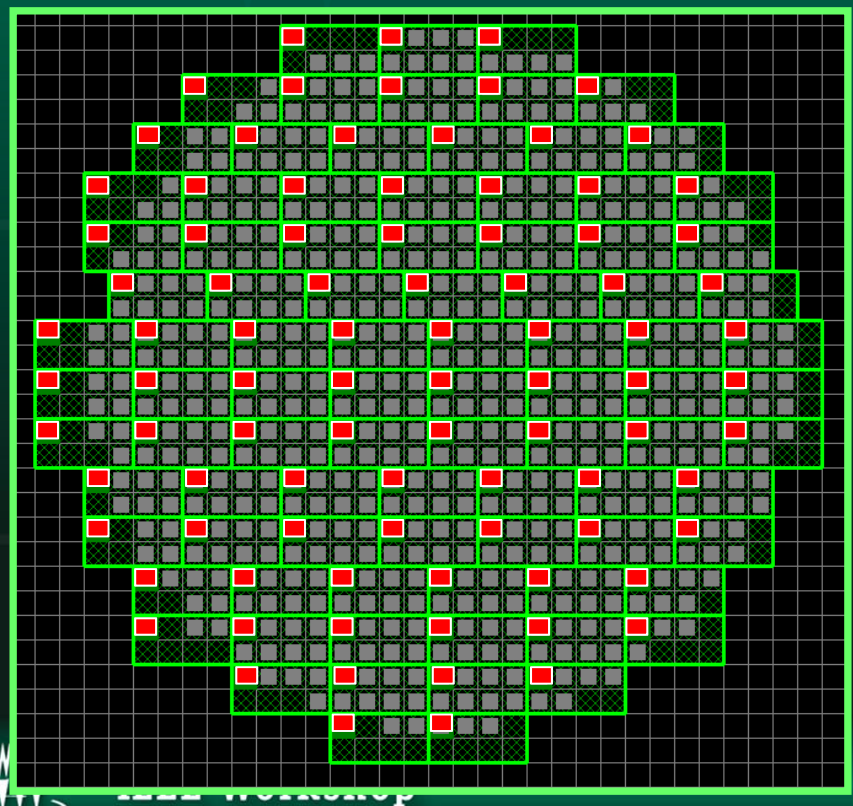
Probe Head

- 8x12, brickwall = 10 TDs
- 8x12, skip R = 10 TDs
- 8x12, skip R&C = 12 TDs



Full Wafer Contactor

- 1 skip R x 5 skip C
  = 8 TDs
  (and only uses 91 DUTs)

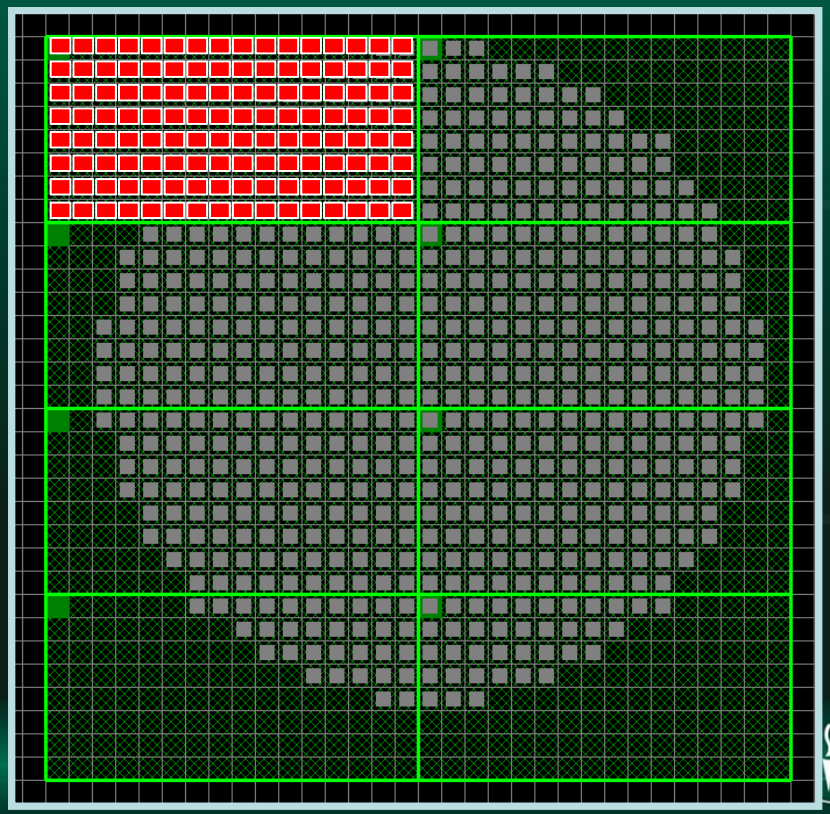


Analysis #1 – 128 DUTs in Parallel

300mm wafer, 10x10 die, 633 DPW

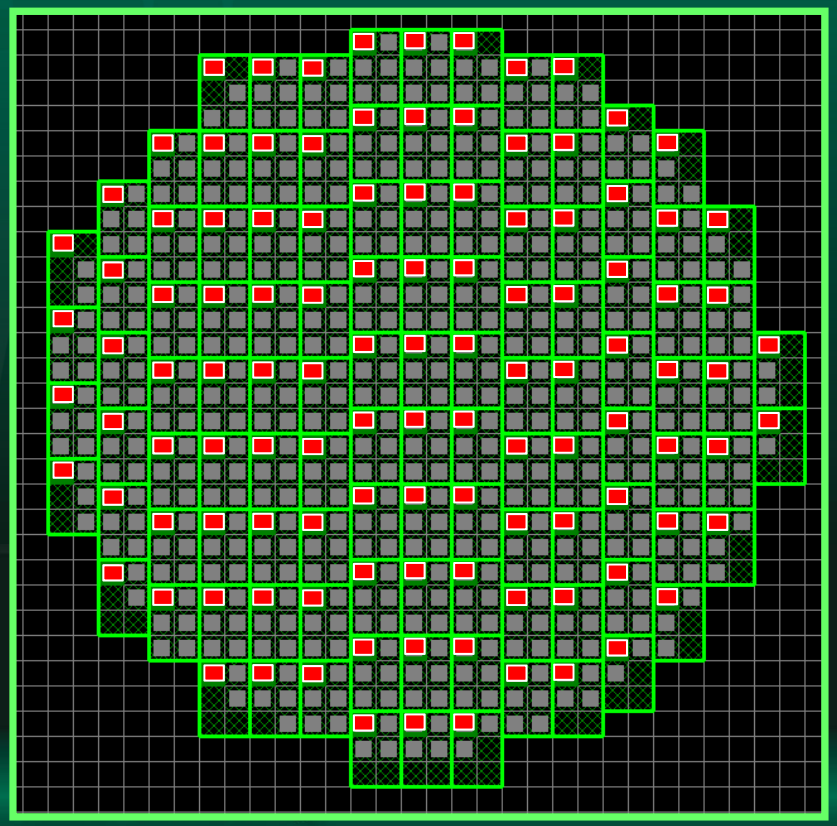
Probe Head

- 8x16, brickwall = 8 TDs
- 8x16 skip R = 8 TDs
- 8x16 skip R&C = 8 TDs



Full Wafer Contactor

- 1 skip R x 2 skip C
  = 6 TDs
  (and only uses 114 DUTs)



Touchdown Efficiency

$$\frac{\#\ TDs_{PH}}{\#\ of\ TDs_{FWC}} = \text{TD Efficiency}$$

If TD Efficiency is < 100% PH is better

If TD Efficiency is > 100% FWC is better

Example 1:

$\#TDs_{PH} = 20$

$\#TDs_{FWC} = 23$

TD efficiency = 20/23 = 87%

Example 2:

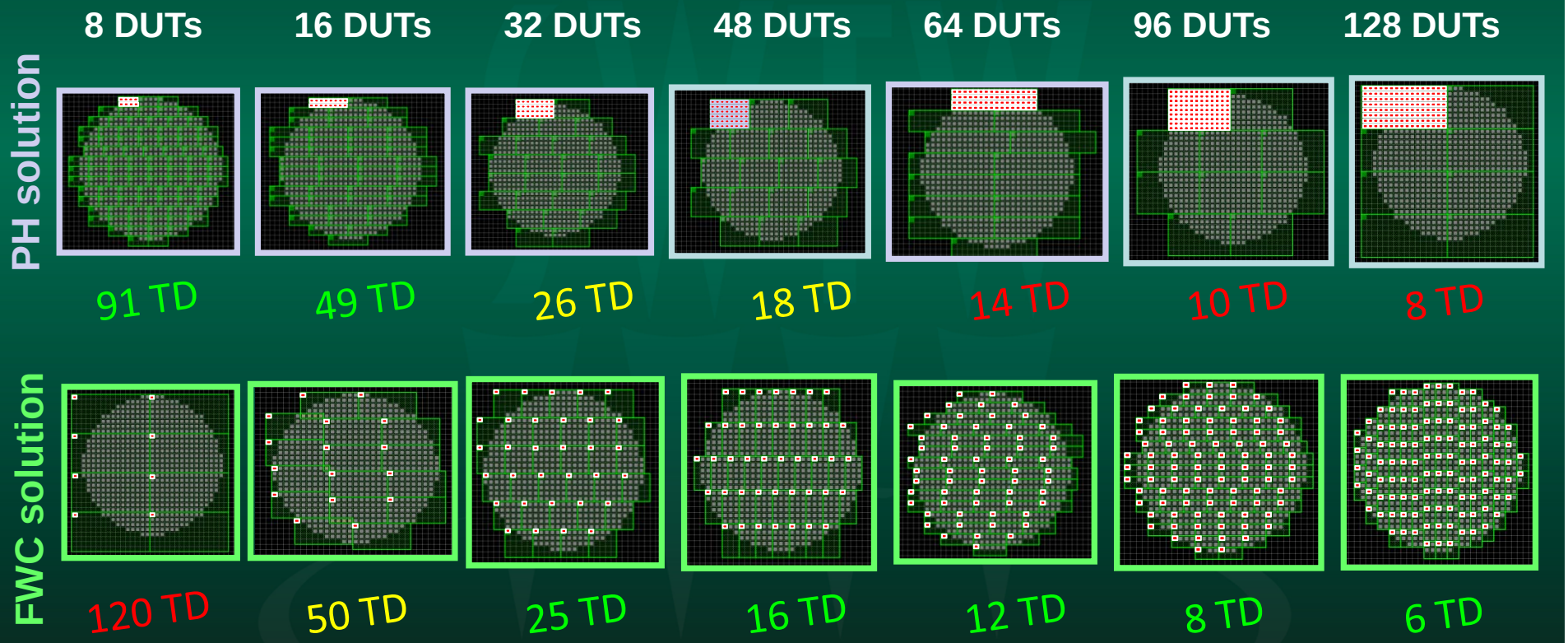
$\#TDs_{PH} = 22$

$\#TDs_{FWC} = 18$

TD efficiency = 22/18 = 122%

Analysis #1 *(same as the last 7 slides condensed to a single slide)*

300mm wafer, 10x10 die, 633 DPW



TD efficiency PH vs FWC

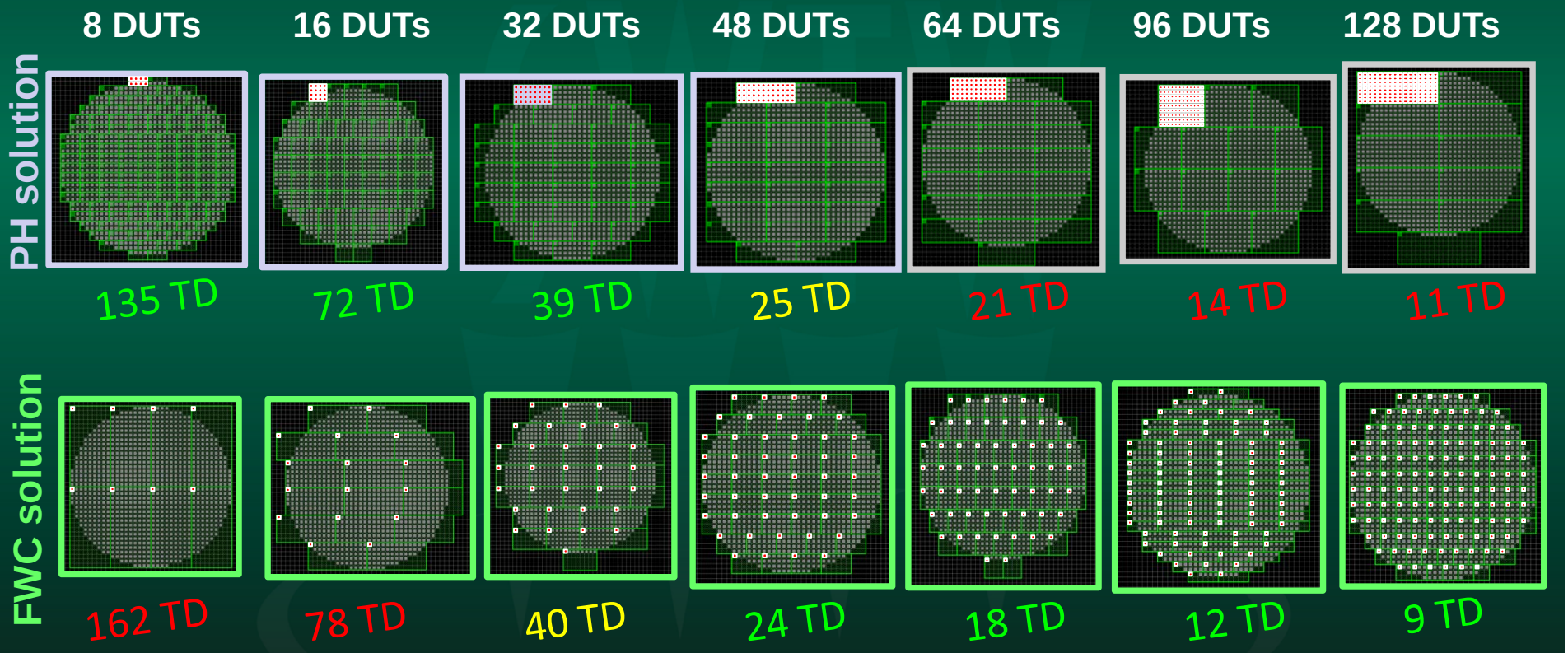
The crossover point

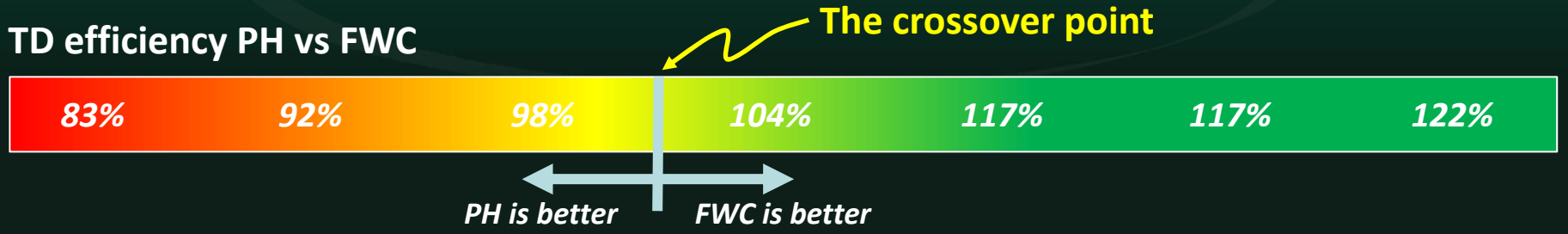
76% 98% 104% 112% 117% 125% 133%

PH is better *FWC is better*

Analysis #2

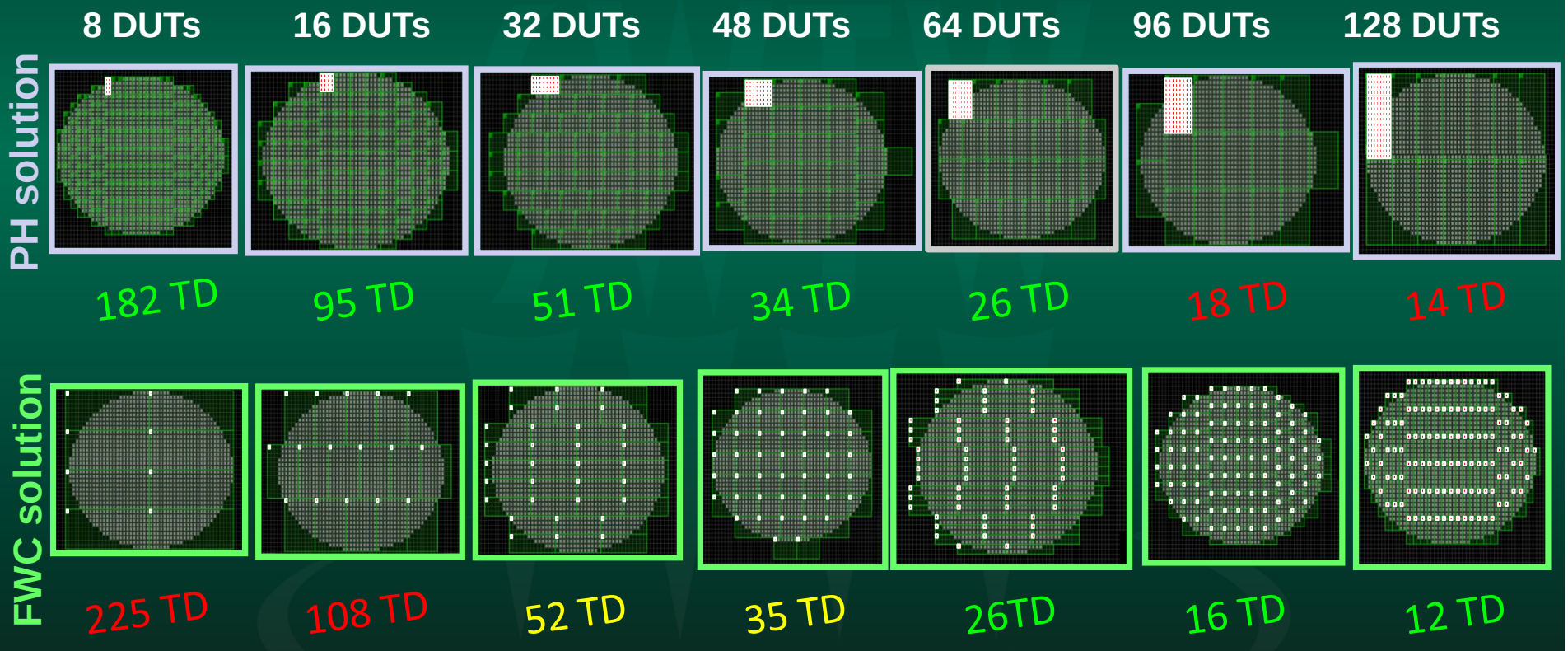
300mm wafer, 8x8 die, 1020 DPW

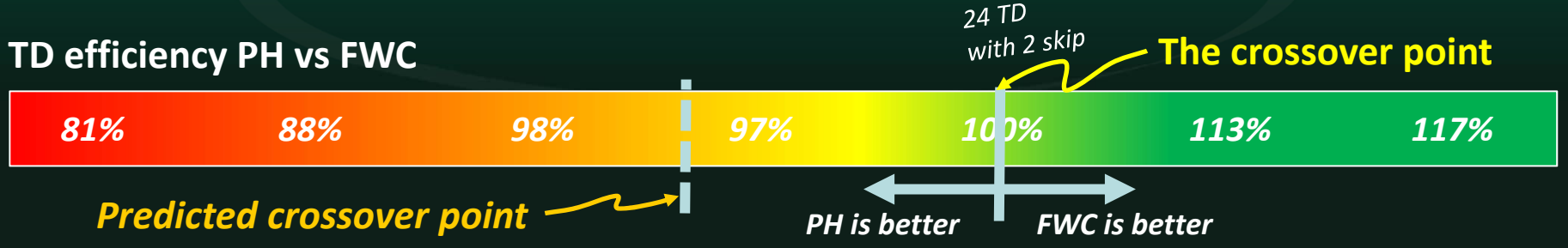




Analysis #3

300mm wafer, 6x8 die, 1372 DPW

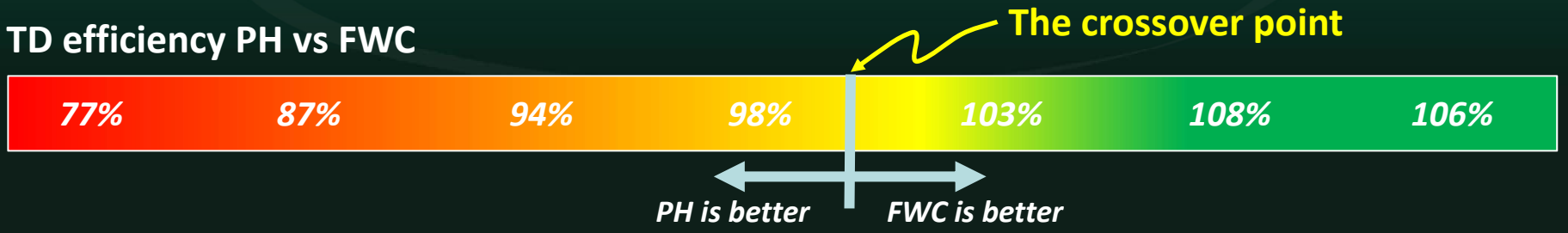




Analysis #4

300mm wafer, 6x6 die, 1845 DPW

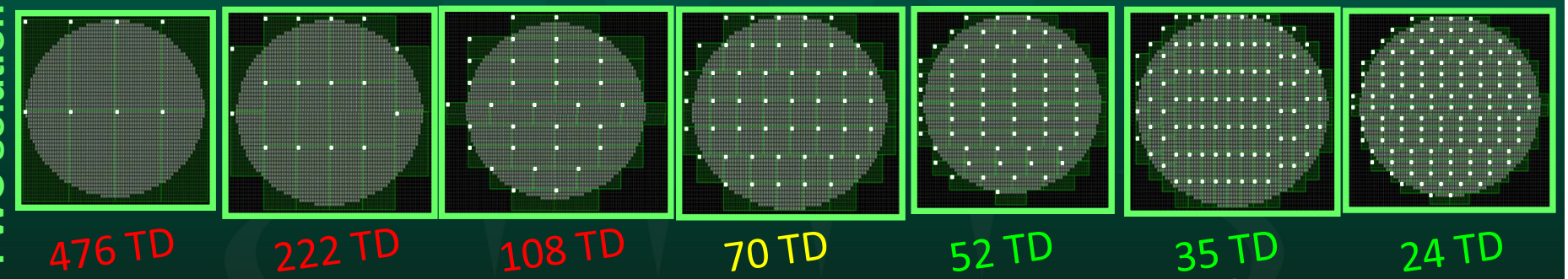
	8 DUTs	16 DUTs	32 DUTs	48 DUTs	64 DUTs	96 DUTs	128 DUTs
PH solution	250 TD	130 TD	68 TD	47 TD	36 TD	26 TD	19 TD
FWC solution	325 TD	150 TD	72 TD	48 TD	35 TD	24 TD	18 TD



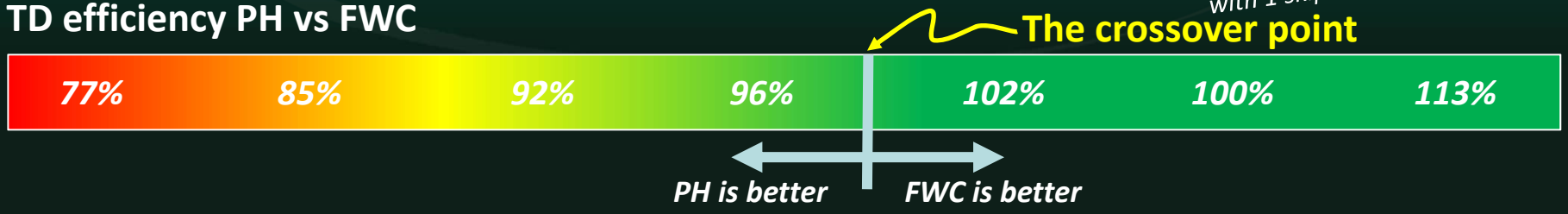
Analysis #5

300mm wafer, 4x6 die, 2798 DPW

	8 DUTs	16 DUTs	32 DUTs	48 DUTs	64 DUTs	96 DUTs	128 DUTs
PH solution	366 TD	189 TD	99 TD	67 TD	53 TD	35 TD	27 TD
FWC solution	476 TD	222 TD	108 TD	70 TD	52 TD	35 TD 33 TD with 1 skip	24 TD



TD efficiency PH vs FWC



The Crossover Ratio

$$\frac{\#\ \text{DUTs}}{\#\ \text{of TDs}_{PH}} = \text{Crossover Ratio}$$

Example 1:

#DUTs = 32

#TDs$_{PH}$ = 64

Crossover Ratio = 32/64 = 0.5

Example 2:

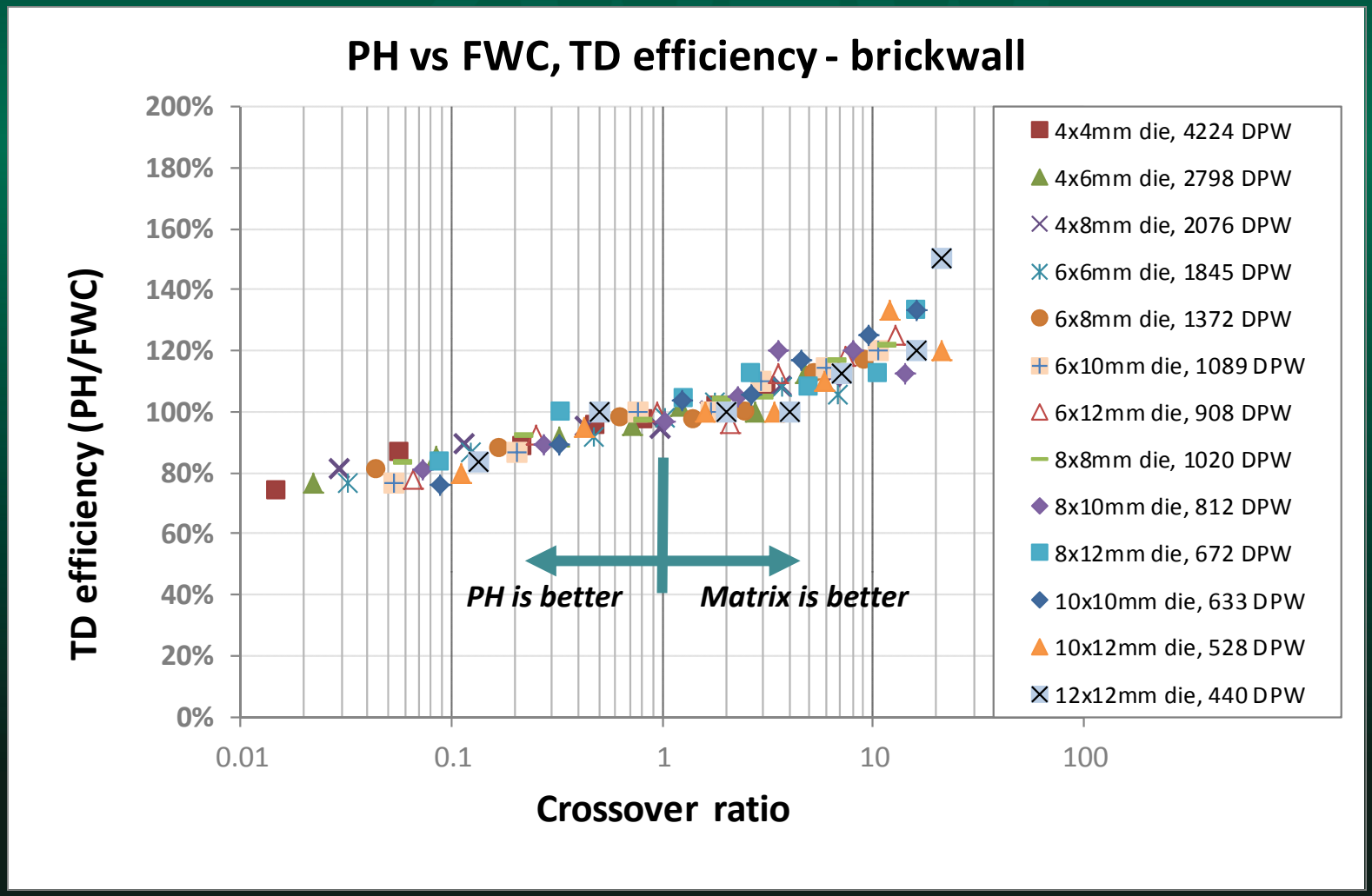
#DUTs = 32

#TDs$_{PH}$ = 16

Crossover Ratio = 32/16 = 2

Analysis #1-13 – Brickwall vs FWC

300mm wafer, 4x4 die – 12x12 in 2mm increments, 8 DUTs – 128 DUTs



The Crossover Formula

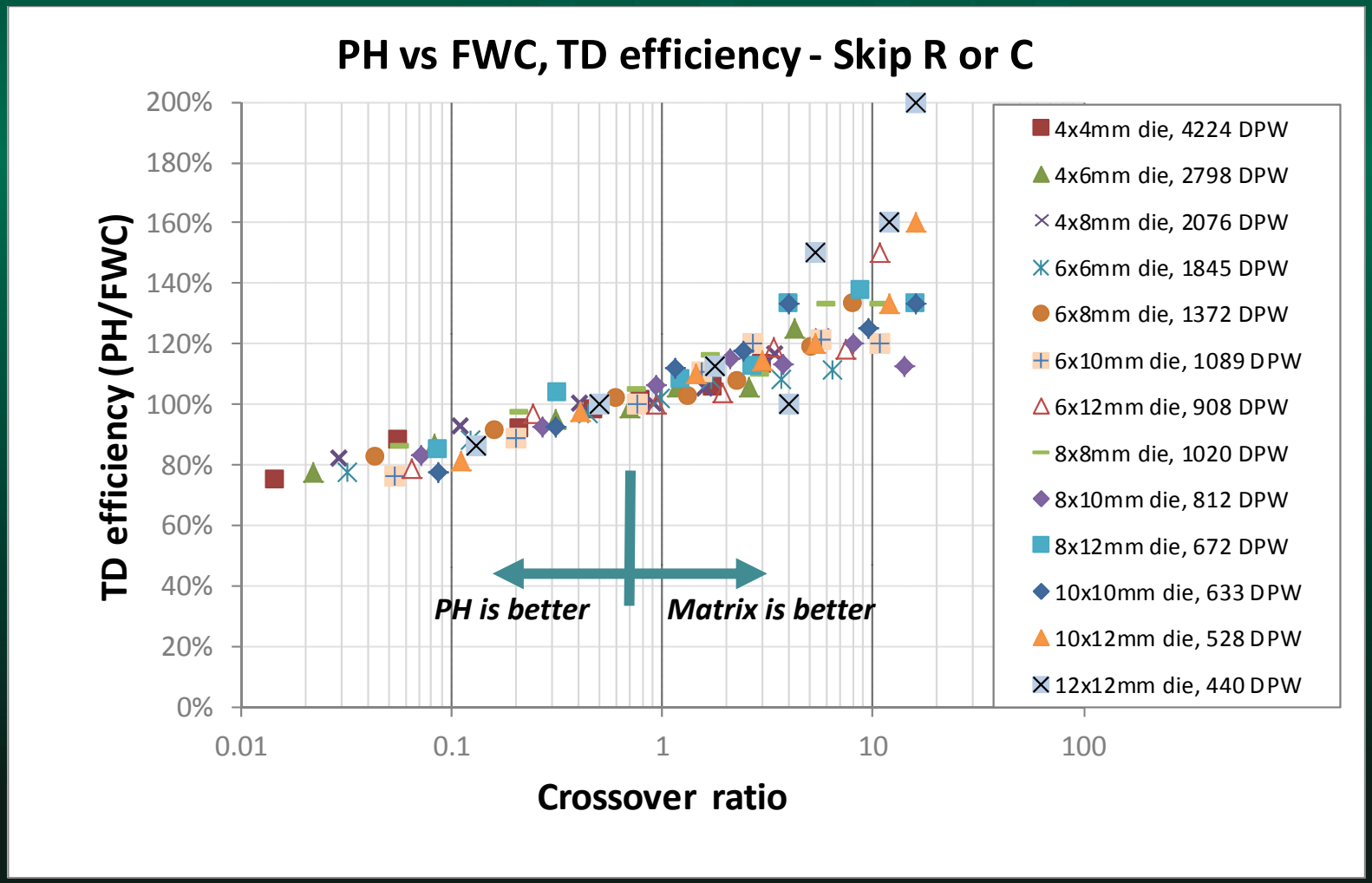
$$\frac{\#\ \text{DUTS}}{\#\ \text{of TDs}_{\text{brickwall}}} = \text{Crossover Ratio}$$

If Crossover ratio > 1, FWC is better

If Crossover ratio < 1, PH is better

Analysis #14-26 – Skip R or C vs FWC

300mm wafer, 4x4 die – 12x12 in 2mm increments, 8 DUTs – 128 DUTs



The Crossover Formula (for skip Row or skip Column)

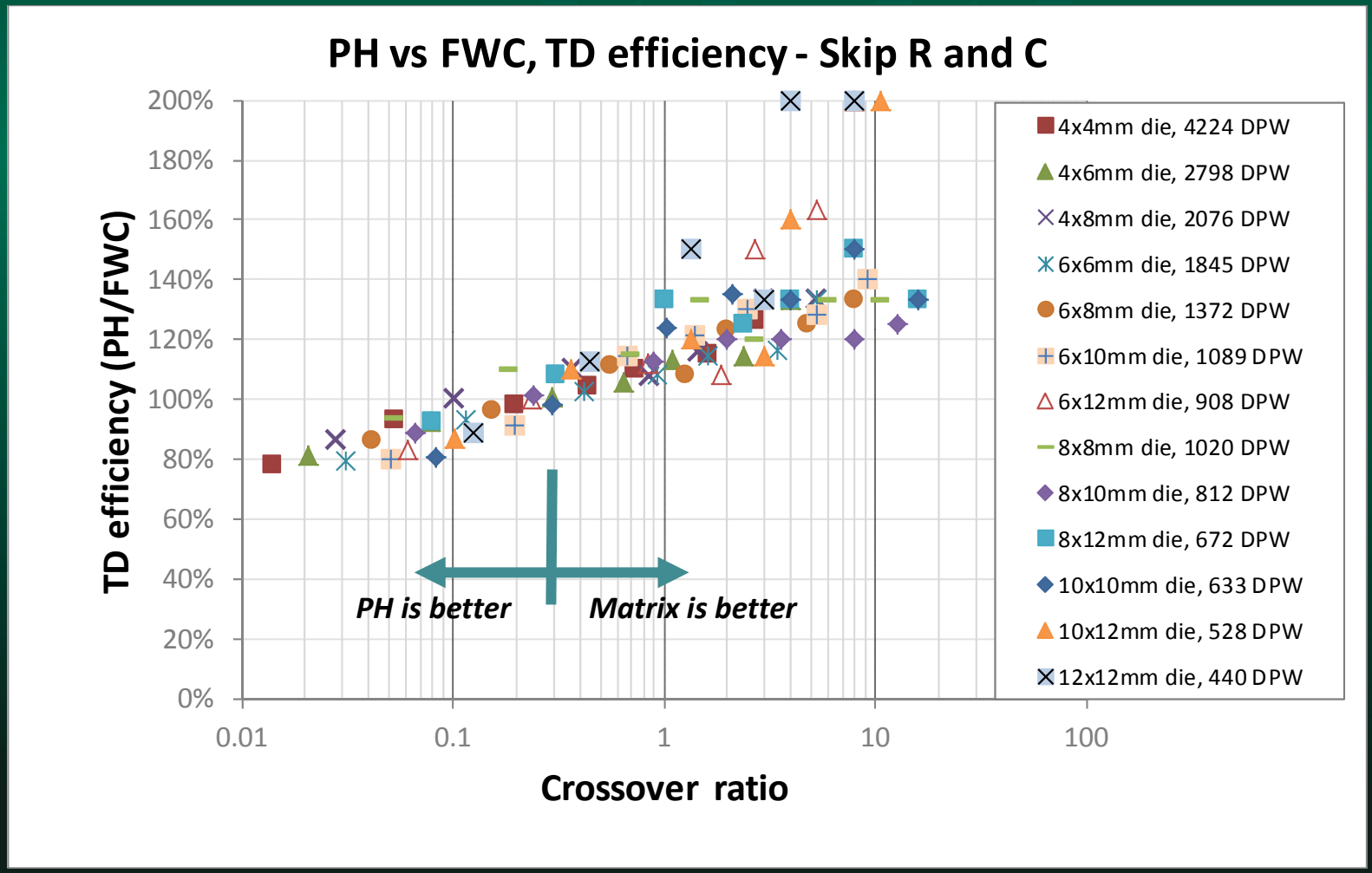
$$\frac{\#\ \text{DUTS}}{\#\ \text{of TDs}_{\text{skipRorC}}} = \text{Crossover Ratio}$$

If Crossover ratio > 0.7, FWC is better

If Crossover ratio < 0.7, PH is better

Analysis #27-39 – Skip R&C vs FWC

300mm wafer, 4x4 die – 12x12 in 2mm increments, 8 DUTs – 128 DUTs



The Crossover Formula (for skip Row and skip Column)

$$\frac{\#\ \text{DUTS}}{\#\ \text{of TDs}_{\text{skipR\&C}}} = \text{Crossover Ratio}$$

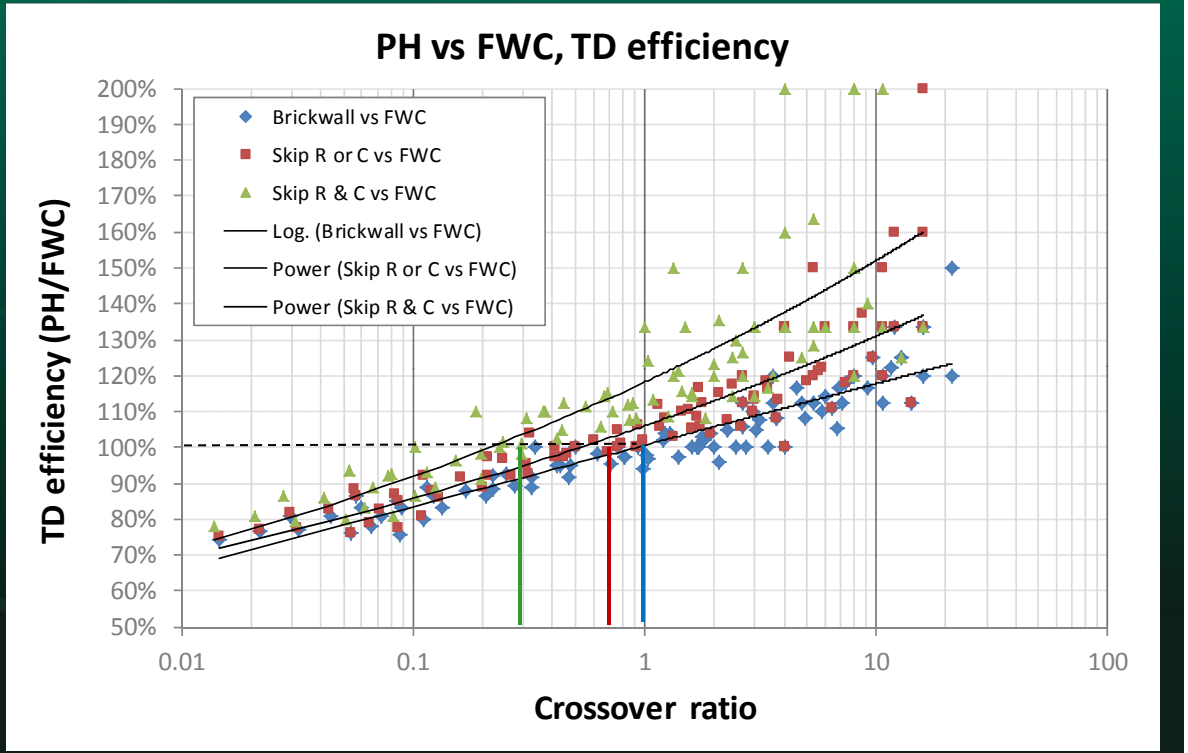
If Crossover ratio > 0.3, FWC is better

If Crossover ratio < 0.3, PH is better

Summary:

A Few Simple Rules of Thumb

- When number of DUTs in parallel exceeds the number of touchdowns, a TrueScale Matrix product will give you better touchdown efficiency than a PH product.
- The larger the ratio of DUTs to TDs, the bigger the TD efficiency benefit.
- Use TrueScale Matrix when Crossover Ratio
  - > 1.0 for brick wall
  - > 0.7 for skip R or C
  - > 0.3 for skip R & C

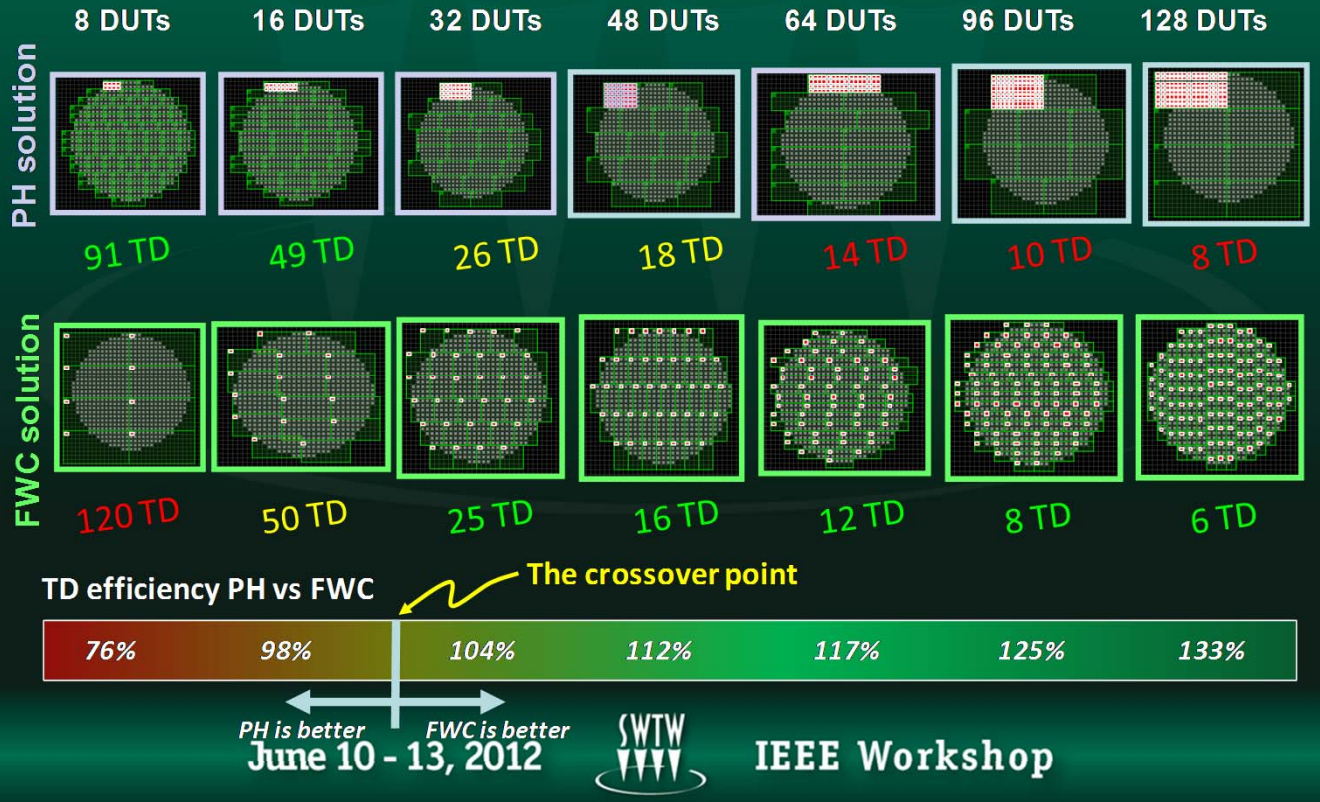


Same Analysis on 200mm wafers

- **Take any 300mm analysis and multiply die & wafer by 0.667**
  - e.g. – 10mmx10mm die on 300mm wafer analysis is EXACTLY the same as 6.67mmx6.67mm on 200mm wafer - crossover occurs at same point
  - Formulas work on 200mm and 300mm wafers

Analysis #40

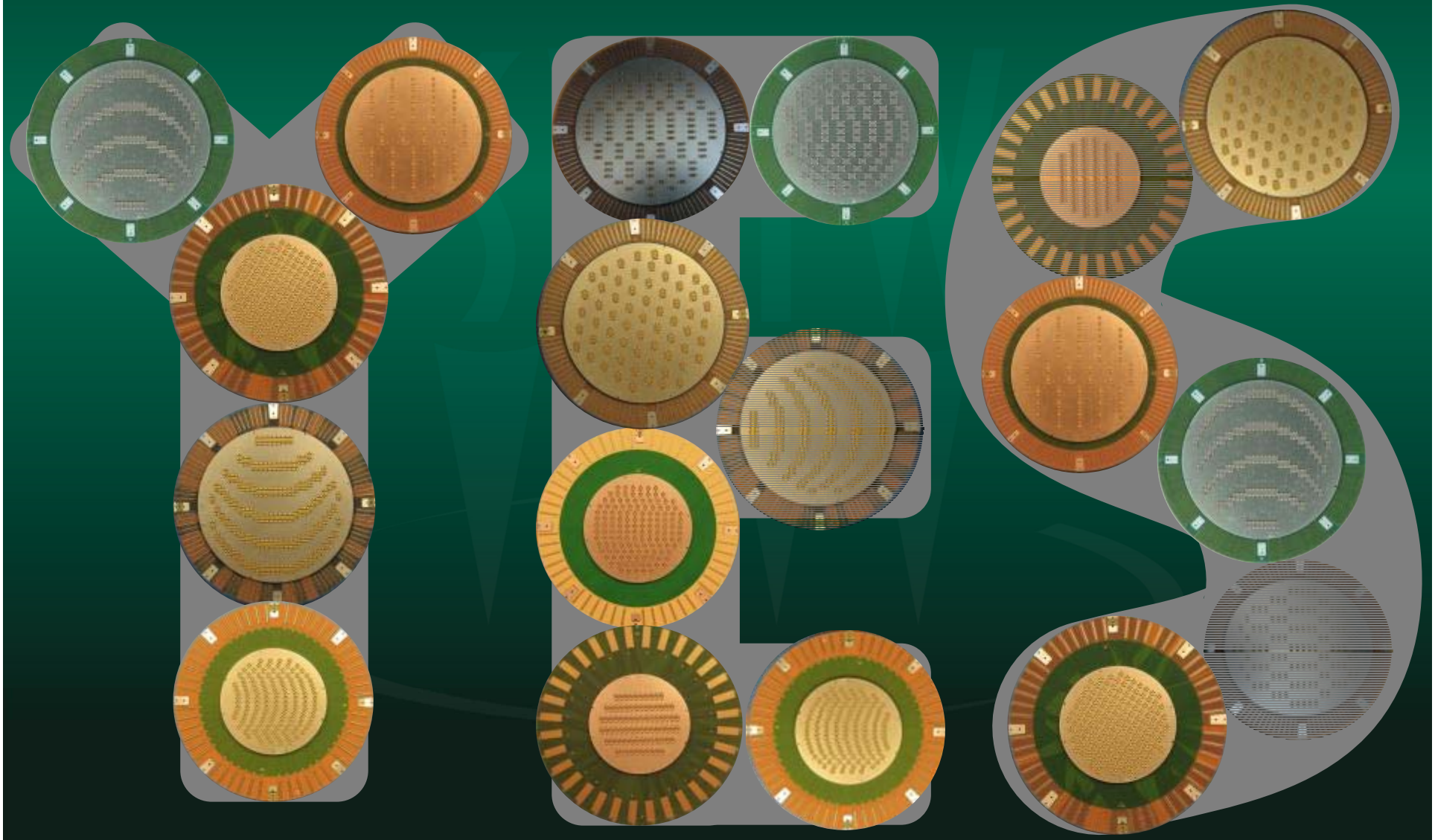
200mm wafer, 6.67x6.67 die, 633 DPW



Additional Benefits of Matrix FWC

- **Electrical Performance**
  - Less crosstalk
  - Better noise isolation
  - More room for components
- **Force balance on chuck**
  - Some probers are quite sensitive to off-center loading
- **Thermal Soak & Stability Performance**
  - Card is nearly always over the chuck

Does it really work?



One final formula:

(with 3 different constants)

DPW = η * # DUTs * # TDs

When # DUTs = # TDs, crossover occurs.
At the crossover point η ≈ 85%.

So:

$$\#DUTs_{\text{Brickwall Crossover}} \approx 1.1\sqrt{DPW}$$

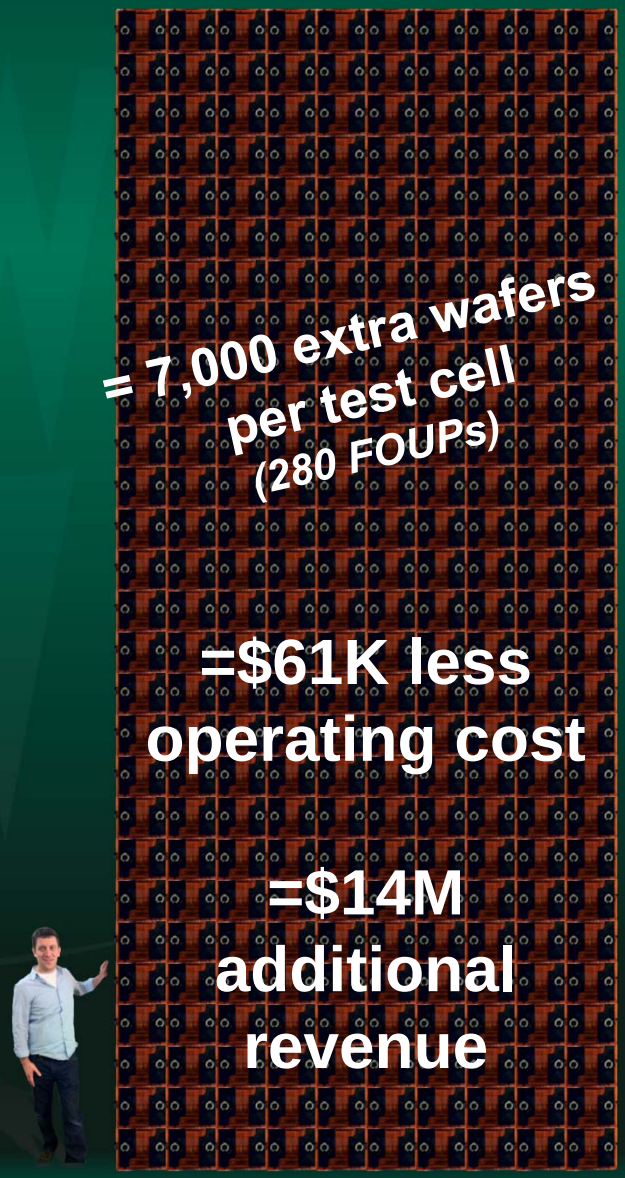
$$\#DUTs_{\text{Skip R or C Crossover}} \approx 0.9\sqrt{DPW}$$

$$\#DUTs_{\text{Skip R \& C Crossover}} \approx 0.6\sqrt{DPW}$$

Return On Investment

- **Using the 10x10, 64 site example:**
  - *Assume 1 min test time*
  - *Running for 18 months*
  - *Assume Test Cell Depreciation + Operating cost = $240K/year (J750 or equiv.)*
  - *Assume overall equipment effectiveness = 75%*
  - *Assume revenue per wafer = $2000*
  - *Model is for 1 test cell*

- **Compared to brickwall: efficiency was 17% higher = 42K vs 49K wafers**



Return On Investment

- **Using the 10x10, 64 site example:**
  - *Assume 1 min test time*
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  - *Assume overall equipment effectiveness = 75%*
  - *Assume revenue per wafer = $2000*
  - *Model is for 1 test cell*

- **Compared to skip R: efficiency was 33% higher = 37K vs 49K wafers**

Thank you

Tim Henson

John Long

Shannon Collier

Michelle Griffing