Exploiting Correcting Codes: On the Effectiveness of ECC Memory Against Rowhammer Attacks

Lucian Cojocar, Kaveh Razavi, Cristiano Giuffrida, Herbert Bos

[redacted] / Ars Leg

, 2018 2:23 AM

> [redacted] wrot
> I can't even co ne would need to do this type

Grad students who have no life. Which is most of them I think. Get enough grad students, and you can parallelize some of the gathering of data.

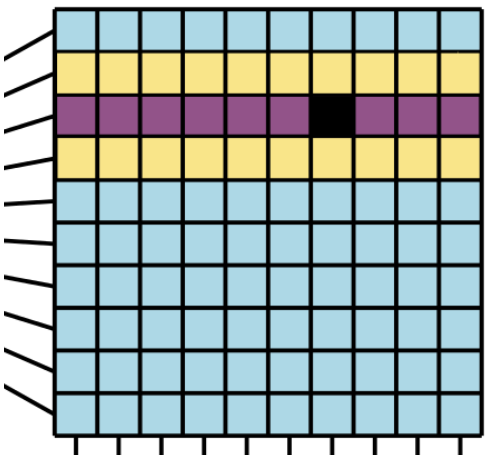
+103 (+107 / -4)

13604 posts | registered 12/22/2003

Rowhammer (RH) causes bits to flip

- Exploit to escalate privilege [Seaborn ’15]
- Exploit to escape sandboxes [Seaborn ’15, Gruss ’18]
- Exploit to compromise confidentiality [Razavi ‘16]
- Exploit different targets:
  - Desktop computers (browser, local shell etc.)
  - On phones [van der Veen ‘17], on GPUs [Frigo ‘18]
  - Over the network [Tatar ‘18, Lipp ‘18]

```
code1a:
  mov (X), %eax
  mov (Y), %ebx
  clflush (X)
  clflush (Y)
  mfence
  jmp code1a
```



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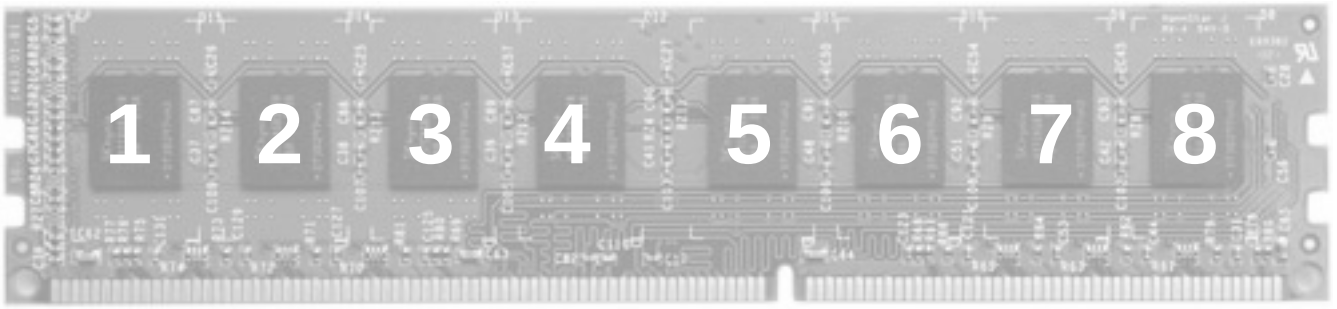
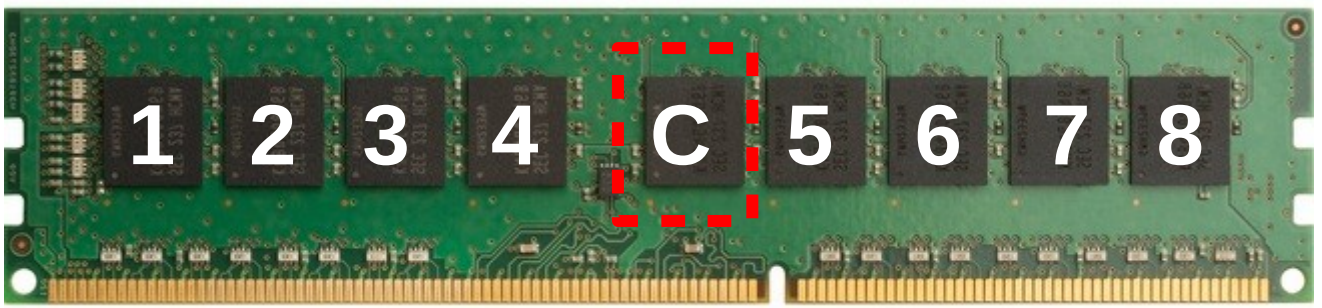
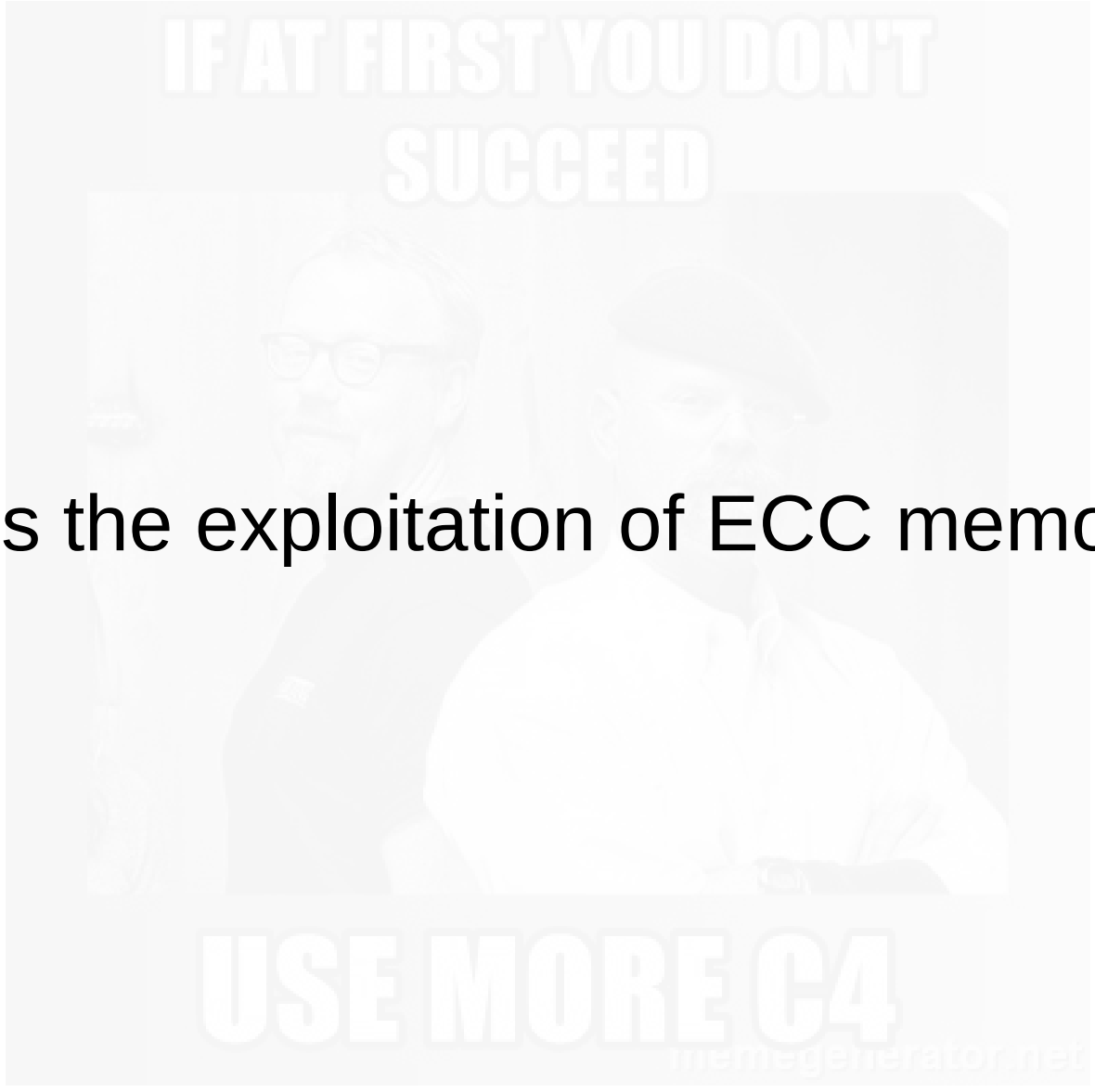


ECCploit, RH on server (ECC) memory



Overview

1) Challenges for RH on ECC memory
2) Single-bit flips on ECC memory
    1) Causing them
    2) Observing them
3) Reverse engineering of ECC functions
4) Performance of Rowhammer on ECC memory



What makes the exploitation of ECC memory difficult?


IF AT FIRST YOU DON'T SUCCEED
USE MORE C4
BIT FLIPS
memegenerator.net

It is hard (and dangerous) to get 3 bit flips

1 bit flipped

2 bits flipped

3 bits flipped

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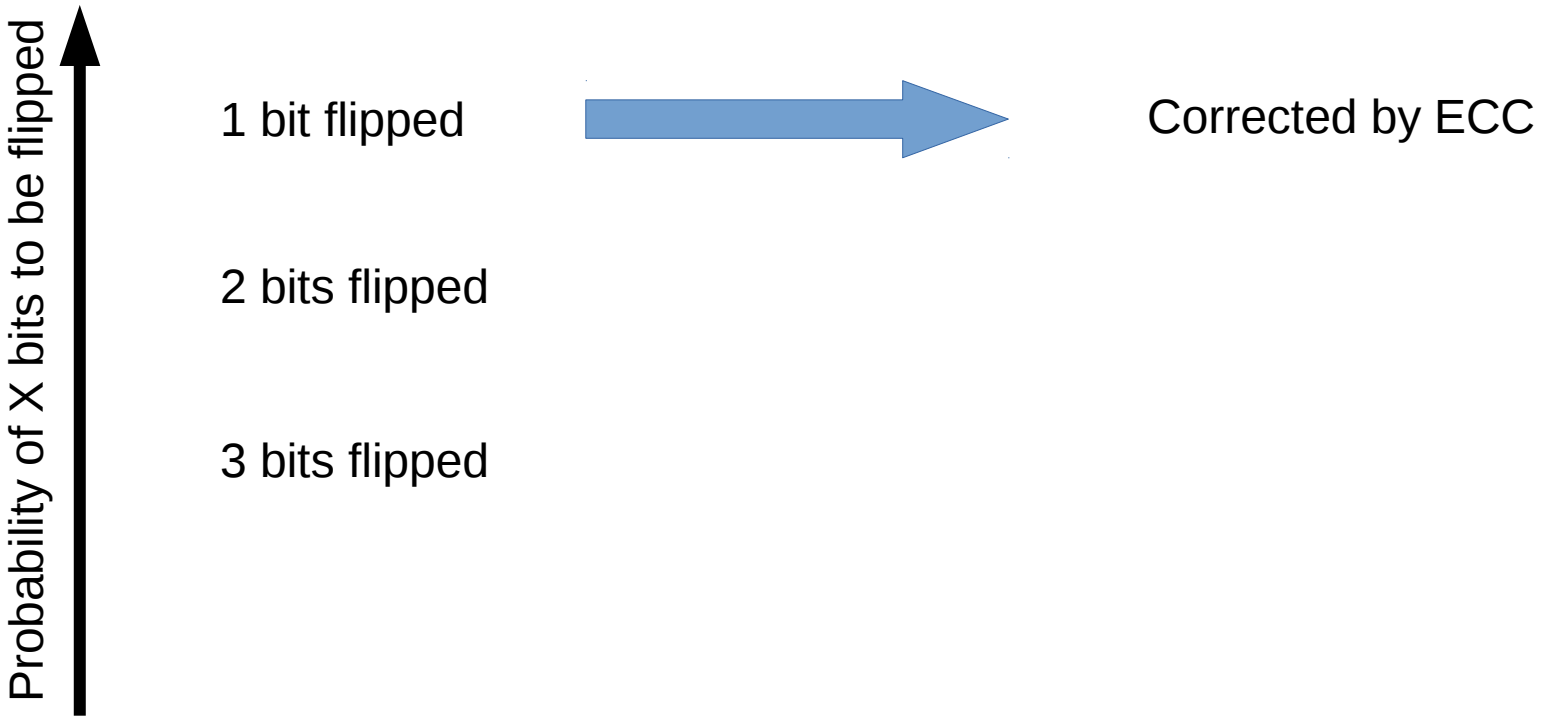

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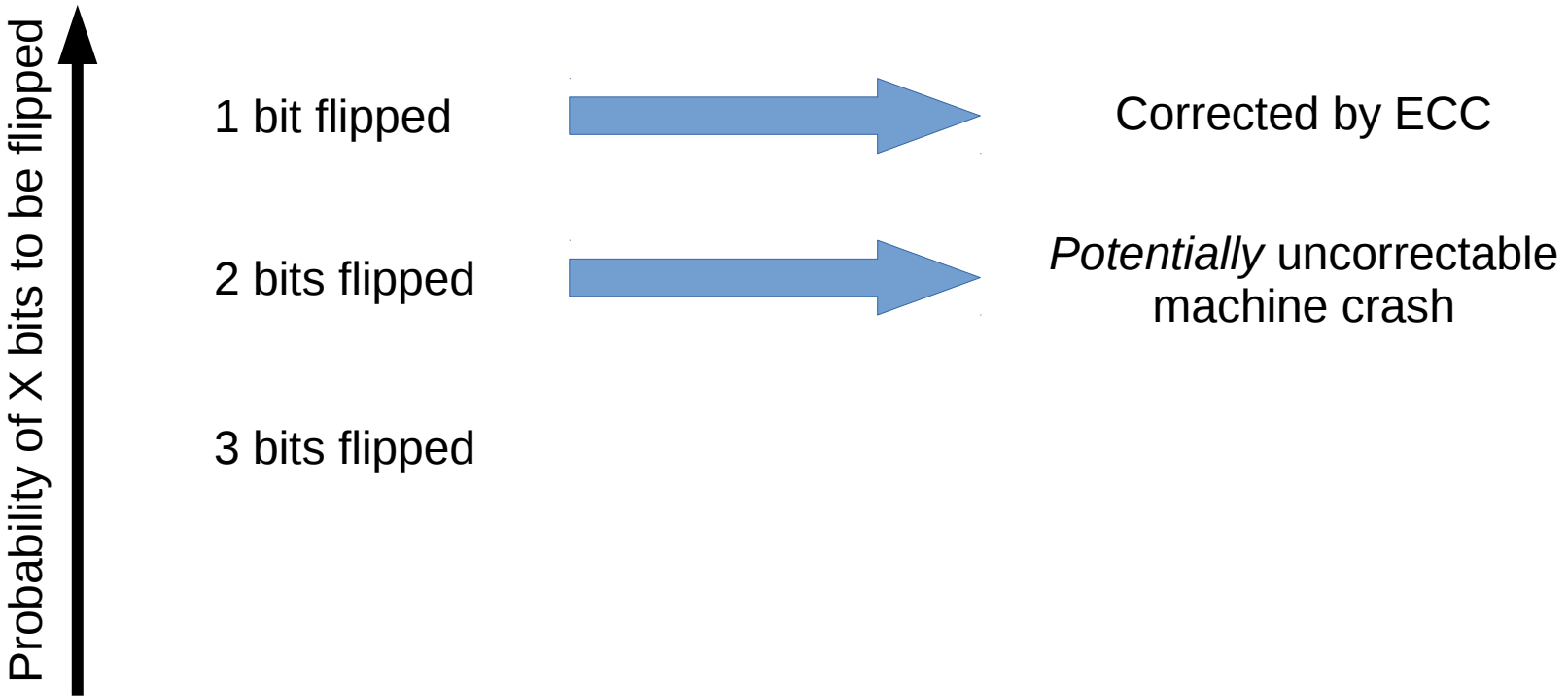

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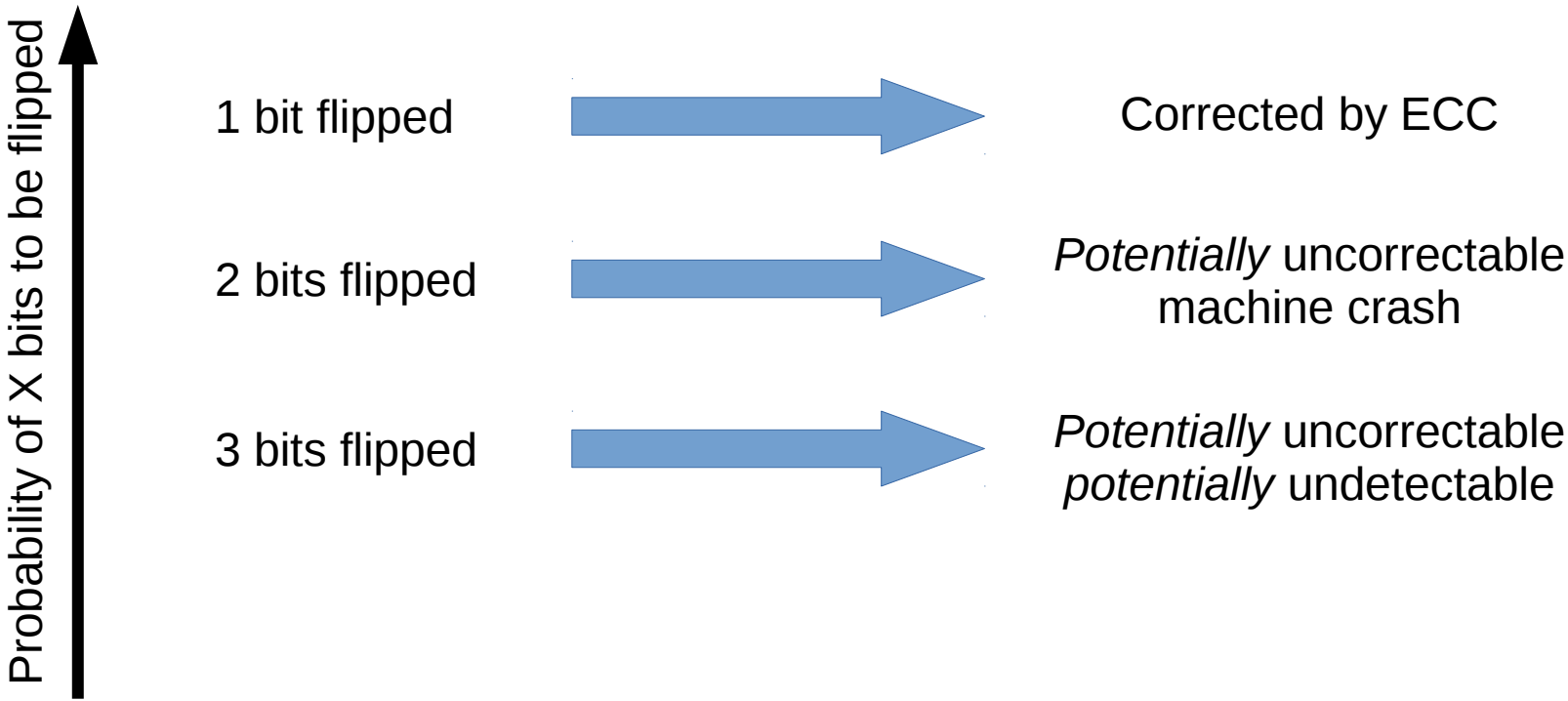

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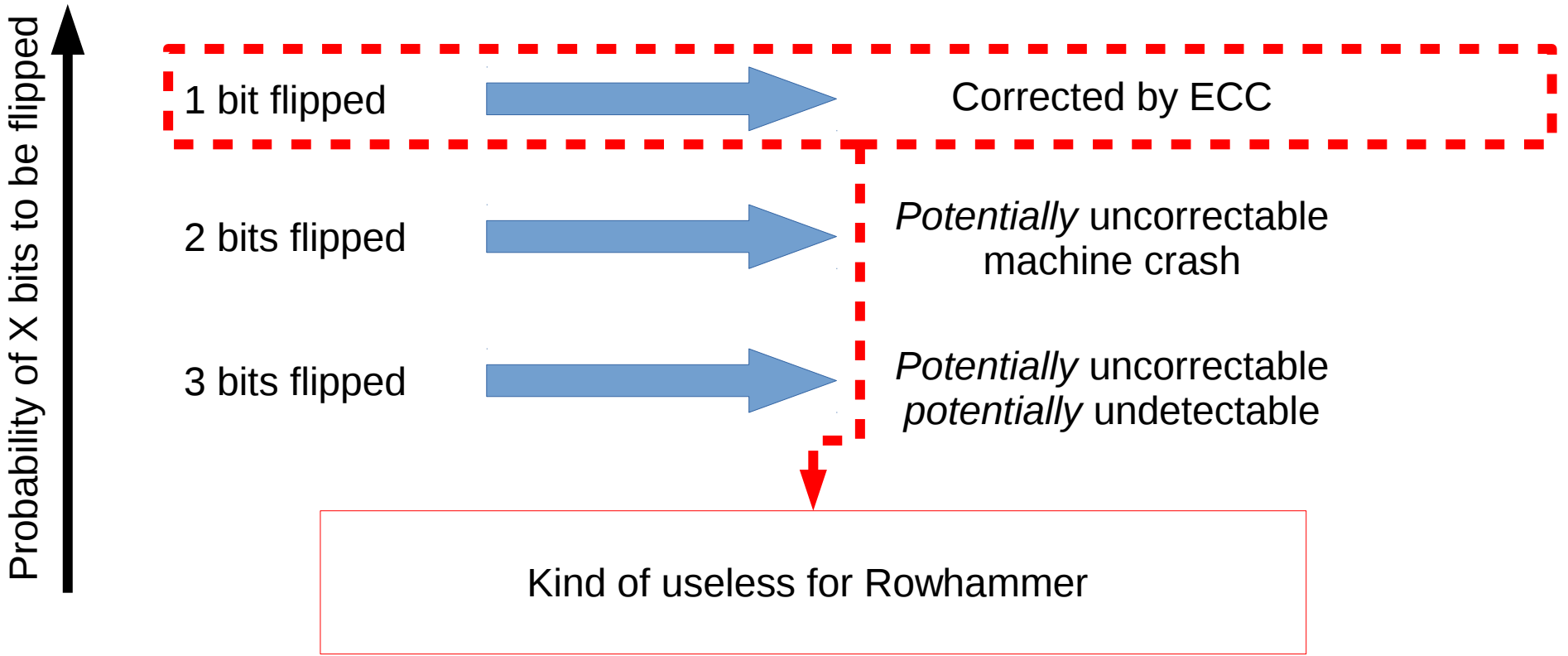

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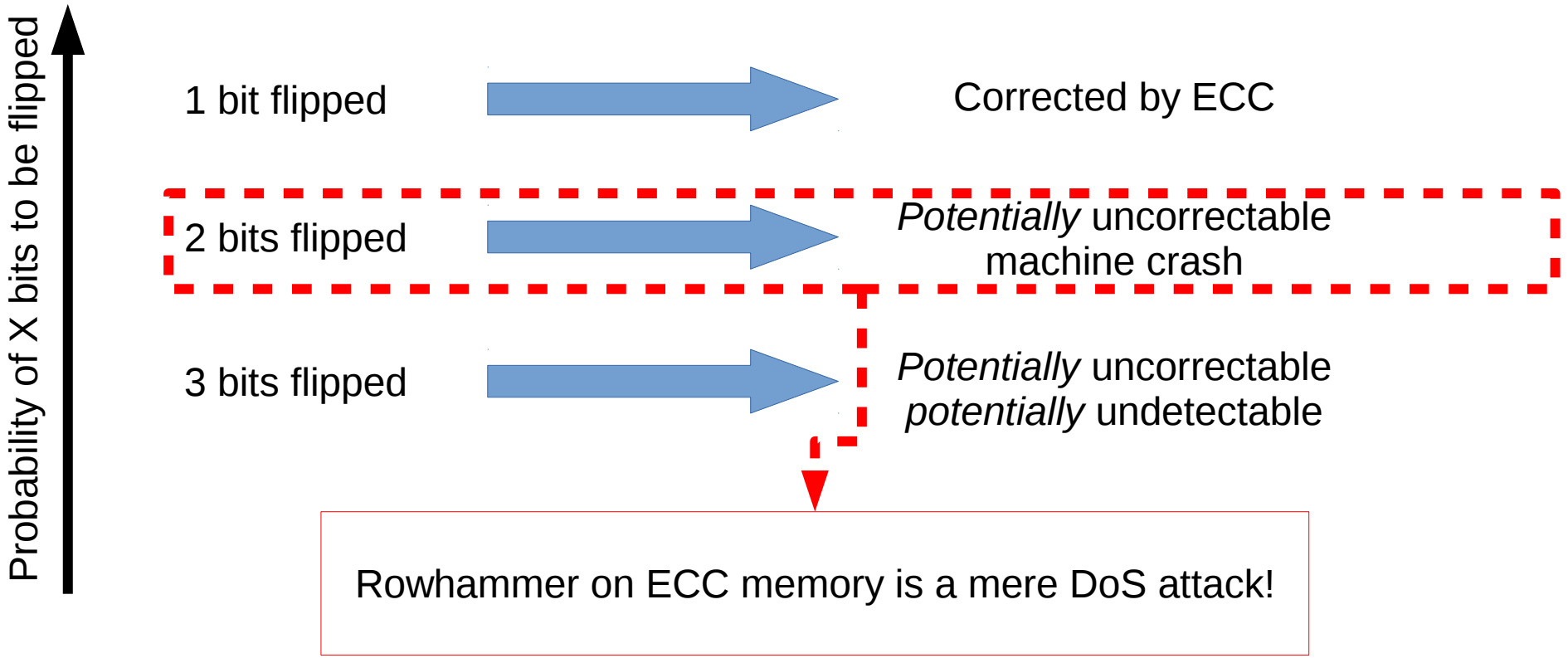

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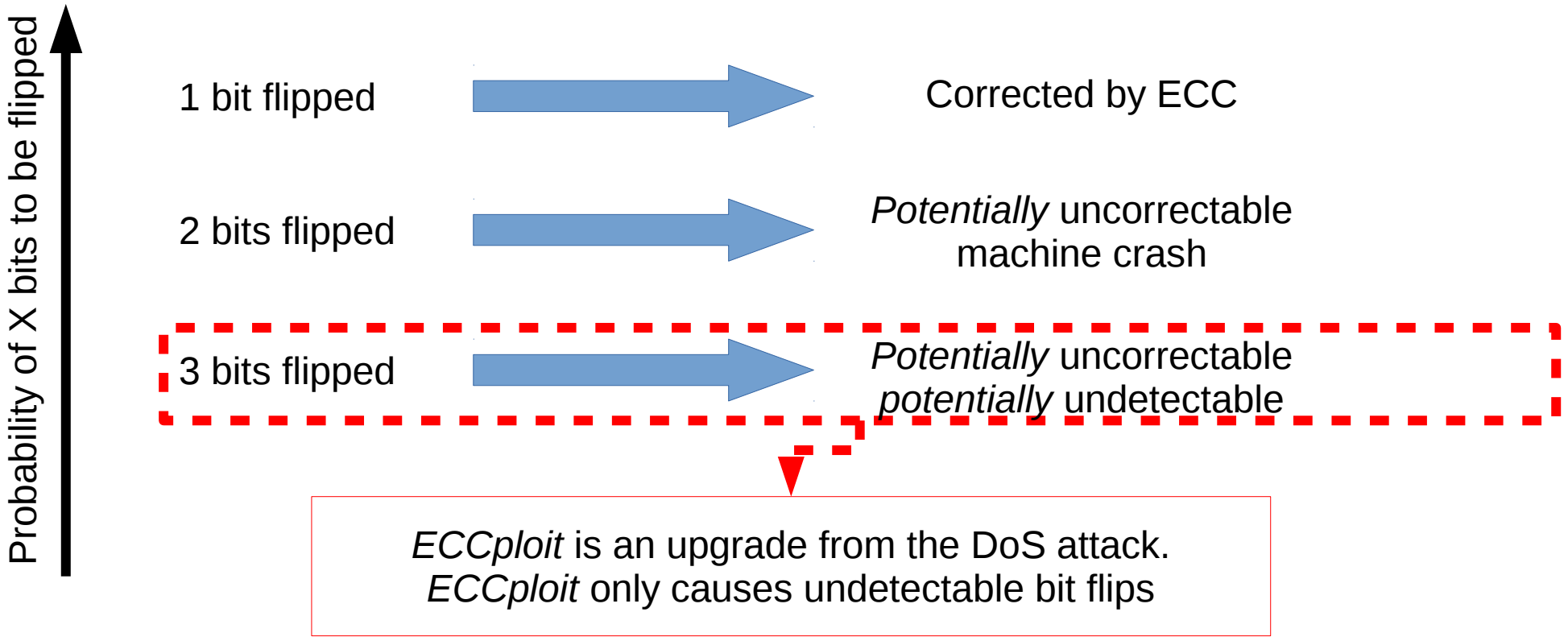
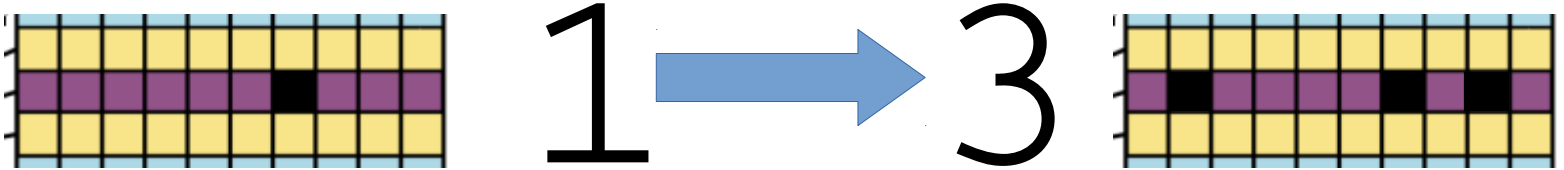
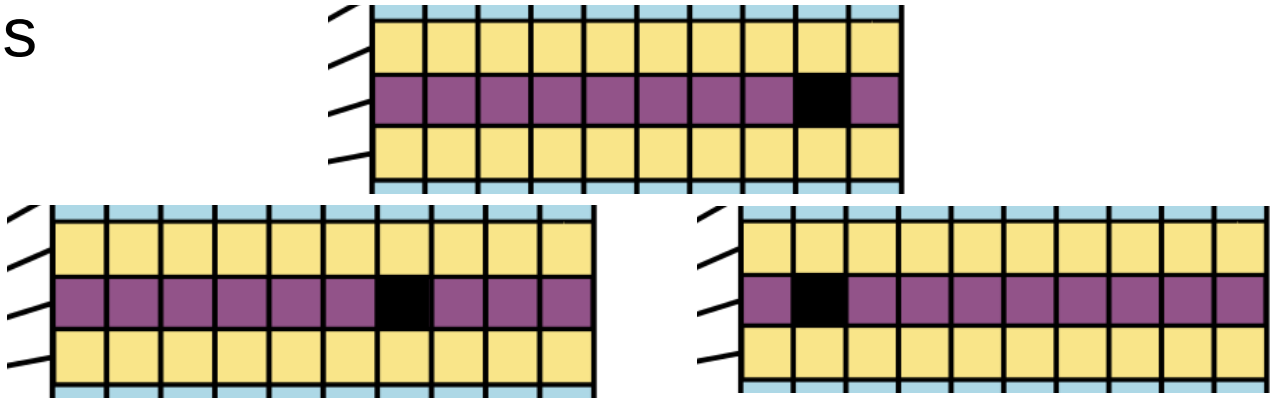


Q: How to get from one bit flip to three bit flips without hitting two bit flips?

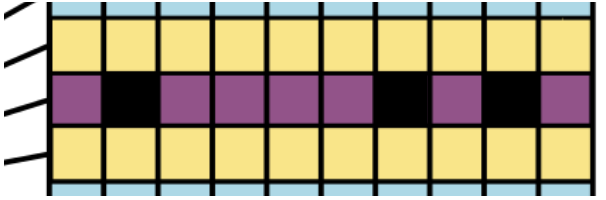


A: Templating bit flips on ECC memory (ECCploit)

1. Get single bit flips



2. Combine them to cause silent corruptions (same ECC)



Challenge: causing a single bit to flip

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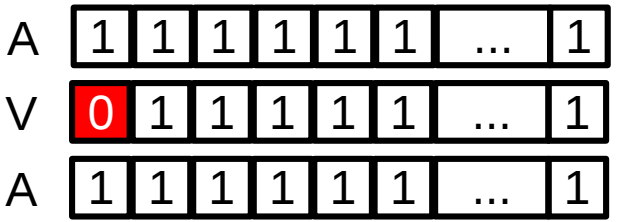

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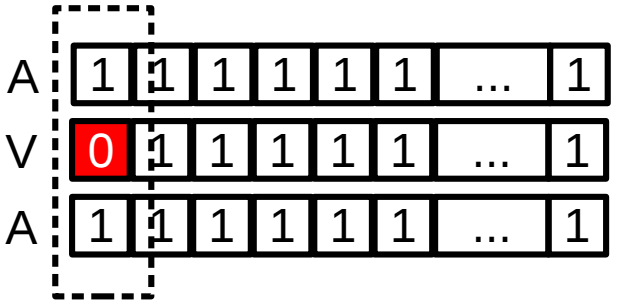

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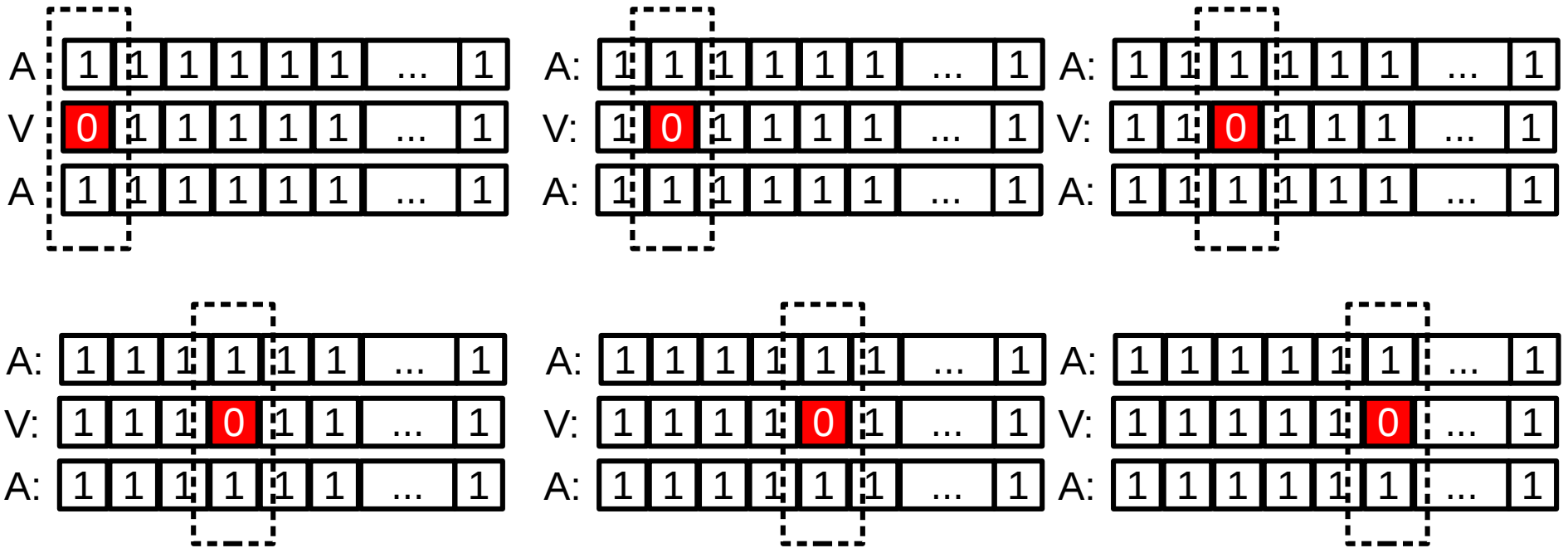

Challenge: observing a single bit flip

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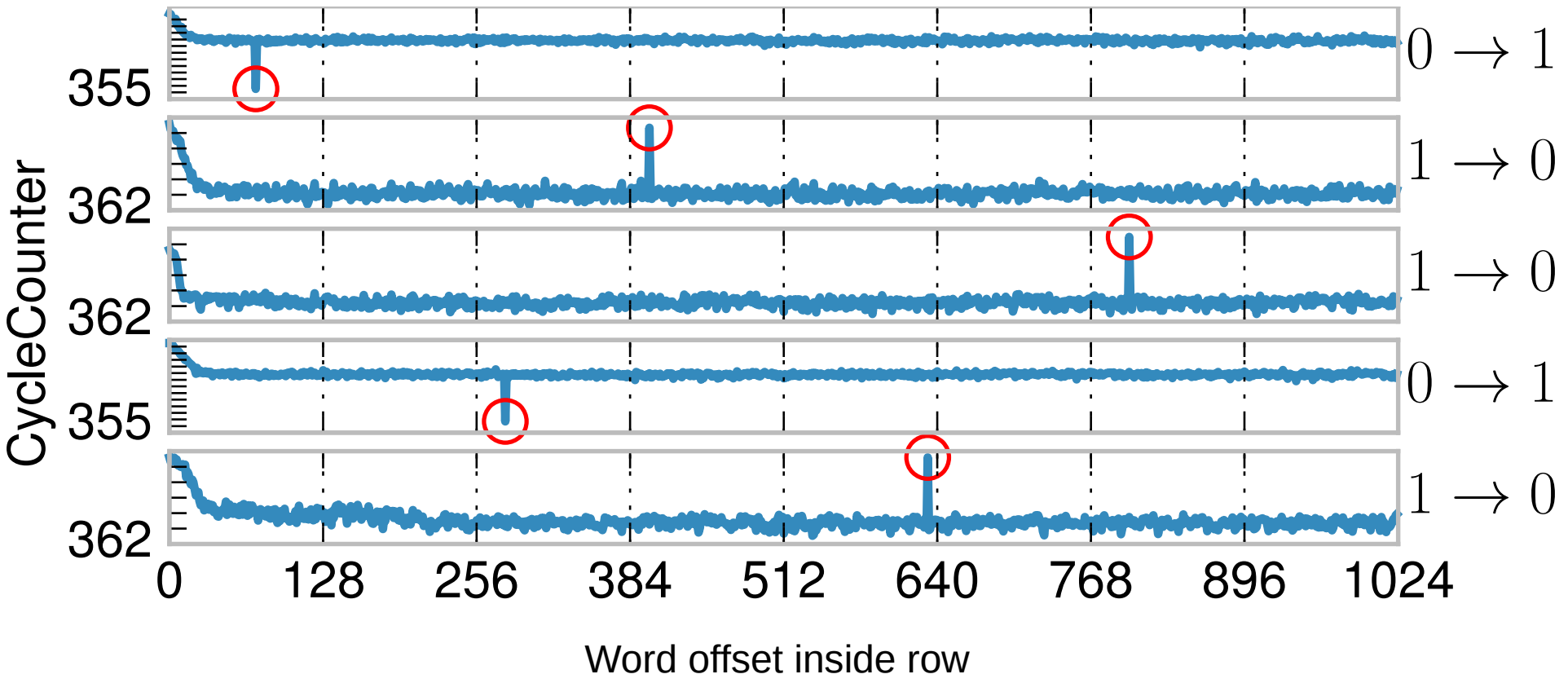
ECC correction is observable



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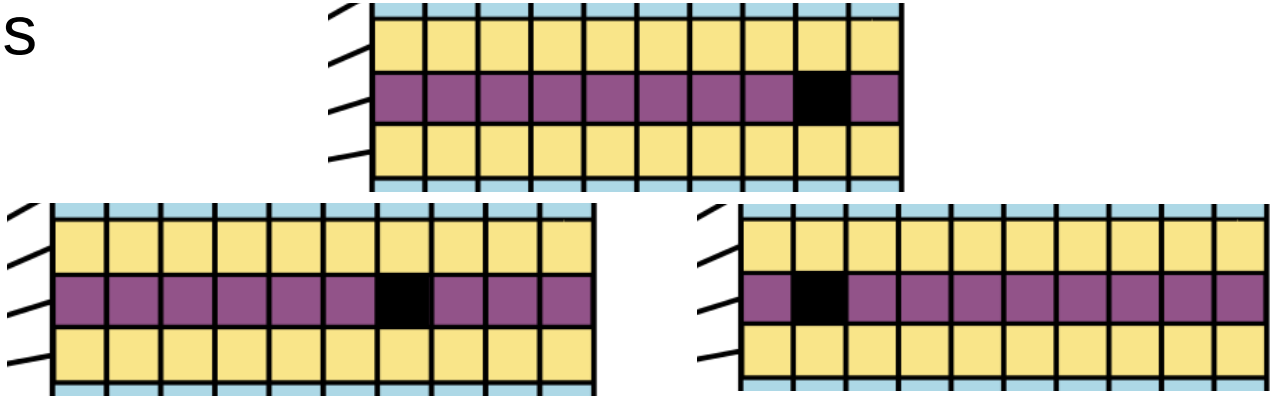

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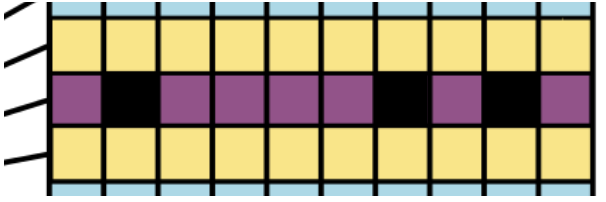

Challenge: finding a suitable 3 bit flip that cause silent corruptions

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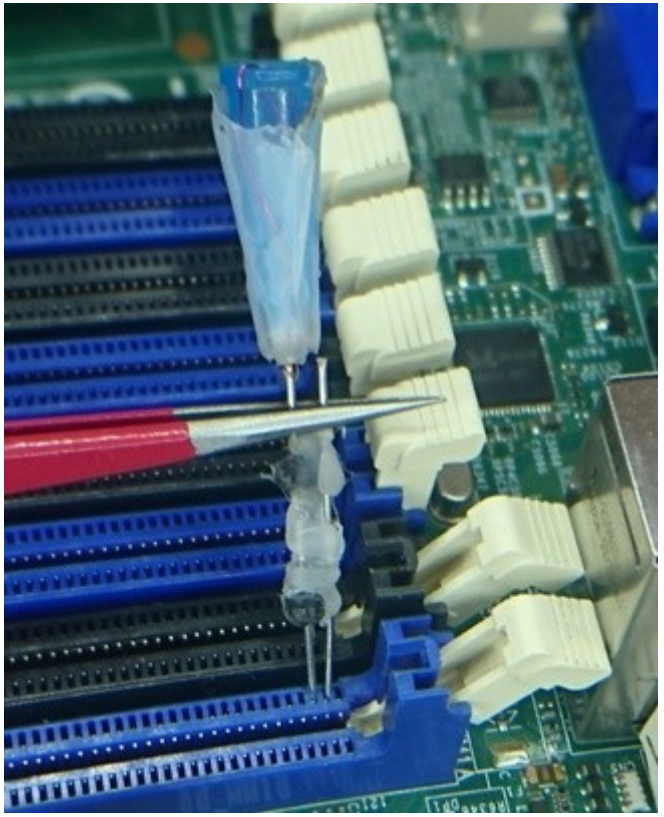
Reverse engineering the ECC implementation

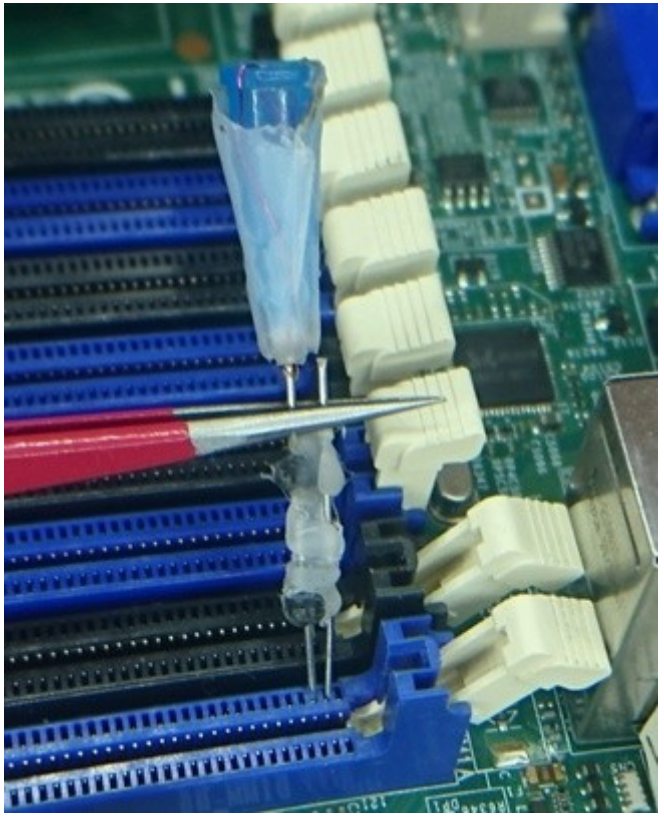
ECC errors reveal the ECC function



Fault injection on the memory bus

Cold-boot attack

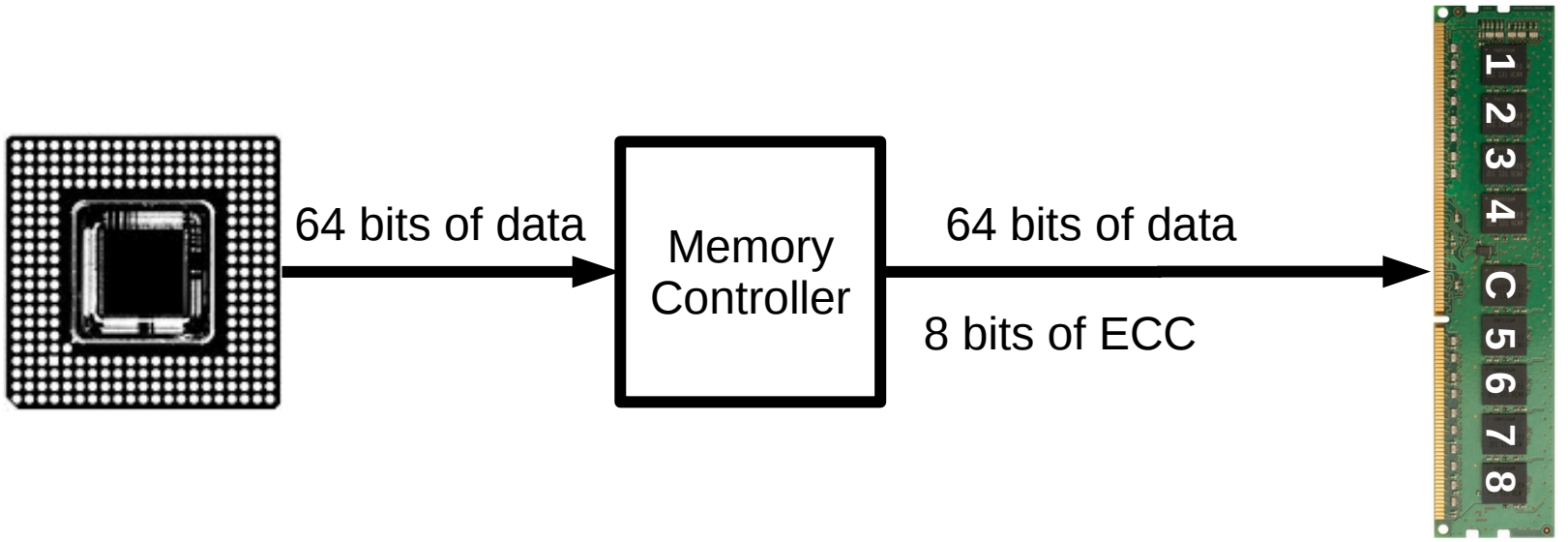
ECC errors reveal the ECC function



Fault injection on the memory bus

Cold-boot attack

CPU writes data and control bits

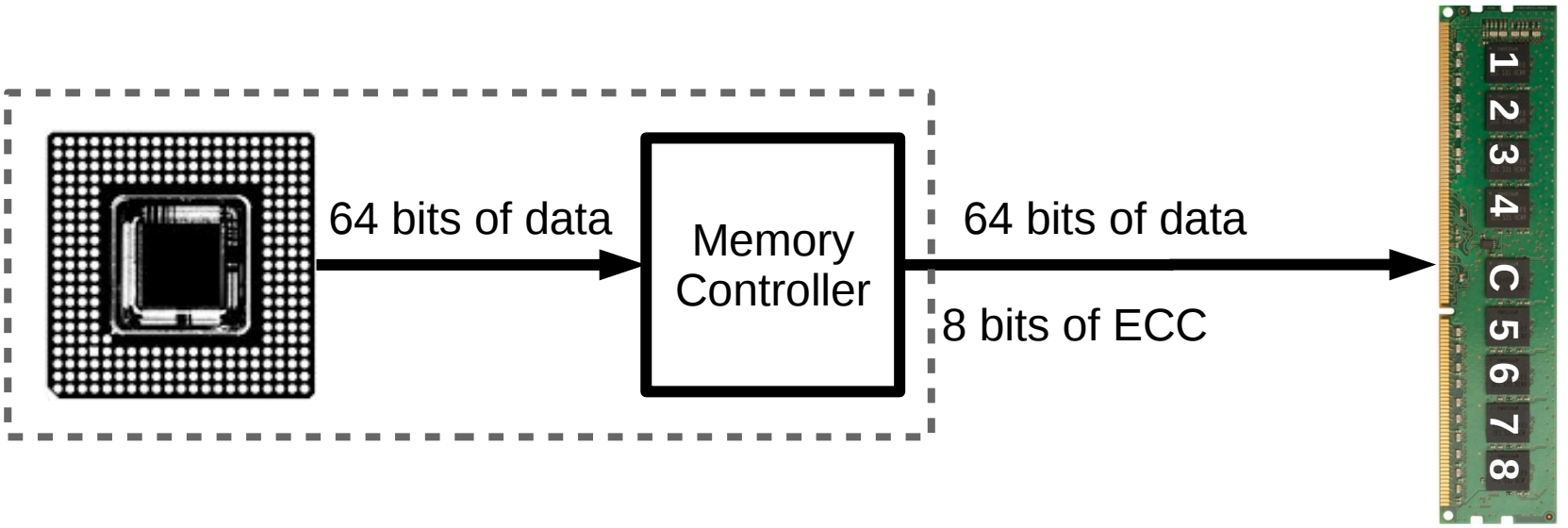



```
*ptr = data;
```

```
ControlBits = ECC(data);
```

ECC bits are stored next to data

CPU writes data and control bits




```
*ptr = data;
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ControlBits = ECC(data);
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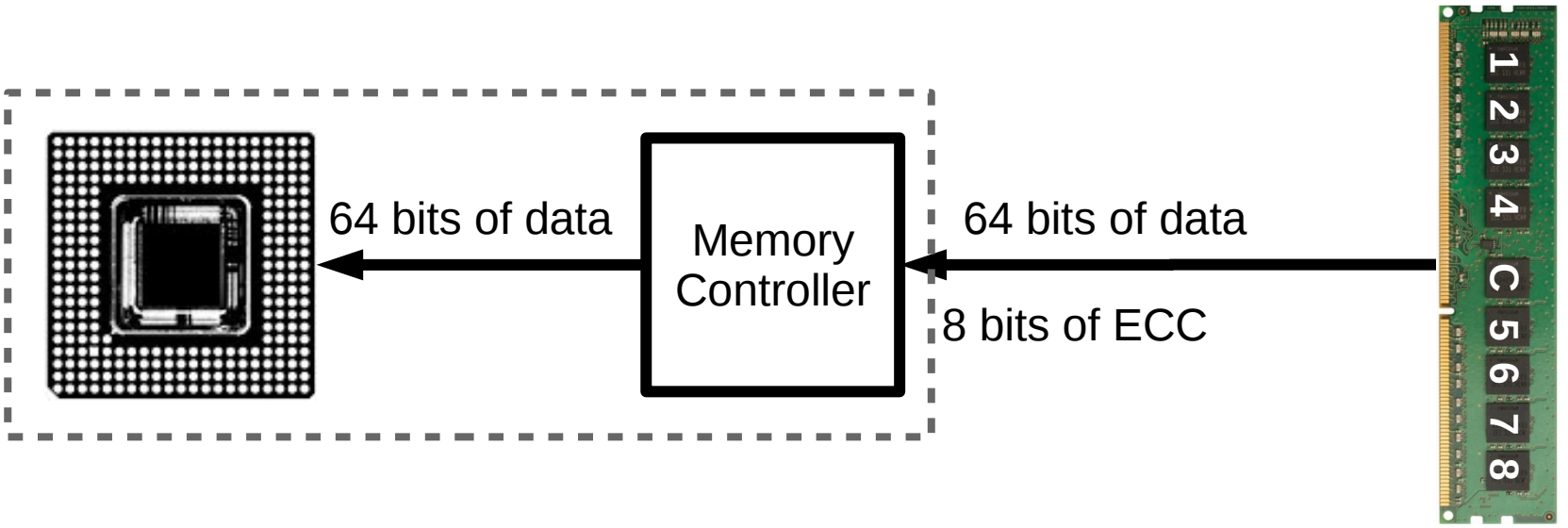
ECC bits are stored next to data

CPU reads data and checks control bits

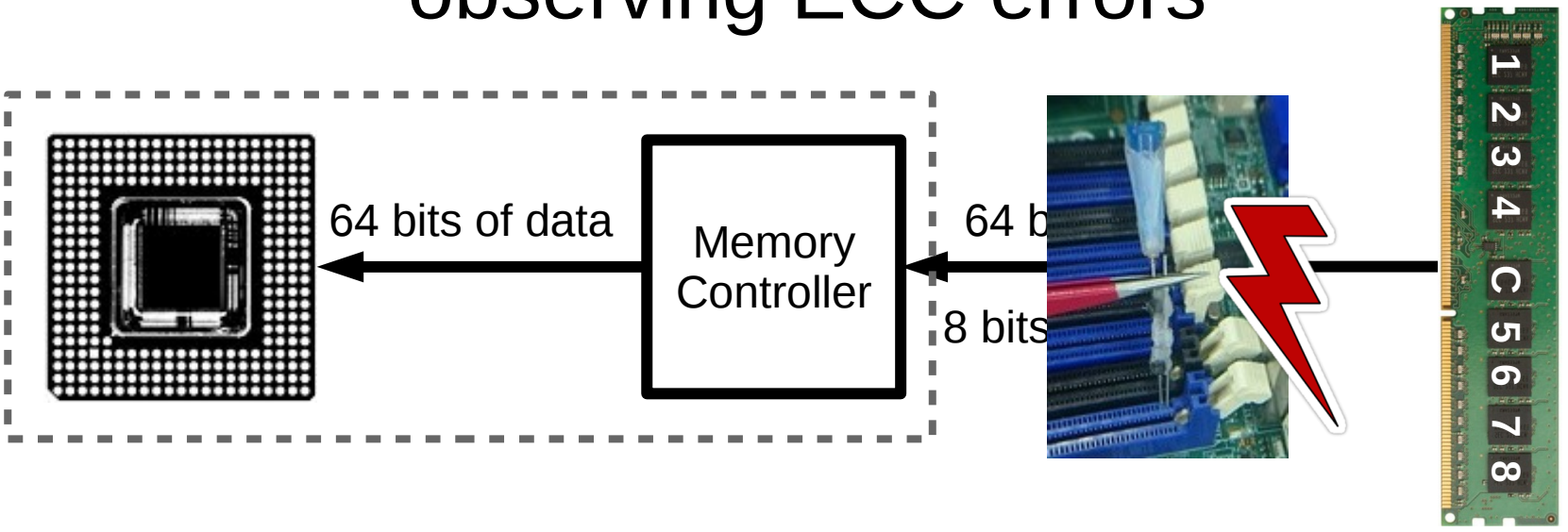



```
data = *ptr;
```

```
CB_exp = ECC(data);
if (CB_read != CB_exp)
    Error(DataForRAS);
```

ECC bits are stored next to data

We can reconstruct the ECC function by observing ECC errors

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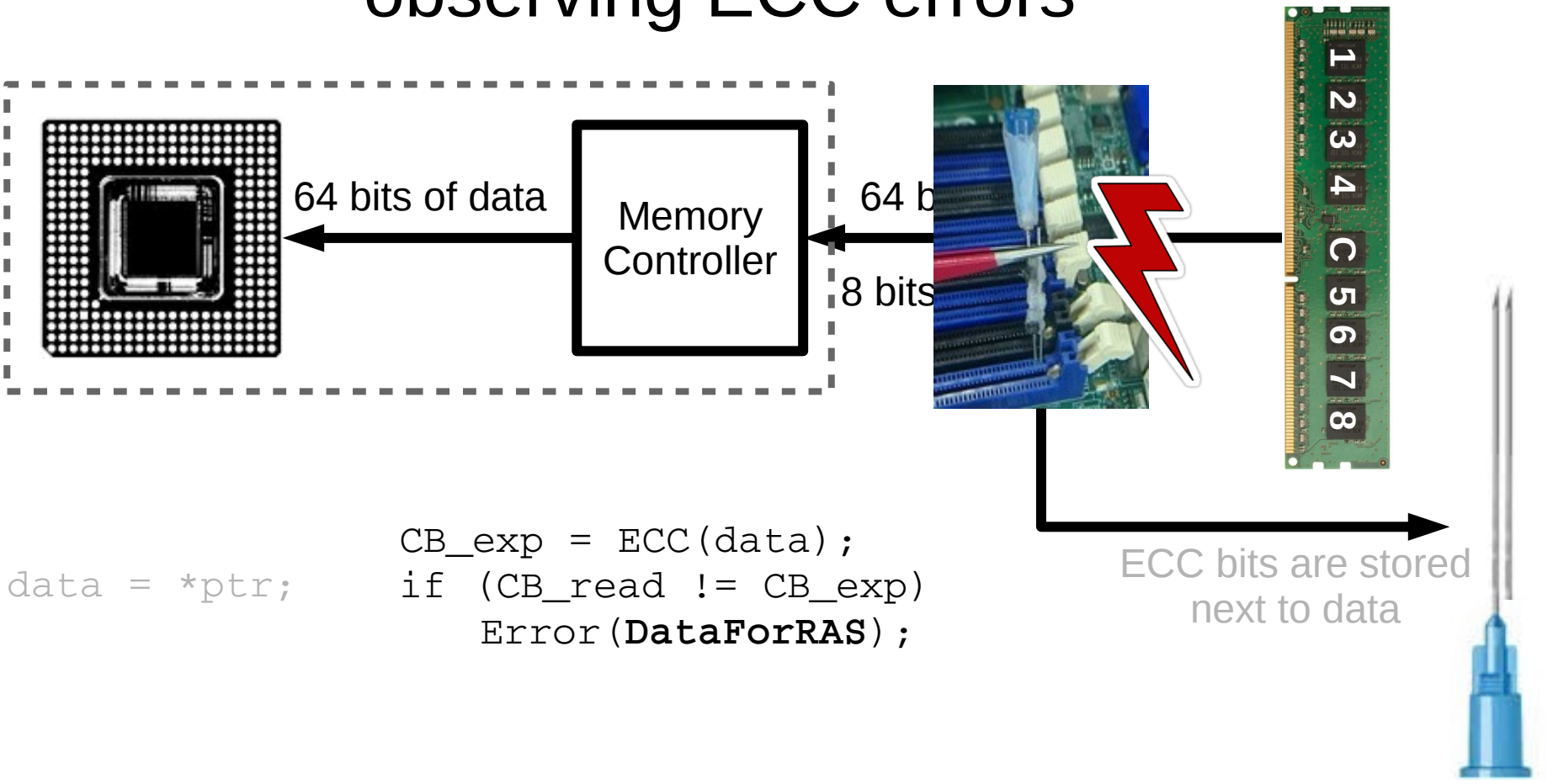


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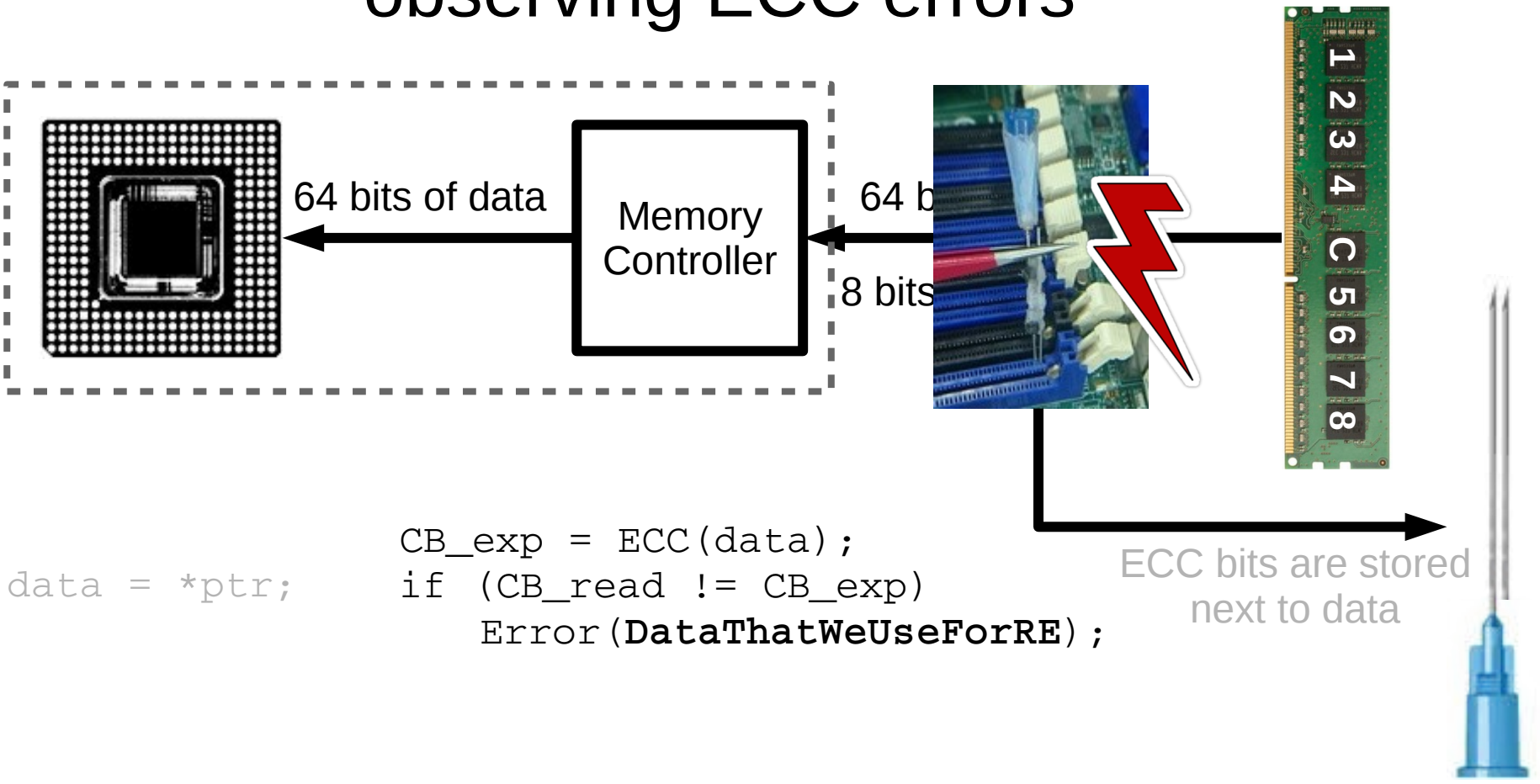


```
data = *ptr;
```

```
CB_exp = ECC(data);
if (CB_read != CB_exp)
    Error(DataThatWeUseForRE);
```

ECCploit attack

1) Recover the ECC function (offline)
2) Template the memory
    1) Avoid crashes by triggering only single-bit flips
    2) Knowing the ECC function, combine single bit flips in undetectable bit flips
3) Massage the memory
4) Run the Exploit

How long it takes to template ECC memory for Rowhammer?*

*On our setup

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- If a perfect side channel (bit granularity) it takes:
  - 32 minutes for PTE or code change
  - 2 hours for the RSA key attack

*On our setup

How long it takes to template ECC memory for Rowhammer?*

- If a perfect side channel (bit granularity) it takes:
  - 32 minutes for PTE or code change
  - 2 hours for the RSA key attack
- If a typical side channel (word granularity) it takes:
  - 19 hours for PTE or code change
  - 3 days for RSA key attack

*On our setup

Error Correcting Codes:
Only Slow Down Rowhammer Attacks

https://vusec.net/projects/eccploit

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https://vusec.net