Beer-recovery attack

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KECCAK

SHA-3 candidate

Keccak

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Sponge with permutation Keccak-*f*[1600]

KECCAK

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Sponge with permutation KECCAK-f[1600]

No external cryptanalysis

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A Trappist beer award

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Sponge with permutation KECCAK-f[1600]

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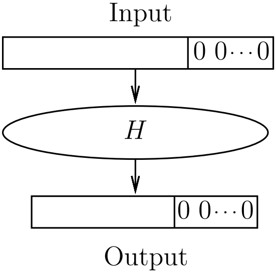
So we start...

CICO problem for KECCAK-f[1600]

KECCAK-f[1600]: $\{0,1\}^{1600} \mapsto \{0,1\}^{1600}$

Constrained Input – Constrained Output (CICO) problem:

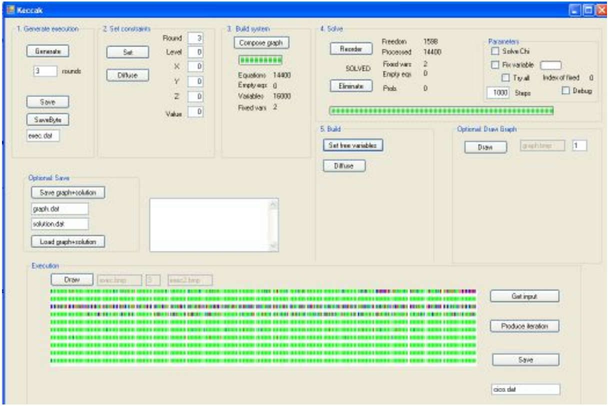
- Fix $X, Y \subset \{0,1\}^{1600}$
- Find many $x \in X,\ y \in Y$: $f(x) = y$
- Hard if X and Y are small



Triangulation tool

- View the transformation as a system of equations
- Fix some input and output bits to 0
- Find solutions with complexity 1

Three rounds (of 18) can be attacked



3 rounds

exec.dat

Round 3
Level 0
X 0
Y 0
Z 0
Value 0

Equations 14400
Empty eqs 0
Variables 16000
Fixed vars 2

SOLVED

Freedom 1598
Processed 14400
Fixed vars 2
Empty eqs 0
Prob. 0

□ Solve Chi
□ Fix variable
□ Try all
Index of fixed 0
1000 Steps
□ Debug

1

graph.dat
solution.dat

3

cico.dat

The tool is online: `https://cryptolux.uni.lu/mediawiki/uploads/0/03/Keccak-tool.zip`

Algebraic analysis

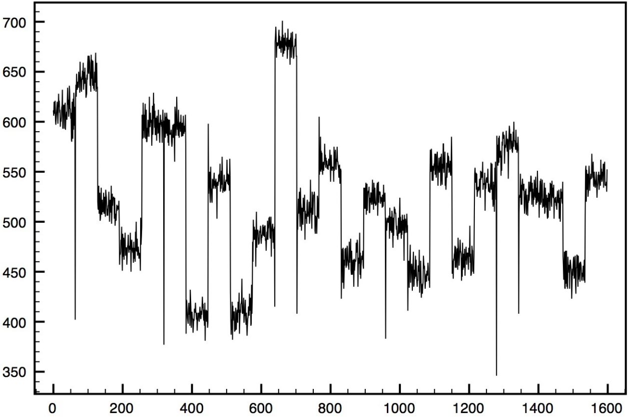
Bounds *b* on the degree given in the spec

($\Rightarrow$ cube tester in 2^{b+1} possible)

Our result: heterogeneous algebraic structure even for small cubes

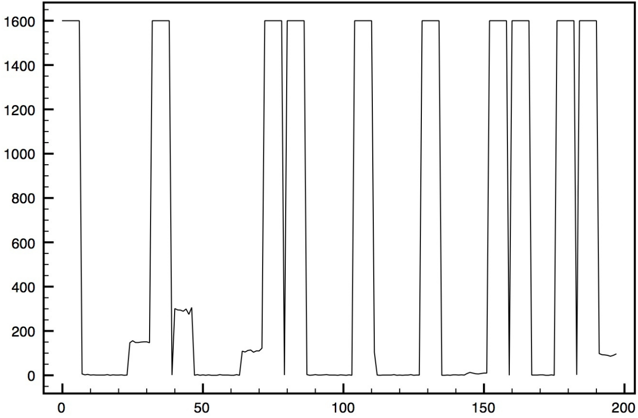
3 rounds, degree-2 cubes

#components attacked $=$ cube position



4 rounds, degree-9 cubes

#components attacked = cube position



KECCAK's doc conjectures 13 rounds enough against distinguishers

Need 11 rounds for maximal degree…

How many rounds for a homogenous (reduced-degree) structure?

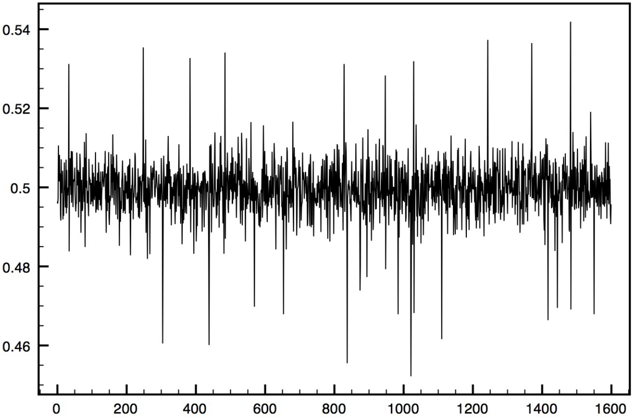
Truncated differentials

First find $\Delta_{\text{in}} \mapsto \Delta_{\text{out}}$ for θ^{-1}
with Hamming weight $|\Delta_{\text{in}}| = 1$, $|\Delta_{\text{out}}| \approx 1600/2$

(conjectured optimal in the documentation)

Used to find probability-1 truncated differential on 3 rounds

On four rounds, still large biases



Conclusions

Inverse permutation more difficult to attack

- faster diffusion
- proba-1 differentials on 1 round only

Results consistent with the designers' analysis

Good security margin