The Hidden Parallelepiped is Back Again: Power Analysis Attacks on Falcon

Morgane Guerreau[1] Ange Martinelli[2] Thomas Ricosset[1]
Mélissa Rossi[2]

[1]Thales, [2]ANSSI

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Introduction

Fast-Fourier Lattice-based
Compact Signatures over NTRU

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Two Power Analysis attacks on Falcon:

- Efficient DPA attack on the preimage computation
- STA on the trapdoor sampler leading to HPP attack

Lattice-based cryptography

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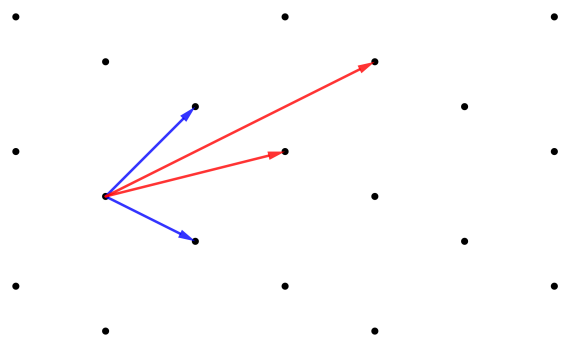

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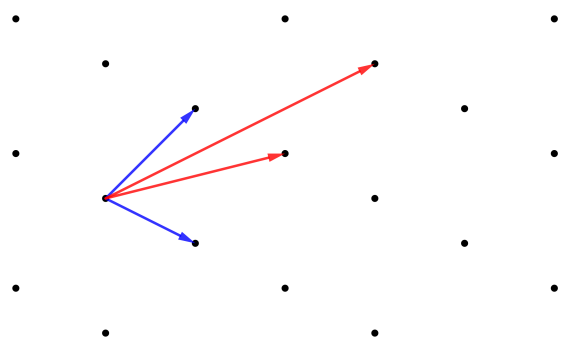

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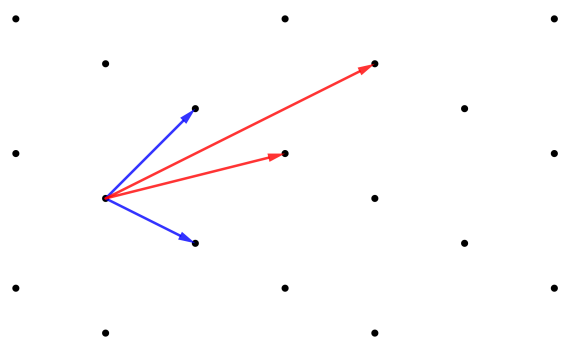

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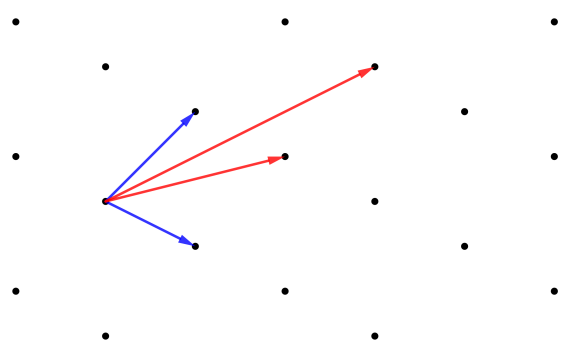

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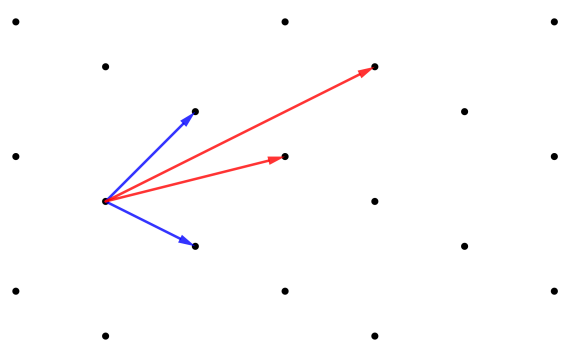

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Note: It is hard to derivate the good basis from the bad basis.

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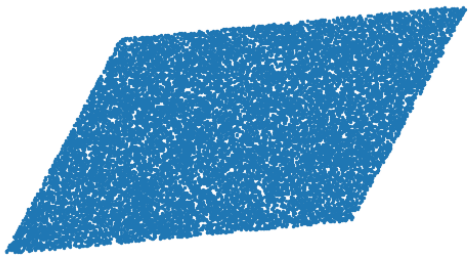

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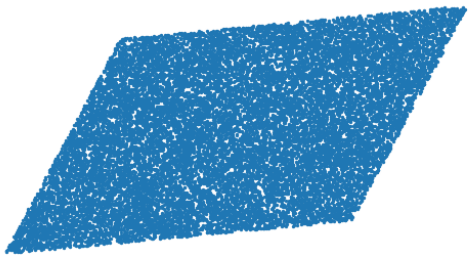

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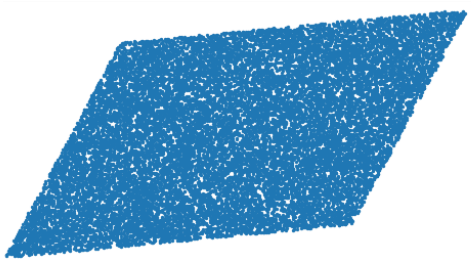

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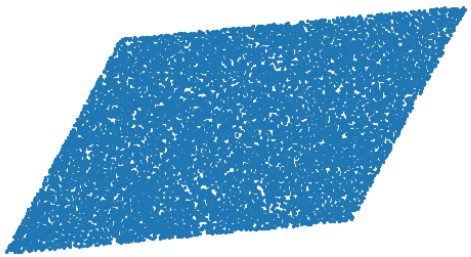

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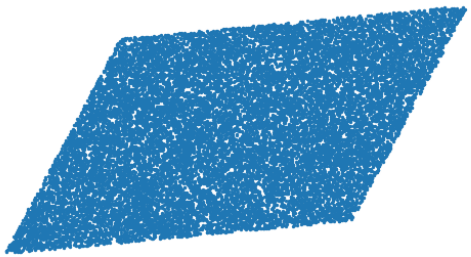

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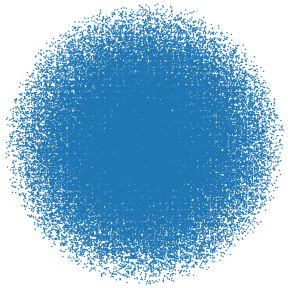

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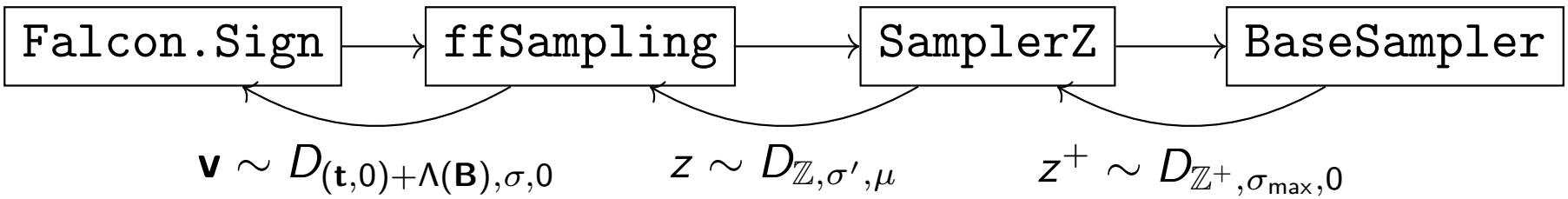

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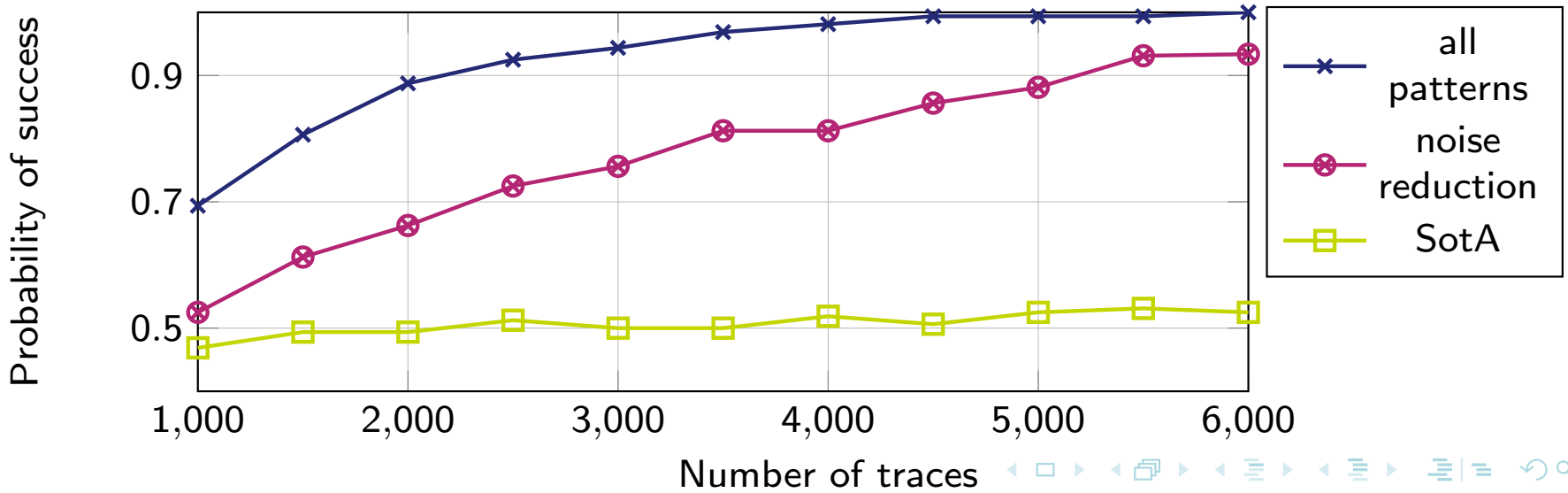

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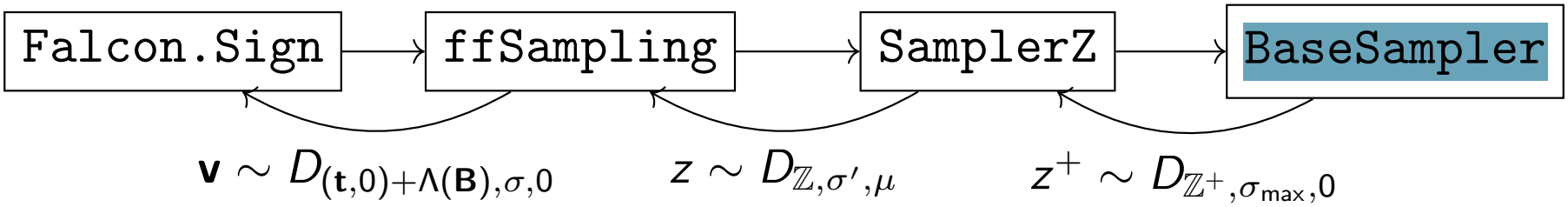
Hidden Parallelepiped attack on the trapdoor sampler

1. Side-channel analysis on the `BaseSampler` to recover samples
2. Utilisation of the samples to disclose a *deformed* parallelepiped
3. Application of HPP solver on filtered signatures
4. Private key recovering (possibly with lattice magic)

1. Side-channel analysis on the BaseSampler



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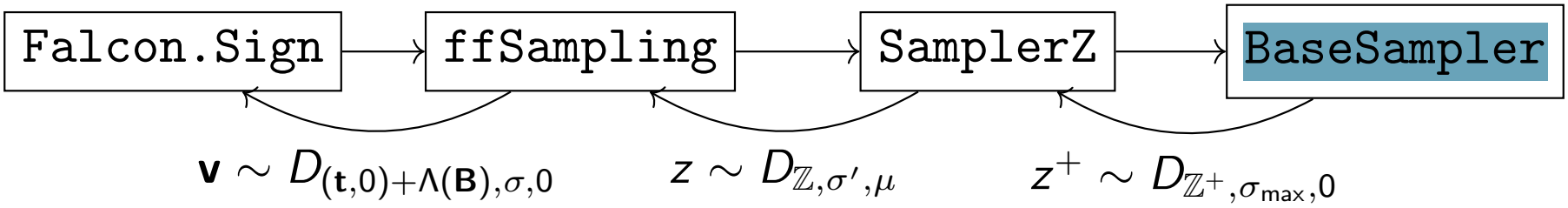

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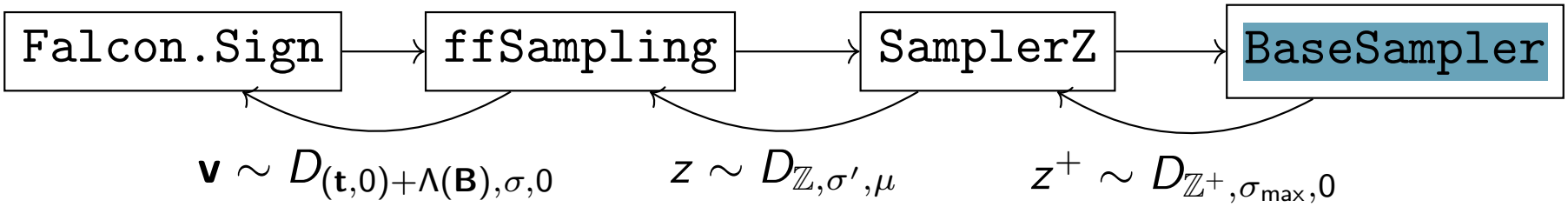

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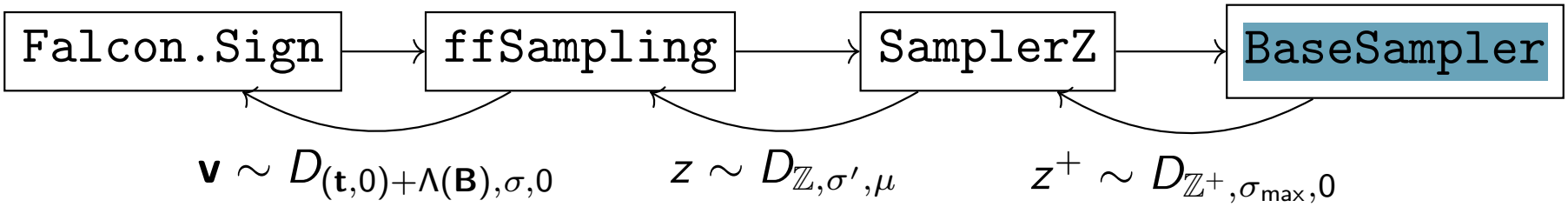

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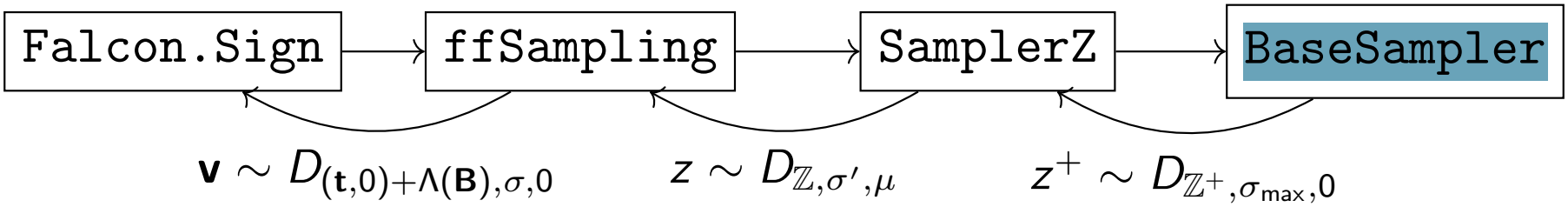

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We are able to retrieve the value of z^+ through STA.

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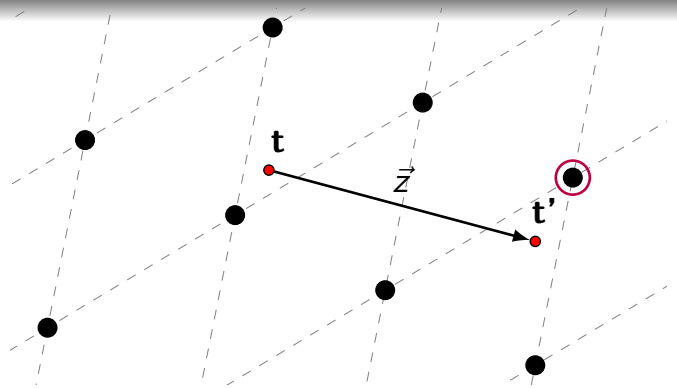
"Shifted" Babai's nearest-plane algorithm: A Gaussian translation vector $\vec{z}$ is applied to $\mathbf{t}$ before solving CVP.



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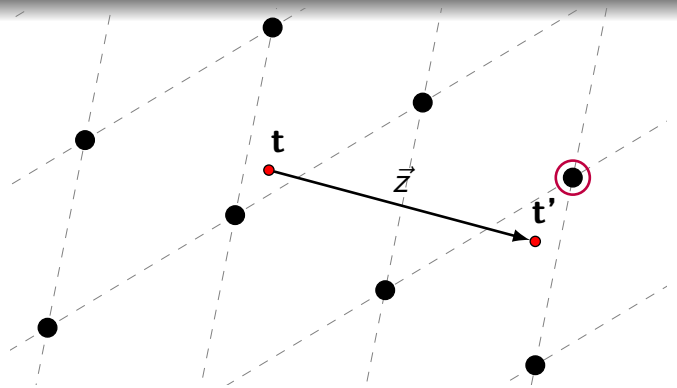

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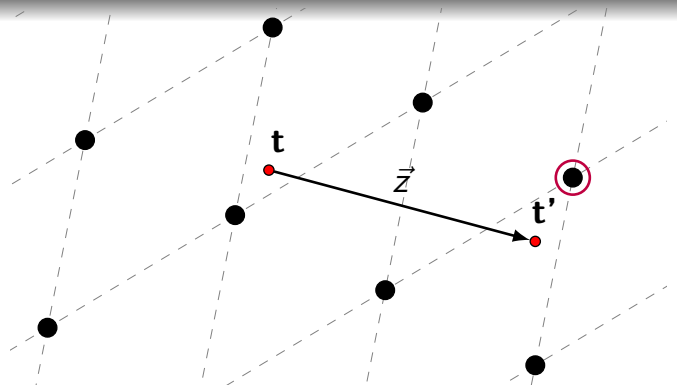

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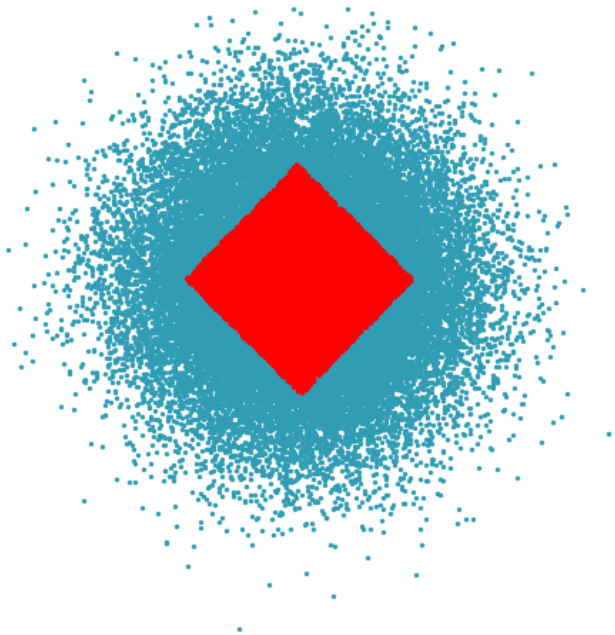

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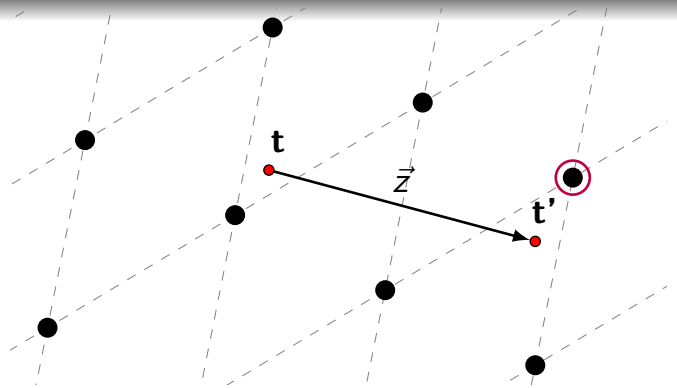

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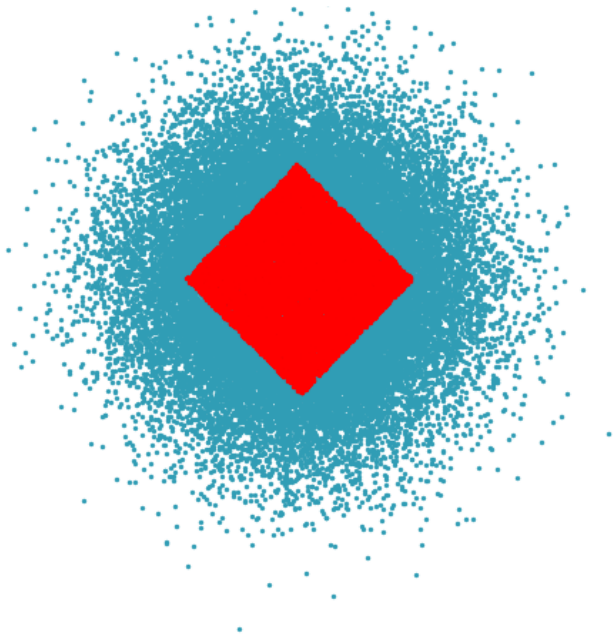

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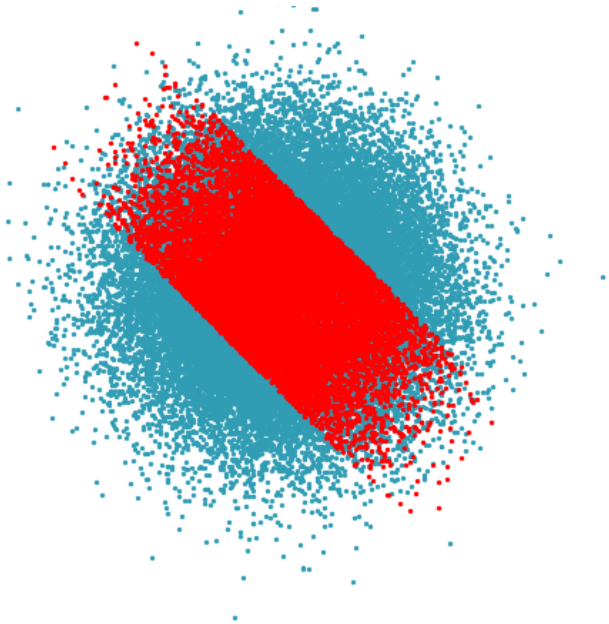

Filtering with only $z_0^+ = 0$

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Useful observation: Because of the algorithm used in Falcon to compute the GSO (`ffLDL` algorithm), we have the following:

$\tilde{\mathbf{b}}_\mathbf{0}, \ldots, \tilde{\mathbf{b}}_\mathbf{3} \approx \mathbf{b}_0, \ldots, \mathbf{b}_3$ and $\tilde{\mathbf{b}}_\mathbf{n}, \ldots, \tilde{\mathbf{b}}_\mathbf{n+3} \approx \mathbf{b}_n, \ldots, \mathbf{b}_{n+3}$

4. Recovering the private key: Falcon-512

- We combine several rows $\mathbf{b_i}$ to attenuate the noise on f, g.

Note: ulterior iterations of HPP solver are much less costly.

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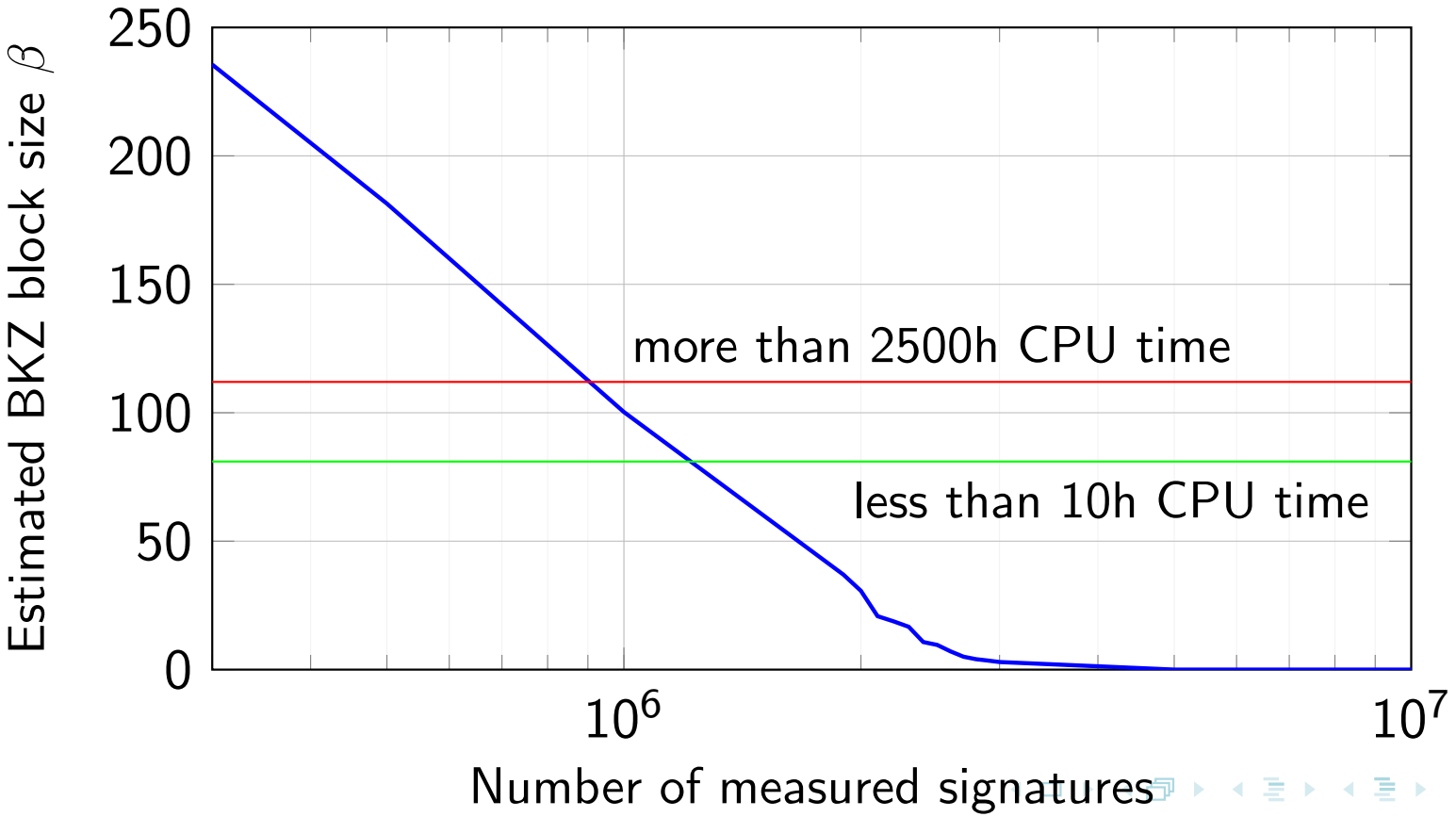

Conclusion

Sign(m, B):

2. $\mathbf{c} \leftarrow \texttt{HashToPoint}(r||m)$
3. $\mathbf{t} \leftarrow \mathbf{c} \cdot \mathbf{B}^{-1}$
4. $\mathbf{v} \leftarrow \texttt{ffSampling}(\mathbf{t}, \mathbf{B})$
5. $\mathbf{s} \leftarrow (\mathbf{t} - \mathbf{v}) \cdot \mathbf{B}$

- preimage computation
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Preimage computation: Improvement of State-of-the-Art attack.
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Questions ?

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Partial countermeasure for BaseSampler

Main idea: invert the sign of the operands to replace the (hardware) underflow by a (logical) overflow.

Replace the last substraction by the following:

1. $b \leftarrow \texttt{0xffffff}$
2. $b := b - \overline{u} + \overline{\mathsf{RCDT}[i]} + c$
3. return $b \gg 24$