YOLO YOSO
Fast and Simple Encryption and Secret Sharing in the YOSO Model

Ignacio Cascudo	IMDEA Software Institute, Madrid
Bernardo David	IT University of Copenhagen
Lydia Garms	Keyless Technologies Limited, London
Anders Konring	IT University of Copenhagen

The YOSO model *(Gentry et al. Crypto 21)*

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- YOSO (You Only Speak Once) MPC Model:
  - Very large pool of parties.
  - Each round is executed by a committee.
  - Each party speaks at most once. Identity of party not known until they speak.
  - Difficulties corruption by adversaries.

From PKE to YOSO

- Traditional MPC:
  - Ideal secure channels
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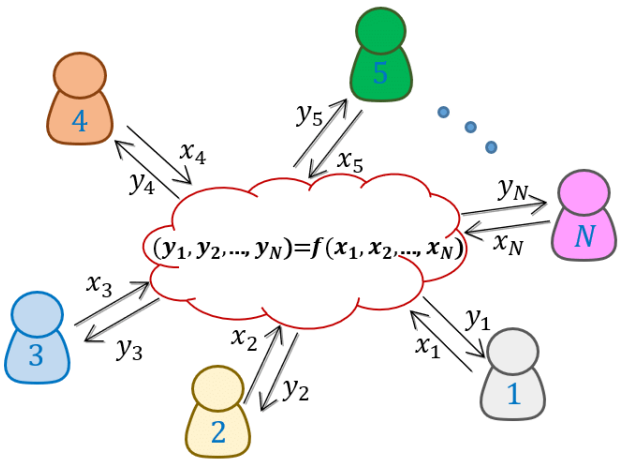

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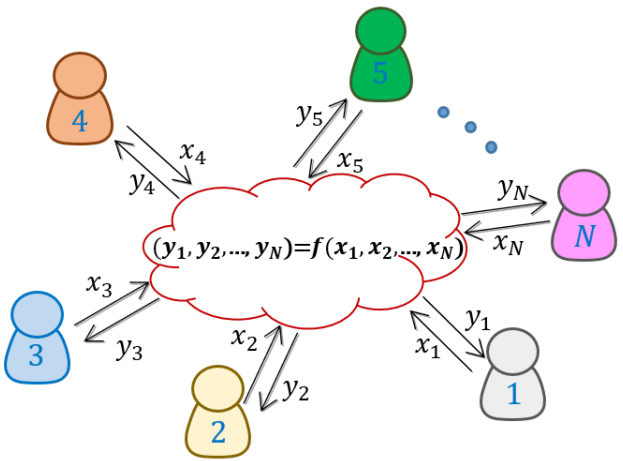
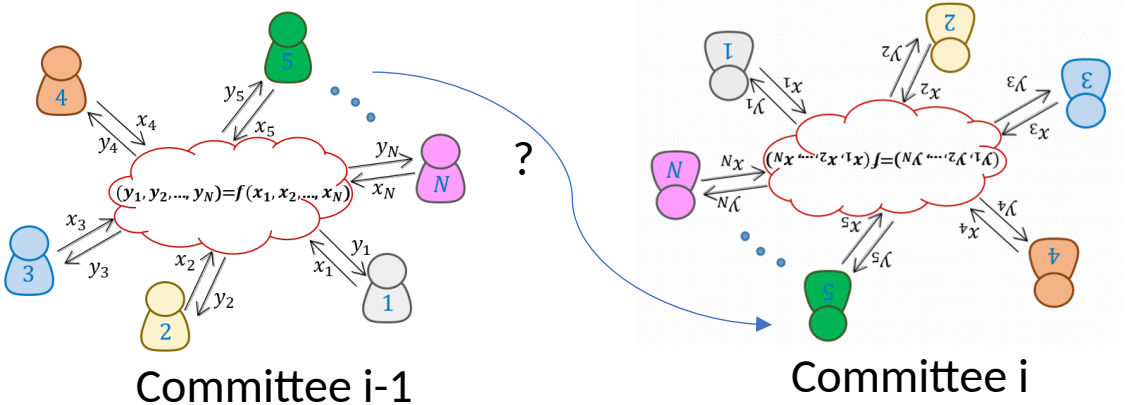


- YOSO MPC :
  - Every round is executed by a different anonymous committee.
  - How to encrypt towards an unknown party?



Previous Approaches

- "**Can a Blockchain keep a secret?**" *(Benhamouda et al., TCC 20)*: committee holds secret shared message, <25% corruption tolerated.

- **YOSO MPC**: idealized model of role assignment and future broadcast

- **Random-index PIR** *(Gentry et al. TCC 21)*: parties retrieve random anonymous public keys

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(*Campanelli et al., Asiacrypt 22*, Friday talk)

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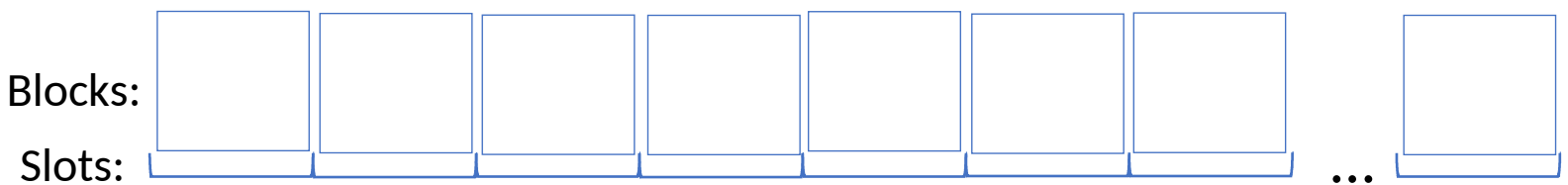

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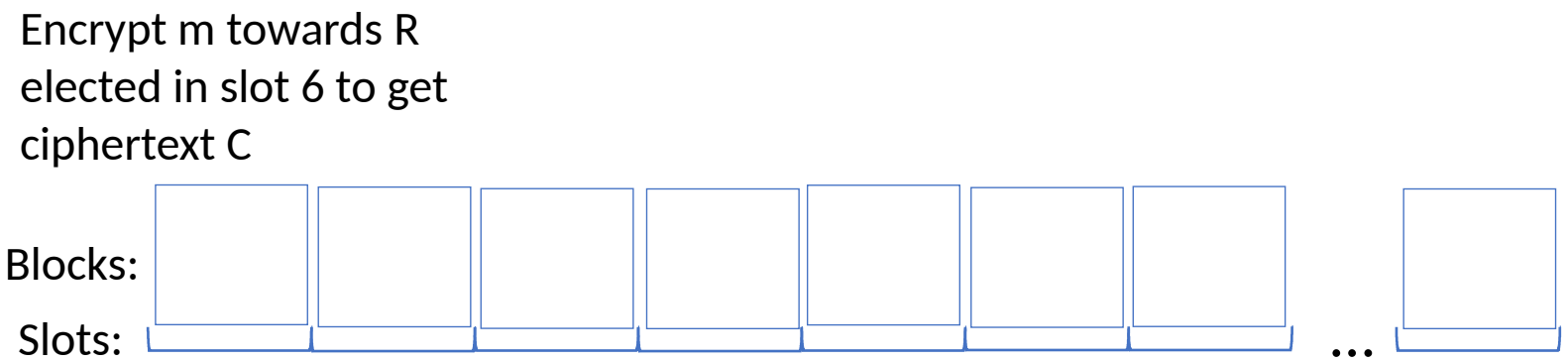

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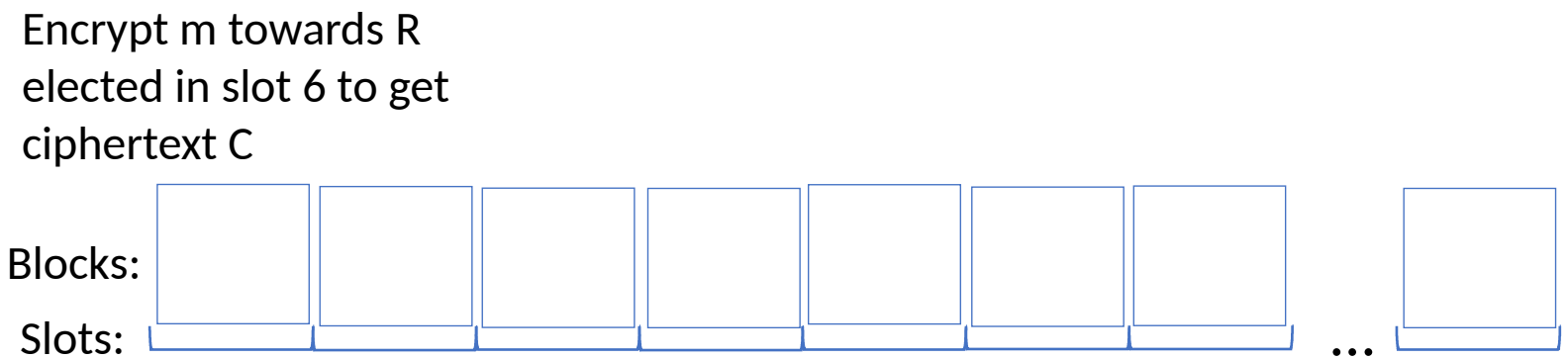

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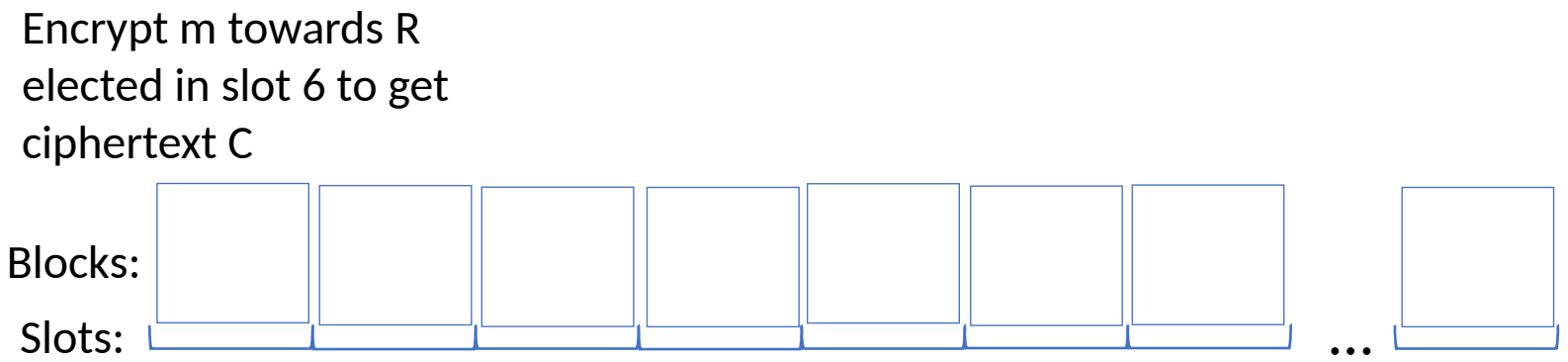

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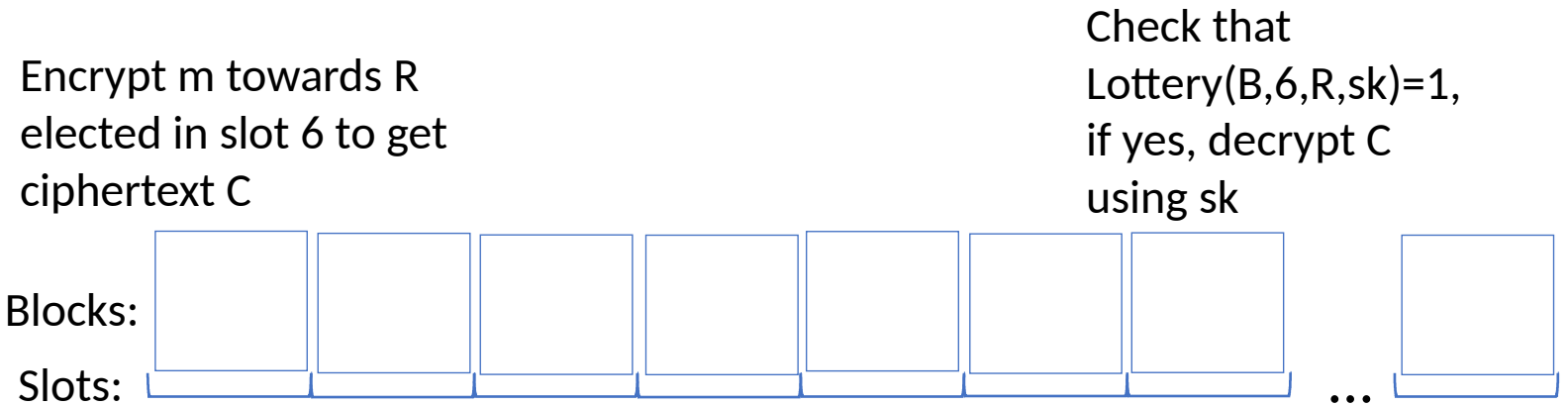

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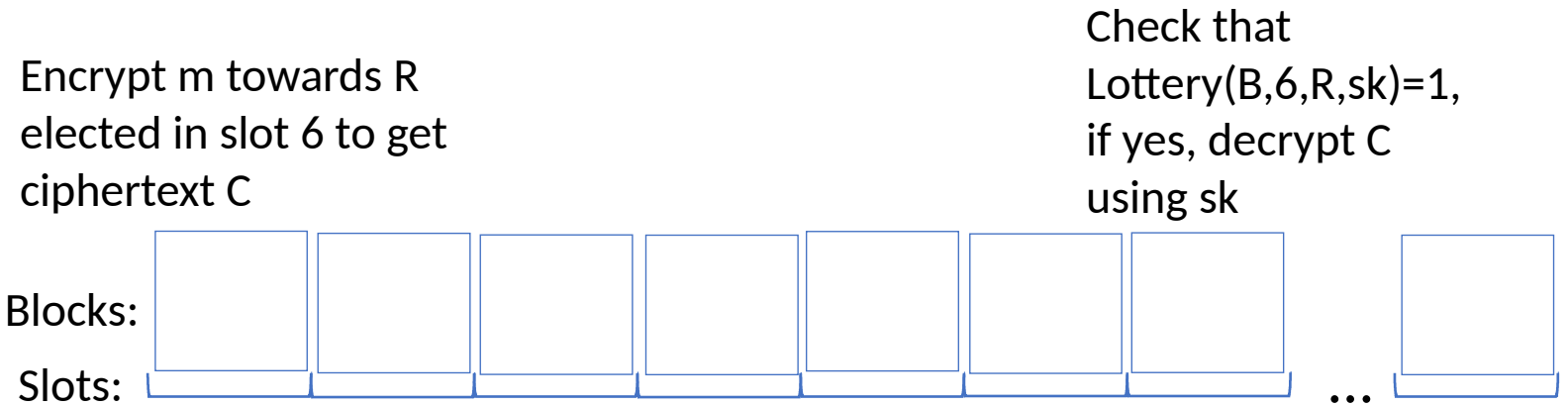

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  - Solutions for ETF in Campanelli et al: O(n) communication
  - Solutions for ECW in this paper: O(1)
- Transformation of ECW into full blown ETF using IBE and a committee that only holds shares of an IBE master secret key

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- PVSS resharing protocols

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- More ellaborated strategy using Camenish-Lysyanskaya signatures: preserves some anonimity even after speaking.
- This is good enough for ECW, but how about secret sharing to a committee? How do we prove consistency between shares?

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PVSS Constructions

- We present two constructions of PVSS:
  - HEPVSS: Generic PVSS from a $\mathbf{Z}_p$-Linearly Homomorphic Encryption (LHE) scheme
  - DHPVSS: DL-based PVSS with **constant size proof of sharing correctness.**

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  - $E(m_1 +_P m_2; r_1 +_R r_2) = E(m_1; r_1) +_C E(m_2; r_2)$
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Secure (indistinguishability of secrets) if Enc IND-CPA.

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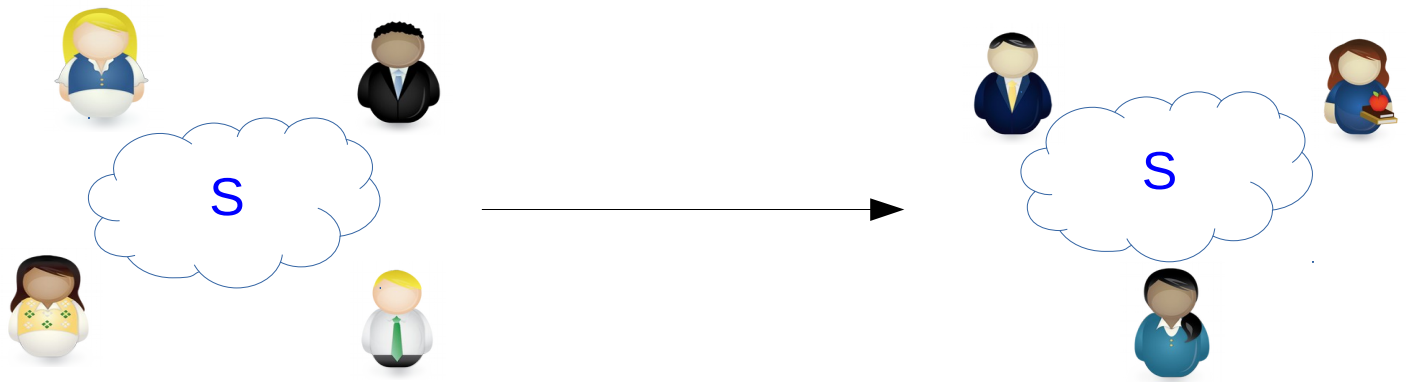

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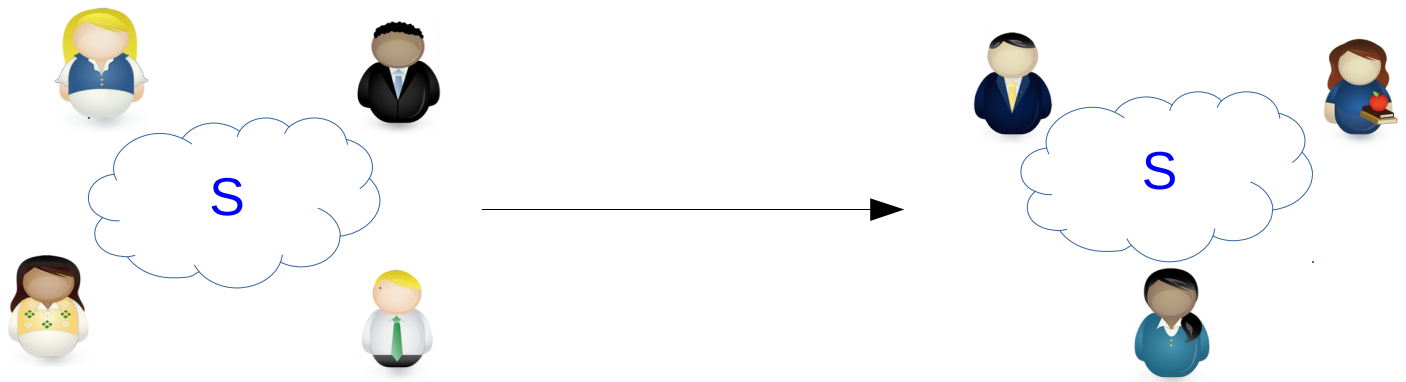
- In particular, this implies proofs of correct reconstruction (n=1, t=0).



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- Dealer publishes:
  - n encrypted shares: each 1 element in $\mathcal{G}$
  - Correctness proof: 2 $\mathbf{Z}_p$ elements

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- A_i encrypted as $C_i=A_i+ sk_D \cdot PK$

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- Extends to group $\mathcal{G}$=<G>:
  - Given C_1,...,C_n in $\langle G \rangle^n$. Sample **d**=(d_1,...,d_n) from $\mathcal{D}$.
    - If $C_i = f(i) \cdot G$, deg f ≤ t, i=1,...,n, then $\Sigma\, d_i \cdot C_i = 0$
    - If not, $\Sigma\, d_i \cdot C_i = 0$ with probability 1/p

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$C_i = f(i) \cdot G + sk_D \cdot PK_i$ $\xrightarrow{C_i,\ i=1,\ldots,n}$ $C_i = f(i) \cdot G + sk_i \cdot PK_D$ $\xrightarrow{sk_i}$ $f(i) \cdot G$

Proof: $(d_1, \ldots, d_n) = H((C_i), (PK_i))$ publicly computable dual codeword (H random oracle)

$$V = \sum d_i C_i = \sum d_i f(i) \cdot G + \sum d_i sk_D \cdot PK_i = sk_D \sum d_i \cdot PK_i = sk_D \cdot U$$

($\sum d_i f(i) \cdot G \to 0$)

π PoK: $sk_D = DL_G(PK_D) = DL_U(V)$

DHPVSS in detail

$PK_D = sk_D \cdot G$

S $\longrightarrow$ $f(i) \cdot G$

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Proof: $(d_1, \ldots, d_n) = H((C_i), (PK_i))$ publicly computable dual codeword (H random oracle)

$$V = \sum d_i C_i = \cancel{\sum d_i f(i) \cdot G}^{0} + \sum d_i sk_D \cdot PK_i = sk_D \sum d_i \cdot PK_i = sk_D \cdot U$$

π PoK: $sk_D = DL_G(PK_D) = DL_U(V)$ $\longrightarrow$ 2 Z_p elements

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- See paper for proofs of correct resharing

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- Parties can only reconstruct the group element s·G, not exponent s
- Possible alternative using *Castagnos-Leguillaumie 15* (not in this paper).
  - “hard DDH groups with easy DL subgroups”.
  - Allow to reconstruct exponent.
  - Attainable with class groups.

Conclusions / Future Work

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- Our new PVSS is the most communication-efficient to date, has other applications such as random beacons
- Future work: PVSS under other assumptions
  - MPC would require to retrieve elements in $\mathbf{Z}_{p,}$ not in $\mathcal{G}$.
  - CL15, Paillier...

Thank you!

https://eprint.iacr.org/2022/242