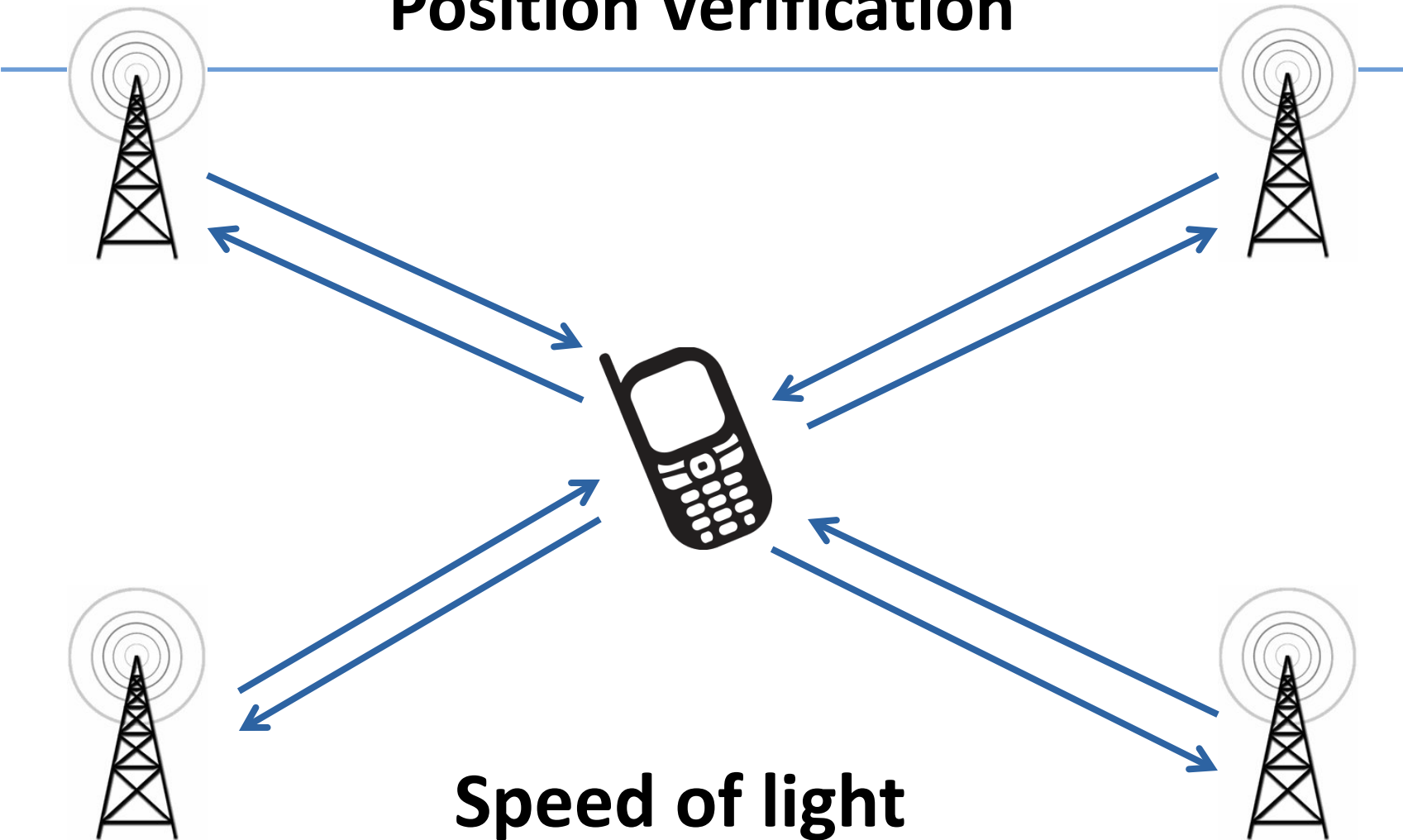


# Quantum Position Verification in the random oracle model

Dominique Unruh

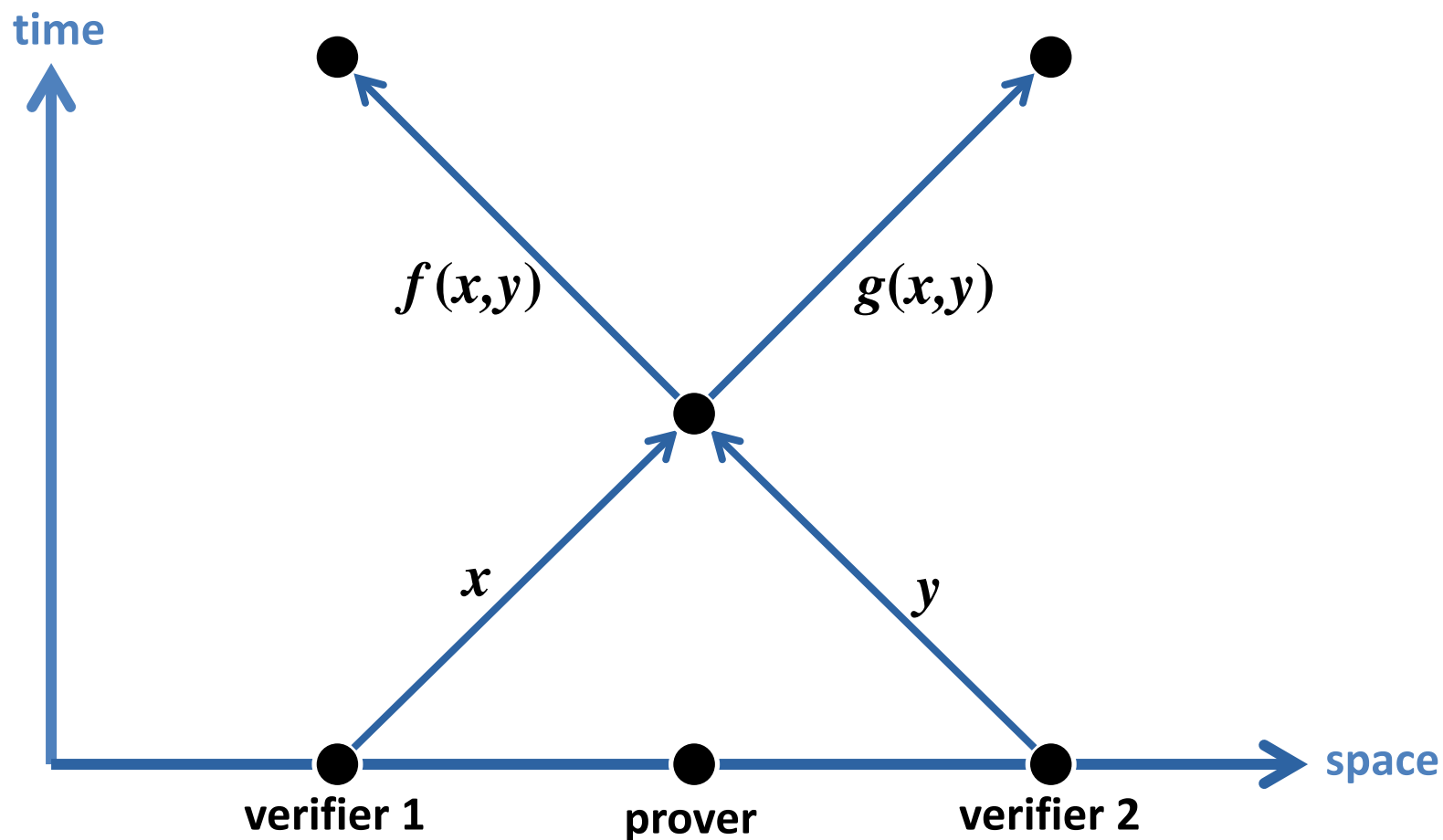
University of Tartu

# Position Verification

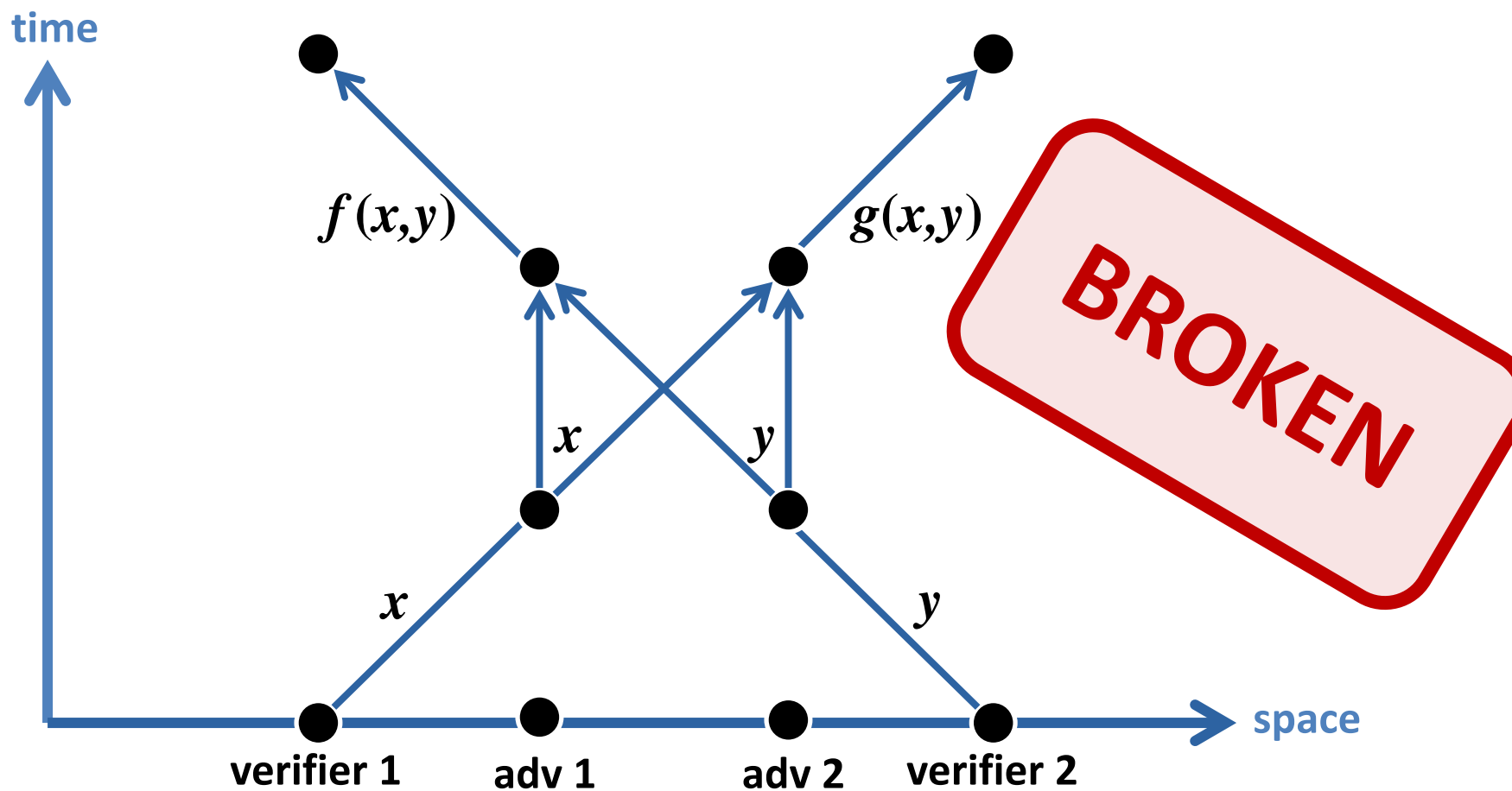


**Speed of light**  
**→ Position verified**

# A generic protocol



# A generic attack



# Impossibility

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- Applies to 3D-protocols as well
- Any number of verifiers
- Any computational assumptions  
(exception: transfer capacity limitations)

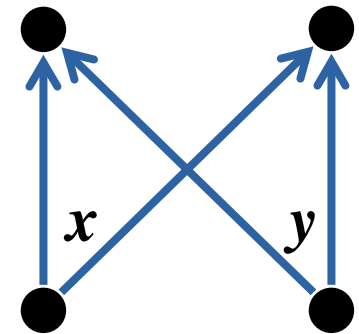
no mirrors?

[CGMO09] Chandran, Goyal, Moriarty, Ostrovsky,  
Position Based Cryptography, Crypto 2009

# Way out: quantum crypto

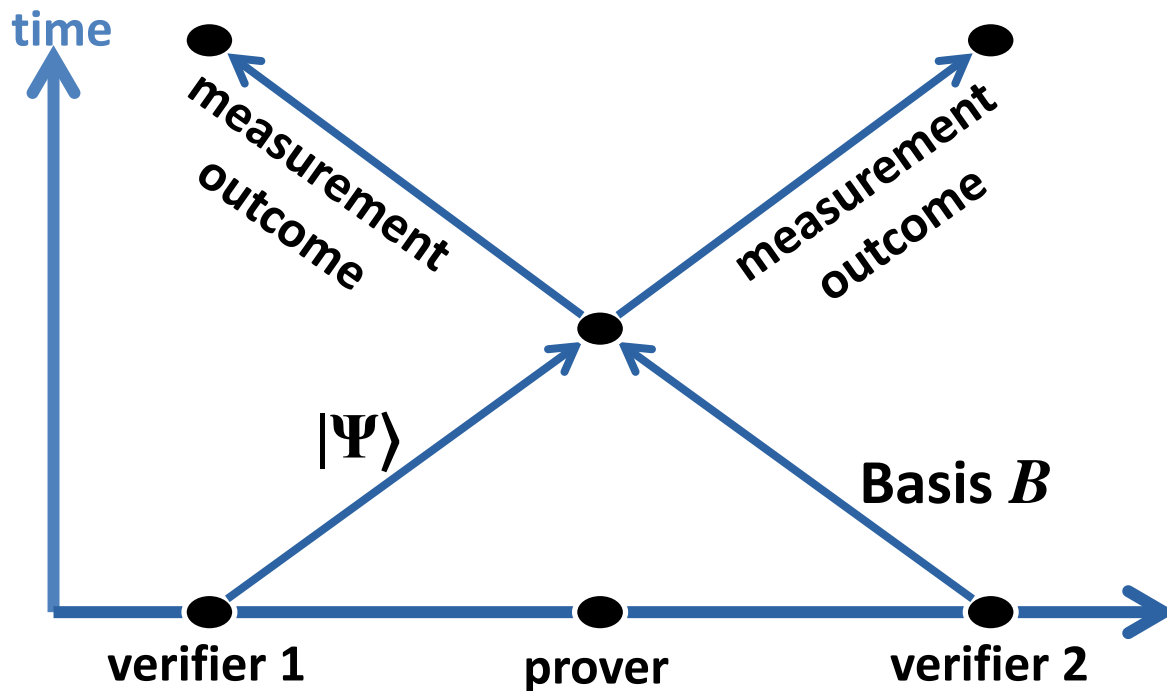
---

- In attack: adversary copies  $x, y$
- If  $x$  or  $y$  quantum: No cloning!
- Attack does not work
- Other attacks?
  - Without computational assumptions:  
Generic attack (exponential entanglement)



[BCF<sup>+</sup>11] Buhrman, Chandran, Fehr, Gelles, Goyal, Ostrovsky, Schafftner: *Position-Based Quantum Crypto*, Crypto 2011

# Quantum crypto: A secure protocol



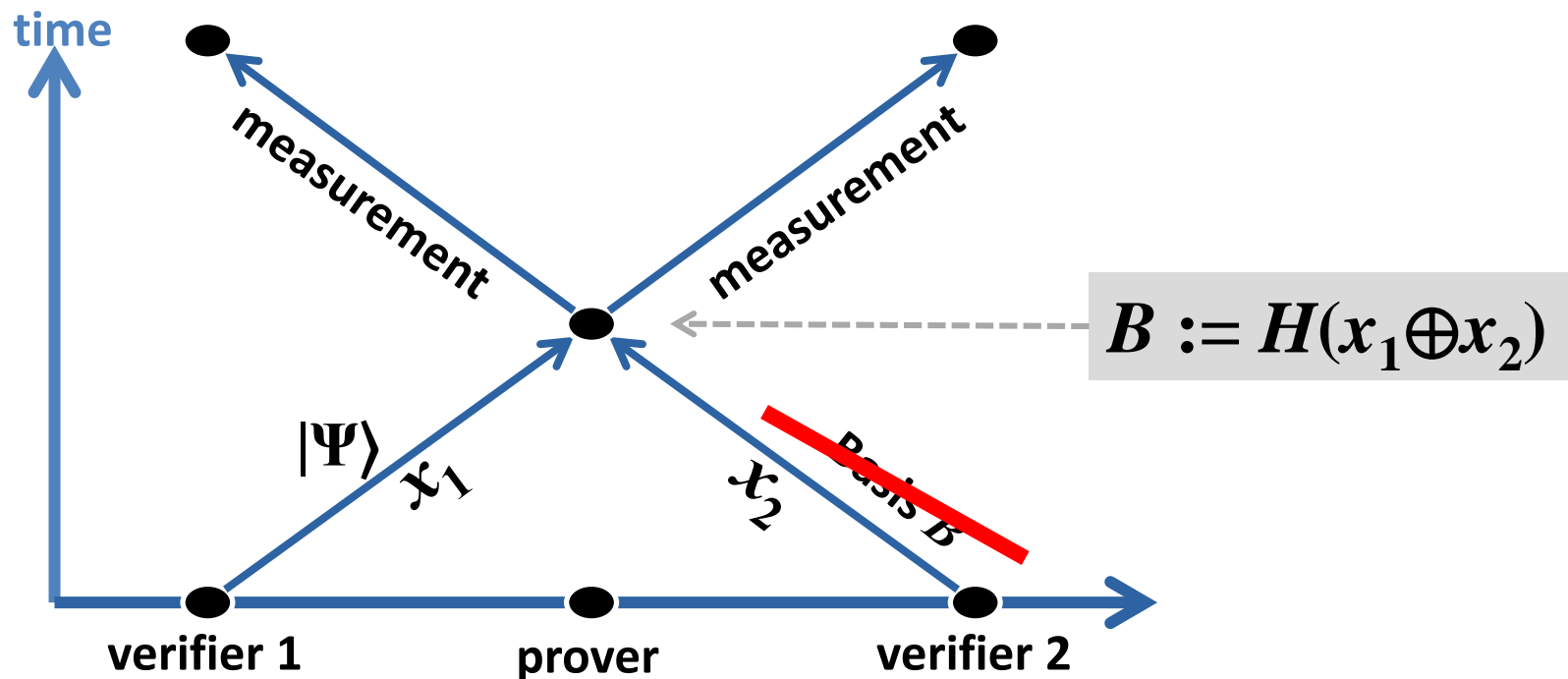
**Assumption:**  
No entangled photons

Only 1D proof

[TFKW13]

Tomamichel, Fehr, Kaniewski, Wehner: *One-Sided Device-Independent QKD and Position-Based Cryptography from Monogamy Games*, Eurocrypt 2013 (and [BCF<sup>+</sup>11])

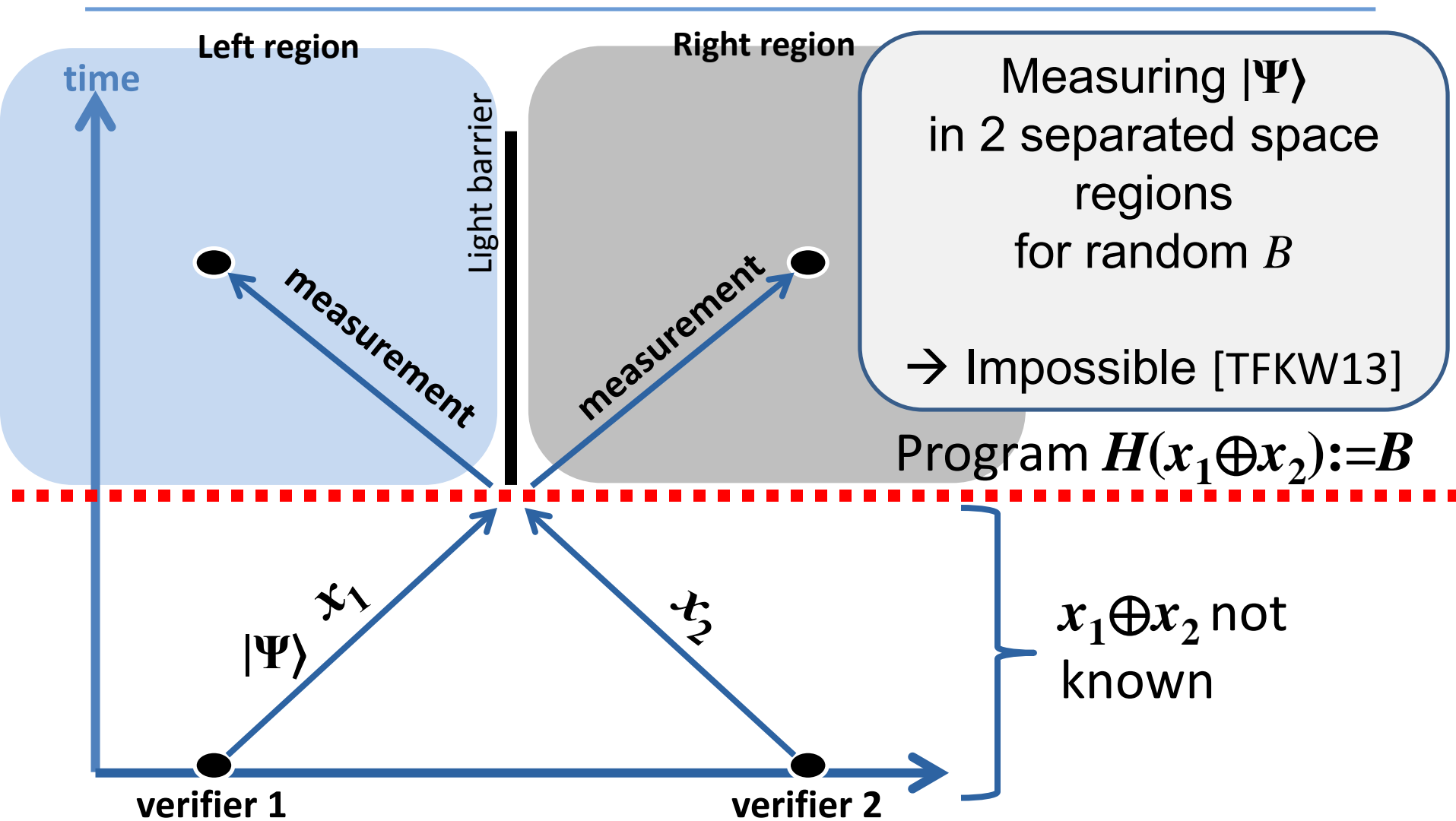
# Our protocol



- Avoids attack
- Provably secure (in random oracle model)

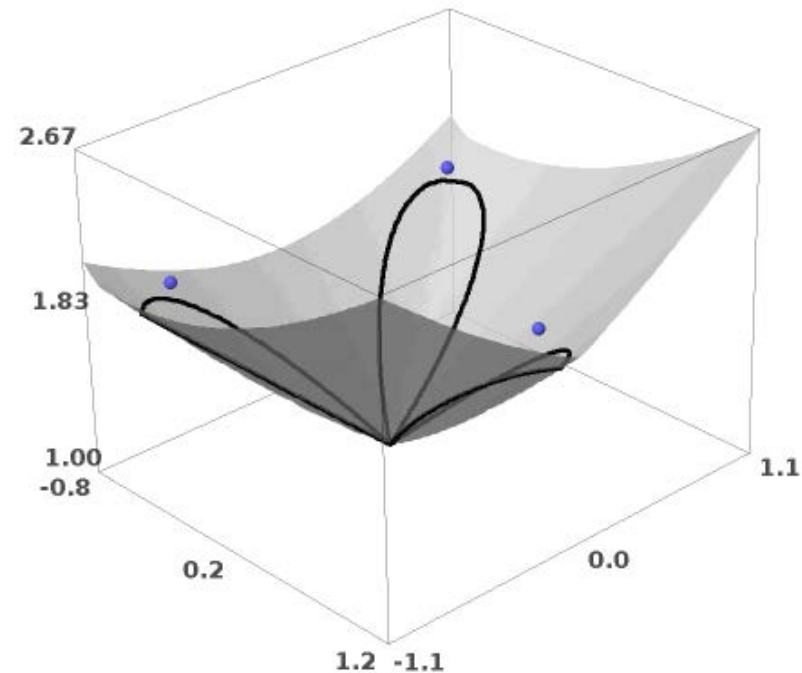


# Security proof (overview, 1D)



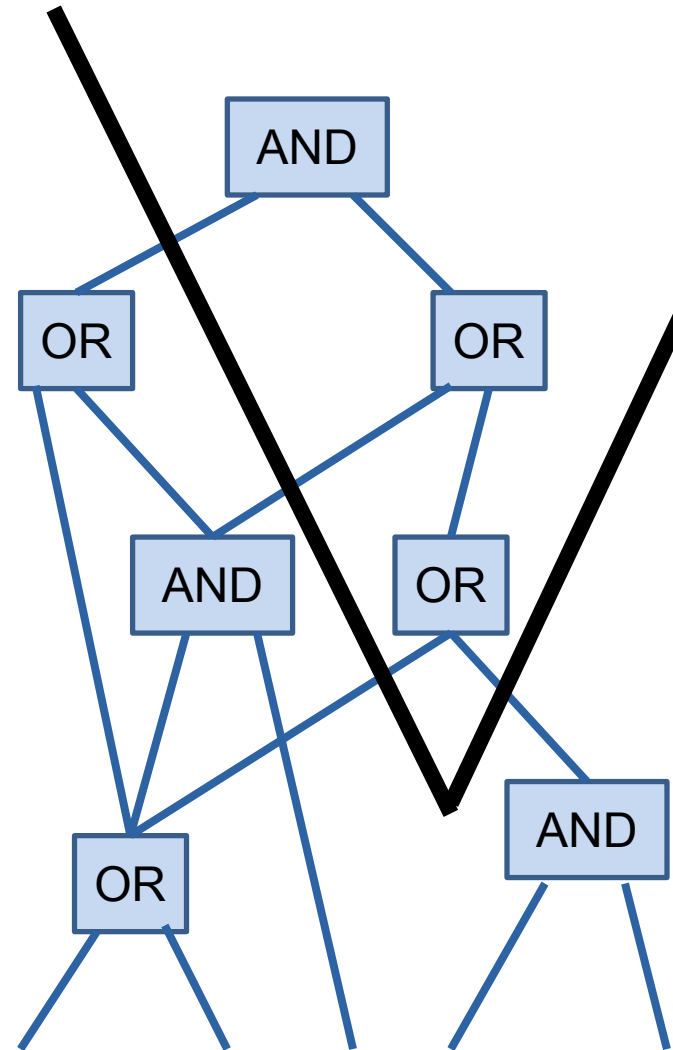
## 3D case

- 3D proof: regions overlap!
- Need to program RO at different times in different locations!
- Leads to curved “programming surface”
- New tool: spacetime circuits



# Proof technique: Space-time circuits

- How to reason about events happening along curved space-time surfaces? Tricky!
- Tool: Space-time circuits
  - No wire leaves light cone
- Then forget about geometry, only connectivity



# Open problems

---

- Improve error tolerance (3.7%)
- Improve precision in 3D case
- Security in standard model (no random oracle)?  
Or even without hardness assumptions?

# I thank for your attention



Logo soup



European Union  
European Social Fund



Investing in your future



DoRa



European Union  
Regional Development Fund



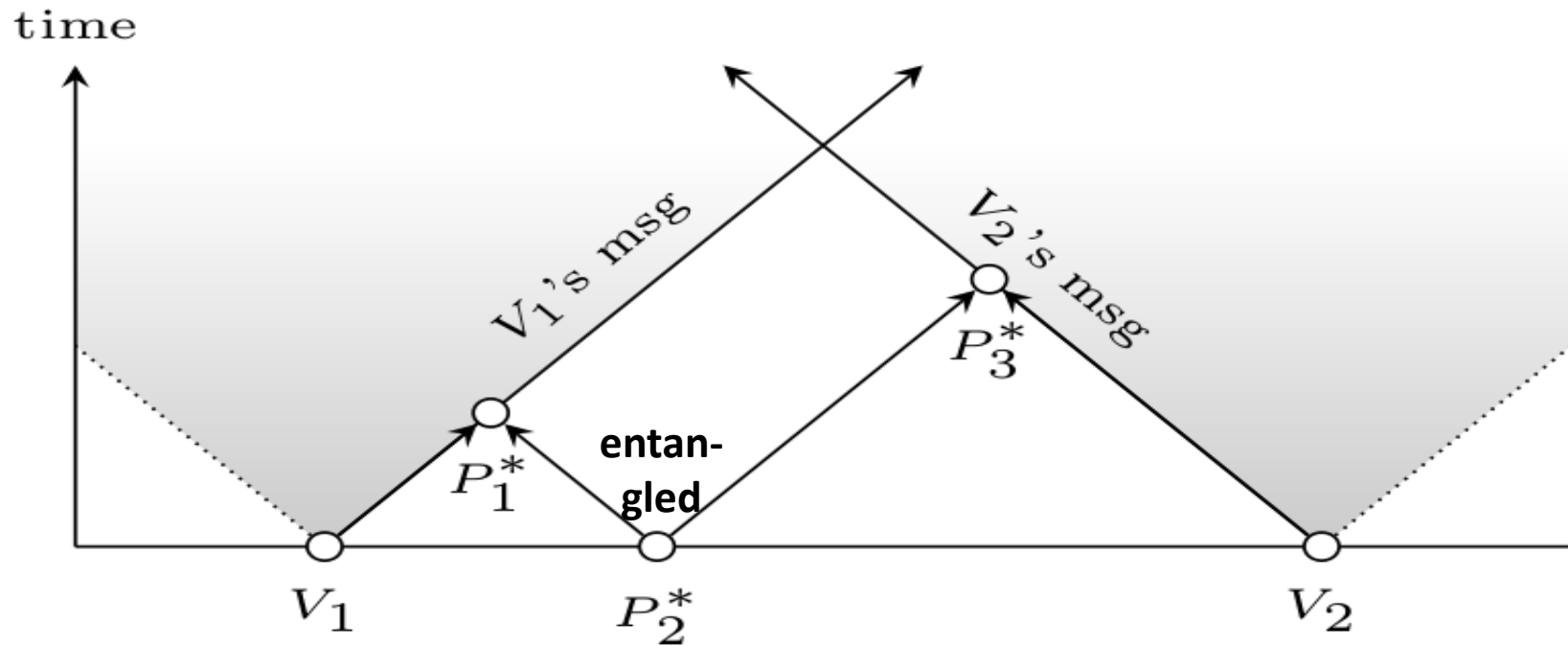
Investing in your future



ESTONIAN COMPUTING

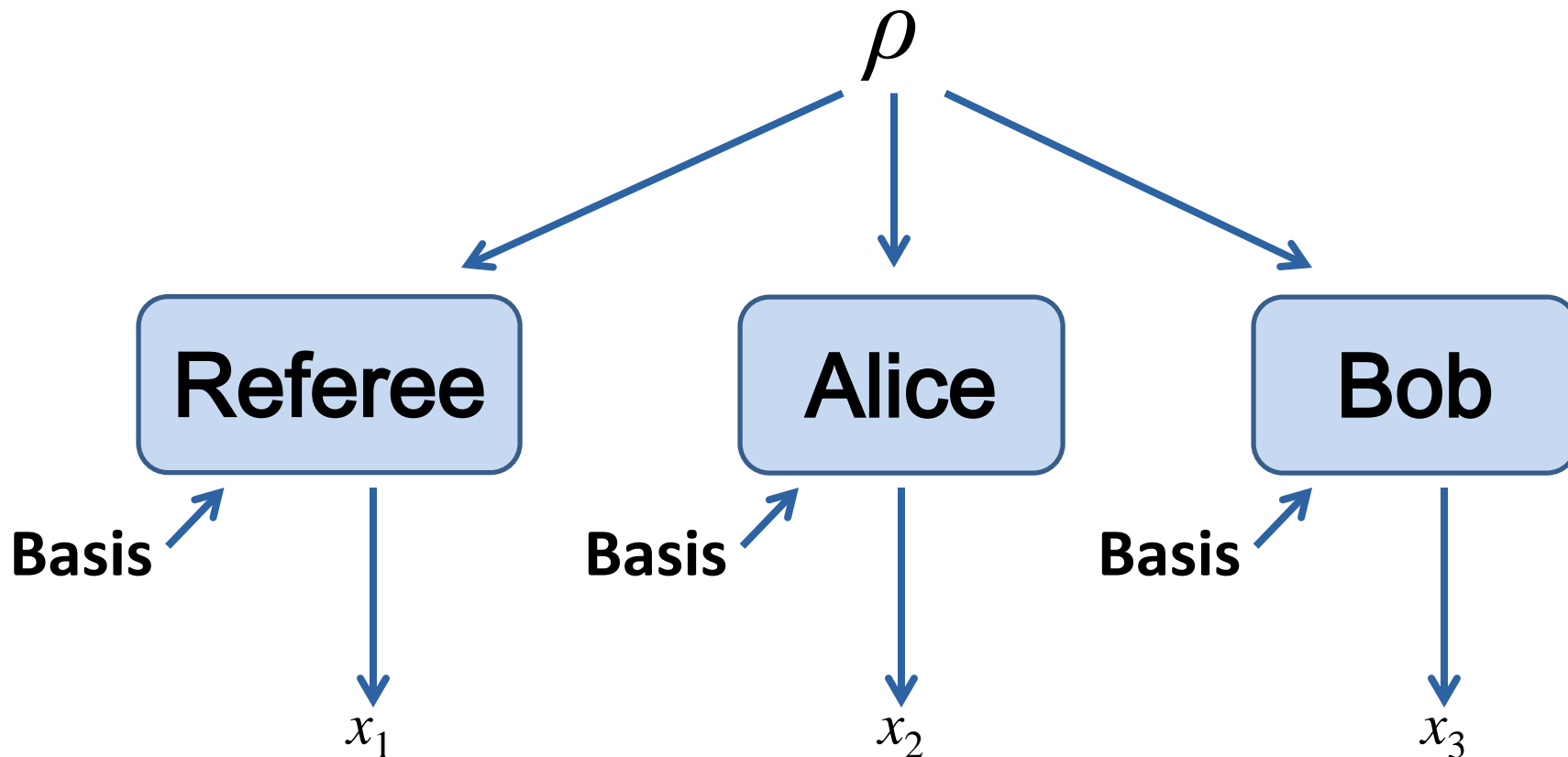
This research was supported  
by European Social Fund's  
Doctoral Studies and  
Internationalisation  
Programme DoRa

# Attack on [TFKW13]



- No entanglement = strong assumption
- Does not work in 3D (bug in [BCF<sup>+</sup>09] proof)

# Monogamy game



$\Pr[x_1=x_2=x_3]$  small

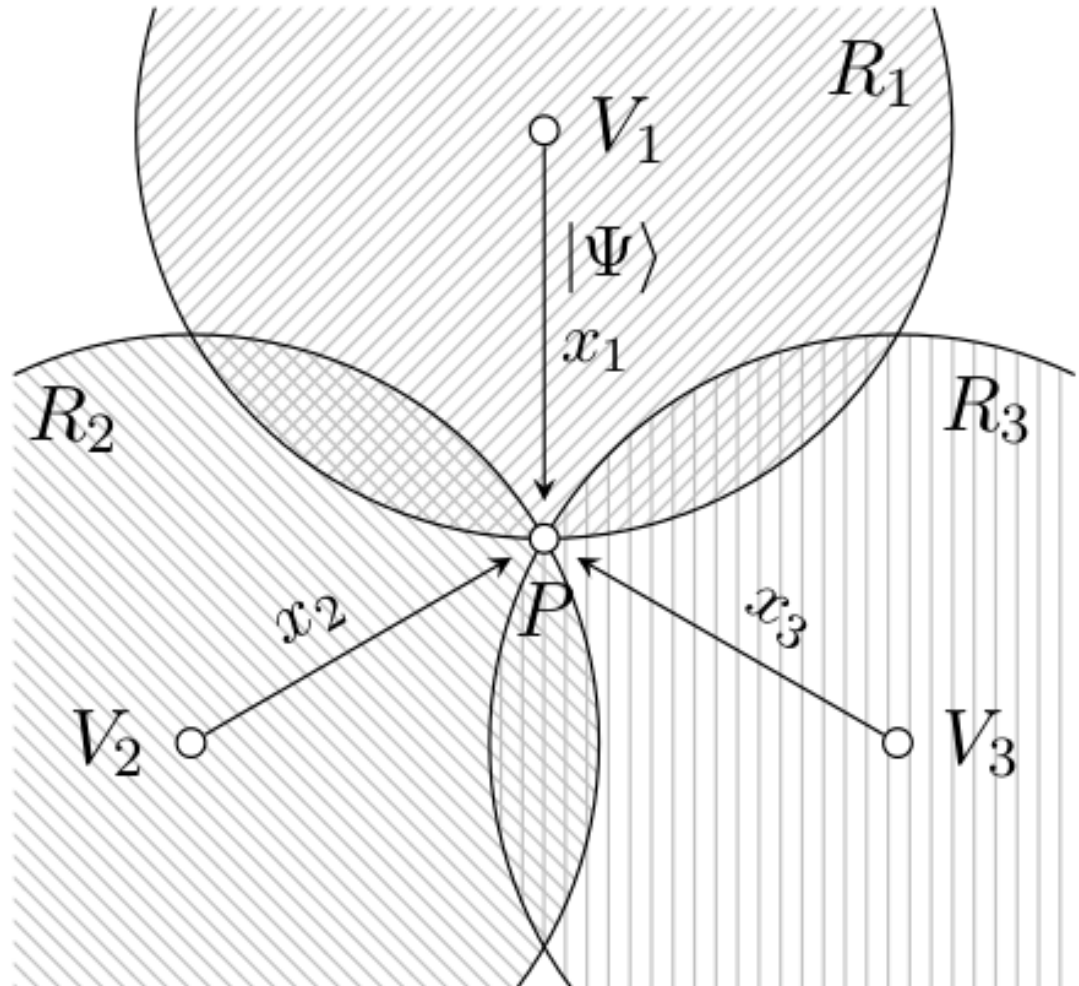
[TFKW13]

# Security in higher dimensions?

## Programming the random oracle:

When all signals reach honest  $P$  (no later!)

**Picture:** Which space-point reaches which verifier after programming





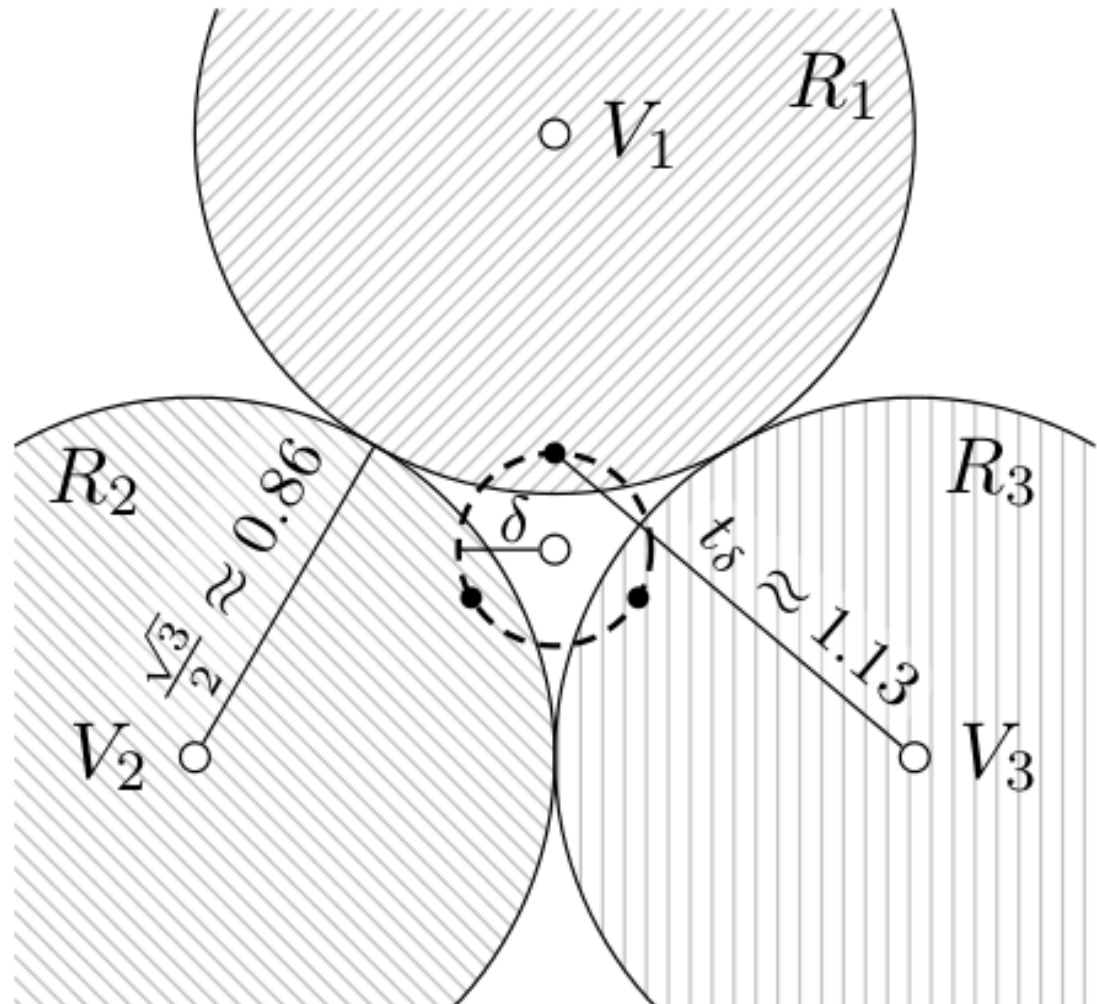
# Programming later?

Assume that  $\text{adv}$  is not in  $\delta$  radius of  $P$ .

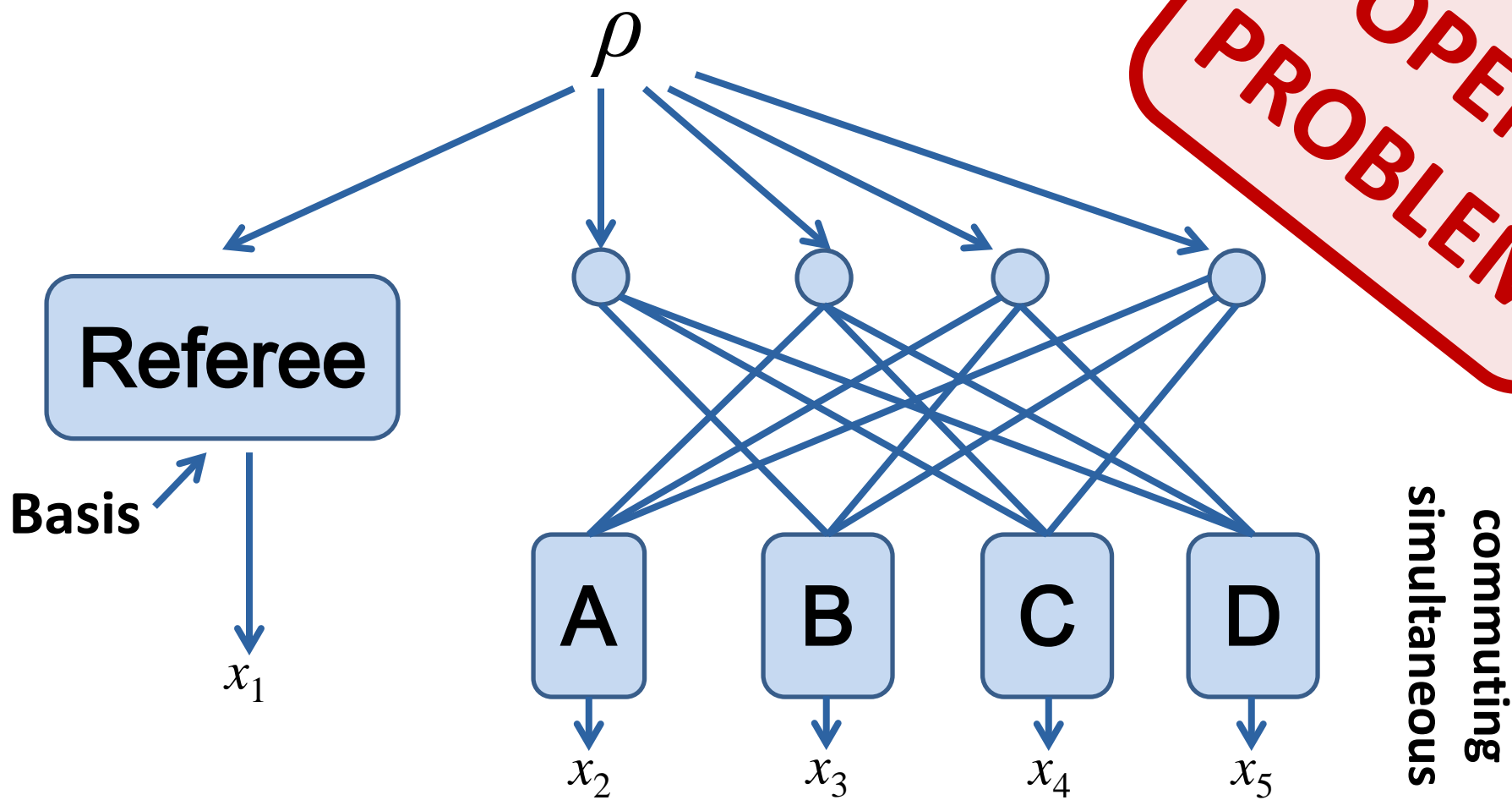
Then achieve non-overlapping regions  $\rightarrow$  apply monogamy

**Quality:**

$$\delta = 0.38 * |V-P|$$

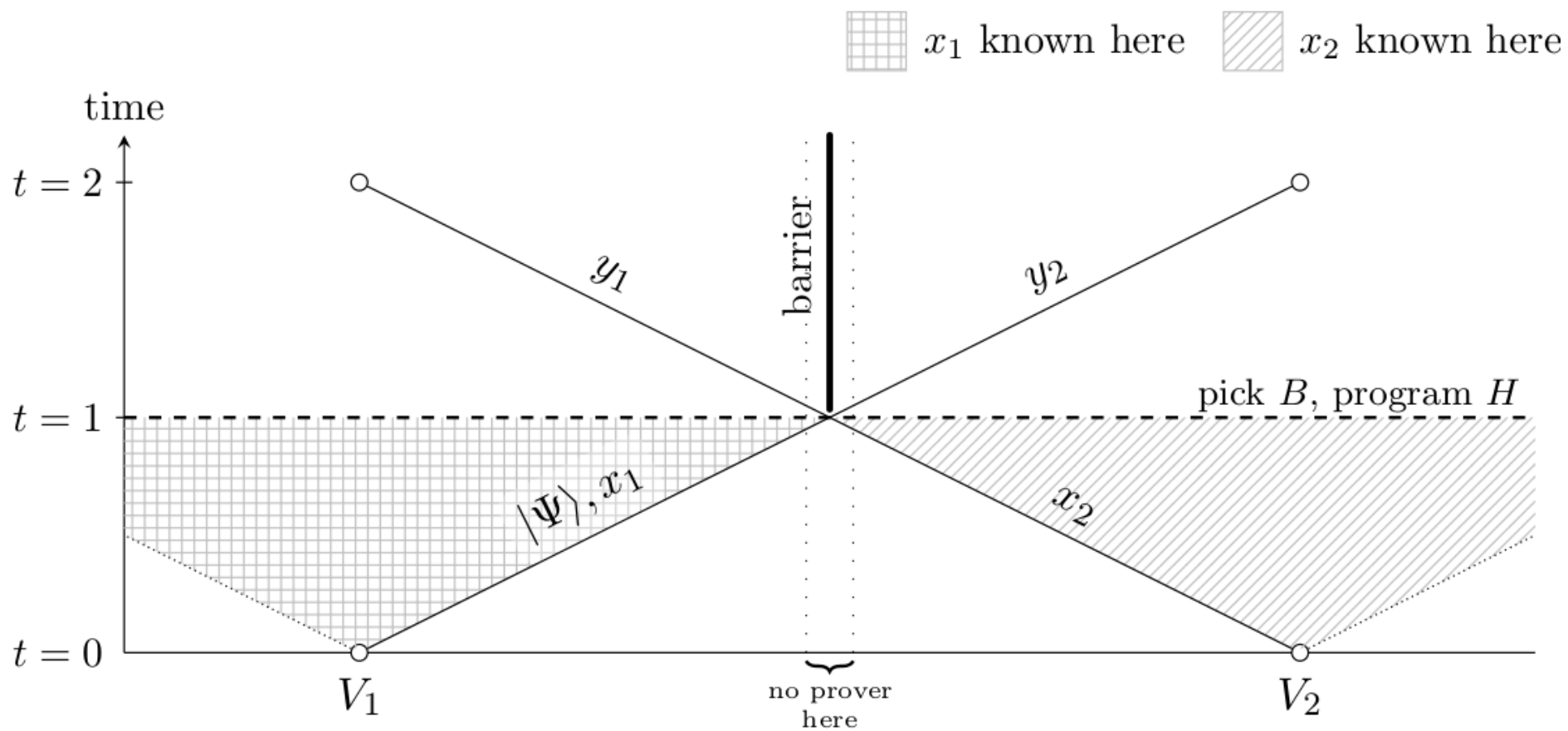


# Multiparty Monogamy Game



$\Pr[\text{all } x_i \text{ equal}] \text{ small??}$

# Security proof



## Result:

- Our protocol is secure if:

Only the honest prover is at a point in spacetime such that:

- Can be reached from all verifiers
- Can reach  $V_1, V_2$

Because monogamy-games for two recipients only

- Geometric condition, e.g. honest prover in the middle of verifier-tetrahedron

# Proof technique: Space-time circuits

- How to reason about events happening along curved space-time surfaces? Tricky!
- Tool: Space-time circuits
  - No wire leaves light cone
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