4D Techniques

DRDT7.3

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Introduction & Metrics

4D

3D

+

High Precision Timing

To mitigate Pile-Up, improve Vertex location, increase Detector Resolution, improve particle identification…

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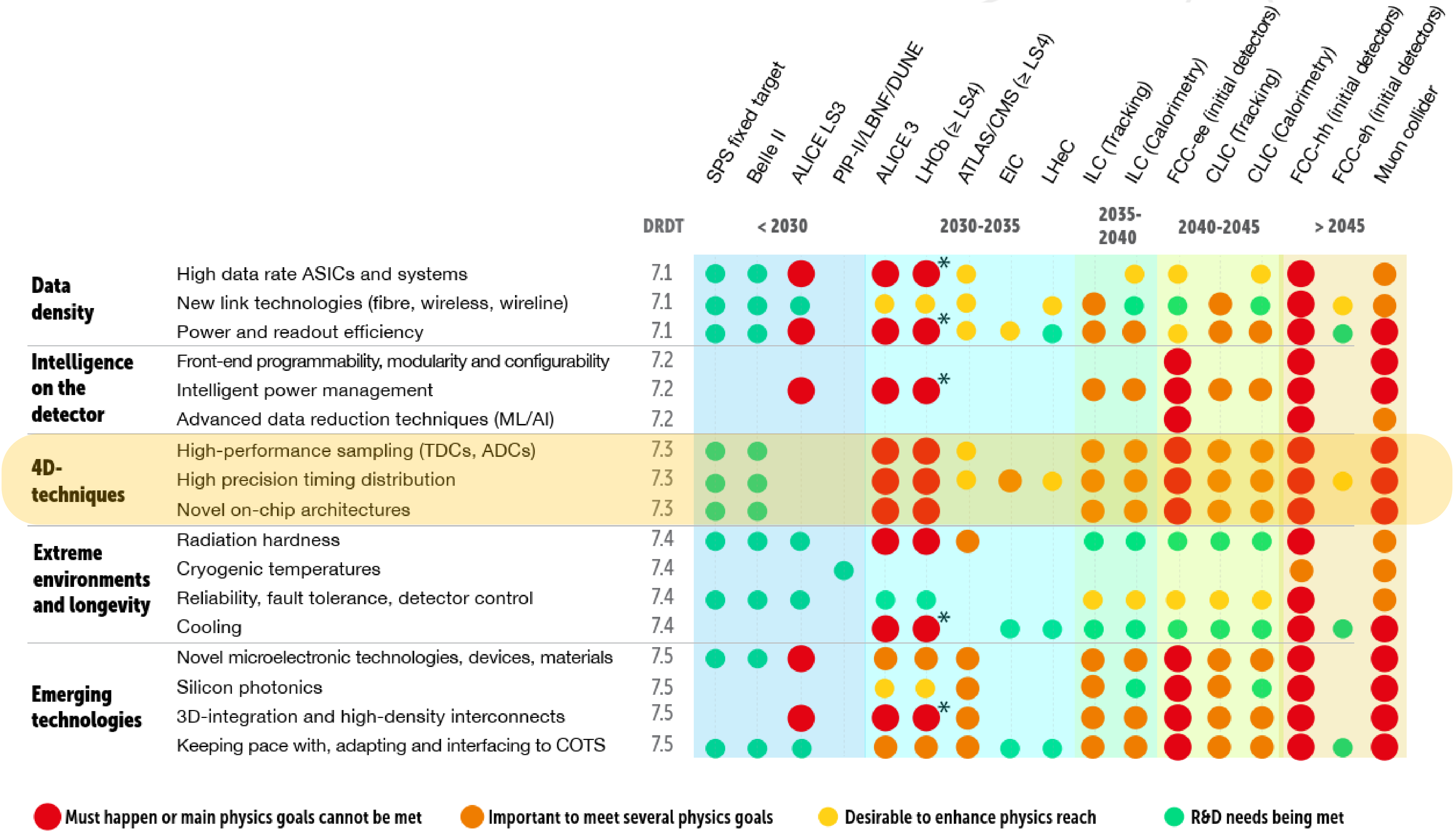
DRD7.3



* LHCb Velo

4D-Techniques - Session Structure

- Timing Distribution & Simulation
  - Timing Metrics *(Sophie Baron, CERN)*
  - Highlight on Detector timing simulation *(Louis d'Eramo, CNRS)*
- 4D in trackers / Novel on-chip architectures
  - Main challenges overview *(Adriano Lai, INFN)*
  - The case of the LHCb Velo Upgrade *(Martin Van Beuzekom, Nikhef)*
- 4D in calorimeters & PID / High-performance sampling
  - Main challenges overview *(Marek Idzik, AGH & Patrick Robbe, IN2P3)*
  - The case of ECAL Upgrade II of LHCb *(Dominique Breton, IN2P3)*
- Discussion
  - identify key challenges and topics to be investigated in the future and potential space for collaborations
    - Your inputs will be key!

Our [biased] view of the challenges ahead, and a selection of examples

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Timing Distribution Challenges

Detector Performance

“**Precision** nanosecond-level **timing** also helps to mitigate pile-up effects”

“achieve a **timing performance** below the 10 ps level”

“**timing precision** down ~ 10 ps by 2030”

“Timing resolution per track”

“Timing precision per hit”

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Timing Requirements

Jitter
Phase Noise

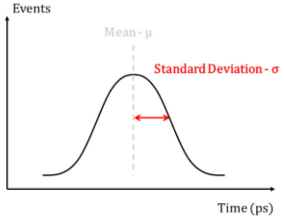
Wander
Determinism

Timing Metrics

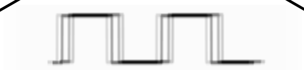
LHC Bunch Clock

Clock Quality

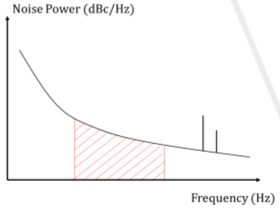
Fast Variations (<1s)



time



freq.

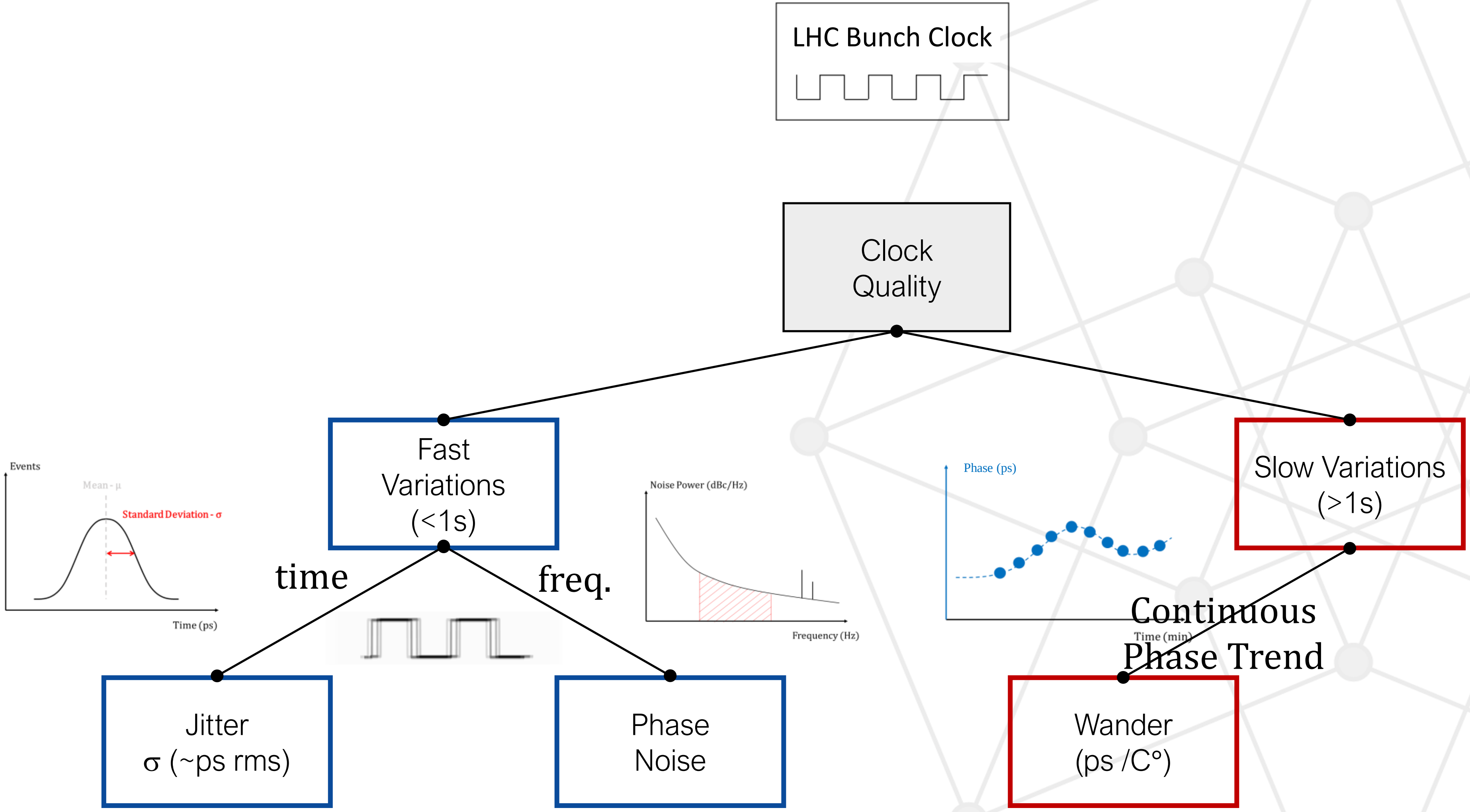


Jitter
σ (~ps rms)

Phase Noise

Electronics noise

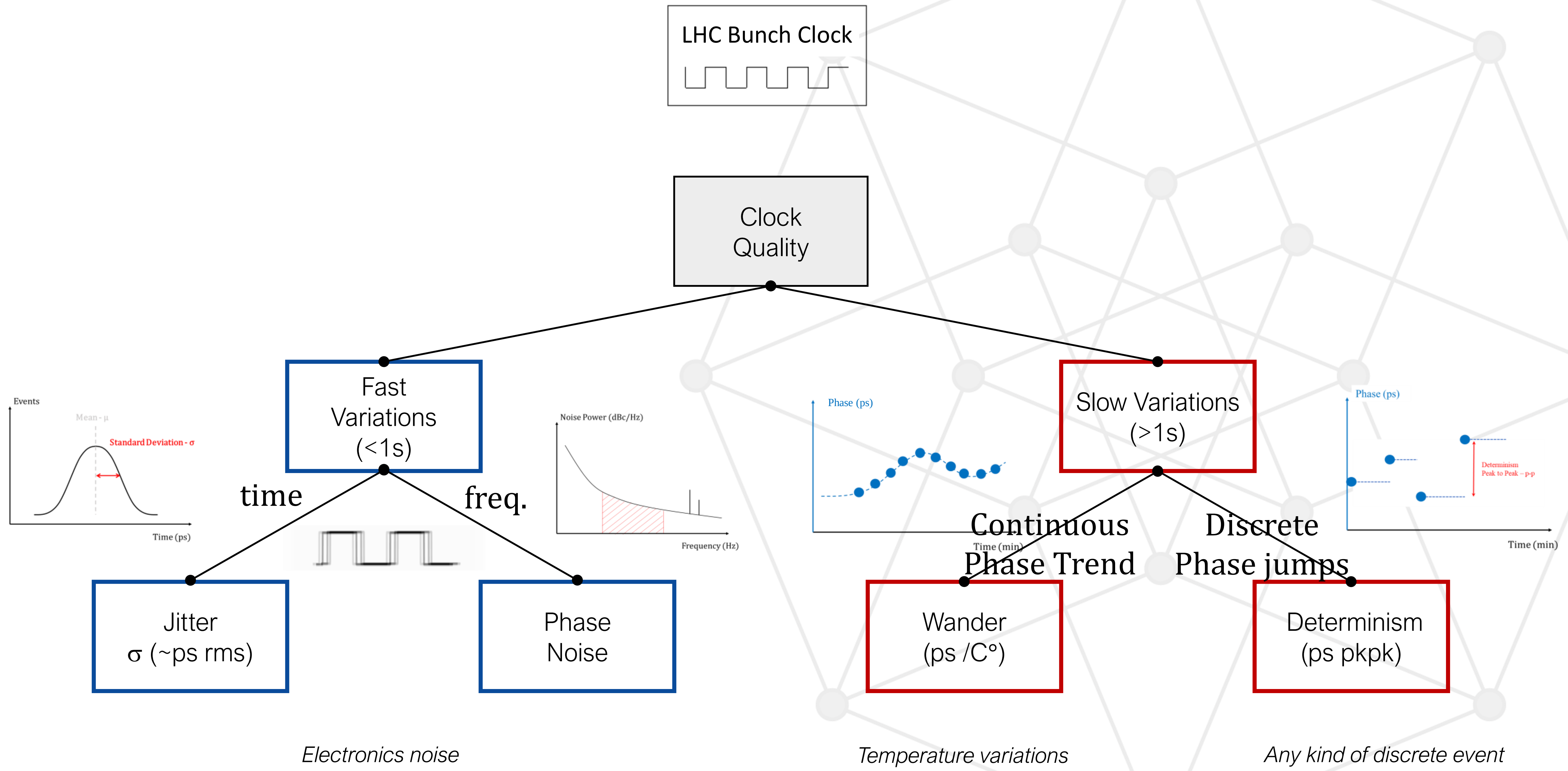
Timing Metrics



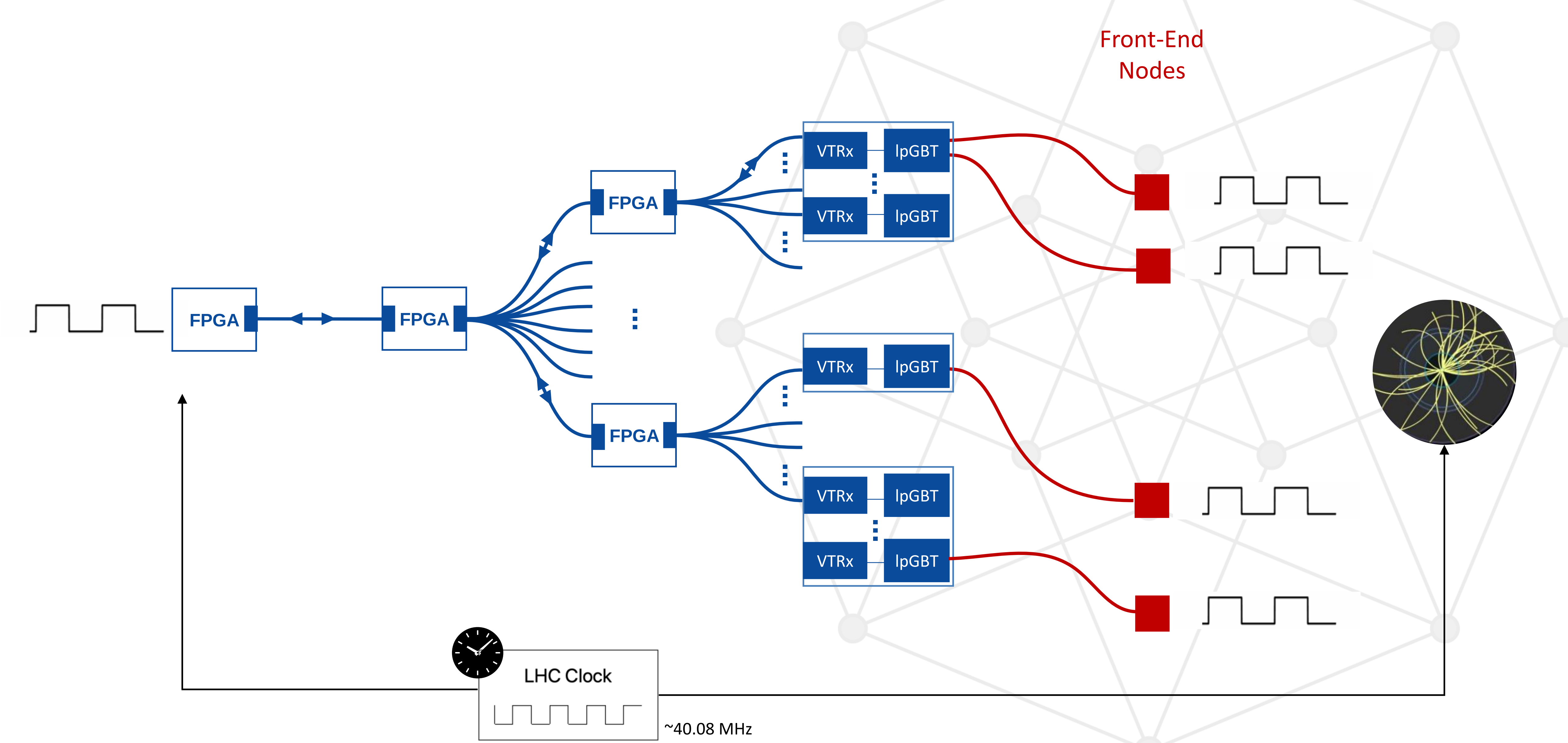
Electronics noise

Temperature variations

Timing Metrics



Timing Distribution



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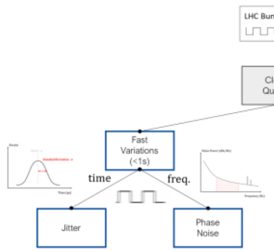
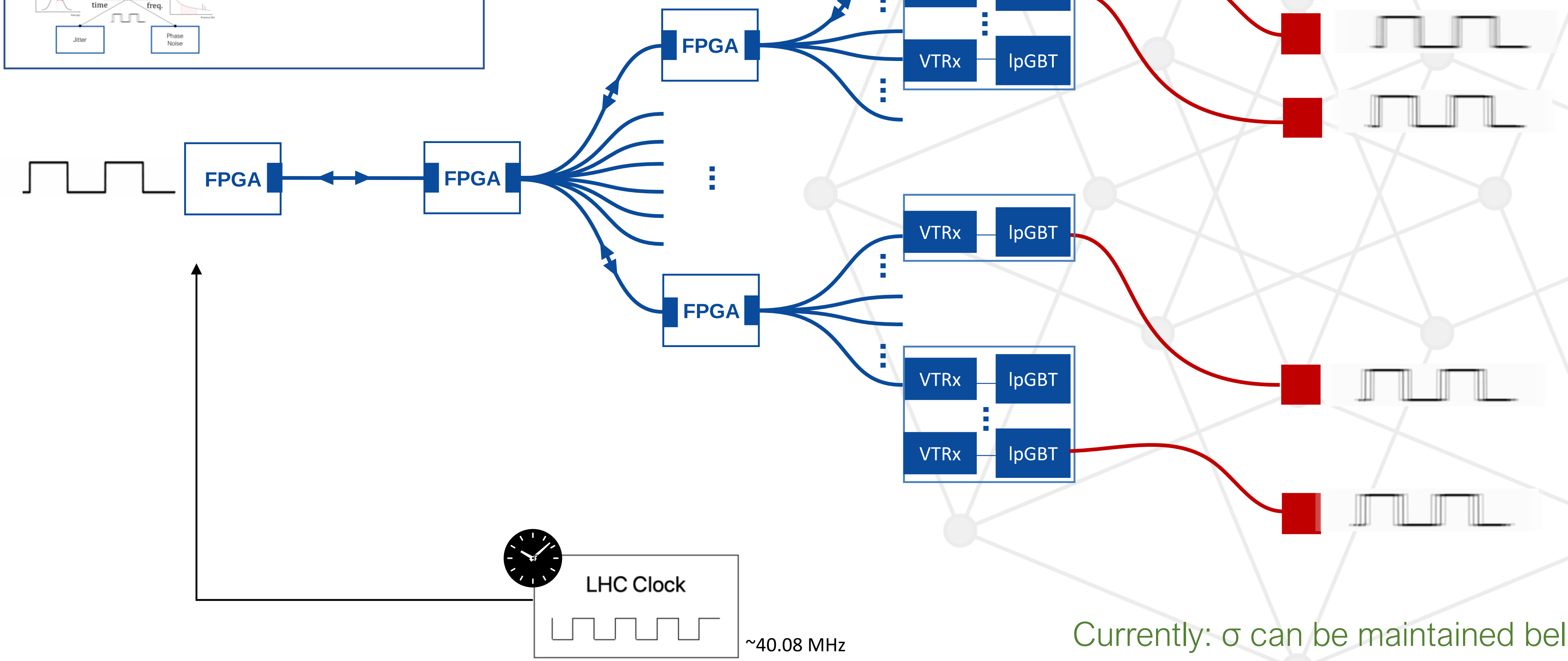
Timing Distribution & Metrics

Jitter & Phase Noise



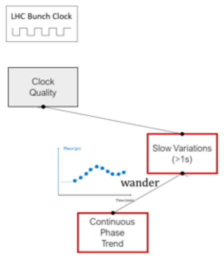
Fast & random effet



Currently: σ can be maintained below 5ps rms

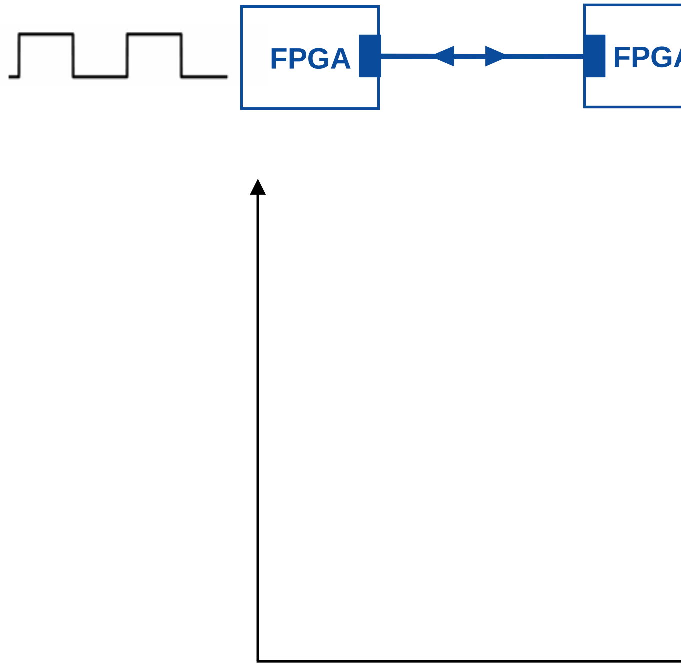
Timing Distribution & Metrics

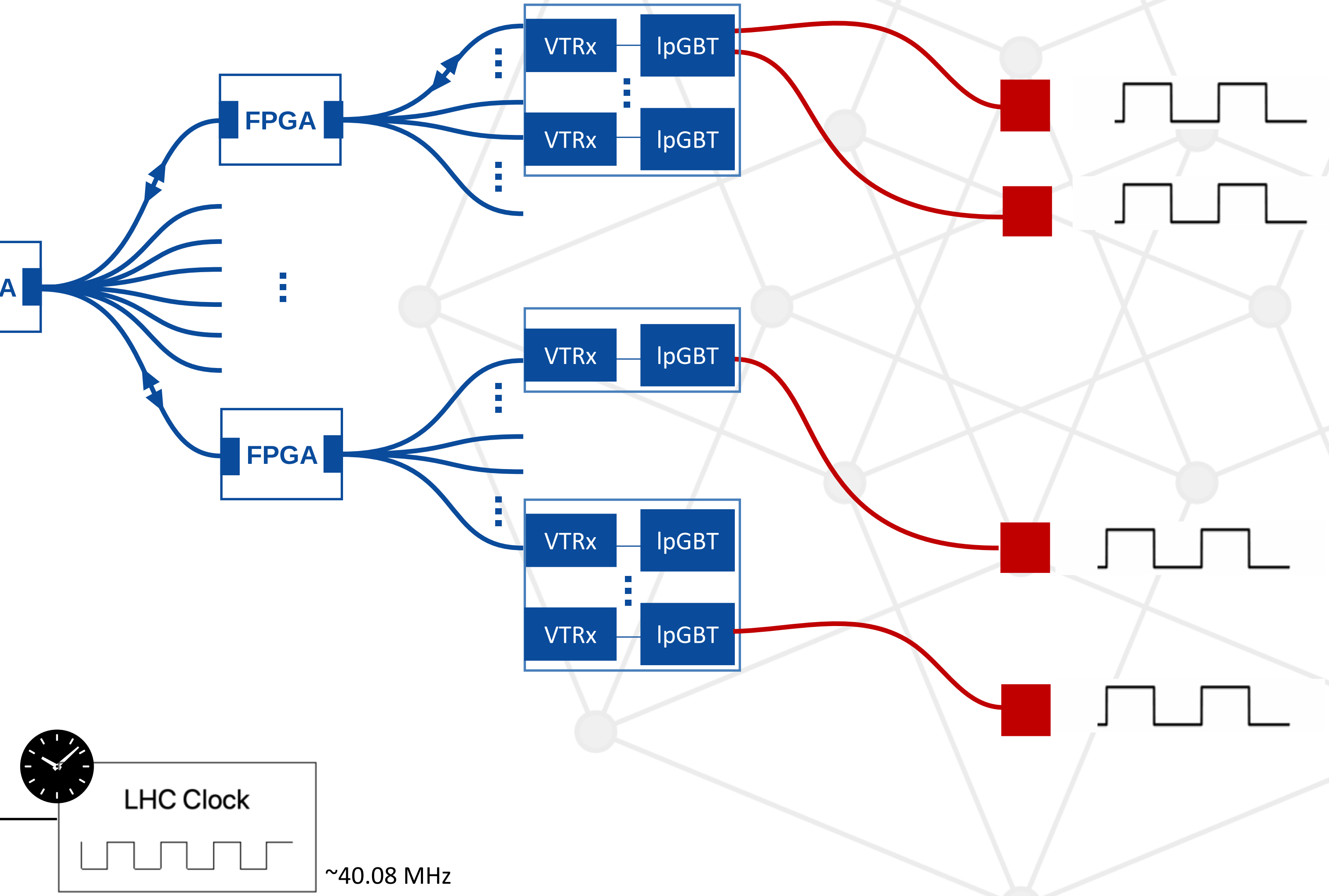
Wander



Temperature Induced Continuous effet

$T=t_0$





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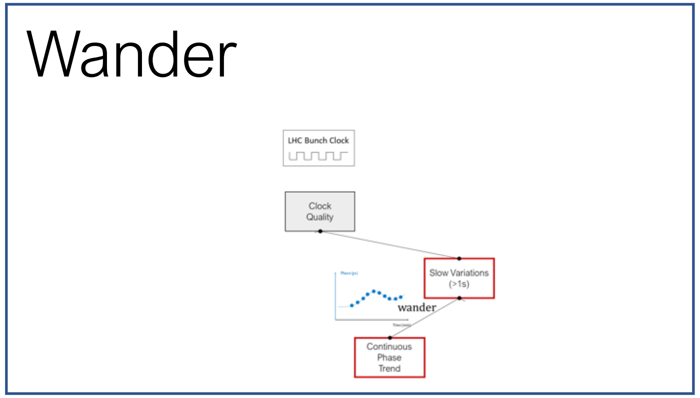
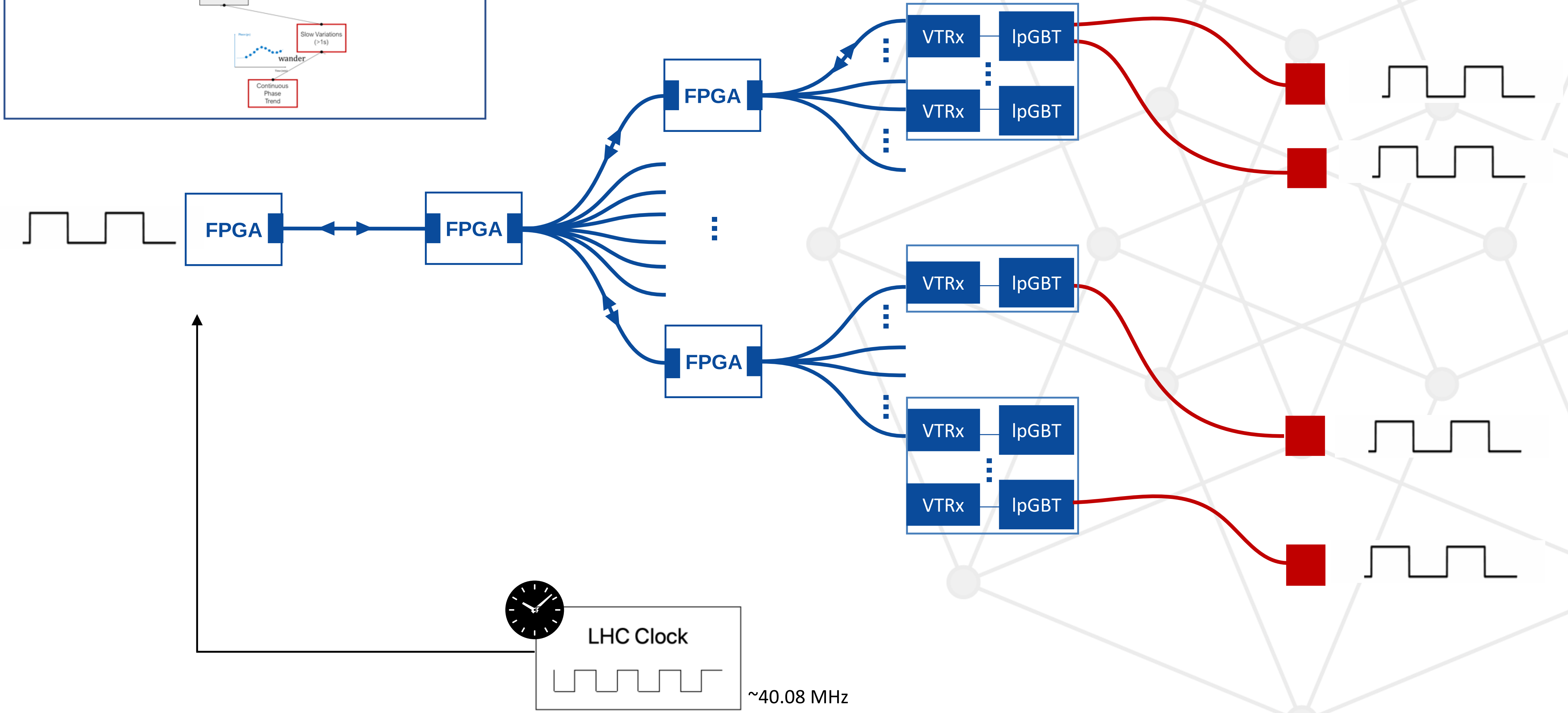
Timing Distribution & Metrics

Wander



Temperature Induced Continuous effet

$T = t_0 + \varepsilon$

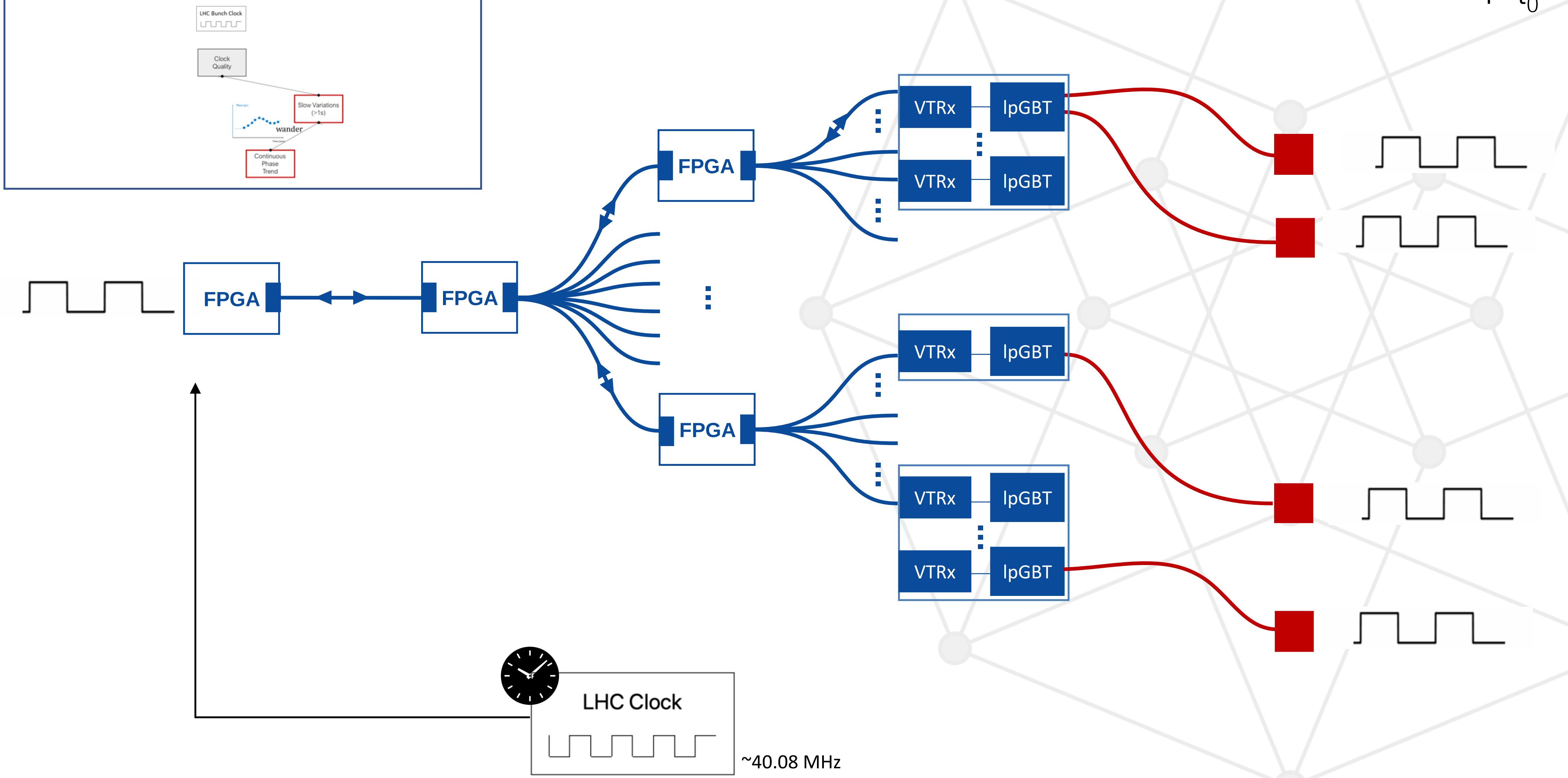


Timing Distribution & Metrics

Wander

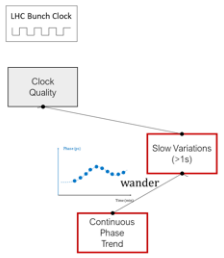
Temperature Induced Continuous effet

$T = t_0 + 2\varepsilon$



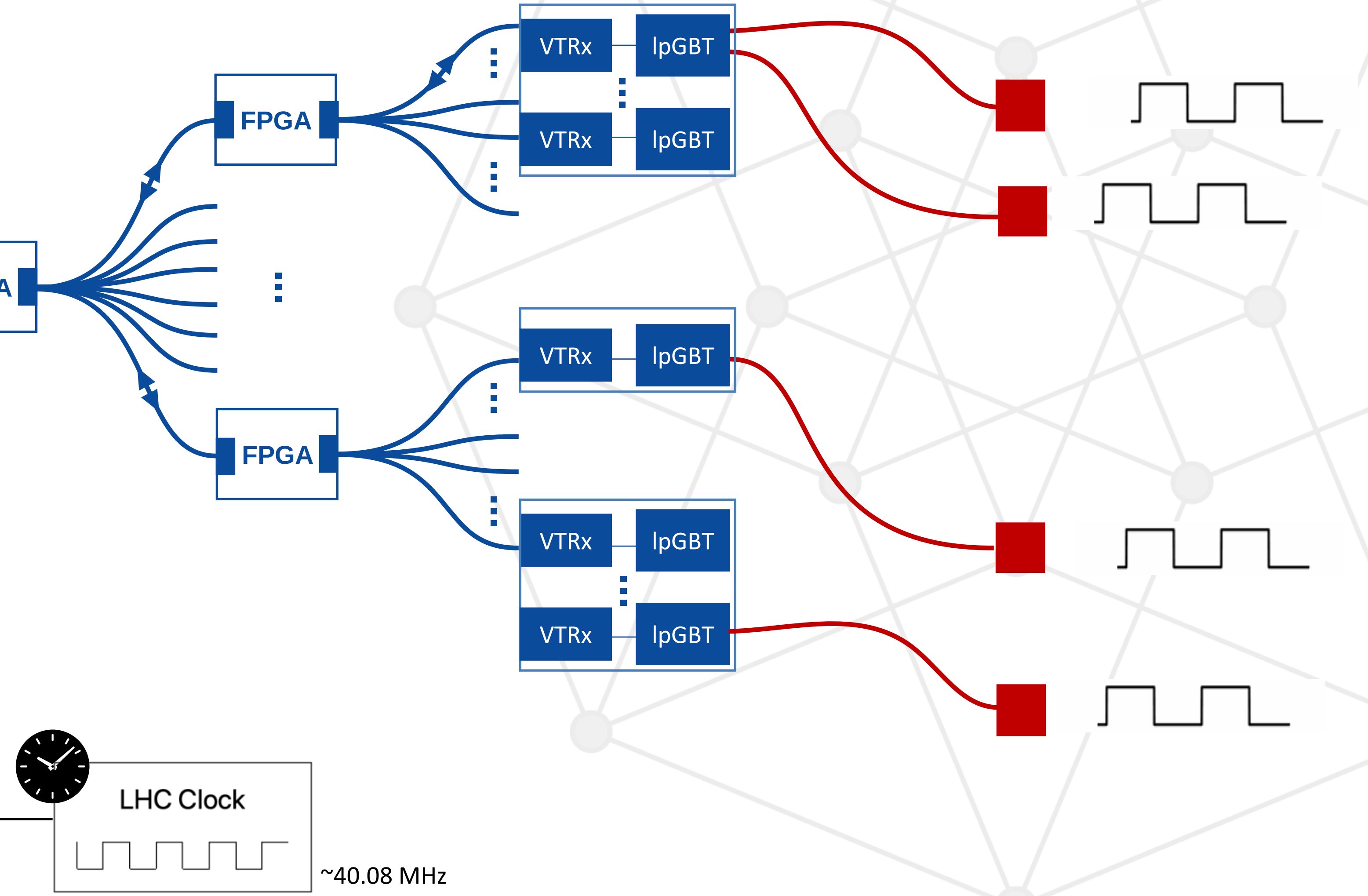
Timing Distribution & Metrics

Wander



Temperature Induced Continuous effet

$T = t_0 + 3\varepsilon$



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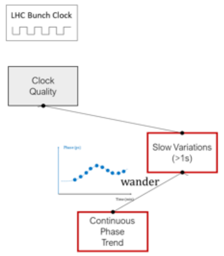
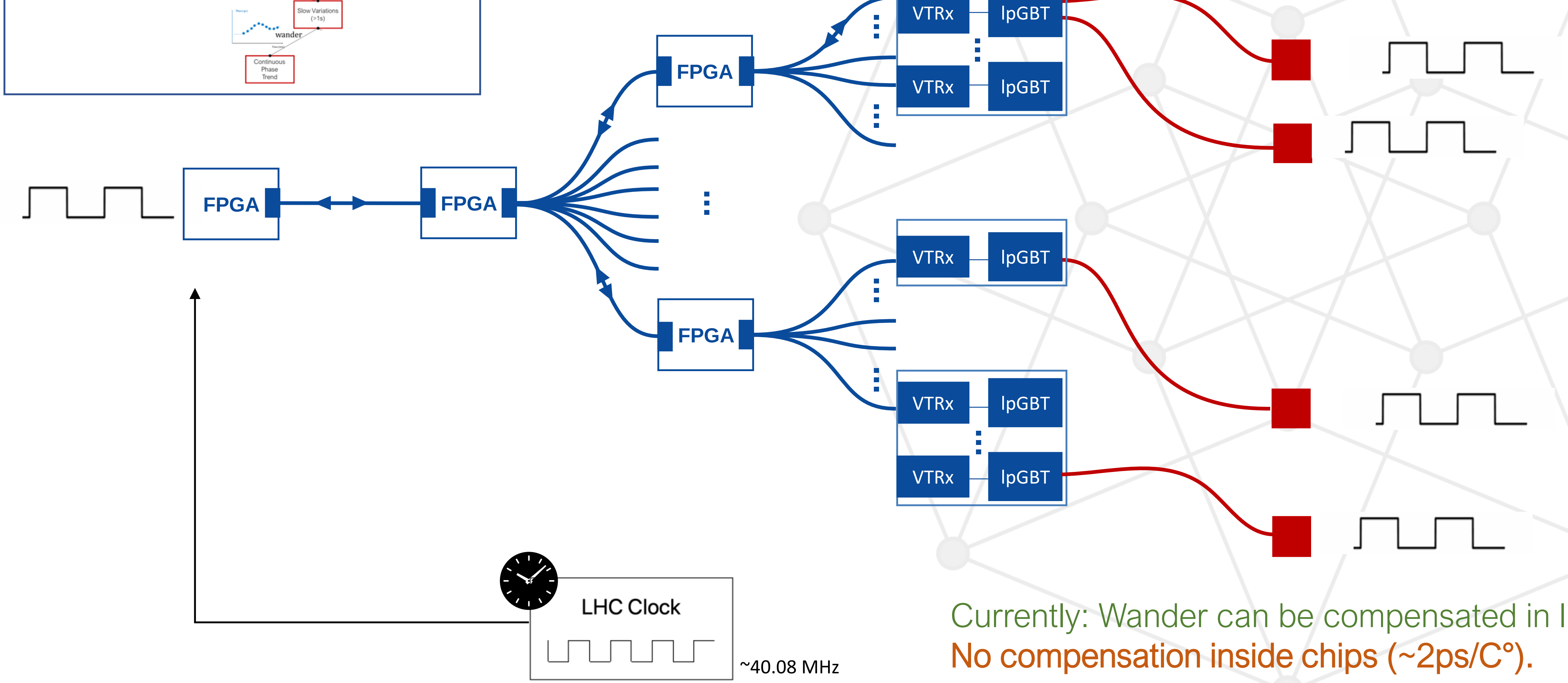
Timing Distribution & Metrics

Wander



Temperature Induced Continuous effet

$T = t_0 + 4\varepsilon$

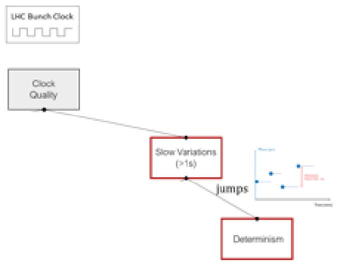


Currently: Wander can be compensated in links.

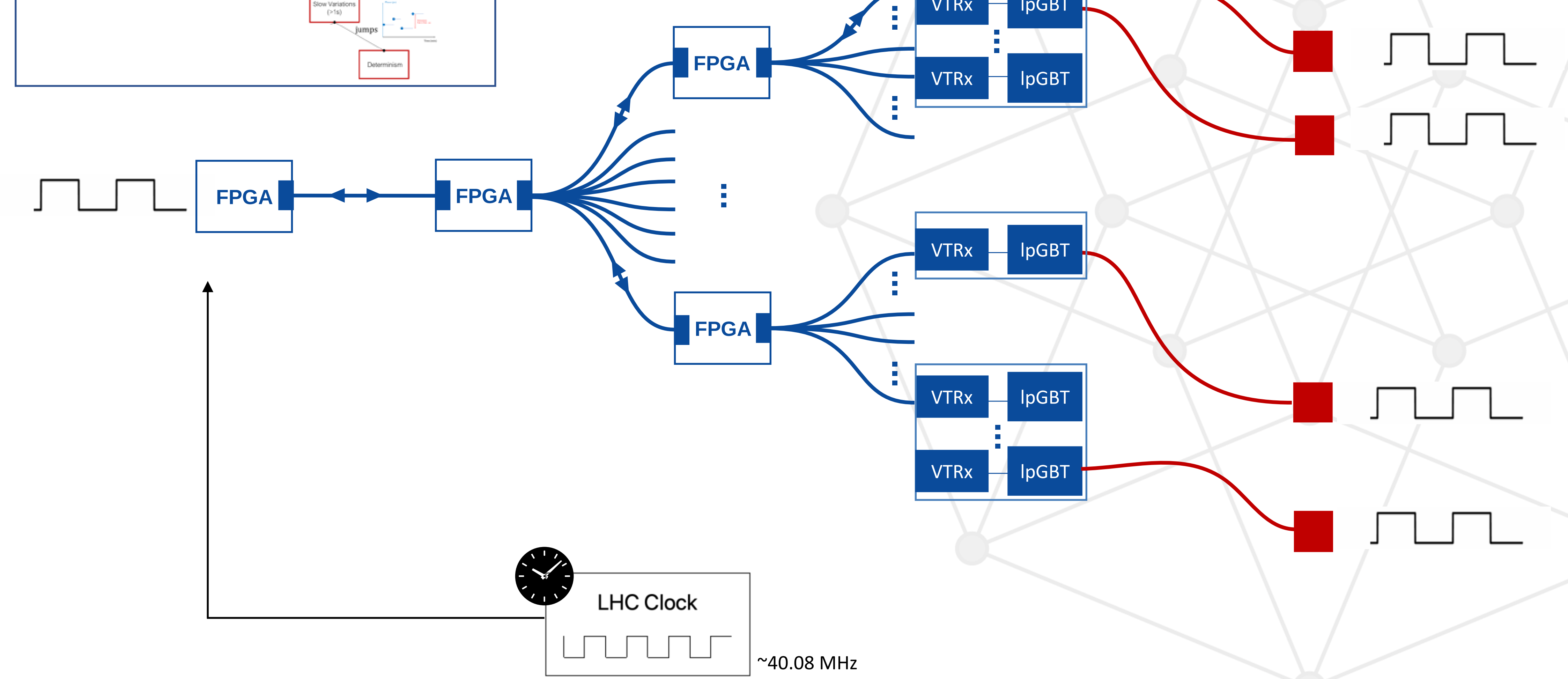
No compensation inside chips (~2ps/C°).

Timing Distribution & Metrics

Determinism

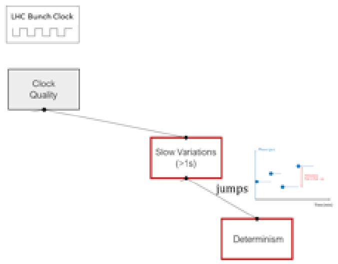


DISCRETE effet



Timing Distribution & Metrics

Determinism



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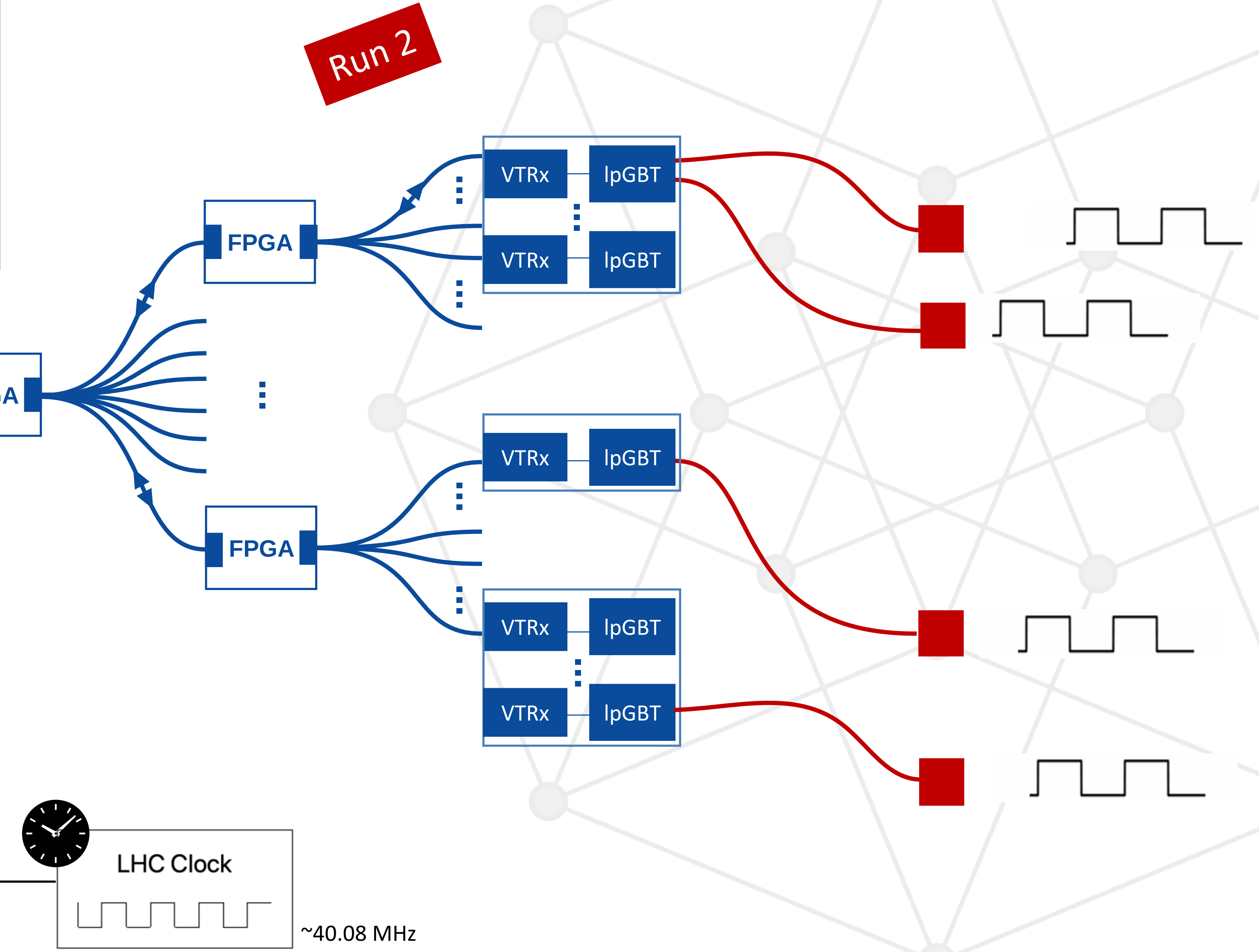

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Timing Distribution & Metrics

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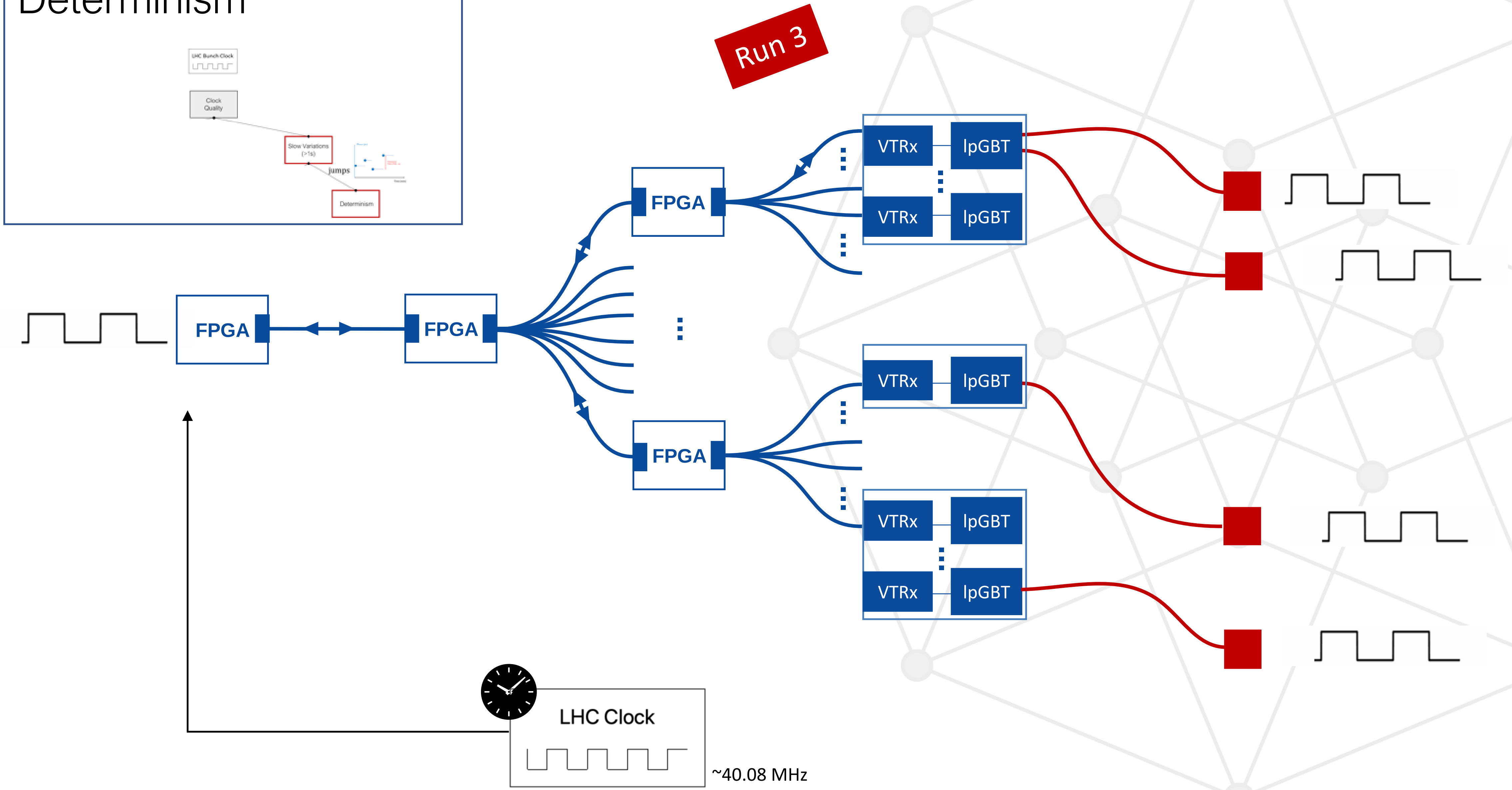

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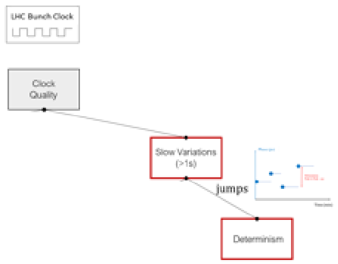
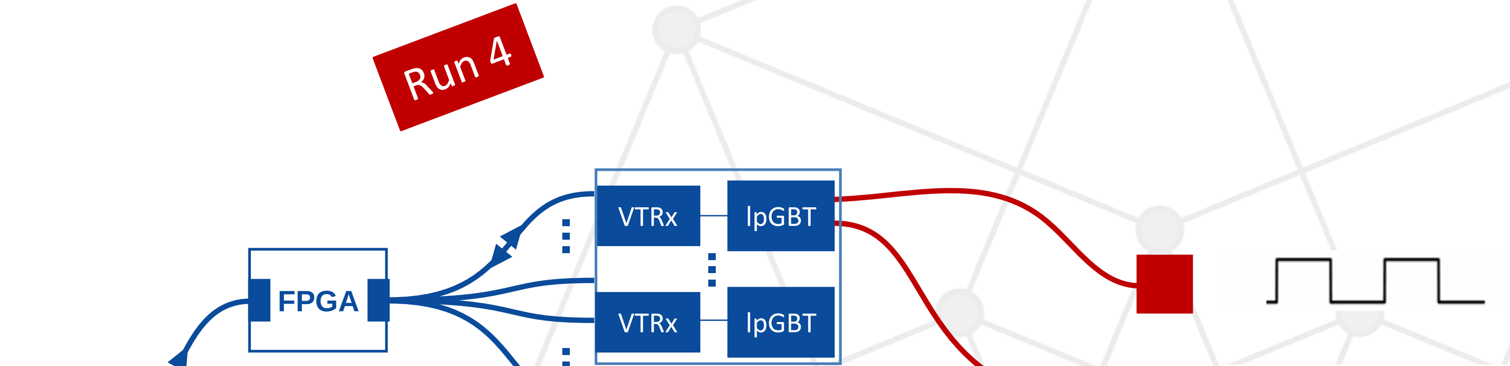
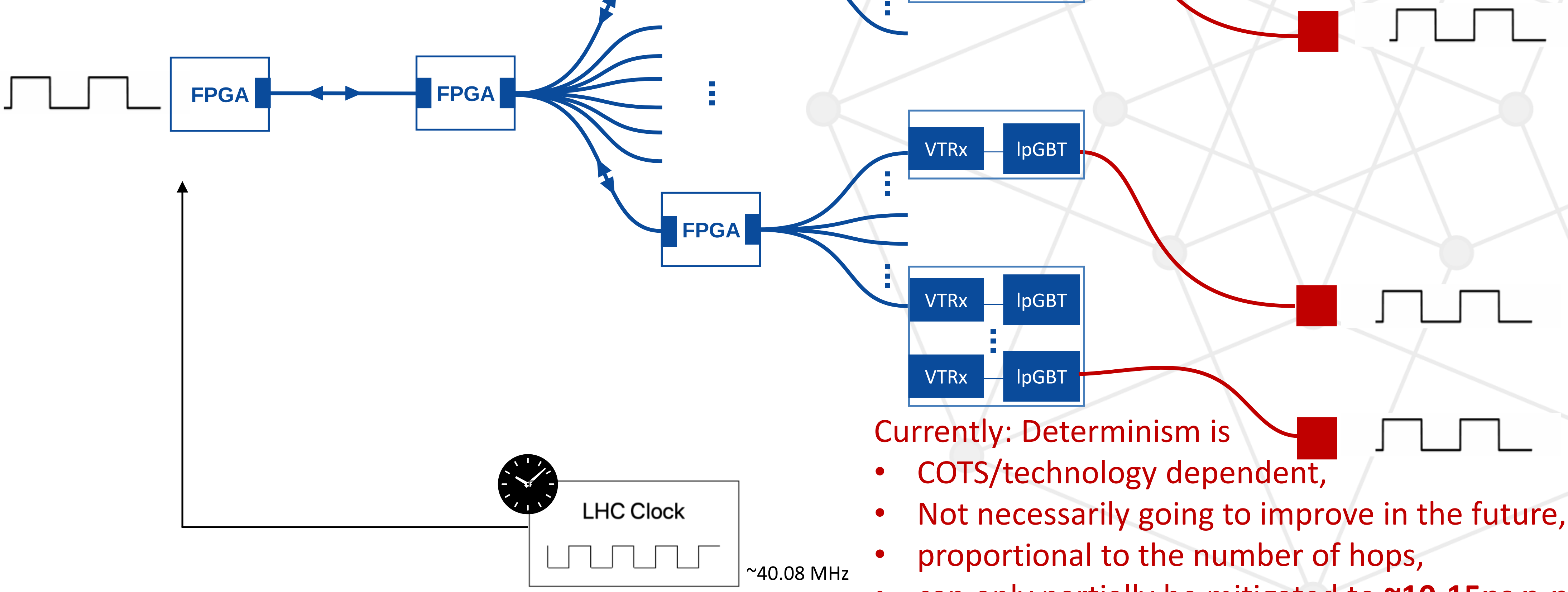


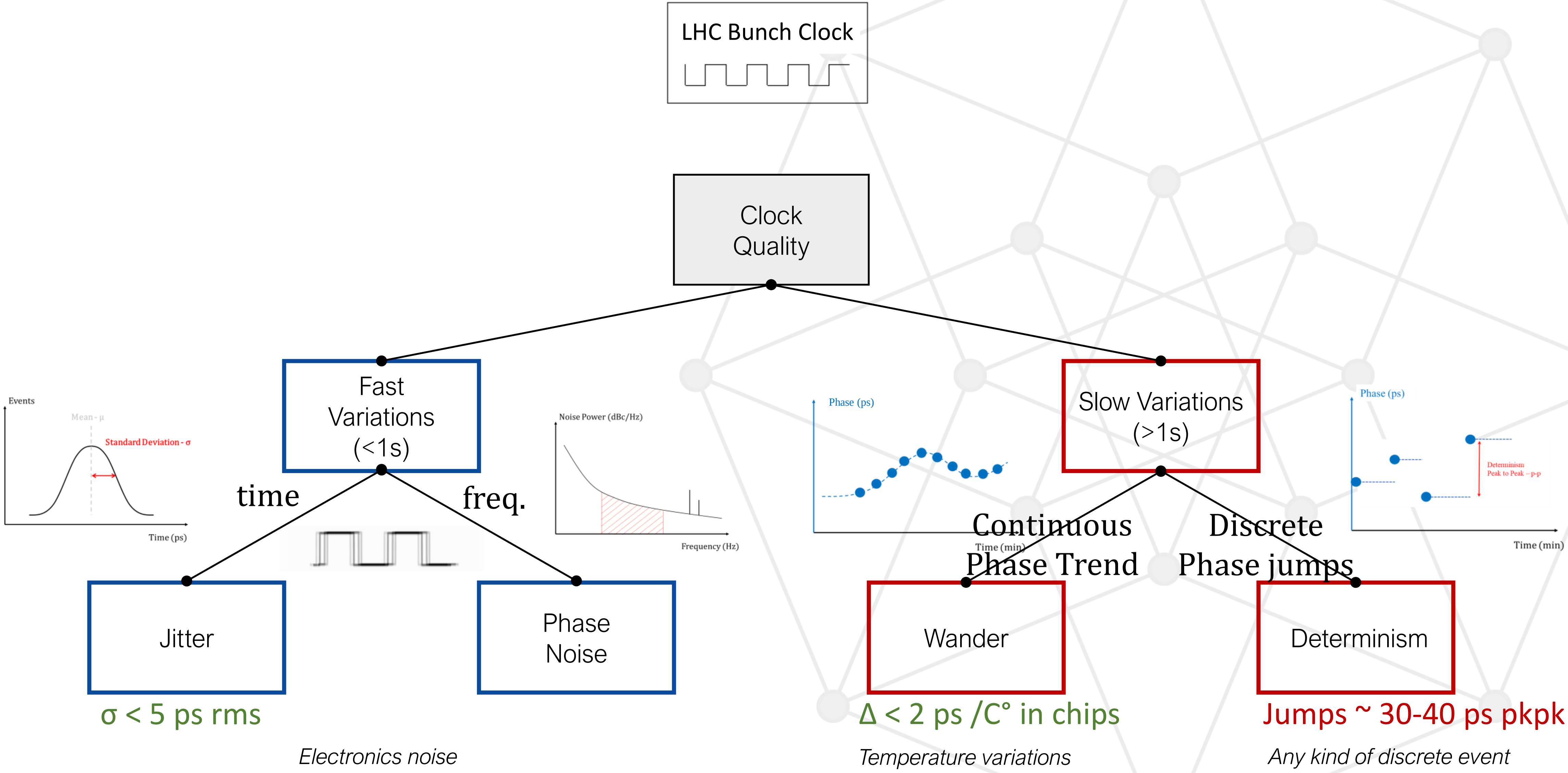




Currently: Determinism is

- COTS/technology dependent,
- Not necessarily going to improve in the future,
- proportional to the number of hops,
- can only partially be mitigated to **~10-15ps p-p per hop**

Timing Metrics (as of today)



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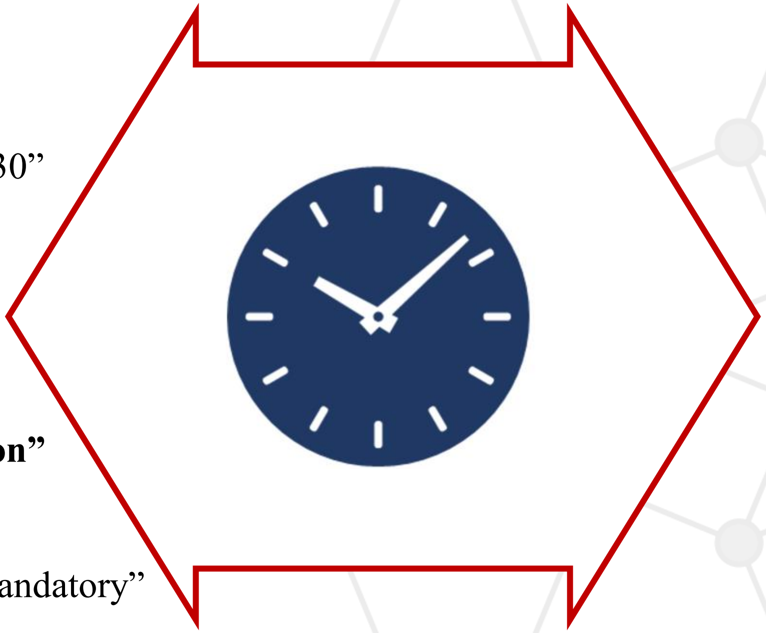

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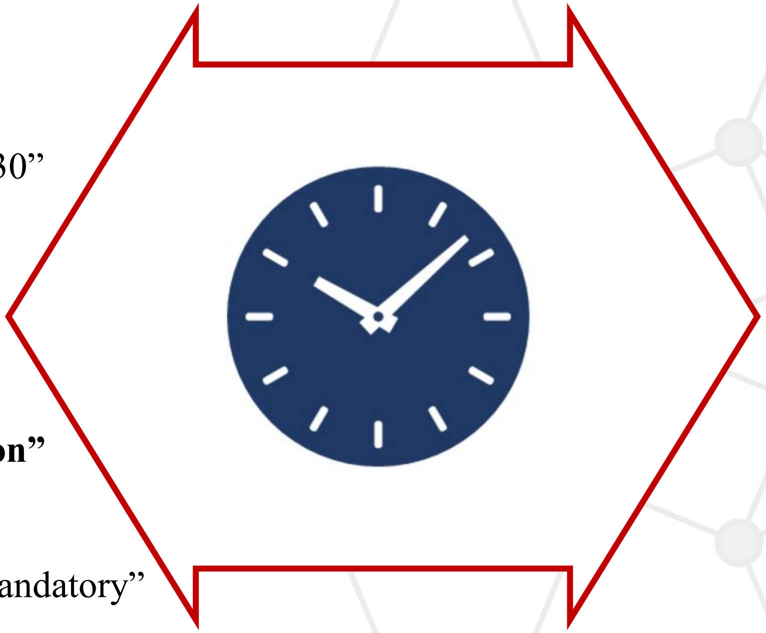

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?

The answer comes in next talk:
Louis d’Eramo (CNRS-IN2P3) on
Simulation Challenges