

The New White Rabbit Based Timing System for the FAIR Facility

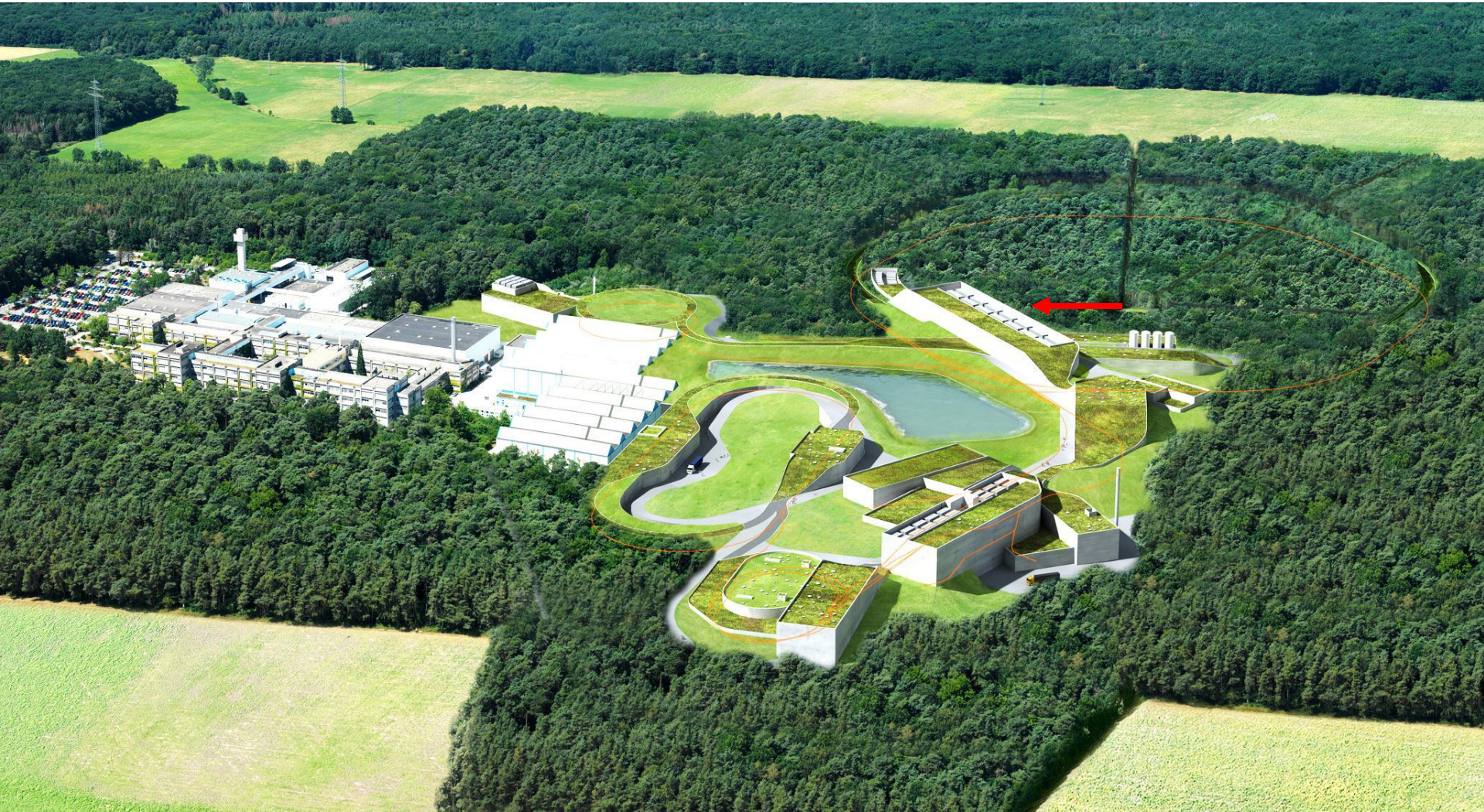


The FAIR Facility
Why Are They Using White Rabbits?
General Machine Timing System
Status & Plans

Acknowledgements

- GSI Timing Team: Marcus Zweig, Stefan Rauch, Mathias Kreider, Cesar Prados, Wesley Terpstra, Ralph Bär, Dietrich Beck
former members: Tibor Fleck, Sergio Mauro
- CERN Timing Team: Tomasz Włostowski, Javier Serrano, Maciej Lipinski, Evangelia Gousiou, Erik van der Bij, Jean-Claude Bau, Pablo Alvarez, ...
- GSI/EE: Jan Hoffmann, Nikolaus Kurz, Holger Brand, ...

Facility for Antiproton and Ion Research





23 November 2011

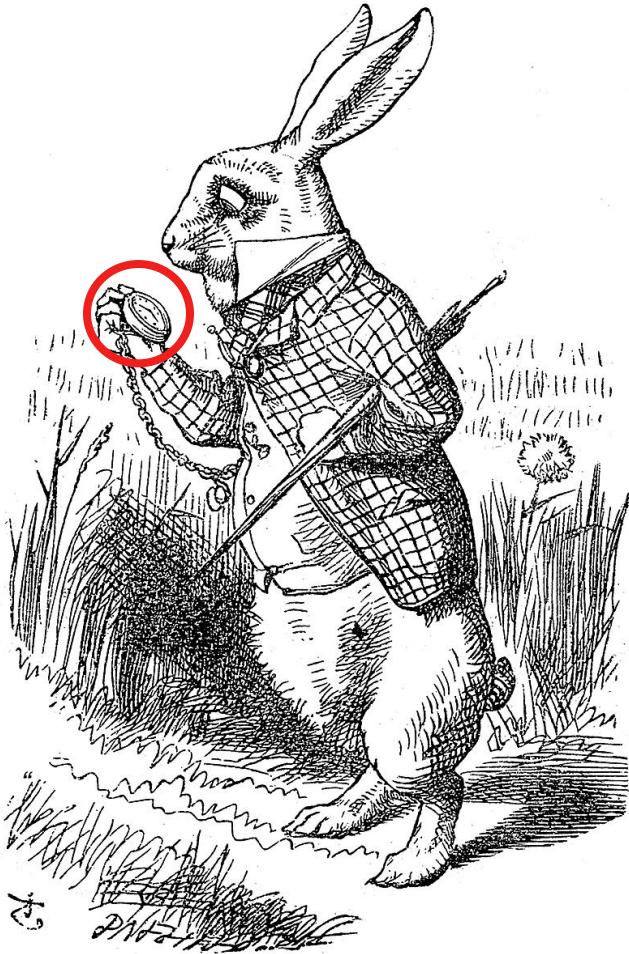


16 November 2012

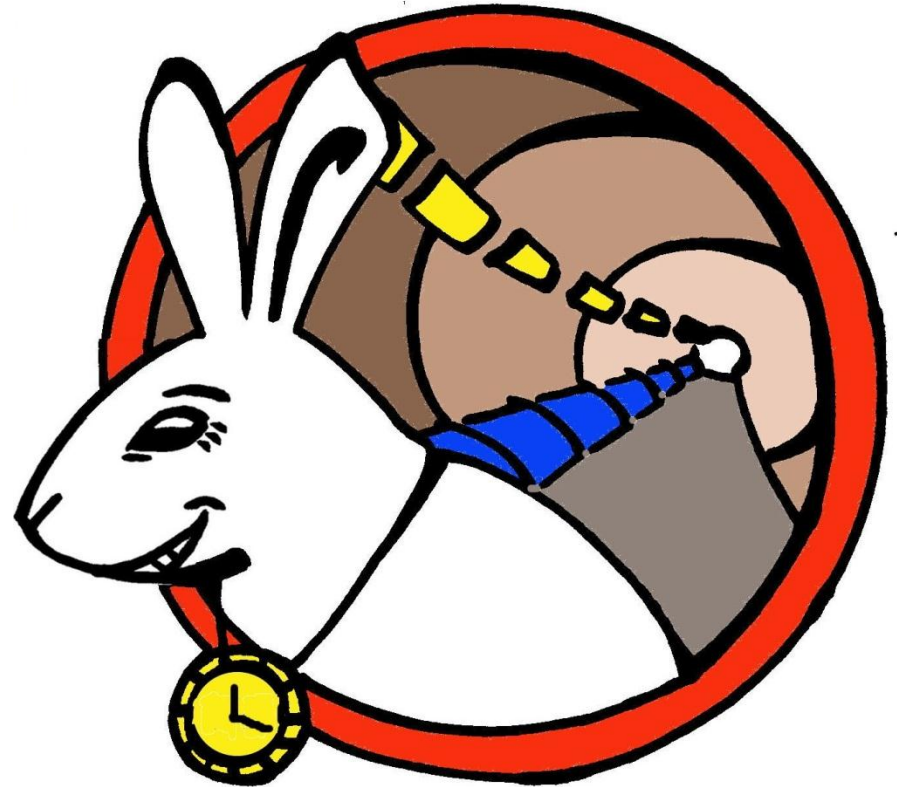


16 November 2012

Who is the White Rabbit (WR)?



"Oh dear! Oh dear! I shall be too late!"
(Alice's Adventures in Wonderland)



"The White Rabbit (WR) project is a multi-laboratory and multi-company effort to bring together the best of the data transfer and timing worlds ..."
(Javier Serrano, Proc. ICALEPCS 2009)

White Rabbit Technology: Cooking Recipe

- network: Gigabit-Ethernet
- PTP (Precision Time Protocol) IEEE1588-2008
 - but: free-running oscillators on network nodes
 - nodes need to re-sync often: lot's of traffic, bad for determinism
 - only 1-100 μ s synchronization of clocks
- SyncE (Synchronous Ethernet)¹
 - node clocks recovered from 125MHz GigE carrier
 - “only” 8ns precision
- precise phase tracking and adjustment¹: sub-ns synchronization

[White Rabbit provides clock and time synchronization with sub-ns precision and low-ps jitter in an Ethernet network.](#)

¹requires dedicated switches

White Rabbit – Some Marketing

- Open and Commercial: the winning combination
- CERN Open Hardware License
 - open designs: schematics, PCB layout, ...
 - hardware produced and supported commercially
- lots of applications: metrology, astronomy, telecommunications, timing systems...
- plans to include White Rabbit into PTPv3 (IEEE-1588)

→ www.ohwr.org: Open Hardware Repository

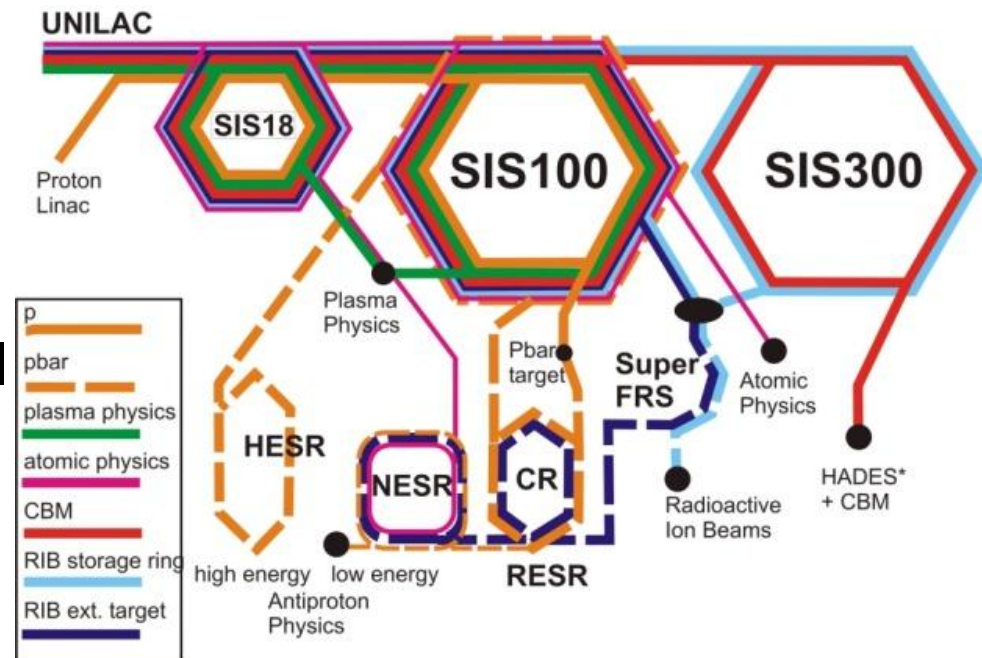


end of introduction ...

... and now the talk starts

Operation at GSI and FAIR

- existing facility - GSI: 3 ion sources, 4 machines @ UNILAC, SIS18, ESR, transport lines
- extended facility – FAIR: SIS100, SIS300, NESR, CR, HESR, CRYRING, Super-FRS, p-linac, 5-10 transport lines,
- ~ 20 machines
- parallel operation
- multiplexed operation
- cycle times: 20ms to hours
- timing system: real-time control

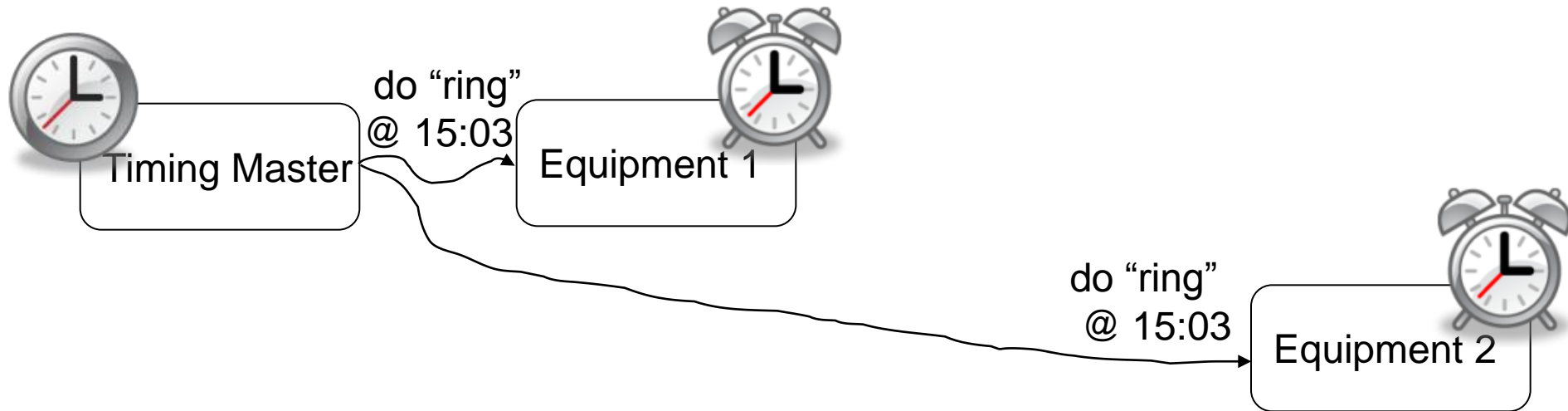


General Machine Timing System (GMT) @ FAIR

- task: trigger and synchronize equipment actions
- 1 μs precision in 99% of all cases
- few ns precision for dedicated tasks, e.g. kickers
- (few ps for rf-systems: BuTiS)
- > 2000 devices connected to timing system
- < 2km distances

Timing System Based on Notion of Time

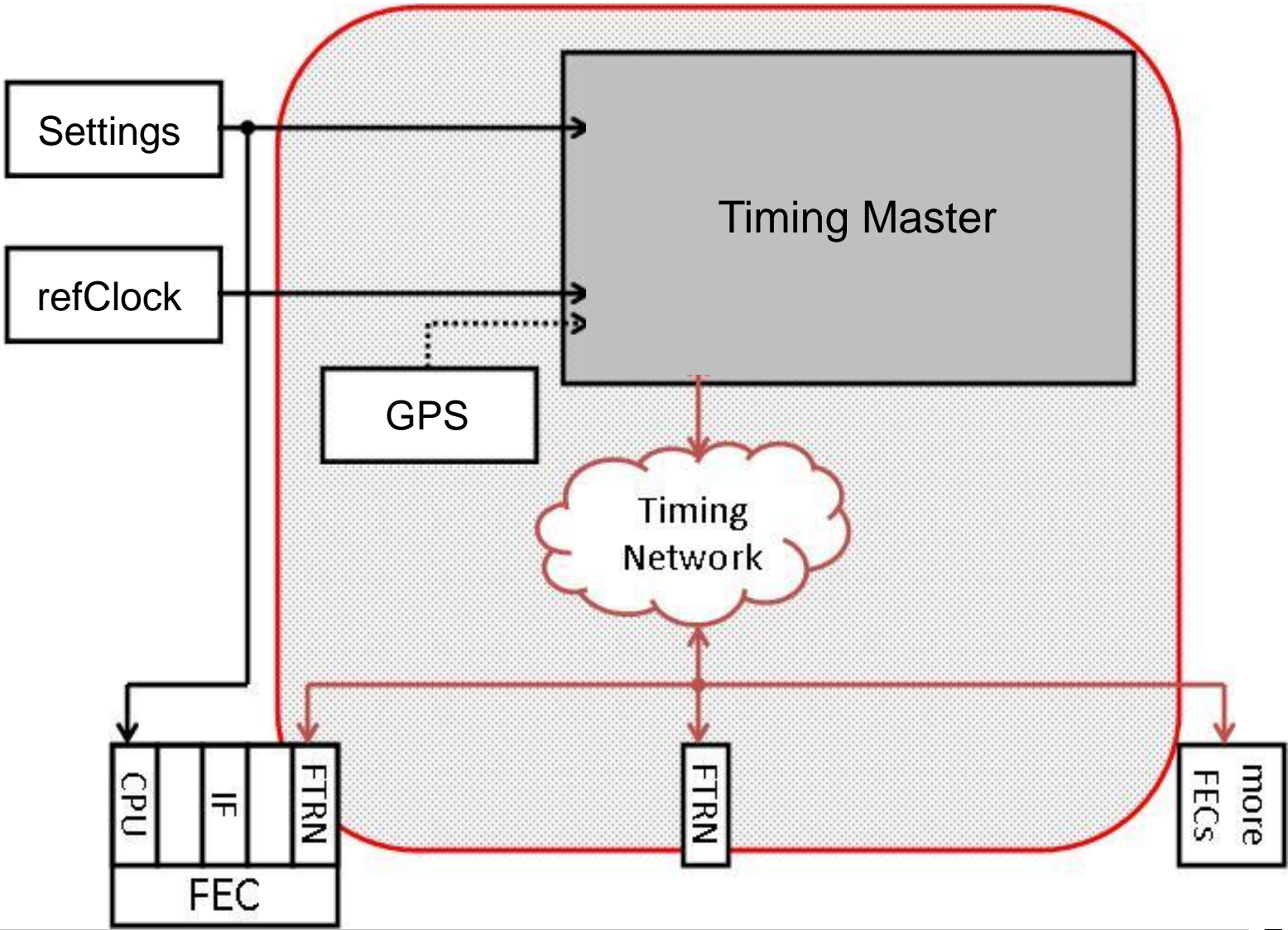
“just a bunch of alarm clocks”



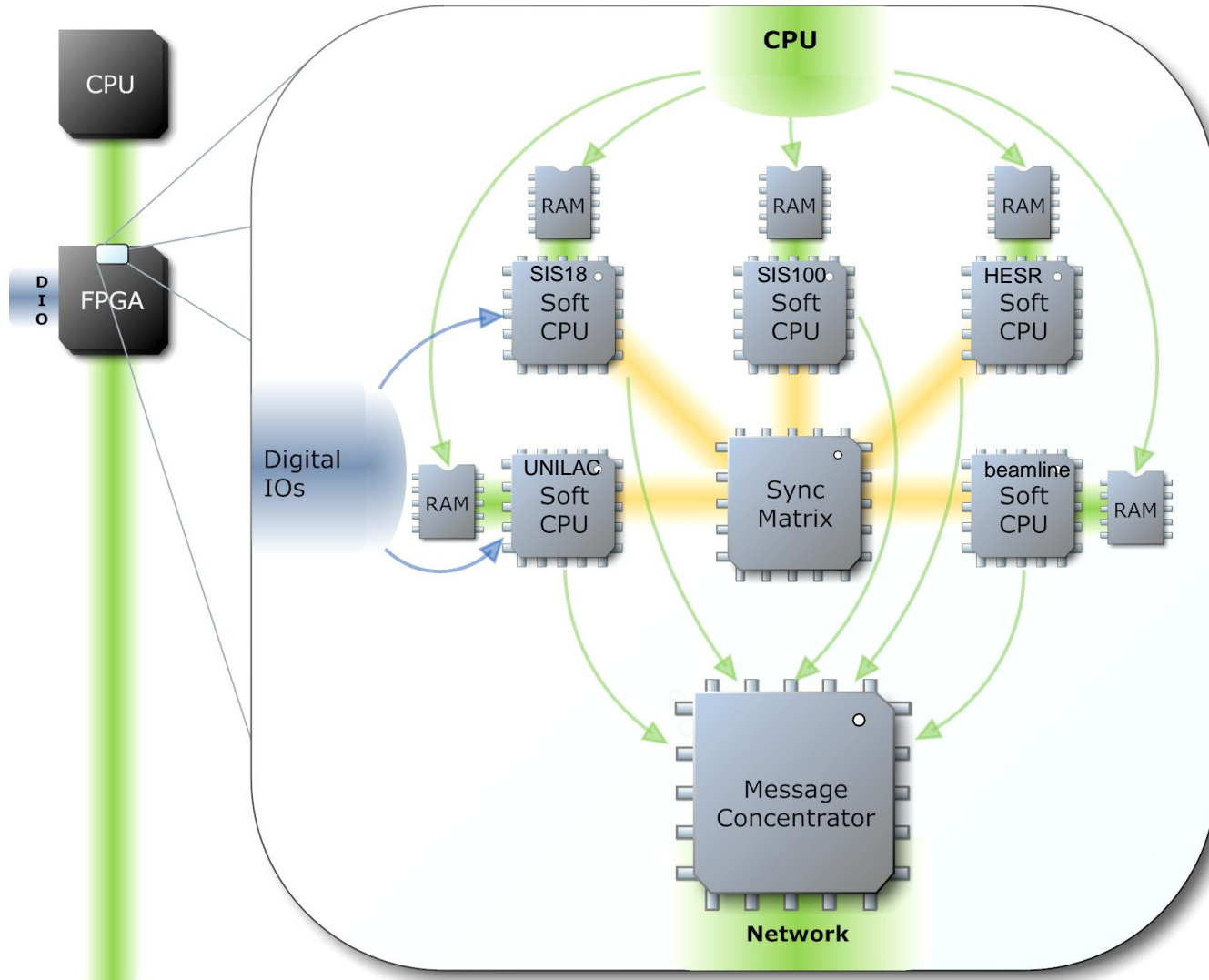
- equipment pre-programmed for autonomous action at a given time
 - action scheduled via [timing-messages](#)
 - trick: [White Rabbit](#) as field-bus provides clock synchronization ~ns
- ⇒ **distribution of information and execution of action are decoupled!!!**
- timing-messages
 - transmission in hard real-time: no hand-shake protocols such as TCP/IP
 - lossless transmission using [forward error correction](#): robustness!

General Machine Timing System @ FAIR

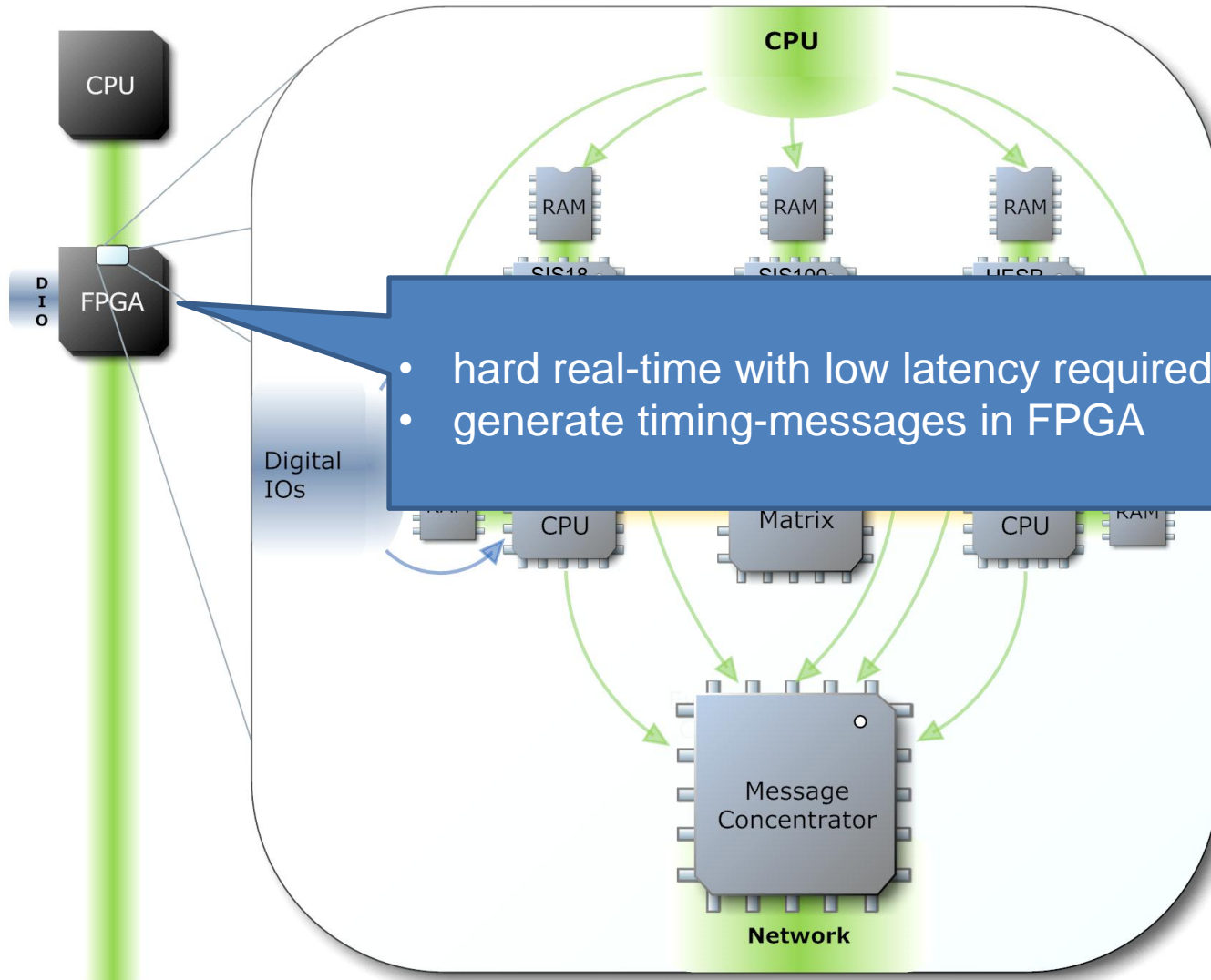
(simplified)



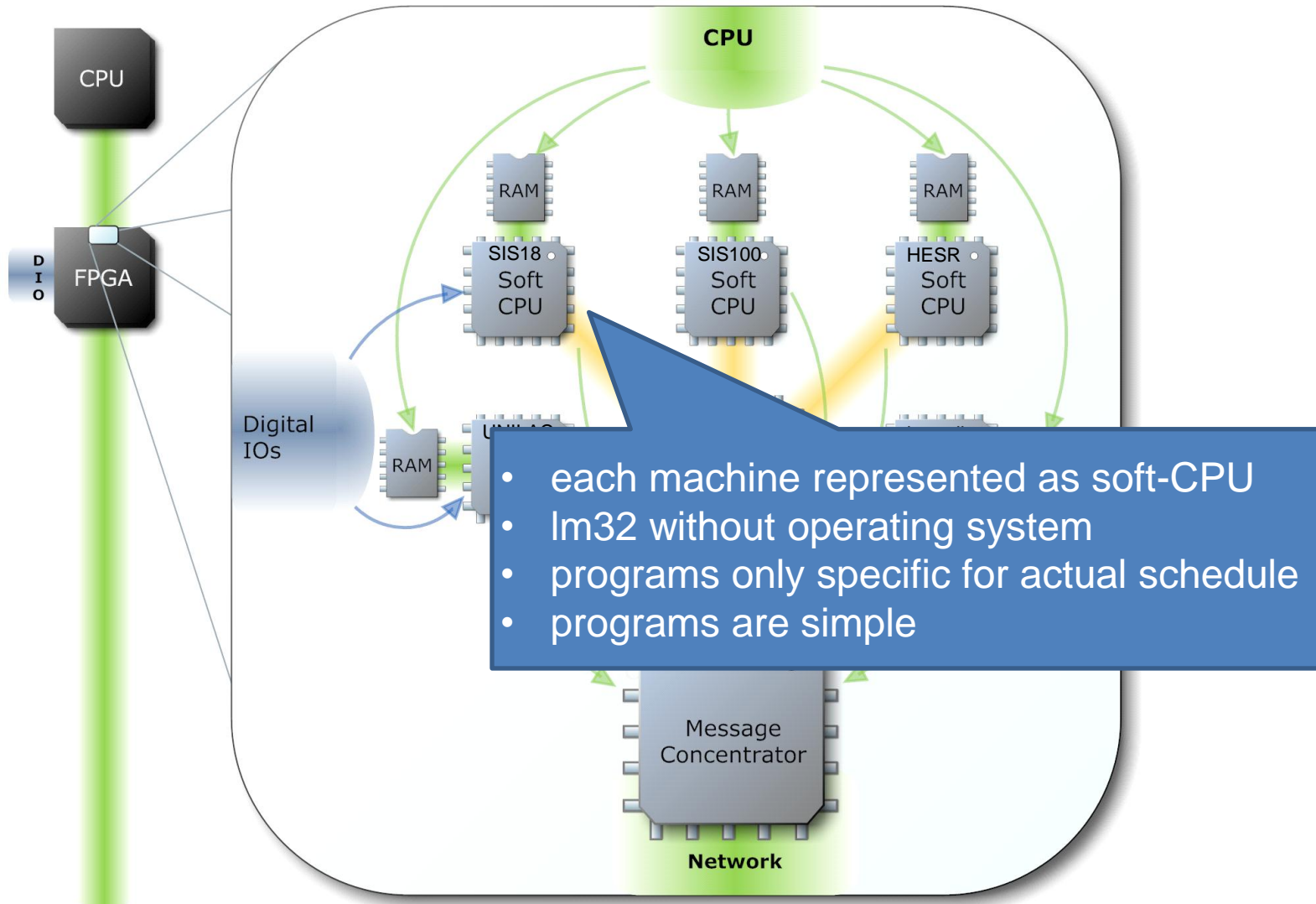
Timing Master



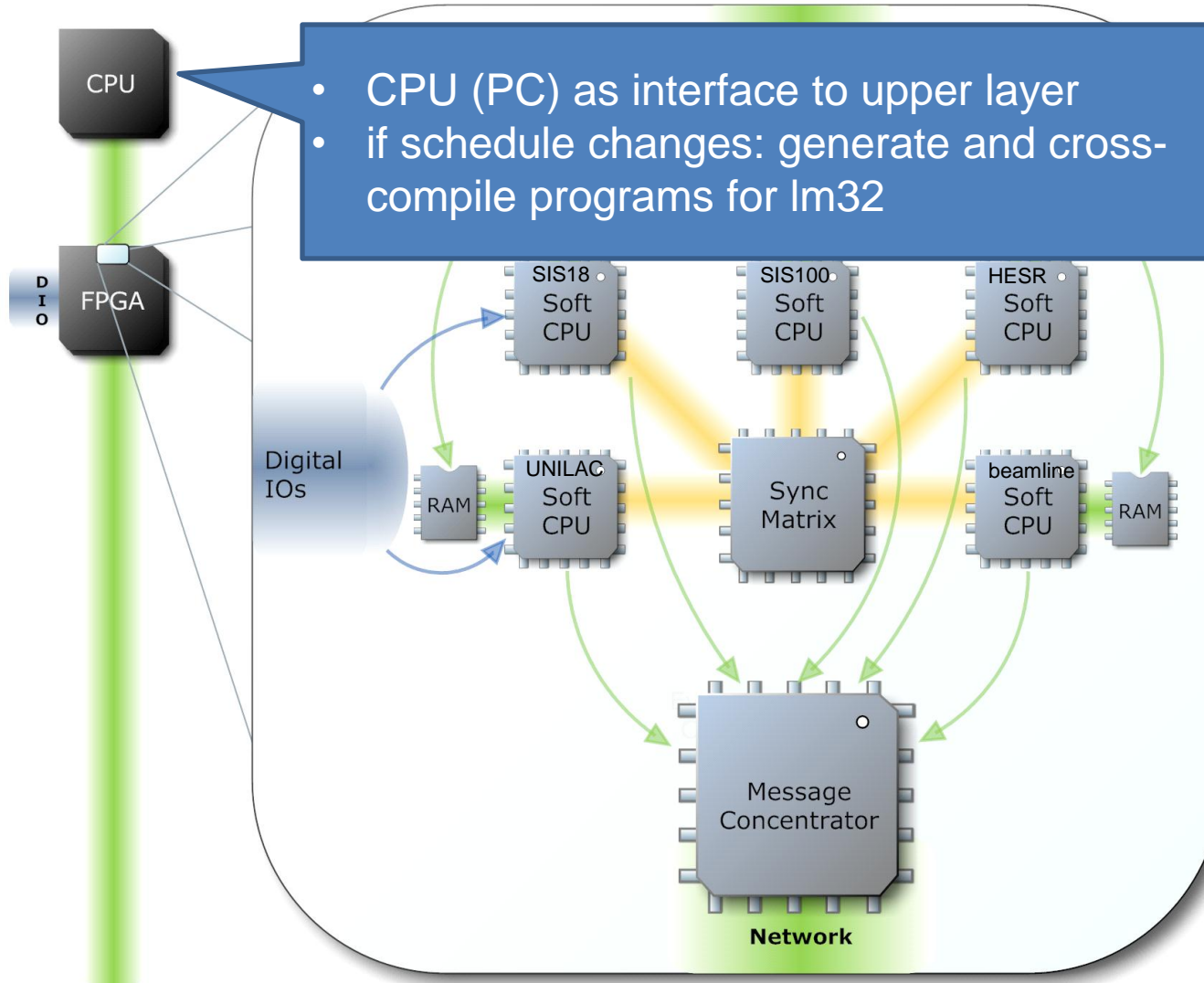
Timing Master



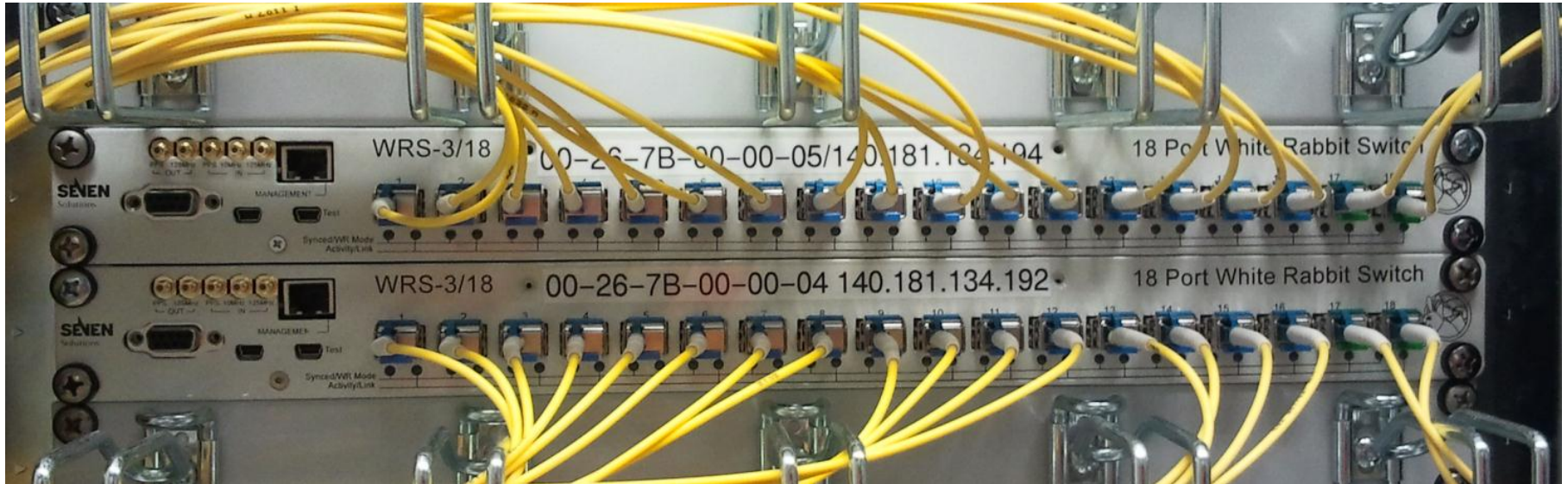
Timing Master



Timing Master



White Rabbit / Timing Network



- dedicated White Rabbit switches
- redundant links between switches
- timing-messages
 - highest-priority with known upper bound latency ($\sim 200\mu\text{s}$)
 - broadcast from timing master to nodes, strictly top-down
 - use cut-through path in switches
- this is a “fieldbus” - no general purpose network

Timing Receiver Nodes @ FAIR

SCU (Scalable Control Unit) – WEPD48

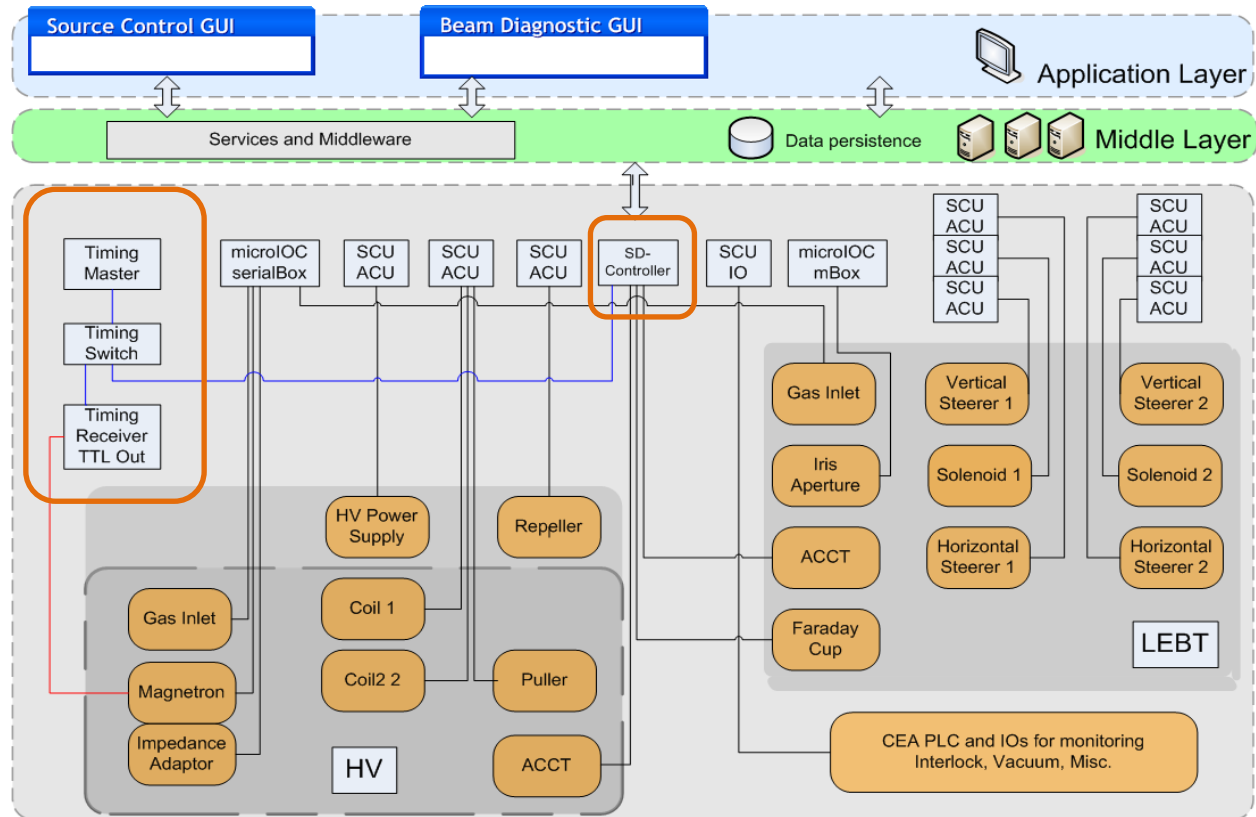
- carrier board with Altera FPGA + White Rabbit
- ...other features like COMExpress module
- “SCU-Bus” master in custom 3U crates
- 1200-1500 units at FAIR
- developed in-house

Other form factors

- μ TCA, PMC, 2x standalone, PCIe, VME
- 500 units
- developed and built as in-kind contribution (Slovenia)



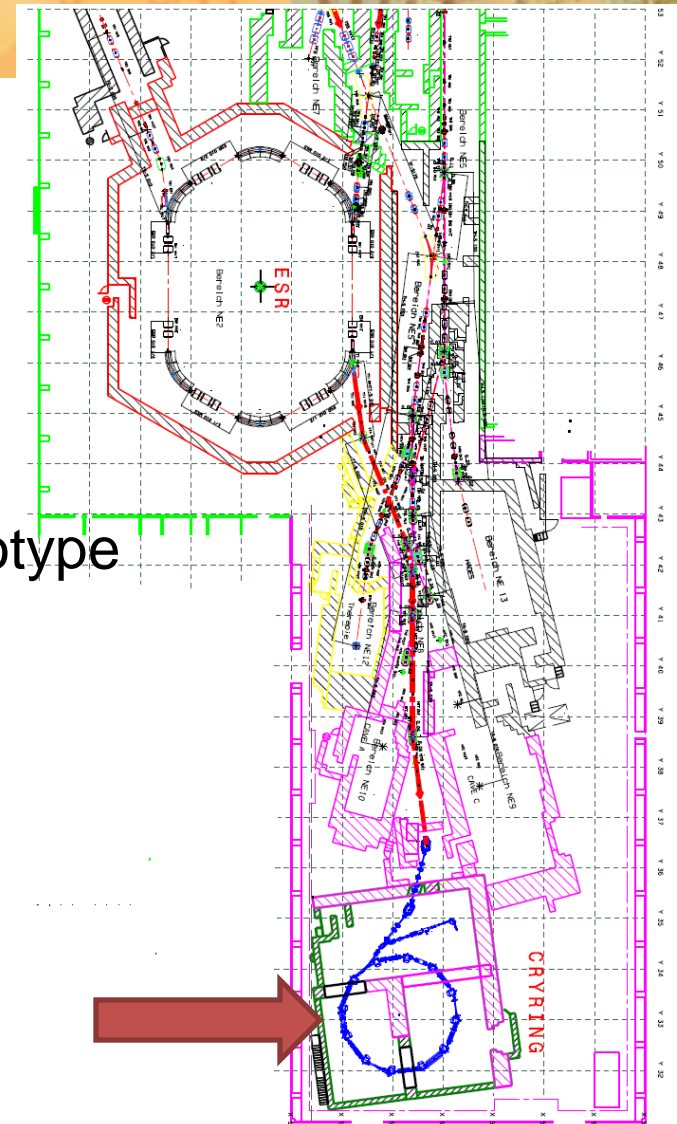
Milestone I: miniCS for p-Linac Source



- first operational timing system - “simple pulse generator”
- ready for shipping to Saclay in June 2013
- standalone operation
- 2x SCU, 2x VME, 1 White Rabbit Switch

Milestone II: CS-CO @ CRYRING @ GSI

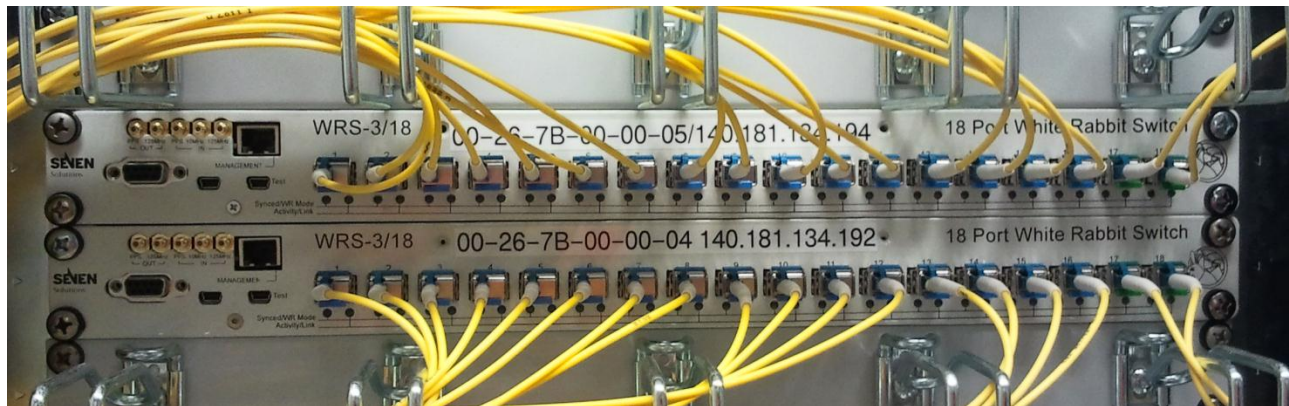
- CRYRING moves from Stockholm to GSI
- commissioning until summer 2014
- connected to ESR
- AND has its own ion source
- test ground for FAIR control system prototype



CRYRING@ESR: A study group report

Status & Outlook

- FAIR project has really started
- White Rabbit works
- timing system of FAIR/GSI as application of White Rabbit
- simple GSI Timing Starter Kit V1.0 (www.ohwr.org)
- prototype of timing system until summer 2014
- final timing system ready 2017/2018





Timing Systems @ FAIR

General Machine Timing System

- based on White Rabbit
- fairly cheap: € 800,- SPEC board
- sub-ns synchronization
- distribution of
 - (clock)
 - time-stamps
 - timing-events
- Controls group

- one global timing master
 - clock derived from BuTiS

Talk T. Fleck, FAIR Technikforum

Bunch phase Timing System (BuTiS)

- invest € 15k per receiver station
- ps precision (100ps/km accuracy)
- 0.5° phase resolution @ 200 MHz
- low phase noise (< -130 dBc/Hz)
- good short term stability
- distribution of
 - clocks!!!
 - NO time-stamps at FAIR
 - NO timing-events
- HF group
- one global BuTiS center

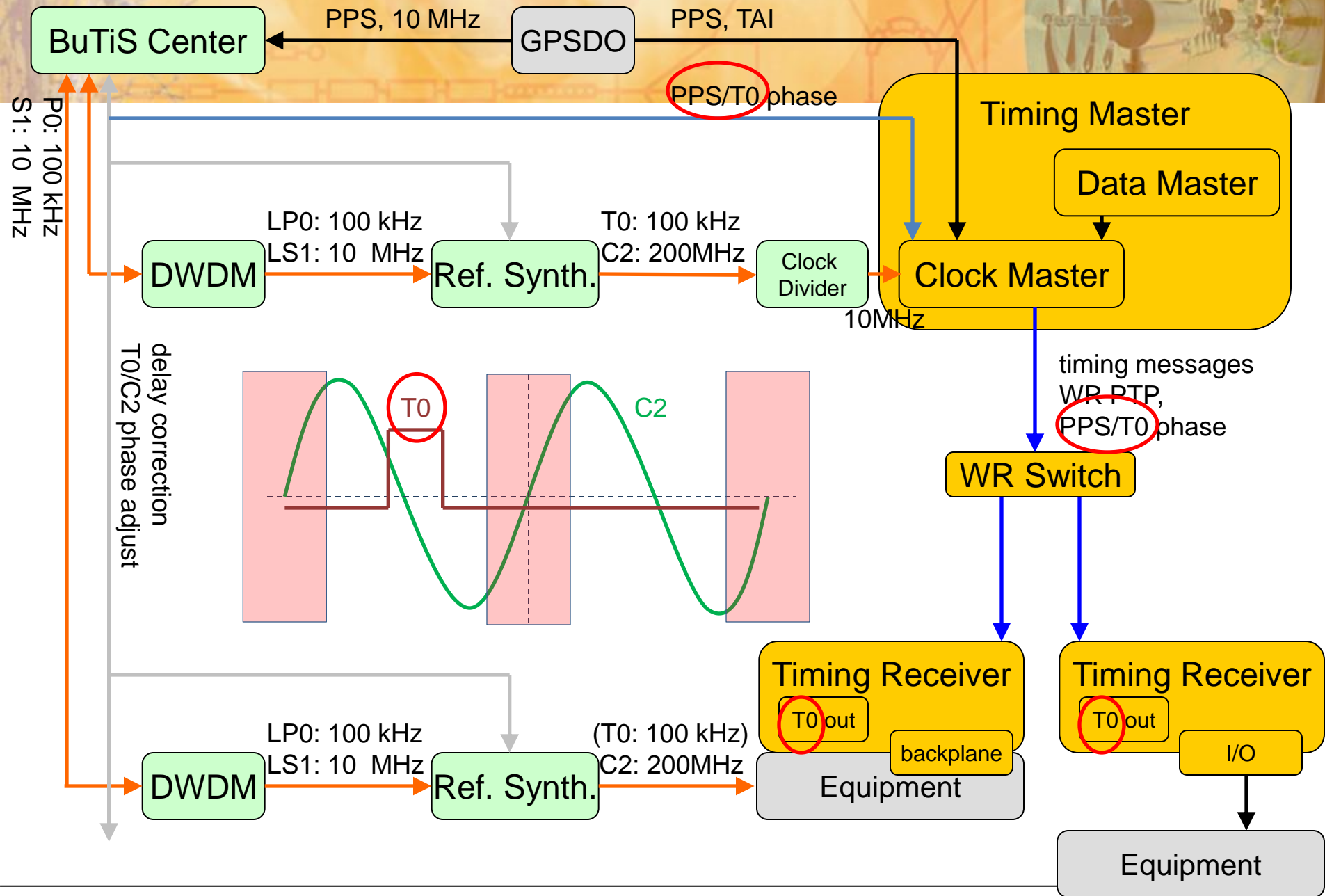
Talk P. Moritz, FAIR Technikforum

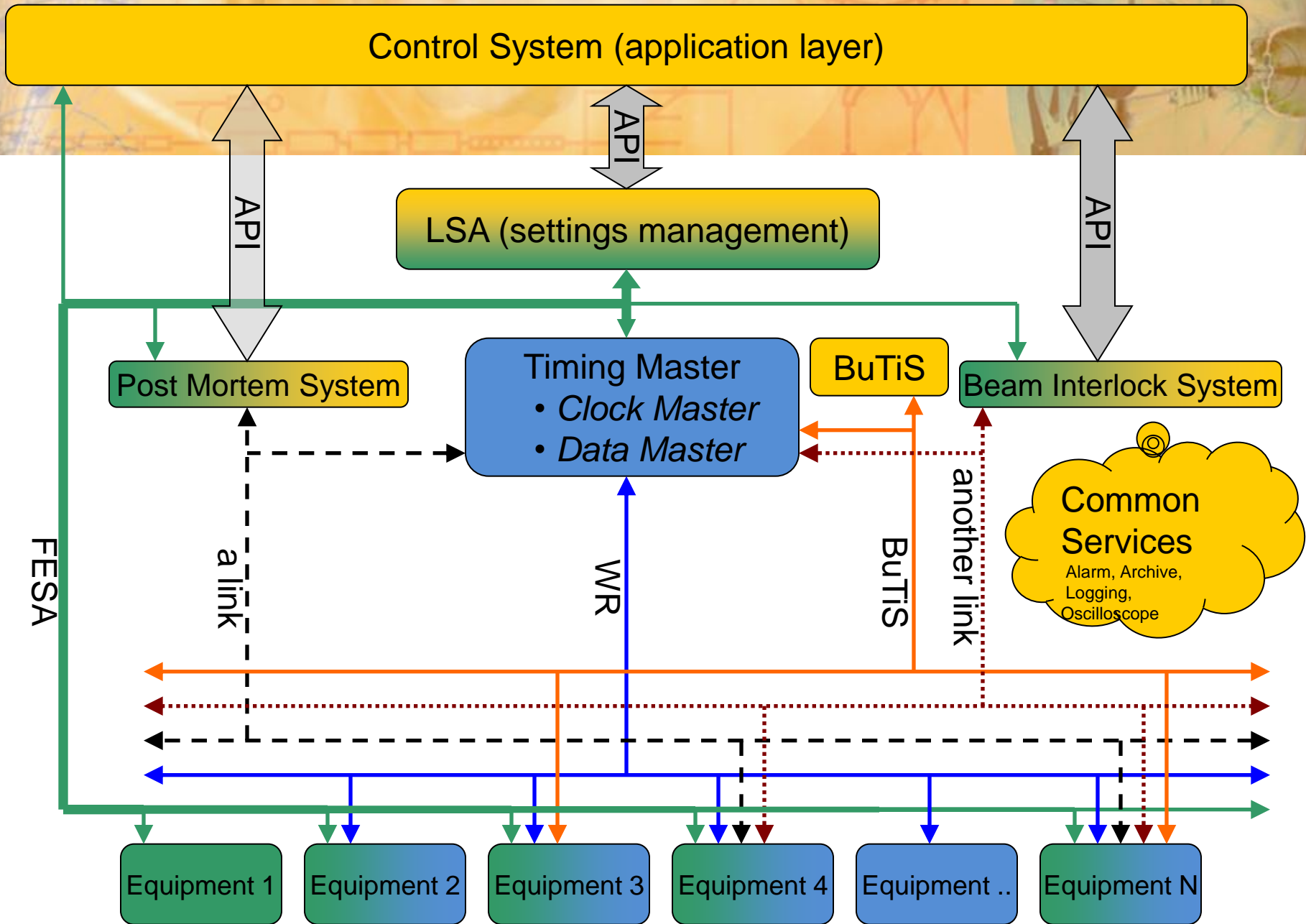
Remark: If you are interested time-stamps, you need White Rabbit.

If you are interested in the most accurate clocks, you need BuTiS.

If you are interested in both, you need both.

GMT – BuTiS Connection





White Rabbit: Open and Commercial

	Commercial	Non-Commercial
Open	Winning Combination Best of both worlds	Support burden for developers. Scalability?
Proprietary	Vendor lock-in	Dedicated Non-reusable projects

- CERN Open Hardware License
 - hardware produced commercially, and
 - open designs: schematics, PCB layout, ...
- software: GPL
- HDL: IGPL
- plans to include White Rabbit into PTPv3 (IEEE-1588)

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