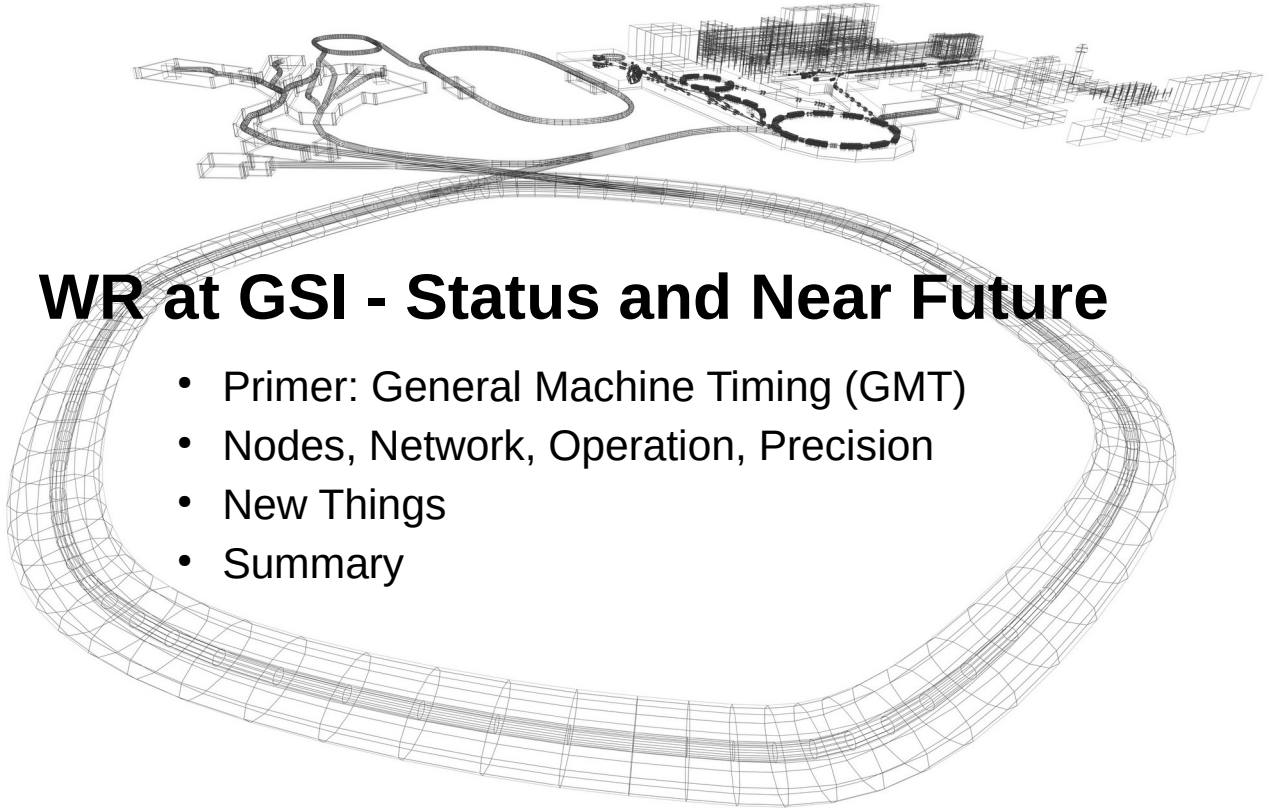
Acknowledgements

- GSI Timing Team: Enkhbold Ochirsuren, Marcus Zweig, Stefan Rauch, Mathias Kreider, Martin Skorsky, Frederic Ameil, Alexander Hahn, Michael Reese [1]
- GSI ACC-IT Team: Peter Pfister, Christoph Handel, Rosemarie Vincelli …
- CERN Team: Greg Daniluk, Maciej Lipinski …
- External: Alessandro Rubini, Adam Wujek …
- ...

[1] Michael left; job opportunity https://www.gsi.de/en/jobscareer/job_offers; C++, STL



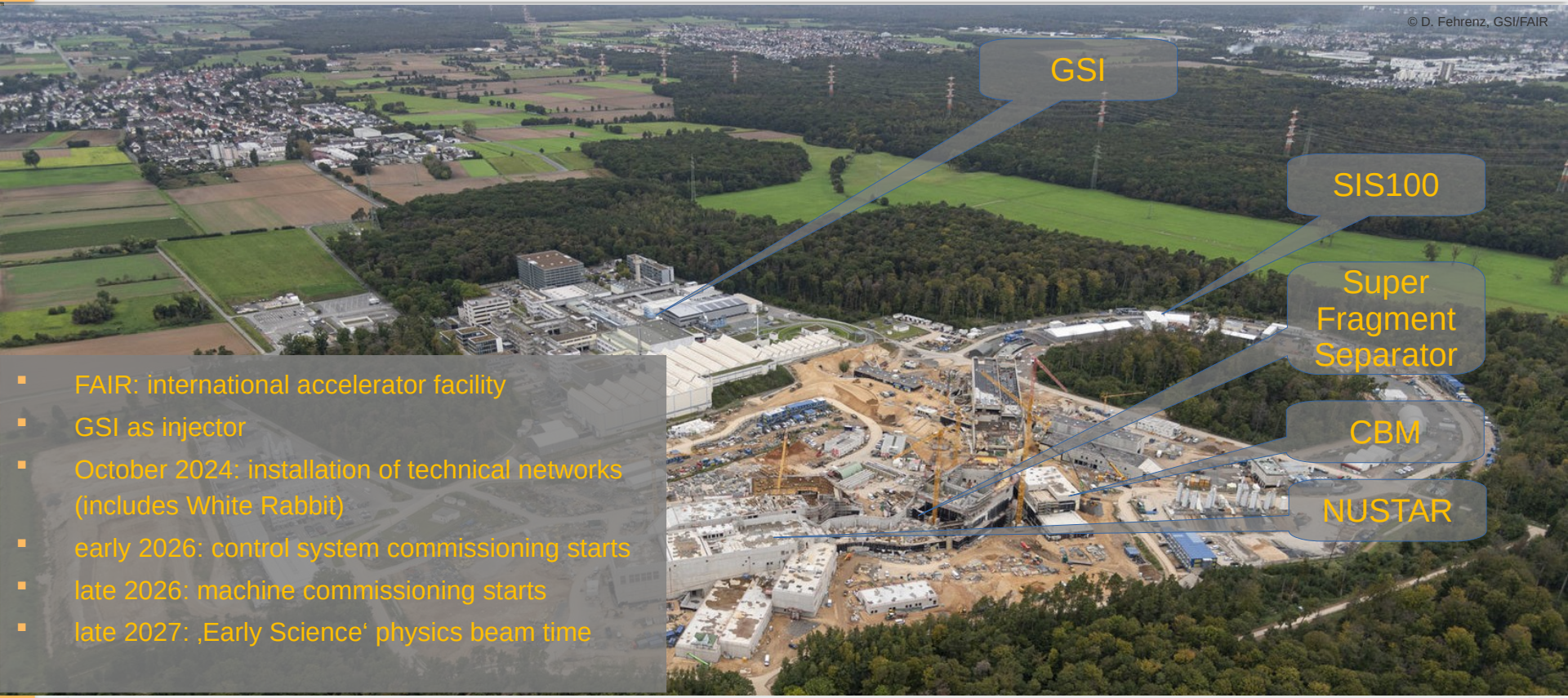
WR at GSI - Status and Near Future

- Primer: General Machine Timing (GMT)
- Nodes, Network, Operation, Precision
- New Things
- Summary

Dietrich Beck, TOS, GSI, d.beck@gsi.de

General Machine Timing: GMT (Some Background)

FAIR from the Control System Perspective



- FAIR: international accelerator facility
- GSI as injector
- October 2024: installation of technical networks (includes White Rabbit)
- early 2026: control system commissioning starts
- late 2026: machine commissioning starts
- late 2027: ‚Early Science' physics beam time

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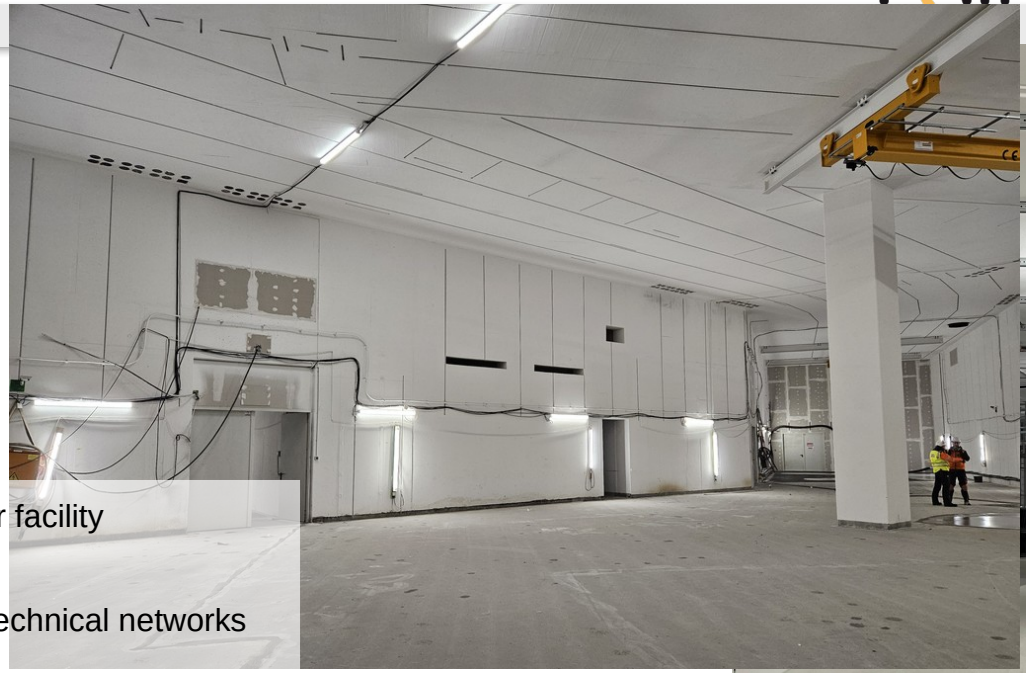

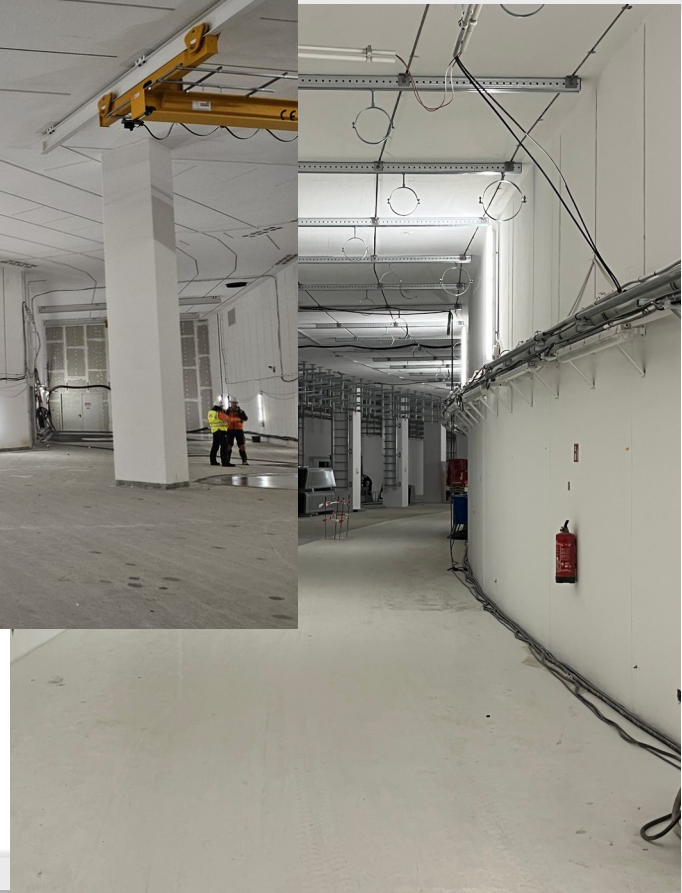

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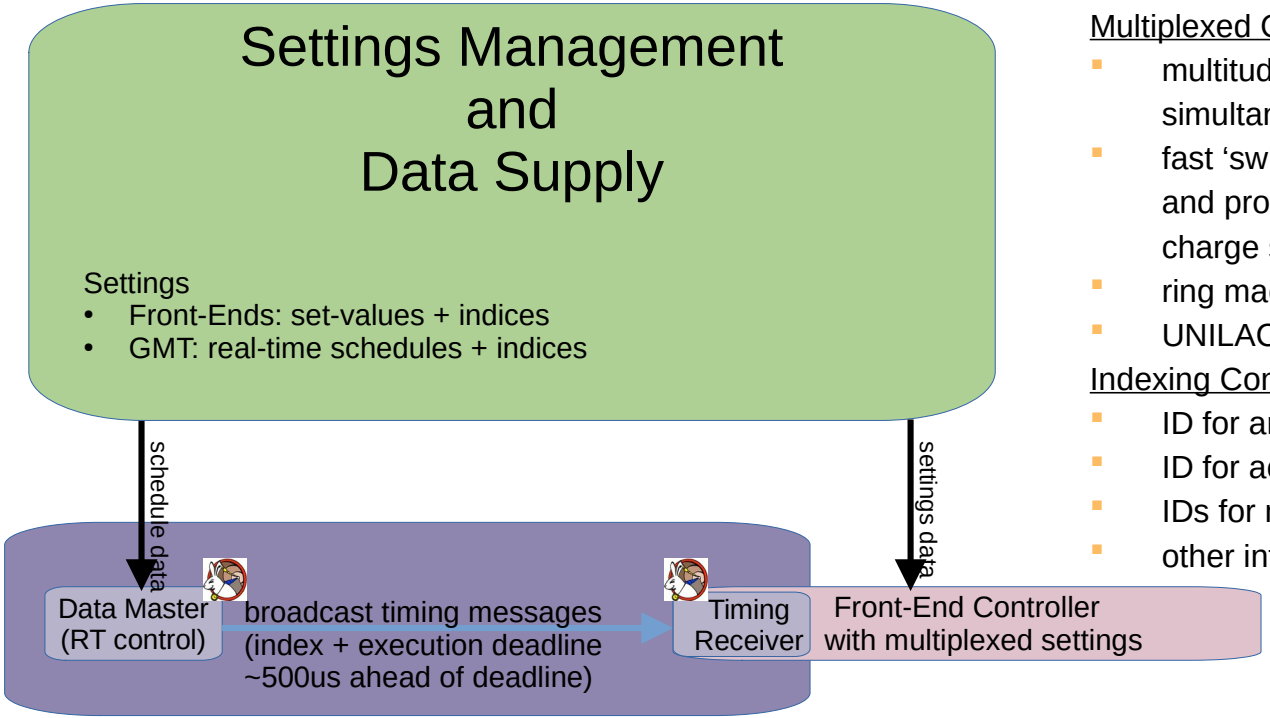
Multiplexed Operation, Control System Stack and General Machine Timing



General Machine Timing System:
trigger Front-Ends with multiplexing index on-time

Multiplexed Operation

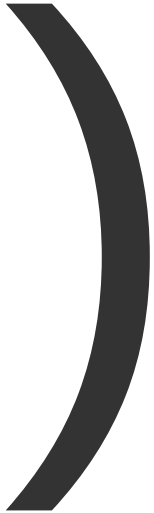
- multitude of beams for many experiments simultaneously
- fast ‘switching’ between beam destinations and properties (element, neutron number, charge state, energy, intensity, focus …)
- ring machines: 1Hz switching
- UNILAC: 50 Hz switching

Indexing Concept

- ID for area, location (‚where‘)
- ID for action (‚what to do‘)
- IDs for multiplexing context (‚which beam‘)
- other information

GSI from the Control System Perspective

- ‘FAIR Control System’ including GMT (White Rabbit) @ GSI campus
- since 2016: CRYRING, (ring, ions-sources, Linac)
- since 2018: SIS18, ESR, all beamlines
- since 2022: synchronization of transfers between all ring machines
- iterative development with each beam-time

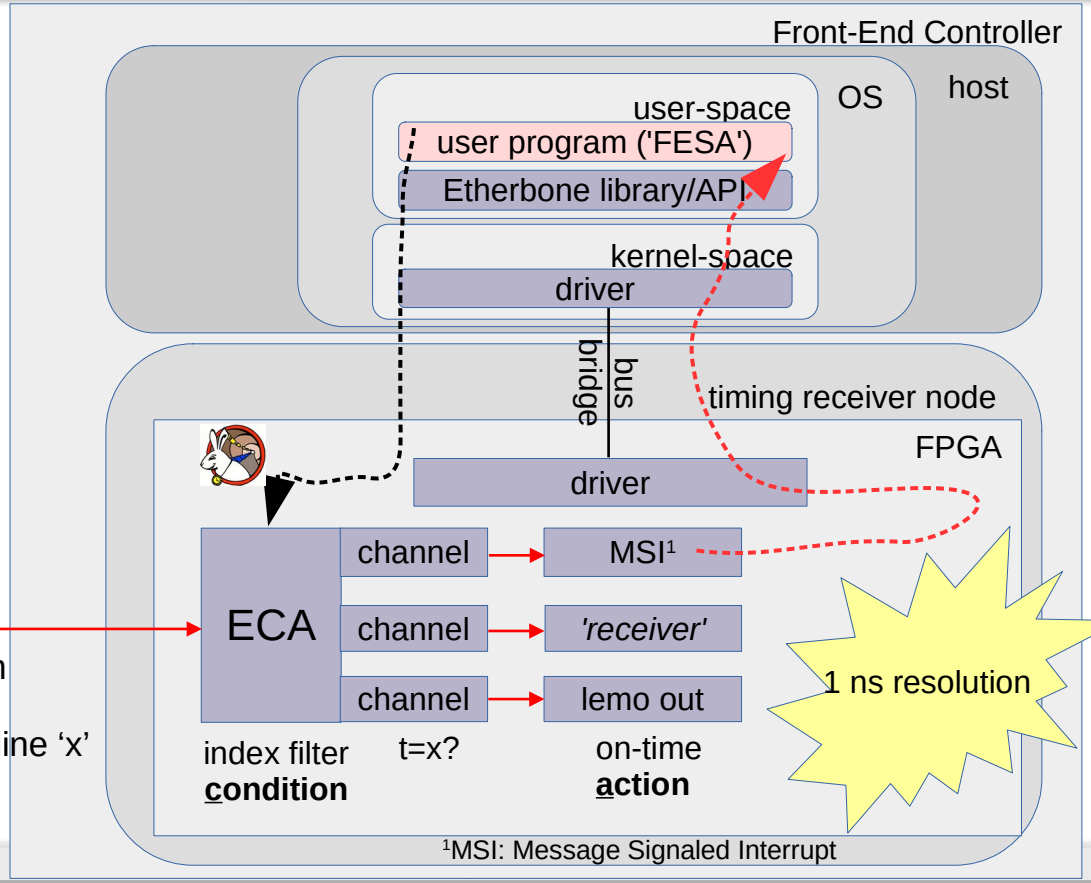


General Machine Timing

Machine Timing
- Event: timing telegram
- Condition: index
- Action: configured, executed on-time

telegram
- index
- deadline ‘x’

event



Common Features for Nodes
'Everything Happens in the FPGA'

no application specific VHDL!

instead:

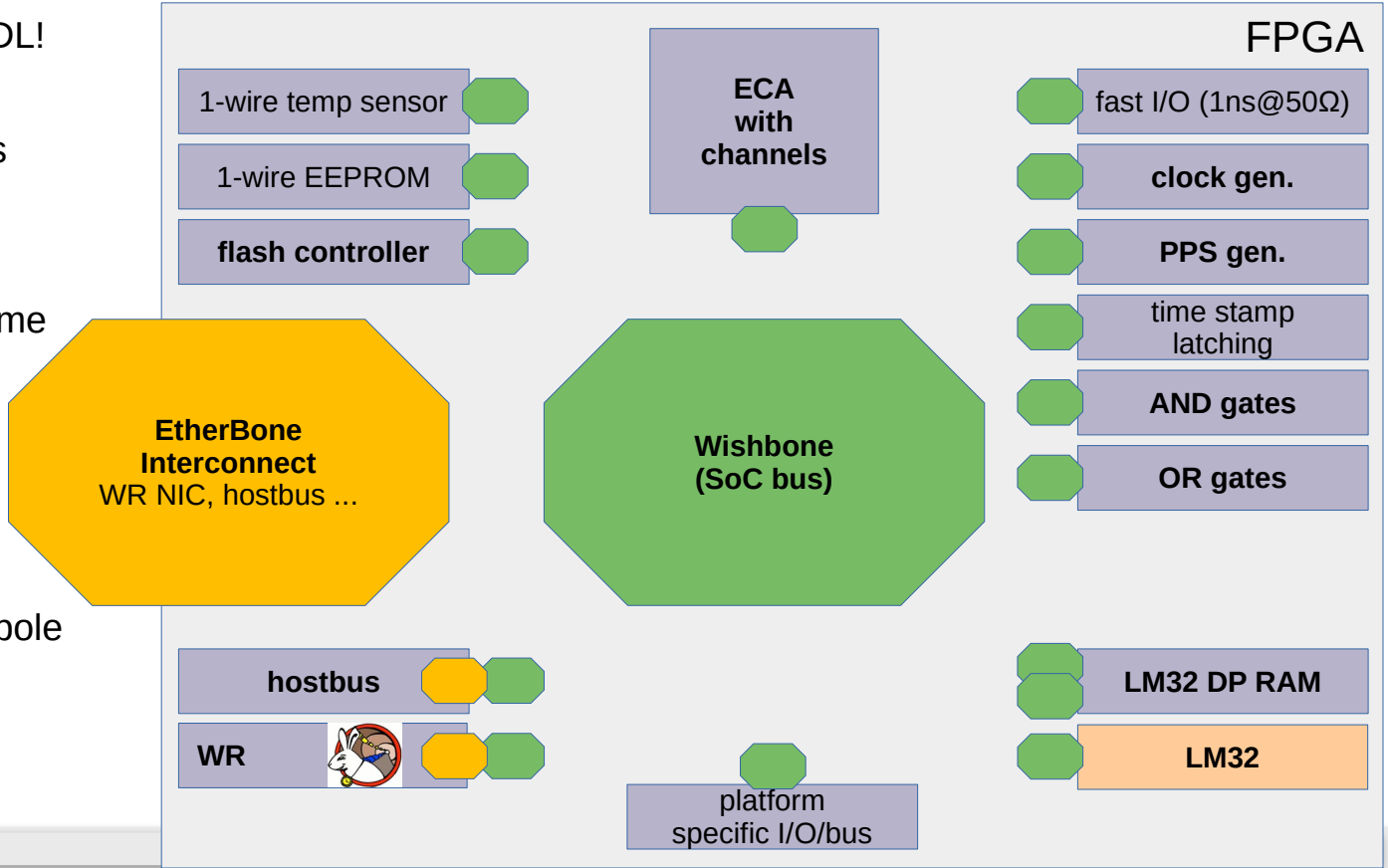
- configuration of IP cores
- ECA
- LM32 user softcore:

  upload binaries at run-time (c-code, OS-less)

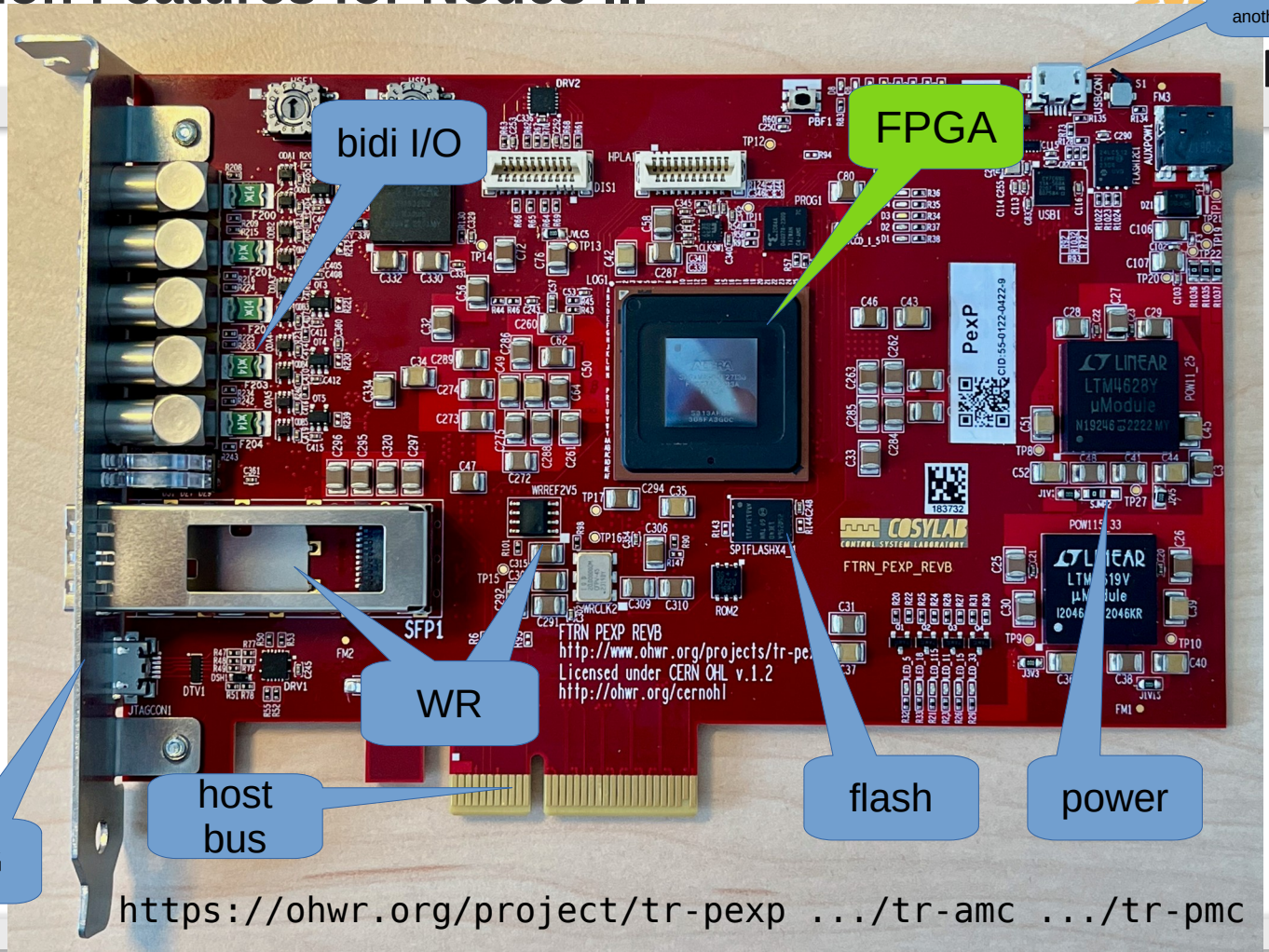
  hard real-time

  synchronosly at many nodes

  example: ramping up dipole magnet current or rf-cavity frequency

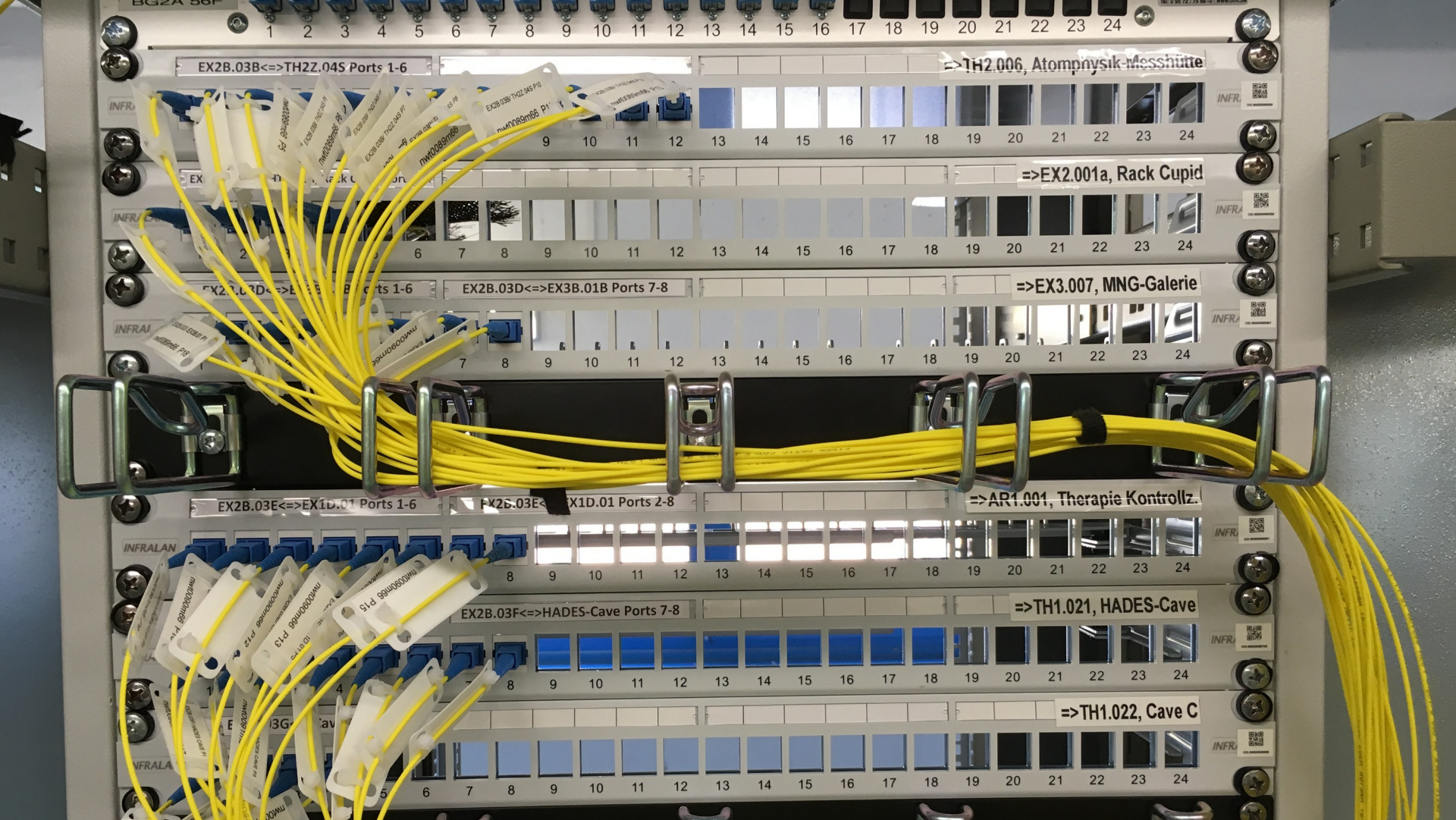


Common Features for Nodes ...



https://ohwr.org/project/tr-pexp .../tr-amc .../tr-pmc


PS20
PS21
YR03KH1
10V=50A
10V=160A
YR02KD
10A =5V
Ua=10V
YR03KV6G
YR03KV7K
YR03KD1D
A
B


EX2B.03B<=>TH2Z.04S Ports 1-6
=>TH2.006, Atomphysik-Messhütte
=>EX2.001a, Rack Cupid
EX2B.03D<=>EX3B.01B Ports 7-8
=>EX3.007, MNG-Galerie
EX2B.03E<=>EX1D.01 Ports 1-6
=>AR1.001, Therapie Kontrollz.
EX2B.03F<=>HADES-Cave Ports 7-8
=>TH1.021, HADES-Cave
=>TH1.022, Cave C

Network Management: Integration into Environment of Accelerator IT

(WRS is an Ethernet switch => crazy idea: treat it like an IT Ethernet switch)

us:

- installation
- (provide lists of WRS and nodes to IT)
- configure WRS (dot-config, generation and rollout via scripts)
- operation (on-call service)

just take care about GMT specific stuff!

important: VLANs

they:

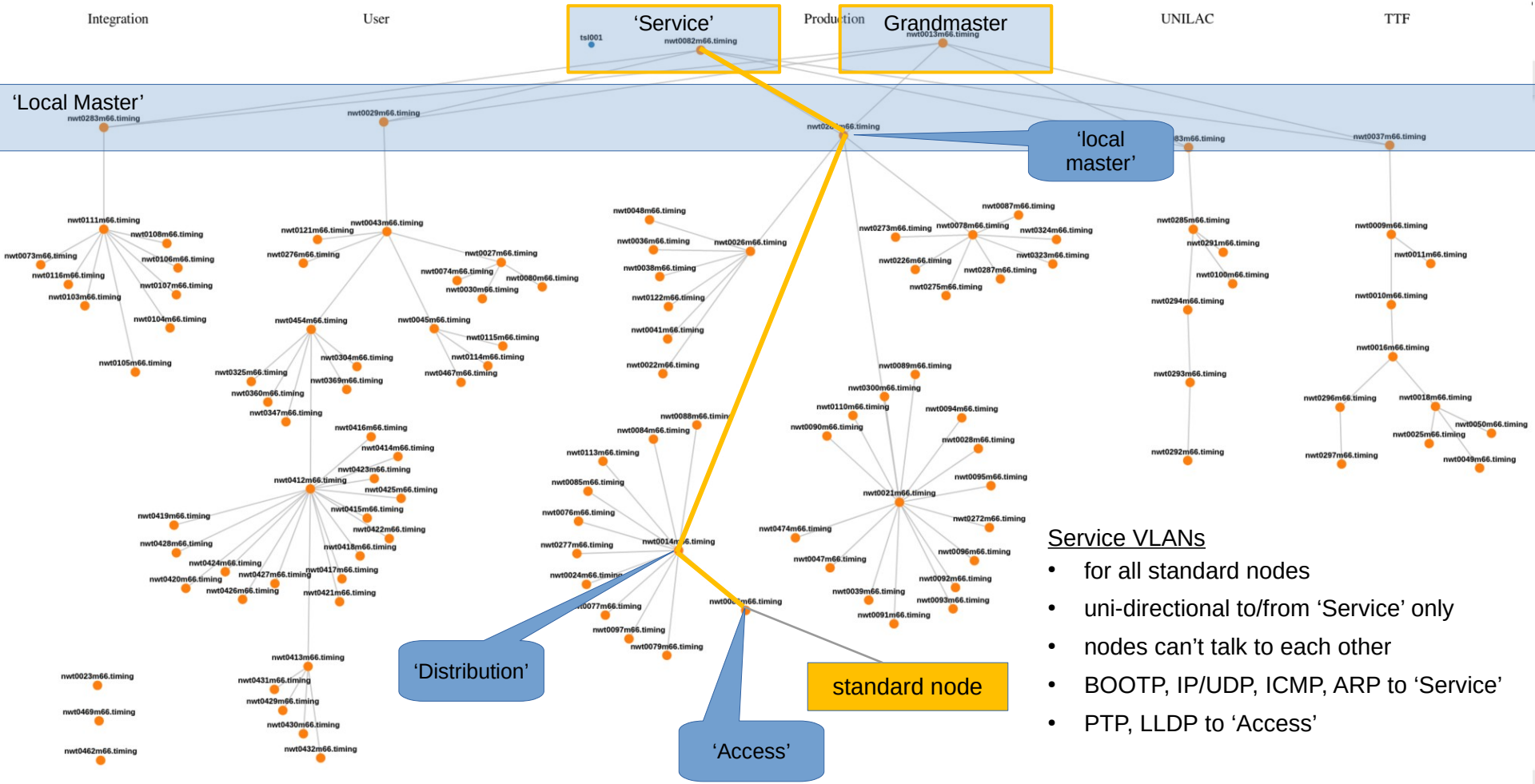
- IP backend, dedicated subnets and VLANs, unique on the campus
- redundant DHCP/BOOTP servers for all WRS and nodes
- redundant name servers for all WRS and nodes
- redundant Radius servers (VLANs, 802.1X)
- protected White Rabbit switch management network (for us ‚plug-and-play')

- 'Icinga' (~ nagios): WRS monitoring (health)
- 'Grafana': monitoring of key parameters (TX/RX packet rates, temperature, upper bound latency …)
- 'Netdisco': auto-discovery of switches and nodes (really cool!)

- user roles, accounts, security, …
- maintenance

Configuration: Timing Group

(inspired by ‘Guidelines for White Rabbit Infrastructure at CERN’)

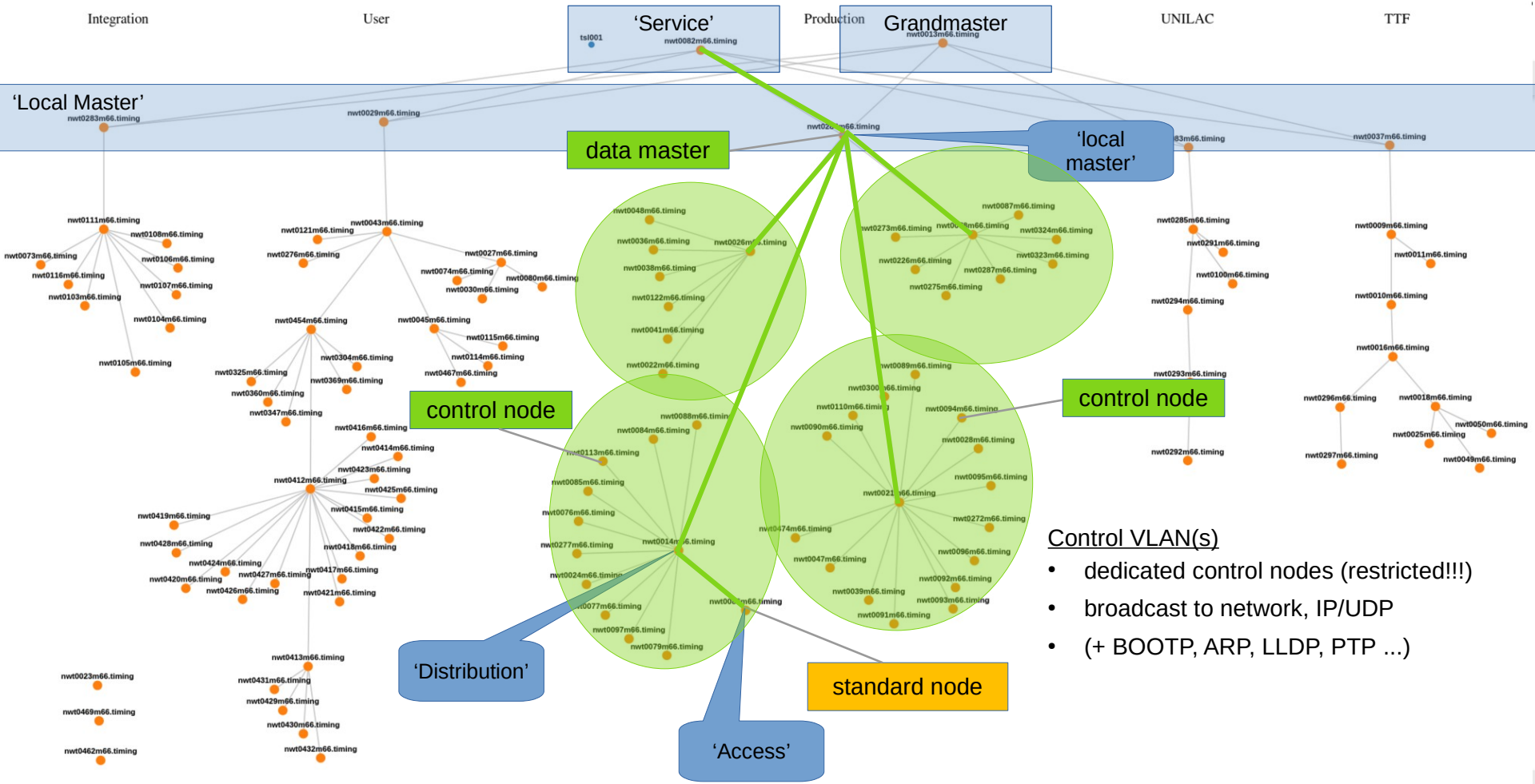


Service VLANs

- for all standard nodes
- uni-directional to/from ‘Service’ only
- nodes can’t talk to each other
- BOOTP, IP/UDP, ICMP, ARP to ‘Service’
- PTP, LLDP to ‘Access’

Configuration: Timing Group

(inspired by ‘Guidelines for White Rabbit Infrastructure at CERN’)

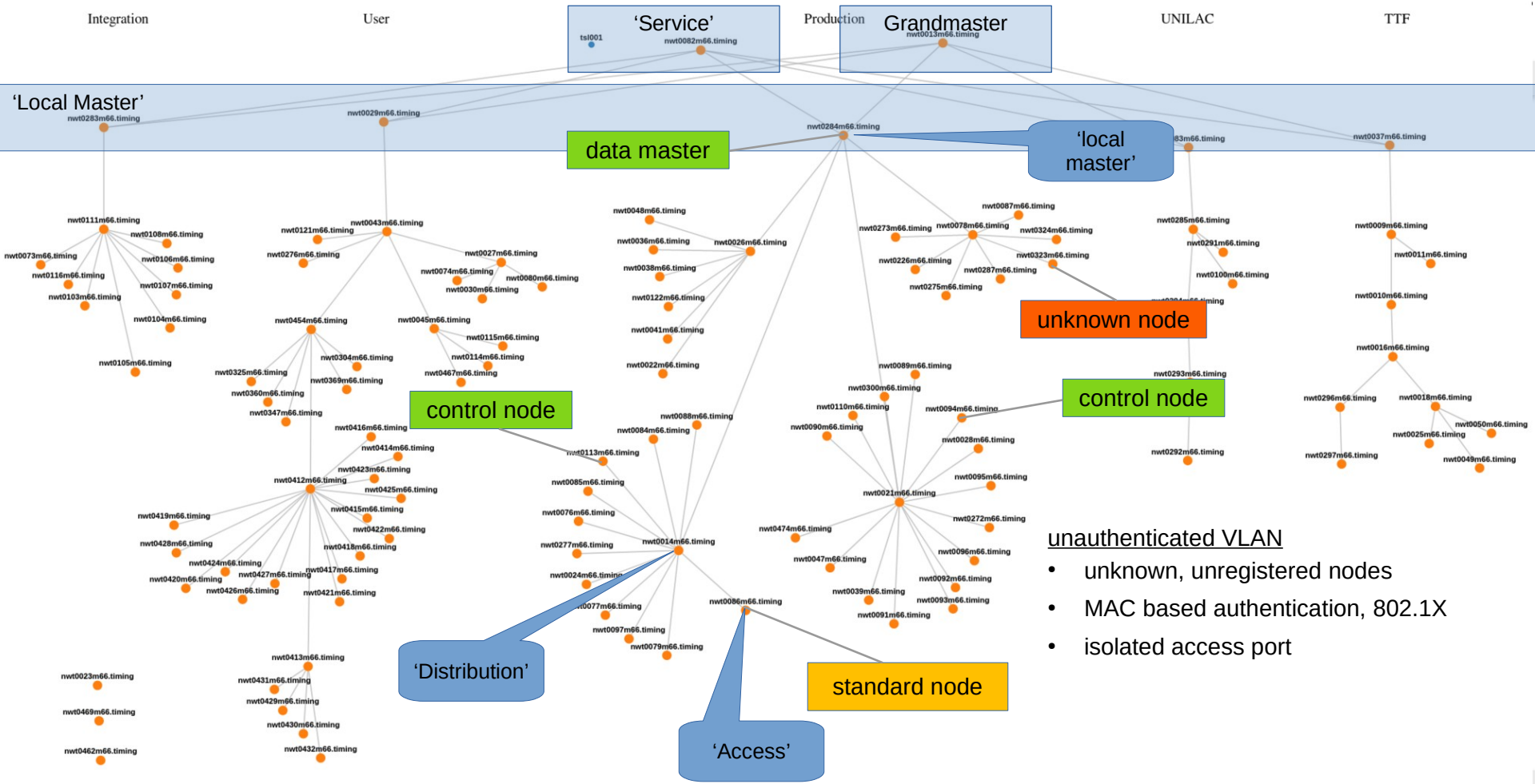


Control VLAN(s)

- dedicated control nodes (restricted!!!)
- broadcast to network, IP/UDP
- (+ BOOTP, ARP, LLDP, PTP ...)

Configuration: Timing Group

(inspired by ‘Guidelines for White Rabbit Infrastructure at CERN’)



<u>unauthenticated VLAN</u>

- unknown, unregistered nodes
- MAC based authentication, 802.1X
- isolated access port

WR @ GSI, Status

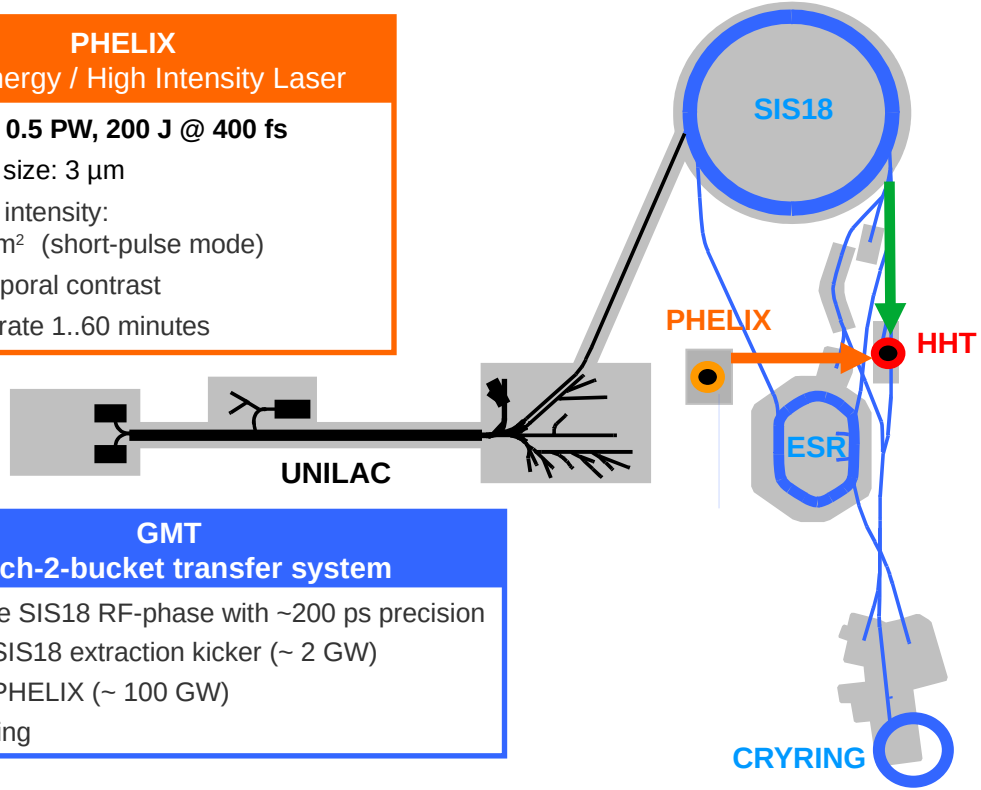
- 67 (104) [333] WR switches for facility operation (in use) [on-site]
  - mainly Creotech and Seven Solutions, some SyncTechnology
  - v6.1 for all operational WRS
  - SFP, mainly CBO (with DDM)
- 332 (416) [2296] WR nodes for facility operation (in use) [on-site]
  - OHWR: TR-PMC, TR-AMC, TR-PEXP; in-house: **SCU** (workhorse)
  - Arria V GX, Arria II GX
  - wrpc-v4.2
  - https://github.com/GSI-CS-CO/bel_projects, current release v6.2.1 ‚fallout‘
- host systems
  - SCU: COM Express
  - non-SCU: uTCA, VME, IPC (1U), Server-PC, other
  - PXE boot of ‚ACO-Ramdisk‘ for **A**ccelerator **CO**ntrol system
  - other

GMT Precision (Accelerator Control)
Sync PHELIX Pulse and Ion Bunch (*)

(*) Zs. Major et al., "High-Energy Laser Facility PHELIX at GSI: Latest Advances and Extended Capabilities", in preparation (2023)

PHELIX
High Energy / High Intensity Laser

Laser bay: 0.5 PW, 200 J @ 400 fs
- focal spot size: 3 µm
- maximum intensity: 5×10^{20} W/cm^2 (short-pulse mode)
- > 10^{11} temporal contrast
- repetition rate 1..60 minutes



SIS18

SIS18, here:
- **extracted bunch**
- length ~100ns
- v/c ~ 0.9

GMT
bunch-2-bucket transfer system
- measure SIS18 RF-phase with ~200 ps precision
- trigger SIS18 extraction kicker (~ 2 GW)
- trigger PHELIX (~ 100 GW)
- monitoring

HHT

PHELIX:
200 J @ 1 – 10 ns, 2ω
15 cm beam diameter
maximum focussed intensity: ~10^{16} W/cm^2

GMT Precision (Accelerator Control)
Sync PHELIX Pulse and Ion Bunch (*)

(*) Zs. Maj

Hig

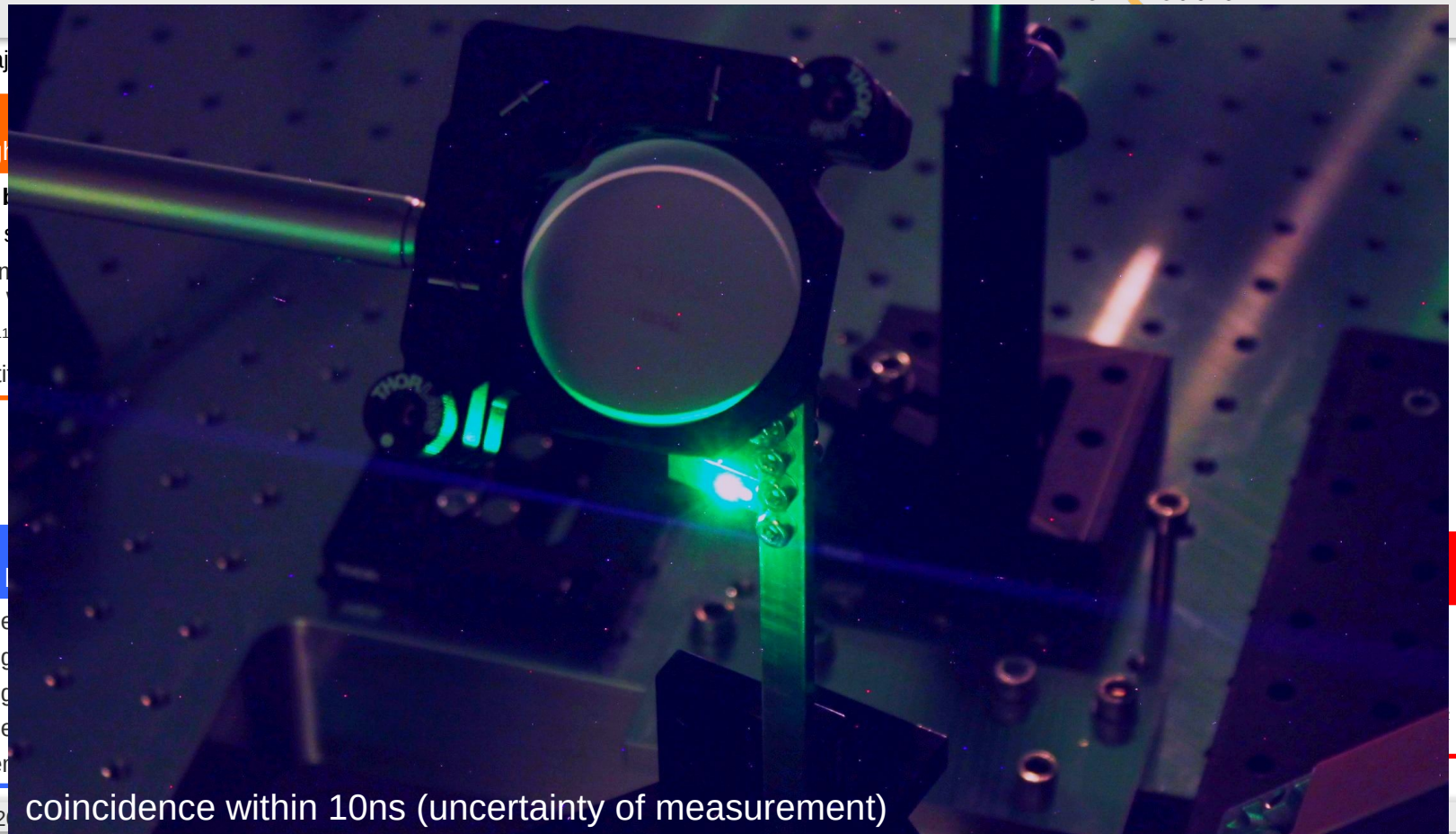
Laser

- focal
- maxi

5x10[20]

- > 10[11]
- repeti

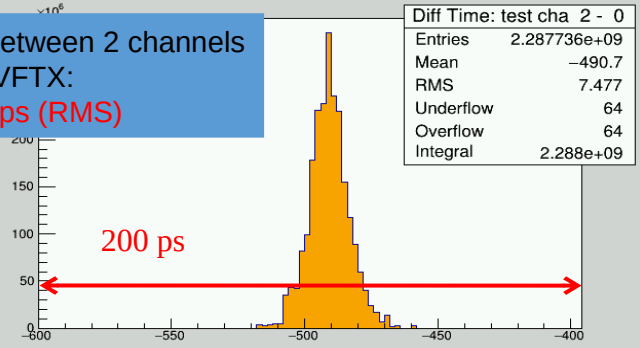
- me
- trig
- trig
- me
- rer



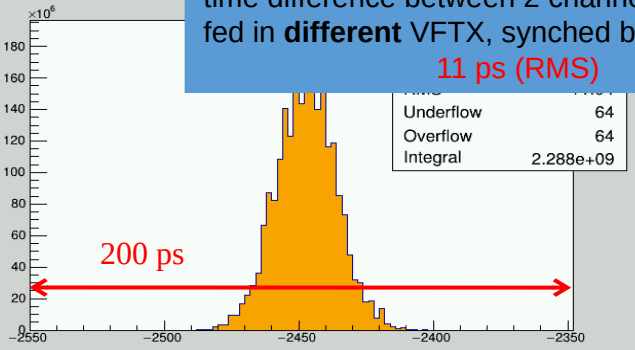
GMT Precision (Experiments, DAQ)
Time-of-Flight Measurements (*)

(*) N. Kurz et al., “White Rabbit 200 MHz Clock Effects on TOF Measured with High Resolution VME TDC VFTX” (2023)

time difference between 2 channels
fed in **identical** VFTX:
7.5 ps (RMS)

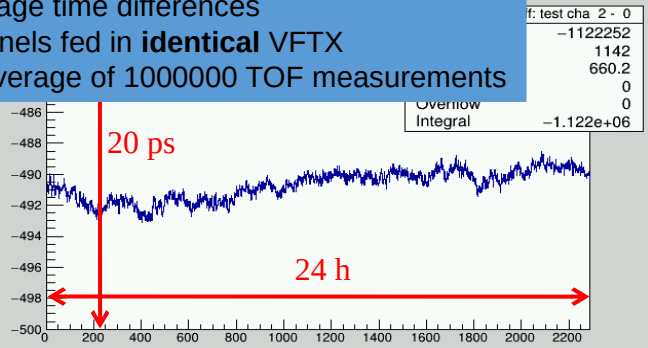


time difference between 2 channels
fed in **different** VFTX, synched by White Rabbit
11 ps (RMS)



→ jitter GMT, WR
~8 ps (RMS)

trending of average time differences
between 2 channels fed in **identical** VFTX
(each entry is average of 1000000 TOF measurements



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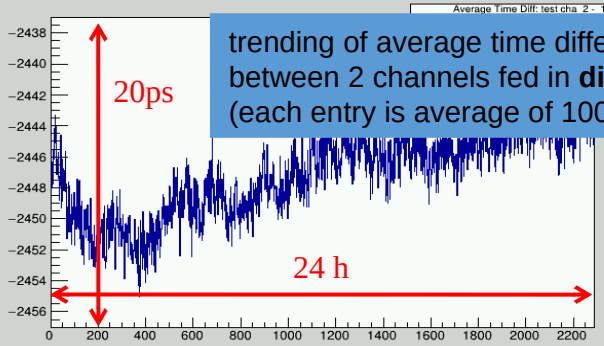
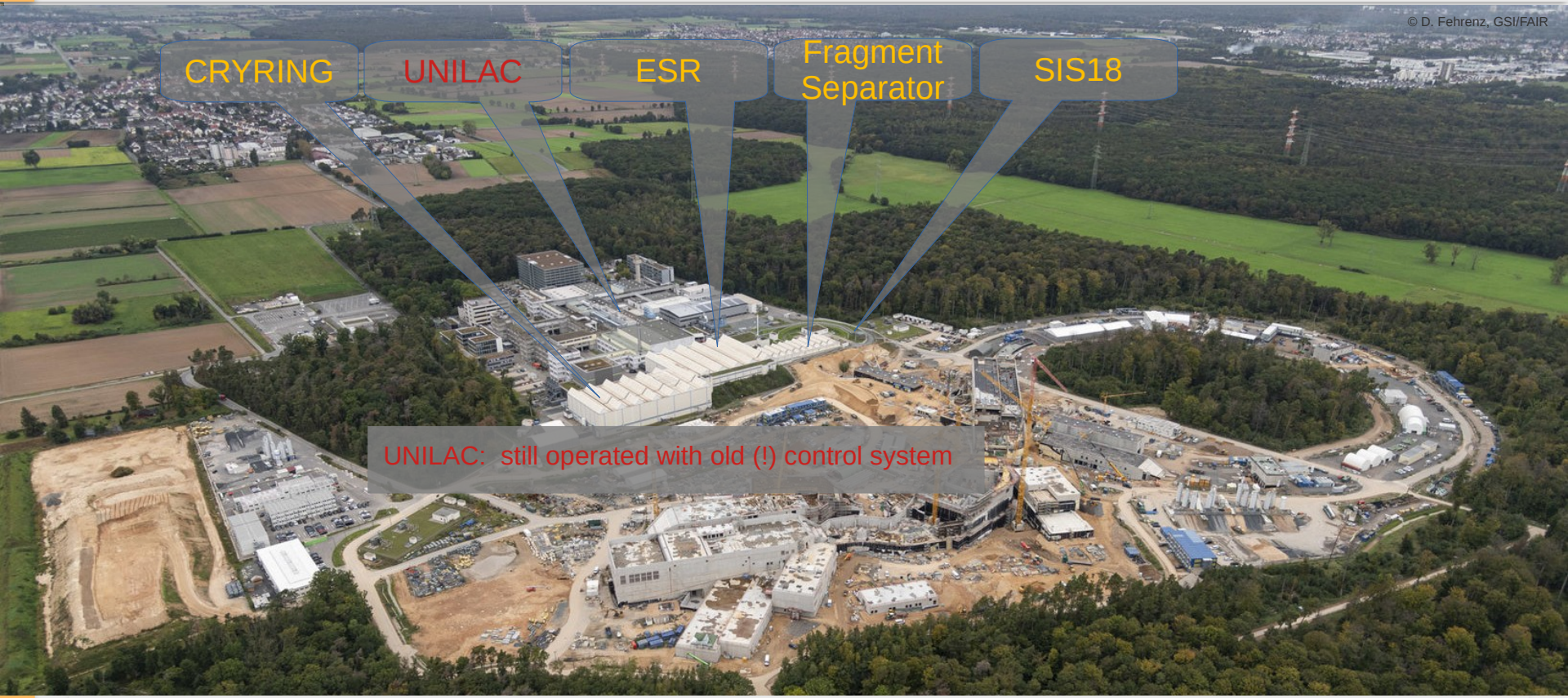
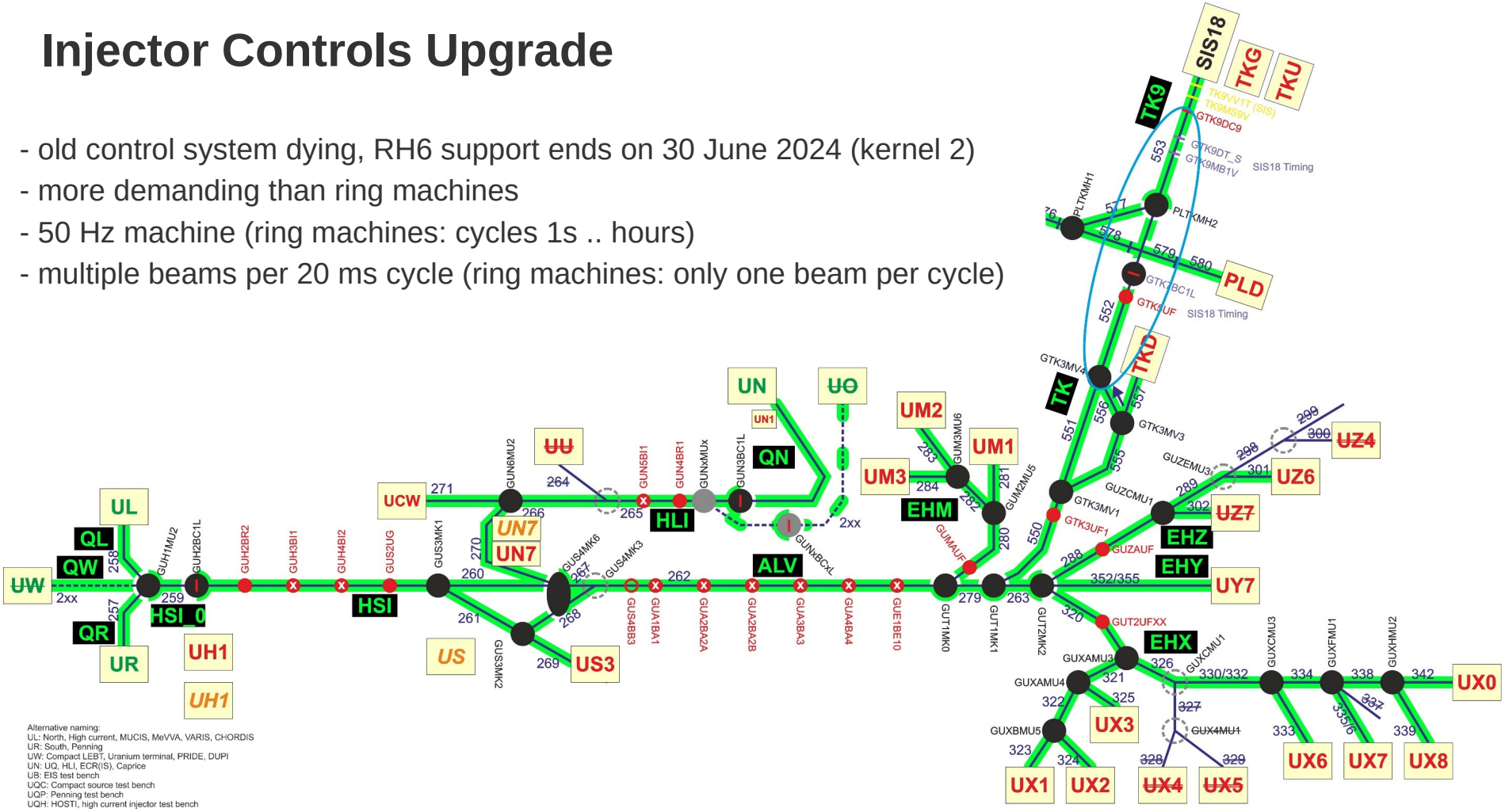


GSI from the Control System Perspective



Injector Controls Upgrade

- old control system dying, RH6 support ends on 30 June 2024 (kernel 2)
- more demanding than ring machines
- 50 Hz machine (ring machines: cycles 1s .. hours)
- multiple beams per 20 ms cycle (ring machines: only one beam per cycle)



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new machine timing
- timing message up to 30 kHz
- higher control system layers plan execution of schedule for long periods ahead of time

GMT concept
- dedicated White Rabbit network
- single Data Master => Data Master cluster
- new Data Master HW
    - more powerful FPGA (Arria 10 GX, big!)
    - (additional on-board PS-RAM)
    - 2nd SFP for synchronization network between DM

old machine timing
- timing messages at 2..3 kHz
- timing system decides autonomously what is played in the next 20 ms cycle
- required little resources (M68 CPUs)

Summary

GSI, all ring machines

- WR based machine timing system **in production** since a few years
- works like a charm; no failures in current beam time which started 5 months ago

GSI, Injector Controls Upgrade

- 1st dry-run with real facility in Juli 2024 (this is soon!!!)
- productive in 2025 or 2026; decision this summer

FAIR

- White Rabbit switches and timing receivers already on-site
- new Data Master hardware in the pipeline
- White Rabbit network installation starts autumn 2024
- machine commissioning 2026
- 1st physics run 2027

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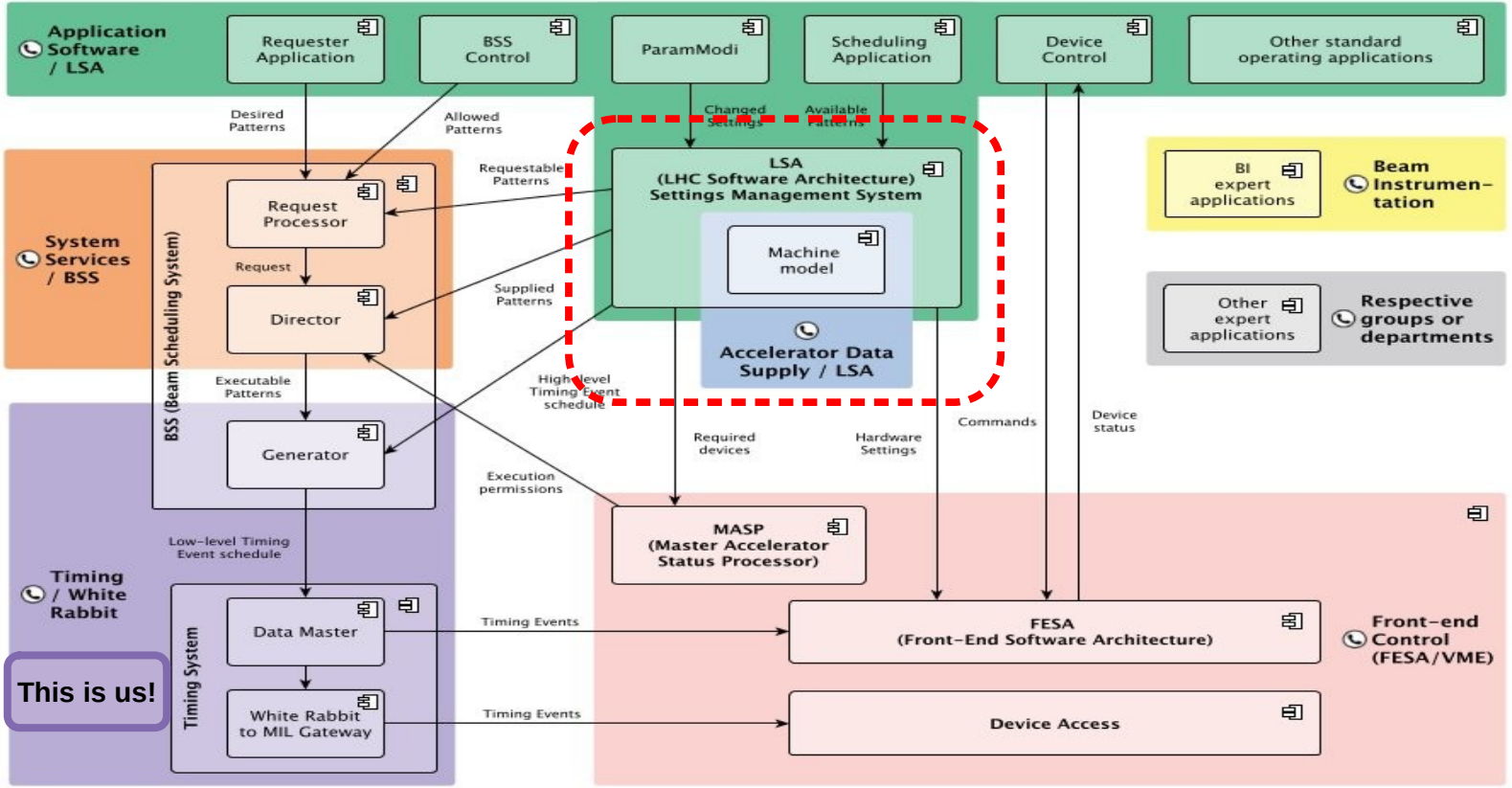
Thank You For Your Attention

WR @ GSI, New

- TR-PEXP timing receivers
  - Arria V GX
    - ~640 pcs delivered as in-kind to FAIR in 2023
    - 5 fast bidi I/O
- Arria 10 GX
    - successor of Arria II and Arria V platforms
- timing release
  - ‚fallout‘ release 2020 + maintenance releases
  - migration from older ramdisk (kernel 3) to newer ramdisk (kernel 5, Yocto)
  - ...
  - migration wrpc 4.2 → wrpc 5 with next major release

Control System Stack – Involvement of Seven Distinct Teams

Who you gonna call?



What is this?
What is it good for?

This is an simplified view on (a part of) the control system's architecture, created with the intention to help you make an educated guess on who to call when something's not working. If you're not sure, don't worry. It'll take time to get to know the new control system structures and no one will get mad if you call the "wrong" group.

Please be aware that the diagram is focused on certain areas of the control system and consequently, other equally important components are missing. Also, consider this diagram to be work-in-progress. If you'd like to contribute, see below.

What do the symbols mean?

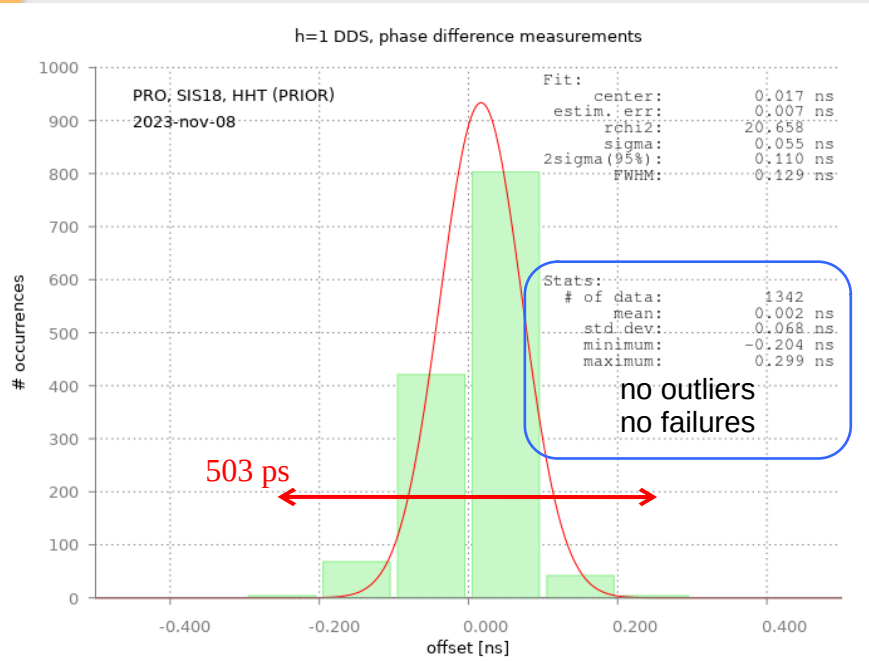
The boxes symbolize applications, components or subsystems of the control system. The arrows stand for data flows between them. The colored regions represent areas of responsibility. The terms next to the telephone icons are taken from FSN (when switched to English) and may help you look up the on-call number you need to dial.

Who can I ask about it?

If you have any questions, comments, suggestions or corrections regarding this diagram, please feel free to call Hanno at -3089 or write to h.huether@gsi.de.

Thanks!

GMT Precision (Accelerator Control)
Sync PHELIX Pulse and Ion Bunch (*)



- measure SIS18 RF-phase
- trigger SIS18 extraction kicker (~ 2 GW)
- trigger PHELIX (~ 100 GW)
- measure kicker probe signal
- remeasure RF-phase

Advances and Extended Capabilities", in preparation (2023)