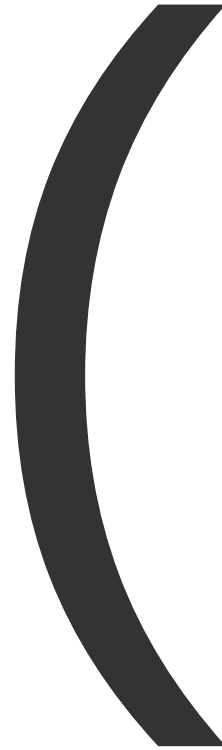# Acknowledgements

- GSI Timing Team: Enkhbold Ochirsuren, Marcus Zweig, Martin Skorsky, Mathias Kreider, Stefan Rauch, Alexander Hahn, Michael Reese, Frederic Ameil

- GSI ACC IT Team: Peter Pfister, Christoph Handel …

- CERN Team: Greg Daniluk, Maciej Lipinski …

- External: Alessandro Rubini, Adam Wujek ...
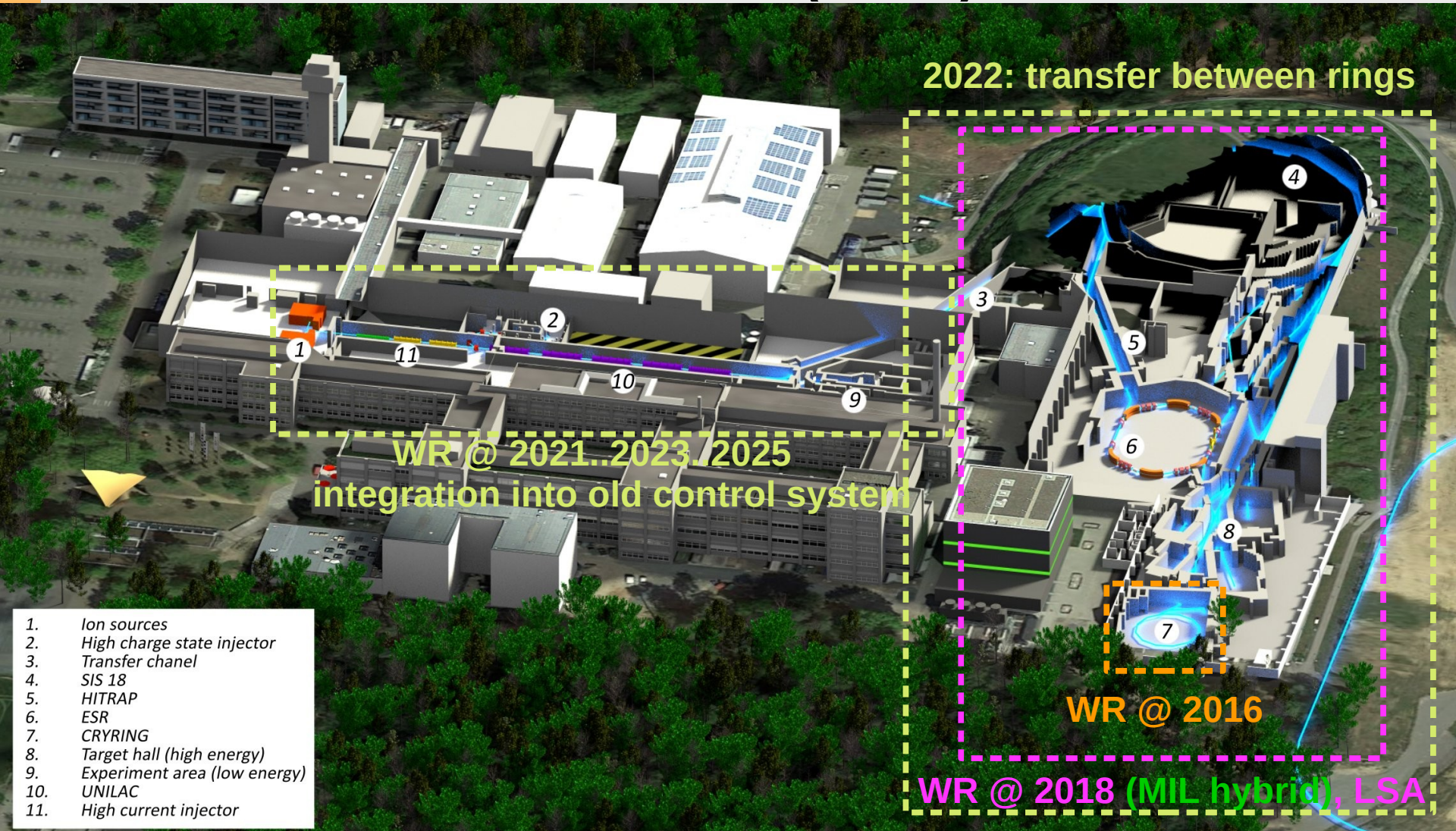
Operational Experience with a WR-based Timing System

- Today: Beam-Time 2022

- Introduction General Machine Timing

- Setup

- Status

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

General Machine Timing (Some Background)

2022: transfer between rings

WR @ 2021..2023..2025
integration into old control system

WR @ 2016

WR @ 2018 (MIL hybrid), LSA

1. Ion sources
2. High charge state injector
3. Transfer chanel
4. SIS 18
5. HITRAP
6. ESR
7. CRYRING
8. Target hall (high energy)
9. Experiment area (low energy)
10. UNILAC
11. High current injector

General Machine Timing

- time distribution
- clock distribution
  - mostly out of scope
  - dedicated system
    by Ring-RF

- Machine Timing
  <u>Event</u>: DM telegram
  <u>Condition</u>: index
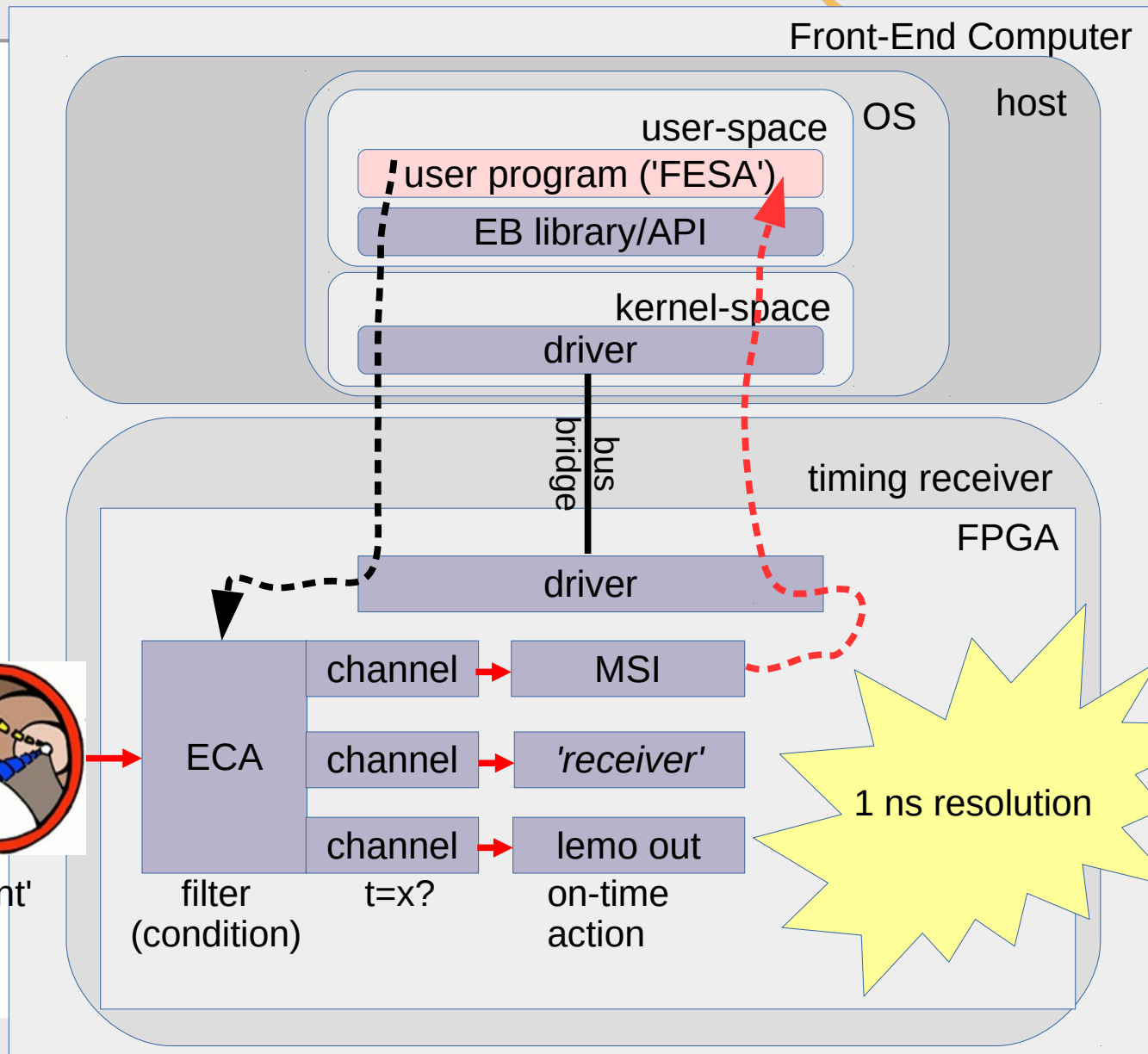 <u>Action</u>: configured,
  executed on-time

Front-End Computer

host

OS

user-space

user program ('FESA')

EB library/API

kernel-space

driver

bus bridge

timing receiver

FPGA

driver

channel → MSI

ECA

channel → *'receiver'*

channel → lemo out

filter
(condition)

t=x?

on-time
action

1 ns resolution

Data Master

broadcast telegrams
- index
- deadline (ns)
- ...

'event'

Info (incomplete)

- need common notion of time: WR-PTP

- broadcast of 'timing messages' with upper bound latency

- no distributed clocks (can do clocks of constant frequencies at nodes)

- ~116 White Rabbit Switches

- five White Rabbit networks

    - Production (49): operation of accelerator facility (ring machines)

    - UNILAC (7): operation of injector (linacs)

    - Integration (10): control system testing

    - User (39): development, labs, …

    - Timing Test Facility (11): timing system testing

- 311 … 1619 nodes (presently seen … registered)

- simple node management (interface for main control room)

- don't trust nodes: simple security (VLANs, 802.1X)

White Rabbit Switches: Five Roles
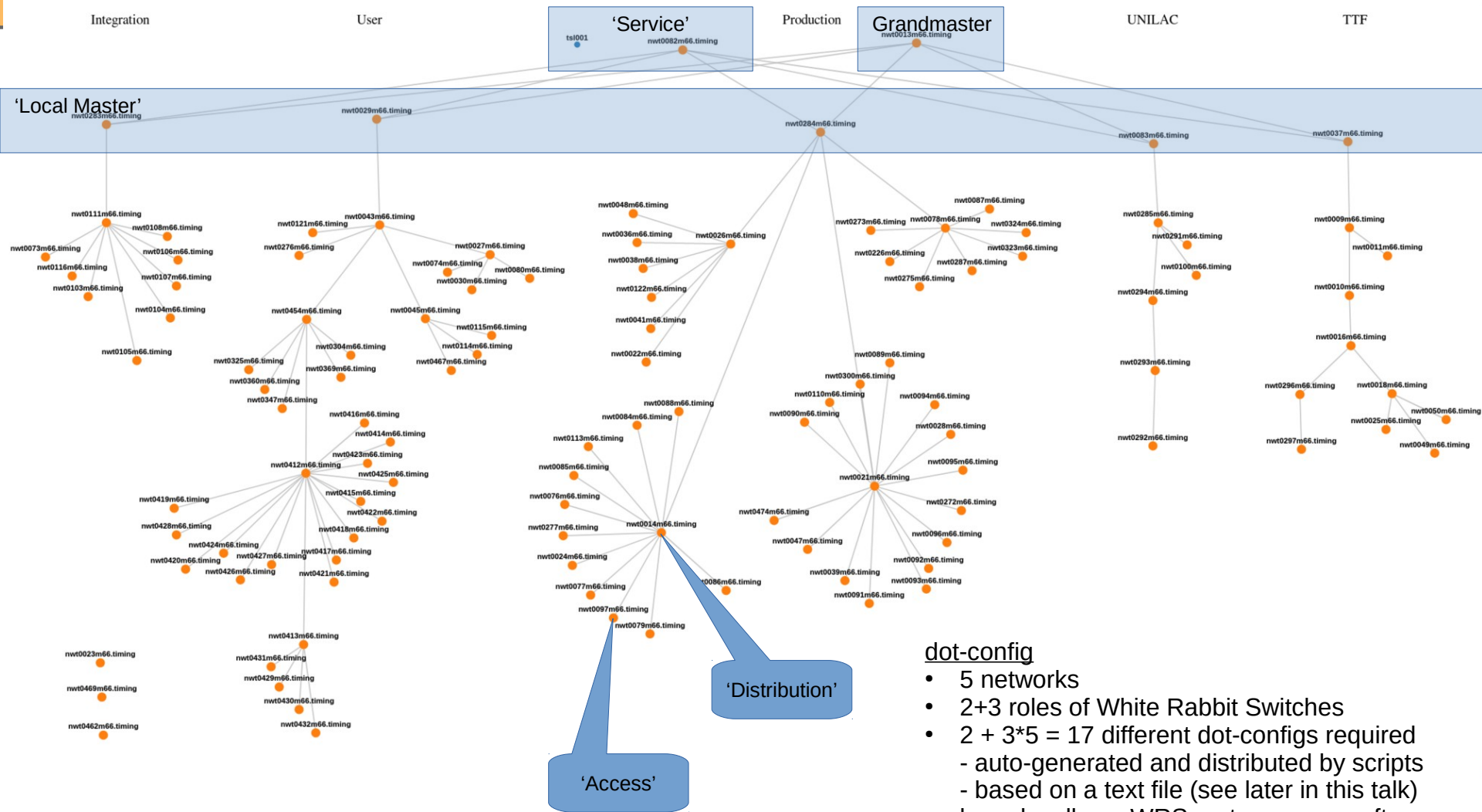
dot-config
- 5 networks
- 2+3 roles of White Rabbit Switches
- 2 + 3*5 = 17 different dot-configs required
  - auto-generated and distributed by scripts
  - based on a text file (see later in this talk)
- keep locally on WRS: auto-recovery after blackout must not depend on other infrastructure

Roles and VLANs
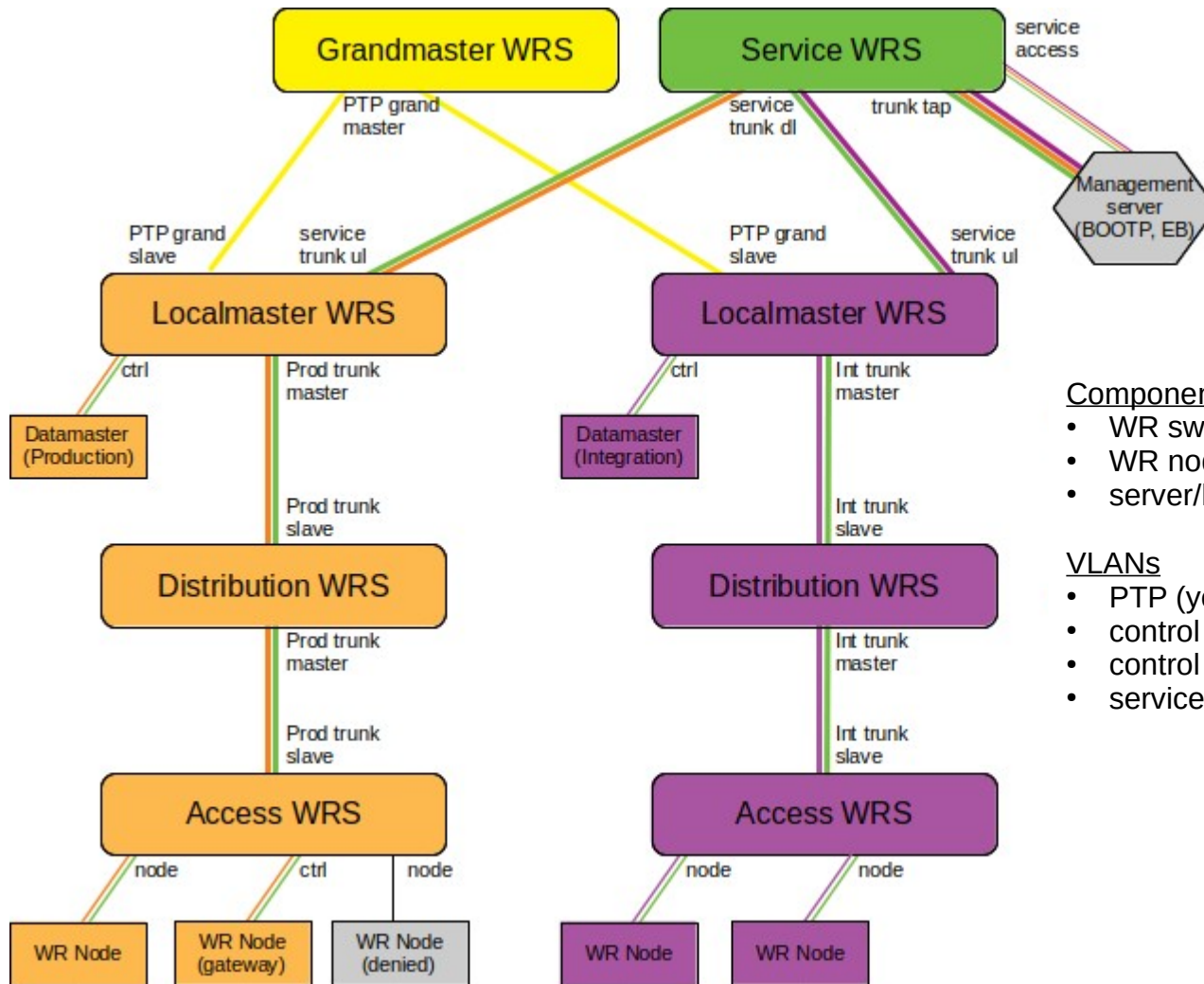
Components
- WR switches (boxes)
- WR nodes (rectangles)
- server/host/IT (hexagon)

VLANs
- PTP (yellow)
- control #1, production (orange)
- control #2, integration (magenta)
- service, 2 * uni-directional (lime)

Roles and VLANs
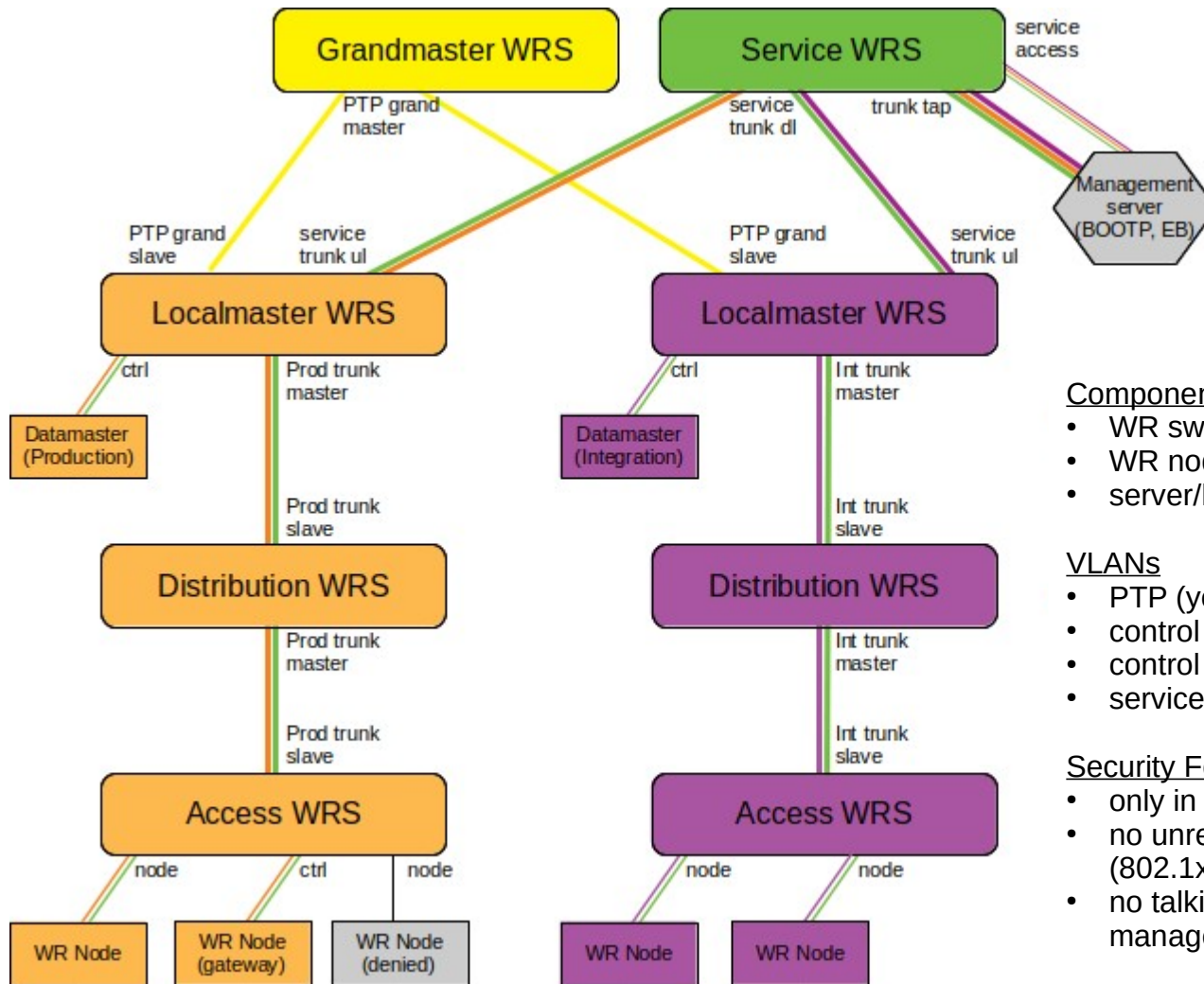
Components
- WR switches (boxes)
- WR nodes (rectangles)
- server/host/IT (hexagon)

VLANs
- PTP (yellow)
- control #1, production (orange)
- control #2, integration (magenta)
- service, 2 * uni-directional (lime)

Security Features for Regular Nodes
- only in **service VLAN**
- no unregistered nodes in service VLAN (802.1x)
- no talking to other nodes – only to management master

We don't trust nodes …

TL;DR: This worked out extremely well

Detailed version:

- idea: maximize use of IT infrastructure managed by IT colleagues

- approach: White Rabbit switch should behave like a normal IT switch

- contribution/help by Alessandro Rubini, Adam Wujek and Christoph Handel

they provide ...

- IP backend, dedicated unique subnets and VLANs on the GSI campus

- redundant DHCP/BOOTP servers for all WRS and nodes

- redundant name servers for all WRS and nodes

- redundant Radius servers (VLANs)

- protected White Rabbit switch management network ('plug-and-play')

- (central firewall management)

- management server for all White Rabbit networks

- FNT-command: tool for documenting installations

- Icinga: WRS monitoring (health)

- Grafana: monitoring of key parameters

- Netdisco: network auto-discovery of switches and nodes (really cool!)

- web server: remote management (dedicated tools)

- all integrated into accelerator IT infrastructure: user roles, accounts, security, **maintenance**

- ...

Integration into IT Environment: Tasks Timing Group

- provide and deploy WRS dot-config, firmware, …

- maintain lists of WRS and nodes (IP, MAC, name, comment)
    - text file, internal git repo
    - imported (git pull) into IP-backend by IT twice per hour
    - simple text files for basic infrastructure – no database; why?
      database depends on network, not available after blackout
      network shall not depend on database

- provide/install/document/maintain/operate WR network
    - cables, fibres, SFPs, switches
    - includes planning of cable routes interconnecting WR switches as well as power, cooling and space in racks
    - N.B.: labeling of cables and documentation are major tasks

- node development
    - involved in hardware development
    - provide gateware, drivers, API
    - registration of nodes at White Rabbit networks is not with IT, but with us (upon requests by users)
      remark: MAC based authentication via 802.1x
    - not our task: installation, operation or monitoring of nodes; done by users

- the usual preparation
  - **data master and nodes**: feature freeze, **release;** 6 months prior beam time (iterative process together with FESA colleagues)
  - **WRS**: ask Adam Wujek to synthesize firmware with latest fixes and stuff, update dot-config, testing …; deployment only in dedicated and rare **maintenance windows**
  - **'integration tests'** with all control system layers; 3-4 months prior beam time
  - several ‚dry-runs' for severe testing at full scale with real equipment, 1-2 months ...
- 24/7 operation
  - ~**6 months of beam operation, including on-call service**
  - shutdown operation, no on-call service

- White Rabbit: flawless operation; diagnostic module in FPGA: no known failures

```
      node, ebStatus, up,   time [s], offset[ms],     sync, dtMax, link, uptime[h], stallMax,  gwBuild,          MAC, #lock
scuxl0005t,       ok,  1, 1648037995,      36997, TRACKING,    16,   UP,   1011.40,     32.9,    6.1.2, 00267b0003ba, 00000
scuxl0006t,       ok,  1, 1648037995,      36997, TRACKING,    16,   UP,   1269.66,     32.9,    6.1.2, 00267b00039a, 00000
scuxl0013t,       ok,  1, 1648037995,      36997, TRACKING,    16,   UP,   1539.13,     32.9,    6.1.2, 00267b00030d, 00000
scuxl0015t,       ok,  1, 1648037996,      36997, TRACKING,    16,   UP,   1632.00,     32.9,    6.1.2, 00267b00039c, 00000
scuxl0016t,       ok,  1, 1648037996,      36997, TRACKING,    16,   UP,   1702.12,     32.9,    6.1.2, 00267b000310, 00000
scuxl0020t,       ok,  1, 1648037996,      36997, TRACKING,    16,   UP,     48.01,     32.9,    6.2.1, 00267b0003cf, 00000
scuxl0021t,       ok,  1, 1648037996,      36997, TRACKING,    16,   UP,    282.61,     32.9,    6.1.2, 00267b00038d, 00000
scuxl0023t,       ok,  1, 1648037996,      36996, TRACKING,    16,   UP,     47.98,     32.9,    6.2.1, 00267b0003a7, 00000
scuxl0025t,       ok,  1, 1648037997,      36997, TRACKING,    16,   UP,   1515.21,     32.8,    6.1.2, 00267b0003b1, 00000
scuxl0026t,       ok,  1, 1648037997,      36997, TRACKING,    16,   UP,   1799.34,     32.8,    6.1.2, 00267b0003de, 00000
scuxl0027t,       ok,  1, 1648037997,      36997, TRACKING,    16,   UP,    360.45,     32.9,    6.1.2, 00267b0003bf, 00000
scuxl0053t,  TIMEOUT, --,        ---,        ---,      ---,   ---,  ---,       ---,      ---,      ---,          ---,   ---
scuxl0068t,       ok,  1, 1648038019,      36997, TRACKING,    16,   UP,   3410.61,      0.0,    6.1.2, 00267b0003aa, 00000
scuxl0116t,       ok,  1, 1648038034,      36997, TRACKING, 719476720,  UP,   3386.58,     32.9,    6.1.2, 00267b0003bb, 00008
scuxl0118t,       ok,  1, 1648038034,      36997, TRACKING,    16,   UP,   1269.68,     32.9,    6.1.2, 00267b000376, 00000
...
```

- the usual preparation
  - **data master and nodes**: feature freeze, **release;** 6 months prior beam time (iterative process together with FESA colleagues)
  - **WRS**: ask Adam Wujek to synthesize firmware with latest fixes and stuff, update dot-config, testing …; deployment only in dedicated and rare **maintenance windows**
  - **'integration tests'** with all control system layers; 3-4 months prior beam time
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- 24/7 operation
  - ~**6 months of beam operation, including on-call service**
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- White Rabbit: flawless operation; diagnostic module in FPGA: no known failures

- our nodes don't like reboot of WRS: in ~10% of case 'no lock' or 'no link'
  - sometimes ifconfig down/up of the WRS port helps
  - better: power-cycle node
  - not a real issue as WRS work reliably

- our data master failed once

- sometimes the OS of Front-End Computers hangs up (not White Rabbits fault); work-around for missing management interface of FECs: ‚eb-reset' via WR network

2022: Experience from Operation II

We have been lucky too:

- not hit by sudden power-cuts as in 2021

- very few other failures - at least not with beam in the machine :-) …

- no bad surprises such as https://ohwr.org/project/wr-switch-sw/issues/239 as in 2021 (BTW: this was a really bad one as it happened on ALL switches almost simultaneously with beam in the full accelerator complex - of course in the middle of the night)

BTW: Since 2022 we have White Rabbit based synchronization **of transfers** between all ring machines, the so-called ‚bunch-to-bucket transfer system' is used in routine operation!

Bunch-to-bucket transfer of hydrogen-like $^{198}Au^{78+}$ @10 MeV/u between the two rings using frequency beating (T_{beat}= 915μs).

Shown is the position (relative to the relevant ring-RF signal) of a single bunch of 1E6 ions observed by beam profile monitors for about 35ms prior extraction (ESR, bottom) and 300ms after injection (CRYRING, right).

b2b transfer

time

time of 1 revolution in the ring
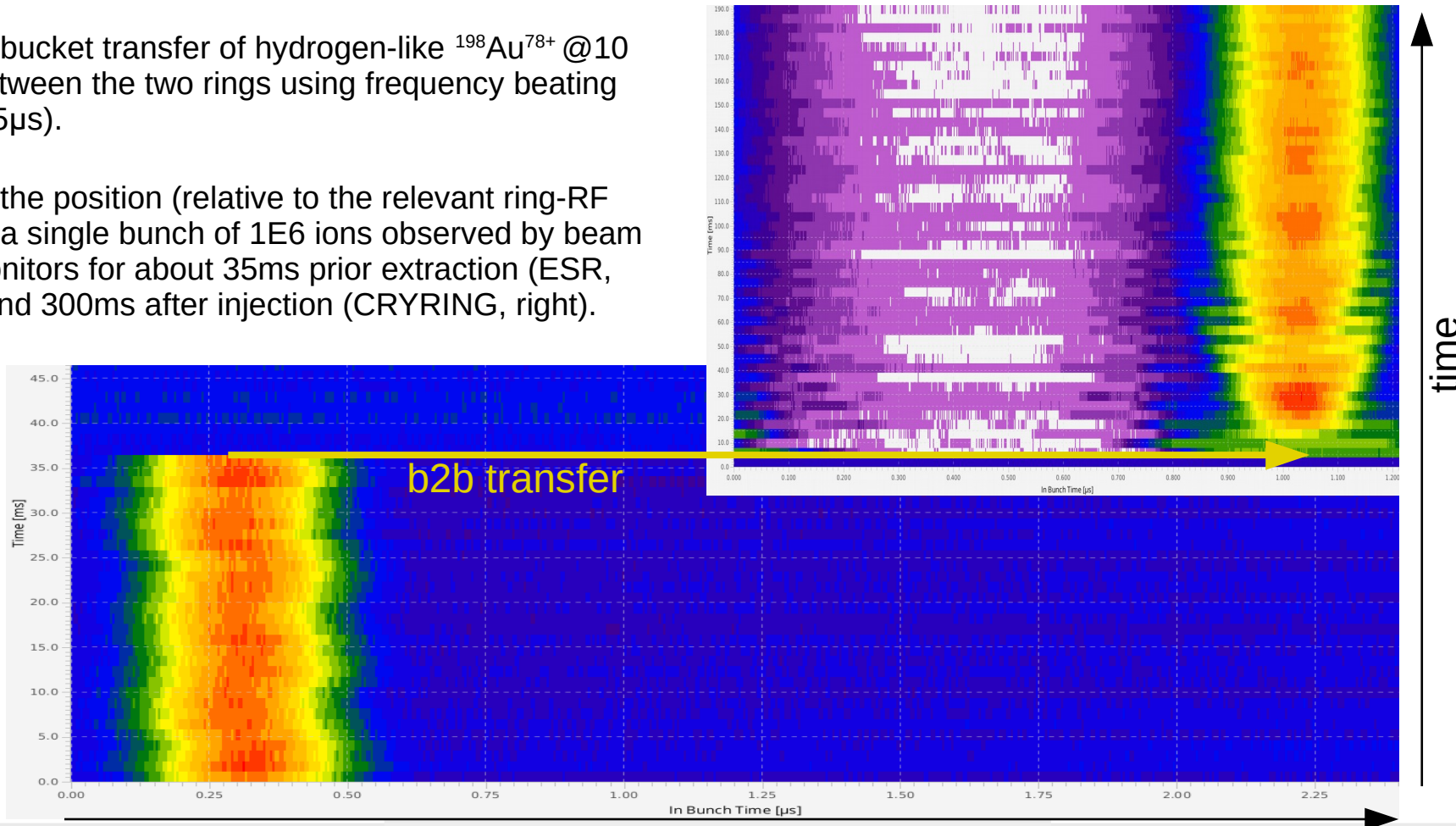
2022: Experience from Operation III

Breaking News … (just in time for the White Rabbit Workshop)

- 2022-Jun-21: high-temperature warning @ WRS '84'
  - FPGA 82.44 PLL: 75.69 PSL: 51.62 PSR: 57.50
  - both fans broken ('broken': fan does not spin at all or **very** slowly)

- 2022-Sep-22: high temperature warning @ WRS '96'
  - FPGA 97.00 PLL: 89.00 PSL 68.00, PSR 72.00
  - both fans broken

- 2022-Sep-29: checked ~45 WRS
  - found 10 WRS with one fan broken, the other fan ok
  - typically: FPGA 51.00 PLL 50.00 PSL 37 PSR 39.00
  - WRS installed in standard racks in supply areas, not in 'caves' or close to equipment
  - fans are Sunon MB40201VX-000U-A99 (life expectancy > 8 years)
  - all WRS are hardware version 3.4, the oldest ones are in operation since 2017
  - this is issue is new - we still have 8 out of 10 spare fans bought in 2016
  - old (but working) fans seem to have less air flow than the freshly replaced ones

- caveats
  - no 'tacho signal' to detect fan failures
  - no rattling noise as warning
  - the 'one-broken-fan-problem' does not show up in temperature monitoring

Summary

- very smooth operation in 2022

- 24/7

- work/changes at network and central components only in dedicated maintenance windows

- **problem with WRS fans**

- cured by fan replacement; just ordered 100 pcs for most urgent repairs

- are we the only ones having this problem?

- use a better fan type? IT colleagues suggest the ones used in Cisco switches which are known to last ~10 years

- and – yes: we have checked all fans of all WRS prior the 2022 beam time

- suggestion for WRS v4: use fans with **known** life expectancy and rpm **readout**