PETRA IV.
NEW DIMENSIONS

Fast Orbit Feedback Control

# MicroTCA based
## FOFB System for PETRA IV

Burak Dursun *on behalf of PETRA IV WP2.08 Project Team*

2022-12-07
11th MicroTCA Workshop for Industry and Research

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

MSK. Maschine Strahlkontrollen

DESY.

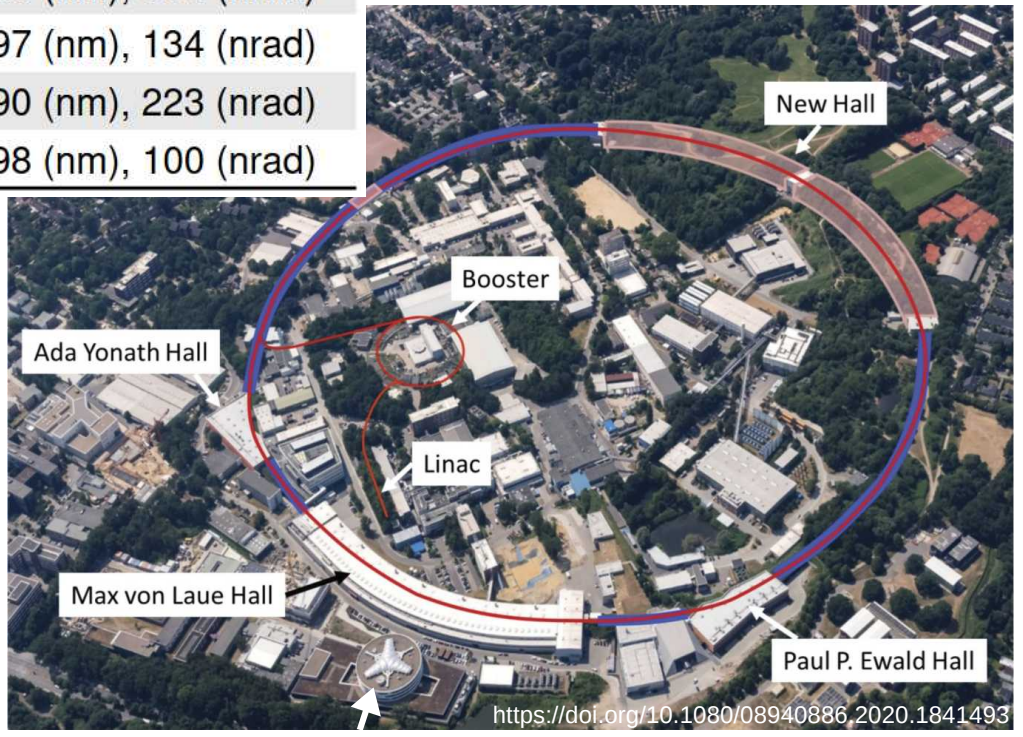
# PETRA IV

## It is not an update but a new machine in PETRA III tunnel

Electron beam stability requirements based upon 10% criteria

| Plane | RMSD max. |
|---|---|
| Horizontal at standard cell IDs | 660 (nm), 302 (nrad) |
| Vertical at standard cell IDs | 297 (nm), 134 (nrad) |
| Horizontal at flagship IDs | 890 (nm), 223 (nrad) |
| Vertical at flagship IDs | 398 (nm), 100 (nrad) |

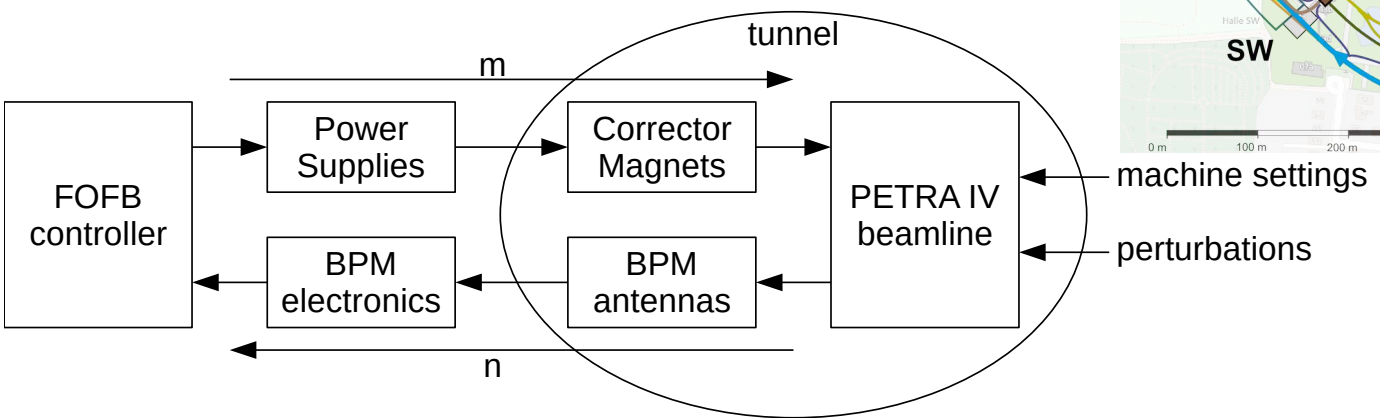
- Aiming for 1 kHz disturbance rejection bandwidth
- RMS deviation on position and pointing angle to be 5-10% of beam size and divergence

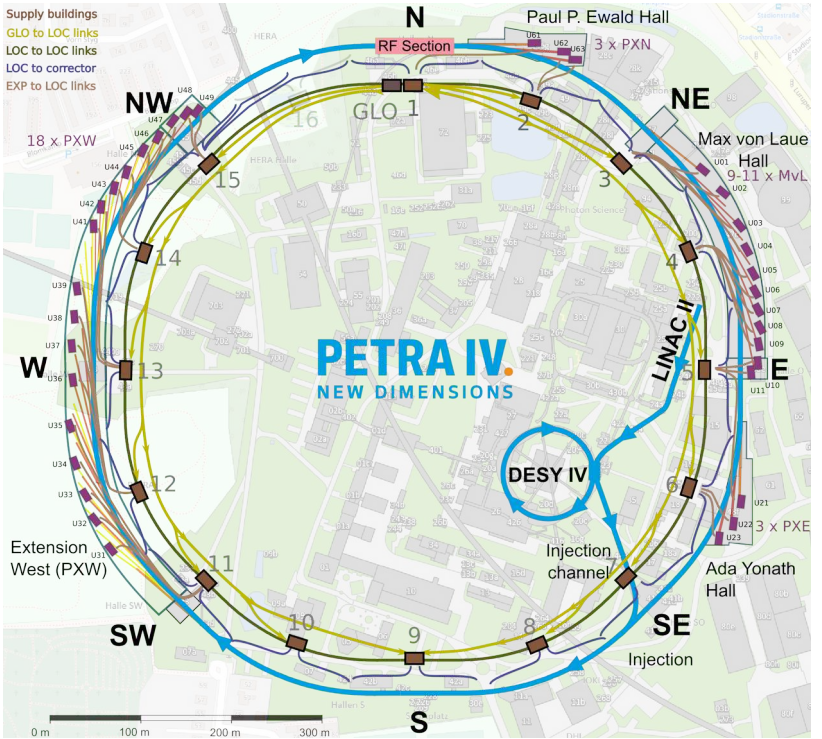


# PETRA IV Fast Orbit Feedback

## A Large (n x m) MIMO System

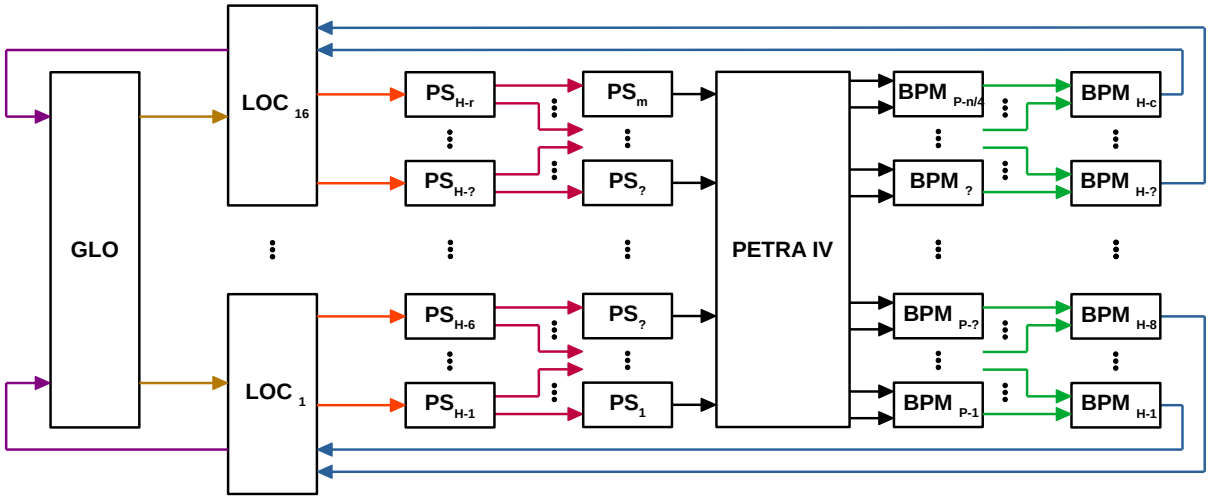
- 789 BPM  = n/2
- 522 Fast Corrector Magnets = m
- 15 access paths to the tunnel
- 16 LOCal nodes and a GLObal node
- GLO, LOC-16 and LOC-1 together at North

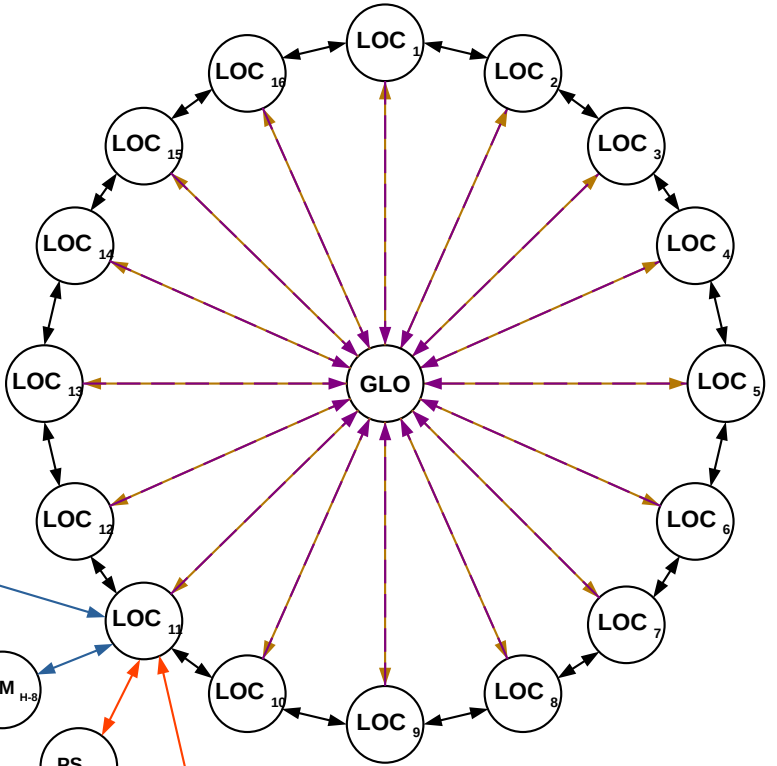


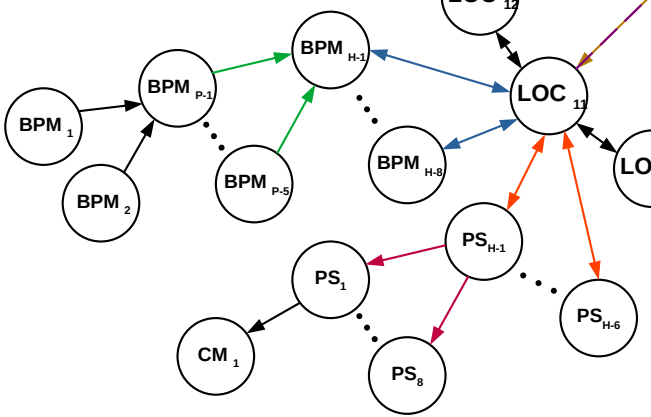



# PETRA IV Fast Orbit Feedback

## Extended Star Topology



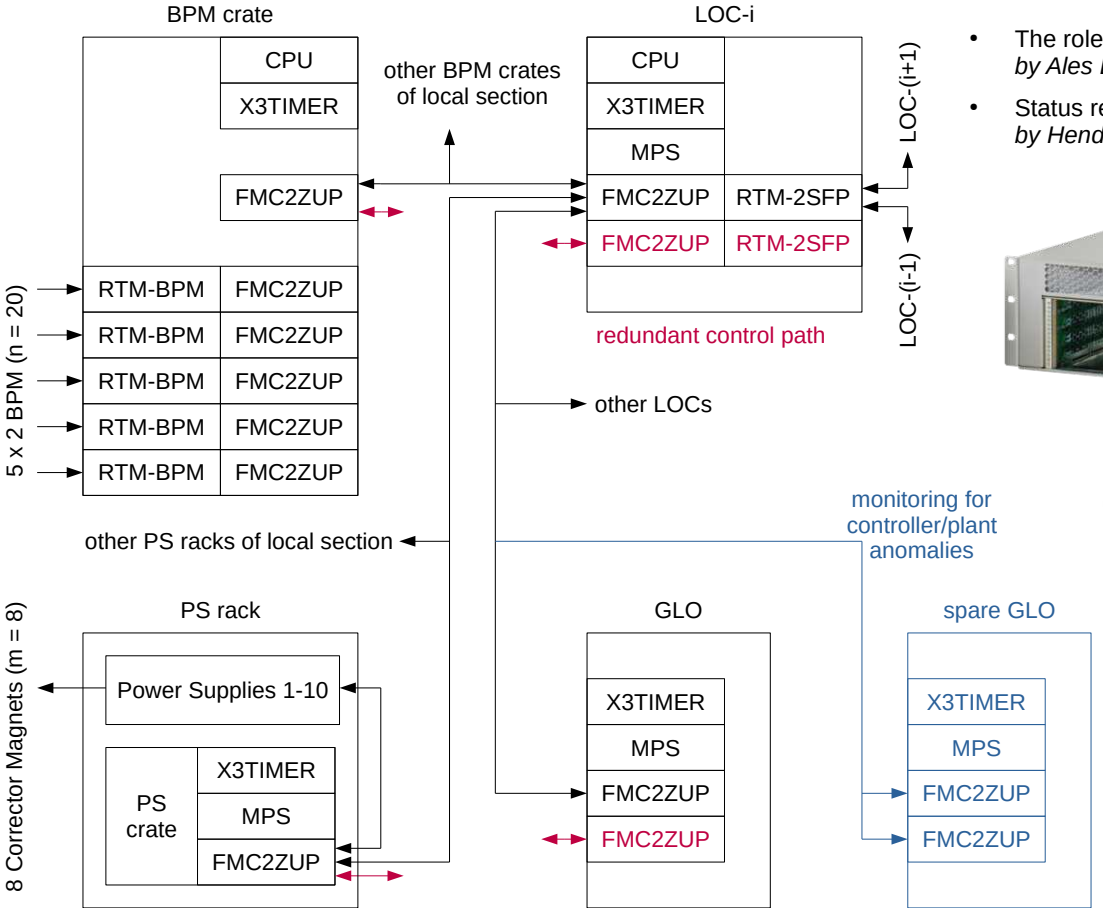




- 8 BPM crates per LOC
  - 5 BPM processors per crate
    - 2 BPM per processor
- 6 PS racks per LOC
  - 8 (+2) PS per rack
    - 1 Corrector Magnet per PS

# PETRA IV Fast Orbit Feedback

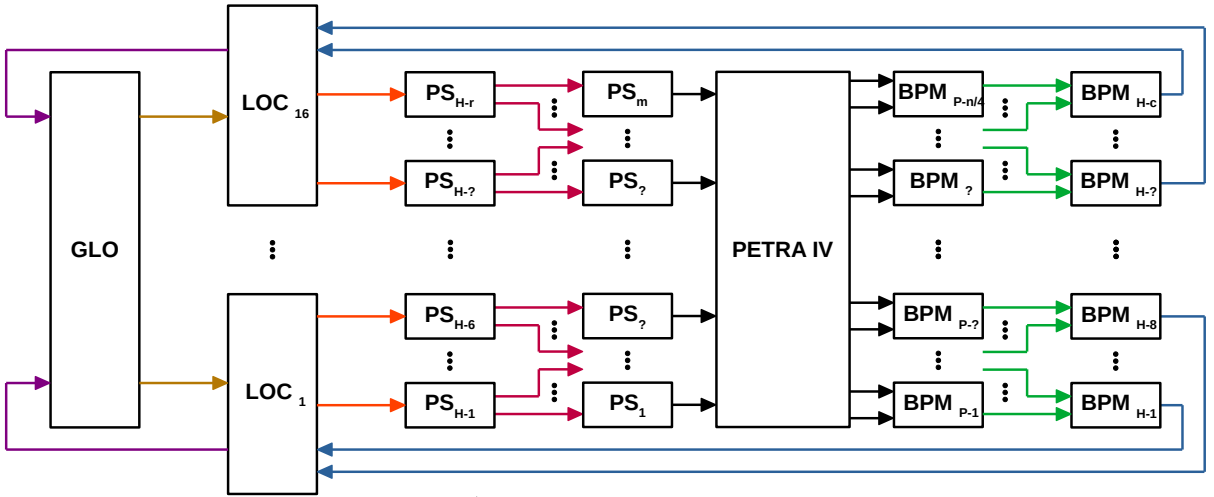
## MicroTCA for FOFB controllers, BPM system, Power Supply datahub, timing and safety




- The role of Libera Brilliance+ in developing the new MicroTCA.4 BPM System for PETRA IV
  *by Ales Bardorfer, Wednesday, Session-5*
- Status report on the PETRA IV timing system development
  *by Hendrik Lippek, Thursday, Session-7*

# PETRA IV Fast Orbit Feedback

## Point to Point Links




**Aurora 8B/10B**
*6.25 Gbps single lane*
*4 bytes lane width*
*framing interface with CRC*
*user_clk @ 156.25 MHz*
*41 clock cycles latency*

**Aurora 64B/66B**
*10 Gbps single lane*
*8 bytes lane width*
*framing interface with CRC*
*user_clk @ 156.25 MHz*
*55 clock cycles latency*

| # | n/4 | | c | | 16 | 1 | 16 | | r | | m |
|---|---|---|---|---|---|---|---|---|---|---|---|
| node | BPM processor | → | BPM datahub | → | LOC FOFB | → | GLO FOFB | → | LOC FOFB | → | PS datahub | → | Power Supply |
| transmission | | backplane | | optical | | optical | | optical | | optical | | optical | |
| payload | | 23040 Bytes | | 17408 Bytes | | 15616 Bytes | | 6400 Bytes | | 7680 Bytes | | 15360 Bytes | |
| throughput | | 3200 Gbps | | 1240 Gbps | | 155 Gbps | | 155 Gbps | | 931 Gbps | | 3860 Gbps | |
| latency | | 262 ns | | 352 ns + Δ | | 6 us | | 6 us | | 352 ns + Δ | | 262 ns | |

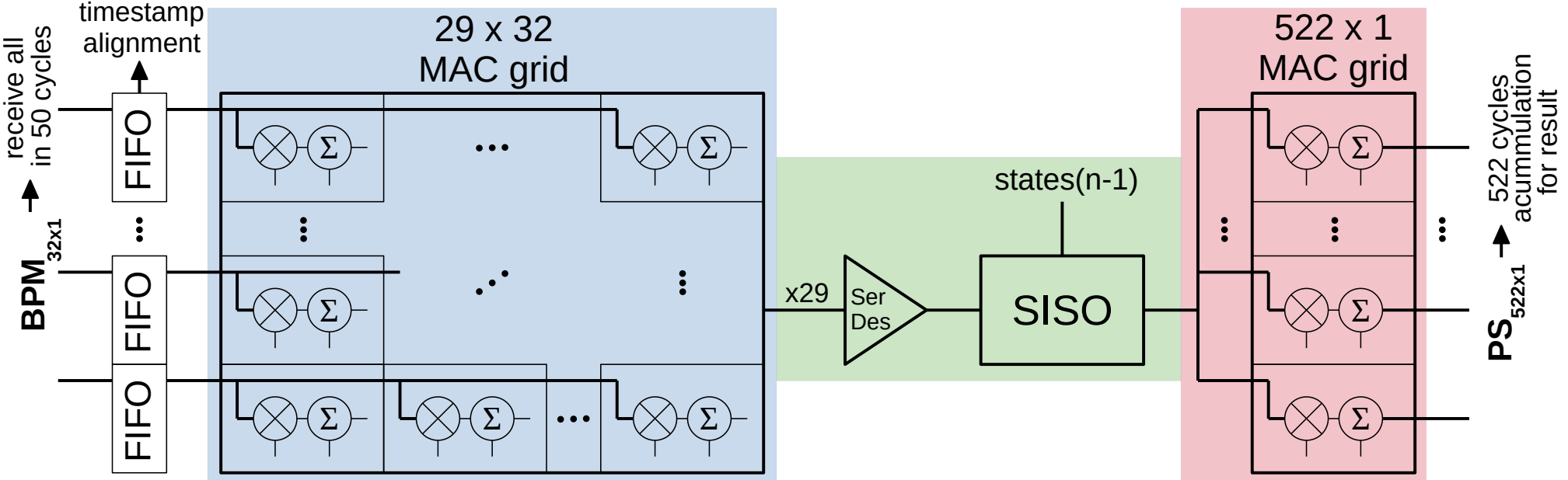
# PETRA IV Fast Orbit Feedback

## Controller Latency

$$\left[\Sigma^{-1}U^{T}\right]_{522\,x\,1578} * BPM_{1578\,x\,1} = \lambda_{522\,x\,1}$$

$$\left[V^{T}\right]_{522\,x\,522} * OUT_{522\,x\,1} = PS_{522\,x\,1}$$

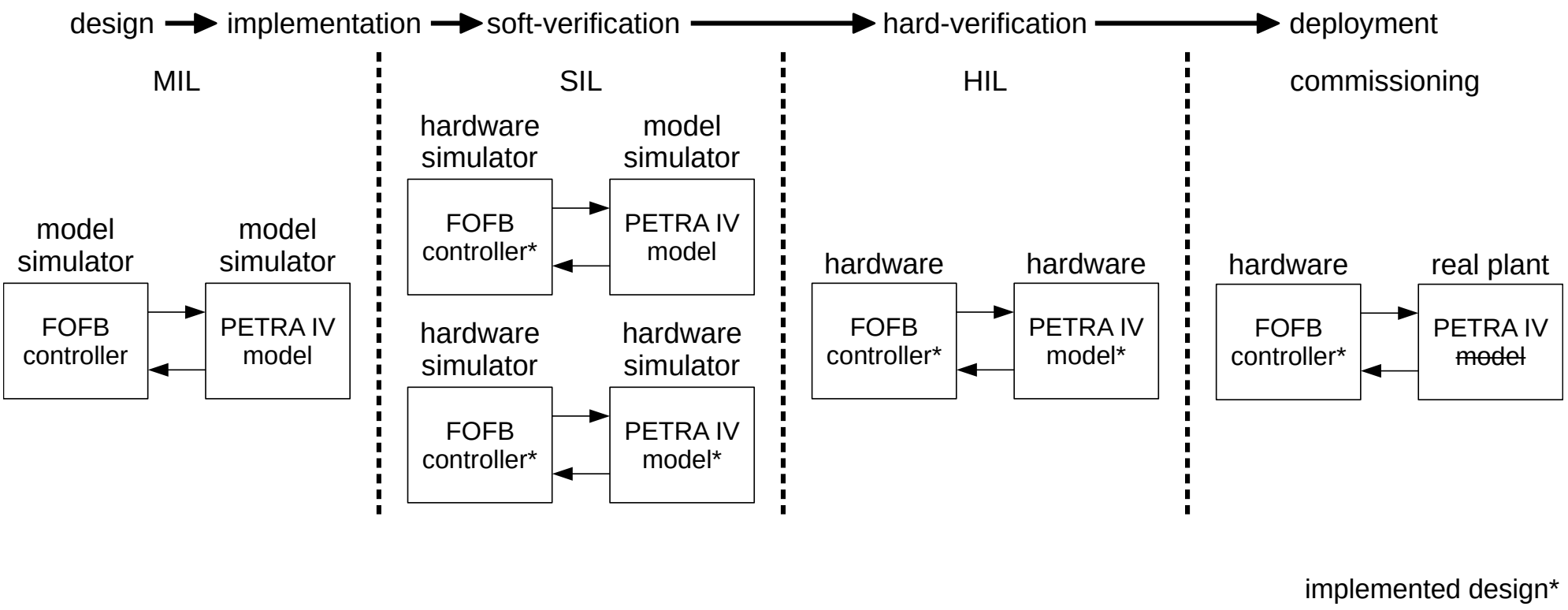
$$\lambda_{522\,x\,1} - REF_{522\,x\,1} \Rightarrow SISO_{522\,x\,1} \Rightarrow OUT_{522\,x\,1}$$




29 parallel row operation with resource sharing

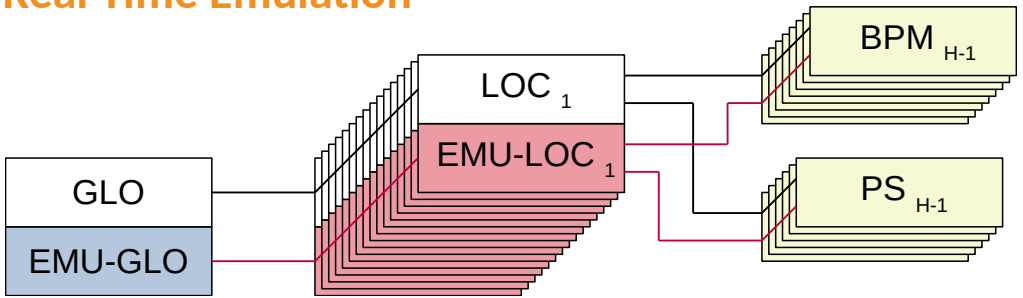
# PETRA IV Fast Orbit Feedback

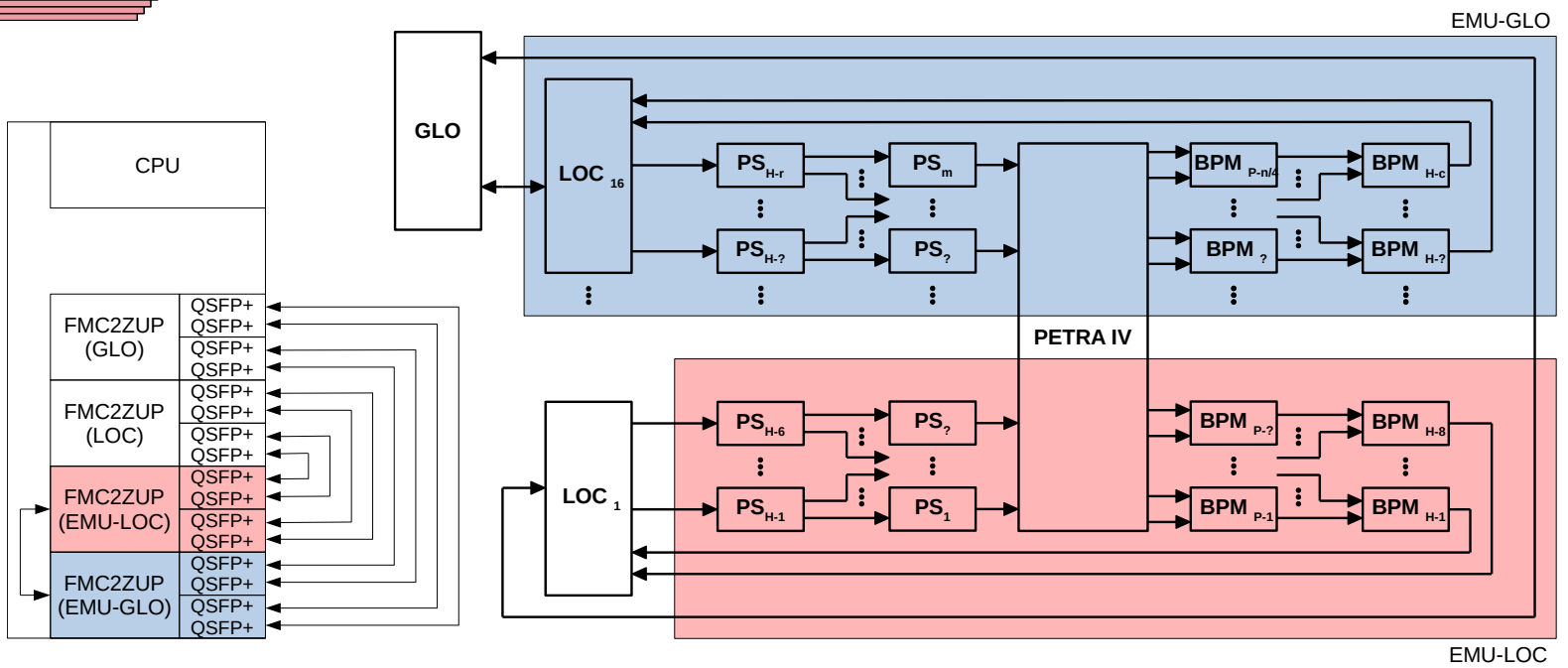
## Model Based Design



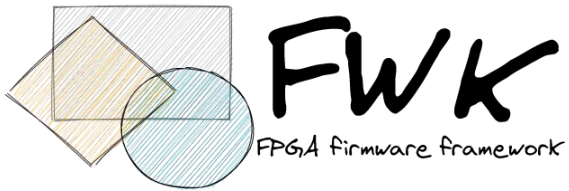
# PETRA IV Fast Orbit Feedback

## Real-Time Emulation



# Firmware & Software Frameworks




**gitlab.desy.de/fpgafw/fwk**

- Open Source FPGA Framework at MSK-DESY
  *by Cagil Gumus, Thursday, Session-7*


**github.com/ChimeraTK**

- ChimeraTK: Teil 1 & 2
  *by Martin Killenberg, Tuesday, Tutorial Sessions*
- Extension of the Python Bindings for the ChimeraTK DeviceAccess Library
  *by Christian Willner, Thursday, Session-8*

# Thank you.

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Fast Orbit Feedback System for PETRA IV

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