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KIT TEN
KIT test center for energy efficiency & grid stability
in large-scale research infrastructures

Addressing Energy Responsibility in Particle Accelerators: Insights from the KITTEN Research Platform

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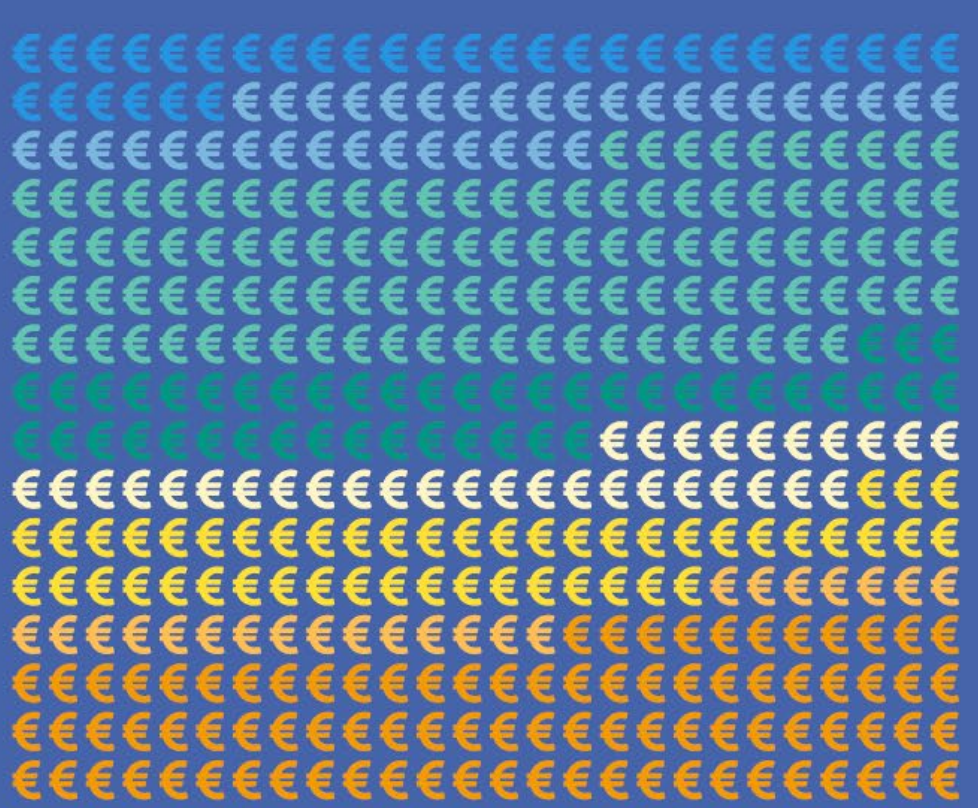
What is our starting point?

Base Load

Around 40% of the base load of 7GWh is related to labs and beamlines. 8% for the insertion devices.

Around 40% goes for the building power and the cooling system.

The storage ring and pumps take only 8% of the base load.



- Ring
- Pumps
- Cooling Central
- Building services
- IDs
- Beamlines
- Labs
- Labs cooling

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A joint venture between the accelerator **KARA** and the test-field **Energy Lab 2.0** to improve the energy use and power quality in large research infrastructures.

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KARA Digital Twin

- Power supply quality improvements
- Integration of energy storage systems
- DC connectivity

Energy Data Dashboard

- Energy management for sustainability purposes
- Energy costs analysis
- Human-Machine-Interface improvements

Fast communication infrastructure for Real Time Digital Twins

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ENERGY LAB 2.0

Digital Twin

RT Simulator

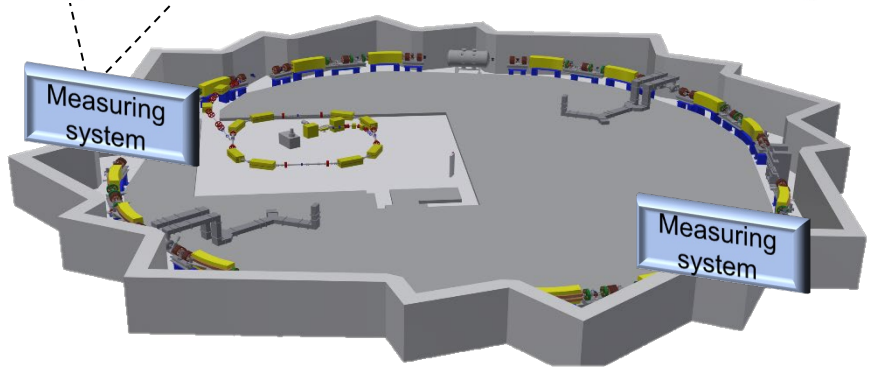
Electrical model of KARA in Simulink

UDP

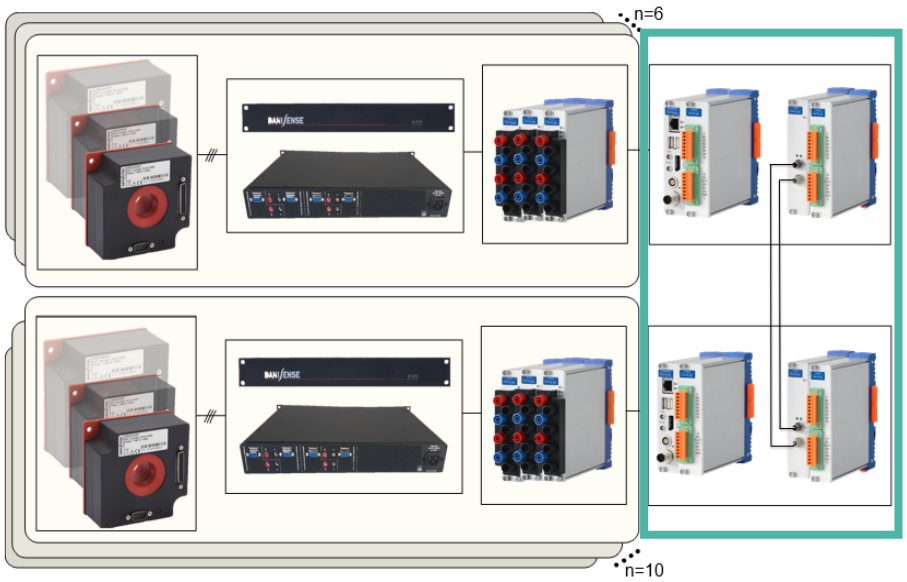
Measured electrical current and Voltage signals

1.5 – 2 km

KARA Karlsruhe Research Accelerator

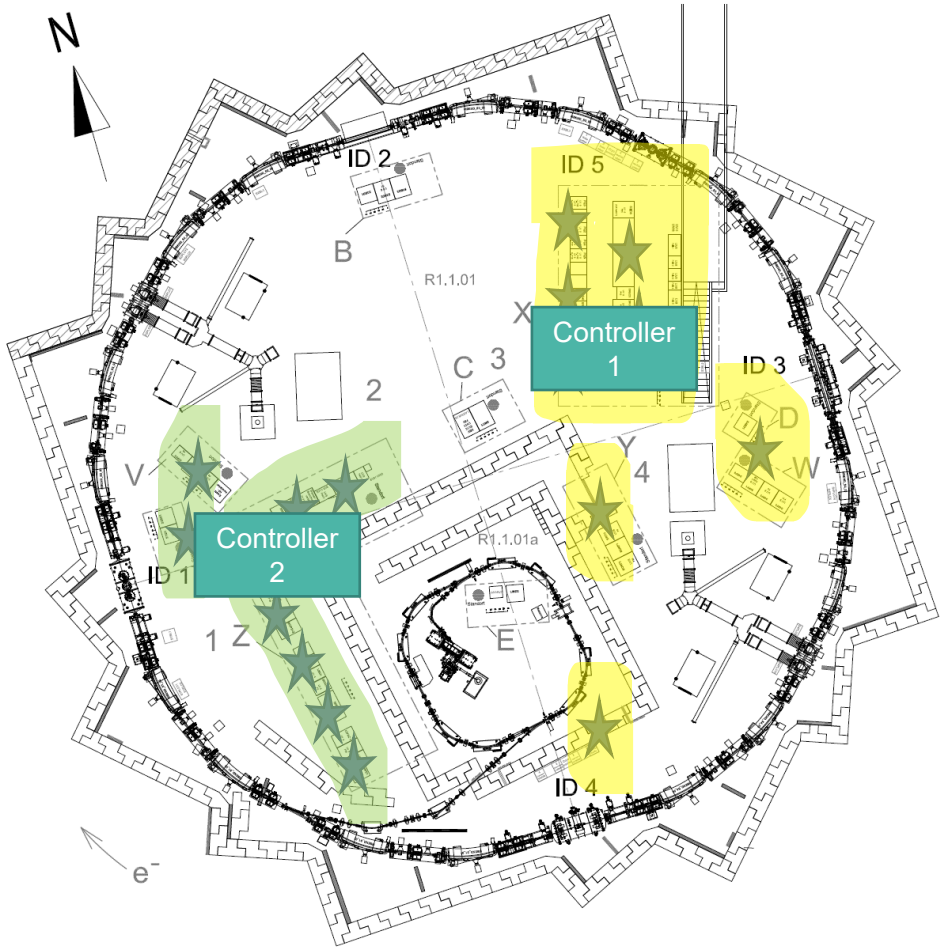


Measurement System Placement



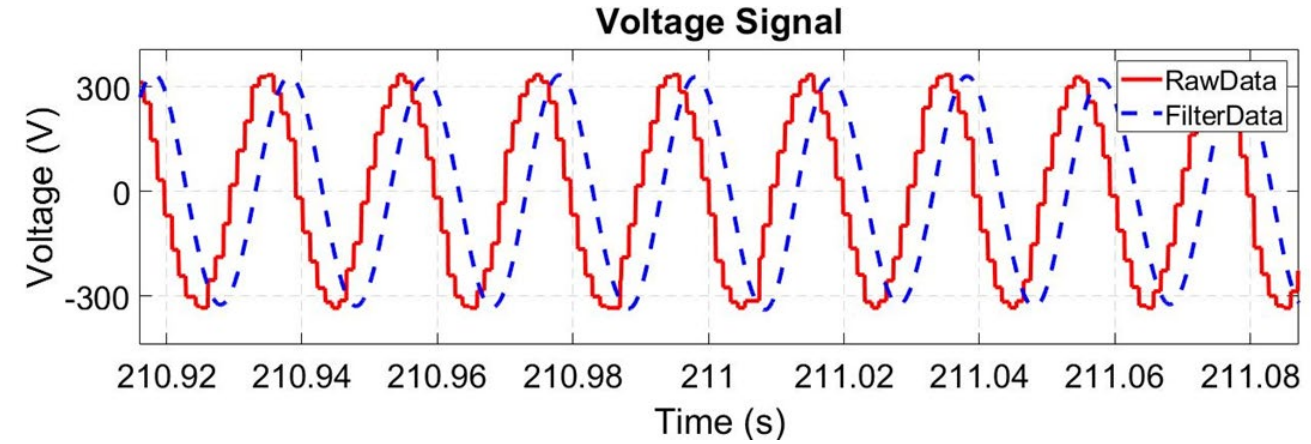
Measurement points

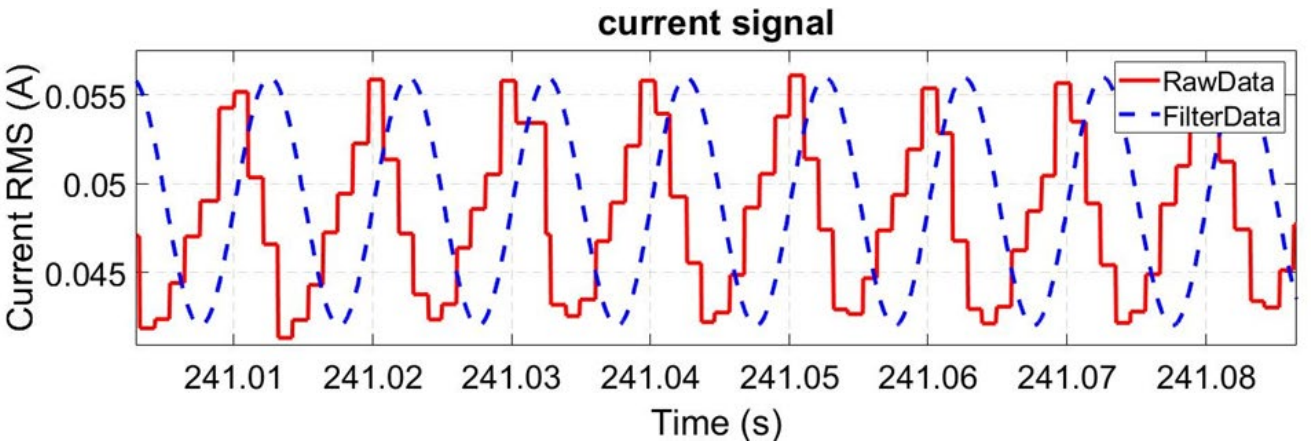
- Injector PS + microtron dipole
- CATACT + CLIC wiggler
- Di-, Quadri-, and Sextuple magnets
- RF system (only partially)



Initial Results

- First data transmission between KARA and Energy Lab 2.0 successful
- With UDP protocol we transmit voltage and current data at 1 kHz
- Good for steady state analysis but not for dynamics
- Next steps:
  - Employing EtherCAT that enables the data transmission up to 10 kHz
  - Lay a dedicated fiber optic connection



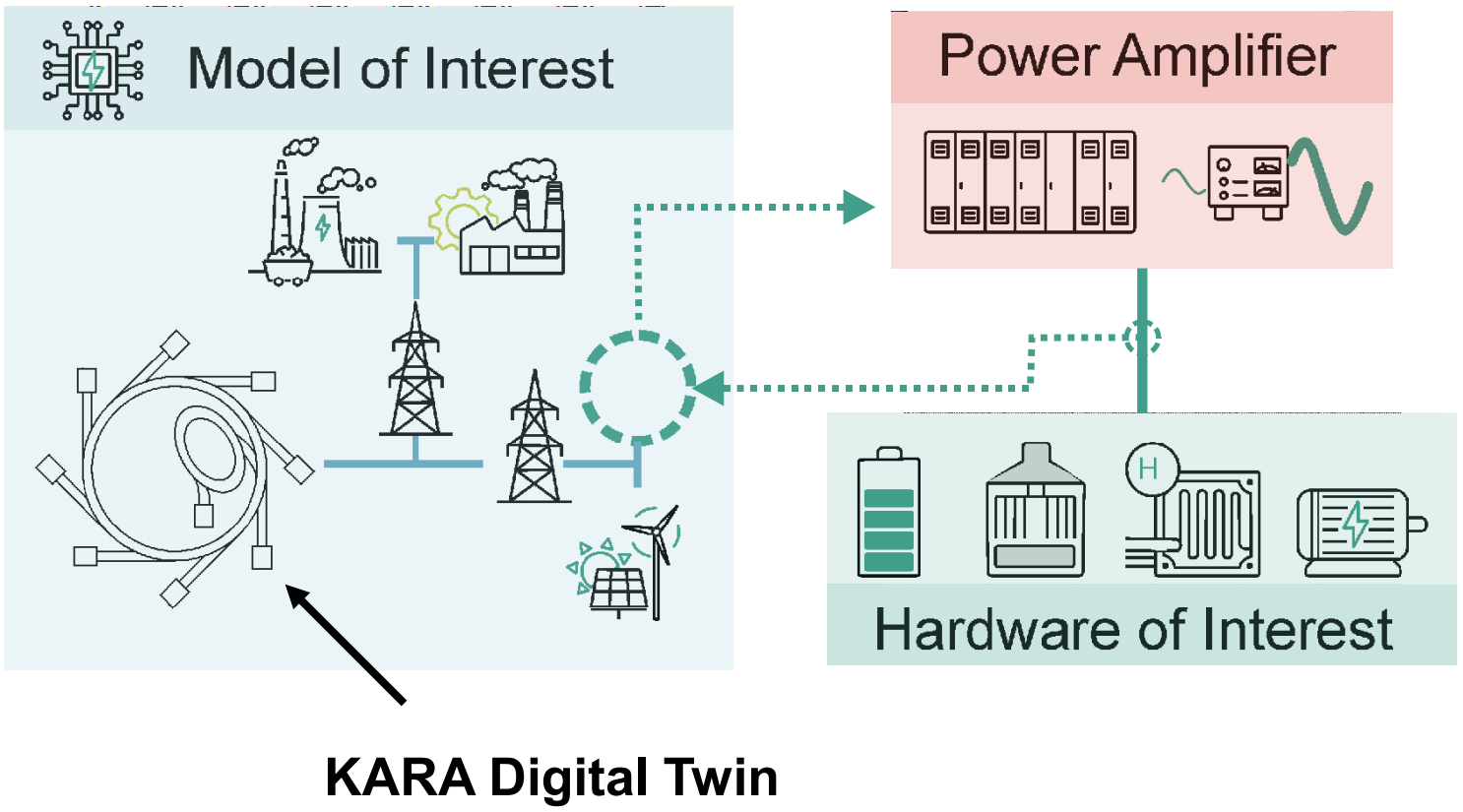


Why a Digital Twin is important?

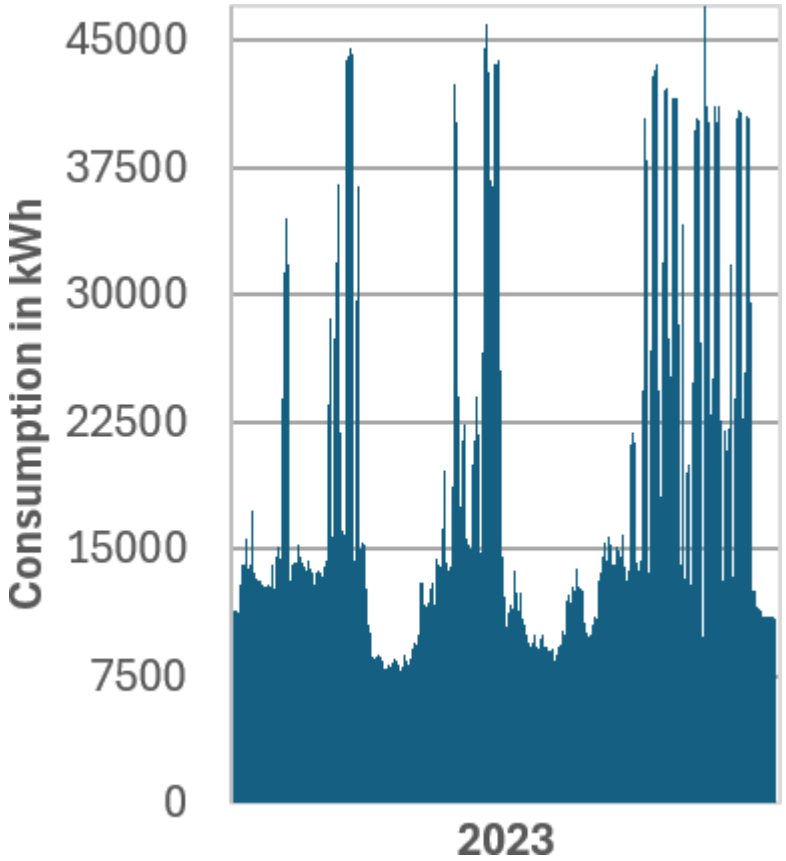
Performing **Power Hardware In the Loop** testing

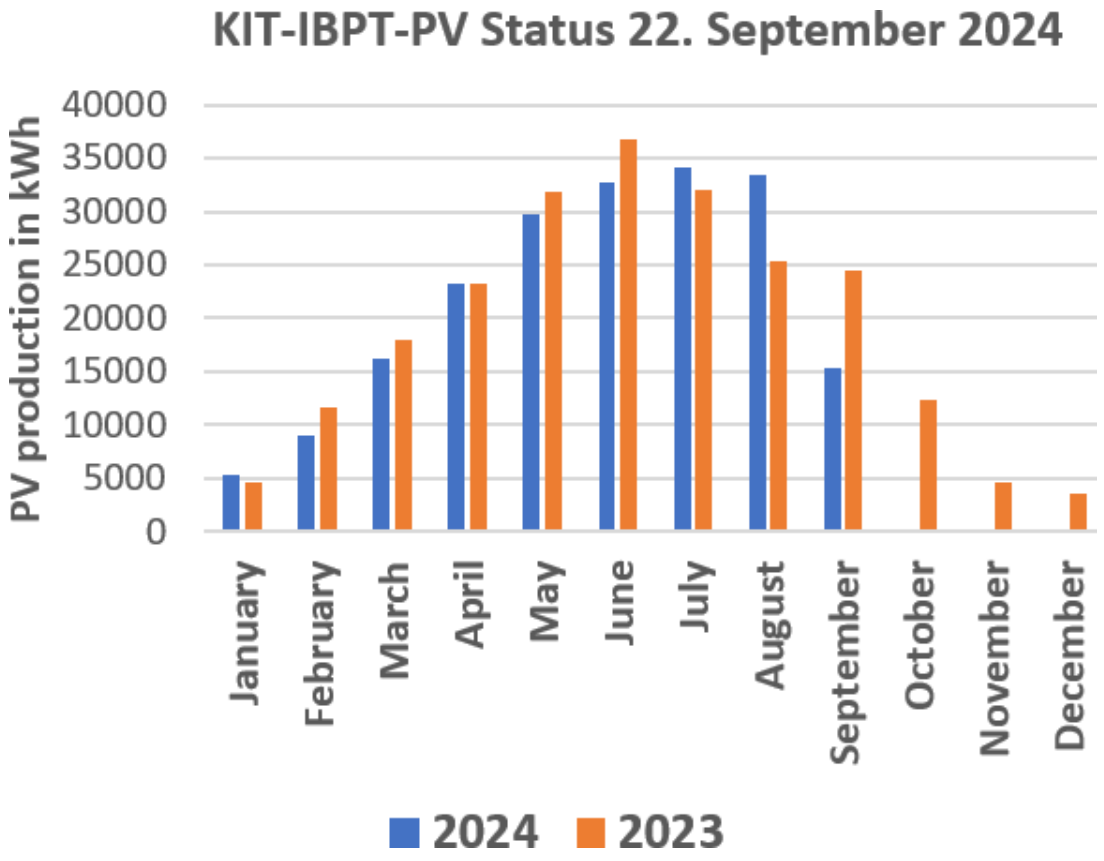
Advantages

- No need of real hardware during testing novel controllers or technologies
- Safer environment for “risky testing” (e.g., faults)
- No need for waiting accelerator shut-down → reduction in integration time



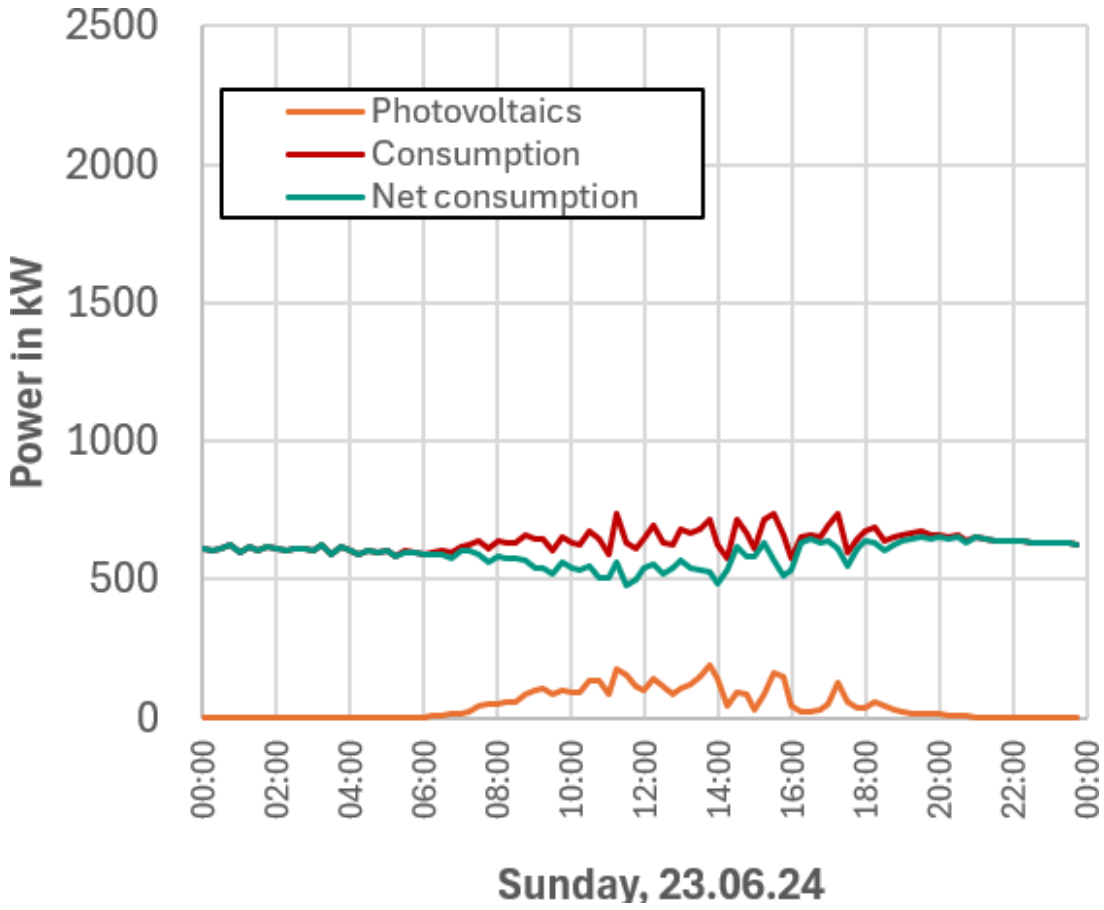
Power consumption per day at KARA in 2023
Power generation with photovoltaics



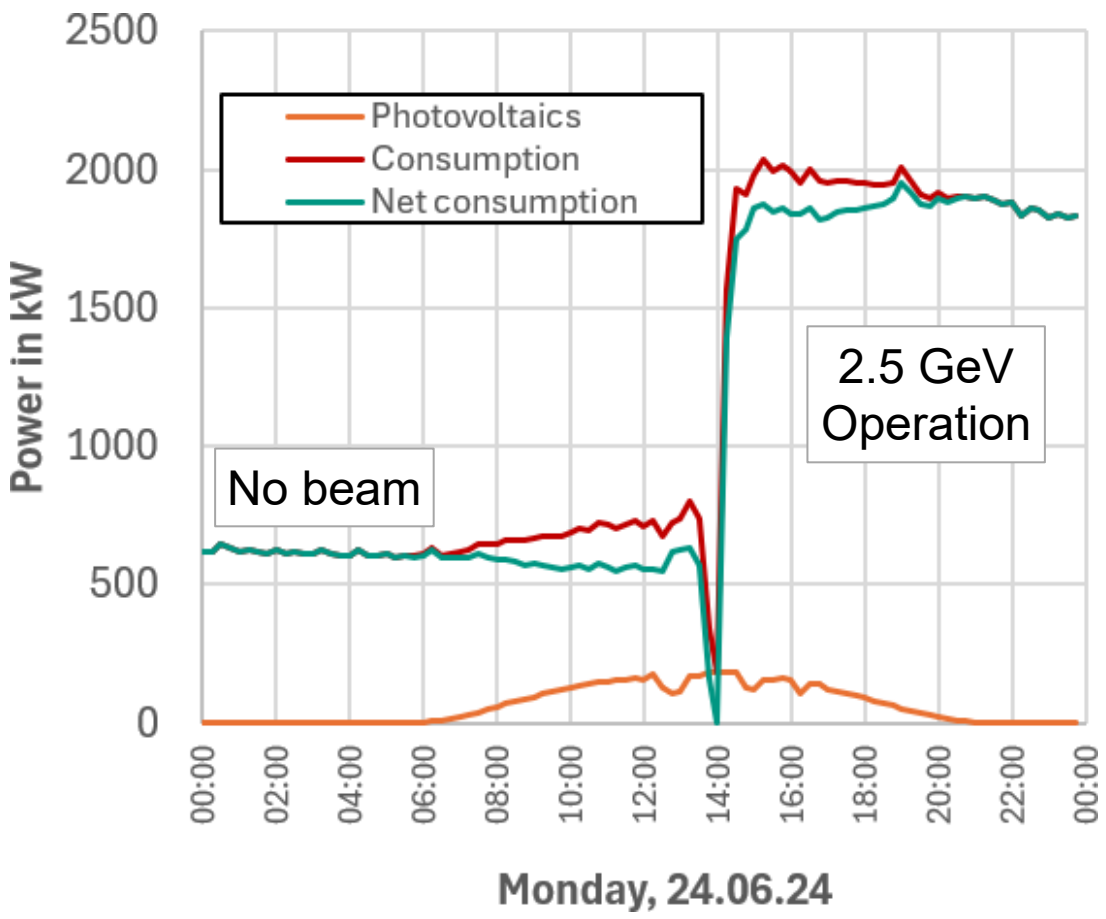


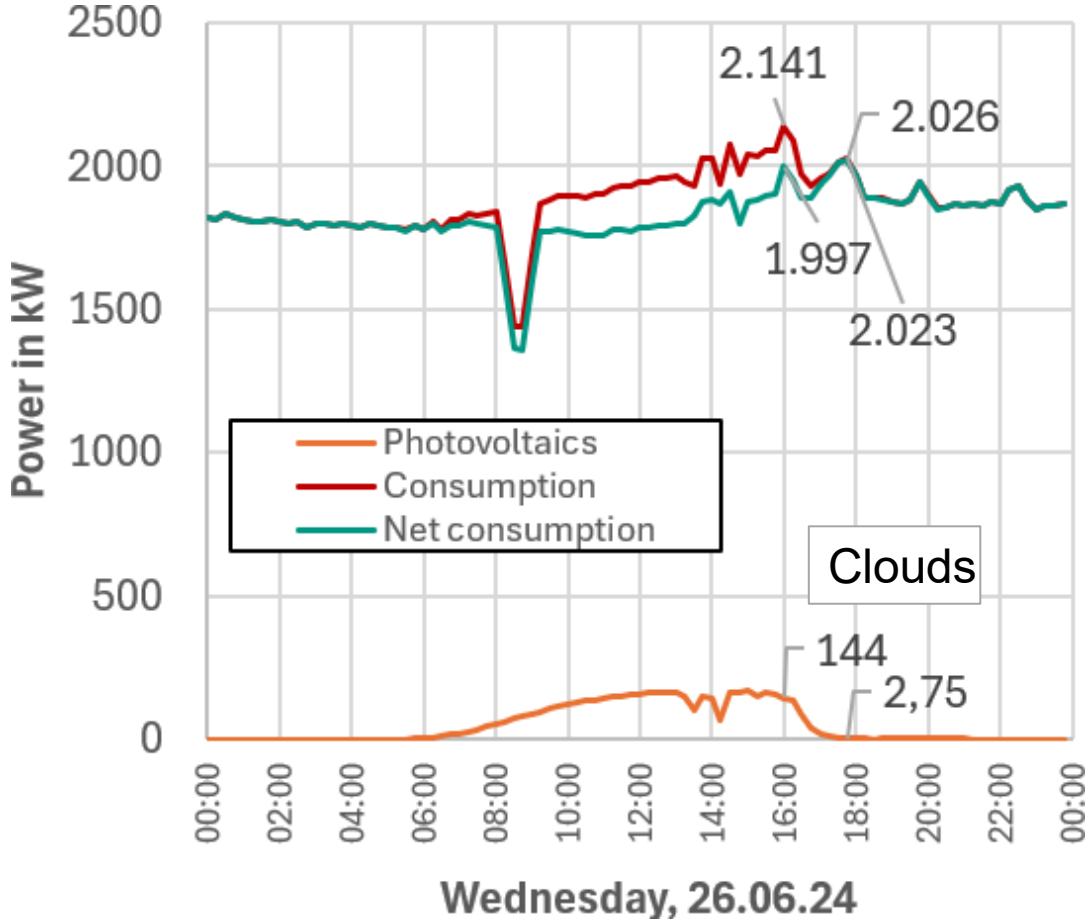
Consumption Research Building incl. Laboratories, Beamlines, Accelerator (here no beam in accelerator)

- Photovoltaics indicates sunlight
- Partially/delayed correlated with outside air temperature (typically some hysteresis – temperature highest typically around 16:00 to 17:00).
- Power consumption related to sunlight heating the walls and roof of the research building with the accelerator, laboratories and beamlines inside.



Photovoltaics to Smooth Consumption Curve
Peak Net Consumption (clouds cover photovoltaics)

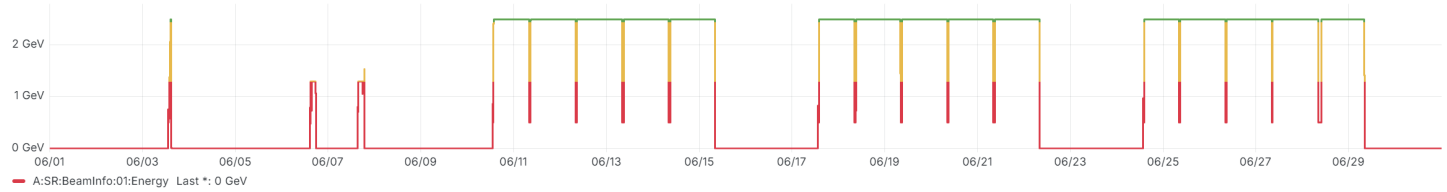




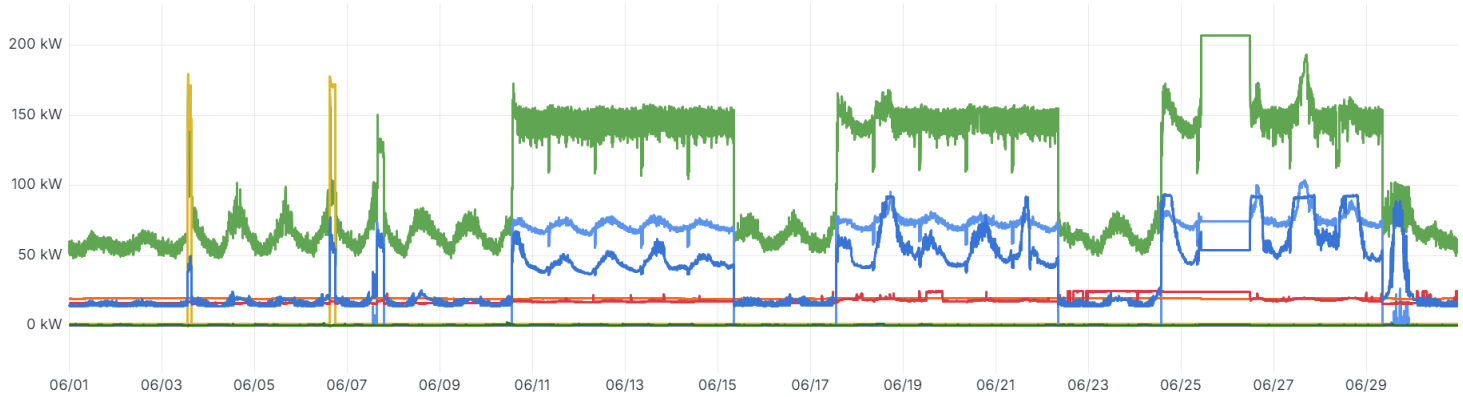
Cooling System Power Dependency on Beam Energy

- We found a correlation between the required cooling power and the beam energy
- There is a cooling power variation from 90 kW in off-line weeks vs. 280 kW during beam operation
- Now studying the dependency on the external temperature → data campaign to be finished in the next weeks

Beam Energy (GeV)



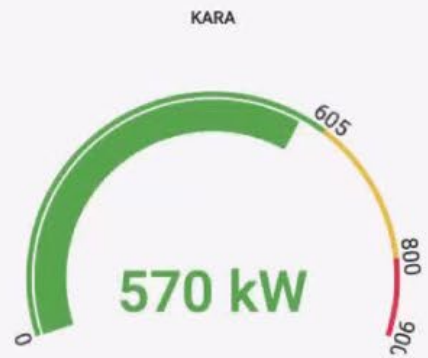
Cooling plants (kW)



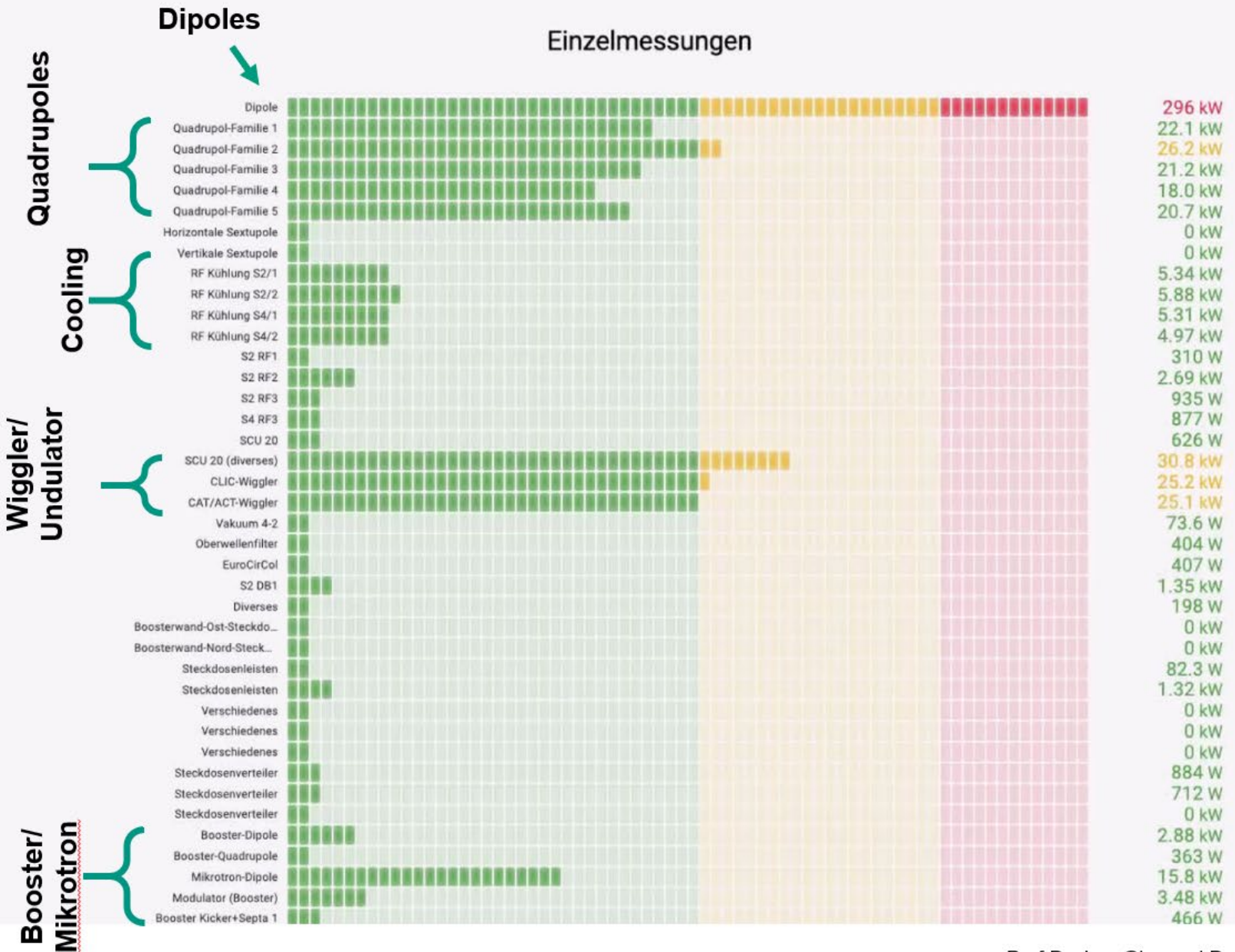
June 2024

Speicherring KARA

Gesamtleistung KARA



Einzelmessungen



KITTEN – Upgrade Testing Possibility at KARA

Energy measures targeting an energy-independent accelerator

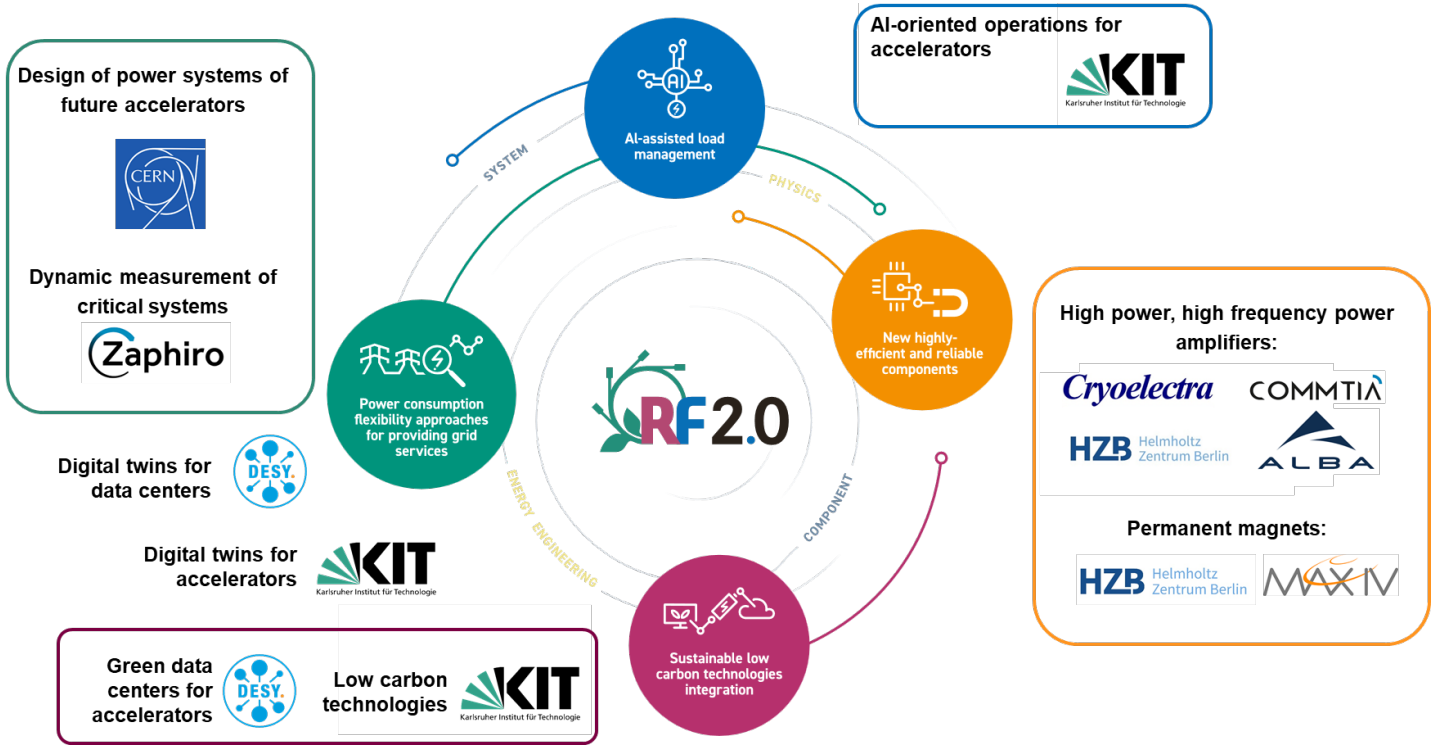
- Photovoltaic (Q4 2024)
  - Doubling installed power (240 kWp → 500 kWp)
- Geothermal Energy System (Q1 2025)
  - 1MW Thermal power, COP=3, passive thermal exchanger
- Battery Energy Storage Systems (Q1 2025)
  - 2x500kW, 2x871=1742kWh → 3.5 hours full power operation
  - Dynamic, 20ms reaction time, suitable for power quality purpose and islanding
- Targeting a **50% / 70%** energy dependency reduction from the public grid

Research Facility 2.0

FACTS

- Horizon Europe Project (2024 – 2027)
- 10 partners, 5.6 M€ Budget
  - 6 accelerators, 4 SMEs
- 4 Demonstrators
  - Efficient Solid State Amplifiers @ALBA, HZB
  - Efficient Permanent Magnets @MAX IV, HZB
  - Phasor Measurement Units @CERN
  - Flexible Data Centers @DESY

<u>Concrete improvement measures for current and future accelerators</u>



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For further information and to follow our project progress visit **www.rf20.eu**

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