

# Investigating next generation of accelerators: The KITTEN test facility for sustainable research infrastructures

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# The starting point

## ■ High energy consumption

- Small accelerators (KARA) → 11GWh
- Large accelerators (FCC) → 1÷2 TWh

≈ Karlsruhe (300.000 inhabitants)

## ■ High power peak

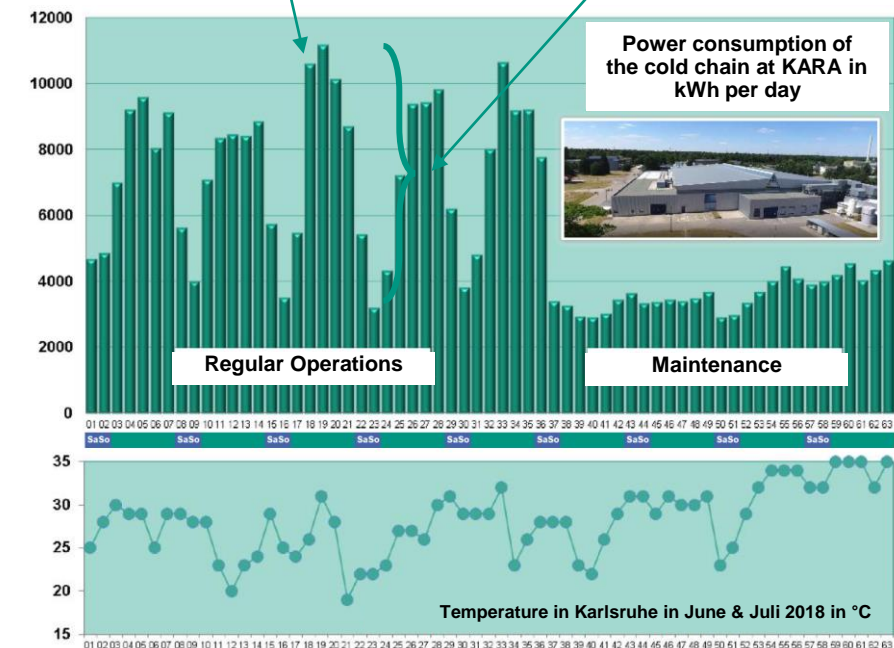
- Large difference between “stand-by” and “beam” operations → KARA 200kW vs. 650kW

## ■ High power supply quality required

- Stable voltage profile → Low inertia grids bring larger and more frequent disturbance
- Low harmonic content → power electronics may create resonances

11GWh ≈ 10.000 citizens city

Variable consumption ≈ 8 MWh





# KIT<sup>+</sup>EN<sup>+</sup>

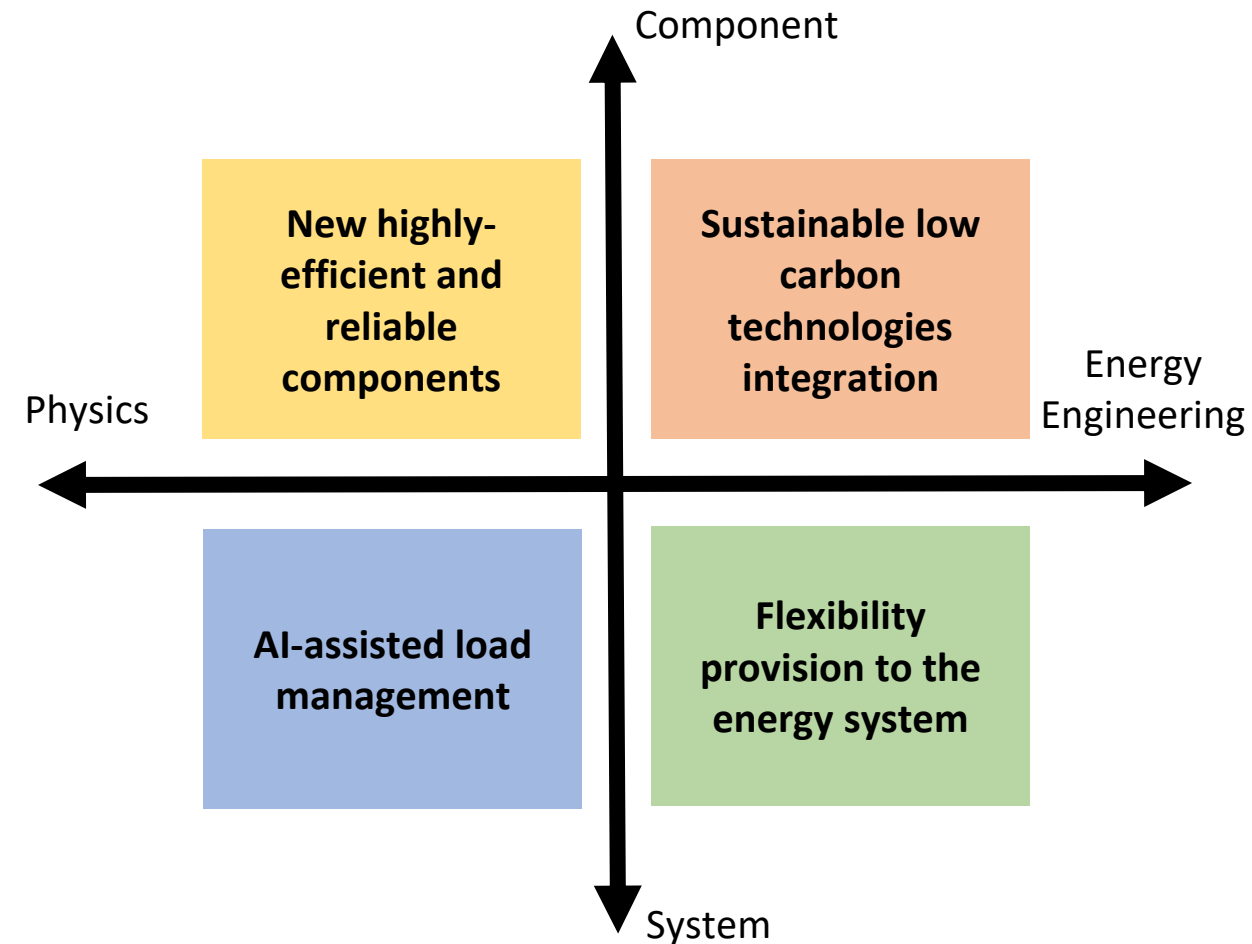
KIT Testfeld für Energieeffizienz und Netzstabilität  
in großen Forschungsinfrastrukturen

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.

# The KITTEN Approach

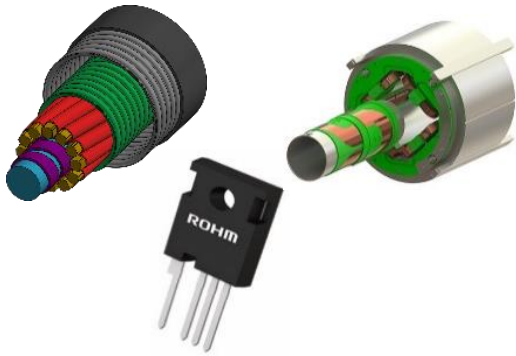
Need to work on 4 different levels

- **Physics / Component** level: new materials and components targeting an efficiency increase
- **Energy / Component** level: integration and optimal operations of sustainable low carbon technologies (e.g., energy storage, renewables)
- **Physics / System** level: improve the efficiency operations in large research facilities using AI
- **Energy / System** level: increase the sustainability of large research facilities in the electrical system



# Potential improvements in the energy solutions\*

## New highly-efficient and reliable components



- HTS-Superconductors
- Variable permanent hybrid magnets
- New cooling concepts
- SiC / GaN-based power electronics

## AI-assisted research infrastructure load management



- Real time digital twin of accelerators
- Optimized energy consumption by AI
- Adjustable power demand

## Low carbon technologies integration



- Optimal integration of ESS with RES
- Sector-coupled Energy management
- Green high power computing
- Geothermal as cooling source

## Flexibility provision to energy system



- 100% Renewable energy sources target
- Power demand flexibility
- New business models for flexibility provision

# The Impact – 4 target groups

## TG2 – System operators

**Actors:** Grid operators (TenneT), eng. companies

**Expected impact:**

- Power flexibility strategies for accelerators and computing centers ( $\geq 10-25\%$ ) for reduced consumption

## TG1 – Large research facilities (current and future ones)

**Actors:** Particle accelerators, data centers

**Expected impact:**

- Electricity costs reduction ( $\geq 10-25\%$ )
- 100% renewable energy supply
- Fully digitalized infrastructure

## TG3 – Technology manufacturers

**Actors:** Manufacturers, software and AI companies

**Expected impact:**

- Improved magnets, power electronics, (TRL 1-3  $\rightarrow$  4-6, -20% consumption)

## TG4 – General Society

**Actors:** medical facilities, schools, public buildings, computing centers

**Expected impact:**

- Higher awareness of sustainable energy solutions
- Training of public managers by means of demonstrators, schools, and workshops.
- Reduction of operation costs for public (hospitals, schools) and private (industry) facilities
- Open-access data & Benchmark results

# KITTEN next accelerators concept

## ■ Goal

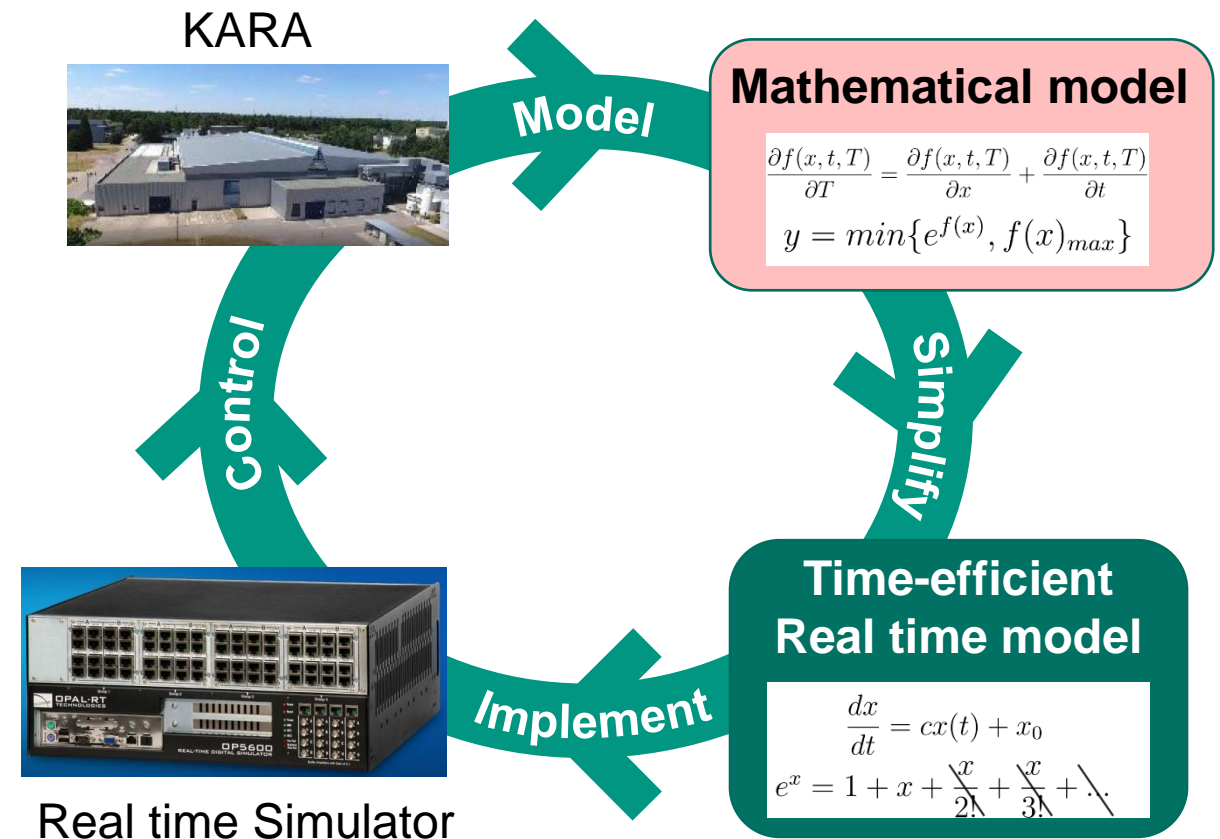
- Develop solutions for stable, efficient and safe operations of accelerators (and not only!)

## ■ How to achieve it?

- KARA → large field measurement availability
- Data-drive models of KARA → IBPT experience is important!
- Time-efficient real time modelling → EL2.0 experience is important!
- Control feedback to KARA

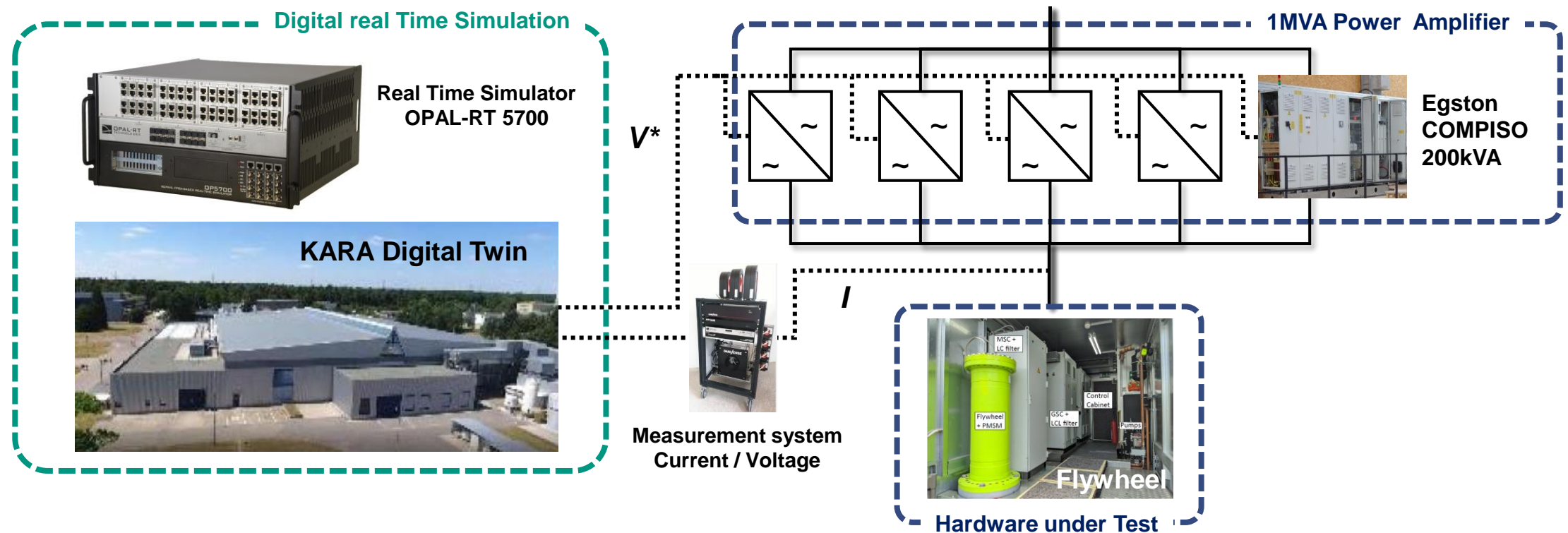
## ■ Expected outcome

- Digital Twin of KARA to be employed for analyzing, developing and testing future energy solutions for accelerators



# Unique selling point: Validation by means of Power Hardware In the Loop

- **Digital real time simulator:** simulate the KARA electrical grid
- **Power amplifier:** reproduce a point of the simulated grid in lab (e.g., measured voltage)
- **Hardware under Test:** this is the technology, which performances we want to test



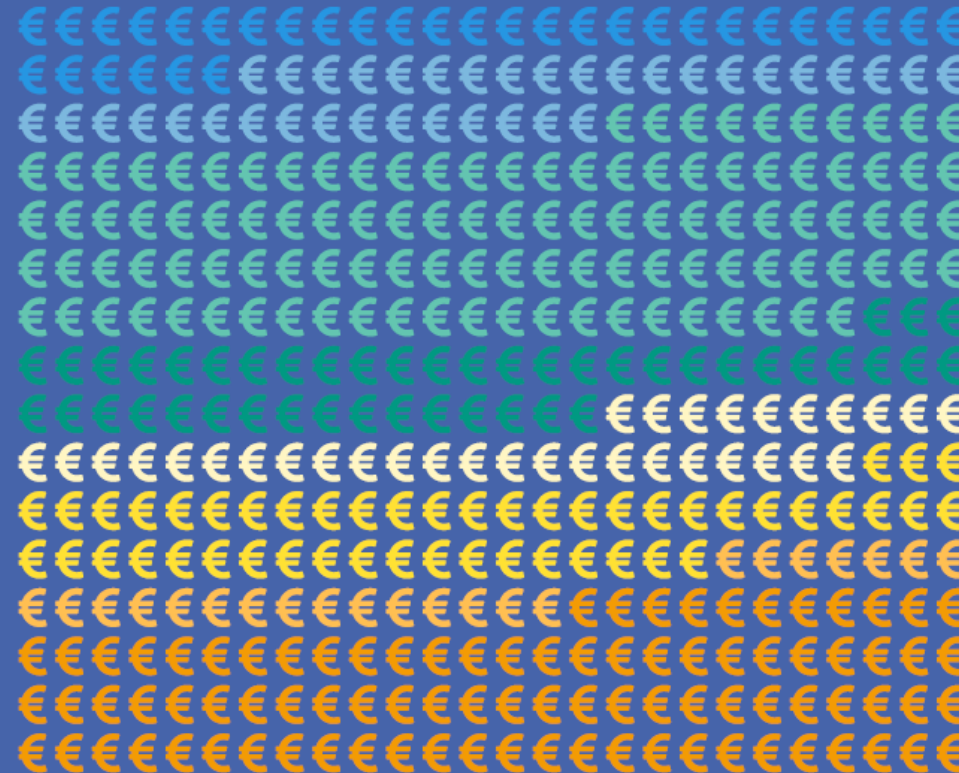
# Cost analysis for KARA – a first analysis

## Base Load

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

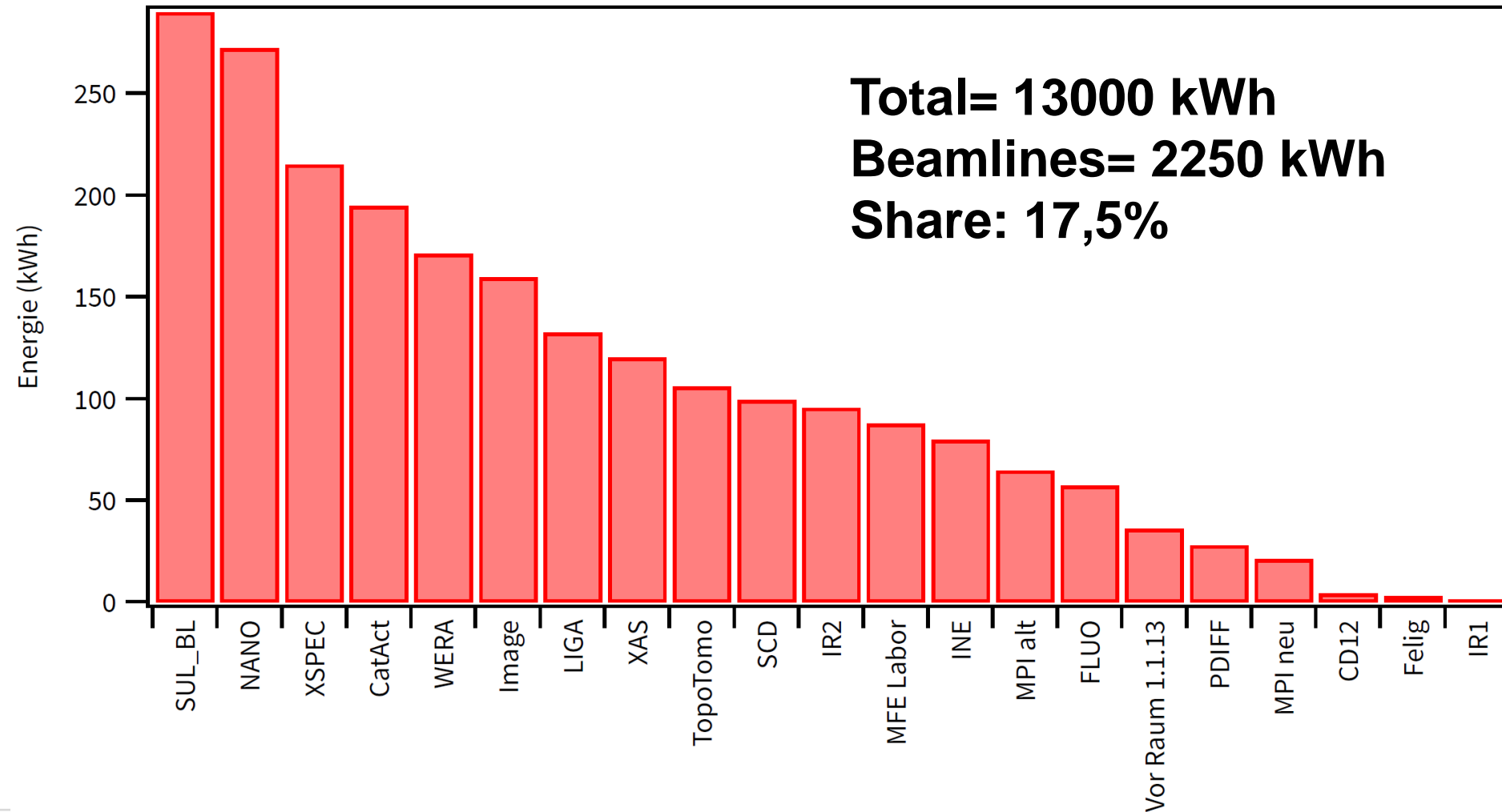
Around 40% goes for the building power and the cooling system.

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



- Speicherring
- Pumpen
- Kältezentrale
- Geb. 348 allg.
- IDs
- Beamlines
- Labore
- Lab. Klima&Lüftung

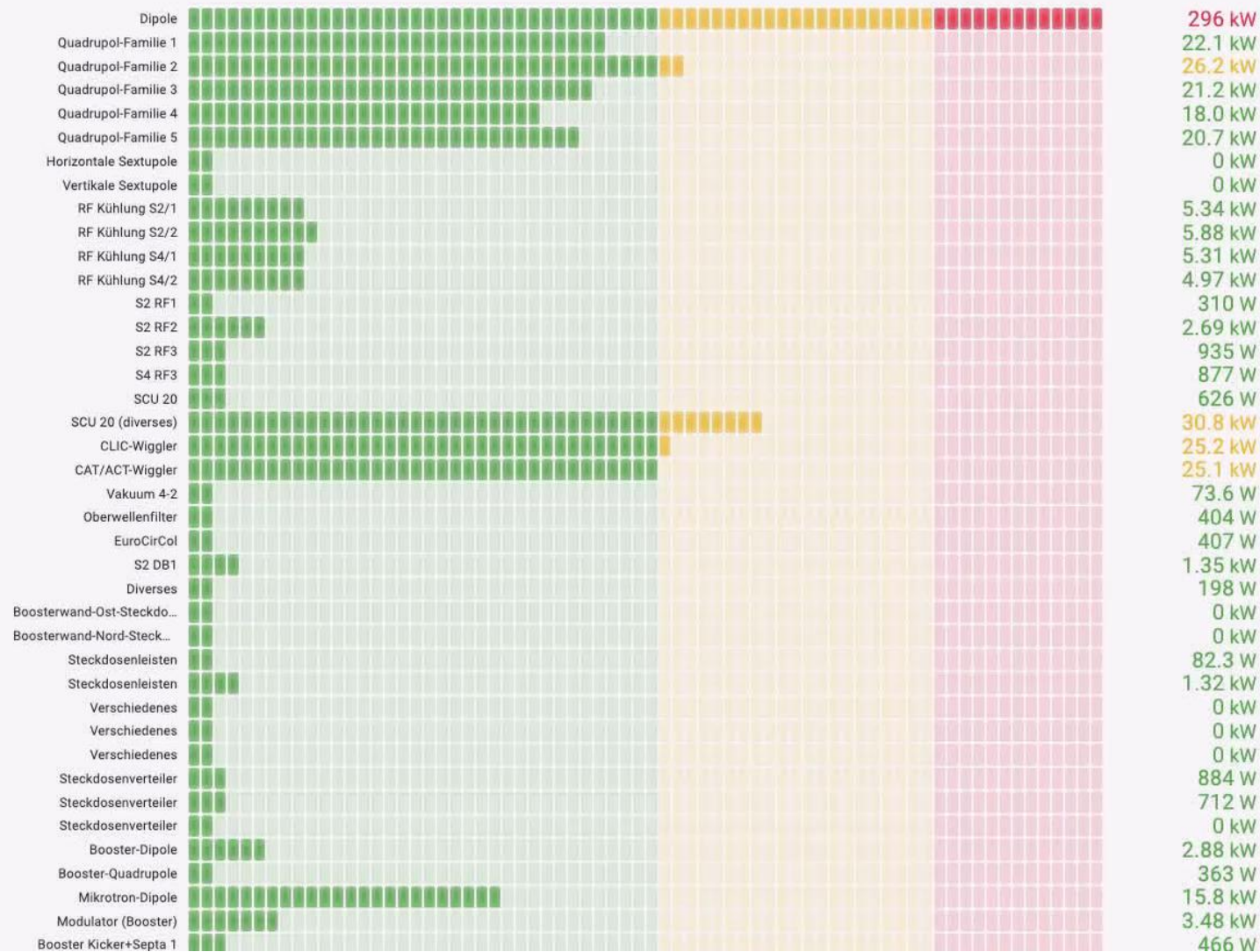
# Beamlines energy consumption – 14.09.2022



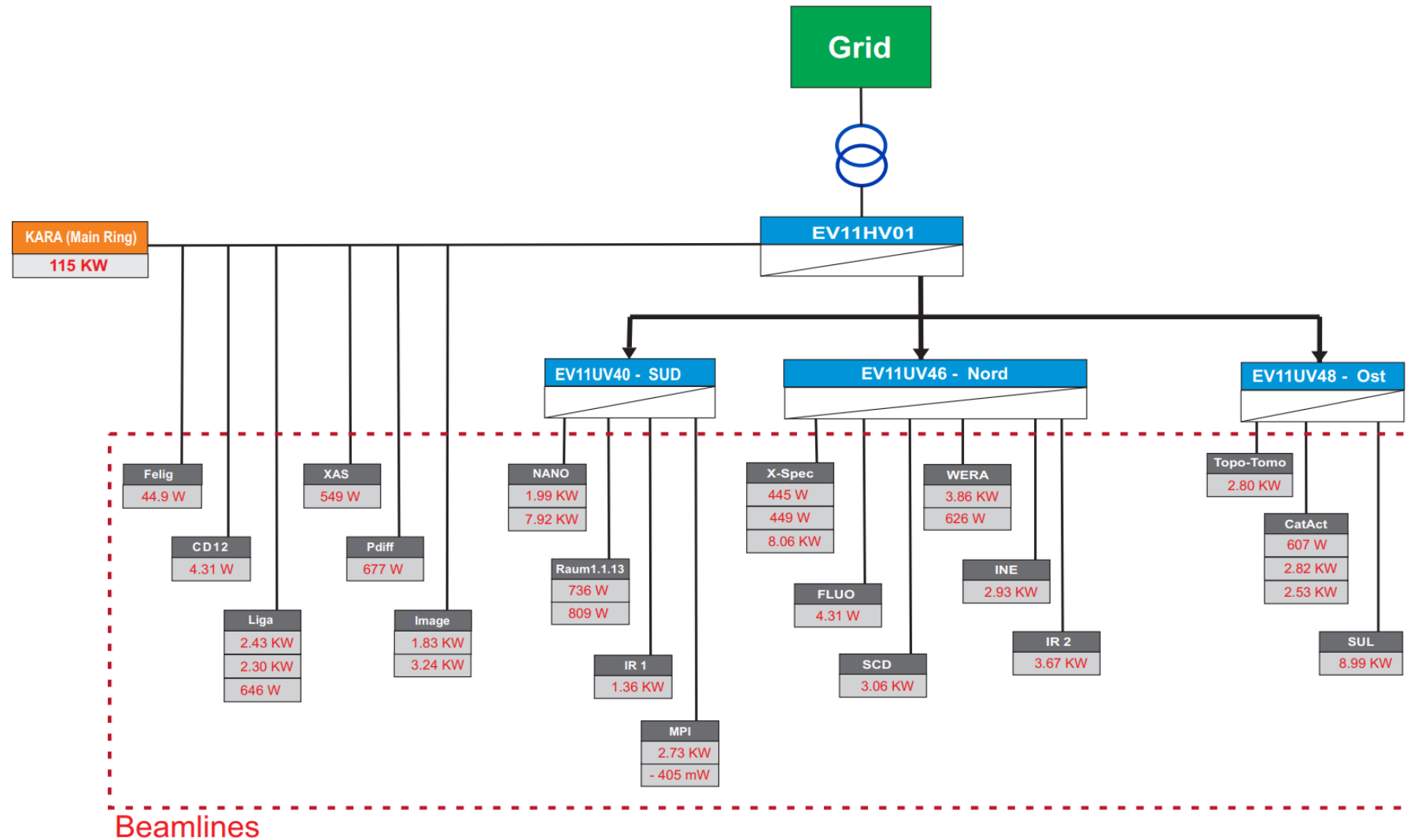
## Gesamtleistung KARA



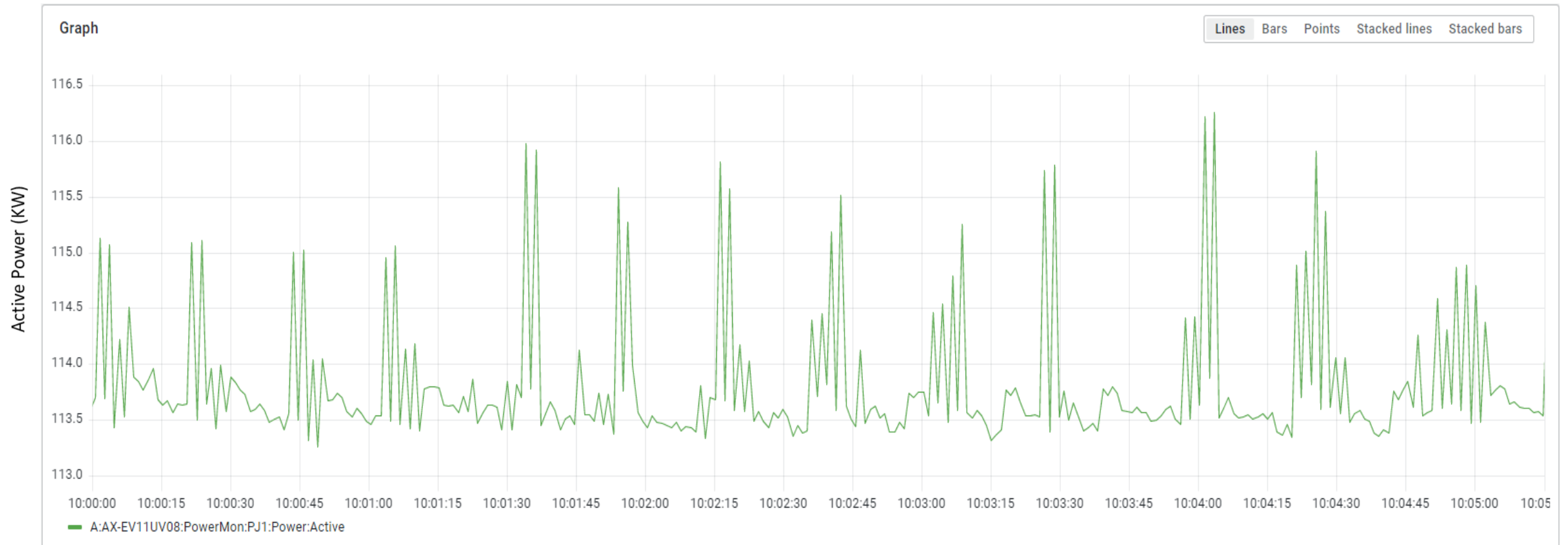
## Einzelmessungen



# Strand scheme of main ring and Beamlines

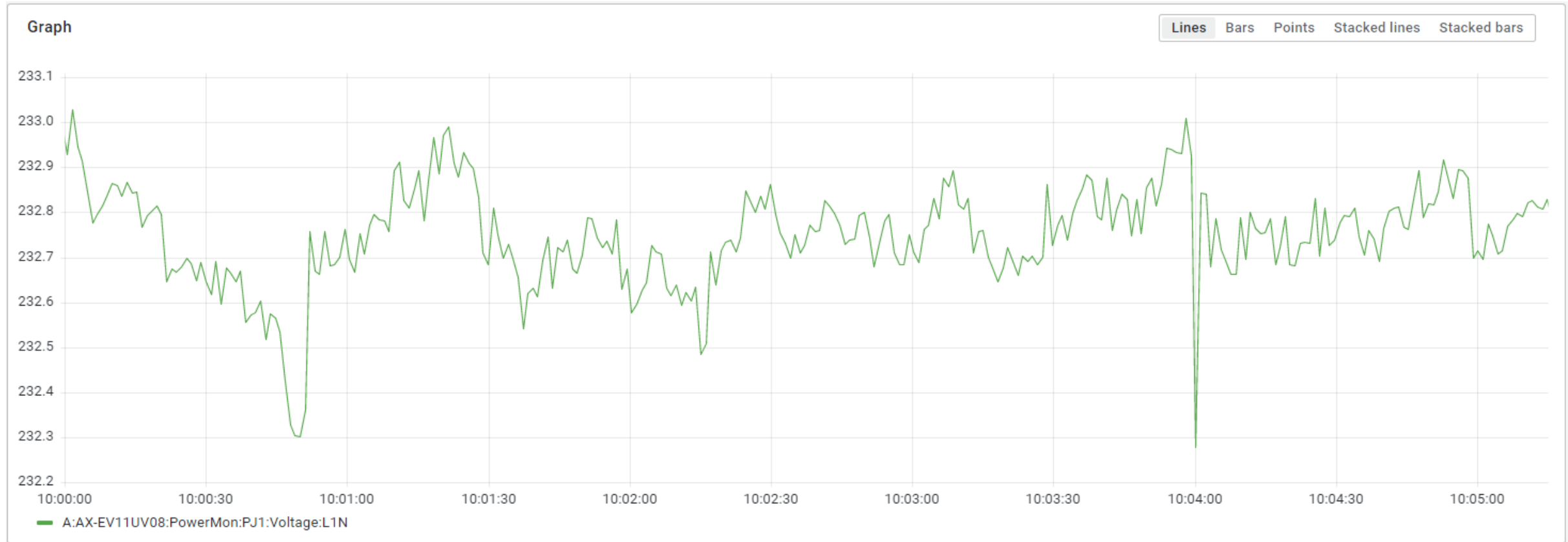


# Active Power Profile of main ring



2023-03-01 10:00:00 to 10:05:15

# Voltage Profile of main ring



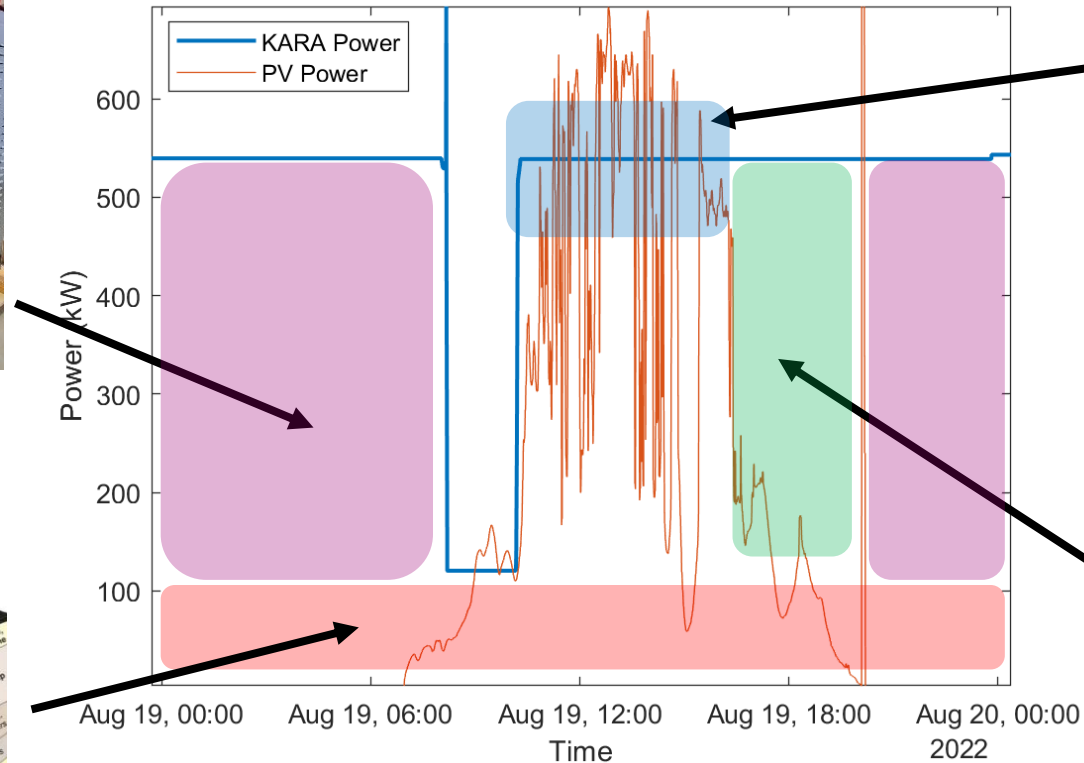
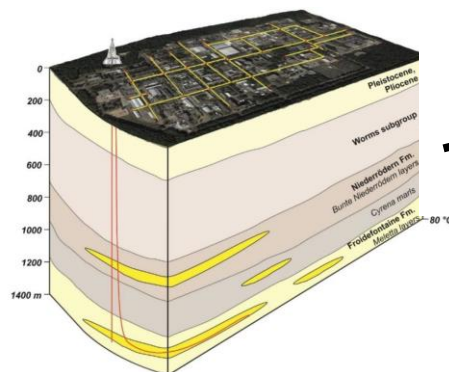
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# Energy storage solutions for accelerators

**Long-term (>12 hours) storage solutions**



**Geothermal**



**Fast dynamics solutions**



**Medium-term solutions**



# KITTEN: a solution for energy management in accelerators

- Large set of expertise in the accelerators' area
  - Energy management, power electronics, technology development and testing
- Availability of large-scale testing infrastructure
  - KARA → test facility for accelerator technologies and study benchmark
  - Energy Lab 2.0 → test facility for high power energy solutions
- Collaboration at national and international level
  - BMBF Project ACCESS on power quality in accelerator
  - Horizon Europe on Sustainable and Efficient Accelerators (ALBA, CERN, DESY, HZB, MAX IV)

# THANK YOU Questions?

**HIRING!!!**  
Looking for talented  
PhDs and Post-docs  
to work on the topic!



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