Solar Energy conversion systems to address needs of Energy Systems 2050 (ES2050)

25.09.2017 UTFSM-Workshop, Santiago del Chile

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Institute for Neutron Physics and Reactor Technology

TOC:

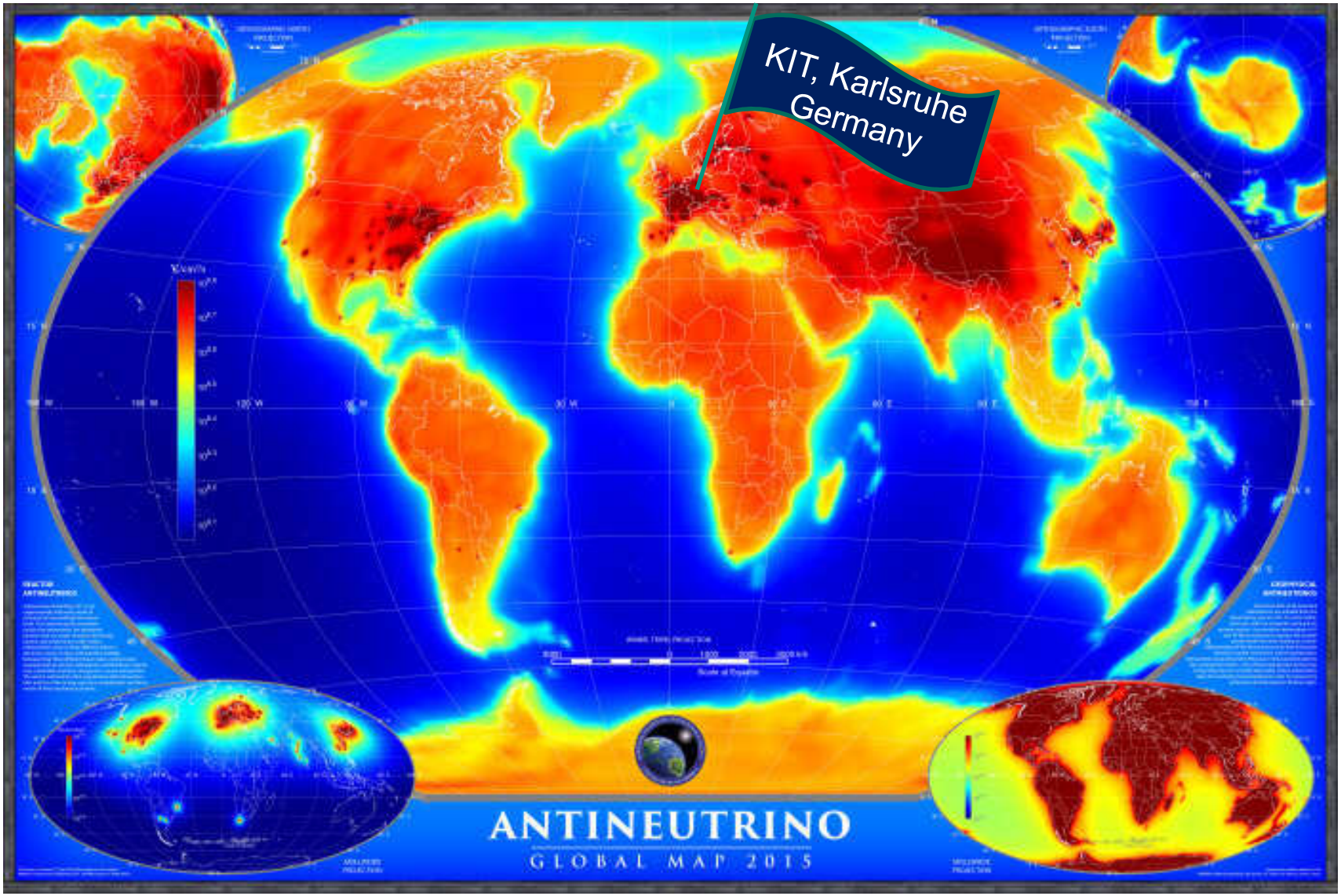
That's me & my institute KIT/INR

Sodium technology at KIT (Past and Today)

Present research activities

Summary

Personal Self-Introduction



Personal Self-Introduction

Short CV

1982 Diploma in solid state physics at university of Heidelberg

1983 Industry as head of the Hardware-In-the-Loop Simulation (HWIL) group

1986 Safety researcher at KfK, predecessor of KIT

1993 PHD in Energy Technology at IKE of University Stuttgart

1994 Responsible head for LWR safety at Institute for Reactor Safety (IRS) at FZK,

2008 Head of the group at Institute for Neutron physics and Reactor technology (INR) at KIT

2012-present: Project leader of KIT liquid-metal research infrastructure (KASOLA; ATEFA, SOLTEC and DITEFA)

2015 Head of Helmholtz AMTEC Center @ KIT

Actual work topics

- Renewable Energies: CSP 2.0 using liquid metals
- FUSION technology: Balance of plant and safety for DEMO fusion power plant
- Simulation of new power generation systems for an energy system 2050+ (ES-2050+)
- NuSafe: Fast liquid metal reactor safety within EU

KIT/INR-Structure

Institutsleitung
- Sekretariate

R. Stieglitz (U. Fischer)

Projekte

Design von Bestrahlungsexp. (F.Arbeiter)	Fusionsneutronik (U.Fischer)	Plasmanahe Komponenten (L. Boccaccini)	Systemdynamik & Sicherheit (W. Hering)	LWR Sicherheit (V.Sanchez)

Expertteams

Anlagen-design – Systemdyn. & Sicherheit (Hering)	Design, Analyse nukl. Komp. Fabrikation, Qualifizierung (Boccaccini)	Kompl. Experimente & Konstruktion (Ghidersa)	Messtechnik & exp. Methodik (Arbeiter)	Neutronik & Kerndaten (Fischer)	Reaktor-physik & -dynamik (Sanchez)	Thermohydr. Simulation & Optimierung (Cheng)

Admin.-tech.Support

Finanzen, Personal- Querschnittsaufgaben (Freiner)

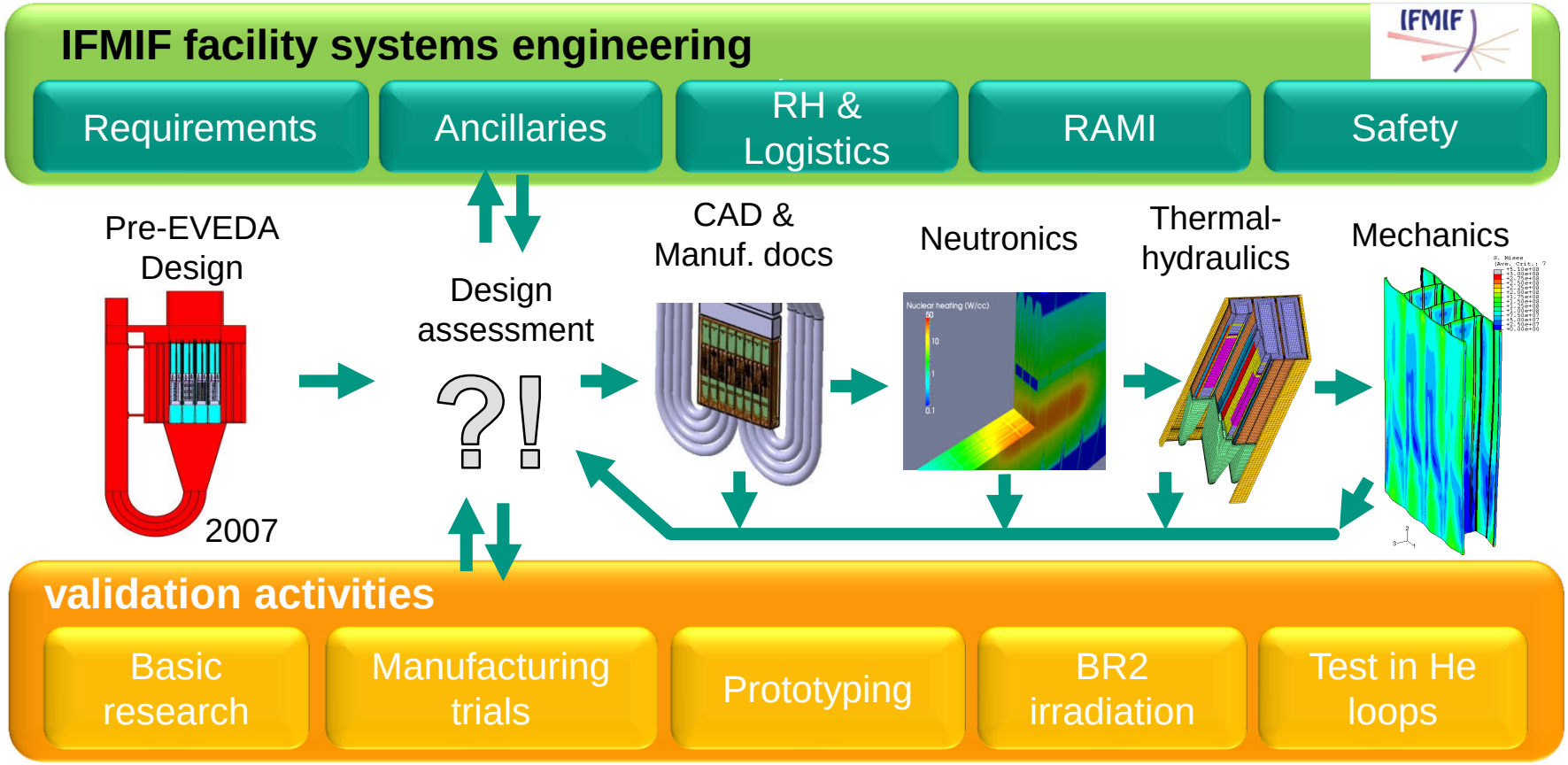
- Personal
- Finanzen
- Projektmanagement
- IT-Services
- mech. Werkstatt & Fertigung
- Elektro- und Messtechnik
- Sicherheit (Laser, Abwasser, (Strahlenschutz, Gefahrstoffe, ..)
- Vertrauensperson

- Matrix structure → Successful realization of large scale R&D Programs
- Centralizing of services → Substitution options, effective use of Resources
- General flexibility → Participation in different projects (coop. ID)

(on all levels!)

Example for INR-Operability

- Elaboration of Management & Realisation plan



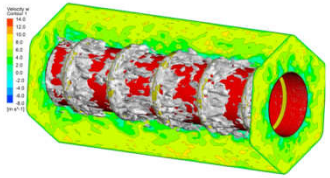
- Time scheduled on scientific challencing objectives
- Availbility of resources in-house & National/International
- Permanent assessment of interfaces +++ …….

INR – Development of methodes

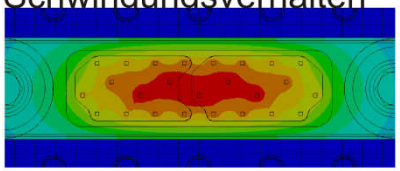
- 3-pillar principle („fundamental science“ ➡ application)

MIKROSKALA

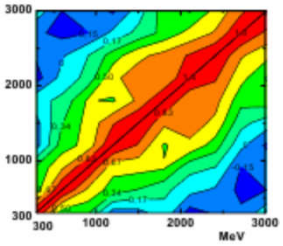
Strömungsmechanik
- Turbulenzmodellierung
- strukturierte Oberflächen
- Diffusion in Strukturen



Festigkeitsmechanik
- Verhalten von Schüttbetten
- Schwingungsverhalten

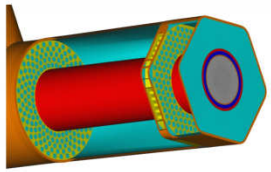


Neutronenphysik
- Fissionyields
- Kerndatenbestimmung
- Detektormodellierung

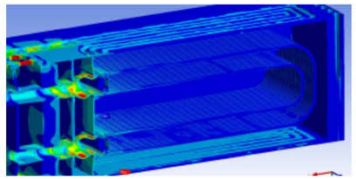


MAKROSKALA

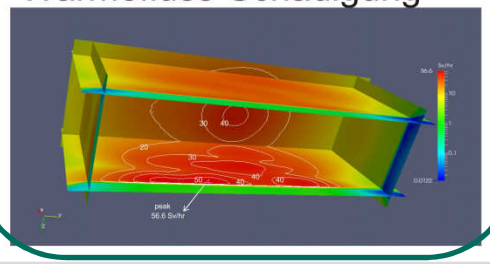
Strömungsmechanik
- CFD- Analysen
- globale Zwei-Phasenmodelle
- Unterkanalrechenwerkzeuge



Festigkeitsmechanik
- FEM -Analysen
- Kraftrekonstruktionsverfahren

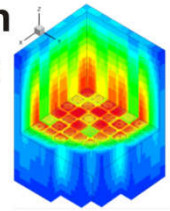


Neutronenphysik
- MC -Berechnung Methoden
- Shutdown-Dosisraten
- Wärmefluss-Schädigung

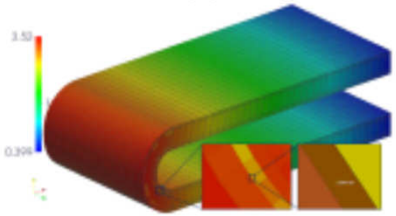


SYSTEMSKALA

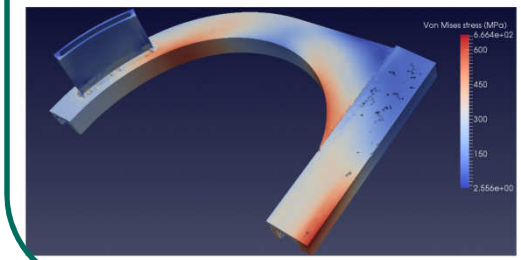
Multiphysik-/Multiskalen-Methoden
- MC/TH Rechnungen
- N/TH Rechnungen



- Strömungs-Struktur Interaktion (FEM/CFD)
- N/TH/FEM Kopplungen



- Mehrphasen-/Mehrkomponenten Ausbreitungsprobleme
- Systemcodes (N/Magnete/Komponeten,+++)

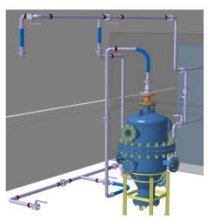


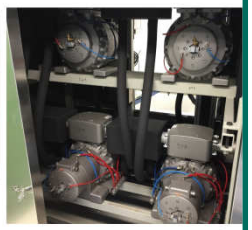
INR – Experimental Evaluation

- Focused on 3-pillar principle
- Cooperation with other institutes at KIT / Germany / Worldwide

GRUNDLAGEN

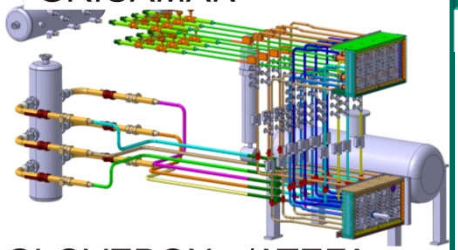
-HETREX



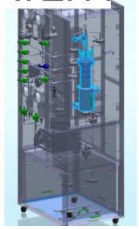


-PREMUX (Bruteinheiten)

-GRICAMAN



-GLOVEBOX /ATEFA

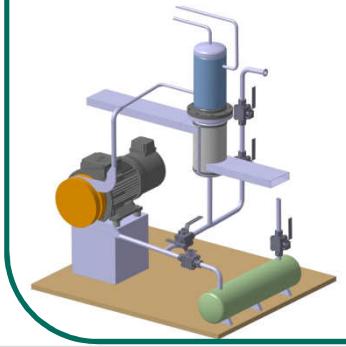


FEASIBILITY

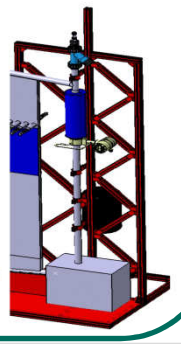
-SIRHEX, HELOKA-LP

-HEMAT , L-STAR

-SOLTEC



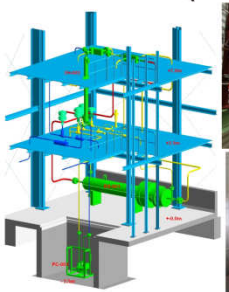
DITEFA



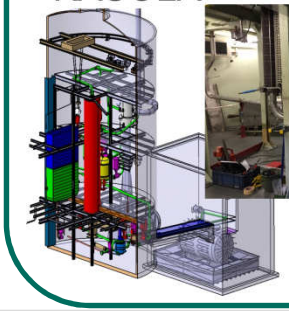
PROTOTYPEN

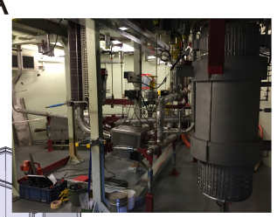
-HELOKA-HP, Elektronen-kanone (800kW)

-KATHELO (HT-Materialien)



- KASOLA





Renewable Energies: CSP 2.0 using liquid metals

- Starts in 2008 as a spin-off of sodium technology used in fission
- Objectives → CSP 2.0
  An innovative second order solution

Activities:

- Analysis of existing developments
- Analysis of capabilities and requirements
- Analysis of requirements in an multimodal energy system 2050+

➔ highly flexible, fast reacting power plant

Actions:

- Development of key components, adequate materials and qualification
- Development of demonstrator and prototype
- Development and qualification of analytical tools (CFD, System codes)
- Provide industrial safety level
- Add AMTEC as topping system

Actions

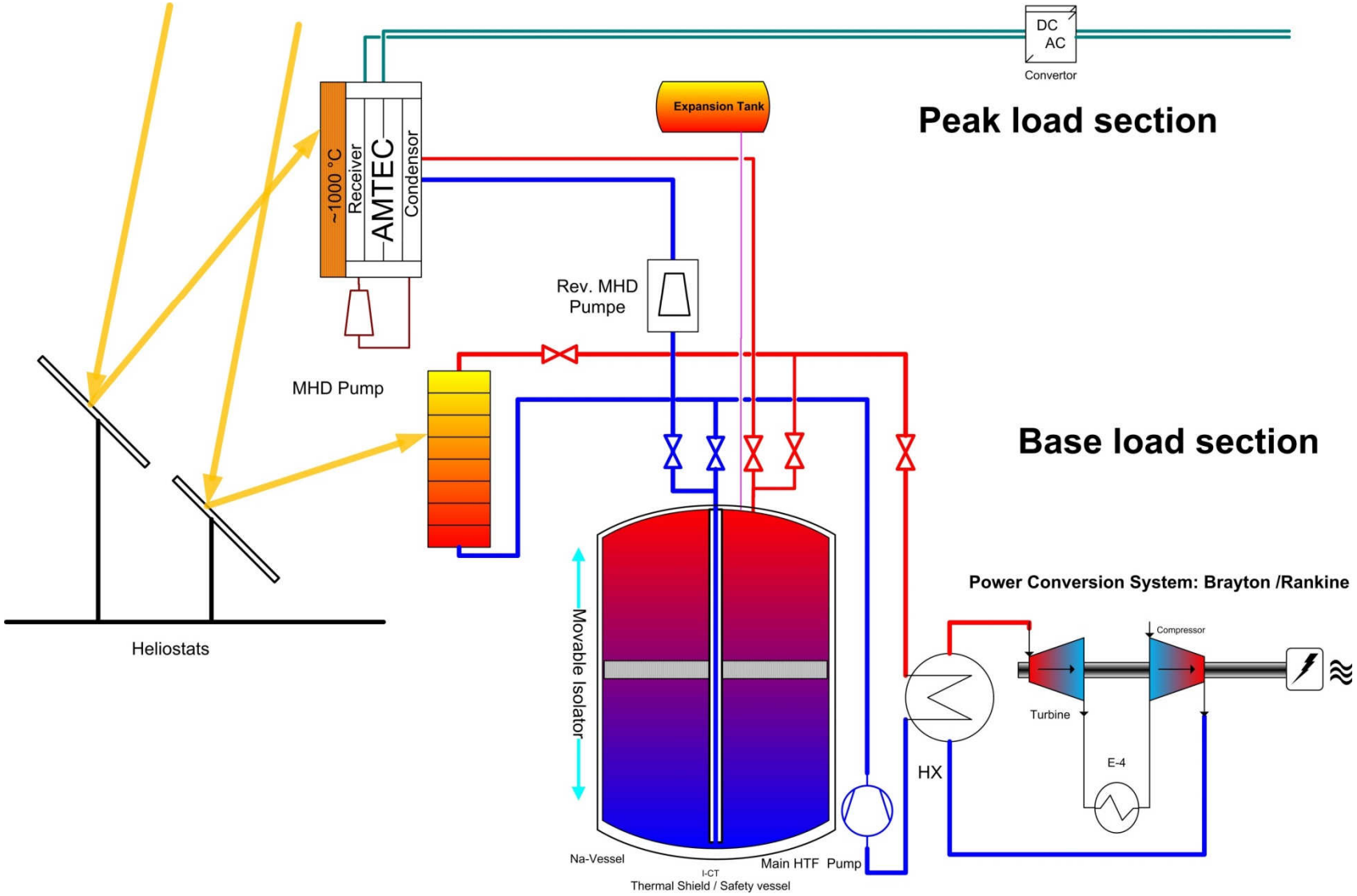
Key components:

- Receiver
- Pumps: 1. mechanical (back-up solution)
  2. Electromagnetic: FLIP, ALIP, EMP, …. (ongoing development)
- Storage/Buffer
  → direct and indirect systems
- Heat exchanger (Steam generator, ….)
- Safety concept and devices
- Qualification of codes for low Prandtl fluids (→ Thomas Schaub)

Priorities:

- System codes and experimental facilities
- Design and materials for receiver and heat exchanger
- Direct energy storage (FlexStor)
- Address industry to see CSP 2.0 as a future market

Vision of CSP 2.0: A&CP

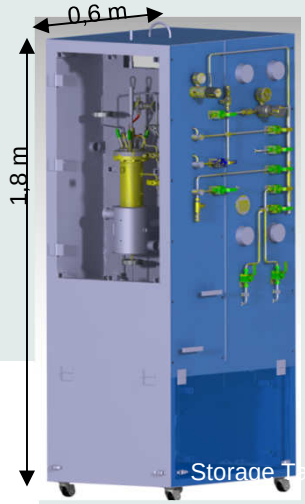


Institute for Neutron Physics and Reactor Technology
Facility design, System dynamics and Safety (ASS)

Experimental facilities at HAC

Basic physics (Electro-chemistry)

AMTEC
ATEFA

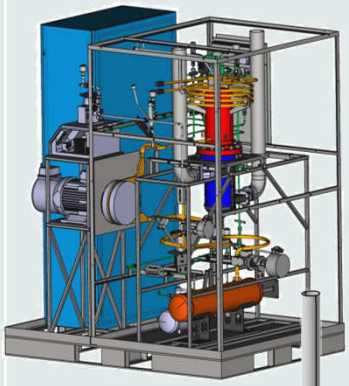


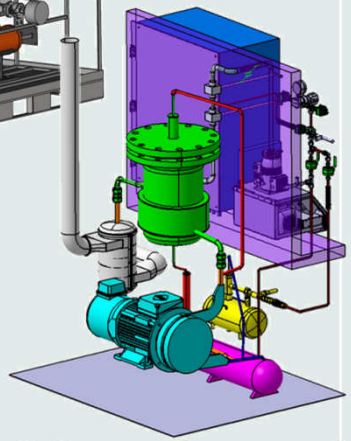
← DITEFA

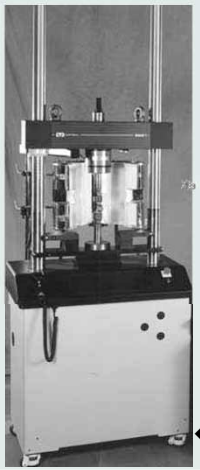
Na-Infrastructure

System level (Materials)

„Energy“ - materials
SOLTEC $1_{AWP} – 2_{IHM}$





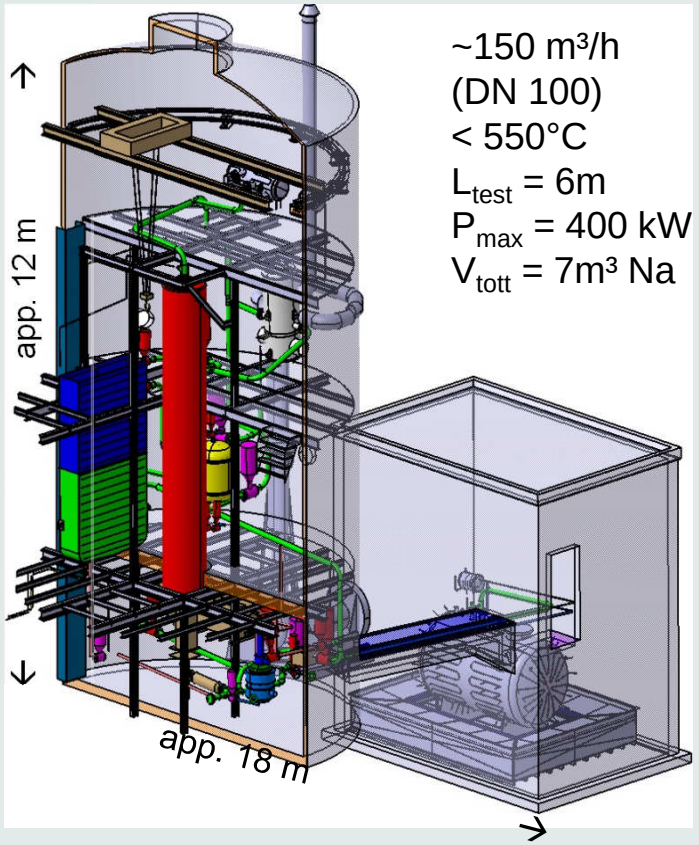


SOLTEC 3_{INR} ←

←CORTINA $_{AWP}$

Medium Scale / Demonstrator (Systems)

Thermal storage
KASOLA facility



~150 m³/h
(DN 100)
< 550°C
L_{test} = 6m
P_{max} = 400 kW
V_{tott} = 7m³ Na

Capabilities and Scientific Program

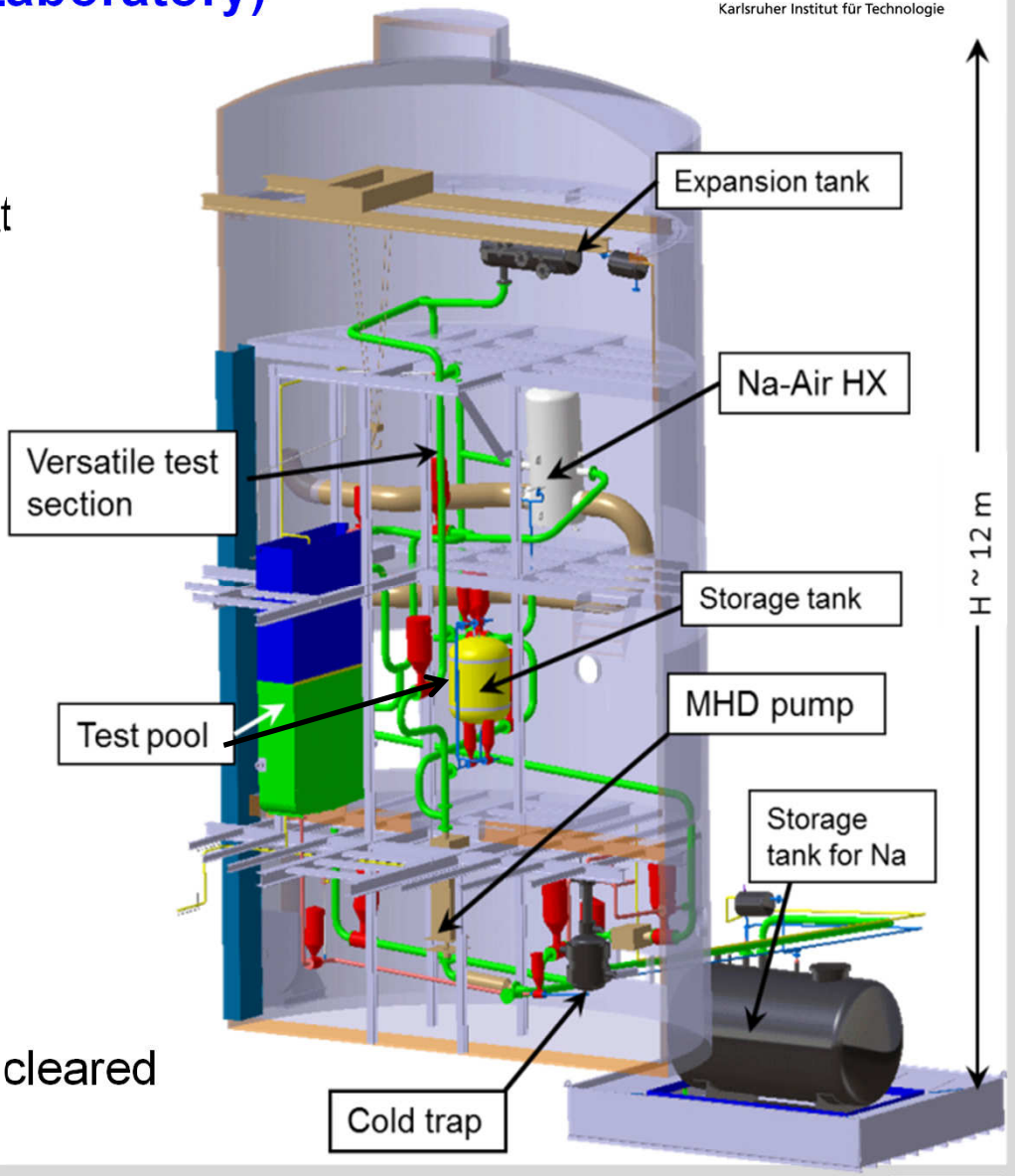
- **KASOLA:** 150m³/h, 7 m³ Na, 550°C
  contributes to safety oriented EU-programs: ENSII+, SESAME, ESFR_*smart*
  → Qualification of CFD and system codes
  → Component and safety tests under real conditions
  → Backbone of KIT-sodium infrastructure (Na-storage, purification, distribution)
- **SOLTEC-1:** IAM-AWP/INR: material qualification in flowing sodium up to 750°C (in oven), LCF (ESFR_*smart*)
- **SOLTEC-2:** IHM: material qualification in flowing sodium under fast thermal transient conditions up to 900°C (in test section)
- **SOLTEC-3:** High temperature loop for direct energy conversion (AMTEC) phase change experiments (ESFR_*smart*) up to 1000 °C
- **ATEFA:** Facility in operation to investigate AMTEC up to 1000 °C
- **DITEFA:** Education and training on liquid metals at room temperature Pre-tests for KASOLA, flow transitions, backward facing step
- **CORTINA:** Infrastructure for corrosion studies in sodium in final built phase
- **AMTEC Laboratory** @INR: in operation

KASOLA (Karlsruhe Sodium Laboratory)

- **Projected for:**
  - Research on liquid metal
  - Development of turbulent LM heat transfer models for CFD tools
  - Component tests (900l pool)
  - LM for CSP 2.0

Status (SiO, QE)

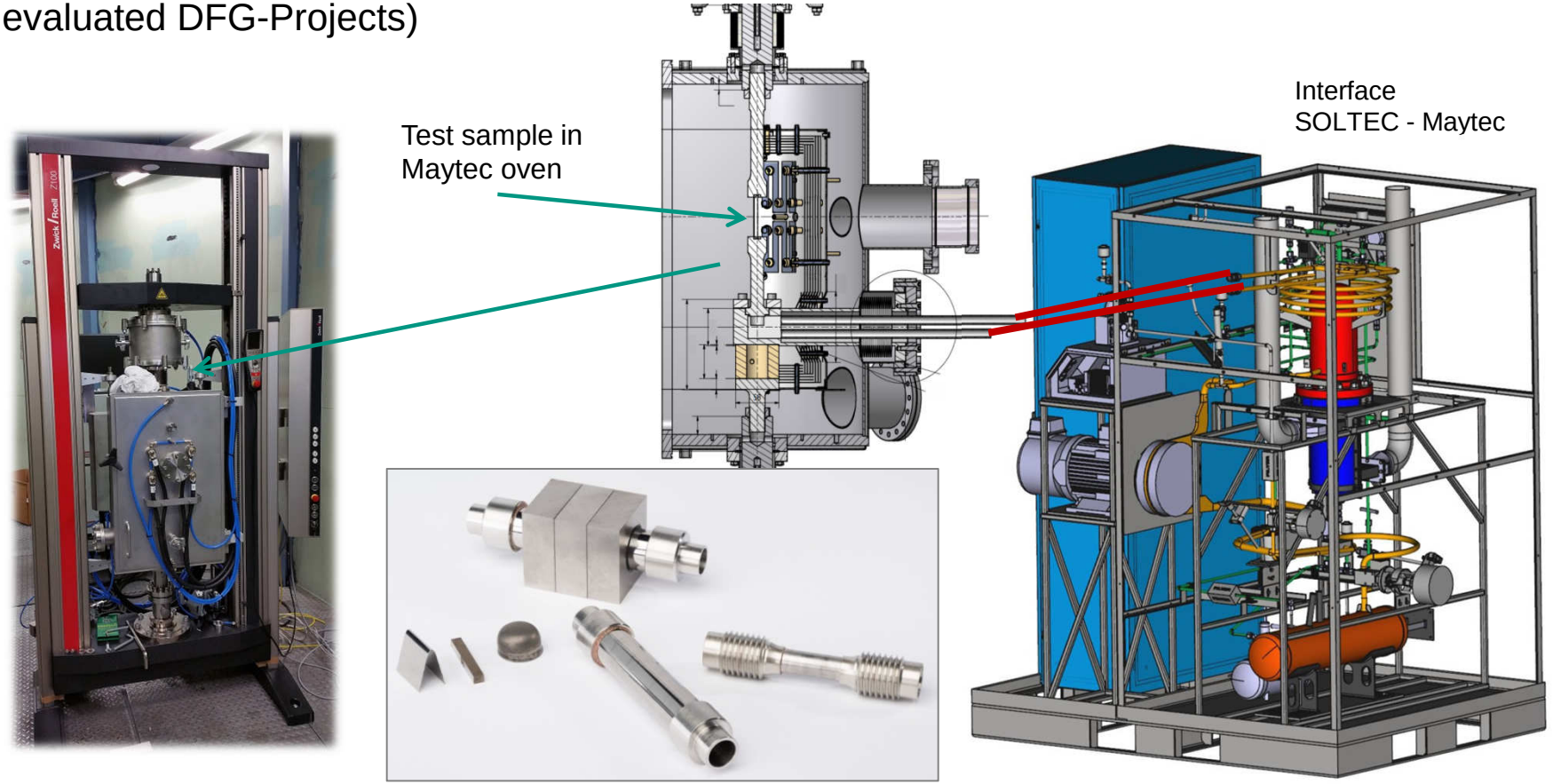
- Cold SIO (set-into-operation) phase finished
- Hot (SiO) in progress:
  - Na liquefied, components tested
  - Check of safety provisions (unexpected behavior detected → correction in work)
- Continuation in KW39/40
- After ISS test (TueV) → Operation cleared



Qualification of Innovative Materials: SOLTEC – 1

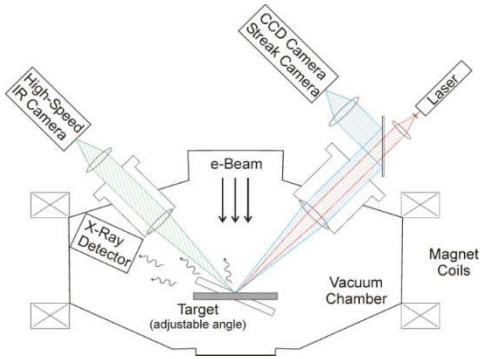
Sodium Loop to TEst materials and Corrosion: for Low Cycle Fatigue (LCF) tests

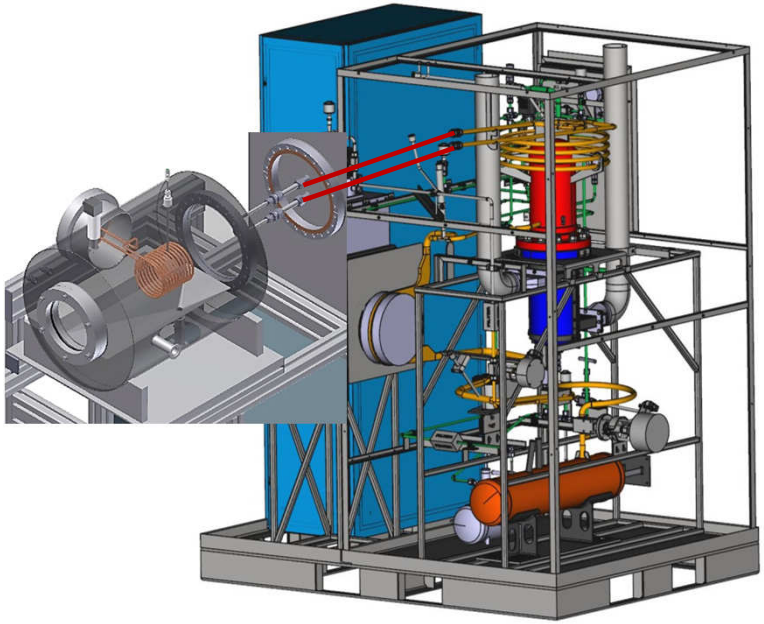
- Materials for tube receiver in CSP
- Ductile refractory metals (W, Mo) (ex. behavior at HT versus LM)
- Ductile behavior of W und Mo via innovative transformation processes (2 positiv evaluated DFG-Projects)



Material challenges: protective coatings: SOLTEC-2

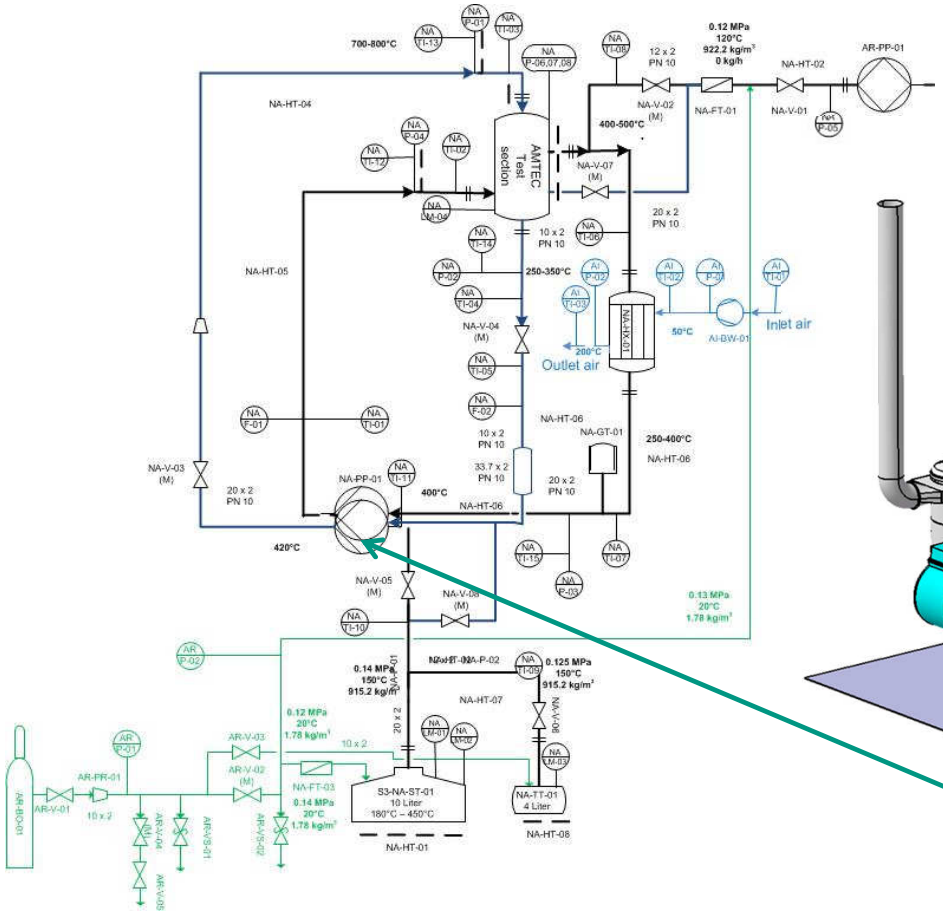
- Material compatibility at high temperatures in contact with liquid PbBi, Sn and **Na**
- and under rapid temperature transients (SOLTEC-2) – Thermal cycling tests at high temperature - ΔT: 650 – 900°C
- Long term stability of protective surface coatings (in/outer surface) using pulsed electron beams (GESA-SOFIE) – **S**urface **O**ptimization facility with **F**ast **I**n-situ diagnostic **E**quipment

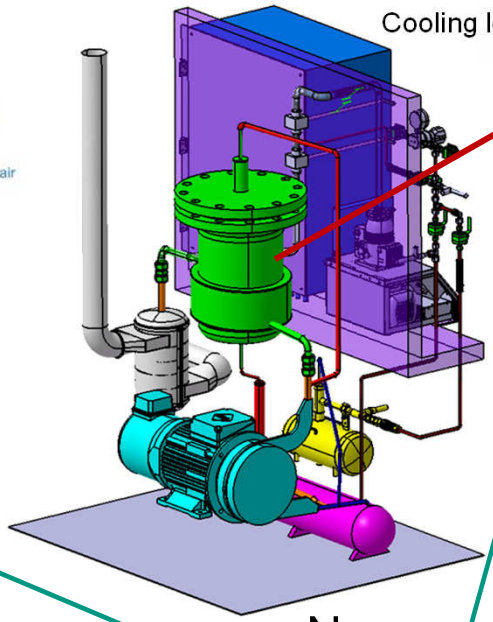


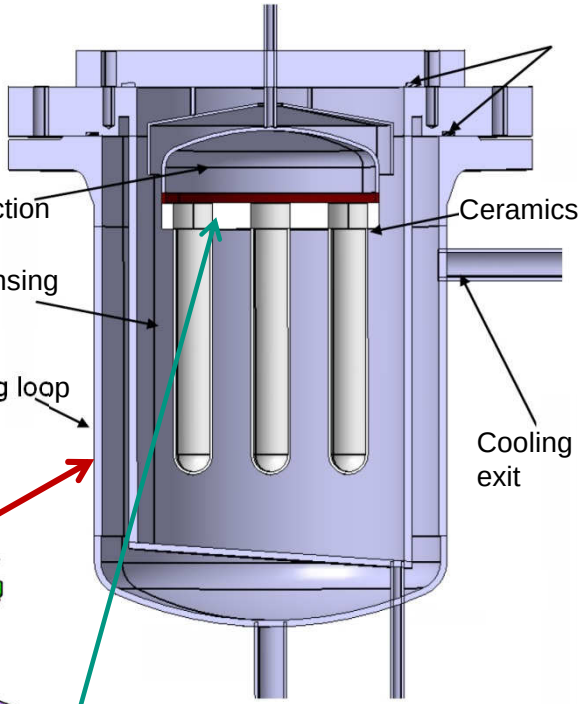


Qualification of AMTEC: SOLTEC-3

- Long term and transient test of AMTEC cells and cluste
  1. single cell (extending ATEFA)
  2. small module (3-7 cells)
  3. stacked modules

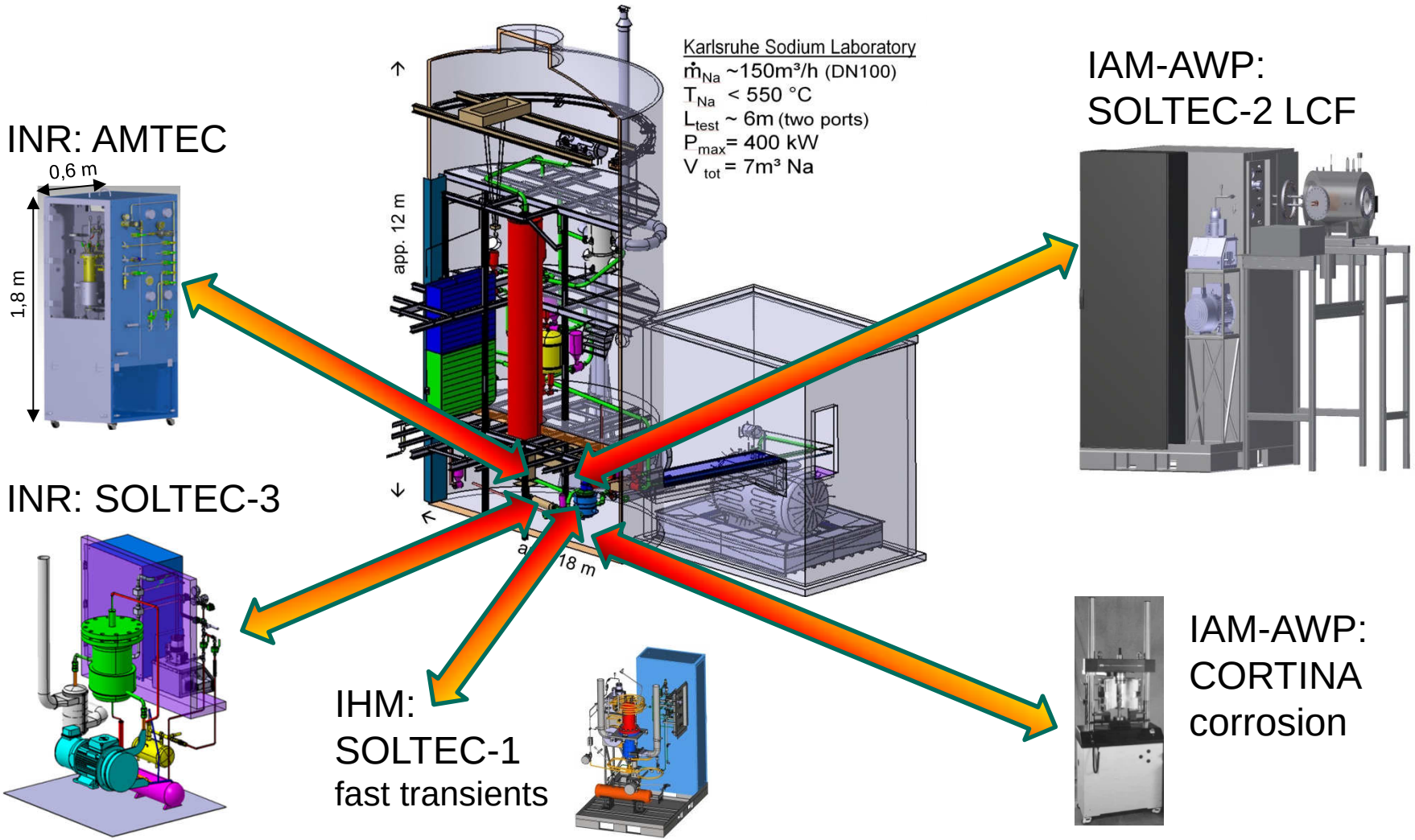






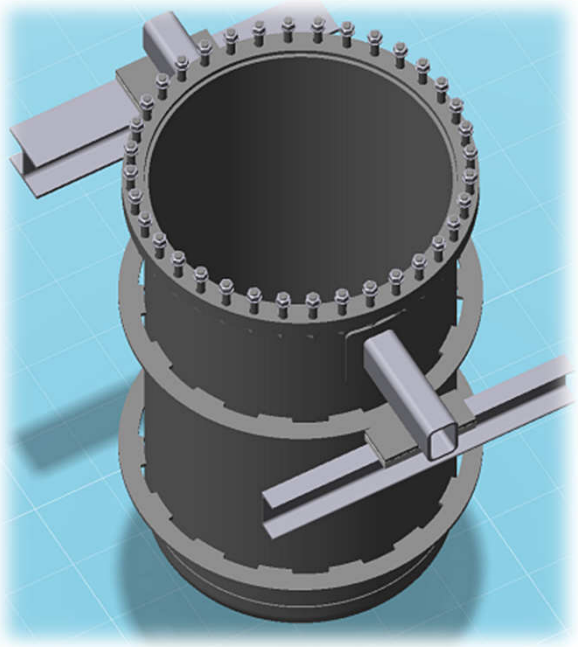
+ New ceramic base plate
+ EMP with two independent loops

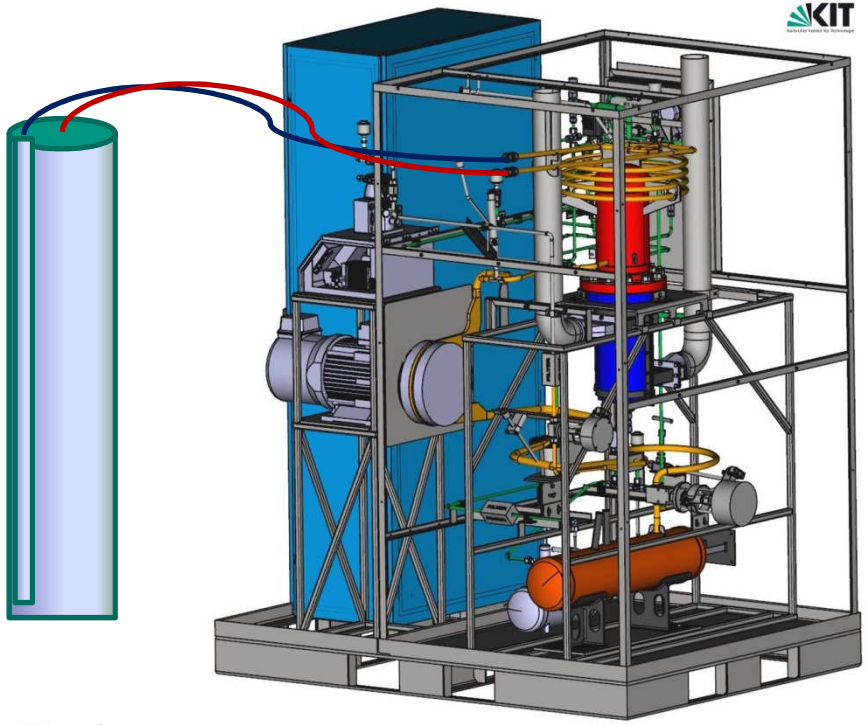
KIT-wide Sodium Infrastructure sharing



Ideas: Qualification of Innovative Flow Sensors

- Small sensors: SOLTEC -1/-2
  - up to 720°C
  - Up to 8 m/s (depending on Δp)
  - Direct attachable by SWAGELOC HT joints
    (qualified by KIT for Sodium up to 800°C)

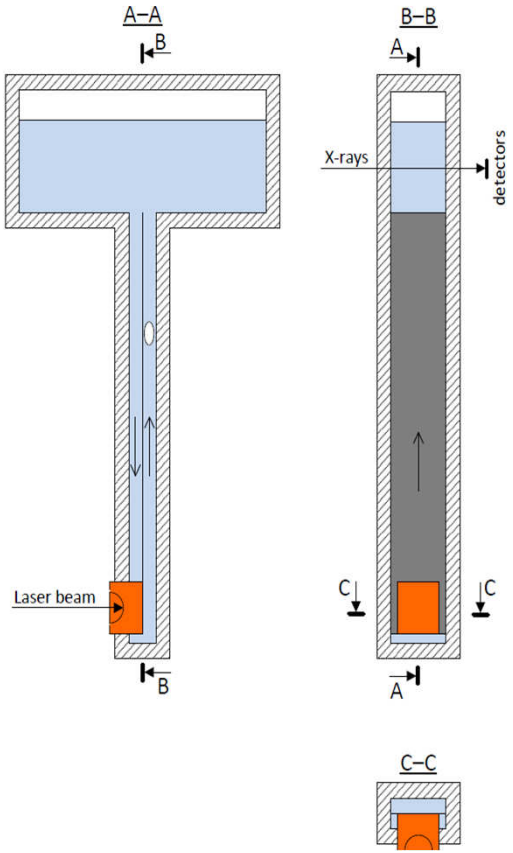


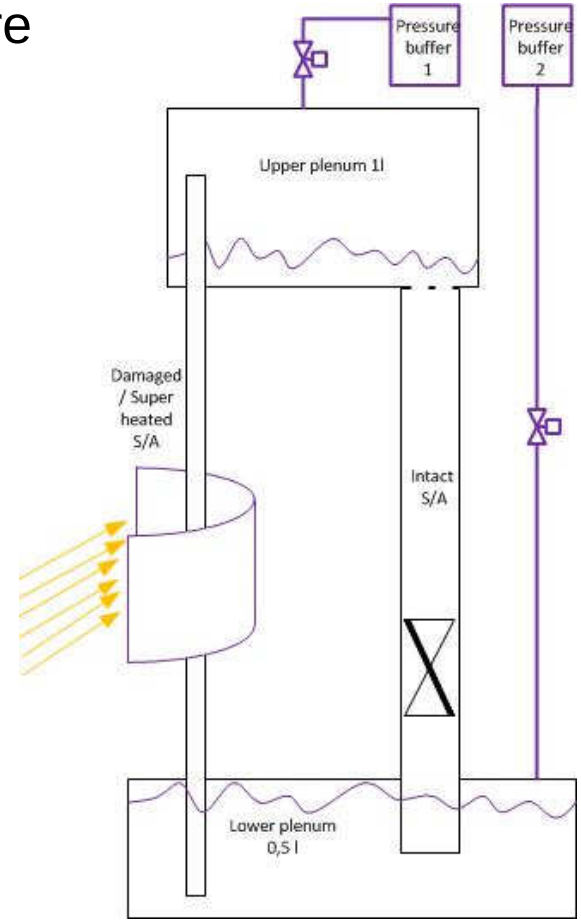


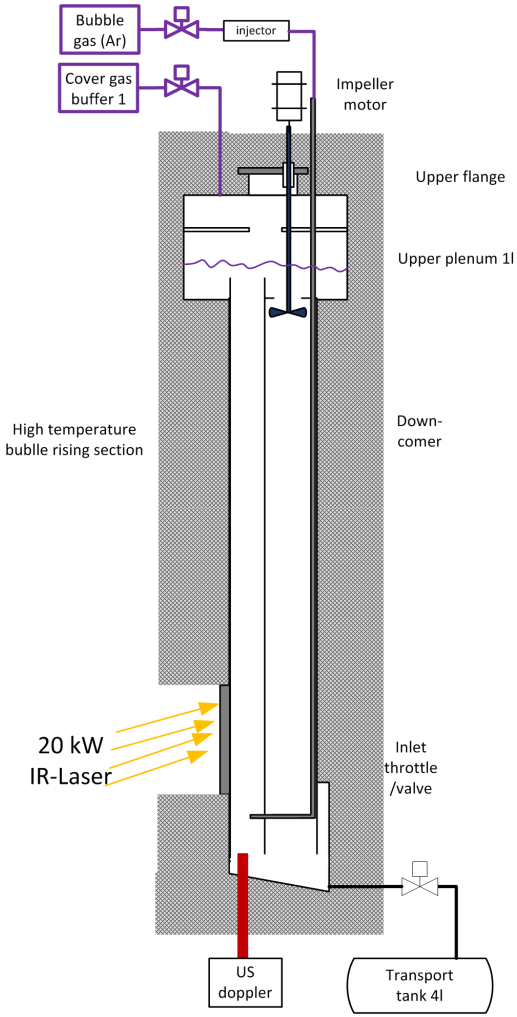
- 3D-sensor arrays: KASOLA FlexStor
  - DN 900
  - Height of ~1,5 m (~1 m³)
  - Integrated in 2018 available in 2019

Ideas: Sodium boiling related tests

- Several concept is discussion using HAC infrastructure







Summary and outlook

- Receiver: **to be tested in SOMMER facility (2018), to be integrated in KASOLA for A&CP demonstrator (2019)**
- Pumps: Electromagnetic: ALIP, EMP:
  → **in operation in KASOLA and SOLTEC, last news: 1 m³/s feasible**
- Storage/Buffer: **FlexStor ordered to be integrated into KASOLA (2018)**
- Heat exchanger: **waiting for material qualification (SOLTEC) results**
- Safety concept and devices: Poster at **SOLARPACES 2017**
  → experiments on sodium boiling projected for 2019
- Qualification of codes for low Prandtl fluids
  Experiments under way to qualify CFD and system codes
  Thomas Schaub: Poster at **SOLARPACES 2017**
- AMTEC **in operation:** **Nerea Diez:** Poster at **SOLARPACES 2017**
- **Industry involvement successful**
  on: plant and safety level, component and pump level
- Step to industrial realization in 2018