From science requirements to application in industry

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RI Research Instruments

Facts and figures

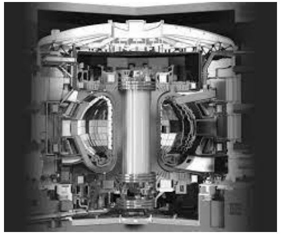
- Founded in 2009
- Employees 420

  ca. 140 physicists, engineers
  ca. 210 manufacturing specialists
- Annual revenue: 70 million EUR
- Established with the core team of ACCEL Instruments GmbH (1994-2009) and of INTERATOM/Siemens
- Company is majority owned by Bruker EST, Inc., management holding significant share of the company

Customers and contribution to revenue

„Big Science“:

• Superconducting RF cavities and accelerator modules	20%
• Normal conducting RF cavities, RFQ’s, linacs	20%
• Fusion equipment	15%
	55%



Industry:

• EUV tools	15%
• Components for EUV lithography machines	30%
	45%

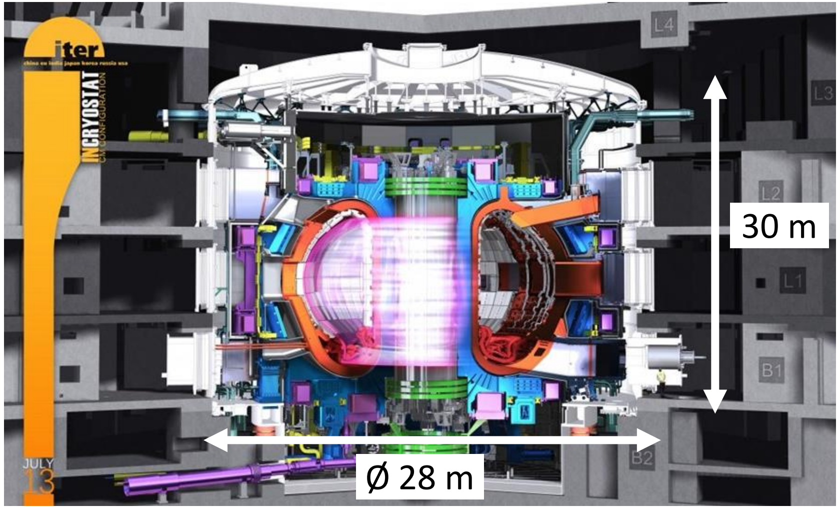
Manufacturing capabilities

RI philosophy: Perform the critical manufacturing steps in house

Milling, turning, metal working, electron-beam welding, TIG welding, vacuum brazing, heat treatment
Leak checking, pressure test, RF testing, dimensional control, vacuum, cryogenics, electropolishing, pickling

Design and manufacturing cryogenic valve boxes for F4E/ITER

ITER - “The Way” to fusion energy



https://www.iter.org/mach/tokamak

RI scope: Design and manufacturing of

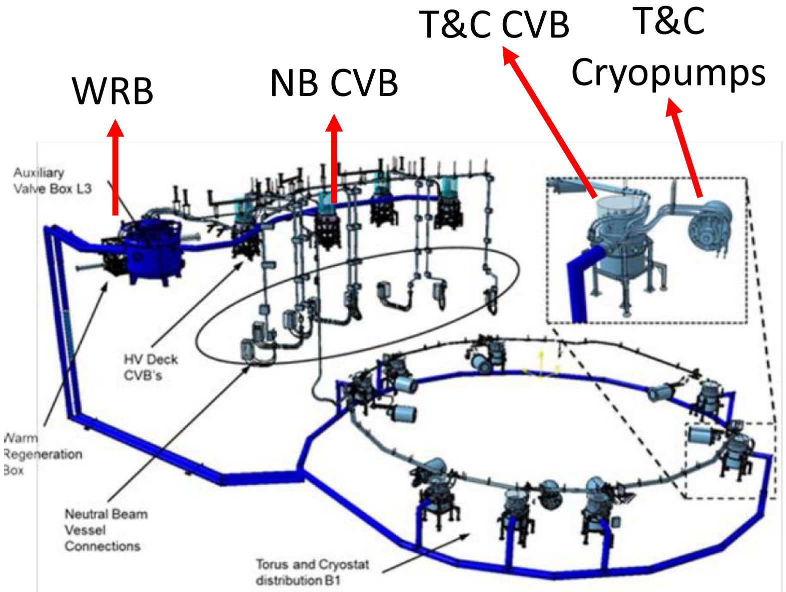
1 **W**arm **R**egeneration **B**ox (WRB), 3 x 3 x 5 m^3

8 **T**orus and **C**ryostat **C**old **V**alve **B**oxes (T&C CVBs), Ø 3 x 4 m

3 **N**eutral **B**eam **C**old **V**alve **B**oxes (NB CVBs), Ø 3 x 4 m

Cryogenic System

To create and maintain low-temperature conditions for the magnet, vacuum pumping and some diagnostics systems



Note: T&C Cryopumps are also in RI scope but not part of this presentation.

Design Requirements

Demanding environment and high-end operation

- Unique cryogenic operating temperature range

  Cryopump operation / regeneration **4-500 K**

  → Design qualification for cryogenic parts to be extended up to 500 K (Bellows, T-sensors)

- Radiation compatibility

  Cumulative equivalent radiation dose of up to **1 MGy**

  → Use of synthetic material very limited (Yes: EPDM, PEEK; No: PTFE, Viton, Neoprene)

  → Materials containing halogens are restricted in use

  → Instrumentation has to be specifically selected and designed

- Equipment is designed to withstand **seismic activities** and other hazards

- High reliability

  → 20 years lifetime with dynamic cycles, operational periods of 18 months

- Pressure equipment according to PED and designed following EN 13445 / EN 13480

  → Additionally 100 % x-ray testing required for PED equipment

- Magnetic field compatibility

  DC modulus up to 150 mT, **modulus variations up to 24 mT/s, 80 mT/s** for short duration

  →Influence on instrumentation/cabling to be considered

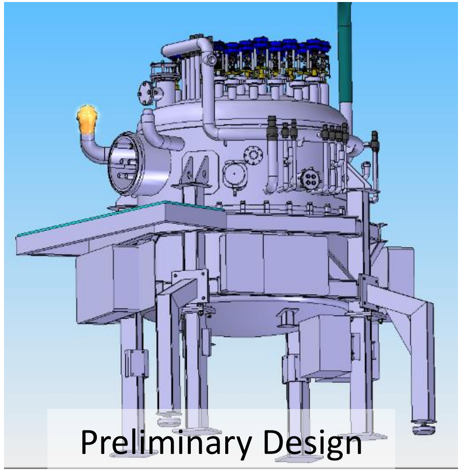
  →Use of austenitic stainless steel only and with low impurity requirements - Co, Ta, Nb)

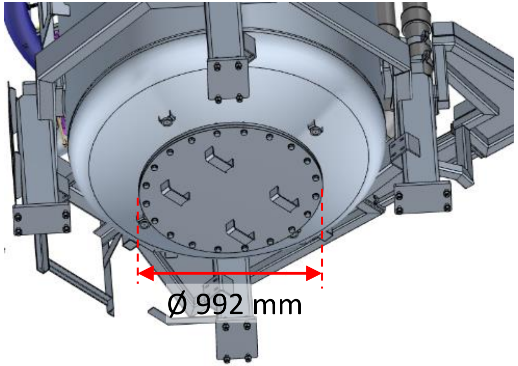
Torus and Cryostat Cold Valve Boxes

Final Design - Internal maintenance concept

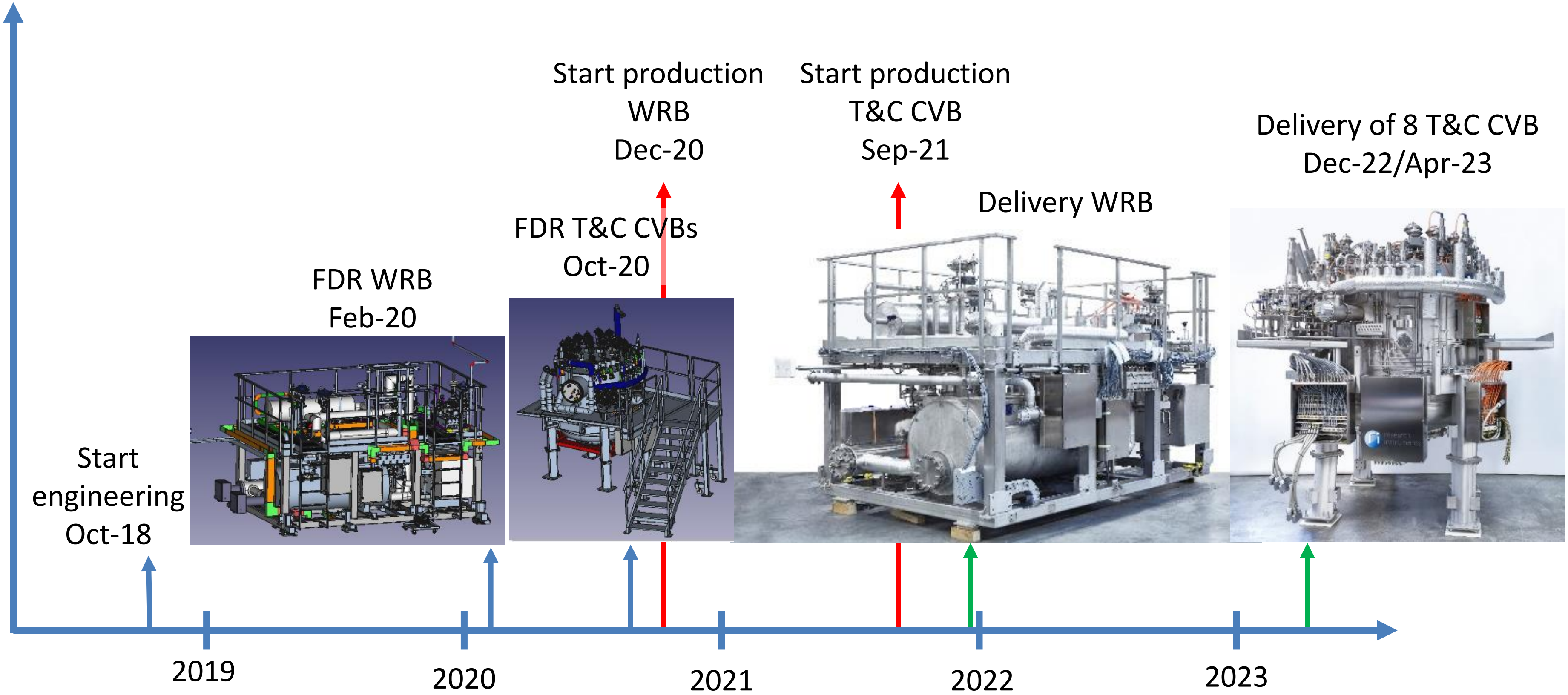
<u>Maintenance flange</u> considered instead of <u>vacuum split flange</u>

- Easily removable as equipped with forklift interface and lighter
- Front maintenance legs can be avoided → handling too difficult in tight Port Cell
- Free available space: 620 x 820 x 1900 mm
- Possible to reach thermal shield top plate and first and second circle of internal piping





Timeline of the project



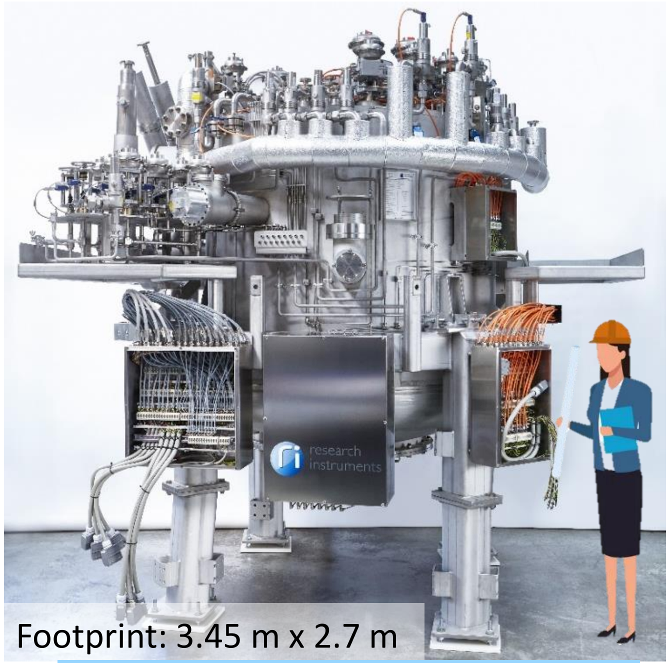
Summary of project and collaboration

- Successful design, manufacturing and delivery of
  - 8 Torus and Cryostat Cold valve Boxes and
  - 1 warm regeneration box for ITER

- What this particularly means:
  - ~9000 welds with ~2800 x-rays per CVB
  - ~ 500 m² of MLI
  - ~800 design and manufacturing documents
  - ~5400 m of cable
  - ~2000 m pneumatic tubing

- Colse and trustful collaboration with F4E/ITER:
  - Knowledge and guidance of F4E/ITER during design phase extremely helpful – we learned from them
  - Trustful cooperation during all project phases key for success
  - Experience of RI and our industrial partner Cryoworld in view of manufacturability and during the manufacturing phase – they learned from us

- Next step: Manufacturing of 3 Neutral Beam Cold Valve Boxes (ongoing)



Footprint: 3.45 m x 2.7 m

We are now ready for design and production of valve boxes for other (commercial) fusion plants

Technology transfer of superconducting RF cryomodules from research laboratories to industry

Superconducting 500 MHz cryomodules

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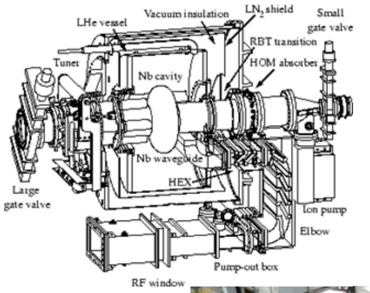
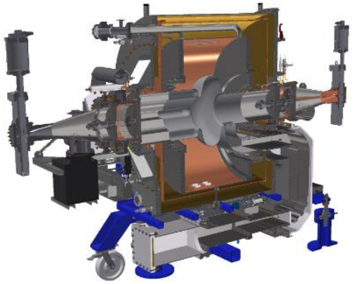
Physics design: Cornell University, USA

- 1999: Taiwan laboratory NSRRC plans upgrade of their Light Source with superconducting 500 MHz cryomodules
- Cornell had designed and built already 4 such 500 MHz cryomodules and operated them in CESR
- RI (ACCEL) offered NSRRC 2 such 500 MHz cryomodules through a technology transfer contract with Cornell
- RI modified the cryomodule design in view of better manufacturability
- Various worldwide customers ordered up to today additional 500 MHz cryomodules making this technology transfer to a big success for Cornell and RI

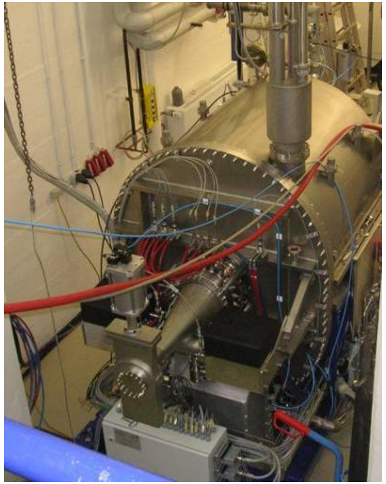




In total 20 SRF modules for various worldwide customers produced (Taiwan, Cornell, Canada, Diamond GB, Shanghai, Pohang Korea, Sirius Brazil)

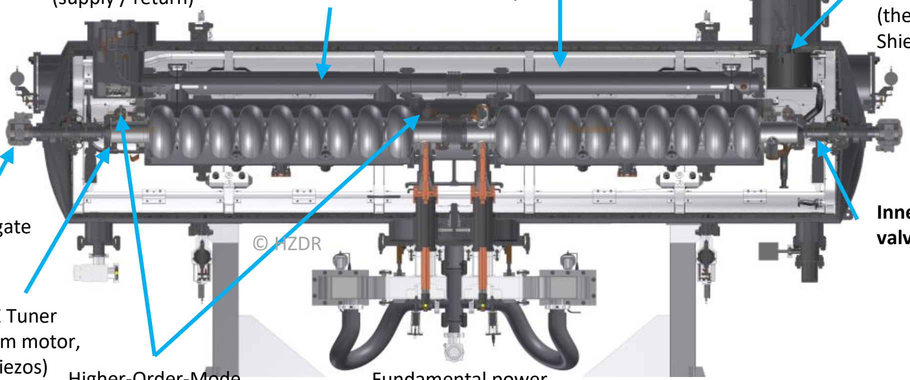
System includes cryogenic valve boxes and transfer lines, control electronics, installation and on site commissioning

FAT, installation and commissioning



Superconducting RF module

1.3 GHz Rossendorf (HZDR) cryomodule based on XFEL/ILC technology



2 SRF modules	for Daresbury,	Great Britain
2 SRF modules	for Ankara,	Turkey
2 SRF modules	for Mainz,	Germany
4 SRF modules	for Polfel,	Poland

Cryomodule design evolution and improvement

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<table>
<tr><th>Project</th><th>Original design</th><th>Turkey modules</th><th>Mainz modules</th><th>POLFEL modules</th></tr>
<tr><td>Cavity treatment</td><td>BCP & HPR</td><td colspan="2">EP / 800 °C / HPR (E-XFEL recipe)</td><td>EP / 900 °C / HPR</td></tr>
<tr><td>FPC</td><td colspan="3">ELBE (fixed Q_{Ext})</td><td>TTF-III (variable Q_{Ext})</td></tr>
<tr><td>Tuner</td><td>ELBE tuner
(lever arms, warm motor)</td><td>ELBE tuner
with Piezos added</td><td colspan="2">E-XFEL (cold SM, piezos)</td></tr>
<tr><td>HOM pickups</td><td>AlO2-ceramic</td><td>Sapphire
with cooling braids</td><td colspan="2">Sapphire with improved cooling braids</td></tr>
<tr><td>Inner magnetic shield</td><td colspan="3">Not installed</td><td>Cryoperm equivalent</td></tr>
<tr><td>Thermal shield</td><td>Aluminum skelleton
LN2 reservoir</td><td colspan="2">Aluminum (improved welding)
LN2 reservoir</td><td>Copper
GHe flow</td></tr>
<tr><td>Gate valves</td><td>Inner only</td><td colspan="2">Inner & outer</td><td>Outer only (string contains VV flange)</td></tr>
<tr><td>Vacuum vessel</td><td>Closed end caps</td><td colspan="2">End caps with maintenance flanges (tuner)</td><td>End flanges
Side flanges (tuner)</td></tr>
<tr><td>Cryo Interface</td><td colspan="2">He-port / N2-port</td><td>Heat exchanger /JT
Improved LN2 supply</td><td>Multi-Channel-Transfer-line port</td></tr>
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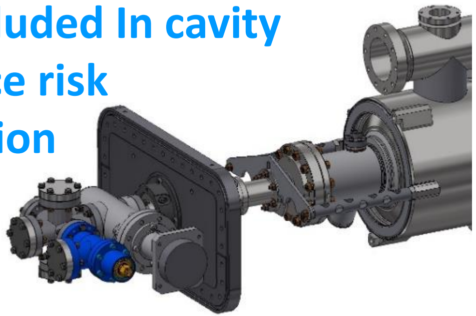
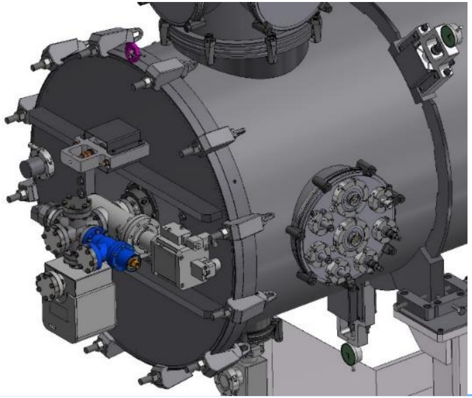
Most important performance improvements

Gate valve included In cavity string to reduce risk of contamination When leaving cleanroom

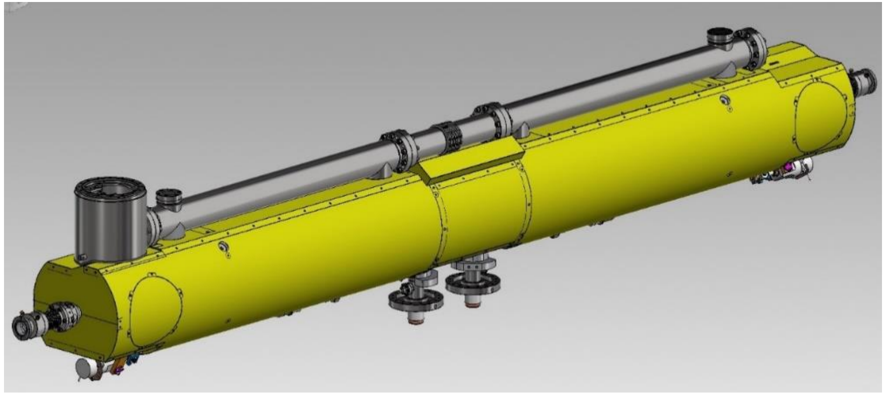


Cavity vacuum is sealed in clean room and not opened again during following cryomodule assembly



Inner magnetic shield for better cavity Q

- CP-EXP-1184 (AdVance Magnetics)
- Wall thickness: 0,5 mm
- Mounted with sliding joints (thermal contraction)



Cryomodule assembly (POLFEL)

Cavity string leaving the cleanroom

Cold mass on assembly jig

Cold mass being equipped with magnetic & thermal shield

Parallel work on different modules in the assembly area

Cryomodule modifications have been proven to optimize the cryomodule for future FEL applications

Cold mass insertion

Next step: 1.3 GHz Nb_3Sn SRF cryomodule

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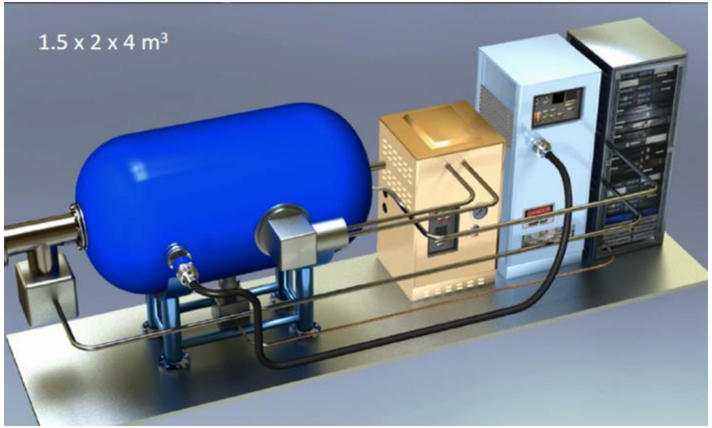
Features of the cryomodule

- Operates at 4.5 K
- Cooled by conduction through cryocoolers (no cryoplant needed)
- 10-40 MeV electrons, 5-10 mA
- 100+ kW beam power
- Various industrial applications possible (sterilization, water treatment, isotope production, ...)



Concept study compact cryogen free SRF accelerator for various use

- Reliable coating of cavity for high performance operation still challenging
- Input coupler for transmission of high RF power needed

- Possible collaboration between laboratory and RI: coating and testing of cavity, remaining manufacturing, installation and commissioning

- **Needed: pilot customer**

Thank you