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Status of the turbine concept for relativistic electron coolers

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Presenting work by I. Alexander, J. Dietrich, A. Hofmann, E. Riehn (HIM)

and Group of V.V. Parkhomchuk, V. Reva at BINP

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Outline

- **Introduction : Accelerator research at HIM**
- **Turbine operation**
- **BINP/HIM Prototype**
- **Near and far future extension plans**

Introduction: What is HIM ?

- **A joint venture between University Mainz & GSI**
- **Founded 2009…**
- **Scientific focus: Physics which can be performed at GSI& FAIR**
- **HIM-Sections: (1) Hadron-spectroscopy, (2)Hadron-structure (PANDA) (3)Theory (e.g. lattice QCD) (4,5)Super-Heavy Elements (two sections: chemistry&physics) (6)Matter & Antimatter**
- **And last but not least: (7)Accelerators and integrated detectors**

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Accelerator research at HIM

Objectives of HIM-section Accelerators and integrated detectors (ACID) (est. 2009)

1. **FAIR: HESR-Cooler support: Beyond 2MV:→4-8MV**
2. **Provide accelerator solutions for SHE research by GSI and JGU groups: low beta SRF ion accelerator cavities**

Mission…

- ACID cooler group does R&D on small, well defined aspects related to the design of relativistic magnetized coolers
- Such small scale research is well adapted to the possibilities of HIM (somewhat in between university research and „big science“)
- Ongoing projects: turbines as power generators for higher voltages >2MV (Poster by I. Alexander)
- Test set-ups for collector optimization & control , non invasive beam diagnostics (Poster by Th. Beiser)

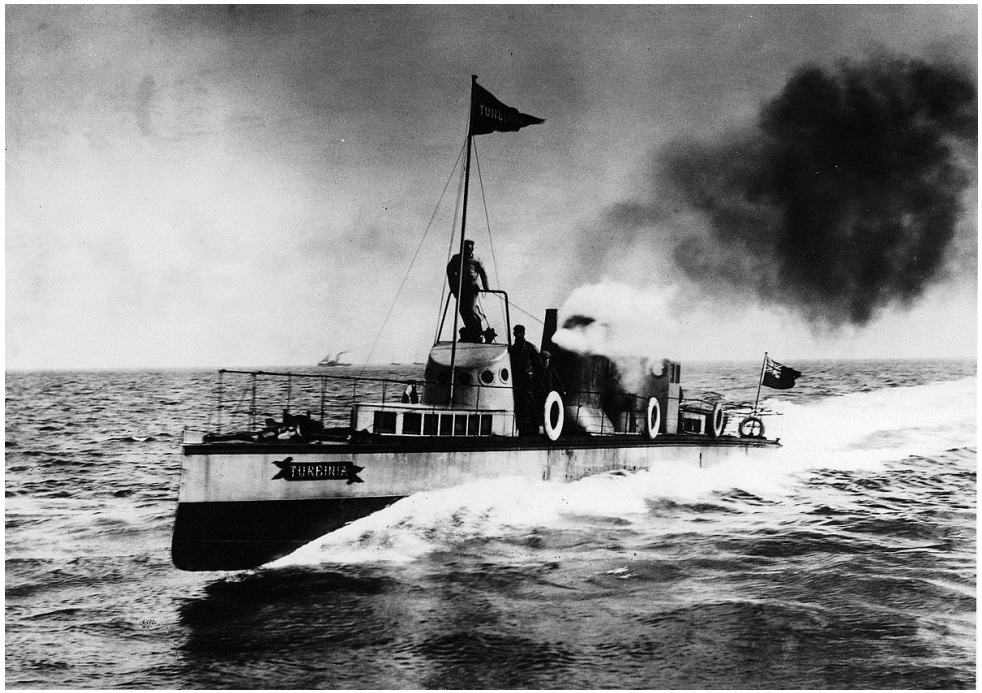
HESR Relativistic cooler - details to be covered

How to power solenoid channel & terminal ?

- More cooling power needed due to stronger beam/target interaction
  → Magnetization of beam required!
- Powering of continuous solenoid channel in d.c. acceleration stage
- Powering of terminal – electronics, source/collector
- Power requirement 50kW or more for supply floating at U>2MV

Conventional solutions: transformer/insulating shaft: May become cumbersome or even unfeasible under these conditions

Turbines (?) !



First Steam-Turbine driven ship
Charles Parsons –Turbinia (1897)
Source: Wikipedia

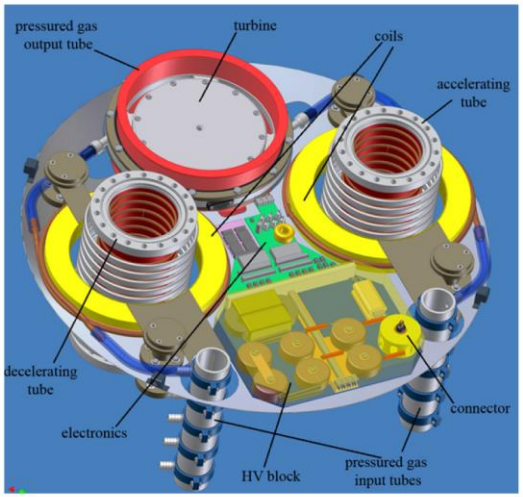
- Use of “turbogenerators” (gas/steam turbine + electrical generator?)

The turbine approach

Solenoids must be powered by floating power supply (e.g. isolated turbogenerator)

- **Not realized** for Jülich 2MV-cooler…
- 19th century technology – but still requires mechanical systems engineering &quality control

→ commercial product should be reliable



First idea for Jülich Cooler ~600 W Turbogen. Powering 60kV + solenoids

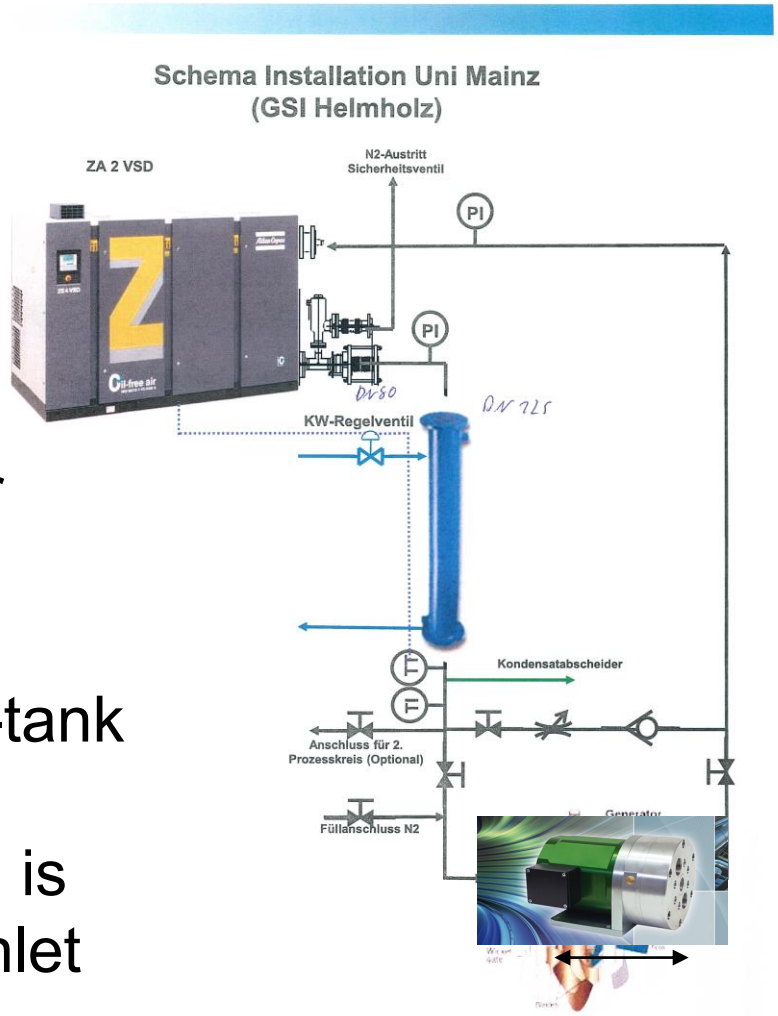
~40cm

5kW Turbogenerators (company: DEPRAG, product name „green energy turbine“) have been purchased

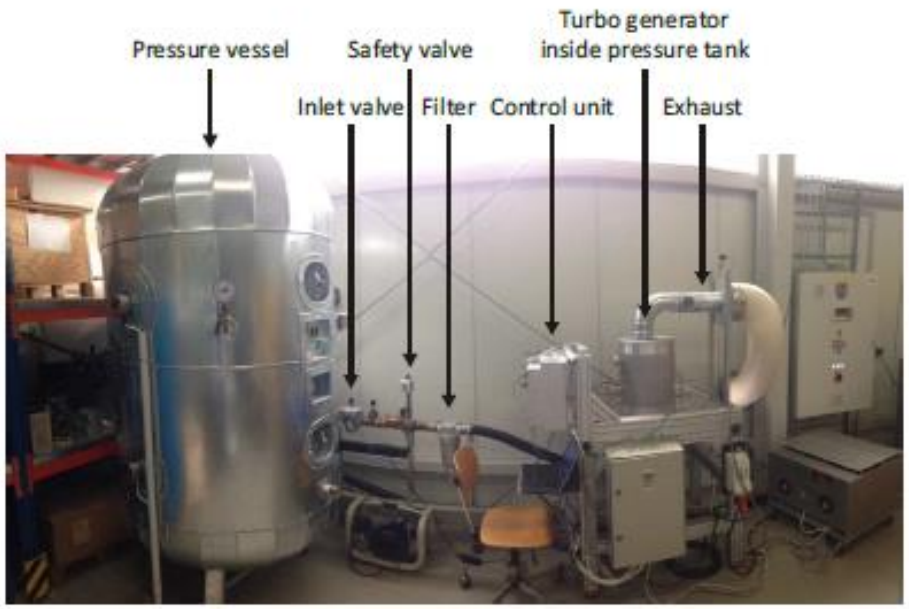
- **Ball bearings (2014)**
- **Gas bearings (2017)**

The turbine approach

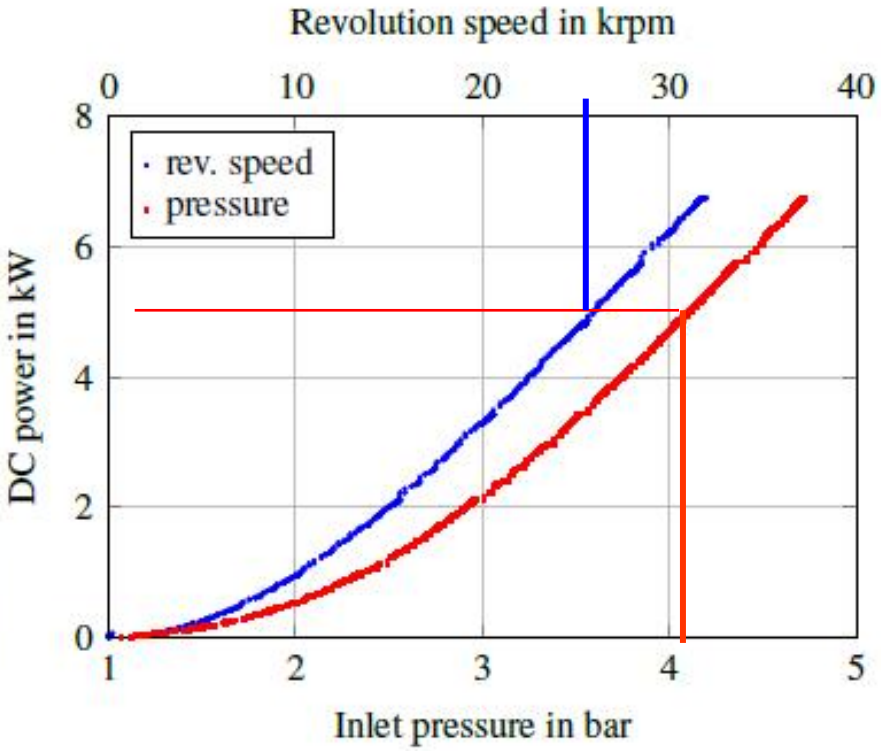
- standard screw compressor generates pressurized medium (dry air or others)
- Guided into pressurized HV-tank (insulating pipes in tank)
- Gas expands in turbine and is redirected to compressor inlet



Test set –up for long term operation at HIM/Mainz



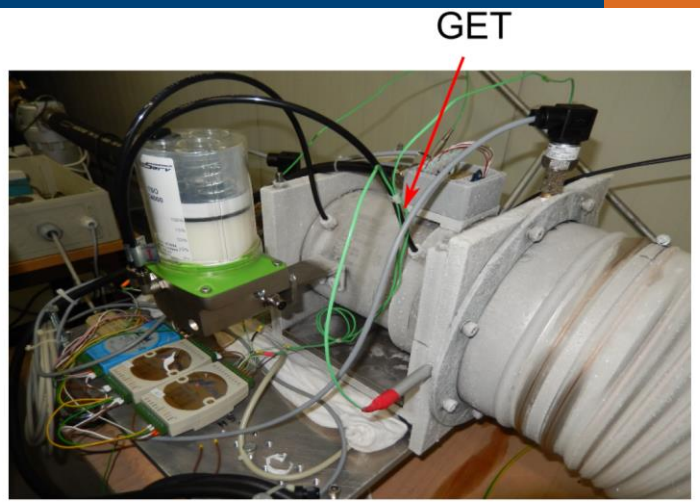
(Compressor not visible)



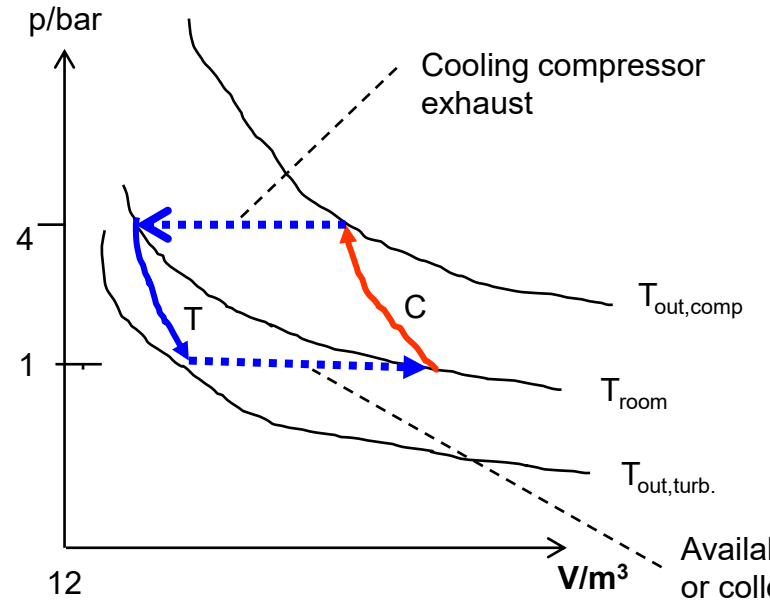
Test Results

- Turbine operated > 1000 hours without failure or relevant wear of bearing at 5kW
- Lubrication of bearings is needed, but minimal (remotely controlled, <0.1 cm^3 once in 1000 hours)
- test of turbine (& lubrication unit) in 10 bar pressurized vessel successful
- Turbine with gas bearings delivered in summer 2017, test pending

Thermal considerations



GET after operation($T_{air,out} = -31\,°C$)



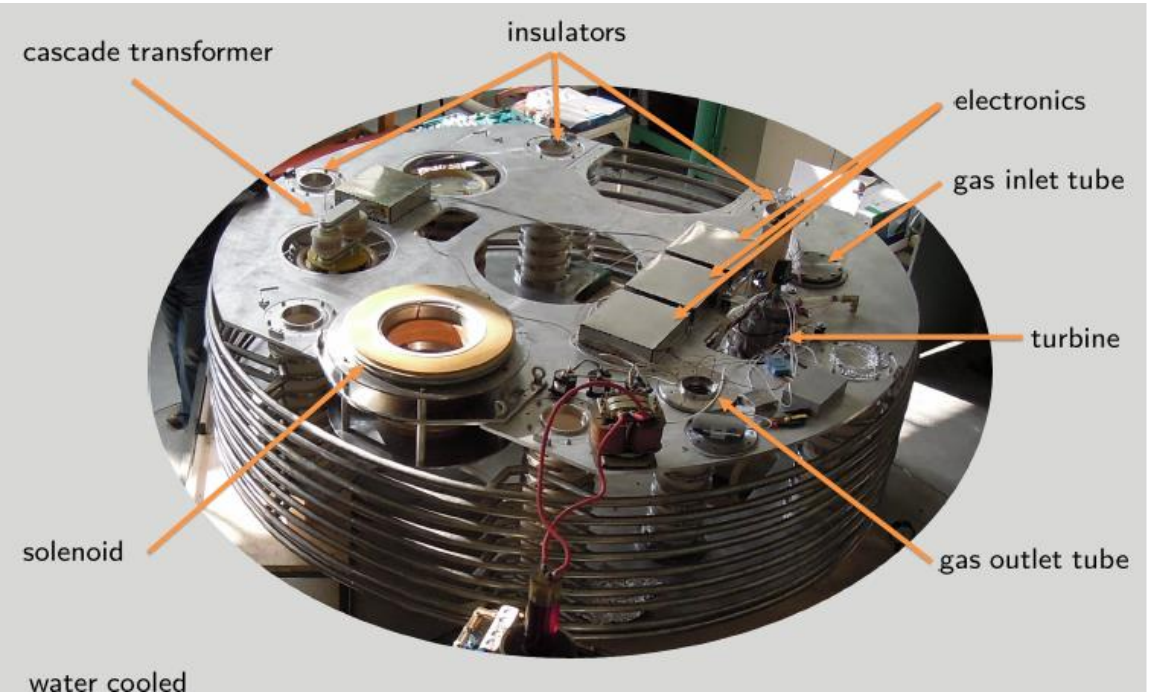
- Cooling of compressed gas reduces efficiency.
- But then, exhaust gas is also cooled due to adiabatic expansion which helps dealing with heat generated by loads inside HV-tank
- Estimated efficiency: 5kW floating power from 30kW (wall plug)
- Compressor wall plug requirement for 8MV HESR cooler would be large (~500kW), but not impractical

HIM- BINP-cooperation

- BINP/HIM contract for fabrication of „prototype“ module
- 5kW turbogenerator integrated into prototype
- turbine powers solenoid on terminal and 600kV d.c. Power supply
- delivery planned spring 2018
- Tests foreseen in HIM experimental hall - Module in pressure vessel (dry air or nitrogen as fluid and insulation gas)

Space for module in pressure vessel

Module status



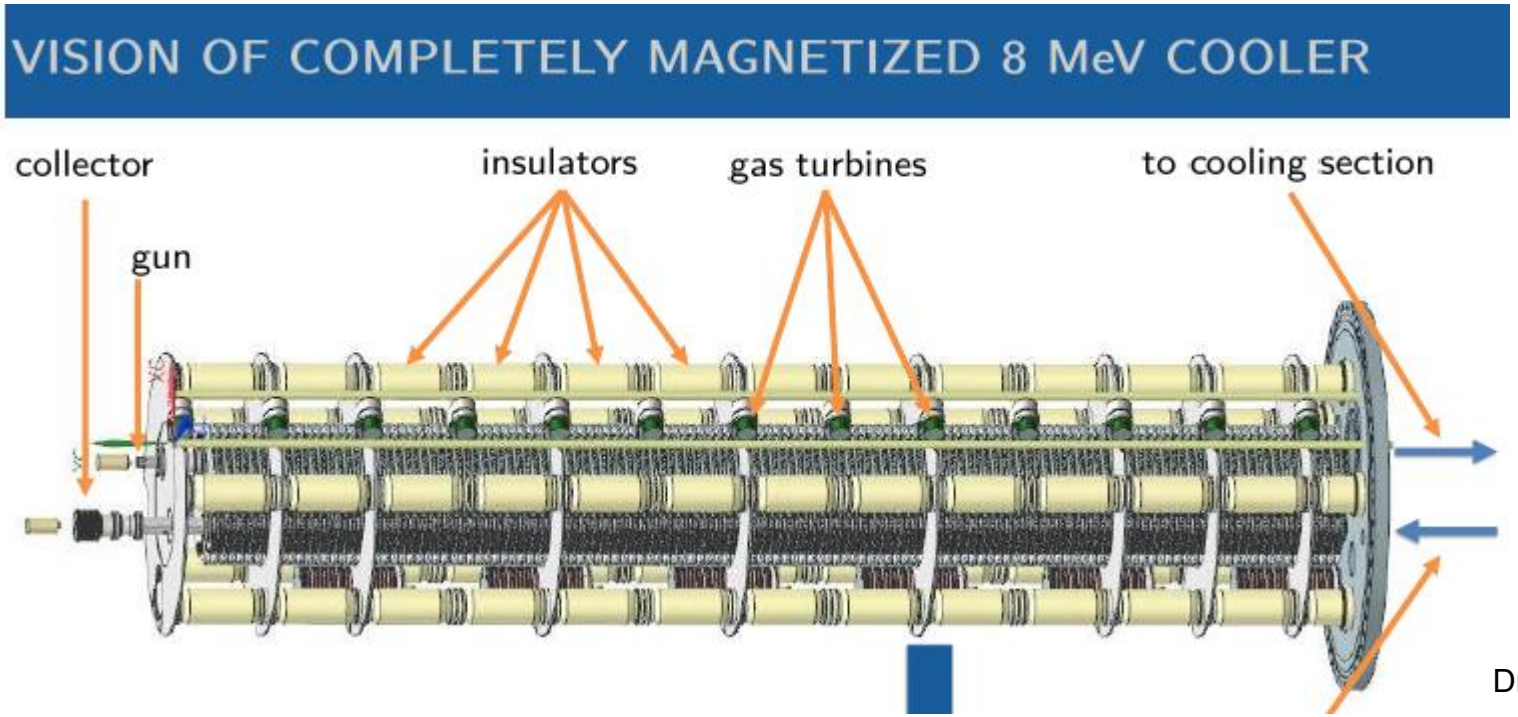
~3m

- Operated at 100kV in air
- Final assembly and testing without pressure vessel at BINP
- pressure vessel under design at HIM
- Installation and system test planned at HIM spring in 2018

Near (and far) future extension plans

Near (and far) future extension plans

The 600kV device should be scalable…

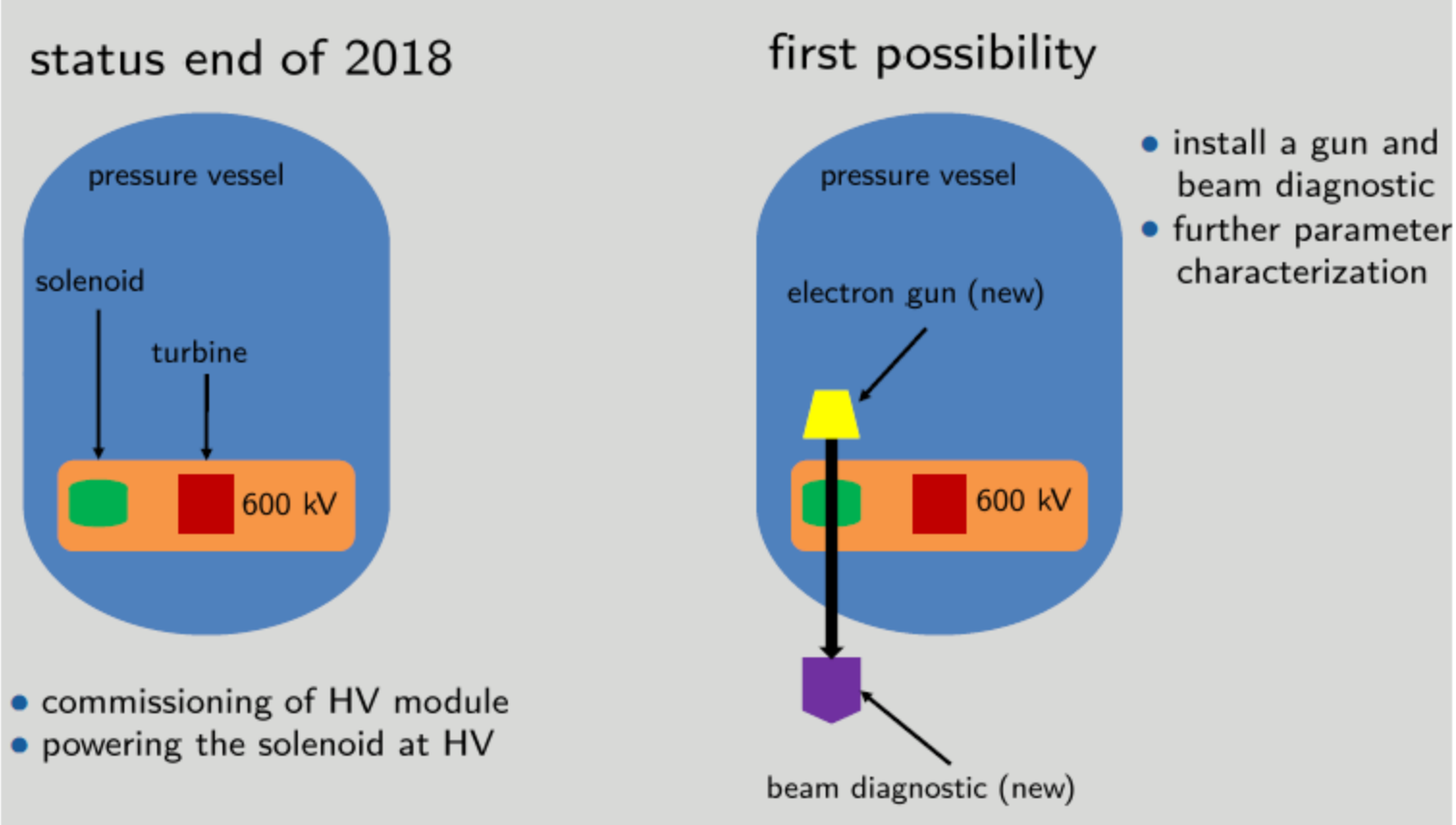


Drawing: V. Reva

..but reliable electron beam operation should be demonstrated first…

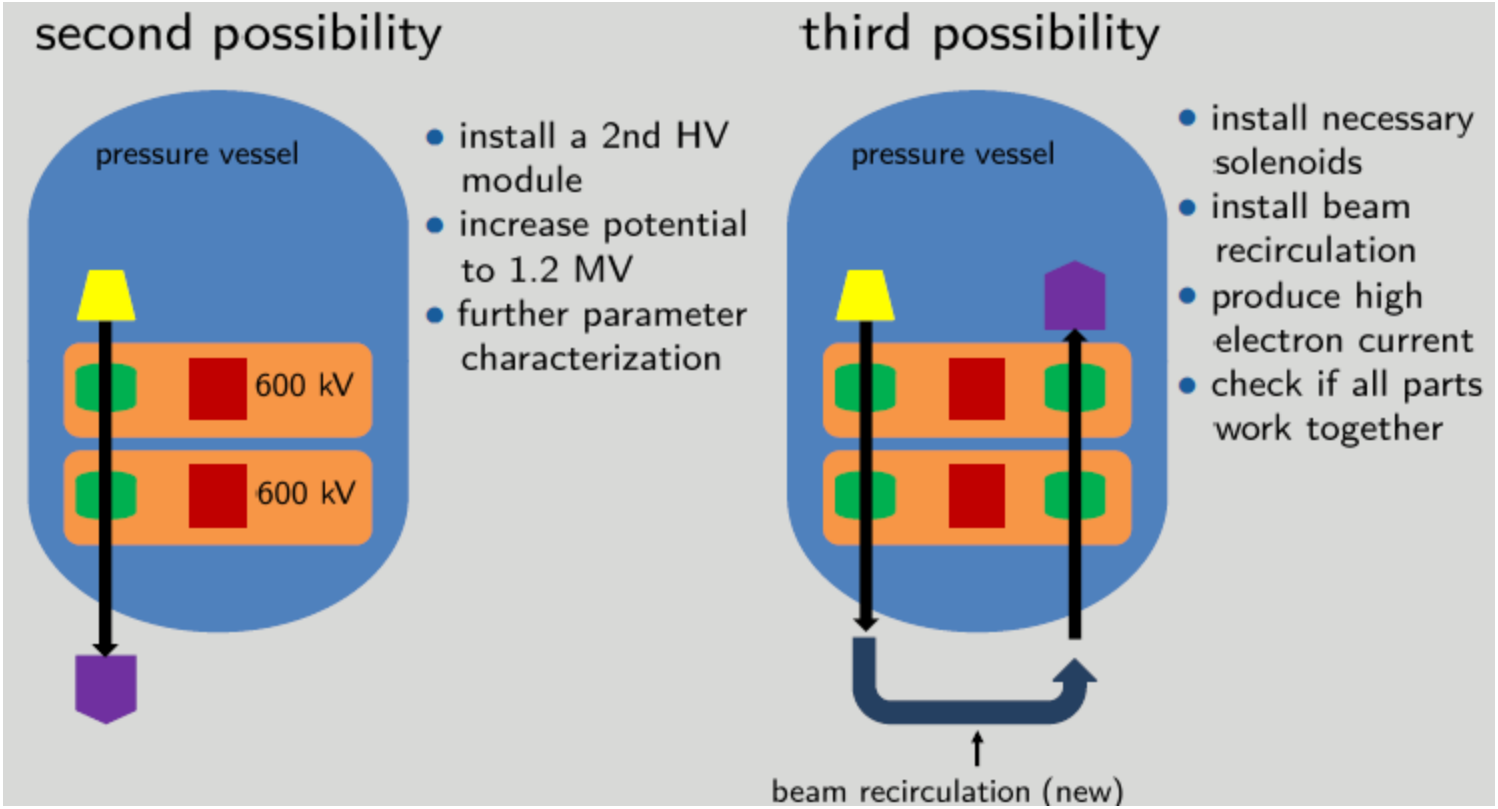
What can be done within the given limitations ?

Near (and far) future extension plans



I. Alexander

Near (and far) future extension plans



Conclusion

- Turbines are qualified as floating power generator for electron coolers
- BINP produces turbine driven HV-Generator for 600 kV+ several kW of power on terminal
- Extensive testing at HIM planned beginning 2018
- Extension towards real electron beam operation will follow
- Qualified system will be scalable towards HESR energies

Thank you!