EnEfficient – sustainable and energy efficient technologies

M.Seidel, PSI

network related to:

efficient and cost effective utilization of electrical power in accelerator based research facilities

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Motivation for EnEfficient

- worldwide scarcity of resources and climate change also impacts research facilities and is of great political importance; energy cost is rising and becomes a critical factor
- next generation accelerator facilities provide a new quality of research opportunities, but often connected with a new quality of energy consumption as well **(EuroXFEL, FAIR, ESS, LHeC, TLEP, ILC, CLIC, Project-X …)**

→ wee need to intensify our efforts to optimize the efficiency of accelerator systems

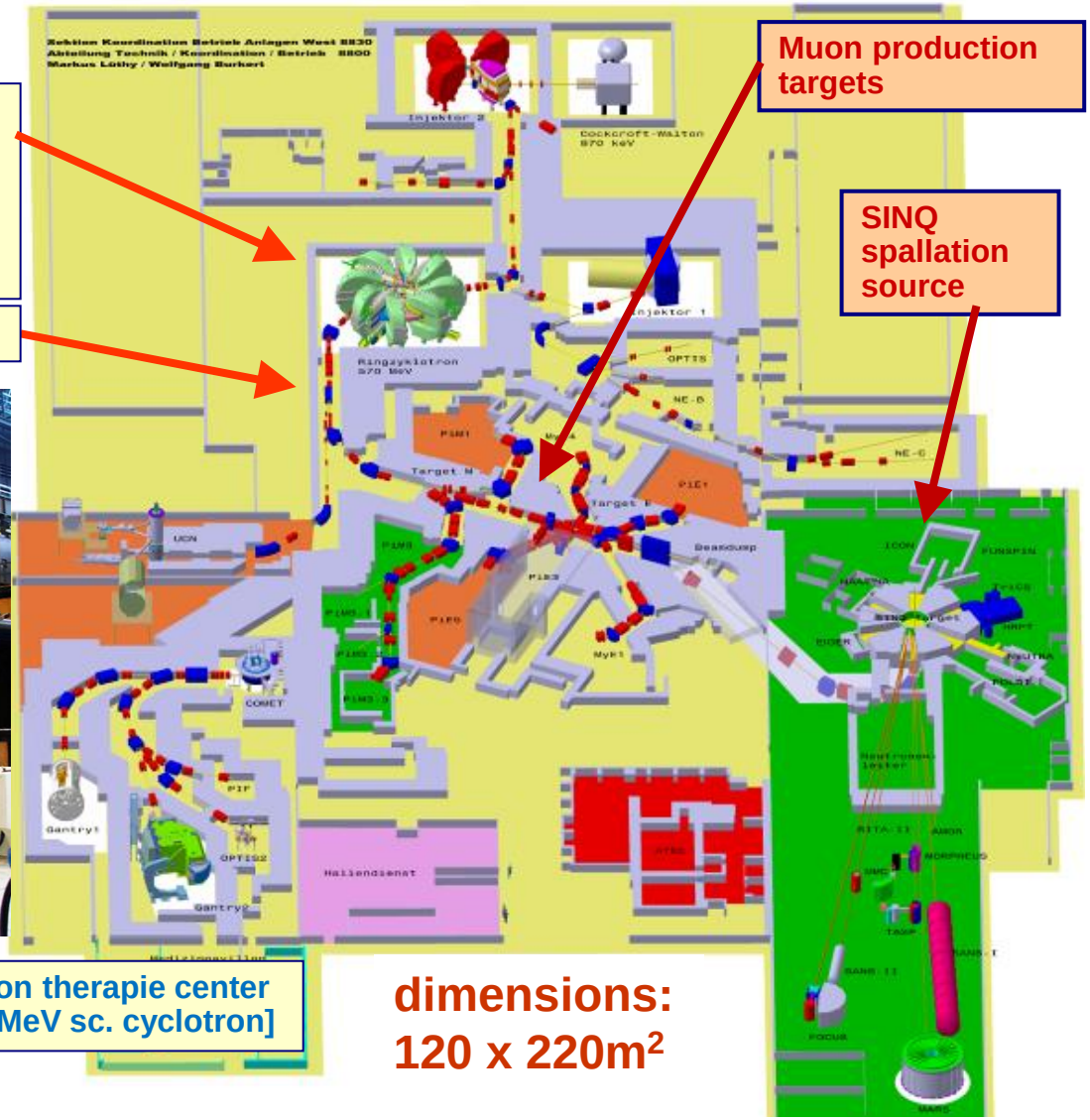
EuCARD² Example: PSI Facility, 10MW

Ring Cyclotron 590 MeV
loss ≈ 10^{-4}

Power transfer through
4 amplifier chains
4 resonators 50MHz

2.2 mA /1.3 MW

50MHz resonator



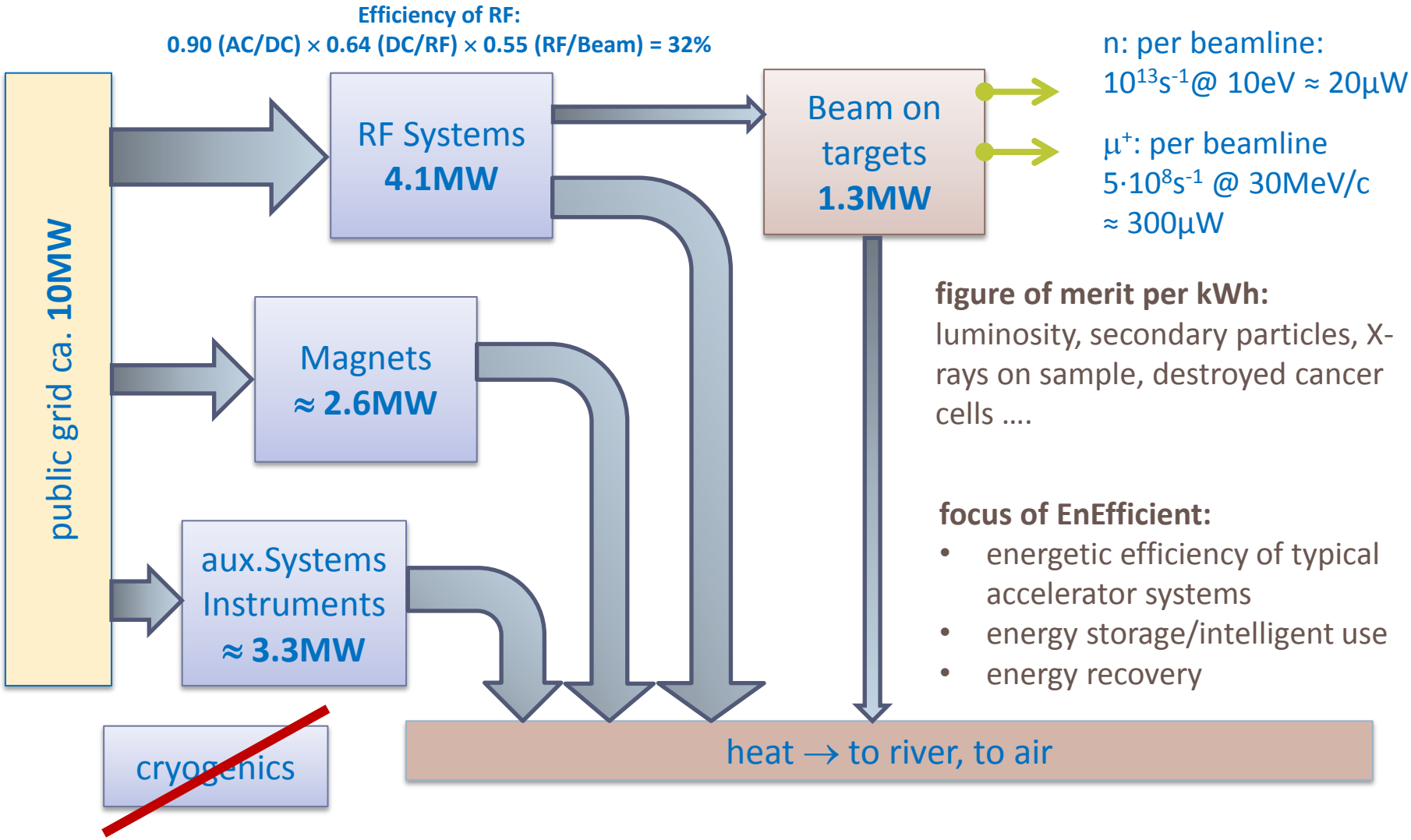
Muon production targets

SINQ spallation source

proton therapie center
[250MeV sc. cyclotron]

dimensions:
120 x 220m²

Example: PSI-HIPA Powerflow



task 1: energy recovery from cooling circuits

- led by Thomas Parker (ESS)
- in any large facility most power is converted finally to heat; this power should be utilized as best as possible
- for best recovery the temperature level of cooling circuits must be high

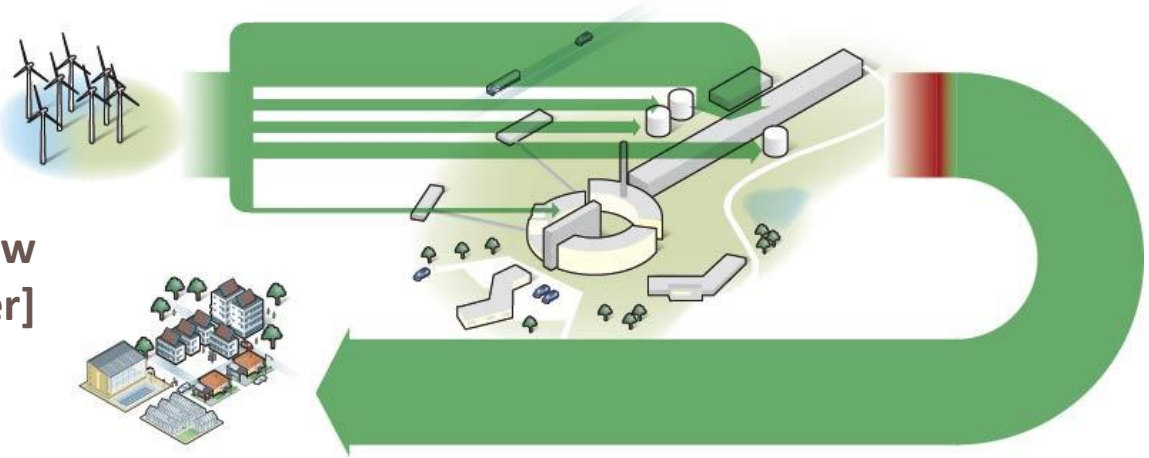
→ discuss the potential/inventory of different facilities, temperature levels and best recovery technologies

→ concerning temperature level – which compromises are acceptable?

task 1: energy recovery from cooling circuits

the European Spallation Source (ESS) in Lund is based on a high power accelerator (5MW)

→ heat recovery methods are planned in from the beginning



ESS power flow [Th.Parker]

task 2: higher electronic efficiency RF power generation

- led by Erk Jensen (CERN)
- for accelerators with high beam power the conversion efficiency from grid to beam is of utmost importance, e.g. ESS, ILC, CLIC, LHeC

→ study efficiency of conventional power sources: klystron, sheet- and multi-beam; also power distribution schemes

→ new devices and concepts, e.g.: multi-beam IOT's with solid state driver; magnetrons with better stability; RF aspects of energy recovery linac for LHeC with 400MW beam power

→ direct recovery of electrical energy from spent RF

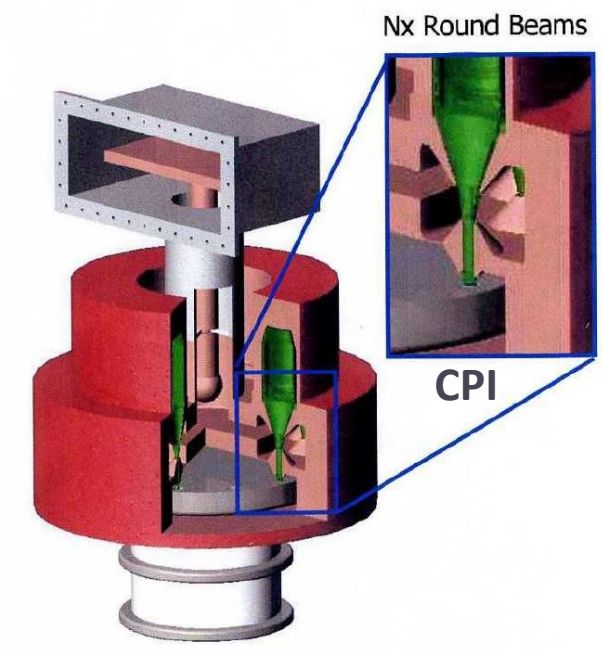
task 2: higher electronic efficiency RF power generation

- IOT's can reach higher efficiency (theoretical 78%) than klystrons and have advantages with regulation behavior
- however, today the max. power is insufficient

→ multi-beam IOT's could provide sufficient power while keeping the advantages

example: study of multi-beam IOT by company CPI

RF Power: 1 MW
frequency range: 650-750 MHz



task 3: short term energy storage systems

- led by Michael Sander (KIT)
- short interruptions of the grid may lead to significant downtimes of large accelerator facilities
- many accelerators operate in cycles / pulsed mode, i.e. their power draw from the grid varies

→ energy storage systems for varying duration and capacity are needed to bridge interruptions and to smooth the power draw from the grid

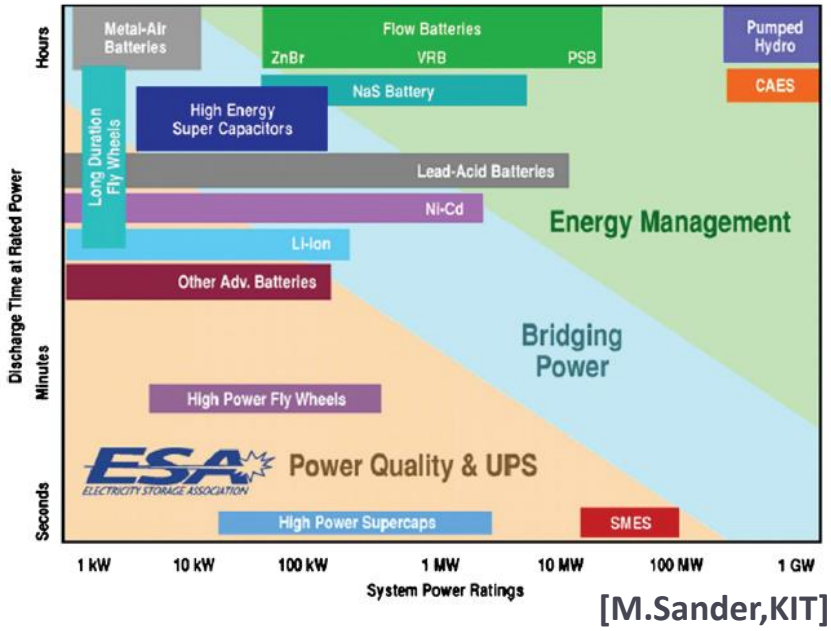
→ goal is to investigate the spectrum of technical solutions for energy storage and to assess their applicability for accelerators; synergies with renewable energies

task 3: short term energy storage systems

comparison of different state-of-the-art energy storage systems (courtesy: ESA)

storage systems include:

- Super- or Ultra-Capacitors
- Superconducting Magnetic Energy Storage (SMES)
- Rechargeable Batteries (e.g. Lead or Lithium Ion Batteries)
- Flywheel Energy Storage



[M.Sander,KIT]

LIQHYSMES is a combination of a superconducting energy storage coil for quick power release, then overtaken by a gas turbine or fuel cells operating with liquid H_2 storage

task 4: virtual power plant

- led by J.Stadlmann (GSI)
- flexibility of the power consumer can save cost and becomes more relevant with increasing contribution of renewable power sources to the grid

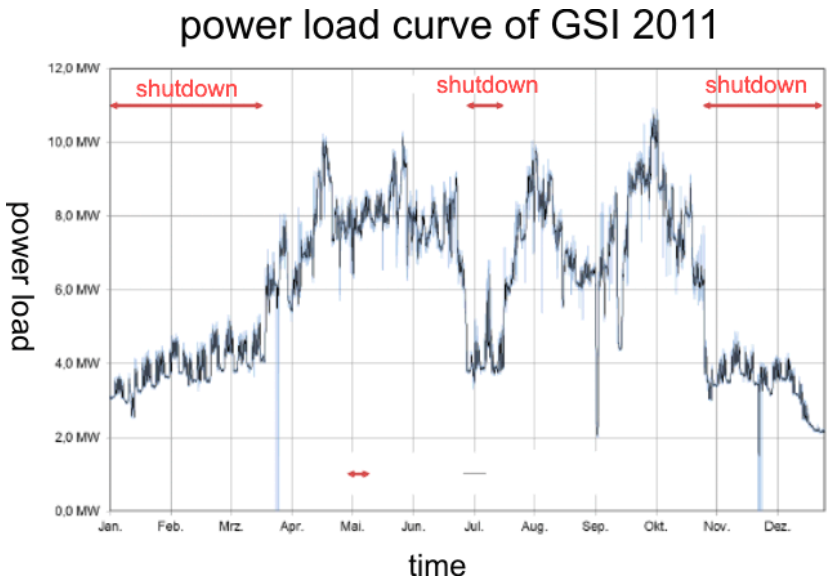
→ explore options to temporarily reduce power consumption in accelerator facilities, for example not refilling a storage ring, depending on supply situation

→ operation modes, automated information exchange with supplier, intelligent control system, potential cost savings per kWh

task 4: virtual power plant

power load example of GSI in 2011, demonstrating the strongly varying load, depending on accelerator status

detailed analysis and coordination of the different consumers in a complex accelerator facility could provide a more even power load and better adaptation to the situation in the grid



[J.Stadlmann, GSI]

task 5: beam transfer channels with low power consumption

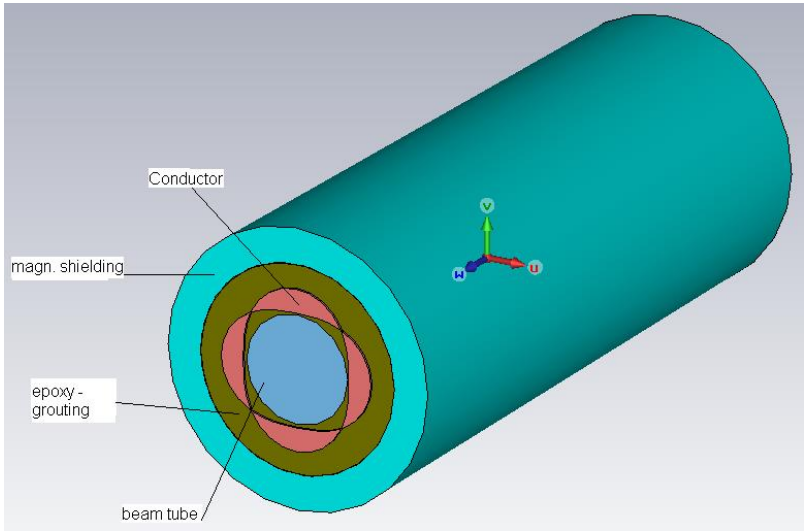
- led by P.Spiller (GSI)
- beam transfer channels using conventional dipole/quadrupole magnets have significant power consumption

→ perform comparative study of alternative schemes using pulsed magnets, permanent magnets or s.c. magnets

→ aspects: power consumption, cost, energy reach, stability/reproducibility

task 5: beam transfer channels with low power consumption

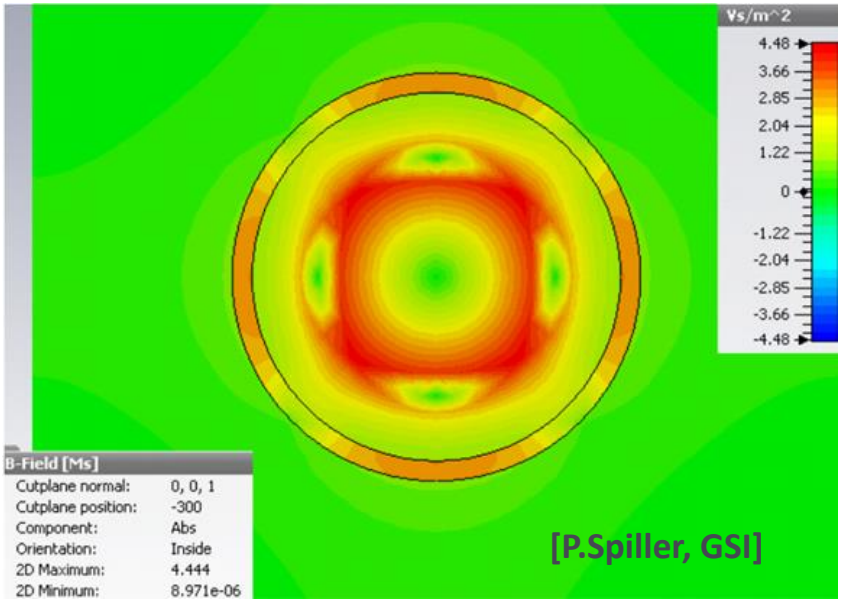
- **pulsed magnets**: for pulsed beams fields are needed only during passage of a beam, i.e. a small fraction of time



magnetic field simulation in CST* at a current peak of 400 kA (on the right)

previous work at GSI:

four conductors arrangements leading the high current pulse; epoxy resin for mechanical stability; laminated shielding of electromagnetic pulse



EnEfficient: summary and outlook

EnEfficient is a **new networking activity** related to efficient utilization of electrical power in accelerator based facilities

the aim is to hold workshops, evaluate present technology, identify areas with promising potential and to initiate development projects; findings and results will be documented

a selection of themes is organized in 5 tasks and will be discussed in a series of workshops; tomorrow first meeting!

at present participating institutes and interested partners: CERN, ESS, GSI, KIT, PSI, possibly CNRS Grenoble, DESY

interested colleagues are very welcome to participate in this network

information and contact under: www.psi.ch\enefficient