

Innovate for Sustainable Accelerating Systems (iSAS)

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Vrije Universiteit Brussel*



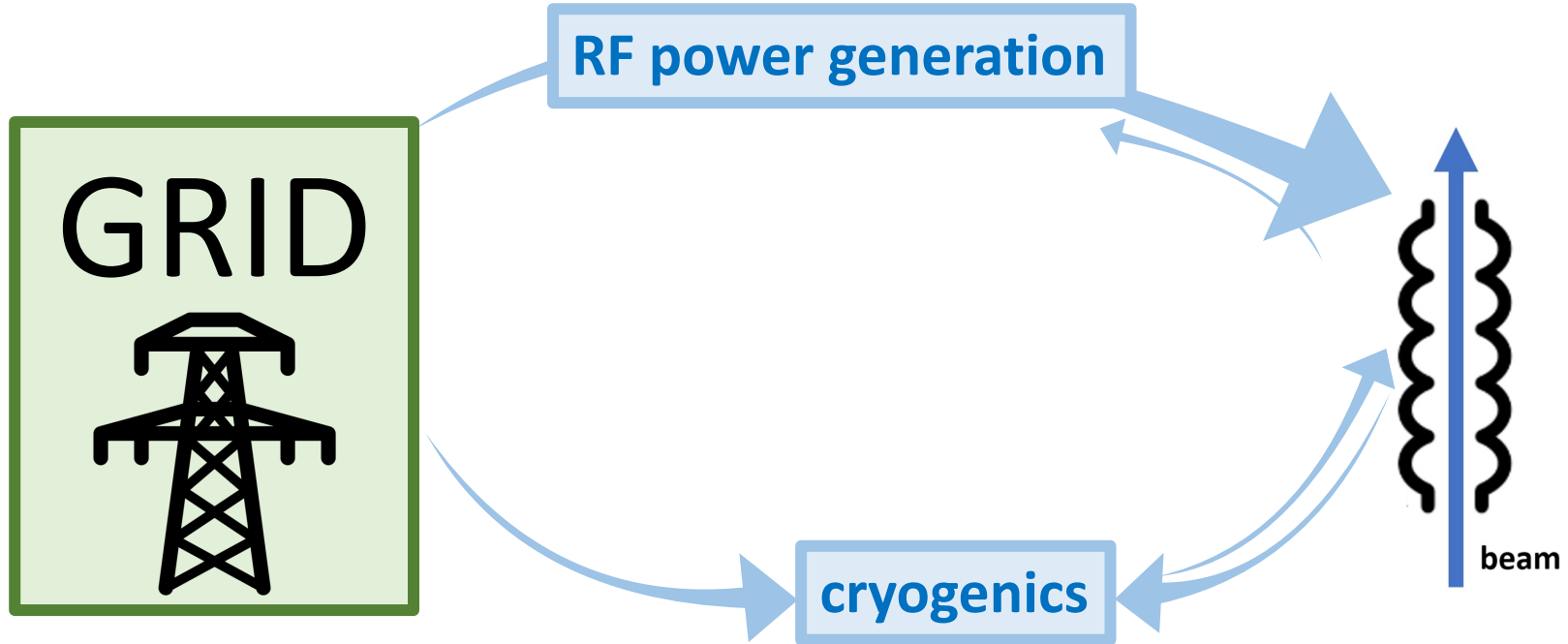
Sustainable Accelerating Systems, January 2023

The energy efficiency of present and future accelerators [...] is and should remain an area requiring constant attention.

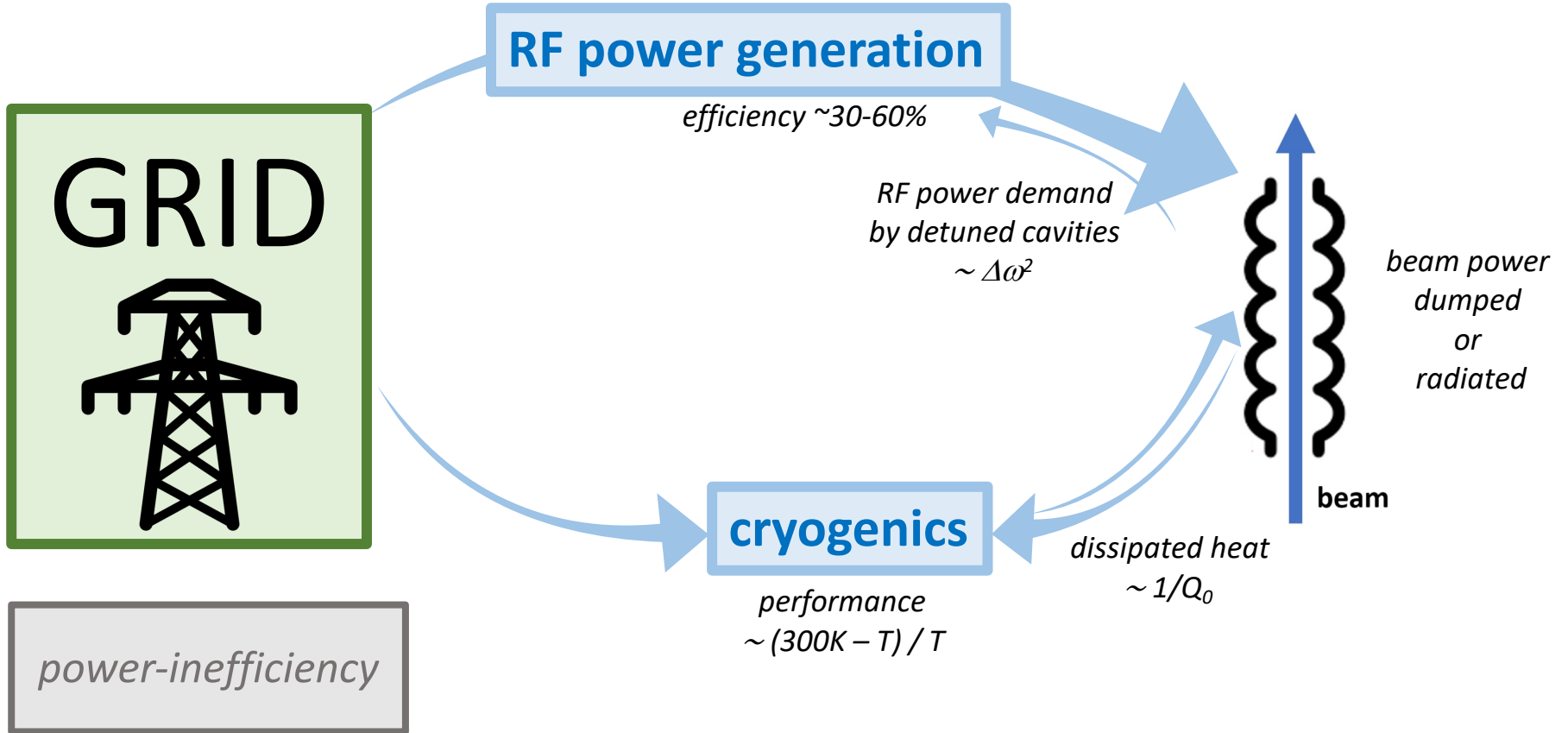
A detailed plan for the [...] saving and re-use of energy should be part of the approval process for any major project.

European Strategy for Particle Physics 2020

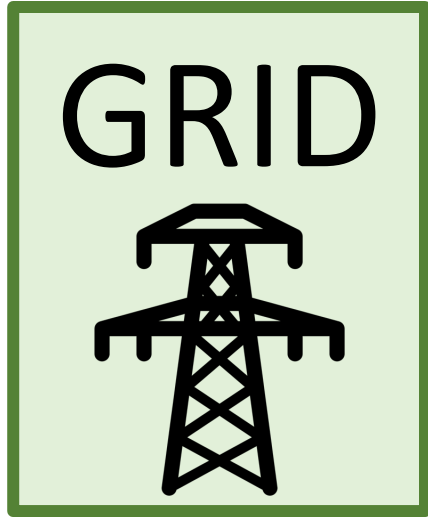
From Grid to Beam



From Grid to Beam



From Grid to Beam



mitigation with novel technologies

improve amplifier efficiency

e.g. solid state amplifiers for oscillating power demands

RF power generation

efficiency ~30-60%

*RF power demand
by detuned cavities
 $\sim \Delta\omega^2$*

dealing with microphonics

e.g. Fast Reactive Tuners

cryogenics

*performance
 $\sim (300K - T) / T$*

operate cavities at higher T & improve Q_0 of cavities

e.g. Nb_3Sn from 2K to 4.4K \rightarrow 3x less cooling power needed

recover the energy from the beam

*e.g. ERL reaching
100% recovery*



*beam power
dumped
or
radiated*

*dissipated heat
 $\sim 1/Q_0$*

From Grid to Beam

improve amplifier efficiency

e.g. solid state amplifiers for oscillators

Accelerating particles will always require a large amount of energy, hence achieving a minimal energy consumption is our unavoidable challenge and duty

**Thought for an overall R&D programme for
“Sustainable Accelerating Systems”**

less energy, less cooling, less power loss, recover beam power

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 $\sim (300\text{K} - T) / T$

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less energy, less cooling, less power loss, recover beam power

ALARA = As Low As Reasonable Achievable
*principle enforced for nuclear safety,
also for energy consumption ?*

operate

e.g. Nb_3Sn from 2K to 4.4K → 3x less cooling power needed

from the European Accelerator R&D Roadmap programme
together engaged into a concrete R&D project

consortium proposal

**“Innovate for Sustainable Accelerating Systems”
(iSAS)**

“Innovate for Sustainable Accelerating Systems”

HORIZON-INFRA-2023-TECH-01-01

New technologies and solutions for reducing the environmental and climate footprint of RIs

REGULATIONS

• Specific conditions

- *Expected EU contribution per project: around 5M EUR.*
- *Consortia must include at least 3 different research infrastructures, each of them being an ESFRI infrastructure, and/or a European Research Infrastructures Consortium (ERIC) or another research infrastructure of European interest (i.e. a research infrastructure which is able to attract users from EU or associated countries other than the country where the infrastructure is located). Consortia should be built around a leading core of at least 3 world-class research infrastructures and can include a wider set of RIs.*
- *Other technological partners, including industry and SMEs, should also be involved, thus promoting innovation and knowledge sharing through co-development of new technical solutions for research infrastructures.*
- *Proposals should built on and explain any synergies and complementarities with previous or current EU grants, including those under other parts of the Framework Programmes.*

• Expected Outcome

- *Reduction of environmental impacts (including climate-related)*
- *Optimisation of resource and energy consumption integrated through the full life cycle of research infrastructures*
- *Increased long-term sustainability of European research infrastructures*

• Scope

- *The aim of this topic is to deliver innovative technologies and solutions which reduce the environmental and climate footprint of RIs through the full life cycle of research infrastructures. Proposals should identify common methodologies, among the concerned RIs, to assess environmental impact and strategies to reduce it, as well as efficiency gains in the broader ecosystem.*
- *Proposals should address the following aspects, as relevant:*
 - *new technologies and solutions for research infrastructures enabling transformative resource efficiency (e.g. energy consumption) and reduction of environmental (including climate-related) impacts, including, when relevant, more sustainable and efficient ways of collecting, processing and providing access to data;*
 - *validation and prototyping;*
 - *training of RI staff for the operation and use of the new solutions;*
 - *action plans to deploy the new developments at wider scale and ensure their sustainability;*
 - *measures to ensure an environmentally effective integration of the solutions in the local contexts;*
 - *societal engagement to foster acceptance of the solutions in the local and regional communities.*

“Innovate for Sustainable Accelerating Systems”

HORIZON-INFRA-2023-TECH-01-01

New technologies and solutions for reducing the environmental impact of research infrastructures

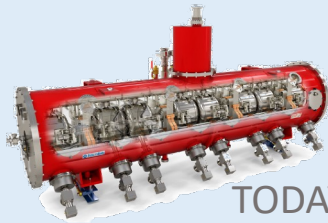
Specific conditions:

Create strong and broad impact with a ~~5M~~ 4M EUR excl overhead EU-project
develop an impactful and well-motivated project that is a catalyser for the implementation of the Accelerator R&D Roadmap

Goal: develop, prototype and validate the essential energy-saving and energy-recovery technologies required to integrate in the design of a novel sustainable LINAC cryomodule with a broad portfolio of applications in industry and at accelerator research infrastructures

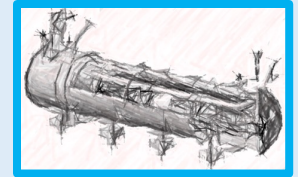
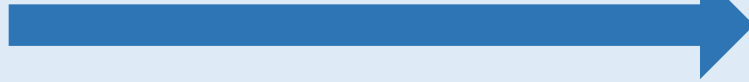
Sustain the impactful 20th-century accelerator applications into an energy-low 21st century!

- relevant:
- validation and prototyping;
 - training of RI staff for the operation and use of the new solutions;
 - action plans to deploy the new developments at wider scale and ensure their sustainability;
 - measures to ensure an environmentally effective integration of the solutions in the local contexts;
 - societal engagement to foster acceptance of the solutions in the local and regional communities.



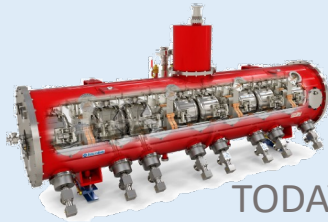
TODAY

**INNOVATE TECHNOLOGIES TOWARDS
A SUSTAINABLE ACCELERATING SYSTEM**



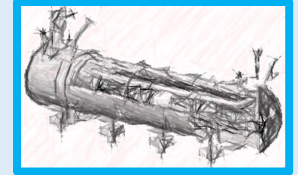
NEW DESIGN

**DEVELOP ENERGY-SAVING & ENERGY-RECOVERY
TECHNOLOGIES ESSENTIAL TO INTEGRATE IN THE
DESIGN OF A SUSTAINABLE LINAC CRYOMODULE**



TODAY

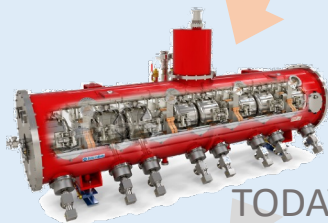
**INNOVATE TECHNOLOGIES TOWARDS
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NEW DESIGN

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High-performant SRF cavities

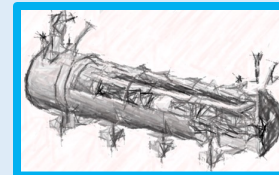
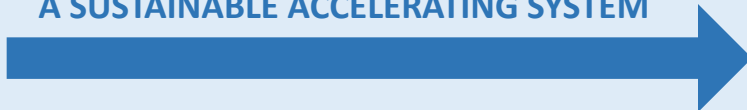


TODAY

Energy Recovery

Optimal use of RF power

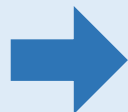
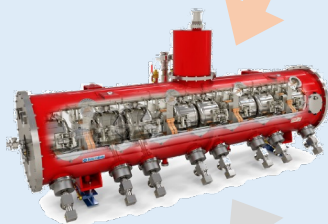
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High-performant SRF cavities



others others

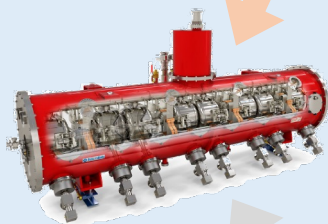
*R&D Pathfinders for new
energy-saving & energy-recovery technologies*

Optimal use of RF power

Energy Recovery

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High-performant SRF cavities

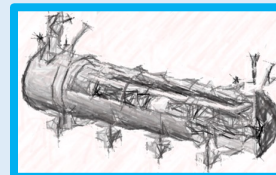


others others

R&D Pathfinders for new energy-saving & energy-recovery technologies

INTEGRATING

integrating new technologies in the design of a new sustainable LINAC cryomodule

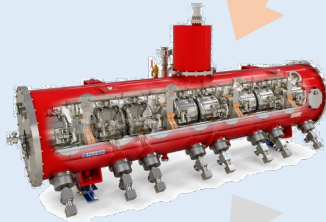


Optimal use of RF power

Energy Recovery

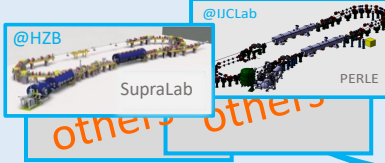
DEVELOP ENERGY-SAVING & ENERGY-RECOVERY TECHNOLOGIES ESSENTIAL TO INTEGRATE IN THE DESIGN OF A SUSTAINABLE LINAC CRYOMODULE

High-performant SRF cavities



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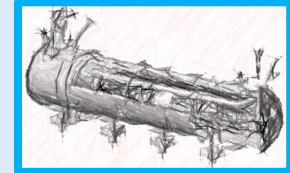
Energy Recovery



R&D Pathfinders for new energy-saving & energy-recovery technologies

INTEGRATING

integrating new technologies in the design of a new sustainable LINAC cryomodule

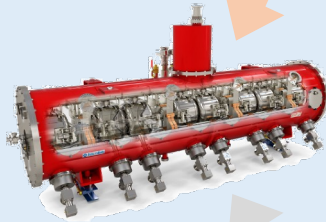


full deployment of energy saving & energy recovery in collider RIs

sustainable accelerator turn-key solutions with breakthrough applications

DEVELOP ENERGY-SAVING & ENERGY-RECOVERY TECHNOLOGIES ESSENTIAL TO INTEGRATE IN THE DESIGN OF A SUSTAINABLE LINAC CRYOMODULE

High-performant SRF cavities



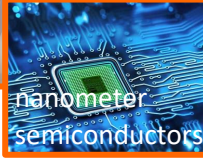
Optimal use of RF power

Energy Recovery

particle therapy



nanometer
semiconductors

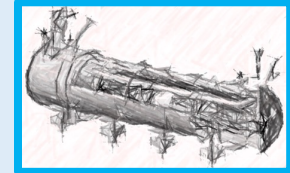


others others

R&D Pathfinders for new energy-saving & energy-recovery technologies

INTEGRATING

integrating new technologies in the design of a new sustainable LINAC cryomodule



SC FELS



ultimate LHC upgrade

L.H.C.

full exploitation LHC highest priority for HEP



ESS upgrade

others



@CERN

ERL Higgs Factory

100 KM LONG
next highest priority collider for HEP

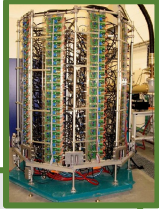
full deployment of energy saving & energy recovery in collider RIs

“Innovate for Sustainable Accelerating Systems”

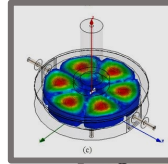
- **AMBITION** – Particle accelerators have become essential instruments to improve our health, environment, safety and high-tech abilities, as well as to unlock new fundamental insights in physics, chemistry, biology, and generally enable scientific breakthroughs that improve our lives. Accelerating particles to higher energies will always require a large amount of energy. In a society where energy sustainability is critical, keeping energy consumption as low as reasonable possible is an unavoidable challenge for both research infrastructures and industry, which collectively operate more than 30.000 accelerators. If you are part of the problem, you must be part of the solution. Accordingly, enhanced collaboration will broaden, expedite and amplify the development and impact of the novel solutions. For example, the annual operation of the next major particle physics collider could, in due time, require up to 4% of the annual energy consumption of a medium-sized European country. The objective of the project is to innovate and reinvent the key technologies of particle accelerating systems such as to minimize energy consumption for all particle accelerators, by developing both specific energy-saving technologies and energy-recovery technologies where energy cannot be saved. This represents a vital transition to sustain applications of the leading 20th century accelerator technology in the 21th century.
- **METHODOLOGY** – With a coherent collaboration between leading European research institutions and industry, several interconnected technologies will be developed, prototyped and tested, each enabling significant energy savings or energy recovery on their own in accelerating particles. Taking into account the developments realised at these unique R&D Pathfinder labs, the novel technologies will be coherently integrated into the design of a new accelerating system optimised for energy savings of the instrument itself and for final energy recovery of the energy given to the accelerated particle beam. The novel LINAC cryomodule will be designed with in mind a portfolio of forthcoming applications, including upgrades of existing research infrastructures. Timescales to innovate, prototype and test new accelerator technologies are understandably long. Therefore, it is essential to collaborate and to enhance the R&D process for energy-sustainable technologies so that they can be implemented without delay and avoiding hampering scientific and industrial progress enabled by accelerating systems.
- **IMPACT** – While several *energy-saving* technologies will be integrated into industrial turn-key solutions with short-term impact on current research infrastructures, this project is also the main pathfinder for the *energy-recovery* capability of future large particle colliders. Both energy-saving and energy-recovery technologies will therefore provide novel opportunities for breakthroughs in fundamental sciences, and in particular enable high-energy particle colliders to go beyond the current frontiers of energy and intensity in an energy-sustainable way. The new technologies will enable the European industry to take a leading role in the semiconductor, particle therapy and free electron laser sectors.

Innovate for Sustainable Accelerating Systems

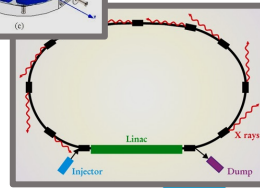
Efficient RF Power use
short-term applications



High-performant SRF cavities
medium-term applications



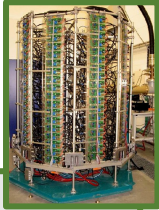
Energy Recovery
long-term applications



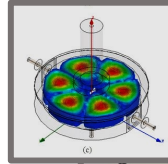
Innovative Technologies

Innovate for Sustainable Accelerating Systems

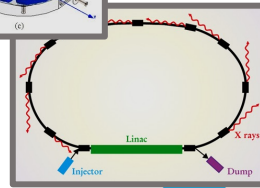
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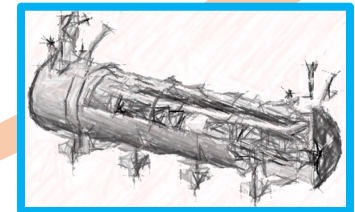
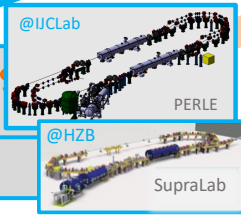
Energy Recovery
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Innovative Technologies

Research Infrastructures
integrate technologies into
a new LINAC cryomodule

others
others

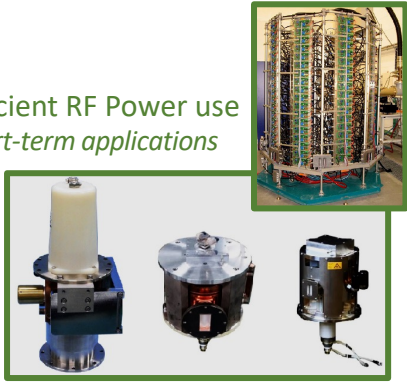


integrating new technologies
in the design of a new
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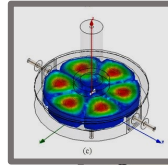
R&D pathfinders for new
energy-saving & energy-recovery technologies

Innovate for Sustainable Accelerating Systems

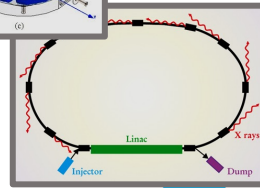
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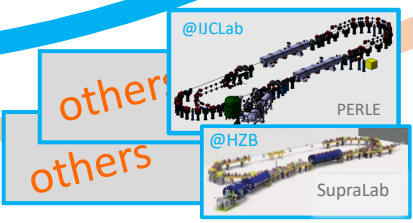


Energy Recovery
long-term applications

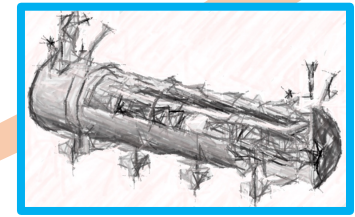


Innovative Technologies

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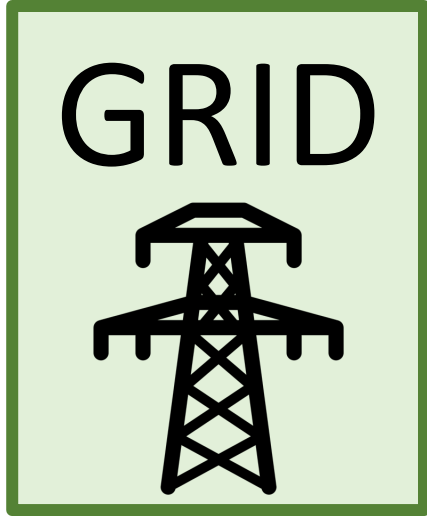


R&D pathfinders for new
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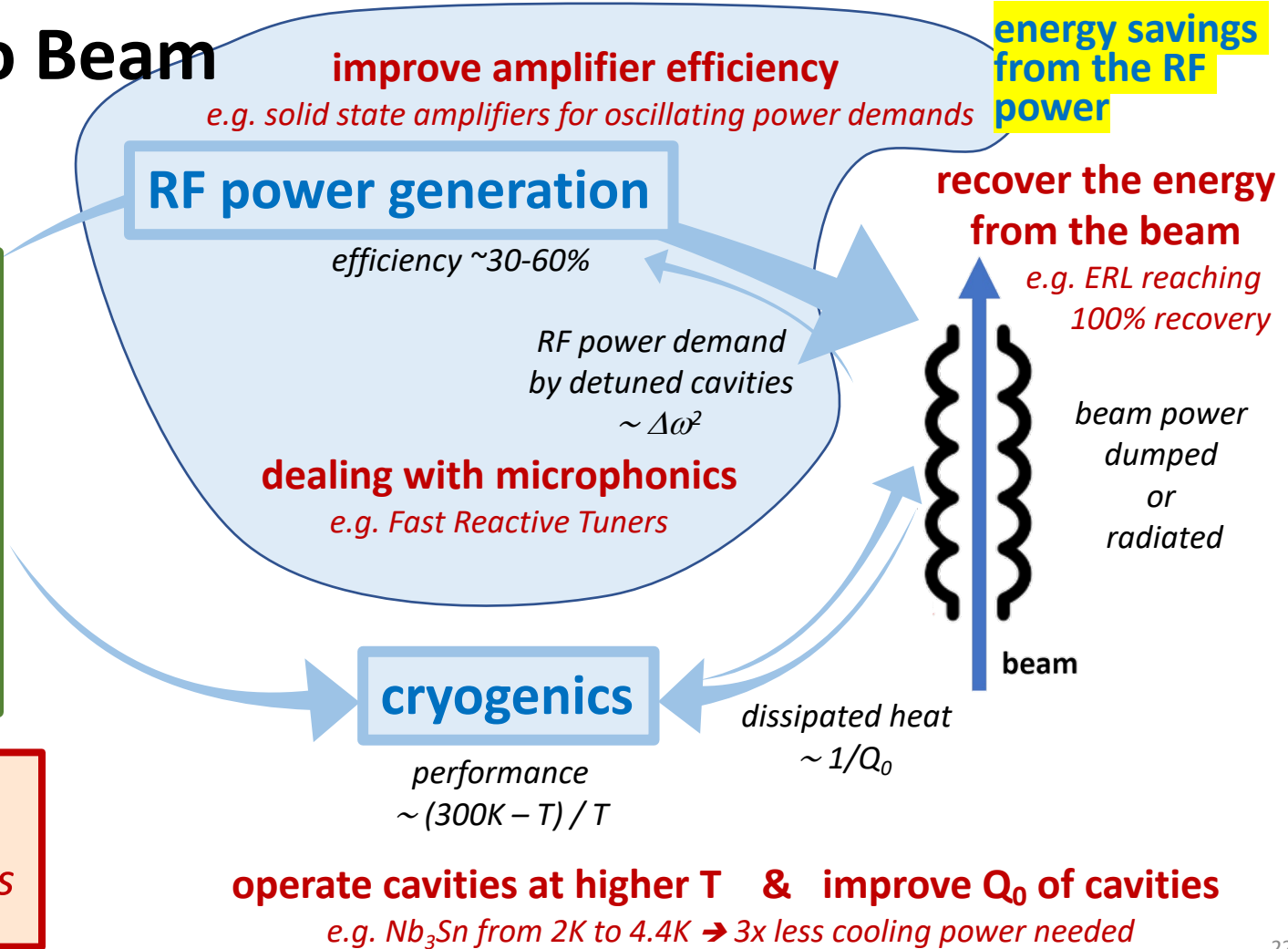


integrating new technologies
in the design of a new
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From Grid to Beam



mitigation with novel technologies



From Grid to Beam

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beam

**energy savings
from the
cryogenics**

cryogenics

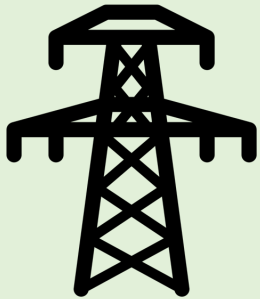
*dissipated heat
 $\sim 1/Q_0$*

*performance
 $\sim (300K - T) / T$*

operate cavities at higher T & improve Q_0 of cavities

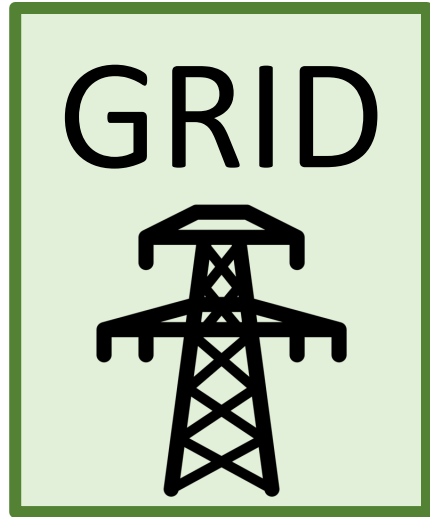
e.g. Nb_3Sn from 2K to 4.4K \rightarrow 3x less cooling power needed

GRID



*mitigation with
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From Grid to Beam



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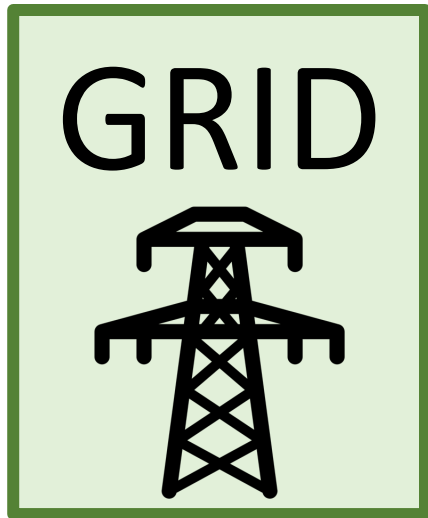
*beam power
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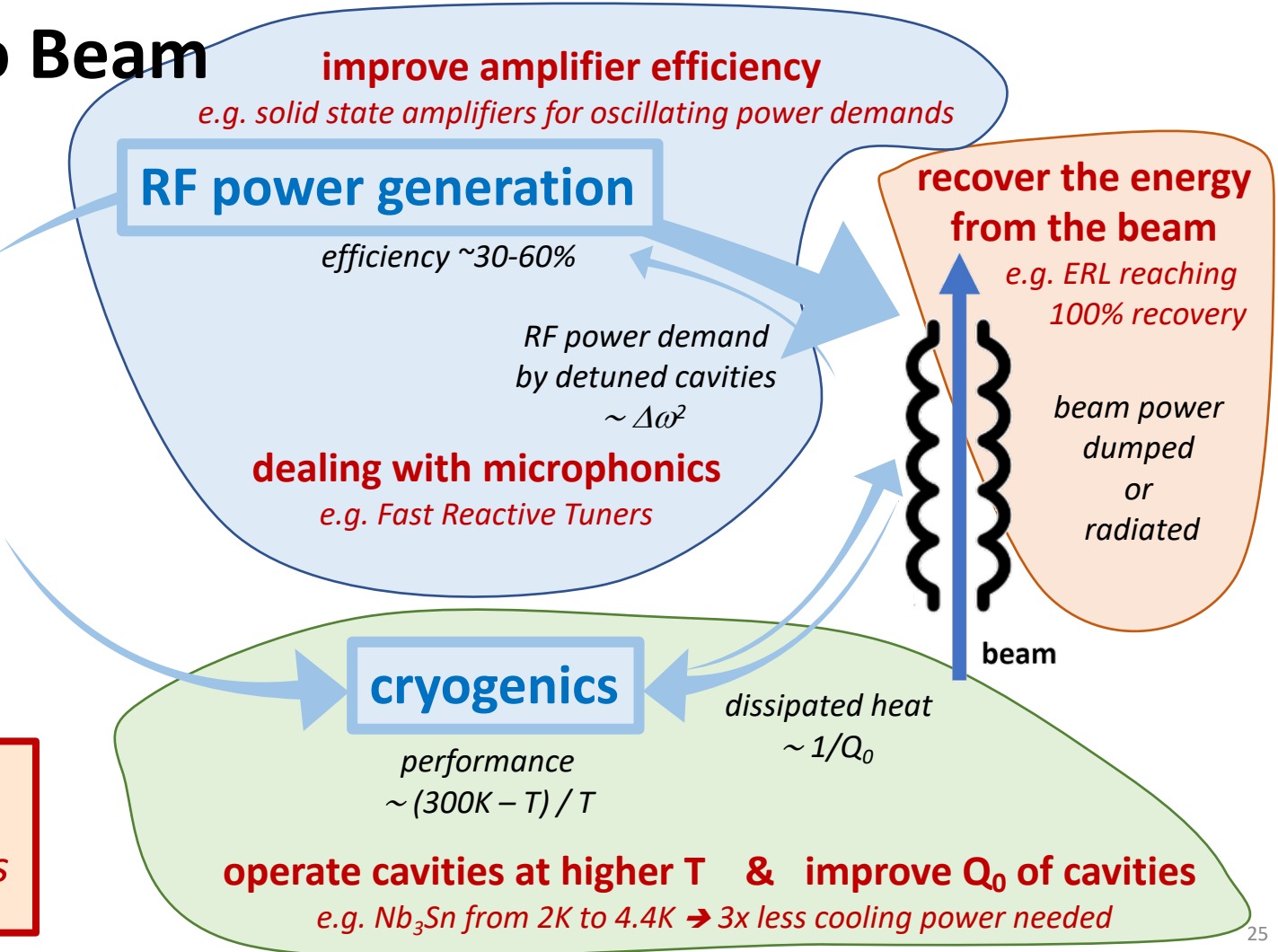
beam

*dissipated heat
 $\sim 1/Q_0$*

From Grid to Beam



mitigation with novel technologies



“Innovate for Sustainable Accelerating Systems” (iSAS)

- **R&D Pathfinders for three Technology Areas (TA) for energy-saving & energy-recovery**

- TA#1: energy savings from the RF power** *(short-term and very wide applications)*

- WP.1.1: optimal integration of Fast Reactive Tuners, LLRF controls (incl. AI) and RF power (e.g. Solid-State Amplifiers) to deal with microphonics (1.3GHz & 800MHz) and energy saving*

- TA#2: energy savings from the cryogenics** *(medium-term and wide applications)*

- WP.2.1: high-temperature SRF cavities (thin films (e.g. Nb₃Sn) on Cu)*

- TA#3: energy savings from the beam** *(long-term and specific applications)*

- WP.3.1: Higher-Order Mode damping and couplers*

- WP.3.2: design, prototype and test cryomodule @ high beam current*

Partners are encouraged to identify matching funds for 20-30% of the equipment and up to 100% of the personnel.

- **Integrate these novel technologies into the design of a new sustainable LINAC cryomodule**

- *based on the initial ESS cryomodules, develop a novel design for an optimally sustainable LINAC cryomodule*
 - *a design ready to be built and operated for various applications in industry and in collider RIs*

- **Integrate energy-saving & energy-recovery technologies in collider RIs**

- *from proof-of-concept ideas to concrete, peer-reviewed and feasible designs*
 - *focus on current and future colliders appearing in particle and nuclear physics strategies, incl. Higgs Factories*

- **Integrate into turn-key solutions and revolutionising applications in industry**

- *industrial partners are to be involved*

“Innovate for Sustainable Accelerating Systems”

MATRIX – To Be Developed

Goal: R&D Pathfinders for technologies feeding into a novel design of an energy-saving & energy-recovery LINAC cryomodule

TA#1: energy savings from the RF power

1. Integrate FRT + LLRF + SSA

TA#2: energy savings from the cryogenics

1. High-Temp SRF (thin films (e.g. Nb₃Sn) on Cu)

TA#3: energy savings from the beam

1. HOM Damping (incl. novel HOM couplers)
2. Design, prototype and test cryomodule @ high beam current

Integrate into the design of a sustainable cryomodule

Integrate sustainable accelerating systems in collider RIs

Integrate into industrial applications

	RI#1 NN	RI#2 NN	RI#3 NN	RI#4 NN	Industry NN	Industry NN
TA#1: energy savings from the RF power 1. Integrate FRT + LLRF + SSA						
TA#2: energy savings from the cryogenics 1. High-Temp SRF (thin films (e.g. Nb ₃ Sn) on Cu)						
TA#3: energy savings from the beam 1. HOM Damping (incl. novel HOM couplers) 2. Design, prototype and test cryomodule @ high beam current						
Integrate into the design of a sustainable cryomodule						
Integrate sustainable accelerating systems in collider RIs						
Integrate into industrial applications						

“Innovate for Sustainable Accelerating Systems”

Initial Money Matrix (initial as guidance to develop the scope)

EU budget

Matching budget

TA#1: energy savings from the RF power

1. Integrate FRT + LLRF + SSA

1.2M EUR

NN EUR + NN FTE

TA#2: energy savings from the cryogenics

1. High-Temp SRF (thin films (e.g. Nb₃Sn) on Cu)

0.55M EUR

NN EUR + NN FTE

TA#3: energy savings from the beam

1. HOM Damping (incl. novel HOM couplers)
2. Design, prototype and test cryomodule @ high beam current

0.15M EUR

NN EUR + NN FTE

1.85M EUR

NN EUR + NN FTE

Integrate into the design of a sustainable cryomodule

0.15M EUR

NN EUR + NN FTE

Integrate sustainable accelerating systems in collider RIs

0.025M EUR

NN EUR + NN FTE

Integrate into industrial applications

0.05M EUR

NN EUR + NN FTE

Coordination & Collaboration & Management

0.012M EUR

NN EUR + NN FTE

Coordination & Collaboration & Management

0.012M EUR

NN EUR + NN FTE

Important note from Ketel Turzo (IJCLab)

The UK partners can be included in the proposal, so in the 5M EUR budget maximum. On the contrary, Swiss applicants can only apply as associated partners. In that case, they are not included in the 5M EUR budget. They have to provide their own budget.
(CERN is Europe, i.e. not Switzerland)

“Innovate for Sustainable Accelerating Systems”

Work Package Conveners to develop the application

TA#1: energy savings from the RF power

1. Integrate FRT + LLRF + SSA

Jens Knobloch & Axel Neumann (HZB)

TA#2: energy savings from the cryogenics

1. High-Temp SRF (thin films (e.g. Nb₃Sn) on Cu)

Cristian Pira (INFN-Legnaro)

TA#3: energy savings from the beam

1. HOM Damping (incl. novel HOM couplers)
2. Design, prototype and test cryomodule @ high beam current

Guillaume Olry (IJCLab)

Integrate into the design of a sustainable cryomodule

NN

Integrate sustainable accelerating systems in collider Ris

NN

Integrate into industrial applications

NN

MILESTONES

WRITING
READING
CLOSING

v0 draft (15 days)
v1 draft (4 days)
v2 draft (2 days)
final version (1 day)

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
J a n u a r y					13	14	15
	16 AGREE ON WP CONVENERS	17 COORD: "INTRO" READY & WTEAM: EXPLORE	18	19	20	21	22
	23	24	25 COORD: GUIDANCE READY FOR WPs	26 WPCON: DRAFT BRIEF SCOPE READY (EACH WP)	27 WTEAM: INITIAL LIST OF PARTNERS READY	28	29
F e b r u a r y	30 WTEAM: AGREE ON WP SCOPE, START WRITING	31	1	2	3	4	5
	6	7	8	9	10 PARTNERS TO DELIVER THEIR ADMIN TEMPLATE	11	12
	13 WPCON & COORD: DELIVER "v0" WP & GENERAL DRAFT	14 WTEAM: "v0" READING	15	16	17 WTEAM: FEEDBACK "v0" READY	18	19
	20 WTEAM: ADAPT SECTIONS	21 COORD: TAIRA PRESENTATION	22	23 WPCON & COORD: DELIVER "v1" ALL SECTIONS	24 WTEAM & READCOM: "v1" READING	25	26
M a r c h	27	28 WTEAM: ALL "v1" COMMENTS RECEIVED	1 WTEAM: ADAPT SECTIONS	2 WPCON & COORD: DELIVER "v2" ALL SECTIONS	3 WTEAM & READCOM: "v2" READING	4	5
	6 WTEAM: ALL "v2" COMMENTS RECEIVED	7 WTEAM: DELIVER "FINAL" VERSION & SUBMIT DRAFT	8 COORD: FINAL READING & ALL PARTNERS TO SIGN-OFF	9 SUBMIT			

AGENDA

All meetings will be added to the indico directory

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
J a n u a r y					13	14	15
	16 WTEAM 14:30 CET: organisational aspects	17	18	19	20	21	22
	23 WTEAM 14:30 CET: first WP scope ideas presentation (1 slide)	24	25	26 <i>WPCON brief (1p) draft scope to WTEAM (email)</i>	27 WTEAM 14:30 CET: discuss scope WPs	28	29
F e b r u a r y	30 WTEAM 14:30 CET: agree on WP scope	31	1	2	3	4	5
	6	7	8	9	10	11	12 <i>WPCON & COORD "v0" sections to WTEAM (email)</i>
	13 WTEAM 14:30 CET: presentation "v0" sections	14	15	16	17 <i>WTEAM "v0" comments received and communicated (email)</i>	18	19
	20 WTEAM 14:30 CET: discussion comments & budget	21	22	23 <i>WPCON & COORD "v1" sections to WTEAM (email)</i>	24 WTEAM 14:30 CET: discussion "v1" full document	25	26
M a r c h	27	28 <i>WTEAM "v1" comments received and communicated (email)</i>	1	2 WTEAM 14:30 CET: discussion open issues	3 <i>COORD "v2" full document to WTEAM (email)</i>	4	5
	6 WTEAM 14:30 CET: "v2" comment received and	7 <i>COORD "final" full document to WTEAM (email)</i>	8 WTEAM 14:30 CET: final discussion and sign-off by partners	9 SUBMIT			

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A.O.B.