Innovate for Sustainable Accelerating Systems (iSAS)

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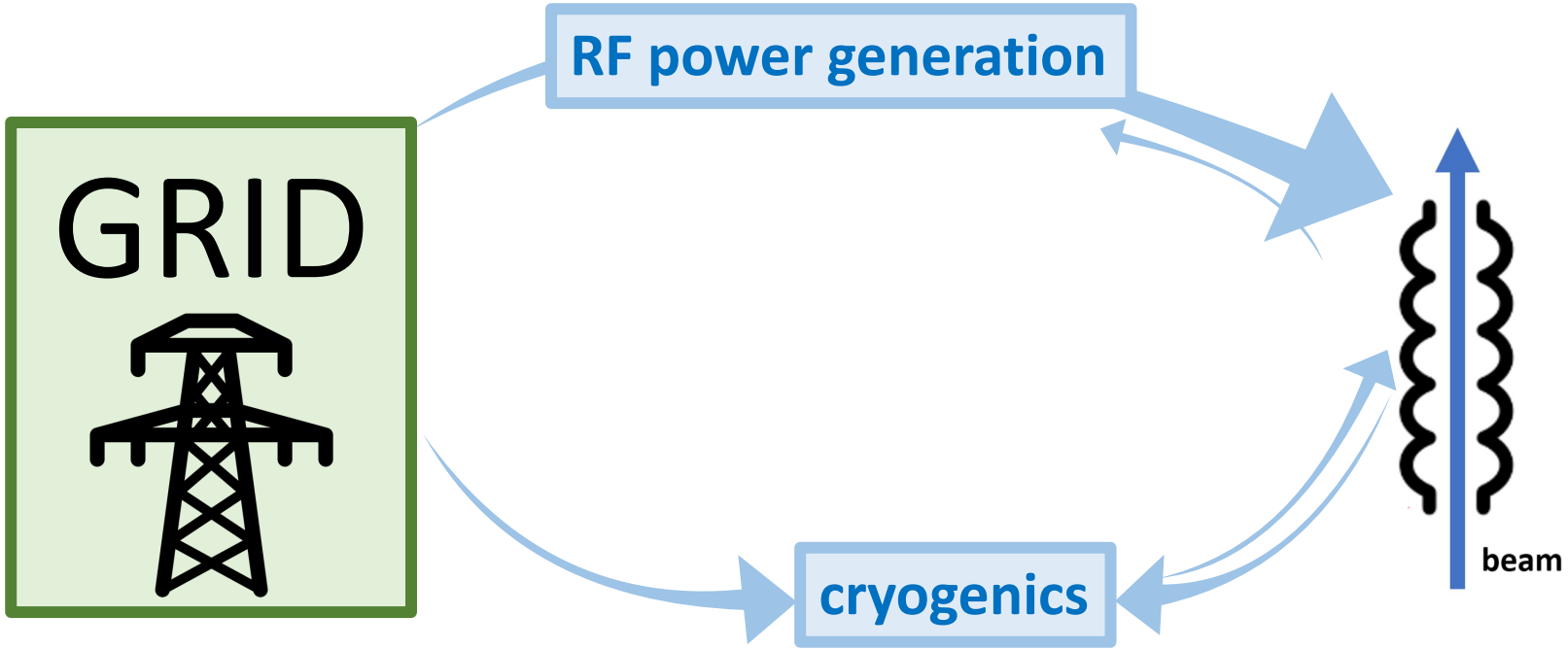
beln

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.

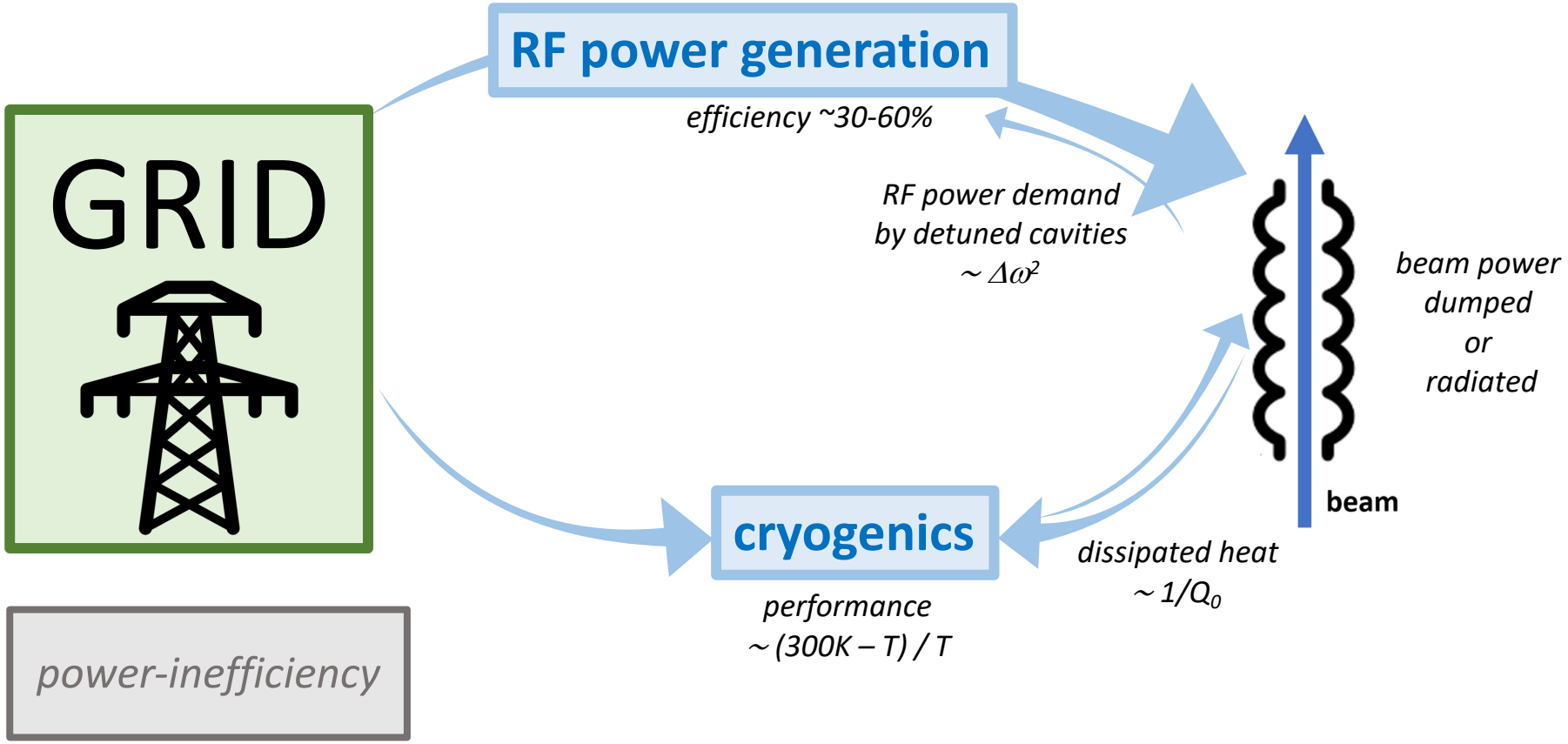
European Strategy for Particle Physics 2020

From Grid to Beam



Picture adopted from M. Seidel (IPAC 2022)

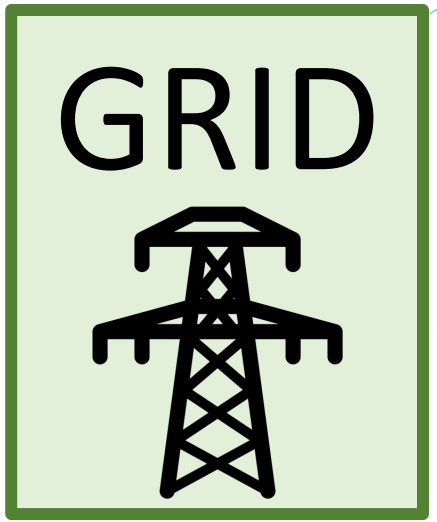
From Grid to Beam



From Grid to Beam

improve amplifier efficiency

e.g. solid state amplifiers for oscillating power demands



RF power generation

efficiency ~30-60%

recover the energy from the beam

e.g. ERL reaching 100% recovery

RF power demand by detuned cavities

$\sim \Delta\omega^2$

dealing with microphonics

e.g. Fast Reactive Tuners

beam power dumped or radiated

cryogenics

performance

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

dissipated heat

$\sim 1/Q_0$

mitigation with novel technologies

operate cavities at higher T & improve Q_0 of cavities

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

From Grid to Beam

improve amplifier efficiency

e.g. solid state amplifiers for oscillat

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

dissipated heat
~ $1/Q_0$

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

ALARA = **A**s **L**ow **A**s **R**easonable **A**chievable

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 envir

- **Specific conditi**

- **S**

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 an 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!

(ERIC) or where the

echnical

ammes.

...print of RIs through the full life cycle of research

...assess environmental impact and strategies to reduce it, as well as efficiency

...relevant:

...gies 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;

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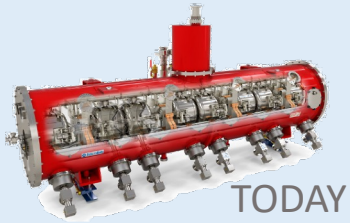
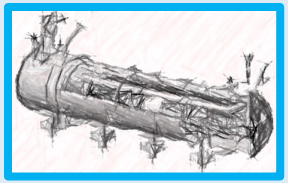


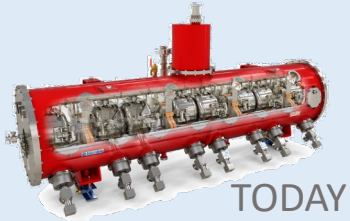
TODAY

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



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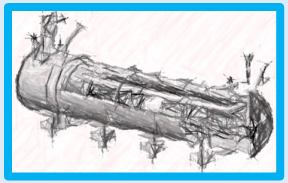

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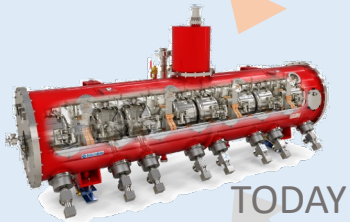
high-T SRF, FRT, LLRF with AI, …

High-performant SRF cavities



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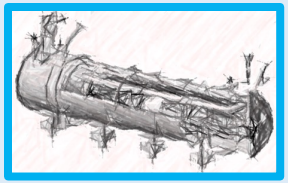

NEW DESIGN

RF power generation

SSA, …

Energy Recovery

HOM damping, 1st CM, …

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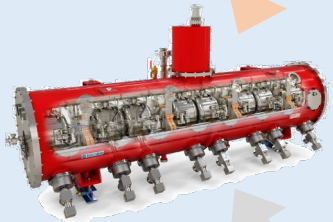

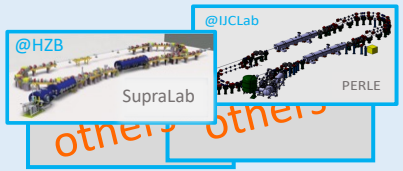

R&D Pathfinders for new energy-saving & energy-recovery technologies

RF power generation

SSA, …

Energy Recovery

HOM damping, 1st CM, …

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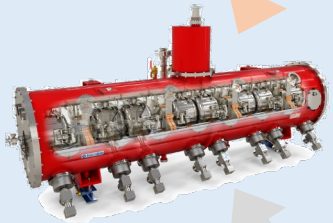

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Energy Recovery

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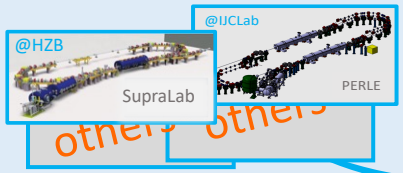
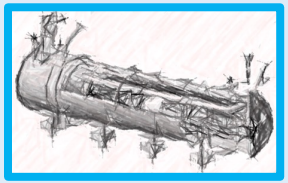


R&D Pathfinders for new energy-saving & energy-recovery technologies

INTEGRATING



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

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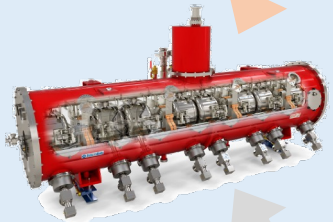

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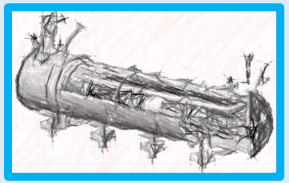
R&D Pathfinders for new energy-saving & energy-recovery technologies

INTEGRATING



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

others

@CERN

full deployment of energy saving & energy recovery in collider RIs

sustainable accelerator turn-key solutions with breakthrough applications

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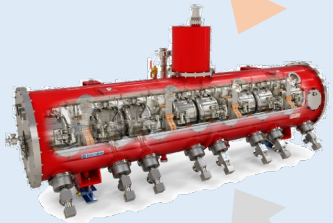

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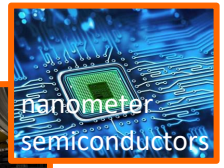
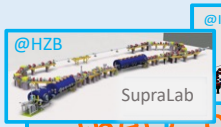
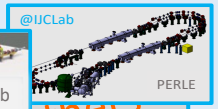


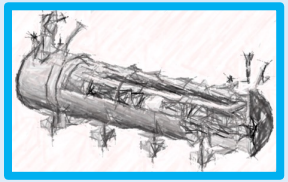




others others

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

INTEGRATING



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

others

full deployment of energy saving & energy recovery in collider RIs

“Innovate for Sustainable Accelerating Systems”

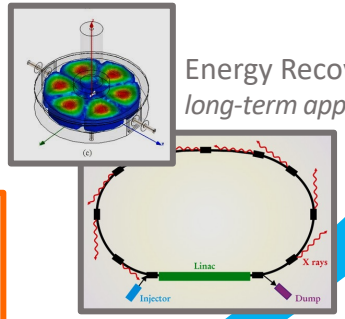
- **AMBITION** – Particle accelerators have become essential instruments to improve our health, environment, safety and high-tech abilities, as well as to unlock new fundamental insights in physics, chemistry, biology, and generally enable scientific breakthroughs that improve our lives. Accelerating 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

RF Power Generation
short-term applications

High-performant SRF cavities
medium-term applications

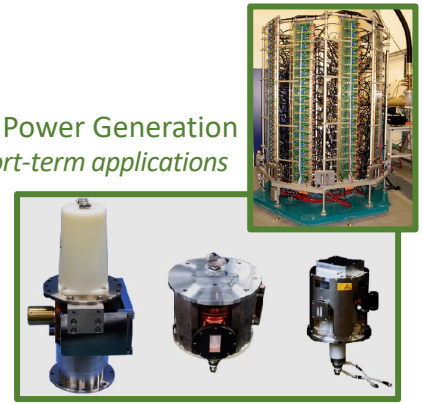
Energy Recovery
long-term applications



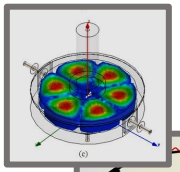
Innovative Technologies

Innovate for Sustainable Accelerating Systems

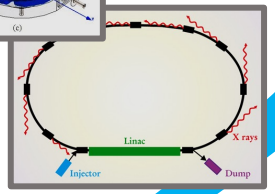
RF Power Generation
short-term applications



High-performant SRF cavities
medium-term applications

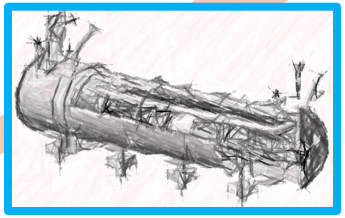


Energy Recovery
long-term applications

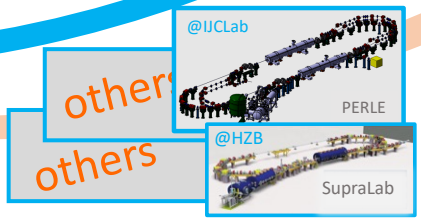


Innovative Technologies

Research Infrastructures
integrate technologies into
a new LINAC cryomodule



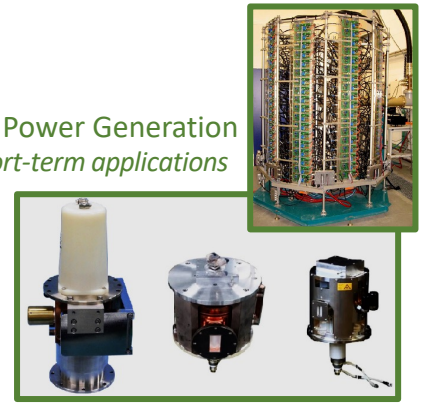
integrating new technologies
in the design of a new
sustainable LINAC cryomodule



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

Innovate for Sustainable Accelerating Systems

RF Power Generation
short-term applications



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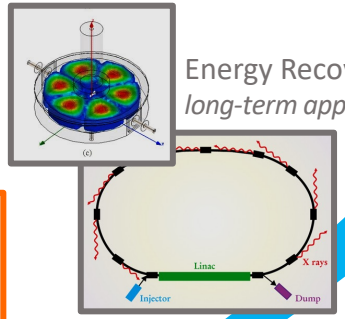

Innovative Technologies

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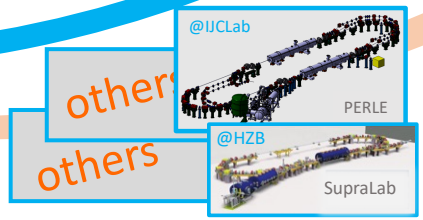
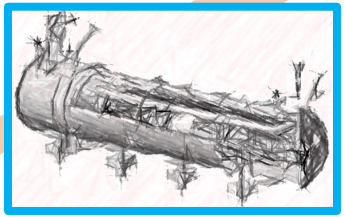


R&D pathfinders for new
energy-saving & energy-recovery technologies



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

“Innovate for Sustainable Accelerating Systems” (iSAS)

- **R&D Pathfinders for three Technology Areas (TA) for energy-saving & energy-recovery**
  - **TA#1: high-efficient RF power generation** *(short-term and very wide applications)*
    - *WP.1.1: alternativet to klystrons develop Solid-State Amplifiers with high efficiency at reduced output RF power*
  - **TA#2: high-performant SRF cavities** *(medium-term and wide applications)*
    - *WP.2.1: high-temperature SRF (thin films (e.g. Nb_3Sn) on Cu)*
    - *WP.2.2: Fast Reactive Tuners to deal with microphonics (1.3GHz & 800MHz)*
    - *WP.2.3: LLRF controls (incl AI), with energy saving & FRT connection*
  - **TA#3: energy recovery aspects of the SRF cavities** *(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

	RI#1 NN	RI#2 NN	RI#3 NN	RI#4 NN	Industry NN	Industry NN
TA#1: high-efficient RF power generation						
1. SSA with high efficiency at reduced output RF power	-	-	-	-	-	-
TA#2: high-performant SRF cavities						
1. High-Temp SRF (thin films (e.g. Nb_3Sn) on Cu)	-	-	-	-	-	-
2. FRT (1.3GHz & 800MHz)	v	v	v	v	v	v
3. LLRF controls with AI (energy saving & FRT connection)	v	v	v	v	v	v
TA#3: energy recovery aspects of the SRF cavities						
1. HOM Damping (incl. novel HOM couplers)	-	-	-	-	-	-
2. Design, prototype and test cryomodule @ high beam current	-	-	-	-	-	-
Integrate into the design of a sustainable cryomodule	v	v	v	v	v	v
Integrate sustainable accelerating systems in collider RIs	v	v	v	v	v	v
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: high-efficient RF power generation		
1. SSA with high efficiency at reduced output RF power	0.4M EUR	NN EUR + NN FTE
TA#2: high-performant SRF cavities		
1. High-Temp SRF (thin films (e.g. Nb_3Sn) on Cu)	0.5M EUR	NN EUR + NN FTE
2. FRT (1.3GHz & 800MHz)	0.7M EUR	NN EUR + NN FTE
3. LLRF controls with AI (energy saving & FRT connection)	0.15M EUR	NN EUR + NN FTE
TA#3: energy recovery aspects of the SRF cavities		
1. HOM Damping (incl. novel HOM couplers)	0.15M EUR	NN EUR + NN FTE
2. Design, prototype and test cryomodule @ high beam current	1.85M EUR	~1M 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	0.225M EUR	NN EUR + NN FTE

“Innovate for Sustainable Accelerating Systems”

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

EU budget … hing budget

TA#1: high-efficient RF power generati…

1. SSA …

…EUR + NN FTE

TA#2: h…

1. High-…
2. FRT (…
3. LLRF …

…EUR + NN FTE
…EUR + NN FTE
…UR + NN FTE

TA#3: en…

1. HOM D…
2. Design…

…R + NN FTE
…UR + 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)

Integrate …	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	0.225M EUR	NN EUR + NN FTE

“Innovate for Sustainable Accelerating Systems”

Input required from each partner

e.g. ESS, MYRRHA, CERN, PSI, STFC, ALBA, INFN, IJCLab, HZB, IRFU, DESY/Hamburg, Siegen, …
e.g. THALES, IBA, …

	Research Partner or Industry NN
TA#1: high-efficient RF power generation 1. SSA with high efficiency at reduced output RF power	Contact, Involvement, matching funds
TA#2: high-performant SRF cavities 1. High-Temp SRF (thin films (e.g. Nb_3Sn) on Cu) 2. FRT (1.3GHz & 800MHz) 3. LLRF controls with AI (energy saving & FRT connection)	Contact, Involvement, matching funds Contact, Involvement, matching funds Contact, Involvement, matching funds
TA#3: energy recovery aspects of the SRF cavities 1. HOM Damping (incl. novel HOM couplers) 2. Design, prototype and test cryomodule @ high beam current	Contact, Involvement, matching funds Contact, Involvement, matching funds
Integrate into the design of a sustainable cryomodule	Contact, Involvement, matching funds
Integrate sustainable accelerating systems in collider RIs	Contact, Involvement, matching funds
Integrate into industrial applications	Contact, Involvement, matching funds

“Innovate for Sustainable Accelerating Systems”

Work Package Conveners to develop the application

	Convener
TA#1: high-efficient RF power generation	
1. SSA with high efficiency at reduced output RF power	Giovanni discussing in RF Coord Panel
TA#2: high-performant SRF cavities	
1. High-Temp SRF (thin films (e.g. Nb_3Sn) on Cu)	**Cristian Pira (INFN-Legnaro)**
2. FRT (1.3GHz & 800MHz)	**Jens Knobloch (HZB)**
3. LLRF controls with AI (energy saving & FRT connection)	**Axel Neumann (HZB)**
TA#3: energy recovery aspects of the SRF cavities	**Guillaume Olry (IJCLab)**
1. HOM Damping (incl. novel HOM couplers)	
2. Design, prototype and test cryomodule @ high beam current	
Integrate into the design of a sustainable cryomodule	NN
Integrate sustainable accelerating systems in collider RIs	NN
Integrate into industrial applications	NN

“Innovate for Sustainable Accelerating Systems”

Preparing the application together:

- **WP conveners (WPCON)**: develop concrete scope, plans, budget, call WP meetings with partners
- **Coordinators (COORD)**: Giovanni Bissofi, Jorgen D’Hondt, Jens Knobloch, Achille Stocchi
- **Experts (EXP)**: Andrew Hutton, Max Klein, … provide Jorgen with additional names
- **EU experts (EUEXP)**: Ketel Turzo, Nathalie Chérel (IJCLab)

- **Scientific Coordination** (at this initial stage): Jorgen D’Hondt
- **Administrative Coordination**: CNRS
- Tuesday Jan 17, we will register the application in the EU online systems
- This will provide us the application templates, and soon we will provide WPCONs with these and guidance
- Digital repositories being prepared (HZB) → SharePoint

Regular ZOOM meetings with the writing team:

- **Writing team (WTEAM)** = all WP conveners + coordinators + experts + EU experts
- Dates: see following slides
- CERN indico directory with links to meetings (incl ZOOM link): https://indico.cern.ch/category/16371/

Reading committee (WP convener text → coordinators & experts → reading committee):

- **Readers** (**READCOM**, content & language): ask members of the TIARA and iFAST preparation team (Jorgen)
- Develop a schedule for the readers (Jorgen)

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
January					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
February	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
March	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
January					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 *WPCON brief (1p) draft scope to WTEAM (email)*	27 WTEAM 14:30 CET: discuss scope WPs	28	29
February	30 WTEAM 14:30 CET: agree on WP scope	31	1	2	3	4	5
	6	7	8	9	10	11	12 *WPCON & COORD "v0" sections to WTEAM (email)*
	13 WTEAM 14:30 CET: presentation "v0" sections	14	15	16	17 *WTEAM "v0" comments received and communicated (email)*	18	19
	20 WTEAM 14:30 CET: discussion comments & budget	21	22	23 *WPCON & COORD "v1" sections to WTEAM (email)*	24 WTEAM 14:30 CET: discussion "v1" full document	25	26
March	27	28 *WTEAM "v1" comments received and communicated (email)*	1	2 WTEAM 14:30 CET: discussion open issues	3 *COORD "v2" full document to WTEAM (email)*	4	5
	6 WTEAM 14:30 CET: "v2" comment received and	7 *COORD "final" full document to WTEAM (email)*	8 WTEAM 14:30 CET: final discussion and sign-off by partners	9 SUBMIT			

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A.O.B.