Innovate for Sustainable Accelerating Systems (iSAS)

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HIGH-ENERGY PHYSICS RESEARCH CENTRE

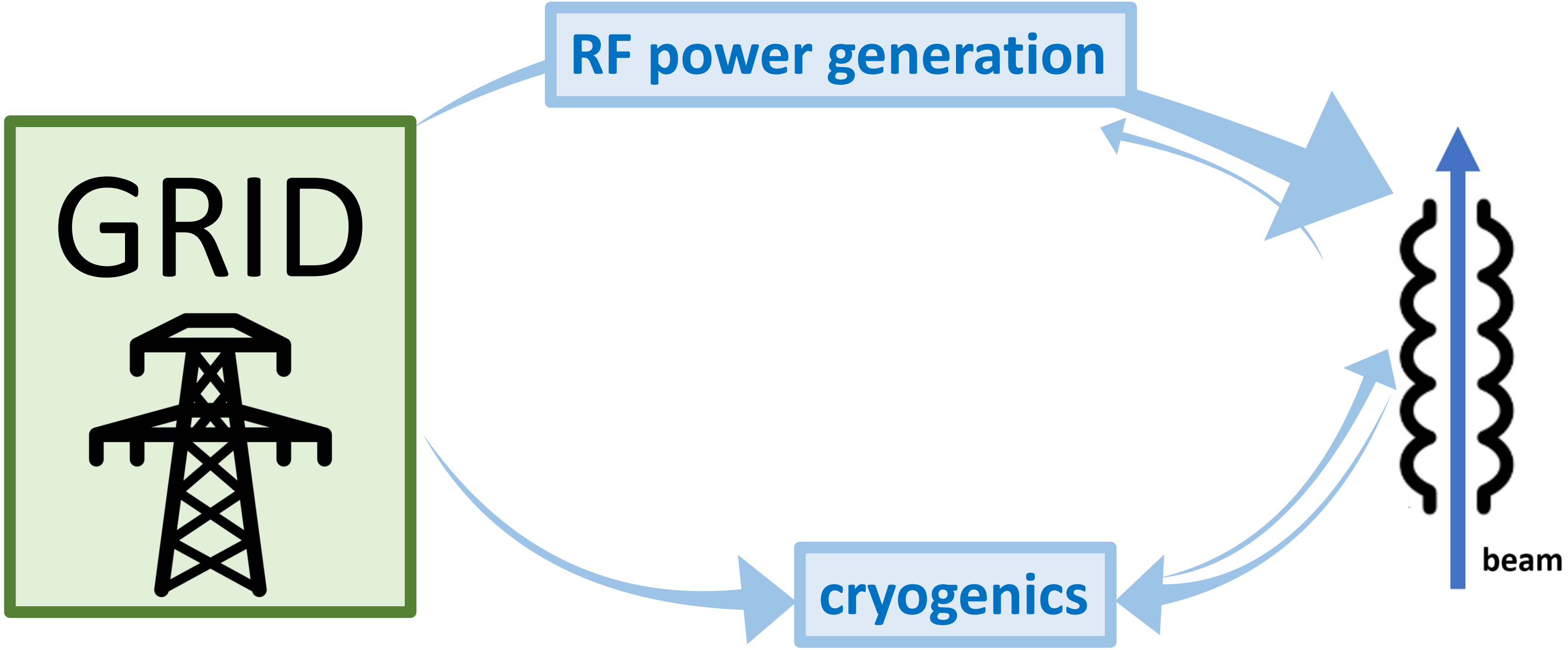
iSAS proposal, February 2023

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

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

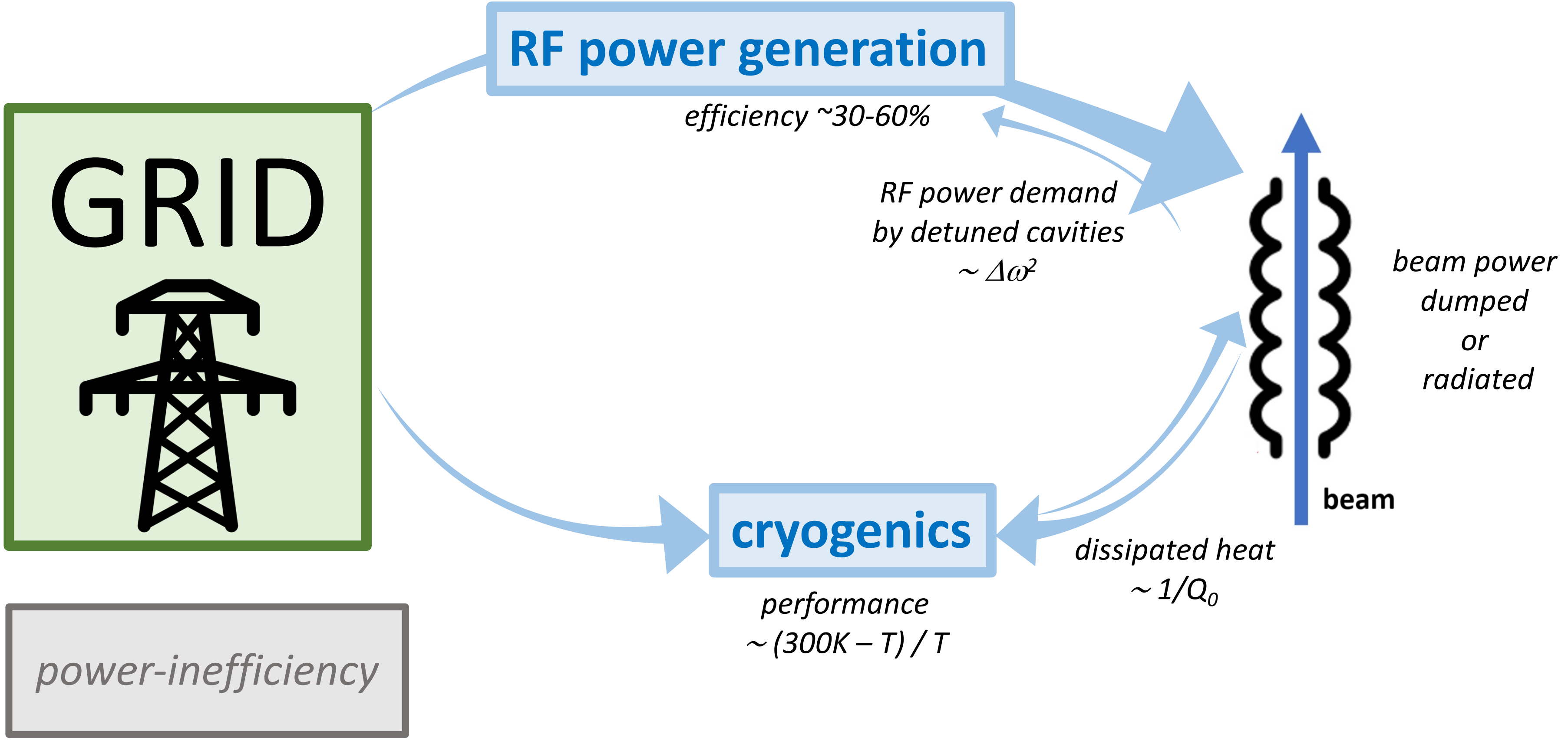
European Strategy for Particle Physics 2020

From Grid to Beam

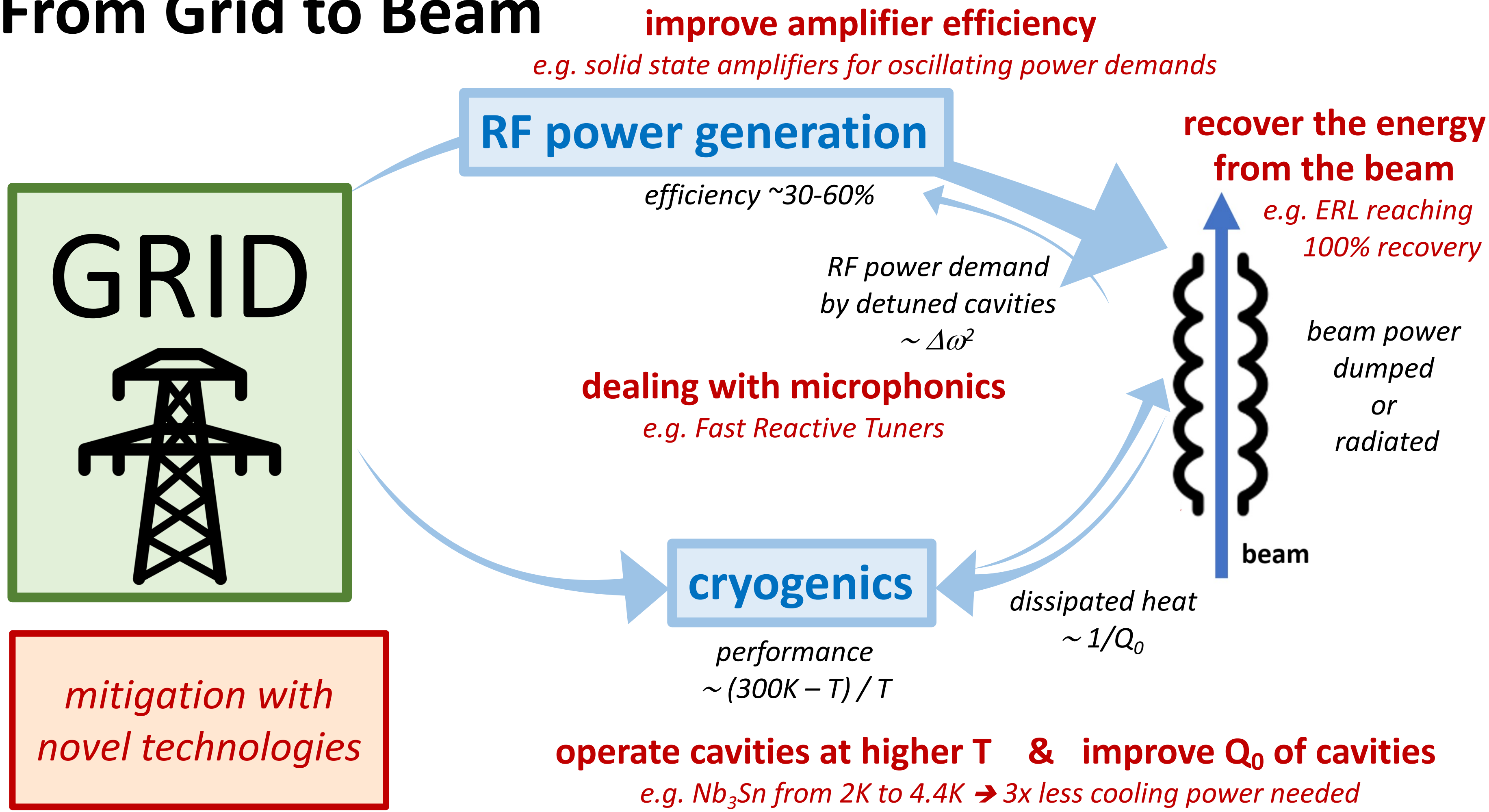


Picture adopted from M. Seidel (IPAC 2022)

From Grid to Beam



From Grid to Beam



From Grid to Beam

energy savings from the RF power

improve amplifier efficiency

e.g. solid state amplifiers for oscillating power demands

RF power generation

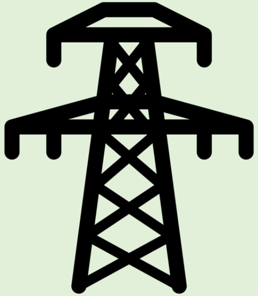
efficiency ~30-60%

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

dealing with microphonics

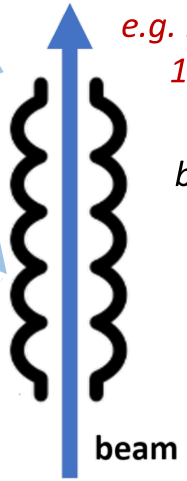
e.g. Fast Reactive Tuners

GRID



recover the energy from the beam

e.g. ERL reaching 100% recovery



beam power dumped or radiated

cryogenics

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

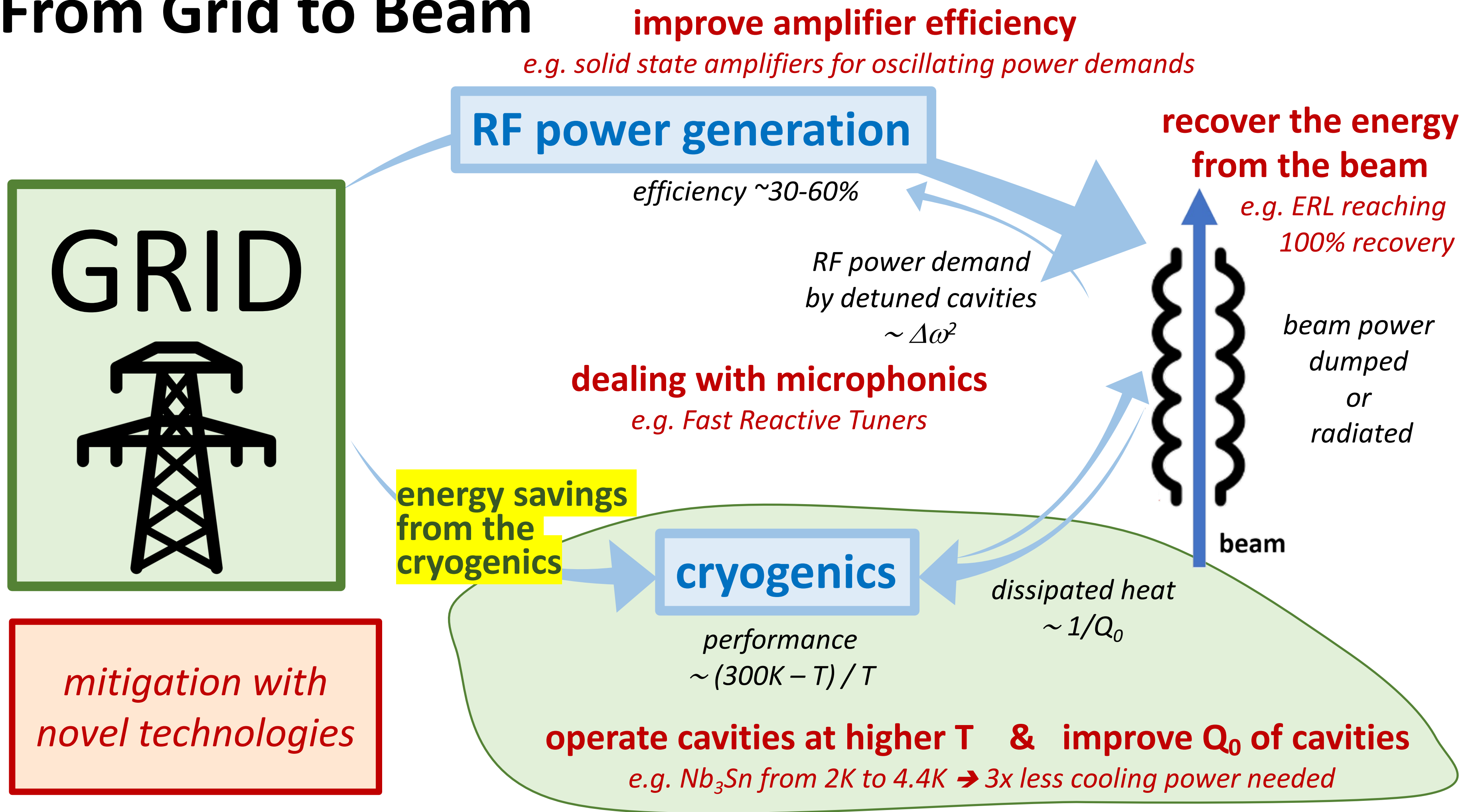
dissipated heat $\sim 1/Q_0$

operate cavities at higher T & improve Q_0 of cavities

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

mitigation with novel technologies

From Grid to Beam



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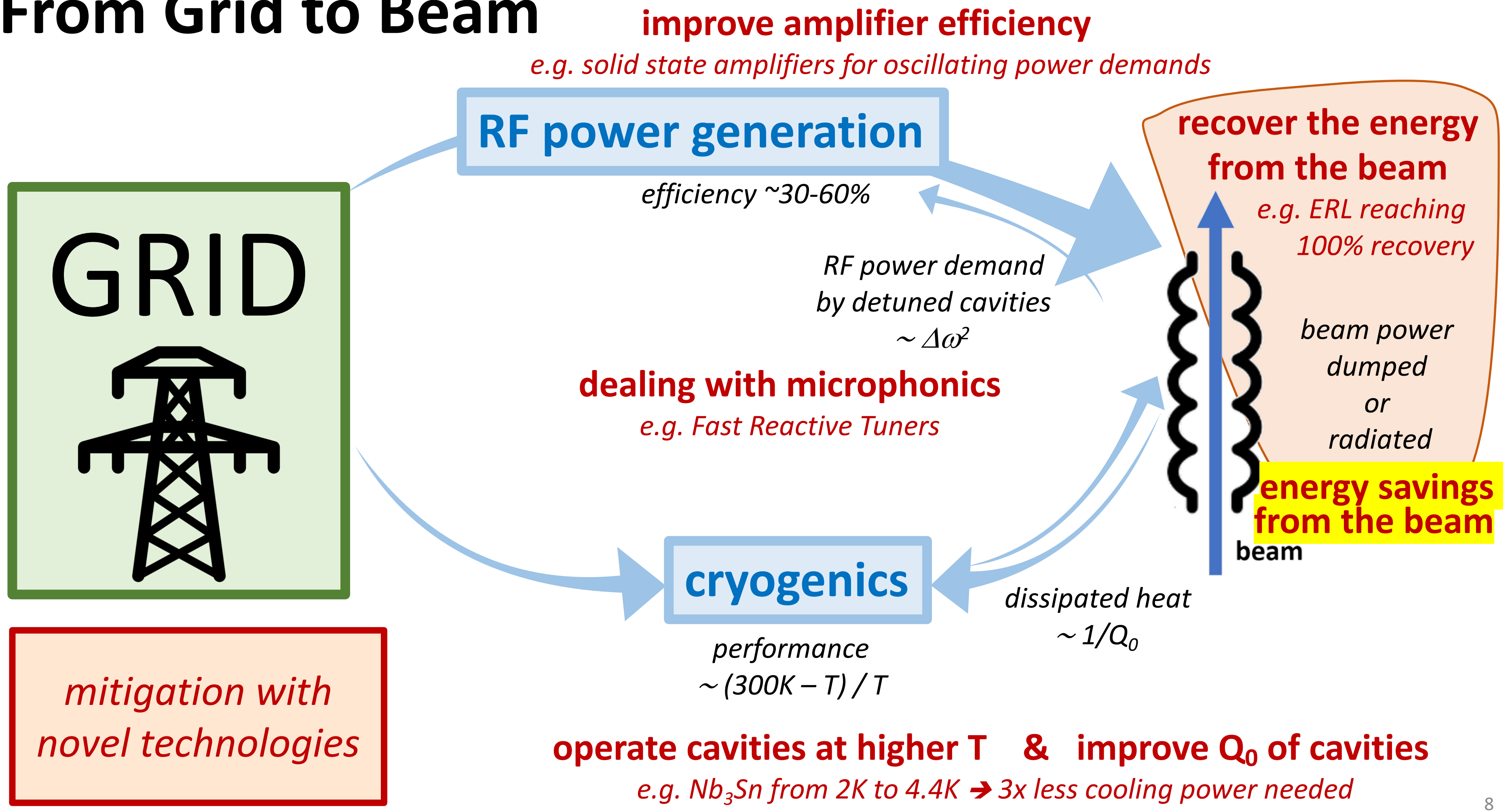

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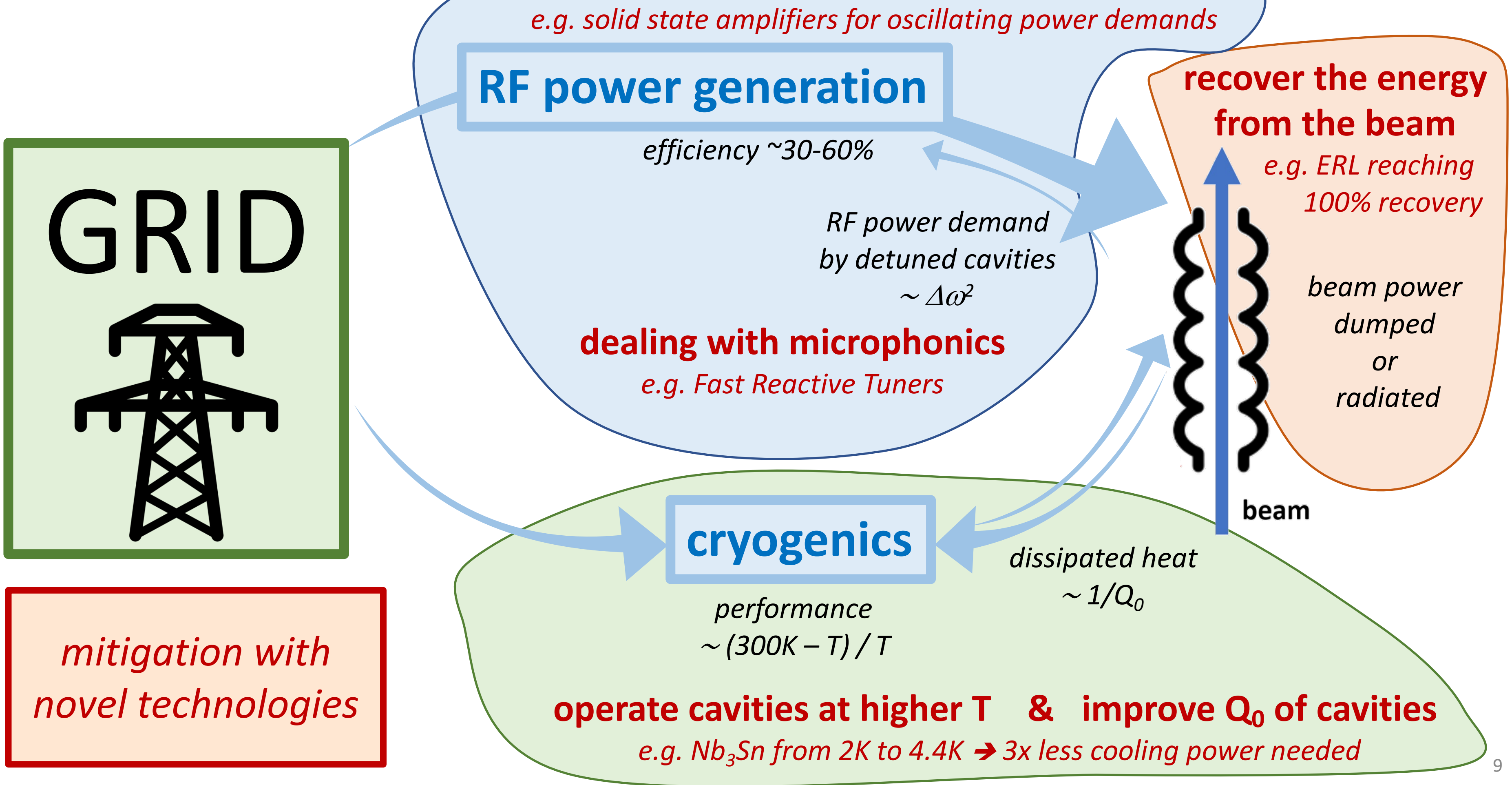

from the overall Accelerator R&D Roadmap
and towards a concrete project to be submitted in the Horizon Europe framework

Innovate for Sustainable Accelerating Systems (iSAS)

we focus on these three main iSAS Technology Areas (TAs) to develop energy-saving solutions

in consultation with the management of TIARA and iFAST

“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.*

Submit by March 9

“Innovate for Sustainable Accelerating Systems”

HORIZON-INFRA-2023-TECH-01-01

New technologies and solutions for reduci

Create strong and broad impact with a 5M EUR 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 existing Research Infrastructures and 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!

(ERIC) or where the

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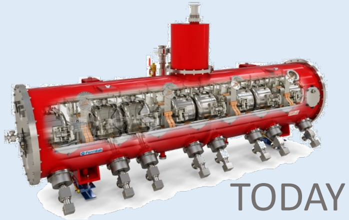
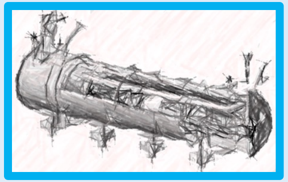
“Innovate for Sustainable Accelerating Systems” – *draft abstract*

- **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 (RIs) and industry, which collectively operate more than 30.000 accelerators. The current accelerator-driven RIs in Europe consume together 1% of Germany’s annual electricity demand, and future RIs might double this. With the ambition to maintain the attractiveness and competitiveness of European RIs and to enable Europe’s Green Deal, we propose to *Innovate for Sustainable Accelerating Systems* (iSAS) by establishing enhanced collaboration across the field to broaden, expedite and amplify the development and impact of novel energy-saving technologies to accelerate particles. The objective of iSAS is to innovate those technologies that have been identified as being the common core of particle accelerating systems to minimize the intrinsic energy consumption in all phases of operation. While in the landscape of accelerator-driven RIs solutions are being developed to reuse the waste heat produced and to operate facilities on opportunistic schedules when energy is available, the iSAS project has a complementary focus on the energy efficiency of the accelerator technologies themselves. This represents a vital transition to sustain the tremendous 20th century applications of the accelerator technology in a green and energy conscious 21st century.
- **METHODOLOGY** – Informed by a recently established European R&D Roadmap for accelerator technology and based on a strong collaboration between leading European research institutions and industry, several interconnected technologies will be developed, prototyped and tested, each enabling significant energy savings on their own in accelerating particles. Considering the developments realised at these unique R&D Pathfinder labs, the new technologies will be coherently integrated into the design of a new universal accelerating system, a LINAC cryomodule, which is optimised for energy savings reaching an as low as reasonably possible energy consumption. The collection of energy-saving technologies and the universal cryomodule design will be developed with in mind a portfolio of forthcoming applications, in particular imminent energy-saving upgrades of existing RIs, for example the (HL-)LHC, ESS and EU XFEL. The timescales to innovate, prototype and test new accelerator technologies are understandably long. It is therefore essential to collaborate to enhance the R&D process so that energy-sustainable technologies can be implemented without delay and avoiding hampering scientific and industrial progress enabled by accelerating systems. Accordingly, iSAS plans for impactful co-development with industrial partners to jointly achieve a technology readiness level sufficient to enter a phase of large-scale production of the new instruments.
- **IMPACT** – While several energy-saving technologies will be integrated into industrial turn-key solutions with short-term impact on current RIs, iSAS is also the main pathfinder for sustainable future particle accelerators and colliders. Unlocked by iSAS, Europe’s leadership will be maintained towards 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. It is iSAS’s long-term goal to reduce the energy footprint of future accelerator-driven RIs by at least half, which would be equivalent to 1% of Germany’s current electricity demand. In parallel, the new sustainable technologies will empower and stimulate the European industry to take a leading role in, for example, the semiconductor and particle therapy sectors.

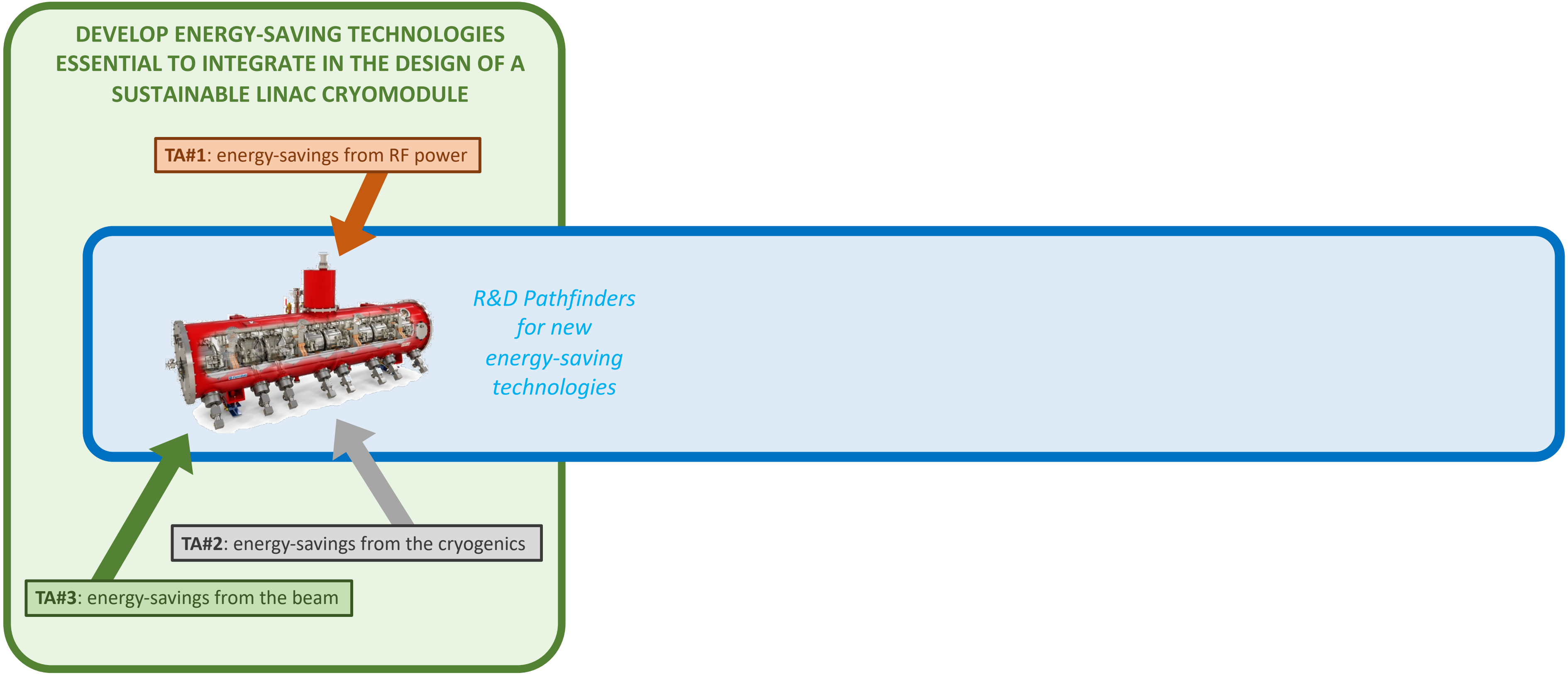


TODAY

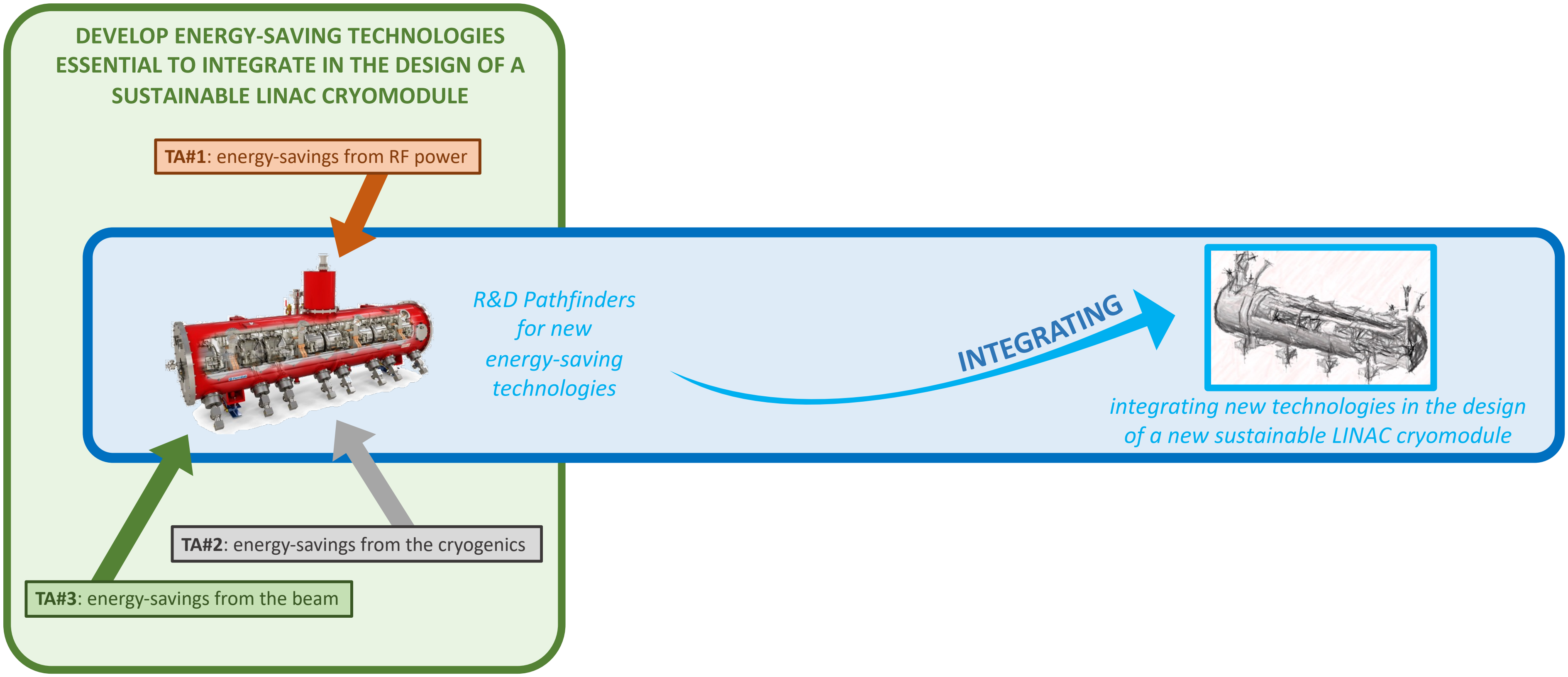
INNOVATE TECHNOLOGIES TOWARDS A SUSTAINABLE ACCELERATING SYSTEM



NEW DESIGN



TA: Technology Area



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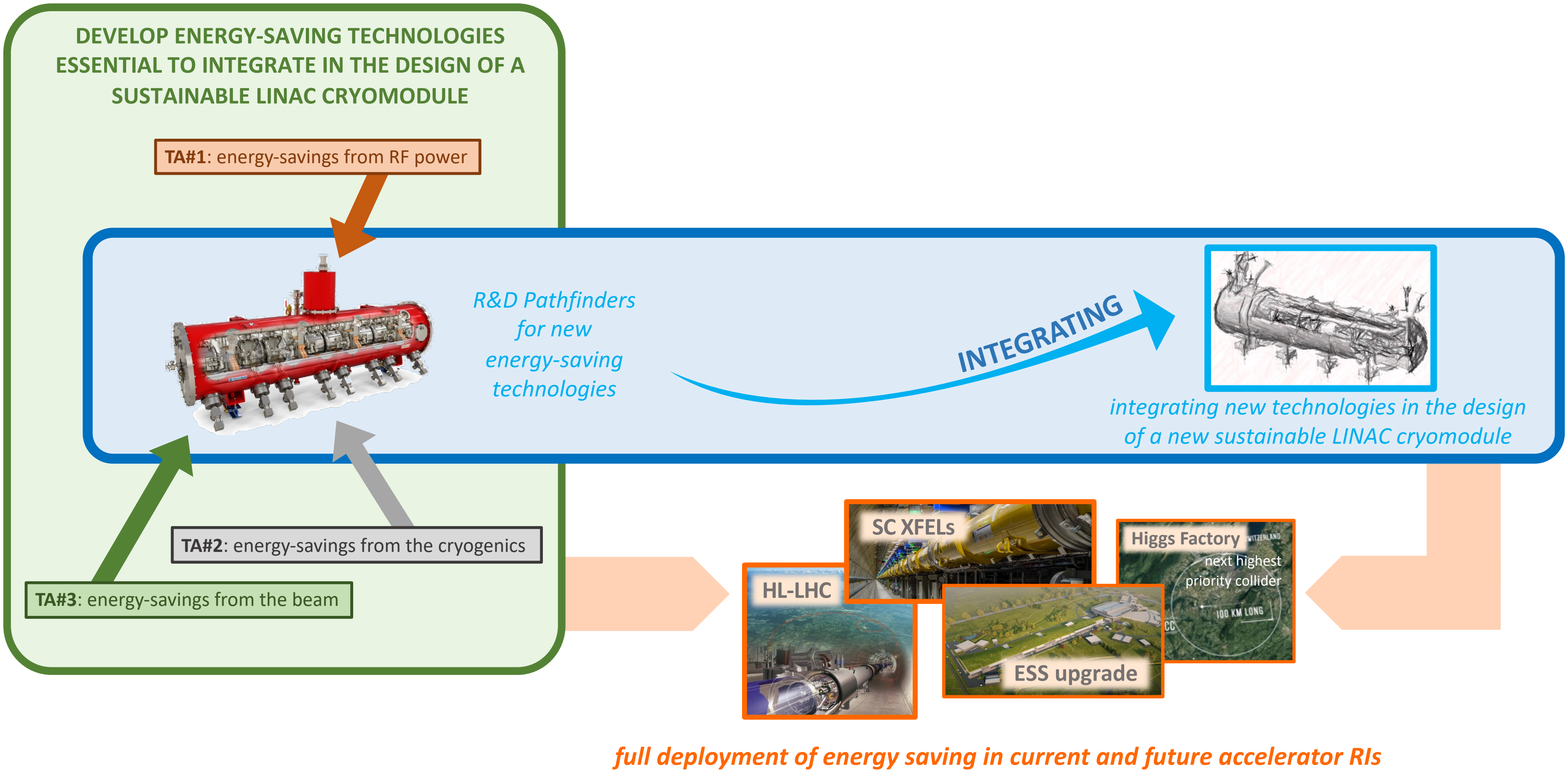

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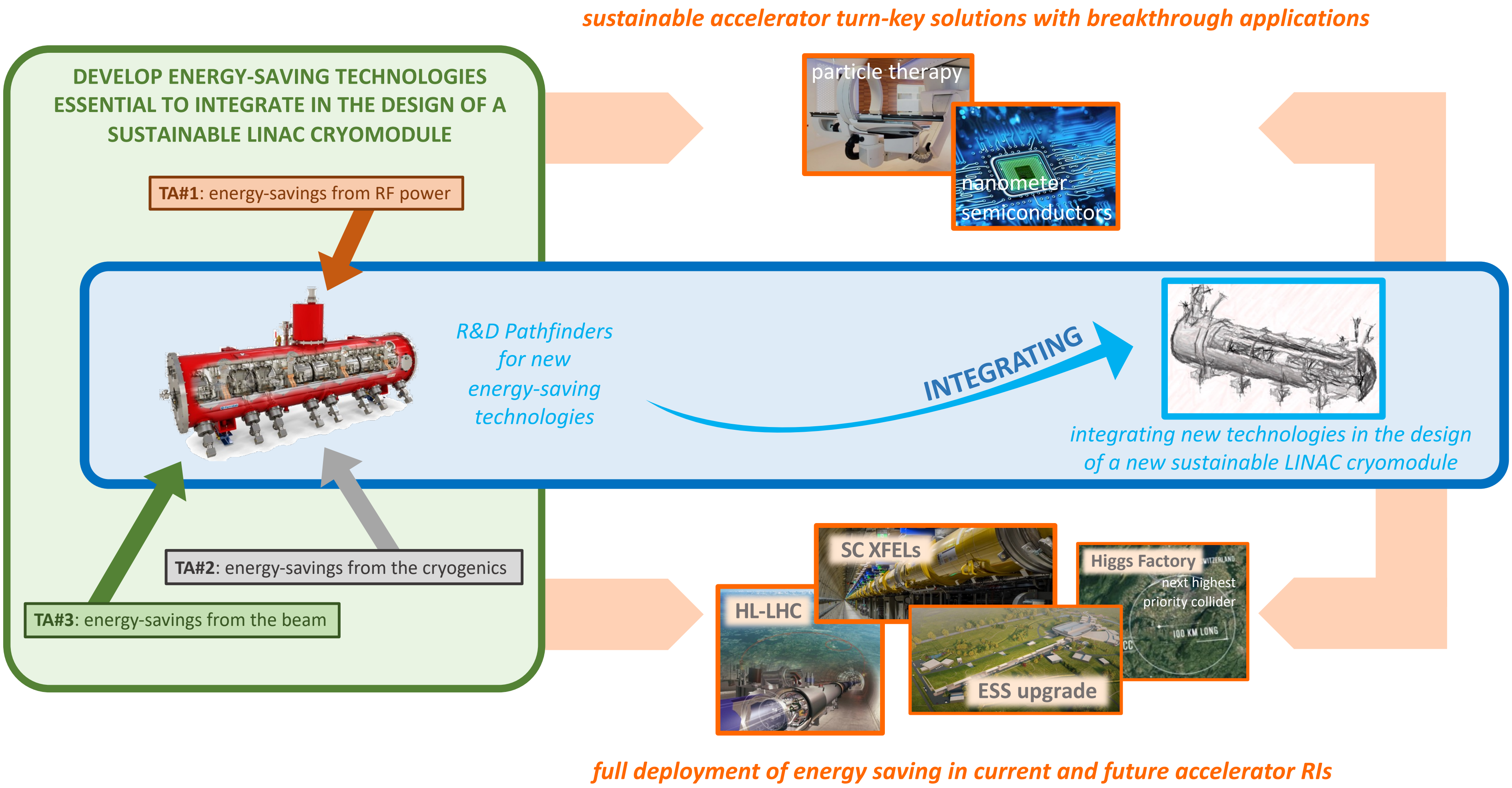
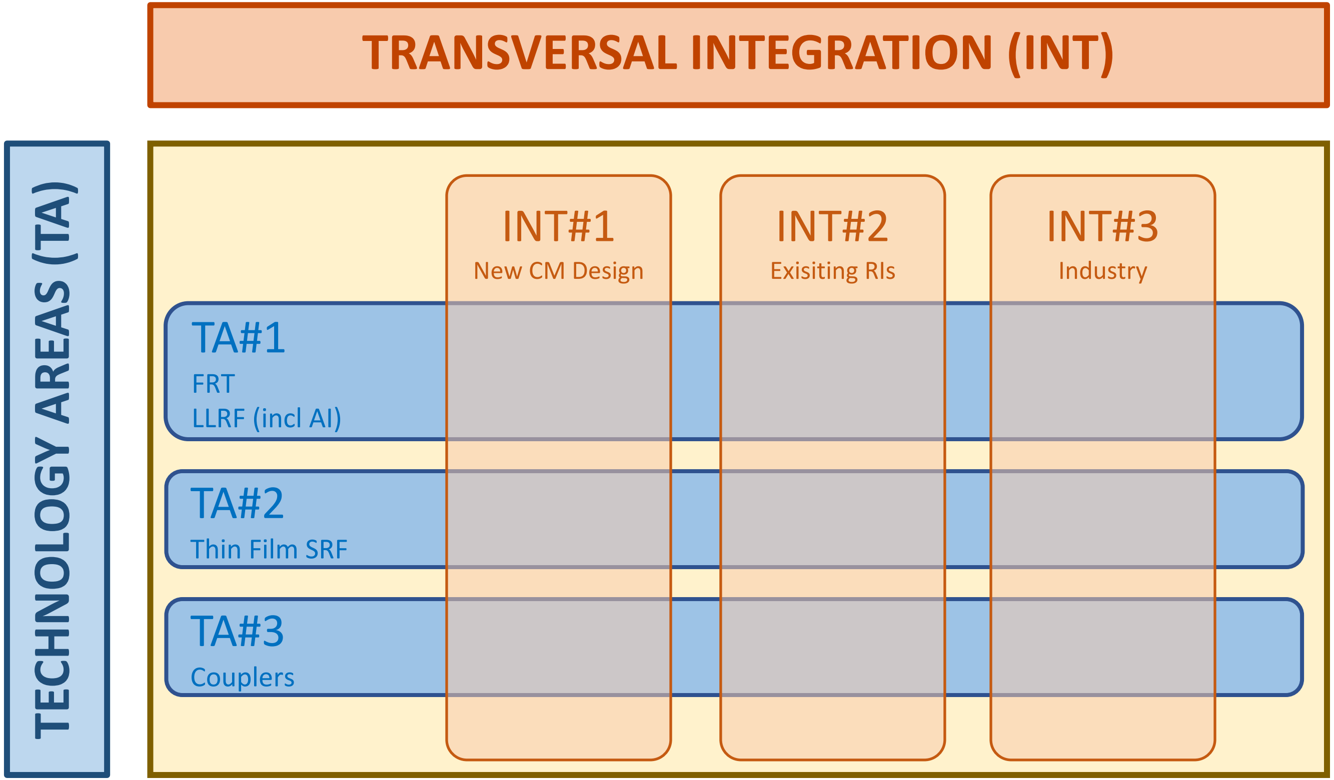


TA: Technology Area

"Innovate for Sustainable Accelerating Systems" (iSAS) – *concrete Work Packages*

- **R&D Pathfinders for three Technology Areas (TA) for energy-saving**
  - **TA#1: energy savings from the RF power** *(short-term and very wide applications)*
    - *WP.1: optimal integration of Fast Reactive Tuners to deal with microphonics (400, 800 and 1300 MHz)*
    - *WP.2: LLRF controls (incl. AI)*
  - **TA#2: energy savings from the cryogenics** *(medium-term and wide applications)*
    - *WP.3: high-temperature SRF cavities (thin films (e.g., Nb_3Sn) on Cu)*
  - **TA#3: energy savings from the beam** *(long-term and specific applications)*
    - *WP.4: Higher-Order Mode damping and fundamental couplers*
- **INT#1: integrate these technologies into the design of a sustainable LINAC cryomodule**
  - *WP.5: based on the ESS cryomodules, develop a parametric design for an optimally sustainable LINAC cryomodule, ready to be adapted and built for various applications in industry and in accelerator RIs*
- **INT#2: integrate these technologies into existing LINAC cryomodules at RIs**
  - *WP.6: engineering aspects to integrate and test energy-saving FRT, HOM and fundamental couplers technologies in existing structures at RIs, with a focus on ESS, HL-LHC, EU XFEL (i.e., addressing directly the scope of this Horizon Europe call)*
- **INT#3: integrate into turn-key solutions and revolutionising applications in industry**
  - *WP.7: prepare the co-developments with industrial partners such that when the new technologies and the new designed LINAC cryomodule are developed and validated their Technology Readiness Level is sufficient such that industry can consider building them*

“Innovate for Sustainable Accelerating Systems” (iSAS) – *cross coordination*



“Innovate for Sustainable Accelerating Systems” (iSAS) – *concrete tasks*

TECHNOLOGY AREAS

DRAFT VERSION
Please send me potential updates

WP.1: Fast Reactive Tuners (lead HZB)
Task 1.1: Coordination – HZB
Task 1.2: FRT for Transient Beam loading – CERN, Uni Lancaster, HZB
Task 1.3: FRT for microphonics – HZB, Uni Lancaster, CERN
Task 1.4: FRT in ERL mode – IJCLab, HZB, Uni Lancaster, ESS

WP.2: LLRF controls, including AI (lead DESY)
Task 2.1: Coordination – DESY
Task 2.2: Charactarize microphonics for LLRF controls – HZB, DESY
Task 2.3: LLRF controls based on mechanical tuners – HZB, DESY
Task 2.4: LLRF controls baed on FE FRT – HZB, DESY
Task 2.5: Integrate controls with AI – HZB, DESY

WP.3: Thin Films for High-Temperature SRF cavities (lead INFN)
Task 3.1: Coordination – INFN
Task 3.2: Develop and validate a new SRF cavity @ 4.2K – STFC, INFN, HZB, CEA
Task 3.3: RF Tunability – HZB, STFC, INFN, CEA
Task 3.4: Flux Trapping – STFC, HZB, STFC, CEA
Task 3.5: Adaptive Layer – CEA, HZB, STFC, INFN

WP.4: HOM Damping and fundamental power couplers (lead CNRS)
Task 4.1: Coordination – CNRS
Task 4.2: Design and prototyping of HOM dampers and fundamental RF couplers – IJCLab, CERN, INFN
Task 4.3: Conditioning, testing and validation of the HOM dampers and fundamental RF couplers – CERN, IJCLab

“Innovate for Sustainable Accelerating Systems” (iSAS) – *concrete tasks*

DRAFT VERSION
Please send me potential updates

INTEGRATION

WP.5: Integrate into the design of a sustainable LINAC cryomodule (lead ESS)
Task 5.1: Coordination – ESS
Task 5.2: Parametric design of a new LINAC cryomodule including energy saving technologies – ESS, IJCLab, CERN

WP.6: Integrate into existing LINAC cryomodules at RIs (lead IJCLab)
Task 6.1: Coordination – IJCLab
Task 6.2: Retrofitting FRT into exisiting cryomodules HL-LHC oriented – Uni Lancaster, CERN
Task 6.3: Adapt the existing ESS cryomodule – IJCLab, ESS, CEA
Task 6.4: Fabrication and validation of components – IJCLab, INFN
Task 6.5: Assembly and test of adapted cryomodules – IJCLab, CEA, ESS

WP.7: Integrate into industrial applications (lead INFN)
Task 8.1: Coordination – INFN
Task 8.2: Dissemination and co-development of technological solutions to industry – INFN, …

"Innovate for Sustainable Accelerating Systems" (iSAS) – *concrete tasks*

DRAFT VERSION
Please send me potential updates

WP.8: Societal aspects (lead IJCLab)

Task 9.1: Coordination – IJCLab
Task 9.2: Training and Early Career – …
Task 9.3: Outreach and Dissemination – …
Task 9.4: Diversity and Equity – …
Task 9.5: Open Science – …

WP.9: Coordination & Management (lead IJCLab)

Task 10.1: Project Coordination and Management Office – IJCLab
Task 10.2: Scientific Coordination – Uni Brussels, INFN, HZB, IJCLab
Task 10.3: Internal communication and Collaboration – IJCLab, STFC
Task 10.4: Relations with other projects in the accelerator landscape – IJCLab, Uni Brussels, INFN, HZB, STFC

“Innovate for Sustainable Accelerating Systems” (iSAS) – *overall budget*

WP	Subject	kEUR
	Energy Savings	
WP.1	FRT	793
WP.2	LLRF	400
WP.3	thin SC films	700
WP.4	HOM and fundamental couplers	400
	TOTAL FOR iSAS Technology R&D	2293
	Intgration	
WP.5	into new design of a sustainable CM	50
WP.6	into existing accelerator-driven RIs	1457
WP.7	into new accelerator-driven RIs	
WP.8	into industrial applications	40
	TOTAL FOR iSAS Integration WPs	1547
WP.9	Societal aspects	40
WP.10	Coordination & Collaboration & Management	120
TOTAL		**4000**

WP coordinators will receive an email from Julie Gendron (CNRS) to update some concrete financial tables with a view to provide all relevant information into the Horizon Europe portal for application.

Status 17 Febr 2023 – DYNAMIC WORK DOCUMENT