ERLS FOR THE FUTURE

Acknowledgments:

Big thank to Jorgen D'Hondt (Vrije Universiteit Brussel), who prepared most of the slides!

Oliver Brüning (CERN) and Peter Williams (STFC)

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OUTLINE

THE BIGGER PICTURE

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SCALES AND NUMBERS

observable universe
8.8 10^{26}m

quarks
< 10^{-19}m

~ 1˙000˙000˙000˙000˙000˙000˙000˙000˙000 meter

~ 0.000˙000˙000˙000˙000˙000˙01 meter

distance to galactic center

distance light travels in one year

farthest human object from Earth (Voyager 1)

distance Earth-sun

biological cell

atoms

proton neutron

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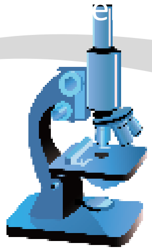
SCALES AND NUMBERS

observable universe
8.8 10^{26}m

visible with our own eyes



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SCALES AND NUMBERS

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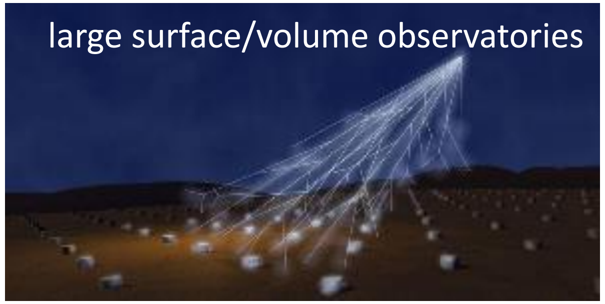

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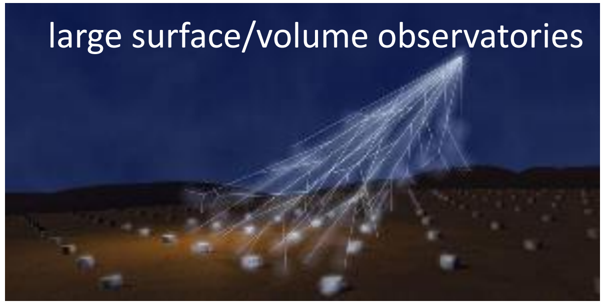
SCALES AND NUMBERS

age universe
4.4 10^{18} s

observable universe
8.8 10^{26}m



visible with our own eyes

quarks
< 10^{-19}m

lifetime top quark
5 10^{-25} s

~ 1˙000˙000˙000˙000˙000˙000˙000˙000˙000 meter

~ 0.000˙000˙000˙000˙000˙000˙01 meter

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farthest human object from Earth (Voyager 1)

distance Earth-sun

biological cell

atoms

proton
neutron

lifetime star
10^{13}-10^{16} s

duration supernova & GRB
0.1-100 s

lifetime proton
> 3 10^{41} s

lifetime kaon ($K^{\pm}$)
1.2 10^{-8} s

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MODEL TO DESCRIBE HOW OBJECTS BEHAVE IN SPACE AND TIME

Jorgen D'Hondt

Basic Principles

FROM INTUITION

e.g. the locality principle:
all matter has the same set of constituents

e.g. the causality principle:
a future state depends only on the present state

e.g. the invariance principle:
space-time is homogeneous

FROM LONG-STANDING OBSERVATIONS

the wave-particle duality principle
the quantisation principle
the cosmological principle
the constant speed of light principle
the uncertainty principle
the equivalence principle

no obvious reason for these long-standing observations to be what they are…

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MODEL TO DESCRIBE HOW OBJECTS BEHAVE IN SPACE AND TIME

Jorgen D'Hondt

Basic Principles → **Fundamental Theories**

MATHEMATICAL FRAMEWORKS HOW OBJECTS BEHAVE

① ***General Relativity*** *(for gravity)*

② ***Quantum Mechanics + Special Relativity = Quantum Field Theory***
(for electromagnetic, weak and strong forces)

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MODEL TO DESCRIBE HOW OBJECTS BEHAVE IN SPACE AND TIME

Jorgen D'Hondt

Basic Principles → Fundamental Theories → Concrete Models

MATHEMATICAL FRAMEWORKS HOW OBJECTS BEHAVE

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} *no obvious reason for these long-standing observations to be what they are…*

APPLY MATHEMATICAL FRAMEWORKS ON OBJECTS

① *General Relativity →* ***Standard Model of Cosmology***

② *Quantum Field Theory →* ***Standard Model of Particle Physics***

need to be valid into even the tiniest cracks of space and time and for all energies or masses of the objects… even at the extremes

A CENTURY OF SCIENTIFIC REVOLUTIONS

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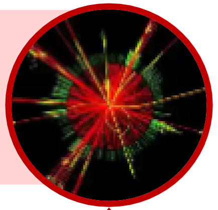
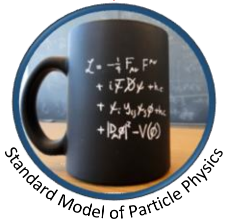
~ 1˙000˙000˙000˙000˙000˙000˙000˙000˙000 meter

~ 0.000˙000˙000˙000˙000˙000˙01 meter

observations how small objects behave in our laboratories





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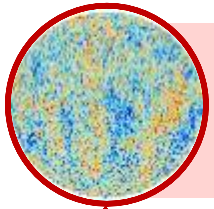
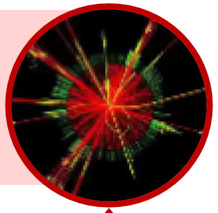


observations how large objects behave in our universe

Standard Model of Cosmology



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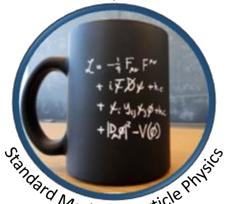

Standard Model of Particle Physics

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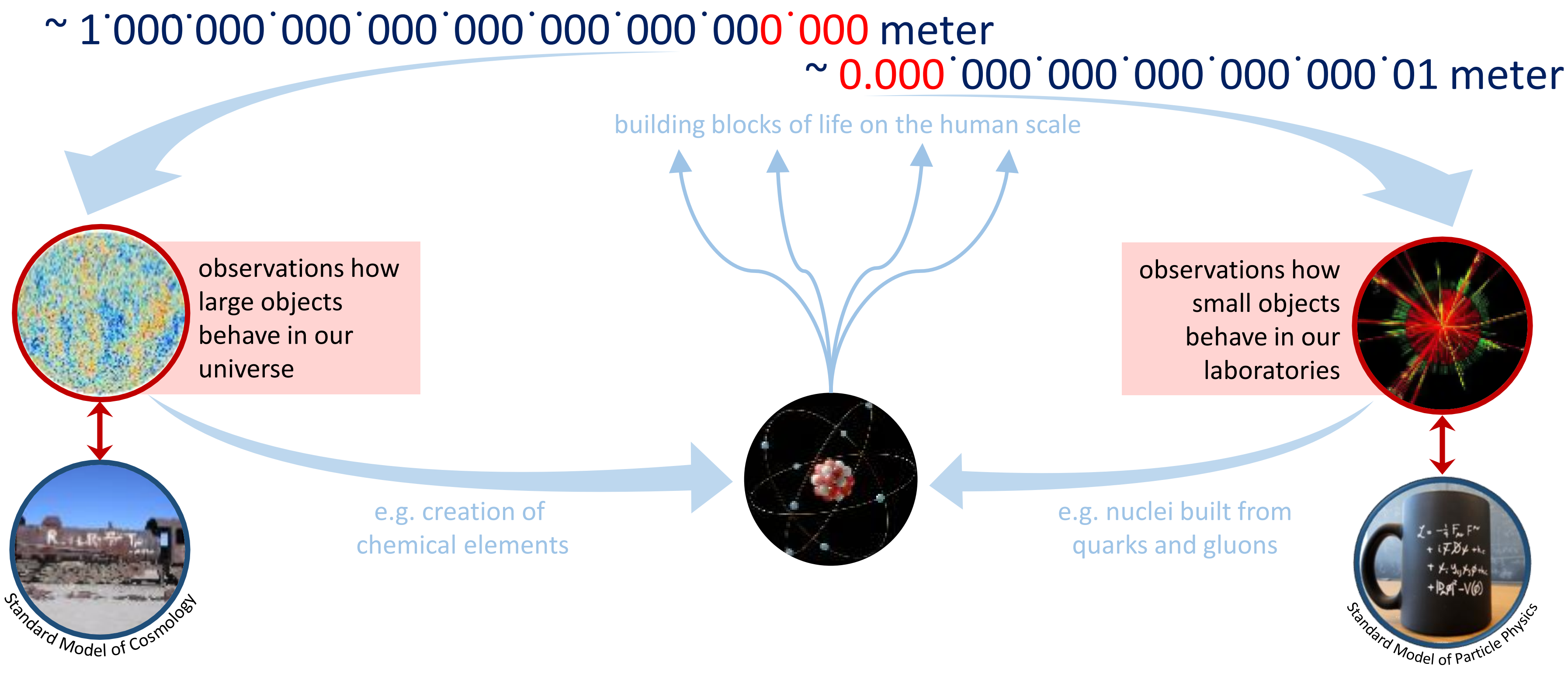

A CENTURY OF SCIENTIFIC REVOLUTIONS

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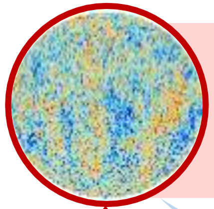
communication
satellites
GPS

World Wide Web
touchscreens

~ 1˙000˙000˙000˙000˙000˙000˙000˙000˙000 meter

~ 0.000˙000˙000˙000˙000˙000˙01 meter

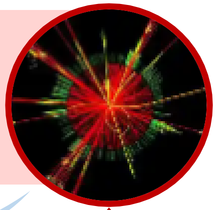
building blocks of life on the human scale



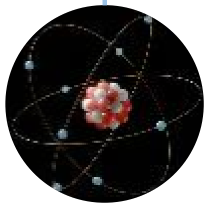
observations how large objects behave in our universe

production of particles and radiation
nuclear diagnosis and medicine

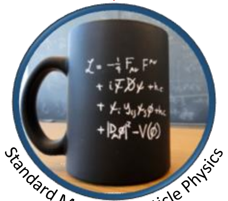
observations how small objects behave in our laboratories



e.g. creation of chemical elements



e.g. nuclei built from quarks and gluons



"Scientific curiosity which ends up in your pocket"

Rolf Heuer (previous Director General of CERN)

THE QUEST FOR UNDERSTANDING PHYSICS

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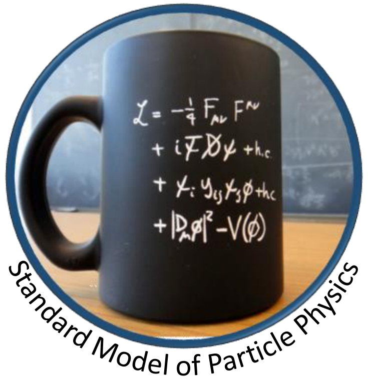
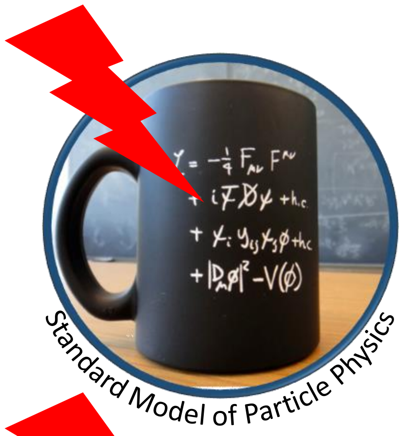


"Problems and Mysteries"

e.g. Abundance of dark matter?
Abundance of matter over antimatter?
What is the origin and engine for high-energy cosmic particles?
Dark energy for an accelerated expansion of the universe?
What caused (and stopped) inflation in the early universe?
Scale of things (why do the numbers miraculously match)?
Pattern of particle masses and mixings?
Dynamics of Electro-Weak symmetry breaking?
How do quarks and gluons give rise to properties of nuclei?...

THE QUEST FOR UNDERSTANDING PHYSICS

Jorgen D'Hondt



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How do quarks and gluons give rise to properties of nuclei?...

Observations of new physics phenomena and/or deviations from the Standard Models are expected to unlock concrete ways to address these puzzling unknowns

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INNOVATIVE TECHNOLOGY

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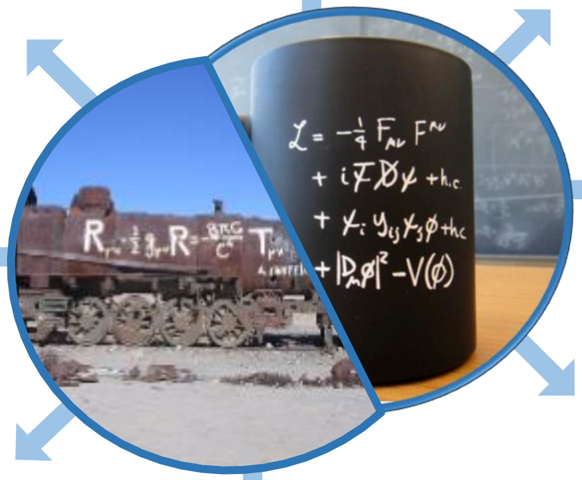
higher energy interactions
in the lab

earlier universe

rarer processes



higher precision

different
observations of the
same phenomenon

higher energetic phenomena
in the universe

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INNOVATIVE TECHNOLOGY

RF cavities, high-field magnets, plasma wakefield acceleration

higher energy interactions in the lab

squeezed-light sources to deal with quantum noise in gravitational-wave detectors

earlier universe

solid-state devices with fast read-out electronics

rarer processes

higher precision

different observations of the same phenomenon

higher energetic phenomena in the universe

computing and software challenge for Multi-Exabyte Data Infrastructures

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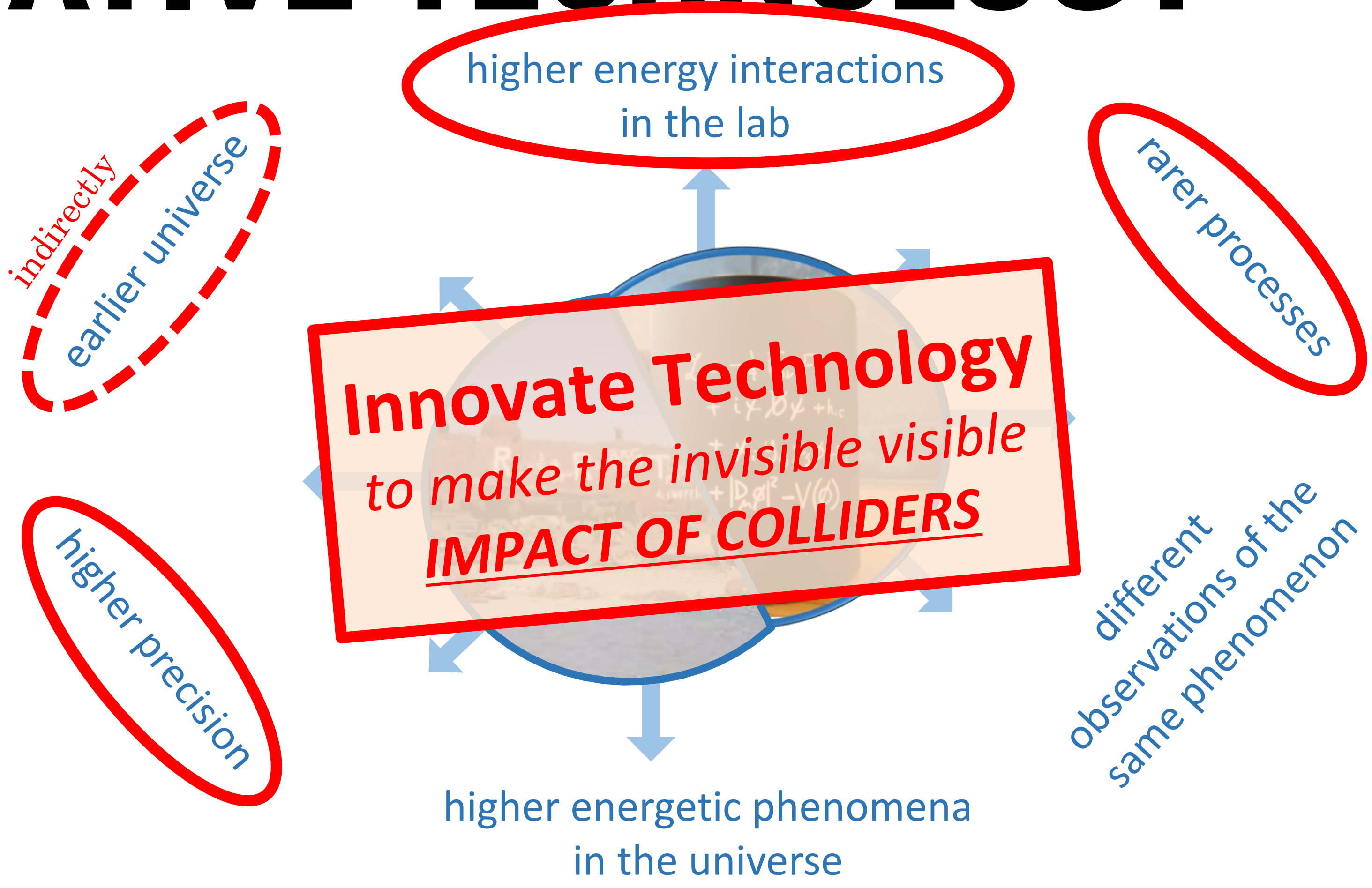
INNOVATIVE TECHNOLOGY



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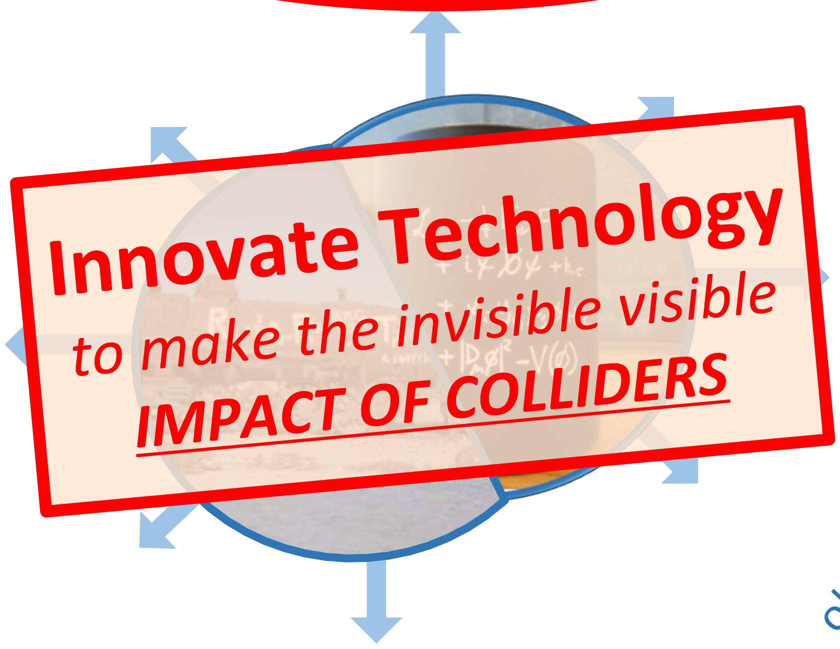
INNOVATIVE TECHNOLOGY

higher energy interactions
in the lab

indirectly
earlier universe

rarer processes



Innovate Technology

to make the invisible visible

IMPACT OF COLLIDERS

higher precision

different
observations of the
same phenomenon

higher energetic phenomena
in the universe

Particle beams required at high energy and high current = high power

!! ENERGY CONSUMPTION !!

POWER BALANCE AND IMPACT ON DESIGN

BASIC STRUCTURES OF A PARTICLE ACCELERATOR

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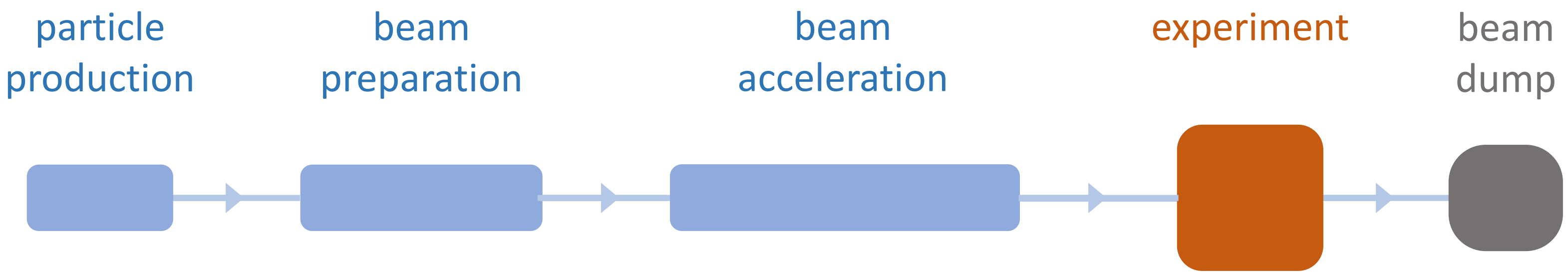

BASIC STRUCTURES OF A PARTICLE ACCELERATOR

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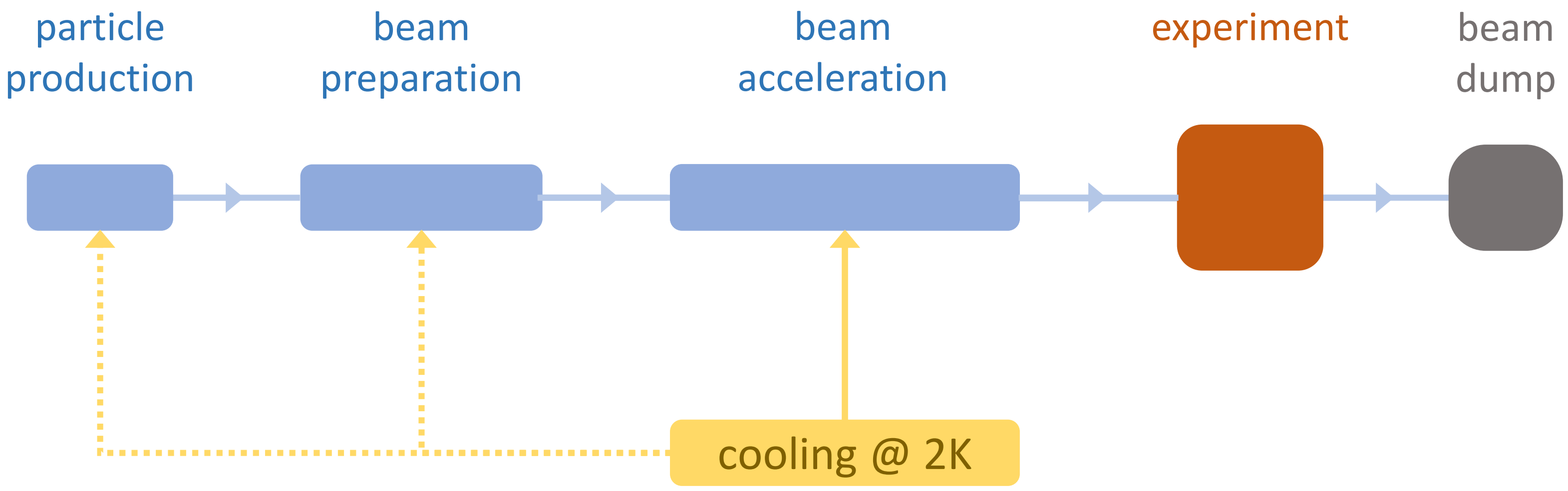

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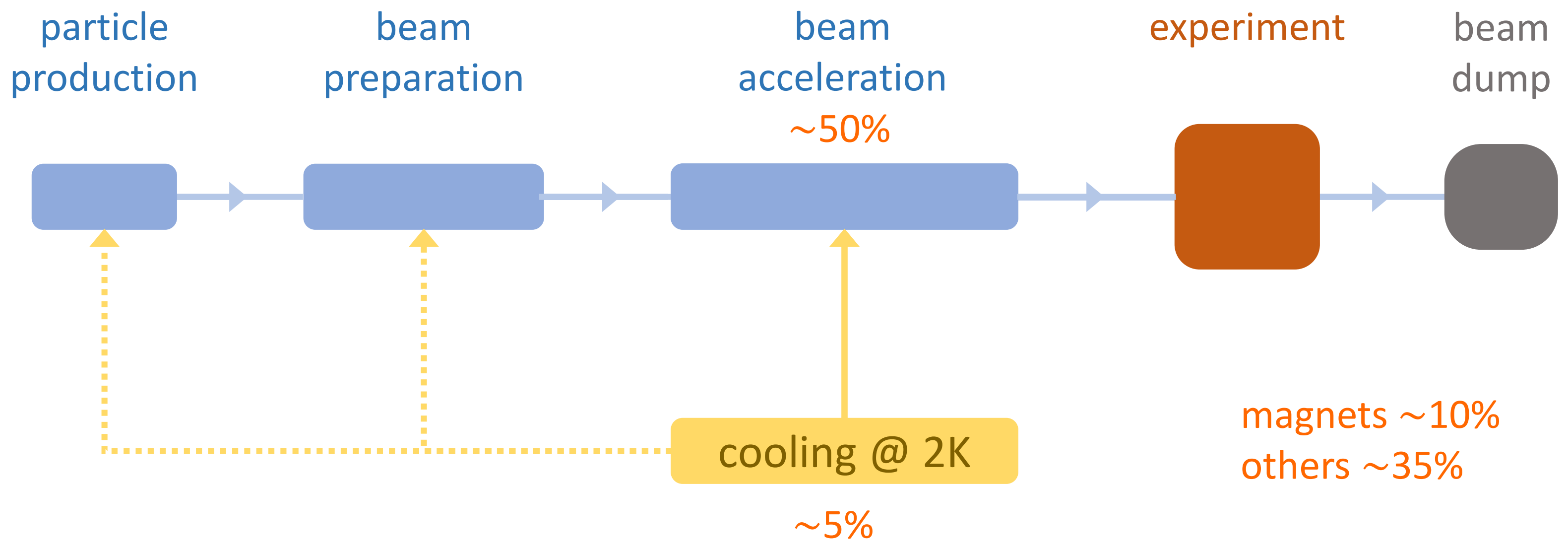

example FCC@250GeV

Typical power consumption for an electron-positron Higgs Factory

the highest priority next collider for particle physics

BASIC STRUCTURES OF A PARTICLE ACCELERATOR

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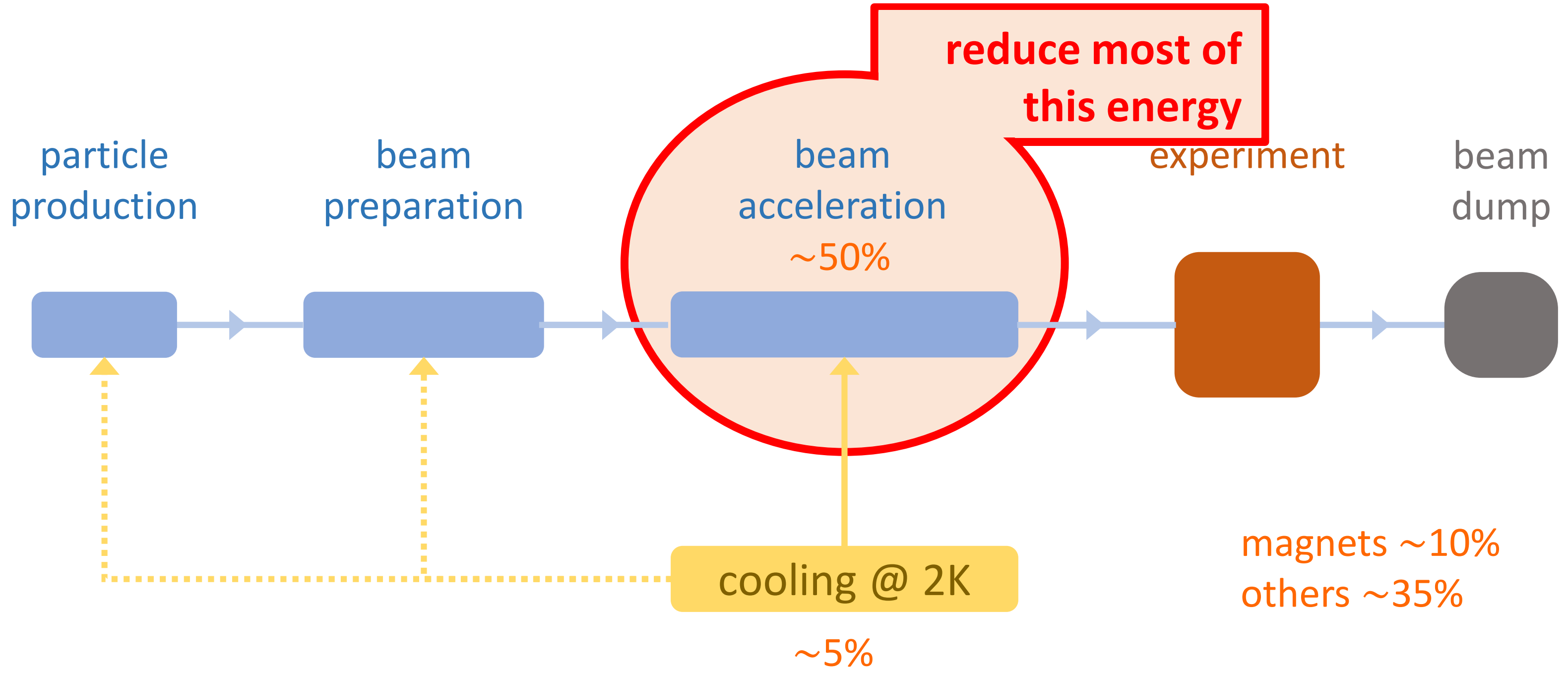

example FCC@250GeV

Typical power consumption for an electron-positron Higgs Factory

the highest priority next collider for particle physics

IMPACT FOR THE CURRENT DESIGNS OF HIGGS FACTORIES

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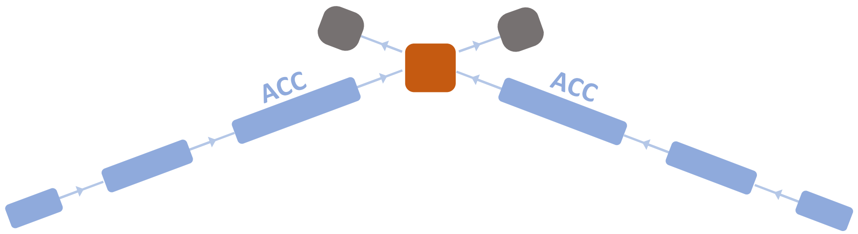
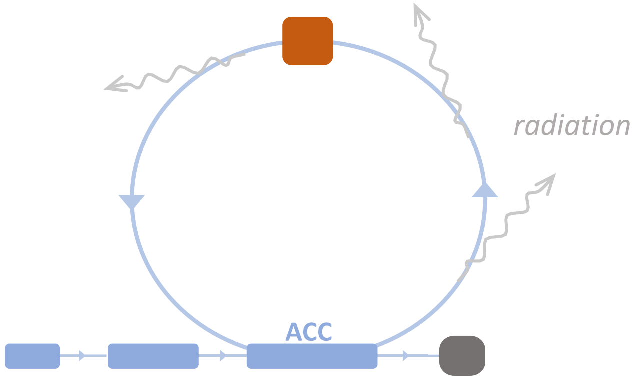
Linear colliders



Circular colliders



dump >99.9999% of the beam power

FCC-ee@250 ≃ 300 MW

~2% of annual electricity consumption in Belgium

radiate away very quickly the beam power

about half of this is dumped or lost due to radiation

OBJECTIVE: develop new accelerating systems that save power with an impact of saving ~1% of Belgium's electricity

IMPACT FOR THE CURRENT DESIGNS OF HIGGS FACTORIES

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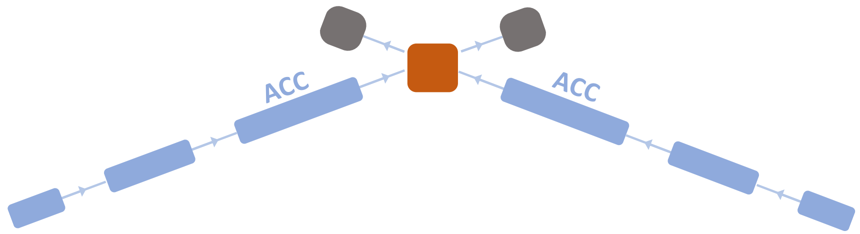
Linear colliders



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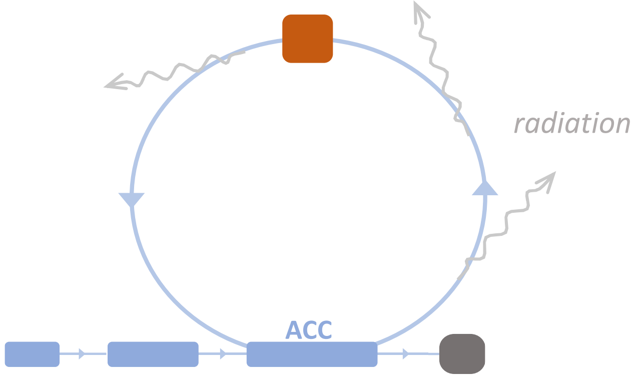

dump >99.9999% of the beam power

FCC-ee@250 ≃ 300 MW

~4% of annual electricity consumption in Belgium

radiate away very quickly the beam power

Energy consumption is reducing in Europe, not excluded with ½ by 2050-2060

about half of this is dumped or lost due to radiation

OBJECTIVE: develop new accelerating systems that save power with an **impact of saving ~2% of Belgium's electricity**

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OBJECTIVE

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

KEY BULIDING BLOCK FOR BEAM ACCELERATION: SRF CRYOMODULE

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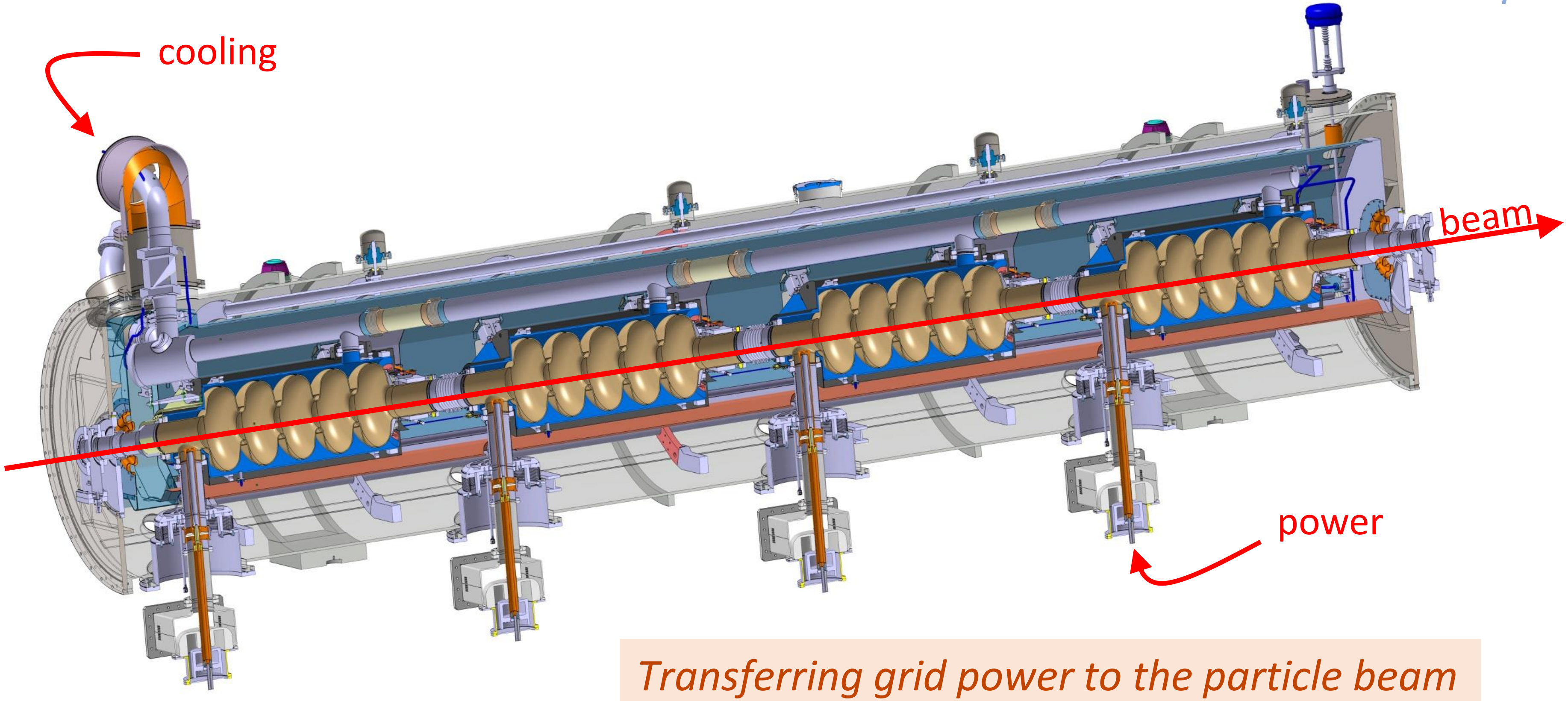
SRF: Superconducting Radio Frequency



Transferring grid power to the particle beam

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FROM GRID TO BEAM

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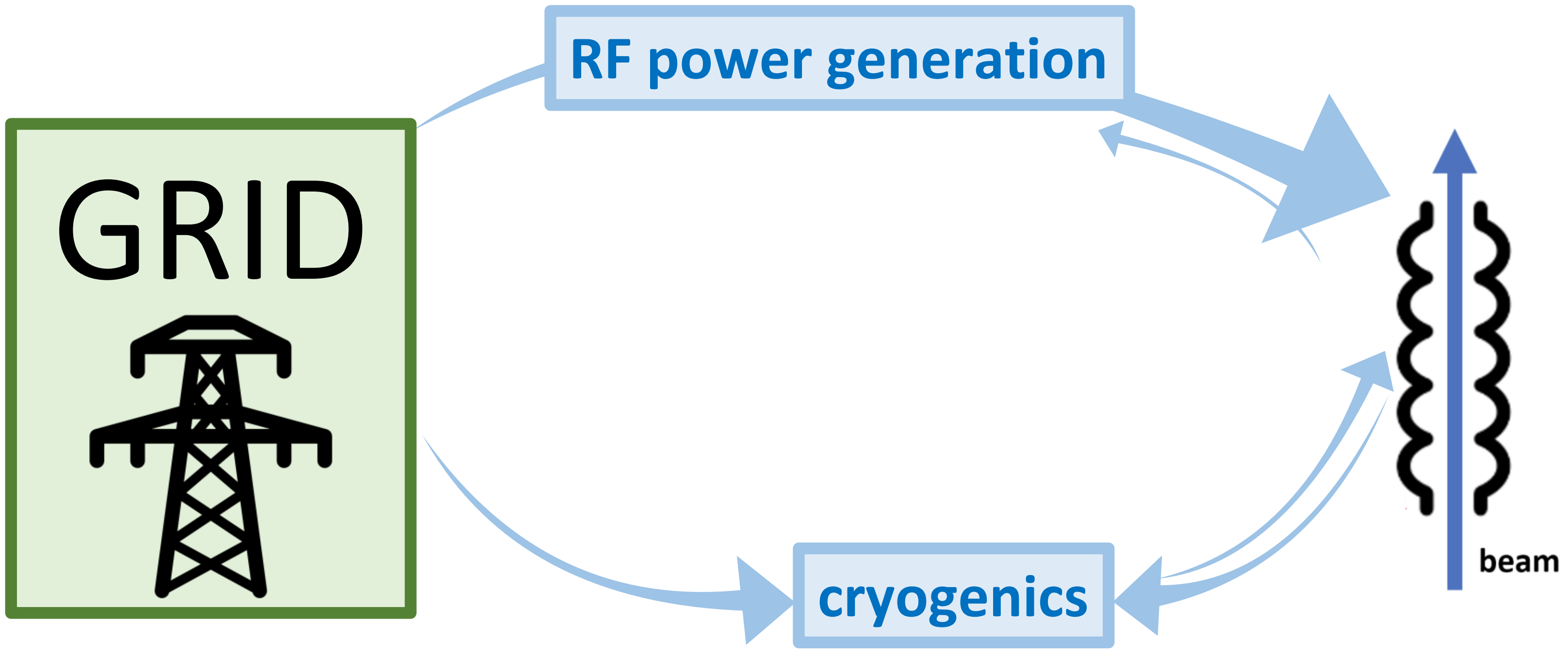

Picture adopted from M. Seidel (IPAC 2022)

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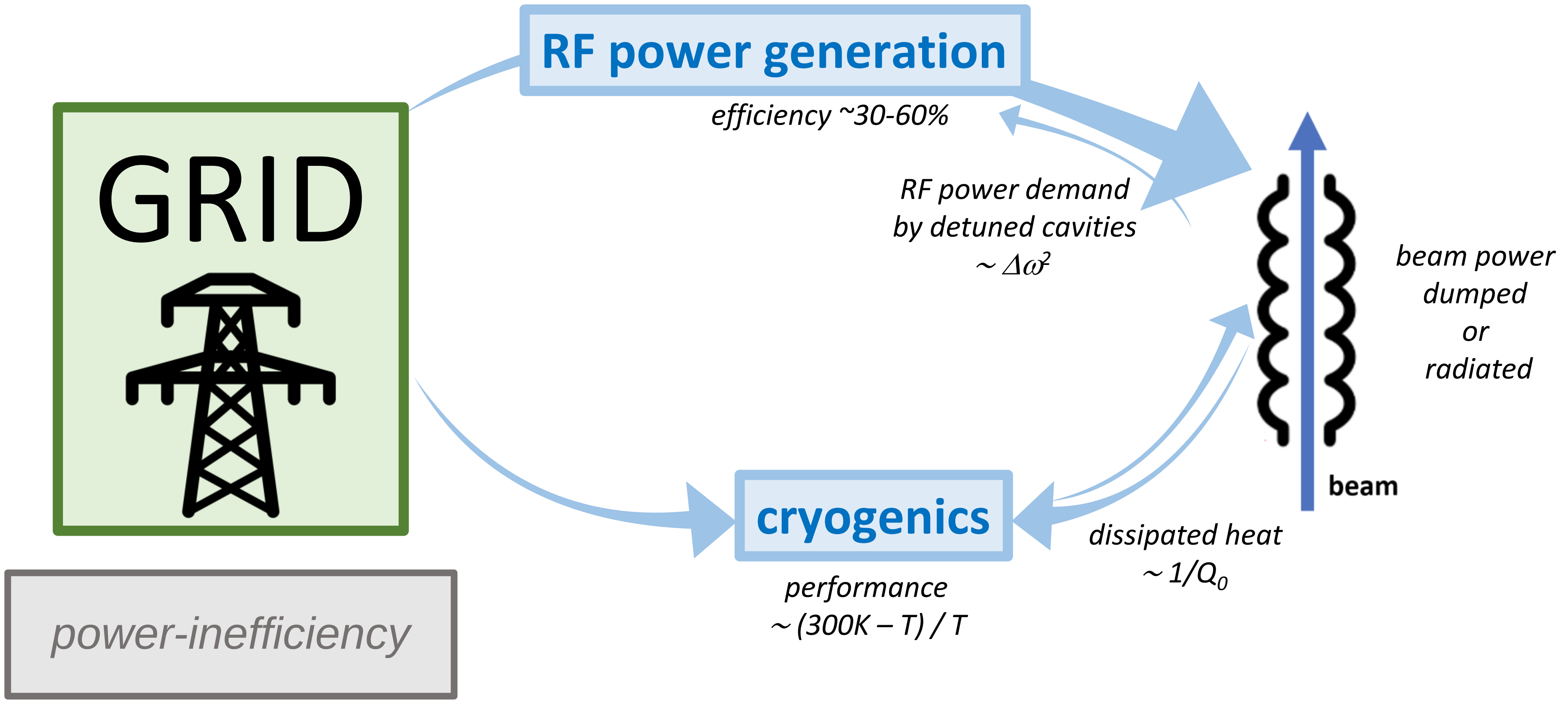
FROM GRID TO BEAM



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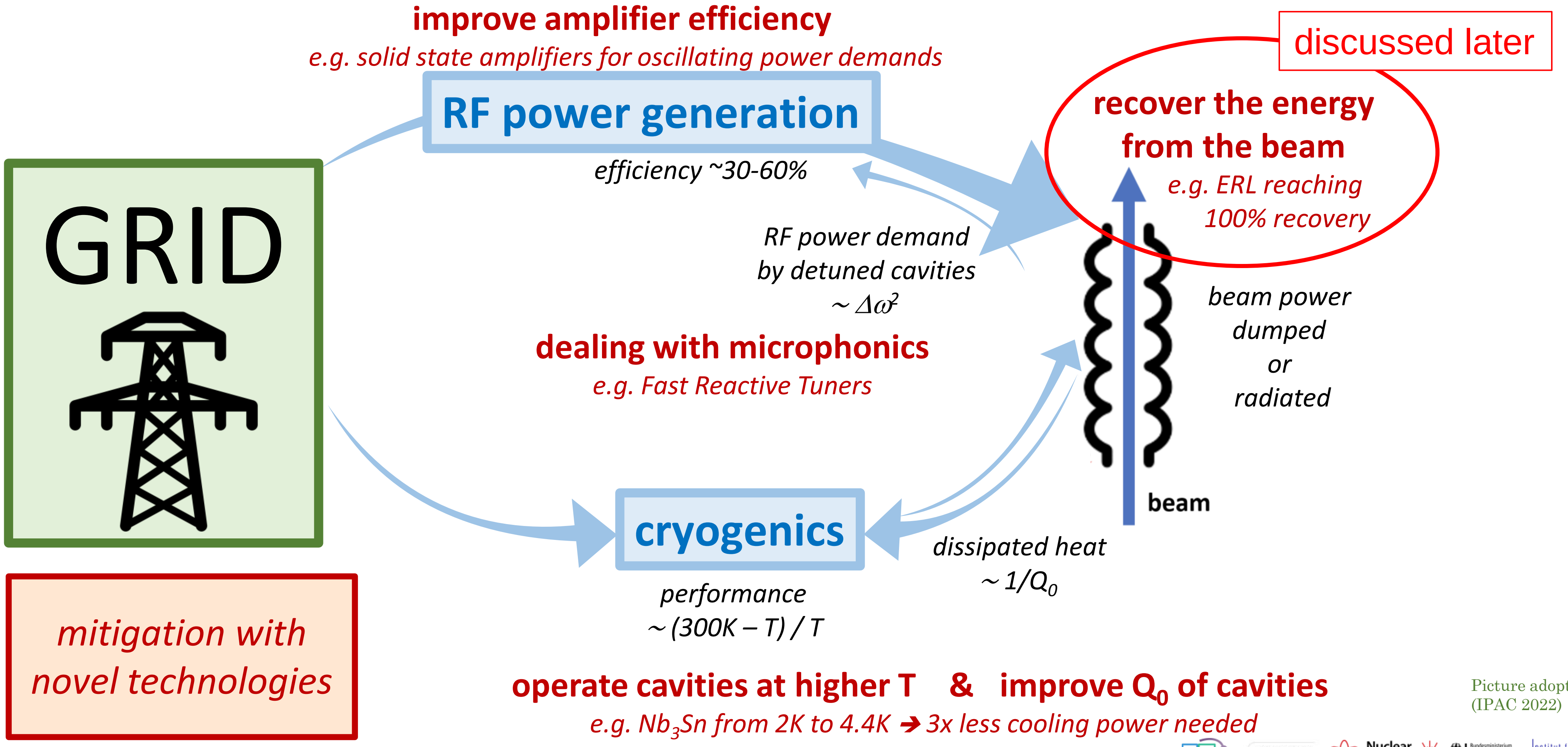

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FROM GRID TO BEAM

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

Thought for an overall R&D programme for "Sustainable Accelerating Systems"

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

e.g. 4.4K SRF in the ERL world is equivalent to HTS in the magnet world

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ALARA = **A**s **L**ow **A**s **R**easonable **A**chievable
principle enforced for nuclear safety,
also for energy consumption ?

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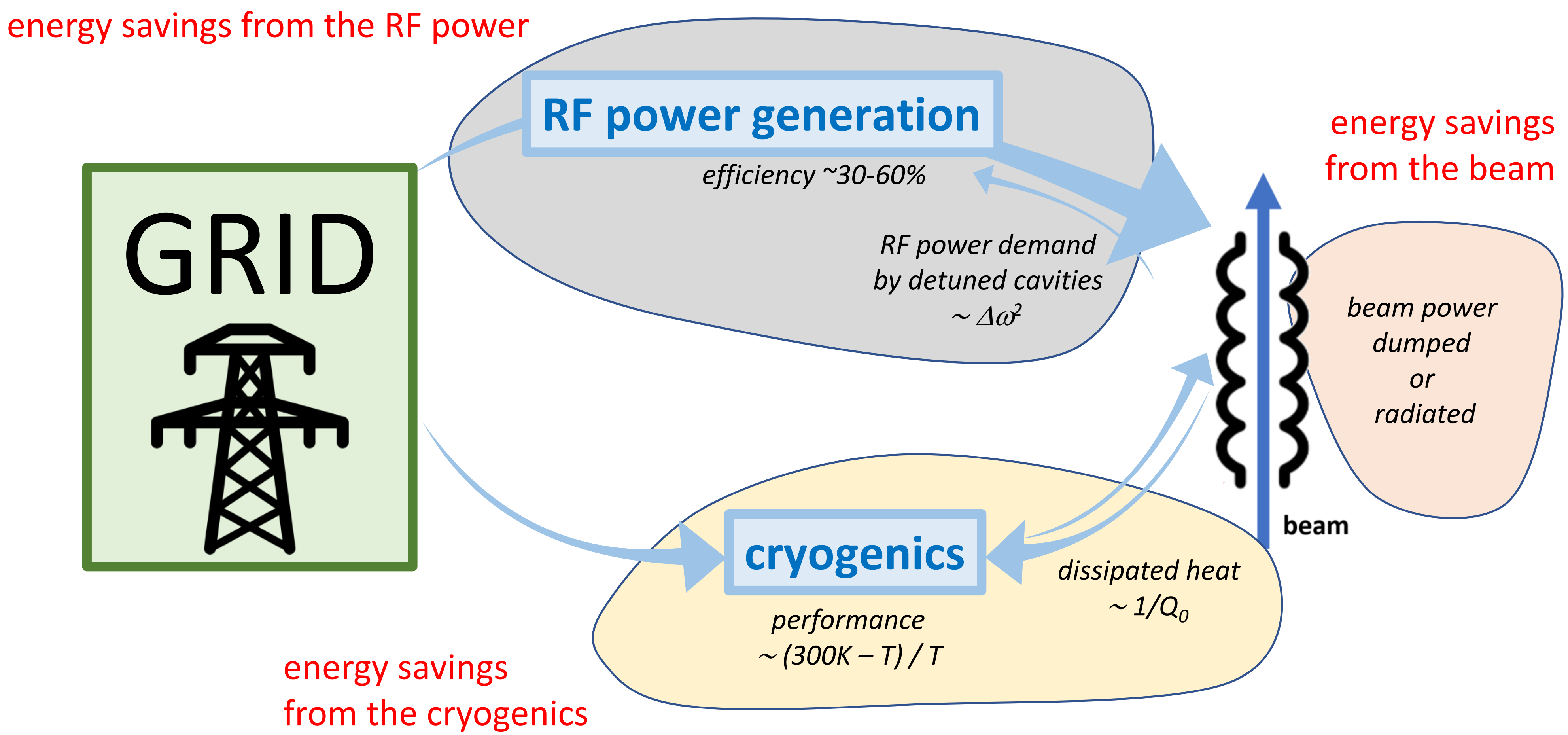
TREE MAIN INNOVATIVE DIRECTIONS



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TREE MAIN INNOVATIVE DIRECTIONS

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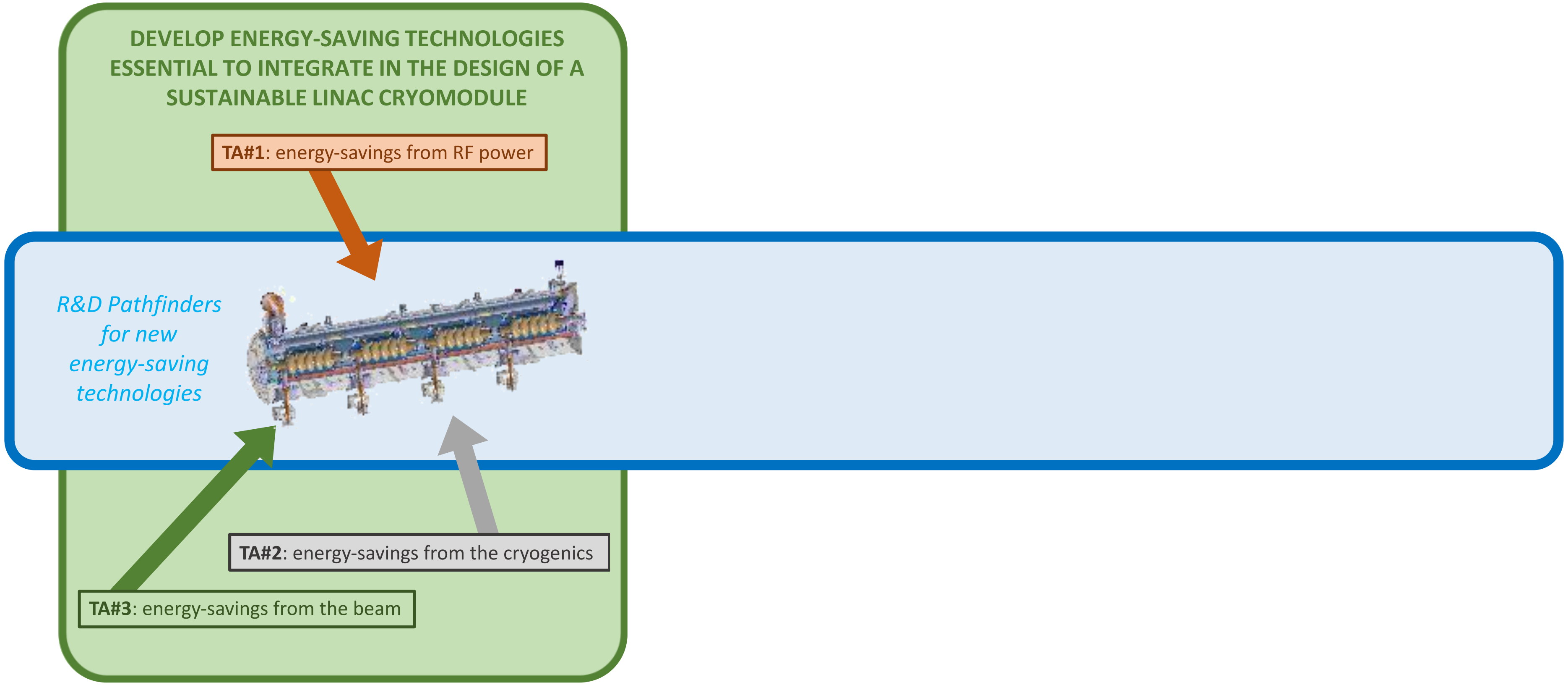

TA: Technology Area

TREE MAIN INNOVATIVE DIRECTIONS

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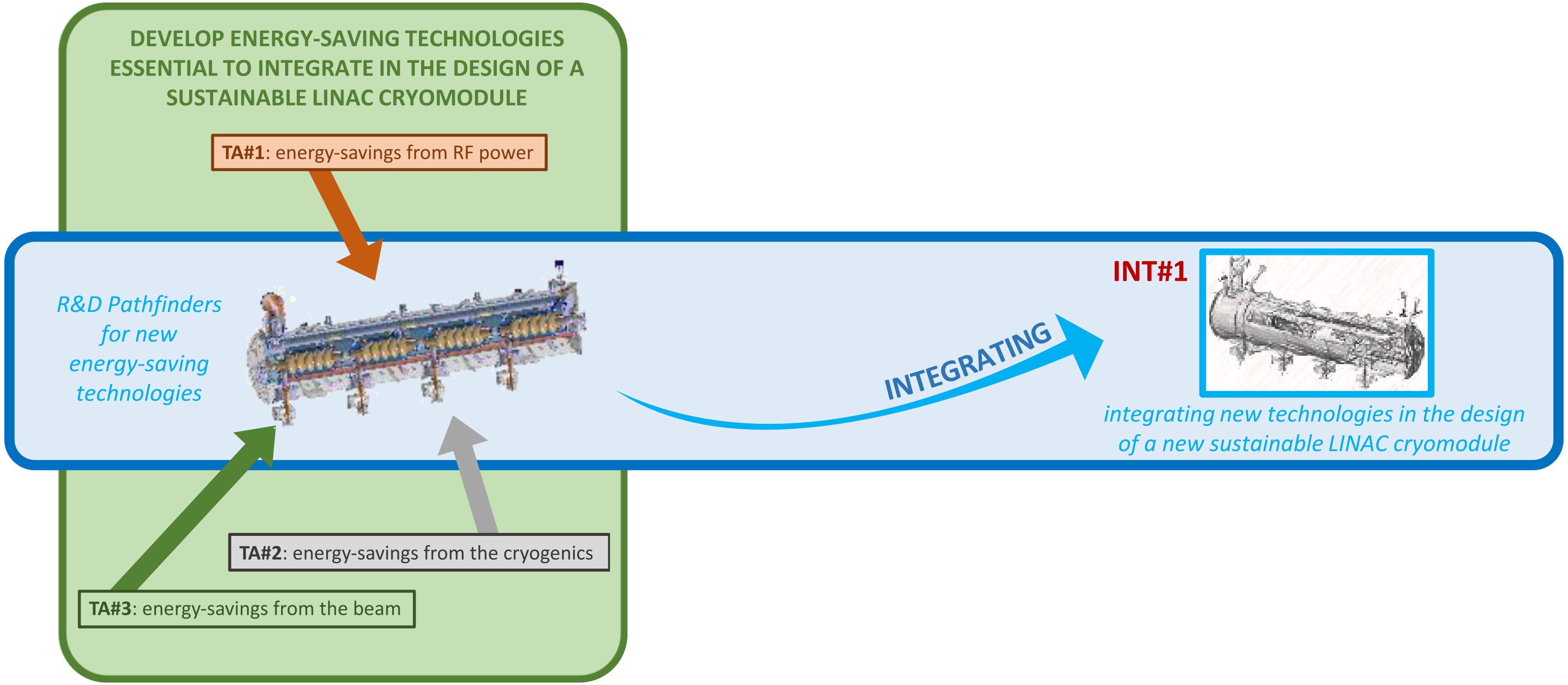

TA: Technology Area, INT: Integration Activities

TREE MAIN INNOVATIVE DIRECTIONS

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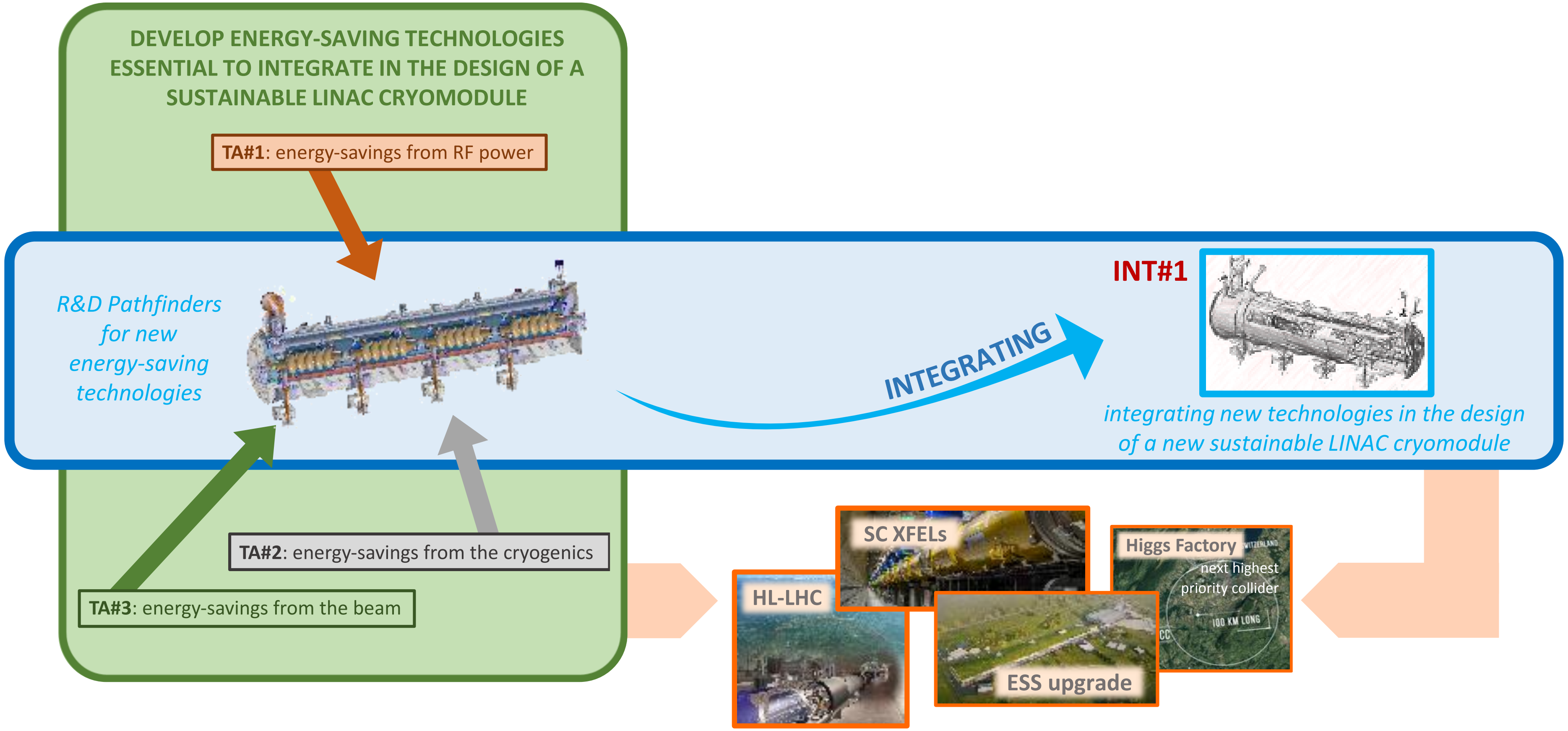

TA: Technology Area, INT: Integration Activities

INT#2: *full deployment of energy saving in current and future accelerator RIs*

RIs: Research Infrastructures

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TREE MAIN INNOVATIVE DIRECTIONS

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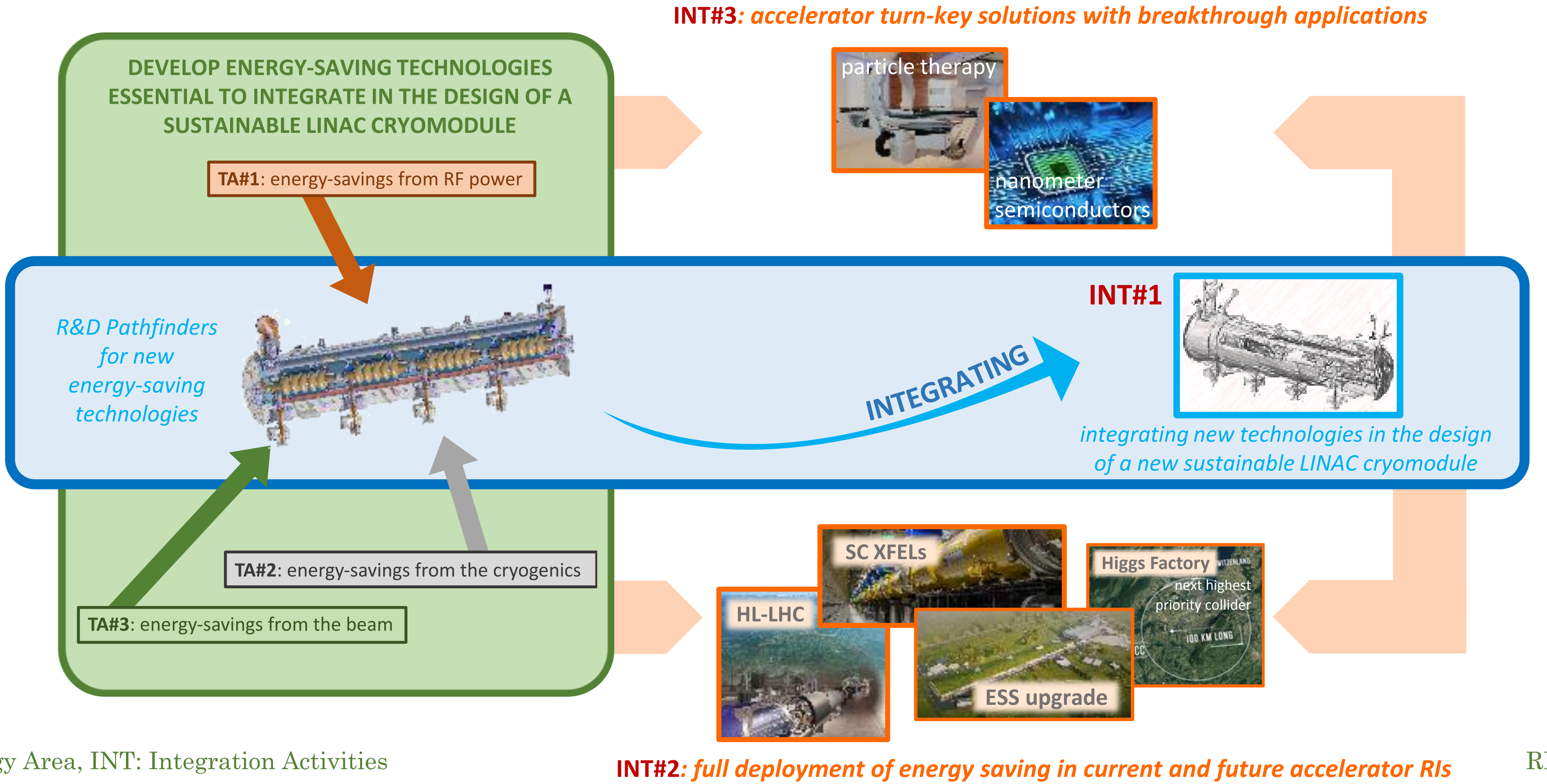

TA: Technology Area, INT: Integration Activities

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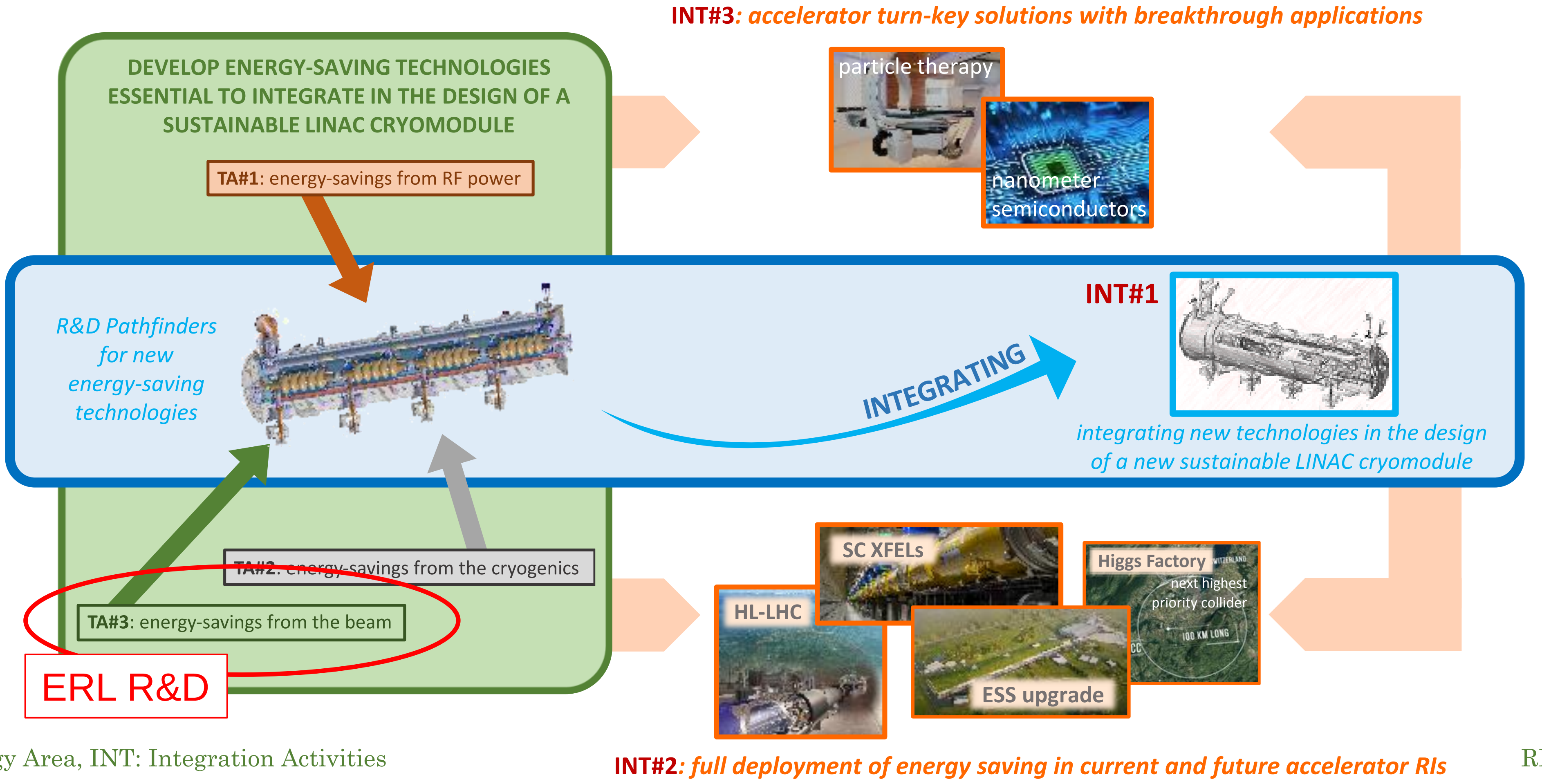

TA: Technology Area, INT: Integration Activities

RIs: Research Infrastructures

The ultimate microscope in hadronic matter:
a high-energy electron-hadron collider

EXAMPLE: AN ULTIMATE MICROSCOPE

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THE SCOPE

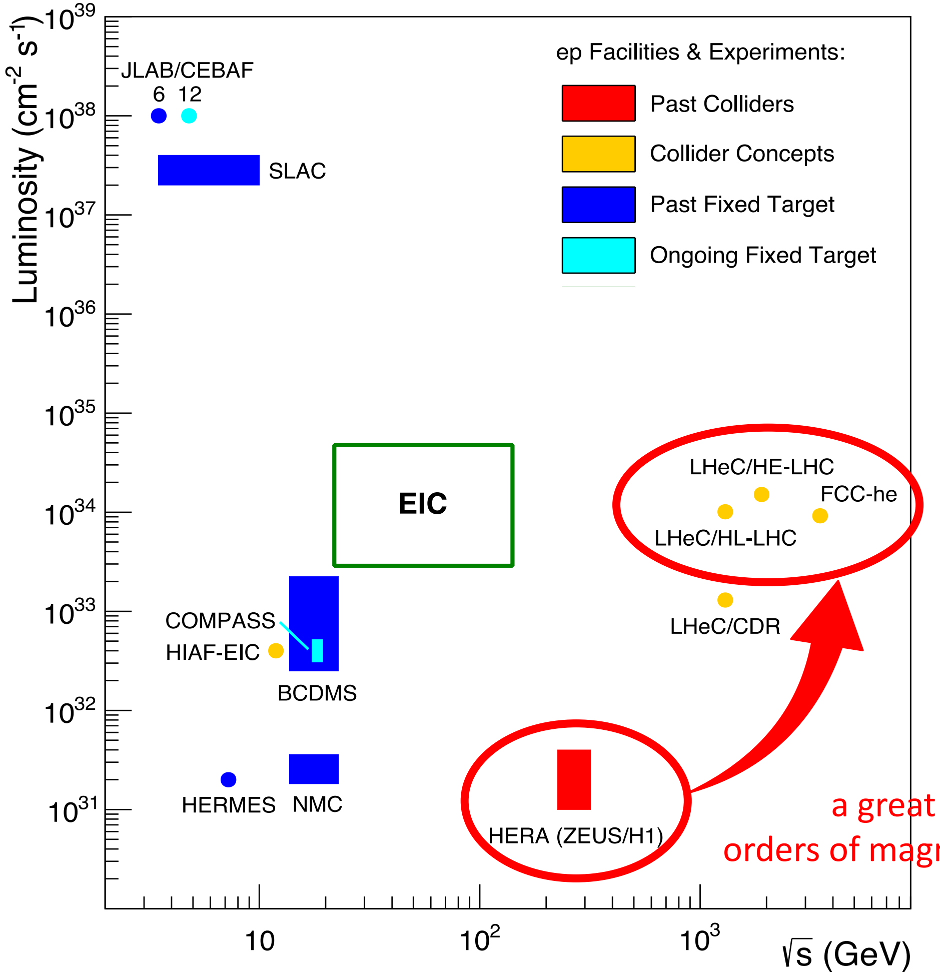
Jorgen D'Hondt

For ep/eA physics, the 2030'ies will be the decade of the EIC

The next ambition for the community will be to enable ep/eA physics both at higher luminosities and at higher energies

Jorgen D'Hondt: In my opinion, major advances in science are enabled either by reaching major steps with today's methods or by the development of major new methods

If we cannot make great strides into the unknown with current methods, we should concentrate on developing new methods



a great stride
orders of magnitude

A PARADIGM SHIFT: HIGH-ENERGY ELECTRON-PROTON COLLIDERS

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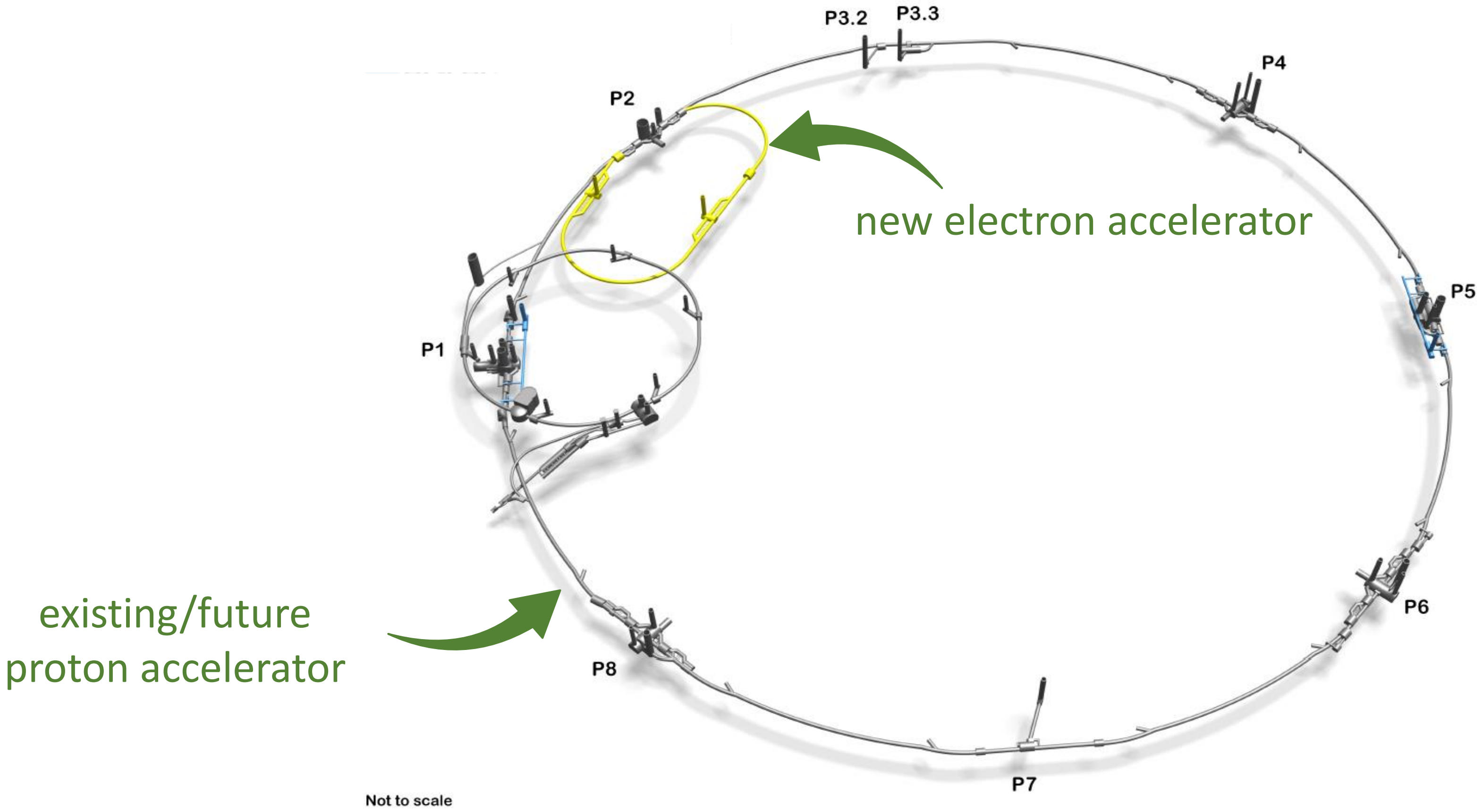
Jorgen D'Hondt



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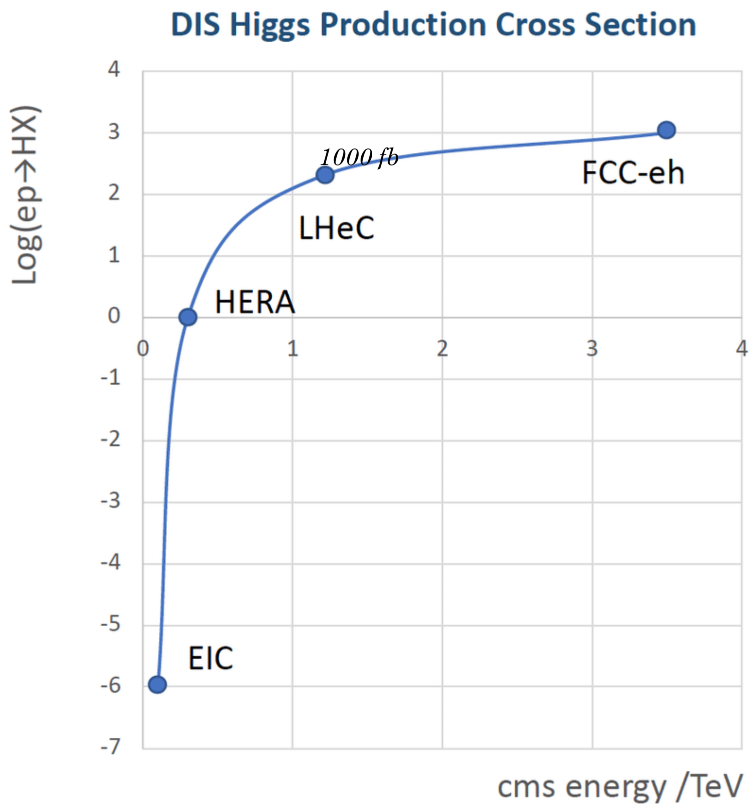
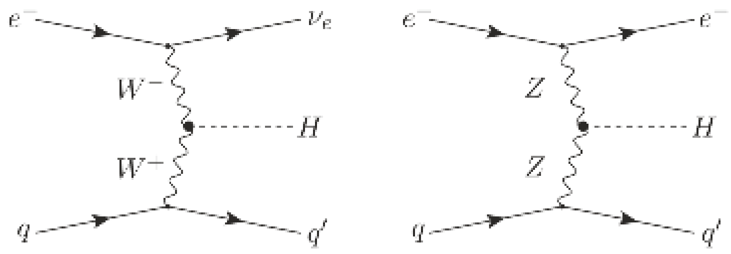
COLLISION ENERGY ABOVE THE THRESHOLD FOR EW/HIGGS/TOP

Jorgen D'Hondt

from mostly QCD-oriented physics to General-Purpose physics



The real game change between HERA and LHC/FCC



Compared to proton collisions, these are reasonably clean Higgs events with much less backgrounds

at these energies, interactions with all particles in the Standard Model can be measured precisely

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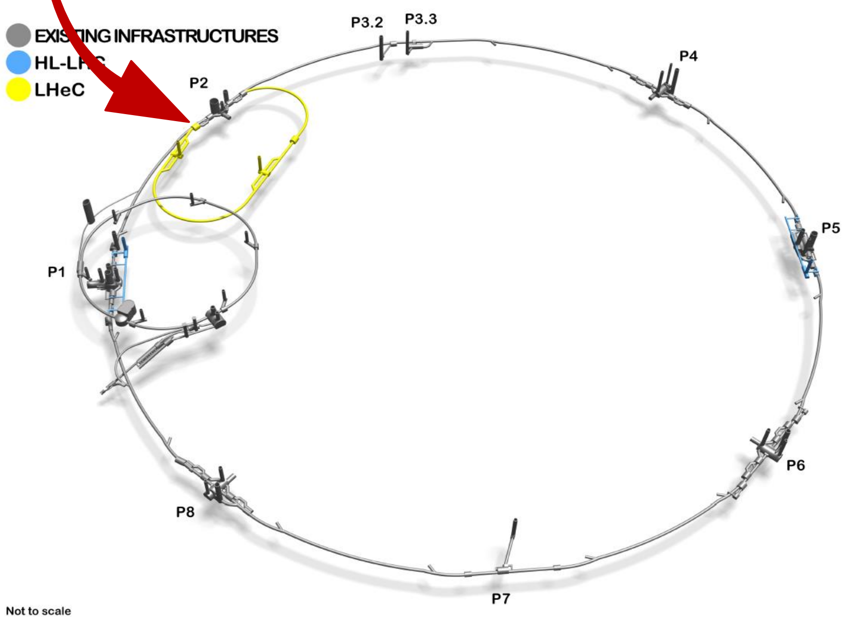
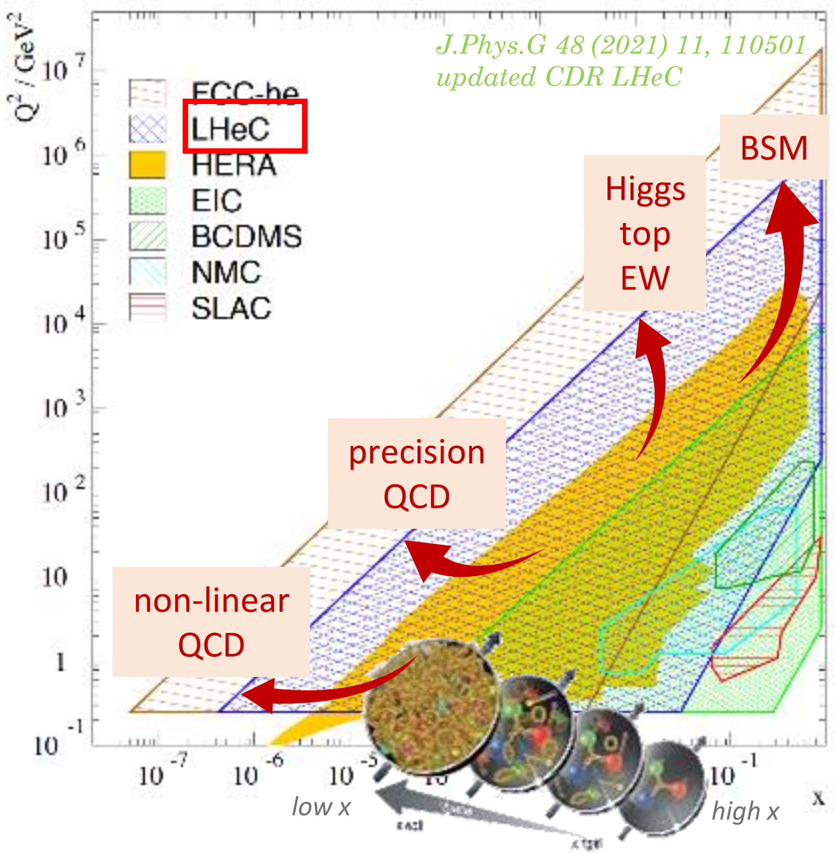
THE LHEC PROGRAM

LHeC (>50 GeV electron beams)
E_{cms} = 0.2 – 1.3 TeV, (Q^2,x) range far beyond HERA
run ep/pp together with the HL-LHC (≳ Run5)





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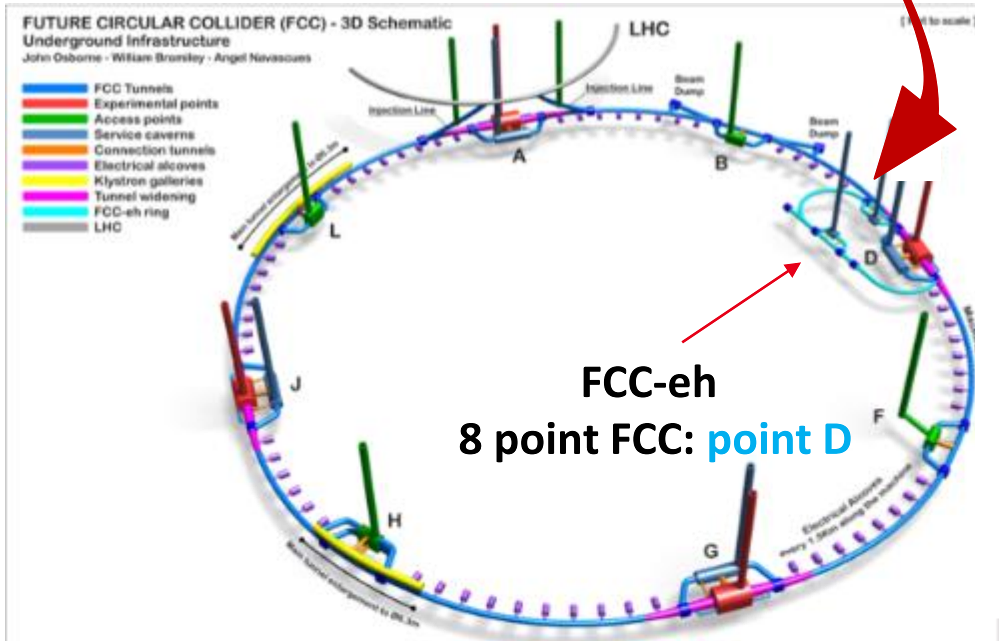
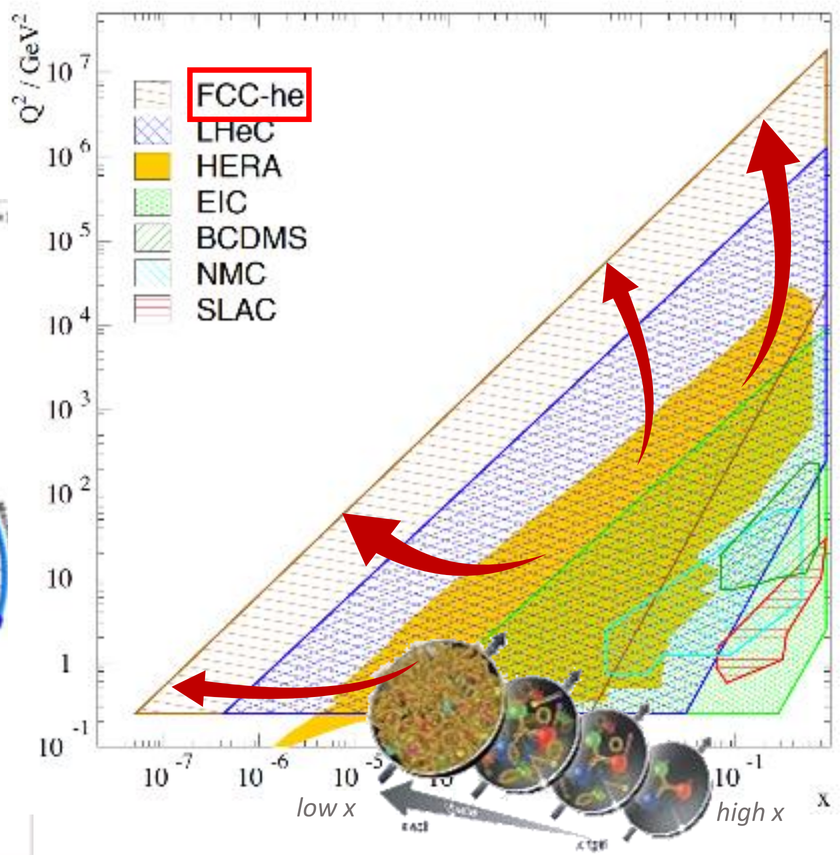
THE FCC-EH PROGRAM

Jorgen D'Hondt

FCC-eh (60 GeV electron beams)
E_{cms} = 3.5 TeV, described in CDR of the FCC
run ep/pp together: FCC-hh + FCC-eh



J. Osborne, W. Bromiley, A. Navascues



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FROM HERA ONWARDS TO HIGH-ENERGY PROTON BEAMS

Jorgen D'Hondt

	HERA	EIC	LHeC	FCC-eh
Host site	DESY	BNL	CERN	CERN
Layout	ring-ring	ring-ring	ERL linac-ring	ERL linac-ring
Circumference hadron/lepton (km)	6.3/6.3	3.8/3.8	26.7/[5.3–8.9]	100/[5.3–8.9]
Number of IRs/IPs	4/2	6/1–2	1	1
Max. CM energy (TeV)	0.32	0.14	1.2	3.5
Crossing angle (mrad)	0	22	0	0
Max. peak luminosity ($cm^{-2} s^{-1}$)	5×10^{31}	1×10^{34}	2.3×10^{34}	1.5×10^{34}
Lepton	Electrons, positrons polarized	Electrons polarized	Electrons unpolarized	Electrons unpolarized
Max. average current (A)	0.058	2.5	0.02	0.02
Max. SR power (MW)	7.2	10	45	45
Main RF frequency (MHz)	500	591	802	802
No. main RF cavities/cryomodules	28	17–18/9–18	448/112	448/112
No. crab RF cavities	–	2	–	–
Hadron	Protons unpolarized	Protons polarized	Protons unpolarized	Protons unpolarized
Max. average current (A)	0.163	1.0	1.1	1.1
Main RF frequency (MHz)	208	591	400	400
No. crab RF cavities/cryomodules	–	12/6	8/4	8/4
No. ERL RF cavities	–	13	–	–

Front. Phys. 10 (2022) 886473

Nuclear Photonics

Institut für Kernphysik S-DALINAC Technische Universität Darmstadt

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FUTURE FLAGSHIP AT THE ENERGY & PRECISION FRONTIER

Jorgen D'Hondt

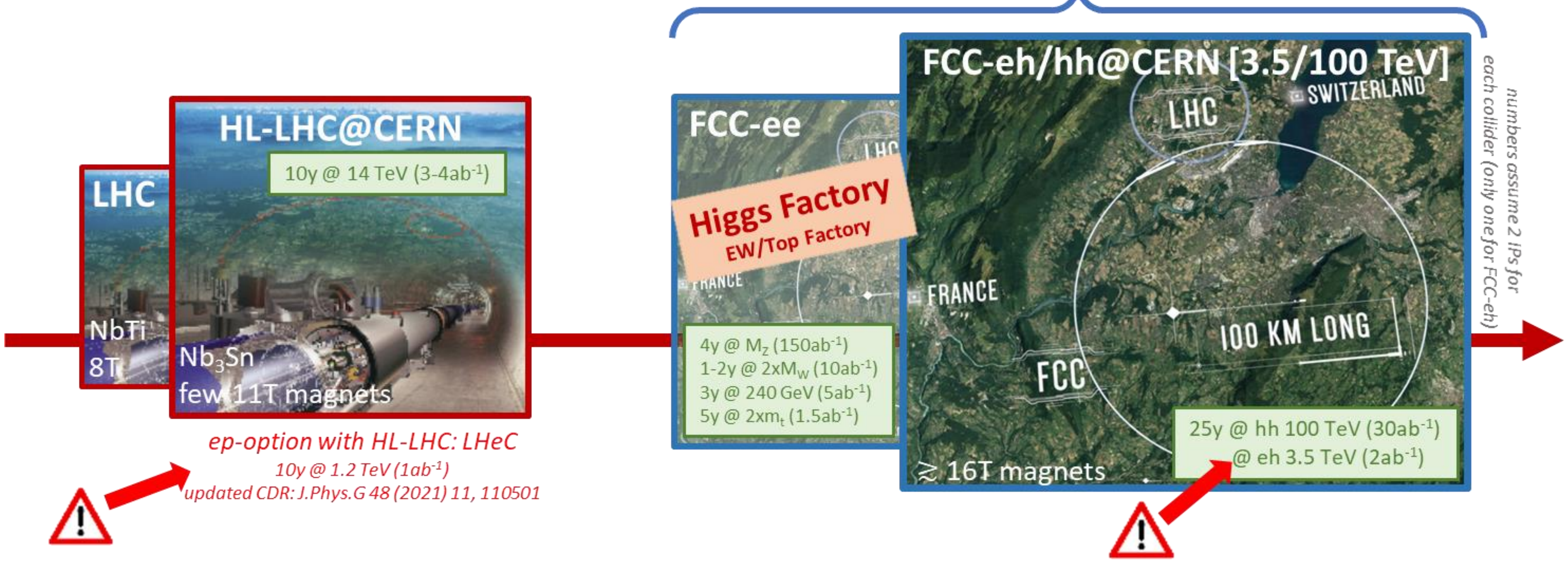
Current flagship (27km)

impressive programme up to ~2040

Future Circular Collider (FCC)

big sister future ambition (100km), beyond 2040

attractive combination of precision & energy frontier



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Jorgen D'Hondt

THE CHALLENGE

High-intensity electron beam

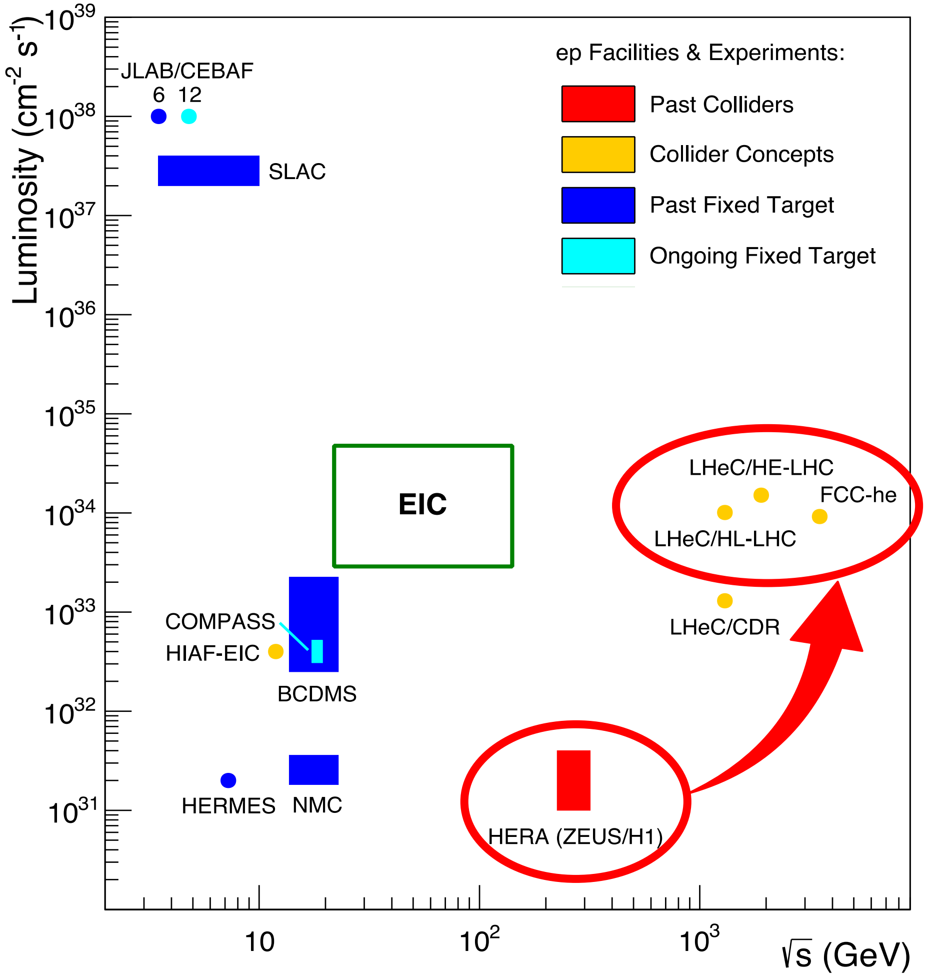
From HERA@DESY to LHeC@CERN

3 orders in magnitude in luminosity
1 order in magnitude in energy

beam current × beam energy
= beam power

LHeC ~ 1 GW beam power

equivalent to the power delivered by a nuclear power plant



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Jorgen D'Hondt

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1 GW beam power

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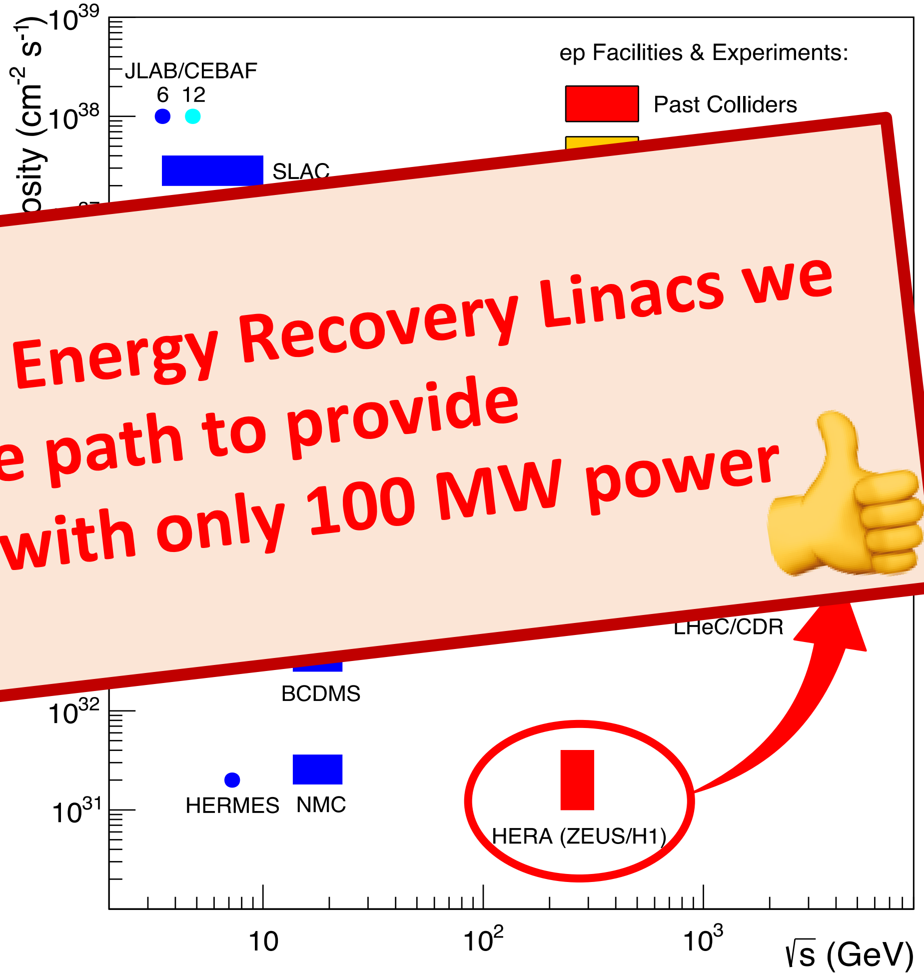

With the planned R&D on Energy Recovery Linacs we will prepare the path to provide a 1 GW electron beam with only 100 MW power

ERL TECHNOLOGY: STATE-OF-THE-ART AND R&D FOR FUTURE

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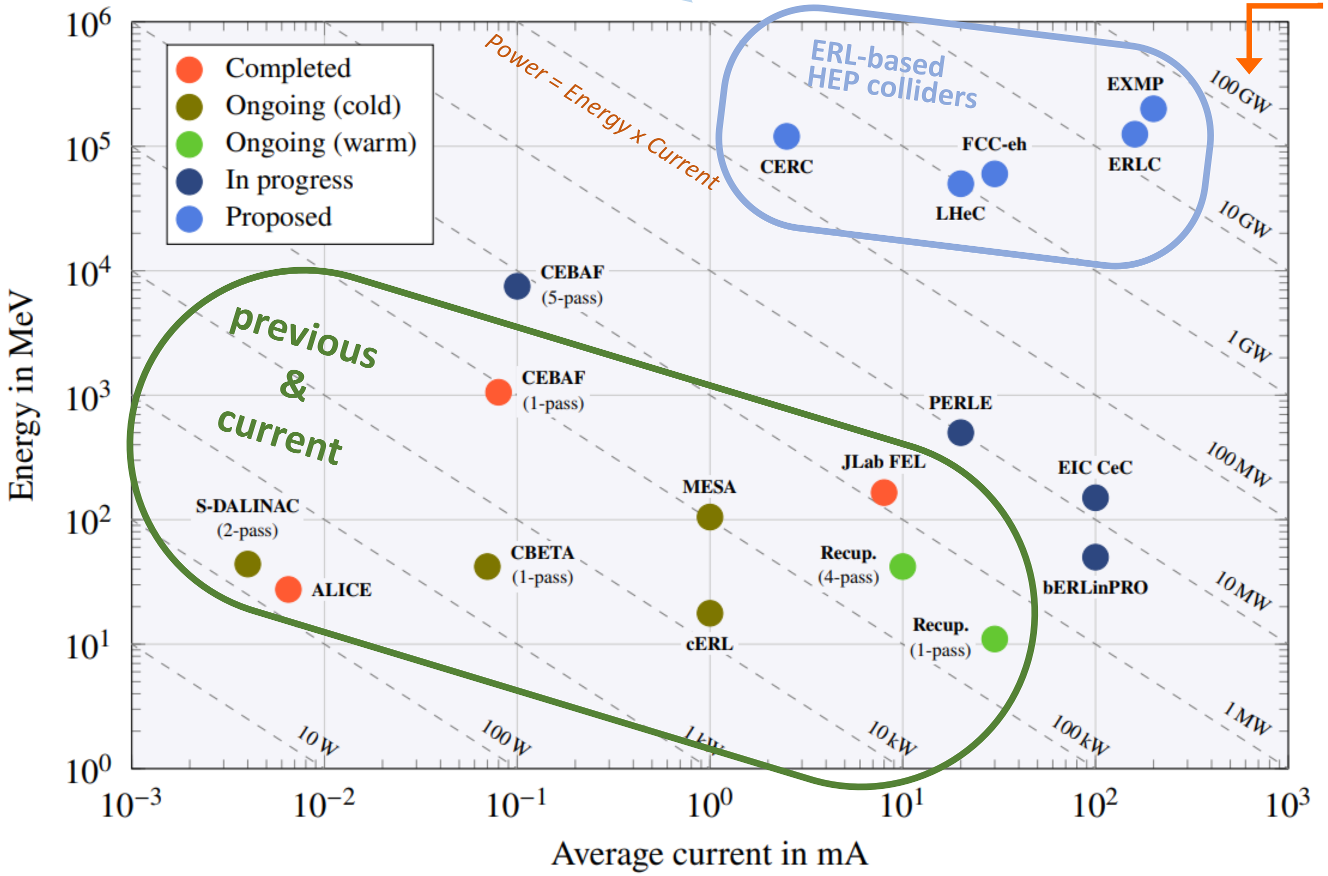
ERL - 50 YEARS OF INNOVATION

Jorgen D'Hondt

nuclear power plant

would be the required external power supply without Energy Recovery



arXiv:2207.02095 [physics.acc-ph]; accepted for publication in JINST

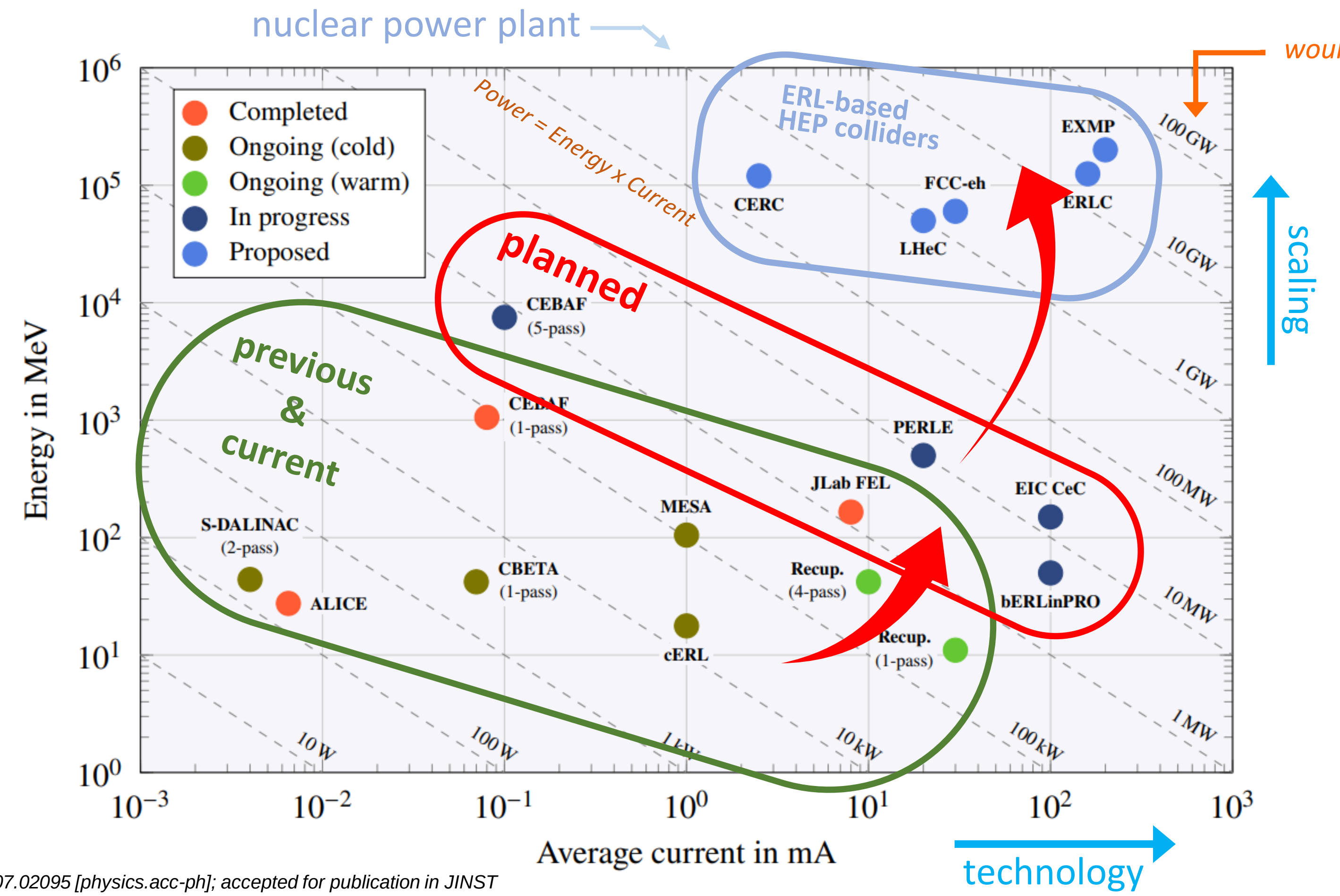
Energy Recovery

great achievements on all aspects and large research infrastructures based on Energy Recovery systems have been operated successfully

TECHNISCHE UNIVERSITÄT DARMSTADT

Jorgen D'Hondt

ERL - 50 YEARS OF INNOVATION



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Energy Recovery

great achievements on all aspects and large research infrastructures based on Energy Recovery systems have been operated successfully

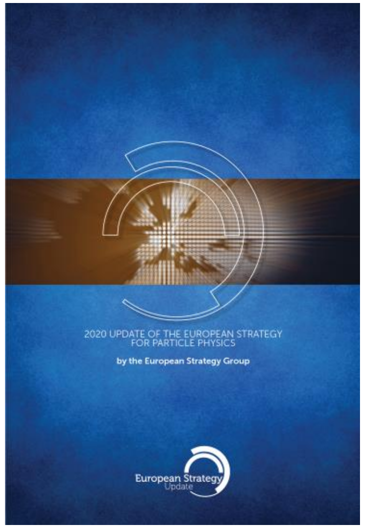
bERLinPro & PERLE

essential accelerator R&D labs with ambitions overlapping with those of the particle physics community

towards high energy & high power

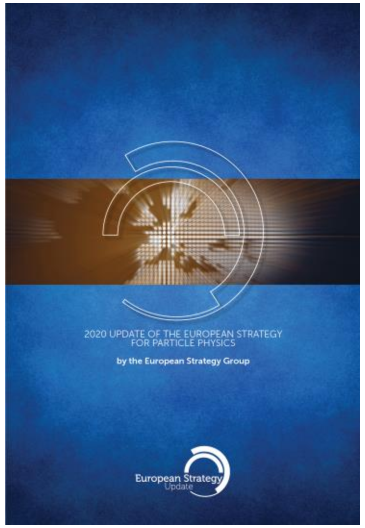
The Development of Energy-Recovery Linacs

arXiv:2207.02095, 237 pages, 5 July 2022



The **2020 European Strategy for Particle Physics** recommended:
“the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies… a roadmap should prioritize the technology…”

Five areas were selected and roadmap panels established for each of: High-Field Magnets, Plasma Acceleration, High-Gradient RF, Muon Beams, and **Energy Recovery Linacs.**



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ERL R&D: Main fields


Prepared for submission to JINST

The Development of Energy-Recovery Linacs

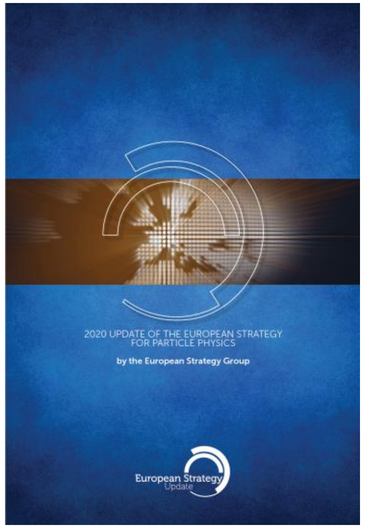
arXiv:2207.02095v2 [physics.acc-ph] 27 Sep 2022

Chris Adolphsen,[t] Kevin Andre,[d,i] Deepa Angal-Kalinin,[f] Michaela Arnold,[g] Kurt Aulenbacher,[j] Steve Benson,[o] Jan Bernauer,[m] Alex Bogacz,[o] Maarten Boonekamp,[l] Reinhard Brinkmann, Max Bruker,[o] Oliver Brüning,[d] Camilla Curatolo,[p] Patxi Duthil,[k] Oliver Fischer,[i] Georg Hoffstaetter,[e,c] Bernhard Holzer,[d] Ben Hounsell,[k,i] Andrew Hutton,[o,1] Erk Jensen,[d] Walid Kaabi,[k] Dmitry Kayran,[c] Max Klein,[i] Jens Knobloch,[a,s] Geoff Krafft,[o] Julius Kühn,[a] Bettina Kuske,[a] Vladimir Litvinenko,[m] Frank Marhauser,[o] Boris Militsyn,[f] Sergei Nagaitsev,[v] George Neil,[o] Axel Neumann,[a] Norbert Pietralla,[g] Bob Rimmer,[o] Luca Serafini,[p] Oleg A. Shevchenko,[b] Nick Shipman,[d,q] Hubert Spiesberger,[j] Olga Tanaka,[n] Valery Telnov,[b,r] Chris Tennant,[o] Cristina Vaccarezza,[h] David Verney,[k] Nikolay Vinokurov,[b] Peter Williams,[f] Akira Yamamoto,[n] Kaoru Yokoya,[n] Frank Zimmermann[d]

[a] Helmholtz-Zentrum Berlin, Berlin, Germany
[b] Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia
[c] Brookhaven National Laboratory, Upton, NY, USA
[d] CERN, Geneva, Switzerland
[e] Cornell University, Ithaca, NY, USA
[f] Daresbury Laboratory (STFC), Daresbury, UK
[g] Technische Universität Darmstadt, Institute for Nuclear Physics, Darmstadt, Germany
[h] INFN, Frascati, Italy
[i] University of Liverpool, Liverpool, UK
[j] University of Mainz, Mainz, Germany
[k] IJCLab, Orsay, France
[l] CEA Saclay, Saclay, France
[m] Center for Frontiers in Nuclear Science, Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY, USA, and RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY, USA
[n] KEK, Tsukuba, Japan
[o] Thomas Jefferson National Accelerator Facility, Newport News, VA, USA
[p] INFN, Milano, Italy, and LASA
[q] Lancaster University, Lancaster, UK
[r] Novosibirsk State University, 630090, Novosibirsk, Russia
[s] University of Siegen, Siegen, Germany
[t] SLAC, Menlo Park, CA, USA
[v] Fermilab, Batavia, IL, USA

E-mail: andrew@jlab.org

[1] Corresponding author.



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Only examples shown

ERL R&D: Main fields

Prepared for submission to JINST

arXiv:2207.02095v2 [physics.acc-ph] 27 Sep 2022

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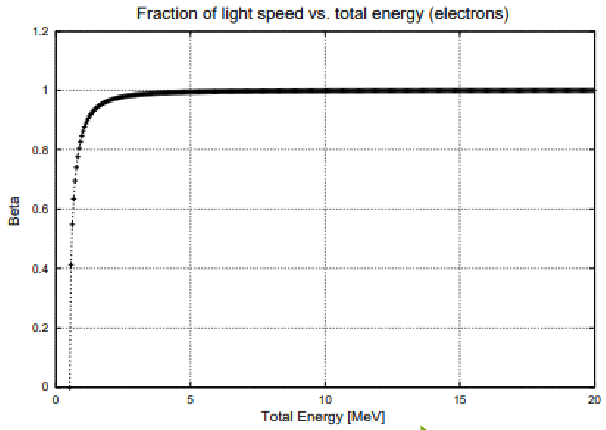
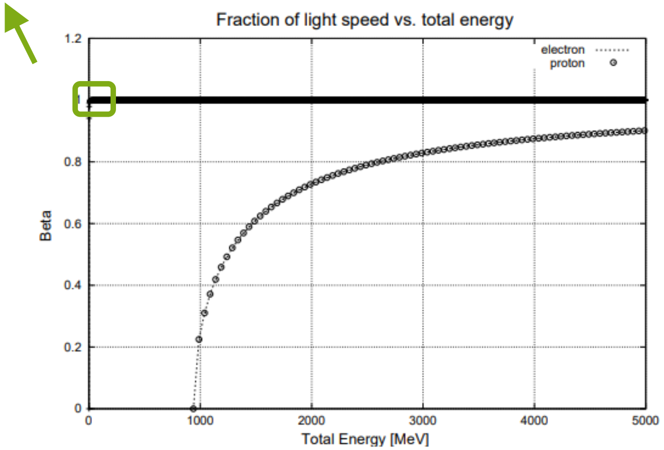
ELECTRONS



Electron: $E_0 = 0.511\ \mathrm{MeV}$
Proton: $E_0 = 938\ \mathrm{MeV}$



- Particles = electrons

Barletta, Spentzouris, Harms, Lecture notes USPAS
https://uspas.fnal.gov/materials/10MIT/Review_of_Relativity.pdf

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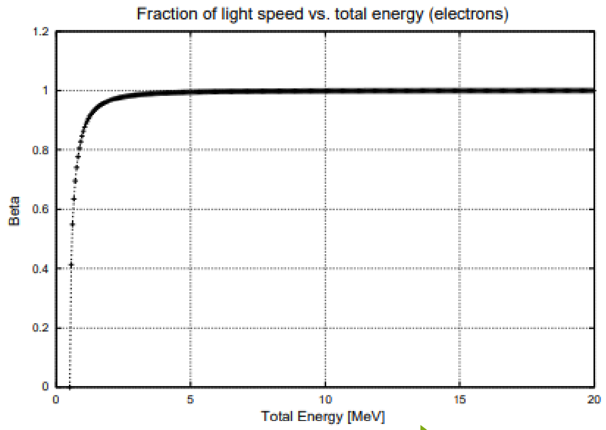
ELECTRONS



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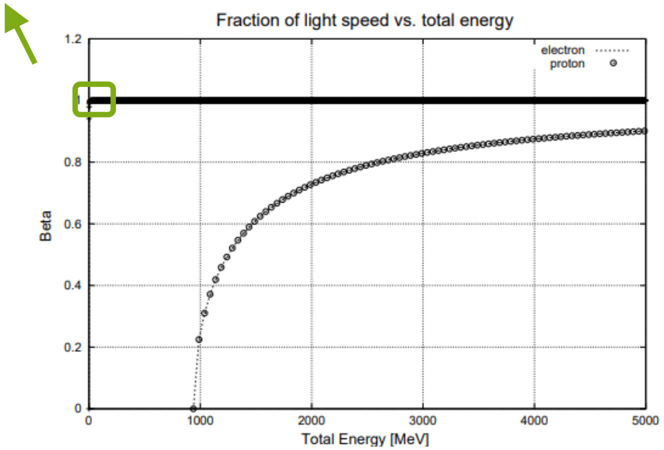
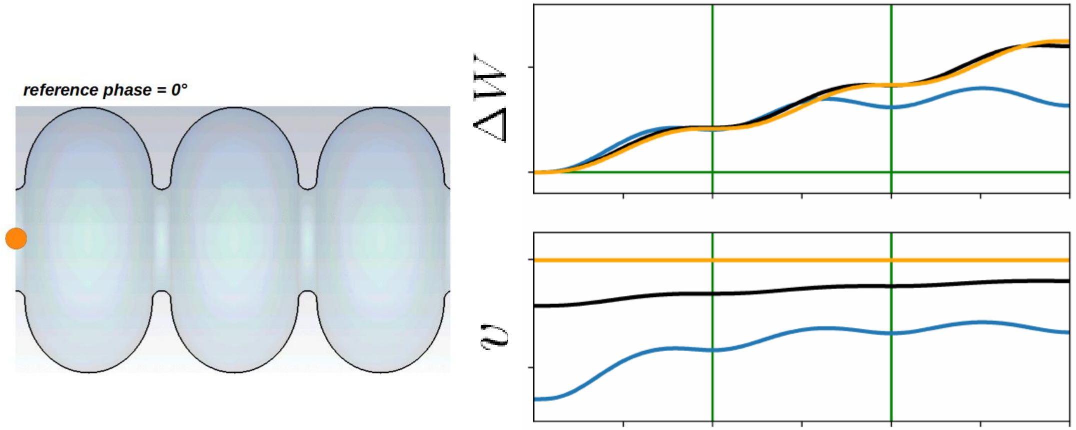


- Particles = electrons
- Although ultra-relativistic at some MeV, phase slippage is an issue
- Speed changes along the cavity
  → Influence of energy gain



Simulation by Felix Schliessmann, TU Darmstadt

Barletta, Spentzouris, Harms, Lecture notes USPAS
https://uspas.fnal.gov/materials/10MIT/Review_of_Relativity.pdf

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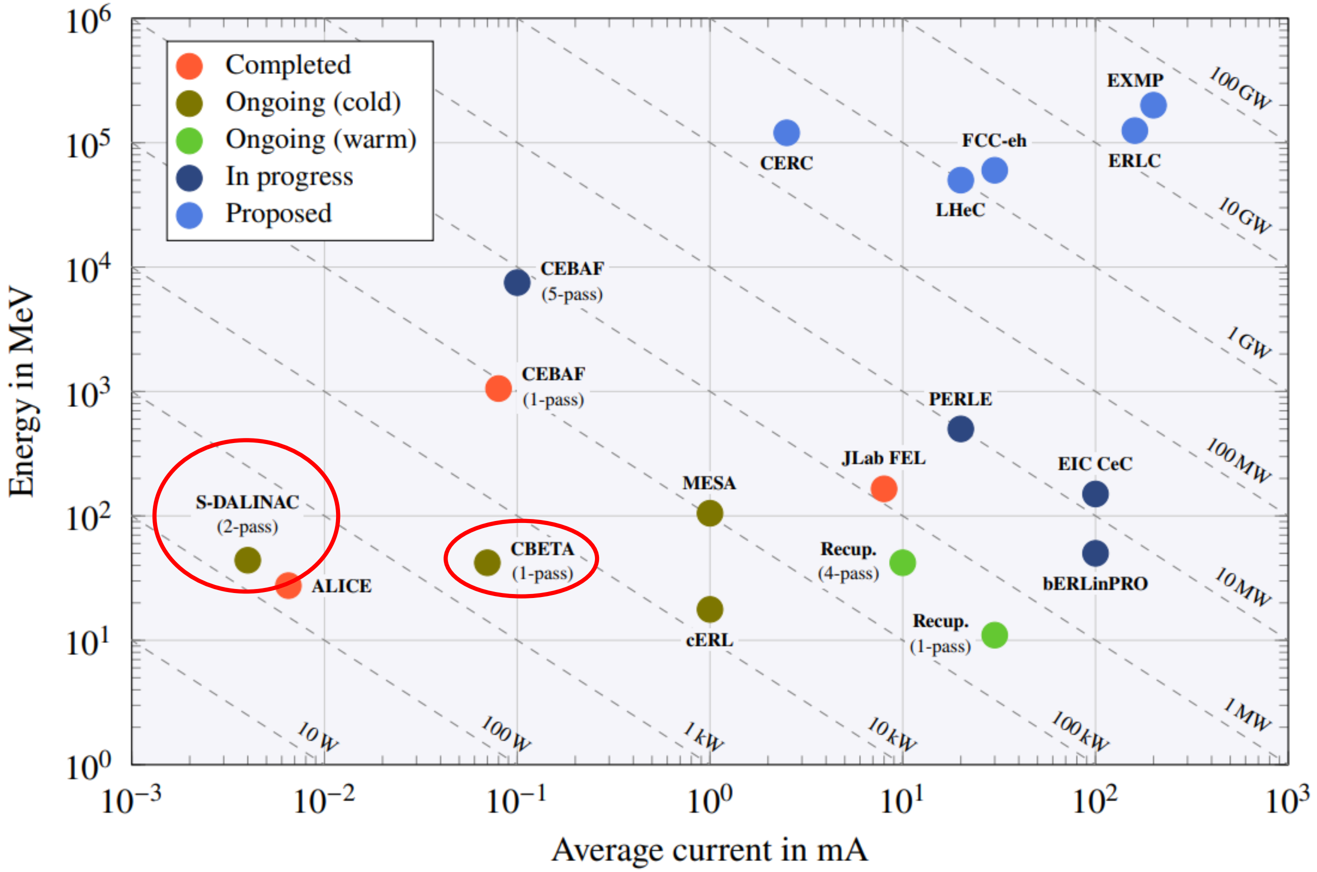
MULTI-TURN ERL OPERATION



arXiv:2207.02095 [physics.acc-ph]; accepted for publication in JINST

Running SRF multi-turn ERLs
- CBETA: 4-turn → 1 nA, beam loss
- S-DALINAC: 2-turn → up to 7μA and max. 87% recovery

Near future SRF multi-turn ERLs
- PERLE
- MESA
- CEBAF (5-pass)

Possible enhancement of multi-turn lattice?
Example S-DALINAC

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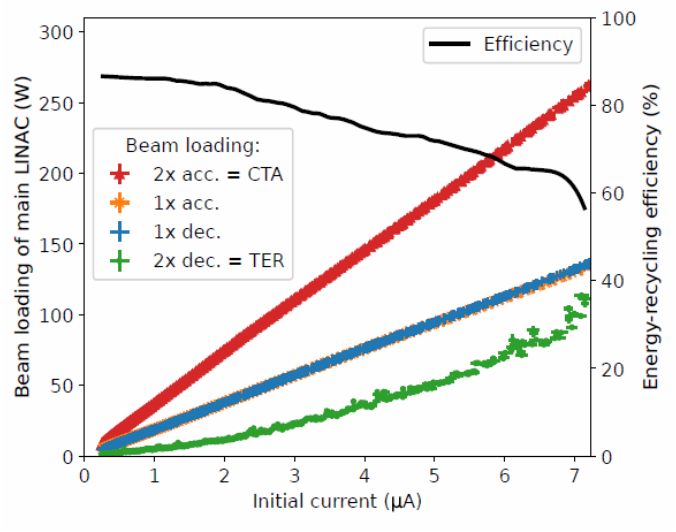
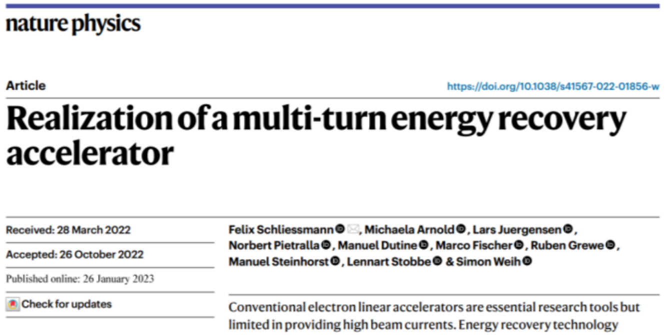
S-DALINAC MULTI-TURN ERL

- First performant energy-recycling multi-turn SRF ERL world-wide



$\max(\eta_{\text{main LINAC}}) \approx 87\ \%$


nature physics

Article

https://doi.org/10.1038/s41567-022-01856-w

Realization of a multi-turn energy recovery accelerator

Received: 28 March 2022

Accepted: 26 October 2022

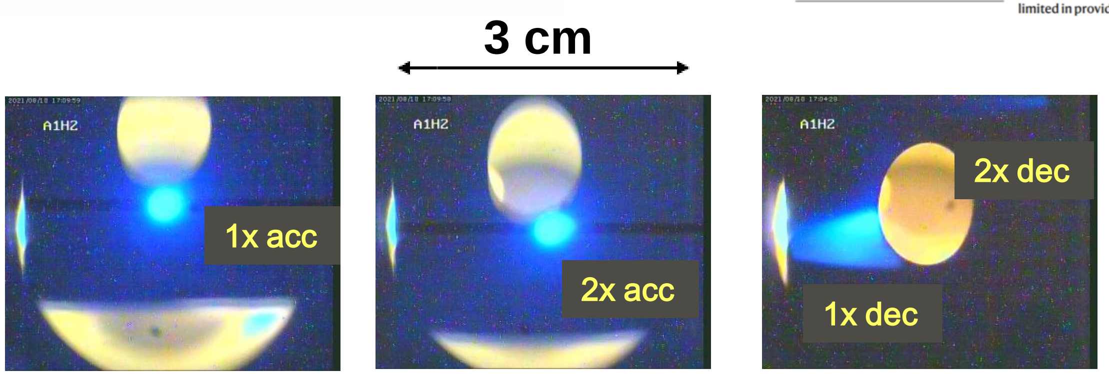
Published online: 26 January 2023

Check for updates

Felix Schliessmann, Michaela Arnold, Lars Juergensen, Norbert Pietralla, Manuel Dutine, Marco Fischer, Ruben Grewe, Manuel Steinhorst, Lennart Stobbe & Simon Weih

Conventional electron linear accelerators are essential research tools but limited in providing high beam currents. Energy recovery technology

- Limits of transverse beam tuning (common beam transport)



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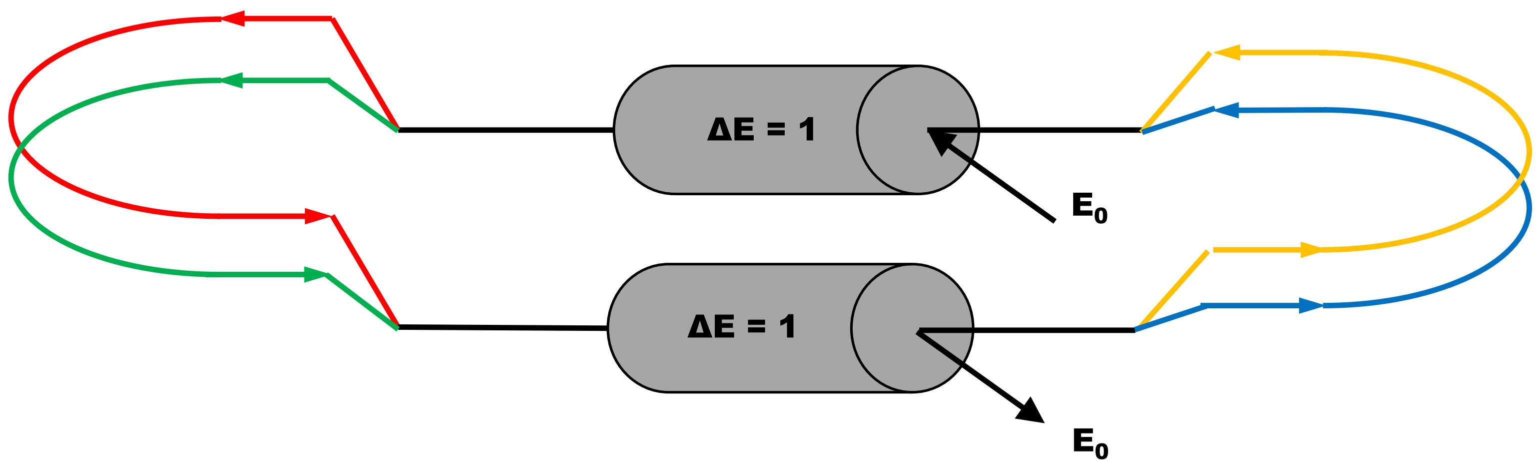
COMMON BEAM TRANSPORT

- Limited in degrees of freedom



E_1 – 1. recirculation (accelerate and decelerate)

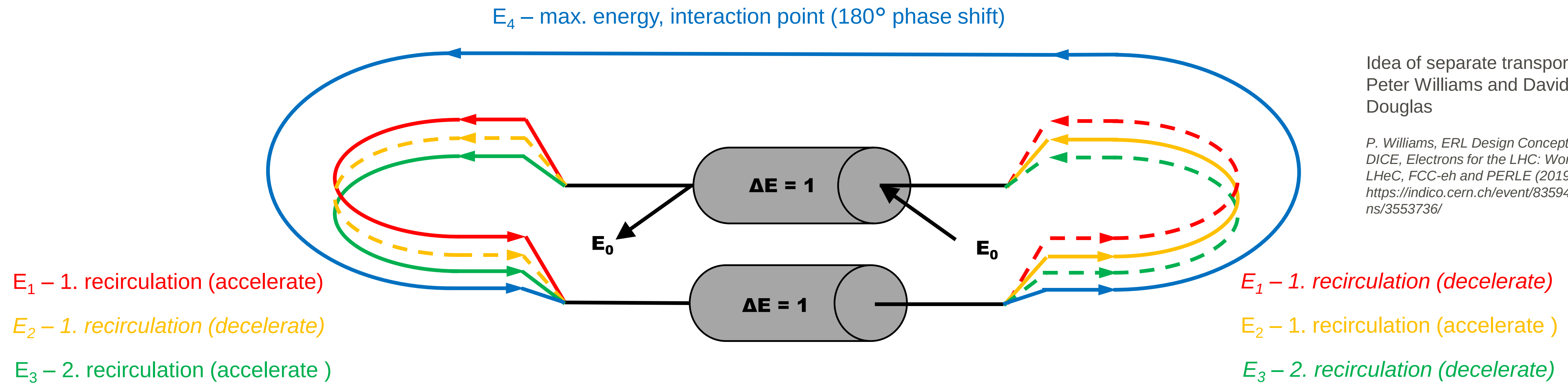
E_3 – 2. recirculation (accelerate and decelerate)

E_2 – 1. recirculation (accelerate and decelerate)

E_4 – max. energy, interaction point (180° phase shift)

SEPARATED BEAM TRANSPORT

- High efficiency, reliability, robustness → separate transport as promising concept
- Proposals of
  - DIANA (Daresbury Industrial Accelerator for Nuclear Applications): ~ 1 GeV, multipass SC-ERL
  - DICE (Darmstadt Individually recirculating Compact ERL): ~ 520 MeV, 20mA, multipass SC-ERL



Idea of separate transport: Peter Williams and David Douglas

P. Williams, ERL Design Concepts DIANA and DICE, Electrons for the LHC: Workshop on the LHeC, FCC-eh and PERLE (2019). https://indico.cern.ch/event/835947/contributions/3553736/

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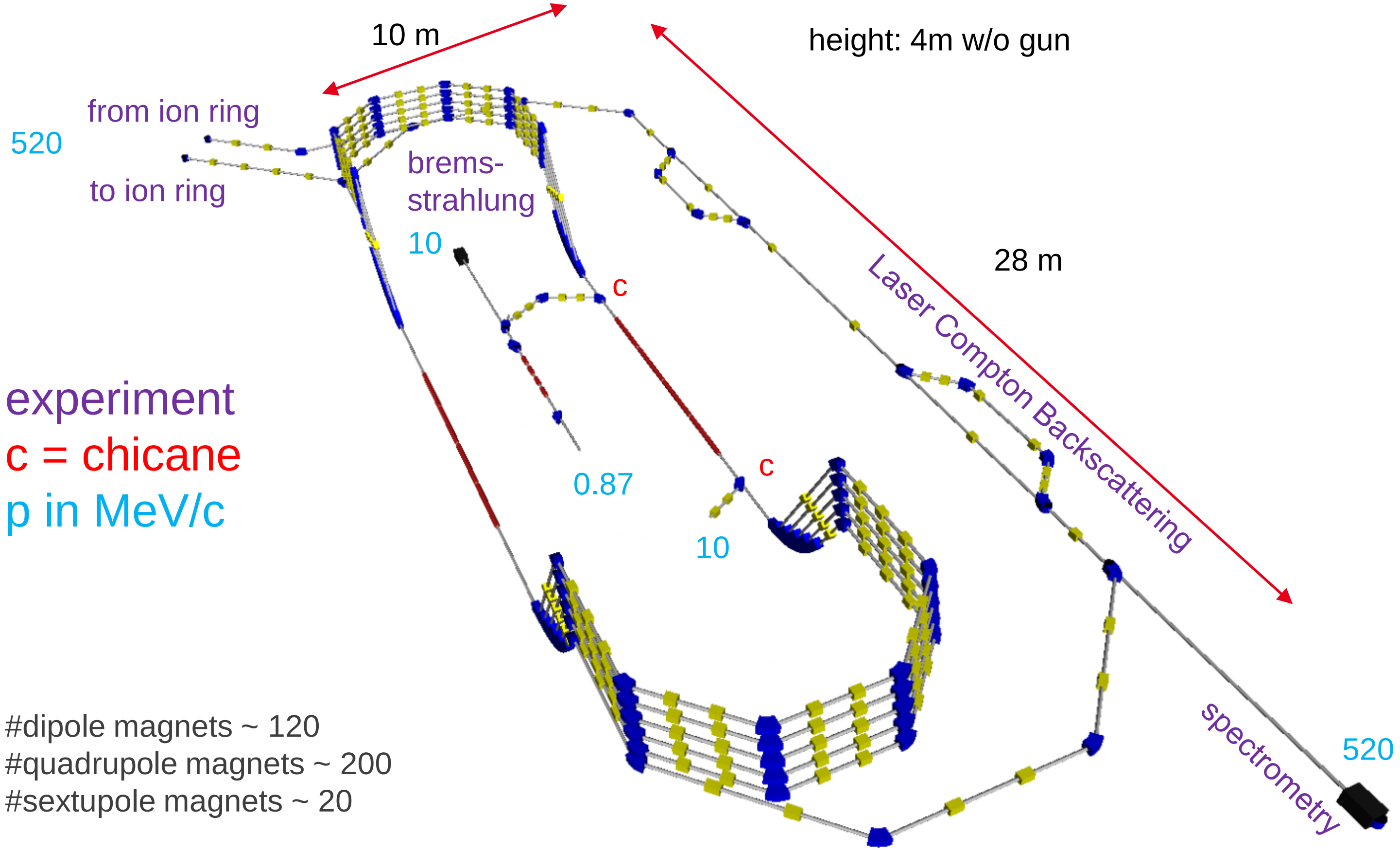
DICE

- Design work in view of a future collider

Parameter	Value
Injection energy	5-10 MeV
Maximum energy	520 MeV
Max. Bunch charge	500 pC
Max. beam current	20 mA
Normalized emittance	4 mm mrad
Bunch length	1.5 – 3 mm
RF frequency	1300 MHz



experiment
c = chicane
p in MeV/c

#dipole magnets ~ 120
#quadrupole magnets ~ 200
#sextupole magnets ~ 20

publication in preparation

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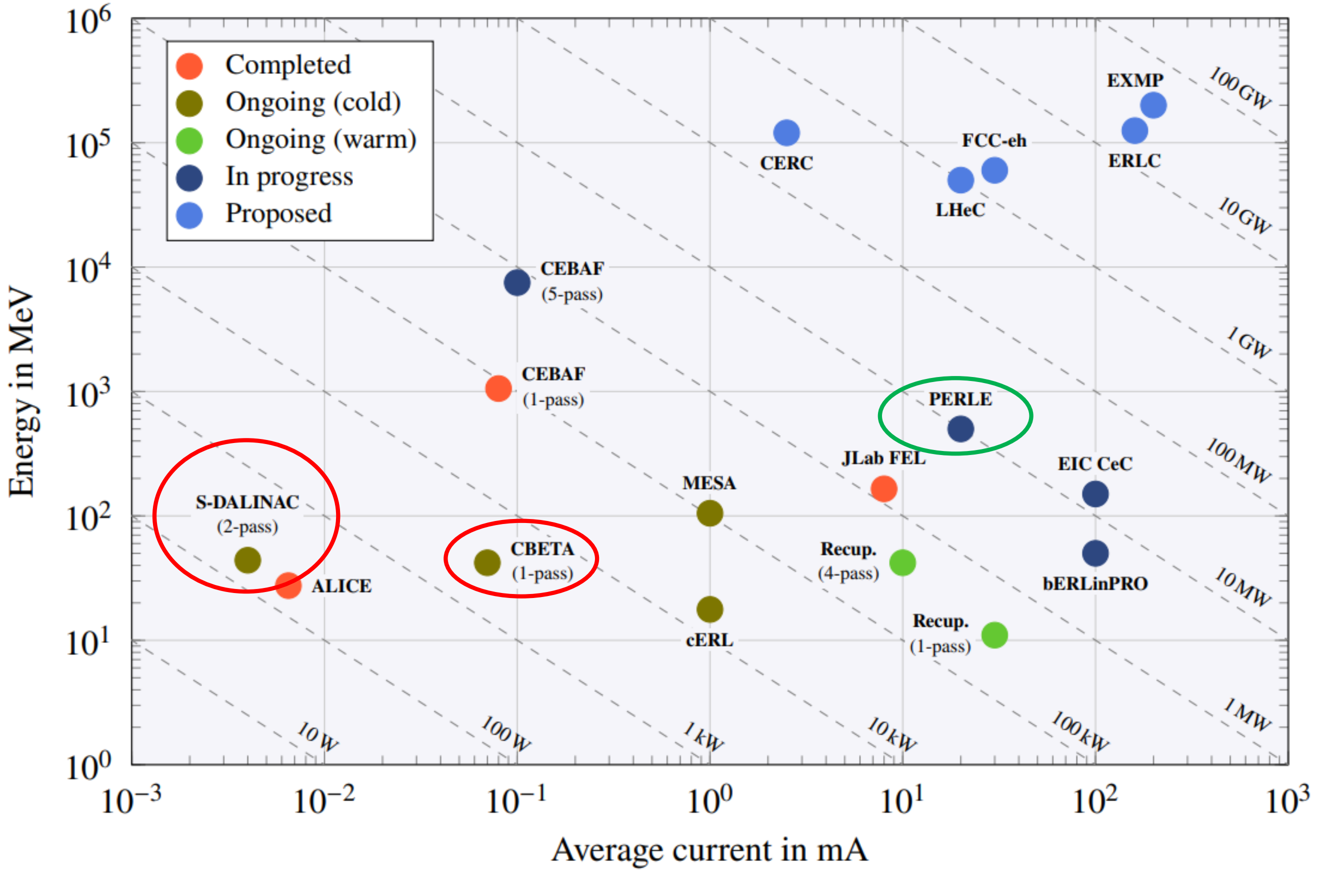
MULTI-TURN ERL OPERATION



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- PERLE
- MESA
- CEBAF (5-pass)

R&D at future multi-turn ERL: PERLE

PERLE @ IJCLab

international collaboration bringing all aspects together to demonstrate readiness of Energy Recovery for HEP collider applications

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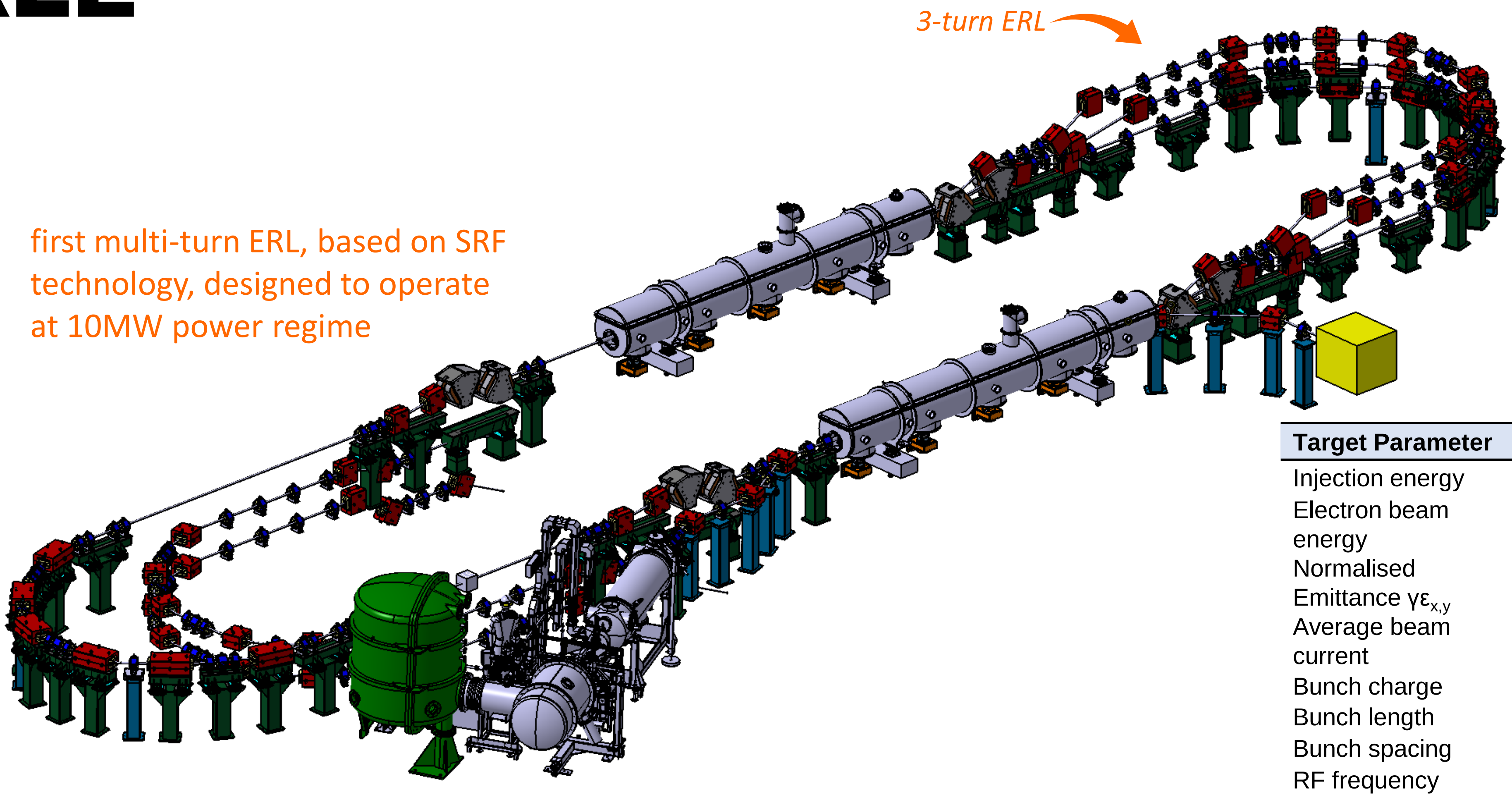
Jorgen D'Hondt

PERLE

first multi-turn ERL, based on SRF technology, designed to operate at 10MW power regime



Target Parameter	Unit	Value
Injection energy	MeV	7
Electron beam energy	MeV	500
Normalised Emittance $\gamma\varepsilon_{x,y}$	mm mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	mm	3
Bunch spacing	ns	25
RF frequency	MHz	801.58
Duty factor		CW

PERLE @ IJCLab
international collaboration with several in-kind contributions

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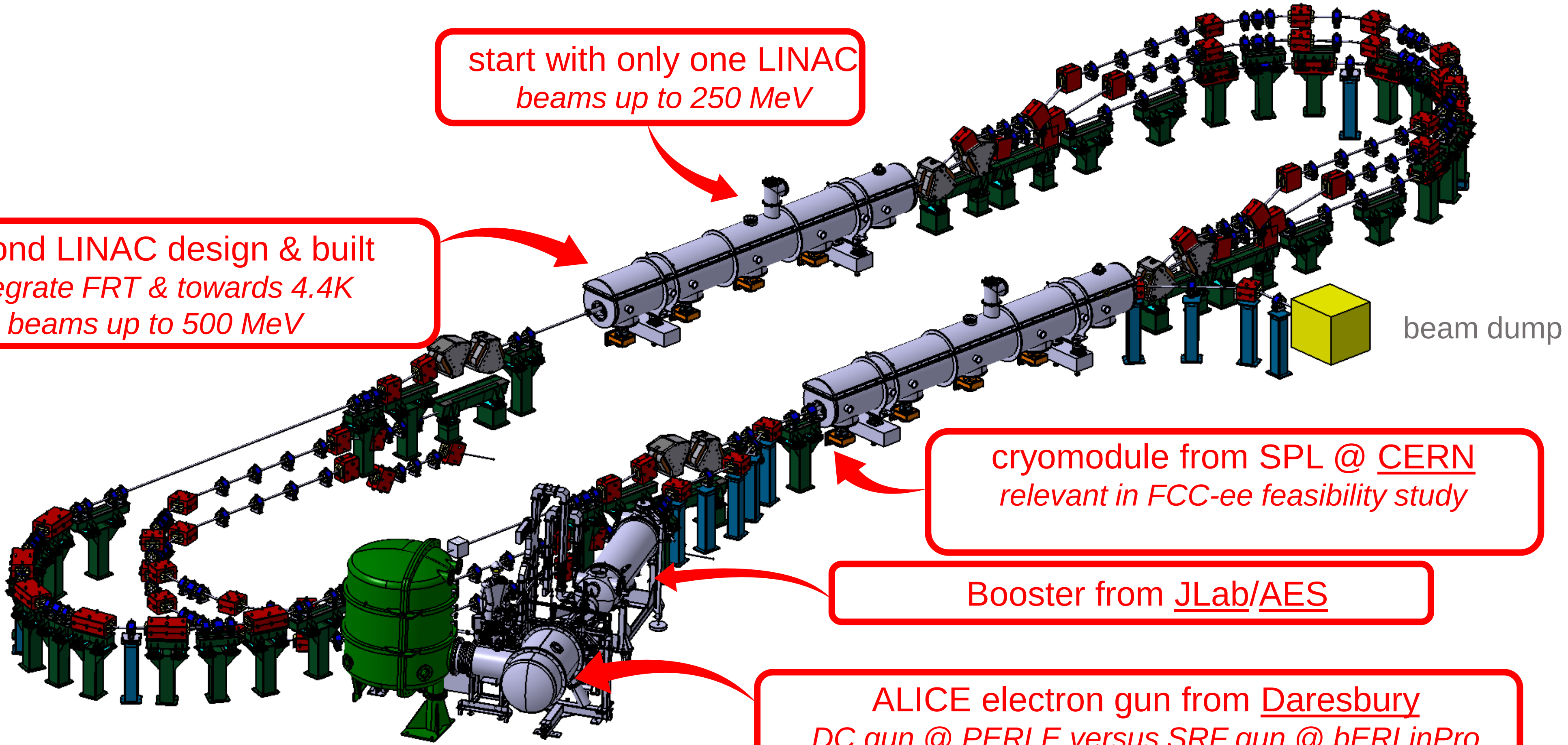
Jorgen D'Hondt

PERLE

start with only one LINAC
beams up to 250 MeV

second LINAC design & built
integrate FRT & towards 4.4K
beams up to 500 MeV



cryomodule from SPL @ CERN
relevant in FCC-ee feasibility study

Booster from JLab/AES

ALICE electron gun from Daresbury
DC gun @ PERLE versus SRF gun @ bERLinPro

PERLE @ IJCLab
international collaboration with several in-kind contributions

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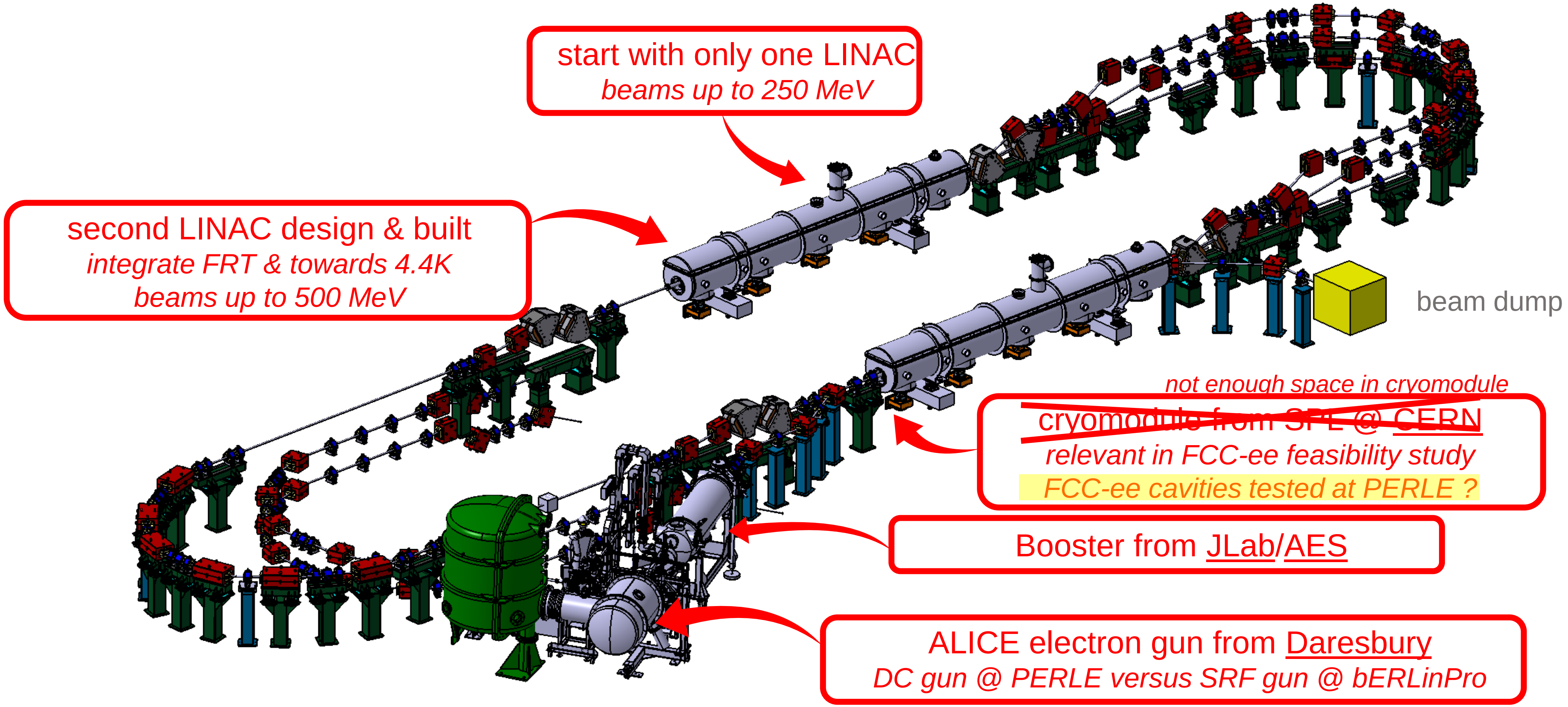
PERLE



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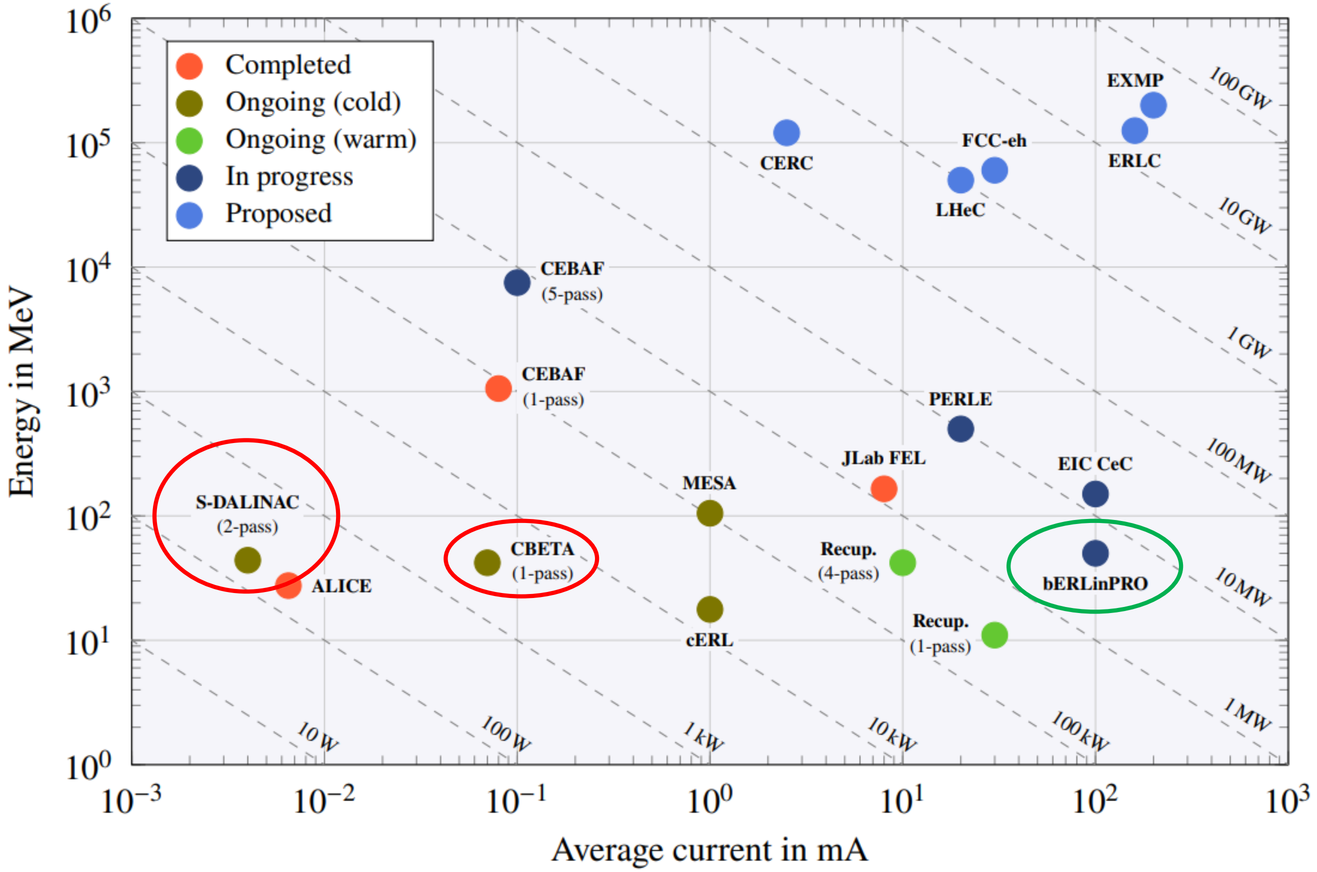
GENERIC ERL R&D



arXiv:2207.02095 [physics.acc-ph]; accepted for publication in JINST

Running SRF multi-turn ERLs
- CBETA: 4-turn → 1 nA, beam loss
- S-DALINAC: 2-turn → up to 7μA and max. 87% recovery

Near future SRF multi-turn ERLs
- PERLE
- MESA
- CEBAF (5-pass)

Versatile test ERL: bERLinPro

bERLinPro @ Helmholtz Zentrum Berlin
generic accelerator R&D with several aspects as stepping stones towards HEP applications

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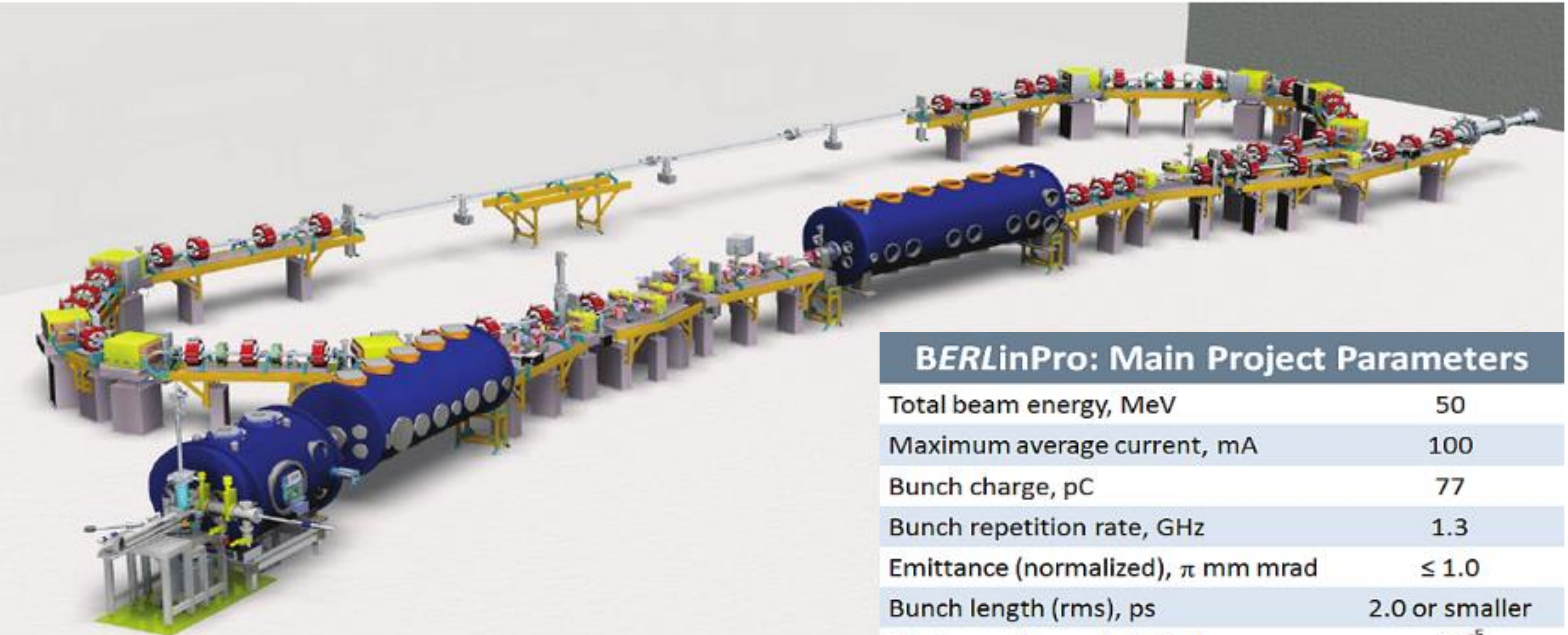
BERLINPRO



BERLinPro: Main Project Parameters	
Total beam energy, MeV	50
Maximum average current, mA	100
Bunch charge, pC	77
Bunch repetition rate, GHz	1.3
Emittance (normalized), π mm mrad	≤ 1.0
Bunch length (rms), ps	2.0 or smaller
Maximum Losses (relative)	$< 10^{-5}$

bERLinPro – Berlin Energy Recovery Linac Project

bERLinPro @ Helmholtz Zentrum Berlin
addressing HEP related challenges

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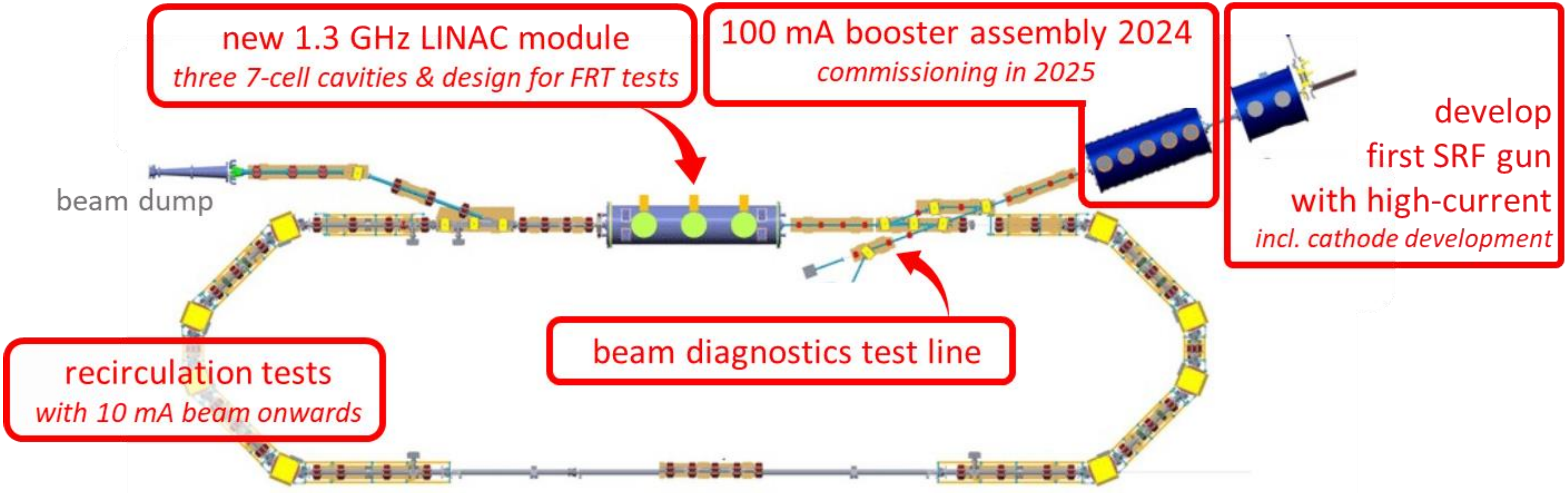
BERLINPRO

bERLinPro ready for operation at 10 mA

contingent on additional budgets upgrades to 100 mA and ERL at 50 MeV can be planned to be operational by 2028



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BERLINPRO

First beam of bERLinPro@SEALab to be expected in 2023

- focus on commissioning injector with SRF gun + diagnostic line
  (map out the reachable parameter space)
- installation of the Booster module
- recirculation, when LINAC funding is secured

SUMMARY

POTENTIAL FUTURE OF ERL TECHNOLOGY

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With stepping stones for innovations in technology to boost our physics reach