Accelerating Nuclear & Particle Physics

united in a quest for fundamental knowledge with synergies at a scientific and technical level

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Vrije Universiteit Brussel

Kick Off Meeting, EURO-LABS, Bologna, 3-5 October 2022

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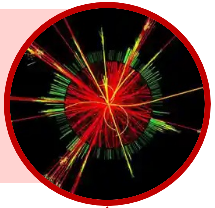
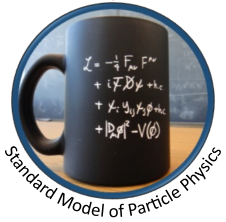
observations how small objects behave in our laboratories





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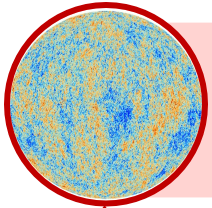
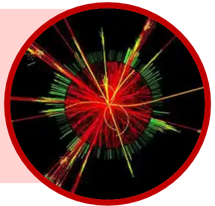
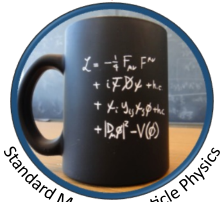


observations how large objects behave in our universe



observations how small objects behave in our laboratories

Standard Model of Cosmology



Standard Model of Particle Physics

Einstein's field equations of gravity from which the Friedmann equations are derived to model the evolution of the universe

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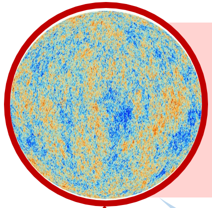
building blocks of life on the human scale



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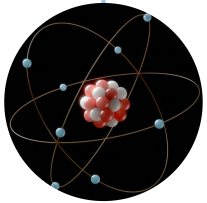
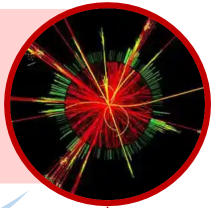
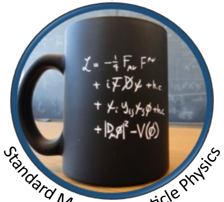


e.g. creation of chemical elements

e.g. nuclei built from quarks and gluons

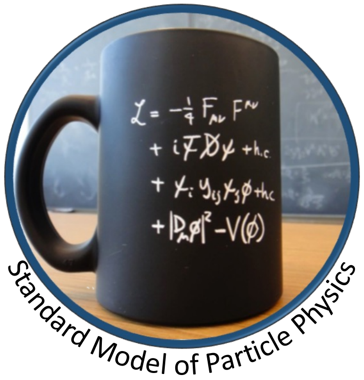
observations how small objects behave in our laboratories





Standard Model of Particle Physics

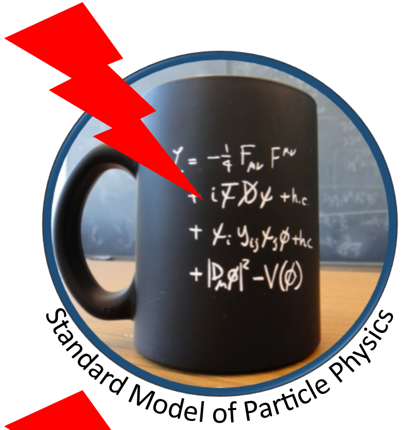
The quest for understanding physics

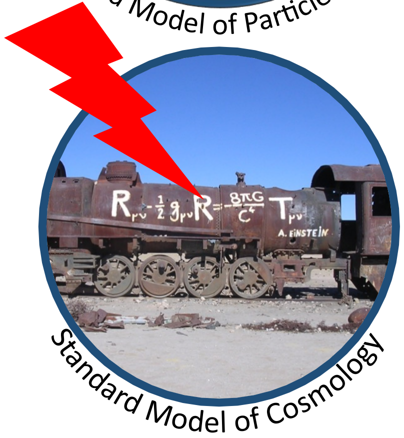


"Problems and Mysteries"

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





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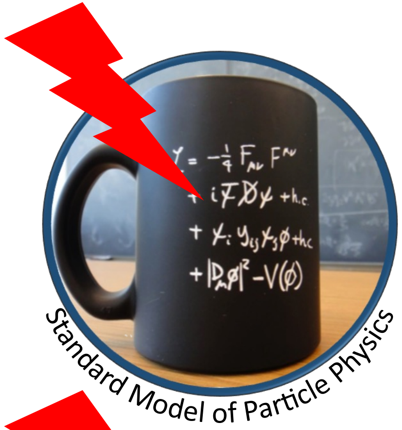
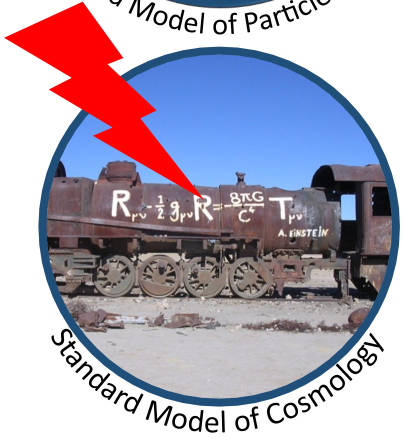
Observations of new physics phenomena and/or deviations from the Standard Models are expected to unlock concrete ways to address these puzzling unknowns

The quest for understanding physics





"Problems and Mysteries"

Accordingly, researchers question among others:

The structure of matter ?

The symmetries in nature ?

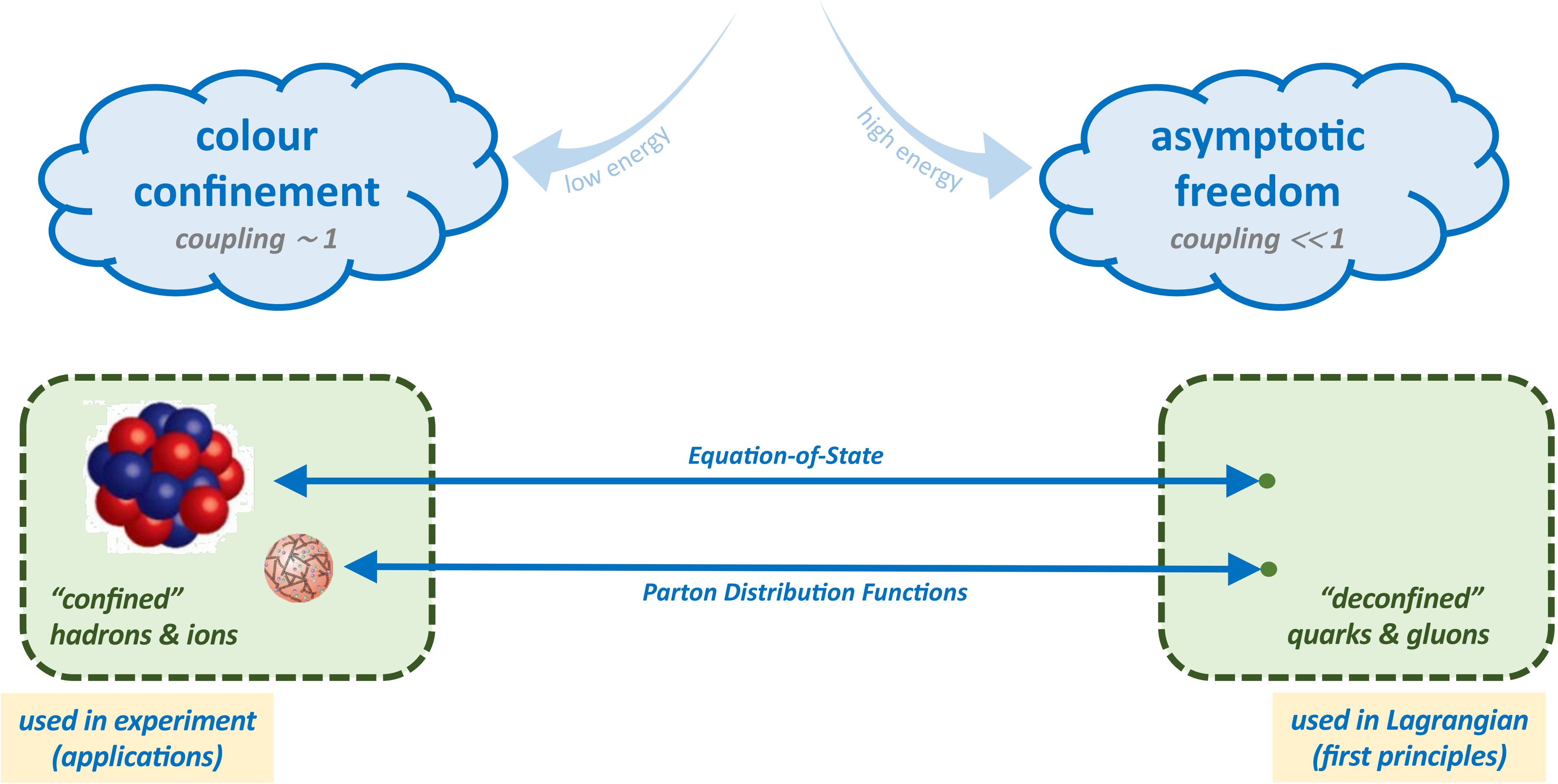
The invisible part of nature ?

When we enter terra incognita along these three scientific axes, there are essential synergies between nuclear and particle physics

①

the structure of matter

Hadrons & Ions are made up of Quarks & Gluons



Hadrons & Ions are made up of Quarks & Gluons

low energy

high energy

colour confinement

coupling ~1

asymptotic freedom

coupling <<1

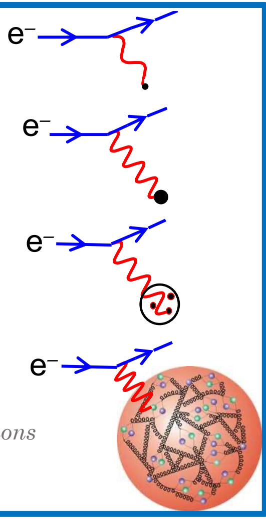
experiments with protons

Low energy

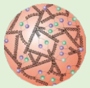
point-like

Very high energy

sea of quarks and gluons



Parton Distribution Functions



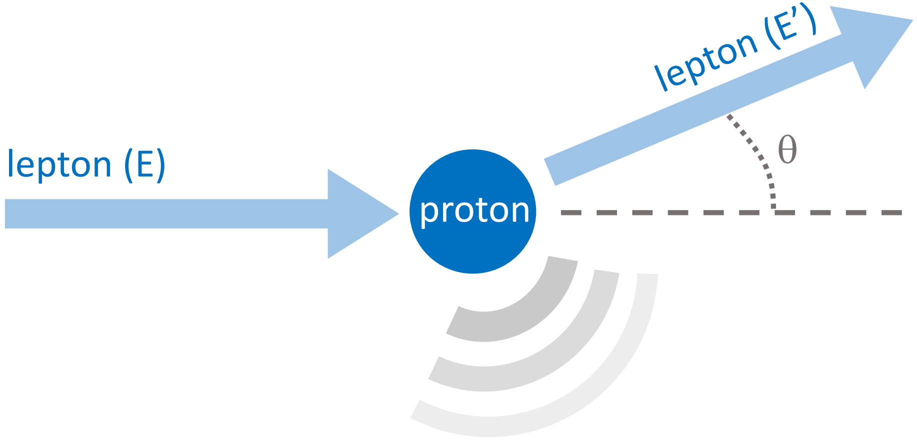
"confined" proton

"deconfined" quarks & gluons

used in experiment (applications)

used in Lagrangian (first principles)

The 50+ years success story of DIS



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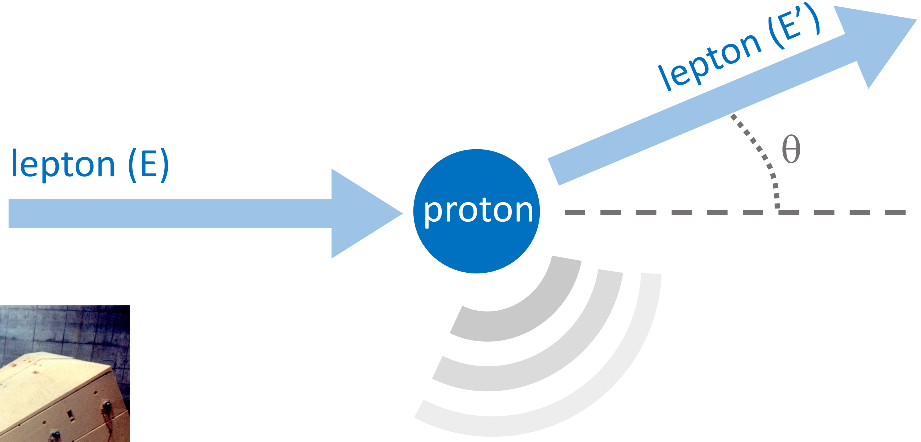

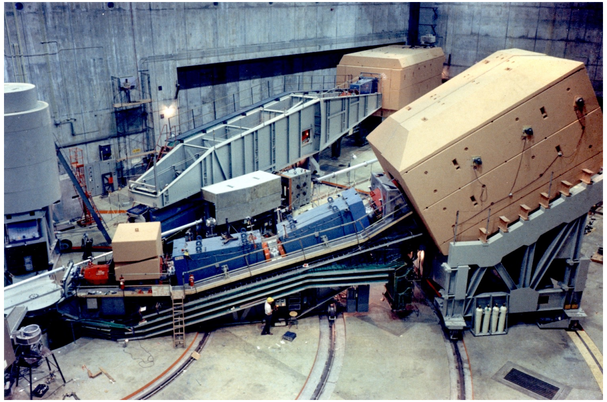

Discovery of quarks

(1968, ep@MIT-SLAC experiment)

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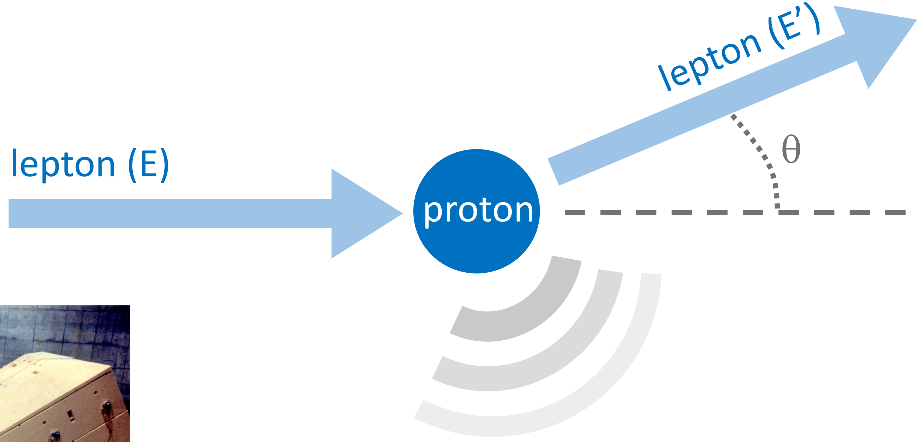

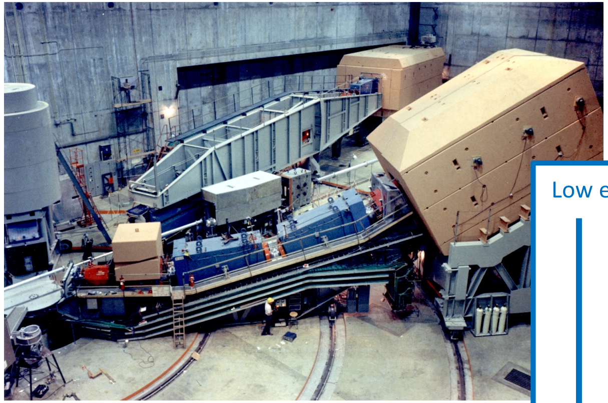

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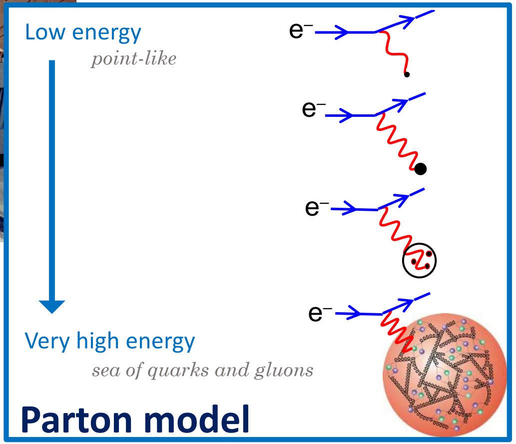

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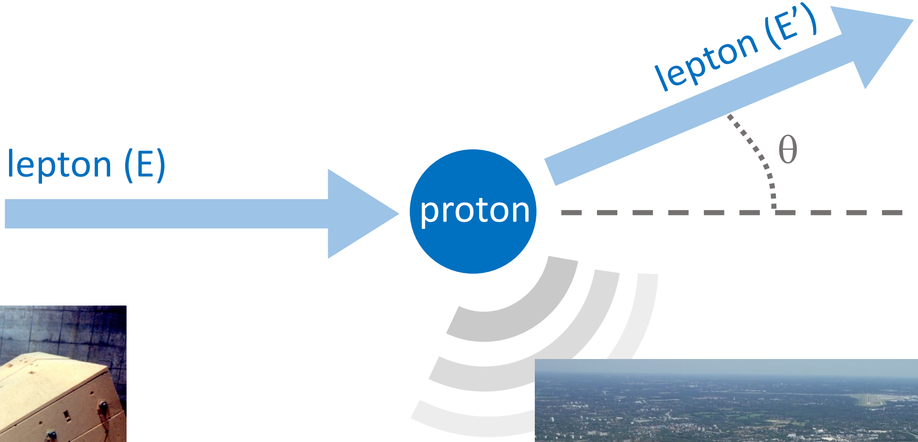

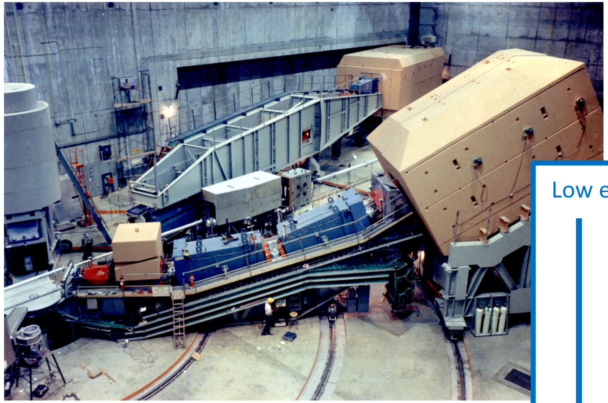

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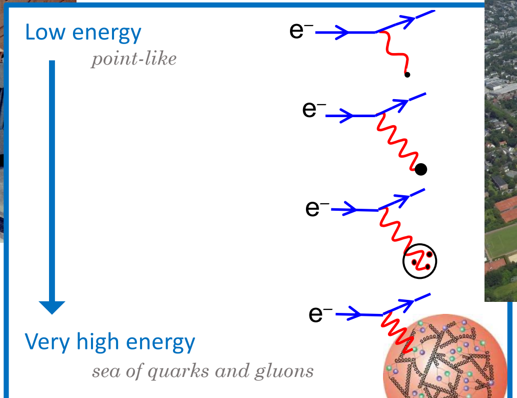
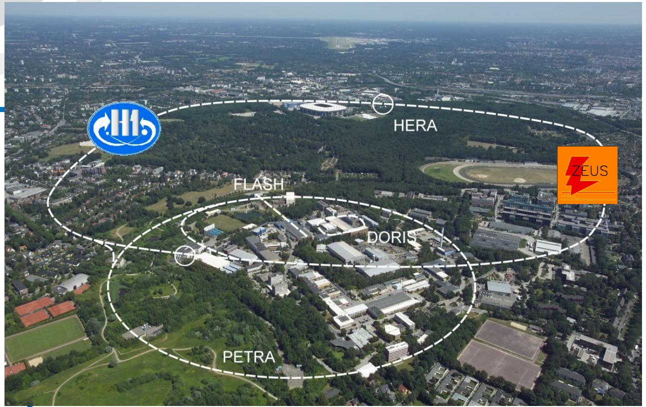


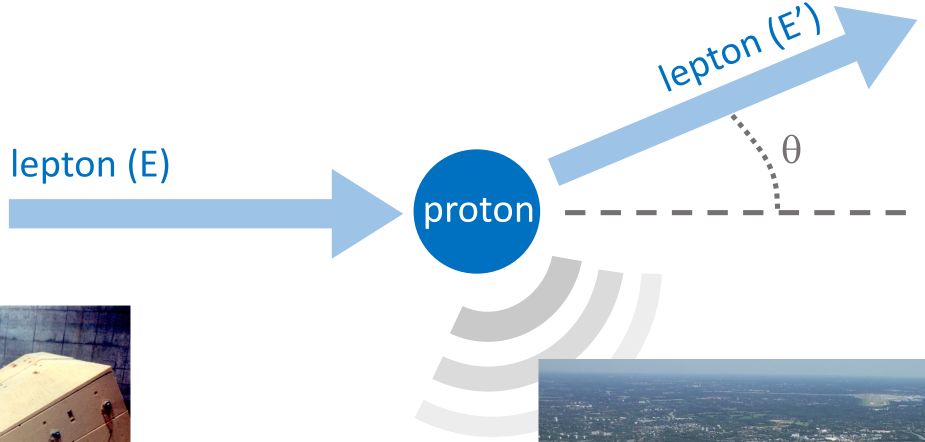
Parton model

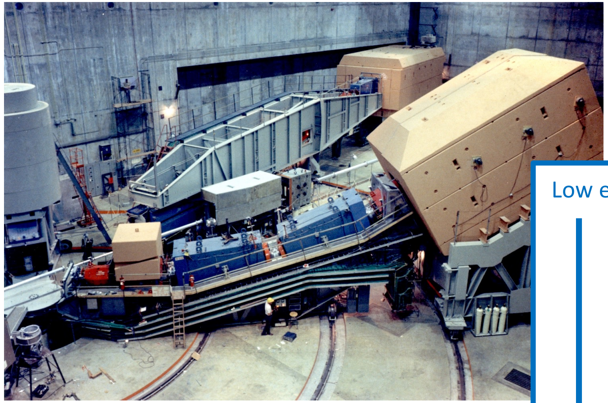


The DIS precision era

(1992-2007, $e^{\pm}p$@HERA)

The 50+ years success story of DIS





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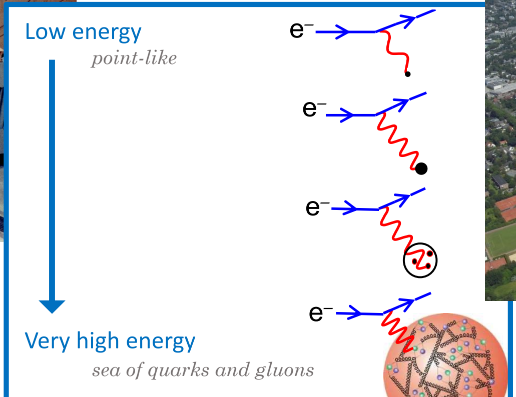

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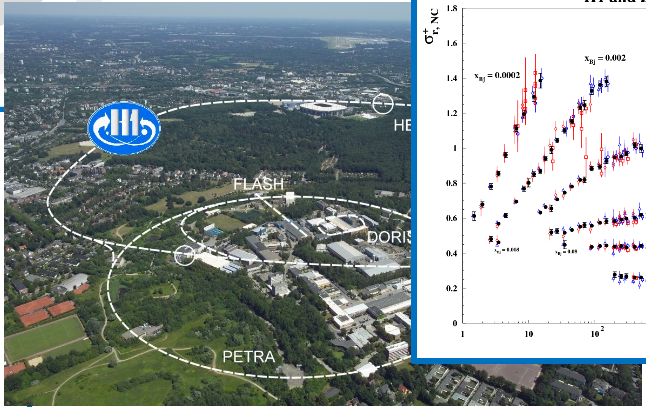

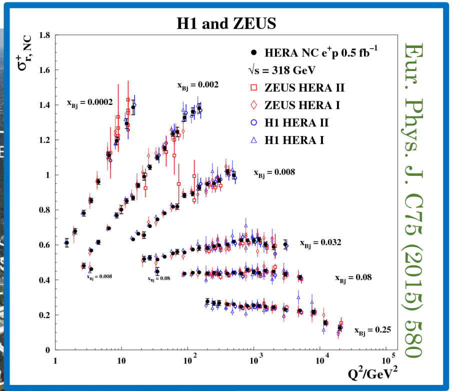

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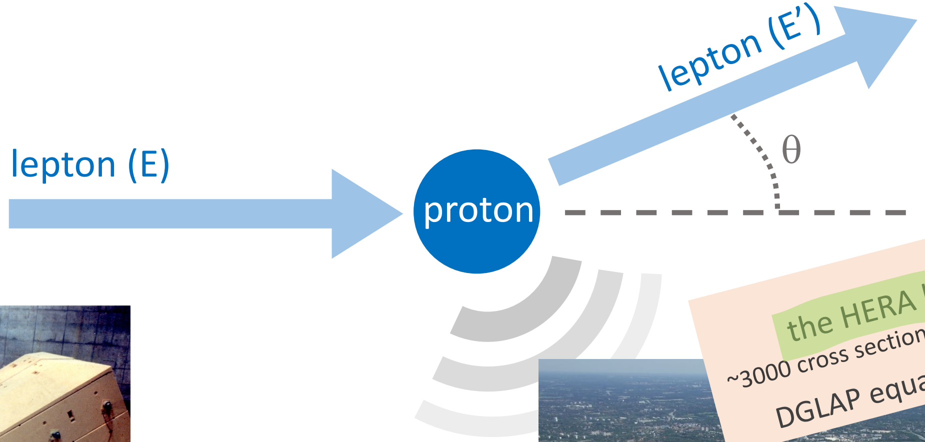

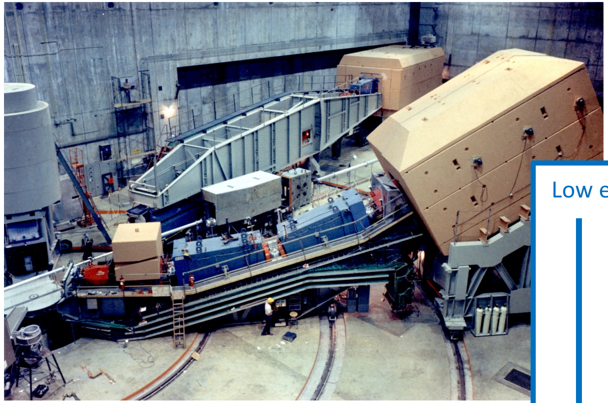

Discovery of quarks

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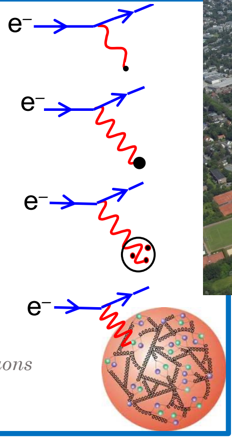
Low energy

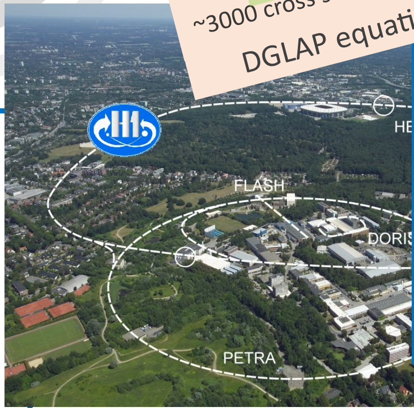
point-like

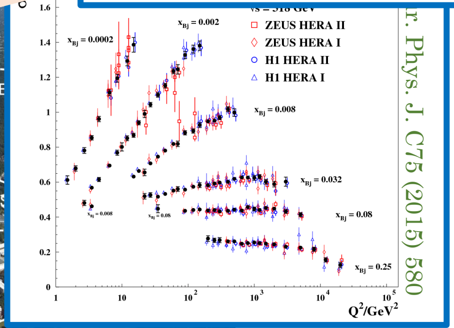


Very high energy

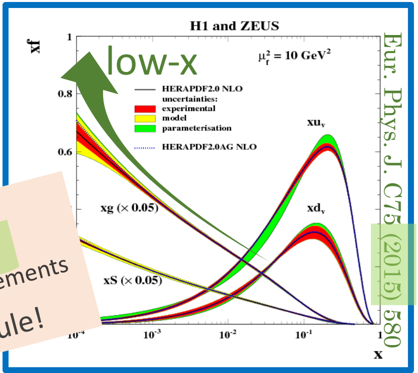
sea of quarks and gluons

Parton model





Parton Distribution Functions



the HERA legacy

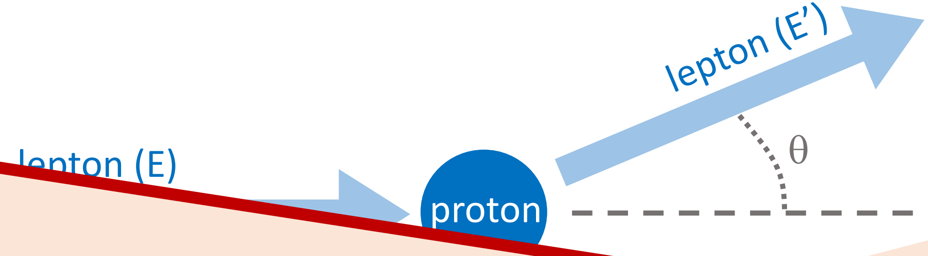
~3000 cross section measurements

DGLAP equations rule!

The DIS precision era

(1992-2007, $e^{\pm}p$@HERA)

The 50+ years success story of DIS



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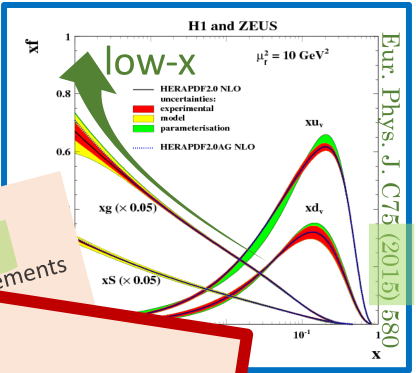
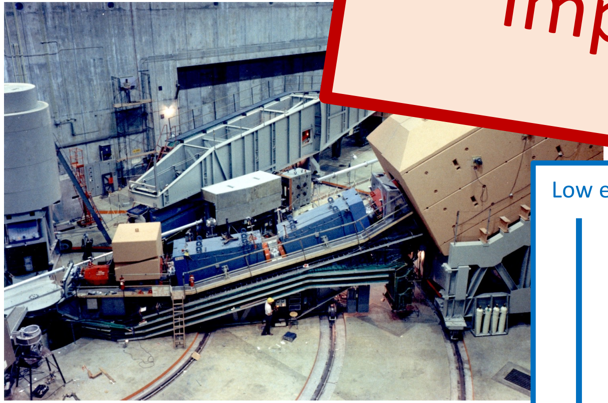


Important for the LHC program



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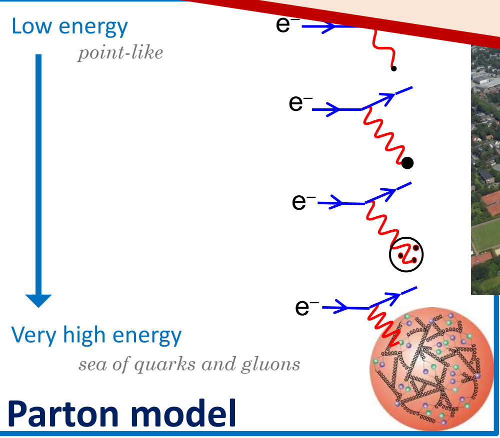
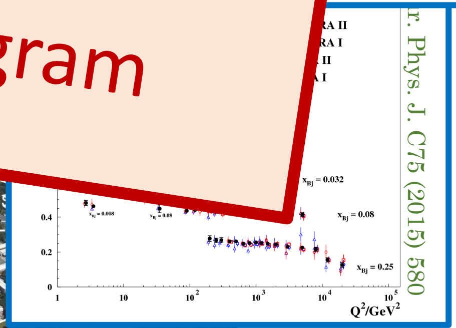


Parton model



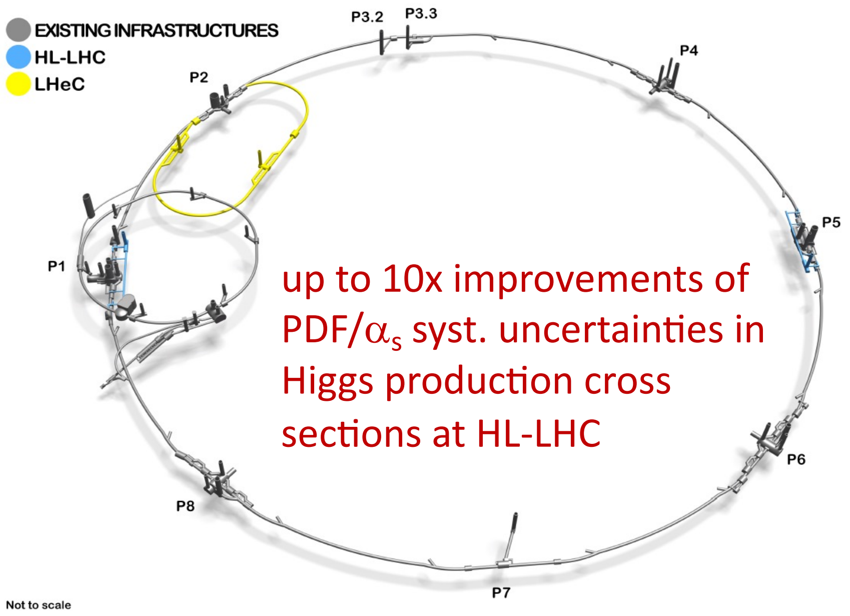
The DIS precision era

(1992-2007, $e^{\pm}$p@HERA)

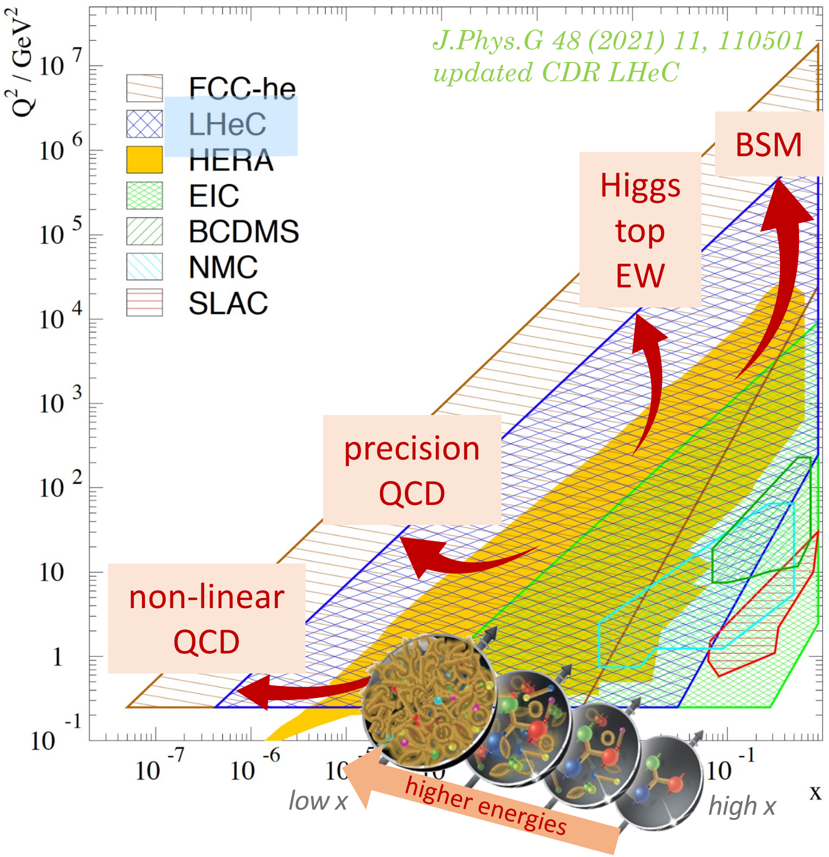
Empowering the (HL-)LHC program with the LHeC

Measurements of proton Parton Distribution Functions are vital to improve the precision

LHeC (up to 60 GeV e^- from Energy Recovery Linac)
E_{cms} = 0.2 – 1.3 TeV, (Q^2,x) range far beyond HERA
run with the HL-LHC (≳ Run5)



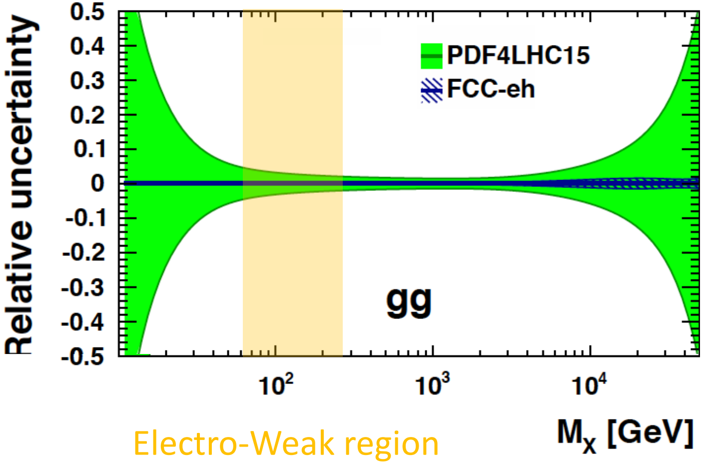
up to 10x improvements of PDF/α_s syst. uncertainties in Higgs production cross sections at HL-LHC



Empowering the FCC-hh program with the FCC-eh

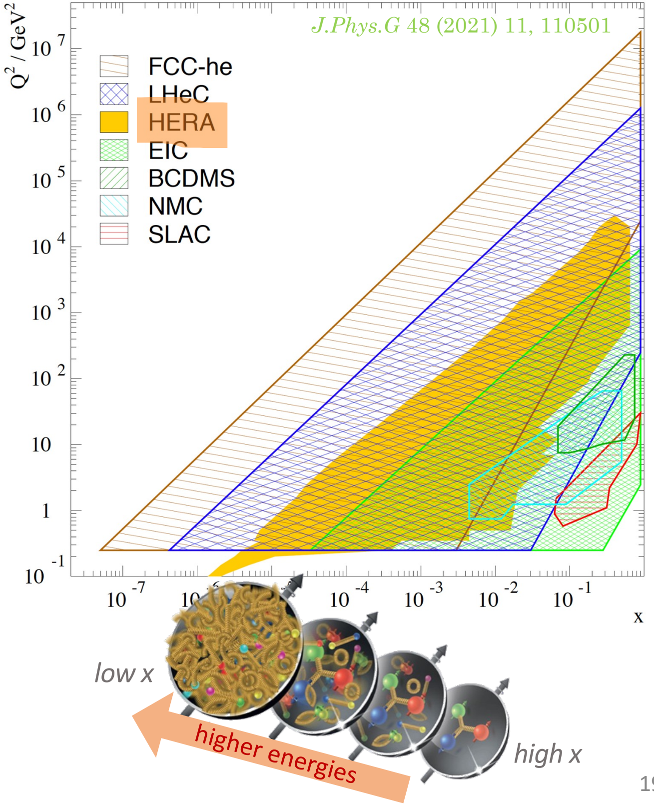
~5-7% uncertainty
on the σ(W,Z,H)

pp @ 100 TeV



Electro-Weak region

Kinematic range Parton Distribution Functions



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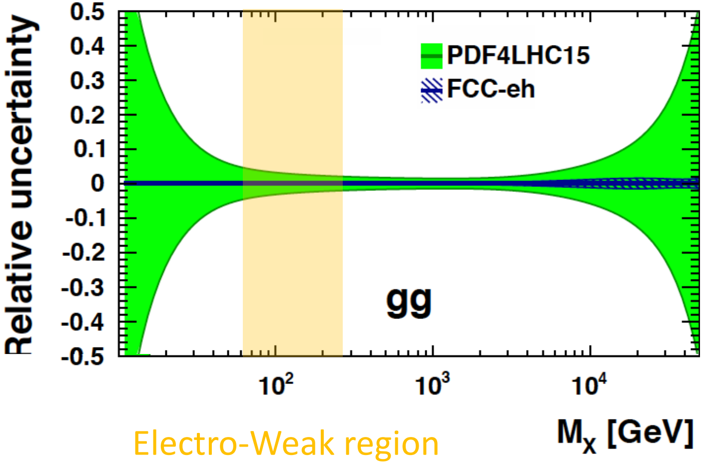


Electro-Weak region

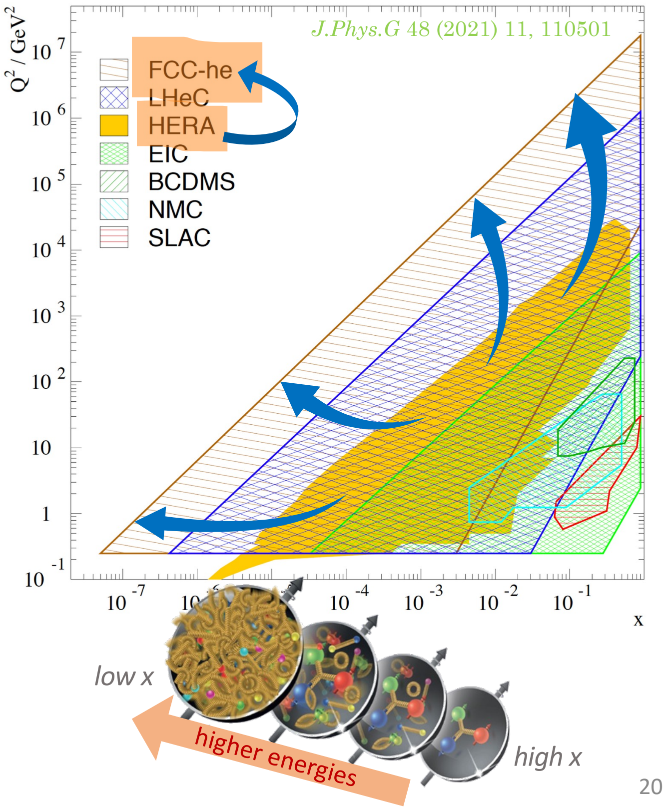
~5-7% uncertainty on the σ(W,Z,H)

no FCC-eh

with FCC-eh

~1% uncertainty on the σ(W,Z,H)

Kinematic range Parton Distribution Functions

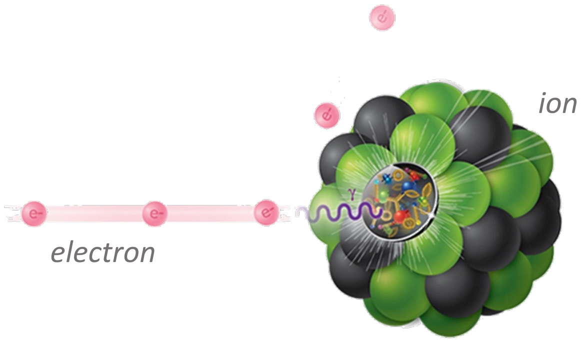


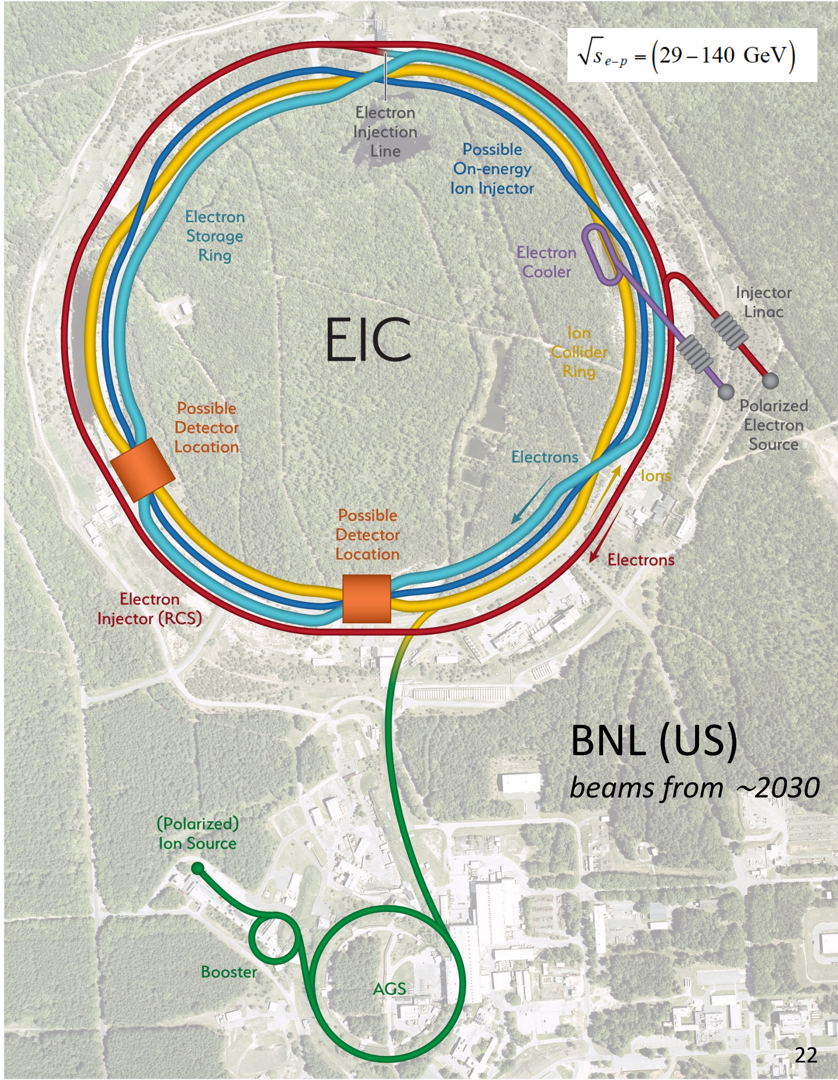
around the corner:
a unique ep & eA scattering facility

Electron-Ion Collider (EIC)

World's 1st polarized e-p/light-ion & 1st eA collider

User Group >1000 members: http://eicug.org





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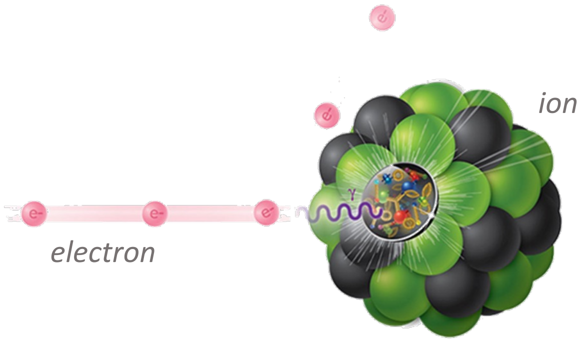
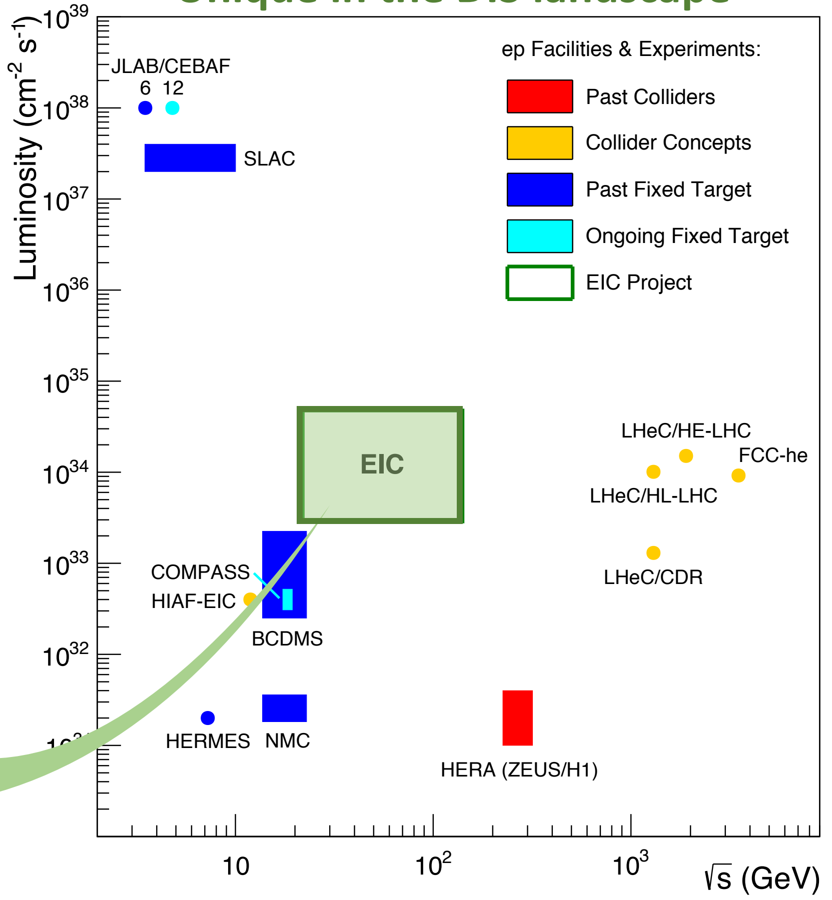


○ High luminosity
○ Wide range in beam energy
○ Polarized lepton & hadron beam
○ Nuclear beam

Unique in the DIS landscape

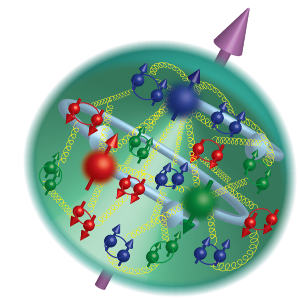


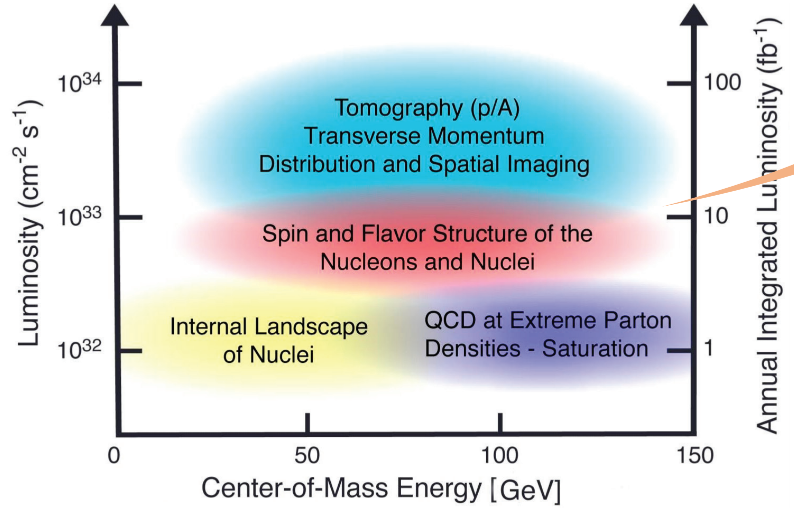
Electron-Ion Collider (EIC)

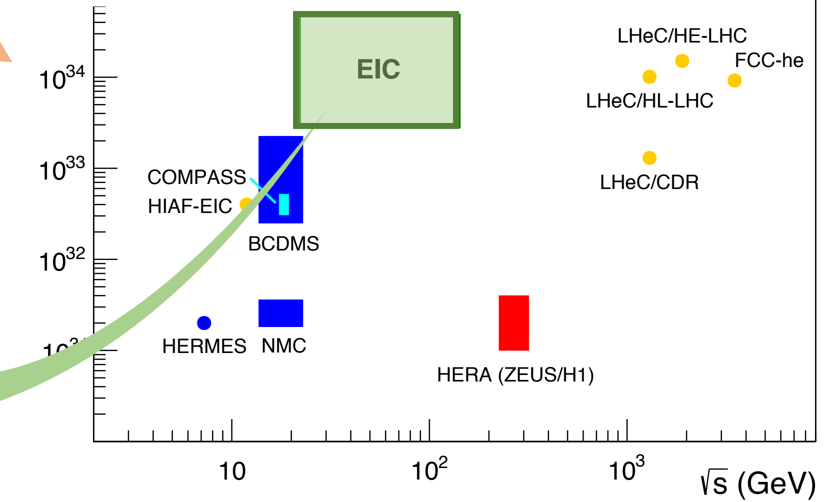
Unique in the DIS landscape

How do the properties of proton and neutrons arise from its constituents?

Towards a 3D partonic image of the proton







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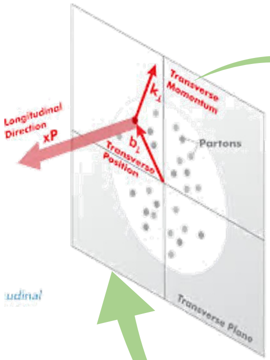

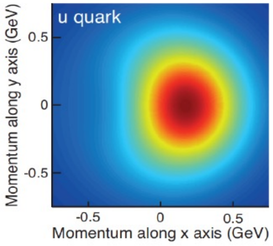

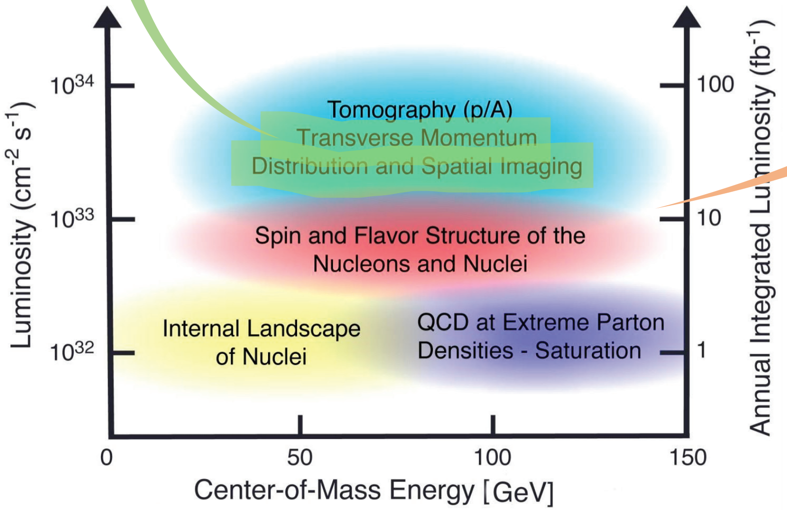

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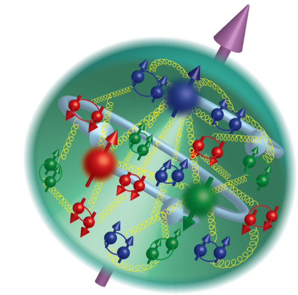

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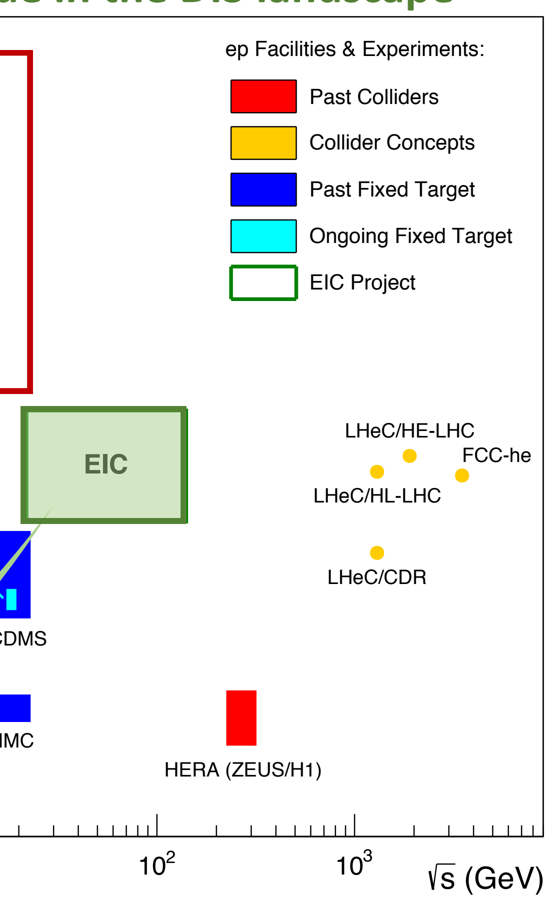
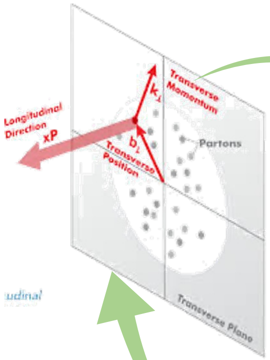
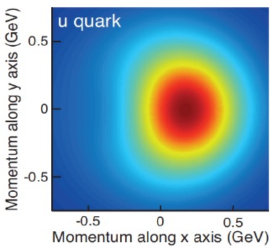
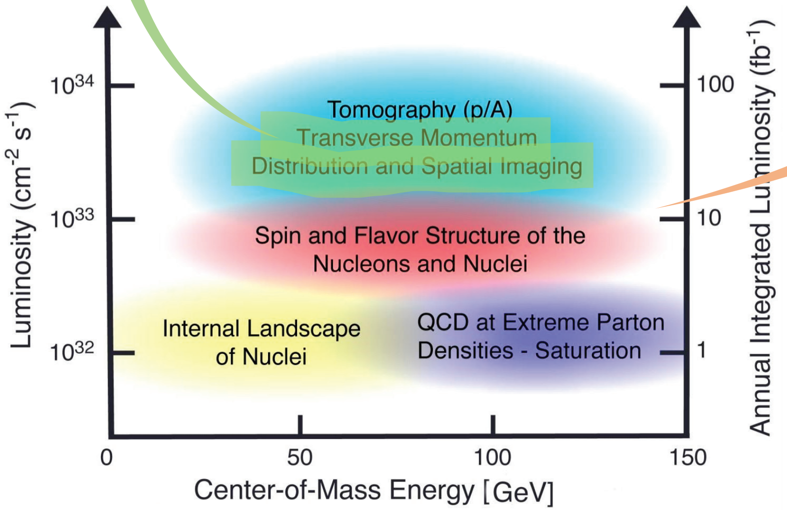


Electron-Ion Collider (EIC)

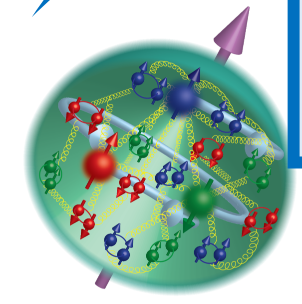




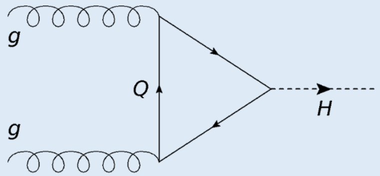


How do the properties of proton and neutrons arise from its constituents?

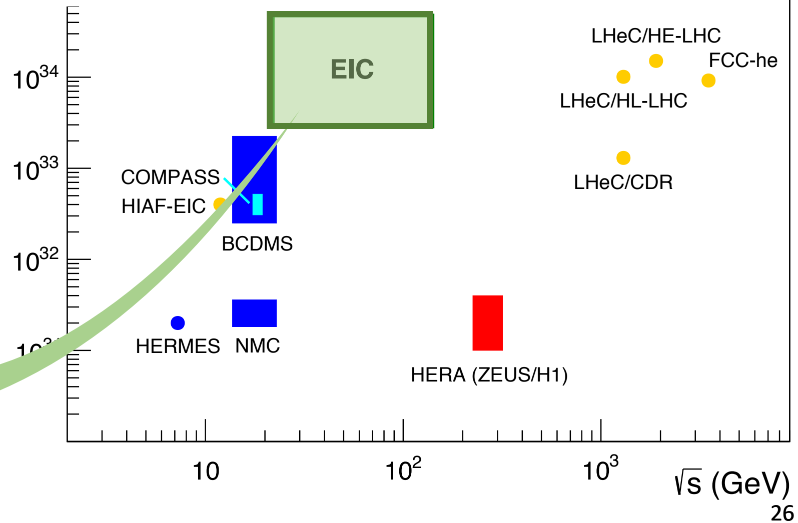
Towards a 3D partonic image of the proton



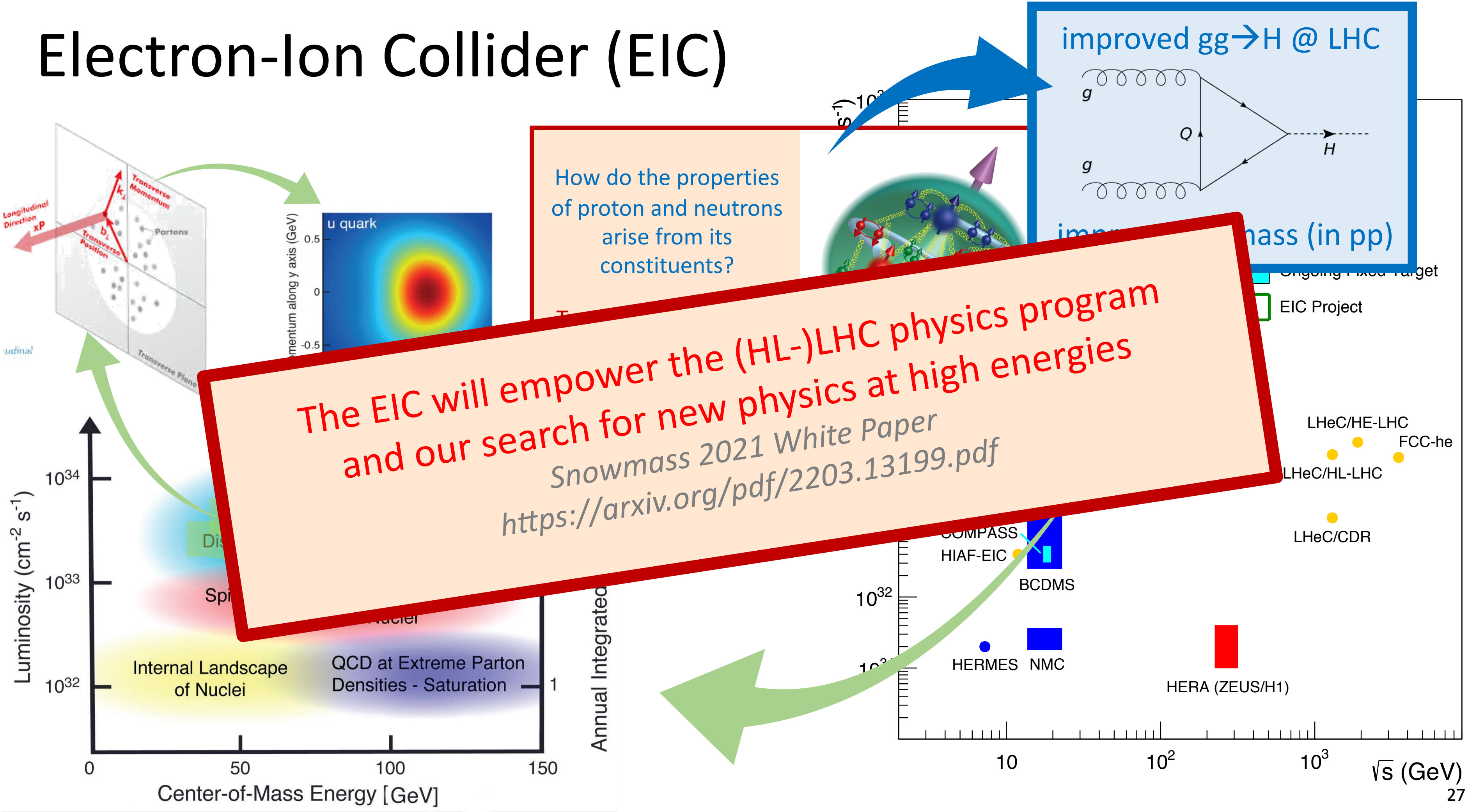
improved gg→H @ LHC



improved W mass (in pp)



Electron-Ion Collider (EIC)



The EIC will empower the (HL-)LHC physics program and our search for new physics at high energies

Snowmass 2021 White Paper
https://arxiv.org/pdf/2203.13199.pdf

From lower to higher energy scattering experiments

A global ep/eA/μA program bridging nuclear & particle physics for a profound understanding of the structure of matter

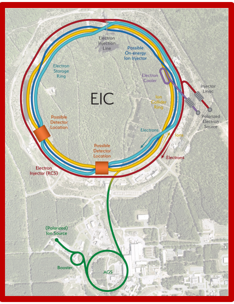
Driven by unique science

nuclear structure
ElectroWeak & Higgs
new physics searches
theory & experiment

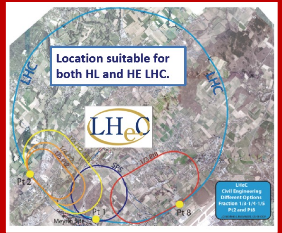
2020'ies

Low-energy scattering
MESA, COMPASS++/AMBER, NA61, …

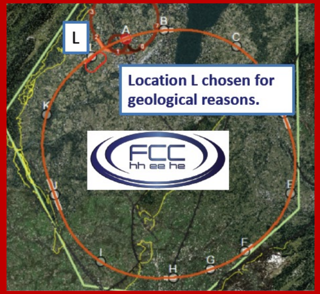
2030'ies



2040'ies



> 2050



Driven by remarkable technology

energy recovery & RF structures
precision detectors
leverage on other colliders

②

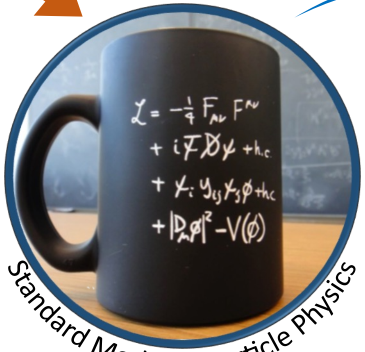
the symmetries in nature

Mathematical description of nature based on its symmetries

Our understanding is not complete… hence where and how do these symmetries break

(Broken) Symmetries

Discrete: C, P, T, CP, CPT
Gauge: U(1) x SU(2) x SU(3)

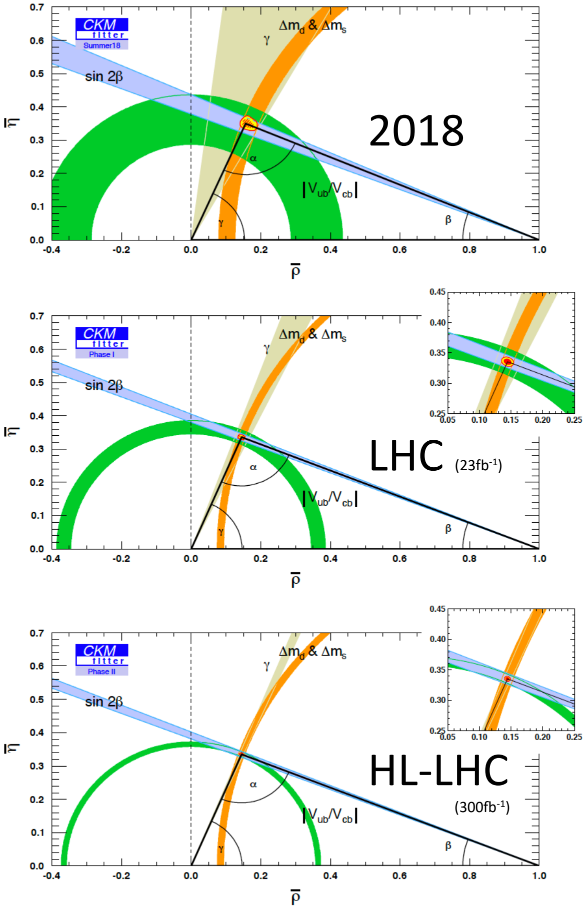


Standard Model of Particle Physics

Search for the tiniest cracks
(e.g.)
Matter vs antimatter
Baryon Number Violation
Lepton Number Violation
Electric Dipole Moments

Interpretations in theoretical frameworks covering nuclear and particle physics

Symmetries matter vs antimatter @ LHC of CERN



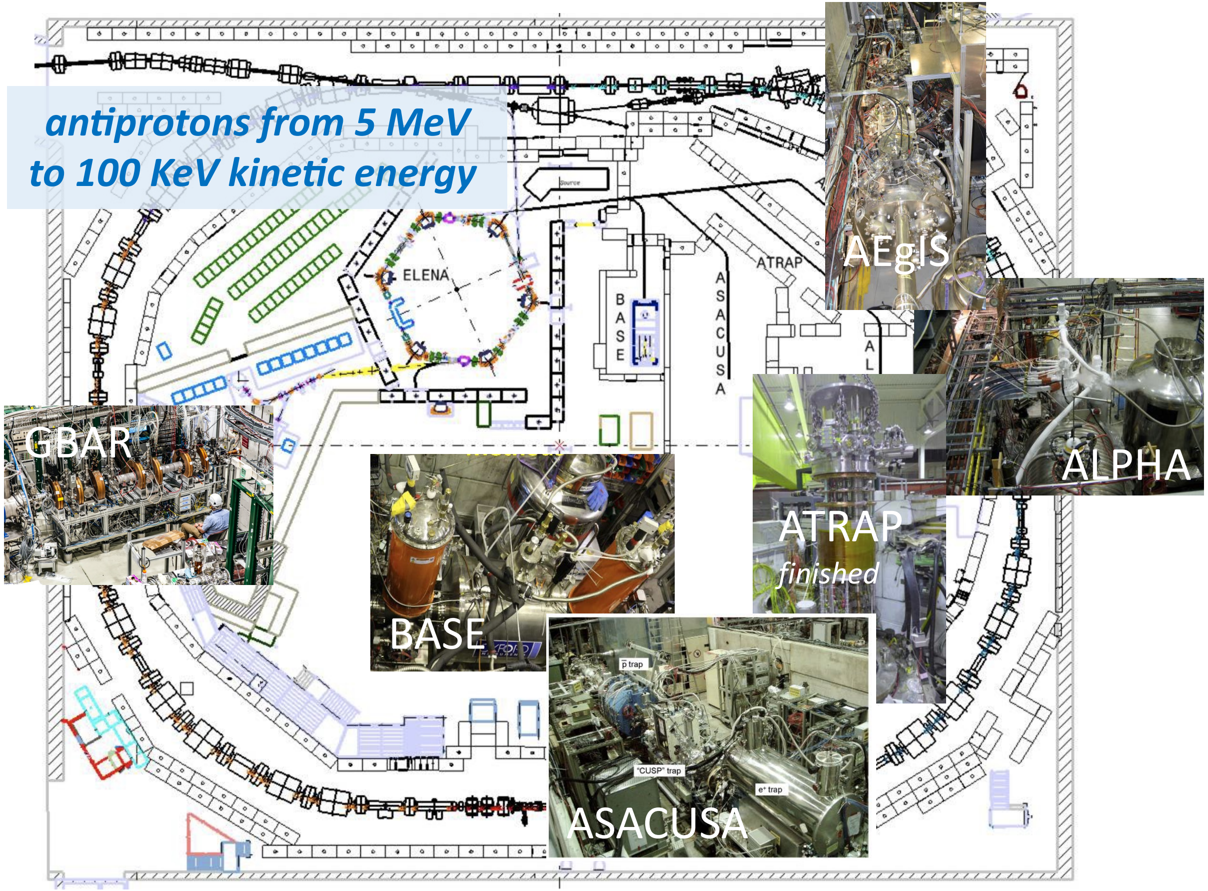
[Physics case for an LHCb Upgrade II, https://arxiv.org/pdf/1808.08865.pdf]

At the highest energies

- Constraining the parameters of the unitary CKM matrix (not predicted by the SM) will provide an extremely precise test of symmetries
- Upcoming improvements from LHC and Belle II
- Sensitivity to new physics up to 10^3-10^6 TeV assuming $\mathcal{O}(1)$ coupling strength, depending on flavour

Symmetries matter vs antimatter @ PS of CERN

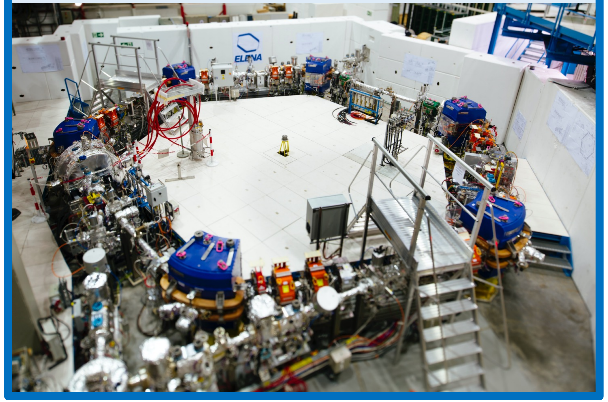
antiprotons from 5 MeV to 100 KeV kinetic energy



At low energies

Devoted to antiproton and antihydrogen properties

ELENA secures antimatter physics for the next decade



AEgIS – Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy
ALPHA – Antihydrogen Laser PHysics Apparatus
ASACUSA – Atomic Spectroscopy And Collisions Using Slow Antiprotons
ATRAP – Antihydrogen TRAP
GBAR – Gravitational Behaviour of Antihydrogen at Rest
BASE – Baryon Antibaryon Symmetry Experiment

Electric Dipole Moment (EDM)

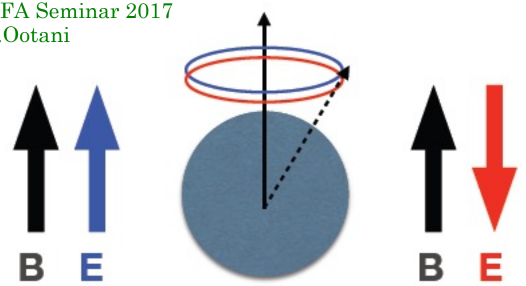
Separation of particle charge along angular momentum axis.

The EDM in the Standard Model is negligible (SM EDM electron 10^{-38} e-cm).

If non-zero it violates symmetries like P, T, CP.

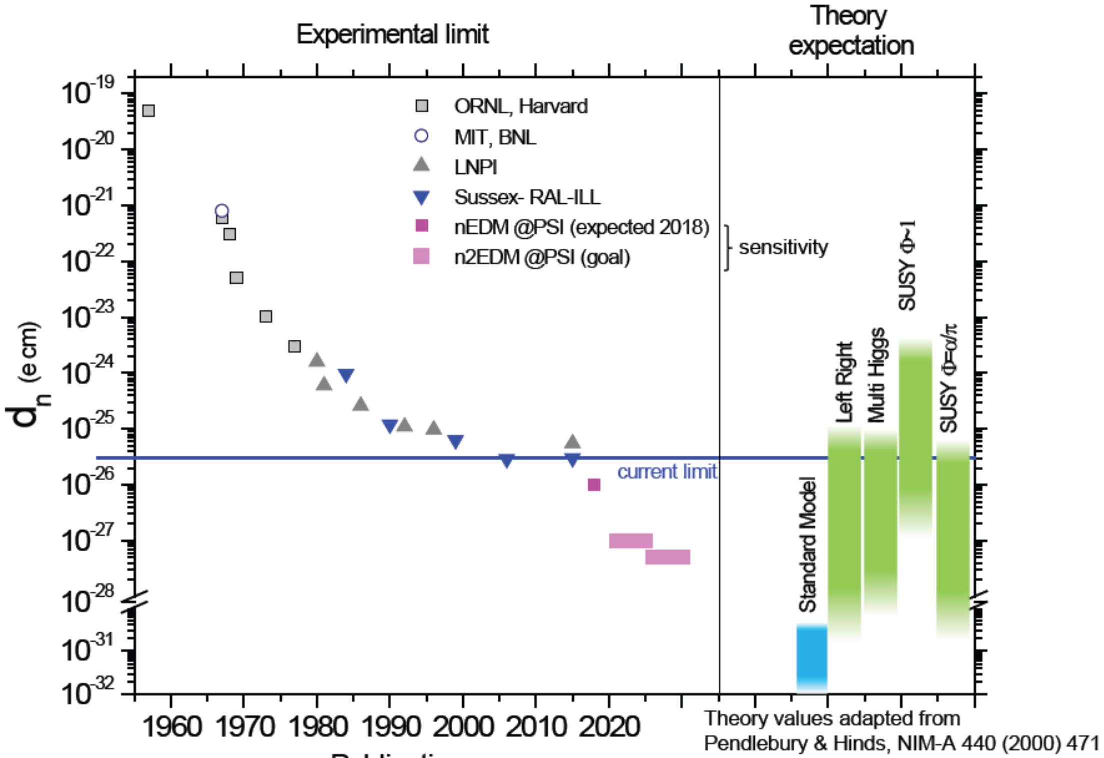
Measure Larmor frequency shift

ICFA Seminar 2017
W.Ootani



$$h\nu_{\uparrow\uparrow} = 2(\mu \cdot B + d \cdot E)$$
$$h\nu_{\uparrow\downarrow} = 2(\mu \cdot B - d \cdot E)$$
$$\rightarrow \quad h\Delta\nu = 4d \cdot E$$

Various systems are used from protons, neutrons and electrons to atoms and molecules.



B. Lauss, nEDM Workshop 2017

Charged-Particle EDMs (CPEDM & JEDI Collaborations)

Towards a prototype storage ring – Feasibility studies

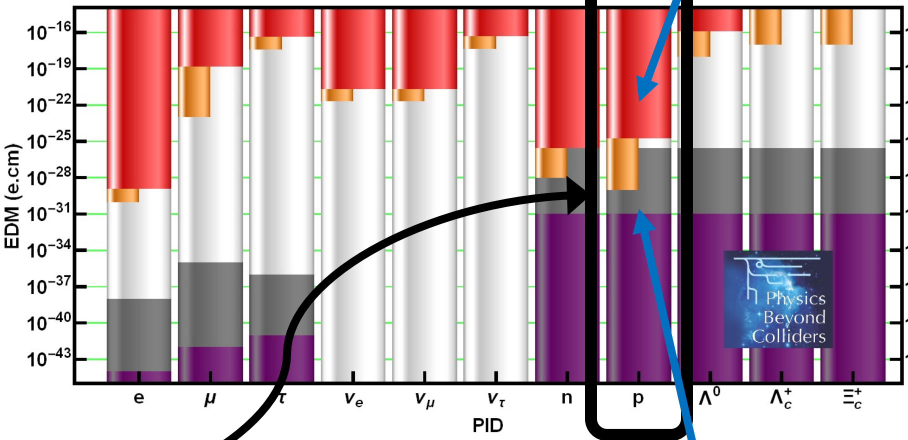
Opportunity to modify the COSY storage ring at the Forschungszentrum Jülich (Germany) towards a demonstrator and R&D for small EDMs

Ultimate goal of a dedicated storage ring with 400-500m circumference is pEDM sensitivity down to 10^{-29} e cm

(today 10^{-26} e cm)

experiment

<$d^{expected}$ and <d^{meas}



SM-CKM and SM-Θ

theory

Probing the fundamental symmetries of nature

Larger and smaller objects are used in nuclear & particle physics, but interpreted in a common framework

③

the invisible part of nature

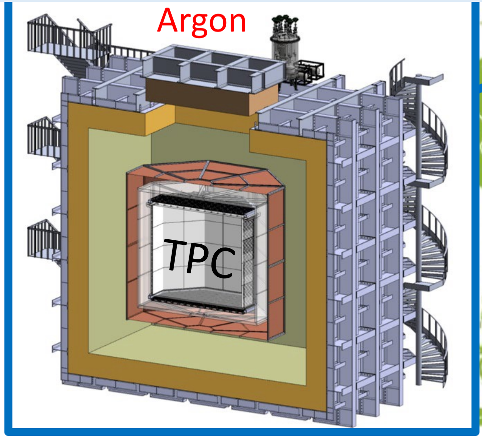
Major underground Facilities – shielding the visible

image courtesy of Susana Cebrián, "Science goes underground"

Major underground Facilities – Dark Matter (WIMP)

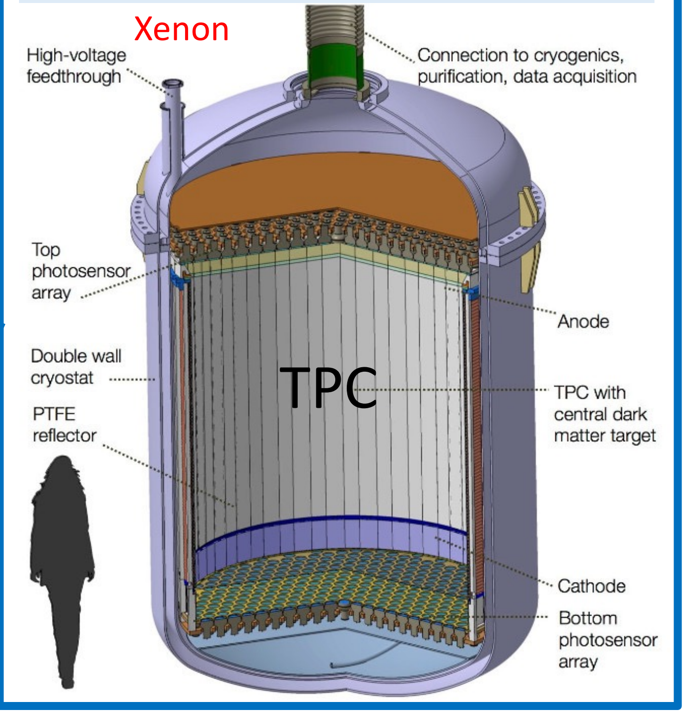
ultimate low background astroparticle physics observatories

DarkSide/DEAP to Argo (300t)



proposal

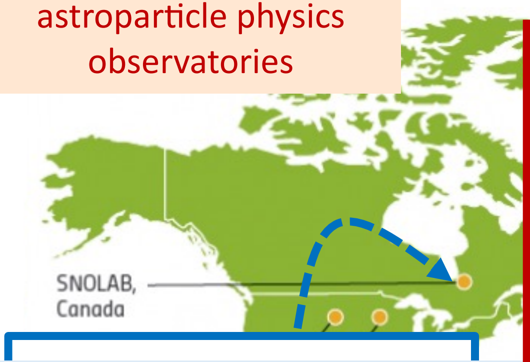
XENON (1-10t) to DARWIN (50t)

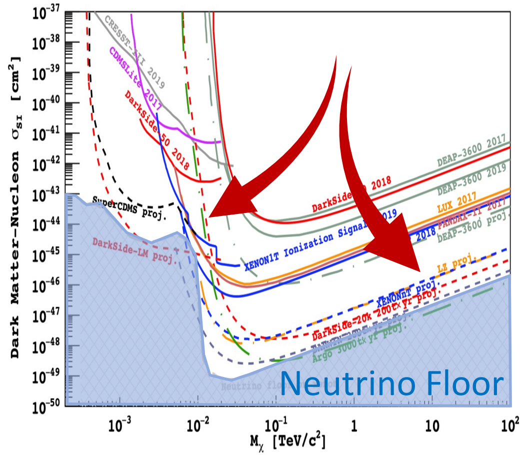


proposal towards CDR (beyond 2027)

Major underground Facilities – Dark Matter (WIMP)

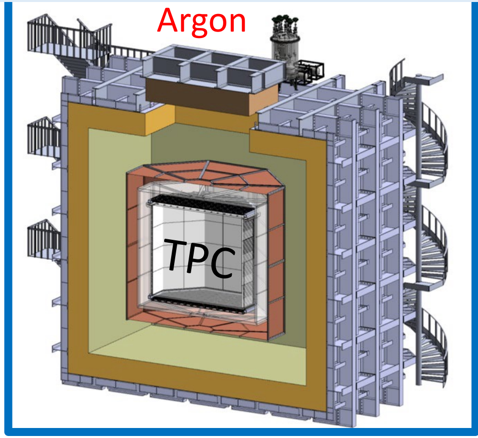
ultimate low background astroparticle physics observatories





reaching the "neutrino floor"
where the νA backgrounds dominate

DarkSide/DEAP to Argo (300t)



proposal

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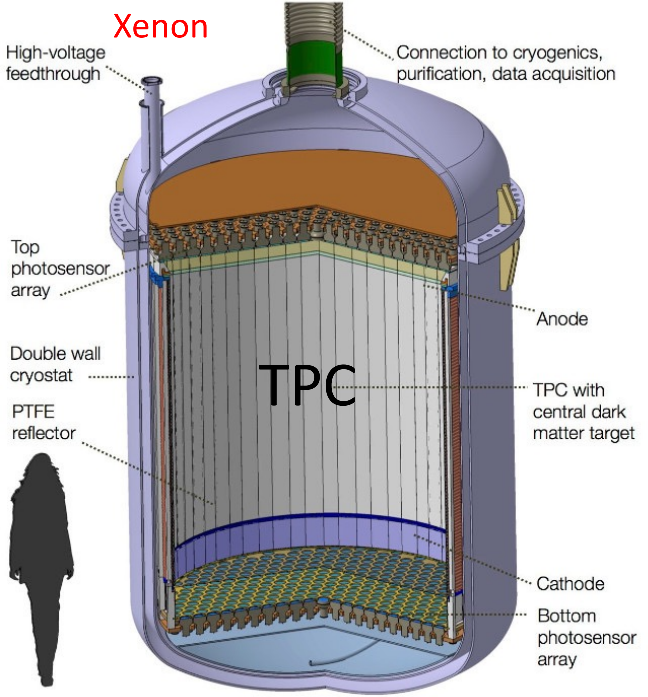
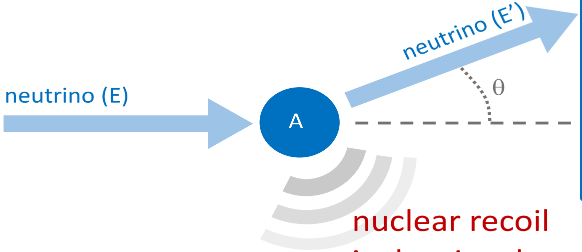


proposal towards CDR (beyond 2027)



nuclear recoil is the signal

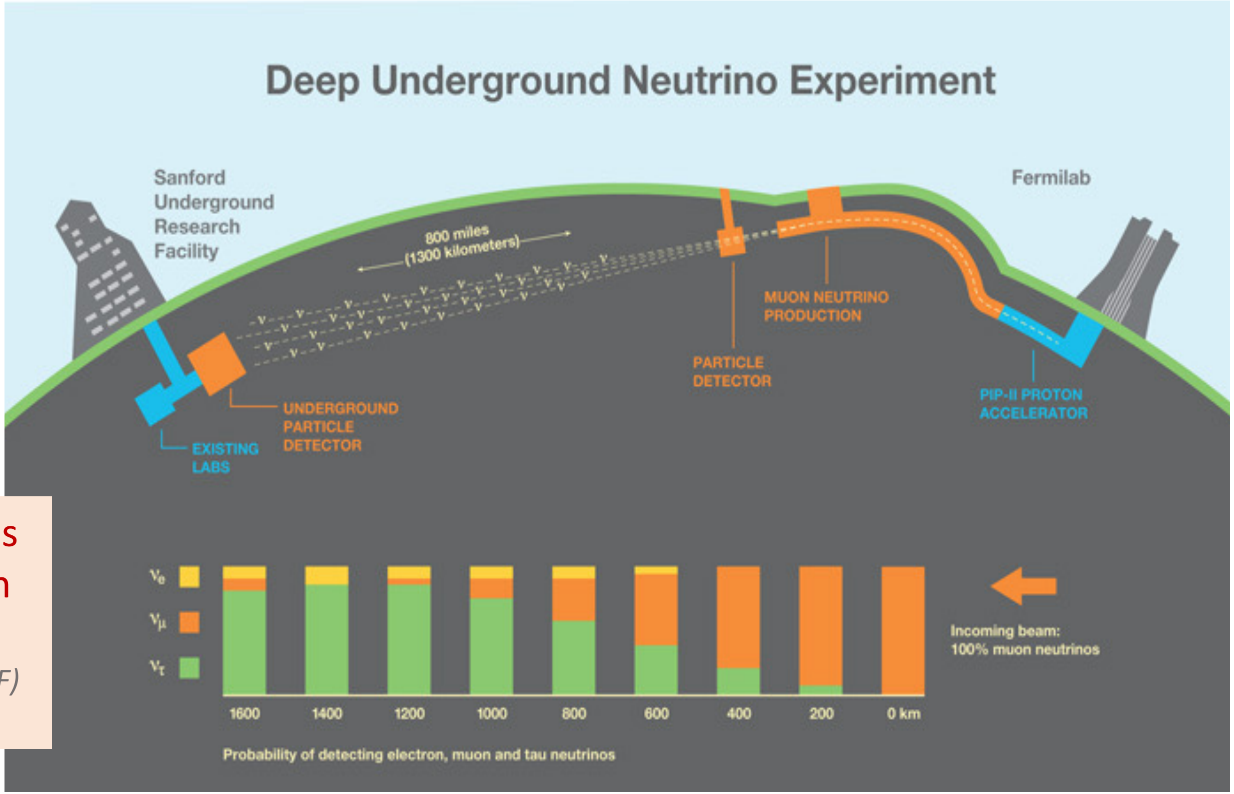
Neutrino sector extends the Standard Model

Because neutrinos oscillate, they have mass… but how to extend the Standard Model?

- *Is a neutrino its own anti-particle?*
- *Is there CP violation in the leptonic sector?*
- *What is the absolute mass scale?*
- *How does the neutrino mass spectrum look like?*

Measure the oscillation probabilities of neutrinos and antineutrinos with ultimate precision

e.g. at the Long-Baseline Neutrino Facility (LBNF) with the DUNE experiment

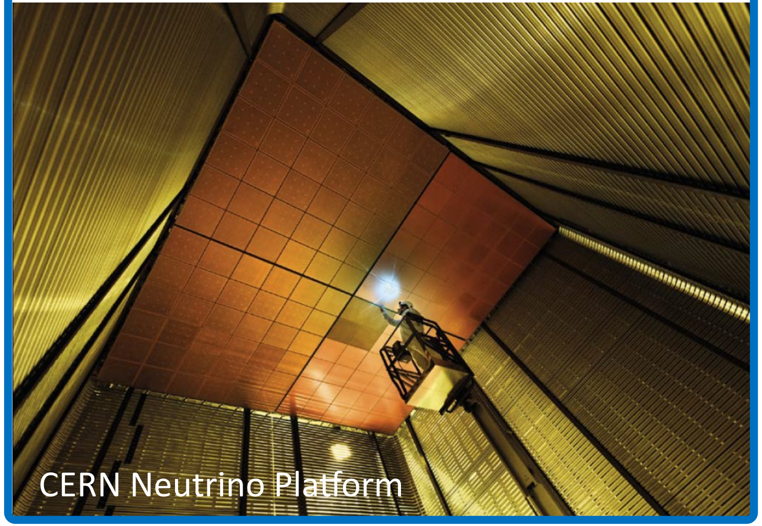


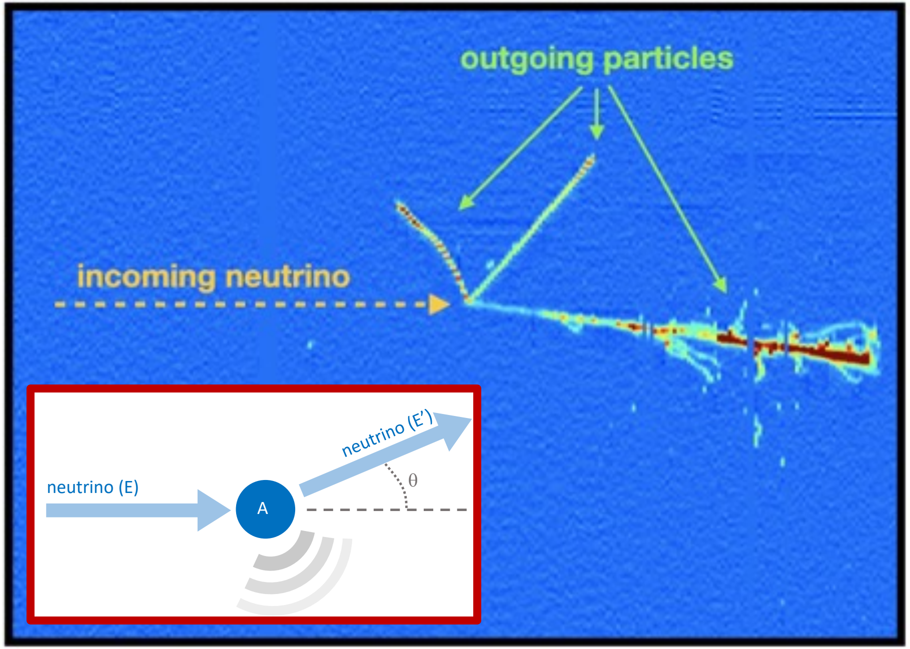
Empowering the neutrino/dark sector quest with DIS

Measurements of νA cross sections are vital to improve the precision (e.g. of the initial neutrino flux)

DUNE @ LBNF

Prototype dual-phase Liquid-Argon TPC

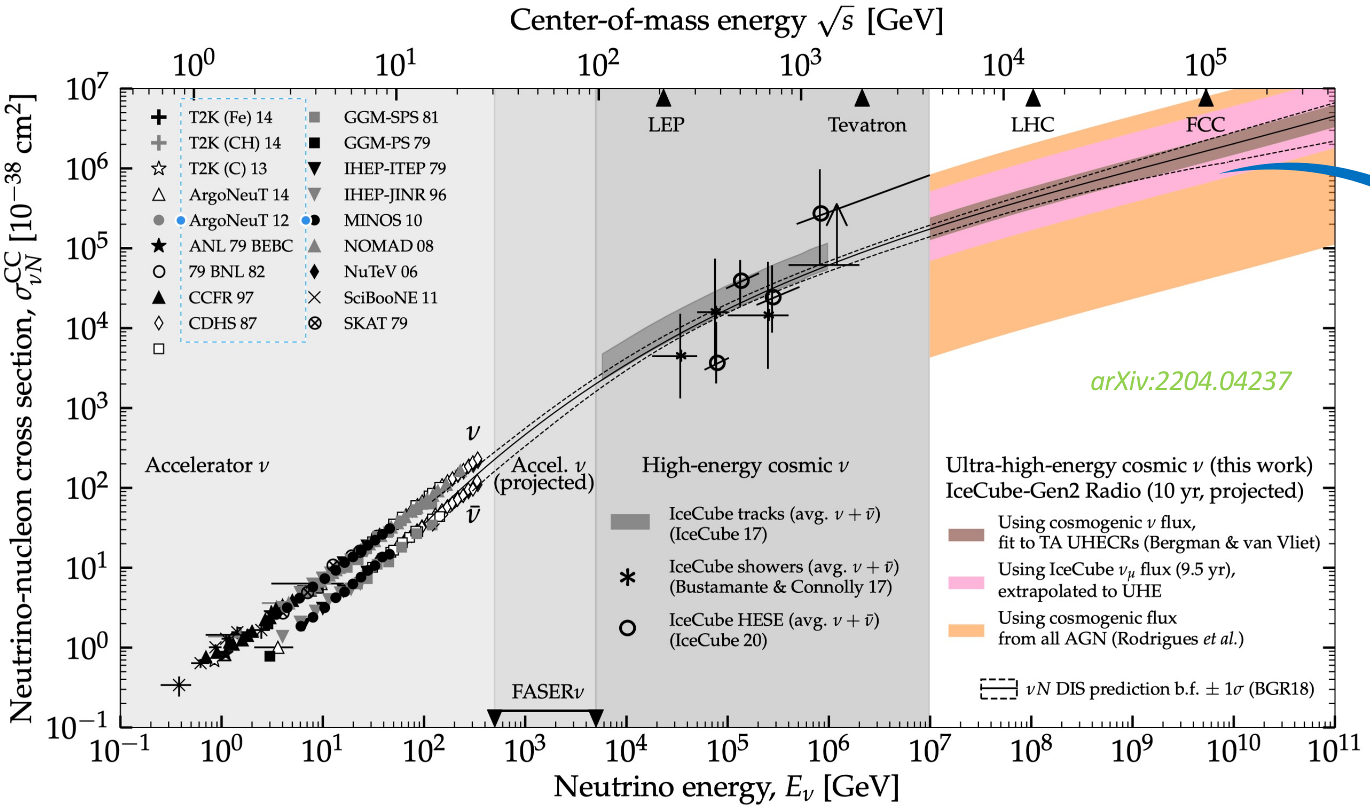




Precise low-energy neutrino DIS-like scattering measurements on nuclear targets are required for DUNE, Super-K/Hyper-K, IceCube, JUNO, …

Scattering with high-energy cosmic neutrinos

Measuring νN cross sections at ultra-high neutrino energies (>100 PeV) offers novel insight into the deep structure of protons and neutrons



IceCube's forecast of measurements of the neutrino charge current cross section through absorption by Earth (>10TeV)

From lower to higher energy ν scattering experiments

A global νN program bridging nuclear & particle physics for a profound understanding of the invisible sector

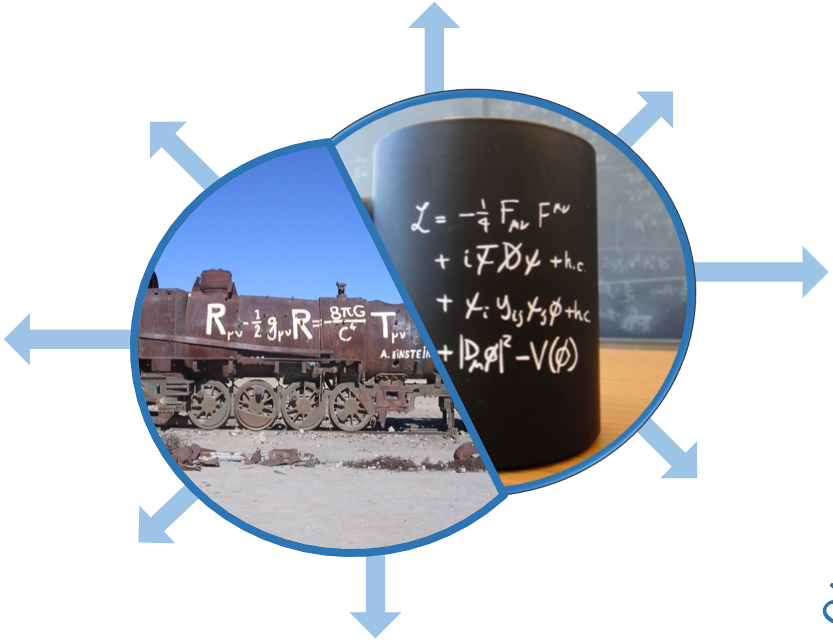
④

novel technologies are required to enable these scientific programs

higher energy interactions
in the lab

earlier universe

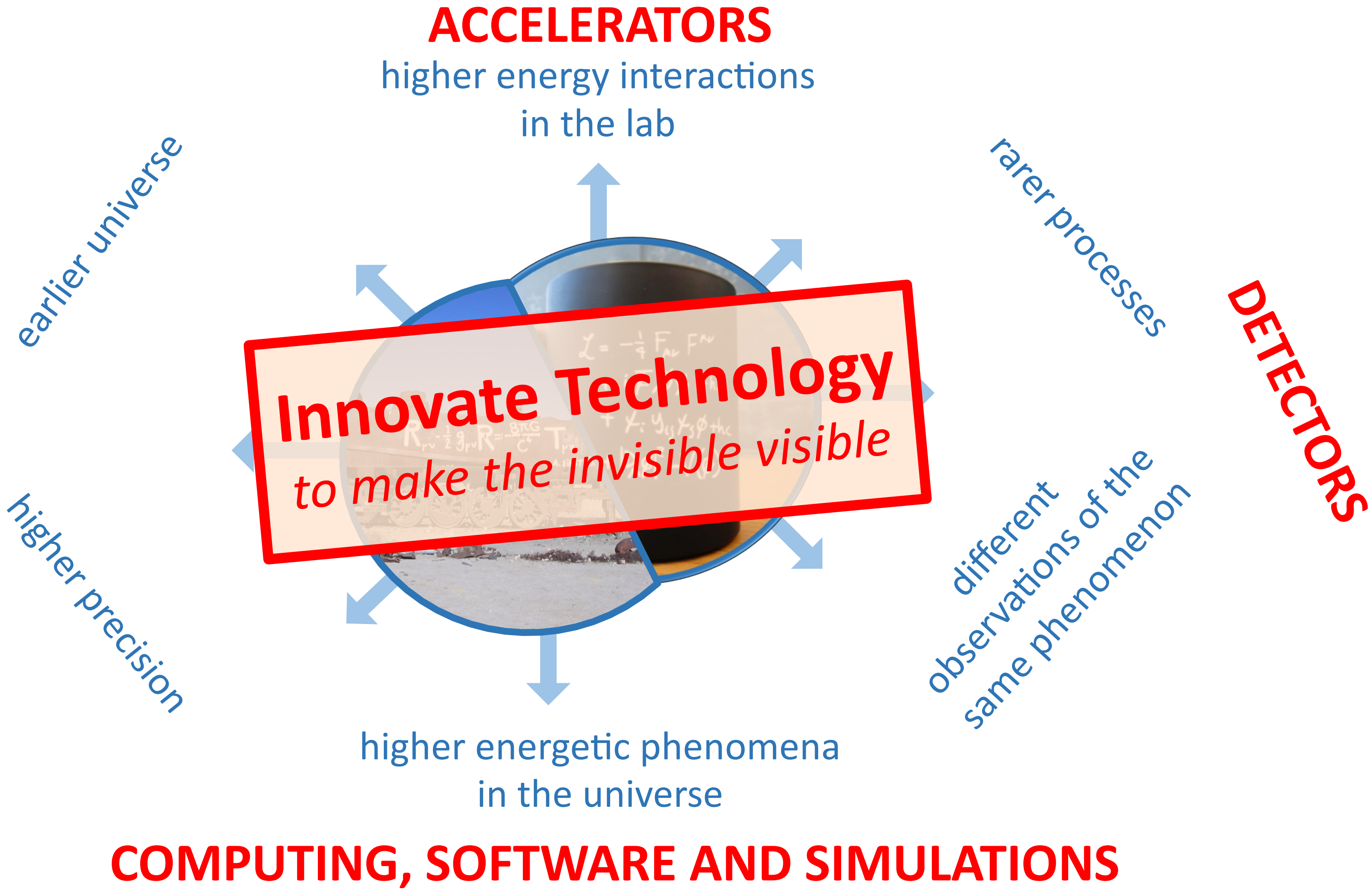
rarer processes

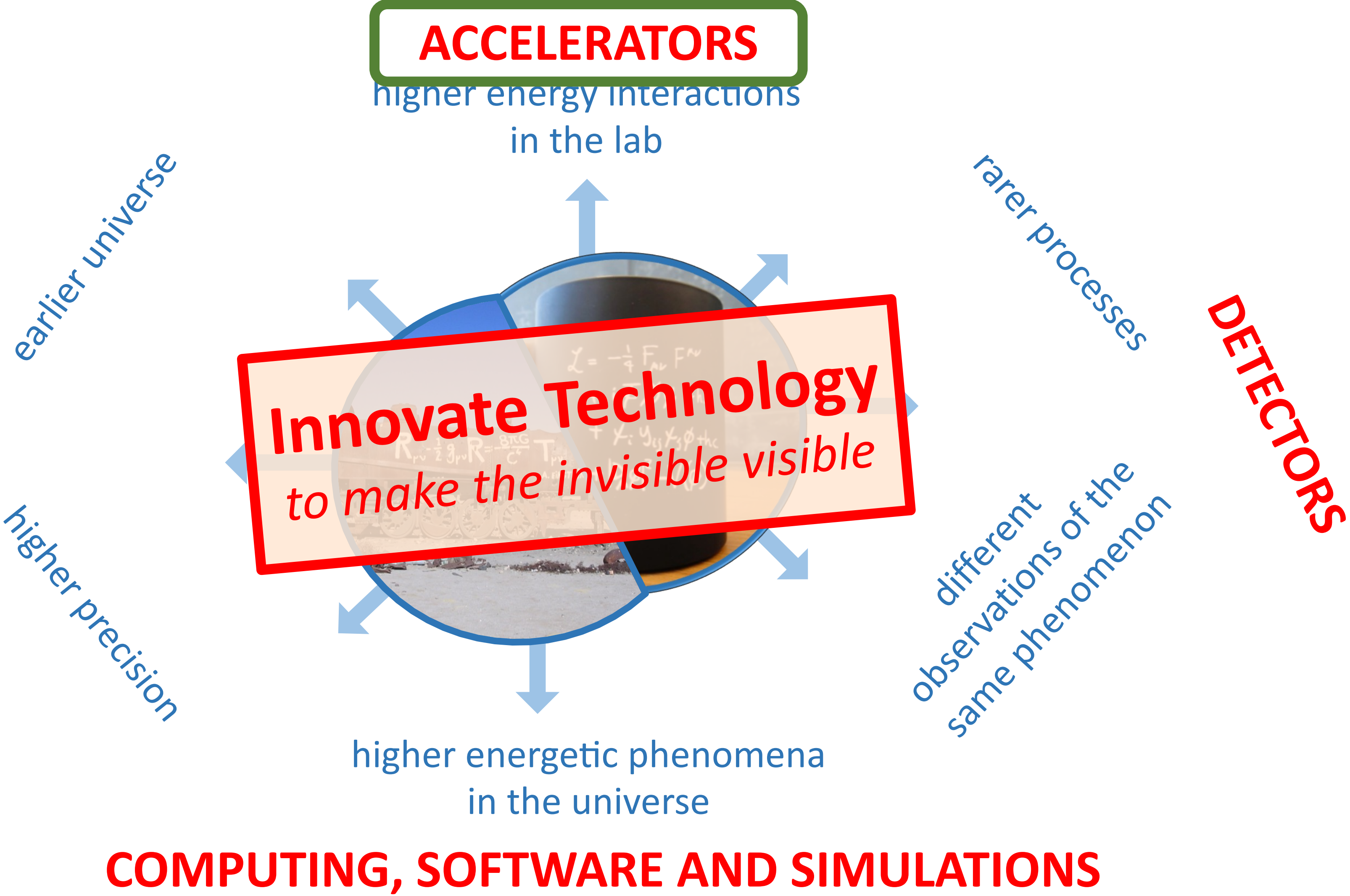


higher precision

different
observations of the
same phenomenon

higher energetic phenomena
in the universe


ACCELERATORS
higher energy interactions
in the lab
earlier universe
rarer processes
DETECTORS
Innovate Technology
to make the invisible visible
higher precision
different
observations of the
same phenomenon
higher energetic phenomena
in the universe
COMPUTING, SOFTWARE AND SIMULATIONS



ACCELERATORS
higher energy interactions
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COMPUTING, SOFTWARE AND SIMULATIONS

Advancing Accelerator Technologies

High-energy & high-intensity beams are required for nuclear and particle physics

European Accelerator R&D Roadmap (2021)

https://arxiv.org/pdf/2201.07895.pdf

- High-field magnets
- RF accelerating structures
- Plasma acceleration
- Muon colliders
- Energy Recovery Linacs (ERL)

Continuous innovations are required in accelerating structures to achieve more bright, energetic and powerful beams for nuclear and particle physics

A high-energy muon collider is as well on the mind
(at CERN… towards a $\mu p/\mu A$ DIS program)

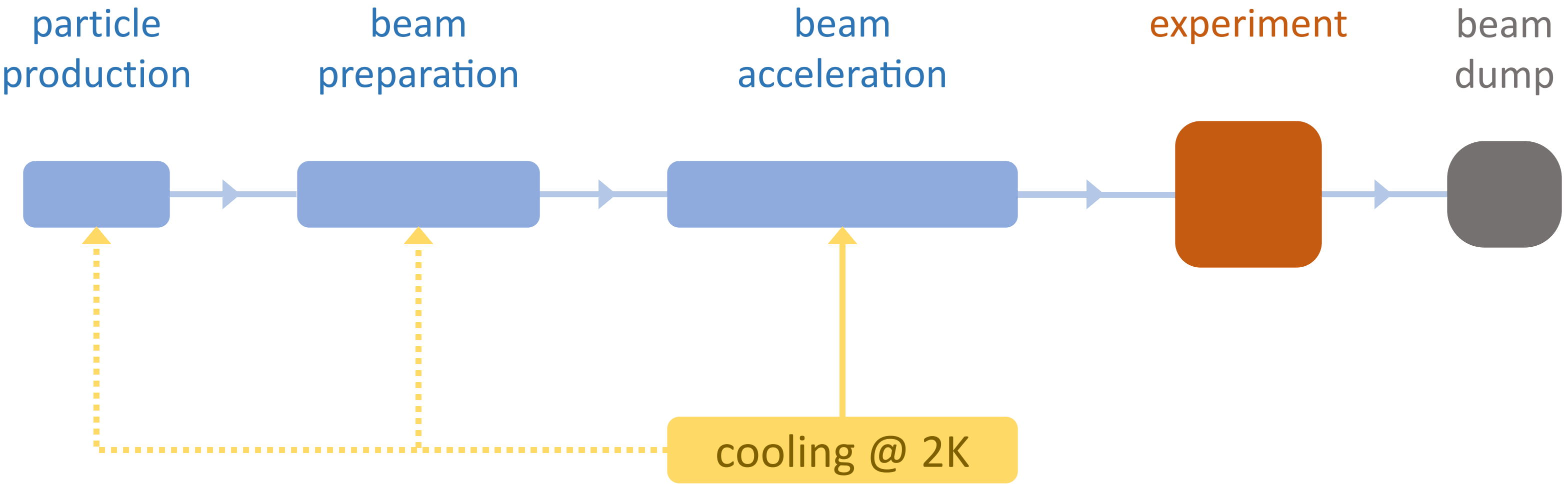
Efficiently recovering the energy from the accelerated particle beam

An overarching theme is the development of
Sustainable Accelerating Structures

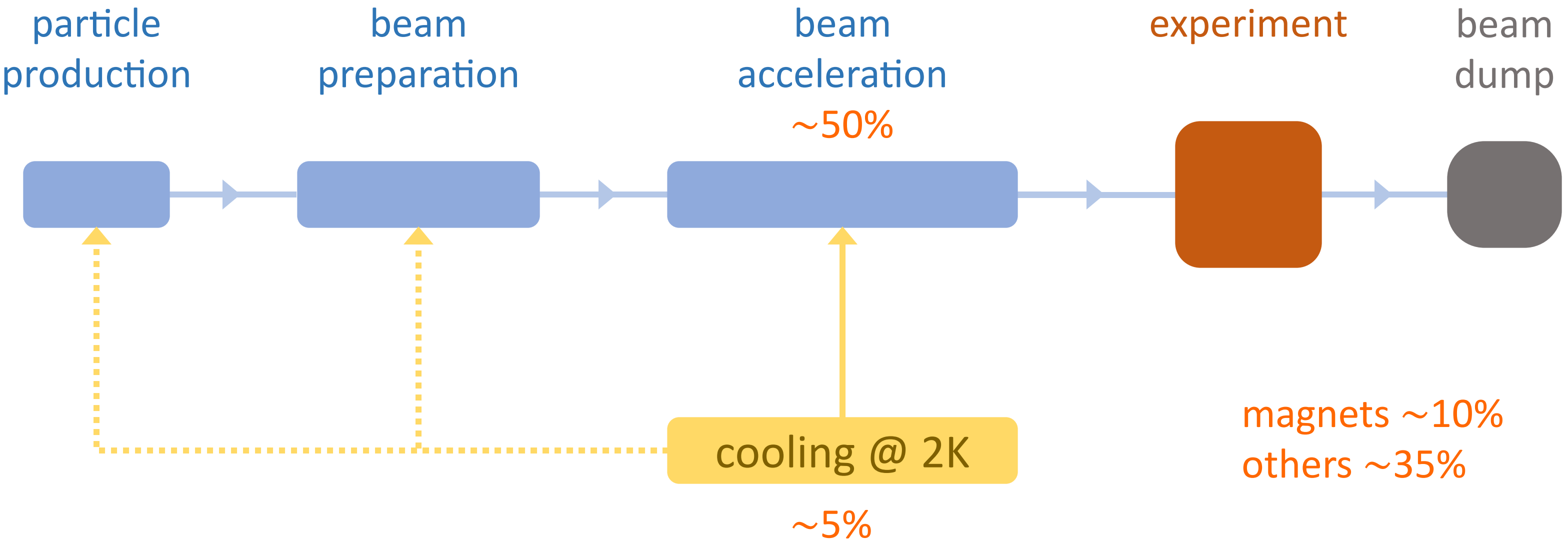
less energy, less cooling, less power loss, recover beam energy

a critical duty and common goal for nuclear and particle physics

Basic structures of a particle accelerator



Basic structures of a particle accelerator

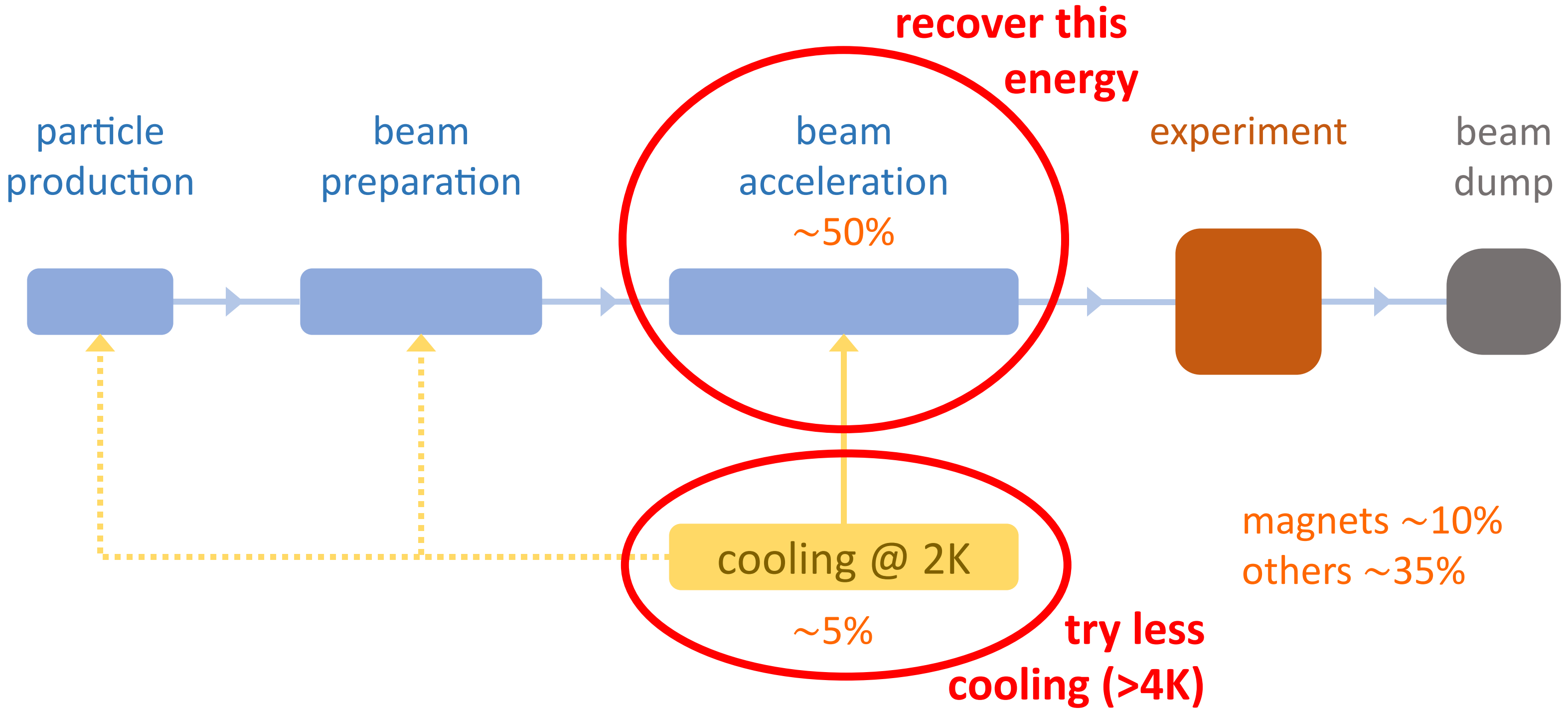


Typical power consumption for an electron-positron Higgs Factory

the highest priority next collider for particle physics

example FCC@250GeV

Basic structures of a particle accelerator



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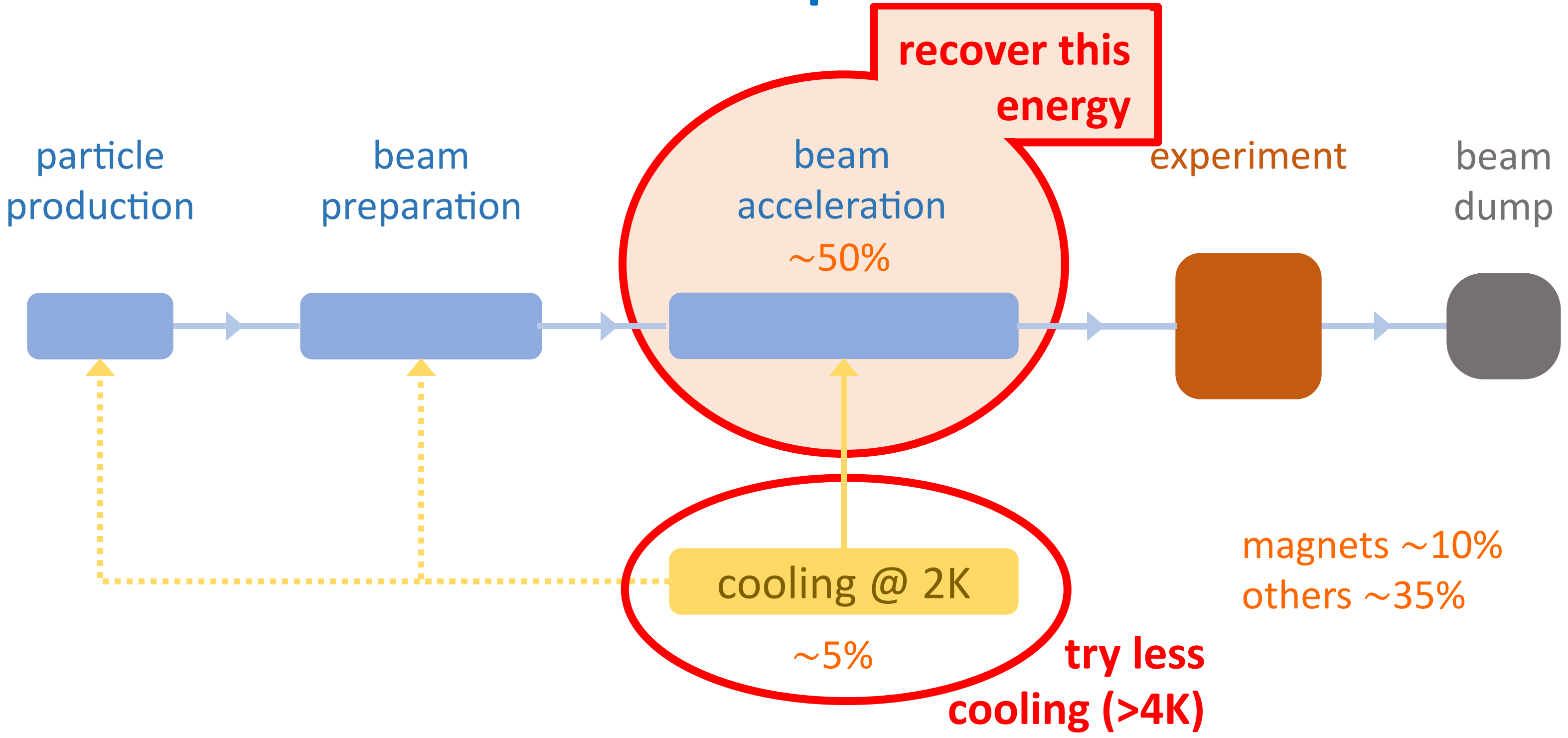


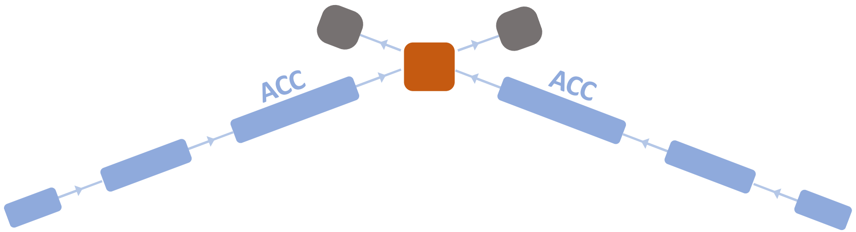
Typical power consumption for an electron-positron Higgs Factory

the highest priority next collider for particle physics

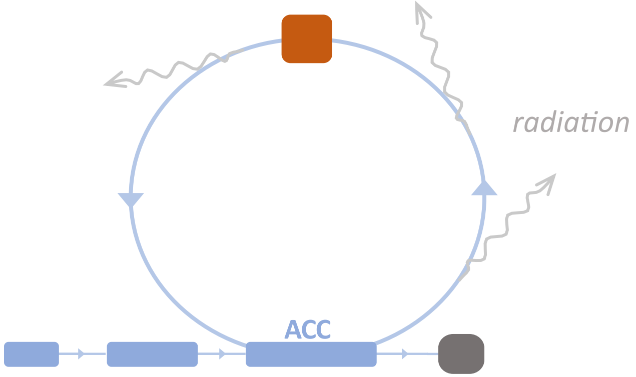
example FCC@250GeV

Designs of high-energy particle colliders

Linear colliders



Circular colliders



dump >99.9999% of the beam power

FCC-ee@250 ≃ 300 MW

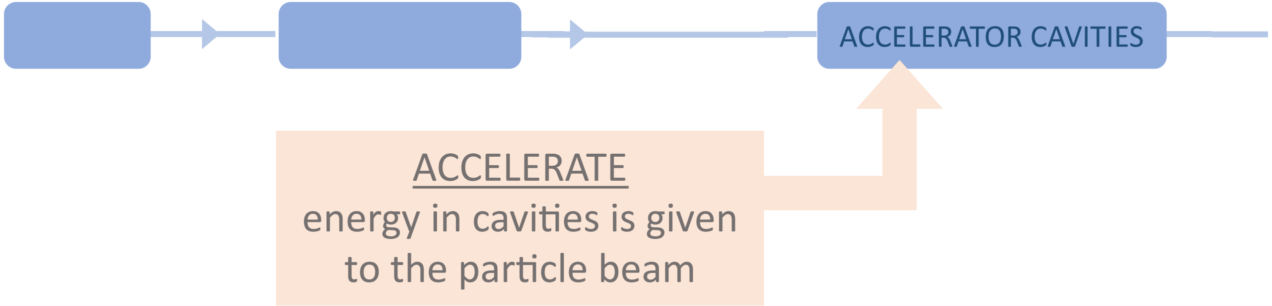
∼2% of annual electricity consumption in Belgium

radiate away very quickly the beam power

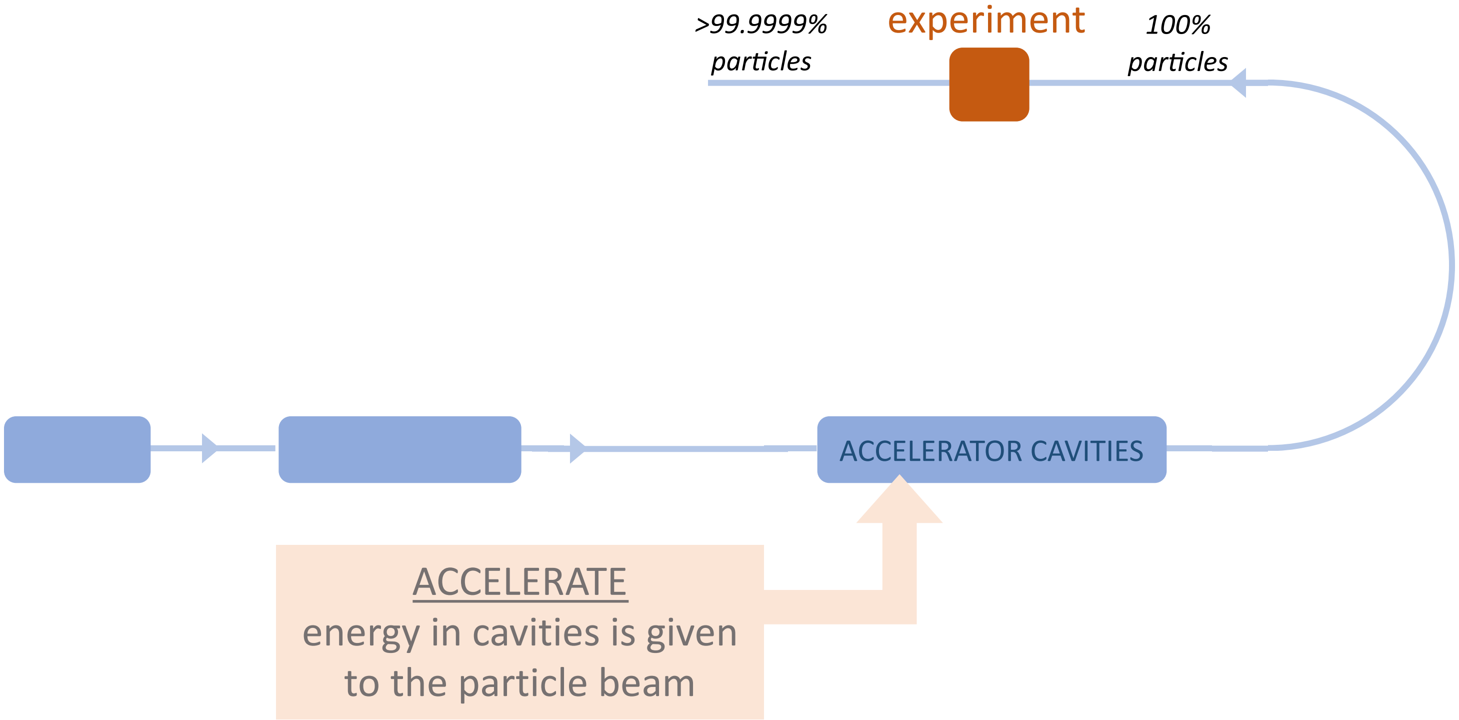
about half of this is dumped or radiated

OBJECTIVE: develop an accelerator technology that recovers this energy with an impact of saving ∼1% of Belgium's electricity

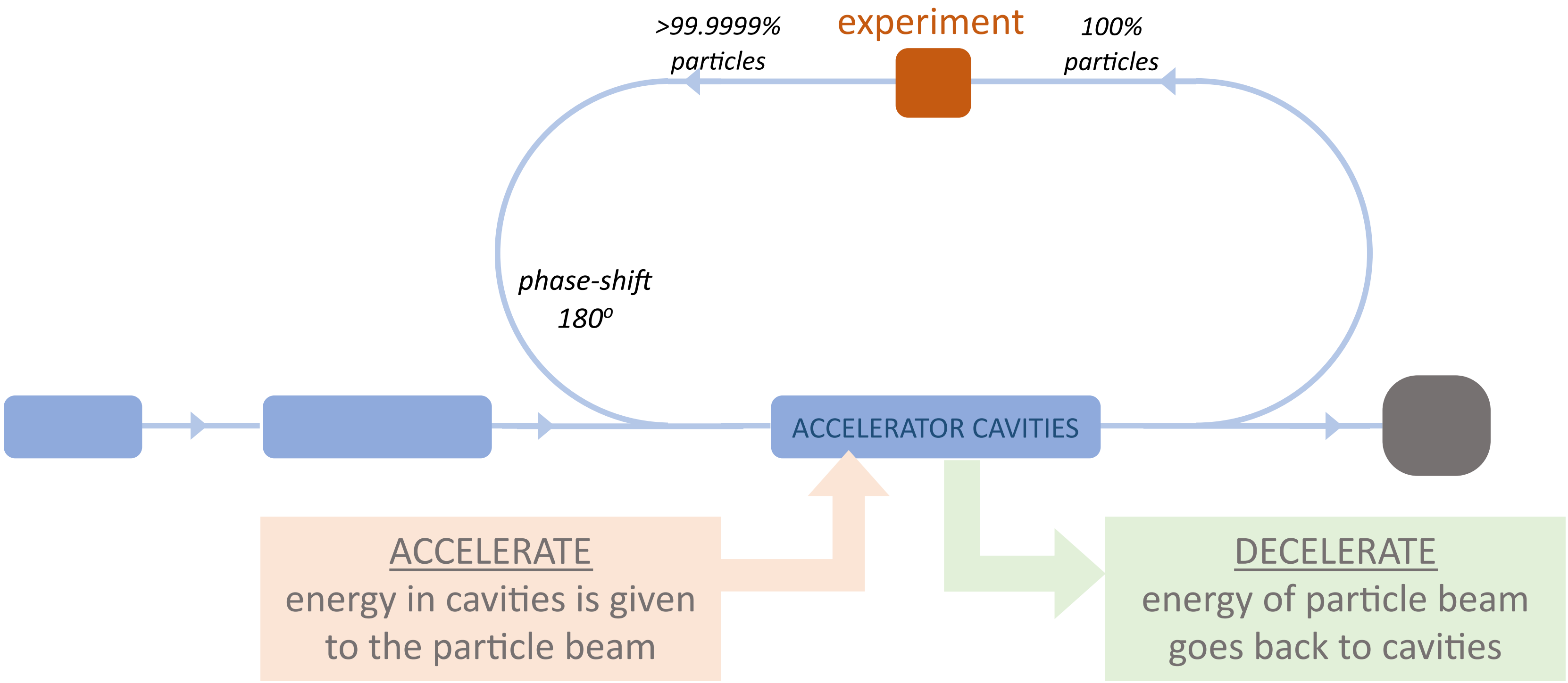
The principle of Energy Recovery



The principle of Energy Recovery



The principle of Energy Recovery



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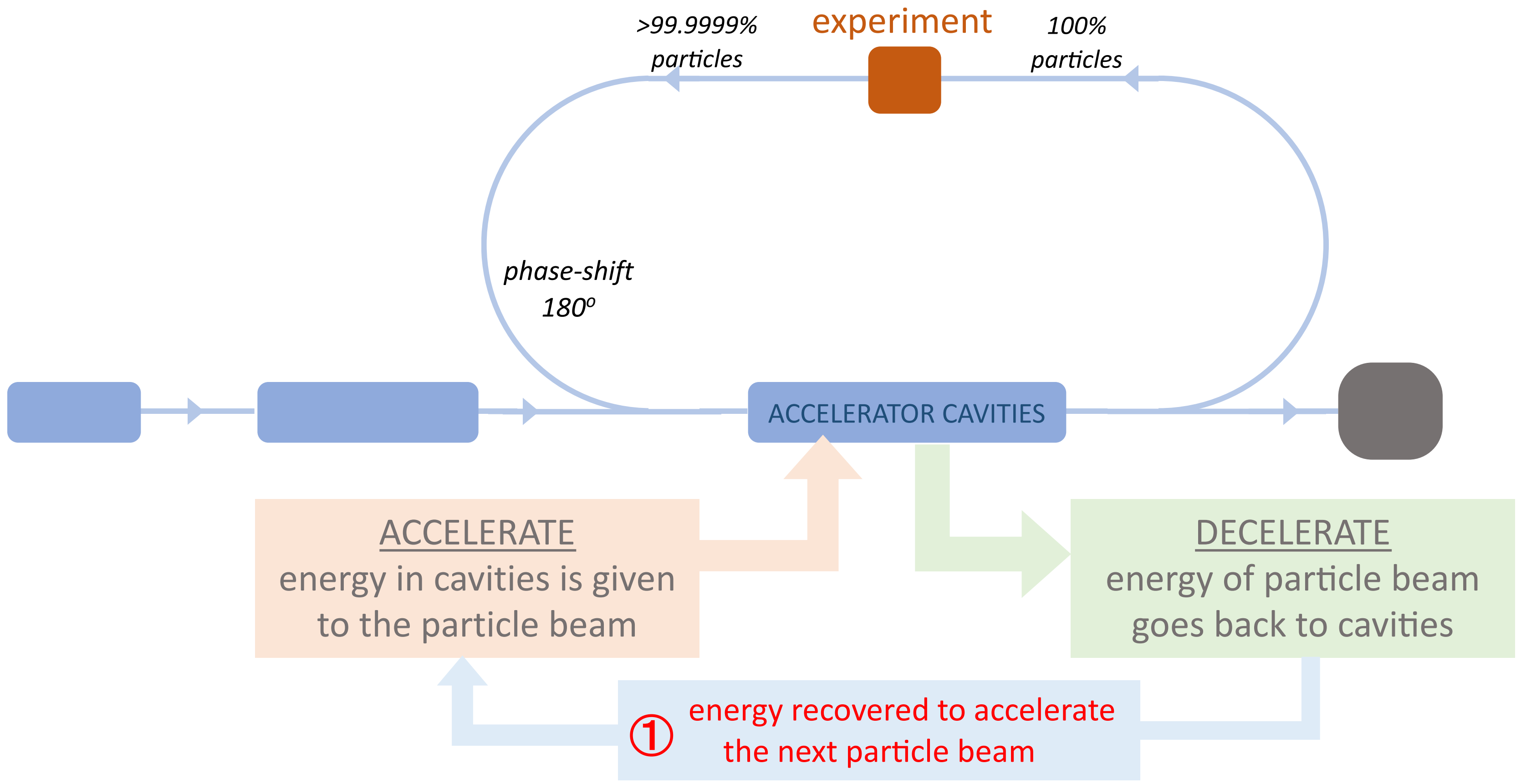

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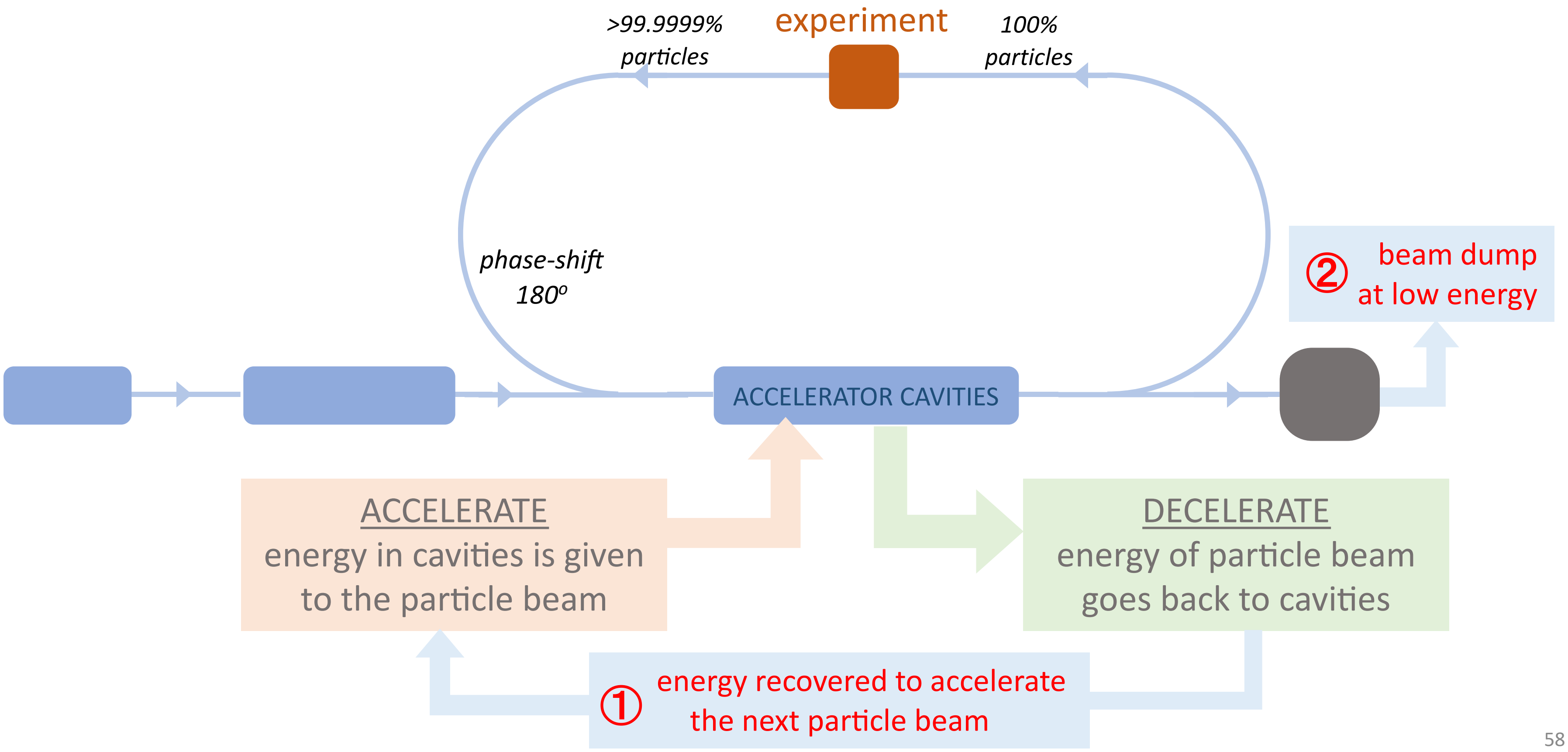

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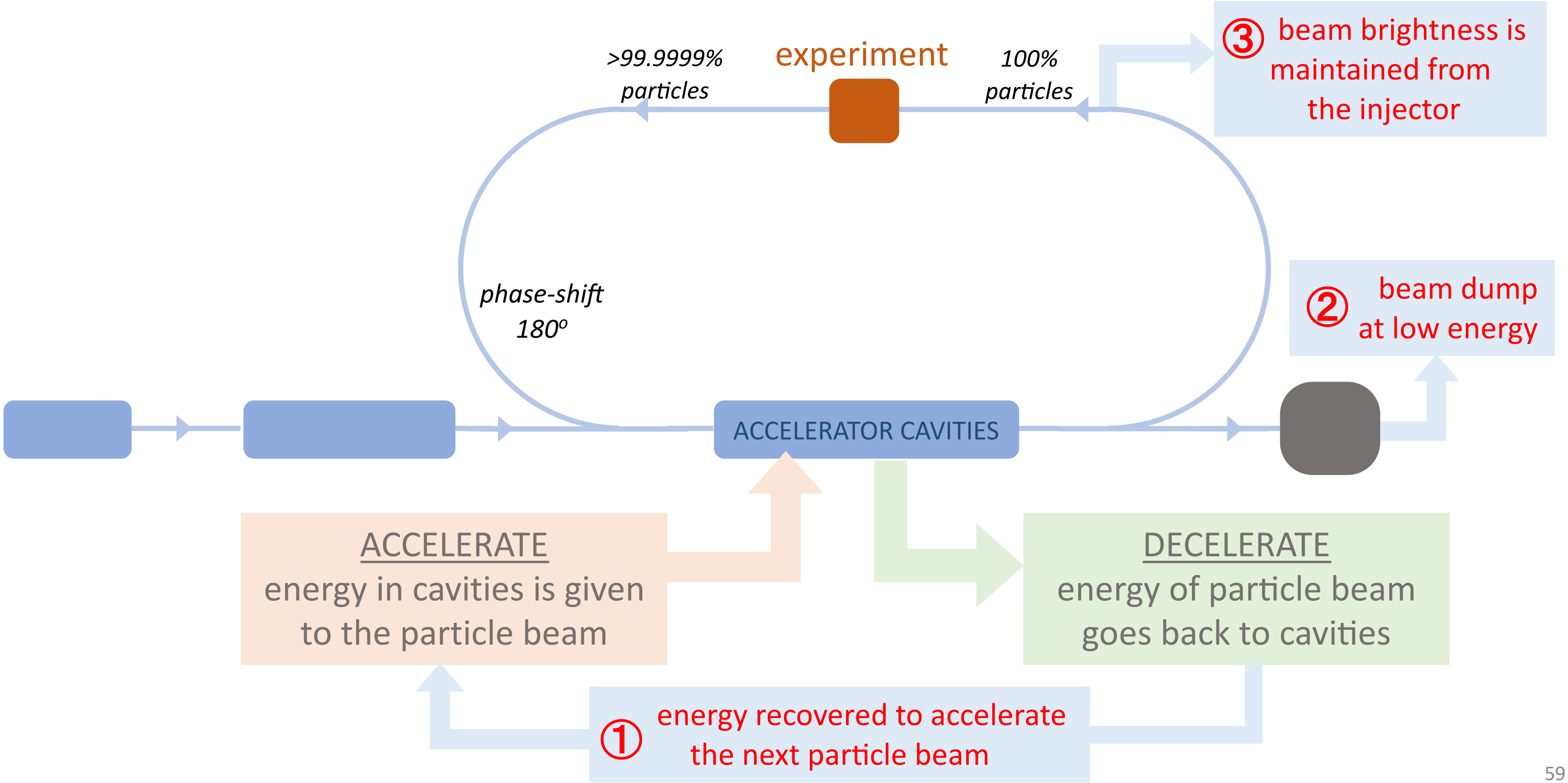
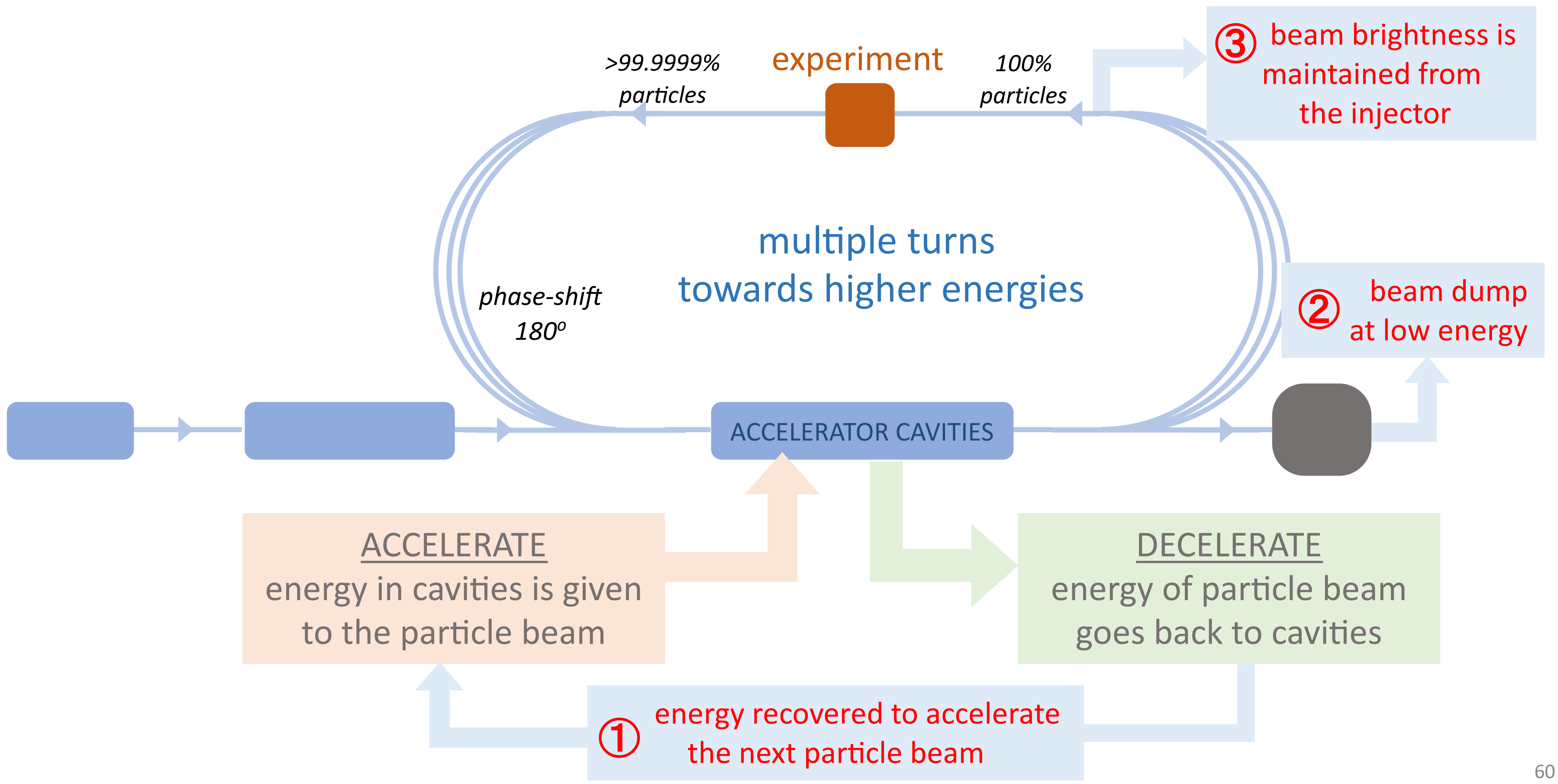
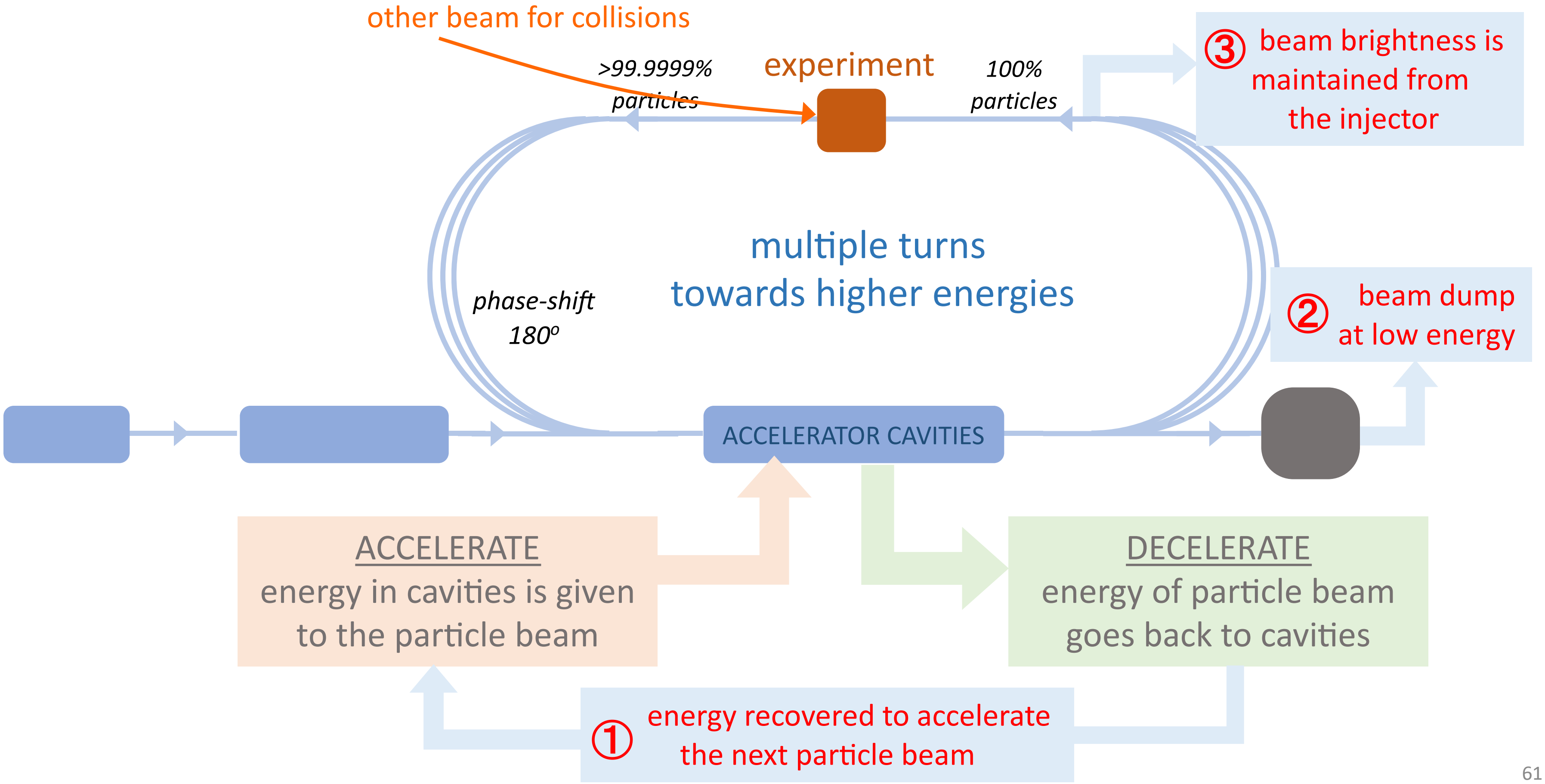


The principle of Energy Recovery

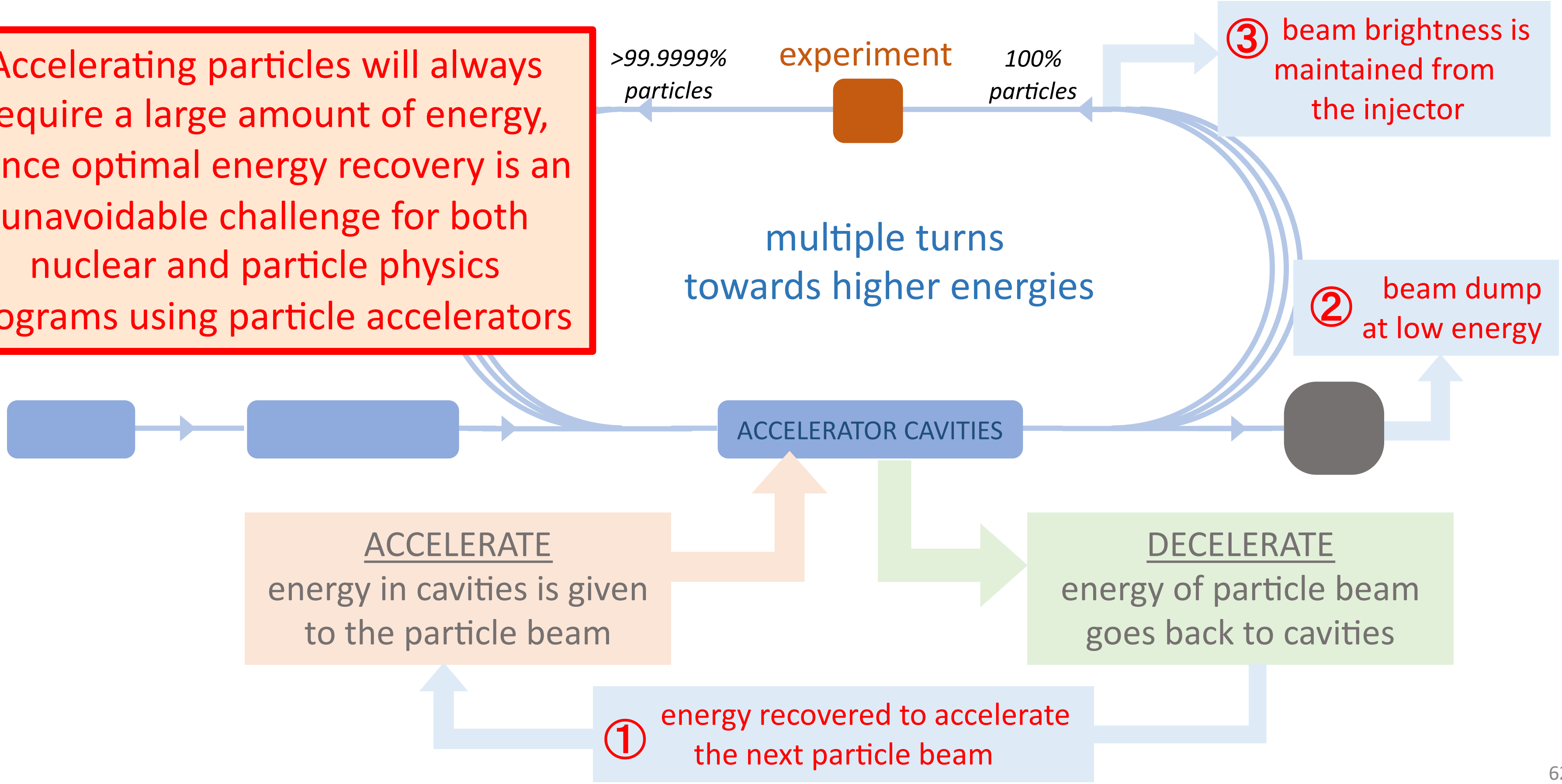


The principle of Energy Recovery



The principle of Energy Recovery

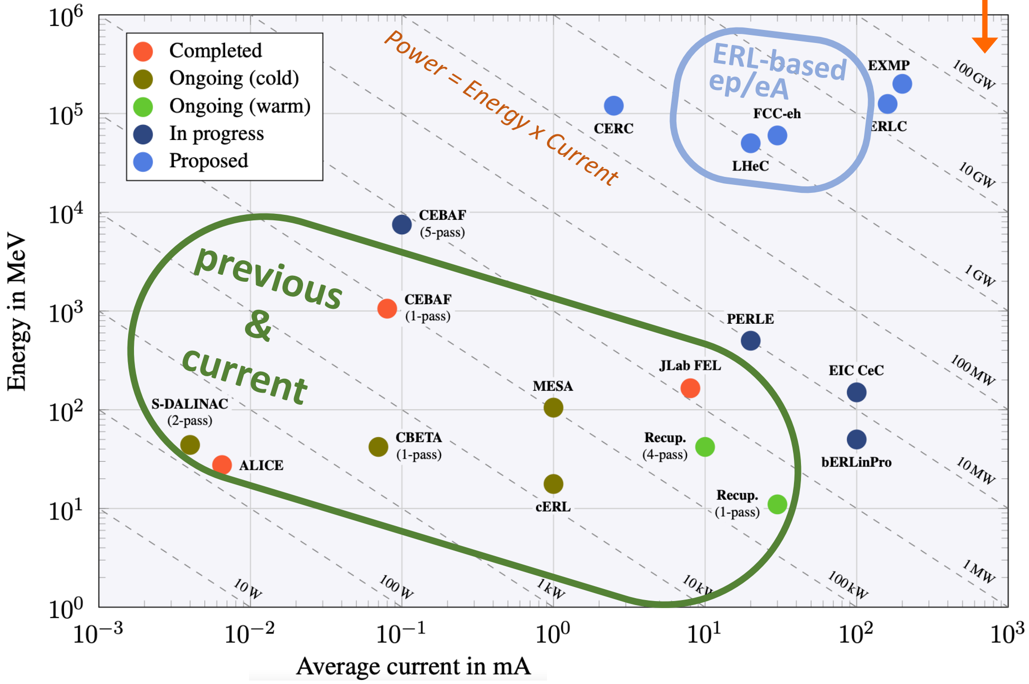
Accelerating particles will always require a large amount of energy, hence optimal energy recovery is an unavoidable challenge for both nuclear and particle physics programs using particle accelerators



Energy Recovery – 50 years of innovation

essential to realise the future ep/eA program

would be the required external power supply without Energy Recovery

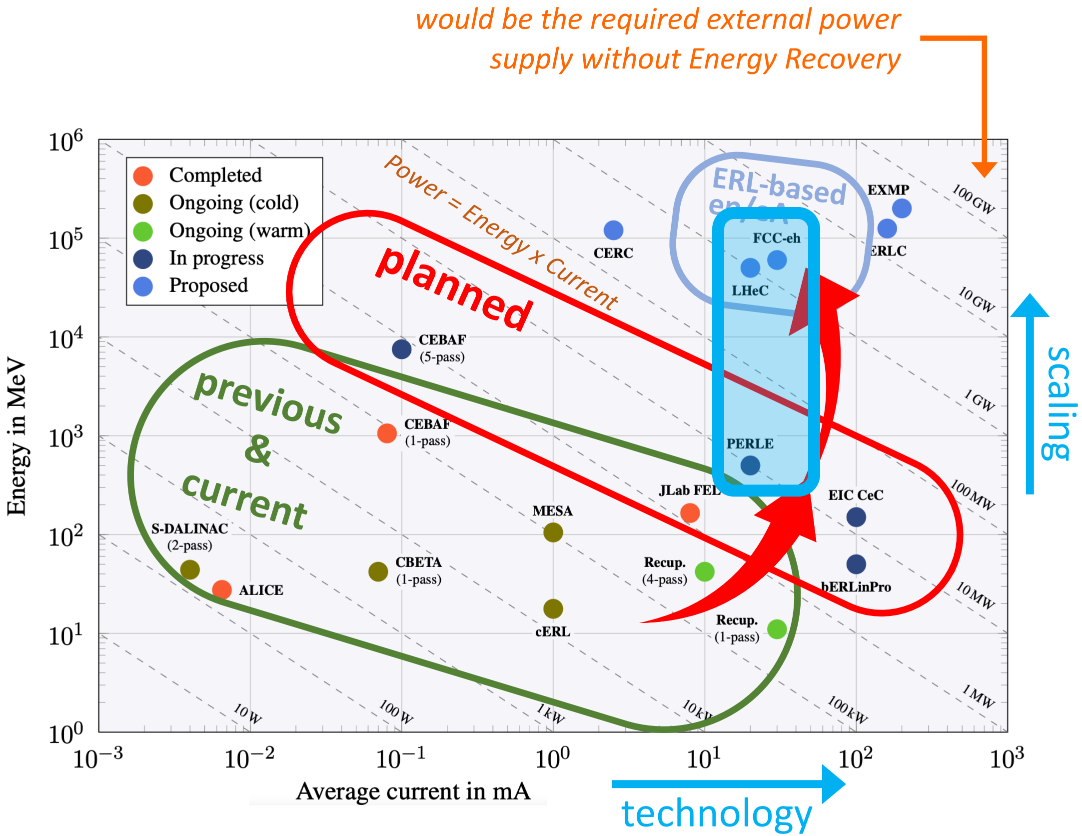


Energy Recovery

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

Energy Recovery – 50 years of innovation

essential to realise the future ep/eA program



Energy Recovery

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

bERLinPro & PERLE

essential technology stepping stones for future ep/eA (and other) implementations of Energy Recovery accelerators

towards high power

The Development of Energy-Recovery Linacs
arXiv:2207.02095, *237 pages, 5 July 2022*

Get together for Sustainable Accelerating Structures

If we had to learn something from this energy crisis…

We are fascinated to discover physics beyond the frontiers of knowledge

Unlocking the terra incognita of fundamental physics requires researchers from across disciplines to exchange the results they achieve

I am delighted to see that EURO-LABS enables the essential next step to foster scientific (exp & th) and technological collaboration while achieving these results

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VUB HIGH-ENERGY PHYSICS RESEARCH CENTRE

Thank you for your attention!

Jorgen.DHondt@vub.be

observable universe

$8.8\ 10^{26}m$

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

distance to galactic center

distance light travels in one year

farthest human object from Earth (Voyager 1)

distance Earth-sun

quarks

$< 10^{-19}m$

~ 0.000˙000˙000˙000˙000˙000˙01 meter

biological cell

atoms

proton
neutron

observable universe
8.8 10^{26}m

visible with our own eyes

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

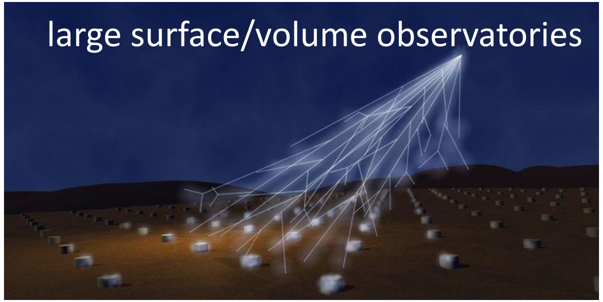
farthest human object from Earth (Voyager 1)

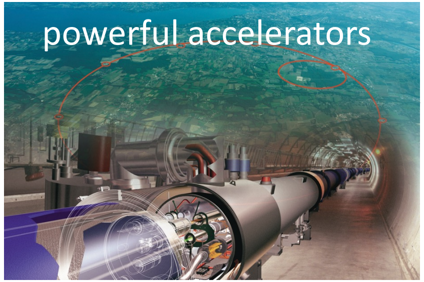
distance Earth-sun

biological cell

atoms

proton neutron





observable universe

$8.8\ 10^{26}m$

visible with our own eyes

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

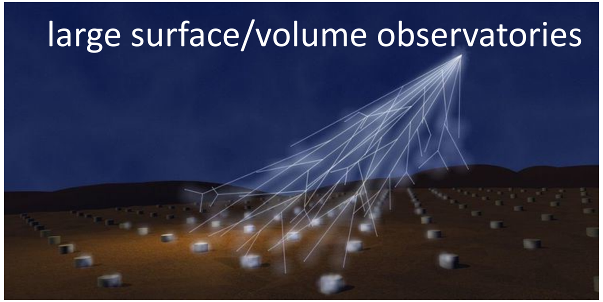
biological cell

atoms

proton neutron

age universe
4.4 10^{18} s

observable universe
8.8 10^{26}m



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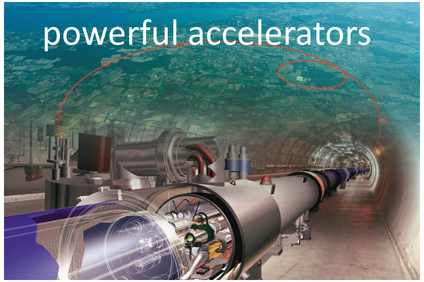

lifetime top quark
5 10^{-25} s

quarks
< 10^{-19}m

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

~ 0.000˙000˙000˙000˙000˙000˙01 meter

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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

Develop a model to describe how objects behave in this space and time

Develop a model to describe how objects behave in this space and time

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…

Develop a model to describe how objects behave in this space and time

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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Fundamental Theories

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(for electromagnetic, weak and strong forces)

Concrete Models

APPLY MATHEMATICAL FRAMEWORKS ON OBJECTS

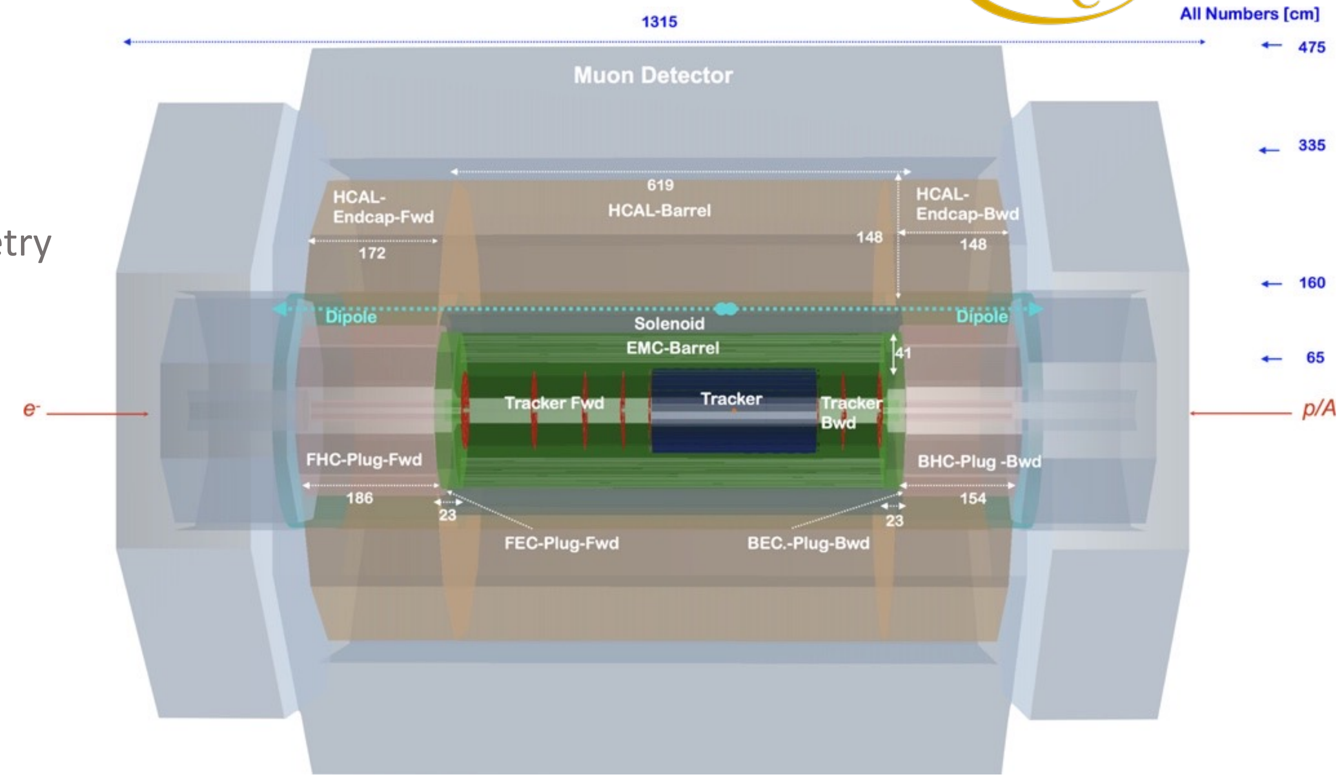
① ***General Relativity → Standard Model of Cosmology***
② ***Quantum Field Theory → Standard Model of Particle Physics***

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

Make the invisible visible – Detector R&D for ep/eA

Dedicated detector R&D efforts are to continue

e.g. LHeC



Major challenges:

- Tracking & Vertexing
- 1° close to the beamline
- High-resolution calorimetry

Make the invisible visible – Detector R&D for ep/eA

Dedicated detector R&D efforts are to continue

European Detector R&D Roadmap (2021)

Major challenges:

- Tracking & Vertexing
- 1° close to the beamline
- High-resolution calorimetry

Synergies with many other major projects, potentially as stepping stones

Potentially one detector for a joint ep/eA and Heavy-Ion program @ HL-LHC/FCC

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Detector Requirements

e.g. Solid State Devices

https://cds.cern.ch/record/2784893?ln=en

Most recent European Strategies

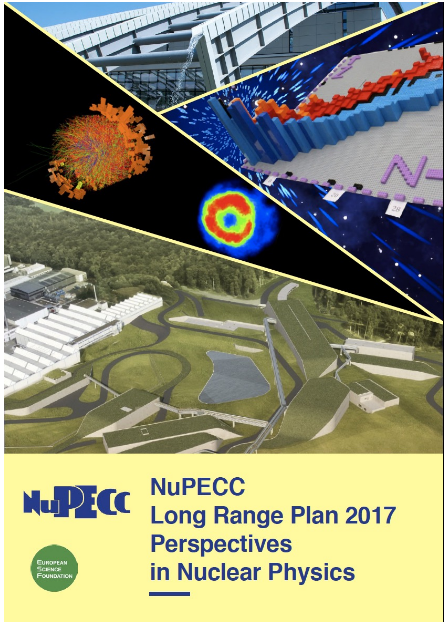
the large …

weblink

2017-2026 European Astroparticle Physics Strategy

… the connection …

weblink



Long Range Plan 2017 Perspectives in Nuclear Physics

… the small

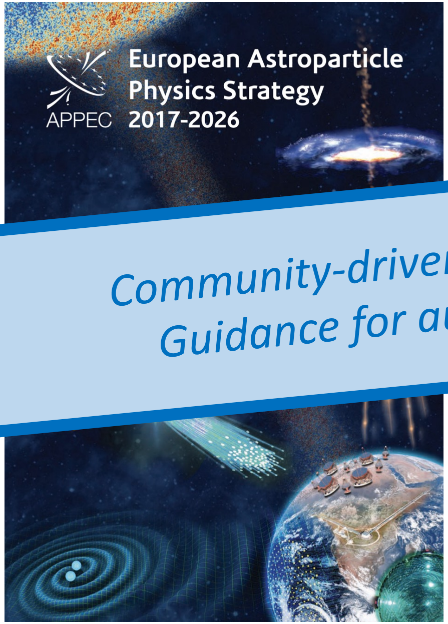
weblink

2020 Update of the European Particle Physics Strategy

Most recent European Strategies

the large … … the connection … … the small

weblink



weblink

weblink

Community-driven strategies reflecting our ambition to address open questions.
Guidance for authorities to develop resource-loaded research programmes.

2017-2026 European Astroparticle Physics Strategy

Long Range Plan 2017 Perspectives in Nuclear Physics

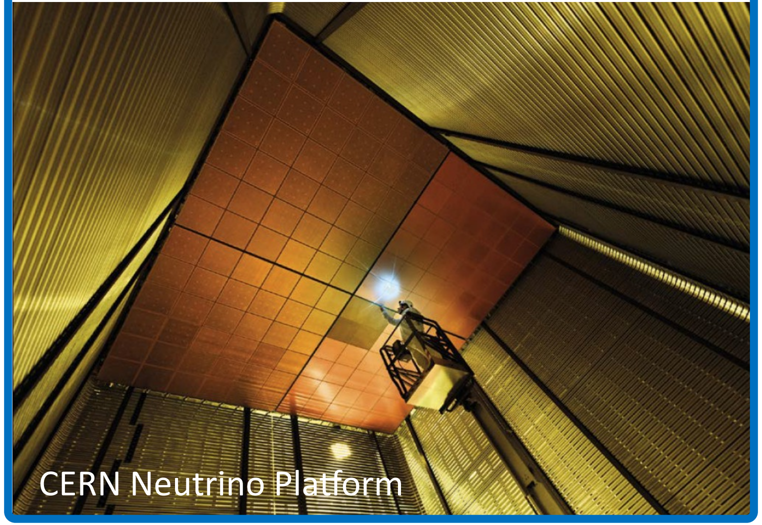
2020 Update of the European Particle Physics Strategy

Neutrino beams in Japan and in the US

CERN's Neutrino Platform in LBNF & DUNE (US), and in T2K (Japan)

DUNE @ LBNF

Prototype dual-phase Liquid-Argon TPC



BabyMIND @ T2K (near detector)

Prototype for Magnetised Iron Neutrino Detector

Within the next decade, we will now much more how to develop the neutrino sector to extend the Standard Model

Hadrons & Ions are made up of Quarks & Gluons

low energy

high energy

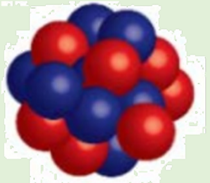
colour confinement

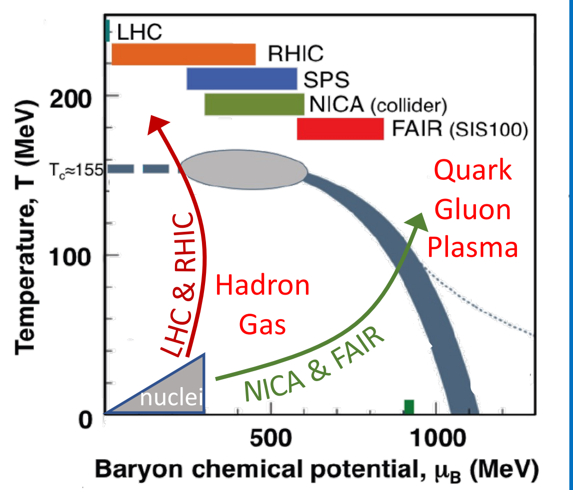
coupling ~1

asymptotic freedom

coupling <<1

experiments with heavy ions





Equation-of-State
(from a gas state to a quark-gluon plasma)

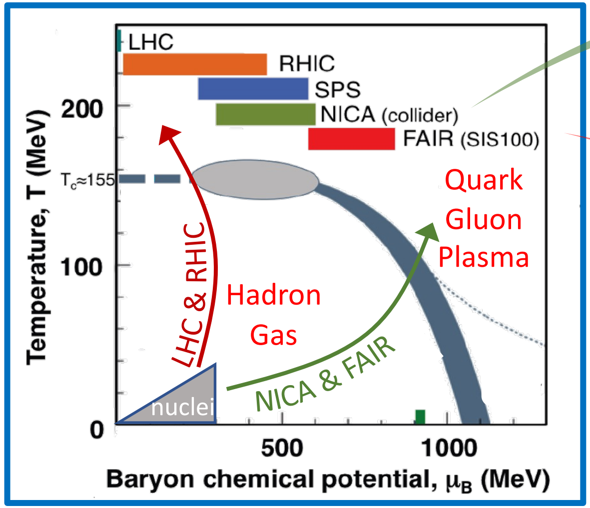
“confined” ions

“deconfined” quarks & gluons

used in experiment (applications)

used in Lagrangian (first principles)

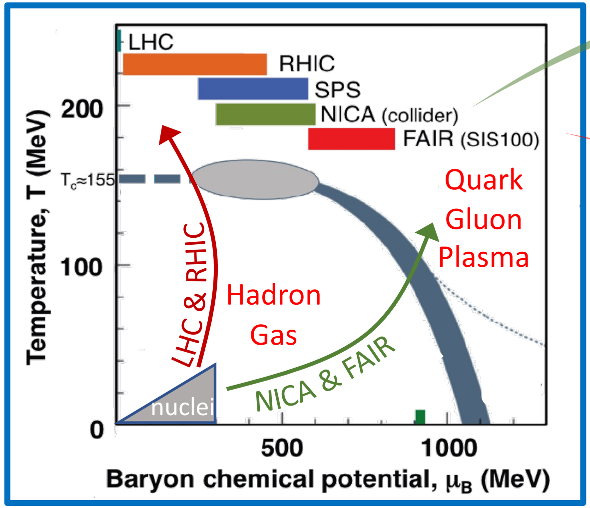
Heavy Ion physics from RHIC & SPS to NICA & FAIR



Nuclotron-based Ion Collider Facility @ JINR

SIS100/300 @ FAIR

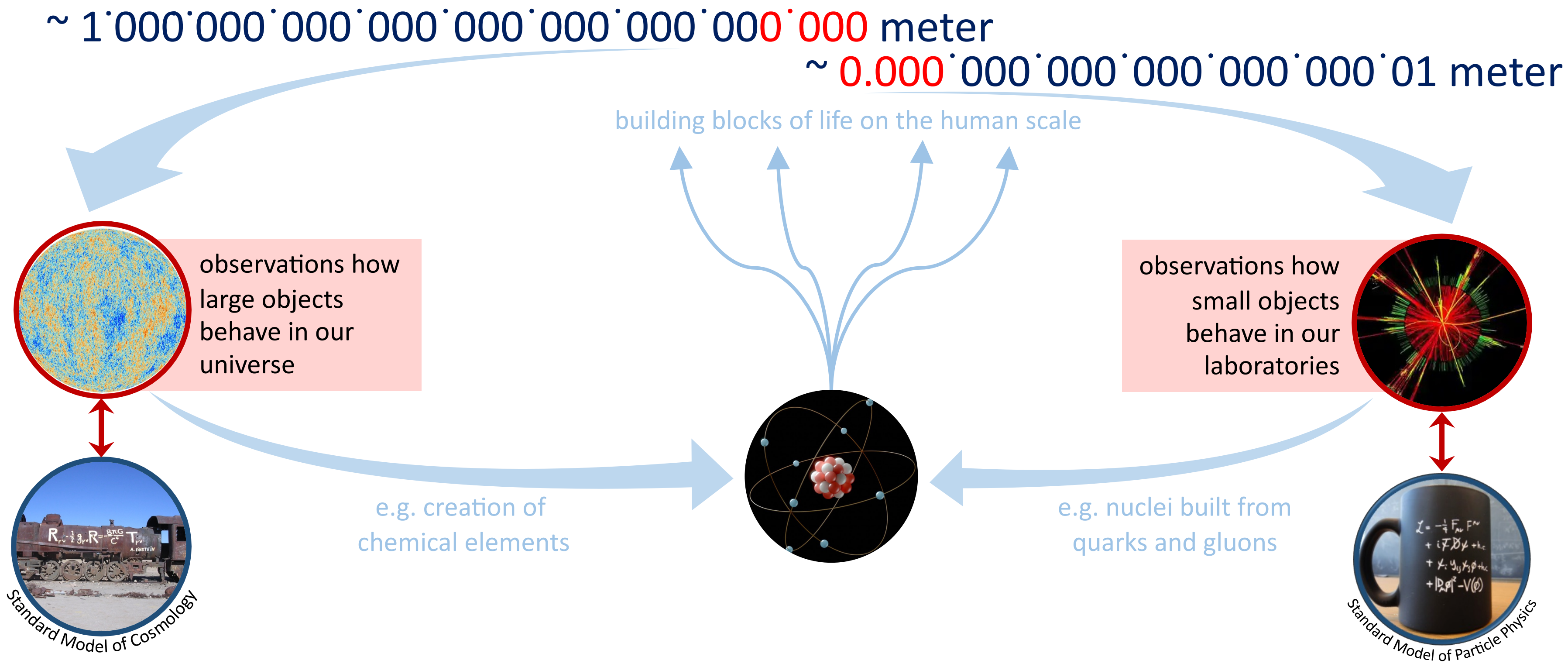
Heavy Ion physics from RHIC & SPS to NICA & FAIR



Nuclotron-based Ion Collider Facility @ JINR

SIS100/300 @ FAIR

- how matter and complexity emerge
- evolution of our Universe
- origin of the chemical elements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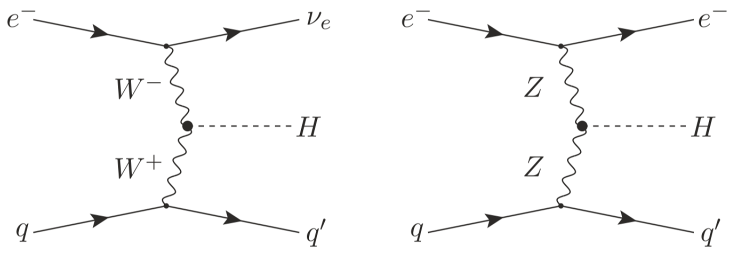
building blocks of life on the human scale
observations how large objects behave in our universe
observations how small objects behave in our laboratories
e.g. creation of chemical elements
e.g. nuclei built from quarks and gluons
Standard Model of Cosmology
Standard Model of Particle Physics

Empowering the (HL-)LHC program with the LHeC

Measurements of proton Parton Distribution Functions are vital to improve the precision

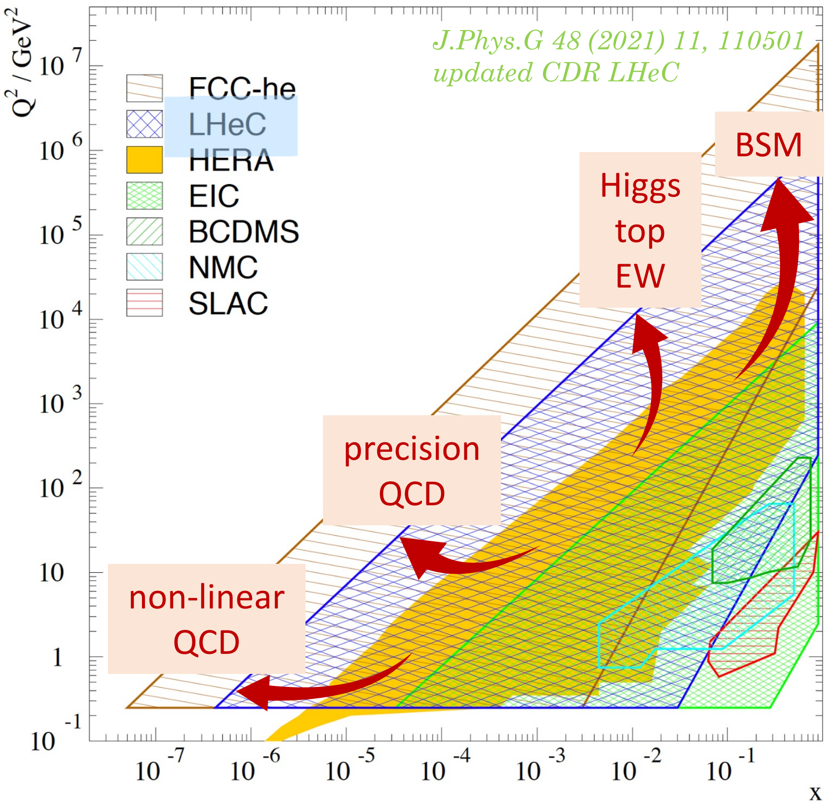
LHeC (up to 60 GeV e^- from Energy Recovery Linac)
E_{cms} = 0.2 – 1.3 TeV, (Q^2,x) range far beyond HERA
run with the HL-LHC ($\gtrsim$ Run5)

Higgs physics at LHeC itself



With respect to the full HL-LHC expectations, the LHeC improves up to a factor of 2-3 for several effective Higgs couplings

e.g. HZZ, HWW, Hγγ, Hcc, Hbb, Hττ



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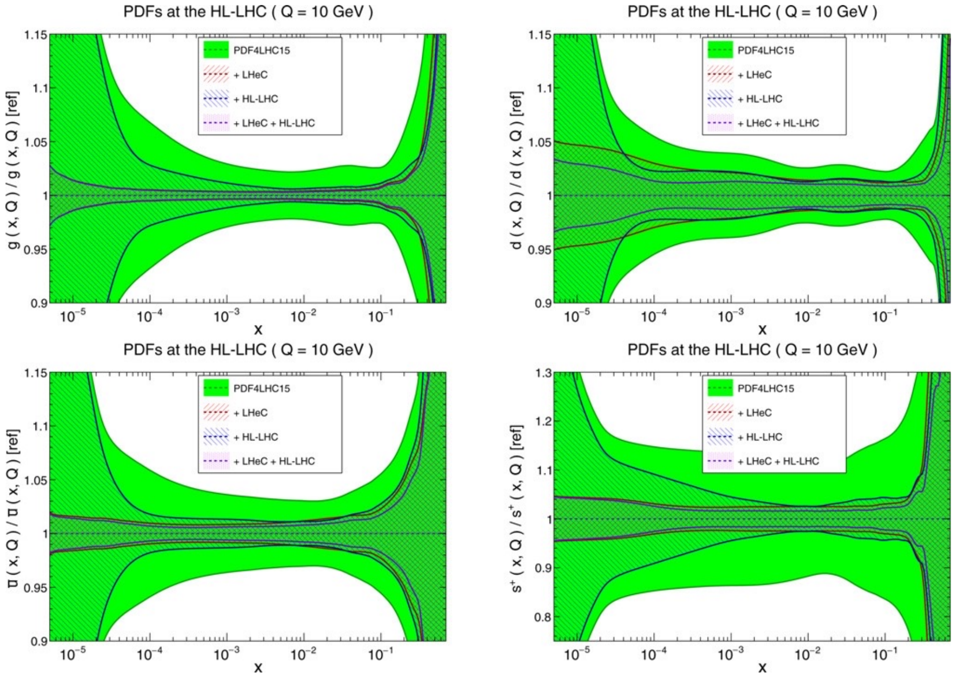
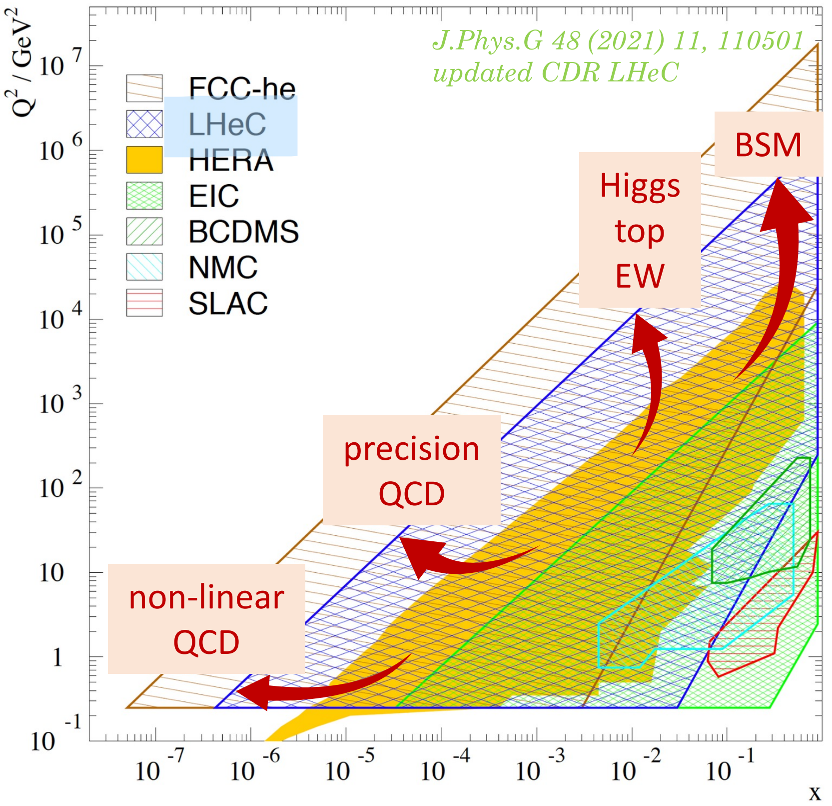
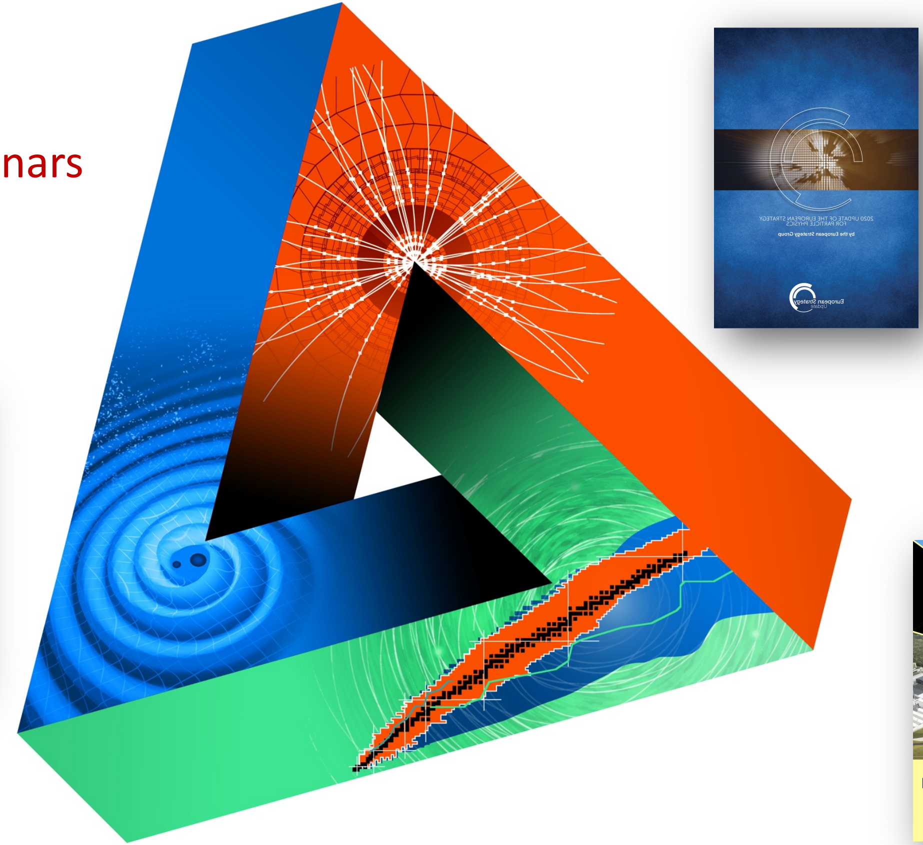




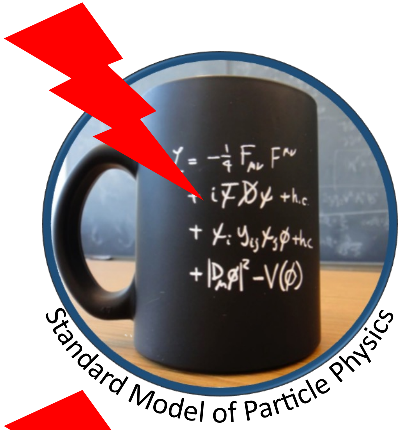
Exploring and strengthening synergies

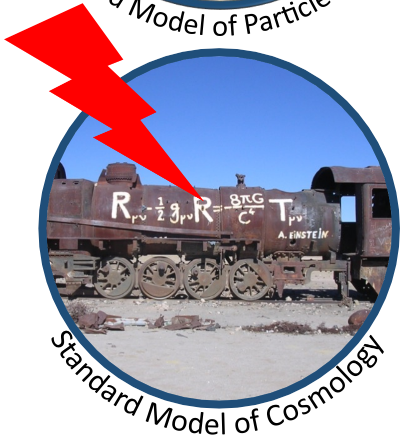
Initiated a series of
Joint ECFA-NuPECC-APPEC Seminars
(JENAS)



ECFA: European Committee for Future Accelerators
NuPECC: Nuclear Physics European Collaboration Committee
APPEC: Astroparticle Physics European Consortium
First JENAS event at Orsay, 2019: https://jenas-2019.lal.in2p3.fr

The quest for understanding physics





The structure of matter ?

The symmetries in nature ?

The invisible part of nature ?

To explore these synergies it is essential to establish joint scientific programs between nuclear and particle physics

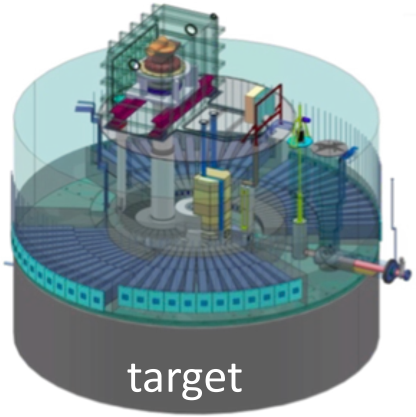
Baryon Number Violation

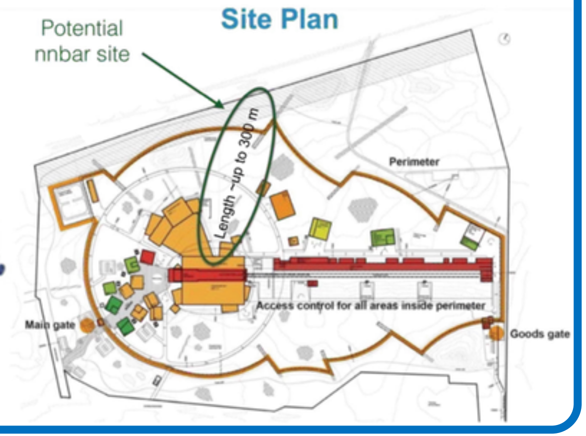
European Spallation Source (ESS) at Lund (Sweden) – Physics with Cold Neutrons

NNBAR experiment – from 2030 onwards

Baryon Number Violation with neutron-antineutron oscillations (up to 300m)

(3 orders of magnitude more sensitivity)





proposal

Linear Accelerator producing up to 5 MW beam of 2 GeV protons

(first science from 2023, full operation 2026)

Charged Lepton Flavour Violation

Towards the MEG-II and Mu3e experiments @ PSI (Switzerland)

Mu3e experiment

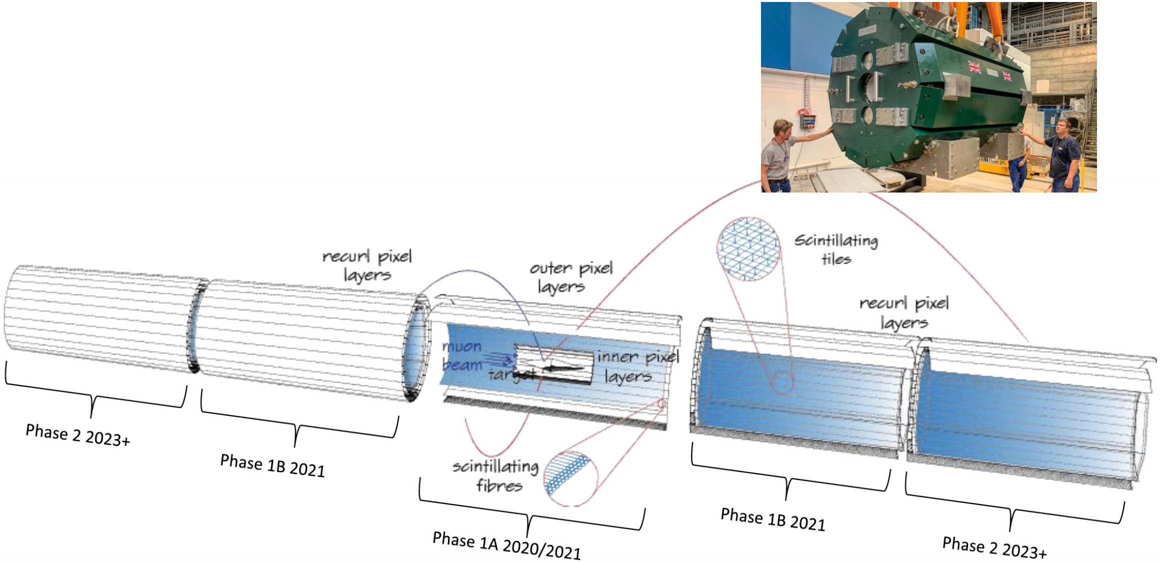
search for $\mu^+ \rightarrow e^+e^-e^+$

new beamline in next 5-10 years with most intense muon beam with $>10^9$ muons/s decaying in the Mu3e detector

sensitivity to $BR(\mu^+ \rightarrow e^+e^-e^+) \sim 10^{-16}$
(10^4 improvement)

being installed

magnet arrival – July 2020



Technical Design: https://arxiv.org/abs/2009.11690