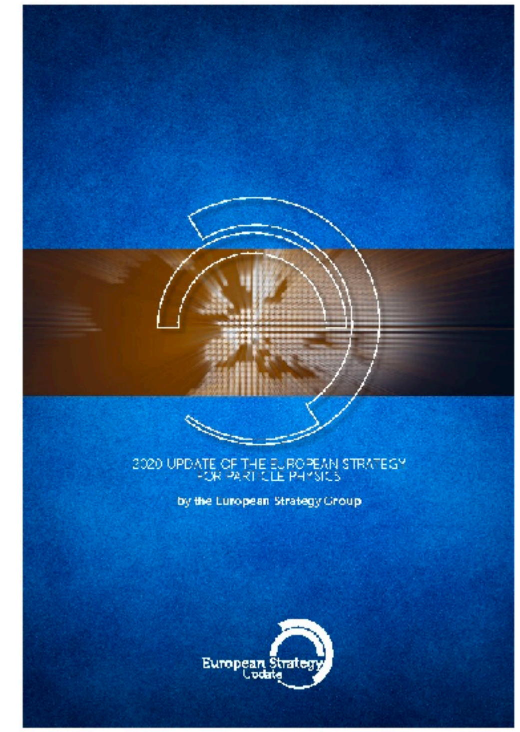
Starting with the Future…

- Everything is driven by our science roadmap
  - Namely, the European Strategy for Particle Physics
- Some future facilities explicitly mentioned:
  - Completion, commissioning, exploitation of HL-LHC
  - Delivery of LNBF/ DUNE
  - Electron-positron Higgs factory
  - Energy frontier proton-proton collider
  - Also increasingly prominent in discussions: muon collider



- Past achievements rest on substantial, sustained technology R&D
  - At least 20 years prior to LHC / HL-LHC
  - Several sequential stages of R&D and industrialisation required
- Future facilities depend yet more strongly on new technology
  - Fundamental R&D challenges presented by long-term machines
  - Efficiency and industrialisation challenges presented by nearer-term machines

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Motivation and Role of R&D Roadmaps

- Focus and balance
  - R&D is needed for specific elements of future facilities
  - But: a place for ‘blue skies’ / ‘disruptive’ developments must be maintained
- Coordination
  - New investment in R&D infrastructure is required, sometimes at large scale
    - Laboratories, test beams, fabrication facilities, cryogenics, lasers, irradiation, metrology …
  - Complementary facilities at labs and institutes must be made available to all
  - Coordination of complementary expertise within R&D collaborations is superior to parallel and disconnected developments
- Connections
  - Close coupling of detectors, accelerator and computing R&D is needed
  - Developments / needs in other fields and in industry are important
  - Common need for strong skills base in instrumentation and technology
- Benefits along the way
  - Large scale demonstrators offer the potential for early scientific return
- Consensus plan needed for efficient and effective use of limited resources

Laboratory Directors Group

- General role, as mandated by CERN Council:
  - Maintain dialogue and coordination between directors of Large Particle Physics Laboratories, including the CERN directorate
  - Provide direct input to the European Strategy for Particle Physics
  - Liaise with the EC and national funding agencies, research institutes, and universities in order to ensure that the LPPLs speak with a single voice
  - Maximise regional and national benefits of investment in fundamental research and in CERN
  - Keep abreast of the activities being undertaken in laboratories outside … as well as by other coordinating groups in particle physics and related areas
- Specific roadmap-related role in 2020/21:
  - Draw up and maintain a prioritised accelerator R&D roadmap towards future large-scale facilities for particle physics
  - Oversee the accelerator R&D activities on the roadmap, with the aim of strengthening cooperation and ensuring effective use of complementary capabilities
- Noting that accelerator R&D is clearly *not* confined to large laboratories
- LDG and ECFA cooperating on roadmaps for accelerator / detector R&D

Roadmap Requirements

- Provide an agreed structure for a coordinated and intensified programme of particle accelerator R&D, including into new technologies, to be coordinated across national laboratories
- Be compatible and commensurate with corresponding roadmaps in detectors, computing and other developments, with a compatible timeline and deliverables
- Be based on the goals of the European Strategy, but defined in its implementation through consultation with the community and, where appropriate, through the work of expert panels
- Take into account, and coordinate with, international activities and work being carried out in other related scientific fields, including development of new large-scale facilities
- Specify a series of concrete deliverables, including demonstrators, over the next decade
- Be designed to inform, through its outcomes, subsequent updates to the European Strategy.
- Focus is 5-10 years – set in the context of a longer overarching programme

Roadmapping Approach

- Stage 1 (overseen by LDG, mandate from CERN Council)
  - Formal process, continuing the momentum of the strategy groups
  - Mirrors the style of the ESPPU
    - Expert discussion panels
    - Wide consultation with the community (some inputs already in place from ESPPU)
    - Determination of a plan with options for investment
  - Culminates in approval of roadmap by CERN Council – and finishes
  - European process, but with strong international inputs
- Stage 2 (driven by the community, LDG in support)
  - Proposals for activities by accelerator R&D networks / community
  - Explicit discussion of possible funding levels and routes
  - Engagement with funding agencies around specific projects
  - Implementation of the R&D roadmap
  - Necessarily a programme with a fully international context
- The roadmap is the 'consensus document' that will open the subsequent discussions on funding and implementation

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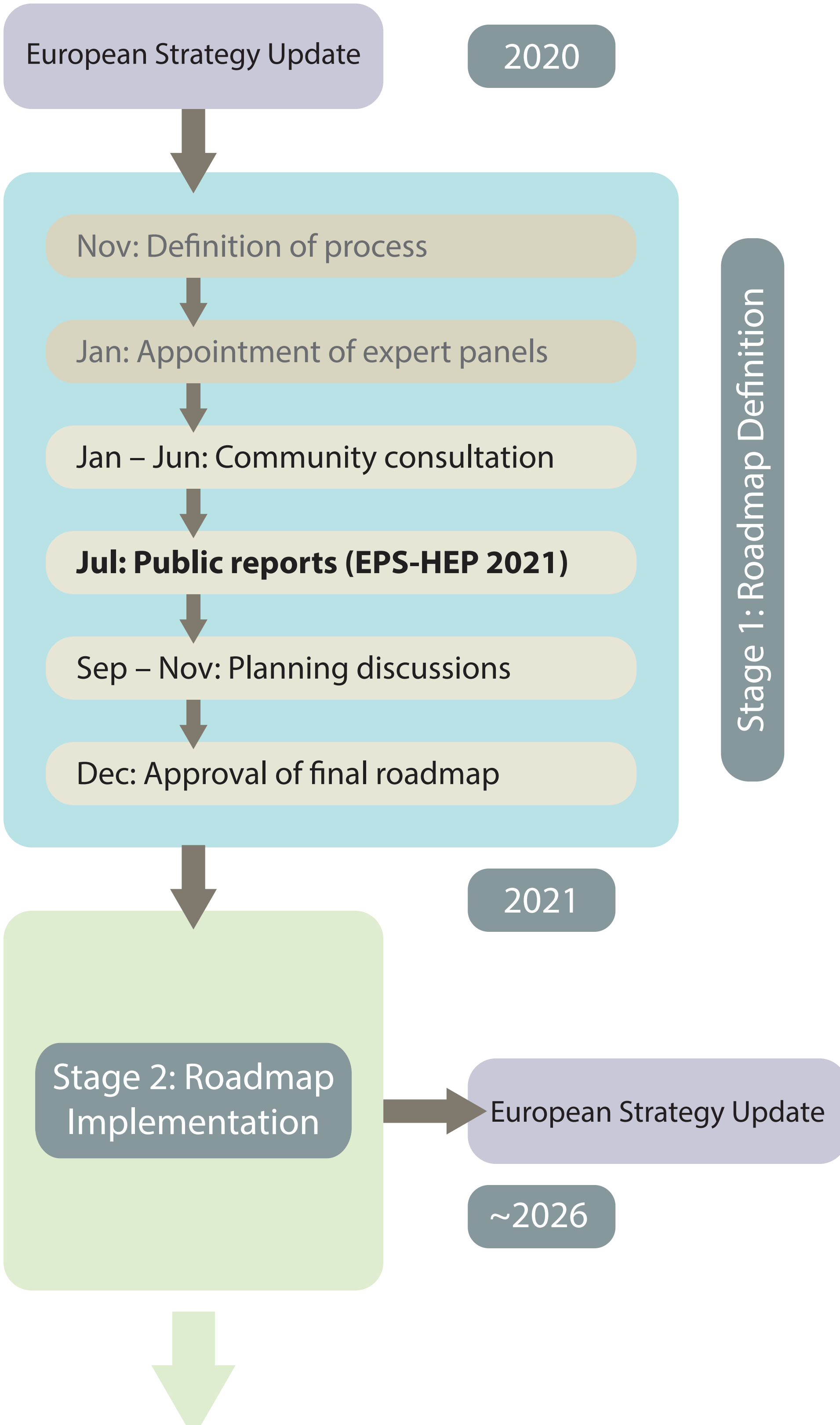
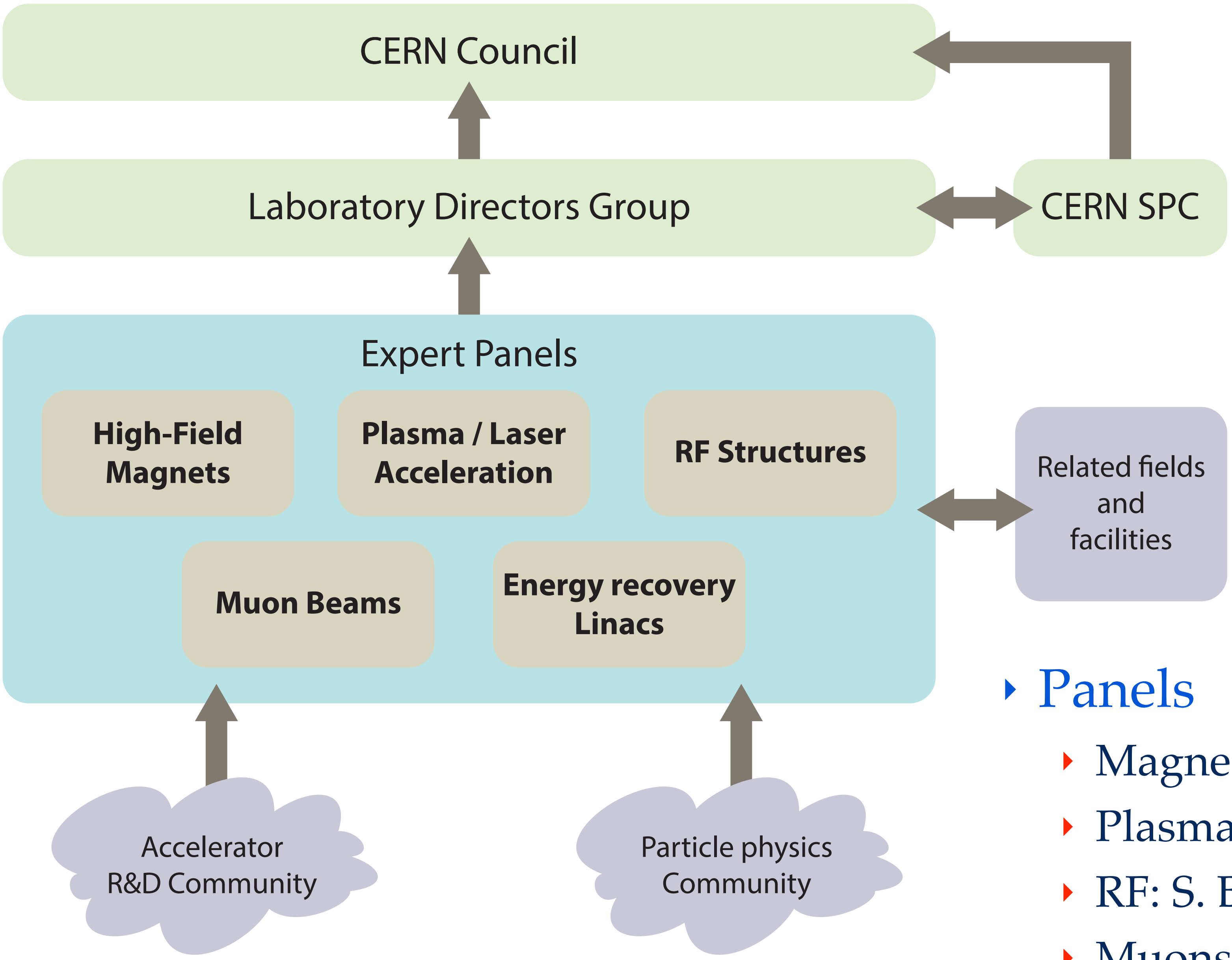
Timeline



- Key dates
  - 9th July: Symposium for the PP community
    - Good attendance by cross-section of community
  - July EPS-HEP: reports by panels and roadmap progress report
  - September Council: presentation and discussion of interim report
  - September – October: 'closed process' to define draft roadmap, scoped plans
  - November: Review and feedback by SPC subcommittee
  - December Council: roadmap endorsement
    - Corresponding to timeline for ECFA detector R&D roadmap
- First draft of the Interim Report now being reviewed by LDG

Expert Panels



- Panels
  - Magnets: P. Vedrine (IRFU)
  - Plasma: R. Assmann (DESY)
  - RF: S. Bousson (IJCLab)
  - Muons: D. Schulte (CERN)
  - ERL: M. Klein (Liverpool)
  - Training / skills area common with ECFA
  - May co-opt additional people for input on ‘crosscutting issues’

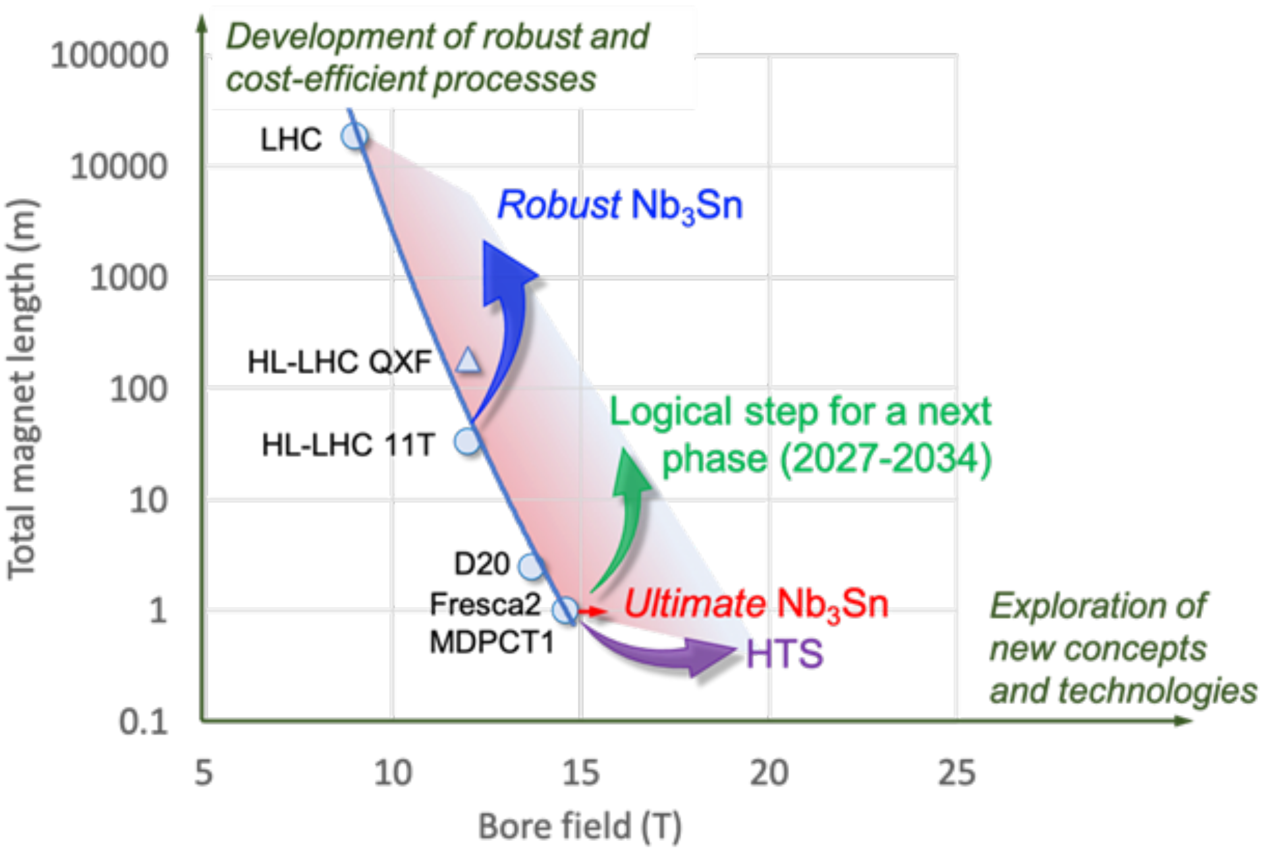
Observations on the Process so far

- Engagement
  - Success in engaging the (international) accelerator physics community
  - Over 50 meetings / workshops, several hundred people involved
  - Some panels already producing 'long reports' summarising all inputs
- Diversity
  - Clearly, the five areas are at a range of scope and maturity
  - The final roadmap must balance medium- and long-term R&D carefully
  - Keep in mind the focus on informing decisions at the next EPPSU
- Synthesis
  - In the end, we require one roadmap not five – also leaving some 'freedom'
  - There are clear cross-links between areas and with current projects
  - We will surely be constrained by resources
    - A key question: what are the hard technical barriers, even in the limit of infinite resources?
- In summary: strong progress, and an excellent start by the panels
  - Many of the topics under discussion are novel, exciting, and with the genuine capability to (sustainably) revolutionise our field in the long term

HFM Summary

Scope of a High Field Magnets R&D Program

- **Demonstrate Nb_3Sn magnet technology for large scale deployment**, pushing it to its practical limits, both in terms of maximum performance as well as production scale
  - Demonstrate Nb_3Sn full potential in terms of ultimate performance (towards 16 T)
  - Develop Nb_3Sn magnet technology for collider-scale production, through robust design, industrial manufacturing processes and cost reduction (benchmark 12 T)
- **Demonstrate suitability of HTS for accelerator magnet applications**, providing a proof-of-principle of HTS magnet technology beyond the reach of Nb_3Sn (towards 20 T)



- **Other key parameters:**
  - Cost of Magnets & R&D
  - Timeline of a realistic development

Page 1

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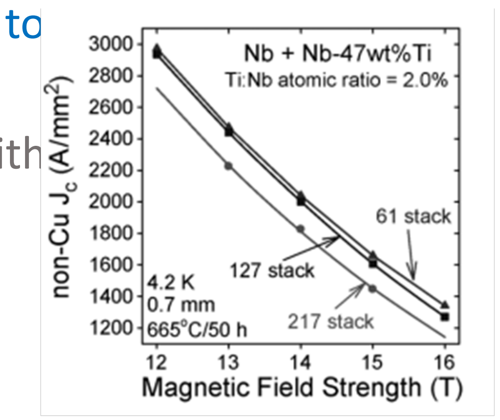
HFM Summary

HIGH FIELD MAGNETS R&D KEY FINDINGS

Conductors

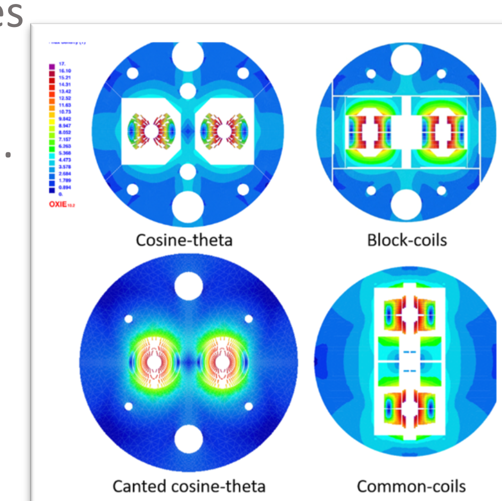
- Nb3Sn is reaching the upper limit of performance. Advances in composition and architecture need to be consolidated (laboratory), and made practical for large-scale production (industry),
- Spectacular electrical performance of HTS tapes, the challenge is now to combine critical current with mechanical and protection properties in practical conductors.
- High temperature operation (20 to 65 K) is an interesting option fro HTS also driven for other fields (fusion and power machinery).



PARRELL *et al.* IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 19, NO. 3, JUNE 2009

Magnets

- A decision on a feasible, cost-effective and practical operating field will be one of the main outcomes of the development work planned in the coming years
- Length effects and electro-thermo-mechanics of Nb3Sn magnets are a crucial issue (11T experience).
- Suitable design options for Nb3Sn magnets have been identified for the various field levels targeted (up to 12 T, 14-16 T range, beyond 15-16 T)
- Field quality is a declared issue for HTS, but this should be revisited using controlled insulated conductors , and possibly transferring a part of the challenges to beam dynamics, diagnostics and controls
- Thermal management of high field magnets (both internal, heat transfer to coolant, and external, heat transfer to cryoplant) will require new engineering solutions that need to be integrated from the start.



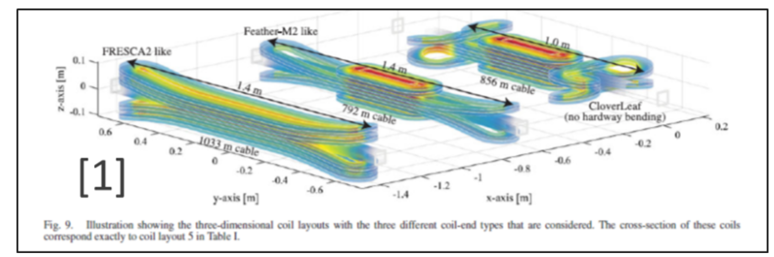
Page 2

HFM Summary

High Field Magnets R&D Roadmap Key points

Conductors

- Advance performance of Nb3Sn wires beyond present state-of-the-art, with a target 1500 A/mm2 at 16 T (mechanical properties, magnetization & stability, cost…) and develop cables with high engineering current density, $J_E \approx 600$ A/mm^2, appropriate to yield a compact and efficient coil design.
- Achieve controlled, homogeneous and reproducible geometrical and electro-mechanical properties for HTS conductor and cables along the full - 1 km target – unit lengths.



Magnets

- Develop Nb3Sn robust (12 T target) and ultimate (towards 16 T) field designs for long magnets in parallel to samples and subscales in an agile mode that incorporates insights from previous steps and by promoting automation and innovations leading to simplified manufacturing processes,
- Manufacture and test HTS sub-scale and insert coils as a “R&D vehicle” to demonstrate operation beyond the reach of Nb3Sn.

- Explore the possibility of intermediate temperature range (10-20 K) and dry magnet (conduction cooled).
- Develop at the partners’ laboratories, dedicated infrastructure suitable for HFM R&D, at the start.
- Evaluate and foster the scientific and societal impact of the HFM R&D, maintaining a tight connection with the HFM stakeholders.

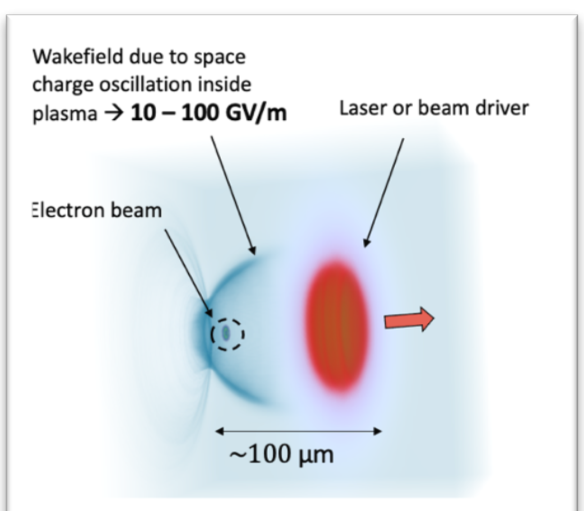
PLA Summary

Expert Panel “High Gradient: Plasma and Laser Accelerators”

Panel members:
Chair: Ralph Assmann (DESY/INFN)
Deputy Chair: Edda Gschwendtner (CERN)
Kevin Cassou (IN2P3/IJCLab), Sebastien Corde (IP Paris), Laura Corner (Liverpool), Brigitte Cros (CNRS UPSay), Massimo Ferarrio (INFN), Simon Hooker (Oxford), Rasmus Ischebeck (PSI), Andrea Latina (CERN), Olle Lundh (Lund), Patric Muggli (MPI Munich), Phi Nghiem (CEA/IRFU), Jens Osterhoff (DESY), Tor Raubenheimer (SLAC), Arnd Specka (IN2PR/LLR), Jorge Vieira (IST), Matthew Wing (UCL).

Panel associated members:
Cameron Geddes (LBNL), Mark Hogan (SLAC)), Wei Lu (Tsinghua U.) , Pietro Musumeci (UCLA)

Illustration from EuPRAXIA, A. Ferran Pousa et al



The mandate of the expert panel on high gradient plasma and laser accelerators is to:

- Develop a long-term roadmap for the next 30 years towards a HEP collider or other HEP applications.
- Develop milestones for the next 10 years taking explicitly into account the plans and needs in related scientific fields as well as the capabilities and interests of the stakeholders.
- Establish key R&D needs matched to the existing and planned R&D facilities.
- Give options and scenarios for European activity level and investment.
- Define deliverables until the next European strategy process in 2026, which allow deciding on the continuation of this R&D line for HEP.

Elaborate **consultation process** with 231 registered participants, 3 townhall meetings, > 60 talks and inputs.

See https://indico.cern.ch/event/1041900/
and https://indico.cern.ch/event/1040116/

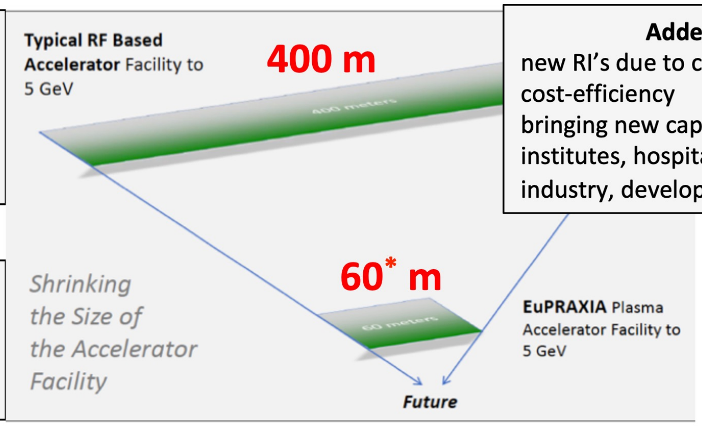
R. Assmann, E. Gschwendtner 1

PLA Summary

Shrinking the Size of the Particle Physics Facility

RF Accelerators
> 30,000 operational – many serve for Health
30 million Volt **per meter**
RF: 90 years of success story for society

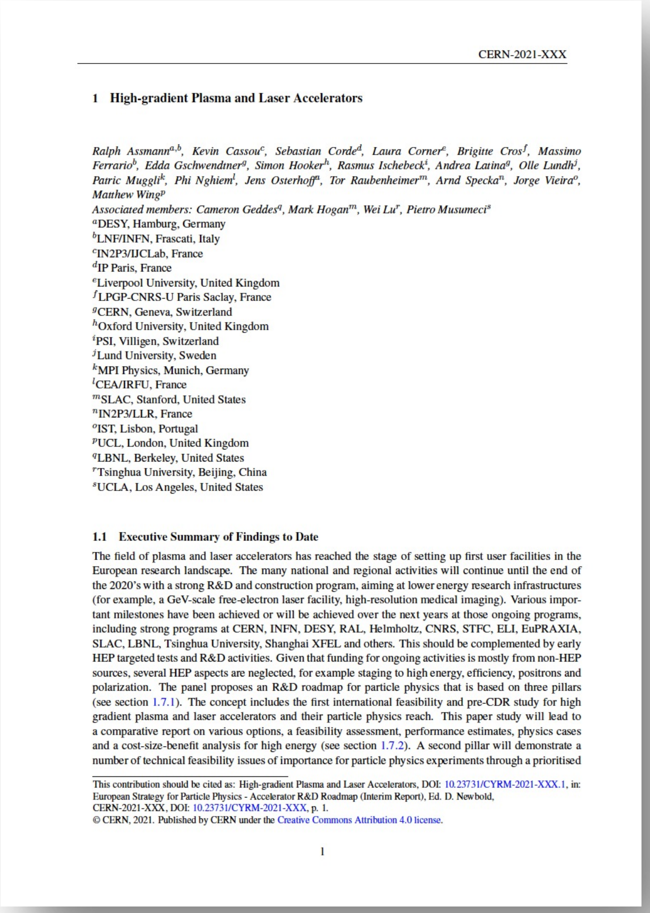
Plasma Accelerators
first user facility to be realized
100,000 million Volt **per meter**



Added value
new RI's due to compactness and cost-efficiency
bringing new capabilities to science, institutes, hospitals, universities, industry, developing countries.

5 GeV example

*realistic design including all required infrastructure for powering, shielding, …


CERN-2021-XXX

1 High-gradient Plasma and Laser Accelerators

Ralph Assmann[a,b], Kevin Cassou[c], Sebastian Corde[d], Laura Corner[e], Brigitte Cros[f], Massimo Ferrario[b], Edda Gschwendtner[g], Simon Hooker[h], Rasmus Ischebeck[i], Andrea Latina[g], Olle Lundh[j], Patric Muggli[k], Phi Nghiem[l], Jens Osterhoff[a], Tor Raubenheimer[m], Arnd Specka[n], Jorge Vieira[o], Matthew Wing[p]
Associated members: Cameron Geddes[q], Mark Hogan[m], Wei Lu[r], Pietro Musumeci[s]
[a]DESY, Hamburg, Germany
[b]LNF/INFN, Frascati, Italy
[c]IN2P3/IJCLab, France
[d]IP Paris, France
[e]Liverpool University, United Kingdom
[f]LPGP-CNRS-U Paris Saclay, France
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[h]Oxford University, United Kingdom
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[l]CEA/IRFU, France
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[n]IN2P3/LLR, France
[o]IST, Lisbon, Portugal
[p]UCL, London, United Kingdom
[q]LBNL, Berkeley, United States
[r]Tsinghua University, Beijing, China
[s]UCLA, Los Angeles, United States

1.1 Executive Summary of Findings to Date

The field of plasma and laser accelerators has reached the stage of setting up first user facilities in the European research landscape. The many national and regional activities will continue until the end of the 2020's with a strong R&D and construction program, aiming at lower energy research infrastructures (for example, a GeV-scale free-electron laser facility, high-resolution medical imaging). Various important milestones have been achieved or will be achieved over the next years at those ongoing programs, including strong programs at CERN, INFN, DESY, RAL, Helmholtz, CNRS, STFC, ELI, EuPRAXIA, SLAC, LBNL, Tsinghua University, Shanghai XFEL and others. This should be complemented by early HEP targeted tests and R&D activities. Given that funding for ongoing activities is mostly from non-HEP sources, several HEP aspects are neglected, for example staging to high energy, efficiency, positrons and polarization. The panel proposes an R&D roadmap for particle physics that is based on three pillars (see section 1.7.1). The concept includes the first international feasibility and pre-CDR study for high gradient plasma and laser accelerators and their particle physics reach. This paper study will lead to a comparative report on various options, a feasibility assessment, performance estimates, physics cases and a cost-size-benefit analysis for high energy (see section 1.7.2). A second pillar will demonstrate a number of technical feasibility issues of importance for particle physics experiments through a prioritised

This contribution should be cited as: High-gradient Plasma and Laser Accelerators, DOI: 10.23731/CYRM-2021-XXX.1, in: European Strategy for Particle Physics - Accelerator R&D Roadmap (Interim Report), Ed. D. Newbold, CERN-2021-XXX, DOI: 10.23731/CYRM-2021-XXX, p. 1.
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1

Can we shrink the **Linear Collider**, provide e^- and e^+ beams in the **TeV** energy regime and produce **> 10^{34} cm^{-2} s^{-1}** luminosity?

Parameter	Unit	PWFA	LWFA	DLA
Bunch charge	nC	1.6	0.64	4.8×10^{-6}
Number of bunches per train	-	1	1	159
Repetition rate of train	kHz	15	15	20,000
Convoluted normalized emittance ($\gamma\sqrt{\epsilon_h\epsilon_v}$)	nm-rad	592	100	0.1
Beam power at 5 GeV	kW	120	48	76
Beam power at 190 GeV	kW	4,560	1,824	2,900
Beam power at 1 TeV	kW	24,000	9,600	15,264
Relative energy spread	%		$\leq$0.35	
Polarization	%		80 (for e^-)	
Efficiency wall-plug to beam (includes drivers)	%		$\geq$10	
Luminosity regime (simple scaled calculation)	$10^{34}cm^{-2}s^{-1}$	1.1	1.0	1.9

Linear collider parameters reviewed for those technologies! LWFA/PWFA = plasma, DLA = dielectric laser accelerator

In addition, **attractive interim facilities** identified on the path to the collider (non-linear QED, dark matter, fixed target, injectors, …)

R. Assmann, E. Gschwendtner 2

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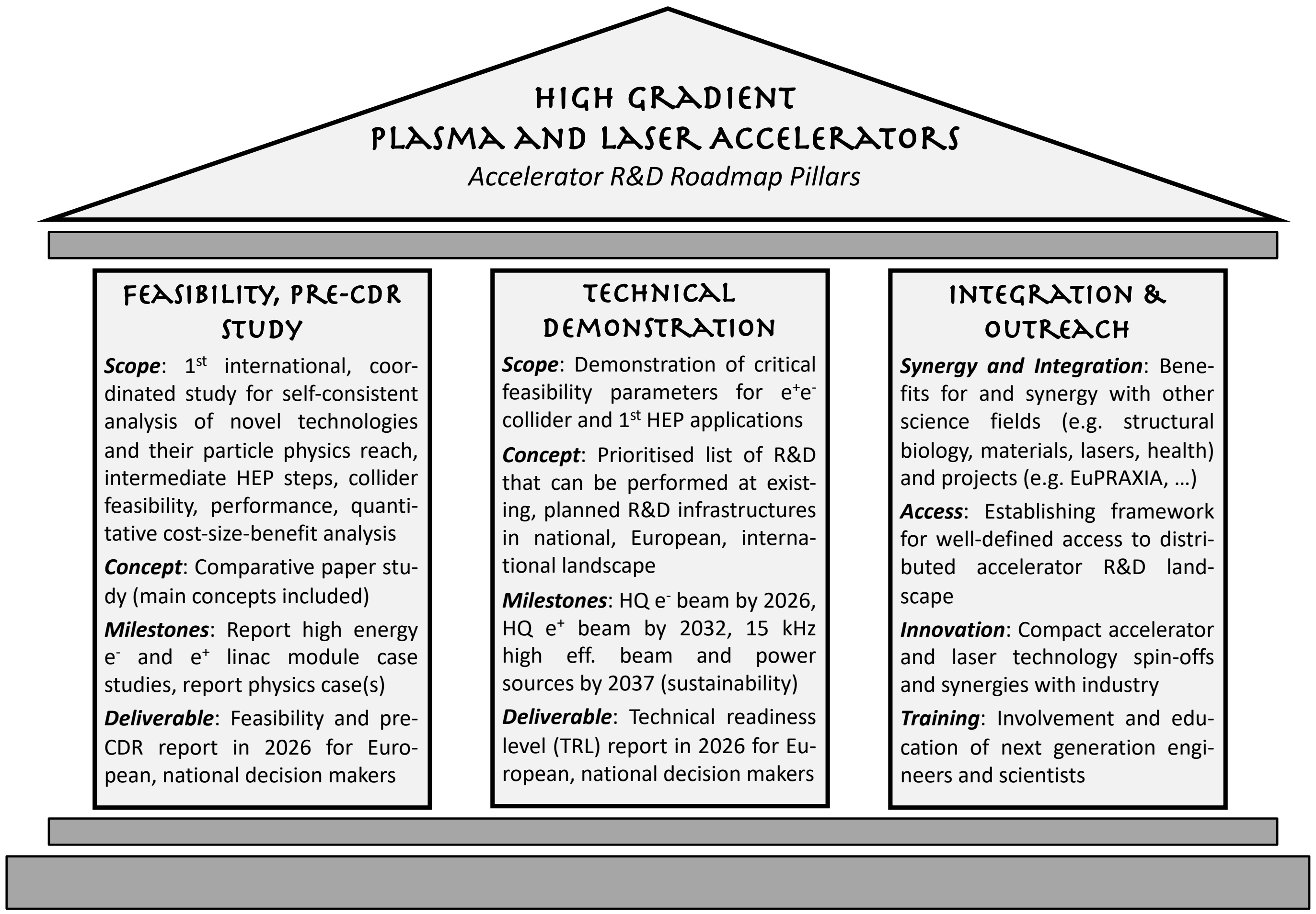
PLA Summary



Input and findings: **56 proposed milestones and deliverables for R&D until 2037**. To be discussed further and prioritized in next step of the roadmap process.

Case studies and parameters defined! **Needs a new, funded pre-CDR study**!

R&D Area	*R&D Topic (in random order)*
Sources of electrons, positrons, plasmas, and high power laser pulses *Address particle physics' unique requirements: 15kHz repetition rate, nanometer emittance, many MJ stored energy, component efficiency at 30-50% level, high rigidity of main beam, need for compact solutions*	High-quality electron beams from a LWFA injector
	Advanced plasma photoguns with ultra-low emittance electron beams
	Compact generation of positron beams up to GeV
	High average power, high effciency laser drivers and schemes
	Hybrid laser-beam driver schemes: demonstration, stability, efficiency
	Development of plasma sources for high-repetition rate, multi-GeV stages
System tests: high quality electrons *R&D often driven by other science fields that will benefit from first, lower energy applications. Results will of prove collider single bunch quality*	Dielectric accelerator module with high quality beam for first applications
	Electron-driven plasma accelerator-based Free-Electron Laser in saturation
	Laser-driven plasma accelerator-based soft-Xray Free-Electron Laser in saturation
	Electron beam with fixed target beam quality from p-PWFA
Collider components *Demonstrate various collider components or aspects that are of critical importance for particle physics applications*	Staging of electron plasma accelerators including in- and outcoupling
	Polarized electrons: targetry, polarimetry, polarization conservation
	Plasma lens R&D, towards transversely tapered designs
	Stable high transformer ratio PWFA with high eff. and low energy spread
	Positron high energy plasma acceleration module
	Proton-driven kJ electron acceleration module
Possible HEP test facility	Possible construction HEP test facility advanced accelerators (start OP in 2035), if in pre-CDR 2026

R. Assmann, E. Gschwendtner 3

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HGRF Initial Findings

	Particle sources	Magnet and Vacuum systems	High Field SC magnets	Normal Conducting RF structures	Superconducting RF cavities	RF power sources	Cryogenics	Instrumentation
ILC	•				•	•	•	•
FCC	•	•	•		•		•	•
PIP-II, MYRRHA					•	•	•	•
JLEIC	•		•	•		•		•
eRHIC, LHeC					•		•	•
DIAMOND2, SLS2		•				•		•
LCLS2-HE, SHINE		•			•		•	•
DONES	•	•		•	•	•	•	•
DEMOs	•		•			•	•	
PERLE					•	•		•
BELA, compact neutron sources	•			•				•

HGRF Initial Findings

Key Technology Areas → *Needed Developments*

Particle sources → *High intensity heavy ions, positron sources, polarized beams*

Magnets and vacuum systems → *Permanent magnets, small chambers evacuation*

High field SC magnets → *High-Tc conductors, cost reduction*

Normal Conducting RF structure → *High precision fabrication and tuning, RF breakdown*

Superconducting RF cavities → *Surface treatments, robotics, cost reduction*

RF power sources →*CW sources, Solid State Amplifiers, high efficiency*

Cryogenics → *High efficiency, cryo-coolers, cryo-safety*

Beam instrumentation → *Optical and RF diagnostics, fast electronics and feedback*

- RF panel currently continuing in 'input' phase
  - Building upon well-founded existing collaborations in this area
  - Interim report expected before September

Muons Summary

The muon collider presents enormous potential for fundamental physics research at the energy frontier.

Not as mature as some other lepton collider options such as ILC and CLIC; but promises attractive cost, power consumption, site size and time scale for the energy frontier, reaching beyond linear colliders.

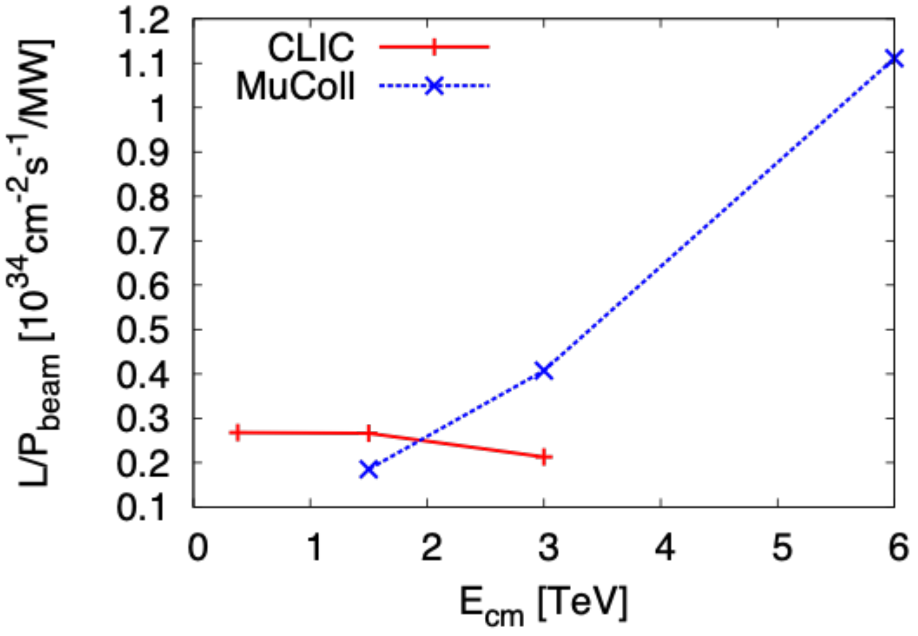
Luminosity target

$\sqrt{s}$	$\int \mathcal{L}dt$
3 TeV	$1\ \mathrm{ab}^{-1}$
10 TeV	$10\ \mathrm{ab}^{-1}$
14 TeV	$20\ \mathrm{ab}^{-1}$

Matches collaboration goal

- Focus on two energy ranges:
  - **3 TeV**, if possible with technology ready for **construction in 15-20 years** (*e.g. if higgs factory is not in Europe, could be next project after HL-LHC*)
  - **10+ TeV**, with more advanced technology, **the reason to do muon colliders** (*long-term sustainability of approach*)
- Explore synergy with other options (neutrino facility/higgs factory at resonance)
- Define **R&D path**

Luminosity per beam power



Muons Summary

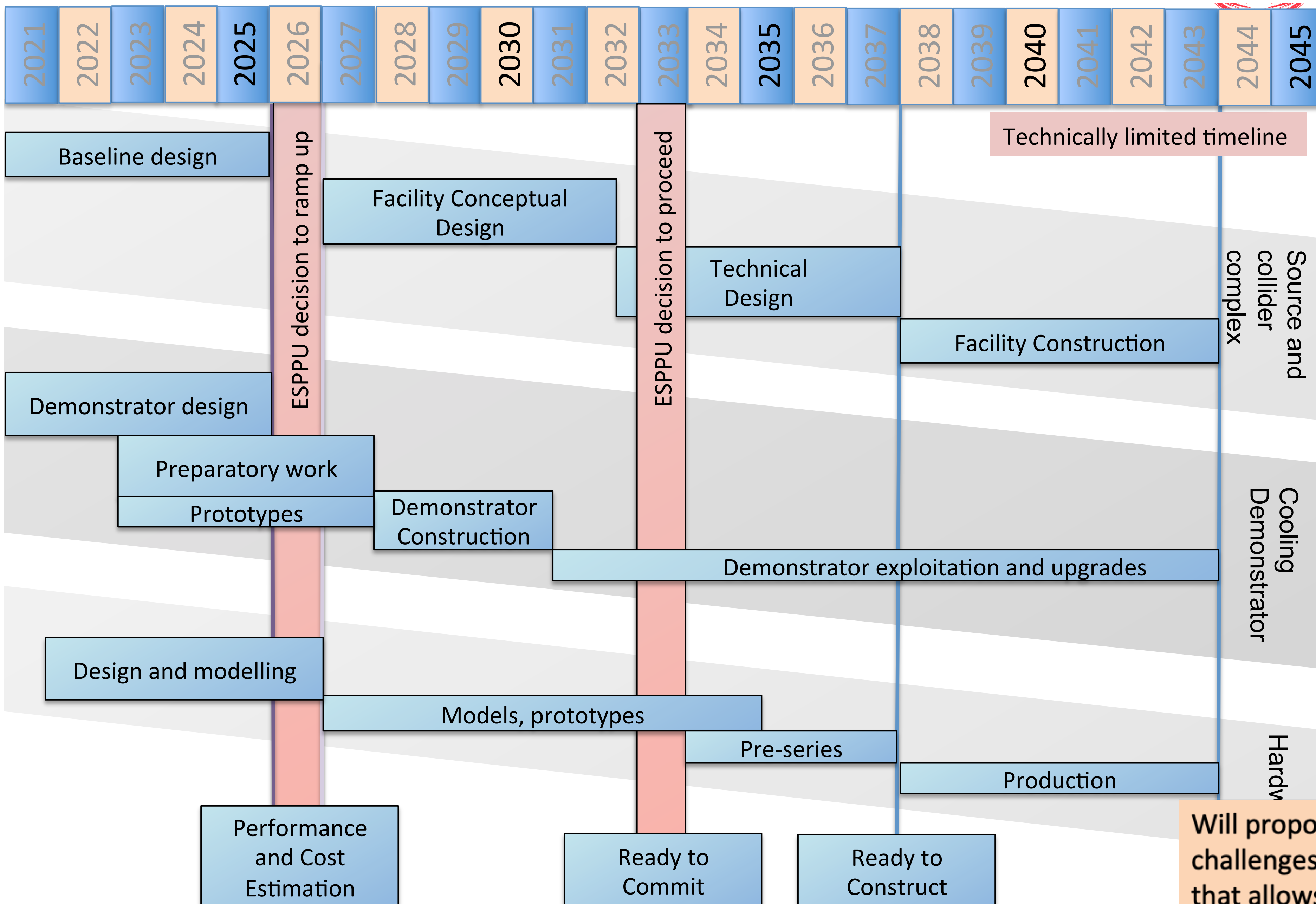
The panel identified the key R&D challenges.

Key areas of challenges:

- Impact on the environment
  - The **neutrino flux mitigation** and its impact on the site
- The impact of **machine induced background** on physics reach (help welcome).
- **High-energy systems** after muon cooling
  - can limit the energy reach via cost, power, technical risk and beam quality
- **High-quality muon beam production**
  - Improvement required based on MAP design improve
  - Need to optimise and prepare **cooling string demonstration** with beam (demonstrator)
- **Ambitious magnets**
  - fast-ramping magnets, high-field solenoids, …
- **Advanced RF**
  - normal conducting high-gradient RF in strong magnetic field, superconducting RF, …
- **Beam loss mitigation** (muon decay and proton beam in target)

At this stage the panel did not identify any showstopper in the concept.
Strong support of feasibility from previous studies.
The panel considers baseline parameter set viable starting point.

Muons Summary



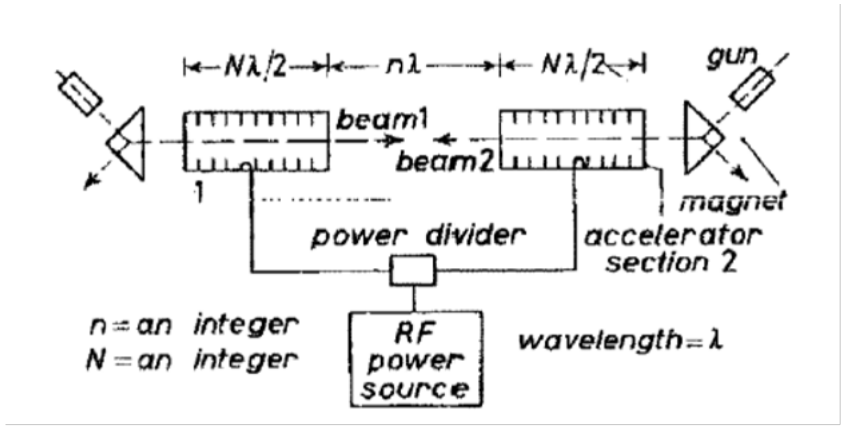
Will propose the R&D effort to address these challenges during the next five years to a level that allows assessment; integrating developments in underlying technologies as they arise in order to ensure the best possible performance.

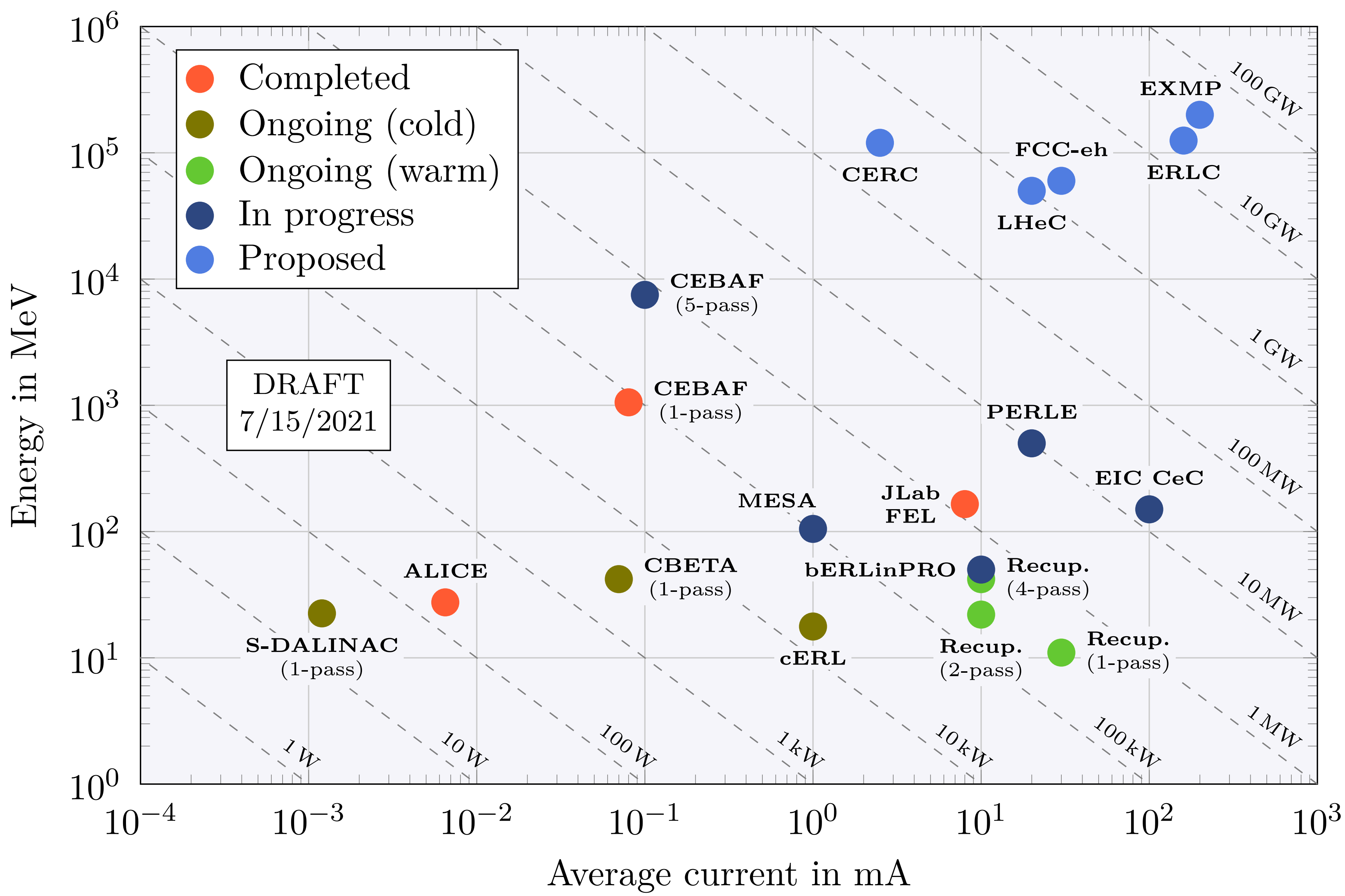
This R&D effort will allow the next ESPPU to make fully informed decisions. It will also benefit equivalent strategy processes in other regions.

ERL Summary

Following a 56 year old idea with the technology of today and tomorrow:

M Tigner A Possible Apparatus for Electron Clashing-Beam Experiments, N.Cim 10(1965)1228





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ERL Summary

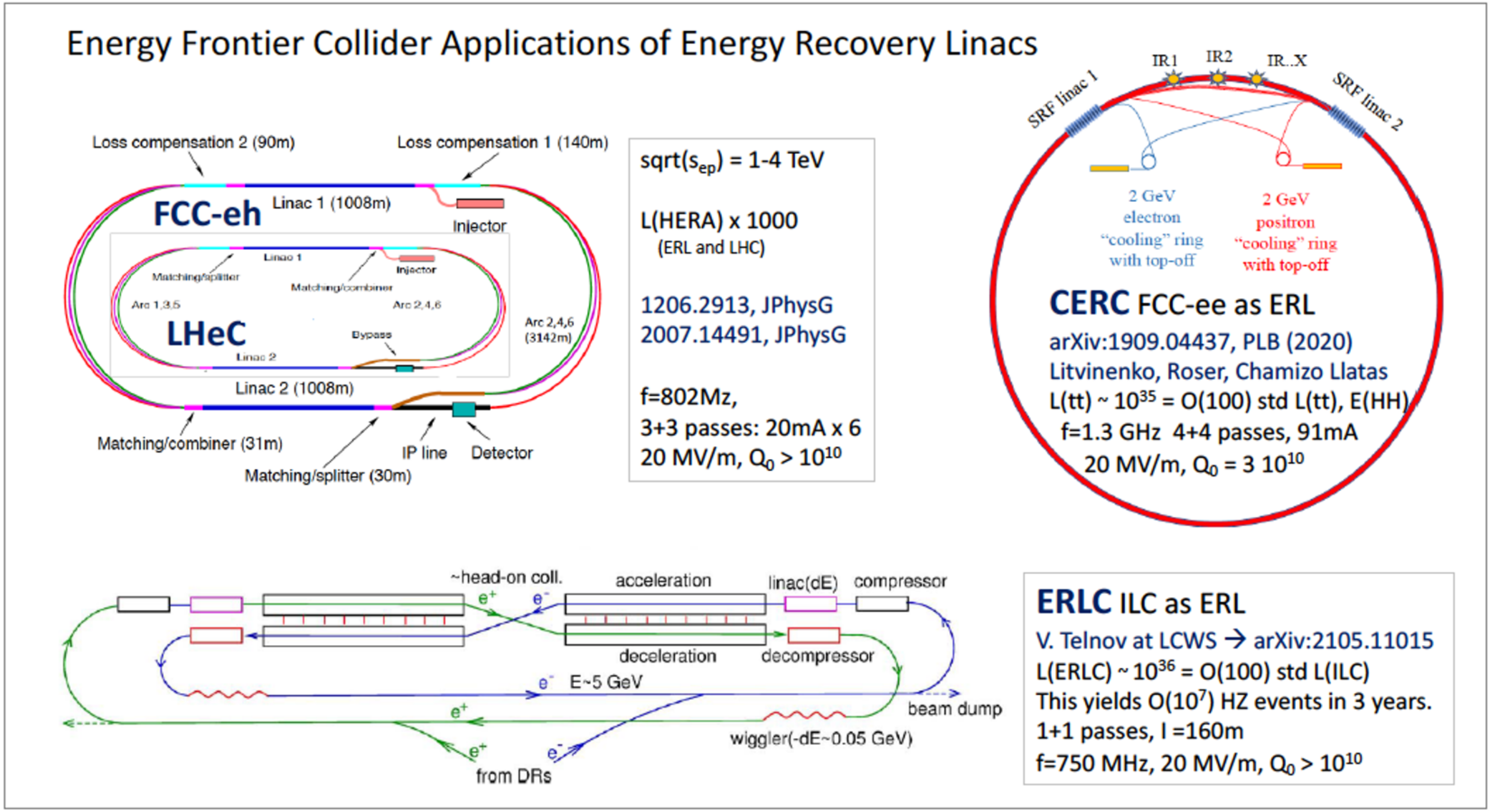


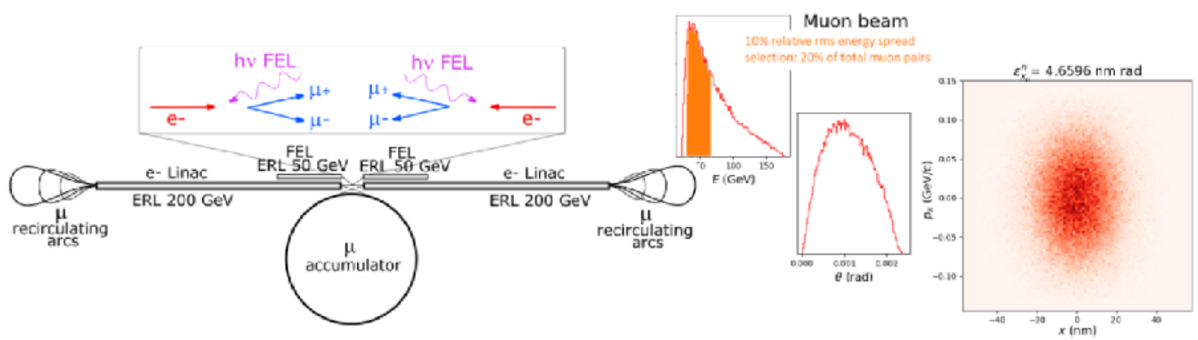
Figure 2: Sketch of possible future colliders based on ERLs: left top: LHeC and FCC-eh; right top: CERC; bottom: ERLC. For more information see the arXiv references displayed.

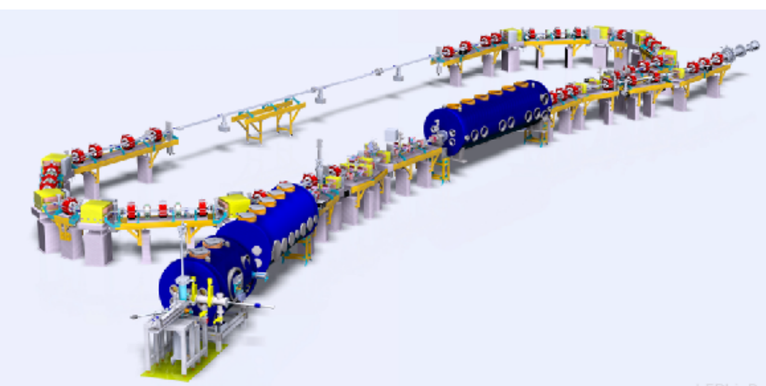
ERL Summary

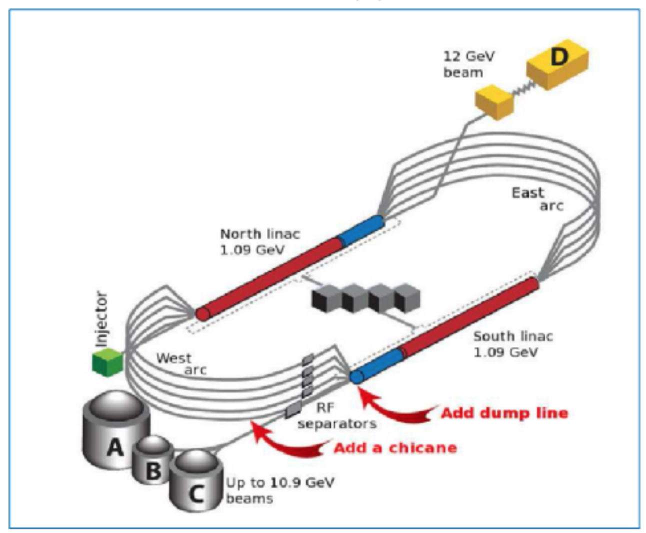
Electrons and X-rays to Muon Pairs (EXMP)

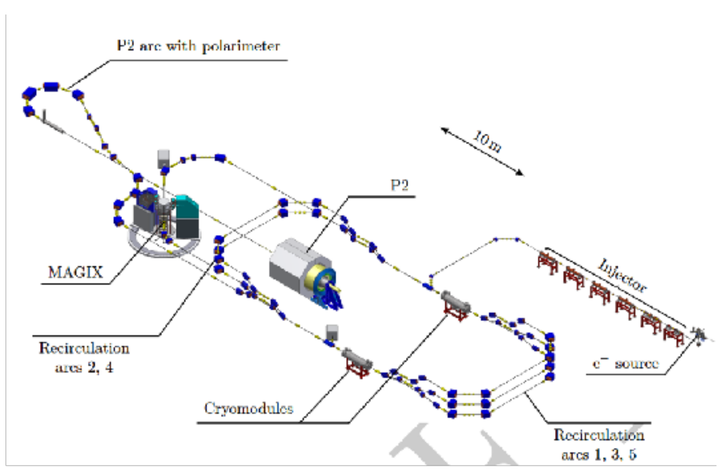
E_e = 200 GeV, $h\nu$ = 150 keV, $E_{CM} \simeq \sqrt{4E_e h\nu + M_e^2}$ = 346 MeV

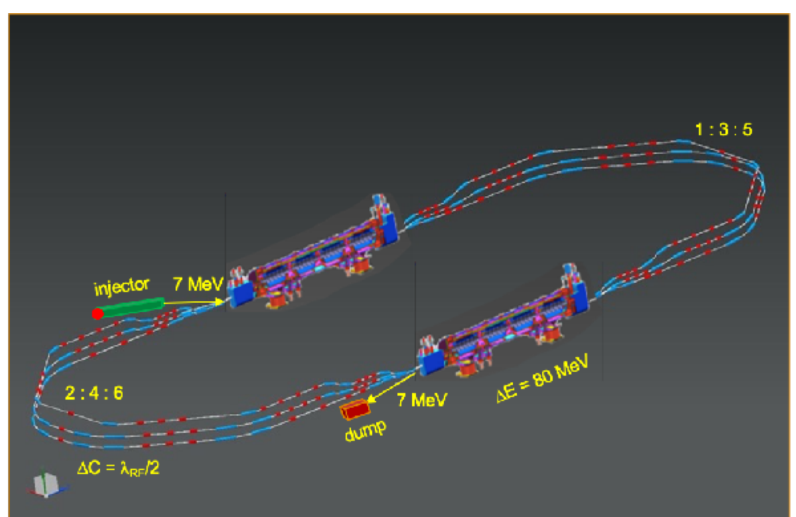
- no target → no target handling, no cooling needed
- no beamstralung, no ring → very tight focus allowed











Based on decades of SRF, FEL, ERL, Facility.. developments*) :

The debate now is about the conditions for ERLs to reach their productivity plateau and the demands on R&D, financial, intellectual and technical support – Roadmap early fall 21

An initial observation (not only) by the panel:

ERLs are more than an appealing technology:

They (cor)respond to **A NEW ERA** in particle and several other fields of physics, industry, accelerators .. in a world that cannot proceed without renewed care for our planet.

Europe's key R&D development prospects:
PERLE (3-turn, 10 MW), bERLinPRO (100 mA)
Concerted global effort (cERL, CEBAF5, etc.)
Including developments outside ERL facilities

Facilities and Experiments Timeline

- ESPPU highlighted multiple potential future collider facilities
  - However, it did not (and could not) give a specific timeline
  - Not everything mentioned in the ESPPU will happen
- However: some assumptions on a facilities timeline are necessary
  - To inform the 'need by' date for detector R&D
  - To inform the constraining time scale / goals for accelerator R&D
  - To define key decision points where studies and results must be ready
- A coarsely-binned timeline has been constructed
  - Based on the evidence assembled for the ESPPU, plus updates and further inputs
  - Taking into account the necessary steps of approval, development and construction for machine, civil engineering and detectors
- Caveats
  - Any attempt at such a timeline is subjective and will not accord with all opinions
    - Nothing that significant choices still await us in subsequent strategy processes
  - It does not, and must not be seen to, represent any sort of plan or recommendation
- Purpose of the timeline is purely to set the context for the R&D plan
  - In other words: to ensure that technology is not the limiting factor for future facilities

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Facilities and Experiments Timeline

The dates shown in the diagram have low precision, and are intended to represent the earliest 'feasible start date' (where a schedule is not already defined), taking into account the necessary steps of approval, development and construction for machine and civil engineering.

< 2030	2030-2035	2035-2040	2040-2045	> 2045
SPS Fixed Target	ALICE/LHCb (>LS4)	ILC	FCC-ee	FCC-hh
Other fixed target, FAIR (hep)	ATLAS/CMS (≥ LS4)	CLIC		FCC-eh
Belle II	EIC			Muon Collider
ALICE LS3	LHeC			
PIP-II/LBNF/DUNE/Hyper-K				

Draft figure still under development

<2025	2025-2030	2030-2035	>2035
Neutrino Telescopes (Km3)	Mu3e Phase II / COMET Phase II	Future Mu3e Experiment	Space-based Quantum Sensor Networks
Axions, ALPs, Dark Matter (DM)	Future muegamma experiment	Light DM Detectors	Functional Quantum Sensor HEP Detectors
Light DM Detectors	Axions, ALPs, DM	Hundred-tonne scale DM detectors	PRISM
Multi-tonne scale DM Detectors	Light DM Detectors	Multi tonne scale 0nbb	
Tonne Scale 0nbb	Hundred-tonne scale DM detectors	Prototype Quantum Sensor HEP Detectors	
100 m Atom Interferometry	Tonne scale 0nbb	Large scale quantum sensor networks	
	Proof of Principle Quantum Sensor HEP Detectors	Space- based Quantum Sensors	
	Dark Radiation	Big Bang (CNB) Detectors	
	Km scale Atom Interferometry		

Draft figure still under development

Informing our Future Plans

- Roadmap should answer the questions posed in ESPPU process
  - Or provide a plan to to answer them in the next five years
- Key questions on R&D
  - What needs to be done towards future facilities? What are the priorities?
  - How long might it take? What is the fastest technically-limited schedule?
  - How much will it cost?
  - What different options and trade-offs exist?
  - What are the linkages between activities?
  - What science can be done on the way?
- What about all the *other* things that must be done?
  - Other important (and nearer term) R&D topics – plus detectors and computing
    - Important topic can be described in summary form in the final report, for the purposes of balance
  - Planning and preparation of specific new facilities
  - Construction and commissioning of HL-LHC
- Ultimately, balance of activities is a question for Council and its advisors
  - These are decisions with long-term consequences for the shape of the field
  - The funding agencies will make their decisions in light of the final roadmap

Conclusion and Questions

- The end product
  - Council (200pp; panel reports plus synthesis) – will subsequently be public
  - Summary report in 'glossy' format for funding agencies etc (10pp)
  - Long reports from panels, possibly published
- From January 2022, the 'implementation phase' should begin
  - Follow-up process is still to be determined for both roadmaps
- Questions for the community (with reference to talks by panel chairs)
  - Are there accelerator R&D requirements not yet captured?
    - Both within the five topical areas, and outside them
  - What are the appropriate target timescales for R&D outputs?
    - Based upon ambitions for future machines, but also potential improvements of current machines
  - What is the optimal balance between 'generic' long term R&D, medium-term topical R&D, and near term concrete studies for new machines?
  - Are there instances where machine and detector R&D must be linked strongly?
  - What opportunities exist for scientific exploitation of the R&D demonstrators?
- Timely feedback is welcome in this last phase of the 'public' discussion
  - Please let us know your views via your ECFA representative, or directly to LDG