Muon Collider – international scenario

International Muon Collider Collaboration - **Project Leader**: Daniel Schulte

Objective:

In time for the next European Strategy for Particle Physics Update, the study aims to **establish whether the investment into a full CDR and a demonstrator is scientifically justified**.

It will provide a baseline concept, well-supported performance expectations and assess the associated key risks as well as cost and power consump5on drivers. It will also identify an R&D path to demonstrate the feasibility of the collider.

Scope:

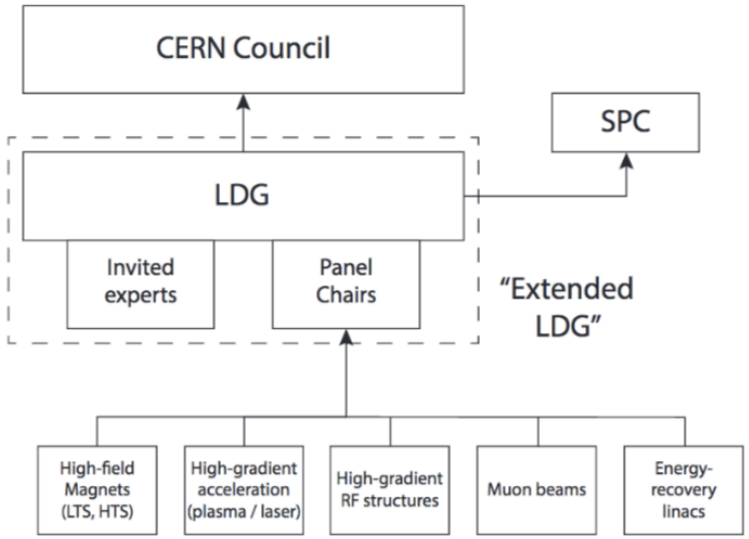
- Focus on two energy ranges:
  - **3 TeV** if possible with technology ready for construction in 10-20years
  - **10+ TeV** with more advanced technology, **the reason to chose muon colliders**
- Explore synergy with other options (neutrino/higgs factory)
- Define **R&D path**

Web page: http://muoncollider.web.cern.ch
Mailing lists:
MUONCOLLIDER_DETECTOR_PHYSICS@cern.ch,
MUONCOLLIDER_FACILITY@cern.ch
go to https://e-groups.cern.ch search for “muoncollider” to subscribe

European Accelerator R&D Roadmap

Council charged Laboratory Directors Group (LDG) to deliver European **Accelerator R&D Roadmap**

Panels
- Magnets: P. Vedrine
- Plasma: R. Assmann
- RF: S. Bousson
- Muons: D. Schulte
- ERL: M. Klein



Muon Beam members: Daniel Schulte (CERN, chair), Mark Palmer (BNL, co-chair), Tabea Arndt (KIT), Antoine Chance (CEA/IRFU) Jean-Pierre Delahaye (retired), Angeles Faus-Golfe (IN2P3/ IJClab), Simone Gilardoni (CERN), Philippe Lebrun (European Scientific Institute), Ken Long (Imperial College London), Elias Metral (CERN), Nadia Pastrone (INFN-Torino), Lionel Quettier (CEA/IRFU), Tor Raubenheimer (SLAC), Chris Rogers (STFC-RAL), Mike Seidel (EPFL and PSI), Diktys Stratakis (FNAL), Akira Yamamoto (KEK and CERN)

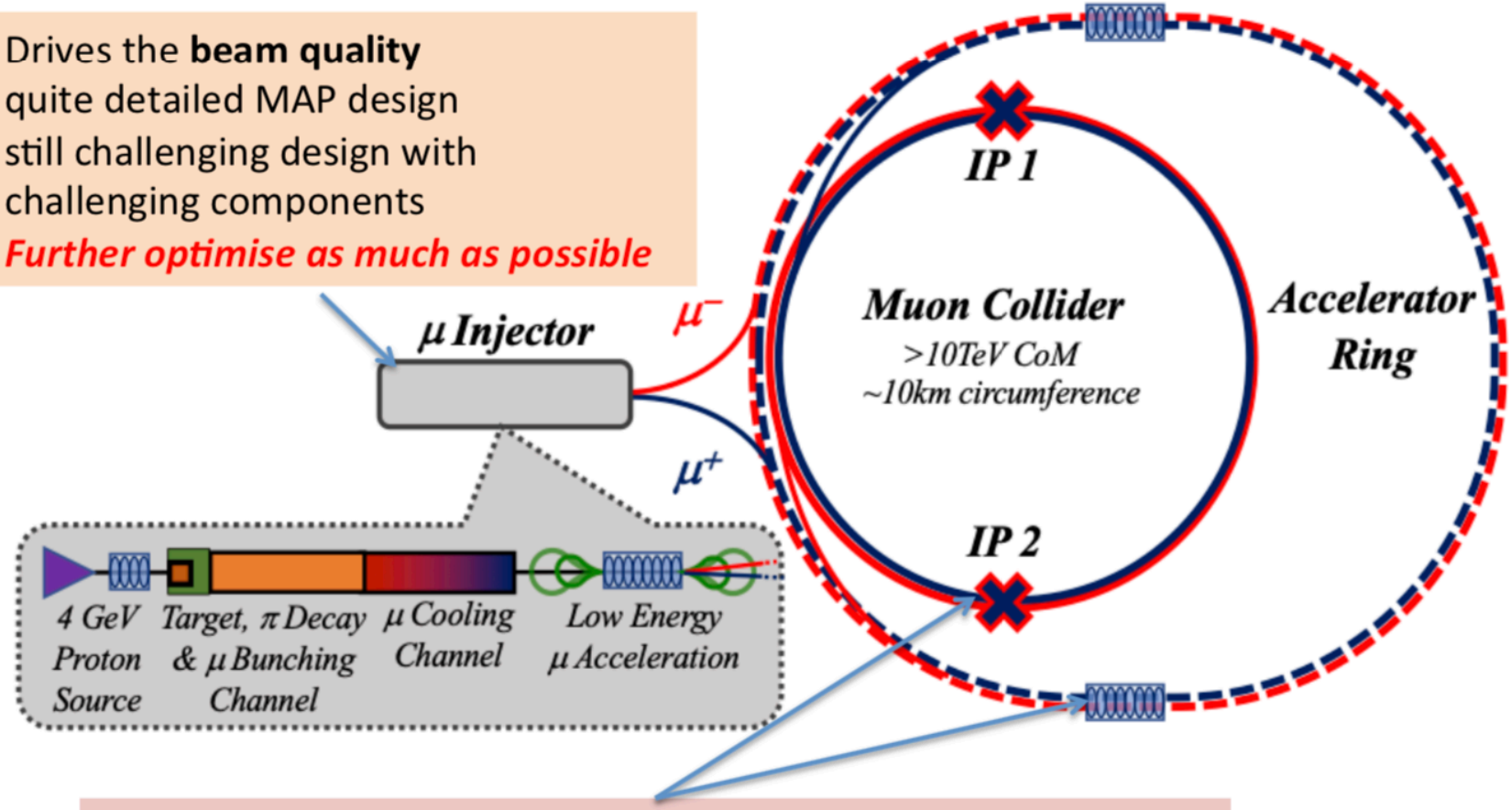
Roles of panel members and European (other regions to be added) contact persons at https://muoncollider.web.cern.ch/organisation

Muon Beam Panel
Community Meeting May 20-21:
https://indico.cern.ch/event/1030726/

RF
Magnets
High-energy complex
Muon production and cooling
Proton complex
Beam Dynamics
Radiation protection and other technologies
MDI

Overall Considerations

Drives the **beam quality**
quite detailed MAP design
still challenging design with
challenging components
Further optimise as much as possible



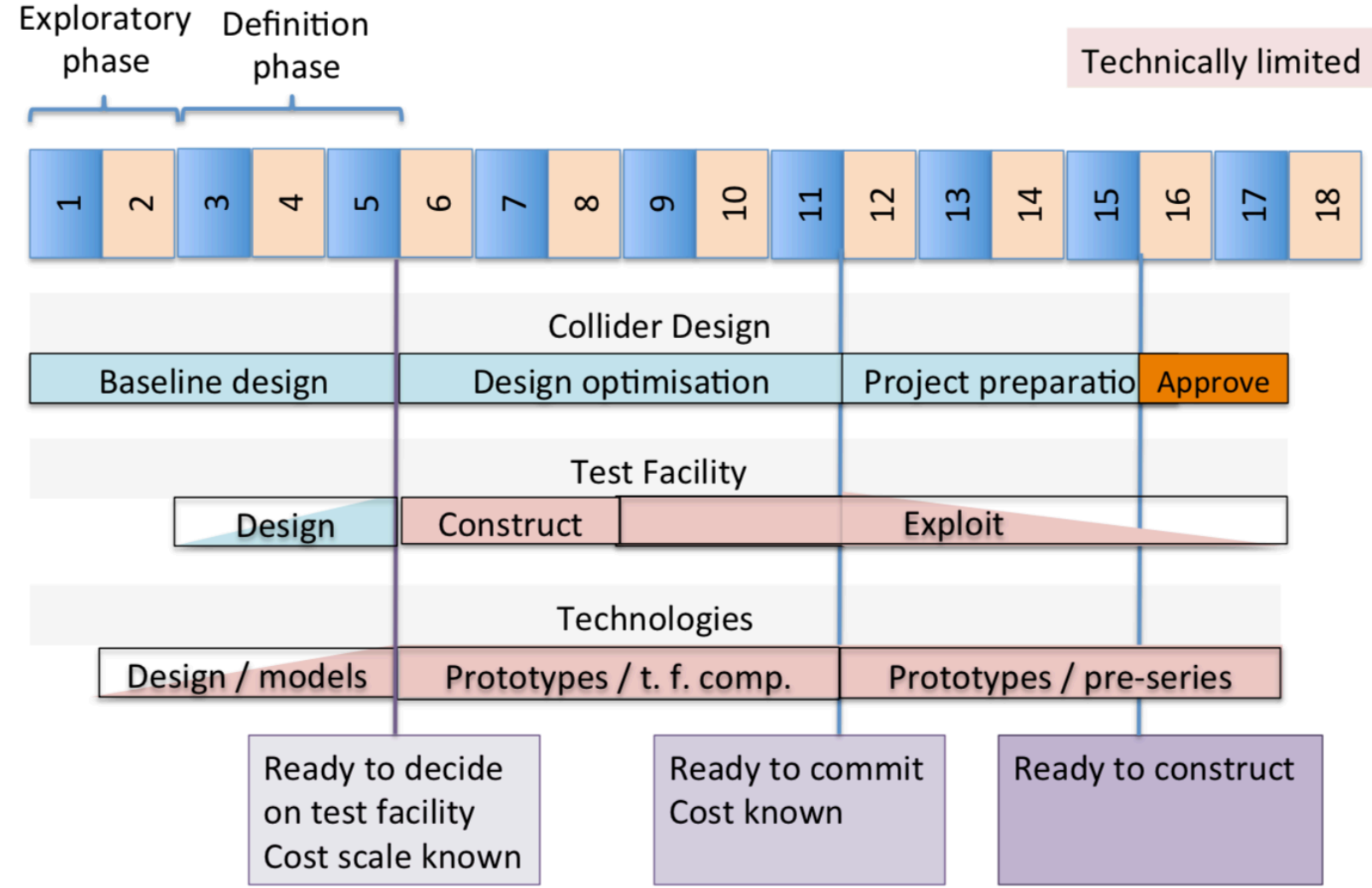
Cost and **power** consumption drivers, limit energy reach
e.g. 30 km accelerator for 10/14 TeV, 10/14 km collider ring
Also impacts **beam quality**
Drives **neutrino radiation** and **beam induced background**
Improve compared to MAP design and design for high-energy

Key Topics

10+ TeV is uncharted territory

- **Physics potential** evaluation
- Impact on the environment
  - The **neutrino radiation** and its impact on the site
- The impact of **machine induced background** on the detector, as it might limit the physics reach.
- **High-energy systems** after the cooling (acceleration, collision, …)
  - This can limit the energy reach via cost, power and beam quality
- **High-quality beam production** of cooled muon beam
  - MAP did study this in detail
  - Need to optimise and prepare test facility

Potential Long-Term Timeline



I.FAST in a nutshell

Web site https://ifast-project.eu/

- Innovation Fostering in Accelerator Science and Technology
- 4 years duration, 01 May 2021 – 30 April 2025
- 48 beneficiaries (SigmaPhi left the project), 14 partner organisations, >20 collaborating institutes.
- 13 Work Packages, 55 Tasks.
- Full cost budget 18.7 M€, EC contribution 10 M€.
- One goal: identify and develop in collaboration with industry the technologies for tomorrow's particle accelerators

Kick-off meeting planned May 4: https://indico.cern.ch/event/1024993

Please register!

Workpackages

WP5
Strategies and milestones for accelerator research and technologies

Identify novel opportunities, possible implementations, and strategic roadmaps for long-term accelerator R&D, to significantly improve the performance of future accelerators**. Support the effort to design a muon collider and to project and plan the required R&D.** …….

Improve performance and sustainability of accelerators

Main tasks in I.FAST

CERN is involved in the following WPs:

- **WP1 Management, coordination and dissemination**: CERN will be the Coordinator of I.FAST and will provide the Coordination Office, including support from the EU Support Office, legal and financial services.
- **WP2 Training, communication and outreach for accelerator science and technology:** CERN will coordinate the I.FAST external communication and outreach activities (Task 2.2), will advise on the innovation seminars at ESI Archamps and will participate to an exchange programme with industry.
- **WP3 Industry engagement:** CERN Knowledge Transfer Group will contribute to the activities of WP3 and WP4.
- **WP4 Managing innovation, new materials:** CERN will manage selection and budget distribution for the internal call for projects from M24. It will study innovative beam windows and materials.
- **WP5 Strategies and milestones for accelerator research and technology:** CERN will participate in the muon collider strategy network, and coordinate a strategy group on Pushing Accelerator Frontiers.
- **WP6 Novel particle accelerators concepts and technology:** CERN will participate in the definition of strategies for plasma acceleration and in the organisation of events.
- **WP7 High brightness accelerators for light sources:** CERN will contribute with its experience with the CLIC damping ring to the definition of techniques to reduce emittance in storage rings. It will contribute to transferring the CLIC varying dipole field technology to a prototype for ELETTRA. It will participate in the construction of X-band cavity prototypes.
- **WP8 Innovative superconducting magnets:** CERN will participate in the design of CCT magnet demonstrators for hadron therapy accelerators, and will provide expertise during construction in industry and testing.
- **WP10 Advanced accelerator technologies:** CERN will participate in the development of electro-optical waveguide sensors.
- **WP11 Sustainable concepts and technologies:** CERN will contribute to the studies on energy management, and will supervise the construction in industry of a high-efficiency klystron prototype.
- **WP13 Technology infrastructure:** CERN will participate in the strategy group on sharing of the European technology infrastructure, and will provide advice in the development of new solid-state RF amplifiers.

MUon collider STrategy network
EU project I.FAST

WP5: Strategies and Milestones for Accelerator Research and Technologies (SMART)

TASK 5.1 INFN, CERN (+BINP), CEA, CRNS, KIT, PSI, STFC + USA not beneficiary

Task 5.1 (MUST)

*A **collider of muons** could be a compact and efficient way to reach energies of interest for future physics discoveries; but, a substantial R&D program is needed to prove its **feasibility** and to assess its **cost**. The first Strategy group in WP5 will prepare the ground for a future high-energy muon collider, by comparing alternative options for muon production and cooling, by developing a baseline collider scenario, and by devising the optimum test facilities to prove its feasibility.*

It will serve as the common ground for a growing international muon-collider collaboration.

Task 5.1 MUST will establish an international collaboration and develop an optimised R&D roadmap towards a future muon collider, including the definition of optimum test facilities and possible intermediate steps.

Muon Collider technology (WP5, Task 5.1)

State-of-art	Ambition	Challenges
Two schemes were proposed to produce muon beams exploiting a proton driver (MAP) and a positron beam on target (LEMMA). Crucial R&D and the ionizing cooling proof of principle were accomplished but further studies and test facilities are still required.	Successful implementation of an international plan to address all studies and key issues towards the design of a muon collider capable to reach multi-TeV collision energies with an adequate luminosity for high-precision measurements and new discoveries.	Establish an organized international collaboration to address key issues and plan future steps. Evaluate reuse of existing infrastructures taking into account neutrino radiation hazards. Design of needed test facilities to address final feasibility.

MUST in I.FAST

Description of exploitable foreground (relevant deliverable)	I.FAST del.	How the foreground may be exploited	IPR measu-res foresee n	Further R&D (if needed)	Sector(s) of application or end user(s)	Timeta ble for comme rcial or other use	Potential/exp ected impact (quantify where possible)
Roadmap for future accelerators	D5.1 M42	Advertise at scientific conferences and industrial events; disseminate plan to policy makers		Further improvem ents and prototype s possible	Accelerator Design and Operation	Long-term	Higher-performance accelerators; input to policy makers
International collaboration plans towards a multi-TeV muon collider	D5.2 M46	Advertise at scientific conferences and industrial events; disseminate plan to policy makers		Test facility, conceptua l design.	Particle Physics and Accelerator Design	Long-term	Future energy-efficient, higher-energy muon collider

How do we plan to co-coordinate our effort?

Now/soon:

- during roadmap preparation
- Identifying key R&Ds ➔ also applying for blue sky funds….
- Demonstrator & test facilities ➔ preparing 1-2 dedicated EU projects

Next:

- Seeking for new EU et al. collaborators
- Network in EU & link in other regions: US, ASIA
- Link to industries…

Do we want to specify different contributions by different groups on specific items?
Targets, Cooling, RF, Magnets,…… MDI

MUon STrategy network - Budget

IFAST	WP5	New concepts, performance improvements										
WP coordinator:		**F. Zimmermann (CERN)**										
Full costs budget per Task												
Beneficiary short name	Person-months	Monthly personnel cost	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (without overheads)	EC requested funding (including overheads)	
Task 5.1	**MUon colliders STrategy network**										**300.000,00**	
INFN	20,0	5.000,00	100.000,00	20.000,00		8.000,00		28.000,00	128.000,00	64.000,00	80.000,00	Torino
CERN	12,0	17.000,00	204.000,00	20.000,00				20.000,00	224.000,00	56.000,00	70.000,00	6PM CP9 + 6 PM postdoc fellow
CEA	5,0	7.800,00	39.000,00	10.000,00		3.000,00		13.000,00	52.000,00	24.000,00	30.000,00	
CNRS	6,0	5.900,00	35.400,00	5.000,00		8.000,00		13.000,00	48.400,00	24.000,00	30.000,00	IJCLAB
KIT	4,5	9.100,00	40.950,00	9.100,00				9.100,00	50.050,00	24.000,00	30.000,00	
PSI	6,0	8.150,00	48.900,00	10.000,00		3.000,00		13.000,00	61.900,00	24.000,00	30.000,00	
UKRI	4,0	10.000,00	40.000,00	10.000,00		3.000,00		13.000,00	53.000,00	24.000,00	30.000,00	STFC

Towards 15’ min talk @ kick-off meeting

OUTLINE

- International framework – baseline design – preparing for next EU Strategy upgrade
- Accelerator R&D Roadmap
- Muon source: target and muon demonstrator
- Technology test facilities ←→ Synergies with industries
- Network in EU & link in other regions: US, ASIA

extras

I.FAST Structure

Difficult to read, but please check the names of Coordinators and Task Leaders and if changes are needed send a mail to myself and to Valerie.

Additional:
WP14 Ethics Requirements
Added by the EC, on data protection and health and safety procedures.

WP1	Management, coordination and dissemination	M. Vretenar (CERN)	Task 1.1	Project management, external coordination, sustainability	M. Vretenar (CERN)	
			Task 1.2	Information flow management and cross-coordination	T. Torims (RTU)	
			Task 1.3	Internal communication and dissemination	P. Foka (GSI)	
			Task 1.4	Relation with other innovation pilots	*M.Losasso (CERN)*	
WP2	Training, communications and outreach for accelerator science and technology in Europe	P. Burrows (UOXF)	Task 2.1	Management	P. Burrows (UOXF)	
			Task 2.2	Communication and outreach	D. Antonio (CERN)	
			Task 2.3	Challenge-based innovation (CBI) with particle accelerators	N. Delerue (CNRS)	
			Task 2.4	Industrial Training associated with knowledge transfer	T. Ekelof (UU)	
WP3	Industry engagement	M. Morandin (INFN)	Task 3.1	Coordination and industrial partnership support	M. Morandin (INFN)	
			Task 3.2	Knowledge transfer and business opportunities in accelerators R&D	Arik Willner (DESY)	
			Task 3.3	Extended participation of industry in collaborative R&D activities	Jose M. Perez (CIEMAT)	
WP4	Managing innovation, new materials	M. Losasso (CERN)	Task 4.1	Innovation management and committee	M. Losasso (CERN)	
			Task 4.2	Management of the Innovation Fund	M. Losasso (CERN)	
			Task 4.3	Innovative beam windows for high-power accelerator applications	M. Losasso (CERN)	M. Tomut (GSI)
			Task 4.4	Large scale Carbide-Carbon Materials for multipurpose applications	F. Carra (CERN)	
WP5	Strategies and Milestones for Accelerator Research and Technologies	F. Zimmermann (CERN), N. Pastrone (INFN), P. Fork (GSI)	Task 5.1	MUon colliders STrategy network (MUST)	N. Pastrone (INFN)	
			Task 5.2	Pushing Accelerator Frontiers (PAF)	F. Zimmermann (CERN)	G. Franchetti (GSI)
			Task 5.3	Improvement of Resonant slow EXtraction spill quality (REX)	P. Fork (GSI)	
WP6	Novel Particle Accelerators Concepts and Technologies	R. Assmann (DESY), …	Task 6.1	Novel Particle Accelerators Concepts and Technologies	R. Assmann (DESY)	
			Task 6.2	LASers for PLasma Accelerators	I. Gizzi (CNR)	
			Task 6.3	Multi-scale Innovative targets for laser-plasma accelerators	C. Thaury (CNRS)	
			Task 6.4	Laser focal spot stabilization systems	F. Mathieu (CNRS)	
WP7	High Brightness Accelerators for Light Sources	R. Bartolini (UOXF), …	Task 7.1	Coordination & communication	R. Bartolini (UOXF)	
			Task 7.2	Enabling Technologies for Ultra-Low Emittance Ring	R. Bartolini (UOXF)	
			Task 7.3	Variable Dipole for the upgrade of the ELETTRA storage ring	Y. Papaphilippou (CERN)	
			Task 7.4	Very high gradient RF Guns operating in the C-band RF technology	D. Alesini (INFN)	
			Task 7.5	CompactLight Prototype Accelerating Structure	G. D'Auria (Elettra)	
WP8	Innovative superconducting magnets	L. Rossi (INFN), L. Quettier (CEA), G. Roux (GSI)	Task 8.1	Coordination and HTS Strategy Group	L. Rossi (INFN)	D. Schoerling (CERN)
			Task 8.2	Preliminary Engineering design of curved CCT magnet	D. Tommasini (CERN)	L. Rossi (INFN)
			Task 8.3	Preliminary Engineering design of HTS CCT	L. Quettier (CEA)	D. Schoerling (CERN)
			Task 8.4	Construction of curved CCT magnet demonstrator	M. Gehring (BNG)	M. Vieweg (Scanditronix)
			Task 8.5	Construction of HTS CCT magnet demonstrator	?	A. Echeandia (Elytt)
			Task 8.6	Development of ReBCO HTS nuclotron cable	T. Winkler (GSI)	G. Roux (GSI)
WP9	Innovative superconducting thin film coated cavities	C. Antoine (CEA), O. Malyshev (UKRI)	Task 9.1	Coordination and Strategy for Innovative Superconducting Accelerating Cavities	C. Antoine (CEA)	O. Malyshev (UKRI)
			Task 9.2	Innovative Superconducting Accelerating Cavities	C. Pira (INFN)	
			Task 9.3	Optimisation of process parameters and target development for SRF cavity coating with A15 material	R. Valizadeh (UKRI)	
			Task 9.4	Surface Engineering by Atomic Layer Deposition (ALD)	T. Proslier (CEA)	
			Task 9.5	Improvement of mechanical and superconducting properties of RF resonator by laser radiation	A. Medvids (RTU)	
			Task 9.6	Optimization of flat SRF thin films production procedure	O. Kugeler (HZB)	
WP10	Advanced Accelerator technologies	T. Torims (RTU), …	Task 10.1	Coordination and communication	T. Torims (RTU)	
			Task 10.2	Additive Manufacturing – Survey of applications and potential developments	M. Vedani (POLIMI)	
			Task 10.3	Refurbishment of accelerator components by AM technologies	T. Torims (RTU)	
			Task 10.4	Development of AM-manufactured superconductive RF cavities	M. Pepato (INFN)	
			Task 10.5	Photon Stimulated Desorption (PSD) from NEG coatings for accelerator vacuum chambers	O. Malyshev (UKRI)	
			Task 10.6	Machine learning techniques for accelerator and target instrumentation	T. Shea (ESS)	
			Task 10.7	Development of electro-optical waveguide sensors as beam electric field sensors	S. Gibson (RHUL)	
WP11	Sustainable concepts and technologies	M. Seidel (PSI)	Task 11.1	Sustainable Concepts for Accelerator driven Research Infrastructures	M. Seidel (PSI)	
			Task 11.2	High Efficiency Klystron Industrial Prototype	E. Jensen (CERN)	O. Brunner (CERN)
			Task 11.3	Permanent Magnet Quadrupoles & Combined Function Magnets for Ultra Low-Emittance Rings	B. Shepherd (UKRI)	
WP12	Societal Applications	R. Edgecock (HUD),	Task 12.1	A Strategy for Implementing Novel Societal Applications of Accelerators	R. Edgecock (HUD)	
			Task 12.2	Design of advanced electron accelerator plant for biohazards treatment	A. Chmeliewski (INCT)	
			Task 12.3	Design of Internal Rf Ion Source for Cyclotrons	J. Perez (CIEMAT)	
WP13	Technology Infrastructure	S. Leray, M.H. Moscatello (CEA)	Task 13.1	Strategy for the development of the AMICI TI	S. Leray (CEA)	M.H. Moscatello (CEA)
			Task 13.2	Developing and promoting services to industry in AMICI TFs	H. Weise (DESY)	R. Wichmann (DESY)
			Task 13.3	New RF amplifiers based on GaN Semiconductors	D. Dancila (UU)	

Resources monitoring

I.FAST budget

Full costs = **18.7 M€**
EC contribution = **10 M€**

→ all partners contribute with a certain amount of matching funds and the funding rate for the beneficiaries is variable but typically 40-50%.

Internal Resource Utilisation Summaries (IRUS)

Purpose: to allow the Coordinator and the GB to monitor the utilisation of resources of each participant, WP and project as a whole.

Content: an estimate (not necessarily actual expenditure) of the full costs related to the project.

Periodicity:

- M12, M18, M36, M48 for the beneficiaries
- M12, M24, M36, M48 for the partner organisations

The IRUS summaries will NOT be sent to the EC and do not have to be formally certified.

IRUS for beneficiary	no.	Period
CERN	1	01.05.2021 - 31.10.2022

WP no.	Person-months used (PM)	Estimated personnel costs €	Estimated other direct costs* €	Total direct costs €	Total indirect costs €	Total estimated costs €
WP1				0	0	**0**
WP2				0	0	**0**
Total	**0**	**0**	**0**	**0**	**0**	**0**

* Equipment, consumables, travels, computing, services, goods

Provide a brief explanation for any significant deviations from the planned man-power utilisation (over-spending or under-spending exceeding 20% with respect to the planning)

Only the costs reported and claimed on the Individual Financial Statements need to be verified and may be subject to EC and/or external audits.