SAC Report

Impact of I.FAST on Acc. Technologies

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I.FAST Scientific Advisory Committee (SAC)

5th and final I.FAST meeting, 20-21 Oct. 2025

Outline

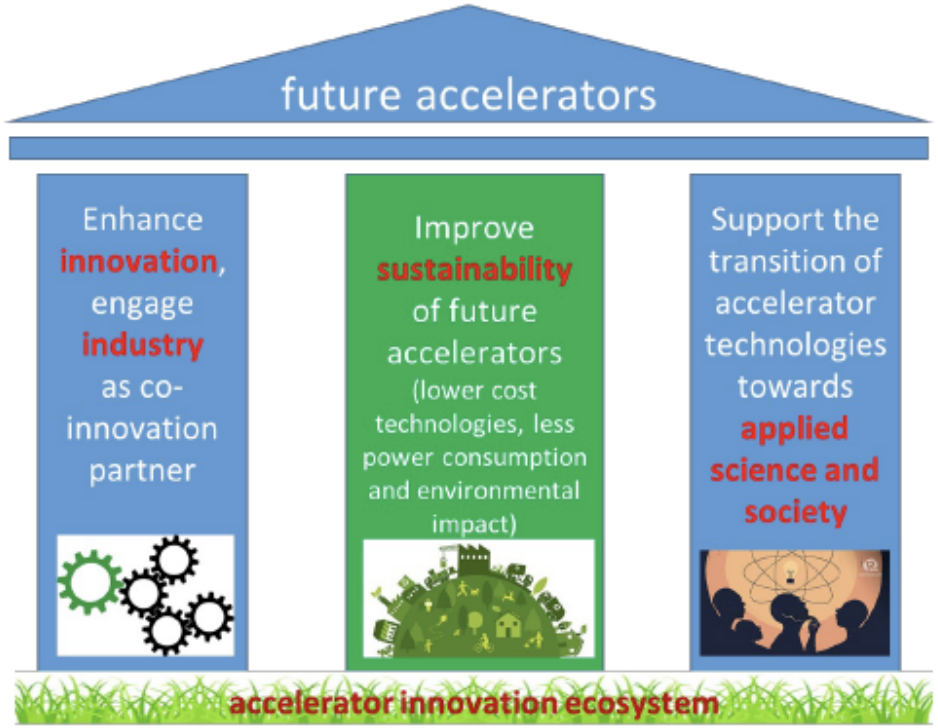
- Overview

- Highlights from I.FAST activities
  - High-level prototyping
  - Impact on accelerator technologies

- Summary

Courtesy: M. Vretenar

Did we achieve our objectives?



Goals of I.FAST:

- As an Innovation Pilot, move to **open innovation**: associate industry to innovation, engage industry as co-innovation partner.
- Structure and enlarge the accelerator **innovation ecosystem**, thanks to 17 industrial partners (35% of total) and 37% new partners w.r.t. previous projects. Integrate technology infrastructure.
- Develop technologies to **improve sustainability** of future accelerators.
- Favour transition of accelerator technologies to **applied science** and **society**.

YES !

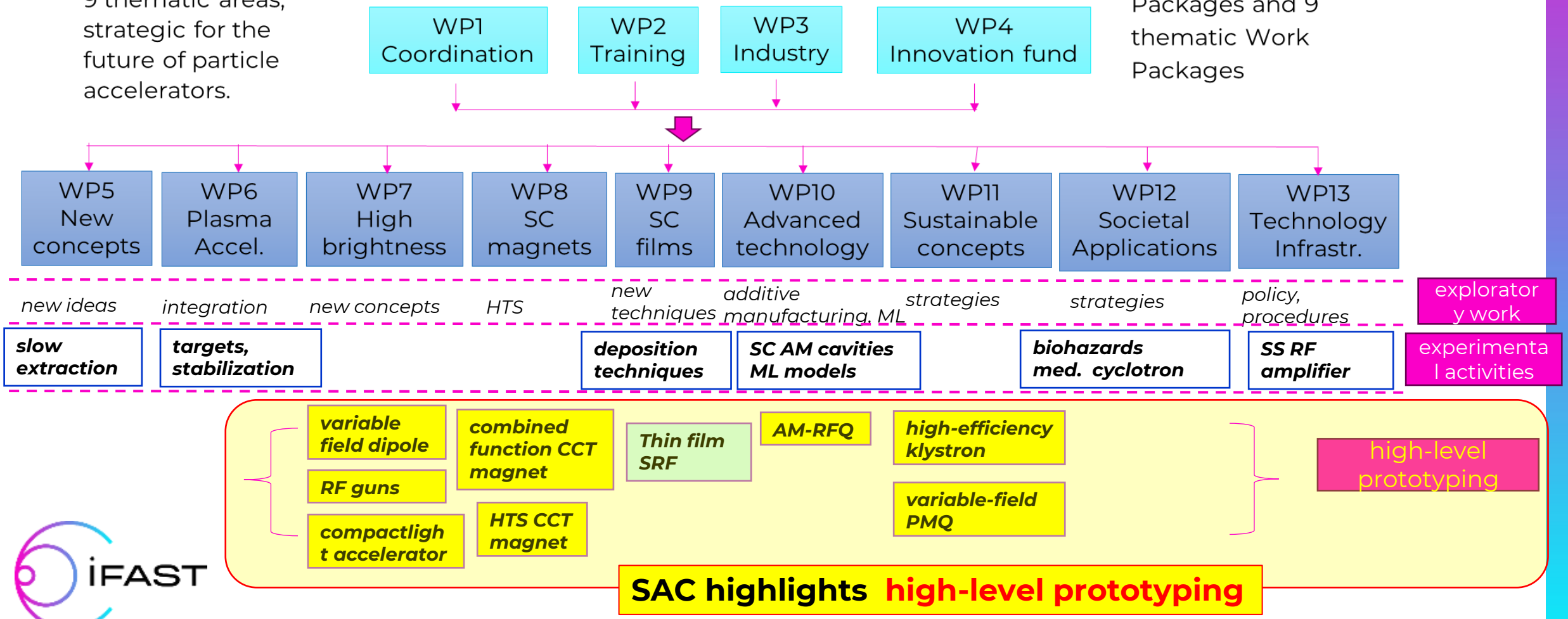
iFAST

The structure of I.FAST

Mixture between exploratory work and prototyping of deep-tech technologies to higher TRL

iFAST activities cover 9 thematic areas, strategic for the future of particle accelerators.

4 support Work Packages and 9 thematic Work Packages



From M. Vretenar, 251021

Some highlights along the main priorities

- 13 innovative prototypes realised with industry (some still ongoing - details in next presentation) - so far, all respecting specifications. Innovation Fund very successful.
- Important industry engagement, setting up of the Accelerator Industry Permanent Forum, final success of the industry exchange programme (5 exchanges, last 2 ongoing).
- Sustainability becoming key component of all our R&D activities.
- Outreach via 4 successful CBI events. Impact on society with accelerators for environment.

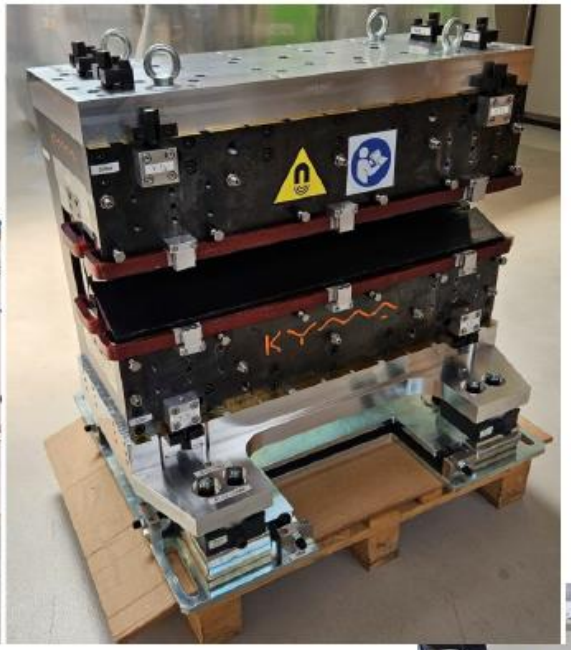
iFAST

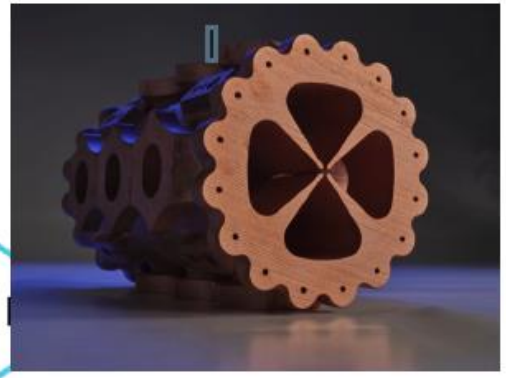
I.FAST Technical Work Packages and Tasks

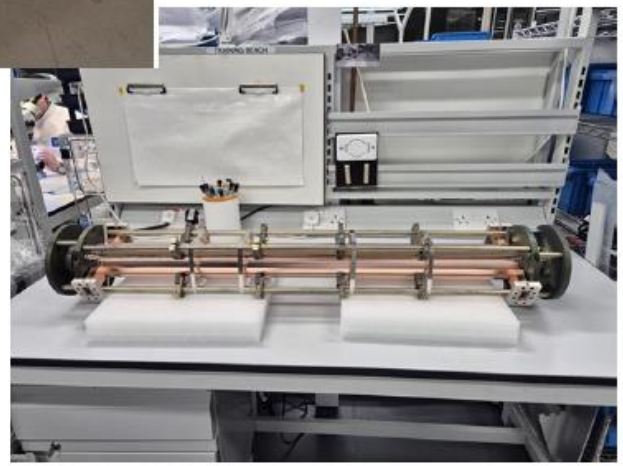
WP	PII	Theme	Task	Task reports given in the 5th meeting	Session
1	--	Management, coordination, and dissemination			
2	I	Training, communications and outreach for accelerator science and technology in Europe	2.1 2.2 2.3	Management Communication and outreach Challenge-based innovation (CBI) w/ .. accelerators	1-2 1-3 4-2
3	I	Industry engagement	3.1	Coordination and industrial partnership support	1-4
4	I. II	Managing innovation, new materials	4.? 4.3, -4	Managing innovation, new materials Innovative beam windows for high-power accelerator applications	3-2 4-5
5	I . II	Strategies & Milestones for Acc. Research & Technologies	5.1 5.2	MUon colliders STrategy network (MUST) Pushing Accelerator Frontiers (PAF)	2-1 2-2
6	I, II	Novel p. accelerator concepts and technologies	6.1 6.2	Novel Accelerators Concepts and Technologies LASers for PLasma Accelerators	1-4 1-5
7	I, II	High Brightness Accelerators for Light Sources	7.1 7.2 **7.3** 7.4 7.5	Coordination & communication Variable Dipole for upgrade of ELETTRA storage R. **Very high gradient RF Guns operating in the C-band RF technology** Compact Light Prototype Accelerating Structure	4.4 **3-3** (---) 4.1
8	I.II	Innovative superconducting	8.5 8.6	Construction of HTS CCT magnet demonstrator Development of ReBCO HTS nuclotron cable	2-3 2-3
9	I, II	Innovative superconducting thin film coated cavities	9.1	**Strategy for Innovative SC Acc/ Cavities**	2-4
10	I, II	Advanced Accelerator technologies	10.1 10.2	Coordination and communication **Additive manufactured RFQ prototype: results and perspectives**	2-5 3-4
11	II	Sustainable concepts and technologies	11.1 11.2 11.3	Sustainable Concepts for Acc. driven Res. Infrastructure **High Efficiency Klystron Industrial Prototype** **Permanent Magnet Quad. & CF Mag/ for UL -Emit. R.**	2-6 (---) 4-3
12	III	Social applications			
13	--	Technology infrastructure			
14	--	Ethics requirements			

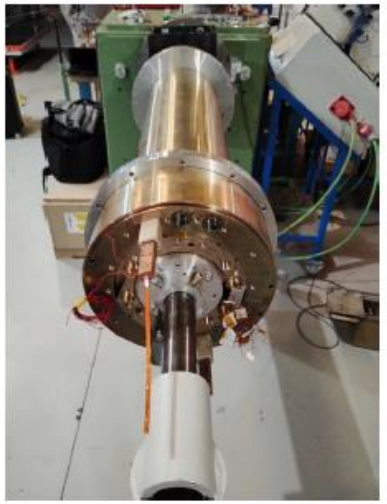
From M. Vretenar, 251021

I.FAST prototypes in pictures









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Highlighting High-level Prototyping

WP7: High Brightness Accelerators for Light Sources

- **Variable Dipole for upgrade of ELETTRA storage R.**
- **Very high gradient RF Guns operating in the C-band RF technology**
- **Compact Light Prototype Accelerating Structure**

WP8: Innovative superconducting

- **Construction of HTS CCT magnet demonstrator**
- **Development of ReBCO HTS nuclotron cable**

WP9: Innovative superconducting thin film coated cavities

- **Strategy for Innovative SC Acc/ Cavities**

WP10: Advanced Accelerator technologies

- **Additive manufactured RFQ prototype: results and perspectives**

WP11: Sustainable concepts and technologies

- **High Efficiency Klystron Industrial Prototype**
- **Permanent Magnet Quad. & CF Mag/ for Ultra-low Emittance Ring.**

How did SAC consider impact?

- **Scientific / technical:** new capabilities, methods and experimental results
- **Economic:** efficiency gains, cost or time savings
- **Societal:** broader benefits, sustainability or safety
- **Collaborative:** partnerships or interdisciplinary collaboration
- **Capabilities:** infrastructure, expertise or new institutional capability
- **Wider impact:** publications, patents, workforce development or innovative training initiatives

We looked also into “lessons learned” and the planned “next steps”

WP7: High Brightness Accelerators for Light Sources

7.3. Longitudinally Variable Dipole of, VADER, Elettra, storage Ring

Achievements:

- Industrial-prototype variable-field permanent-magnet dipole, enabling ultra-low-emittance rings w/o cryogenics.
- Delivered 2.3 T peak field with 10 - 23 T/m gradient; lattice simulations show ~2× emittance reduction
- Reached TRL 6; reusable magnet-design and measurement toolchain established.

Impact:

- Power-free design reduces lifetime energy and maintenance costs; manufacturable at scale (KYMA).

Future: Finalize magnet qualification, integrate into Elettra 2.0, extend concept to damping-ring and ULER applications.

WP7: High Brightness Accelerators for Light Sources

7.4. Very high gradient RF Guns operating in the C-band RF technology

Achievements:

- Established complete photocathode production/characterization chain for next-generation FEL and ERL injectors.
- Demonstrated robust multi-alkali and semiconductor cathodes with improved quantum efficiency and >100 h lifetime under UHV.
- Improved reliability and reduced replacement frequency, leading to lower downtime and cost, cathode-handling procedures transferable across labs.
- Reduced toxic-material handling and activated-cesium waste; supports safer, cleaner cathode operations.

Impact:

- Permanent photocathode test stands commissioned (CERN and INFN); trained new generation of injector physicists and surface scientists.

Future: Accelerate lifetime modelling, vacuum conditioning and industrial-grade sealed-cathodes for ERLs & XFELs.

WP8: Innovative Superconducting Magnets

8.5 Construction of Combined CCT Magnet Demonstrator based on LTS

Achievements:

- Developed machining, magnet winding and impregnation methods ensuring mechanical stability, build to tolerances.
- Constructed magnet with NbTi ropes + 1 copper strand.
- Completed low voltage electrical tests.
- Delivered magnet with 4T dipole and 5 T/m quadrupole.
- Demonstrated magnet and validation tests: ramped at 0.2 - 0.4 T/s.

Impact:

- Future application for compact and industrical SC magnets, such as medical beamline/applications.

Future: cryogenic qualification tests at Uppsala to validate design and demonstrate industrial scalability.

WP8: Innovative Superconducting Magnets

8.6 HTS CCT Magnet Demonstrator, and ReBCO HTS nuclotron cable

Achievements:

- Developed infrastructure and expertise with custom tooling, winding, and assembly processes.
- Constructed magnet with new layout using 2-tapes cable (980 A) with 20 HTS cables; completed HV tests up to 1 kV.
- Demonstrated ramp validation to 0.4 T/s with AC losses compatible with 20 K conduction cooling system.
- Delivered 4 T dipole for operation at 20 K (factor 5 higher power efficiency than at 4.5 K) .

Impact:

- Potential to transform the field of superconducting magnet for particle accelerators and for other societal applications.
- Established European Strategy Group to explore HTS magnets for accelerator, consolidated leadership in HTS magnet development; developed strong industrial partnerships with industry.

Future: cryogenic qualification tests at INFN-LASA

WP9: Thin-Film coated RF Cavities

9.1. Innovative Superconducting Accelerating Cavities

Achievements:

- Established Europe-wide partnerships / interdisciplinary collaborations.
- Collaborated closely with industry (with some external challenges which were successfully overcome).
- Developed new capabilities in Nb3Sn cavity coating (at INFN and UKRI); delivered first prototype of 1.3 GHz.
- Advanced surface engineering technologies (ALD and PVD deposition facilities).
- Developed new laser treatment facility and documented the “lessons learned”.

Impact:

- Sustainability for particle accelerators, lower construction (higher E) and operation cost (higher temp. and higher Q).

Future: RF testing of Nb3Sn coated cavity (STFC, CEA, H2B), coating of Cu cavities, tests of multilayer coatings and other SC materials, RF test of 1.3 GHz Nb-coated cavity irradiated by laser.

WP10: Advance Accelerator Technologies

10.2. Additive manufactured RFQ prototype: results and perspectives

Achievements:

- First LPBF-Cu RFQ module (with one-step printing), vacuum-tight to 10^{-10} mbar·L·s^{-1}.
- High-field tests up to 31 MV/m; path toward 40 MV/m target.
- Validated the EM design; frequency shift understood & corrective plan in place.
- Strong industry link through Rösler and training on advanced manufacturing finishing
- Demonstrated feasibility in principle of joint-free RF structures, although significant challenges remain.
- Developed post-processing treatment for inaccessible vane tips, reduced surface roughness from ~10 to ~ 1.7 microns.

Impact:

- Enables compact, faster and potentially cheaper accelerator builds
- Significant design freedom for integrated cooling/tuning features

Future: Results fed into EPITA plans: demonstrate > 85% of nominal Q-value at nominal design power, beam-validated advanced manufacture RFQ and IH-DTL.

WP11: Sustainable concepts and technologies

11.2. High Efficiency Klystron Industrial Prototype

Achievements::

- 400 MHz High Efficiency Klystron prototype demonstrated
- It was already reported in the 4th annual meeting.

Impact:

- The most critical impact for any future accelerator programs, and significant contribution to the sustainability.

Future: To be extended in EPITA.

WP11: Sustainable concepts and technologies

11.3. Permanent Magnet Quad. & CF Mag/ for Ultra Low Emittance Ring

Achievements:

- Constructed combined function mright agnets with NdFeB permanent magnet blocks, with 0.6 T dipole field and 30 T/m gradient (Q).
- Developed ‘ice cube’ tray non-magnetic folder blocks and robust mechanical structure design.

Impact:

- Extreme sustainability and operational cost saving

Future: Prototype to be tested with beam. Modular production and further engineering.

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Summary (1/2)

- **The SAC congratulates excellent progress** demonstrated by the I.FAST program during the period 2021-2025.

- **SAC would like to highlight** in particular the efficient project management and coordination of this very large and diverse consortium.

- **The (near-full) completion of all WPs** with 53 challenging deliverables is a major success, in particular in view of the significant challenges faced, including COVID, the war in Ukraine, and the global materials / cost crisis.

Summary (2/2)

- **I.FAST has successfully achieved** its goals across the three pillars underpinning the development of future accelerators: open innovation, innovation ecosystem and improved sustainability.
- **The project has successfully transitioned** novel accelerator technology to applied science and society, and stimulated industrial engagement (Industry Advisory Board, IAB), several successful workshops connected with I.FAST Annual Meetings and establishing the Accelerator science and technology Industry Permanent Forum (AIPF).
- **High-level prototypes were realized** in several work packages, boosting existing accelerator technologies and future particle accelerator R&D programs.

The SAC welcomes the transfer and extensions of the most successful activities to the proposed Enabling Partnerships for Innovation & accelerator Technology Advancement project, EPITA.

Acknowledgements

SAC would like to thank I.FAST team and all presenters for their very ***clear, focused and informative talks****.*

SAC appreciates I.FAST team accepting SAC's feedback and reflecting it to the succeeding activities.

Special thanks go to Maurizo, Valerie, and the Local Organizers & Supports for this final I.FAST meeting successfully organized.

Backup

Agenda:

Courtesy: V. Brunner

	START	END	DURATION	TITLE	SPEAKER	
TUESDAY 21/10/2025						
	IFAST Meeting - Session 1 - Introduction, Communication, Training, Industry					
	14:00	14:20	0:20	Introduction by the Project Coordinator	M. Vretenar (CERN)	
	14:20	14:30	0:10	Training initiatives: outcome and perspectives	P. Burrows (UOXF)	WP2
	14:30	14:45	0:15	The I.FAST impact on Accelerator Communication and Outreach	Ph. Burrows for Thoms Brent	WP2
	14:45	15:05	0:20	Industry collaboration: the I.FAST legacy	M. Morandin (INFN)	WP3
	15:05	15:20	0:15	Novel particle accelerators: progress in the last 4 years	R. Pompili (INFN) for M. Ferrario	WP6
	15:20	15:35	0:15	Lasers for Plasma Accelerators - outcomes and results	L. Gizzi (CNR)	WP6
	15:35	16:05	0:30	Coffee Break		
	IFAST Meeting - Session 2					
	16:05	16:20	0:15	Progress of the International Muon Collider Collaboration	N. Pastrone (INFN)	WP5
	16:20	16:35	0:15	Progress at the accelerator frontier	G. Franchetti (GSI)	WP5
	16:35	16:55	0:20	The I.FAST superconduting magnet prototypes	E. De Matteis (INFN)	WP8
	16:55	17:15	0:20	Superconducting thin films: impact and legacy of I.FAST	O. Malyshev/C. Antoine	WP9
	17:15	17:35	0:20	Additive manufacturing in the accelerator community: where are we	A. Ratkus (RTU)	WP10
	17:35	17:50	0:15	Progress on sustainability	D. Volker (DESY)	WP11
	20:00	23:00	3:00	*Dinner (Café Papon, Rue Henri-Fazy 1, 1204 Genève)*		
WEDNESDAY 22/10/2025						

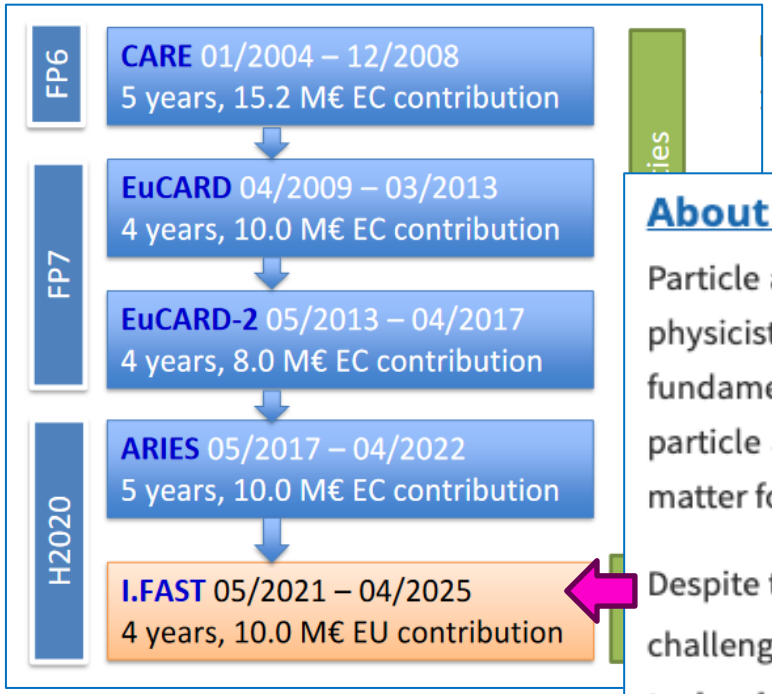
Agenda:

Courtesy: V. Brunner

	IFAST Meeting - Session 3					
	9:00	9:30	0:30	European Strategy: large collider proposals	Ph. Burrow (UOXF)	
	9:30	9:50	0:20	Outlook of the Innovation Fund projects	L. Garolfi (TERA)	WP4
	9:50	10:10	0:20	Final results of the Longitudinally Variable Dipole	F. Toral	WP7
	10:10	10:30	0:20	The Additive manufactured RFQ prototype: results and perspectives	T. Romano (Polimi/RTU)	WP10
	10:30	11:00	0:30	Coffee Break		
	IFAST Meeting - Session 4					
	11:00	11:20	0:20	Results and experience with the CompactLight Prototype structures	G. Dauria (Elettra)	WP7
	11:20	11:30	0:10	The CBI legacy	N. Delerue	WP2
	11:30	11:50	0:20	The HEPTO prototype: final results and outlook	B. Shepherd (STFC)	WP11
	11:50	12:10	0:20	Ongoing upgrades and outlook on ultra-low emittance rings	R. Bartolini (DESY)	WP7
	12:10	12:30	0:20	The I.FAST progress in beam windows and materials	M. Tomut, F. Carra	WP4
	12:30	14:00	1:30	Lunch Break		
	IFAST Meeting - Closing Session					
	14:00	14:30	0:30	CERN Programmes	O. Brüning (CERN)	
	14:30	14:50	0:20	The EPITA proposal, a new instrument for the accelerator community	T. Torims, CERN	OK
	14:50	15:10	0:20	Outlook on future EC calls	M. Vretenar / J.M. Perez	
	15:10	15:25	0:15	I.FAST Financial outlook	C. Levointurier-Vajda	
	15:25	15:45	0:20	Presentation by the SAC: impact of I.FAST on accelerator technologies		
	15:45	16:00	0:15	Concluding remarks	M. Vretenar	
	16:00			*Adjourn*		

Courtesy: M. Vretenar

I.FAST Aiming at:



About the project

Particle accelerators deliver huge amounts of energy into tiny volumes of matter at subatomic scale, allowing particle physicists to penetrate into the heart of matter. The byproducts of these activities have a wealth of applications from fundamental science to applied science, medicine and industry. Differing in specifications, dimensions, and cost, particle accelerators share the same basic principles and technology and the same ambition: to unveil the secrets of matter for the benefit of humankind.

Despite their wide range of applications and high level of maturity and success, particle accelerators face a potentially challenging transition into the future. Innovation is needed to identify and **develop new sustainable accelerator technologies** capable of reaching the performance required by particle physicists at an acceptable impact on society; and to favor the **transfer of key technologies**, developed over the last decades, to particle accelerators used for applied science (photon and neutron sources) and for societal applications (medicine, industry, environment).

I.FAST aims to allow Europe to maintain leadership in fundamental particle physics and other fields of science based on particle accelerators, providing European industry with a portfolio of advanced accelerator technologies, thus contributing to the construction and upgrade of the next generation of accelerator-based Research Infrastructures, the creation of jobs, and ultimately long-term growth.

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Courtesy: V. Brunner

WP6	Novel Particle Accelerators Concepts and Technologies	M. Ferrario (INFN)	Task 6.1	Novel Particle Accelerators Concepts and Technologies	M. Ferrario (INFN)	
			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 (DESY), …	Task 7.1	Coordination & communication	R. Bartolini (DESY)	
			Task 7.2	Enabling Technologies for Ultra-Low Emittance Ring	R. Bartolini (DESY)	
			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	E. De Matteis (INFN), L. Quettier (CEA), C. Roux (GSI)	Task 8.1	Coordination and HTS Strategy Group	E. De Matteis (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	S. Sorti (INFN)	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)	M. Gehring (BNG)
			Task 8.6	Development of ReBCO HTS nuclotron cable	T. Winkler (GSI)	C. 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	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)	A.Ratkus (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	A.Ratkus (RTU)	
			Task 10.4	Development of AM-manufactured superconductive RF cavities	A. Pepato (INFN)	
			Task 10.5	Photon Stimulated Desorption (PSD) from NEG coatings for accelerator vacuum cham	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	N. Catalan (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)	A. Sagatova (STU)
			Task 12.2	Design of advanced electron accelerator plant for biohazards treatment	A. Chmielewski (INCT)	
			Task 12.3	Design of Internal Rf Ion Source for Cyclotrons	J. M. Perez (CIEMAT)	
WP13	Technology Infrastructure	S. Leray (CEA)	Task 13.1	Strategy for the development of the AMICI TI	S. Leray (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)	

From M. Vretenar, 251021

The 13 I.FAST high-level prototypes

N.	WP	Prototype	Status
1	7	Longitudinally variable dipole	D7.3 – *missing accept.*
2	7	Two high-gradient C-band RF guns	D7.4 - *completed*
3	7	CompactLight structure prototype 1	D7.5 – *missing meas.*
4	7	CompactLight structure prototype 2	D7.6 – *missing meas.*
5	8	Combined CCT magnet demonstrator	D8.4 – *completed?*
6	8	HTS CCT magnet demonstrator	D8.5 – *missing meas.*
7	9	Coated cavity	D9.3 – *completed*
8	9	Multilayer coated cavities	D9.4 - *completed*
9	10	RFQ prototype	*completed*
10	11	Klystron prototype	D11.2 - *completed*
11	11	Adjustable PM quadrupole	D11.3 - *completed*
12	12	Internal RF source for cyclotrons	D12.3 – *completed*
13	13	GaN amplifier module	D13.3 - *completed*

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From M. Vretenar, 251021

SAC Observations and recommended actions

SAC Message	Action
Expand communication output (publication quotas, communication liaisons in WPs, communication trainings for WPs). Secure CBI sustainability (alumni, spin-off funding). Broaden communication audiences. (schools, policy makers).	Lack of time and resources to implement in last 6 months of I.FAST. Message passed to EPITA that plans to hire a full-time person for communication and outreach.
Provide new concepts legacy catalogue (summary, maturity, use, next steps).	Resources were limited to Workshops, but message transferred to T5.2.
Continue in next project high-field HTS magnets, SC RF with A15 (Nb3SN and other), AM technology, advanced acceleration technologies, …	Message taken, see presentation on EPITA proposal.
Publish sustainability assessment approach as a reusable I.FAST framework, promoted across RIs.	Will be part of EPITA
For major hardware outcomes, provide TRL status update, intended use case, estimated maturity. Cross-WP “lessons learned” report on best practices.	Message passed to speakers for this meeting, lessons learned will be compiled.
At final meeting, showcase project outcomes (demos, roadmaps, partner matchmaking).	Message passed.
Consistent use of terminology and metrics.	To be implemented (via TIARA?)
Knowledge valorisation, start-up support in I.FAST2	See EPITA presentation