



ARIES Final Review

Project structure, goals and achievements

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Maurizio Vretenar, CERN, Project Coordinator

ARIES in a nutshell

Accelerator Research and Innovation for European Science and Society

Total cost **24 M€**;
EC contribution
10 M€
4 year duration
extended to **5**
(2017 – 22)

Integrating Activity
for collaborative R&D
on **particle**
accelerators

18 WP's
45 partners
18 EU
countries



2017: ARIES kick-off meeting at the CERN Globe of Innovation

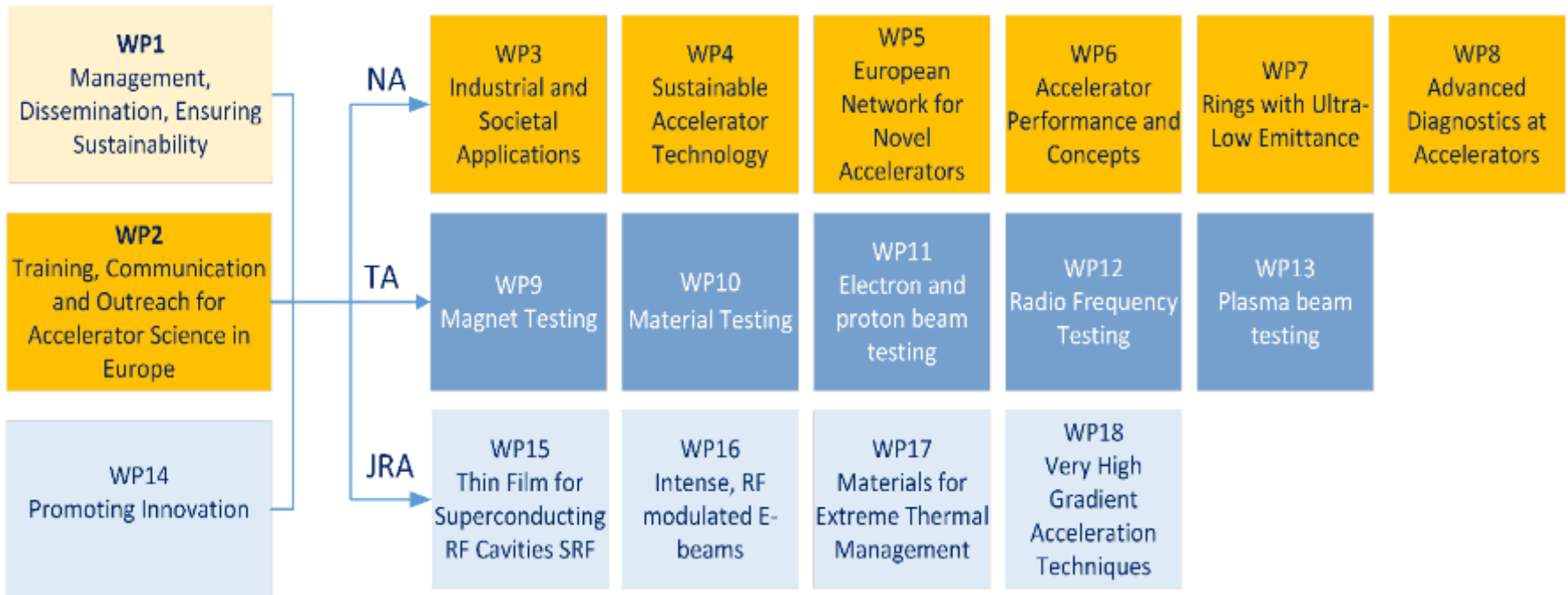


More than 400 people (**454** in our lists!) working together for the progress of **accelerator science and technology**

Structure, goals, processes



ARIES Structure and Themes



18 Work Packages (WP's):

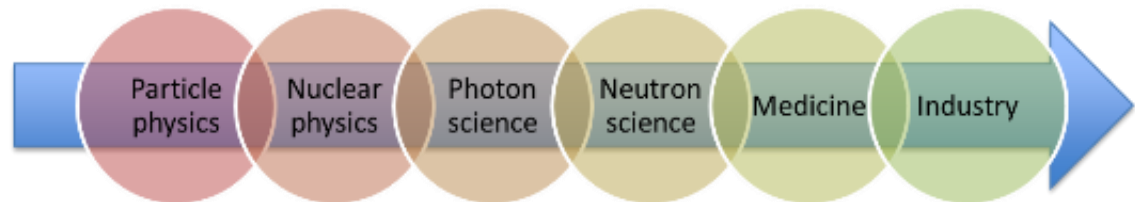
- 5 Network WP's on strategic themes: applications, sustainability, new concepts, extreme designs and performance, instrumentation.
- 5 Transnational Access WP's providing access to test facilities to validate new concepts.
- 5 Joint Research Activity WP's for experimental validation of selected technologies.
- 3 transverse WP's for management, training & communication, innovation.

The ARIES topics

The ARIES work programme is designed to include strategic accelerator developments that are:

- ✓ not covered by ongoing national – laboratory projects
- ✓ with added value from **collaboration**
- ✓ focused at the **long-term future** of the field
- ✓ common to **different accelerator platforms**
- ✓ **high-risk high-gain** activities

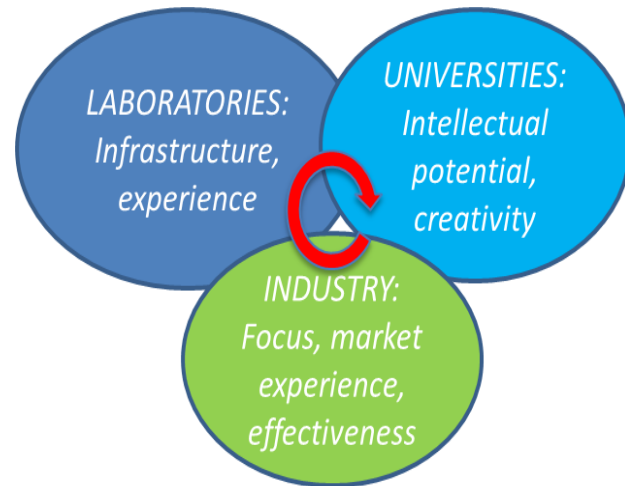
The topics were selected by an internal committee managed by the TIARA (Test Infrastructure and Accelerator Research Area) Collaboration, where the main actors of European accelerator R&D are represented.



ARIES aims at the common development of accelerator technologies serving **different user communities**: particle physics, synchrotron light sources, nuclear physics, neutron sources, medical and industrial applications.

The ARIES community

- 42 partners from 18 European countries
- Goals: connect the **technological core of Europe** with its **dynamic periphery**, connect the **large laboratories** with **universities, research centers and industries**.
- 12 Laboratories and research institutions, 21 Universities and research centres, 8 industries.



80% of EU Research Infrastructure
is based in only 4 countries

The ARIES Objectives (from Annex I)

1. **Develop novel concepts and technologies** to improve the performance of the present generation, and to increase the performance, affordability, reliability, sustainability, and broader application of next-generation accelerators.
2. Provide European researchers and industry with **access to top-class accelerator research infrastructures** needed for the development of new technologies.
3. Enlarge and advance the **integration of the European particle accelerator community** through new geographical and interdisciplinary connections between the operators of accelerator infrastructures, universities and industries.
4. Enhance **innovation** in the accelerator community by involving industry in the setting up of **co-innovation programmes** and in the selection and promotion of innovative technologies, and by supporting the societal applications of accelerators.
5. Ensure the **long-term sustainability** of particle accelerator research by defining scenarios and **strategic roadmaps** for the future integration of accelerator facilities and by setting a framework for the scientific and technical **training of young European researchers**, which is vital for the development of new ideas.

The four ARIES pillars



excellence

Develop **key accelerator technologies** to make more performant, affordable, reliable and sustainable the present and future accelerators

Improve the European **accelerator infrastructure**



access

New scheme of Transnational Access opening **14 accelerator test facilities**

Enlarged consortium with **20 new partners** in accelerator projects and **6 new countries** in the East and South of Europe



innovation

Enhanced **industrial participation** (7 industries and 1 association)

3 new **co-innovation programmes** with industry

Development of **societal applications** (medicine, industry, environment)

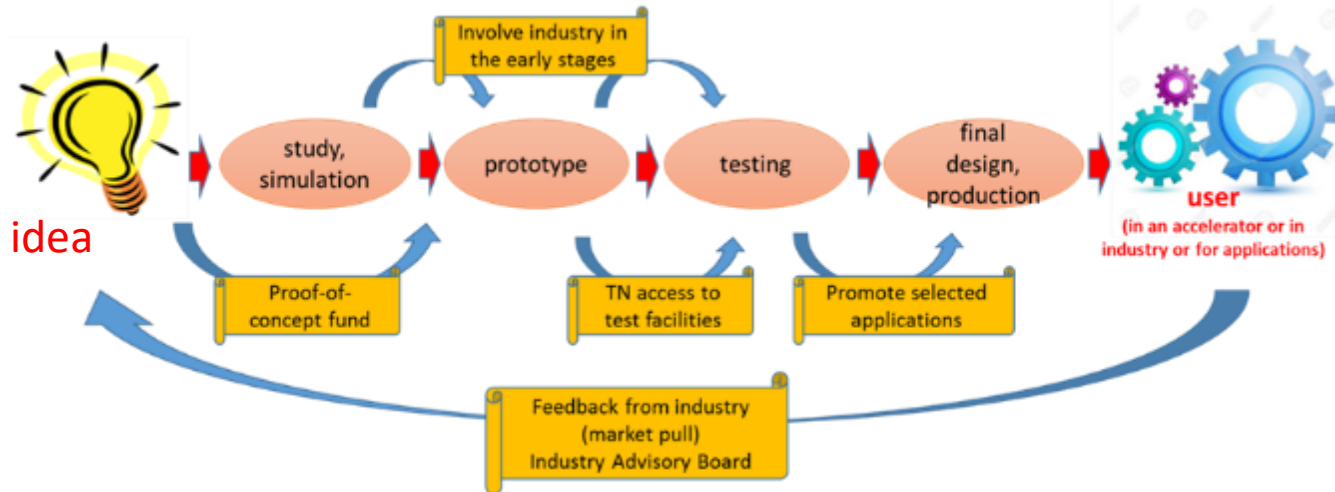


sustainability

Joint programme with TIARA to develop a **model for sustainable accelerator science** in Europe

Training programme for the new generations of accelerator scientists and engineers

Innovation Strategy



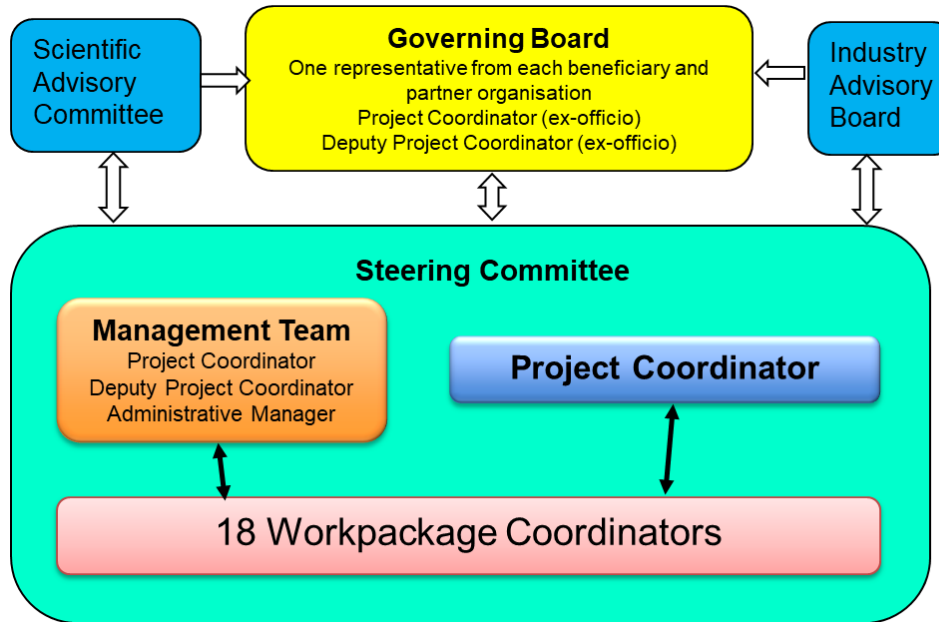
Support to all stages of the innovation process:

- **Proof-of-concept innovation fund:** for Business Plan preparation, market assessment, demonstration in connection with industry of the technological viability of new ideas.
- **Industrial Advisory Board:** provide business consultation (eg. business plans) and support market assessments (“market pull”).
- **ARIES meets industry events**
- **3 co-innovation programmes with industry:**
 - breakthrough in the cost per kAm of industrial High Temperature Superconductors
 - production of materials for extreme thermal management
 - production of a standardized timing for medical and industrial applications.

ARIES Management

SAC members
Akira Yamamoto (KEK)
T. Raubenheimer (SLAC)

→ M. Vretenar
Project Coordinator
→ S. Stavrev
Admin. manager
→ V. Brunner
Project Assistant



IAB members	
SigmaPhi	J.L. Lancelot
Elytt	J. Lucas
Elekta	J. Allen
GE	T. Eriksson

6 Annual Meetings:

- 2017 kick-off, CERN, 140 participants
- 2018 Riga (LV), 114 participants
- 2019 Budapest (HU), 155 participants
- 2020 on-line, 150 participants
- 2021 on-line, 200 participants
- 2022 CERN, 129 participants

All meetings accessible on <https://indico.cern.ch/category/8746/>
(247 events!)

ARIES Bulletin (3 times/year) and regular communication to keep together a very diverse community!

18 Steering Committee meetings
22 Industrial meetings



ARIES WP Coordinators and Tasks

WP	Type	Name	Acronym	Coordinator	Tasks
1	MGT	Management, dissemination, ensuring sustainability	MADISU	M. Vretenar (CERN)	Management - Internal communication, dissemination, scientific publications and monographs - sustainability of particle accelerator research in Europe
2	NA	Training, Communication and Outreach for Accelerator Science in Europe	TCO	P. Burrows (UOXF)	communications/outreach activities - training activities - e-learning course
3	NA	Industrial and societal applications	ISA	R. Edgecock (HUD)	Electron beam applications, technology - Electron beam new applications - medium energy electron beams - Radioisotope
4	NA	Efficient energy management	EEM	M. Seidel (PSI)	High Efficiency RF Power Sources - efficiency of the target station - SRF power conversion - operation of pulsed magnets
5	NA	European Network for Novel Accelerators	EuroNNAC	R. Assmann (DESY)	European Strategy Plasma acc. - Dielectric laser acc. - EAAC workshop - Young scientist networking
6	NA	Accelerator Performance and Concepts	APEC	F. Zimmermann (CERN)	Beam Quality Control in Hadron Storage Rings - Reliability and availability - Improved beam stabilisation - Beam quality control in linacs - far future concepts
7	NA	Rings with ultra-low emittance	RULE	R. Bartolini (UOXF)	Injection systems - beam dynamics and technology - beam test and commissioning
8	NA	Advanced Diagnostics at Accelerators	ADA	P. Forck (GSI)	Advanced Instrumentation for hadron LINACs - Hadron Synchrotrons - 3rd Generation Light Sources - FELs
9	TA	Magnet testing		M. Bajko (CERN)	SM18 (CERN) - FREIA (UU)
10	TA	Material testing		N. Charitonidis (CERN)	HiRadMat (CERN) - UNILAC, M-Branch (GSI)
11	TA	Electron and proton beam testing		R. Ruprecht (KIT)	ANKA (KIT), VELA (STFC), IPHI (CEA), SINBAD (DESY), FLUTE (KIT)
12	TA	Radio Frequency testing		R. Ruber (UU)	FREIA (UU), XBOX (CERN)
13	TA	Plasma beam testing		B. Cros (CNRS)	Apollon (CNRS), LIDyL (CNRS), LULAL (LUND)
14	JRA	Promoting innovation	PI	M. Losasso (CERN)	Proof of Concept innovation fund - Collaboration with Industry - Resistant materials - HTS magnet technologies - Timing system in a box
15	JRA	Thin Film for Superconducting RF Cavities	TF-SRF	O. Malyshev (STFC)	Surface preparation - Deposition and analysis - Superconductivity evaluation
16	JRA	Intense, RF modulated e-beams	IRME	D. Ondreka (GSI)	Electron gun - power modulator - beam dynamics and engineering - Dynamics studies and machine experiments
17	JRA	Materials for extreme thermal management	PowerMat	A. Bertarelli (CERN), M. Tomut (GSI)	Materials development and characterization - Dynamic testing and online monitoring - Simulation of irradiation effects and mitigation method - Broader accelerator and societal application
18	JRA	Very High Gradient Acceleration Techniques	VHGAT	A. Specka (CNRS)	Multistage LWFA - LWFA with exotic laser beams - Laser driven dielectric accelerators - Pushing back the charge frontier

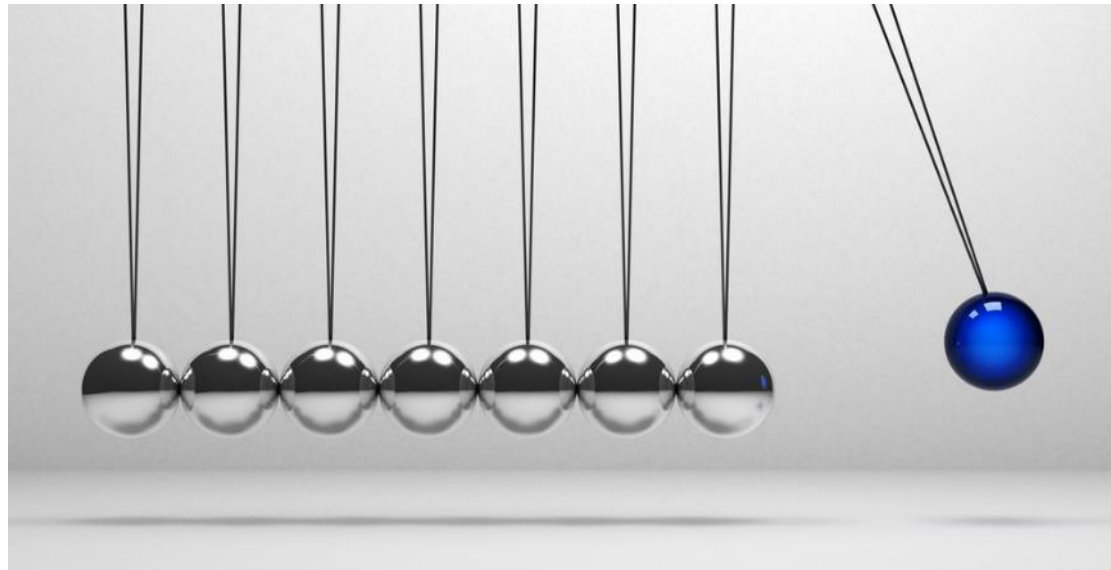
19 high-profile
Work Package
Coordinators
from 6 countries
16% female.

ARIES and COVID-19

ARIES was fully hit by the Covid crisis during its **critical 3rd year** (February 2020 = M33). Consequences and solutions:

- The Networks were encouraged to move immediately **all events on-line**. Unfortunately the dimension of “**networking**” was lost with all its direct contacts, but the result was an **increase in workshop attendance**, in particular from outside Europe. New formats were explored (e.g. workshops spread over many days). In general, Networks could keep their schedule.
- **User access** to TA facilities was almost impossible for a long time. **Virtual access** was encouraged but turned out to be possible only for few facilities. An **extension** by one year allowed to partially compensate for the delays.
- Some JRA’s were delayed because of difficult **access to laboratories and experimental facilities**. Some **extensions** (up to 8 months) were agreed to partially compensate for the delays.
- The ARIES Management has encouraged the WP’s, in particular Networks, to use the **unspent travel budget to support young students and post-docs** who could contribute to improving the quality of the project deliverables. This partly explains the higher ration personnel/material expenditures with respect to Annex I.

Outcomes and Impact



ARIES in numbers – workshops, publications, deliverables, milestones

WP	Type		Organised Workshops	Publications				Deliverables		Milestones	
				P1	P2	P3	Total	number	pages	number	pages
1	NA	Management		0	0	1	1	1	22	9	85
2	NA	Training, Communication	3	1	0	1	2	3	111	3	42
3	NA	Societals Applications	1	2	2	0	4	4	126	4	95
4	NA	Energy Efficiency	6	0	0	3	3	4	164	5	49
5	NA	Novel Accelerators	2	2	1	1	4	2	31	4	44
6	NA	Performance, Concepts	27	24	21	14	59	5	163	7	200
7	NA	Ultra-low emittance rings	7	1	0	0	1	4	93	6	36
8	NA	Advanced Diagnostics	11	1	2	2	5	4	227	3	30
9	TA	Magnet Testing		0	0	0	0	1			
10	TA	Material Testing		11	8	6	25	1			
11	TA	Beam Testing		0	3	2	5	1			
12	TA	RF Testing		1	5	5	11	1			
13	TA	Plasma beam Testing		0	1	2	3	1			
14	JRA	Innovation	5	0	1	1	2	5	73	7	152
15	JRA	Thin films for SRF		0	9	12	21	4	195	4	44
16	JRA	Modulated e-gun		0	1	4	5	3	61	5	83
17	JRA	Power Materials	4	4	6	7	17	3	157	5	113
18	JRA	Very high gradient tech.		3	2	1	6	5	130	4	36
		TOTALS	66	50	62	62	174	52	1,553	66	1,009

ARIES has produced some 3,000 pages of reports!

Deliverable D16.3

We have 1,553 pages of Deliverables, but one page is still missing!

- **WP16** (design and prototyping of a modulated electron gun for **electron lenses** – focusing and deflection of a proton beam using an intense electron beam) was one of the most impacted by Covid. The laboratories were closed for a long time, and limitations to travel forced to build the test stand at Frankfurt University instead of CERN.
- After many technical problems and delays, the **prototype e-gun** was installed on the test stand and fully characterised in early 2022.
- Beam tests were foreseen in May 2022. Unfortunately, it turned out that impurities of the cooling water led to an uneven water flow that caused **overheating of the insulators** of the gun and forced to suspend the tests. After reviewing the gun, adding flow control and temperature sensors, the **conditioning** of the gun restarted in June 2022.
- After conditioning, beam tests are expected to start **after summer**.
- The **deliverable D16.3** describes the preparation for the tests, but the final beam results are not present. All is ready for beam extraction and beam measurements will come in a couple of months.

ARIES in numbers – Transnational Access

WP	Facility	Projects					Users					Access Units				
		P1	P2	P3	Total	Total Annex 1	P1	P2	P3	Total	Total Annex 1	P1	P2	P3	Total	Total Annex 1
9	MagNet	4	0	2	6	4	22	3	12	37	30	944	200	788	1'932	1300
	Gersemi	0	0	1	1	3	0	0	4	4	15	0	0	0	0	1,800
10	HiRadMat	6	1	5	12	7	29	0	12	41	39	1,328	328	770	2,426	664
	UNILAC	2	2	0	4	6	21	12	0	33	50	104	408	432	944	768
11	ANKA	3	2	2	7	7	6	8	13	27	22	180	1,688	778	2,646	900
	FLUTE	2	0	0	2	3	9	0	0	9	11	56	80	320	456	308
	IPHI	1	1	0	2	1	8	5	0	13	8	72	0	0	72	72
	SINBAD	0	0	2	2	3	0	0	5	5	12	0	0	242	242	210
	VELA	1	1	2	4	5	0	11	5	16	25	0	80	104	184	288
12	HNOSS	2	2	0	4	4	18	24	7	49	44	1,330	2,084	1,080	4,494	3,790
	XBox	2	2	0	4	4	13	11	6	30	24	1,680	2,500	6,521	10,701	7,500
13	APOLLON	0	0	1	1	1	0	0	5	5	3	0	0	30	30	0
	LPA-UHI100	1	1	0	2	3	5	6	0	11	16	152	176	0	328	488
	LULAL	1	2	1	4	5	0	20	10	30	30	0	517	271	788	768
		25	14	16	55	56	131	100	79	310	329	5,846	8,061	11,336	25,243	18,856
					-0.018					-0.058						1.339

ARIES has provided 329 individual users from 56 projects with >25,000 hours of access to advanced accelerator test facilities

Some comments on Transnational Access

- The ARIES TA included some of the **most advanced European facilities** for testing new accelerator techniques and devices: out of the 14 facilities, **6 were still in construction** when the proposal was submitted, and **3 others aimed at hosting users for the first time**.
- The start of ARIES TA was very **slow for most of the facilities**: technical problems slowed down the start-up of the new facilities, and attracting users to the new facilities required some effort and time. Covid-19 did not help.
- In these conditions, the Coordinator encouraged the successful facilities **to exceed their target of access units**, to compensate for possible lack of access on other facilities.
- Eventually, **in P3 all facilities except one started operation**, and only 2 (3) stayed below their target. The result is that globally ARIES has exceeded its target in access units by **34%** (25'243/18'856). Projects and Users are however slightly below target (by **2%** and **6%**).

Impact and main achievements – Networks

1. Two WP6 Workshops have relaunched after many years the study in Europe of the **Muon Collider**, a possible alternative to high-energy colliders with higher efficiency and lower environmental impact. In 2020, muon collider studies have received the support of the *European Strategy for Particle Physics* (ESPP) upgrade.
2. WP5 has actively promoted **plasma and laser based acceleration**, contributing to the integration of the *EuPRAXIA plasma-based FEL in the ESFRI Roadmap*, and to the *support of the ESPP upgrade*.
3. New applications to society have been identified and supported by WP3, in particular for the **environment** (**ship exhaust cleaning, fertilisers from sewage sludge, treatment of ballast water**, etc.). These techniques will be now pursued by specially formed collaborations applying to funding agencies.
4. The WP6 Workshops have paved the way for several new perspectives for accelerators (detection of **gravitational waves, gamma factory, crystals and nanostructures**, etc.).
5. WP5 has explored new techniques to **reduce energy consumption** in accelerators, e.g. with more **efficient pulsed beam transport systems**.

Impact and main achievements – JRA's

1. **High Temperature Superconductivity** magnet studies have continued in Europe over the last 5 years only thanks to ARIES, and are now *part of the ESPP Upgrade programme*. ARIES has defined the industrial process to produce thin high-temperature superconducting tapes.
2. The **Proof-of-Concept Innovation Fund** has defined a fast and efficient scheme for support of innovative projects with industry participation, now *adopted on a larger scale by I.FAST*. Main outcome is the prototype testing of *ship exhausts cleaning with electron beams*.
3. A major step in the **practical implementation of electron lenses** to *focus and collimate intense particle beams* has been made with development and prototyping of the critical **modulated electron gun**. Two test stands will remain available after ARIES.
4. A new generation of **copper-diamond composites**, to be used for the LHC upgrade, and of new **chromium carbide – graphite composites**, to be further developed in I.FAST, has been developed to allow *managing the huge beam powers of future collider projects*.
5. New techniques for **coating and polishing of superconducting thin films** have been developed with the goal of *reducing cost and increasing efficiency of accelerating systems*. Will be tested on full prototypes in I.FAST.

Impact and main achievements – TA's and other

1. The ARIES **MOOC ((Massive Open Online Course))** for master-level students has been completed and made available on a dedicated platform: <http://mooc.particle-accelerators.eu/>.
2. The ARIES **strategy for co-innovation with industry** in the early stage of particle accelerator R&D has been the foundation for preparing the new Innovation Pilot project I.FAST (Innovation Fostering in Accelerator Science and Technology), which includes 1/3 of industrial partners.
3. The ARIES **Transnational Access** has opened to users 9 new facilities across Europe and will be continued and strengthened in the new EURO-LABS project recently approved (14 facilities, 6 from ARIES).
4. ARIES has prepared a solid study on **future directions for a sustainable accelerator science in Europe** (D1.1) that is the basis for the ongoing discussions between the accelerator community and the European Commission.

Global scientific impact: ARIES and the ESPP

The conclusions of the **2020 update of the European Strategy for Particle Physics** fully incorporate the strategic objectives of ARIES, and build many of their accelerator R&D recommendations on the results of ARIES:

- **Strengthen the European ecosystem of research centres:** *one of the main goals of ARIES.*
- **Launch a vigorous R&D on innovative accelerator technologies:** *was the main goal of ARIES, and continues now in I.FAST (HTS magnets, muon colliders, plasma acceleration)*
- **Develop synergies with neighbouring fields:** *ARIES has launched a strong synergetic effort with synchrotron light sources, neutron sources, and industrial/societal applications.*
- **Mitigate environmental impact of particle physics:** *one of the key themes of ARIES.*
- **Knowledge and technology transfer, training of next generation, education and communication:** *key topics in ARIES.*



Out of the 20 ESPP statements, as many as 10 were already part of the ARIES programme!

The end

ARIES has been a **formidable scientific and human adventure** that, beyond its immediate achievements, has contributed to shaping the priorities of accelerator science research and innovation in this XXIst century.

All this has been possible only thanks to qualities of the **people** behind it:

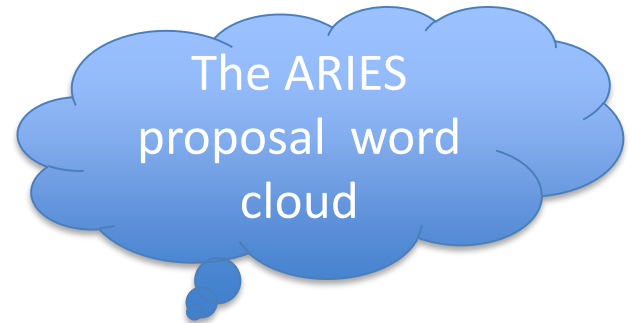
- ❖ the engagement and motivation of the ARIES community: WP Coordinators, Task Leaders, participants;
- ❖ the reactivity and competence of our project management team: Valérie and the CERN EU office (Svet, Livia, Sabrina);
- ❖ The constant help and support of the RI Unit of European Commission DG/RTD and now of the REA Agency.



Thank You!



Thank you for your attention



Did we succeed in transforming all our ambitions (“will”) into reality (“has”)?