This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

From EuCARD-2 to ARIES

TIARA Meeting, Warsaw, 19 June 2017

Maurizio Vretenar, Coordinator

Bye Bye EuCARD-2

- Last Annual Meeting in Glasgow, March 2017
- Special session on Final Reporting
- Governing Board did not agree on reallocation of unused budget to ARIES – will be redistributed to EuCARD-2 partners that have invested more resources than foreseen.

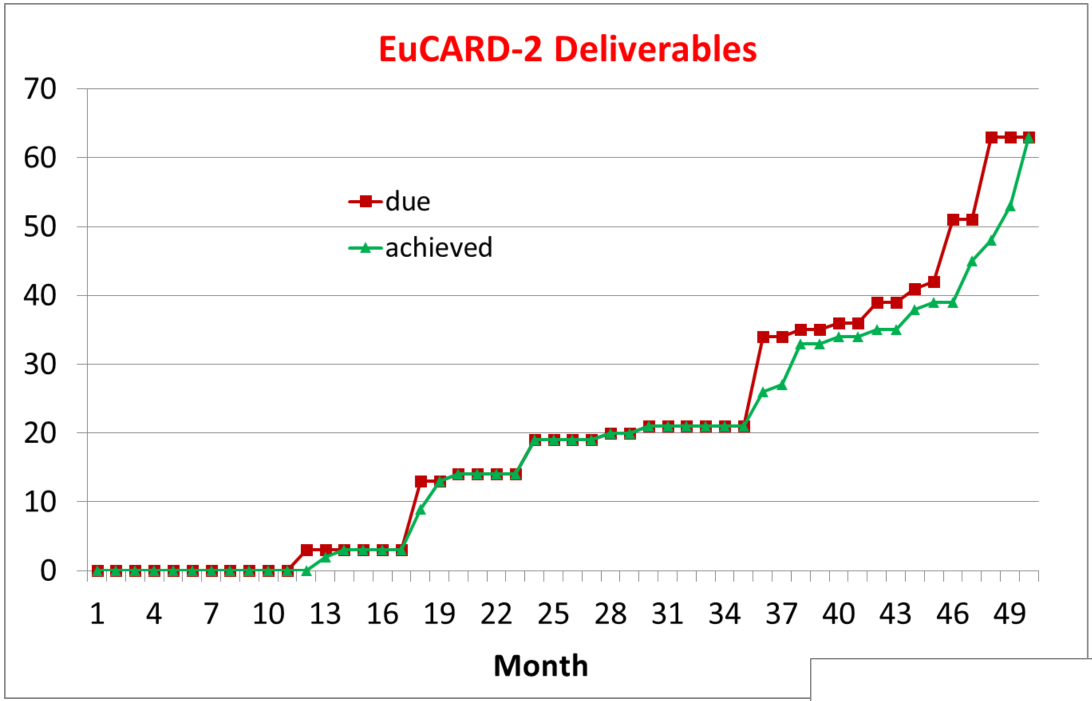
A critical overlap

- End of EuCARD-2: 30 April, 2017
- Final deadline for submitting all deliverables and reporting: 30 June, 2017.
- Start of ARIES: 1 May, 2017
- ARIES final preparation from March, 2017

Critical overlap for the two projects and overload of paperwork, reporting and meetings in the 4 months between March and June 2017.

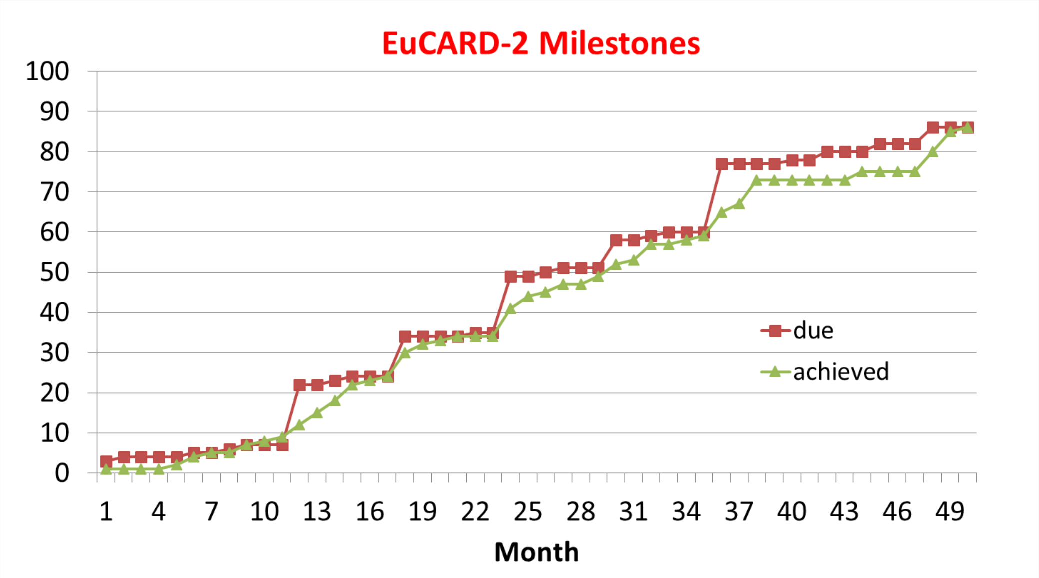
We are slowly getting out of the troubles thanks to the support of the CERN EU office and of the EuCARD2 WP Coordinators.

EuCARD2 Deliverables and Milestones



Not too bad, all deliverables except 1 ready, 3 still in the approval phase

23 deliverable reports produced and processed in the last 4 months!



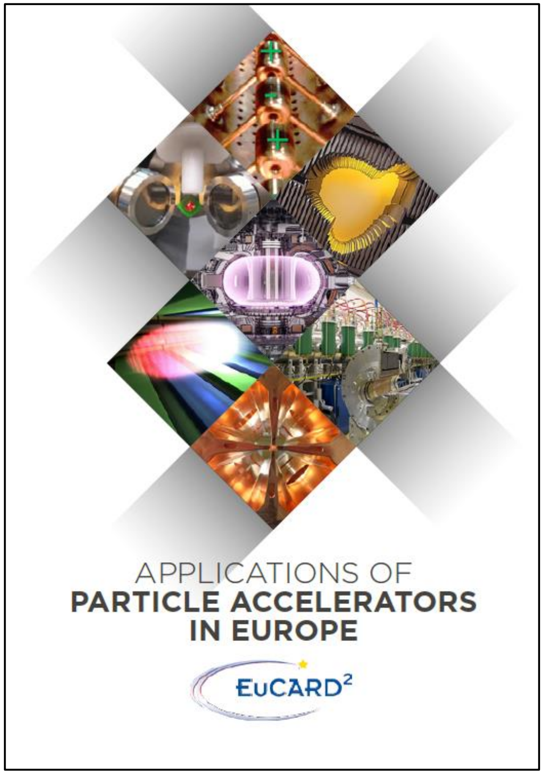
EuCARD-2 Final Reporting

- Periodic Report 3 (last year) completed, in the approval phase
- The Final Report (100-page document intended for a wide diffusion, summarising all outcomes of the project): draft completed last Friday, submitted for comments and approval to WP Coordinators and Governing Board members.
- Will be sent to the EC and printed as last EuCARD-2 monograph.

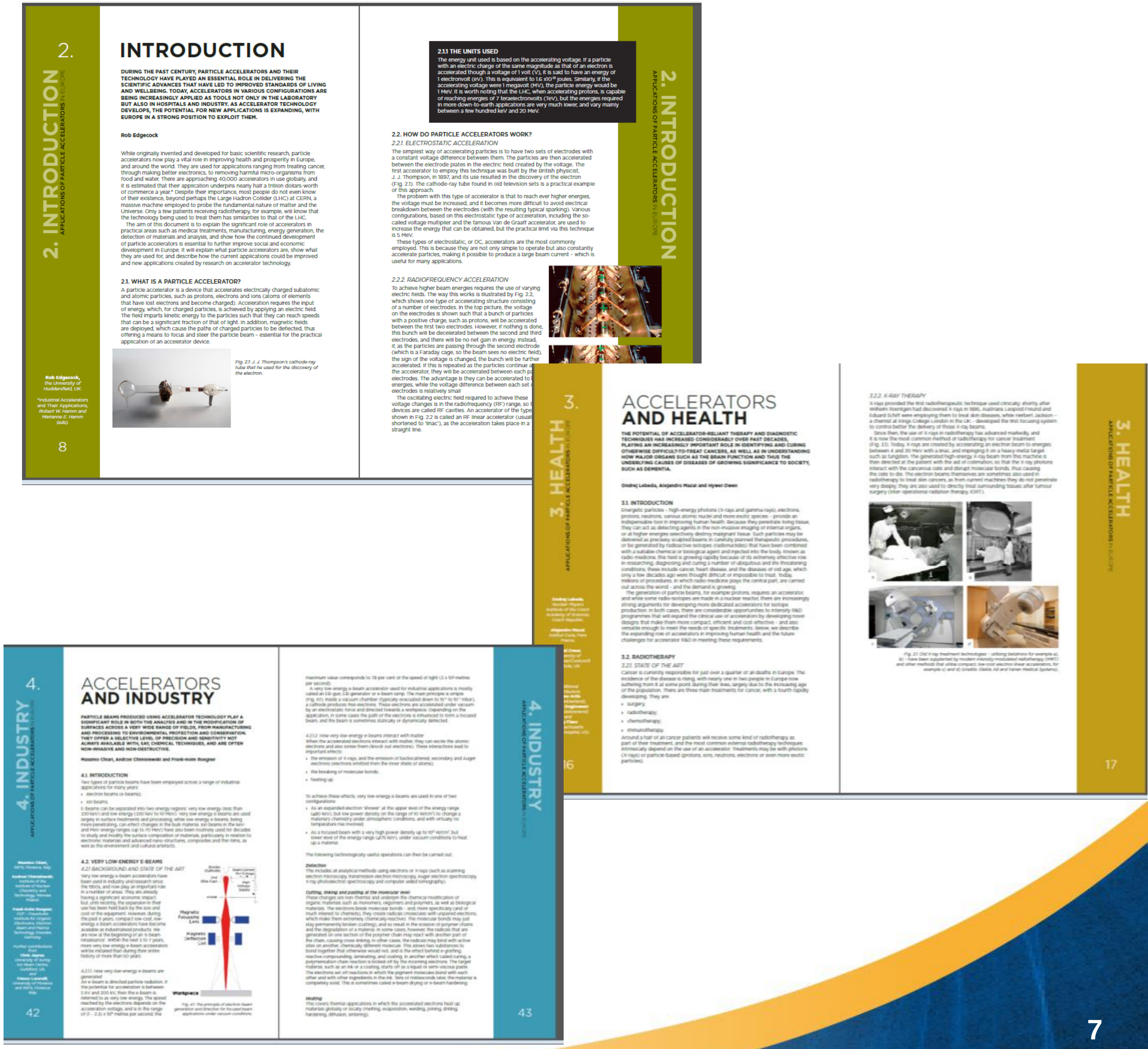
The APAE report

- WP4 (Accelerator Applications) has completed the Applications of Particle Accelerators in Europe (APAE) document.
- 113-page reference document, describes current applications of accelerators, achievable improvements, possible new applications and actions necessary to achieve these applications.
- Complemented by a 6-page summary brochure for general public and policy-makers.
- Important investment in time, effort and cost (assistance of a professional science writer and of a graphics designer).
- Accessible at http://apae.ific.uv.es/apae/
- Will be now printed (as EuCARD2 monograph) in 220 copies: 120 for the usual EuCARD2 distribution + 100 additional copies for the authors and for further distribution (cost about 15 EUR/copy)

APAE Document



APPLICATIONS OF
PARTICLE ACCELERATORS
IN EUROPE



2.

2. INTRODUCTION
APPLICATIONS OF PARTICLE ACCELERATORS IN EUROPE

INTRODUCTION

DURING THE PAST CENTURY, PARTICLE ACCELERATORS AND THEIR TECHNOLOGY HAVE PLAYED AN ESSENTIAL ROLE IN DELIVERING THE SCIENTIFIC ADVANCES THAT HAVE LED TO IMPROVED STANDARDS OF LIVING AND WELLBEING. TODAY, ACCELERATORS IN VARIOUS CONFIGURATIONS ARE BEING INCREASINGLY APPLIED AS TOOLS NOT ONLY IN THE LABORATORY BUT ALSO IN HOSPITALS AND INDUSTRY. AS ACCELERATOR TECHNOLOGY DEVELOPS, THE POTENTIAL FOR NEW APPLICATIONS IS EXPANDING, WITH EUROPE IN A STRONG POSITION TO EXPLOIT THEM.

Rob Edgecock

While originally invented and developed for basic scientific research, particle accelerators now play a vital role in improving health and prosperity in Europe, and around the world. They are used for applications ranging from treating cancer, through making better electronics, to removing harmful micro-organisms from food and water. There are approaching 40,000 accelerators in use globally, and it is estimated that their application underpins nearly half a trillion dollars-worth of commerce a year.* Despite their importance, most people do not even know of their existence, beyond perhaps the Large Hadron Collider (LHC) at CERN, a massive machine employed to probe the fundamental nature of matter and the Universe. Only a few patients receiving radiotherapy, for example, will know that the technology being used to treat them has similarities to that of the LHC.

The aim of this document is to explain the significant role of accelerators in practical areas such as medical treatments, manufacturing, energy generation, the detection of materials and analysis, and show how the continued development of particle accelerators is essential to further improve social and economic development in Europe. It will explain what particle accelerators are, show what they are used for, and describe how the current applications could be improved and new applications created by research on accelerator technology.

2.1. WHAT IS A PARTICLE ACCELERATOR?

A particle accelerator is a device that accelerates electrically charged subatomic and atomic particles, such as protons, electrons and ions (atoms of elements that have lost electrons and become charged). Acceleration requires the input of energy, which, for charged particles, is achieved by applying an electric field. The field imparts kinetic energy to the particles such that they can reach speeds that can be a significant fraction of that of light. In addition, magnetic fields are deployed, which cause the paths of charged particles to be deflected, thus offering a means to focus and steer the particle beam – essential for the practical application of an accelerator device.

Fig. 2.1: J. J. Thompson's cathode-ray tube that he used for the discovery of the electron.

Rob Edgecock,
the University of Huddersfield, UK.

*Industrial Accelerators and Their Applications, *Robert W. Hamm and Marianne E. Hamm (eds).*

8

2.1.1 THE UNITS USED

The energy unit used is based on the accelerating voltage. If a particle with an electric charge of the same magnitude as that of an electron is accelerated though a voltage of 1 volt (V), it is said to have an energy of 1 electronvolt (eV). This is equivalent to 1.6 $\times 10^{-19}$ joules. Similarly, if the accelerating voltage were 1 megavolt (MV), the particle energy would be 1 MeV. It is worth noting that the LHC, when accelerating protons, is capable of reaching energies of 7 teraelectronvolts (TeV), but the energies required in more down-to-earth applications are very much lower, and vary mainly between a few hundred keV and 20 MeV.

2.2. HOW DO PARTICLE ACCELERATORS WORK?

2.2.1. ELECTROSTATIC ACCELERATION

The simplest way of accelerating particles is to have two sets of electrodes with a constant voltage difference between them. The particles are then accelerated between the electrode plates in the electric field created by the voltage. The first accelerator to employ this technique was built by the British physicist, J. J. Thompson, in 1897, and its use resulted in the discovery of the electron (Fig. 2.1). The cathode-ray tube found in old television sets is a practical example of this approach.

The problem with this type of accelerator is that to reach ever higher energies, the voltage must be increased, and it becomes more difficult to avoid electrical breakdown between the electrodes (with the resulting typical sparking). Various configurations, based on this electrostatic type of acceleration, including the so-called voltage multiplier and the famous Van de Graaff accelerator, are used to increase the energy that can be obtained, but the practical limit via this technique is 5 MeV.

These types of electrostatic, or DC, accelerators are the most commonly employed. This is because they are not only simple to operate but also constantly accelerate particles, making it possible to produce a large beam current – which is useful for many applications.

2.2.2. RADIOFREQUENCY ACCELERATION

To achieve higher beam energies requires the use of varying electric fields. The way this works is illustrated by Fig. 2.2, which shows one type of accelerating structure consisting of a number of electrodes. In the top picture, the voltage on the electrodes is shown such that a bunch of particles with a positive charge, such as protons, will be accelerated between the first two electrodes. However, if nothing is done, this bunch will be decelerated between the second and third electrodes, and there will be no net gain in energy. Instead, if, as the particles are passing through the second electrode (which is a Faraday cage, so the beam sees no electric field), the sign of the voltage is changed, the bunch will be further accelerated. If this is repeated as the particles continue a the accelerator, they will be accelerated between each pa electrodes. The advantage is they can be accelerated to energies, while the voltage difference between each set electrodes is relatively small

The oscillating electric field required to achieve these voltage changes is in the radiofrequency (RF) range, so t devices are called RF cavities. An accelerator of the type shown in Fig. 2.2 is called an RF linear accelerator (usuall shortened to 'linac'), as the acceleration takes place in a straight line.

3.

3. HEALTH

ACCELERATORS
AND HEALTH

THE POTENTIAL OF ACCELERATOR-RELIANT THERAPY AND DIAGNOSTIC TECHNIQUES HAS INCREASED CONSIDERABLY OVER PAST DECADES, PLAYING AN INCREASINGLY IMPORTANT ROLE IN IDENTIFYING AND CURING OTHERWISE DIFFICULT-TO-TREAT CANCERS, AS WELL AS IN UNDERSTANDING HOW MAJOR ORGANS SUCH AS THE BRAIN FUNCTION AND THUS THE UNDERLYING CAUSES OF DISEASES OF GROWING SIGNIFICANCE TO SOCIETY, SUCH AS DEMENTIA.

Ondrej Lebeda, Alejandro Mazal and Hywel Owen

3.1. INTRODUCTION

3.2. RADIOTHERAPY

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4.

4. INDUSTRY

ACCELERATORS
AND INDUSTRY

PARTICLE BEAMS PRODUCED USING ACCELERATOR TECHNOLOGY PLAY A SIGNIFICANT ROLE IN BOTH THE ANALYSIS AND IN THE MODIFICATION OF SURFACES ACROSS A VERY WIDE RANGE OF FIELDS, FROM MANUFACTURING AND PROCESSING TO ENVIRONMENTAL PROTECTION AND CONSERVATION. THEY OFFER A SELECTIVE LEVEL OF PRECISION AND SENSITIVITY NOT ALWAYS AVAILABLE WITH, SAY, CHEMICAL TECHNIQUES, AND ARE OFTEN NON-INVASIVE AND NON-DESTRUCTIVE.

Massimo Chiari, Andrzej Chmielewski and Frank-Holm Roegner

4.1. INTRODUCTION

Two types of particle beams have been employed across a range of industrial applications for many years:

- electron beams (e-beams);
- ion beams.

4.2. VERY LOW-ENERGY E-BEAMS

42

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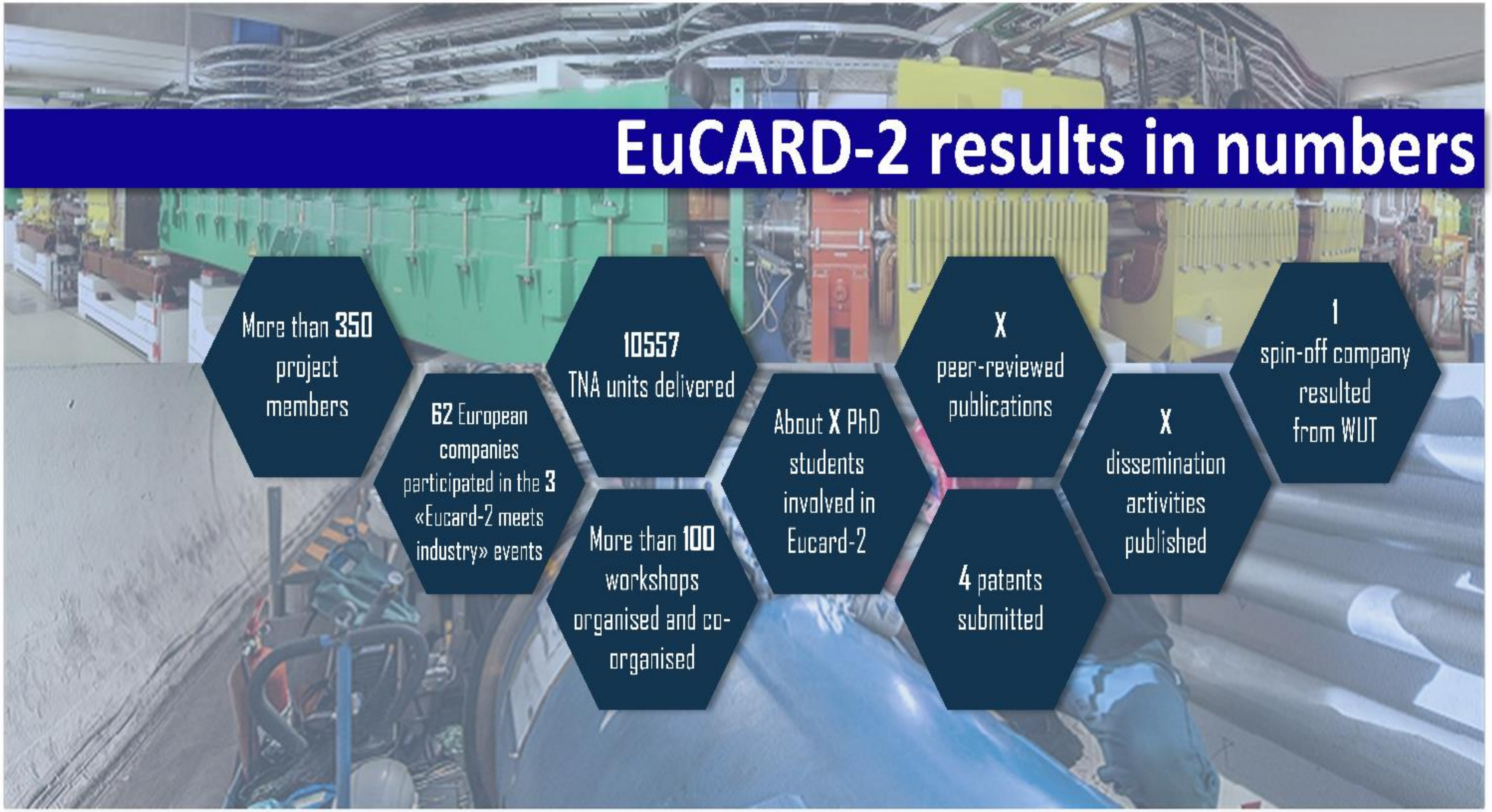
Overview table (work in progress)



EuCARD-2 results in numbers

More than **350** project members

62 European companies participated in the **3** «Eucard-2 meets industry» events

10557 TNA units delivered

More than **100** workshops organised and co-organised

About **X** PhD students involved in Eucard-2

X peer-reviewed publications

4 patents submitted

X dissemination activities published

1 spin-off company resulted from WUT

EuCARD2 scientific highlights – Networks, TA

1. Identified compact proton accelerators for isotope production and intense low-energy electron accelerators for environmental applications as most promising fields for societal applications of accelerators, and organised collaborations with industry.
2. Produced surveys and developed accelerator components (tunable permanent quadrupoles, high-efficiency klystrons) to increase energy efficiency in accelerators.
3. Contributed to the developement of new schemes and designs for frontier accelerators (muon colliders, advanced photonics, etc.).
4. Federated communities of damping rings, advanced factories and synchrotron light sources, resulting in the emergence of 4th generation light sources based on MBAs.
5. Coordinated the plasma accelerator community, resulting in the EuPRAXIA DS and in new concepts for plasma-based colliders.
6. Provided access to 3 test facilities (111 users from 33 institutes, total of 10’157 access hours).

EuCARD2 scientific highlights – JRAs

1. Selected conductor, tape layout, cable geometry and magnet design for HTS accelerator magnets.
2. Developed and charactereised the world record current density tape in YBCO (1338 A/mm2 for a 4 mm tape).
3. Designed, built and tested an HTS coil (aligned block) inside a magnet (result: 6 kA at B>3 T).
4. Identified, produced and tested new grades of Molybdenum carbide-graphite collimator materials that will be used for HL-LHC.
5. Developed a new deposition scheme for Nb on Cu.
6. Demonstrated high-brightness electron beams from laser plasma acceleration and femtosecond synchronisation.
7. Contributed to the initial success (demostration of self-modulation instability) of the AWAKE proton-driven experiment.

Welcome to ARIES !

- Kick-off meeting May 4 and 5, 2017
- 134 participants, 19 (14%) from industry, 22 countries

Kick-off highlights

- 1st meeting of Governing Board, elected as chair Nicholas Sammut from University of Malta. He is going to participate to Steering Committee meetings and contribute to the management of the project.
- Useful industry meeting with the 19 industrial participants (goal: information on the ongoing and future co-innovation activities on accelerator R&D).
- All WP’s have organised parallel kick-off sessions for their WP: the work is really starting.

ARIES Status

- All beneficiaries except 1 have signed the Consortium Agreement.
- After a long discussion with its legal service, the last partner has agreed to give its signature only on Tuesday last week.
- The 1st payment has been already sent to all partners that have signed the Consortium Agreement.
- Discussions are still going on on the composition of the Scientific Advisory Committee (3 members, external to the project) and of the Industry Advisory Board.

ARIES Management - Networks

WP	WP name	Task	Task name	Task leader name	Task leader organi
WP1	Management, dissemination, ensuring sustainability	1.1	Management	Maurizio Vretenar	CERN
		1.2	Internal communication, dissemination, scientific publications and monograph	Jennifer Toes	CERN
		1.3	Sustainability of Particle Accelerator Research in Europe	Roy Aleksan	CEA
WP2	Training, Communication and Outreach for Accelerator Science (TCO)	2.1	Coordination and work package communication	Philip Burrows	U. Oxford
		2.2	Coordination, support and enhancement of communications/outreach activitie	Jennifer Toes	CERN
		2.3	Coordination, support and enhancement of training activities for accelerators i	Yogi Rutambhara	ESS
		2.4	Provide an e-learning course: introduction to accelerator science, engineering	Nicolas Delerue	CNRS
WP3	Industrial and Societal Applications (ISA)	3.1	Coordination and Communication	Rob Edgecock	HUD
		3.2	Low energy electron beam applications: new technology development	Frank-Holm Roegner	FEP
		3.3	Low energy electron beam applications: new applications	Andrzej Chmielewski	INCT
		3.4	Medium energy electron beams	Angeles Faus-Golfe	CNRS
		3.5	Radioisotope production	Conception Oliver	CIEMAT
WP4	Efficient Energy Management (EEM)	4.1	Coordination and Communication	Mike Seidel	PSI
		4.2	High Efficiency RF Power Sources	Claude Marchand	CEA
		4.3	Increasing energy efficiency of the spallation target station	Michael Wohlmuther	PSI
		4.4	High Efficiency SRF power conversion	Frank Gerigk	CERN
		4.5	Efficient operation of pulsed magnets	Peter Spiller	GSI
WP5	European Network for Novel Accelerators (EuroNNAC)	5.1	Coordination and Communication	Ralph Assmann	DESY
		5.2	European Strategy Plasma Accelerators	Ralph Assmann	DESY
		5.2		Arnd Specka	CEA
		5.2		Alban Mosnier	CEA
		5.3	European Strategy Dielectric Accelerators	Ralph Assmann	DESY
		5.4	European Advanced Accelerator Concepts Workshop (EAAC)	Massimo Ferrario	INFN
		5.5	Young Scientist Networking and Academic Standards	Roman Walczak	Oxford Univ
		5.5		Bernhard Holzer	CERN
WP6	Accelerator Performance and Concepts (APEC)	6.1	Coordination and communication	Frank Zimmermann	CERN
				Giuliano Franchetti	GSI
		6.2	Beam Quality Control in Hadron Storage Rings and Synchrotrons	Giuliano Franchetti	GSI
				Frank Zimmermann	CERN
		6.3	Reliability and Availability of Particle Accelerators	Johannes Gutleber	CERN
				Klaus Hoeppner	HIT
		6.4	Improved Beam Stabilization	Alessandro Drago	INFN-LNF
		6.5	Beam Quality Control in Linacs and Energy Recovery Linacs	Florian Hug	JGU Mainz
		6.6	Far Future Concepts & Feasibility	Marco Zanetti	INFN & U. Padova
				Frank Zimmermann	CERN
WP7	Rings with Ultra-Low Emittance (RULE)	7.1	Coordination and Communication	Riccardo Bartolini	U. Oxford
		7.2	Injection Systems for ultra-low emittance rings	Michael Boege	PSI
		7.3	Beam dynamics and technology for ultra-low emittance rings	Marica Biagini	INFN
				Ruytaro Nagaoka	SOLEIL
				Ioannis Papaphilippou	CERN
		7.4	Beam tests and commissioning of ultra-low emittance rings	Anke-Susanne Mueller	KIT
WP8	Advanced Diagnostics at Accelerators (ADA)	8.1	Coordination and Communication	Peter Forck	GSI
		8.2	Advanced instrumentation for hadron LINACs	Peter Forck	GSI
		8.3	Advanced instrumentation for hadron synchrotrons	Rhodri Jones	CERN
		8.4	Advanced instrumentation for 3rd generation light sources	Francis Perez	ALBA-CELLS
		8.5	Advanced instrumentation for FELs	Kay Wittenburg	DESY

ARIES Management - JRAs

WP9	Magnet testing	9.1	MagNet	Marta Bajko	CERN
		9.2	Gersemi	Roger Ruber	U.Uppsala
WP10	Material testing	10.1	HiRadMat	Adrian Fabich (Yacine Kadi)	CERN
		10.2	UNILAC	Daniel Severin	GSI
WP11	Electron & proton beam testing	11.1	ANKA	Jerome Schwindling	CEA
		11.2	FLUTE	Robert Ruprecht	KIT
		11.3	IPHI	Jerome Schwindling	CEA
		11.4	SINBAD	Ulrich Dorda	DESY
		11.5	VELA	Anthony Gleeson	STFC
WP12	Radio Frequency testing	12.1	HNOSS	Roger Ruber	U.Uppsala
		12.2	Xbox	Walter Wuensch	CERN
WP13	Plasma beam testing	13.1	APOLLON	Brigitte Cros	CNRS
		13.2	LPA-UHI100	Brigitte Cros	CNRS
				Sandrine Dobosz Dufrenoy	CEA
		13.3	LULAL	Olle Lundh	U. Lund
WP14	Promoting Innovation (PI)	14.1	Coordination and Communication	Marcello Losasso	CERN
		14.2	Proof-of-Concept (PoC) innovation fund	Marcello Losasso	CERN
		14.3	Collaboration with industry. Production of material samples of carbide-graphite	Marcello Losasso	CERN
		14.4	Industrial production of materials for extreme thermal management	Federico Carra	CERN
		14.5	High Temperature Superconducting (HTS) innovative process for accelerator m	Lucio Rossi	CERN
		14.6	Industrialisation of REDNet Accelerator Timing System for Industrial and Medi	Johannes Gutleber	CERN
WP15	Thin film for Superconducting RF Cavities (TF-SRF)	15.1	Coordination and Communication	Oleg Malyshev	STFC
		15.2	Substrate surface preparation	Enzo Palmieri	INFN
		15.3	Thin film deposition and analysis	Reza Valizadeh	STFC
		15.4	Superconductivity evaluation	Oliver Kugeler	HZB
WP16	Intense, RF modulated E-beams (IRME)	16.1	Coordination and Communication	David Ondreka	GSI
		16.2	System Integration	David Ondreka	GSI
		16.3	Electron Gun and Power Modulator	Kathrin Schulte	U. Frankfurt
		16.4	Test Stand and Beam Diagnostics	Adriana Rossi	CERN
WP17	Materials for extreme thermal management (PowerMat)	17.1	Coordination and Communication	Alessandro Bertarelli	CERN
				Marilena Tomut	GSI
		17.2	Materials development and characterization	Alessandro Bertarelli	CERN
		17.3	Dynamic testing and online monitoring	Lorenzo Peroni	POLITO
		17.4	Simulation of irradiation effects and mitigation method	Anton Lechner	CERN
		17.5	Broader accelerator and societal application	Marilena Tomut	GSI
WP18	Very High Gradient Acceleration Techniques	18.1	Coordination and Communication	Arnd Specka	LLR
		18.2	Enabling multi-stage LWFA	Antoine Chance	CEA
		18.3	LWFA with exotic laser beams	Jorge Vieira	IST
		18.4	Laser driven dielectric accelerator	Ulrich Dorda	DESY
		18.5	Pushing back the charge frontier	Cedric Thaury	CNRS

ARIES – Next steps

- Steering committee meetings in September (video) and in November/December (F2F, CERN).
- 1st Annual Meeting in Riga (Latvia) in one of the 3 slots: 23-27.4 / 14-19.5 / 28.5-1.6