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Action to be taken | *Voting Procedure*

For Information	**EUROPEAN STRATEGY SESSION OF COUNCIL RESTRICTED** 8th Session **18 September 2009**	-

WORKING DOCUMENT TOWARDS "TIARA, A PROPOSAL FOR ENSURING THE SUSTAINABILITY OF ACCELERATOR R&D IN EUROPE"

This paper briefly sets out the main motivation and implementation goals for the TIARA (Test Infrastructure and Accelerator Research Area) initiative.
The document is presented to Council for information and discussion. To initiate this project an FP7 Preparatory Phase project is in the process of being submitted, as described in document CERN-COUNCIL-S/048.

TIARA, a proposal for ensuring the sustainability of accelerator R&D in Europe.

Executive summary

The main objective of this proposal is to develop a sustainable European framework enabling the coordinated implementation of a ***joint*** particle accelerator ***R&D programme*** in Europe and the ***integration of the required infrastructures***, with the aim of accelerating the Research and Development on state-of-the-art and new accelerator technologies, and to strengthen education and training in accelerator science.

In order to achieve the above objectives, it is proposed to create a pan-European distributed ***Test Infrastructure and Accelerator Research Area (TIARA) covering a wide range of fields with a coordinating structure***, the role of which would be to implement the means to achieve the above objective**.**

As a first step towards TIARA, it is proposed to launch a **Preparatory Phase project**, partially financed by the EC, with the aim of reaching a consensus on the scientific, political, administrative and financial issues related to the creation of TIARA.

1. Introduction

The study of the sub-nuclear structure of matter, the search for and study of elementary particles as well as understanding the origin of their mass and the fundamental forces governing their interactions require the most advanced particle accelerators. Similar statements are appropriate for several other scientific fields, such as, but not only, nuclear physics, solid state physics, biology, clinical medical and industrial applications. In many areas, the techniques involved for the development of these accelerators are innovative and necessitate significant progress beyond the state-of-the-art, which often leads to important breakthroughs in several fields of science.

The upgrade of existing infrastructures, by improving their performances and/or by furthering their reliability and efficiency on the one hand, and the realization of new accelerators on the other hand, rely crucially on strong and steady Research and Technical Development (RTD) programmes, the magnitude and diversity of which surpasses the intellectual, technical and financial resources of a single laboratory or institution, and thus necessitate a large international effort. Furthermore, given that the size of these accelerators generally requires the industrialisation of the developed techniques, ensuring an appropriate collaboration and efficient technology transfer with industry by promoting relevant partnerships is very important.

In summary, particle accelerators constitute indispensable and major tools for the development of the knowledge-based society and beyond, through technology transfer, to the building of a knowledge-based economy.

2. Scientific Fields

Many different fields require state-of-the-art accelerators, from fundamental and basic research to scientific, clinical and industrial applications. The technical requirements include a broad range of energy[1], intensities and probes. We indicate those fields below and specify briefly the main requirements in terms of accelerators.

a. **Particle Physics accelerators**
   The study of particle physics requires the use of very high energy and/or high intensity accelerators or colliders with electron (positron), muon, neutrino, proton (antiproton) beams
b. **Hadronic and Nuclear Physics accelerators**
   The study of matter states requires low/medium energy and/or high intensity accelerators or colliders with electron/positron, proton/antiproton and light to heavy ion beams
c. **Accelerators for light sources**
   Many studies on condensed or solid state physics, biology, geology, human sciences require the use of low/medium energy and high intensity electron accelerators
d. **Accelerators for neutron sources**
   The development of neutron spallation sources requires medium energy and high intensity proton accelerators
e. **Accelerators for material irradiation for fusion reactors**
   The study of material for fusion reactors will be carried out with medium energy and high intensity deuteron accelerators
f. **Accelerators for the development of transmutation reactors**
   The transmutation of radioactive waste requires medium energy and high intensity proton accelerators
g. **Medical accelerators**
   A large number of medical accelerators are used to treat cancers. The vast majority of these are electron linear accelerators. However, low energy proton or ion accelerators are also used to cure cancer tumours, which are difficult to treat by conventional means.
h. **Industrial accelerators**
   Many industrial applications and processes require low energy electron, proton and ion accelerators. The utilisation of such accelerators covers a wide range of applications such as ion implantation for the semiconductor industry, electron cutting and welding, electron beam and X-ray irradiators, radioisotope production, non-destructive testing and imaging, ion beam analysis, neutron generators.

The cost of “research” accelerators (**a-f** in the list above) is generally very large (>100 M€) and only a limited number (~100) of such accelerators are or will be available in Europe. The construction of such accelerators constitutes an estimated average direct market of about 1000M€ per year. Some examples are LHC at CERN, SIS at GSI, DAPhNE at LNF, SPIRAL at GANIL, ISIS at RAL, SOLEIL and Diamond in France and the UK. Other projects are under construction such as XFEL at DESY, FAIR at GSI, MYRRHA in Belgium and others are planned such as ESS in Lund, IFMIF, ILC or CLIC, intense neutrino beams and super B Factories.

[1]For the sake of simplicity, we arbitrarily define low-energy (< 1GeV), medium-energy (> 1 GeV and < 100 GeV) and high-energy (>100 GeV)

"Clinical" and "production" accelerators are used as medical or industrial tools (**g** and **h** in the list above). The cost of such accelerators is much lower than "research" accelerators but there are a large number of these (>27000), thus constituting an annual direct market of ~3000 M€ with typical annual growth of 10% per year. It should be noted that the use of these accelerators generates an indirect market which is 10 to 100 times larger depending on the domain of application.

3. The context for particle physics

For particle physics, shared R&D targeted at a specific project was initiated in the 1990s by the TESLA Technology Collaboration for developing the technology of a superconducting linear accelerator.

However, since then the vital need for a strong and coordinated European multipurpose accelerator R&D programme has rapidly emerged, as emphasised in 2001 by ECFA in the report ECFA/01/213 on "the Future of Accelerator-based Particle Physics in Europe".

The directors of STFC, CERN, CEA/DAPNIA, DESY, IN2P3/Orsay, LNF and PSI, in consultation with ECFA, thus decided in 2002 to form a European Steering Group on Accelerator R&D (ESGARD). The mandate of ESGARD was to develop and implement a strategy and to optimise and enhance Research and Technical Development in the field of accelerator physics in Europe. The main objectives were to promote

- "mutual coordination and facilitate the pooling of European resources",
- "a coherent and coordinated utilization and development of infrastructures",
- "inter-disciplinary collaboration including industry",

ESGARD's main action was to develop a consistent set of pan-European collaborative accelerator R&D programmes carried out by a large number of institutes in the same way as for the construction of large particle physics detectors.

More recently, accelerator R&D was given very high priority by the CERN Council as part of "The European Strategy for Particle Physics" established in 2006 and has thus also taken its place on the ESFRI Roadmap[2].

4. Coordinated RTD projects within the 6th and 7th EC Framework Programs

To achieve its aims, ESGARD coordinated the preparation of an initial proposal, the CARE project, for EU funding in the 6th Framework Programme and then supervised the submission of a coherent set of additional bids generated from CARE activities.

4.1 Strategy developed by ESGARD

The strategy developed to promote accelerator R&D was to use the incentive of the Framework Programmes of the European Commission:

[2] In the ESFRI Roadmap 2008 document, one reads as the priorities for Particle Physics on page 72 "it is vital to strengthen the advance accelerator R&D programme in Europe, providing a strong technological basis for future projects in particle physics".

- to develop a general multipurpose R&D programme including some of the high priority issues together with a strong set of networking activities,
- from which the emergence of further specific projects could be encouraged.

This approach has been very successful and many accelerator R&D programs have been initiated.

4.2 The present situation

The above strategy has been implemented successfully and several R&D projects have been developed and launched. The programmes approved within the FP6 and FP7 are summarised in the tables below.

Table 1. Overview and schedule of the accelerator R&D projects approved by the EC.

<table>
<tr><th></th><th></th><th colspan="5">FP6</th><th colspan="4">FP7</th><th></th></tr>
<tr><th>Project Type</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th></tr>
<tr><td>I3/IA</td><td></td><td colspan="5">CARE (3 networks e, n, p)</td><td colspan="4">EuCARD</td><td></td></tr>
<tr><td>I3/IA</td><td></td><td colspan="5">CARE/SRF (LC)</td><td colspan="4">EuCARD/SRF</td><td></td></tr>
<tr><td>I3/IA</td><td></td><td colspan="5">CARE/PHIN (LC)</td><td colspan="4">EuCARD/SRF-ANAC</td><td></td></tr>
<tr><td>I3/IA</td><td></td><td colspan="5">CARE/HIPPI (p Lin. inj.)</td><td colspan="4">EuCARD/SRF-ColMat</td><td></td></tr>
<tr><td>I3/IA</td><td></td><td colspan="5">CARE/NED (mag.)</td><td colspan="4">EuCARD/HFM</td><td></td></tr>
<tr><td>Prep.-Phase</td><td></td><td></td><td></td><td></td><td></td><td colspan="3">SLHC (pColl.)</td><td></td><td></td><td></td></tr>
<tr><td>Design Study</td><td></td><td></td><td colspan="4">EUROTEV (LC)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Prep.-Phase</td><td></td><td></td><td></td><td></td><td></td><td colspan="4">ILC-HiGrade (ILC)</td><td></td><td></td></tr>
<tr><td>Design Study</td><td></td><td></td><td colspan="4">EURISOL (n b-beams)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Design Study</td><td></td><td></td><td></td><td></td><td></td><td colspan="5">EURO-Nu</td><td></td></tr>
<tr><td>NEST</td><td></td><td></td><td></td><td colspan="3">EUROLEAP (plas.)</td><td colspan="4">EuCARD/ANAC</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">EuCARD/ANAC (F-Fact.)</td><td></td></tr>
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In summary a total of 8 R&D projects, mainly for particle physics accelerators, have been developed covering all high priority technological aspects over a period of 9 years and amounting to a total cost of about 191 M€, out of which 59.6 M€ is financed by the EC. It should be noted that several of these projects include R&D activities beyond the sole need of particle physics.

Despite these successful developments, there are worries about the sustainability of accelerator R&D. Indeed the ongoing projects depend either

- on large accelerator projects being considered and the R&D might stop during or after the construction phase
- on the schedule of the EC calls, their approval and funding level
- and have a limited cross-disciplinary involvement.

5. Research and Development programs

The R&D programs needed prior to the construction of accelerators can be classified in 3 broad categories.

1. ***Exploratory R&D***
   This is basic R&D, undertaken to test the feasibility of a conceptual idea and to develop innovative technologies. It generally leads to conceptual feasibility assessments.
2. ***Targeted R&D***
   This R&D is needed to demonstrate the technical feasibility of a specific project with the validation of the technology by the development of prototypes of the main and/or critical components of the proposed accelerator, as well as their system integration.
3. ***Industrialization R&D***
   This is the indispensible step before launching construction, aimed at ensuring the mass production of the accelerator components at the lowest possible cost.

6. Required infrastructures

The ultimate goal of accelerator R&D is to build a new generation of "research" accelerators, which are used for carrying out single-disciplinary or multidisciplinary researches and thus act as user facilities. However, the technological breakthroughs generated by R&D also have a direct impact on the health sector and industry by offering the possibility to develop more powerful, efficient and cost-effective accelerators.

In order to carry out an efficient and sustainable accelerator R&D programme, different types and levels of infrastructures are required.

6.1 Test accelerators for carrying accelerator R&D

These accelerators are used full or part-time to carry out accelerator research and demonstrate technical feasibility. Examples are CTF3 (CERN), FLASH (DESY), MICE (STFC), IPHI(CEA), PHIL (CNRS), ELBE Photo-injector line (FZD)…

6.2 Specific large-scale facilities

Specific large-scale facilities are required to develop and test large accelerator components (clean rooms, chemical treatment facilities, coating facilities, large cryostats, magnet test stands, high power RF systems…).

6.3 Laboratory facilities

Laboratory facilities are required to develop and test small accelerator components and instrumentation (high frequency analyzers, material analysis facilities…).

7. Potential partners

Several types of partner collaborate to carry out accelerator R&D. They belong to different structures and posses different levels of facilities.

7.1 Large-scale laboratories

Generally these are international or national laboratories that host large-scale infrastructures such as described in section 6.1 or 6.2. Their expertise and personnel are therefore vital for the development of a strong R&D programme. These laboratories also possess most of the types of facilities described in section 6.3. Without being exhaustive, examples are CERN, DESY, GANIL, LN Frascati, RAL. These laboratories are part of international or national organisations, like CERN, Helmhotz association, CEA, CNRS, INFN, STFC etc.

7.2 Universities

The universities are essential for the long-term sustainability of this field. Indeed, in addition to their strong expertise and highly qualified personnel, they play a vital role in the teaching and training of young accelerator physicists, including both theoretical and experimental aspects. The size and level of facilities varies greatly from one university to another.

7.3 Small or medium-scale units

In several countries, there exist smaller laboratories or divisions within user facilities, which are not part of universities and have valuable expertise, facilities and resources useful for carrying out specific R&D. However, they often need to work in close connection with large-scale laboratories or universities to carry out their research.

7.4 Industry

A number of industrial companies own some of the types of infrastructures that are useful for developing accelerators. Without being exhaustive, examples of such companies are Accel, EAS, IBA, Thales, Zanon. Although they own a wide range of infrastructure, in general they do not have test accelerators for carrying out accelerator R&D. However, joint studies of the industrialisation of accelerator components at the R&D level are a very important aspect potentially leading to significant cost savings.

Table 2. Summary table of the infrastructures versus the organisms owning them.

	LSL	**University**	**SMU**	**Industry**
Production accelerators	X			
Test accelerators	X			?
Large scale equipments	X	X		X
Lab. equipments	X	X	X	X

8. Ensuring stronger coordination and sustainability

8.1 A step beyond

It is essential to ensure that the infrastructures/facilities vital for carrying out accelerator R&D are available in Europe, are well matched to needs and sustainable.

Although a strong European programme has now been established in the field of accelerator R&D, the launching of many of these activities has been closely connected to the FP calls and is therefore dependent on EC approval and funding.

The main consequence of this approach is that the schedule of the projects is linked to the schedule of the calls and the scope of the projects is constrained by the recommendations of the referees set by the EC and limited by the funding available in the calls.

In the long term, there is no guarantee that all the R&D projects needed for particle physics accelerators will continue to be financed by the EC nor that the scope, the schedule and funding level of the calls will match the needs of the community. Other fields such as nuclear physics or photon/neutron sources etc. are likely to face the same problems.

Therefore, while keeping the strong and fruitful contacts with the EC and continuing to follow closely the evolution of the Framework Programmes, it would be desirable to develop a more general strategy, a long-lasting structure and procedures that will ensure the sustainability of this vital activity in Europe.

8.2 The objectives

<u>In view of the above, it is highly desirable to develop an organisational structure and mechanism to ensure an efficient and lively long-term accelerator R&D programme in Europe, which includes</u>

- **The integration of R&D infrastructures and offered services in a general framework**
  - This integration ensures that Europe has the necessary and accessible test infrastructures and facilities to carry out the R&D programmes needed. It is necessary to ensure that these infrastructures are maintained and upgraded as required.
- **The launching of a set of consistent integrated accelerator R&D projects**
  - Being able to launch appropriate collaborative R&D projects independent of the EC call schedule and funding constraints is a crucial aspect that needs to be included in a European accelerator R&D programme.
  - At the same time, the important impact of the EC is acknowledged and it is necessary to build on and continue the fruitful collaboration with the EC, which has been instrumental in enhancing Europe's capacity in the field of accelerator R&D. Integrating the EC support in a general framework would thus be very important.
- **The promotion of education and training in accelerator science**
  - In order to ensure the sustainability of accelerator R&D, it is vital to promote vigorously education and training in accelerator science in Europe. Various initiatives should be investigated, such as facilitating the organization of summer schools, internships for masters students, promotion of European accelerator masters, training in accelerator operation, exchange of scientists, etc.
- **A model for financing accelerator R&D Europe-wide**
  - It is essential to develop a general funding scheme which is conducive to achieving the required R&D programme and acceptable for the partners.

8.3 Creating TIARA

In order to achieve the above objectives, it is proposed to create a sustainable framework through the establishment of a pan-European distributed **Test Infrastructure and Accelerator Research Area (TIARA) with a central coordinating structure, the role of which would be to implement the means to achieve the above objectives.**

In particular, **TIARA** would aim at

- Elaborating a ***common strategy*** toward the development of accelerators in Europe, i.e.
    - Carrying out a shared strategic analysis of the accelerator requirements and perspectives
    - Developing a common strategy toward the development of accelerators
    - Developing a common accelerator R&D strategy based on a continuous survey and evaluation of European R&D requirements
- Developing a ***joint accelerator R&D programme*** in Europe, i.e.
    - Initiating and coordinating the launch of collaborative accelerator R&D projects by providing partial funding
    - Overseeing the progress of the accelerator R&D projects
    - Monitoring and promoting the exchange of information and personnel within and across fields
    - Establishing a partnership with European industry to hand over mature, technology-driven R&D
- Developing a ***pan-European distributed accelerator research infrastructure***
    - Monitoring and coordinating the use and development of the European test infrastructures for accelerator R&D
        - extracting maximum value from existing infrastructures and estimating operating costs (including manpower)
    - Monitoring access, including industry involvement
    - Identifying weaknesses and needed upgrades/investments and assessing their costs
    - Making recommendations for upgrading or constructing new infrastructures as well as their corresponding R&D programmes
- Promoting ***education and training in accelerator science***
    - After a survey of education and training in accelerator science in Europe, encouraging the development of support programmes to strengthen this area further such as facilitating the organisation of summer schools, internships for masters students, promotion of European accelerator masters, training in accelerator operation, exchange of scientists etc.
- Strengthening ***collaboration with industry***
    - Understanding industry's requirements in terms of accelerators and related accelerator R&D infrastructures and programmes
    - Investigating how to industrialise recent technologies
    - Establishing a Technology Roadmap for industrial development of future accelerator components.

TIARA would be useful to get a coordinated European framework for

- <u>different fields</u> needing state-of-the-art and/or cost effective accelerators to carry out joint accelerator R&D using large infrastructures
- <u>the different partners</u> (national laboratories, universities, industry) to develop common projects and exchange expertise on state-of-the-art technologies
- <u>the countries</u> to develop and invest in their own infrastructures and research centres that they propose as part of TIARA, within a Europe-wide coordination.
- <u>Europe</u> to ensure world leadership in the field of accelerators

In summary, TIARA combines both the establishment of a **<u>distributed pan-European Research Infrastructure and a multi-field Joint Programming activity</u>**. These two aspects are non-dissociable since carrying out accelerator R&D projects requires the availability and the accessibility of large infrastructures.

9. Summary

This document discusses the organisation of accelerator R&D, the scientific fields requiring state-of-the-art particle accelerators, the partners and the infrastructures needed for carrying out an efficient European accelerator R&D programme. A project to ensure a stronger coordination and a sustainable multidisciplinary pan-European accelerator R&D programme is being elaborated and it is thus proposed to submit a proposal (TIARA-PP) in response to the EC call on preparatory phase projects, with the aim of converging on the scientific, political, administrative and financial issues related to the creation of TIARA