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Executive summary:

Referring to the "Preparation Plan for the European Participation in the International Linear Collider", we discuss prospects and ideas for a European involvement in the construction – and in the preparation for construction – of the International Linear Collider.

It is understood that with lack of a formally defined project and with agreement between funding agencies on the funding of it, no commitments of any sort can be made. Nevertheless, a careful consideration of European capabilities and experiences – won, e.g., during the construction of the European XFEL or, currently, of the ESS – shows that European institutions and industries can contribute to virtually any part of the ILC. Based on these experiences, also models for contributions and ideas for main contributors can be formulated.

1. INTRODUCTION

The central component of the International Linear Collider (ILC) are the roughly 8000 Niobium superconducting radio-frequency (SRF) cavities used to accelerate the electrons and positrons to their final energies. The production of these is a major endeavour that cannot be handled by one laboratory or even by one nation alone – the key words are internationalisation, industrialisation and quality assurance.

With the European XFEL – in operation at DESY, Hamburg, since September 2017 – a 10% prototype for the ILC accelerator has been built and commissioned, and invaluable experience has been gained that will be vital input for the construction of the ILC.

However, without a clear ILC project defined, and without commitments from any government – let alone the Japanese one – it is premature to discuss a sharing of this tremendous task of SRF production. Instead, E-AJDE was instrumental in putting together a vision for such a sharing not only of the SRF parts, but also of all other accelerator components required. This vision is known as the "Preparation Plan for the European Participation in the Construction of the International Linear Collider" [1]; it was submitted to CERN Council in June 2018. The plan is supposed to complement, to a certain level and without commitments, the KEK ILC Action Plan [2] published in 2016. This KEK ILC Action Plan is intended to prepare the Japanese laboratory for a major contribution to the ILC construction. Together, the two plans – potentially complemented by similar documents from the Americas – could give a feeling about how the ILC might be realised.

Since the European preparation plan is also an E-JADE document, we will not repeat all details but will simply highlight the most important statements and assumptions.

2. THE EUROPEAN PREPARATION PLAN

The European preparation plan complements the KEK ILC Action Plan from 2016 and provides an overview of European expertise and possible contributions to the ILC preparation phase[1]. It is based on the assumption that ILC will be realized as an international project led by Japan, with a strong international participation. It does not provide or rely on specific levels of the European contribution to the project but builds on the European capabilities and technical expertise.

In the first part of the document the on-going activities with relevance to the ILC in Europe are reviewed, identifying the areas where European groups and industries have extensive knowhow and expertise. The European expertise and participation in ILC studies during the last decade are very broad and in particular the European XFEL project at DESY has been pivotal in establishing European capabilities.

The ILC Preparation Phase, currently foreseen for 2019-2022, needs to be initiated by a positive statement from the Japanese government about hosting the ILC, followed by a European strategy update that ranks European participation in the ILC as a high-priority item. The preparation phase focuses on preparation for construction and agreement on the definition of deliverables and their allocation to regions. The European groups will concentrate on

[1] The text in Sect. 2 partly follows very closely the executive summary of the EPP [1].

preparation for their deliverables including working with and preparing European industry. Europe and European scientists, as part of an international project team, will also participate in the overall finalisation of the design, while in parallel contributing to the work of setting up the overall structure and governance of the ILC project and of the associated laboratory.

The construction phase will start after the ILC laboratory has been established, currently foreseen from 2023, and intergovernmental agreements are in place. At the current stage, only the existing capabilities of the European groups relevant for this phase can be outlined in broad terms. As mentioned above, the detailed contributions will have to be defined during the preparation phase and formalised by inter-governmental agreements. The main in-kind contribution from Europe would fall in the time frame beyond 2025.

Being most relevant for the near future, this document outlines how the preparation phase can be organised. In terms of efficiency, impact and industrial contribution a wide European project is desirable, with CERN playing a central role in coordinating the efforts.

2.1. ASSUMPTIONS

The EPP assumes the following for the ILC preparation and construction:

- The EPP distinguishes three phases of ILC preparation:
  - In the pre-preparation phase (assumed to be 2017/18), the on-going activities with relevance to the ILC in Europe are reviewed. This is also the topic of numerous E-JADE deliverables (i.e this one, MDIPlan D22, LCOPT D19, EDMSDoc D21).
  - In the preparation phase 29109-22, which needs to be initiated by a positive statement from Japan and which will also bring about a statement from the European strategy update process, the focus will be on the preparation of construction, on legal agreements and funding decisions, on preparation of relevant industries, and on final R&D and design work.
  - The construction phase 2023 and beyond will start after the ILC laboratory has been established and intergovernmental agreements are in place.

	Germany	France		Italy	Poland			Russia	Spain
	DESY	CEA Saclay	LAL	INFN Milan	IFJ PAN	WUT	NCBJ	BINP	CIEMAT
Linac									
Cryomodules	✓	✓		✓					
SCRF Cavities	✓			✓					
Power Couplers	✓		✓						
HOM Couplers							✓		
Frequency Tuners	✓								
Cold Vacuum	✓							✓	
Cavity String Assembly	✓	✓							
SC Magnets	✓				✓				✓
Infrastructure									
AMTF	✓				✓	✓		✓	
Cryogenics	✓								
Sites & Buildings									
AMTF hall	✓								

Figure 1: Responsibility matrix for cryomodule production and testing for the European XFEL [1].

- It is assumed that Europe has a very strong scientific, technical and industrial basis to make significant contributions to the construction of virtually any part of the ILC machine and detectors. This is to the largest extent due to the very large past engagement of Europe in the ILC project, in particular (relevant for this report) in the fields of ADI and SRF.
    - The EPP describes the seven major activities with ILC relevance in Europea that are currently ongoing: European XFEL, ESS SRF, ATF/ATF2, CLIC, E-JADE, LC detectors, and GDE/LCC/ADI.
    - Figure 1 from Ref. [1] shows the responsibility matrix for cryomodule production and testing for the European XFEL (a 10% prototype of the ILC). It demonstrates that Europe is well capable of producing any part of the ILC machine.
- The preparation phase will be used for three main purposes: i) Technical preparation of the major European deliverables foresen for the construction phase; ii) organisation of a strong European design office; and iii) negotiations about the final European contributions, about the organisation of the project, and about a future governance model for the ILC.
- The overall resources needed during the four-year preparation phase are estimated to be 5% of the material and 10% of the personnel foreseen for the initial 250 GeV accelerator project. The EPP assumes it to be appropriate to consider a European investment of 1/3 of the overall effort required in the preparation phase, corresponding to an estimated 85 MEUR and 250 FTE years integrated over the four years, i.e. roughly something like 30 MEUR per year. This corresponds roughly to the funds for the CLIC and FCC projects, with the significant different that due its more mature status ILC requires more engineering power, relatively seen.

2.2. SRF PRODUCTION – THE PREPARATION PHASE

According to the EPP, and considering the above-sketched assumptions, European SRF activities for the ILC in the preparation phase could develop along four main axes (note that we do not discuss here in detail any other components than SRF, in contrast to the EPP [1]):

- Cavity fabrication and preparation (possibly led by DESY) with a view towards cost reduction, better reproducibility, and higher yield, new preparation procedures, and on knowledge and technology transfer to industry.
- Fundamental power couplers (possibly led by CNRS LAL-Orsay) would focus on value engineering of RF coupler production and relevant industrialisation studies. One goal would be a more efficient, streamlined and cost effective coupler production.
- Automation of module assembly (CEA-Saclay): This package would focus on the implementation of robotics in the string and module assembly (reduction of assembly costs, elimination of assembly mistakes, standardisation of procedures, …).
- Inter-laboratory dissemination: The former European XFEL collaborating institutes, led by DESY, could initiate a process of dissemination of know-how and experience across ILC partner labs on issues which require global developments and solutions beyond the borders of the three regions, such as: module transport, RF tests and RF distribution, tunnel layout and installation, beam commissioning and operation.

Organisationally, the preparation phase could follow the model of the MoU-based project studies CLIC and FCC currently ongoing at CERN: These operate through international collaborations with more than 50 institutes each. A similar collaboration could be set up for an European ILC preparatory project running from 2019 to 2022 and providing a basis for preparing the European participation in the ILC and for formalized discussions on project structure, European funding, governance issues, and European deliverables. This collaboration could be funded partly by CERN and partly by outside collaboration partners, as is the case also for CLIC and FCC.

2.3. SRF PRODUCTION – THE CONSTRUCTION PHASE

As has been discussed above, European institutions – laboratories and industries – are capable of productng virtually any component of the ILC. As there are no formal negotiations ongoing, the EPP cannot suggest a specific model – the actual European contribution having to be be defined by negotiations at a later stage and no formal commitment being possible at this stage. However, the EPP makes four clear points for the construction phase:

- All models for the external contributions to the project are focussed on some parts of the non-CFS (civil engineering and conventional facilities) components of the ILC accelerator. The CFS work and components will naturally be constructed in — and installed and commissioned by — the host nation. Given European expertise, it is widely assumed that a dominating fraction of the European in-kind contribution will be in the form of cryomodules. However, a European contribution to ILC would naturally include other items in addition to cryomodules. In this context – related to European capabilities and expertise – it is important to notice that the European XFEL project at DESY corresponds to around 16% of the non-CFS ILC project.
- European industry will be very competitive —- relying on the expertise and experience for the European XFEL, ESS also LCLS-II at SLAC — to provide industrial production capacity for not only European in-kind deliverables, but also to other construction centres.
- For the construction phase spending, the majority of the linear accelerator associated costs (SCRF cryomodule, HLRF and controls) are assumed to scale with the production rate of cryomodules, over an approximately seven-year period. As a result the major spending during the ILC construction phase can be expected in years four through seven, i.e. 2026-9, when the HL-LHC upgrade will have been completed.
- The financial contribution to the detector construction and operation is typically assumed to be proportional to the number of authors of the detector collaboration. To gauge the potential interest within Europe, the European involvement in ongoing experiments can be used. The European share in the energy-frontier LHC detectors ATLAS and CMS at CERN is about 48% while the European share in the Belle II experiment at KEK is about 38%.

The organizational structure of the European contribution during the construction phase is not known today. However, a significant document was approved by Council [3] during the enlargement process in 2009–2010 concerning the organisation of large international projects, referred to as “global projects”. The CERN Council document states that a participation in global projects, like a European participation in the ILC in Japan, can be organised through

CERN, i.e. the coordination of European participation in global projects elsewhere is considered to be within the mandate of the organisation.

Also relevant is the relationship between CERN Council and the European Commission. CERN oversees the execution of the European strategy for particle physics and cooperates with the EC in its implementation, and CERN Council, based on the European strategy for particle physics, provides input to the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI). It is therefore clearly very important that the European participation in the ILC is fully confirmed in the next European strategy update.

Given the physics interests in a future e^+e^- accelerator, the ILC project is likely to imply a substantial investment from the European perspective. Various financing models for European contribution can be envisaged. The organisation of the European efforts towards a coherent contribution to ILC from Europe, scientifically and technically with CERN in a central coordinating role, seems to be the most realistic and effective scenario.

3. CONCLUSIONS

With the discussed preparation plan, and together with the KEK ILC Action Plan, a sound basis for tackling the task of sharing the work of ILC construction between the various potential players in the game has been laid. Once green light for ILC construction is given, and funding agencies have agreed on their individual contributions to the project, the plans can serve as blueprints and can easily be filled with life, detailing the individual contributions not only to the SRF components, but to the entire ILC machine.

REFERENCES

[1] P. Bambade et al., *Preparation Plan for the European Participation in the International Linear Collider*. Submitted to CERN Council, June 2018.

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[3] Council Working Group on the Scientific and Geographical Enlargement of CERN, Global accelerator projects and their governance. 154th Session of Council, 2010 (access restricted).