FCC Special Technologies Work Package

Dr. José Miguel JIMENEZ
Dr. Olivier BRUNNER

FCC Special Technologies
Mandate

- Study the special technologies including conceptual aspects required for the FCC accelerator and identify the possible design and performance limitations for the accelerator.
- Identify challenges, opportunities for technological breakthroughs and set the R&D program.
  - Understand impacts of technologies
  - Prioritize R&D topics
  - Define scope, schedule, cost guidelines
  - Reporting on Specific Technologies R&D Programs
- Set up collaborations to address standard FCC issues and R&D opportunities

- The R&D activities will then be followed in the frame of the Accelerator R&D Work Package which is sub-divided in three Sub-Work Packages:
  - High field Magnet Program
  - Superconducting RF Program
  - Special Technology Program (all except Magnet and RF)

Introduction

- Special technologies are fundamental for this study

  Need to identify the challenges, the showstoppers…

  …and the opportunities for technology breakthroughs.

  This last point will complement perfectly the Physic Cases to get an approval for the next step…

  …and these are the domains where we need your help.

Introduction

- Magnets and RF cavities
  - are the driving accelerator components which come in mind when addressing FCC hh and ee respectively…
- However other components must follow:
  - All impacted by Beam-induced dynamic effects such as:
    - Vacuum, proximity cryogenics and beam instrumentation.
    - FCC hh and ee will have all complexities of SR Facilities
  - All which are energy related: injection and extraction kickers, septa, electronics…
  - All which are Power related: collimators, beam dump
- Thus decided to rearrange the WBS accordingly.

FCC Special Technologies

WBS items for FCC-hh, FCC-ee and FCC-he

- Energy related
  - Beam transfer elements requirements and conceptual design
- Power related
  - Collimation systems and absorber requirements and conceptual design
  - Dump and stopper requirements and conceptual design
- Beam related
  - Vacuum system requirements and conceptual design
  - Proximity cryogenics for superconducting magnets and RF
  - Beam diagnostics requirements and conceptual design
- Reliability related
  - Machine protection system requirements and conceptual design
  - Quench protection and stored energy management requirements and concepts
- Radiation related
  - Shielding
  - Normal magnet requirements and element conceptual design
- Accelerator related
  - Machine detector interface system needs and conceptual design
  - RF system requirements and conceptual design
  - Power converter requirements and conceptual design
  - Control system requirements
  - Element support, survey and alignment requirements and concepts

FCC Special Technologies
Setting the Work Package

- Since the Collaboration meeting held in September and using similar approach than for EuroCirCol:

- Progress has been made towards identification of critical items:
  - Definition of scope, deliverables and milestones;
  - All information has been summarised in a document (can be downloaded from (indico).

- CERN resource impact has been evaluated in order to provide feedback to potential partners.

FCC Special Technologies

Items included in Work Package (1/2)

- 1 EuroCirCol WP4 proposal
  - 1.1 Cryogenic beam vacuum system conception
- 2 Cryogenics challenges
  - 2.1 Magnetic refrigeration for SC RF cavities
  - 2.2 Proximity Cryogenics for FCC-hh
- 3 Beam Transfer challenges
  - 3.1 Kicker generator with solid state switch technology
  - 3.2 Kicker magnet R&D
  - 3.3 Septum magnet R&D
  - 3.4 Fast electronics, triggering and switch controls
- 4 Manufacturing technologies
  - 4.1 High velocity forming of superconducting RF structures
  - 4.2 Additive manufacturing for RF structures
  - 4.3 Novel materials for the high-energy frontier
- 5 Normal Conducting magnets
  - 5.1 Radiation hard easily pluggable normal conducting coils and ancillaries
  - 5.2 Compact magnets & air cooled windings
- 6 Transverse Feedback systems
  - 6.1 Transverse Feedback (TFB)

FCC Special Technologies
Items included in Work Package (2/2)

- 7 Collimators & Dumps energy simulations
  - 7.1 Energy Simulation Challenges: Best Materials for Collimators and Dumps?
  - 7.2 Beam induced damage and hydrodynamic tunnelling
  - 7.3 Remote handling and impact on Accelerator design & Infrastructures
- 8 Beam Instrumentation
  - 8.1 Beam loss monitors (BLM) for FCC-hh
  - 8.2 Beam size measurement for FCC-hh
  - 8.3 Beam instrumentation (others)
- 9 Beam Vacuum
  - 9.1 FCC hh Vacuum challenges
  - 9.2 FCC ee Vacuum challenges
  - 9.3 HTS Coating techniques for impedance mitigation
- 10 Insulation Vacuum
  - 10.1 Helium leaks mitigation
- 11 Radiation Hardness of Electronics
  - 11.1 Radiation Hardness Assurance (RHA)
- 12 Magnets & Machine protection
  - 12.1 Architecture of powering and protection systems for high field circuits
  - 12.2 Concept & Architecture of the machine protection and interlock systems
  - 12.3 HTS magnet protection

Dr. José Miguel JIMENEZ (Coordinator)
CERN, Technology Department
Dr. Olivier BRUNNER (Deputy Coordinator)
CERN, Beams Department

FCC Special Technologies

Items included in Work Package – with details

1 EuroCirCol WP4 proposal [by F. PEREZ (ALBA)]

- 1.1 Cryogenic beam vacuum system conception
  - (see next slide)

FCC Special Technologies
Items included in Work Package – with details

EuroCirCol (WP4): Cryogenic beam vacuum system conception

- Objectives
  - Evaluate the impact of the arc design on technology requirements
  - Develop an overall, integrated design for the cryogenic beam vacuum system consisting of (1) beam-screen, (2) proximity cryogenics, (3) magnet cold bore and (4) vacuum system
  - Determine the needs for advancing individual technologies to meet the requirements
  - Study synchrotron radiation heat load absorption and mitigation of the photo-electrons generation
  - Consider novel mitigation techniques, e.g. based on frequent discrete photon absorbers
- Description of Work
  - Task 4.1: Work Package Coordination (ALBA)
  - Task 4.2: Study beam-induced vacuum effects (ALBA, CERN)
  - Task 4.3: Mitigate beam-induced vacuum effects (STFC, CERN)
  - Task 4.4: Study vacuum stability at cryogenic temperature (INFN, CERN)
  - Task 4.5: Develop conceptual design for cryogenic beam vacuum system (CERN, CIEMAT)
  - Task 4.6: Measurements on cryogenic beam vacuum system prototype (KIT, INFN, CERN)

** Collaboration with KEK Photon Factory for measurements @ warm of photo-desorption and photo-electron yields of different materials under variable angle of incidence.*
** similar studies but @ cryogenic temperature being discussed with BINP Novosibirsk.*

FCC Special Technologies

Items included in Work Package – with details

1 EuroCirCol WP4 proposal [by F. PEREZ (ALBA)]

- 1.1 Cryogenic beam vacuum system conception
  - (see previous slide)

2 Cryogenics challenges [by L. TAVIAN (CERN)]

- 2.1 Magnetic refrigeration for SC RF cavities
  - Feasibility study on magnetic refrigeration allowing reaching temperature down to 1.6 K with a continuous refrigeration capacity of 5 kW.
- 2.2 Proximity Cryogenics for FCC-hh
  - Conceptual design of the proximity cryogenics for the:
    - Superconducting magnets (FCC-hh)
    - Beam Screen (FCC-hh)

FCC Special Technologies
Items included in Work Package – with details

- 1 EuroCirCol WP4 proposal
  - 1.1 Cryogenic beam vacuum system conception

Objectives
1. Thorough understanding of the electro-hydraulic forming process applied to copper and niobium geometries for Superconducting RF structures. 2. Characterisation and modelisation of copper and niobium for fast forming. 3. Production of a niobium functional structure.
Description of Work
Task 1: learning period, first simple EHF tests on copper and simple geometries Milestone 1: Identification of key project issues and required contributions. Deliverable 1: Report on the state of sheet metal forming for SRF applications, potential of EHF, state-of-the-art, detailed project plan for numerical simulation, forming, testing. Task 2: project programme Milestone 2: production of simulations and formed components Deliverable 2: Report covering EHF tests, comparisons with numerical simulations, testing and qualification of produced structures in copper and niobium. Task 3: application of know-how to structural components Milestone 3: production of a functional, complex geometry SRF component in niobium Deliverable 3: Final structural component, summary report of findings.

FCC Special Technologies
Items included in Work Package – with details

3 Beam Transfer challenges [by B. GODDARD (CERN)]

- 3.1 Kicker generator with solid state switch technology
  - Define key parameters for FCC injection and extraction kickers
  - Investigate individual solid state switch characteristics
  - Design and prototype a solid state inductive adder generator for fast rise time, short kicker pulses
- 3.2 Kicker magnet R&D
  - Define key parameters for FCC injection kicker magnets;
  - Determine shielding required for anticipated FCC beam spectrum;
  - Develop the beam screen to achieve:
    - adequately low, broadband, beam coupling impedance;
    - fast field rise-time;
    - acceptable high voltage behaviour.
  - Develop means of adequately cooling the ferrite yoke

FCC Special Technologies

Items included in Work Package – with details

3 Beam Transfer challenges [by B. GODDARD (CERN)]

- 3.3 Septum magnet R&D
  - Define key parameters for FCC injection and extraction septum magnets;
  - Perform design study for Super Conducting extraction septum;
  - Perform magnetic and mechanical design for high field Lambertson and massless septa;
  - Construct and test one short prototype septum magnet
- 3.4 Fast electronics, triggering and switch controls
  - Investigate mitigation measures for radiation to electronics close to beam
  - Develop concepts for compact fast control electronics close to magnets
  - Develop ultra-high-reliability triggering and synchronisation concepts for highly segmented systems

FCC Special Technologies
Items included in Work Package – with details

4 Manufacturing technologies [by F. BERTINELLI (CERN)]

- 4.1 High velocity forming of superconducting RF structures
  - Thorough understanding of the electro-hydraulic forming process applied to copper and niobium geometries for Superconducting RF structures.
  - Characterisation and modelisation of copper and niobium for fast forming.
  - Production of a niobium functional structure.
- 4.2 Additive manufacturing for RF structures
  - The results will enable the introduction of AM as a qualified, referenced alternative for the production of RF accelerating structures throughout laboratories world-wide.
  - To provide much needed data into the properties of copper and niobium parts manufactured by laser and electron beam sintering, as well as identifying a pathway for developing and introducing new powders for the AM process which will be useful across industry sectors. The innovative concept of the research includes the unusual materials, and the need for good conductivity and UHV properties.
  - Production of a niobium functional structure.

FCC Special Technologies
Items included in Work Package – with details

4 Manufacturing technologies [by F. BERTINELLI (CERN)]

- 4.3 Novel materials for the high-energy frontier
  - Explore and review physical limits of existing materials for Beam Interacting Devices under extreme energy deposition.
  - Research, develop, characterize and model novel materials with the potential to approach or meet FCC challenges for accelerator devices interacting with the particle beam.
  - Adapt and extend state-of-the-art simulation methods to the FCC high energy frontier.
  - Maximize testing capability in HiRadMat and explore complementary testing methods overcoming HiRadMat beam energy and intensity limitations.

FCC Special Technologies

Items included in Work Package – with details

5 Normal Conducting magnets [D. TOMMASINI (CERN)]

- 5.1 Radiation hard easily pluggable normal conducting coils and ancillaries
  - Develop coil insulation materials and schemes for accelerator normal conducting magnets capable of withstanding operational voltages of up to 5 kV after having been exposed to radiation doses of 300 MGy, in presence of humidity and possibly of ozone.
  - Develop fast connectable radiation resistant hydraulic and electrical joints
  - Integrate the above mentioned connection in global solution to enable the construction of “plug-in” magnet units, which would possibly be remotely handled and aligned.
- 5.2 Compact magnets & air cooled windings
  - Compact magnets, decrease costs and footprint, may result in energy efficiency
  - Air-cooled windings, low current density for reduced energy consumption

FCC Special Technologies

Items included in Work Package – with details

6 Transverse Feedback systems [by W. HOFLE (CERN)]

- 6.1 Transverse Feedback (TFB)
  - FCC-hh: focus on specification using CERN LHC ADT experience
    - coupled bunch feedback with options for 5 ns and 25 ns bunch spacing (driven by resistive wall instability fast instability rise times)
    - bandwidth up to 100 MHz for 5 ns option to cover all CBMs
    - injection damping kicker waveform a challenge (ripple), aperture
    - feasibility of intra-bunch GHz feedback (TMCI), R&D in SPS
    - use of feedback for abort gap and injection cleaning waveform a challenge (see LHC)
    - transverse blow-up to counteract synchrotron radiation damping new
    - needed R&D for the technology for kicker and power systems
    - 100 MHz for the 5 ns option, likely base-band with flatter frequency response than LHC
    - TMCI feedback option with GHz technology.
  - FCC-ee: focus on technology using B factory experience
    - coupled bunch feedback with options of down to 20 ns spacing and lower ?
    - beam pick-ups for high frequencies, best frequency and scheme for bunch motion detection
    - signal processing for short bunches, fast ADCs, DACs and processing
    - challenges: feedback algorithms for fast growth times
    - Is TMCI instability an issue?

FCC Special Technologies
Items included in Work Package – with details

7 Collimators & Dumps energy simulations [by R. LOSITO (CERN)]

- 7.1 Energy Simulation Challenges: Best Materials for Collimators and Dumps?
  - Study of energy deposition
  - Identification of candidate materials
- 7.2 Beam induced damage and hydrodynamic tunnelling
  - Study of the limits
- 7.3 Remote handling and impact on Accelerator design & Infrastructures
  - Evaluate the compatibility of the LHC integration with remote handling and propose a new concept of acceleration-infrastructure interface which will ease this remote handling.
  - Development of radiation tolerant positioning systems including actuation and position sensing with submicrometer accuracy and repeatability.
  - Development of a remote handling concept allowing the maintenance and repair of collimators and other activated systems from the control room using telemanipulators.

FCC Special Technologies
Items included in Work Package – with details

8 Beam Instrumentation [by R. JONES (CERN)]

- 8.1 Beam loss monitors (BLM) for FCC-hh
  - Find a viable technology for a large distributed beam loss monitoring system, providing maximal machine coverage and localisation better than 1m.
- 8.2 Beam size measurement for FCC-hh
  - Show the feasibility of using synchrotron radiation for absolute beam size measurement in FCC-hh.
- 8.3 Beam instrumentation (others)
  - Produce a feasibility study for all beam diagnostic instruments required for the FCC-hh and FCC-ee options

FCC Special Technologies
Items included in Work Package – with details

9 Beam Vacuum [by P. CHIGGIATO (CERN)]

- 9.1 FCC hh Vacuum challenges
  - Find out the best materials and surface coatings for the FCC-hh arcs beam pipe (and/or) beam screen in terms of performance, feasibility, and costs.
  - Provide inputs for instability simulations (Secondary electron Yield, Reflectivity & Photon Yield) for all material and material coatings at all relevant temperatures.
  - Validate full compatibility of chosen materials with all vacuum issues, impedance and other relevant aspects.
- 9.2 FCC ee Vacuum challenges
  - Find out the best vacuum system for the FCC-ee arcs and experimental regions in terms of performance, feasibility, and costs.
- 9.3 HTS Coating techniques for impedance mitigation
  - Feasibility study of HTS coatings for the reduction of the beampipe impedance of FCC-hh

10 Insulation Vacuum [by P. CHIGGIATO (CERN)]

- 10.1 Helium leaks mitigation
  - Study the feasibility of an alternative/complementary pumping in the insulation vacuum of the FCC-hh, for example pumping by cryosorption.

FCC Special Technologies
Items included in Work Package – with details

11 Radiation Hardness of Electronics [M. CAPEANS (CERN)]

- 11.1 Radiation Hardness Assurance (RHA)
  - FCC will need a massive amount of electronic systems in the accelerator tunnel, the Particle Detectors, and in the side galleries to control and monitor the various infrastructures and systems such as power converters, vacuum, cryogenics, RF systems, etc.
    - One challenge for control and powering systems of the FCC will be linked to the size of the installation, thus requiring: (i) high availability of systems; (ii) alternative powering and communication technologies; (iii) long-distance maintenance options.
    - Radiation levels at FCC will roughly scale with energy and, as LHC has shown, degradation of components under radiation can become a major showstopper.
  - Two parallel and complementary approaches are needed: reduce equipment dose by developing shielding for service electronics, and develop electronics and equipment radiation resistant to FCC radiation levels.
  - The FCC R&D on Radiation Hardness Assurance (RHA) deals with the last aspect, and in particular:
    - RHA consists of all activities undertaken to ensure that the electronics and materials developed for FCC perform to their design specifications after exposure to the FCC radiation environment.
    - RHA deals with environment definition, part selection, part testing, radiation tolerant design, and FCC subsystems requirements.

FCC Special Technologies

Items included in Work Package – with details

12 Magnets & Machine protection [by A. SIEMKO (CERN)]

- 12.1 Architecture of powering and protection systems for high field circuits
  - Propose architectures and technologies for the protection of high field circuits. Towards future accelerators, opportunities are immediate and shall include operational aspects, for example, remote controls to minimise First Line interventions and maintenances.
- 12.2 Concept & Architecture of the machine protection and interlock systems
  - Develop the architecture of the machine protection and interlock system for a larger accelerator scale as compared to LHC.
- 12.3 HTS magnet protection
  - Study and propose a detection method applicable for hybrid magnets with HTS inserts, including cold powering systems (links and current leads).

FCC Special Technologies

Items included in Work Package – with details

And similarly,

Deliverables and milestones have been defined…

FCC Special Technologies
Work Package Deliverables & Milestones

1 EuroCirCol WP4 proposal [ALBA & TE-VSC]	Expected
1.1 Cryogenic beam vacuum system conception	
D4.1: Analysis of vacuum stability at cryogenic temperature	**M22**
D4.2: Measurements of vacuum chamber at light source	**M28**
D4.3: Preliminary beam screen and beam pipe engineering design	**M29**
D4.4: Analysis of beam-induced vacuum effects	**M36**
2 Cryogenics challenges [by Laurent TAVIAN (TE-CRG)]	
2.1 Magnetic refrigeration for SC RF cavities	
D1. Deliver a study report on new architectures and technologies	**M30**
2.2 Proximity Cryogenics for FCC-hh	
D1. Deliver the PhD thesis on the conceptual design	**M36**

FCC Special Technologies
Work Package Deliverables & Milestones

3 Beam Transfer challenges [by Brennan GODDARD (TE-ABT)]	
3.1 Kicker generator with solid state switch technology	
D1: Detailed proposal	M2
D2: Concepts and parameters	M6
D3: Components and design	M24
D4: Construct prototype	M36
D5: Test prototype	M42
D6: Document results	M48
3.2 Kicker magnet R&D	
D1: Detailed proposal	M2
D2: Concepts and parameters	M6
D3: Beam screen design	M30
D4: Ferrite cooling design	M30
D5: Construct prototype screen	M36
D6: Test prototype	M42
D7: Document results	M48
3.3 Septum magnet R&D	
D1: Detailed proposal	M2
D2: Concepts and parameters	M6
D3: SC septum design study	M18
D4: Magnetic material selection	M18
D5: Magnetic design	M30
D6: Build prototype	M36
D7: Test prototype	M42
D8: Document results	M48
3.4 Fast electronics, triggering and switch controls	
D1. Technical report	M12
D2. Radiation mitigation	M18
D3. New sensor pilot project	M30
D4. Triggering and synchronisation test bench	M42
D5. Document results	M48

FCC Special Technologies
Work Package Deliverables & Milestones

4 Manufacturing technologies [by Francesco BERTINELLI (EN-MME)]	
4.1 High velocity forming of superconducting RF structures	
D1. First simple EHF tests	**M6**
D2. Project programme	**M24**
D3. Application of know-how to structural components	**M6**
4.2 Additive manufacturing for RF structures	
D1. Report: mechanical properties of copper parts (mechanical, conductivity).	**M24**
D2. Report: mechanical properties of niobium parts (mechanical, conductivity).	**M24**
D3. Report: suitability of parts for UHV applications.	**M36**
D4. Dissemination of results through journal paper(s) and conference presentation(s).	**M48**
4.3 Novel materials for the high-energy frontier	
D1. Detailed Proposal (specification, timeline, resources, collaborations setup …)	**4**
D2.Characterization campaign of existing materials	
D2-1. Data analysis of performed experimental tests and literature review	**18**
D2-2. Report on existing materials	**24**
D3. Research and development of novel materials	
D3-1. Optimize manufacturing processes of advanced materials	**18**
D3-2. Explore and test advanced coating concepts	**24**
D3-3. Design proposal for advanced collimators	**36**
D3-4. Develop and characterize novel graphitic materials	**48**
D4. Simulation methods for the high energy frontier	
D4-1. Identify suitable numerical tools for simulations of extreme phenomena	**12**
D4-2. Consolidate database on constitutive models for existing materials	**18**
D4-3. Coupling between FLUKA and Autodyn for extreme cases	**24**
D4-4. Simulate and benchmark extreme cases with alternative hydrodynamic codes	**36**
D5. Experimental methods and tests	
D5-1. Perform experiment in HiRadMat on multi-material test-bench	**18**
D5-2. Thermo-physical and metallurgical testing of existing materials	**18**
D5-3. High strain-rate, high temperature mechanical testing of advanced materials	**36**
D5-4. Explore and perform alternative testing methods with high energy facilities	**48**

FCC Special Technologies
Work Package Deliverables & Milestones

5 Normal Conducting magnets [Davide TOMMASINI (TE-MSC)]	
5.1 Radiation hard easily pluggable normal conducting coils and ancillaries	
D1: Coil Insulation (Complement to activities in the frame of LHC Consolidation and HL-LHC)	
D1-1: Review of the available information and identification of the 2-3 most interesting technologies, proposal of a detailed test plan (radiation mechanics and electric)	**M12**
D1-2: Test of the selected technology in the virgin state	**M18**
D1-3: Result of 1st tests after low number of fatigue cycle and low radiation dose	**M24**
D1-4: Result of 2nd tests with full number of fatigue cycle and high radiation dose	**M36**
D2: Hydraulic fittings	
D2-1: Review of the state of the art, proposals of technologies and related test plan	**M12**
D2-2: Results of the test campaign on virgin samples	**M18**
D2-3: Results of the test campaign on samples submitted to the relevant life cycle	**M24**
D3: Electrical connections	
D3-1: Review of the state of the art, proposals of technologies and related test plan	**M12**
D3-2: Results of the test campaign on virgin samples	**M18**
D3-3: Results of the test campaign on samples submitted to the relevant life cycle	**M24**
D4: Proposal of a solution integrating the alignment, electrical connection and hydraulic fittings for fast assembly	**M48**
5.2 Compact magnets & air cooled windings	
D1. Small aperture, requires high precision and tight tolerances	**M36**
D2. Alternative yoke materials (Fe-Co)	**M36**
D3. Study low current density for reduced energy consumption	**M36**
6 Transverse Feedback systems [by Wolfgang HOFLE (BE-RF)]	
6.1 Transverse Feedback (TFB)	
D1. Freeze machine parameters for study	**M6**
D2. Input from ABP and ABT to feedback design	**M12**
D3. Coupled bunch feedback conceptual design frozen	**M15**
D4. SPS TMCI feedback study completed sufficiently to conclude	**M18**
D5. Decision on need and implementation of a TMCI feedback	**M24**
D6. Detailed work	**M36**

FCC Special Technologies

Work Package Deliverables & Milestones

7 Collimators & Dumps energy simulations [by Roberto LOSITO (EN-STI)]	
7.1 Energy Simulation Challenges: Best Materials for Collimators and Dumps?	
D1. Provide a reliable account of the radiation shower	**M12**
D2. Calculate thermal load and structural damage	**M24**
7.2 Beam induced damage and hydrodynamic tunnelling	
D1. Identify partners for material characterisation	**M12**
D2. Test candidate materials in HiRadMat	**M36**
7.3 Remote handling and impact on Accelerator design & Infrastructures	
D1. Development of the remote handling concept	**M12**
D2. Integration study for the remote handling/manipulation	**M36**
D3. Irradiation test of present equipment	**M36**
D4. Development of the concept for an easily disposable collimator	**M24**
D5. Study of disposal options	**M24**
8 Beam Instrumentation [by Rhodri JONES (BE-BI)]	
8.1 Beam loss monitors (BLM) for FCC-hh	
D1: Report on existing technologies	**M12**
D2-1: Setting an experimental program	**M24**
D2-2: Results of the experimental program	**M36**
8.2 Beam size measurement for FCC-hh	
D1: Result on best wavelength	**M12**
D2: Conceptual design	**M36**
8.3 Beam instrumentation (others)	
D1: Procedure of feasibility study	**M24**

FCC Special Technologies

Work Package Deliverables & Milestones

9 Beam Vacuum [by Paolo CHIGGIATO (TE-VSC)]	
9.1 FCC ee Vacuum challenges	
D1: Detailed proposal	M3
D2: formalize economic aspects of proposal	M6
D3: Define access to Synchrotron Radiation at BESSY 2	M24
D4: Production and mechanical analysis of test samples	M36
D5: experimental work on test samples	M42
D6: Document results	M48
9.1 FCC ee Vacuum challenges	
D1-1: Scale-up from LEP	M12
D1-2: Option with localised absorbers	M18
D1-3: Option with extensive use of NEG coatings	M24
D2: Cost evaluation of 3 options	M30
D3-1: Prototype of dipole	M30
D3-2: Prototype of dipole tested under SR	M36
9.2 HTS Coating techniques for impedance mitigation	
D1: Identify best deposition techniques	M24
D2: Measurement of electronic properties	M30
D3: Vacuum performances of coatings	M36
D4: RadTol of the coatings in particular superconducting properties	M36
10 Insulation Vacuum [by Paolo CHIGGIATO (TE-VSC)]	
10.1 Helium leaks mitigation	
D1: Literature review on similar topic	M6
D2: Proposal of adsorbers materials	M12
D3-1: Prototype of adsorber available	M24
D3-2: Prototype of adsorber measured	M36

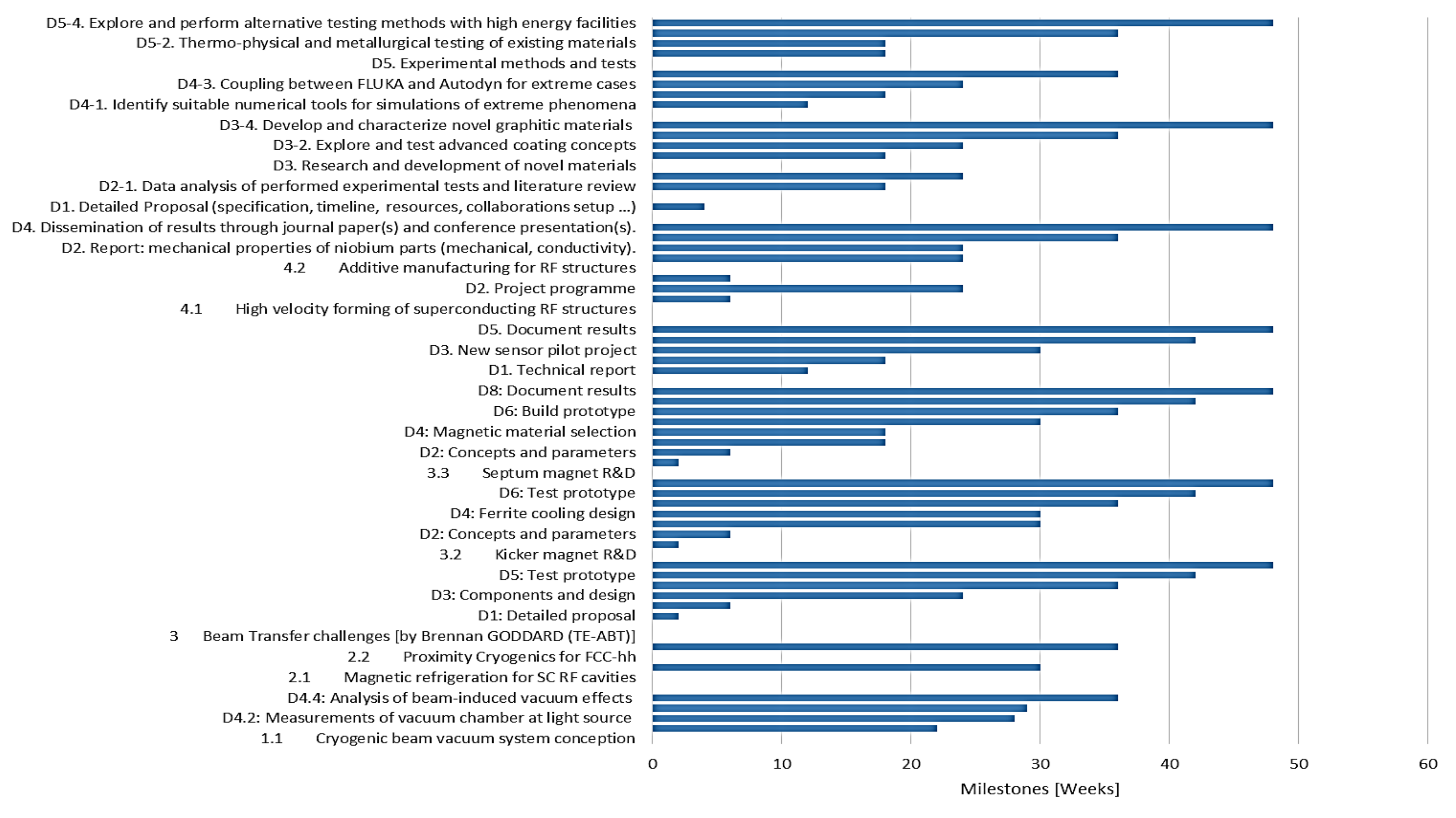
Dr. José Miguel JIMENEZ (Coordinator)
CERN, Technology Department
Dr. Olivier BRUNNER (Deputy Coordinator)
CERN, Beams Department

FCC Special Technologies
Work Package Deliverables & Milestones

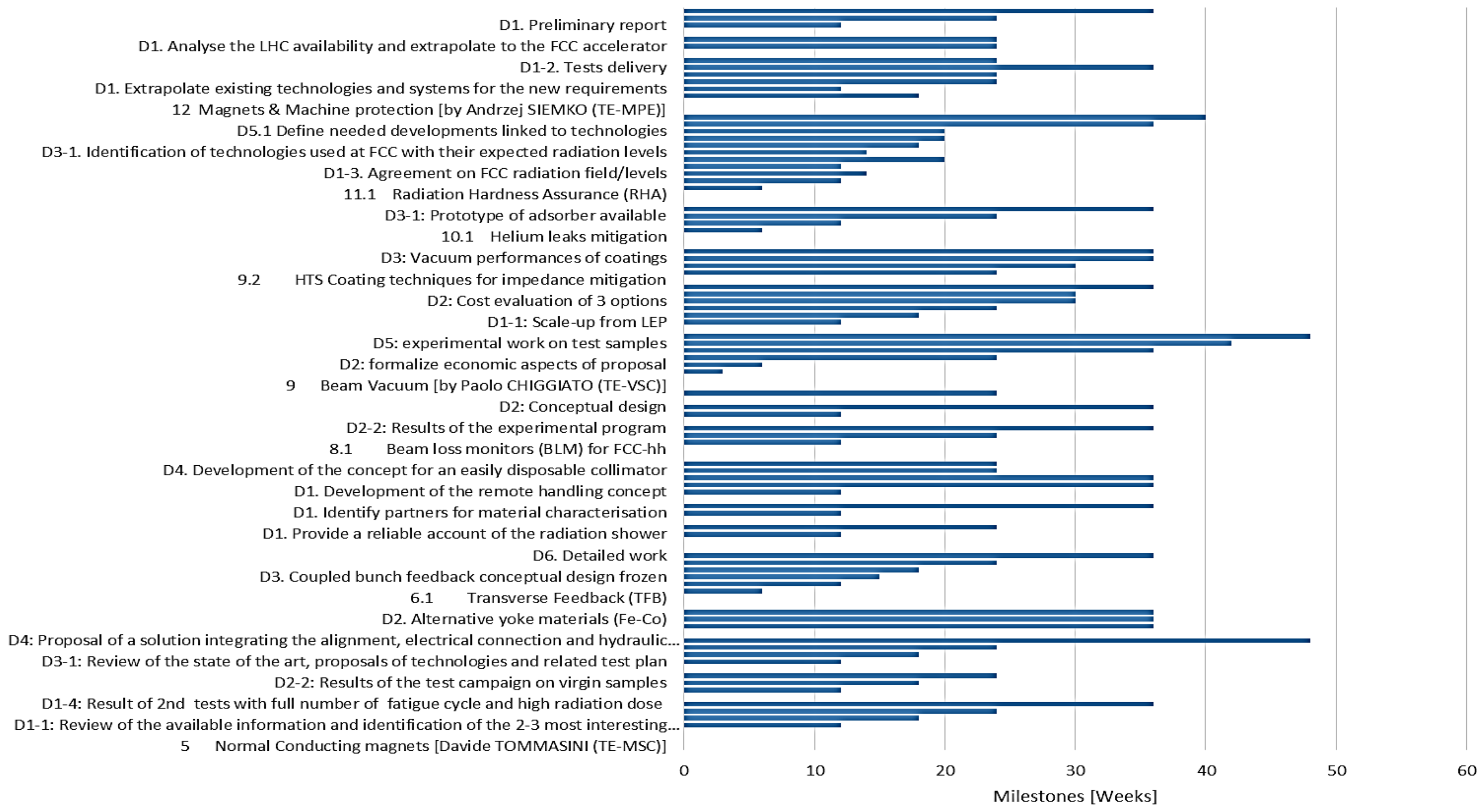
11 Radiation Hardness of Electronics [Mar CAPEANS (PH-DT)]	
11.1 Radiation Hardness Assurance (RHA)	
D1-1. Evaluation of FLUKA models' needs	**M6**
D1-2. FLUKA tuning for FCC	**M12**
D1-3. Agreement on FCC radiation field/levels	**M14**
D2-1. Define FCC qualification requirements	**M12**
D2-2. Evaluation of current irradiation facilities and testing infrastructure	**M20**
D3-1. Identification of technologies used at FCC with their expected radiation levels	**M14**
D3-2. Catalogue of critical equipment (technology, supplier, function, etc.)	**M18**
D4.1 Evaluate HL-LHC VS FCC needs of rad hard components	**M20**
D5.1 Define needed developments linked to technologies	**M20**
D5.2 Radiation tester of advanced components/systems	**M36**
D5.3 Radiation sensor	**M40**
12 Magnets & Machine protection [by Andrzej SIEMKO (TE-MPE)]	
12.1 Architecture of powering and protection systems for high field circuits	
D1. Analyse the LHC concept	**M18**
D1. Extrapolate existing technologies and systems for the new requirements	**M12**
D2. Propose new concept for energy dump system	**M24**
D1-1. Report on feasibility based on HL-LHC experience	**M24**
D1-2. Tests delivery	**M36**
D2. Propose required diode parameters	**M24**
12.2 Concept & Architecture of the machine protection and interlock systems	
D1. Analyse the LHC availability and extrapolate to the FCC accelerator	**M24**
D2. Preliminary design report	**M24**
12.3 HTS magnet protection	
D1. Preliminary report	**M12**
D2. Prototype of system	**M24**
D3. Preliminary report of feasibility	**M36**

FCC Special Technologies

Work Package Milestones & Milestones

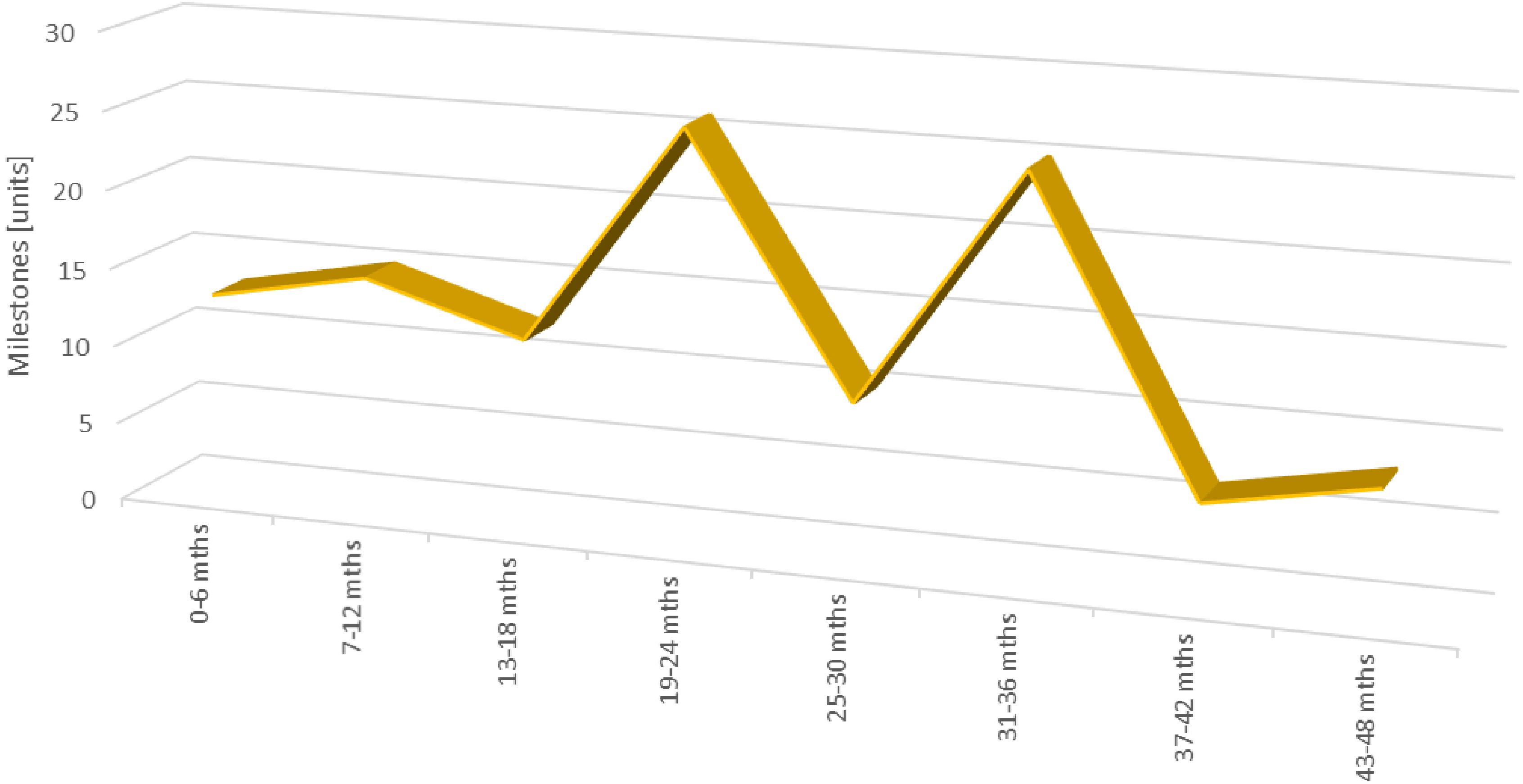


FCC Special Technologies
Work Package Milestones & Milestones



FCC Special Technologies
Work Package Milestones & Milestones

…time is challenging us!



FCC Special Technologies

Items included in Work Package – with details

And finally,

CERN Personnel and Material assessments have been defined…

FCC Special Technologies

Work Package CERN Resources (Personnel & Material)

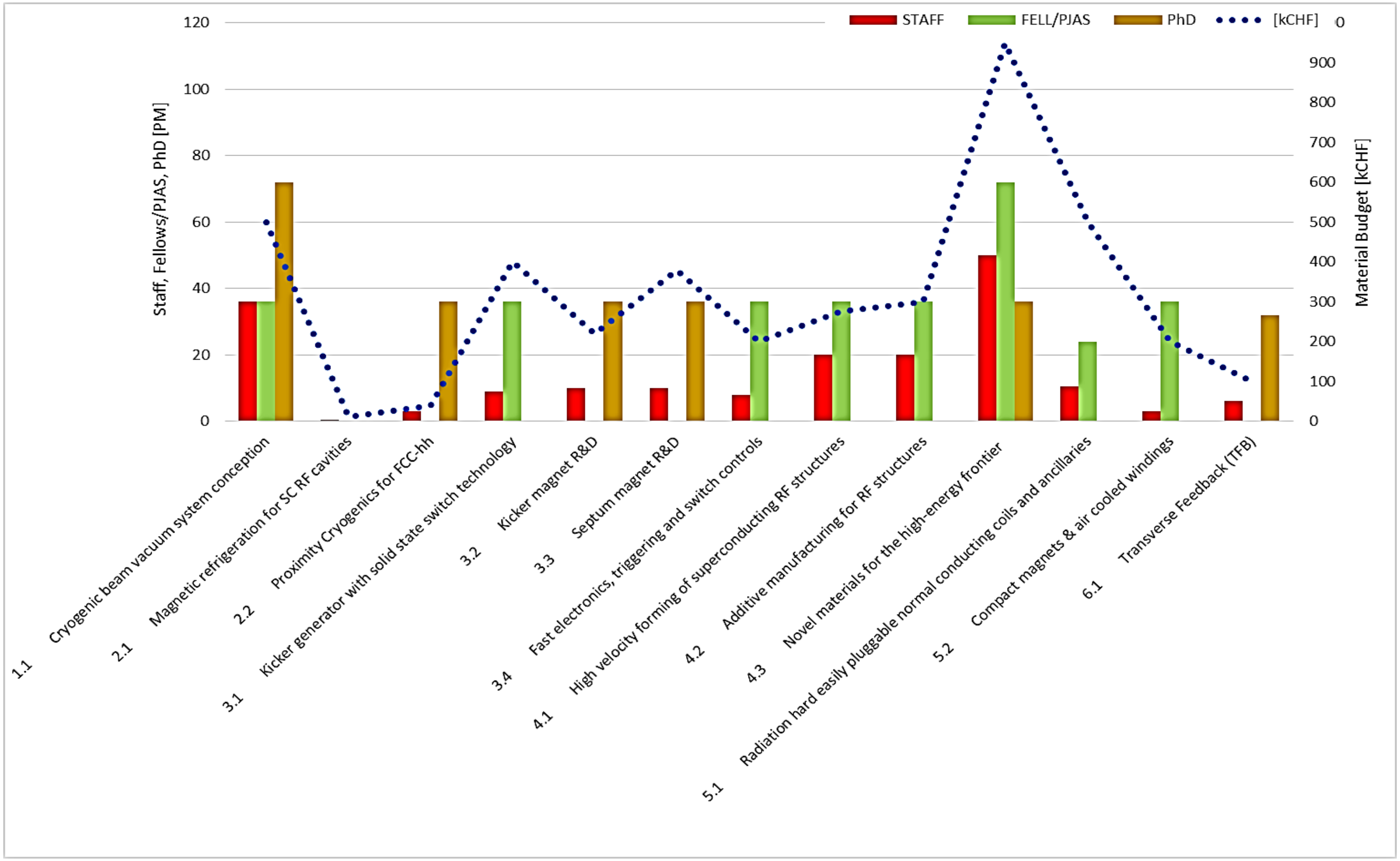
	CERN Resources (Manpower) [PM]			CERN Resources (Material)
	STAFF	FELL/PJAS	PhD	[kCHF]
1 EuroCirCol WP4 proposal [ALBA & TE-VSC]				
1.1 Cryogenic beam vacuum system conception	36	36	72	500
2 Cryogenics challenges [by Laurent TAVIAN (TE-CRG)]				
2.1 Magnetic refrigeration for SC RF cavities	0.5	0	0	10
2.2 Proximity Cryogenics for FCC-hh	3	0	36	40
3 Beam Transfer challenges [by Brennan GODDARD (TE-ABT)]				
3.1 Kicker generator with solid state switch technology	9	36	0	400
3.2 Kicker magnet R&D	10	0	36	220
3.3 Septum magnet R&D	10	0	36	380
3.4 Fast electronics, triggering and switch controls	8	36	0	200
4 Manufacturing technologies [by Francesco BERTINELLI (EN-MME)]				
4.1 High velocity forming of superconducting RF structures	20	36	0	275
4.2 Additive manufacturing for RF structures	20	36	0	300
4.3 Novel materials for the high-energy frontier	50	72	36	950
5 Normal Conducting magnets [Davide TOMMASINI (TE-MSC)]				
5.1 Radiation hard easily pluggable normal conducting coils and ancillaries	10.5	24	0	500
5.2 Compact magnets & air cooled windings	3	36	0	200
6 Transverse Feedback systems [by Wolfgang HOFLE (BE-RF)]				
6.1 Transverse Feedback (TFB)	6	0	32	100
7 Collimators & Dumps energy simulations [by Roberto LOSITO (EN-STI)]				
7.1 Energy Simulation Challenges: Best Materials for Collimators and Dumps?	6	24	0	50
7.2 Beam induced damage and hydrodynamic tunnelling	8	0	36	400
7.3 Remote handling and impact on Accelerator design & Infrastructures	9	60	0	960

FCC Special Technologies

Work Package CERN Resources (Personnel & Material)

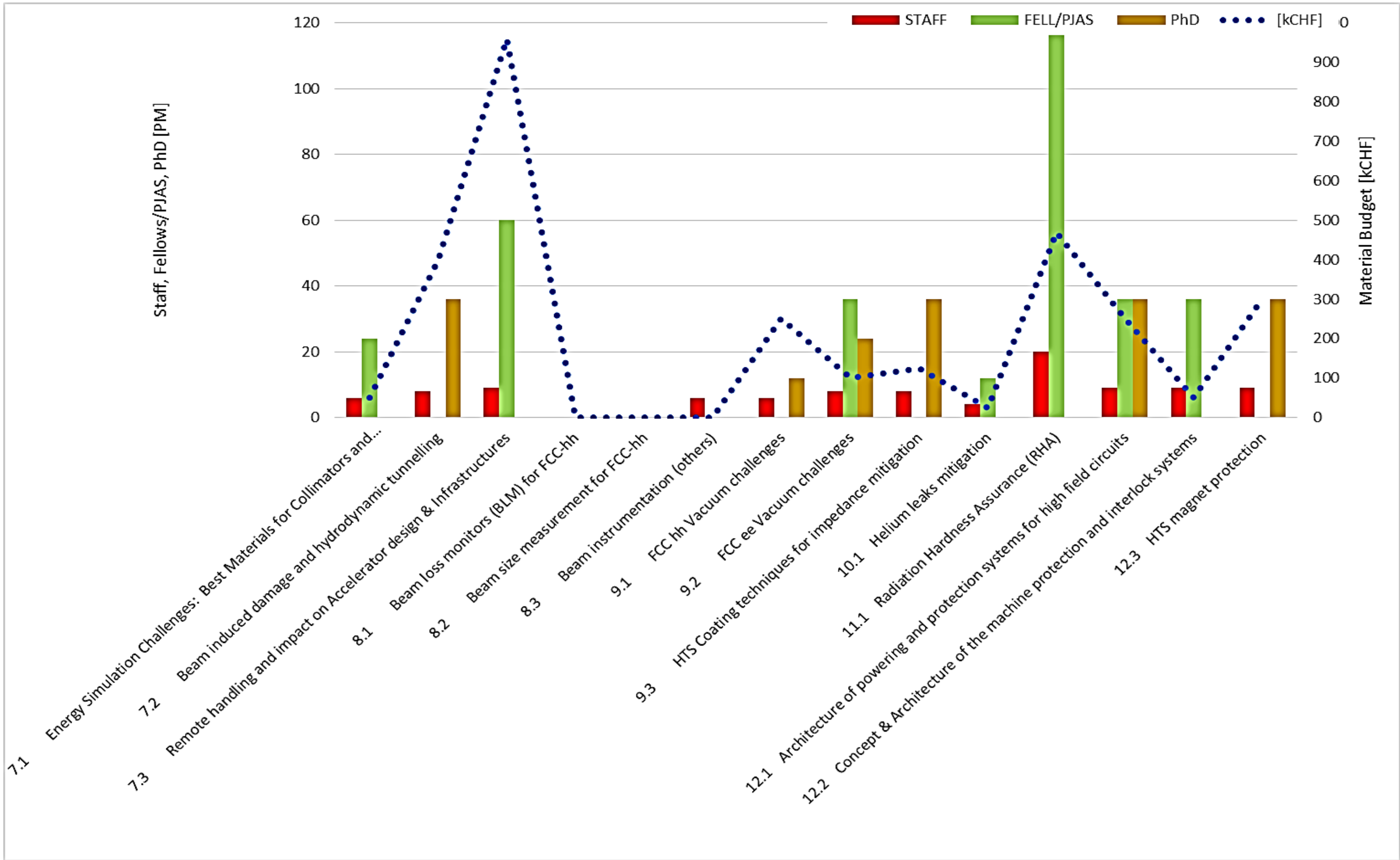
	CERN Resources (Manpower) [PM]			CERN Resources (Material)
	STAFF	FELL/PJAS	PhD	[kCHF]
8 Beam Instrumentation [by Rhodri JONES (BE-BI)]				
8.1 Beam loss monitors (BLM) for FCC-hh	0	0	0	0
8.2 Beam size measurement for FCC-hh	0	0	0	0
8.3 Beam instrumentation (others)	6	0	0	0
9 Beam Vacuum [by Paolo CHIGGIATO (TE-VSC)]				
9.1 FCC hh Vacuum challenges	6	0	12	250
9.2 FCC ee Vacuum challenges	8	36	24	100
9.3 HTS Coating techniques for impedance mitigation	8	0	36	125
10 Insulation Vacuum [by Paolo CHIGGIATO (TE-VSC)]				
10.1 Helium leaks mitigation	4	12	0	25
11 Radiation Hardness of Electronics [Mar CAPEANS (PH-DT)]				
11.1 Radiation Hardness Assurance (RHA)	20	120	0	470
12 Magnets & Machine protection [by Andrzej SIEMKO (TE-MPE)]				
12.1 Architecture of powering and protection systems for high field circuits	9	36	36	250
12.2 Concept & Architecture of the machine protection and interlock systems	9	36	0	50
12.3 HTS magnet protection	9	0	36	300

FCC Special Technologies
Work Package CERN Resources (Personnel & Material)



FCC Special Technologies

Work Package CERN Resources (Personnel & Material)



FCC Special Technologies

Program for Washington Workshop (1/5)

- A unique place to discuss opportunities of Collaborations…
- Special Technologies got a wide schedule program!

FCC Special Technologies
Program for Washington Workshop (1/5)

- Plenary Session (Monday 23/3, 16.00 – 17.00)
  - Special Technologies Overview [J.M. Jimenez (CERN)]

- **Session 1 (Wednesday 25/3, 17.30 – 19.00)**
  Cryogenic Beam Vacuum System Conception
  - Cryogenic beam vacuum specificities applicable to FCC hh
    [V. Baglin (CERN)]
  - Cold test stands for cryogenic beam vacuum qualification
    [A. Krasnov (BINP)]
  - The KEK photon beamline for desorption studies: preliminary results and plans for future studies in the FCC hh context
    [Y. Tanimoto (KEK)]
  - Present and future surface modifications for the mitigation of electron clouds in cryogenic beam vacuum systems
    [R. Valizadeh (STFC)]
  - Potential countermeasures against the very large SR heat load in FCC-hh
    [R. Cimino (LNF-INFN)]

FCC Special Technologies
Program for Washington Workshop (2/5)

- **Session 2 (Thursday 26/3, 08.30 – 10.00)**
  Technologies R&D

  - Potential reduction of the beam impedance by using HTS coating technology (incl. FCC hh compatibility issues)
    [G. Stupakov (SLAC)]
  - R&D on non-invasive beam profile measurements
    [A. Jeff, Univ. of Liverpool]
  - RadHard Warm Magnet Coils
    [P. Fessia (CERN)]
  - Study of a Magnetic Refrigeration Stage
    [F. Millet, CEA]

FCC Special Technologies

Program for Washington Workshop (3/5)

- **Session 3 (Thursday 26/3, 10.30 – 12.00)**
  Beam Transfer & Instrumentation

  - Superconducting Septa and Fast Ramped Cos Theta Magnets
    [E. Fischer (GSI)]
  - Further R&D on beam instrumentation for HE proton colliders
    [H. Schmickler (CERN)]
  - Semiconductor Switch designs
    [M. Barnes (CERN)]
  - Beam Dump concepts & Design
    [W. Bartmann (CERN)]

FCC Special Technologies

Program for Washington Workshop (4/5)

- **Session 4 (Thursday 26/3, 13.30 – 15.00)**
  Beam Dump & Collimators: Materials & Engineering breakthroughs

  - Evolution and Limits of the Present Collimation Materials Studies
    [A. Bertarelli (CERN)]
  - Energy Deposition Challenges: Best Materials for Collimators?
    [A. Lechner (CERN)]
  - State-of-the-Art and Future of Additive Manufacturing
    [D. France (3T RPDT)]
  - Photon absorbers, can we expect a revolution with 3D printing?
    [S. Scott (UK Diamond Synchroton Light Source)]

FCC Special Technologies

Program for Washington Workshop (5/5)

- **Session 5 (Thursday 26/3, 15.30 – 17.00)**
  Magnets (Resistive) & Machine Protection

  - Architecture of powering and protection systems for high field circuits
    [A. Siemko (CERN)]
  - Concept & Architecture of the machine protection systems
    [R. Schmidt (CERN)]
  - Beam induced damage and hydrodynamic tunnelling
    [N. TAHIR (GSI)]
  - R2E technology challenges for the future
    [R. Baumann (Texas Instruments (TI))]

Closing remarks

- Progress made towards identification of critical items;
- Scope, deliverables and milestones are compiled;
- CERN Resource impact evaluated
  - Provides feedback to potential partners;
- Scenario "a la carte", come and talk with us.
- For CERN…
  - Prioritisation to be made following this meeting
  - Feedback and options for collaborations will help arbitrations.

Closing remarks
WP Organisation

- Need regular feedback from hh, ee and he Parameters & Layout

- Meeting once/month (with Video connection)
  - Feedback from sub-WPs
    - Resource implementation
    - Deliverable refinement
    - Milestone tracking
  - Special topics: Report technical difficulties and progresses

- EuroCirCol WP4 Coordination meetings
  - Chaired by F. Perez (ALBA)

Setting Collaborations…

- Range of technologies to be covered is wide

and

- We need be on time within 3 years with the CDR…

- Thus, we would like to focus on:
  - Identified showstoppers.
  - Required technological breakthroughs.

…an evaluation will quickly be made to address and assess the required R&D levels… preventing ourselves to got TDR levels.

We need you on-board!

Acknowledgements

- Many thanks to all contributors who helped us to complete the first version of the scope of the FCC Special Technologies,

- and more specifically: B. Goddard, A. Bertarelli, F. Bertinelli, M. Capeans, P. Chiggiato, A. Dallocchio, G. Favre, P. Fessia, W. Hofle, R. Jones, A. Kasnov, R. Losito, O. Malichev, A. Siemko, Y. Tanimoto, L. Tavian, D. Tommasini.

CERN