FCC RF Coordination Meeting

September 23, 2016

2016 in a nutshell (1)

FCC-ee RF mini review

8 March 2016
CERN
Europe/Zurich timezone

The FCC-ee RF review is a brainstorming related to the conceptual configurations for the FCC-ee SRF system.

This review will address, among others, the following topics:

- Overview and requirements;
- Optimum configurations for different operation points;
- Staging schemes;
- Synergies with hadron collider RF system;
- Basic cavity parameters (frequency, #cells);
- Beam loading compensation and higher order mode damping;
- Consequences of large detuning and low revolution frequency.

The goals are to obtain feedback whether the overall design approach appears sound, to identify a baseline scenario, and to profit from your advice on possible challenges and potential improvements.

Starts 8 Mar 2016 08:30
Ends 8 Mar 2016 21:20
Europe/Zurich

CERN
40-S2-B01 - Salle Bohr

Program

- Welcome and reviews goals (M. Benedikt)
- Introduction to FCC and the main beam parameters for ee and hh (F. Zimmermann)
- Beam dynamics issues for FCC-hh (E. Shaposhnikova)
- Beam dynamics issues for FCC-ee (R. Calaga)
- Status of coating technologies for superconducting applications (A. Sublet)
- Operating SC cavities in CW (S. Aull)
- Interelationships and limits (N. Schwerg)
- Cavity design approaches and HOM damping (S. Gorgi Zadeh)
- RF concepts (O. Brunner)

Reviewers

- Gunther Geschonke, CERN (CH)
- Alban Mosnier, CEA - Saclay IRFU (FR)
- Katsunobu Oide, KEK (JP)
- Flemming Pedersen, CERN (CH)
- Robert Rimmer, Jefferson Lab (US)
- Ursula van Rienen, University of Rostock (DE)

Overall impressions (from the reviewers)

- Much work and thought has gone into evaluating the requirements for the four FCC-ee configurations plus FCC-hh.
- We agree that it is not optimal to try to make one RF configuration cover all options.
- Analysis already highlights some limits that should be examined closely to see if they can be improved by further R&D.
- Physics requirements and beam dynamics limitations drive some parameter choices, it is highly desirable to have some stability in the parameters to allow RF optimization to proceed.

Recommendations – a selection

Possible Challenges and potential improvements

- Instability budgets and impact on RF parameters
- Cavity shape and HOM damping scheme
  - Loss parameter – include tapers and transitions
  - Include th
  - Include be
  - Tailor cavi
  - If HOM po
  - Consider 4
- Power couple
  - Hard (but
- RF power sou
  - One sourc
- High Q_{ext} has
  - Transient
- Lessons learn

Thin film SRF R&D

- Thin film techn
  performance, e
- Recent results
  on 3D cavities.
- Cost savings at
  using typical m
- A15 compound
  long way to go

Cavity Design (UV)

- Better focus right away on two clearly different designs:
  - 1-cell cavity optimized for Z w
    - Low frequency, e.g. 400 MHz
    - R&D in thin-film technology e
  - Multicell cavity optimized for
    - High frequency – check what
    - Do not limit yourself too earl
- Don't stick to only one tradi
  one cavity should be taken i
- Minimize number and lengt
- "Boundary conditions", i.e. l
  fixed as soon as possible, at
  and detailed design studies

Cavity Design and HOM Damping (UV

- Optimize cell shape with regard to HOMs and Multipacting
- Study whole cryostat, n
  - Can be easily done by co
- Damp propagating HOM
- Look out for innovative
  each single cell besides
- In the cavity design not
  based shaped e.g.
- Mechanical fabrication
  design

(6) Beam loading compensation and (higher order mode damping)

- Beam loading in si
  machines: hh, Z, W
- Beam loading is al
  machines, where
  operating at optim
  SC RF)

(1) D. Boussard, P. Brown & J. Tückmant

(7) Consequences of large detuning and low revolution frequency

- Fast growing longitudinal coupled bunch instabilities
- Beam gap induced transients
- For FCC hh, Z & W mach
  reactive beam power co
  fundamental mode imp
  feedback.
- This has an important i
  cavity choice as feedbac
  difficult[2]

(2) D. Boussard, H. P. Kindermann, V. Rossi. RF

Generalities

- Recommendation: start asap instability calculations (analytical and simulations) with a preliminary fixed RF configuration (for both extreme working points: Z-pole and tt_{bar})
  CBI, Rs wall instab, microwve instab, TMCI, …
- Impedance and loss factor: Sum vacuum chamber (extrapolation fr existing rings) + Cavity including tapers (short bunches !)
- Landau damping: Take into account RF modulation (Qs spread) due beam gap

⇒ that's why the WP was reshuffled!

- more emphasis on RF scenarios, parameter layout, cavity design and beam interaction

2016 in a nutshell (2)

Plenary session:

- **RF R&D Overview**, E. Jensen (CERN) *(10')*
- **Special Topic: Towards very efficient RF power amplifiers**, E. Jensen (CERN) *(20')*

RF concepts and directions for R&D *(90')* (B. Rimmer, JLAB)

- **RF system parameters for Z, W, H and tt**, O. Brunner (CERN)
- **Beam dynamics: RF requirements for the FCC-hh and FCC-ee options,** E. Chapochnikova (CERN)
- **Perspective on future challenges for very high energy hadron colliders**, Mike Blaskewicz (BNL)
- **Experience gained with the LHC LLRF system and challenges for FCC**, Ph. Baudrenghien (CERN)

Recent designs and progress *(90')* (U. van-Rienen, Uni Rostock)

- **Overview talk on ERL's**, J. Knobloch (HZB)
- **Cavity Design and Construction Experiences,** G. Hoffstaetter (Cornell) *(overview of concepts)*
- **RF Systems for the JLab Electron Ion Collider,** B. Rimmer (JLAB)
- **First Results of SRF Cavity Fabrication by Electro-Hydraulic Forming at CERN**, E. Cantergiani (FCC Fellow)

Material, cavities and cryomodules R&D *(90')* (J. Knobloch, HZB)

- **Advances on seamless cavities and Nb/Cu coatings,** E. Palmieri (LNL)
- **NB/Cu: advances**, S. Aull (FCC Fellow)
- **Bulk based technologies,** A. Romanenko (Fermilab)
- **Beyond bulk Nb**, AM Valente (JLab)
- **Innovative Nb3Sn Thin Film Approaches and their Potential for Research and Applications**, E. BARZI (Fermilab) *(10'+5')*

RF efficiency optimization *(90')* (E. Jensen, CERN)

- **Energy Efficiency of Particle Accelerators,** John Seeman (SLAC)
- **Advances and results towards super-efficient klystrons**, C. Lingwood (Lancaster Univ)
- **Kladistron – the klystron with adiabatic bunching,** F. Peauger (CEA Saclay)
- **Recent developments and perspectives,** I. Syratchev (CERN)

Posters

- Superconducting sputtered Nb3Sn films for SRF applications, K. Ilyina (FCC Fellow, TE/VSC)
- SRF Cavities High Q Development for CW Accelerators, A. Grasselino (Fermilab)
- Quench Mechanism in Nitrogen-Doped Cavities, M. Checchin (Fermilab)
- Quench-Induced Quality Factor Degradation in Superconducting Resonators, M. Checchin (Fermilab)
- Trapped flux dissipation in SRF cavities, Martina Martinello (Fermilab)
- Magnetic Flux Expulsion Studies of Horizontally Cooled Single Cell Cavity, Martina Martinello (Fermilab)
- Cavity optimization for the FCC_ee, Shahnam Gorgi Zadeh (Uni Rostock)
- A report on the CBMM-JLab SRF science technology of ingot niobium summary workshop, MYNENI, Ganapati (ISOHIM)

- 4 ½ day sessions: 18 talks
- 10 posters

Work Package Structure and Collaborations

N. Schwerg

University of Rostock
- H-machine Cavities

MEPHY
- HOM damping for the Z-machine

BINP
- 400 MHz Cavity

WP 5: CERN/LNL/STFC collaboration (P. Chiggiato)
- coating
- cavity fabrication
- material analysis

JLAB
- 800 MHz 5-cell
- Cryomodule optimization

CEA Saclay
- Cryomodule production

Lancaster University

Collaboration

WP 4: Cavity Fabrication (Karl)
- High velocity forming

WP 6: Cryomodule challenges (Karl)
- Cost estimate
- FPC

WP 2: Cavity design & beam interaction (Andy)
- Cavity Design
- LLRF studies
- Beam Dynamics
- Specific Beam – Cavity interaction

WP 7: High efficiency power sources (Igor)
- HEIKA collaboration
- Resotrode effort

Design and Technology

WP 1: RF system, RF scenarios and parameters layout (Nikolai)
- Model of the RF system and collection of design constraints
- Machine comparison

WP 3: Cavity Material and Performance (Walter)
- SRF material development and optimization

Generic

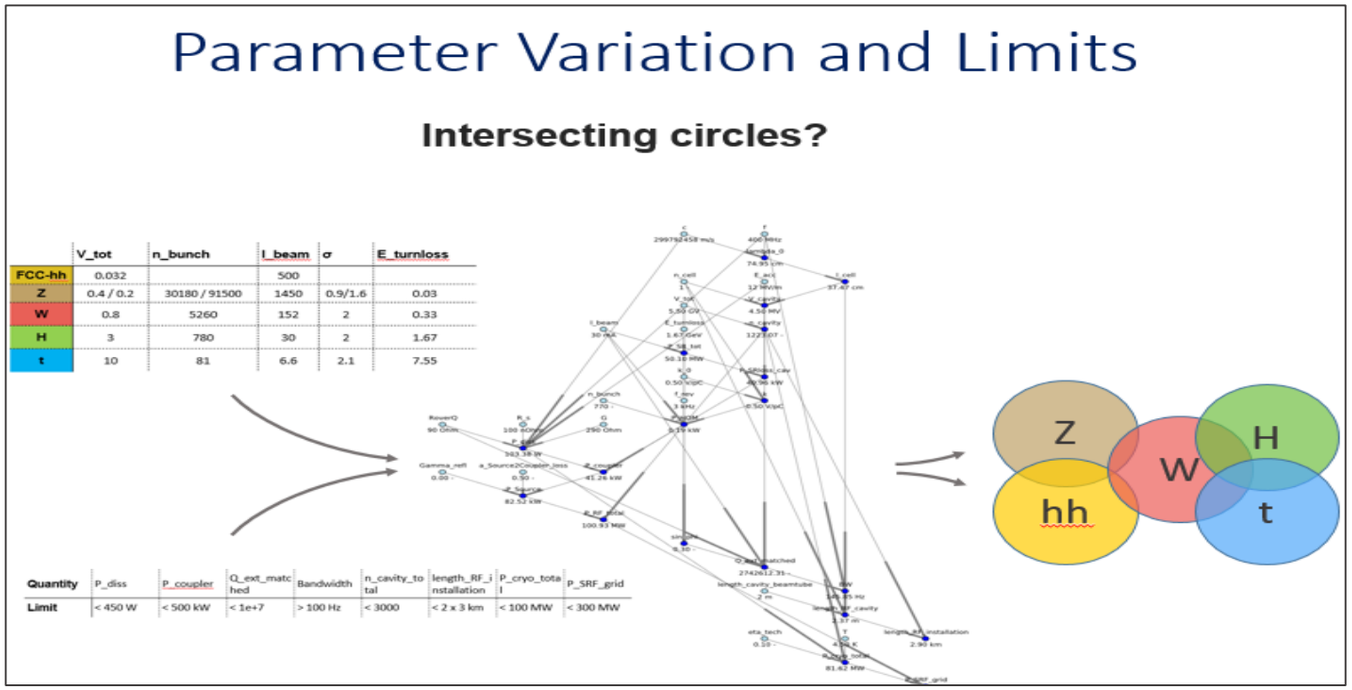
FCC RF WP news

- 1 RF SCENARIOS AND PARAMETERS LAYOUT (N. SCHWERG)
  - 1.1 RF SCENARIOS AND PARAMETERS LAYOUT FOR FCC_EE
  - 1.2 RF SCENARIOS AND PARAMETERS LAYOUT FOR FCC_HH
- 2 CAVITY DESIGN AND BEAM INTERACTION (A. BUTTERWORTH)
  - 2.1 CAVITY IMPEDANCE AND HOMS
  - 2.2 ACCELERATING CAVITY DESIGN AND HOM COUPLERS
  - 2.3 2ND HARMONIC CAVITY DESIGN AND HOM COUPLERS
- 3 CAVITY MATERIAL AND PERFORMANCE (WALTER VENTURINI DELSOLARO)
  - 3.1 CAVITY MATERIAL AND PERFORMANCE
- 4 CAVITY FABRICATION (KARL SCHIRM)
  - 4.1 CAVITY FABRICATION
  - 4.2 HIGH VELOCITY FORMING OF SUPERCONDUCTING RF STRUCTURES
- 5 COLLABORATION AGREEMENT CERN/LNL/STFC (KE2722/BE/FCC) (P. CHIGGIATO)
  - 5.1 FRAMEWORK FOR SCIENTIFIC COLLABORATION IN SUPERCONDUCTING RF CAVITIES TECHNOLOGY
- 6 CRYOMODULE CHALLENGES (KARL SCHIRM)
  - 6.1 CRYOMODULE DESIGN
  - 6.2 FUNDAMENTAL POWER COUPLERS
  - 6.3 CRYOMODULE DESIGN
- 7 EFFICIENCY OF RF POWER GENERATION (I. SYRATCHEV)
  - 7.1 DEVELOPMENT OF VERY HIGH EFFICIENCY KLYSTRONS (HEIKA)
  - 7.2 DEVELOPMENT OF ALTERNATIVE HIGH EFFICIENCY RF POWER DEVICES – THE RESOTRODE INITIATIVE
  - 7.3 HIGH EFFICIENCY KLYSTRONS DEVELOPMENT & CONSTRUCTION

WP1: RF SCENARIOS AND PARAMETERS LAYOUT (N. SCHWERG)

- 1 RF SCENARIOS AND PARAMETERS LAYOUT (N. SCHWERG)
  - 1.1 RF SCENARIOS AND PARAMETERS LAYOUT FOR FCC_EE
  - 1.2 RF SCENARIOS AND PARAMETERS LAYOUT FOR FCC_HH

in preparation/ongoing



	V_tot	n_bunch	I_beam	σ	E_turnloss
FCC-hh	0.032		500		
Z	0.4 / 0.2	30180 / 91500	1450	0.9/1.6	0.03
W	0.8	5260	152	2	0.33
H	3	780	30	2	1.67
t	10	81	6.6	2.1	7.55

Quantity	P_diss	P_coupler	Q_ext_matched	Bandwidth	n_cavity_total	length_RF_installation	P_cryo_total	P_SRF_grid
Limit	< 450 W	< 500 kW	< 1e+7	> 100 Hz	< 3000	< 2 x 3 km	< 100 MW	< 300 MW

Scope:

- define the machine aspects of the ee and hh-machine
- provide parameters and inputs for other WP
- examine limits to see if they can be improved by further R&D

Status:

- WP document in preparation
- Work in progress
- Weekly brainstorming meetings

WP2: CAVITY DESIGN AND BEAM INTERACTION (A. BUTTERWORTH)

- 2 CAVITY DESIGN AND BEAM INTERACTION (A. BUTTERWORTH)
  - 2.1
  - 2.2
  - 2.3

in preparation

Scope:

- Impedance budget estimates from RF cavities and stability limits for the different lepton and hadron schemes
- Cavity design
- HOM damping
- Beam dynamic challenges
- LLRF challenges

Status:

- WP document in preparation
- Collaboration with Rostock University ongoing (PHD student)

Collaborations:

- Rostock University (Shahnam): focus on 800MHz cavities for the Higgs machine
- MEPHY (to be defined): focus on 400MHz cavities for the Z machine + damping schemes (?)
- RF-BR (Juan/Elena): filling schemes, stability limits, etc (to be detailed)
- RF-FB (Wolfgang/Philippe?): concentrate on defining the challenges for the LLRF systems

WP3: CAVITY MATERIAL AND PERFORMANCE (WALTER VENTURINI DELSOLARO)

- 3 CAVITY MATERIAL AND PERFORMANCE (WALTER VENTURINI DELSOLARO)
  - 3.1 CAVITY MATERIAL AND PERFORMANCE

ongoing

Scope:

- Investigation of classical and novel materials for their RF performance limits at moderate to high fields, at frequencies in the 400–800 MHz range.

Status:

- WP description up to date
- Weekly meeting organized (?)

Collaborations:

- University of Geneva: Collaboration signed recently
- Wien TU?

WP4 CAVITY FABRICATION (KARL / MIKKO)

- 4 CAVITY FABRICATION (KARL SCHIRM)
  - 4.1 CAVITY FABRICATION — in preparation
  - 4.2 HIGH VELOCITY FORMING OF SUPERCONDUCTING RF STRUCTURES — ongoing

Scope:

- Investigation of innovative cavity fabrication processes

Status:

- Complete WP description
- Collaboration agreement signed with Jlab -> detailed discussion shall start soon
- Collaboration with BINP to be investigated
- Collaboration with Bmax ongoing smoothly. Elisa leaving!?
- need to complete WP document asasp

Collaborations:

- TE/MME (Bmax)
- JLAB
- BINP?

WP5 COLLABORATION AGREEMENT CERN/LNL/STFC (KE2722/BE/FCC) (P. CHIGGIATO)

- 5 COLLABORATION AGREEMENT CERN/LNL/STFC (KE2722/BE/FCC) (P. CHIGGIATO)
  - 5.1 FRAMEWORK FOR SCIENTIFIC COLLABORATION IN SUPERCONDUCTING RF CAVITIES TECHNOLOGY

in peparation

Scope:

- Fabrication, coating and characterisation of seamless cavities

Status:

- WP document to be updated
- Addendum to the collaboration under signature (waiting for INFN's green light)
- Design of the 800MHz 2 cell cavity defined (Rama's 5 cells without inner 3 cells)

Collaborations:

- INFN
- STFC

WP6 CRYOMODULE CHALLENGES (KARL SCHIRM)

- 6 CRYOMODULE CHALLENGES (KARL SCHIRM)
  - 6.1 CRYOMODULE DESIGN
  - 6.2 FUNDAMENTAL POWER COUPLERS
  - 6.3 CRYOMODULE DESIGN

in preparation

Scope:

- Identify and address cryomodule challenges
- cost study (Nb/Cu @ 4.5K vs bulk Nb @ 2K)
- FPC challenges (movable couplers for FCC-hh, FPC impact on CM design for the Higgs machine

Status:

- WP document to be produced
- Discussions with JLab to be restarted
- Contact lost with CEA Saclay
- WP1 & 2 need to provide FPC parameters

Collaborations:

- JLAB
- CEA Saclay

WP7 EFFICIENCY OF RF POWER GENERATION (I. SYRATCHEV)

- 7 EFFICIENCY OF RF POWER GENERATION (I. SYRATCHEV)
  - 7.1 DEVELOPMENT OF VERY HIGH EFFICIENCY KLYSTRONS (HEIKA)
  - 7.2 DEVELOPMENT OF ALTERNATIVE HIGH EFFICIENCY RF POWER DEVICES – THE RESOTRODE INITIATIVE
  - 7.3 HIGH EFFICIENCY KLYSTRONS DEVELOPMENT & CONSTRUCTION

ongoing

Scope:

- Identify and address cryomodule challenges
- cost study (Nb/Cu @ 4.5K vs bulk Nb @ 2K)
- FPC challenges (movable couplers for FCC-hh, FPC impact on CM design for the Higgs machine

Status:

- WP document to be updated/completed
- FCC support to EIKA (ULAN) under study (coll. agreement in discussion)
- Resotrode initiative: first round of discussions with THALES
- Fabrication of a high efficiency tube – scenarios under study

Collaborations/participants:

- THALES, ULAN, CPI, ESS, THOSHIBA,

Conclusion and next steps

- Coherent WP
- Complete WP description -> “publishable” by November
- Progress with MEPHY, CEA SACLAY, JLAB (?)
- WP meetings
  - Weekly brainstorming meetings (WP 1&2)
  - Collaboration with LNL/STFC – design and material preparation (Sergio?)
  - WP 4 & 6: common meeting? Karl/Mikko
- Define the goals for the next FCC week in Berlin
- “Start thinking” CDR