SRF R&D Program
CDR plan and status

O. Brunner (CERN) on behalf of all the WP participants
WP1: RF scenarios and parameter layout
WP2: Cavity design and beam-cavity interactions
WP3: Cavity material & performance
WP4: **CERN-LNL-STFC Collaboration agreement** on cavity material & cavity fabrication
WP5: Innovative cavity fabrication techniques
WP6: Cryomodule challenges
WP7: High efficiency klystron technology
WP8: Nb/Cu crab cavity for FCC_hh
WP9: Fundamental power couplers

Ongoing collaboration agreements:
- Rostock University
- Frankfurt University
- Geneva University
- Lancaster University
- FNAL
- JLAB
- BINP (in preparation)
WP1: RF scenarios and parameter layout

WP2: Cavity design and beam - cavity interaction

WP3: Cavity material & performance

WP4: CERN-LNL-STFC Collaboration agreement on cavity material & cavity fabrication

WP5: Innovative cavity fabrication techniques

WP6: Cryomodule challenges

WP7: High efficient klystron technology

WP8: Nb/Cu crab cavity for FCC FCC_hh

WP9: Fundamental power couplers
Framework of the study

- Define “ideal” RF system for each machine
- Identify technology choices and R&D perspectives
- Propose optimum baseline scenario (fabrication, installation, cost)
RF scenarios and parameter layout

1. RF system model ✓
2. Layout optimization for each machine
   • Limiting factors ✓
   • Design choices and alternatives ✓
3. Baseline scenario
   • Timeline: installation and operation ✓
   • Optimized scenario and options ✓
4. Cost and study model ✓
5. Sensitivity study ✓

N. Schwerg's talk (Tuesday)
Cavity design and beam-cavity interaction

1. Cavity design:
   • High energy
     • Aim at acceleration efficiency ✓
   • High intensity
     • Optimize cell shape with regard to HOMs ✓
     • HOM damping schemes ✓

2. Beam dynamics:
   • Single and coupled bunch stability ✓
   • Impedance studies & HOM power
   • Implications of 5 ns bunch spacing for the FCC-hh injector chain ✓

3. Analysis of the need for a RF harmonic system ✓

4. Low Level RF ✓

->several talks in RF & FCC-hh machine design sessions on Tuesday
Cavity material & performance

Enhance collaborative effort to evaluate and understand the ultimate performance of the 400 - 800 MHz cavities

1. Review of technology choices and limits
   • *SRF Material Options for FCC* (S. Aull et al., submitted to PRAB)

2. R&D and perspectives
   • Bulk Nb:
     • $N_{\text{doping}}$: (FNAL collaboration)
   • Nb/Cu:
     • Development of innovative coating techniques (HIPIMS (CERN), HIPIMS & ECR (JLAB), ECR (FNAL))
     • Improvement surface preparation and Nb coating (CERN-LNL-STFC collaboration)
     • Characterization facility and benchmarking (STFC)
   • Alternative materials A15, strong potential - long term R&D
     • Nb$_3$Sn on Nb (FNAL collaboration)
     • Nb$_3$Sn on Cu
     • V$_3$Si
     • Characterization facility and benchmarking (STFC, UNIGE, CERN)

several talks in RF sessions 2 & 4 (Tuesday)
Innovative cavity fabrication techniques

Development of fast & cost effective cavity fabrication techniques

1. **High velocity hydroforming:**
   - Determine forming limits of high-velocity Electro-Hydraulic Forming (EHF) for Cu structures as substrate for superconducting coating (and for bulk Nb)

2. **Spinning:**
   - Efforts towards seamless cavity fabrication (LNL)

3. **Surface treatment: Electro-polishing:**
   - Developments on vertical and/or horizontal EP for 400/800MHz copper cavities

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C. Abajo Clemente & Bmax, 2017

E. Palmieri (LNL), FCC week 2016
WP6: Cryomodule challenges

1. Specific topics of interest for FCC (and many other machines!)
   a. Modular CM design approach to hold various different cavities ✓
   b. Impact of cooling control on CM design ✓
   c. Optimisation of clean room assembly procedures ✓
   d. CM cost model ✓
High efficiency klystron technology

1. Development of new klystron bunching technologies to strongly increase RF power production efficiency was initiated at CERN in 2013 (HEIKA)

2. Fabrication of the first high efficiency CSM tube

FCC: 100MW beam power ≈ 165 MW grid power
=> every 1 % gain in efficiency ≈ 10 GWh/year (≈ 0.4M€/year)

85.7% in PIC simulations

Single beam, 1.4 MW, 0.8 GHz, 133.9 kV, 12.551 A, μ K=0.263

See I. Syratchev's talk on Tuesday
Innovative crab cavity design for FCC_hh

- Very interesting development which provides:
  - low longitudinal and transverse impedances
  - natural damping for HOMs

1. Design and simulation ✓
2. Fabrication is ongoing ✓
3. Nb coating system is under development ✓

### Design and simulation

- RF frequency: 400 MHz
- Total voltage: 18 MV (uncertainty ±20%)
- Available length: 20 m
- Beam separation: 250 mm (maybe 204 soon)
- Average beta in the ring: (339+67)/2 = 203 m
- Beta*: 0.3
- Crossing angle: 89 urad
- Beta at CC location: 10100 ± 10900

### Schematic layout:

E. Cruz-Alaniz, Nov. 2016, Barcelona

See R. Calaga’s talk on Tuesday
Fundamental power couplers

Impedance reduction is crucial
- minimize the number of cavities
- more power per FPC (beyond the S-o-A)

1. Very high CW power FPC (1MW?)
2. Variable and Adjustable FPC
   - Adaptable to different $Q_{ext}$
3. Large series production

See E. Montesinos ‘s talk on Tuesday

High Power Couplers, examples

- Highest CW power reached on a test stand
  - APT coupler (700 MHz) Los Alamos
  - Coaxial coupler
  - Two RF windows
  - High pumping speed
  - 1 MW in TW
  - 850 kW in SW
Conclusions

• A complete SRF R&D program
• A “solid” baseline scenario has been selected
• R&D challenges and limits have been defined
• The way is paved for the study and the CDR to go off smoothly

Skeleton of CDR

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