Infrastructure and Operation Summary

John Osborne, CERN

Report on behalf of FCC Infrastructure and Operation WG,
all FCC study teams
Special thanks to Volker Mertens

FCC Week 2017
Berlin, 2 June 2017
Overview (V. Mertens, 25′+5′) Monday

- civil engineering
- electricity
- ventilation
- logistics
- transport

Infrastructure and Operation related programme

- cryogenics
- operation
- reliability
- safety

All sessions as input for review

Summary of IO related parallel sessions and posters (J. Osborne, 15′)

Poster listed in V. Mertens Monday presentation
"Berlin" baseline 97.75km

Highlights:
- Avoids Jura and Pre-Alps limestone.
- Only one sector containing limestone.
- Significantly reduced total shaft length.
- Experimental Site at Point A on existing CERN land.
- Avoids extremely large overburden.

Civil engineering optimisation and design development (J. L. Stanyard)
Key CE issues and possible solutions

**Issue: Tunnel excavation through water bearing moraines**
Possible Solutions:
- a) Excavation using a multi-mode earth pressure balanced TBM.
- b) Employ a double-lining method for waterproofing.

**Issue: Unavoidable Mandallaz Limestone formation**
Possible Solutions:
- a) Drill & Blast excavation method
- b) Systematic exploration ahead of excavation

**Issue: Exceptionally deep shaft at point F**
Possible Solutions:
- a) Remove shaft
- b) Replace with a shaft of a smaller diameter
- c) Replace with an inclined access tunnel
Tunnel Optimistatation Tool capabilities and limitations

- TOT is only as powerful as the data behind it.
  - Topographical data is very accurate
  - Certain areas of geological data more accurate than others.
  - Interpreted data from existing maps and boreholes.
  - Site Investigation is required to significantly improve understanding.

- Automation of the tool is a possibility but challenging.
  - Optimisation algorithm such as ROXIE (previously used at CERN for magnet design optimisation) could be used.
  - The challenge is the large number of variables.
  - Not all variables are easily quantified.
  - Potential for automating certain features such as shaft positions once the layout and siting are fixed.
Berlin Schematic – Single Tunnel

- Electrical alcoves introduced at 1.5 km spacing
- Additional shaft introduced at each experimental point
- Survey Galleries introduced at experimental points
- Beam Dumps both located at Point D
- Secondary experimental Points moved to B & L
CE Cost and Schedule Studies

• Cost & Schedule Study launched in September 2016
• Two sets of consultants engaged to work independently.

Phase 1
Cost & Schedule estimate for “baseline” single tunnel design.*

Phase 2
Cost & Schedule implications of variations considered:
• Double tunnel design
• Shallow option
• Alternative tunnel diameters
• Alternative shaft diameters
• Alternative cavern dimensions
• ee machine requirements
• Alternative schedule + Inclined access tunnels

Phase 3
Refinement of results from Phases 1 and 2:
• Review to include updates made to baselined design.
• Incorporate desirable variations from Phase 2.

*Some changes have been made since the study was launched including raising the profile and introduction of third shaft at experimental points.
CE Schedule Studies

Draft to be verified.

- First two sectors complete in 4 years, 11 months.
- Construction complete in 6 years, 5 months.

Close co-ordination with Julie Coupard
ee machine CE requirements

• Tunnel widening required around points A & G to accommodate ee lattice.

• Design is not fully developed: potential for a combination of double tunnel and enlargement caverns to accommodate lattice.

• For Cost & Schedule study: 1.8 km of tunnel widening on either side of IPs at A and G considered.

*not the latest ee plot, but the one that was used for initial costing exercise
Inclined tunnel possibilities (instead of vertical shafts)

- Study launched with Amberg Engineering following FCC week 2016 to verify feasibility of inclined access tunnels.
- Main questions:
  - Can a shaft be replaced with a 6.0 m diameter tunnel and a TBM be launched from the bottom?
  - What is the estimate for possible time saving?
- Feasibility of logistics confirmed.
- Confirmed that some time reductions are possible – construction of inclined access can start during procurement of TBM.
Need ~ 1 km straight sections for collimation. Slope constraints for He flow and transport. Normal conducting magnets preferred.
Why is experimental point L preferred?

Positives:
- Low geological risk compared to other locations, anticipated tunnelling in molasse only.
- Close to current CERN site.
- FCC ring relatively shallow at this point, therefore shallower shafts.

Remaining problems:
- Potential clash with injection lines needs to be studied.
- Located inside the FCC ring so integration with other structures to be studied.
- Depth below Rhone to be evaluated.
Magnets OD 1480 m (all included)
QRL OD 1200 mm (all included)
Tunnel cross section, FCC-ee
Limited civil engineering
Same beam height as LHC

⇒ Magnets OD ca. 1200 m (all included) – study in //
QRL (sector shorter than at FCC) OD ca. 850 mm (all included)
Re-routing of services abeam the cryogenics service module not yet studied
Magnet suspended during „handover“ from transport vehicle to installation transfer table

Today: 16 T magnet R&D (D. Tommasini) and other presentations
Supply and Distribution of Electrical Energy

FCC week 2017, Berlin

Davide Bozzini - CERN

With the contribution of the FCC Infrastructure & Operation Working Group and CERN Electrical Group members
Supply and Distribution of Electrical Energy

Power Consumption Estimate FCC-hh

- **FCC week 2015**
  - First estimate for FCC-hh scaled on 4 x LHC design report and systems estimate when available

- **FCC week 2016**
  - Definition of maximum target power consumption for FCC-hh at 555 MVA

- **FCC week 2017**
  - Two approaches for FCC-hh
    - Input from machine/ system designers
    - Scaled from LHC real consumption

<table>
<thead>
<tr>
<th>System</th>
<th>FCC week 2015</th>
<th>FCC week 2016</th>
<th>FCC week 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Machine</td>
<td>Scaling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>designers</td>
<td>from LHC</td>
<td></td>
</tr>
<tr>
<td>FCC-hh</td>
<td>585</td>
<td>423</td>
<td>347</td>
</tr>
<tr>
<td>Injectors</td>
<td></td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>Data centers</td>
<td></td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Values expressed in MVA – Considered Power Factor = 0.9

- Two approaches adopted
- Estimates are coming down
Supply and Distribution of Electrical Energy

Availability of power at European grid level

- Based on mid long term plan (2030) of the network operator
- Additional **200 MW are available** simultaneously at each 400 kV source (I, II, III)
- Total power higher than 600 MW will require **major hardware changes** at the European grid level
- Maximum available power in case of N-1 availability of the sources might **impact the transit of power at grid level**
- Power availability on existing sources operated at lower voltages (230 kV and 132 kV) is **included in the same budget** (3 x 200 MW)

-3 sources exist
-network capable
Supply and Distribution of Electrical Energy

Geneva Based Related Aspects

- Current civil engineering baseline includes 4 access points on Swiss and 8 access points on French territory
- The three main sources are located in France
- Swiss and French local (second) sources are operated respectively at the following different voltage levels 18 kV and 20 kV
- Access points are located in urbanised and agricultural areas

-Surface impacts to be evaluated
Conclusions

With respect to the CDR ...

• Powering of the FCC-hh and FCC-ee from the European grid - Feasible
• Baseline transmission and distribution layout for FCC-hh - Available
• Functional concept for the electrical distribution in the arcs for the FCC-hh - Available
• The same exercise for FCC-ee and HE-LHC – To be initiated
• Inputs for an FCC-hh electrical infrastructure cost and schedule review based on the proposed baseline - Available

... and from a conceptual design study point of view

• Comparative study for the transmission line between points - To be completed
• Power consumption estimates and location - To be continued
A ventilation system for the FCC tunnel

M. Nonis, G. Peon – CERN EN Department / CV Group

FCC Week, 1st June 2017
Ventilation Systems

Main Input Parameters: Geometry

<table>
<thead>
<tr>
<th>General Input data</th>
<th>Compartment Input data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross section area</td>
<td>Number of Compartments</td>
</tr>
<tr>
<td>17.7 m²</td>
<td>24</td>
</tr>
<tr>
<td>Max. sector length</td>
<td>Compartment length</td>
</tr>
<tr>
<td>10.5 km</td>
<td>440 m</td>
</tr>
<tr>
<td>Maximum Temperature (running conditions)</td>
<td>Volume Compartment</td>
</tr>
<tr>
<td>32°C (to be confirmed)</td>
<td>7788 m³</td>
</tr>
<tr>
<td>Maximum dew point</td>
<td></td>
</tr>
<tr>
<td>12°C (to be confirmed)</td>
<td></td>
</tr>
</tbody>
</table>

-main parameters better understood
Approx. Maximum 240 KW from magnets/transmission lines other equipment

### Ventilation Systems

#### Main Input Parameters: Estimated Loads in the Sectors to the Air

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>FROM MAGNETS (kW)</th>
<th>TRANSMISSION LINE (kW)</th>
<th>OTHERS (kW)</th>
<th>TOTAL (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>60</td>
<td>13</td>
<td>39</td>
<td>112</td>
</tr>
<tr>
<td>B-C</td>
<td>110</td>
<td>21</td>
<td>65</td>
<td>196</td>
</tr>
<tr>
<td>C-D</td>
<td>140</td>
<td>24</td>
<td>75</td>
<td>239</td>
</tr>
<tr>
<td>D-E</td>
<td>120</td>
<td>24</td>
<td>75</td>
<td>219</td>
</tr>
<tr>
<td>E-F</td>
<td>110</td>
<td>21</td>
<td>65</td>
<td>196</td>
</tr>
<tr>
<td>F-G</td>
<td>50</td>
<td>12</td>
<td>39</td>
<td>101</td>
</tr>
<tr>
<td>G-H</td>
<td>50</td>
<td>12</td>
<td>39</td>
<td>101</td>
</tr>
<tr>
<td>H-I</td>
<td>110</td>
<td>21</td>
<td>65</td>
<td>196</td>
</tr>
<tr>
<td>I-J</td>
<td>120</td>
<td>24</td>
<td>75</td>
<td>219</td>
</tr>
<tr>
<td>J-K</td>
<td>140</td>
<td>24</td>
<td>75</td>
<td>239</td>
</tr>
<tr>
<td>K-L</td>
<td>110</td>
<td>21</td>
<td>65</td>
<td>196</td>
</tr>
<tr>
<td>L-A</td>
<td>60</td>
<td>12</td>
<td>39</td>
<td>111</td>
</tr>
</tbody>
</table>
Ventilation Systems

Ventilation in degraded conditions: worst case scenario

- Combination of previous scenarios:
  - Extraction AHU breaks down;
  - During an emergency situation (smoke or helium release);
  - Interaction between extraction units of two adjacent sectors
  - Assuming nom. flow 25000 m³/h and max. flow 50000 m³/h

Many scenarios simulated
Conclusions and further steps

• The design of the ventilation system is adapted to the new configuration (compartmentalised);
• Estimated heat loads to the air of the tunnel can be cooled by the air without any additional cooling
  • Though tunnel wall temperature needs further study
  • Heat load estimations need validation
• The ventilation system ensures the required functionality during normal and degraded conditions;
• The foreseen pressure differential cascade and airlocks to prevent less activated zones to be exposed to air from more activated areas has also been addressed;
• The singularities in each type of point have been addressed.
• Next steps: validation of the concept and more detailed design
Several Logistics scenarios being studied
Logistics

Different Routes to CERN and Transport Modes

MarSelle to CERN:
- Using barge/road transport:
  - Seaship to Marseille
  - Barge to Mâcon
  - Road transport to CERN
- Using only road transport:
  - Seaship to Marseille
  - Road transport to CERN

Rotterdam to CERN:
- Using barge/road transport:
  - Seaship to Rotterdam
  - Barge to Basel
  - Road transport to CERN
- Using only road transport:
  - Seaship to Rotterdam
  - Road transport to CERN

© Fraunhofer - Slide 17
Cryogenics

Towards a conceptual design for FCC cryogenics

Laurent Tavian,
CERN, ATS-DO

On behalf of the FCC cryogenics study collaboration

1st June 2017
Cryogenics

FCC cryogenics studies

- MoU signed
- Addendum 1 signed
- Addendum 2 signed

New w/r to Roma
Cryogenics

10 Cryo plants at 6 sites. Each plant approx. 10km supply.
Cryogenics

Distribution systems now more defined
E.g. Vertical Line C for Liquid Helium transfer added
Substantial progress in various domains.

Next important steps:
- FCC-hh: Complete the engineering studies with our industrial partners (Air Liquide and Linde)
- FCC-hh & HE-LHC: Cryogenic transients during resistive transitions $\rightarrow$ impact on quench valve size & number and on cold-mass design pressure.
- FCC-hh & HE-LHC: Energy buffering during magnet current ramp-up and fast ramp-down $\rightarrow$ impact on helium inventory (is 33 l/m (400 t) sufficient?)
- FCC-ee: Refine the staging scenario with 400 MHz (4.5 K) and/or 800 MHz (2 K).
- All: Operational margin discussion/definition $\rightarrow$ impact on capital and operation cost

2017 studies:
- Cyroplants
- Transient operation Mode
**Initial operation schedule**

5-yr cycles

- 18 m shutdown
- 1 m yearly stop
- 1 m commissioning
- 10 m operation

**Comparison of turn-around times**

<table>
<thead>
<tr>
<th>Phase</th>
<th>FCC th.</th>
<th>LHC th.</th>
<th>LHC 2015</th>
<th>LHC 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup</td>
<td>10</td>
<td>10</td>
<td>222.7</td>
<td>158.5</td>
</tr>
<tr>
<td>Injection</td>
<td>40*)</td>
<td>38</td>
<td>58.1</td>
<td>51.6</td>
</tr>
<tr>
<td>Pre-ramp</td>
<td>5</td>
<td>4</td>
<td>5.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Ramp</td>
<td>20</td>
<td>20</td>
<td>20.4</td>
<td>20.4</td>
</tr>
<tr>
<td>Flattop</td>
<td>5</td>
<td>5</td>
<td>4.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Squeeze</td>
<td>3</td>
<td>18</td>
<td>13.1</td>
<td>18.0</td>
</tr>
<tr>
<td>Adjust</td>
<td>5</td>
<td>10</td>
<td>12.5</td>
<td>14.1</td>
</tr>
<tr>
<td>Ramp down</td>
<td>20</td>
<td>31</td>
<td>41.0</td>
<td>41.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>108 min (1.8 h)</td>
<td>132 min (2.2 h)</td>
<td>378 min (6.3 h)</td>
<td>312 min (5.2 h)</td>
</tr>
</tbody>
</table>

**3.5yrs of operations in 5yr cycle**

- Total of 162 m of physics (p + ions)
- 6 x 1 wk MD + 1 wk stop per 5-yr cycle

**Long setup times mainly due to system failures**

- FCC to be designed for utmost availability (fault tolerance or quick repair between runs).
- Injection time depends on injector chain availability and beam quality control.

**Thursday 15:30: FCC-hh operation schedule and turnaroud (A. Niemi/Tampere UT)**
FCC Availability Studies

Andrea Apollonio – CERN TE-MPE
Arto Niemi – CERN BE-ICS

FCC Week – Berlin 2017

Luminosity goals very challenging but appear achievable
Phase 1 : 1.25
Phase 2 : 5

IF the FCC will exhibit the same overall LHC availability, the production goals can be achieved (NB: despite the increased number of systems and higher energies)
Availability and Integrated Luminosity Studies

Injector Options - Assumptions

Scenario 1

- Upgraded LHC:
  - Present day LHC failure rates
  - No experiments
  - No failures due to high energies (UFOs, training quenches)

Scenario 2

- Superconducting SPS
  - SC-magnets
  - Quench protection
  - Power converters
  - 3 Cryogenic plants

IMPORTANT: Availability is not the only parameter to be considered when comparing injector options. This study does not include considerations on costs, electricity consumption, magnets’ field quality, constraints on transfer lines design, work required to replace existing accelerator systems, project schedule, etc.

Injection from Superconducting SPS seems promising from availability point of view.
Safety Strategy for CDR, T. Otto

Systematic collection of Hazards, ordered by:

- Technology
  - S.c. magnets
  - N.c. magnets
  - Cryogenics
  - Vacuum
  - Powering
  - Transport
  - ... others

- Project Phase
  - Construction
  - Service Installation
  - Accelerator installation
  - Commissioning
  - Operation
  - Technical Stop
  - Long Shut-down
  - Dismantling

- Location in the facility
  - Surface
  - Shaft
  - Long Straight Section
  - Arc Tunnel
  - Caverns
  - ... others

Potential of a substance, activity or process to cause harm

Standard best practices where available to try and render hazards inoffensive
Example: Typical chain between technology and the hazard
Safety Strategy for CDR

If Standard best practice not applicable, this risk assessment method will be adopted.

- Objective
- Performance Criterion
- Test Fire
- Trial Design
- Evaluate

In case of fire, no loss of human life
Nobody exposed to dangerous CO conc.
location ignition source, combustible material, heat release power
building structure, occupation frequency, safety devices (alarms)

Does trial design meet performance criteria?
Yes: adopt trial design
No: Improve trial design
Radioprotection matters

High-radiation areas

FCC-hh arc residual dose rate

FCC-hh detector residual dose rate

Radiation hazards lists (prompt stray radiation, activated air, X-rays ...)

Radioprotection matters (M. Widorski)
FLUKA simulations advancing for new layout. Possible extra shielding needed at alcoves.
Surveying and Alignment

- Geodesy
  - GPS measurement campaign of the CERN Geodetic Network
    - To redetermine the transformation parameters between Cern Coordinates System and International one
  - Simulation of the underground network accuracy depending on distance between shafts (5/10 km)

Surveying and Alignment (2)

- Geodesy (ctd)
  - Calculation of a new geoid on the whole FCC area (Swiss topo with data from french IGN) on going

- Alignment
  - Application of the wire offset measurement technique with wires of 200m, test in the LHC (Poster)

-GPS measurements in CERN area planned for 2017.
-First indications suggest that the 5km intermediate shafts might not be required, but to be confirmed.
-Wire tests in LHC P8 area provided some interesting results.
Future Circular Collider Study
John Osborne
3rd FCC Week, Berlin, 29 May – 2 June 2017

Conceptual Design Report for I&O matters

1 – PHYSICS

2 Hadron Collider Summary

3 – Hadron Collider Comprehensive
   Accelerator
   Injectors
   Technologies
   Infrastructure
   Operation
   Experiment

4 Lepton Collider Summary

5 – Lepton Collider Comprehensive
   Accelerator
   Injectors
   Technologies
   Infrastructure
   Operation
   Experiment

6 High Energy LHC Summary

7 – High Energy LHC Comprehensive
   Accelerator
   Injectors
   Infrastructure

Refs to FCC-hh, HL-LHC, LHeC

• Documents the performed studies
• Material to support the baseline concepts
• A basis for the next phase
• Highlights remaining work
• Lists alternatives
• …

Concise description of main concepts and key points
Concluding remarks

- Impressive progress by Infrastructure and Operation working group

- Need to conclude by end of the summer on a Baseline Layout, Cross Sections etc. to allow more in-depth studies which are in accordance with the Performance Based Safety Criteria

- Cost and Schedule studies to be further developed

- Intensive effort will be required over the coming months to complete the CDR in 2018.

Big thanks to presenters, chairpersons and organisers
THANK YOU FOR YOUR ATTENTION

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