Infrastructures and implementation

Volker Mertens, CERN

gratefully acknowledging the contributions of
the FCC Infrastructure and Operation WG and sub-WGs,
all FCC study teams and
the collaborating partners (list in annex)

FCC Week 2019
Brussels, 24 June 2019

Infrastructure and Operation topics

- Geology & civil engineering
- Integration
- Electricity distribution
- Cryogenics
- Cooling & ventilation
- Transport & handling
- Installation
- Planning & coordination
- Geodesy, survey & alignment
- Controls
- Computing
- Communications & networks

- General safety
- Fire safety
- Access control
- Radiation protection
- Environmental protection
- Power/energy consumption
- Energy efficiency
- Operation & maintenance concepts
- Availability & reliability
- ...

Full structure in https://fcc.web.cern.ch/Documents/Organisation/WBS.pdf, hdg "3".

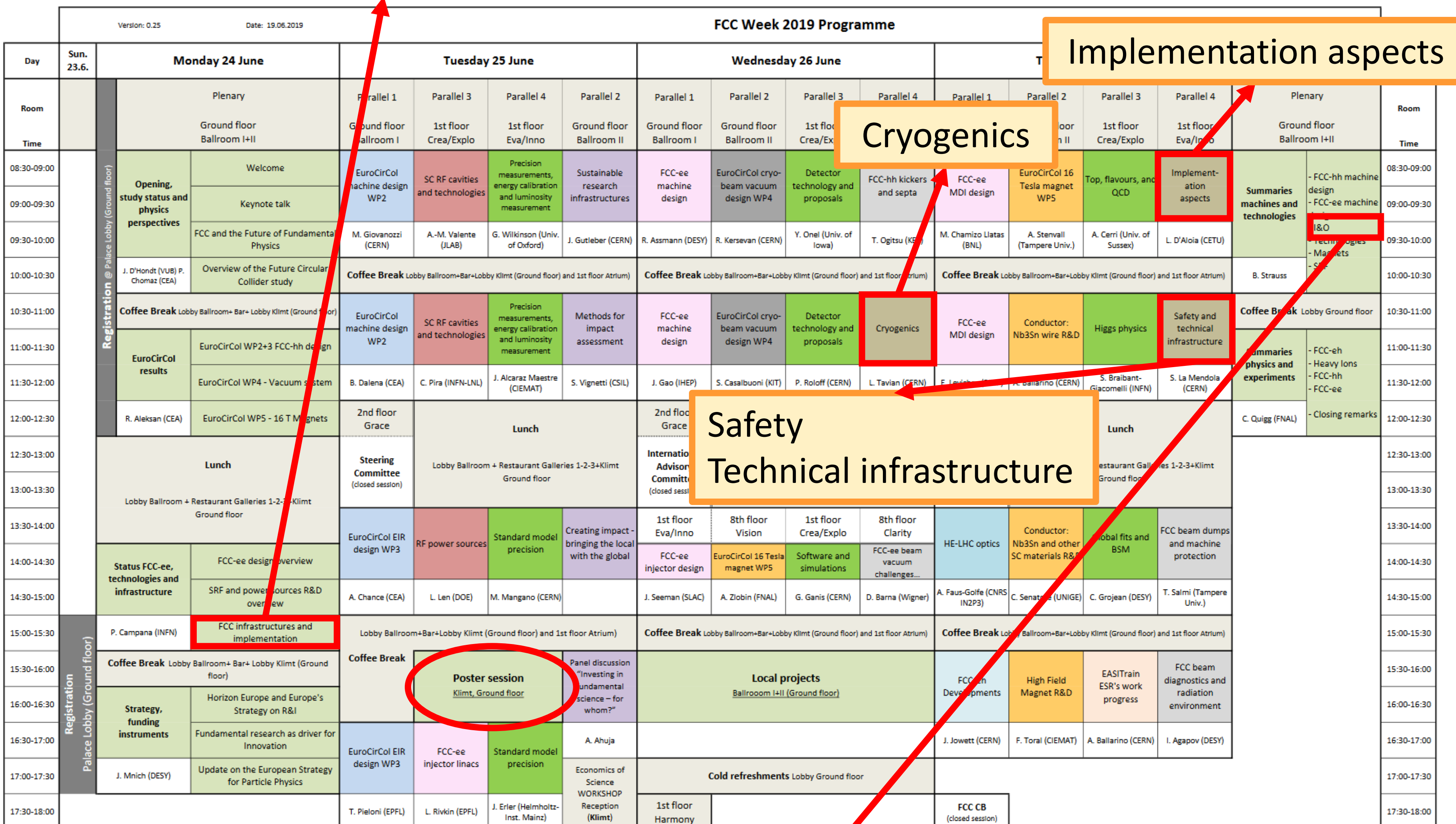
Amsterdam 2018 for reference:
https://indico.cern.ch/event/656491/contributions/2915646/attachments/1628719/2595760/FCC_IO_Overview_Amsterdam_VM_090418.pdf

Total of 35 slides

Infrastructure + implementation rel. prog.

Overview (V. Mertens, 25‘+5‘)

Wednesday-Thursday



Summary of IO related parallel sessions and posters (J. Gutleber, 15‘+5‘)

Oral presentations

Poster list in annex

Monday, 24.6.2019
- IO overview, 25+5‘, V. Mertens

Wednesday, 26.6.2019, **Cryogenics**, chair: L. Tavian
- Outcome of the engineering studies for the FCC-hh cryoplants, 25‘+5‘, F. Millet (CEA Grenoble)
- FCC-hh inner-triplet cryogenics , 15‘+5‘, C. Kotnig
- Improved concept of the Nelium Turbo-Brayton cycle for the FCC-hh beam screen cooling , 15‘+5‘, S. Savelyeva (TU Dresden)
- Transient conjugate heat transfer numerical simulation in superfluid helium, 15‘+5‘, A. Vitrano (CEA Saclay)

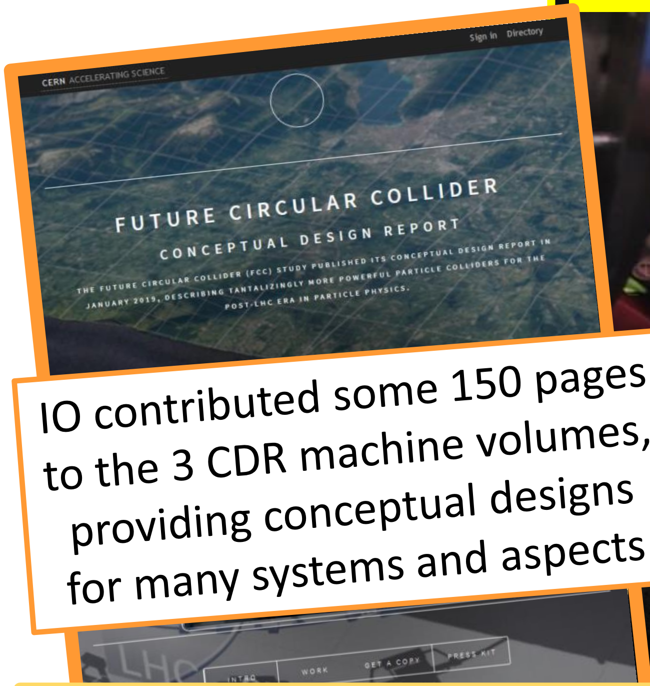
Thursday, 27.6.2019, **Implementation aspects**, chair: L. D‘Aloia (CETU)
- Activities with Host States, 20‘+5‘, J. Gutleber
- FCC Host States implementation – institutional and administrative framework, 20‘+0‘, O. Martin (MAE)
- Civil engineering summary – cost drivers, risk factors, schedule for preparatory phase, 15‘+5‘, A. Tudora
- Excavation material use strategy, 10‘+5‘, Prof. R. Galler (U Leoben)
- Analysis of excavation materials in view of re-use, 10‘+0‘, M. Haas (U Leoben)

Thursday, 27.6.2019, **Safety and technical infrastructure**, chair: S. La Mendola
- Safety topics requiring further investigation, 17‘+5‘, T. Otto
- Study of HE-LHC ventilation strategy in case of fire, 17‘+5‘, O. Rios
- Update on R2E and heat load simulations, 17‘+4‘, J. Hunt
- Geodetic infrastructure and alignment – planning and studies, 20‘+5‘, M. Jones

Friday, 28.6.2019
- IO summary, 15+5‘, J. Gutleber

Blue info boxes → presentations

Since Amsterdam …

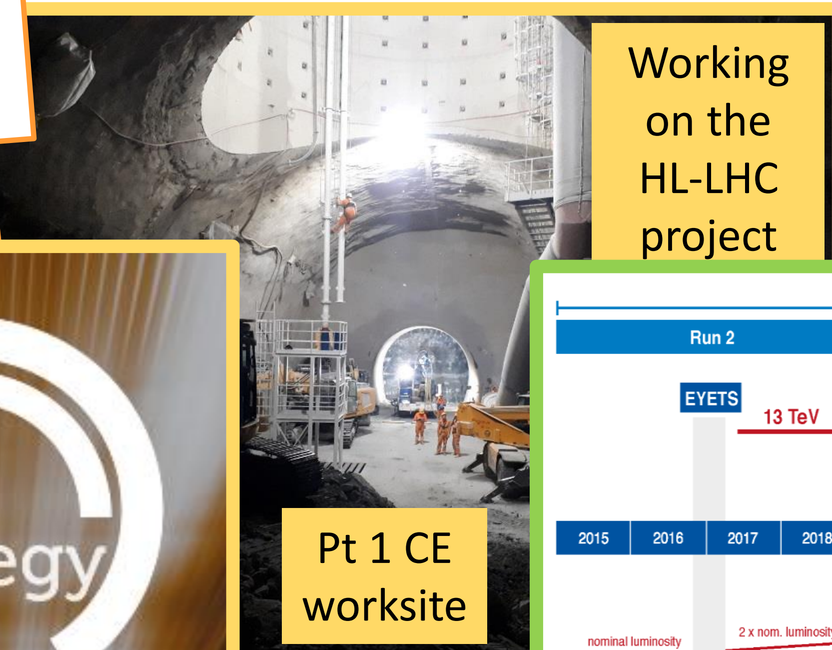


IO contributed some 150 pages to the 3 CDR machine volumes, providing conceptual designs for many systems and aspects

LHC diode insulation

Long shutdown 2

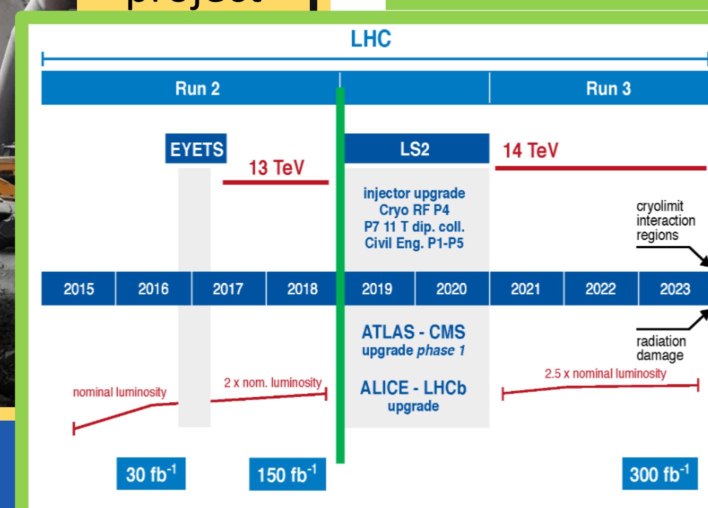
PSB power converter renovation/upgrade



Working on the HL-LHC project

Pt 1 CE worksite

Preparing for a smooth restart of Run 3



Institutional + administrative framework

Several main challenges ...

Institutional:

2 Host States, with different institutional architectures, different legislation, ...

Environmental:

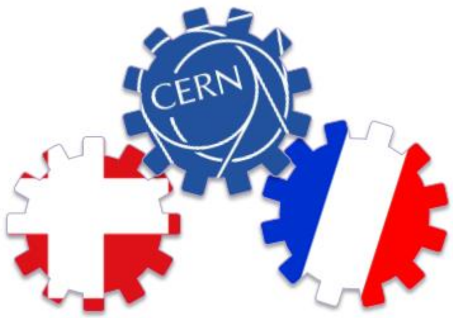
Densily populated area, land scarcity, protected zones, ...

Timeframe:

Full-speed work in 2019-2025 to prepare for possible project approval

1 interlocutor:
French state

2 interlocutors
Swiss Confederation
Cantonal State of Geneva



Main administrative tasks identified
(among them environmental impact study, public debate, preparation for land provision, ...)

Lots of work ahead until 2025

Keywords: trust, anticipation/cooperation,
environmental and legal exemplarity, local acceptance/communication

Thursday, 8:30: FCC Host States implementation – institutional and administrative framework (O. Martin)

O. Martin / MAE (France)

Activities with Host States

Subsidiarity Principle (valid in EU including F, as well as CH):
Social and political issues should be dealt with at the most immediate (or local) level that is consistent with their resolution.

Public projects need to ensure that all relevant stakeholders are involved
from an early concept phase.
Decisions to support a project are based on public acceptance,
significantly before the decision to construct.
Significant time needed for preparatory phase
(letting benefit the later implementation phase since decision based on broad public support).

Cooperation with France

- Regular working meetings with the general secretary of the Auvergne-Rhône-Alpes region (SGAR) since 2016, following a spontaneous interest of the region's "Préfecture" to accompany CERN in a forward-looking development process
- MoU signed by Cerema (public entity accompanying territorial developments, ensuring implementation ecologic and socio-urbanistic principles)
  - **First study** on "territorial constraints and opportunities" **completed in 2018**
  - **Development of a workable schedule towards a construction in 2028**
  - Preliminary study of additional territorial infrastructure needs
- MoU signed by CETU (Center for tunnel studies)
  - Workshop series to **structure the work for an excavation material management plan** as support document to prepare **studies for re-use** and as input to EIA processes.

Cooperation with Switzerland

- Working group "Future projects" within the "Structure de Concertation Permanente" since January 2018 with representatives from the Canton of Geneva, the Confederation and the Permanent Mission of Switzerland at the International Organisations
- Commonly **developed** (Switzerland + CERN) with the help of an external consultancy office (LD) two possible **administrative scenarios** to prepare a construction project as baseline to distribute the tasks between canton and confederation
- Performed **a preliminary review of the collider placement** in the region with the support of an external expert office (Ecotec)
- Continued consultancy of the canton for the placement optimisation

Thursday, 8:30: Activities with Host States (J. Gutleber)

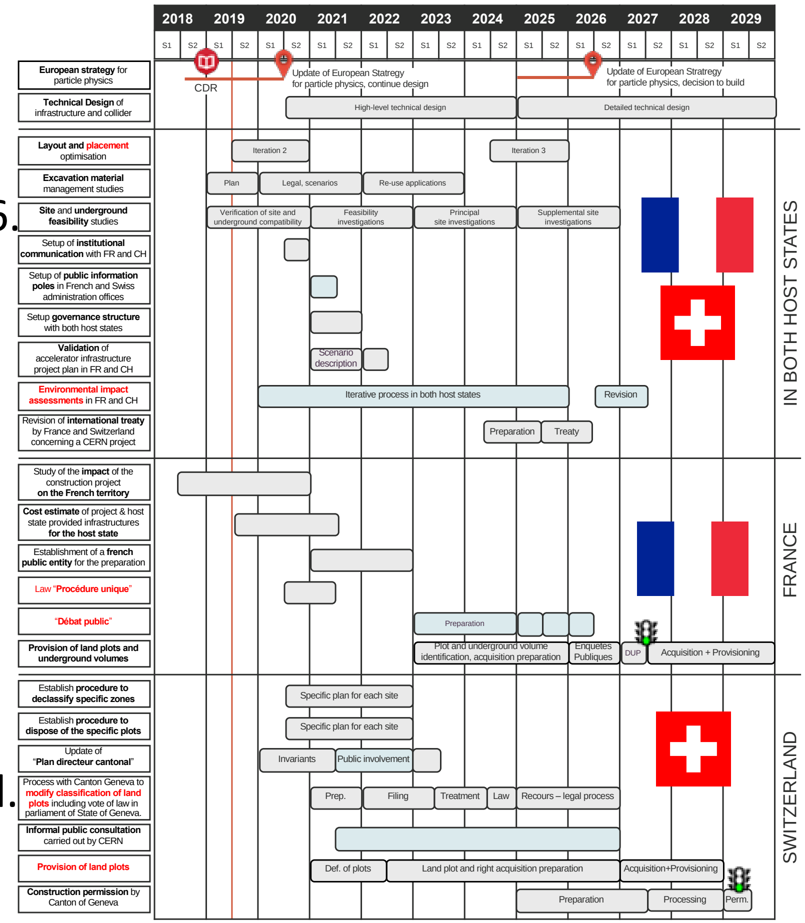
J. Gutleber / ATS-DO

Activities with Host States

Processes exist and have been identified,
in F and CH and for topics of transnational interest.

These need to be carried out as soon as possible
BEFORE a possible project decision with timeframe 2026.
The processes are "project scenario specific"
(i.e. concrete, not generic).

Host States are actively supporting this approach
and willing to collaborate.
All institutional and public stakeholders to be involved
as from 2020.
Timing and proper sequencing of activities is crucial
(dependencies).
The processes in the 2 Host States need to be integrated.



„Preparatory phase project" (and team) to be set up.
Document the invariants and parts of the scenarios
which still contain some degrees of freedom (by mid-2020).
This documentation will be baseline for „political scenario validations".

Thursday, 8:30: Activities with Host States (J. Gutleber)

J. Gutleber / ATS-DO

Activities with Host States

Highest priority now to optimise the FCC placement

éviter réduire compenser

Baseline document set

Following the commonly agreed "avoid-reduce-mitigate" approach using a documented risk management process.

Working together with public offices and companies with experience in large-scale projects in the region.

Constraint list for each country established. → Example (F)

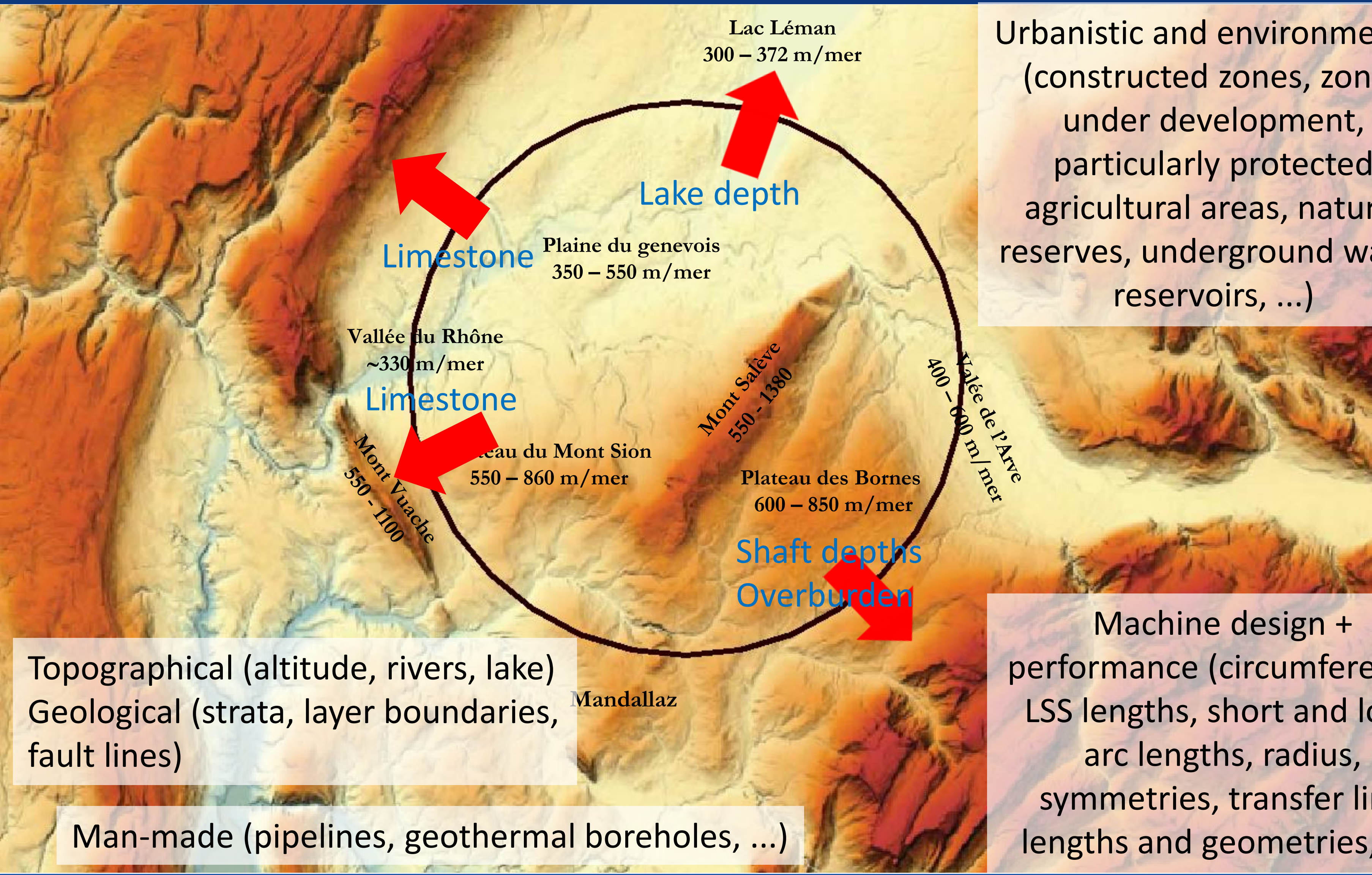
- Masse d'eau souterraine
- Ecoulement masse d'eau
- Biodiversité: inventaire
- Biodiversité: protections
- SRCE Rhône Alpes
- Biodiversité et eau
- Risques: argiles
- Risques: inondations
- Risques: sismique
- Risques: technologiques
- Densité population
- Unités paysagères
- Protections paysagères
- Documents urbanisme
- Réseau d'électrique
- Réseau routier

Idem opportunities listed which need to be further analysed (infrastructure network, socio-economic, ...).

Thursday, 8:30: Activities with Host States (J. Gutleber)

J. Gutleber / ATS-DO

Footprint constraints and criteria



Urbanistic and environmental (constructed zones, zones under development, particularly protected agricultural areas, natural reserves, underground water reservoirs, ...)

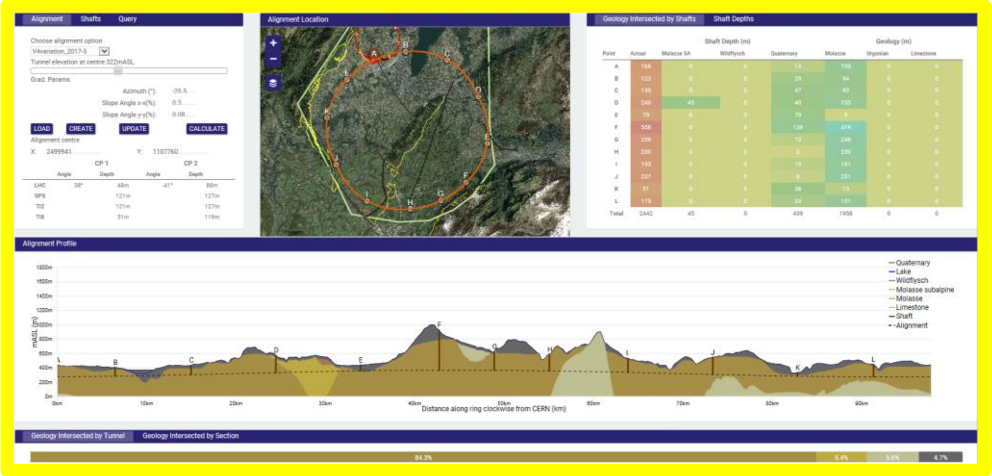
Topographical (altitude, rivers, lake)
Geological (strata, layer boundaries, fault lines)

Man-made (pipelines, geothermal boreholes, ...)

Machine design + performance (circumference, LSS lengths, short and long arc lengths, radius, symmetries, transfer line lengths and geometries, ...)

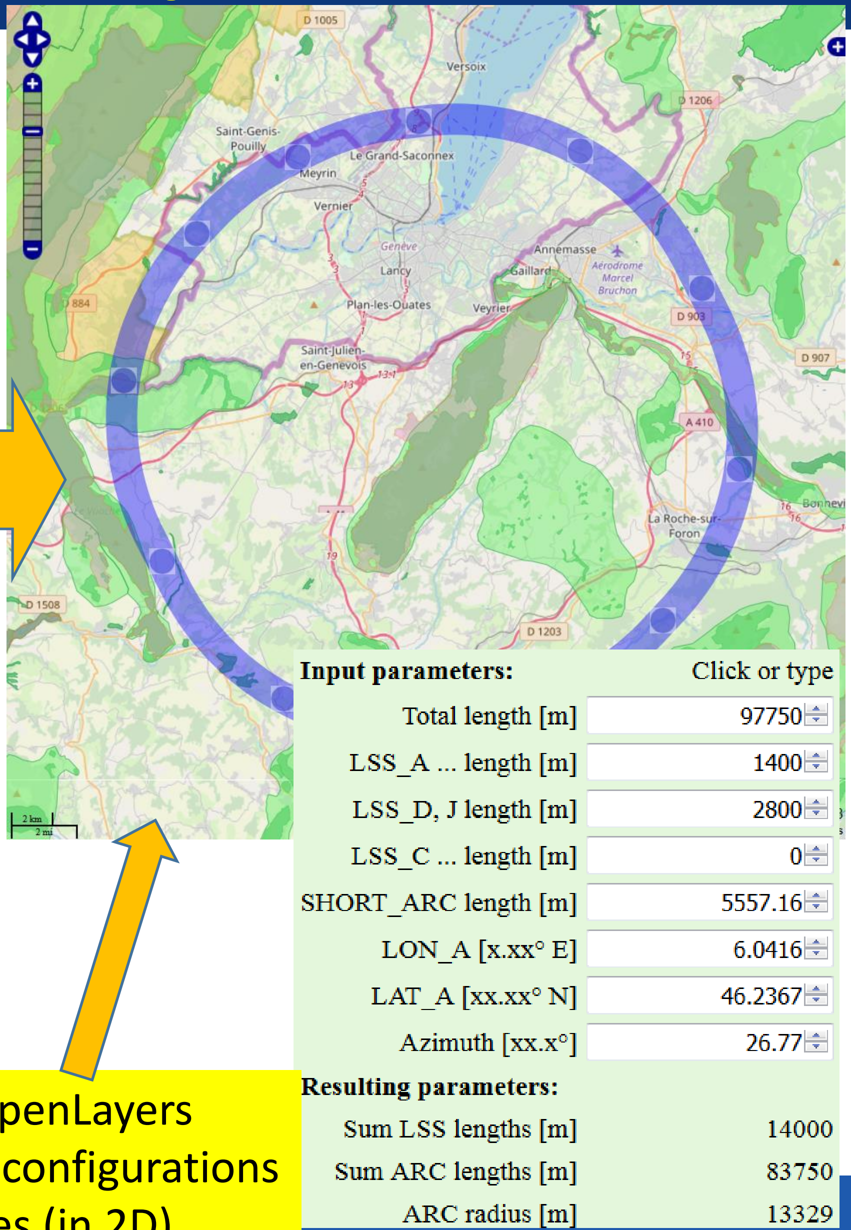
Speed-up of footprint exploration

Tunnel Optimisation Tool (TOT)



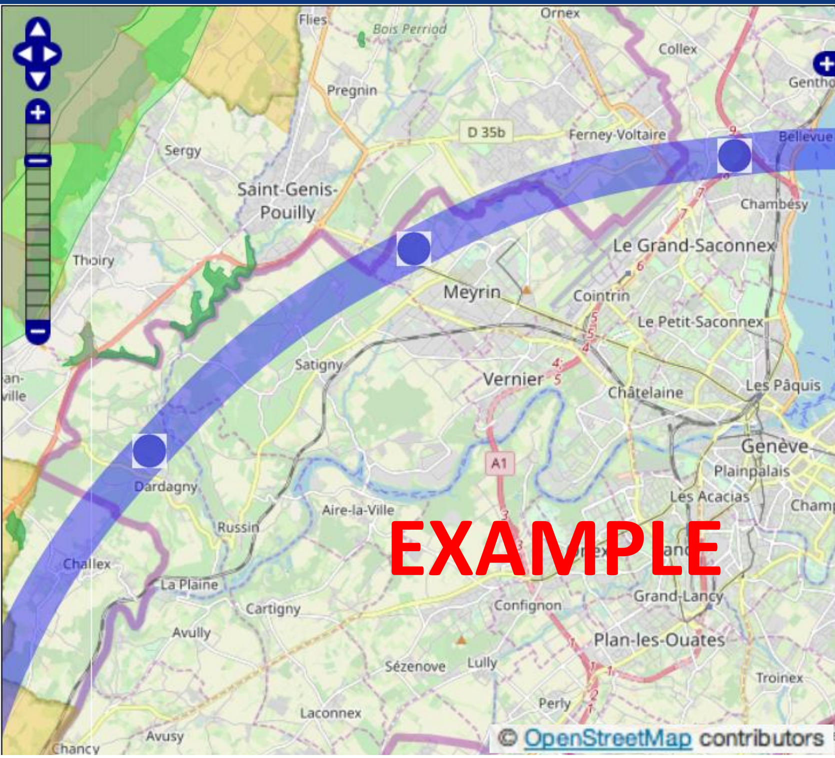
CE oriented; strong points:
3D geometry, geological layers, shaft depths,
opportunities for inclined access (replacing a shaft)

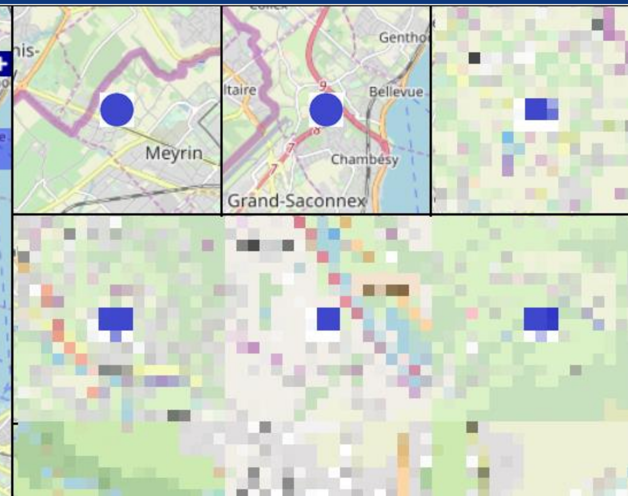
but time- and manpower-intensive iterations
when wanting to test different collider shapes
(circumference, LSS/arc lengths,
other constraints like protected zones)



JavaScript front-end based on OpenStreetMap/OpenLayers
allows rapid first exploration of different access point configurations
wrt to constraints from surface features and zones (in 2D).

Footprint exploration





Input parameters:	Click or type
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LSS_A ... length [m]	1400
LSS_D, J length [m]	2800
LSS_C ... length [m]	0
SHORT_ARC length [m]	4705
LON_A [xx.xx° E]	6.057
LAT_A [xx.xx° N]	46.2357
Azimuth [xx.x°]	26.77
Resulting parameters:	
Sum LSS lengths [m]	14000
Sum ARC lengths [m]	83756
ARC radius [m]	13330

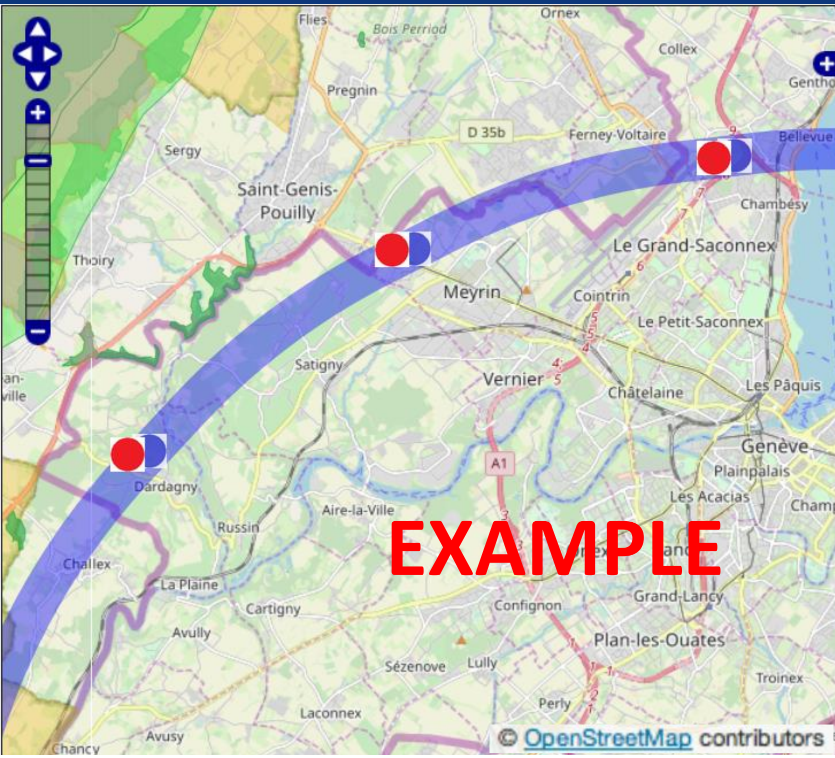
Map data: © OpenStreetMap contributors (copyright and license)
Library/API: OpenLayers
Zones (F): Inventaire National du Patrimoine Naturel
ESRI Shapefile → .KMZ format conversion: QGIS

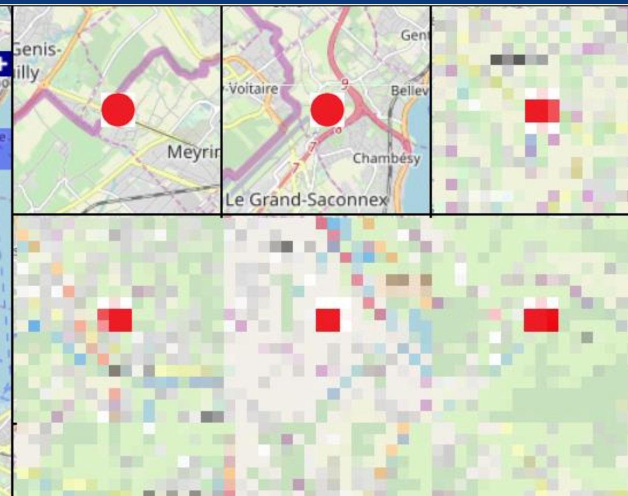
Varying all indicated input parameters
(within „reasonable“ limits, e.g. „SHORT_ARC“ length only in multiples of FODO cells).

Once a new set of suitable surface points has been identified
→ further exploration and optimisation of CE/geological aspects with TOT
(depths, tilt, geology, overburden, ...).

Could enhance that software by 3D or even automatic optimisation wrt exclusion zones
(good comprehensive parametrisation not evident).

Footprint exploration





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ARC radius [m]	13329

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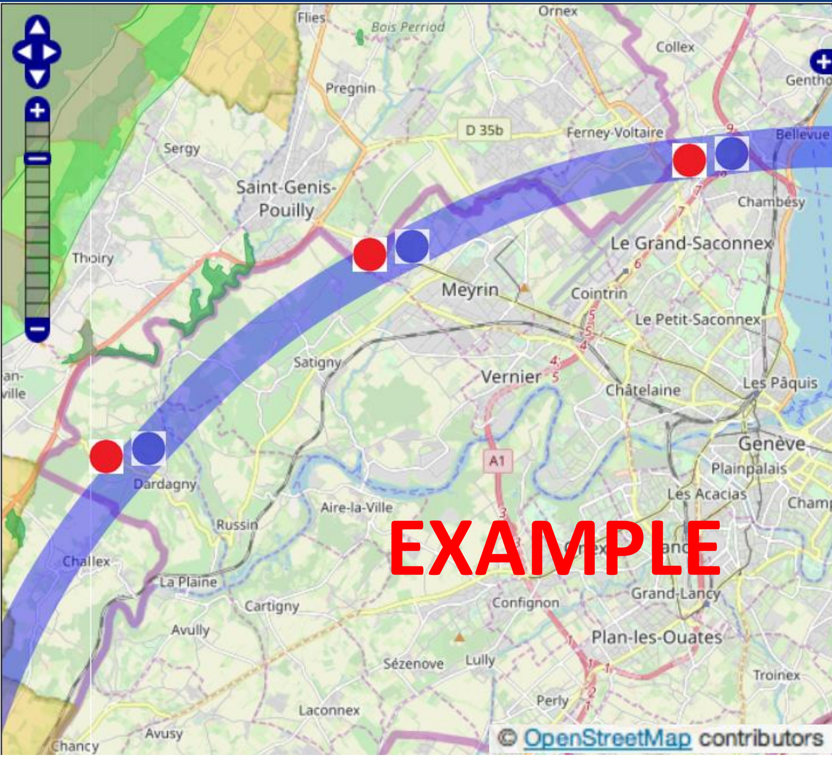

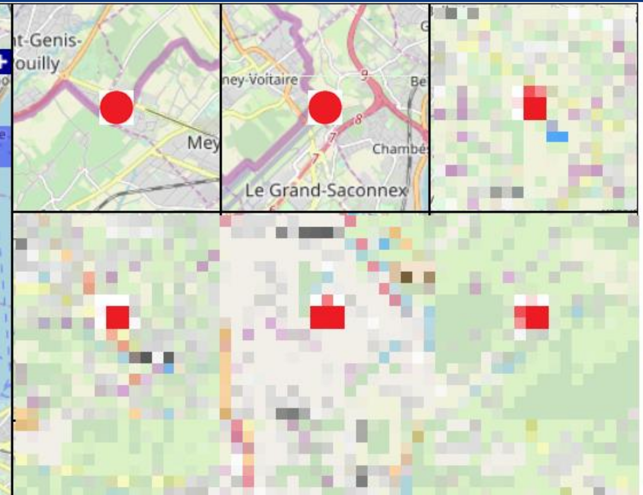

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ARC radius [m]	13329

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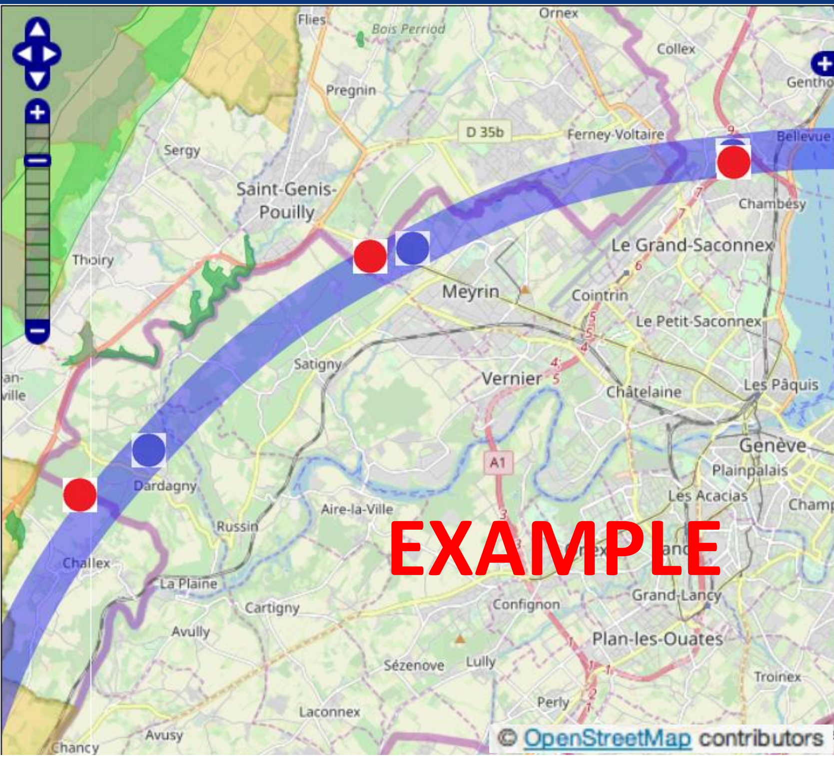

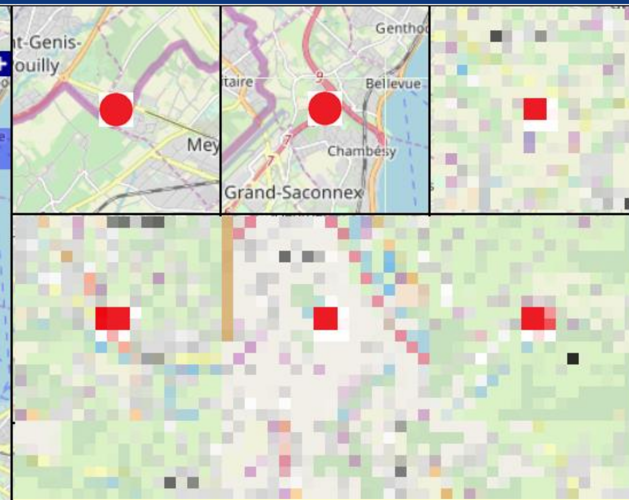

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LAT_A [xx.xx° N]	46.2344
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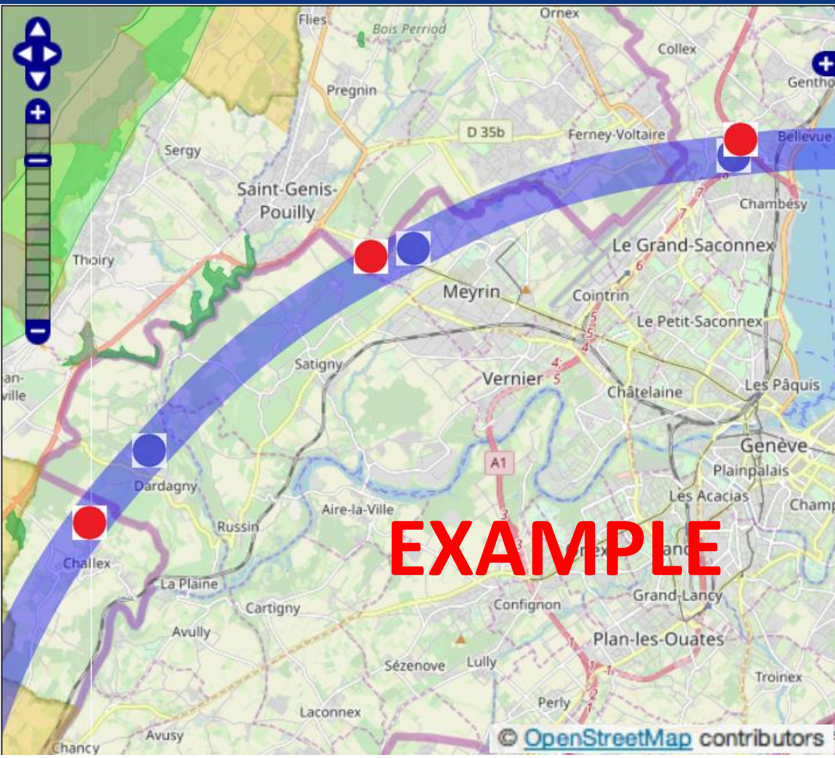

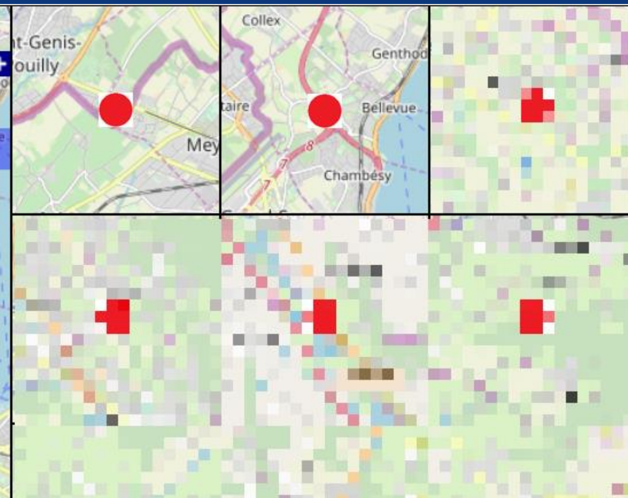

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CE study progress

Cost and schedule estimate compatible with the CDR baseline for all 3 machines: FCC-hh, FCC-ee and FCC-eh

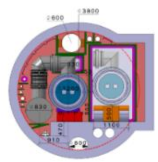
Refinement of results (fire compartments, cavern spacing)

Additional ILF studies (cash flow, spoil volume per site, HL-LHC cost comparison)

HE-LHC

Requirements gathered from cryogenics, electricity and HVAC, which determined the modifications needed for HE-LHC for civil engineering

Cost estimate produced



Spoil Management

Study of the molasse re-use (approx. 9 Mm^3 of spoil in total)

Samples tested from HL-LHC sites

Positioning

Development of common method to assess risks of surface sites, first reviews

Layout optimisation based on geology, shafts depth, construction risks

Ongoing work:

- Surface site investigation
- Site investigation planning
- Spoil management study
- Transfer line design

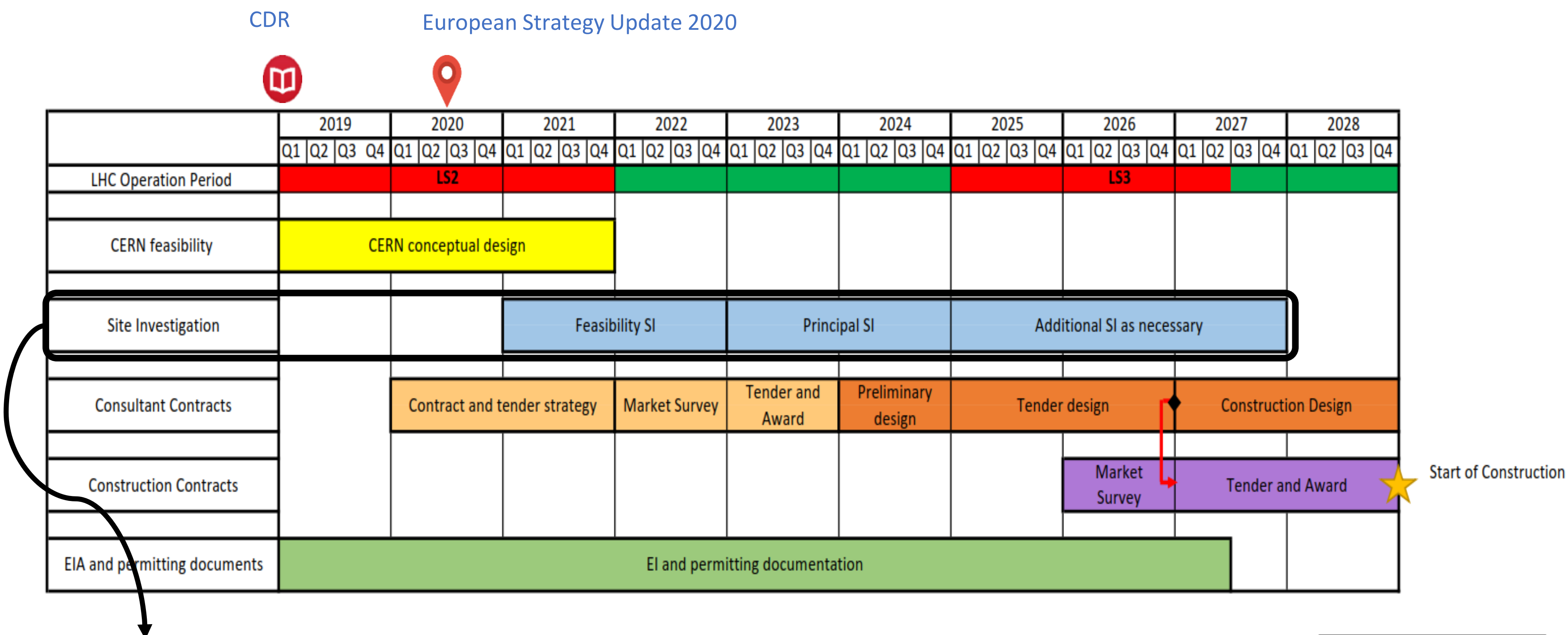
May 2018 → Aug. 2018 → Sep. 2018 → Dec. 2018 → Jan.- June 2019 → Ongoing

CDR volumes submitted to Update of European Strategy for Particle Physics

Thursday, 8:30: Civil engineering summary – cost drivers, risk factors, schedule for preparatory phase (A. Tudora)

A. Tudora + J. Osborne / SMB-SE

Schedule for preparatory phase



Feasibility SI (2021-2022)

- Walkover survey
- Geophysical investigation of all access points, Geneva Lake crossing, Rhône and Arve Valley

Principal SI (2023-2024)

Phase 1 – site investigations required for the development of preliminary design
Phase 2 – confirmation of geological profiles and engineering design parameters
Phase 3 – additional explorations needed for refined cost estimate

Types of site investigations:

- Boreholes
- Site testing (e.g. in-situ stress test, point load testing, SPT, CPT, permeability tests)
- Rock laboratory testing (e.g. uniaxial compressive strength, petrographic studies)

Additional SI (2025-2027)

Additional data might be required after preliminary design for a more detailed geological evaluation

Thursday, 8:30: Civil engineering summary – cost drivers, risk factors, schedule for preparatory phase (A. Tudora)

A. Tudora + J. Osborne / SMB-SE

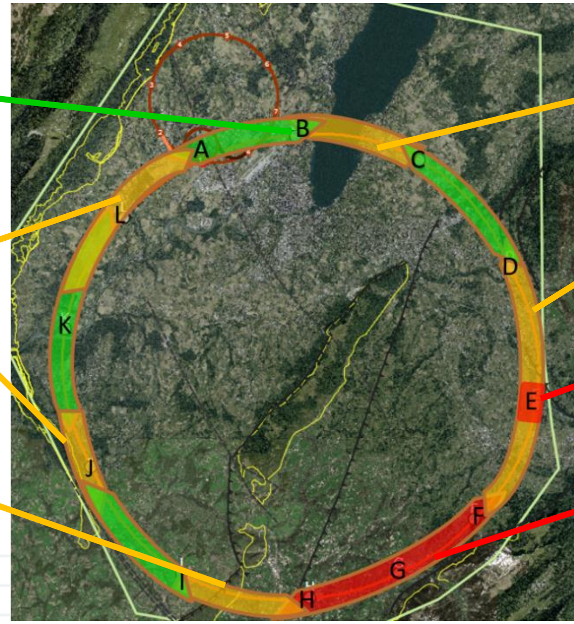
Geological uncertainty

and features of interest

- Information near to CERN is strong due to previous experience on LEP/LHC.
- Multiple deep boreholes in the area.

- Alignment close to limestone rockhead.
- The exact location and angle of the limestone/molasse interface undefined.

- Limestone formation known, but characteristics and locations of karsts unknown.

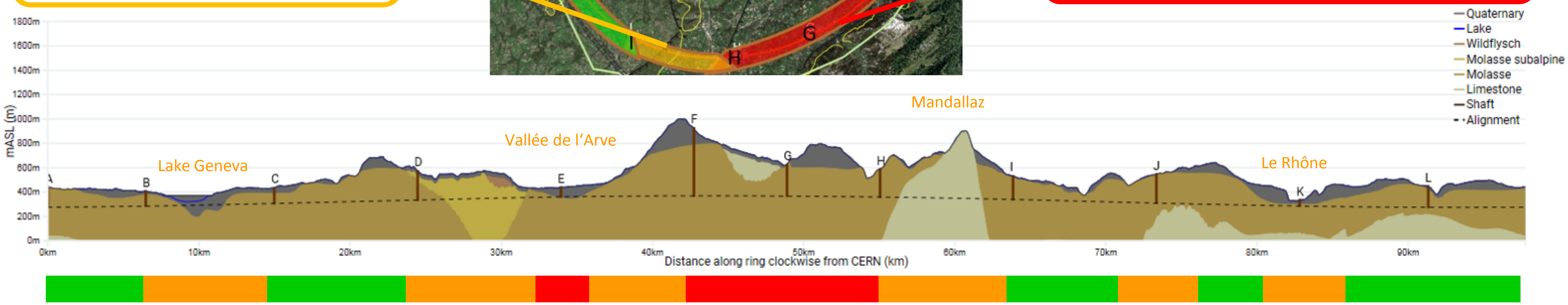


- Seismic and borehole information for lake crossing from proposed road tunnel, but layered nature of lake bed leads to uncertainty.

- Location of the interface between molasse and molasse subalpine uncertain, tunnel alignment in proximity.

- Moraine/molasse interface uncertain, cavern close to interface.
- Lack of deep boreholes in area.

- Lack of deep borehole in area.
- Complex faulted region.
- Molasse/limestone interface uncertain.

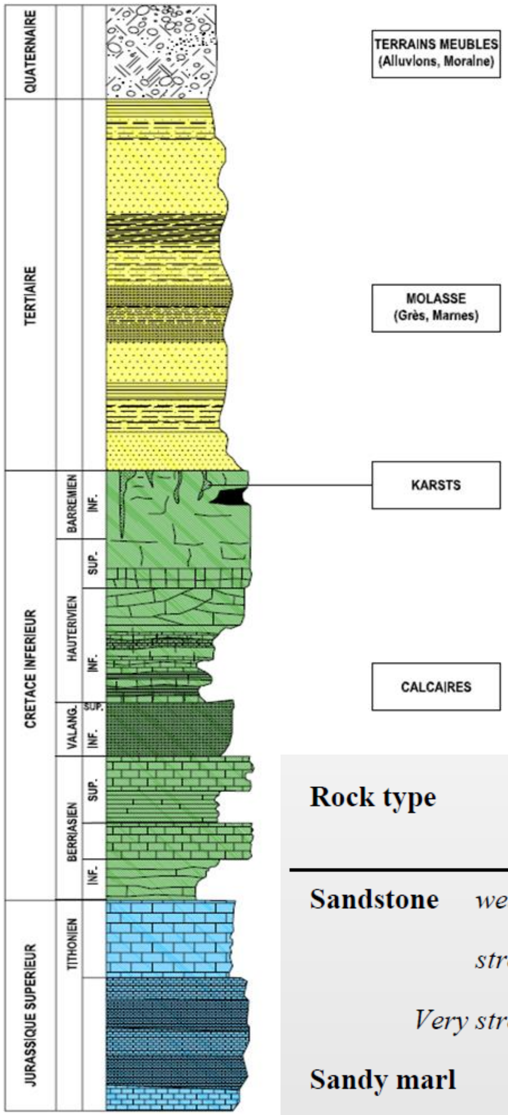


Main geological features of interest											
	Shafts in shallow moraine deposits; Point of connection to LHC in deep moraines	Crossing of Lake Geneva and deep shaft in moraine	Reported faulting and interfaces between molasses types and deep shaft in moraine	Low cover to the Arve alluviums	Deepest point of the project	Possible interfaces with limestone and deep shaft in moraine	Interfaces between limestone and molasse. Possibly karst and Mandallaz fault	Interfaces between limestone and molasse. Zones of low rock head and cover with possibility of poor rock	Possible interfaces with limestone at depth and worsening ground towards K	Low cover to the Rhône alluviums	Allondon Fault and possible zones of poor rock, level of limestone

Thursday, 8:30: Civil engineering summary – cost drivers, risk factors, schedule for preparatory phase (A. Tudora)

A. Tudora + J. Osborne / SMB-SE

Geology in region



- **Moraines**
  - Glacial deposits comprising gravel, sands, silt and clay
  - Water bearing unit
  - Low strength
- **Molasse**
  - Mixture of sandstones, marls and formations of intermediate composition
  - Considered good excavation rock
  - Relatively dry and stable
  - Relatively soft rock
  - However, some risk involved: structural instability (swelling, creep, squeezing)
- **Limestone**
  - Hard rock
  - Normally considered as sound tunneling rock
  - In this region fractures and karsts encountered
  - High inflow rates measured during LEP construction (600 l/sec)
  - Clay-silt sediments in water filling karsts

Rock type		Average σc (Mpa)
Sandstone	*weak*	10.6
	strong	22.8
	Very strong	48.4
Sandy marl		13.4
Marl		5.7

Molasse Compression strengths

M. Haas / Montanuniversität Leoben + SMB-SE

Study of molasse re-use

Montanuniversität Leoben
Chair of Subsurface Engineering
Geotechnics and Underground Constructions
Head: Univ.Prof. Dipl.-Ing. Dr.mont. Robert Galler

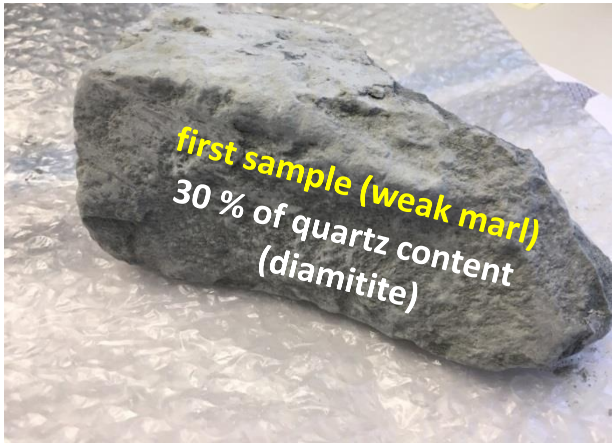
M. Haas / Montanuniversität Leoben + SMB-SE

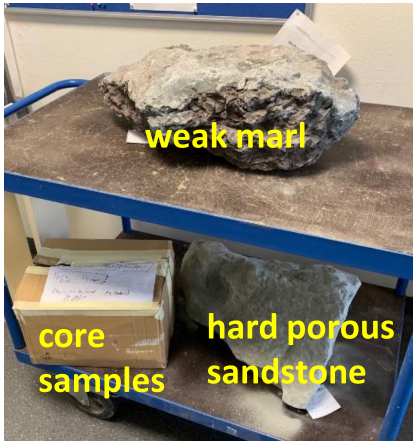
Done so far

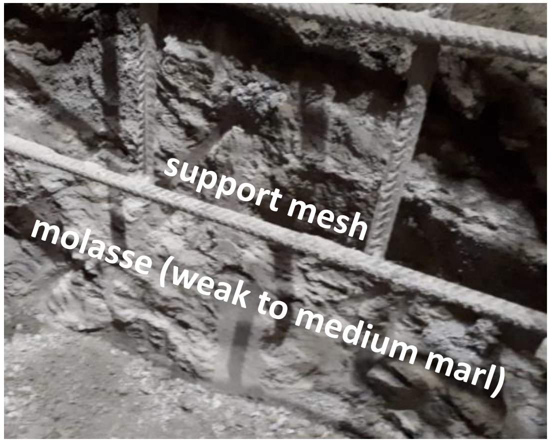
- Legal and technical literature research
- Derivation of legal framework ("state-of-the-art") for the treatment and re-use of tunnel excavation material, explicitly for the FCC study
- Close cooperation with GESDEC, CETU, MARTI AG, SETEC
  - Received laboratory results (pollution analyses)
  - Point 1 construction site, exchanging data
- First samples taken at HL-LHC Point 1 and tested:
  - Chemical composition
  - Mineralogical composition

To come

- Regular meetings with CETU & GESDEC to derive a French & Swiss guideline
- Further sampling (up to 100) along FCC path to:
  - Obtain new mineralogical, chemical, petrophysical & geotechnical data + combine them with existing data from previous projects (e.g. LHC, SPS, …)
  - Distinguish between "red" and "grey" molasse
  - Taken samples from HL-LHC Point 5
  - Re-use with regard to excavation method (e.g. TBM type)





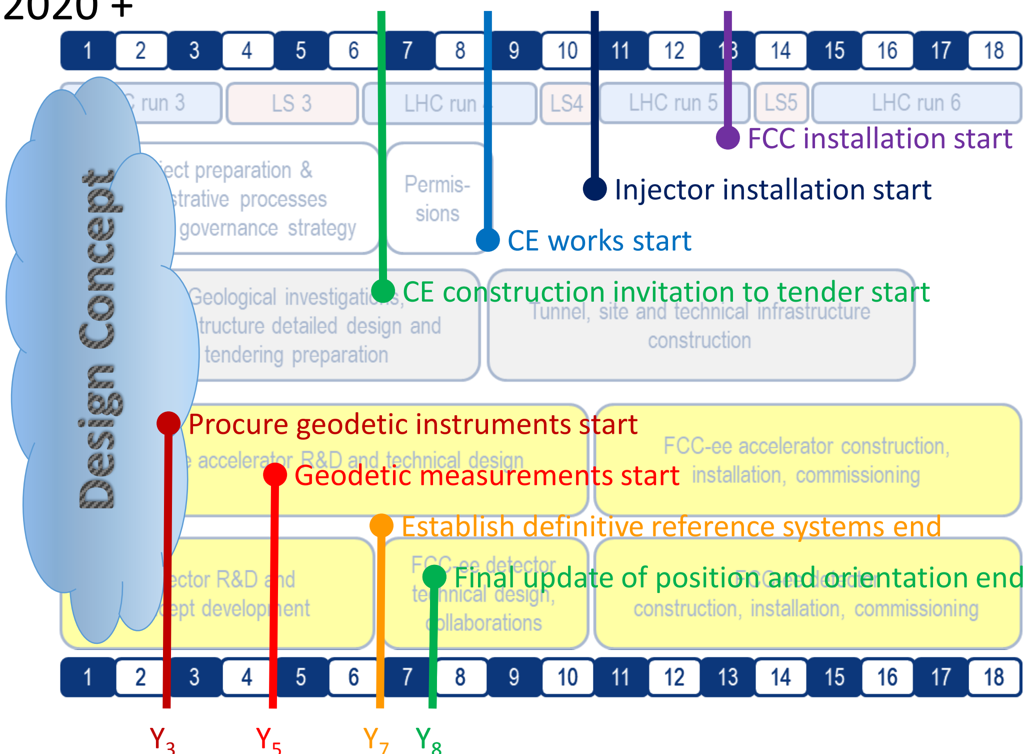


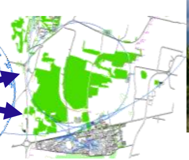
Thursday, 8:30:
Excavation material use strategy (Prof. R. Galler)
Analysis of excavation materials in view of re-use (M. Haas)

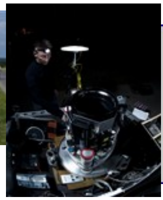
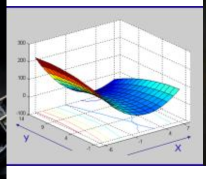
GESDEC = Service de géologie, sols et déchets (Genève / CH)
CETU = Centre d'études des tunnels / F

Geodesy

Reference point coordinates for CE construction




Accelerator information required:

- Theoretical design
- FCC-ee integration model
- Metrology & alignment precisions

To be developed:

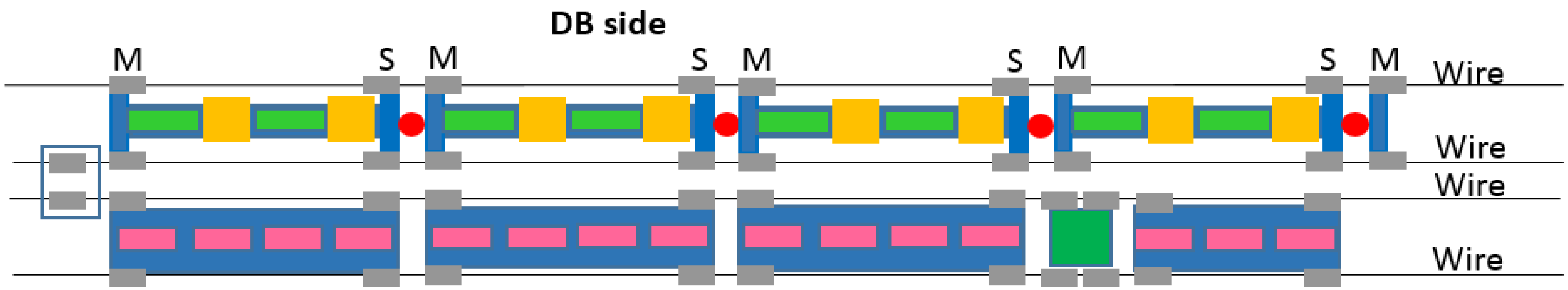
- Geodetic surface reference Network
- Reference systems and transformation algorithms
- Gravity field model
- Geodetic transformation software

Organisational:

- Planning
- Resources

Thursday, 10:30: Geodetic infrastructure and alignment – planning and studies (M. Jones)

FCC-ee alignment + position monitoring



CLIC design

- Articulation point
- WPS sensor
- Metrological plate (MRN)

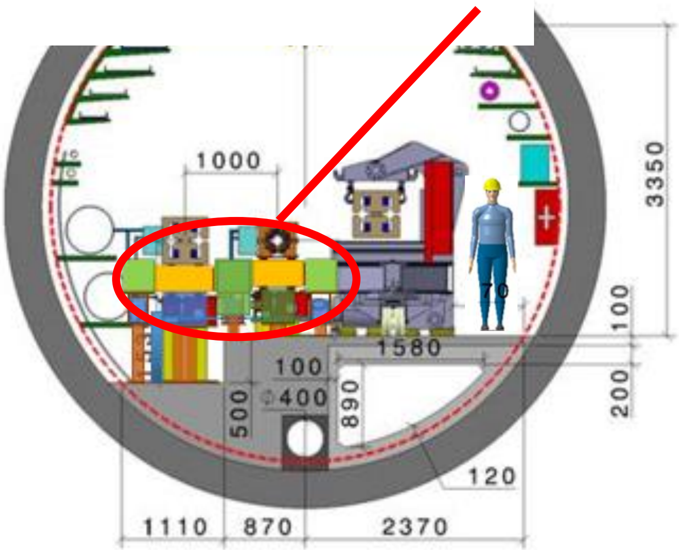
Master cradle:
- 2 WPS
- 3 linear actuators

Slave cradle:
- 2 WPS

Detailed integration and accessibility to be studied

Concept based on design for CLIC

- Full remote position monitoring and alignment system
- Wire position sensors (WPS)
- Hydrostatic levelling sensors
- Motorised positioning system

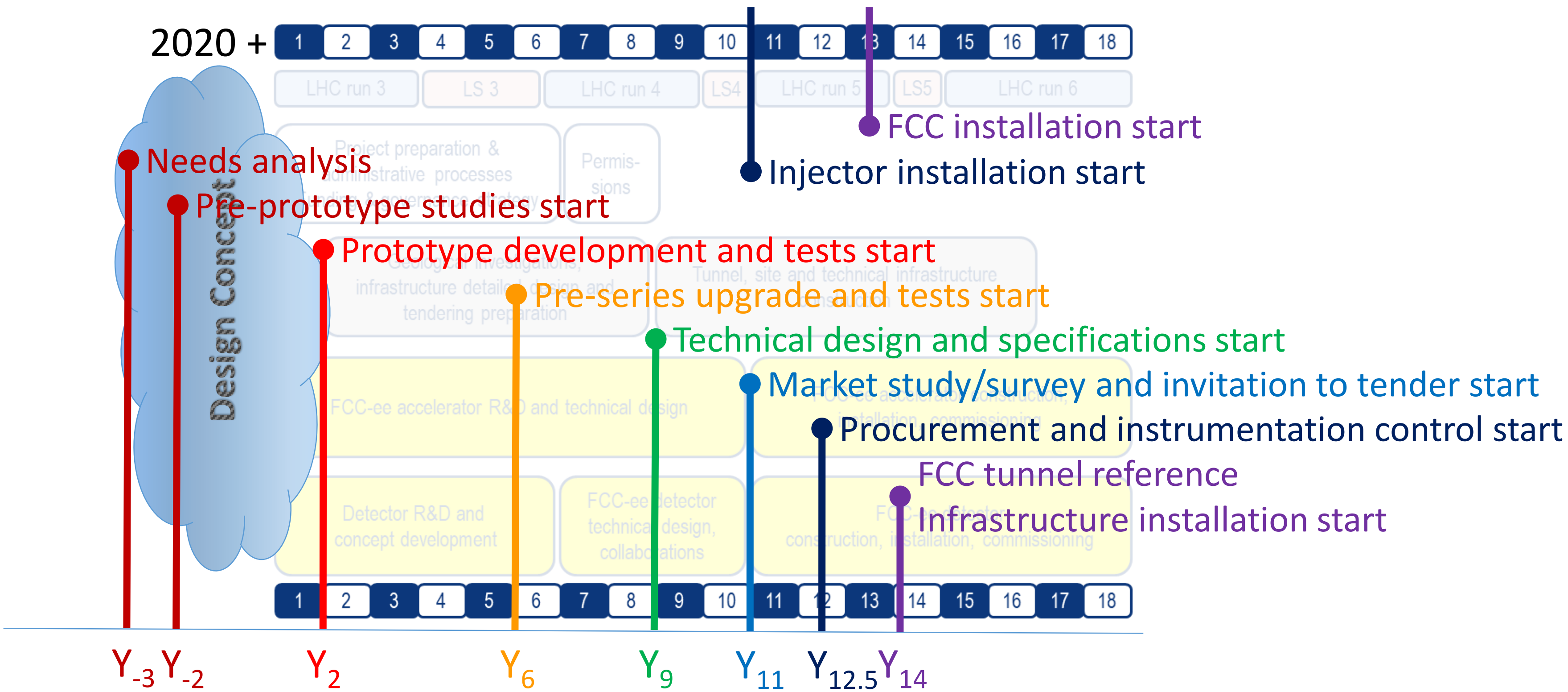


Thursday, 10:30: Geodetic infrastructure and alignment – planning and studies (M. Jones)

M. Jones / EN-SMM

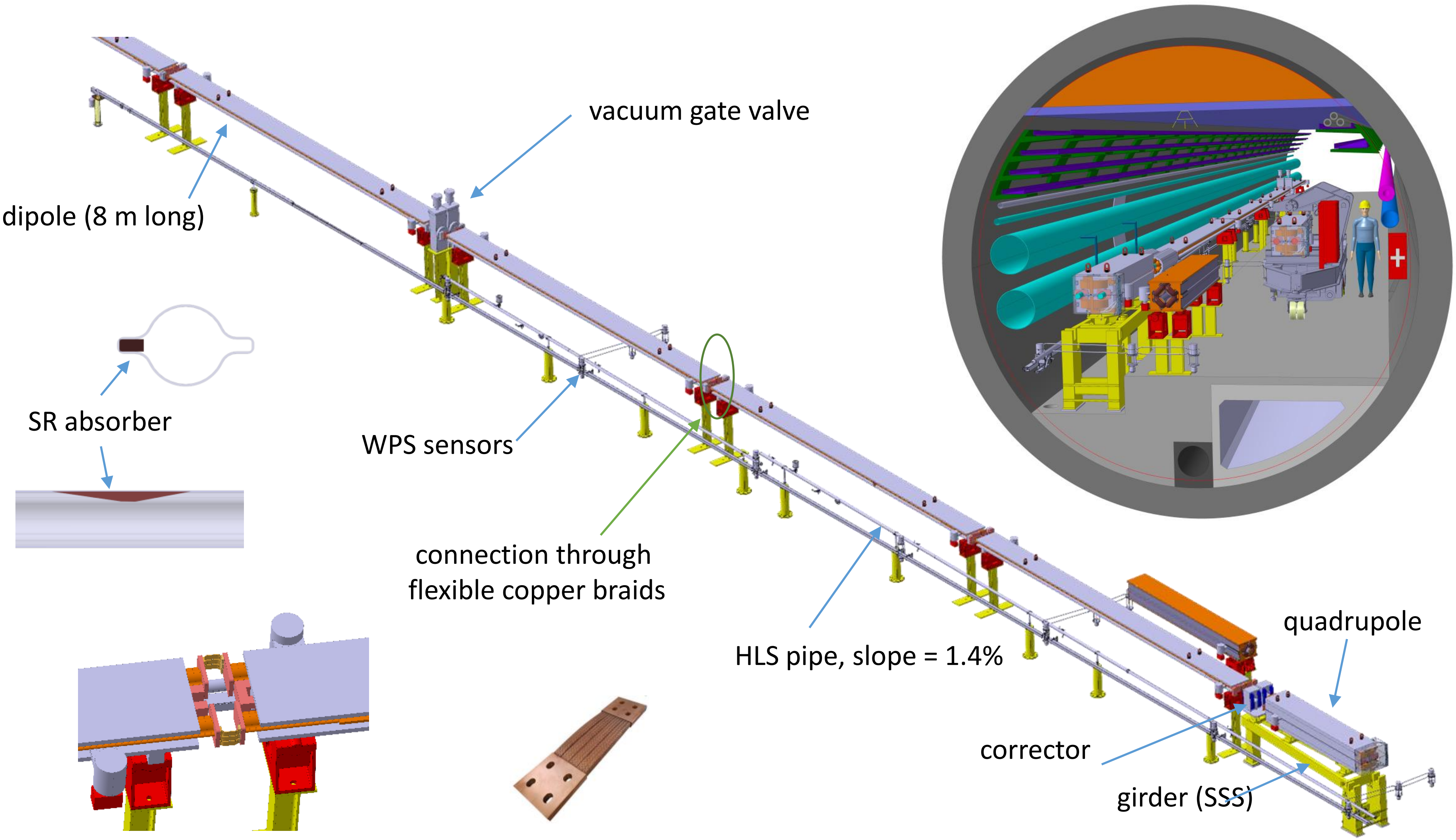
FCC-ee alignment + pos. monitoring system

Main and booster ring preparatory activities



Thursday, 10:30: Geodetic infrastructure and alignment – planning and studies (M. Jones)

FCC-ee integration



F. Valchkova-Georgieva / EN-ACE

Cryogenics

Full session on Wednesday, 10:30

2 engineering studies of large FCC-hh cryogenic plants with industrial partners:

- Completed with Linde
- Close to completion with Air Liquide Advanced Technology

→ No showstoppers: 100 kW equivalent at 4.5 K (including 15 kW at 1.8 K) refrigerators are feasible with additional R&D on warm and cold compressors

Outcome of the engineering studies for the FCC-hh cryoplants (F. Millet)

Cooling of high-luminosity FCC-hh inner triplet magnets:

- Very large specific heat loads due to deposited secondaries:
  - up to 140 W/m deposited on the magnet cold masses
  - 2 orders of magnitude above the heat loads of standard FCC-hh dipoles
- Optimization of the cooling method:
  - four bayonet heat exchangers in parallel
  - split of Q1 into 3 cryo-magnets to keep the bayonet heat exchanger diameter < 100 mm

FCC-hh inner-triplet cryogenics (C. Kotnig)

EASITrain program:

4 fellowships with following deliverables:

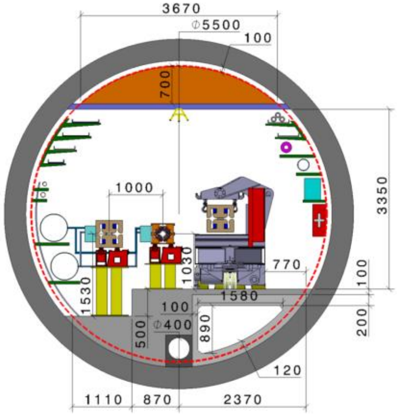
- Architectures and models for superconducting magnet cooling (CEA)
- Specification for Nelium refrigeration system (TUD) →
- Specification of optimised heat extraction for magnet coils (CEA)
- Turbo compressor test bench operational (USTUTT)

Improved concept of the Nelium Turbo-Brayton cycle for FCC-hh beam screen cooling (S. Savelyeva / TU D)

Transient conjugate heat transfer numerical simulation in superfluid helium (A. Vitrano / CEA Saclay)

L. Tavian / ATS-DO

Cooling and ventilation



Integration:

- Air ducts (embedded in concrete floor) to air diffusors
- Fire dampers for smoke extraction system
- Water sub-distribution (manifolds)

FCC-ee design:

- With regard to FCC-hh equipment size → economic and integration impact
- Cost model according to the installation sequence, planning and other constraints
- Further RF ventilation studies

Environmental impact:

- Raw water supply points and distribution depending on locally available flow rate
- Similarly, reject of water into the clear water drain or in the sewage
- Heat recovery possibilities at the different surface points and heat use in the local areas

Operation:

- Maintenance strategy for 3 or 4 year long accelerator runs.

M. Nonis + G. Peon / EN-CV

Powering

Studying the optimised, high quality, powering strategy for magnets + sensitive loads; 3 topics:

Power converter design:

- Main criteria: simplicity and reliability
- Target is to be modular (as already successfully implemented at CERN)
- Permitting energy recovery

Power quality:

- Power factor = 1 required at the connection to the 400 kV electrical grid
- Transient voltage dip immunity: analysis of sensitive load and the transmission grid for FCC
  → currently evaluating the potential of DC networks,
  combined with a new method for dip mitigation

Safety in underground structures:

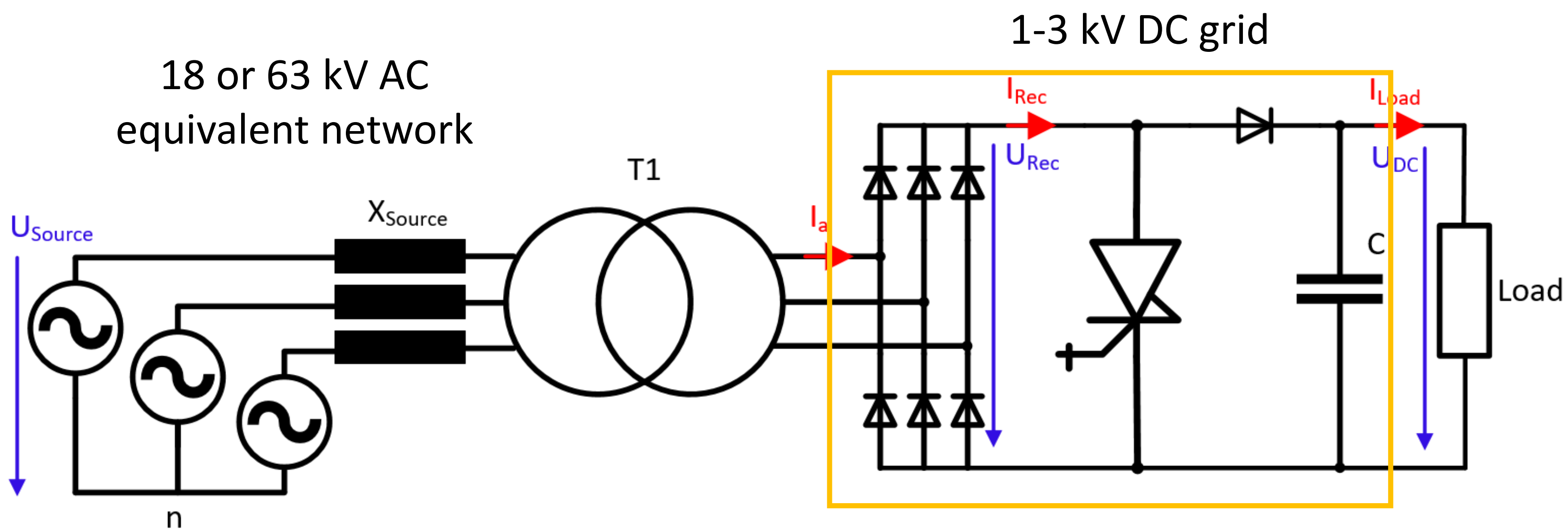
- Large scale energy storage (if required) would be at the surface
- Reduction of equipment and infrastructure in the tunnel

T. Höhn / TU Graz + TE-EPC colleagues

Powering

New method for transient voltage dip mitigation in medium voltage DC grids:

A boost converter topology combined with a DC grid



Advantages: cost efficiency, low losses and excellent mitigation performance
Potential applications: particle accelerators, large industrial production proc. with sensitive load

This proposal is now under evaluation, to integrate it into the EN-EL FCC baseline for power distribution and the powering strategy from TE-EPC.

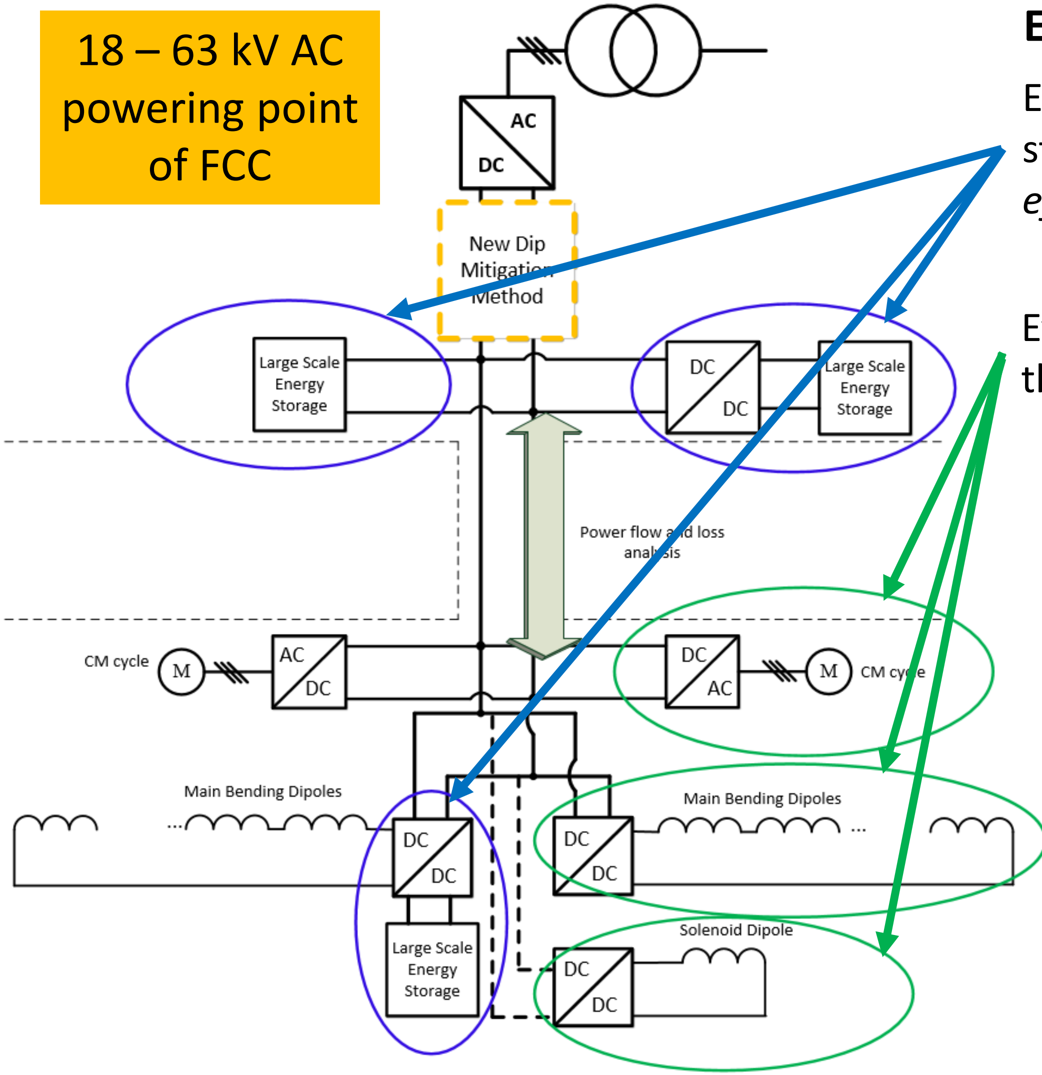
Main point being analysed: is there an overall system benefit by introducing a DC grid ?

Further reading: Int'l Conf on DC Microgrids
https://power.aitech.ac.jp/ICDCM2019/

T. Höhn / TU Graz + TE-EPC colleagues

Powering

18 – 63 kV AC powering point of FCC



Example of a powering layout

Evaluate *if* there is a need for large scale energy storage, *where* to place it and how to connect it *efficiently.*

Evaluate which loads can *efficiently* connect to the grid.

The grid design needs to consider:

Switchgear available: established breakers and relays are preferred

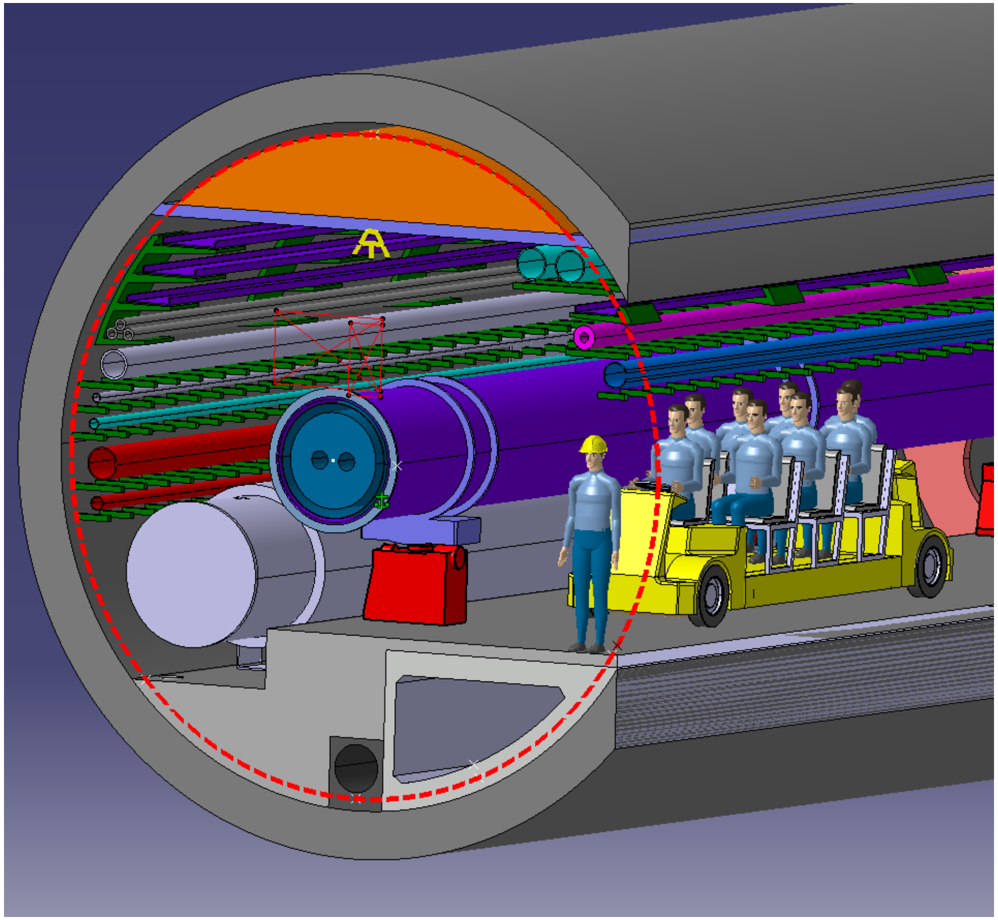
Reduce conversion stages and equipment installed in the tunnel (compared to AC grid)

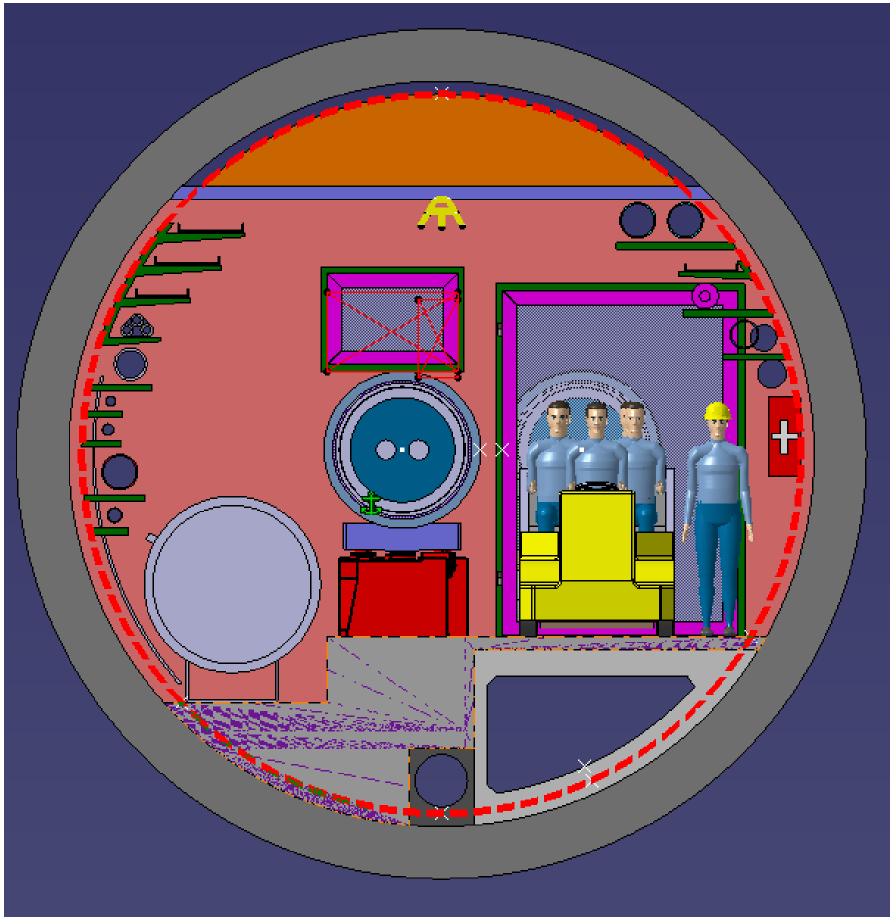
Energy recovery: re-use (or re-storage) of energy in the magnets

Selectivity: only the faulted load is separated from the grid, whereas other load continue operation

Scalable: to adapt easily to all FCC powering points, since the power demand between them varies considerably

Transport





Faster system for transport of personnel (ca. 25 km/h).

Safety

T. Otto / TE
A. Henriques, S. La Mendola, O. Rios, M. Widorski / HSE

The CDR Safety Study (including a fire safety assessment) demonstrated that the planned facilities can meet the Life Safety Objectives

Fire safety studies for TDR phase:

- Practical “details” of fire compartmentalization (installation, transport)
- Organisation of Fire and Rescue Service

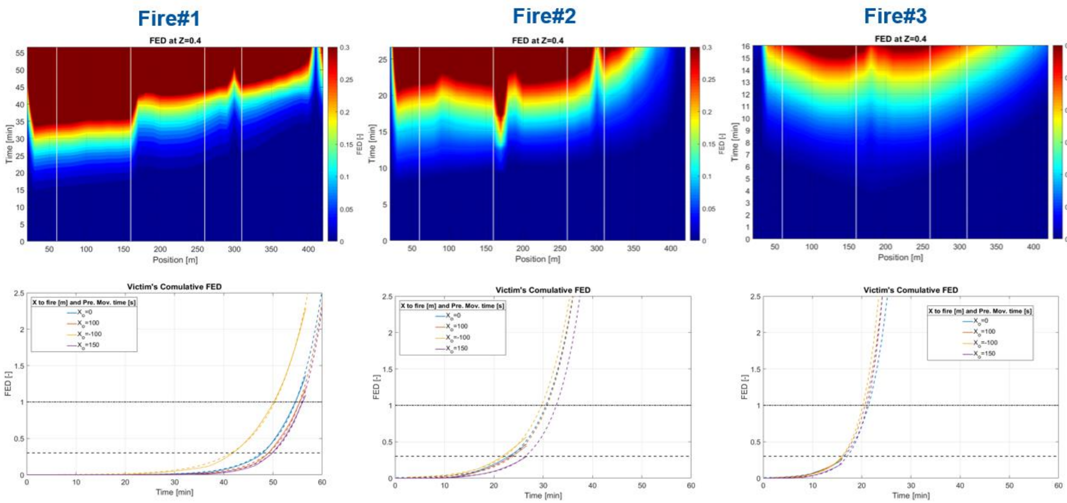
Thursday, 10:30: Safety topics requiring further investigation (T. Otto)

Thursday, 10:50: Study of HE-LHC ventilation strategy in case of fire (O. Rios)

HE-LHC ventilation in case of fire

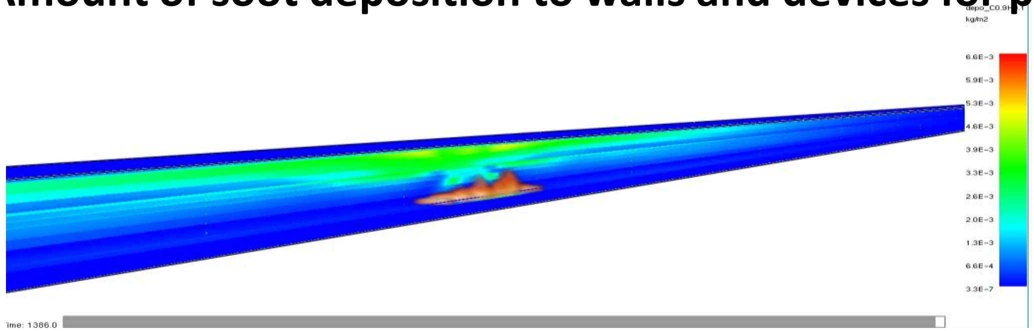
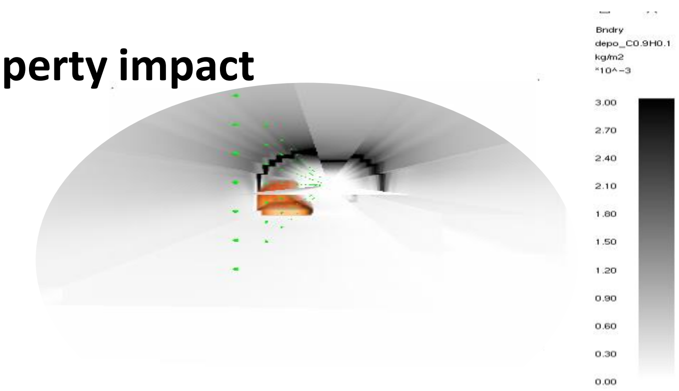
O. Rios, S. La Mendola/ HSE

Fractional Effective Dose (FED) for toxicant assessment on victims



Fire Fighters intervention time impact on Life Safety

Amount of soot deposition to walls and devices for property impact

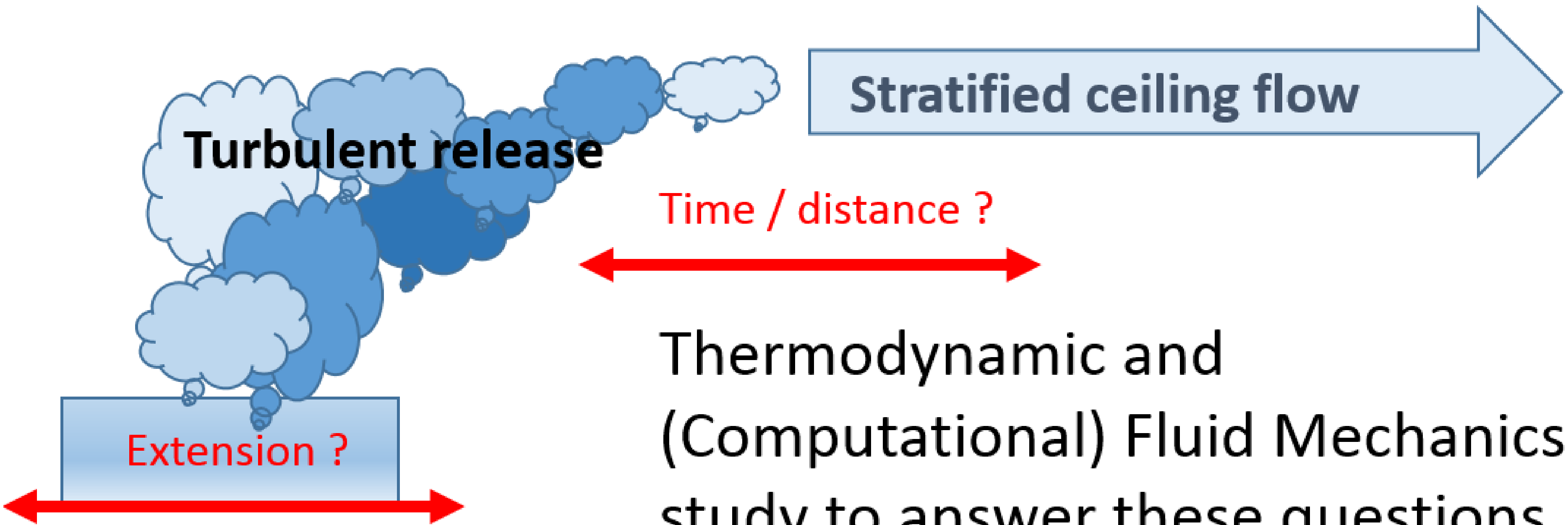
Thursday, 10:50: Study of HE-LHC ventilation strategy in case of fire (O. Rios)

Safety

T. Otto / TE, A. Henriques, S. La Mendola, O. Rios, M. Widorski / HSE

Cryogenic safety studies for TDR phase:

- More accurate description of Helium releases
- Interaction of cold Helium with compartment walls and smoke extraction



Thermodynamic and (Computational) Fluid Mechanics study to answer these questions

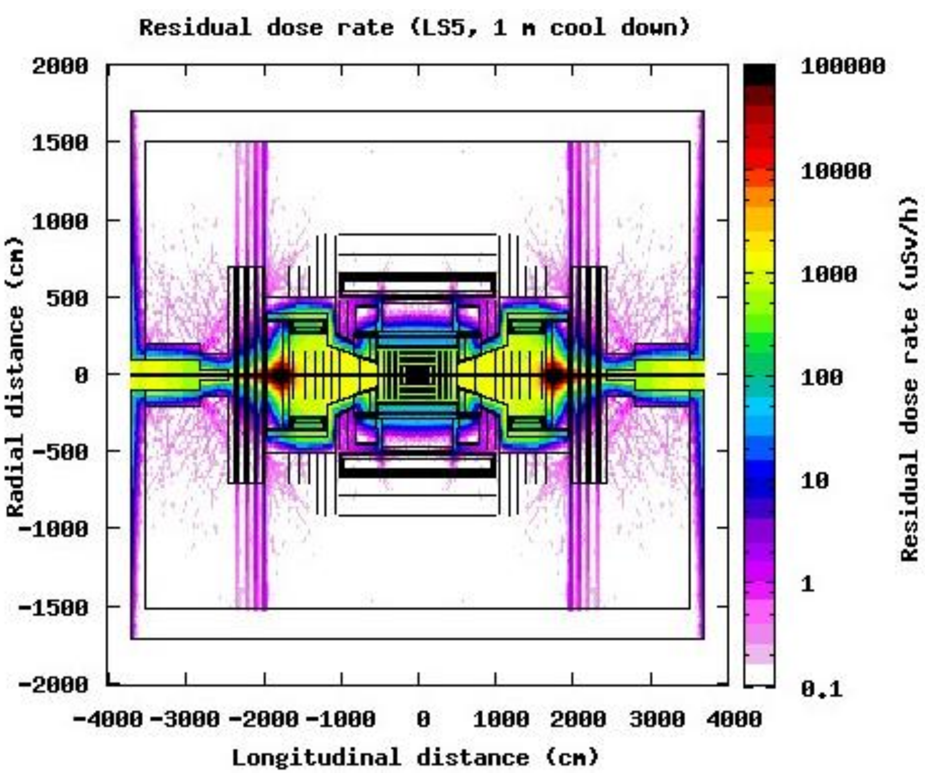
Thursday, 10:30: Safety topics requiring further investigation (T. Otto)

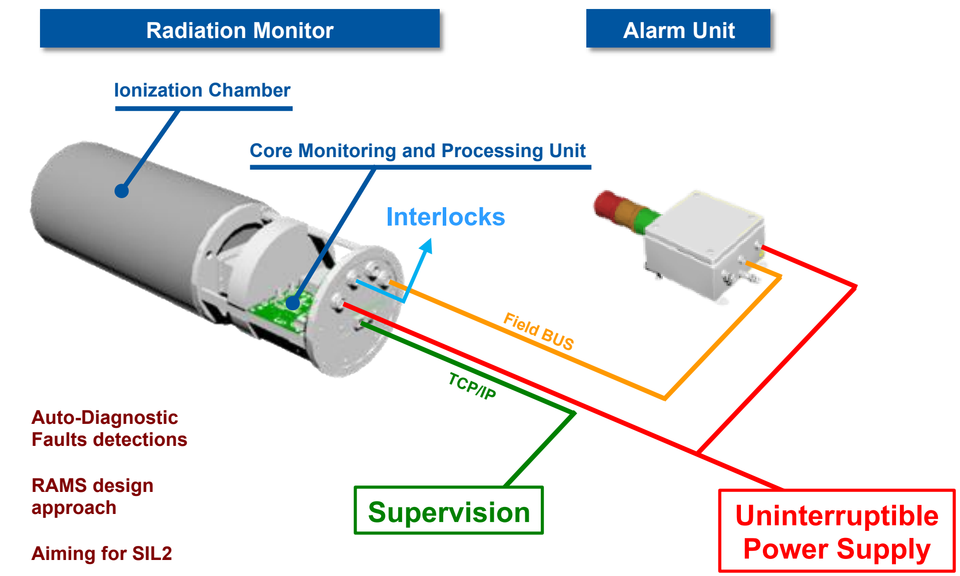
Safety

T. Otto / TE, A. Henriques, S. La Mendola, O. Rios, M. Widorski / HSE

Radiation protection studies for TDR phase:

- Radioactivity in experiments , synchrotron radiation
- Management of released air and water
- Radiation monitoring programme





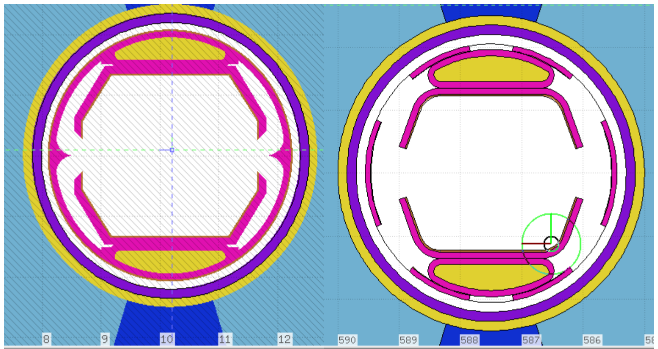
CROME

CERN Radiation Monitoring Electronics

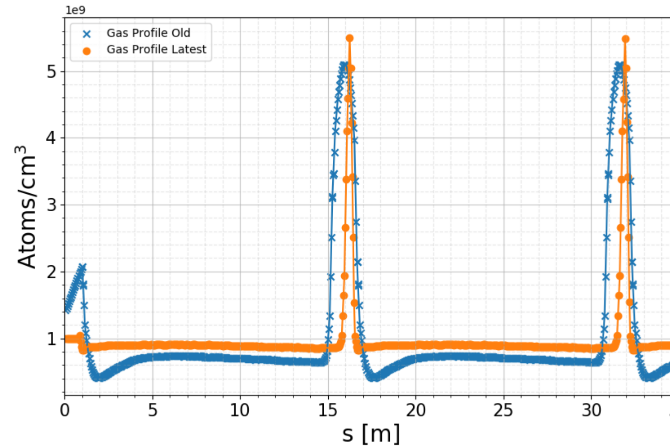
Thursday, 10:30: Safety topics requiring further investigation (T. Otto)

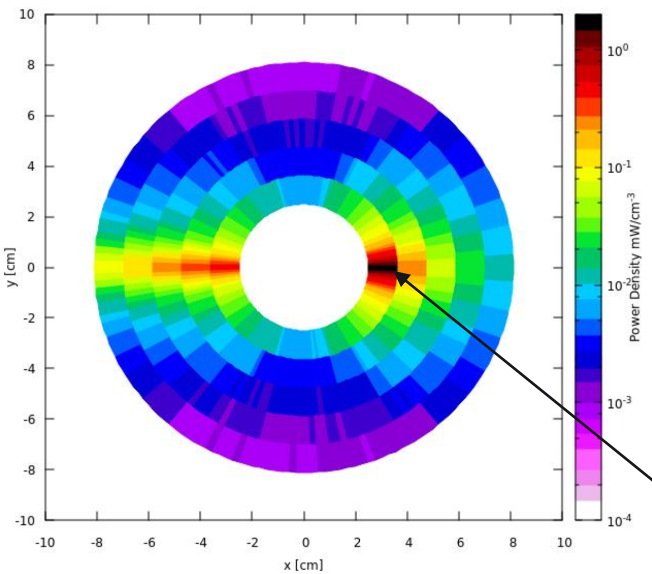
Beam-gas losses

Beam screen



Latest residual gas profile





Peak power density in coils: 1.64 mW/cm^3

Updated beam screen design provides less shielding for coils and cold mass.

Beam screen now absorbing ~5 % of power loss density as opposed to 16 % previously.

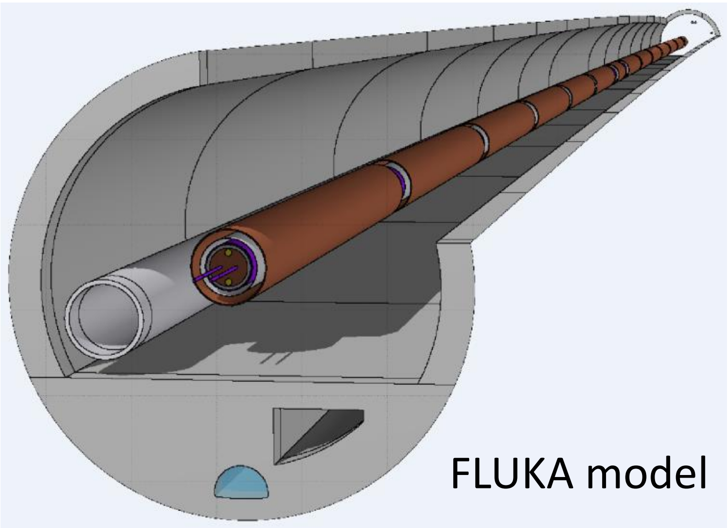
86 % absorbed by cold mass.

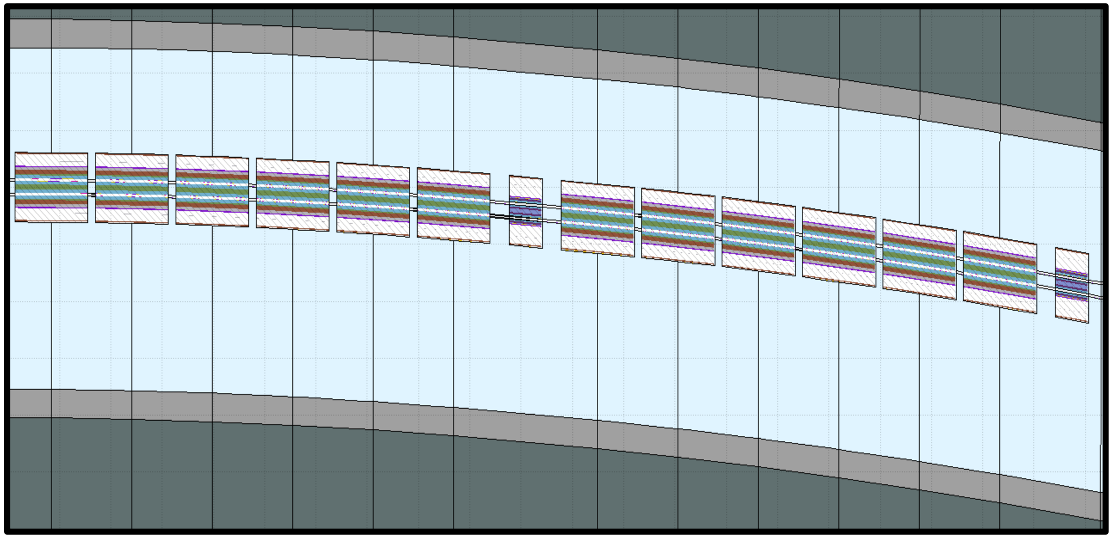
Most impacted dipole receives 278 mW/m on cold mass.

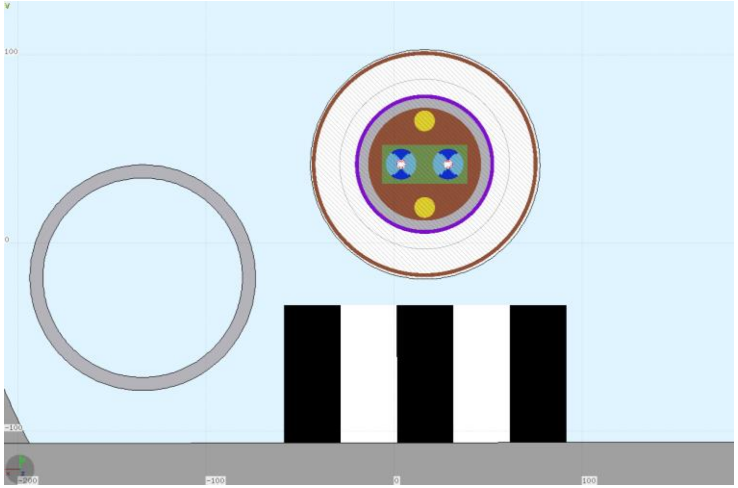
Thursday, 10:30: Update on R2E and heat load simulations (J. Hunt)

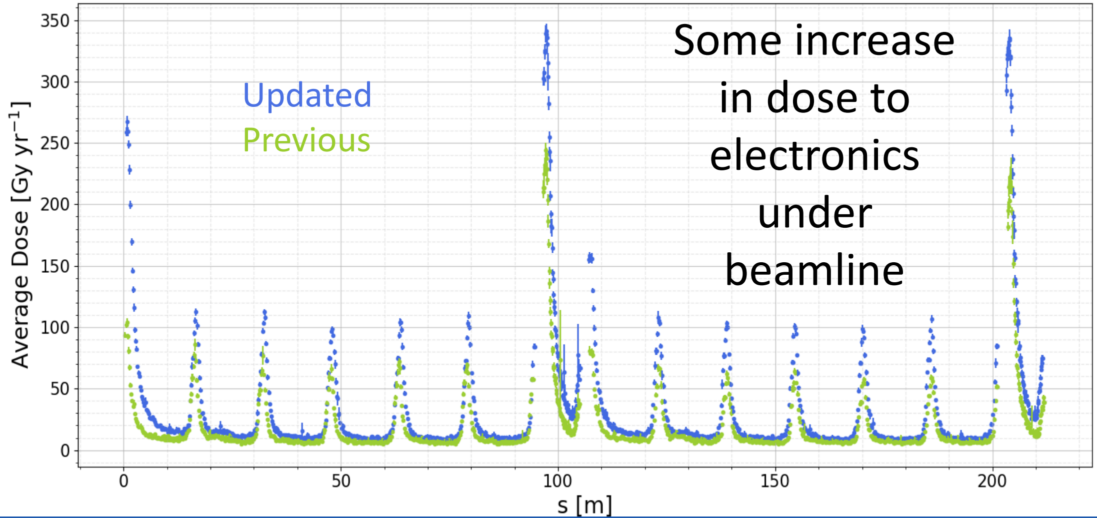
R2E impact

Full 214 m arc cell (axis not to scale)







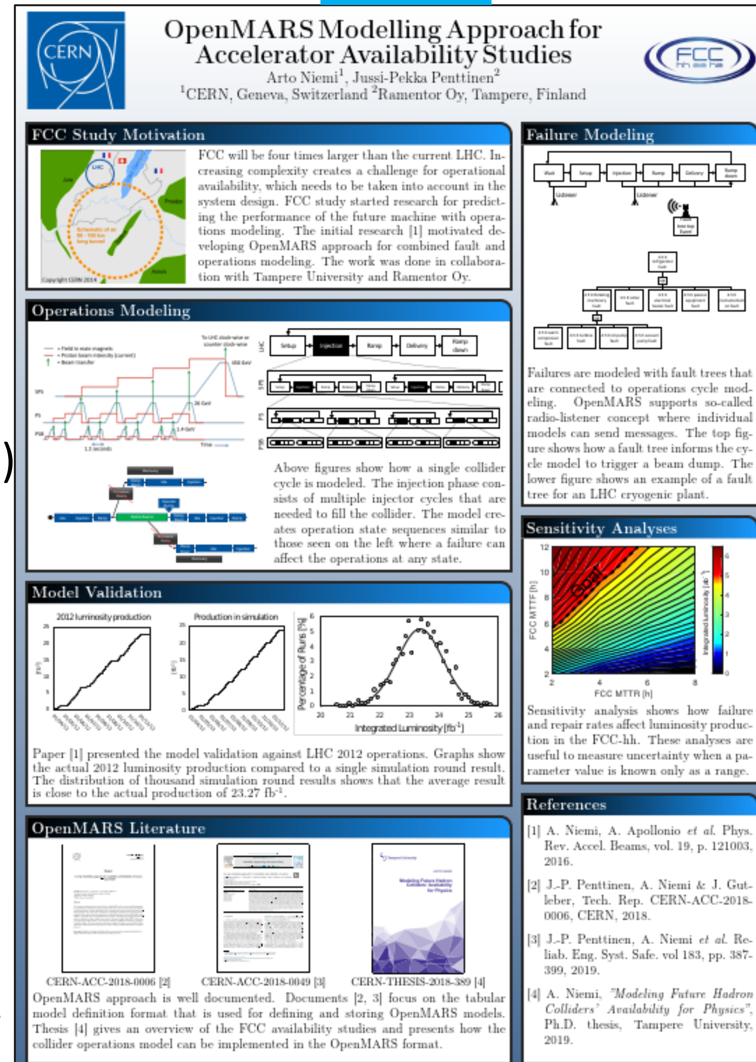


FCC-ee availability

Generally, e+e- colliders have a good availability track record

FCC-ee will be larger and operate with higher energy

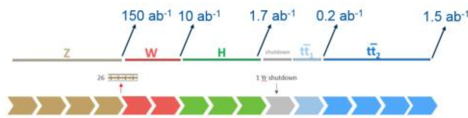
Poster



Study*) aim is to identify aspects where:

- New technologies are used
- System complexity scales up
- Known technology is used in new environment

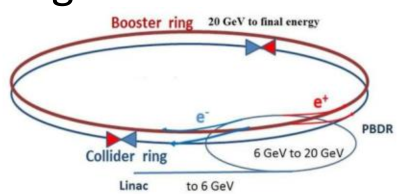
Model input:



Operational scenario

FCC-ee complex composition (assuming sub-availabilities)

SPS experience (also linac option)



Critical systems:

RF

Magnet supplies (power, cooling)

Electrical distribution (network perturbations)

Energy storage

Operational efficiency (filling time, rejected injections)

→ Redundancy in key systems can help.

→ Identify and document risks and solutions, focus R&D.

*) In collaboration with U Tampere + Ramentor Oy

Wednesday, 10:30: Machine availability for FCC-ee (A. Niemi)

A. Niemi / BE-OP

Concluding remarks

IOWG team active and motivated (despite being involved in many other activities).

CDR contributions delivered (CDR qualified as „adequate level for the current project stage”).

Work ongoing (and more planned) to consolidate, iterate on and deepen certain areas.

Currently main focus on
- optimising the footprint
- getting the preparatory phase railed up (administrative processes)
- planning for preparatory works (geodesy, CE site investigations, ...)

Much intensive work to come during the next phase.

Looking forward for news from

MERCI DE VOTRE ATTENTION !
DANK U WEL VOOR UW AANDACHT !

LOOKING FORWARD TO
INTERESTING PRESENTATIONS
AND STIMULATING DISCUSSIONS

Annex

Collaborations I

Cryogenics

- TU Wroclaw – Design pressure impact of the FCC-hh cryogenic distribution system and superconducting magnet cryostats on the heat inleaks at different temperature levels
- CEA Grenoble – New architectures and technologies for innovative helium refrigeration above 4.5 K and in superfluid helium at 1.8 K and 1.6 K including magnetic refrigeration
- TU Dresden – Ne-He cycle producing large refrigeration capacity above 40 K for the cooling of the FCC beam screens, thermal shields and HTS current leads
- U Stuttgart– Characterization of centrifugal compressors

Safety (fire safety engineering, FCC-FSEC)

- ESS – Ignition probabilities of materials and equipment; intervention procedures for classified accelerator areas
- FNAL – Tunnel fire dynamics and egress studies based on a broad range of different US underground installations
- DESY – Data on tested fire detection and protection measures for particle accelerators
- JRC Jülich Research Centre / University of Wuppertal – Optimisation of Computational Fluid Dynamics tools for fire safety related calculations
- Lund University – Fire and egress scenarios typical for accelerator facilities and their special geometries, including fire testing and virtual reality
- MAX IV – Knowledge transfer on fire statistics for physics laboratories

…

Collaborations II

…

- LBL – Peer review of performance based design approach
- BNL – Peer review of performance based design approach
- FNAL – Tunnel fire dynamics and egress studies based on a broad range of different US underground
- NIST – Further development of the CFD code Fire Dynamics Simulator (FDS)

Reliability, availability

- TU Tampere – RAMS design methods and tools to be applied to particle accelerators
- TU Delft – RAMS modeling of LHC cryogenic system
- Univ. Stuttgart – Reliability engineering training

Transport & Logistics

- FIML Dortmund – Transport and logistics modeling and consulting

Plus direct or indirect support from industrial and informal support from institutional partners (referenced in the respective presentations).

IO related posters

Availability:

- OpenMARS modelling approach for accelerator availability studies
  (A. Niemi, J.-P. Penttinen / Ramentor Oy)

Cryogenics:

- Cooling of the refrigerant with chilled water before the inlet of the compressor
  (H. Quanck / TU Dresden et al.)
- Fluid mixtures properties modeling (J. Tkaczuk / CEA Grenoble)
- Optimisation of a multi-stage turbocompressor architecture operating with a neon-helium gas mixture (M. P. Podeur, D. M. A. Vogt / U Stuttgart)
- Test rig for the experimental evaluation of turbo-compressor impeller designs for light gases
  (M. P. Podeur / U Stuttgart et al.)
- Field test results of self-calibrating cryogenic mass flow meter WEKASENSE
  (M. Okanovic / WEKA AG et al.)