FUTURE CIRCULAR COLLIDER

Summary of the Infrastructure Sessions

K Hanke, CERN

FCC week 2022, Paris

SUMMARY OF THE INFRASTRUCTURE SESSIONS

K Hanke, CERN
FCC week 2022, Paris

Infrastructure Sessions

Day	Monday	Tuesday				Wednesday			Thursday				Friday	Time
Room / Time	Plenary Campus Cordeliers room 470 p.	Parallel 1 Jussieu CICSU room 80 p.	Parallel 2 Jussieu CICSU room 80 p.	Parallel 3 Jussieu CICSU room 80 p.	Parrallel 4 Jussieu CICSU room 30 p.	Parallel 1 Campus Cordeliers room 155 p.	Parallel 2 Campus Cordeliers room 75 p.	Parallel 3 Réfectoire Cordeliers room 100 p.	Parallel 1 Campus Cordeliers room 470 p.	Parallel 2 Campus Cordeliers room 155 p.	Parallel 3 Campus Cordeliers room 75 p.	Parallel 4 Réfectoire Cordeliers room 100 p.	Plenary Campus Cordeliers room 470 p.	Room / Time
09:00-09:30		FCCee accelerator FCCIS WP2	Phy Programme/ Performance	FCCIS WP4 Socio Econom		FCC hh accelerator	PED: EPOL	FCCIS WP3 Placement	Reserve	PED/ACC: FCCee EPOL	RF Points for FCC-ee	Technology	**Plenary session**	09:00-09:30
09:30-10:00	**Plenary session**													09:30-10:00
10:00-10:30		Chairperson	Chairperson	Chairperson		Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	10:00-10:30
10:30-11:00	*Coffee break*	*Coffee break*				*Coffee break*			*Coffee break*				*Coffee break*	10:30-11:00
11:00-11:30	**Plenary session**	FCCee accelerator FCCIS WP2	Phy Programme/ Performance	SRF Directions for R&D	*Dialogue group CLOSED*	Technology	PED: Detector Concepts	Civil Engineering	Reserve	PED/ACC: FCCee MDI	Electricity and Cooling	Technology	**Plenary session**	11:00-11:30
11:30-12:00														11:30-12:00
12:00-12:30	Chairperson	Chairperson	Chairperson	Chairperson	F. Eder	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	12:00-12:30
12:30-13:00														12:30-13:00
13:00-13:30	*Lunch break*	*Lunch break*				*Lunch break*			*Lunch break*					13:00-13:30
13:30-14:00														13:30-14:00
14:00-14:30	**Plenary session**	FCCee injector FEB	Phy Programme/ Performance	Technology SRF	*SC meeting CLOSED*	FCCee accelerator	PED: Detector Concepts	FCCIS WP5 Collaboration	Reserve	PED/ACC: FCCee MDI	Transport & logistics, Safety			14:00-14:30
14:30-15:00														14:30-15:00
15:00-15:30		Chairperson	Chairperson	Chairperson	F. Gianotti	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson	Chairperson			15:00-15:30
15:30-16:00	Chairperson	*Coffee break*				*Coffee break*			*Coffee break*					15:30-16:00
16:00-16:30	*Coffee break*	FCCee injector FEB	Phy Programme/ Performance	Technology SRF	*SC meeting CLOSED*	FCCee accelerator	TI Geodesy and survey	FCCIS WP5 Communication	**France special plenary session** (Campus or Réfectoire Cordeliers)					16:00-16:30
16:30-17:00	**Plenary session**													16:30-17:00
17:00-17:30		Chairperson	Chairperson	Chairperson	F. Gianotti	Chairperson	Chairperson	Chairperson	Chairperson					17:00-17:30

Geodesy and Survey

4:00 PM	**Technical Infrastructures** - Andreas Wieser (until 5:30 PM) (Bilsky PASQUIER)
4:00 PM	Geodesy for science and society - Sébastien Guillaume Sebastien Guillaume (Bilsky PASQUIER)
4:18 PM	Experiences from the Gotthard Base Tunnel project - Mr Adrian Ryf (Bilsky PASQUIER)
4:36 PM	Gravity Field Modelling - Julia Azumi Koch (ETHZ - Inst. Geodesy and Photogrammetry) (Bilsky PASQUIER)
4:54 PM	Coordinate reference and networks - Matej Varga (Bilsky PASQUIER)
5:12 PM	Handling geodetic challenges at CERN - Benjamin Weyer (CERN) (Bilsky PASQUIER)

S Guilleaume, *Geodesy for Science and Society (remote)*

Introduction to problematic and concepts of geodesy

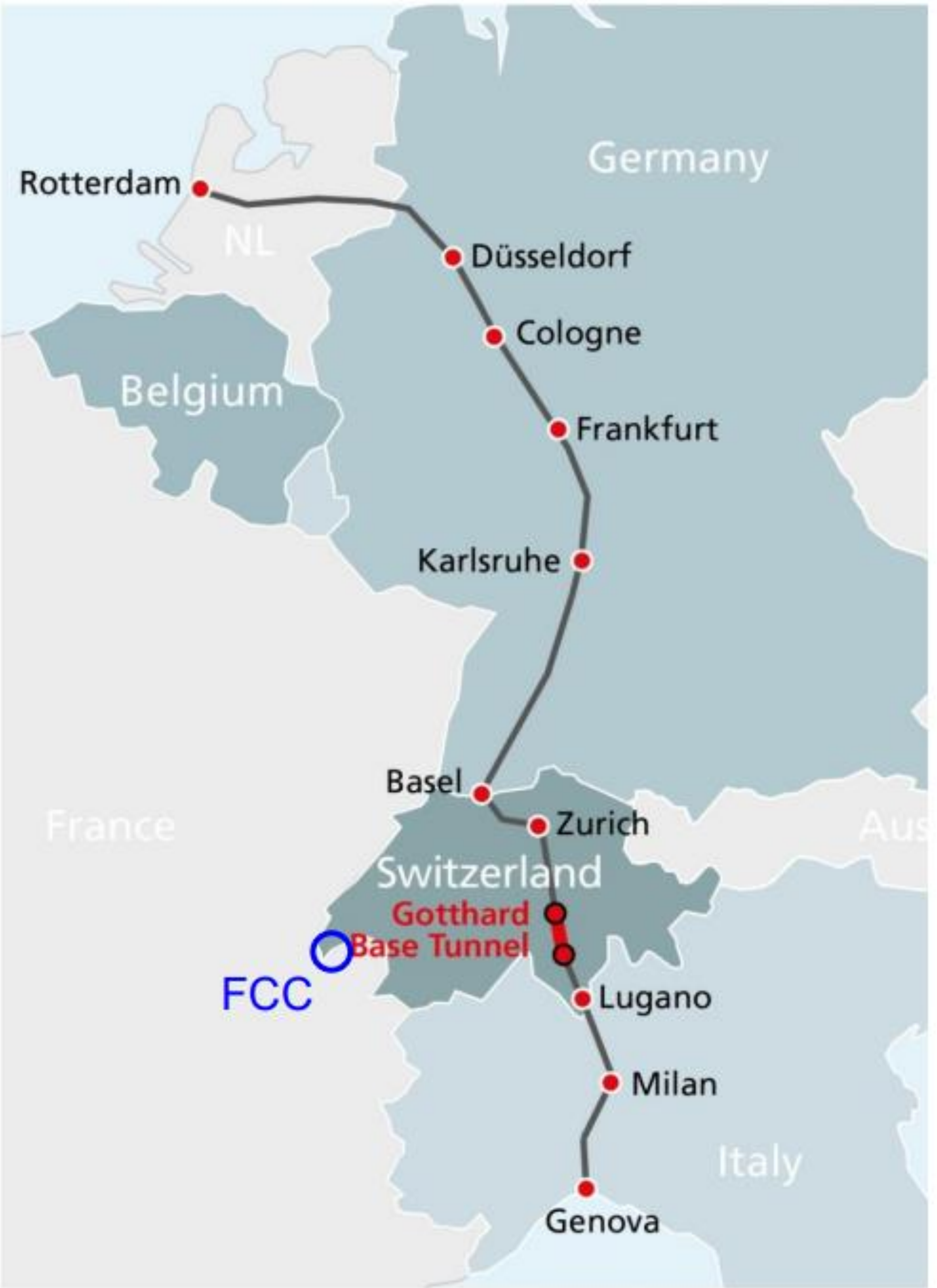
1. Determination of position of objects
2. Determination of gravity field and its geometry

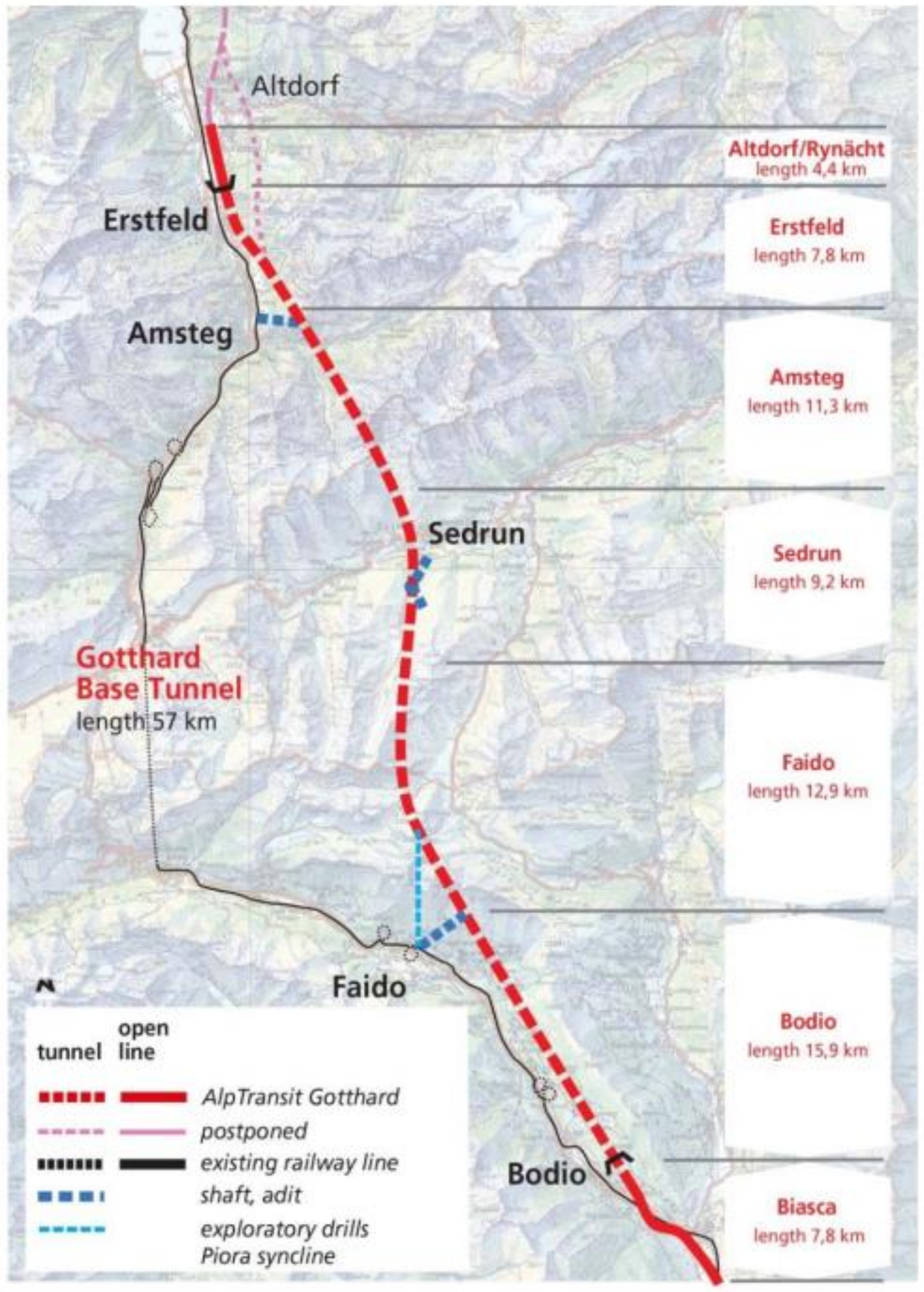
Density variations can perturb measurement
Choice of coordinate system is essential

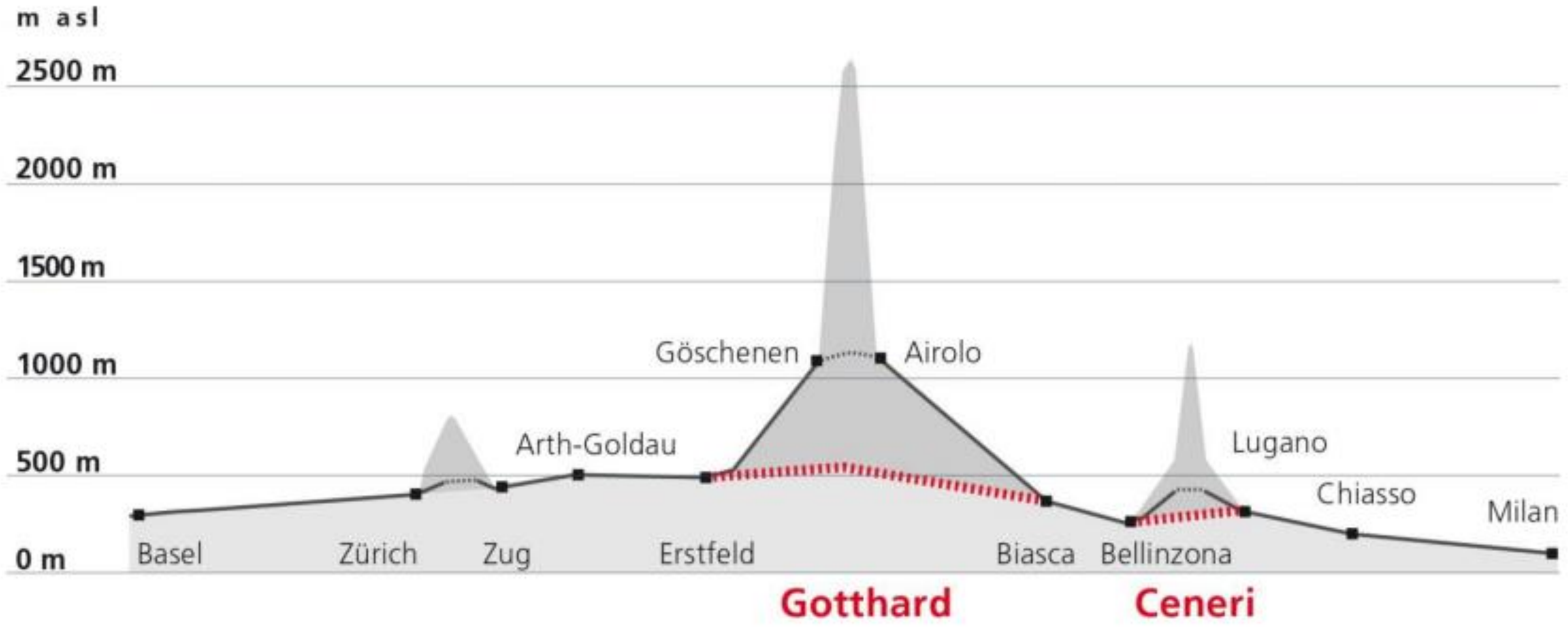
Different techniques how to determine the gravity field

A Ryf, *Experience from the Gotthard Base Project (remote)*

Part of the Rail Freight Corridor Rotterdam – Genoa, length 57 km, flat railway route through the Alps, opened in 2016







Longest railway tunnel in the world 57 km
Tolerance 25 cm for position and direction, 12 cm for height (achieved 8 cm in direction, 1 cm height)
Survey at the surface (e.g. dams) is needed
FCC monitoring will be necessary

Transmission of direction with gyroscope and inertial measurement unit (IMU) as an independent control

Gyromat 2000

IMU platform in the shaft hoisting system

IMU with 3 acceleration sensors and 3 laser gyros

connection with the tunnel network with autocollimation

velocity of hoisting system: 16 m/s

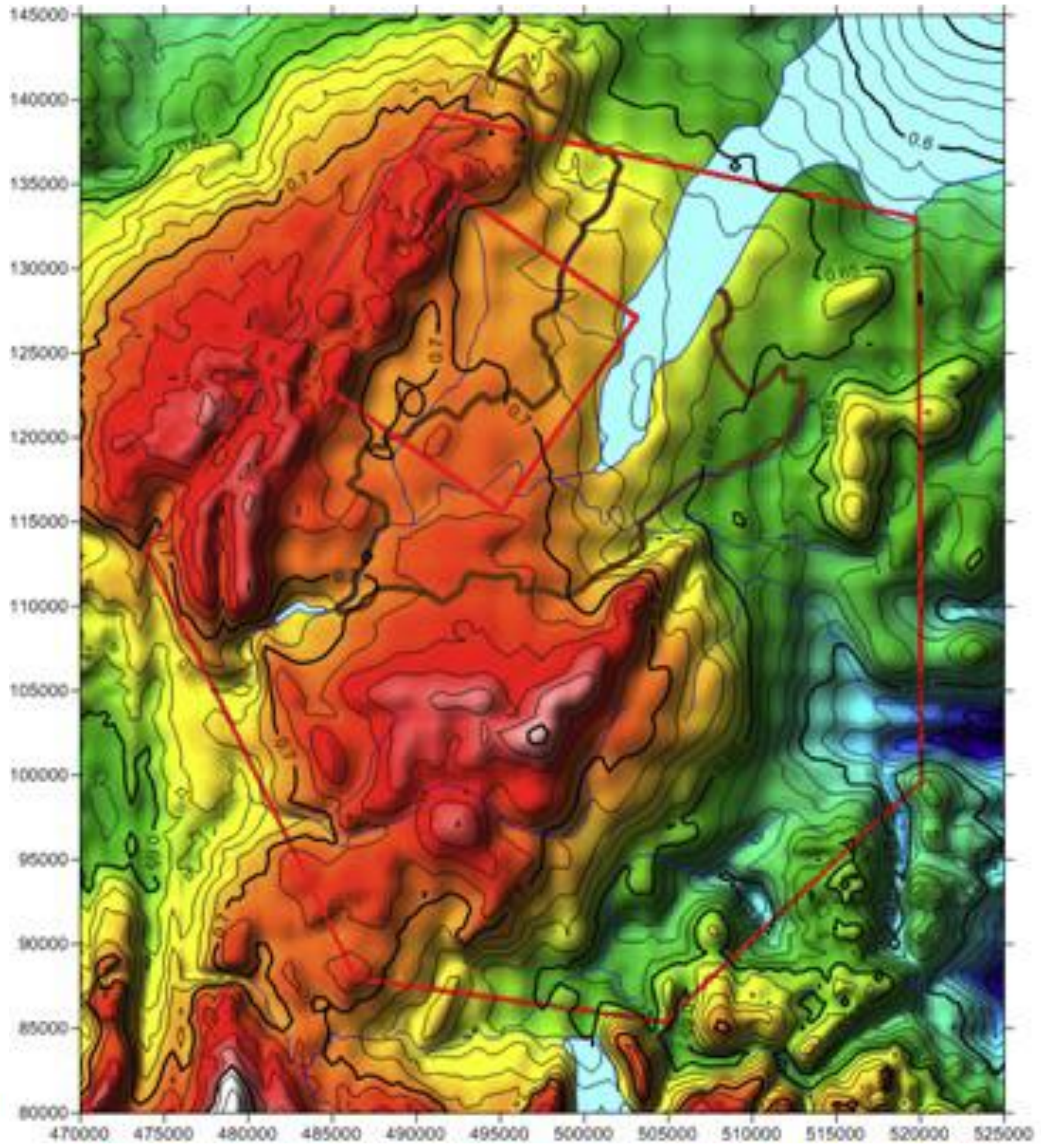
Accuracy oft the direction transfer: 1.3 mgon (gyroscope), 1.5 mgon (IMU)

The FCC is built almost entirely over shafts several 100 m deep.
One of the biggest challenges for the surveyors is the highly accurate and reliable transmission of direction in the shafts.

J A Koch, *Gravity Field Modelling (remote)*

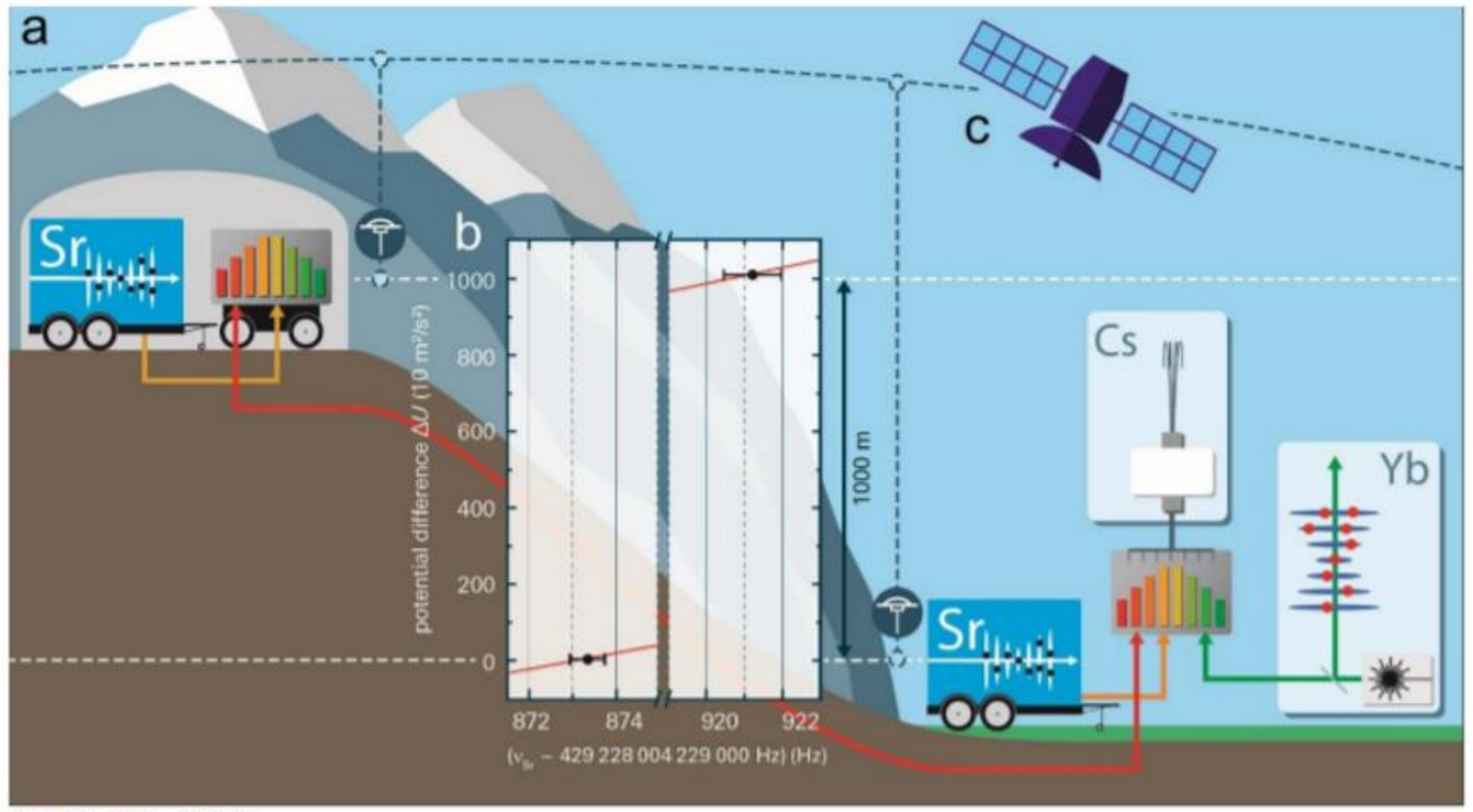
A gravity field model allows the computation of the
- Gravity potential (Geoid)
- Gravity acceleration **g**
- Deflection of the Vertical

Available model is insufficient!
Instrument absolute gravimeter
Gravity corrected height differences
Is an issue for FCC



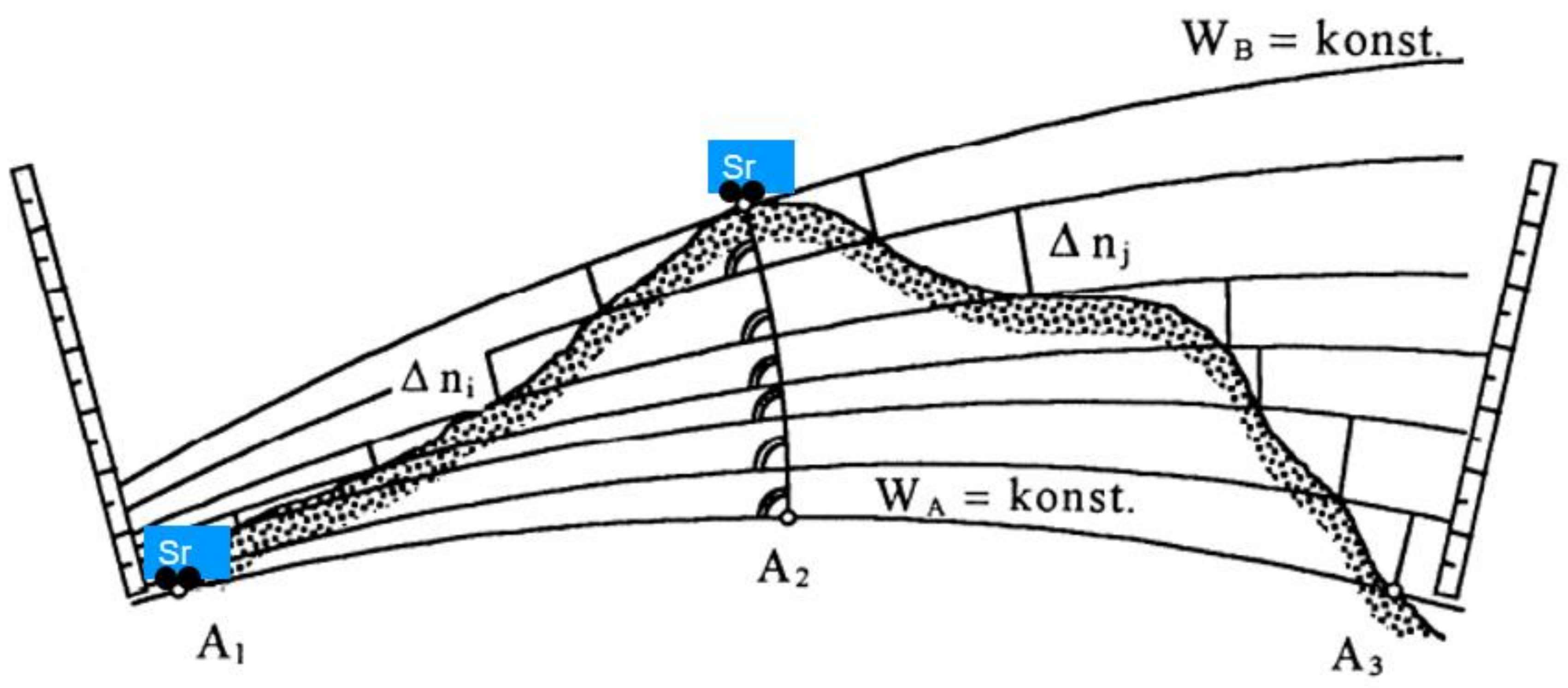
Available gravity field model

Instrumentation and Data Usage

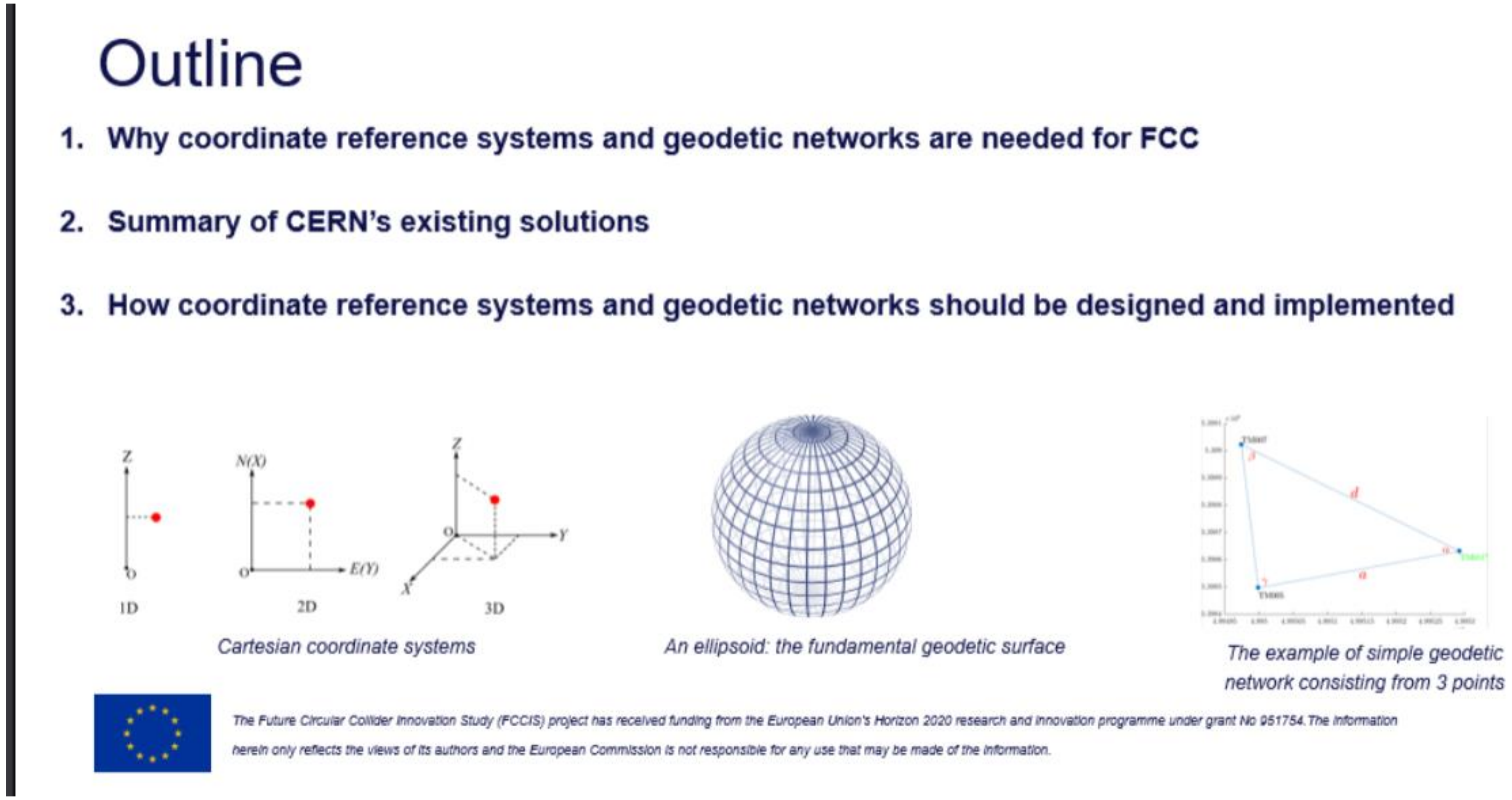


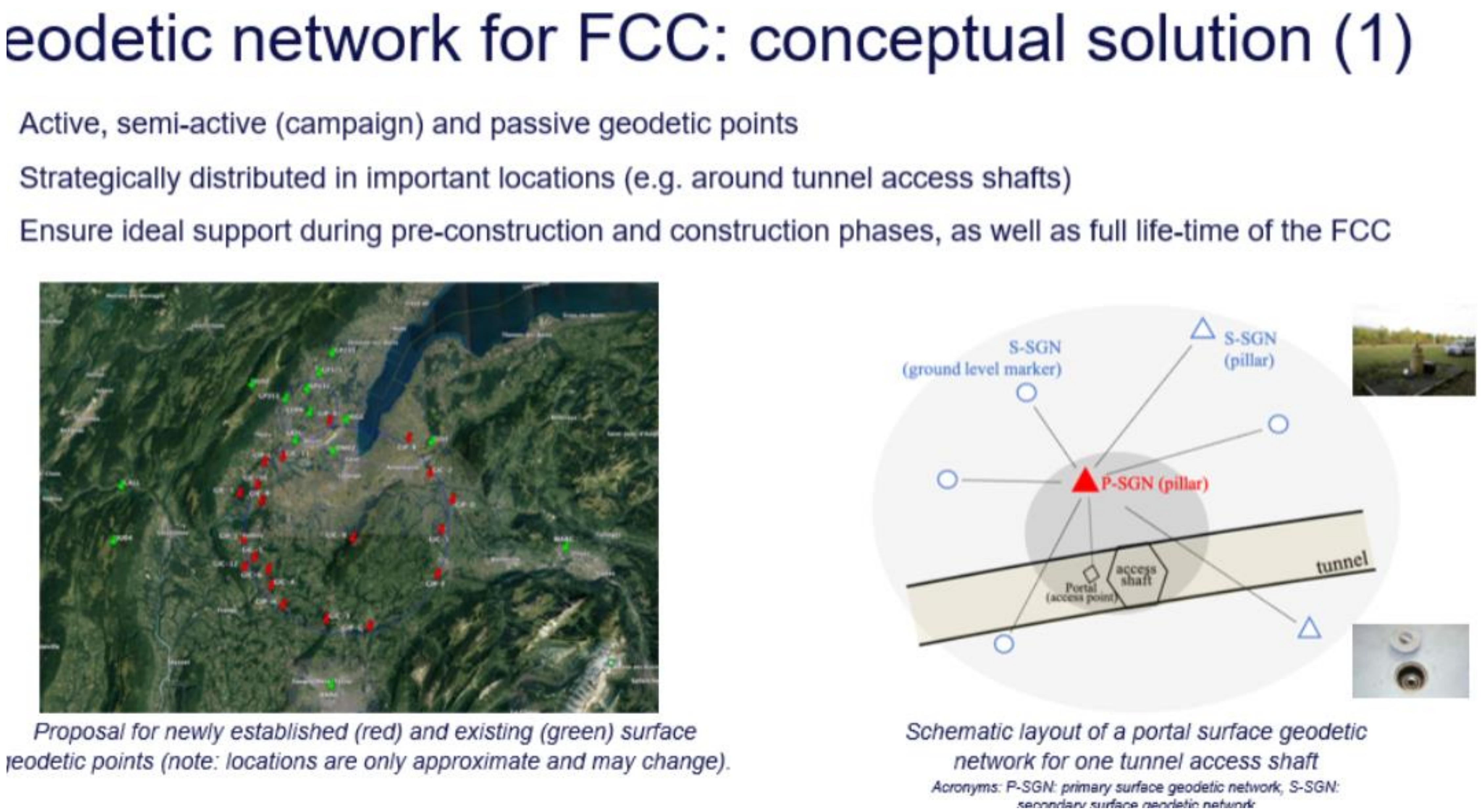
(Grotti et al., 2017)

Einstein's theory of General Relativity:
"Gravitational time dilatation" occurs whenever there is a difference in the strength of gravity



M Varga, *Coordinate Reference and Networks*





CRS Coordinate Reference System
Existing situation at CERN needs clarification
Proposed conceptual solution for FCC

Geodetic networks
Taking into account local constraints

B Weyer, *Handling Geodetic Challenges at CERN*

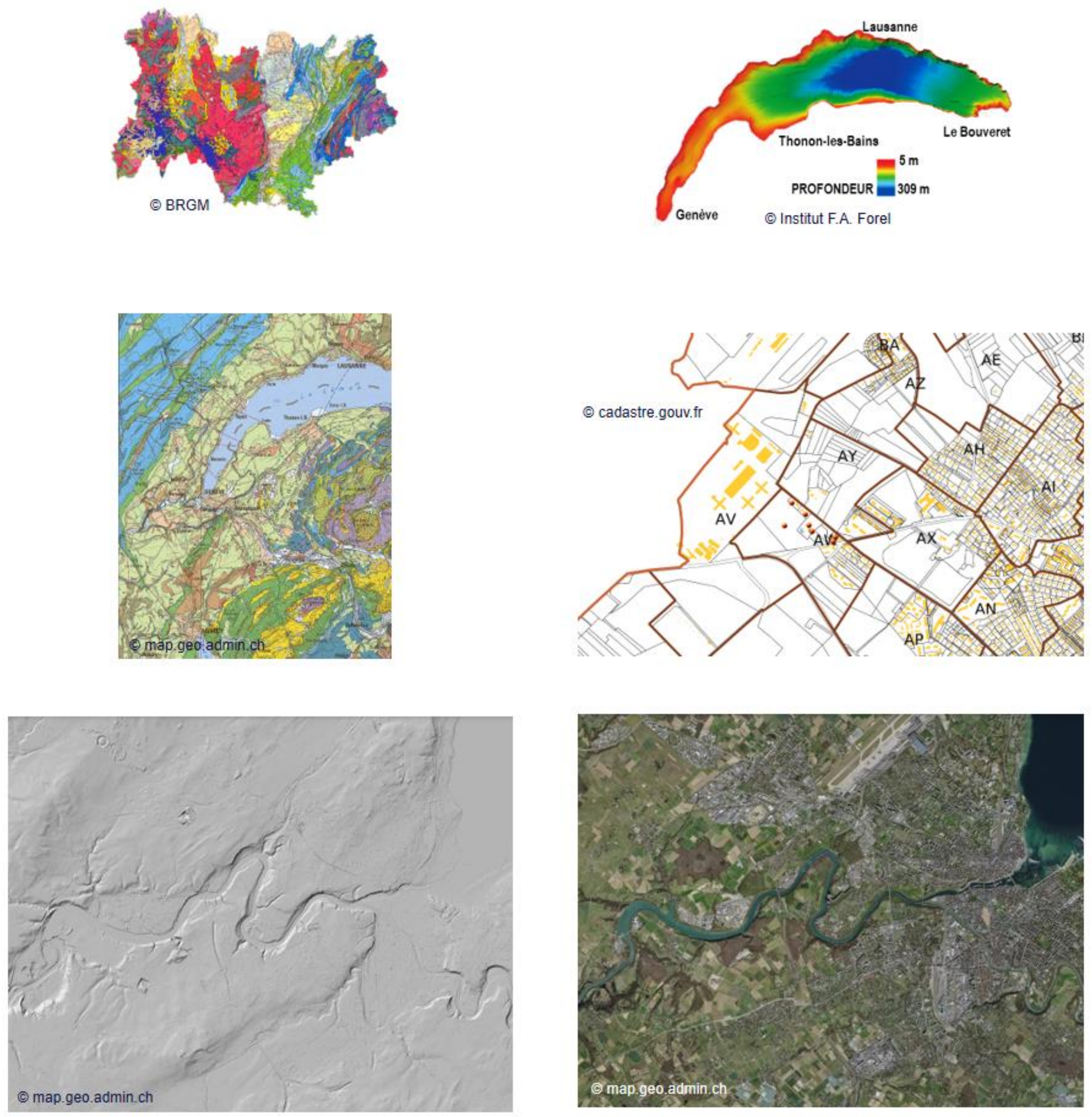
CCS (CERN Coordinate System)

- The CCS is the reference system at CERN
- Originated from the PS and has evolved with each major extension of the CERN: SPS, LEP
- Extent limited to the current CERN area
- Adapted for local survey and alignment of the machine within the CERN but not for mapping and civil engineering works
- Need to be updated to be in line with current best geodetic practices

Geodesy and GIS

Geographic Information System

- GIS developed and maintained by the SCE-SAM-TG section: https://gis.cern.ch/fcc
- Gather existing georeferenced data from various type
  - Trajectory of the FCC
  - Geological models
  - Digital terrain and bathymetric models
  - Cadastre
  - Orthophotographies
  - Roads
- Coordinate systems:
  - WGS84, RGF93, CHTRF93, NTF, CH1903, CCS…
- Will integrate new data
- Need to unify all data and to be able to transform data in a specific system for the different stakeholders



Historic origin, coordinate system center in the PS
MAD coordinates vs coordinate system
From MAD-X to real world

Geographic Information System
Accuracy is key
Adapting prodecures for FCC in collaboration with ETHZ

RF Points for FCC-ee

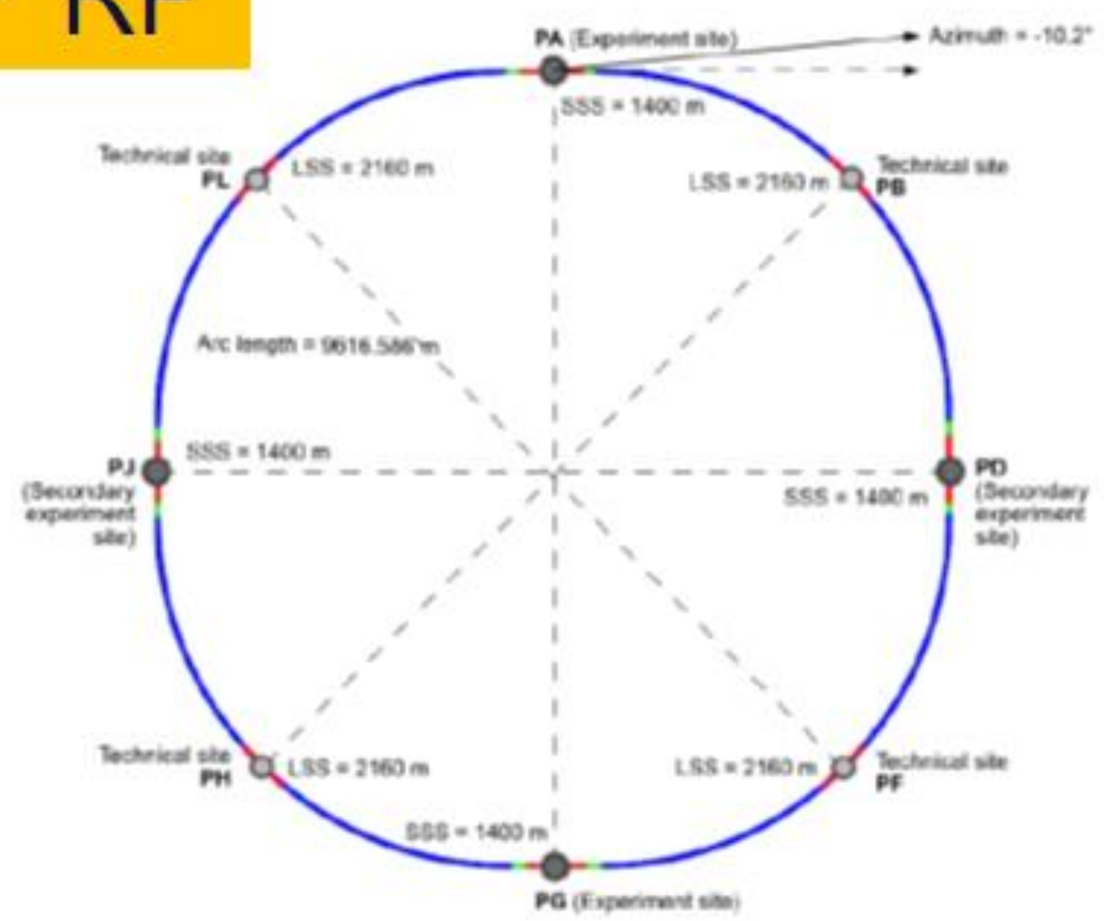
9:00 AM	**Technical Infrastructures** - Jean-Philippe Tock (CERN) (until 10:30 AM) ()
9:00 AM	The RF System of FCC-ee – General Considerations - Klaus Hanke (CERN) ()
9:30 AM	Integration of FCC-ee RF Sections - Dr Fani Valchkova-Georgieva ()
10:00 AM	Update on the cryogenic design for the FCC-ee machine - Laurent Delprat (CERN) ()

K Hanke, *The RF System for FCC-ee – General Considerations*

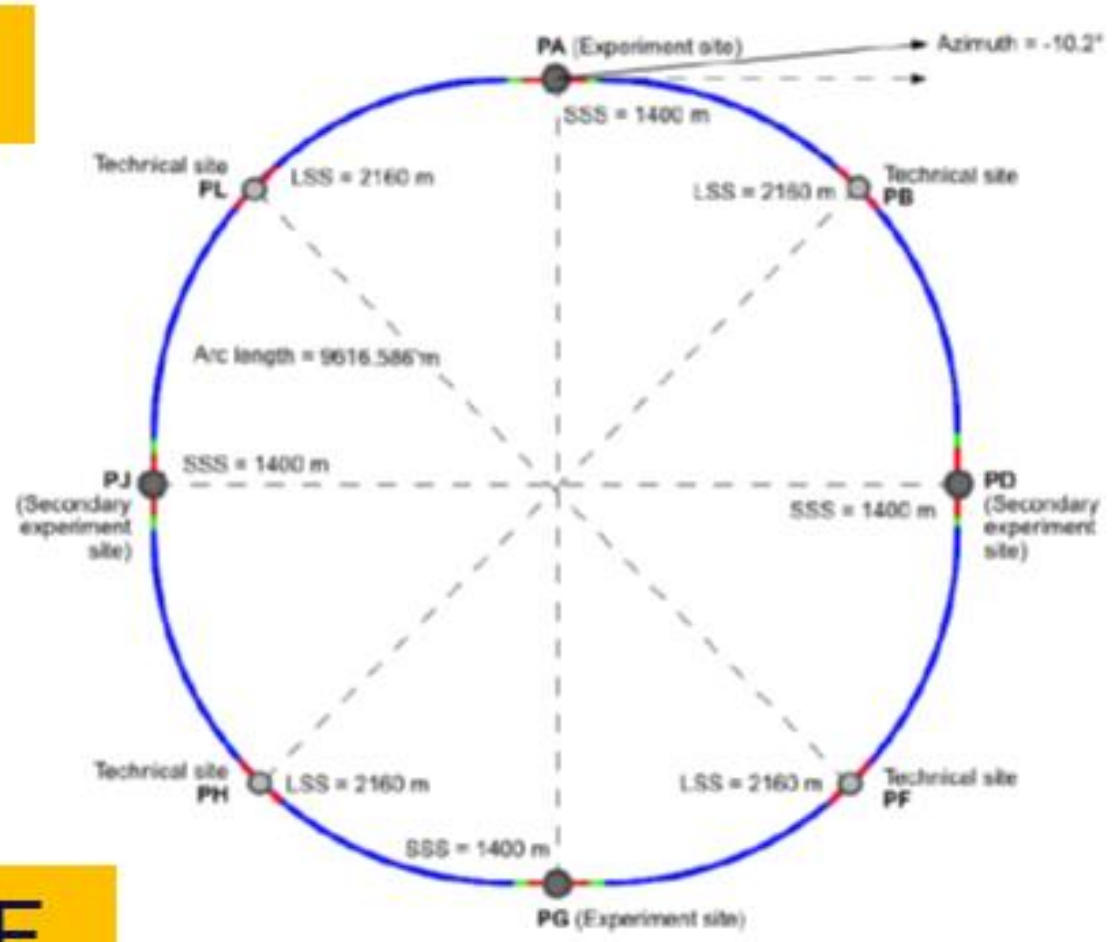
Physics Constraints

Infrastructure Constraints

e- and e+ RF



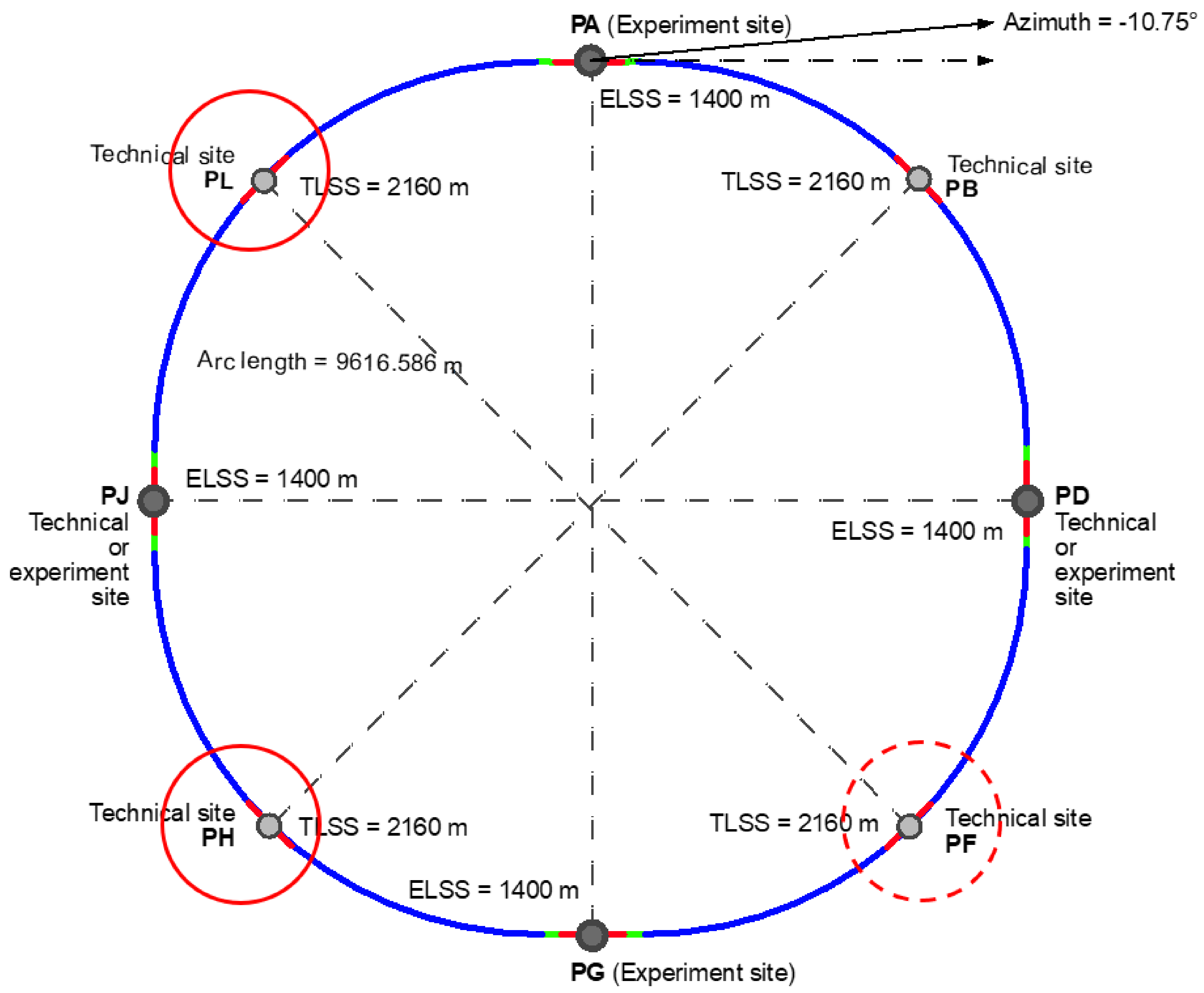
e- and e+ RF



e- and e+ RF

W, Z, H: Single RF point

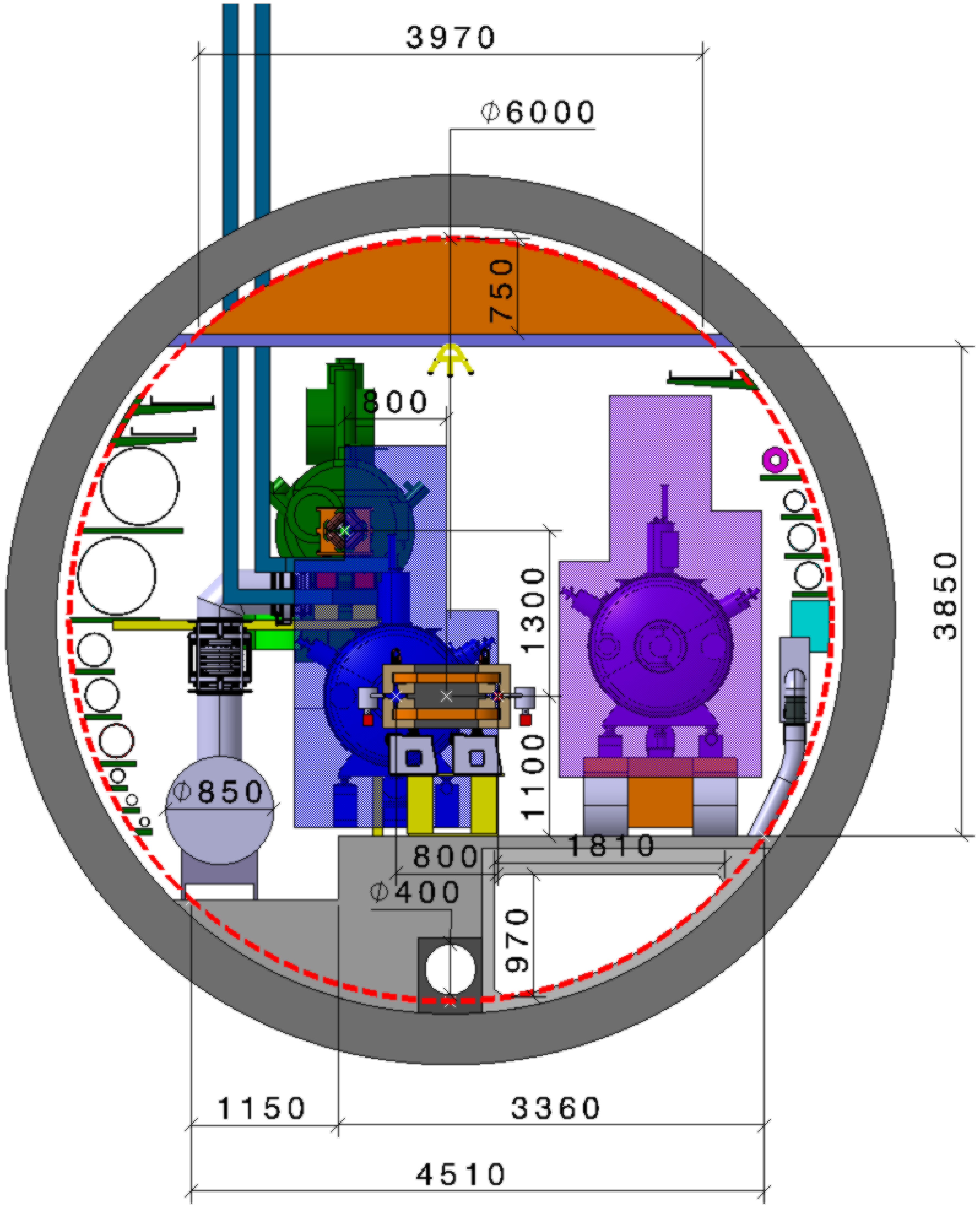
ttbar: two RF points, do not need to be opposite points



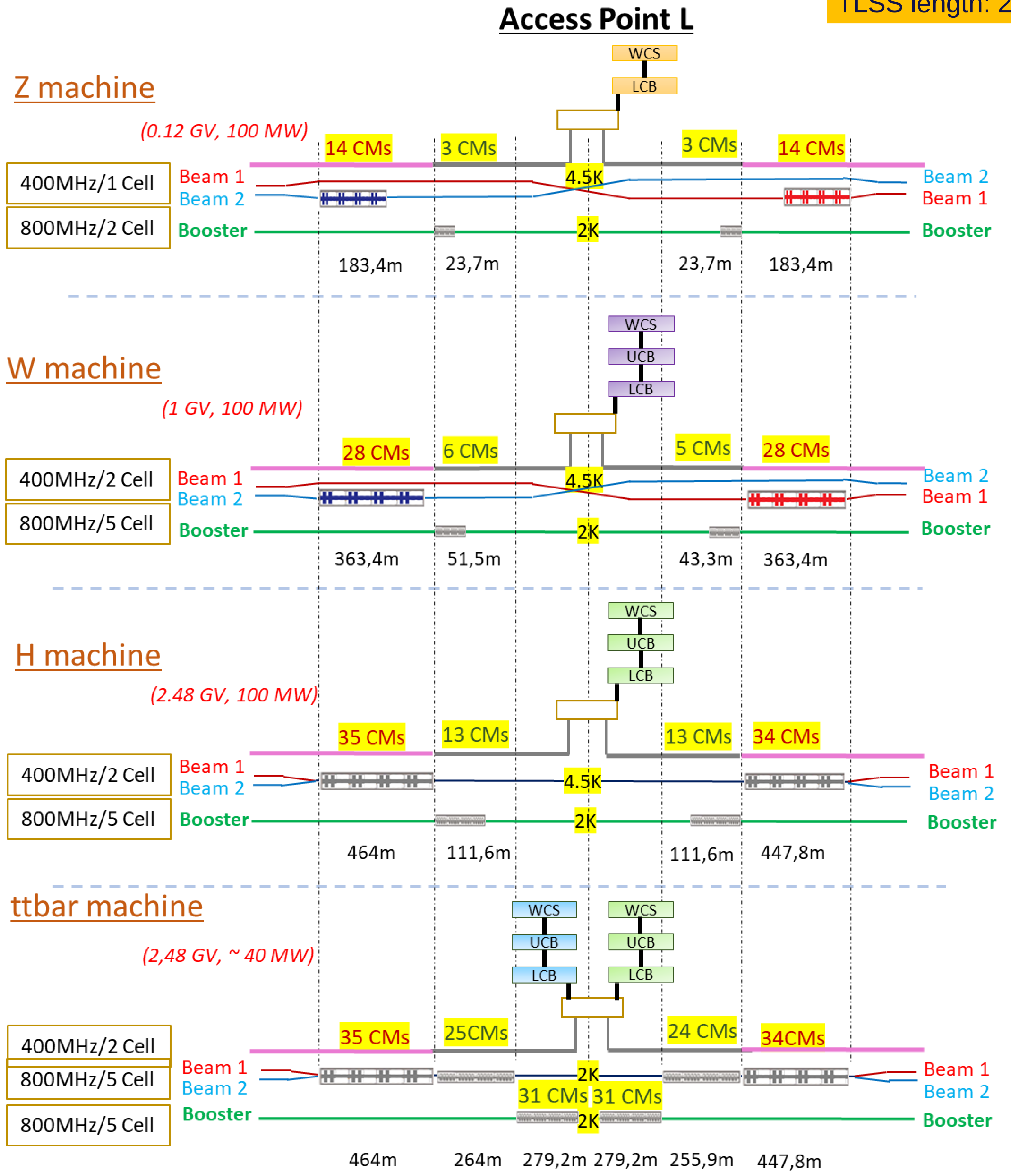
- Exclude experimental points and point B
- L and H fit nicely integration wise, accessibility and infrastructure
- F is not preferred (large lateral displacement of access shaft)

F Valchkova-Georgieva, *Integration of FCC-ee RF Sections*

RF Section tunnel integration



TLSS length: 2160 m

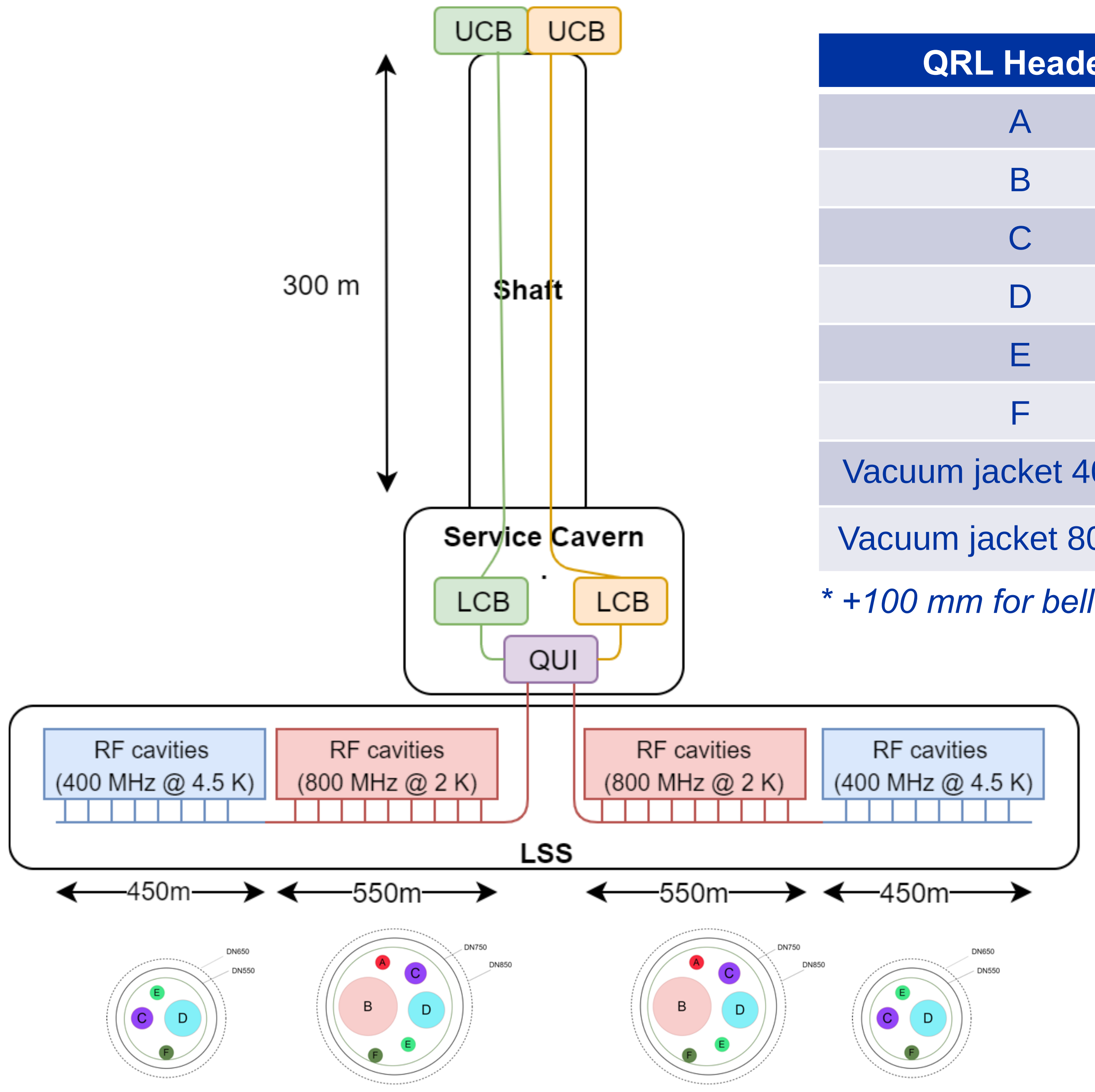


TOTAL RF LENGTH: 1990,1 m

L Delprat, *Update on the cryogenic design for the FCC-ee machine*

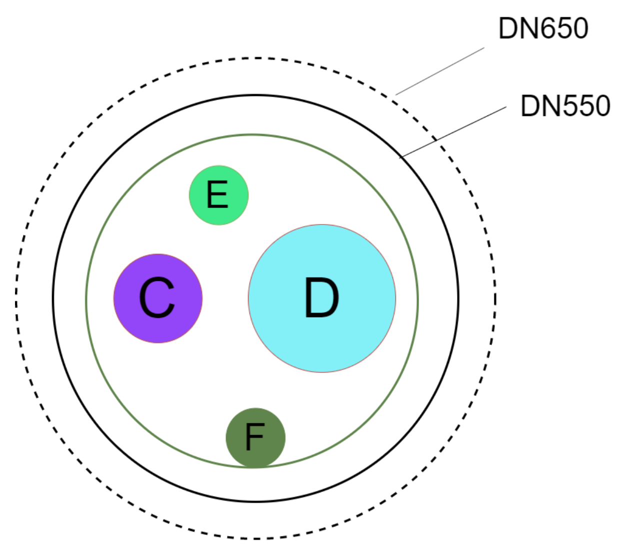
- Updated inventory of cryo needs and architecture (has much evolved since CDR)
- Point L settled, point H options under investigation

RF point L

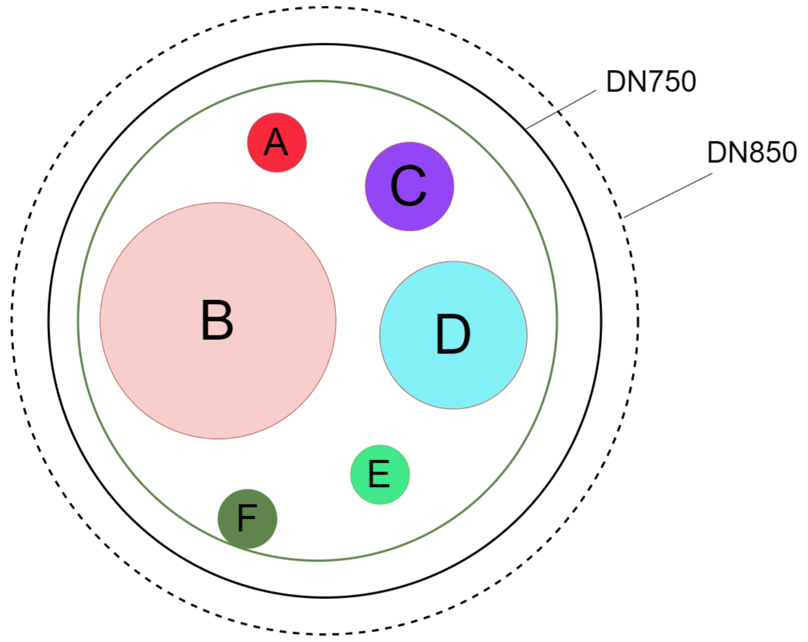


QRL Header	Diameter (mm)
A	80
B	320
C	120
D	200
E	80
F	80
Vacuum jacket 400MHz	550*
Vacuum jacket 800 MHz	750*

** +100 mm for bellows and flanges*



QRL cross section for 400 MHz cryomodules

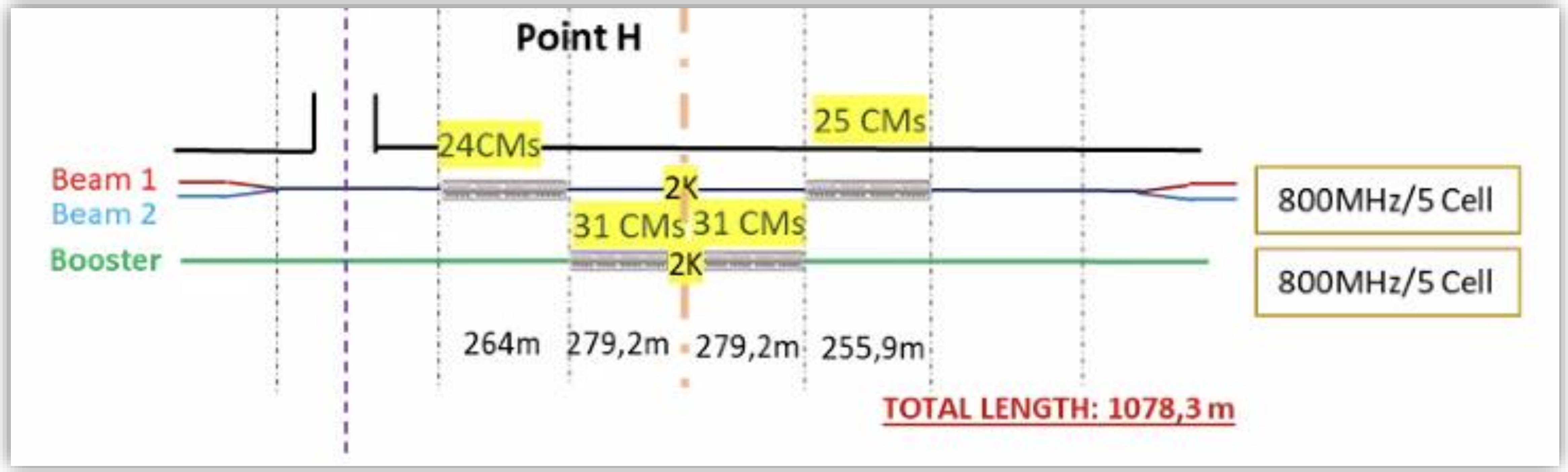


QRL cross section for 800 MHz cryomodules

RF point H

3 different options studied due to access pit location geographical constraints

- Option 1: all cryo installed in a dedicated cavern at the LSS center
- Option 2: half of cryo installed in a dedicated cavern at the LSS center
- Option 3: all cryo installed in the usual service cavern



Electricity and Cooling

11:00 AM	**Technical Infrastructures** - Ingo Ruehl (CERN) (until 12:30 PM) ()
11:00 AM	Update of the power demand for FCC-ee - Jean-Paul Burnet (CERN) ()
11:30 AM	Update on FCC electrical network and grid connection - Mario Parodi (CERN) ()
12:00 PM	Cooling and ventilation systems for the new FCC configuration - Guillermo Peon (CERN) ()

J P Burnet, *Update of the Power Demand for FCC-ee*

- Update of the power demand / main loads for FCC-ee
- Distribution of the power demand by points and by the beam energies
- Estimation of energy consumption per machine configurations
- Optimization of the accelerator systems to reduce the power demand
- Ways to reduce the energy consumption

Big Five:
RF
Cryo
Booster Magnets
Collider Magnets
Cooling & Ventilation

Plus others: general services, computing, …

Updated power demand for FCC-ee per working point

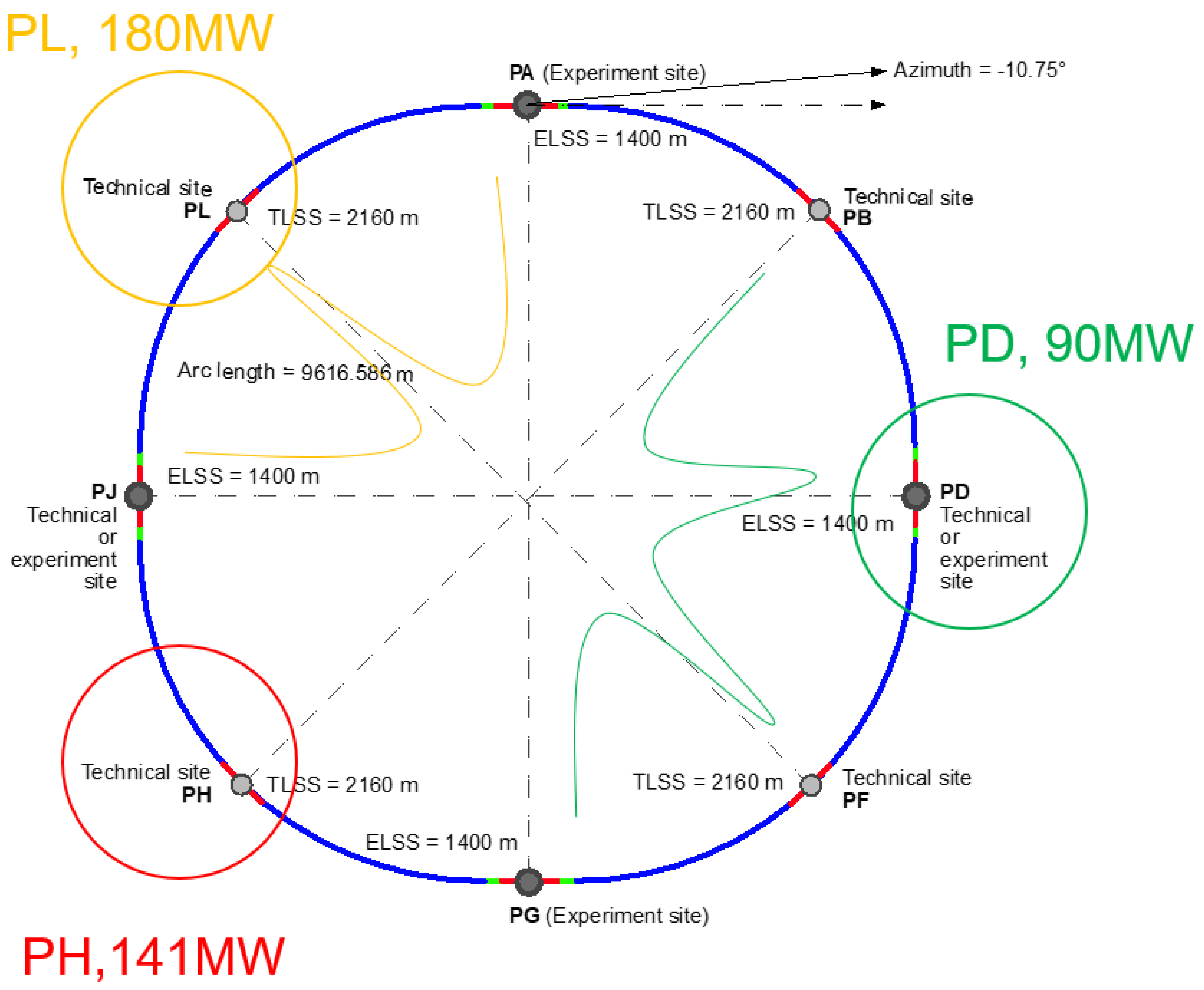
		Z	W	H	TT
Beam energy (GeV)		45.6	80	120	182.5
Magnet current		25%	44%	66%	100%
Power ratio		6%	19%	43%	100%
PRF EL (MW)	Storage	146	146	146	146
PRFb EL (MW)	Booster	2	2	2	2
Pcryo (MW)	Storage	1	7	17	50
Pcryo (MW)	Booster	0.01	0.08	0.19	0.56
Pcv (MW)	all	33	34	36	40.2
PEL magnets (MW)	Stroage	6	17	39	89
PEL magnets (MW)	Booster	1	3	5	11
Experiments (MW)	Pt A & G	8	8	8	8
Data centers (MW)	Pt A & G	4	4	4	4
General services (MW)		36	36	36	36
Power during beam operation (MW)		237	257	293	387
Average power / year (MW)		143	154	174	225

J P Burnet, *Update of the Power Demand for FCC-ee*

Infrastructure needed for FCC-ee

2 high power demands,
Point L 101MW, 40% 400MHz
Point H, 141MW, 60% 800MHz
Need 2 main sub-stations for RF loads.
Need an additional sub-station for East part of the machine.

		Max power (MW)
Point A	Experiment	28
Point B		22
Point D		22
Point F		22
Point G	experiment	28
Point H	RF TT	141
Point J		22
Point L	RF Z,W,H	101

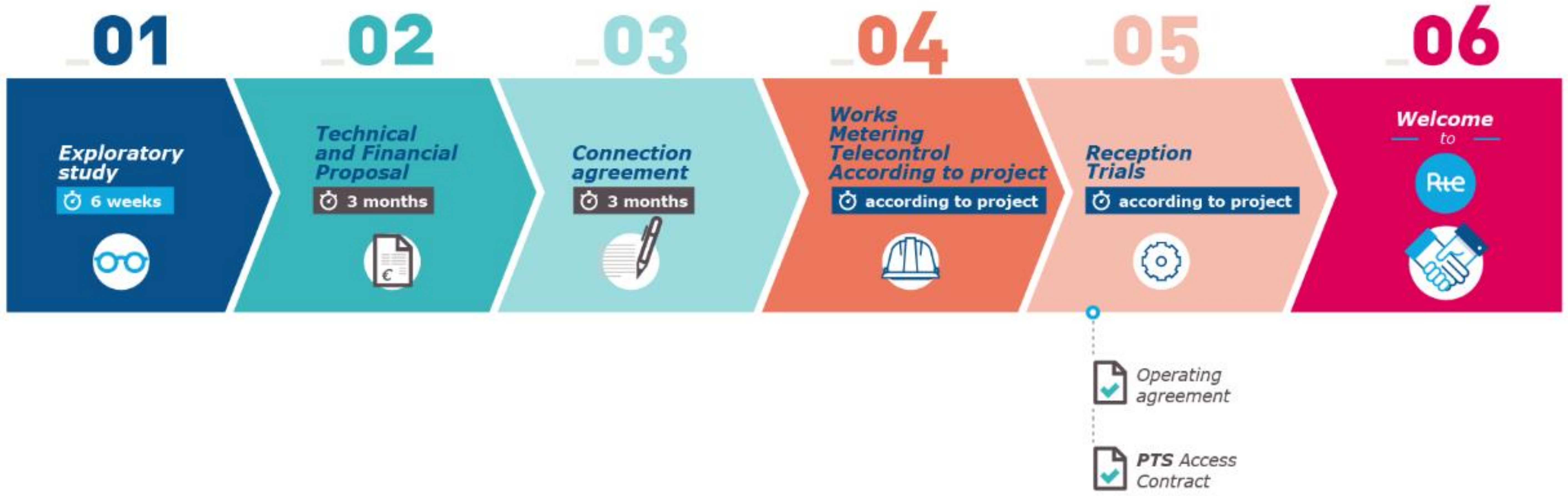


Lots of ideas how to reduce power consumption being explored!

M Parodi, *Update on FCC Electrical Network and Grid Connection*

- Updated load estimate (has much evolved since CDR)

- Adaptation to the 8-points new layout
- Confirmation of n. 3 connection points to RTE grid:
  - n. 2 HV connections at RF points
  - n. 1 HV connection at point D (preferred) or point F (possible)
- Internal closed 132 kV transmission loop
  - Balanced power flow
  - High reliability
  - Existing control and protection technologies suitable for the topology
  - Adapt to move towards FCC-hh
  - Cost of investment Vs. FCC RAMS requirement: analysis to be performed

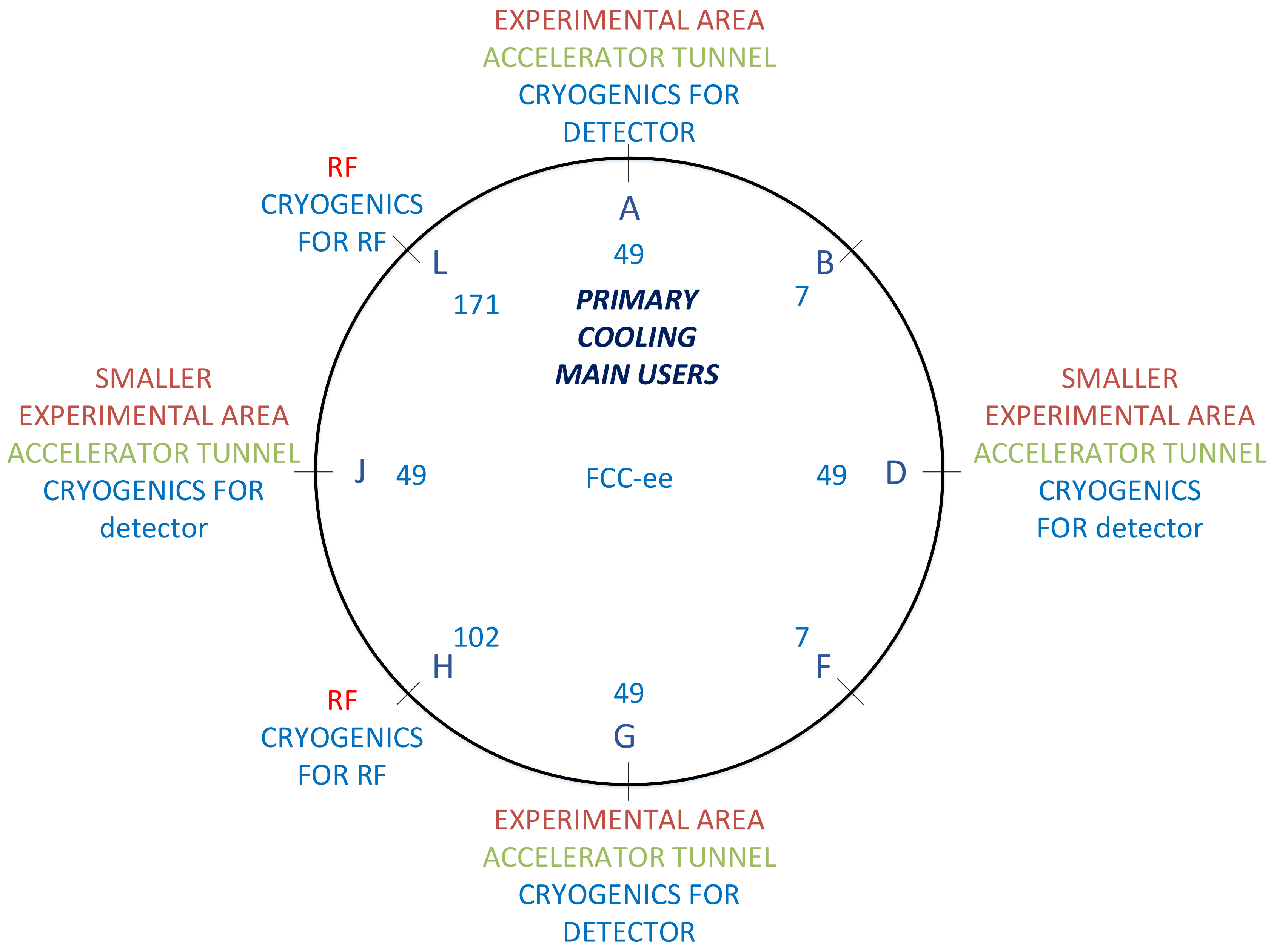


- Collaboration with French electricity provider RTE
- The overall power demands justifies a connection to RTE 400 kV (or alternatively 225 kV) grid
- The first step (exploratory study) is free of charge and not binding. Data Collection Sheet available online.
- The further study and execution phases need investment and commitment from both parties
- The technical solutions include upgraded to RTE upstream infrastructure where required

G Peon, *Cooling and Ventilation Systems for the new FCC-ee Configuration*

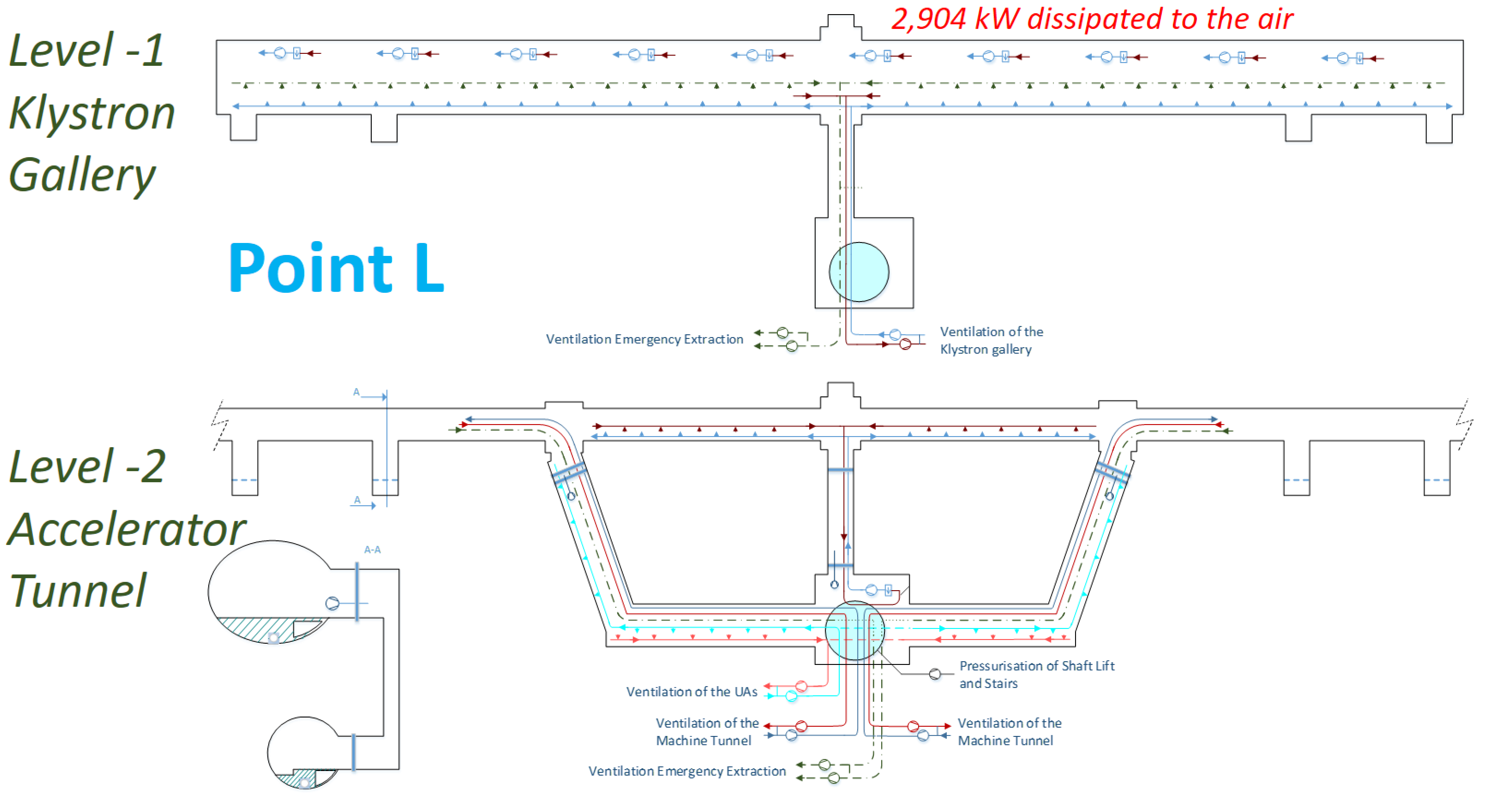
Updated inventory of water cooling power needs

FCC-ee COOLING POWER NEEDS FOR PRIMARY CIRCUITS (MW)							
Point	Cryogenics	Experiment	General Services	Power Converters (RF)	Chilled water	From underground	**TOTAL**
PA		0.5	2		4,6	41.5	**48.6**
PB			2		3,9	1.0	**7.0**
PD		0.5	2		4,6	41.5	**48.6**
PF			2		3,9	1.0	**7.0**
PG		0.5	2		4,6	41.5	**48.6**
PH	48		2	4	8.4	41.6	**103.9**
PJ		0.5	2		4,6	41.5	**48.6**
PL	95		2	6	10.3	60.9	**174.2**



Ventilation:
Heat loads in air collected (surface and underground)

Ventilation of the RF areas in the underground



Transport and Safety

2:00 PM	**Technical Infrastructures** - Christian Prasse (until 3:30 PM) ()
2:00 PM	Transport requirements - Cristiana Colloca (CERN) ()
2:20 PM	First thoughts on transport options - Dr Michael Schmidt (Fraunhofer Institute for Material Flow and Logistics) ()
2:45 PM	The FCC Safety Feasibility Study - Thomas Otto (CERN) ()
3:10 PM	Robots for Safety in FCC - Oriol Rios (CERN) ()

C Colloca, *Transport Requirements*

Requirements for underground transport and handling of magnets

Collider ring

Magnets will be installed as follows:

- 5800 single dipoles
- 492 single quadrupoles
- 1256 units made up of quadrupole-sextupole and supporting girder (Q-S)
- 1152 units made up of quadrupole-sextupole-sextupole and supporting girder (Q-S-S)

Unit	Q-S	Q-S-S
Length [cm]	520	700
Width [cm]	60	60
Height [cm]	100	100
Weight [kg]	6620	7400

Updated inventory considering FCC-ee (Booster and collider) magnets!

Requirements for underground transport of people

- Vehicle shall be used to transport personnel with material and evacuate them in case of emergency;
- Max speed: 30 km/h (lower for material);
- Minimum capacity: 6 people - 500 kg (possibly a bit more)
  - Materials payload: 1000 kg
  - Total capacity: 1500 – 2000 kg
- Battery powered;
- Possibility for autonomous drive to be investigated;
- Vehicles connected between them and/or with a centralized system;
- Modular design allowing the mounting of different platforms;
- Hosting equipment for autonomous or remote interventions (minimise human access to the tunnel).

M Schmidt, *First Thoughts on Transport Options*

The current projects focusses on transportation of magnets and people plus an update of the overall logistics concept

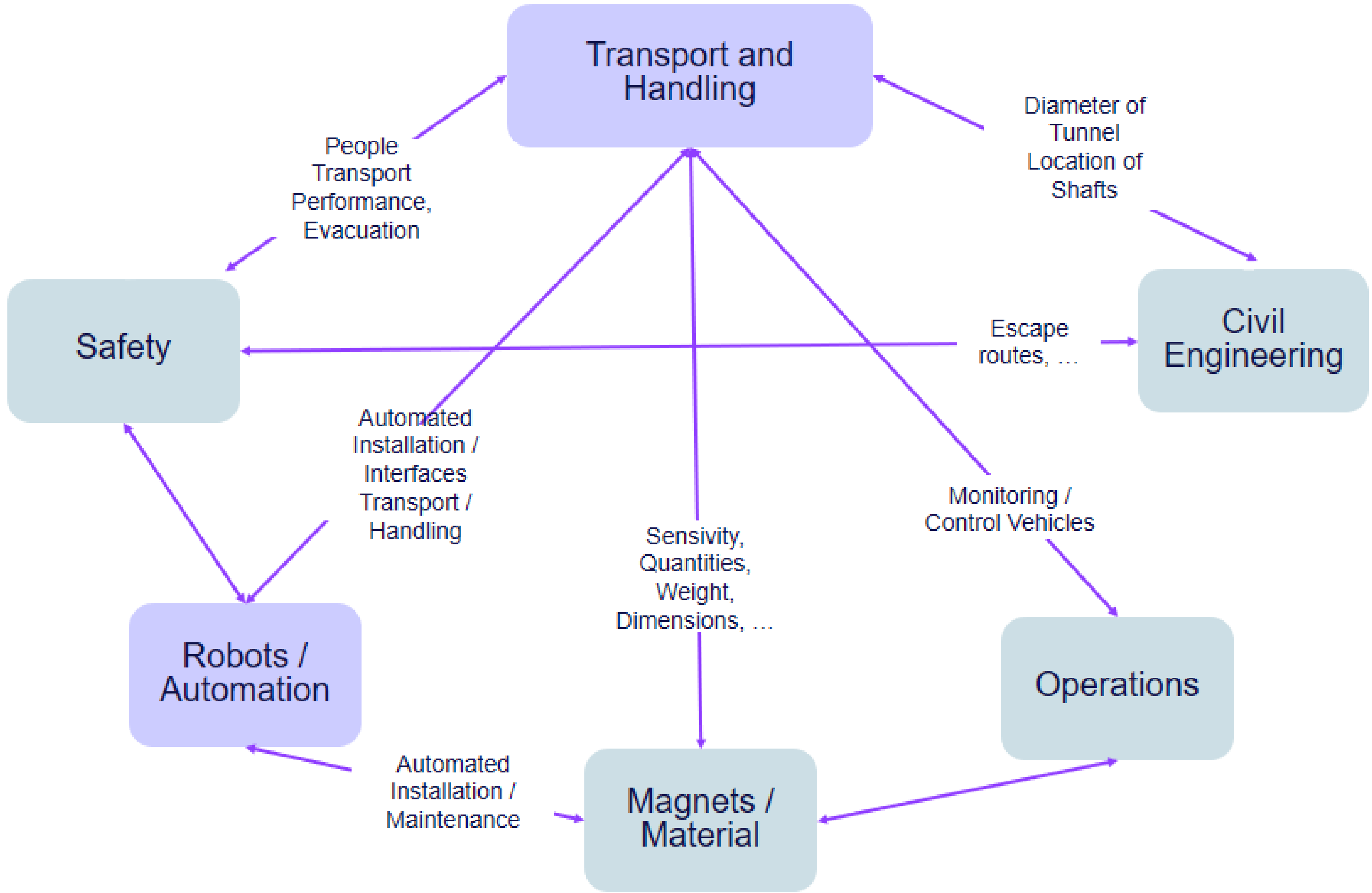
Fraunhofer IML

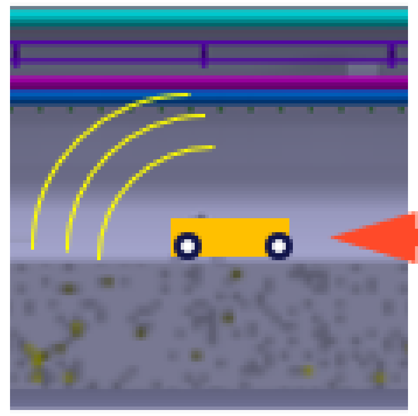
Within this work, different use cases resp. project phases as well as functional units and logistic units will be considered.

Scenarios / Phases

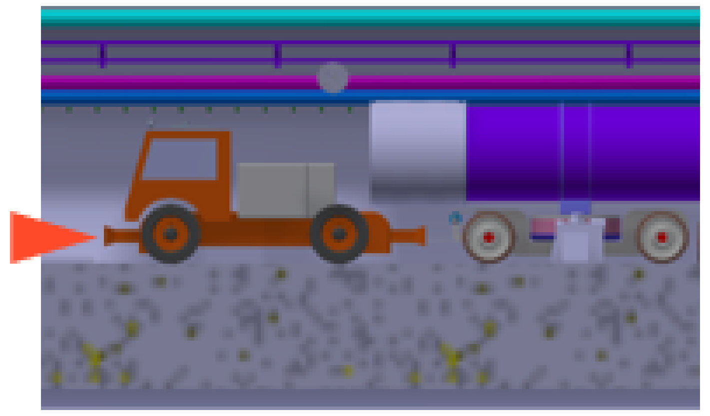
- Supply of Equipment (Magnets / Materials)
- Installation
- Technical Stops during Operation, e.g. maintenance
- Dismanteling

Evacuation





Length of the braking distance of the transport convoy from full speed to standstill



T Otto, *The FCC Safety Feasibility Study*

- The Safety Workpackage answers safety challenges which are specific to an underground high-energy particle accelerator:
  - Fire Safety
  - Cryogenic Safety
  - Beam- and access safety
  - Ionising radiation, in the facility and the environment
- Supported by a hazard register and summarised in a safety report

The FCC Safety Working Group

Thomas Otto	ATS-DO	Study coordination, editor
André Henriques	HSE-OHS	Occupational health and safety
Oriol Rios	HSE-OHS	Fire and emergency response
Ghislain Roy	BE-ABP	Operational safety, personnel safety systems
Pavol Vojtyla	HSE-RP	Environmental impact of ionising radiation
Markus Widorski	HSE-RP	Radiation protection

Safety-minded individuals from the wider collaboration are invited to join us and work on specific topics

CERN HiLumi HL-LHC PROJECT

EDMS NO.	REV.	VALIDITY
2567867	0.2	IN WORK

REFERENCE : [OTHER REFERENCES]

Hazard	SBP	Details and description of the mitigation measures	Further actions
Physical Hazards (continued)			
Temperature: cold gas/liquid	5.3.2	In case of Helium release by safety device or leak **T:** Safety devices turned away from occupied areas **O:** Access restriction to certain areas	Safety Reports
Temperature: Surface, cold	5.3.2	In case of rupture of insulation vacuum. **O:** as under "ODH, Temperature: cold"	Safety Reports
Under- or overpressure	5.3.1, 5.3.2, 5.6.2	Even in case of total loss of helium from cold powering and IT magnets, no significant pressure build-up in the area	
Radiation, ionising			
Activated air or gases		After operation with beam **O:** waiting time in agreement with RP before accessing IT area	
Activated solids	EDMS 2398424, 2398506	Components in the tunnel (Q1-Q3, CP, D1, DCM, DFX, end of DSHx) will become activated after beam operation.	Radiation protection measures following Safety Code F apply. Interventions shall be coordinated with RP.
Particle beam		Beam operation will activate the exposed components. **T:** The Co-content of all equipment in the tunnel shall be ALARA.	Derogations for Co-content of equipment in the component specific safety files, see table 1.
Radiation damage, electronics (R2E)			
Radiation damage, mechanical			
Radioactive aerosols			
Radioactive surface contamination		Activated dust in IT area **O:** measurement by RP **T:** specific PPE if required	
Radiation, non-ionising			
Laser	5.8.3.		
Microwaves	5.8.1.		

Hazard Register for HL-LHC

O Rios, *Robots for Safety in FCC*

Robots in Emergency Situation

- FCC CDR foresees different ceiling-mounted robots for tasks such as:
  - Monitoring
  - Handling light components
  - Alignment: measurement and correction
  - Assistance in emergency situations
    - Early monitoring of the fire event. Support CFRS initial tactical plan
    - Early fire suppression with extinguishing substances
    - Evacuation guidance

Challenges for (Safety) robots integration

- Doors: FCC fire safety concept relies on doors every 440m. Those need to be prepared for robot automatic crossing (and shutting close afterwards)
- Degraded intervention scenarios (heat, communication…). The faster response, the less degraded
- FAIL SAFE. Robot does not obstruct evacuation! Rail mounted is best solution!
- Interaction between ROBOT interventions and evac.
- RAIL SCE ANSYS sims!!

Robots for Search and Rescue

➢ First test of for **FB-CERNbot** collaboration for search and rescue in disaster zones

Collaboration with HSE-FRS

Thanks to all speakers and chairpersons!