ETH zürich

CHART

FCC Geodesy

Advances in high-precision gravity field determination, geodetic reference frames and geodetic infrastructure for the FCC region

Benedikt Soja, Andreas Wieser

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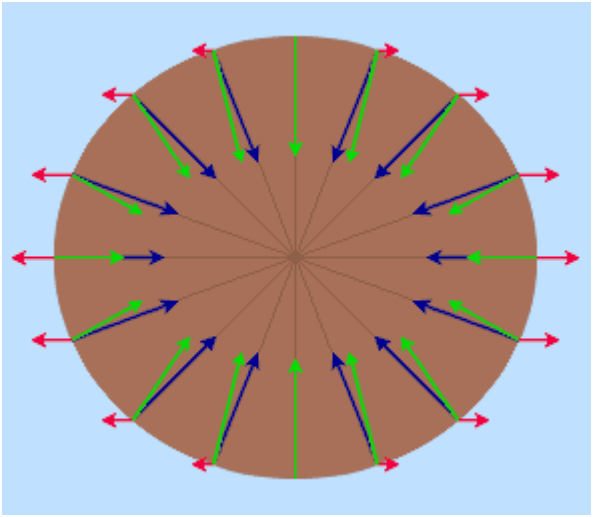
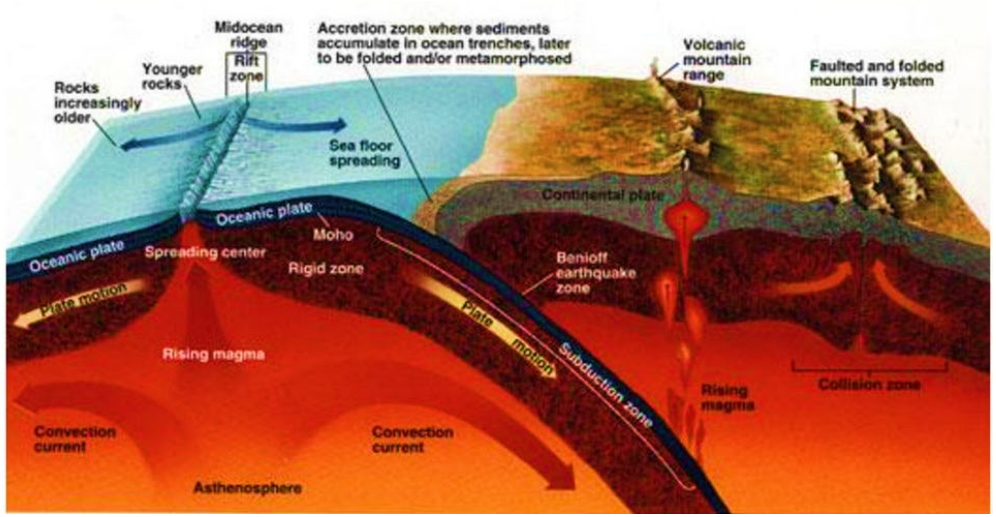
Background

1. Rotation of the Earth → geometrical shape resembles an oblate spheroid (ellipsoid)

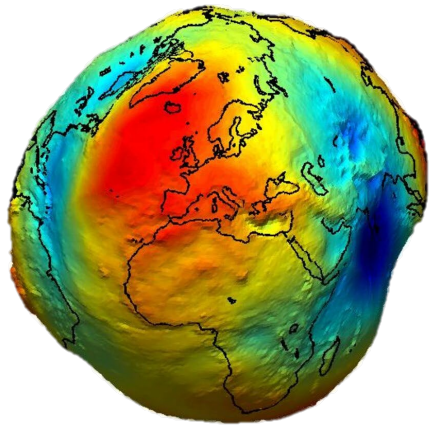
2. Density variations in the Earth system
   - magma distributions, geological compositions, deep sea trenches, mountain ranges, …

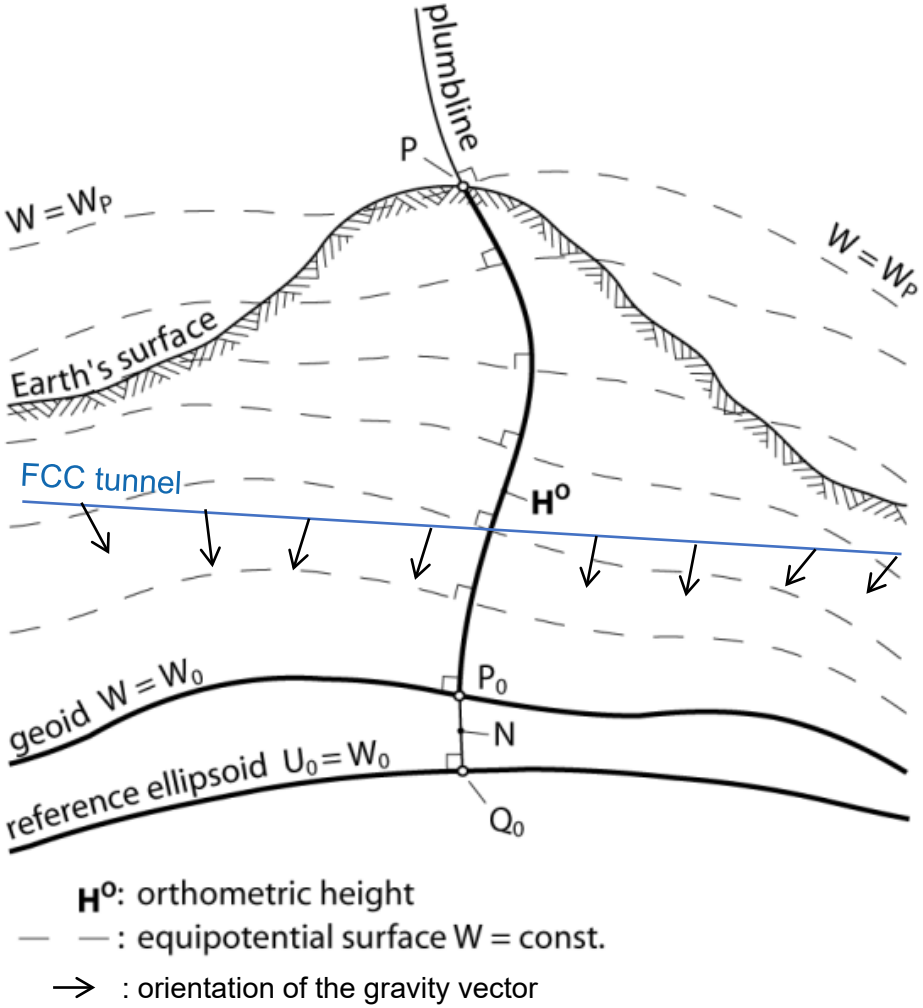




Geometric vs. physical heights

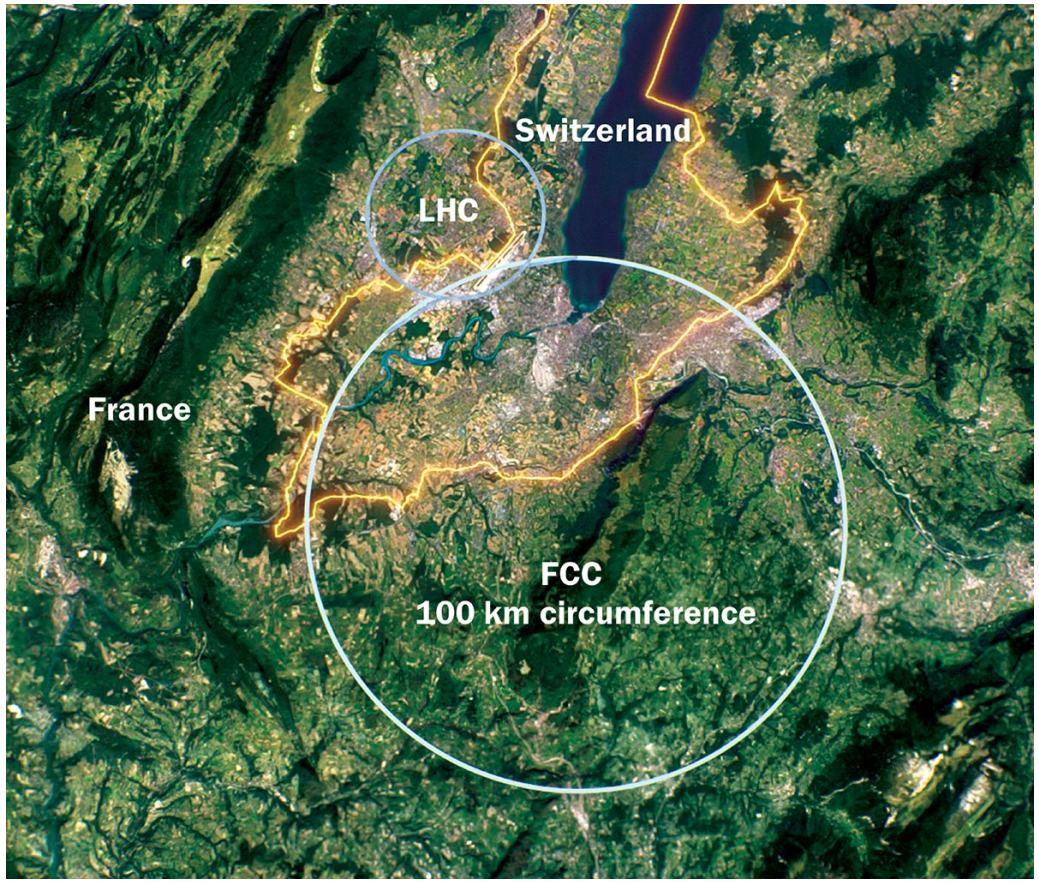
- Geometric heights: based on reference ellipsoid
- Physical heights: based on “geoid”
  - Equipotential surface: no water flow
  - Gravity force acts perpendicular





Motivation

- FCC site around ten times larger than the current CERN site
- CERN Geoid Model – CG2000 now more than 20 years old
- Most of the related geodetic reference frames and infrastructure even older
- Increased alignment requirements for FCC experiments

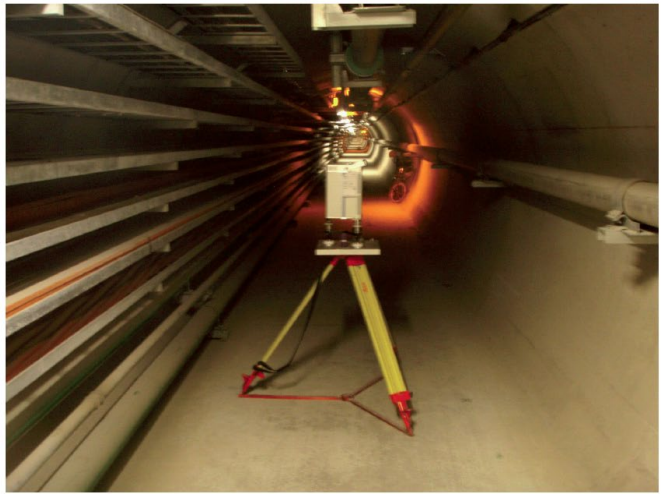


Goals of the FCC Geodesy Study

Two major goals:

1. Determination of a high-precision gravity field model for the FCC region (geoid < 1 cm)
2. Conceptual development of the geodetic reference frames and geodetic infrastructure

→ basis for the construction, operation and maintenance of the FCC



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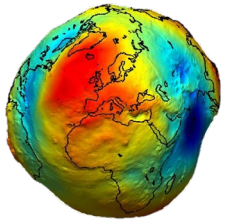
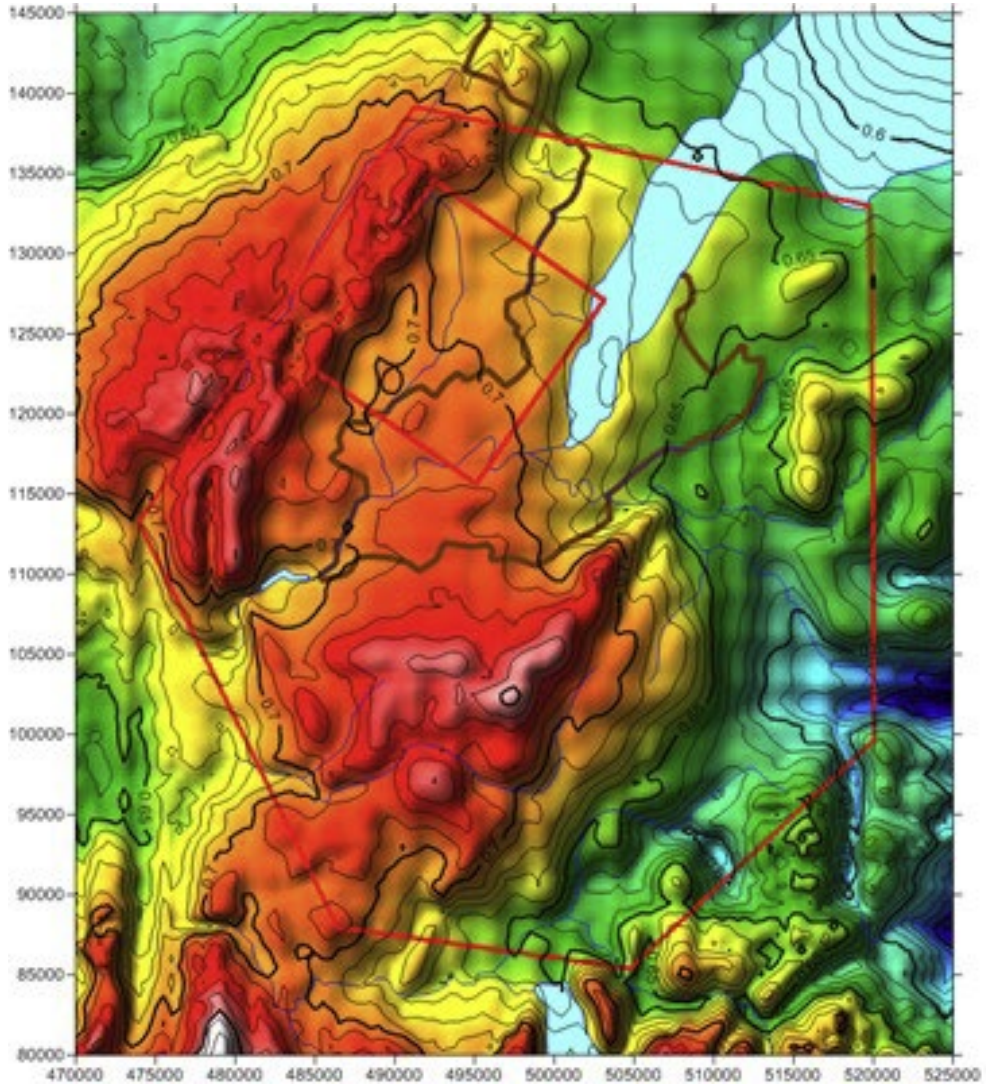


Available gravity field models

- Switzerland
  - CHGeo98 (CG2000)
  - CHGeo2004
- France
  - QGF98
  - RAF98
  - QGF2016
  - RAF09
  - RAF2018b
- Global Models
  - EGM2008
  - GOCO05s
- CERN
  - CG1985
  - CG2000
- D-A-CH
  - D-A-CH-Geoid
  - European Alps Geoid
- Europe
  - EGG2015



Difference: CHGeo2004 - QGF98

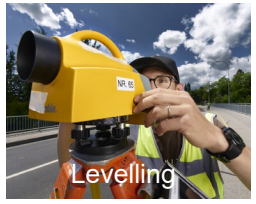
Mean offset: 67 cm
Stand. Dev.: 4.1 cm

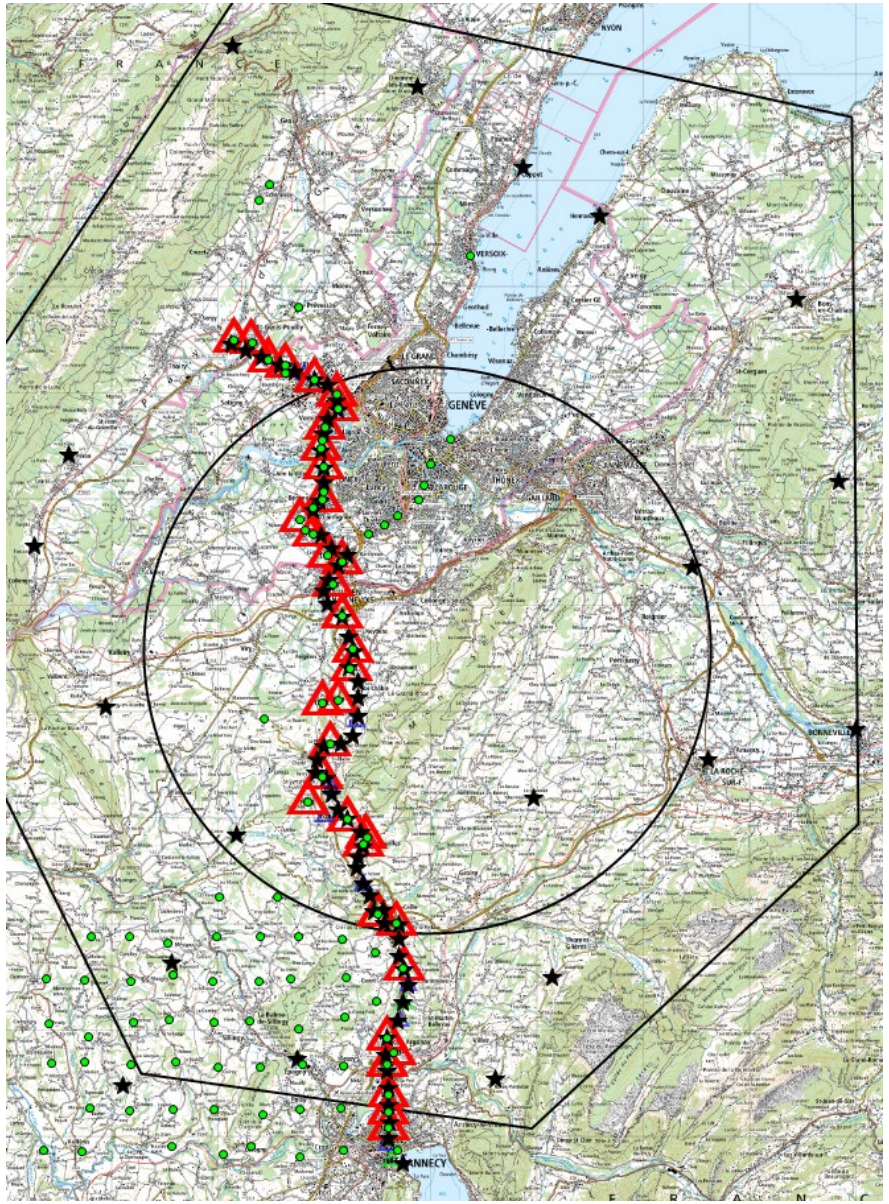
High-accuracy profile for validation

- Purpose: validation of the geoid models with independent measurements

- Successfully established a high-accuracy profile
  - Length 40 km

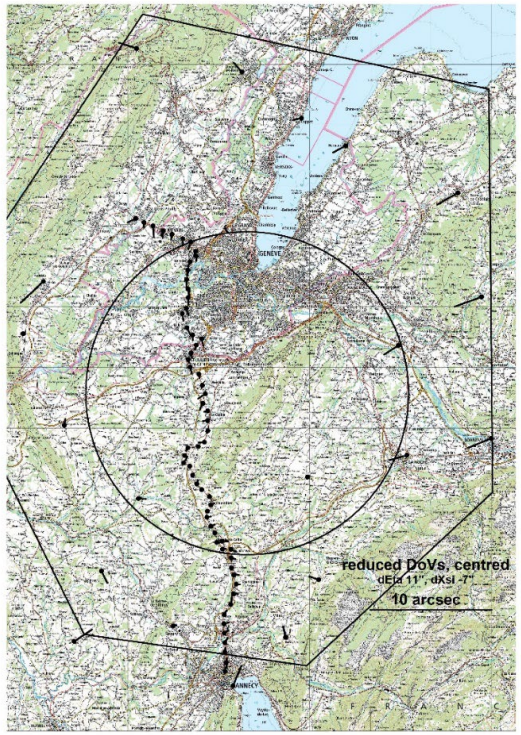
- Various measurements:
  - ~40 GNSS/levelling stations (△)
  - ~80 Deflections of the Vertical (★)
  - ~50 gravity stations (●)
  - ~50 gravity stations NW of Annecy (filling data gaps)





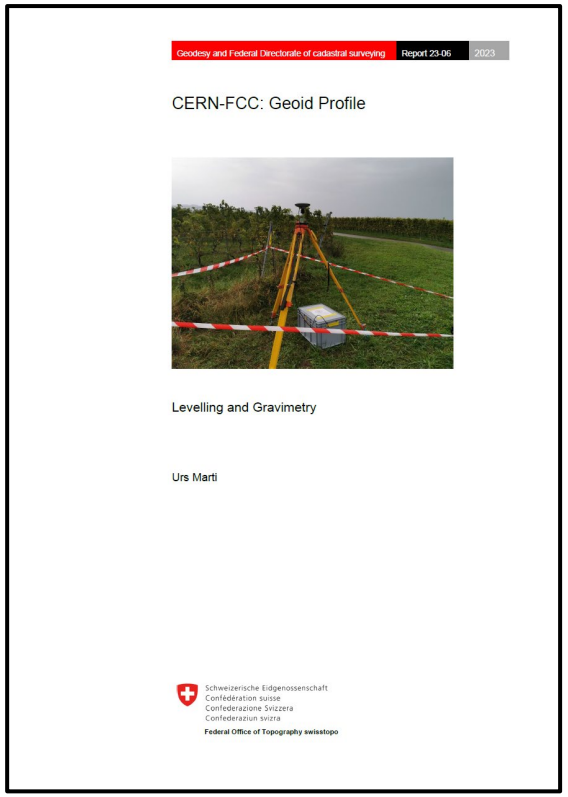
High-accuracy profile for validation

- Final results delivered for all measurements
  - Example: deflections of the vertical



Daniel Willi, swisstopo
Sébastien Guillaume, HEIG-VD

- Report on levelling and gravimetry published

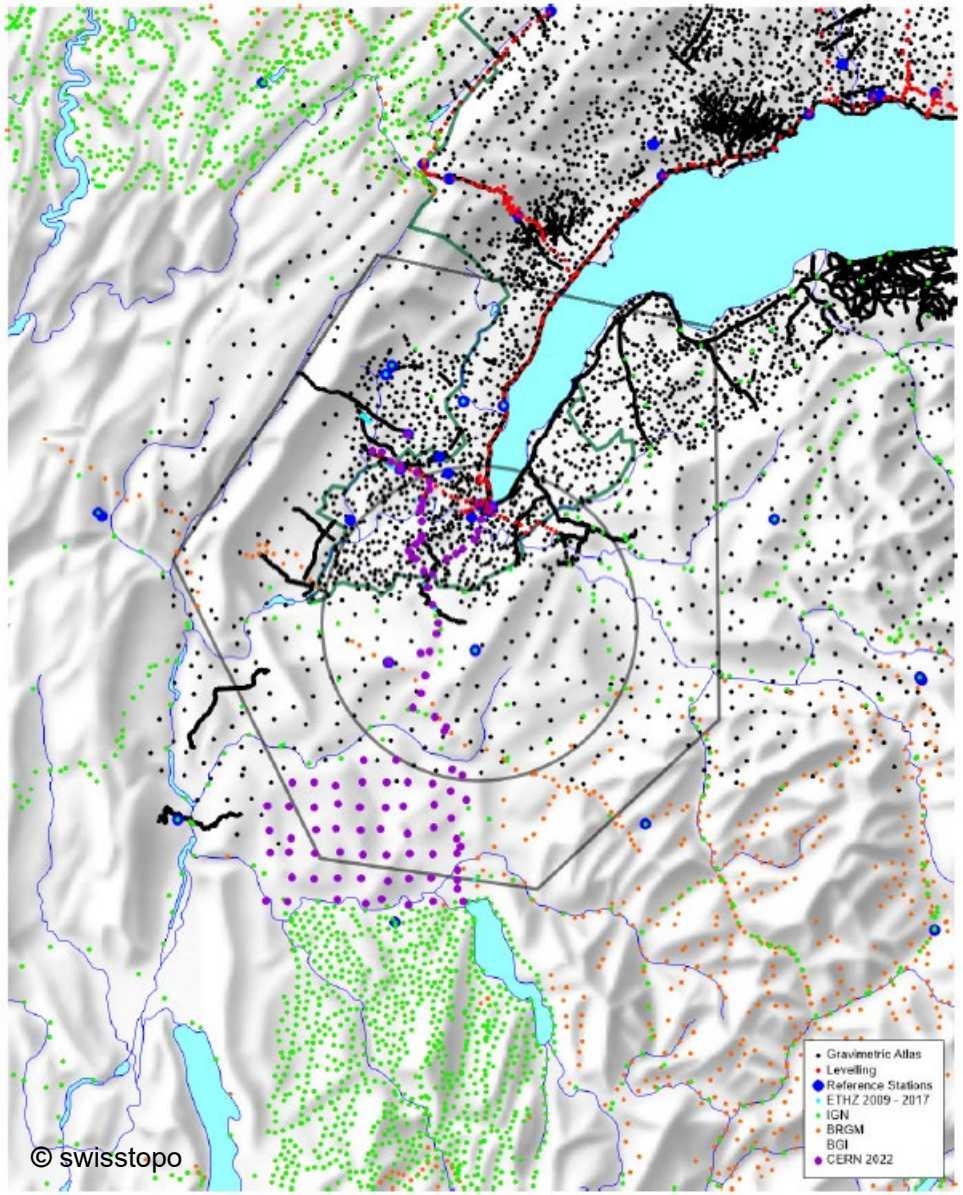


Urs Marti, swisstopo

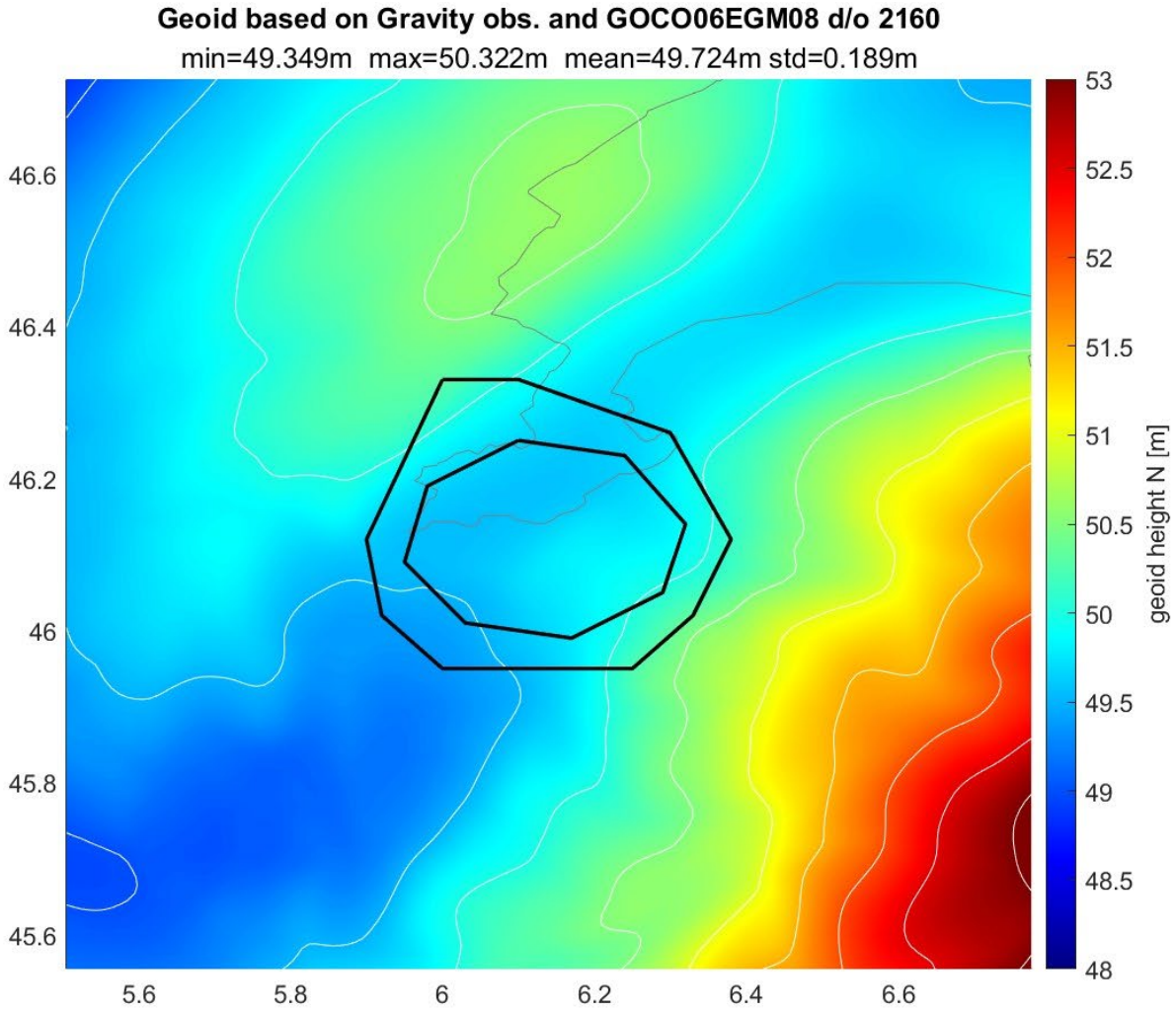
Toward a new gravity field model for the FCC region

- Available data:
  - ~10'000 gravity measurements
  - ~50 deflections of the vertical
  - Digital elevation model
  - Density map (lakes, glaciers, Ivrea body, Po valley, GeoMol: Geneva-Savoy area, etc.)

- Available software:
  - TU Graz (Groops)
  - Swisstopo (Quawirk, Hitcol)
  - DTU Space (Gravsoft)
  - UNB (SHGeo)

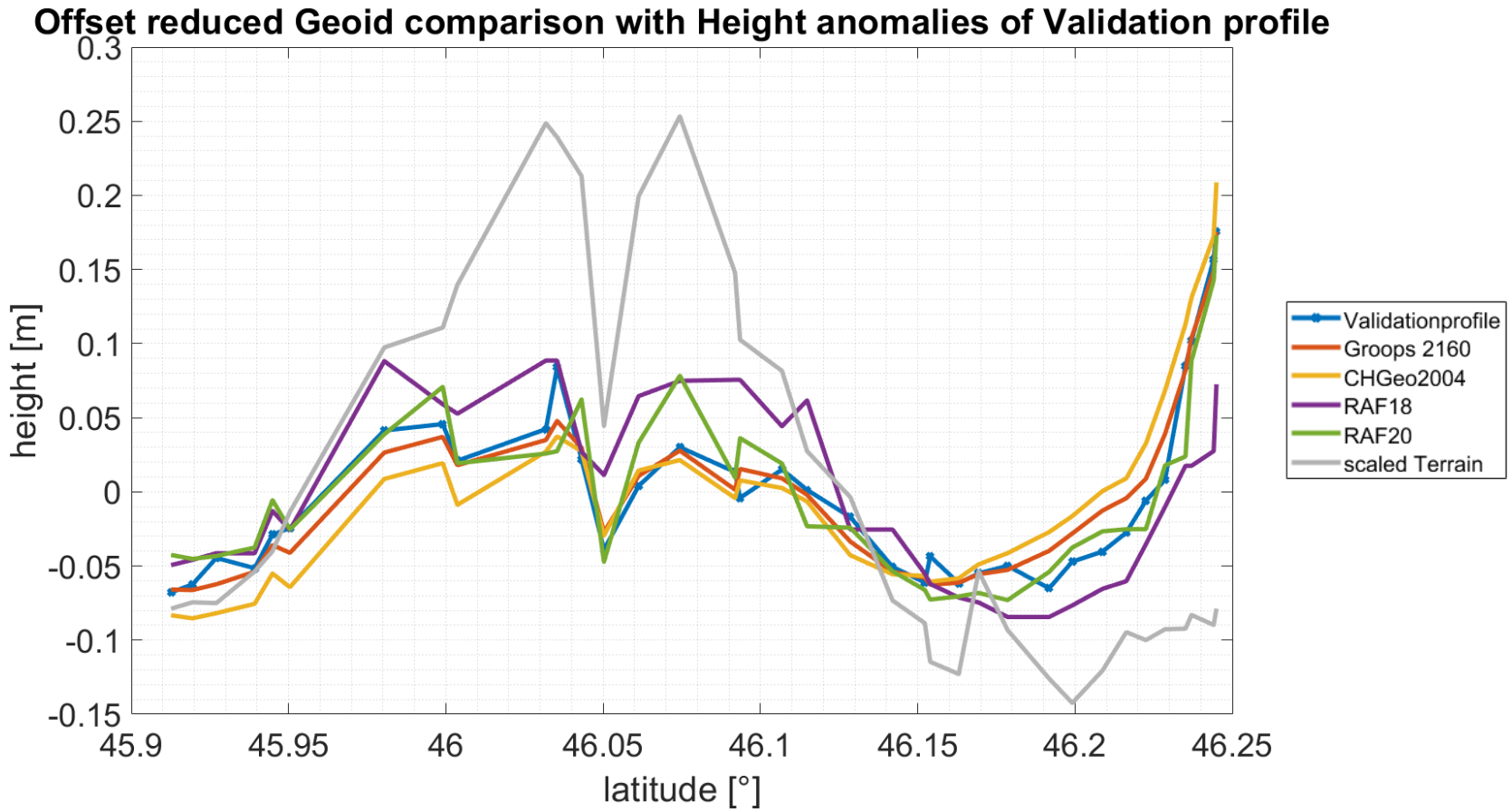


Initial FCC geoid solution with a subset of available data



“Groops 2160“

Comparison with high-accuracy profile



Comparison with FCC validation profile	Groops 2160	CHGeo2004	RAF18	RAF20
Offset [cm]	41.9	18.8	49.6	49.6
Standard deviation [cm]	1.5	2.7	4.6	2.4

Julia Koch, ETH

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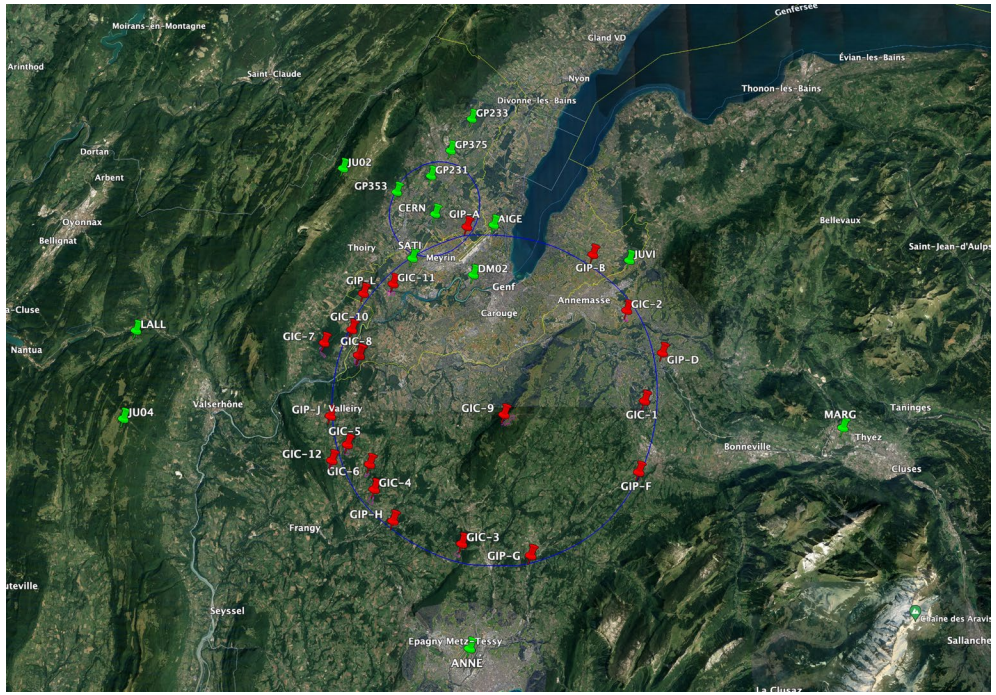
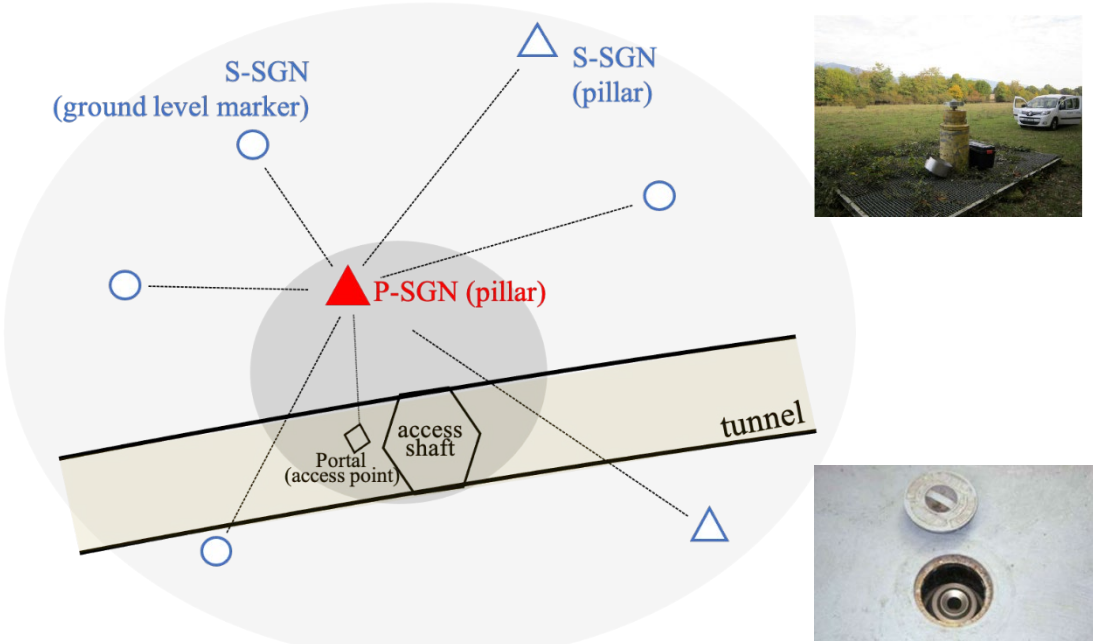
Geodetic network for the FCC: conceptual solution

- Active, semi-active (campaign) and passive geodetic points
- Strategically distributed at important locations (e.g., around tunnel access shafts)
- Ensure ideal support during pre-construction and construction phases, and full life-time of the FCC



Proposal for surface geodetic points: to be newly established (red) and existing (green)



Schematic layout of a portal surface geodetic network for one tunnel access shaft

Implementation of Primary Surface Geodetic Network (P-SGN)

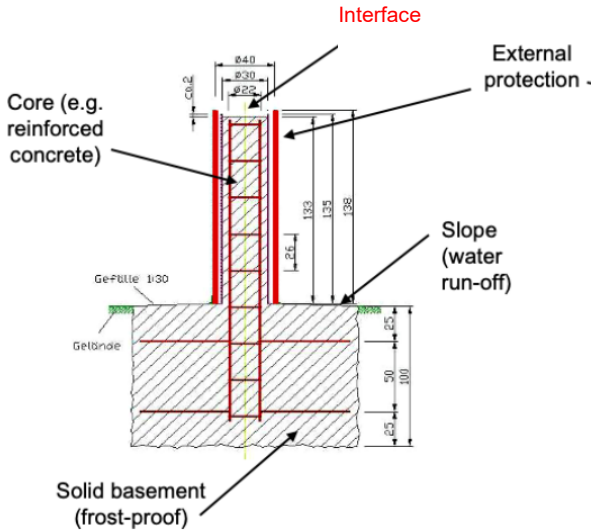
- Sites selected
- Agreement to build the pillars

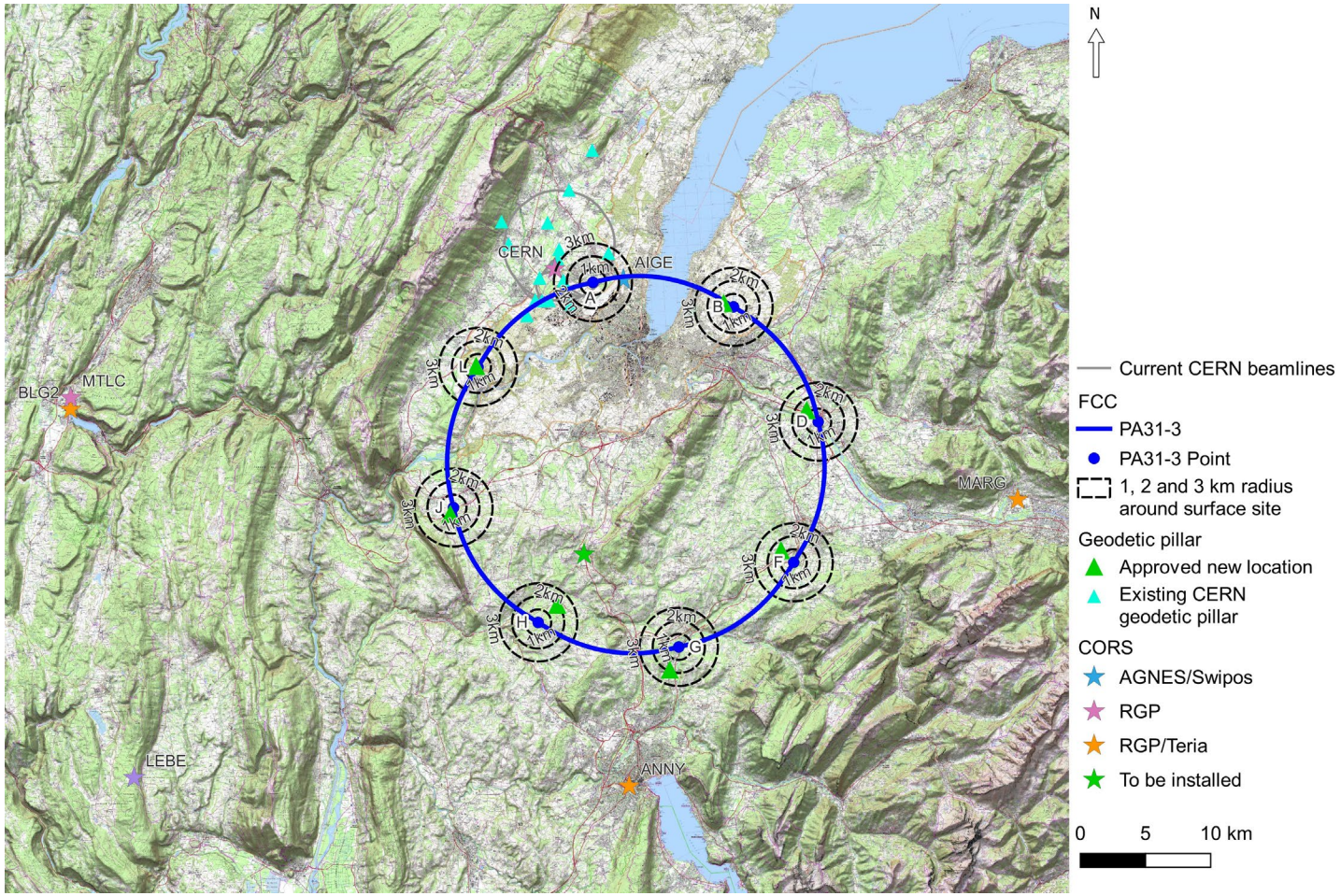
IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Bundesamt für Landestopografie swisstopo
Office fédéral de topographie swisstopo
Federal Office of Topography swisstopo

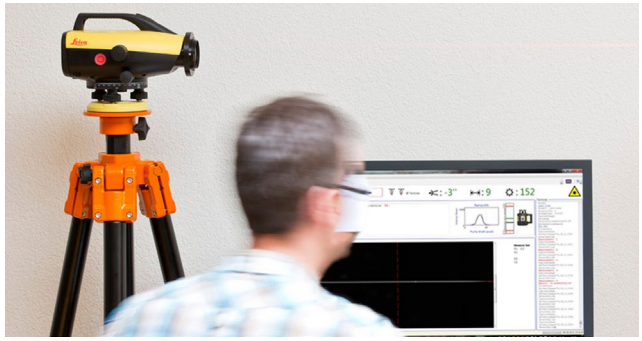




Benjamin Weyer, CERN

Calibration of geodetic equipment during the operational phase

- Proposed concept for quality control of the geodetic equipment
  - (field) tests to be performed by CERN for all instruments
  - calibration to be performed mostly by CERN



	CERN	Manufacturer	Research /public institution	Independent private company
Laser scanner	●●	●●●		
Laser tracker		●●●	●●	
Level staff	●●●		●●	
Level, Digital	●●●	●●	●●	
Meteo sensors	●●●	●●●	●●	●●
Prism/reflector	●●●	●●	●●	
RGB camera	●●●		●●	
Total station	●●●	●●	●●	
Legend: (●●●): preferably; (●●): optionally; (●): only if required; (no dot): not recommended				

Matej Varga, ETH

Conclusions

- FCC requires a **< 1 cm geoid**, not possible with existing solutions
- **High-accuracy profile for validation:** final solutions delivered for all measurement types
- **Initial geoid successfully computed**, agreement with validation profile of 1.5 cm
- **Conceptual for geodetic surface network** approaching realization
- **Concept for instrument calibration** proposed for operational phase

- Next steps:
  - **Improved geoid model**, considering deflections of the vertical and dynamic changes
  - Methods for **position and orientation transfer** into the FCC tunnel

Backup

Dynamic gravity field: modeling of time-variable effects

- Example: surges, Lake of Geneva