Hélène Mainaud Durand

GEODETIC STUDIES FOR FCC

Special thanks to Mark JONES

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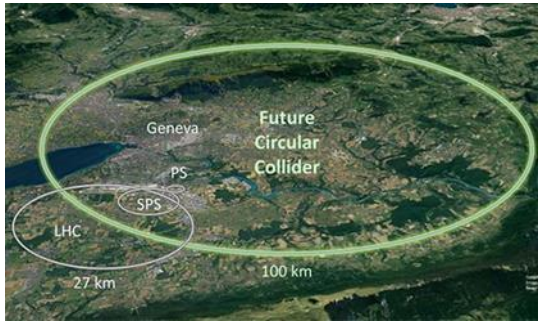
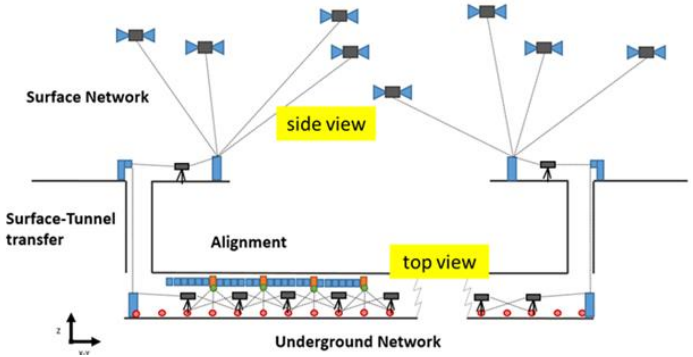
WHY DO WE NEED GEODETIC STUDIES?

Motivation of geodetic studies



FCC versus LHC

- FCC 10 times larger than LHC
- Reference frames and infrastructure go back to LEP (80s)
- The installation of components girders will start before the final completion of the whole tunnel ring, i.e., without a complete underground geodetic network.
- The alignment tolerances of the components underground are tighter.

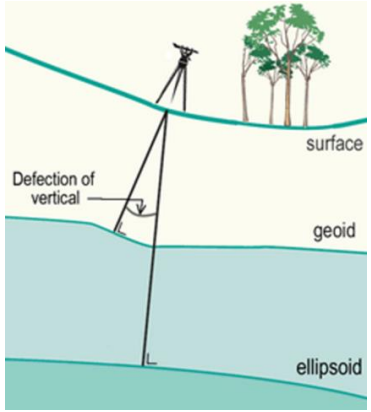


[1] Lorem Ipsum Dolor

Motivation of geodetic studies

About geodesy…

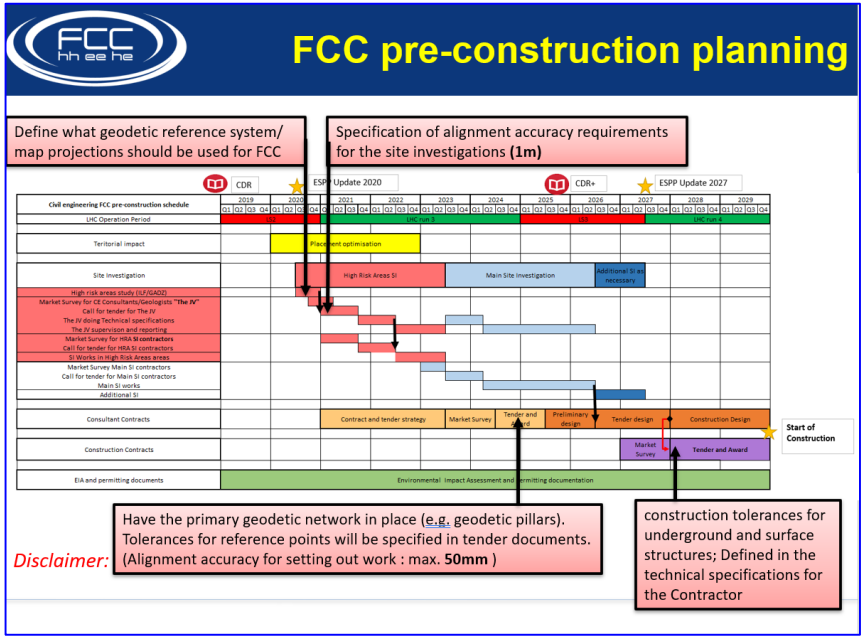
- All the FCC machine will be located in an inclined plane
- The major part of Survey instrumentation and alignment sensors refer w.r.t. gravity
- Two surfaces to model the Earth:
  - Ellipsoid
  - Geoid
- Very important to determine the link between both at the highest possible accuracy



Motivation of geodetic studies

Civil Engineering : input required from BE-GM

- Detailed description of reference systems: geodetic, map projection, local and height reference surface
- Surface geodetic reference network
- Control baselines for Survey instruments
- Survey building requirements
- Reference system transformation software
- Coordinates and transformation parameters for 3D models, drawings, maps
- Input into geodetic survey specifications



COLLABORATION ON GEODETIC STUDIES

Collaboration on geodetic studies

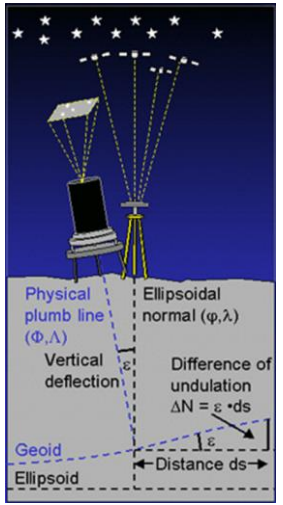
Context and objectives:

- Agreement + addendum signed in November 2020 (FCC-GOV-CC-0203 / KE4929/ATS, with funding from CHART) between CERN and:
  - ETH Zürich, Institute of Geodesy and Photogrammetry (Prof. Wieser, Prof. Rothacher)
  - Federal Office of Topography, Swisstopo : Dr. Willi
  - School of management and Eng. Vaud, Inst. Of Territorial Eng.(Prof. Guillaume)
- Two major objectives (corresponding to 2 work units)
  - Determination of a high-precision gravity field model for the FCC region
  - Improvement of the Geodetic reference frames and the geodetic infrastructure.

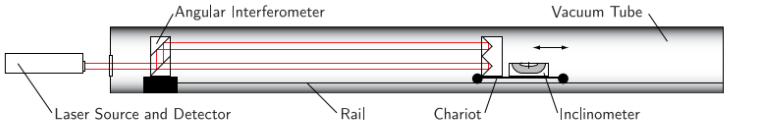
Collaboration on geodetic studies

Determination of high-precision gravity field models for the FCC region

- Database of methodologies, instruments and auxiliary data for gravity field determination
- Initial gravity field model for the FCC region
- Validation dataset from profile measurement campaign
- Report on the suitability of the deflectometer for gravity field determination
- Conceptual design report for establishing gravity field models for different alignment requirements
- Conceptual design report for the establishment of a dynamic gravity field



[S. Guillaume]



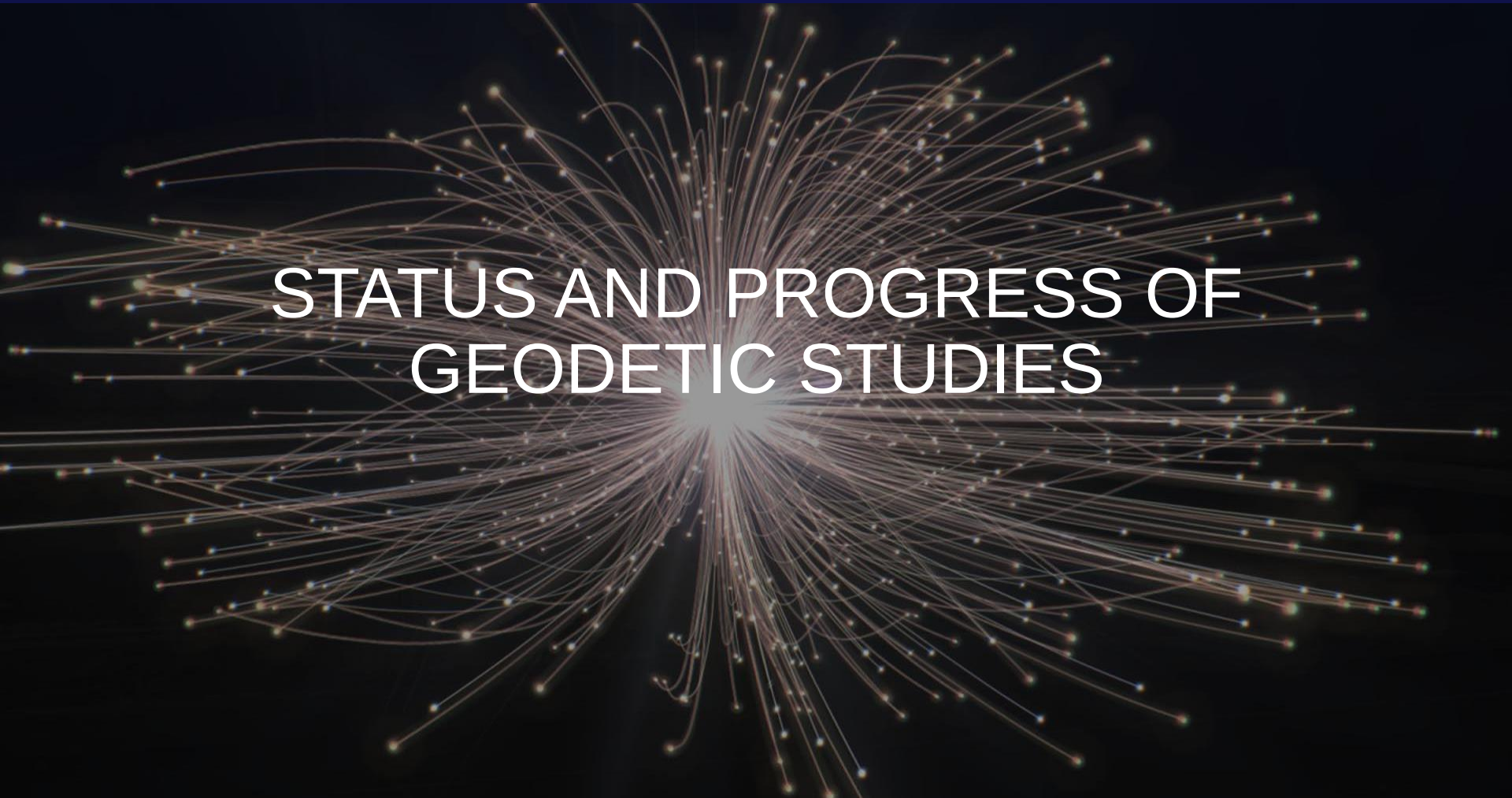
Idea of determining vertical deflections as angle between interferometer and inclinomete measurements

[M. Schmid]

Collaboration on geodetic studies

Improvement of the Geodetic Reference Frames and the Geodetic Infrastructure

- Report on the proposition of a horizontal geodetic datum and a cartographic map projection for the FCC
- Conceptual design report for the establishment of a surface geodetic reference network including control baselines
- Database of methodologies and instruments for position and orientation transfer into the FCC tunnel
- Conceptual design report for the connection of the geodetic underground monitoring system to the civil engineering one
- Conceptual design report for a calibration, control and test facility of the geodetic equipment needed during construction and operation of the FCC

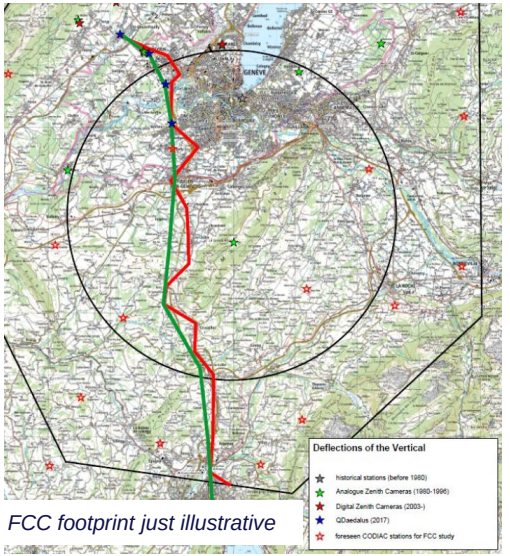


STATUS AND PROGRESS OF GEODETIC STUDIES

Status of geodetic studies

Determination of High-Precision gravity field models for the FCC region

- Doct. Student to start soon
- Profile measurement campaign well advanced:
  - Astro-zenithal measurements performed & analyzed
  - Levelling measurements done
  - GNSS measurements to be scheduled.
- Deflectometer under refurbishment



FCC footprint just illustrative

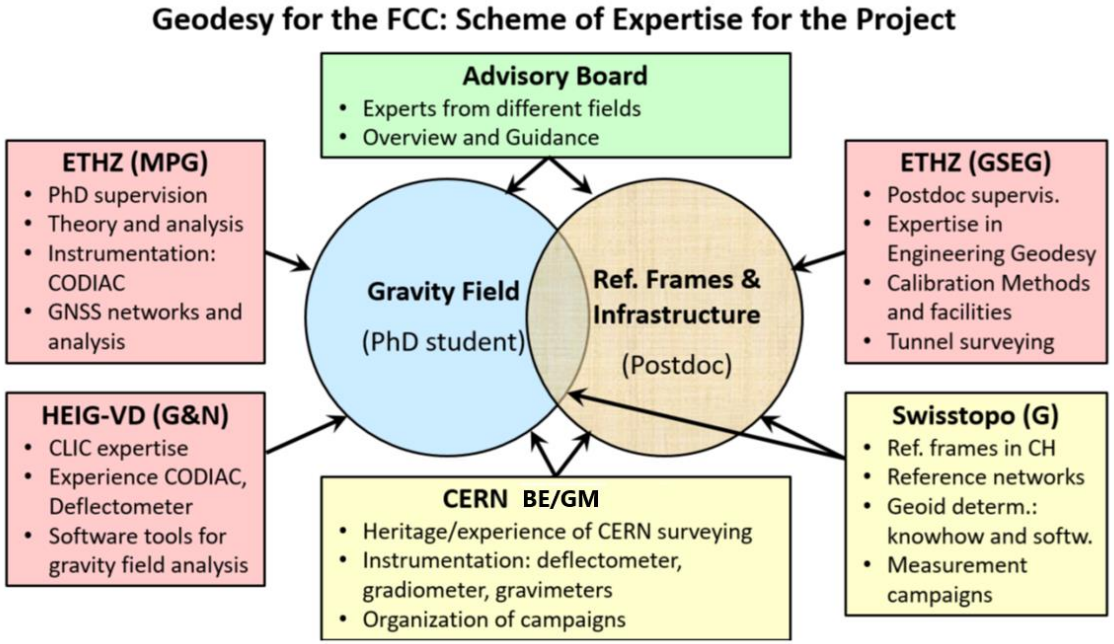
Status & progress

Improvement of the Geodetic Reference Frames and the Geodetic Infrastructure

- Post-Doc. Started on the 1st of February 2021: Matej Varga under the supervision of Prof. Wieser.
- Report on the proposition of a horizontal geodetic datum and a cartographic map projection for the FCC: first draft to be issued before end of June.
- Finalization of the report in September

WP ORGANIZATION AND REVIEW OF ACTIVITIES

Organisation of WP



Technical Infrastructure WG

Geodesy and Survey:

H. Mainaud Durand
Prof. A. Wieser
L. Watrelot

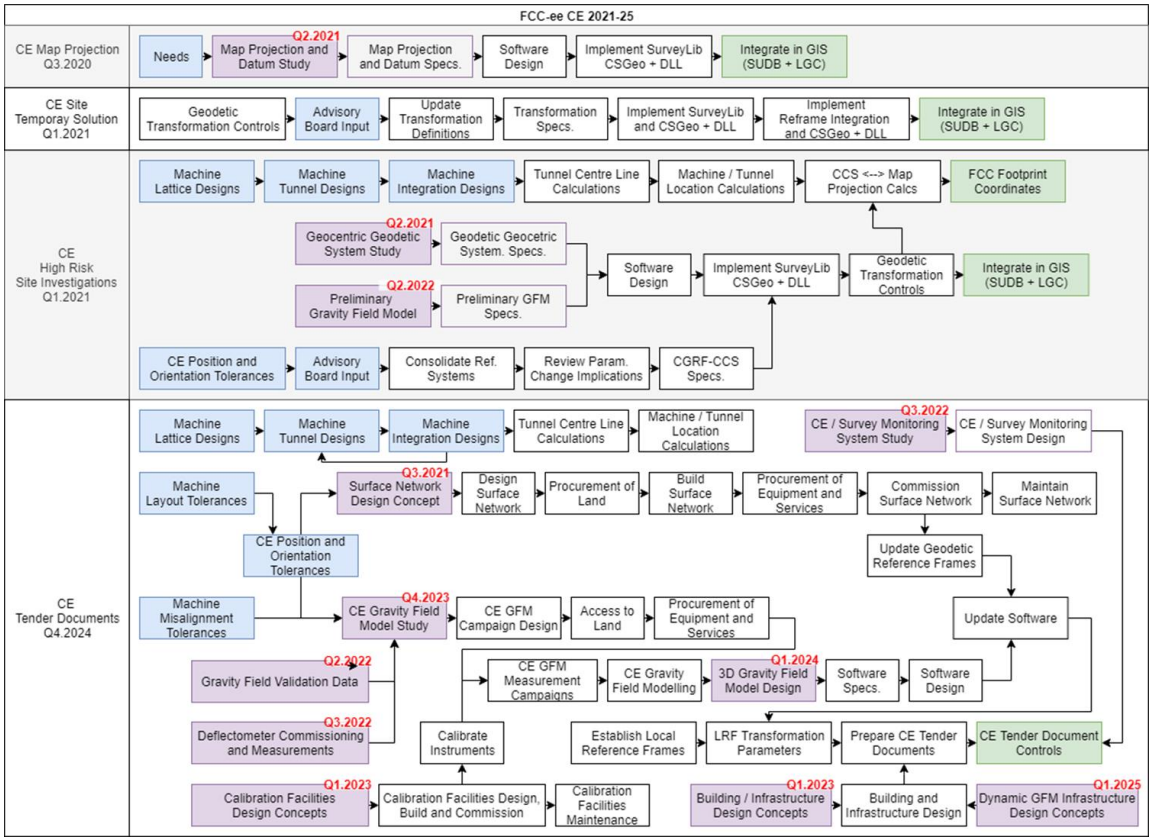
No resources currently available in BE/GM

New geodesist staff on 1st October 2021

Review of activities

Between 2021-2025

- Input needed
- To be performed by BE/GM
- Deliverables from collab.
- Final deliverable



Very ambitious program:

- Only achievable with additional manpower
- If the surface network can be built

Review of activities

Beyond 2025

- Finalize the 2021-2025 delayed activities:
  - Measurements of the surface network and their integration in software
  - Measurement campaign for the design of the 3D gravity field model
  - Building and commissioning of the calibration facilities
- Implement the concepts proposed in the collaboration to get:
  - Mathematical reference systems and transformation algorithms
  - Geodetic transformation software
  - Gravity field models
- Develop and test specific instruments (in-situ vertical deflection measurements, vertical transfer through shafts)
- Prepare the documentation, software tools needed for CE tender documents
- Perform and control the calculations and studies on FCC footprint scenarios, position and orientation of machines

Conclusion

From J. Gervaise: «Geodesy and metrology at CERN: a source of economy for the SPS programme. 17 nov. 1976, CDS Link

I. INTRODUCTION

It would seem important, when discussing the high-precision geodetic and metrological survey techniques used in the construction of large particle accelerators, to emphasize the extensive savings which can be gained by any laboratory which undertakes the construction of the second-generation giant proton synchrotrons (400 - 500 GeV).

As a first approximation, it is generally believed that accuracy is costly in terms of time, money and staff. The term "costly" is misleading and only used for budget purposes. The speed and accuracy with which the CERN Survey Group installed the quadrupole and dipole magnets in the Super Proton Synchrotron (SPS) tunnel resulted in substantial savings. Only two months elapsed between the moment when protons were first injected into the accelerator and when they reached the design energy of 400 GeV at an intensity of 3.10^{12} protons per pulse. This time would certainly have been greater if the elements in the ring had not been installed within the prescribed tolerances. Although it is impossible to place a monetary figure on the time saved by CERN, it is likely to have been considerably greater than the budget of the Survey Group.

Having drawn attention to this point, the purpose of this paper is to explain how the Survey Group achieved these results.

VIII. CONCLUSION

Although it was not possible here to go beyond a general description, this paper has shown how the Survey Group took up the three challenges to their technical skill during the construction of the 400 GeV proton synchrotron.

From the budget standpoint, it is very difficult to place a figure on the savings made owing to the successful outcome of the Group's activities. On looking back, it is hardly conceivable that the boring machine would not return to its starting point with acceptable tolerances. On the other hand, it is quite understandable that, because of the early start of the provisional installation work, it might have been necessary, during final installation, to remove all the magnets which were first installed in sextants 3 and 4, shift the supports and reinstall the magnets and beam control equipment, with all the consequent disturbances to the vacuum and busbar systems.

The excitement of the engineers and physicists responsible for the construction of the accelerator on learning that protons had orbited the ring for the first time clearly illustrates the relief felt when such a complex machine as an accelerator operates correctly from the very first moment. The first photographs of the closed orbit gave the Survey team concrete proof of the success of their work. Here too, if it had been necessary to align the machine by moving quadrupoles as a result of beam measurements and repeat this a number of times, this would have proved an extremely time-consuming task taking many months. Furthermore, it would no doubt have had serious repercussions on CERN's personnel budget and necessitated considerable capital investment.

Thank you
for your attention.