Update of the magnetic measurement benches of the ESRF

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Co-Authors : Gaël Le Bec, Reine Versteegen, Lorenzo Bortot

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ESRF | The European Synchrotron

ACKNOWLEDGMENTS

Special thanks

Joël Chavanne
Head of the IDM group

Gaël Le Bec
New IDM group leader

Damien Coulon
Mechanical Engineer

Many thanks to all the Insertion Devices and Magnets team

OUTLINE

I. Introduction
- Magnetic measurements at the ESRF

II. Stretched Wire Bench
- Bench design
- CE compliance

III. Hall Probe Bench
- Bench design
- 3 axis Hall probes

IV. Bench Software
- Current Igor software
- Python software development

V. Conclusion and prospects

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I . INTRODUCTION

ESRF Aerial view

ESRF – The European synchrotron

- Light source built in 1994 and upgraded in 2020 with EBS
- Located in the French Alps in Grenoble
- 6 GeV – 200mA machine
- 844 m long storage ring with about 1000 accelerator magnets
- 32 straight sections with 72 undulators
- 44 beamlines welcoming 9000 scientists every year, researching material physics, chemistry, structural biology, nanotech…

I . INTRODUCTION

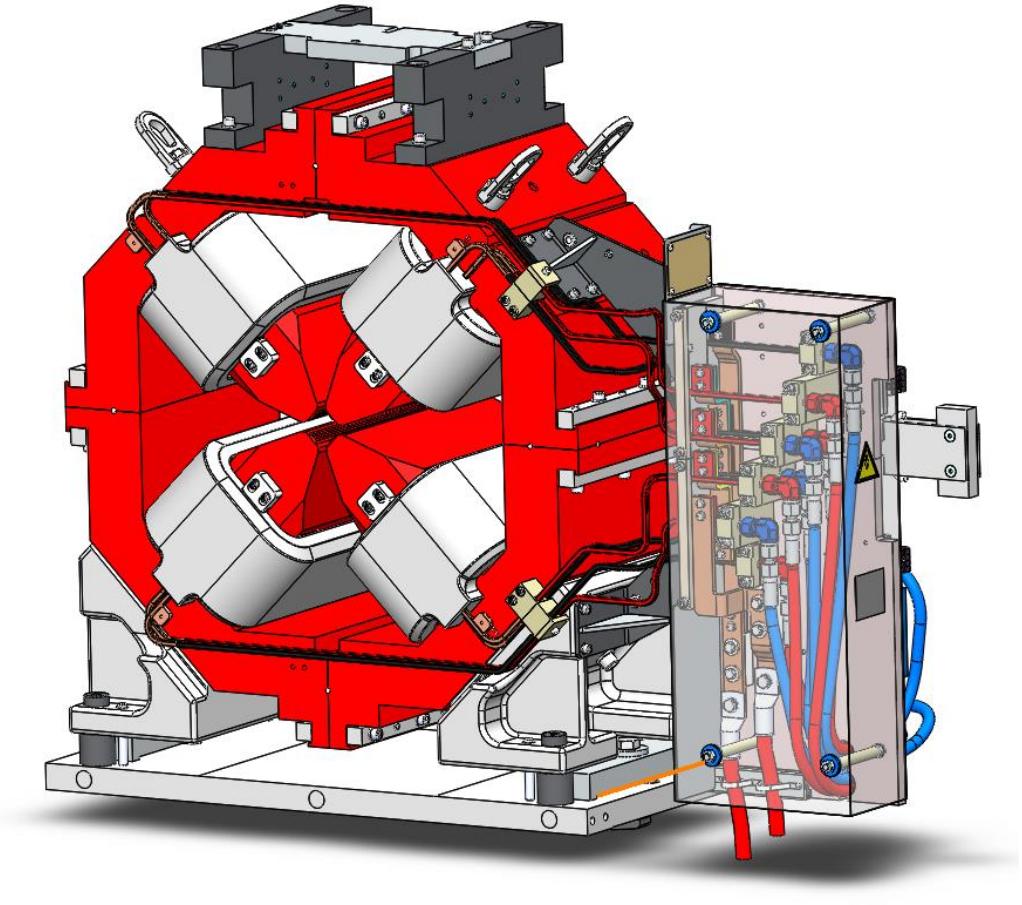
Insertion Devices & Magnets team :

- 12 members, ID specialists, control specialists, magnetic measurement specialists and technicians :

G. Le Bec, R. Versteegen, C. Benaberrahmane, L. Bortot, F. Revol, B. Cottin, G. Giroud, F. Bidault, F. Perratone, J. Caverot, M. Michel, L. Samaille

- Relocated in ESRF01 after EBS completion, about 1000m^2, LN2 network for CPMU measurements

IDM Lab in ESRF01



EBS SR Quadrupole, 20T/m

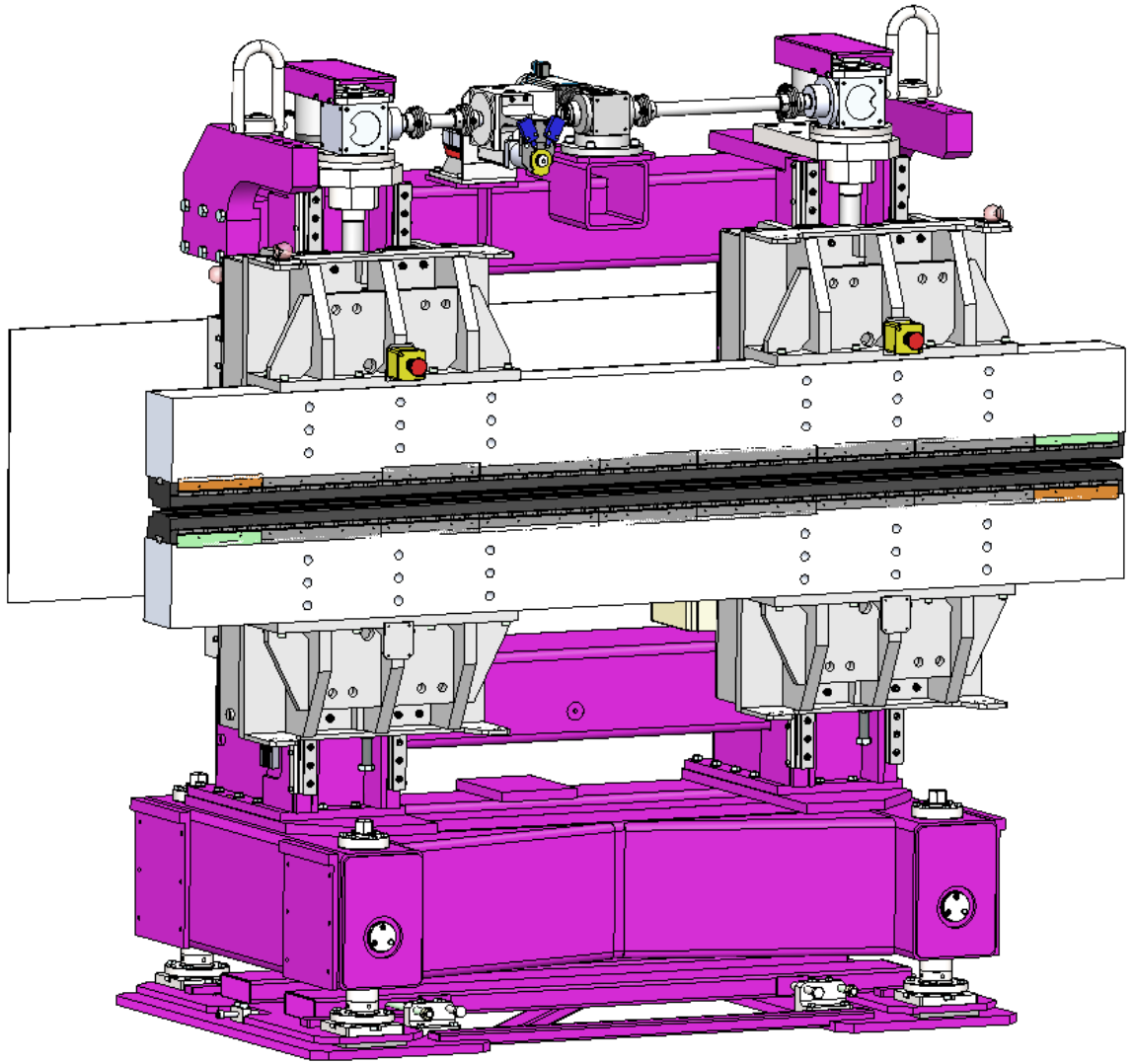
Accelerator magnets measurements

Use of a stretched wire bench for :

- Field & gradient measurements
- Multipole harmonic analysis
- Magnetic center measurement
- Roll, Pitch and Yaw angles measurement
- Magnetic length

Results with 20T/m 50cm long, 33mm radius quadrupole

	Typ. repeatability	
Magnetic center position	2	µm
Pitch and yaw angles	0.1	mrad
Roll angle	0.1	mrad
Integrated field	0.2	G m



Long taper permanent magnet undulator

Undulators measurements

Use of a stretched wire bench for :

- Individual magnet field integral measurements for sorting assembly lists
- Magnets (and poles if hybrid) assembled on bench
- Field integral measurement of the undulator during the assembly and tuning process

Use of a Hall probe bench for :

- 3 axis field measurements along undulator
- Optimization of the electron trajectory, optical phase and magnetic angle

Bench upgrade motivations

Stretched wire bench :

- **Improve** measuring **capability** before EBS
- **Improve** wire position for **fiducialization** of EBS magnets
- CE certified for commercial purposes

Hall probe bench :

- **Easier** hybrid undulator **assembly process** with on bench touch probe and assembly tools
- **Faster** undulator **measurement** for shimming and optimization
- Update of our 20yo in house 3D Hall design
- CE certification

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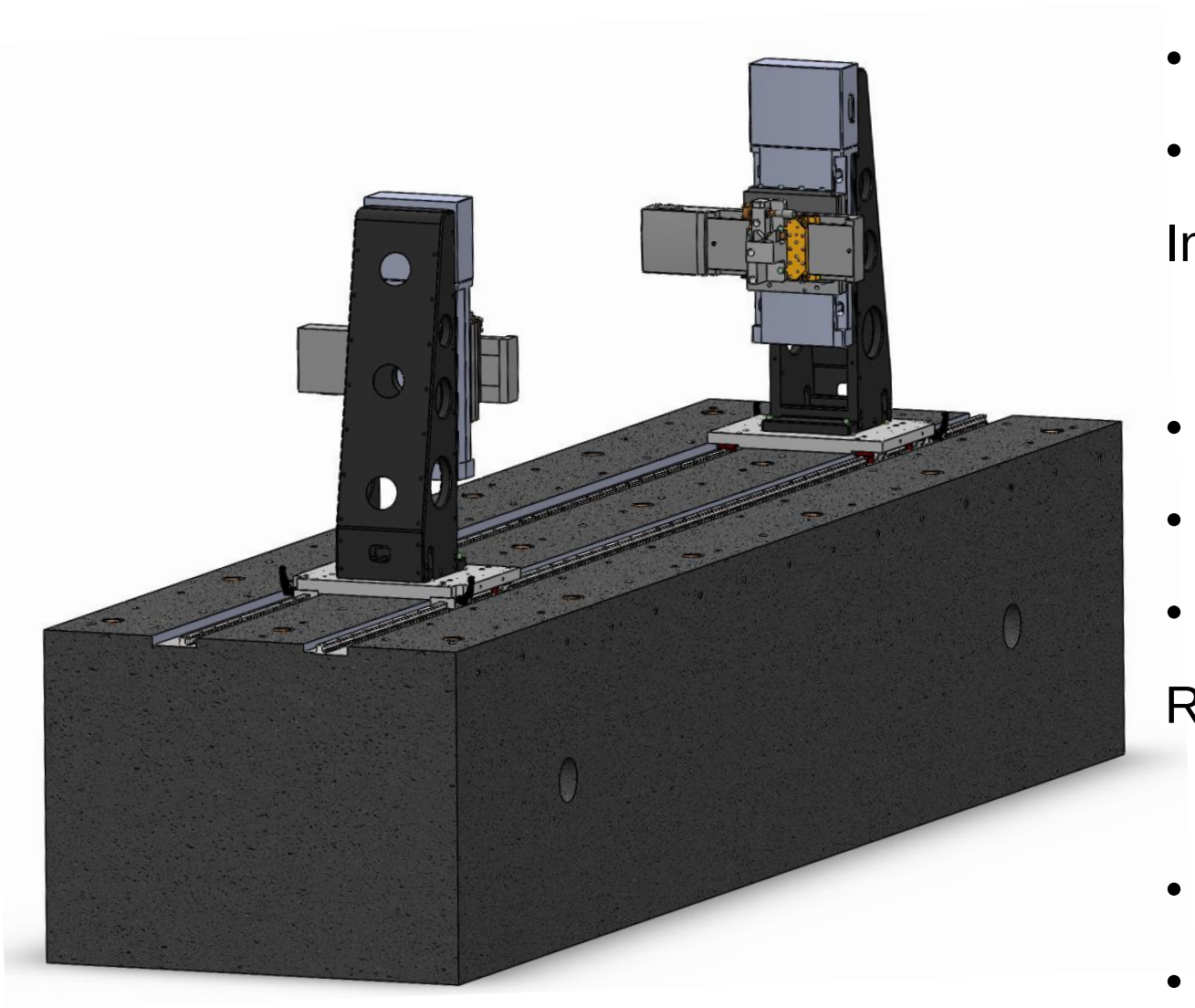
II. STRETCHED WIRE BENCH - DESIGN



ESRF stretched Wire bench CAD

- Mostly 100µm Ti90 Al6 V4 wire, up to 2m
- Keithley 2182A nanovoltmeter

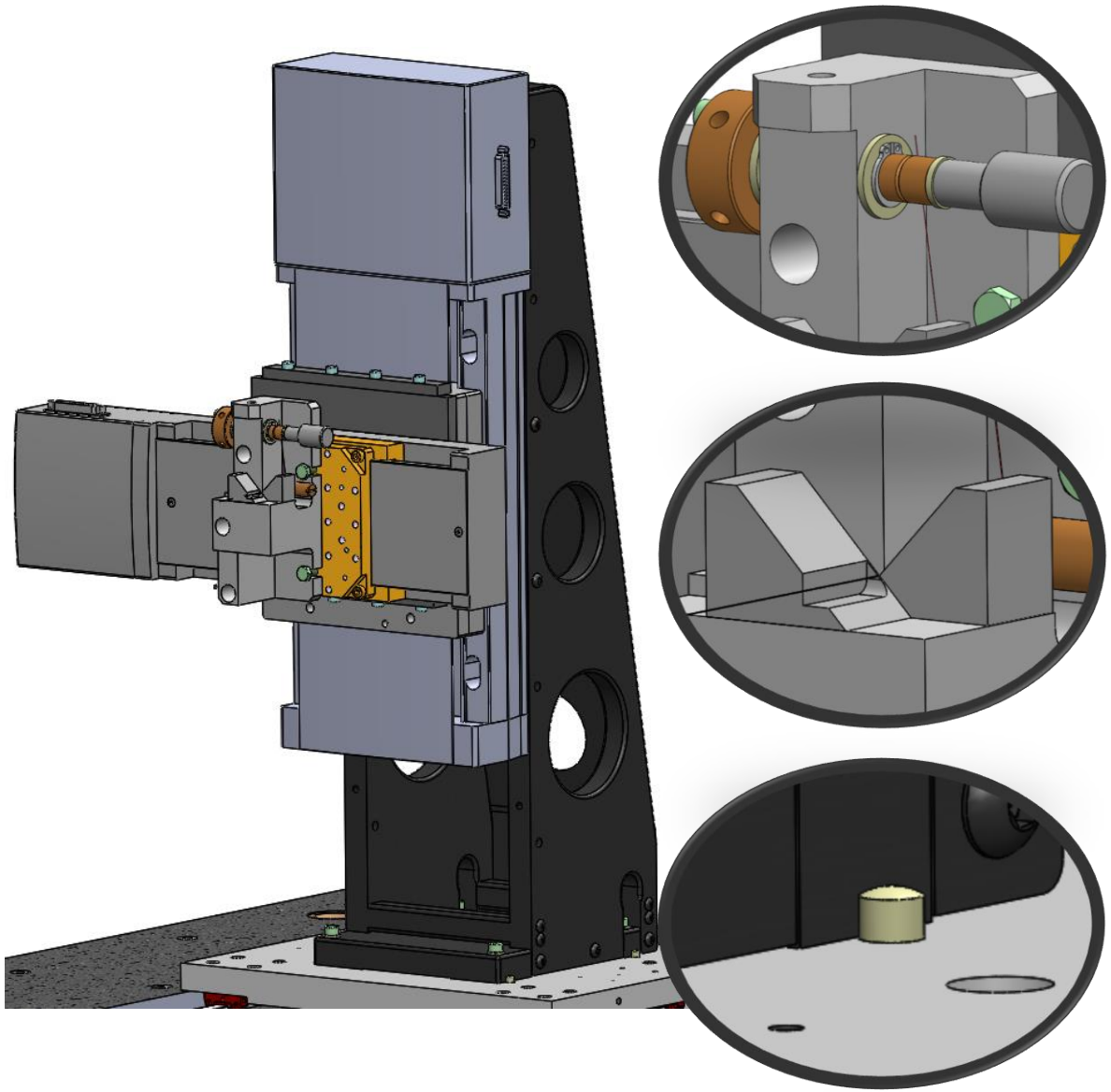
Integrated field repeatability 0.2 Gm

- Newport ILS-100CC horizontal stage
- Newport IMS-100V vertical stage
- XPS RLD4 motion controller

Repeatability 0.5 µm

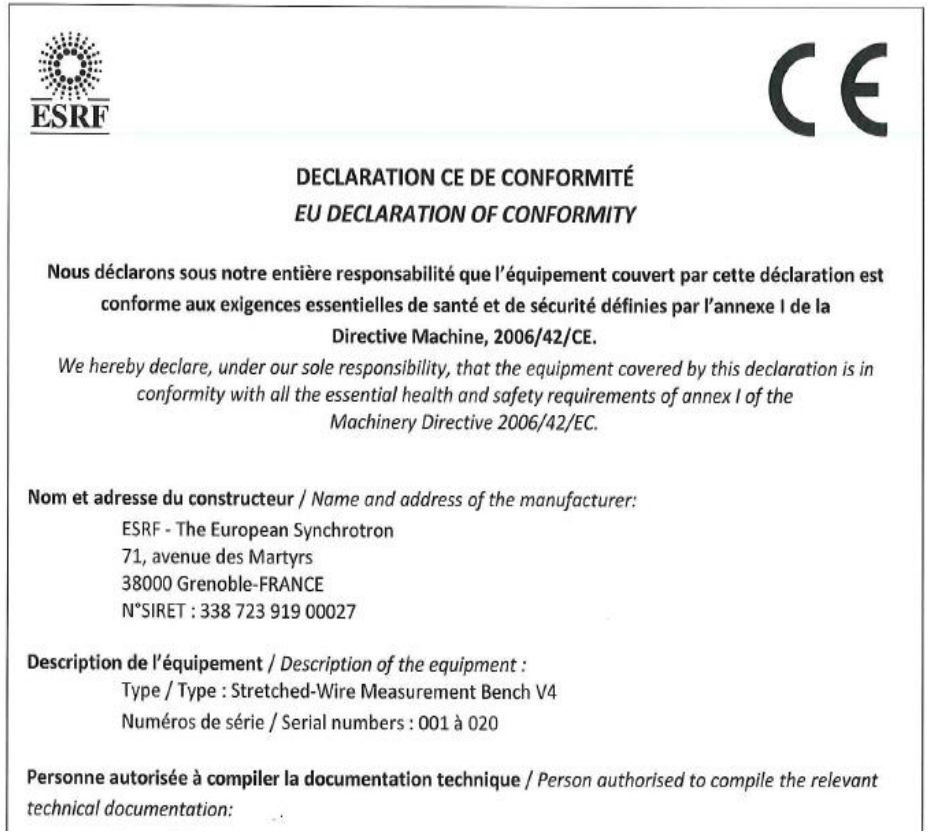
- 80 x 60 x 300 cm granite table
- 4.4 Tons

II. STRETCHED WIRE BENCH - DESIGN



- Orthogonality plate, checked with interferometers, shimmed
- Tensioning system, wire frequency stretched to 50Hz multiple.
- V shaped wire support, measured with FARO arm,
- Alignment pins, checked with FARO arm, shimmed

II. STRETCHED WIRE BENCH – CE COMPLIANCE



ESRF

CE

DECLARATION CE DE CONFORMITÉ

EU DECLARATION OF CONFORMITY

Nous déclarons sous notre entière responsabilité que l'équipement couvert par cette déclaration est conforme aux exigences essentielles de santé et de sécurité définies par l'annexe I de la Directive Machine, 2006/42/CE.

We hereby declare, under our sole responsibility, that the equipment covered by this declaration is in conformity with all the essential health and safety requirements of annex I of the Machinery Directive 2006/42/EC.

Nom et adresse du constructeur / *Name and address of the manufacturer:*

ESRF - The European Synchrotron
71, avenue des Martyrs
38000 Grenoble-FRANCE
N°SIRET : 338 723 919 00027

Description de l'équipement / *Description of the equipment :*

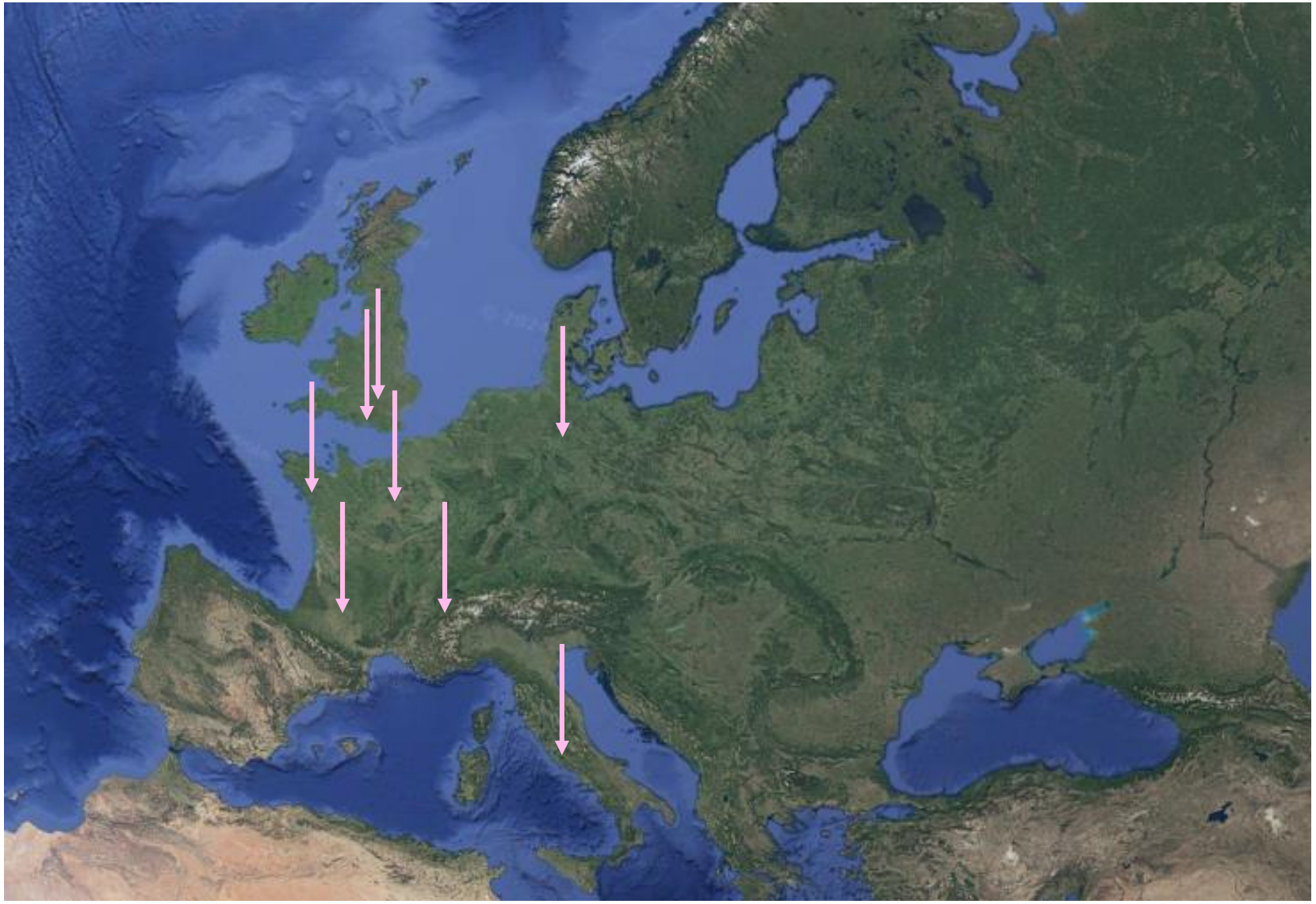
Type / Type : Stretched-Wire Measurement Bench V4
Numéros de série / Serial numbers : 001 à 020

Personne autorisée à compiler la documentation technique / *Person authorised to compile the relevant technical documentation:*

Bench now CE certified

- Complies to Machinery directive 2006/42/EC
- Mainly uses commercial components
- Complete user manual
- Emergency stop buttons
- Handling procedure
- Work area requirements

II. ESRF STRETCHED WIRE BENCHES LOCATIONS



- More than 10 benches installed across Europe
- Trusting partners such as Soleil, Tesla, Sigmaphi, SEF and more
- Bench being build for PAL in Korea

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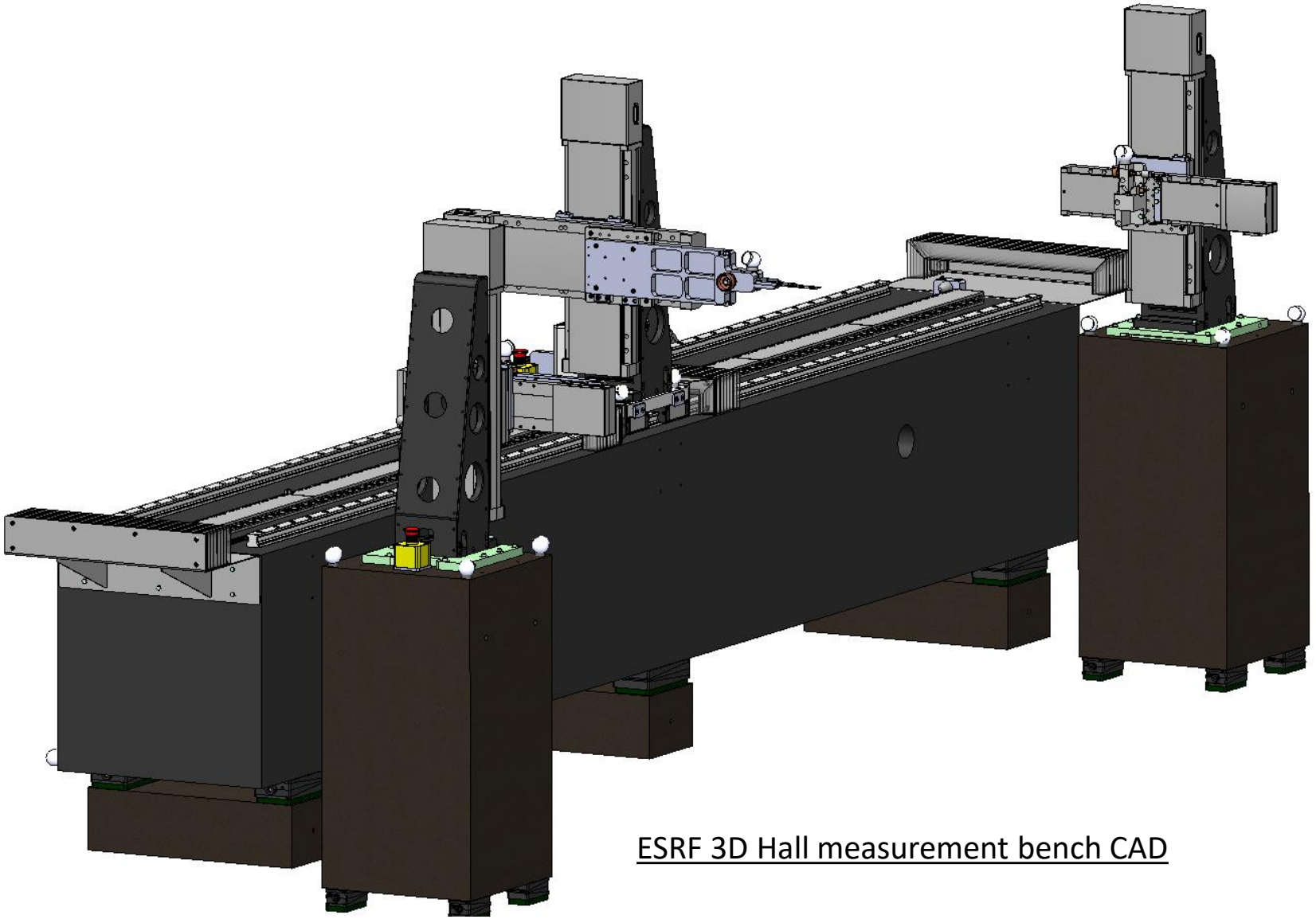
III. HALL PROBE BENCH – NEW DESIGN



ESRF 3D Hall measurement bench CAD

Prototype under development at ESRF

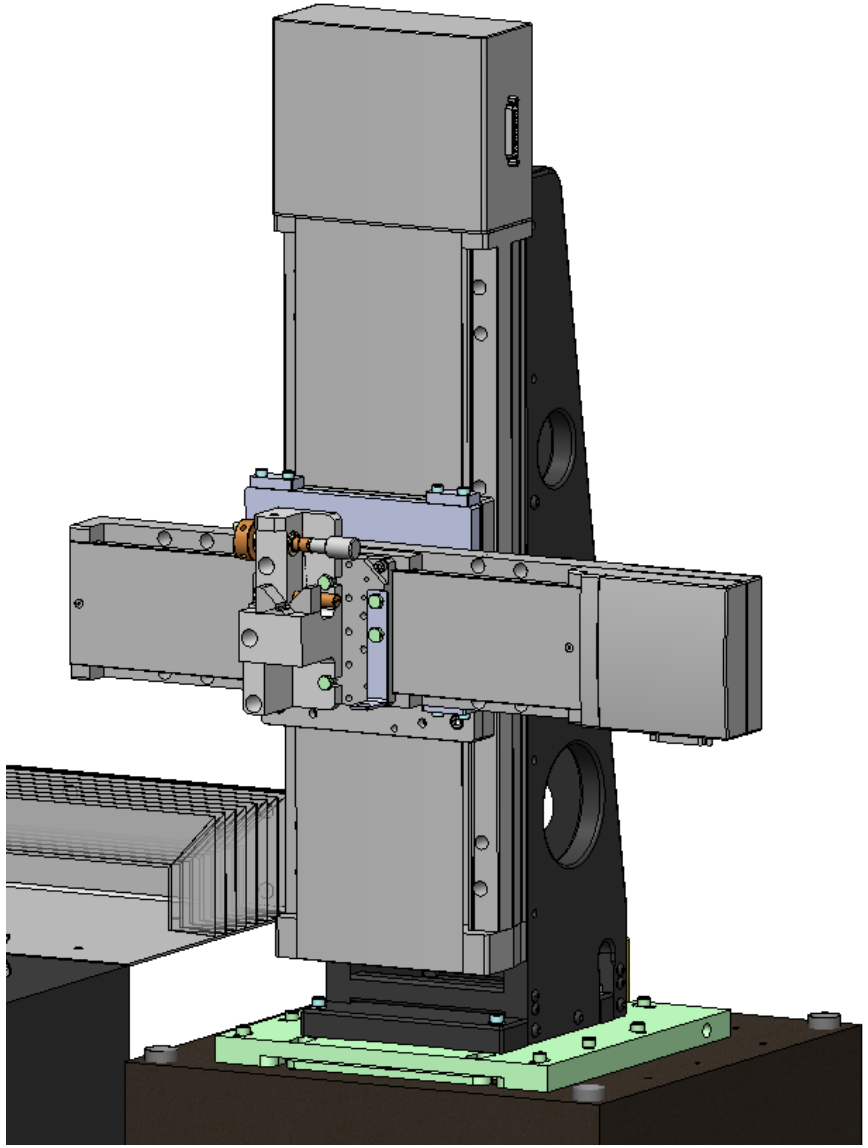
- 4m granite for 3D Hall probe
- 2 satellite granite SW Bench

Needed to measure undulator field integrals and racetrack boundaries

(see IMMW20 talk from G.Le Bec)

- Fit either a measuring table or an undulator

III. HALL PROBE BENCH - DESIGN



- Mostly 300µm Carbon wire, 3.3m
- Keithley 2182A nanovoltmeter

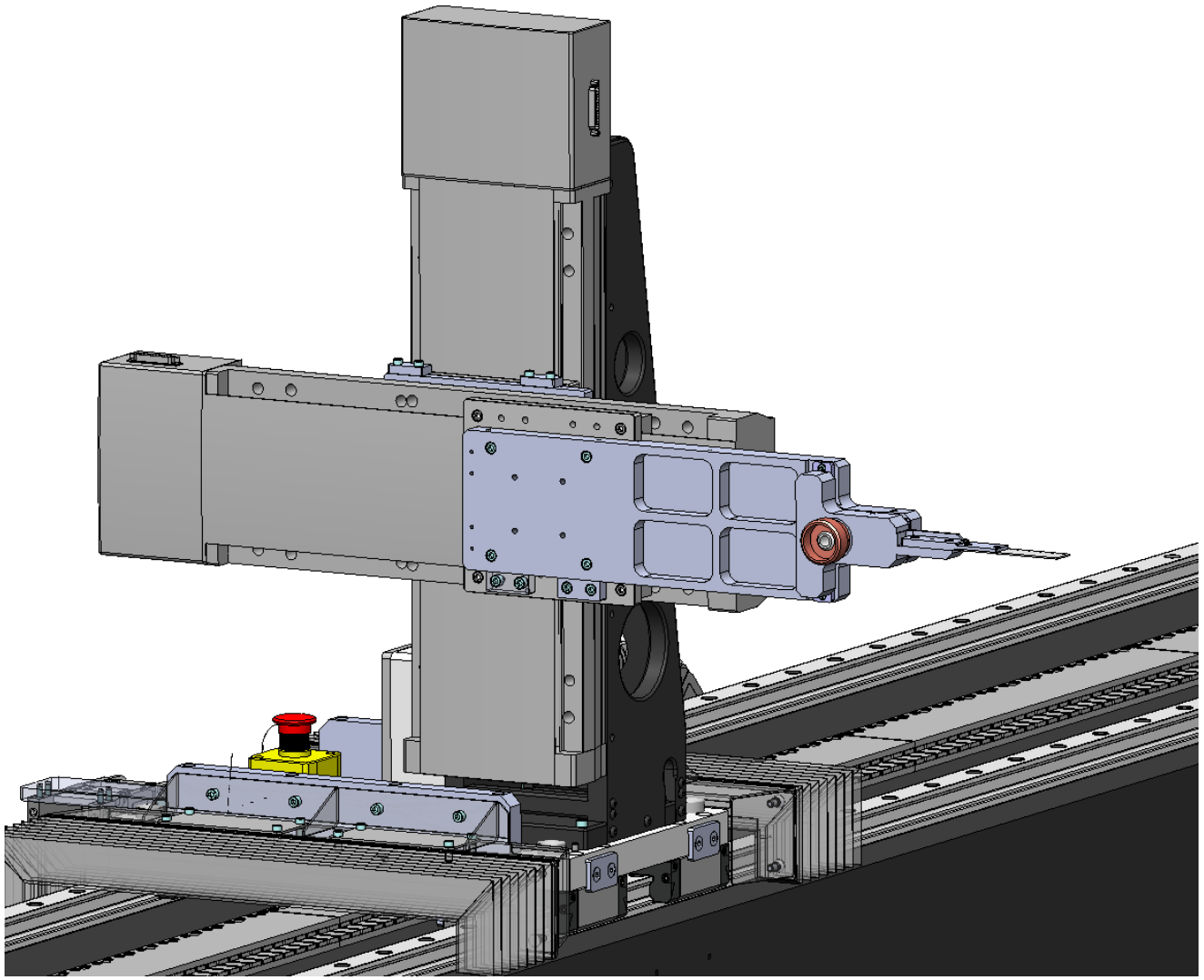
Integrated field repeatability 0.2 Gm

- Newport ILS-250CC horizontal stage
- Newport IMS-300V vertical stage
- XPS D8 motion controller

Repeatability 0.5 µm

- Z axis rotation plate needed

III. HALL PROBE BENCH - DESIGN



- Newport IMS-300CC horizontal stage
- Newport IMS-300V vertical stage

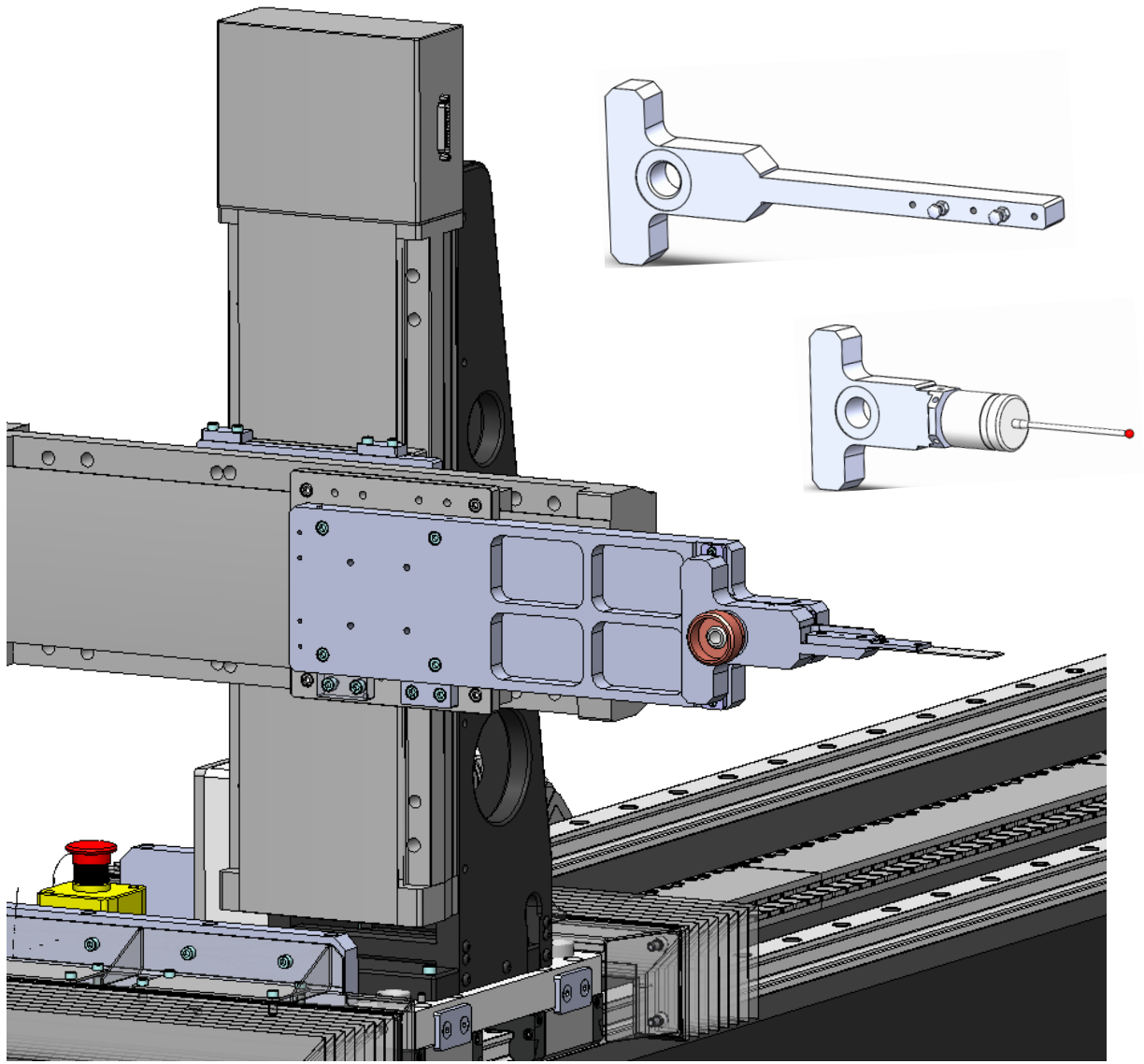
Repeatability 0.5 µm

- Tecnotion UL9 linear motor with Heidenhain LIDA 405 encoder

Accuracy 5 µm; Repeatability of 2 µm

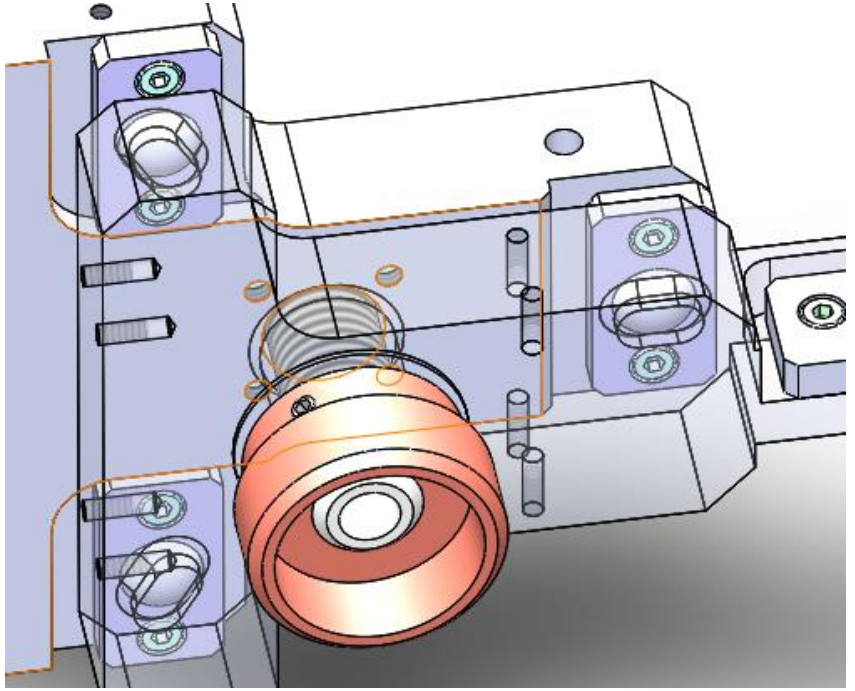
- XPS EDBL driver
- 250W continuous, 1000W peak
- Acceleration up to 400mm/s^2
- Linear motion up to 400mm/s

III. HALL PROBE BENCH - DESIGN

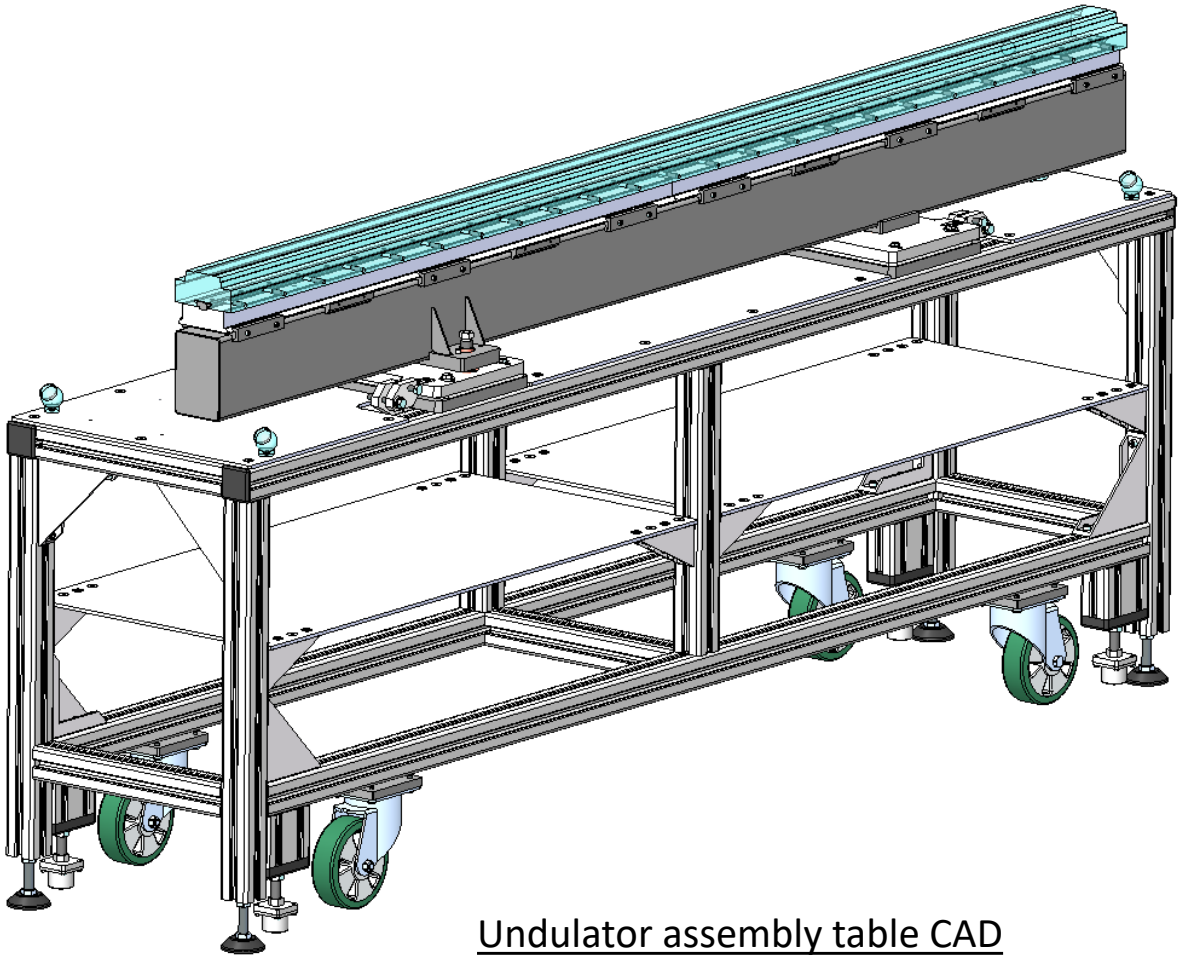


- Quick mount for hall PCB, touch probe and assembly tools
- 3 axis hall sensor to determine
- Renishaw RMP 40 touch probe

1 µm repeatability for module positioning



III. HALL PROBE BENCH - DESIGN



Undulator assembly table CAD

- Ergonomic mounting table
- 5 axis adjustments to align with bench
- Suited to all our types of undulators
- Use of the bench arm with assembly tools for positioning
- Position check and optimization with touch probe and hall probe
- Minimize the optimization process on undulator frame

III. HALL PROBE BENCH – DESIGN

- Similar to SW Bench
- Designed with CE compliant commercial parts
- New risk with moving parts

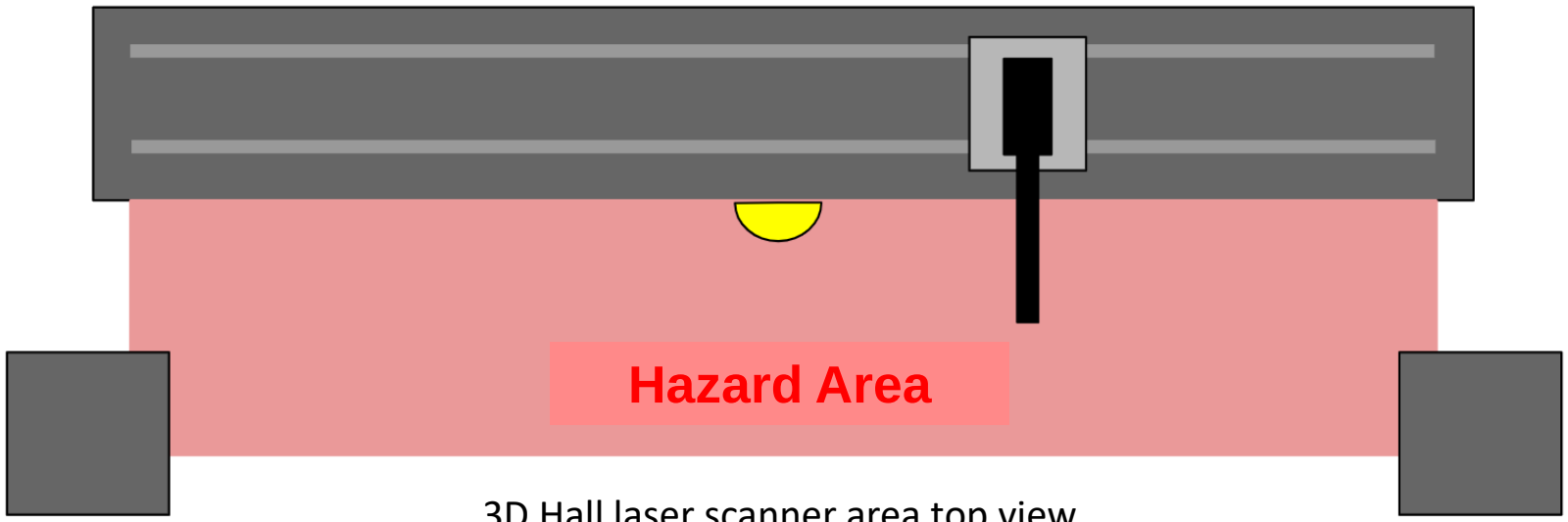
- Old design :

7A @ 44V – set to 5 cm/s => 15N to stop

- New design :

25A @ 96V – set to 40cm/s => 960N to stop

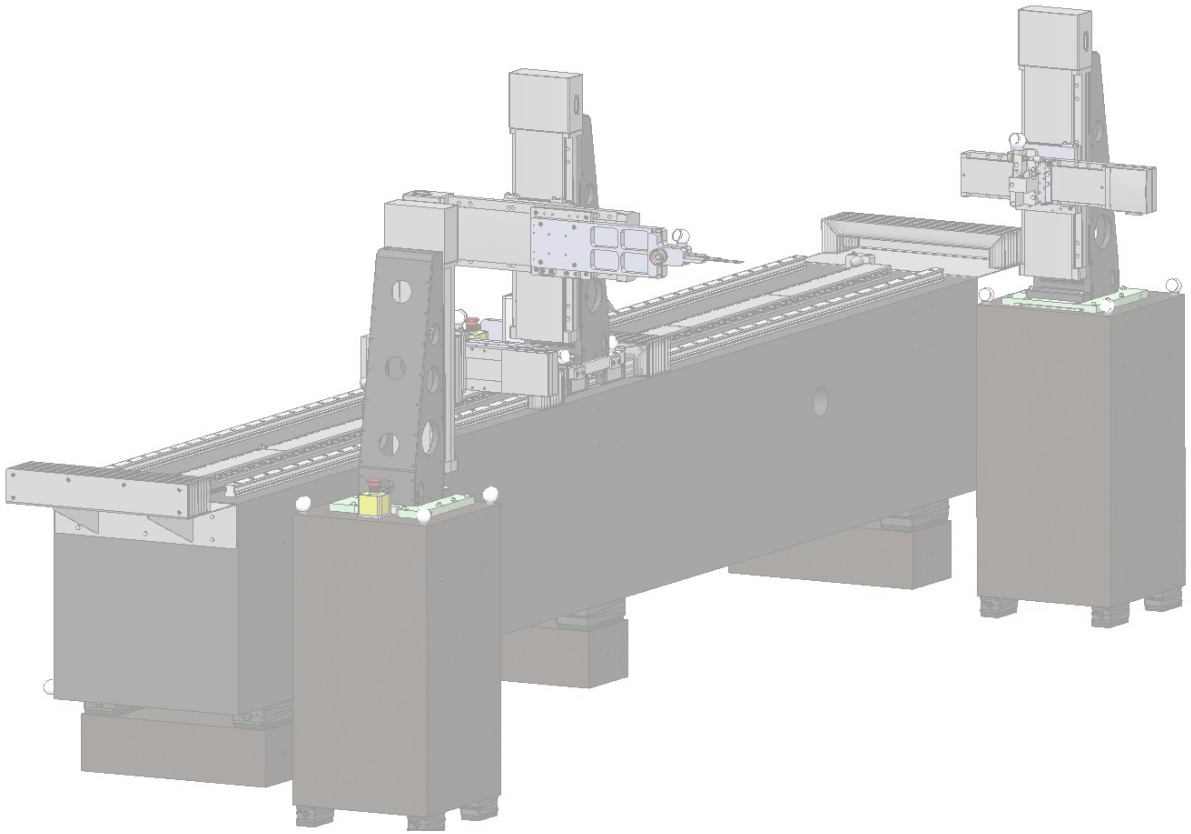
→ Keyence laser scanner tests



3D Hall laser scanner area top view

Keyence laser scanner

III. HALL PROBE BENCH – 3 AXIS HALL PROBES



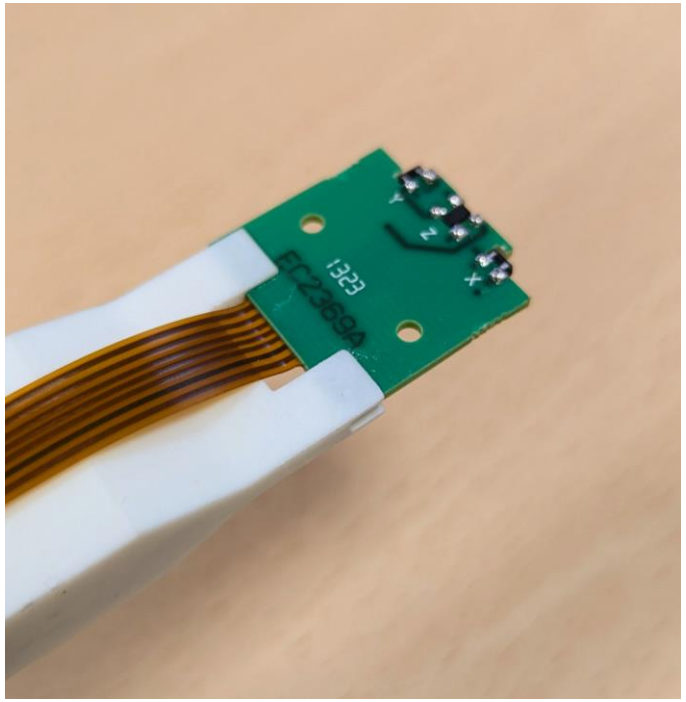
Needs for a new 3D Hall sensor

- Less than 3mm thick with PCB
- Measure fields from 10mT to 2T
- Good orthogonality
- Analog outputs for XPS triggering

→ In house design

→ Commercial sensor

III. HALL PROBE BENCH – 3 AXIS HALL PROBES



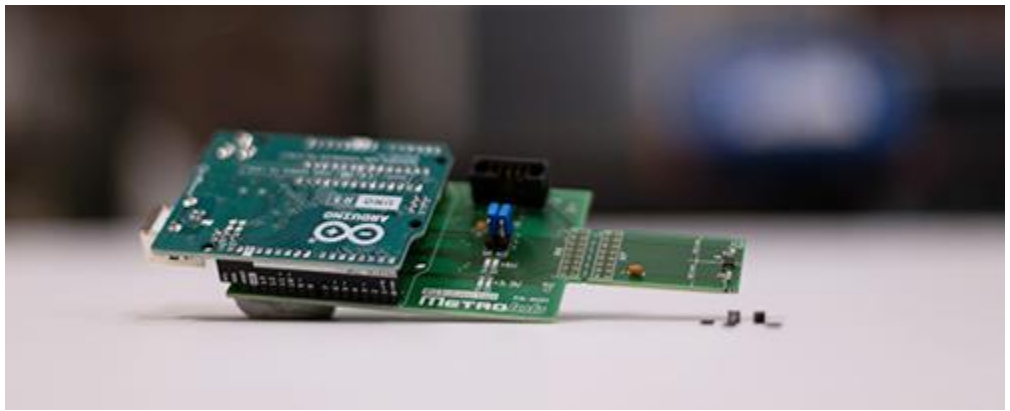
3 axis ESRF Hall probe refresh

In house design with 3 analog hall sensors :

- Refresh of a design from the 2000s
- Cheap and easy to integrate
- 2.5mm thick for measurements at gap 4.5mm
- Orthogonality to characterize with undulator
- Calibration with NMR in a dipole.
- Tests with NI 6356 and NI 6421 DAQ

III. HALL PROBE BENCH – 3 AXIS HALL PROBES

Senis SENM3Dx



Metrolab MV2

Commercial sensor :

- Either Senis SENM3Dx or Metrolab MV2
- Harder to integrate on custom PCB
- Orthogonality guaranteed by supplier
- Calibration with NMR probe in a dipole.

→ Tests with Arduino and NI 6421 DAQ (Metrolab)

→ Tests with Raspberry and NI 6421 DAQ (Senis)

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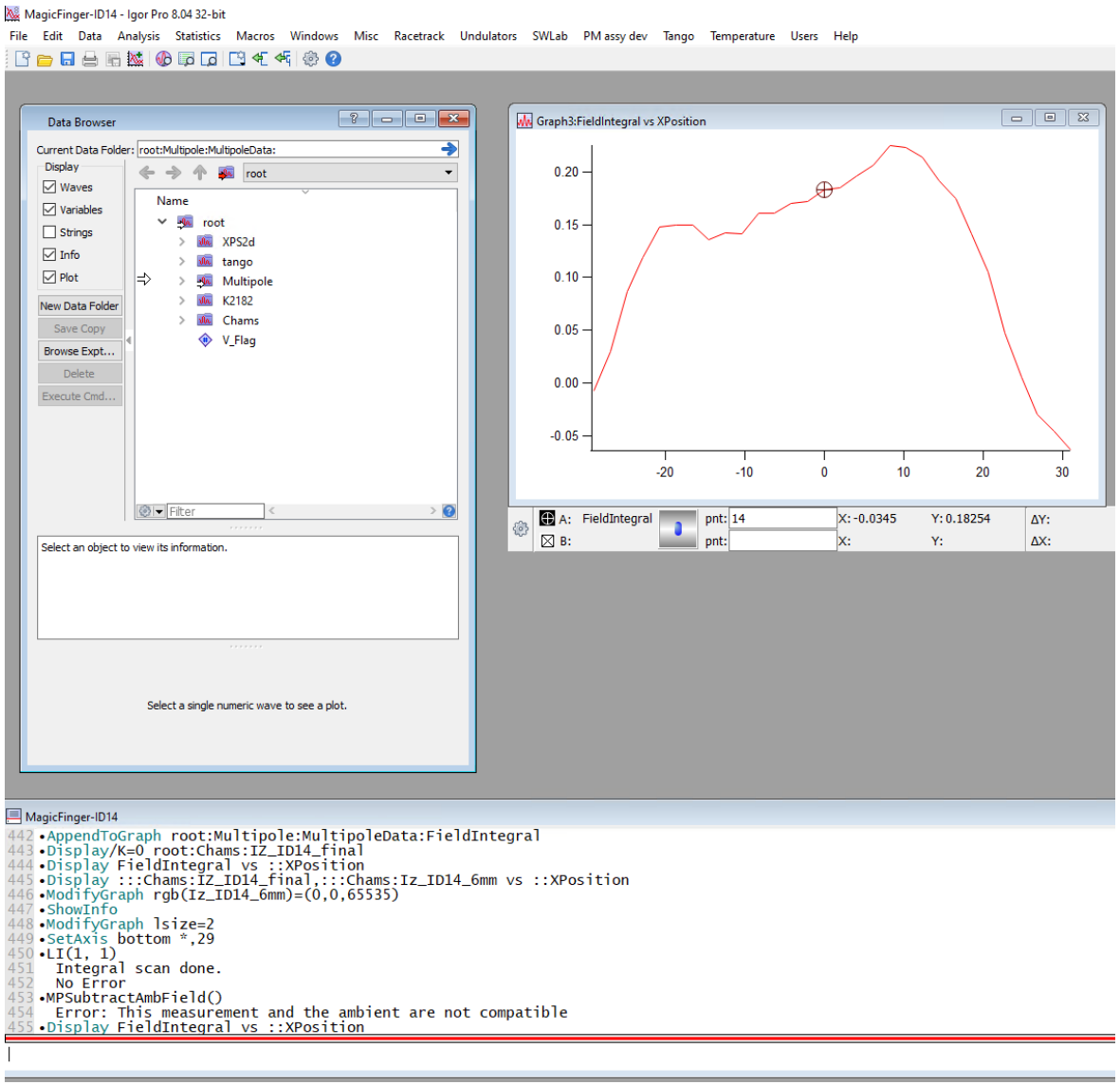
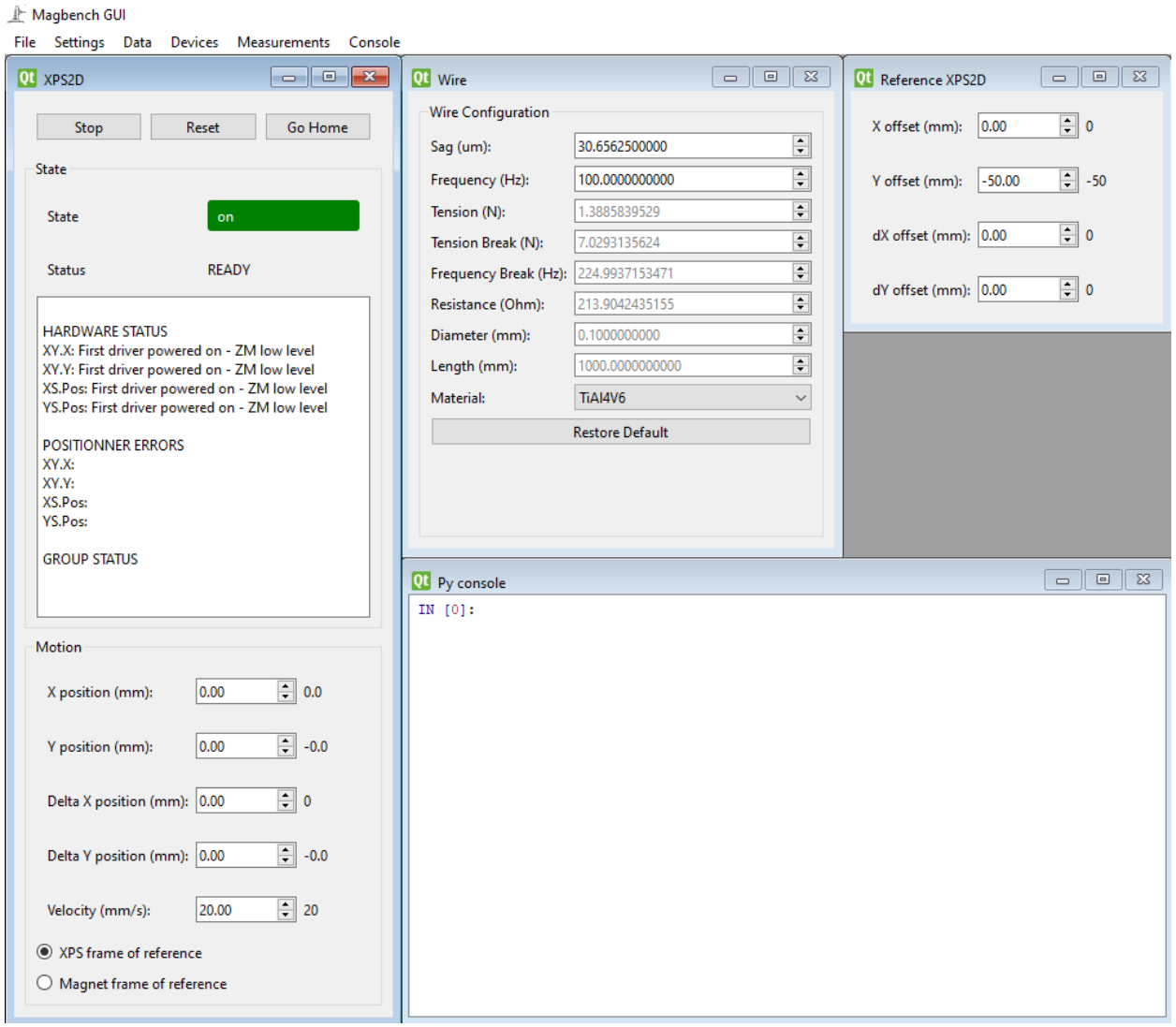


Current software

- Igor Pro interface
- C++/Igor XOP code to drive motors and Keithley
- Igor license and XOPtk license needed
- Non trivial to maintain and to further develop
- Steep learning curve

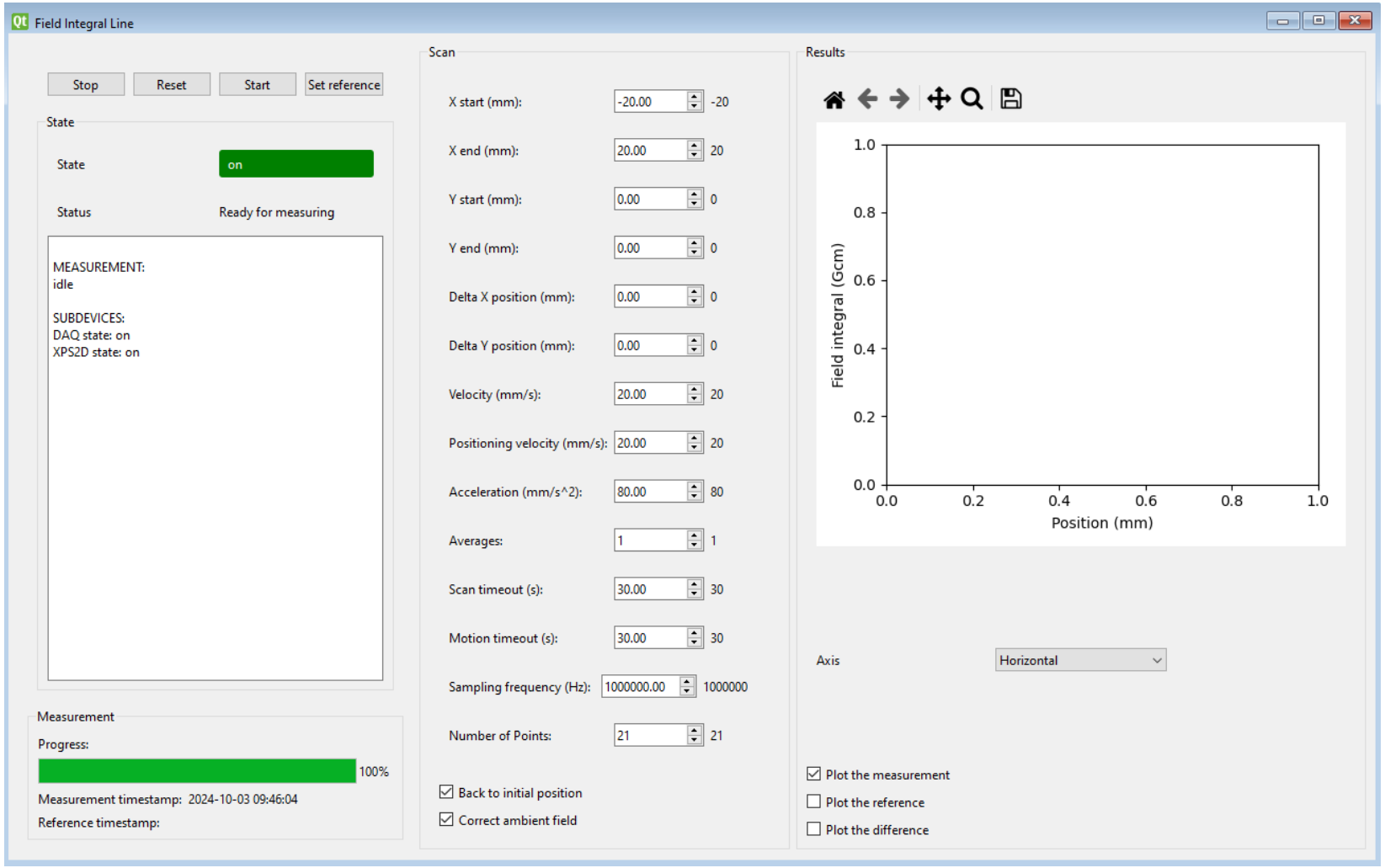
IV. BENCH SOFTWARE



Python software in development

- Simple python GUI
- Python code to drive motors and Keithley
- Freeware and open source
- Object oriented software
- Easier to build upon for power users
- External libraries dependence
- Being finalized for SW Benches
- Work in progress for Hall bench

IV. BENCH SOFTWARE DEVELOPMENT STATUS



Measurements ready

- Field integral line
- Field integral Circle
- Field integral point
- Magnet Sequencer
- Wire tension

To do

- Harmonic analysis
- Magnet center & angle
- Hall scan
- Touch probe measurements
- Various data processing tools to help with undulator tuning
- …

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CONCLUSION AND PROSPECTS

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- Stretched wire measurement bench has been updated and CE certified
- 3D Hall probe measurement bench update is in progress

3D hall sensor and safety laser scanner tests to be done before continuing the certification process

- Python based software is in progress and being finalized for SW applications

Prospects

- Future focus on magnet tomograph prototype (see IMMW21 presentation from G. Le Bec)
- Future upgrade on in vacuum measurement bench

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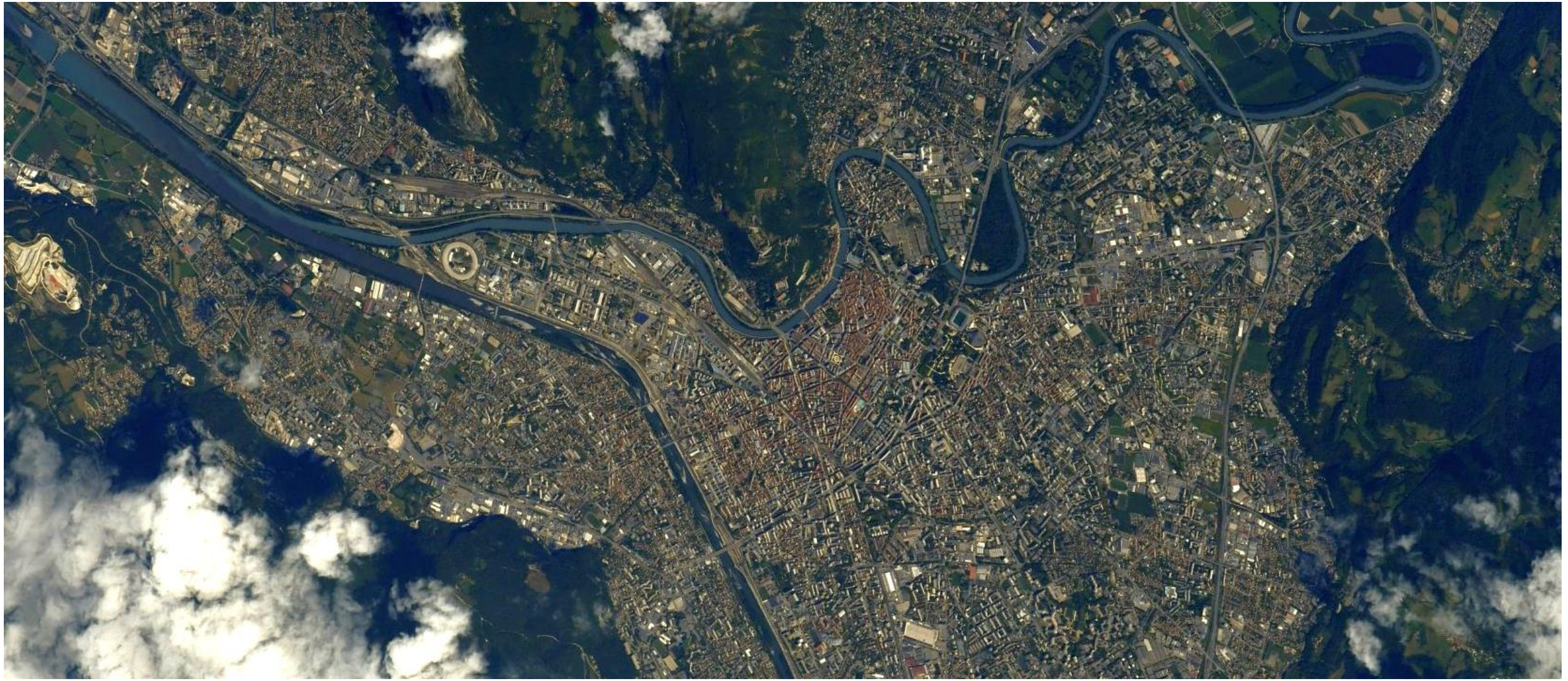

Grenoble and ESRF as seen from ISS – Thomas Pesquet 2021

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