Installation and use of magnetic measurement benches

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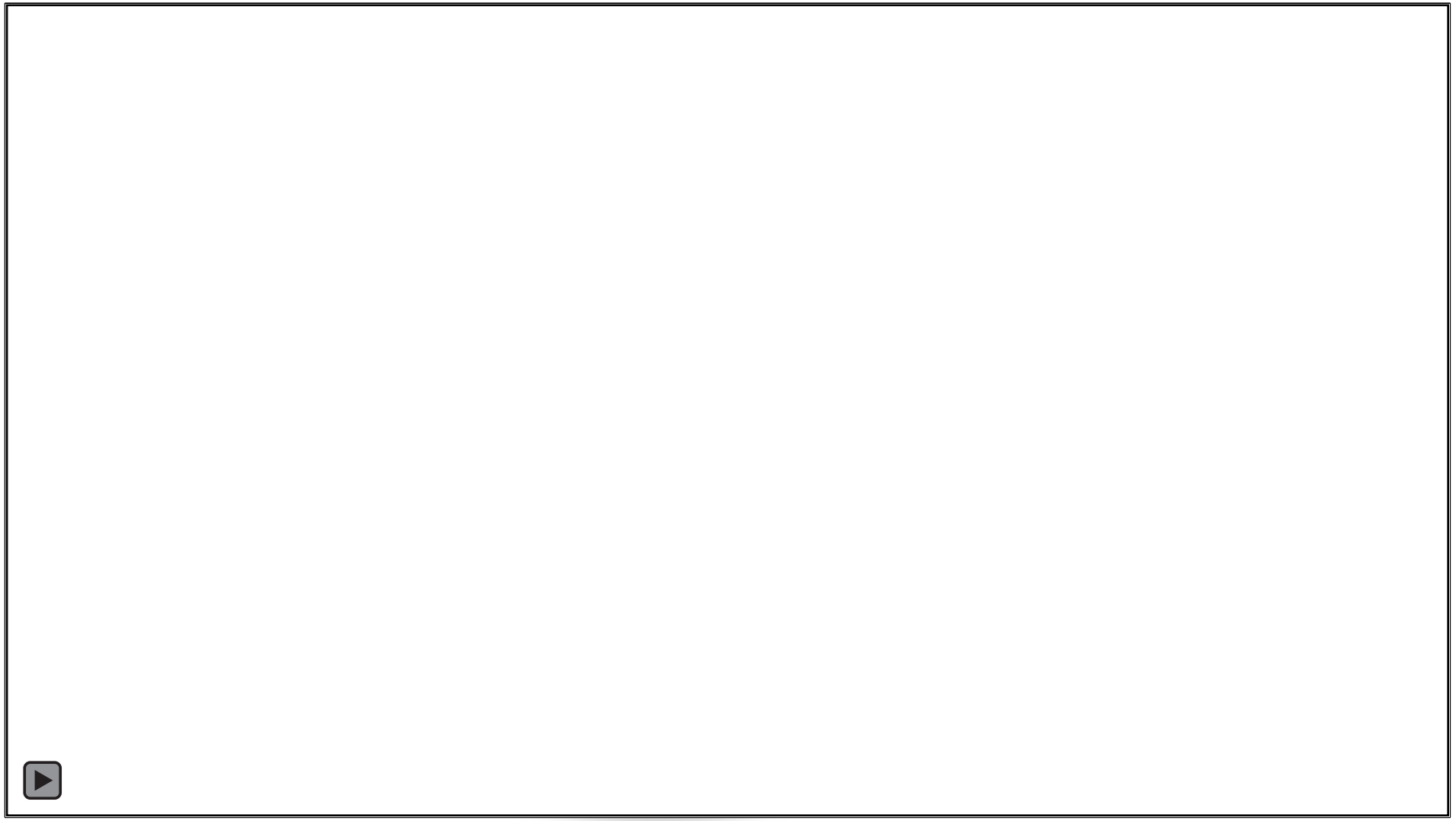
- ESRF/EBS
- Magnetic Measurement Benches
- Magnetic measurement and Alignment
- Feedback and conclusion

ESRF/EBS

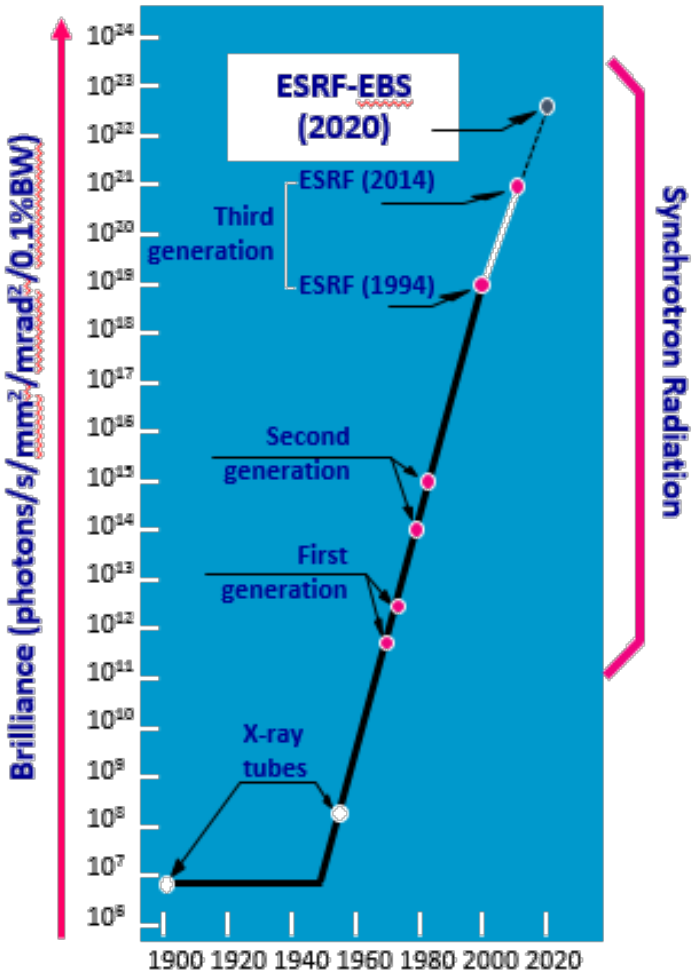
ESRF EBS: an ambitious new standard for synchrotron storage rings

ESRF/EBS



ESRF/EBS

ESRF EBS: an ambitious new standard for synchrotron storage rings

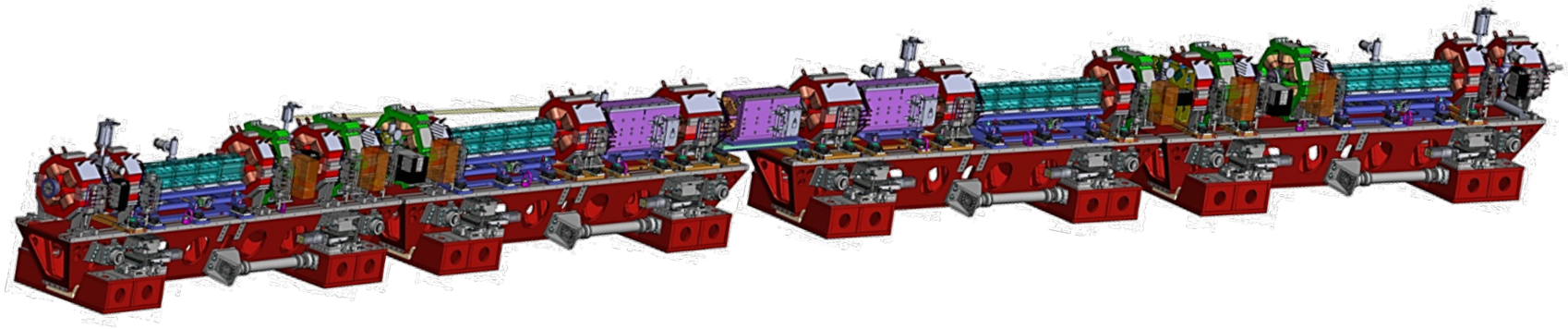


The ESRF designs a new generation of synchrotrons
A new design for the storage ring

- 31 magnets (19 currently) + correctors

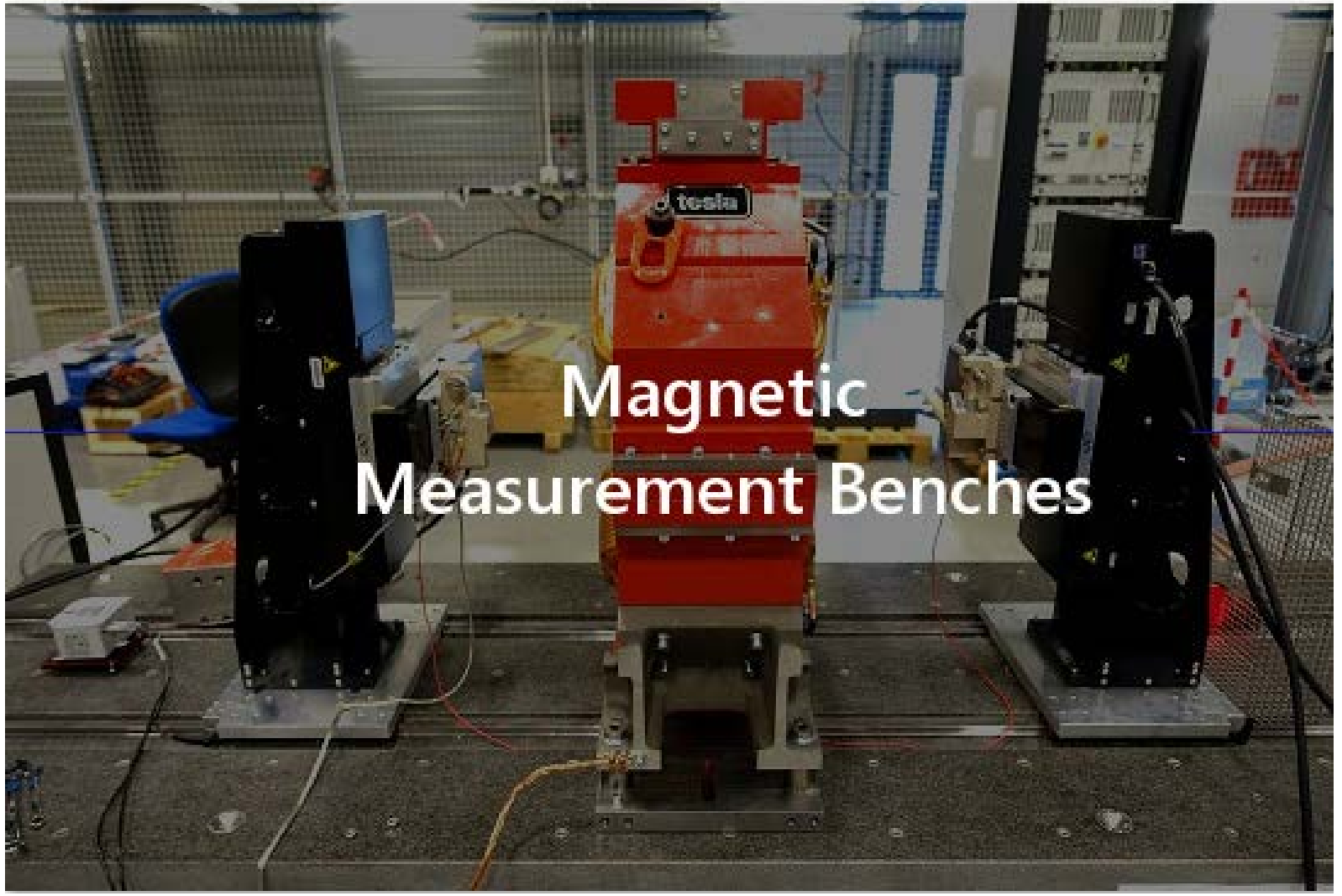
X32 cells

=> low emittance (less divergence and smaller beam in size)



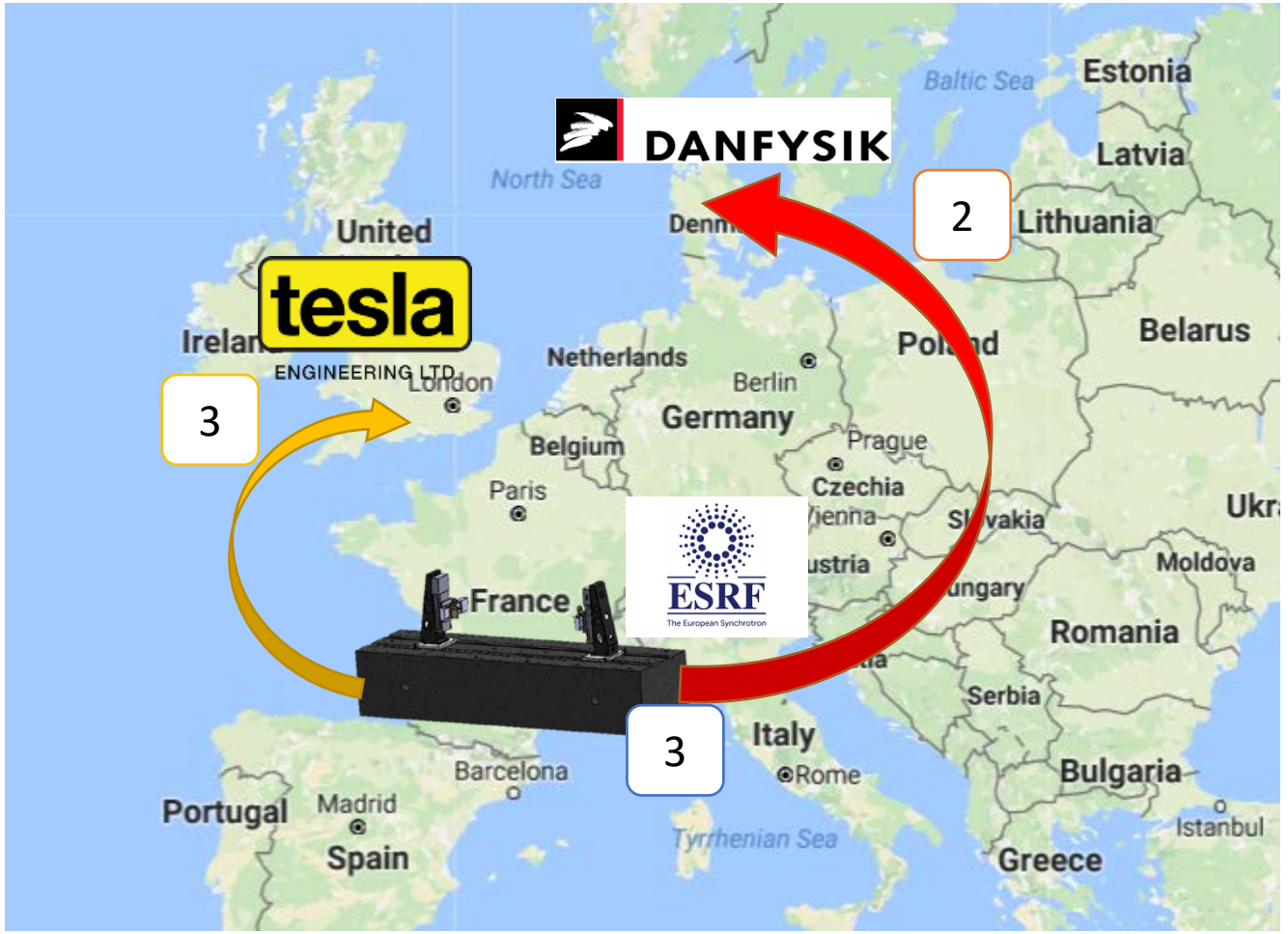
Magnetic Measurement Benches

A Light For Science



Benches installation

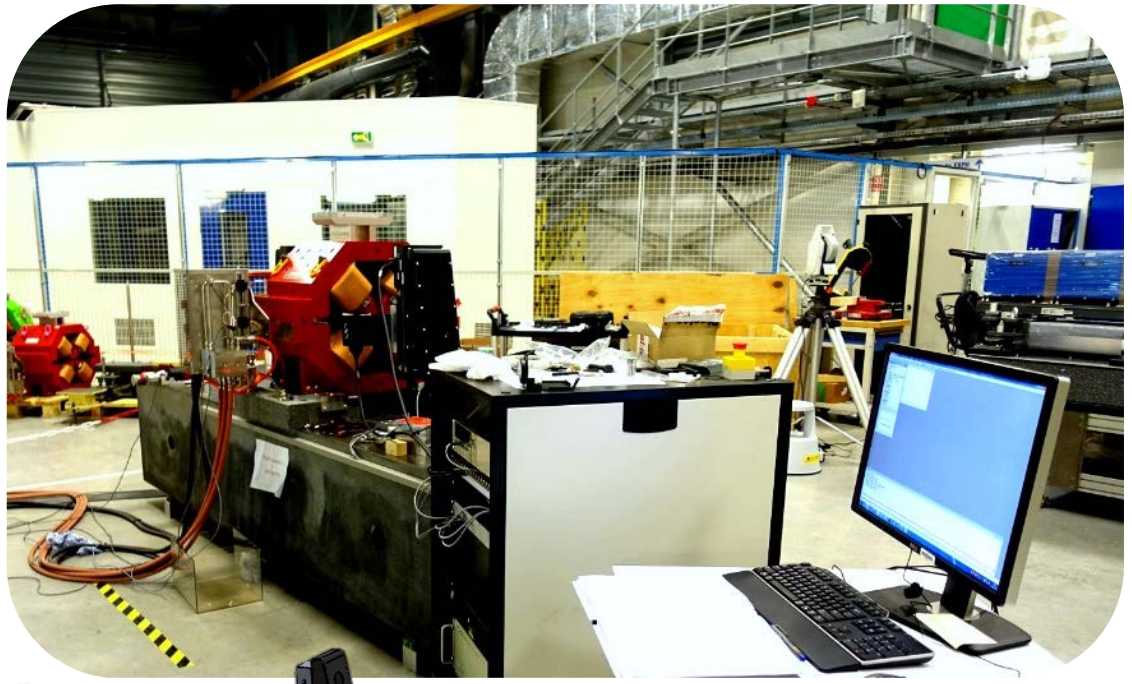
- **What for / where ?**
  - Danfysik
    - 2 Quadrupoles
    - 2 Sextupoles (+shim)
  - Tesla
    - 4 Quadrupoles (+shim)
    - 2 Dipole-Quadrupoles
  - ESRF
    - 5 Dipole modules
    - 2 Dipole Assemblies
    - Quality Control + Development

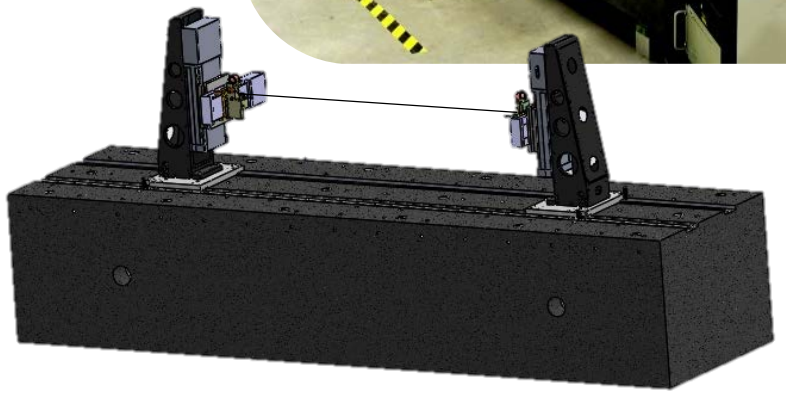


Magnetic Measurement Benches

- **Hardware and interface**
  - Granite benches + supports
  - Motion control
    - Horizontal and Vertical Newport Linear stages + XPS controller
  - Rackmount pc
    - (Win7) + acquisition board
  - Keitley 2182 nanovoltmeter
  - Titanium wire
  - IGOR software (Wavemetrics)

  + Power supply and Water





Magnetic Measurement Benches

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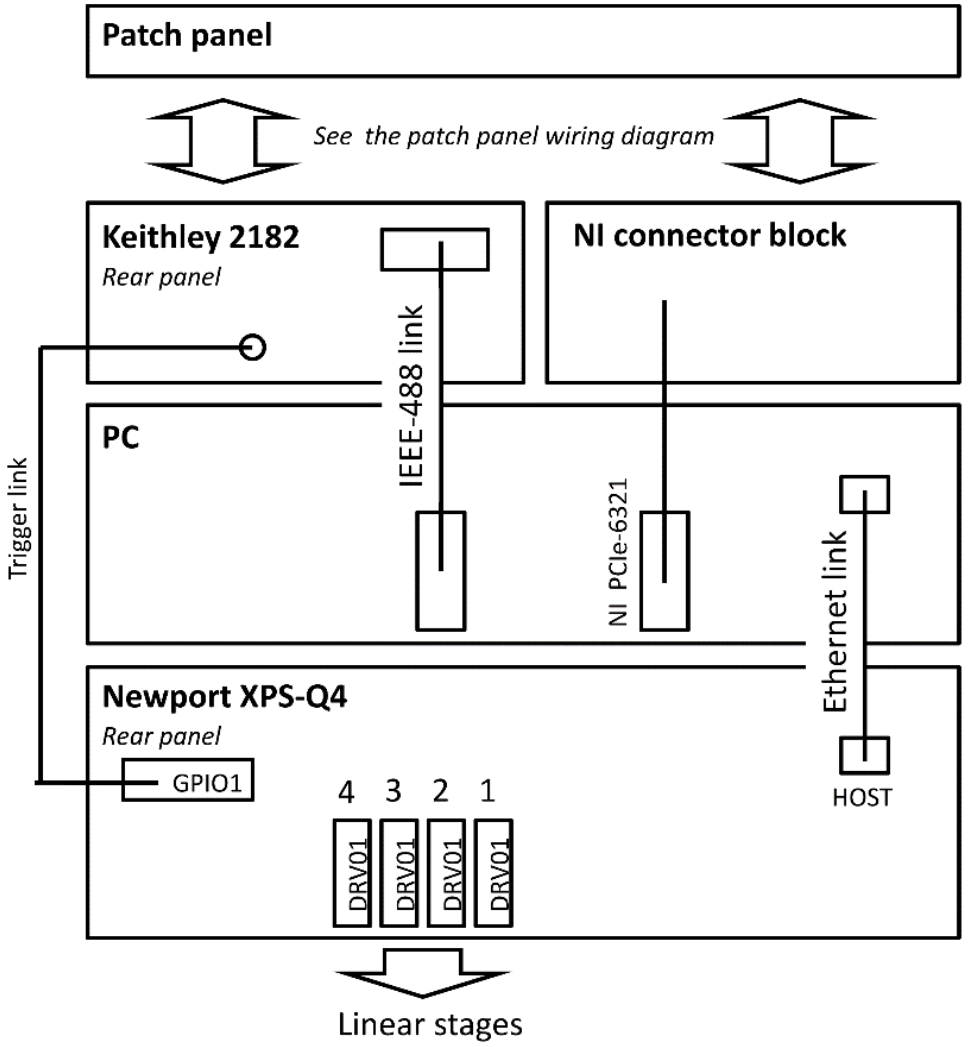
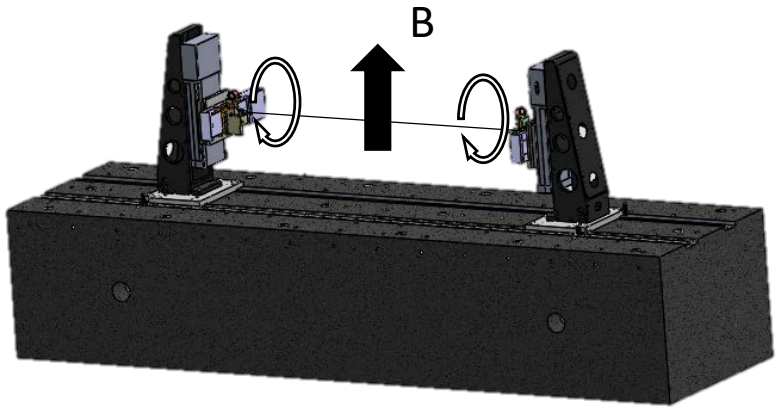
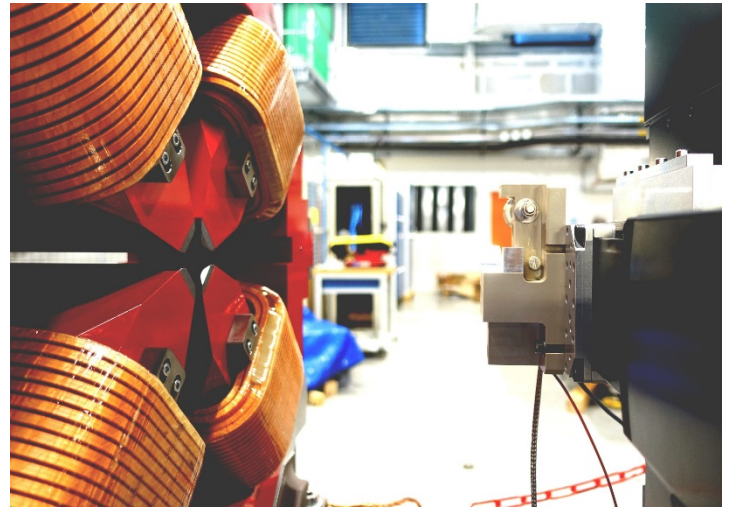


- **Measurement method – Stretched wire**



$$I = -\langle e \rangle \frac{T}{L}$$

- I: first field integral
- <e>: average of measured tension over time T
- L: Measurement length



Normal multipole coefficient

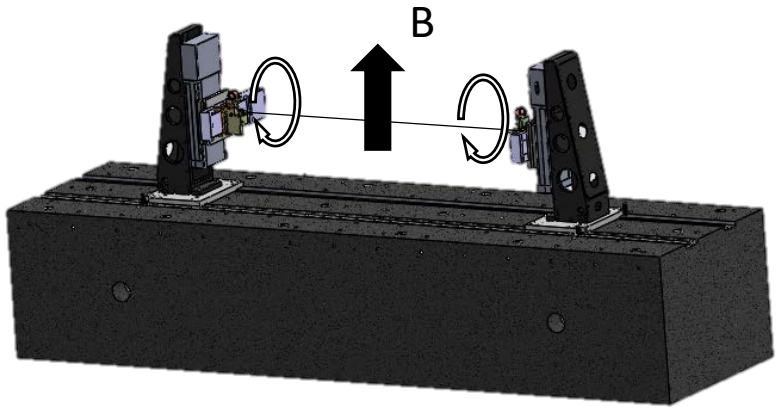
$$I_\rho = \sum_{n=1}^{\infty} (a_n cos(n\theta) + b_n sin(n\theta)) \left(\frac{\rho}{\rho_0}\right)^n$$

skew multipole coefficient

- **Gradient / strength**
- **Alignment**
- **Centre**
- **Roll Angle**

Magnetic Measurement Benches

• Measurement method – Stretched wire



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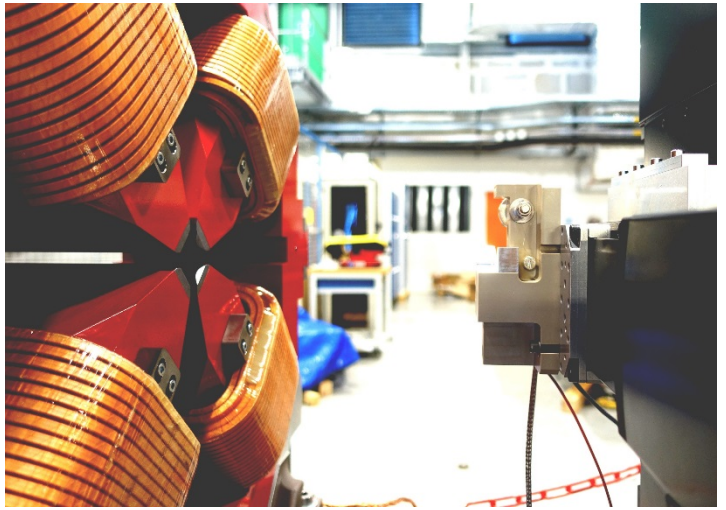

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skew multipole coefficient

	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

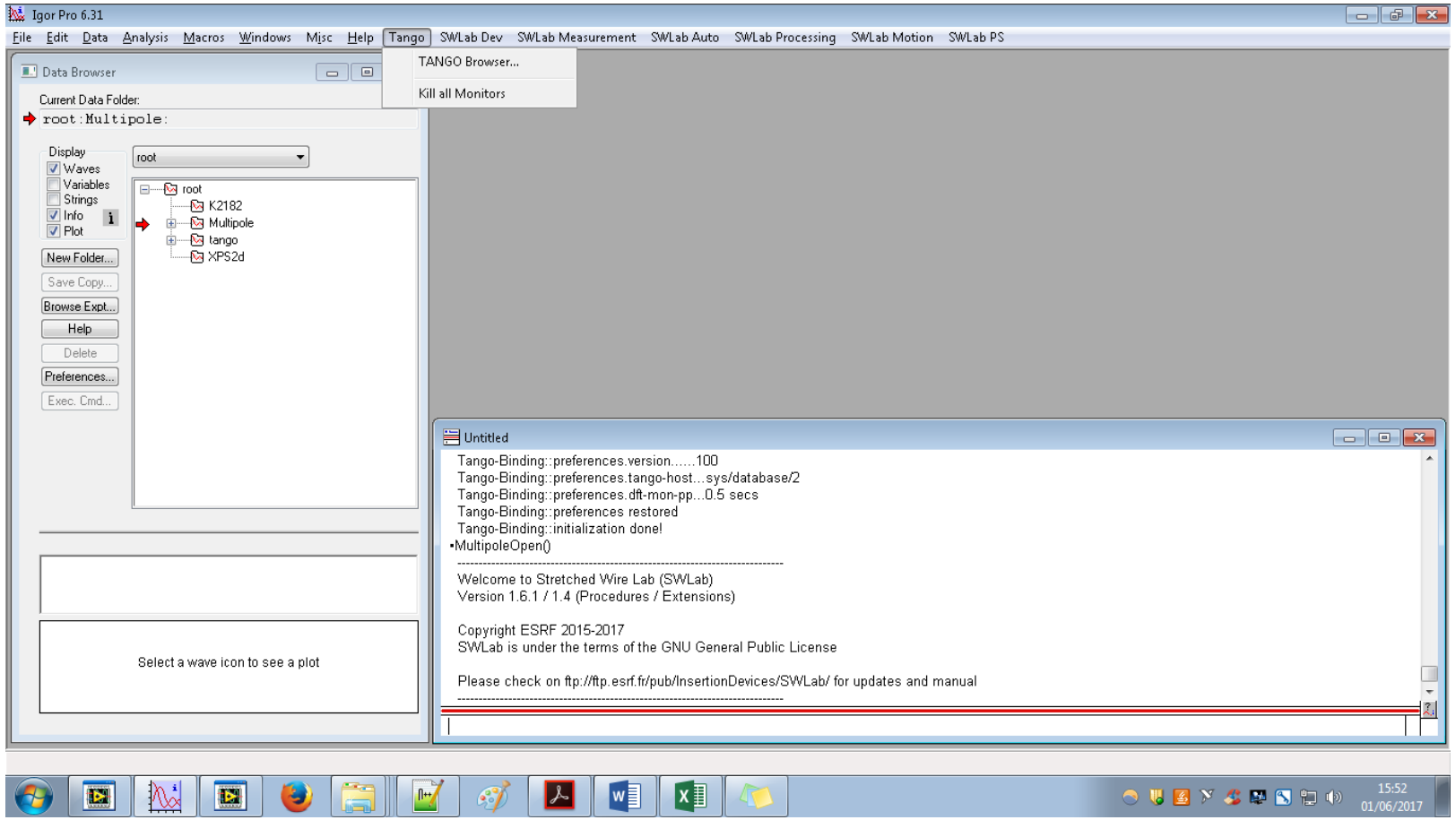
Magnetic Measurement Benches

- **Software (IGOR plugins)**
  - DLLs are developed in C++ thanks to extensions added to IGOR
  - It is also possible to write Procedures directly in IGOR language

→ New versions mainly contain new measurement/alignment sequences or bug corrections

Magnetic Measurement Benches

- **Software (IGOR plugins)**

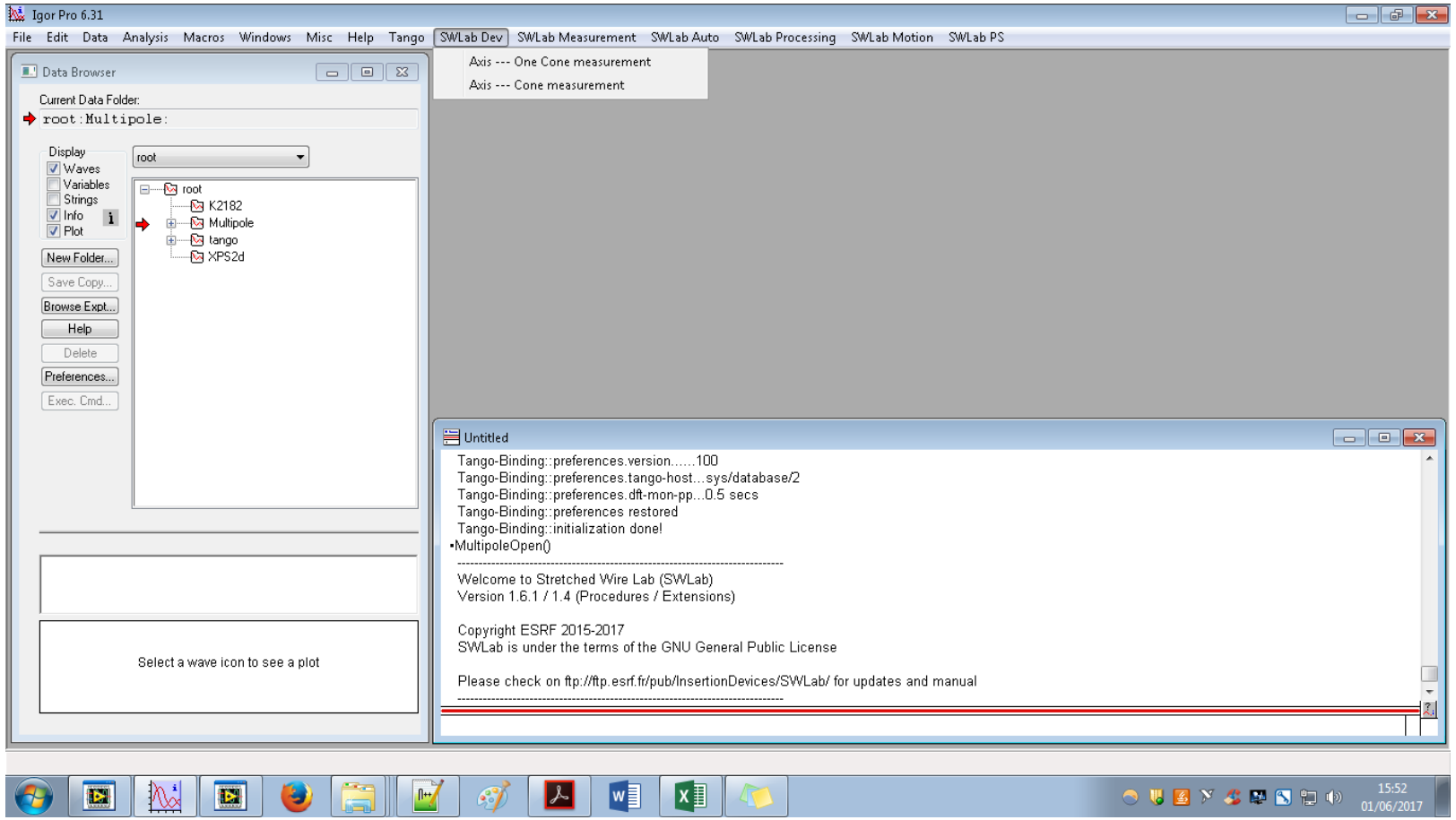


- **TANGO**

  → Tool from ESRF used to manage devices connected to a server (onsite version)

Magnetic Measurement Benches

- **Software (IGOR plugins)**

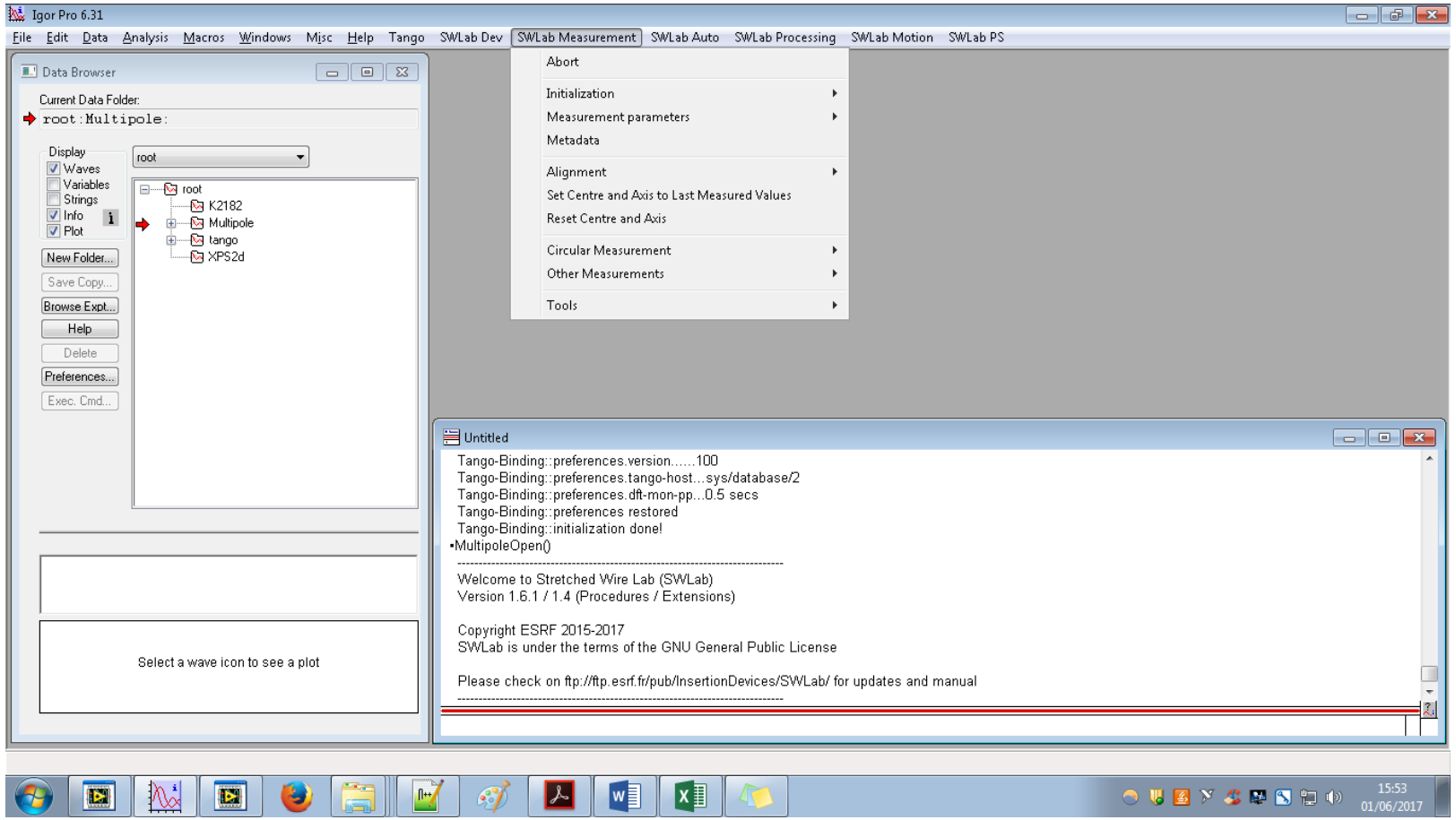


- **SWLab Dev**

  → For development of the software (onsite version)

Magnetic Measurement Benches

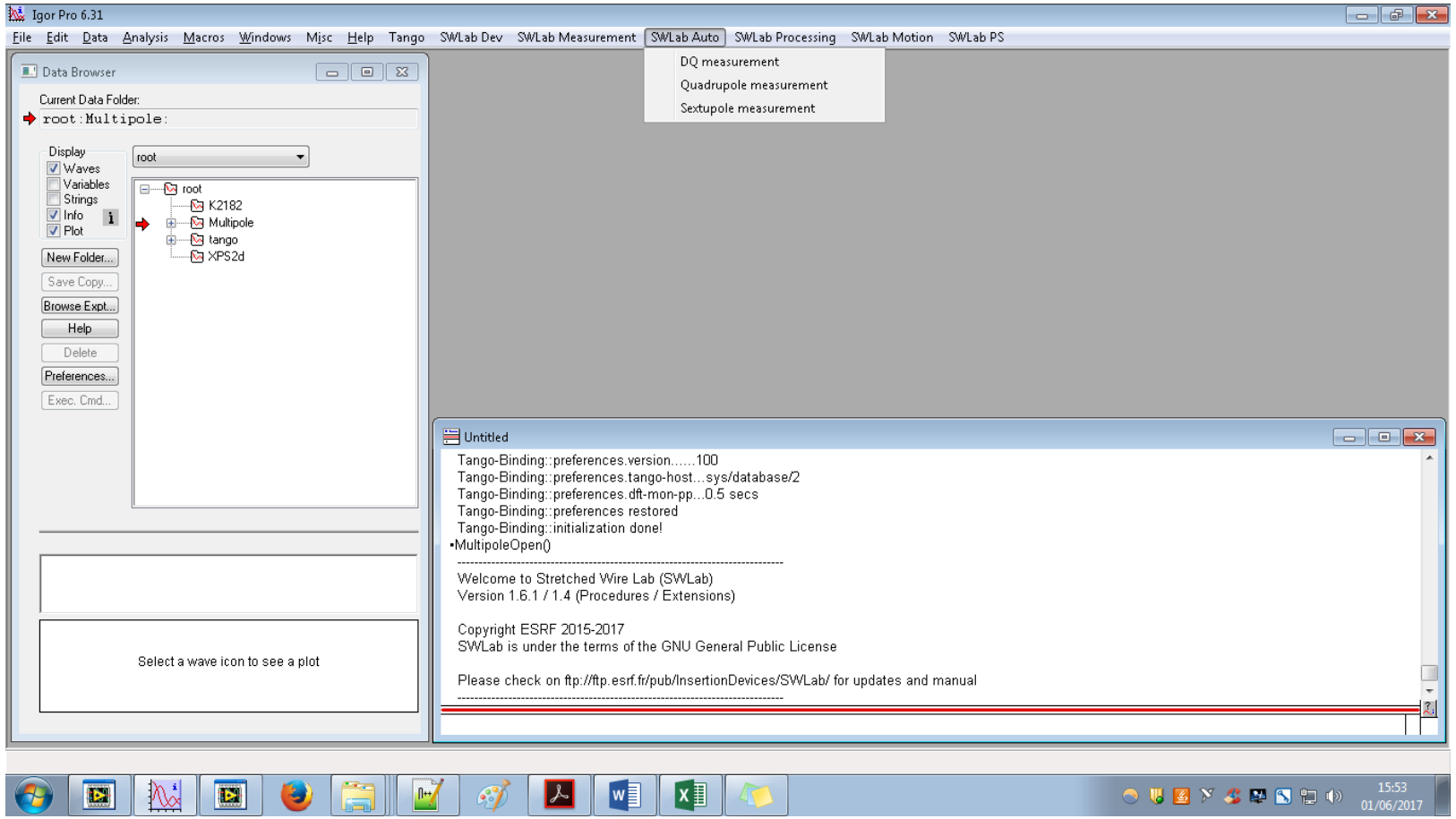
- **Software (IGOR plugins)**



- **SWLab Measurement**
  - →All tools useful to execute the measurements
    - →Load or save parameters
    - →Alignment
    - →Circular Measurements
    - →Is a measurement running?
  - →Used by ESRF Staff for debugging or development

Magnetic Measurement Benches

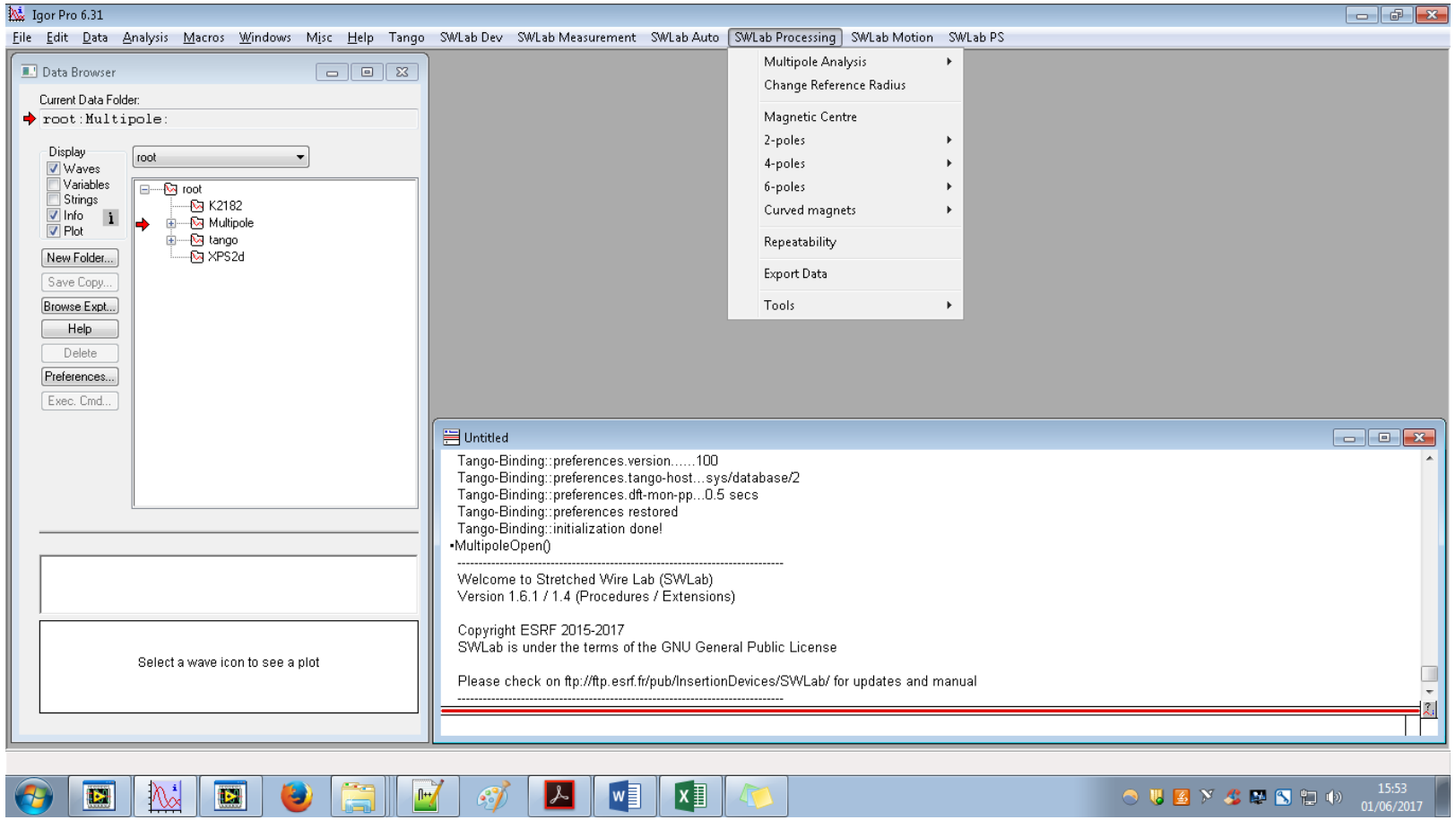
- **Software (IGOR plugins)**



- **SWLab Auto**
  - → Full automatic magnetic measurement sequence for the different cases (Dipole-Quadrupoles, Quadrupoles, Sextupoles)
  - → Used by magnet suppliers and quality control

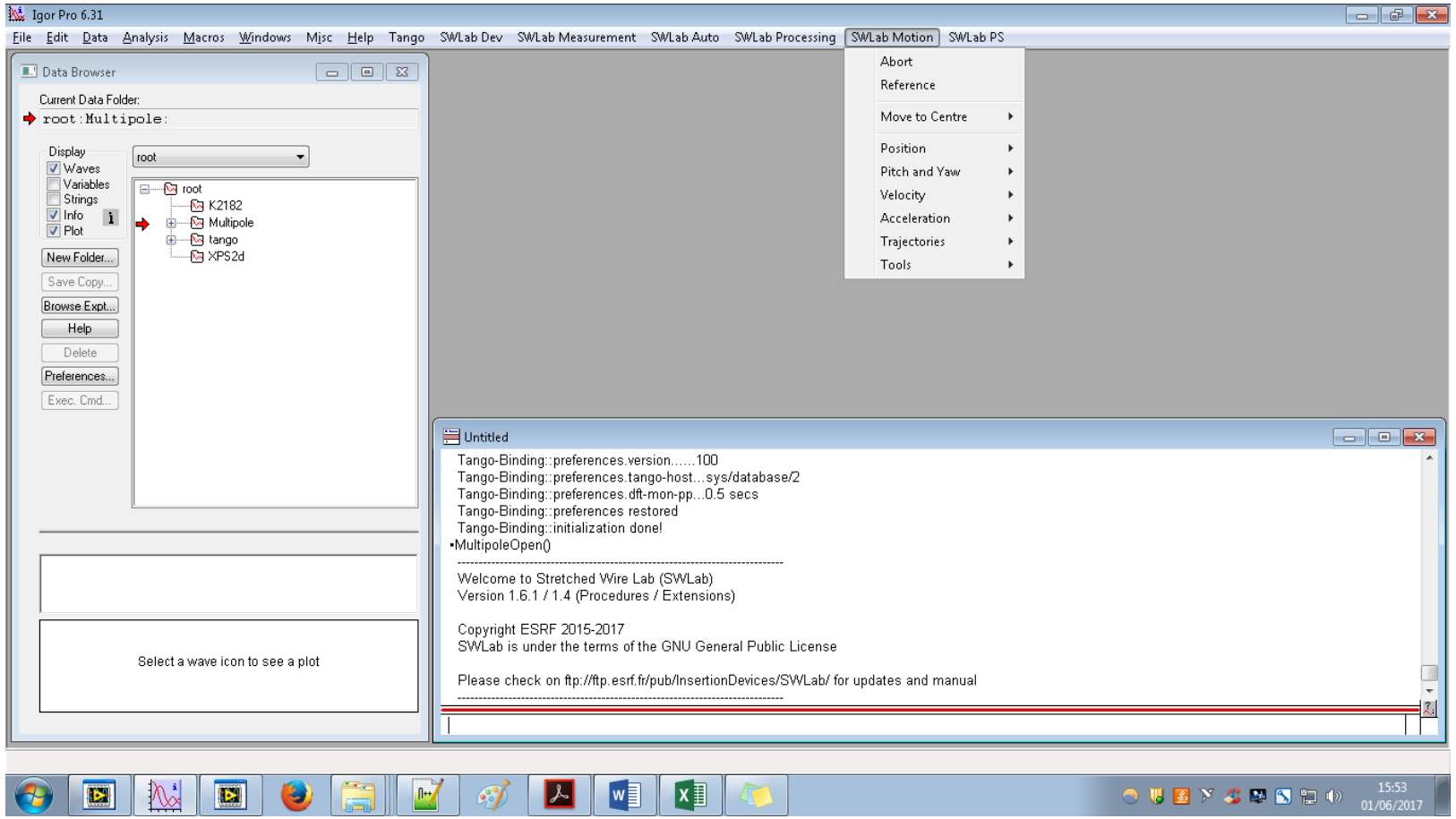
Magnetic Measurement Benches

- **Software (IGOR plugins)**



- **SWLab processing**
  - →Multipole Analysis
  - →Magnetic Centre, Roll Angle, Gradient, Strength computing
  - →Some other tools like data export, repeatability study, computation for curved magnets…

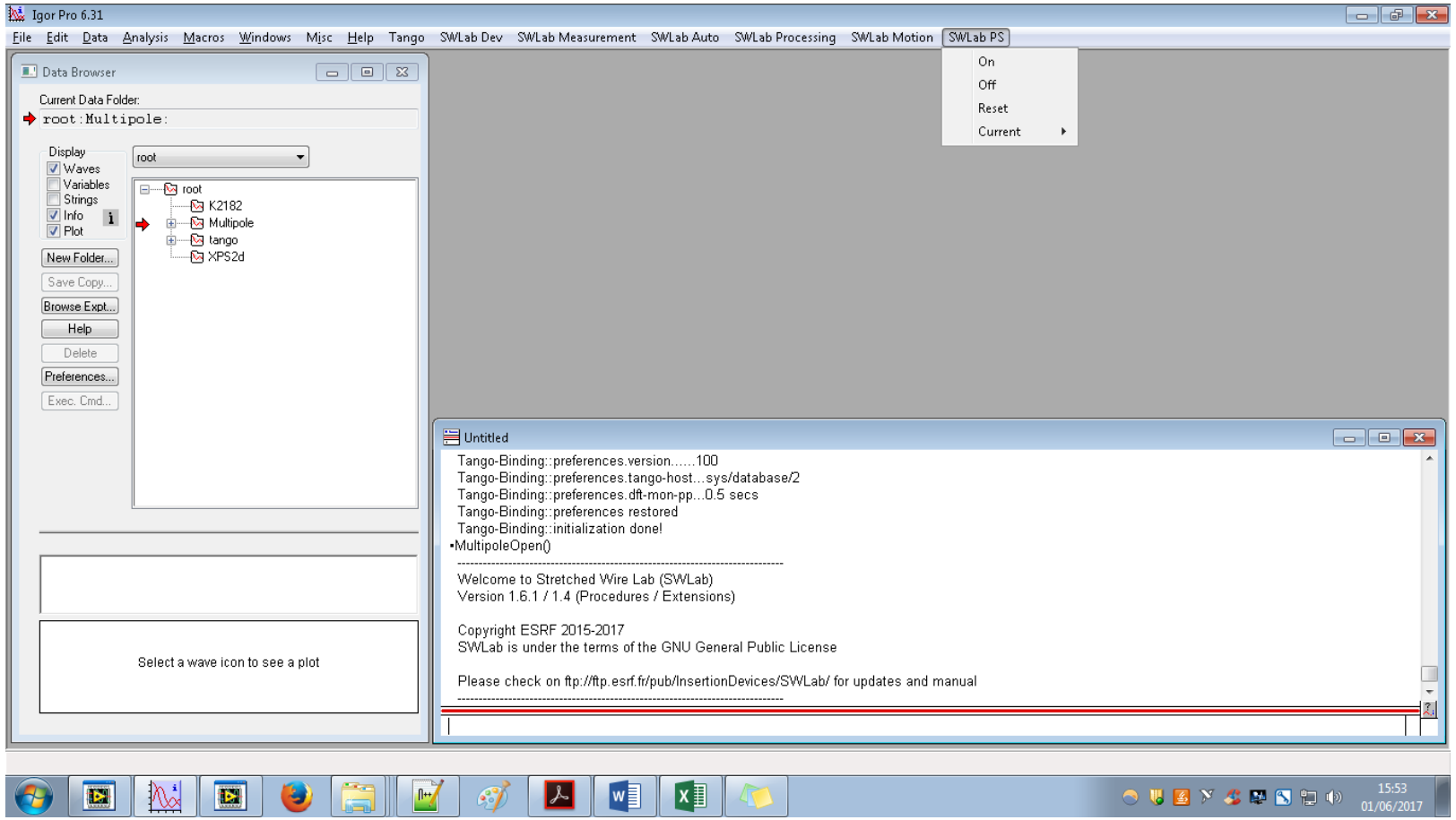
- **Software (IGOR plugins)**



- **SWLab Motion**
  - →Dedicated to move the stages thanks to the XPS motion controller
  - →Different tools to manage the motion (velocity, acceleration, trajectory, position…)

Magnetic Measurement Benches

- **Software (IGOR plugins)**

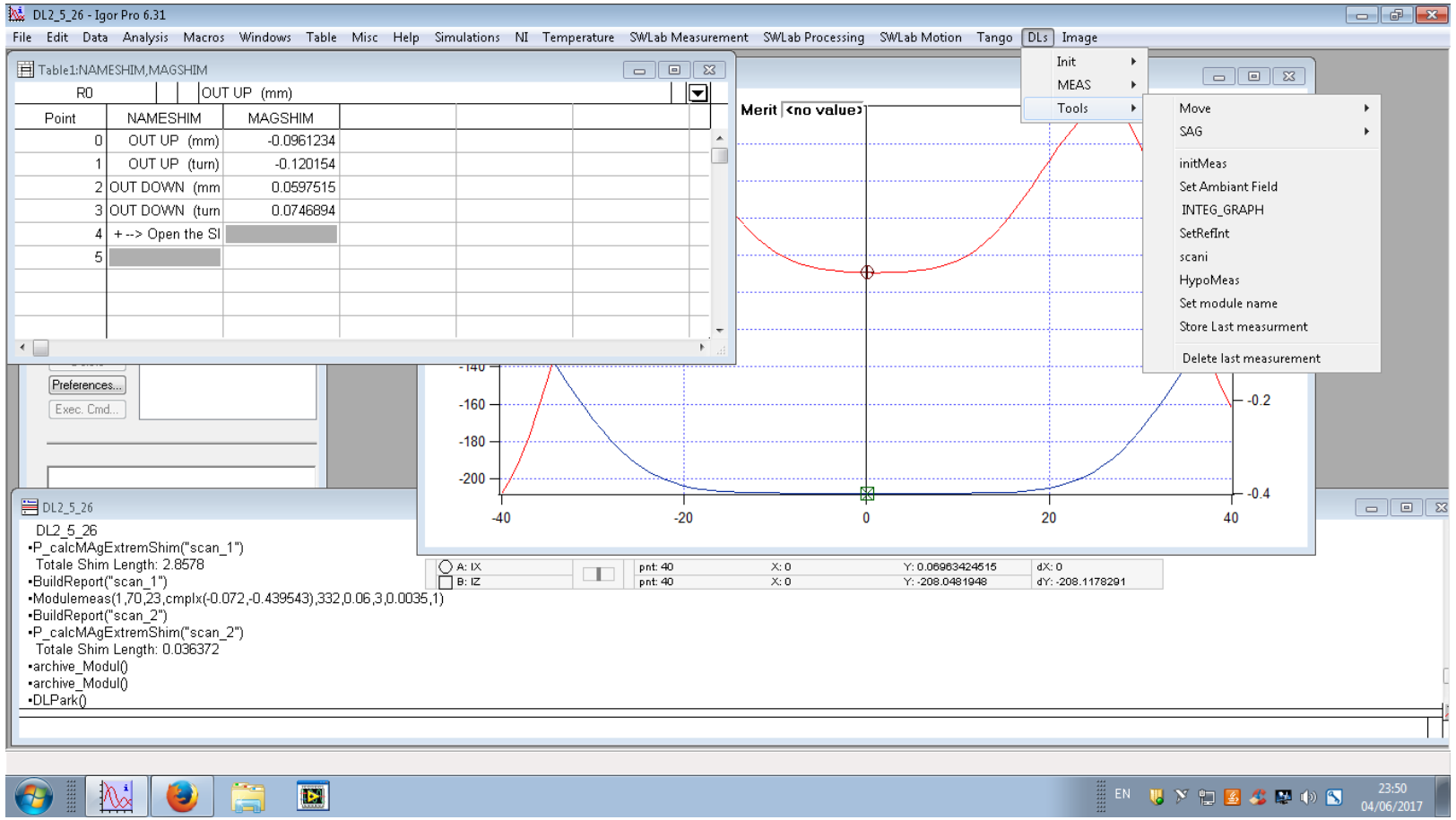


- **SWLabPS**

  → To manage Power Supply (onsite version)

Magnetic Measurement Benches

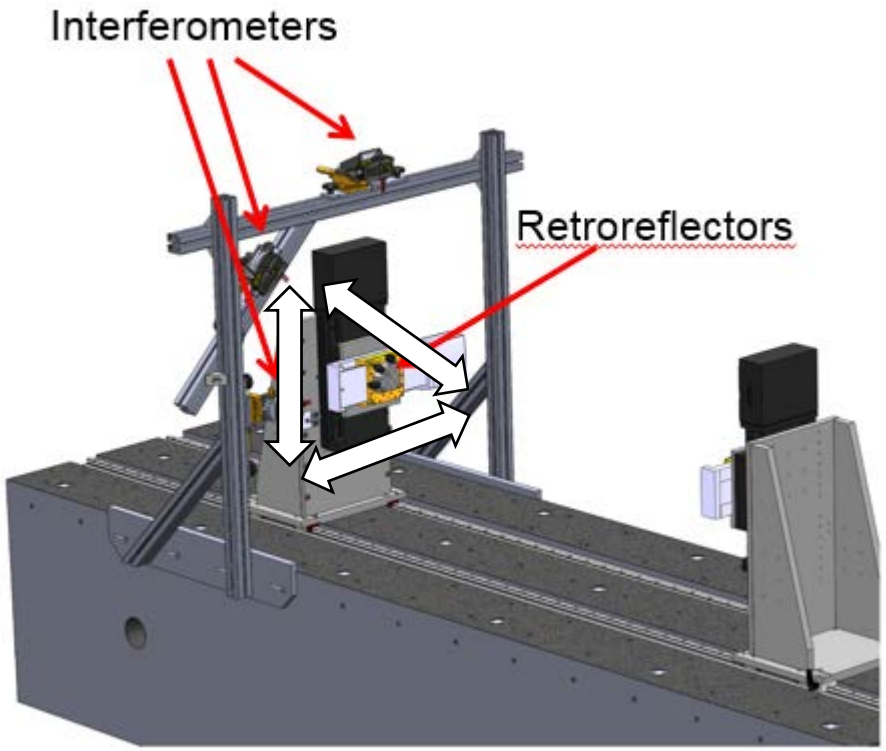
- **Software (IGOR plugins)**



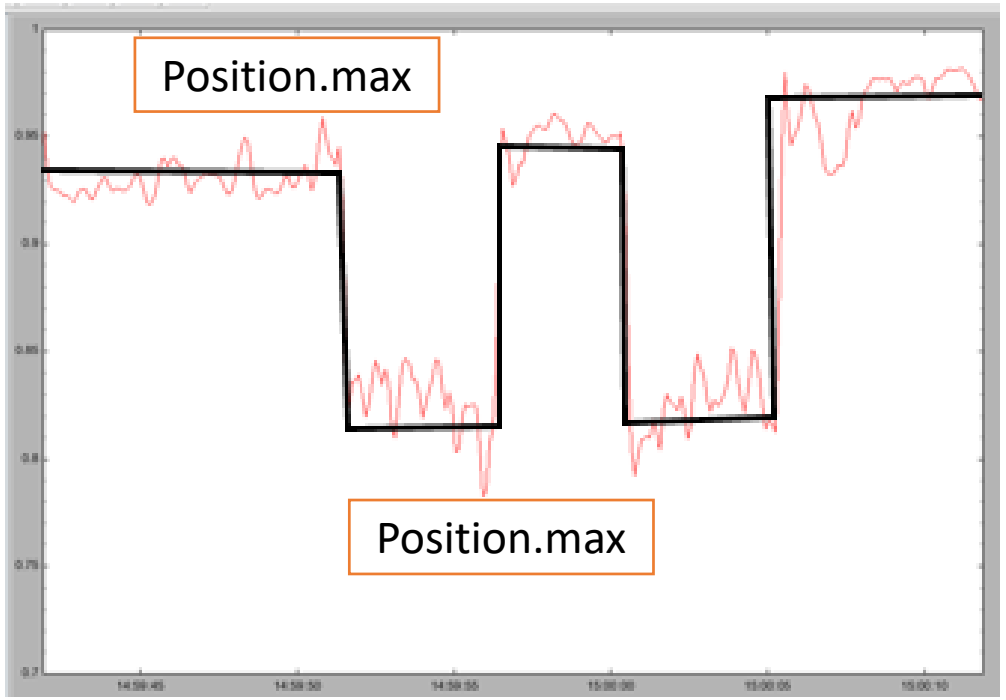
- **DLs**
  - → Proceed magnet measurement for modules and complete dipole assemblies
  - → Ambiant, module measurement, shim computing…

Magnetic Measurement Benches

- **Stages Calibration**
  - Renishaw ML-10 laser interferometer



Signal amplitude (laser interferometer X – Z or X/Z)



Time

- **Alignment of interferometers**
  - Move the stages from position max to –max
  - Try to get slot signal for each interferometer

• Stages Calibration

- Renishaw ML-10 laser interferometer

- **Stage calibration**
  - Measure distances (d_{XY}, d_X, d_Y) and compute angle between stages
  - Install shims if necessary and re-align interferometers
  - Fill correction tables in XPS calibration

$$\theta_{stages} = cos^{-1}\left(\frac{(d_{XY}^2 - d_X^2 - d_Y^2)}{2d_X d_Y}\right)$$

```
29  [ZS.Pos]
30  PlugNumber = 2
31  StageName = 08SIF4518
32  ;--- Time flasher
33  TimeFlasherBaseFrequency = 40e6
34  ;--- CIE08CompensatedPCO mode
35  CIE08CompensatedPCOMode = Disabled  ; Enabled or Disabled
36  ;CIE08CompensatedPCOMaximumDataNumber = 1000000 ; Value <= 1000000
37  ;--- Secondary positioner
38  SecondaryPositionerGantry = Disabled
```

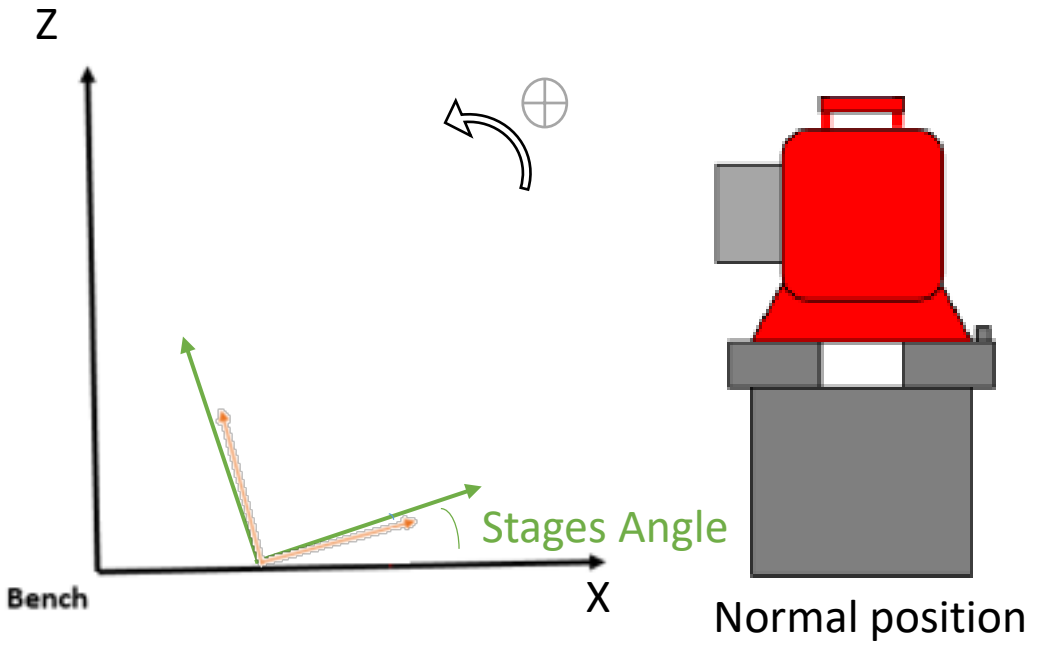
PositionerMappingFileName = IMS-4518.txt

IMS-4518.txt

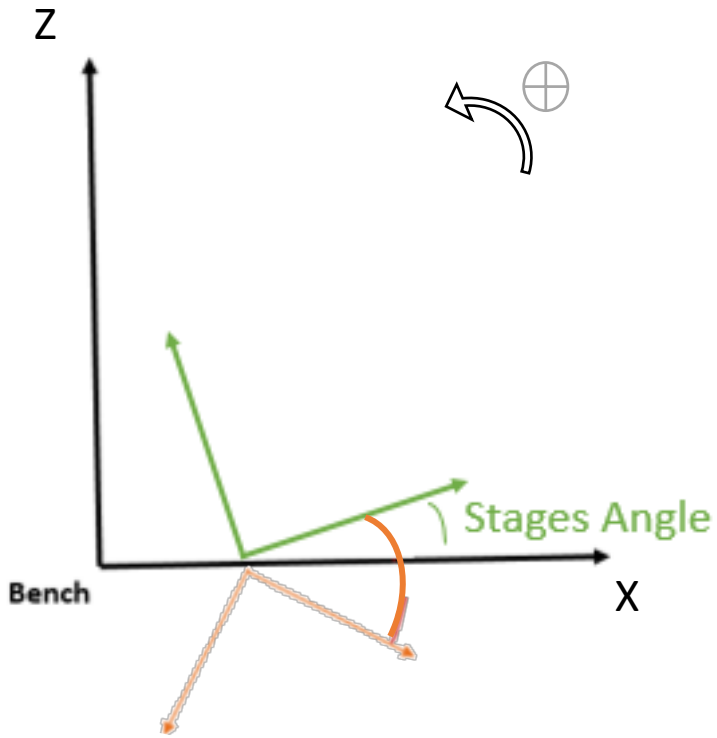
```
1   -59.1    0
2   -59 0.0014
3   -54 0.0023
4   -49 0.0032
5   -44 0.0033
6   -39 0.0034
7   -34 0.0031
8   -29 0.003
9   -24 0.0027
```

Magnetic Measurement Benches

- **Calibration**
  - Stages to Bench angle



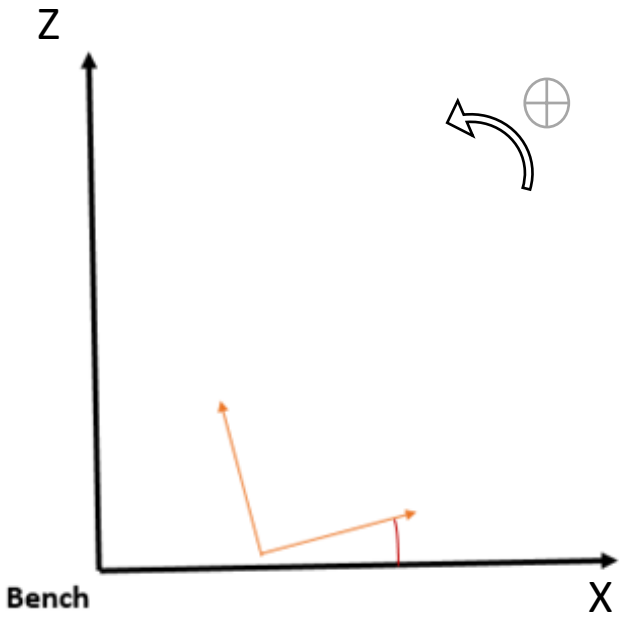
Normal position

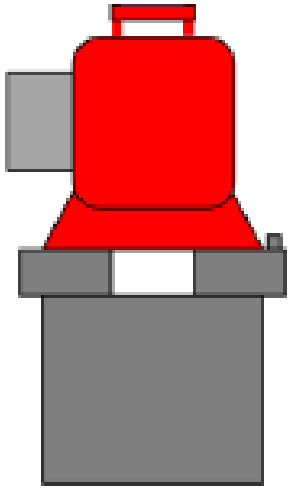


Rotated position

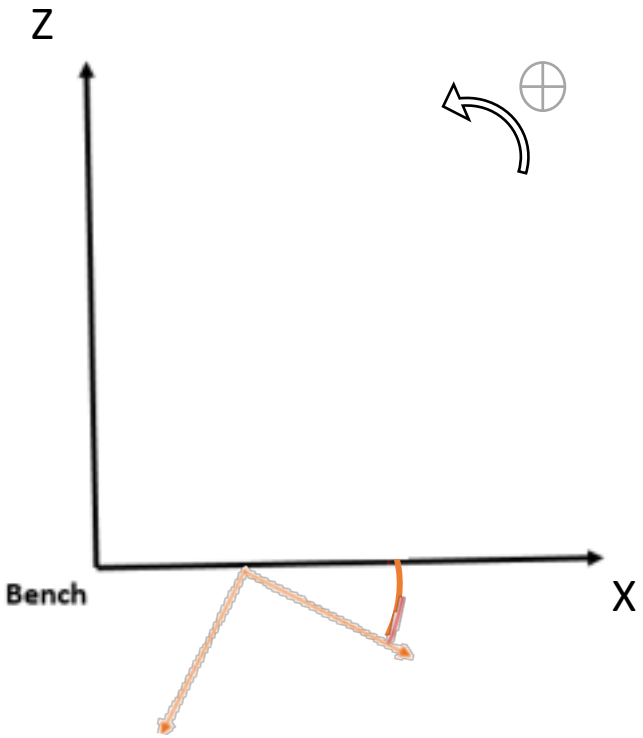
⇨ Average of the two measurements gives us the stages angle to the bench

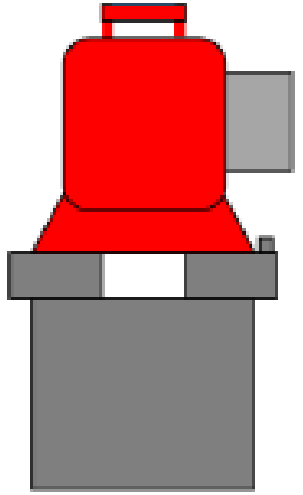
- **Calibration**
  - Stages to Bench angle





Normal position

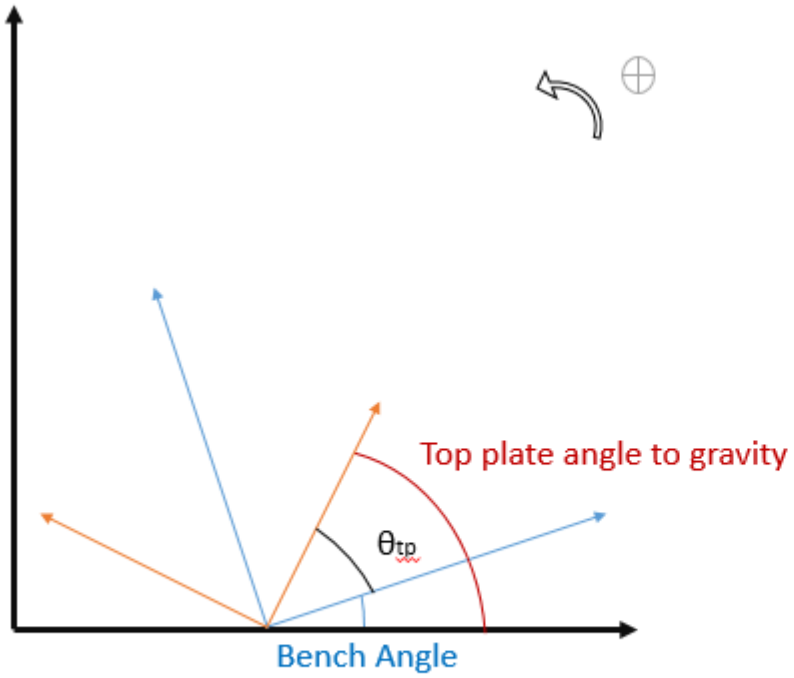


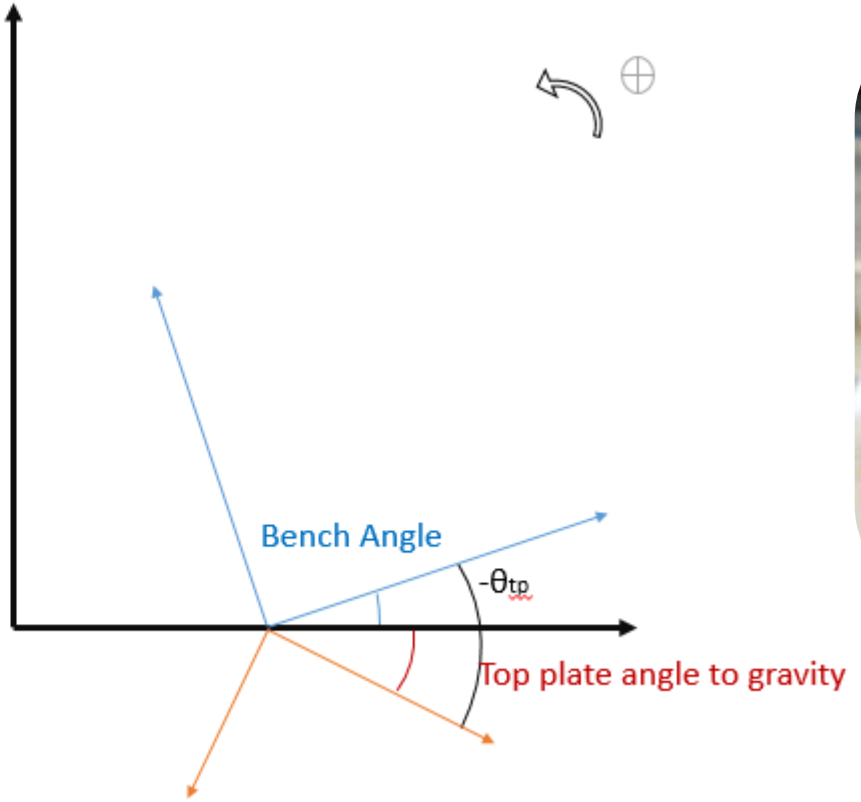


Rotated position

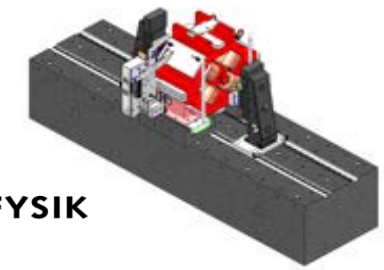
Average must be null if we want to get rid of stage angle

- **Calibration**
  - **Bench to Gravity angle**
    - With the same kind of tip, we can get the bench angle to the gravity thanks to an inclinometer

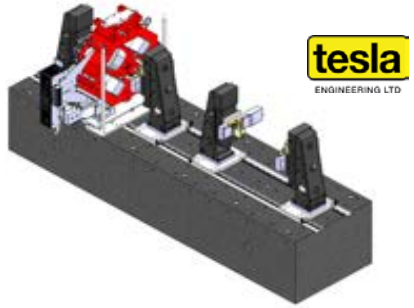




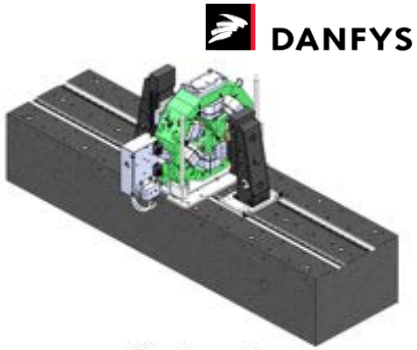
- **Calibration**
  - **Bench Axis and centre (Faro ARM or Laser tracker)**
    - →must define an axis and a centre from the specifications for each magnet/bench
    - →used to pre-align the magnets for measurement



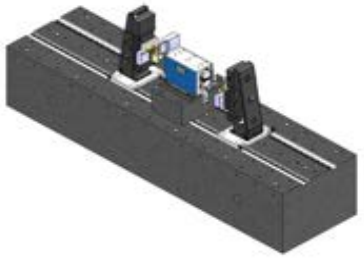
High gradient quads



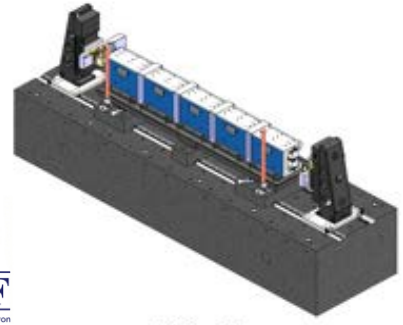
High gradient quads, 2 stands



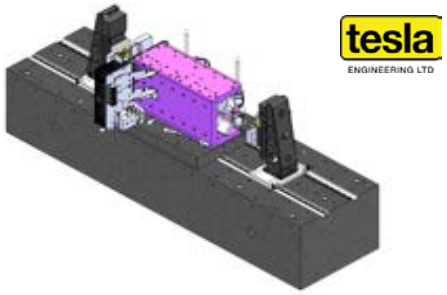
Sextupoles



Dipole modules



Dipoles



Dipole-quadrupoles

Magnetic Measurement

A Light For Science

Magnetic Measurement

- **Automatic measurements**

Between

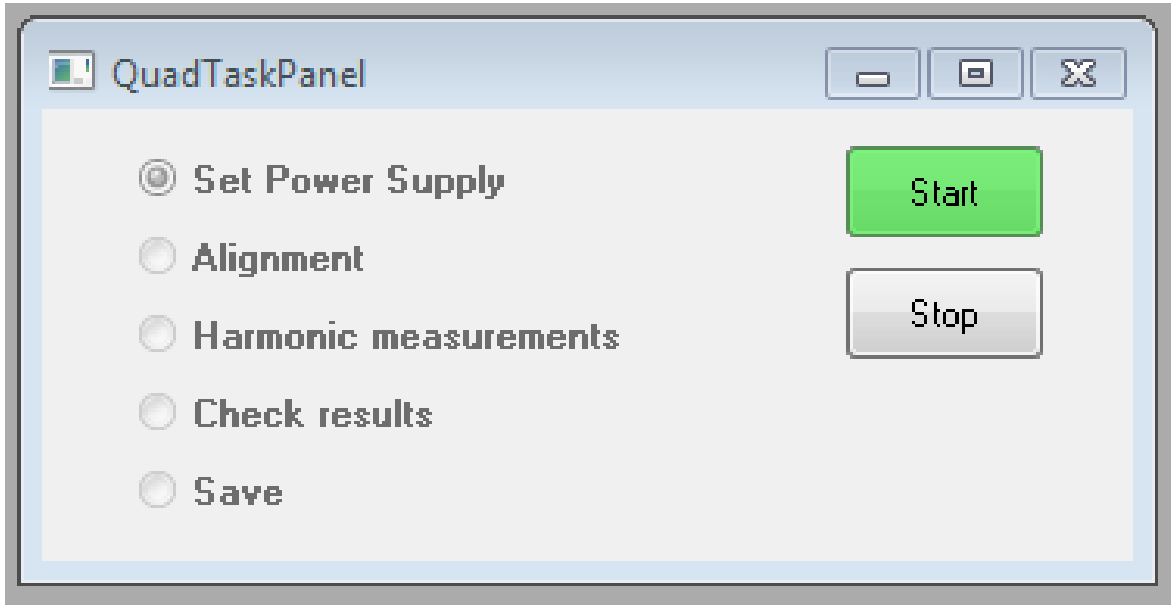
What I want to do – what I think I do – what I really do – what I want you to do
What I think - What I want to say - What I think I say - What I really say
What you want to hear - What you think you hear - What you really hear
What you want to understand - What you think you understand - What you really understand
What you want to do – what you think you do – what you really do
There are seventeen possibilities that we have communication issues and we do not do the same thing

But let's give it a try…

inspired by Attempt - B. Werber

Magnetic Measurement

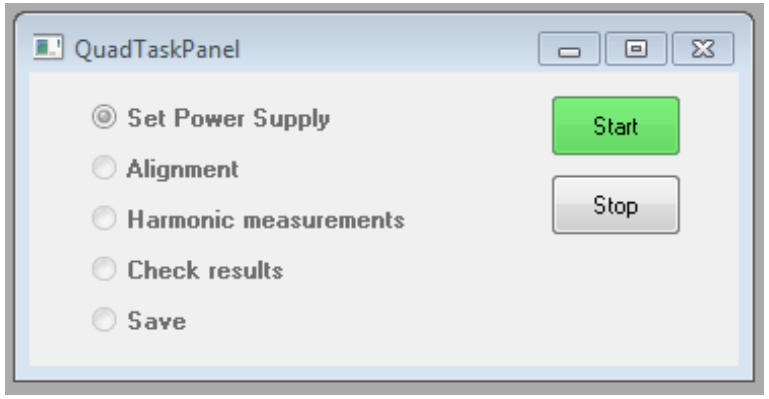
- **Automatic measurements**

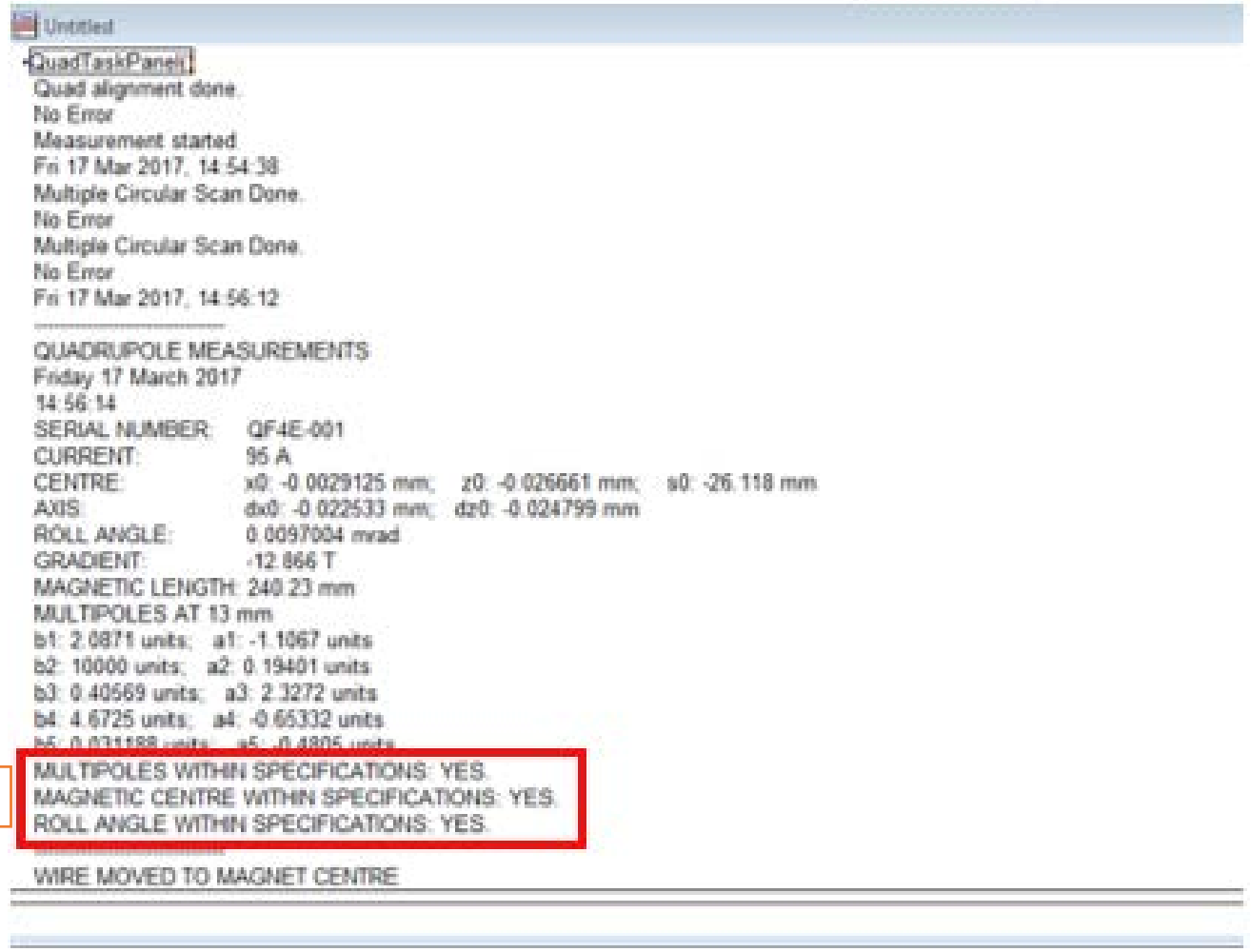


- Magnetic axis/centre for the measurement
- Circular Measurement (for multipoles)
- Multipole analysis (for Rollangle, strength, gradient…)
- Result export

Magnetic Measurement

- **Automatic measurements**

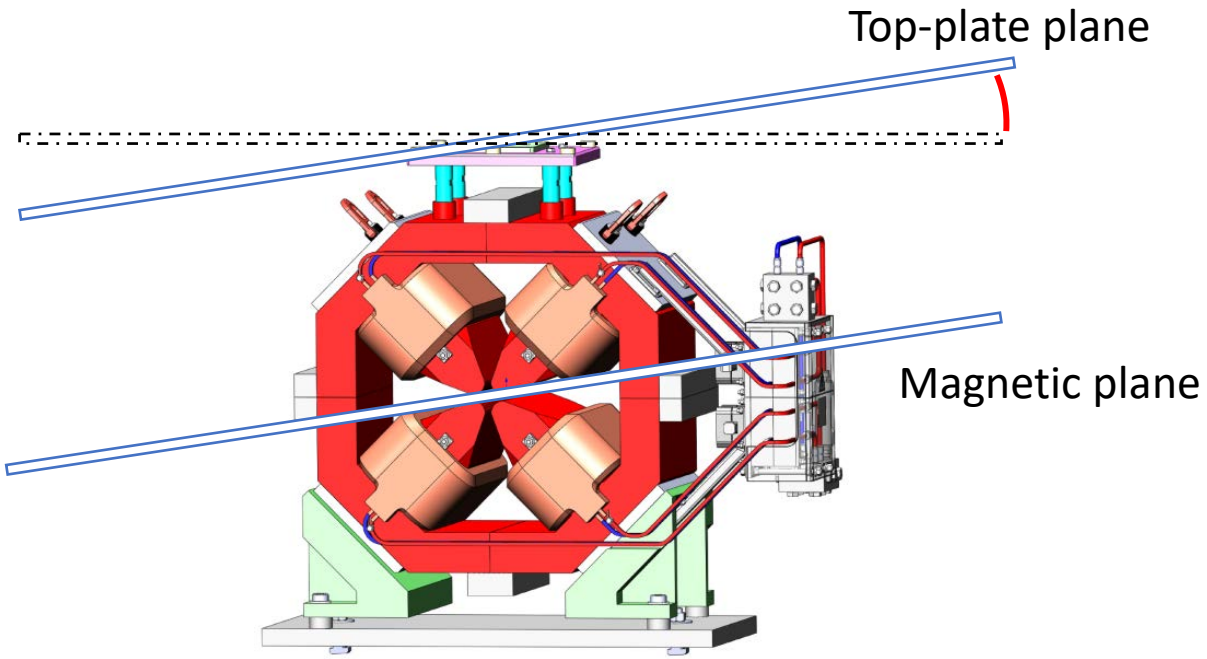


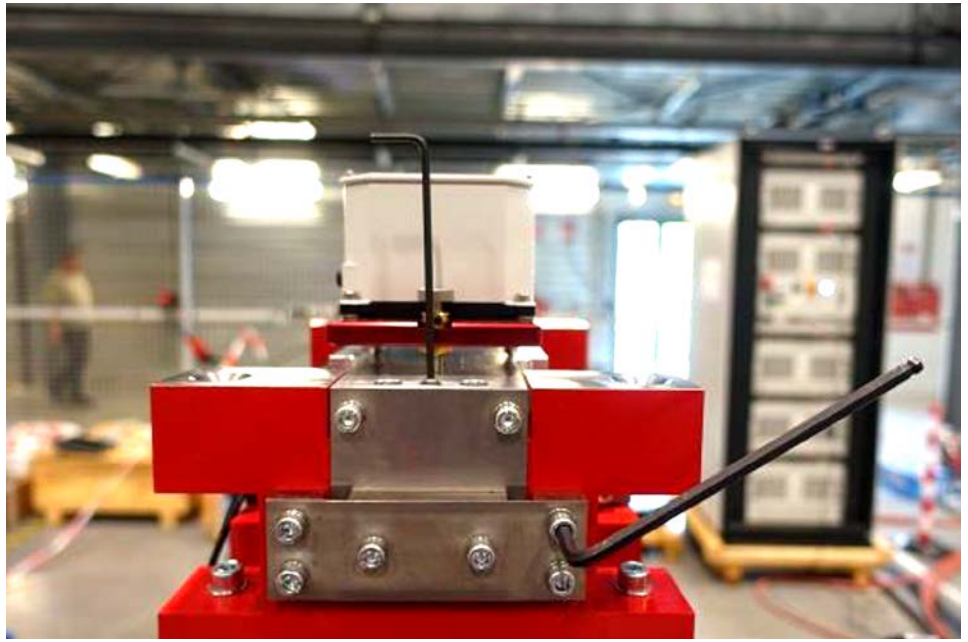


Install shims if rollAngle not in tolerance

Magnet Alignment

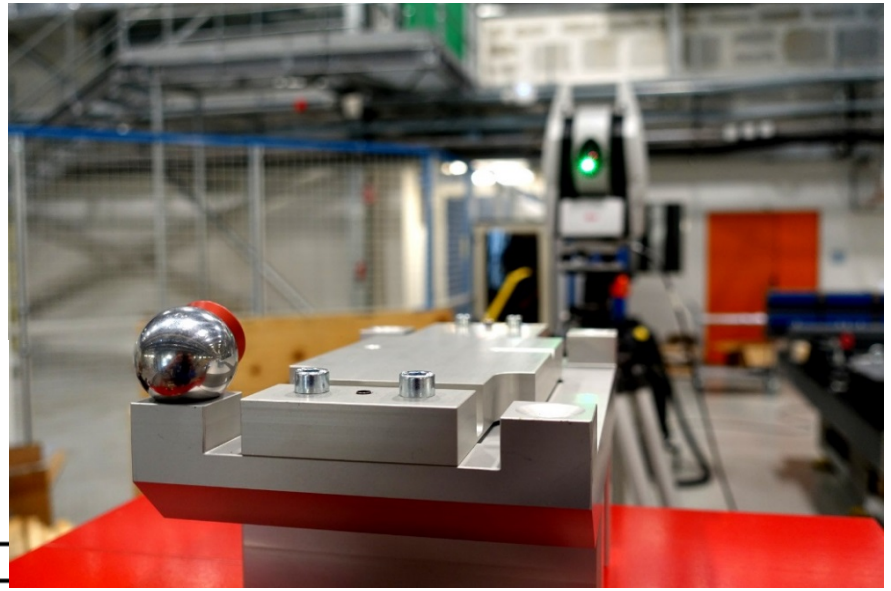
- **Fiducialization (Alignment)**
  - **Top-plate → parallel to the magnetic plane**
    - Quadrupoles and sextupoles
    - Leica Nivel 210 inclinometer + support





Magnet Alignment

- **Fiducialization (Alignment)**
  - 3d-measurement
    - Faro-Arm – Laser tracker…



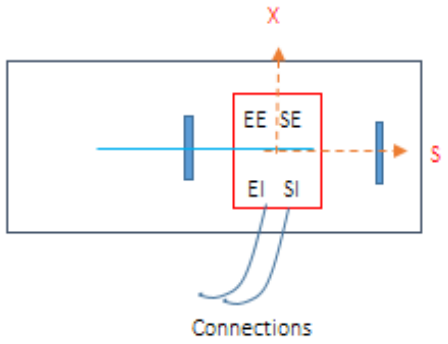
Reference System

Origin	Wire centre
S Axis	Measurement wire
X Axis	perpendicular to S axis in the bench horizontal plane
Z Axis	Perpendicular to the OSX plane

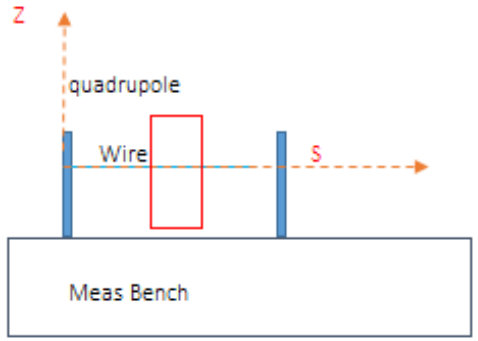
Roll Angle

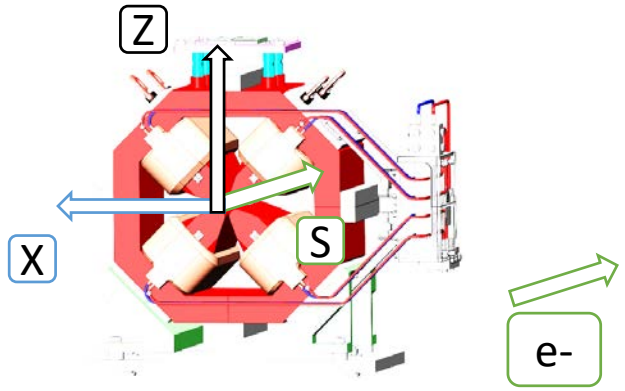
PlateToMag Roll Angle (mrad)=	-0.0044169
PlateToGravity Roll Angle (mrad)=	0.1295

Top view



Side view





Magnet Alignment

- **Fiducialization (Alignment)**
  - 3d-measurement
    - Correction from roll angle

Magnetic measurements (Igor)				
Magnetic angle	-0.249	mrad		
Top plate angle to gravity (mrad)	-0.198	mrad		
Faro Arm Measurements				
Point	**Sphere Diameter (mm)**	**X (mm)**	**Z (mm)**	**S (mm)**
SE	38.118	129.956	434.877	71.231
SI	38.114	-130.033	435.118	71.263
EI	38.105	-130.043	435.099	-64.681
EE	38.12	129.949	434.855	-64.74
Corrections	**Sphere Diameter (mm)**	**X (mm)**	**Z (mm)**	**S (mm)**
SE	38.118	130.06	434.845	71.231
SI	38.114	-129.92	435.15	71.263
EI	38.105	-129.93	435.131	-64.681
EE	38.12	130.06	434.823	-64.740

In bench plane

$$R(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

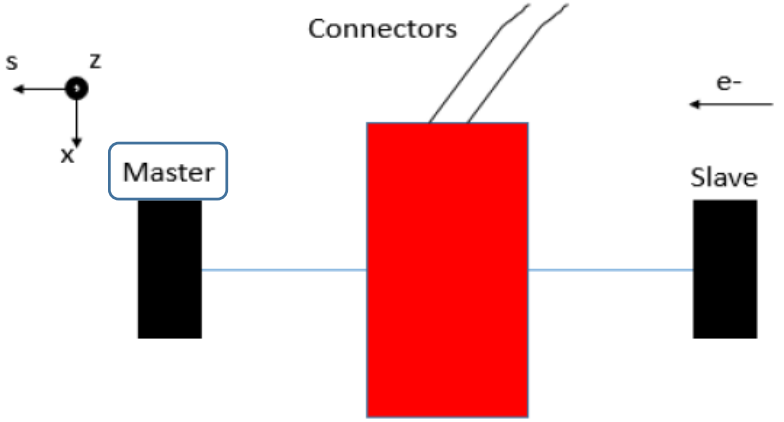
In magnetic plane

Feedback - Quality control

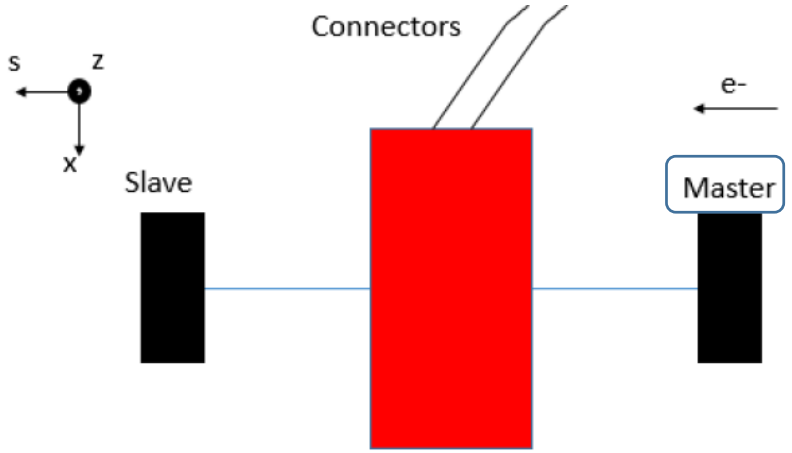
Feedback - Quality control

A Light For Science

- **Gave the opportunity to correct mistakes in procedure**



Roll angle(Igor Pro) = Magnetic plane to gravity angle



Rollangle(Igor Pro) = Gravity to magnetic plane angle

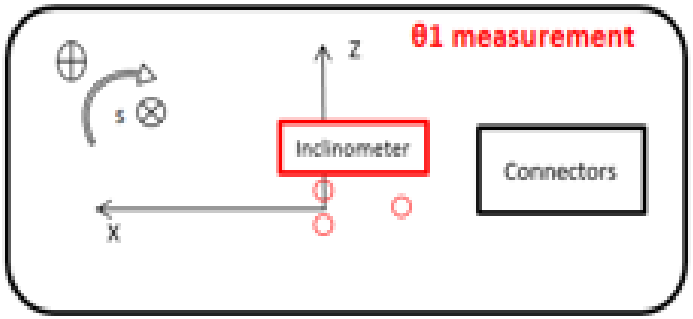
Feedback - Quality control

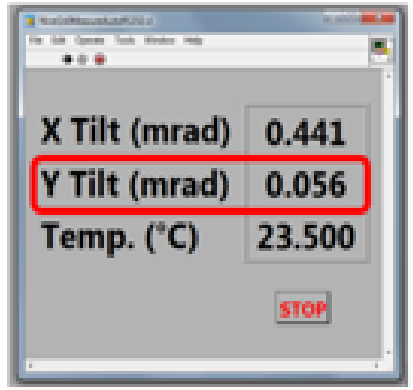
A Light For Science

- **Gave the opportunity to correct mistakes in procedure**
  - Inclinometer utilization

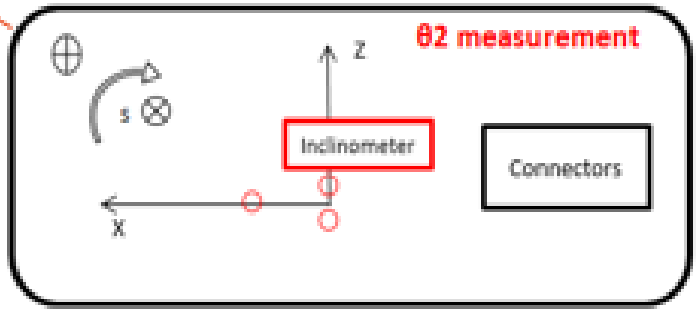
BENCH1	Roll Angle	
θBToG(B1)	0.13175	(constant)
RollAngle=θBTomag	0.0097004	< ENTER VALUE
θmagToG	0.1220496	
θ1	0.056	< ENTER VALUE
θ2	-0.23	< ENTER VALUE
θPlateToGravity	0.143	<<<< VALUE TO REPORT AT THE END OF PROC
θ2Reach	-0.2090496	< PUT θ2 TO THIS VALUE
θPlateToMag	0.0209504	< END OF PROCEDURE IF GREEN (abs < 0.025 mrad) <<<< VALUE TO REPORT AT THE END OF PROC

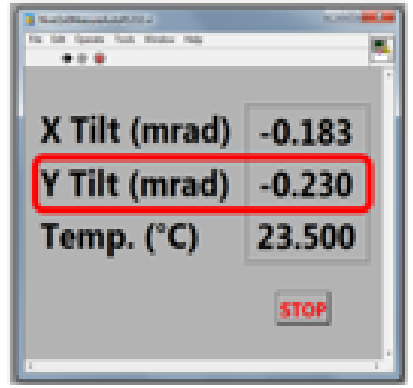
ROLL ANGLE: 0.0097004 mrad





Magnet must not move





Results - Quality control

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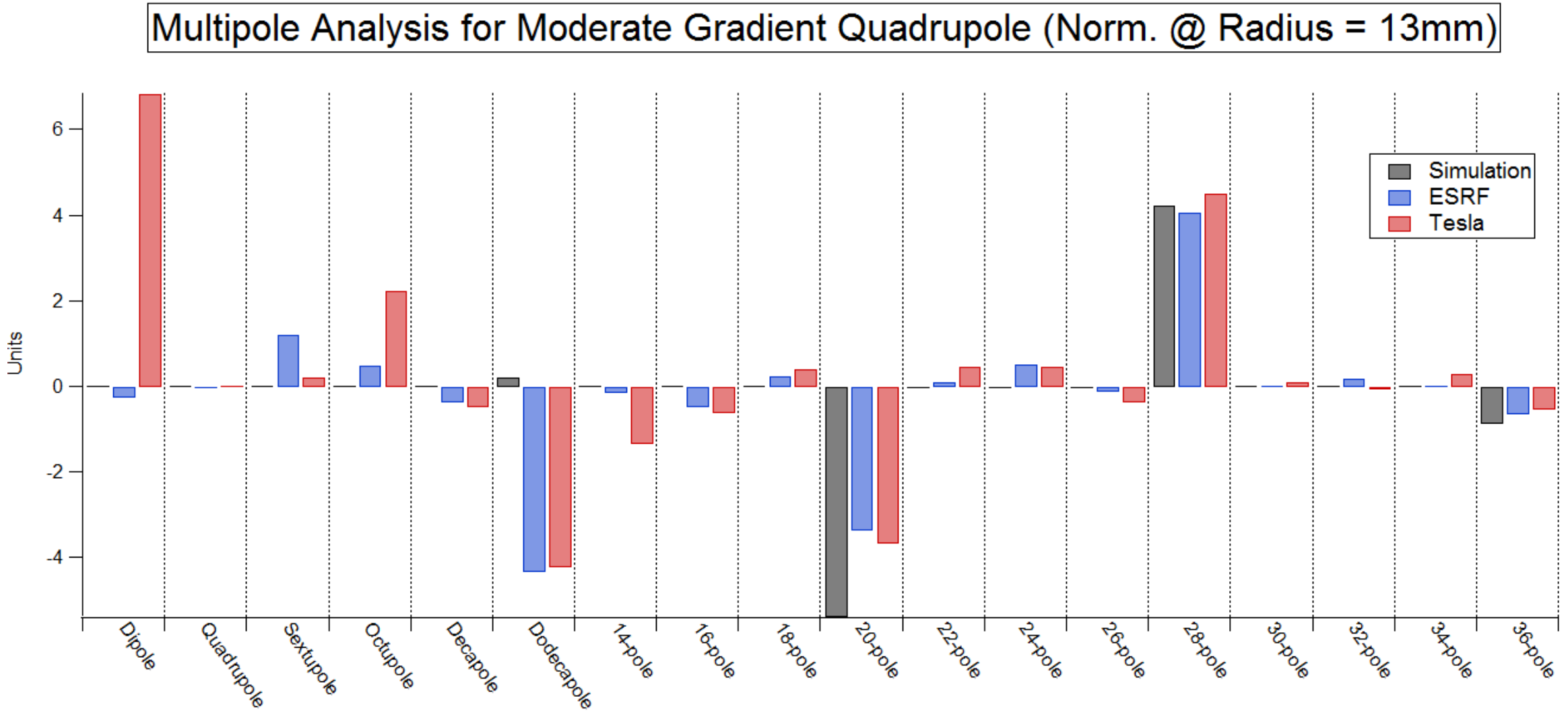

Results - Quality control

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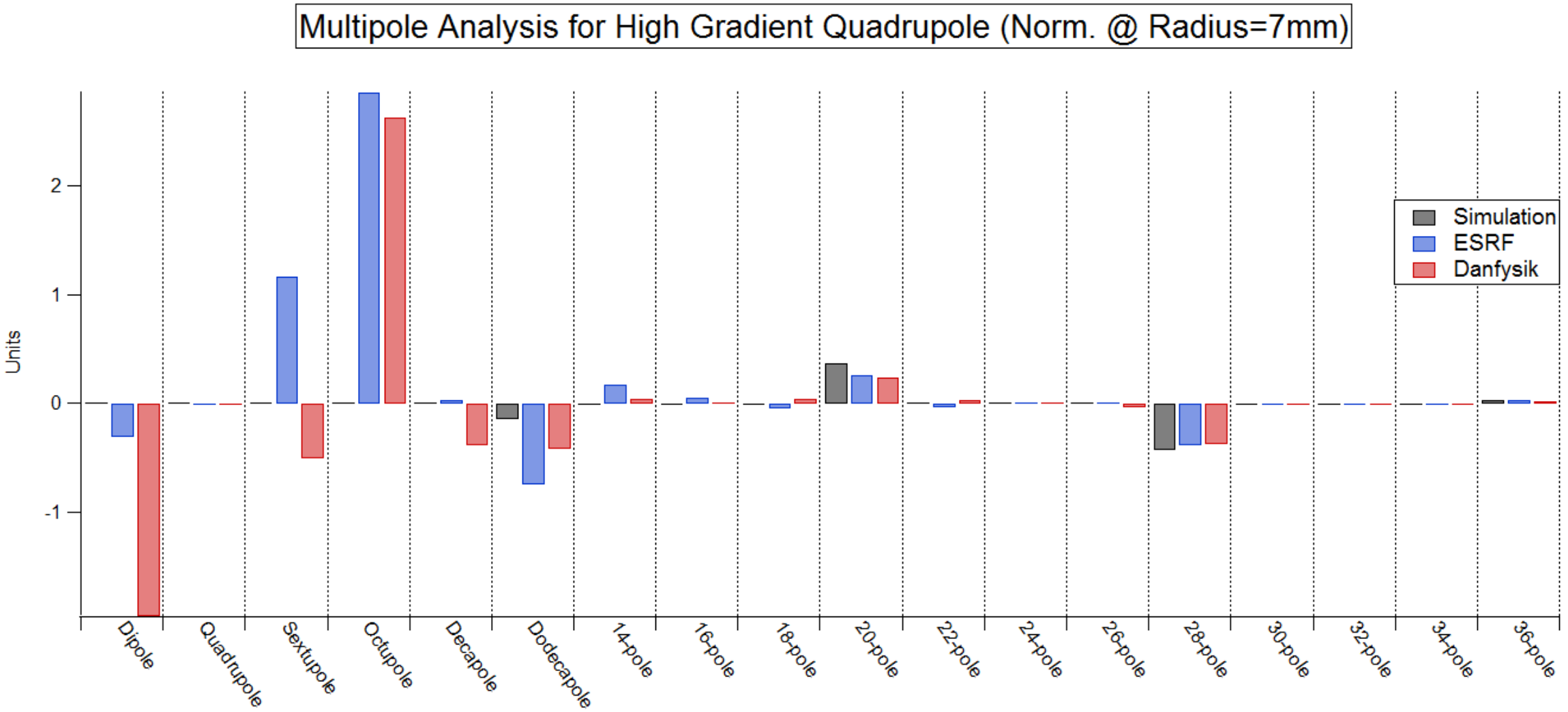

Results - Quality control

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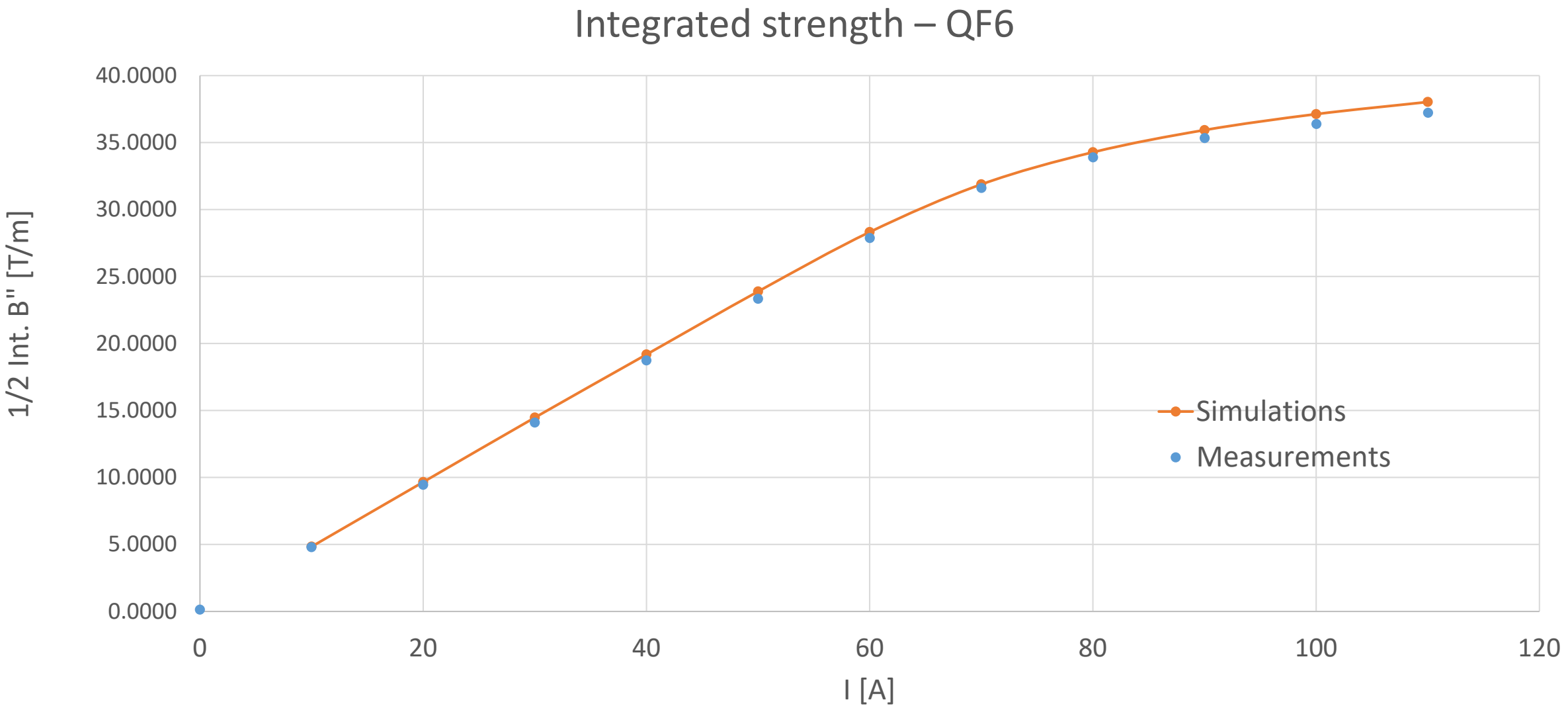
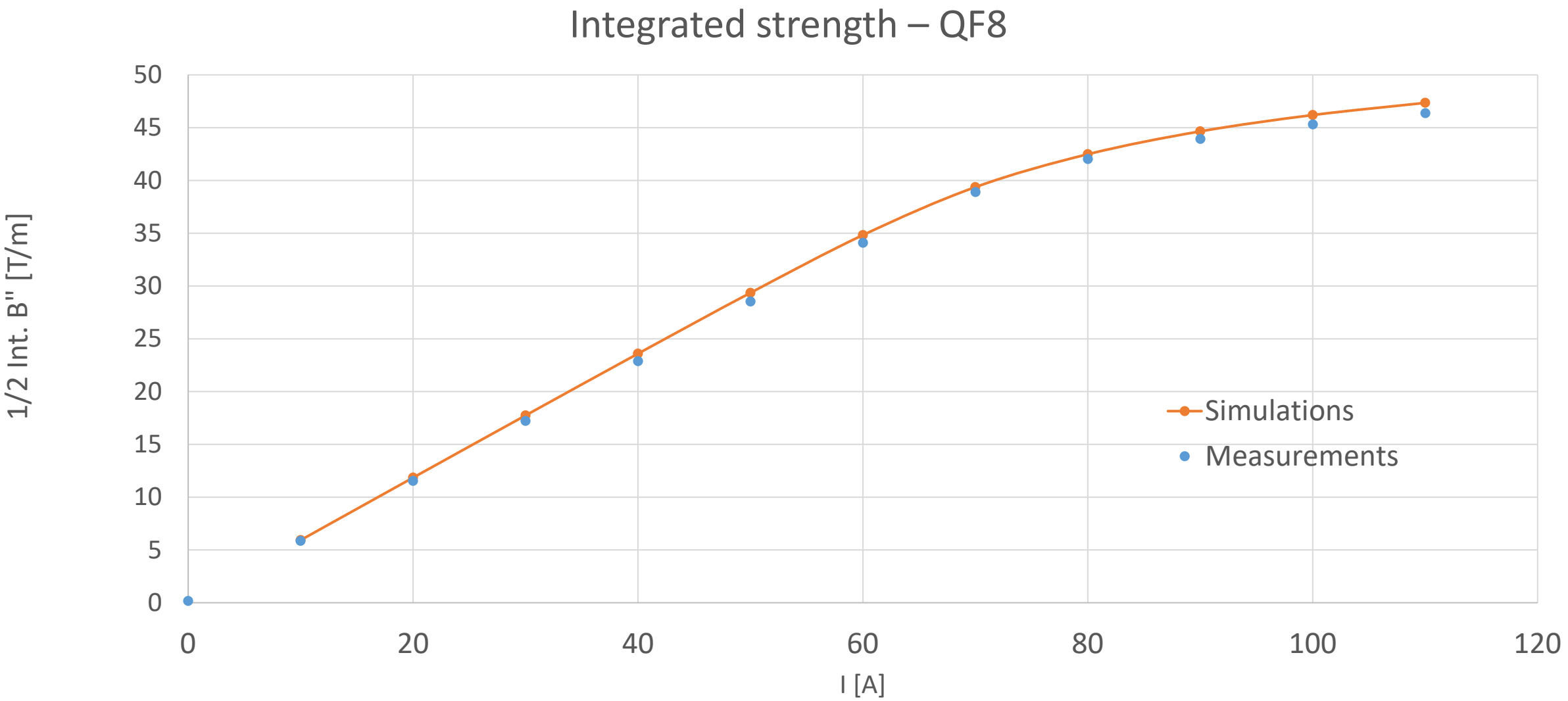


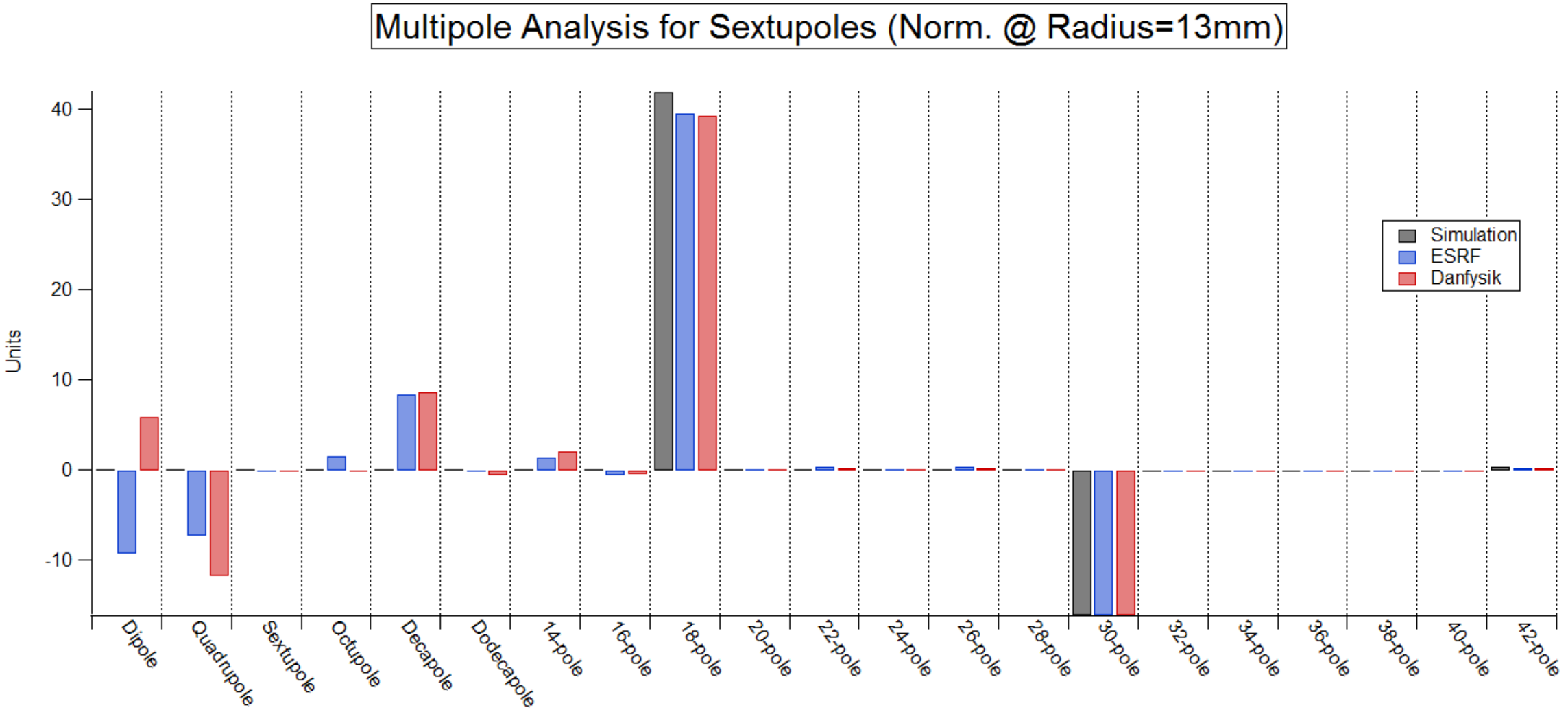
Results - Quality control

A Light For Science



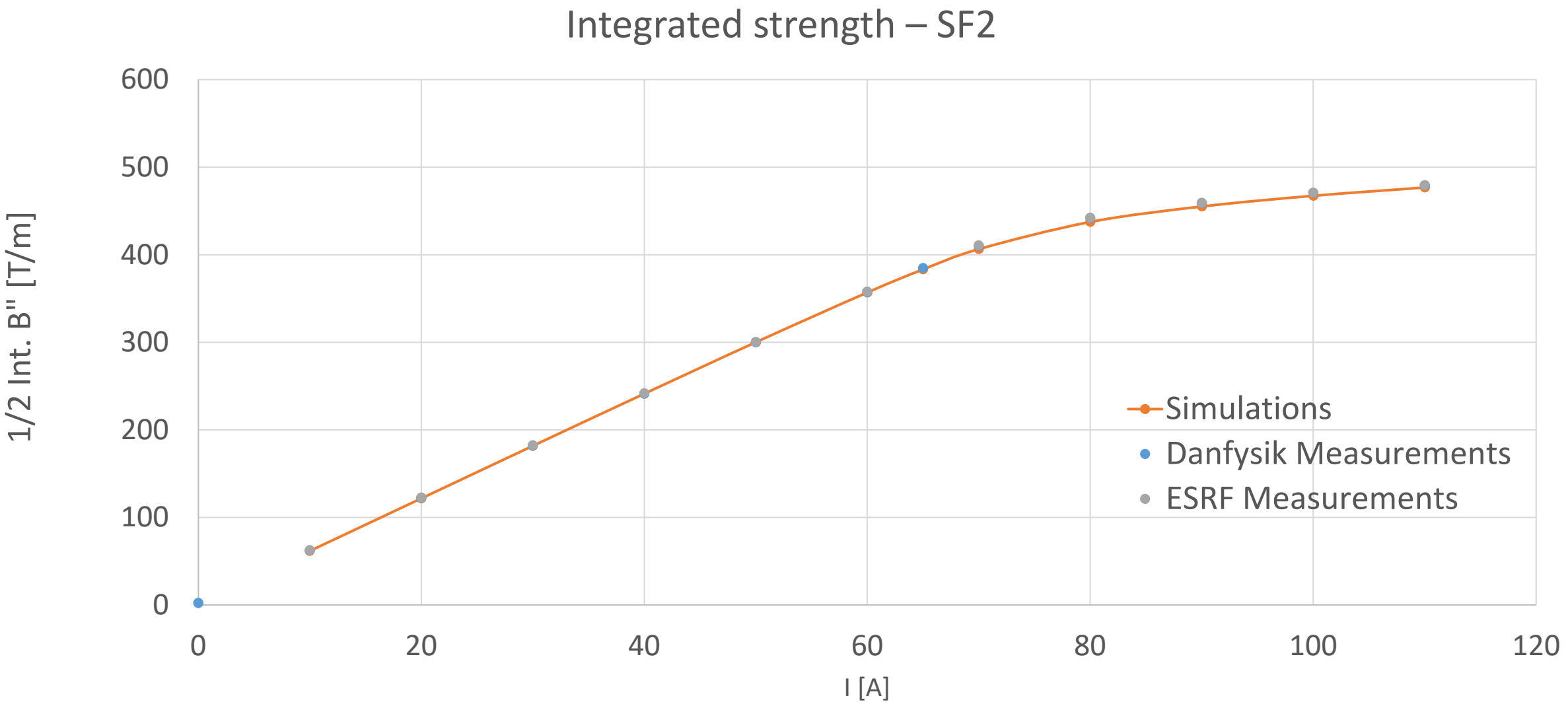
Results - Quality control

A Light For Science



Results - Quality control

A Light For Science



To Conclude

- **Calibration and launch of measurements**
  - Done for all the benches (2016-2017)
  - Some Verification to bring (DQ – next week) and alignment procedure to show to the manufacturer
- **Measurements**
  - Automatic magnetic measurements – Manual fiducialization
  - Magnetic measurements fit well the simulation
  - Repeatability between mag. measurement at supplier premises and at the ESRF is quite accurate
  - Still some 3D-measurement issues to solve

→ Bench installation, bug corrections, measurement follow-up is quite challenging but once everything is settled we will have time to check magnets to do quality control and then, develop new tools and technics.