Magnetic Measurements At ESRF

Loïc Lefebvre, Gaël Le Bec, Joël Chavanne, Christophe Penel, Eric Fene, Philippe Arnoux, Chamseddine Benabderrahmane, Grégory Giroud, Maxime Paulin, Franck Bidaut, Reine Verstreigen, Bertrand Cottin, Franck Revol

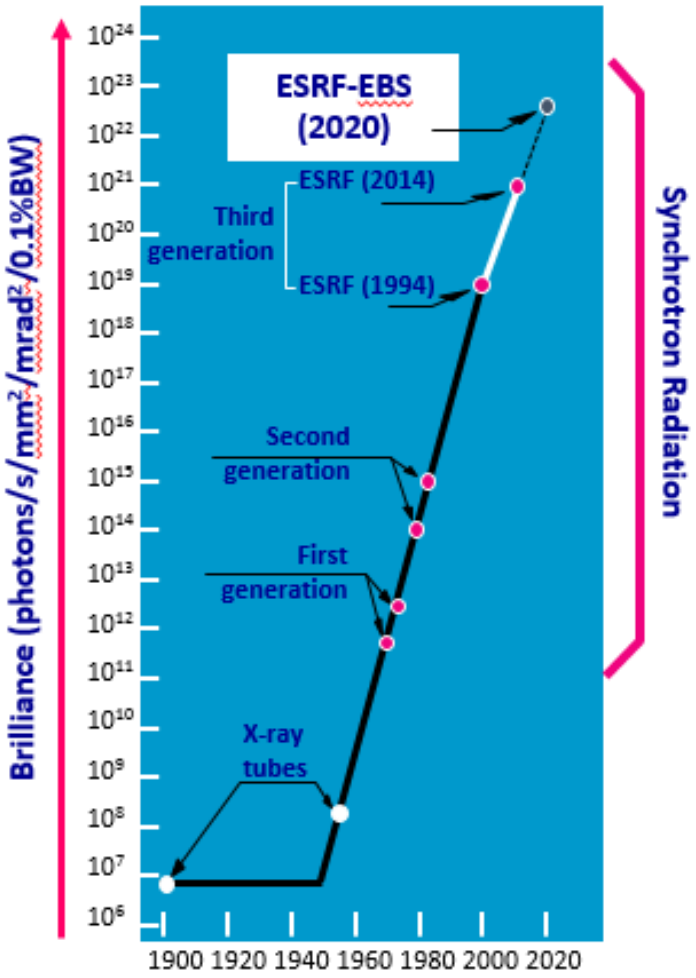
ESRF – The European Synchrotron, Grenoble, France

loic.lefebvre@esrf.fr

Contents

- Context
  - ESRF-EBS
  - Magnetic measurements benches
- Magnetic Measurements
  - Quadrupoles
  - Sextupoles
  - Permanent magnet dipoles
  - Dipole-quadrupoles
- Fiducialization
  - Issues and feedback

ESRF/EBS

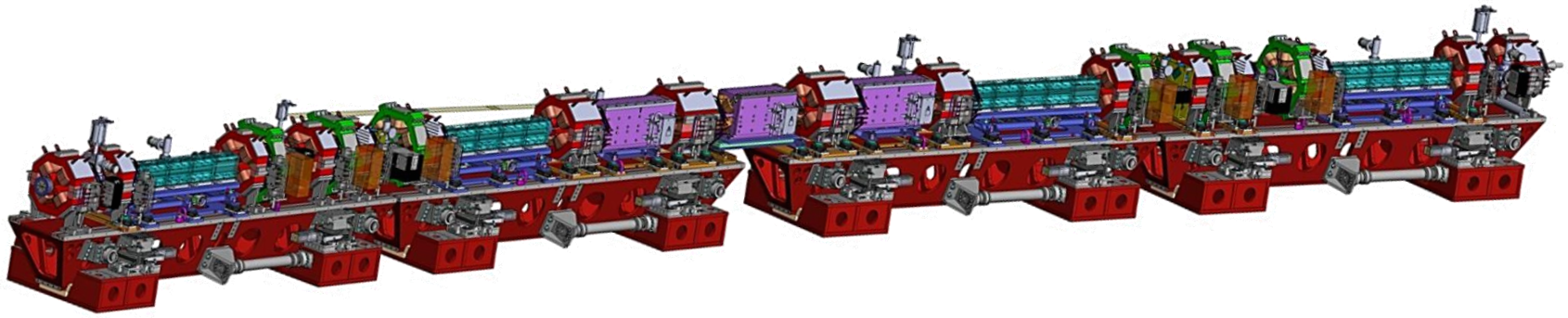


The ESRF designs a new generation of synchrotrons
A new design for the storage ring

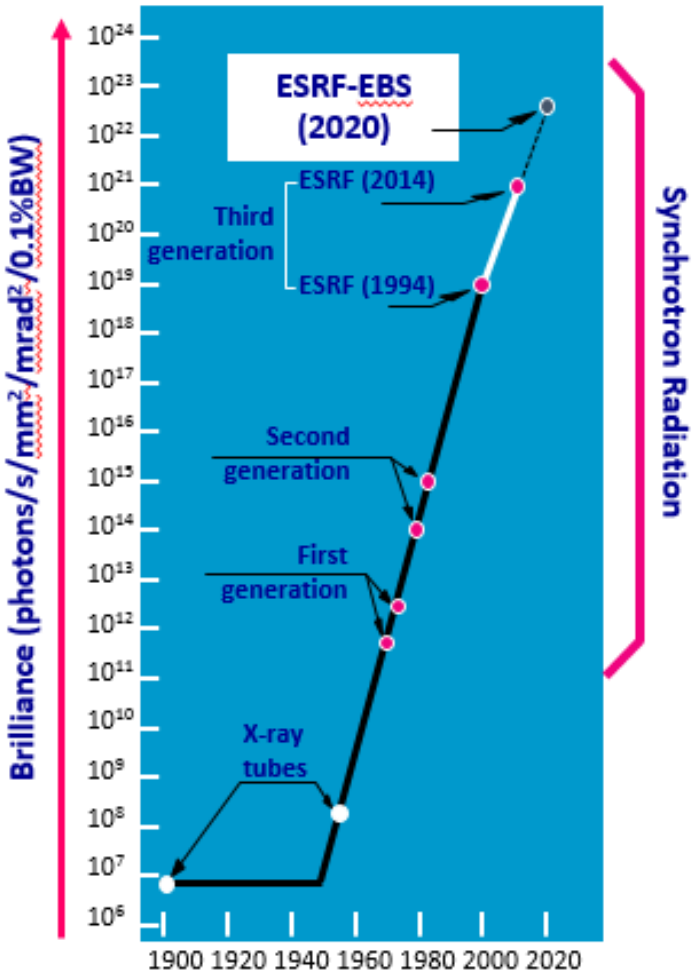
- 31 magnets + correctors

X32 cells

=> Low emittance – 4nm to < 140pm



ESRF/EBS

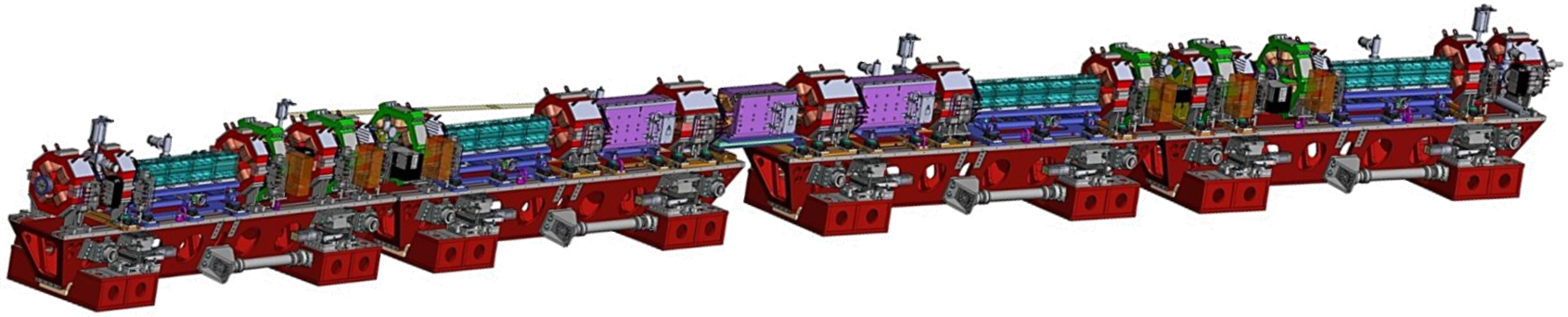


The ESRF designs a new generation of synchrotrons
A new design for the storage ring

- 31 magnets + correctors

X32 cells

=> Low emittance – 4nm to < 140pm



No failure for IDM !!

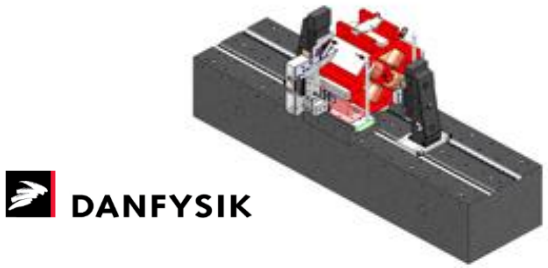
Magnetic Measurement Benches

A Light For Science

→Check multipoles

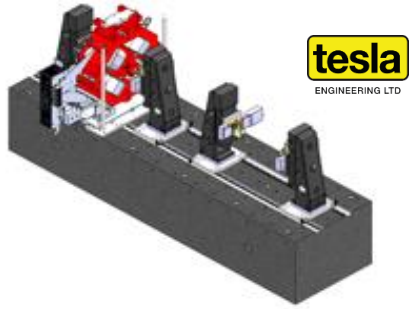
→Shim the magnets (low gradient quadrupoles and sextupoles)

→ Align the wire according to the magnet field for fiducialization



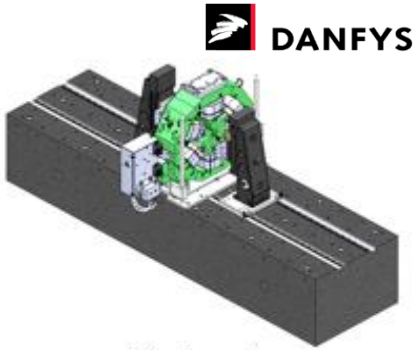
DANFYSIK

High gradient quads



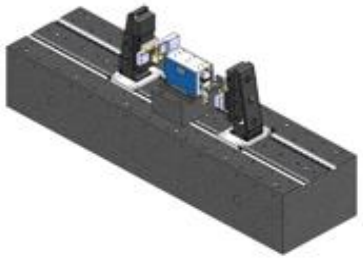
tesla ENGINEERING LTD

High gradient quads, 2 stands



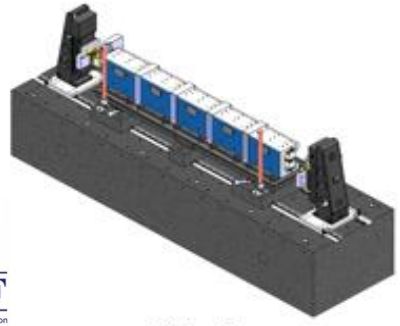
DANFYSIK

Sextupoles



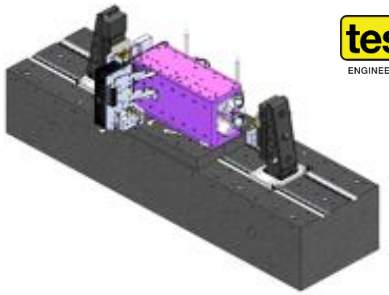
ESRF The European Synchrotron

Dipole modules



ESRF The European Synchrotron

Dipoles

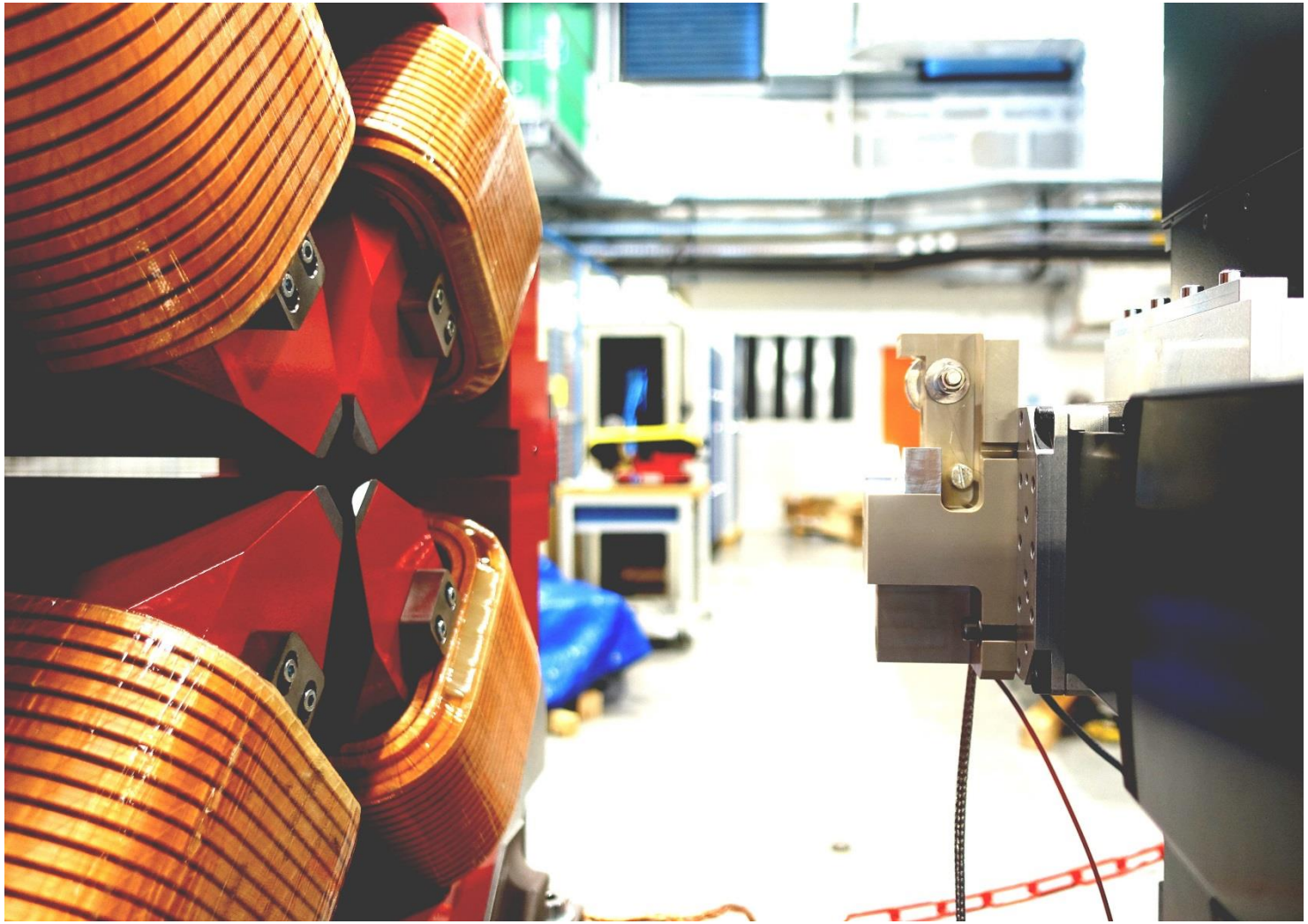


tesla ENGINEERING LTD

Dipole-quadrupoles

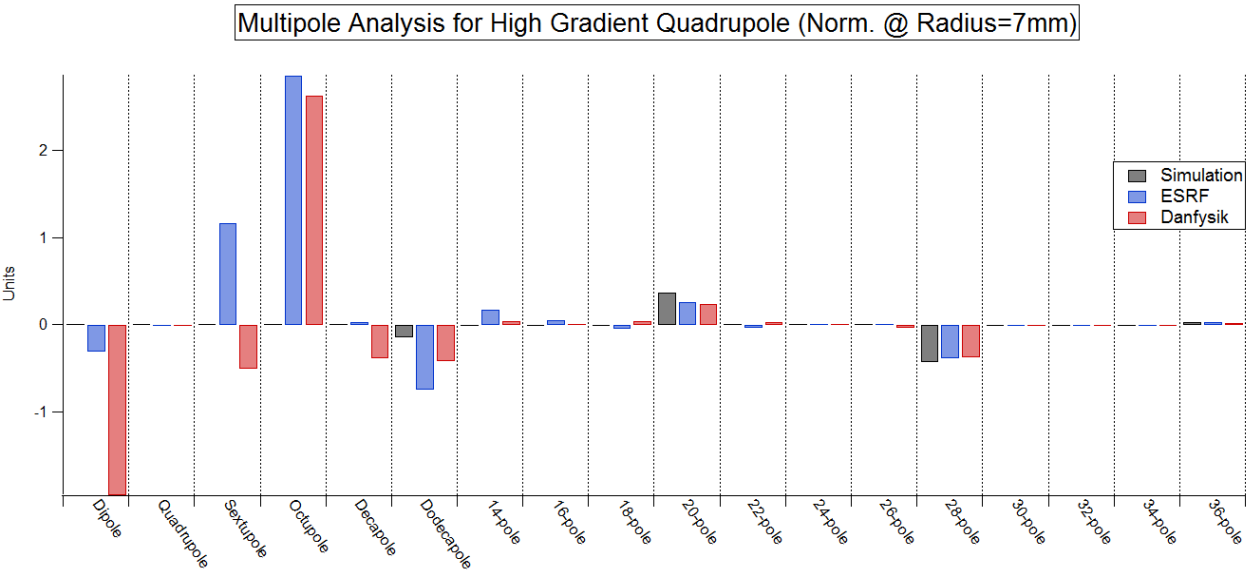
Quadrupole measurements

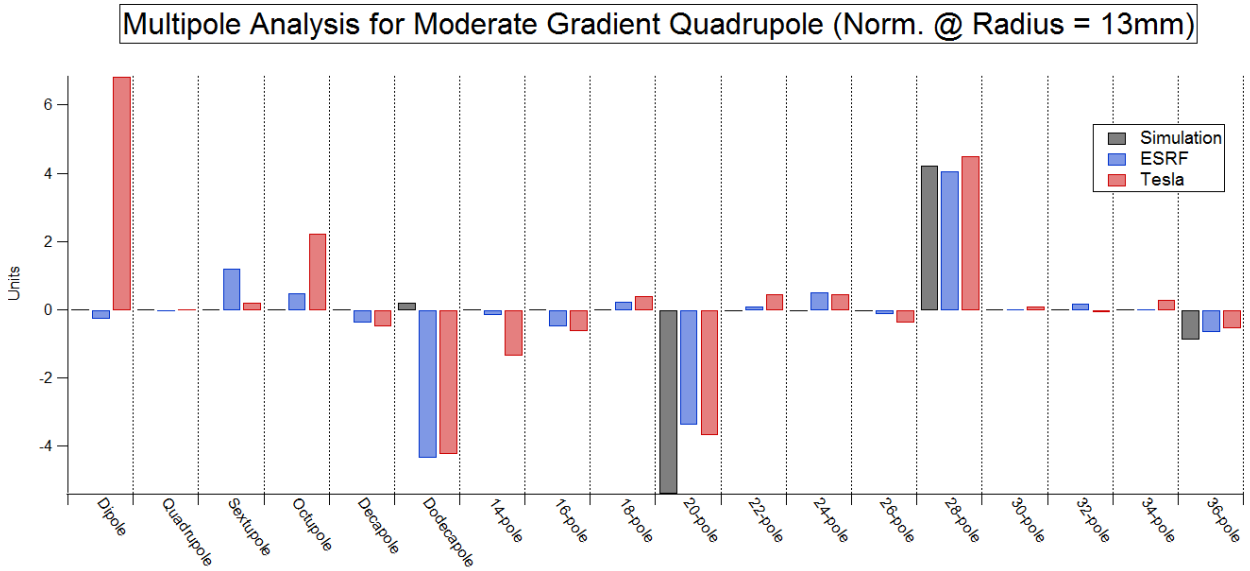
A Light For Science



Quadrupole measurements

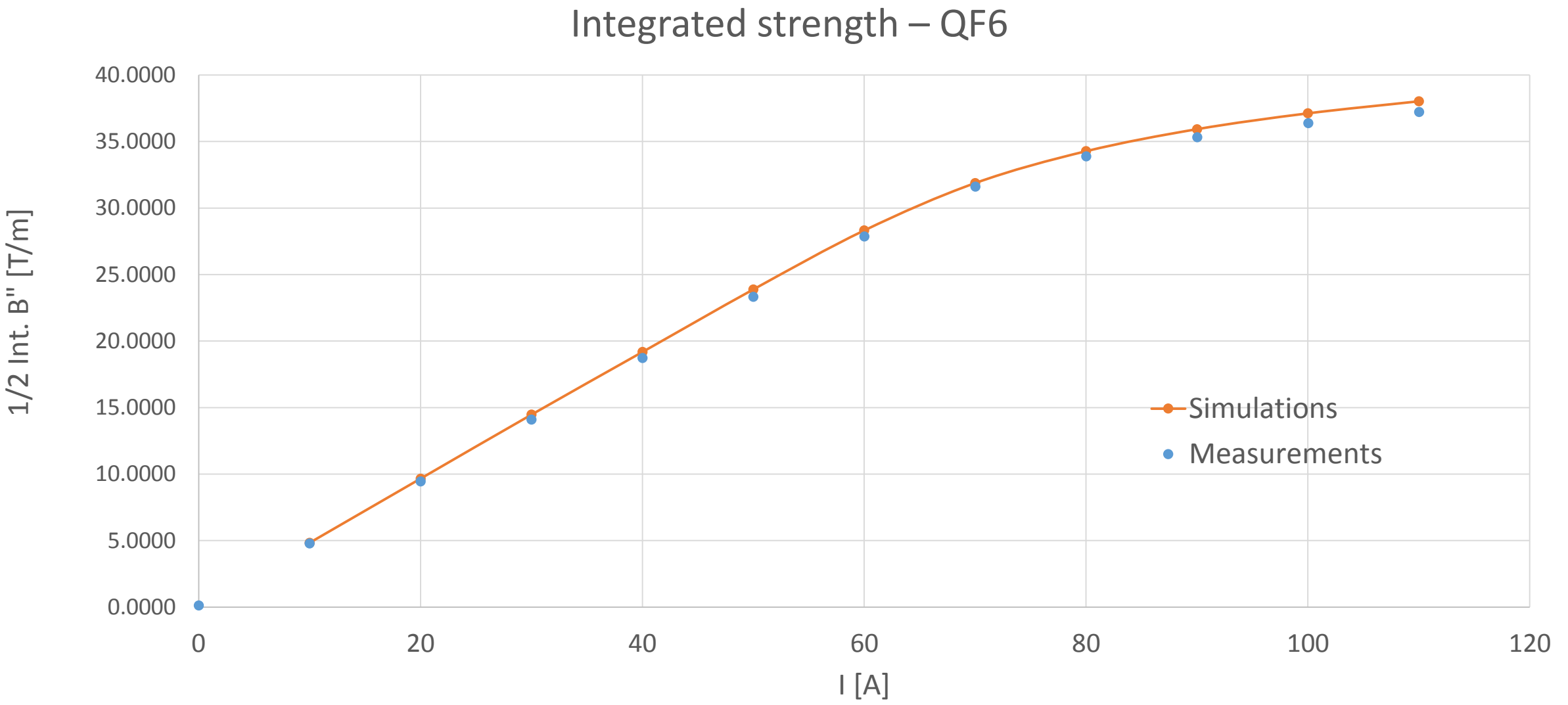
- **Harmonics**





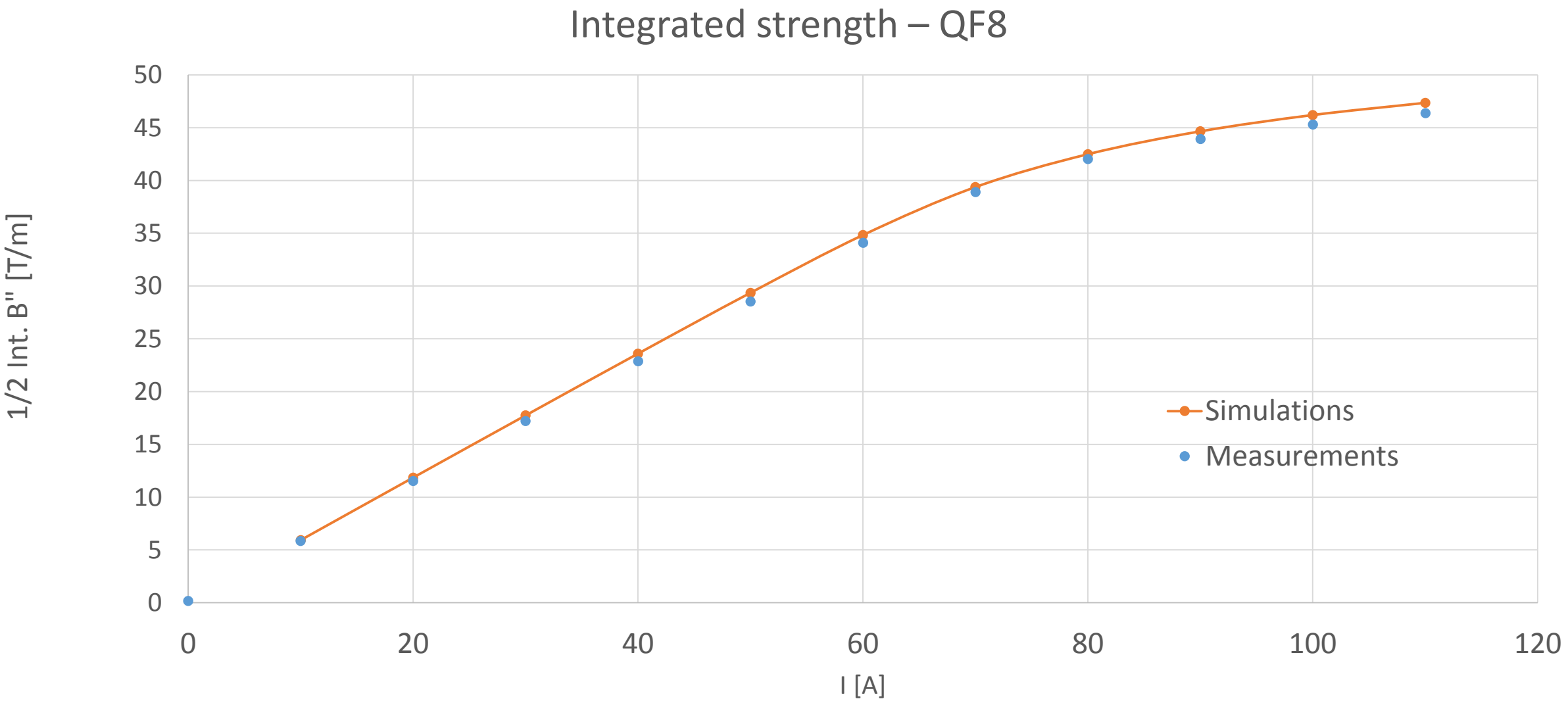
Quadrupole measurements

A Light For Science



Quadrupole measurements

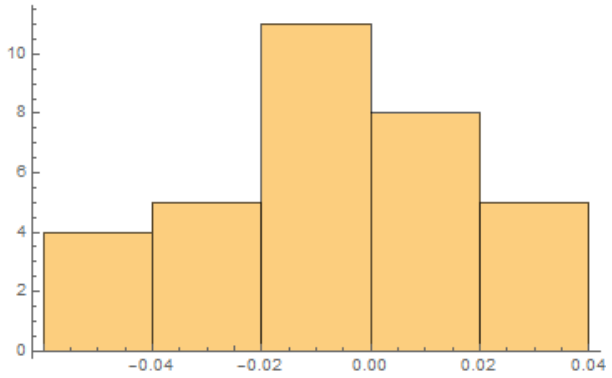
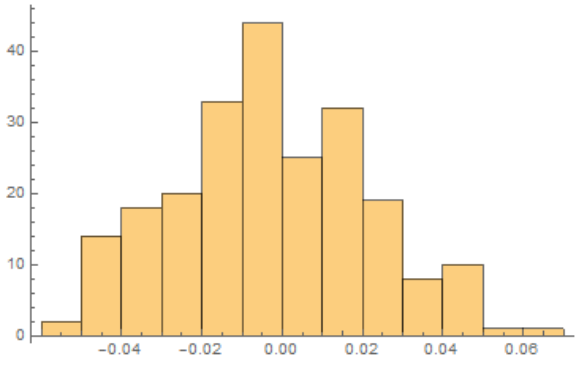
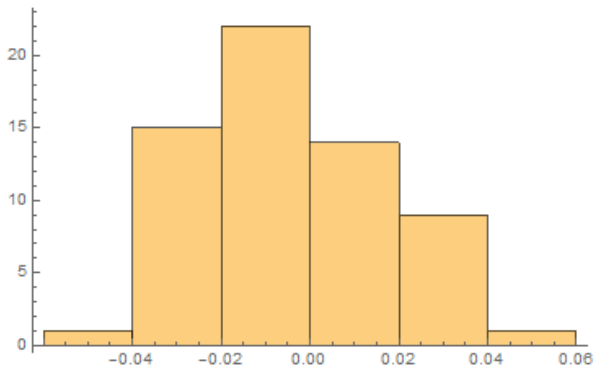
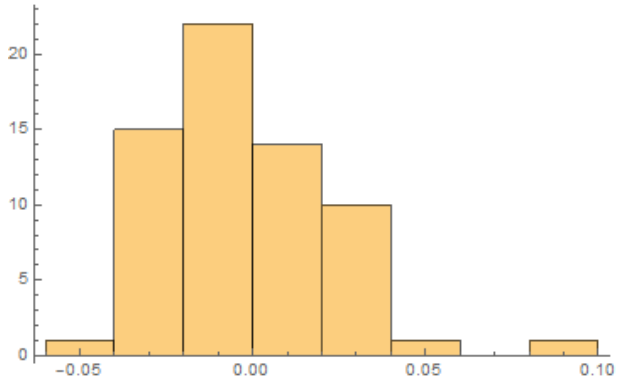
A Light For Science



Quadrupole measurements

A Light For Science

- **Vertical position – shimmed quadrupoles**

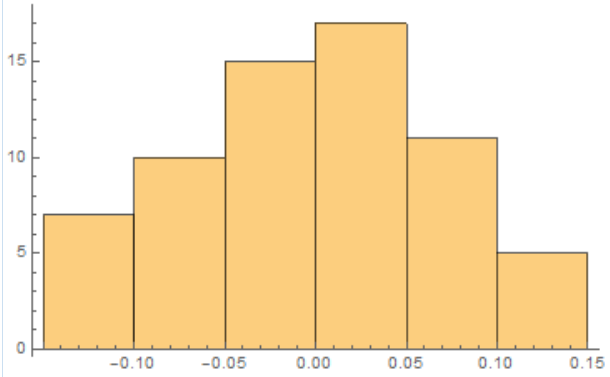
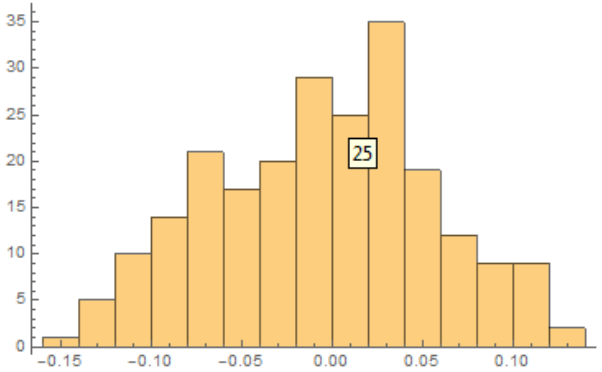
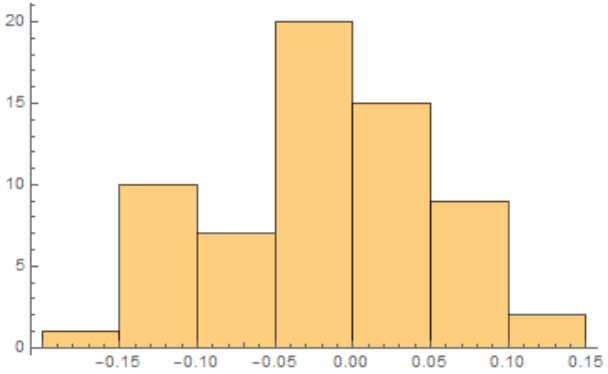
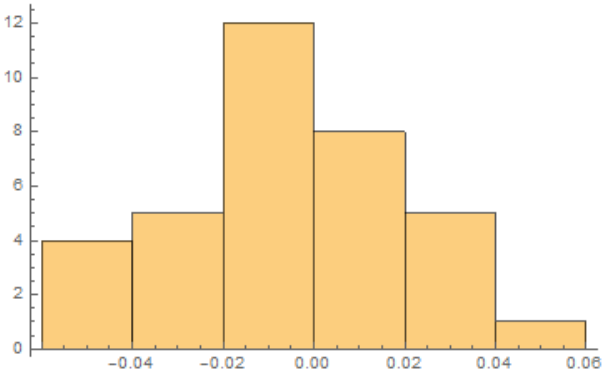
QF1 (65 magnets)	QD2 (228 magnets)	QD3 (64 magnets)	QF4E (35 magnets)
			
Average: 6 µm	-3 µm	-4 µm	-2 µm
Std dev : 23 µm	24 µm	21 µm	24 µm

Tolerances : 50 µm after shimming

Quadrupole measurements

A Light For Science

- **Roll Angle – shimmed quadrupoles**

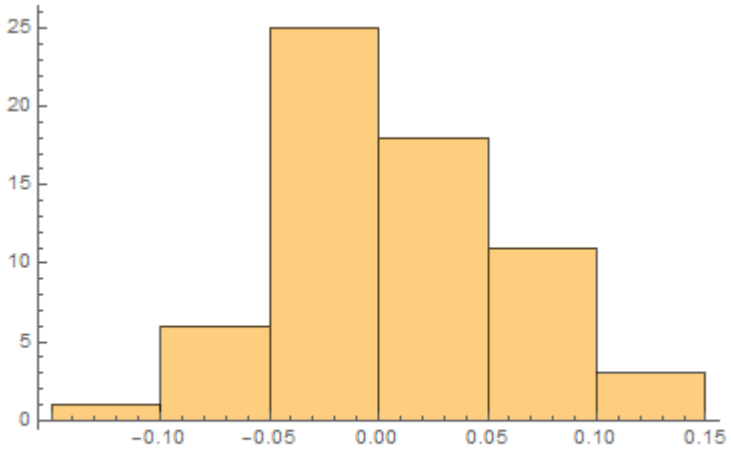
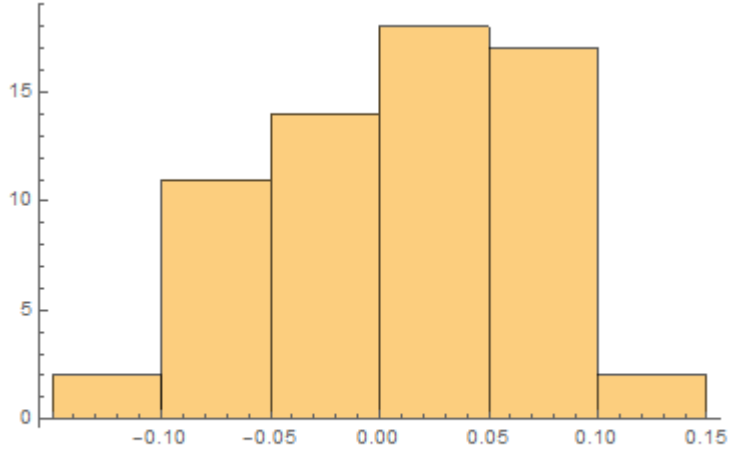
QF1 (65 magnets)	QD2 (228 magnets)	QD3 (64 magnets)	QF4E (35 magnets)
			
Average: -0.00217167 mrad Standard deviation: 0.070382 mrad	Average: -0.00512516 mrad Standard deviation: 0.0610034 mrad	Average: -0.0191501 mrad Standard deviation: 0.0680204 mrad	Average: -0.00494886 mm Standard deviation: 0.0245648 mm
Average: -2 µrad	-5 µrad	-19 µrad	-5 µrad
Std dev : 70 µrad	61 µrad	68 µrad	25 µrad

Tolerances: 130 µrad after shimming

Quadrupole measurements

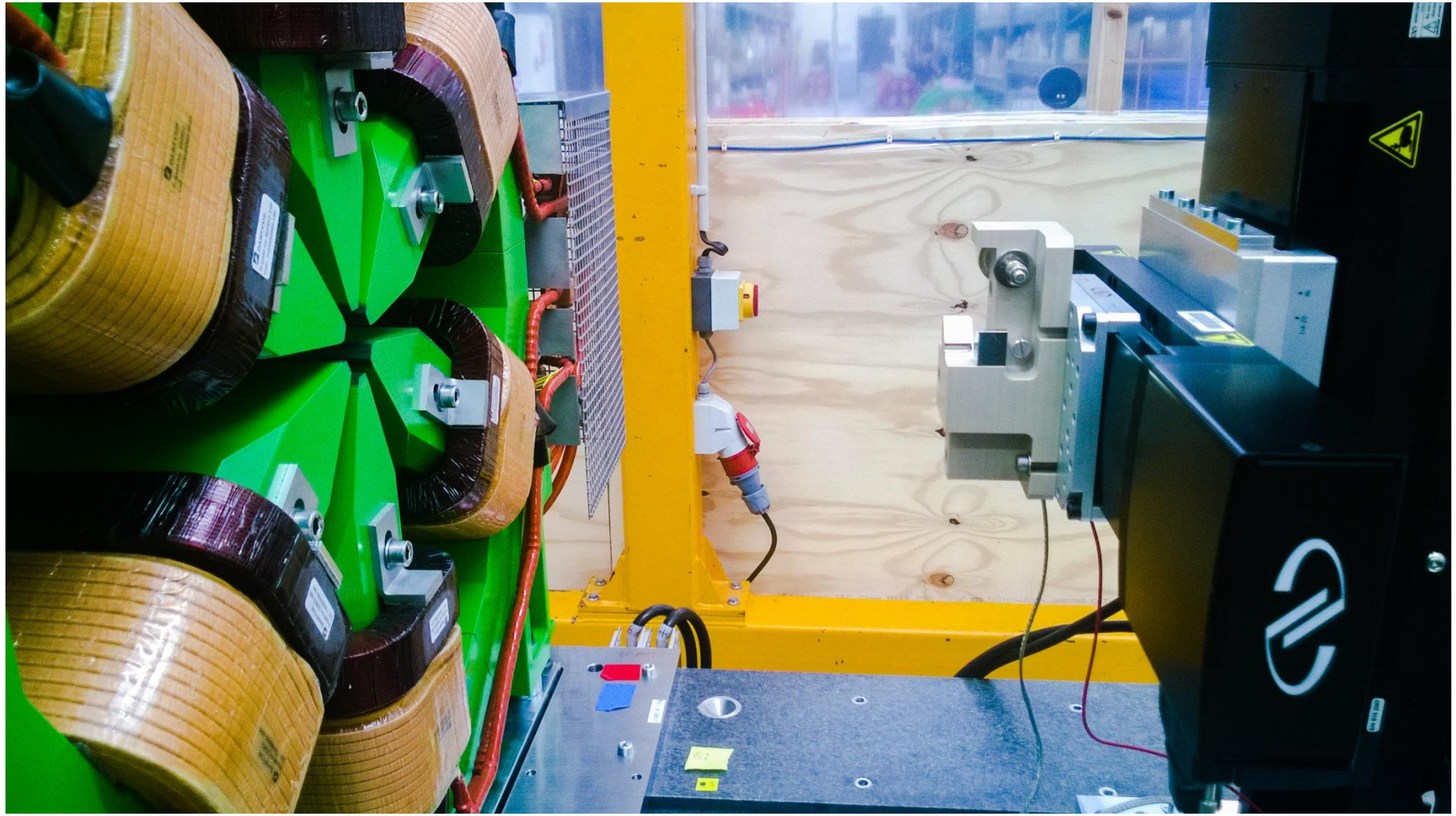
A Light For Science

- **Roll Angle – unshimmed quadrupoles**

QF8 (64 magnets)	QF6 (64 magnets)
 Average: 0.0065226 mrad Standard deviation: 0.0505402 mrad	 Average: 0.0077242 mrad Standard deviation: 0.0585658 mrad
Average: 6 µrad	8 µrad
Std dev : 51 µrad	59 µrad

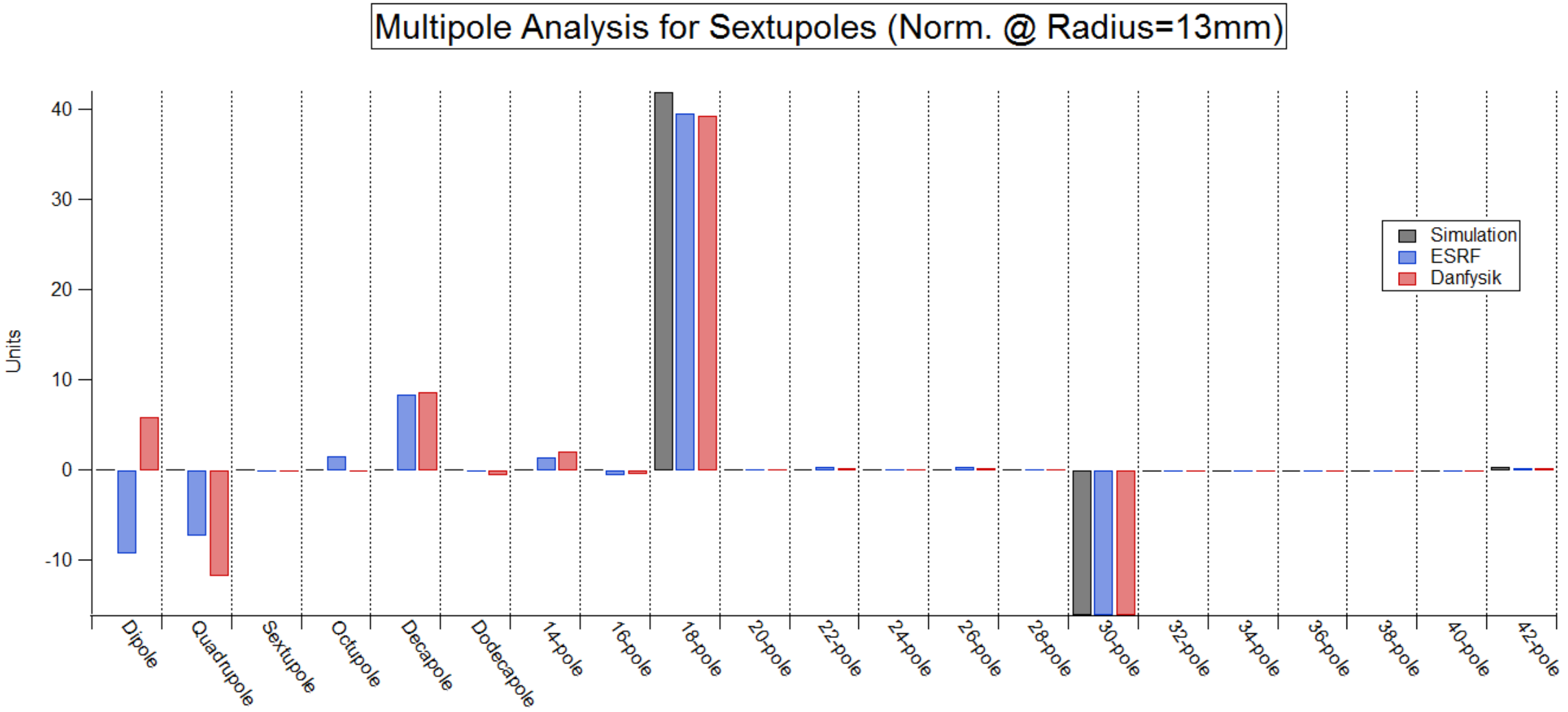
Bottom support were set according to a first magnetic measurement

Sextupole Measurements



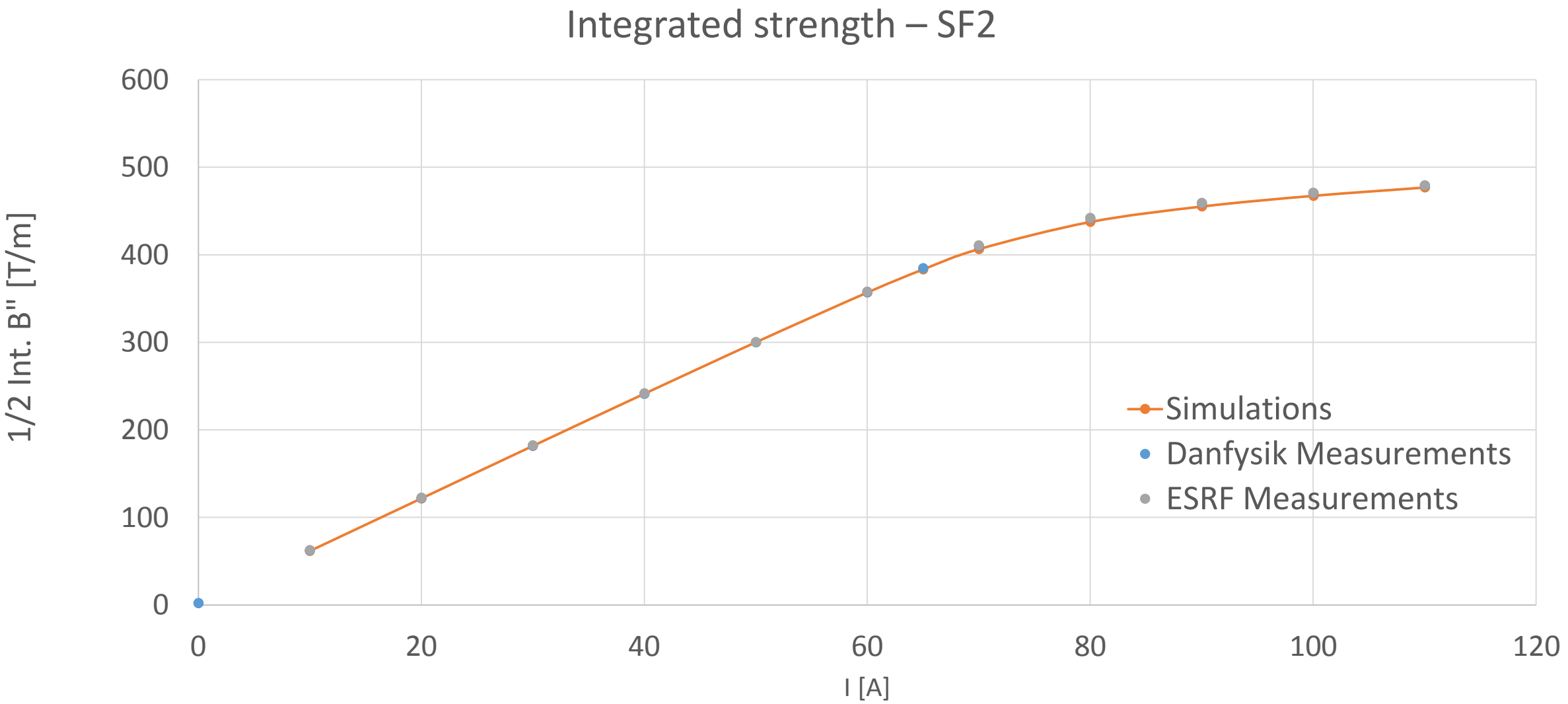
Sextupole Measurements

A Light For Science



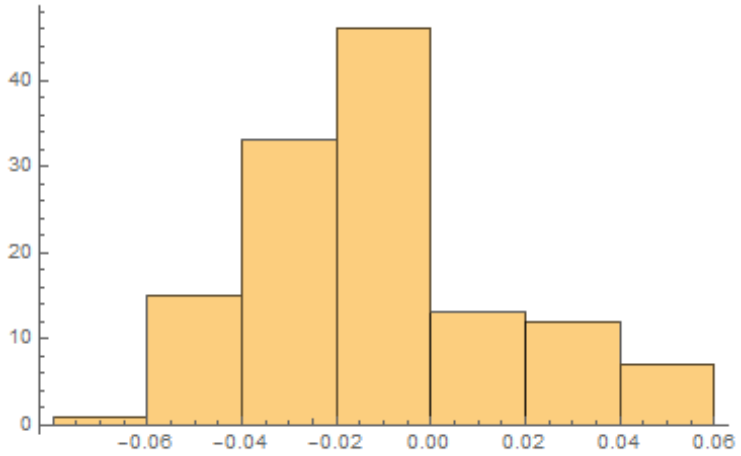
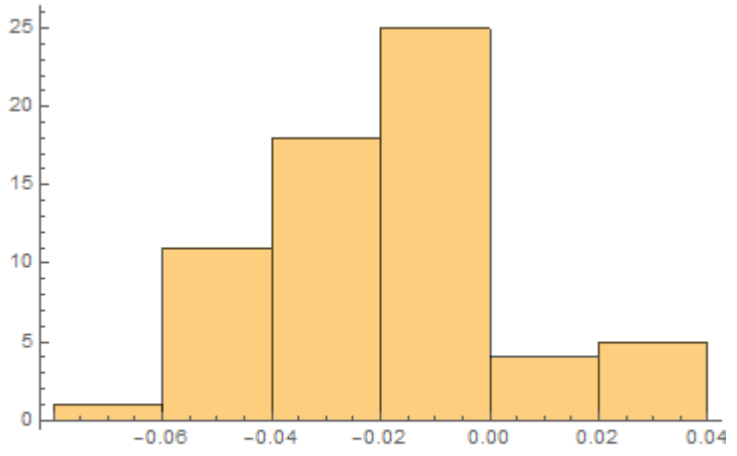
Sextupole Measurements

A Light For Science



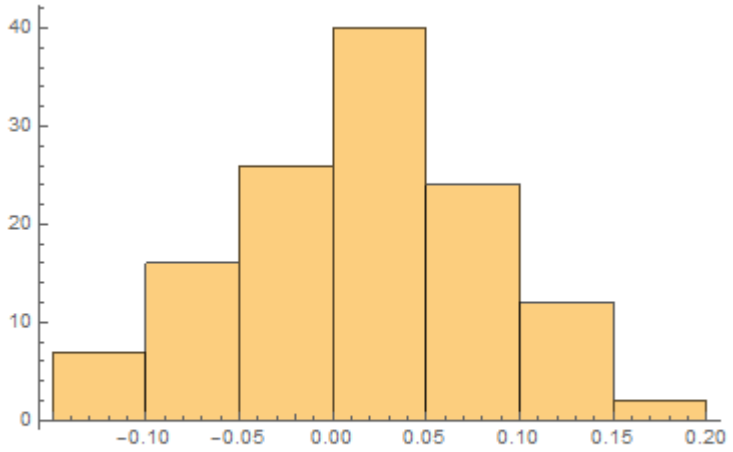
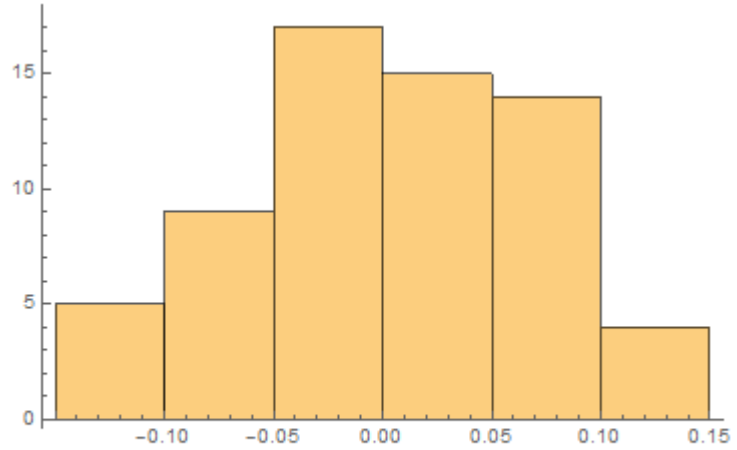
Sextupole Measurements

- **Vertical position – shimmed sextupoles**

SD1 (127 magnets)	SF2 (64 magnets)
	
Average: -0.0107009 mm Standard deviation: 0.0262049 mm	Average: -0.0193499 mm Standard deviation: 0.0208462 mm
Average: -11 µm	-19 µm
Std dev : 26 µm	21 µm

Sextupole Measurements

- **Roll Angle – shimmed sextupoles**

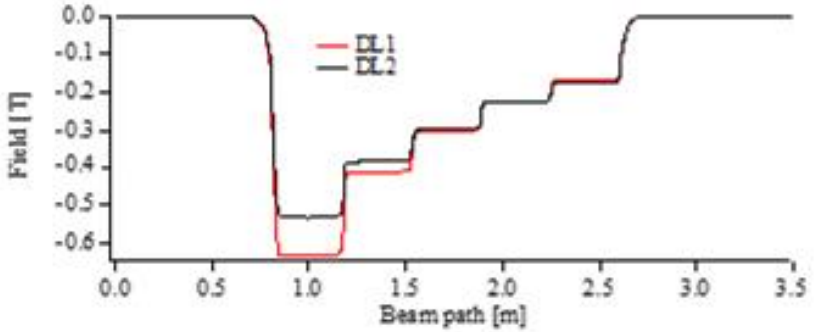
SD1 (127 magnets)	SF2 (64 magnets)
 Average: 0.0147478 mrad Standard deviation: 0.0682541 mrad	 Average: 0.00515634 mrad Standard deviation: 0.0651499 mrad
Average: 14 µrad	5 µrad
Std dev : 70 µrad	65 µrad

Permanent Magnet Dipole

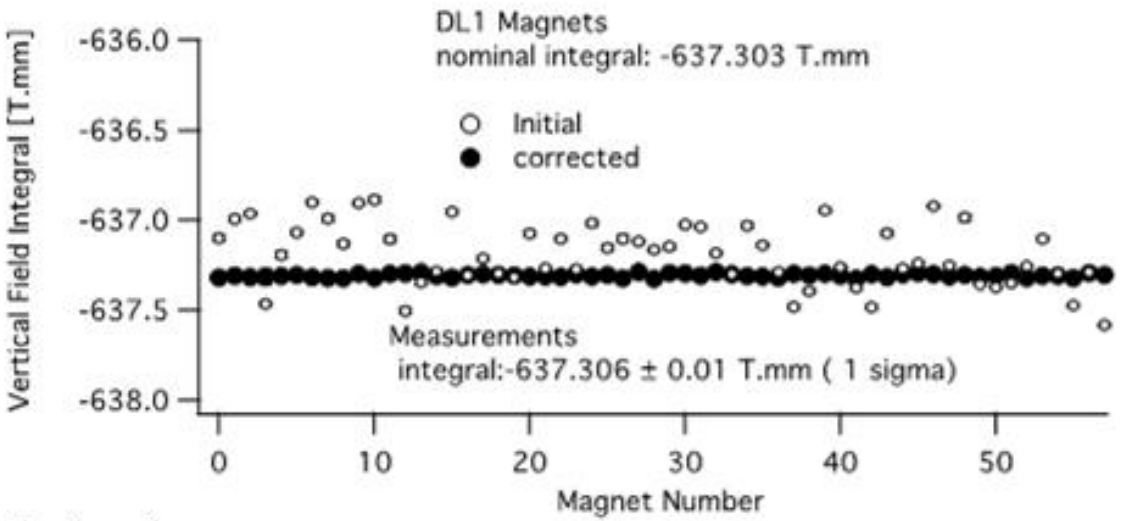
A Light For Science

Dipoles with longitudinal gradient

- 5 modules/DL: 5 field steps
- Length: 1.85 m
- 128 units (64 DL1, 64 DL2)
- PM material: Sm_2Co_{17} ~ 12000 blocks
- Construction completed in September 2017



Movable flux shunt, fine adjustment



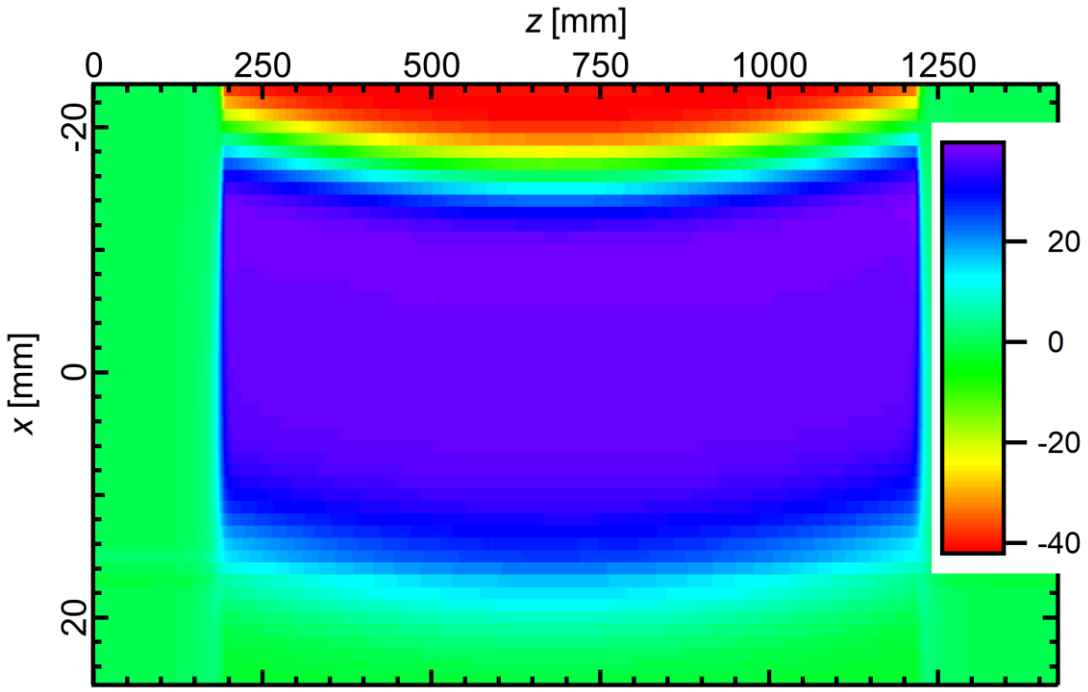
Passive temperature compensation, FeNi flux shunts : Temp. Coef < 20 ppm/C

Courtesy Joël Chavanne

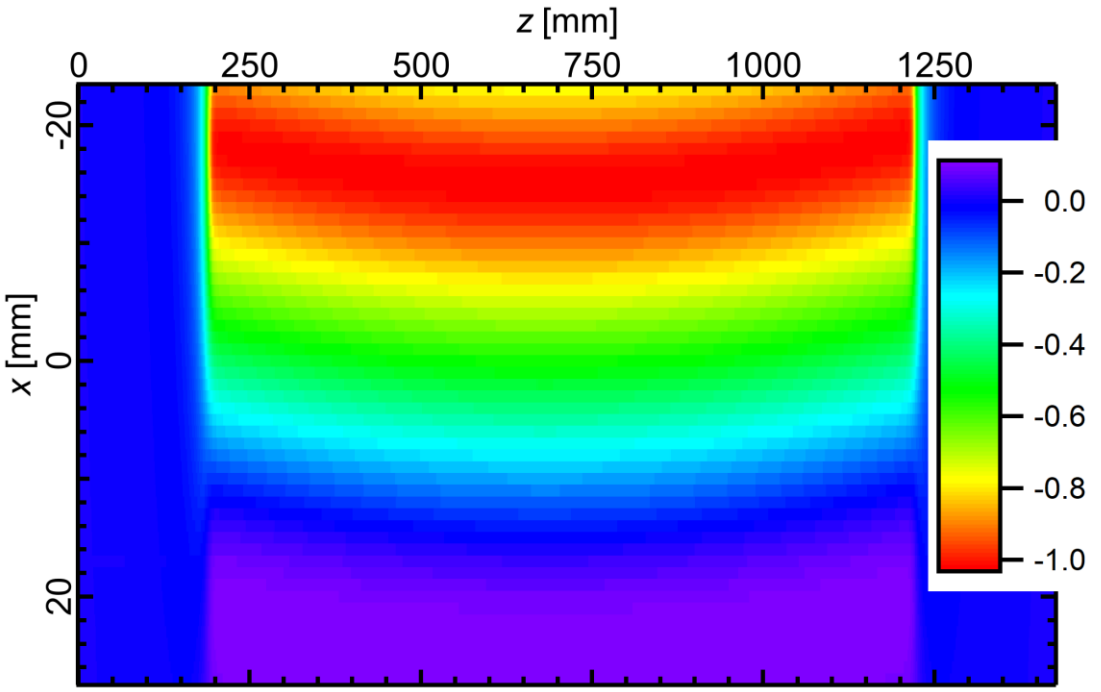
DQ Measurements

Dipole-Quadrupole (DQ) field and gradient (Hall probe)

Gradient



Field



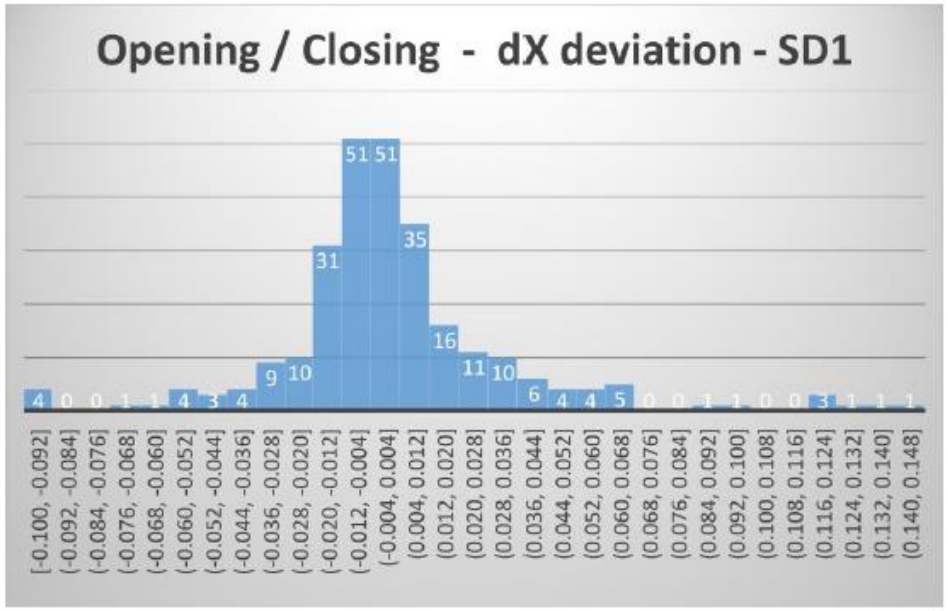
- Get the magnetic length
- Not precise enough to get all the multipoles

Courtesy Gaël Le Bec

Fiducialization

Fiducialization

A Light For Science

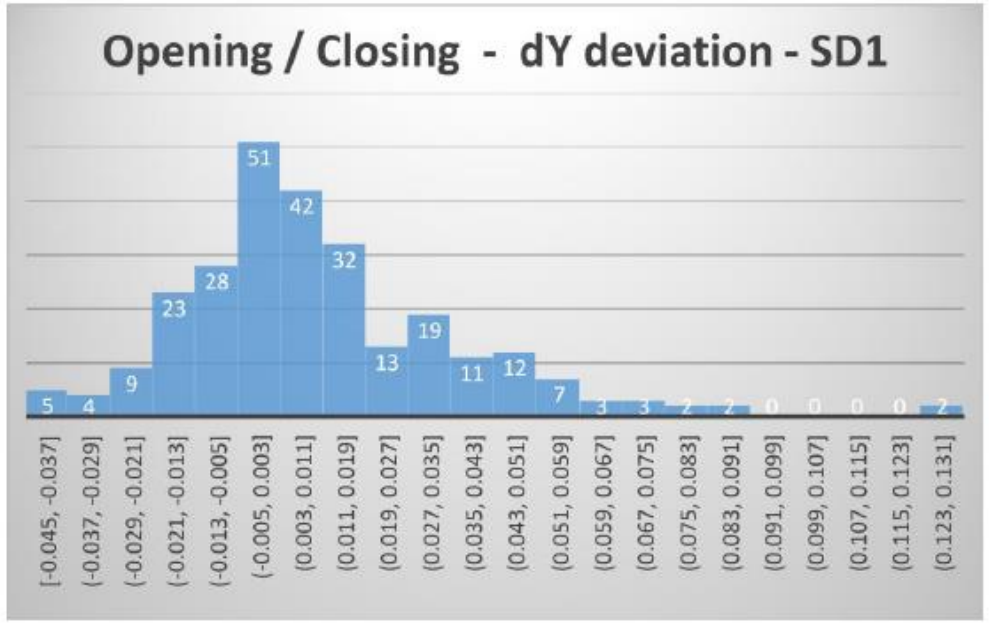


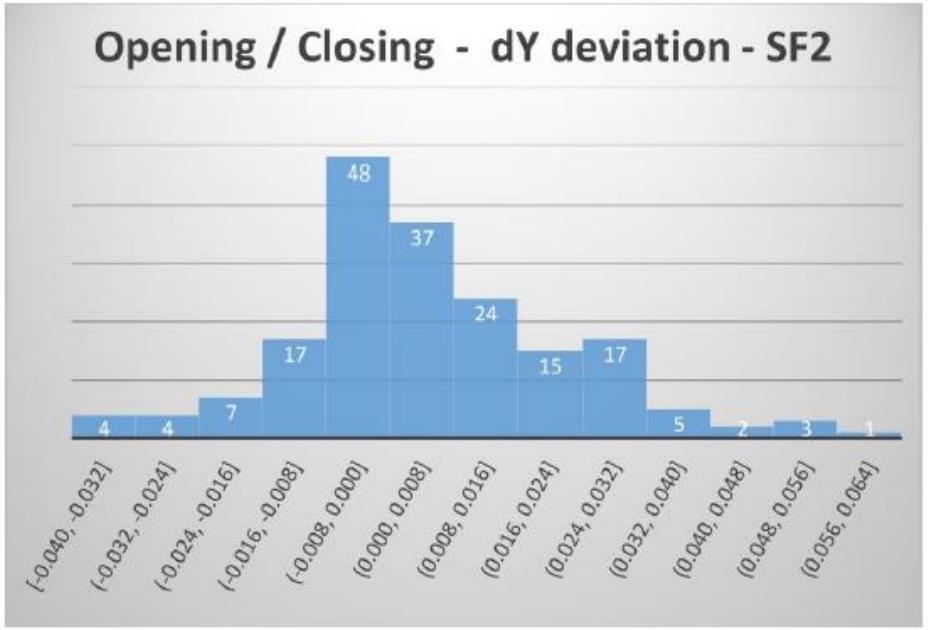
dX – SD1 (mm)	
Min	-0.100
Max	0.143
Average	0.002
Std	0.033

dX – SF2 (mm)	
Min	-0.035
Max	0.098
Average	0.010
Std	0.021

Fiducialization

A Light For Science





dY – SD1 (mm)	
Min	-0.045
Max	0.130
Average	0.011
Std	0.026

dY – SF2 (mm)	
Min	-0.040
Max	0.058
Average	0.005
Std	0.017

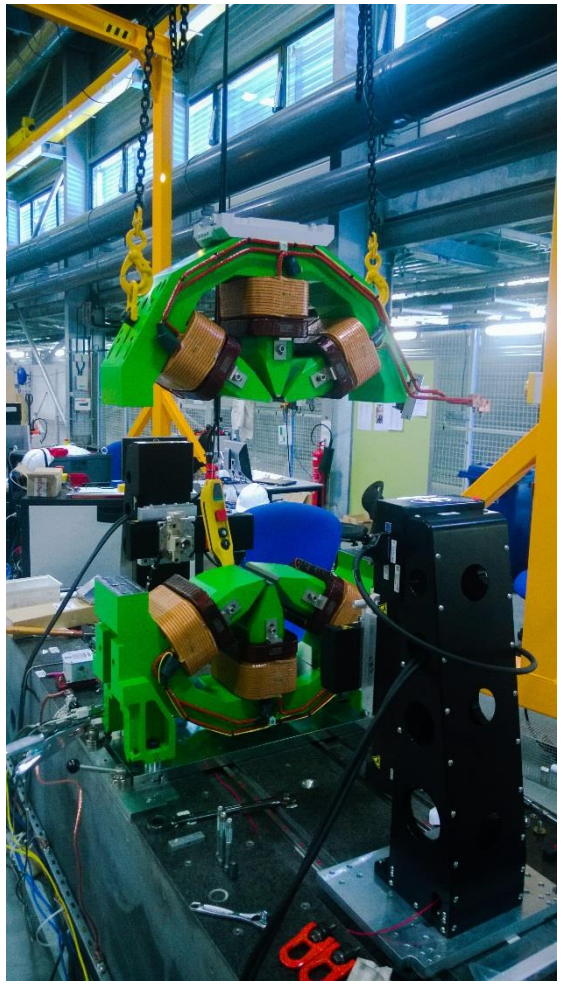
Fiducialization

A Light For Science

dZ – SD1 (mm)	
Min	-0.028
Max	0.013
Average	-0.001
Std	0.007

dZ – SD1 (mm)	
Min	-0.021
Max	0.015
Average	0.000
Std	0.006

Fiducialization



67 SD1 magnets were analysed for this study.
15 (22%) of the SD1 magnets have planimetric reassembly repeatability errors larger than 50µm.

46 SF2 magnets have been analysed for this study.
4 (9%) of the SF2 magnets have planimetric reassembly repeatability errors larger than 50µm.

47 QD3 magnets were analysed for this study.
No QD3 magnets have planimetric reassembly repeatability errors larger than 50µm.

Feedback and conclusion

- **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
- **Fiducialization**
  - Issues with FARO/Romer Arm
  - Must guarantee a good follow-up every week with a reference magnet
  - Can reveal issues on the design – take time with technicians at each state (power supply, mechanical, vacuum…) to listen to their advices.
- **What we do next ?**

→Bench installation, bug corrections
Measurement follow-up is quite challenging but once everything is settled we have now time to develop new tools and technics.

→Sextupole correctors and refurbishment of IDs is the next step

THANK YOU

FOR YOUR ATTENTION

IDM Group @ ski - 2018