Accelerator Magnet Design,

Optimization, Measurement,

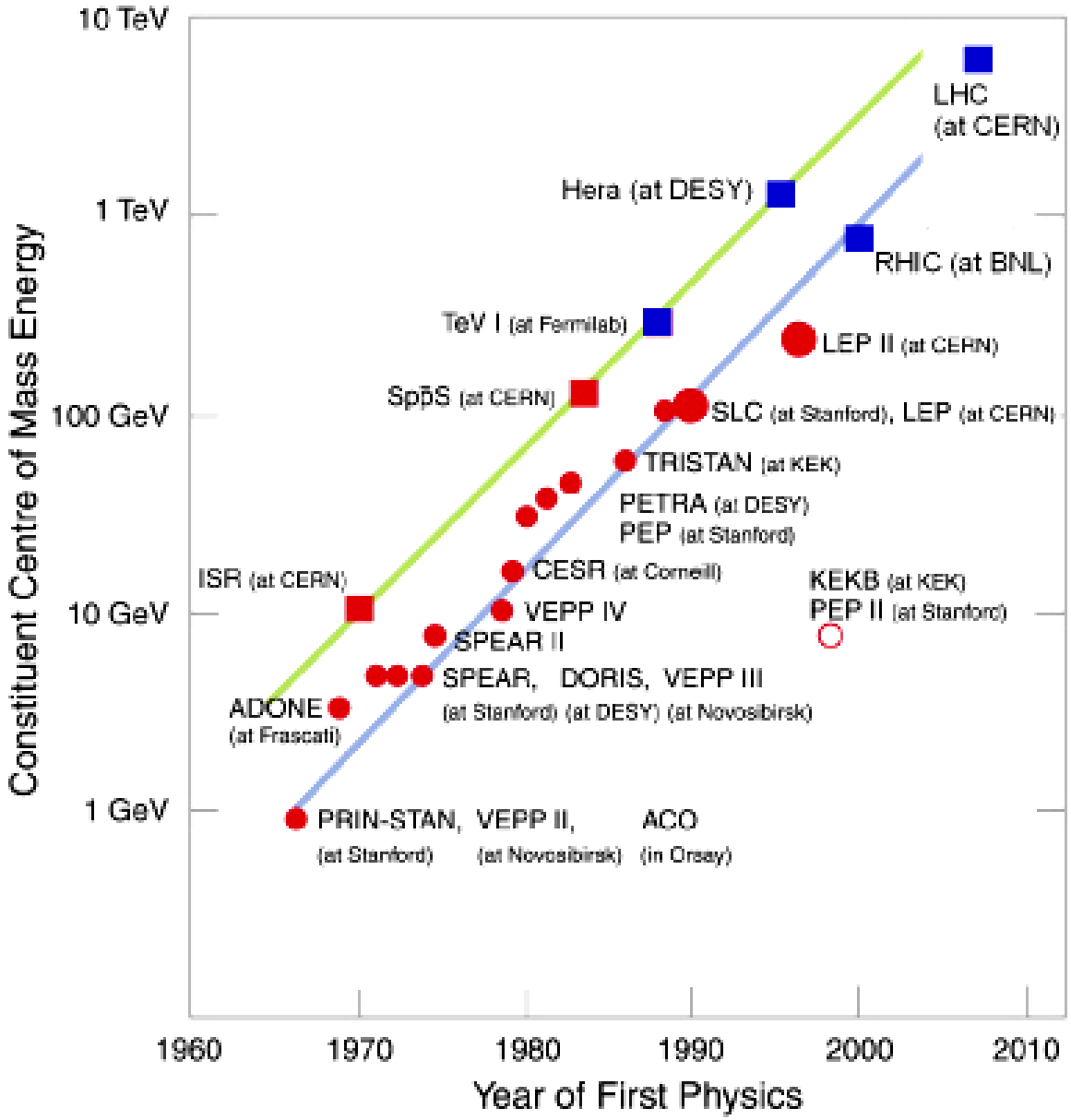
Quality Assurance, Commissioning

S. Russenschuck

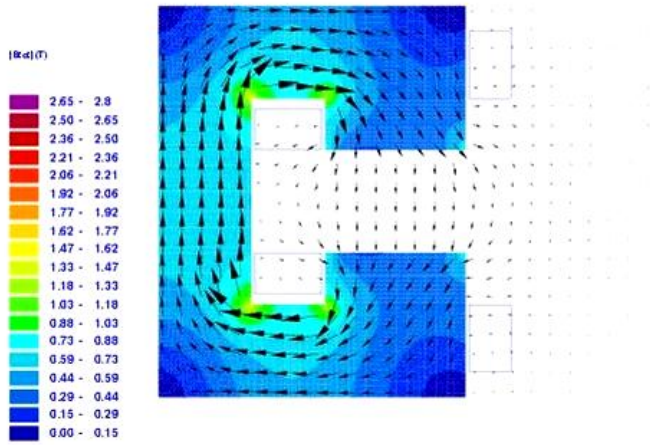
CERN TE-MSC-MM

JUAS 2012

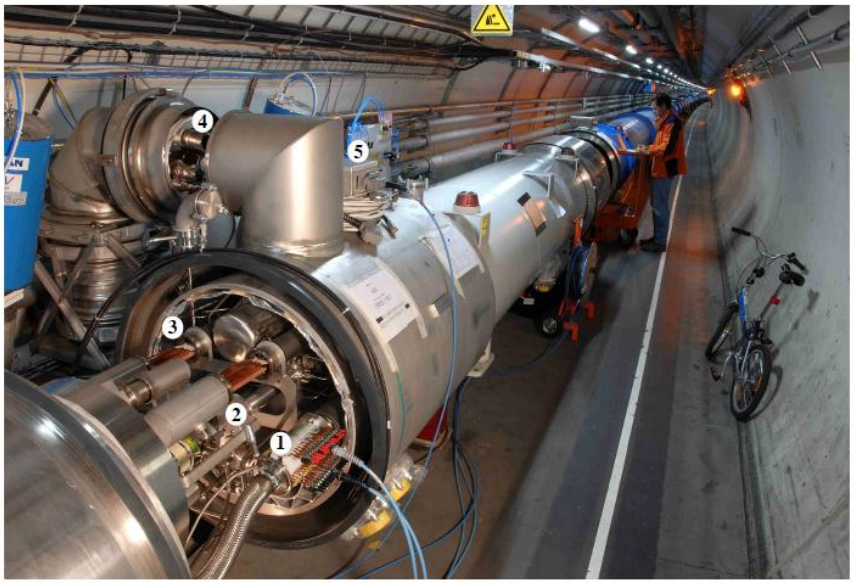
Livingston Plot

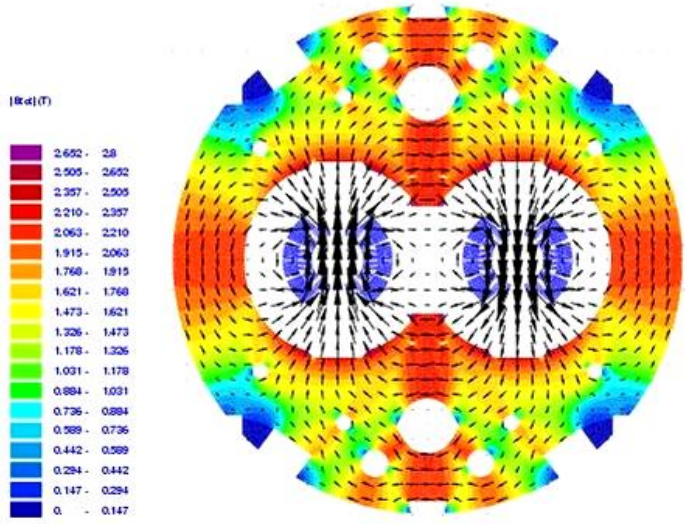


Normal Conducting Versus Superconducting Accelerator Magnets



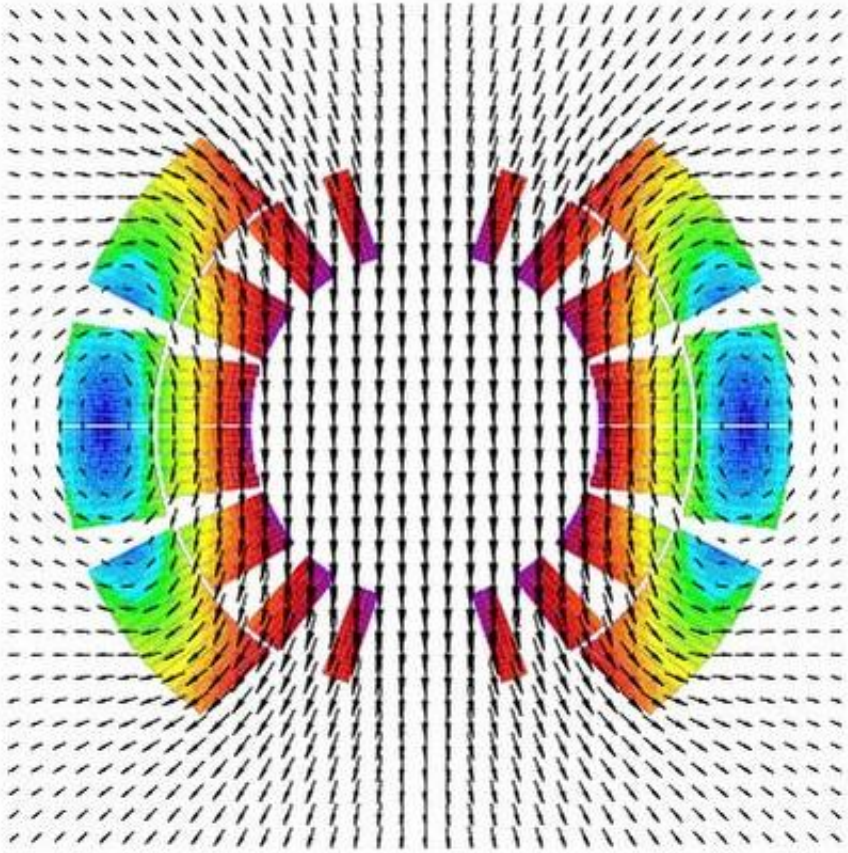
$N \cdot I = 4480$ A $\quad B_1 = 0.13$ T $\quad B_s = 0.042$ T $\quad$ Fill.fac. 0.27



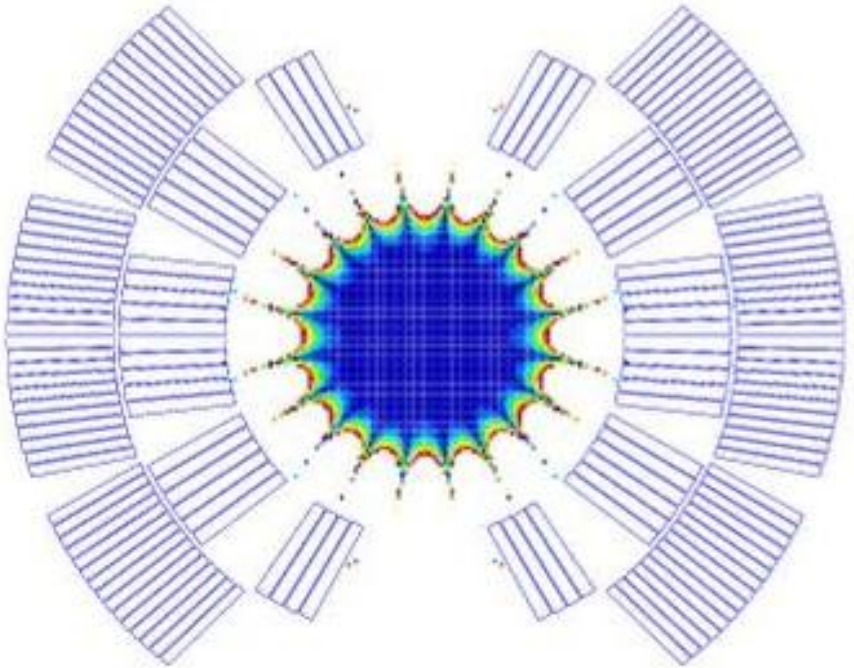


$N \cdot I = 2x944000$ A $\quad B_1 = 8.32$ T $\quad B_s = 7.44$ T

Field Quality

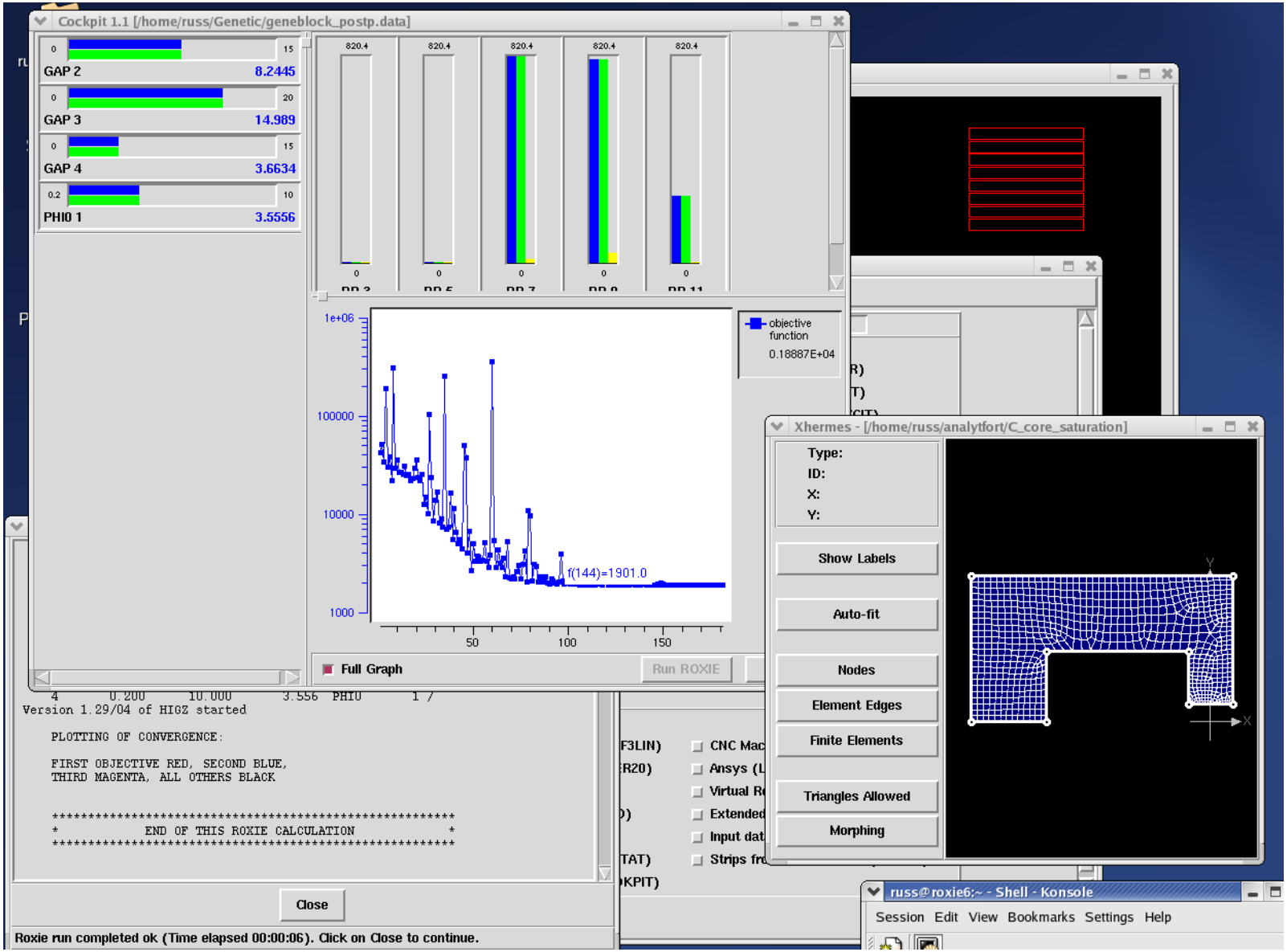


Field map



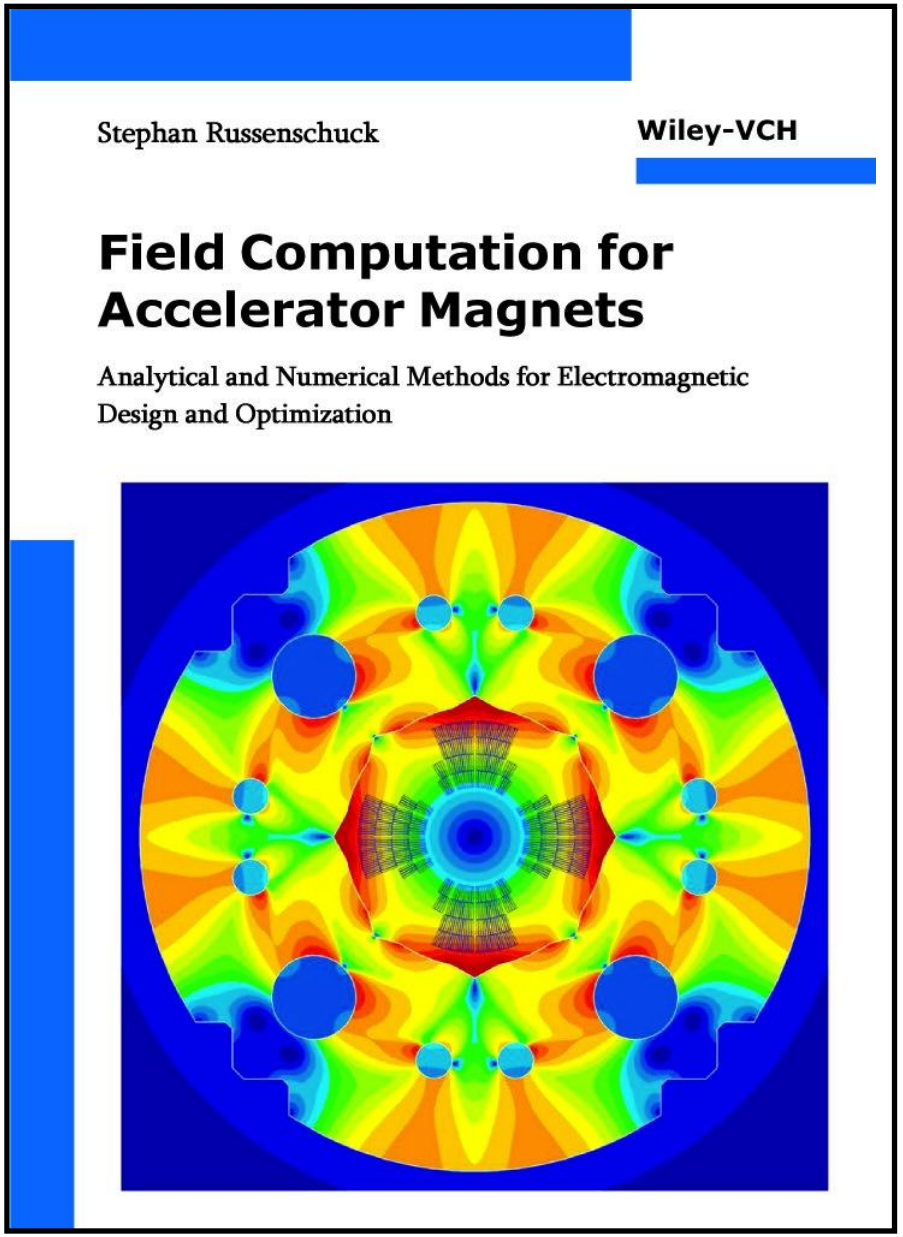
Good field region

ROXIE User's Interface



Analytical and Numerical Field Computation

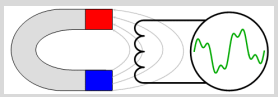
- Linear Algebra
- Vectoranalysis
- Harmonic Fields
- Green's functions and imaging currents
- Complex analysis
- Differential geometry
- Numerical field computation
- Hysteresis modeling
- Coupled Systems
- Mathematical optimization



1	2	3	4	5	6
JUAS 2012	Monday Feb 20th	Tuesday Feb 21st	Wednesday Feb 22nd	Thursday Feb 23rd	Friday Feb 24th
9:00					
	Magnets design lecture *S. Russenschuck*	**Magnets design** lecture *S. Russenschuck*	**Superconducting magnets** lecture *M. Wilson*	**NC MAGNETS** **COMPUTER WORK**	
10:00 10:15	**Coffee Break**	**Coffee Break**	**Coffee Break**	**Coffee Break**	***Bus leaves at 8h30 at JUAS***
	Magnets design lecture *S. Russenschuck*	**Magnets design** lecture *S. Russenschuck*	**Superconducting magnets** tutorial *M. Wilson*	**NC MAGNETS** **COMPUTER WORK**	**PRACTICAL WORKS AT CERN**
11:15	**Magnets design** lecture *S. Russenschuck*	**Magnets design** lecture *S. Russenschuck*	**Superconducting magnets** lecture *M. Wilson*		
12:15	**LUNCH**	**LUNCH**	**LUNCH**	**LUNCH**	
14:00	**Normal Conducting magnets** lecture *T. Zickler*	**Superconducting magnets** lecture *M. Wilson*	**Superconducting magnets** lecture *M. Wilson*	**SC MAGNETS** **COMPUTER WORK**	**1) RF** **2) VACUUM** **3) MAGNETS** **4) CRYOGENY**
15:00	**Normal Conducting magnets** lecture *T. Zickler*	**Superconducting magnets** lecture *M. Wilson*	**Mini workshop magnets** *S. Russenschuck*	*. Russenschuck*	
16:00 16:15	**Coffee Break**	**Coffee Break**	**Coffee Break**	**Coffee Break**	
	Normal Conducting magnets lecture *T. Zickler*	**Superconducting magnets** tutorial *M. Wilson*	**Mini workshop magnets** *S. Russenschuck*	**Seminar Effects of radiation in particle accelerators** *R. Losito*	***Return scheduled at 18h30***
17:15					

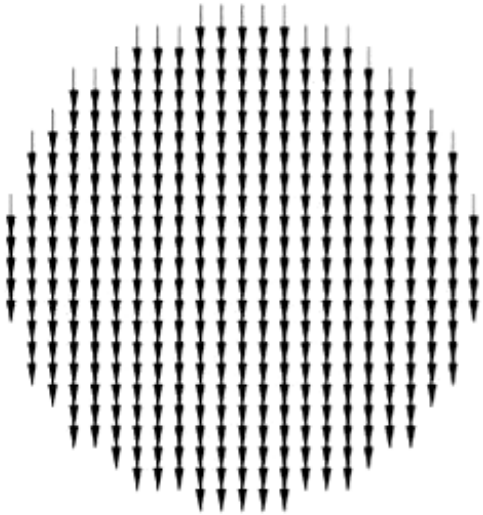
Expected "Training" Results for Thursday

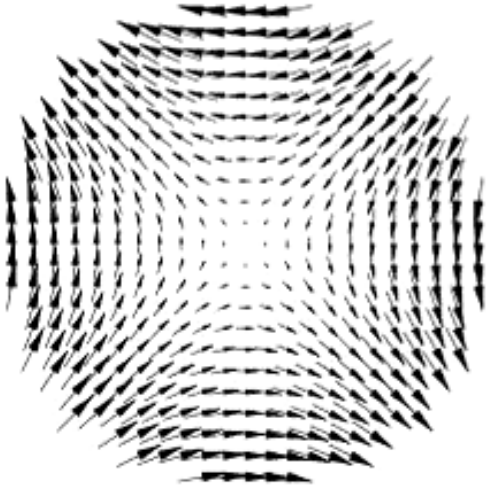
- Normal conducting magnets
  - Scaling of excitation currents and iron saturation
  - Multipole components
  - Position of the excitation coil
  - Pole shape
  - Yoke thickness
  - Reduced field
- Superconducting magnets
  - Imaging method
  - Reduced field
  - Saturation and yoke dimension
  - Sensitivity to coil-block deformations
  - Scaling of multipoles
  - Feed-down

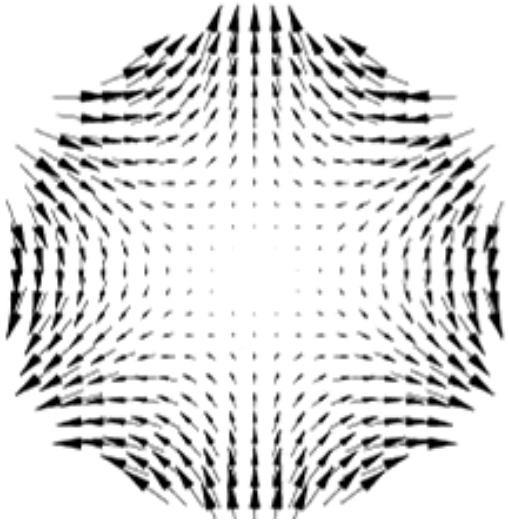


Series Measurements of the LHC Magnets

Dipole, Quadrupole, and Sextupole

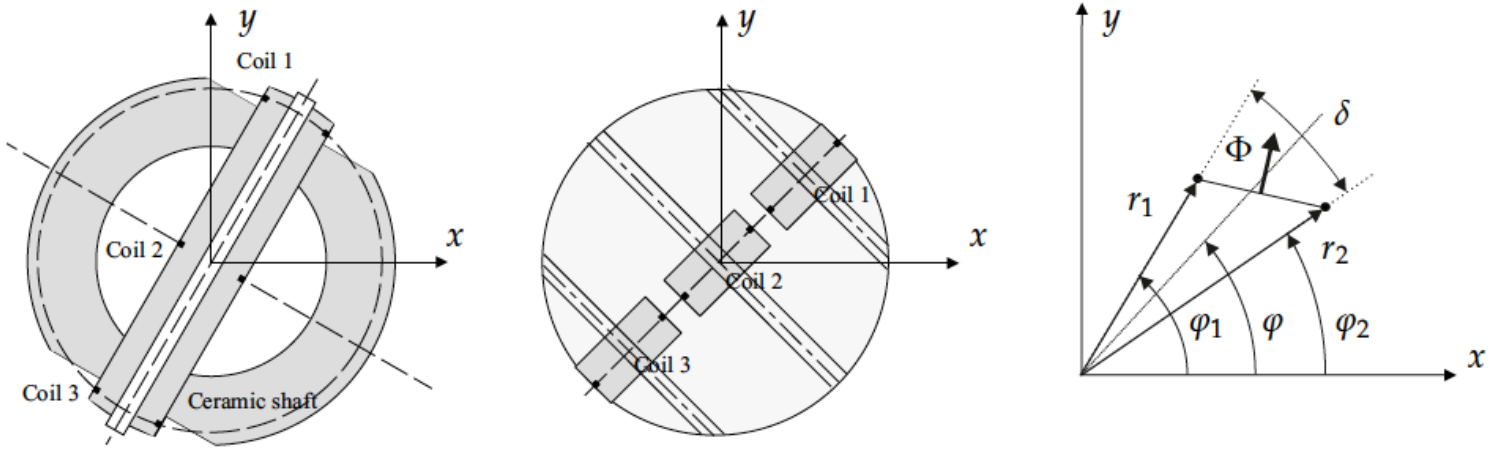






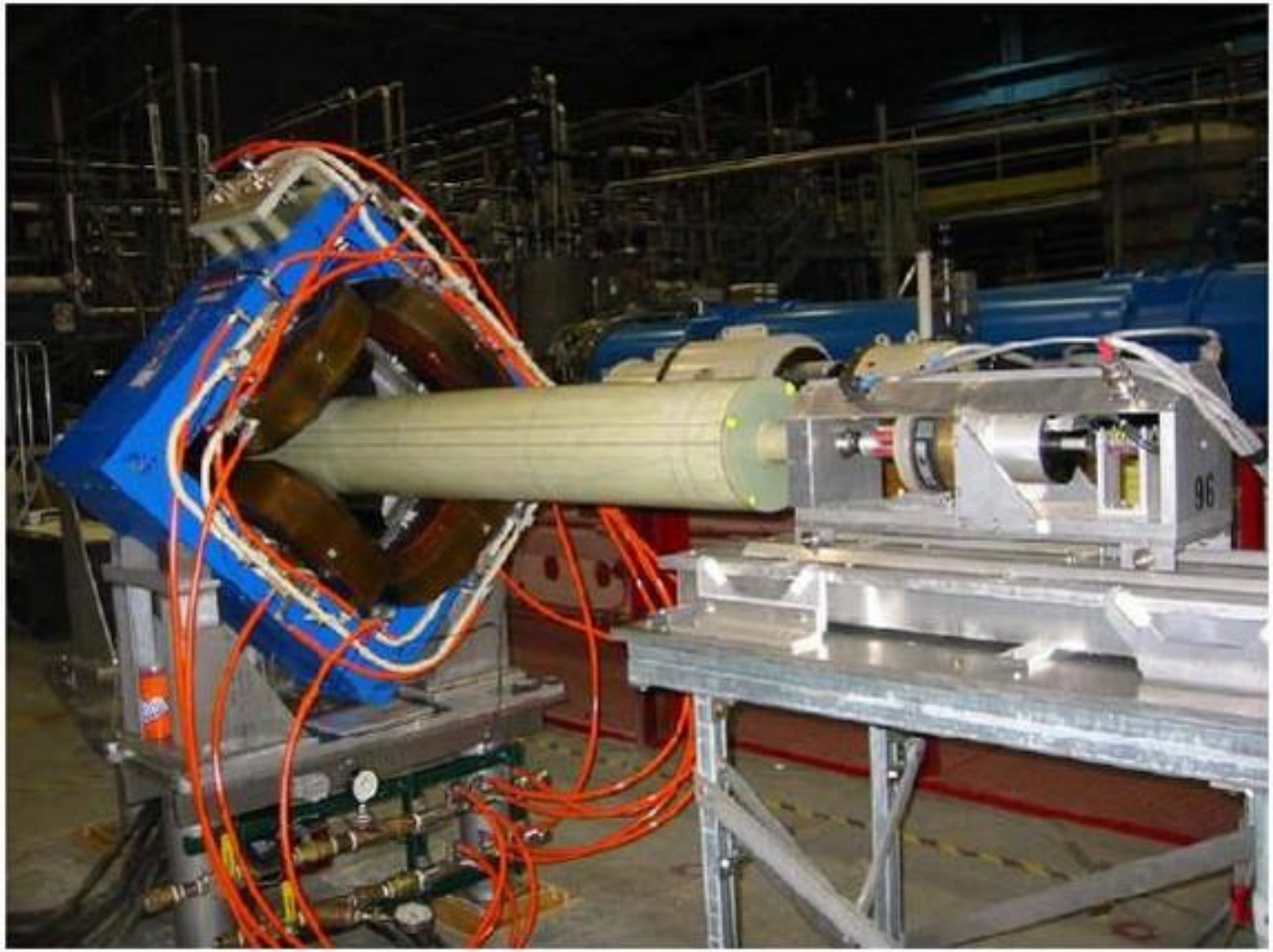
Harmonic Fields 4: Field Probes, Flux loops

$$\Phi = N \int_{\mathscr{A}} \mathbf{B} \cdot \mathrm{d}\mathbf{a} = N \int_{\mathscr{A}} \operatorname{curl} \mathbf{A} \cdot \mathrm{d}\mathbf{a} = N \int_{\partial \mathscr{A}} \mathbf{A} \cdot \mathrm{d}\mathbf{r} = N\ell \left[A_z(\mathscr{P}_1) - A_z(\mathscr{P}_2) \right],$$

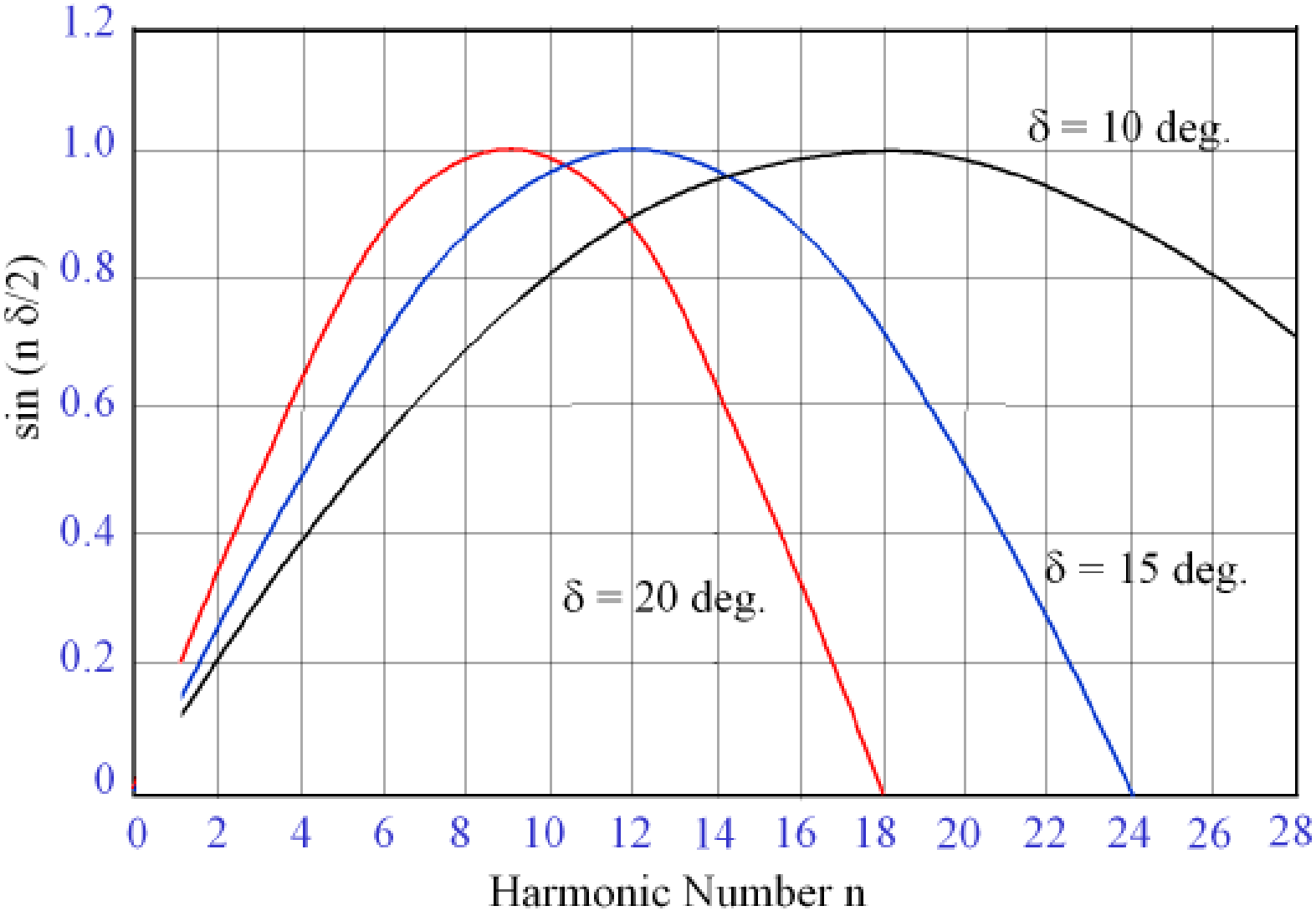


$$\Phi(\varphi(t)) = \sum_{n=1}^{\infty} \frac{\ell}{r_0^{n-1}} \left[K_n^{\mathrm{rad}} \left(B_n(r_0) \cos n\varphi - A_n(r_0) \sin n\varphi \right) + K_n^{\tan} \left(B_n(r_0) \sin n\varphi + A_n(r_0) \cos n\varphi \right) \right],$$

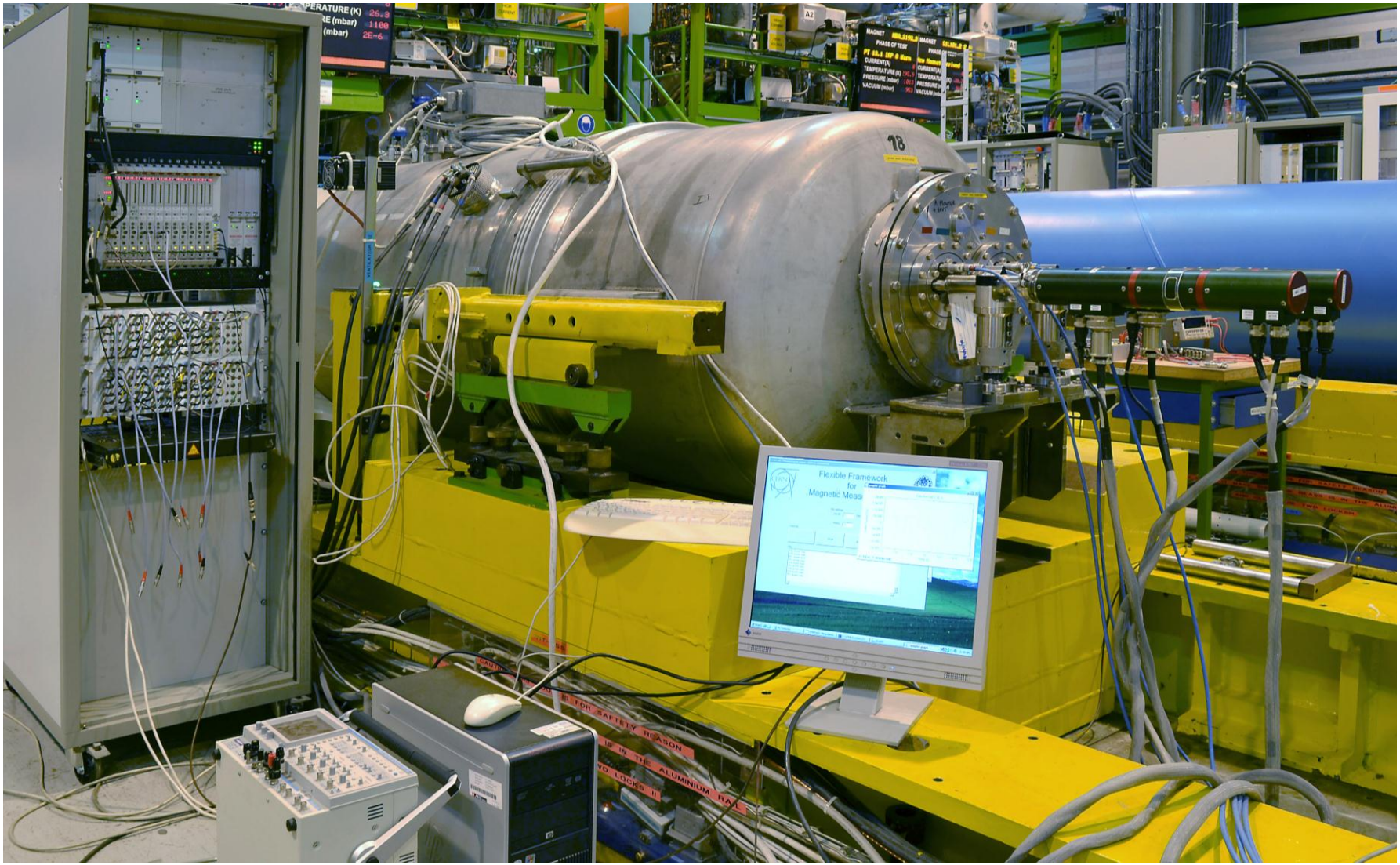
Rotating Coil Measurements: Calibration



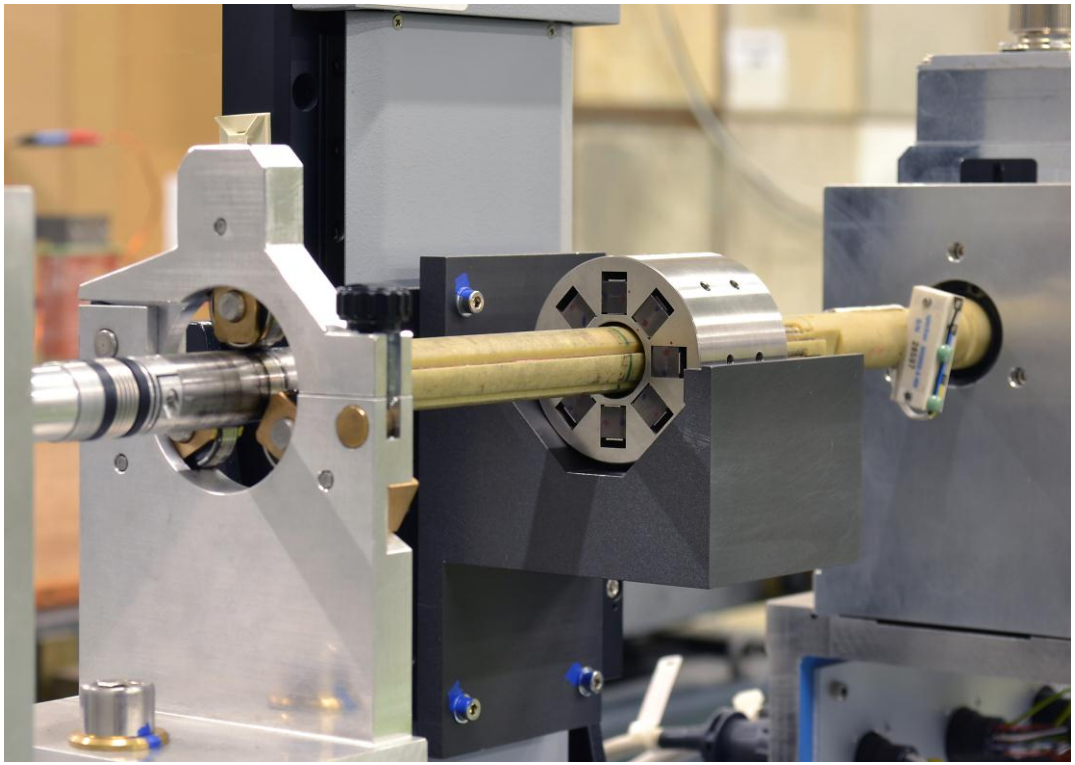
Opening Angle of Rotating Coils



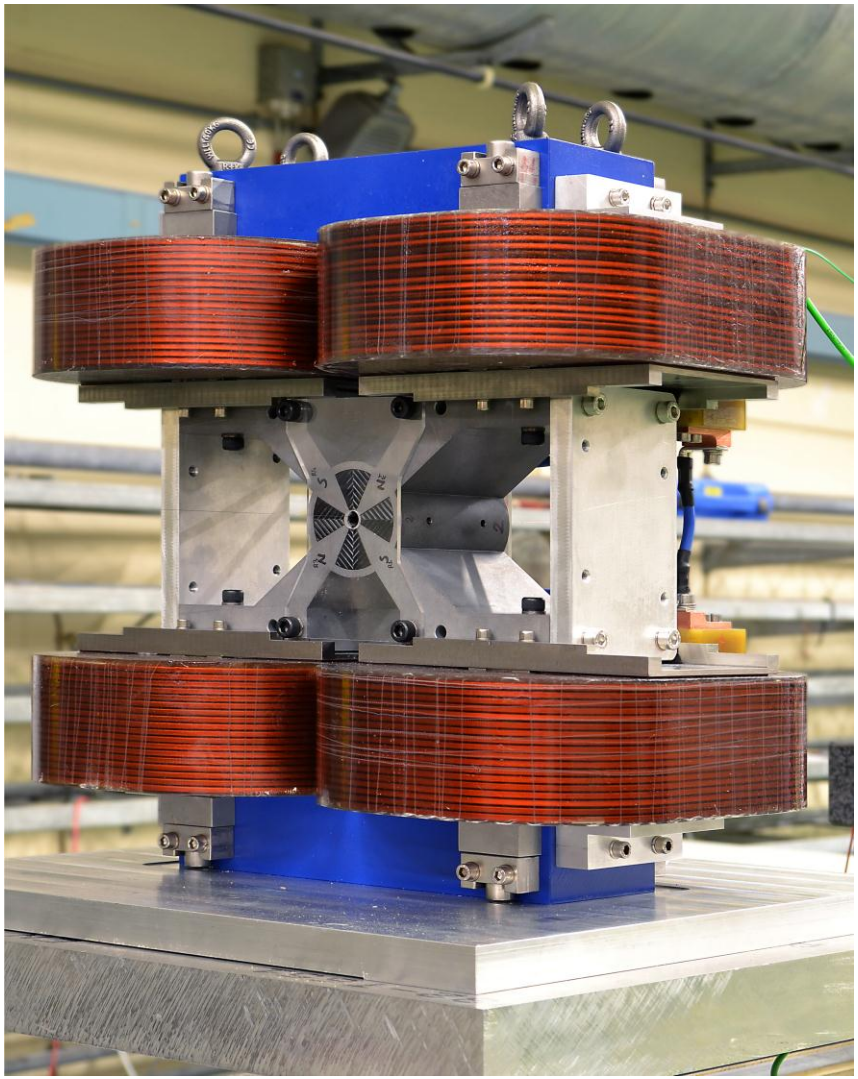
Rotating Coil Measurements



Magnetic Field Measurements



Rotating coil measurement system



Stretched wire

Practical Work on Normal-Conducting Magnets

- Introduction to different magnet types
- Manufacturing technologies
  - Coil
  - Yoke
  - Auxiliary parts: Interlock, cooling, alignment targets
  - Materials in NC magnets

- Practical work – Quality assurance
  - Tests and measurements during and after production