A NEW DATA ACQUISITION SOFTWARE AND ANALYSIS FOR ACCURATE MAGNETIC FIELD INTEGRAL MEASUREMENT AT BNL INSERTION DEVICES LABORATORY

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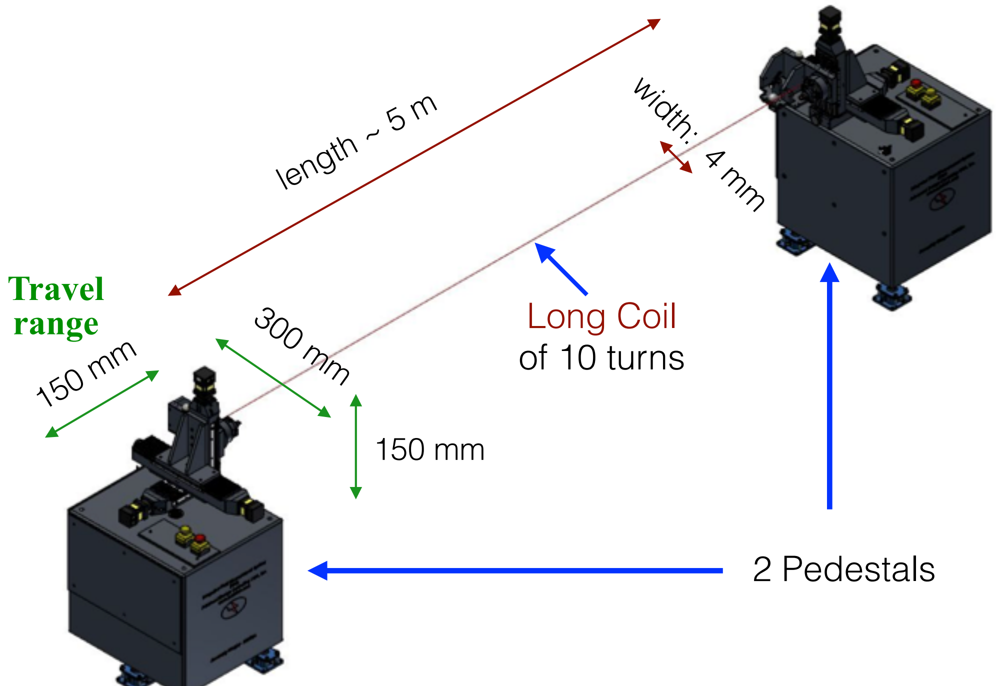
Germany

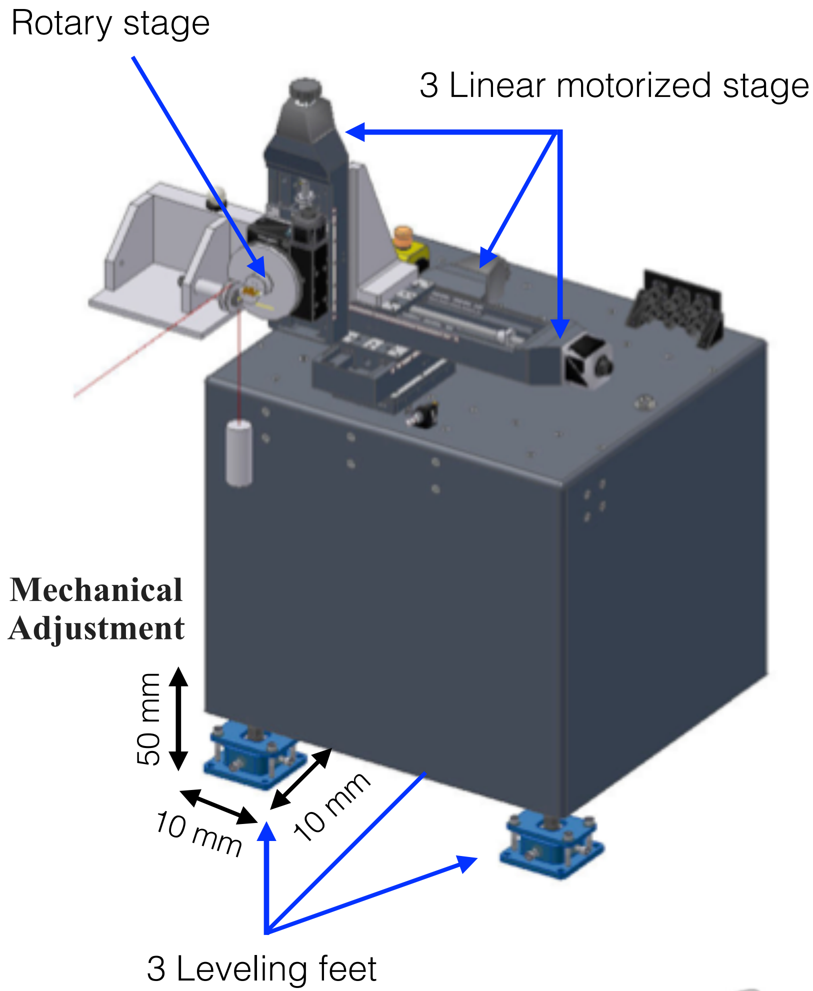
Outline

- IFMS Overview
- Measurement Techniques
- Data Acquisition Software
- Magnetic Performance & Results
- Conclusion

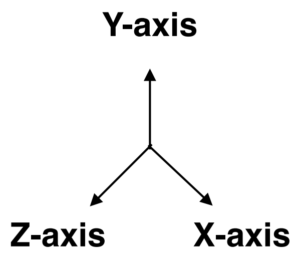
IFMS Overview

IFMS: Integrated Field Measurement System*





- Reference surface flatness ±5 µm.
- Weight of each granite support: 1580 kg



*supplied by ADC USA, Inc

IFMS Overview

Delta Tau GeoBrick PMAC-2

Motion Controller

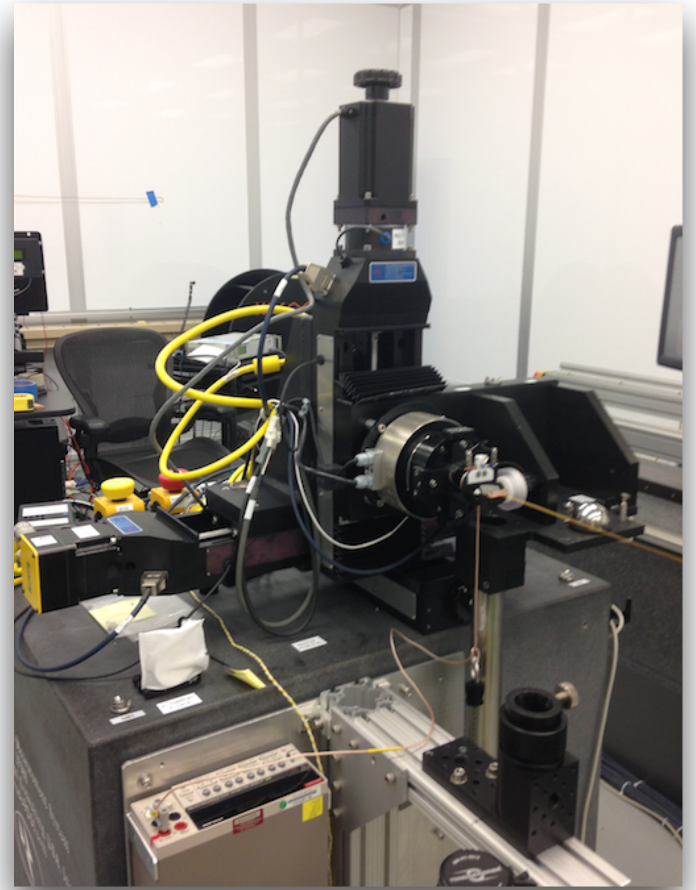
- *Eight servomotors*
- *master-slave configuration*
- *Closed loop mode*
- *Limit/home switches*

Linear X, Y and Z stages:

Encoder resolution: 0.1 µm
Absolute accuracy: ±1 µm
Pitch and yaw angles: ± 50 µrad

Rotary stage:

Full 360° capacity
Encoder resolution: 0.005 deg
Angular accuracy: ≤ 40 arc sec
Angular repeatability: ≤ 2 arc sec



Keithley DMM 2701

Digital Multimeter

- 6½-digit (22-bit) resolution
- Serial communication RS-232
- Integration time 16.67 ms (1 PLCs)
- Repeating average digital filter

Measurement Techniques

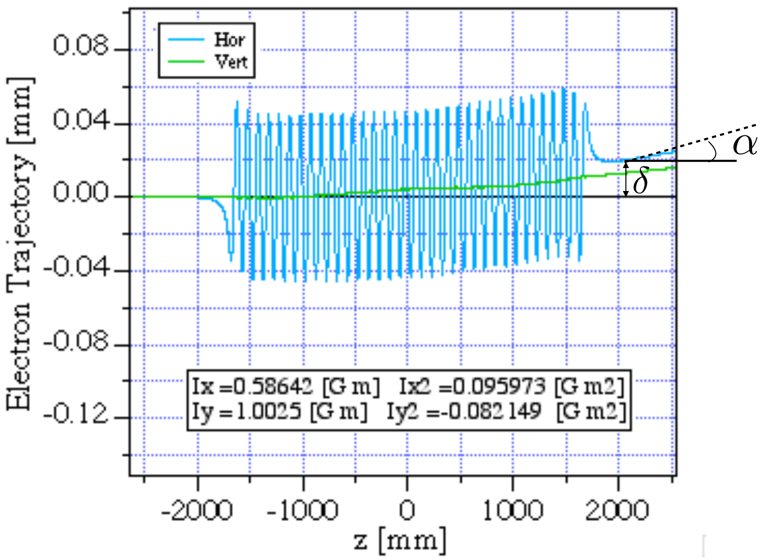
Integrals of the transverse field components Bx and By along the longitudinal axis Z

First Field Integrals: [G m]

$$I_x(x) = \int_{-\infty}^{+\infty} B_x(z)dz \qquad I_y(x) = \int_{-\infty}^{+\infty} B_y(z)dz$$

Second Field Integrals: [G m²]

$$II_x(x) = \int_{-\infty}^{+\infty}\int_{-\infty}^{z} B_x(z')dz'dz \qquad II_y(x) = \int_{-\infty}^{+\infty}\int_{-\infty}^{z} B_y(z')dz'dz$$



2.4 m Damping Wiggler λ_p= 100 mm, 1.8 T

The field integrals can be used to calculate the electron's final position and angle:

net change in angle: $$\alpha = \frac{e}{\gamma m_0 c} I_y$$

net change in position: $$\delta = -\frac{e}{\gamma m_0 c} II_y$$

same for Ix,IIx

We want to minimize the net effect on the electron trajectory

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Measurement Techniques

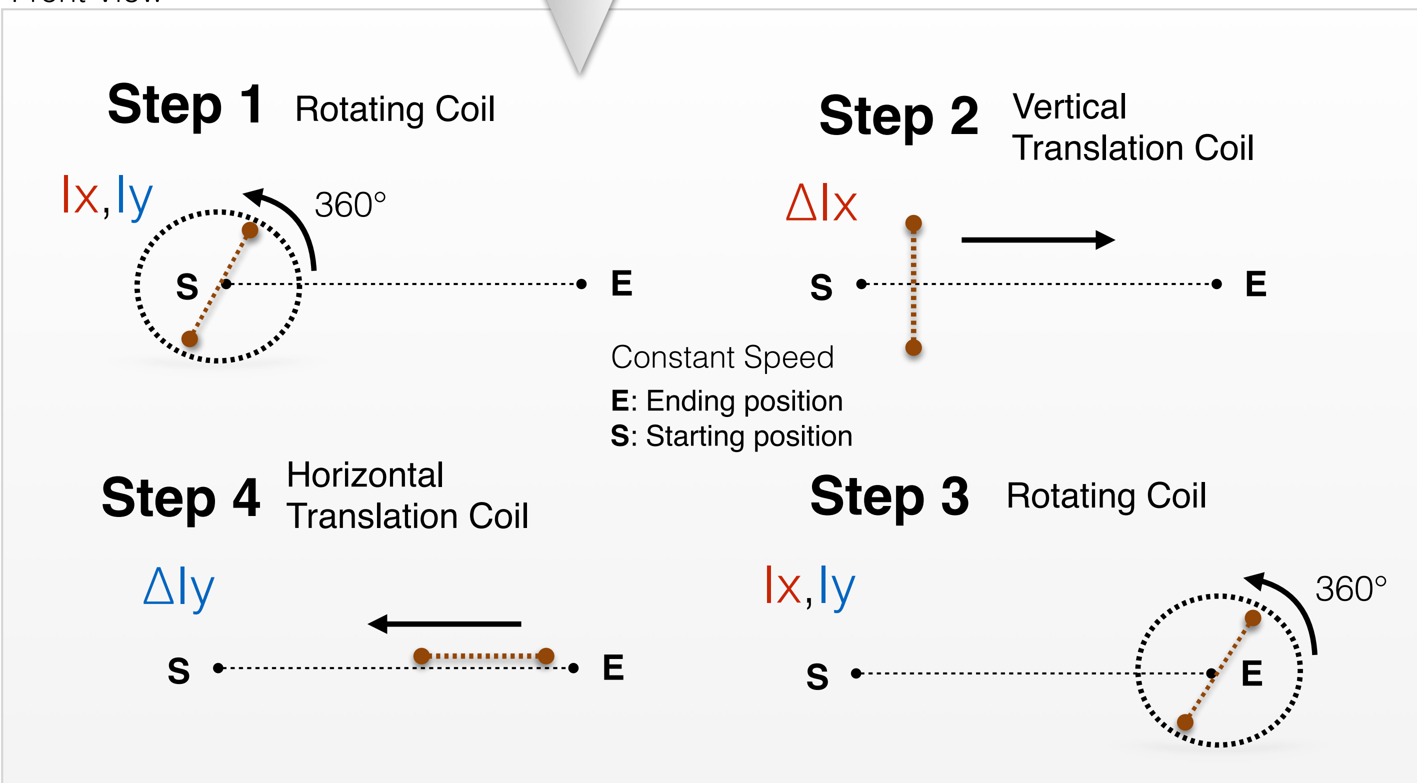
Accuracy σ
Measurement Time

2 methods

2 methods	Advantages	Disadvantages
"Point-by-Point" Measurement	**3 G cm**	**~ 15 minutes**
"On-the-Fly" Measurement	**~ 3 mins**	**5 G cm**

using 30 mm range, step 1 mm and a scan speed of 55 mm/s

Front View



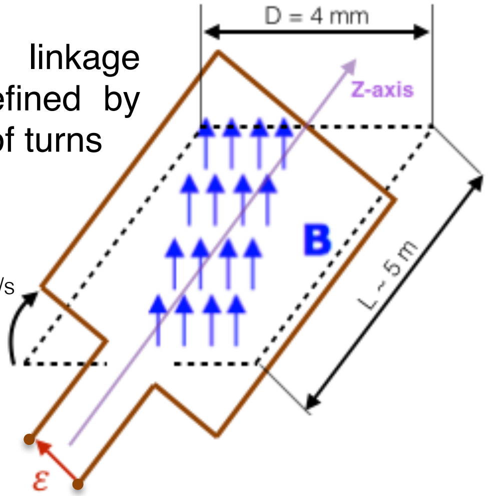
Measurement Techniques

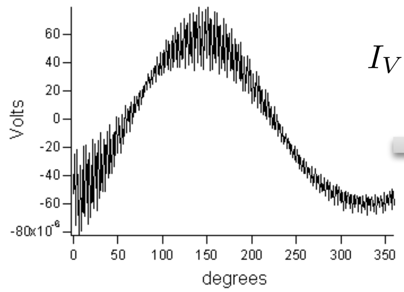
Rotating Coil

Φ is the magnetic flux linkage through the surface defined by the coil, with N number of turns

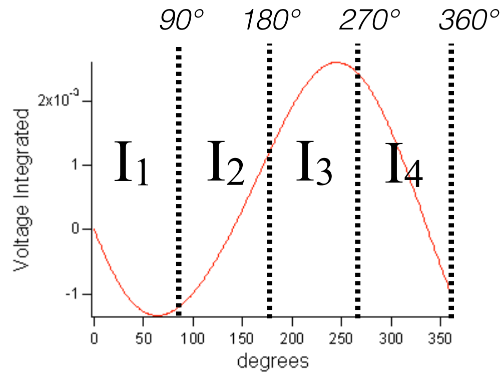
$$\epsilon = -N\frac{d\Phi}{dt}$$

Faraday's Law



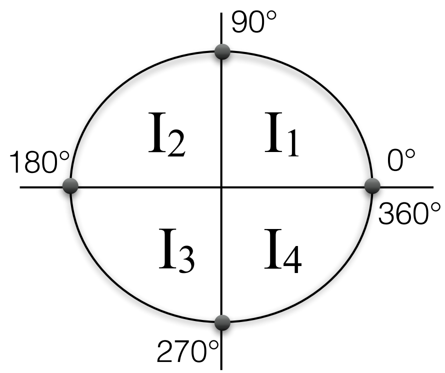


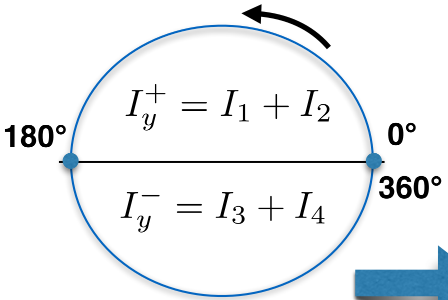
$$I_V = \int_0^{360} \epsilon d\theta$$



$$I_V = I_1 + I_2 + I_3 + I_4$$

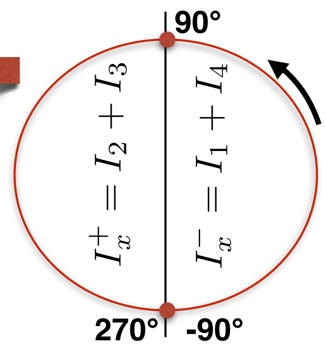
$$\int_{t_1}^{t_2} \epsilon dt \underset{*}{\cong} ND(I_y \int_{\theta_1}^{\theta_2} Sin\theta d\theta + I_x \int_{\theta_1}^{\theta_2} Cos\theta d\theta)$$





$$I_x = \frac{I_x^+ - I_x^-}{2}$$

$$I_y = \frac{I_y^+ - I_y^-}{2}$$



*Assuming that variation of the magnetic field within the width of the coil is small enough

Measurement Techniques

Translation Coil

$$\epsilon = -N\frac{d\Phi}{dt}$$

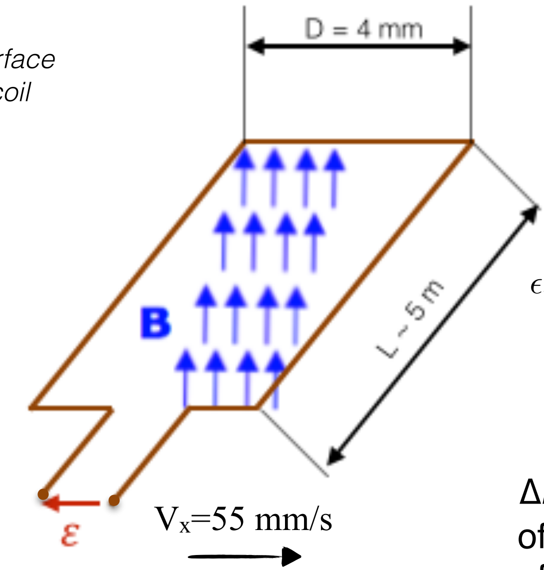
Faraday's Law

$$\epsilon = -N\frac{d}{dt}\int_S (B_y Cos\theta - B_x Sin\theta) dS$$

Measurement of the vertical component

The coil is oriented horizontally

S=DL surface of the coil



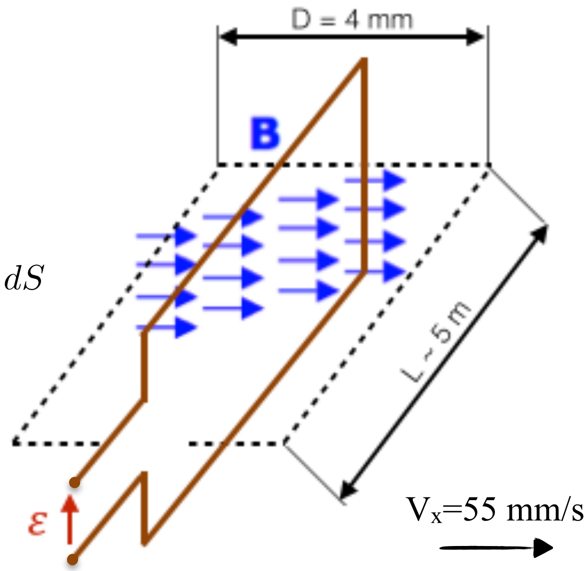
θ=0

$$\epsilon_y = -N\frac{d}{dt}\int_S B_y dS$$

$$\Delta I_y = -\frac{\int \epsilon_y dt}{ND}$$

Measurement of the horizontal component

The coil is oriented vertically

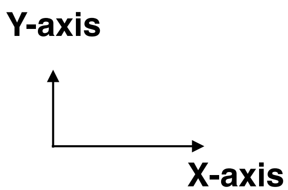


θ=90°

$$\epsilon_x = -N\frac{d}{dt}\int_S B_x dS$$

$$\Delta I_x = -\frac{\int \epsilon_x dt}{ND}$$

ΔIy and ΔIx are the transversal variations of the vertical and horizontal components of the field integral over the distance X scanned during the measurement time.



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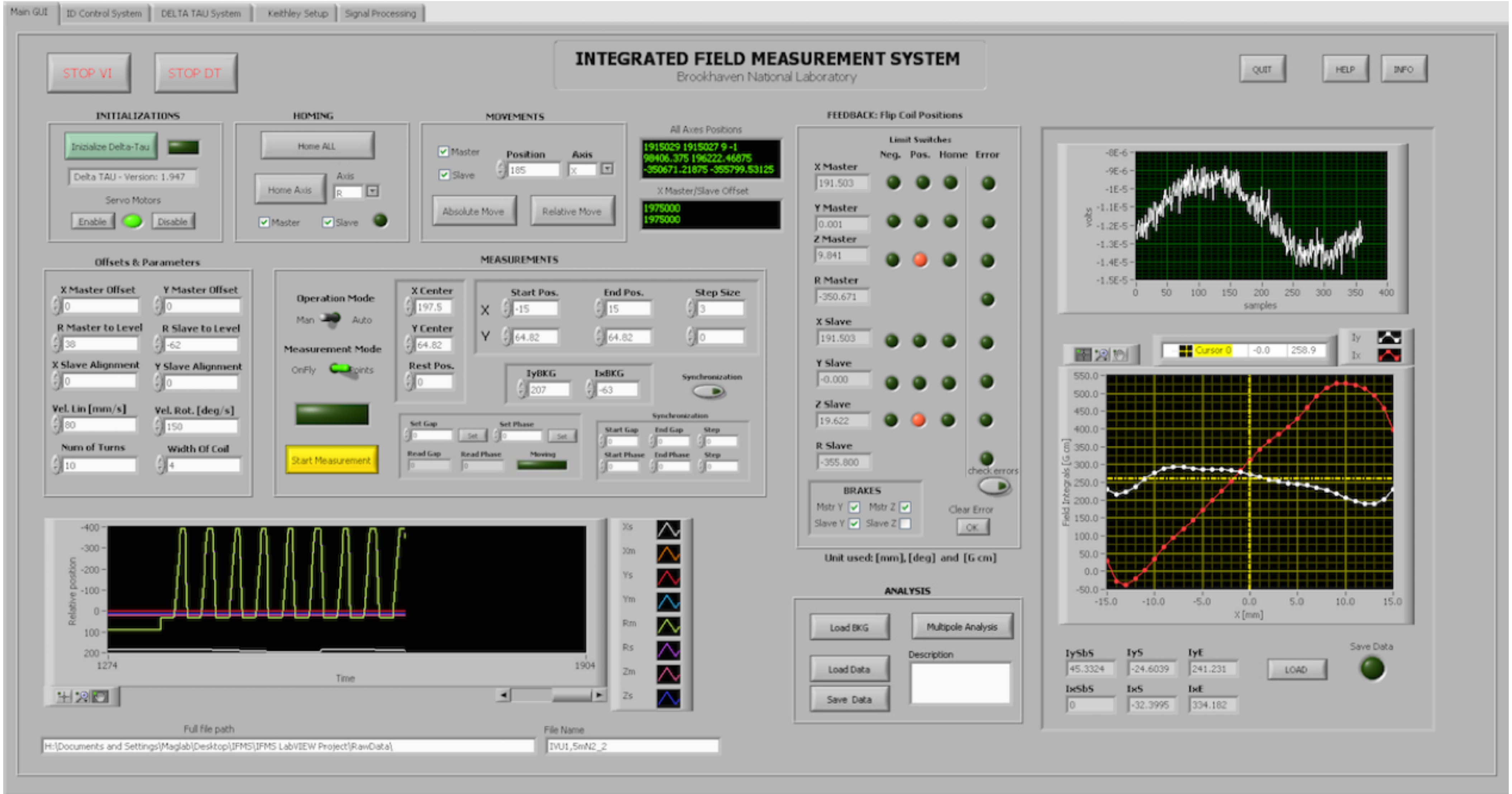
Data Acquisition Software

Although the insertion devices are very different, we strived to find a common design to make them look similar to the operator and to hide the different levels of complexity behind a common user-friendly interface.



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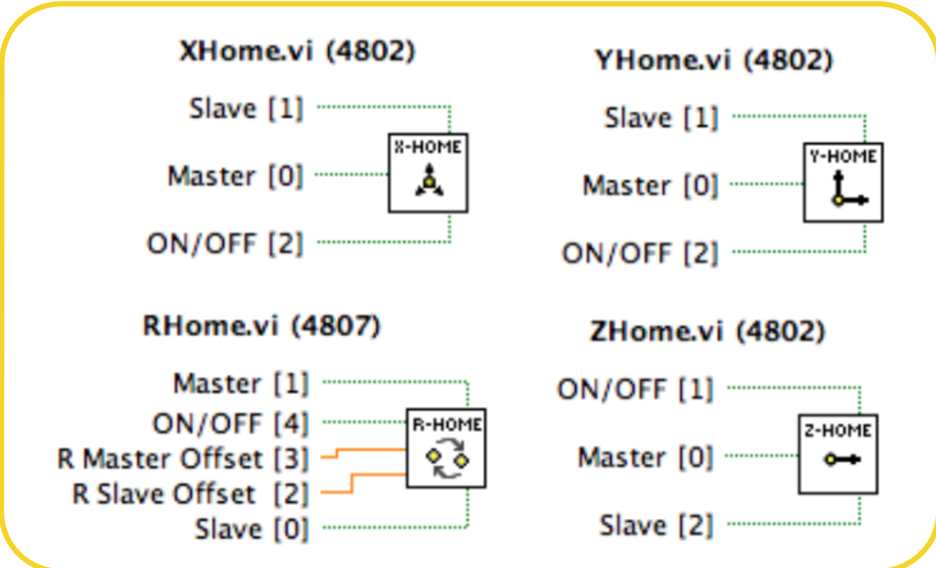
Data Acquisition Software

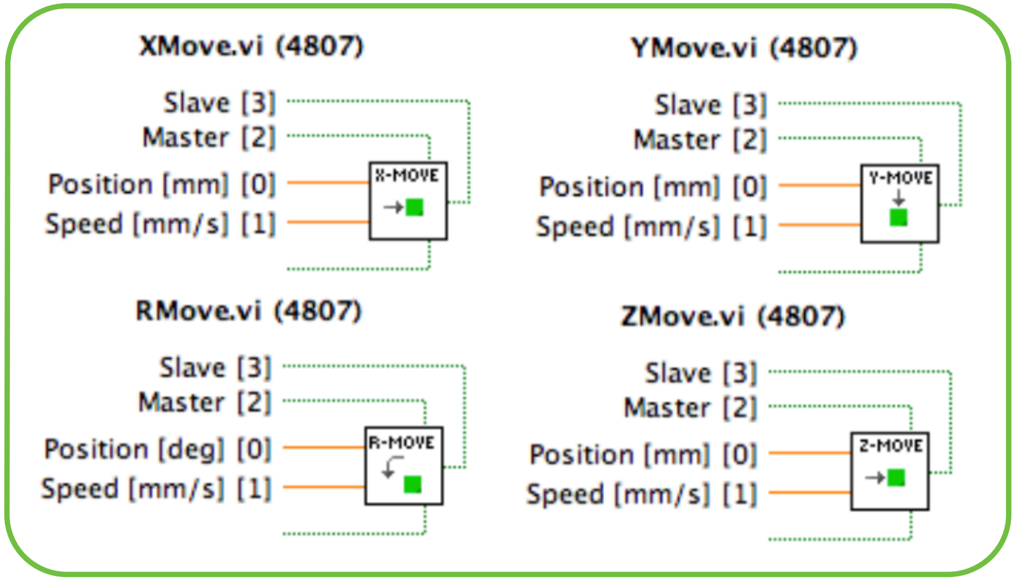
The new software has been developed using a modular programming approach, separating the functionality of the software into independent and interchangeable modules known as **subVIs,** each of which accomplishes everything necessary to execute only one specific aspect of the desired process.

Delta Tau START UP

HOMING

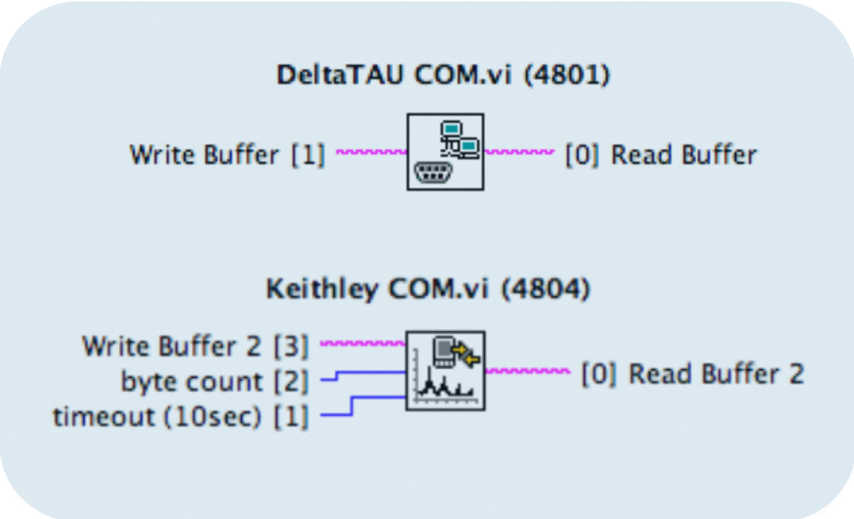


MOVEMENTS



Data Acquisition Software

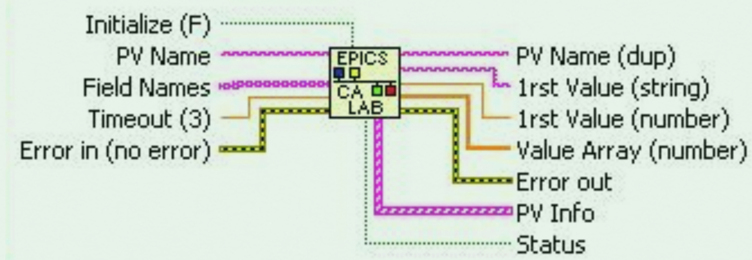
Standard communication serial RS-232 port



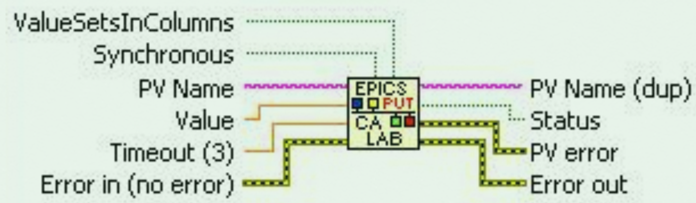
EPICS Experimental Physics and Industrial Control System is a set of collaboratively developed software tools, libraries, and applications used to create distributed real-time control systems. It is used extensively in particle accelerators throughout the world and is the main control system used at **NSLS-II**

The channel access communication between LabVIEW and **EPICS** is created using the **CaLab*** interface

CaLab GET: for reading values of EPICS variables



CaLab PUT: for writing values to EPICS variables



CaLab is a user-friendly, lightweight and high performance interface between LabVIEW™ and EPICS .

*Helmholtz-Zentrum Berlin für Materialien und Energie GmbH , Berlin, Germany (HZB). *http://www-csr.bessy.de/control/SoftDist/CA_Lab*

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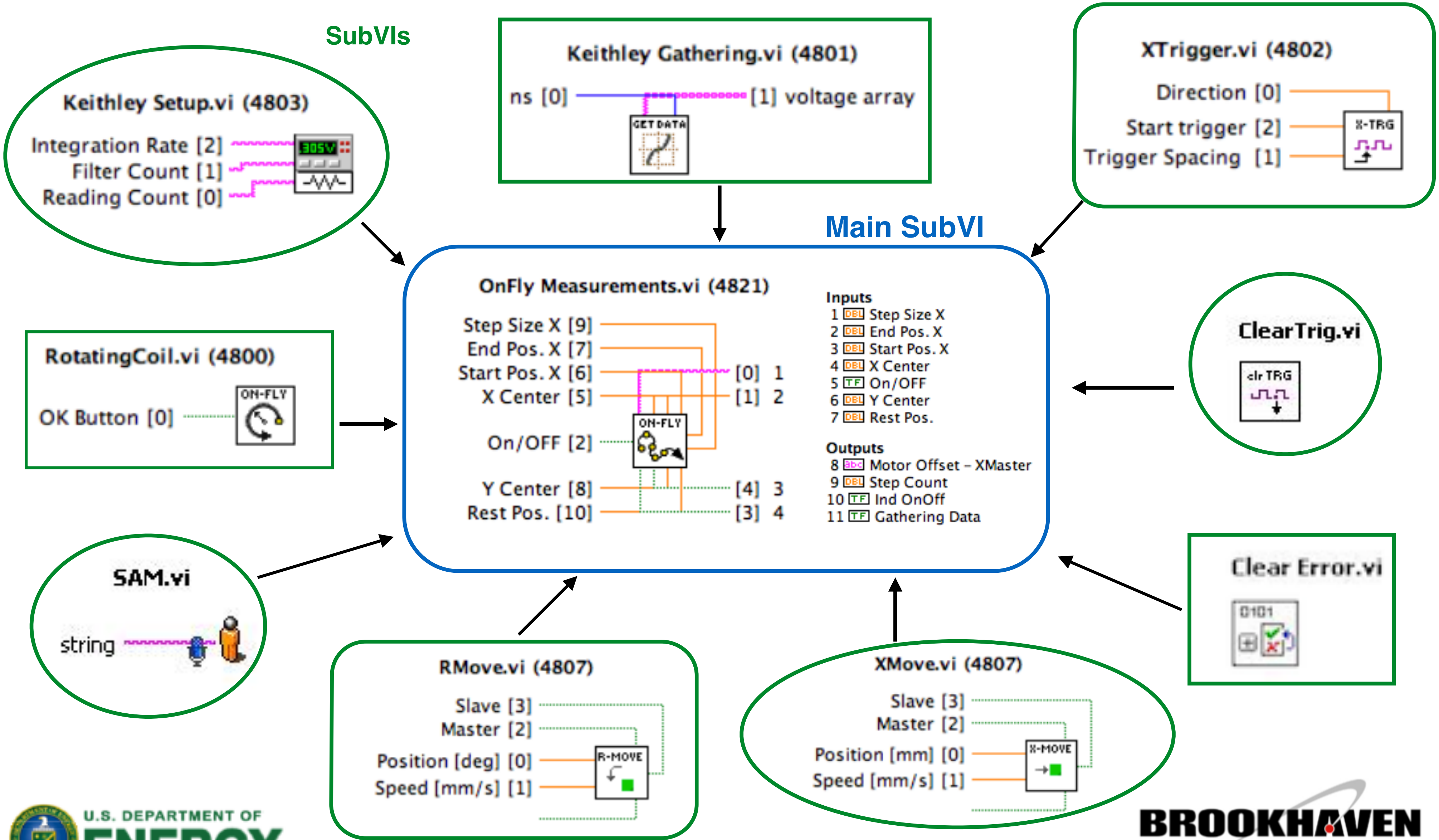
Data Acquisition Software

A set of SubVIs are embedded in the main SubVI in order to control and synchronise independently the various hardware components of the measurement system.



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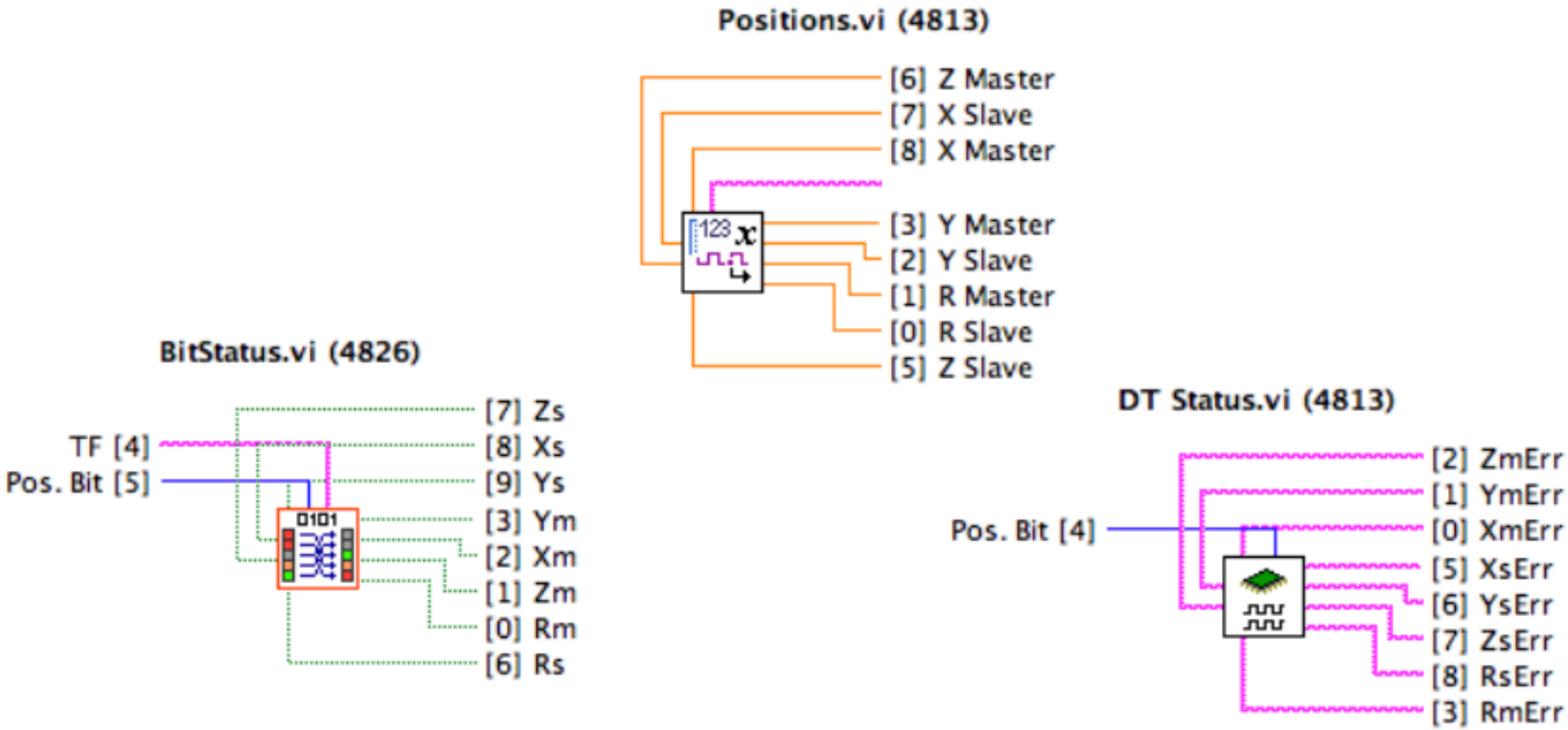
Data Acquisition Software

A real-time monitoring of the global status of all motors on the system.

Conditions on each axis such as position, home and limit switches, following error and amplifier fault error are checked and made visible on the main panel during the measurement process



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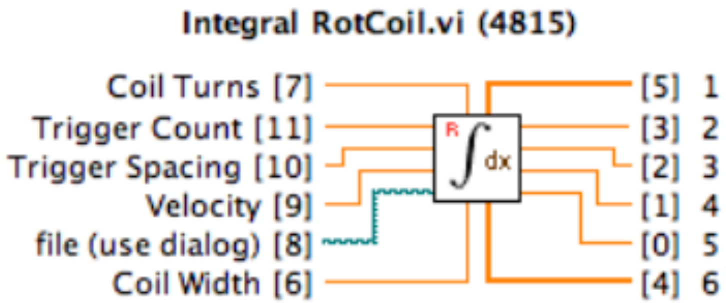
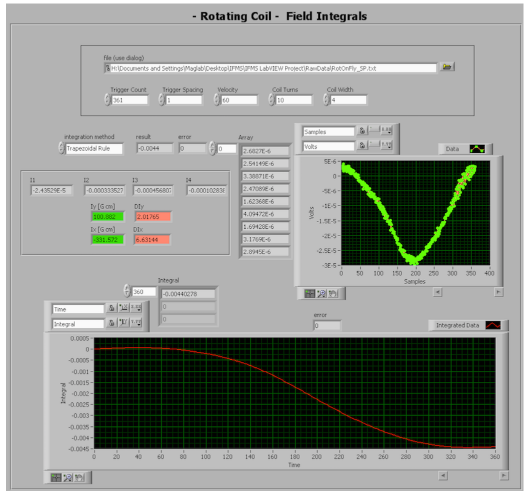
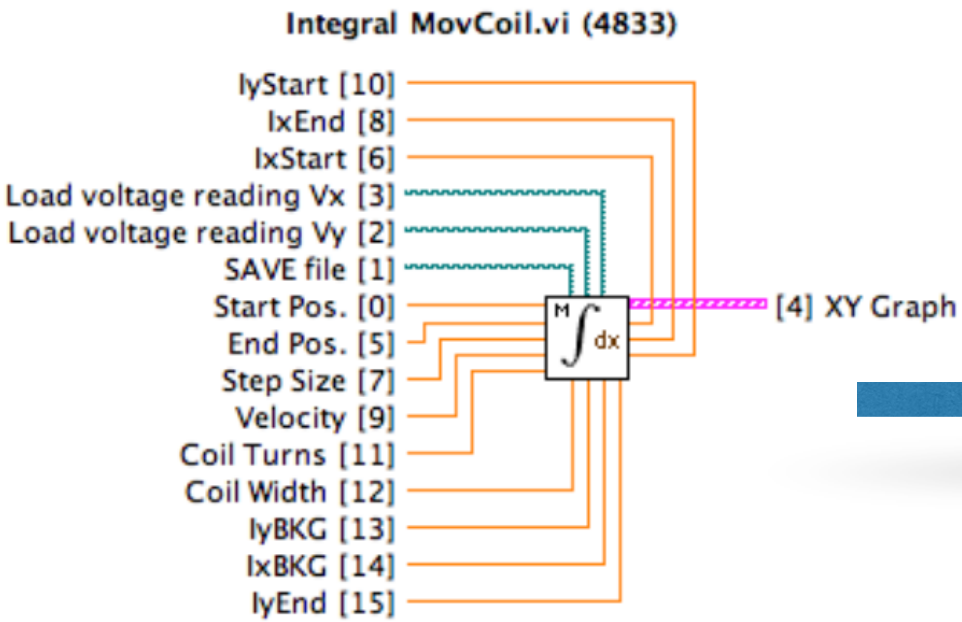
Data Acquisition Software

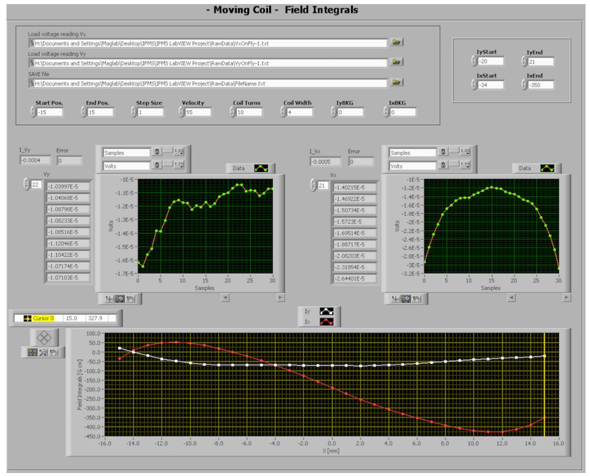
Each SubVI can operate as a **stand-alone program** or in conjunction with the other component.

Control Pannel









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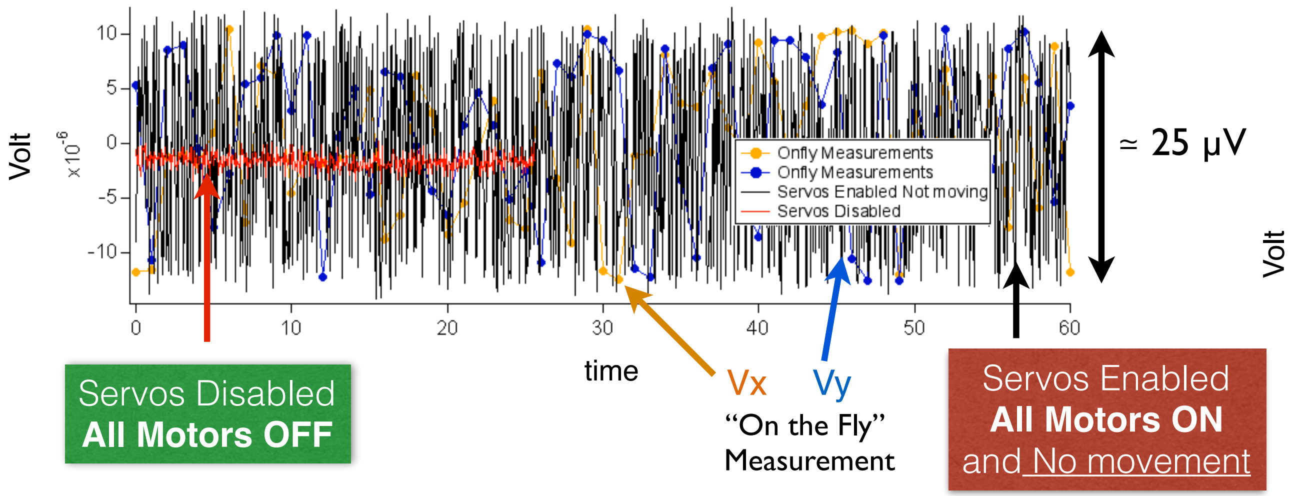
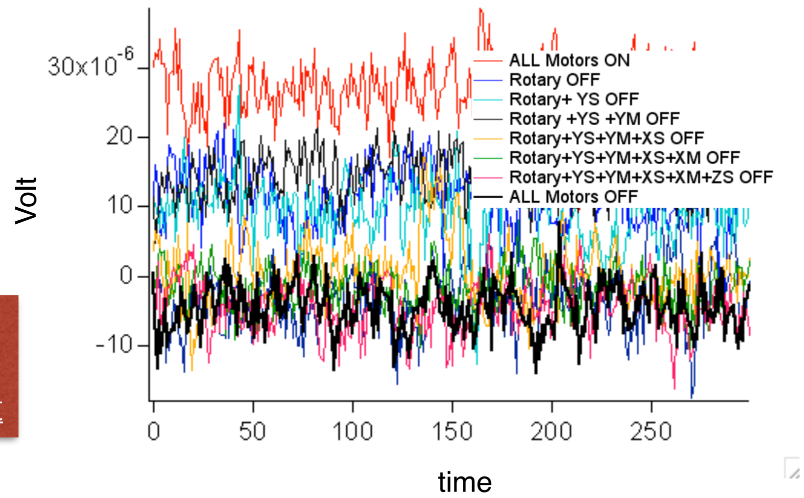
Magnetic Performance & Results

Electromechanical resonance noise from the motors was detected in the measurements

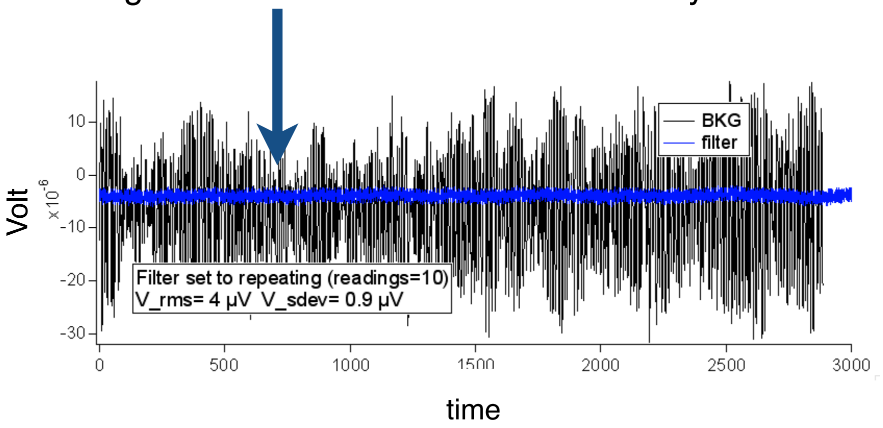


The main contribution to the noise comes from X_Slave and Rotary Motors.

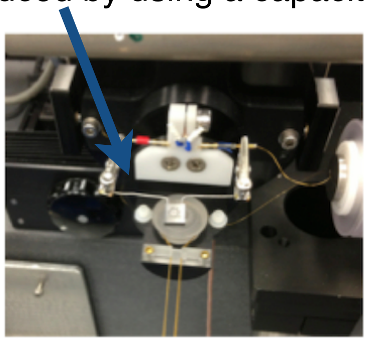


Solutions

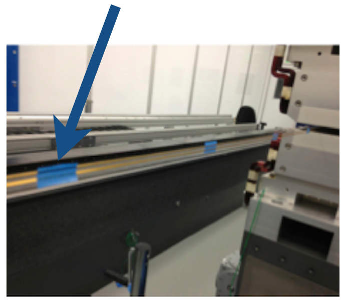
Digital FILTER is used to stabilize noisy measurements



High frequency electrical noise is reduced by using a capacitor



In order to reduce the vibration due to the translation movement adhesive tape is applied on the coil



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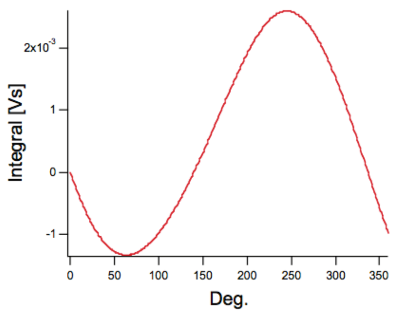
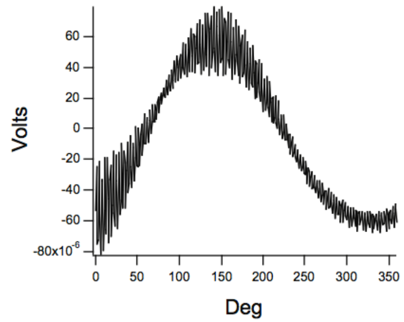
Magnetic Performance & Results

Point-by-Point measurement

Ix:
V_npnts= 8; V V_avg= -443.75; V_sdev= 2.4676;
V_rms= 443.756; V_adev= 2.05962
Iy:
V_npnts= 8; V_avg= -250.722;V_sdev= 3.47578;
V_rms= 250.743; V_adev= 2.41359;

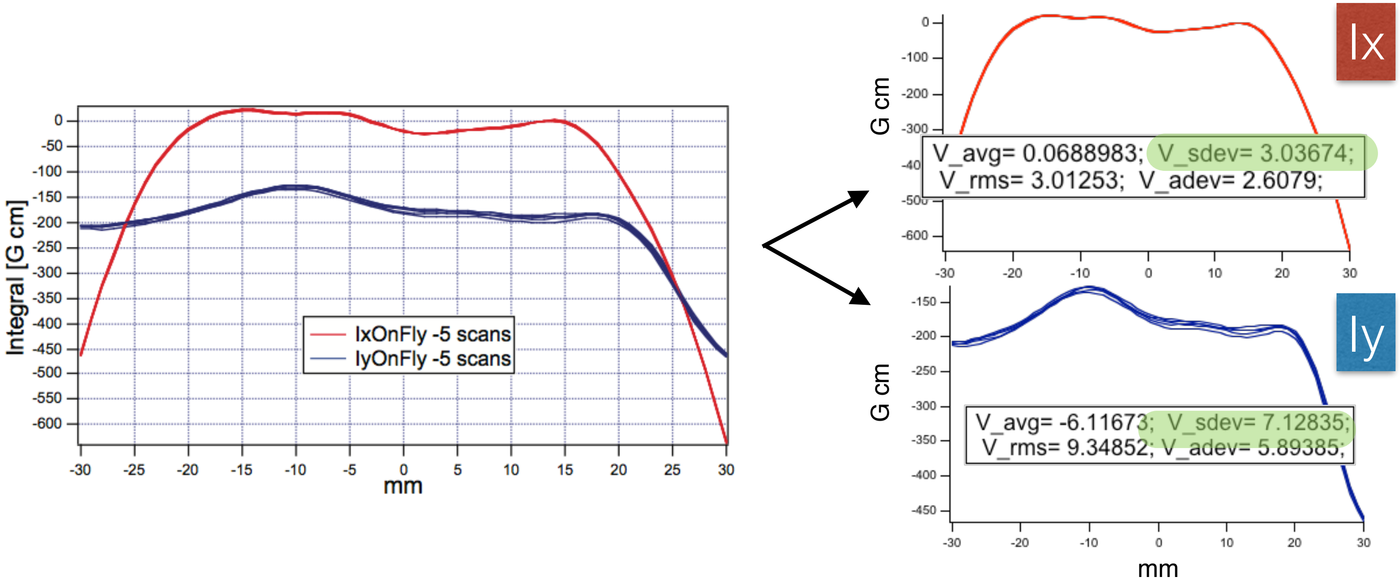
Point	Ix [G cm]	Iy [G cm]
0	-441.088	-250.774
1	-446.745	-251.877
2	-445.049	-254.942
3	-447.127	-253.705
4	-443.177	-250.233
5	-440.857	-248.663
6	-444.317	-243.616
7	-441.639	-251.967





Repeatability
Iy : 3.5 G cm
Ix : 2.5 G cm

On-the-Fly measurement



Repeatability
Iy : 7 G cm
Ix : 3 G cm

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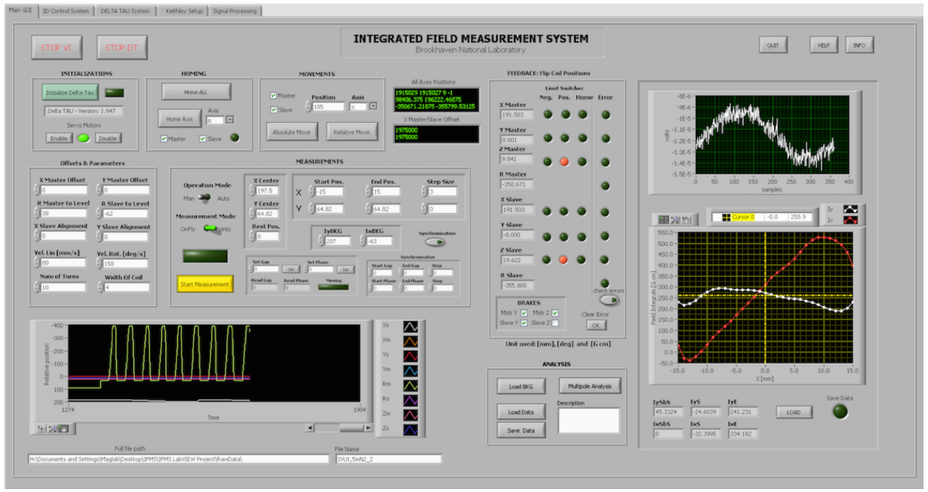
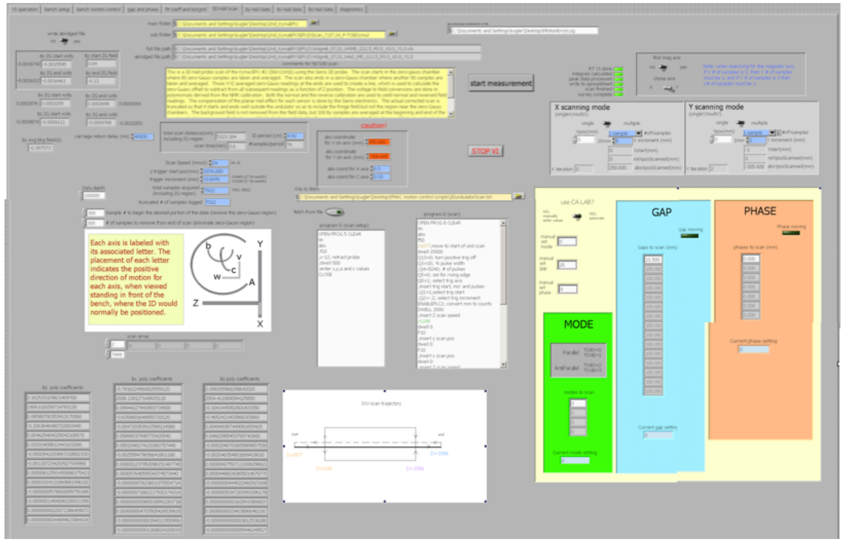
Conclusion

Next goal is to create a hybrid of the two existing GUIs (IFMS for the **Flip Coil bench** and HP for the **Hall Probe bench)** in order to incorporate in a single user-friendly GUI all of the functionalities of the two measurement systems

IFMS Software



HP Software



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and

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