

Overview of Magnetic Measurements of Insertion Devices at DESY

Pavel Vagin, Andreas Schöps, Markus Tischer
IMMW-21, Grenoble, 24-28 June 2019

Outline

1 Overview

- Individual magnet measurement for sorting
- Undulator measurement with Hall probe & stretched wire
- Undulator alignment & tuning

2 Various Measurement activities

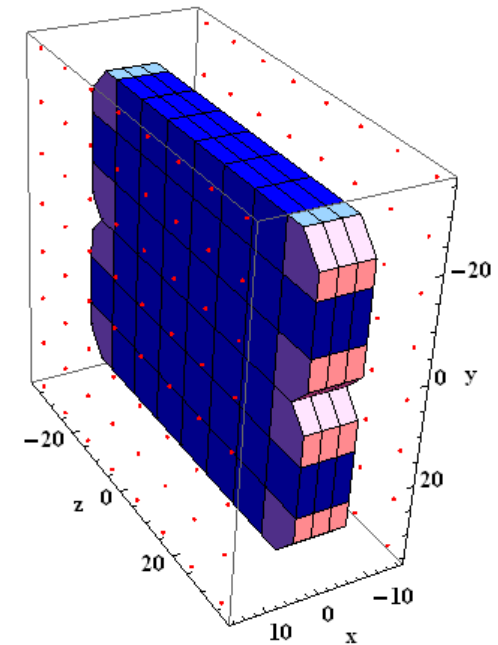
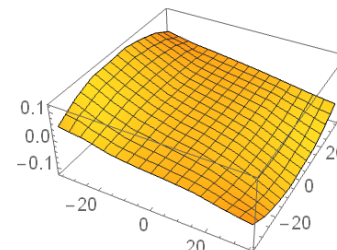
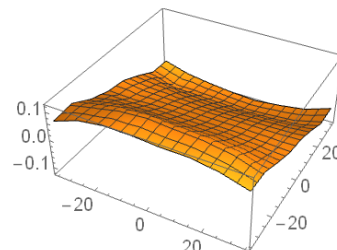
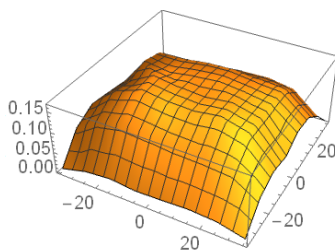
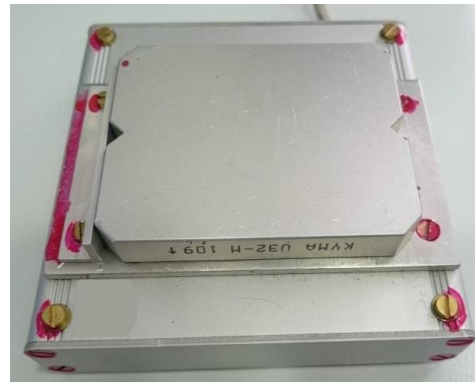
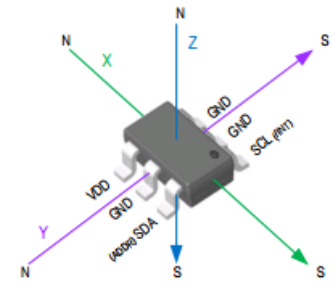
- In-tunnel measurements & shimming
- IVU

3 Measurement activities to come

- APPLE-3 with force compensation
- Variable period undulator

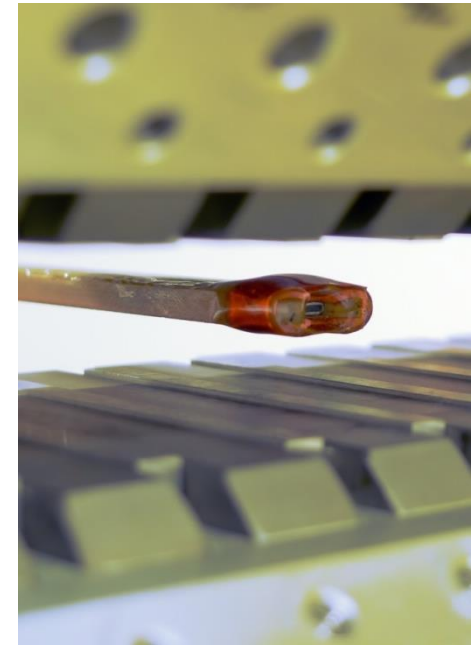
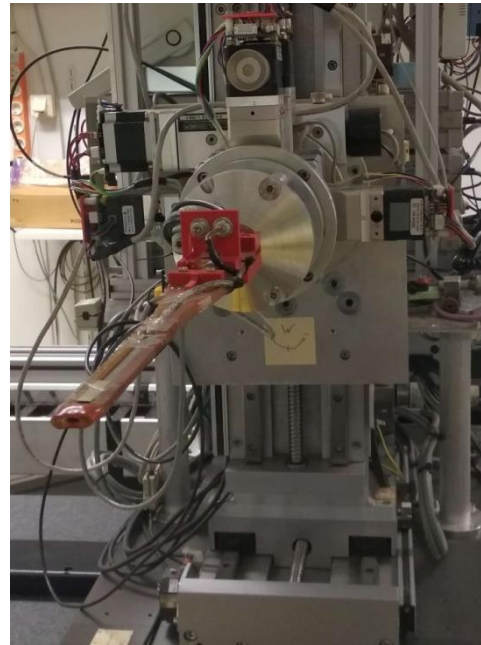
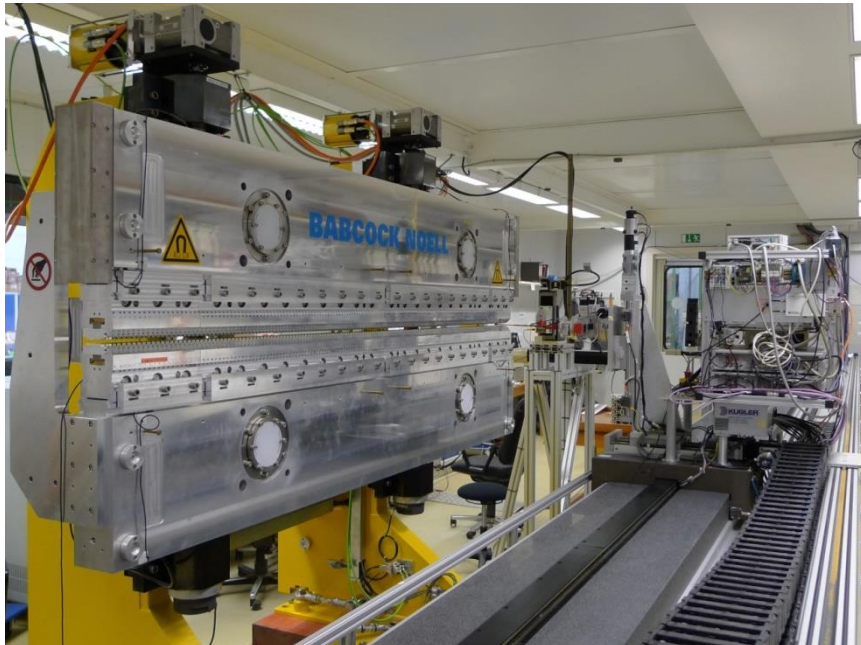
Single magnet field mapping

- Infineon TLV394D integrated 3D Hall sensor, $\pm 200\text{mT}$ range
- Built-in 12-bit ADC (100 $\mu\text{T}/\text{LSB}$), temperature sensor, I2C interface
- 3x3mm TSOP-6 footprint, 5mm sensor pitch
- Linear ($<1\text{LSB}$) field measurement range up to $\pm 130\text{mT}$
- Angular positioning error and gain calibrated with NMR
- Measurement of the whole field map within few seconds
- Updated “parallel” readout, oversampling to improve resolution



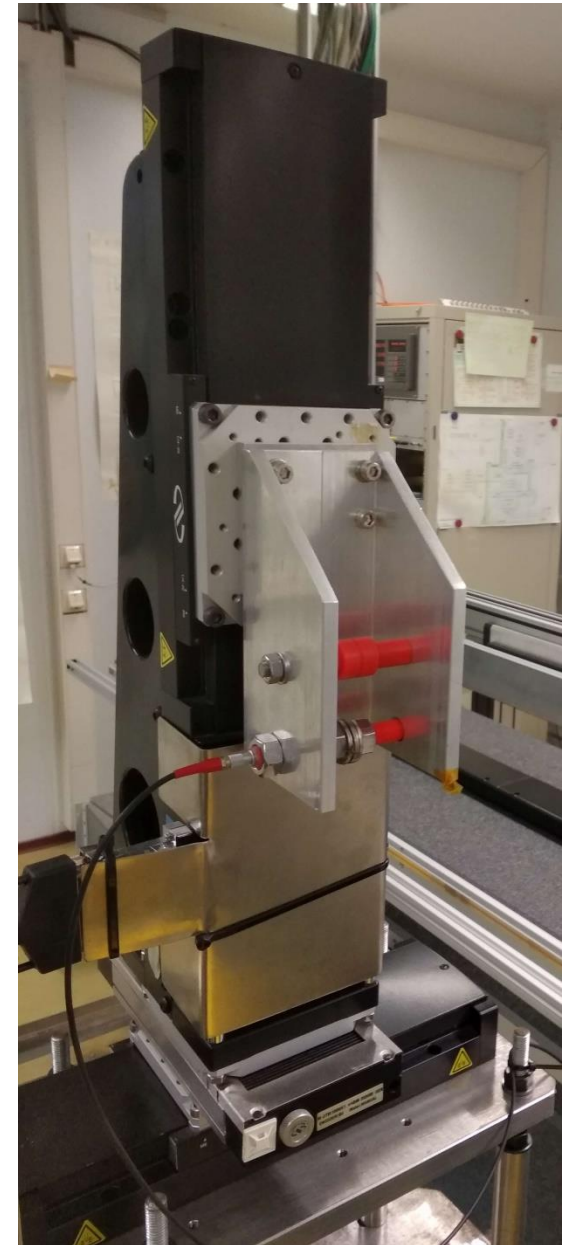
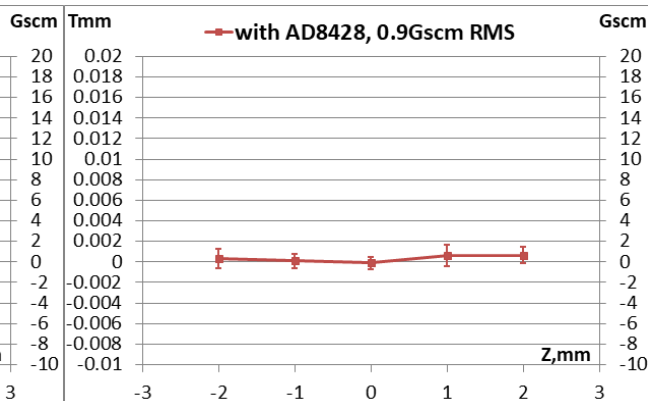
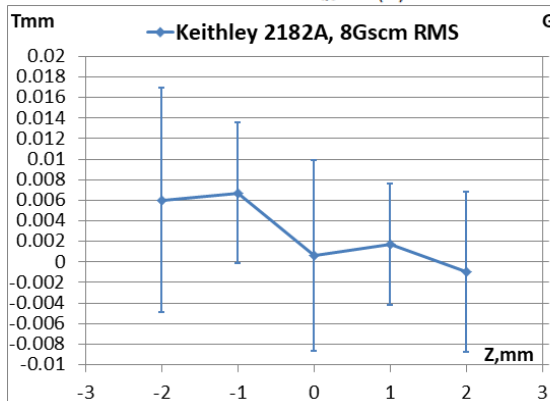
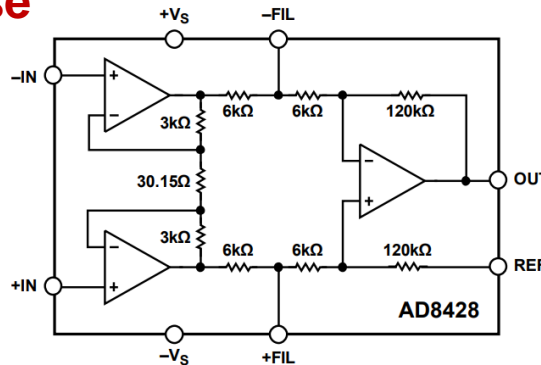
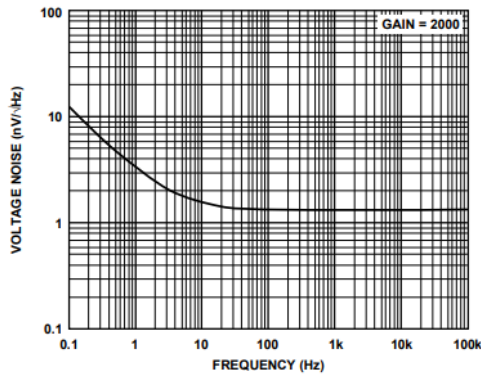
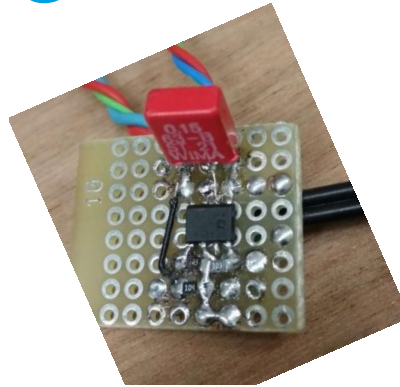
Bench

- 12m & 7m KUGLER granite benches
- 6 DoF goniometer
- 1D SENIS, FWBELL probes + search coil for horizontal field
- Dipole magnet for NMR calibration of the Hall probes

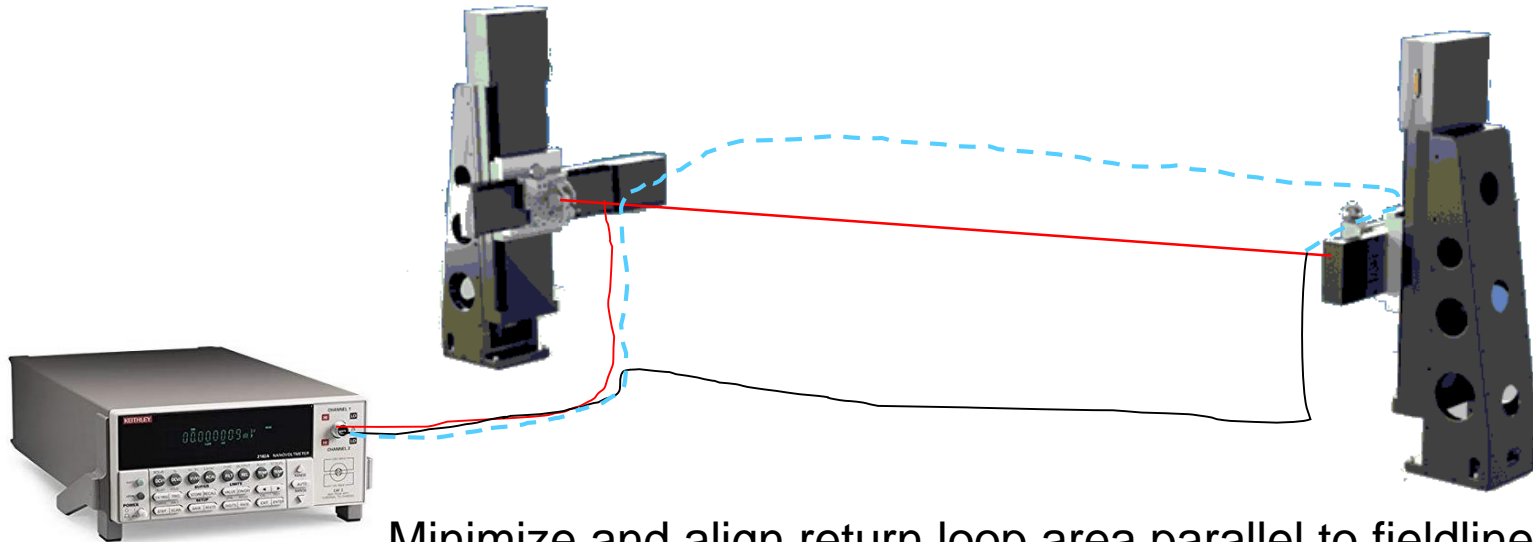
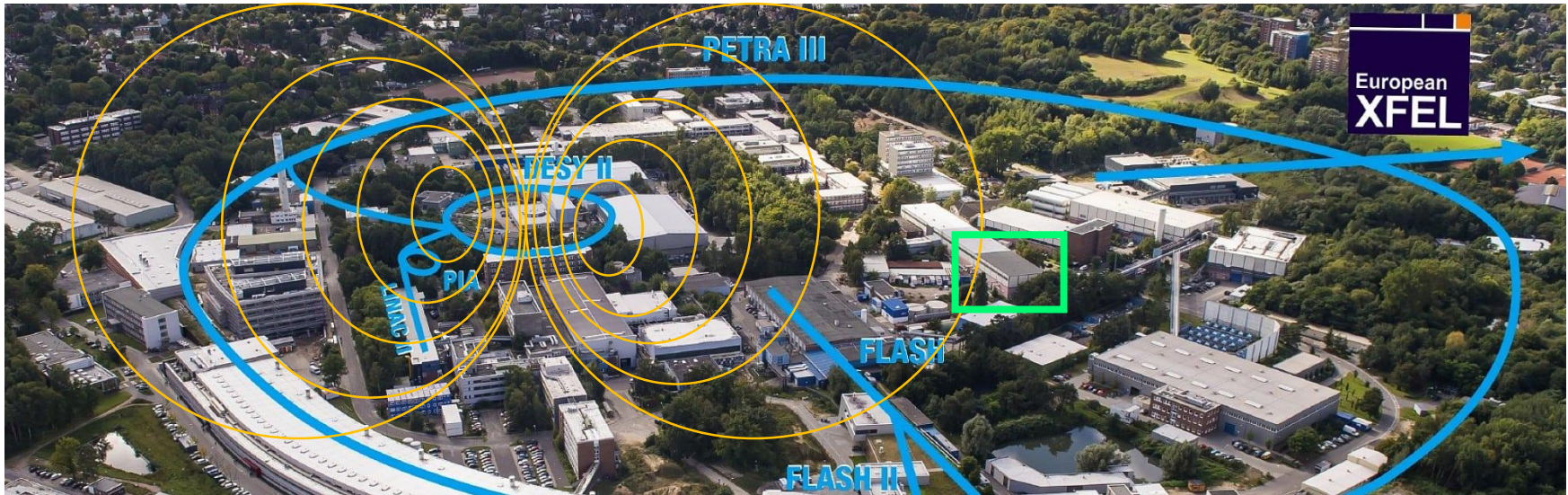


Stretched wire

- 2D Newport stages
- Keithley 2182A nanovoltmeter
- Single stretched wire
- $\sim 10\text{Gscm}$ noise at 1mm step
- $60\text{Ohm} \sim 1\text{nV}/\sqrt{\text{Hz}} \sim 0.6\text{Gscm}$
- **Test of AD8428 preamplifier:**
 $1.5\text{nV}/\sqrt{\text{Hz}} \sim 1\text{Gs}\cdot\text{cm}$ noise



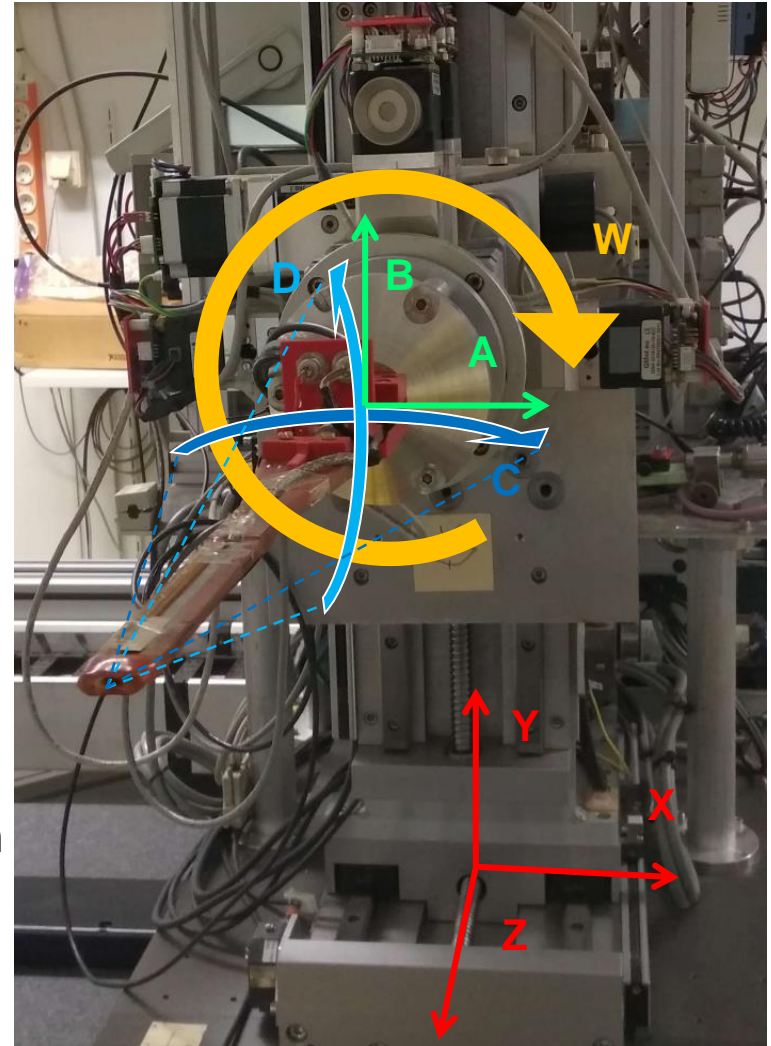
Stretched wire return loop



Minimize and align return loop area parallel to fieldlines to reduce EMI!

Undulator alignment

- Alignment of X, Y, Z, roll, pitch, yaw with respect to the measurement bench
 - accuracy $\sim 10\mu\text{m}$, $\sim 0.01\text{mrad}$
- Same procedure for alignment of longitudinal and also transverse gap taper
 - accuracy $\sim 1\mu\text{rad}$ longitudinal, $\sim 1\mu\text{m}$ taper
 $\sim 0.05\text{mrad}$ transverse ($\sim 30\text{mm}$ base)
- C&D angles to minimize horizontal coil signal
- A&B offsets to set Hall probe exactly to rotation center of W
- $W=0$ & $W=180$ eliminate even order nonlinearities

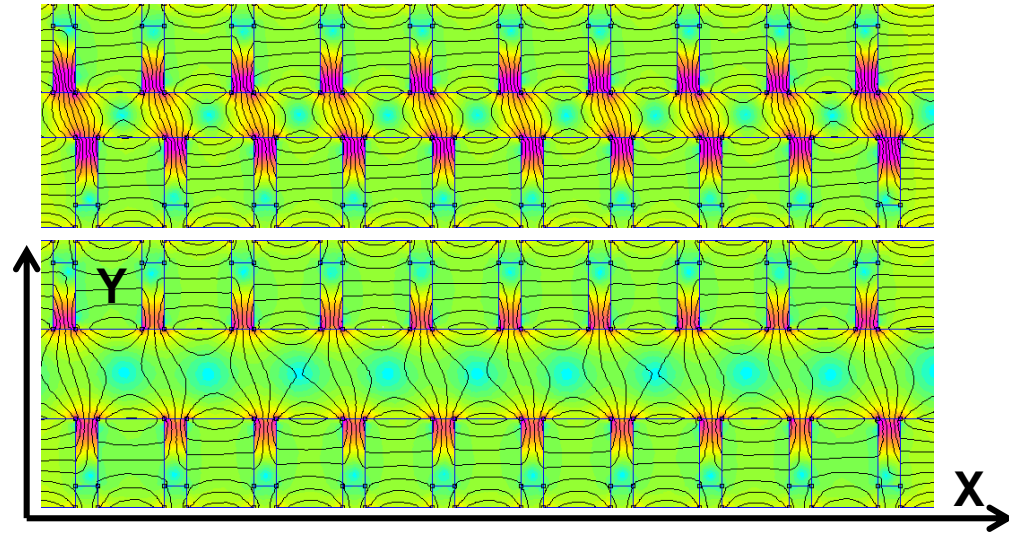


Undulator alignment

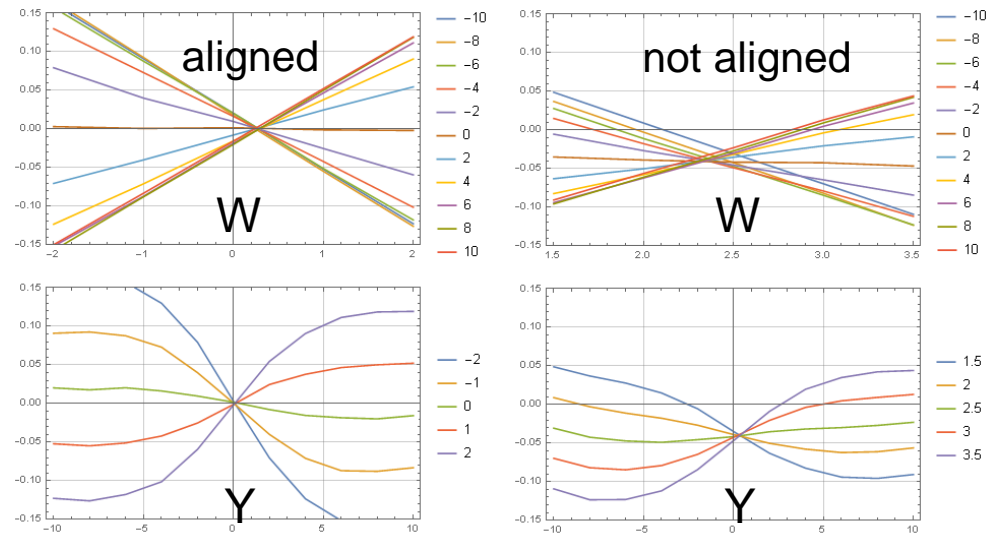
- W offset & Longitudinal Alignment of top vs. bottom magnet girders (mechanically difficult to measure)

→ 2-dimensional scans of peak field X positions vs. Y-pos. and W-angle

→ typ. accuracy $\sim 20\mu\text{m}$

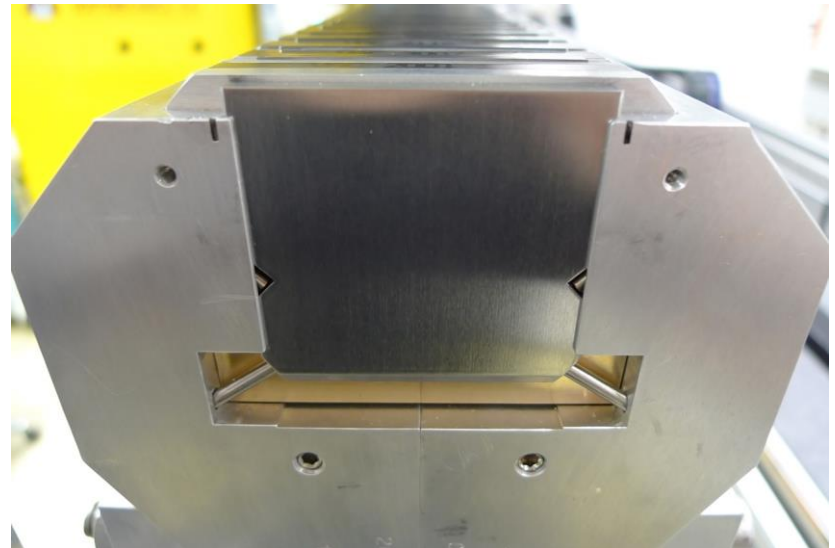
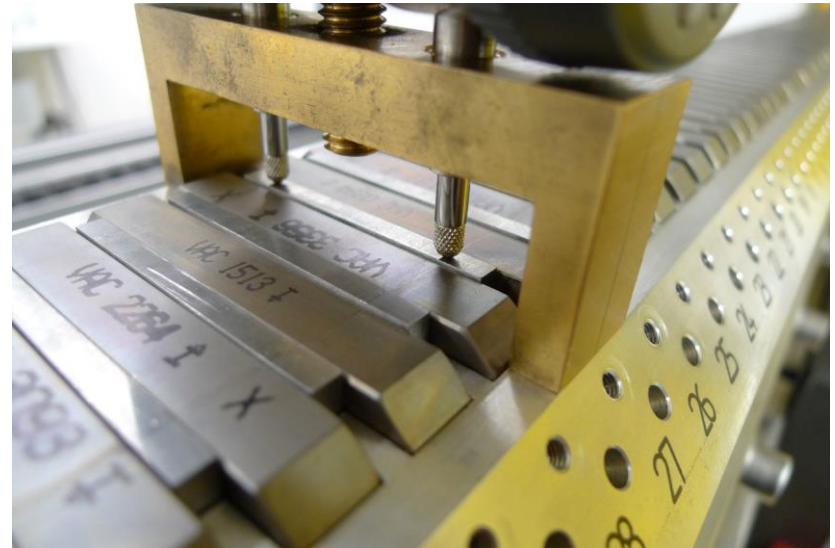
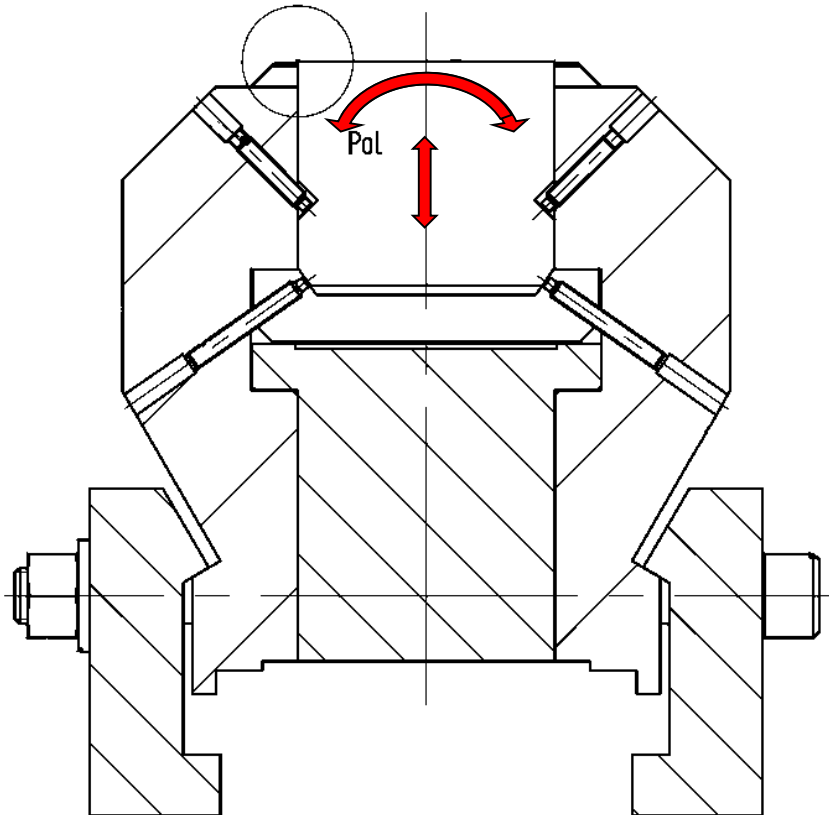


X offset for different Y and W



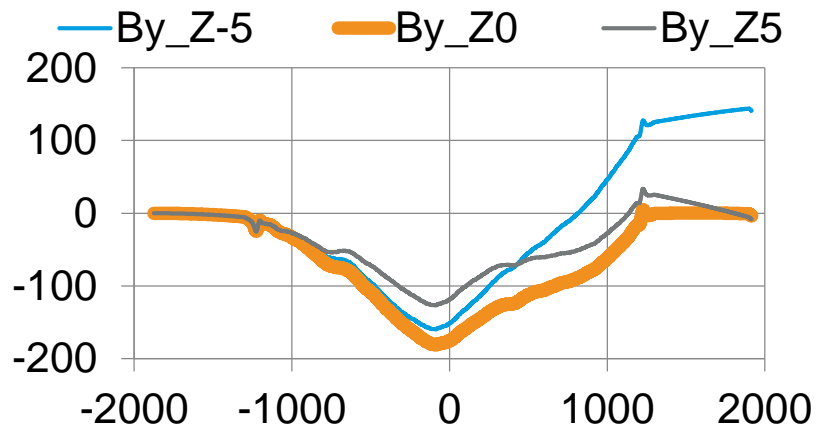
Pole tuning

- Virtual shimming by 4 screws
- Individual pole shift and tilt
- Continuous adjustment ($\sim 2\mu\text{m}$)
- Fast tuning, 2m device < day

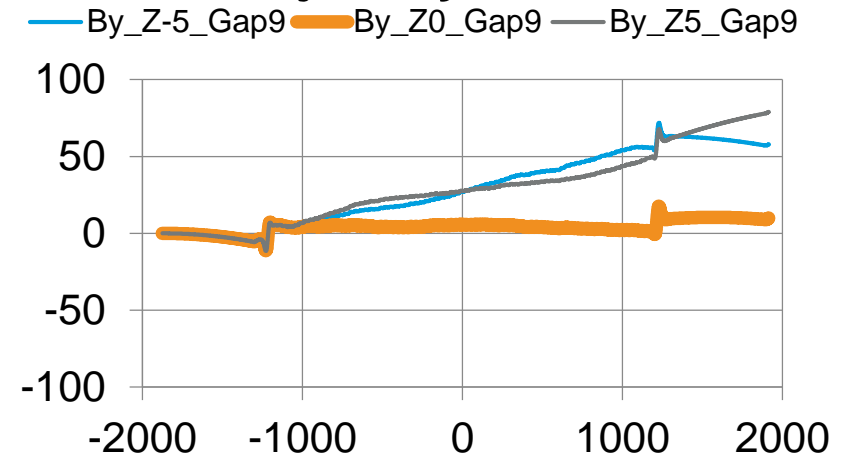


Tuning

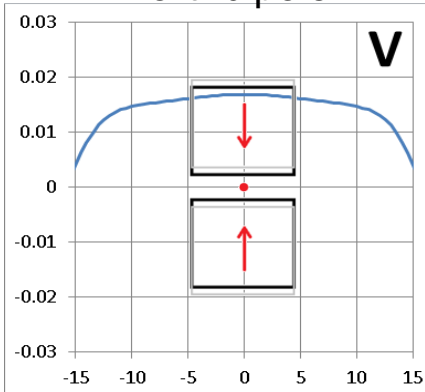
Trajectory initial



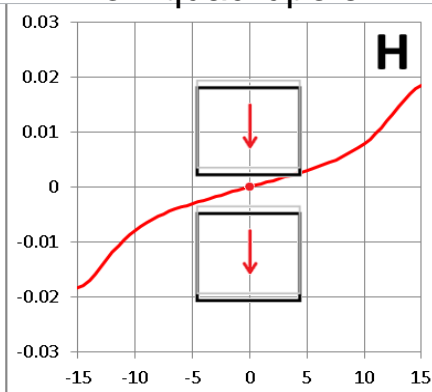
Trajectory tuned



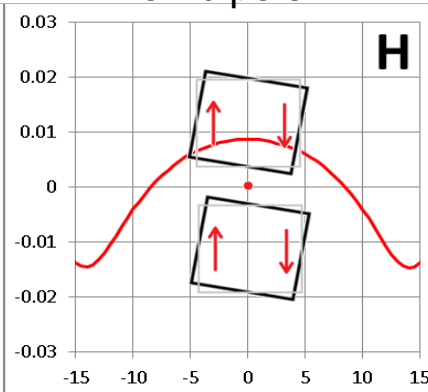
vert. dipole



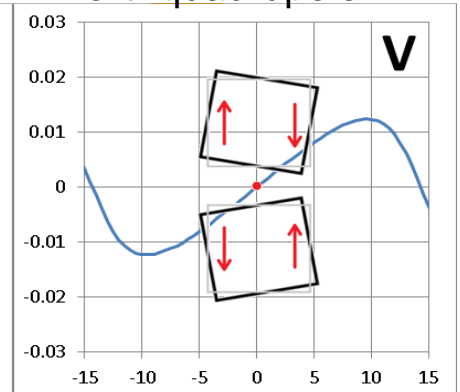
hor. quadrupole



hor. dipole

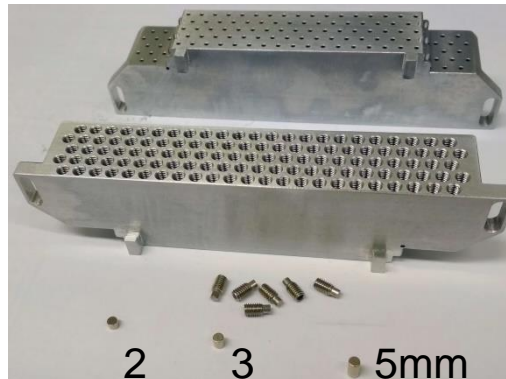
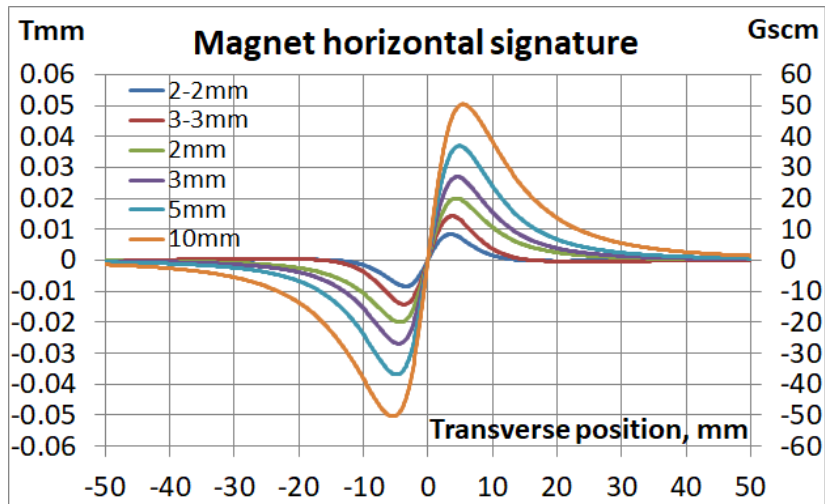
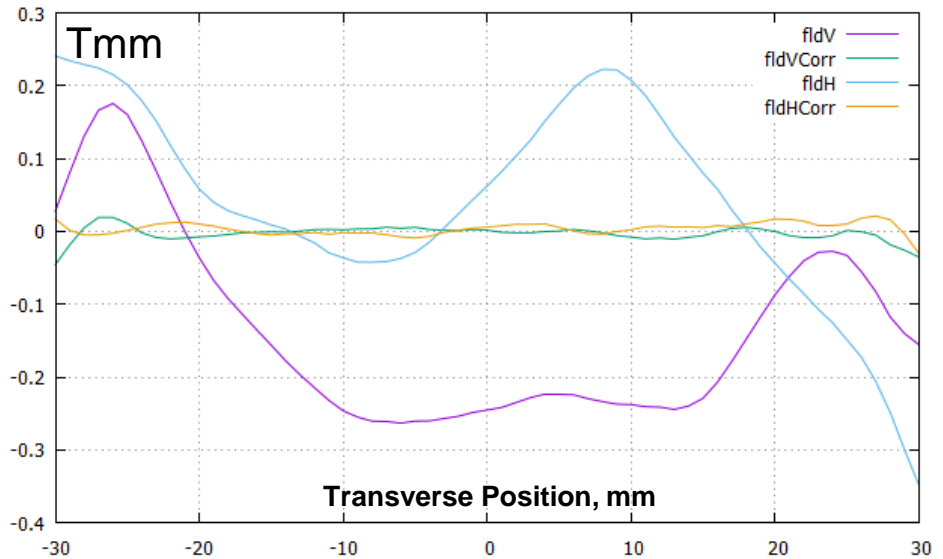
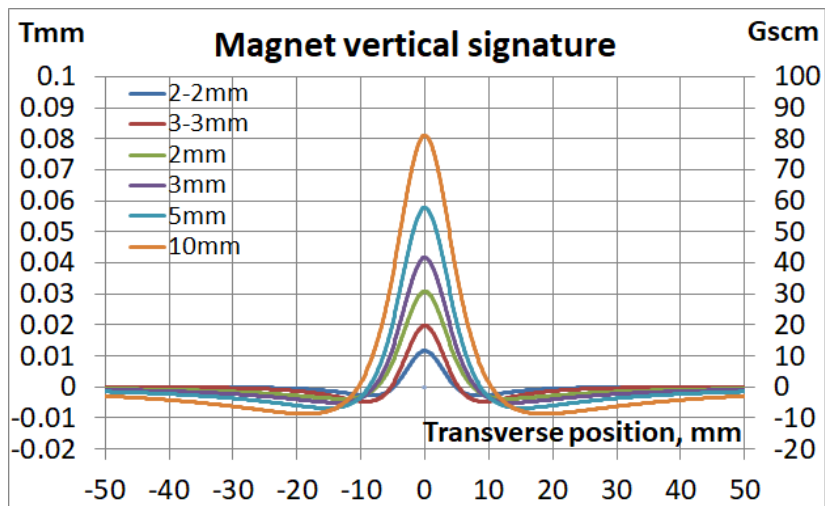


vert. quadrupole



- Phase error < 1deg
- Off-axis trajectory correction (remove quadrupoles)

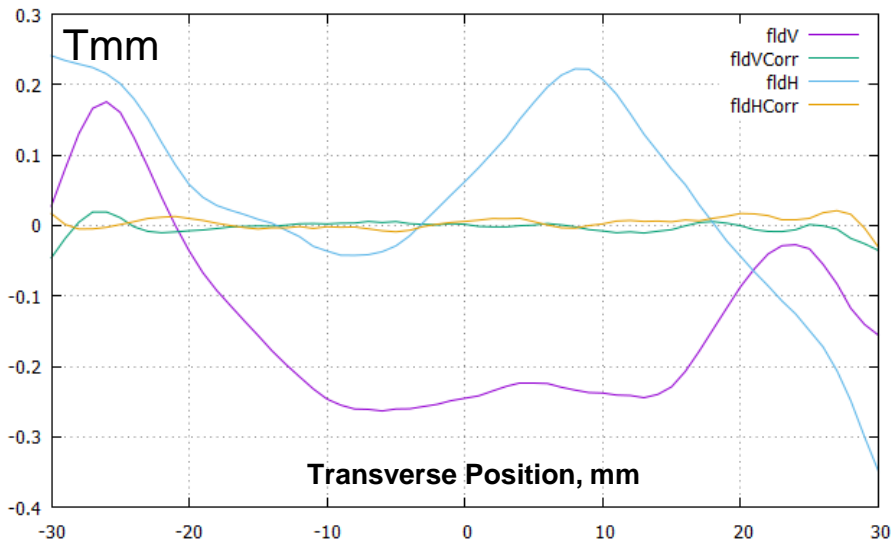
Magic fingers



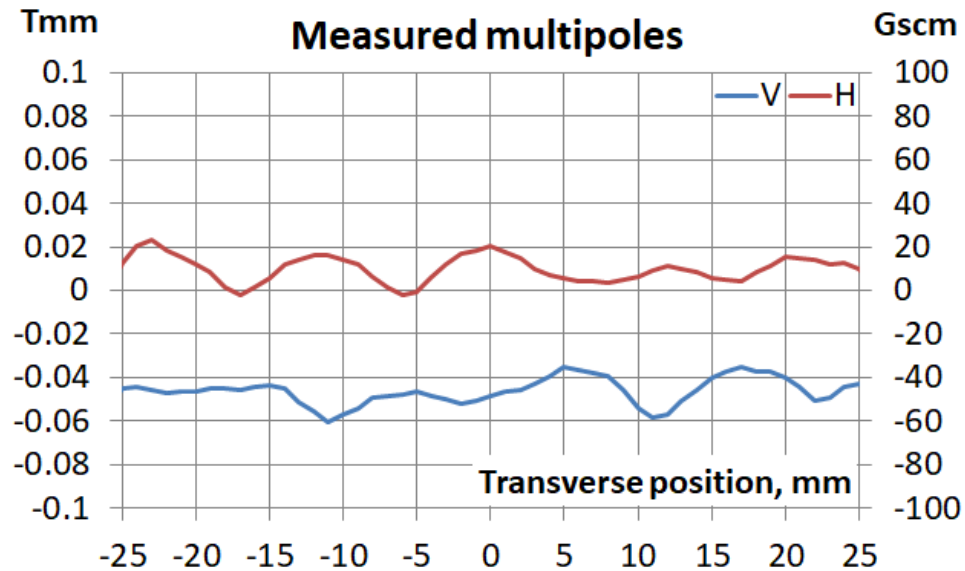
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2	-16	-30.4	-2mm	-10mm	-10mm	-10mm	-10mm	-5mm	-10mm	-10mm	-10mm	-10mm
3	-15	-28.5	+10mm	-10mm	+5mm	+5mm	+10mm	-10mm	+5mm	+5mm	+5mm	+5mm
4	-14	-26.6	+5mm	0	0	+5mm	+10mm	+10mm	0	+5mm	+5mm	+5mm
5	-13	-24.7	+5mm	+2mm	-10mm	+10mm	+10mm	+2mm	-10mm	+5mm	+5mm	+5mm
6	-12	-22.8	0	0	0	0	+10mm	0	+2mm	0	+2mm	+2mm
7	-11	-20.9	0	0	-5mm	+10mm	0	-2mm	+2mm	+10mm	+10mm	+10mm
8	-10	-19	0	0	+2mm	-2mm	0	+5mm	-2mm	+5mm	+5mm	+5mm
9	-9	-17.1	+5mm	+10mm	-2mm	+2mm	+5mm	+10mm	-2mm	+5mm	+5mm	+5mm
10	-8	-15.2	0	0	0	0	0	0	0	0	0	0
11	-7	-13.3	0	0	0	0	0	0	0	0	0	0
12	-6	-11.4	+2mm	+2mm	+5mm	+2mm	+2mm	+2mm	+10mm	+2mm	+2mm	+2mm
13	-5	-9.5	0	0	0	0	0	+5mm	-2mm	0	0	0
14	-4	-7.6	+5mm	0	0	0	+5mm	-5mm	+2mm	0	0	0
15	-3	-5.7	-10mm	+10mm	0	0	-10mm	+10mm	0	0	0	0
16	-2	-3.8	0	0	0	0	+2mm	+2mm	0	0	0	0
17	-1	-1.9	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	1	1.9	0	0	0	0	0	0	0	0	0	0
20	2	3.8	0	0	0	0	0	0	0	0	0	0
21	3	5.7	0	+5mm	0	0	0	+5mm	0	0	0	0
22	4	7.6	0	0	0	0	+2mm	+2mm	0	+2mm	+2mm	+2mm
23	5	9.5	0	0	+5mm	+2mm	0	0	+10mm	+5mm	+5mm	+5mm
24	6	11.4	+5mm	-2mm	+2mm	+2mm	+5mm	-2mm	+2mm	+2mm	+2mm	+2mm
25	7	13.3	+10mm	+5mm	0	0	+10mm	+10mm	0	0	0	0
26	8	15.2	0	0	0	0	+5mm	-5mm	+2mm	0	0	0
27	9	17.1	0	0	+10mm	+10mm	0	0	+10mm	+10mm	+10mm	+10mm
28	10	19	+10mm	+2mm	-5mm	-2mm	+10mm	+5mm	-5mm	-2mm	-2mm	-2mm
29	11	20.9	+10mm	-5mm	-5mm	-5mm	+10mm	-10mm	-5mm	-5mm	-5mm	-5mm
30	12	22.8	+10mm	-2mm	-10mm	+10mm	+10mm	-2mm	0	+10mm	+10mm	+10mm
31	13	24.7	0	+2mm	-10mm	+10mm	+5mm	+2mm	-2mm	+10mm	+10mm	+10mm
32	14	26.6	+10mm	0	-5mm	+5mm	+10mm	0	+10mm	+10mm	+10mm	+10mm
33	15	28.5	+5mm	+5mm	+10mm	-10mm	+10mm	+10mm	+10mm	+10mm	+2mm	+2mm
34	16	30.4	-2mm	-10mm	+5mm	-5mm	-2mm	-10mm	+10mm	-10mm	-10mm	-10mm

- Brute-force enumeration of possible magnet configurations to minimize multipoles

Magic fingers



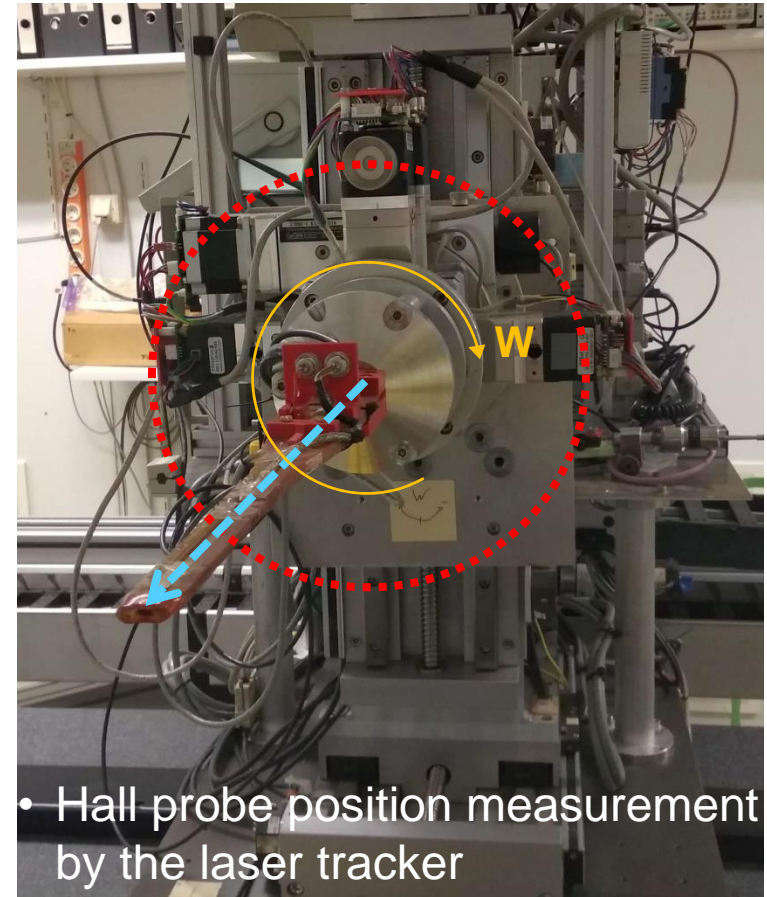
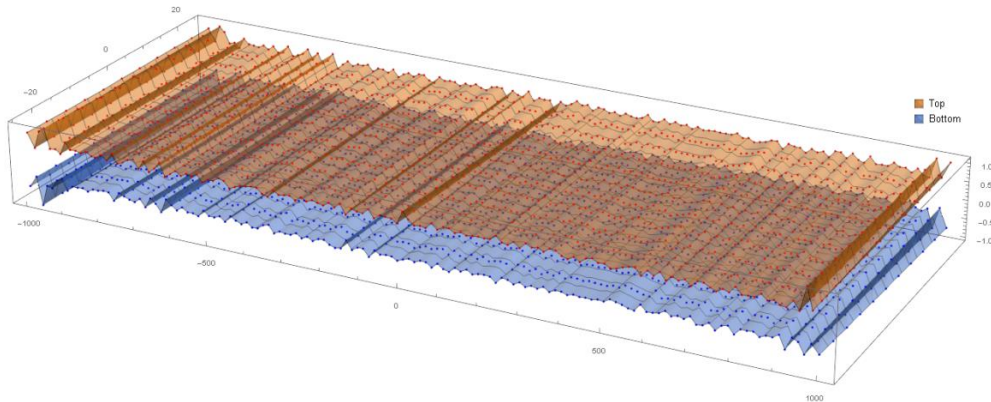
Before tuning and correction prediction



After tuning

- ± 10 Gscm multipole flatness in ± 25 mm transverse range

Transfer measurements



- Touchprobe: Hall probe bench turns to an automated CMM
- Additional reference mark to match coordinate systems
- Measurement of the magnetic axis with a laser tracker by rotating W

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- Individual magnet measurement for sorting
- Undulator measurement with Hall probe & stretched wire
- Undulator alignment & tuning

2 Various Measurement activities

- In-tunnel measurements & shimming
- IVU

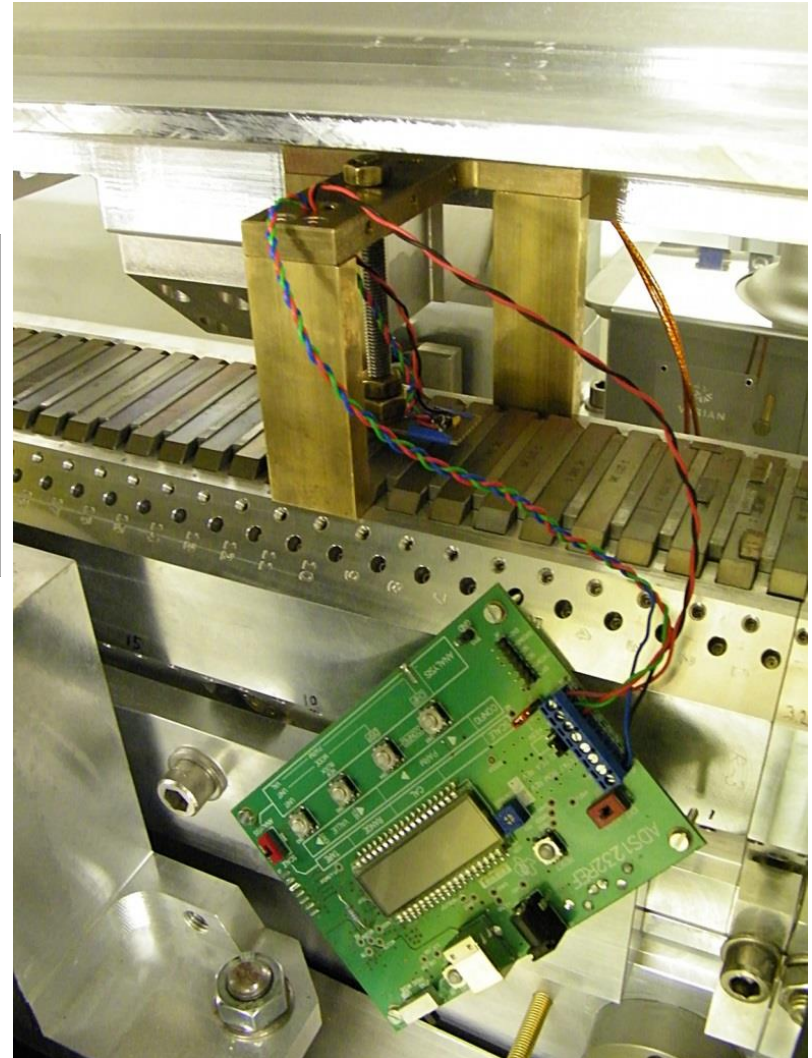
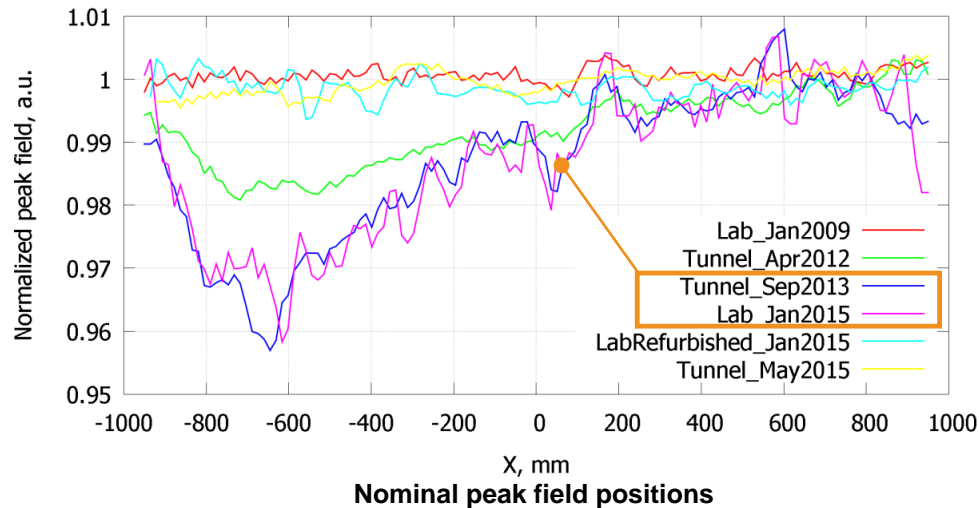
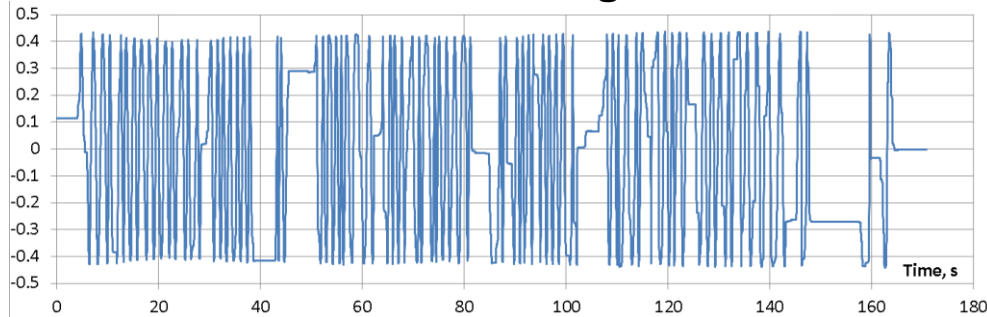
3 Measurement activities to come

- APPLE-3 with force compensation
- Variable period undulator

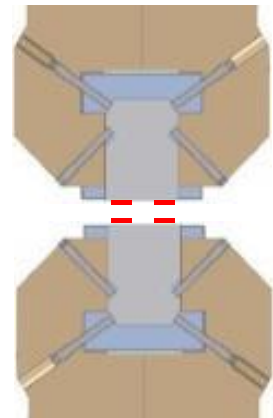
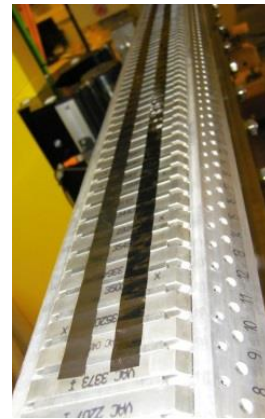
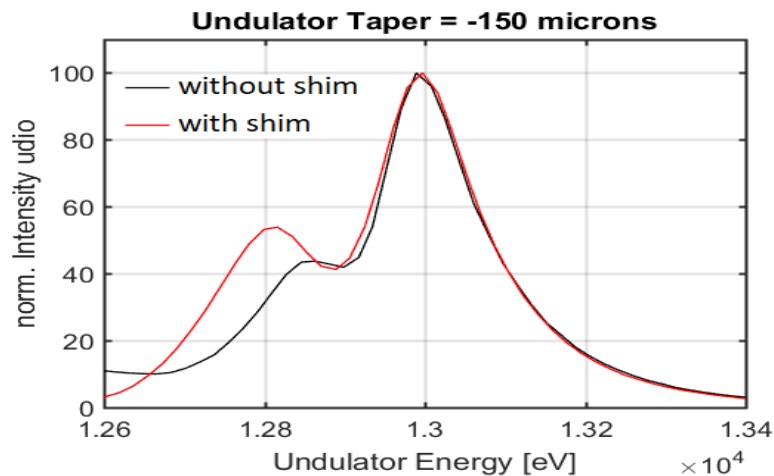
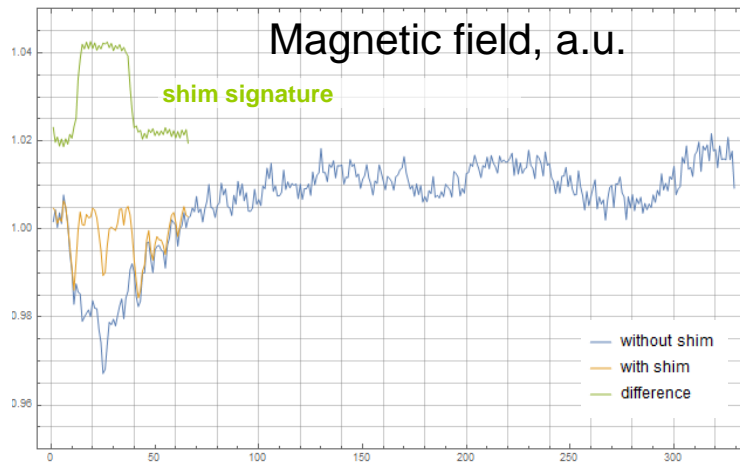
Measurements in the tunnel

- AD22151G Integrated Hall sensors
- ADS1232REF ADC Evaluation Board
- 1% absolute accuracy, **0.1% reproducibility**
- Separate measurements of top and bottom

Raw data, Hall voltage vs time



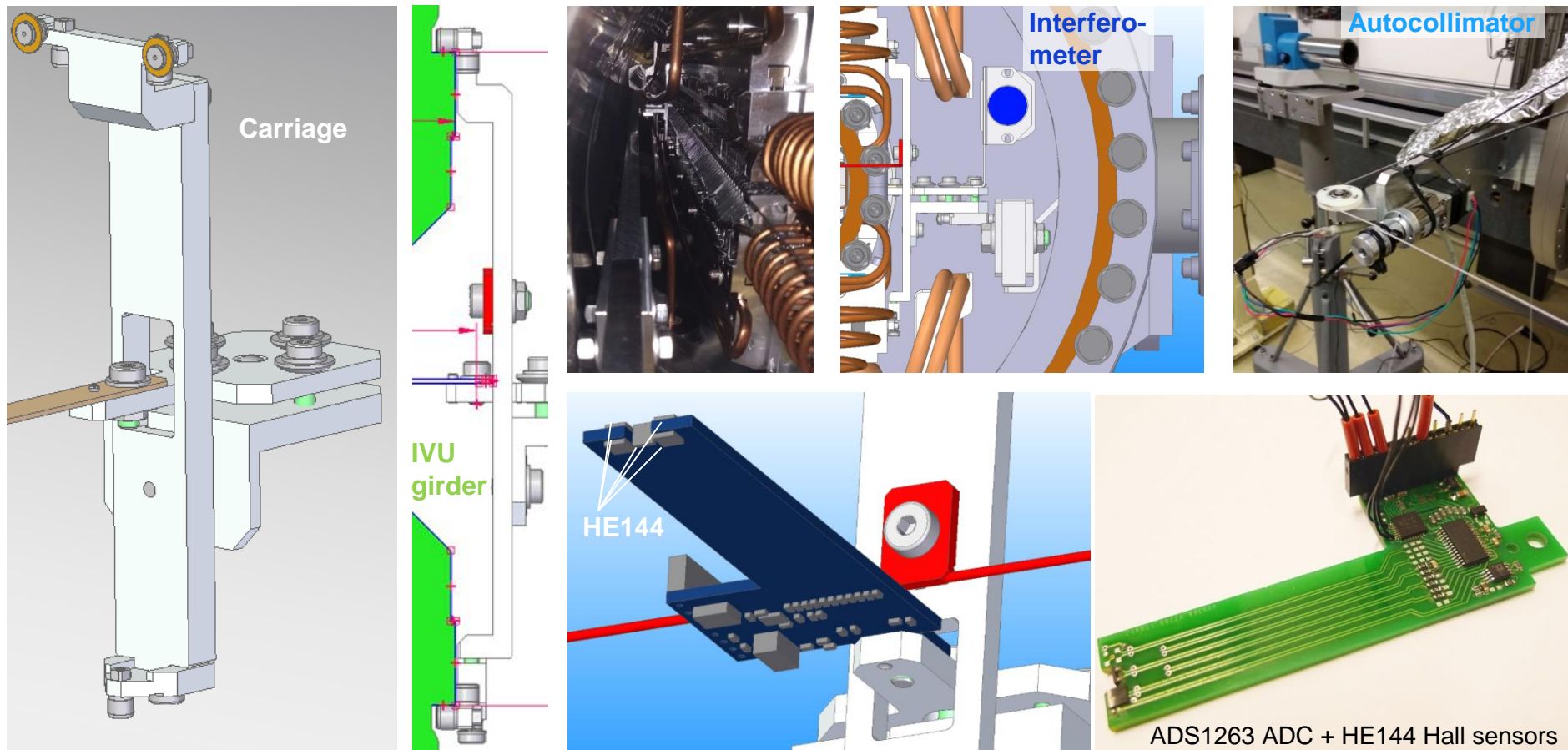
Shimming in the tunnel



IMMW20, M. Tischer

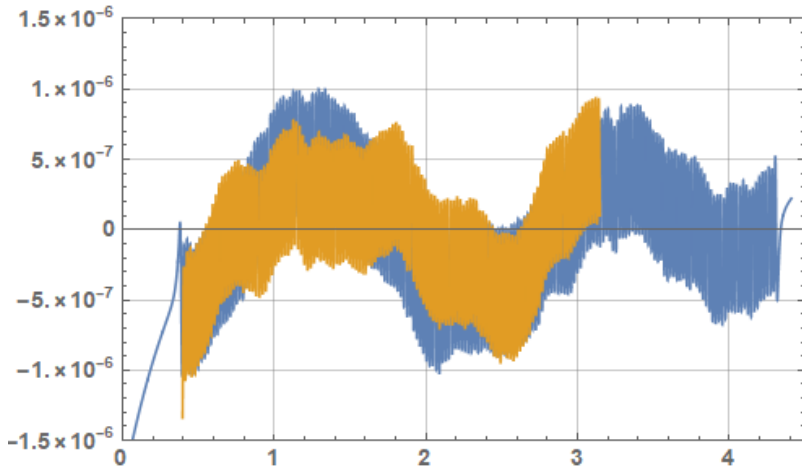
- Field increase above the poles, field decrease due to shunting between poles
- Holes to reduce shunting
- Total length is integer number of periods \rightarrow zero impact on field integrals

IVU measurement

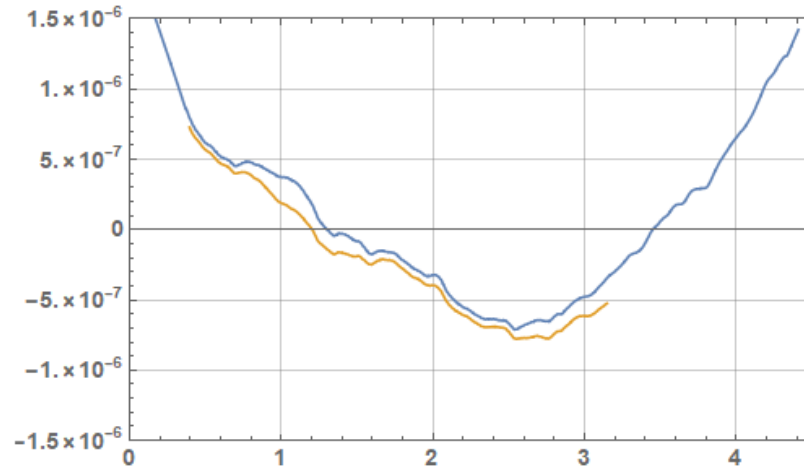


- Undulator girder as guiding rail, stepper motor + wire to pull the carriage
- Interferometer position measurement, autocollimator angular correction
- Multiple HE144 hall sensors + ADS1263 ADC

Trajectory V, m

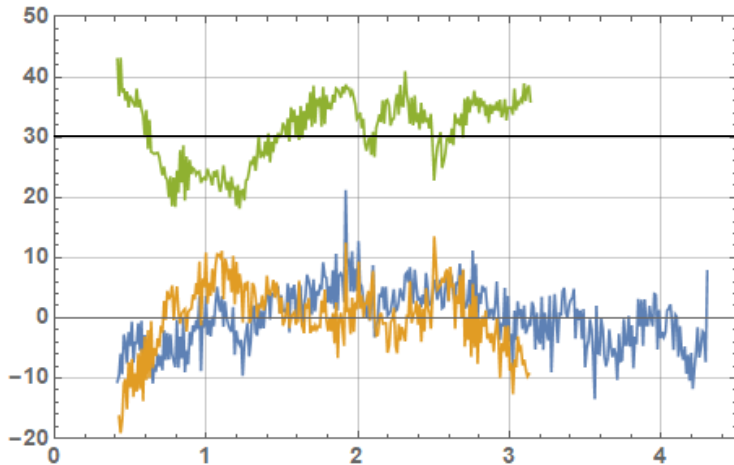


Trajectory H, m

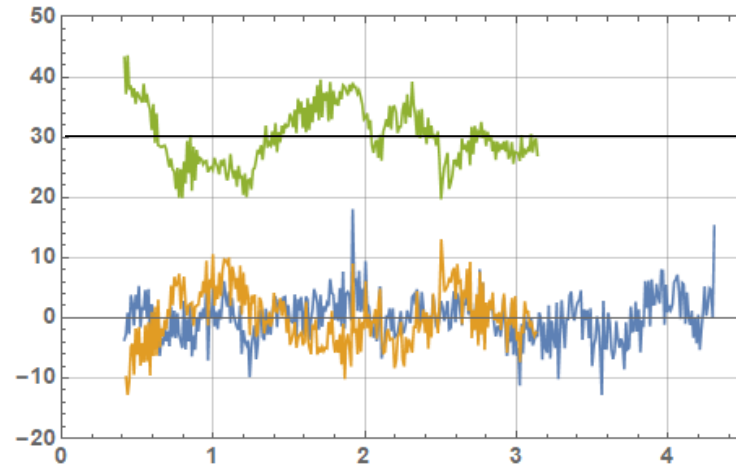


— SAFALI
— CARRIAGE

Phase error



Phase error, taper correction



— SAFALI
— CARRIAGE
— DIFF

- Comparable measurements, characteristic features resolved in both systems
- Differences in both systems originate from positioning errors (mostly yaw & roll)

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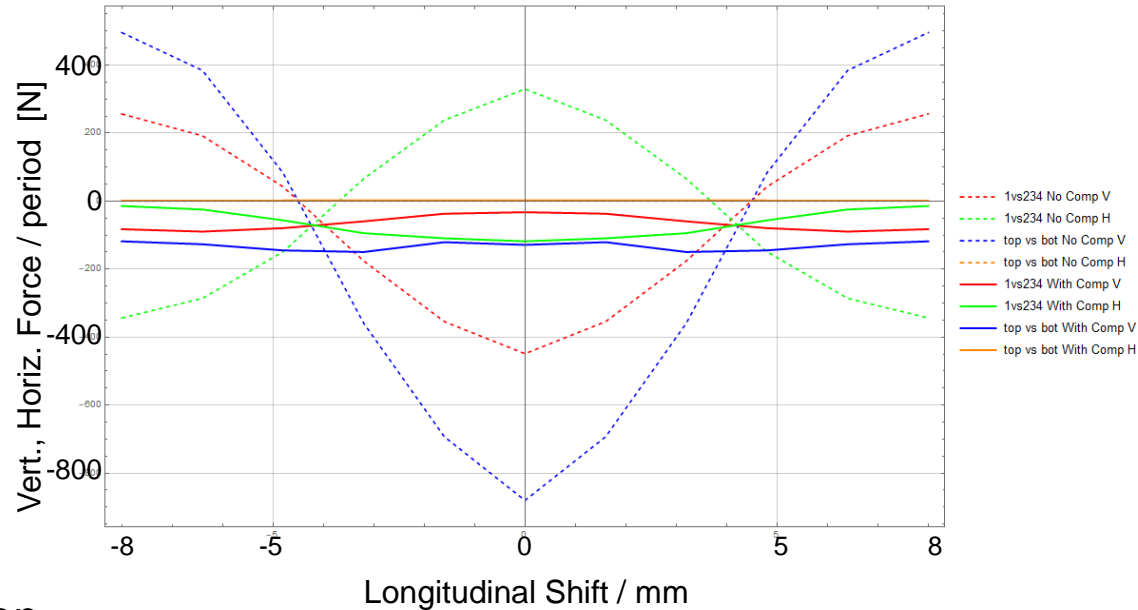
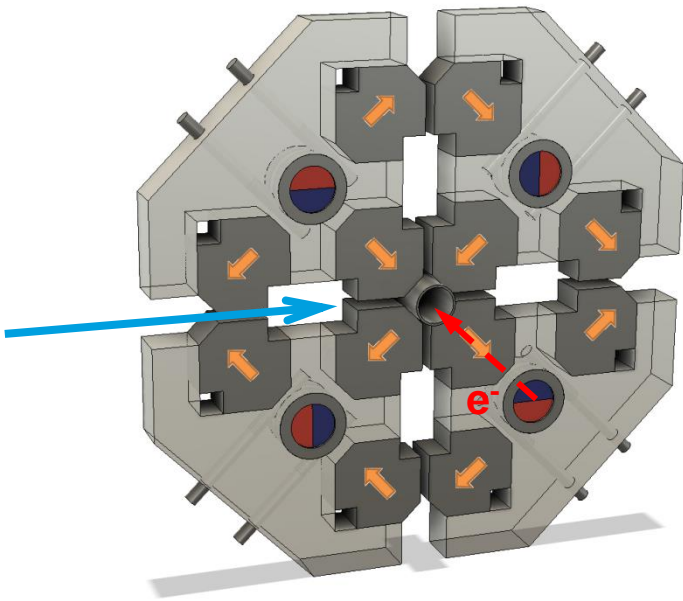
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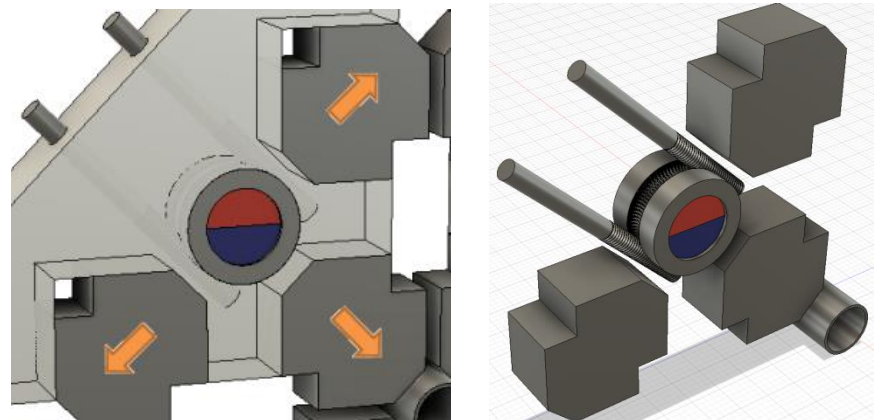
3 Measurement activities to come

- APPLE-III with force compensation
- Variable period undulator

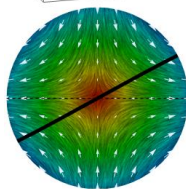
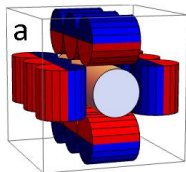
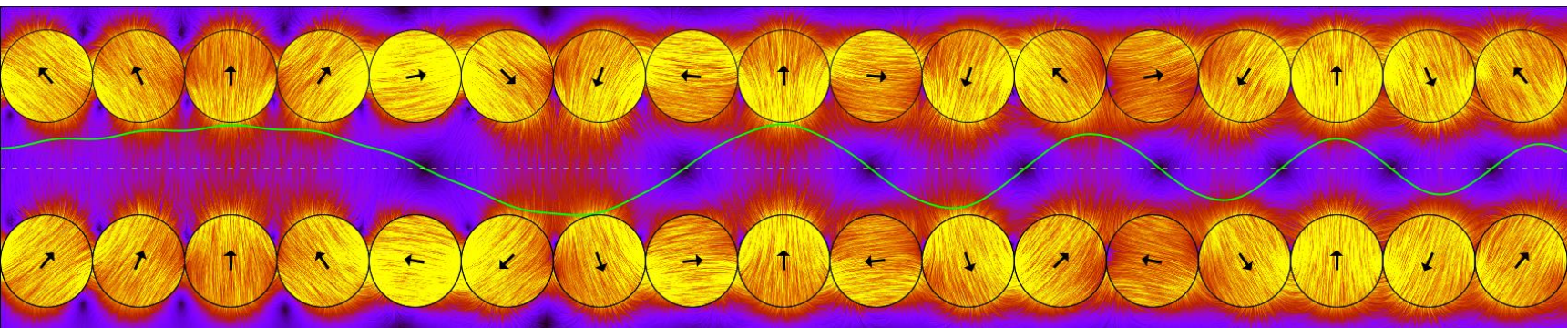
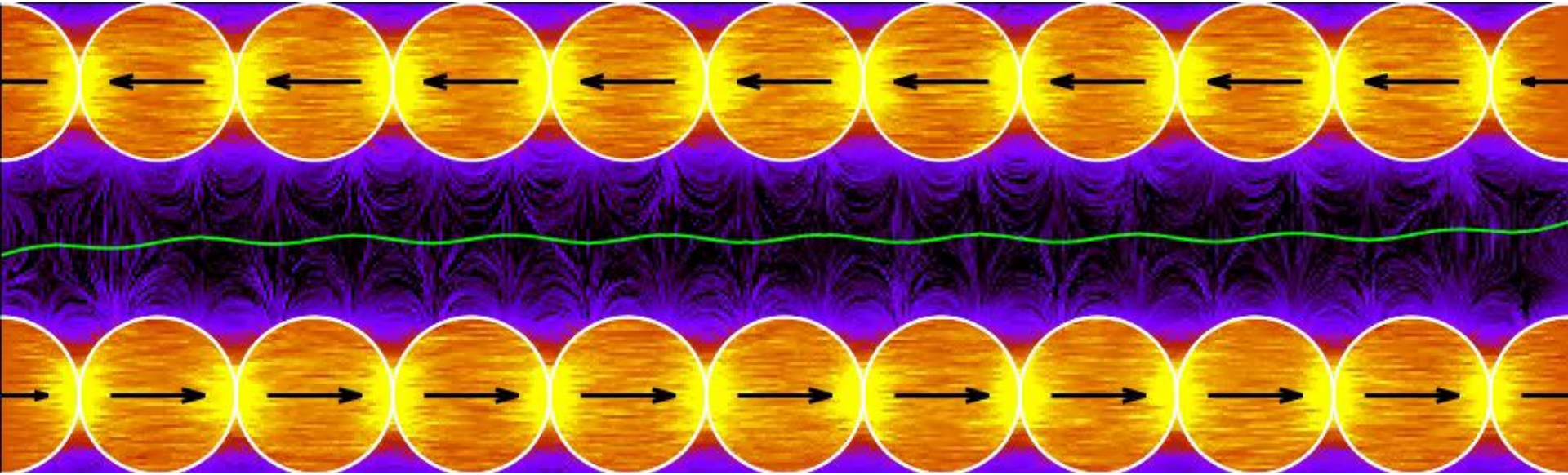
APPLE-III



- Same magnets for compensation
- x3 magnet pool for sorting
- Force reduction up to factor of 8
- “Continuous” correction magnet
- Measurement with a normal bench through 1mm side gap
- Customized Hall probe holder



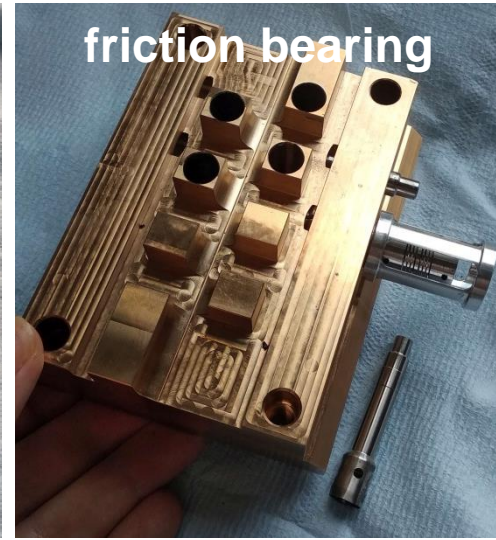
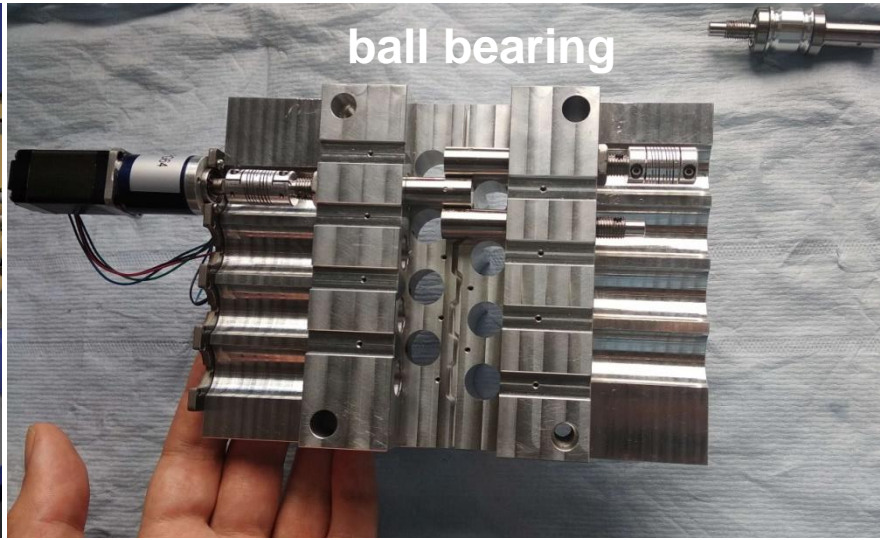
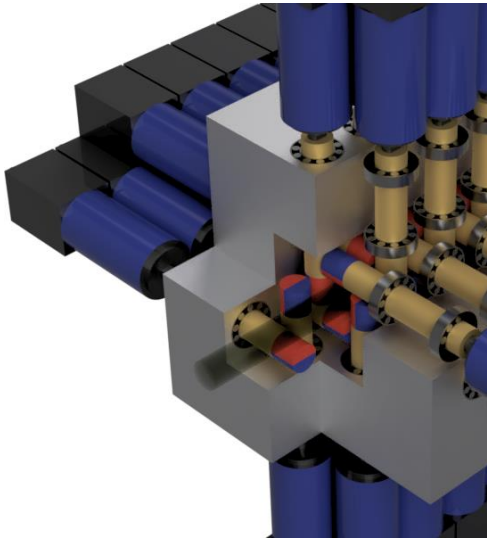
Variable period undulator



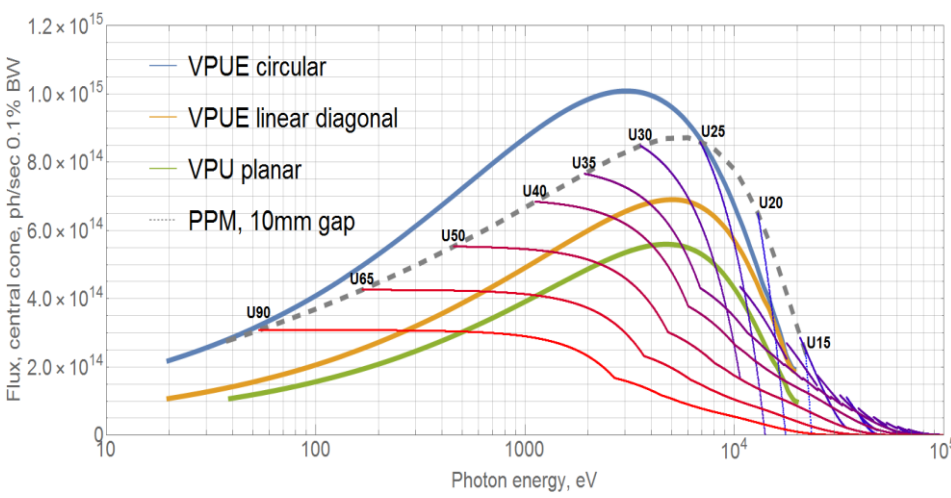
90 T/m

- Arbitrary shaped magnetic field

Variable period undulator



SRI-2018, AIP Conference Proceedings 2054, 030024 (2019); <https://doi.org/10.1063/1.5084587>



- Stretched wire measurements of the individual magnets inside the structure

Thank you!

Contact

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