Magnetic Measurements and Tuning of FLASH II Undulators.

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HELMHOLTZ | ASSOCIATION

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DESY

Conclusion

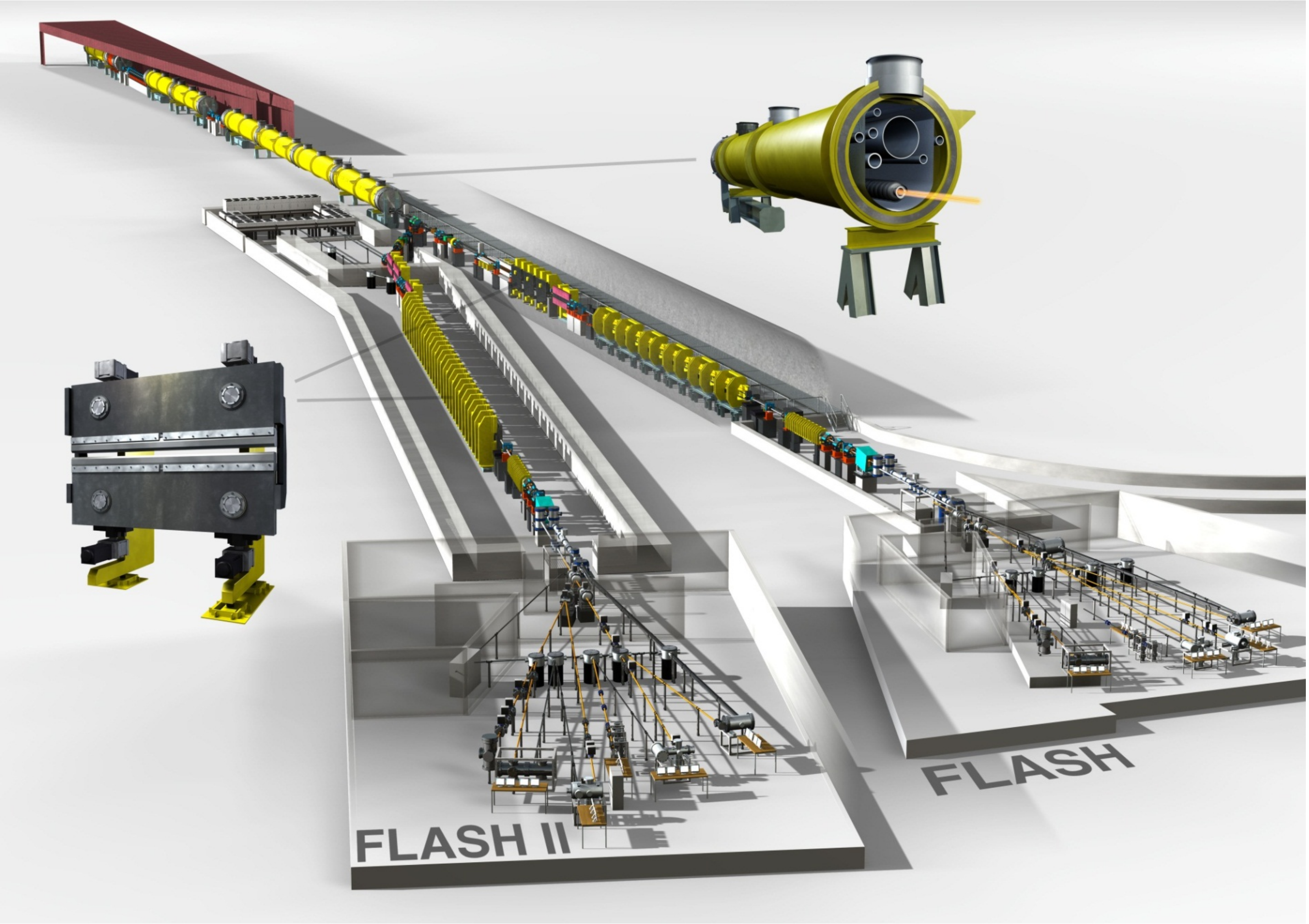
> FLASH II - IDs

- Improved mechanical design based on PETRA IDs
- Smaller end-kick gap dependence
- Transfer measurements consider the actual pole contour
- Installation of 12 IDs in late 2013

> Magnetic Measurements

- Hall probe calibration issues observed
- Characterization of various integrators in order to improve wire & coil measurements

FLASH II



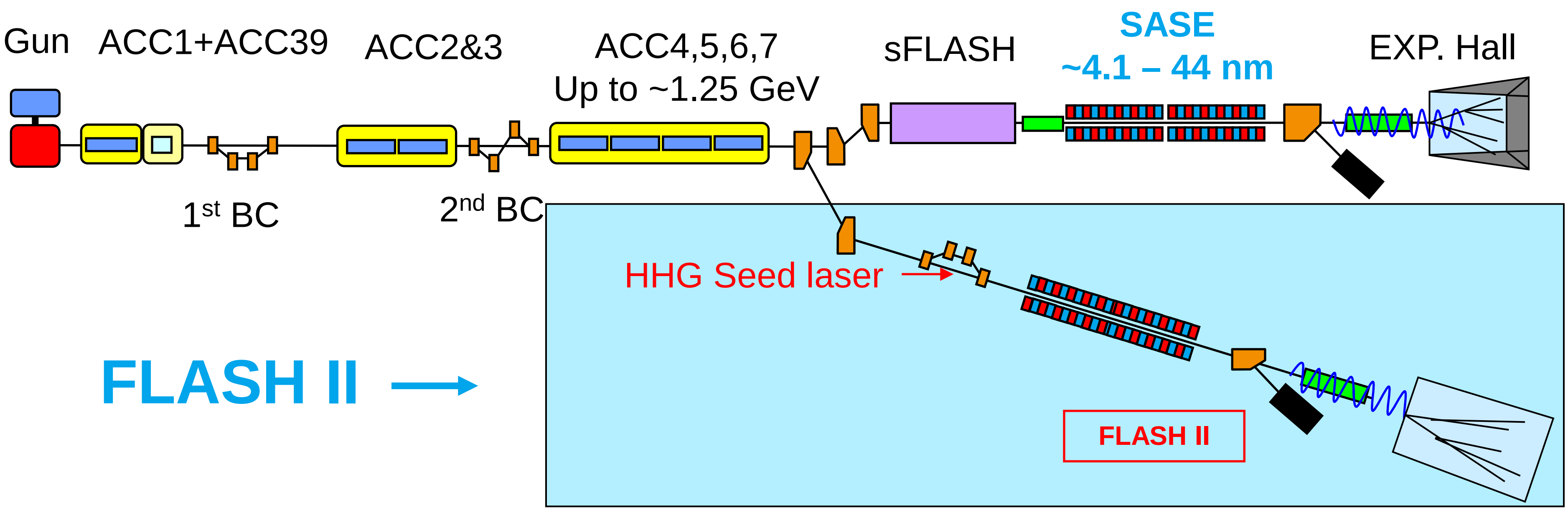
FLASH II

Beam parameters	
Beam energy	0.5 – 1.25 GeV
Normalized emittance	1.4 – 3 mm mrad
Energy spread	0.5 MeV
Peak current	2.5 kA
Bunches per second	<8000
Bunch charge	0.02 – 1 nC

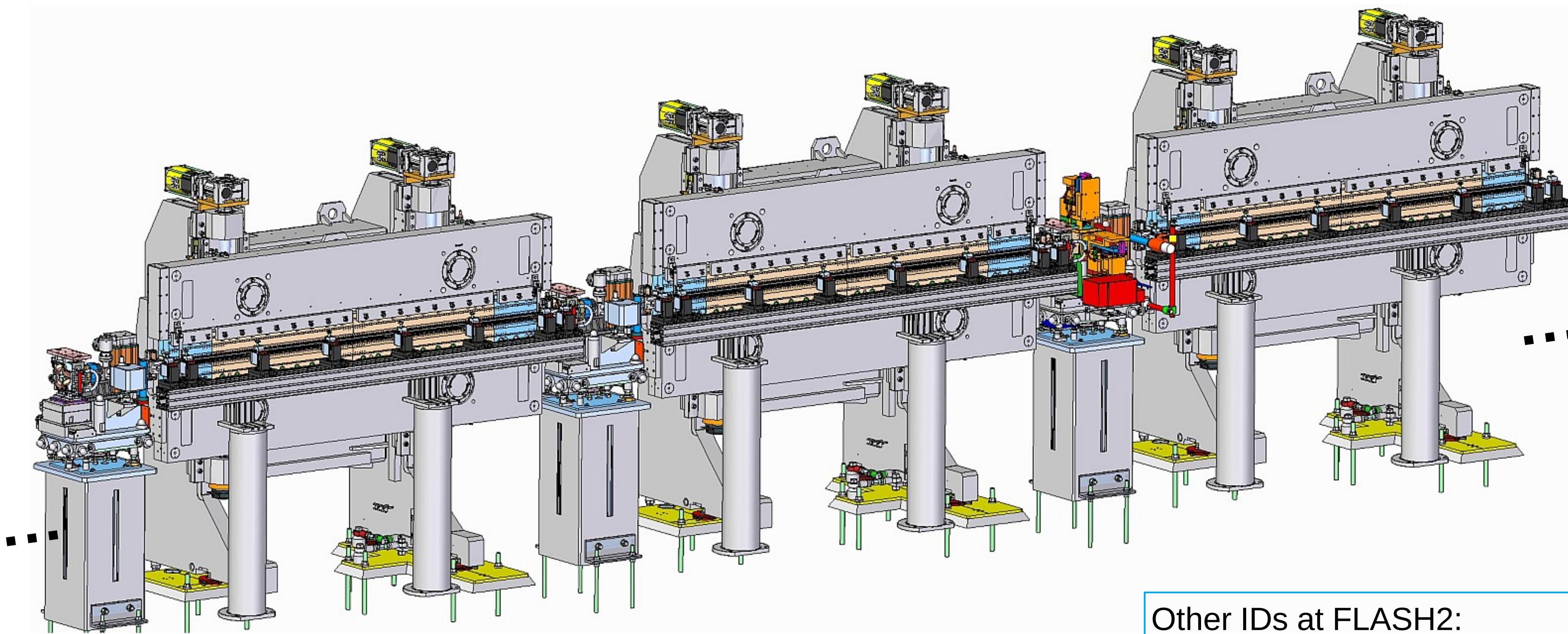
SASE undulators	
Period length	31.4 mm
Segments length	2.5 m
No. of segments	12
Focusing structure	FODO

Radiation	SASE
Wavelength range SASE	4-60 nm
FWHM pulse length	10-500 fs
Peak power	1-5 GW
Bandwidth	0.5 – 2%
Number of pulses	<8000
Peak brilliance*	10^{28}-10^{31}
Pulse energy	1-500 µJ

* 1/(s mm^2 $mrad^2$ 0.1%)



FLASH II SASE Undulator Section



Other IDs at FLASH2:
- Optical modulator (1m)
- THz em.-Undulator (3.5m)
- Seeding IDs (future upgrade)
- 2^{nd} harm. AfterBurner, (EPU,future)

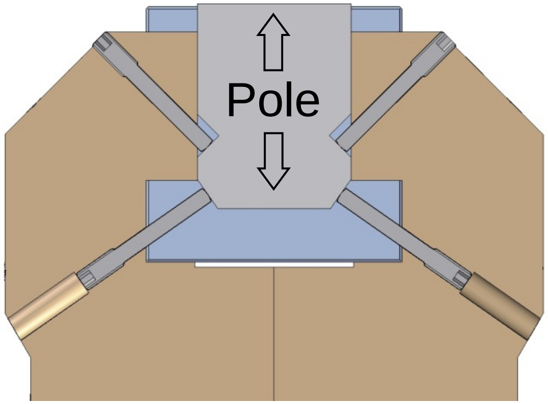
- 12 ID segments separated by diagnostic intersections
- similar optics as for present sFLASH undulators
- U32 undulators

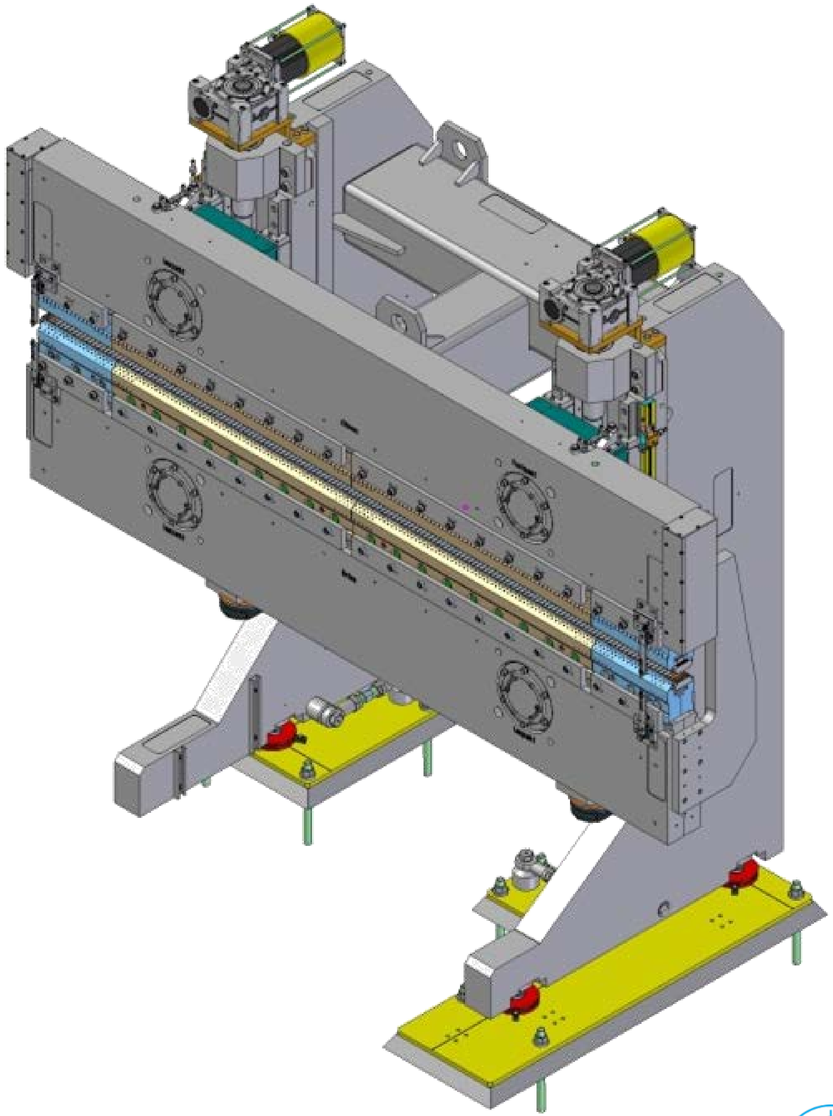
λ_u	= 31.4 mm
g_{min}	= 9.0 mm
B_{peak}	= 0.98 T
K	= 2.87
L	= 12 × 2.5 m

- Intersection comprises quadrupole, phase shifter (e.m.), BPM, OTR / wire scanner

FLASH II undulator

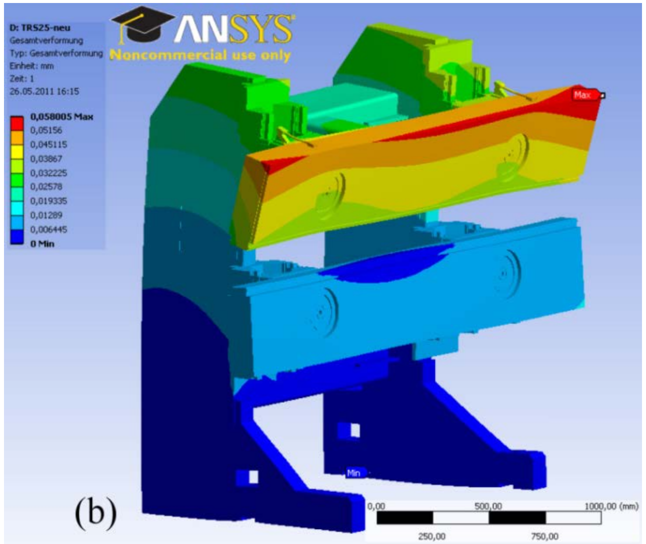
- Period: 31.4 mm
- Gap: 9.0 mm
- Field: 0.98 T
- Kmax: 2.87
- Length: 2.5 m
- Load: 15 kN

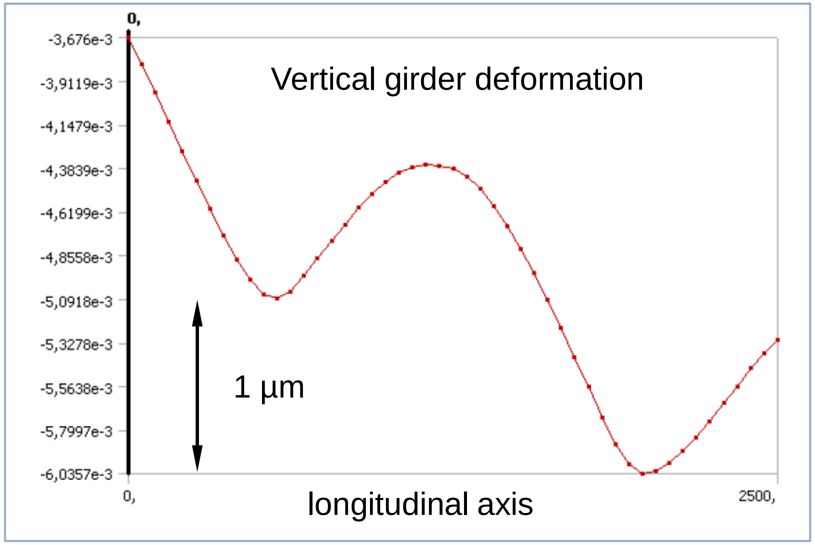




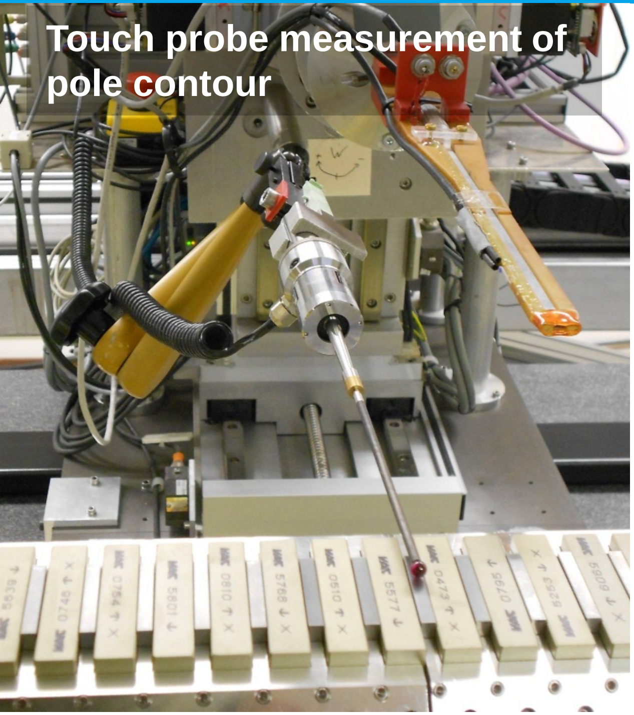
Support structure

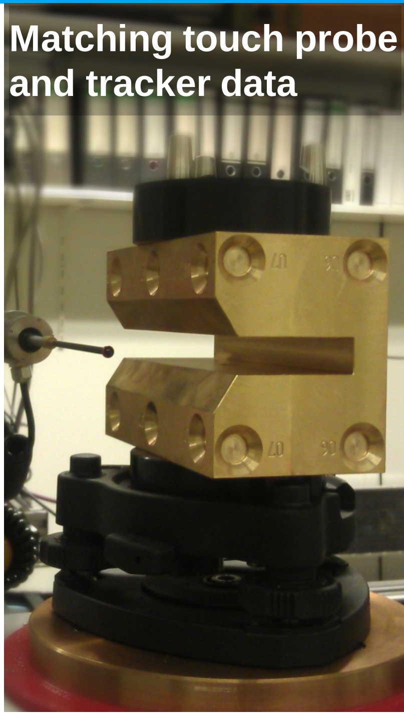
- Same concept for FLASH II and PETRA Extension undulators
  (based on 2m devices used for PETRA III)
- Various mechanical improvements (stiffness, adjustment, floor mount)
- Less than 2 µm girder deformation under magnetic load
- Revised drive system: 2 motors and 2 pairs of left/right-handed spindles
- New linear encoder gap measurement system

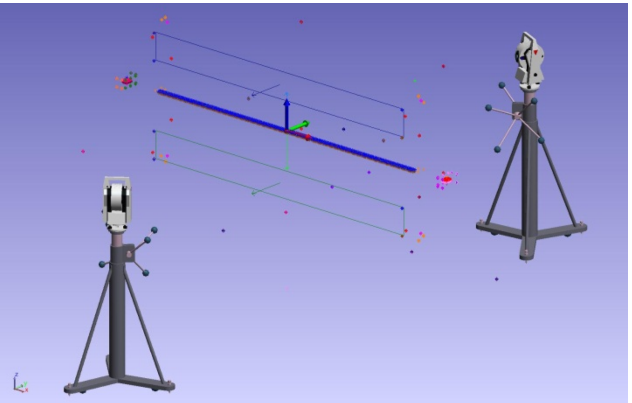


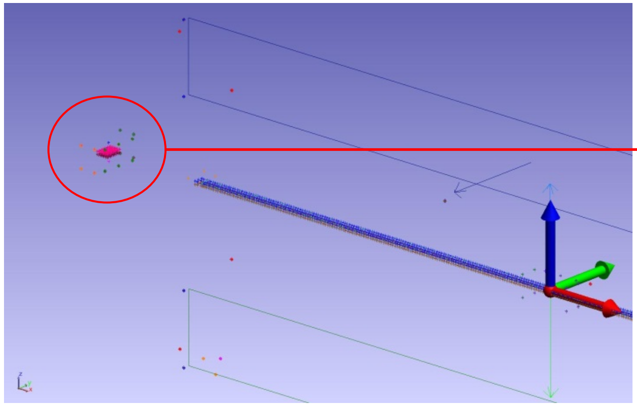


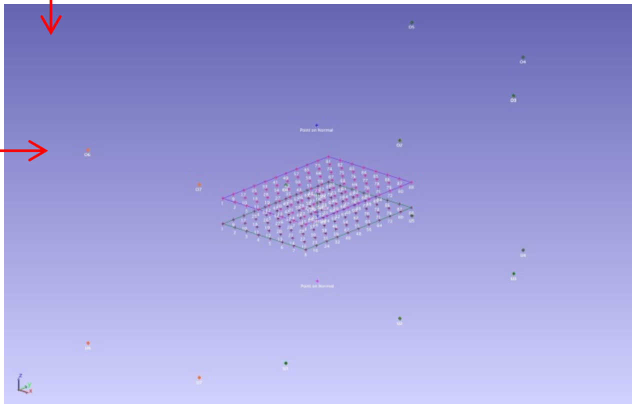
Transfer measurements







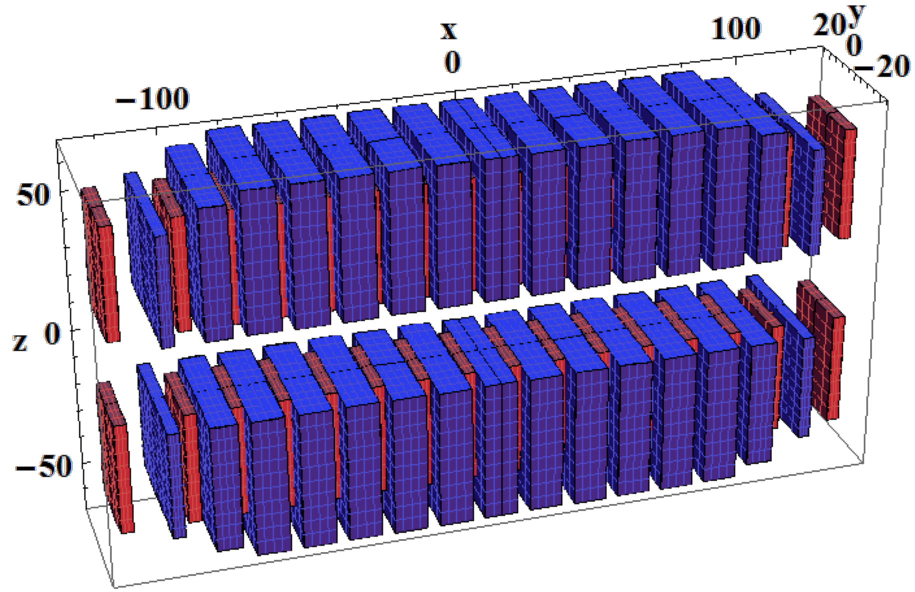


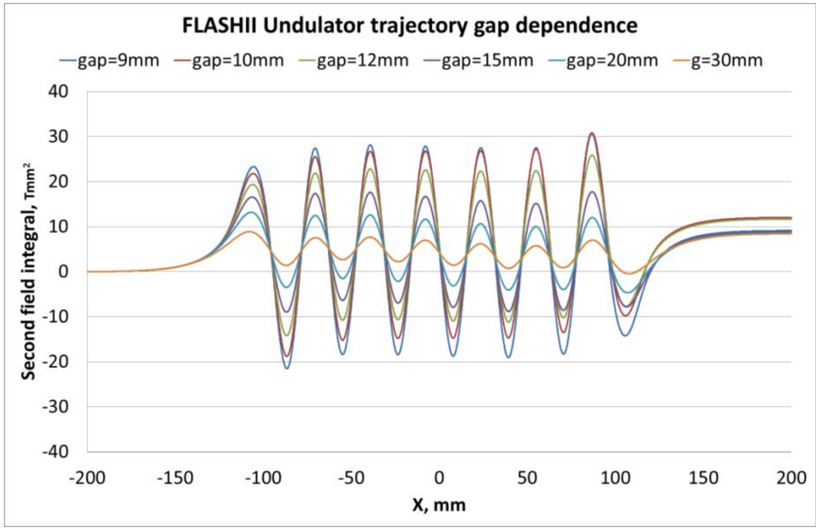


End structure

Parameters to optimize:
Last 2 magnets size (x,z), position(x,z)
Last 2 poles position(x)

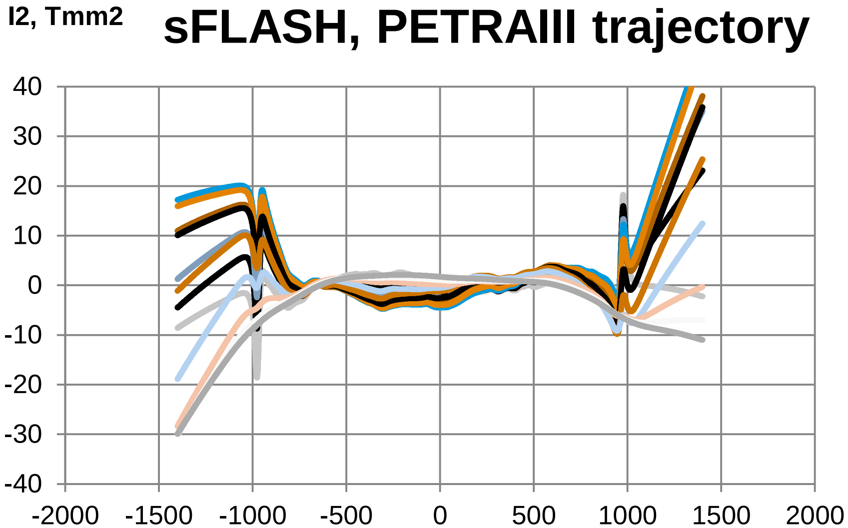
1) Calculate endkick gap dependence of present configuration
2) Change each parameter a little
3) Calculate endkick gap dependence signature of each parameter
4) Find weights of signatures using least squares, that would compensate gap dependence best
5) Apply constrains: poles & magnets should not collide, limit maximum changes, to stay in linear range
6) Repeat



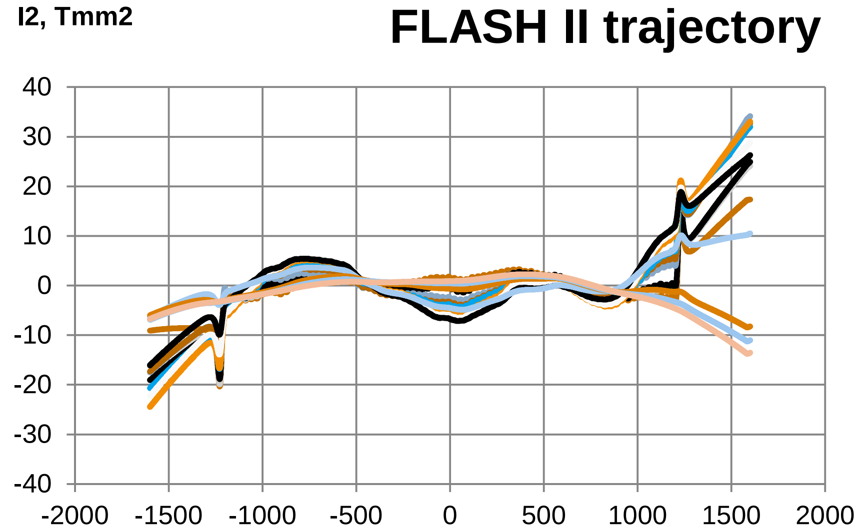


Endkicks gap dependence

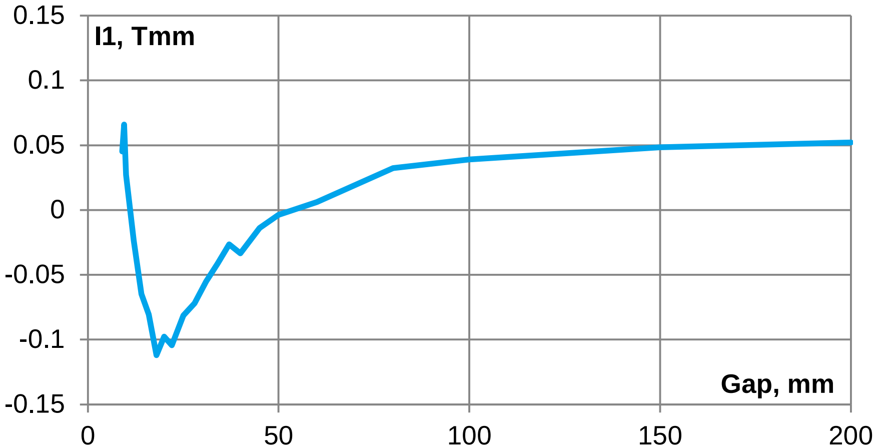
sFLASH, PETRAIII trajectory



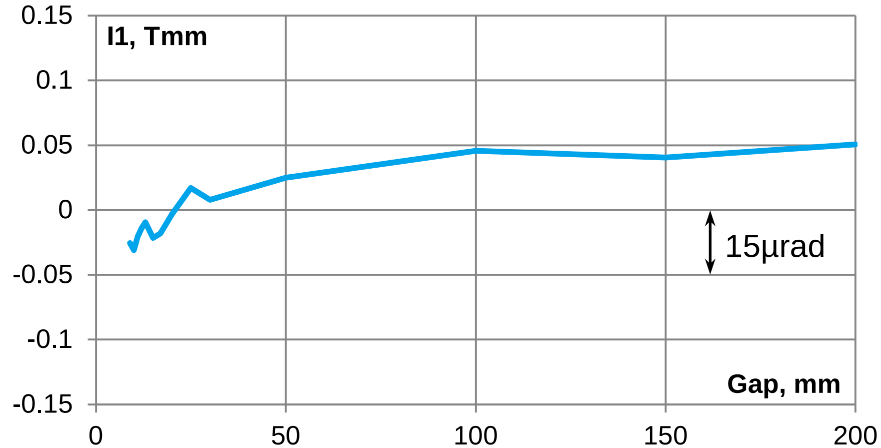
FLASH II trajectory



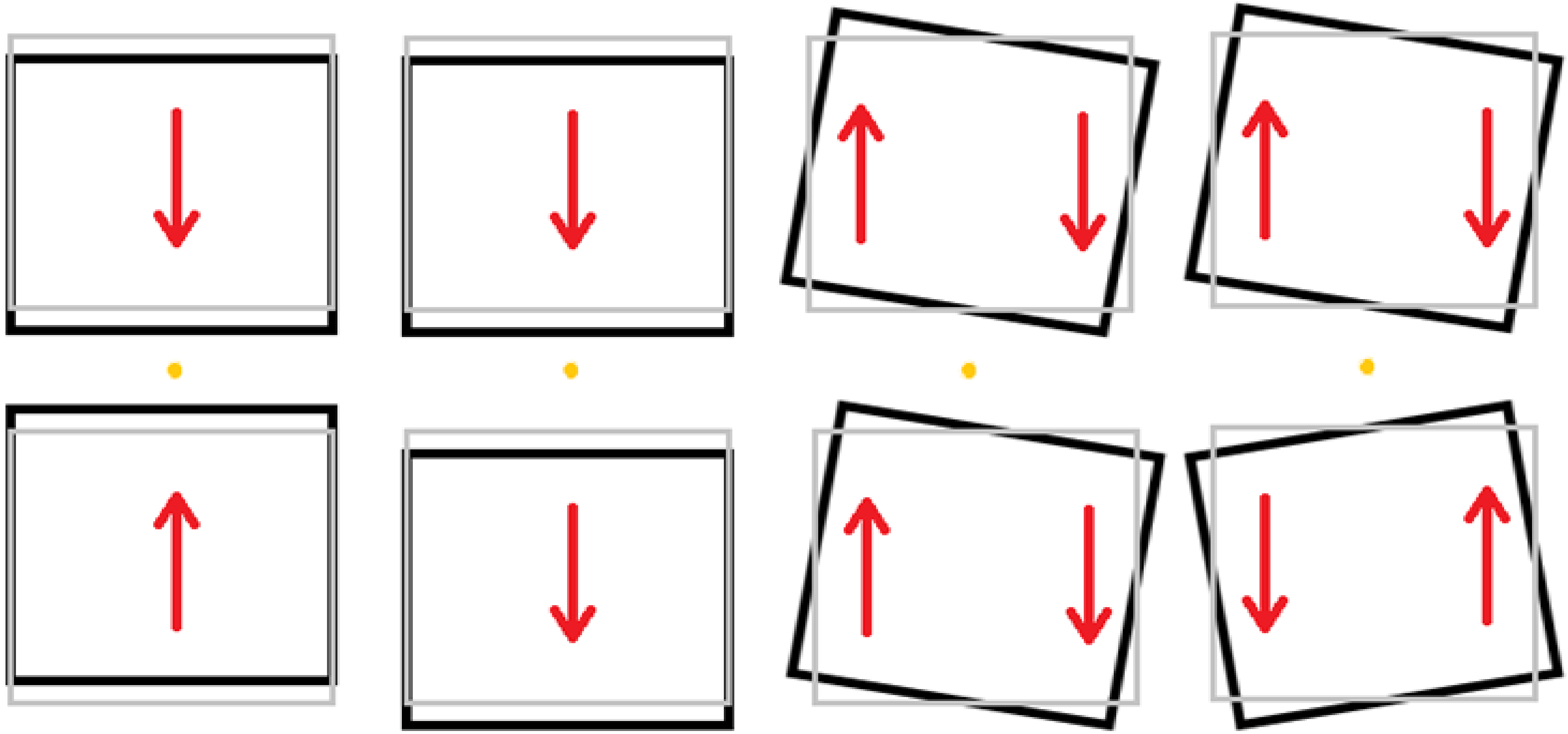
1st integral gap dependence



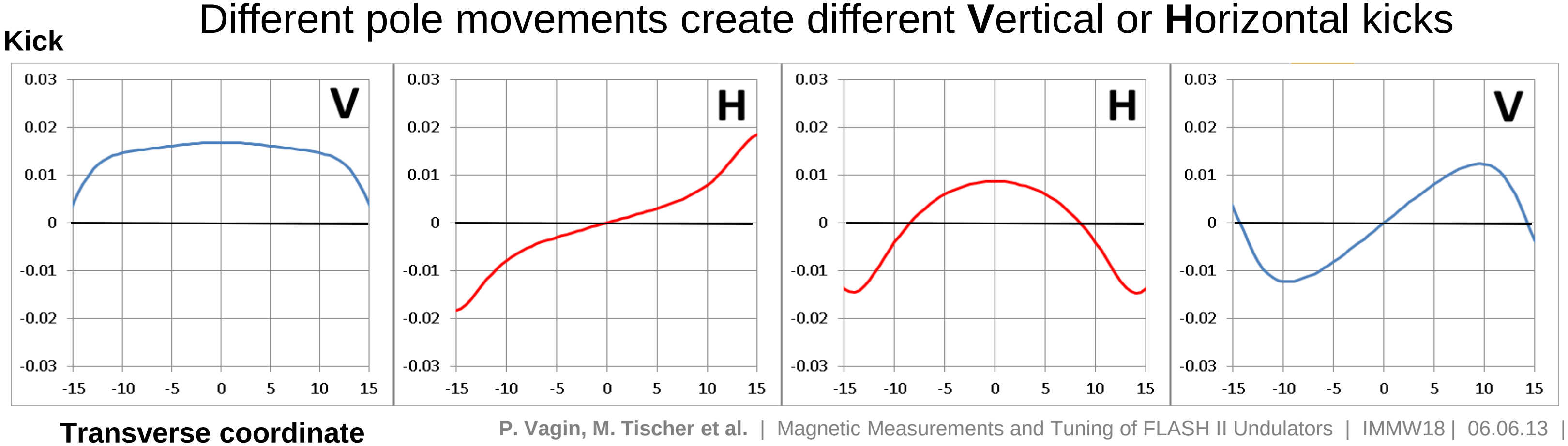
1st integral gap dependence



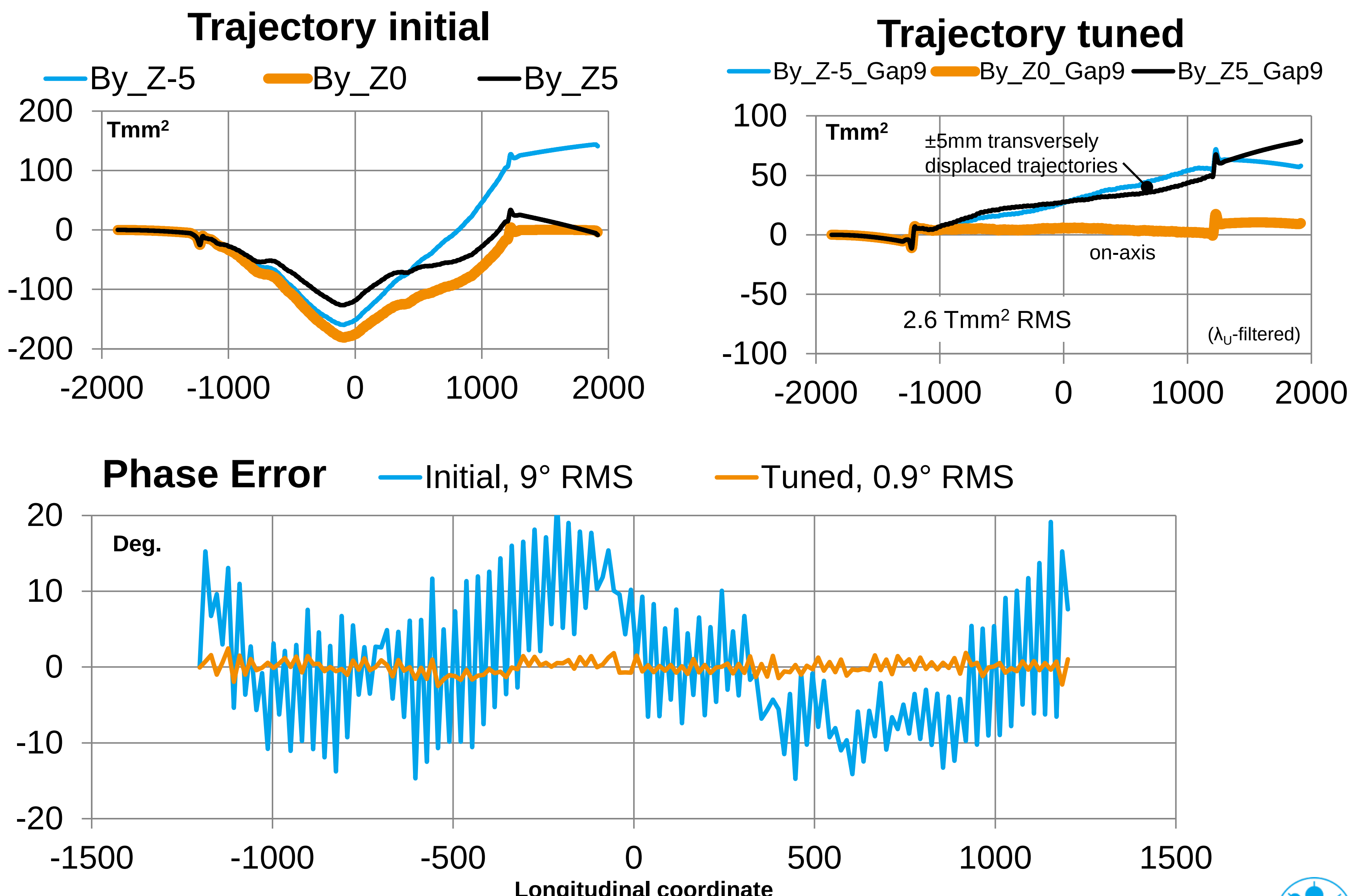
Pole tuning



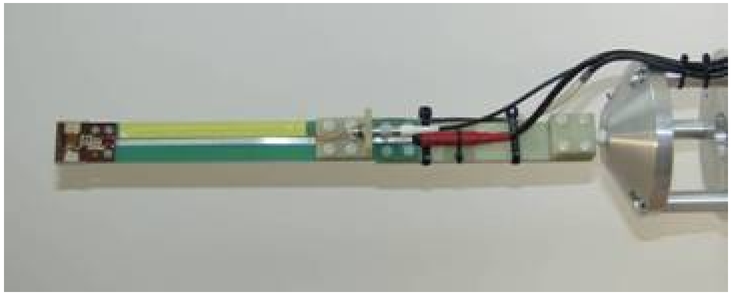
Different pole movements create different **V**ertical or **H**orizontal kicks

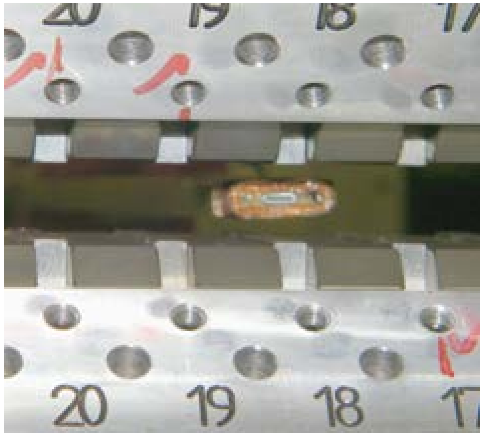


Pole tuning results



Measurement Bench / Stretched Wire Probe

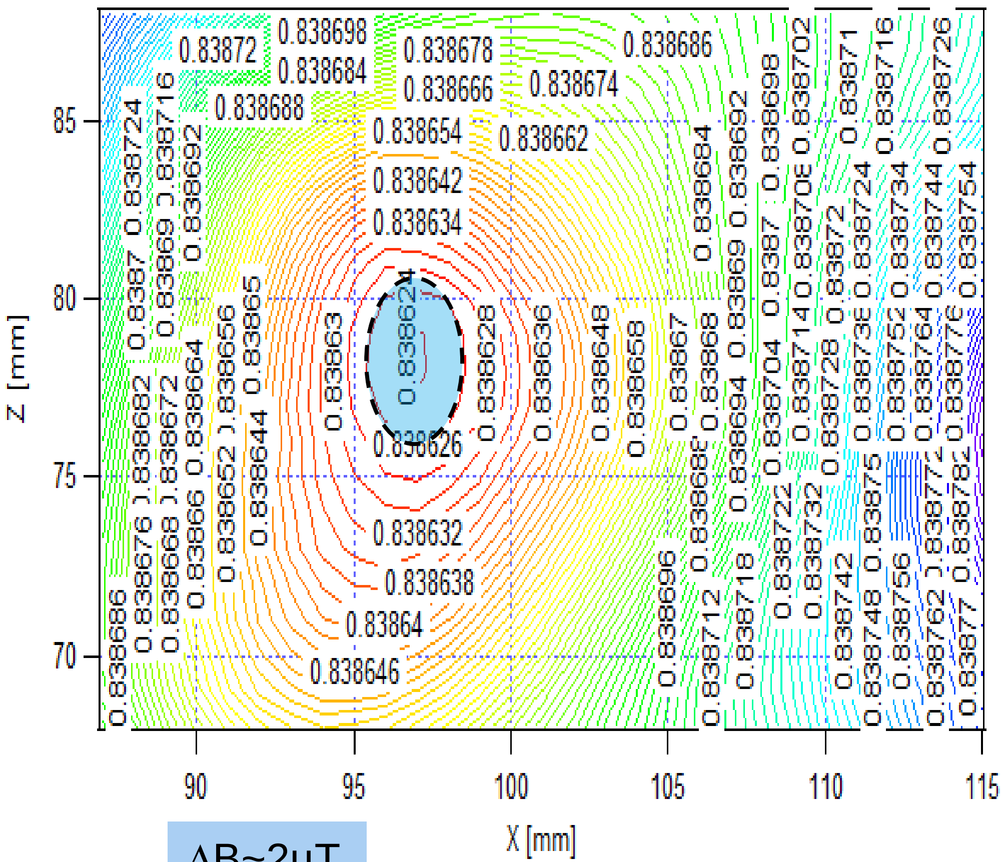




- Hall probe → vertical field
  1D-probe Bell FWB710
- Pick-up coil → horizontal field
  ~5x10mm^2, N~5000
- Stretched wire probe
  Single stretched wire (∅100µm CuBe)

Hall probe calibration

Field map of calibration magnet



ΔB~2µT

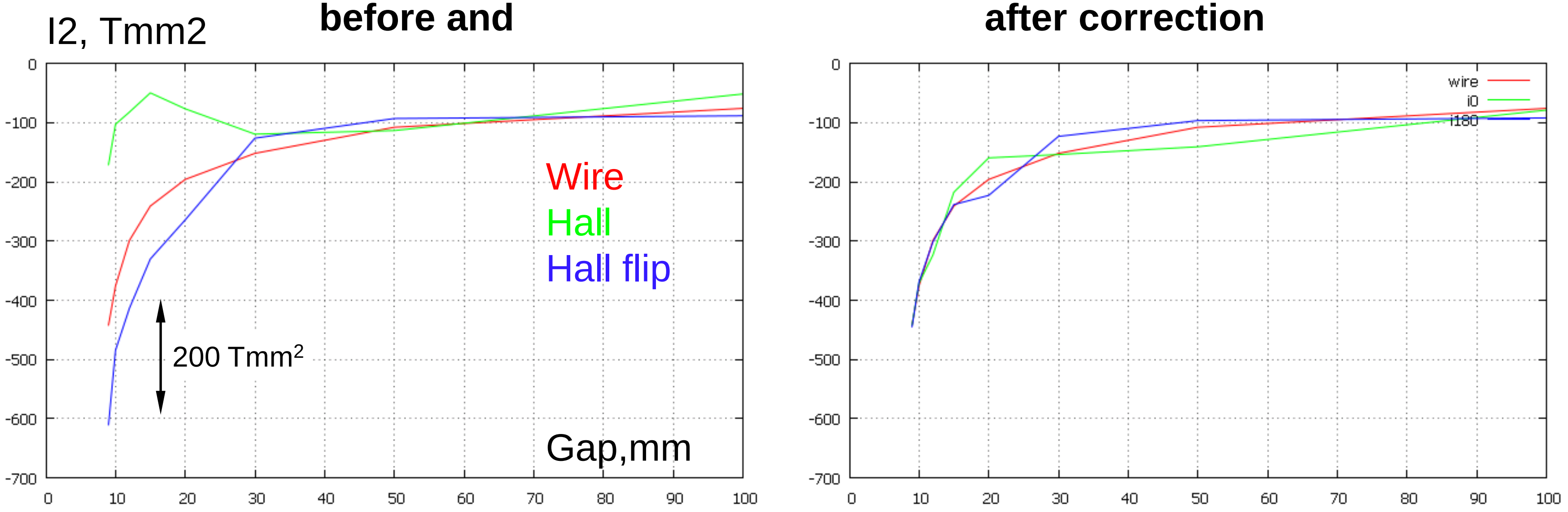
Better alignment of Hall and NMR probe with motorized stages

Adjustment of pole face improves current dependent shift of field plateau

Hall probe calibration correction by stretched wire

2nd Field integral gap dependence

before and **after correction**



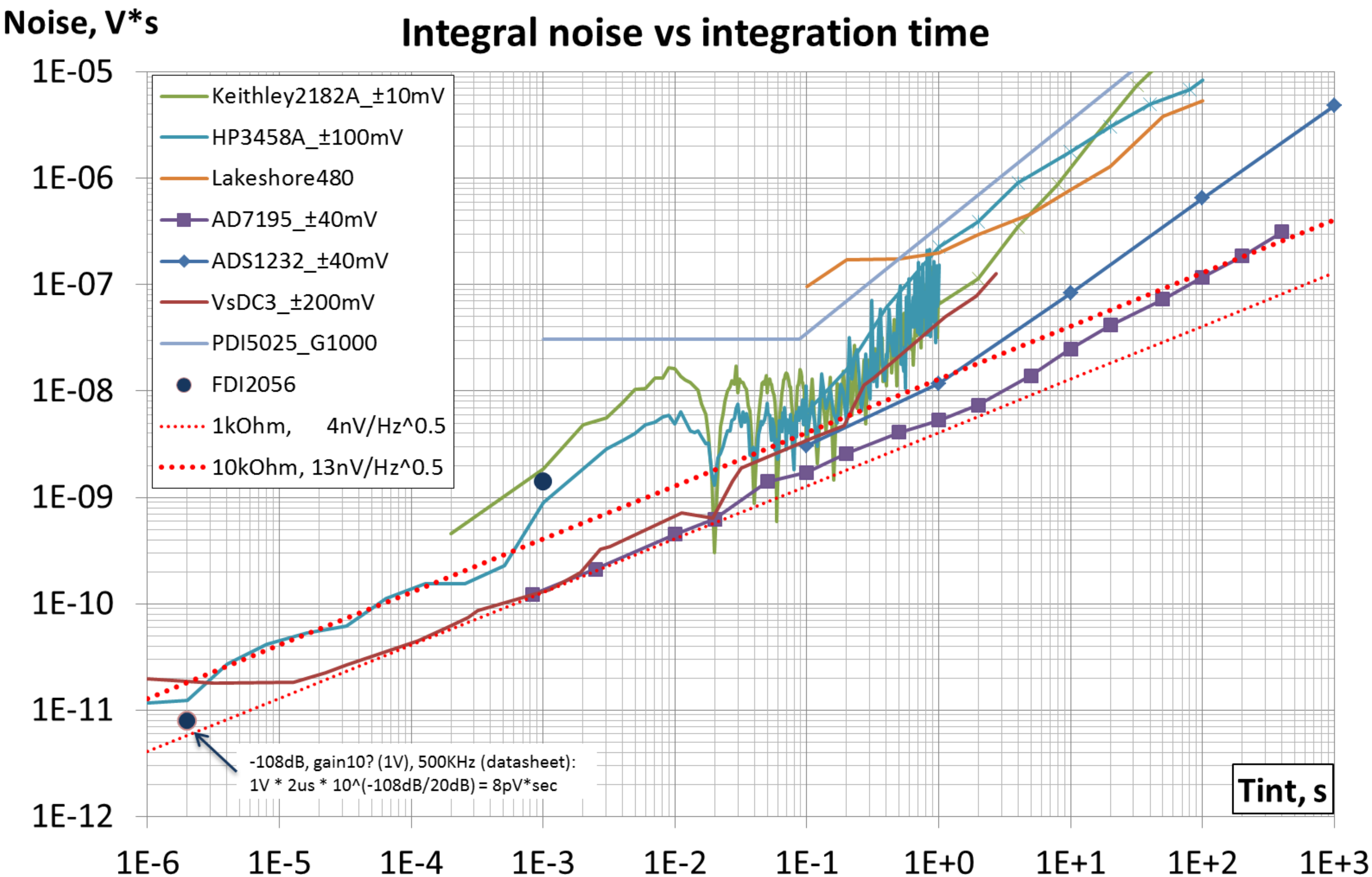
Field integrals measured by stretched wire and hall probe, normal and 180°-flipped, were different: corresponding to ~50uT difference in the average field.

Hall probe calibration is represented by high order polynomial, built using NMR measurements in a calibration magnet; 10µT reproducibility (inclusive 180° flip)

By adjusting even order coefficients, it is possible to minimize difference between hall probe, and stretched wire.

Empirical correction for an error which is not yet understood

Digital integrator’s noise level



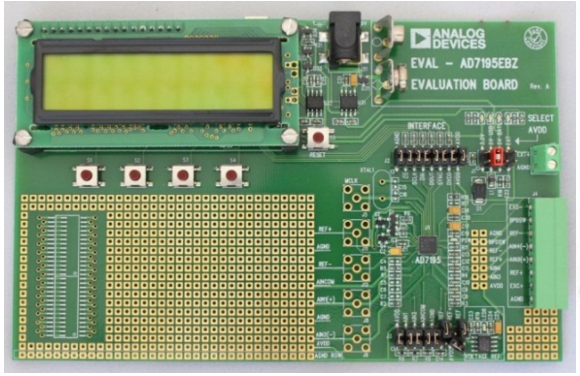
Budker Insitiute of Nuclear Physics: VsDC

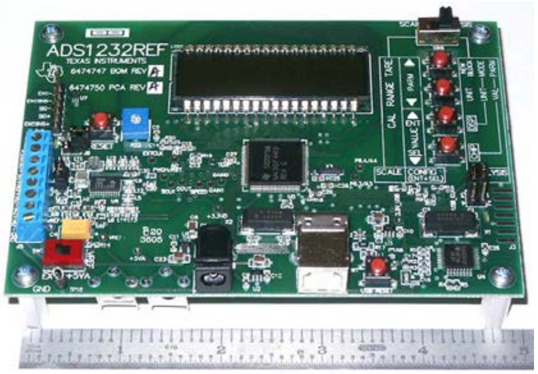
	VsDC2(CAN)	VsDC3(VME)
ADC	2 ch, 300ksps, 24bit resolution	
Input ranges	±0.2V .. ±10V	±0.2V; ±2V PGA
Integral SNR at 10 μs at 1 ms at 1 s	 $5\cdot10^{-5}$ 10^{-6} $5\cdot10^{-7}$	 10^{-5} $5\cdot10^{-7}$ 10^{-7}
Absolute error at 10 μs at 100 μs > 1 ms	 10^{-3} 10^{-4} 10^{-5}	 10^{-3} 10^{-4} 10^{-5}
Non-linearity	20 ppm max	
Gain error	5 ppm max	
Offset error	±1 μV	
Triggering accuracy	±2 ns	
From factor	3U 4HP Eurocard	6U 4HP Eurocard

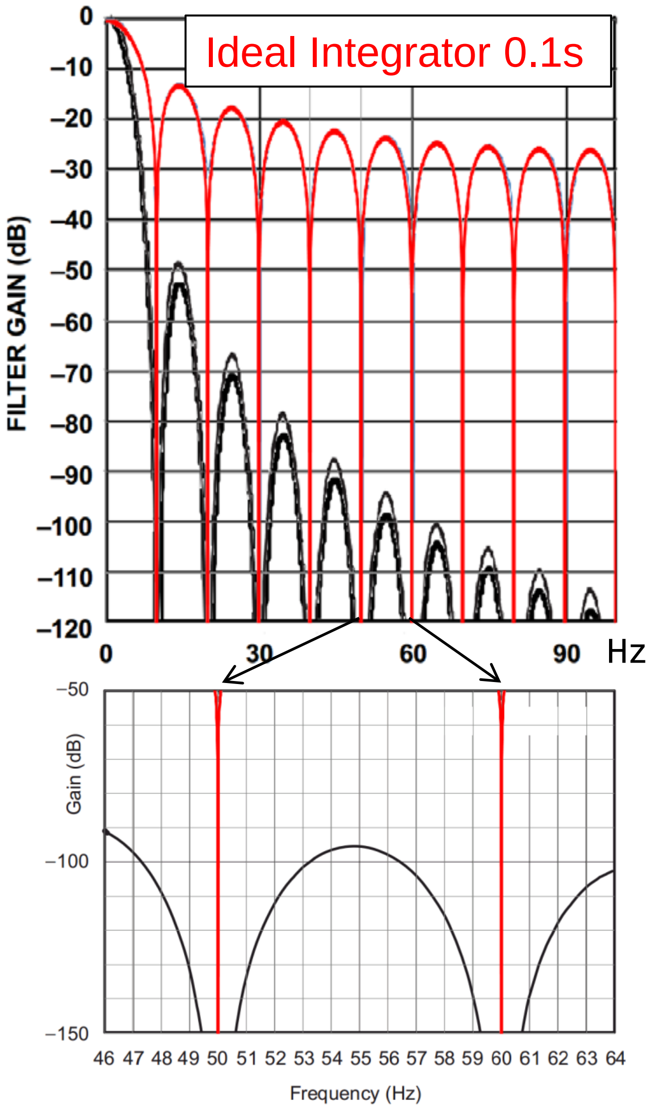
Low Noise Sigma-delta ADC Evaluation Boards

	AD7195EBZ	ADS1232REF
Resolution, bits	24	24
Output rate, Hz	5 .. 4800	10 or 80
Input Range, PGA	±20mV.. ±2.5V	±40mV.. ±5V
Input Noise@10Hz	11nV RMS	17nV RMS
Offset error *	0.5uV, 5nV/°C	0.1uV, 10nV/°C
ADC Gain drift	1ppm/°C	2.5ppm/°C
Nonlinearity, max	15ppm	20ppm
Price	59$	49$

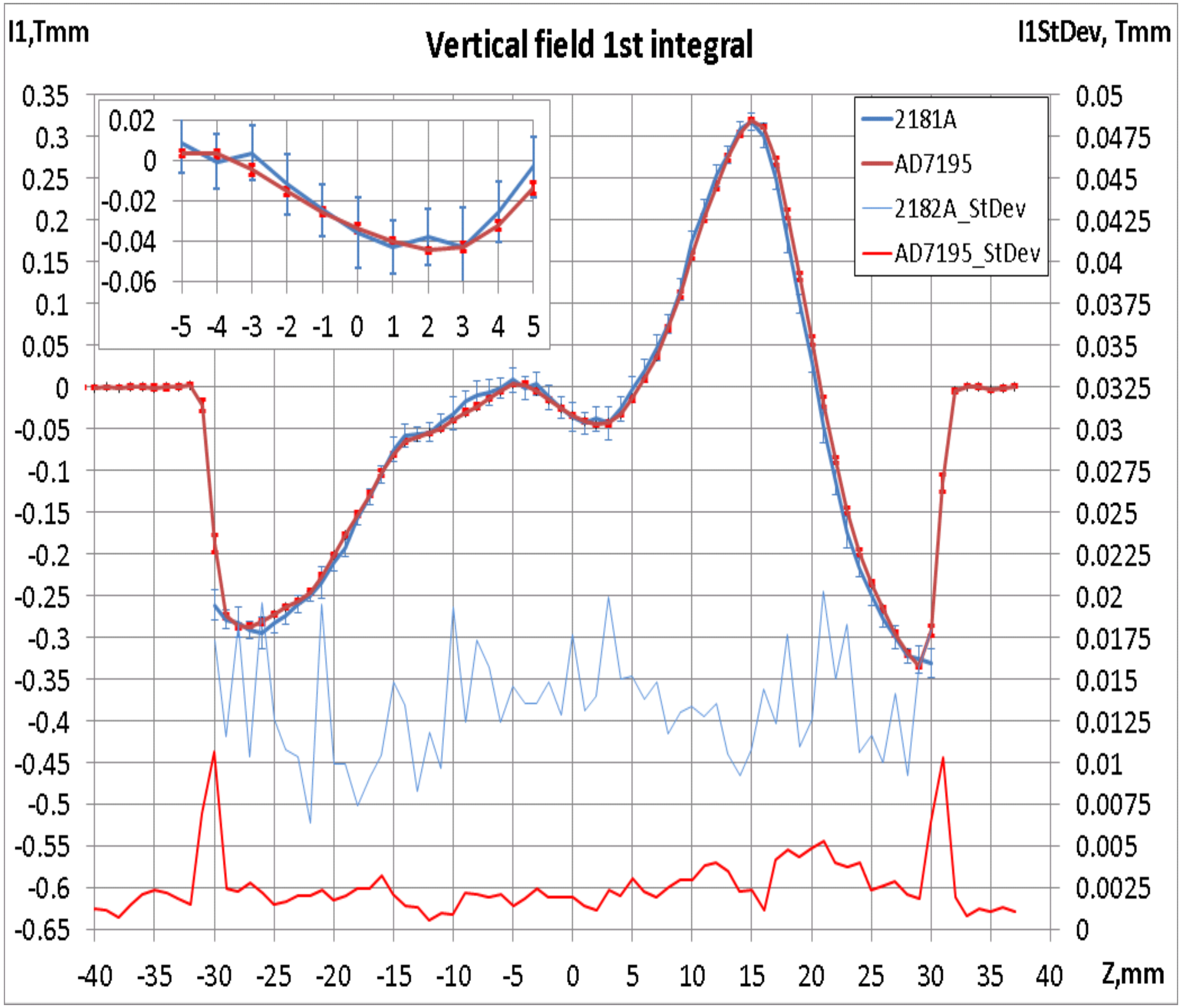
*autocalibration







Stretched wire continuous movement



$$U(t) = -\frac{d\Phi}{dt} = BL\frac{dx}{dt};$$
$$I_1(x) = U(x)/v$$

Present setup:

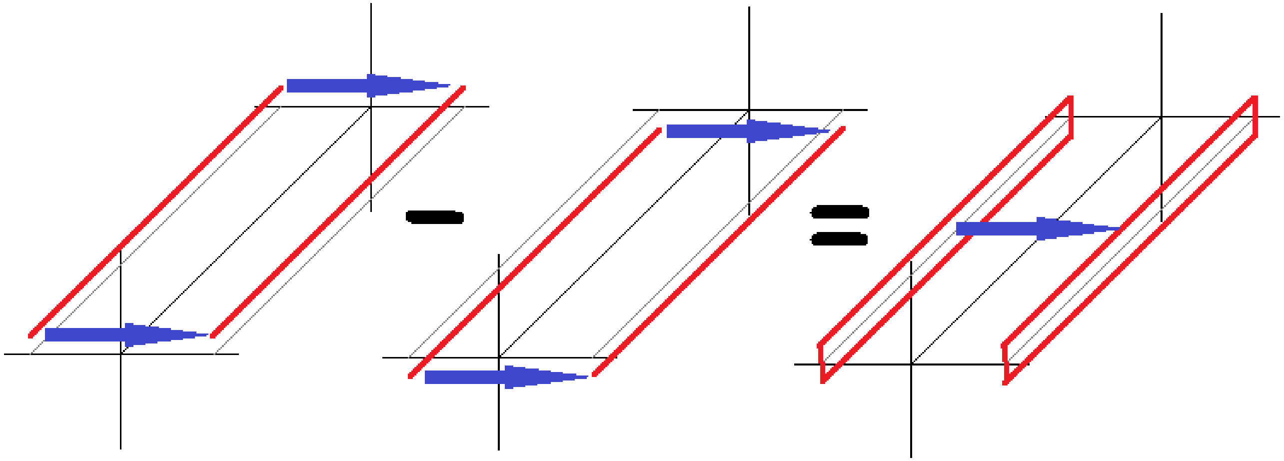
- Keithley 2182A DVM
- 1mm step motion
- ~400ms integration time
- 15 mTmm noise
- 1.5 sec per point
- 100 sec measurement (60pts)

Test setup:

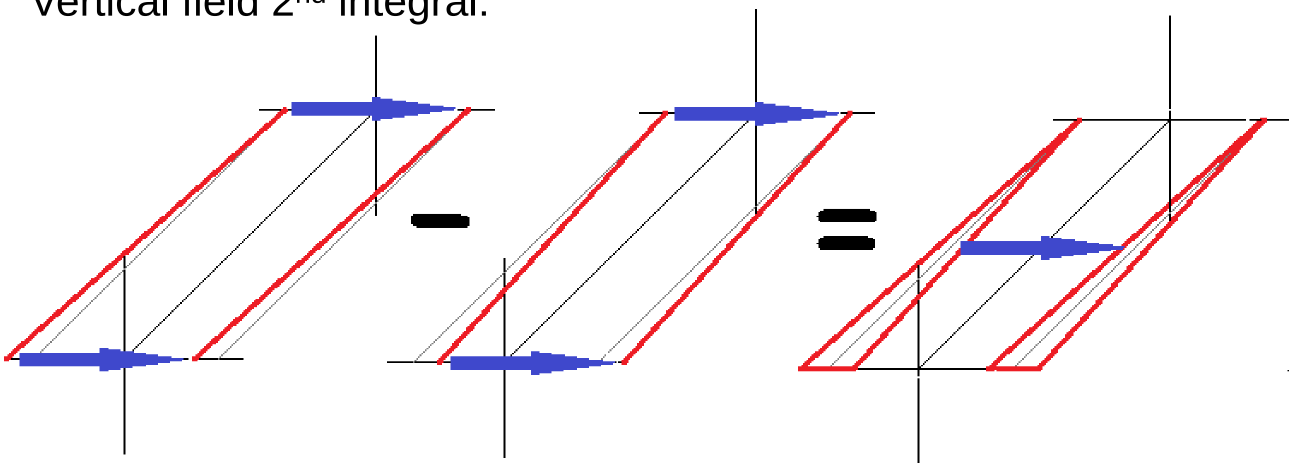
- AD7195EBZ
- Continuous motion
- 10Hz rate, 10mm/s
- 3mTmm noise
- 0.1 sec per point
- 8 sec measurement

Using single stretched wire to simulate various coils

Horizontal field 1st integral:



Vertical field 2nd integral:

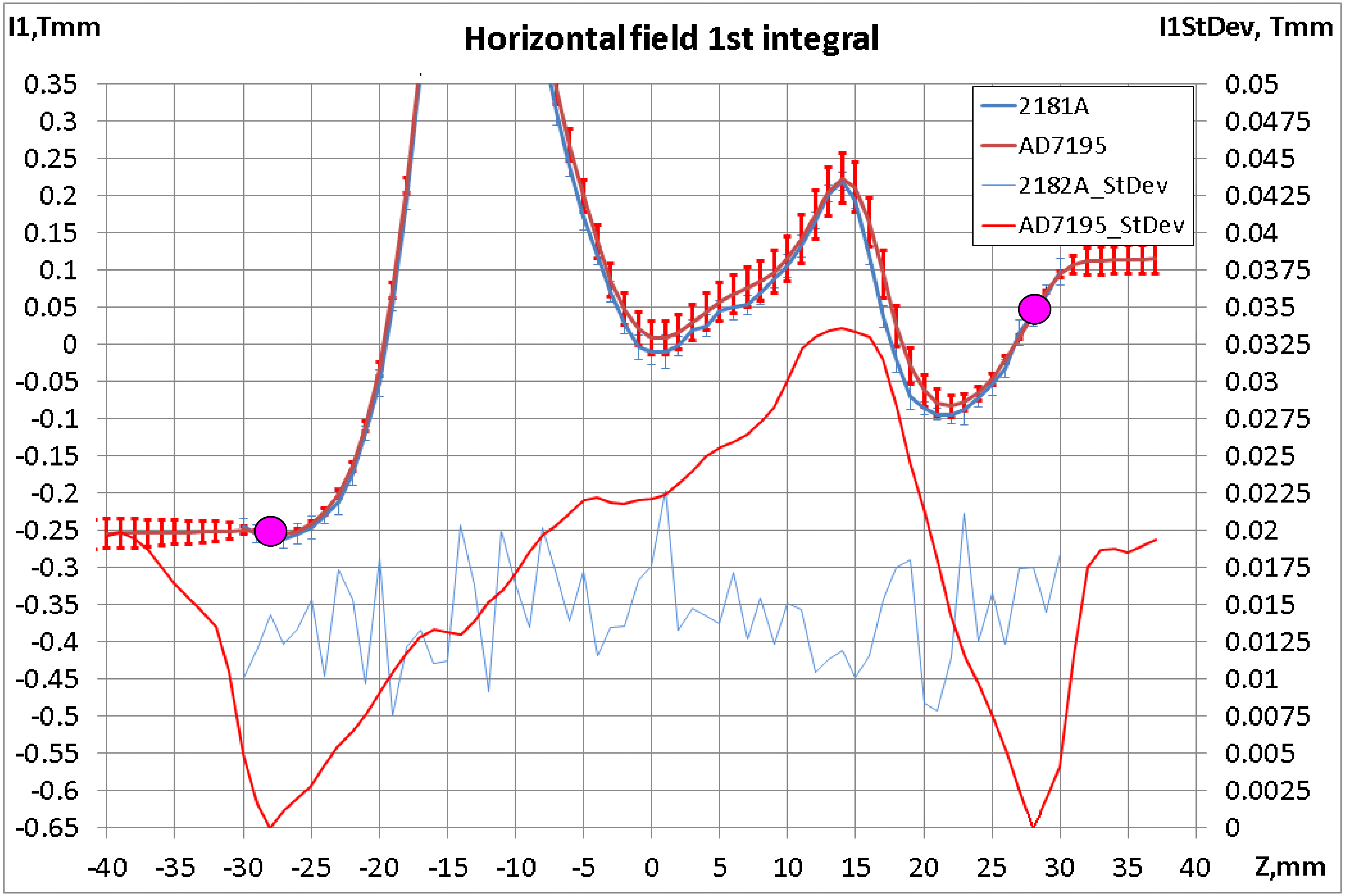


Two measurements required:
Noise √2 higher.

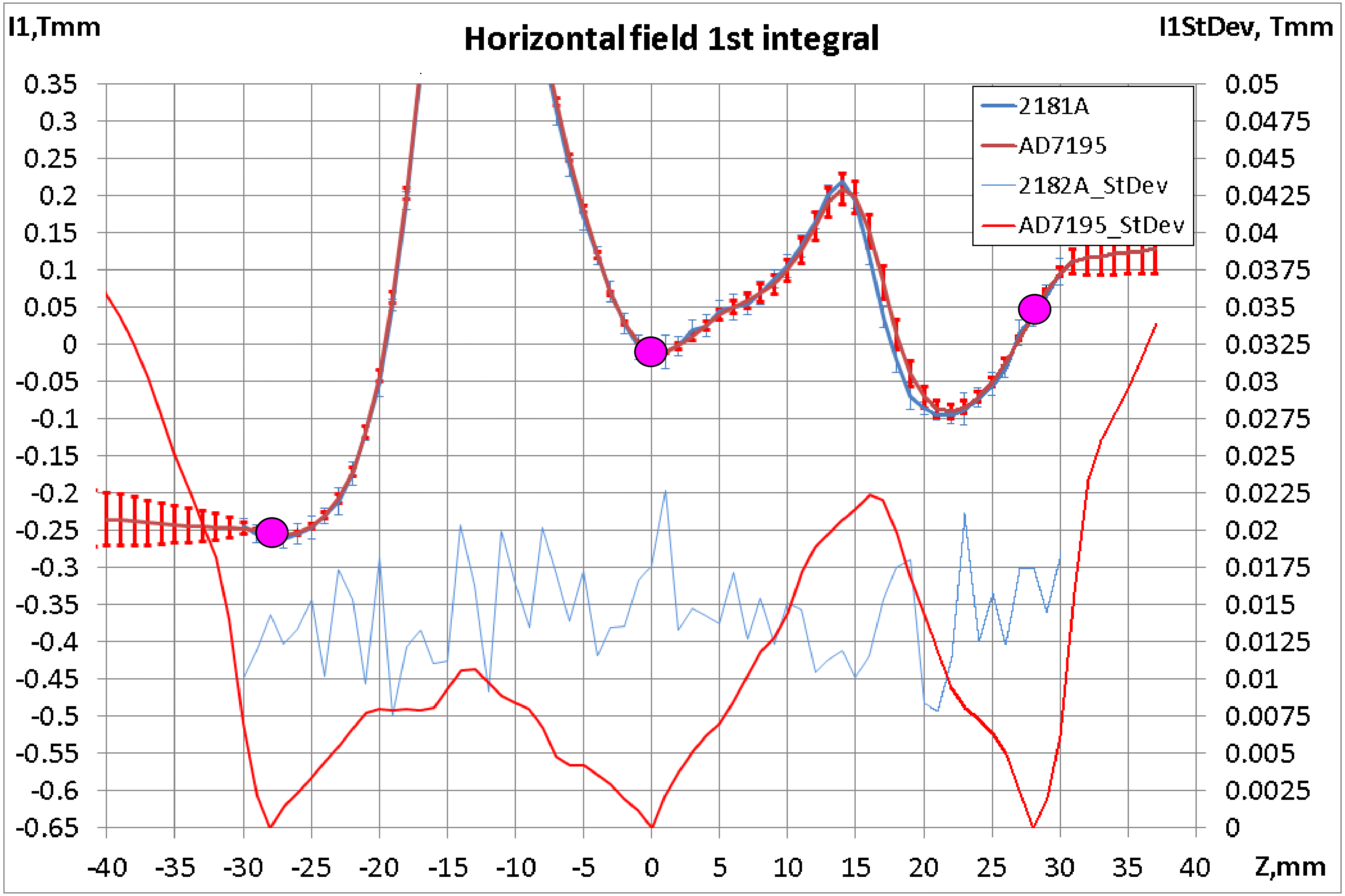
Derivative dI/dy measured:
Integration increases noise

No absolute value:
Additional measurements of absolute values required

Horizontal field 1st integral, linear background (2 points)



Horizontal field 1st integral, parabolic background (3 points)



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