

Dynamic Magnetic Stray Fields in CLIC

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Outline

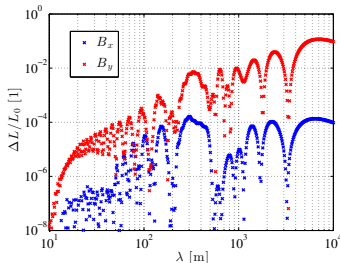
- 1 **MOTIVATION**
- 2 **MEASUREMENTS**
 - CTF3
 - PS
 - XBOX
- 3 **CONCLUSIONS & PROSPECTS**

MOTIVATION

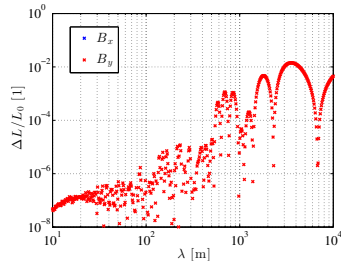
CLIC-BDS Sensitivity to Stray Fields

- In 2010 simulation study of stray field impact on CLIC [†]
 - Tolerance of \approx nT for the BDS (collimation section)
 - Mitigation techniques (shielding, feed-forward system)
 - Lack of measurements on equipment
- Presently J. Pfungster calculations confirm tolerances and critical sections to Stray Field variations

Due to position offset



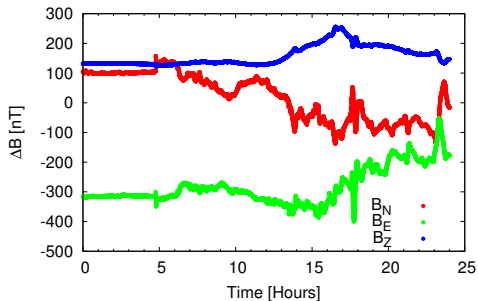
Due to angle offset



[†]J. Snuverink et al, WEPE023, IPAC'10

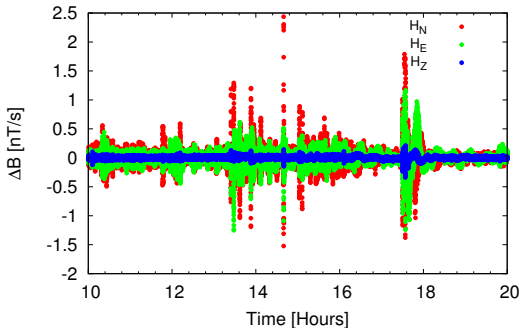
Magnetic Field Variation

- Natural Magnetic Fields (Earth's field, geomagnetic storm)
 - \vec{B} -fields due to technical equipment
-
- Geomagnetic storm at Tihany Geophysical Observatory ^a
 - Magnetic field expressed in XYZ components (X-North, Y-Eastern, Z-Vertical)
 - Max. $\Delta\vec{B}$ observed during severe storm $\approx \mu\text{T}$ (infrequent and predictable)



^asimilar latitude as Geneva
Data courtesy of B. Heilig

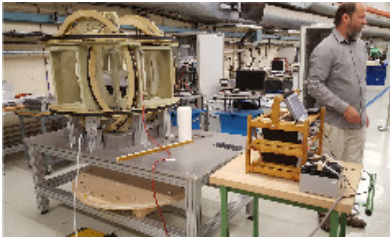
Magnetic Field Variation



- Maximum variation observed at 1 Hz is \approx nT
- Measurements at higher frequencies would be needed to cope with the fields generated by equipment
- Might be compensated by means of feed-back system

STRAY FIELD MEASUREMENTS @ CERN

Measurement Set-up



LEMI-035 magnetometer



MAIN TECHNICAL PARAMETERS

Measurement range	± 70000 nT
Magnetic field variation range (w/o additional compensation)	± 1000 nT
Analog output sensitivity	5 mV/nT
Analog output range	± 4.8 V
Frequency band, 4th order Butterworth low-pass filter	0...20 Hz
Noise level at 1 Hz	< 10 pT

- Compact, portable and easy to set-up
- Specifications are not perfectly fitted to our requirements
 - Data acquisition at 128 Hz
 - Filter cut-off of the magnetometer is at 20 Hz
 - **Not operational under radiation**

Scenes

- 1st measurement campaign: 20/06/2016-29/06/2016
- 2nd measurement campaign: 16/01/2017-20/01/2017

- CTF3

- PS Ring

- XBOX

- AD Hall

- PACMAN

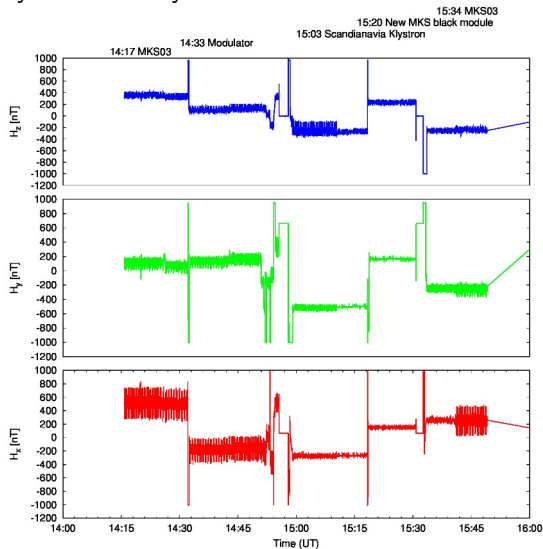
- LINAC-4



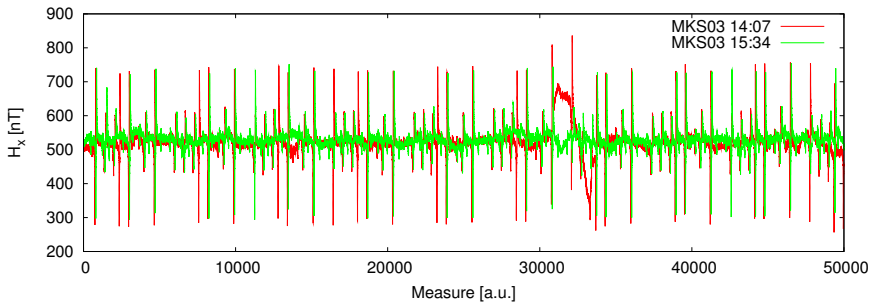
CTF3

Measurement at the Klystron Gallery

- MKS03
- Modulator
- Scandinavia
- New MKS
- MKS03



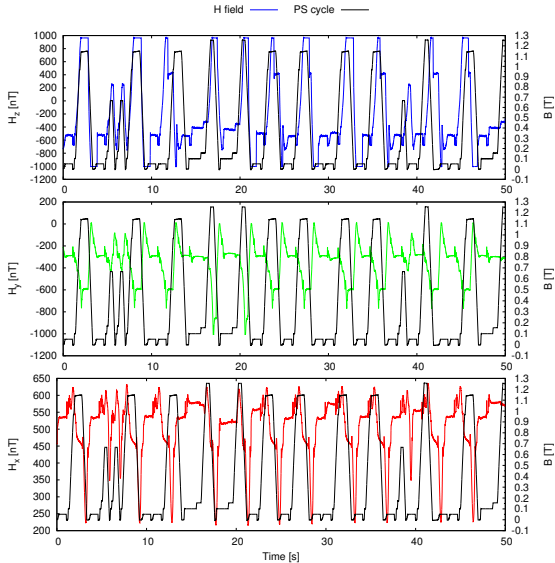
A common pattern was observed at all locations



Is this coming from the PS?

Proton Synchrotron Pulsing

Clear correlation between measured signal and PS cycle

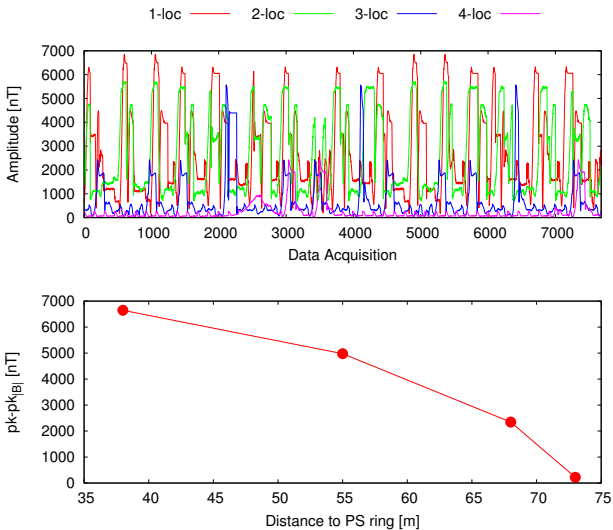


Proton Synchrotron



		Measurement Spots			
		L1	L2	L3	L4
Distance to center	[m]	62	45	31	27
Duration	[min]	12	9	2	5

Clear correlation between measured signal and PS cycle

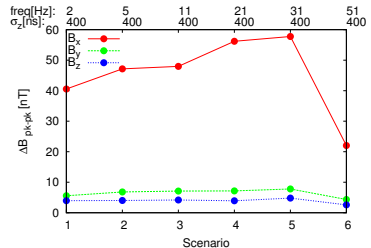
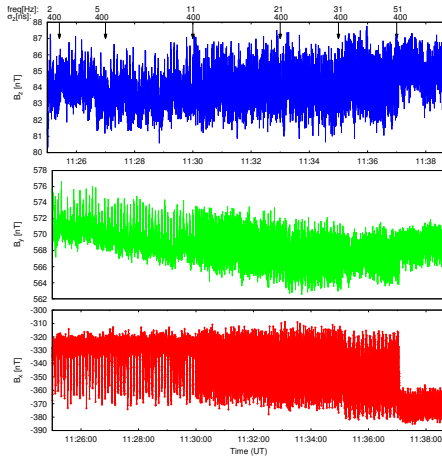


Signal is attenuated as we move towards PS center

XBOX

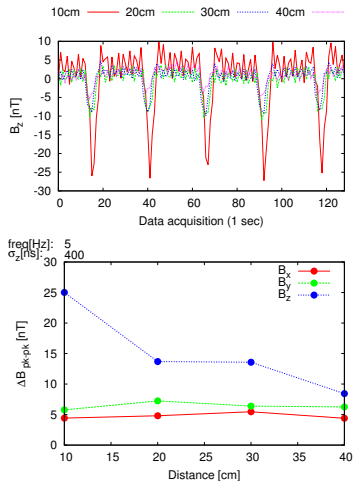
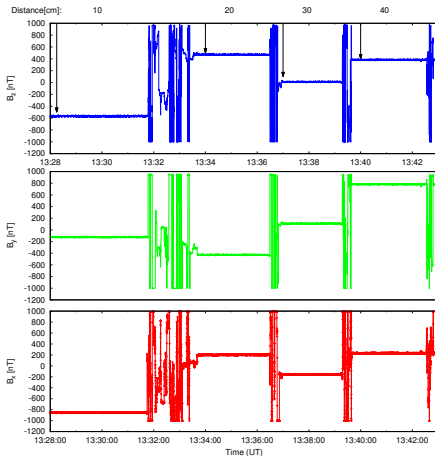
Klystron-A

- Measurement on 17/01/2017: Sensor was located 1 cm below the waveguide. X-axis perpendicular to waveguide. Frequency scan



Klystron-A

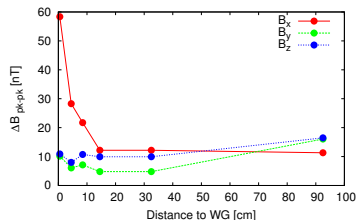
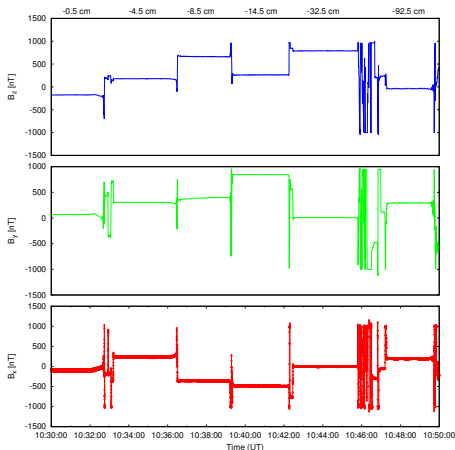
- Measurement on 17/01/2017: Distance scan (horizontally). Sensor was next to waveguide. Z-axis perpendicular to waveguide



XBOX

Klystron-C&D

- Measurements on 19/01/2017: Distance scan (vertically). Sensor was below the waveguide. X-axis perpendicular to waveguide



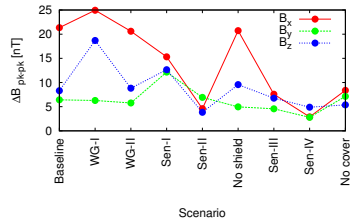
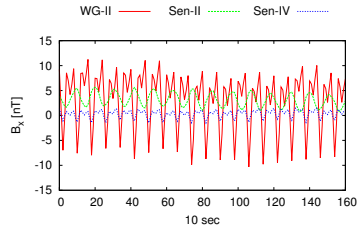
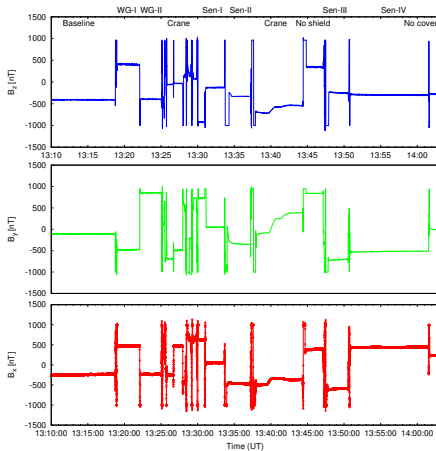
Data is consistent with a current of 13 mA (assuming an infinitely straight current)

Shielding

- Shield waveguide (soft- μ -material)
- Shield sensor (Aluminium pipe, soft- μ -material)

Scenario	Starting Time	Finishing Time	Observations
	[H:M:S]	[H:M:S]	
Baseline	13:10:00	13:18:00	Sensor 7cm below WG
WG-I	13:20:00	13:22:00	Shielding WG
WG-II	13:23:00	13:25:00	Shielding WG without contact
Sen-I	13:32:00	13:34:00	Shielding MS 25cm from WG
Sen-II	13:35:00	13:37:00	Shielding MS 7cm from WG
No shield	13:45:00	13:47:00	No shielding
Sen-III	13:49:00	13:51:00	Shielding MS 7cm from WG
Sen-III	13:52:00	14:00:00	Shielding MS 7cm from WG and covered
No cover	14:01:00	14:03:00	Shielding MS 7cm from WG without cover

Shielding

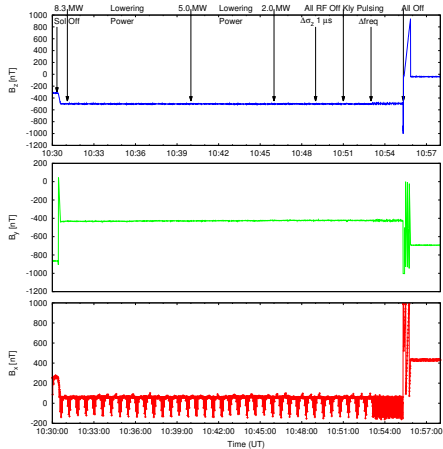




XBOX

Source

- Power scan
- Pulse width scan
- On/Off low-level RF
- On/Off Solenoid



CONCLUSIONS & PROSPECTS

Conclusions & Prospects

- BDS is most sensitive to wavelength (≈ 7 km), 12% $\mathcal{L}_{\text{loss}}$ for 1 nT amplitude stray field without any countermeasure
- Natural and man-made magnetic field sources are well-above that tolerance at Earth's surface
- Variations of $\geq \mu T$ are observed at CTF3 due to the PS cycle
- Variations of tens of nT are observed closed to the waveguides
 - Signal can be shielded by a soft- μ material
- \vec{B} measurements underground
- 2D stray field spectrum would be very helpful
- Potential implications of PS and XBOX results on CLIC
- Better understanding of the XBOX results. Is it relevant to the Klystron-based option?
- Developing strategies for mitigating intolerable variations of magnetic field

Acknowledgements

- All the people working at the XBOX, specially M. Volpi
- The CTF3 team, specially W. Farabolini
- C. Carli for allowing us to measure at the AD hall
- A. Lombardi for arranging our visit at LINAC-4
- D. Tshilumba for his help during the PACMAN measurement

Thank you for your attention!

BACK-UP

Antiproton Decelerator

Baseline measurement was taken outside bldg. 193 (**Loc-0**). Time[†] lapse: 12:27- 12:40

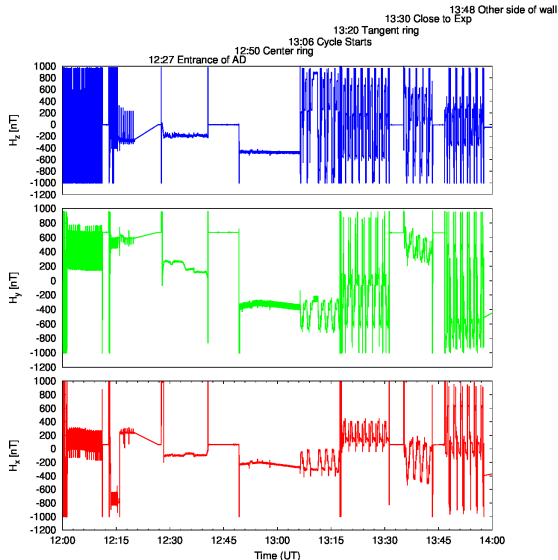
4 additional locations were considered for measurements inside the AD hall;

- Center of ELENA ring (**Loc-1**)
 - Cycling OFF (Time lapse: 12:50-13:06)
 - Cycling ON (Time lapse: 13:06-13:18)
- Tangent of the Ring (**Loc-2**)
(Time lapse: 13:20-13:30)
- Close to Experiment (**Loc-3**)
(Time lapse: 13:36-13:43)
- Close to AD ring (**Loc-4**)
(Time lapse: 13:48-13:58)

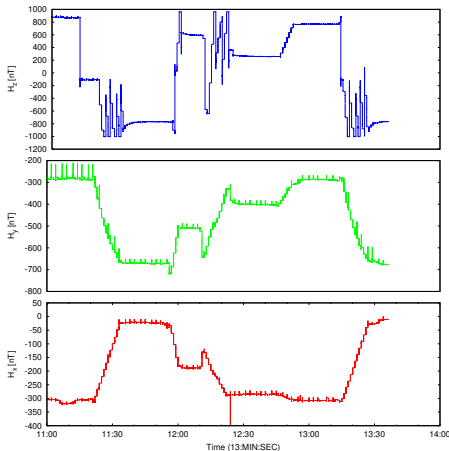
[†]UTC time

Measurement

Observed variations of few μT when AD is pulsing

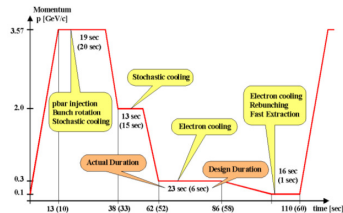


Zoom In @ Loc-1



†

Sketch of AD magnetic cycle[†]
 Expected duration ≈ 60 s



[†]Figure taken from *Status and Prospects for the AD and ELENA*, Lars V. Jorgensen / CERN / BE-OP

LINAC-4

