Upgrade of the Fast Beam Intensity Measurement System for the CERN PS Complex

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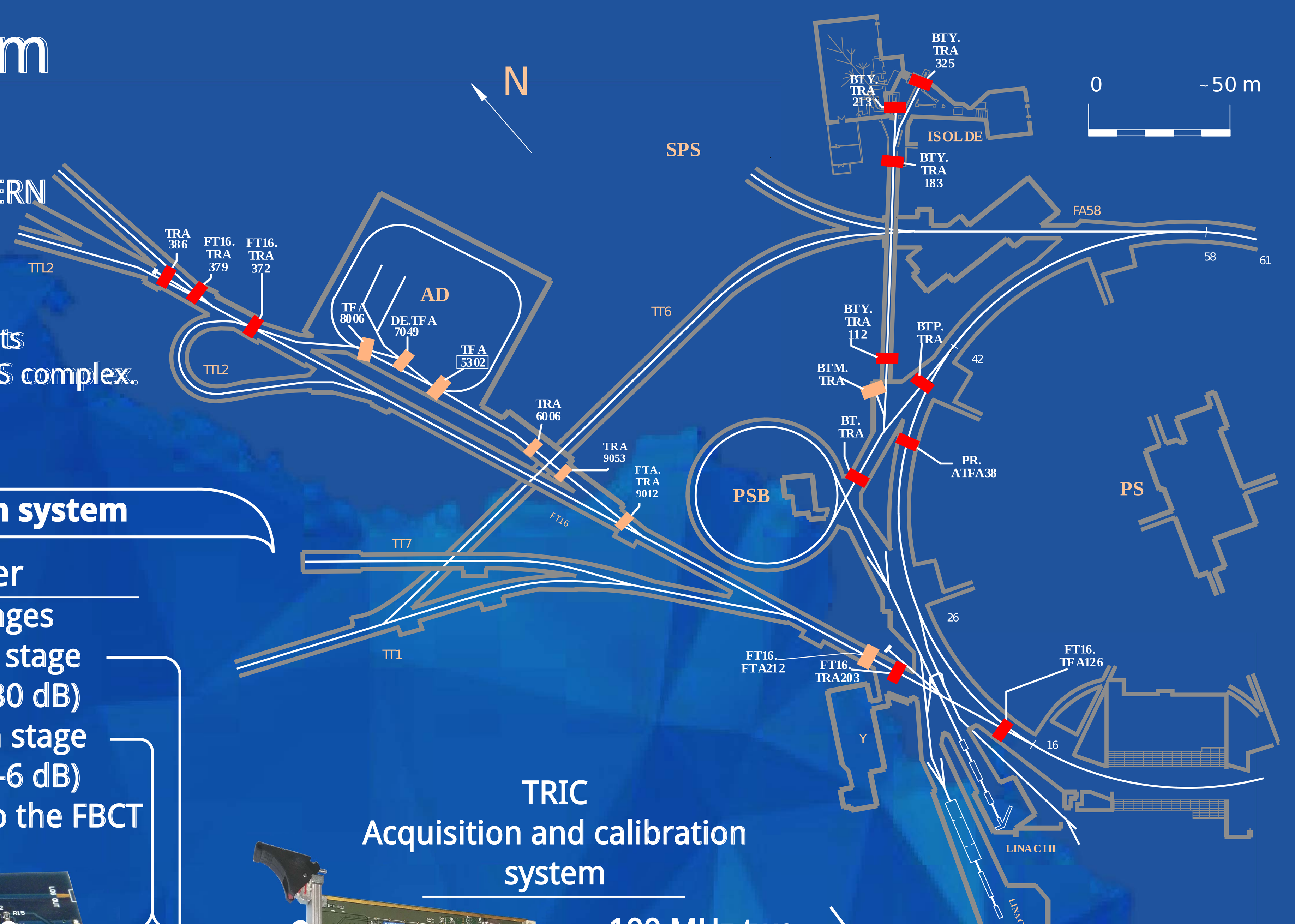


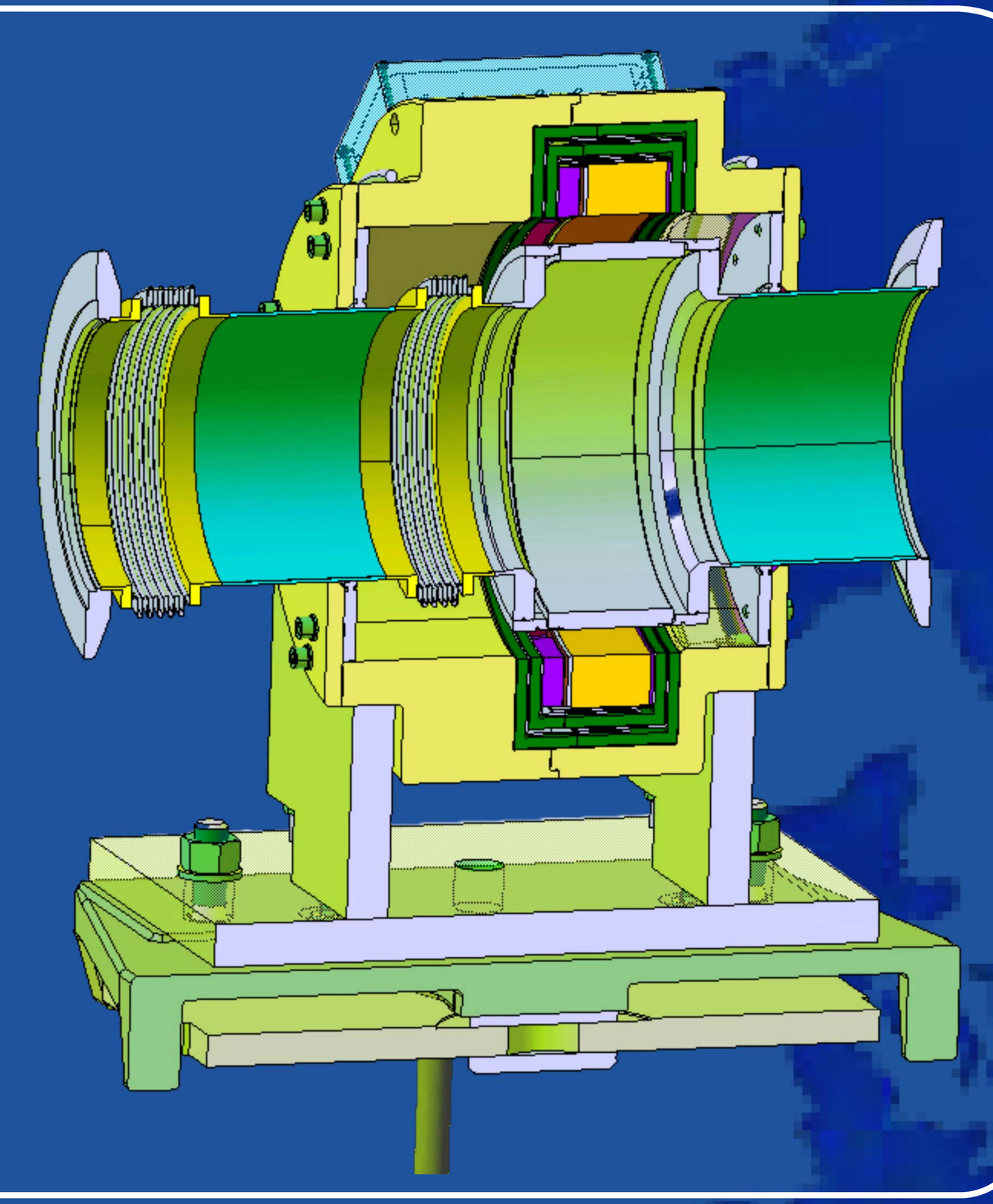
The CERN Proton Synchrotron complex (CPS) has been operational for over 50 years. During this time the Fast Beam Current Transformers (FBCTs) have only been repaired when they ceased to function, or individually modified to cope with new requests. This strategy resulted in a large variation of designs, making their maintenance difficult and limiting the precision with which comparisons could be made between transformers for the measurement of beam intensity transmission. During the first long shut-down of the CERN LHC and its injectors (LS1) these systems have undergone a major consolidation, with detectors and acquisition electronics upgraded to provide a uniform measurement system throughout the PS complex. This paper discusses the solutions used and analyses the first beam measurement results.

New FBCT design

Toroid
- beam position independent
- large aperture (>150 mm)
- bunch to bunch measurement bandwidth

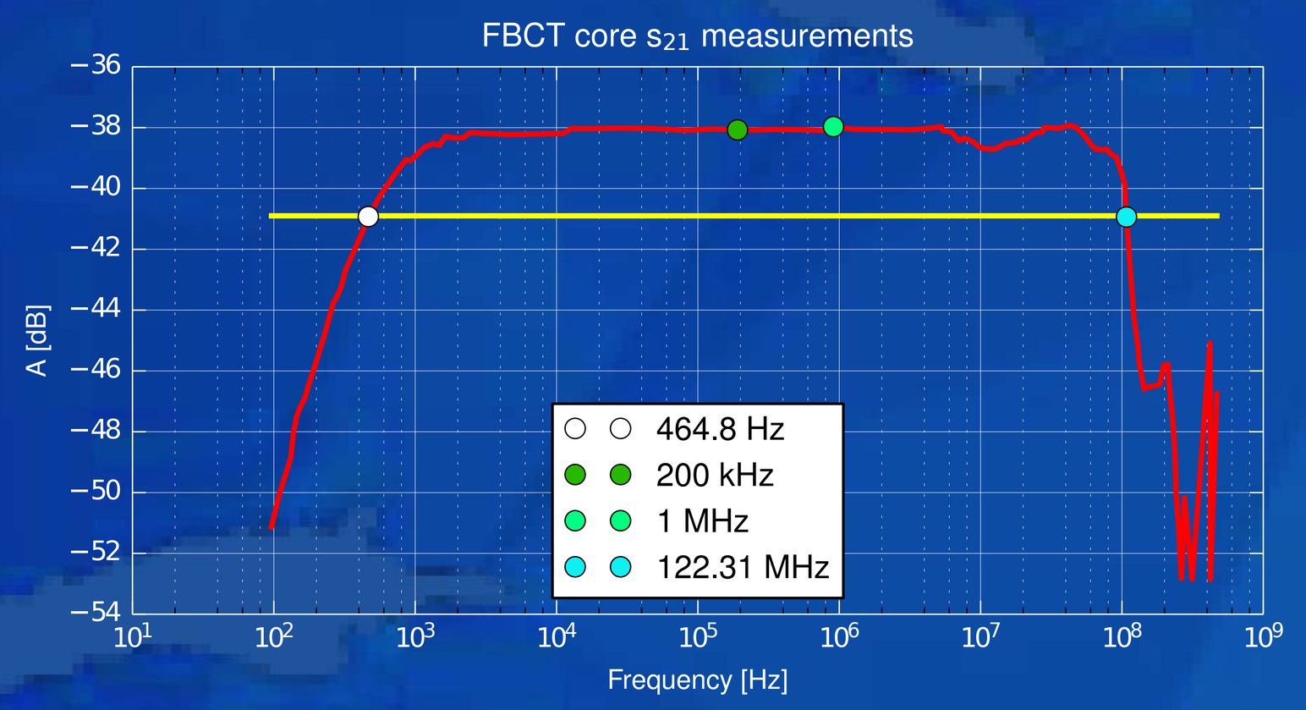
FBCT housing
- combination of Armco and μMetal magnetic shielding
- common design for the PS complex

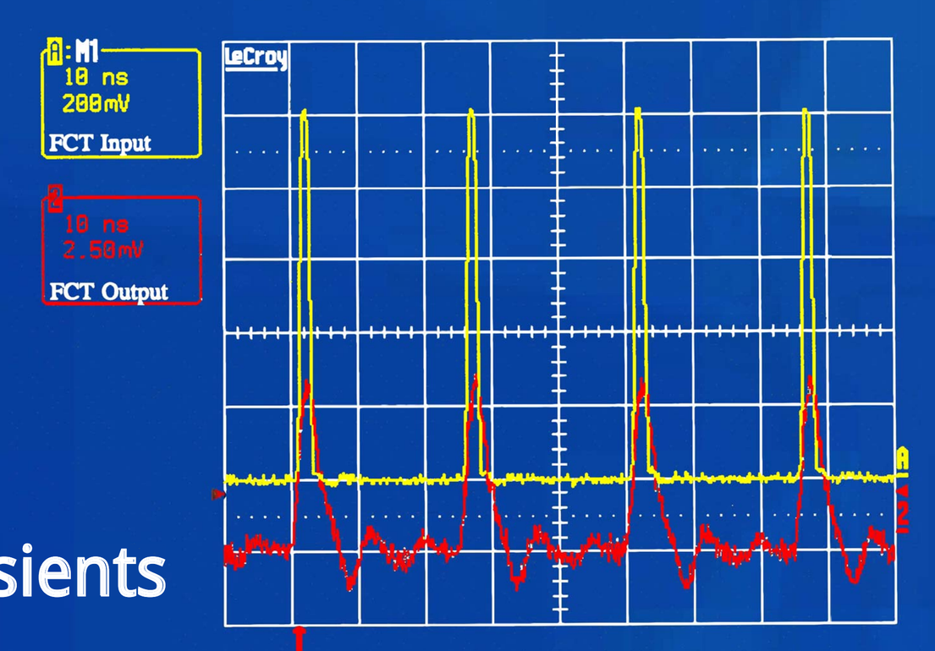
Vacuum chamber
- ceramics insertion
- bellows



The FBCT toroid properties

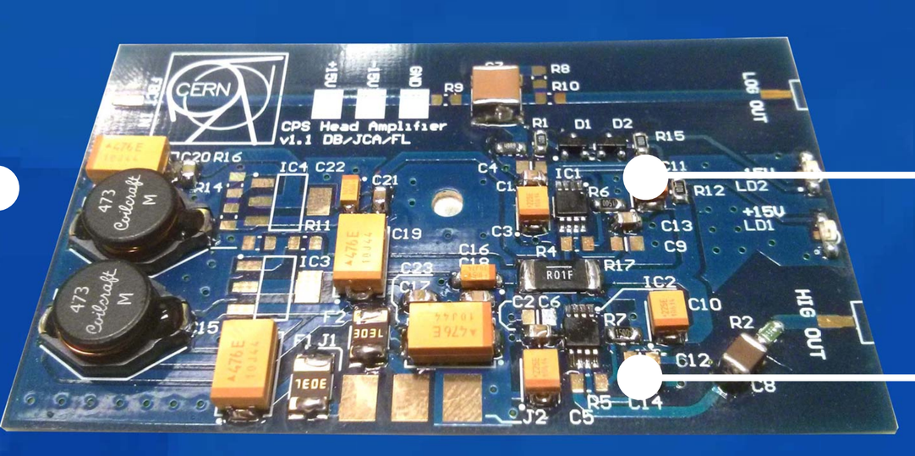
CT-M1.25-S: 40:1
- turn ratio 40:1
- internal diameter 210 mm
- non-measurable position dependence (measured with beams)
- risetime 2.8 ns, LF cut-off 350-500 Hz (0.25 %/μs)
- 120 MHz BW ok to measure bunch to bunch with 100 ns bunch spacing
- 25 ns requires additional signal treatment due to the toroid's transients



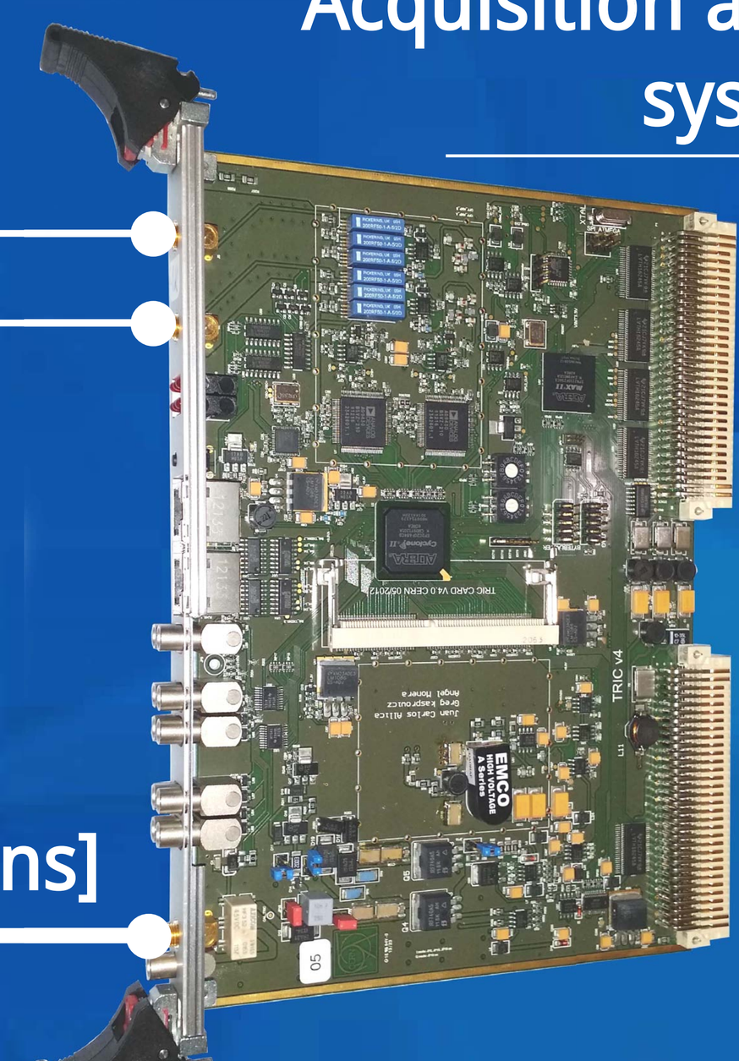


Acquisition system

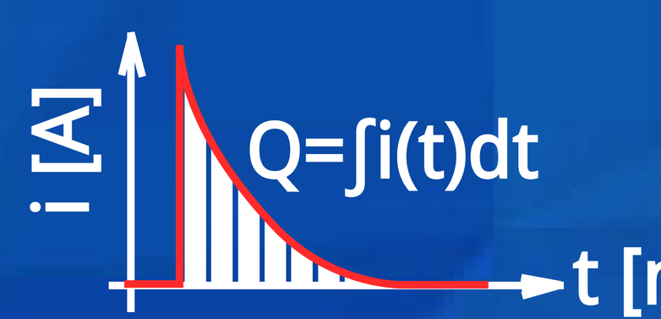
Amplifier
- two dynamic ranges
- 18 MHz high gain stage (+30 dB)
- 120 MHz low gain stage (-6 dB)
- installed close to the FBCT

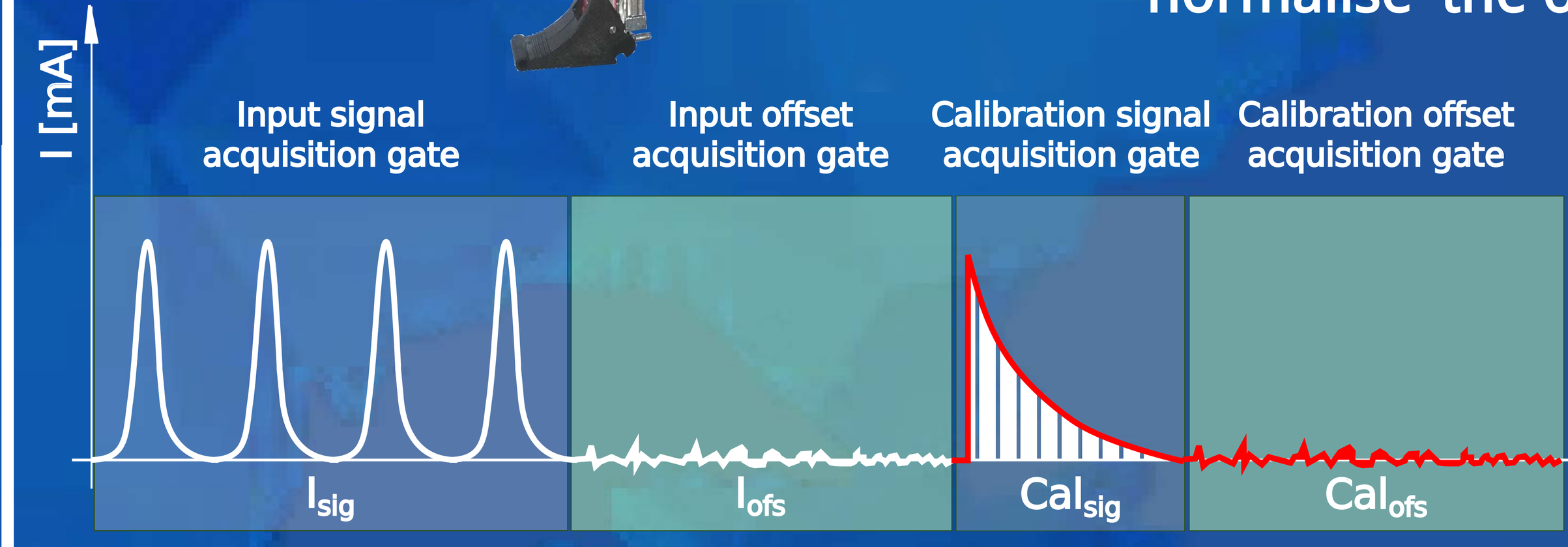


TRIC Acquisition and calibration system



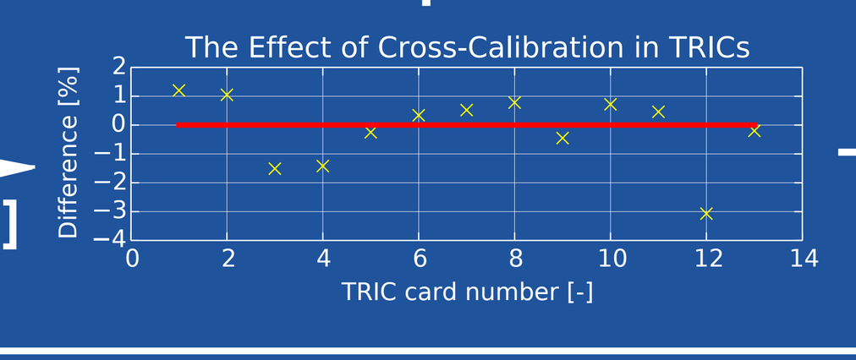
- 100 MHz two channels acquisition
- calibration pulse generation synchronized with the acquisition
- measurement using 4 integrating windows
- all TRICs are cross-calibrated to minimise the relative measurement error using a master TRIC card generating a reference signal used to 'normalise' the other TRICs measured values





$$N_p = \frac{I_{sig} - I_{ofs}}{Cal_{sig} - Cal_{ofs}} \cdot Cal_q \cdot \eta$$

# of charges in the calibration pulse

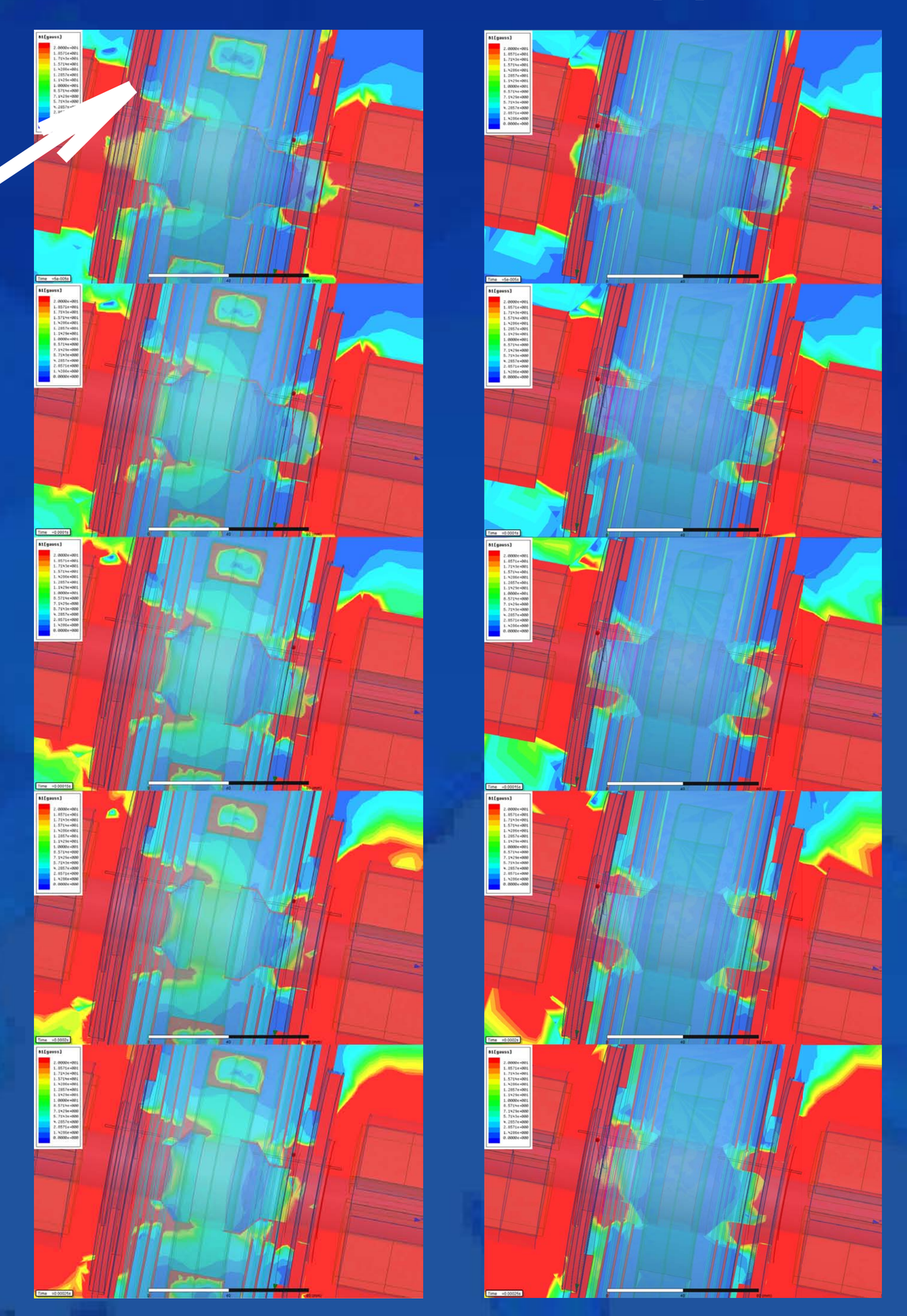


The FBCT Ceramics insert design

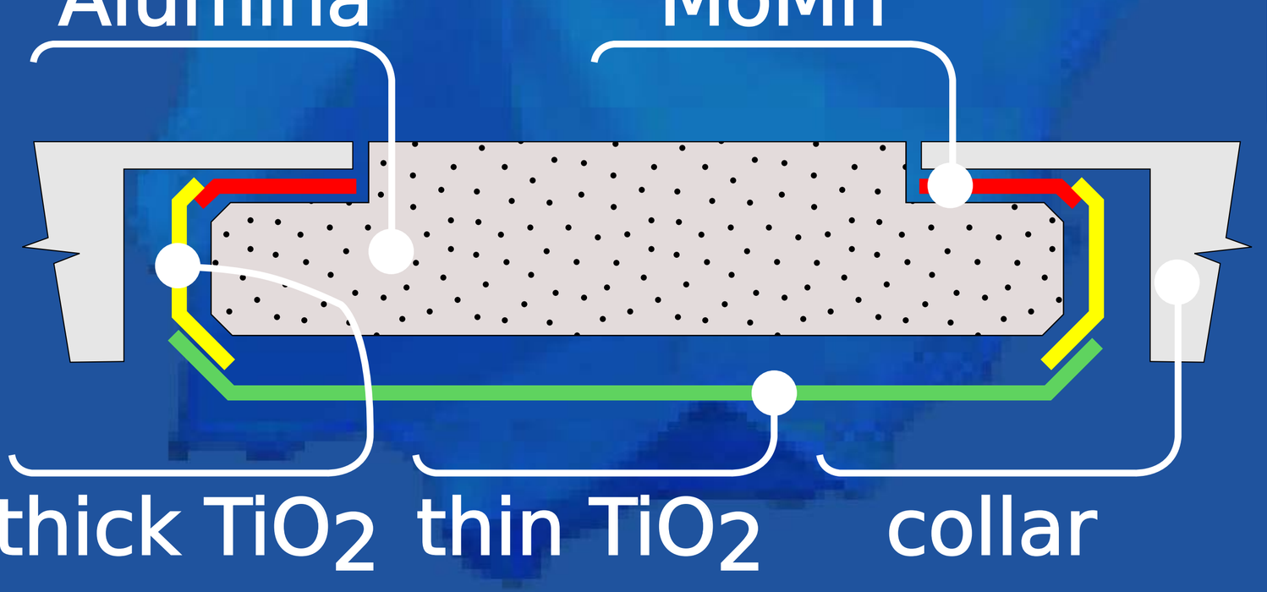
Copper/Kovar collars?
- simulations made in Maxwell
- Kovar = high permeability

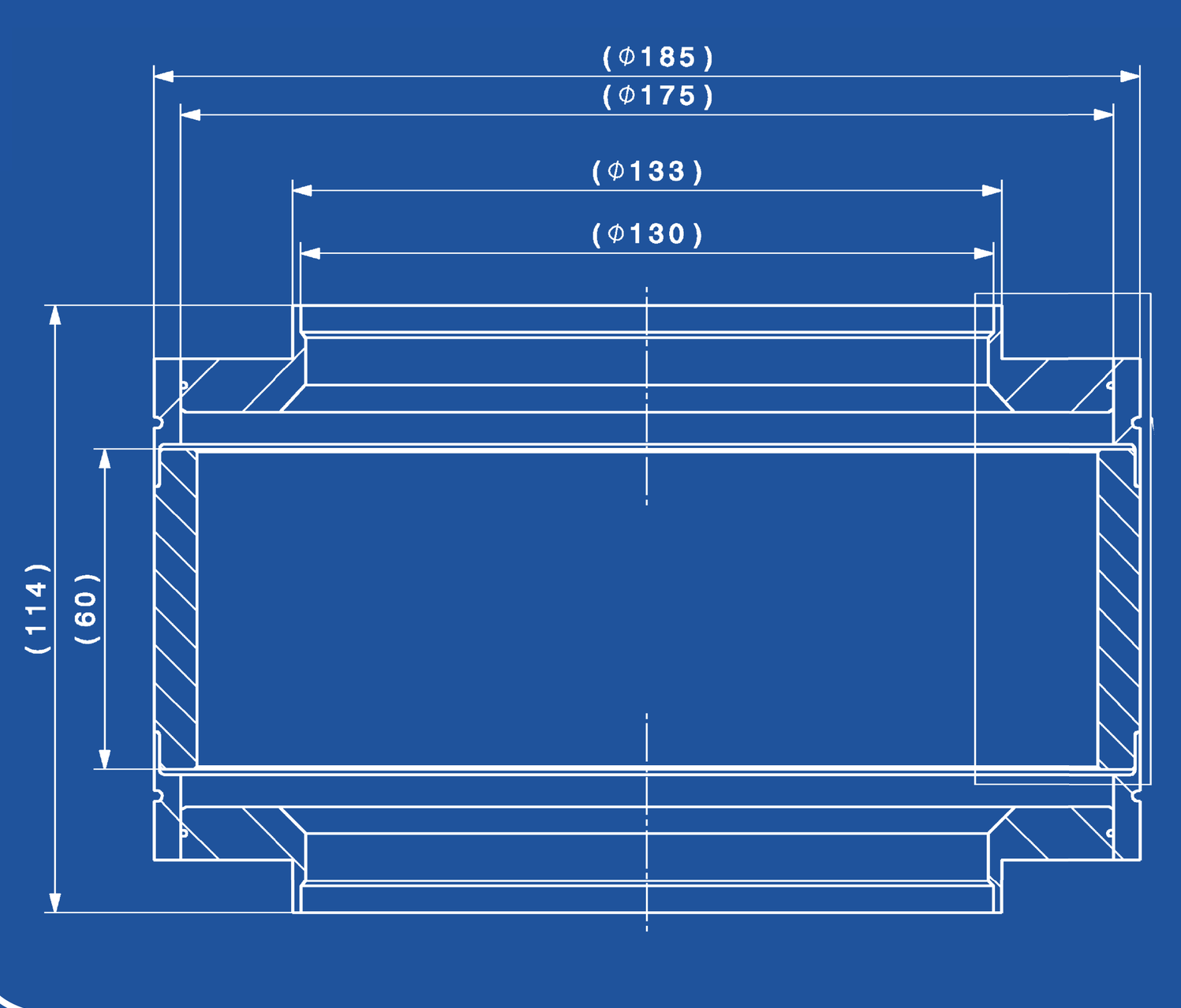
EXT. FIELD COUPLES TO TOROID

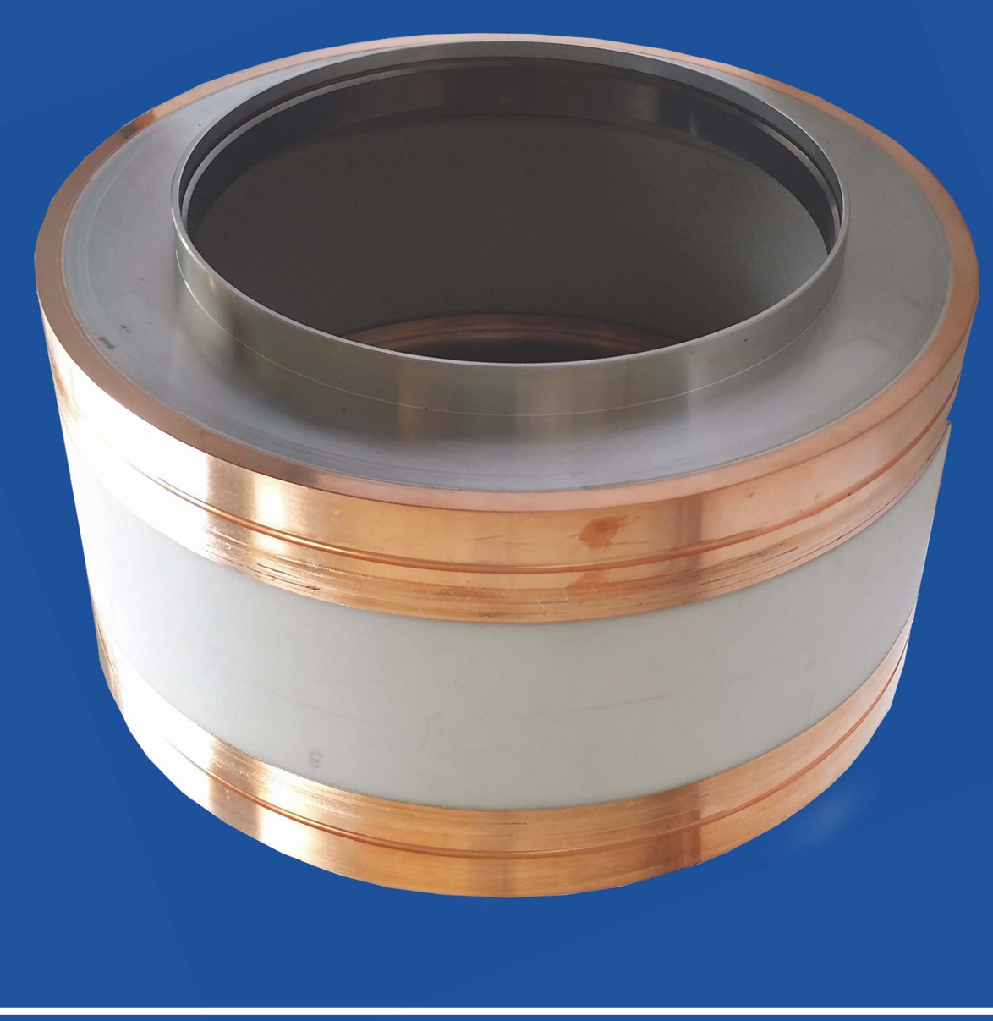
Ceramics fabrication
- 98% pure Alumina with MoMn coating
- Alumina-OFE Copper-Stainless steel connection
- 20-25 Ω Ti coating deposit in two steps process



- thick $TiO_2 \approx 2\ \Omega$
- thin $TiO_2 \approx 20\ \Omega$
- further oxidation in air gives the total layer resistance of ≈ 20-25 Ω



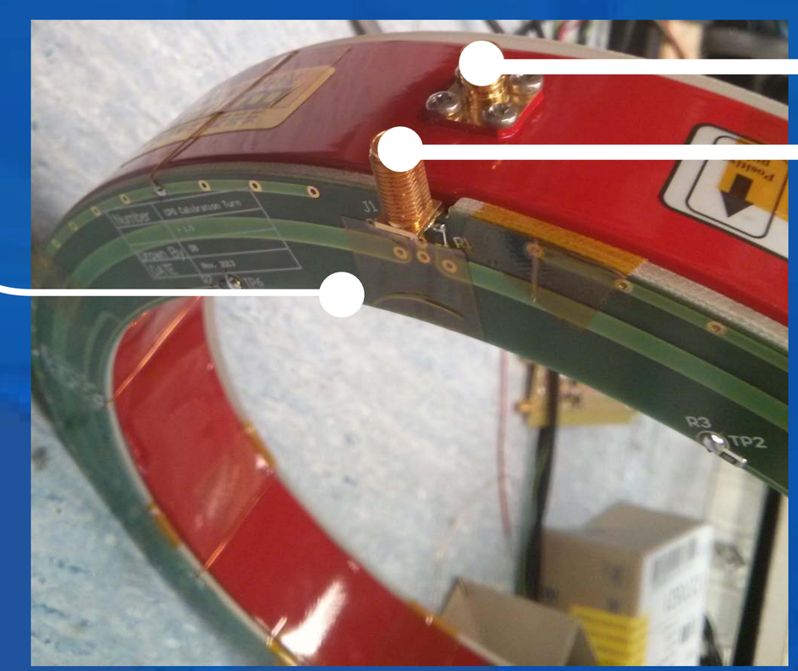


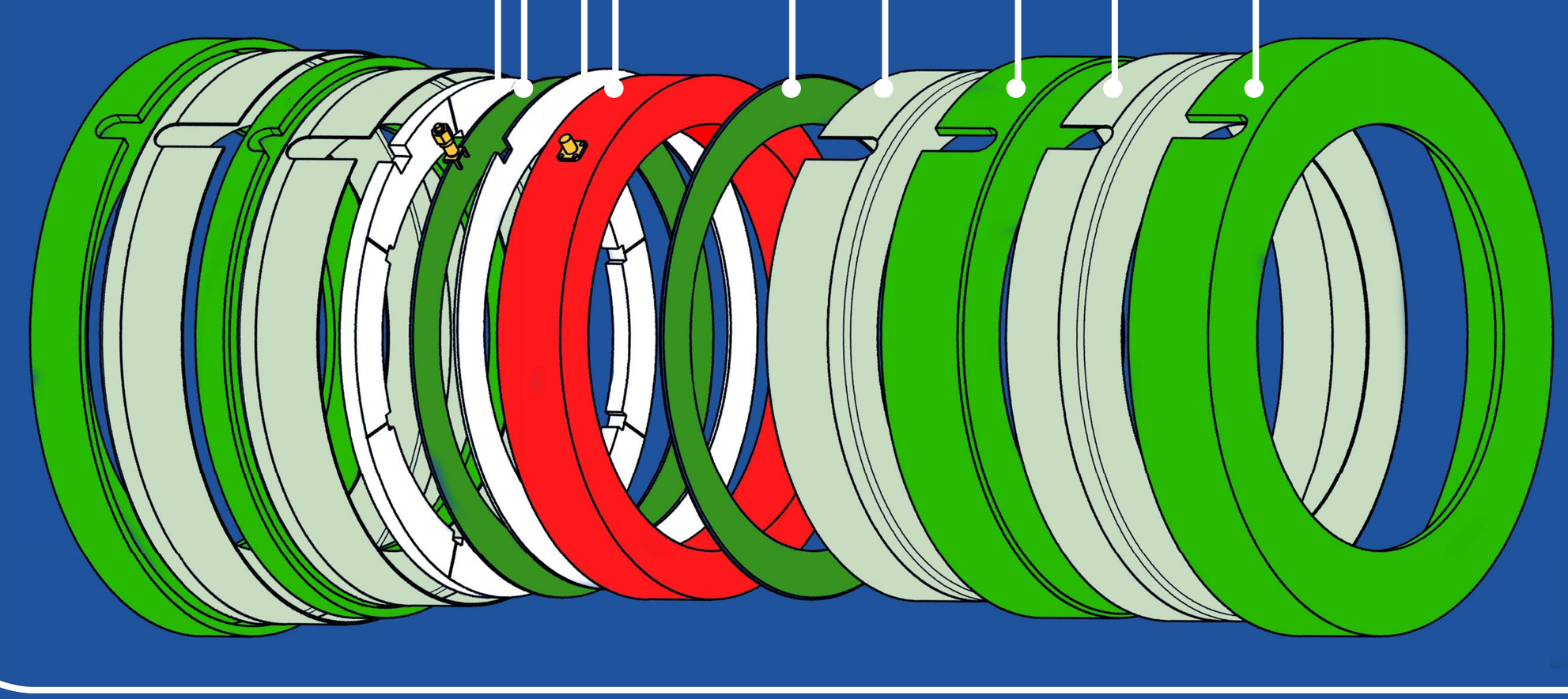


The complete FBCT assembly

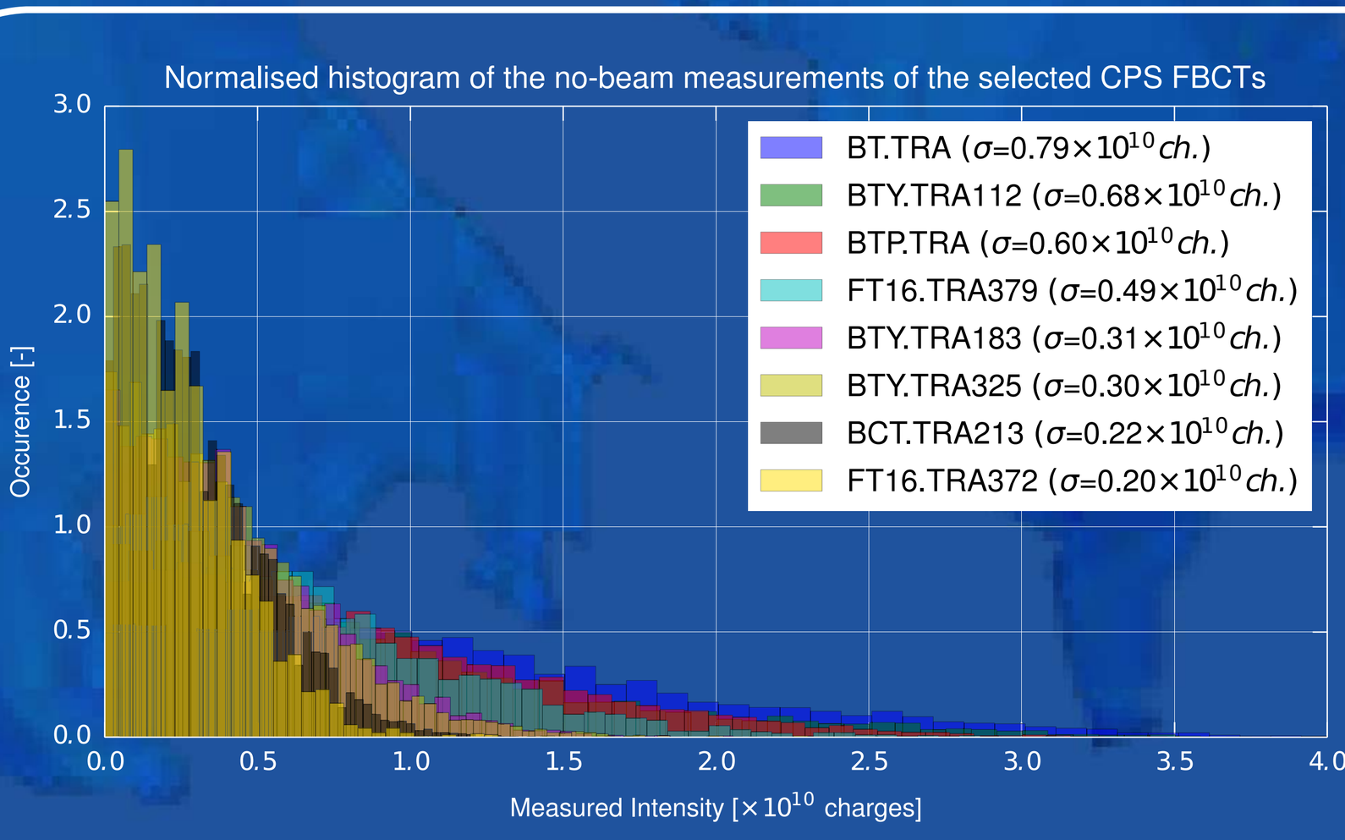
- two magnetic μMetal shieldings protect the toroid against external magnetic field
- μMetal thermally treated (1080 °C) to increase μ_r

- Armco housing (high B_{sat} and μ_r) for further protection against ext. mag. field, thermally treated (870 °C)
- silver coating (25 μm) to provide a well defined low-impedance path for the wall image current
- calibration turn installed on the side of the toroid
- 8 parallel turns form a 50 Ω calibration turn

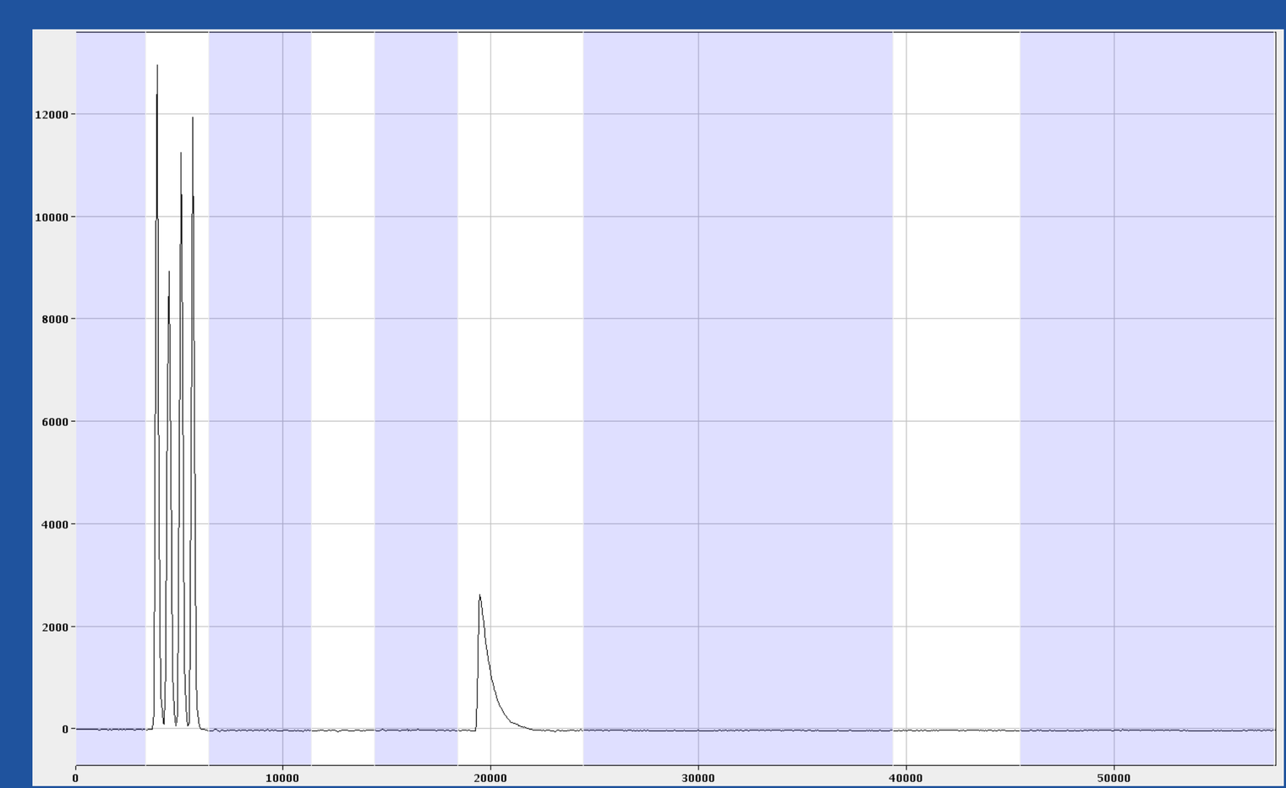




The measurement results

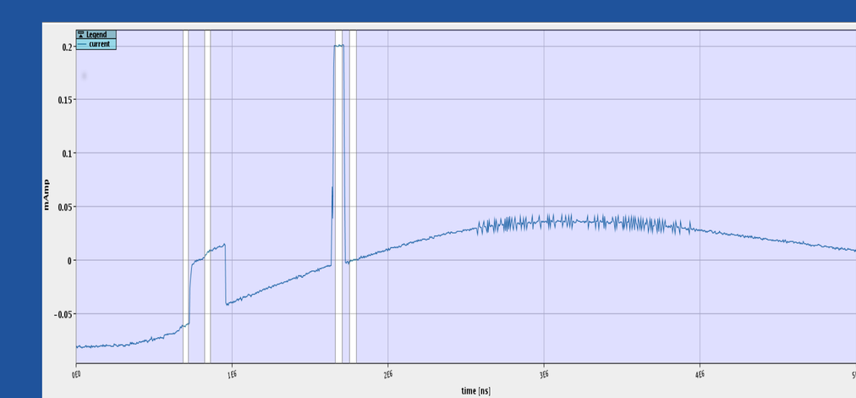


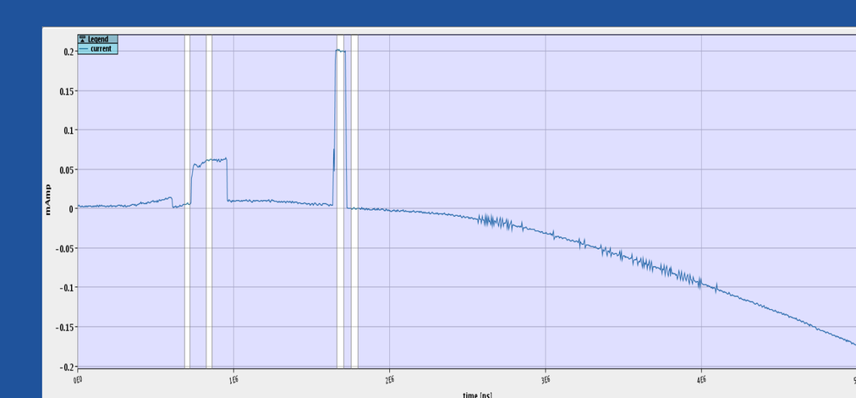
- normalised histogram of the low-gain channel noise measurements of the selected PS complex FBCTs
- noise floor of $0.8 \cdot 10^{10}$ charges (worst case) suitable for the PS beams
- LHC/SPS beams require high-gain channel, noise measurements in progress



correctly set up FBCT measurement. The picture shows the measurement of the 4 bunches extracted from the PSB to the ISOLDE

Problem:
- magnetic coupling from nearby quadrupoles cause for some FBCTs low-frequency base line displacement
- offset compensation does not work efficiently





- CERN $Linac_4$ uses 2 point sampling to compensate for the slope before summing the sampled data ...

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