Measurement challenges for the CLIC study

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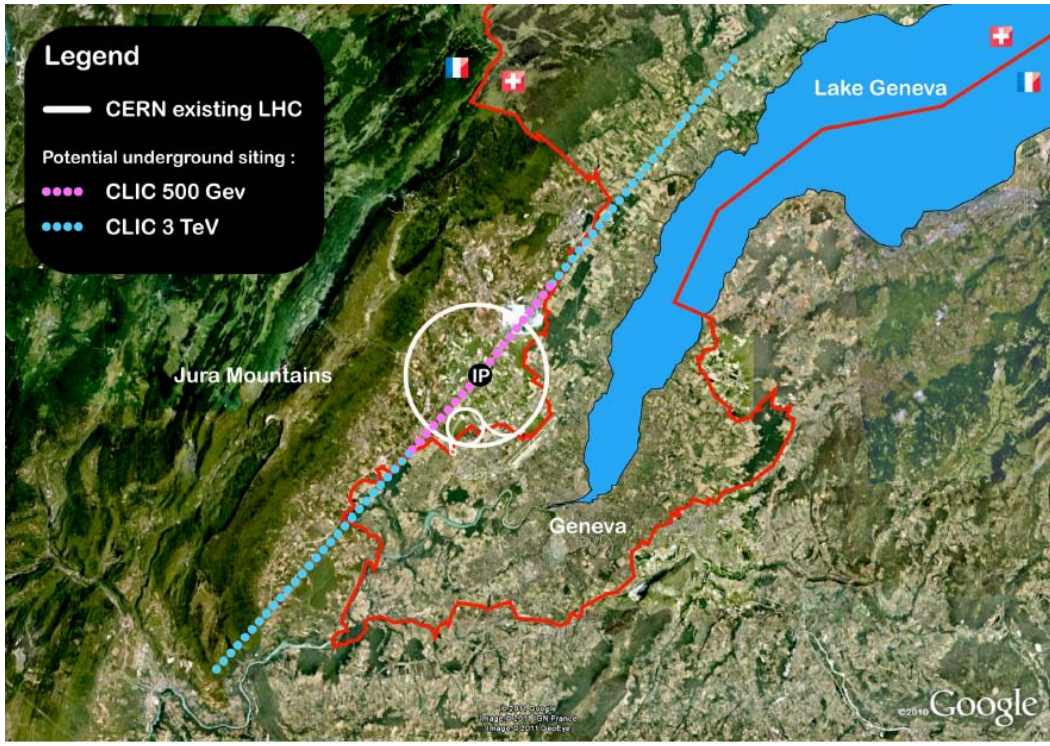
Overview

- ➔ Compact Linear Collider Introduction
  - Main Beam
  - Drive beam
- ➔ Magnets function and types
- ➔ Alignment and stabilization
- ➔ Techniques used to measure
- ➔ Results of measurements
  - Drive Beam Quadrupole Daresbury
  - Drive Beam Quadrupole Danfysik
  - Machine Detector Interface QD0
- ➔ Conclusions

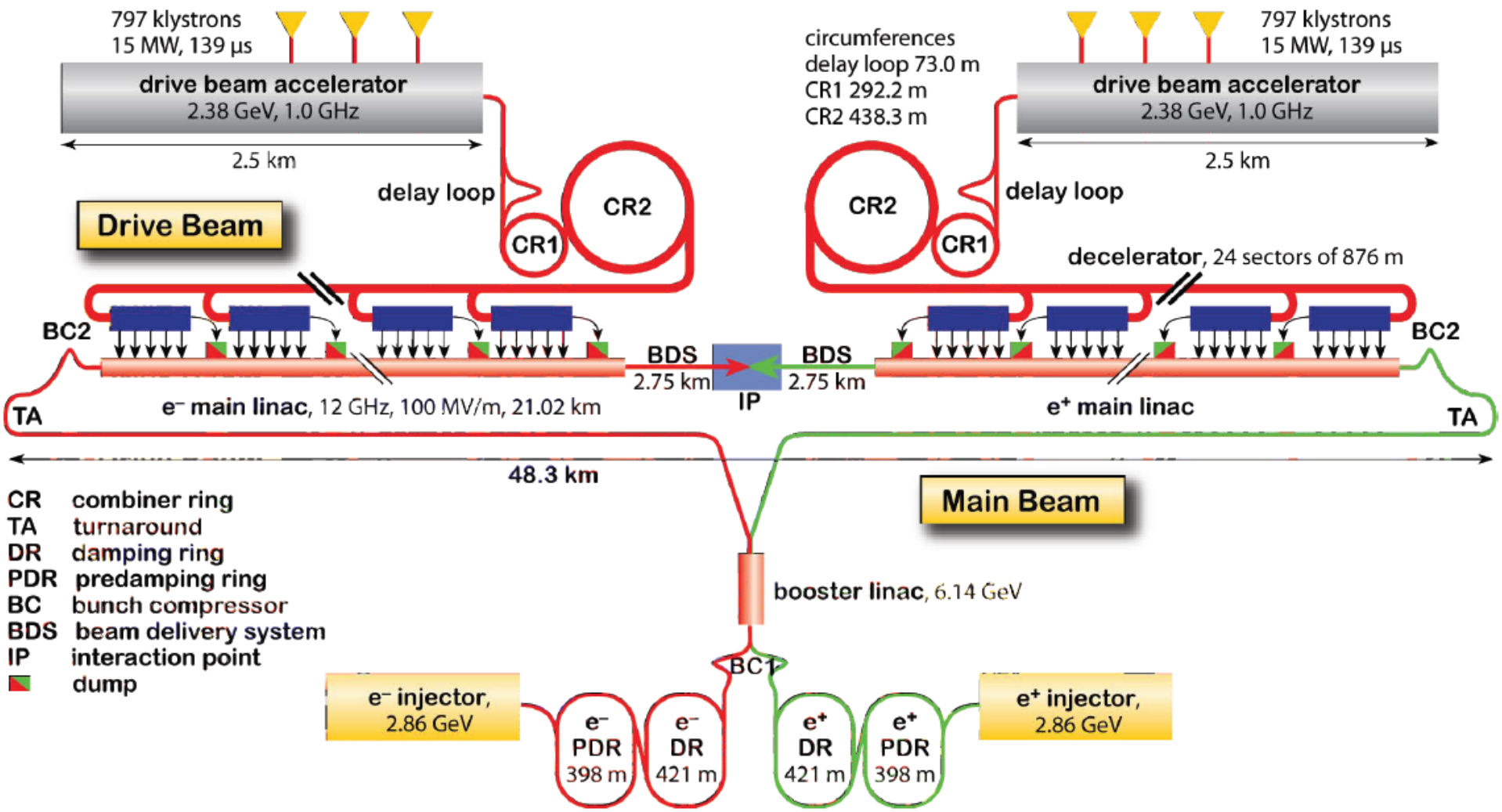
Introduction Compact Linear Collider Study

- New physics to discover (Dark Matter, SUSY?)
- Higgs production and study
- LEP 209 GeV closed in 2000
- International Collaboration with 44 partners in 22 countries like experiments
- Linear instead of circular (Synchrotron Radiation)
- Resistive magnets (ILC Super Conducting RF)
- Flexible Energy 0.5-3 TeV (CM Energy), 100 MV/m
- Waiting LHC Results to decide
- Novel technology, Power Extraction and Transfer Structures (PETS)12 GHz to accelerate Main Beam
- Very low rate of failure, < 3×10^{-7} per pulse per metre, is a must for the accelerating structures
- Very tight alignment constraints ~µm and active stabilization for Main Beam σ_x = 1.5 nm & σ_y = 5 nm
- Modularity (~ 2 m long)

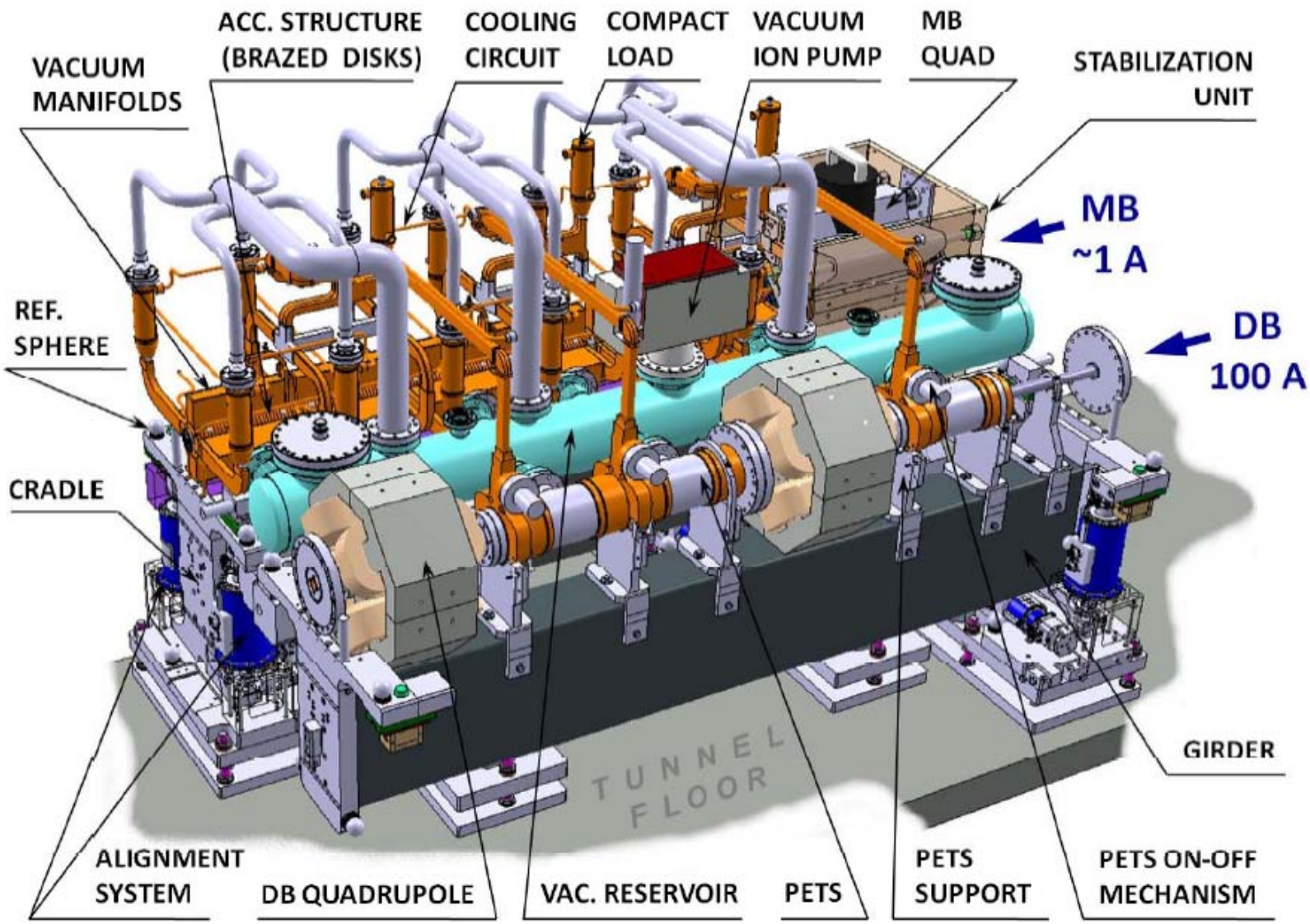


Description [units]	500 GeV	3 TeV
Total (peak 1%) luminosity	$2.3\ (1.4)\times10^{34}$	$5.9\ (2.0)\times10^{34}$
Total site length [km]	13.0	48.4
Loaded accel. gradient [MV/m]	80	100
Main Linac RF frequency [GHz]	12	
Beam power/beam [MW]	4.9	14
Bunch charge [10^9 e^+/e^-]	6.8	3.72
Bunch separation [ns]	0.5	
Bunch length [μm]	72	44
Beam pulse duration [ns]	177	156
Repetition rate [Hz]	50	
Hor./vert. norm. emitt. [$10^{-6}/10^{-9}$m]	2.4/25	0.66/20
Hor./vert. IP beam size [nm]	202/2.3	40/1

CLIC beam scheme



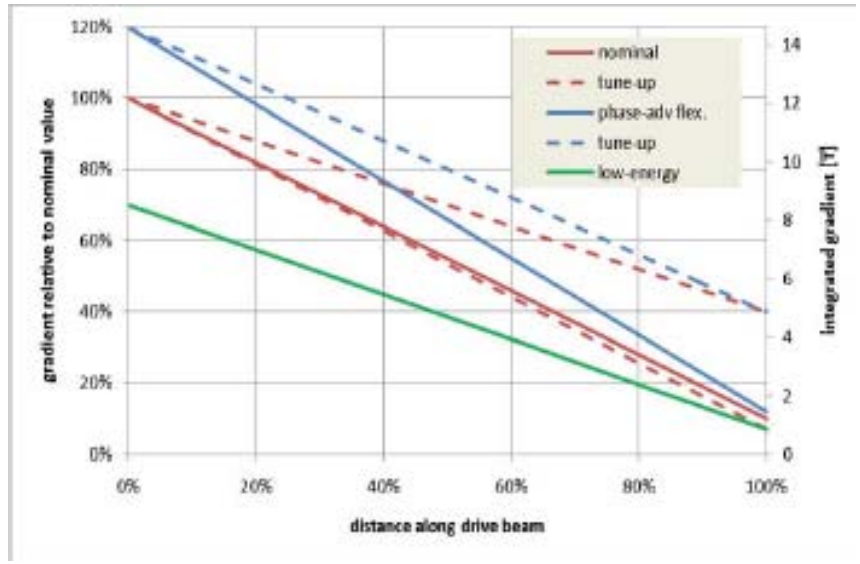
CLIC module with two Beam elements



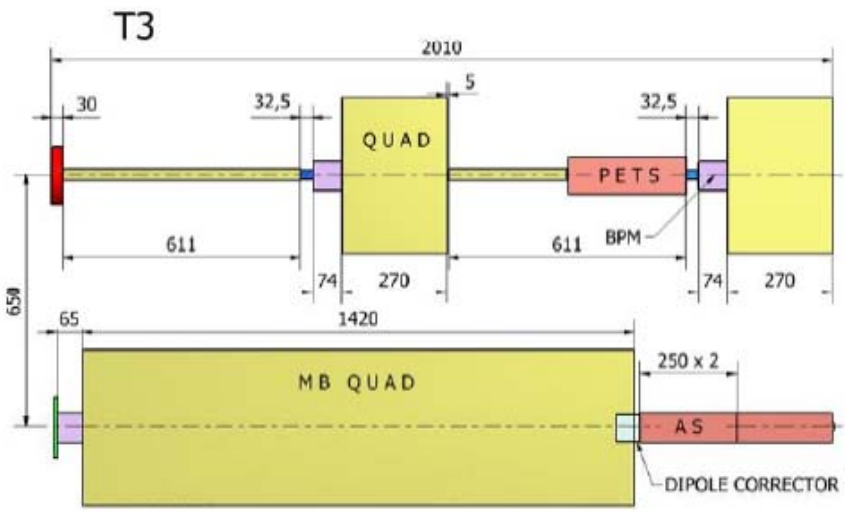
Types of CLIC modules and number of magnets

- 4020 Main Beam Quadrupoles with Gradient 200 T/m and 10 mm aperture

Quadrupole type	Magnetic length [mm]	Quantity
Type-1	350	308
Type-2	850	1276
Type-3	1350	964
Type-4	1850	1472



- 41400 Drive Beam Quadrupoles with Gradient in the range 81.2 - 8.12 T/m and 26 mm aperture with two options: resistive or tuneable PMQ
- 52 Superconducting wigglers
- 4020 Beam steering correctors
- Final Doublet Quadrupoles in the Machine Detector Interface QF1 and QD0 (575 T/m and 8 mm aperture)

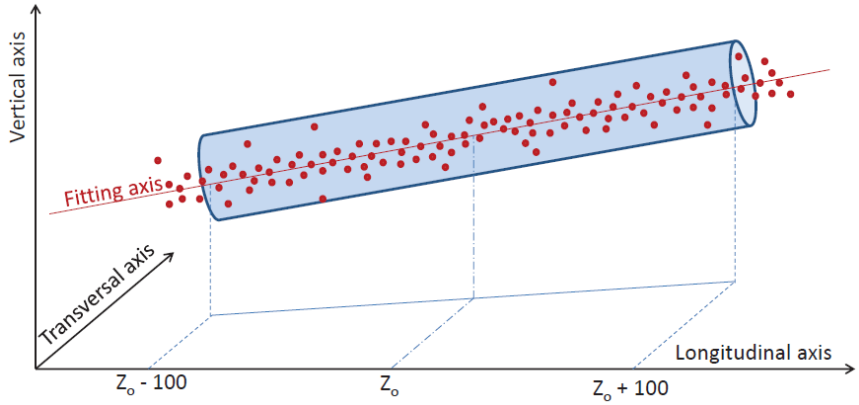


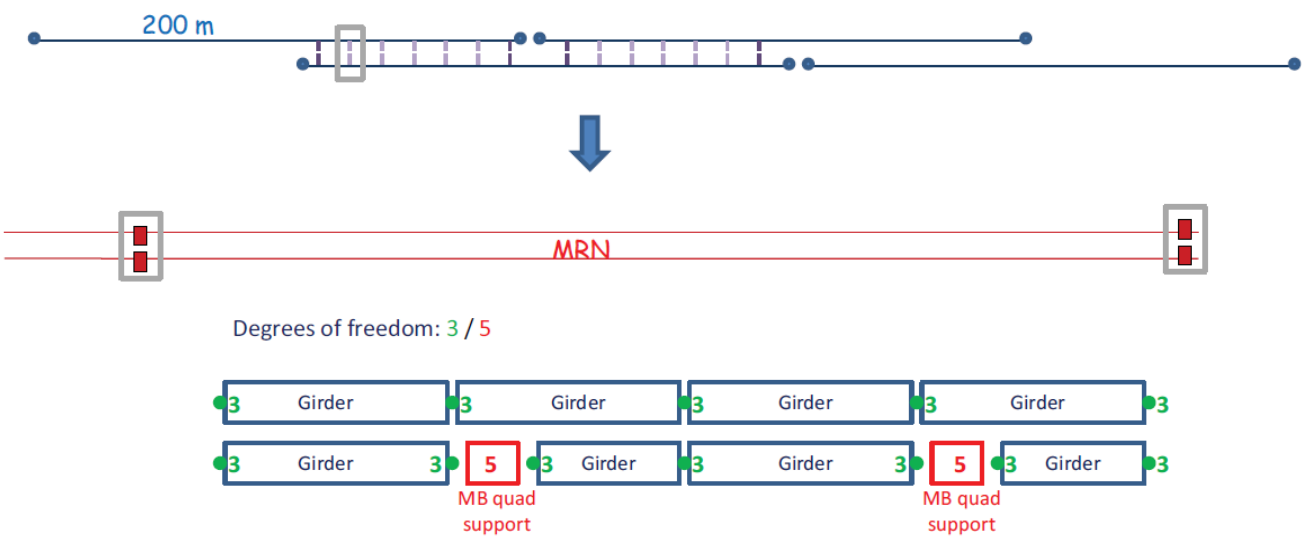
c) Type 3 module

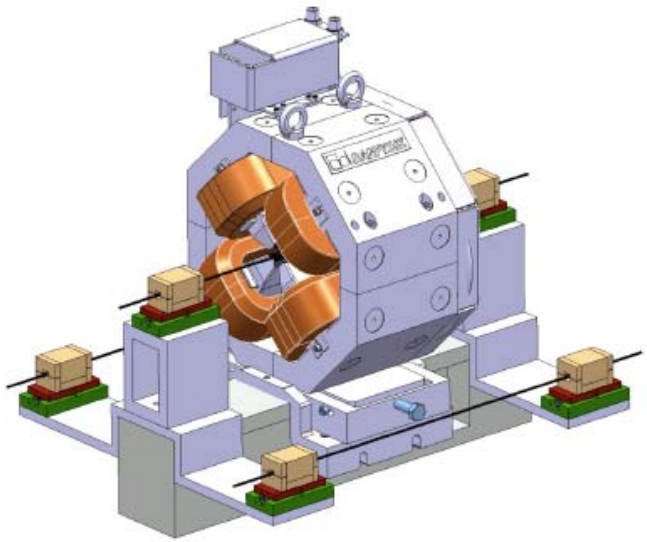
CLIC Pre-Alignment and stabilization

- Mechanical pre-alignment ~±0.1 mm w.r.t. Metrological Reference Network (MRN)
- For Main Beam and Beam Delivery System few µm (200 m window)
- Support Pre-alignment Network (SPN) few µm over 10 m
- Several components pre-aligned on supports:
  - Girders for RF components of MB and DB
  - Interface plates for MB Quads
- Cam movers for 5 DOF re-adjustment of MBQ (nm)

and high-resolution linear actuators for 3 DOF DBQ and MB girders

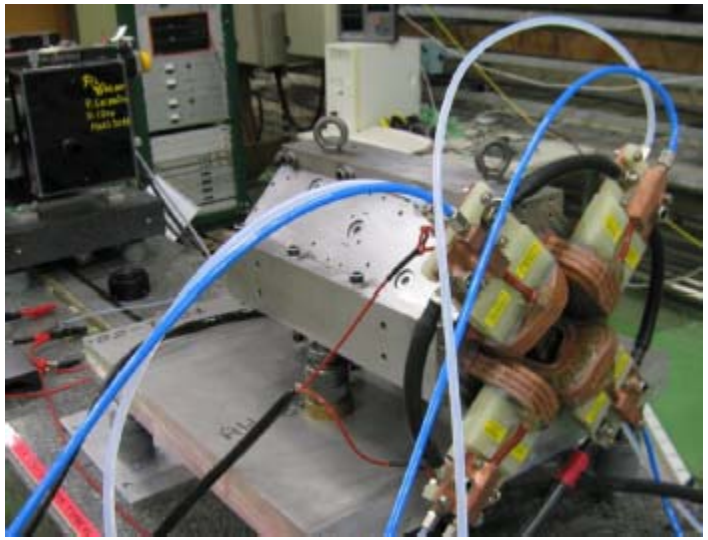


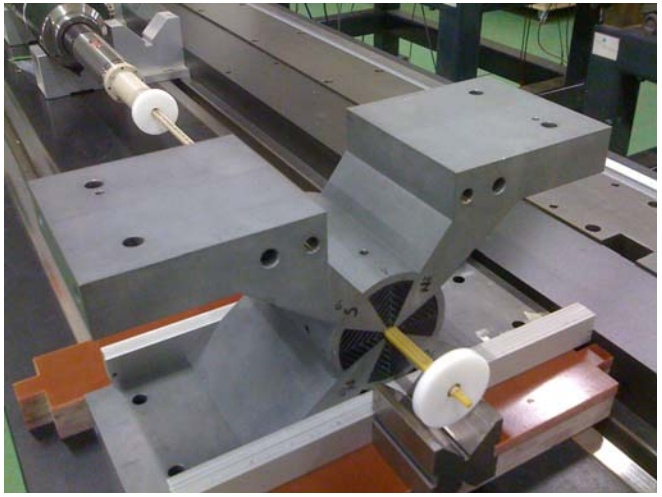


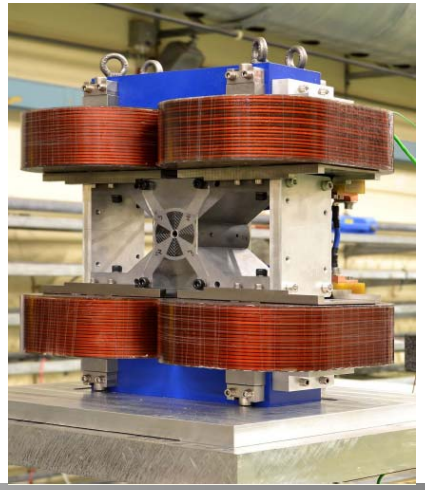


Techniques used for the magnetic measurements

- ➔ Field Quality, roll angle and Gradient MM for DBQ magnets (26 mm aperture)
  - Rotating Coil : LINAC4 bench for DBQ magnets
- ➔ Field Quality, Roll angle and gradient MM for MBQ magnets (10 mm aperture) and D0 magnets (8 mm aperture)
  - Single Stretched Wire & Oscillating wire (New method)
  - New Printed Circuit Board rotating coil shaft (R&D)



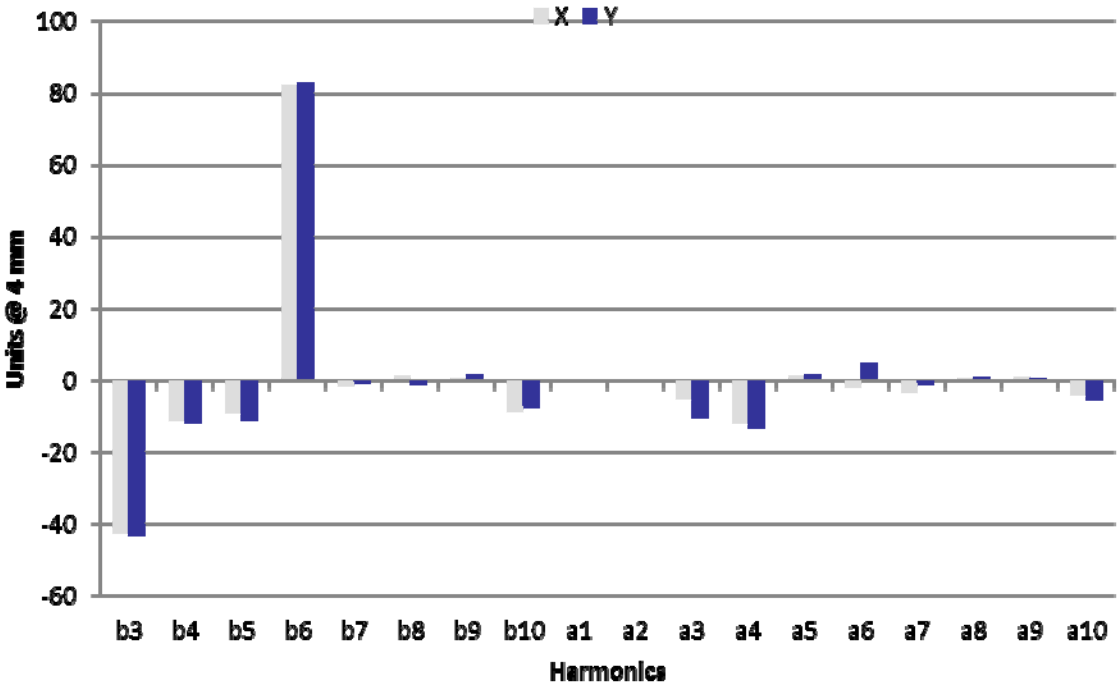


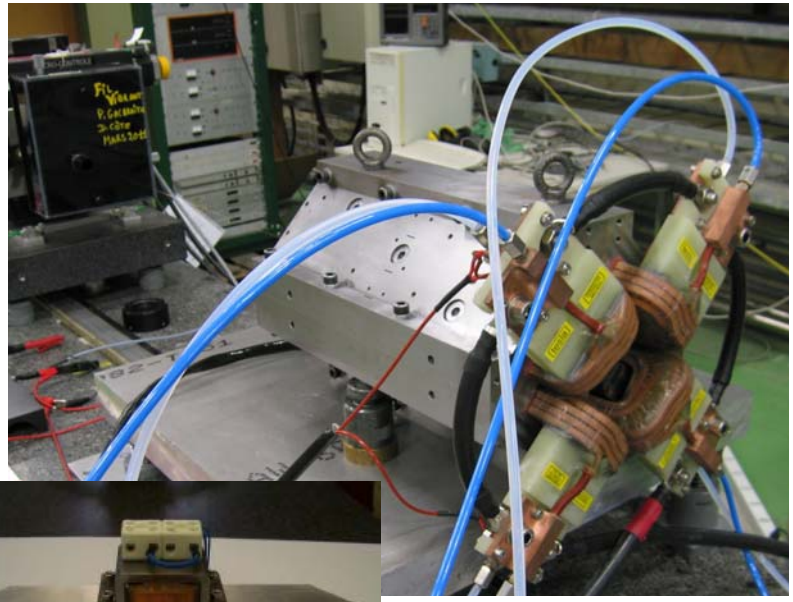


Main Beam Quadrupole prototype measurements

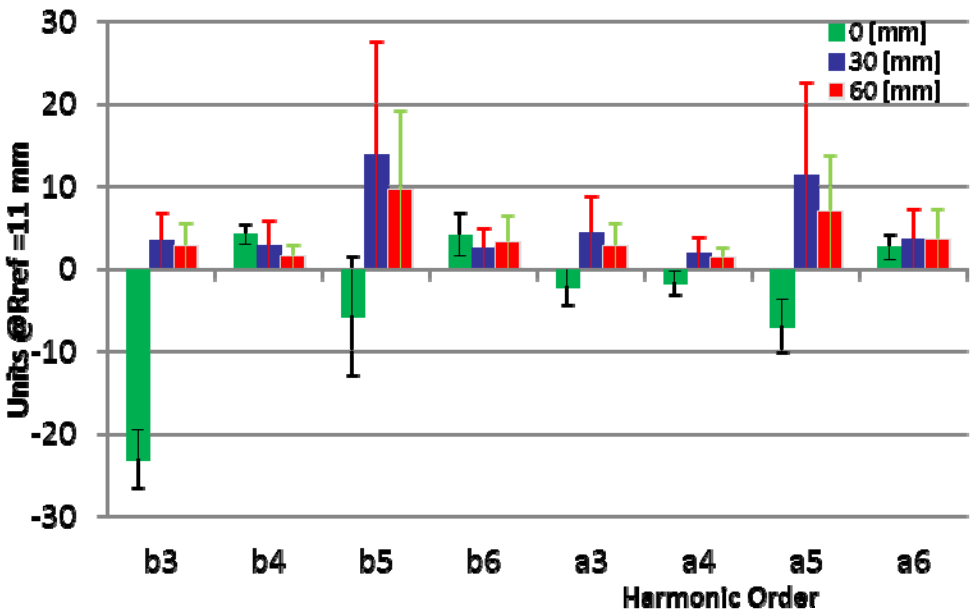
- Type 1 MBQ
  - 334 mm length
  - 70 T Integrated Gradient
  - 126 A Nominal Current
  - 10 mm Aperture
  - Dipole Steering Correctors

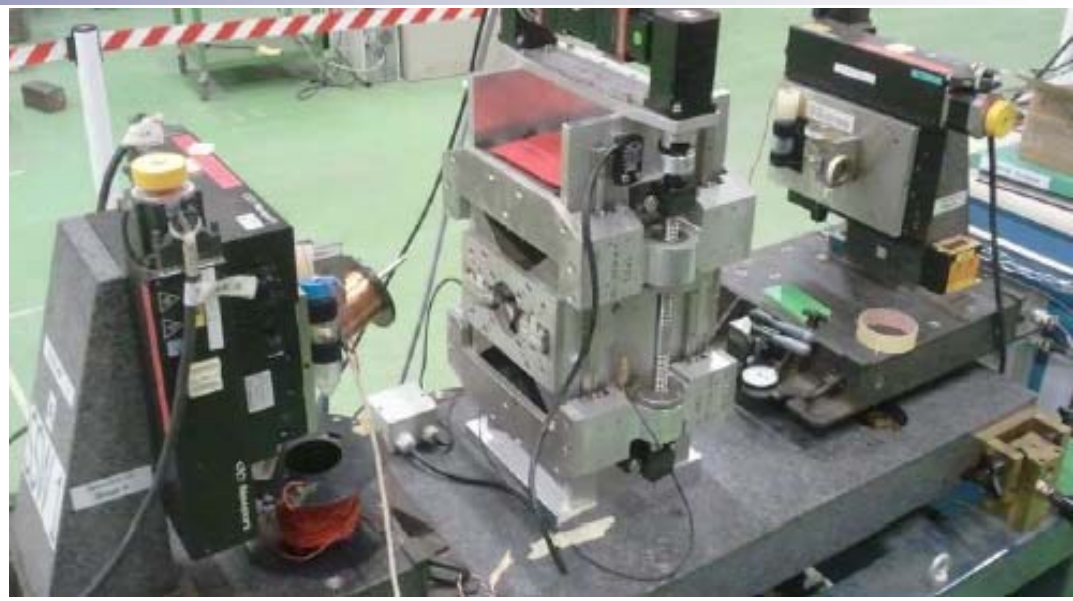
Parameter [unit]	Value
Yoke length [mm]	1844
Magnet length [mm]	1901.8
Yoke weight [kg]	$80\times4=320$
Conductor weight [kg]	$12.5\times4=50$
Total magnet weight [kg]	370
Cooling circuits per magnet	4
Height/width [mm]	5.6
Hole diameter [mm]	3.6
$x=y$ [mm]	1
r [mm]	1
Turns per pole	17
Conductor length per pole [m]	68
Current [A]	126
Current density [A/mm^2]	6.01
Resistance [mΩ]	241.3
Inductance [mH]	42.8
Power [W]	3831
Voltage [V]	30.4

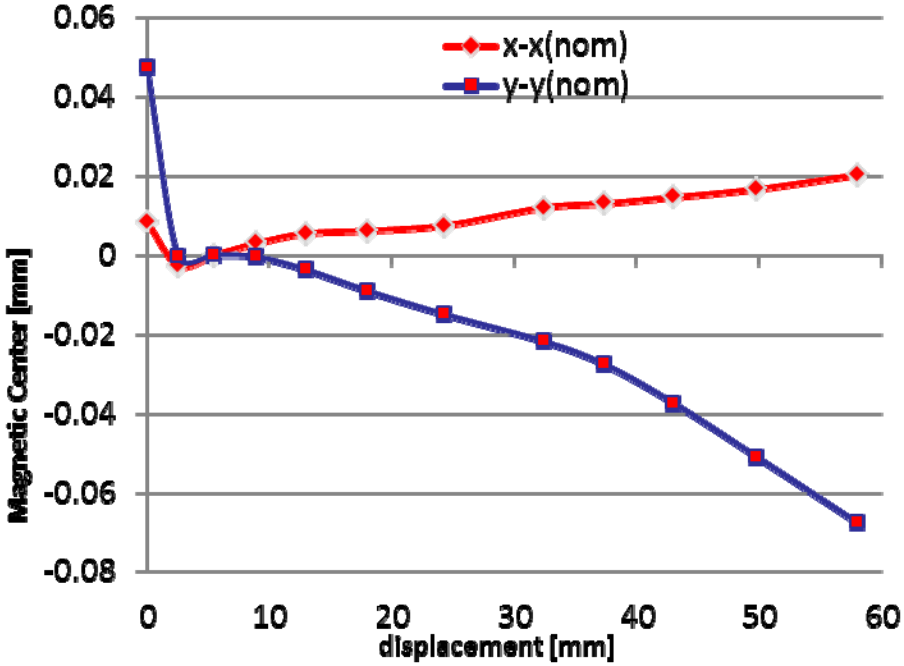


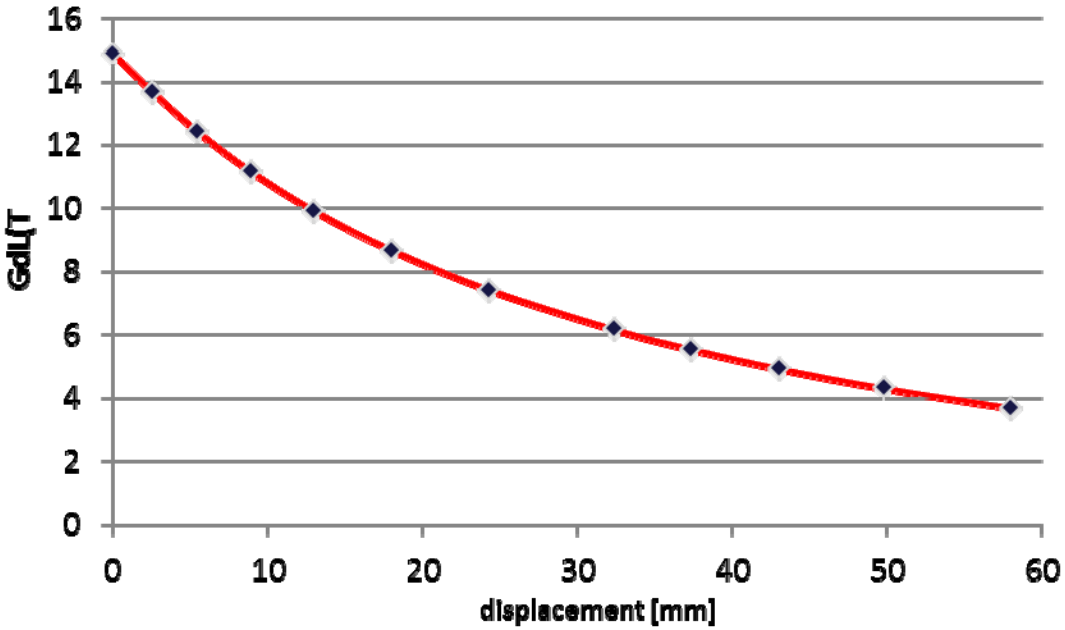


Drive Beam Quadrupole Daresbury prototype (Permanent Magnet) measurements

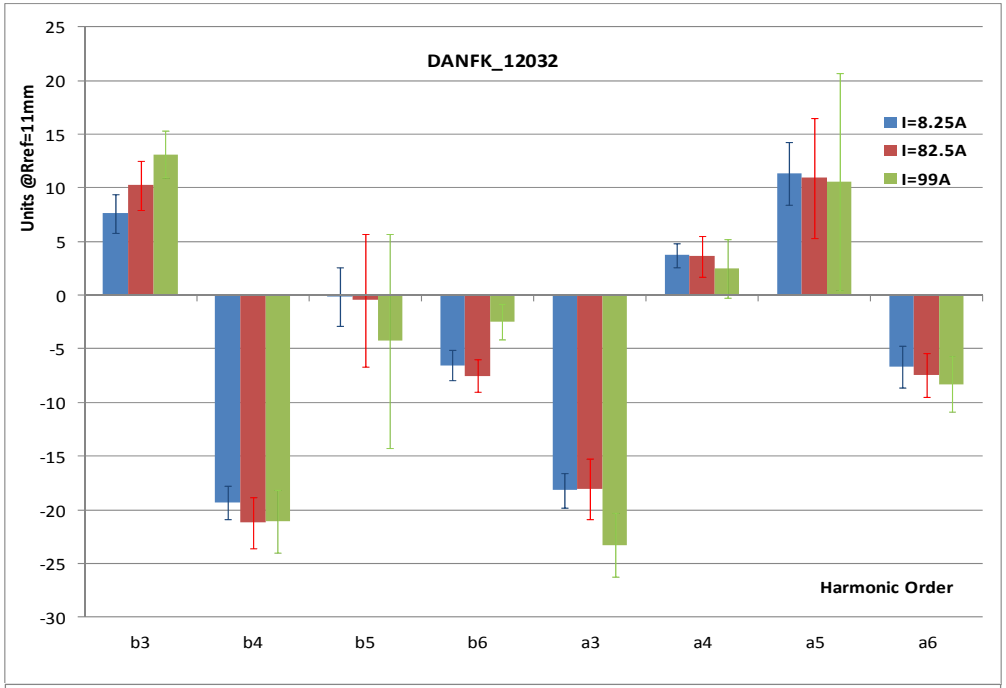


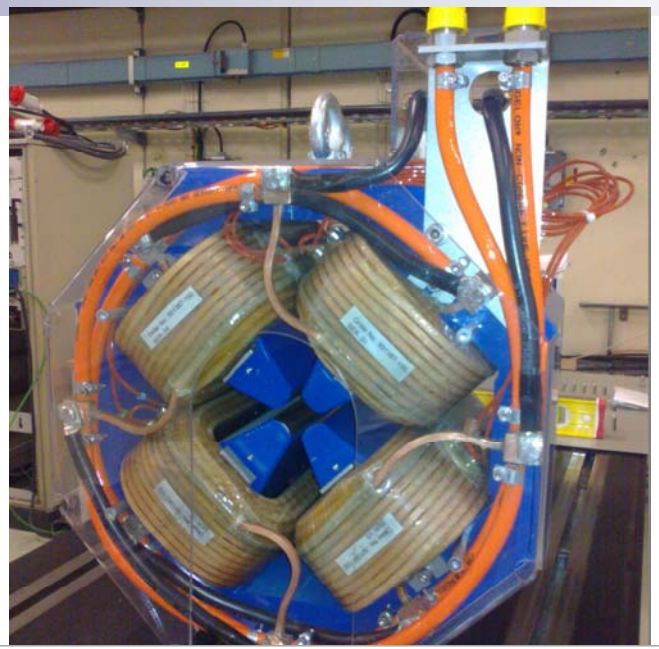


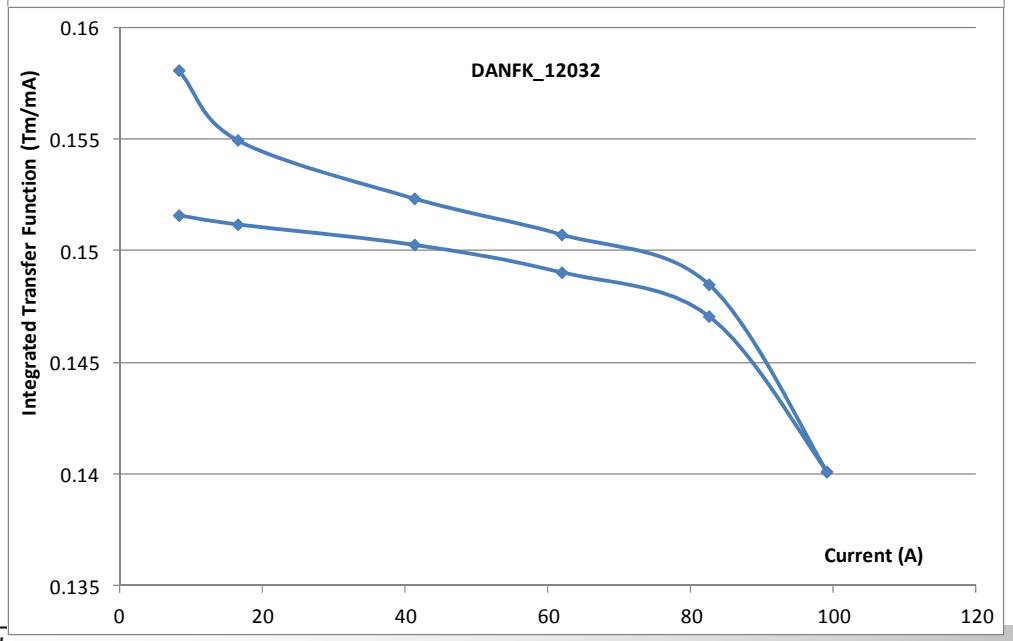


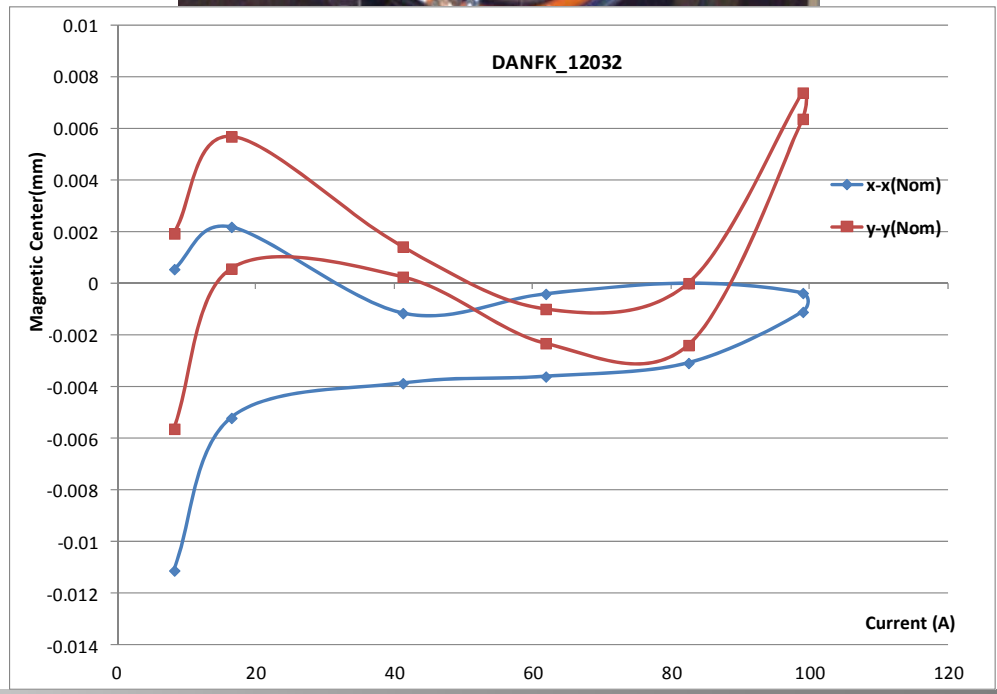


Drive Beam Quadrupole Danfysik prototype (Resistive) measurements









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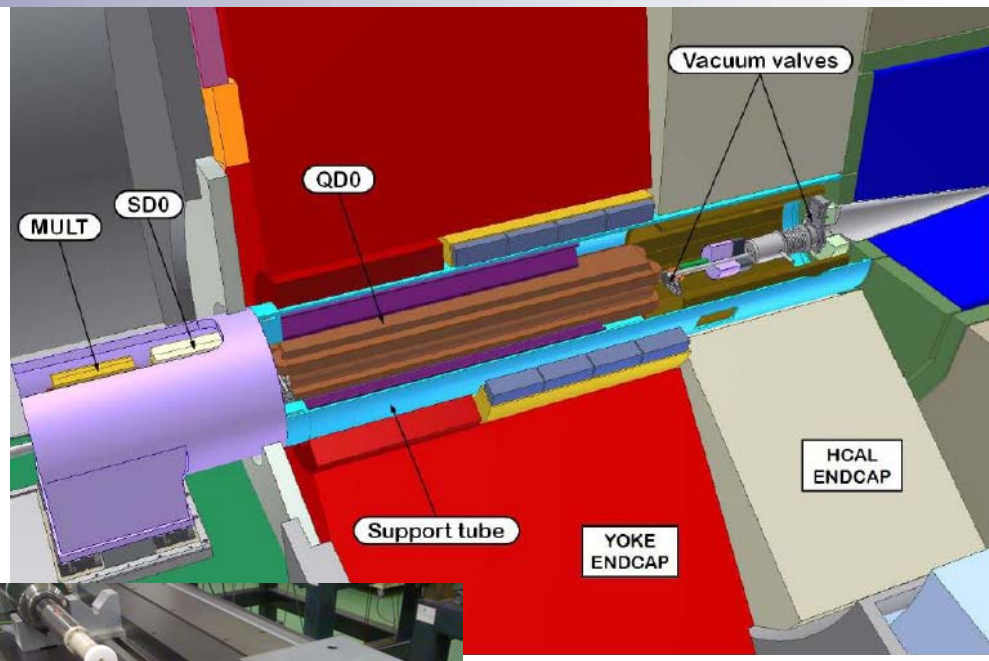
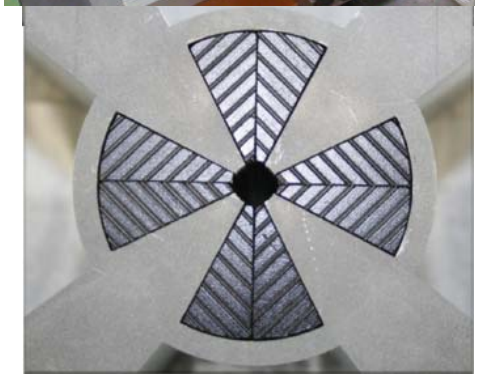
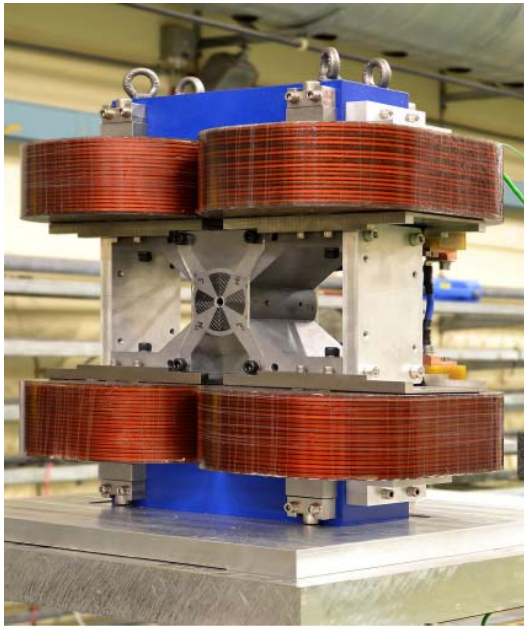
Machine Detector Interface magnetic layout with L* = 3.5 m

- Machine Detector magnets
- SD0 sextupole corrector
- Antisolenoid to protect QD0 from powerful detector solenoid
- QD0 Final focus quadrupole
  - Very compact high gradient (575 T/m)
  - Inside the experiments
  - Very tight alignment stability (active stabilisation)
  - Very long 2.73 m
  - Small bore 8.25 mm
  - Good Field Region radius 1 mm
  - Hybrid design
  - Two different materials $Nd_2Fe_{14}B$ and Sm_2Co_{17} for Permanent magnets

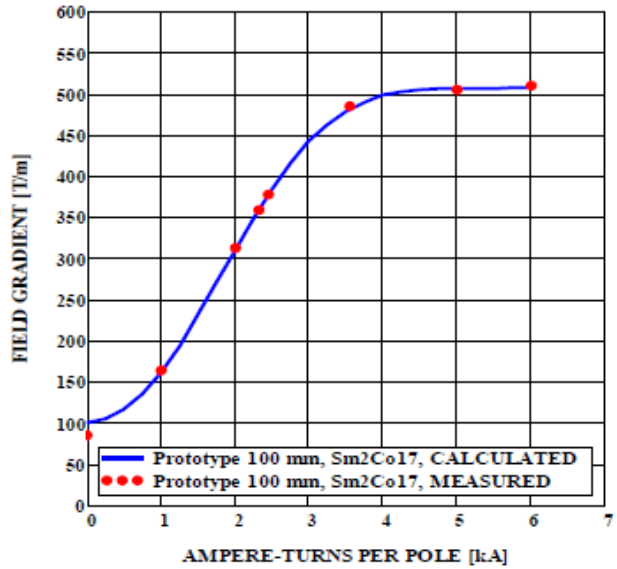


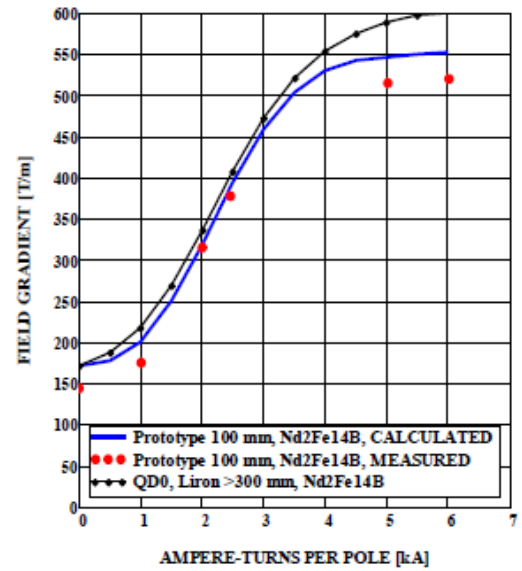


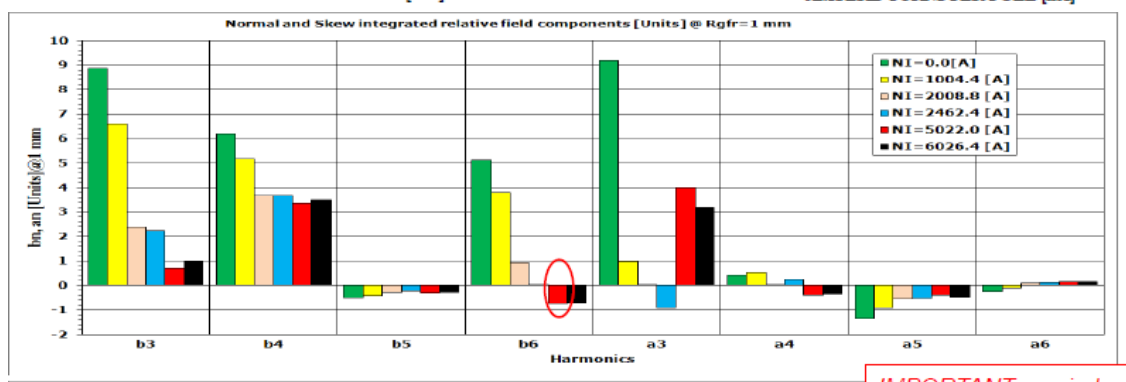


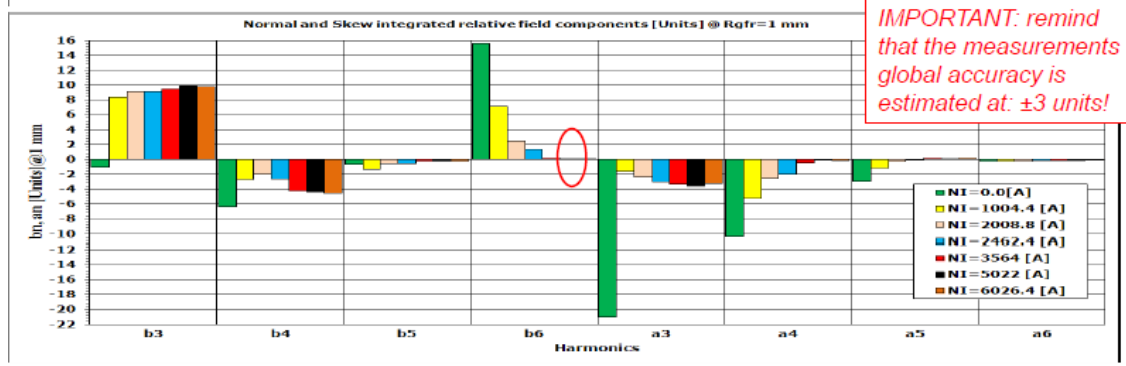
QD0 magnetic measurements results

- Maximum gradient measured with Sm2Co17 in good agreement with FEA computation. Second material not so good. Maybe due to incorrect magnetization
- Stability of the magnetic axis was found inside ±2.5 µm along the powering curve
- Magnet cycling precise and repeatable, minimum hysteresis
- Field harmonics @ 1 mm Rref in the required tolerances (10 units) measured with oscillating wire method
- PM blocks to be measured with 3D Helmholtz coils system
- Longer prototype to be manufactured









IMPORTANT: remind that the measurements global accuracy is estimated at: ±3 units!

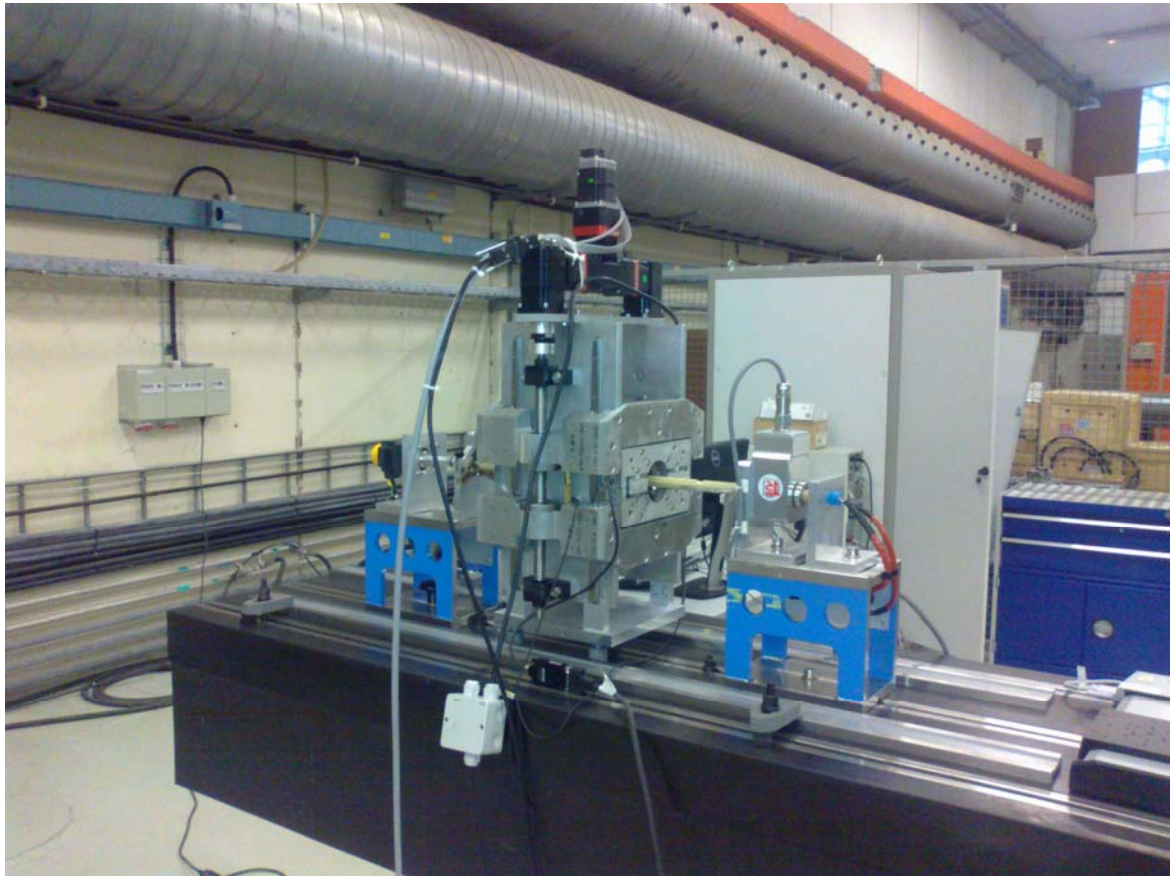
Summary of magnetic measurements results

- Main Beam Quadrupole
  - Axis to be checked
  - Gradient OK, agreement with simulations
  - Field Quality not OK, bad machining of poles (tight tolerances!)
- Drive Beam Quadrupole Daresbury
  - Axis not OK
  - Gradient OK
  - Field Quality not OK
- Drive Beam Quadrupole Danfysik
  - Axis not OK
  - Gradient OK
  - Field Quality not OK
- QD0
  - Axis OK, inside 2.5 µm for the powering cycle
  - Gradient OK for Sm but not OK for Nd , -6% (PM blocks issue)
  - Field Quality quite good

Conclusions

- ➔ CLIC is a challenging project
- ➔ Dimensions and number of magnets are impressive
- ➔ Alignment and stabilization are critical
- ➔ In the magnetic measurements the oscillating wire method finds a very good reason to perform
- ➔ Results help to improve short prototypes
- ➔ Many opportunities for Permanent magnet solutions
- ➔ Waiting LHC results for decisions. TDR starting

Daresbury Permanent Magnet Quadrupole for Drive Beam



DBQ Tunable Permanent Magnet