MAGNETS AND INSERTION DEVICES FOR THE ESRF II

OUTLINE

- Magnetic design
- R&D and Magnetic measurements
- IDs & BM sources
- Summary

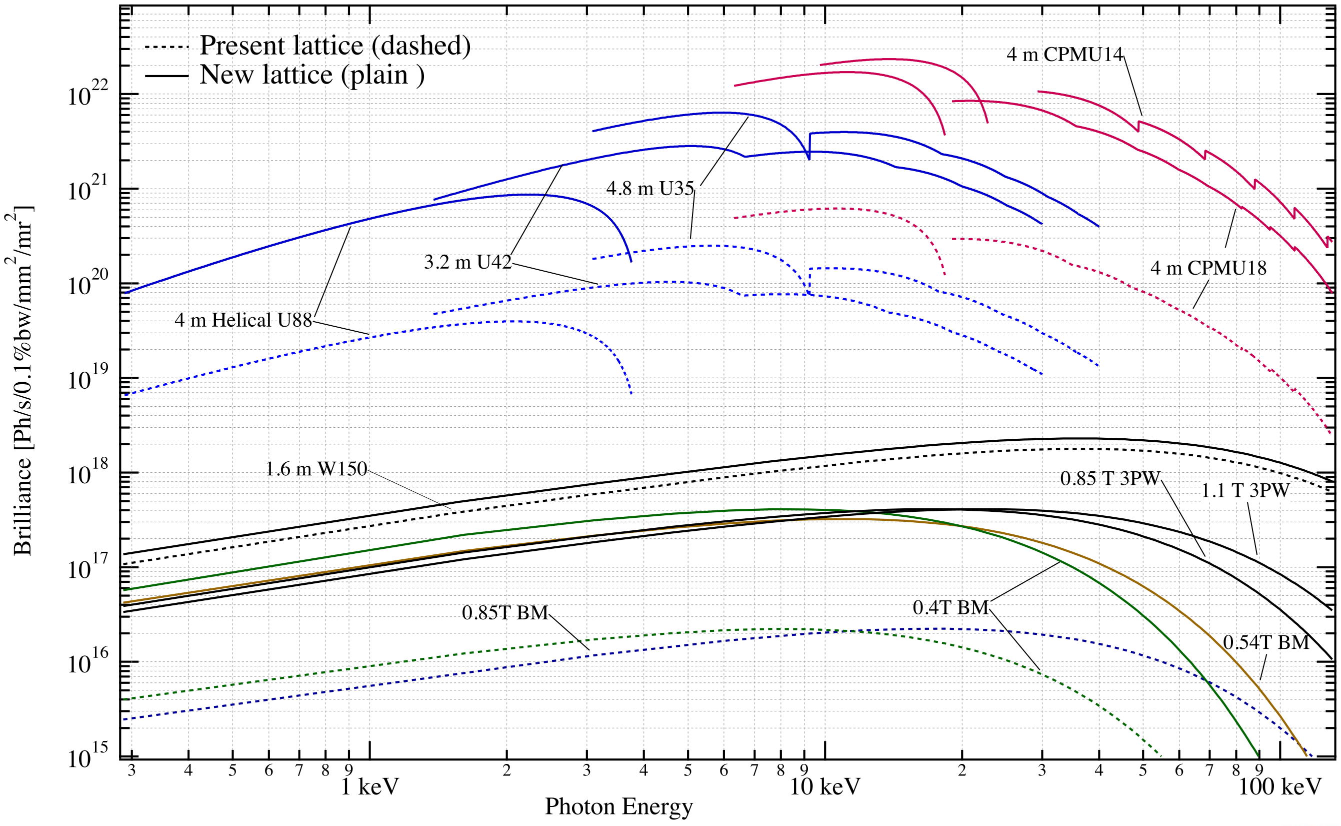
J. Chavanne
G. Lebec
C. Benabderrahmane
C.Penel

On behalf the accelerator upgrade project team

ESRF UPGRADE: SMALLER HORIZONTAL EMITTANCE

4 nm (present) →150 pm in 2019/2020

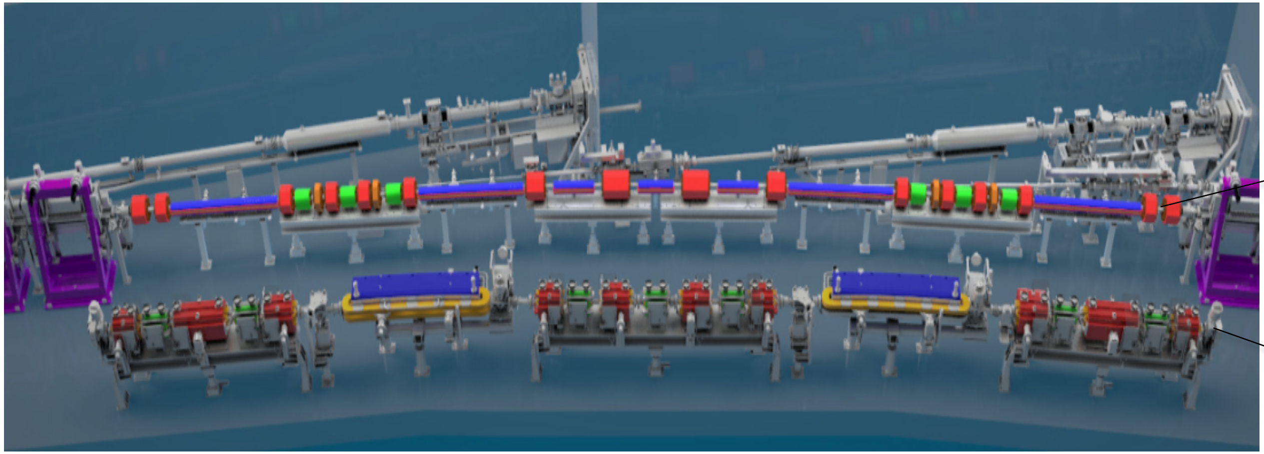
- Increased brilliance of X-ray sources : factor ~ 25 for undulators
- Increased coherent fraction in undulator beams



PRELIMINARY REMARKS

Specificity of ESRF accelerator upgrade

2BA-> 7BA with same circumference (844m)
Same source position at ID straight sections



New 7BA

existing

- 1096 magnets to build

○ Longitudinal compactness: limited space between magnets (~ few centimeters)
○ Common denominator for upgraded facilities

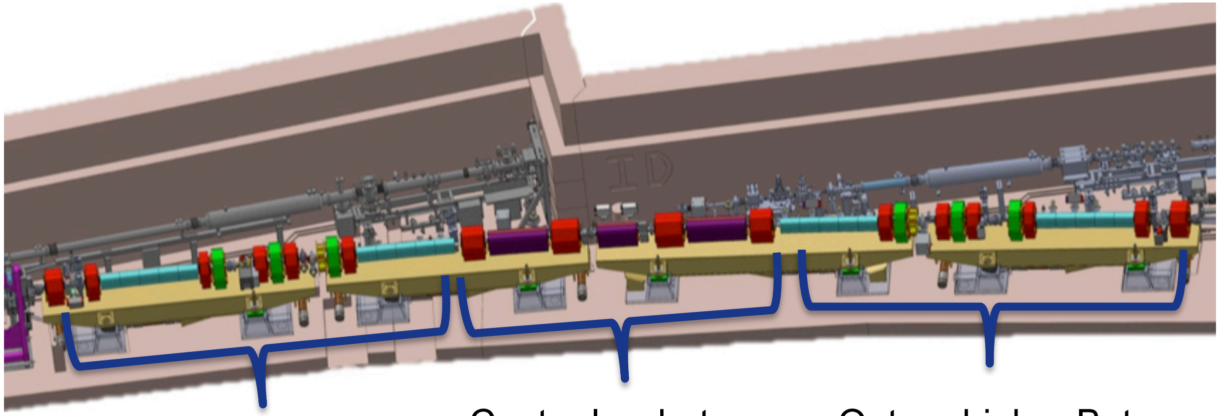
PRELIMINARY REMARKS (CONT.)

Magnet apertures [mm]

type	Existing	new
Dipole	50	25
Quadrupoles	72	25 - 32
Sextupoles	72	38

- Apertures reduced by a factor ~ 2
- Constraints on vacuum chamber design

GOOD FIELD REGIONS (GFR)



Outer , higher Beta

Center low beta

Outer , higher Beta

Two (elliptical) GFRs defined:

	Outer HxV [mm^2]	Center HxV [mm^2]
GRF radius (HxV)	13x9	7x5

Mostly dictated by (off axis) injection requirements

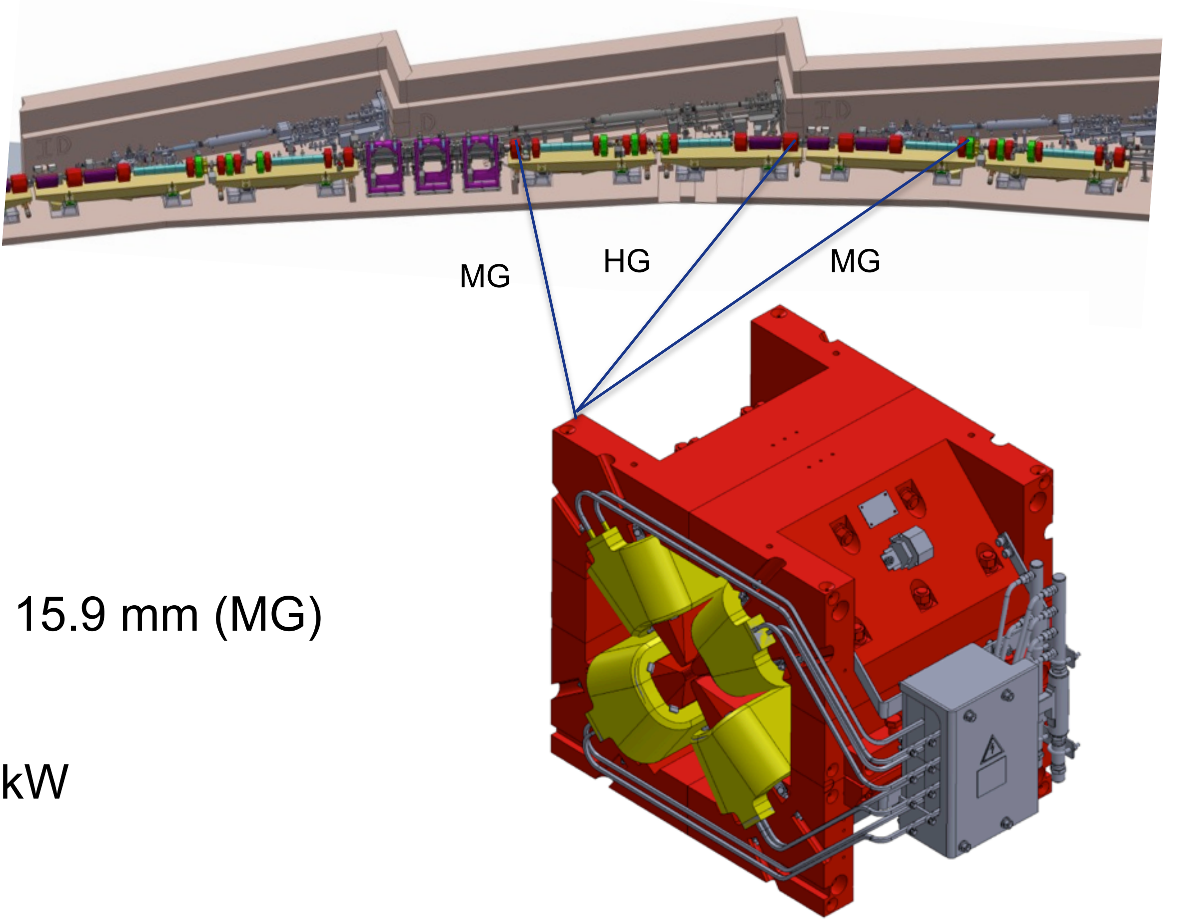
FIELD QUALITY

Magnet type	GFR radius [mm]	Field quality (systematic)	Tuning range [%]
DL	13	$DB/B < 10^{-3}$	0
DQ	7	$DG/G < 10^{-2}$	Gradient: +/- 2
Q – 50 T/m	13	$DB/B < 5\ 10^{-3}$	55 – 110
Q – 85 T/m	7	$DB/B < 5\ 10^{-4}$	95 – 105
S	13	$DH/H < 0.1$	20 – 130
O	13		0 – 145

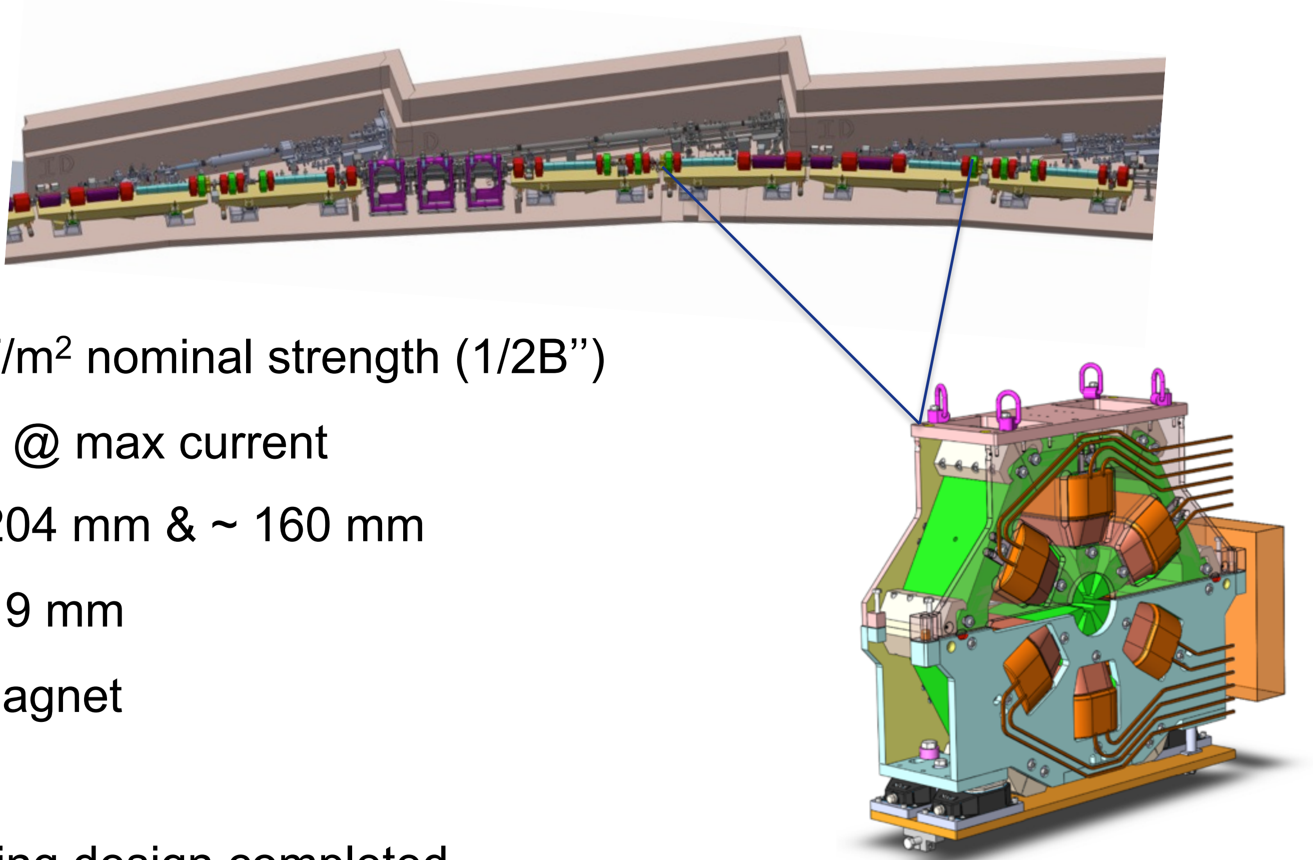
QUADRUPOLES

Parameters

- Moderate gradient: 51 T/m
  - length 0.16…0.29 m
  - 12 units/cell
- High gradient: 85 T/m,
  - length 0.39…0.48 m
  - 4 units/cell
- Bore radius: 12.8 mm (HG) / 15.9 mm (MG)
- min. Vertical gap: 11 mm
- Power consumption: 1…1.6 kW
- Solid / laminated iron yoke
- HG prototype under construction



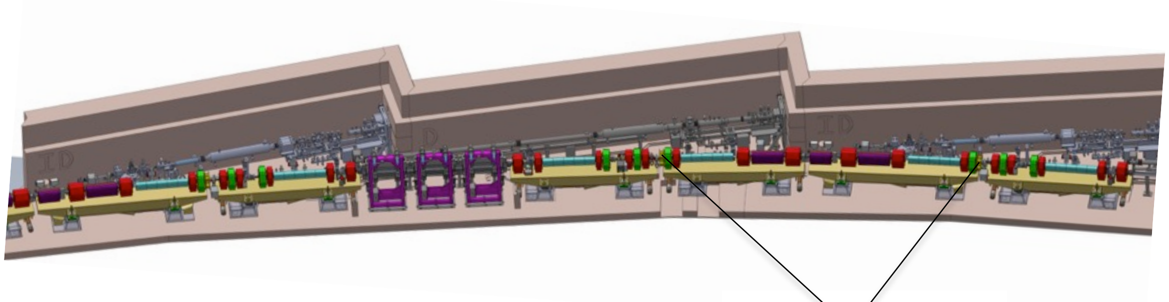
SEXTUPOLES

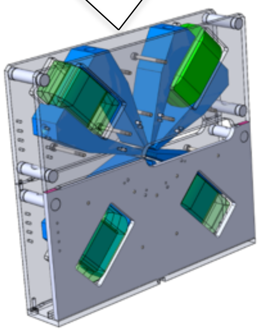


Parameters

- 900…1600 T/m^2 nominal strength (1/2B'')
- ~ 2200 T/m^2 @ max current
- Iron length 204 mm & ~ 160 mm
- bore radius 19 mm
- Laminated magnet
- 6 units/cell
- 1st Engineering design completed
- 2nd simplified version under completion

OCTUPOLES



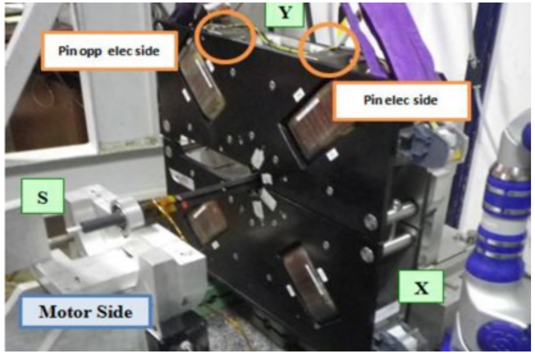


parameters

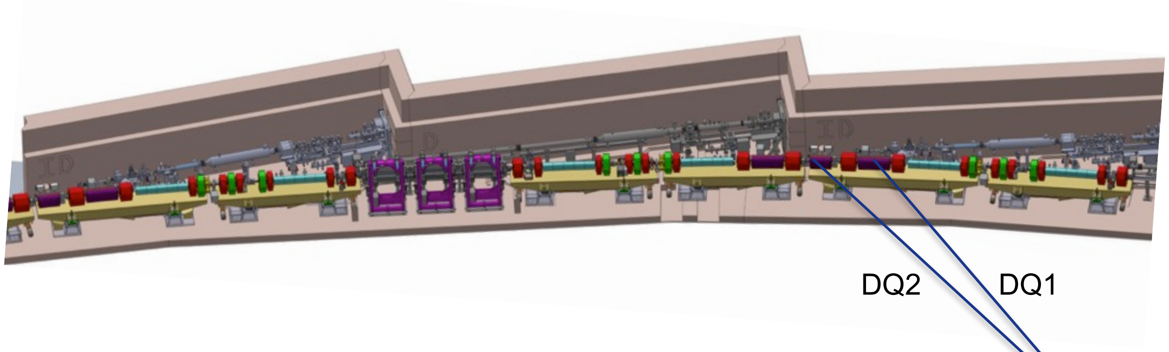
- Strength: up to 65 10^3 T/m^3
- Solid iron poles
- 2 units/cell

Prototype

- First prototype built (Sigmaphi) and measured
- Measured int. strength: 4504 T/m^2 @ 6.2A
- air-cooled coils

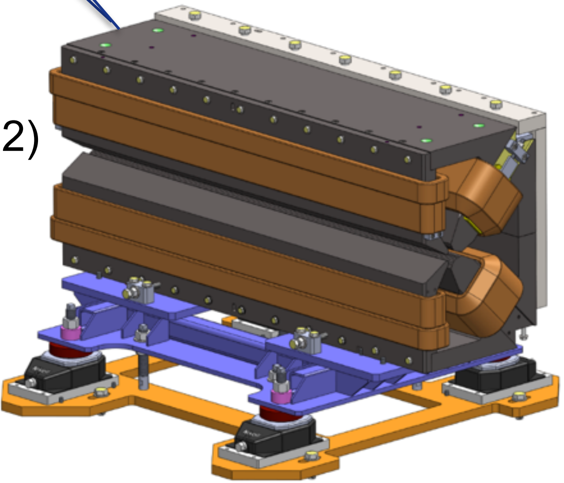


COMBINED DIPOLE-QUADRUPOLES



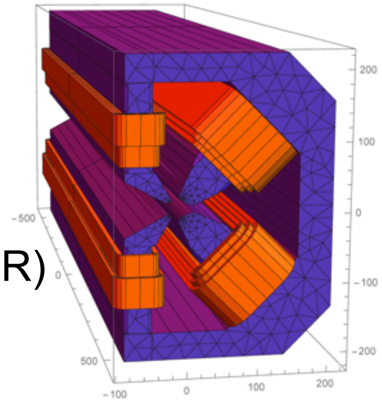
Parameters

- " Half quadrupole" concept
- "Single-sided" magnet: easy access on one side
- 0.54 T, 33.9 T/m, 1.08 m (DQ1), and 0.43 T, 33.7 T/m, 0.72 m (DQ2)
- Same pole shape and magnet curvature for DQ1 and DQ2
- Trimming coils: +/-2 % gradient at fixed field
- Solid iron magnet
- 3 units/cell

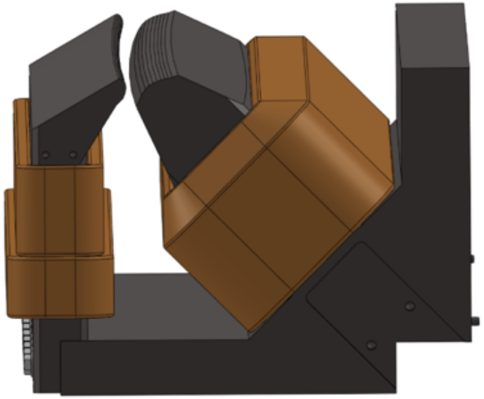


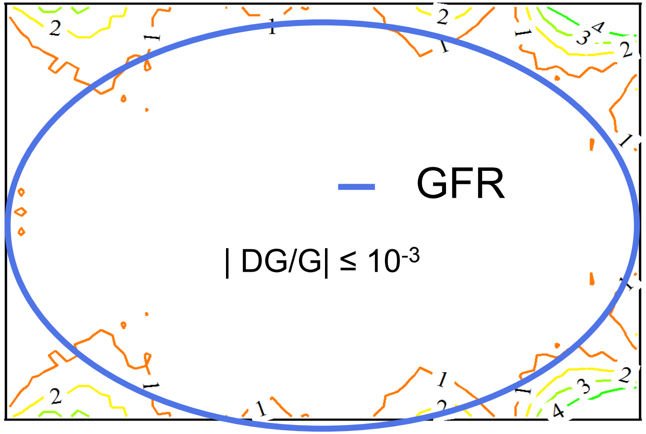
COMBINED DIPOLE-QUADRUPOLES

Magnetic design



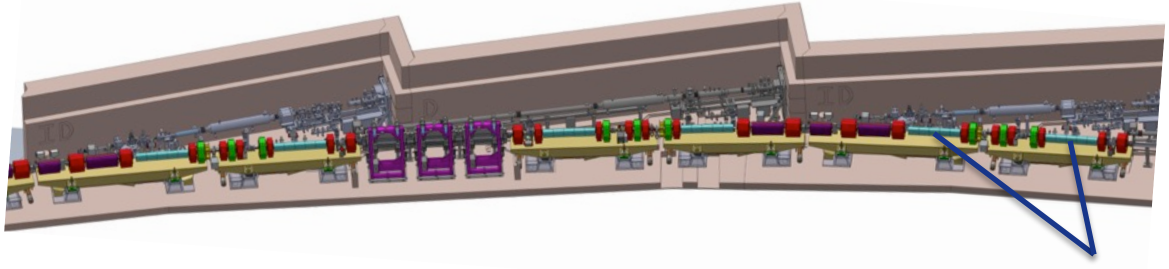
- Field integrated along a curved path
- Field integrals on the boundary of an elliptic Good Field Region (GFR)

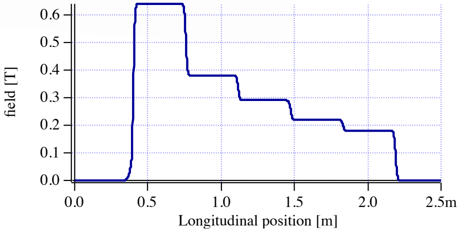




DG/G expressed in 10^{-3}. Specification: $DG/G < 10^{-2}$.
GFR: 7x5 mm. Integration on an arc.

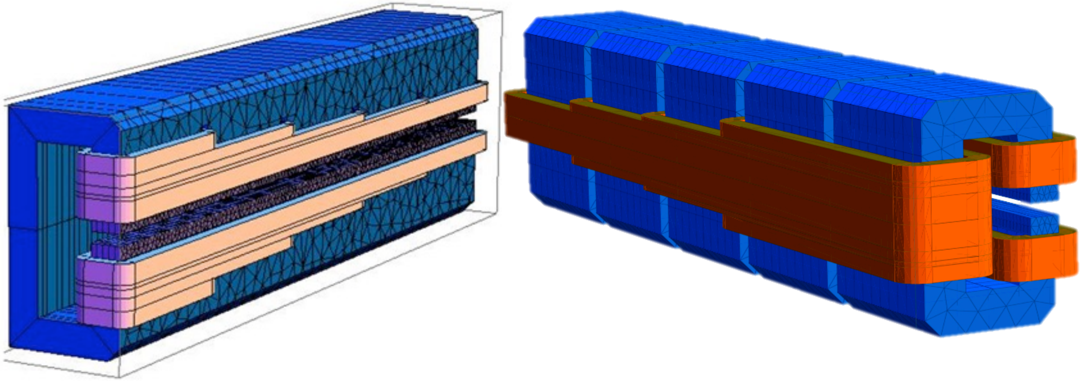
DL MAGNETIC DESIGN



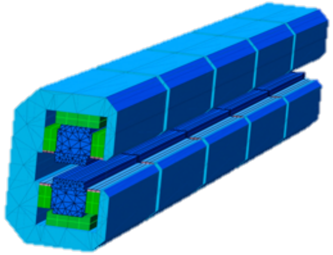


Different magnetic designs visited @ ESRF

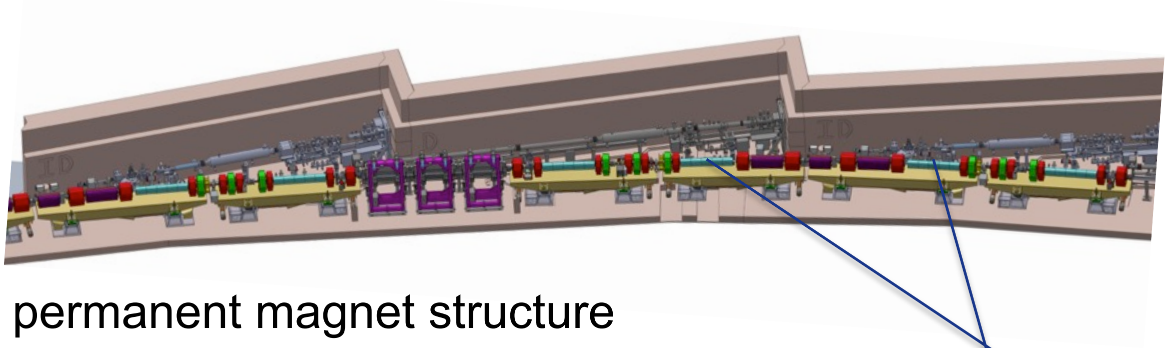
Resistive DLs



Permanent Magnet DLS

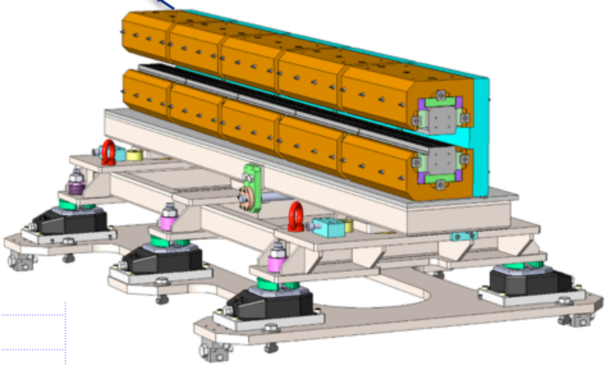


DLS- DIPOLES WITH LONGITUDINAL FIELD GRADIENT

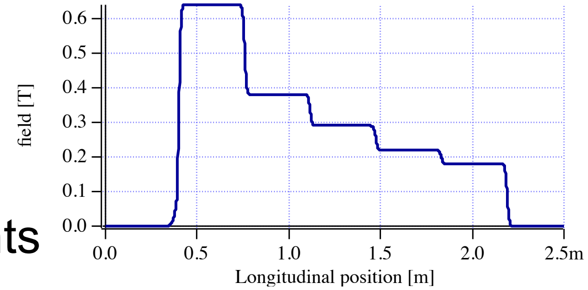


Parameters

- Iron dominated permanent magnet structure
- High coercivity Sm_2Co_{17} PM material
  - High stability against radiation induced demagnetization
- 5 modules with different field /dipole
- Total length 1788 mm
- magnetic gap 25 mm
- solid iron magnet
- prototypes under measurements
- 4 units/cell



128 units needed

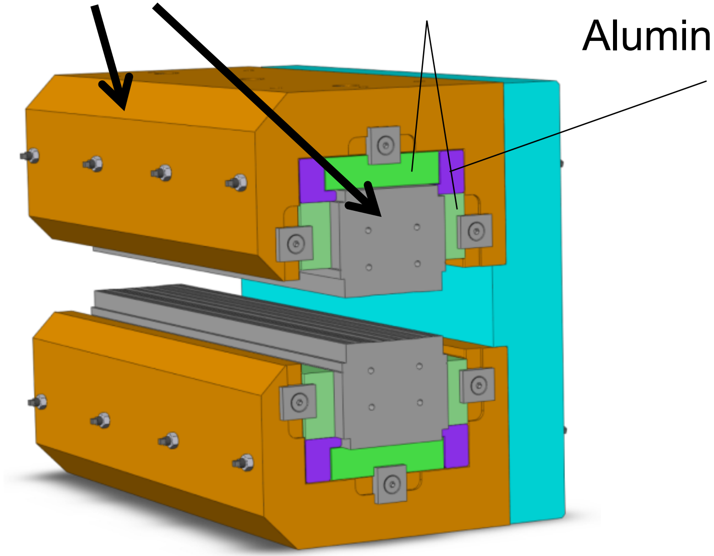


DL field profile

PM DIPOLE MODULES

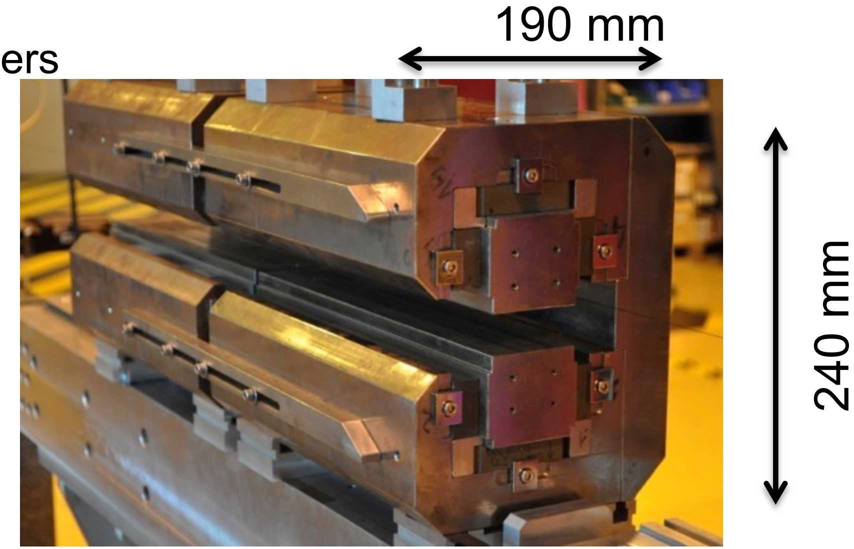
DL module

Number of PM blocks is module dependent



From concept

Weight ~ 83 kg/module

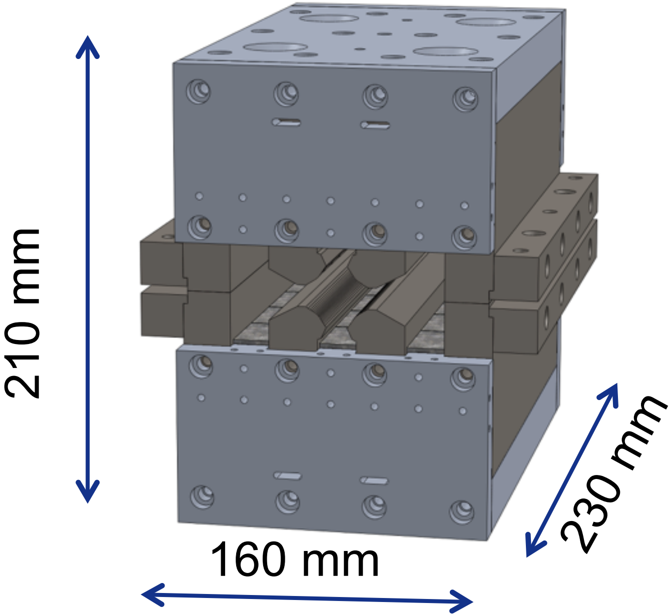


to real structure (2 modules)

Target: setup a low cost simple design

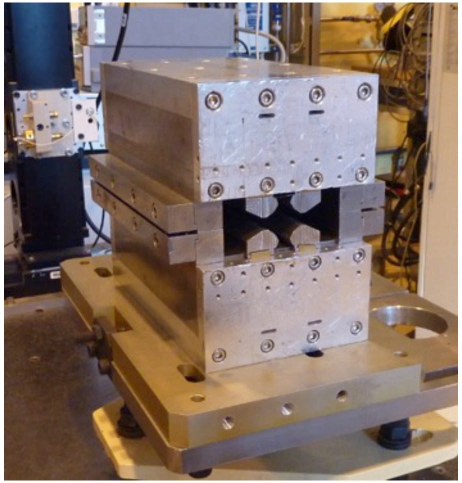
PM STRUCTURES R&D : HIGH GRADIENT COMPACT QUADRUPOLES

R&D topic, not committed for the ongoing upgrade



Parameters

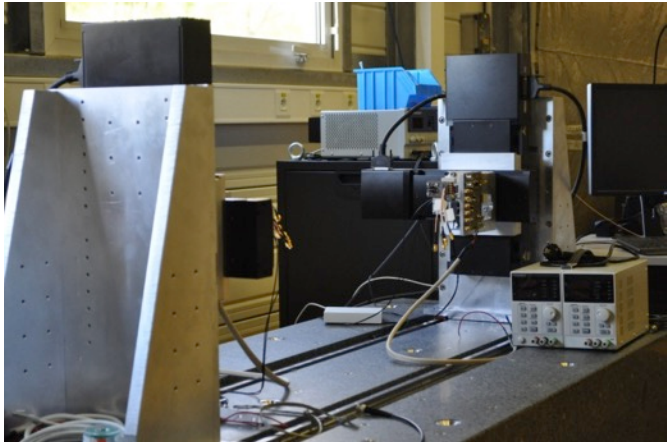
- 82 T/m gradient
- Simple PM rectangular shape
- $|DG/G| < 10^{-3}$ @ 7mm horizontal (measured)
- Easy correction (shimming)
- vertical pole gap: 10.2 mm
- Length 230 mm
- 40 kg



MEASUREMENT BENCHES

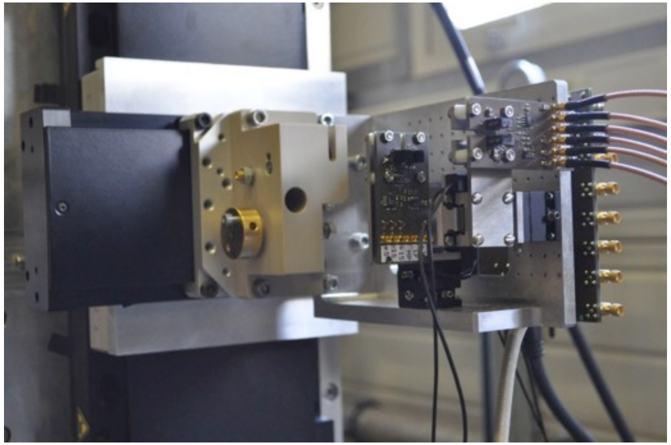
Stretched wire bench

- New measurement methods
- New calibration procedures
- Simplification of the control software



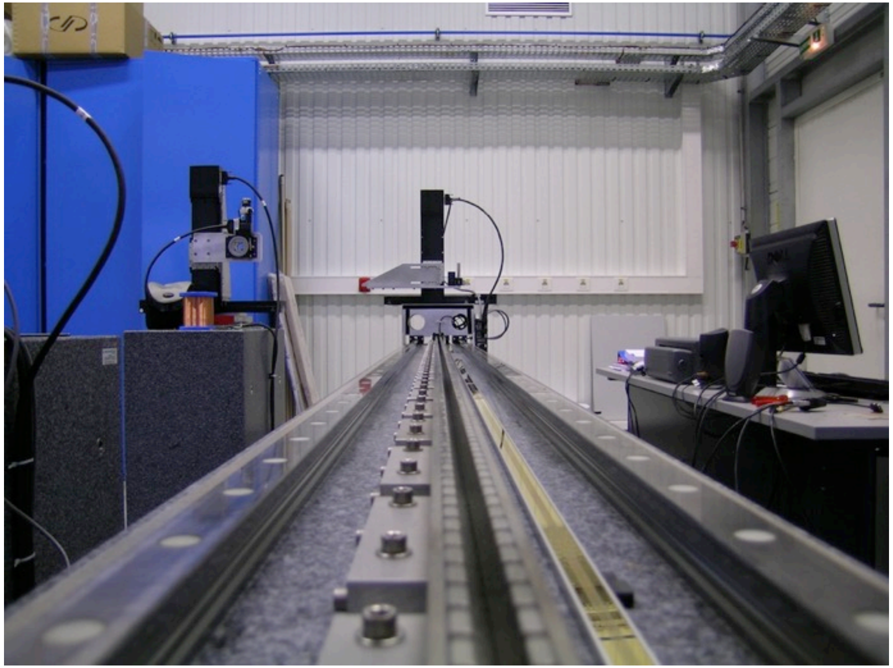
Vibrating wire bench

- Development of the wire position monitors
- Generator for wire excitation
- Vibrating wire analysis R&D
- = Same bench as stretched + vibrating wire layer



MEASURING BENCHES : LOCAL FIELD MAPPING

Hall probe benches as used for IDs

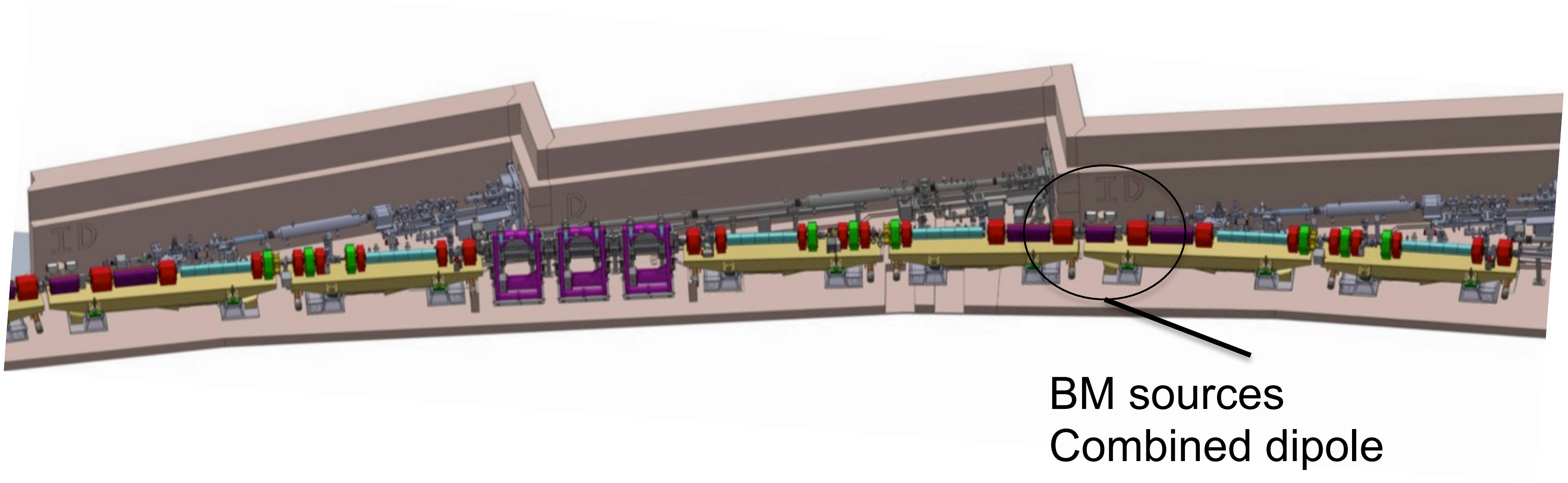


- Developed at ESRF
- Several units in use
- Linear motors
- 3D hall sensors
- On the fly measurements
- Well performing hall data processing

- New implementation

- Accurate 3D trajectory of hall probe
  - NEWPORT XPS controllers (already existing)
  - To be used for curved prototypes/pre-series magnets (DQs, DLs)

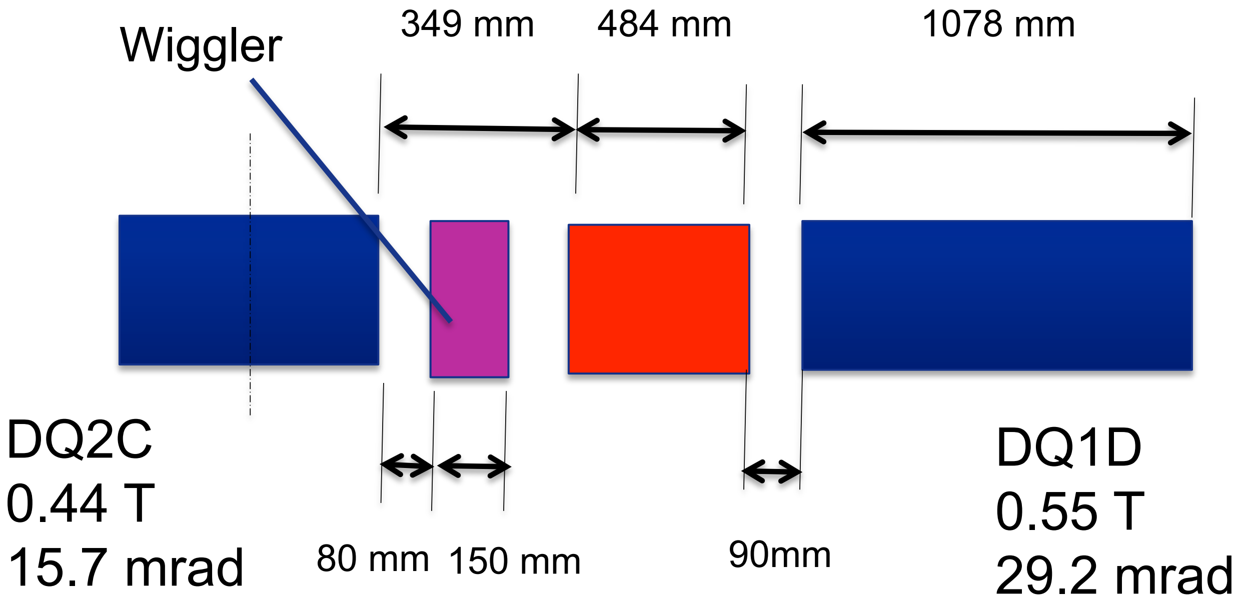
PHOTON SOURCES: BM TYPE RADIATION


BM sources
Combined dipole quadrupole (DQ)
Short wiggler

- Implementation of short Wigglers
  - Compensates lower field BM source
  - Restore hard X-ray capacity for BLs
  - Short devices ~ 150 mm size
  - Mini Insertion Device

MINI WIGGLER IMPLEMENTATION

installed downstream of first dipole



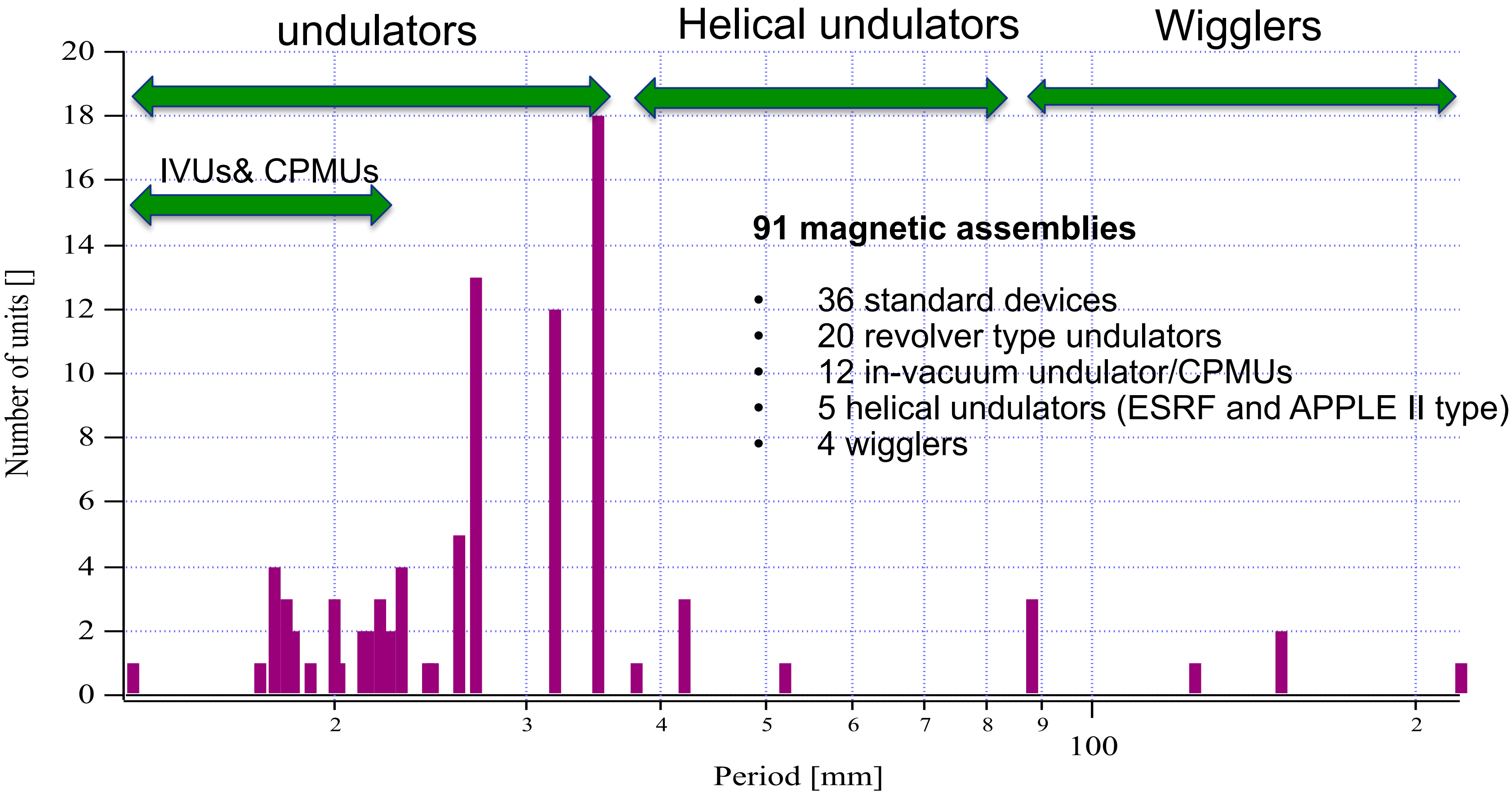
features
- fixed gap simple device devices (~ portable device)
- Field adaptable to beamline needs

INSERTION DEVICES

Most of existing devices will be used in the upgraded storage ring

- 6 GeV → 6 GeV
- Achieved field quality compatible with new emittance (~ 90 % of devices)
- reverse engineering needed in a few straight sections (6 m → 5 m)

ID IN OPERATION @ ESRF



91 magnetic assemblies

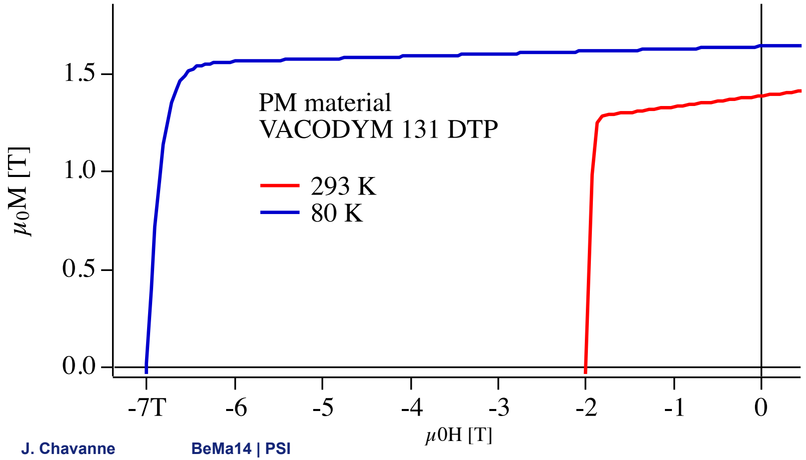
- 36 standard devices
- 20 revolver type undulators
- 12 in-vacuum undulator/CPMUs
- 5 helical undulators (ESRF and APPLE II type)
- 4 wigglers

Specificity of ESRF: wide spectrum in ID period

PHOTON SOURCES: SMALL GAP DEVICES

R&D pursued on CPMUs
3rd device under construction

- New PM material developed by Vacuumschmelze
- PrFeB, Br =1.62 T,| $\mu_0 Hc_J$|>7 T @ 80 K
- includes Grain boundary Diffusion
- New magnetic measurement system
- Installation mid-2015
- Period 14.5 mm, L=2 m, Min. gap 4.3 mm,
- Peak field: 1.23 T ,K=1.67 @ min. gapq



SUMMARY

- ESRF II lattice requires enquires several new types of magnets

- Magnet design mostly completed
  - Innovative concepts (PM DLs, DQs)
  - Still a lot to do
- Ongoing measurements of prototypes provide useful feedback

- Engineering design at suitable stage for tendering processes
  - Technical specs starting
  - calls for tenders mid 2015/2016

- Development of magnetic measurement tools

- New BM type sources (mini wigglers)
- Existing IDs used in the upgraded storage ring
- Smaller gap/shorter periods CPMUs

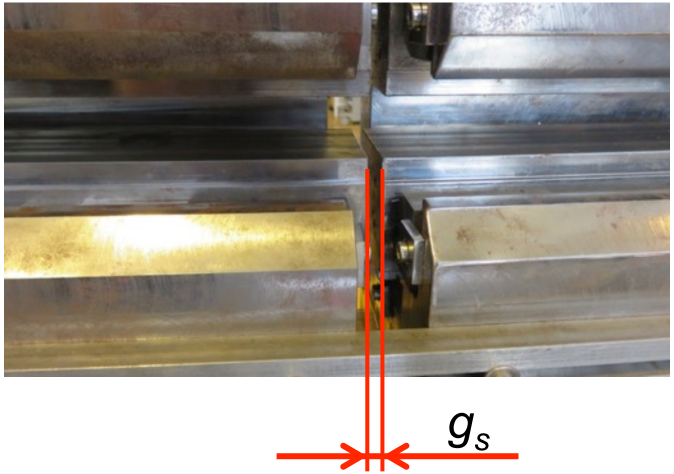
THE END

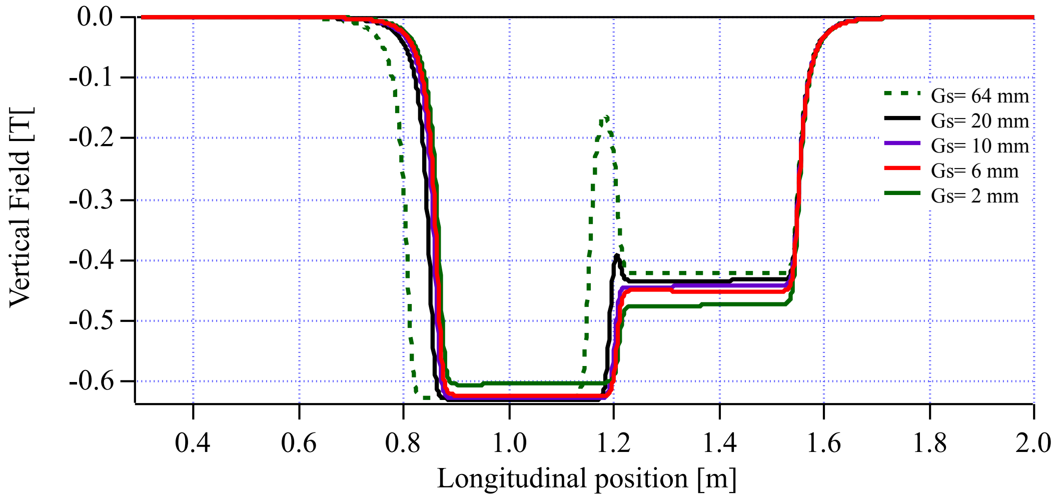
Thank you

DL – LONGITUDINAL GRADIENT DIPOLES

Longitudinal field profile

- field sharing controlled with longitudinal gap (g_s = 3 ~ 6 mm)
- very moderate longitudinal force (even cancelled in some cases)
- The “optimum” g_s changes between the modules of the full magnet (field step dependence)

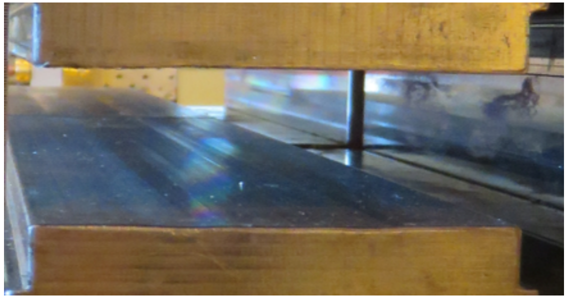




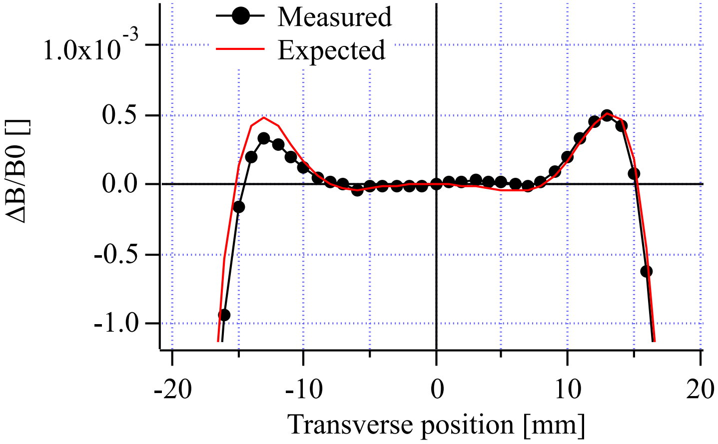
DL – LONGITUDINAL GRADIENT DIPOLES

Homogeneity of central field

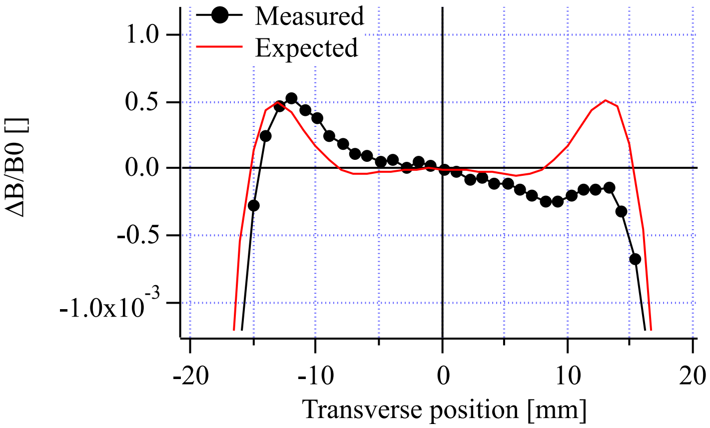
- Quality dominated by pole faces parallelism
- May need refinement of mechanical tolerances
- Easy and fast mechanical correction (shimming)
- Tolerance: D*B*/*B* < 10^{-3} @13 mm



Optimized pole shape



Module 2 (Hall probe meas.)

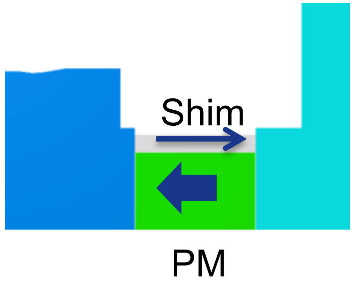


Module 1 (Hall probe meas.)

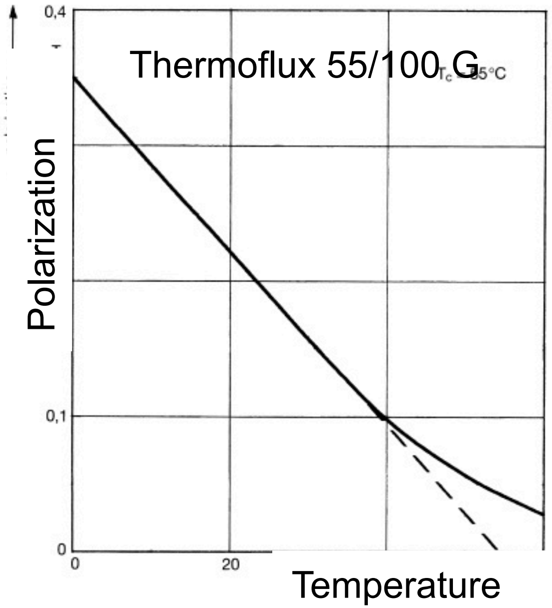
TEMPERATURE COMPENSATION

Temperature compensation

- Fe-Ni material (Thermoflux 55/100 G) used for passive compensation
- Tested with **NdFeB** magnets (thermal coefficient 3 times larger than for Sm_2Co_{17} magnets)



Correction scheme



Measured performance on prototype:

- NMR probe measurements
- $\Delta B/B/dT = 10^{-4}/C$ / mm of shim @ 0.64 T
- Agree well with simulation

- DL field can be easily stabilized (Sm_2Co_{17})
  - stability < 5 $10^{-5}/C$
  - 290 kg Fe-Ni needed for all 128 DLs
  - DL field reduced by ~ 1.2 %