PAUL SCHERRER INSTITUT

MT 26
International Conference on Magnet Technology
Vancouver, Canada | 2019

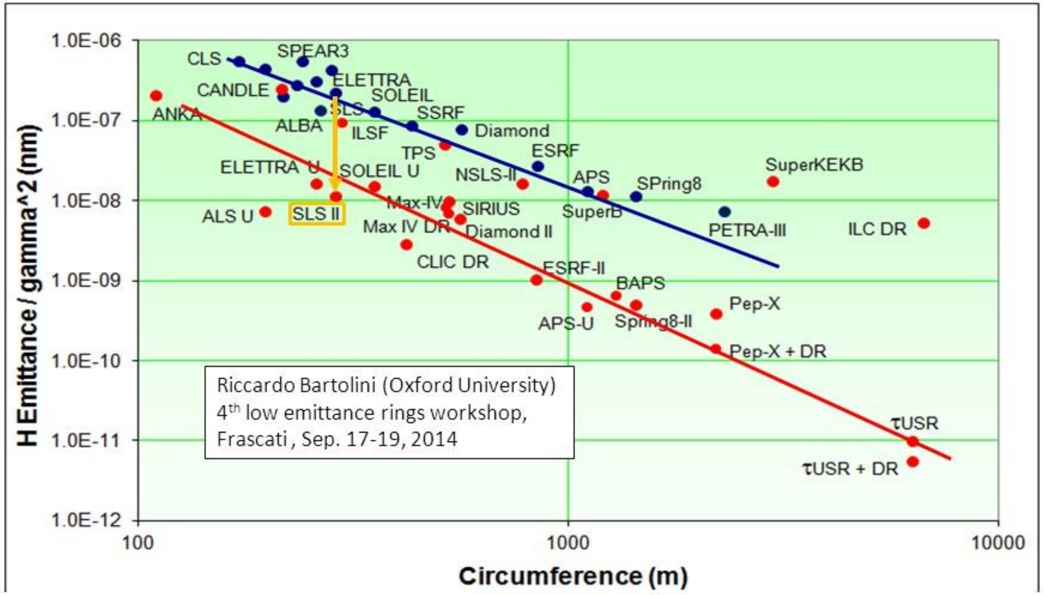
C. Calzolaio, A. Gabard, P. Lerch, G. Montenero, M. Negrazus, S. Sidorov, V. Vrankovic and S. Sanfilippo

Longitudinal gradient bend magnets for the upgrade of the Swiss Light Source storage ring

Why do we need an upgrade?

In order to stay competitive in future, the new storage ring has to provide a factor
<u>> 30 lower emittance</u> at the same circumference and beam energy.

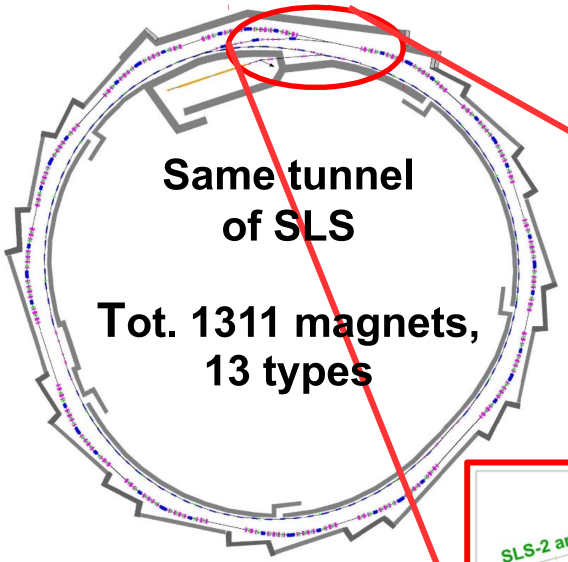
The storage ring generational change



Storage rings in operation (•) and planned (•).
The old (—) and the new (—) generation.

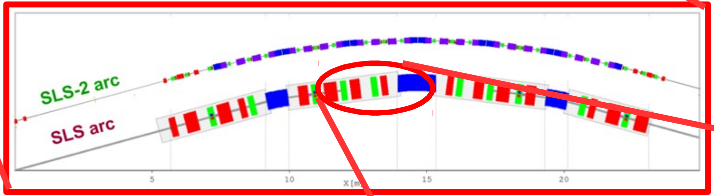
A. Streun, PSI: Beam dynamics and lattice proposal for SLS-2 BeMa-2, Bad Zurzach, Dec. 1-4, 2014 4

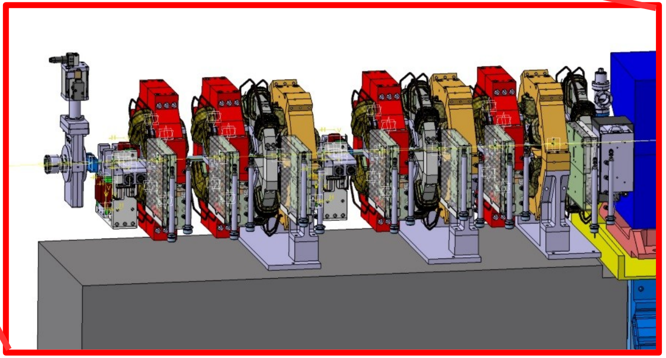
SLS upgrade: magnets zoo



Same tunnel of SLS

Tot. 1311 magnets, 13 types





- 888 Combined function room temperature electro-magnets;
- 420 permanent magnets
    - 60 longitudinal gradient bend (LGB);
- 3 Superbend magnets:
    - 2x4T, Nb-Ti
    - 1x5T, Nb-Ti

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SLS upgrade: magnets zoo

Space in the tunnel is very tight

Energy consumption

Reduced operational cost

- 888 Combined function room temperature electro-magnets;
- 420 permanent magnets
  - 60 longitudinal gradient bend (LGB);
- 3 Superbend magnets:
  - 2x4T, Nb-Ti
  - 1x5T, Nb-Ti

SLS upgrade: magnets zoo

Hard X-ray source
~80-100 keV

- 888 Combined function room temperature electro-magnets;
- 420 permanent magnets
  - 60 longitudinal gradient bend (LGB);
- 3 Superbend magnets:
  - 2x4T, Nb-Ti
  - 1x5T, Nb-Ti

Outline

- Longitudinal gradient bend (**LGB**) magnets based on permanent magnet (PM): **PM-LGB**
  - Magnets assembly procedure;
  - Variable gap to produce the longitudinal gradient;
  - Segmented pole to produce the variable gap.

- Superconducting longitudinal gradient bend magnet: **SC-LGB**
  - Open geometry;
  - Integrated vacuum chamber.

- Conclusions and further developments.

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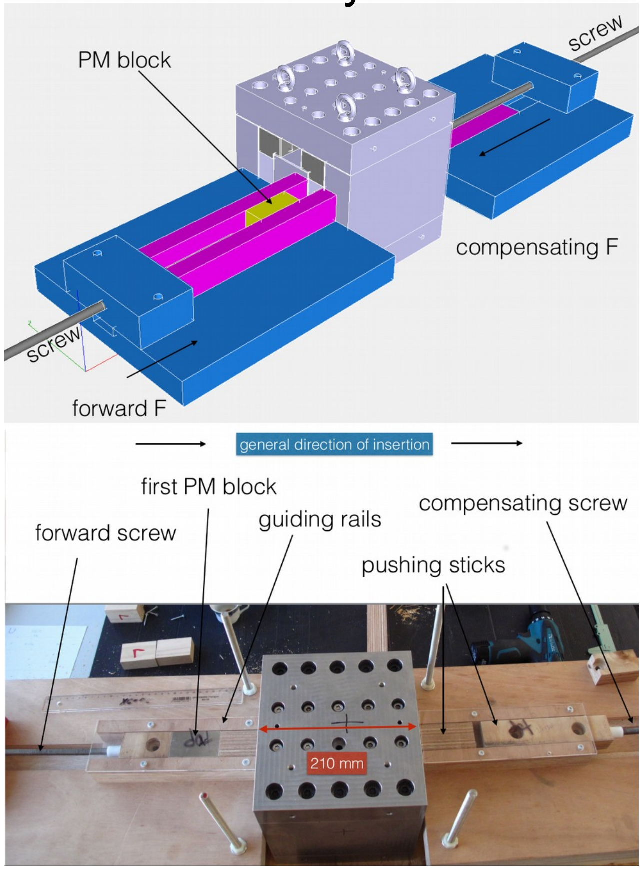
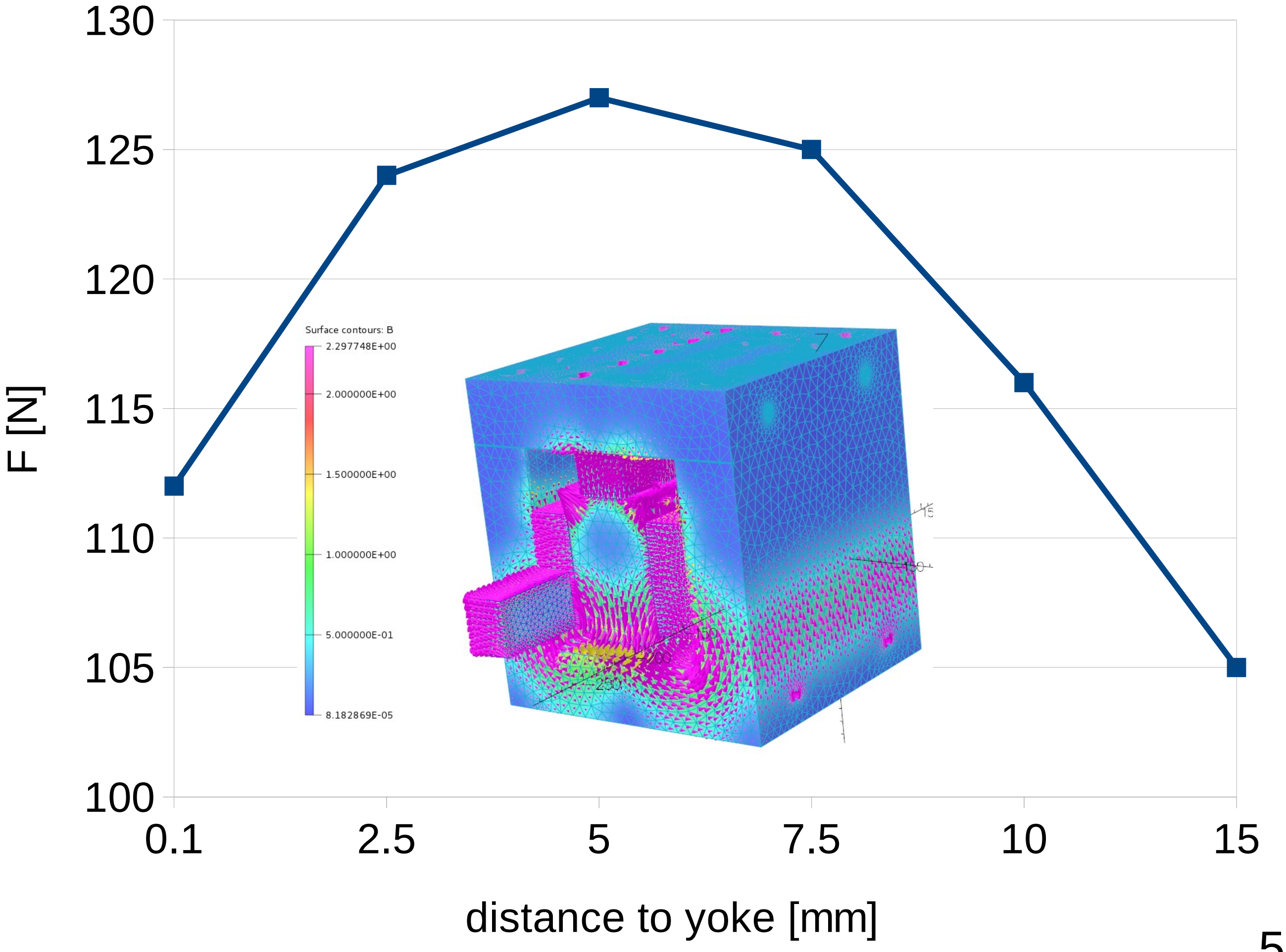
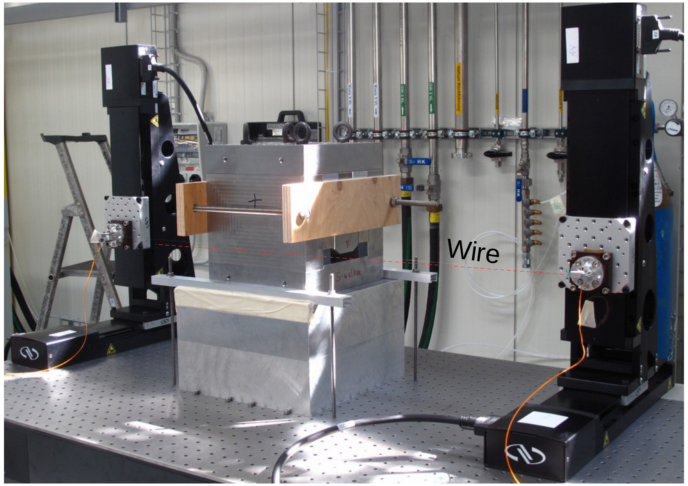
PM-LGB: assembly procedure

Assembly tool

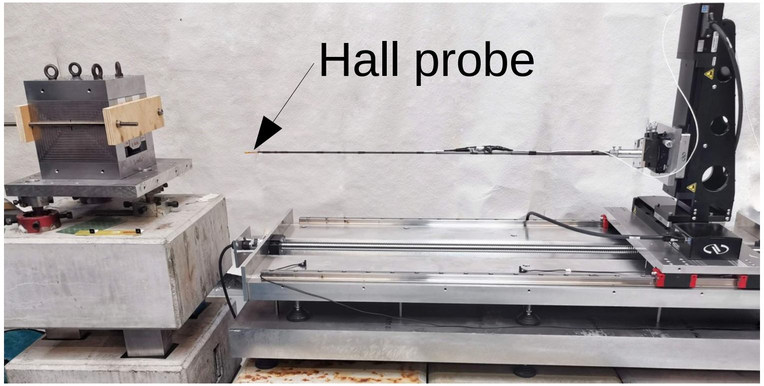




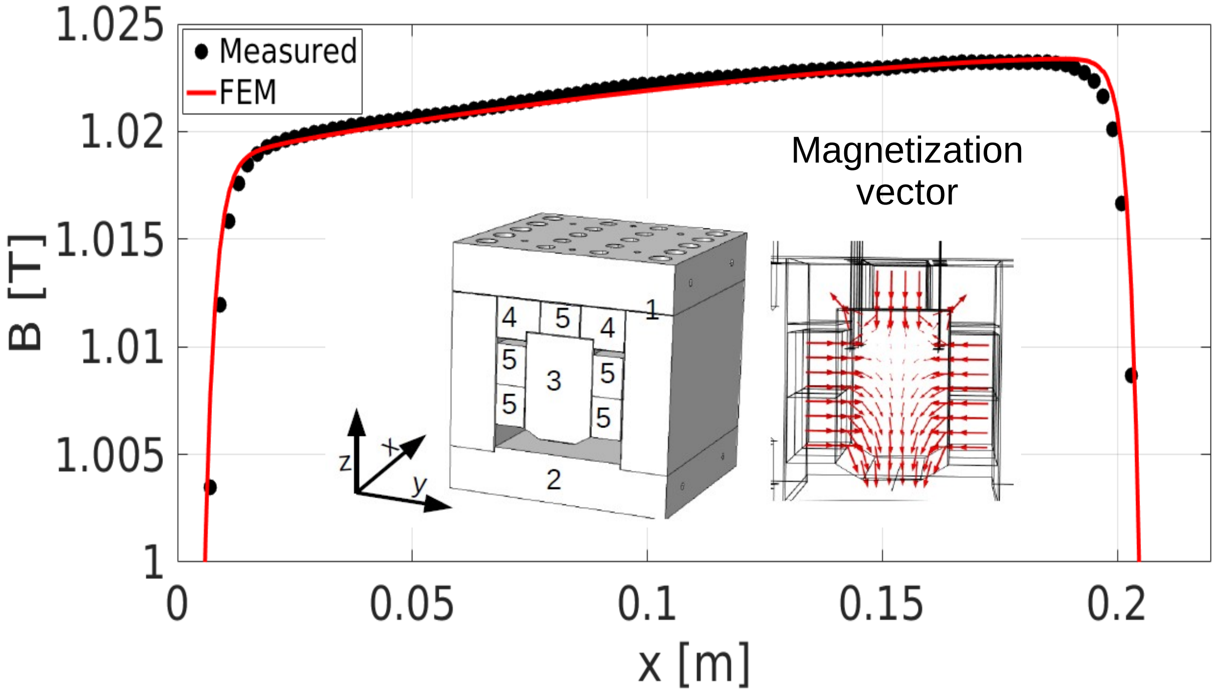
PM-LGB: 1st prototype



Moving wire: field integral (G. Montenero).

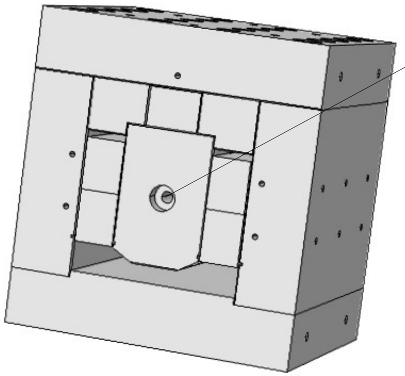


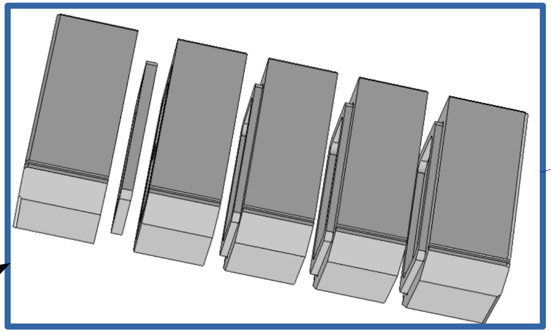
Field mapper (P. La Marca).

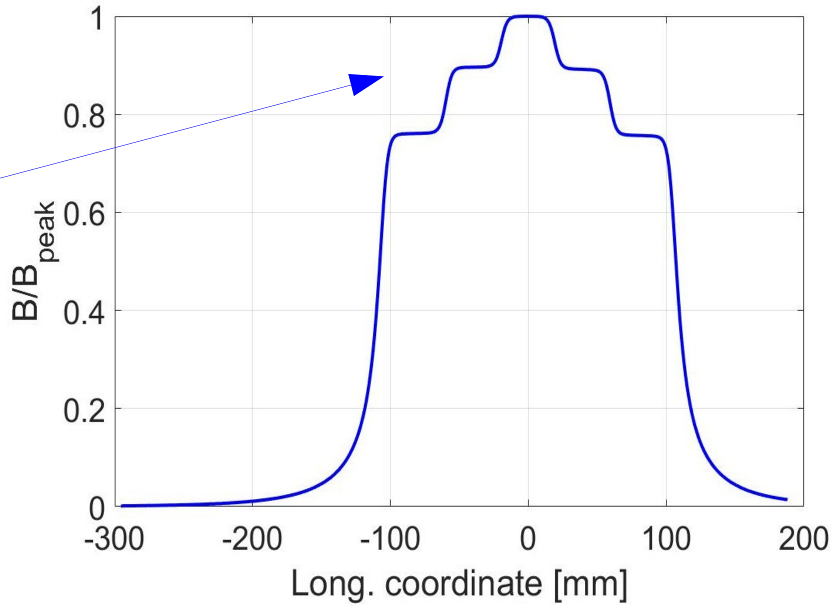


1: return yoke; 2: mirror plate; 3: pole; 4: Al pole supports; 5: PM blocks.

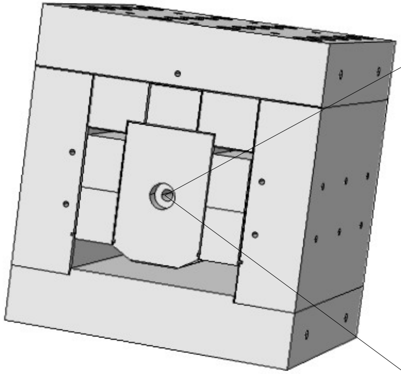
PM-LGB:
two approaches to produce the gradient: scale prototypes

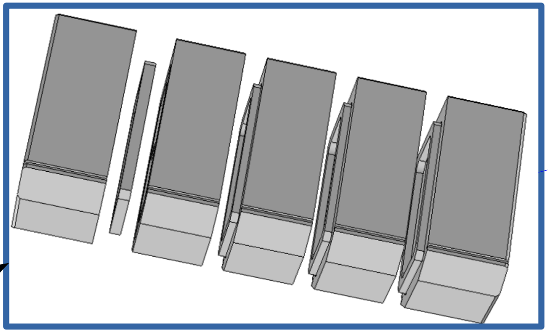


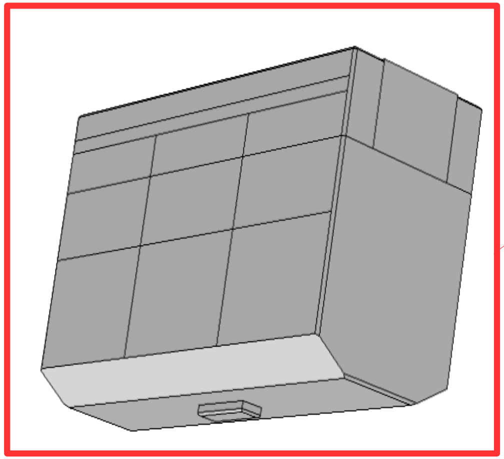


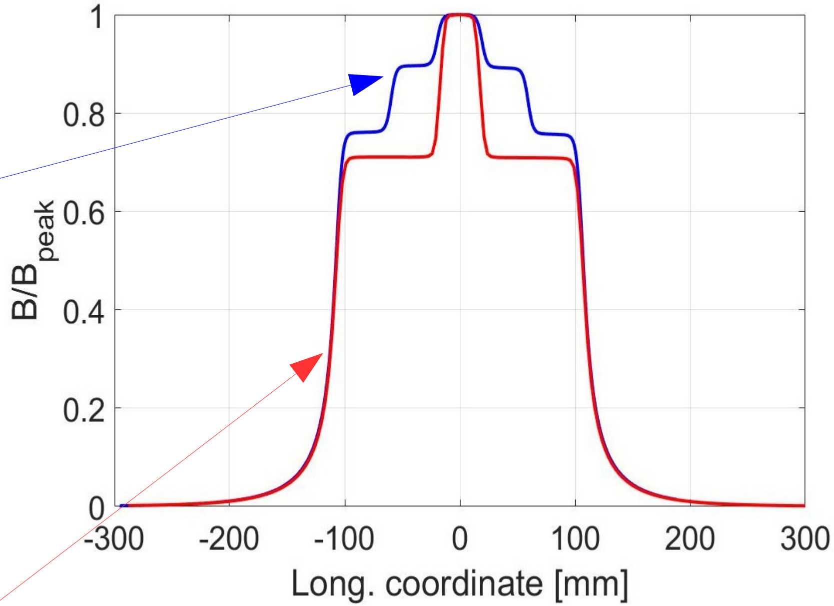


PM-LGB:
two approaches to produce the gradient: scale prototypes





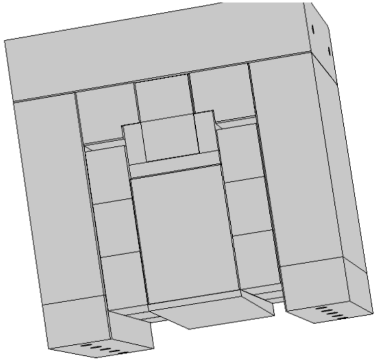




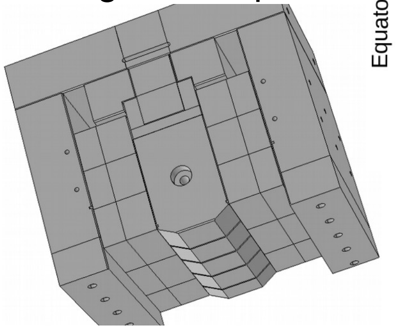
	Segmented pole	Variable gap
gap [mm]	13.0	10.0 (to 13.0)
Tot. PMs mass [kg]	9.42	4.40
N. of PMs/size[mm]	7/30x40x70	15/30x40x70
Average B field at PMs [T]	1.0	0.8
Tot. Fe mass [kg]	68.0	69.0
Peak field [T]	0.56	1.44
$\int B\,dl$ [Tm]	0.10	0.23

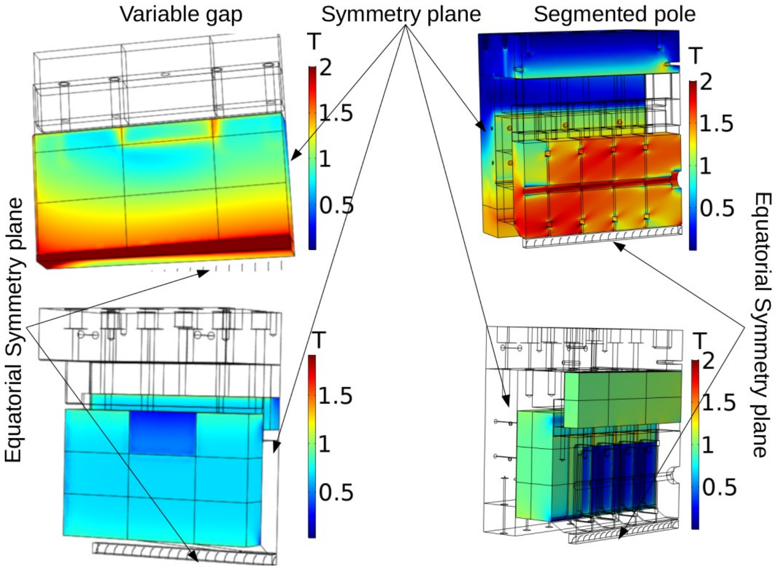
PM-LGB: two approaches to produce the gradient: full scale models

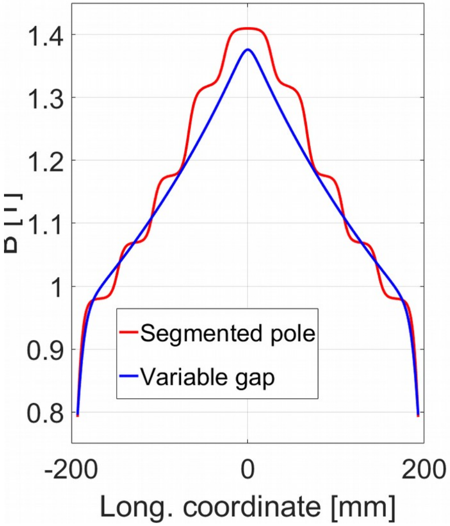
Variable gap

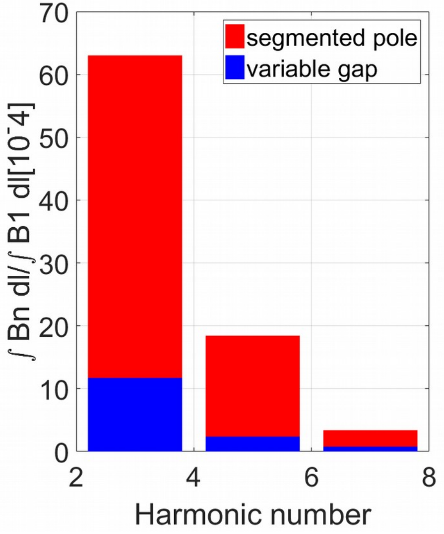


Segmented pole



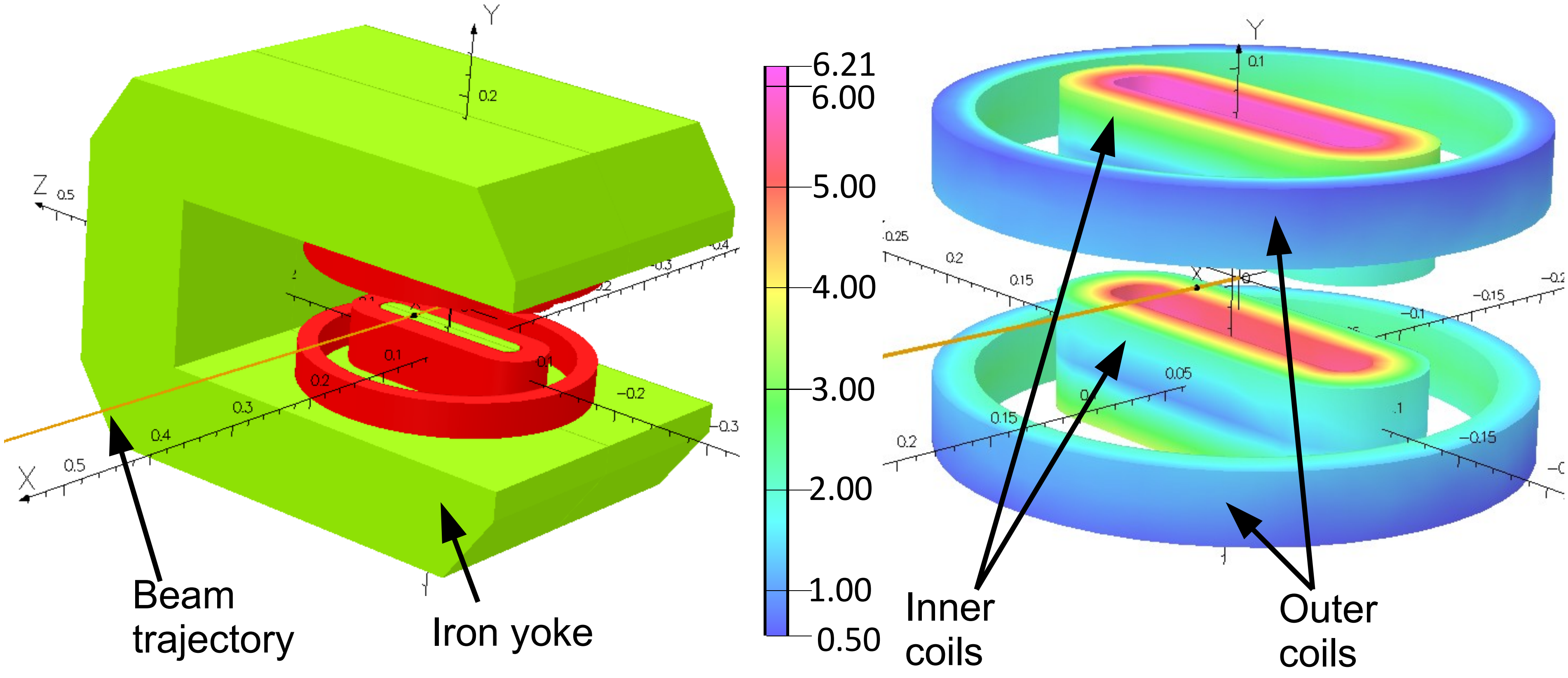






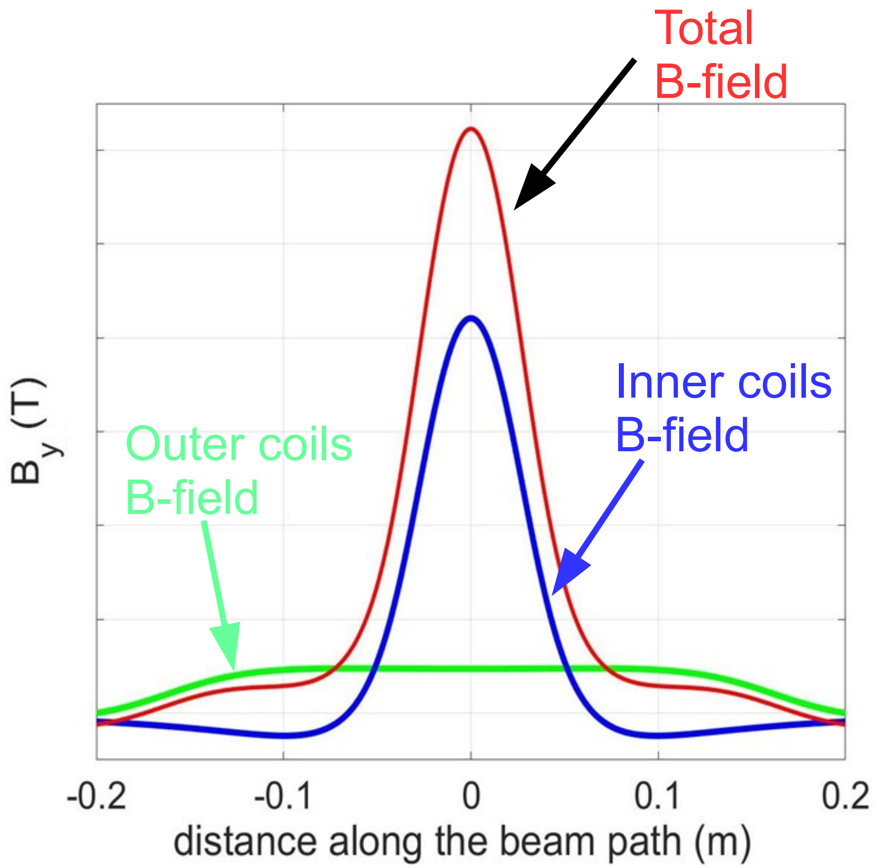
	Segmented pole	Variable gap
gap [mm]	22.0	22.0 (to 42.0)
Tot. PMs mass [kg]	25.45	24.20
N. of PMs/size[mm]	11/30x40x70 + 5/22x40x70	12/30x40x70
Average B field at PMs [T]	0.98	0.67
Tot. Fe mass [kg]	106.5	102.0
$\int$B dl [Tm]	0.48	0.48

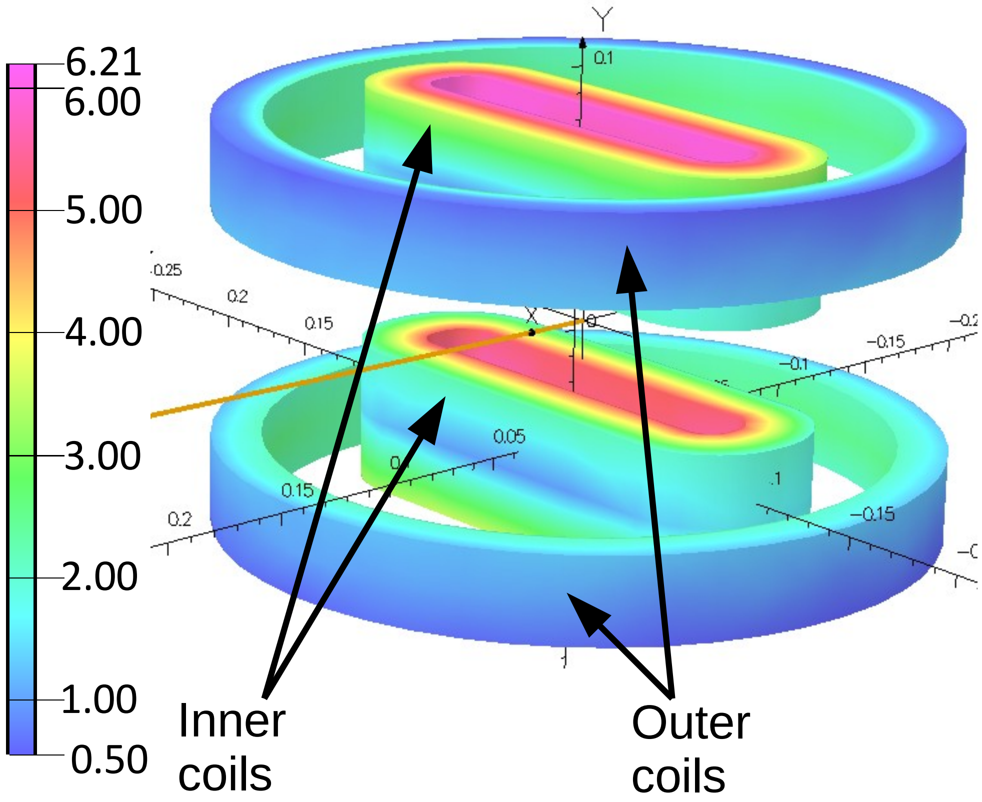
SC-LGB



Y
Z
X
Beam
trajectory
Iron yoke
6.21
6.00
5.00
4.00
3.00
2.00
1.00
0.50
Inner
coils
Outer
coils

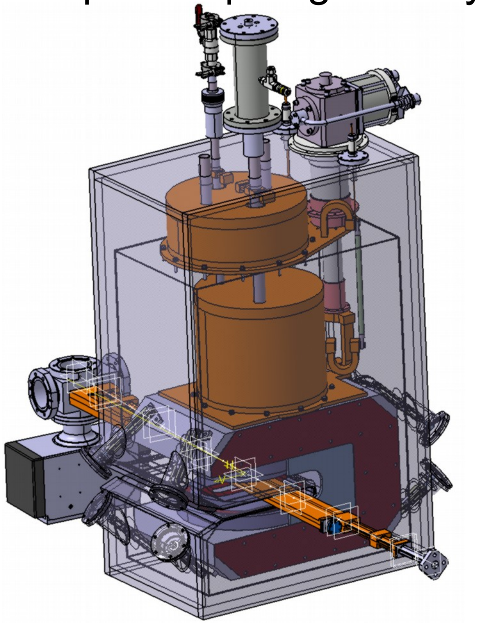
SC-LGB


Total
B-field
Inner coils
B-field
Outer coils
B-field
B_y (T)
-0.2
-0.1
0
0.1
0.2
distance along the beam path (m)

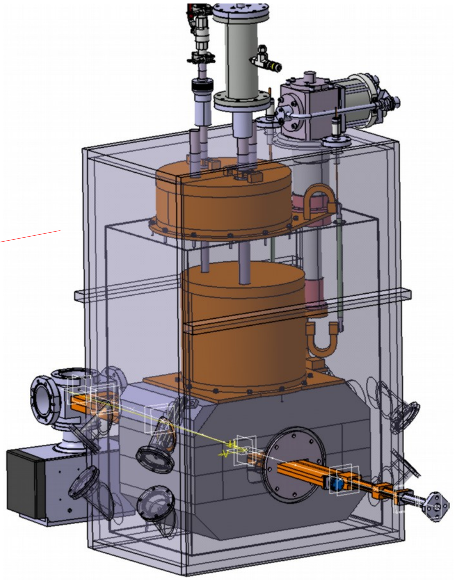

6.21
6.00
5.00
4.00
3.00
2.00
1.00
0.50
Y
X
Inner
coils
Outer
coils

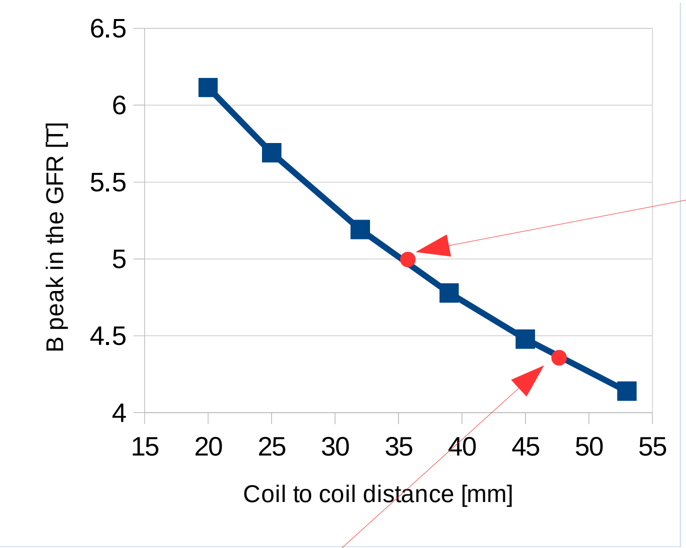
SC-LGB

C-shaped – open geometry

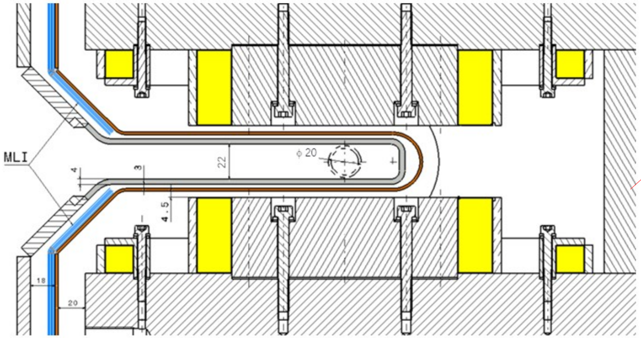


Integrated vacuum chamber

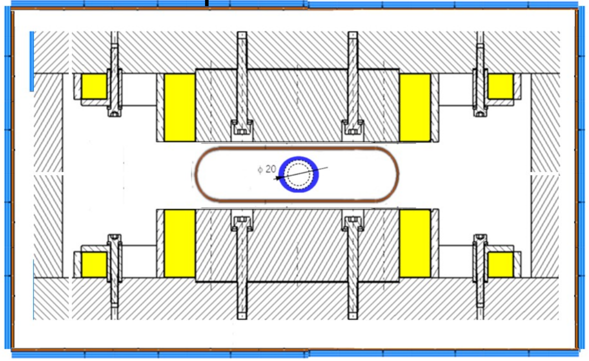




Vertical Gap: 46 mm

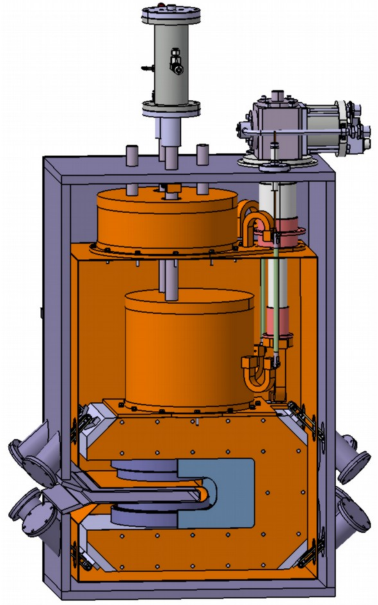


Vertical Gap: 35 mm



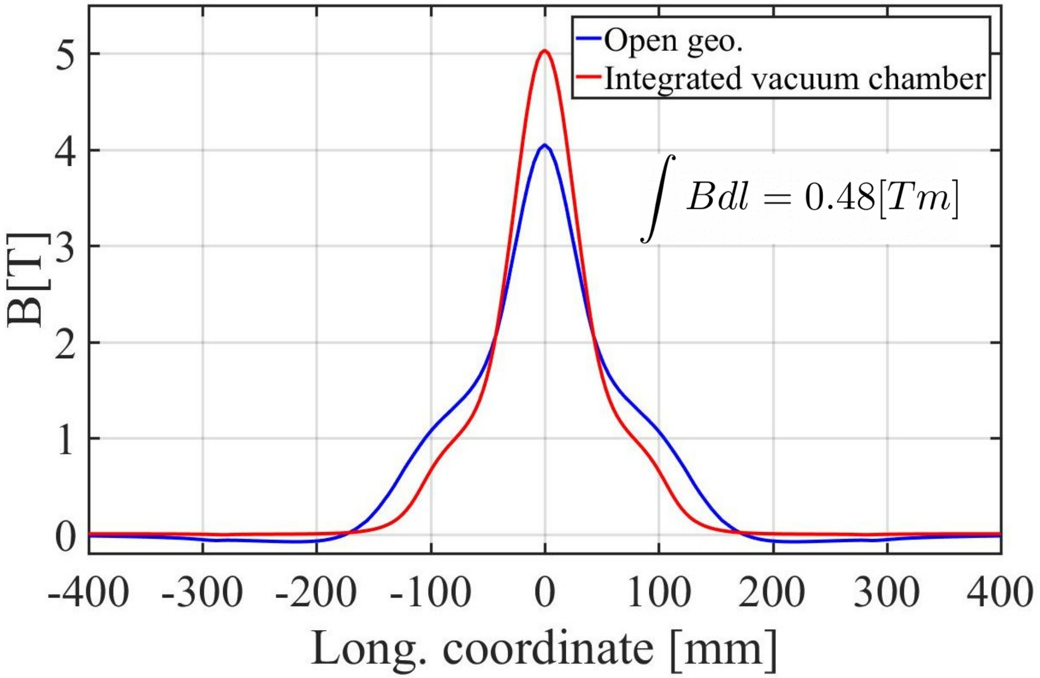
SC-LGB

C-shaped – open geometry

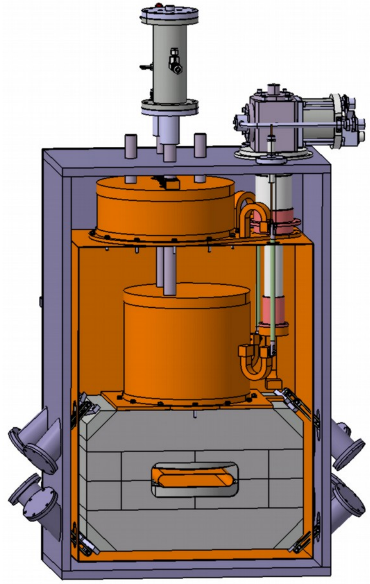


Rico Hübscher

	Open geometry	Integrated vacuum chamber
gap [mm]	46.0	35.0
$B_{peak}[T]$	≤ 4	> 4
Installation	easier	more difficult



Integrated vacuum chamber



Conclusions

- The SLS2 requires Longitudinal Gradient Bend Magnets;
- We explored two technologies:
  Permanent magnet (B~1.3T) & Superconducting magnets(4T<B<5T);

- A procedure to assemble permanent magnets has been validated;
- The FEM tools were benchmarked against the measurements of the prototypes;
- The FEM tools show we can reach the requirements in terms of peak field and field integral;

- At three locations around the storage ring the permanent magnets will be substituted with superconducting magnets;
- Two concepts have been developed:
  open geometry (B<4T) and integrated vacuum chamber (B>4T);
- Next step: technical review and call for tenders.

Thanks for your attention.

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Additional slides

SLS upgrade task

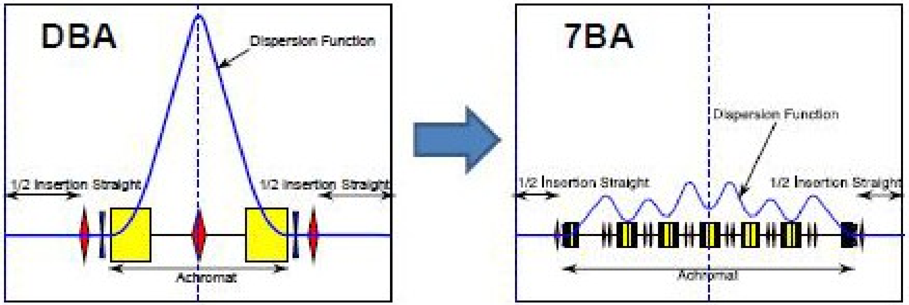
In order to stay competitive in future, the new storage ring has to provide a factor <u>> 30 lower emittance</u> at the same circumference and beam energy.

$$B_{average}(\lambda) \sim \frac{N_{photon}(\lambda)}{\varepsilon_x \cdot \varepsilon_y}$$

Lattice design evolution from double- and triple-bend achromats (DBA, TBA) to multi-bend achromats: increase N_D.

$$\varepsilon_x = C_L \frac{E^2}{N_D^3}, \quad \varepsilon_x \underbrace{\propto}_{\text{Fixed E}} \frac{1}{C^3}$$

C_L = lattice constant
N_D = # dipoles
C = Circumference

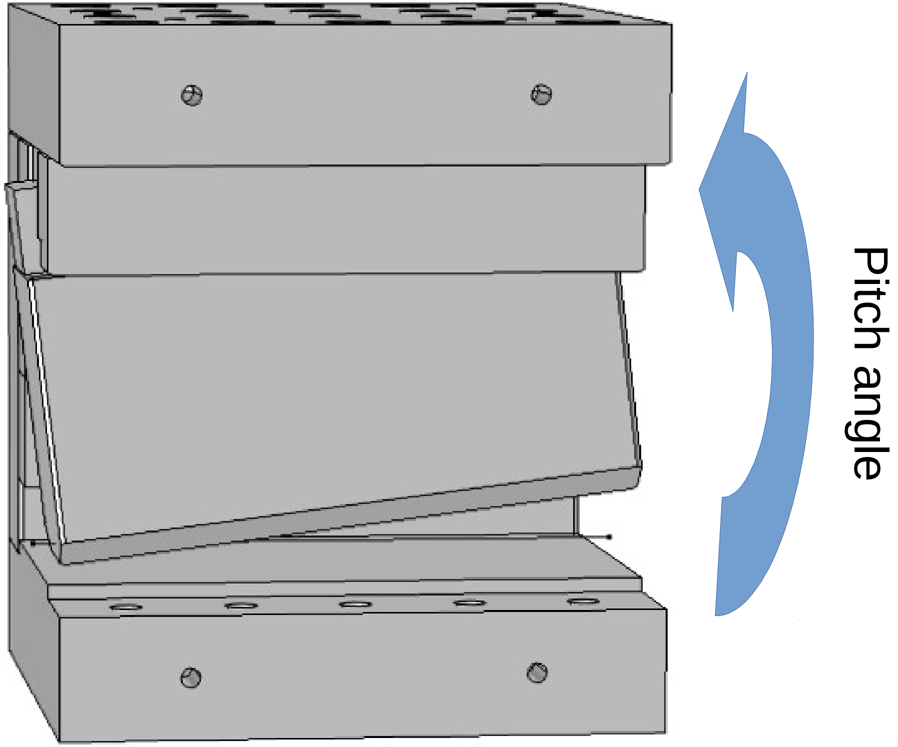


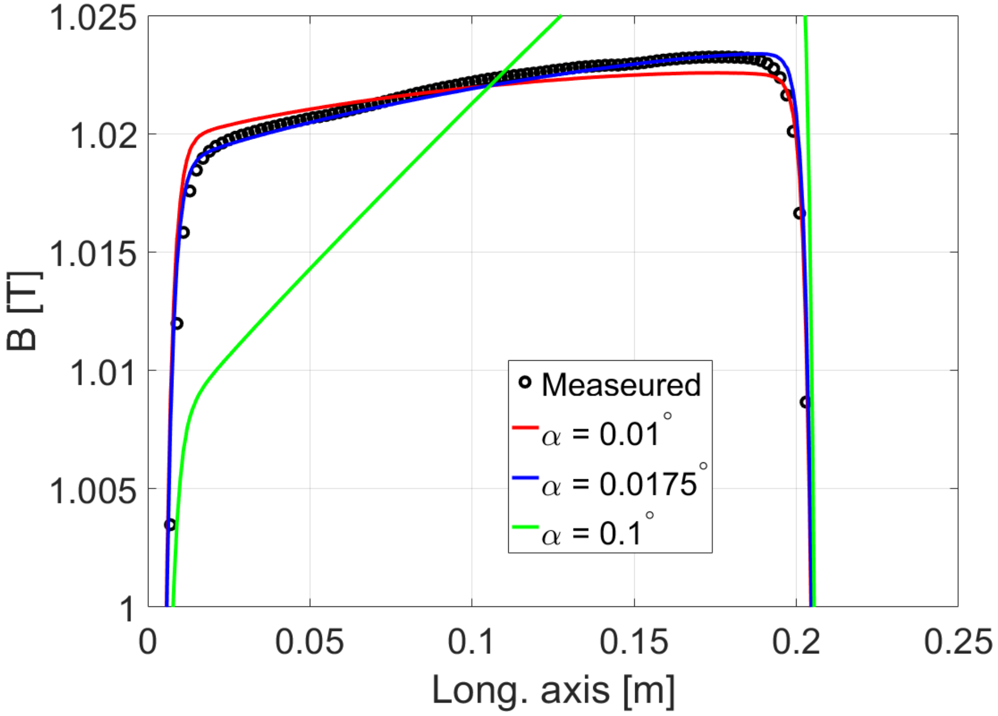
Strong Focusing and Low Dispersion

First used for MAX-IV.

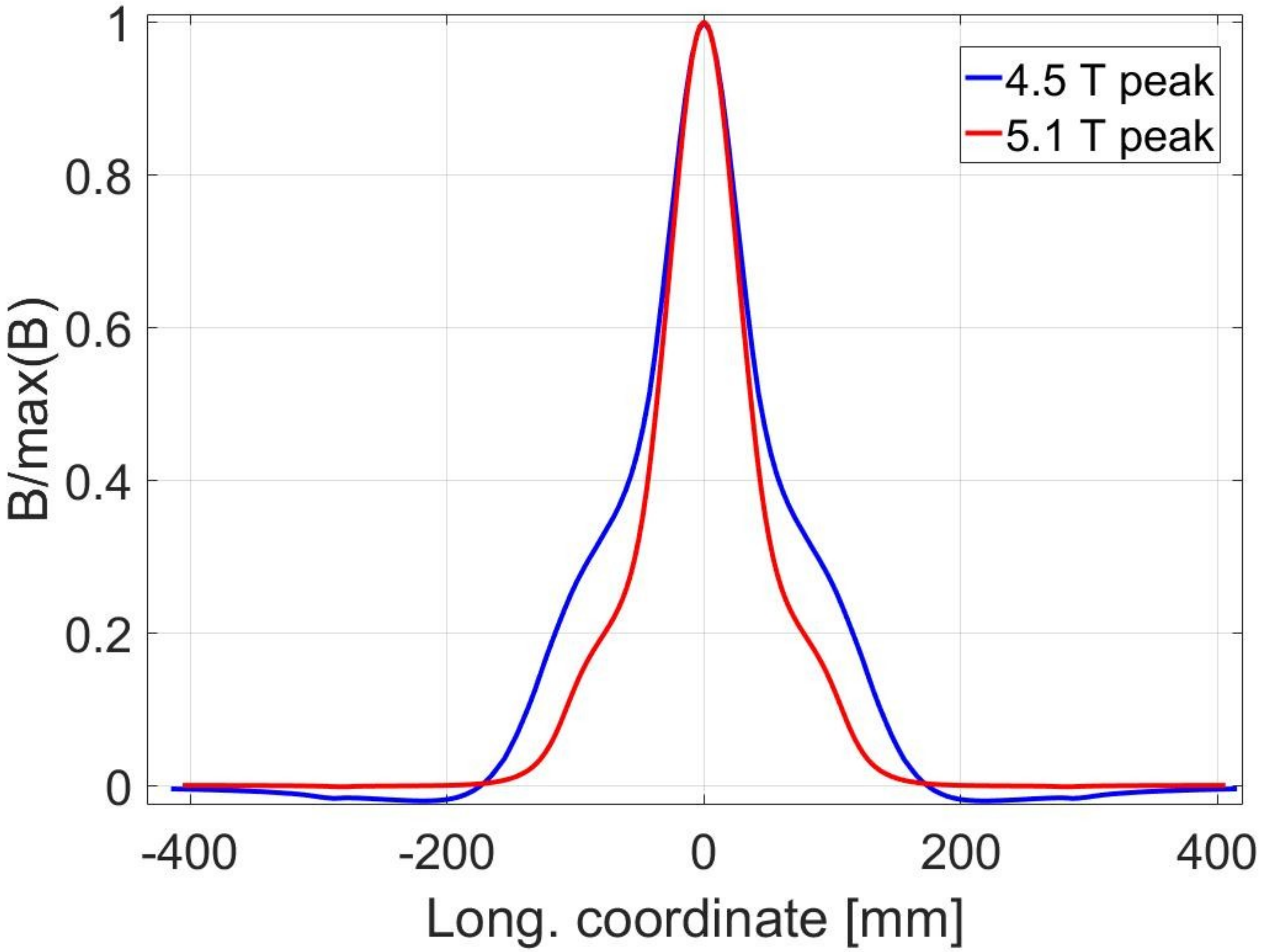
D. Einfeld *et al.*, Proc. PAC 95, Dallas TX

Pitch rotation





SC-LGB



4.5 T peak
5.1 T peak
B/max(B)
1
0.8
0.6
0.4
0.2
0
-400
-200
0
200
400
Long. coordinate [mm]