ElFast – XFEL Workshop

Warm Magnets

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Outline

- Inhouse information
- Magnets at FLASH
- First magnet proposal for XFEL
- Exotic magnets for XFEL
- Time schedule

Informations for Magnet Design

- Lattice design of the machine

  → magnet types, quantity, quality and strength

- Vacuum system

  → magnet aperture / gap height and width

- Utilities

  power supplies; cooling water; temperature stabilization

  → magnet coil design

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- Beam Diagnostics

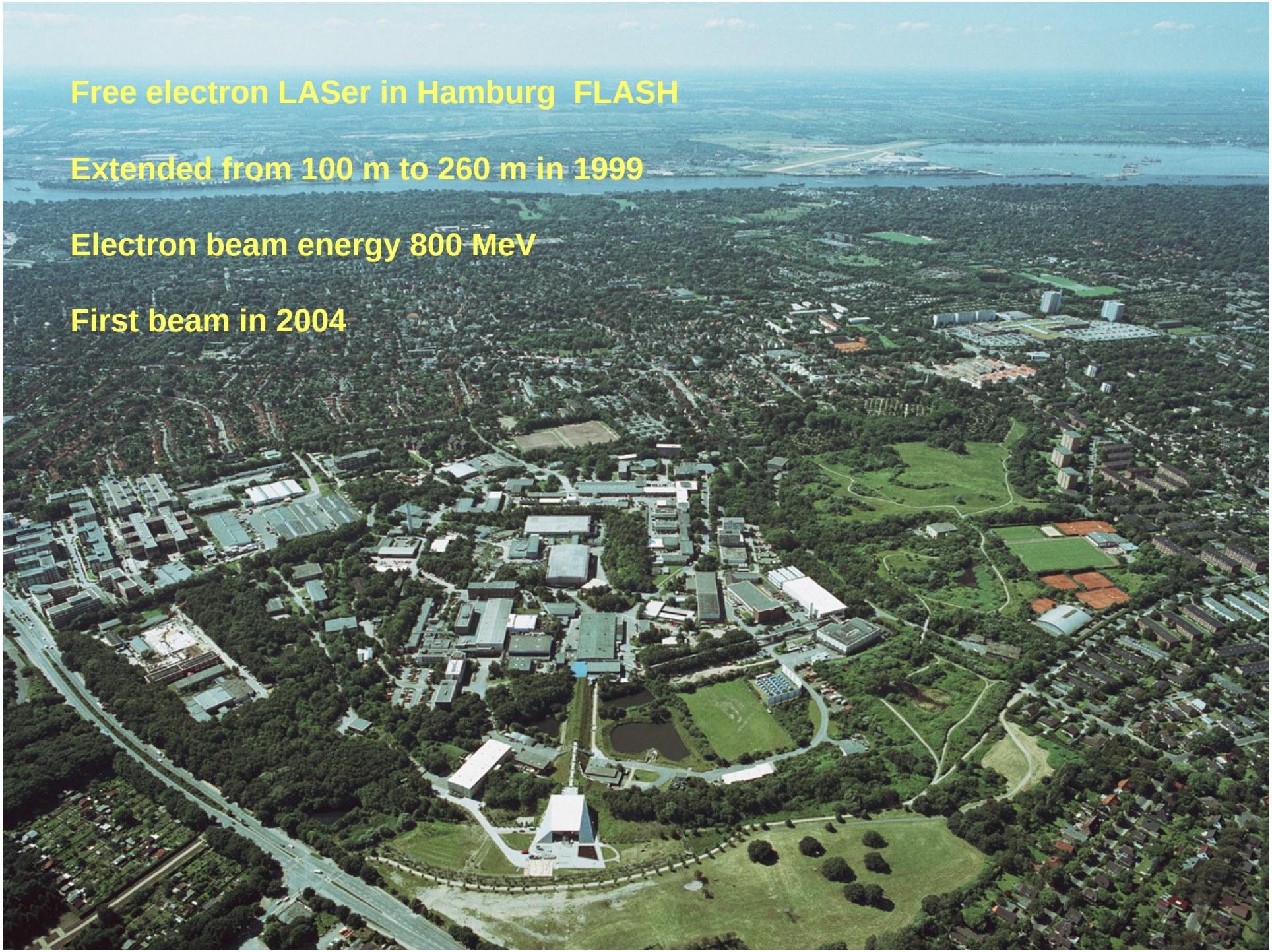
  → special magnet design?

- Tunnel Layout and Installation

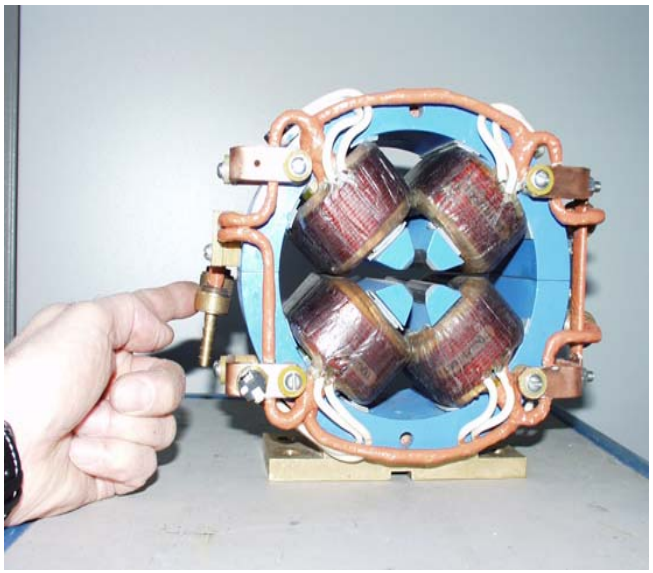
  → magnet weight and geometry

- Survey and Alignment

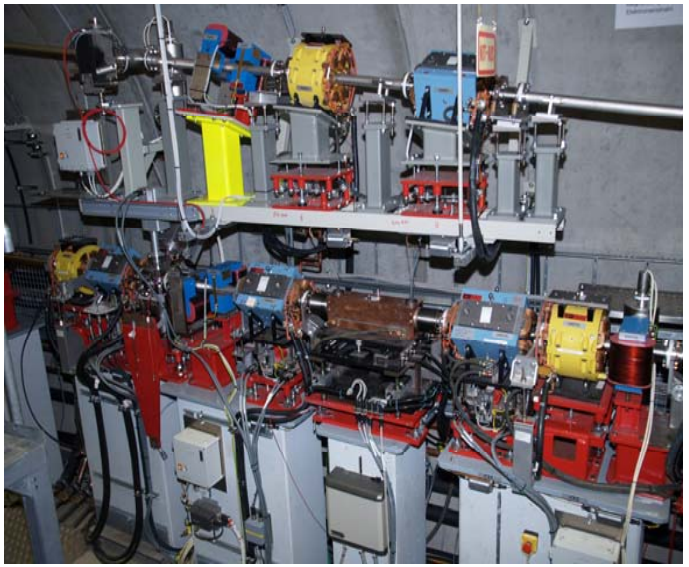
  → special equipment added to the magnet

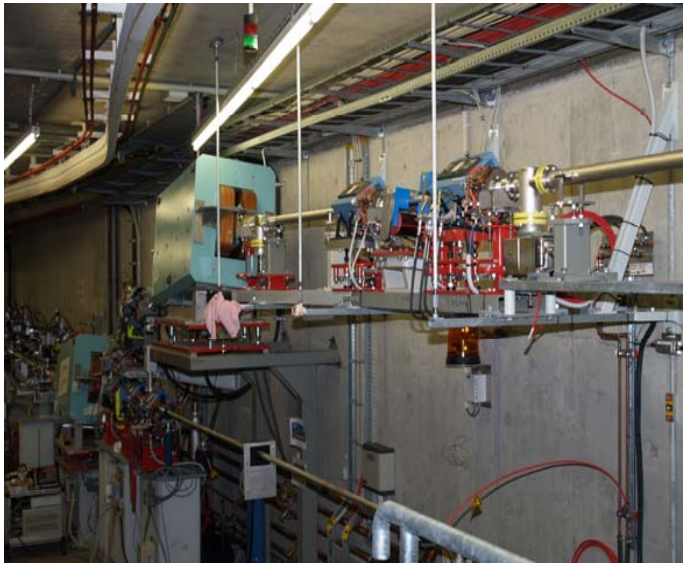

Free electron LASer in Hamburg FLASH
Extended from 100 m to 260 m in 1999
Electron beam energy 800 MeV
First beam in 2004

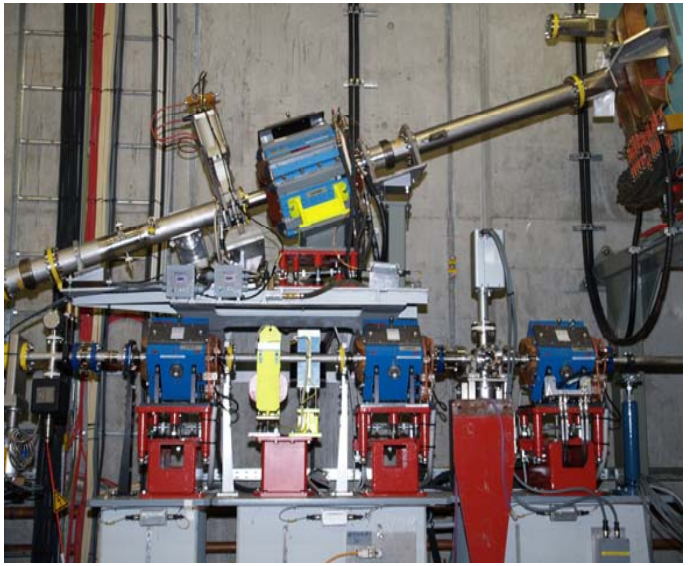
Magnets for FLASH



Magnets in the FLASH tunnel







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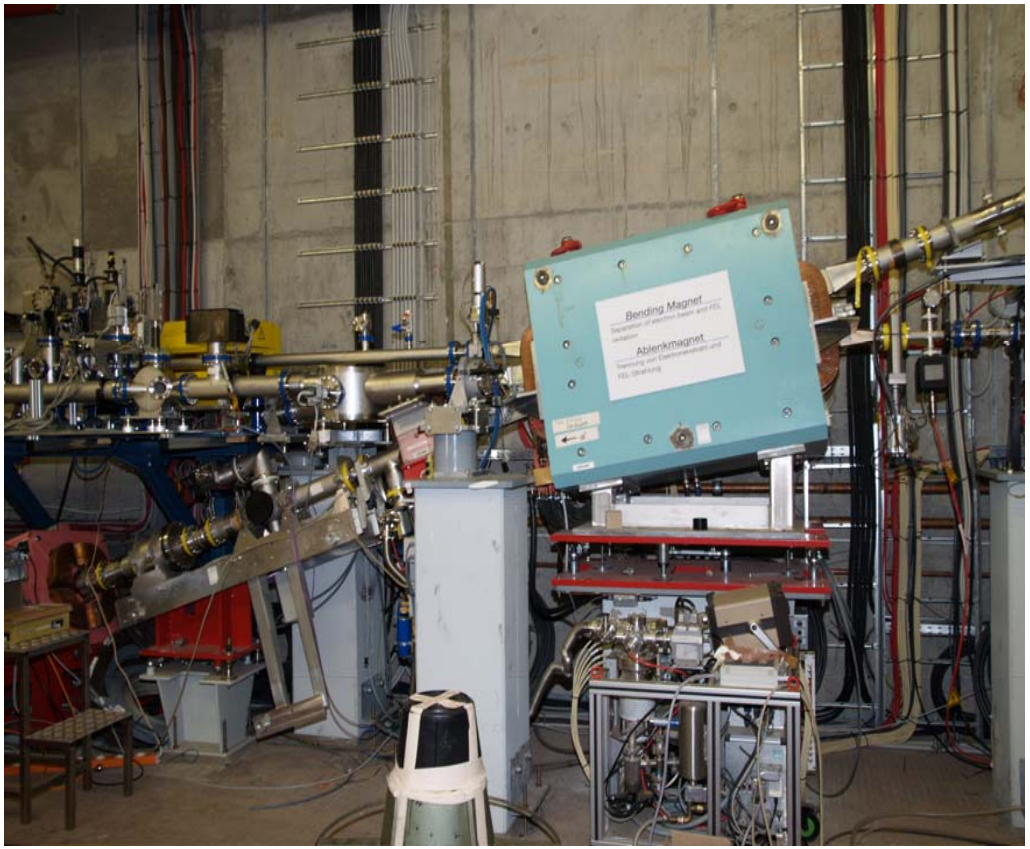
Near dump region



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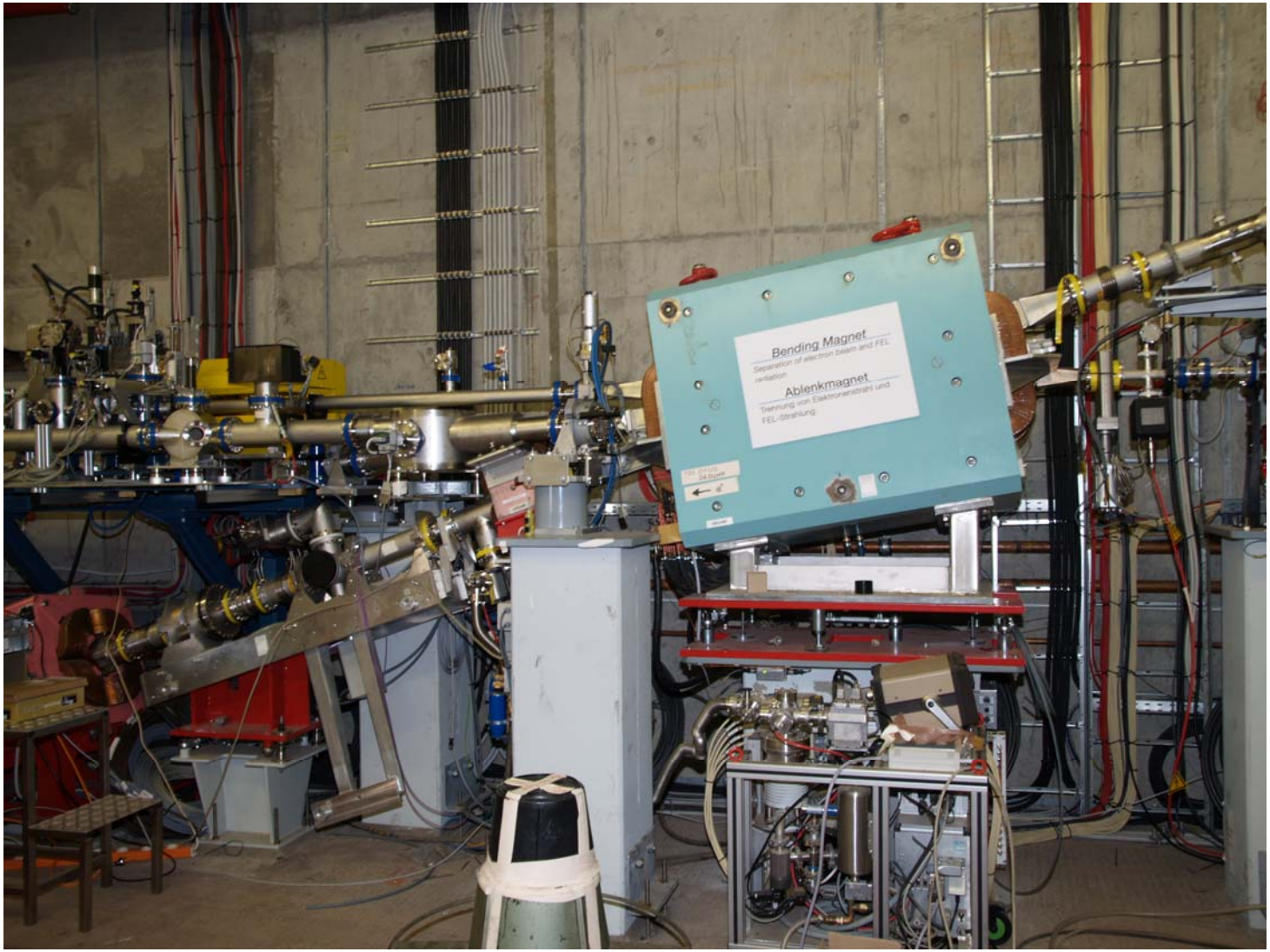
Bending Magnet
Separation of electron beam and FEL radiation
Ablenkmagnet
Trennung von Elektronenstrahl und FEL-Strahlung

Magnet design starts with the following lists derived from the desired lattice.

	Name	Count	Length [m]	Halfgap Boreradius [m]	Emin [GeV]	Emax [GeV]	Gmax [T/m$^{(-n+1)}$]	Bpole [T]
Quadrupoles	QI	48	0,25	0,02	0,1	0,15	2,401601	0,048032021
	QA	121	0,2	0,006	6	25	25,01668	0,150100067
	QB	92	0,5	0,02	6	25	20,01334	0,400266845
	QC	27	0,3	0,02	0,1	0,8	7,115855	0,1423171
	QD	17	0,3	0,02	0,5	3	20,01334	0,400266845
	QE	47	1	0,03	6	25	33,35557	1,000667111
	QF	49	0,5	0,03	6	25	33,35557	1,000667111
	QG	6	3	0,05	6	25	22,23705	1,111852346
Multipoles	SEXT	36	0,4	0,03	6	25	2084,723	0,938125417
	OCT	6	0,4	0,03	6	25	104236,2	0,469062708

	Name	Count	Length [m]	Halfgap Boreradius [m]	Emin [GeV]	Emax [GeV]	Gmax [T/m$^{(-n+1)}$]	Bpole [T]
Dipoles	BA	4	0,3	0,02	0,1	0,8	0,667111	0,667111408
	BI	6	0,5	0,02	0,1	0,15	0,314209	0,314209473
	BF	2	1	0,02	0,1	0,8	0,931464	0,931463642
	BG	2	2,5	0,02	0,5	3	1,397195	1,397195464
	BB	4	0,3	0,02	0,5	3	1,267512	1,267511674
	BC	8	5	0,03	6	25	0,087558	0,087558372
	BE	6	2,5	0,03	6	25	0,730487	0,730486991
	BD	10	4	0,03	6	25	0,416945	0,41694463
	BV	4	5	0,03	6	25	1,455971	1,455970647
	BW	3	7,5	0,03	6	25	1,455415	1,455414721
	BS	107	0,165	0,006	6	25	0,050539	0,050538743
	BX	8	0,5	0,05	6	25	0,383589	0,383589059

	Name	Count	Length [m]	Halfgap Boreradius [m]	Emin [GeV]	Emax [GeV]	Gmax [T/m$^{(-n+1)}$]	Bpole [T]
Correction Magnets	KHA	121	0,055	0,006	6	25	0,045485	0,045484869
	KVA	121	0,055	0,006	6	25	0,045485	0,045484869
	KHI	24	0,1	0,02	0,1	0,15	0,003002	0,003002001
	KVI	24	0,1	0,02	0,1	0,15	0,003002	0,003002001
	KHB	46	0,1	0,02	6	25	0,050033	0,050033356
	KVB	46	0,1	0,02	6	25	0,050033	0,050033356
	KHC	13,5	0,1	0,02	0,1	0,8	0,010674	0,010673783
	KVC	13,5	0,1	0,02	0,1	0,8	0,010674	0,010673783
	KHD	8,5	0,1	0,02	0,5	3	0,03002	0,030020013
	KVD	8,5	0,1	0,02	0,5	3	0,03002	0,030020013
	KHE	23,5	0,2	0,03	6	25	0,083389	0,083388926
	KVE	23,5	0,2	0,03	6	25	0,083389	0,083388926
	KHF	24,5	0,2	0,03	6	25	0,041694	0,041694463
	KVF	24,5	0,2	0,03	6	25	0,041694	0,041694463
	KHG	6	0,2	0,05	6	25	0,166778	0,166777852
	KVG	6	0,2	0,05	6	25	0,166778	0,166777852

More requirements for magnet design

- Power supplies for the magnet coils:
  input current between
  500 A and 1000 A (200 V to 500 V) (dipole);
  100 A and 400 A (100 V to 150 V) (quadrupole);
  50 A and 100 A (50 V to 100 V) (sextupole).

- Cooling water system for the magnet coils:
  water pressure 6 bar; pressure drop 4 bar.

First Magnet proposal

Quadrupol and Multipol magnets:

Name	Length	Bore radius	B_{pole}	Current	max. Power losses	Total weight	Water flow rate	Water over heating
	m	m	T	A	kW	kg	l/min	°C
QI	0.25	0.02	0.05	5	0.04	35	Air cooled	20
QA	0.2	0.006	0.15	40	0.05	25	0.8	<5
QB	0.5	0.02	0.40	170	1.9	150	1.32	20
QC	0.3	0.02	0.14	60	0.16	90	0.57	<5
QD	0.3	0.02	0.40	170	1.3	90	0.57	33
QE	1.0	0.03	1.00	390	18	1300	6.3	40
QF	0.5	0.05	1.00	390	10.8	600	7.8	20
QG	3.0	0.05	1.11	960	77	6500	44.5	35
SEXT	0.4/0.45	0.03	0.94/0.84	450	20.6	500	7.05	39
OCT	0.4	0.03	0.47	90	2.42	740	1.6	22

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Dipole magnets:

Name	Length	Gap	B_{max}	Current	max Power losses	Total weight	Water flow rate	Water over heating
	m	m	T	A	kW	kg	l/min	°C
BA	0.3	0.04	0.667	480	2.6	260	1.3	28
BI	0.5	0.04	0.314	670	1.9	280	2.1	<15
BF	1.0	0.04	0.931	440	8.8	1800	9.1	24
BG	2.5	0.04	1.397	660	39.9	4500	19.2	30
BB	0.3	0.04	1.268	900	9.2	450	3.7	36
BC	5.0	0.06	0.088	120	0.8	5550	0.4	31
BE	2.5	0.06	0.730	450	15.4	8450	6.1	37
BD	4.0	0.06	0.417	540	20	4100	11.4	24
BV/BW	2.5 (5/7.5)	0.06	1.456	890	71.4	8450	31.1	33
B1	0.055	0.012	0.152	80	0.56	6.2	0.77	<12
BVHP (BX)	0.5	0.1	0.384	690	10.8	515	7.3	21
BVHM (BX)	1.0 (0.5)	0.1	0.384	690	15.6	950	17.2	<15

Cont'd

Corrector magnets:

Name	Length	Gap	B_{max}	Current	max. Power losses	Total weight	Temp.over heating
	m	m	T	A	W	kg	°C
KHA	0,055	0,012	0.045	9,0	2,2	2,5	<30
KHI	0,1	0,04	0,003	10	0,55	2,5	
KHB	0,1	0,04	0,050	10	12,1	9	
KHC	0,1	0,04	0,011	2,5	3,5	9	
KHD	0,1	0,04	0,030	6	8,0	9	
KHE	0,2	0,06	0,083	10	50	50	
KHF	0,2	0,06	0,042	5,0	25	50	
KHG	0,2	0,1	0,167	9,5	250	190	

KHB, KHC, KHD one magnet type
KHE, KHF one magnet type

Position of the magnets

KHB/C/D total 136

KHE/F total 96

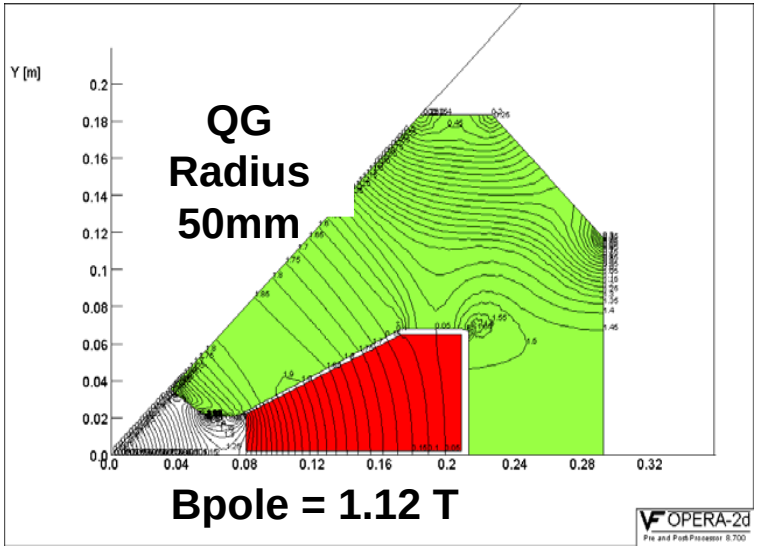
	Name	Count	Length [m]	Comment
Quadrupoles	QI	48	0,25	INJECTOR
	QA	121	0,2	UNDULATOR
	QB	92	0,5	BEAM DISTRIBUTION
	QC	27	0,3	BUNCH COMPRESSOR & DIAGNOSTIC 1
	QD	17	0,3	BUNCH COMPRESSOR & DIAGNOSTIC 2
	QE	47	1	BEAM DISTRIBUTION
	QF	49	0,5	BEAM DISTRIBUTION
	QG	6	3	BEAM DUMP
Correction Magnets	KHA	121 * 2	0,055	UNDULATOR
	KHI	24 * 2	0,1	INJECTOR
	KHB	46 * 2	0,1	BEAM DISTRIBUTION
	KHC	13,5 * 2	0,1	BUNCH COMPRESSOR & DIAGNOSTIC 1
	KHD	8,5 * 2	0,1	BUNCH COMPRESSOR & DIAGNOSTIC 2
	KHE	23,5 * 2	0,2	BEAM DISTRIBUTION
	KHF	24,5 * 2	0,2	BEAM DISTRIBUTION
	KHG	6 * 2	0,2	BEAM DUMP
Dipoles	BA	4	0,3	BUNCH COMPRESSOR 1 CHICANE
	BI	6	0,5	INJECTOR DOGLEG
	BF	2	1	BUNCH COMPRESSOR 1 DUMP
	BG	2	2,5	BUNCH COMPRESSOR 2 DUMP
	BB	4	0,3	BUNCH COMPRESSOR 2 CHICANE
	BC	8	5	COLLIMATION DOGLEG
	BE	6	2,5	BEAM DISTRIBUTION XS2&3&4
	BD	10	4	BEAM DISTRIBUTION XS1
	BV	4	5	BEAM DUMP1&2
	BW	3	7,5	BEAM DUMP0
	BS	107	0,165	UNDULATOR CHICANE
	BX	8	0,5	DIAGNOSTIC WIGGLER BEAM DUMP1&2
Multipoles	SEXT	36	0,4	COLLIMATION, XS1-4
	OCT	6	0,4	COLLIMATION, XS1-4

Total amount of magnets

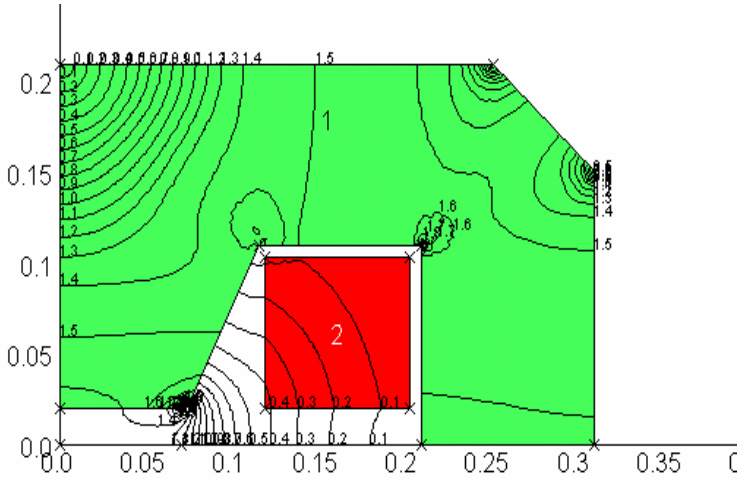
57 dipole magnets

450 multipole magnets

534 corrector magnets

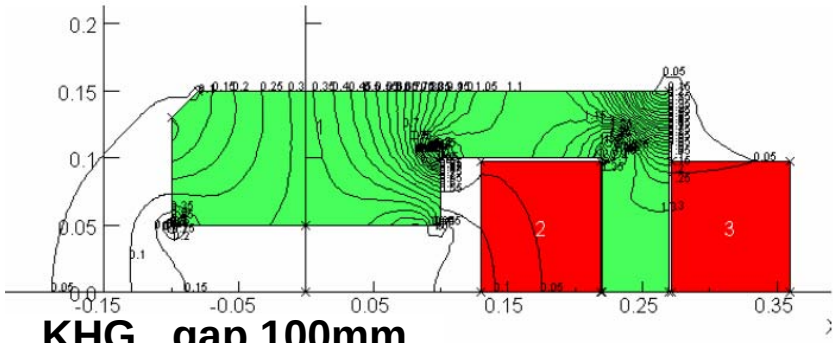


Bpole = 1.12 T



BG gap 40mm

B = 1.4 T



KHG gap 100mm

B = 0,167 T

Black lines in the figures are |B| = const [T] lines

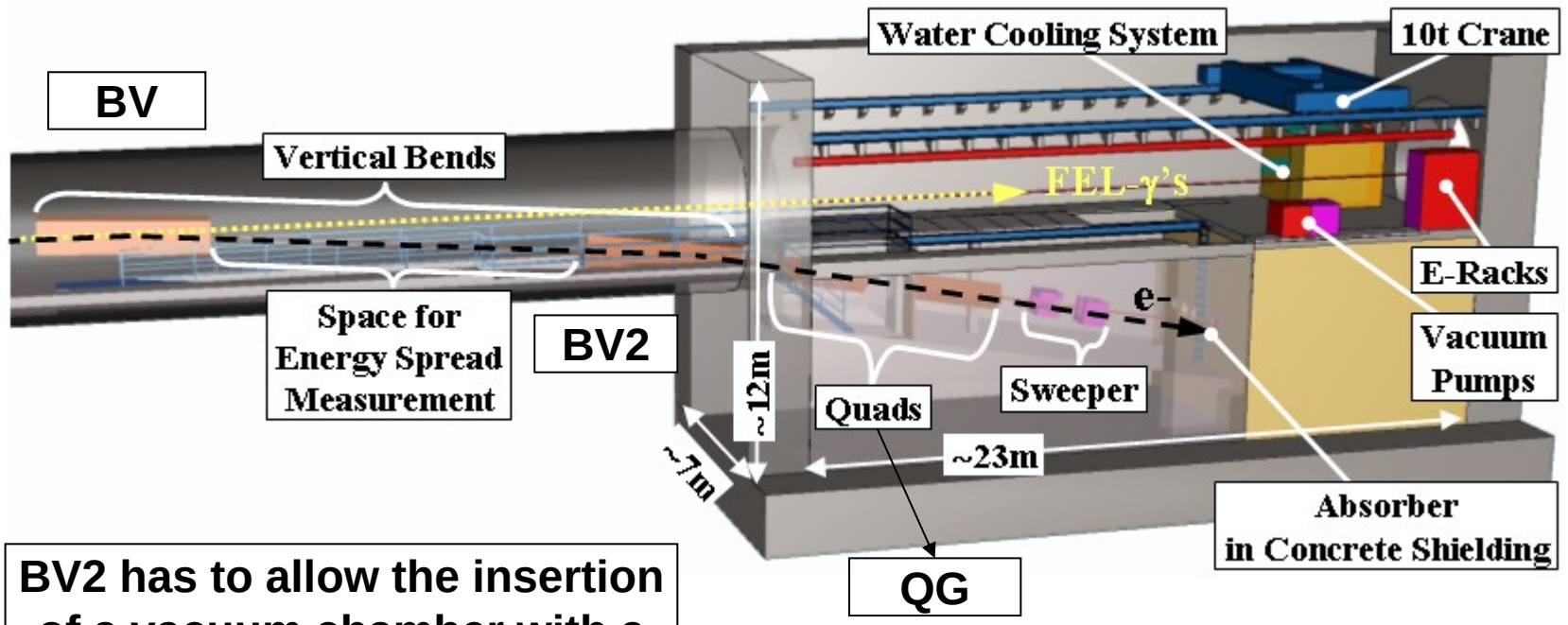
- End of first magnet proposal for the XFEL

- Exotic magnets, one example

  → combined function magnet BV

Combined function magnet BV

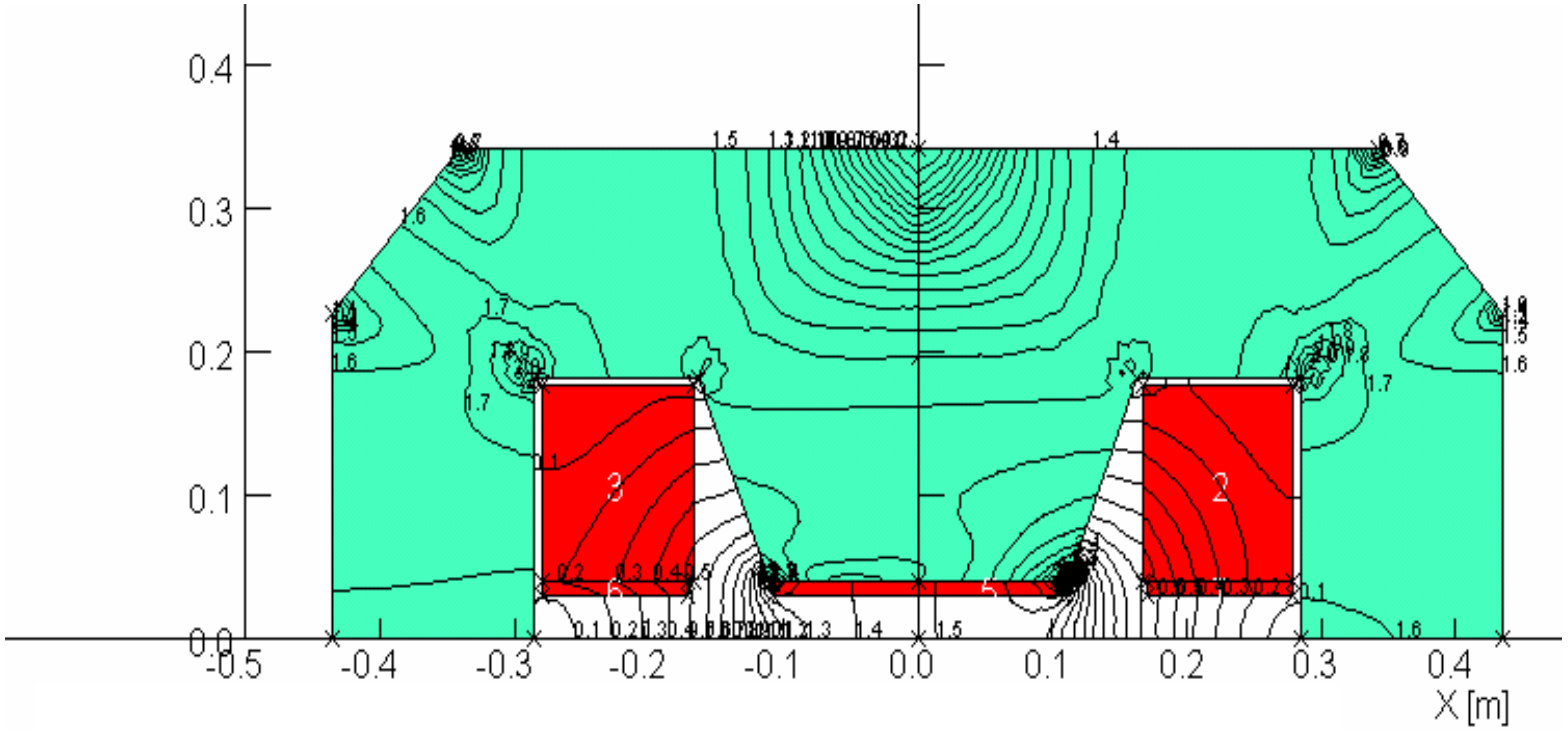
Layout of the dump region



BV2 has to allow the insertion of a vacuum chamber with a photon beam exit.

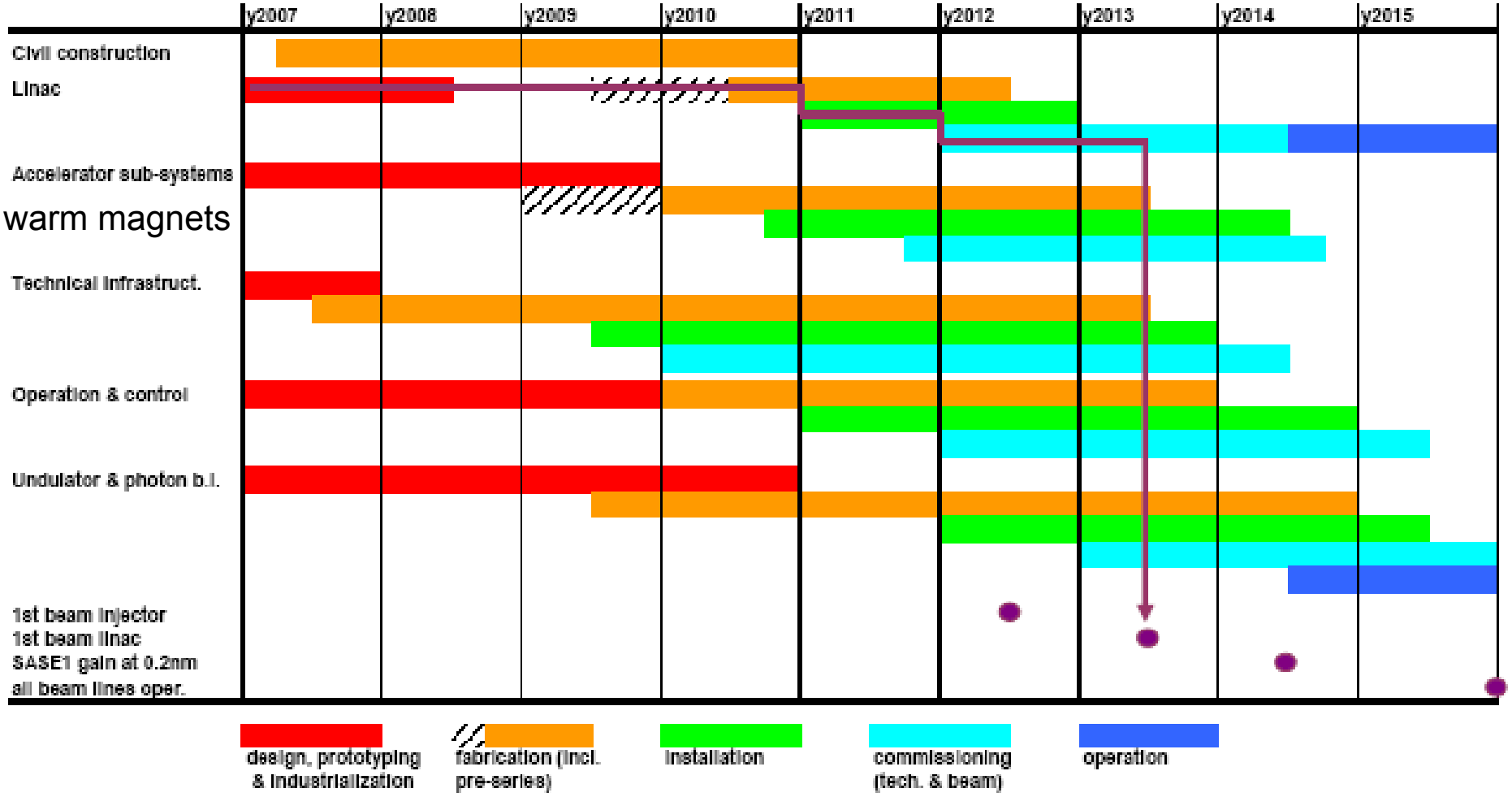
Combined function magnet BV

BV with integrated quadrupole at
maximum dipole field



|B|=const (T) lines for BV, (Bpole=1.478T,Gpole=1.61T/m)

Time Schedule



Time Schedule

- In 2008:
  10 month for ordering procedure (in-house):
  - Technical specification for different magnet types.
  - Start call for tenders and placing.

- In 2009:
  Start magnet fabrication including magnetic field measurements at the companies.

- From 2010 onward:
  Acceptance tests at DESY and installation in the tunnel.