Elettra Sincrotrone Triest

Status of Elettra and Future plans

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On behalf of the Elettra Team

Outline

- Introduction
- Statistics
- Current developments
- *Mid – term possibilities*
- *Long-term vision*

Elettra 2.4 GeV 3rd generation synchrotron radiation facility

FERMI 1.5 GeV Seeded Free Electron Laser Facility

The accelerators

Elettra :

- 2.4 GeV third generation light source
- 2.5 GeV Booster (can go up to 2.7 and maybe higher)
- 100 MeV conventional linac
- 27 beam lines including a SR-FEL 130nm + 2 in construction

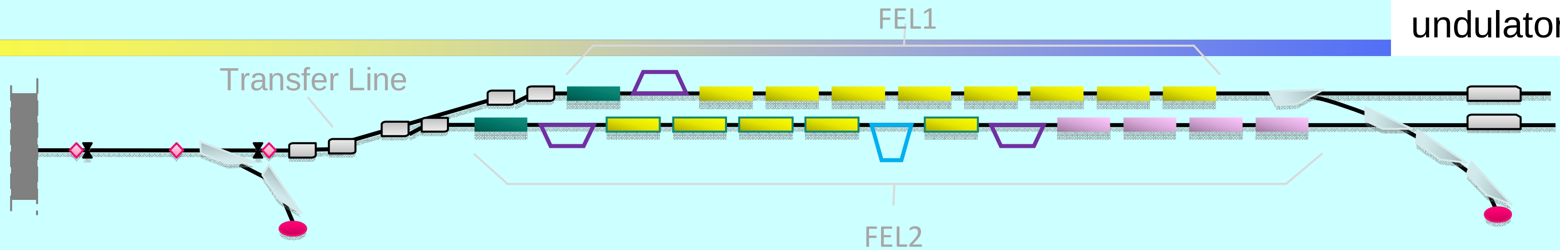
FERMI@Elettra :

- 1.2 -1.8 GeV linac with photon injector
- a double x120 m e- beam transport line + APPLE II type undulators (polarization)
- 3 beam lines + 1 THz in construction

FERMI@Elettra single-pass FEL user-facility

Elettra Sincrotrone Trieste

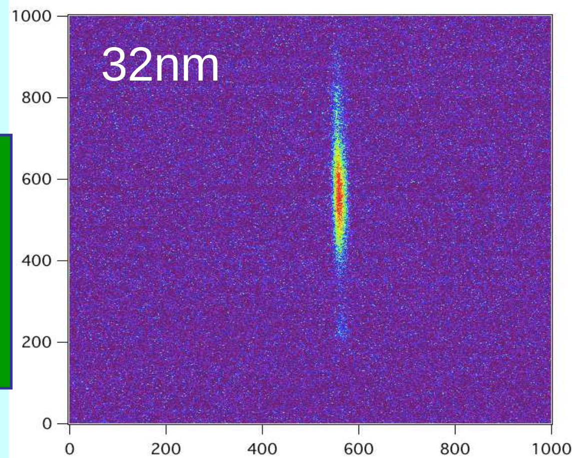
undulator hall



Two separate FEL amplifiers will cover the spectral range from 100 nm (12eV) to 4 nm (320 eV) and ~100fs photon pulses with the following characteristics.

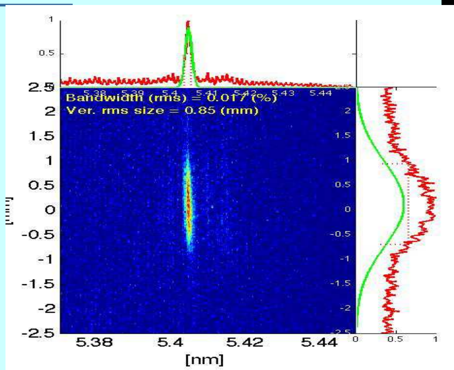
❑ high peak power	0.3 – GW's range
❑ short temporal structure	sub-ps to 10 fs time scale
❑ tunable wavelength	APPLE II-type undulators
❑ variable polarization	horizontal/circular/vertical
❑ seeded harmonic cascade	longitud. and transv. coherence

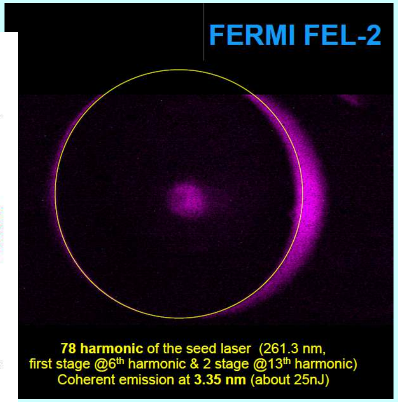
FEL 1 already gives beam time for users at about 20 nm



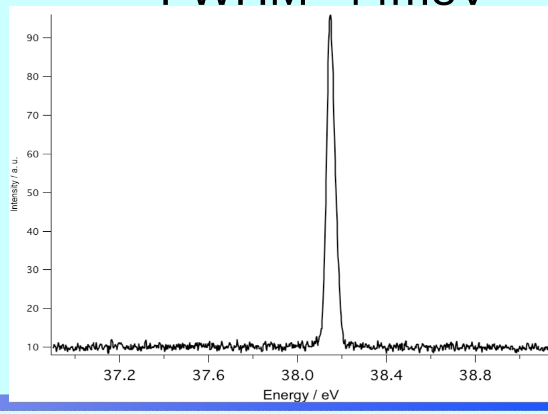
Courtesy M. Svandrlik

FEL 2 is a double stage HGHG range 20-4 nm. First stage seeded by a Ti:Sa (260 nm), second stage seeded by the first stage, in commissioning





FWHM~44meV



Elettra storage ring

Elettra Sincrotrone Trieste

Circumference 259.2 m

Energy 2 (and 2.4) GeV

Emittance 7 nm-rad & 1% coupl

Beam dim @IDs 250/14 um

alpha=1.6x10-3 / nat. bl=25 ps
with 3HC -> 100 ps

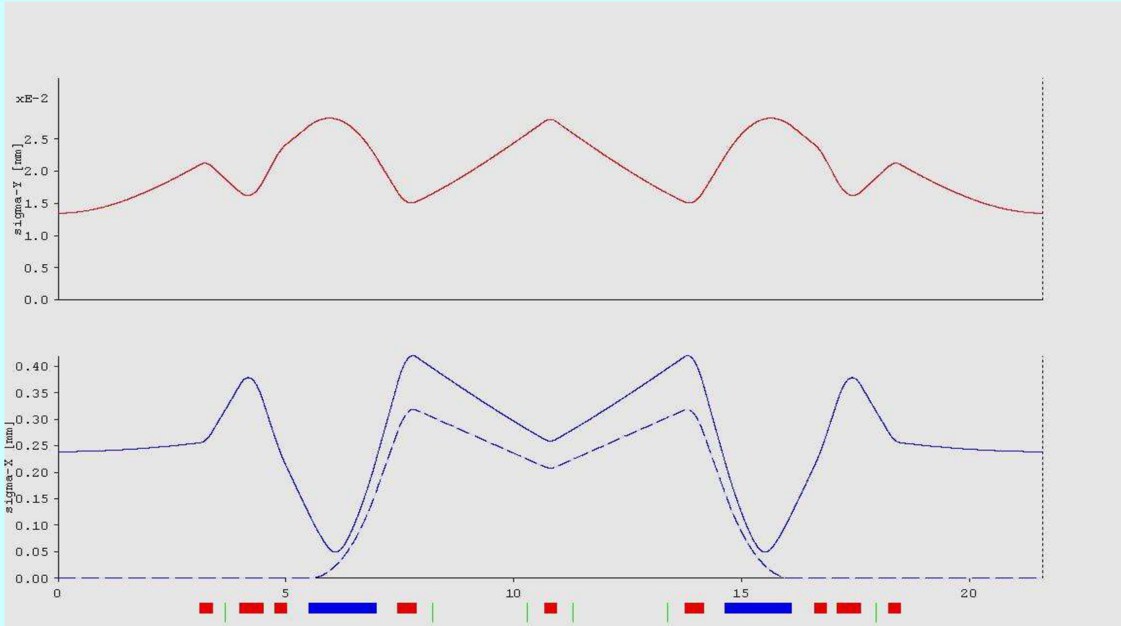
Tune 14.3, 8.2

E_spread 7.9 10-4

ΔE/turn 254 keV,

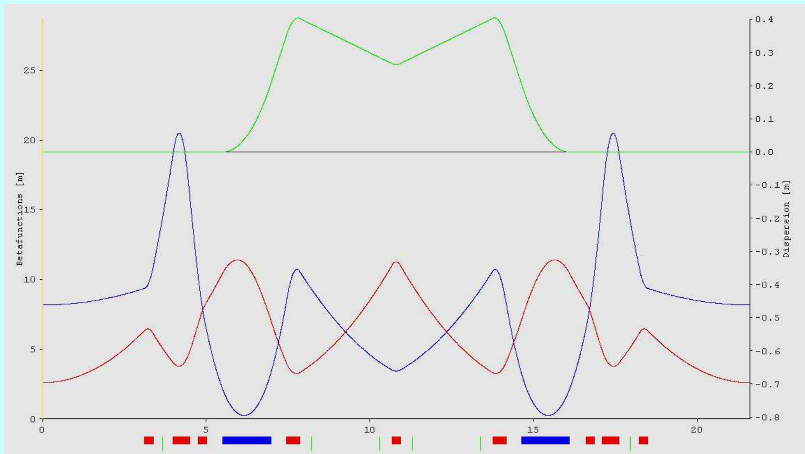
Damping times (msec)

X 10.4, Y 13.6 E 8



Bends: field 1.2 T and gradient 2.86 T/m
Quads: max gradient 15 T/m
Sext: max gradient 70 T/m^2

Chamber 82x53 and 73x9 mm (straights)



Ids of the Beam Lines

Elettra Sincrotrone Trieste

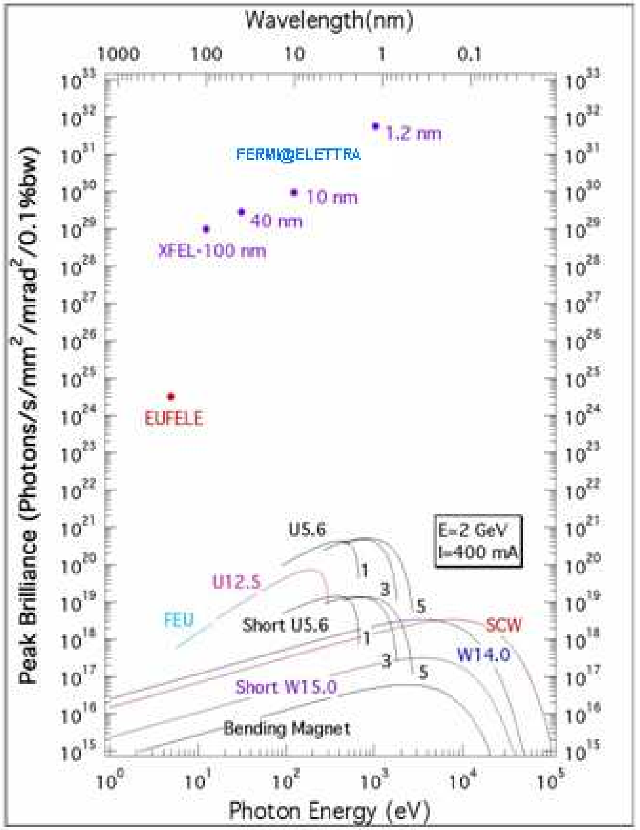
22 ID segments + 1 SCW installed

6 bending magnet source points serving 8 beam lines + 1 IR

ID	type	section	Period (mm)	Nper	gap (mm)	status
U5.6	PM/Linear	12 short	56	18	23	operating
EU10.0	PM/Elliptical	1	100	20+20	13.5	operating
U4.6	PM/Linear	2	46	2 x 49	13.5	operating
U12.5	PM/Linear	3	125	3 x 12	32.0	operating
EEW	EM/Elliptical	4	212	16	18.0	operating
W14.0	HYB/Linear	5	140	3 x 9.5	22.0	operating
U12.5	PM/Linear	6	125	3 x 12	29.0	operating
U8.0	PM/Linear	7	80	19	26.0	operating
EU4.8	PM/Elliptical	8	48	44	19.0	operating
EU7.7	PM/Elliptical	8	77	28	19.0	operating
EU6.0	PM/Elliptical	9	60	36	19.0	operating
EU12.5	PM/Elliptical/QP	9	125	17	18.6	operating
FEU	PM/Figure-8	10	140	16+16	19.0	operating
SCW	SC/Linear	11	64	24.5	10.7	ready

PM = Permanent Magnet, HYB = Hybrid, EM = Electromagnetic,
SCW = Superconducting, QP = Quasi-Periodic

Brightness of ELETTRAPhoton Sources



U4.6 constructed by KYMA as also all Elliptical IDs of FERMI

SR Operating Issues

- **Two energies:** 2 GeV at 75% and 2.4 GeV at 25% of user scheduled time
- **Top-up:** since May 2010 (ΔI=1 mA , interval 5 min at 2 and 20 min at 2.4 GeV)
- **Filling patterns:**
  "standard": 310 /170 mA (2 /2.4 GeV), 410 bunch train (in 432)
  "hybrid": 2.0 GeV: 315 mA, 410 bunch train + single bunch
  2.4 GeV: 170 mA, 410 bunch train + single bunch

2010: 4720 h scheduled, 94.6/96.1% uptime, MTBF = 42/52 h

2011: 5000 h scheduled, 95.7/96.8% uptime, MTBF = 45/53 h

2012: 5016 h scheduled, 96.1/97.1% uptime, MTBF = 57/71 h

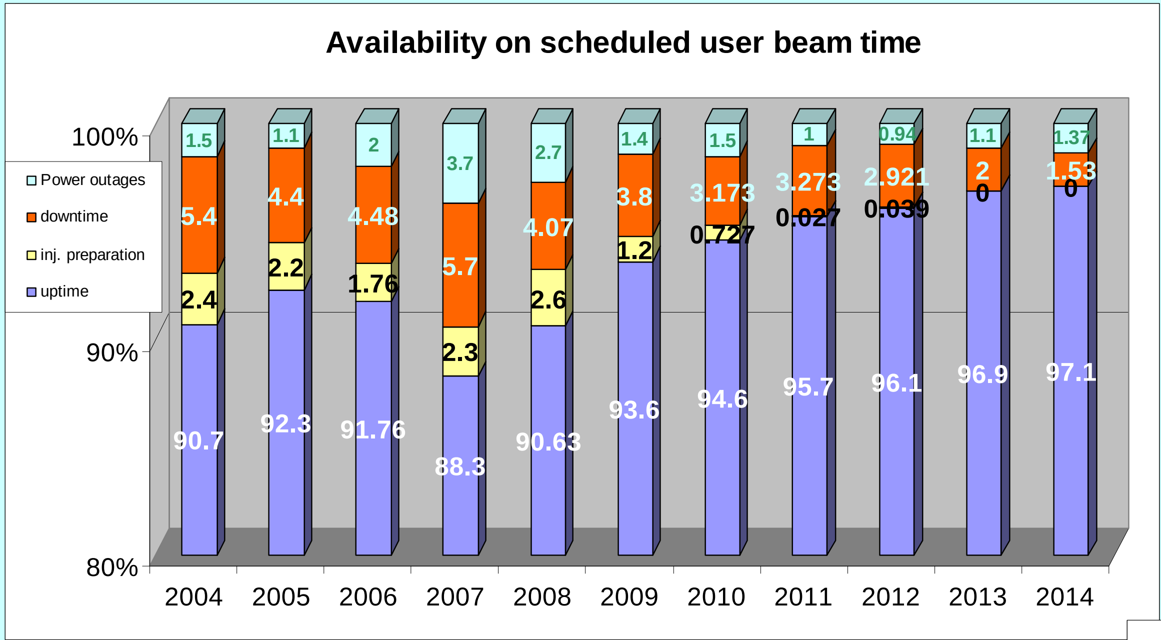
2013: 5016 h scheduled, 96.9/98.0% uptime, MTBF = 60/77 h

2014 so far 80.1% of total user scheduled time:

4041 h scheduled, 97.1/98.5 % uptime, MTBF = 66/85 h

█ =*Excluding external electricity power failures/outages*

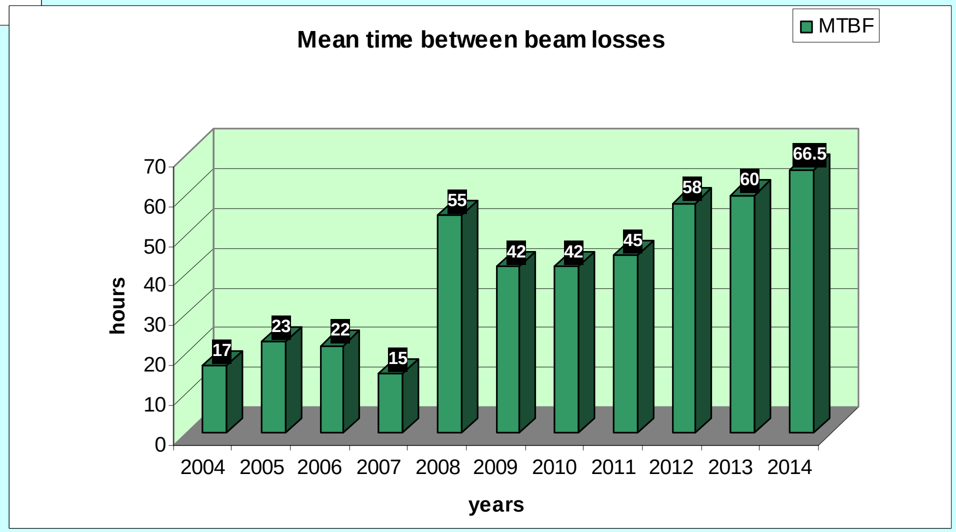
Statistics



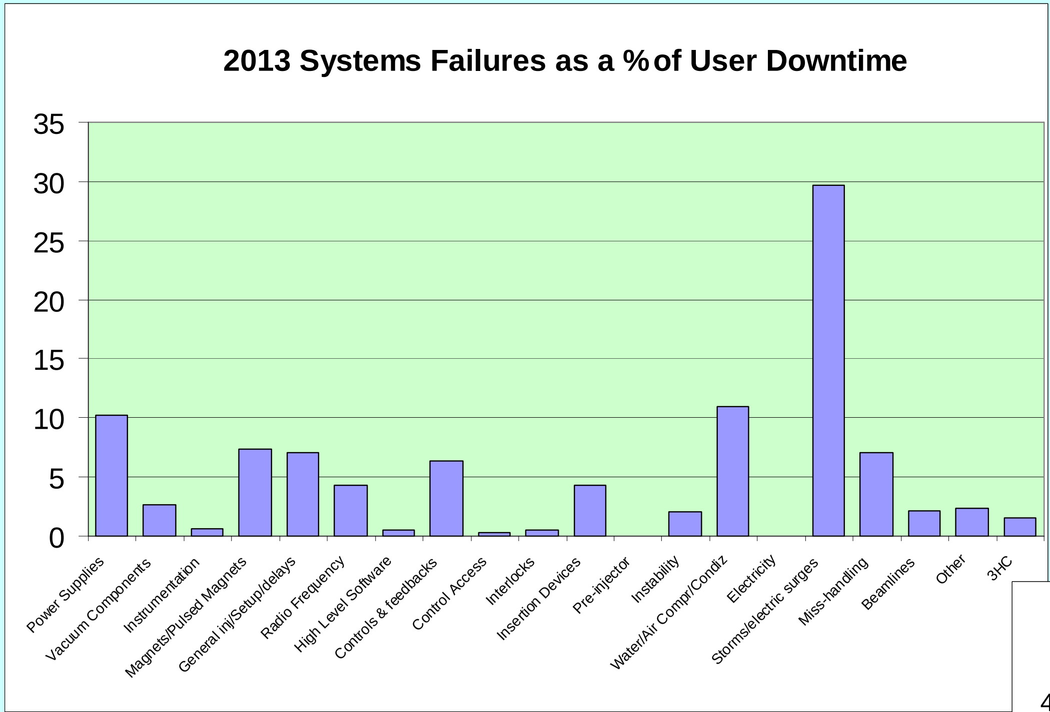
User down time due to injectors 2013, 2014 0%

Mean fault duration ~ 1 hour

Max running without a beam dump: 650 hours , the max average is about 300 hours



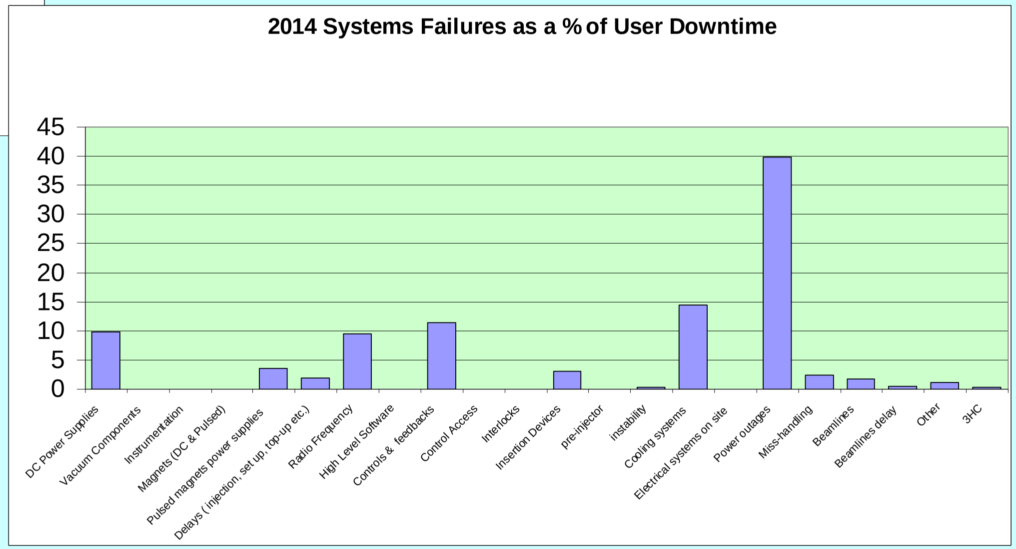
Systems failures



User down time due to injectors 2013 & 2014 0%

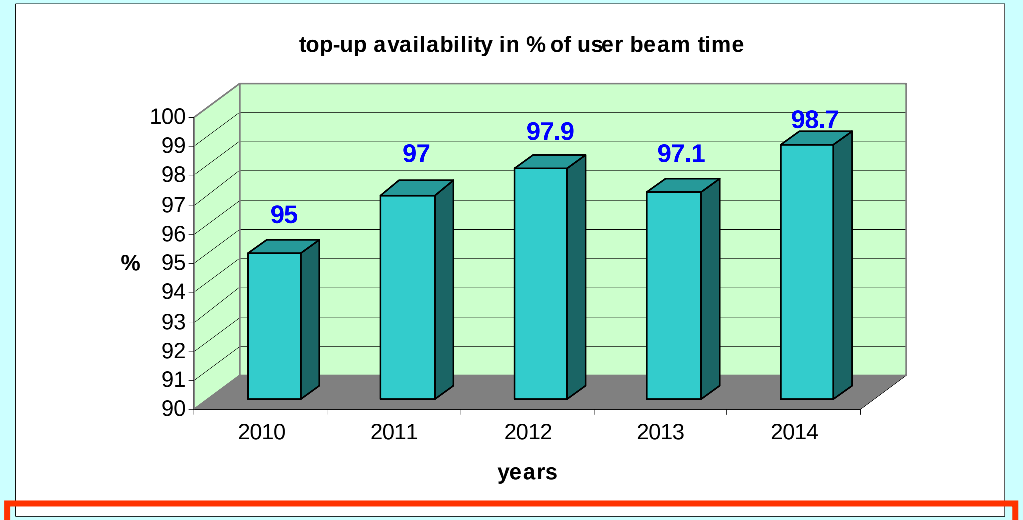
As of November 1st 80.1% of the 2014 scheduled user time

Power outages contribute <2 % to the user down-time BUT are very disturbing and the major contributor (30 - 40%) of the down-time

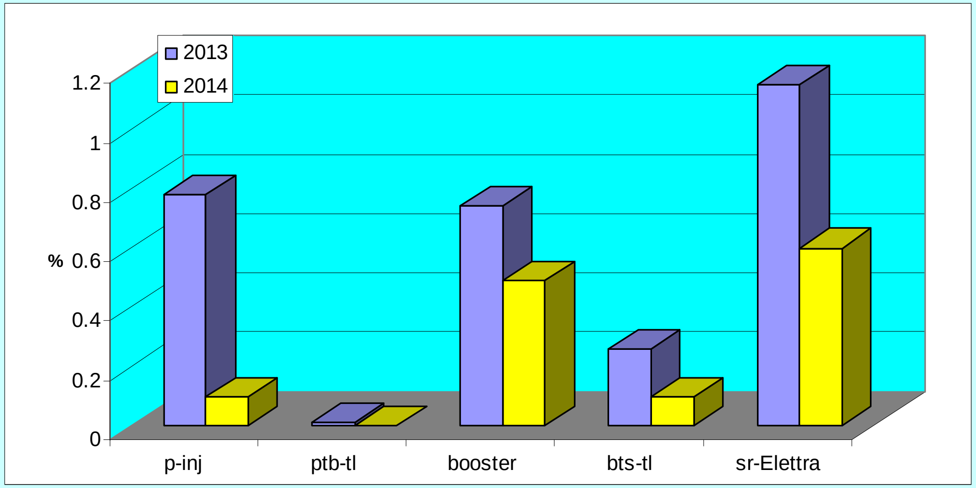


Top-up statistics

During top-up systems run well and the top-up % of user beam-time is high ~ 98%. The remaining 2% is due to failures that, however, do not impact on the availability.



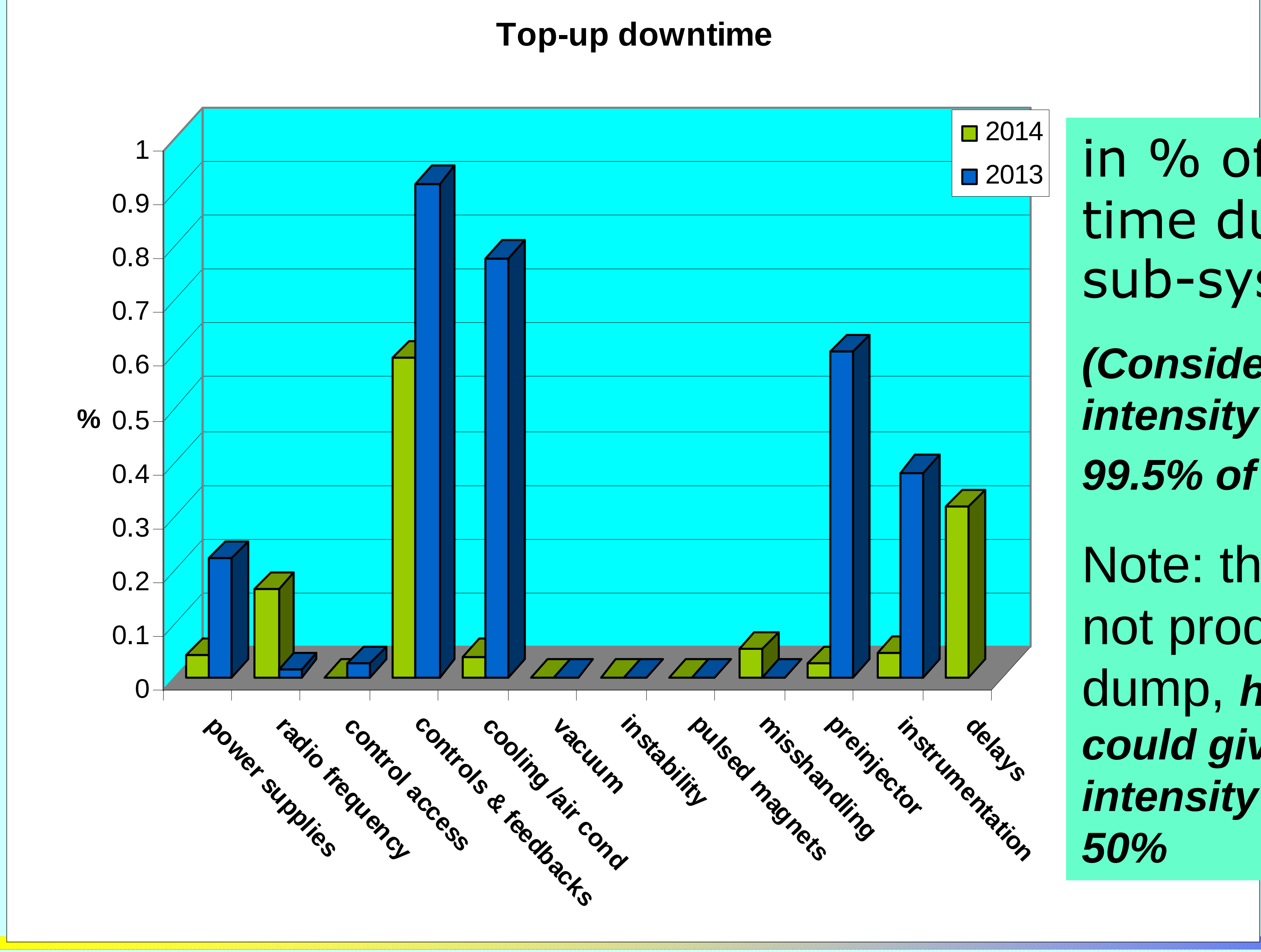
Top-up failures in % of user beam time due to various parts of the complex



Orbit stability requirements met most of the time provided that ambient temperature is within the defined limits, i.e., ± 0.5oC

The long term (>24 h) is **≤ ±** 5 µm ptp (max value for >120 h). Short term stability (< 24 hours) is at 2% of the beam size ~v 600nm

Top-up downtime



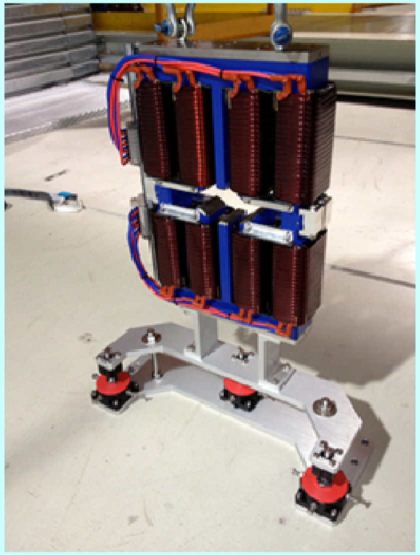
in % of user beam-time due to various sub-systems.

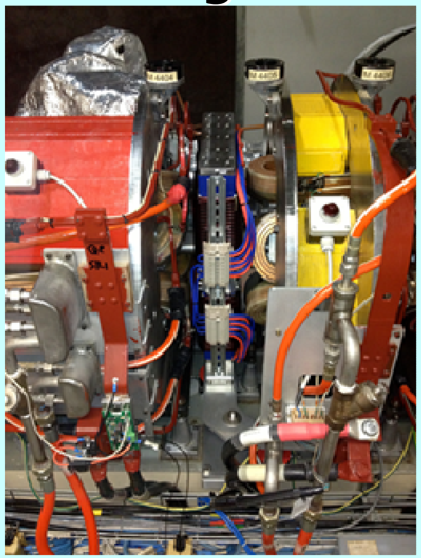
(Considered when the intensity is less than 99.5% of the nominal)

Note: those failures did not produced a beam dump, ***however they could give a down-time if intensity dropped below 50%***

Short term developments

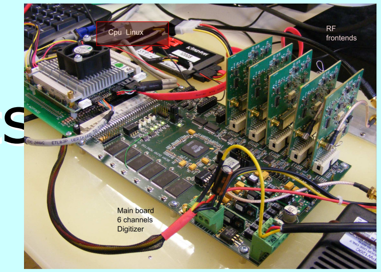
- √ Top up in hybrid mode -> done
- √ Upgrade to 200 mA at 2.4 GeV
- √ Photon bpms (new concept working prototype)
- √ Digital low level RF
- √ PS-controls upgrade (first part)
- √ Build booster power supplies modules
- ❑ Stabilize ambient temperature to ±0.5° C -> starting
- ❑ Additional correctors for full control of the dipole source points -> (Elettra design , air cooled ,four installed, 2 more to follow- very thin- realized by KYMA)





Short term developments

- √ Refurbished superconducting wiggler by BINP institute (Novosibirsk) (3.5 T,64 mm,49 periods)->2 new BLs
- √ Interlocks upgrade
- √ Elettra operates mainly from the common control room
- √ MML (Matlab Middle Layer) installation for real time modeling /measurements
- √ Beam dump fast diagnostics



- ❑ Upgrade bpm detectors-> project started
- ❑ Emittance real-time measuring system-> in progress
- ❑ RF upgrade -> in progress (solid state)

Mid - term possibilities

The following items are considered:

- Energy (can go up to 2.7 GeV but rad.prot. licence up to 2.5 GeV)
- Intensity (maybe to 400 mA but BLs not ready)
- **Brilliance and beam size**
- Reshuffling space (possible but not likely)
- Bunch length and fill patterns (low alpha mode achieved but no interest)
- Super-bends and **in-vacuum ids** (in discussion)

Brilliance and beam size

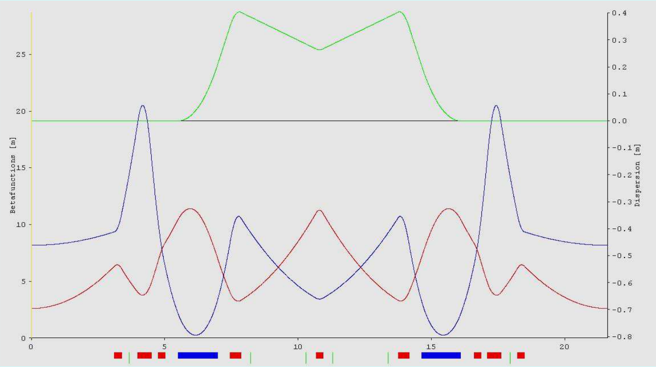
- Higher brilliance may be achieved by changing the existing optics down to 2.5 nmrad (2 GeV) without any additional hardware.

A study to examine impact on the beam lines (heat load) is completed with report (Ivan Cudin), with current intensities in the current machine no problem due to heat load

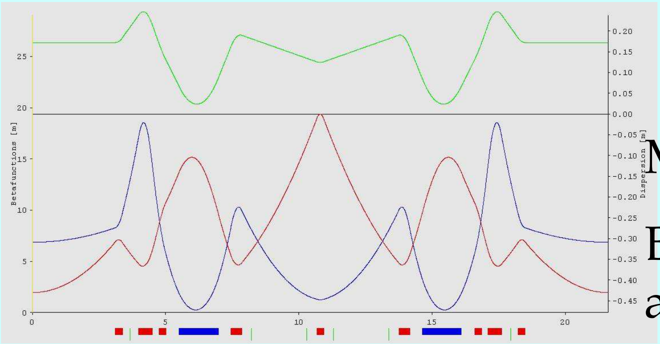
- To control coupling and hence the vertical beam size, skew quads are needed.

Preliminary study for adding skew quads (S. Di Mitri et al. tomorrows talk)

Reduction to 2.5 nm

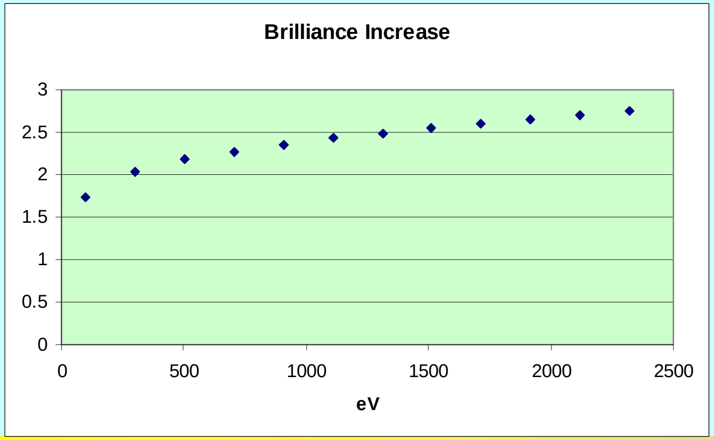


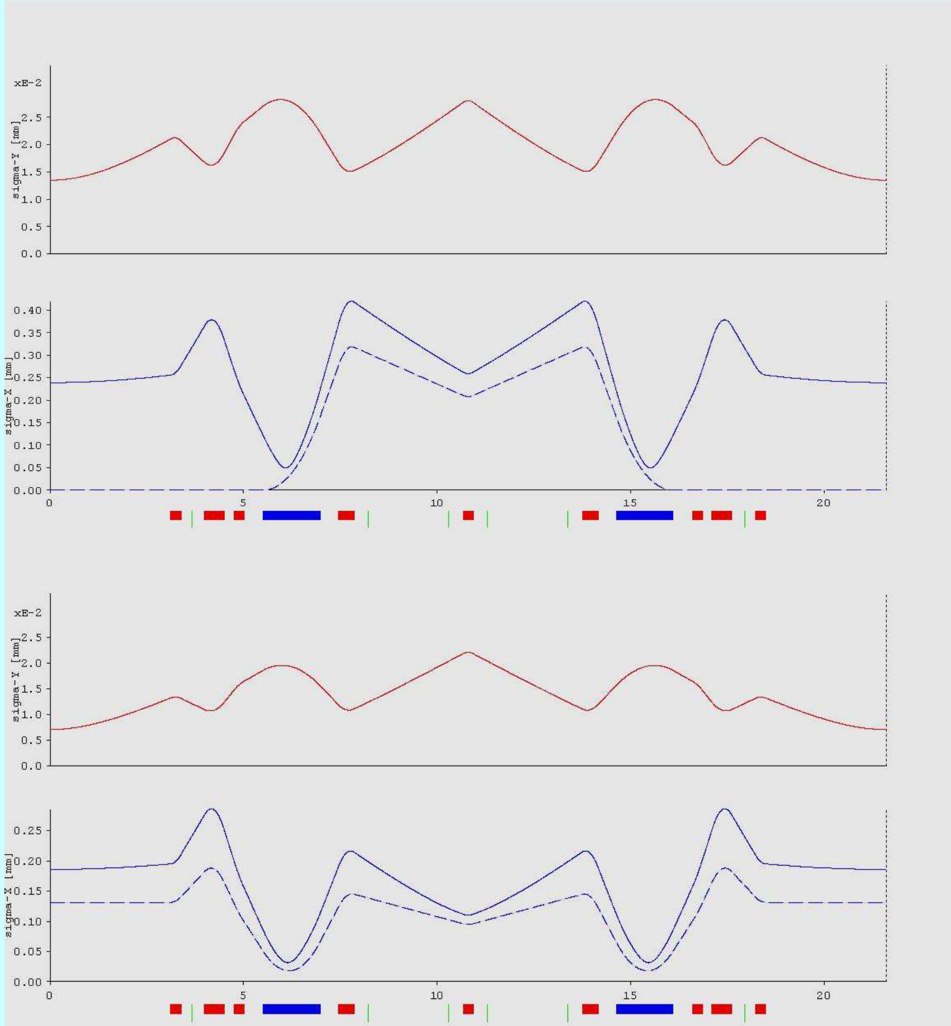
Current; 7 nmrad



Modified; 2.5 nmrad

Brilliance increase x2 and smaller spot size





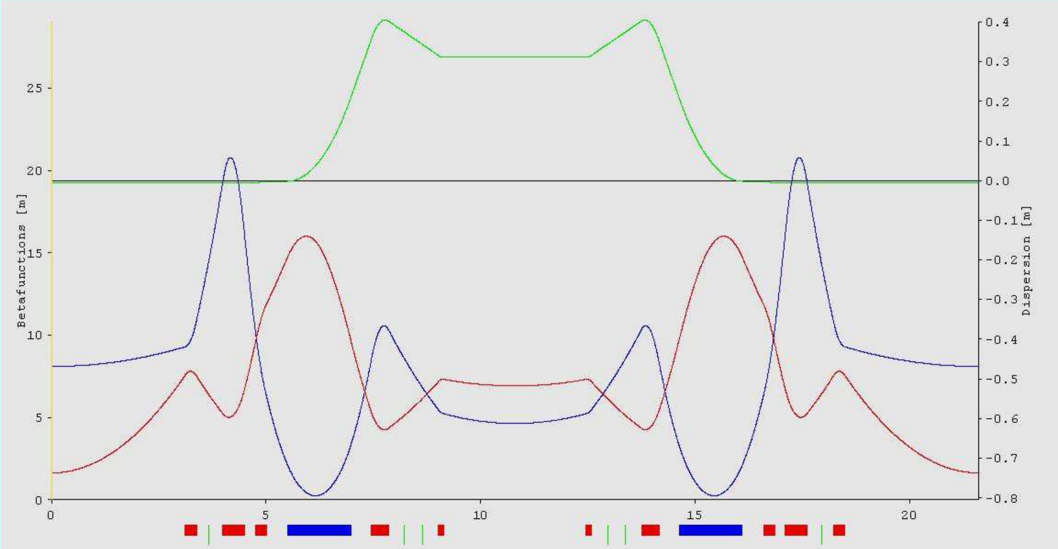
2 GeV 100 mA, period 46mm, Np=98, L=4.5m

Elettra variation for space

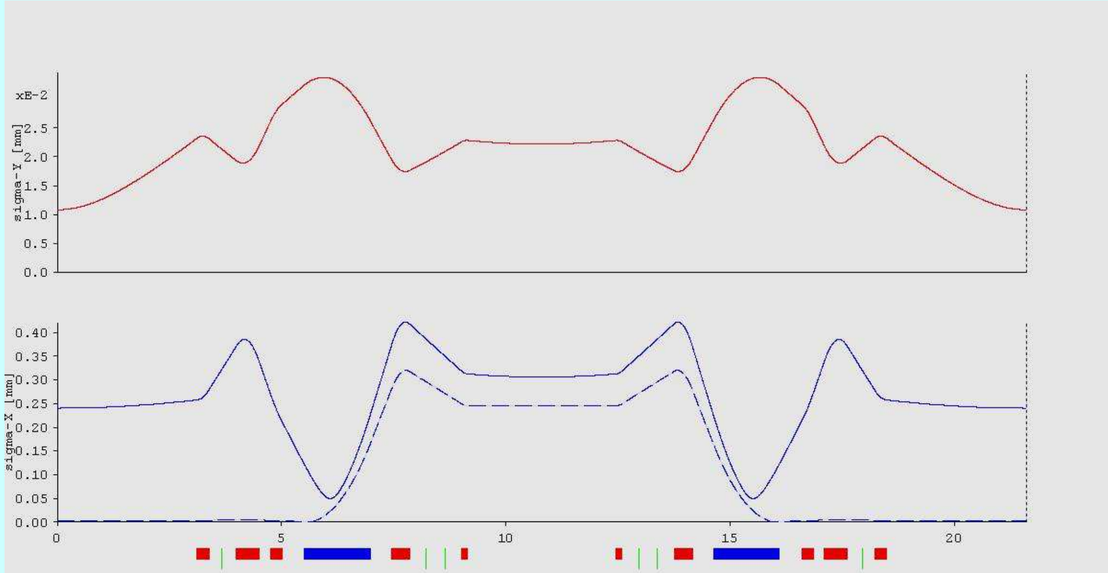
Emit: 7 nmrad

Tunes 14.3 8.2

Chroms -42 ,- 16



About 2.5 m unified free space can be gained (now is 1+1.5)



Fill patterns and Bunch length

- Any pattern possible on request
- Hybrid fill is already supported in top-up.
- Some interest also for KAC mode (kick and cancel)

- Due to 3HC shorter pulse in normal operations is not possible.
- Dedicated shifts for a shorter pulse could be possible (over tuning 3HC at nominal intensity or nominal setup of 3HC at lower intensity)
- For shorter pulses of few ps the low alpha mode is needed, has been established but needs further studies in order to become operative
- Femto -slicing possible but not yet done (in discussion but not likely due to FERMI).

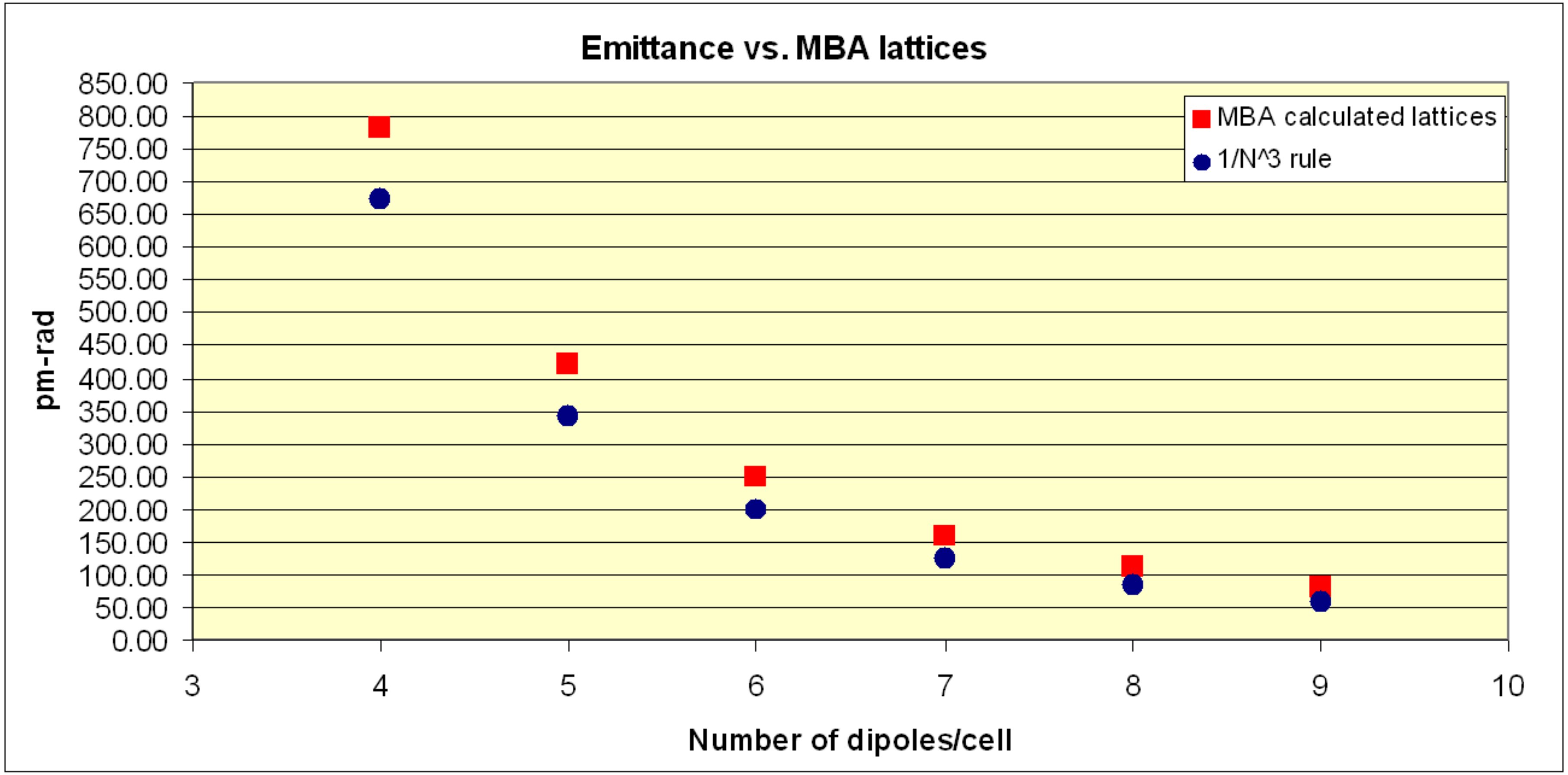
Long –term vision: Elettra 2.0

Requirements

- Same building, same position C~259.2 m
- Energy 2 GeV
- Brilliance increase at 1 keV by more than 1 order of magnitude
- H-spot size less ≤ 50 um
- Maintain the existing ID straight sections
- Maintain the existing bending magnet beam lines
- Multi-bunch current 350 mA, maintain the filling patterns as before (hybrid, single bunch etc.)
- free space not less than that of Elettra, LS: 6 m (4.5 for Ids) + (SS: 1.1 m , SLS: 1.46 m for RF / short IDs / instruments) total 8.56 m
- Use off axis injection
- 6+6 months downtime for installation and commissioning

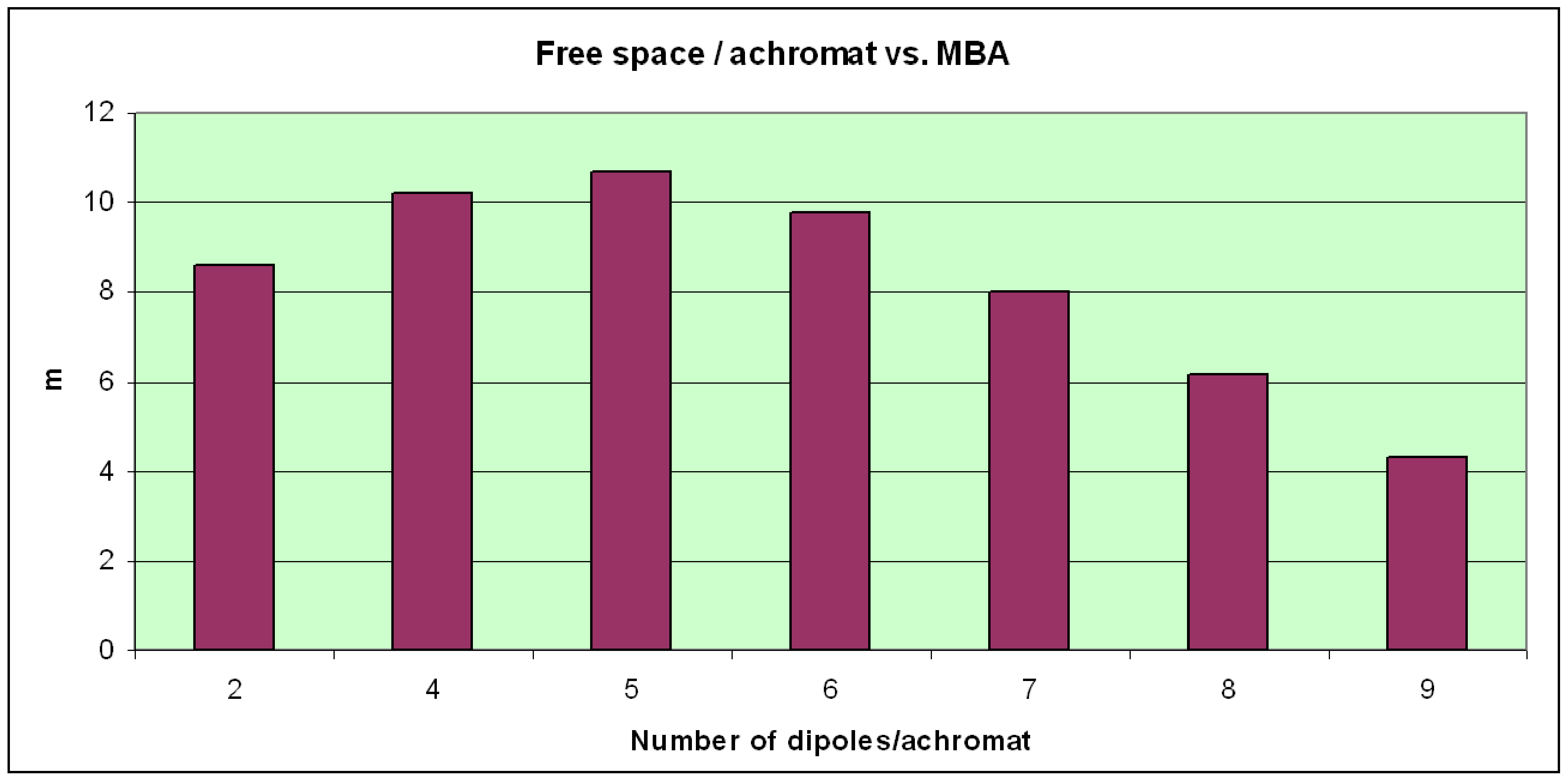
M-bend achromats and emittance

Lattices up to 9-bend achromats have been produced and examined



Elettra nominal: at 2 GeV 7000 pm-rad (and at 2.4 GeV 10000 pm-rad)

Free space



Free space / achromat vs. MBA
m
12
10
8
6
4
2
0
2
4
5
6
7
8
9
Number of dipoles/achromat

6BA appears best solution for Elettra

Energy 2 GeV

Emittance 0.251 nmrad -> 28 times reduction

Beam dim 32/22 um *(round beam)* **or 40/2.2 um at 1% coupling**

alpha=3x10^{-4} -> shorter bunches by a factor of 2

Tune 33.32, 8.38, chrom -60

Espread 7 10-4

DE/turn 178.5 keV,

Damping times (msec)

X 12.4, Y 19.3 E 13.5

Dipoles: field 0.8 T and gradient 19 T/m

Quads: K max 9.5 -> 64 T/m -> 12.8 T (l=0.2 m)

Sext: max K2=100 (700 T/m^2)

Chamber 22x7 mm and 22x22

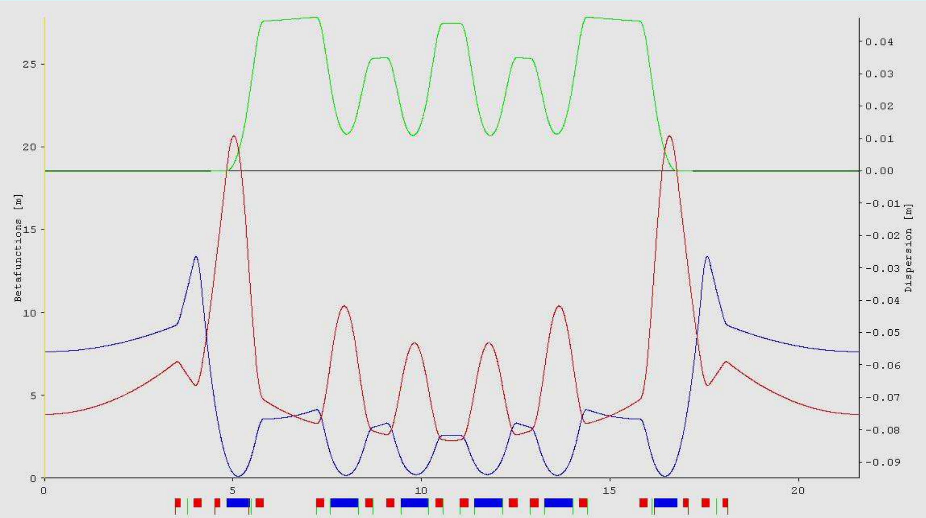
Elettra nominal:

Dipoles: field 1.2 T and gradient 2.86 T/m

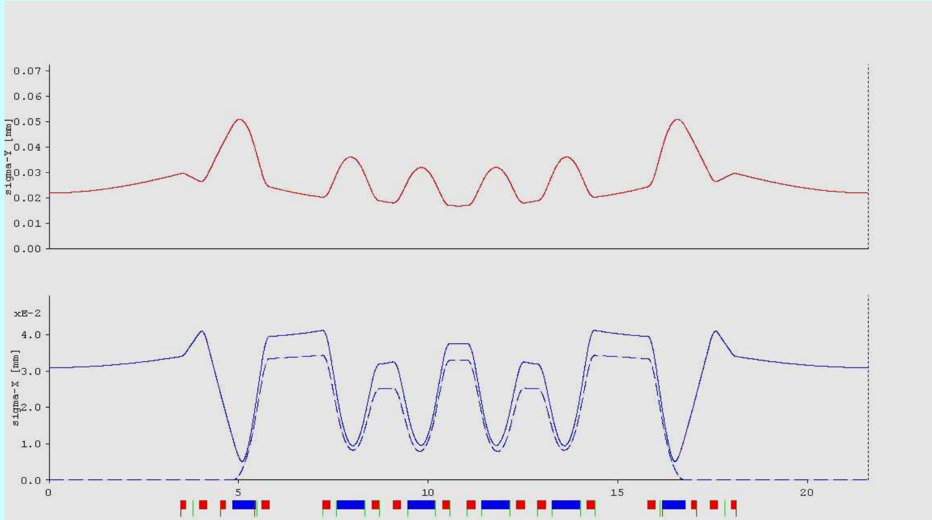
Quads: max gradient 15 T/m

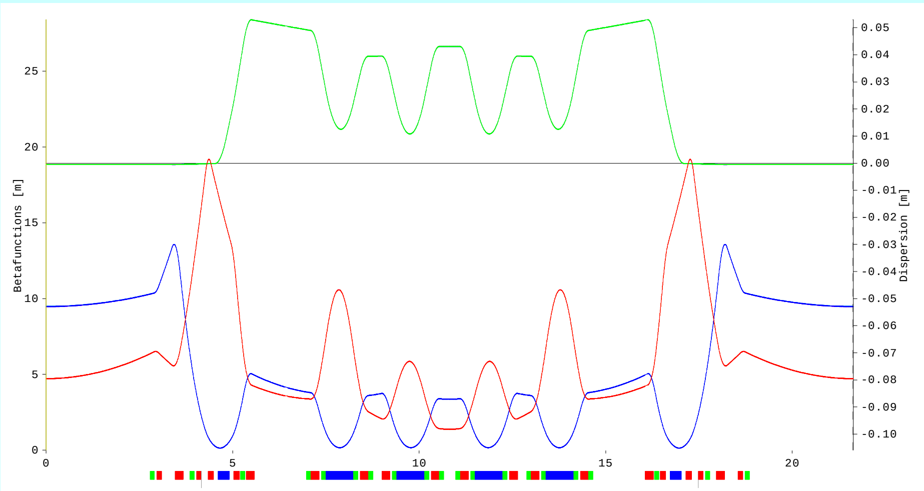
Sext: max gradient 70 T/m^2

6BA – versions



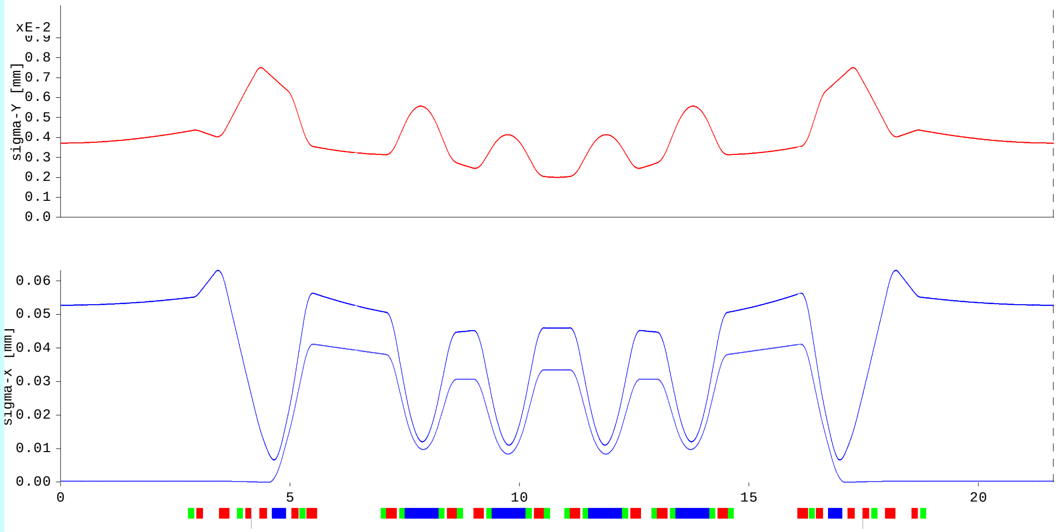
Low dispersion - Beam dimensions in shorts straights match the long ones

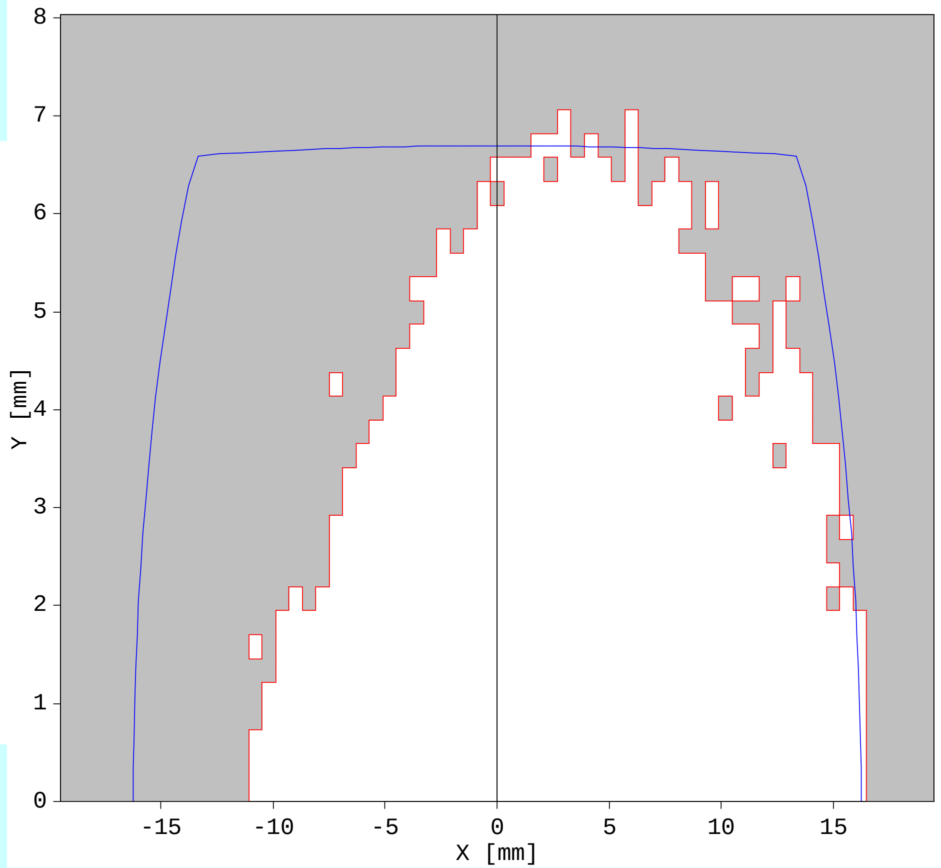




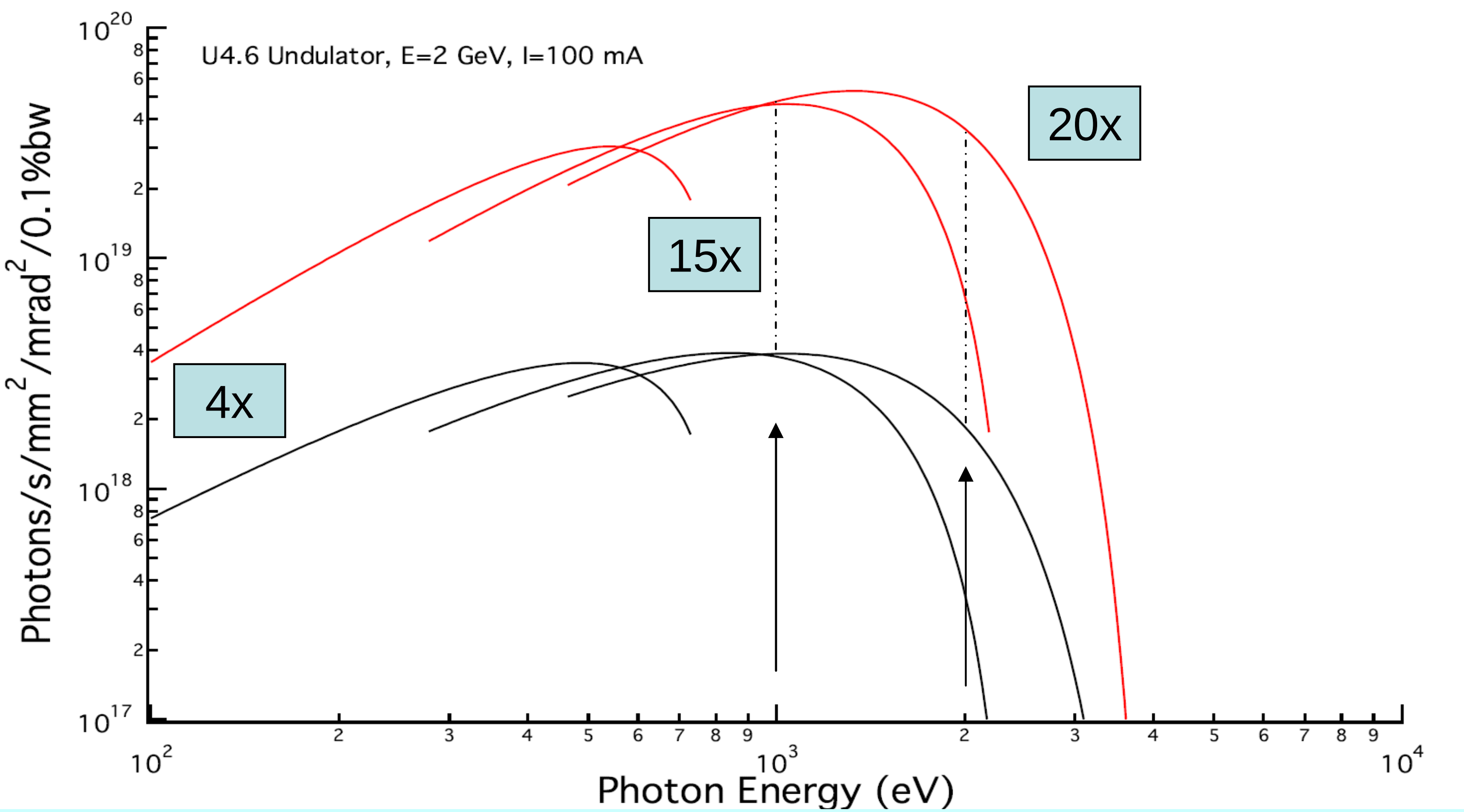
Another solution with 1.4 T dipoles at the arc extremes

Emit: 0.290 nmrad
Qx=33.33 Qy=9.19
Chrom corrected to +1
dE/turn: 217 keV


xE-2
sigma-Y [mm]
sigma-X [mm]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
5
10
15
20


Y [mm]
X [mm]
8
7
6
5
4
3
2
1
0
-15
-10
-5
0
5
10
15

Brilliance vs. emittance for an undulator for Soft X-rays



Super ESCA @ 2 GeV 100 mA

Graph by B. Diviacco

Brilliance increasing as expected

Spot size/div decreased by a factor of 5

Elettra : 7 nmrad
Beam dimensions:
x,y (245,14) µm
x’,y’ (28, 6) µrad

Long straights - 0.25 nm-rad

Beam dimensions:

x,y (43,3.0) µm

x’,y’ (5.7, 0.8) µrad

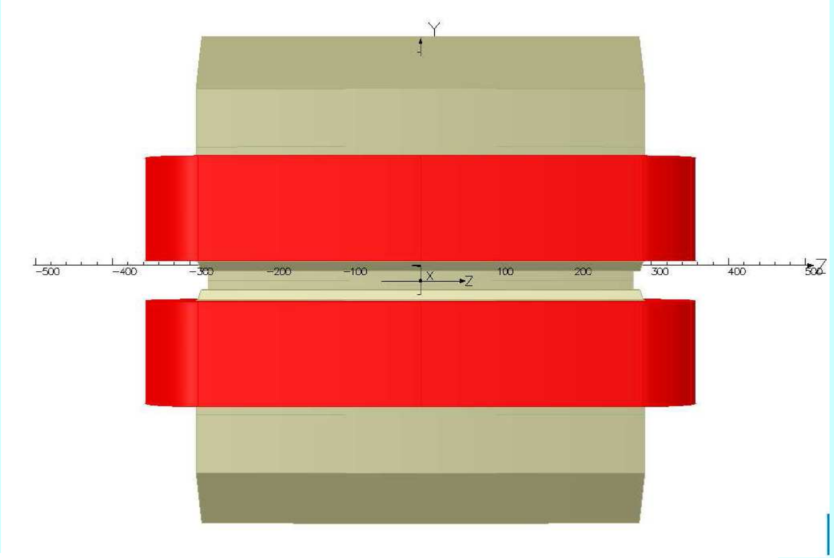
0.25 nm-rad – short straights

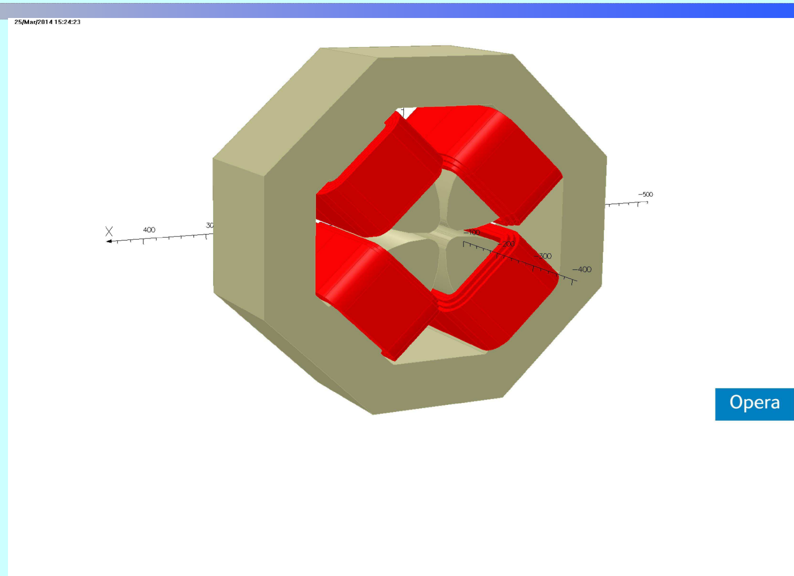
Beam dimensions:

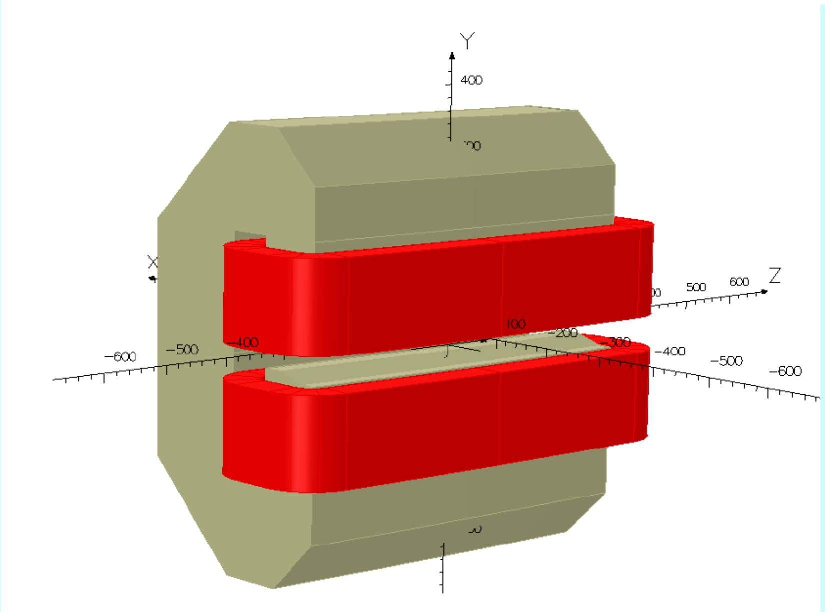
x,y (45,3.1) µm

x’,y’ (8, 0.9) µrad

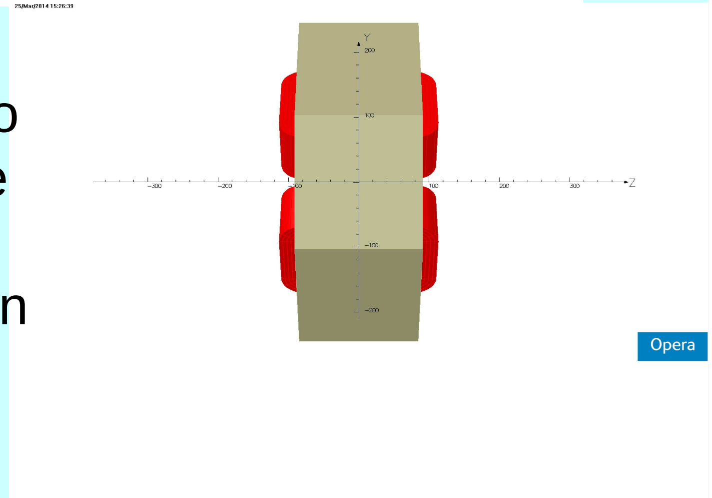
Dipoles and quadrupoles



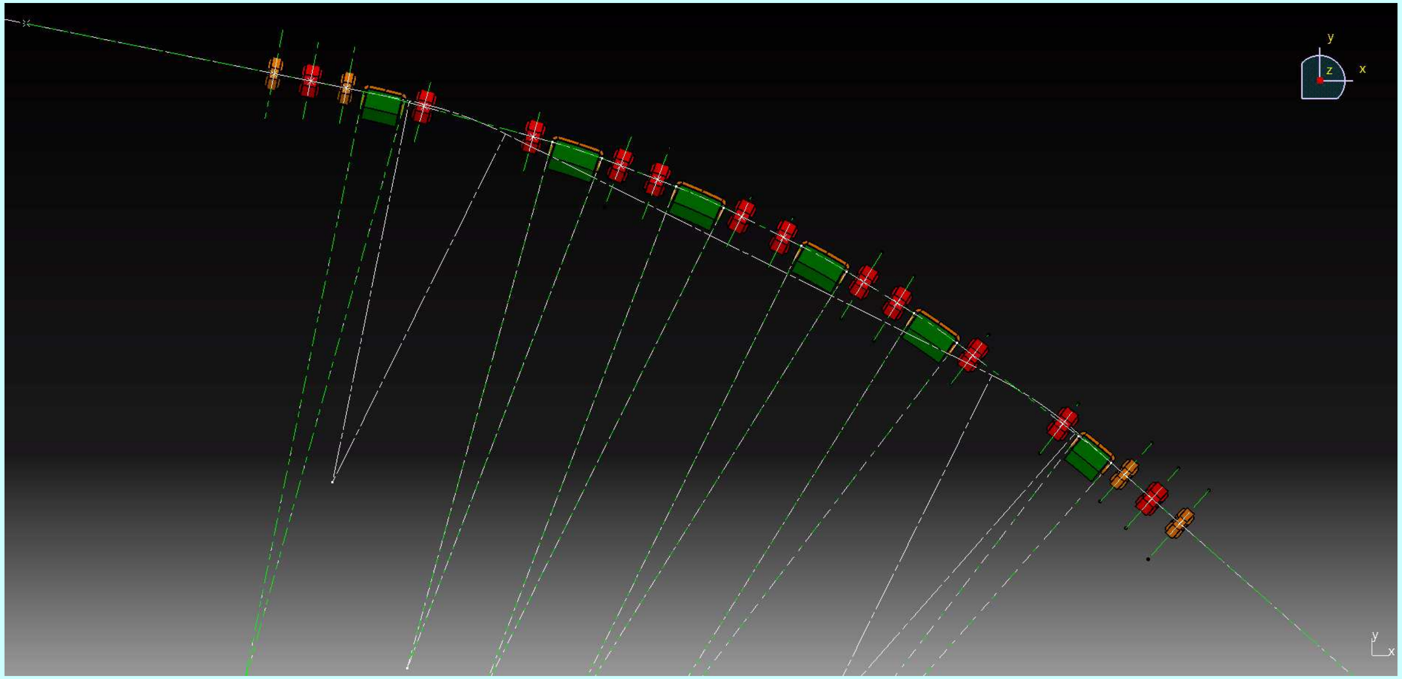




Not final but important to see also the dimensions. Use of new materials such as Cobalt – Iron alloys will also be considered



Opera, D. Castronovo



Elettra 2.0 is 300 - 900 mm longer, arc 400 mm (radial) but fits on the old girders

Schedule: CD ready spring 2016 - estimate 4 years to completion – earliest new machine summer 2021 (if money available)

Costs about 85 million including infrastructures

and manpower ~50 people

Elettra and Elettra 2.0

Parameter	Units	Current Elettra	Elettra 2.0
Circumference	m	259.2	259.5
Energy	GeV	2 - 2.4	2
Horizontal emittance	pmrad	7000	230-290
Vertical emittance	pmrad	70 (1% coupl)	2.5 (250 round beam)
Beam size @ ID (σx,σy)	μm	245 , 14 (1% coupl)	43,3 (31,22 round beam)
Beam size at short ID	μm	350 , 22 (1% coupl)	45,3 (39,21 round beam)
Beam size @ Bend	μm	150, 28 (1% coupl)	17,7 (12,48 round beam)
Bunch length	ps	25 (100 with 3HC)	12.5 (70-100 with 3HC)
Energy spread	ΔE/E %	0.08	0.07
Bending angle	degree	15	5.5 and 4

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