Feb 5, 2015

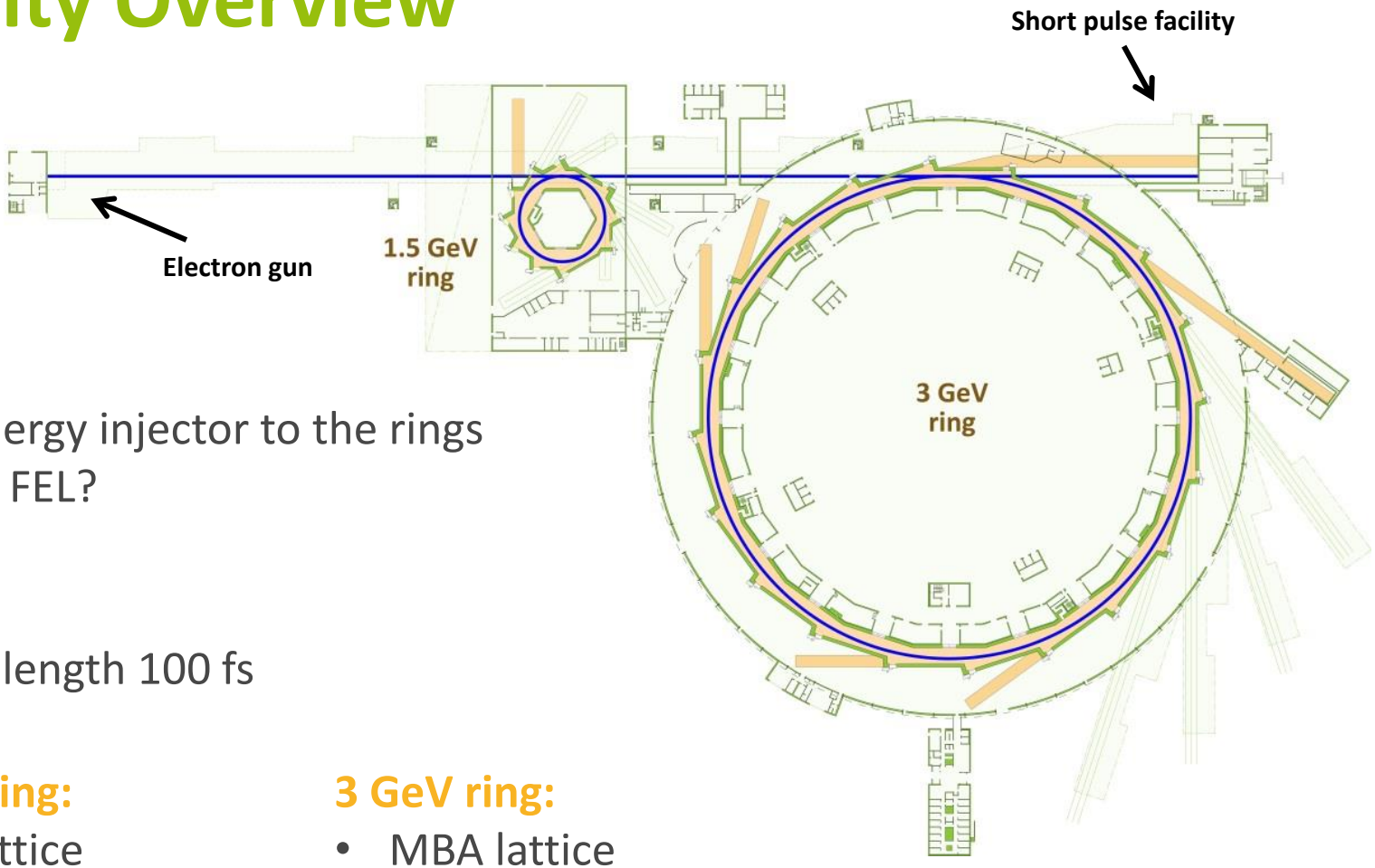
TIMING AT MAX IV FROM THE ACCELERATOR PERSPECTIVE

TERESIA OLSSON

Workshop on Timing Modes for Low-emittance Storage Rings
March 25-27, 2015, Lund

Photo: Perry Nordeng

Facility Overview



Linac:

- 250 m
- Full-energy injector to the rings
- Future FEL?

SPF:

- Bunch length 100 fs

1.5 GeV ring:

- DBA lattice
- Emittance 6 nm rad
- Soft X-ray users

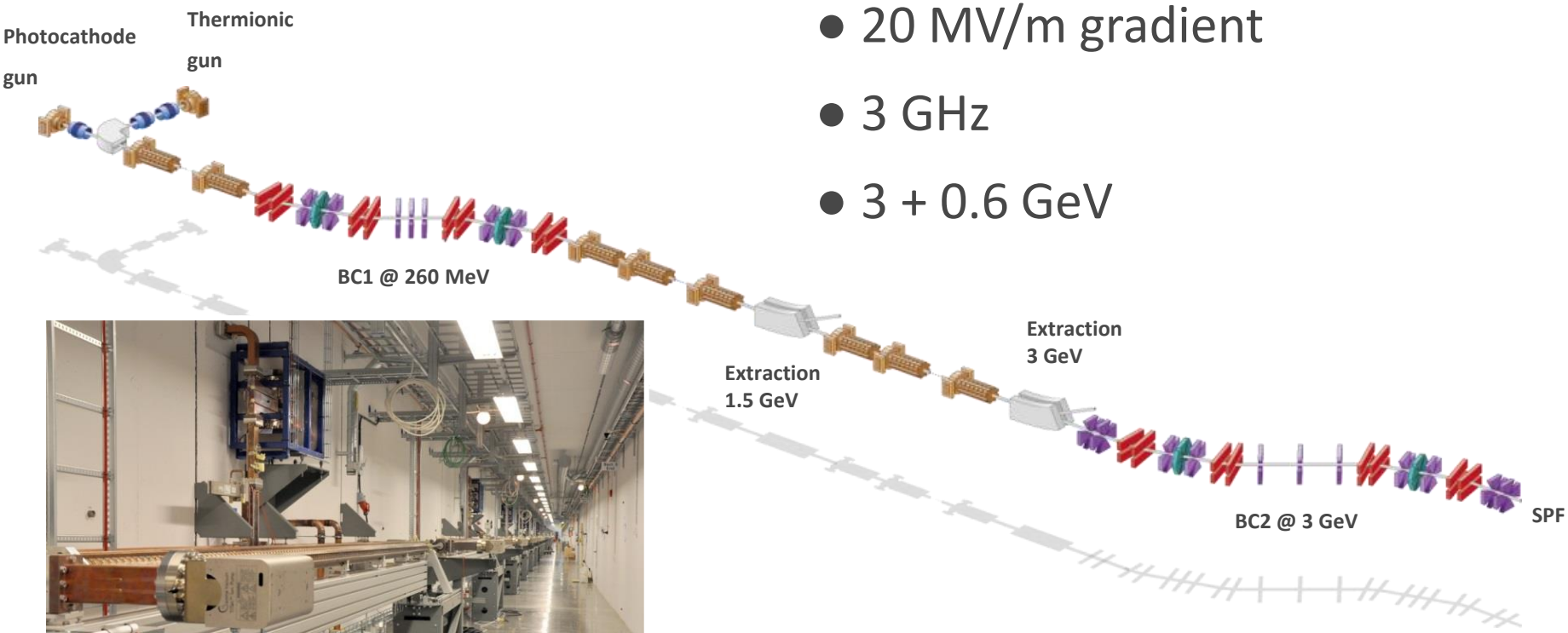
3 GeV ring:

- MBA lattice
- Emittance ~0.3 nm rad (bare)
- Hard X-ray users

Facility Overview

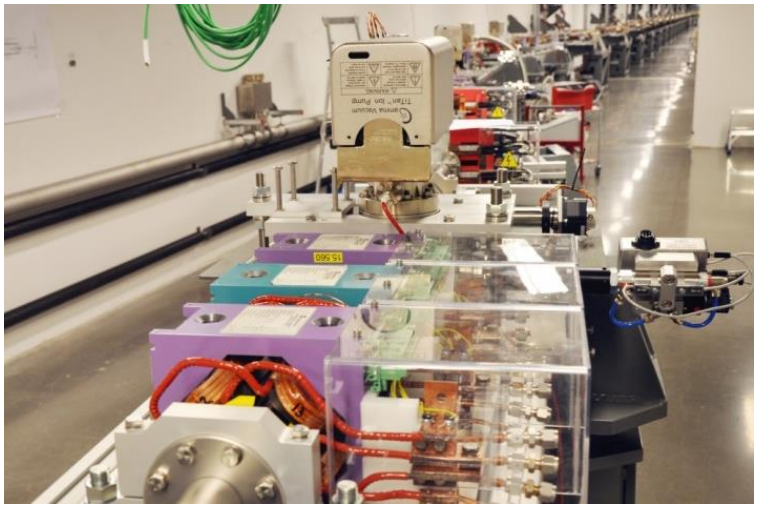
Linac

- 39 warm s-band linac structures
- 20 MV/m gradient
- 3 GHz
- 3 + 0.6 GeV



Courtesy of Sara Thorin

Linac



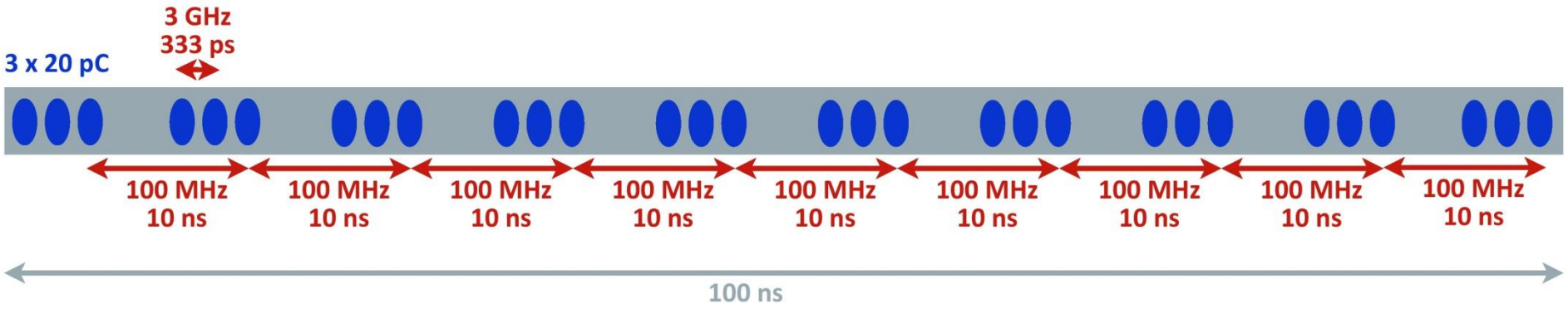
Courtesy of Sara Thorin

Injection Schemes

	Ring injection	SPF injection
Electron gun	Thermionic	Photocathode
Energy	1.5 GeV/ 3 GeV	3 GeV
Rep. rate	10 Hz	100 Hz
Charge	0.6-1 nC/shot	100 pC
Norm. emittance	10 mm mrad	1 mm mrad
Energy spread	<0.2%	<0.4%

Time Structure for Ring Injection

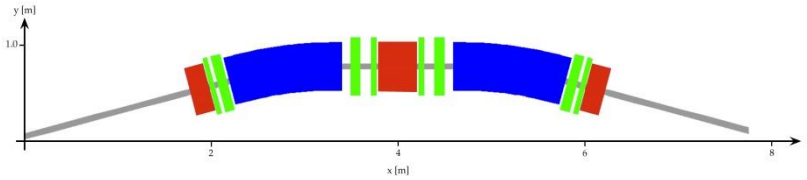
- Acceleration on-crest to avoid compression.
- Rep. rate 10 Hz
- 1 shot = 100 ns bunch train.
- Chopper to modify 3 GHz time structure to 100 MHz and create 100 ns shot. Chopper properties can be modified to achieve other time structures, e.g. single-bunch injection.
- Top-up operation, ~2 s/inj., inj. every 6 min./ring (1% current loss).



MAX IV Storage Rings

1.5 GeV ring

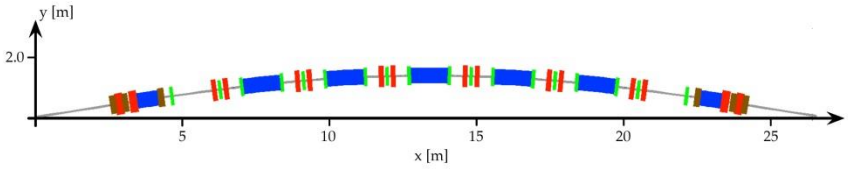
Horizontal emittance	6 nm rad
Circumference	96 m
Current	500 mA
Charge per bunch	5 nC
Max no of bunches	32
No of user straights	10



Double-bend achromat

3 GeV ring

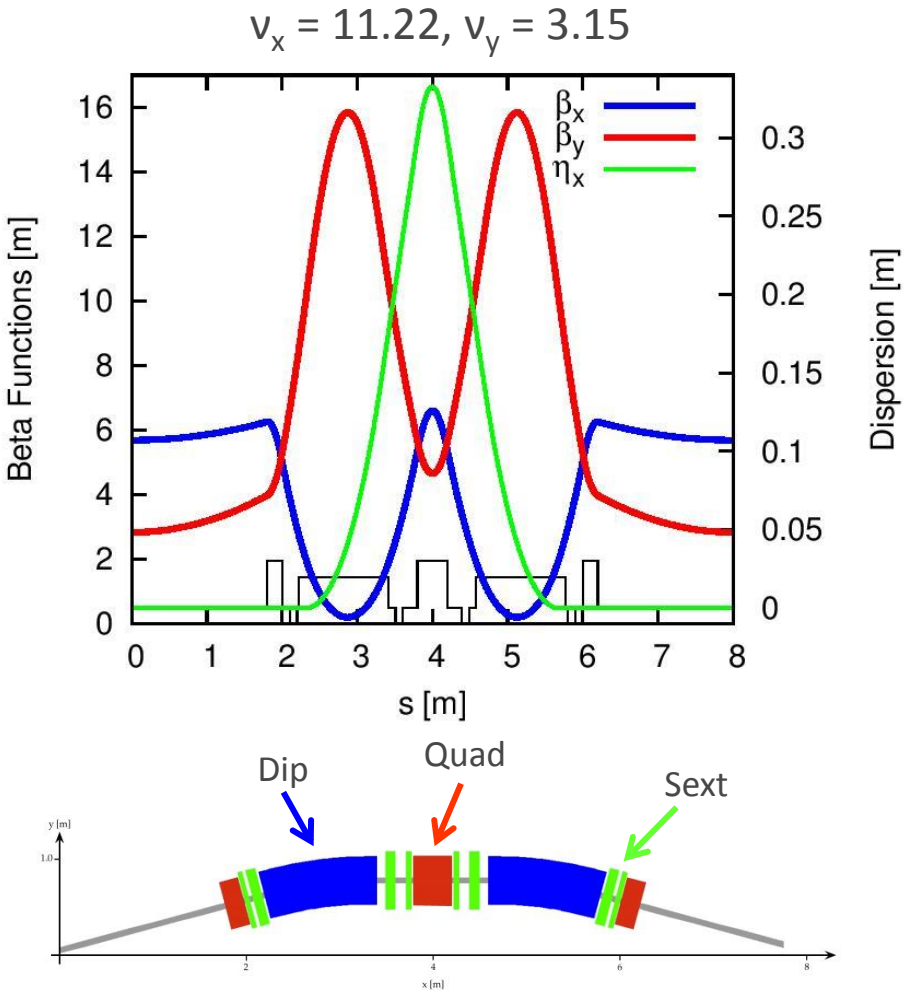
Horizontal emittance	0.3 nm rad
Circumference	528 m
Current	500 mA
Charge per bunch	5 nC
Max no of bunches	176
No of user straights	19



7-bend achromat

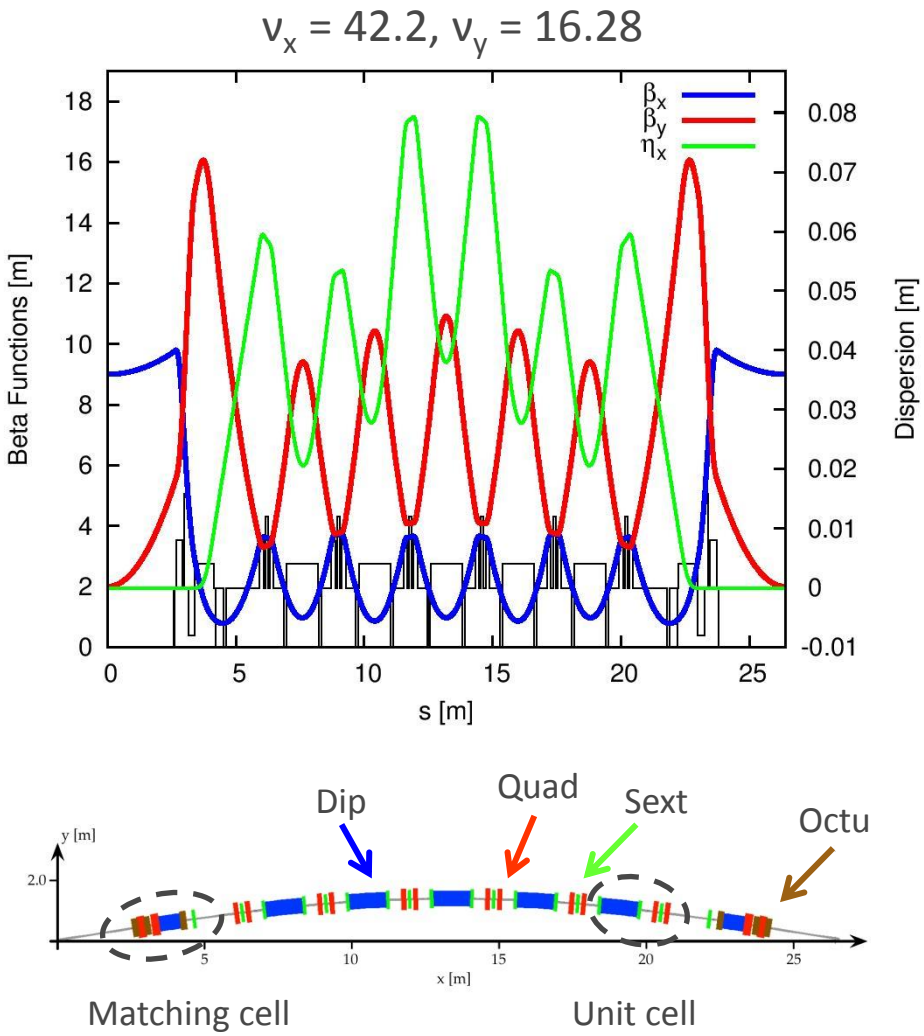
MAX IV 1.5 GeV Ring Lattice

- 12 double-bend achromats.
- Dip with defocusing gradient (can be varied with pole-face strips).
- 2 focusing quad families with focusing sext comp & 2 defocusing sext families.
  $\xi_{x0} = -22.981$
  $\xi_{y0} = -17.141 \rightarrow \xi_{x,y} = +2$
- 2 correction sext families to correct chromaticity further.
  $\rightarrow \xi_{x,y} = +1$



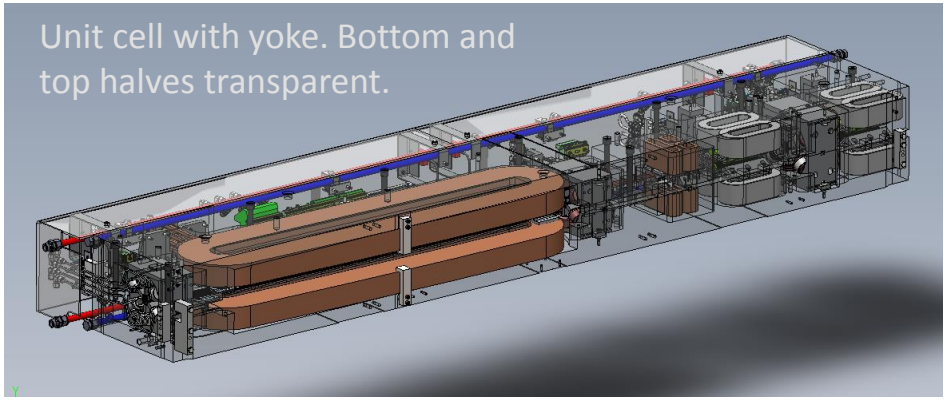
MAX IV 3 GeV Ring Lattice

- 20 7-bend achromats.
- 5 units cells & 2 matching cells.
- Dip with defocusing gradient (can be varied with pole-face strips).
- 3 focusing quad families & 1 defocusing quad family.
- 3 focusing sext families & 2 defocusing sext families.
  $\xi_{x0} = -49.984$
  $\xi_{y0} = -50.198$ $\rightarrow \xi_{x,y} = +1$
- 3 octu families.

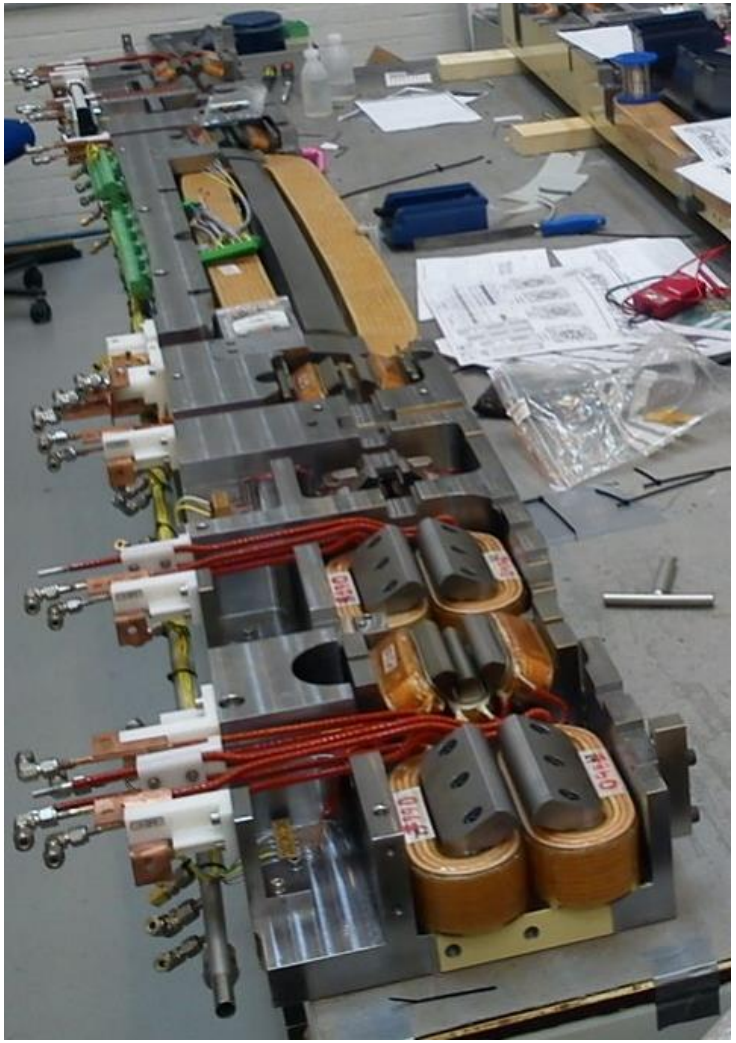


Magnet Concept

- Concept: Integrated unit containing several magnet elements:
  - Vibration stability
  - Internal alignment given by machining tolerances
  - Easier installation



Courtesy of Martin Johansson



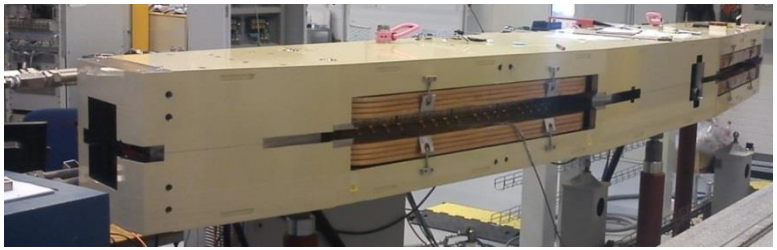
Ring Magnets and NEG

1.5 GeV ring

- Magnet aperture Ø28-51 mm.
- Steel vacuum chamber.

3 GeV ring

- Magnet aperture Ø25 mm enabled by NEG-coated Cu vacuum chambers.
- One block (2.3-3.4 m) machined out of common iron block. Mechanical tolerance: ± 20 µm.



Courtesy of Martin Johansson

Diagnostics

- Some examples of available diagnostics in the ring:
  - BPMs that can be run in turn-by-turn mode.
  - Synchrotron light monitors (enable emittance measurements): 1 at dispersive region + 1 at non-dispersive region (possible to measure energy spread).
  - 2 orbit feedback systems (slow and fast).
  - Strip-line pick-up (used for tune measurements).
- We do not yet plan to have:
  - Bunch-by-bunch feedback system.
  - Streak camera.

Installation & Commissioning

- Linac:
  - Ongoing: Commissioning, reached 3 GeV and dump at end.
- 3 GeV ring:
  - Ongoing: Installation of magnets and vacuum chambers
  - Start of commissioning: 23 July 2015
  - Operational: 10 June, 2016
- 1.5 GeV ring:
  - Ongoing: Concrete supports installed
  - Start of commissioning: 18 December, 2015
  - Operational: 17 June, 2016

Inauguration: 21 June, 2016

RF Parameters

1.5 GeV ring

Main RF frequency	99.931 MHz
Max. overall RF voltage	2 x 280 kV
HC frequency	3 x 99.931 MHz
No of HCs	2
Momentum compaction	3.06e-3
Natural bunch length (at max. overvoltage)	14.6 mm
Maximum bunch length	63.8 mm

Bunch lengthening ~4 times

3 GeV ring

Main RF frequency	99.931 MHz
Max. overall RF voltage	6 x 300 MV
HC frequency	3 x 99.931 MHz
No of HCs	3
Momentum compaction	0.306e-3
Natural bunch length (at max. overvoltage)	8.8 mm
Maximum bunch length	49.6 mm

Bunch lengthening ~5 times

Harmonic Cavities and Bunch Lengthening

- Rings designed for uniform multi-bunch filling pattern w/o ion-clearing gap.
- HCs to damp instabilites and increase Touschek lifetime by increasing bunch length.
  3 GeV ring: also conserve ultralow emittance at high bunch charge (IBS).
- HCs operate in passive mode → bunch lengthening depends on filling pattern and cavity tuning.

Instability Studies

Threshold currents(mA) in MAX IV 3 GeV ring considering different effects

effect / plane	ξ	Z_{geom}		Z_{geom} + RW		Z_{geom} + RW_{5IDs}
		HC off	HC on	HC off	HC on	HC on
Longitudinal	-	620	970	-	-	-
Horizontal	0.0	2010	2020	120	140	-
	1.0	>2050	17100	150	3500	-
	1.2	5040	21900	-	-	-
Vertical	0.0	920	710	40	40	-
	1.0	2200	10400	-	950	380
	1.2	3170	15100	50	1250	540

*in mA

Harmonic cavity is crucial for successful operation!

LER workshop, September 2014 Galina Skripka

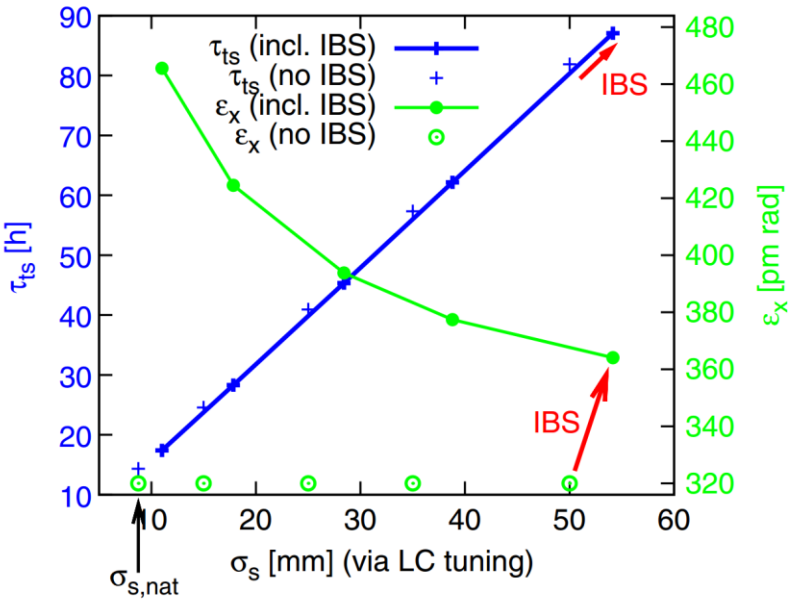
Courtesy of Galina Skripka

Touschek Lifetime & IBS

Courtesy of Simon C. Leemann
PRST-AB 17, 050705 (2014)

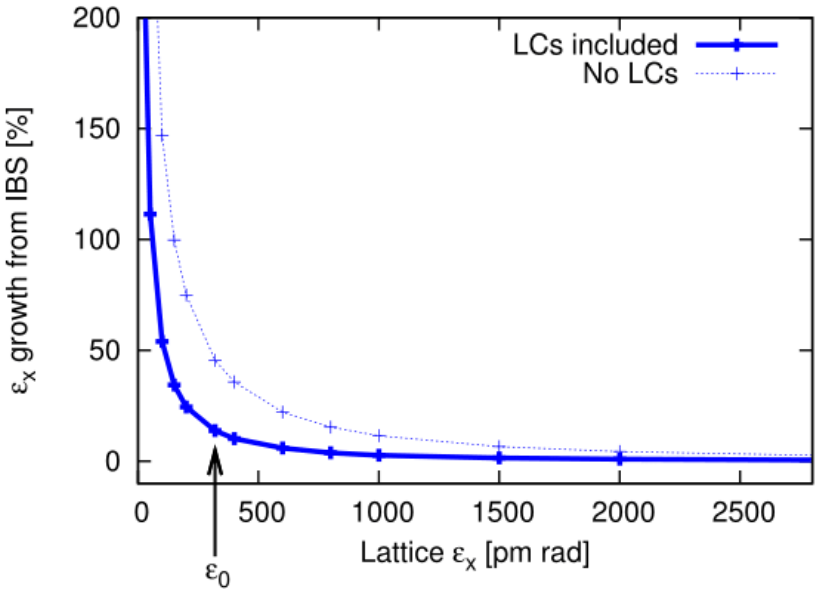
Touschek lifetime

- Bunch lengthening → incr. lifetime.
- Lifetime important to avoid interruption of SPF operation.



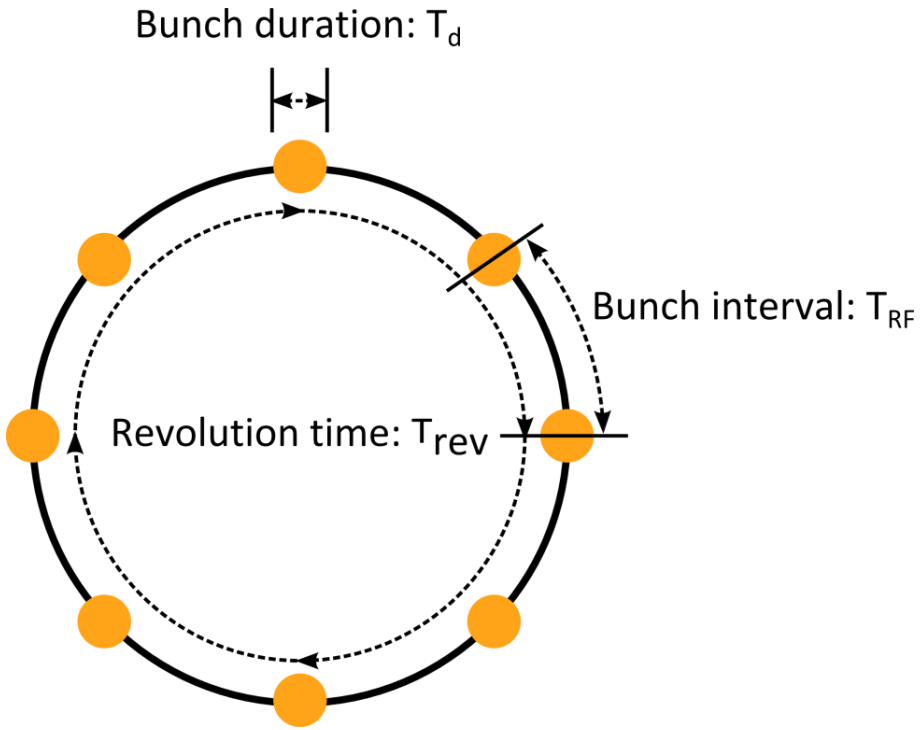
Emittance blowup

- IBS causes emittance blowup.
- 3 GeV ring: IBS blows up emittance by 45 %. HCs can reduce to 13 %.



Timing Properties

- T_{rev}: Revolution period of a bunch, determined by ring circumference.
- T_{RF}: Time between bunches, determined by RF frequency, depends on filling pattern.
- T_d: Bunch duration, depends on settings of main RF cavities, harmonic cavities, and IBS.



	Rep. rate [T_{rev}]	T_{RF}	T_d
SPF	100 Hz	10^7 ns	0.1 ps
1.5 GeV ring	3.13 MHz [0.32 µs]	10 ns	~50 ps (no HCs) to ~213 ps (with HCs)
3 GeV ring	0.57 MHz [1.76 µs]	10 ns	~30 ps (no HCs) to ~165 ps (with HCs)

Workshop Motivation & Ideas for Future Work

Priority from user input

1. Create adequate time structure.
2. Decrease bunch length.

Ideas for Machine Development

- Filling patterns with passive HCs
  - Single bunch
  - Hybrid modes
- Resonant pulse picking (PPRE)
- Pseudo single bunch

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What do we need to do to be able to serve both single-bunch and multi-bunch users simultaneously at low-emittance storage rings?


MAX IV