MAX IV Status

Pedro F. Tavares - on behalf of the MAX IV team

MAX IV Laboratory

Summary

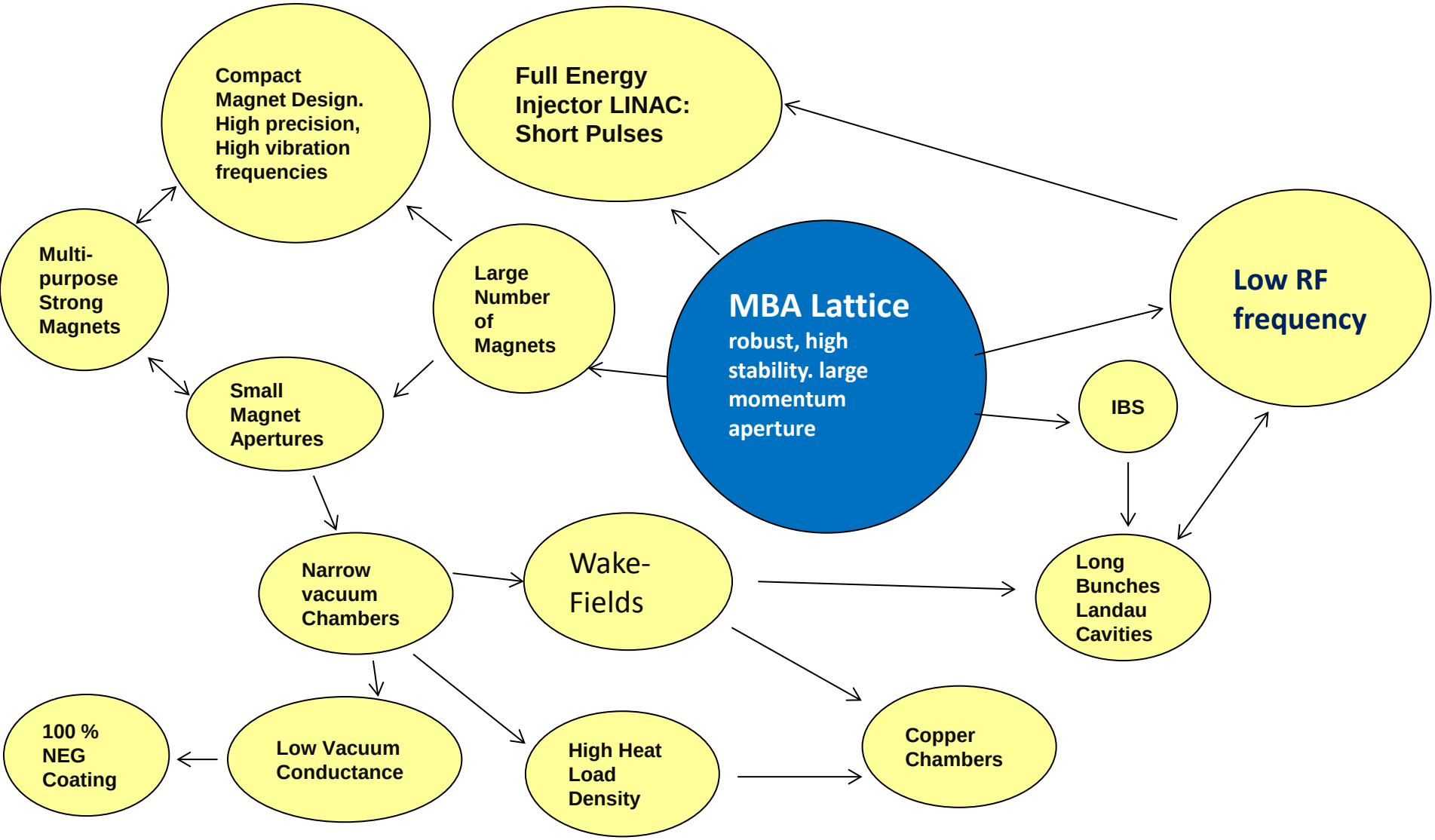
- The MAX IV Design Concept
- MAX IV Parameters
- Storage Ring Subsystem Status
  - DC Magnets
  - Pulsed Magnets
  - Vacuum Chambers
  - RF System
  - Power Supplies
- MAX IV LINAC Commissioning Results
- Conclusions - The Next Steps

The MAX IV Approach

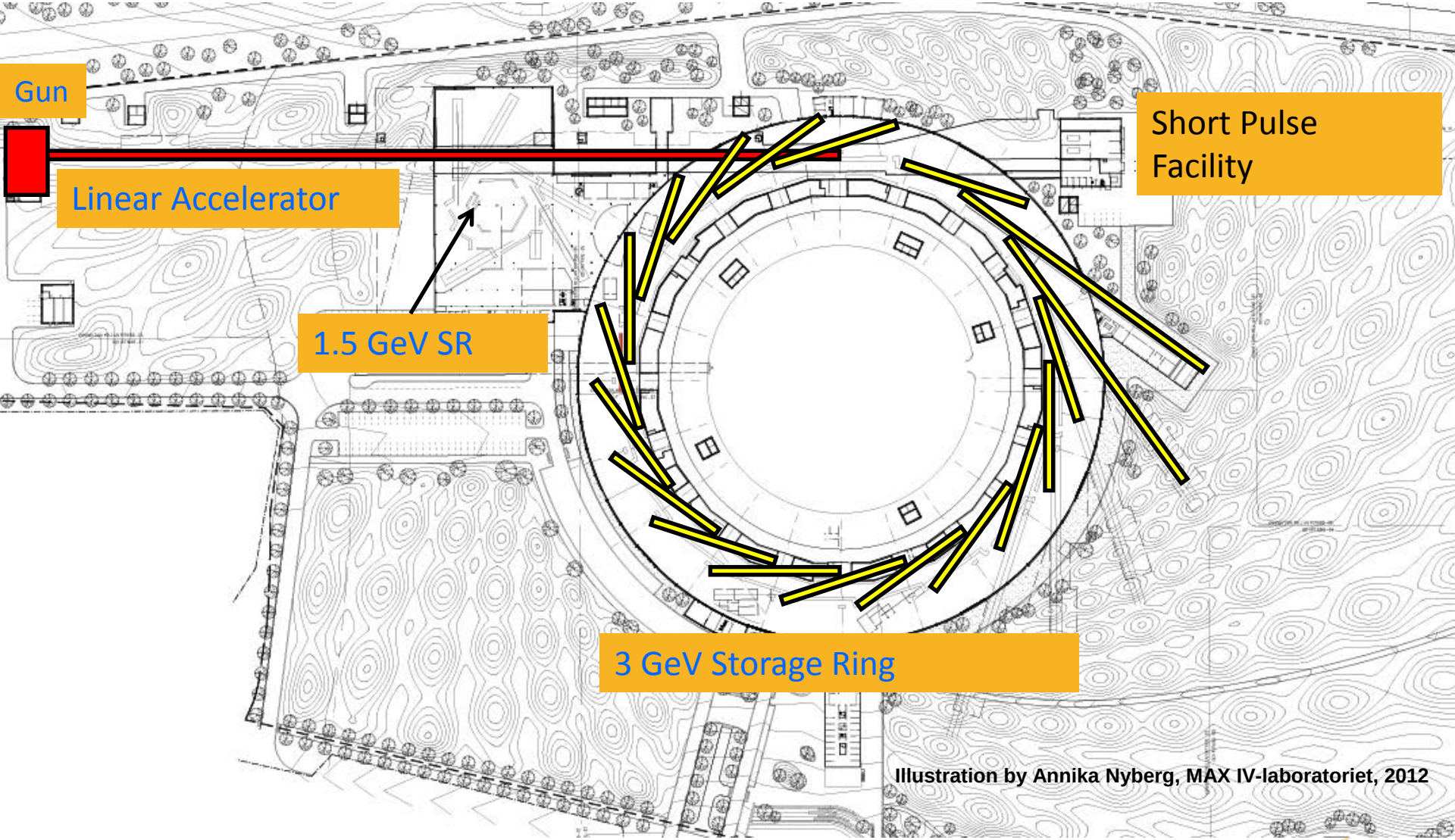
- Different machines for different uses:

1. A high energy ring with ultra-low emittance for hard X-ray users.
2. A low emittance low energy ring for soft radiation users.
3. A LINAC based source for generating short pulses and allowing for future development of FEL source.

MAX IV - An integrated Solution



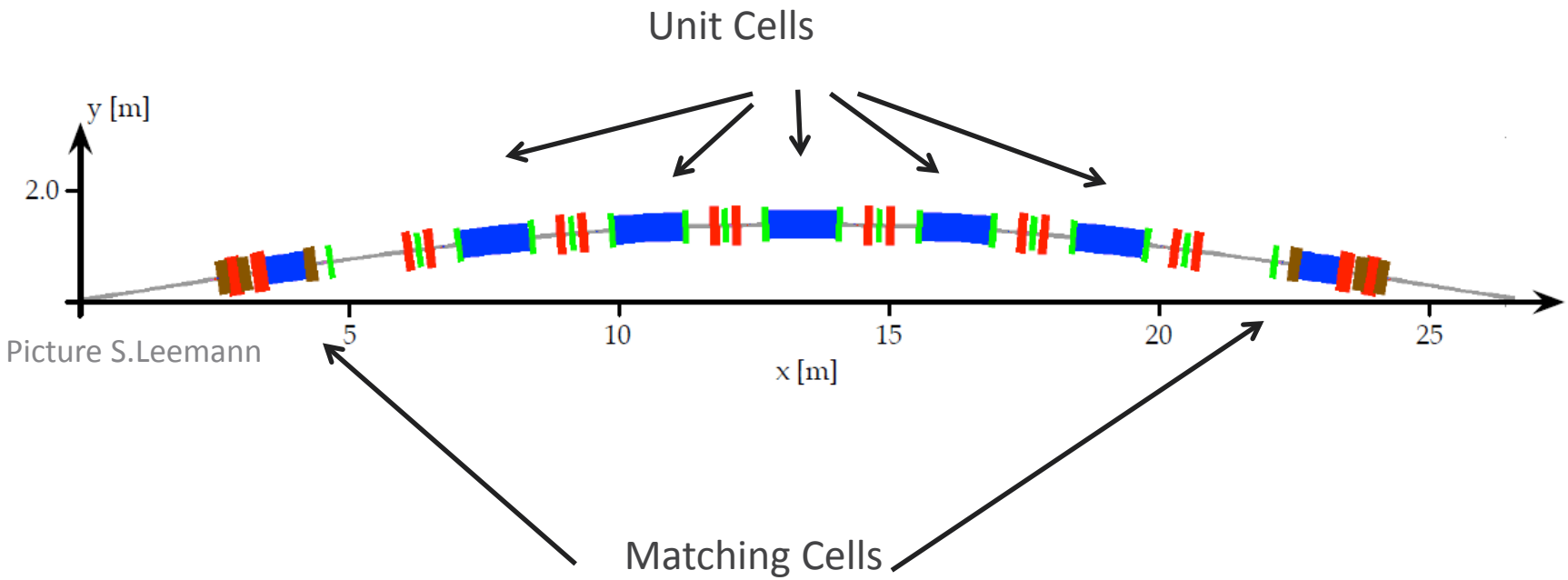
MAX IV – an overview



Energy	3	GeV
Current	500	mA
Emittance	0.2 - 0.33	nm rad
Circumference	528	mA
# straight sections	20 × 5 m	

The MAX IV 3 GeV ring Lattice

7-bend achromat
20 periods



Picture S.Leemann

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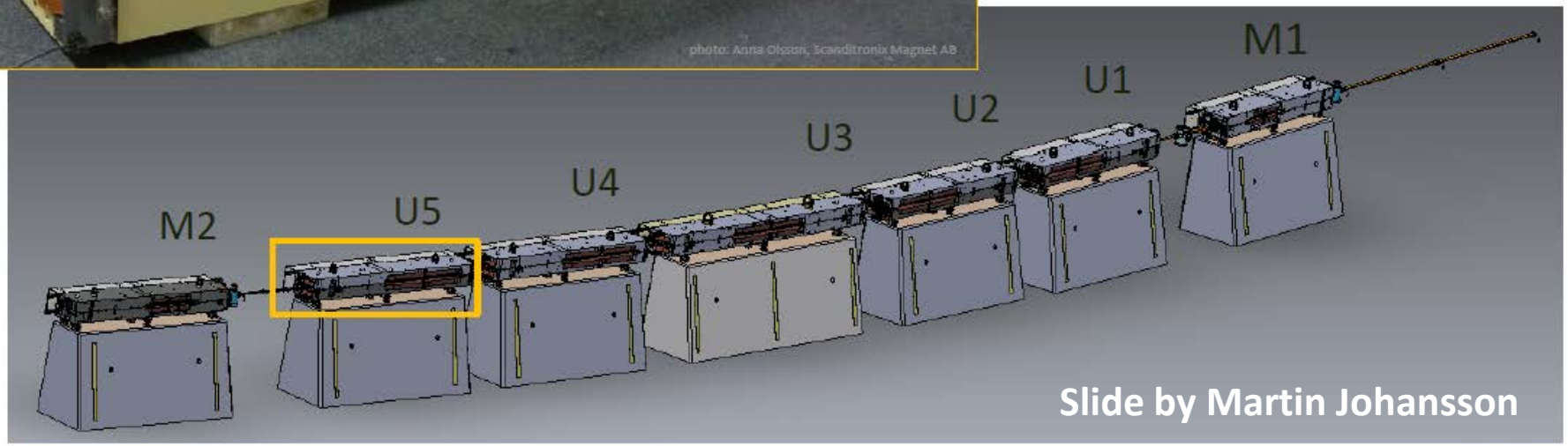
MAX IV 3 GeV Ring DC Magnets

- *Each cell is realized as one mechanical unit containing all magnet elements.*
- *Each unit consists of a bottom and a top yoke half, machined out of one solid iron block, 2.3-3.4 m long*.

- a U5 bottom half →
- ↓ an assembled U5



Slide by Martin Johansson

MAX IV DC Magnets

- Magnetic and Mechanical Design by MAX IV Lab.
- Production and Magnetic Measurements contracted out to industry (two companies).
- Suppliers deliver fully assembled units ready for installation.
- Suppliers are responsible for mechanical tolerances / Maxlab is responsible for magnetic performance.
- Tolerances (dipole surf. and quad/6pole/8pole guiding surf.): ±20 µm.
- MAX IV provided the material (ARMCO grade 4) for the yokes for the two manufacturers.
- Integrated magnet concept:
  - Common yoke allows achieving tight relative alignment within block.
  - Lean design pushes up eigenfrequencies
  - System integration done by industry allows streamlined installation
  - *Assumption: mechanical behaviour defines the magnetic behaviour*

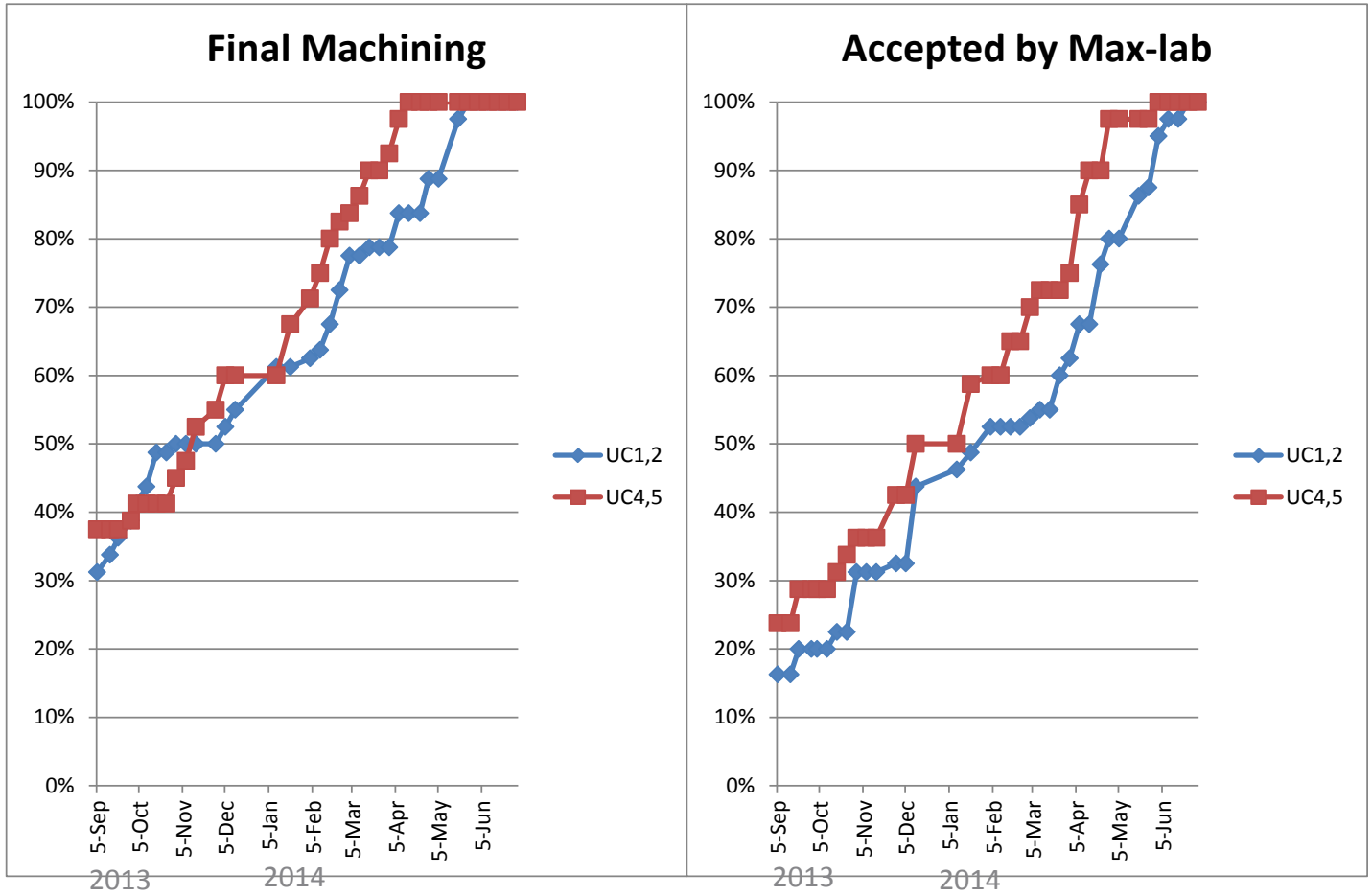
MAX IV DC Magnets Production

- Contracts signed in September 2011.
- Major Challenges
  - Achieving acceptable production throughput for precise yoke machining and mechanical measurements.
  - Verifying/Certifying magnetic measurement capabilities at the suppliers.
  - Integration with Vacuum/Support designs.

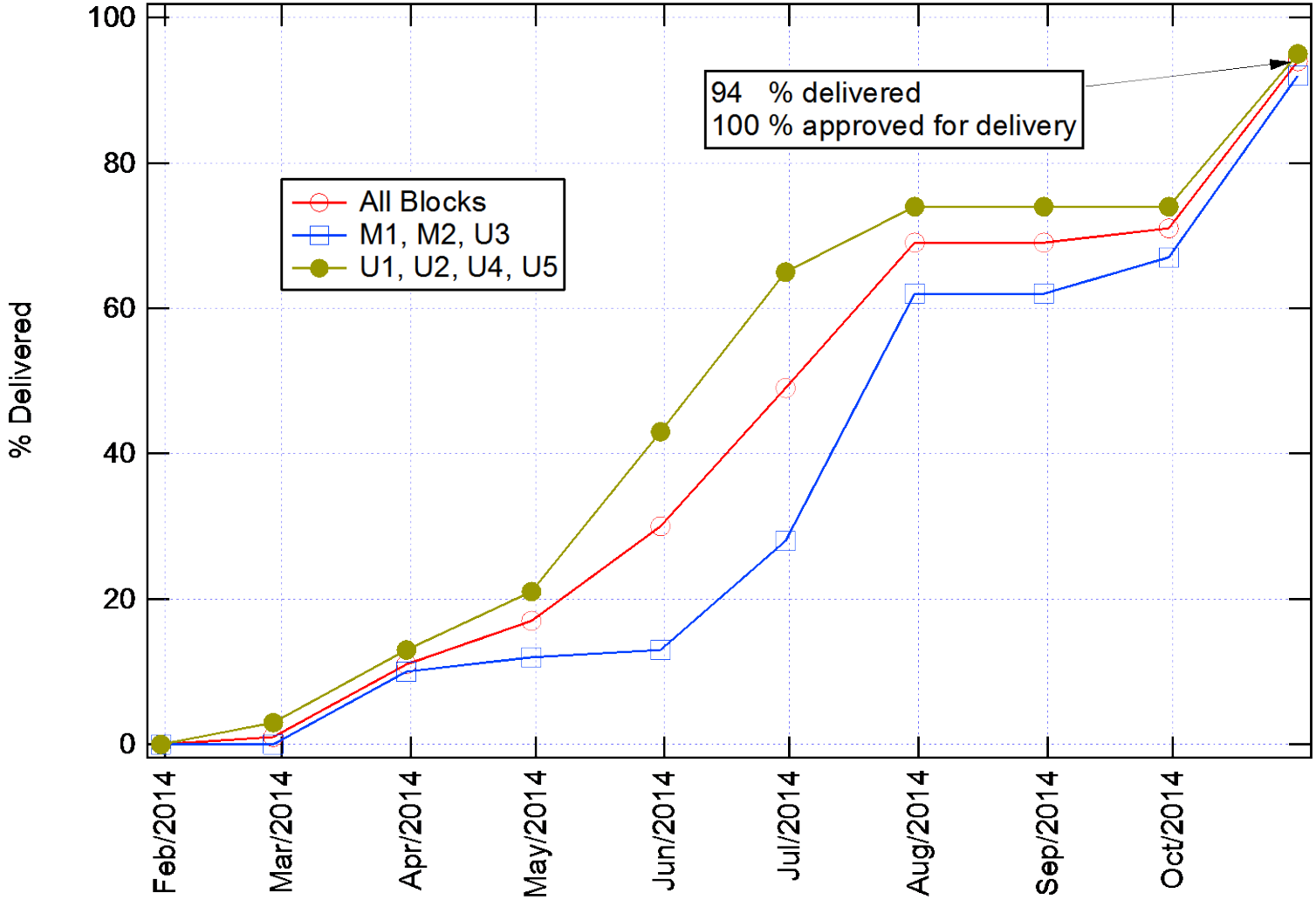
3 GeV Ring Magnets – Production History

U1, U2, U4, U5 – Yoke Machining

Pre-series yoke machining approved September 2012



DC Magnet Production History and Status



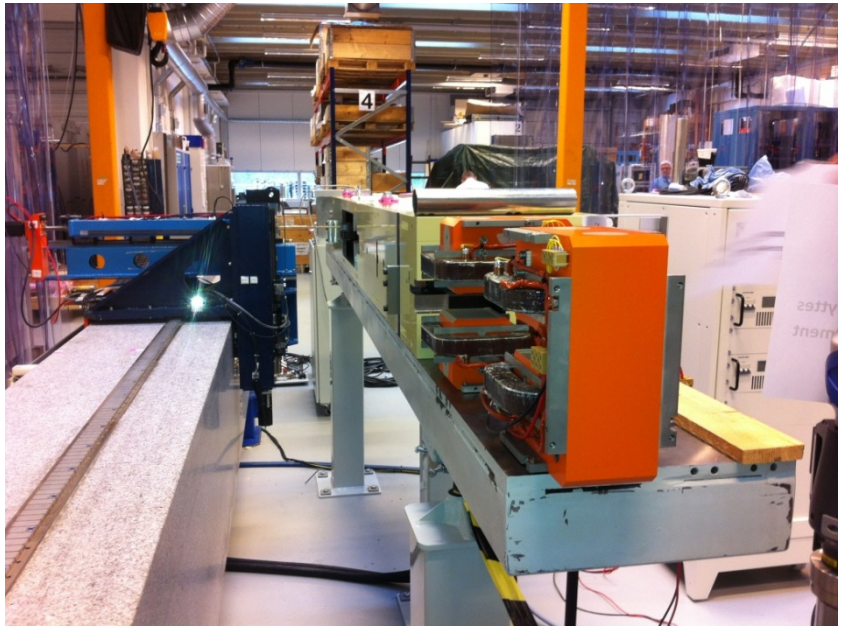
Magnet Measurement Results - Highlights

Dipoles	140
Quadrupoles	320
Sextupoles	360
Octupoles	120
Correctors	380
TOTAL	1320

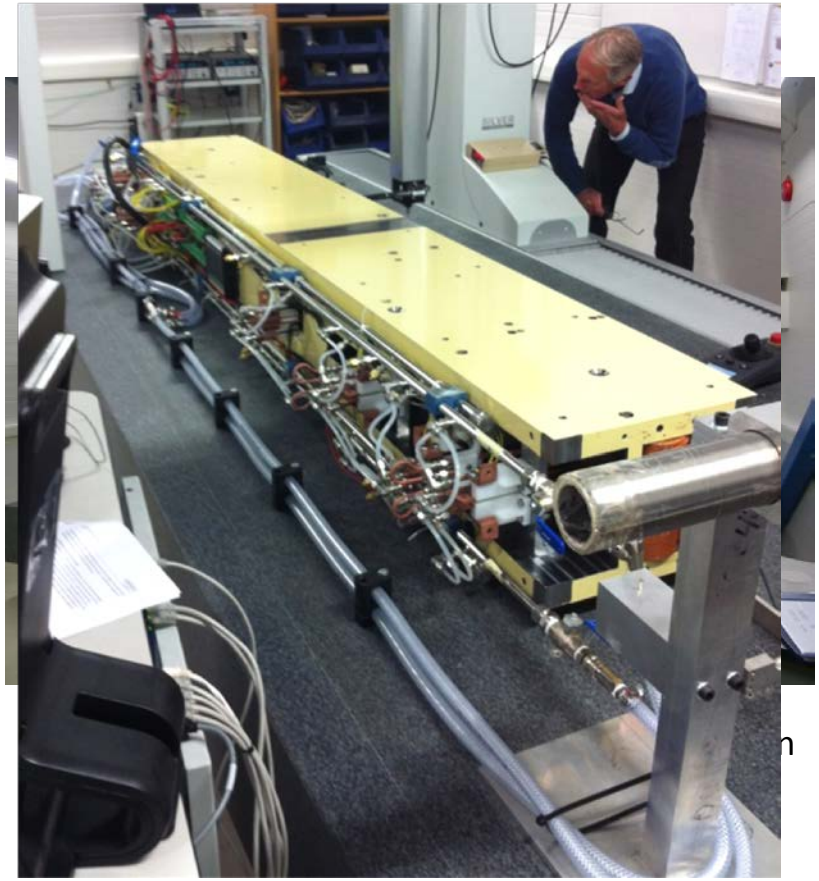
Hall Probe

Rotating Coil

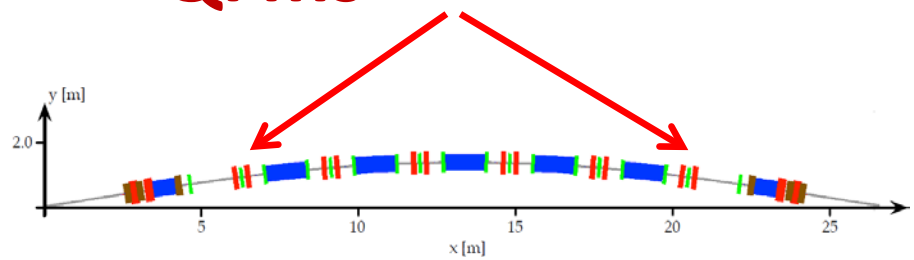
Magnet Characterization Benches – Hall

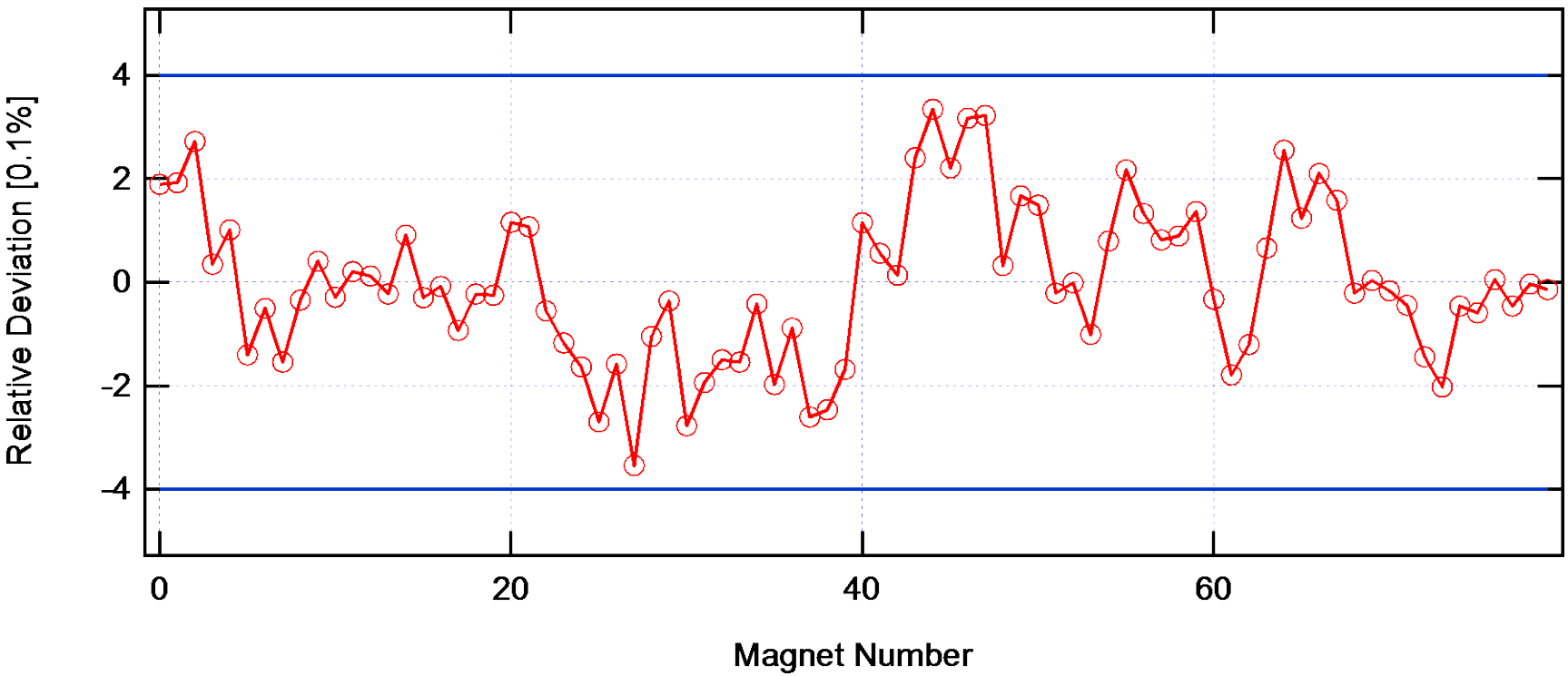


DF: Adapted ID bench from ADC



Result Highlights: Spread of main component in QFms





After grouping into families

Grouped by Straights

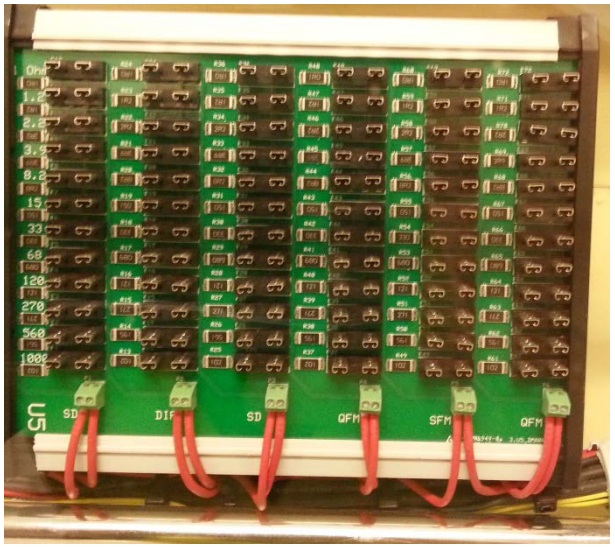
Grouped by Achromats

	MAX deviation to average within any family [0.1%]	Standard Deviation over all families [0.1%]
QFE	1.4	0.6
QDE	1.5	0.8
QFm	0.8	0.6
QF	0.9	0.2
SXDE	2.4	1.2
SXFm	4.1	2.1
SXFo	2.7	1.6
SXFi	4.2	1.2
SXD	8.5	4.5
OXX	3.0	3.1
OXY	7.5	3.2
OYY	5.3	1.8

INTEGRATED DIPOLE		
	MAX deviation to average within family [0.1%]	Standard Deviation over family [0.1%]
M blocks	3.7	1.1
U blocks	2.6	0.9
INTEGRATED QUADRUPOLE		
M blocks	3.1	1.2
U blocks	3.4	1.1

Dipoles in All M Blocks series connected to one ps

Dipoles in All U Blocks series connected to one ps

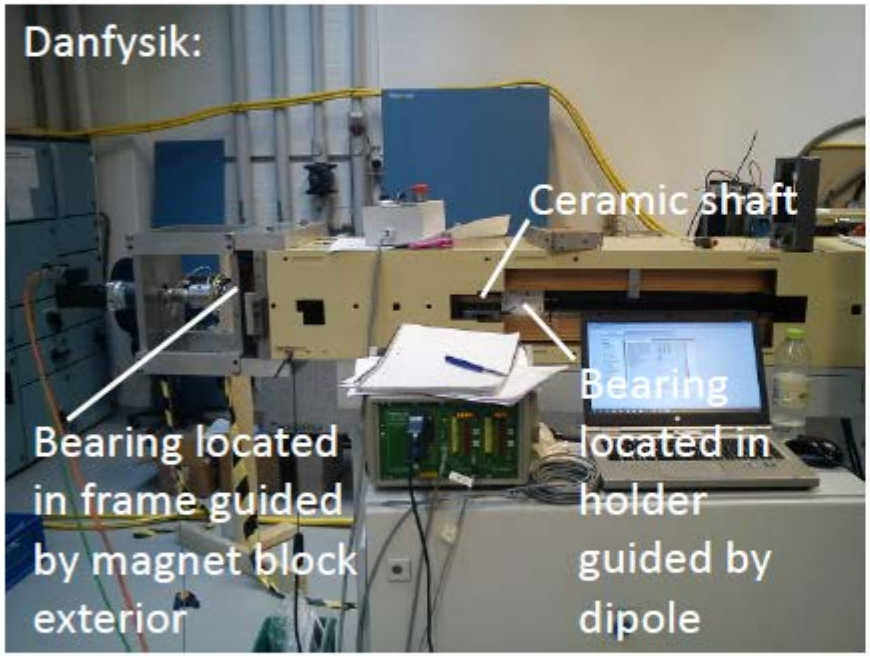


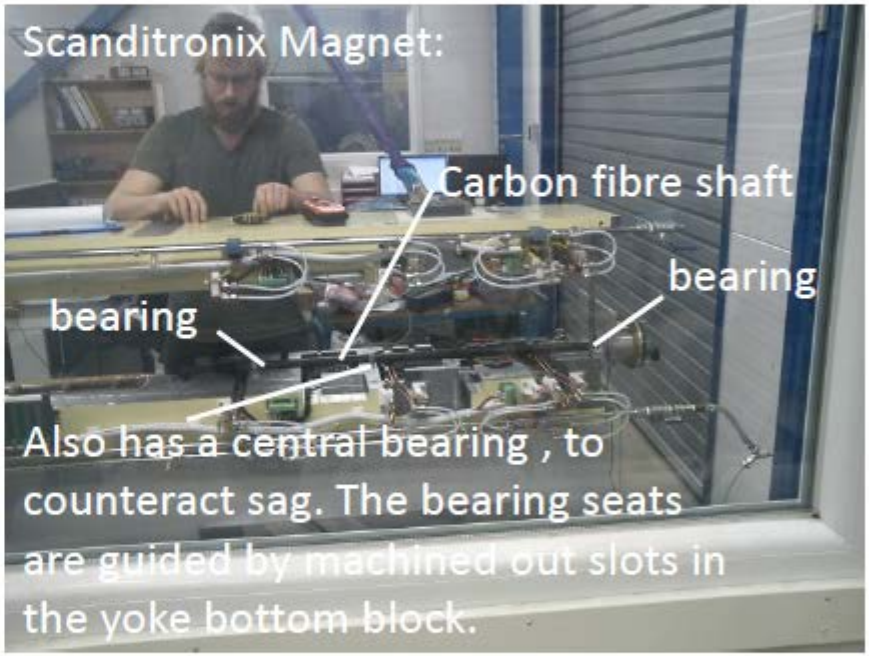
Only QF magnets in U3 are adjusted (trim coils). No shunting used

Slide by Martin Johansson

3 GeV field measurement results – alignment within magnet blocks

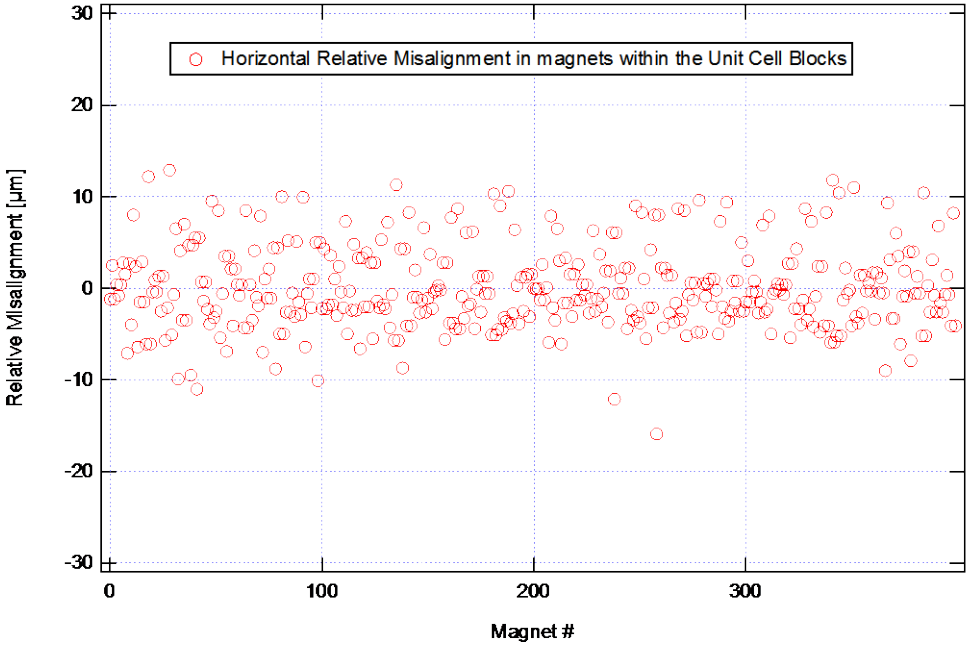
- Both magnet suppliers chose solutions with a long rotating shaft containing several measurement coil, located at each magnet element:





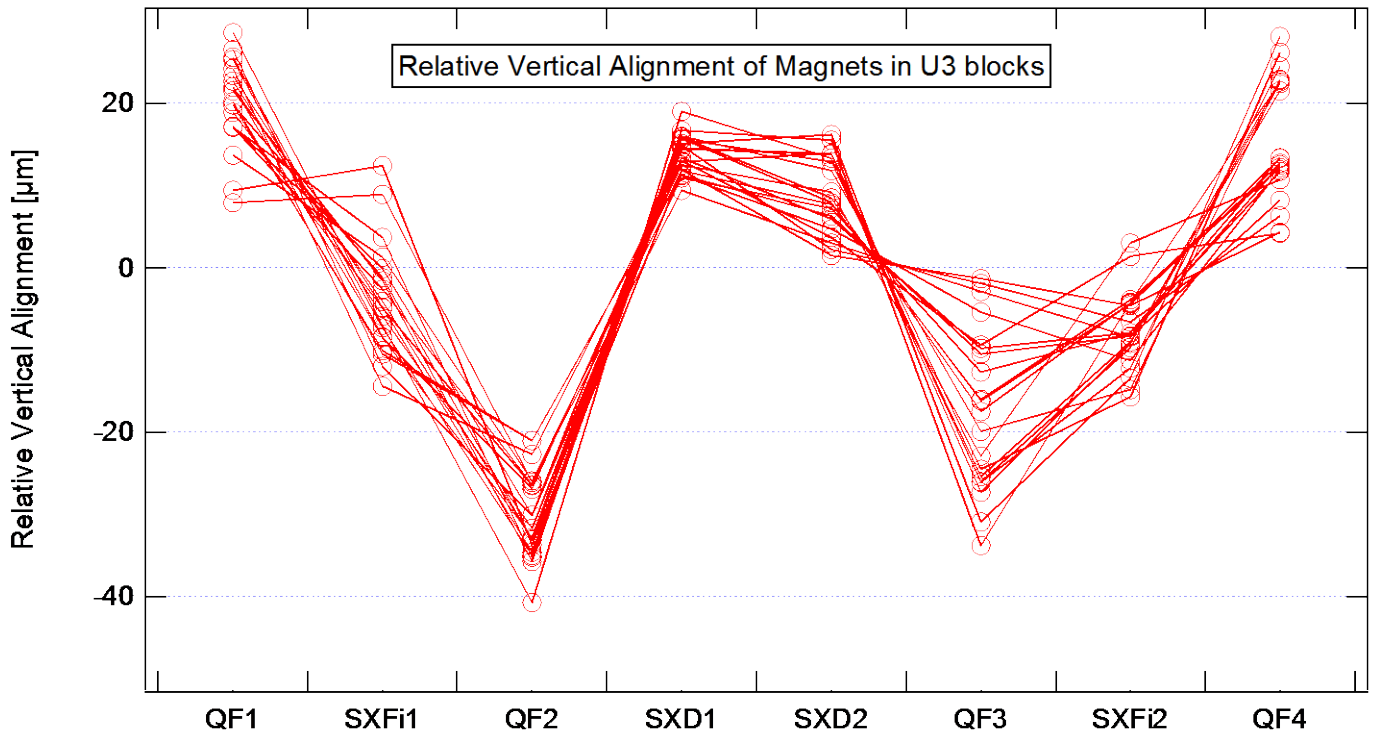
- Magnets technical specification requires rotating axis to be aligned within ±0.1 mm to magnet block ref. surfaces, which is rather relaxed.
- Magnet spec. based on principle decision that we believe magnetic centres are given by mechanical locations of pole profiles, we do not attempt to fiducialize to field measured locations.

Relative Misalignments within the Unit cell Blocks



	RMS Misalignment	
	Horizontal [µm]	Vertical [µm]
Quads	4.5	12.7
Sexts	5.0	9.7
Octupoles	4.1	9.5

Rotating coil shaft sag – U3 magnet blocks



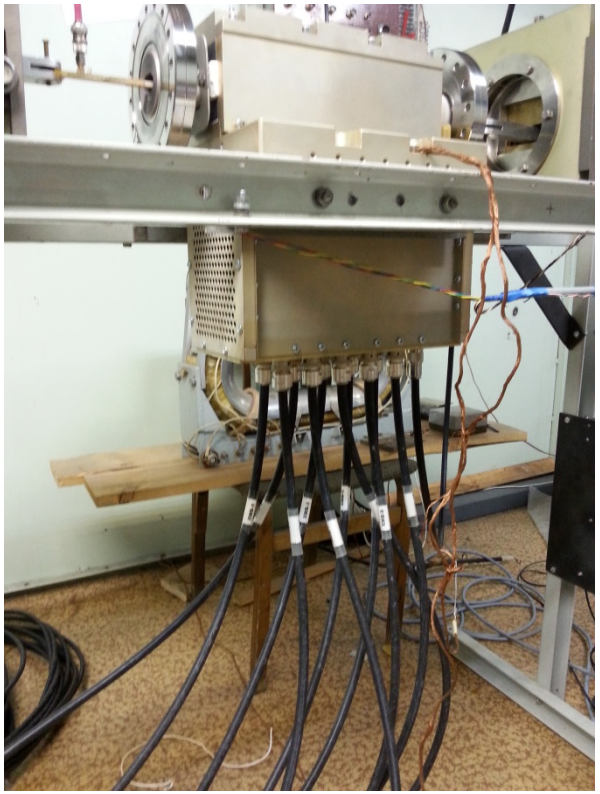
Simplified analytic estimate of the sag
ceramic shaft length = 1.2m ,
outer radius = 11 mm, inner radius = 7 mm

$$Sag = \frac{5}{384}\frac{W_0 L^3}{EI} \approx 60\ \mu\mathrm{m}$$

Sag compensated RMS vertical misalignment for U3 blocks: 7.3 µm:

Pulsed Magnets – Dipole Kickers

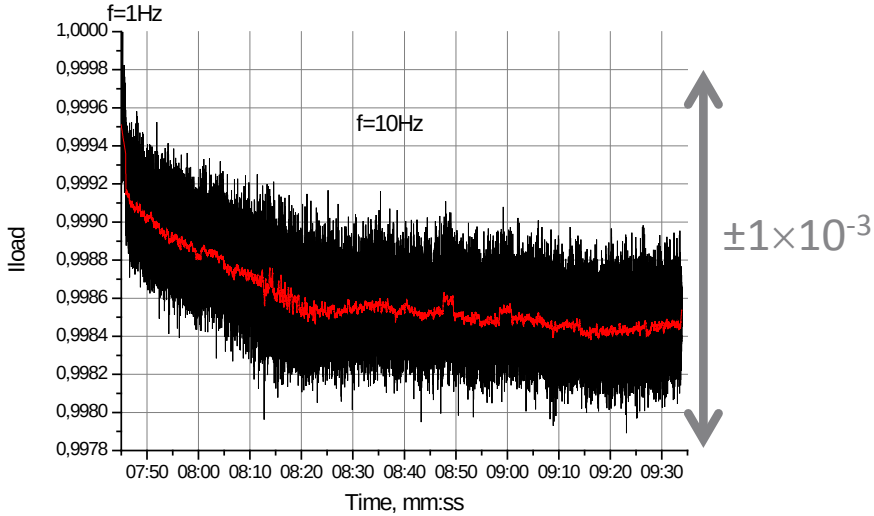
- FAT of all Injection kickers and pingers done at Budker Institute 11th – 12th August 2014.
- Kickers delivered to MAX IV in October 2014
- Site Acceptance tests planned for December 2014.



3 GeV ring kicker on the magnetic measurement stand

Pulsed Power Supply

Results of 1.5 GeV kicker pulser testing.



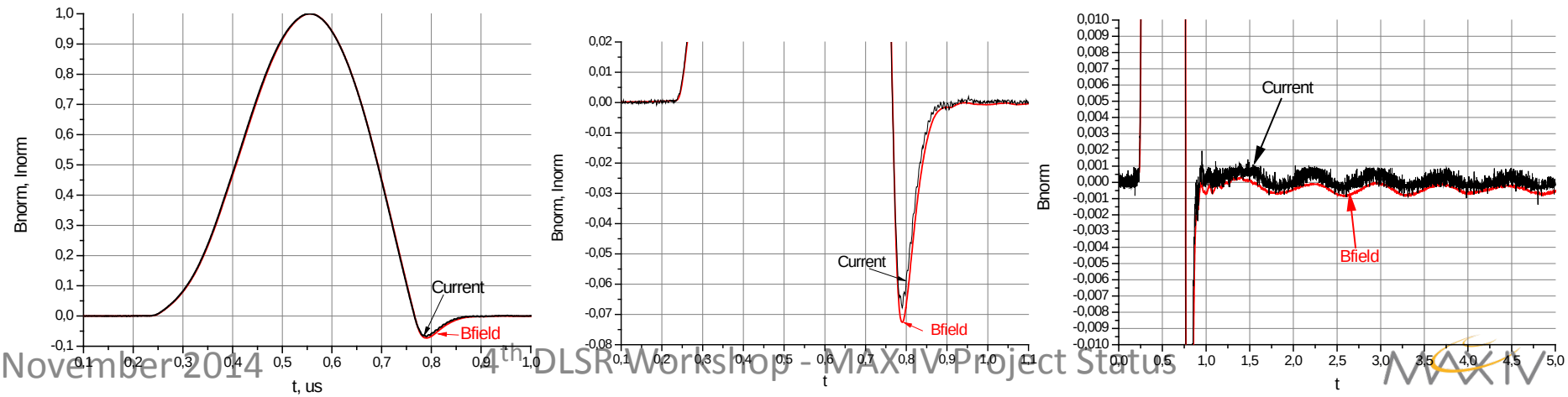
1.5GeV kicker power supply run at 7.8kV charging voltage. Iload=1040A.

Lecroy WS62Xs oscilloscope with noise reduction (+3bit) and signal shifting.

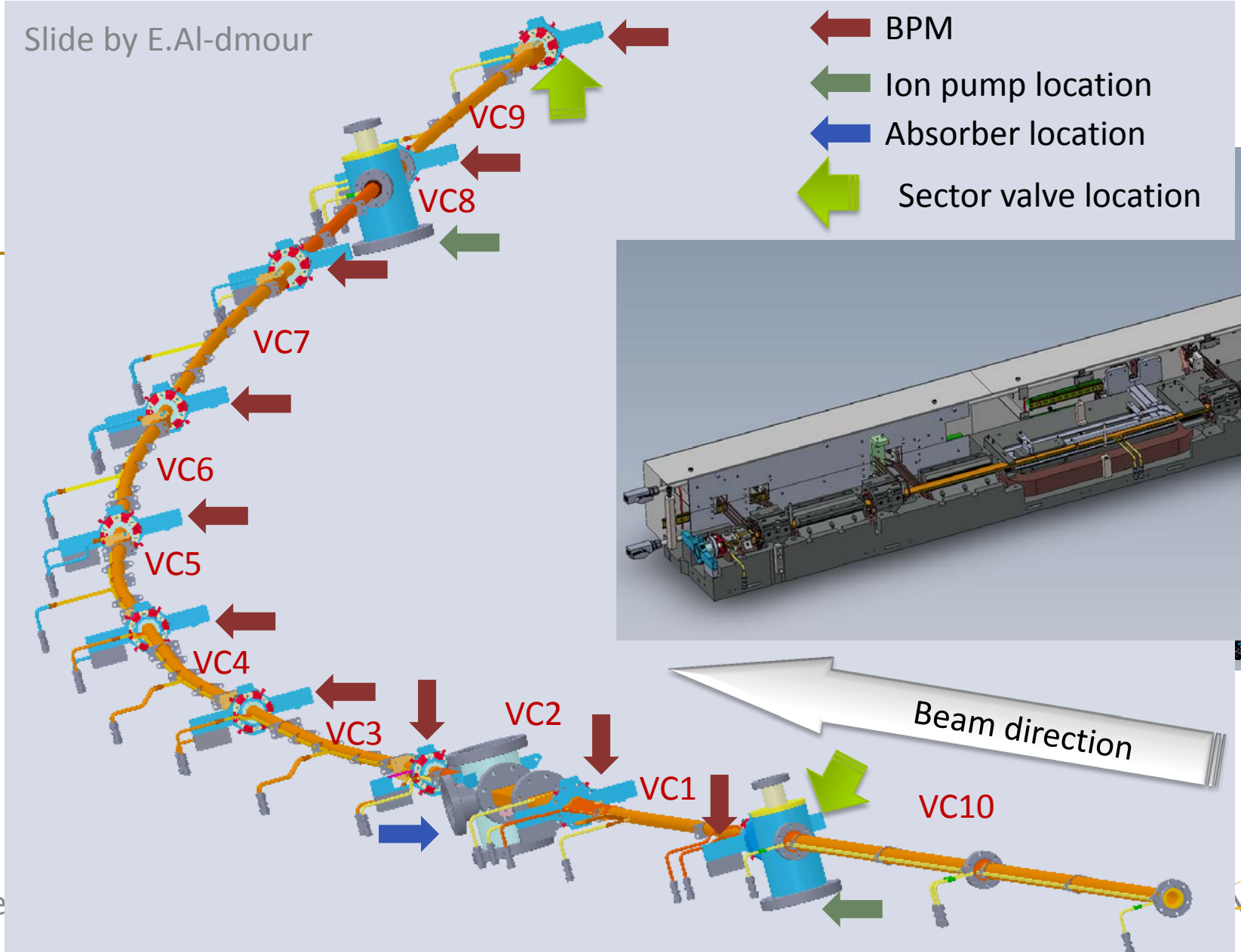
Total number of shots during the tests ~5*10^5 at nominal current and 10Hz rep. rate.

Slide by BINP

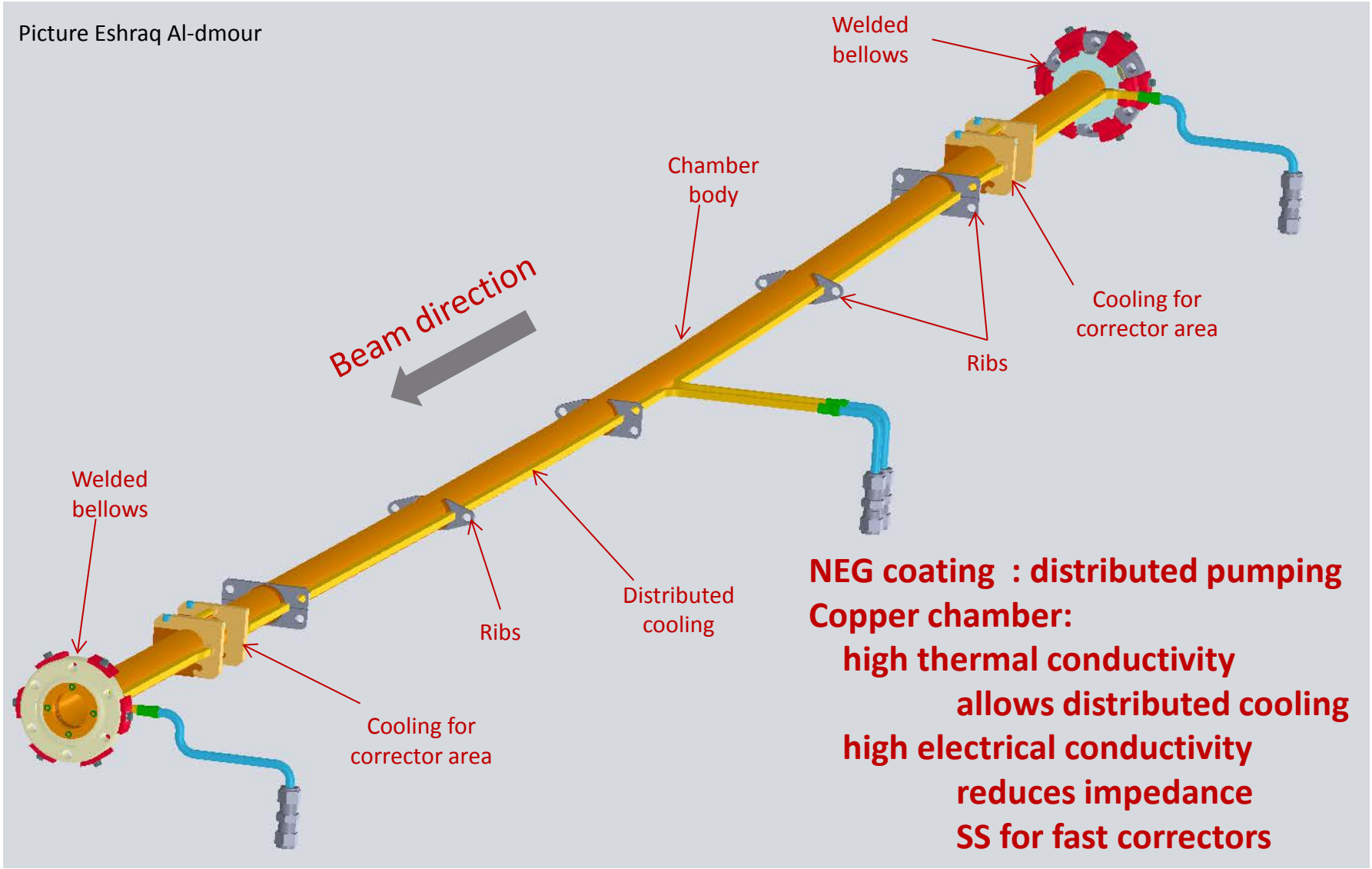
Waveforms of the magnet current and magnetic field. Imax=1013A, Bmax=480G.



MAX IV 3 GeV ring vacuum system layout



MAX IV 3 GeV Ring Vacuum System

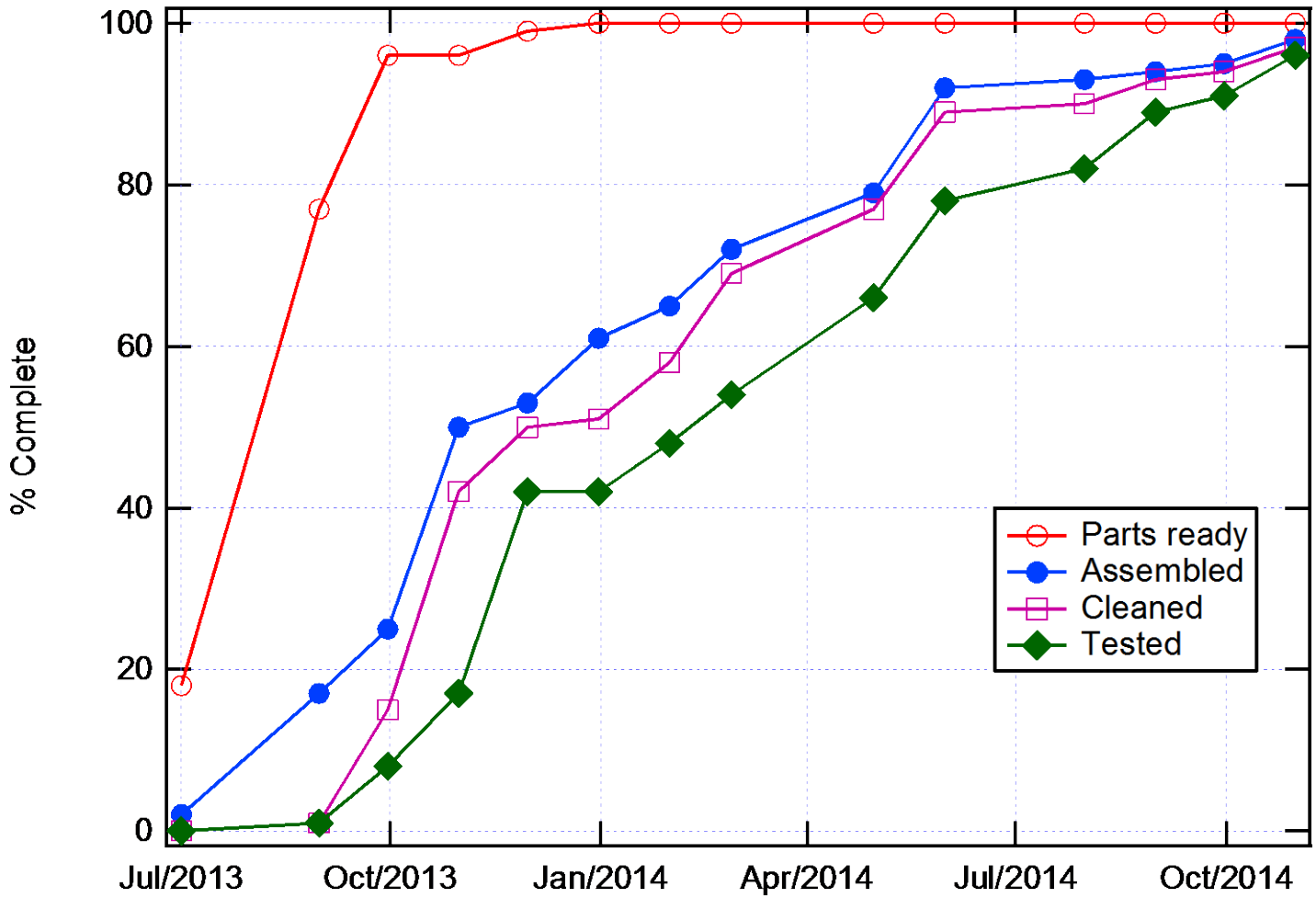


NEG coating : distributed pumping

Copper chamber:

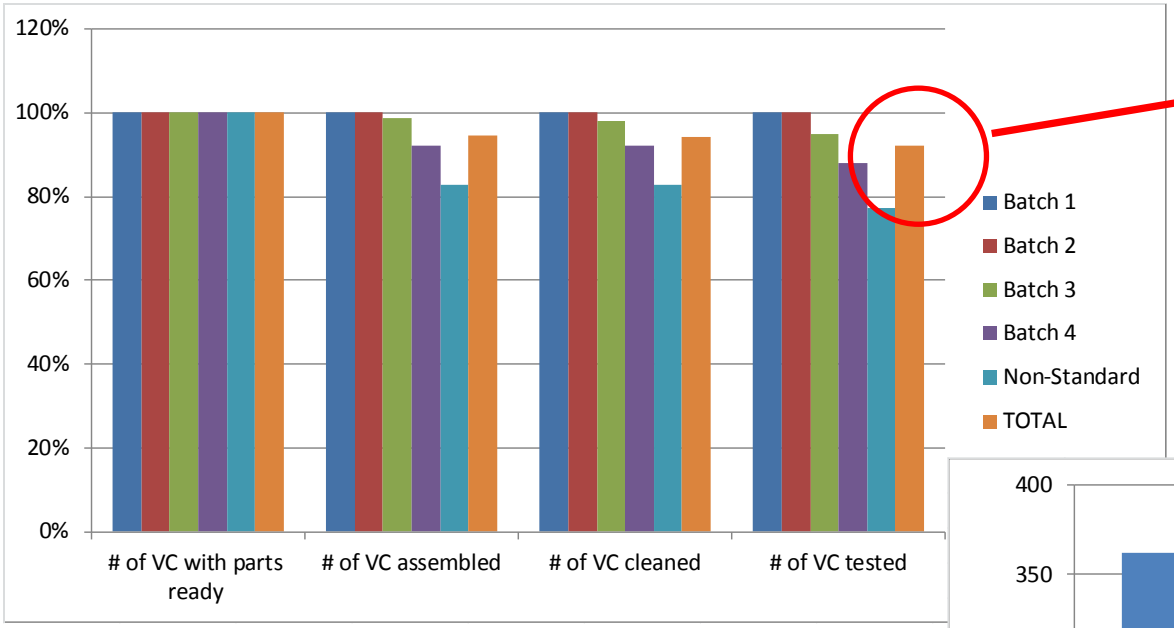
- **high thermal conductivity**
  - **allows distributed cooling**
- **high electrical conductivity**
  - **reduces impedance**
  - **SS for fast correctors**

Chamber Production History and Status

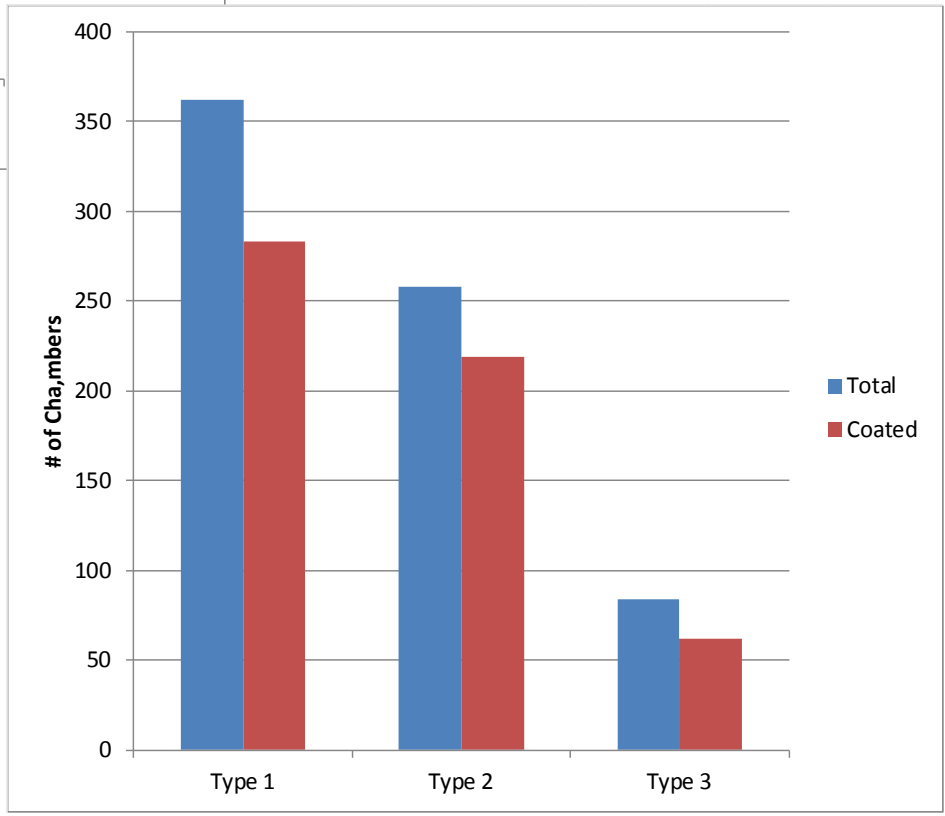


"standard " chambers

Chamber Production and Coating Status



92% of all chambers tested and approved



80% of the chambers successfully NEG coated

First Assembly Results from MAX IV – Mockup tests

Pictures by Chiara Pasquino

Mockup Tests

Baking oven assembled around the chamber

Chamber hanging from strongback

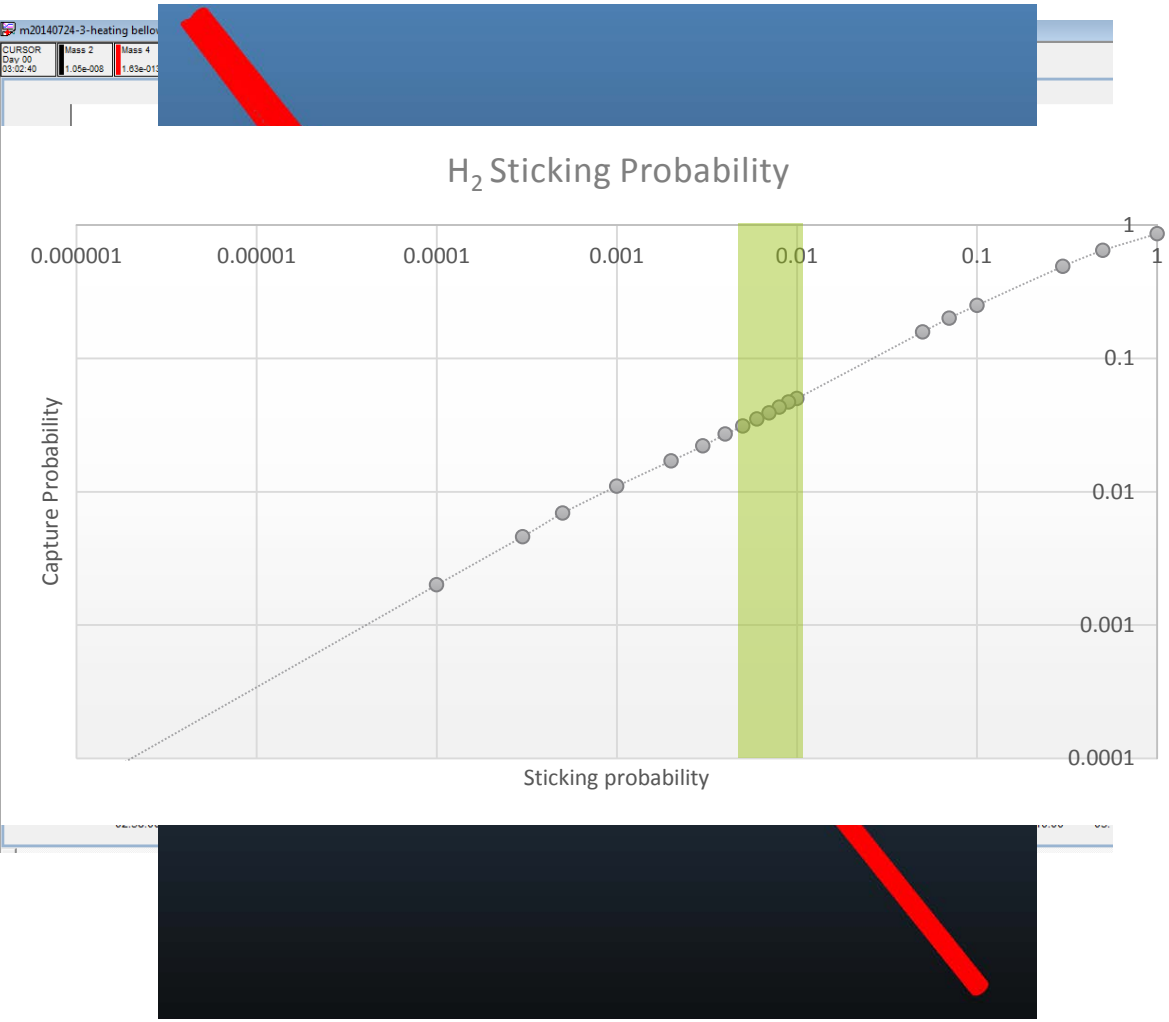
Pictures by Chiara Pasquino

Vacuum performances: first remarks

- No leaks were found at any stage
- No contaminations were detected (halogens peaks, hydrocarbons..)
- The ultimate pressure after activation was below the sensitivity of our pressure gauges (below $1*10^{-10}$ mbar) and of the SIPs (low reliability in low pressure ranges due to field emission).

Slide by Chiara Pasquino

Vacuum performances: monitoring and evaluating



In order to estimate the effective pumping speed after activation, it is possible to inject a small flow of H_2 gas into the system (i.e. heating the bellow of the pumping group at different temperatures). The difference in pressure during injection with the SIP on and off will give an evaluation of the effective pumping speed of the NEG. It is possible to translate that into a sticking probability thanks to a molflow simulation.

$$\frac{\Delta P_{OFF}}{\Delta P_{ON}} = \frac{S_{NEG} + S_{IP}}{S_{NEG}}$$

$$S_{NEG} = \frac{\Delta P_{ON}}{\Delta P_{OFF} - \Delta P_{ON}} S_{IP}$$

RF Cavities

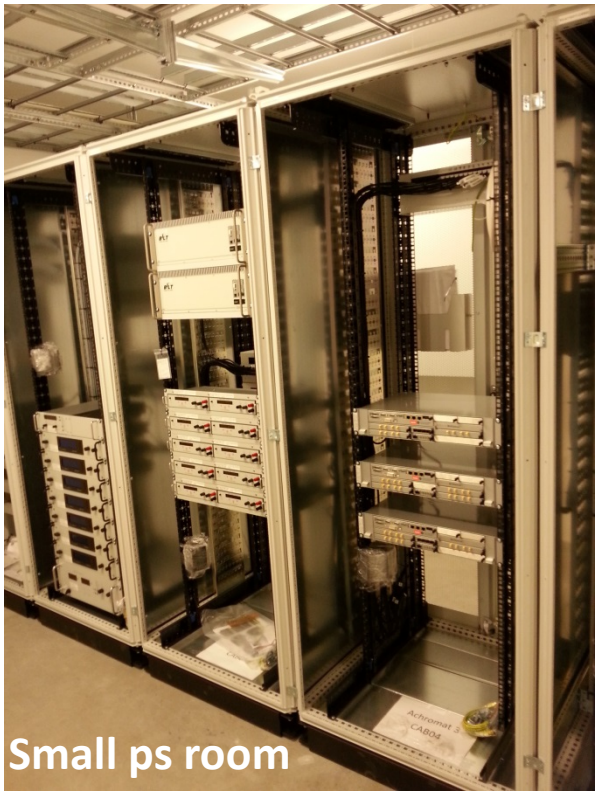
- ALL 100 MHz RF Cavities delivered, 4 cavities conditioned at high power
- All 300 MHz Landau cavities and tuning systems delivered.
- All Temperature regulating systems are built and tested.

High Power RF Plants

- Four contracts placed
  - RF amplifiers
  - Circulators
  - Transmission lines
  - Integration
- Circulators and Transmission lines delivered Oct/Nov 2014.
- 60 kW commercial solid state transmitters under construction
- First pair of SS transmitters planned for Dec. 2014

Magnet Power Supplies

- All Magnet PS for the 3 GeV ring are delivered (no fast correctors)
- All Magnet PS for the 1.5 GeV ring are delivered (no fast correctors)
- PS installation started


Small ps room

Large ps room

Large ps room

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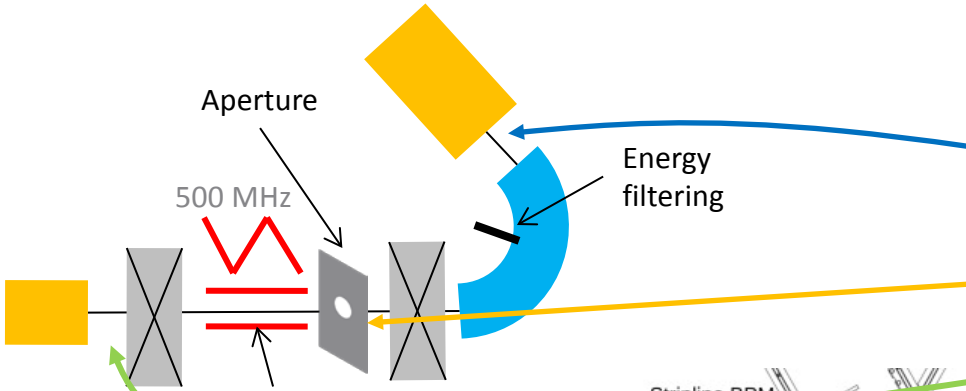
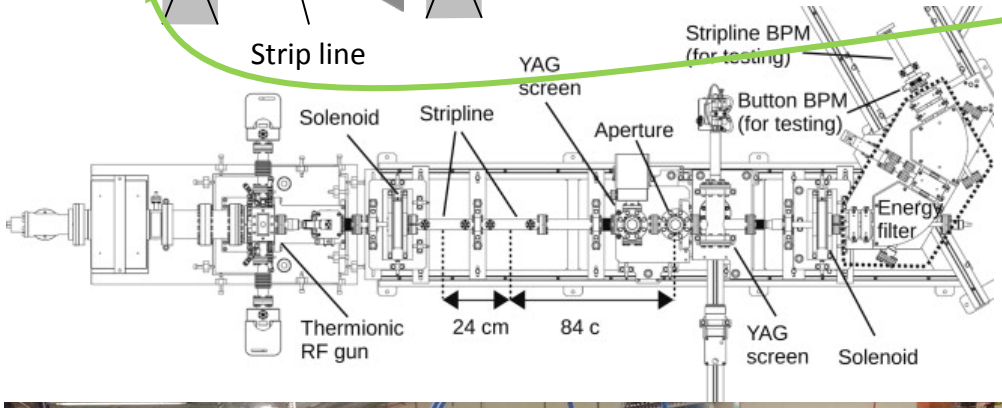
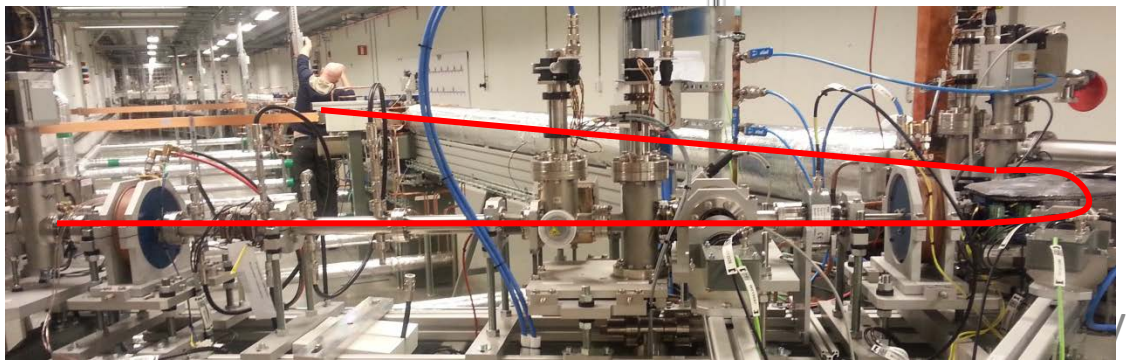
Thermionic RF gun commissioning

Slide by Sara Thorin

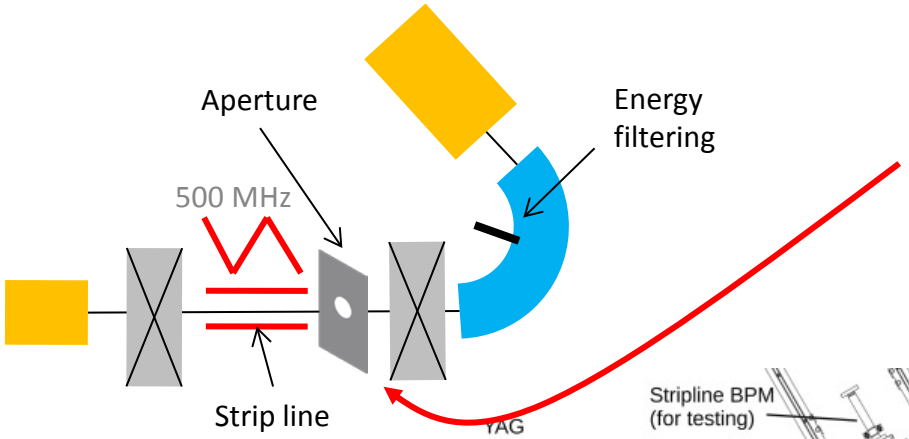




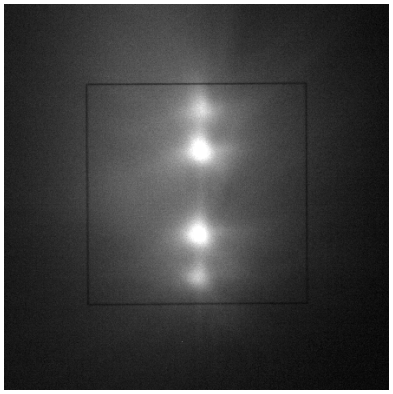


Commissioning parameters	
Charge	0.75 nC/shot
Rep rate	2 Hz
Chopper f	500 MHz

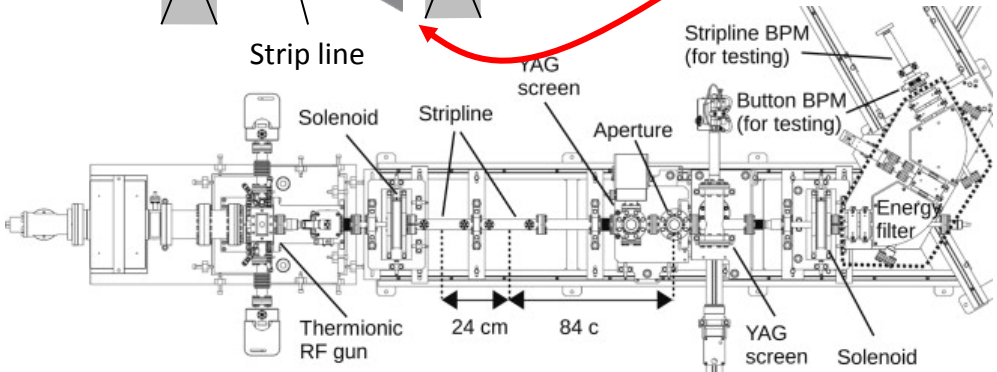
Thermionic gun commissioning

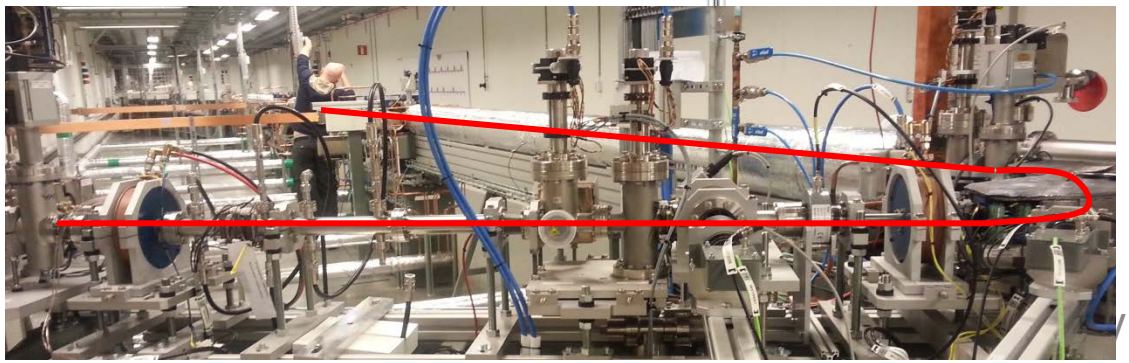


No aperture



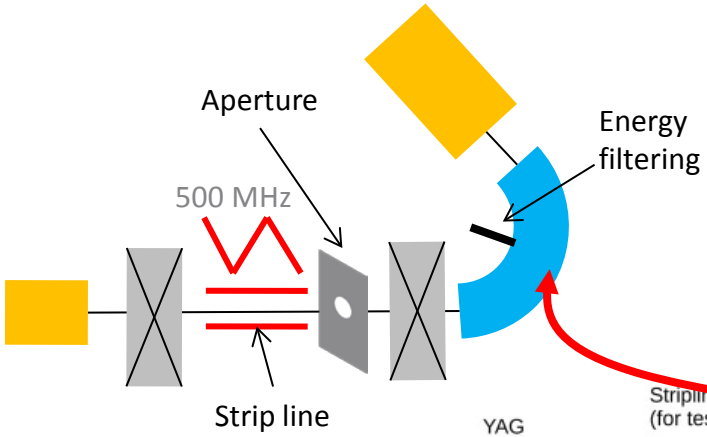
With aperture

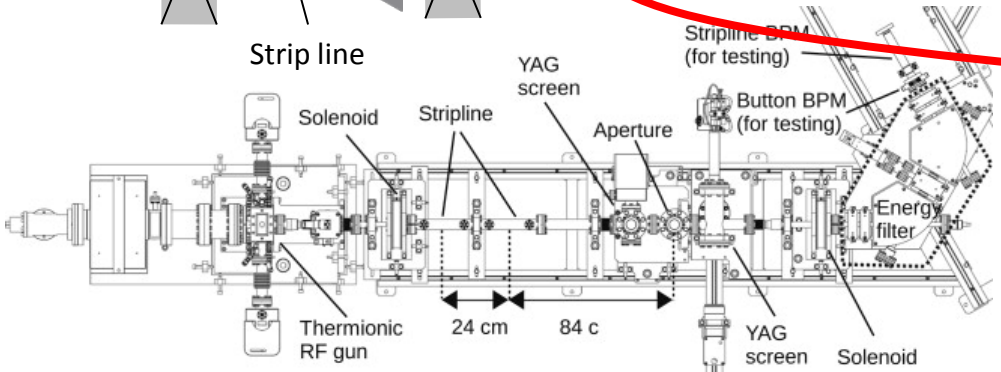




Slide by Sara Thorin

Thermionic gun commissioning





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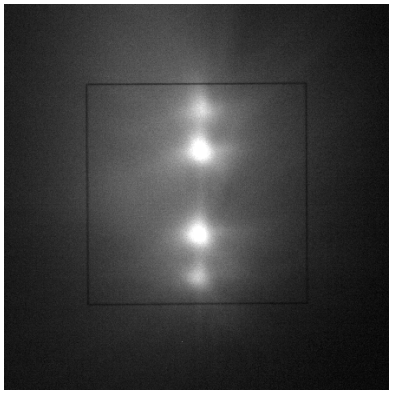

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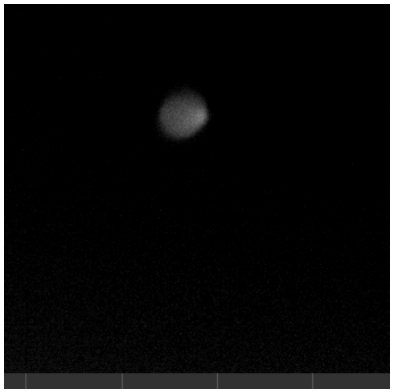

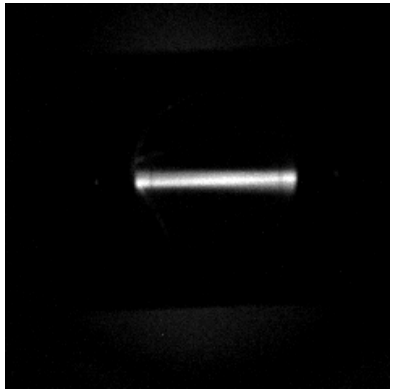

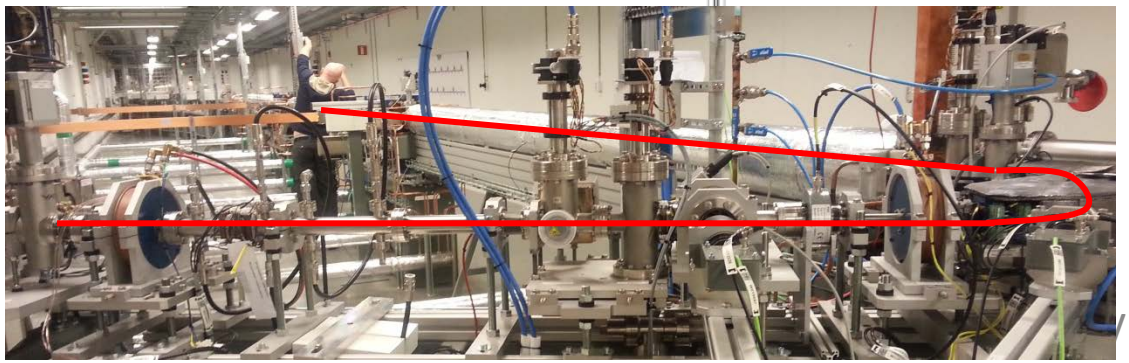

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Thermionic gun commissioning

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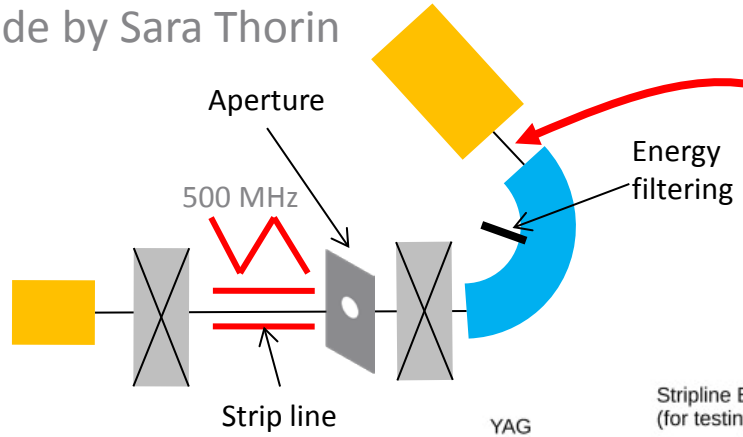

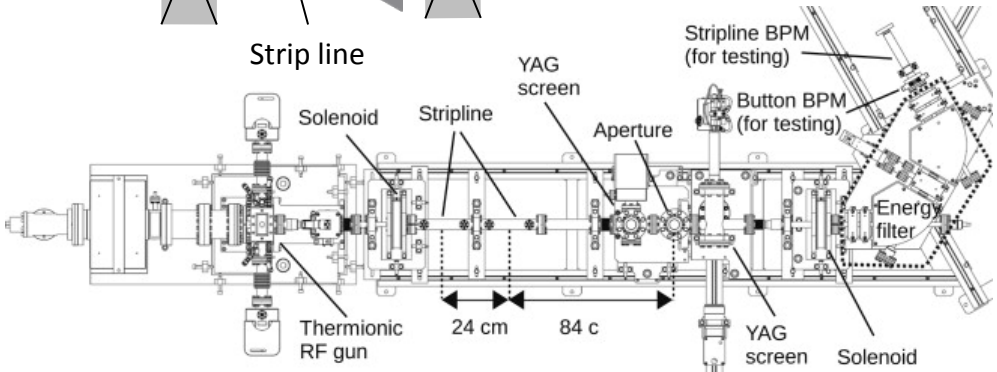

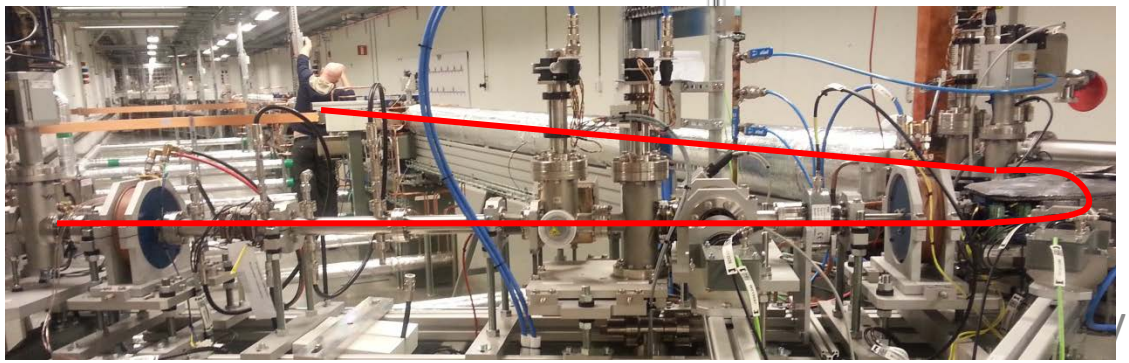

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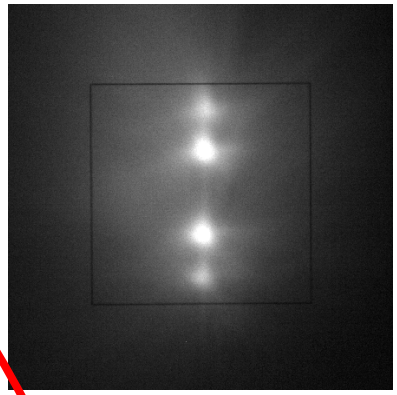
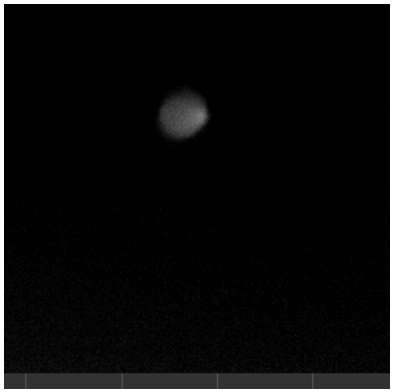
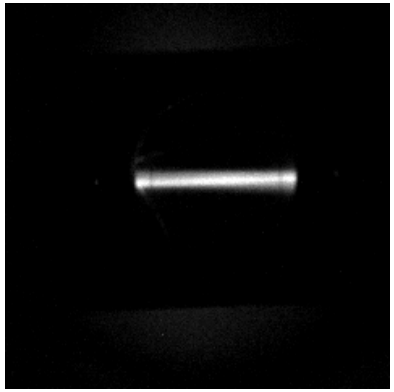
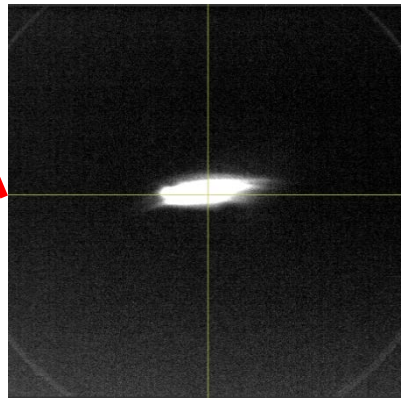


With aperture

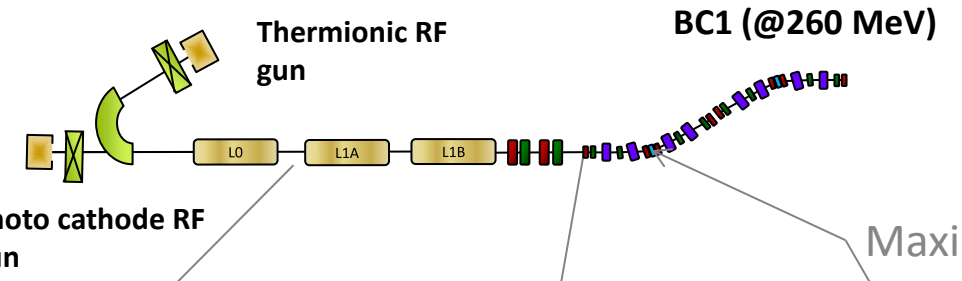


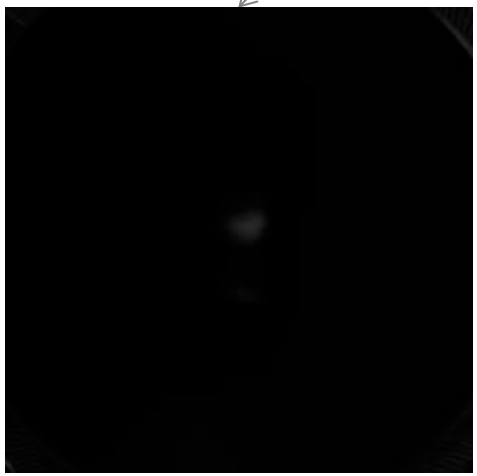


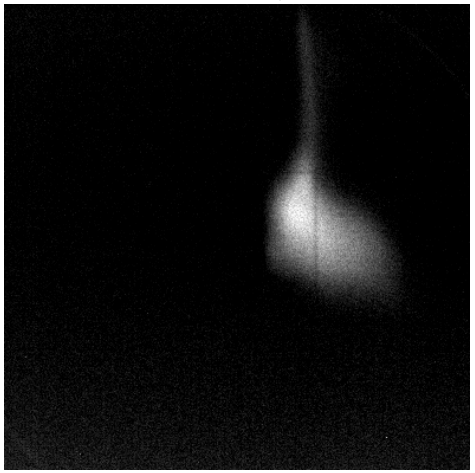


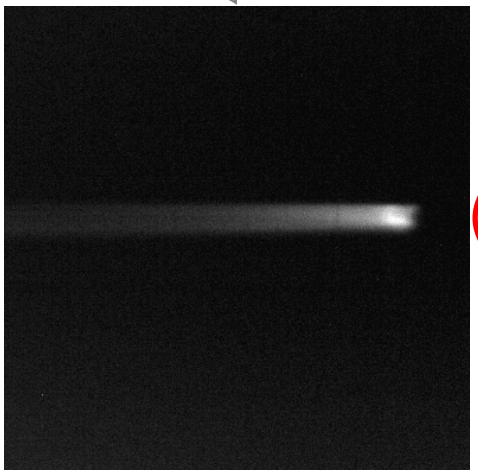
Slide by Sara Thorin

Commissioning









Beam energy 280 MeV

Conclusions – Next Steps

- Components of most subsystems in the 3 GeV ring have been delivered and FAT/SAT results confirm our expectations.
- No show stoppers with the most innovative/risky subsystems (magnets, chambers) .
- Mock-up tests have confirmed expected performance/installation sequence for chambers/magnets.
- Installation of the 3 GeV ring has started and is expect to extend up until mid 2015.
- Commissioning of the LINEAR accelerator is under way.
- Major unknown at the moment
  - RF Transmitters