Max IV Project Status Report

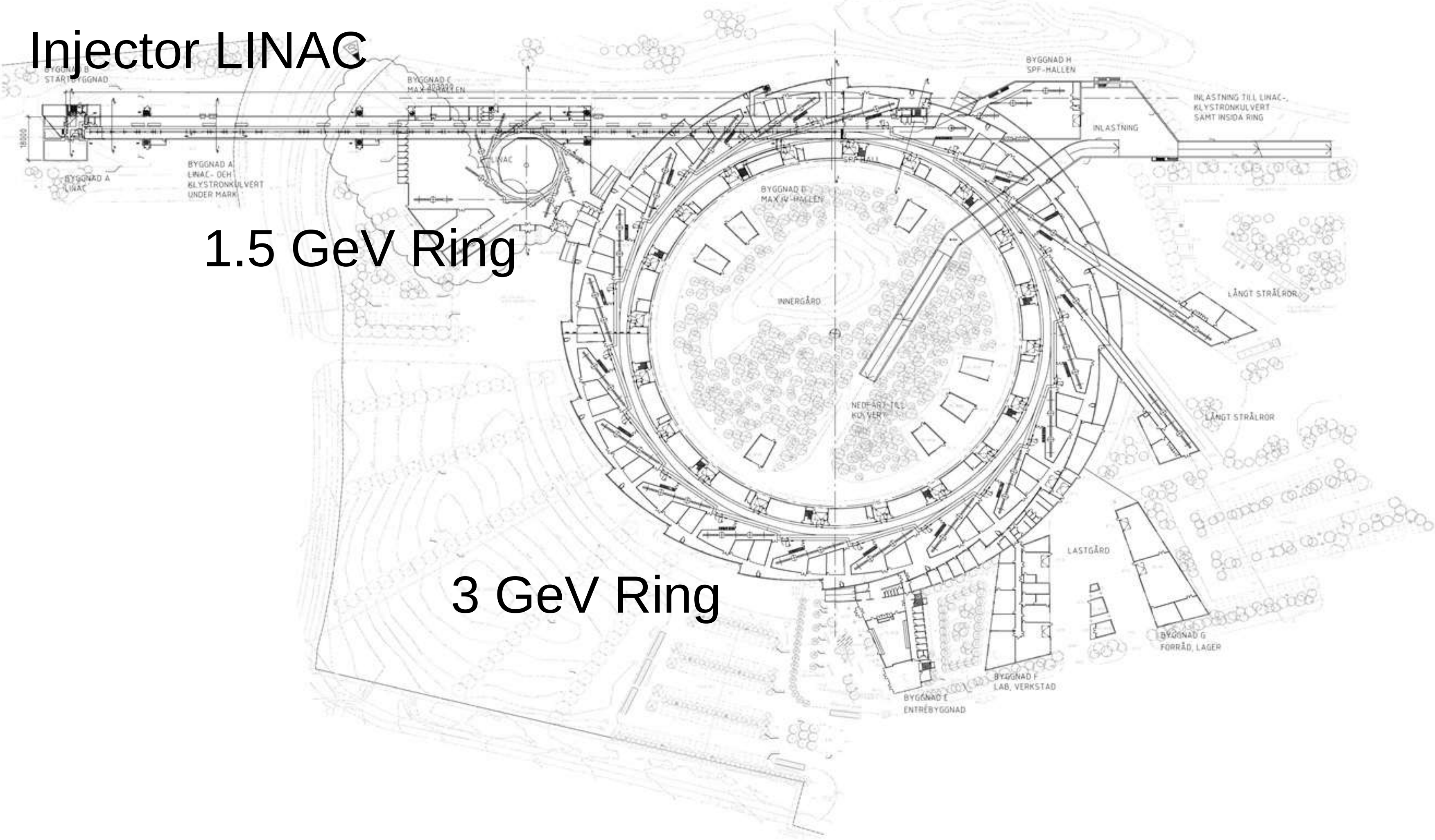
Pedro F. Tavares, on behalf of the Max IV Project Team

ESLS XIX
23rd & 24th November 2011, ISA, Aarhus University, DK

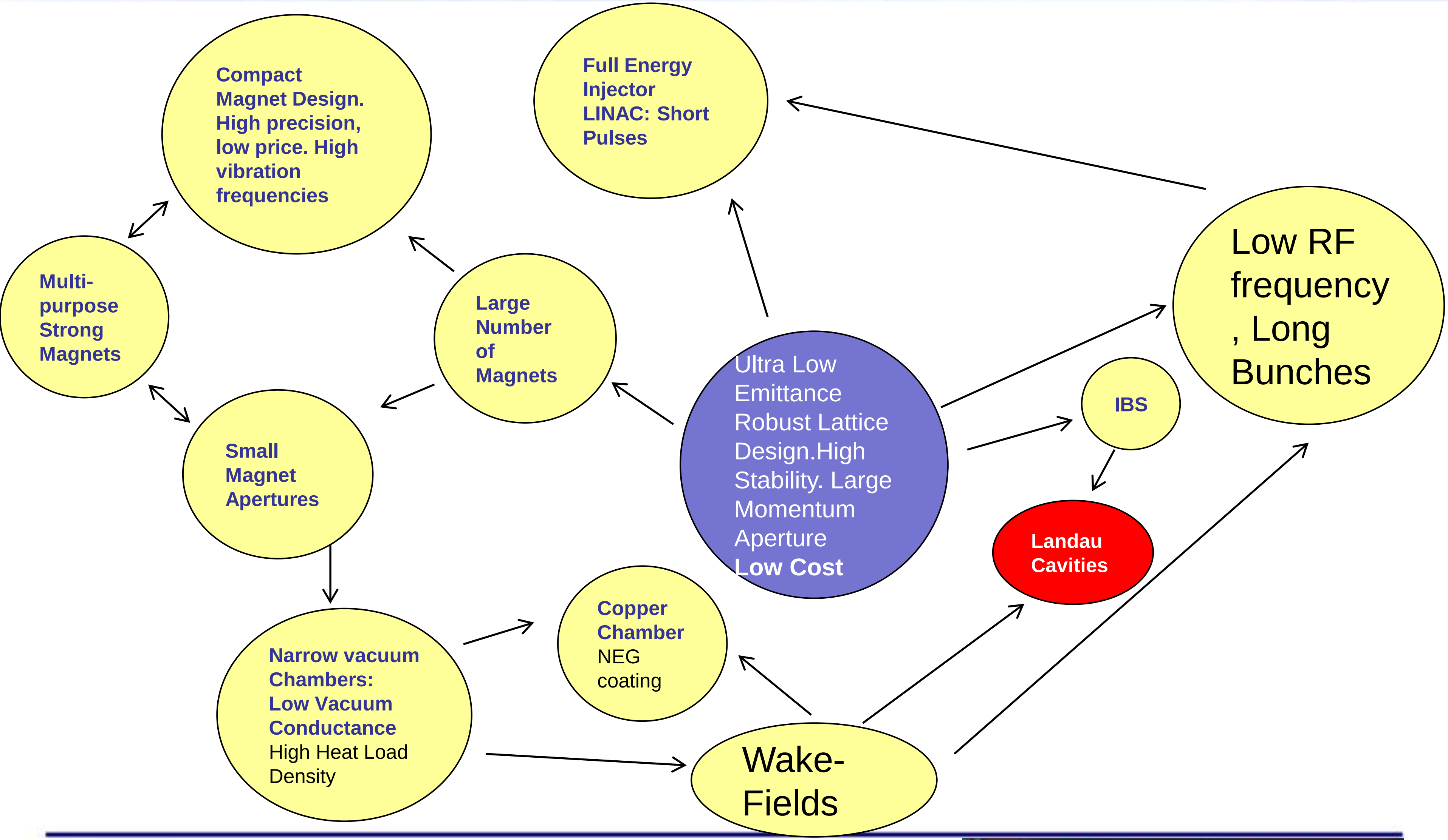
Outline

- **Introduction**
- **3 GeV Ring**
  - Lattice and Injection
  - Vacuum System
  - Magnets
  - RF System
- **1.5 GeV Ring**
  - Vacuum System
  - Magnets
- **LINAC Injector**
- **Schedule**

Facility Lay-Out



An integrated Solution

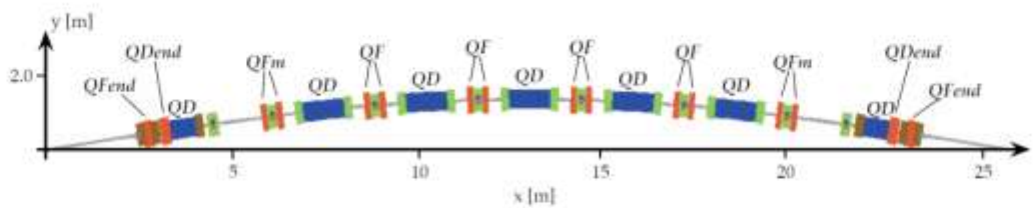


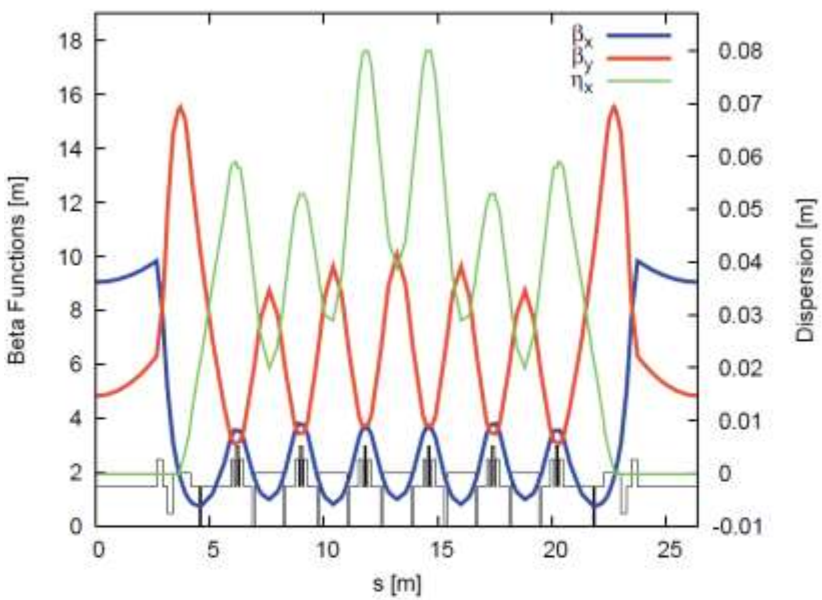
Storage Rings Parameters

	High Energy	Low Energy	
Energy	3	1.5	GeV
Average Current	500	500	mA
Circumference	528	96	m
Horizontal Emittance	0.2 - 0.4	6	nm rad
# Straight Sections	20	12	
Length of Straight Section	4.8	3.5	m
Hor Beam Size	45	184	µm
Vert Beam Size	2	13	µm
Beam Lifetime	10	10	hours

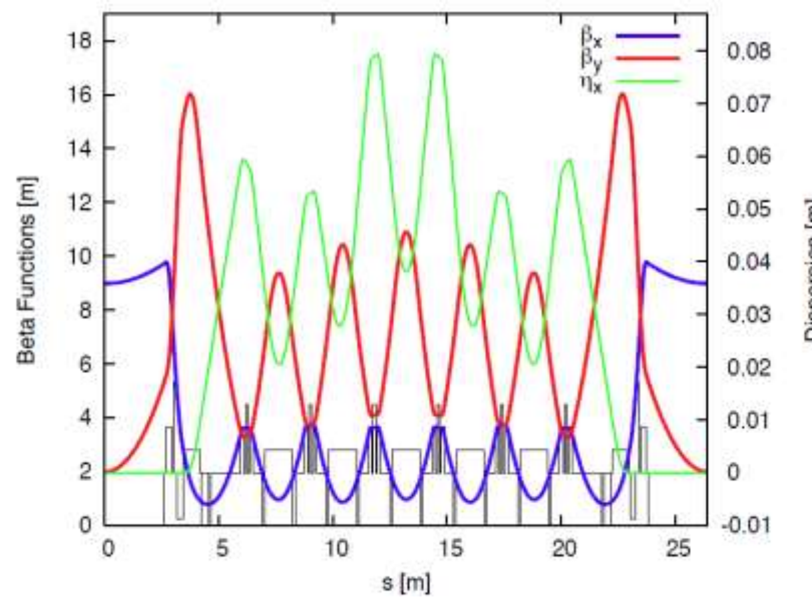
Modified Storage Ring Optics

Motivation: Dynamic correction of IDs is now done only with Quadrupole Dublets in long straights.



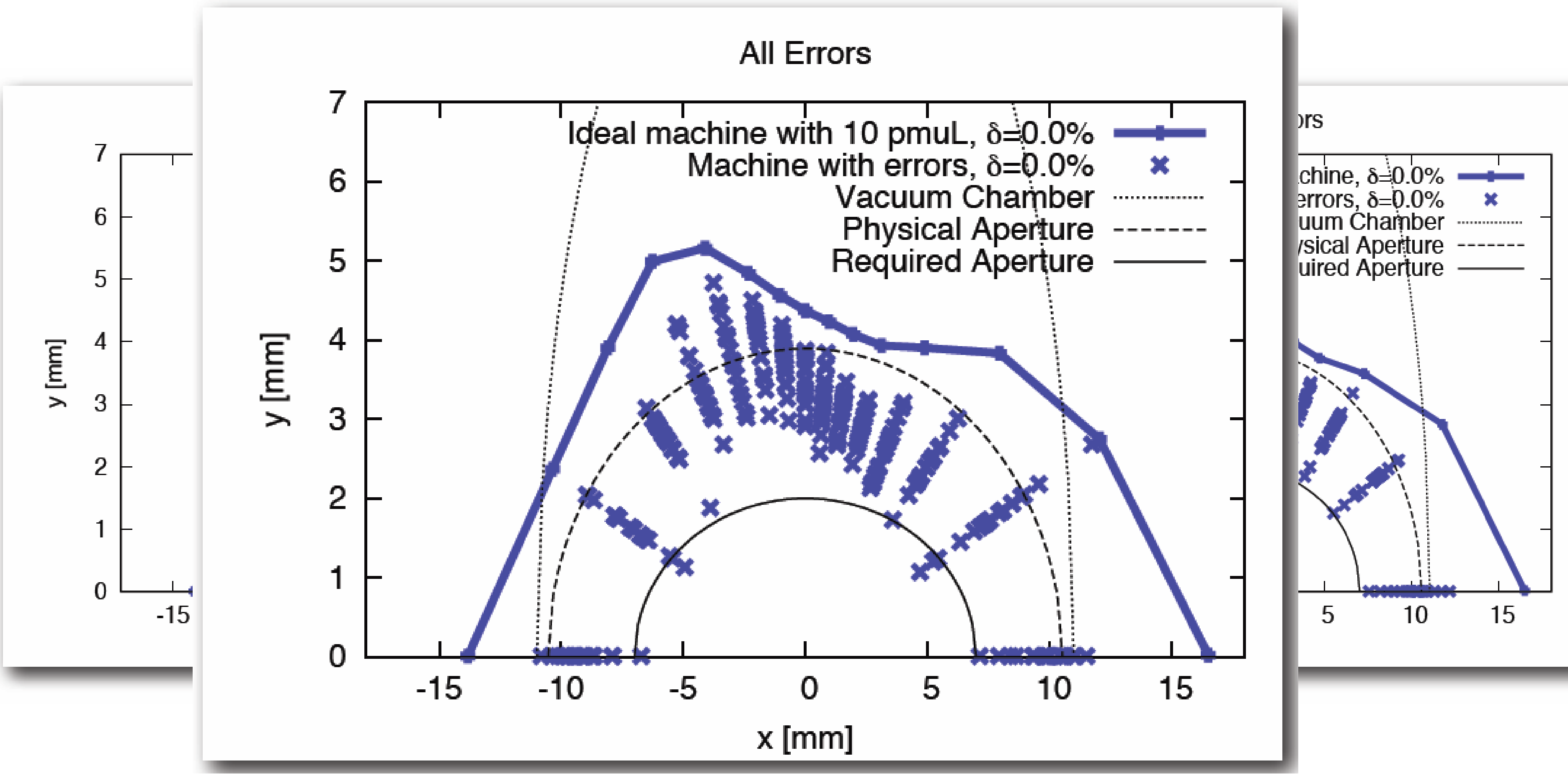


Old Optics

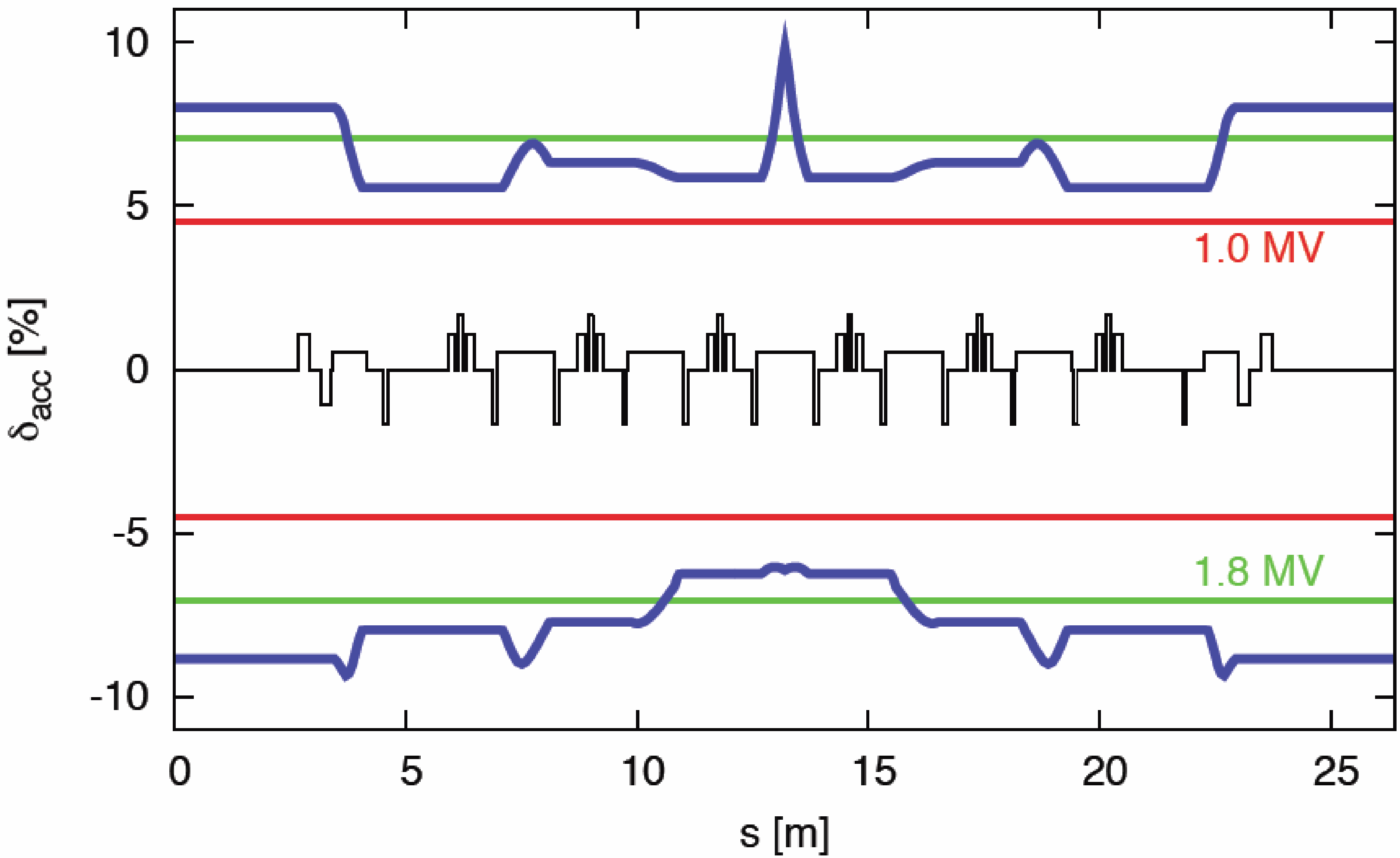


New Optics

Dynamic Aperture

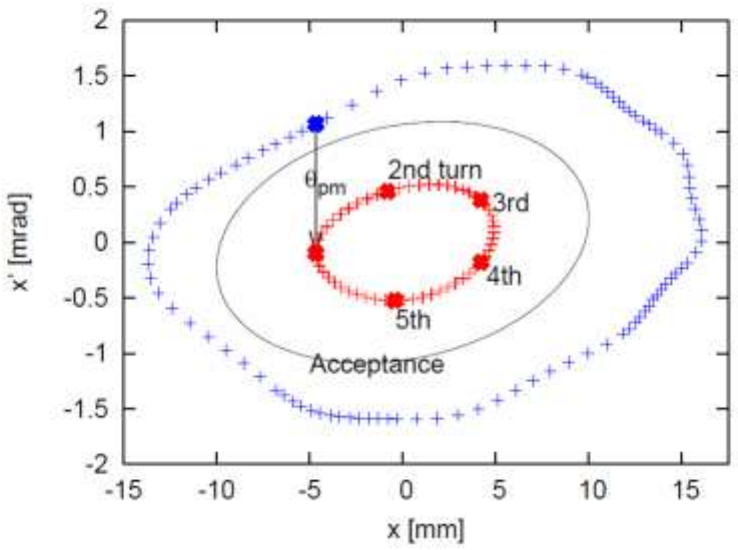


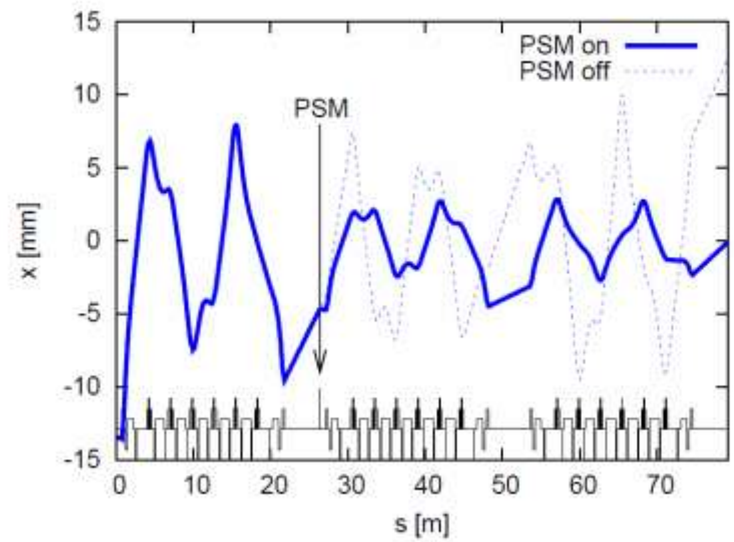
Lattice Momentum Acceptance



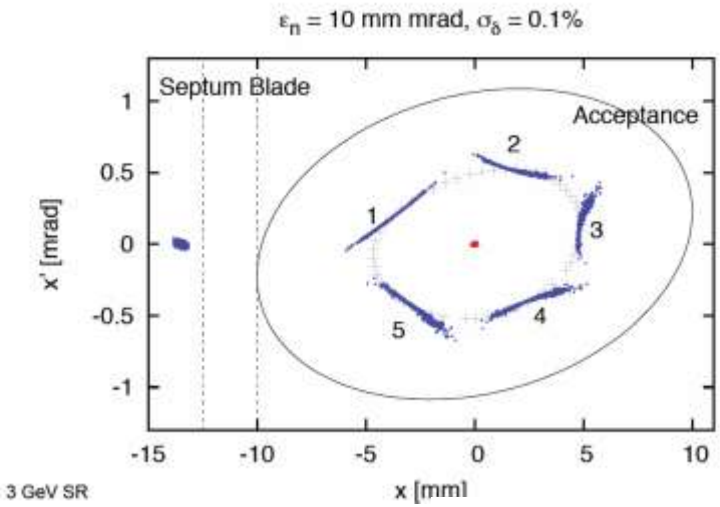
Injection Studies

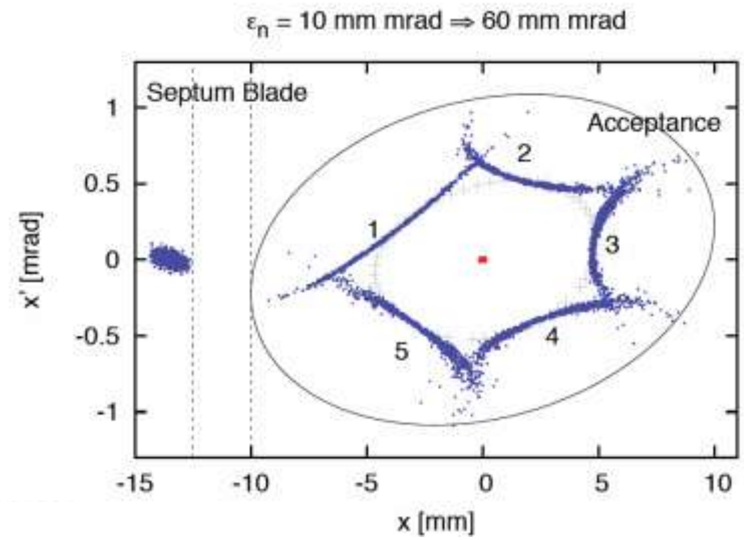
Single Multipole Kicker Injection has been chosen as the standard injection scheme into both rings

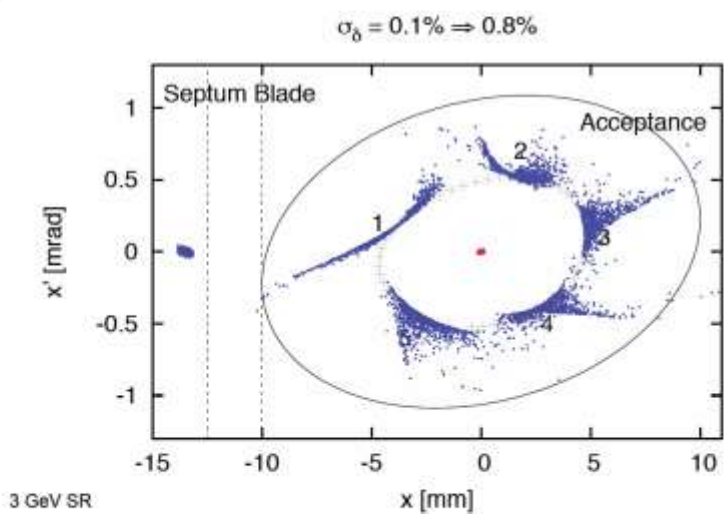




Injection Studies





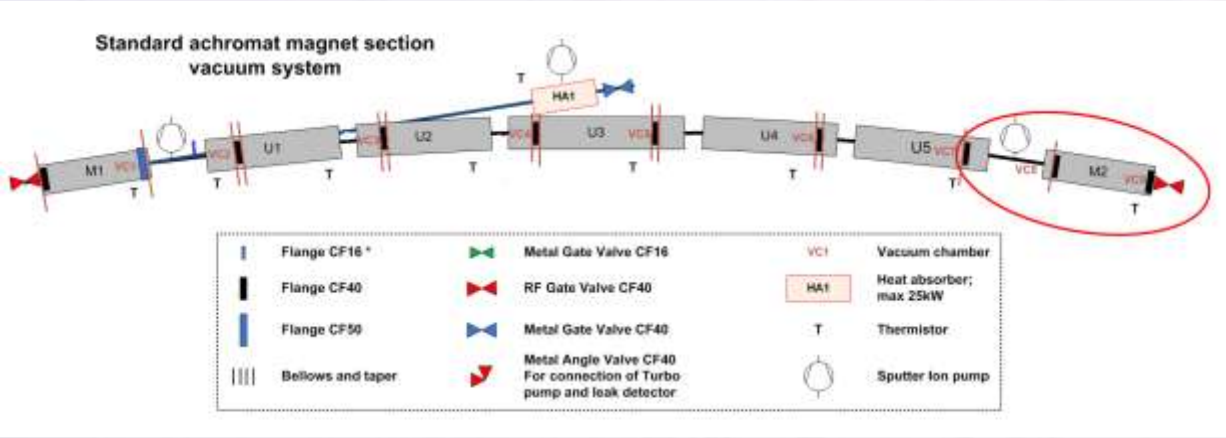


Multipole Kicker Specs

Multipole Kicker	Pos. of Injected Beam [mm]	Integrated Field @ IB [1E-4T.m]	Magnet Length [cm]	Total Length (flange to flange) [cm]	Pulse Duration [µs]	Horizontal Full Beam Stay-Clear [mm]	Vertical Full Beam Stay-Clear [mm]
3 GeV Ring MIK	-4.66	117	30	40	3.5	22	12
1.5 GeV Ring MIK	-5.84	117	40	50	0.64	28	11

		3 GeV Sextupole	1.5 GeV Sextupole	KEK Sextupole
Magnet length	m	0.3	0.4	0.3
Aperture radius	m	0.018	0.021	0.033
Gradient	T/m^2	1801	861	207
N		1	1	1
Current	A	2786	2114	3000
Inductance	H	3.55E-06	4.74E-06	4.30E-06
Half-sine base	s	3.50E-06	6.40E-07	2.40E-06
Voltage	V	8887	49169	16886
Capacitance	F	3.49E-07	8.76E-09	1.36E-07
Pole Tip Field	kgauss	5.84	3.80	2.26
Pulser Power	MVA	24.76	103.96	50.66

Vacuum chambers 3 GeV Ring



Magnet aperture = 25 mm
Section length = 22 m

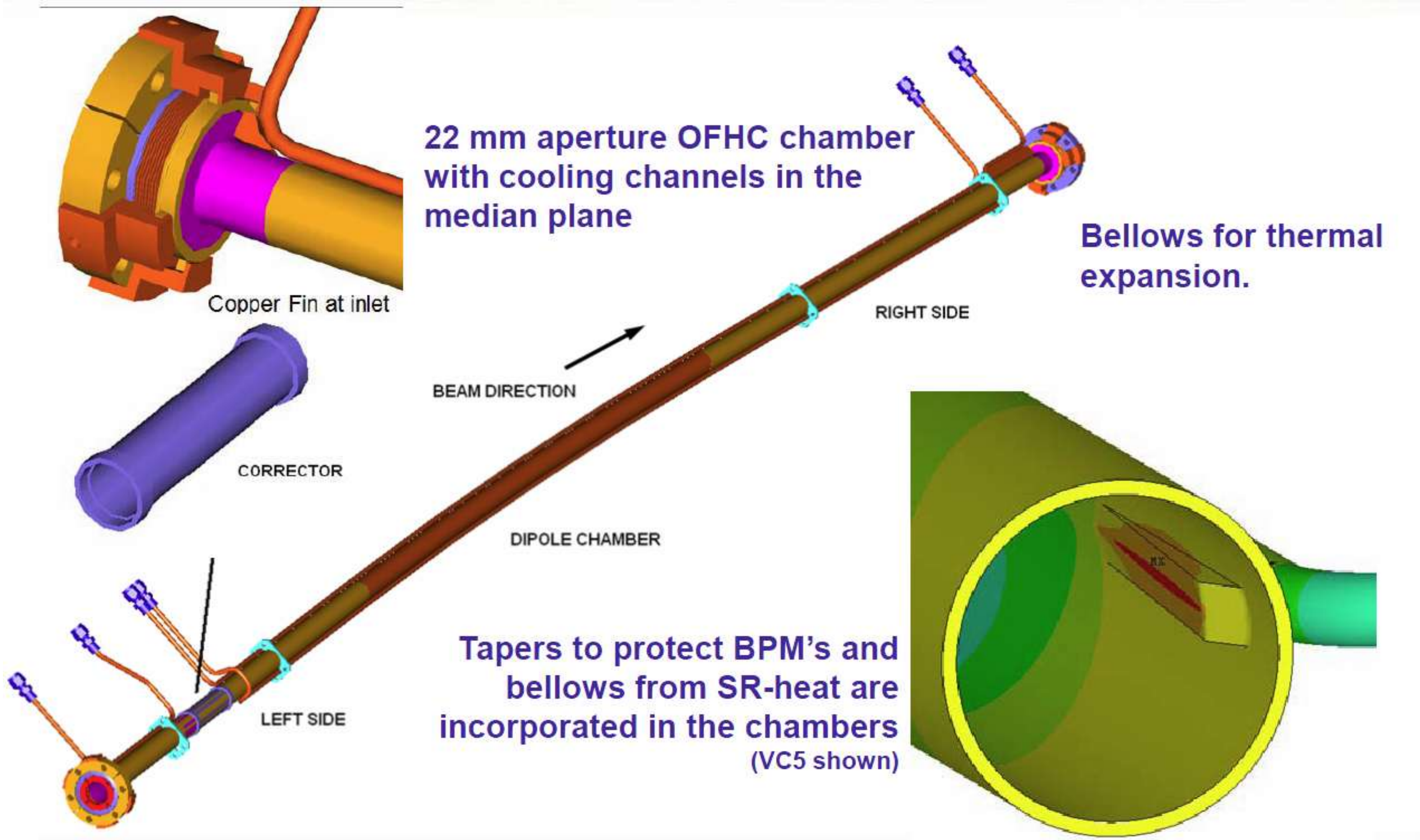
Detailed Design done by ALBA.

Design Review Meeting in May 2011.

Main Technical Issues

- **Chamber is mostly a copper tube. SS/Al needed at some locations.**
- **High Heat load from IDs.**
- **Tight mechanical tolerances – minimize BPM motion.**
- **NEG Coating (small apertures)**

Typical Chamber



22 mm aperture OFHC chamber with cooling channels in the median plane

Bellows for thermal expansion.

Tapers to protect BPM's and bellows from SR-heat are incorporated in the chambers
(VC5 shown)

Vacuum System Design 3 GeV Ring

First Version of CFT drawings and specification documents delivered by ALBA July 2011. Version 2.0 ready November 2011:

- Stainless steel chambers in existing correctors replaced with copper.
- Simplified cooling circuits.
- Simplified Geometry for VC1, use regular OFHC copper, rather than glidcop – reduced heat load from insertion devices.
- New weak fast correctors added.
- Detailed design for chamber supports and cooling tubes – integration with magnet blocks cross-checked.

Steel to Copper: Why ?

- **Simplifies construction – reduce the need for joining dissimilar materials (brazing).**
- **Simplifies cooling circuits.**
- **Eliminates or reduces the need for chamber tapers to protect the stainless steel parts from incidence of synchrotron radiation**
- **Reduces risks in NEG coating:** ***if a brazed piece has coating problems (peel off) it cannot be recoated – the cleaning will attack the braze and the whole piece may need to be scrapped*****.**
- **But, …. this means that fast orbit correction has to be done with other correctors (see later)**

Vacuum System Procurement

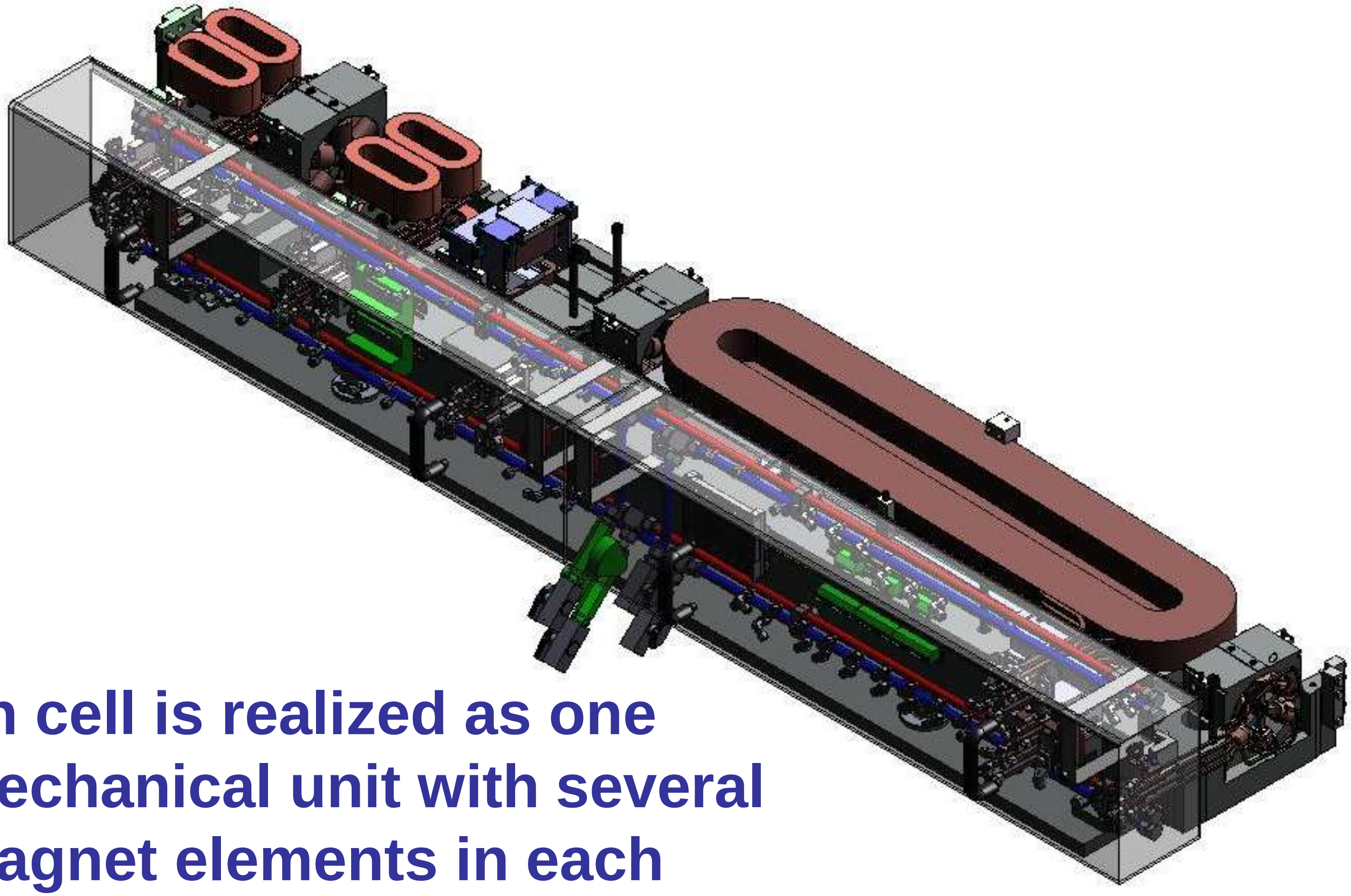
Prequalification Tender published. 7 Companies selected.

CFT for main chambers by the end of 2011.

CERN collaboration established:

- Development of coating procedure for special chambers.
- Certification of cleaning at manufacturing companies.
- Training. (Max lab staff at CERN for about 9 months from November)

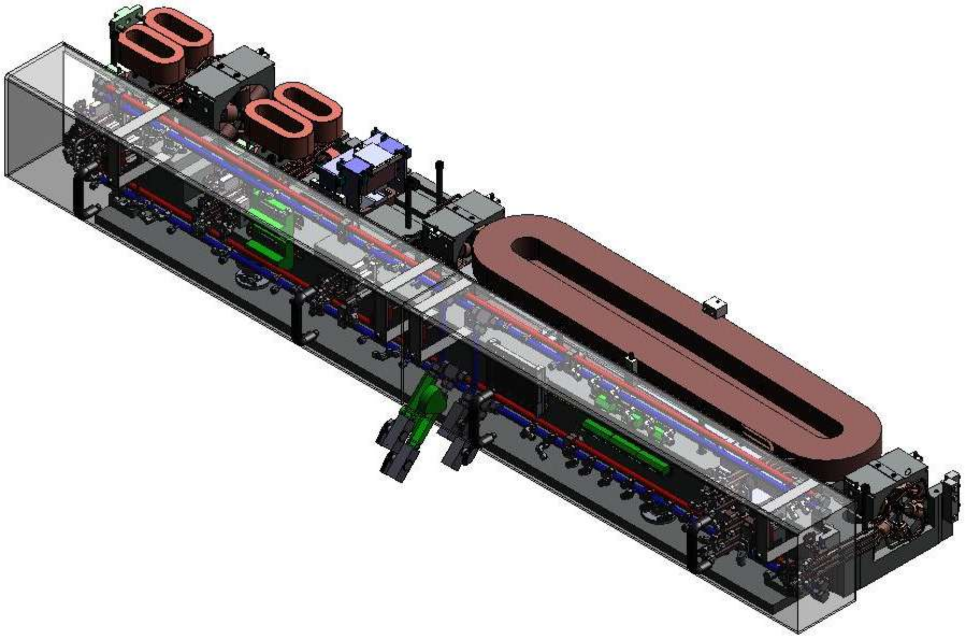
3GeV Storage Ring Magnets



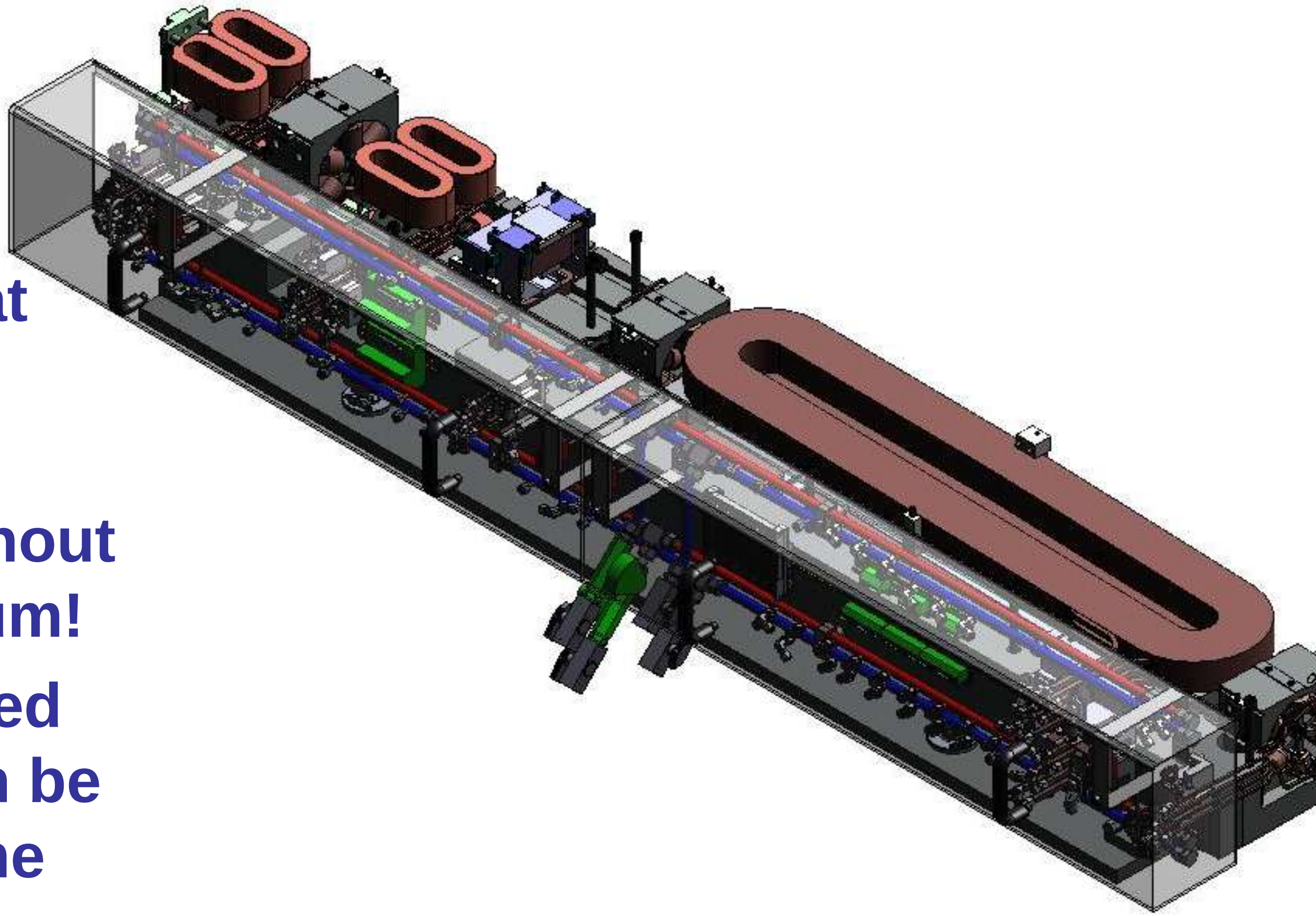
Each cell is realized as one mechanical unit with several magnet elements in each

Main challenges for manufacturing:

- Tight Mechanical tolerances.
- Production capacity: 140 cells -> 1320 magnet elements -> 5800 magnet coils, 6840 yoke parts
- Field meas. accuracy and throughput
- Correct wiring: XX XXX trim- and ts-connections to terminals with correct position, polarity and marking.



Interesting features:



- Designed to be dismountable at mid plane
- Coils can be exchanged without breaking vacuum!
- Magnets connected to same PS can be shunted to same strength

Main challenges for us, during manufacturing:

- Evaluation of mech. meas. data (6840 parts -> 2640 magnet halves).
- Evaluation of field meas. data (1320 magnet elements)
- Time schedule monitoring, investigations, inspection visits… Emphasis on reaching tolerances in first stage, then production pace.

Status - design

Basic design (pole shapes, coil design, etc) completed early 2010

3D cad started mid 2010 -> first draft set of drawings in October -> request for quotation set of drawings Jan 2011 ->

Technical spec for purchase completed Feb 2011.

***Concept is purchase complete assembled magnets with cabling and everything from subcontractors. We are responsible for magnetic design. They are responsible for mech. tolerances and perform field meas. to our specs*.**

Status - manufacturing

Iron blocks (294 pcs, ca 300t) delivered July 2011.

Contract for 3 GeV Ring Magnets Signed September 12th, 2011.

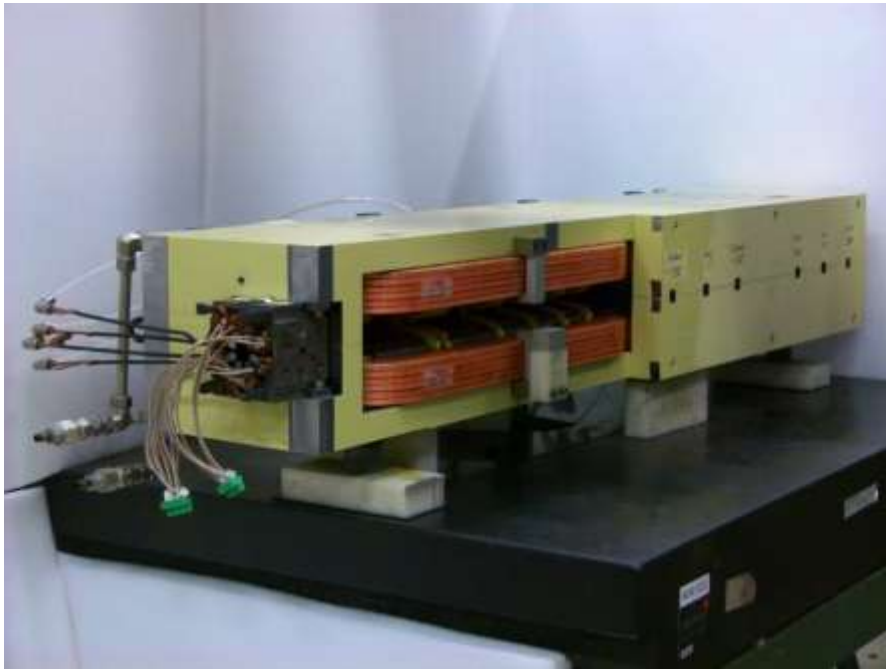
Danfysik (M1, M2, U3) and Scanditronix Magnet (U1,U2,U4,U5)

Both companies will build measuring benches.

Delivery of pre-series planned for~9 months after contract signature.

Delivery of all magnets by December 2013.

Prototype 3 GeV Ring Magnet Block



Field	0.52	T
Gradient	8.6	T/m
Gap (pole center)	28	mm
Number	100 + 40	

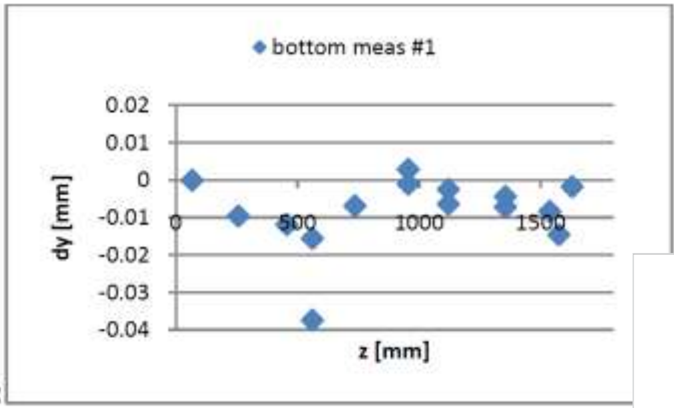
Several Magnets Machined out of a Single Solid Iron Block

mc prototype measurements

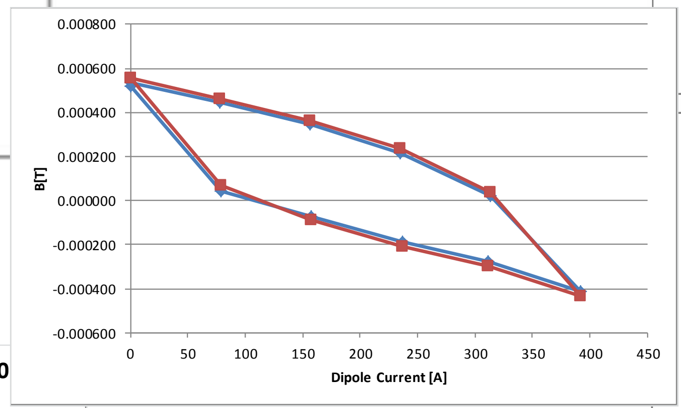
- No showstoppers in machining of large yoke block halves
- Practical feedback to mechanical design/drawings
- Field strengths, temperature rises, etc verified
- Dipole field shape close to spec
- Pole face strips gives 4% gradient adjustment, but also produces a dipole component.
- QFend and 8poles – no surprises
- No cross talk, except QDend(DIPm) .

Example Measurements

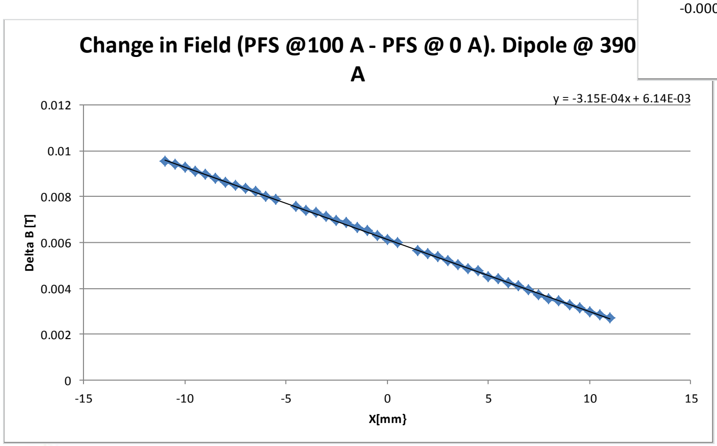
Mechanical Measurement – Bottom yoke



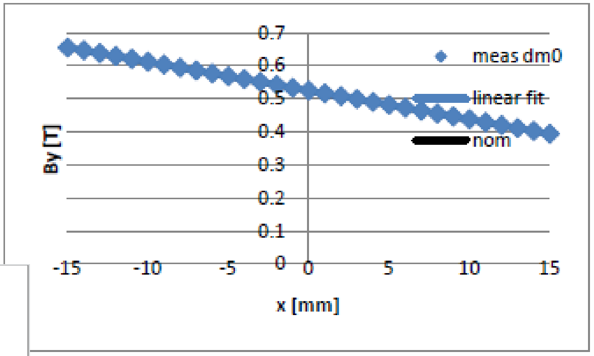
Cross-Talk

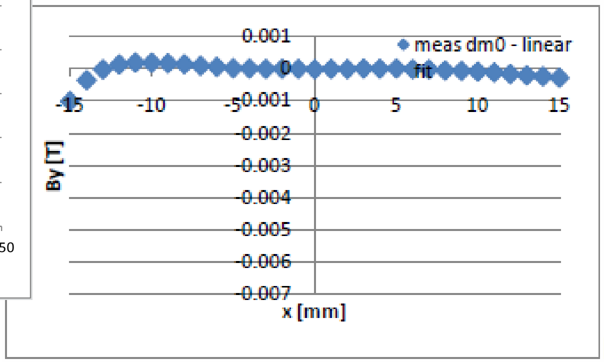


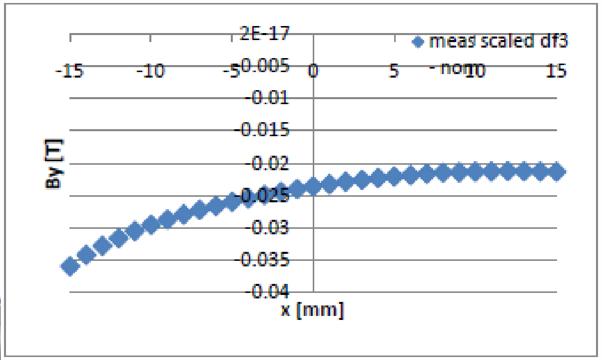
Pole Face Strips



Dipole Field Map







RF Systems 3 GeV Ring

Main Cavities (100 MHz Capacity loaded, Max-lab design):

- **Contract Signed with RI in Feb 2011**
- **Cavity Design Review Meeting June.**
- **Pre-series cavity delivery : Feb 2012..**
- **120 kW Power couples ordered.**
- **First delivery: Feb 2012.**

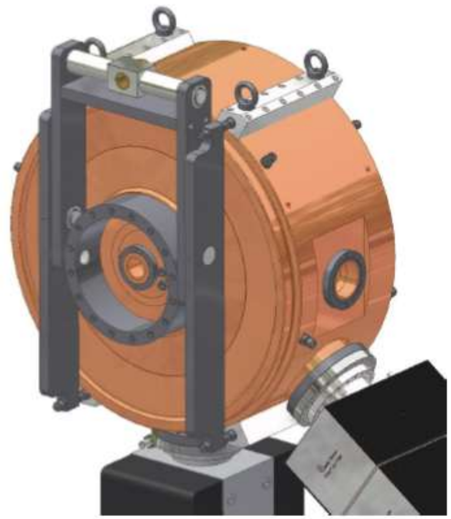
Design Issues

RF

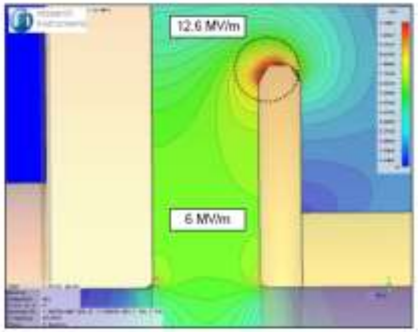
Thermal

EB welding

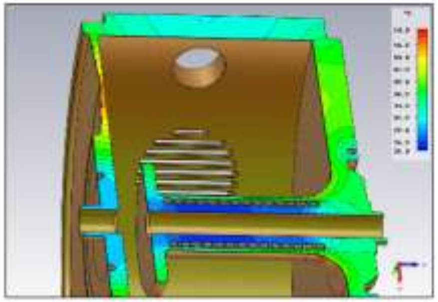
Tuning mechanism



Tuning Mechanism



RF



Thermal

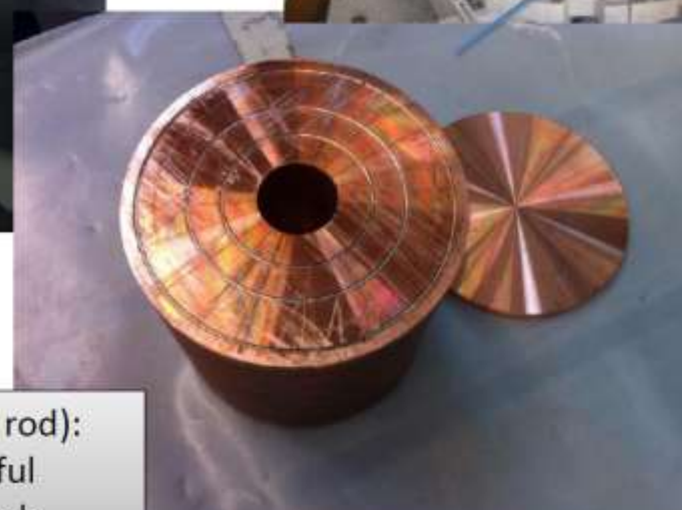
Tuning plate

Pre-series Cavity

Production Status

research instruments

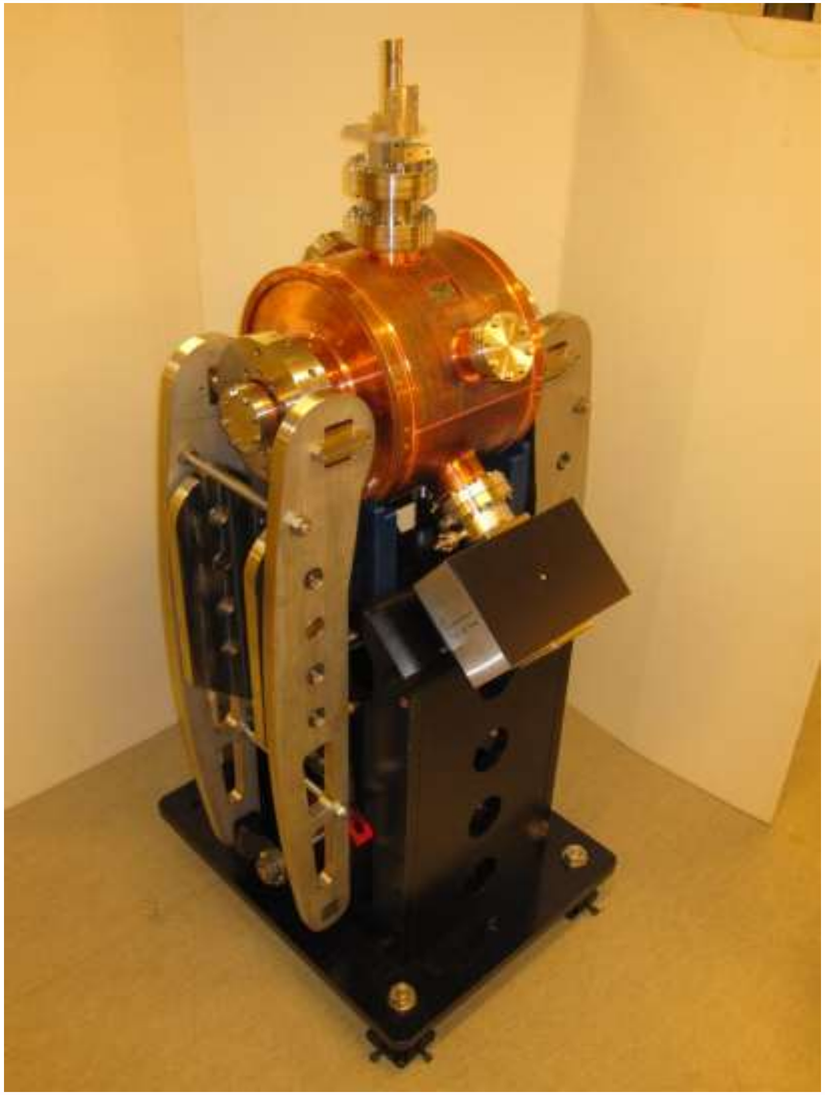
Pre-milling of the mantle is finished,
Final milling this week



Braze test piece (inner rod):
1st braze stage successful
2nd braze stage this week

RF System – Harmonic Cavity

- **Prototype Landau Cavity construction successfully finished at RI.**
- **Mechanical assembly done at Max-lab. Low Level RF tests at MAX-lab in early October**
- **Tests with Beam on going at MAX III**



RF Systems: Low Level RF

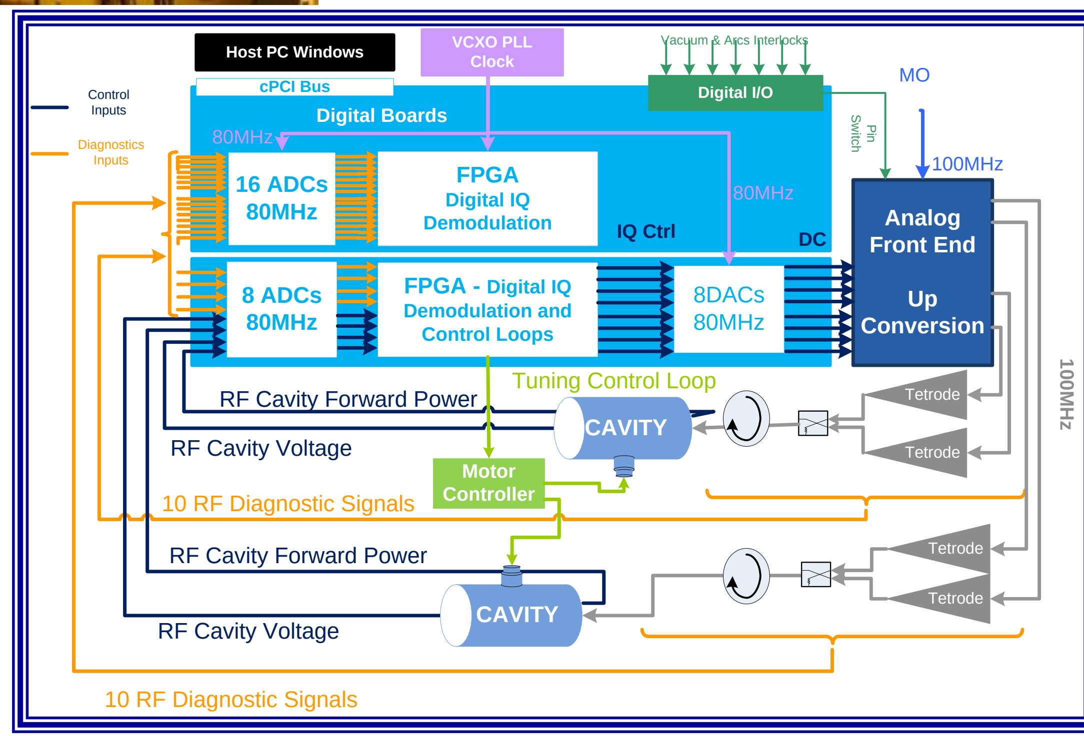
Design by A.Solom

	Resolution	Bandwidth	Dynamic Range
Amplitude Loop	< 0.5% rms	< 10kHz	30dB
Phase Loop	< 0.5° rms	< 10kHz	360°
Tuning	< ± 1°	< 1kHz	< ± 75°

Prototype Assembled and Tested at MAX-lab

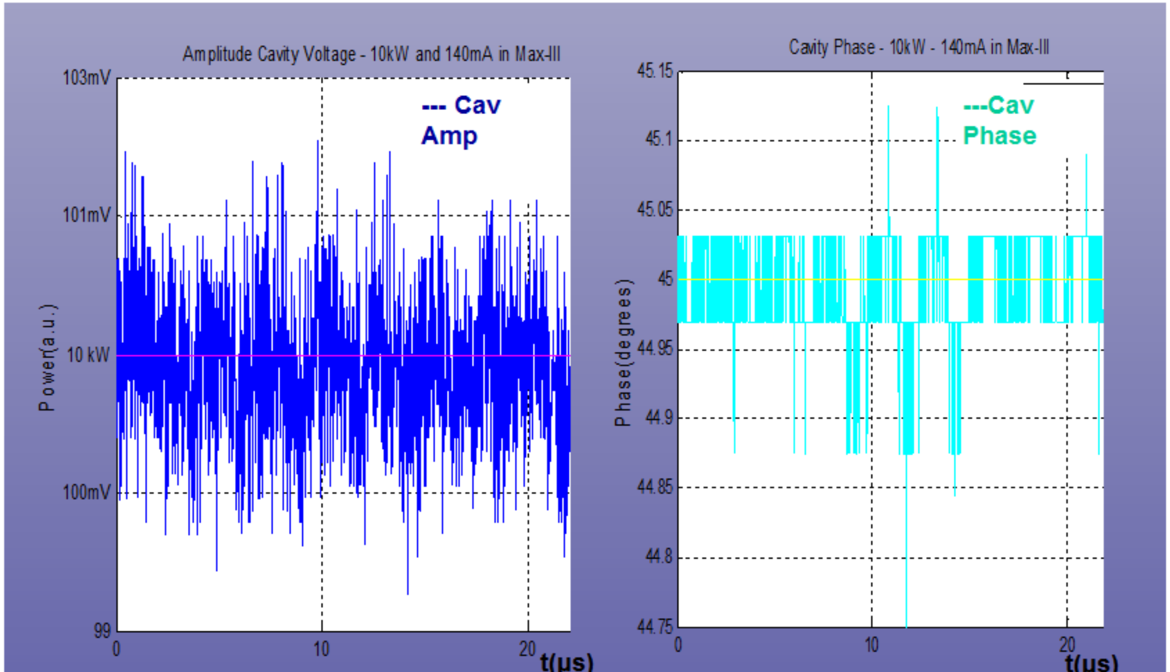
First Successful tests with Beam at MAX-III in September 2011.

200 mA ramped with voltage and frequency loops engaged.

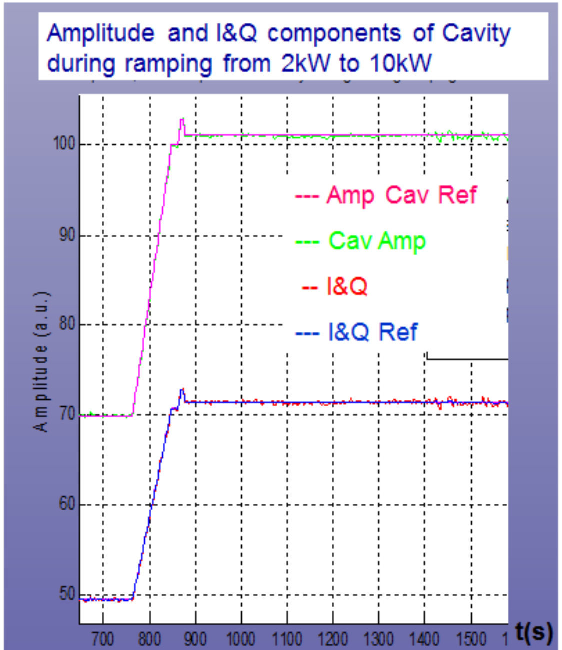


RF Systems: LLRF Test Results

	Loop resolution at 2kW	Loop resolution at 10kW
I&Q Cavity Voltage	0.12 % rms	0.14 % rms
	2mVpp	2.5mVpp
Amplitude Voltage	0.48% rms	0.5% rms
	2.5mVpp	3mVpp
Phase	0.24º rms	0.3º rms
	0.3ºpp	0.5ºpp



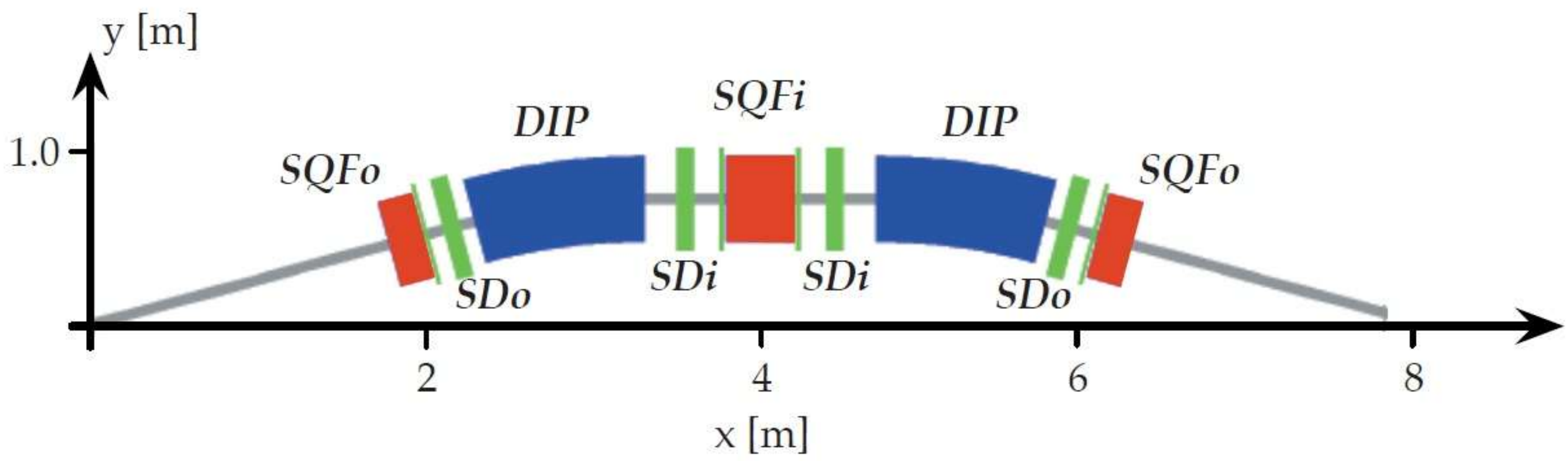
Fast Diagnostics of LLRF: Signasl acquired at 80MHz



Slow Diagnostics of LLRF: Signasl acquired at 1Hz

1.5 GeV Ring / Solaris

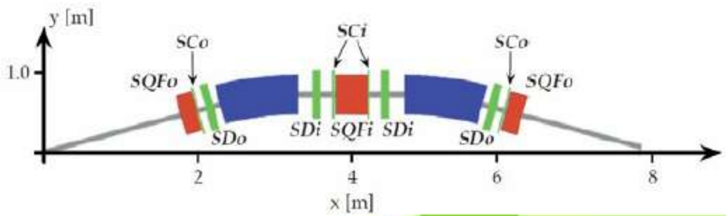
- First iteration of 3D magnet design completed October 2011 → modified optics.
- Vacuum design on-going at ALBA.
- RF cavities same as for 3 GeV Ring.

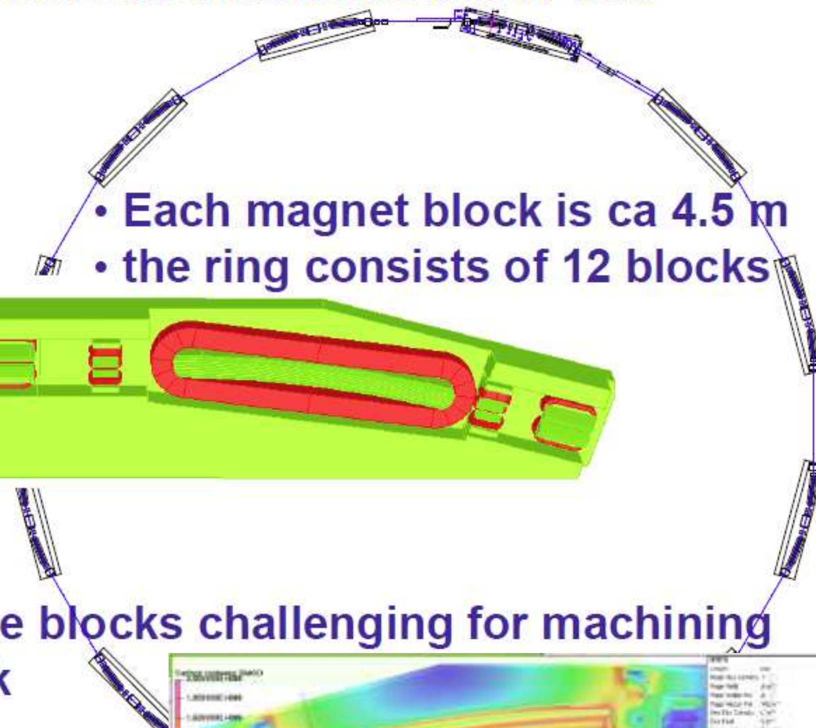


Magnet Design

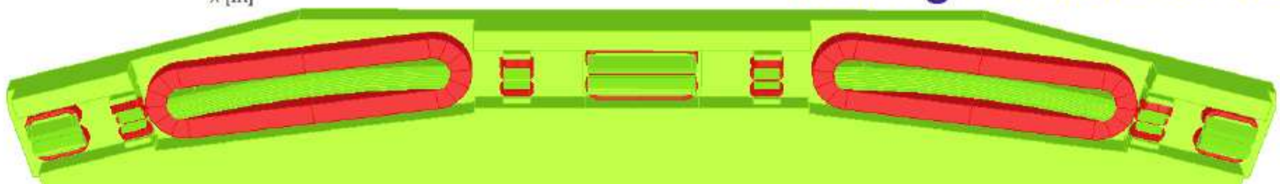
The magnet design concept is identical to the 3 GeV ring

– All magnet elements within each DBA are machined out of one solid iron block.



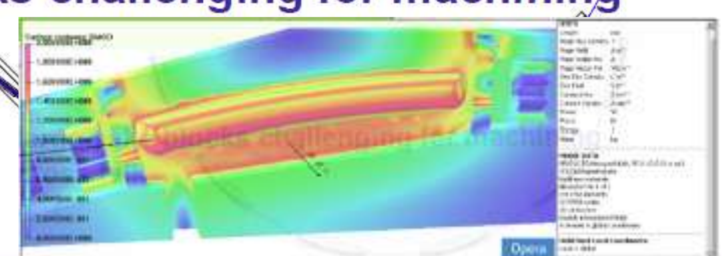


- Each magnet block is ca 4.5 m
- the ring consists of 12 blocks



motivation:

+	-
compactness	large yoke blocks challenging for machining
vibration stability	cross talk
alignment precision	... ?
less time on installation	



1.5 GeV Ring Vacuum System

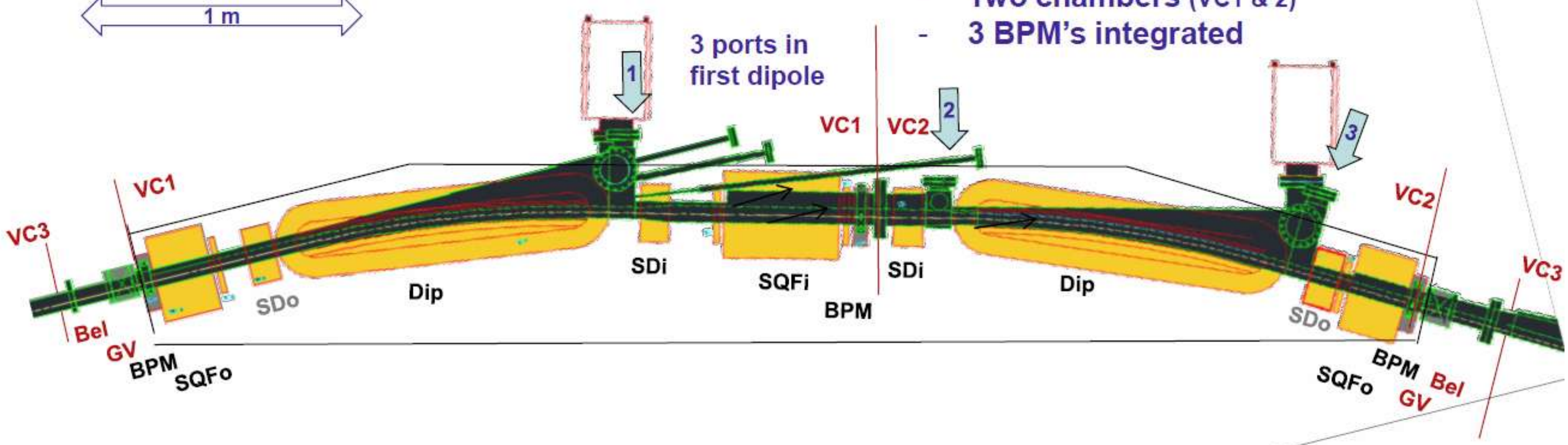
- Stainless steel chambers
- Discrete heat absorbers
- Ion pumps and TSP - No NEG

  Motivation
  - Conductance larger than in the 3 GeV ring
  - Layout similar to MAX II
  - The production is decoupled from the 3 GeV ring
  - No activation of chambers needed
  - Less handling of heavy iron blocks (5 tons)
- Beam ports from the first dipole
  - MAX IV: primarily ID's in the long straights
  - Solaris: start with SR from dipoles

1.5 GeV Ring Vacuum System

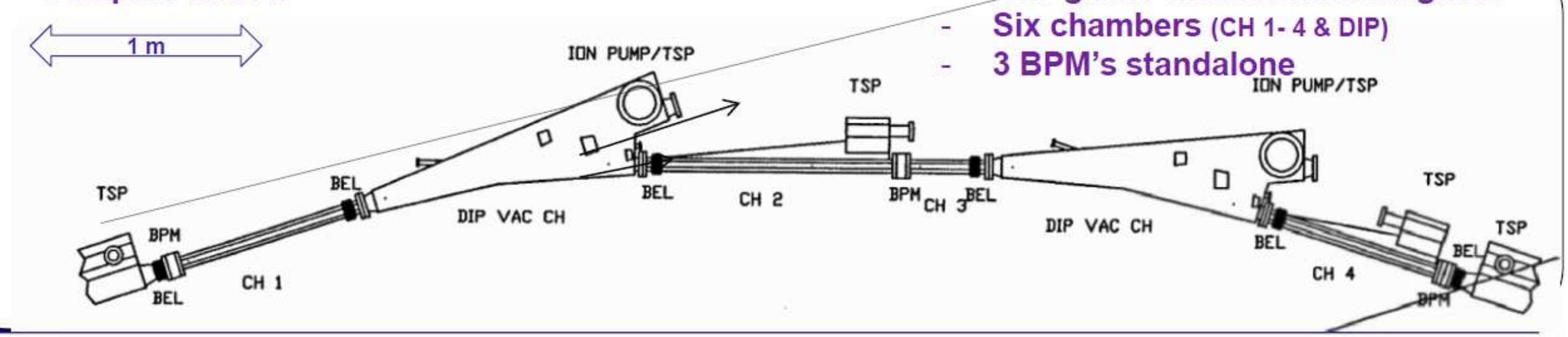
Layout under work: ver. 2

- One magnet block (girder)
- Two chambers (VC1 & 2)
- 3 BPM's integrated

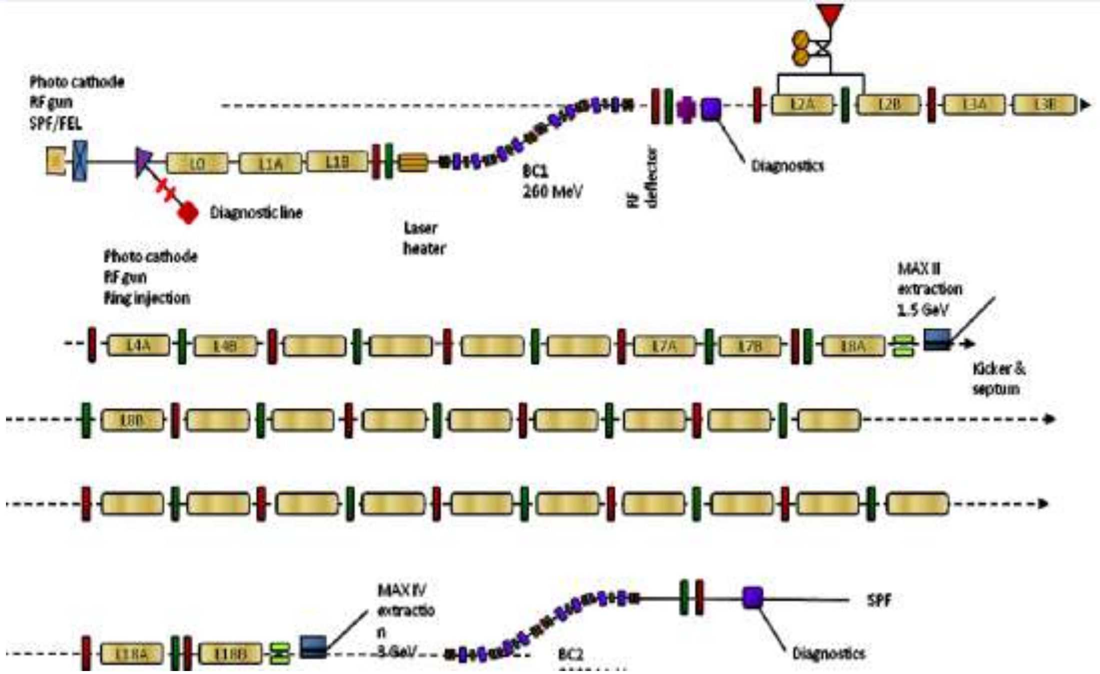


Compare MAX II

- One girder with discrete magnets
- Six chambers (CH 1- 4 & DIP)
- 3 BPM's standalone

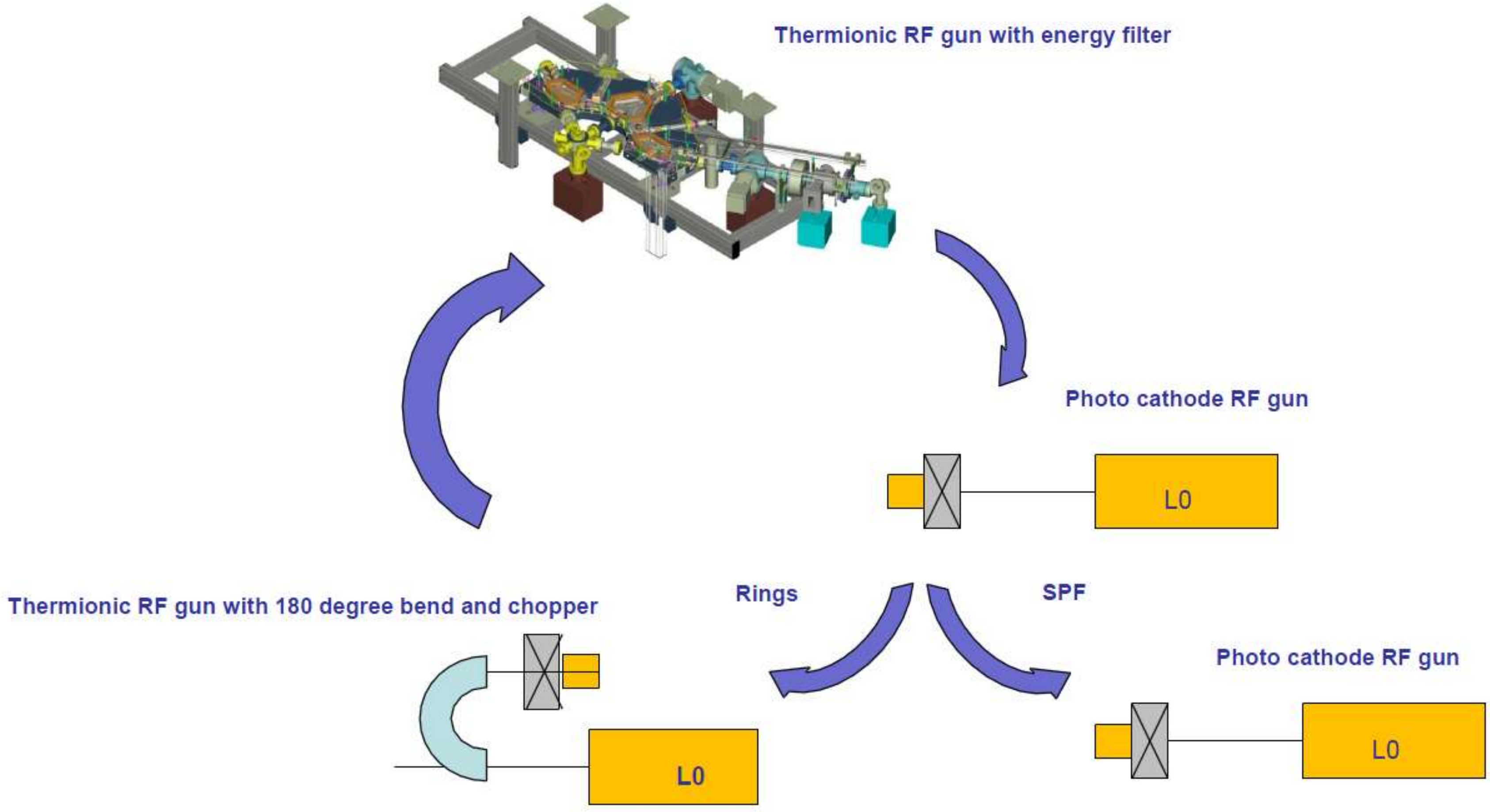


LINAC

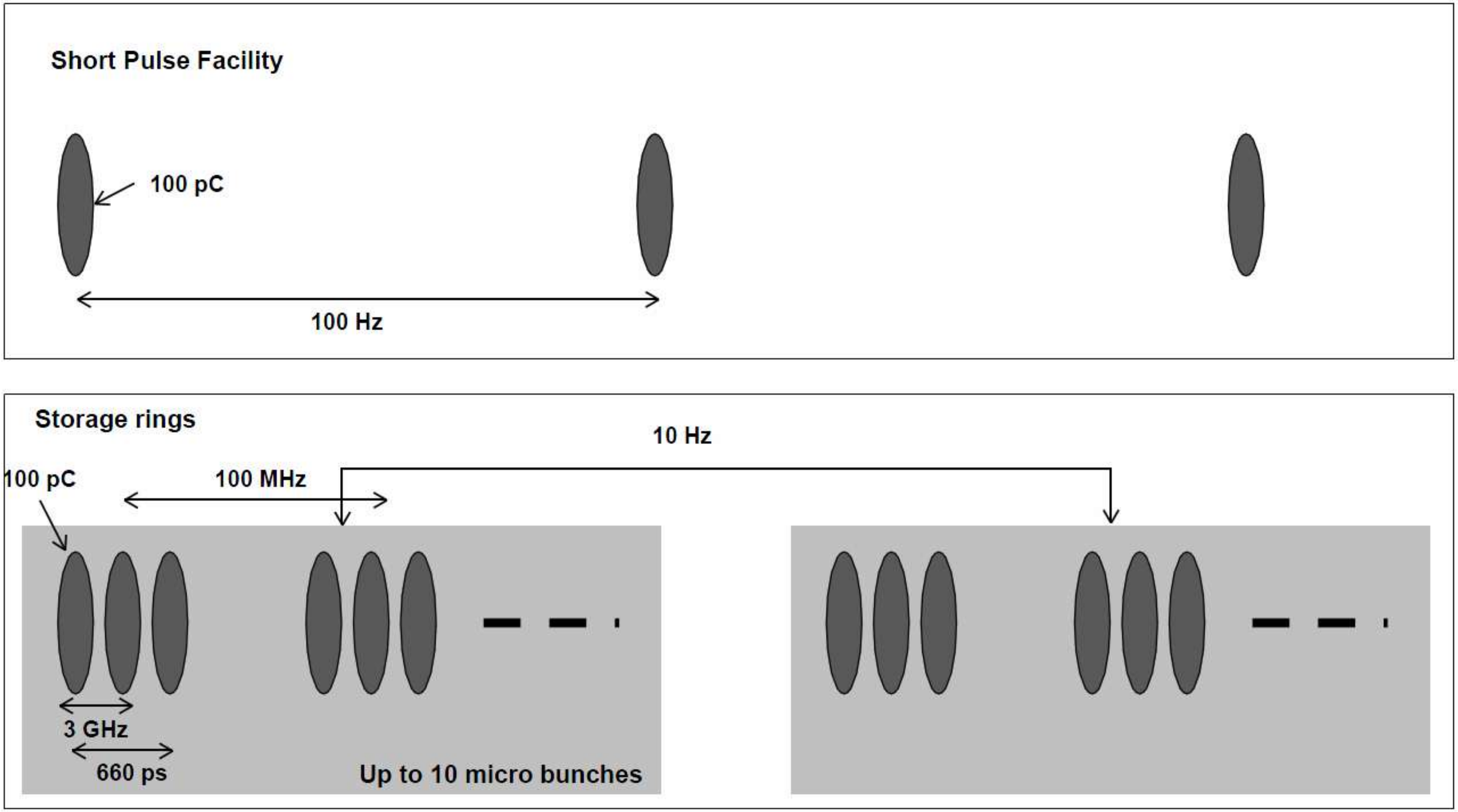


- Modulators being built by Scandinova
- Acc. Structures being built by RI
- Gun Test Stand at Max-lab
- CFT for Magnets published

New electron gun lay-out

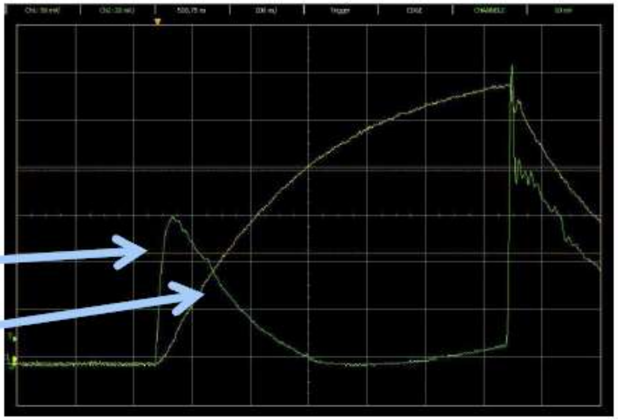


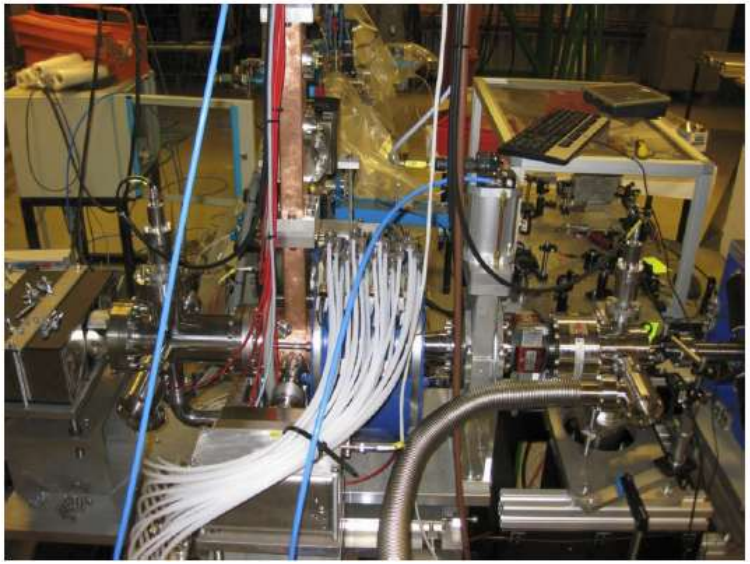
Time Structure



Gun Test-Stand

- Under vacuum
- SLED tested
- Gun cavity frequency tested
- RF conditioning started
- E-field measurements
- Reflected power measurements





3 GeV Ring Achromat Mock-Up

Project Milestones

ID	WBS	Task Name	Milestone (2009–2020)
1	**1**	**Accelerator Systems**	
6	1.2	Injector LINAC ready	2015 February 26
7	**1.3**	**Max IV 3 GeV Ring**	
81	1.3.2	3GeV Ring Magnets delivered	2013 December 31
106	**1.3.4**	**Vacuum System**	
208	1.3.5	3 GeV Ring Vacuum System delivered	2014 June 18
316	1.3.7	3 GeV Ring RF Cavities Delivered	2013 July 23
412	1.3.14	Start of 3 GeV Ring Installation	2014 February 27
580	1.3.17	Start of 3 GeV Ring Commissioning	2015 February 26
598	**1.4**	3 Gev Ring Operational	2016 January 01
599	1.5	3 GeV Ring Final Specs Achieved	2017 February 24
600	**1.6**	**Max IV 1.5 GeV Ring**	
622	1.6.2	1.5 GeV Ring Magnets Delivered	2014 August 18
654	**1.6.4**	**Vacuum System**	
697	1.6.5	1.5 GeV Ring Vacuum Chambers Delivered	2014 October 13
731	1.6.7	1.5 GeV Ring RF Cavities Delivered	2013 October 01
798	1.6.14	Start of 1.5 GeV Ring Installation	2014 October 15
903	1.6.17	Start of 1.5 GeV Ring Commissioning	2015 July 16
912	1.7	1.5 GeV Ring Operational	2016 May 05
913	1.8	1.5 GeV Ring Final Specs Achieved	2017 January 12
914	**2**	**Conventional Facilities**	
925	3	Beneficial Occupancy of Ring Building	2013 October 31

Thank You!

MAX-lab

ESLS XIX
23rd & 24th November 2011, ISA, Aarhus University, DK