ESRF II
Engineering Challenges

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On behalf of the Accelerator Project Phase II Team

Overview

Engineering Challenges

Project Start up

- Cad tools
- Existing drawings; SR, Booster , Buildings …
- Organization & Resource

Engineering

- Lattice constraints
- Ray tracing & absorbers
- Vacuum chambers
- Girders & Supports
- Magnets
- Straight sections

Conclusion

CAD Tools

Management and uses of Large Assemblies Design

In order to ensure that the CAD assemblies are operable, by our own staff as well as subcontracting staffs.

The main goal is to be able to work efficiently, at the minimum, on assemblies including several cells and their front ends ,the complete injection (cells 3 and 4).

Geometric references

In 3D solid-modeling, the manipulated components (parts and assemblies) are obligatory build on the basis of geometrical to ensure a reliable shared use by all stakeholders.

This improves efficiency and reliability particularly for the CAD construction and the verification of numerical assemblies

Product Data Management (PDM) solutions

Product Data Management software to manage files, parts, assemblies and drawings. PDM helps to ensure the workflow, the revision process and offers electronic approvals to update revisions

CAD Software

Autocad/Catia/Hand made ⇒ Solidworks

Drawings

Existing drawings

- 2D autocad
- 3D CATIA
- Hand made drawings
- Booster
- SR tunnel

Inventory

Drawings update

- Solidworks 3D models
  - SR tunnel
  - Reference drawings …

Definition of design rules

Layout

- Necessary at early stage
- Installation phase preparation
- Exiting drawings & New drawings

Control & verification

Organization

Vacuum chambers | Magnets | Girders | Supports | Injection Cell,TL2* | Straight Sections | Booster TL1*

Layout Integration Modeling

Design

Prototypes & tests

Procedures

Specifications CFT
Contract follow-up

*TLx: tranfert line x

Definition:

- Objectives & deliverables
- Planning
- Budget envelope

Reality:

- Resource from ≠ divisions
- Learning curve
- Work coherency

Resource

Machine operation & maintenance

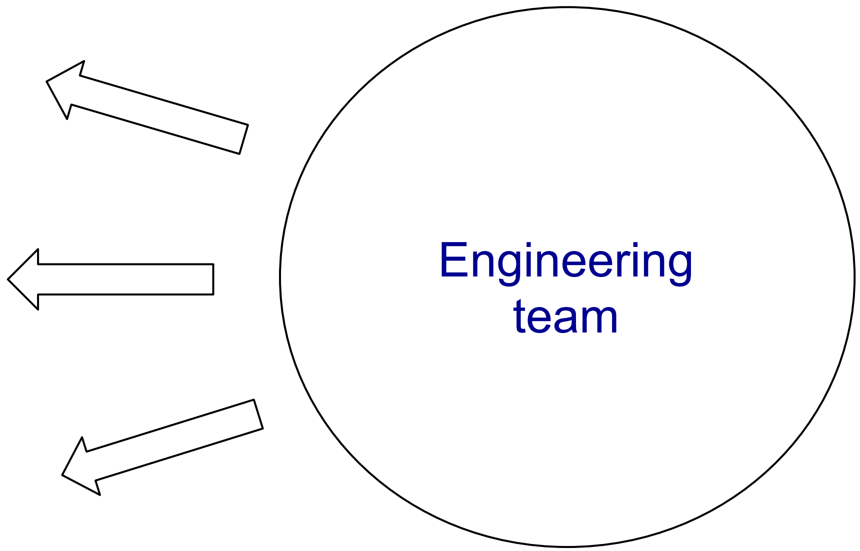
- RF cavities
- SR Top-up mode
- Straight sections update

Beam lines projects

- BL upgrade
- Engineering support
- Development in instrumentation

ESRF II

- Design
- Procurement
- Installation

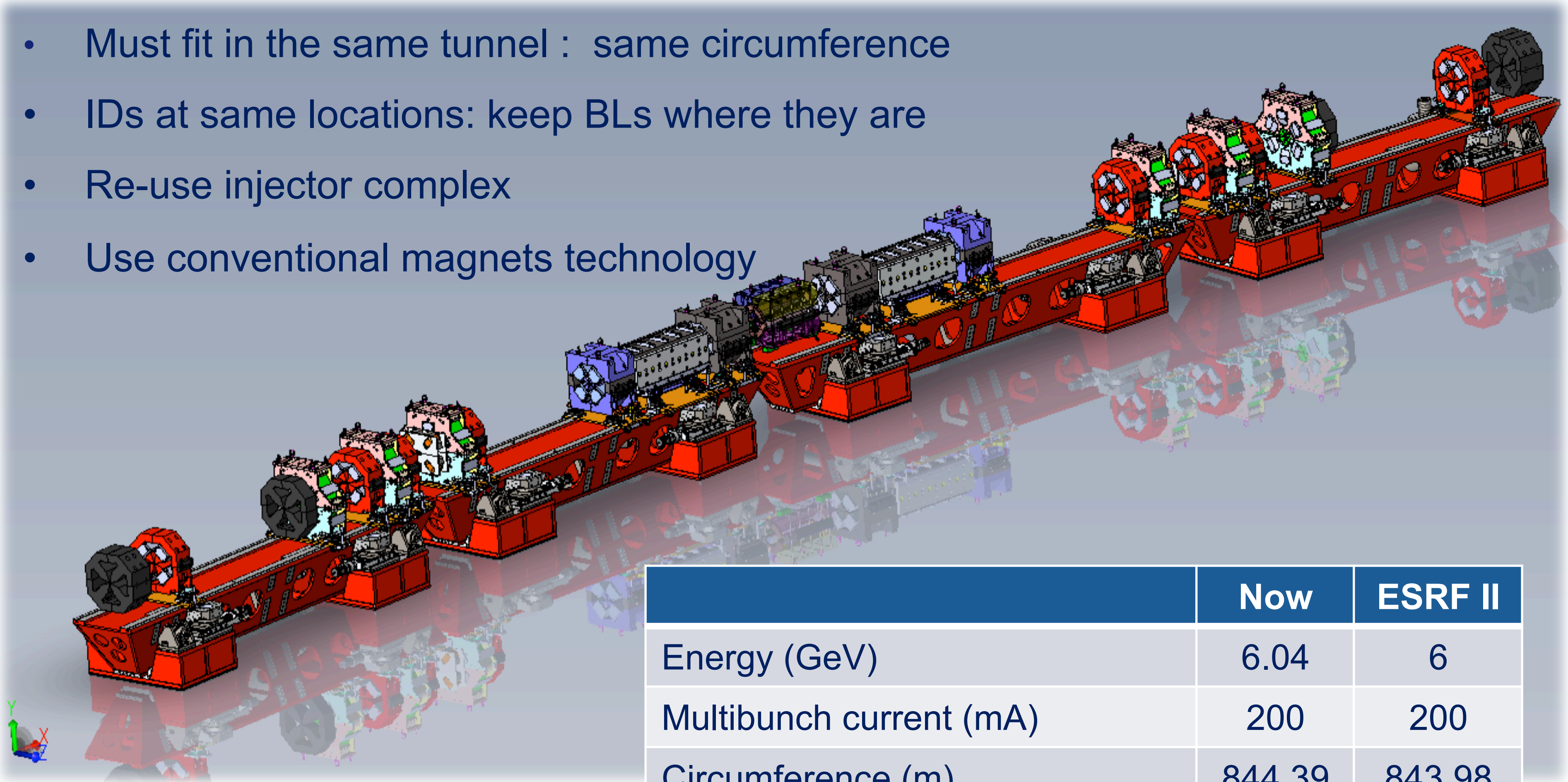


ESRF II:

- Resource not fully dedicated to ESRF II upgrade
- Engineering priorities

Engineering

- Must fit in the same tunnel : same circumference
- IDs at same locations: keep BLs where they are
- Re-use injector complex
- Use conventional magnets technology

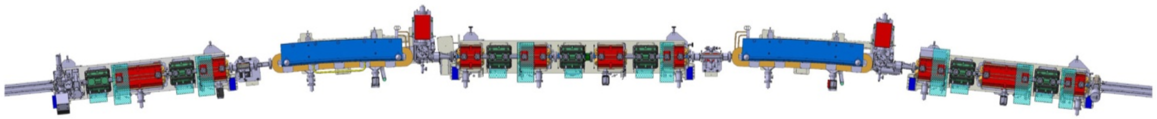


	Now	ESRF II
Energy (GeV)	6.04	6
Multibunch current (mA)	200	200
Circumference (m)	844.39	843.98
Horizontal emittance (pm-mrad)	4000	150
Vertical emittance (pm-mrad)	4	5

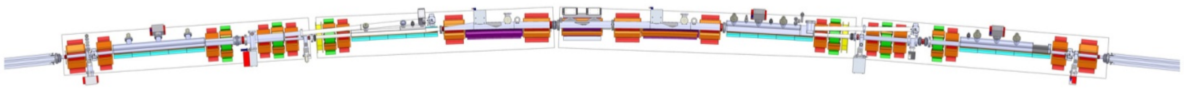
Lattice contraints - Free space

Present ESRF Double Bend Achromat:

- 2 dipoles + 15 quad., Sext.) per cell
- ID length : 5m, 6m, 7m



ESRF Storage Ring = 32 cells
each cell = 26.4m long



ESRF II Hybrid 7 Bend Achromat:

- 4 dipoles + 3 dipoles-quad + 24 quad., sext., oct) per cell
- ID length : 5m

Free space between magnets (total for one cell): 3.4m instead of 8m today

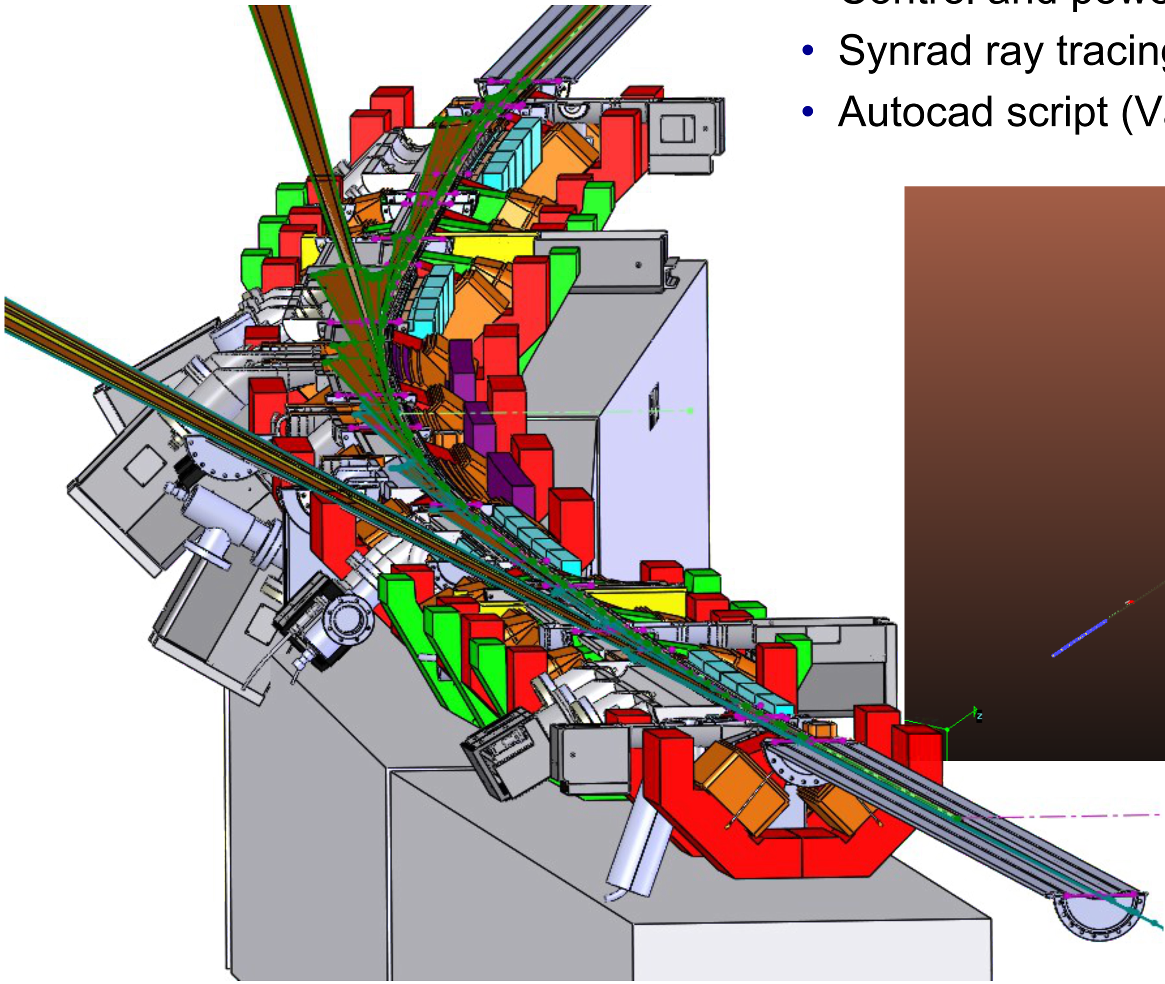
Main engineering challenge:

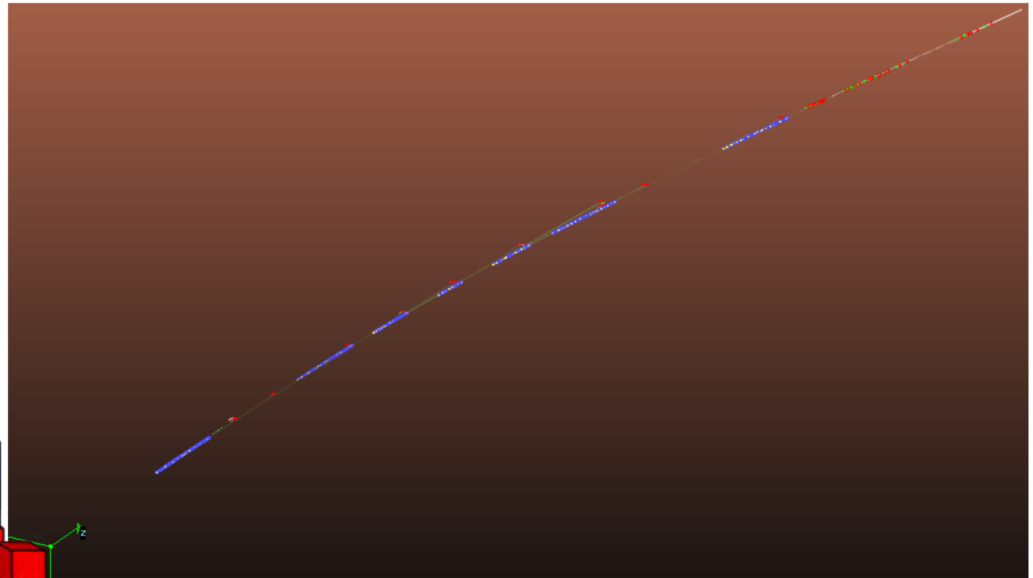
- Lack of space

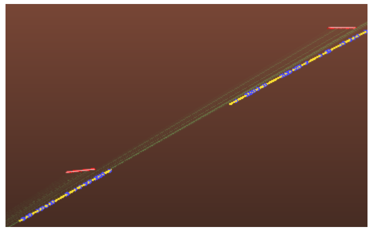
Ray tracing

Ray tracing & power distribution:

- Solidworks ray-tracing
- Control and power calc using excel
- Synrad ray tracing
- Autocad script (Vacuum group development)







Lattice S28a

E= 6.00 GeV

I= 200 mA

* Crotch 1 vert incidence angle not applied

Crotch 2 noze vert incidence angle not applied

	Side cooling brazed	non brazed	brazed	non brazed
a_v (degree)			asin(4)	asin(4)
(W/mm)	10	10	10	6
Pa_{limit} (W/mm^2)	19.28	22.95	39.46	47.52

Pt n°	Src	Src n°	D ebeam	d	α	β	σ	V_{beam}	Pl	Pa	Ptot	Q'/ absorber	H_{beam}	Absorber Δ Y	Absorber length	Chamber/position	Pa norm inc	Horizontal Incidence		angle a_H	
			mm	m	degree	degree	mm	mm	W/mm	W/mm2	W	[mbar l/s]	mm	[mm]	[mm]		W/mm2	°			
H1	DL1E_5	5	78.7	9.093	2.140	4.247	0.77	1.94	1.01	0.52	196.91	1.79E-08	0.77	10.2	270.2	Absorber 1	7.00	any	any	any	any
H2	DL1E_5	5	68.5	9.299	2.017	4.124	0.79	1.99	0.96	0.48			0.79				6.69	any	any	any	any
* H3	DL1A_5	5	51.7	2.554	1.534	88.480	0.22	0.55	48.35	88.63			0.22				88.66	12.56	15.00	26.43	32.41
											1177.67	1.27E-07	0.19	26.7	26.7	Crotch 1					
* H4	DL1A_4	4	25.0	2.130	0.888	89.126	0.18	0.46	34.03	74.78			0.18				74.79	14.94	17.87	31.84	39.45
H5	DL1A_4	4	45.5	3.208	0.979	21.374	0.27	0.69	8.24	12.02	345.49	6.04E-08	0.27	20.5	58.7	Absorber 2	32.98	35.77	44.09	any	any
H6	DL1A_3	3	25.0	2.869	0.580	20.976	0.24	0.61	6.86	11.20			0.24				31.28	38.05	47.19	any	any
H7	DL1A_3	3	74.9	5.588	2.317	45.381	0.48	1.19	7.01	5.87	377.98	9.35E-08	0.48	46.9	68.6	Absorber 3	8.25	any	any	any	any
H8	DL1A_1	1	28.0	4.881	1.789	44.853	0.42	1.04	4.61	4.42			0.42				6.27	any	any	any	any
H9	DL1A_1	1	79.1	6.277	3.508	17.475	0.53	1.34	1.52	1.14	1032.77	2.25E-07	0.53	51.1	203.9	Absorber 4	3.79	any	any	any	any
H10	DL2B_4	4	28.0	1.892	2.317	7.202	0.16	0.40	4.80	11.89			0.16				94.85	11.73	14.00	24.58	30.07
H11	DL2B_4	4	94.9	3.485	3.300	26.271	0.30	0.74	9.21	12.37	986.73	1.16E-07	0.26			Absorber 5 a	27.95	43.62	55.20	any	any
H12	DL2B_5	5	60.0	3.090	2.626	25.598	0.26	0.66	13.96	21.16			0.30	34.9	87.9		48.97	23.19	27.95	53.69	76.02
H13	DL2B_5	5	72.0	3.317	4.387	10.662	0.28	0.71	5.57	7.87	382.78	4.32E-08	0.28			absorber 5 b	42.51	26.97	32.67	68.15	any
H14	DQ1B	B	60.0	2.576	4.079	10.355	0.22	0.55	6.95	12.64			0.22	12.0	85.8		70.32	15.91	19.05	34.14	42.52
H15	DQ1B	B	124.4	3.986	2.479	19.621	0.34	0.85	8.39	9.86	1127.53	1.27E-07	0.34	41.2	145.8	Absorber 6a	29.35	41.06	51.43	any	any
H16	DQ1B	B	83.2	3.660	3.431	18.900	0.31	0.78	8.82	11.28			0.31				34.83	33.61	41.22	any	any
H17	DQ1B	B	105.3	4.058	3.487	21.275	0.35	0.87	8.91	10.28	1248.42	1.41E-07	0.35	45.3	147.1	Absorber 6b	28.33	42.90	54.12	any	any
H18	DQ1B	B	60.0	3.696	2.713	20.500	0.31	0.79	9.44	11.96			0.31				34.14	34.38	42.23	any	any
H21	DQ1B	B	189.7	5.874	2.761	16.405	0.50	1.25	4.79	3.82	1255.29	1.69E-07	0.00	189.7	283.3	Crotch 2 FE side	13.52	any	any	any	any
H22	DQ2C	C	130.0	4.525	1.849	15.493	0.39	0.97	4.73	4.90			0.50				18.34	any	any	any	any
* H19	DQ1D	D	69.0	2.759	2.840	89.686	0.24	0.59	36.10	61.28	1134.10	1.28E-07	0.24	29.0	29.0	Crotch 2 noze	61.29	18.34	21.99	40.08	50.84
* H20	DQ1D	D	40.0	2.338	2.187	90.339	0.20	0.50	42.59	85.30			0.20				85.30	13.06	15.61	27.56	33.86
H23	DQ1D	D	59.7	2.666	9.433	6.275	0.23	0.57	4.08	7.17	505.94	5.71E-08	0.23	43.1	283.3	Crotch 2 ext side	65.63	17.08	20.47	36.96	46.39
H24	DQ1D	D	102.8	3.313	2.294	5.708	0.28	0.71	2.99	4.23			0.28				42.50	26.98	32.68	68.20	any
H25	DQ1D	D	47.6	2.492	2.294	6.813	0.21	0.53	4.74	8.91	1224.59	8.76E+00	0.21	22.6	280.9	Crotch 2 int side	75.12	14.87	17.79	31.69	39.24
H26	DL2D_5	5	25.0	1.621	1.483	3.802	0.14	0.35	4.09	11.81			0.14				178.05	6.22	7.41	12.80	15.48
H27	DL2D_5	5	53.4	2.597	1.595	9.868	0.22	0.55	6.59	11.88	819.85	1.01E-07	0.22			Absorber 7	69.33	16.15	19.33	34.69	43.27
H28	DL2D_4	4	30.0	2.317	0.969	9.242	0.20	0.49	5.03	10.16			0.20	62.3	162.7		63.26	17.75	21.27	38.60	48.70
H29	DL2D_4	4	115.7	5.992	2.834	60.967	0.51	1.28	10.58	8.27	856.39	1.81E-07	0.51	90.7	106.7	Absorber 8	9.46	any	any	any	any
H30	DL2D_1	1	25.0	4.812	1.866	59.999	0.41	1.03	5.74	5.58			0.41				6.45	any	any	any	any
H31	DL2D_1	1	49.9	5.530	1.916	15.628	0.47	1.18	1.55	1.31	612.51	1.54E-07	0.47			Absorber 9	4.88	any	any	any	any
H32	DL1E_4	4	25.0	1.722	1.290	1.083	0.15	0.37	0.80	2.16			0.14	24.9	105.0		114.38	9.70	11.57	20.18	24.55
H33	DL1E_3	3	32.0	2.019	1.195	1.195	0.17	0.43	0.57	1.32	1355.00	1.55E-07	0.17	0.0	5025.0	CV AL 5073 *					
H34	DL1E_5	5	32.0	6.361	0.292	0.292	0.54	1.36	0.10	0.07			0.54								

* length without flanges

Power SR absorbers	14639.96	[W]
Power FE BM	642.36	[W]
Power ID FE	1042.24	[W]
Total Power	16324.6	[W]
Total Power Theo.	16324.56	[W]

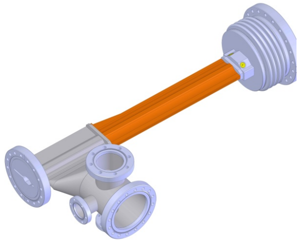
Total photodesorption (without CV AL5073)	1.94E-06	[mbar l/s]
(mol.photo Desorption yield copper η)	2.00E-06	[mol/ph]
Phot Flux	1.543E+17	[photons/s/mrad]

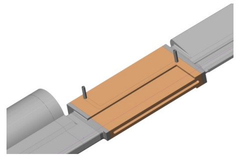
Pt nº Abs points, marked in the drawings
Src synchrotron radiation source type
Src nº nº synchrotron radiation source
D e-beam distance Abs point to e-beam
d (mm) distance from source point to Absorber Pt
α(degree º) angle between X-ray and e-beam orbit
β (degree º) X-ray incidence angle on the absorbers
σ (mm) Gaussian vertical height of X-ray
Pl (W/mm) linear power density on the absorber in the horizontal plan
Pa (W/mm2) surface power density on the absorber
Ptot (W) total power on the absorber
Chamber/position name of vacuum chamber /position
Xabs absorber X coordinate (origin middle straight section)
Yabs absorber Y coordinate (origin middle straight section)

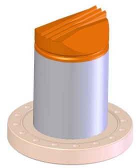
Absorbers

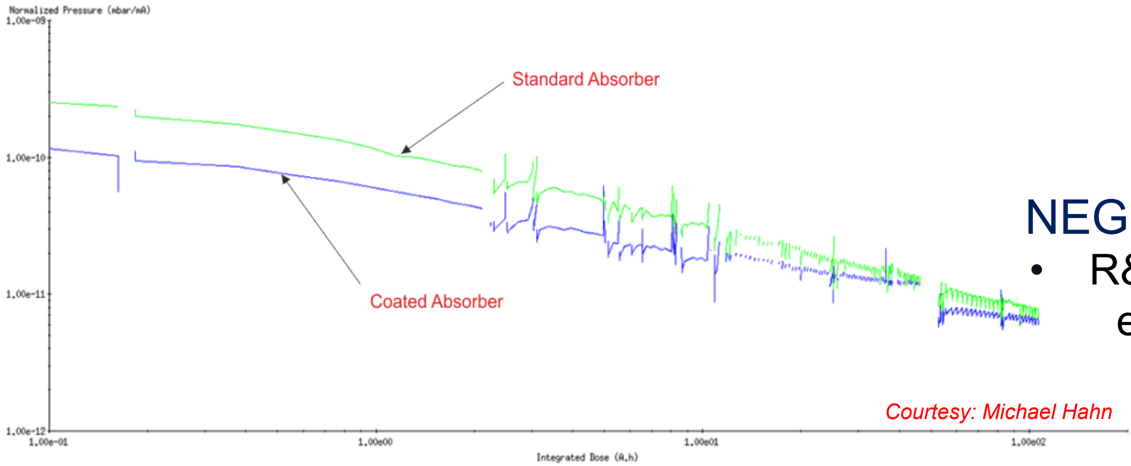
- Integrated or removable
- Local
- Material : Cu OFE, CuCr1Zr, GlidCop

- Avoid brazing if possible







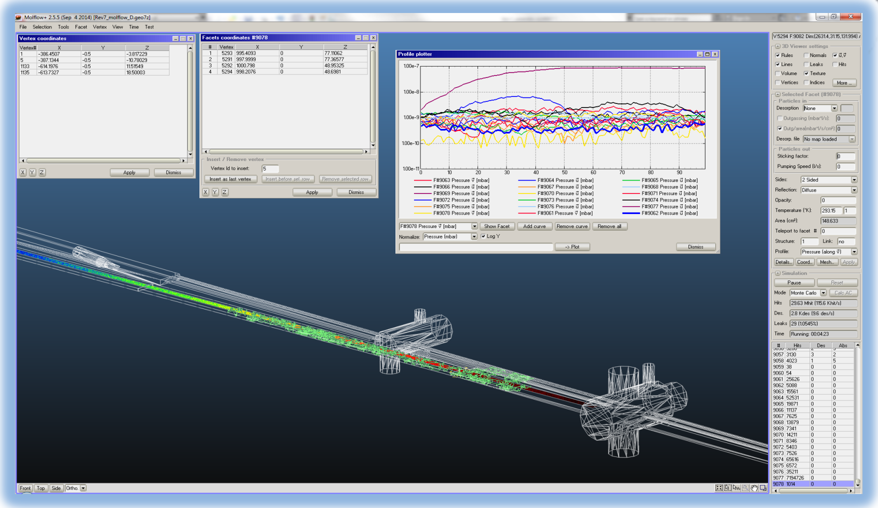


Courtesy: Michael Hahn

NEG coating

- R&D is continuing with the objective to explore if it is advantageous to coat the photon absorbers of the new machine

Vacuum chambers



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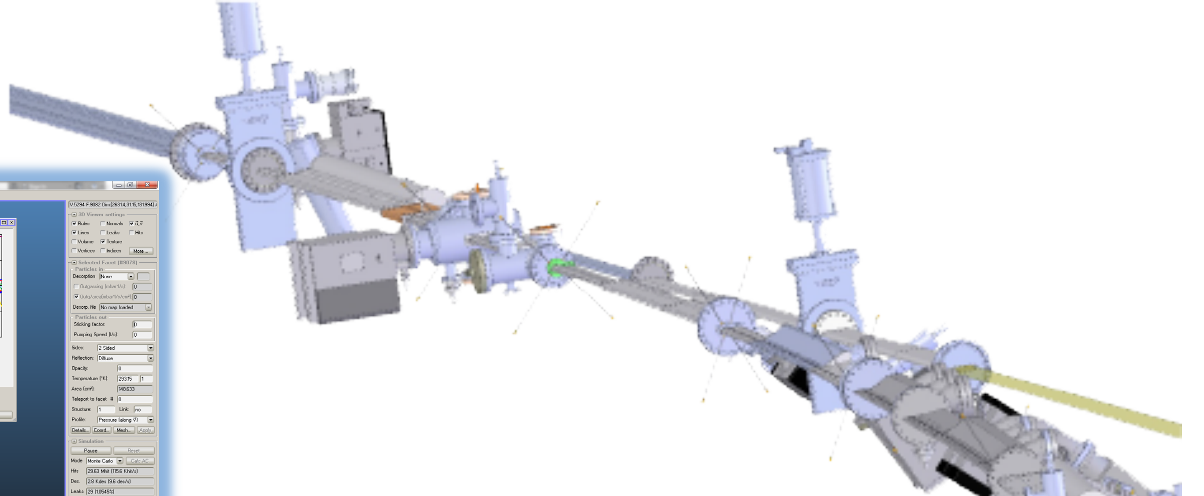
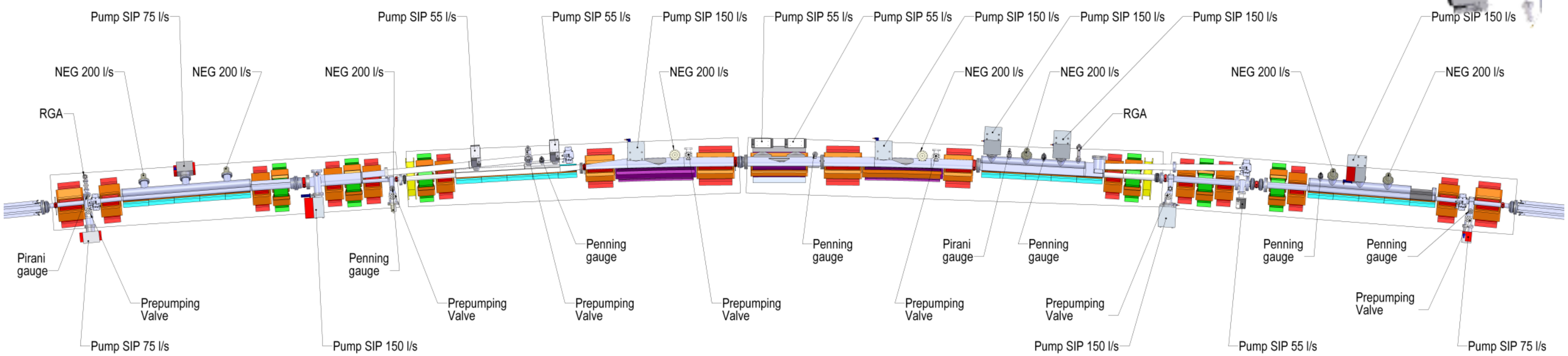
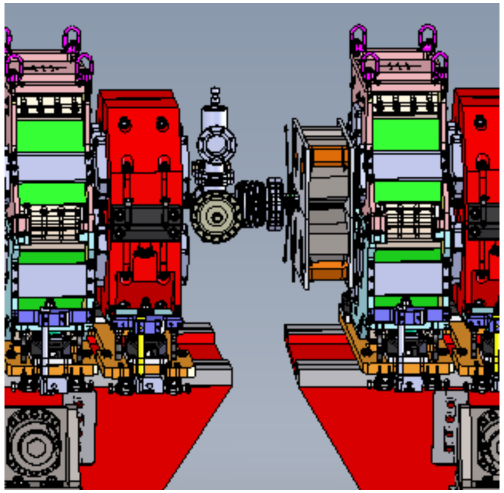
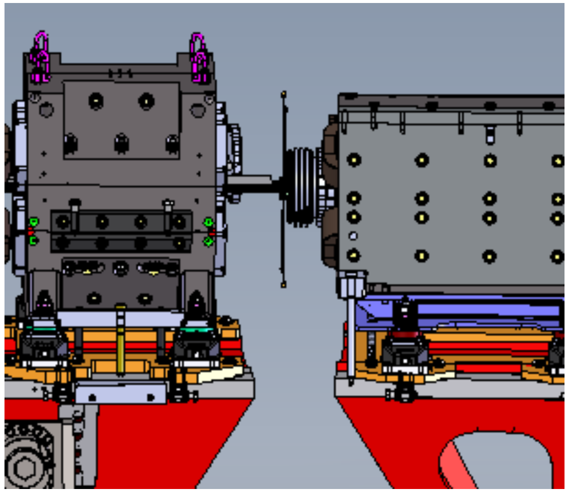


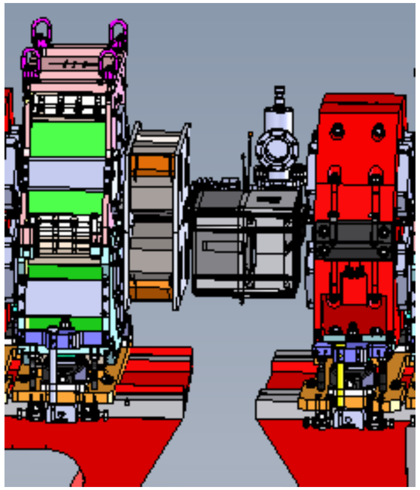
- 3D model of the vacuum volume of a complete cell has been imported into Molflow
- Lot of 'handwork' is still required to describe functional surfaces



Vacuum chambers







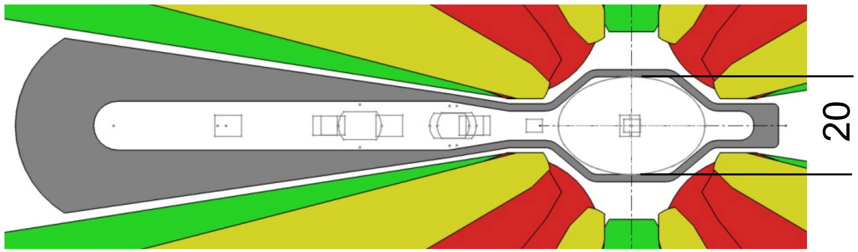
Girders interface :

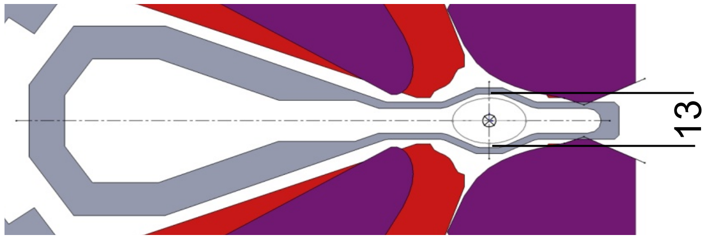
- Removable part to ease girder preparation and installation
- Front-End vacuum chamber vicinity
- Difficulty to find space to put flanges
- Support system
- Short RF fingers/bellows

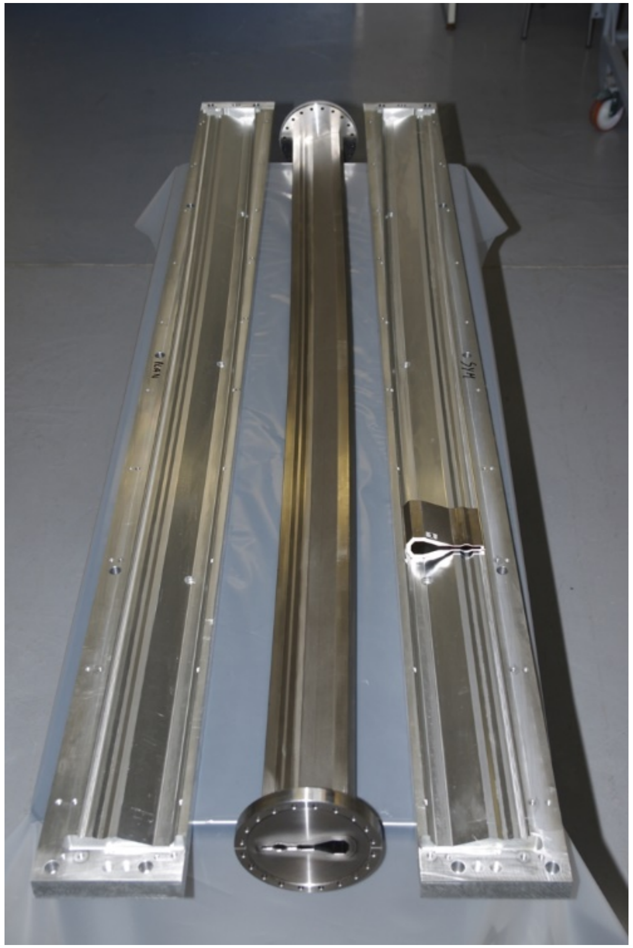
Vacuum chambers

Technical issues:

- Beam stay clear
- Bakeout material
- Profiles, manufacturing process
- Raw material
- Absorbers, ray tracing
- RF fingers, transitions, FE, impedance…
- Vacuum performance
- NEG coating (Chambers & & 12)

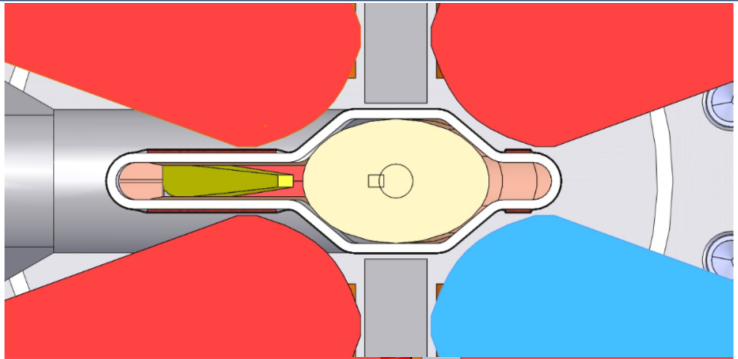


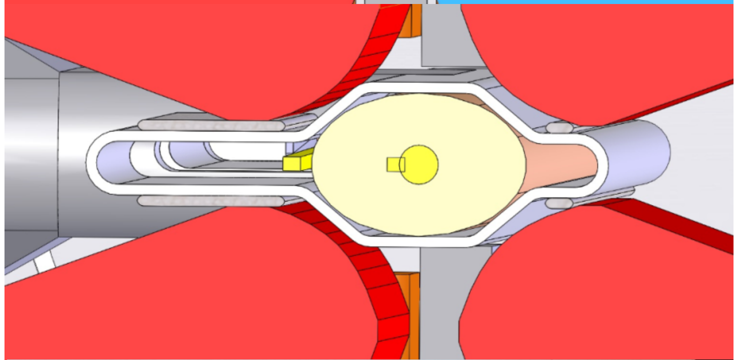




Central part: Stainless steel
Vacuum chamber prototype

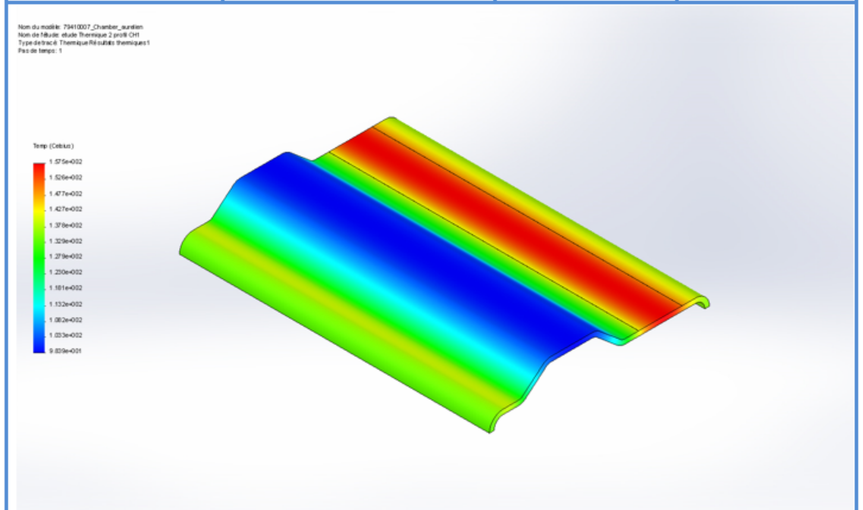
Vacuum chambers bakeout





- Different configurations of heating element arrangement are under study
- Thermal simulation is being carried out by means of FE module of Solid Works
- Radiation resistance tests are on the way on the existing machine

Nom	Type	Min	Max
Résultats thermiques1	TEMP: Température	98.3935 Celsius Noeud: 7734	157.503 Celsius Noeud: 28727



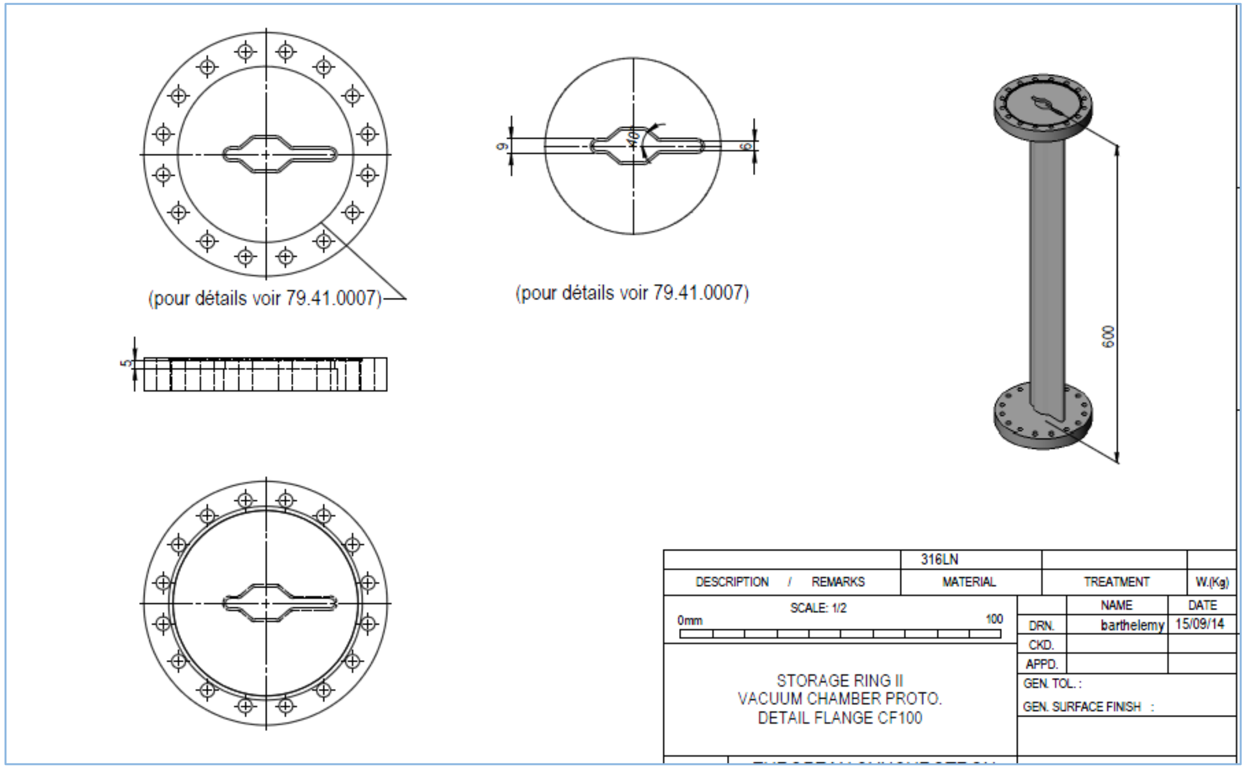
79410007_Chamber_aurelien-etude Thermique 2 profil CH1-Résultats thermiques-Résultats thermiques1

Courtesy: Michael Hahn

Vacuum chambers NEG coating

NEG Coating tests

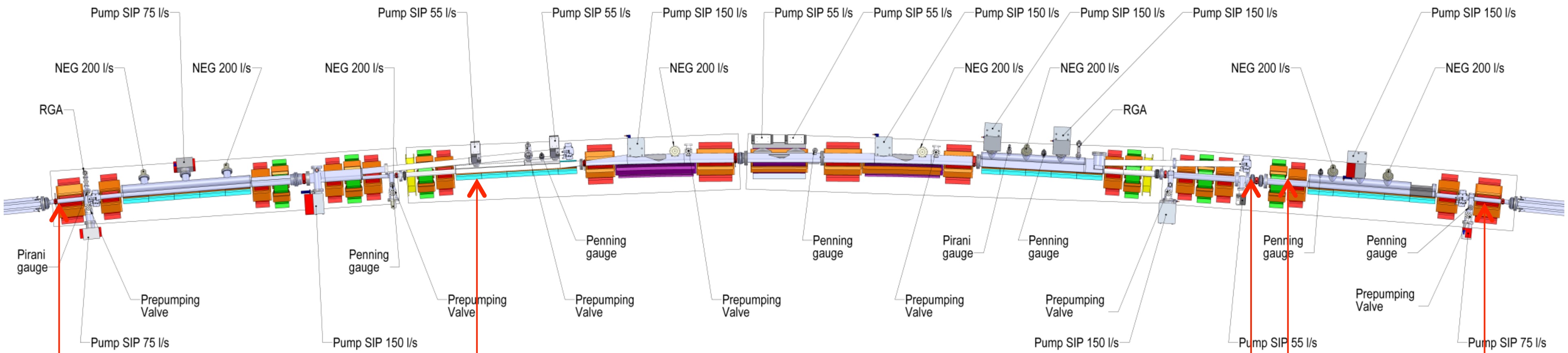
- The current design of the chamber cross section contains a slot of 6mm inner vertical height
- For ID chambers the NEG coating has been limited to vertical height slightly smaller than 8mm

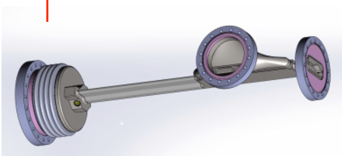


- The prototype chamber will be used for validation of thermal simulation and for development of a reliable coating concept

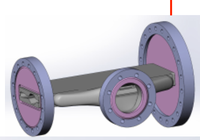
Courtesy: Michael Hahn

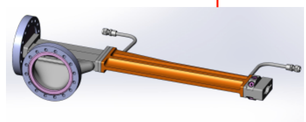
Vacuum chambers

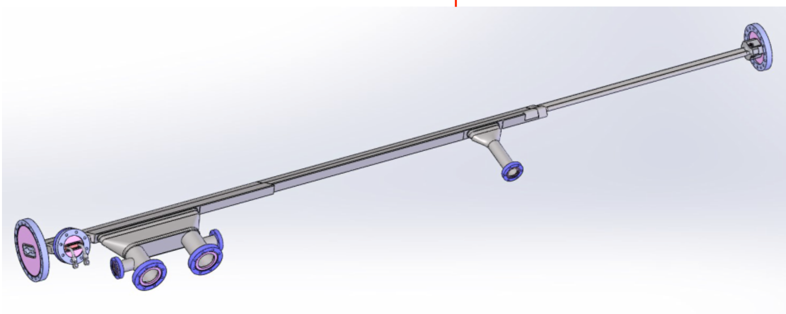


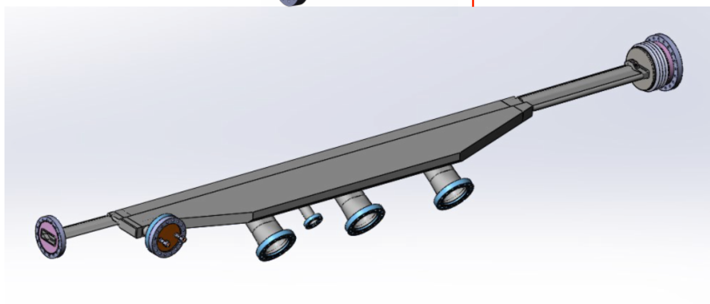


- Design in progress
- Vacuum and impedance calculation validation









INPUT DATA

- Girder length = 5.2m, magnets weight = 6 000kg
  - Static positioning required

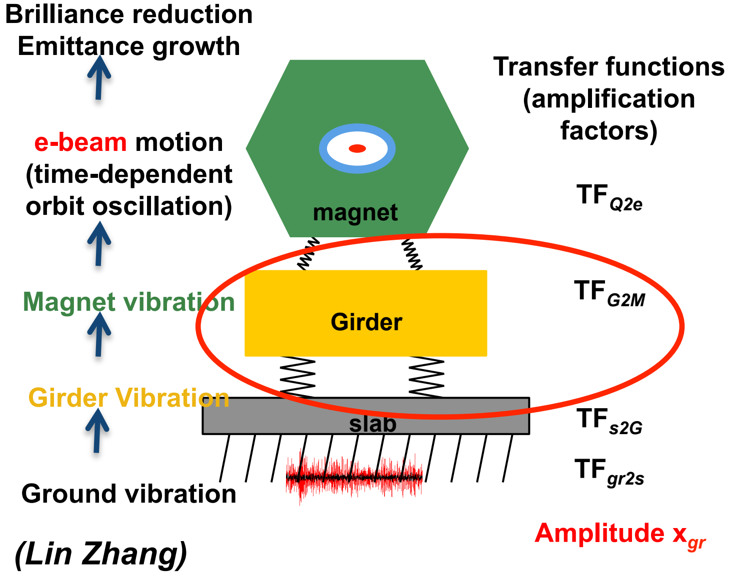
	HORIZONTAL (Y)	VERTICAL (Z)
Girder to girder	50 μm	50 μm

- ESRF site and slabs large displacements
  - Static = 150 μm / 6 months
- Vibration level = high compared to other sites

GIRDER PROJECT SPECIFICATION

- Motorized Z adjustment resolution 5μm
- Manual Y adjustment resolution 5μm
- 1st natural frequency = 50Hz (design criteria)
  35Hz (measured target)

Vibration amplification ground to beam



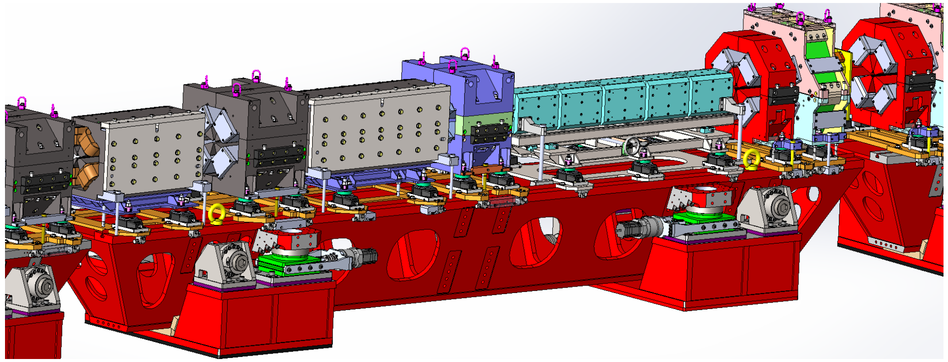
Challenges
- High precision positioning requirements, motorization
- High stability requirements
- Lack of space
- Budget limits

Difficult to match

Courtesy: Filippo Cianciosi

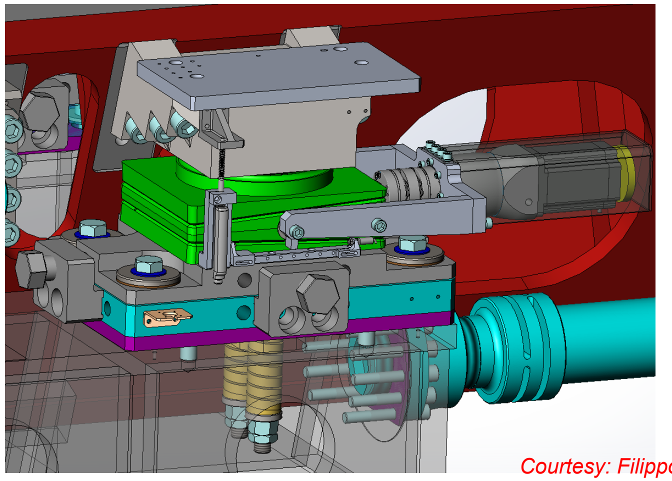
Girder design, the orthogonal heptapod

- 4 motorized adjustable supports in Z direction
- 3 manual horizontal jacks (one in X, two in Y)
- There is 1 degree of hyperstaticity in the vertical direction, a carefully adj of the 4 feets is required
- Technology:
- Girder material: carbon steel
- Typical tickness: 30mm (20-50)
- Piece junction:
- full penetration and continous welding



Support & adjustment

- Wedge Airloc 414-KSKC (modified) with integrated spherical socket
- Limit switches & encoder
- Sliding surface, skid made with bronze with coating



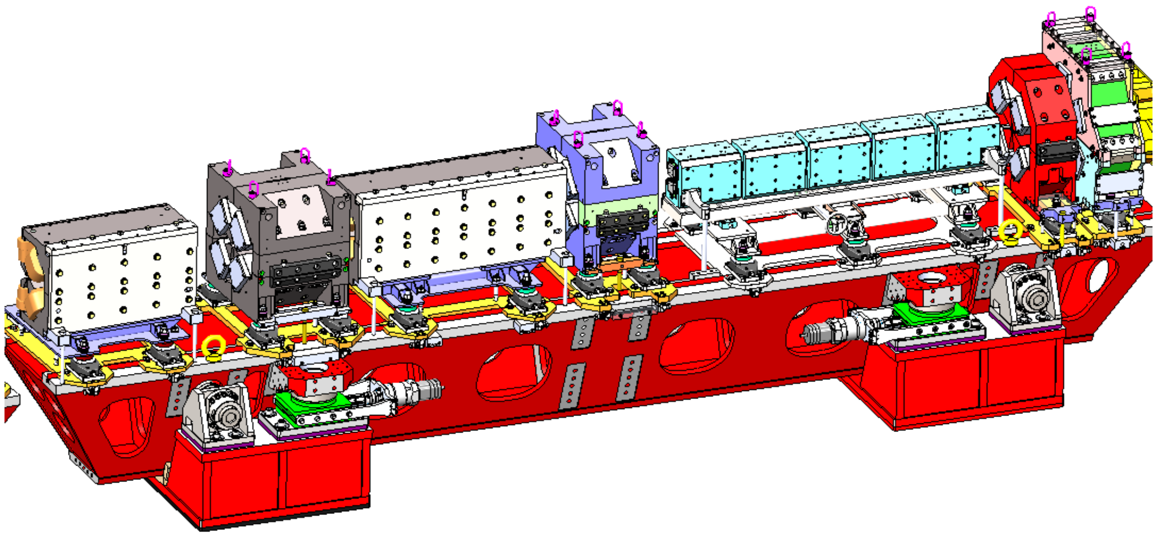
Courtesy: Filippo Cianciosi

Girders

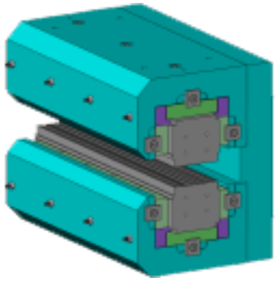
Girders parameters

- Dimensions
- Stability performance
- Adjustment system
- Installation aspect
- Cooling & cables required space

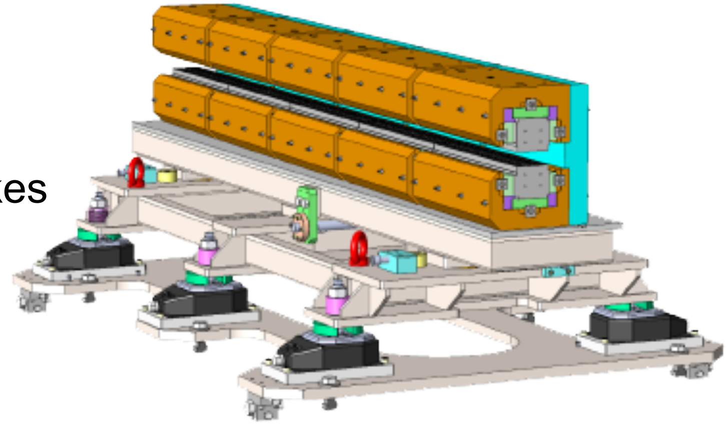
- Tests on prototype scheduled March 2015



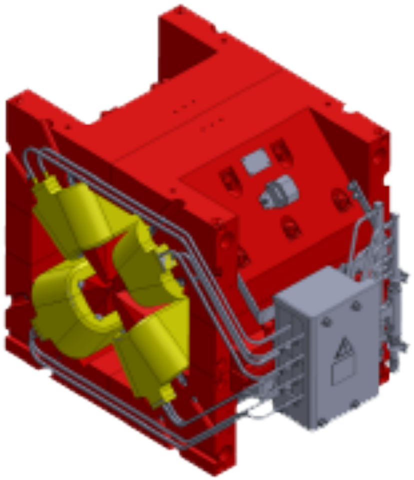
Magnets design



DL
- Permanent magnets with machined yokes
- Prototypes are being characterised
- No major technical issue

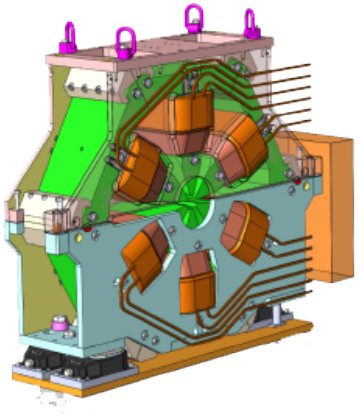


- Support allowing to remove DL during bakeout



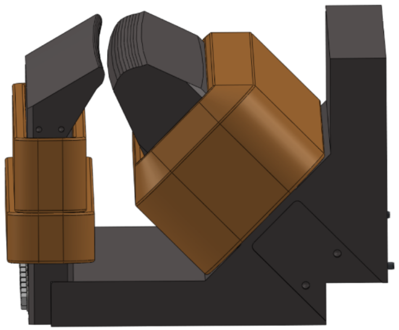
Quadrupoles
- Quarter yokes machined independently
- +/- 20 µm tolerance expected after assembly
- Quarter yoke assembly: solutions to be tested (accuracy, repeatability)
- Technical issues
  - Raw material cost & procurement
  - Machining tolerances

Magnets design



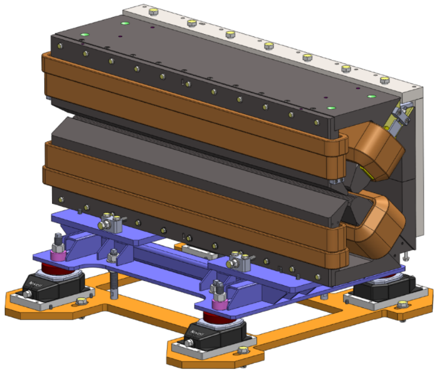
Sextupoles

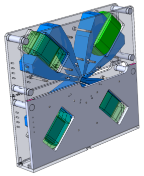
- Laminated magnet
- 1st Engineering design completed in May 2014
- "Heavy" mechanical design: stainless steel frame, large clamps, …
- Simplified design in progress
- No major technical issues
  - Girder fixation not easy due to small length



DQ Dipole Quadrupoles

- 3D model complete
- Engineering design in progress
- Mechanical prototype to be ordered end 2014
  - technical issues:
    - Machining tolerances





Octupoles & Correctors

- no major technical issues
  - Octupole prototype received

Magnets

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Magnet type		Quantity	Field strength		Iron length	
Dipoles with longitudinal gradient	DL	128	0.17-0.67	T	1788	mm
Dipole quadrupoles	DQ	96	0.43-0.54 34	T T/m	1078	mm
Moderate gradient quadrupoles	Q	384	52	T/m	162-295	mm
High gradient quadrupoles	Q	128	85	T/m	388-484	mm
Sextupoles	S	192	900-2200	T/m^2	204	mm
Octupoles	O	64	$51.2\ 10^3$	T/m^3	120	mm
Correctors H(V)	C	96	0.08	T	120	mm

- 1088 magnets

- Quantity (Manufacturing time)
- Design required detail level
- Raw material
- Manufacturing difficulty (tolerances)
- Required space around the magnet
- Stay clear area (vacuum chambers)
- Fiducialization strategy
- Fixation system
- Electrical & water connections

Alignment tolerances

Required:	DX	DY	DS	DPSI	DK
	μm	μm	μm	μrad	10^-4
DL	>100	>100	1000	500	10
DQ, QF[68]	70	50	500	200	5
Q[DF][1-5]	100	85	500	500	5
SFD	70	50	500	1000	35
OF	100	100	500	1000	

DX *horizontal perpendicular to the beam*
DY *vertical perpendicular to the beam*
DS *along the beam*
DPSI *is the rotation about the beam axis*

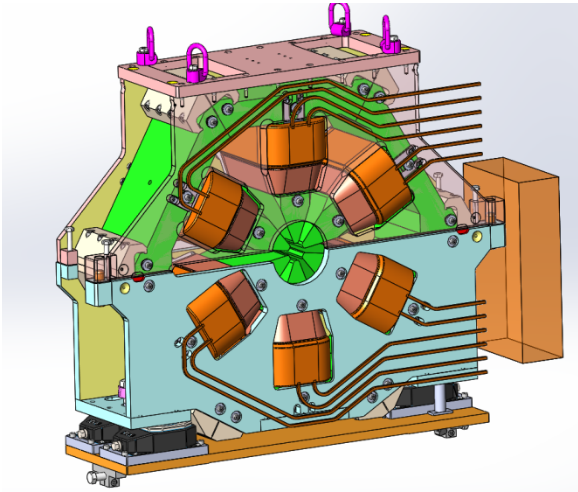
Magnets Supports

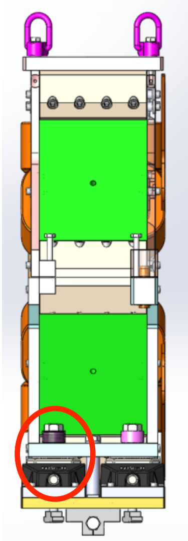
A light for Science

Proposed design with preloaded wedges

(sextupole, Quadrupoles, DQ, DL)

- Sextupole mounted on 3 preloaded (2 tons) precision conical wedges.





Preload 2 tons with Belleville spring washers

PROS

- No clamping effect
- Easy and fast to align
- high vertical stiffness
- (2000N/µm)
- Multiple points support
- Z and Y independent
- compactness in vertical
- Commercial units

CONS

- horizontal stiffness is unknown → characterization = Mechanical and Vibration tests
- Need high preload (>2 tons)

Lot of different straight sections

- 1 7m canted
- 6 6m (2 canted)
- 9 with In-vacuum undulators
- 3 RF
- 12 Others (standard 5m)
- 1 Injection

Each section is different and needs to be looked at in detail

- Transitions
- RF fingers
- Internal profiles
- In-vacuum undulators inside components, water cooling channels…

Straight sections upgrade

- Time & resource consuming during machine shutdown

Conclusion

- Organization
  - Deliverables & responsible persons
  - Master planning
- Vacuum chambers
  - Manufacturing tolerances
  - Manufacturing process
  - Absorbers (2nd croth)
  - Limited space
- Magnets
  - Magnets design details level
  - Machining Tolerances for Quad's
- Girders & supports
  - Prototype results
  - Magnets positioning system