Engineering Challenges of Future Light Sources

Project Sirius

Regis Neuenschwander

On behalf of the Engineering Division

Mechanical Technology Group
Brazilian Synchrotron Light Laboratory
www.lnls.br

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sirius

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Some Engineering Challenges of Some Future Light Sources

(and how we are dealing with them at Sirius)

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Content

- Introduction
- Slab
- Supports
- Magnets
- RF
- Vacuum
- BPM
- FOFB

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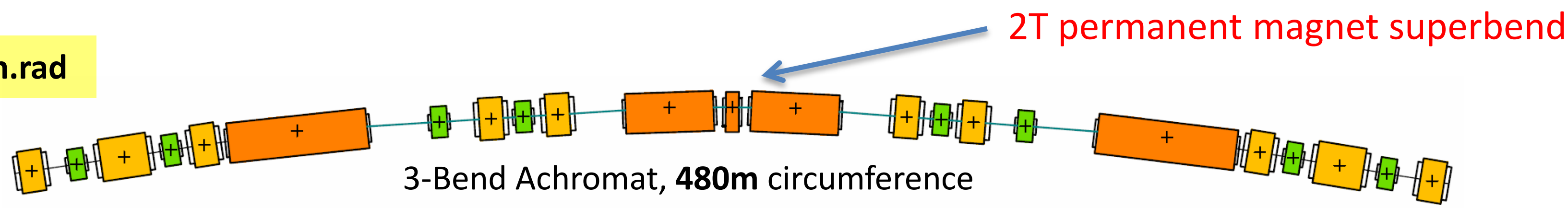
A little bit of Sirius history (2008…)

- Sirius before Machine Advisory Committee meeting in June 2012

Emittance: **1.7 nm.rad**



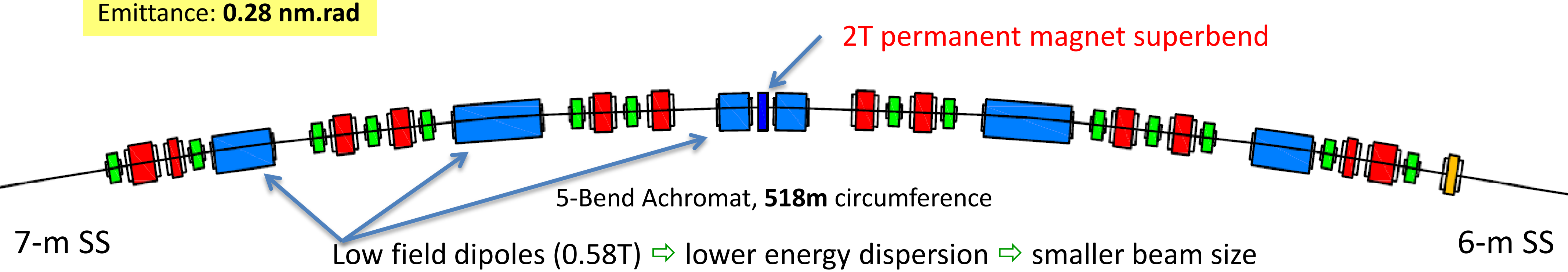
- MAC recommendation

"6. The present lattice design is excellent by today's standards, but the committee urges LNLS to **push for tomorrow's brightness standard (e.g. <1 nm emittance)**."

Helmut Wiedemann (Stanford/SLAC emeritus), Robert Hettel (SLAC), Mikael Eriksson (MAX), Albin Wrulich (SLS)

- Sirius after MAC recommendation

Emittance: **0.28 nm.rad**



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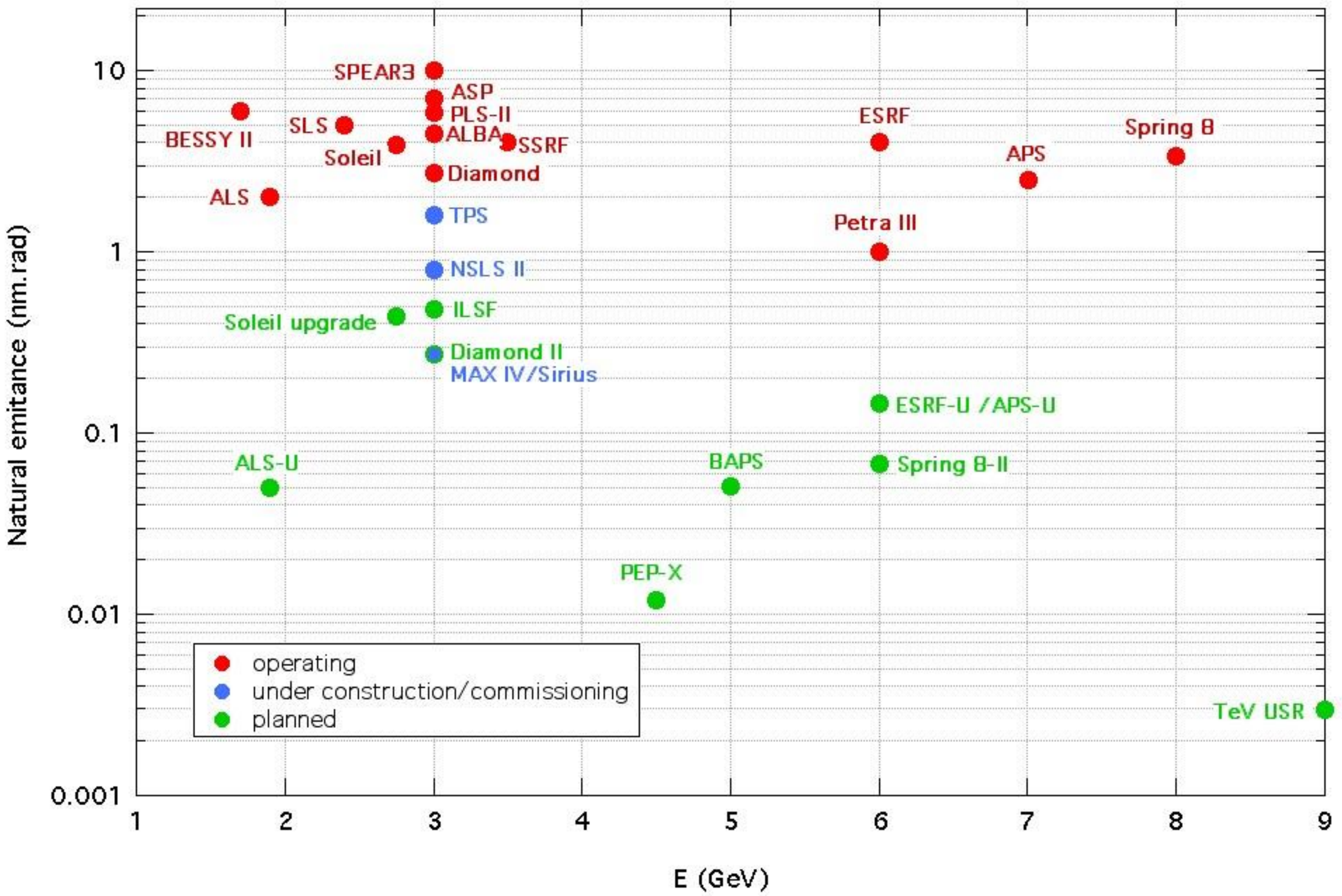
Natural emittance of some Light Sources



Liu Lin (LNLS), Z. Zhao (SSRF), R. Bartolini (DLS),...

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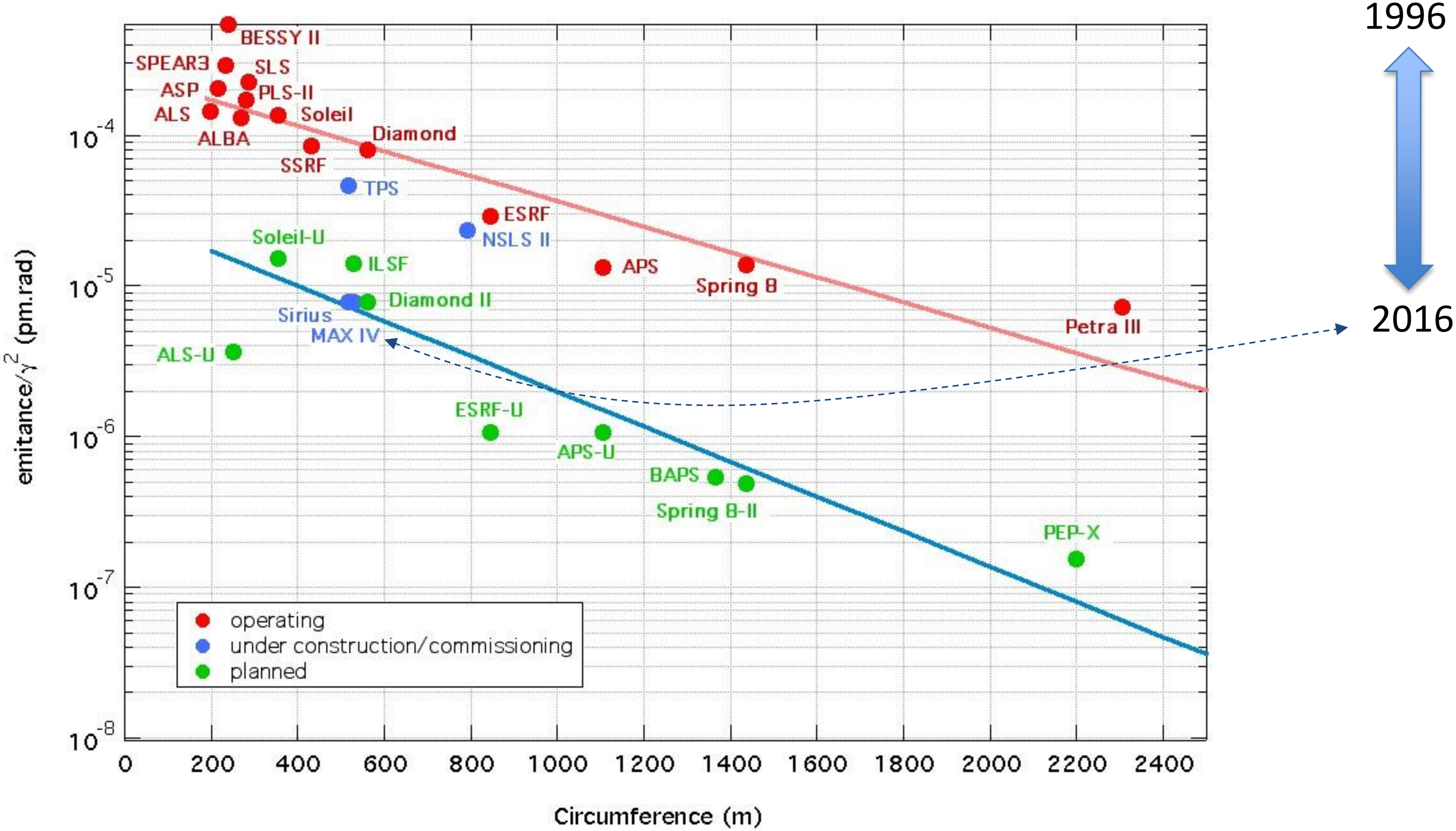
Natural emittance of some Light Sources

IPAC

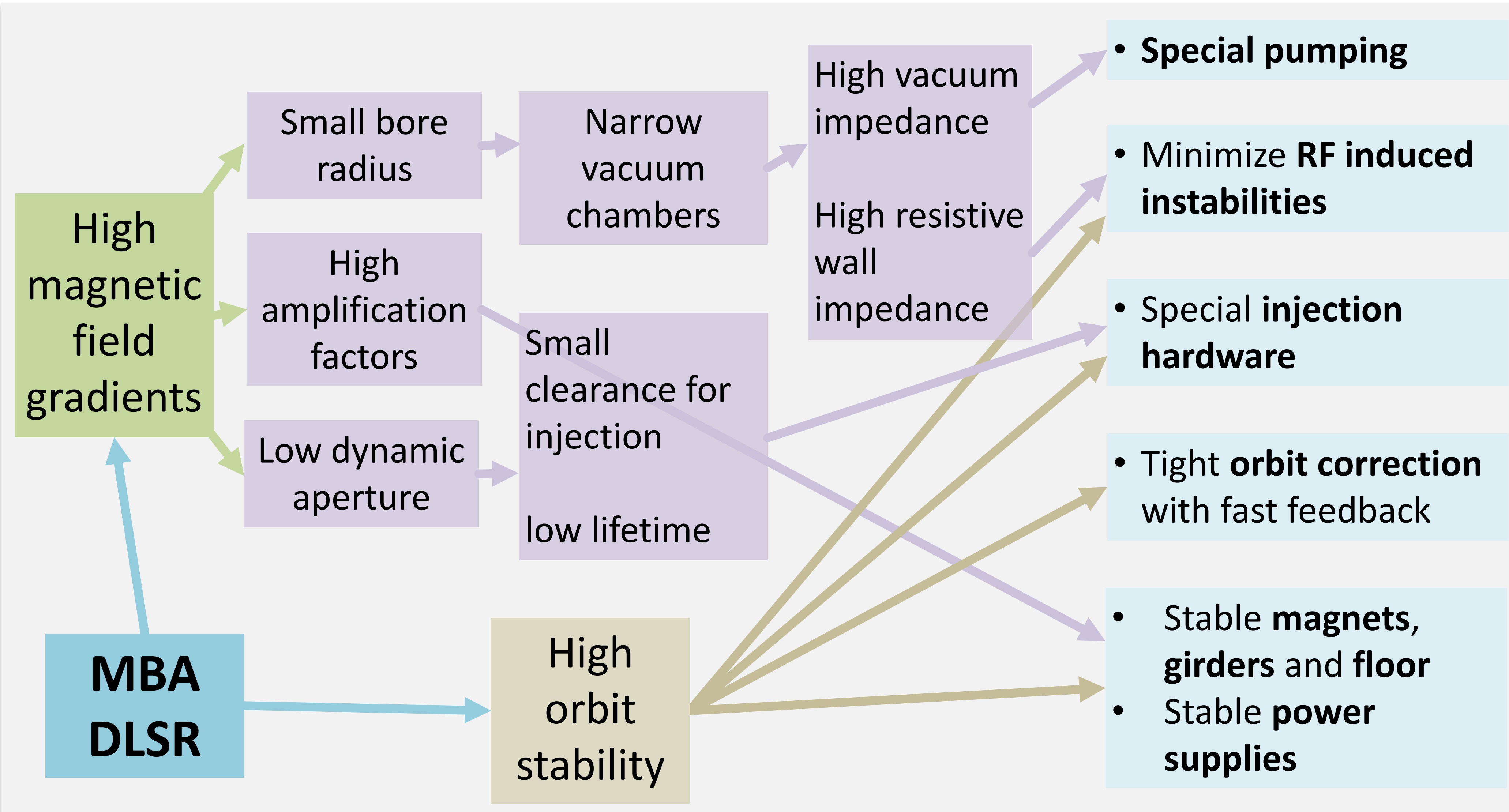
Design of a Diffraction Limited Light Source (DIFL)

D. Einfeld, J. Schaper, Fachhochschule Ostfriesland, Constantiaplatz 4, D-26723 Emden
M. Plesko, Institute Jozef Stefan, Jamova 39, P.O.B. 100, SLO-61111 Ljubljana



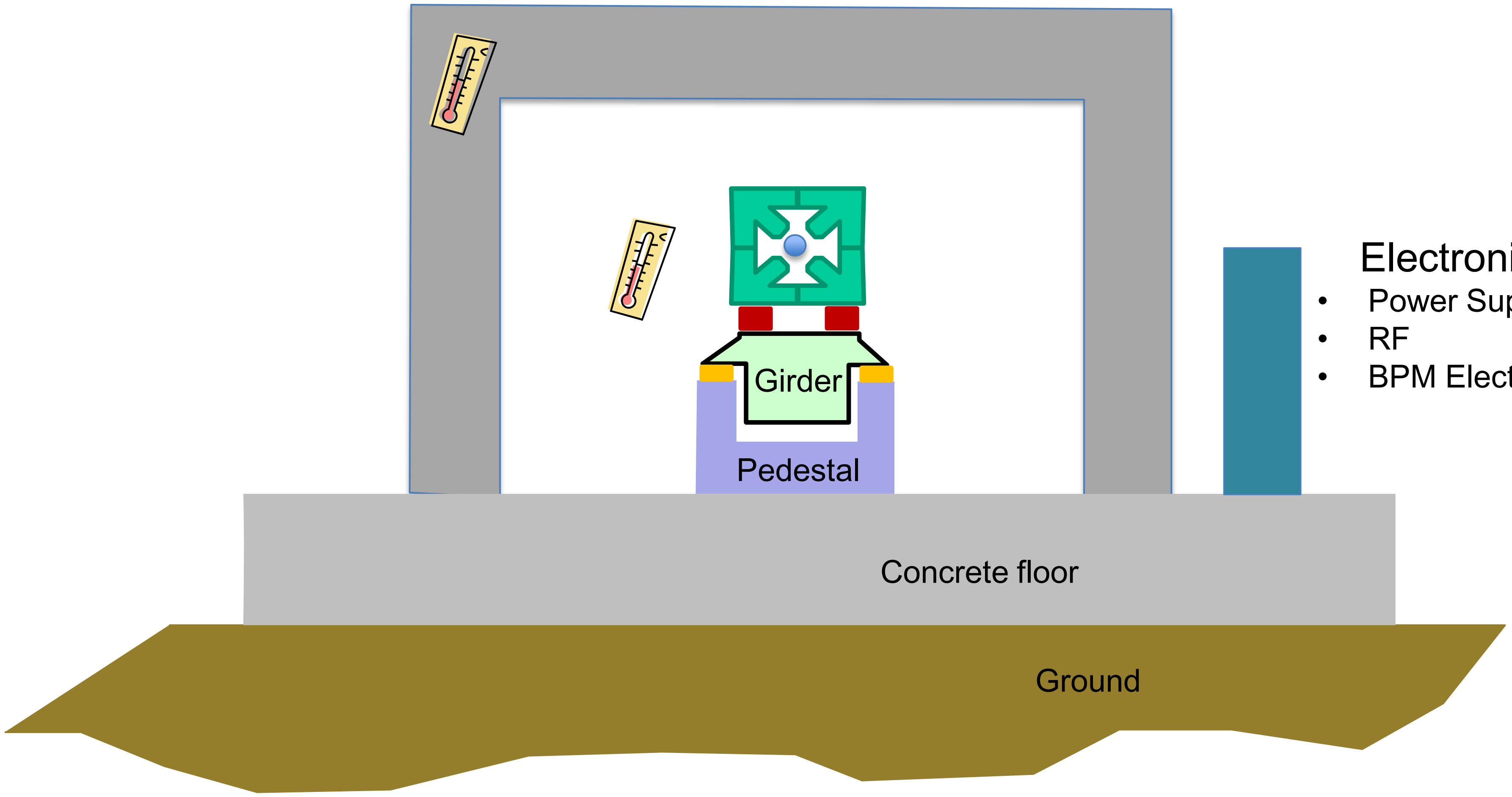
Liu Lin (LNLS), Z. Zhao (SSRF), R. Bartolini (DLS),...

Multiple Bend Achromat chain reaction diagram



Courtesy Ricardo Rodrigues

It's all about stability !



Electronics

- Power Supplies
- RF
- BPM Electronics

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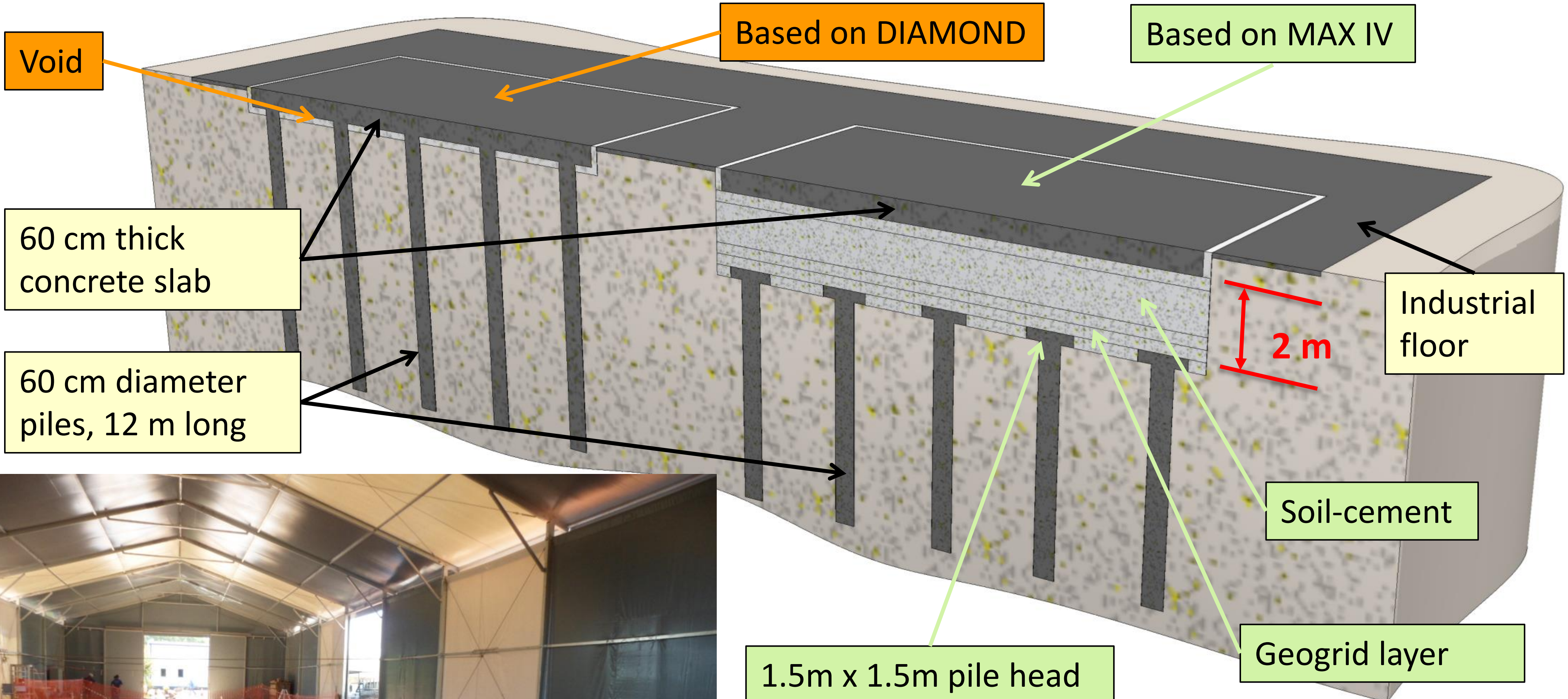
Prototype Slabs (13.5m x 6.5m each)



Chosen after analysis of different labs: *Petra III, ESRF extension, Alba, NSLS II…*

and important talks with: *Nick Simos, Markus Schloesser, Lluis Miralles, Yves Dabin, Jim Kay, Brian Jensen…*

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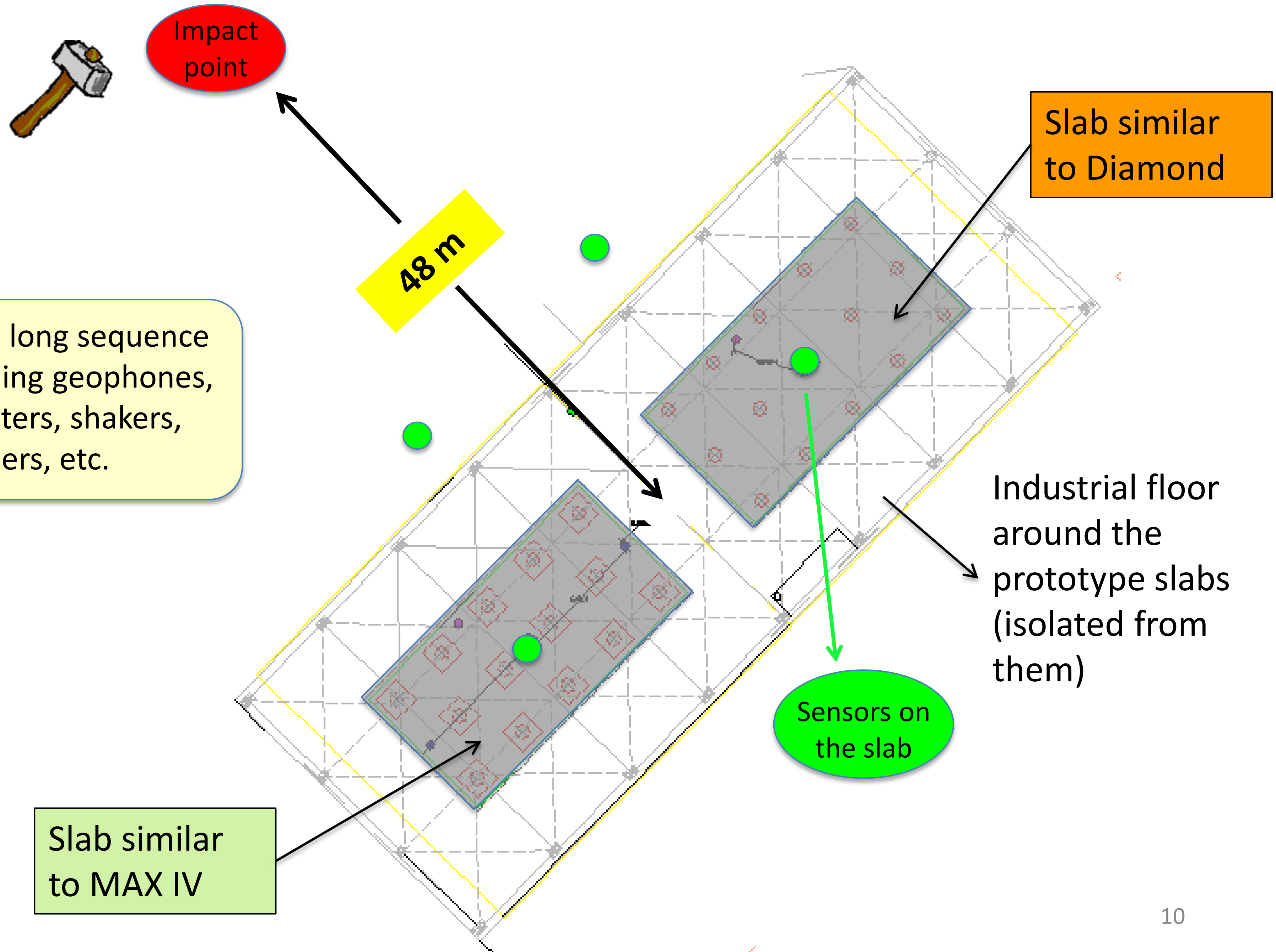
Slab's response to an external vibration source

…to resume a long sequence of tests including geophones, accelerometers, shakers, hammers, etc.



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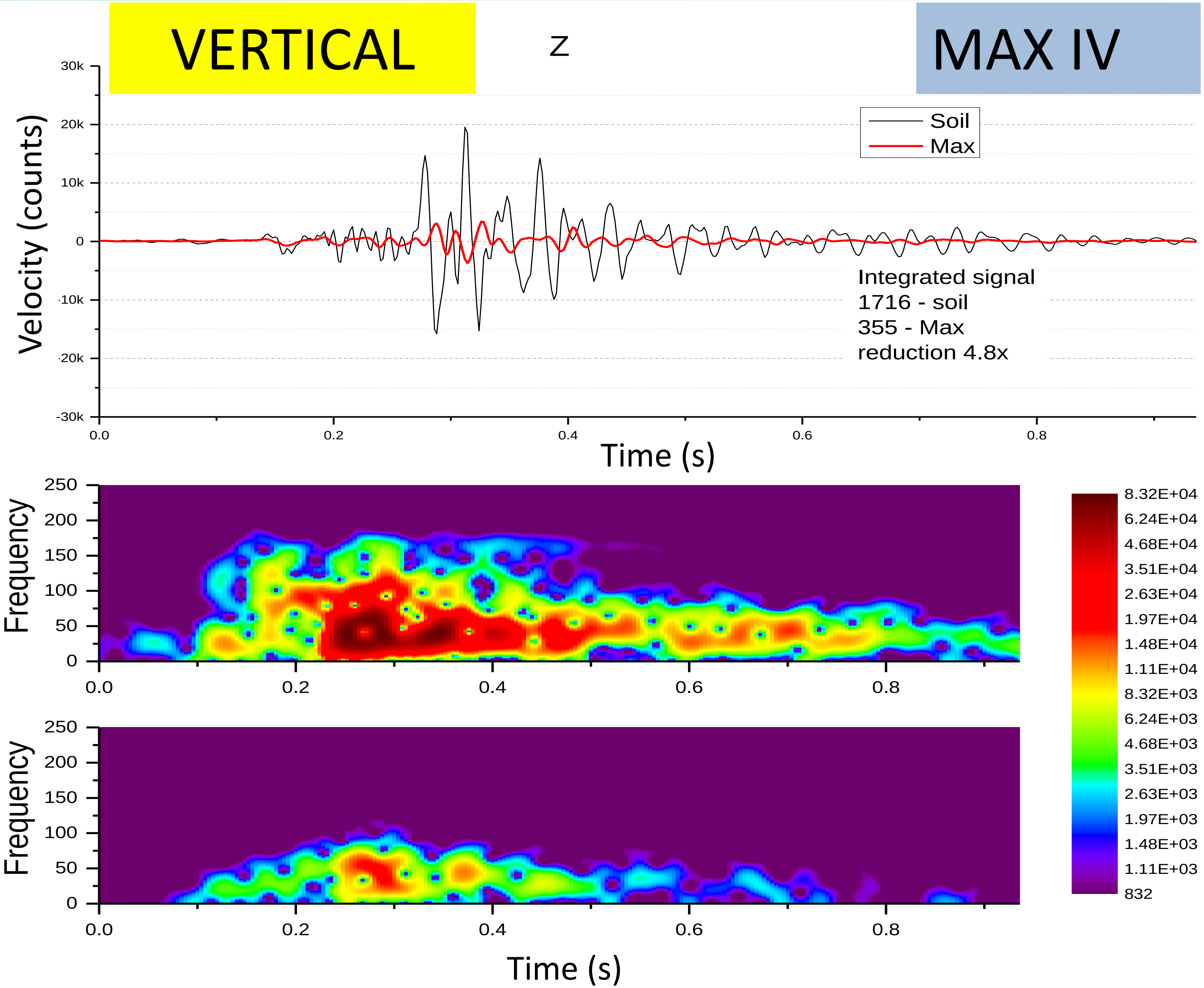
Slab's response to an external vibration source



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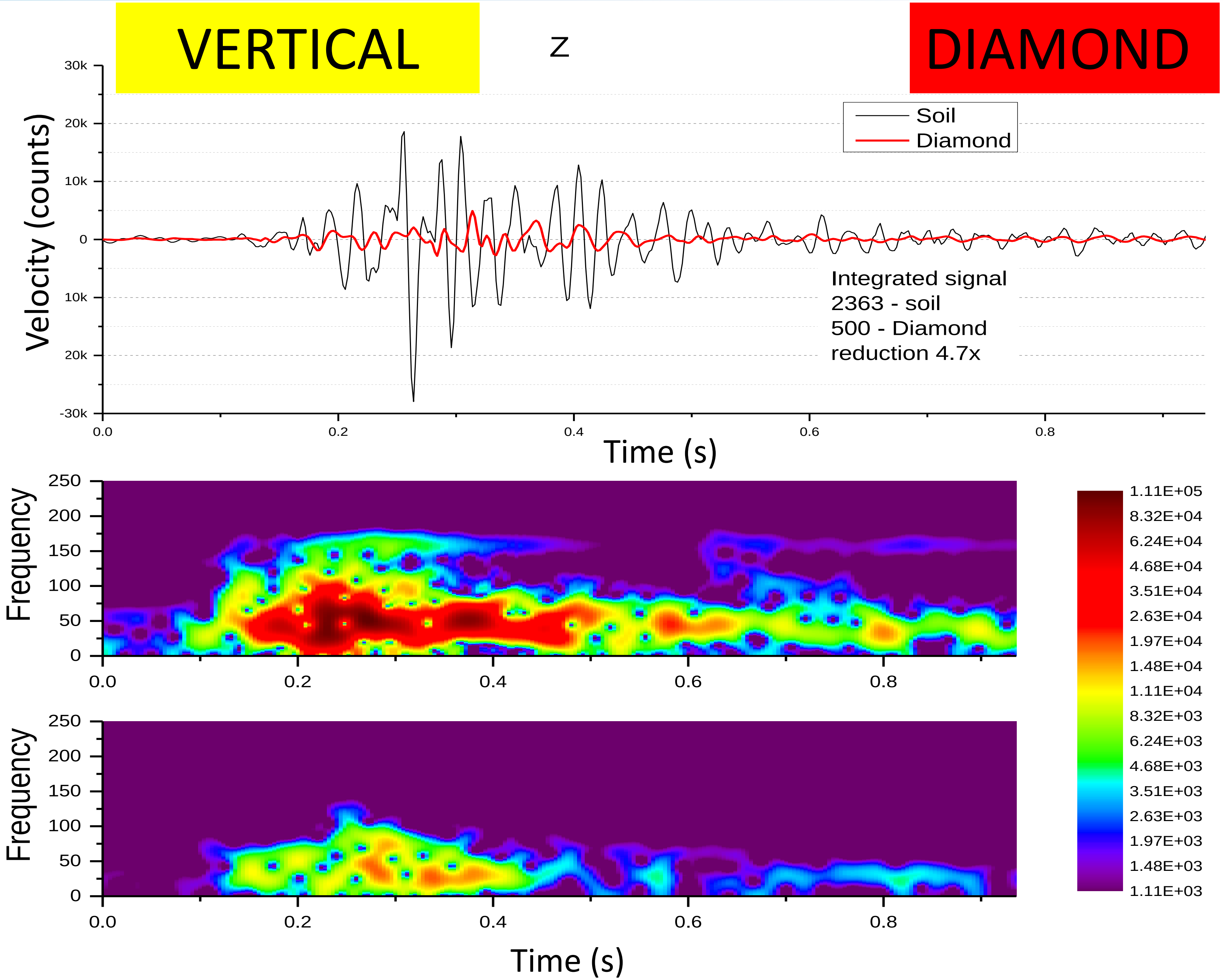
Slab's response to an external vibration source



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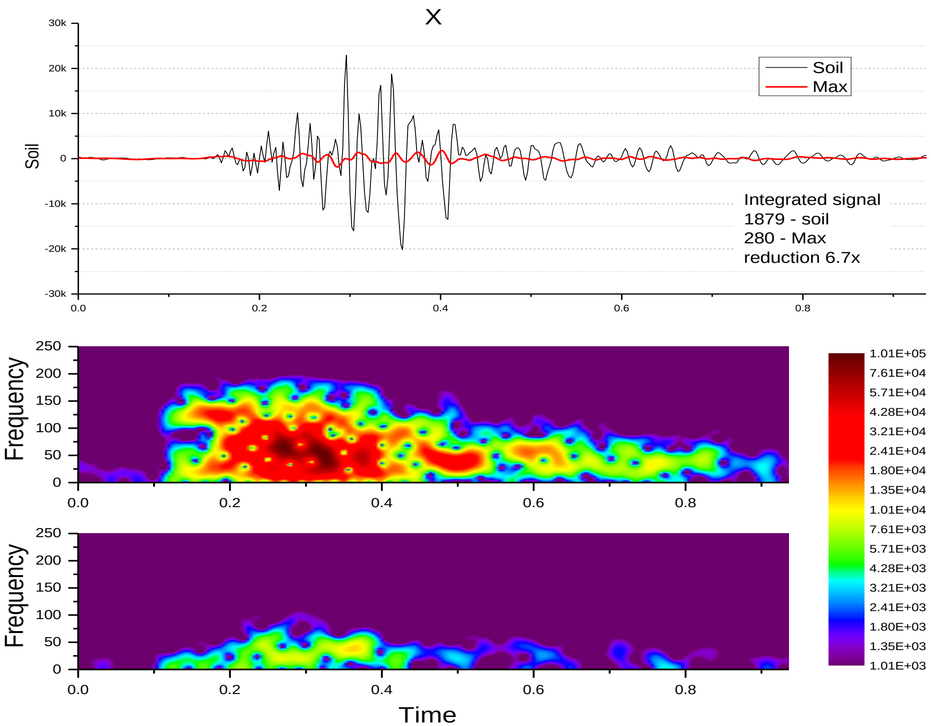
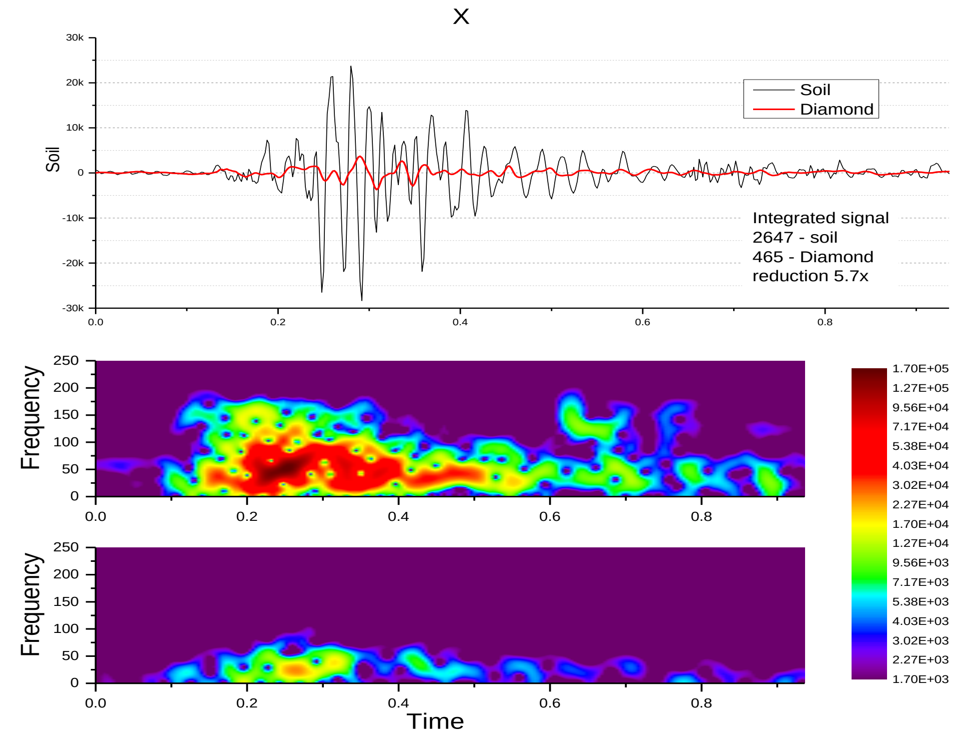
Slab's response to an external vibration source

HORIZONTAL

MAX IV



DIAMOND



Attenuation factor from external excitation		
	Vertical	Horizontal
MAX IV	4.8	6.7
DIAMOND	4.7	5.7

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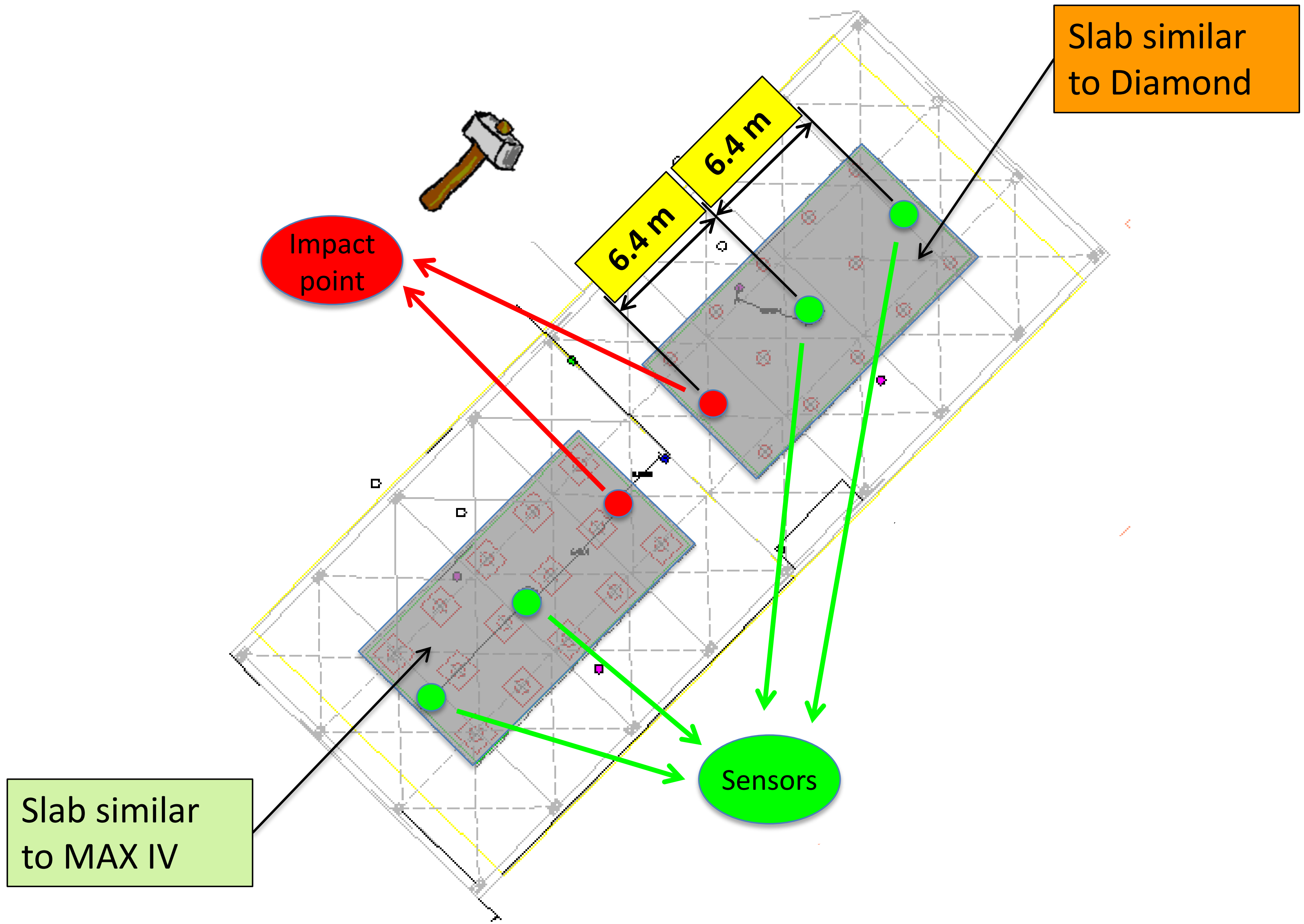
"On the slab" impact point



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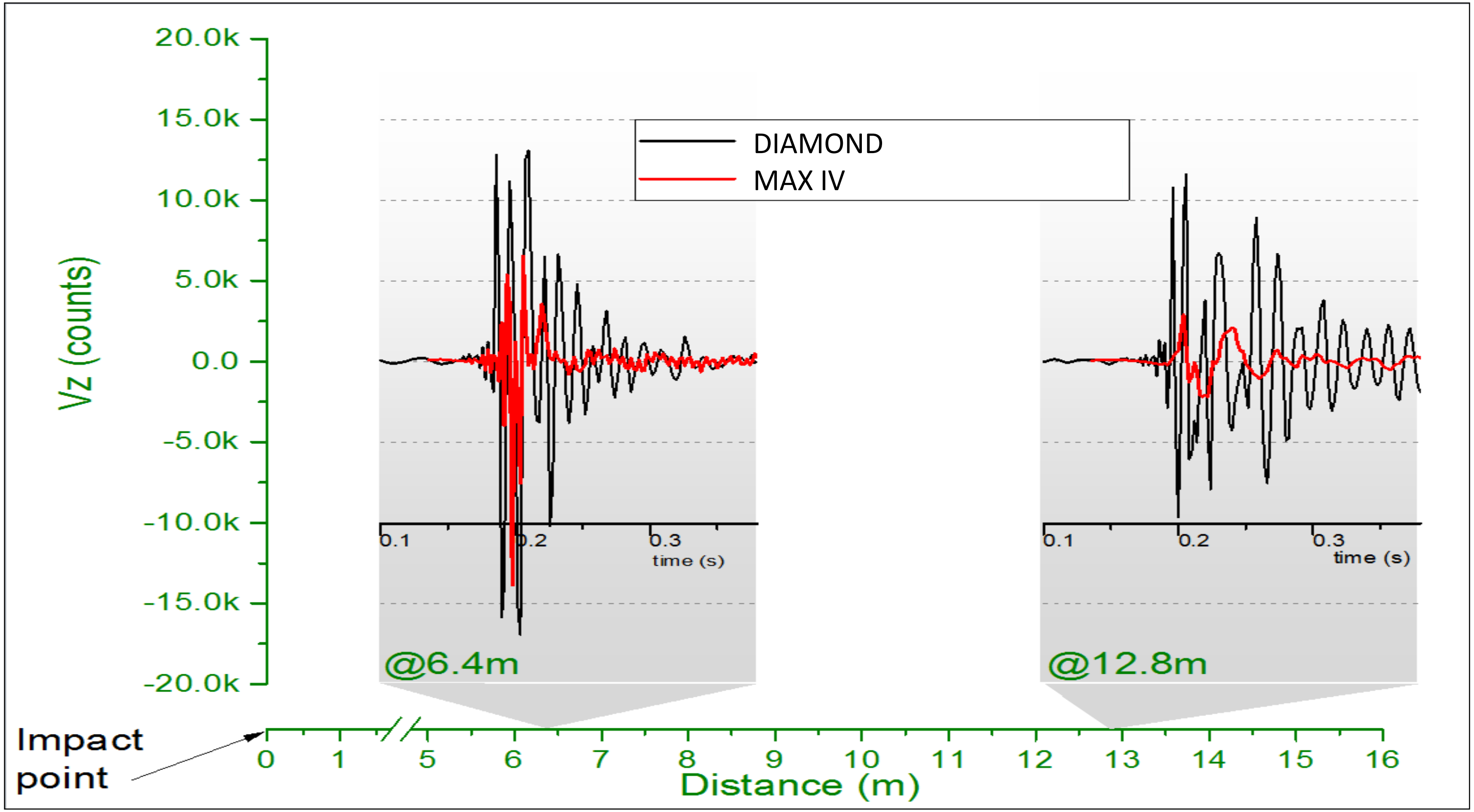

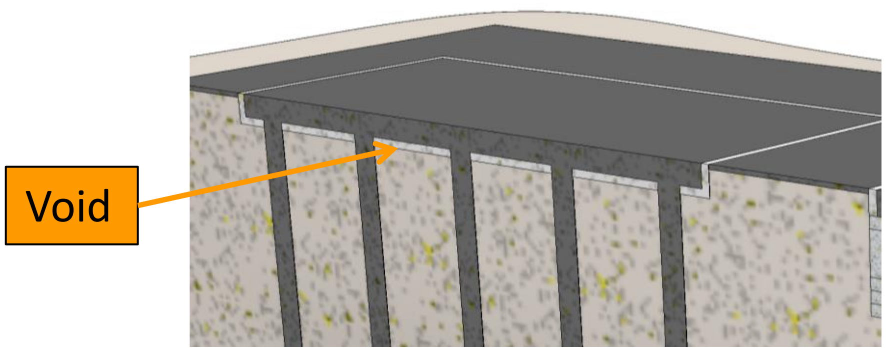

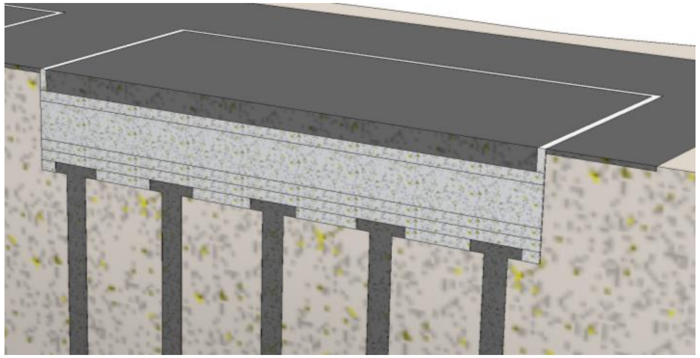

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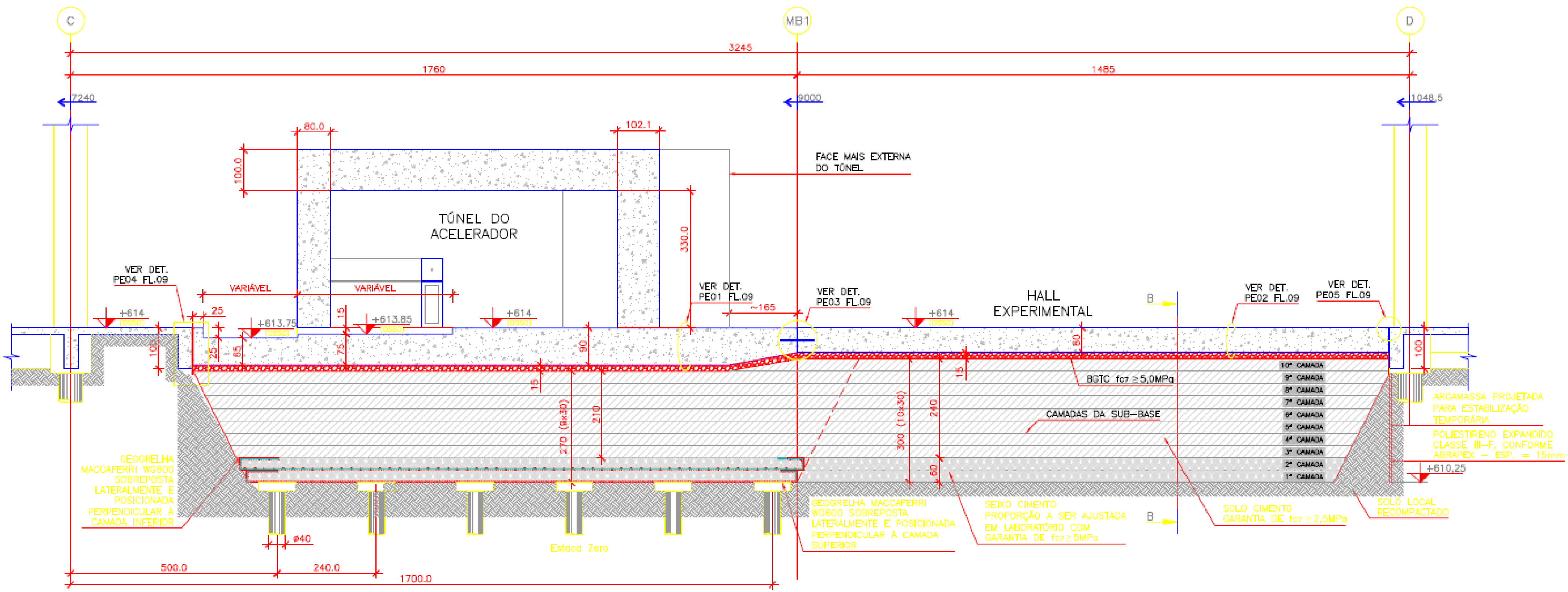
Final configuration for the Sirius foundations*



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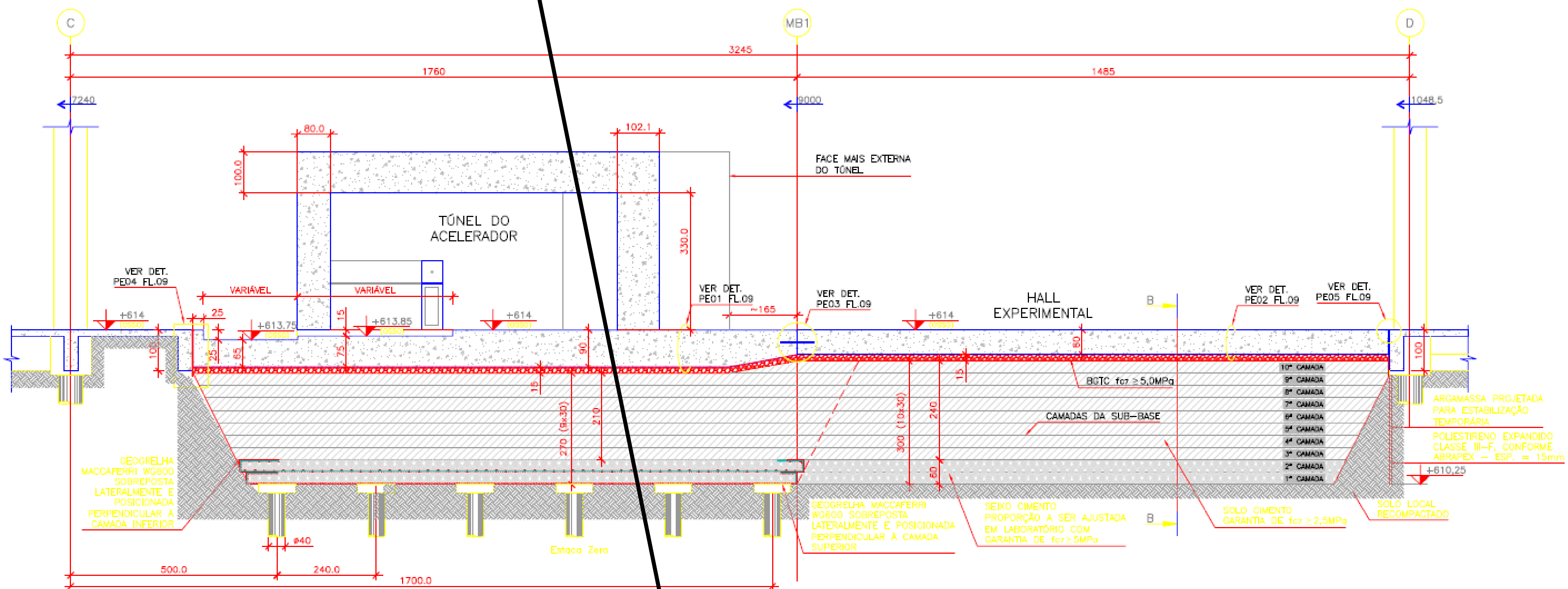
Final* configuration for the Sirius foundations



We still have some margin for small changes. Comments are welcome during the coffee-break !!!!

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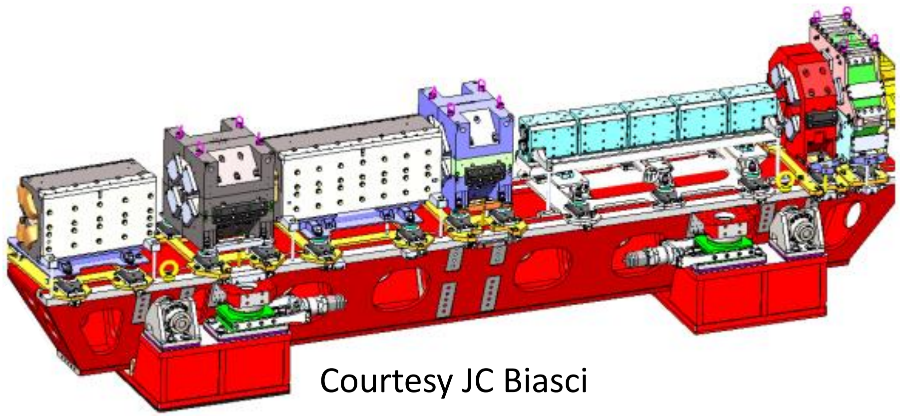
Magnet + Girder options

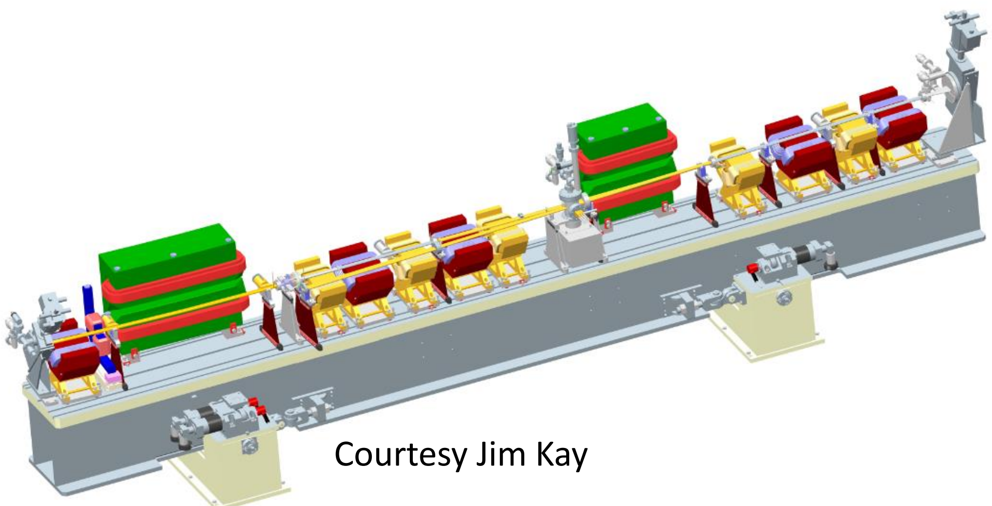


Courtesy JC Biasci

Adjustable magnets

ESRF II, NSLS II...

- *High precision machined magnets*
- *Rigid girder and pedestal*

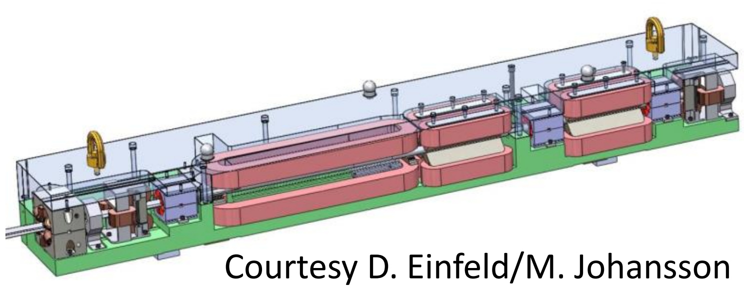


Courtesy Jim Kay

Shimmed (or glued) magnets

DIAMOND II, SLS, TPS, PETRA III…

- *High precision machined magnets*
- *Rigid girder and pedestal*
- *High precision girder*



Courtesy D. Einfeld/M. Johansson

Magnet block

MAX IV…

- *High precision machined magnets*
- *Rigid block and pedestal*
- *High precision block*

Alignment

Stability

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Girder solutions

Overview on magnet–girder assembly

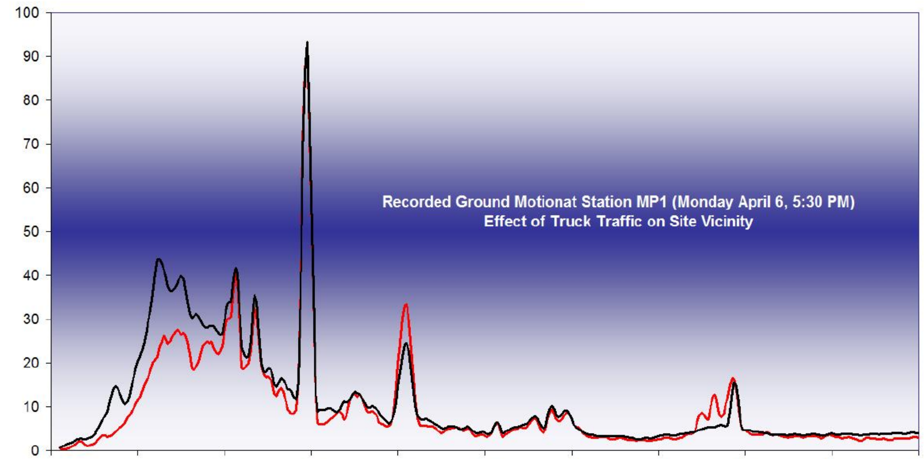
Light Source	description	f_1 (Hz)	$TF_{s2M\&G}$
ESRF	3 motorized jacks, remote alignment, manual horizontal adjustment, unsufficient stiffness	10 (7)	1.3 (2.2)
Spring-8	6 support points, stiff alignment mechanism	19	1.9
APS	4 Wedge Jacks	9.5 (10.5)	1.5 (9)
Petra III	Similar to Diamond: Girder pedestals, 5 cam systems, beam based girder alignement		
SLS	Girder pedestals, 5 cam systems, beam based girder alignement	15.5	
Soleil	4-points support when operation, 3 Airloc jacks when alignement	46	1.0
Diamond	Girder pedestals, 5 cam systems, remote alignement	16.3	4.6
SSRF	3 support points, Wedge Jacks and ball bearing, + 3 assistant supports	23	1.3
Alba	Fixed, 6- point support + vertical fixation	28	
NSLS II	8-points support, fixed, manual alignment	30	1.4
TPS (proto)	6 cam systems + locking systems	30	

Workshop on Accelerator R&D for USR, Beijing, 30 Oct – 1 Nov., 2012, Engineering considerations / L. ZHANG

Typical free field ground motion at LNLS site

Spectral Amplitude (µm/s²)

Courtesy Nick Simos



0 Freq (Hz) 100

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Girder for the storage ring

Sirius first version ← Petra III ← Diamond ← SLS...

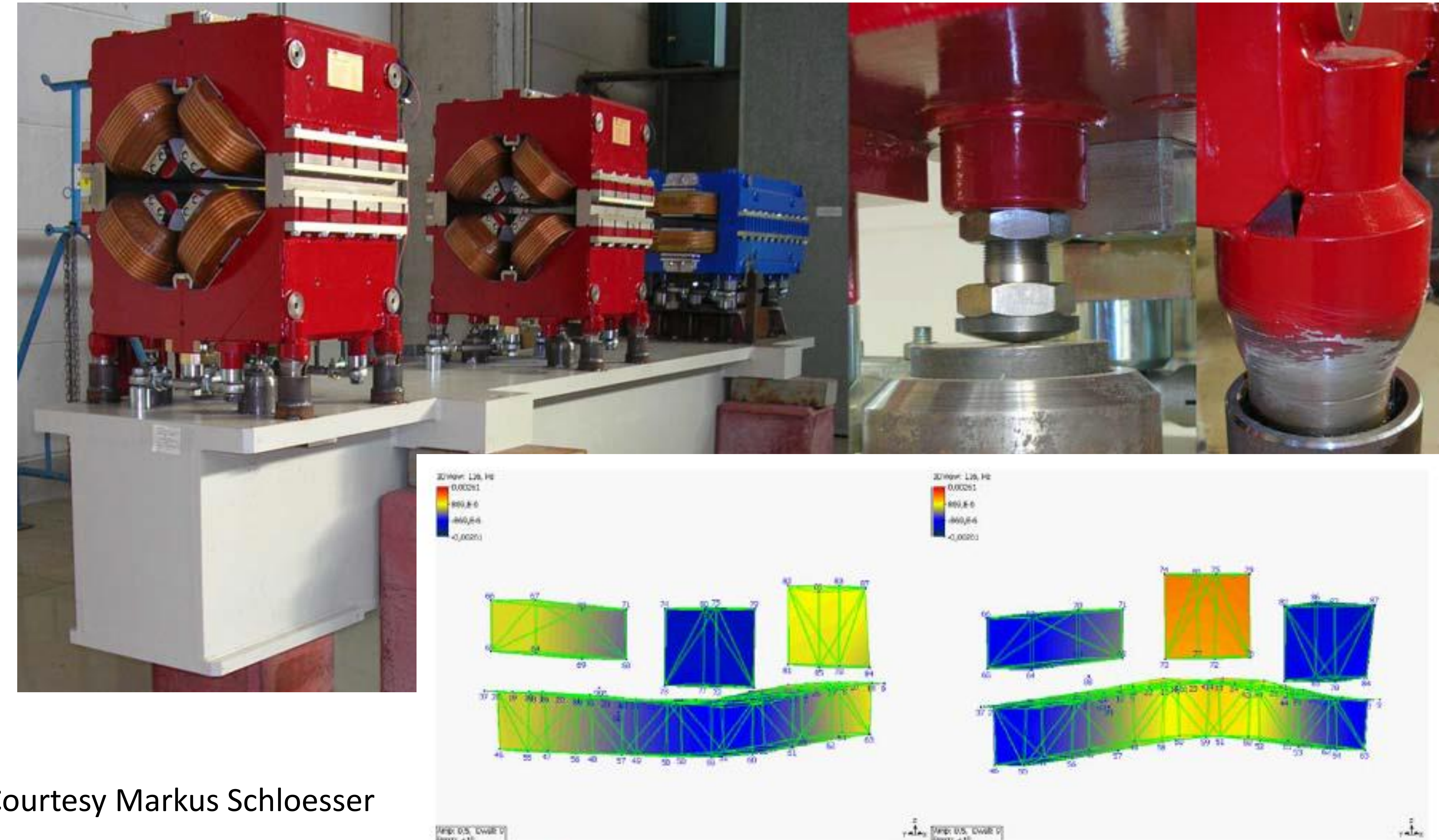

Figure 7: First vertical modal shape of girder at 116 Hz, girder on concrete stands

Courtesy Markus Schloesser

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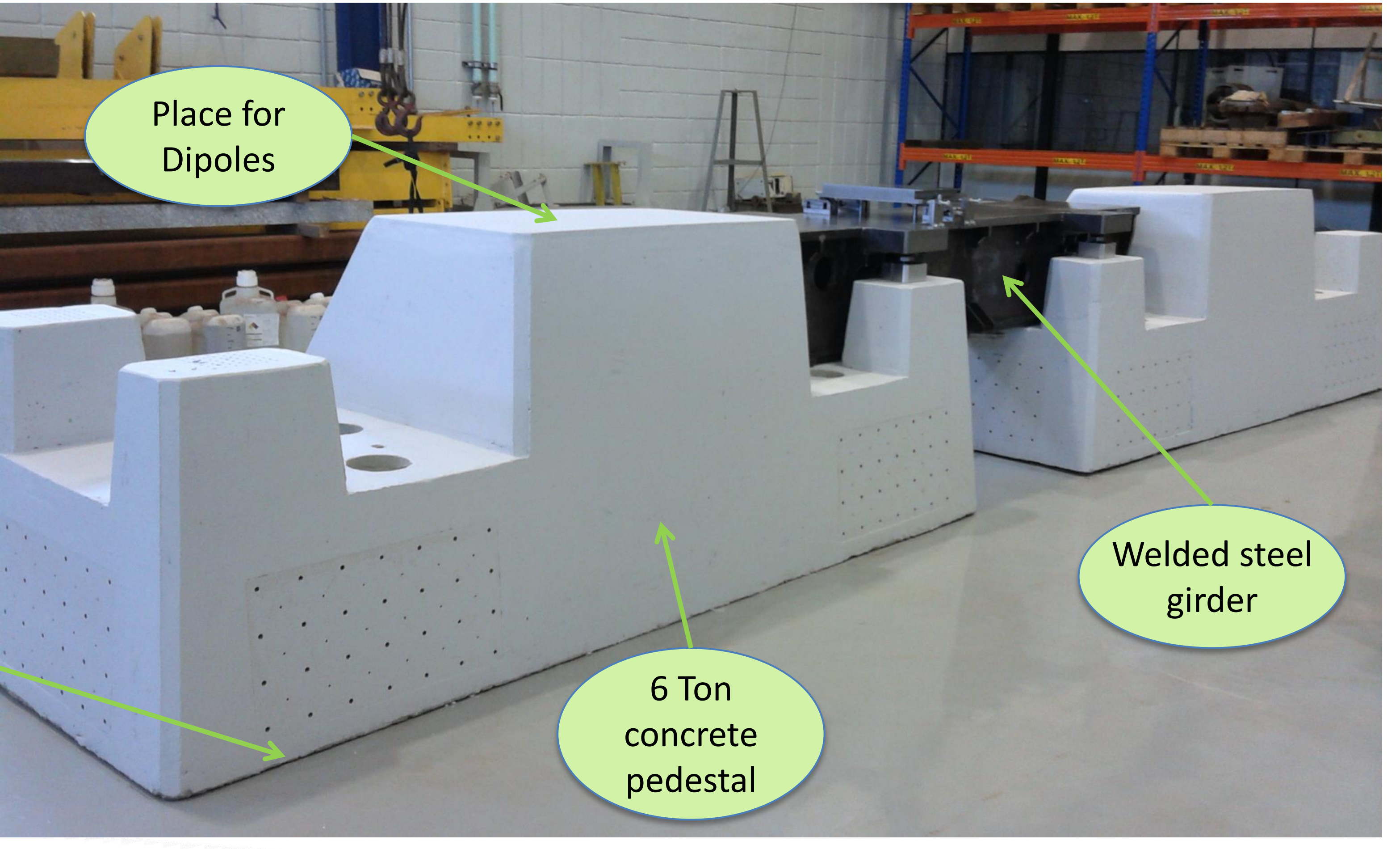
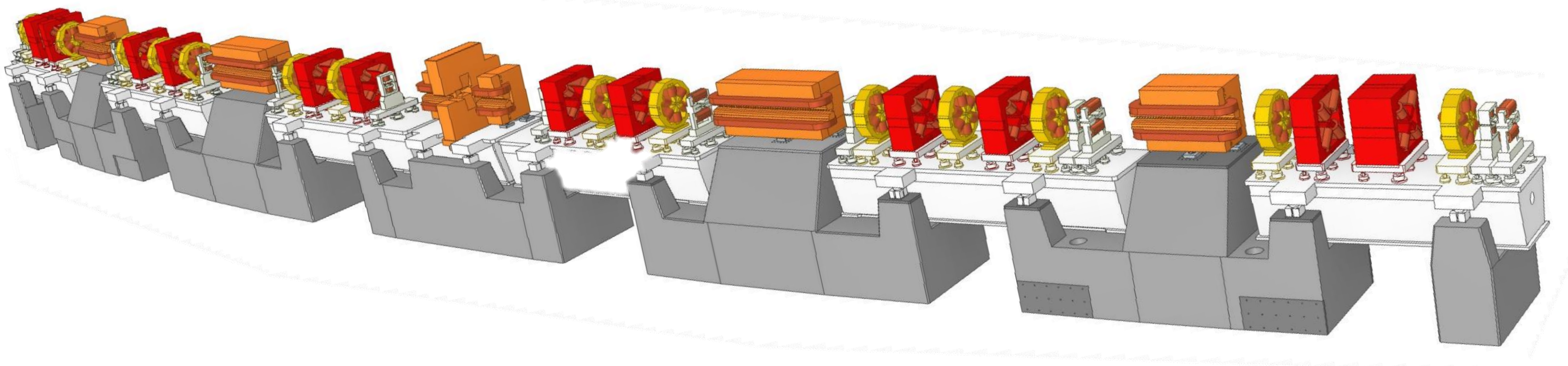
Girder and pedestal prototypes





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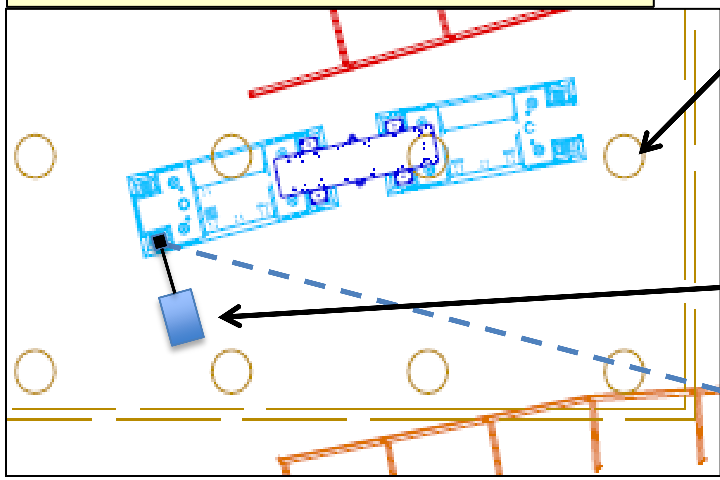
Pedestal stiffness measurement

Pedestal position on top of DIAMOND slab

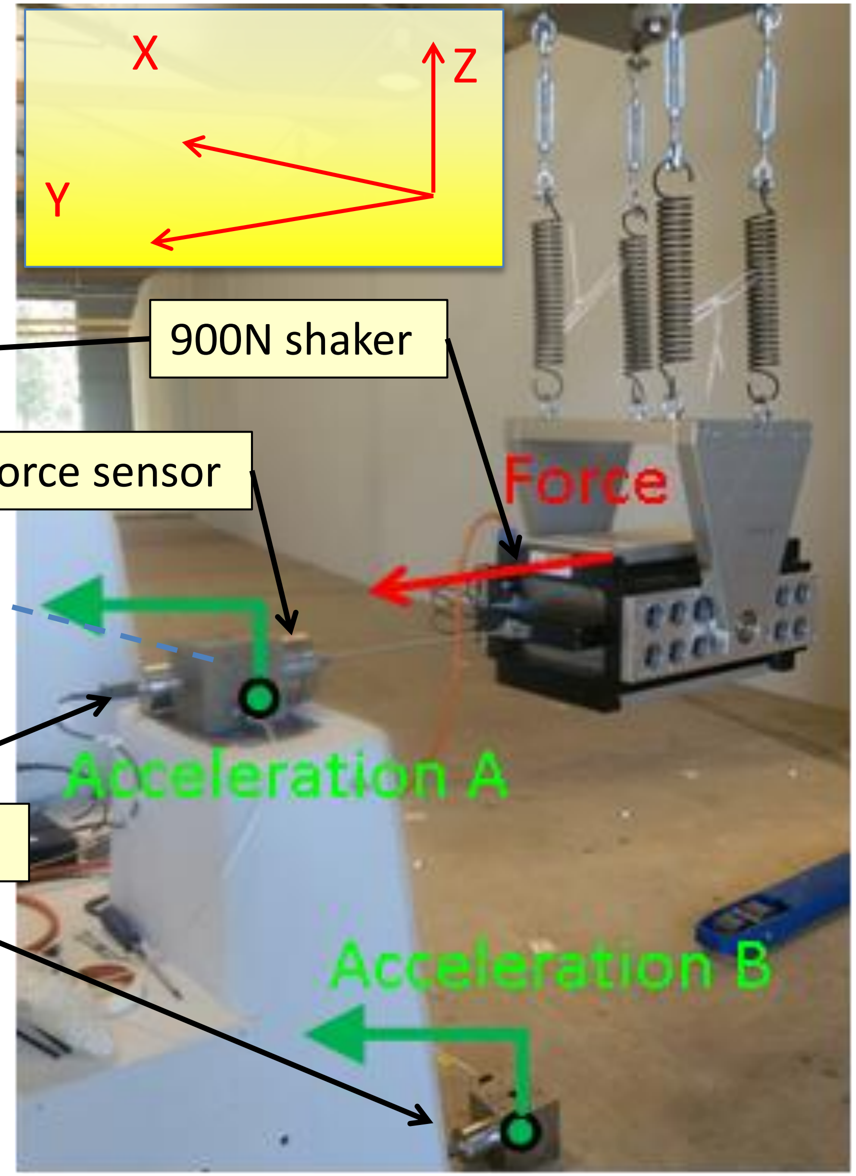


Piles

900N shaker

Force sensor

Accelerometers



Measured stiffness (10-150Hz)

Direction	Stiffness [N/µm]
X-direction	770
Y-direction	410
Z-direction, excluding floor	4900
Z-direction, including floor	2000

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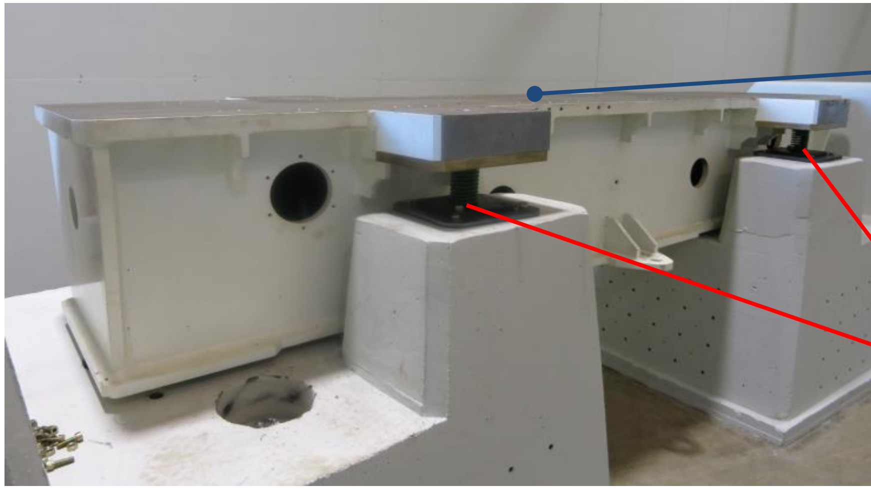
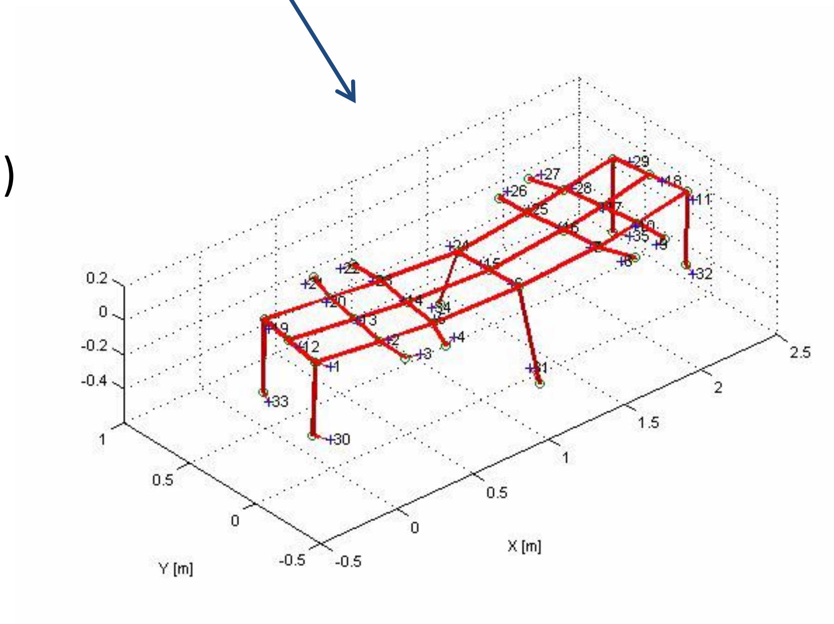
Girder free mode measurements

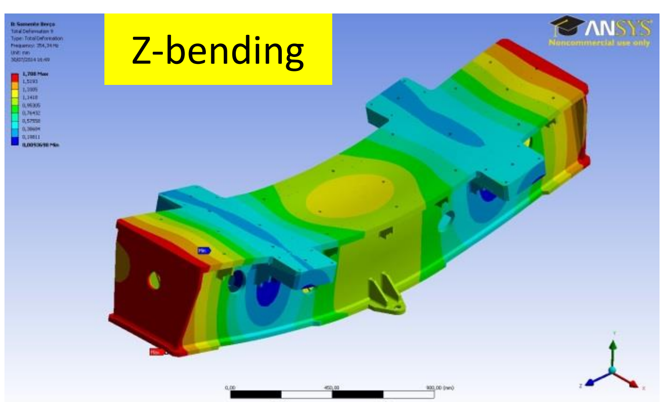


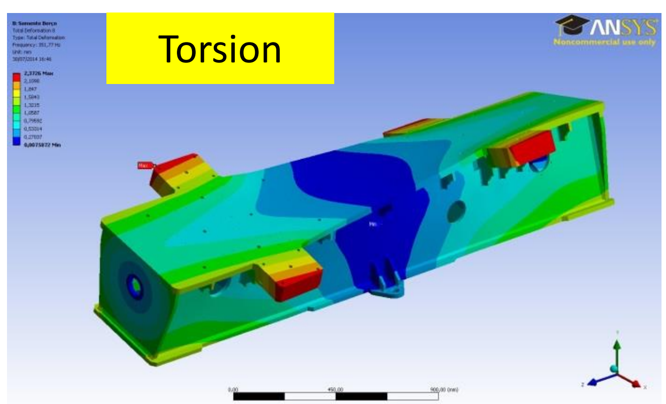
Springs
(2Hz resonance)

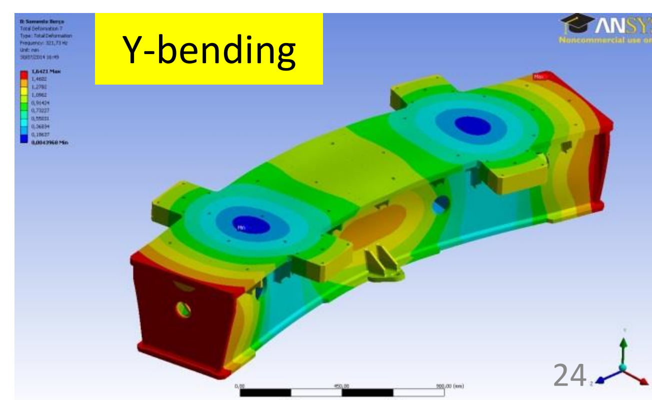
Accelerometers installed in 35 positions



Mode	Frequency [Hz]	Predicted by FEM [Hz]
Y-bending	319	322
Torsion	333	352
Z-bending	354	354
Plate membrane mode	501	
Second order Z-bending	552	







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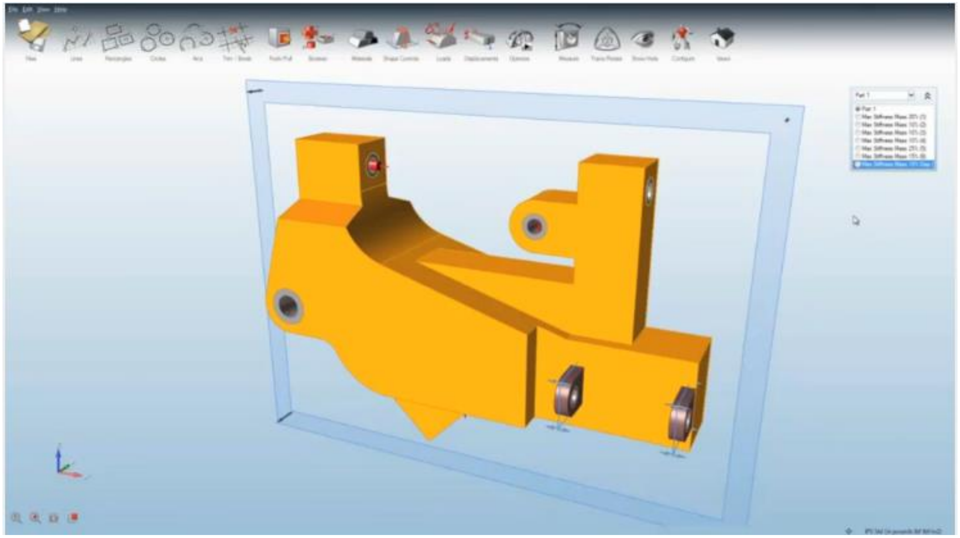
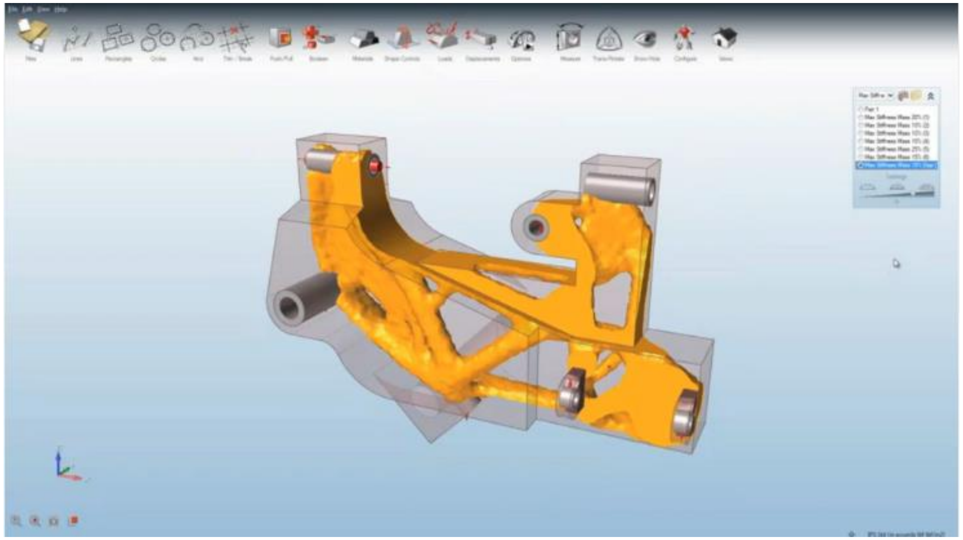
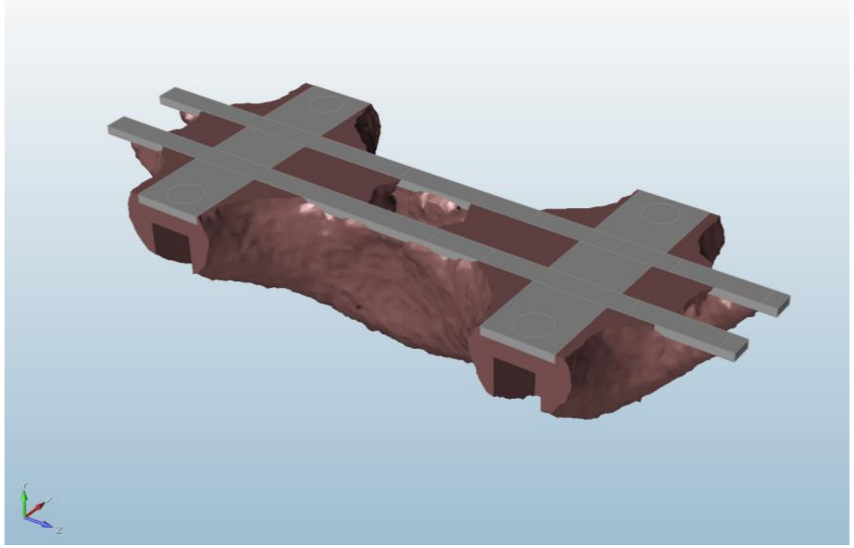
Girder optimization

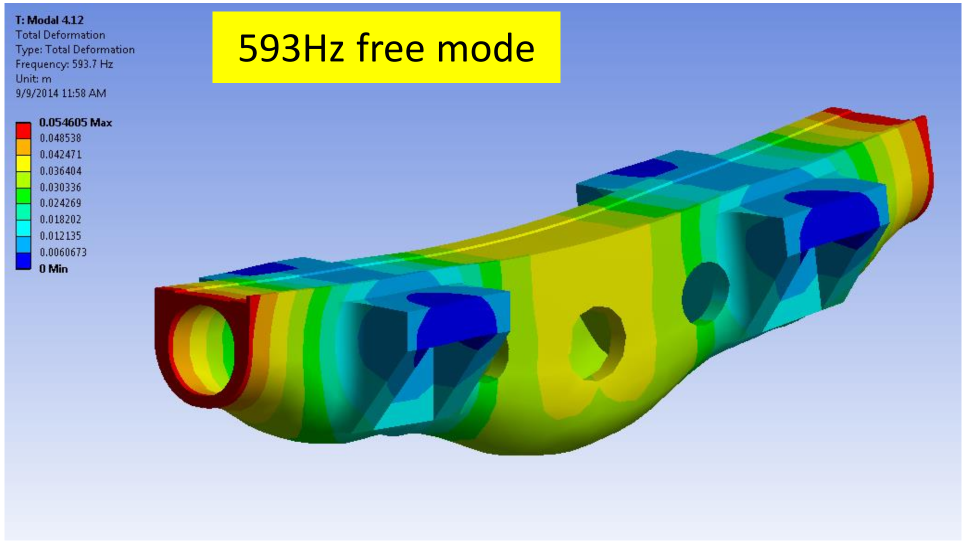
Optimization software Inspire™





"Inspire(d)" girder





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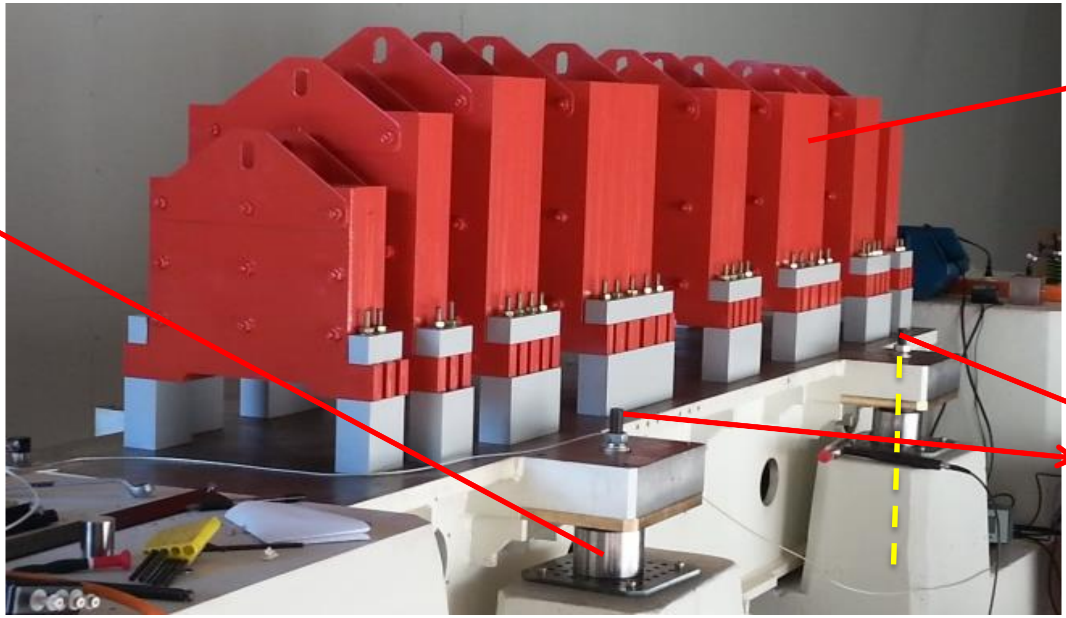
Transmissibility measurements

Solid steel spacer

Precision levelling wedges

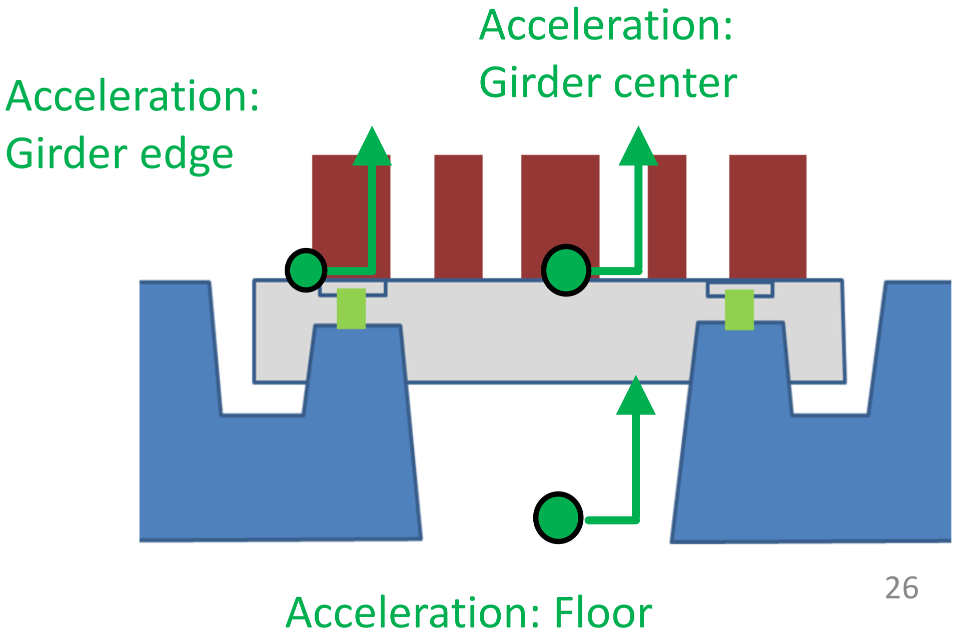


Dummy magnets

Locking screws (on the concrete)

900N Shaker

Shaker Force



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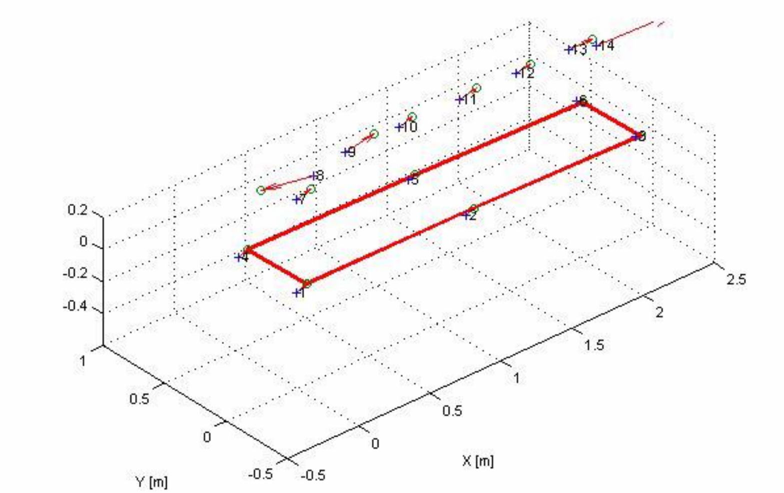
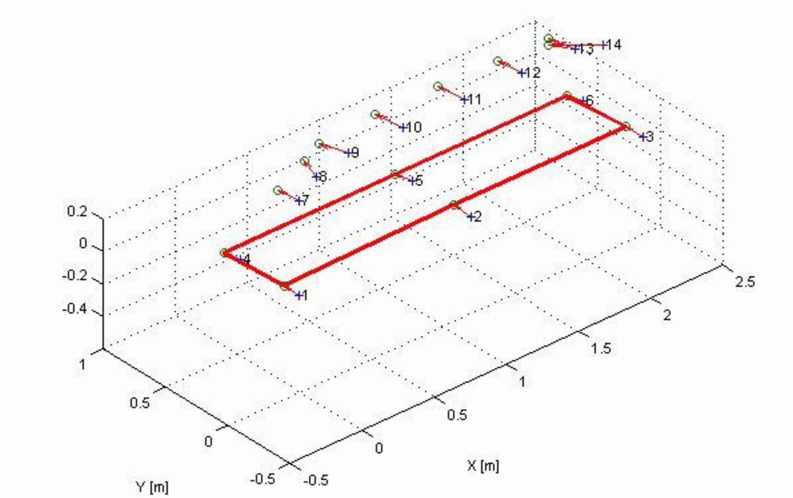
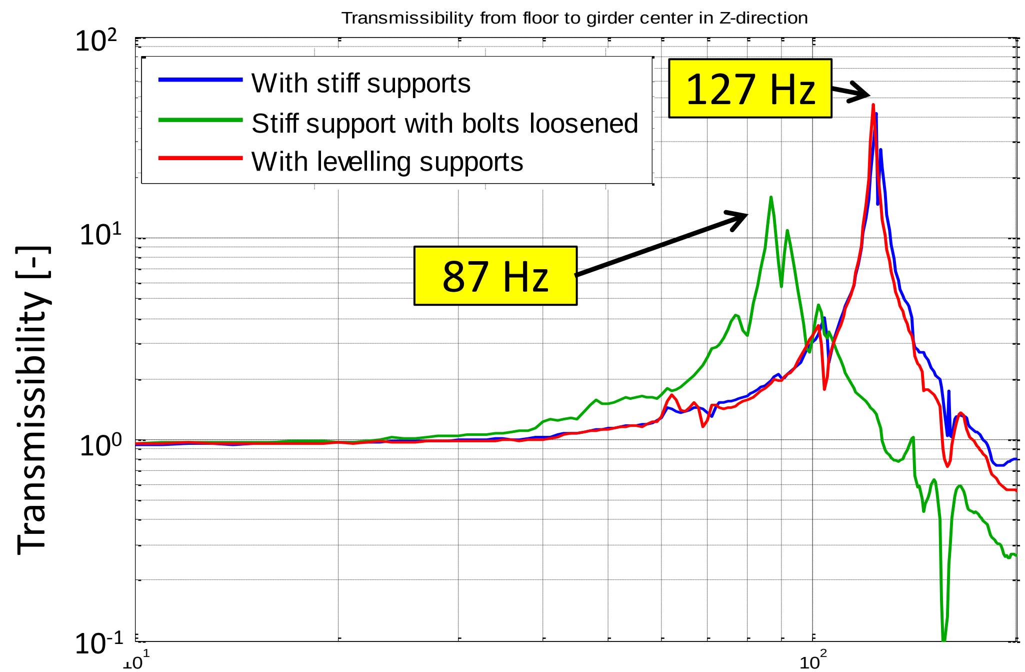
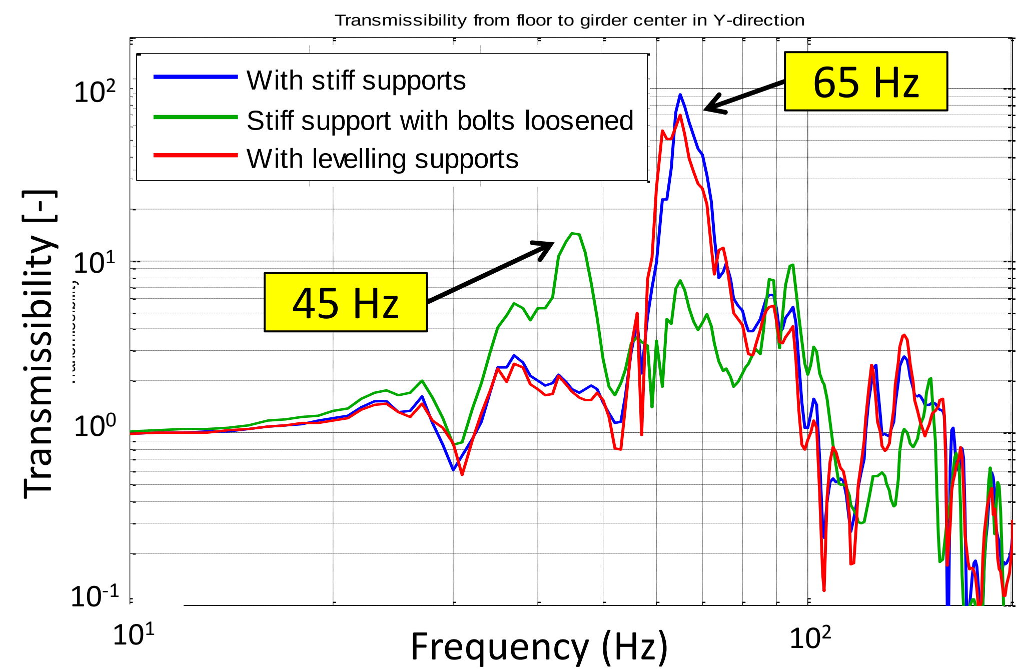
Transmissibility measurements







Z



Y

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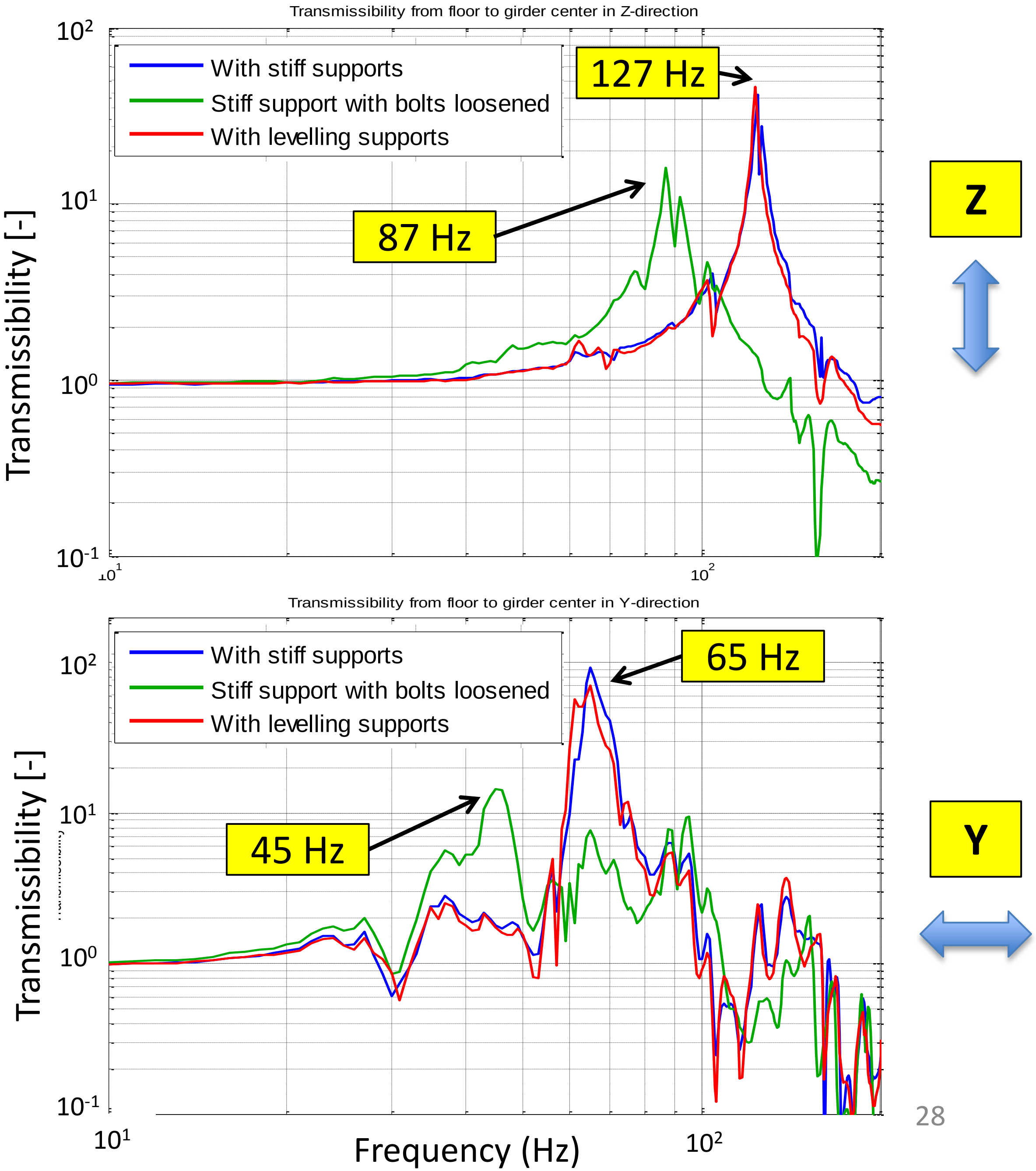
Transmissibility measurements

The goal to have all resonance modes above 100 Hz is not so far.



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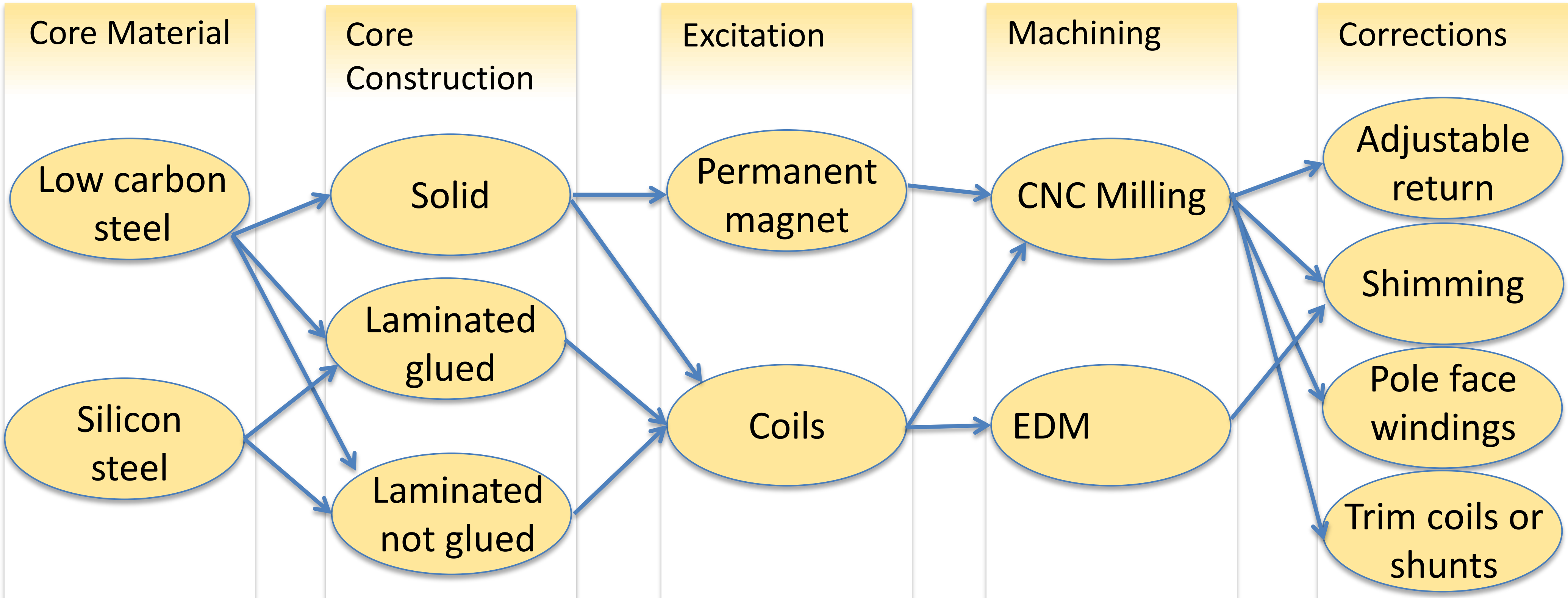
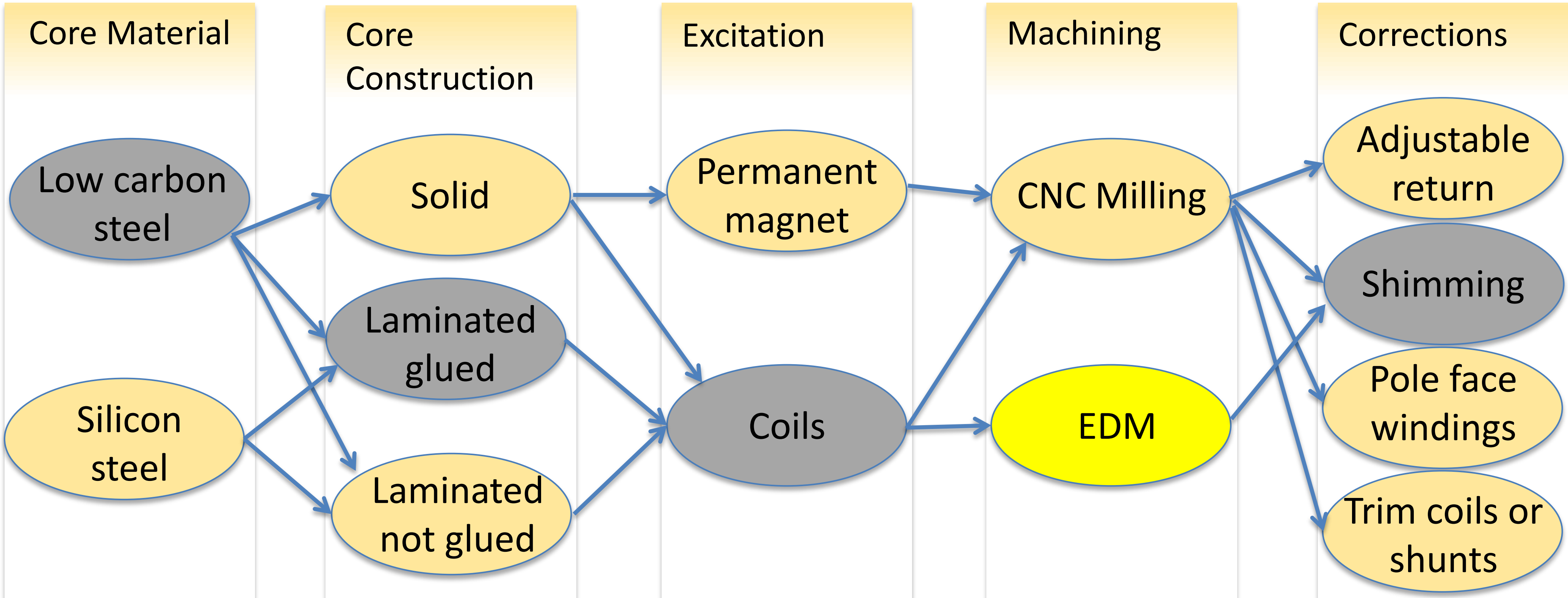
Magnet design and manufacturing



Magnet design and manufacturing



- NSLS-II Sextupole
- ALS Sextupole

- Reduces stacked errors
- High precision

- Time consuming (20 h)

ALS (SINAP)


NSLS-II (IHEP)

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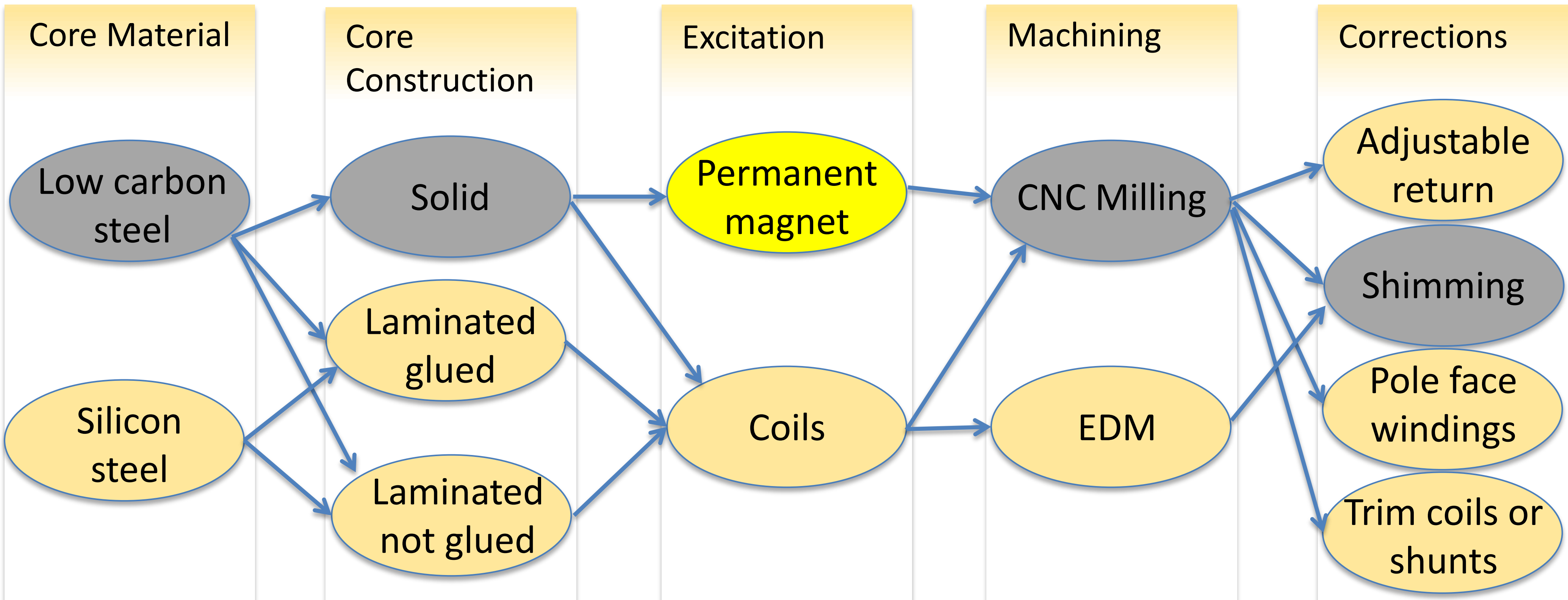
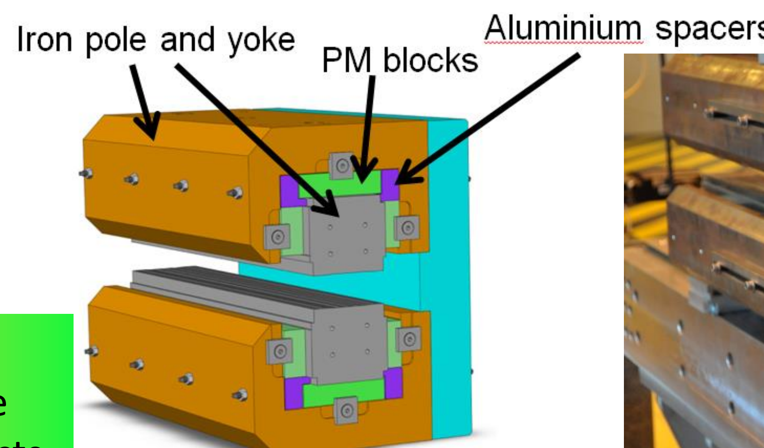
Magnet design and manufacturing

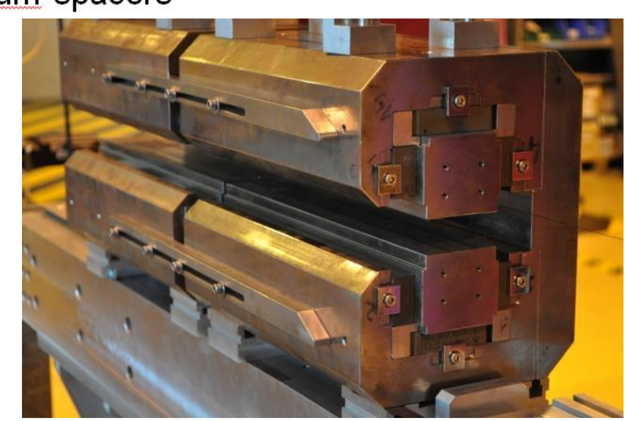


- SIRIUS low field Dipole *
- SIRIUS 2T Dipole
- ESRF II
- SPRING-8 II

- No ripple
- No electricity bill
- No water vibration

- Fine tuning
- Radiation damage
- Temperature effects





Courtesy J. Chavanne

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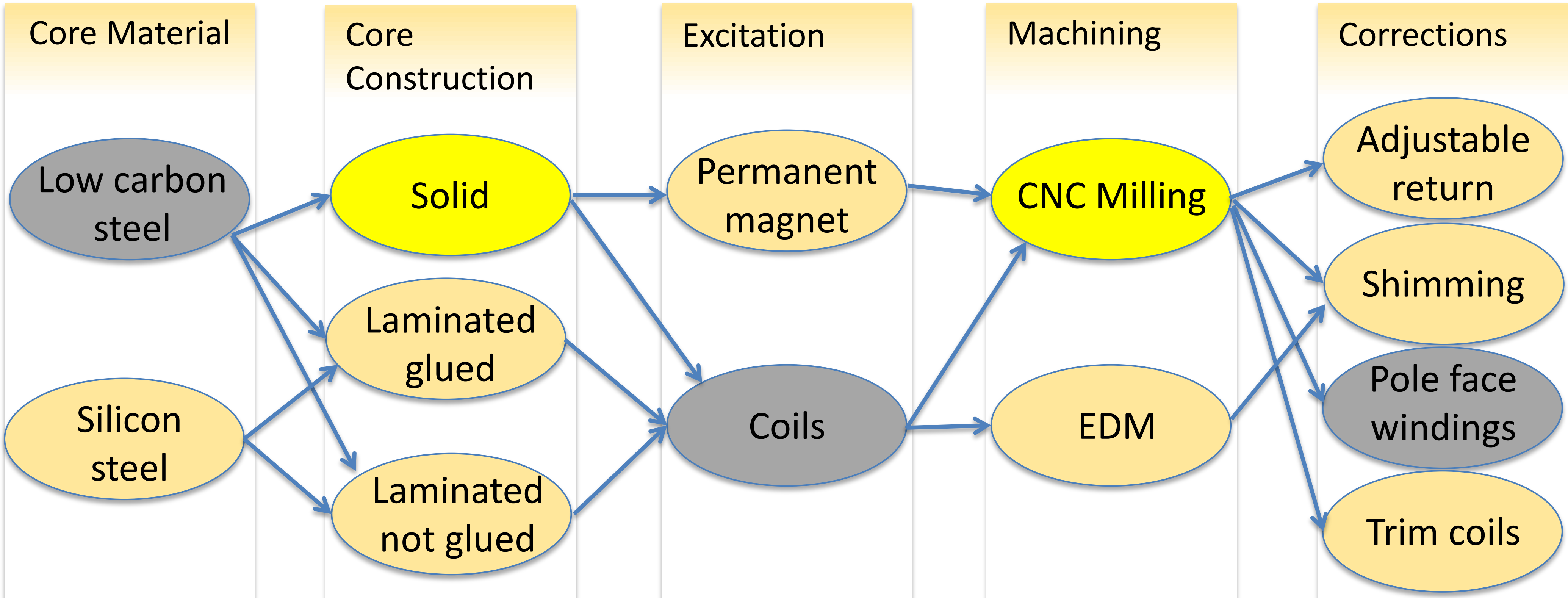
Magnet design and manufacturing



- MAX-IV

- No alignment
- High rigidity

- Need of high quality and homogeneous steel
- Hard to measure

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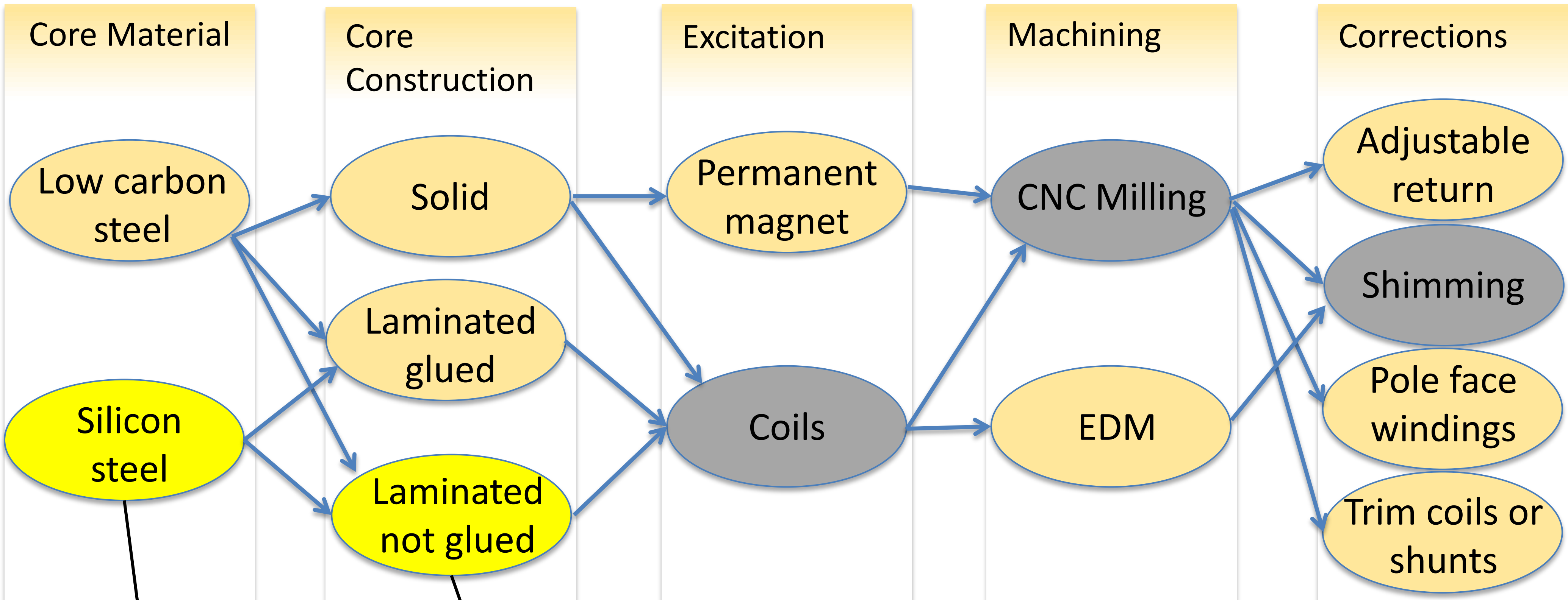
Sirius storage ring magnet design and manufacturing



- SIRIUS

- Standard material for our magnet supplier
- Low hysteresis make combined magnets more linear

- Used before in our 6 Tons dipoles
- Compatible with our supplier know-how

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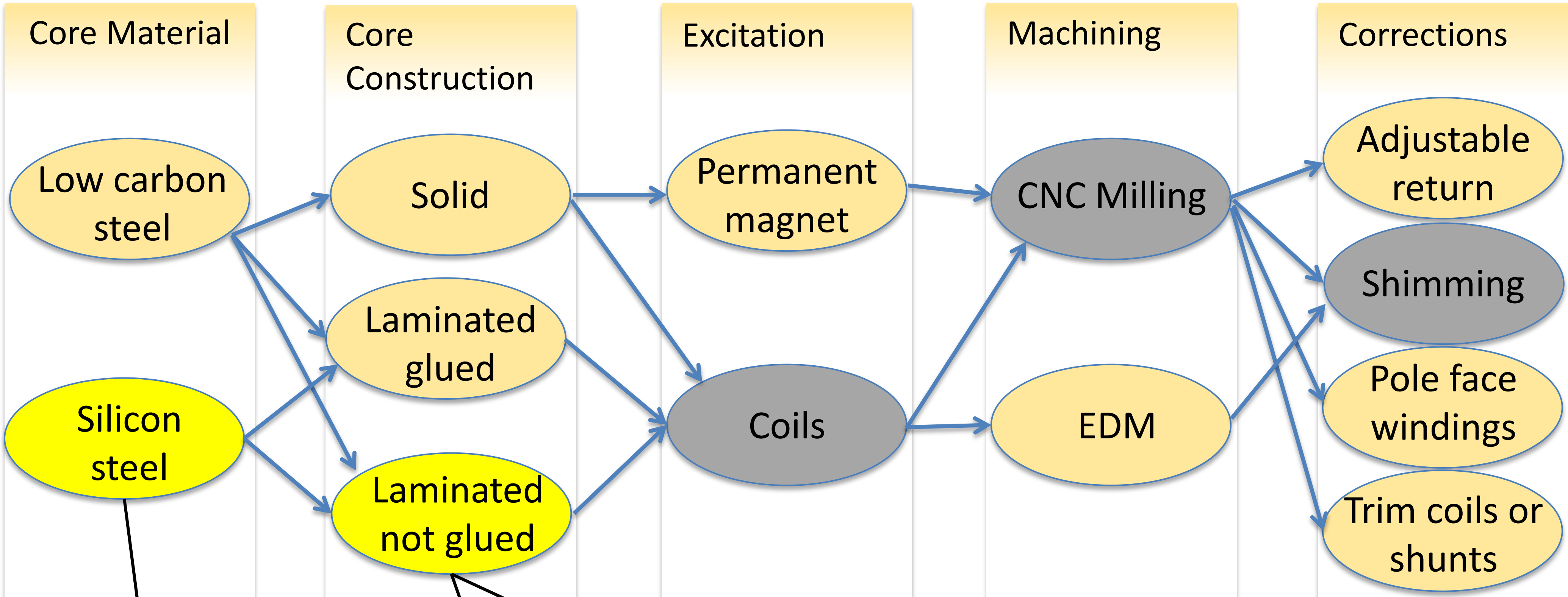
Sirius storage ring magnet design and manufacturing



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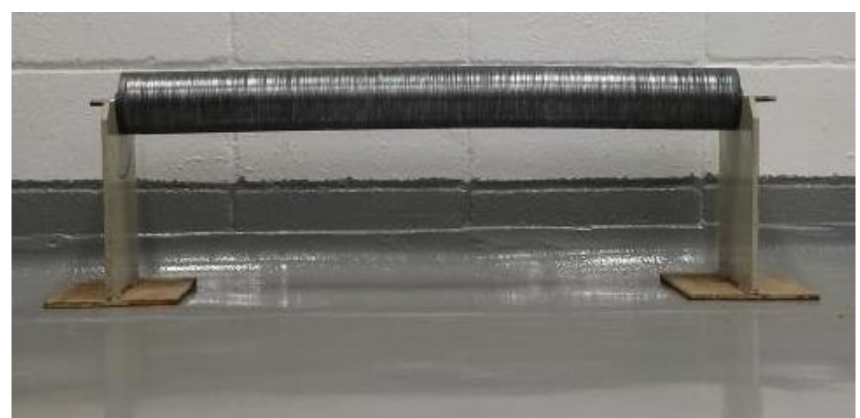

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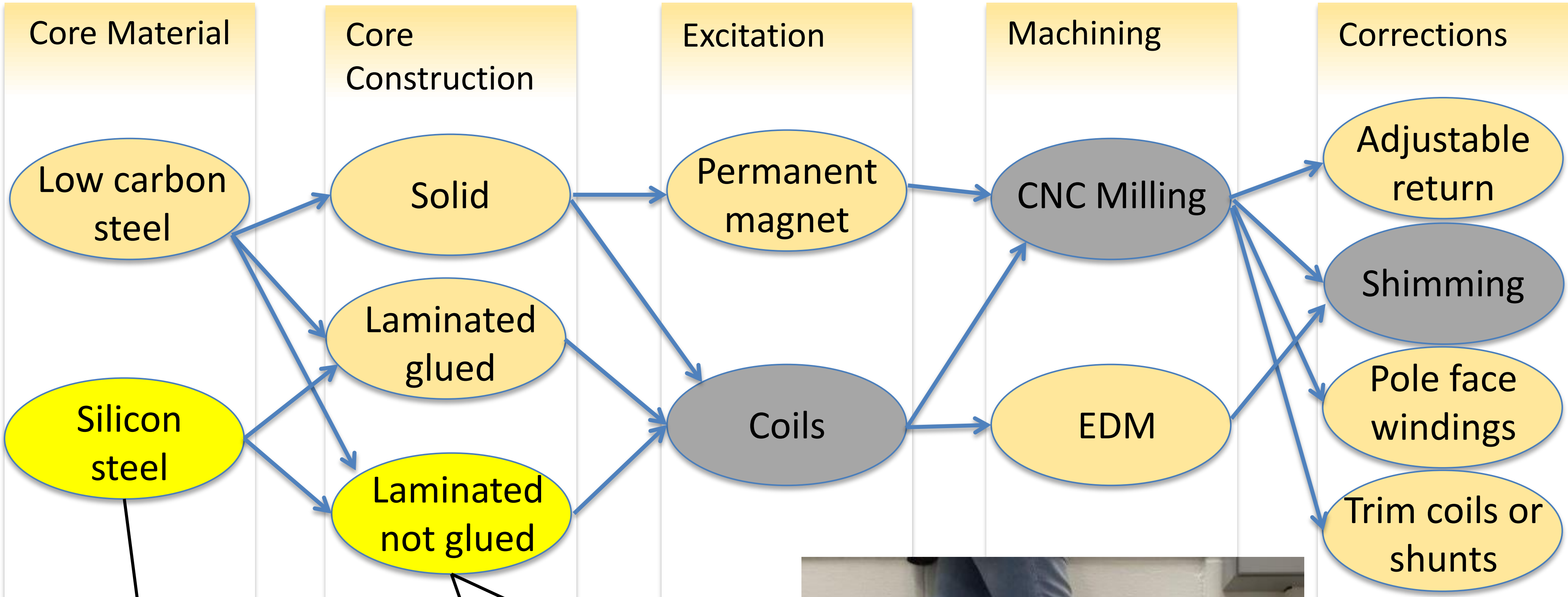
Sirius storage ring magnet design and manufacturing



- SIRIUS

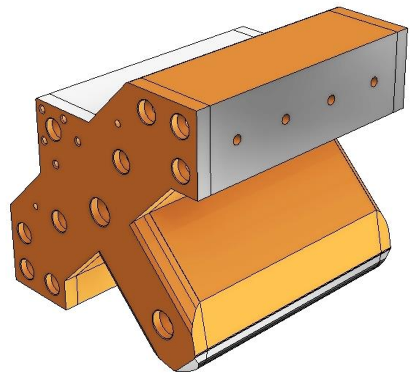
- Standard material for our magnet supplier
- Low hysteresis make combined magnets more linear

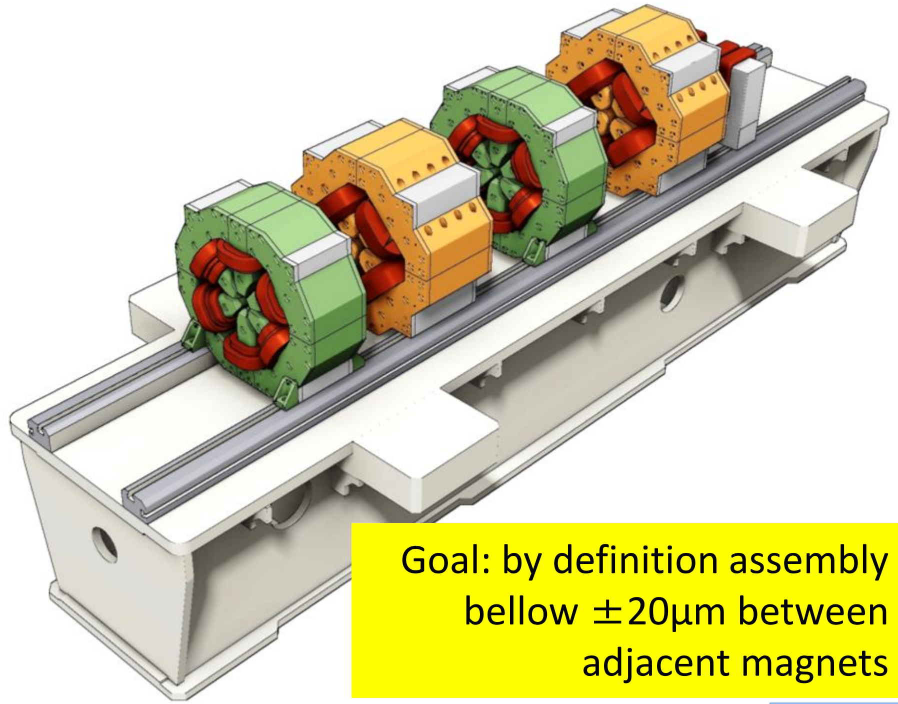
- Used before in our 6 Tons dipoles
- Compatible with our supplier know-how

If you can not convince them using just mathematics...

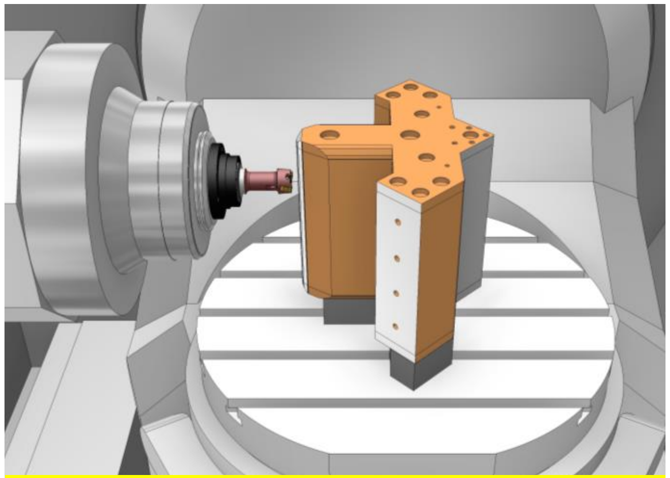
LNLS Laboratório Nacional de Luz Síncrotron
sirius
CNPEM

Sirius storage ring magnet design and manufacturing

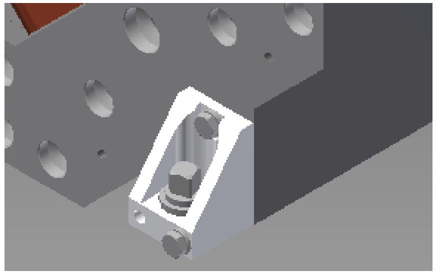


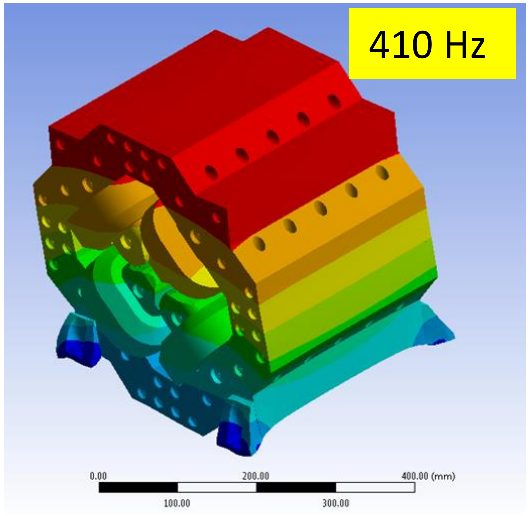


Goal: by definition assembly bellow ±20µm between adjacent magnets

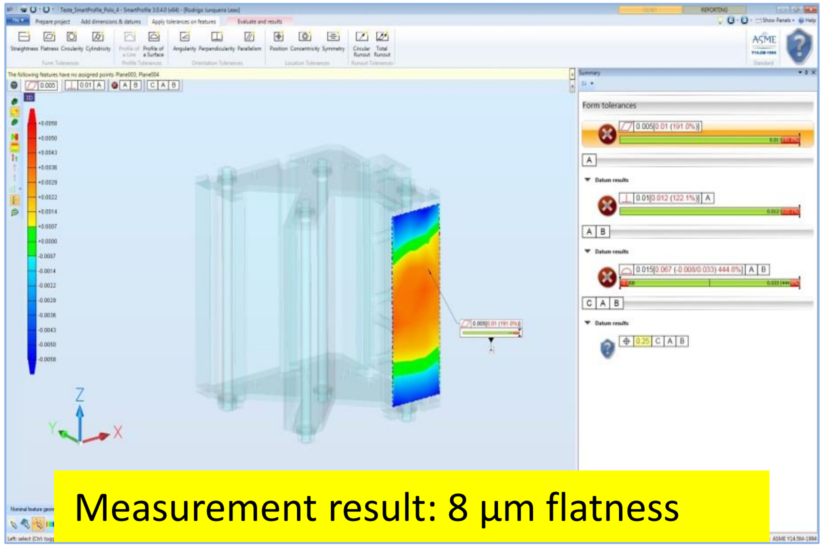


One setup for all reference surfaces





Mechanical measurement

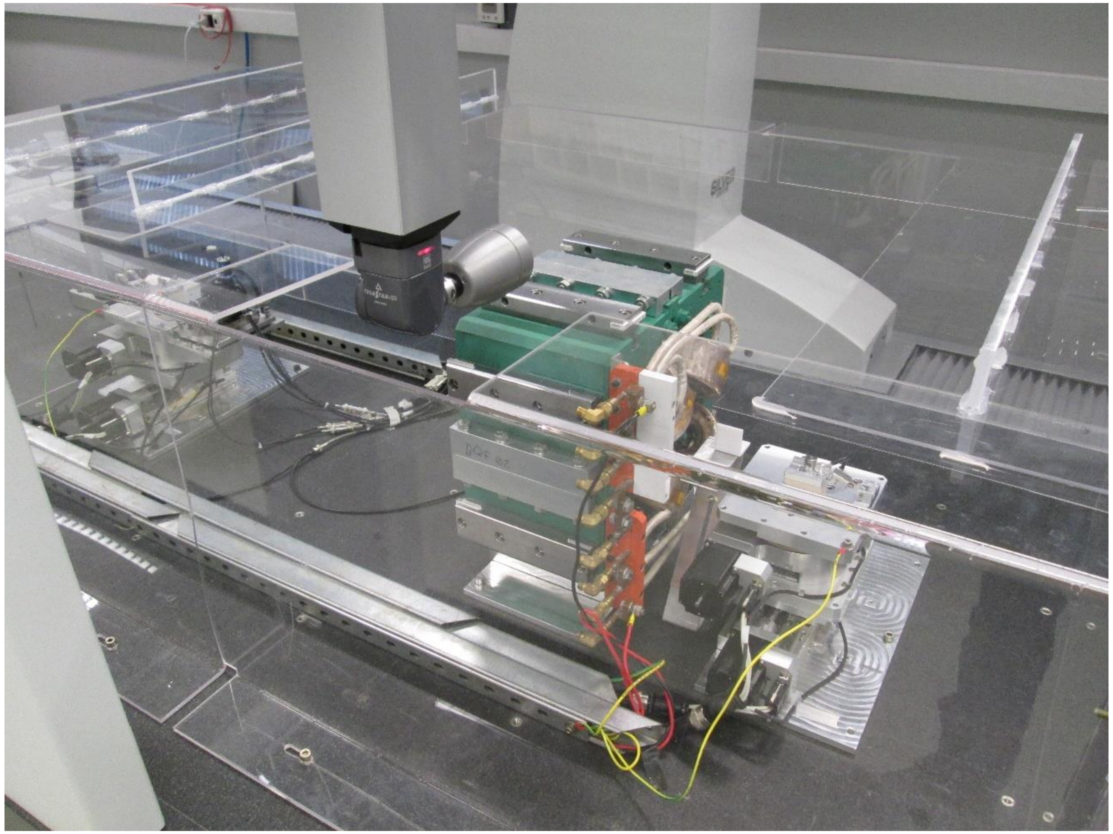


Measurement result: 8 µm flatness

Vibrating wire measurement

In parallel, just in case....

Vibrating wire bench on a CMM



Final uncertainty – 1σ

Uncertainty budget	x_m (μm)	y_m (μm)	z_m (μm)	$pitch_m$ (mrad)	yaw_m (mrad)	$roll_m$ (mrad)
Magnetic repeatability	6.3	7.3	-	-	-	6.3
Magnetic accuracy	-	1.3	-	0.0175	-	-
Geometrical survey	2.7	4.0	1.5	0.0200	0.0134	0.0042
Total	6.9	8.4	1.5	> 0.0266	> 0.0134	6.3

Content

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Solid State RF Amplifier @ LNLS

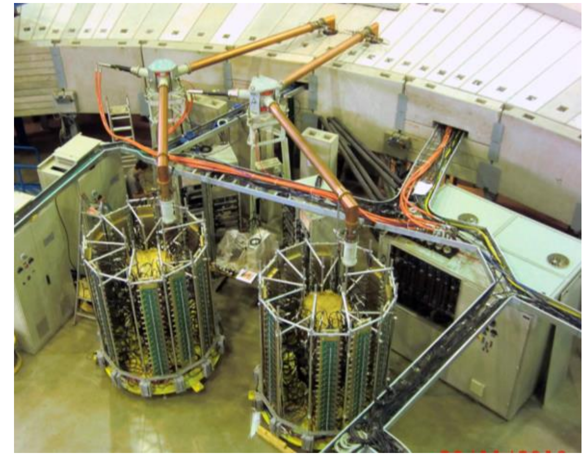
Collaboration with LURE/SOLEIL since 1999

(special tanks to Ti Ruan)

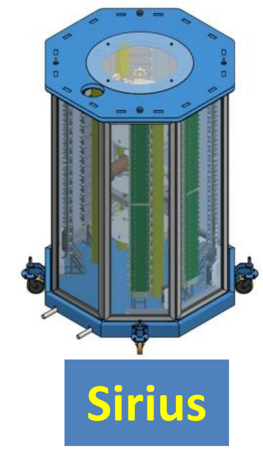
1999 - Prototype module with 230W
2001 - Booster operating with 900W
2007 – Booster upgraded to 2.2kW
2010 – Storage Ring operating with 2 x 50 kW SSA

- Excellent reliability, high MTBF
- No beam loss due to module failures
- 4 years in routine operation – 7 modules failed (out of 324), 6 fixed in house
- Whole SSA – 4 beam losses in 4 years due to failures in water flow meters and power supplies

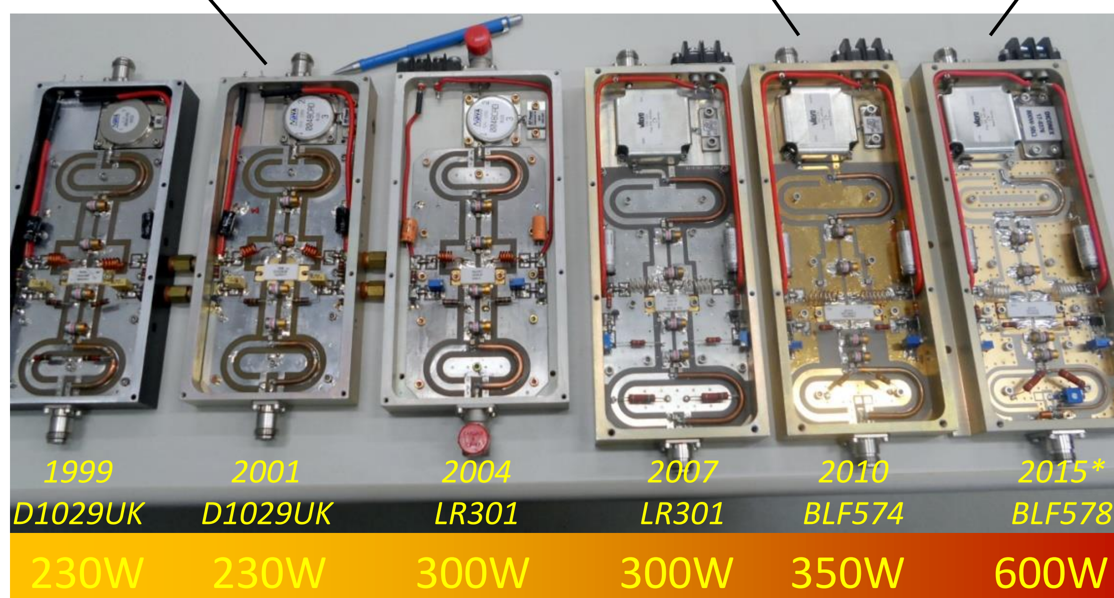
2001 – Booster
900 W @ 476 MHz
ELETTRA Cavity



2010 – Storage Ring
2 x 50 kW @ 476 MHz
ELETTRA Cavities



2015 - Booster
50 kW @ 500 MHz



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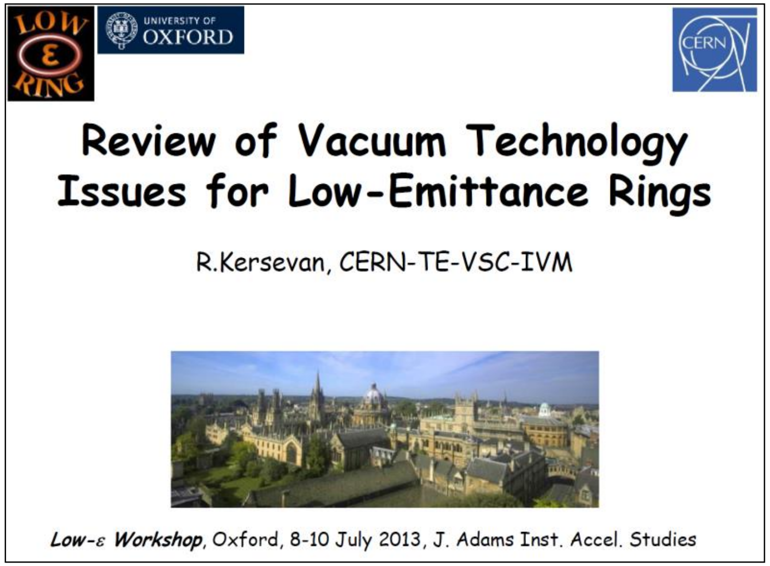
Vacuum system – flange concepts



Some flange concepts
(L. Schulz - SLS-TME-TA-2001-0188, 2001)

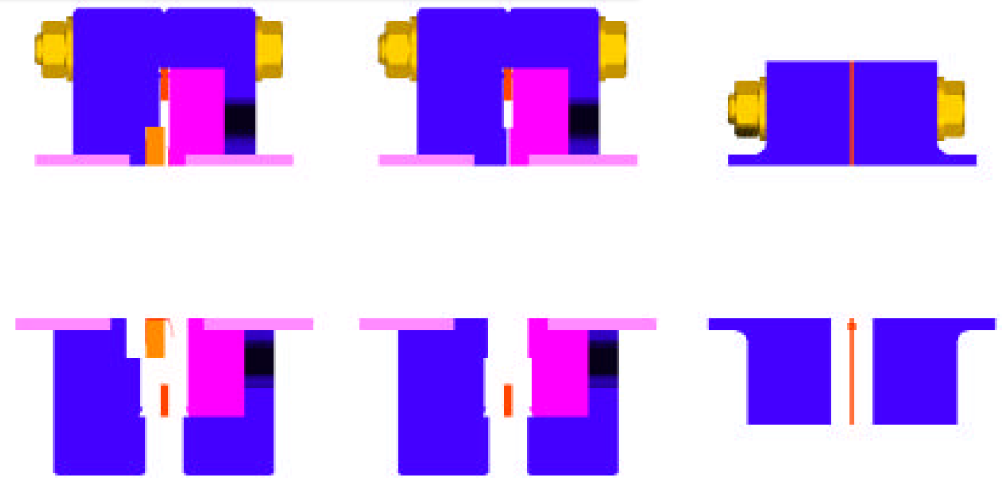
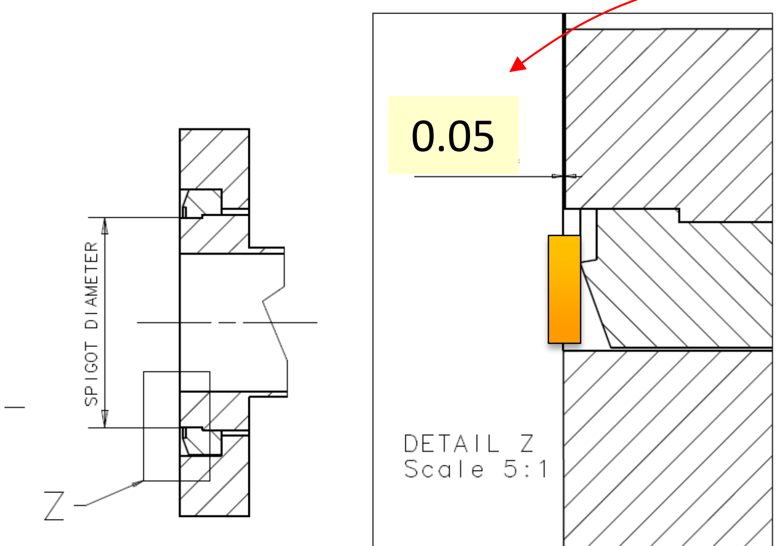
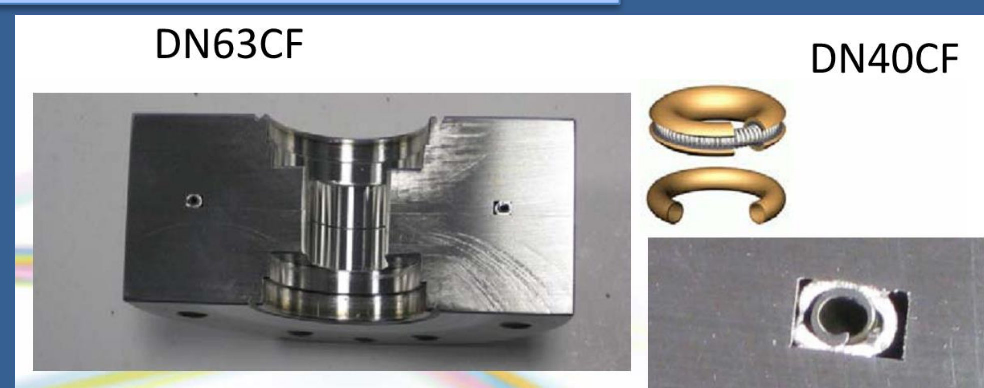


Fig. 4a CF Flange with RF bridge   Fig. 4b CF Flange with 0.5 mm gap   Fig. 4c Flat Seal Flange

MAX IV flanges - based on Spigot
(P.F. Tavares- A bema dynamics perspective , 2014)



Diamond flanges - based on Helicoflex
(M. Cox - DLSR Workshop, 2014)



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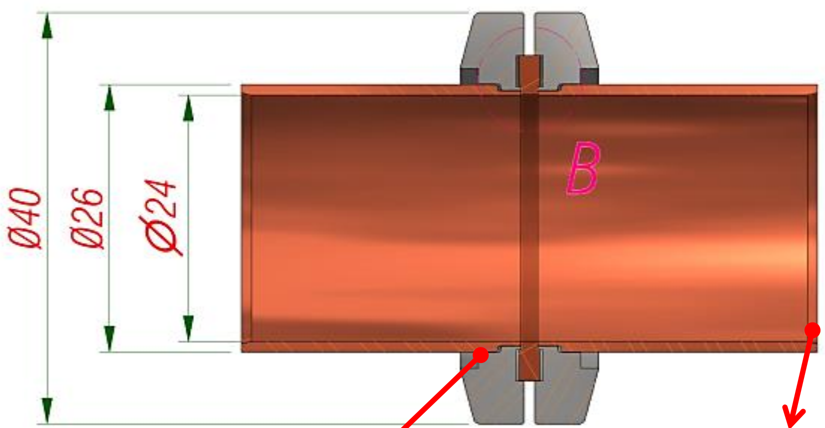
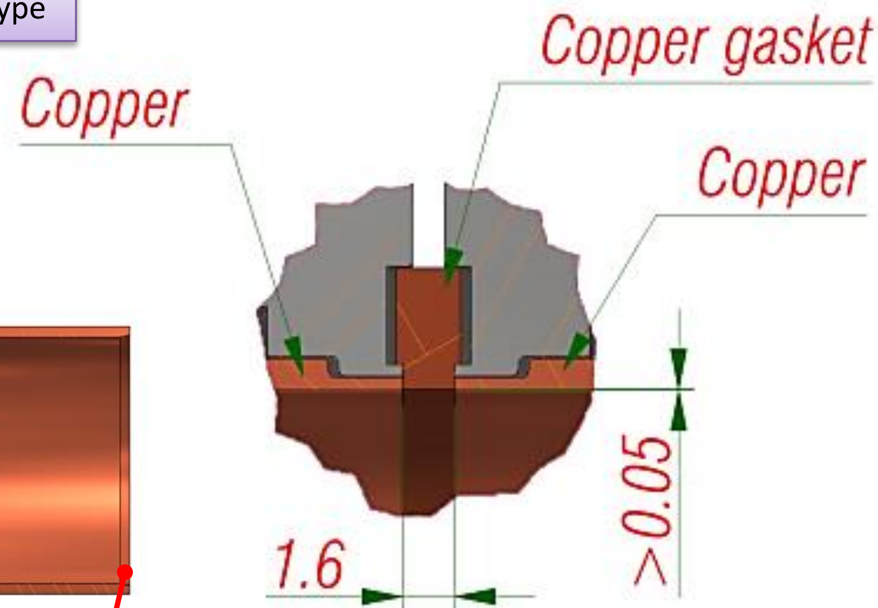
Vacuum system – flange concepts

Sirius flanges – based on a modified **KEK MO**-type

Chain-clamp design



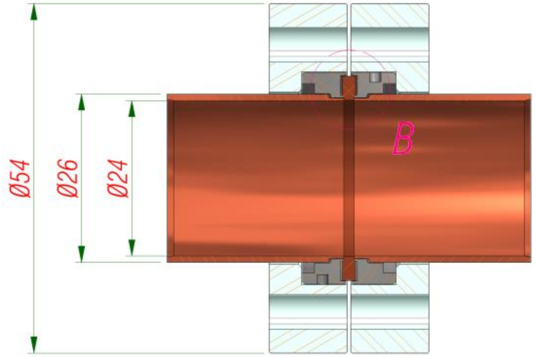


UHV leak tight with 3.5 N.m

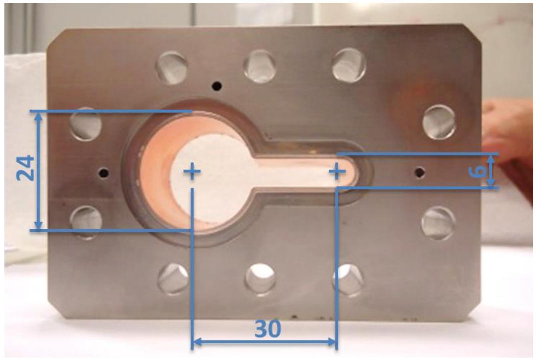
Brazed joint

to be TIG welded

Standard design



Keyhole design



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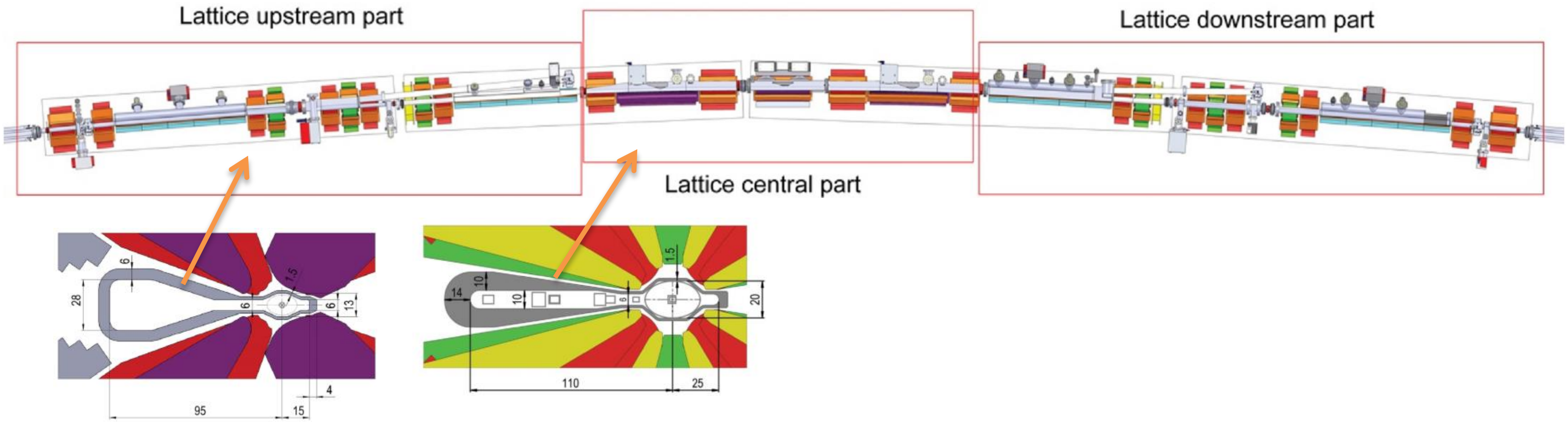
Discrete pumping strategy (ESRF II, SPRING8 II, DIAMOND II)

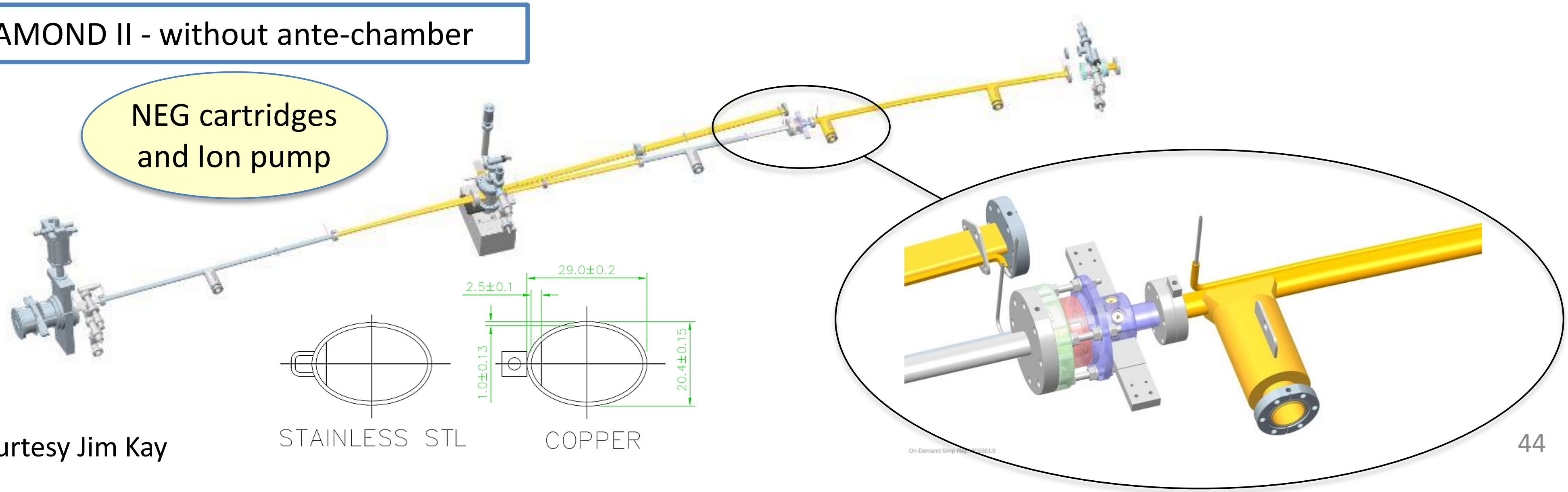
ESRF II - with ante-chamber



Courtesy JC Biasci

DIAMOND II - without ante-chamber

NEG cartridges and Ion pump



Courtesy Jim Kay

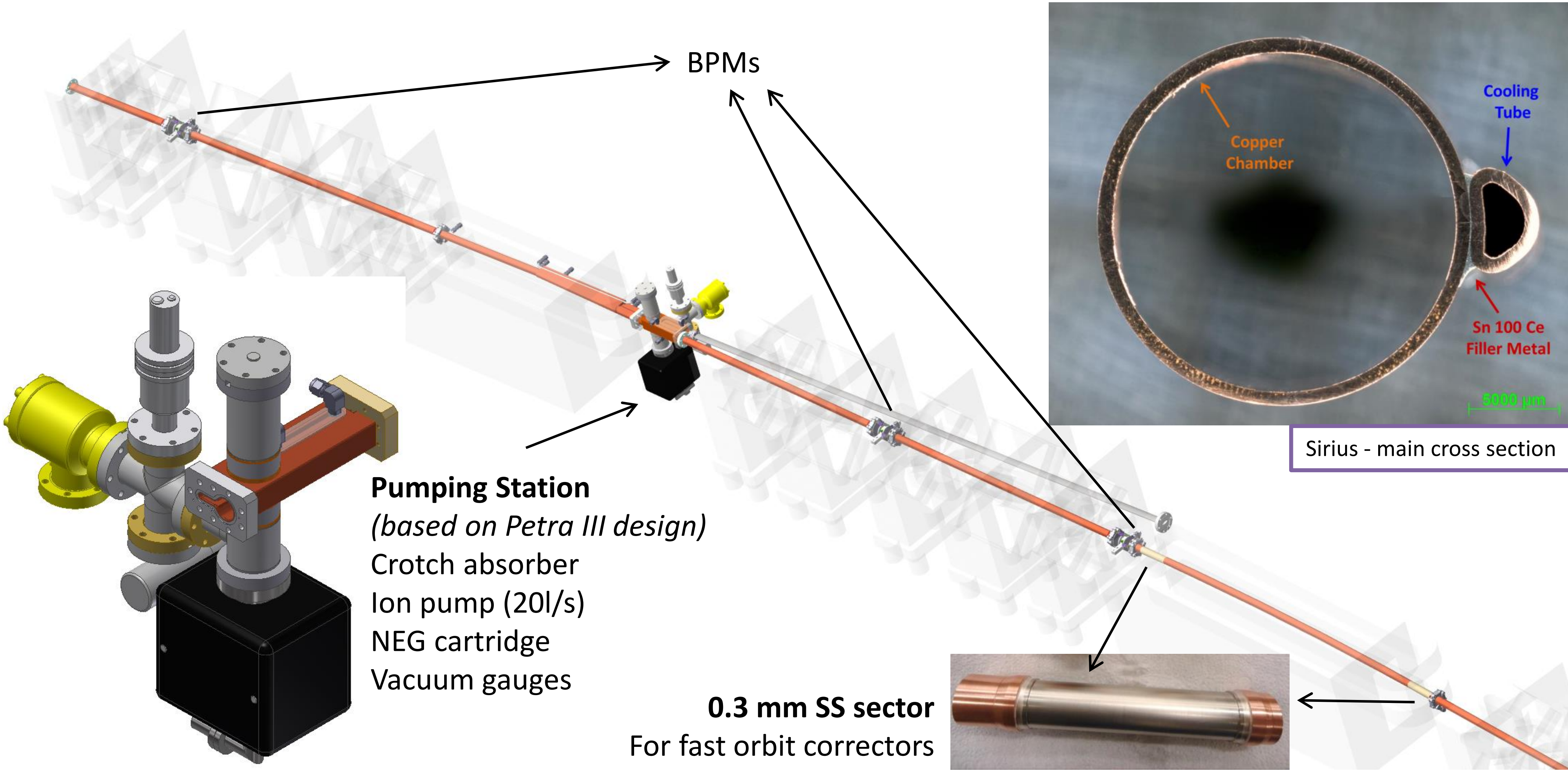
Full NEG coated strategy (MAX IV, SIRIUS)

Pros (full NEG coated strategy)**:**

- Simple chamber's design
- More compact -> space saving
- Low PSD yield -> Fast vacuum conditioning

Cons (full NEG coated strategy)**:**

- Limited number of activations (10 …?...30)
- High temperature bake-out for NEG activation
- Many bellows to accommodate chamber's expansion during bake-out



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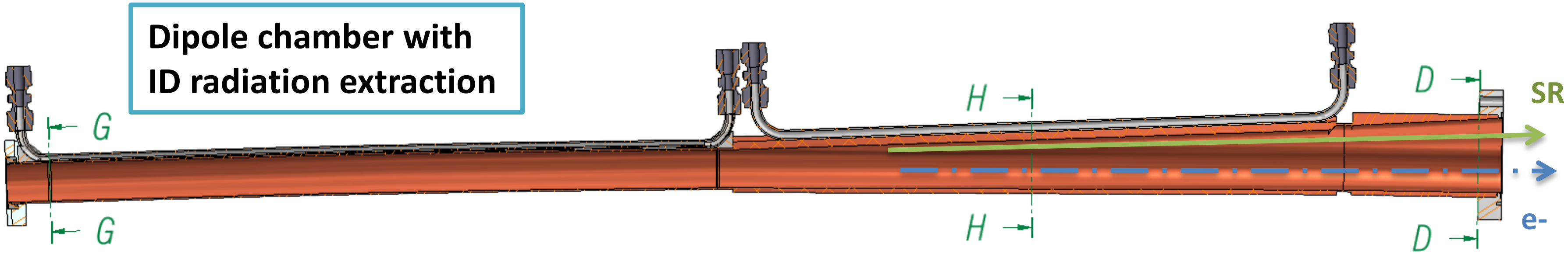
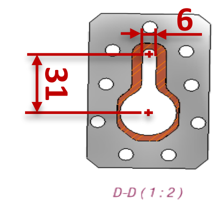
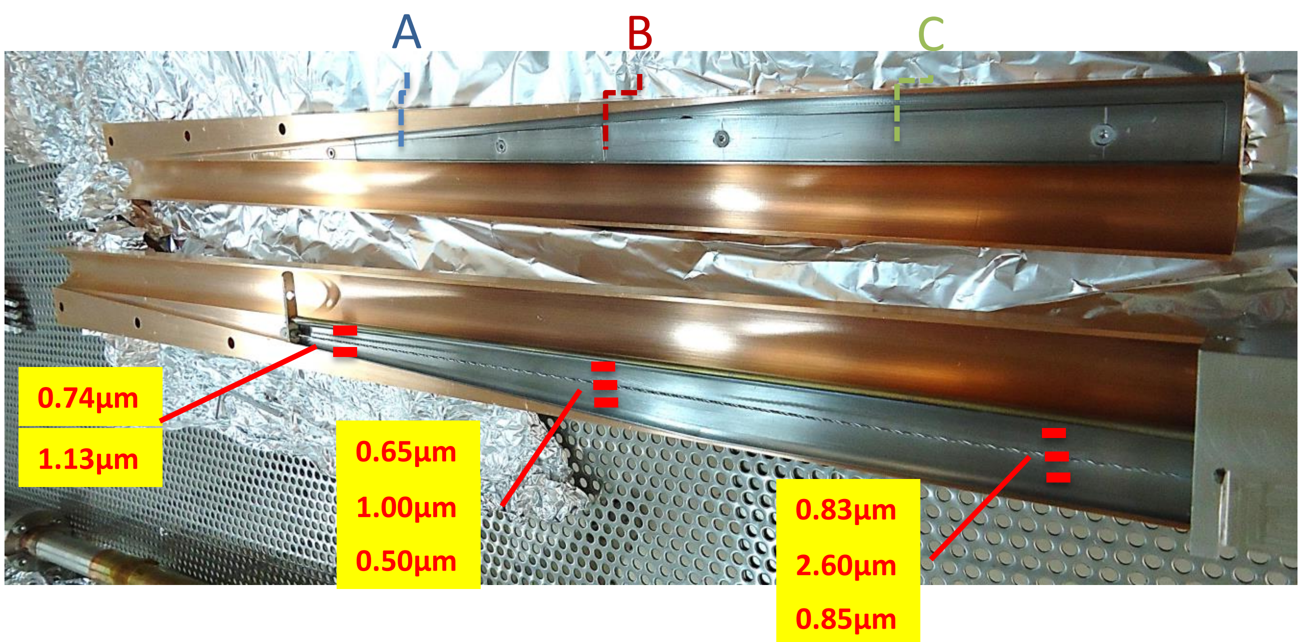
Vacuum system - NEG coating R&D for narrow gap sectors

Dipole chamber with ID radiation extraction







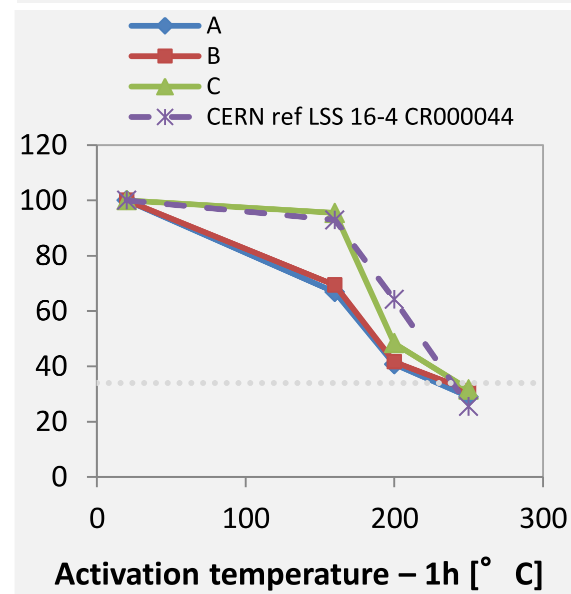
Coating procedure (2 steps):

1. Coating of the circular profile
2. Coating of the narrow gap – " keyhole" sector

Coating thickness set to 2µm

NEG film activation
(XPS analysis)

Oxygen 1s peak area reduction [%]



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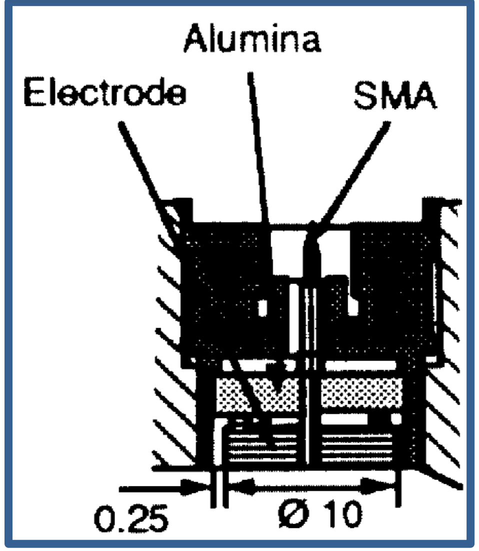
Historical BPM Design Tendency

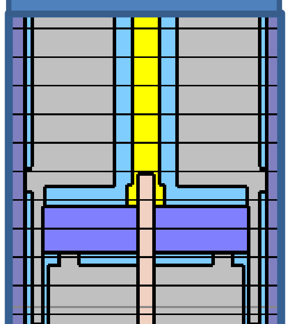
time

ESRF



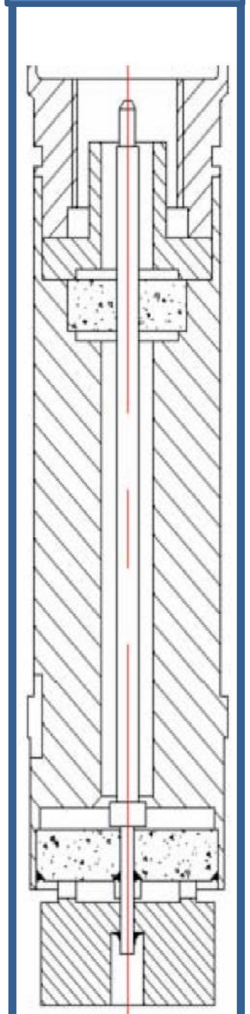
r_{button} = 5 mm
σ_{HxV} = 402 × 7.9 μm²

Diamond



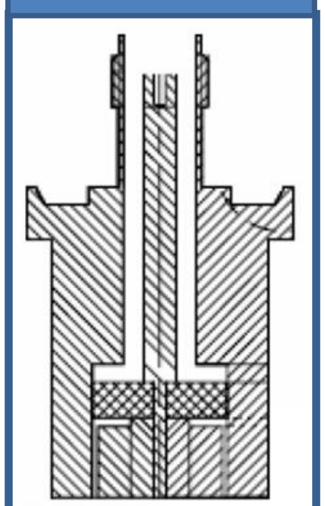
r_{button} = 5.5 mm
σ_{HxV} = 235 × 2.8 μm²

SOLEIL



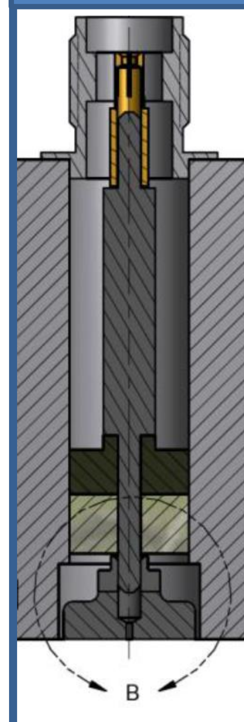
r_{button} = 5 mm
σ_{HxV} = 388 × 8.08 μm²

ALBA



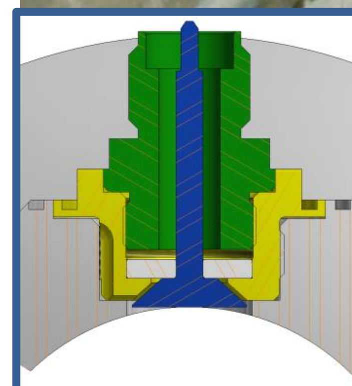
r_{button} = 3.5 mm
σ_{HxV} = 131 × 7.6 μm²

NSLS-II



r_{button} = 3.5 mm
σ_{HxV} = 28 × 2.6 μm²

Sirius



r_{button} = 3 mm
σ_{HxV} = 19.8 × 2.0 μm²

Same relative scale

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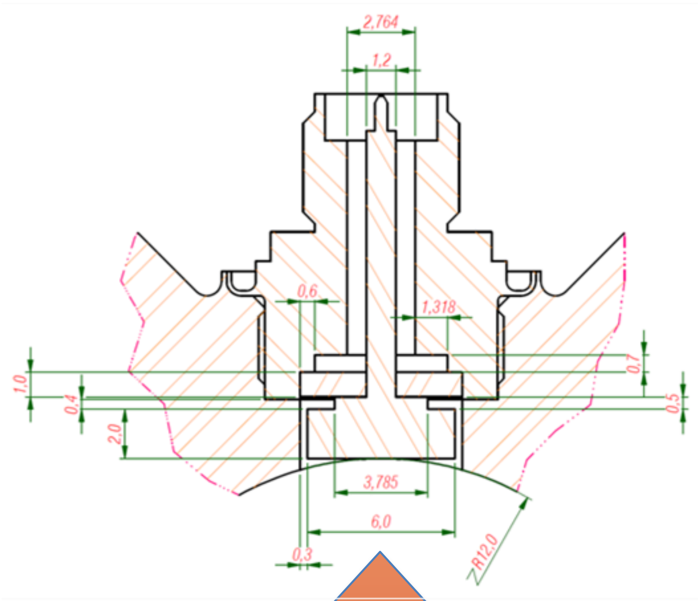
Button Geometry Choice

Step-Shaped BPM Button

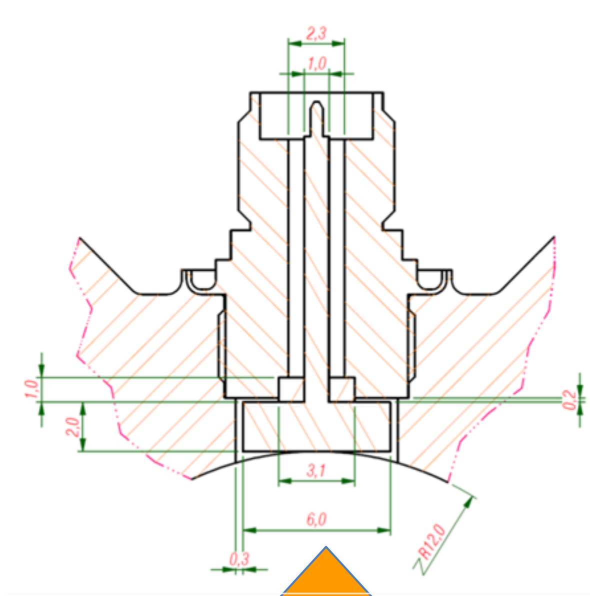
Based on the geometry style implemented at ALBA.



Input power

Flat BPM Button

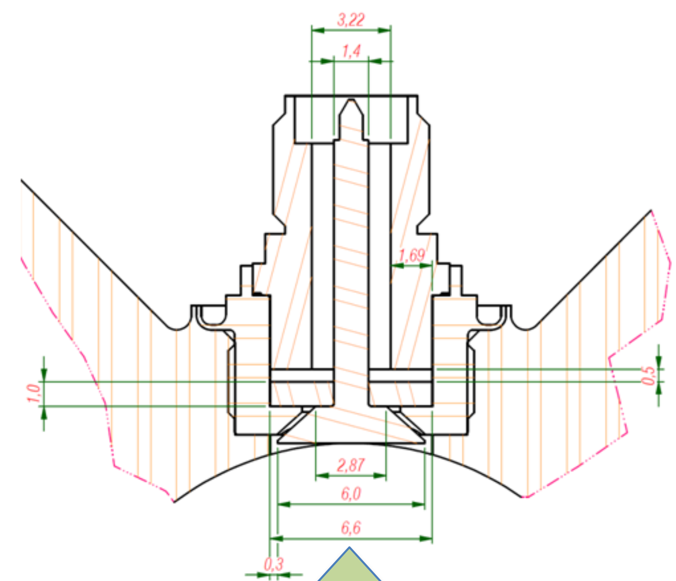
Reduced ceramics dimensions to decrease wakelosses.



37% reduction

Bell-Shaped BPM Button

Conical profile shifts the HOMs to higher frequencies.



50% reduction

From electromagnetic (wakefield) simulations, wakelosses are calculated

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Sirius BPM Challenges/New Ideas

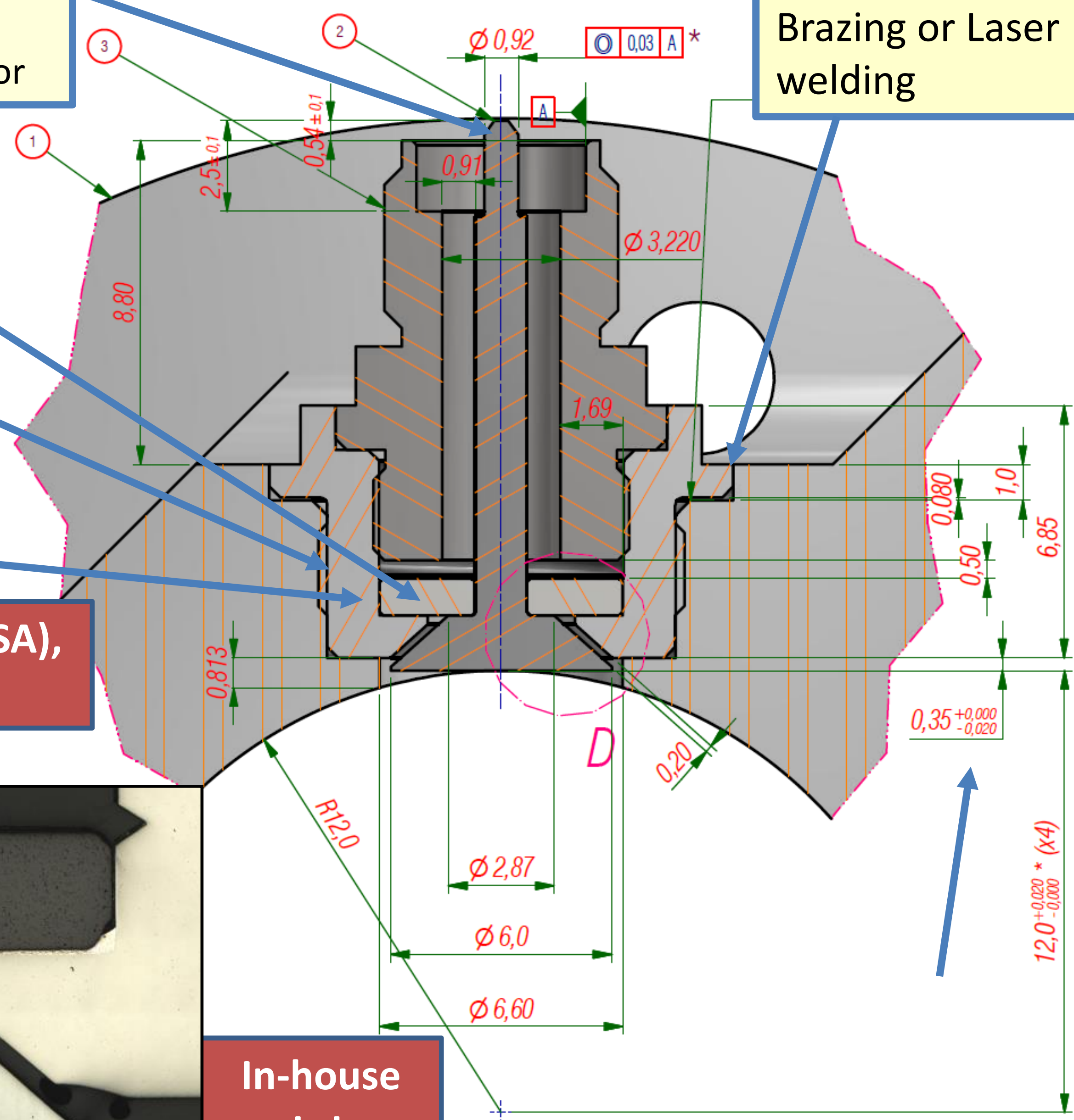
Brazed Al2O3 insulator, 1 mm thickness.

Threads: thermal contact, RF shielding and fixation

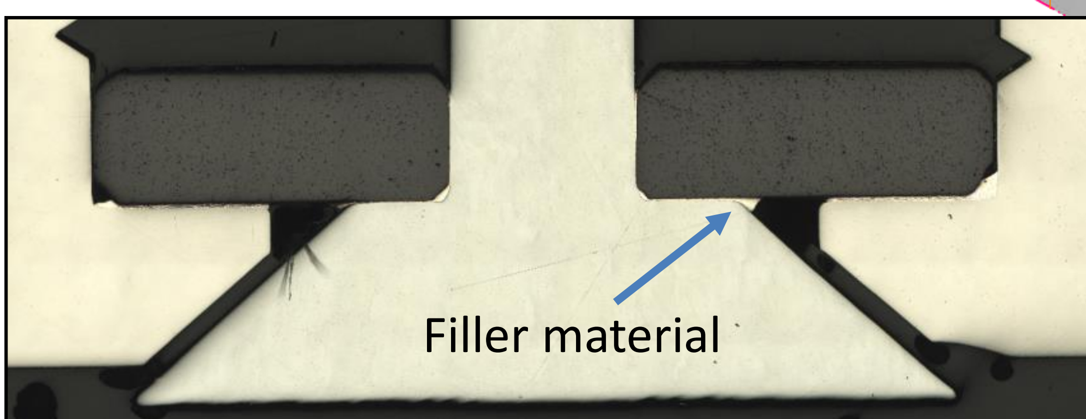
Kovar housing (magnetic). Ti alloy as non-magnetic alternative metal.

RP-SMA connector

Brazing or Laser welding



Prototypes already ordered from MDC (USA), VACOM (Germany), Kyocera (Japan)



In-house prototype

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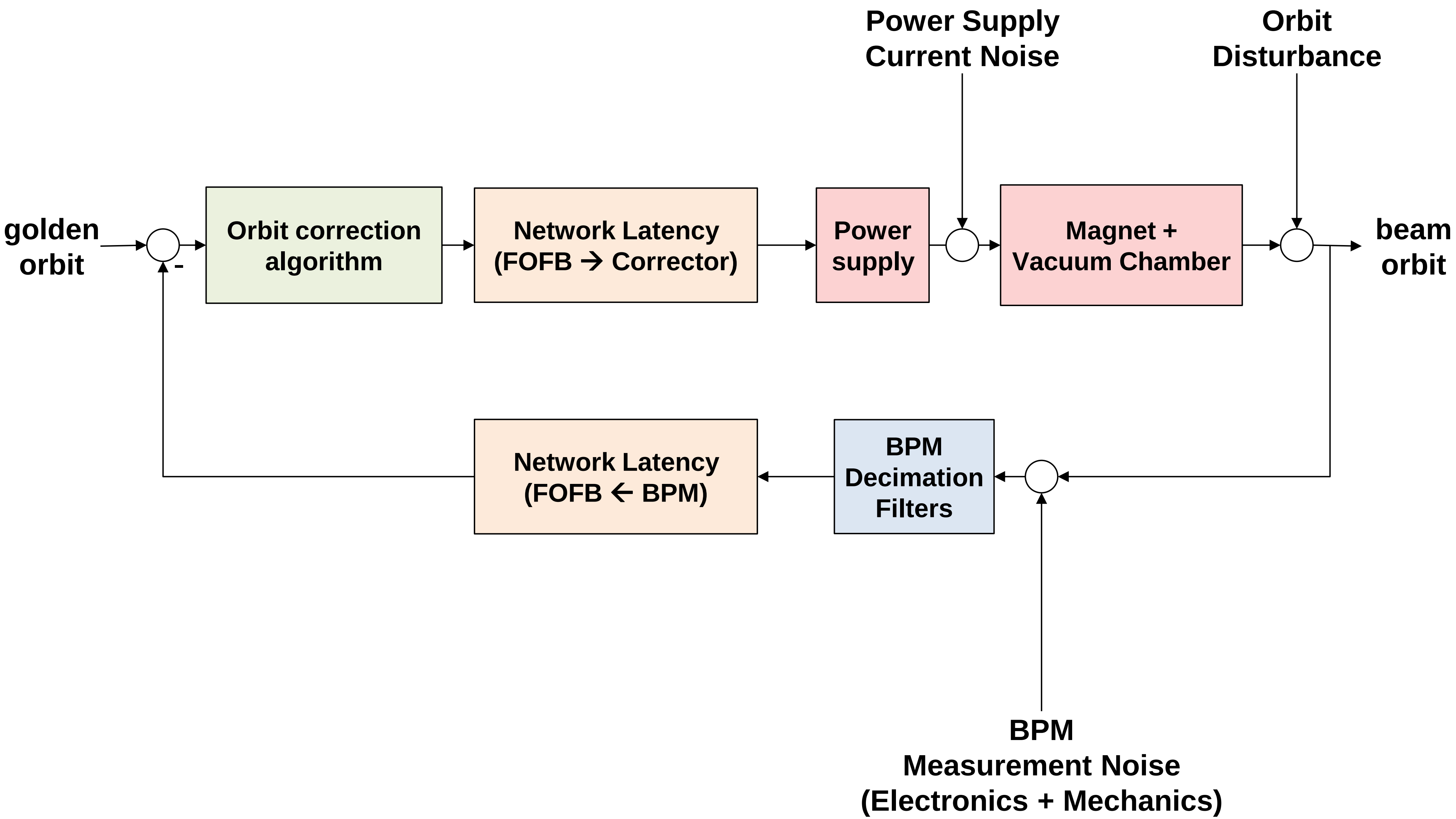
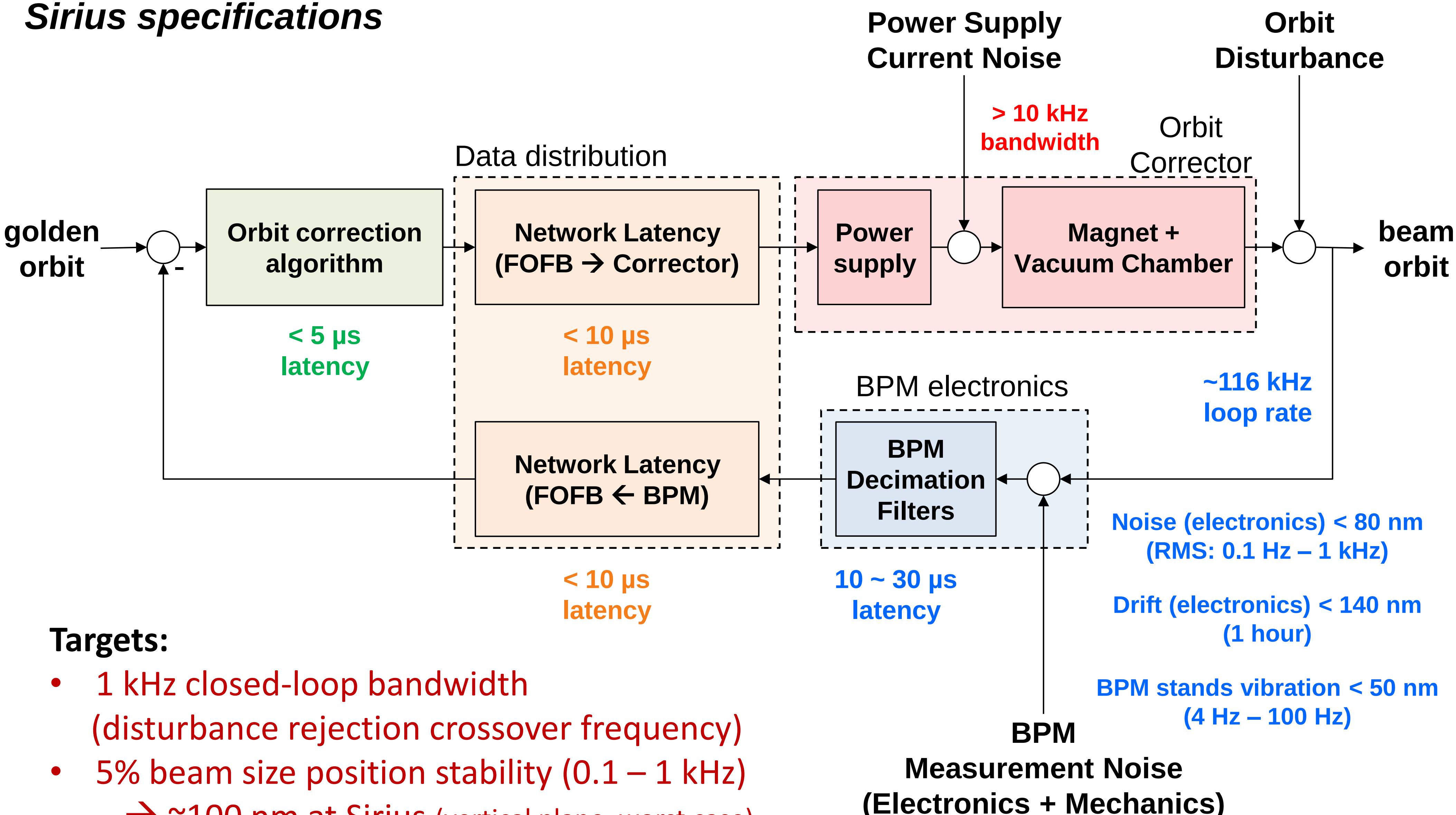
Fast Orbit Feedback



Fast Orbit Feedback

Sirius specifications

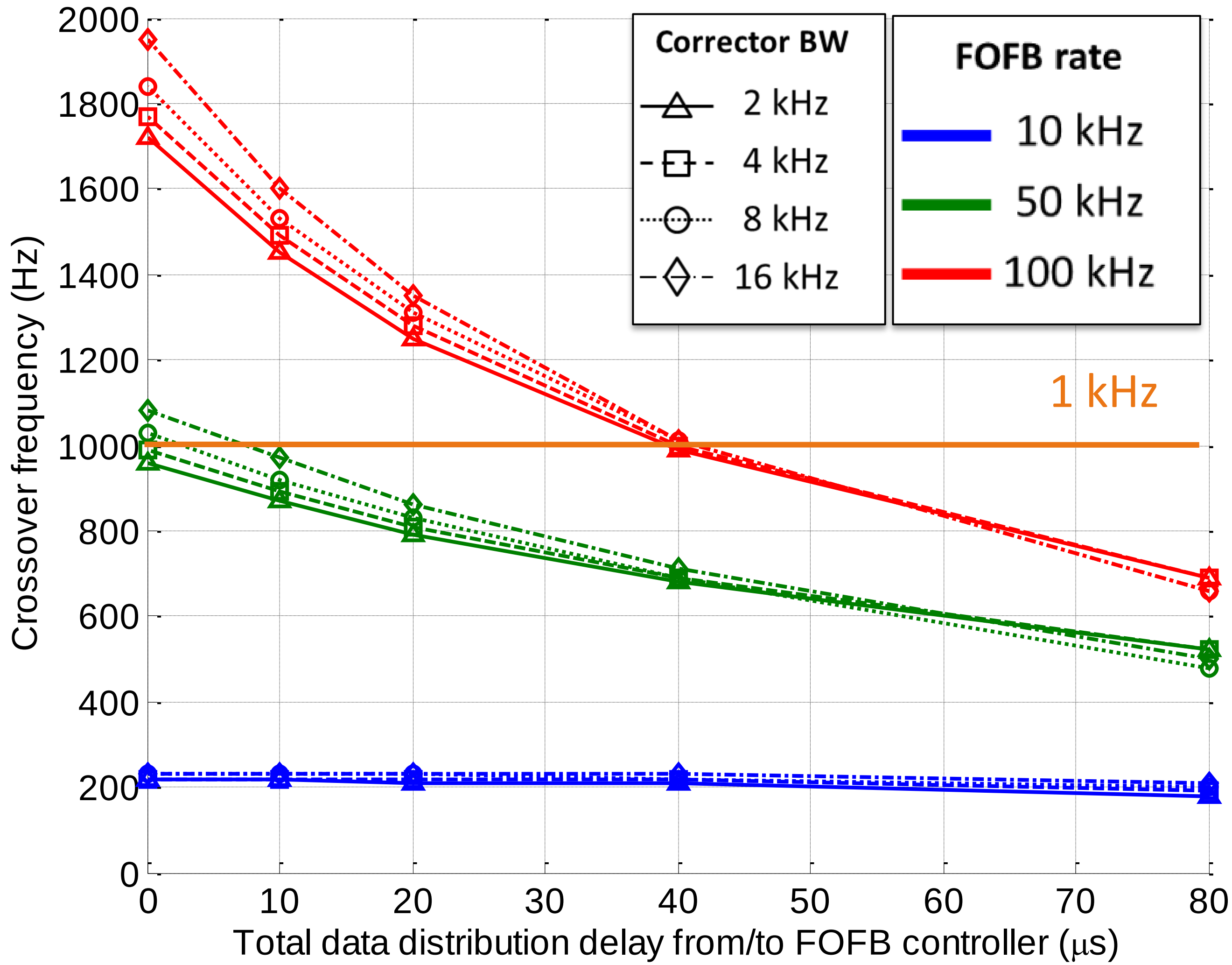


Targets:

- 1 kHz closed-loop bandwidth (disturbance rejection crossover frequency)
- 5% beam size position stability (0.1 – 1 kHz)
  → ~100 nm at Sirius (vertical plane, worst case)

Fast Orbit Feedback

Possible to achieve 1 kHz crossover frequency with present technology at reasonable cost



Parameters used in FOFB simulation

Vacuum chamber	15 kHz bandwidth
BPM group delay	3x FOFB sampling period
Control algorithm	Simple PI controller tuned for maximum disturbances amplification of 5 dB

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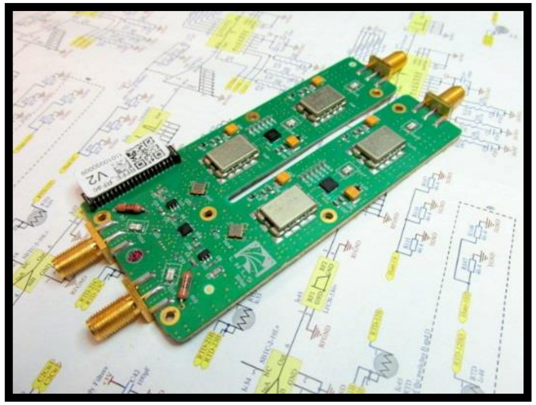
BPM Electronics

RF Front-End

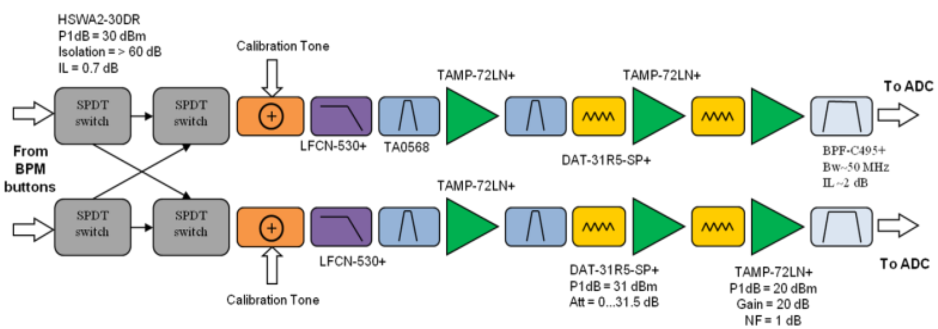


RF signals

ADC + FPGA boards

Digital signals

MicroTCA crate



Analog performance (resolution, drifts, nonlinearity)

- Dominated by RF Front-End + ADC + clocking
- Switching frequency ~ 115 kHz

Open-source software and hardware facilitate collaboration

Signal Processing, Data Acquisition and Control Platform

- System maintainability
- High-end communication interfaces enable FOFB
- DSP algorithms flexibility

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Some final comments:

- The Light Source community is crossing a very exciting era, with hundreds of new developments under way and dozens new machines expected for next 10 years.
- It is still an open community and the international cooperation is one of the most important engineering tool.

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- It is still an open community and the international cooperation is one of the most important engineering tool.

- **Success to all projects**

Thank you