Progress with building Sirius

Some highlights of the current status

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LNLS Accelerator Physics Group

on behalf of the Sirius Project Team

High Brightness Synchrotron Light Sources Workshop (HBSLS 2017)
BNL/NSLS-II, USA, April 26th-28th, 2017.

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES

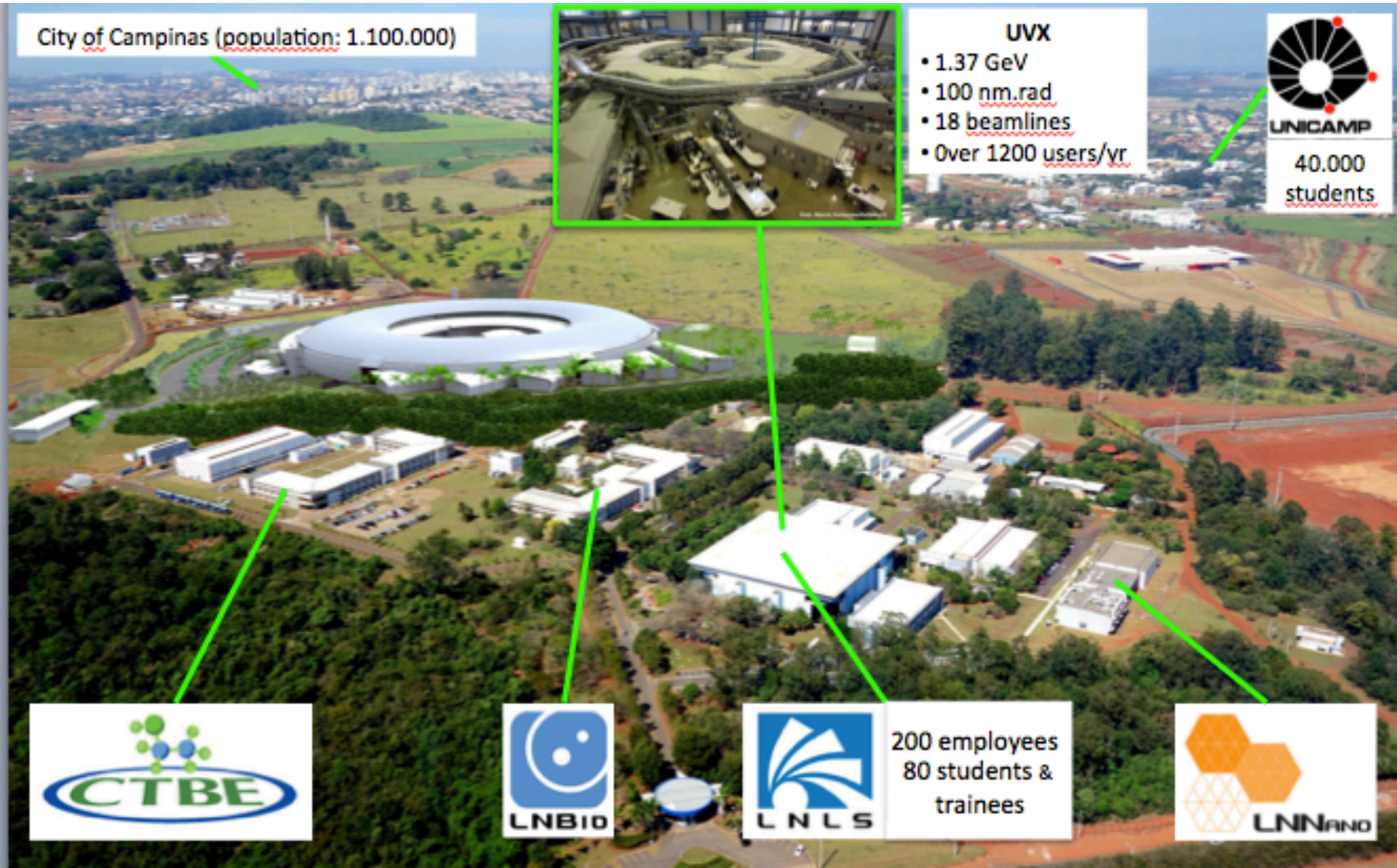
BRASIL

CNPEM

Summary

- Introduction
- Optics
- Buildings and high stability floor
- Magnets
- Girders
- Vacuum
- BPMs
- Injection
- Conclusion

CNPEM Campus



Sirius building construction (~50% concluded in 04/2017)

First beam 2018 – Open in 2019

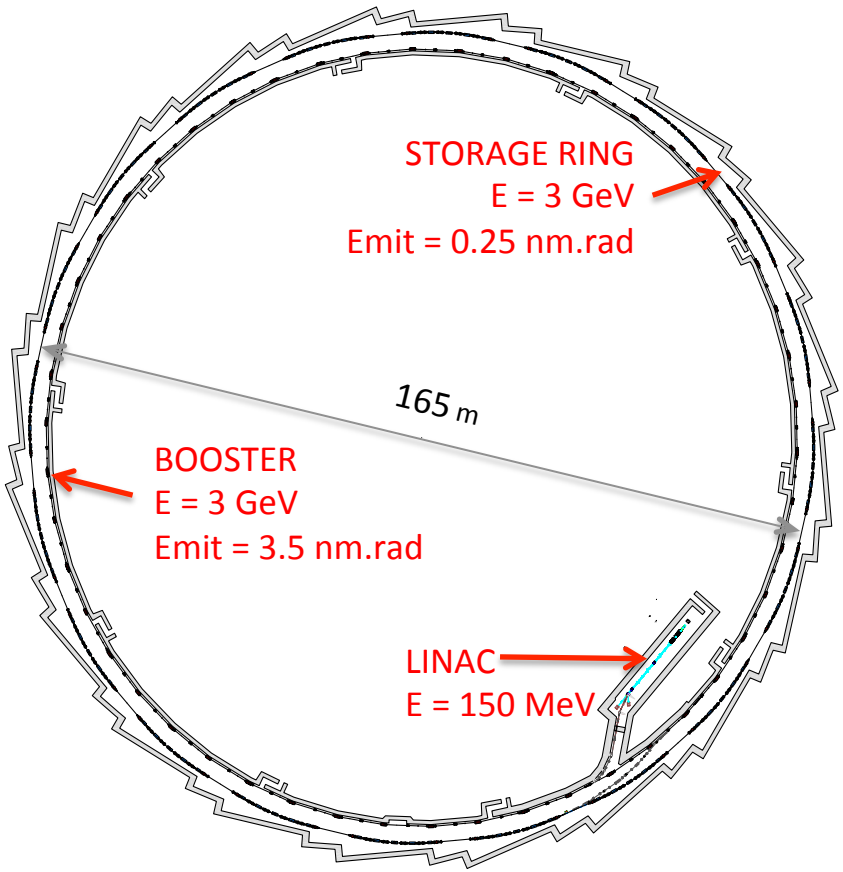
Budget

- Accelerators 100 M US$
- 13 beamlines 140 M US$
- Building 213 M US$
- Human Res 57 M US$
- Total 510 M US$

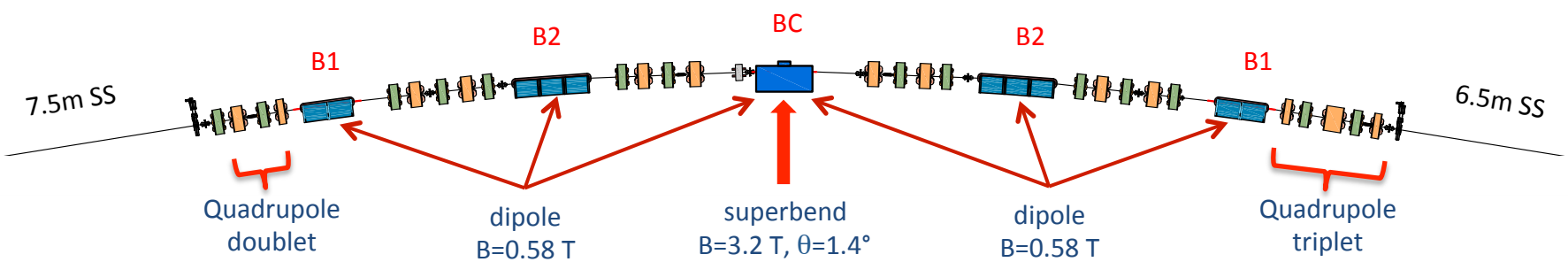
Schedule

- Jan.2015 start of building construction
- Oct.2017 start of machine installation
- Jul.2018 start of SR commissioning
- Sep.2018 phase 1 operation (20mA, NCC)
- Feb.2019 phase 2 operaton (100mA, SCC)

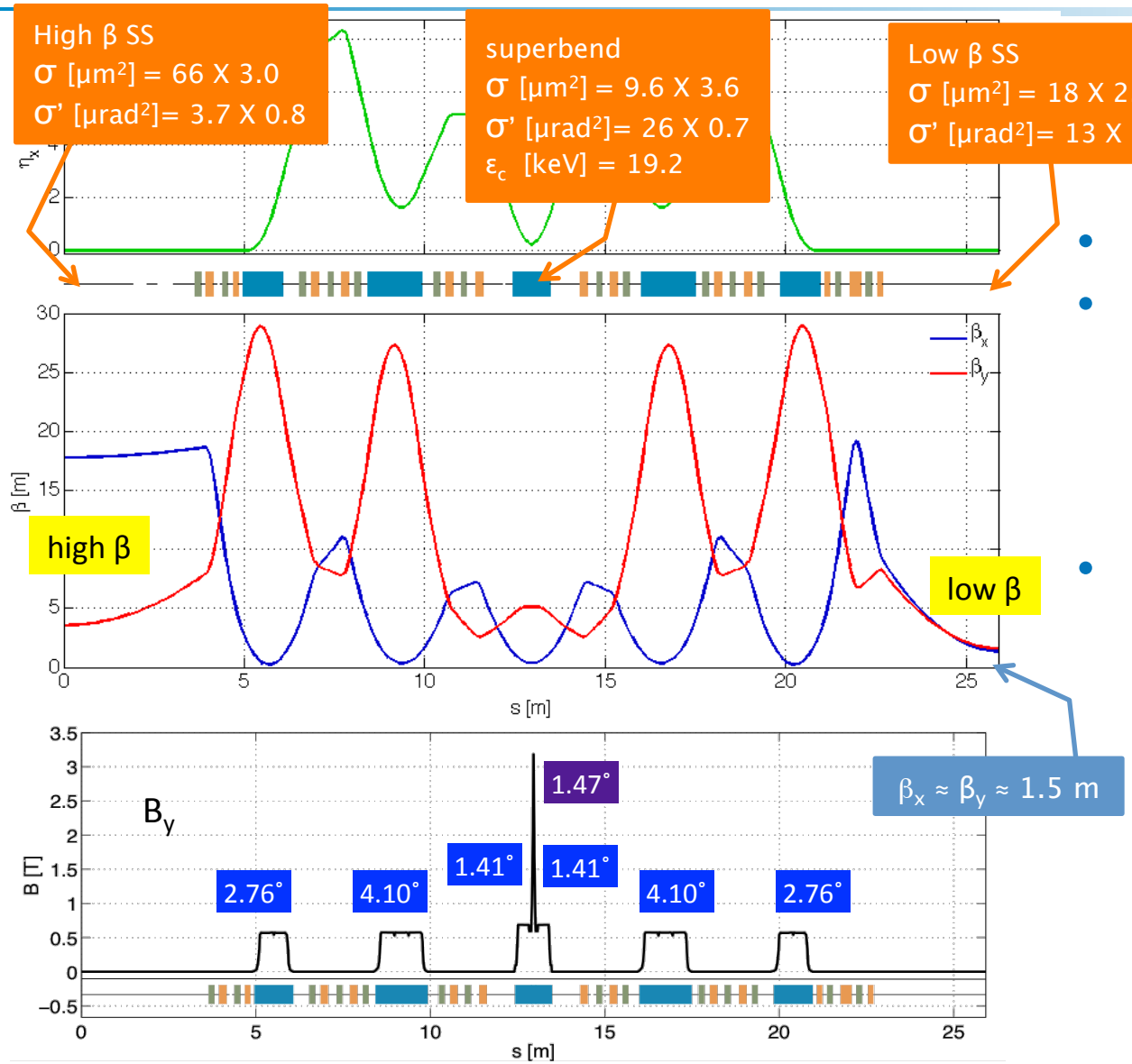
Sirius main parameters (SI.V21.02-S05.03)



Storage Ring	
Beam energy	3.0 GeV
Circumference	518.4 m
Lattice	20 x 5BA
Hor. emittance (bare lat.)	0.25 nm.rad
Hor. emittance (with IDs)	→ 0.15 nm.rad
Betatron tunes (H/V)	49.11 / 14.17
Natural chrom. (H/V)	-119.0 / -81.2
rms energy spread	0.85×10^{-3}
Energy loss/turn (dipoles)	473 keV
Dam. times (H/V/L) [ms]	16.9 / 22.0 / 12.9
Nominal current, top up	350 mA



Low β optics (SI.V21.02-S05.03)

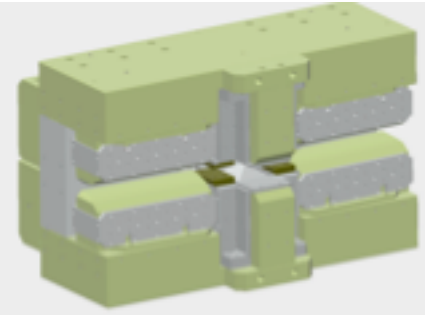


d symmetric optics with 5 high and 15 low β sections.

- Achromatic cells.
- At low β sections
  - $\beta_x \approx \beta_y \approx 1.5$ m
  - Optimized electron and photon beam phase-space matching for undulators.
- At superbend
  - Strong focusing of dispersion and β_x functions
  - Beam size: 9.5 x 3.5 μm²

Low field dipoles with different deflections, but same field and gradient (same unit block).

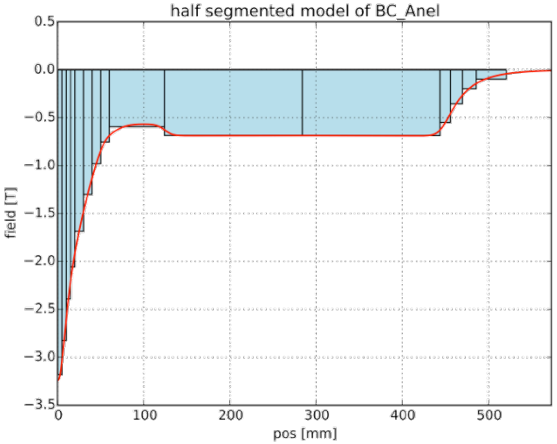
Superbends (no wigglers allowed)



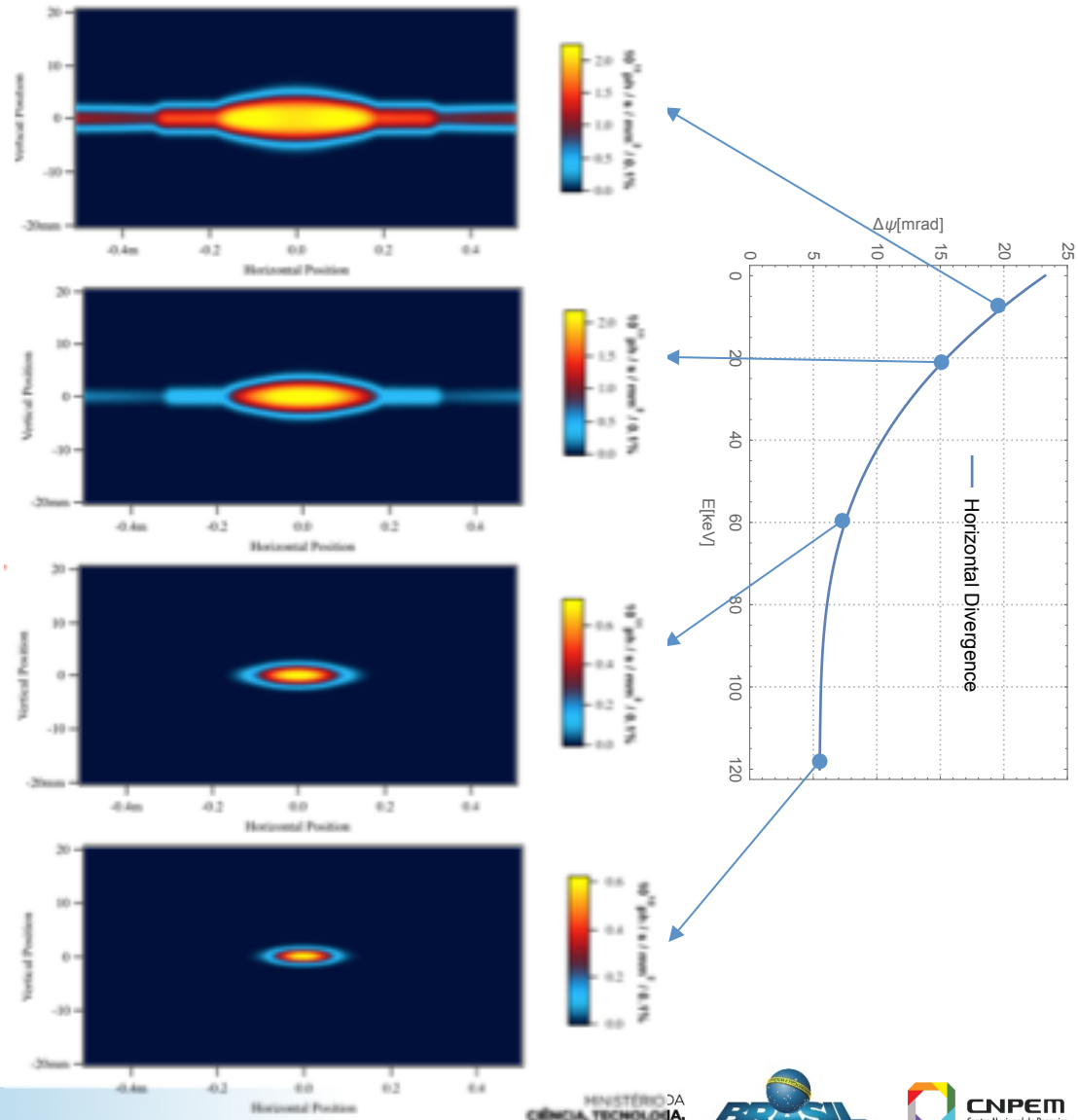
Permanent magnet (NdFeB)

High field insert (3.2 T) superbend

- 19 keV critical energy at peak
- Hard X-rays produced only at beamline exit
- Total energy loss/turn from dipoles = 473 keV

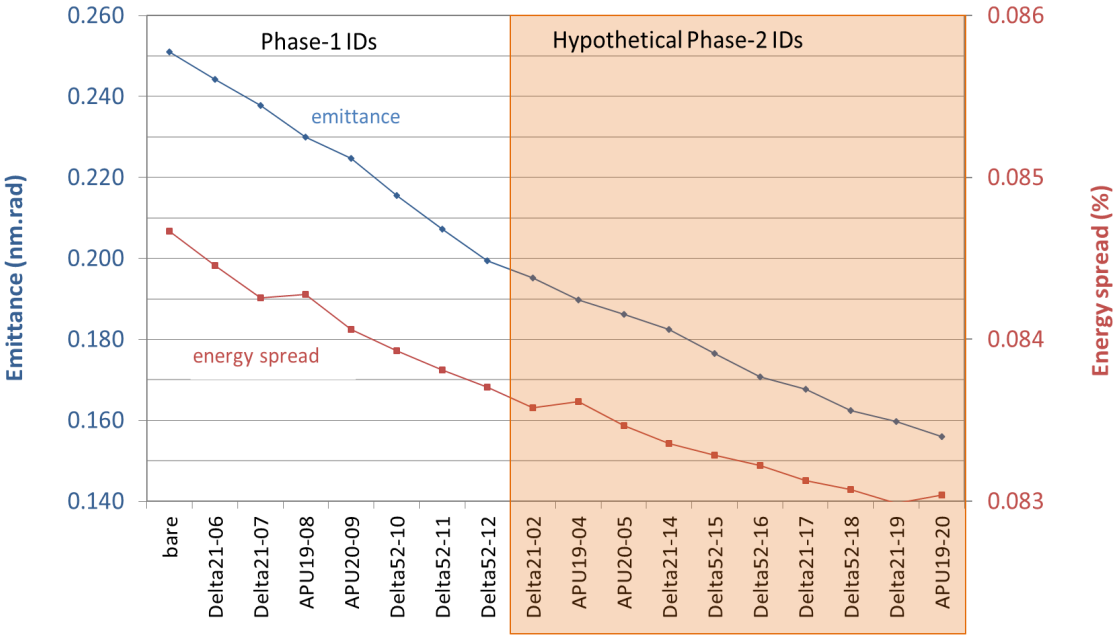


From SRW:



James Citadini (james.citadini@lnls.br)

Effect of IDs on emittance and energy spread



Sirius Phase-1 Beamlines

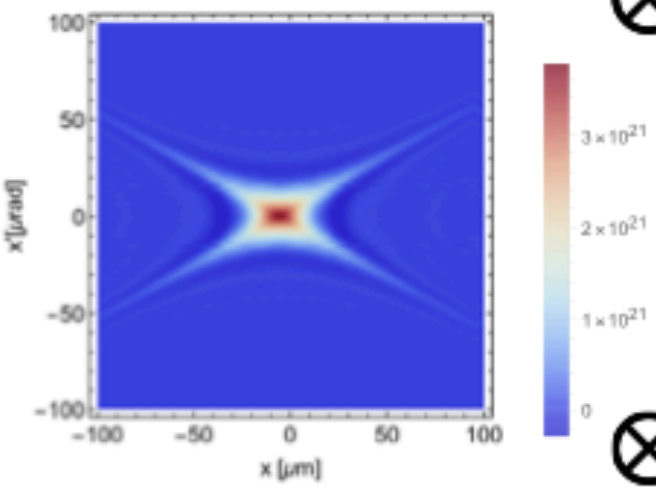
Beamline	ID Type	SS	β_x
CARNAÚBA	Delta21	06	low
EMA	APU19	08	low
CATERETÊ	Delta21	07	low
IPÊ	Delta52	11	low
SABIÁ	Delta52	10	low
MANACÁ	APU20	09	high
PGM++	Delta52	12	low

Sirius IDs

ID Type	B_0 [T]	λ [mm]	L [m]	K_{max}	gap [mm]
Delta21	1.12	21	2.4	2.2	7.0
Delta52	1.19	52	3.6	5.85	13.85
APU19	1.28	19	2.4	2.3	5.0
APU20	1.07	20	2.4	2.0	6.2

Diffraction Limit: low emittance is not all!
Phase Space Matching (from SPECTRA)

SINGLE PHOTON'S "PHASE SPACE" (900 eV)
(Wigner Distribution Function)
from single electron



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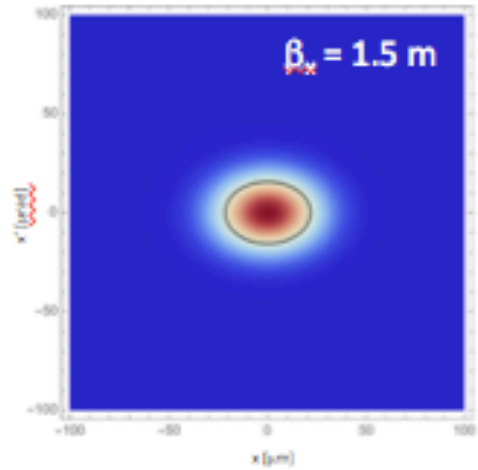
ELECTRONS PHASE SPACE
(HORIZONTAL)



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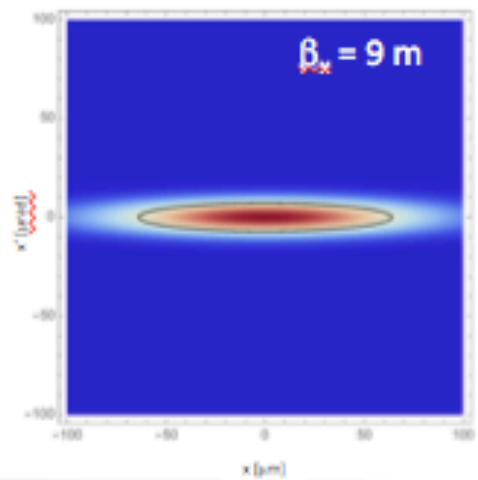

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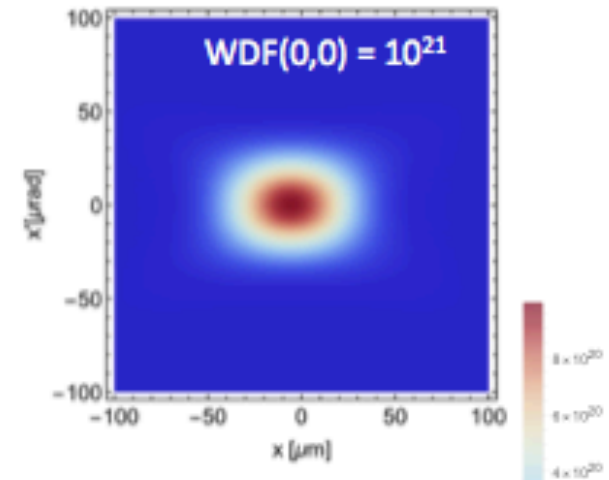
AVERAGE PHOTON'S "PHASE SPACE"
(Wigner Distribution Function=Brilliance)



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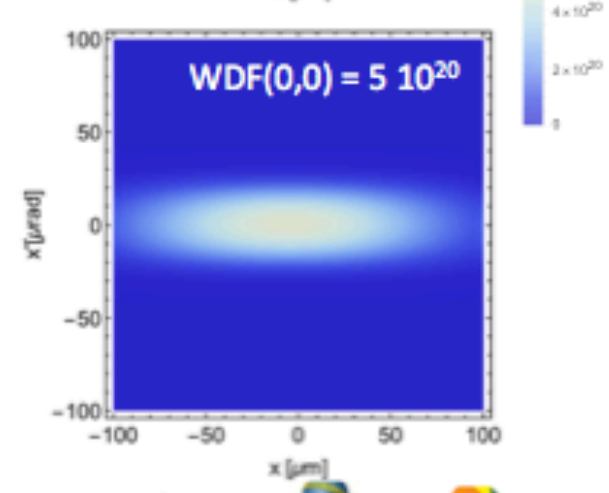
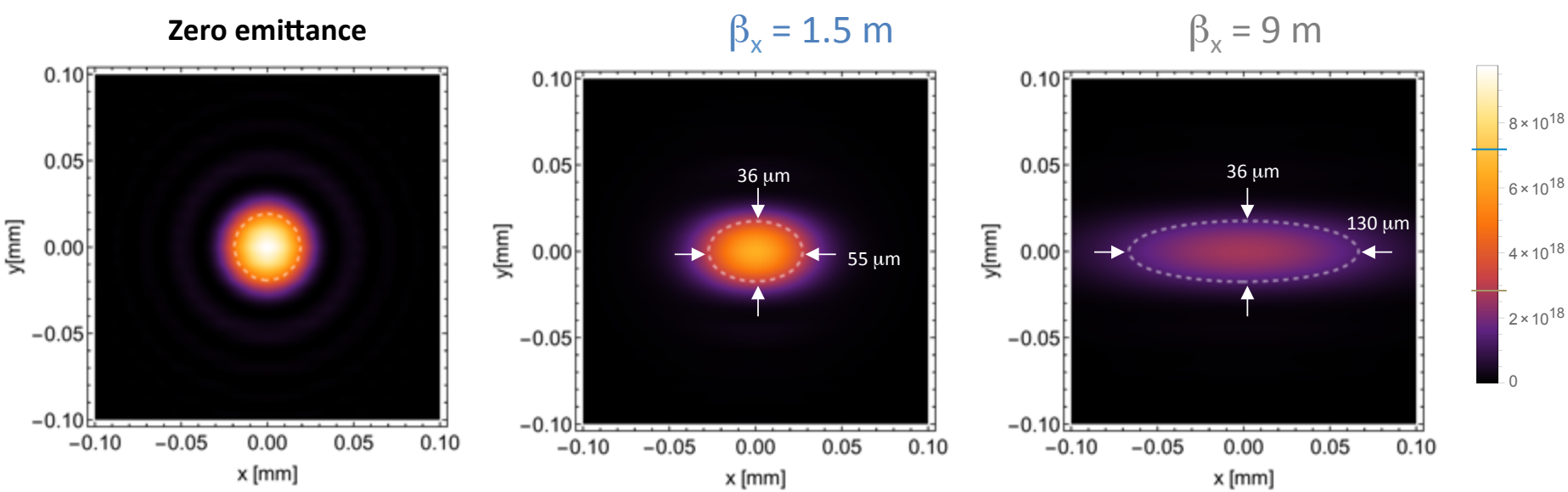


Courtesy: Harry Westfahl Jr.

Source Size @ 900 eV (λ = 1.4 nm)

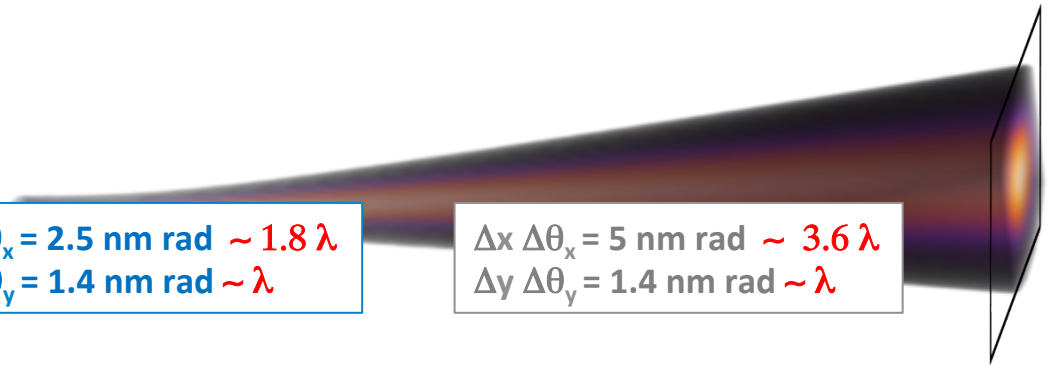
λ_u = 50 mm, K = 1.4, L_u = 3.6 m



Courtesy: Harry Westfahl Jr.

Source Divergence @ 900 eV (λ = 1.4 nm)

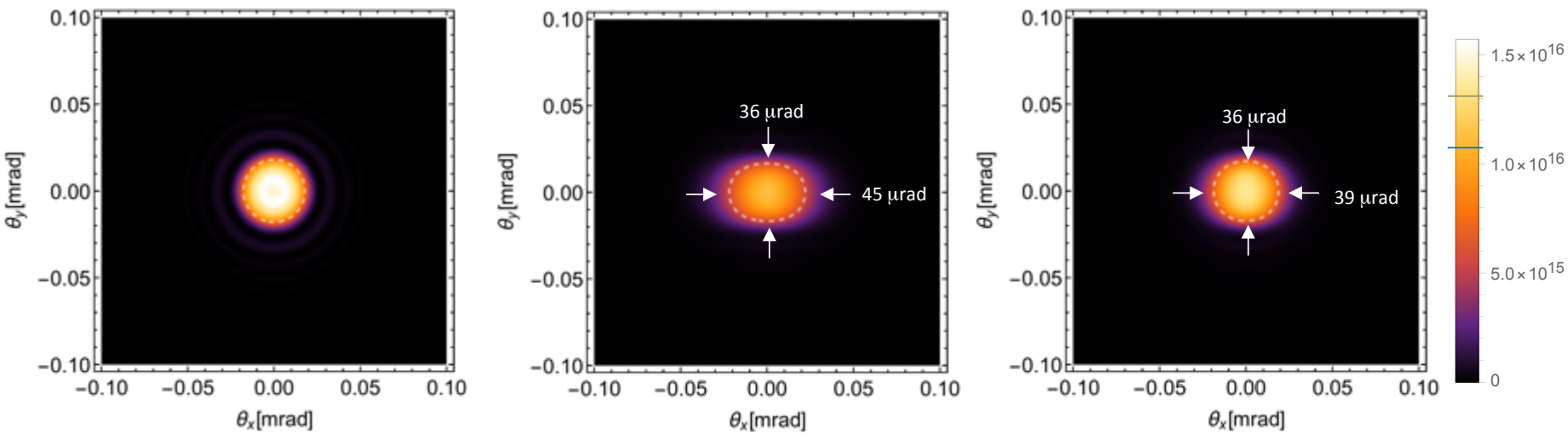
λ_u = 50 mm, K = 1.4, L_u = 3.6 m



$\Delta x\ \Delta\theta_x$ = 2.5 nm rad ~ 1.8 λ
$\Delta y\ \Delta\theta_y$ = 1.4 nm rad ~ λ

$\Delta x\ \Delta\theta_x$ = 5 nm rad ~ 3.6 λ
$\Delta y\ \Delta\theta_y$ = 1.4 nm rad ~ λ

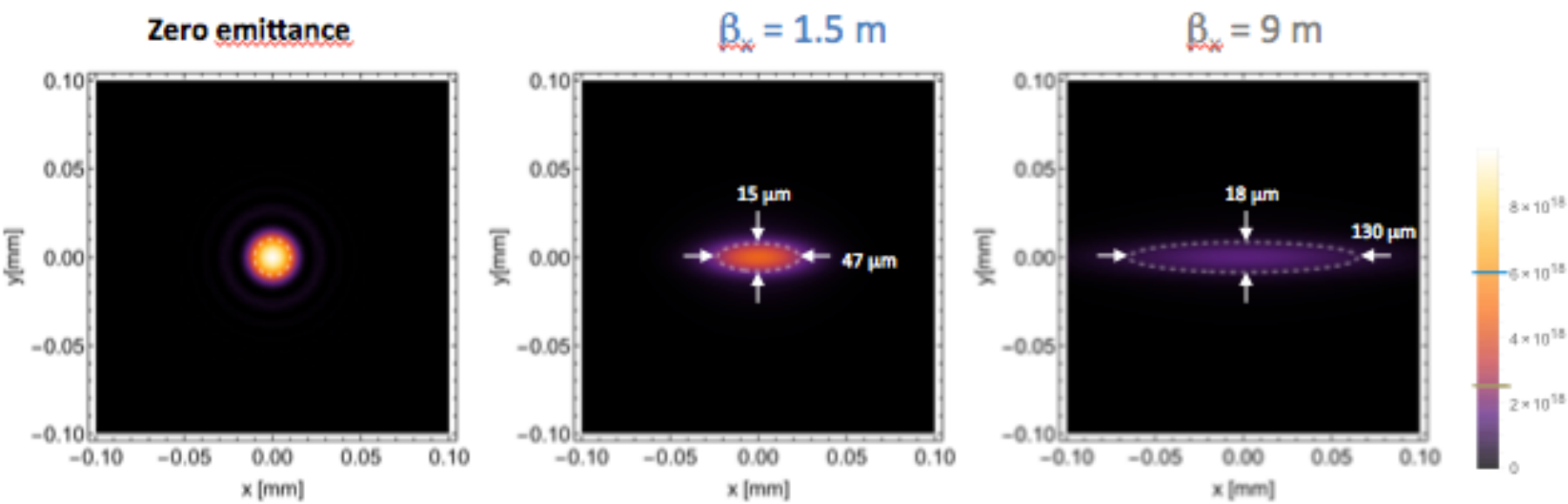
Zero emittance | β_x = 1.5 m | β_x = 9 m



Courtesy: Harry Westfahl Jr.

Source Size @ 3.5 keV (λ = 0.35 nm)

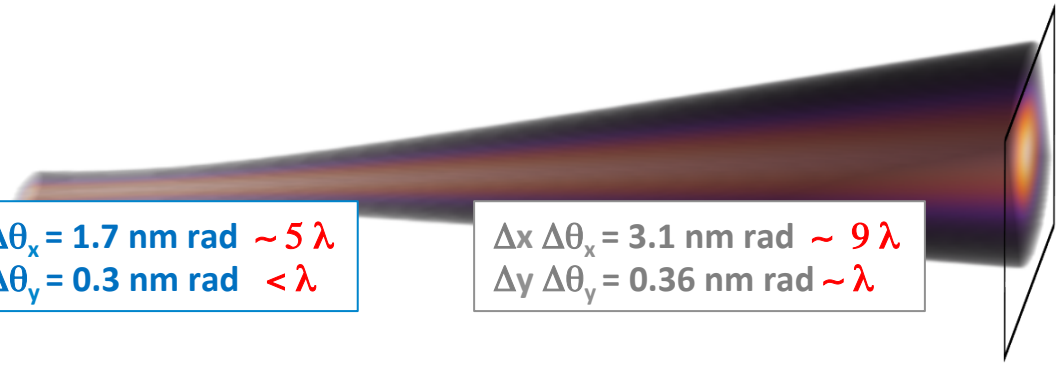
λ_u = 17 mm, K = 0.95, L_u = 4 m



Courtesy: Harry Westfahl Jr.

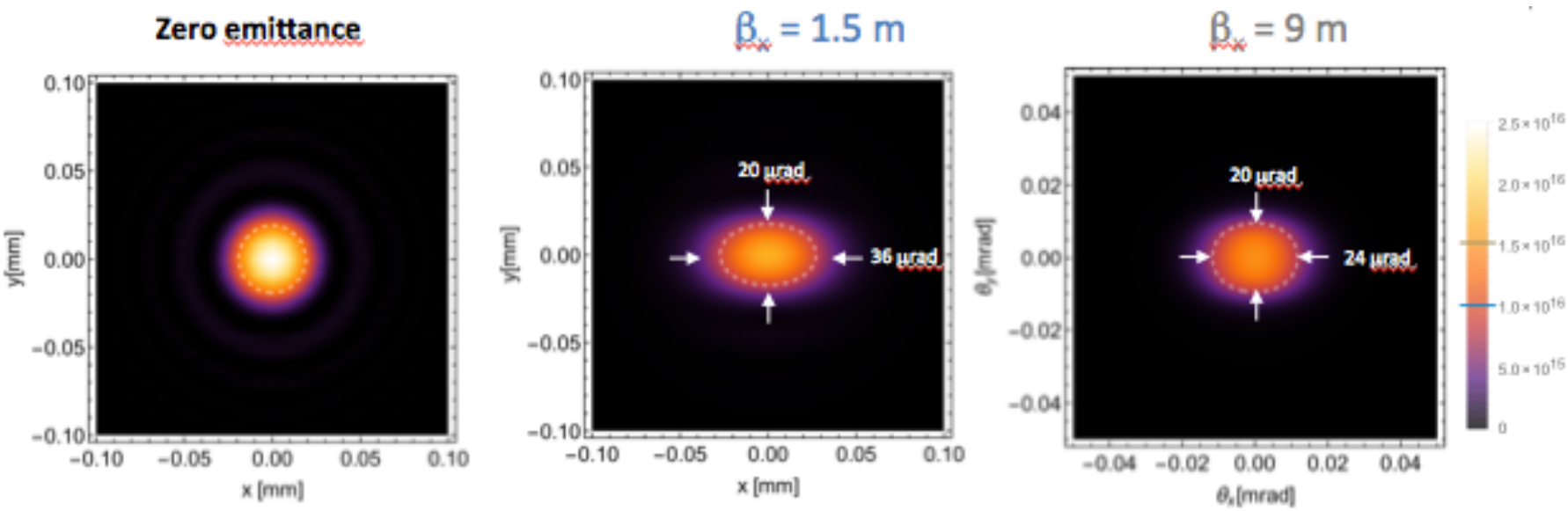
Source Divergence @ 3.5 keV (λ = 0.35 nm)

λ_u = 17 mm, K = 0.95, L_u = 4 m



$\Delta x\ \Delta\theta_x$ = 1.7 nm rad ~ 5 λ
$\Delta y\ \Delta\theta_y$ = 0.3 nm rad < λ

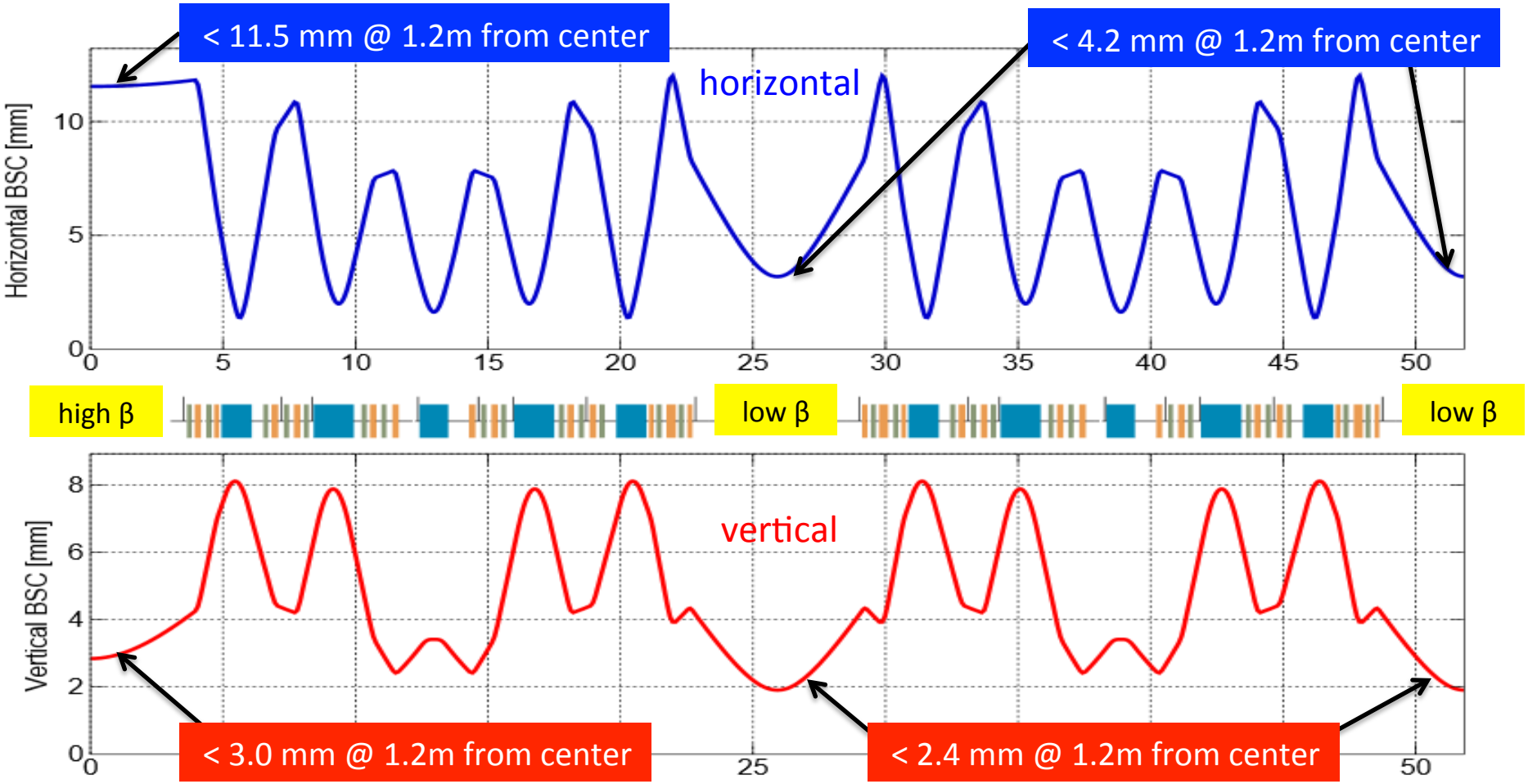
$\Delta x\ \Delta\theta_x$ = 3.1 nm rad ~ 9 λ
$\Delta y\ \Delta\theta_y$ = 0.36 nm rad ~ λ



Courtesy: Harry Westfahl Jr.

Low β optics: Beam Stay-Clear (SI.V21.02-S05.03)

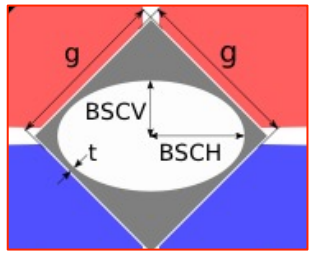
Sirius IDs will be based on Delta and APU undulators.

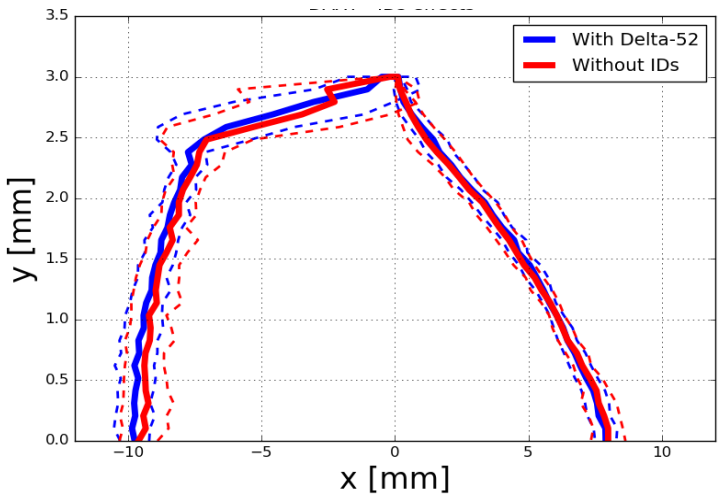


Low β optics: Insertion Devices

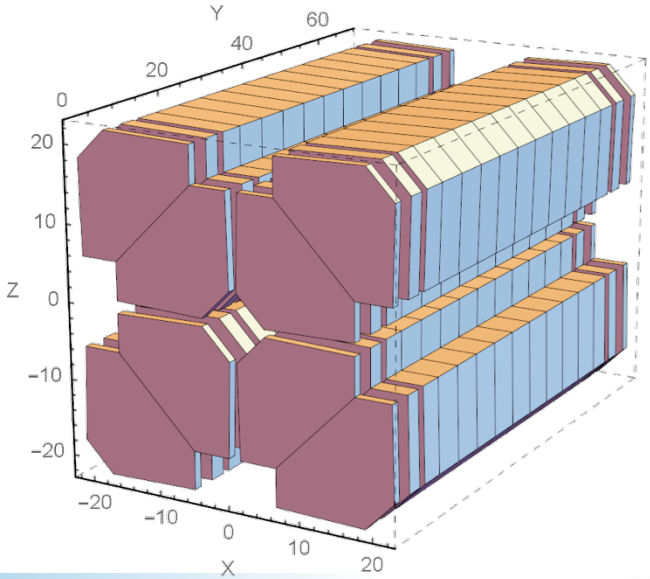
- Delta Undulators
  - Possible for Sirius due to small Hor. BSC
  - Smoother K changes
  - Horizontal, Vertical and Circular x-ray polarizations on the same energy range
  - Do not introduce strong harmful multipoles

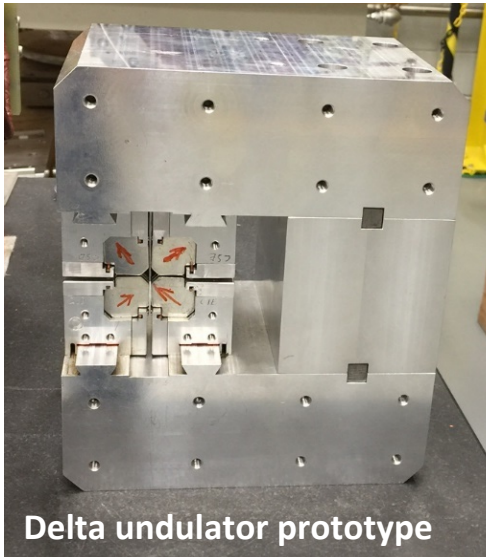
	B_0 [T]	λ [mm]	L [m]	K_{max}	Diag. gap [mm]
Delta21	1.12	21	2.4	2.2	7.0
Delta52	1.19	52	3.6	5.85	13.85



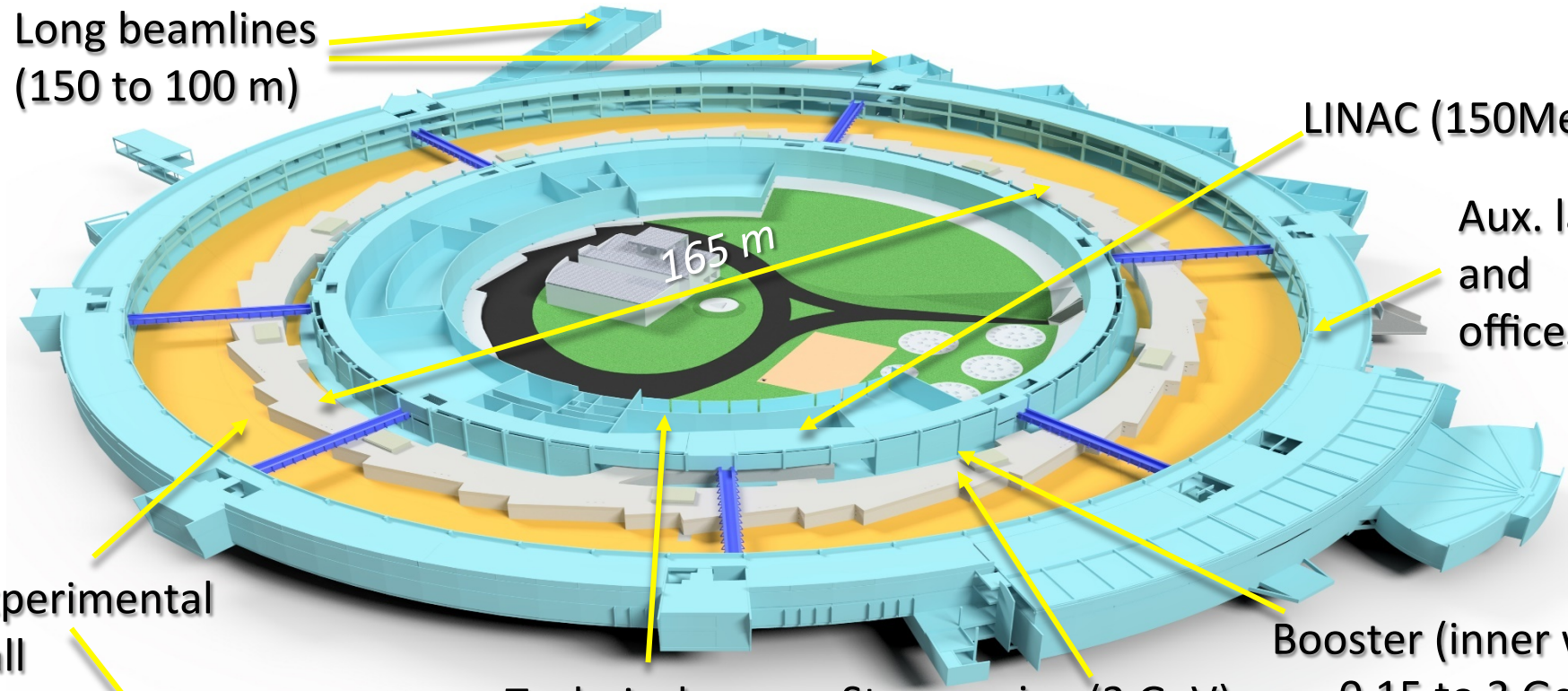


Effect of 14 Delta52 on DA
7 in each polarization (H/V) distributed in low beta sections

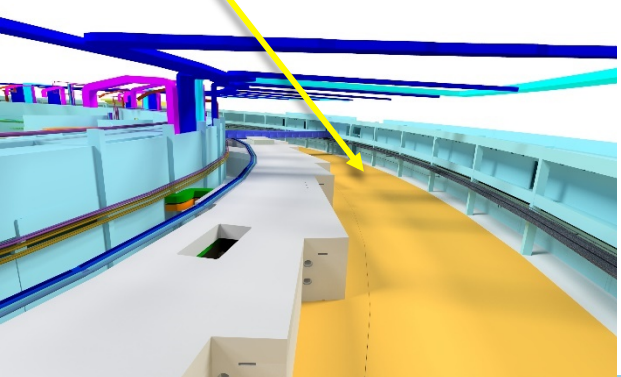


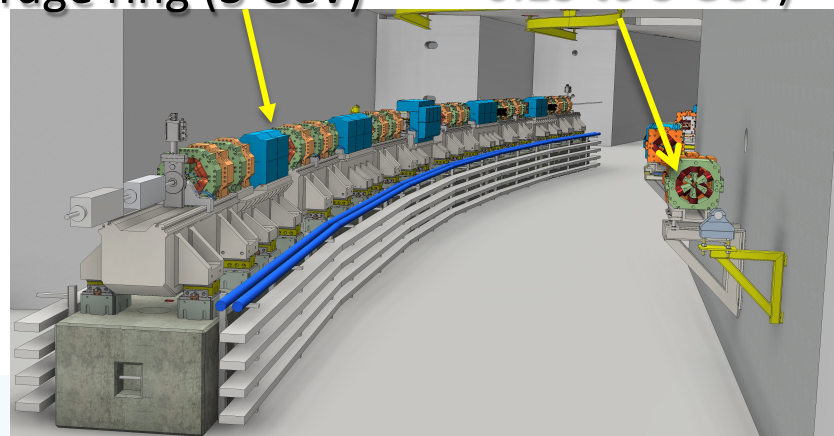


Sirius Building

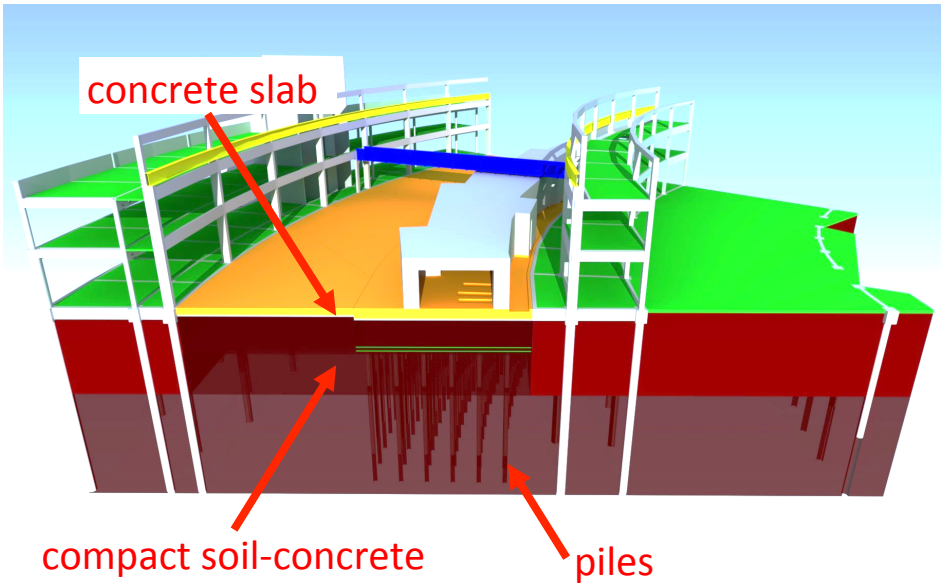


- Electrical energy
- Cooling water plant
- Compressed air
- Air conditioning
- LHe plant
- RF amplifiers
- Power supplies
- Control room





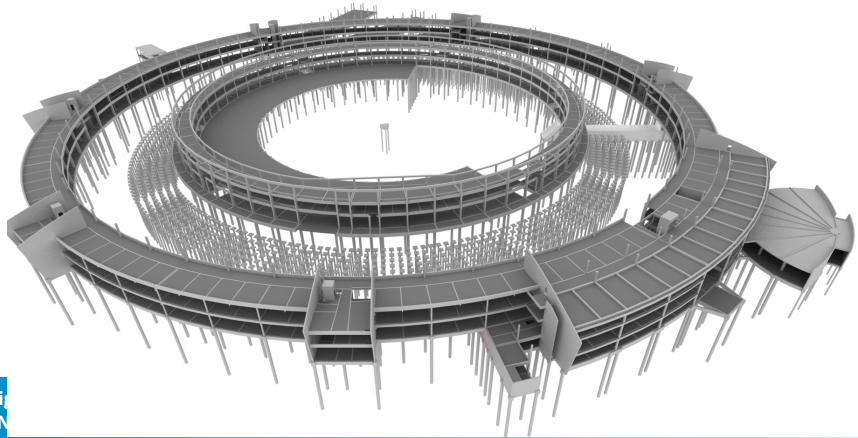
High stability floor



Binary structure for the high stability floor:

- > 3 m deep compacted layer of soil-concrete
- 90 (60) cm concrete slab for machine tunnel (experimental hall)

1500 piles (10 to 15 m deep) under the machine tunnel to provide long term stability due to the 'cut and fill' operation on the site.

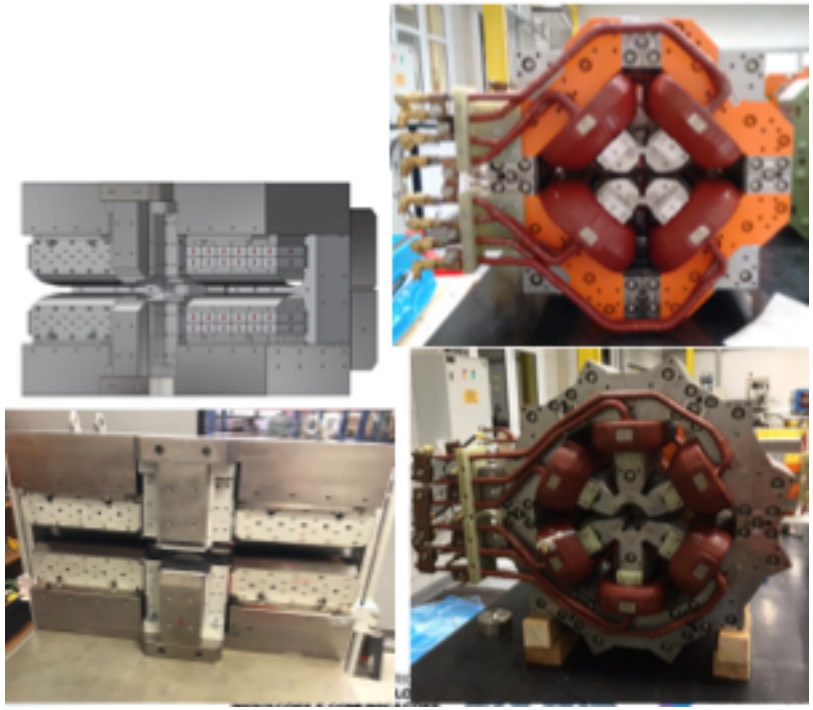


Magnets production

James Citadini (james.citadini@lnls.br)

Booster

- (a) 50 Focusing Quadrupoles – **delivered**
- (b) 35 Sextupoles – **delivered**
- (c) 50 Dipoles – **delivered**
- (d) 50 Correctors – **delivered**
- (e) Defocusing Quadrupoles – **delivered**



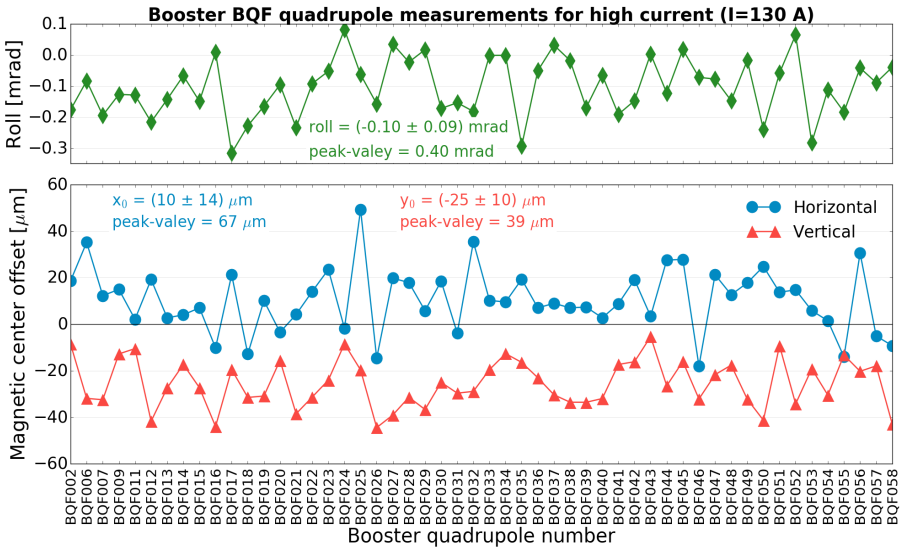
Storage Ring

- 20 BC Dipoles – **in production (in-house)**
- 80 Low Field Dipoles – **prototyping, delivery 03/2018**
- 260 Quadrupoles – **in production, delivery 08/2017**
- 280 Multifunction Sextupoles – **in production, delivery 12/2017**
- 80 Fast Correctors – **in design, delivery 05/2018**

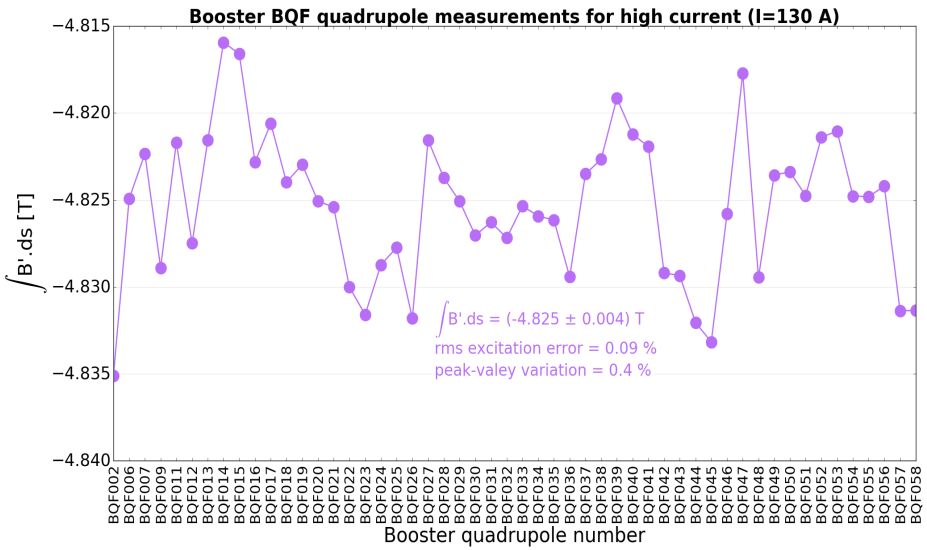
  (will not be available on Day-1, can be installed without breaking vacuum)

Booster quadrupoles magnetic measurements

Magnetic center and roll angle



Excitation



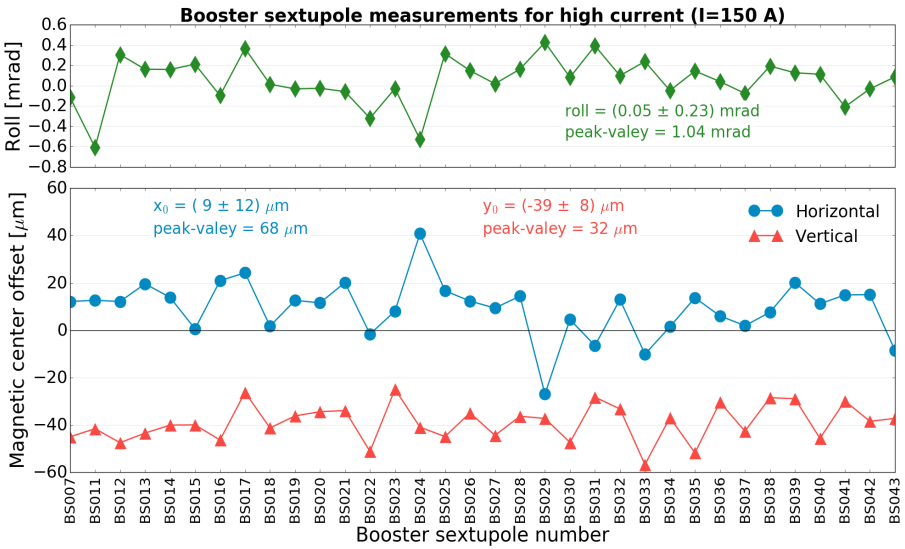
Booster quad. error measurements		
alignment, x	10 ± 14	μm
alignment, y	-25 ± 10	μm
roll	- 0.1 ± 0.09	mrad
excitation	0.01	%

Storage ring quad. error specs.		
alignment	40	μm
roll	0.3	mrad
excitation	0.05	%

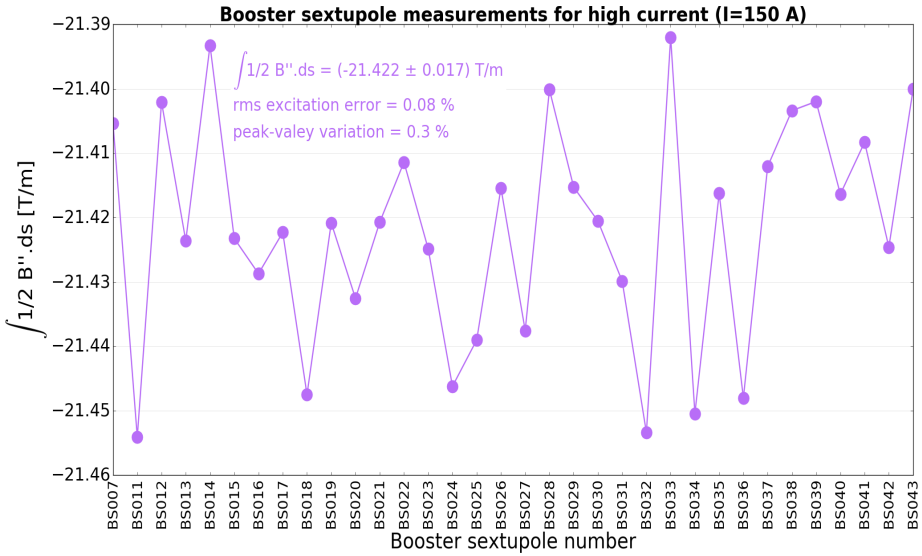
Measurements confirm good quality of Booster quads: they satisfy requirements for SR quads.

Booster sextupoles magnetic measurements

Magnetic center and roll angle



Excitation

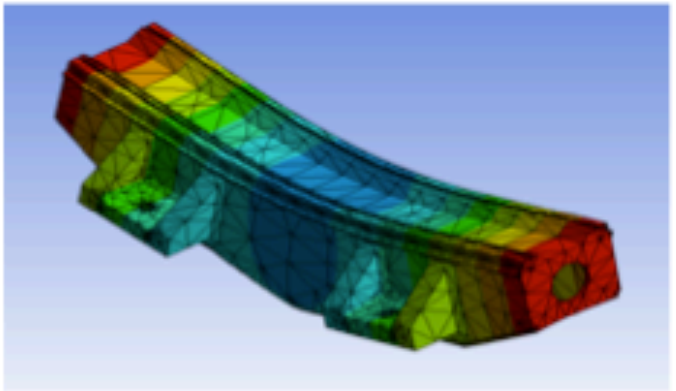


Booster sext. error measurements		
alignment, x	9 ± 12	μm
alignment, y	-39 ± 8	μm
roll	0.05 ± 0.23	mrad
excitation	0.08	%

Storage ring sext. error specs.		
alignment	40	μm
roll	0.3	mrad
excitation	0.05	%

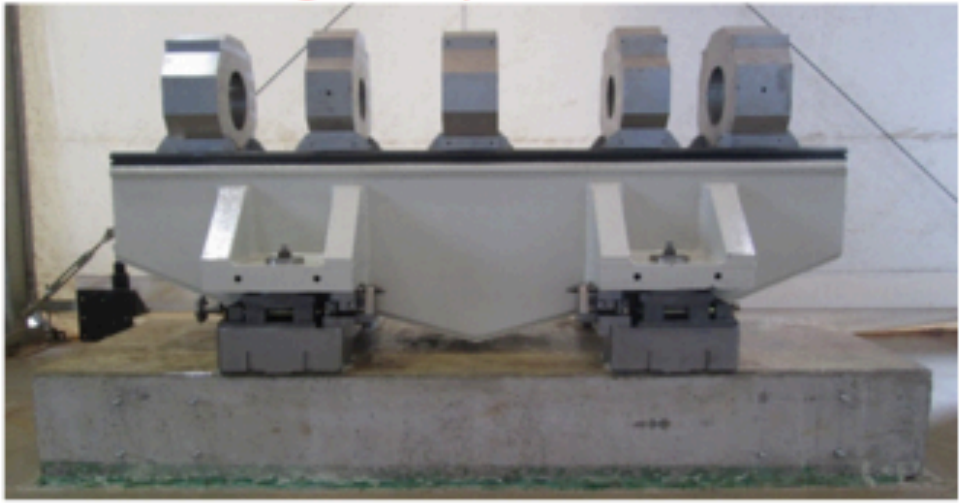
Final girder prototype

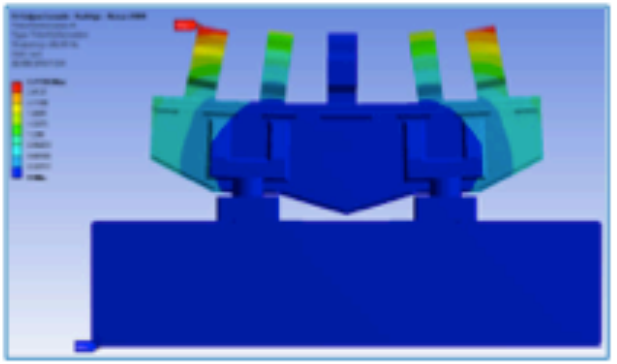
Welded girder

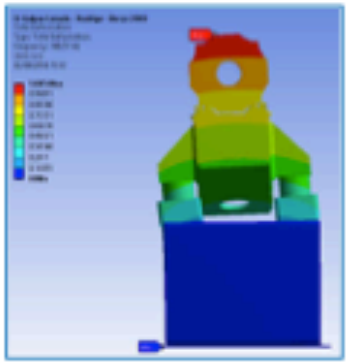


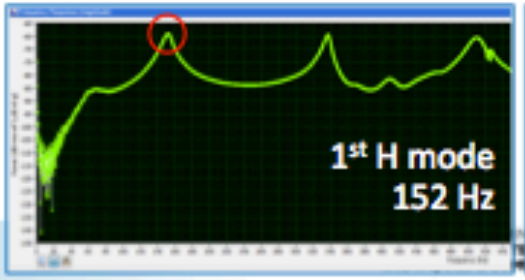
First mode frequency:
511 Hz (measured)
515 Hz (calculated)

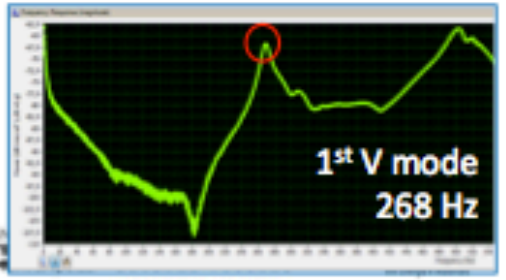
Integrated optimization



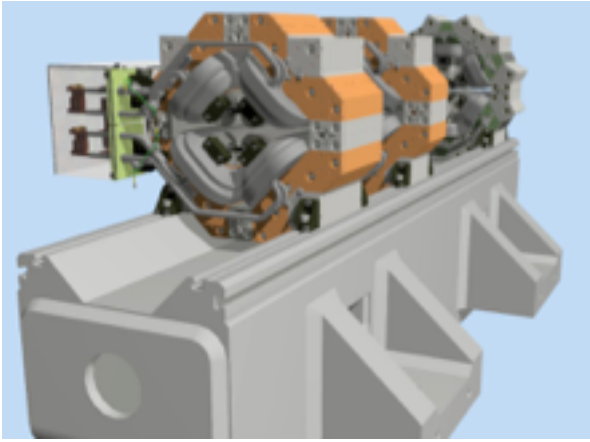


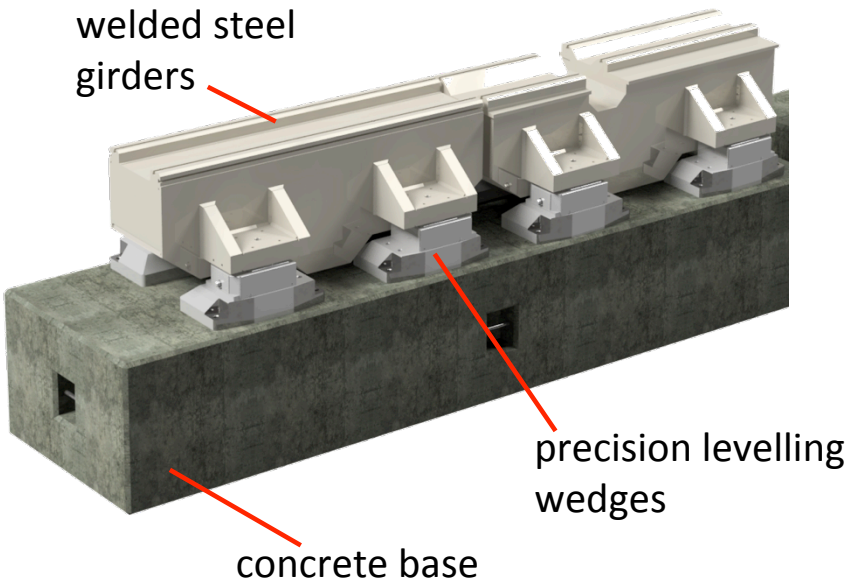






Magnet alignment and support system



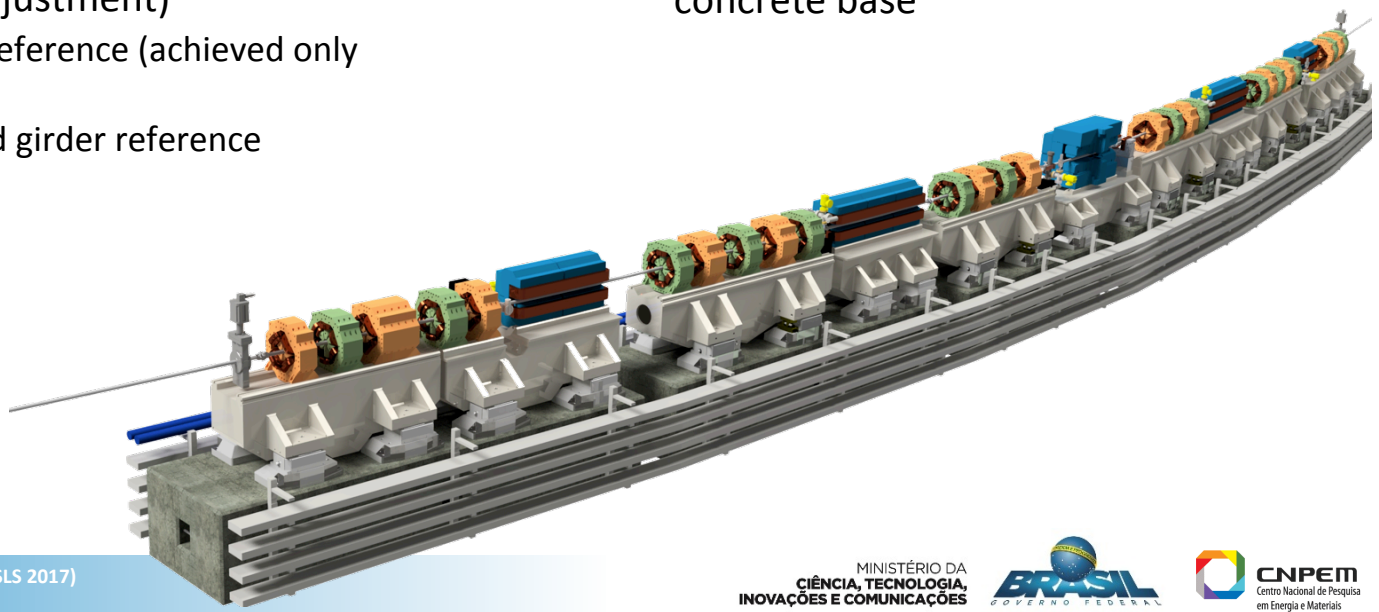


The magnets are positioned on the girder by reference surfaces (no adjustment)

- High precision magnet reference (achieved only by stacking laminations)
- High precision machined girder reference

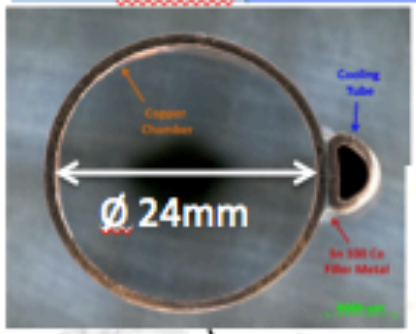
Integrated optimization

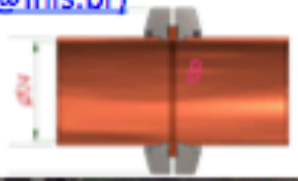
- Smaller magnets
- Lower center of mass
- Welded steel girders
- Special levelling wedges



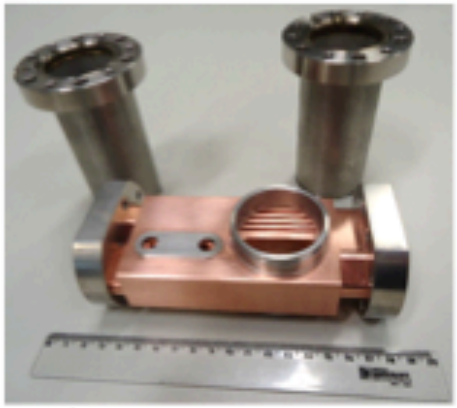
NEG coated SR copper vacuum chambers

Rafael Molena (rafael.molena@lnls.br)

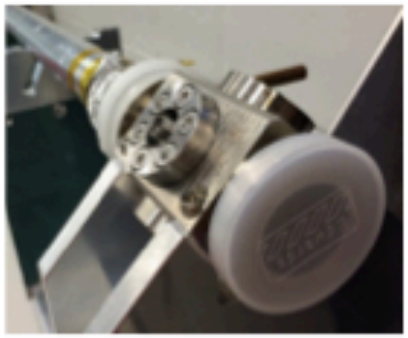




Low impedance flange
Zero gap copper seal



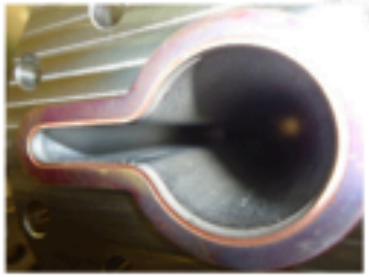
Pumping Station /
Crotch absorber



BPM

Bellows and Flanges
RF shielding

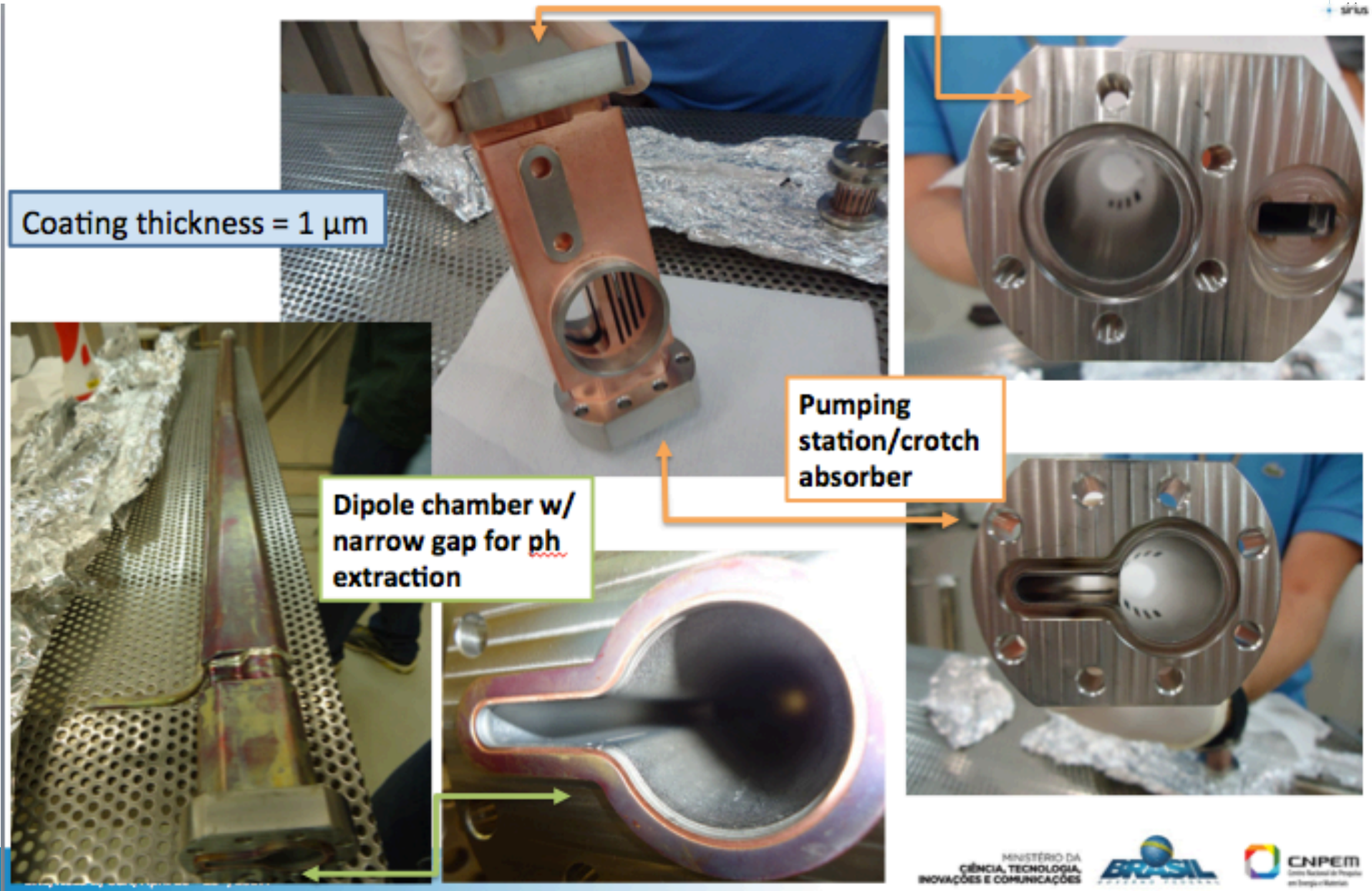
Dipole chamber with narrow gap (keyhole)
ID radiation extraction



NEG coating of narrow gaps

0.3 mm SS sector
For fast orbit correctors

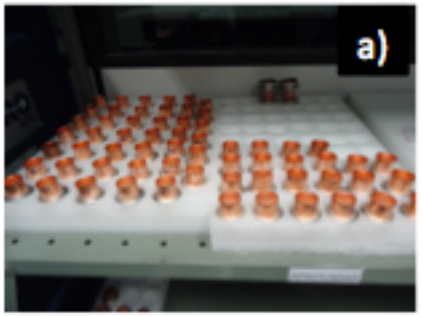
In-house NEG coating R&D – Results: narrow gap coating of real prototypes

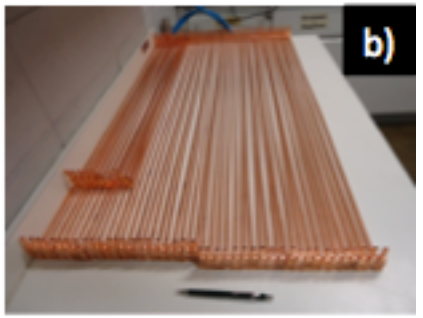


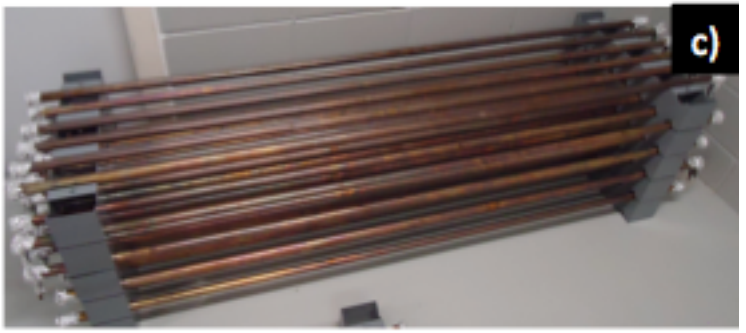
Vacuum System Status

Present Status:

a) Standard circular flanges are brazed;
b) Cooling tubes w/ special copper connectors are brazed;
c) Vacuum chambers for straight sections (between RF shielded valves) are NEG coated;
d) 80% of copper tubes are machined, pre-cleaned and ready for welding;
e) Chromatic chambers are being NEG coated (we can coat 18 meters of chambers per run);
f) 2nd revised design of pumping station/crotch absorber is being prototyped;

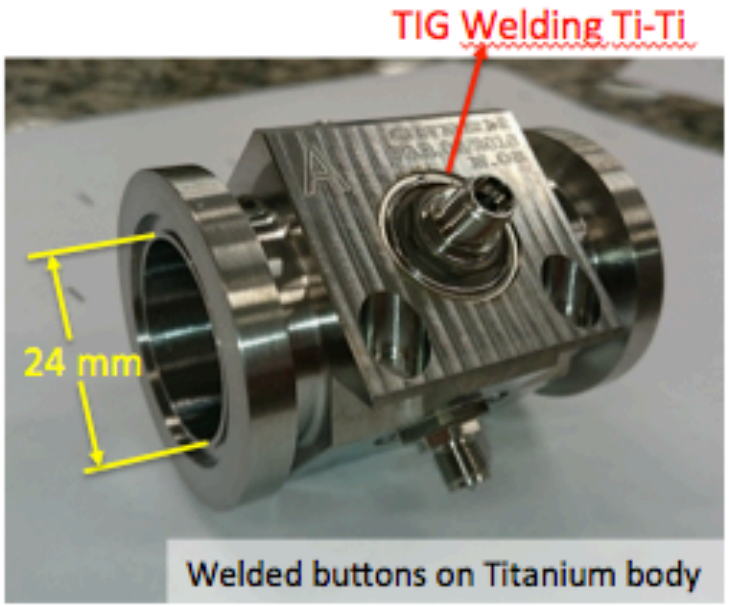


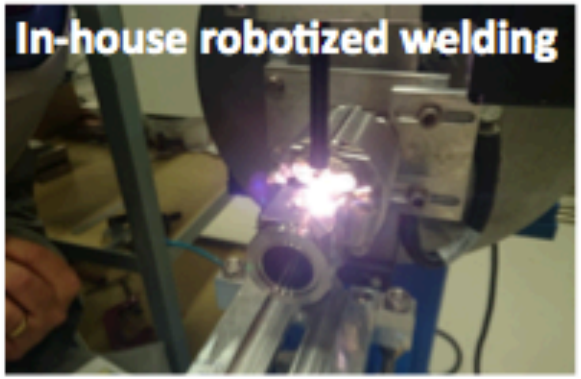


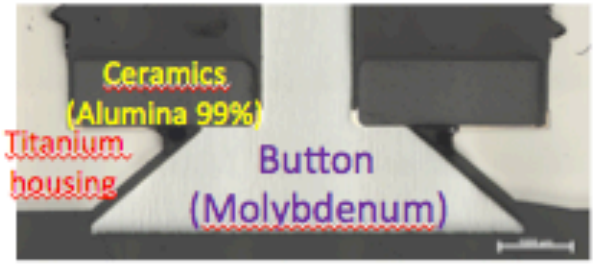


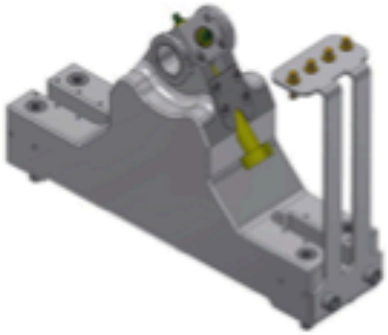
Activity	Finalization
Booster stainless steel chambers	10/2017
NEG deposition of chromatic chambers	06/2017
NEG deposition of dipole and special chambers	01/2018
Start of vacuum chambers assembly	02/2018

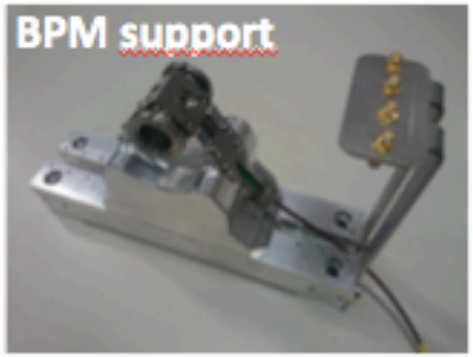
Sirius BPMs





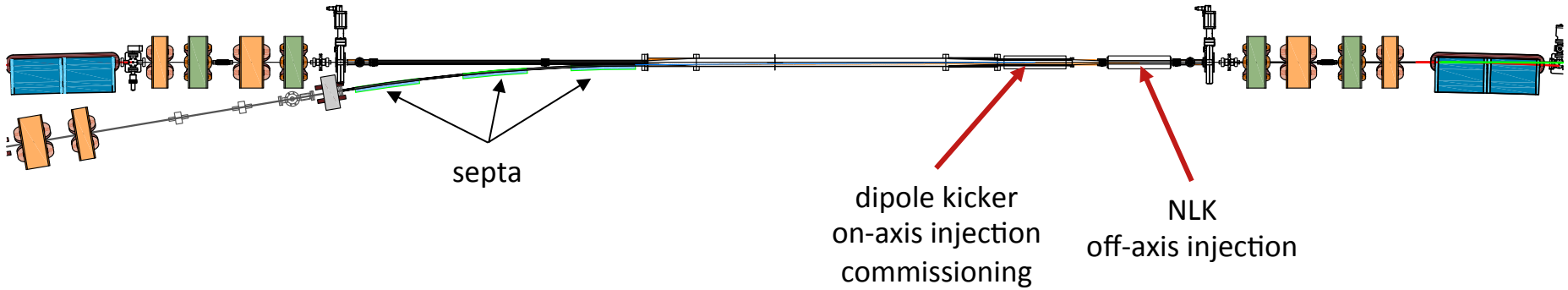


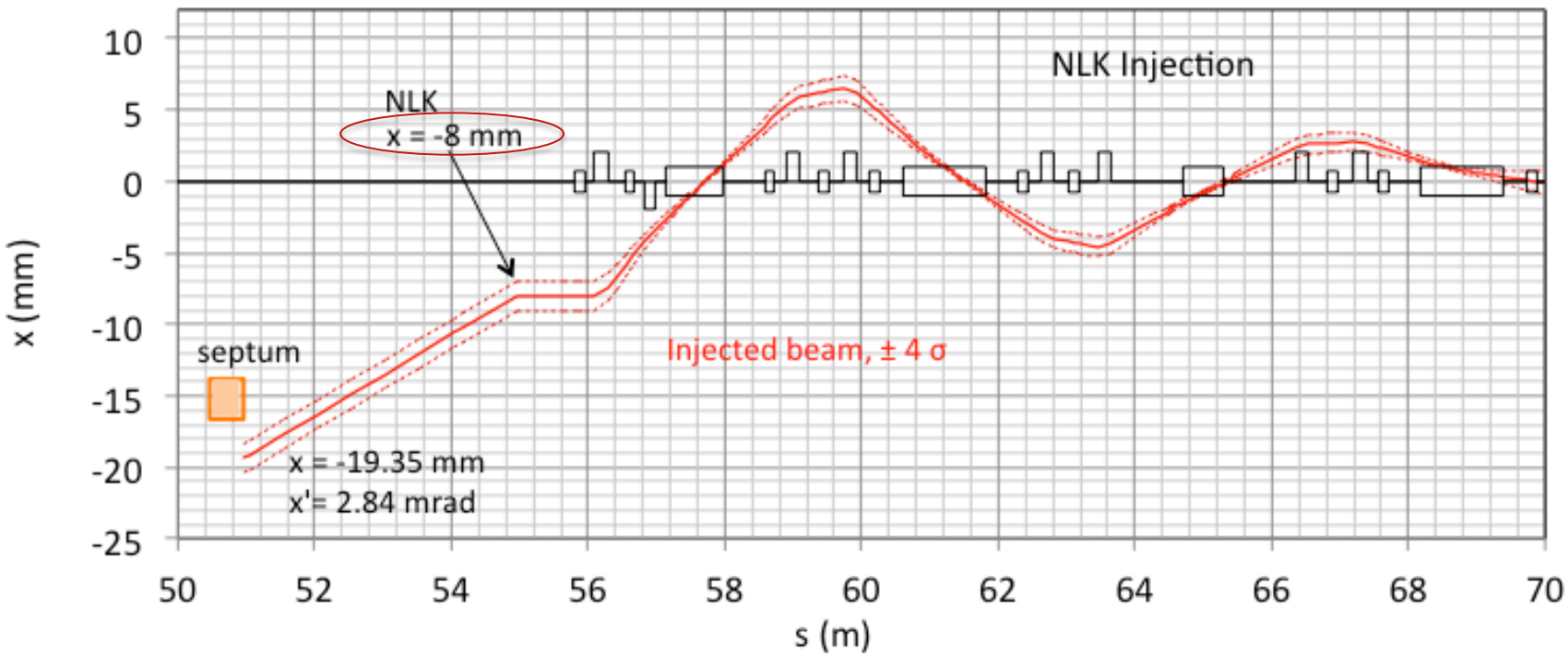




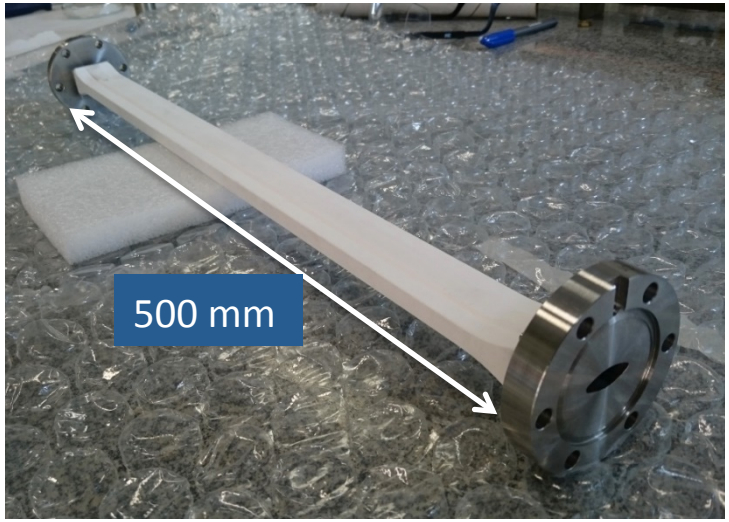
- 160 BPMs – under production
  - All BPM parts contracted to Brazilian industry
  - In-house button assembly and brazing
  - In-house welding of buttons to the BPM body

Non Linear Kicker injection

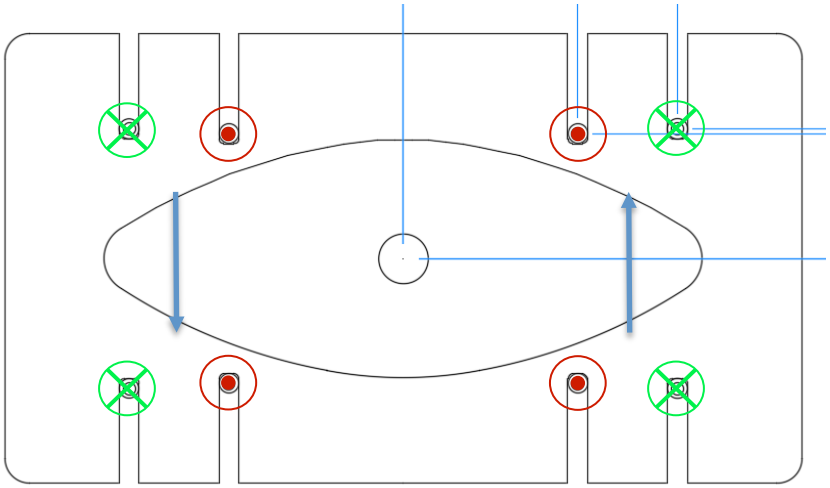




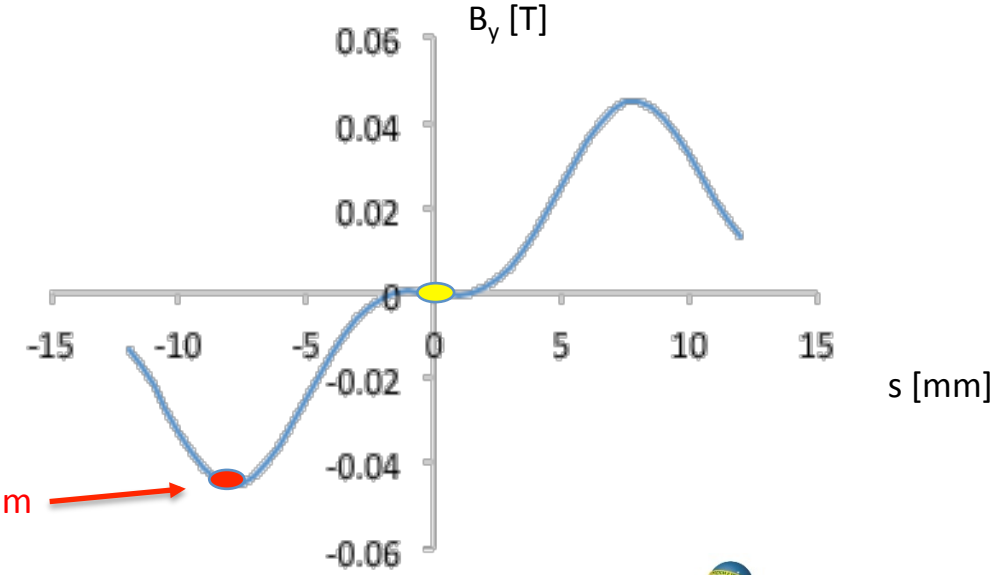
Non Linear Kicker ceramic chamber



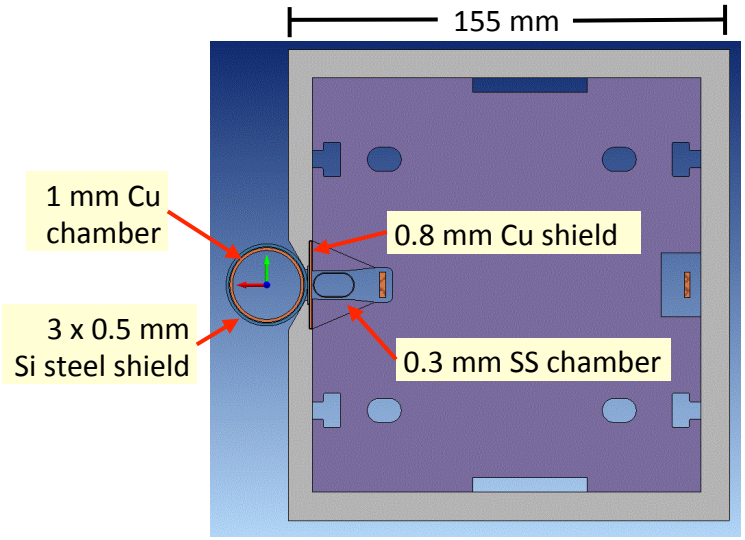
First prototype with flanges

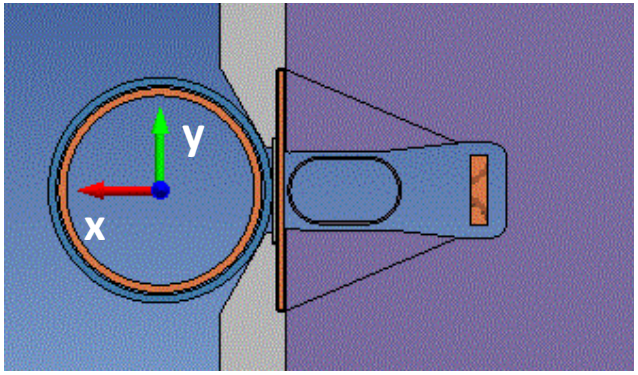


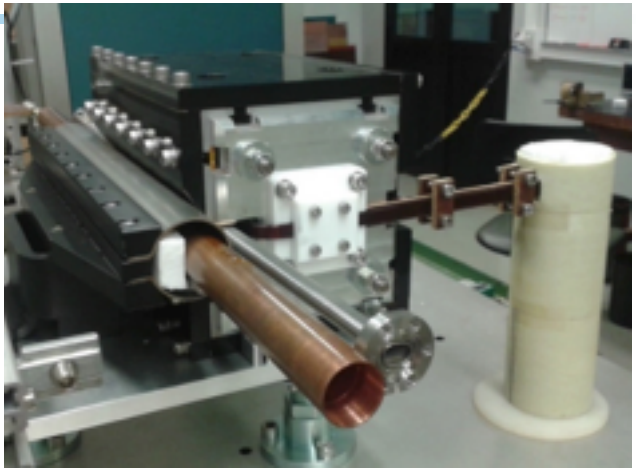
Field @ peak	800 Gauss
Current	1600 A
Voltage	900 V
Pulse width	3.4 µs

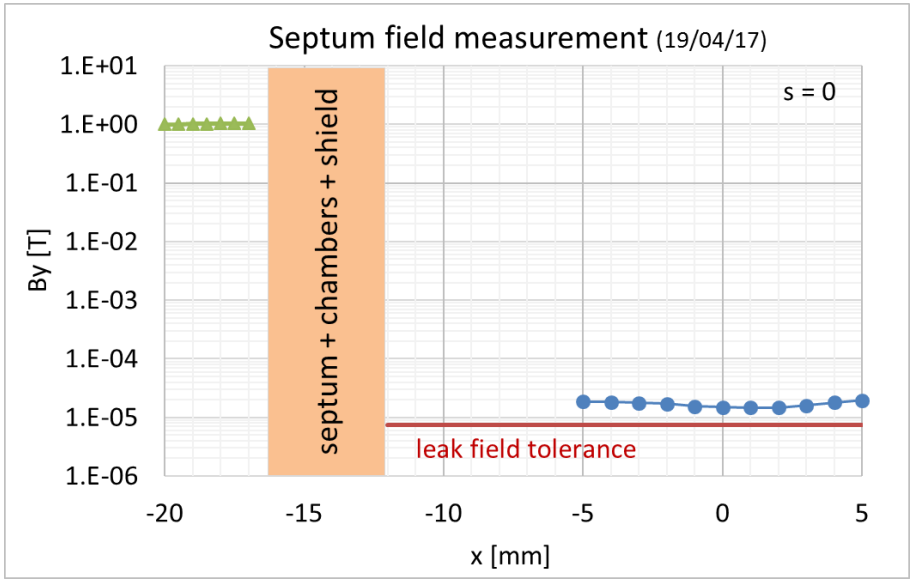


Septum prototype measurements









The septum still needs a fator 2 improvement in the leak field. A modification in the Si steel shield is underway.

Conclusions

- Project is on schedule and on budget
  - > 80% in-house developments and transfer to local industries.
  - Accelerator parts are under production.
  - Special care was put on stability issues at all stages, from the ground, to the tunnel, to concrete bases, leveling wedges, girders, magnets, BPMs, vacuum and diagnostics systems components.
  - Strong interaction between beamline scientists and machine people.

- Despite current difficulties in Brazil, the Sirius project is considered a top priority for the Science Ministry