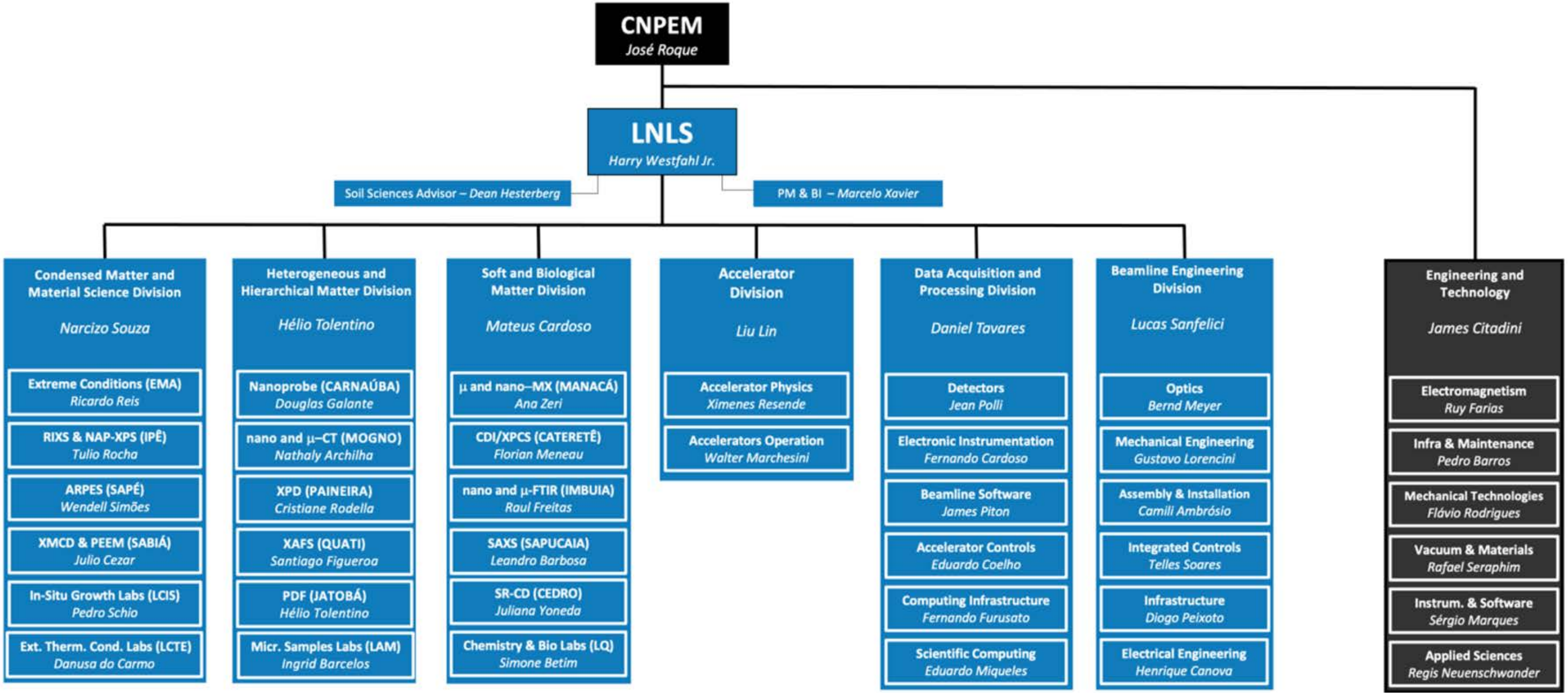
The Present and Future of the LNLS User Program on Sirius

Harry Westfahl Jr. – LNLS/CNPEM

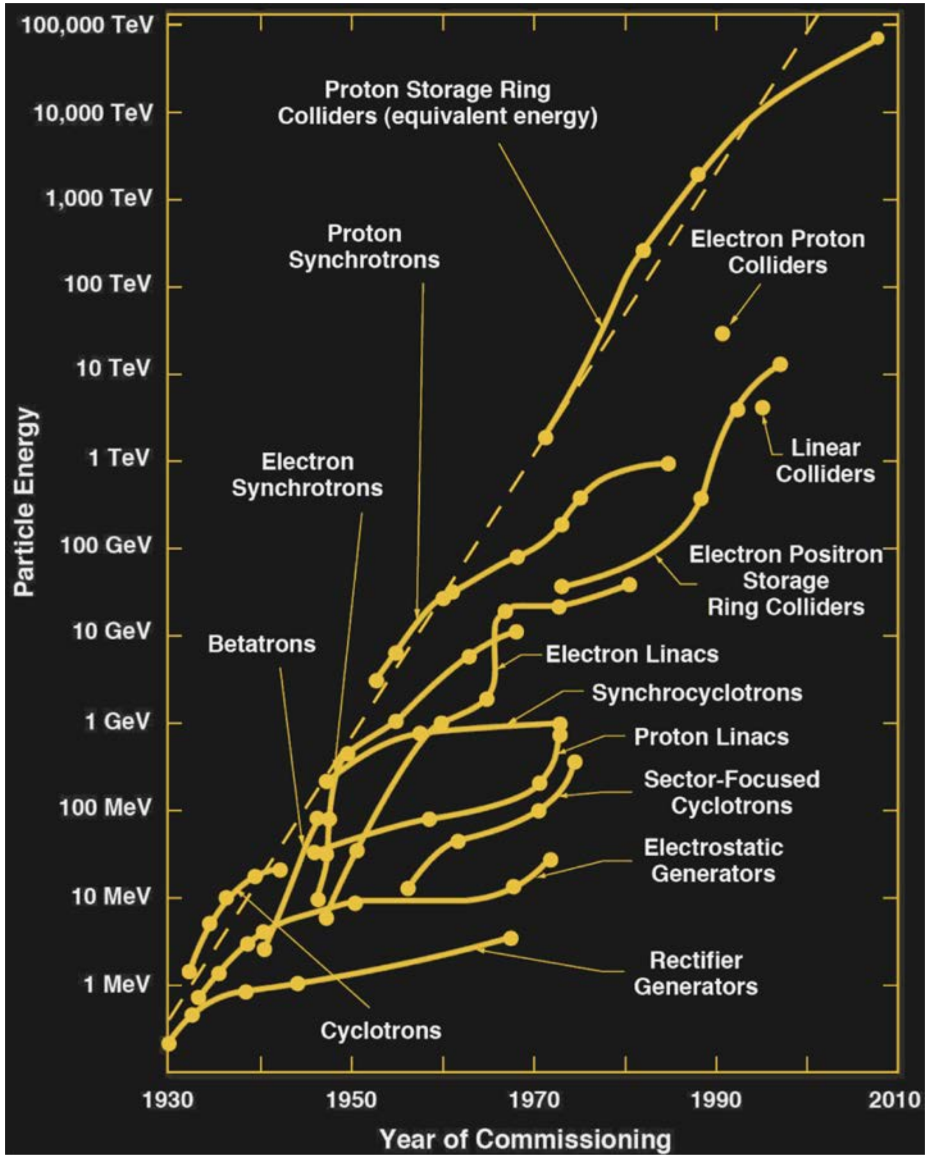
LNLS Organization Chart



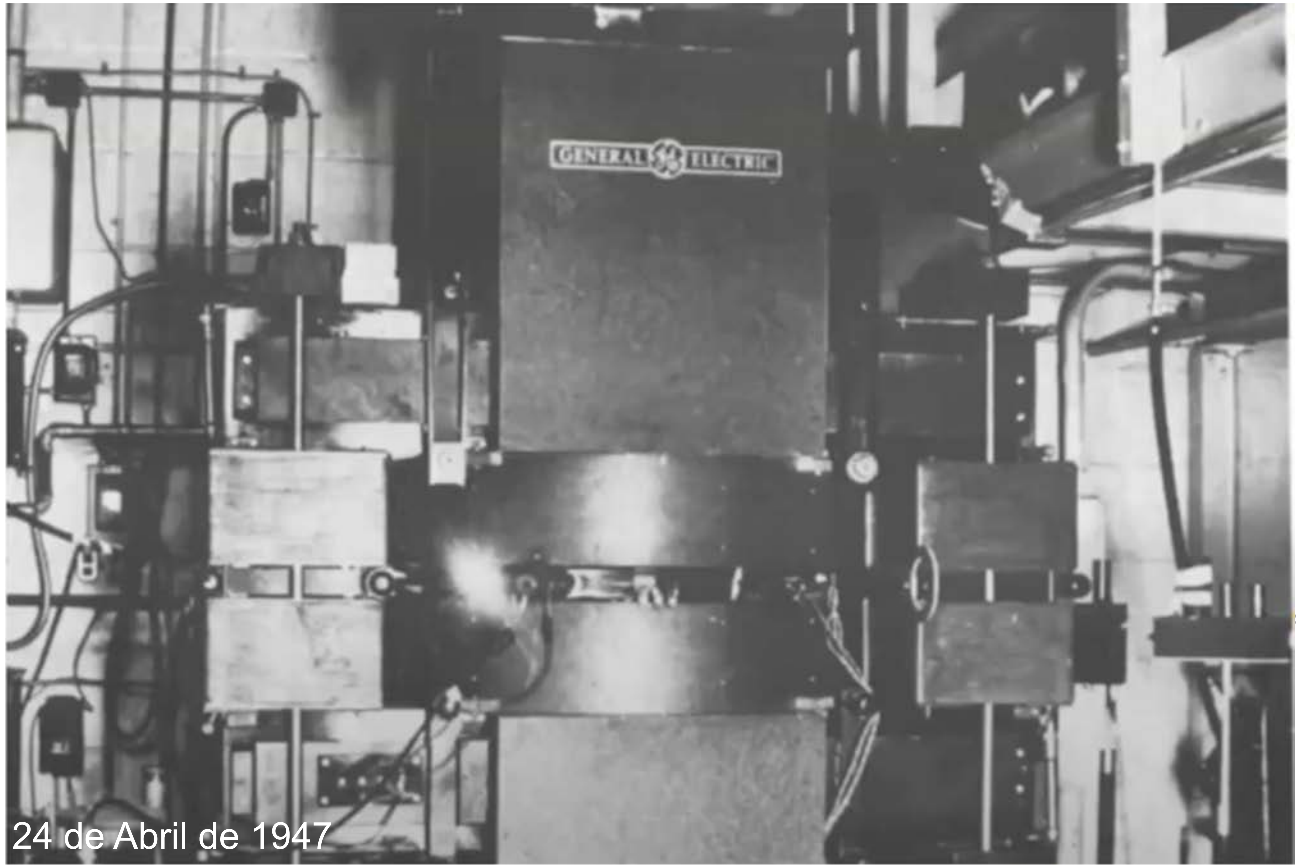
Synchrotron History

How did we get here?

Evolution of Particle Accelerator Energy

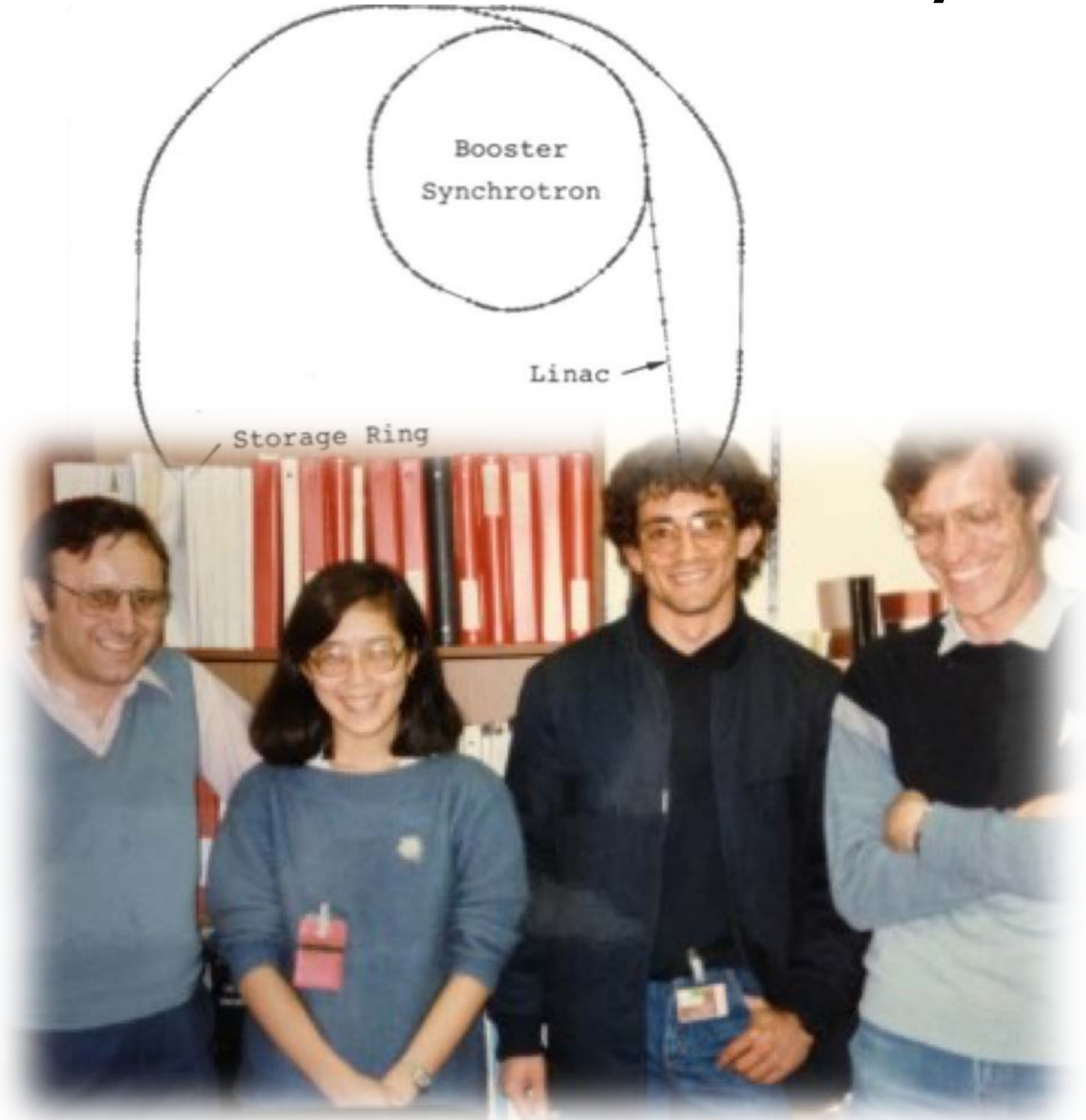


First observation of Synchrotron Light
(70 Mev Synchrotron at GE) – 75 anos



From https://hackaday.com/2020/07/29/smashing-the-atom-a-brief-history-of-particle-accelerators/livingston-2/

The birth of synchrotron science in Brazil

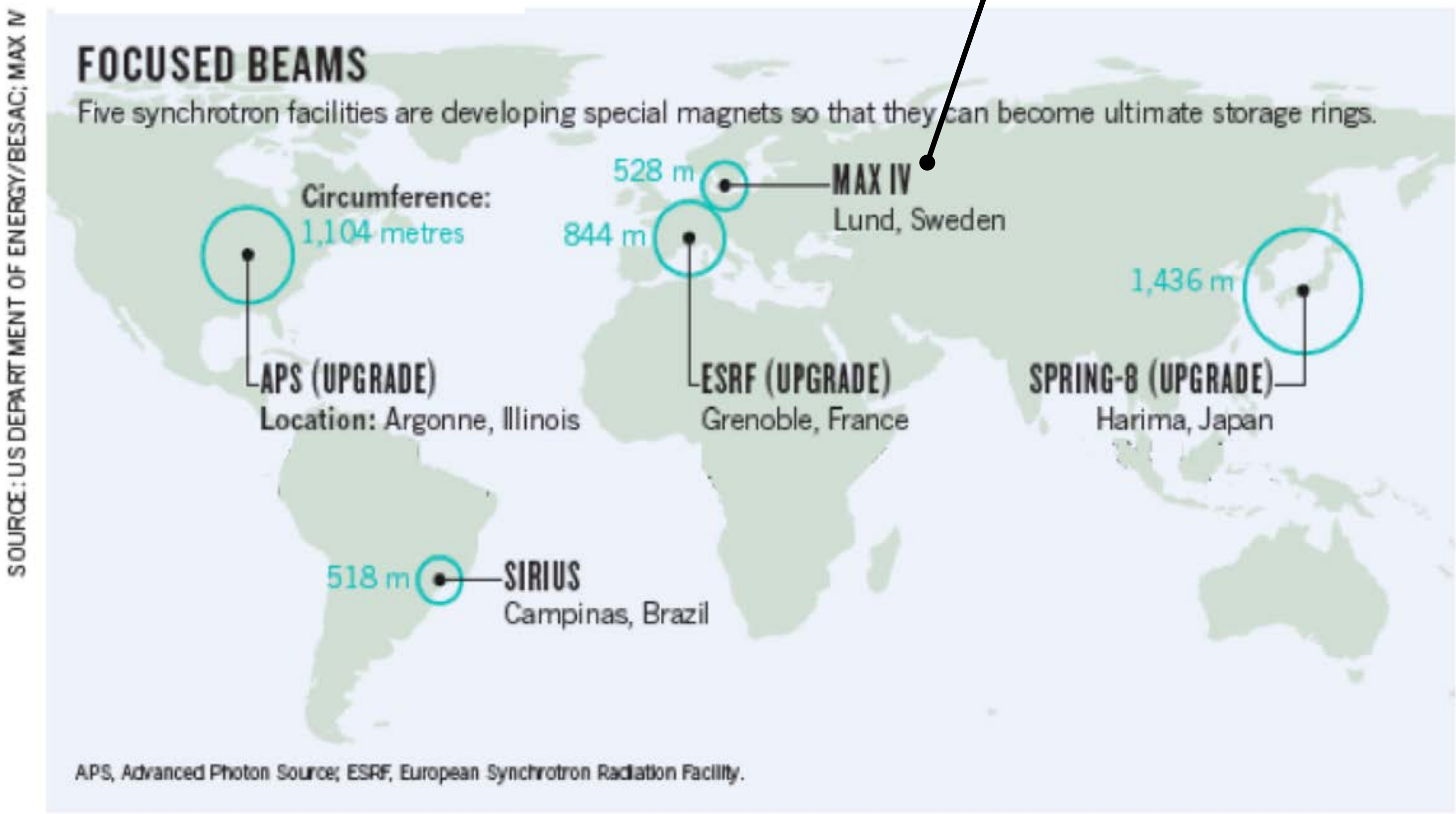


Helmut Wiedemann, Liu Lin, Hélio Tolentino and Ricardo Rodrigues

Ricardo Rodrigues, Ruy Farias e Cylon Gonçalves da Silva, Pedro Tavares, Liu Lin, Lúcia Jahnel, Aldo Craeivich, Fernando da Silva Rafael e Carlos Scorzato

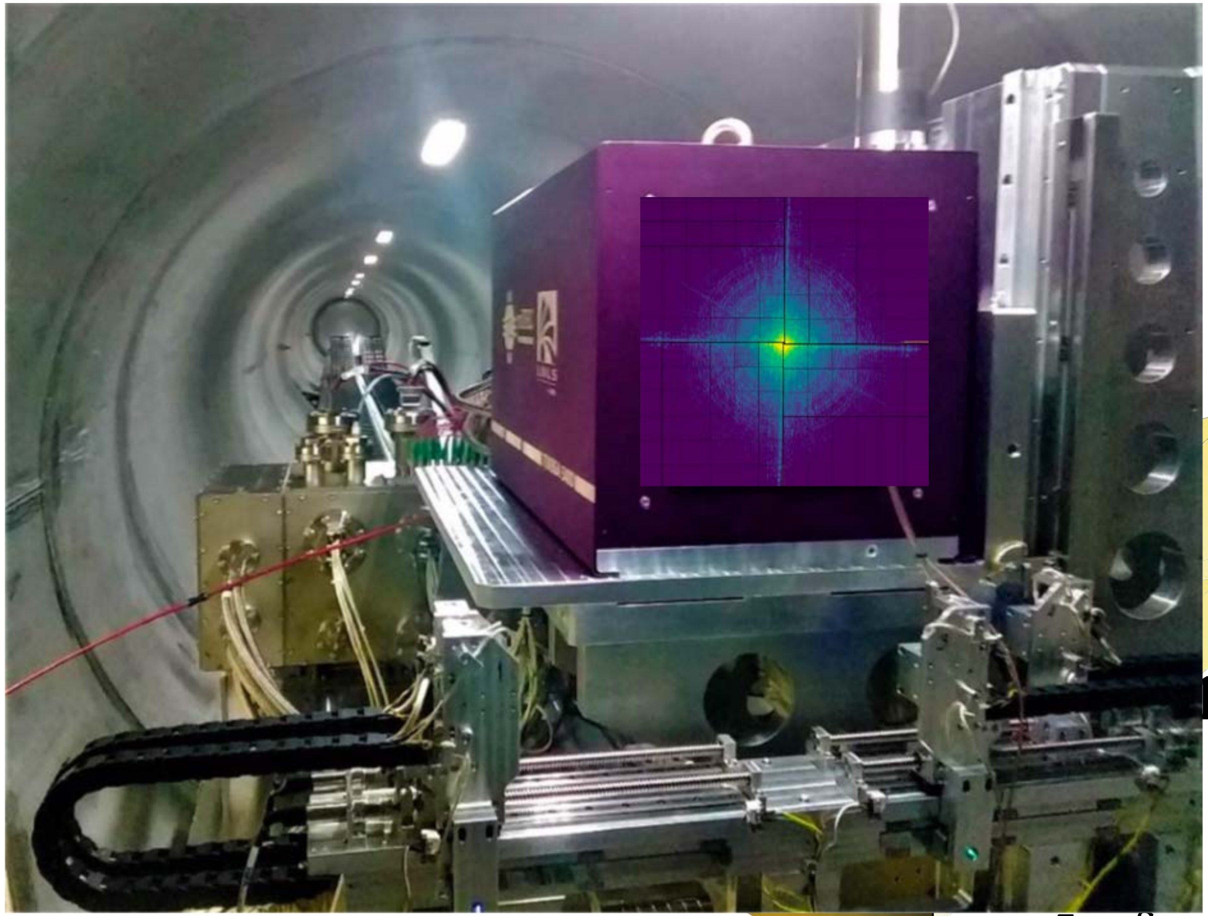
2016 - 1st MBA synchrotron – 4G / DLSR

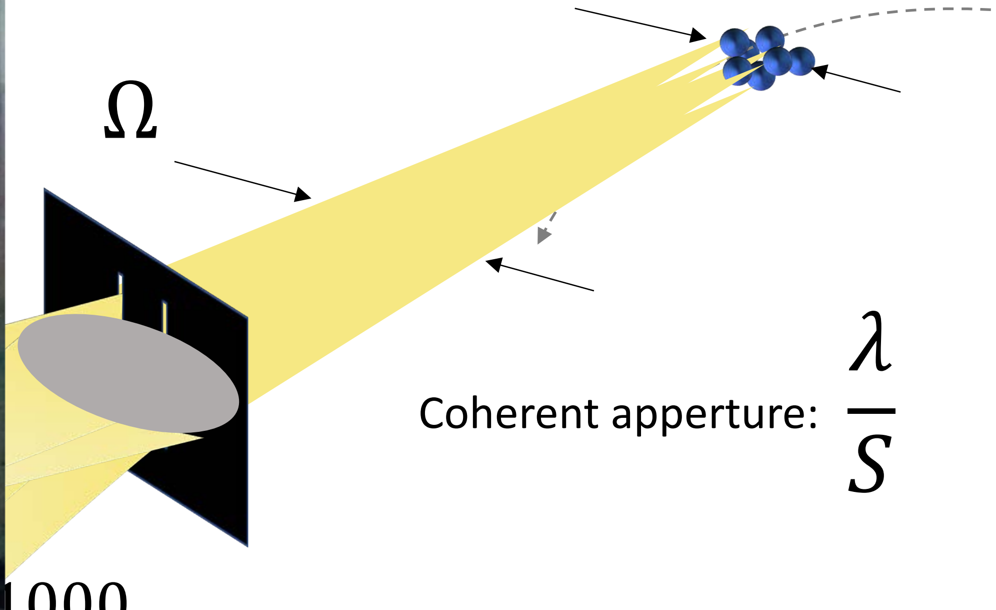
nature



12 SEPTEMBER 2013 | VOL 501 | NATURE | 149

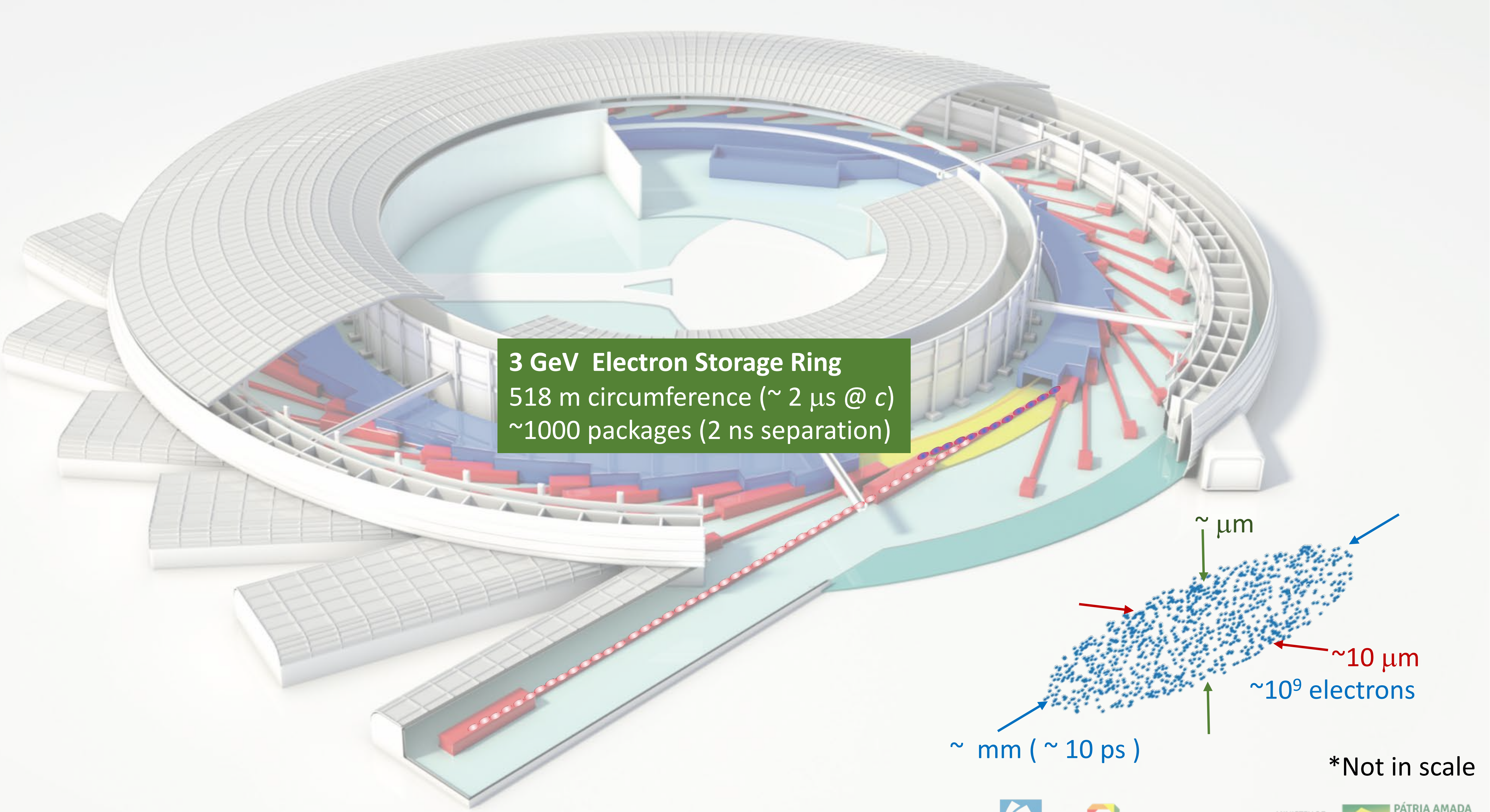
Source size (electron beam) is key. The smaller the better!





For $\delta \sim nm\,, S \sim \mu m$

πMEGA: 144 Medipix 3RX chips
Hexa Si sensors
1000 fps @ 24 bits
(with πtec)


3 GeV Electron Storage Ring
518 m circumference (~ 2 μs @ *c*)
~1000 packages (2 ns separation)
~ μm
~10 μm
~10⁹ electrons
~ mm (~ 10 ps)
*Not in scale


October 2018


sirius
ACELERANDO
O FUTURO
DA CIÊNCIA

2018 to 2021

MANACA - first publication

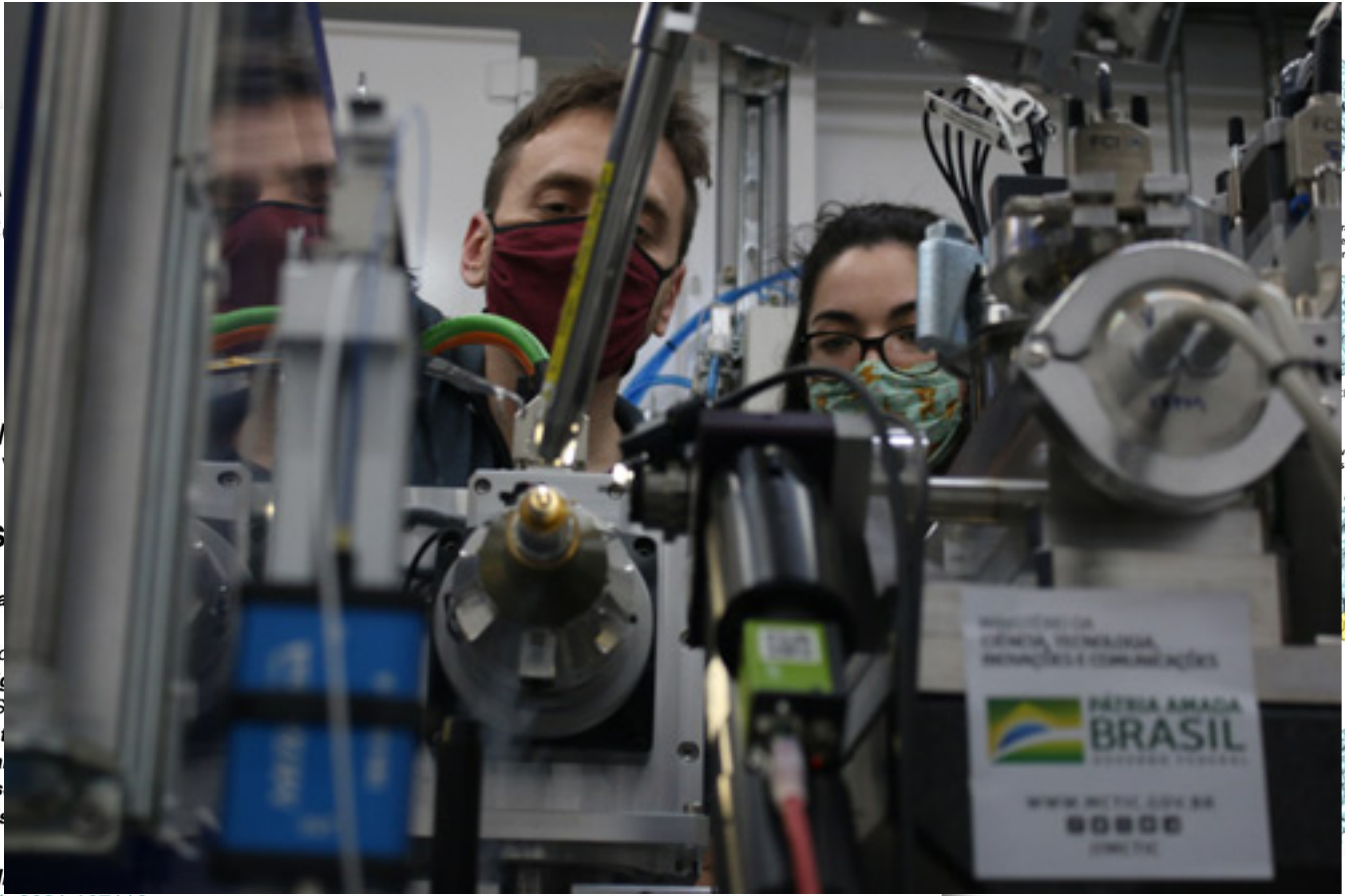
A
C

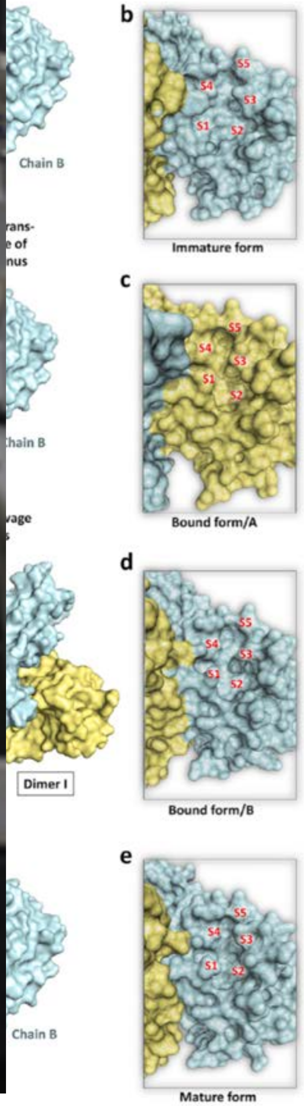
G. D. Noske [1‡], A. M
G. M. A. Lima [2†], H.
M. C. L. C. Freire [1],
G. Oliva [1*] and A. S

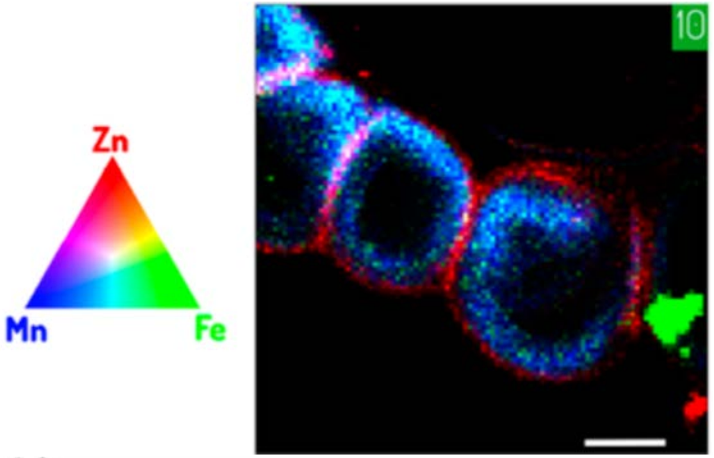
1 - Institute of Physics of Sa
Carlos 13563-120, Brazil
2 - BioMAX, MAX IV Laborat
3 - Brazilian Synchrotron Lig
Code 13083-970 Campinas, S
4 - Diamond Light Source Lt
5 - Research Complex at Ha
6 - Centre for Medicines Dis
7 - Department of Biochemis

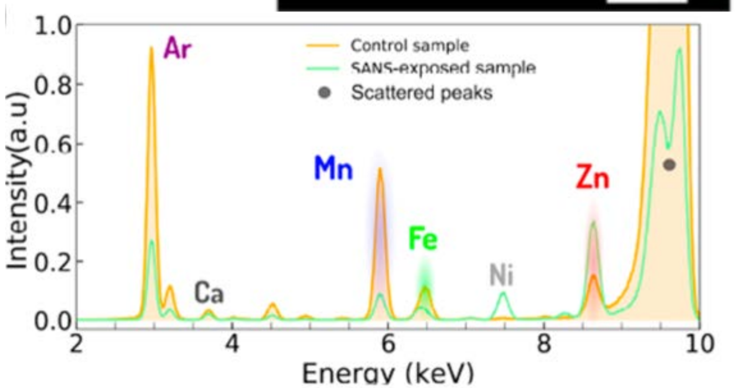
Correspondence to G. Ol

https://doi.org/10.1016/j.jmb.2021.167118
Edited by Eric O. Freed









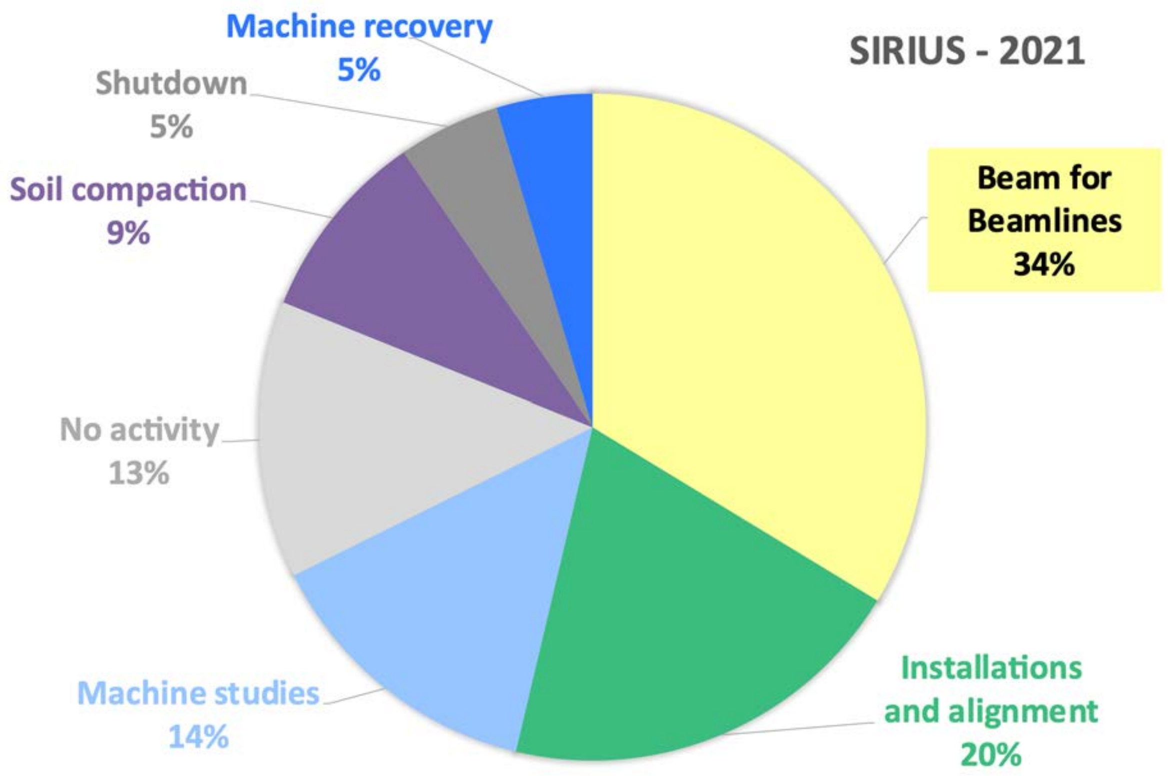
Julia A. Barbosa et al. ACS Appl. Mater. Interfaces 2022

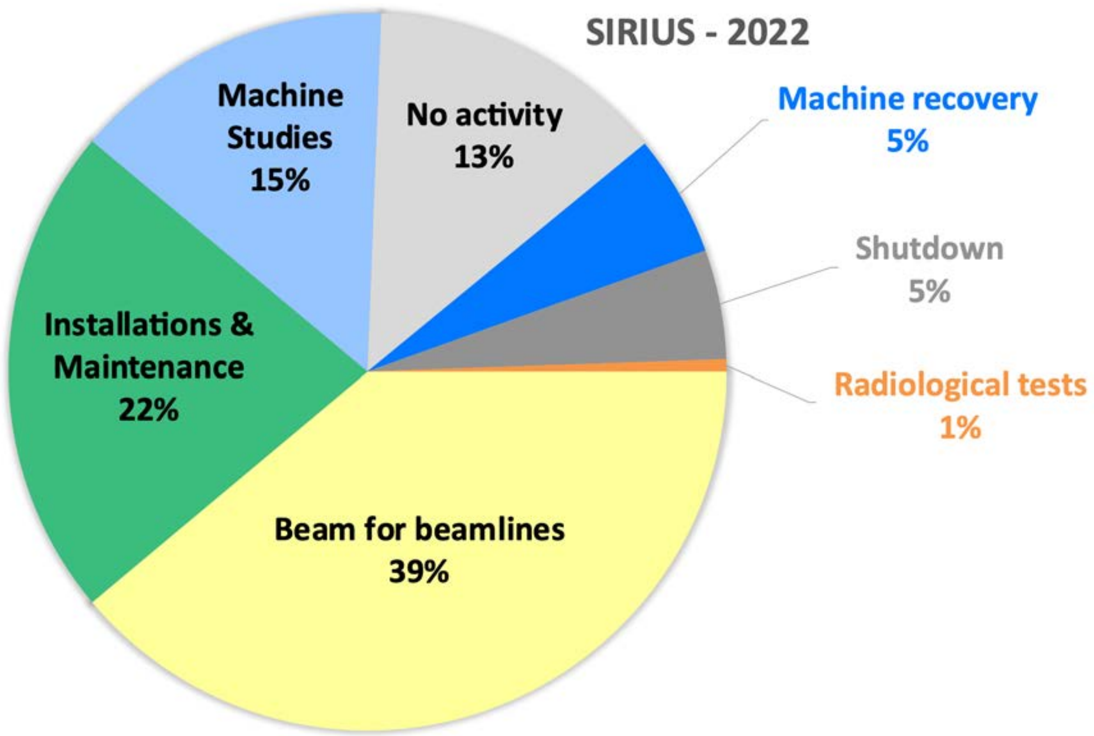
courtesy of Helio Tolentino

Beamline and Accelerator Commissioning

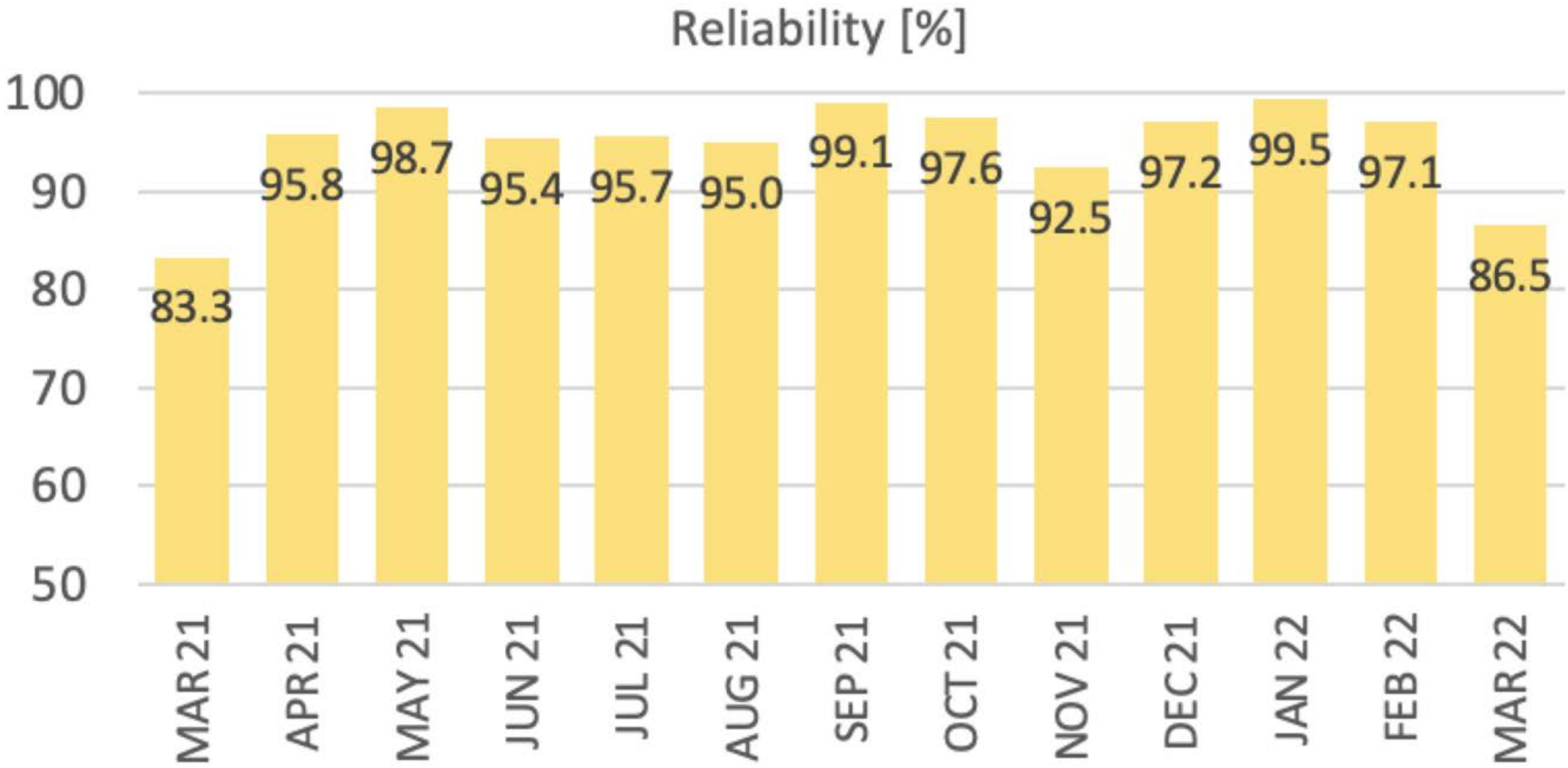
Restarting the User Science Program

Operation


SIRIUS - 2021
Machine recovery
5%
Shutdown
5%
Soil compaction
9%
No activity
13%
Machine studies
14%
Installations
and alignment
20%
Beam for
Beamlines
34%


SIRIUS - 2022
Machine
Studies
15%
No activity
13%
Machine recovery
5%
Shutdown
5%
Radiological tests
1%
Installations &
Maintenance
22%
Beam for beamlines
39%

Reliability



Beamline Scientific Commissioning with user proposals

Beamline	# proposals in 2021	# proposals 2022 (until today)
MANACÁ	36	13
IMBUIA	14 (micro) / 5 (nano)	08 (micro) / 04 (nano)
CATERETÊ	-	07
CARNAÚBA	22	24
EMA	03	11
TOTAL	**80**	**67** ⇢ **100 (Goal for 2022)**

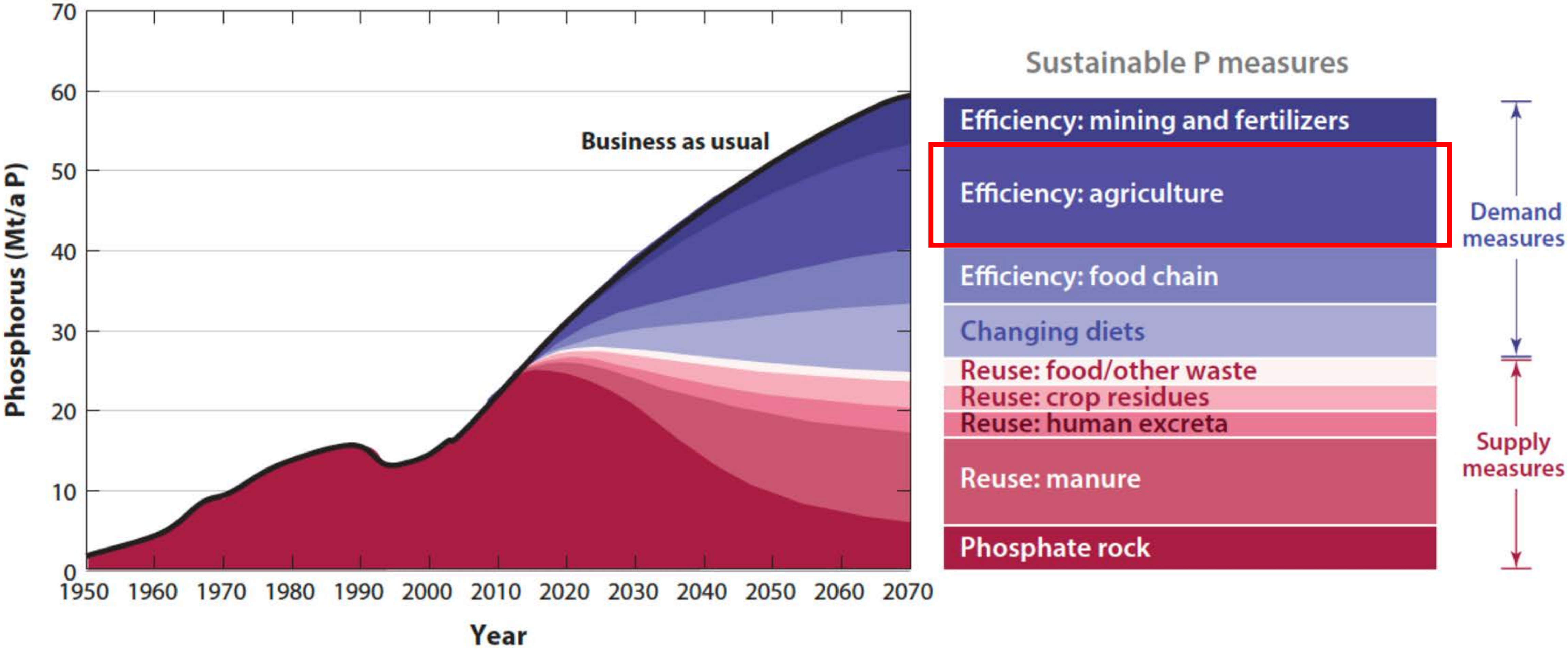
Sirius Science

Scientific Commissioning Examples

Soil Sciences and Agriculture

Where is our soil phosphate?

Phosphorus demand for food security rising

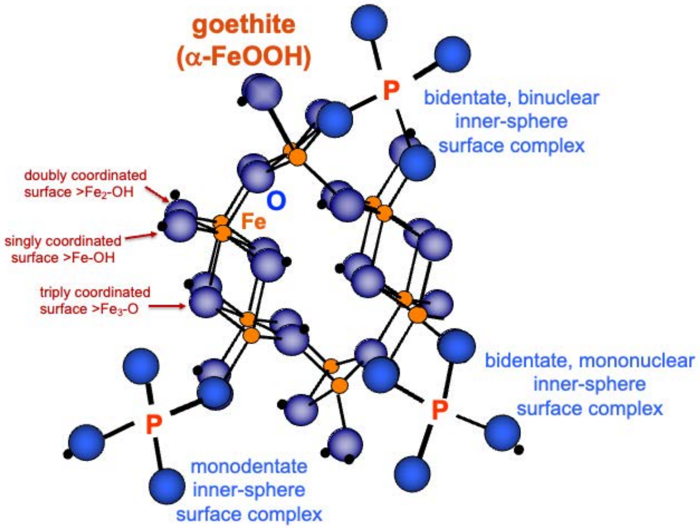


Cordell and White, 2014. Ann. Rev. Environ. Resour.

Bayveye, 2015. Rev. Brasil Cien. Solo. 39:637

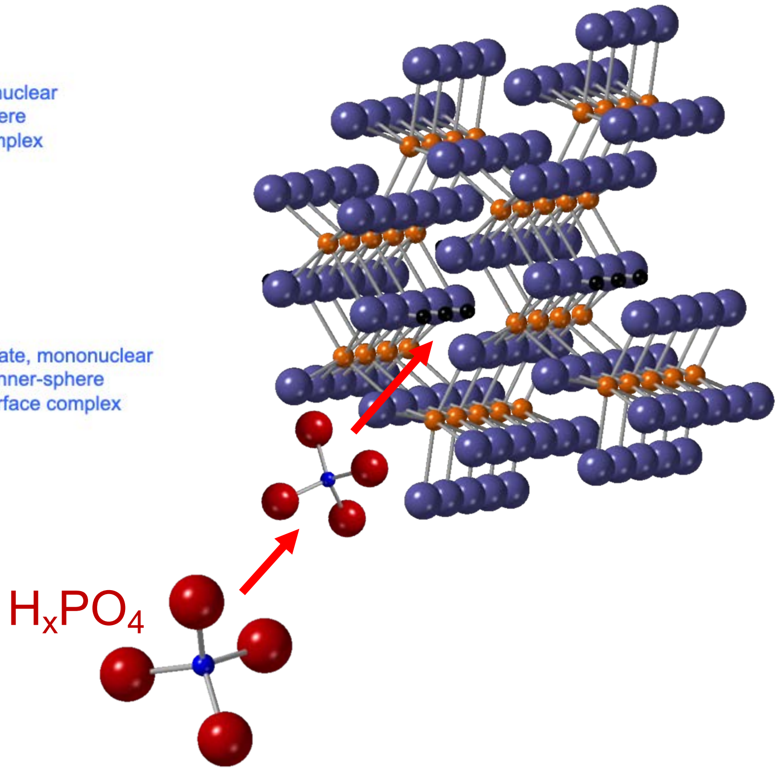
Hypothesis for Phosphate "fixation"

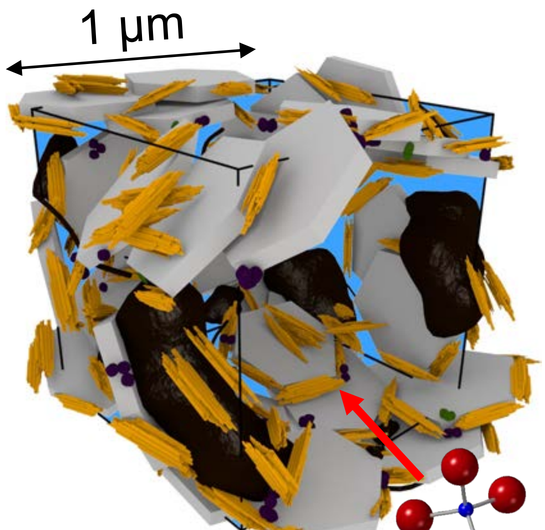
"central dogma"



drawing from Hesterberg, Ferreira, Bordonal, Souza-Filho. Topics in Soil Science XI, SBCS (in press)

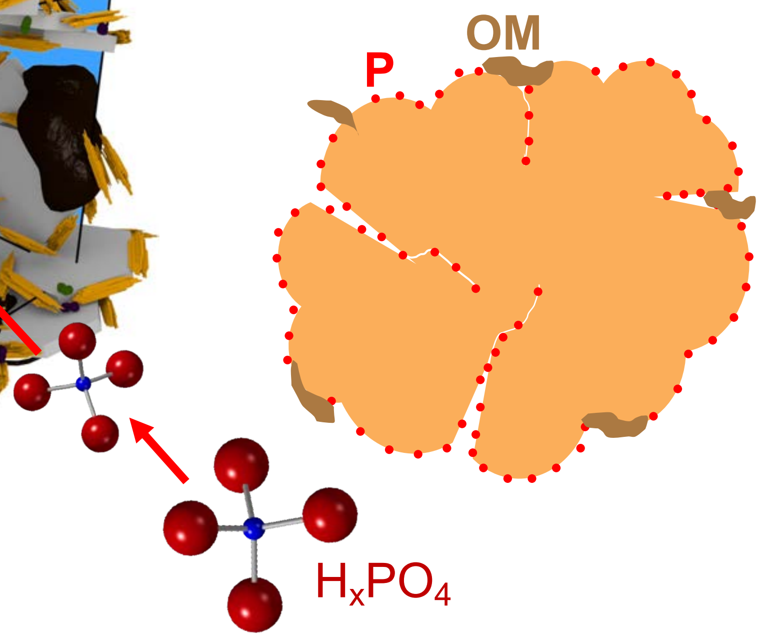
Barrow et al. 2021. Plant Soil. 459:1





Drawing by Derek Elliot

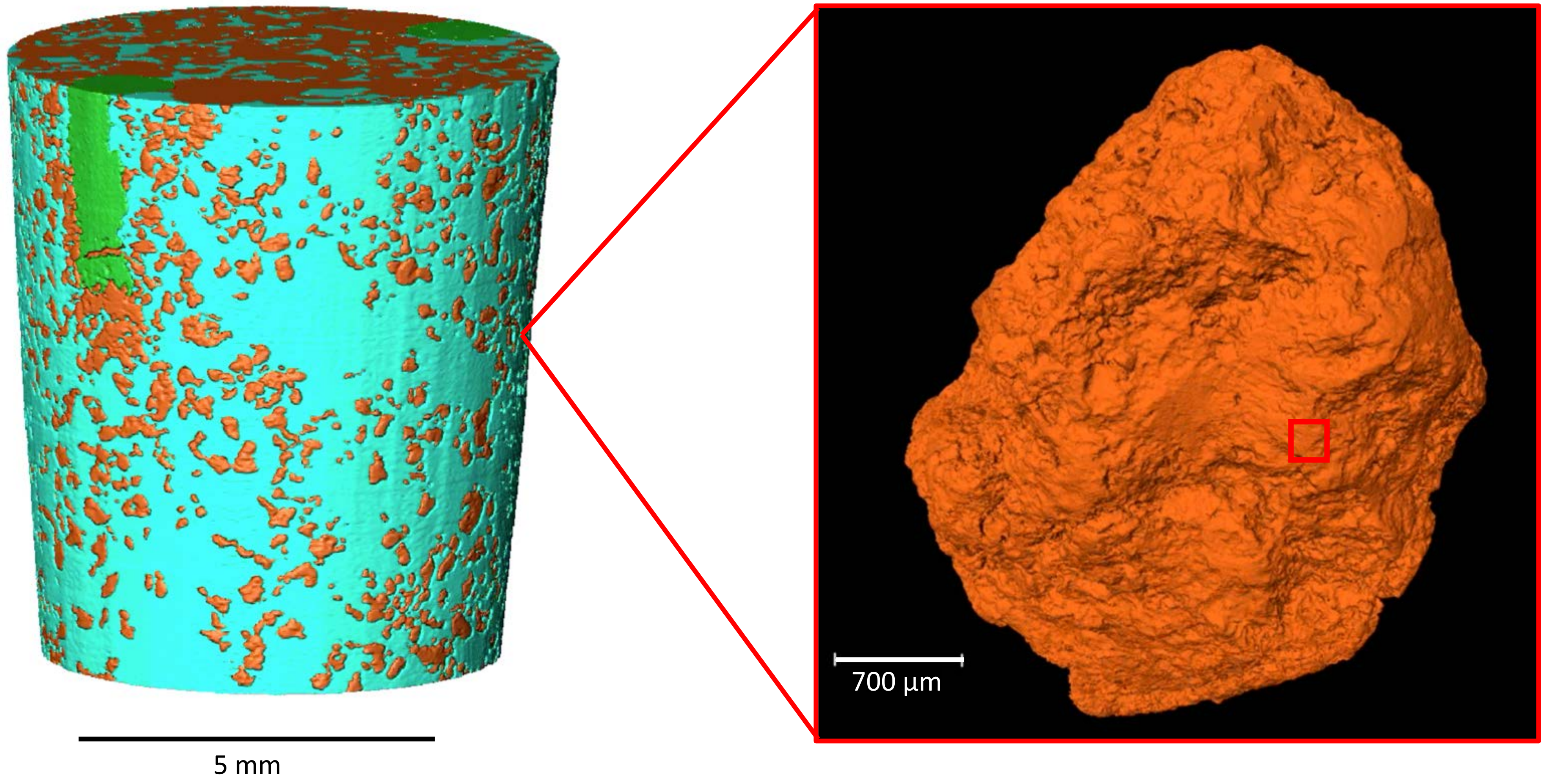
Smolders, Vermeiren et al. 2021.
(Goldschmidt 2021 keynote)



Courtesy: Dean Hesterberg

3D Imaging from plant roots and soil agregates

@MOGNO

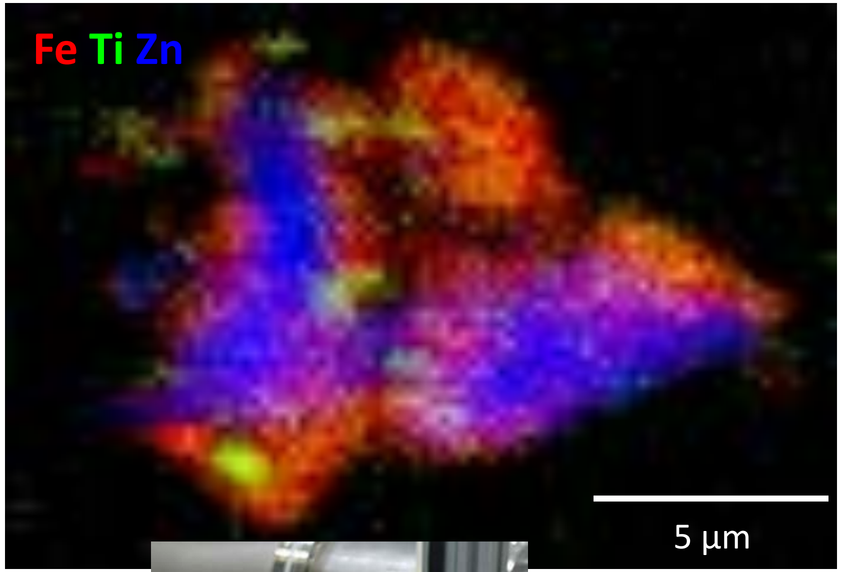


courtesy of Talita Ferreira

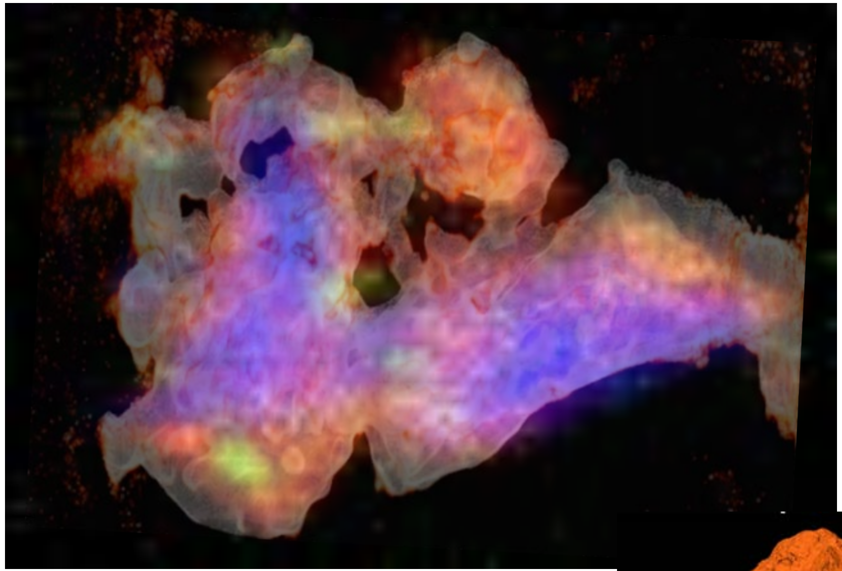
Integrating data on **micro**agregates

@ CARNAÚBA & CATERETÊ

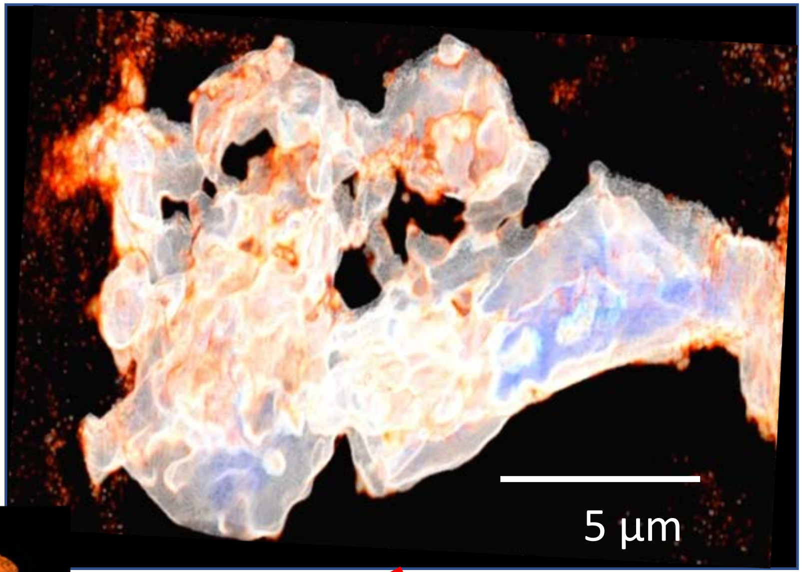
Chemical Image (μ-XRF)
CARNAÚBA

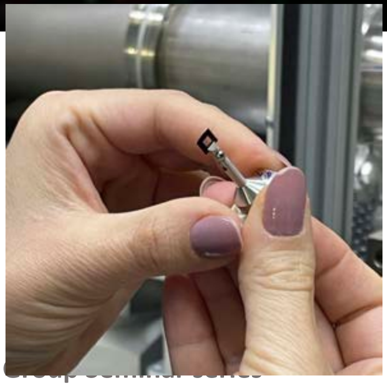


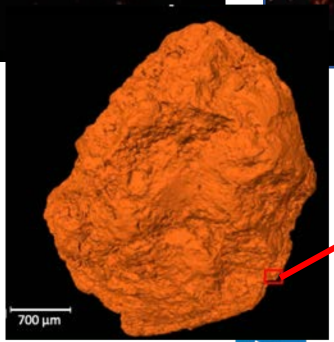
Overlay
CATERETÊ & CARNAÚBA



Diffraction image
CATERETÊ





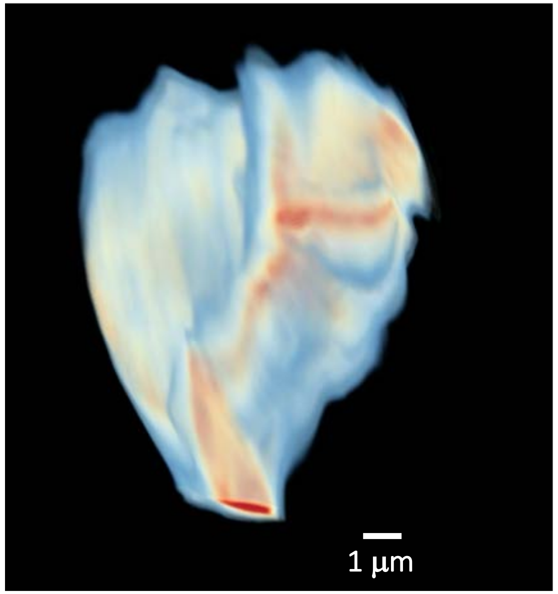


courtesy of Dean Hesterberg

Soil Microorganisms & Enzimes

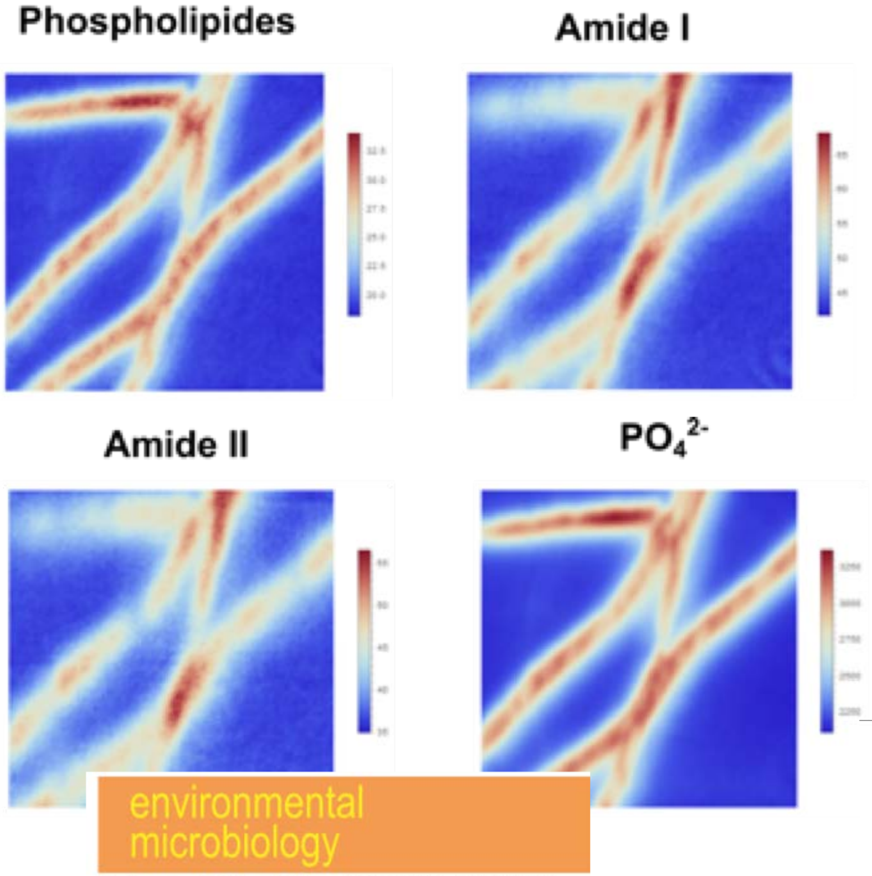
Soil Microagregate w/ Microorganism (?) @CATERETÊ

courtesy of Dean Hesterberg



Fungal IR image @ IMBUIA

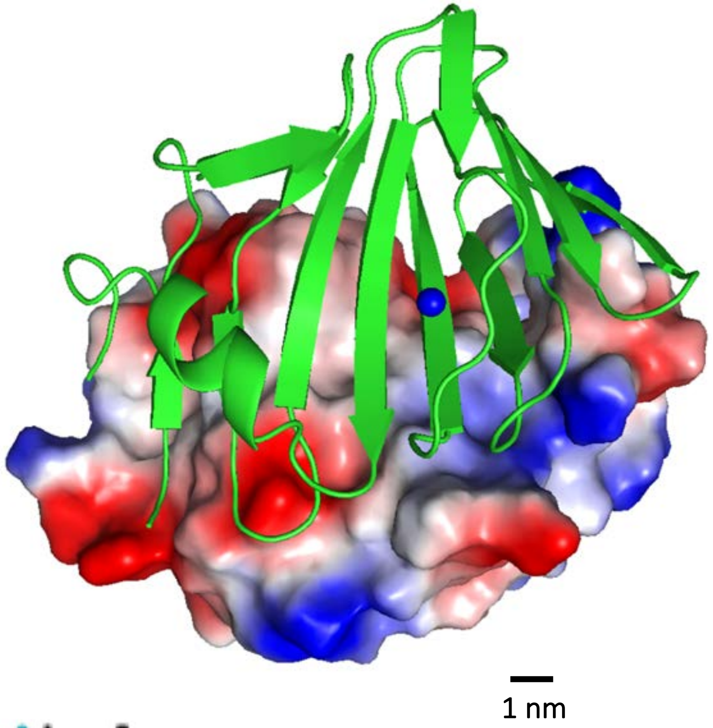
courtesy of Juliana Velasco



Environmental Microbiology (2022) **24**(3), 1430–1453

Enzime structure @ MANACÁ

courtesy of Mario Murakami

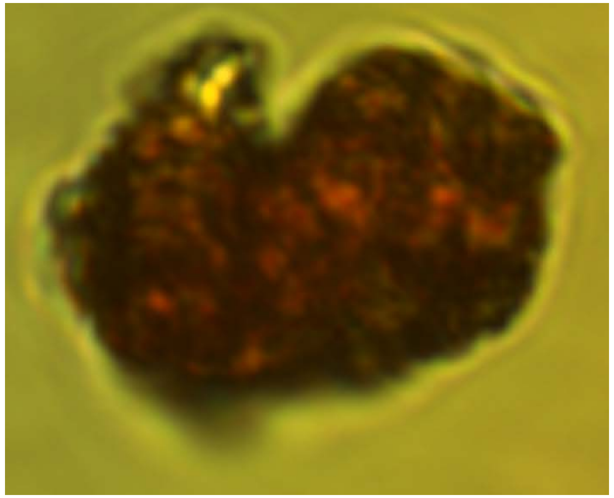


lnbr

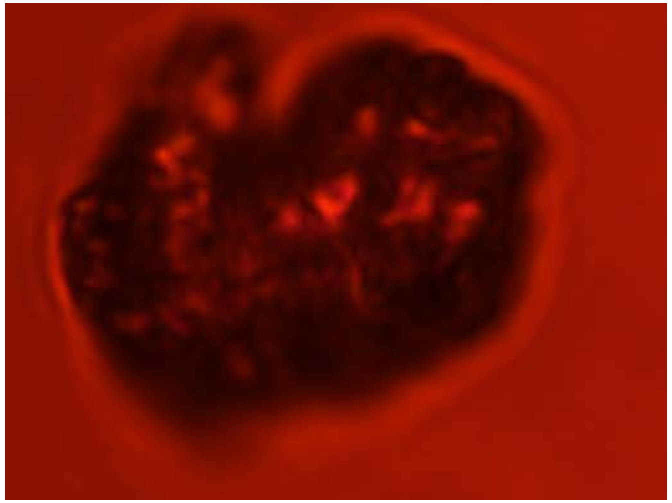
Multimodal Imaging of Microagregates

Courtesy: Dean Hesterberg

visible microscopy

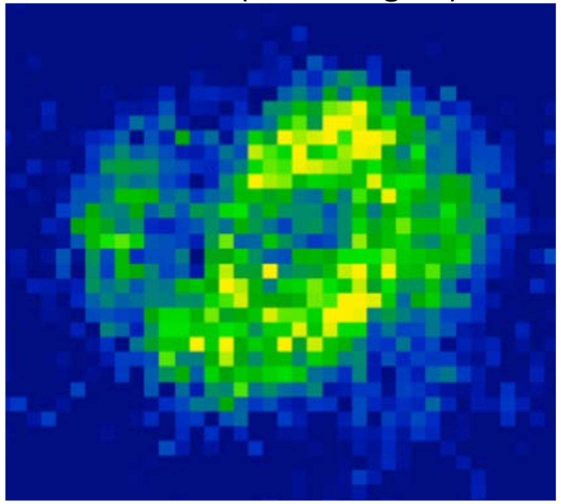


visible (λ=535 nm) fluorescence

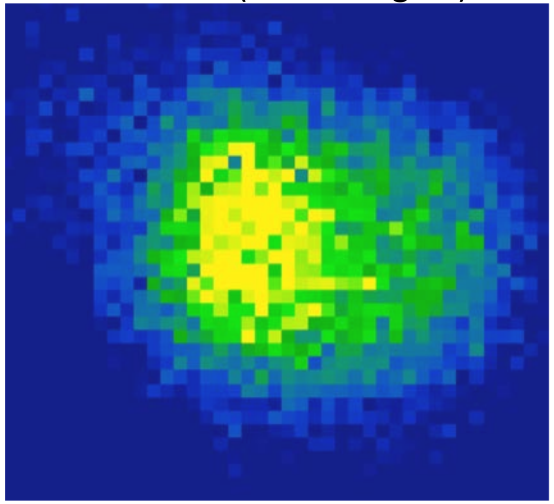


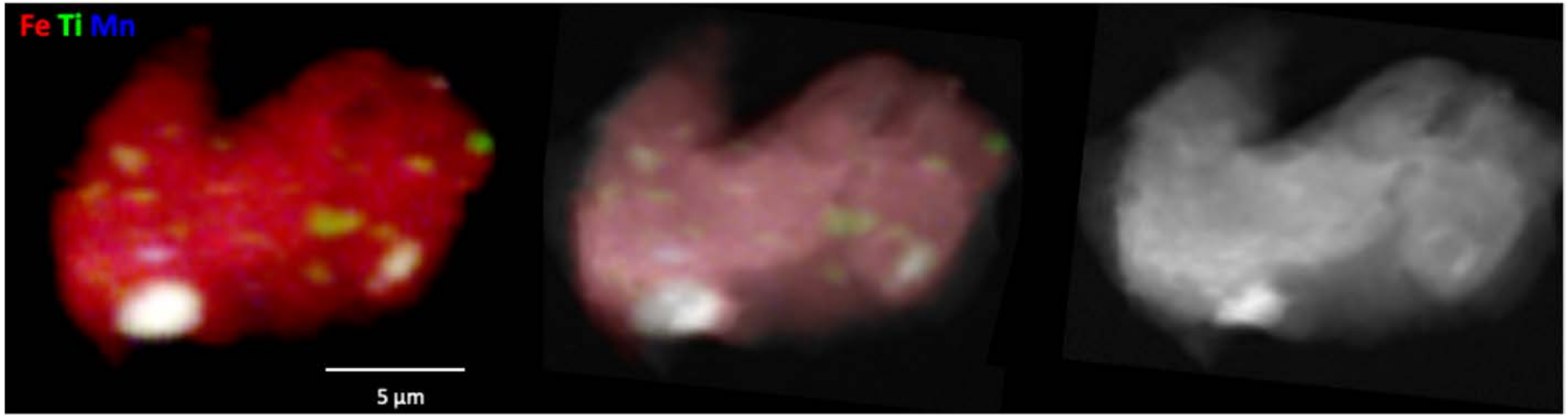
Fourier transform infrared (FTIR)

1650 cm^{-1} (amide region)



1034 cm^{-1} (silicate region)

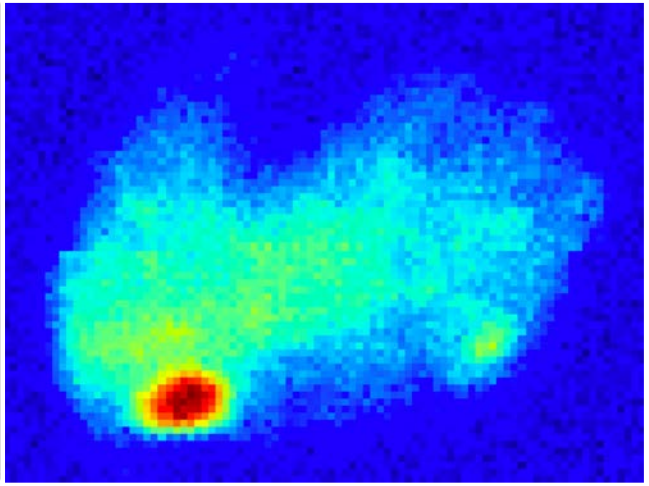




µ-XRF

overlay

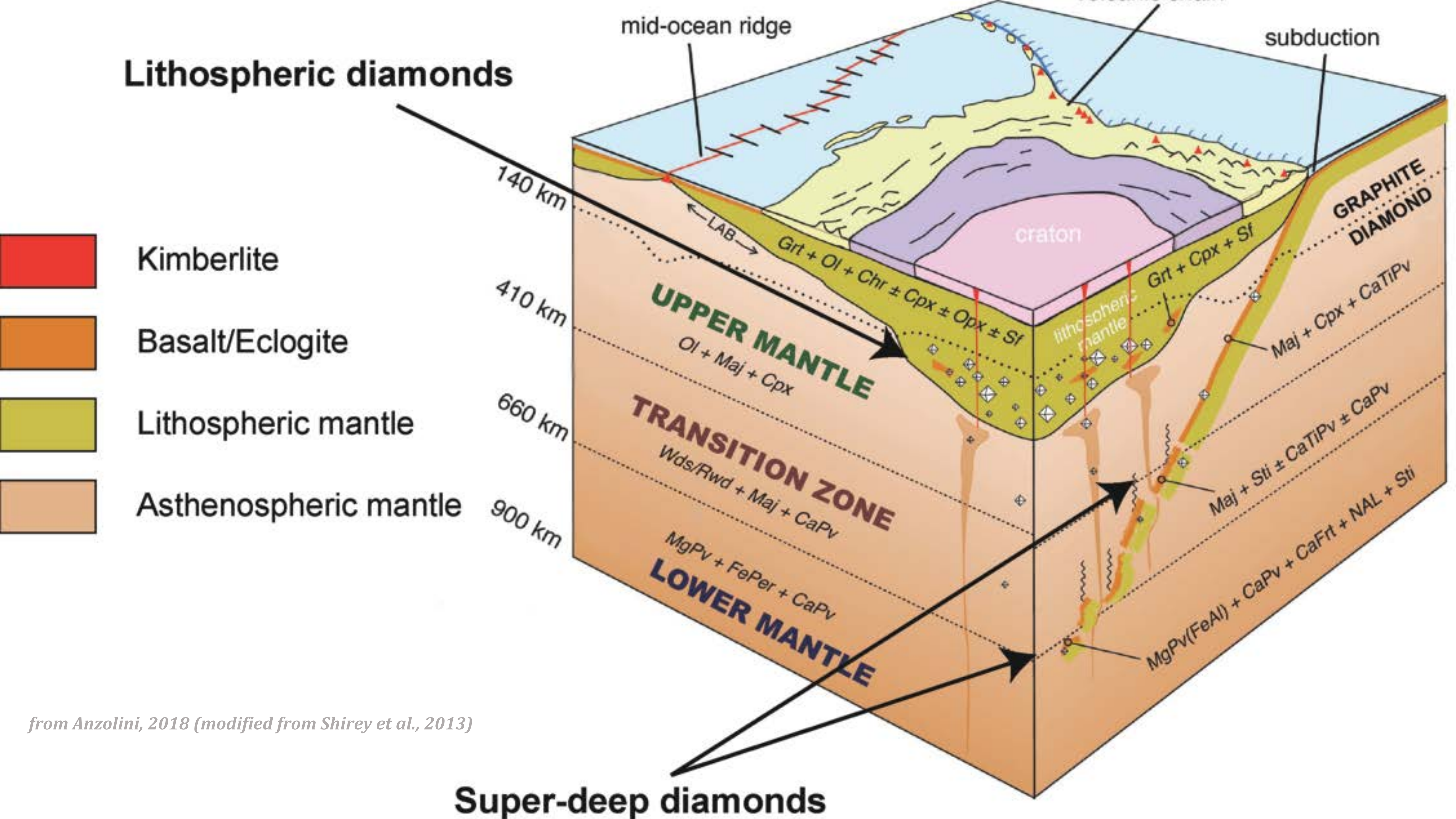
CDI



STXM @ 9.75 keV

Geoscience

How was the earth mantle formed?



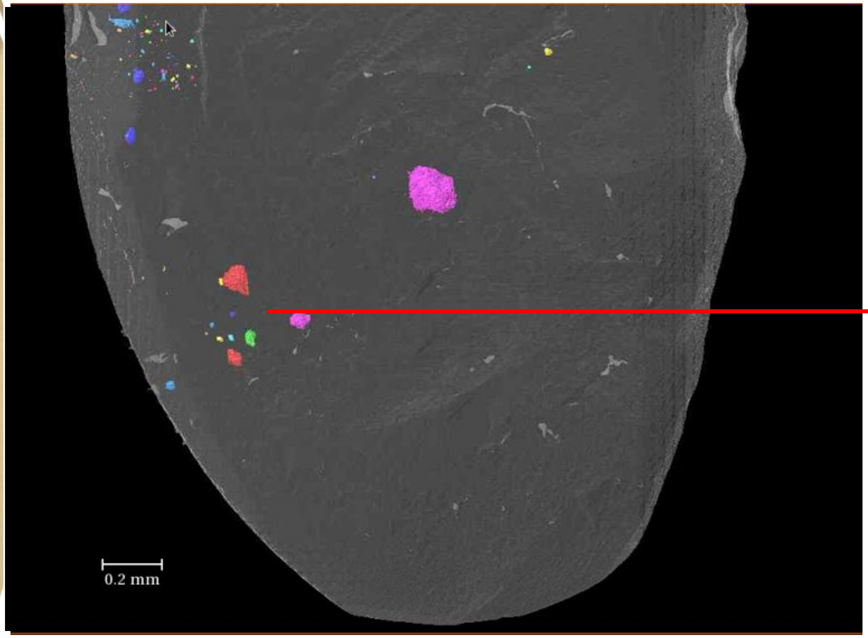
from Anzolini, 2018 (modified from Shirey et al., 2013)

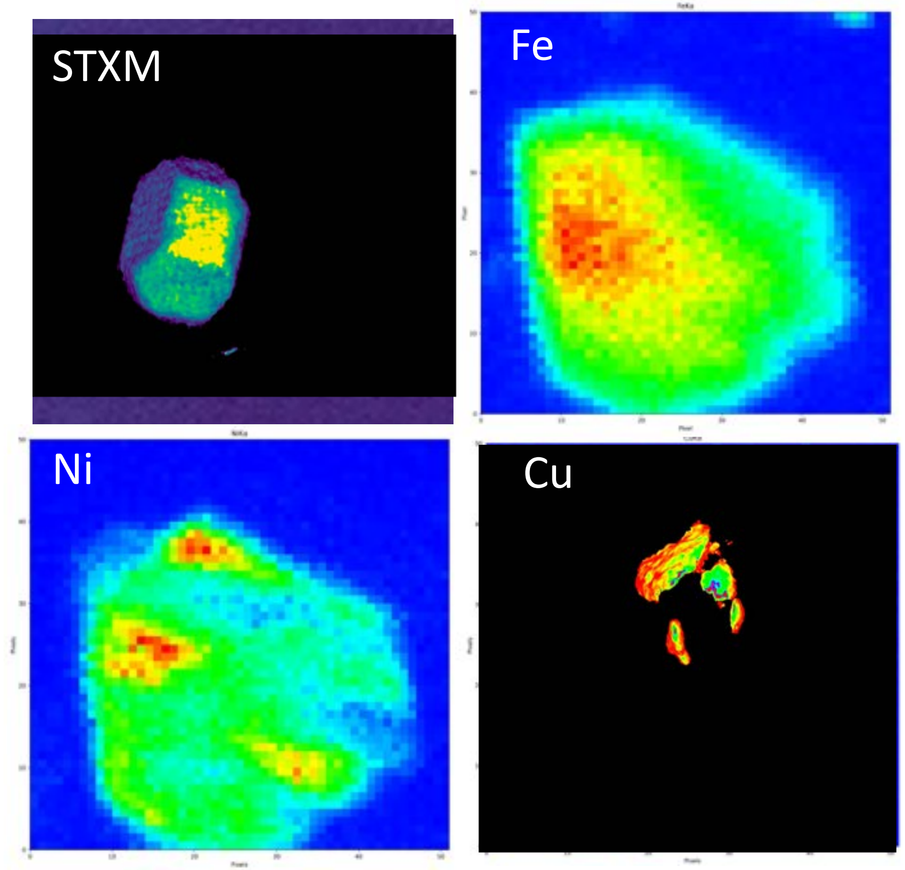
Superdeep Diamonds

@ MOGNO & CARNAÚBA

Diamante de Juína, Mato Grosso

μ CT (@ MOGNO)



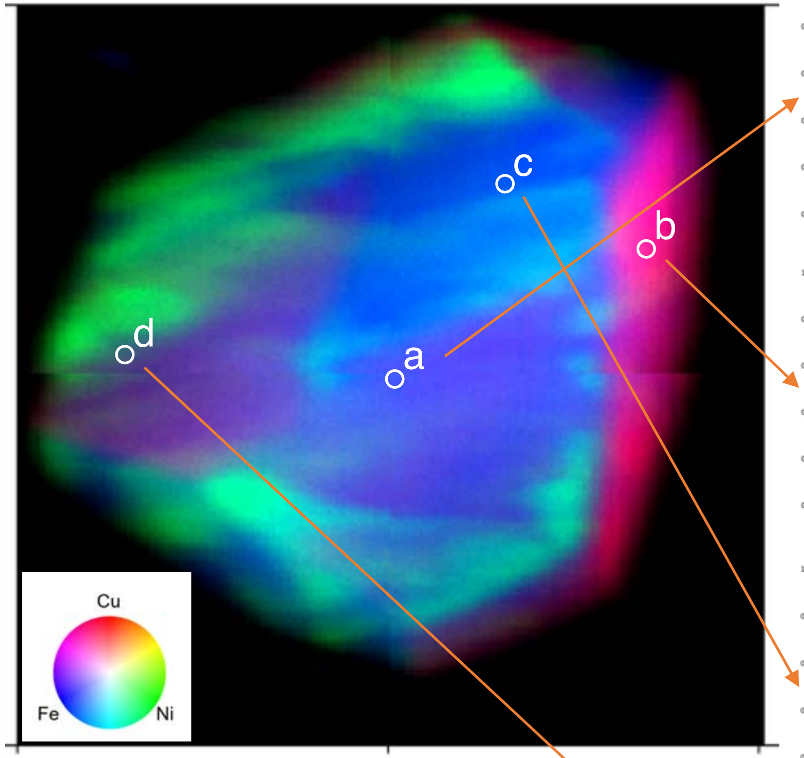


- E=12 keV
- Beam size 550 nm x 250 nm

courtesy of Helio Tolentino and Fernanda Gervasoni

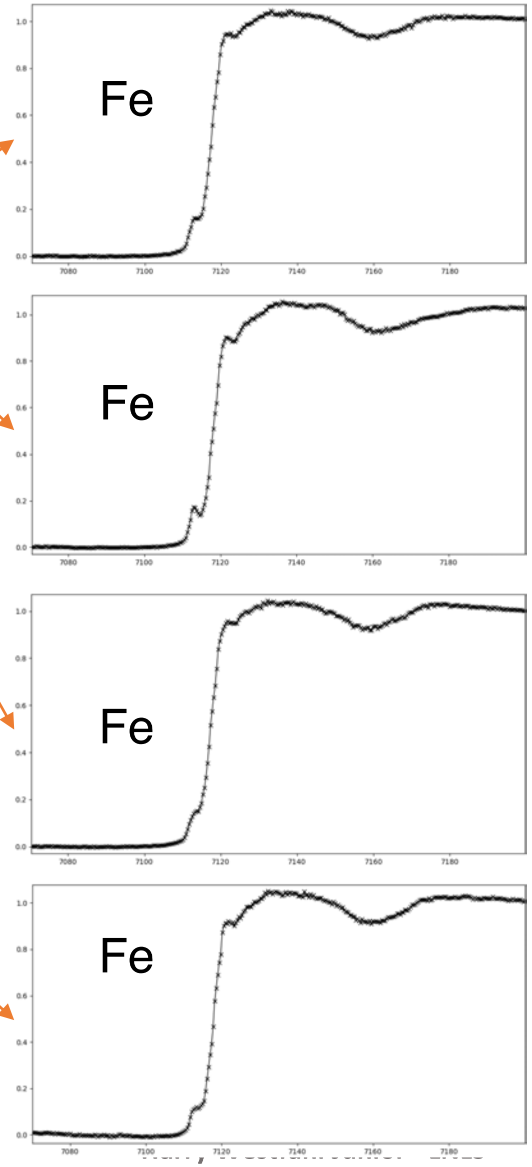
XAS Microscopy analysis

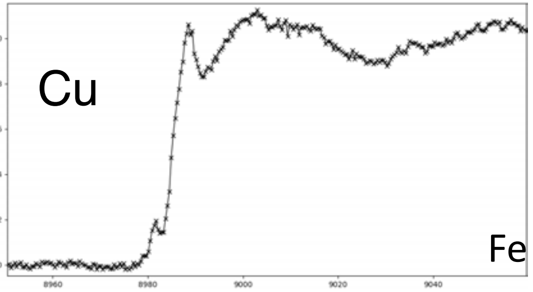
10 x 10 um^2 - XRF 3-color image



courtesy of Helio Tolentino and Fernanda Gervasoni

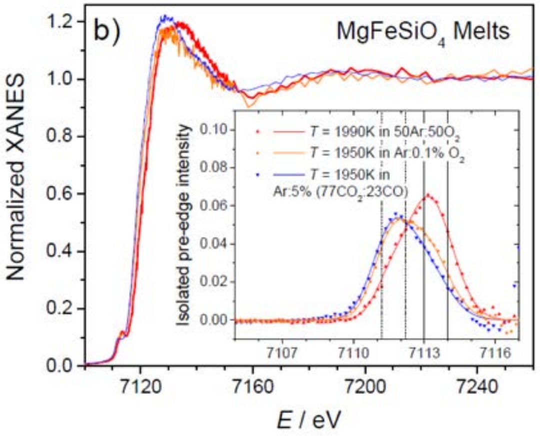
X-ray absorption spectroscopy





XANES indicates amorphized phases, which are normally found in interstellar environments

Fe K-edge XANES of molten MgFeSiO4



Alderman et al, Chemical Geology, 2017

Soft Matter

What makes a good nano(filtration) membrane?

Polymeric Membranes

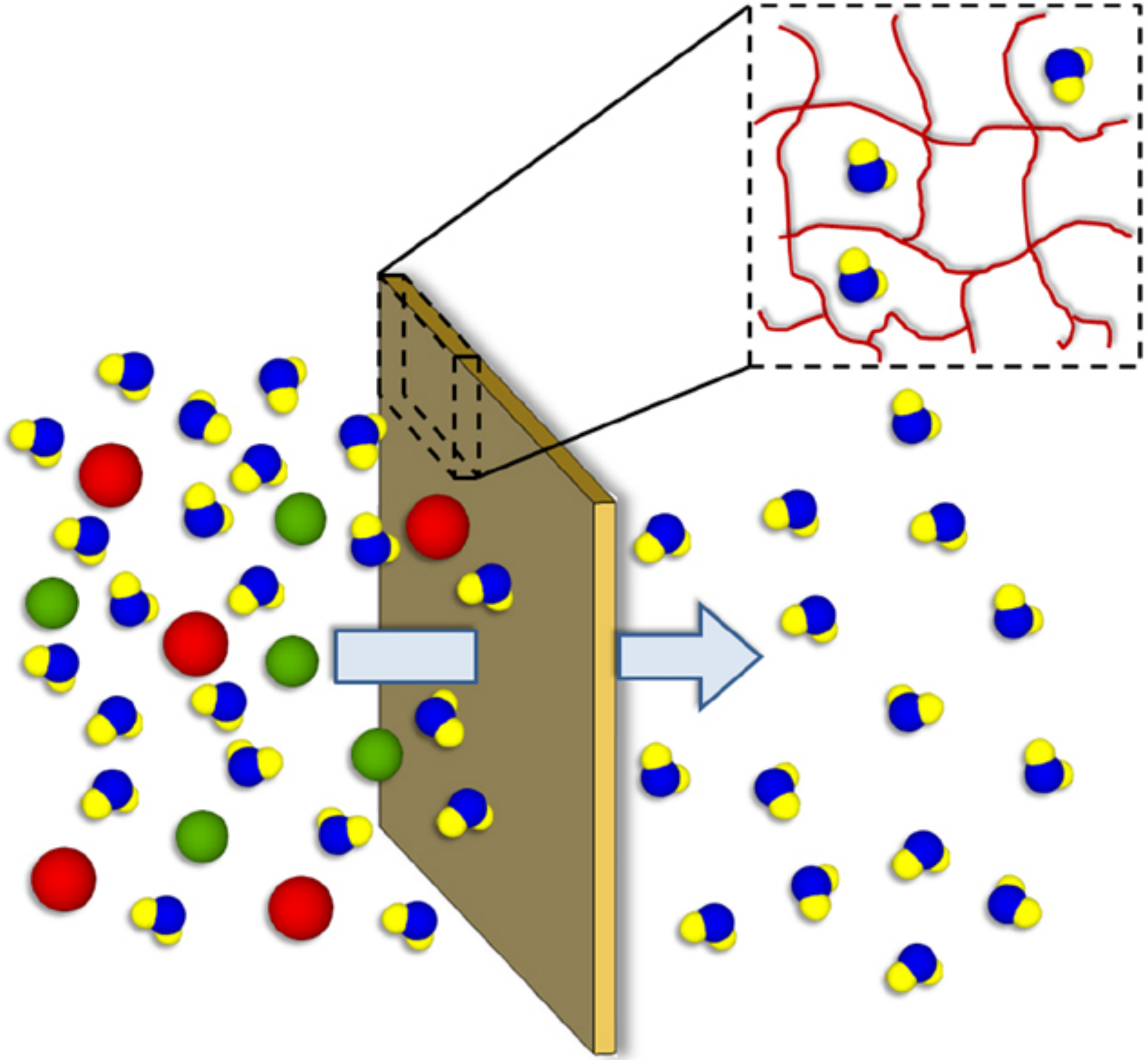
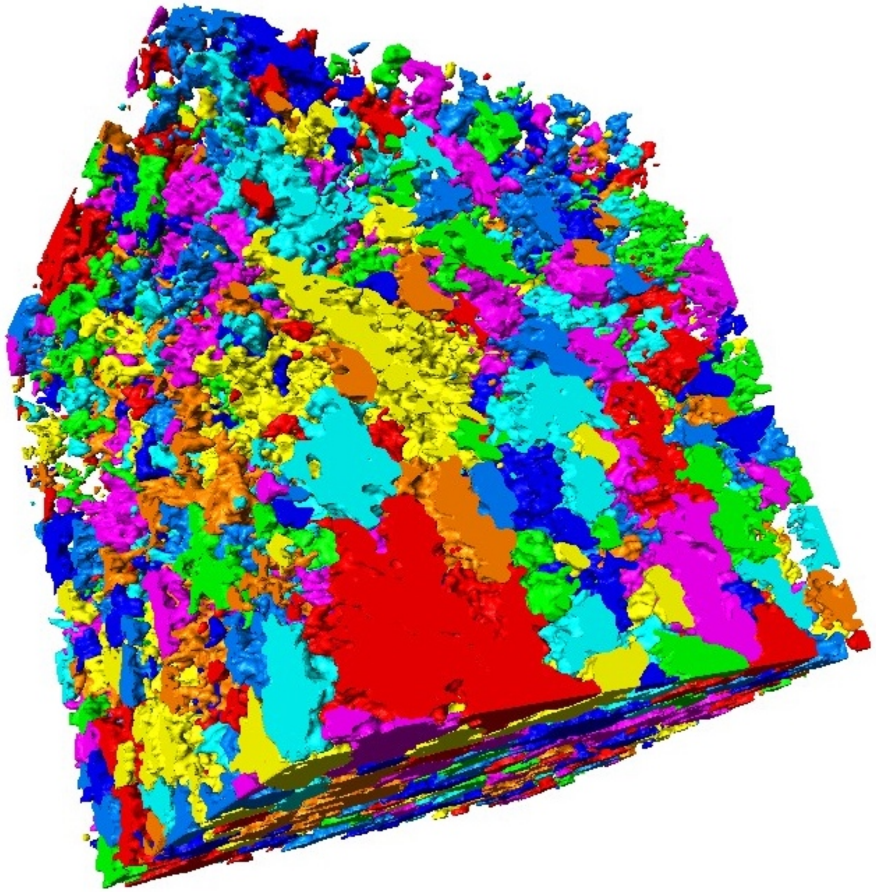
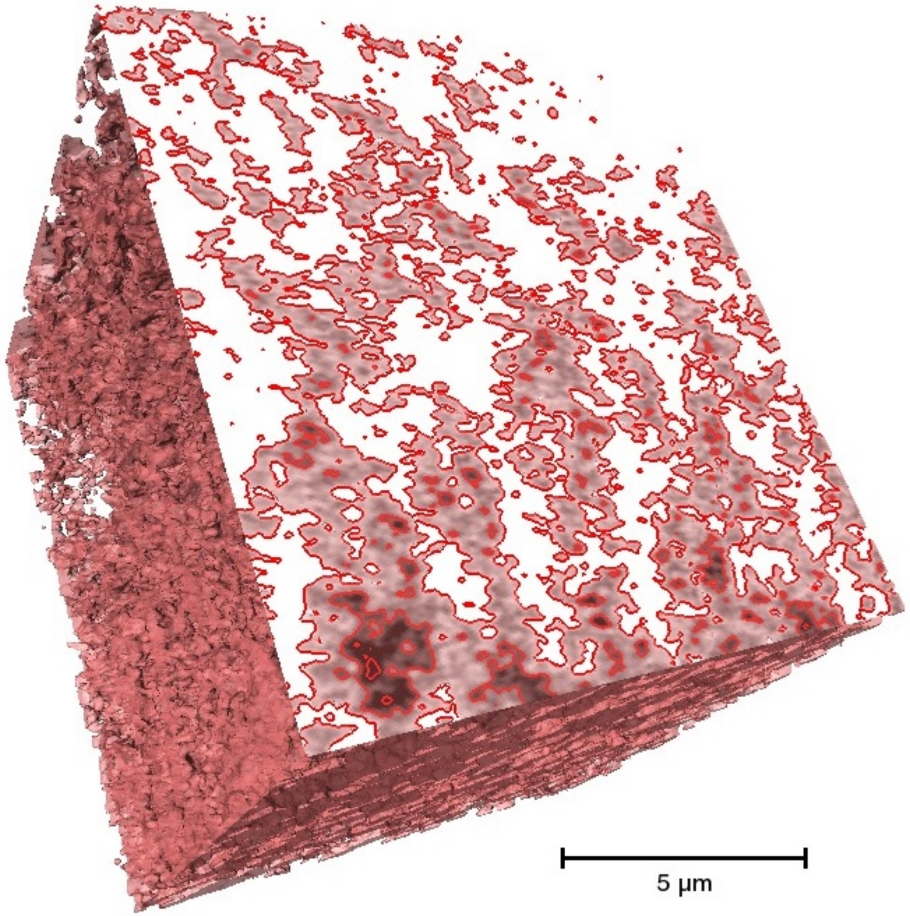


Image from https://www.nist.gov/programs-projects/polymer-membranes

Polymeric Membranes for filtration

@ CATERETÊ





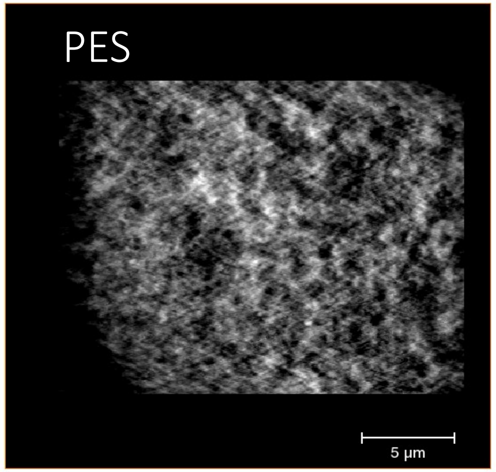
Courtesy: Florian Meneau and Suzana Nunes

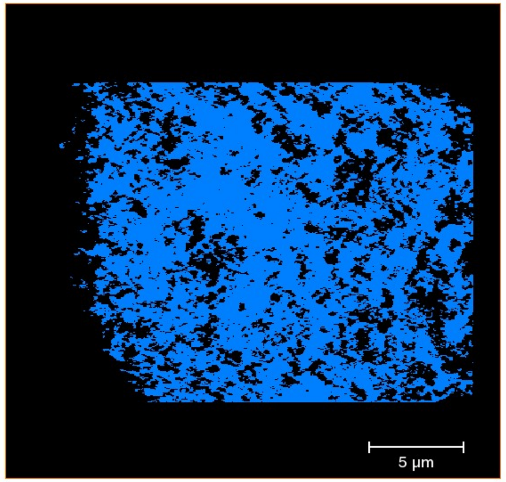
Quantitative analysis of pore connectivity

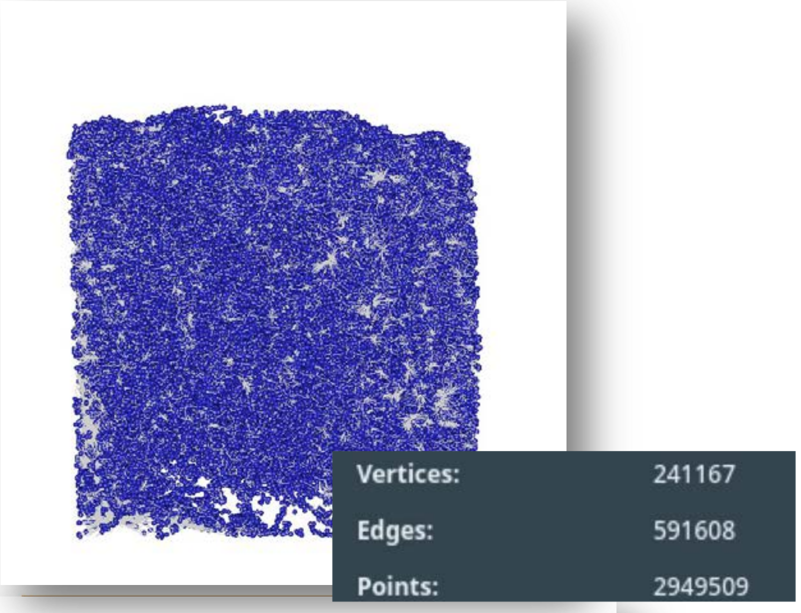
Network analysis
(skeleton)

3D resolution:

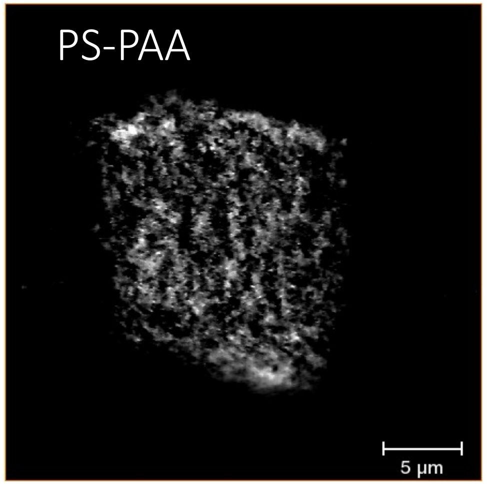
- **69 nm**

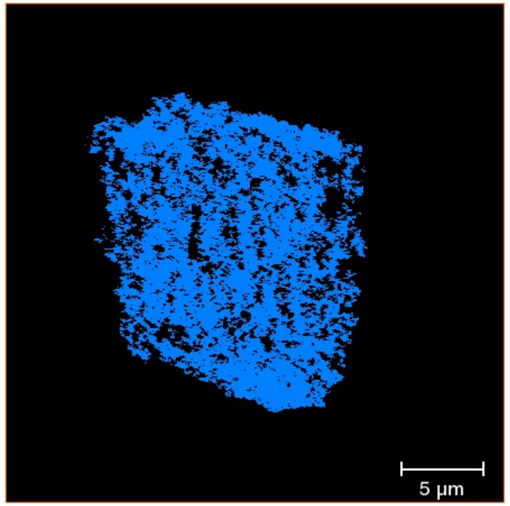


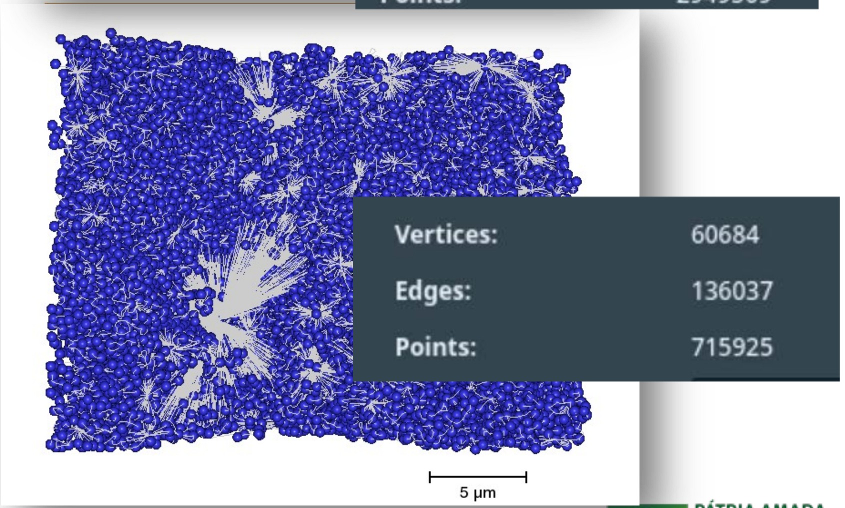




- **33 nm**





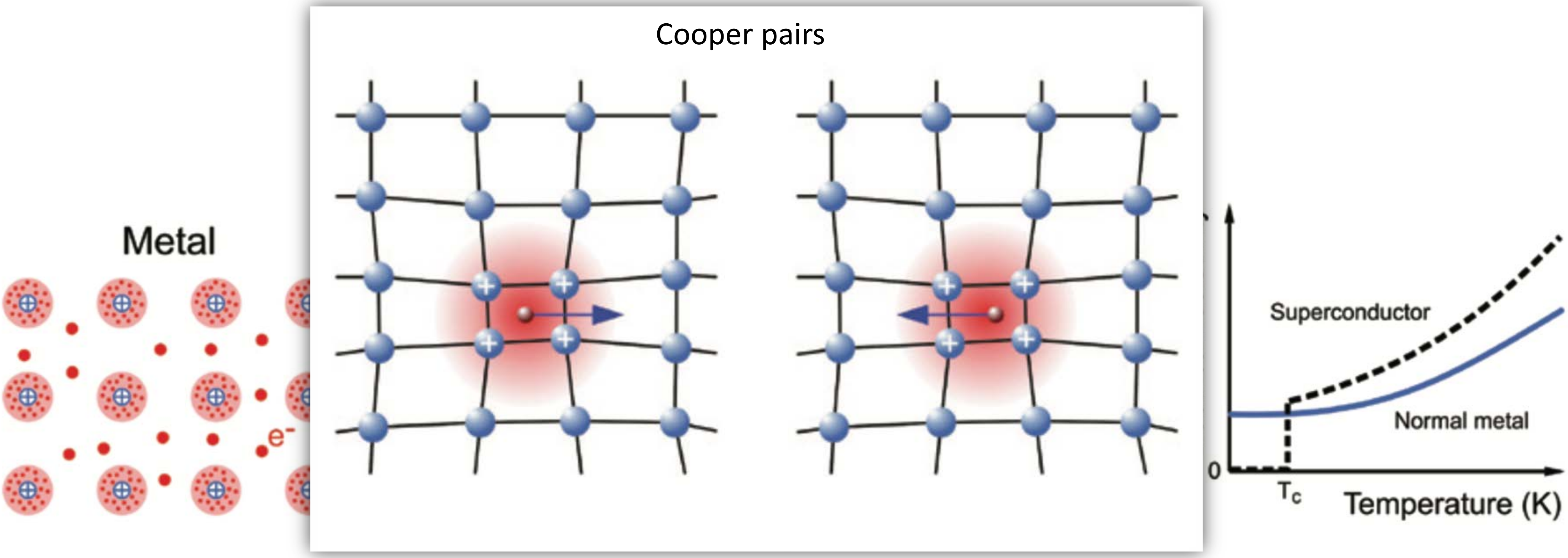


Courtesy: Florian Meneau and Suzana Nunes

Superconductivity

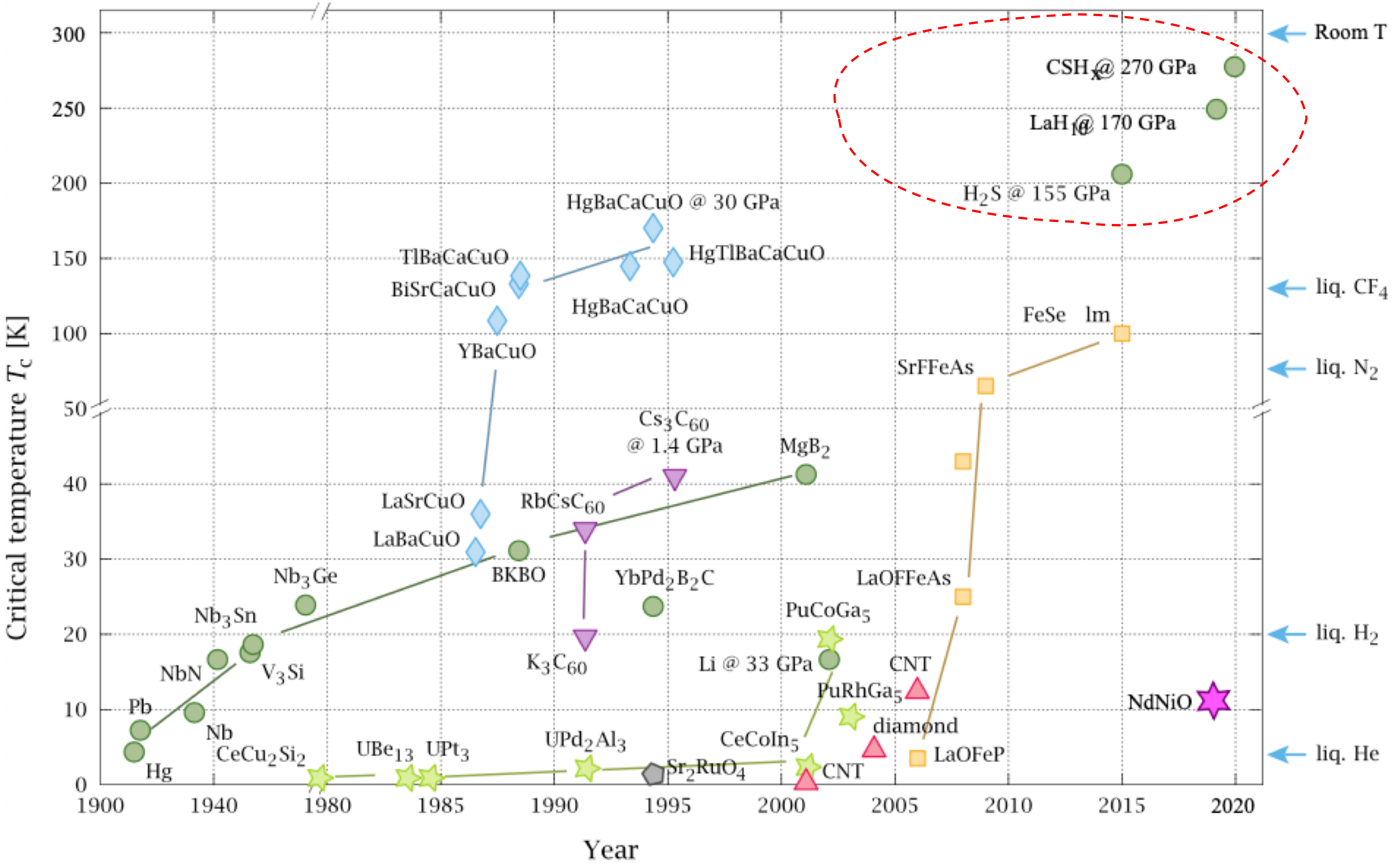
Why a superconductor under high pressure?

Superconductivity



From Bussmann-Holder and Keller, https://doi.org/10.1515/znb-2019-0103

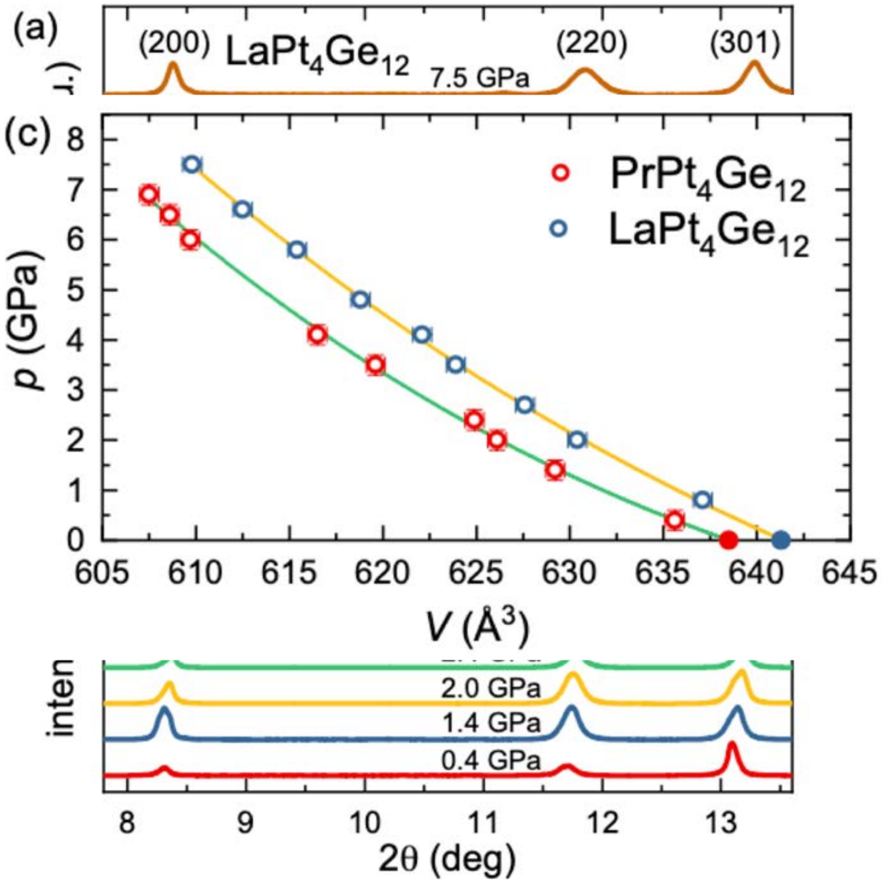
Superconductor materials timeline

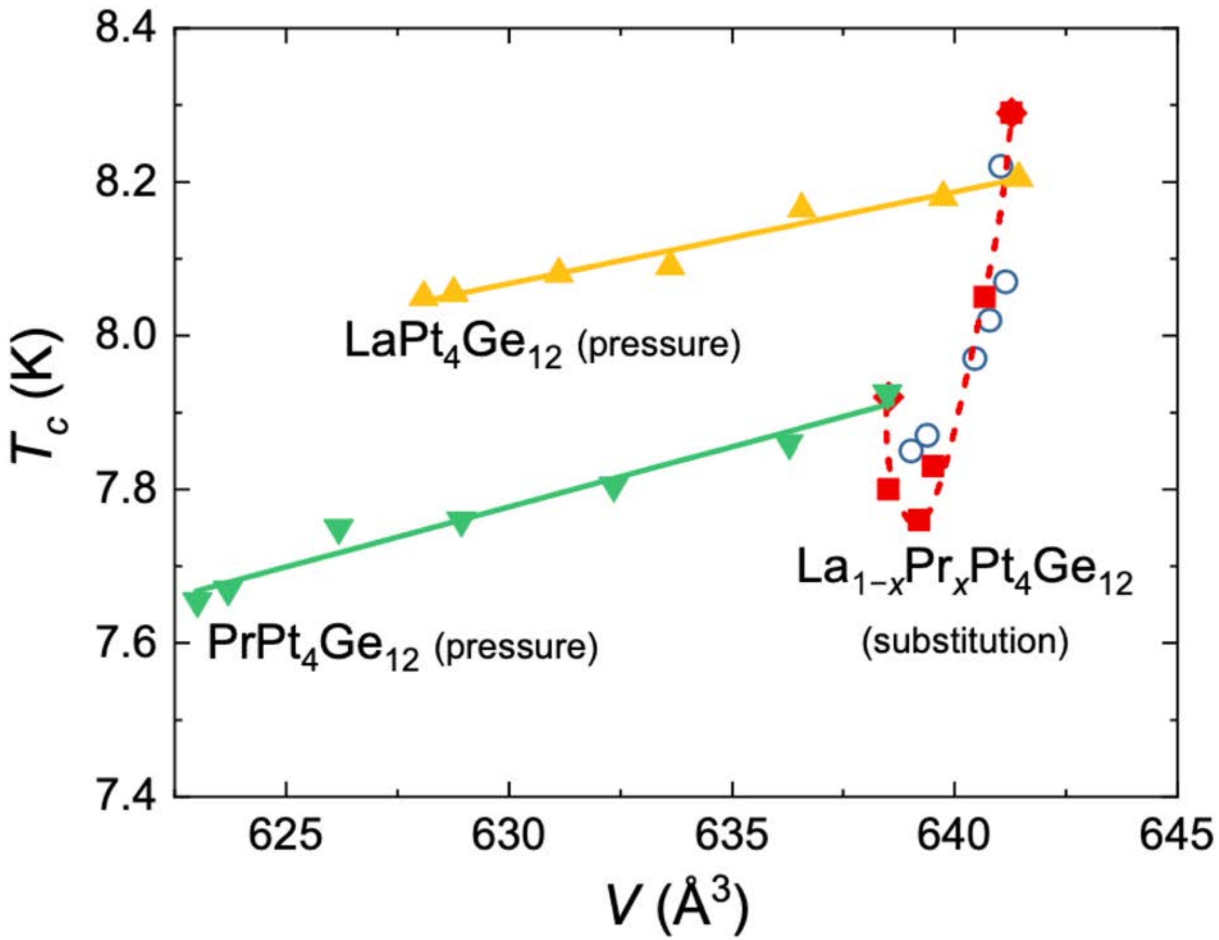


https://commons.wikimedia.org/wiki/File:Timeline_of_Superconductivity_from_1900_to_2015.svg

Superconductivity under pressure
@ EMA

Materials **2022**, *15*, 2743. https://doi.org/10.3390/ma15082743



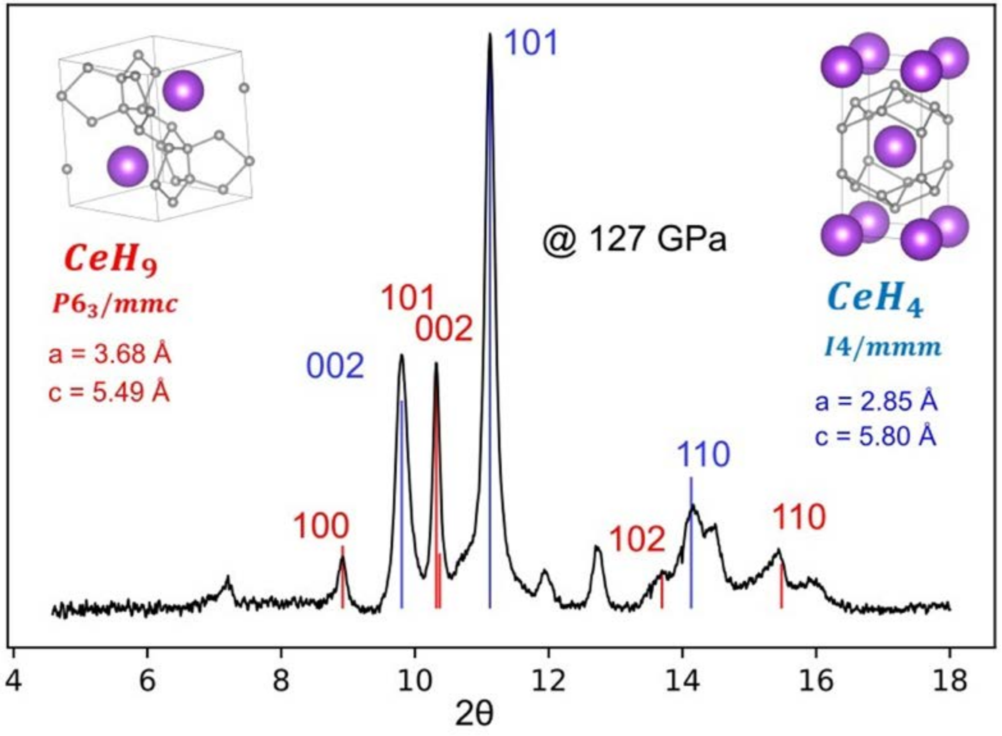


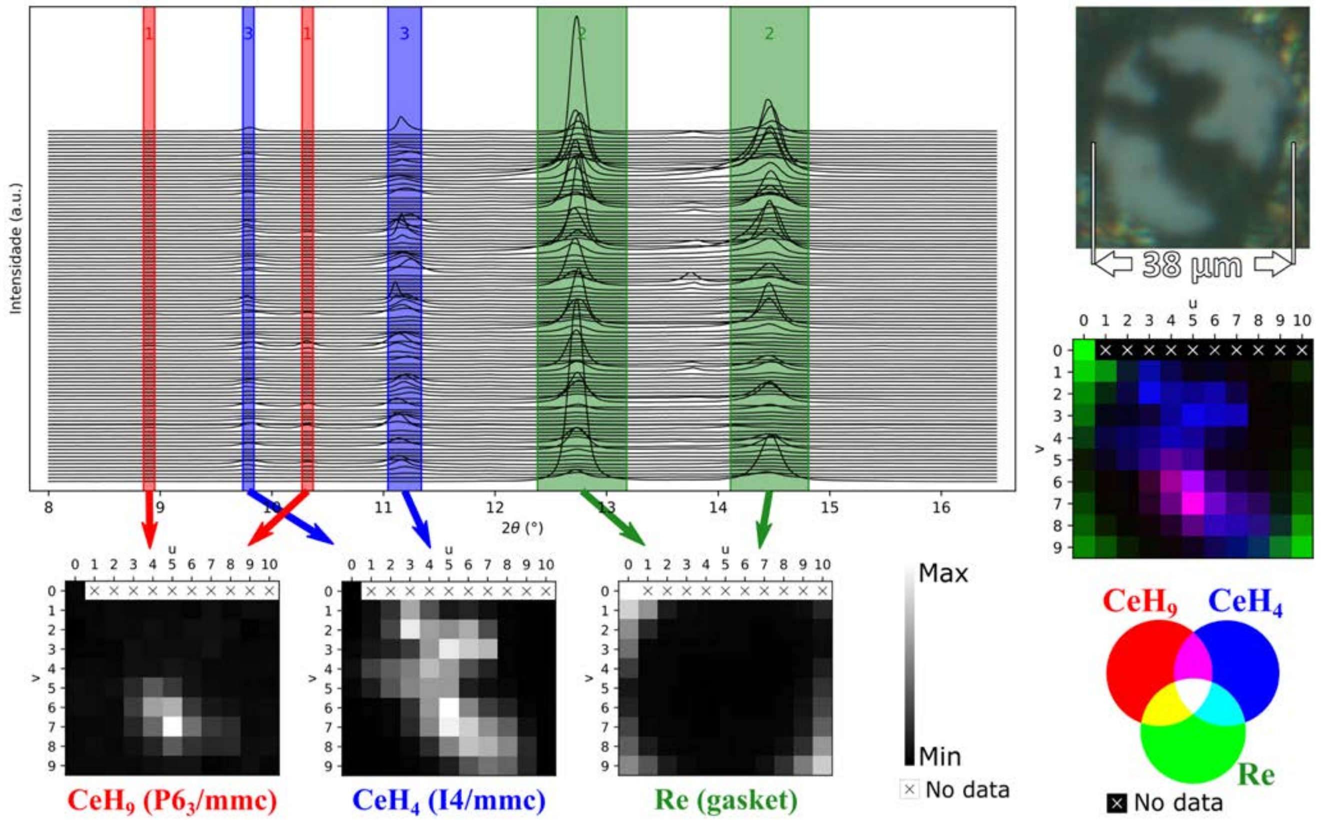
High pressure powder experiments

@ EMA

ex-situ synthesis

- 127 GPa
- 2100 K laser heating (~10μm spot)





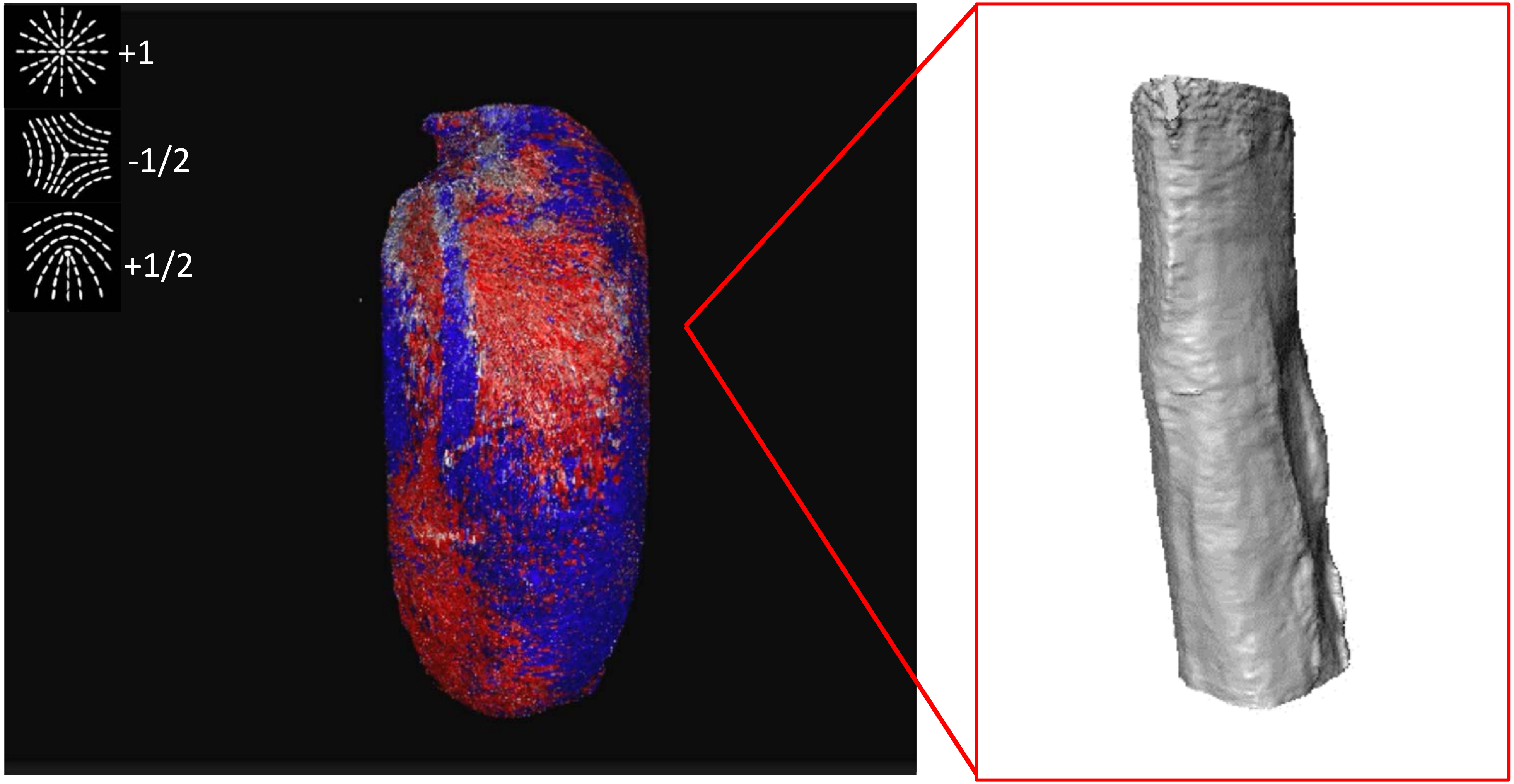
courtesy of Ricardo Reis

Biology and Medicine

How do cardiac cells organize to pump blood?

Ultrastructure and cell-cell coupling of cardiac myocytes

@ MOGNO & CATERETÊ



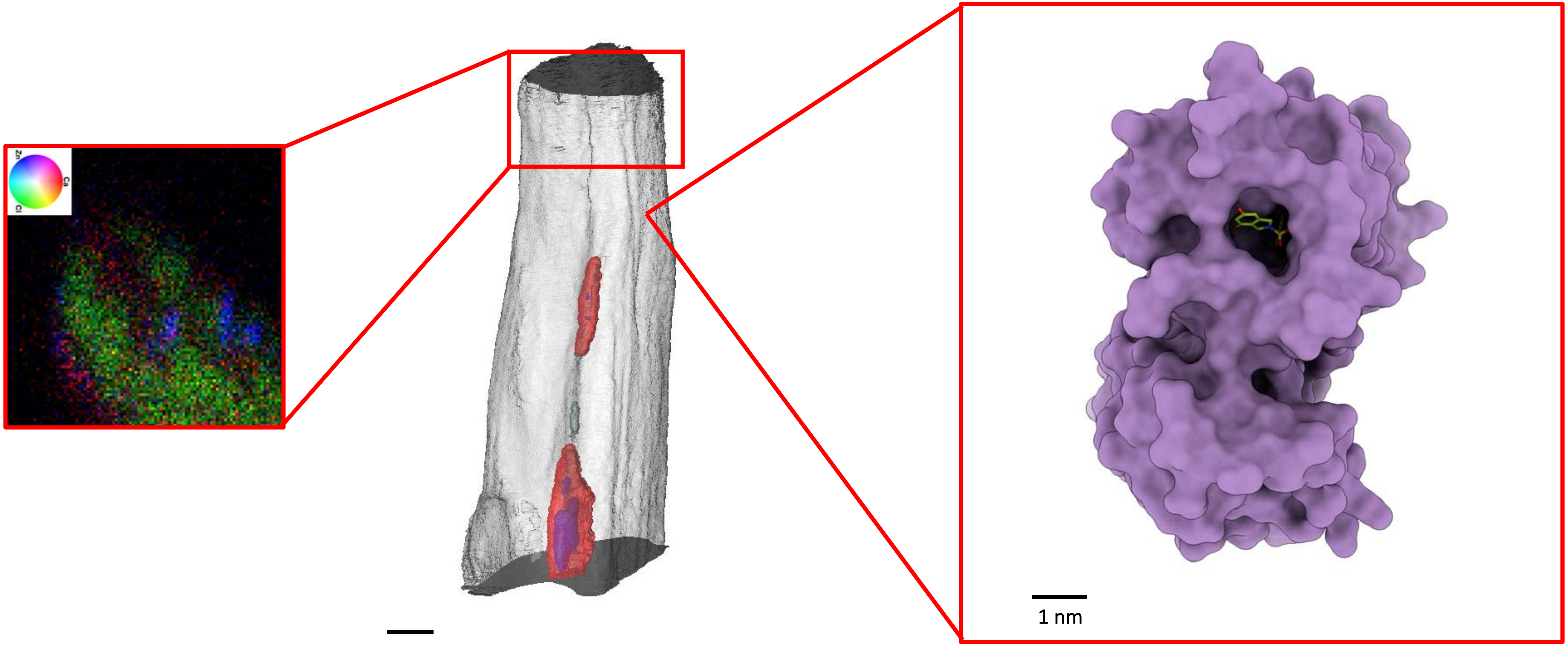
courtesy of Murilo de Carvalho / Carla Polo

X-Ray Crystallography (Complex + inhibitor)

X-Ray Nano-XRF of Cardiomyocyte

@ MANACÁ

@ CARNAÚBA



courtesy of Alisson Cardoso / Carla Polo / Douglas Galante

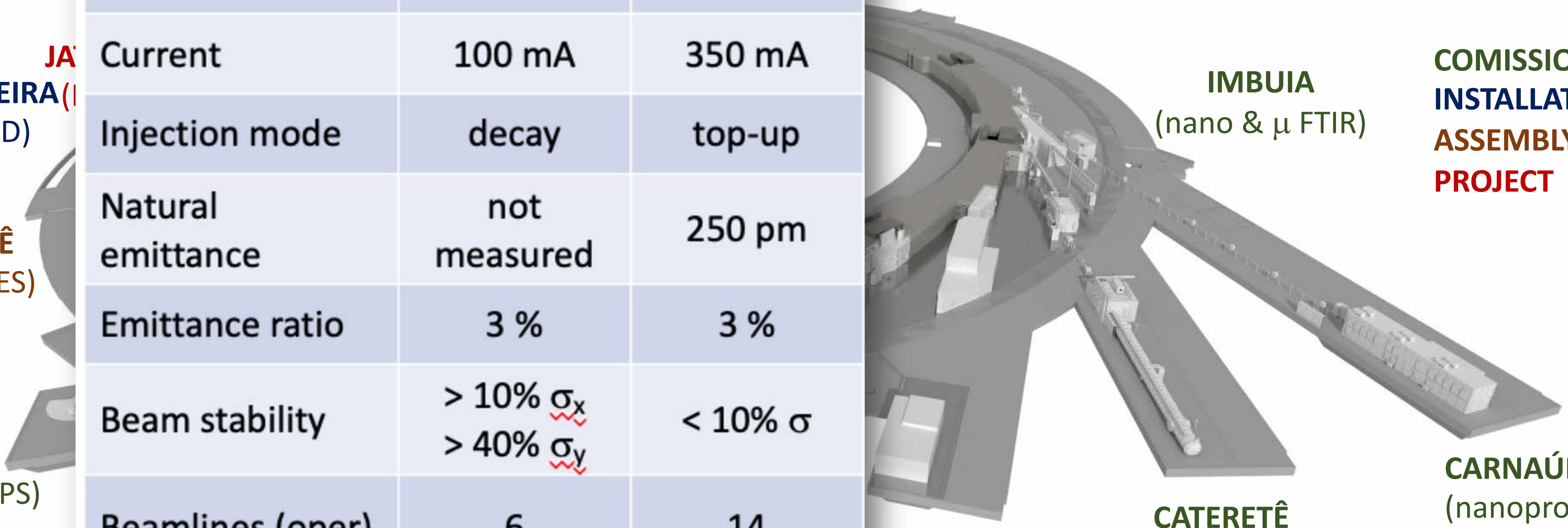
Sirius Project

Timeline

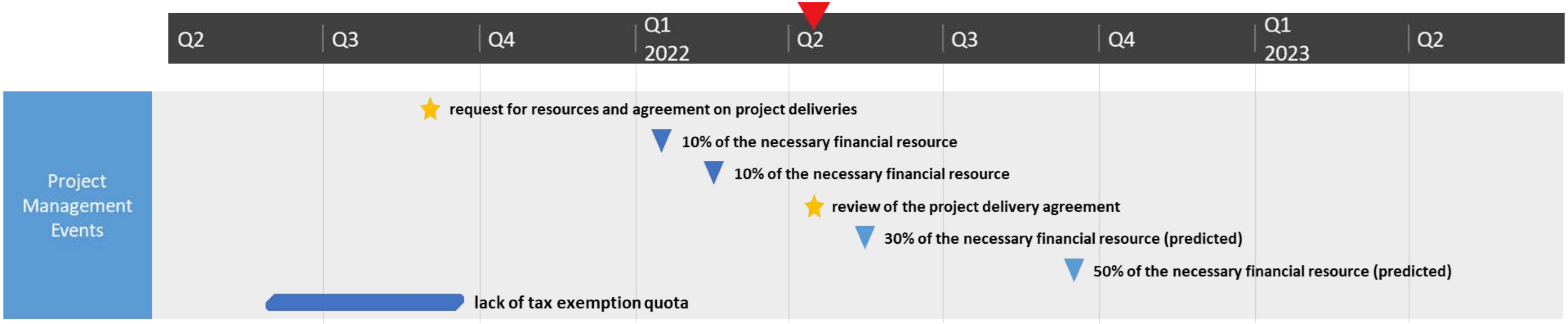
Sirius Phase 1

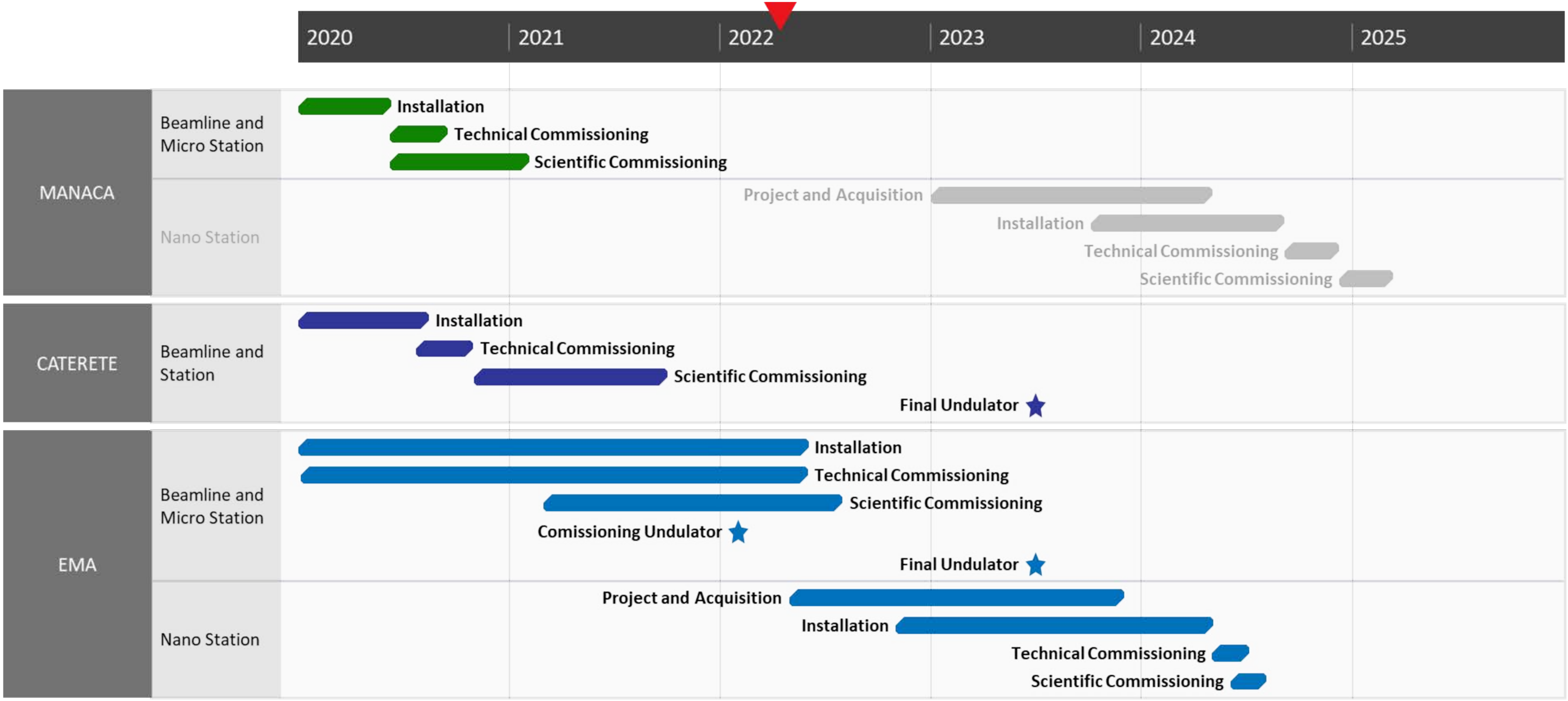
https://www.lnls.cnpem.br/beamlines/

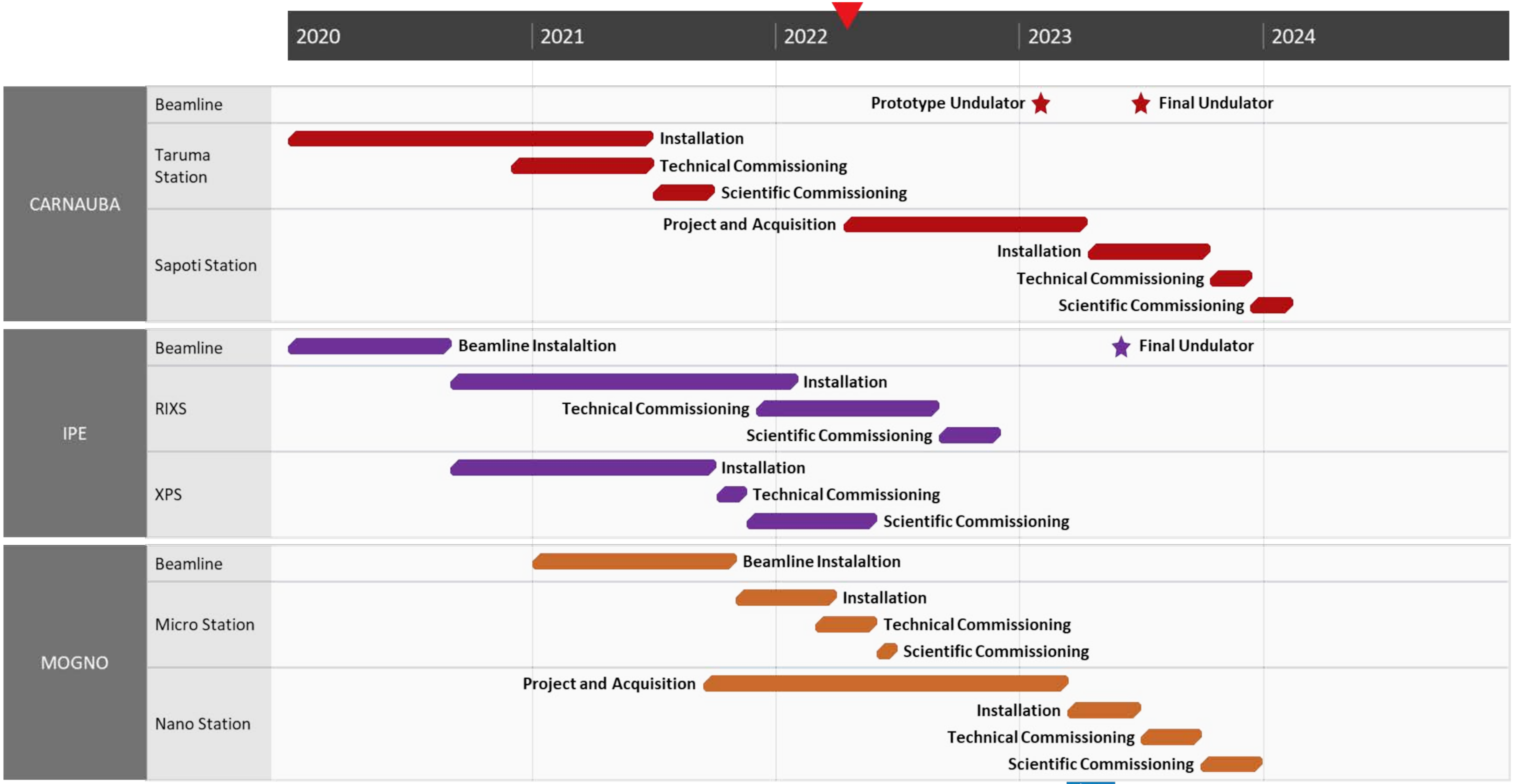
Parameter	April 2022	Sirius Phase-I
Beam energy	3.0 GeV	3.0 GeV
Current	100 mA	350 mA
Injection mode	decay	top-up
Natural emittance	not measured	250 pm
Emittance ratio	3 %	3 %
Beam stability	$> 10\%\ \sigma_x$ $> 40\%\ \sigma_y$	$< 10\%\ \sigma$
Beamlines (oper)	6	14



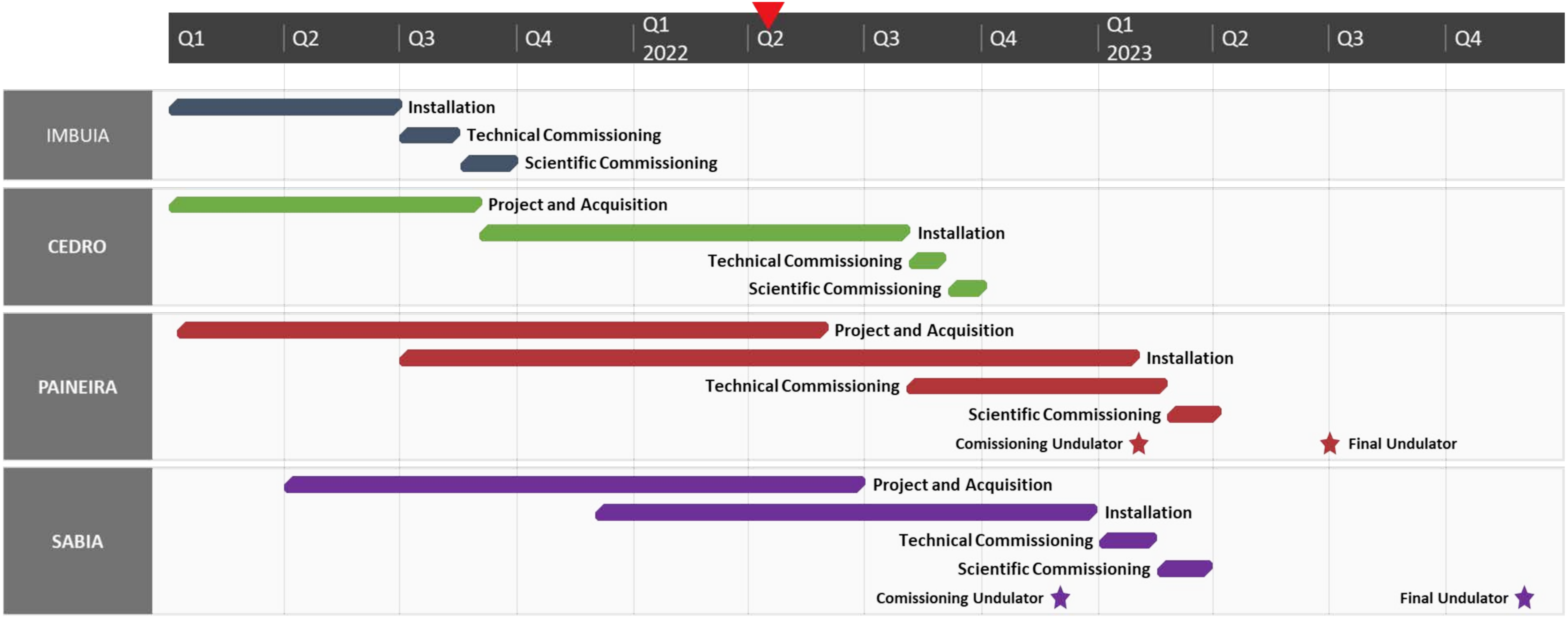
FNDCT funding required for Phase 1 completion (the last 20%)



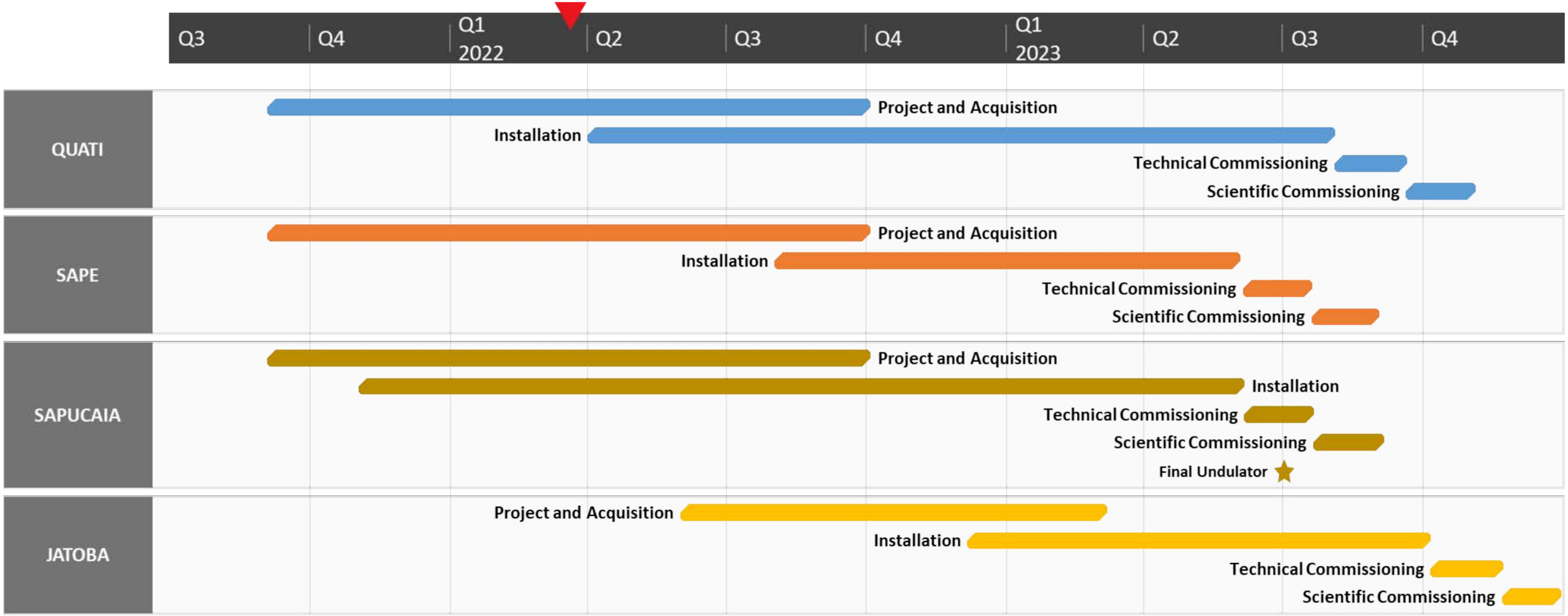

2020
2021
2022
2023
2024
2025
MANACA
Beamline and Micro Station
Installation
Technical Commissioning
Scientific Commissioning
Nano Station
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
CATERETE
Beamline and Station
Installation
Technical Commissioning
Scientific Commissioning
Final Undulator
EMA
Beamline and Micro Station
Installation
Technical Commissioning
Scientific Commissioning
Comissioning Undulator
Final Undulator
Nano Station
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning



2020
2021
2022
2023
2024
CARNAUBA
Beamline
Prototype Undulator
Final Undulator
Taruma Station
Installation
Technical Commissioning
Scientific Commissioning
Sapoti Station
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
IPE
Beamline
Beamline Instalaltion
Final Undulator
RIXS
Installation
Technical Commissioning
Scientific Commissioning
XPS
Installation
Technical Commissioning
Scientific Commissioning
MOGNO
Beamline
Beamline Instalaltion
Micro Station
Installation
Technical Commissioning
Scientific Commissioning
Nano Station
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning



Q1
Q2
Q3
Q4
Q1 2022
Q2
Q3
Q4
Q1 2023
Q2
Q3
Q4
IMBUIA
Installation
Technical Commissioning
Scientific Commissioning
CEDRO
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
PAINEIRA
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
Comissioning Undulator
Final Undulator
SABIA
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
Comissioning Undulator
Final Undulator


Q3
Q4
Q1 2022
Q2
Q3
Q4
Q1 2023
Q2
Q3
Q4
QUATI
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
SAPE
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
SAPUCAIA
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning
Final Undulator
JATOBA
Project and Acquisition
Installation
Technical Commissioning
Scientific Commissioning

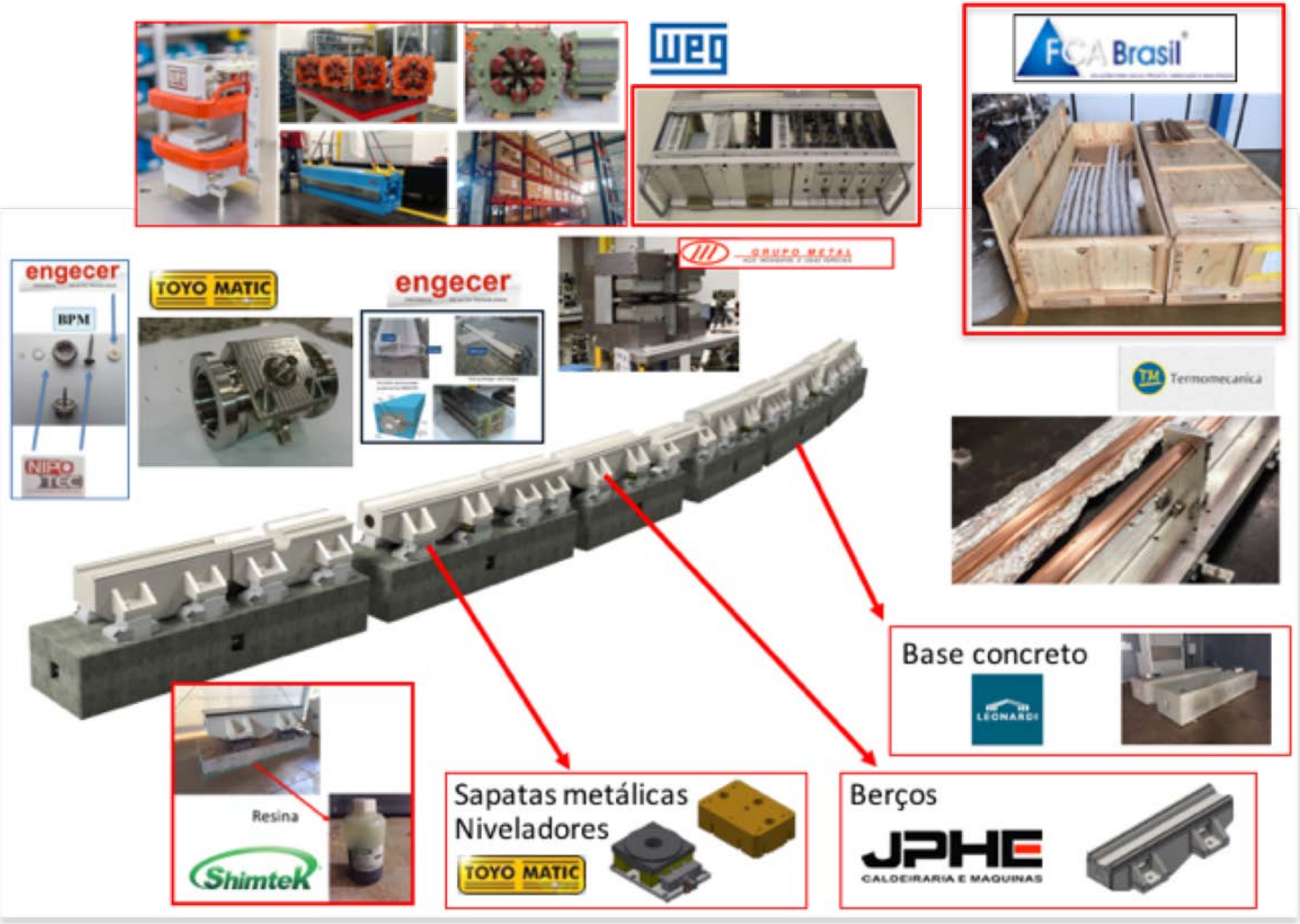
Some of the possible Phase 2 Beamlines

(based on the inputs from the user community)

Based on inputs from the user community – still in discussion!

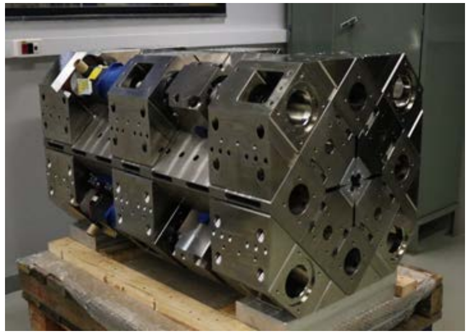
- Hard X-Ray beamline for Materials Science
- Nanoprobe for Serial Crystallography (at MANACA extension)
- Tender X-ray beamline for spectromicroscopy in agro-environmental science
- Beamline for charge density analysis and high Q-space resolution XRD
- NAP-XPS beamline
- Far-Infrared SNOM
- Hard X-Ray beamline for electronic and nuclear inelastic x-ray scattering
- …
- 3 X-Ray Imaging in BSL3/BSL4 bio contained environments – Soft, Tender, and Hard X-Ray Imaging (Conceptual Design Funded)

Interaction with Brazilian industries



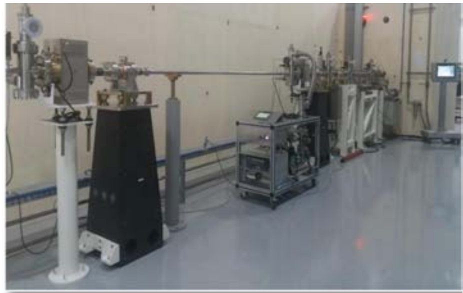
So far ~ 86% expenditures in Brazil

πTEC
PI-TECNOLOGIA

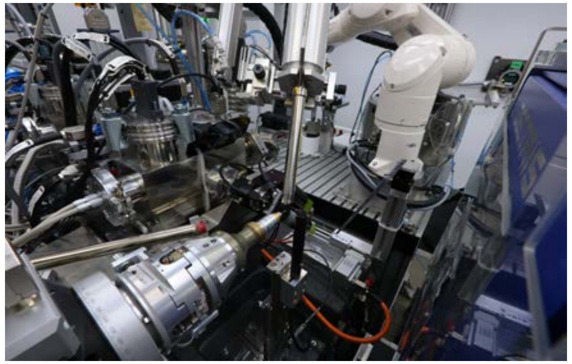


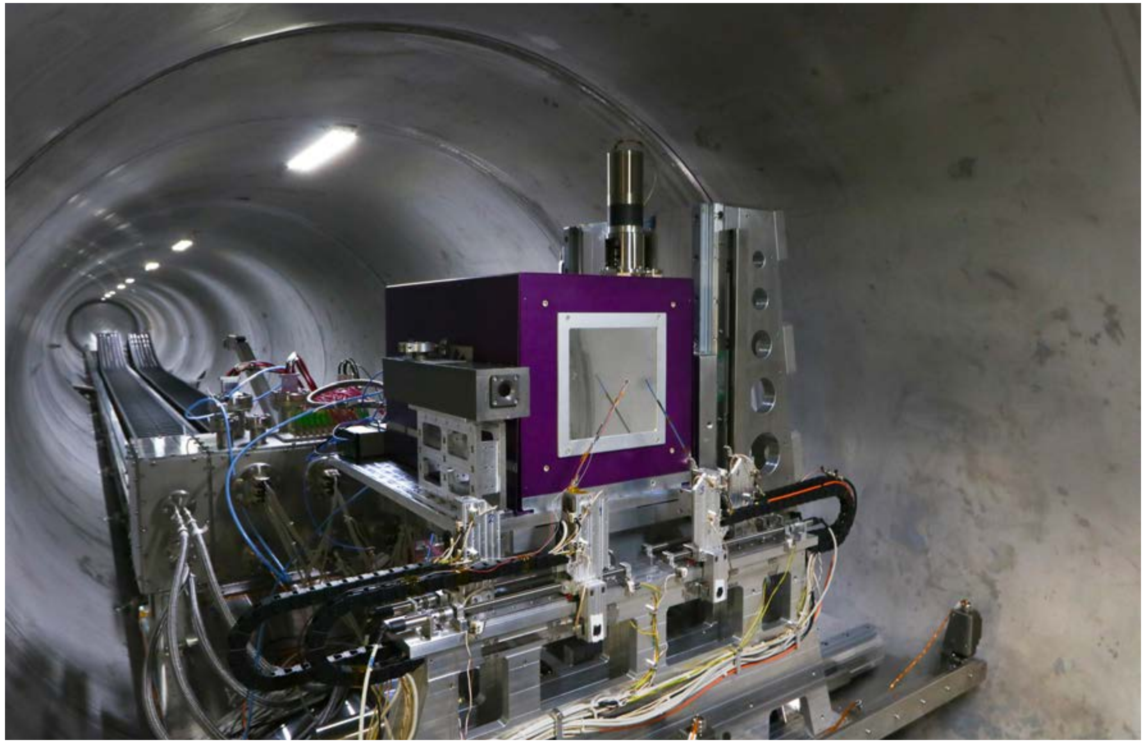
TOYO MATIC

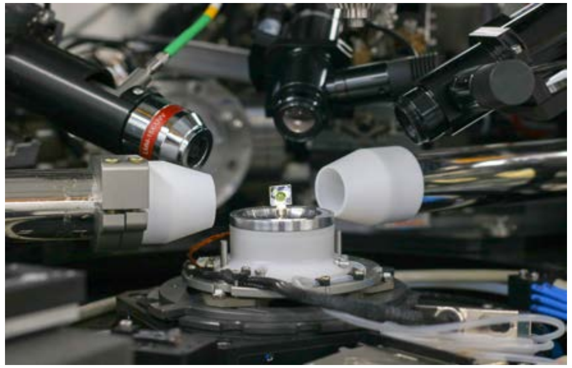
BIOTEC

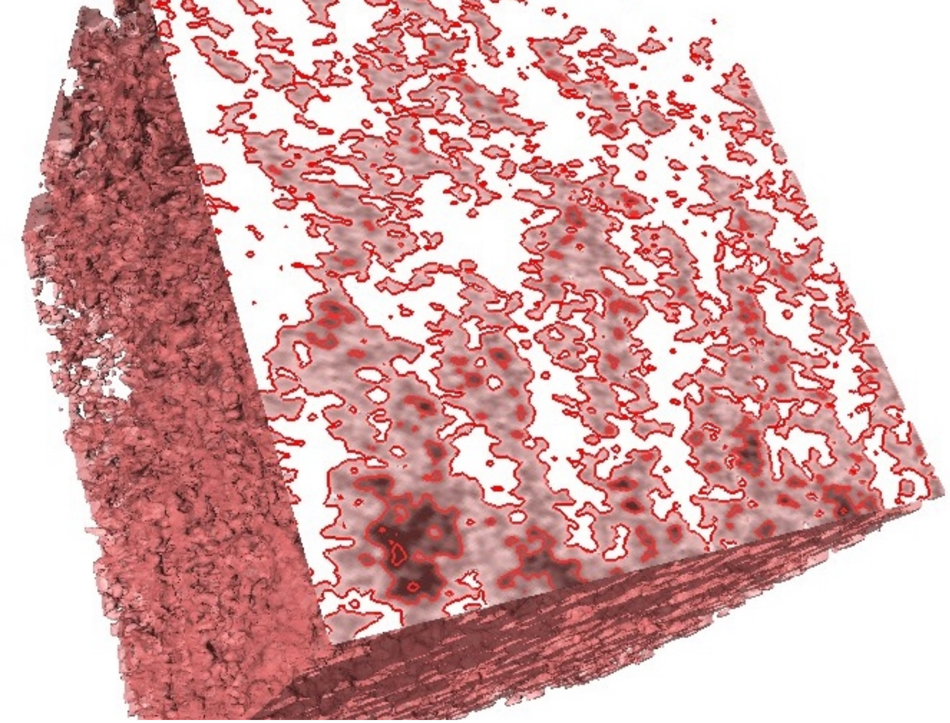


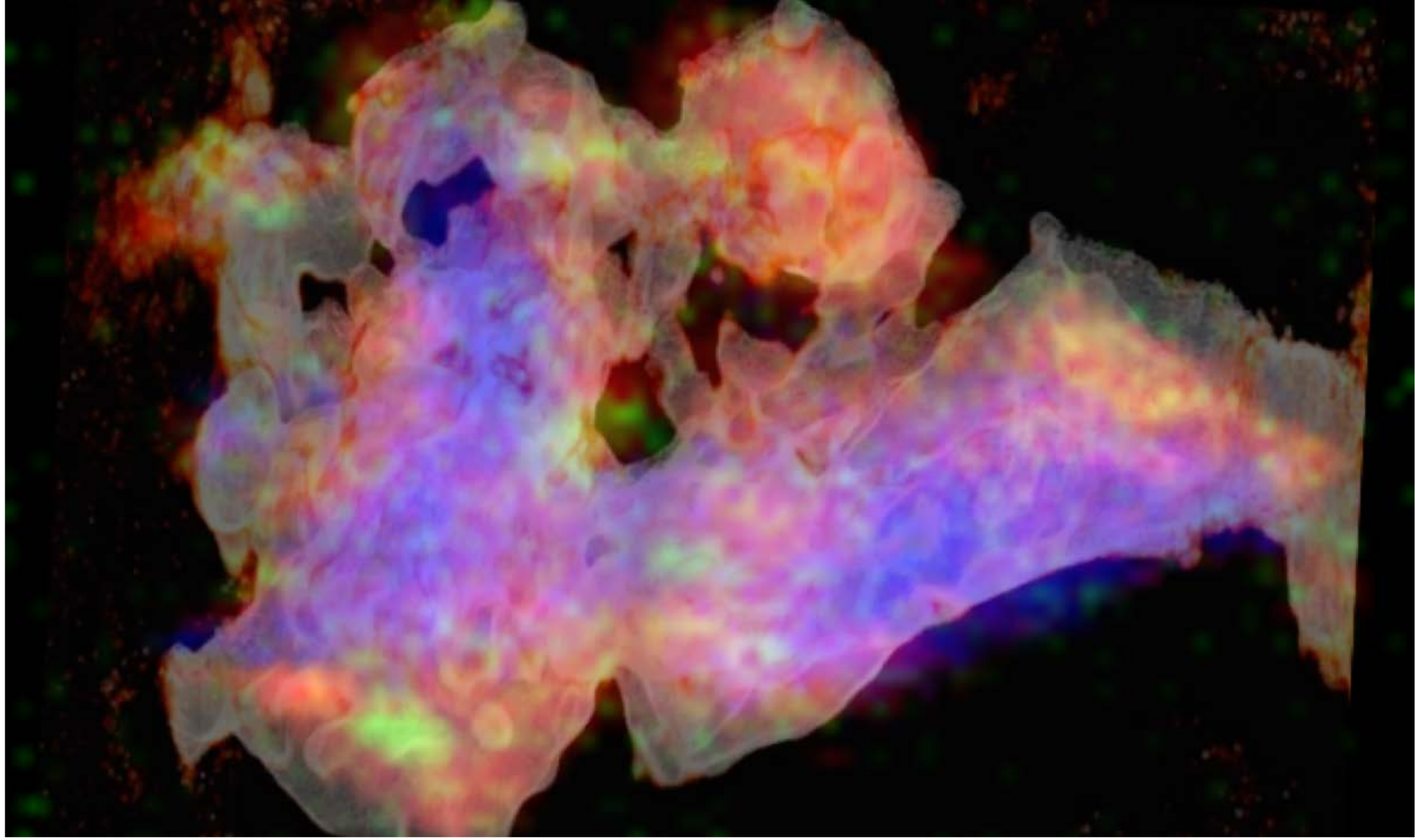
FCA Brasil
SOLUÇÕES PARA VÁCUO: PROJETO, FABRICAÇÃO E MANUTENÇÃO

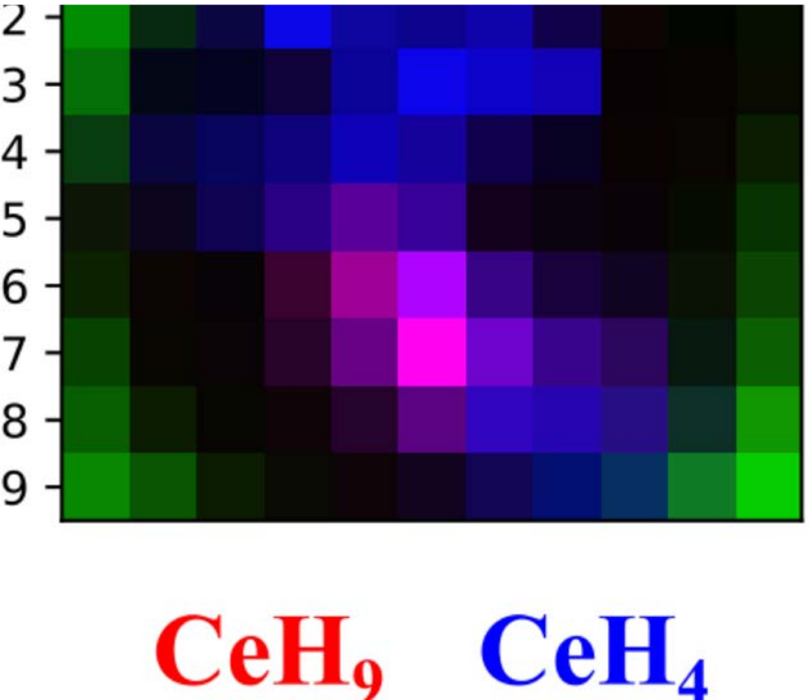








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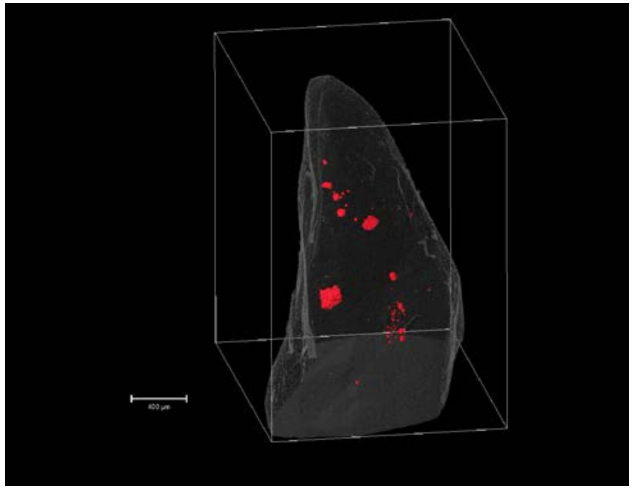
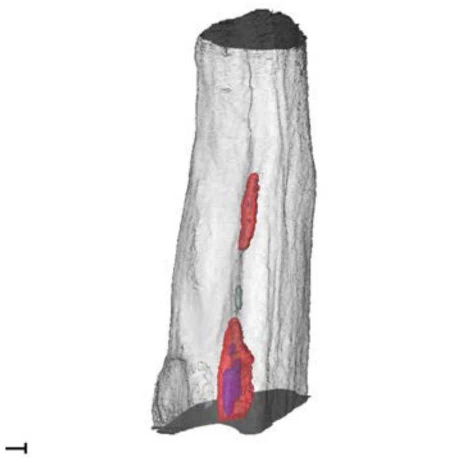
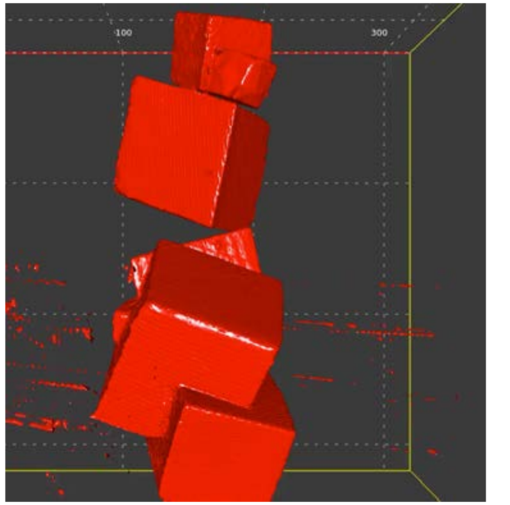
7
8
9
CeH_9 CeH_4

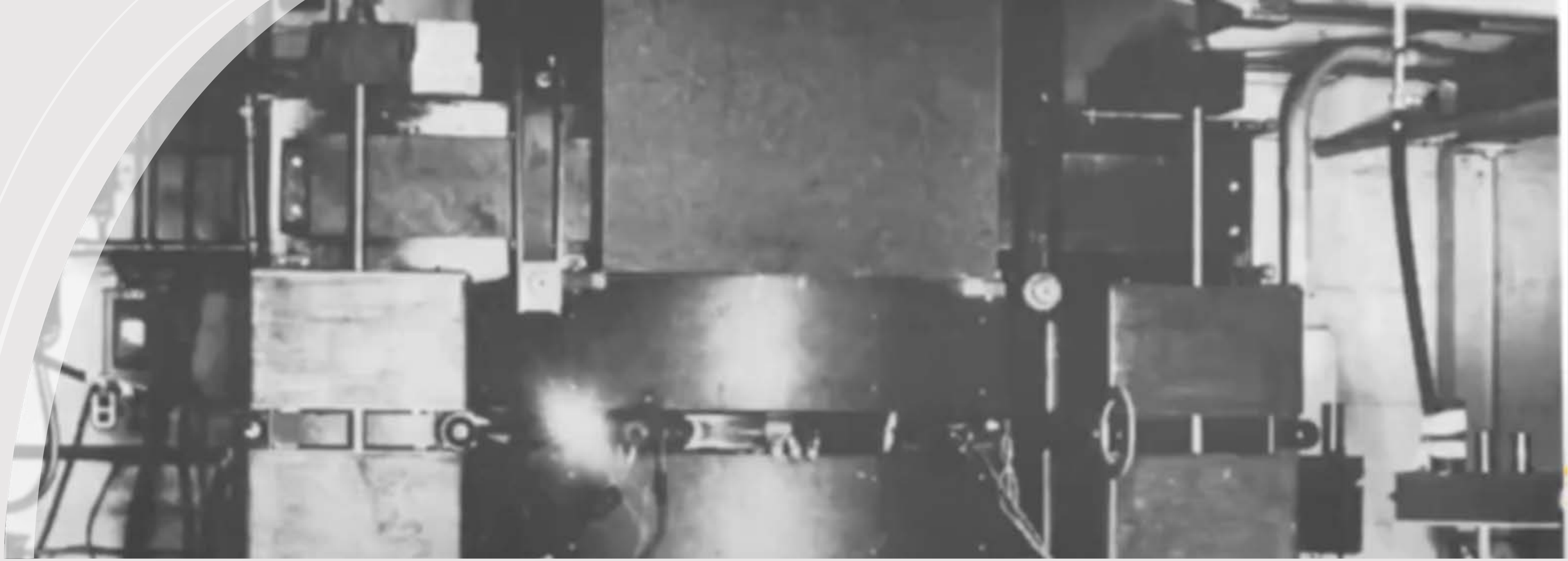





100
300

Training schools and Workshops

https://cnpem.br/events/#top



Homenagem ao professor

RICARDO RODRIGUES

1951 - 2020