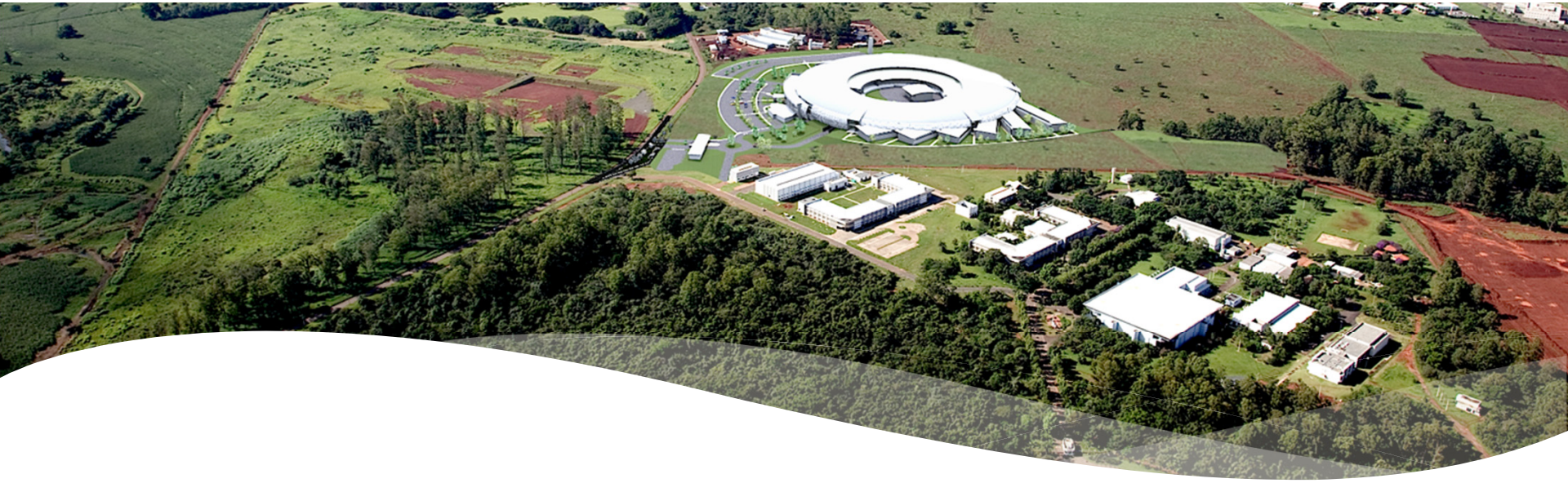

Commissioning of the Open Source Sirius BPM Electronics

Daniel de Oliveira Tavares

on behalf of the LNLS Beam Diagnostics Group

September 11, 2018

7th International Beam Instrumentation Conference (IBIC 2018), September 9th - 13th .

CNPEM
Centro Nacional de Pesquisa em Energia e Materiais

Outline

- **Sirius Light Source Status**
- **Sirius BPM Electronics Overview**
- **Manufacturing**
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  - System Integration and Failures
- **Issues found**
- **Achieved Performance**
  - Measurement Resolution
  - Beam Current Dependence
  - Long-term Drift
- **Next Steps**
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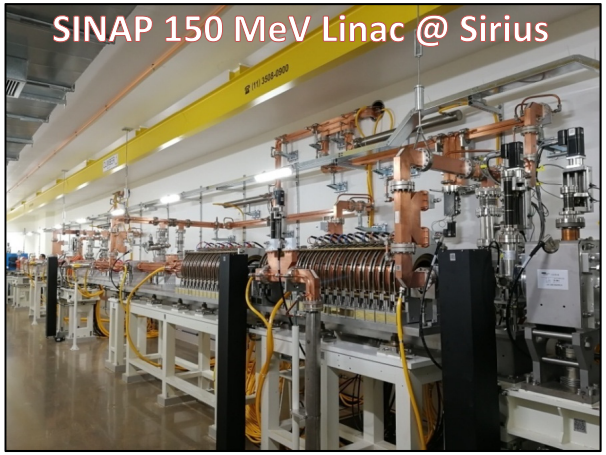
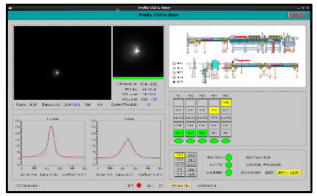
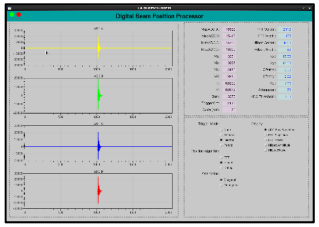
Sirius – new 4th generation light source in Brazil

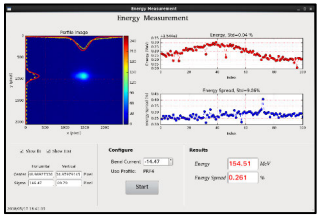
Sirius – new 4th generation light source in Brazil

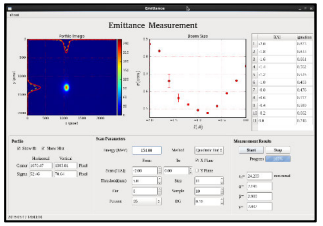
Sirius – new 4th generation light source in Brazil

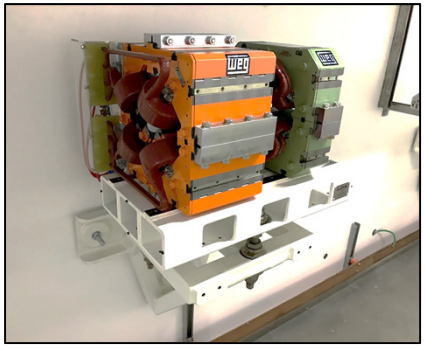












Booster and LTB transfer line in final installation phase →

Simultaneous installation of Storage Ring

← Turn-key LINAC was successfully commissioned in April-May 2018 together with SINAP team

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Sirius BPM Electronics Overview

BPM Rack Front View

BPM Rack Rear view

Proceedings of IBIC2013, Oxford, UK — MOPC09

DEVELOPMENT OF THE SIRIUS RF BPM ELECTRONICS

D. O. Tavares#, R. A. Baron, F. H. Cardoso, S. R. Marques, J. L. B. Neto, L. M. Russo, LNLS, Campinas, SP, Brazil
A. P. Byszuk, G. Kasprowicz, A. J. Wojeński, Warsaw University of Technology, Warsaw, Poland

WECOCB07 — Proceedings of ICALEPCS2013, San Francisco, CA, USA

DEVELOPMENT OF AN OPEN-SOURCE HARDWARE PLATFORM FOR SIRIUS BPM AND ORBIT FEEDBACK

D. O. Tavares#, R. A. Baron, F. H. Cardoso, S. R. Marques, L. M. Russo, LNLS, Campinas, Brazil
A. P. Byszuk, G. Kasprowicz, A. J. Wojeński, Warsaw University of Technology, Warsaw, Poland

WEPC07 — Proceedings of IBIC2013, Oxford, UK

DEVELOPMENT OF THE RF FRONT END ELECTRONICS FOR THE SIRIUS BPM SYSTEM

R. A. Baron, F. H. Cardoso, J. L. B. Neto, S. R. Marques, LNLS, Campinas, Brazil
J.-C. Denard, SOLEIL, Paris, France

Proceedings of IBIC2014, Monterey, CA, USA — WECYB3

STATUS OF THE SIRIUS RF BPM ELECTRONICS

S. R. Marques#, R. A. Baron, G. B. M. Bruno, F. H. Cardoso, L. A. Martins, J. L. Brito Neto, L. M. Russo, D. O. Tavares, LNLS, Campinas, SP, Brazil

THDAPLCO03 — Proceedings of PCaPAC2016, Campinas, Brazil

GATEWARE AND SOFTWARE FRAMEWORKS FOR SIRIUS BPM ELECTRONICS

L. M. Russo*, J. V. F. Filho, LNLS, Campinas, SP, Brazil

Proceedings of PCaPAC2016, Campinas, Brazil — THHWPLCO04

OPEN HARDWARE EXPERIENCE ON LNLS' BEAM DIAGNOSTICS

G. B. M. Bruno*, D. O. Tavares, H. A. Silva, F. C. Sant'Anna, J. L. Brito Neto, L. M. Russo, L. A. Martins, S. R. Marques
LNLS, Campinas, Brazil

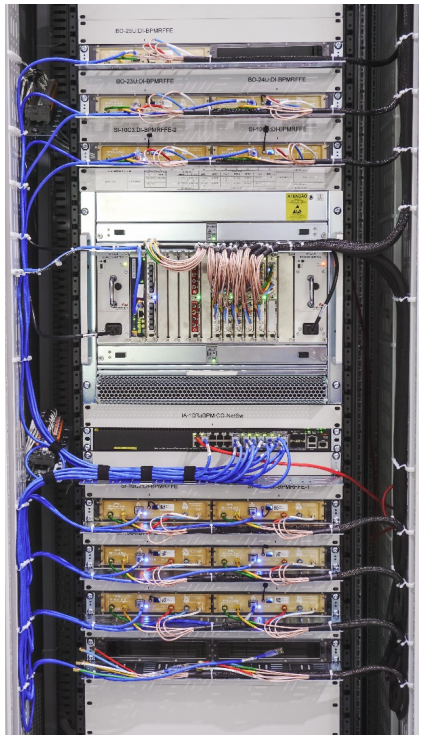
16th Int. Conf. on Accelerator and Large Experimental Control Systems — ICALEPCS2017, Barcelona, Spain — JACoW Publishing
ISBN: 978-3-95450-193-9 — doi:10.18429/JACoW-ICALEPCS2017-THPHA149

SOFTWARE AND GATEWARE DEVELOPMENT FOR SIRIUS BPM ELECTRONICS USING A SERVICE-ORIENTED ARCHITECTURE

L. M. Russo*, LNLS, Campinas, SP, Brazil

Sirius BPM Electronics Overview

BPM Rack Front View



RFFE Modules

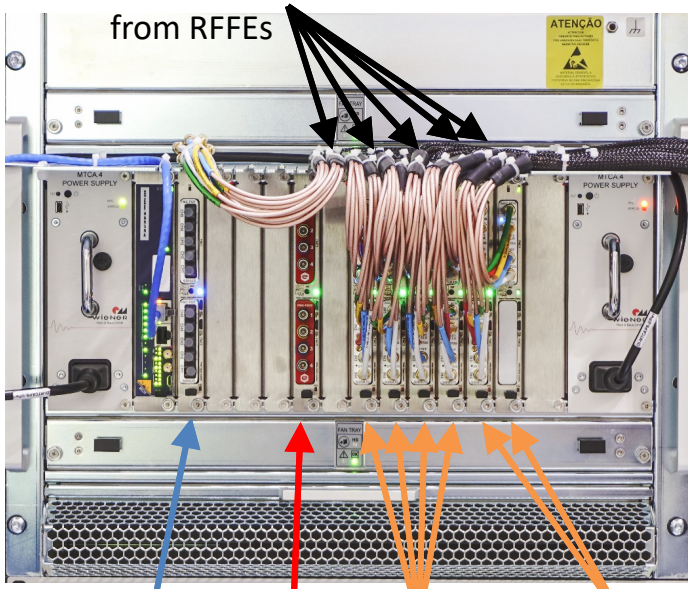
MicroTCA.4 crate

Ethernet switch

RFFE Modules

BPM Rack Rear view

RF Cables from RFFEs



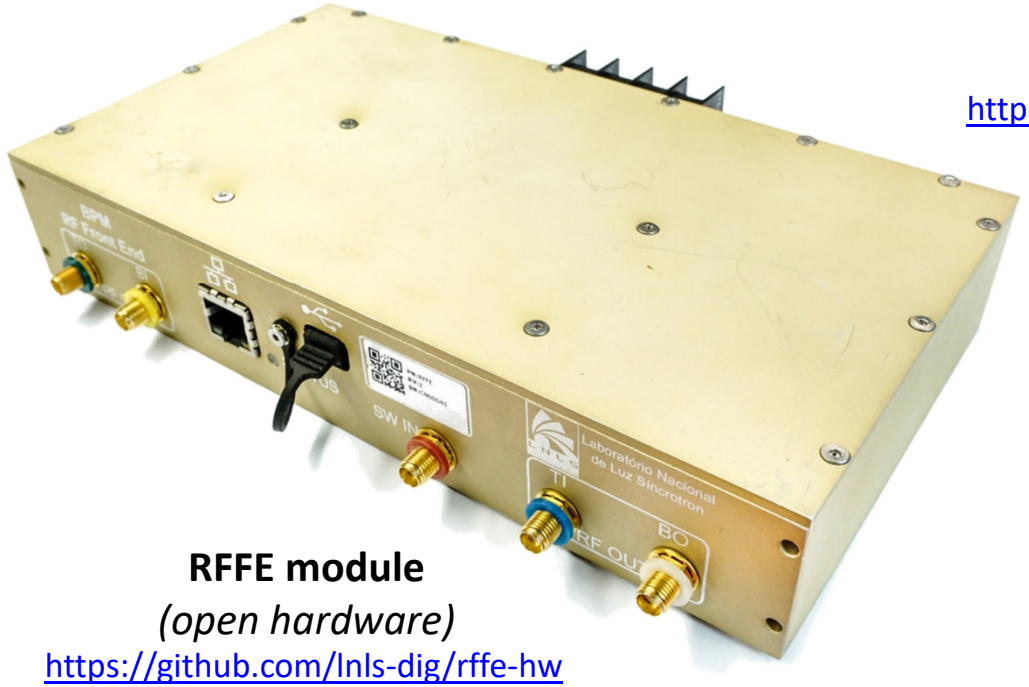
Timing event receiver

Storage Ring RF digitizers

Booster RF digitizers

XBPM digital picoammeters (I/O modules by CAENels)

Hardware modules



RFFE module

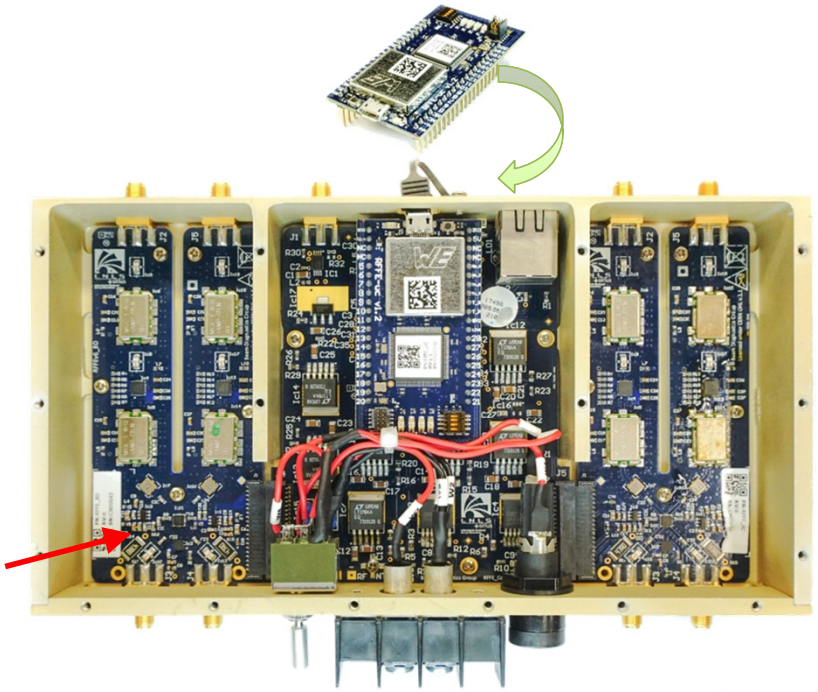
(open hardware)

https://github.com/lnls-dig/rffe-hw

RFFE-uC

(open hardware)

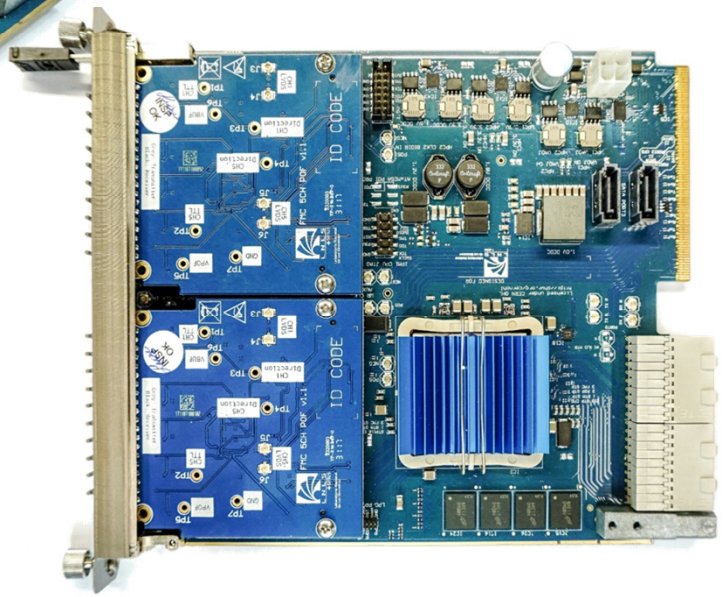
https://github.com/lnls-dig/rffe-uc-hw



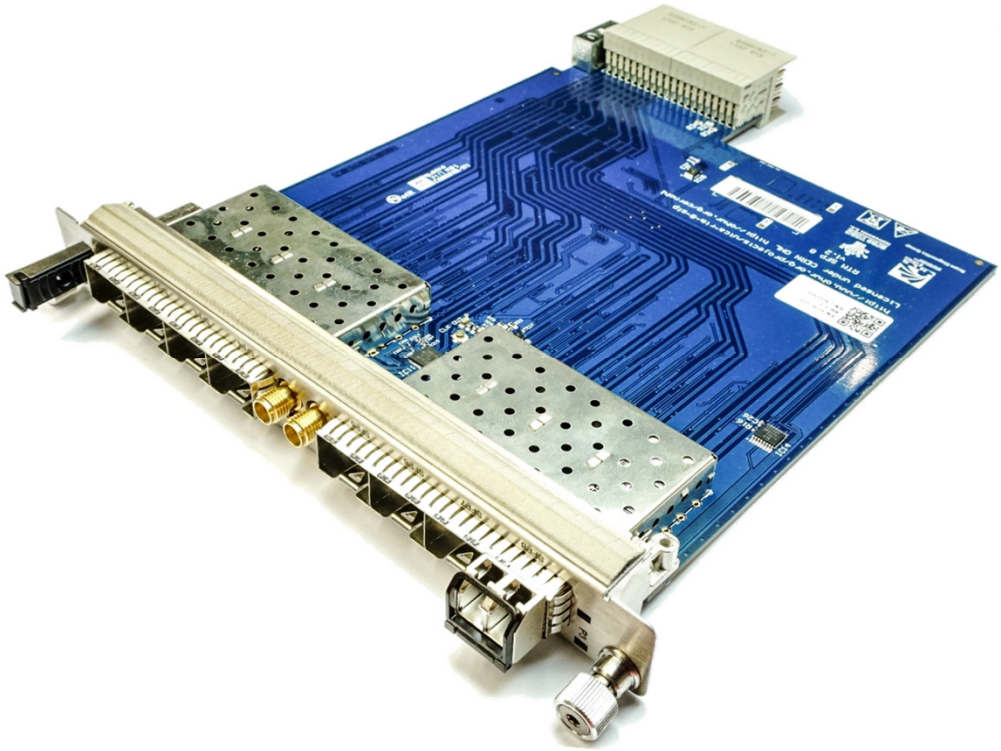
2x2 RF channel switching for gain drift compensation

Hardware modules

AMC FMC Carrier (AFC)
MicroTCA.4 FPGA board
(open hardware)
https://www.ohwr.org/projects/afc



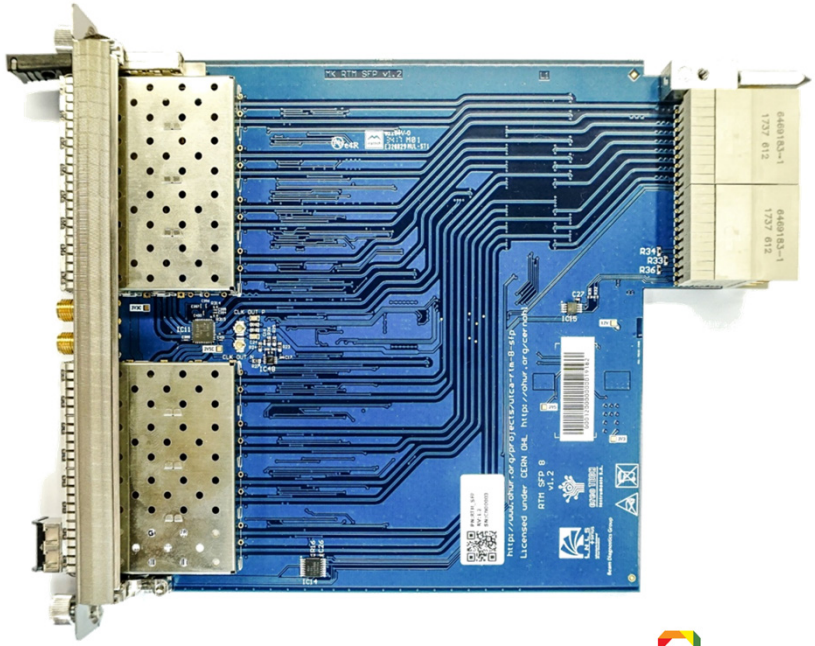
Hardware modules



MicroTCA RTM 8 SFP

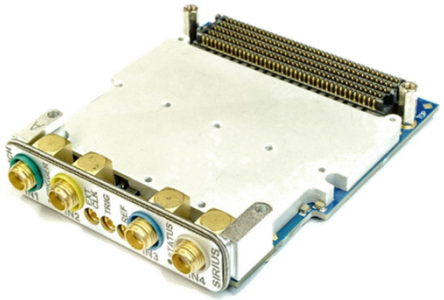
(open hardware)

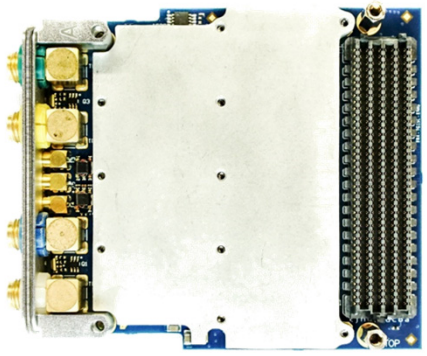
https://github.com/lnls-dig/utca-rtm-8-sfp-hw



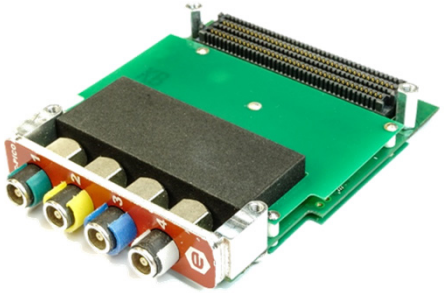
Hardware modules

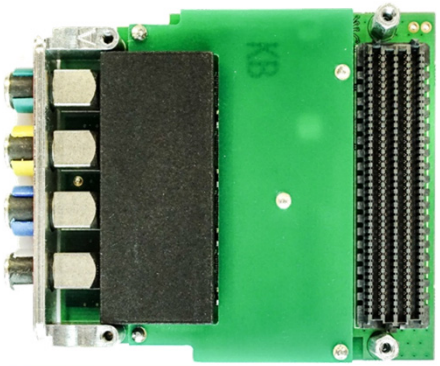
FMC ADC 250 MS/s 16-bit 4-channel
(open hardware)
https://github.com/lnls-dig/fmc250-hw



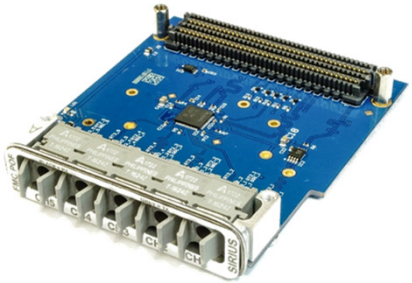


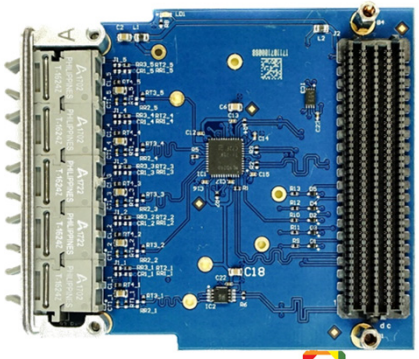
FMC-Pico-1M4
(by CAENels)



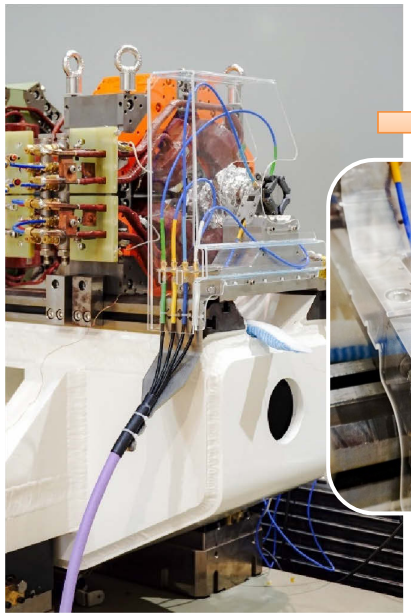


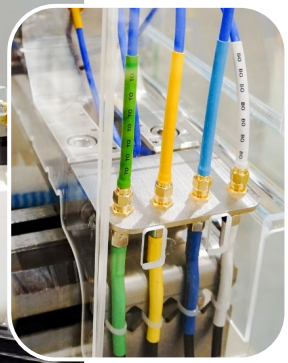
FMC POF 5-channel
(open hardware)
https://github.com/lnls-dig/fmc-5POF-hw





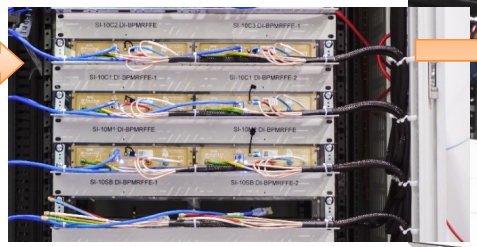
Sirius BPM Electronics Overview - Cables



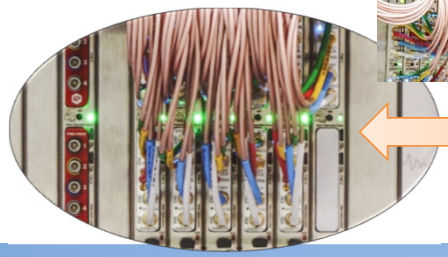


Semi-rigid coaxial cables
Pick-up → Patch panel
0.5 meter

Long Coaxial Cables
4 delay-matched LMR195 extruded within a common encapsulation
Patch panel → RFFE input
25 m – 70 m



Intra Rack Cables
Double shielded RG316
RFFE output → Digitizer
2 meters



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Manufacturing – Selection and Procurement

Sirius qualifies suppliers for the high-tech market

May 02, 2018

Brazilian firms are developing equipment for the new synchrotron and acquiring the capabilities to be global suppliers. In São Paulo, FAPESP and FINEP selected 23 proposals submitted by 18 firms to develop components for Sirius (*photo: CNPEM*)

Cadservice (Brazil)

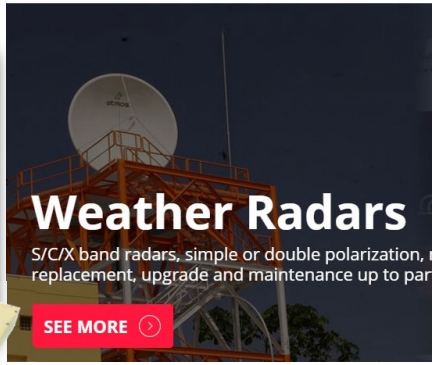
RFFE boards

Produza (Brazil)

FMC POF 5-ch

ATMOS Sistemas (Brazil)

System Integrator



creoTECH Instruments S.A.

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SPACE | SCIENTIFIC INSTRUMENTATION | CONTRACT MANUFACTURING | PRODUCTS

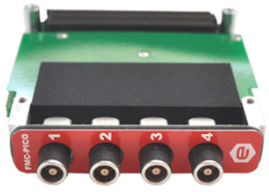
Creotech (Poland)

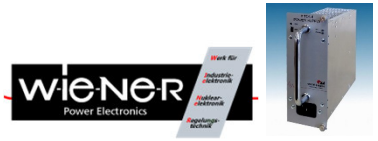
AMC, RTM and FMC

CAENels Gear For Science

FMC-Pico-1M4

4-channel 20-bit 1 MSPS FMC Floating Ammeter





Manufacturing – System Integration

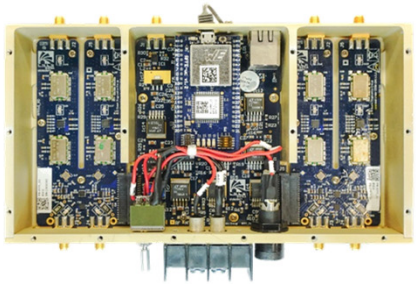
Individual boards testing

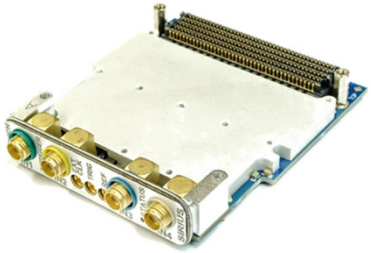
100-hour burn-in

Manufacturing – System Integration

Failure rate for different BPM equipment tested at ATMOS Sistemas

Equipment	Total	Rejected	Failure %
RFFE (RF boards)	520	20	3.8%
RFFE (Control board)	260	1	0.4%
AFC	175	7	4.0%
FMC ADC	257	11	4.3%
Intra-rack Cables	1180	14	1.2%



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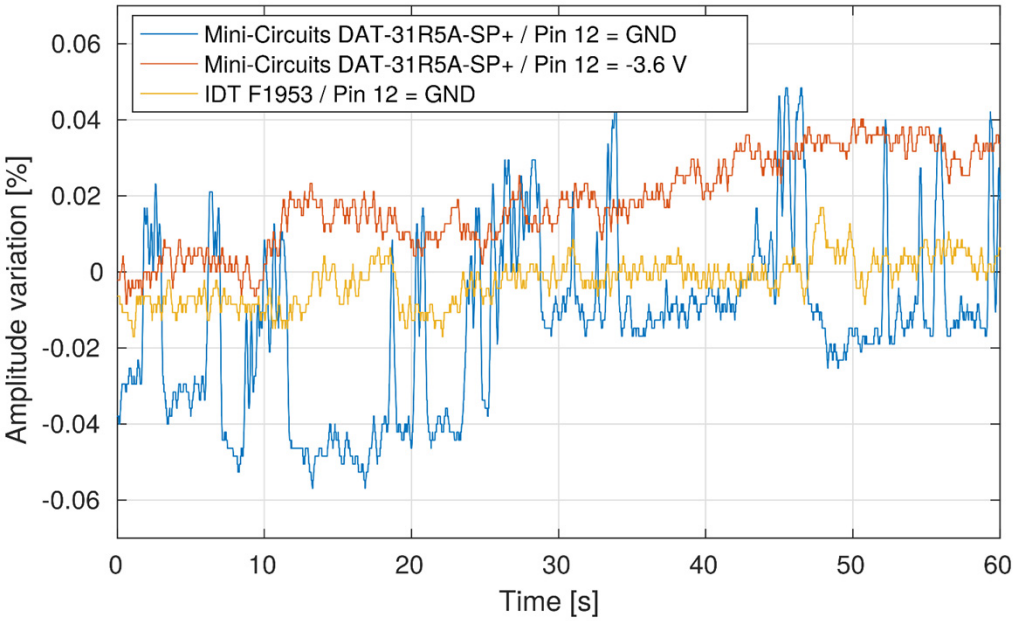
Issues Found (RFFE Attenuator)

Issue: random gain variations in the order of 0.05% on RF channels due to Mini-Circuits RF digital step attenuator issue.

Possible cure: replacement of attenuator by footprint-compatible device from another supplier (IDT).

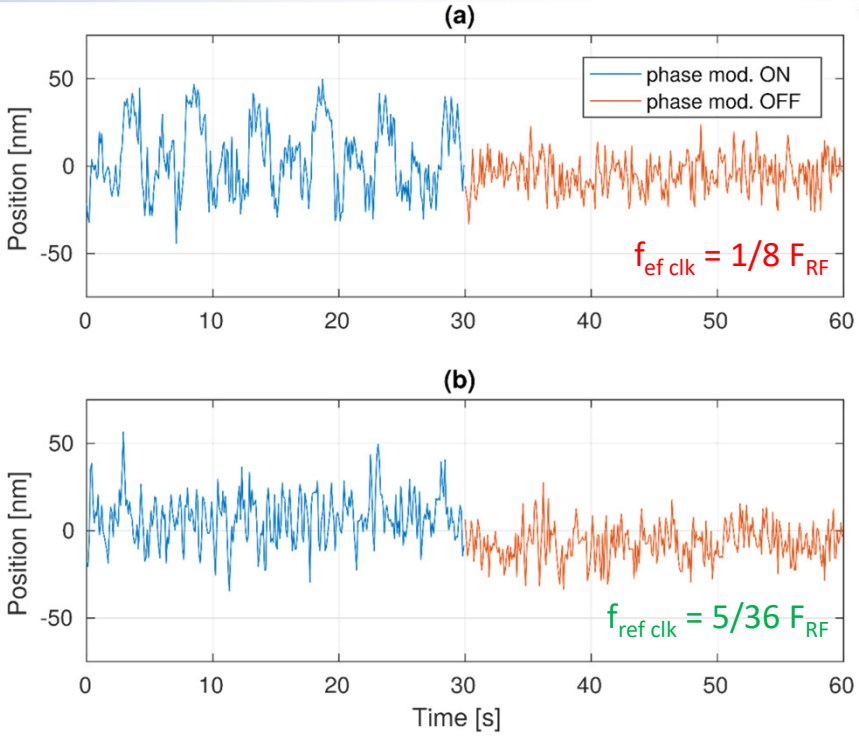


Attenuator gain behavior measured at zero span and 5 Hz resolution bandwidth. Mini-Circuits B14-TB-342 and IDT F1953EVBI evaluation kits were used.

Issues Found (EMI - Reference Clock Interference)

Issue: 8th harmonic of reference clock interfering with RF signals causing phase dependence of the position measurements

Cure: change the reference clock from 1/8 F_{RF} (62.5 MHz) to 5/36 F_{RF} (69.44 MHz) in order to avoid harmonics near at the RF frequency

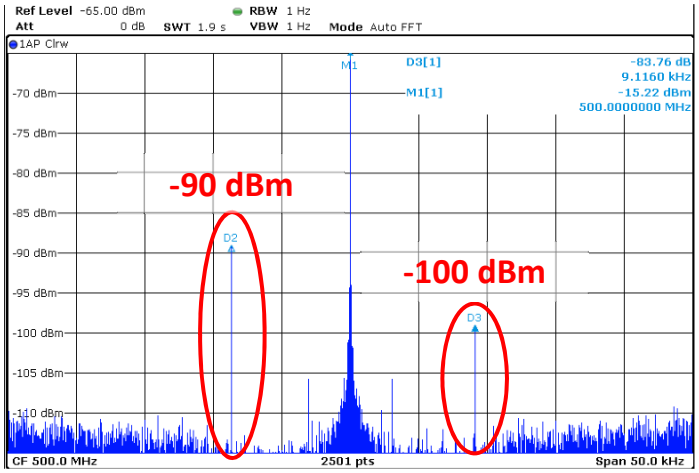


Position measurement variation caused by 5 Hz phase modulation in RF signal caused by reference clock intereference

Issues found (EMI - RFFE μC Ethernet PHY)

Issue: harmonics of microcontroller Ethernet 125 MHz clock recovery circuitry coupling to RF signals

commercial mbed microcontroller board



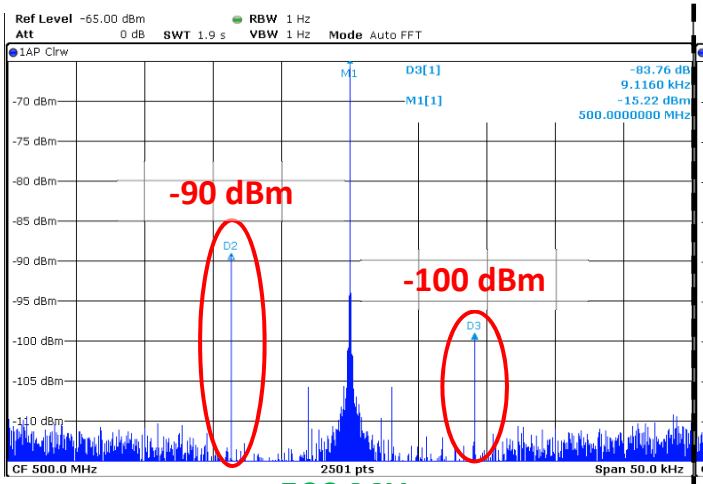
Issues found (EMI - RFFE μC Ethernet PHY)

Issue: harmonics of microcontroller Ethernet 125 MHz clock recovery circuitry coupling to RF signals

Cure: new microcontroller board designed to prevent EMI and providing spread-spectrum clock generator technique

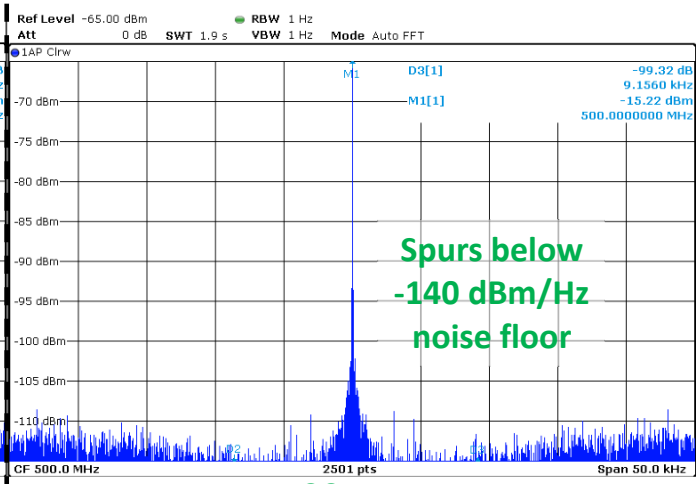
commercial mbed microcontroller board

open source RFFE-uC board designed at LNLS



500 MHz

50 kHz



500 MHz

50 kHz

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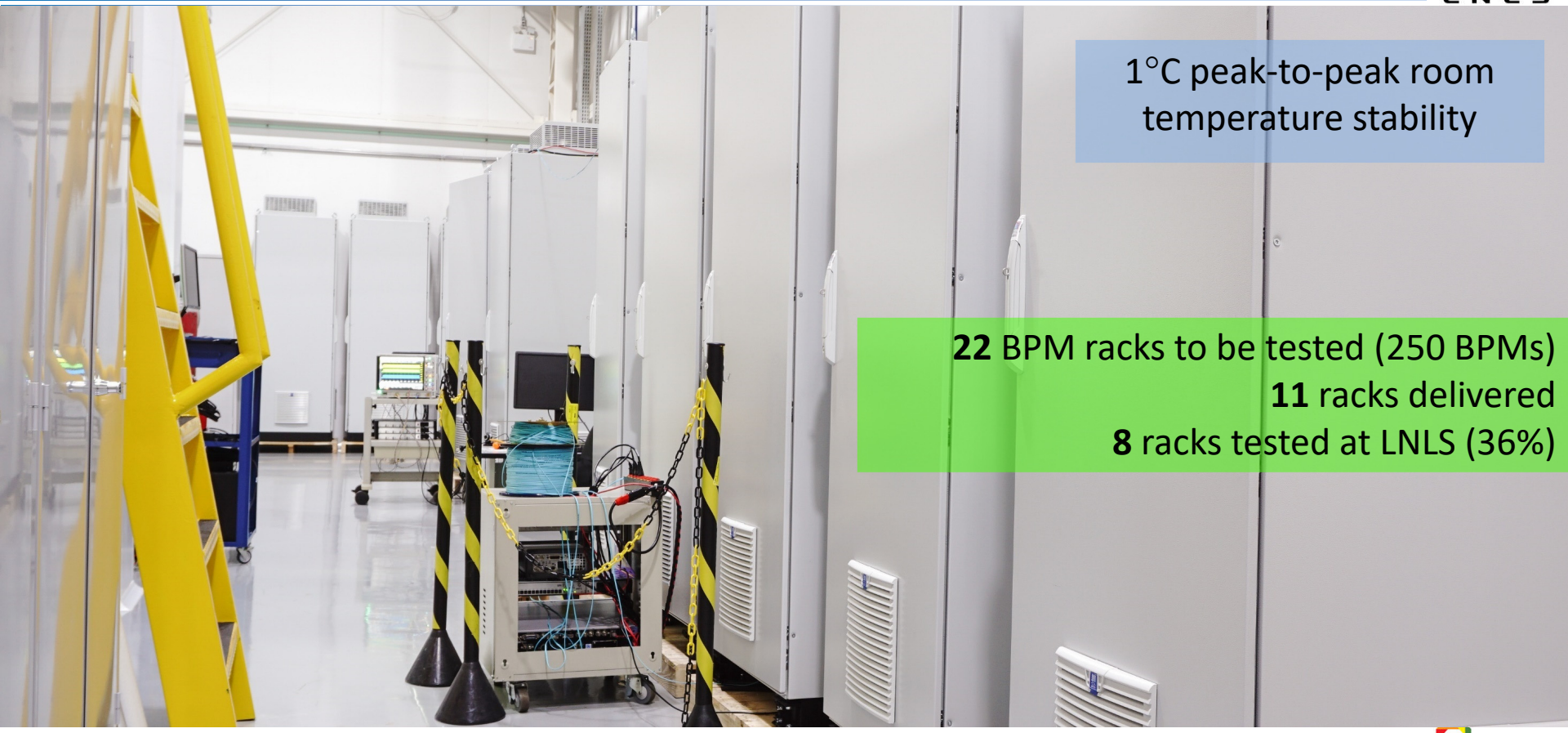
Performance tests setup

1°C peak-to-peak room temperature stability

Performance tests setup



1°C peak-to-peak room temperature stability

22 BPM racks to be tested (250 BPMs)
11 racks delivered
8 racks tested at LNLS (36%)

Performance tests setup

Movable testing rack

Timing and RF signals

- Fiber optics
- Ethernet switch
- AW signal generator Keysight 33500B
- SINAP Event Generator (EVG)
- R&S SMA100A RF signal generator

Inside the BPM rack

(not shown in the picture)

- 1x 1:16 splitter
- 13x 1:4 splitters (one per BPM)
- 1 dB and 2 dB attenuators → simulates 0.5 mm off-centered beam in both planes

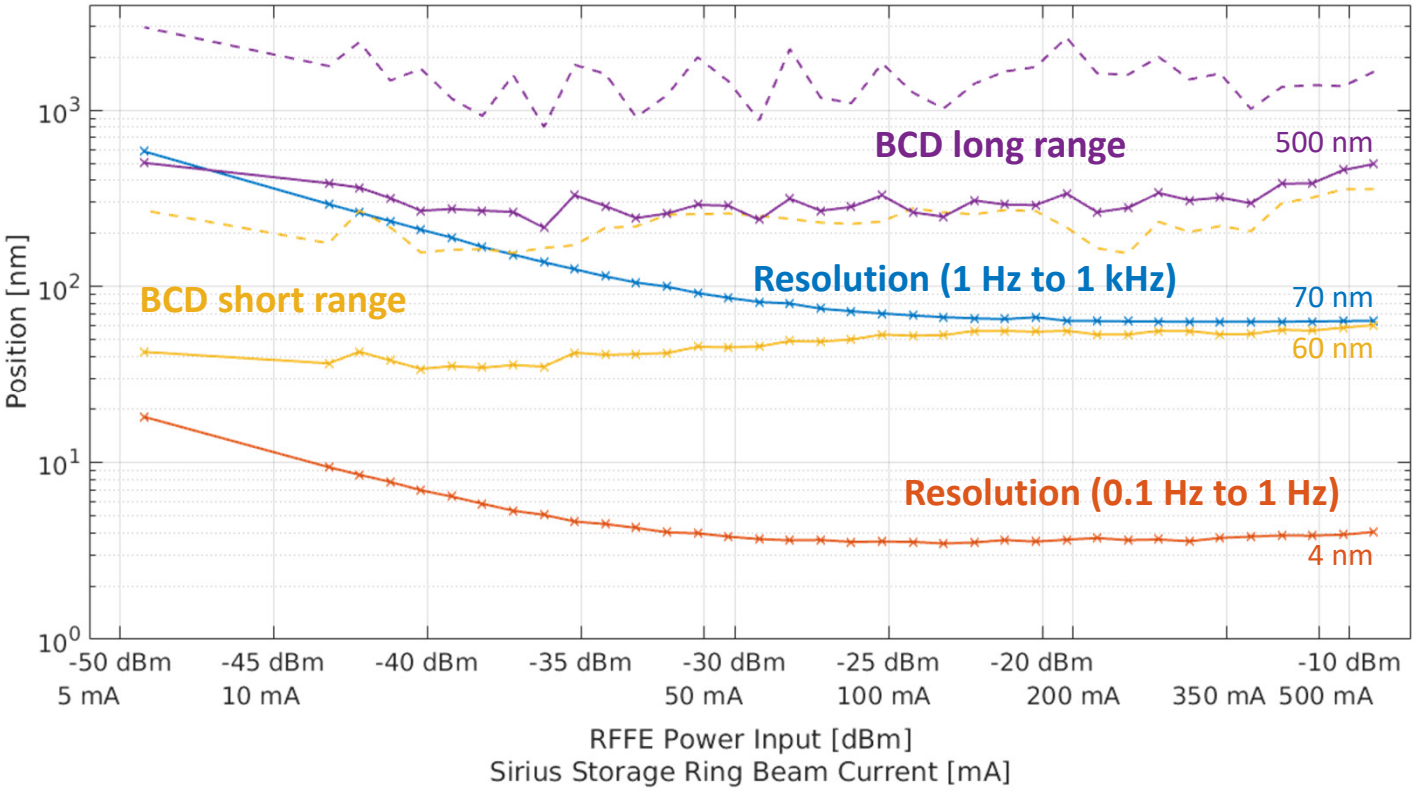
Achieved performance: Resolution and BCD

Beam current Dependence (BCD) vs. **Resolution** trade-off

Optimized for **BCD**: **-5.6 dBm** power level at ADC board input (8% of ADC full-scale)

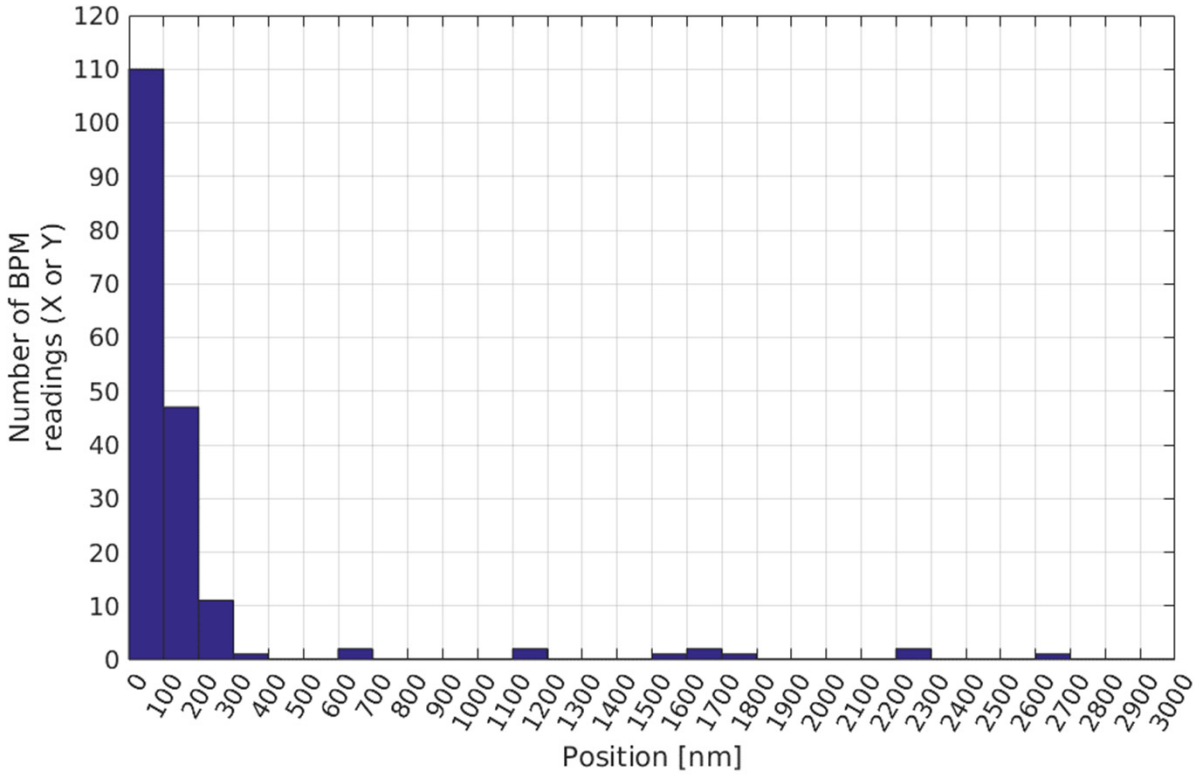
BCD long range
30% variation
(decay mode)

BCD short range
2% variation
(top-up)



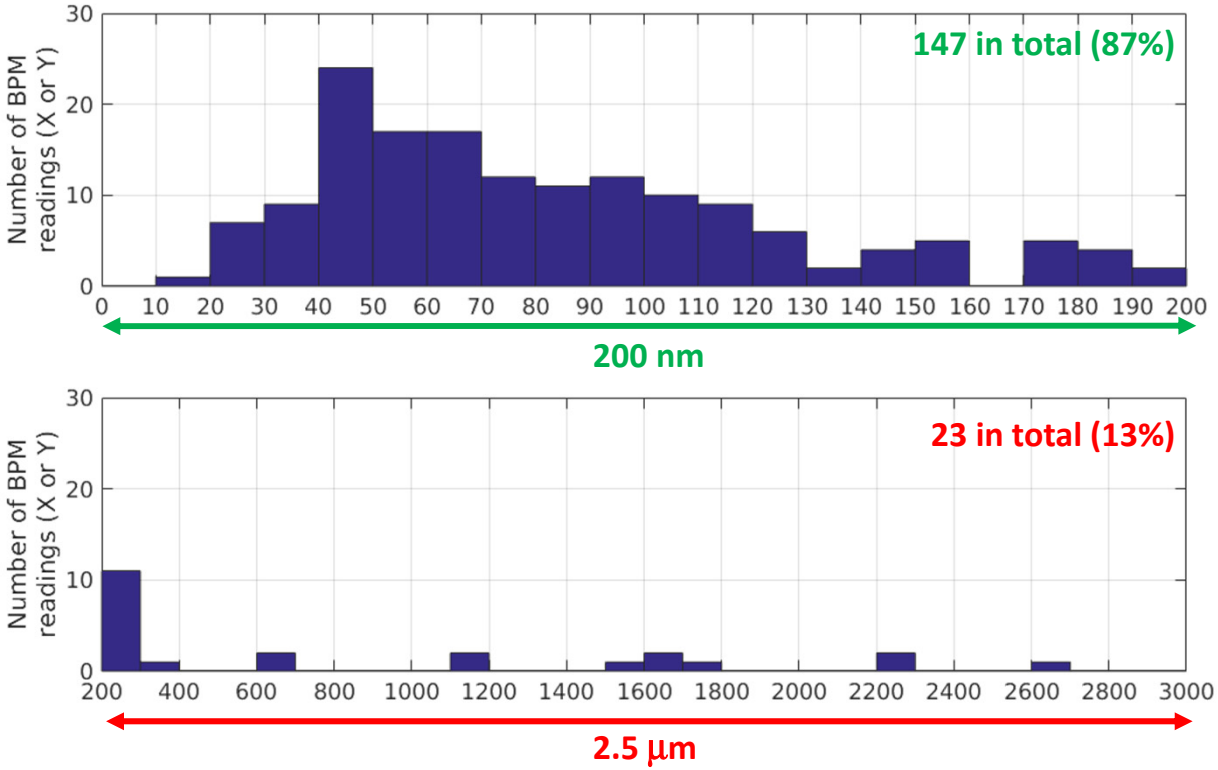
Achieved performance: Long-term Drift

- 90 tested BPMs (36%) – 180 BPM X and Y readings
- 8-hour peak-to-peak drift
- 1 minute sampling period (decimated from 10 Hz data stream)
- $K_X = K_Y = 10$ mm

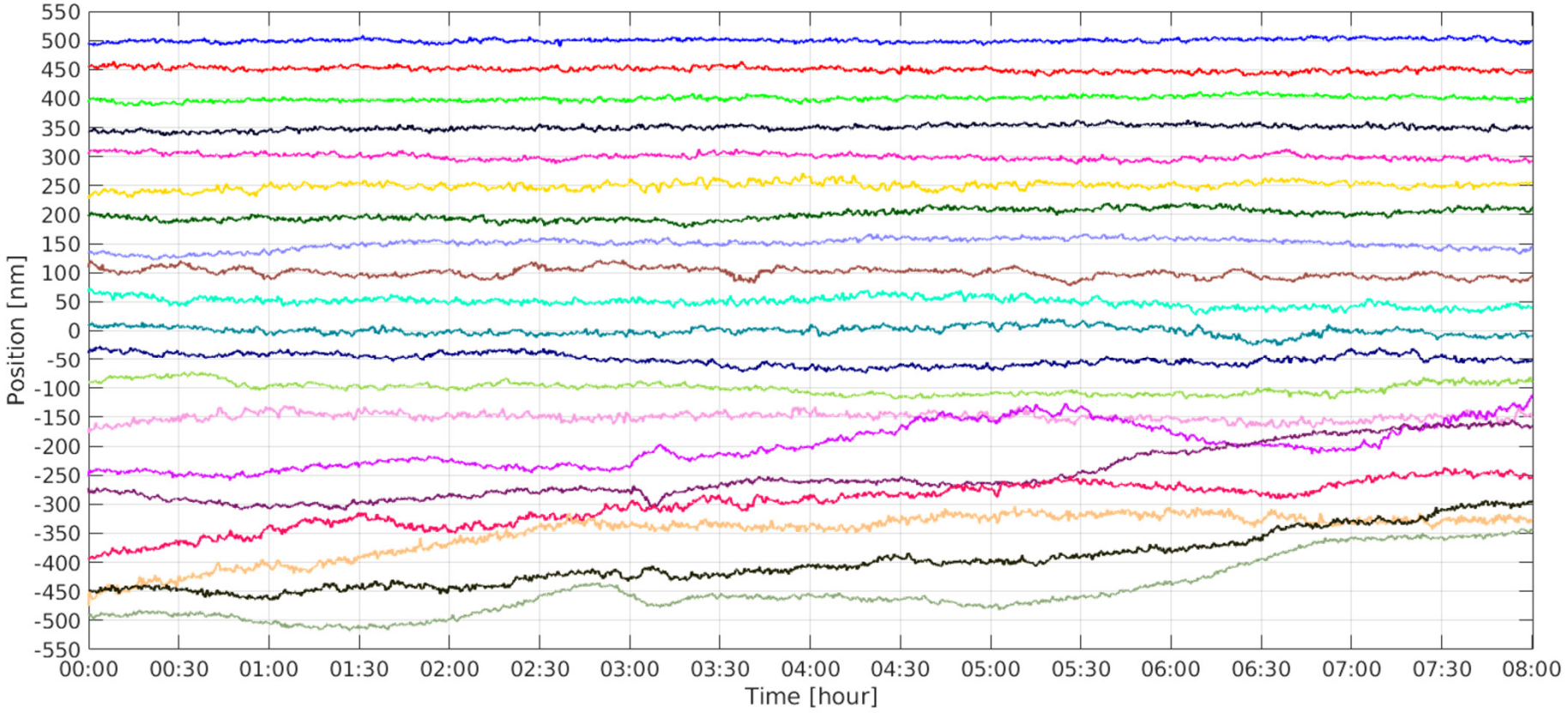


Achieved performance: Long-term Drift

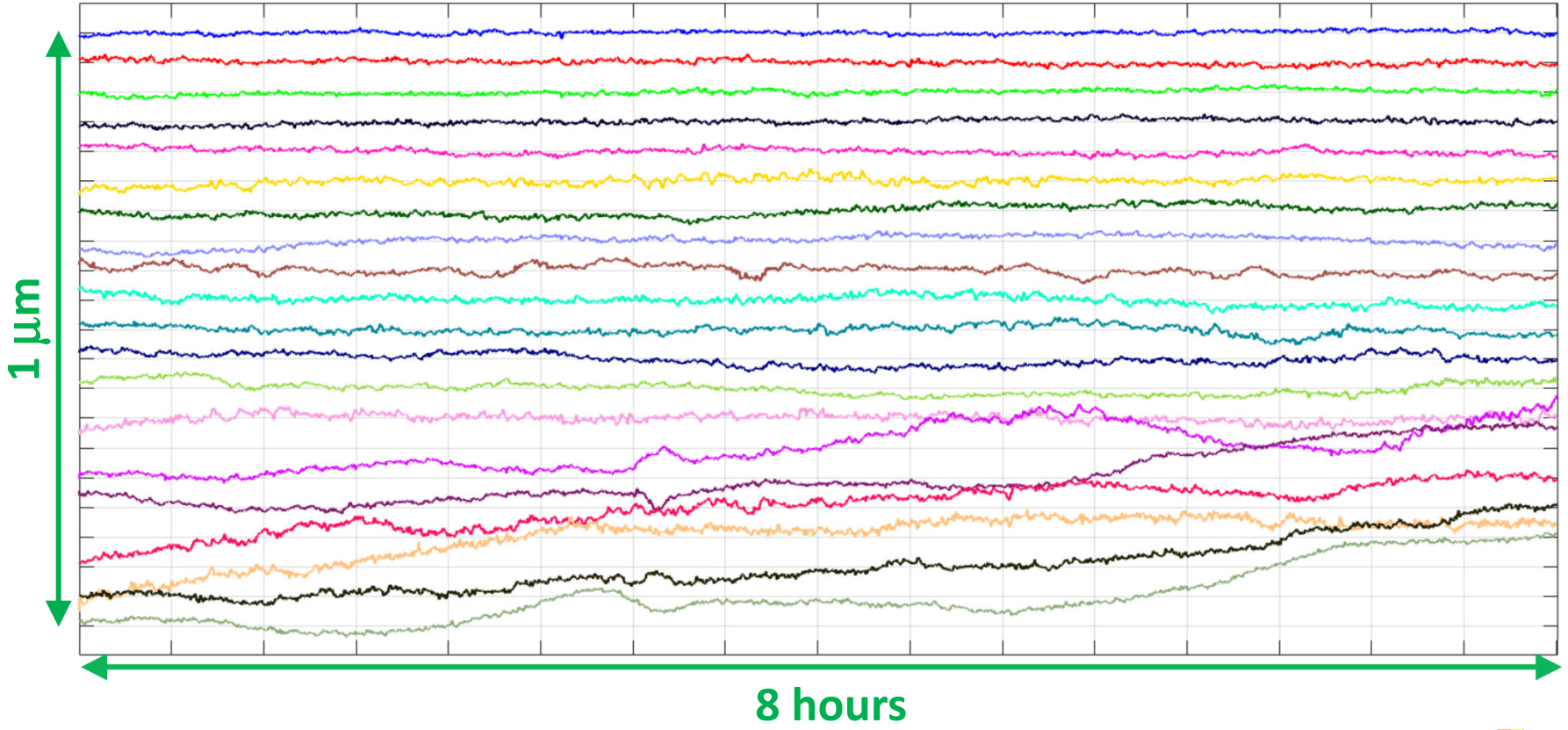
- 2 out-of-specification BPMs have defective RFFE modules
- The remaining out-of-specification BPMs are under investigation



Achieved performance: Long-term Drift



Achieved performance: Long-term Drift



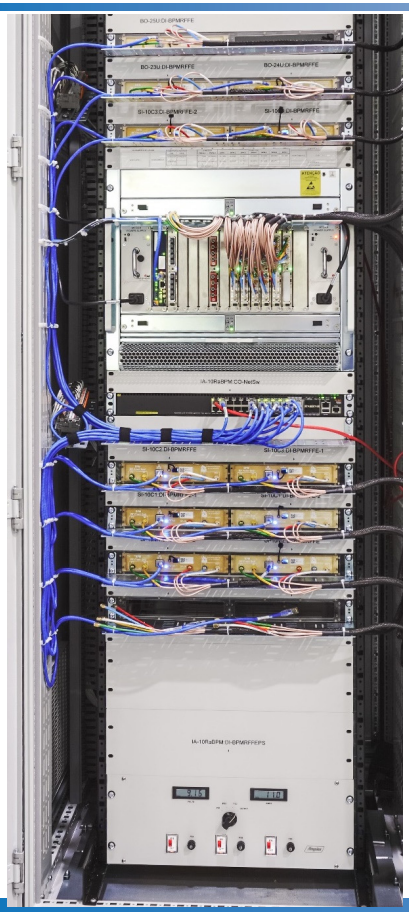
Outline

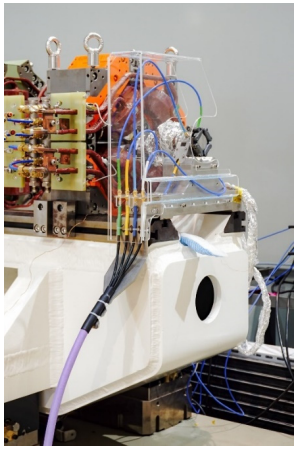
- Sirius Light Source Status
- Sirius BPM Electronics Overview
- Manufacturing
  - Manufacturer Selection and Procurement
  - System Integration and Failures
- Issues found
- Achieved Performance
  - Measurement Resolution
  - Beam Current Dependence
  - Long-term Drift
- **Next Steps**
- Conclusion

Next Steps

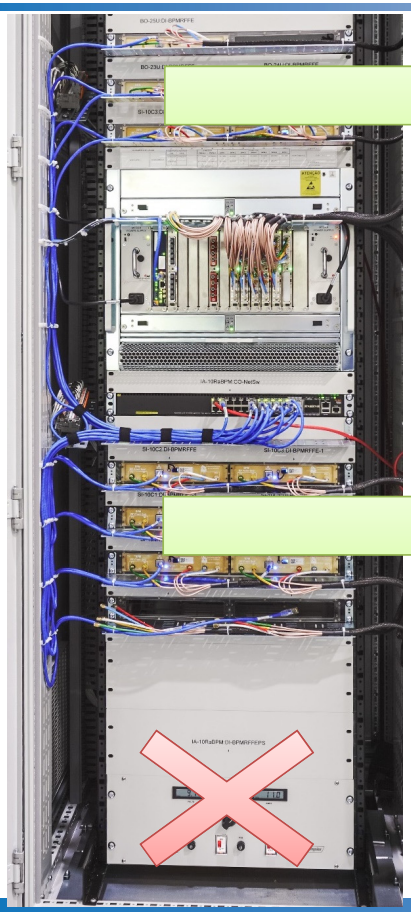
- Installation of BPM cables in tunnel and instrumentation rooms
- Commissioning with real beam signals before the end of 2018 (low energy transfer line and booster)
- MicroTCA.4 RTM Fast Orbit Corrector Power Supply design
  - 8-channel – 10 kHz bandwidth – maximum 1 A current (30 µrad)
  - Design validation board: https://github.com/lnls-dig/rtm-damp-dvb
  - Final design: https://github.com/lnls-dig/rtm-damp-hw (still to come)
- In the longer term: idea to compensate for drifts caused by the long coaxial cables…

Future plans – First idea

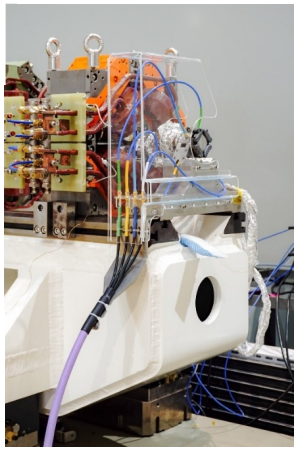




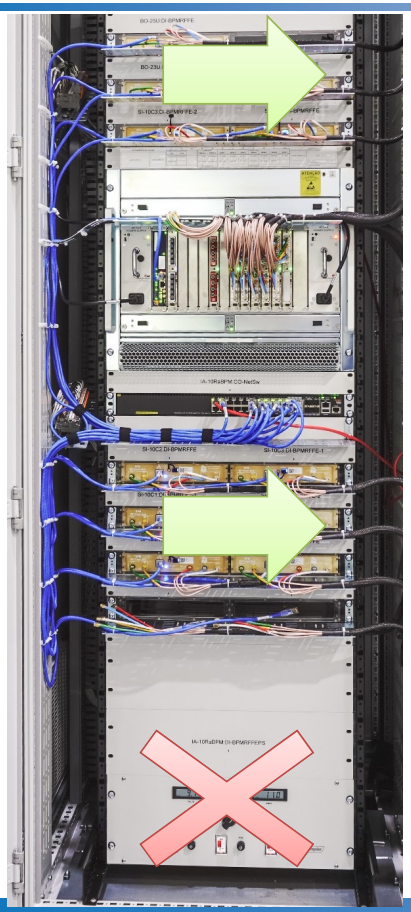
Future plans – First idea



Move RFFEs to the tunnel, close pick-ups

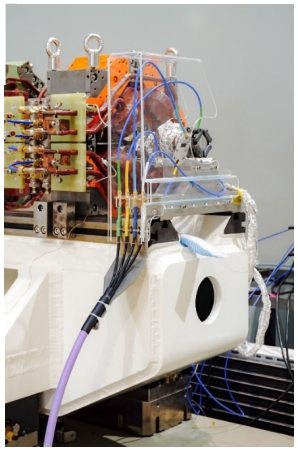


Future plans – First idea



Move RFFEs to the tunnel

- RF channels switching also compensates for long cables' drifts
- Reuse cables and digitizers
- Get RFFE power supply from already existing PoE Ethernet switch
- Redesign only RFFE control board – keep analog modules
- Challenges
  - Electronics inside the tunnel
  - Filtering high RF harmonics at the RFFE input



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Conclusion

- Sirius BPM Electronics is in its final stage of deployment - many issues were found and solved
- Main open issue: RFFE attenuator needs replacement
- Failure rates and achieved performance points to a smooth commissioning with real beam
- Modularity, adherence to industry standards and open hardware strategy lower the barriers for collaboration


Thank you for your attention!


IA-10RaBPM:CO-NetSw
SI-10C2:DI-BPMRFFE
SI-10C3:DI-BPMRFFE-1
SI-10C1:DI-BPMRFFE-1
SI-10C1:DI-BPMRFFE-2
SI-10M1:DI-BPMRFFE
SI-10SB:DI-BPMRFFE-1
SI-10SB:DI-BPMRFFE-2


ATENÇÃO
MTCA.4
POWER SUPPLY
FAN TRAY