



WP6B outlook on IT String Operation

Michele Martino – CERN
on behalf of WP6B



14th HL-LHC Collaboration Meeting – Genova – Italia – October 8th 2024

Brief summary of the installation steps



All WP6B equipment installed
but WCBs and 18kA crowbar
January 2024



Installation of WCBs
April 2024

First Commissioning Steps

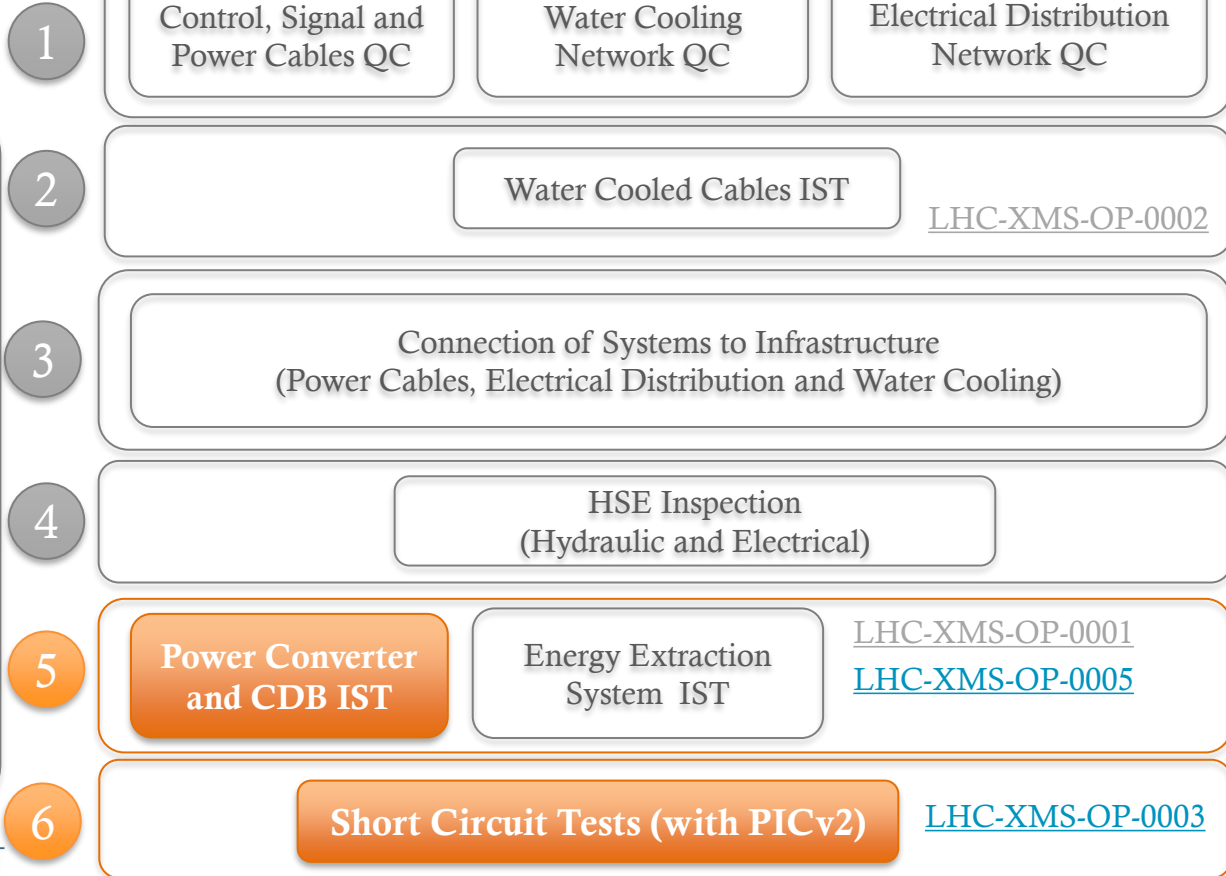
Results

[“IST and SCT in the IT String: results”](#)

by S. Yammine – WP16
Parallel Session –
Wednesday October
9th – 11:30

[“Experience with WP6B equipment operation in the HL-LHC IT String”](#)

by H. Thiesen – MCF
Parallel Session-
Thursday October
10th – 9:10



Lessons learnt

[“Experience with WP6B equipment operation in the HL-LHC IT String”](#)

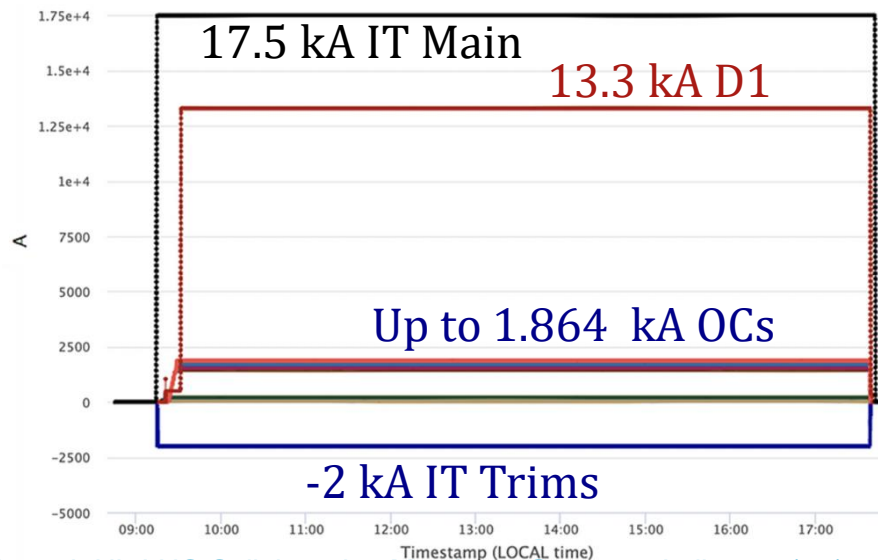
by H. Thiesen – MCF
Parallel Session-
Thursday October
10th – 9:10

+
Dedicated sessions
in WP15 in [May](#) and
[September](#) 2024

First Commissioning Steps

- Successful completion of ISTs and SCTs in May'24 with 8h Heat Run at Ultimate Currents _{or beyond} ✓ when “boring” Marta Bajko words is good news
- 18kA RPAFE proto tested for the first time in IT String
- Tests included all WP6B equipment with short circuits implemented by means of the dedicated CLs mock-up put in place by WP16

A big thank you to all teams involved in WP6B and other WPs !



Courtesy of Marta Bajko (TE-MPE/WP16)

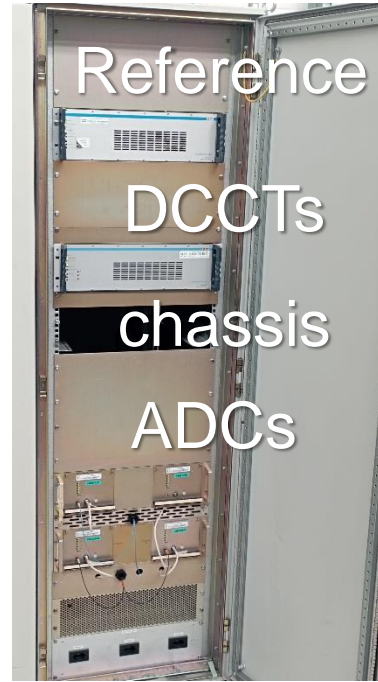
Status of WP6B IT String equipment

- 18kA IT main – RPAFE **x1**
 - IT String **baseline** configuration: **prototype** [it does not go into HL-LHC URs in LS3]
 - 10 proto subs (each composed by **1x** Input, **1x** Output, **1x** ESS, **2x** DC/DC 1kA modules)
 - 2 pre-series Class 0 DCCTs heads mounted in RPAFE rack, chassis mounted in measurement rack RYABC
 - 2 (external) pre-series Class 0 ADCs HPM-7177s mounted in measurement rack RYABC
 - 1 pre-series crowbar ($E \leq 42$ MJ, diode-based, several modules)
 - **Δ**Configuration during ISTs and SCTs
 - 1 pre-series Class 0 DCCT chassis ok, head not fully Class 0 compliant
 - 1 (external) pre-series Class 0 ADCs HPM-7177s mounted in measurement rack RYABC
 - **no crowbar** : not needed for ISTs and SCTs, racks to house the modules are in place
 - **Δ**Configuration today at IT String
 - **no subs** : the power modules are now in the 1st series frame in B.377 for full testing

Status of WP6B IT String equipment

- 14kA D1 – RPAFF **x1**
 - IT String **baseline** configuration: **prototype** [it does not go into HL-LHC URs in LS3]
 - 8 proto subs (each composed by **1x** Input, **2x** Output modules)
 - 2 pre-series Class 0 DCCTs heads mounted in RPAFF rack, chassis mounted in measurement rack RYABC
 - 2 (external) pre-series Class 0 ADCs HPM-7177s mounted in measurement rack RYABC
 - 1 proto diode-based crowbar (3 independent free-wheeling paths)
 - **Δ**Configuration during ISTs and SCTs
 - **7** operational proto subs : the 8th proto sub needs repairing
 - **1** pre-series Class 0 DCCT chassis ok, **head not fully Class 0 compliant**
 - **1** (external) pre-series Class 0 ADCs HPM-7177s mounted in measurement rack RYABC
 - **Δ**Configuration today at IT String
 - **no subs** : the power modules are now in B.377 for full testing

Status of WP6B IT String equipment



Status of WP6B IT String equipment

- 2kA IT Trims – RPBAF **x2**
 - IT String **baseline** configuration: **pre-series**
 - 6 pre-series subs (rated 400A)
 - 2 pre-series Class 2 DCCTs_{heads and chassis both mounted in RPBAF rack}
 - 2 (external) pre-series Class 0 ADCs_{HPM-7177s mounted in RPBAF rack}
 - 1 pre-series diode-based crowbar
 - **Δ**Configuration during ISTs and SCTs
 - 1 temporary DCCT_{SY-EPC spare – head and chassis mounted in RPBAF rack}
 - 0 (external) pre-series Class 0 ADCs, using FGC3.1 **internal ADC** (ANA103) instead
 - **Δ**Configuration today at IT String
 - one of the two RPBAF is fully equipped, the temporary DCCT chassis of the other one has been de-installed
 - **water distribution** already **improved*** although strictly needed only in the URs 😊

*: 195th TCC – M. Martino - [Technical update WP6B](#) – 24/05/2024

Status of WP6B IT String equipment

- 2kA Orbit Correctors – RPBAE **x6**
 - IT String **baseline** configuration: **pre-series**
 - 6 pre-series subs (rated 400A)
 - 2 pre-series Class 2 DCCTs heads and chassis both mounted in RPBAE rack
 - 2 (external) pre-series Class 0 ADCs HPM-7177s mounted in RPBAE rack
 - 1 pre-series thyristor-based crowbar
 - **Δ**Configuration during ISTs and SCTs
 - **1** temporary DCCT SY-EPC spare – head and chassis mounted in RPBAE rack
 - **0** (external) pre-series Class 0 ADCs, using FGC3.1 **internal ADC** (ANA103) instead
 - **Δ**Configuration today at IT String
 - one of the six RPBAE is fully equipped, the temporary DCCT chassis of the other five have been de-installed
 - **water distribution** already **improved** although strictly needed only in the URs 😊

*: 195th TCC – M. Martino - [Technical update WP6B](#) – 24/05/2024

Status of WP6B IT String equipment

- 200A SF 2nd order Corrector – RPMBG **x1**
 - IT String **baseline** configuration: **series**
 - as operational R2E-LHC-600A-10V units, but special EES in HL-LHC grounded at mid-EES
 - Class 3 accuracy performance of rating = 600A
 - **Δ**Configuration during ISTs and SCTs
 - no discrepancies
 - it requires a series inductance to safely perform SCTs (due to EES)*
 - **Δ**Configuration today at IT String
 - no discrepancies

Status of WP6B IT String equipment

- 120A SF HO Correctors – RPLBB **x8**
 - IT String **baseline** configuration: **spare LHC** [they don't go into HL-LHC URs in LS3]
 - as LHC-120A-10V units currently in operation in LHC
 - FGCLite Controller (as in the HL-LHC machine), Class 4 performance of rating = 120A
 - **Δ**Configuration during ISTs and SCTs
 - no discrepancies
 - **Δ**Configuration today at IT String
 - no discrepancies

Status of WP6B IT String equipment

- 35A Q1a Trim – RPLAD **x1**
 - IT String **baseline** configuration: **prototype** [it does not go into HL-LHC URs in LS3]
 - 2 proto subs (rated 60A)
 - 2 generic Class 4 DCCTs current output with RegFGC3 I2V conversion board
 - 2 (internal) FGC3.1 ADCs (ANA103)
 - 1 proto crowbar (**$I_{\text{peak}} = 3.5 \text{ kA}$** , thyristor-based)
 - **Δ**Configuration during ISTs and SCTs
 - no discrepancies
 - **Δ**Configuration today at IT String
 - no discrepancies

Status of WP6B IT String equipment

- CDBs 18kA **x2** 18kA and 14kA
 - IT String **baseline** configuration: (pre)series
 - Δ Configuration during ISTs and SCTs
 - no discrepancies
 - Δ Configuration today at IT String
 - no discrepancies
- CDBs 2kA **x8** and 600A **x2** 35A + warm diodes
 - IT String **baseline** configuration: (pre)series
 - Δ Configuration during ISTs and SCTs
 - no discrepancies
 - Δ Configuration today at IT String
 - no discrepancies
- WCBBs 18kA **x4** 18kA x2 and 14kA x2
 - IT String **baseline** : (pre)series
 - Δ Configuration during ISTs and SCTs
 - no discrepancies
 - WCPs do not comply yet in terms of electrical isolation
 - Δ Configuration today at IT String
 - no discrepancies
- Control Electronics
 - Infrastructure is fully operational ✓
 - WorldFIP_{FGCLite} + FGC_{etherFGC3.1} + PLC_{CDBs}
 - Currently installed IT Interlock Panel proto is validated ✓

Readiness for IT String operation

WP6B fundamental milestones: 1st “Ampere” in the magnets

WP6B equipment in
IT String Baseline
configuration

03/10/2024

EN-ACE/EN-IM
Scheduling Tools



End Q2 2025 “120As”
27/10/2025



RCBX + RQSX3
10/11/2025



RD1
01/12/2025



RQX
15/12/2025

Readiness for IT String operation

- 18kA IT main – RPAFE **x1**
 - Proto subs currently used for full precision **by end'24** and power tests **by Q2 2025**
 - 1st pre-series diode-based crowbar unit to be received and tested by end'24, installation in IT String during Q2 2025
 - Internal busbars (within subs racks) to be reworked in IT String in Q2 2025
 - Class 0 ADCs series=_{pre-series} is available ✓, 2nd unit to be installed in RYABC_{measurement rack}
 - 1 head Class 0 DCCT pre-series **expected to be fully Class 0 compliant** expected by end'24 to be added to the currently installed one **not fully Class 0 compliant**
 - option: remove installed DCCT head(s) and install 2 series ones if delivery in advance of June'25 full series is expected by end of July'25

Readiness for IT String operation

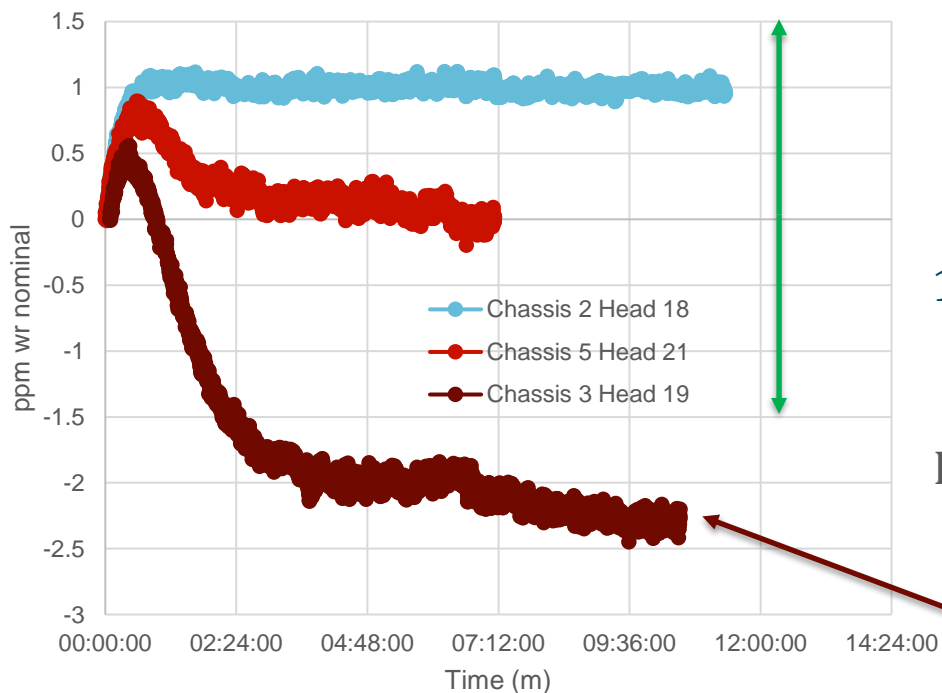
- 14kA RD1 – RPAFF **x1**
 - Proto subs currently used for full precision **by end'24** and power tests **by Q2 2025**
 - 8th sub to be repaired and installed in the IT String by end of Q2 2025
 - Class 0 ADCs series=_{pre-series} is available ✓, 2nd unit to be installed in RYABC_{measurement rack}
 - 2nd pre-series DCCT head **not fully Class 0 compliant** already available to be added to the currently installed one **also not fully Class 0 compliant**
 - option: remove installed DCCT head(s) and install 2 series ones if delivery in advance of June'25 full series is expected by end of July'25

Readiness for IT String operation

- 2kA IT Trims – RPBAF **x2**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAF
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊 , 2 units (heads and chassis) to be installed in each RPBAE in H1'25
- 2kA Orbit Correctors – RPBAE **x6**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAE
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊 , 2 units (heads and chassis) to be installed in each RPBAE in H1'25

Readiness for IT String operation

12 Hour Drift after nominal Current Step (2kA)
Excluding first 5 Minutes



$\pm 1.5 \text{ ppm}_{\text{max}}$ Spec for Class 2 DCCT
(irrespective of ADCs)

$\pm 5 \text{ ppm}_{\text{max}}$ Spec for Class 2 PC
(isothermal with Class 0 ADCs)

$15.5 \text{ ppm}_{2 \times \text{rms}}$ Spec for Class 2 PC
(with Class 0 ADCs)

Low risk for the Class 2 PC (i.e. overall)
performance 😊

Furthermore, we think we know where this
slight out of spec performance is coming from

Readiness for IT String operation

- 2kA IT Trims – RPBAF **x2**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAF
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊, 2 units (heads and chassis) to be installed in each RPBAE in H1'25
- 2kA Orbit Correctors – RPBAE **x6**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAE
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊, 2 units (heads and chassis) to be installed in each RPBAE in H1'25
- 200A SF 2nd order Corrector – RPMBG **x1**
 - new validated PIC-compatible Fast Abort interlock board to be installed
 - scheduled in Nov'24 in the IT String unit, then in the remaining 3 RPMBGs x the machine
 - to be implemented also in the R2E-LHC-600A-10V already installed in the LHC

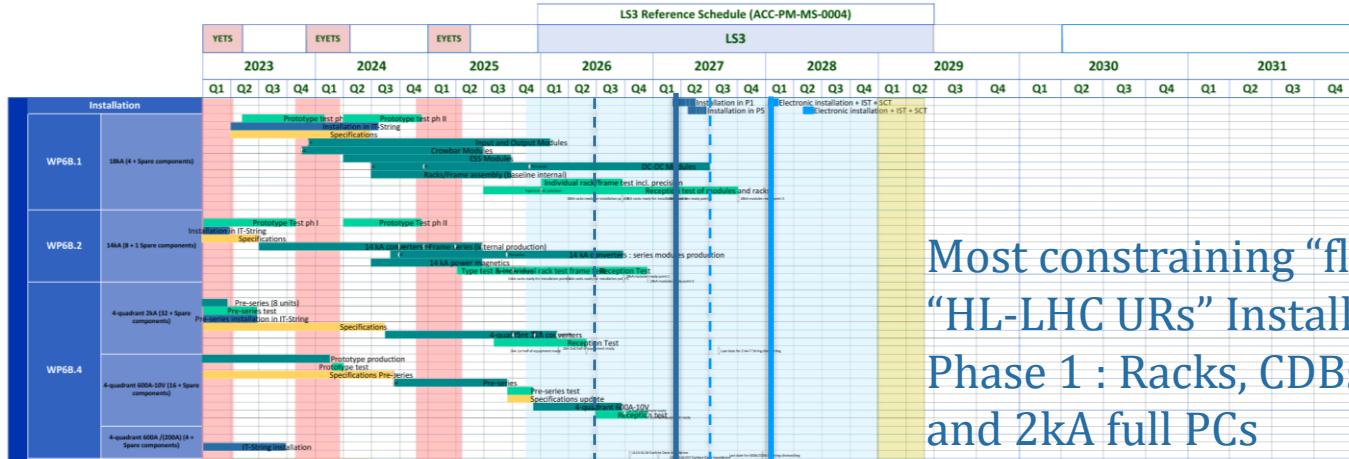
Readiness for IT String operation

- 120A SF HO Correctors – RPLBB **x8**
 - ready for operation ✓
- 35A Q1a Trim – RPLAD **x1**
 - ready for operation ✓
- CDBs 18kA **x2** 18kA and 14kA
 - ready for operation ✓
- CDBs 2kA **x8** and 600A **x2** 35A + warm diodes
 - ready for operation ✓
- WCBBs 18kA **x4** 18kA x2 and 14kA x2
 - ready for operation ✓ although with noncompliant WCPs **plan B: flushing WCBBs x ElQA**
 - improved mounting options of the failing Kapton foils have been identified and components ordered for in situ testing
 - WCPs are expected to be made compliant with ElQA by end of Q2 2025*
- Control Electronics
 - ready for operation ✓
 - option: new **pre-series** IT Interlock Panel to be installed if production completed in H1'25

*: if needed tests campaigns can be fitted in IT String agenda in H1'25

Readiness for the

installation in HL-LHC URs



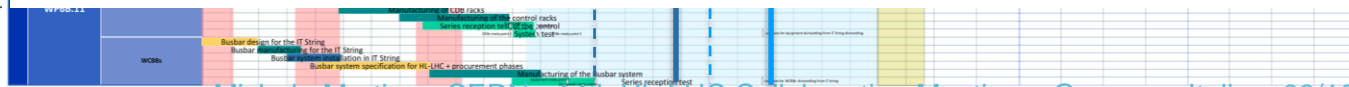
Most constraining “float” for “HL-LHC URs” Installation Phase 1 : Racks, CDBs/WCBBs and 2kA full PCs

Delivery dates presented in this InWork Masterplan are deemed realistic today, although a few important production contracts (power modules and other equipment) are still to be adjudicated.

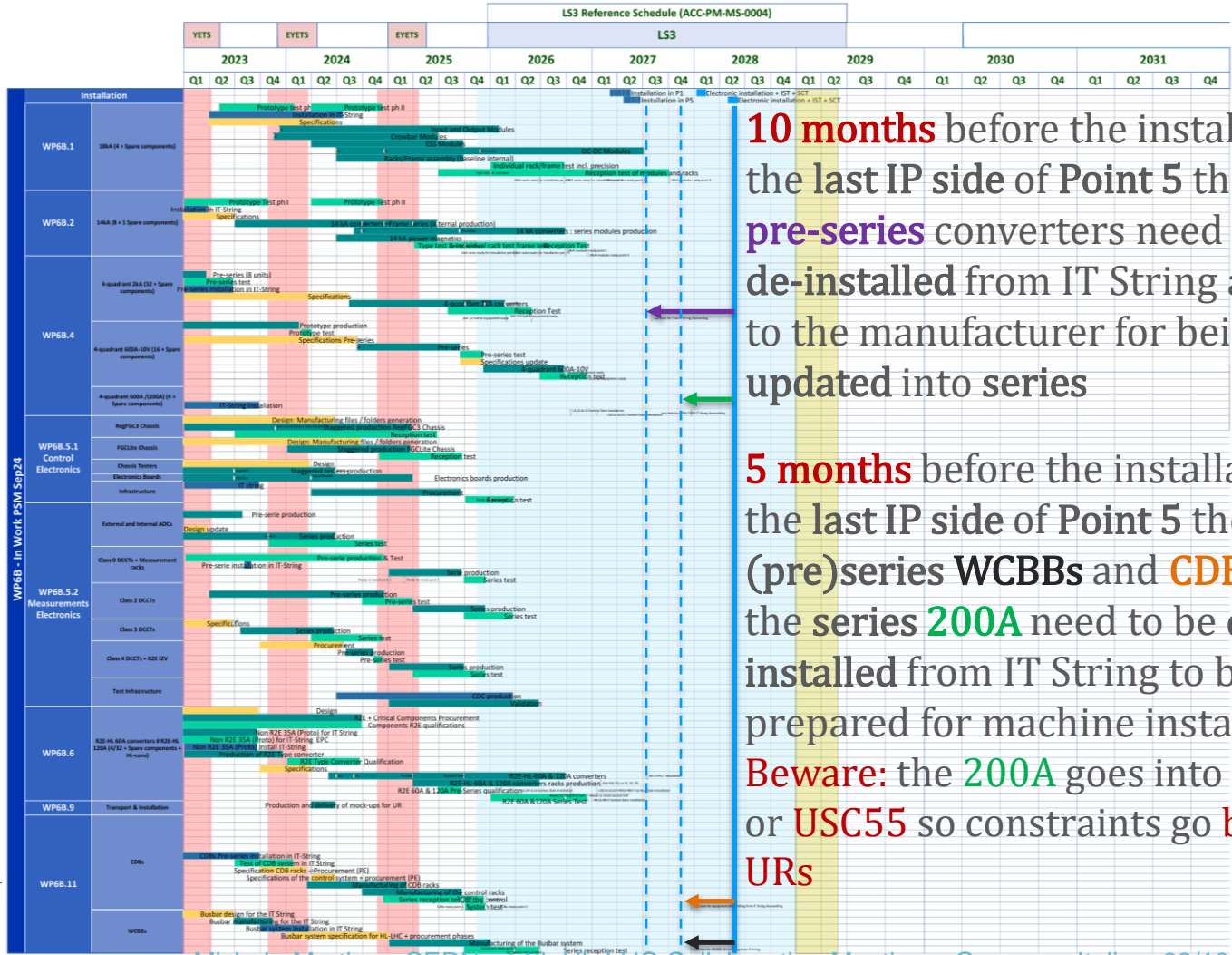


Most constraining “float” for “HL-LHC URs” Installation Phase 2 : Power modules + 600A PCs + 35A PCs

With the recently approved LS3 shift these margins can only increase!



“Constraints” for installation in LS3 of the IT String equipment



10 months before the installation of the last IP side of Point 5 the **2kA pre-series** converters need to be de-installed from IT String and sent to the manufacturer for being updated into series

5 months before the installation of the last IP side of Point 5 the (pre)series **WCBBs** and **CDBs** and the series **200A** need to be de-installed from IT String to be prepared for machine installation **Beware:** the **200A** goes into **UL557** or **USC55** so constraints go **beyond URs**



Conclusion in two words

Positive outlook



Conclusion in a few (additional) words

- WP6B equipment has been the **first_{non WP16}** equipment to be installed in IT String and to **complete** with others the **first hardware commissioning steps**
- ISTs and SCTs have been **completed successfully** although **not as part of the baseline planned sequence**
- WP6B equipment in IT String was and is **not 100% baseline** although this had no consequences for the completion of the first commissioning steps
- **No showstoppers** to reach WP6B goal of **baseline hardware by end Q2 2025**
 - furthermore **1st Ampere** in any of the magnets is scheduled only in Q4 2025
- **Readiness for installation in the machine is looking good**
 - even with the pre LS3 shift **sufficient margins exist** although few but **important contracts still need to be adjudicated**
 - also the **constraints** for the WP6B equipment that goes in the last IP side of Pt 5 offer **non negligible margins** after the end of the IT String operation



Thank you for your kind attention

Credits to: V. Montabonnet, S. Pittet, N. Kuczerowski, V. R. Herrero Gonzales, B. Todd, M. Cerqueira Bastos, R. Murillo Garcia, Y. Thurel, C. Coupat, H. Thiesen



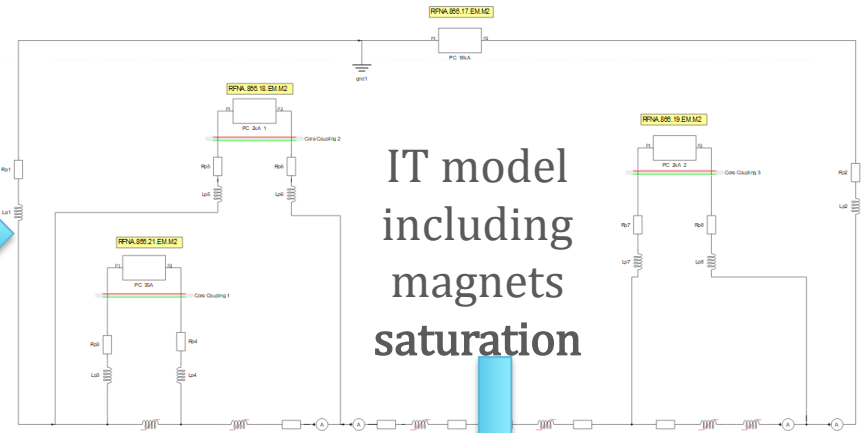
Spare Slides



Readiness for IT String operation

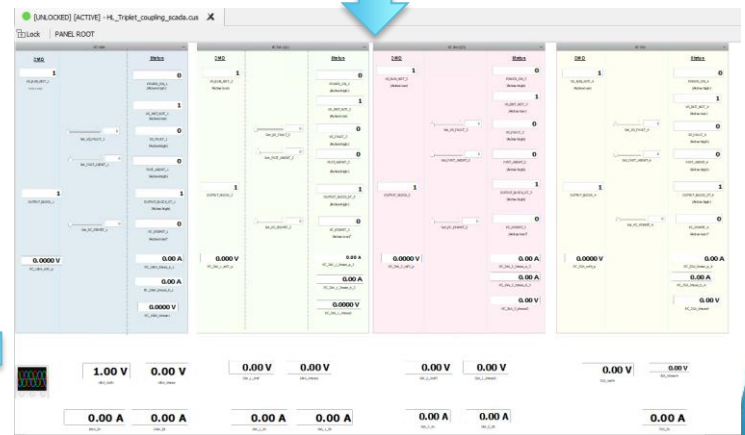


HIL IT decoupling control SW tester [Typhoon]



IT model including magnets saturation

- Preliminary tests in '23 and '24 were **successful*** and lead to solving already minor issues such as **initialization**
- Configuration tools* prepared to speed up commissioning
- Final HIL validation expected by end Q1 2025

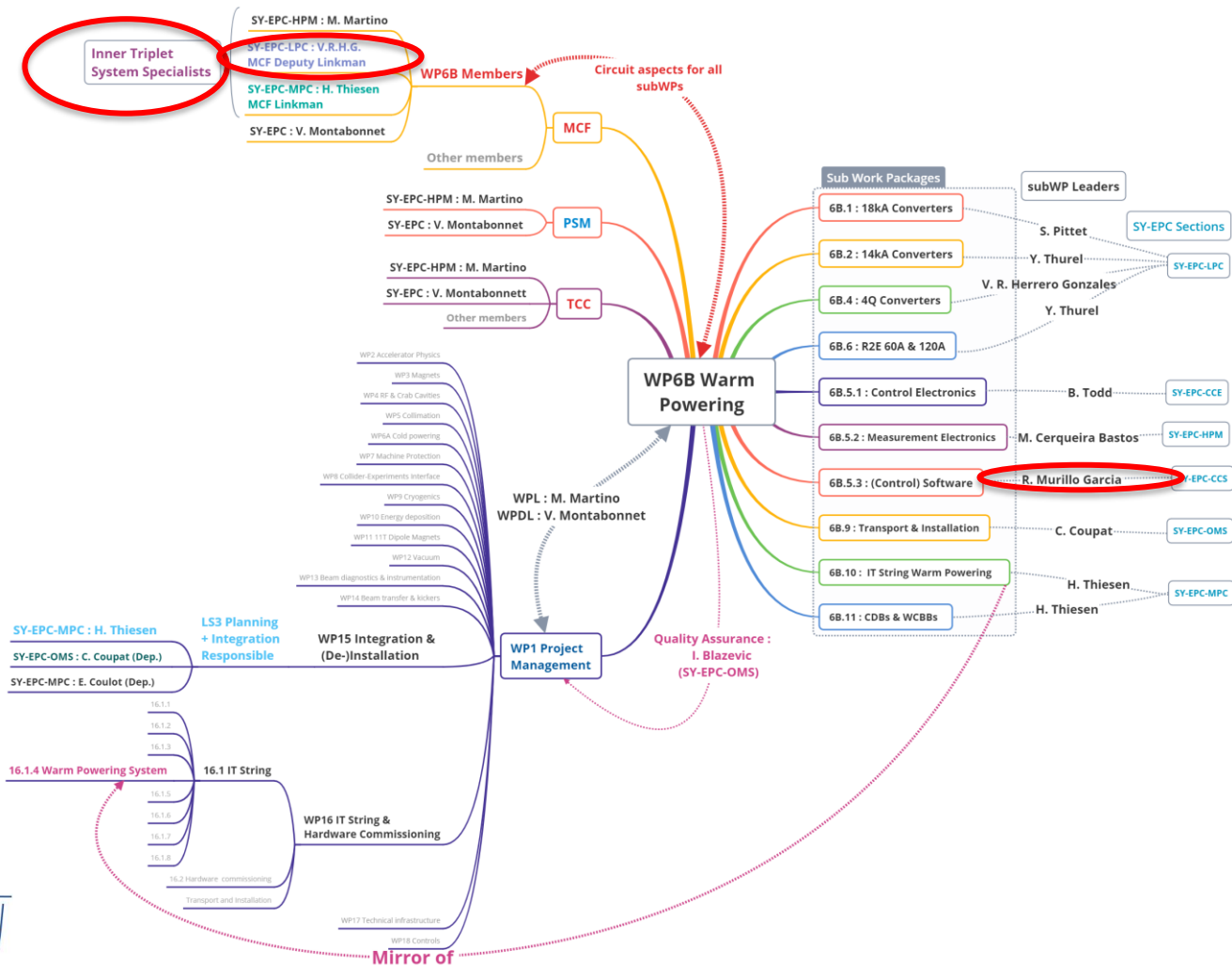


FGC Commander		Connect	Disconnect	Select	Gateway	FGC	Config	Database	Analy	
PL	OP	VS	PC	I_REF	I_MEAS	V_REF	V_MEAS	FGC	4 / 4	
LK	NL	OF	OF	0.00	1.74	0.00	0.00	⚡	RFNA.866.17.EM.M2	OK
LK	NL	OF	OF	0.00	0.16	0.00	0.00	⚡	RFNA.866.18.EM.M2	OK
LK	NL	OF	OF	0.00	0.14	0.00	0.00	⚡	RFNA.866.19.EM.M2	OK
LK	NL	OF	OF	0.00	0.00	0.00	0.00	⚡	RFNA.866.21.EM.M2	OK

*: 195th TCC – M. Martino - [Technical update WP6B](#) – 24/05/2024



WP6B – Who's who



Readiness for IT String operation

- 2kA IT Trims – RPBAF **x2**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAF
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊, 2 units (heads and chassis) to be installed in each RPBAE in H1'25
- 2kA Orbit Correctors – RPBAE **x6**
 - Class 0 ADCs series _{=pre-series} is available, 2 units to be installed in RPBAE
 - pre-series Class 2 DCCTs expected by end of '24, to date 3x pre-series units are accepted 😊, 2 units (heads and chassis) to be installed in each RPBAE in H1'25
- 200A SF 2nd order Corrector – RPMBG **x1**
 - new validated PIC-compatible Fast Abort interlock board to be installed
 - scheduled in Nov'24 in the IT String unit, then in the remaining 3 RPMBGs x the machine
 - to be implemented also in the R2E-LHC-600A-10V already installed in the LHC