# LLRF commissioning of the European XFEL.

## RF gun and first linac RF station

Julien Branlard, for the LLRF team

IPAC 2015

Richmond VA, May 5th 2015

HELMHOLTZ ASSOCIATION

DESY

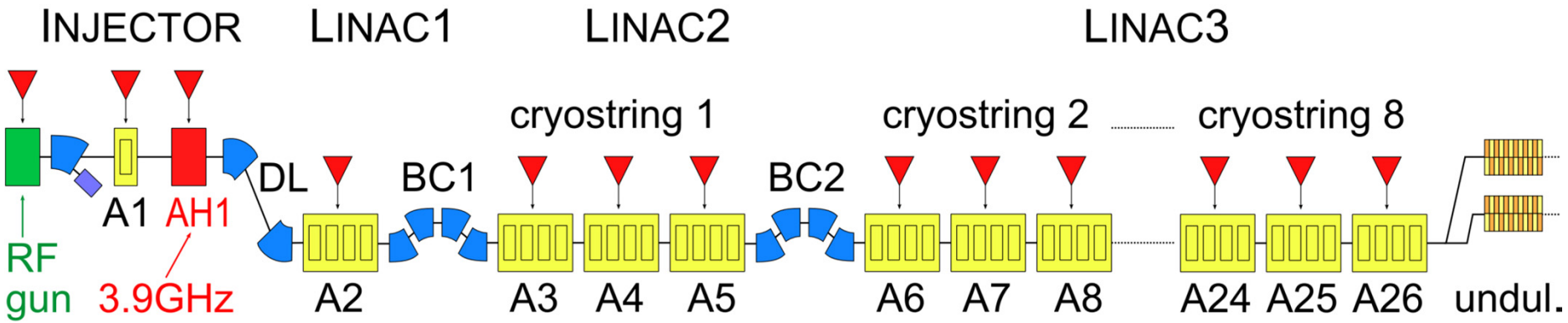
# Talk Overview

- XFEL accelerator and the RF gun
- Schedule
- Tunnel installation and commissioning
- Closing remarks

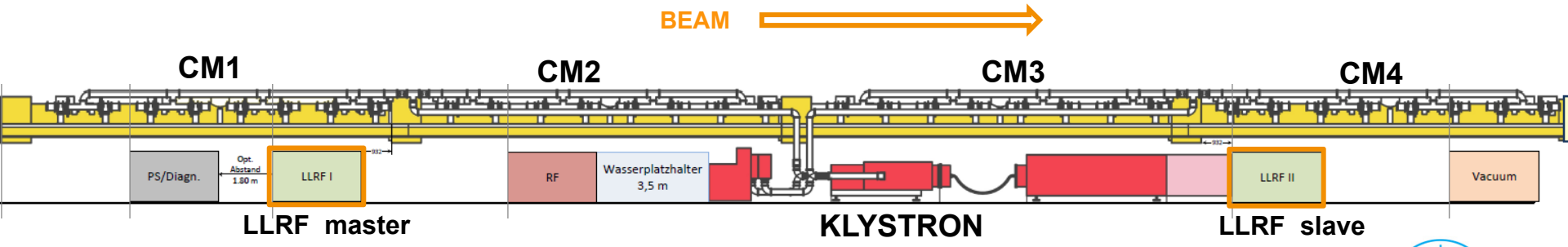



DESY

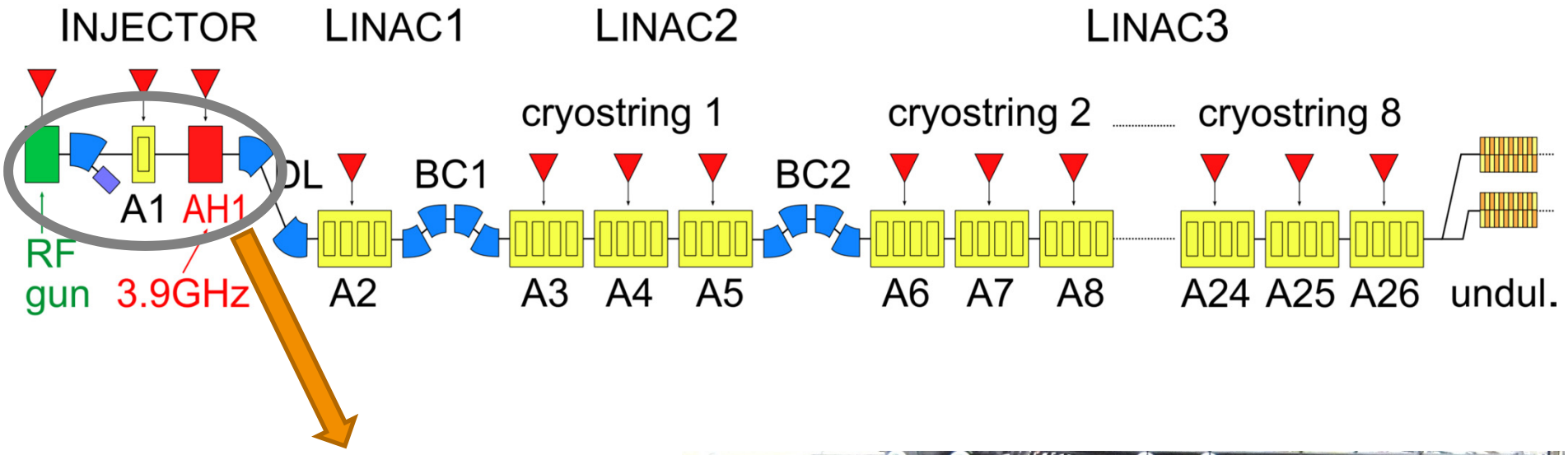
# The European XFEL: OVERVIEW

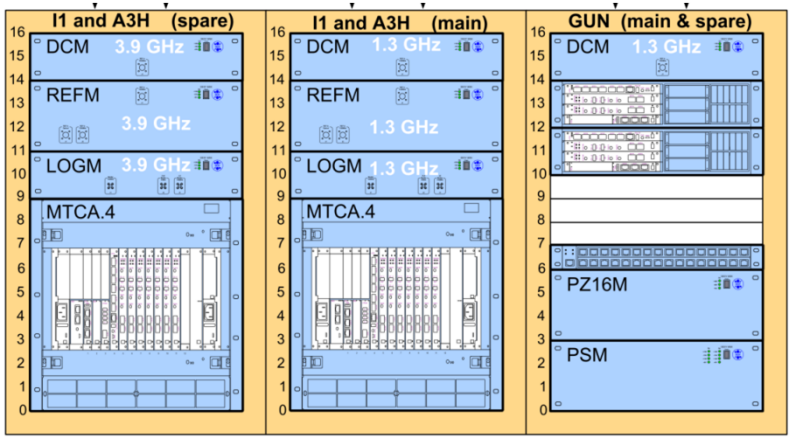


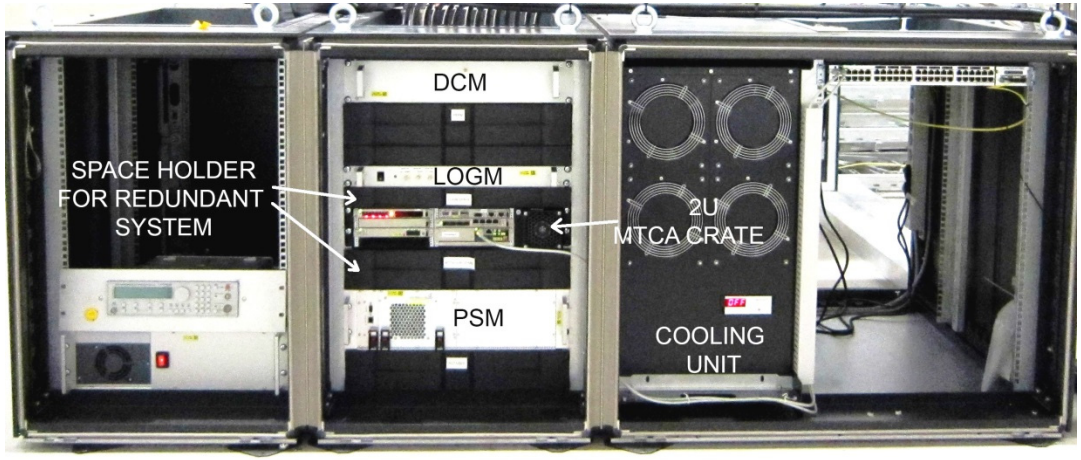

- 808 superconducting 1.3 GHz TESLA RF cavities
- 101 cryomodules (8 cavities)
- 25 RF stations (4 cryomodules)
- **1 LLRF system / RF station (i.e. per klystron)**



# The European XFEL: INJECTOR

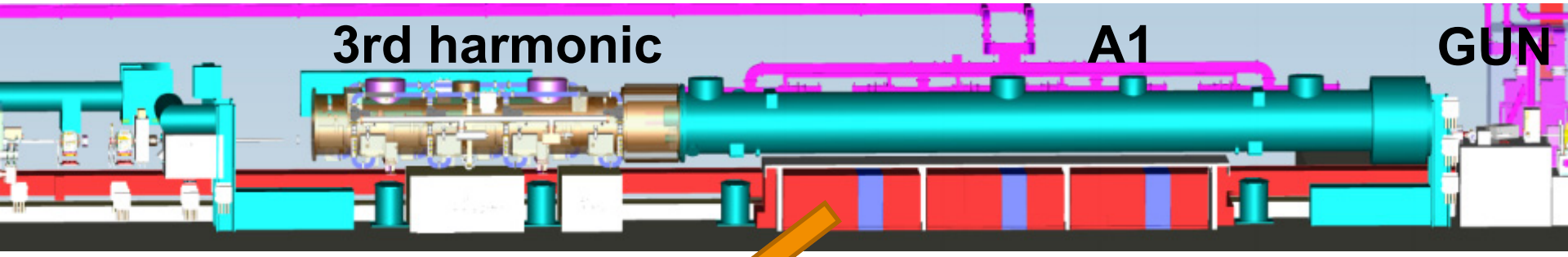


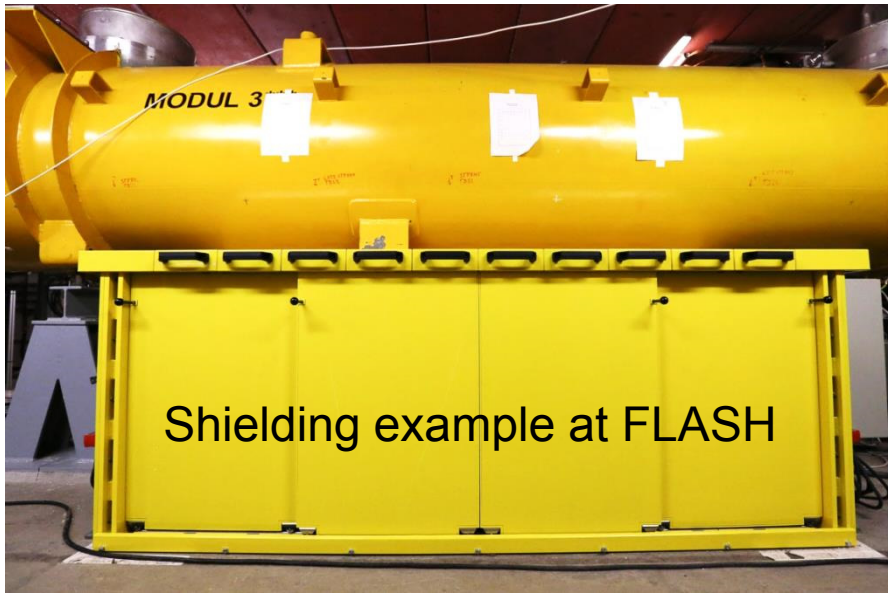




**DCM**: Drift calibration module
**REFM**: Reference synchronization and distribution
**LOGM**: Local oscillator generation and distribution
**PZ16M**: Piezo controller (16 cavities)
**PSM**: Power supply

# The European XFEL: INJECTOR

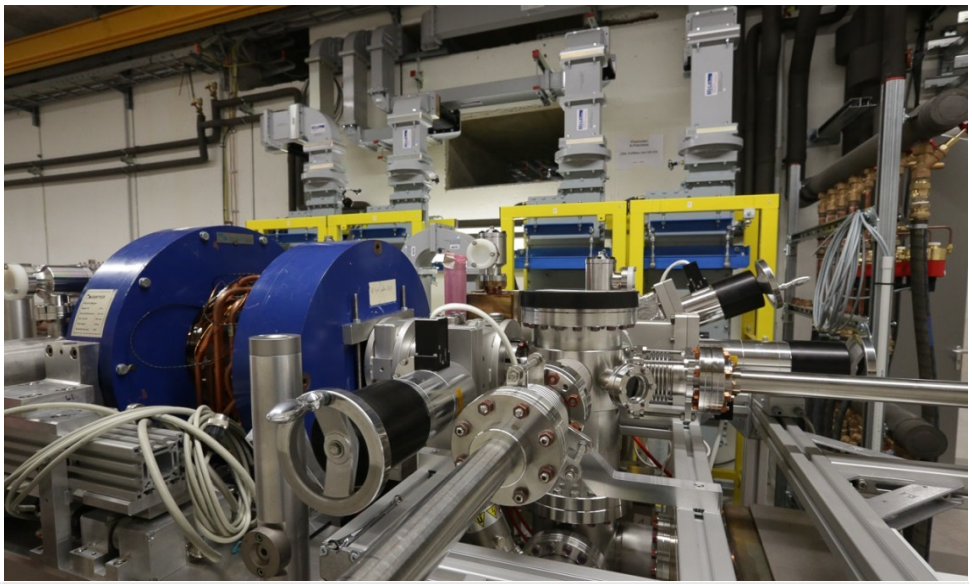


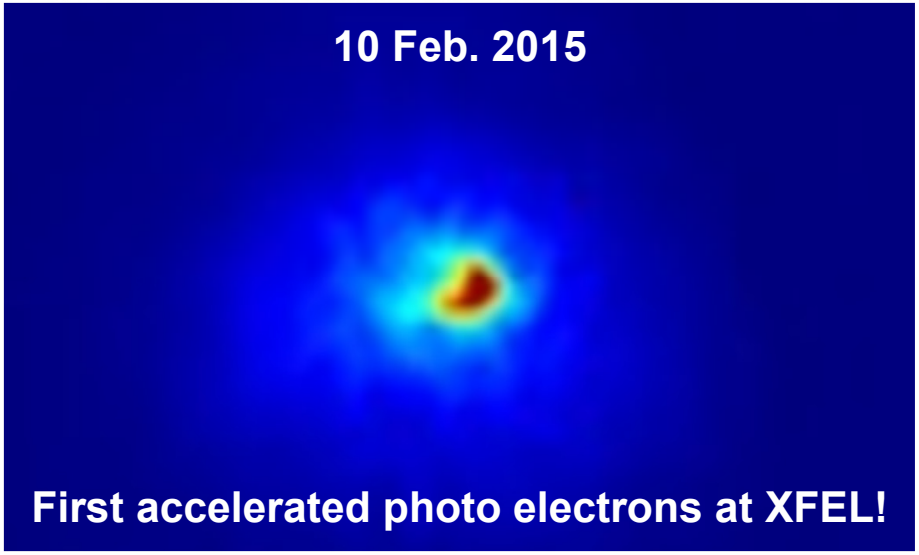


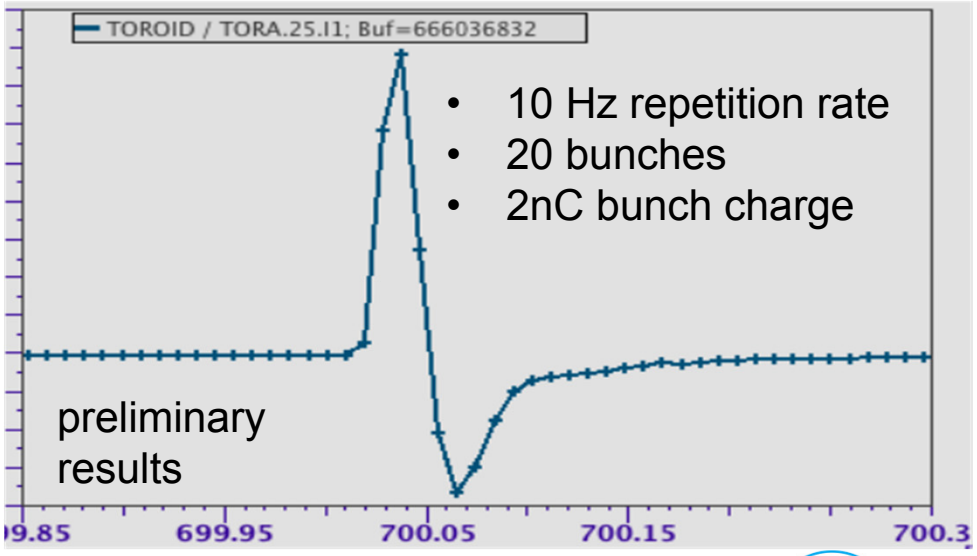



| | | |
|---|---|---|
| GUN: | commissioning since | Dec. 2013 |
| A1: | installation | May 2015 |
| AH1: | installation | August 2015 |
| Injector: | cool down | October 2015 |

# The European XFEL: INJECTOR >>> FIRST BEAM <<<

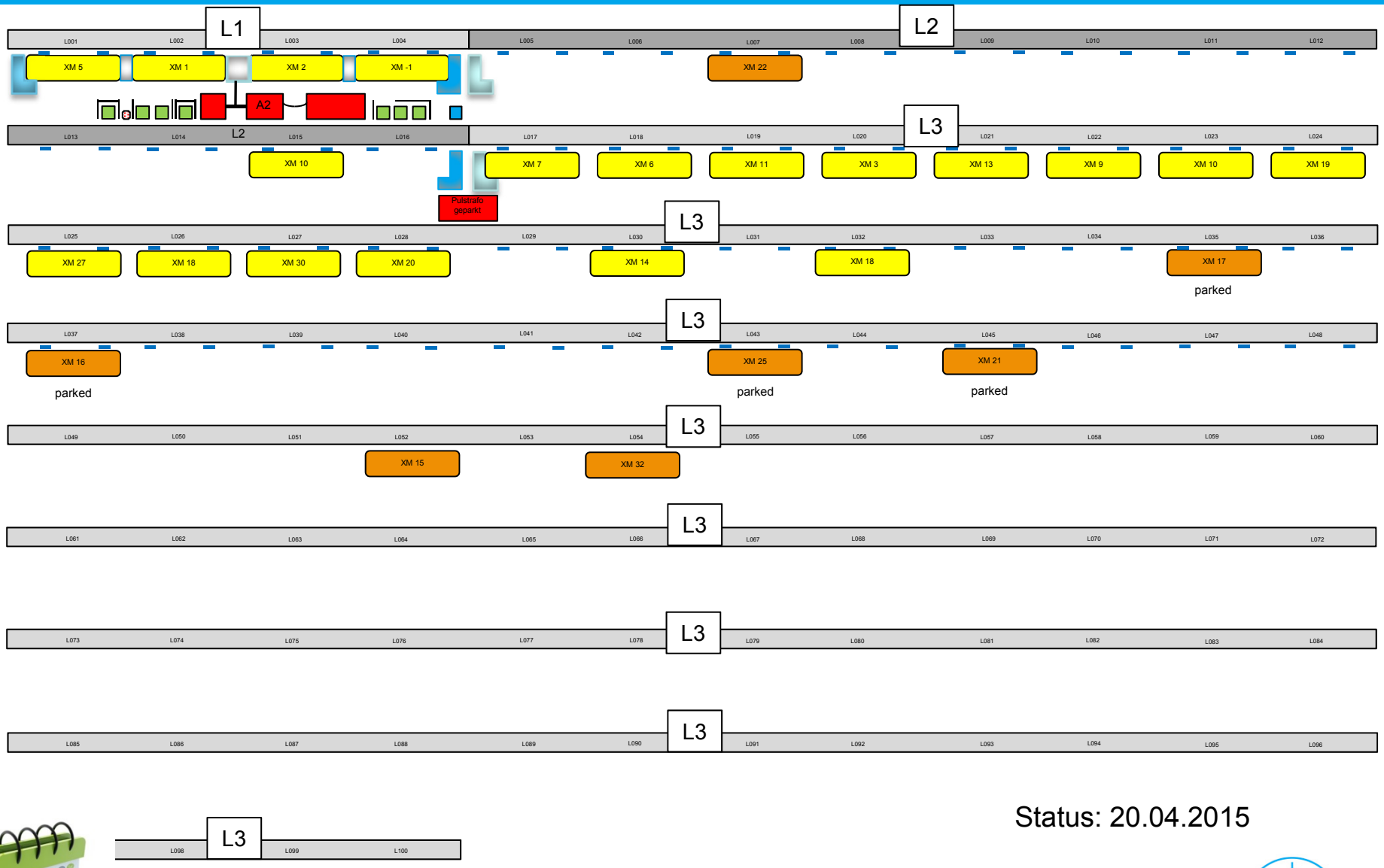




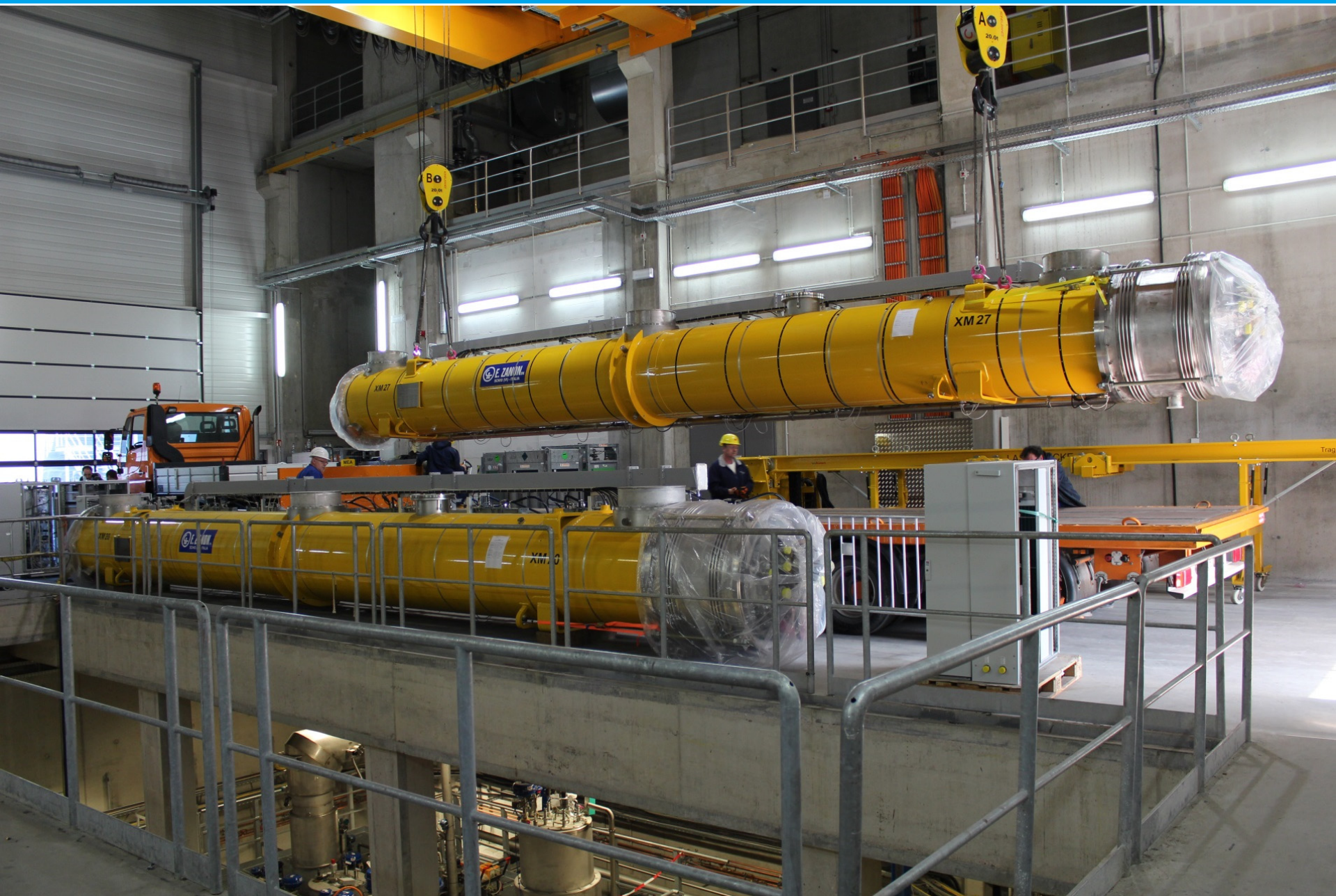

Courtesy, F. Brinker

# SCHEDULE : TUNNEL OVERVIEW




Status: 20.04.2015

# MODULE TRANSPORT



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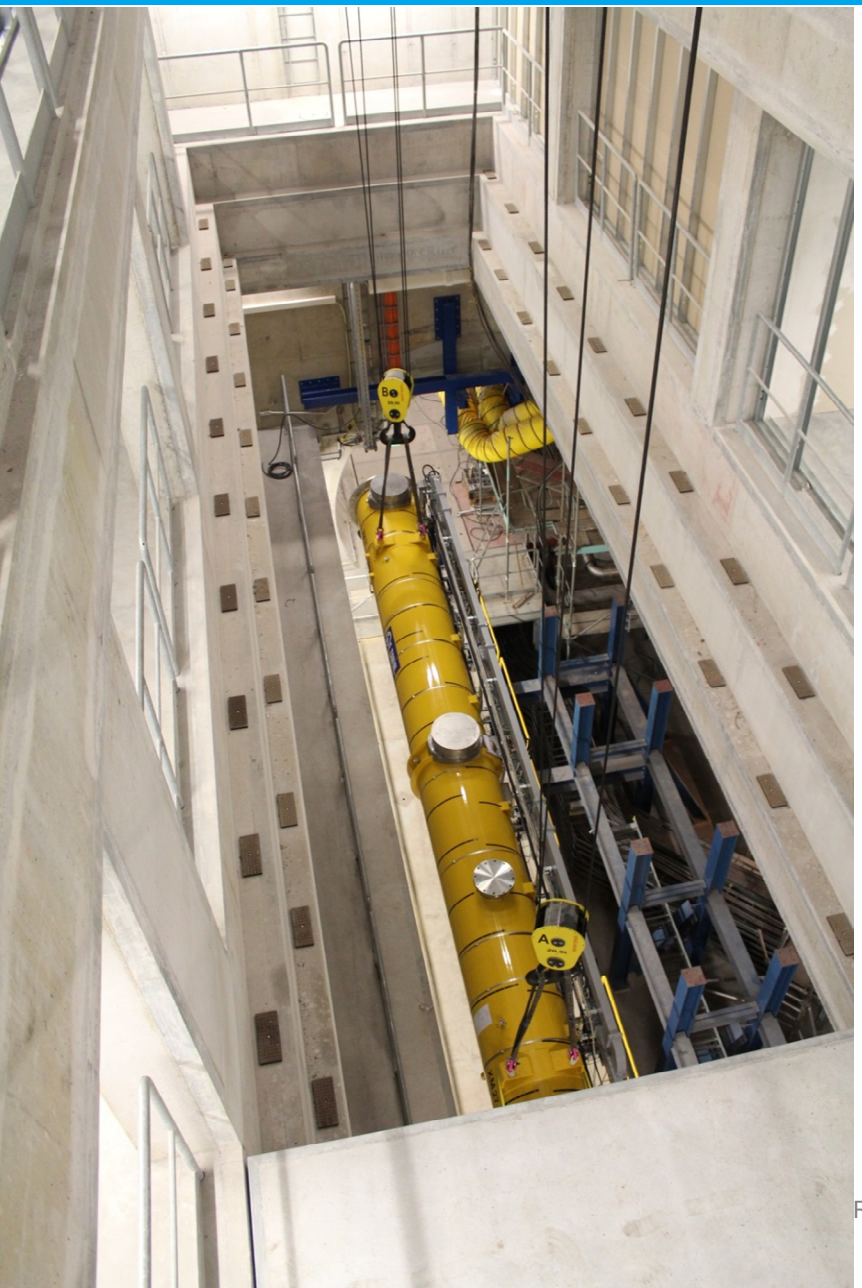
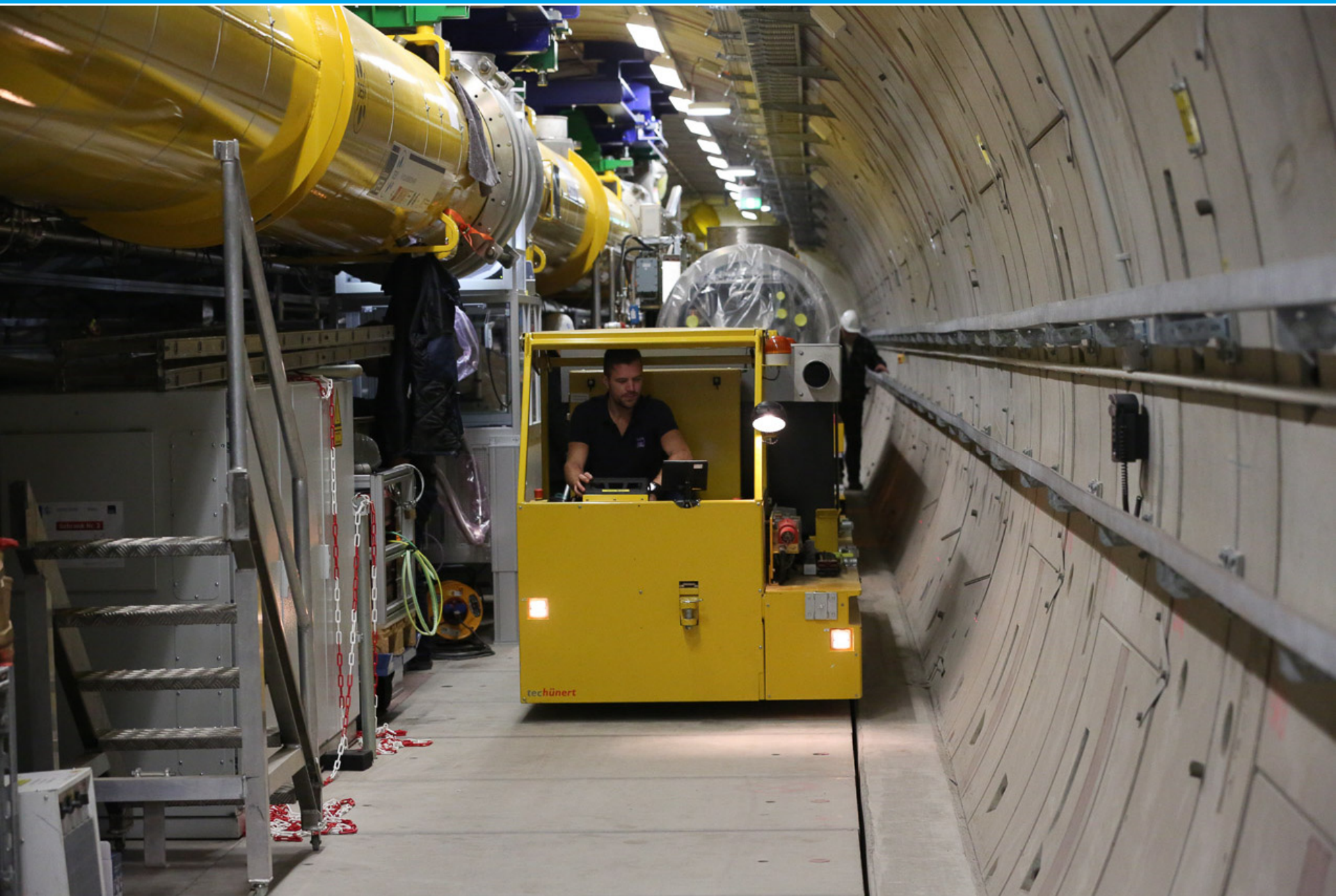
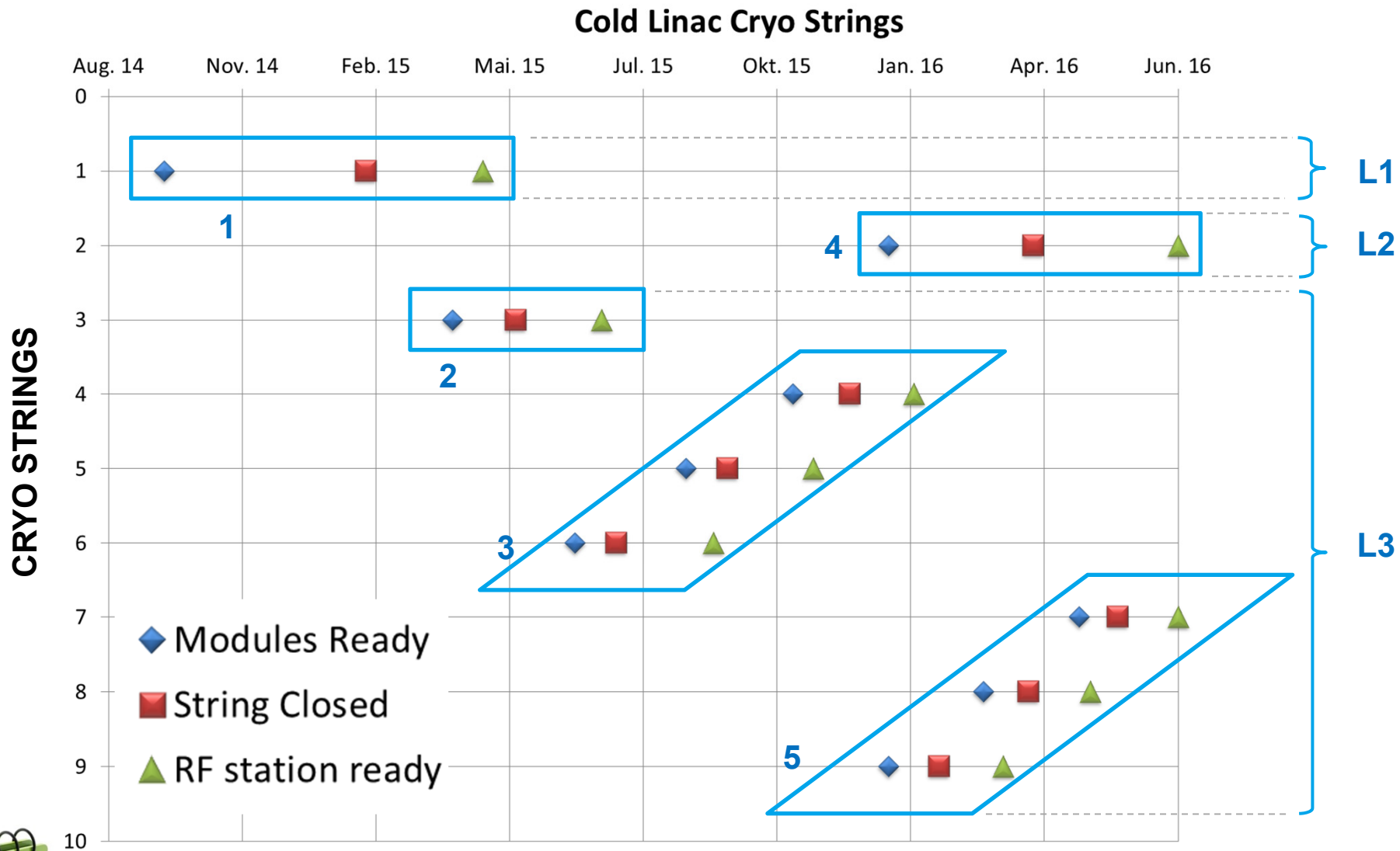


# MODULE TRANSPORT

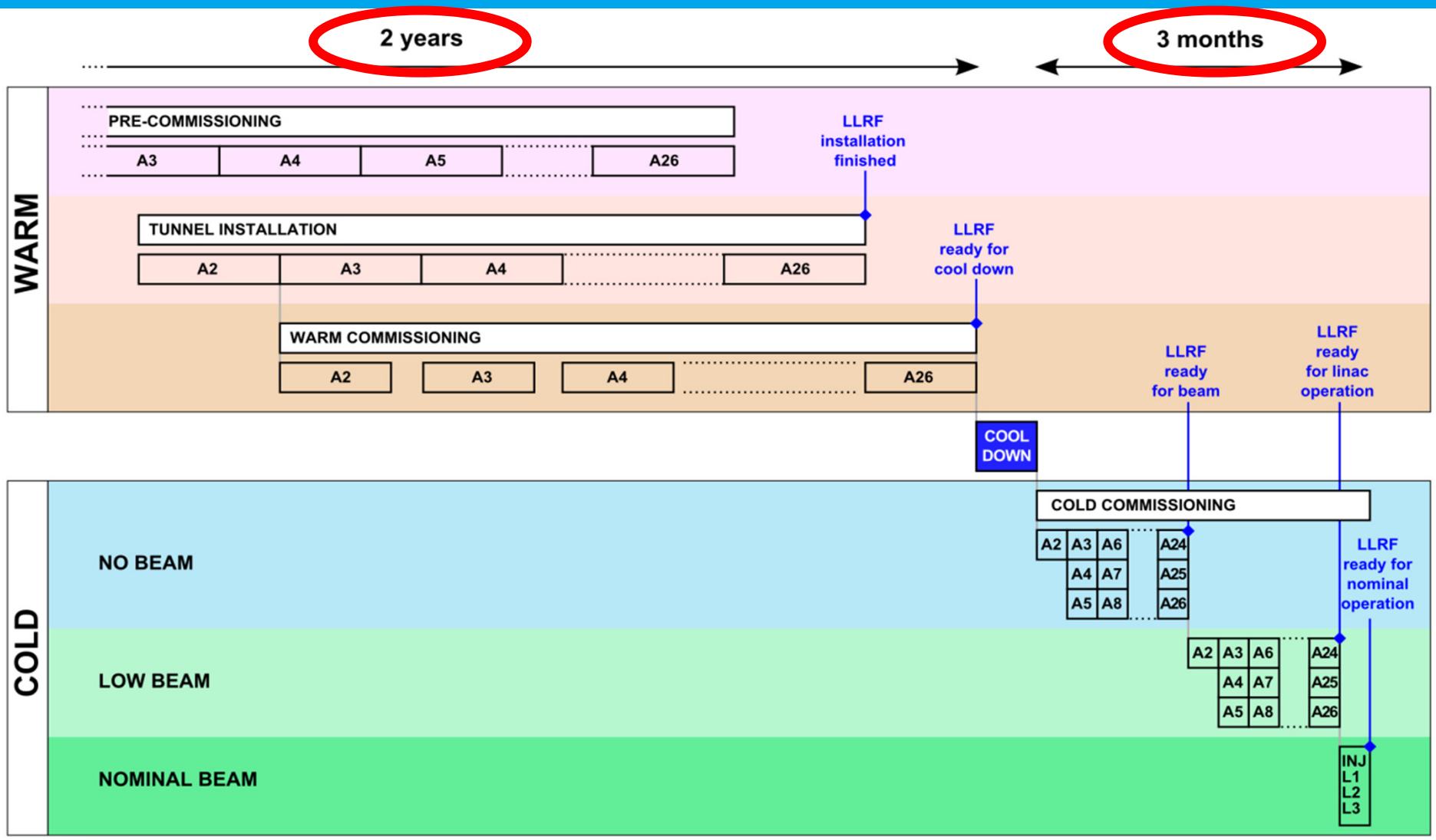


# SCHEDULE : TUNNEL INSTALLATION



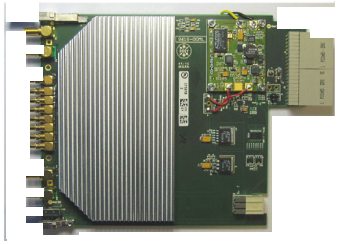

Courtesy, M. Huening

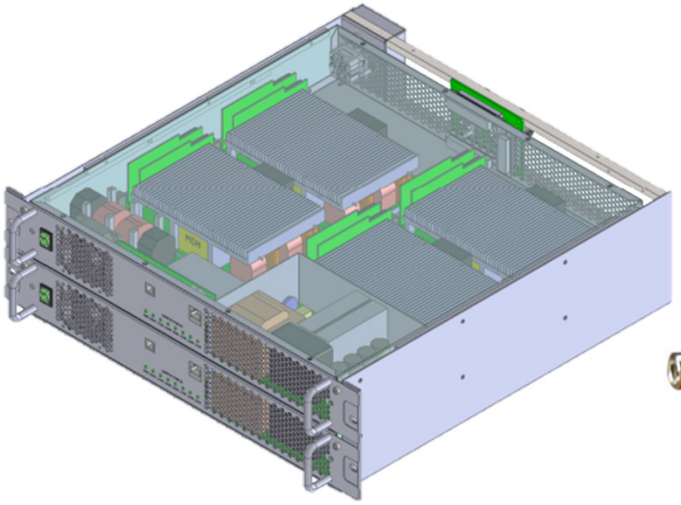
# SCHEDULE : BEYOND THE INSTALLATION




# INSTALLATION STEPS

- Incoming inspection
- Device test
- Crate installation
- Rack installation
- Tunnel installation



# INSTALLATION STEPS

- Incoming inspection

a. Delivery
b. Archiving of shipping documentation
c. **Device labelling**
d. **Database documentation**
e. Review of the company tests (present? complete ?)
f. **Random verification of company tests**
g. Storage and “ready-for-test” notification
h. Incoming inspection sheet sign off




**Deutsches Elektronen-Synchrotron**
Ein Forschungszentrum der Helmholtz-Gemeinschaft

| Title: | WP02 LLRF<br>hardware incoming inspection sign-off sheet |
|---|---|

| Device: | | Quantity: | |
|---|---|---|---|
| Order number: | | Reception date: | |

| | | OK | NOK | N/A |
|---|---|---|---|---|
| Shipment documentation archived | | ☐ | ☐ | ☐ |
| Labelling done | | ☐ | ☐ | |
| KDS entry done | | ☐ | ☐ | |
| Factory tests documentation present and reviewed | | ☐ | ☐ | ☐ |
| Factory tests randomly checked | | ☐ | ☐ | ☐ |
| Unit #: | | | | |
| Results (passed / failed) : | | ☐ | ☐ | |
| Failure report (if failed) : | | | | |
| Ready-for-test notification sent | | ☐ | ☐ | ☐ |

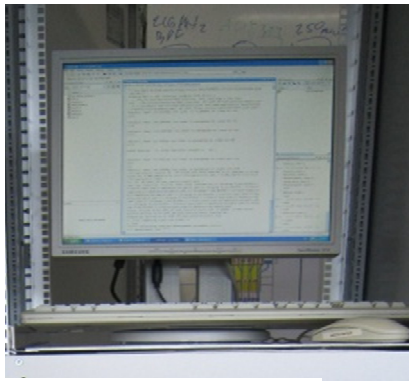
| Incoming inspection signed-off: | | | |
|---|---|---|---|
| | by | signature | date |
| | | | |
| | | EDMS upload date: | |

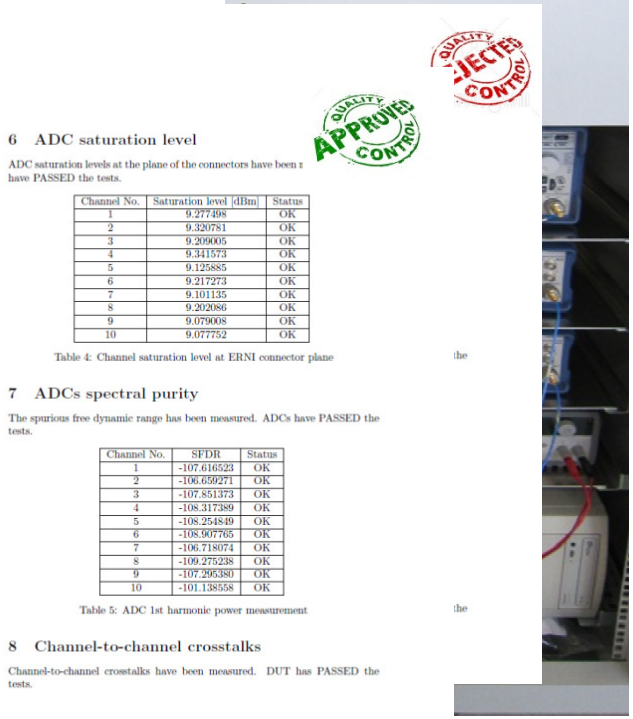


# INSTALLATION STEPS

- Incoming inspection
- Device test

a. Test stand prepared for given device and calibrated
b. Device is installed in test stand and test is carried
c. Test report is generated, stored in database
**d. Device is marked as tested / approved (sticker)**
e. Storage and “ready for installation” notification





6 ADC saturation level

ADC saturation levels at the plane of the connectors have been r
have PASSED the tests.

| Channel No. | Saturation level [dBm] | Status |
|---|---|---|
| 1 | 9.277498 | OK |
| 2 | 9.320781 | OK |
| 3 | 9.209005 | OK |
| 4 | 9.341573 | OK |
| 5 | 9.125885 | OK |
| 6 | 9.217273 | OK |
| 7 | 9.101135 | OK |
| 8 | 9.202086 | OK |
| 9 | 9.079008 | OK |
| 10 | 9.077752 | OK |

Table 4: Channel saturation level at ERNI connector plane

7 ADCs spectral purity

The spurious free dynamic range has been measured. ADCs have PASSED the tests.

| Channel No. | SFDR | Status |
|---|---|---|
| 1 | -107.616523 | OK |
| 2 | -106.659271 | OK |
| 3 | -107.851373 | OK |
| 4 | -108.317389 | OK |
| 5 | -108.254849 | OK |
| 6 | -108.907765 | OK |
| 7 | -106.718074 | OK |
| 8 | -109.275238 | OK |
| 9 | -107.295380 | OK |
| 10 | -101.138558 | OK |

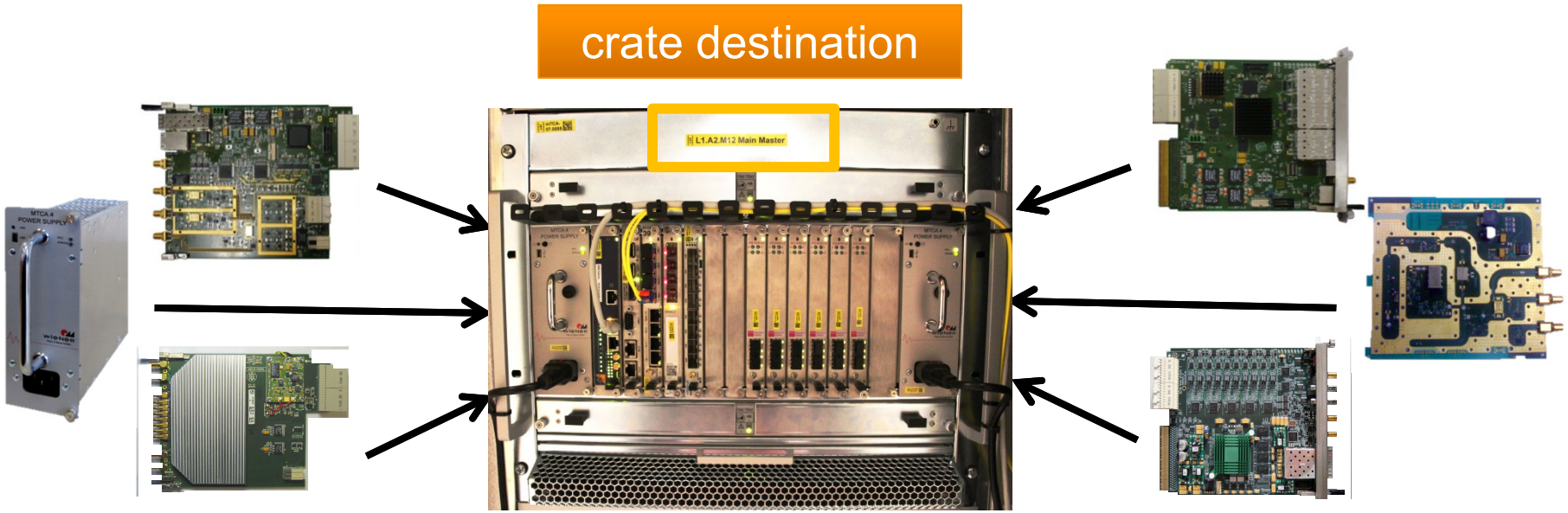
Table 5: ADC 1st harmonic power measurement

8 Channel-to-channel crosstalks

Channel-to-channel crosstalks have been measured. DUT has PASSED the tests.

# INSTALLATION STEPS

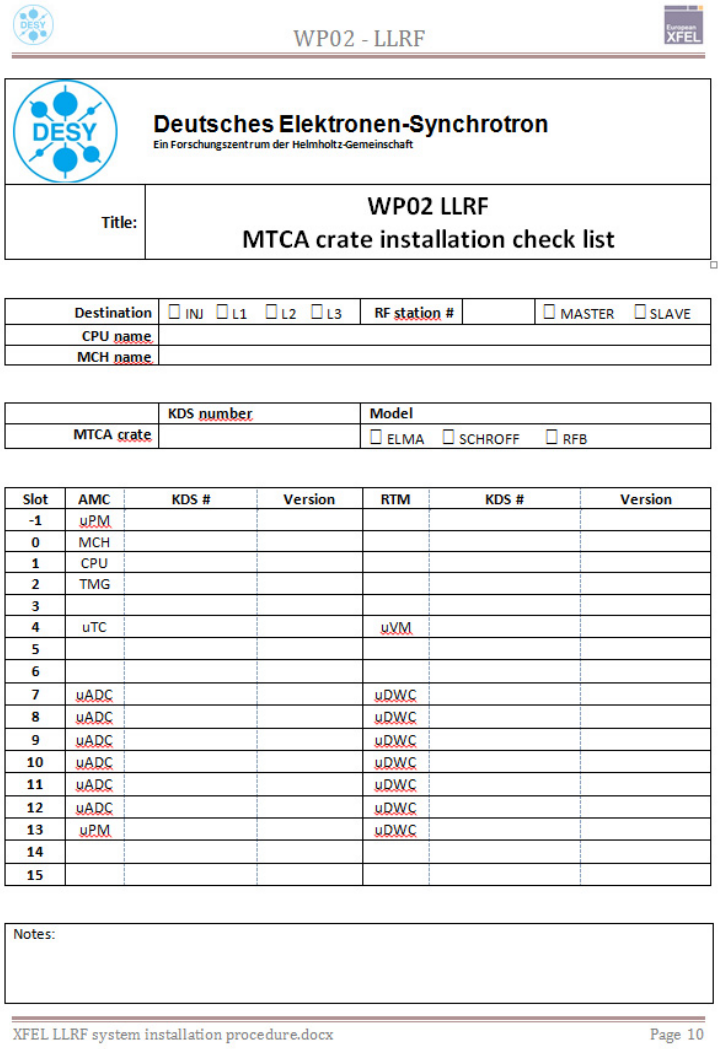
- Incoming inspection
- Device test
- Crate installation




# INSTALLATION STEPS

- Incoming inspection
- Device test
- Crate installation

a. Selection of components from storage
b. Crate infrastructure assembly
   (MTCA crate , MCH, CPU, uPM), power on
c. Basic functionality checks
   (telnet, verification of MCH settings)
d. Crate full population is performed
   (all MTCA components)
e. **Basic functionality checks**
   (PCIe, verification of drivers)
f. **Installation of servers**
   (llrf, timer, MPS, watchdog, diagnostics)
g. Fill-in crate assembly checklist report
h. Storage of assembled LLRF crate
i. Notification “ready for cabinet assembly” is sent
j. Crate assembly check list uploaded in database



WP02 - LLRF

Deutsches Elektronen-Synchrotron
Ein Forschungszentrum der Helmholtz-Gemeinschaft

| Title: | WP02 LLRF<br>MTCA crate installation check list |
|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Destination | ☐ INJ | ☐ L1 | ☐ L2 | ☐ L3 | RF station # | | ☐ MASTER | ☐ SLAVE |
| CPU name | | | | | | | | |
| MCH name | | | | | | | | |

| | KDS number | Model |
|---|---|---|
| MTCA crate | | ☐ ELMA ☐ SCHROFF ☐ RFB |

| Slot | AMC | KDS # | Version | RTM | KDS # | Version |
|---|---|---|---|---|---|---|
| -1 | uPM | | | | | |
| 0 | MCH | | | | | |
| 1 | CPU | | | | | |
| 2 | TMG | | | | | |
| 3 | | | | | | |
| 4 | uTC | | | uVM | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | uADC | | | uDWC | | |
| 8 | uADC | | | uDWC | | |
| 9 | uADC | | | uDWC | | |
| 10 | uADC | | | uDWC | | |
| 11 | uADC | | | uDWC | | |
| 12 | uADC | | | uDWC | | |
| 13 | uPM | | | uDWC | | |
| 14 | | | | | | |
| 15 | | | | | | |

Notes:

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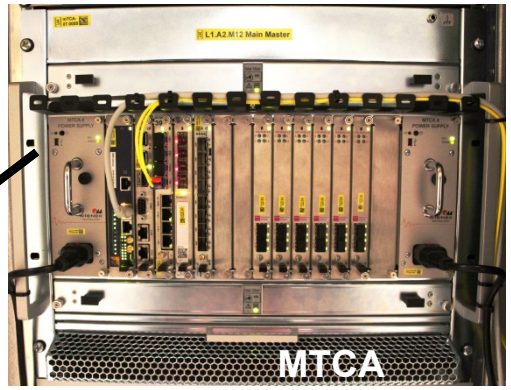
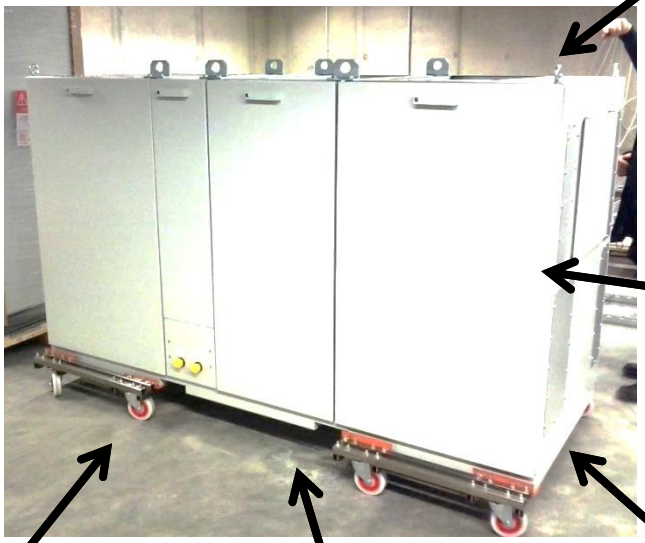
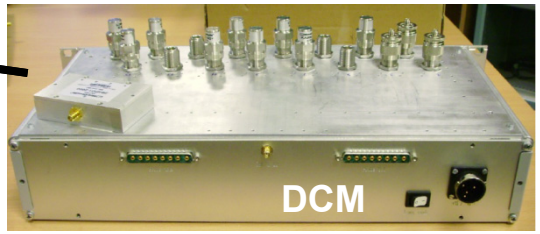
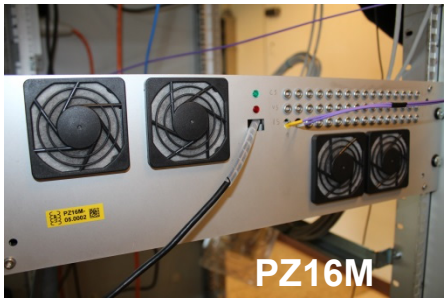
# INSTALLATION STEPS

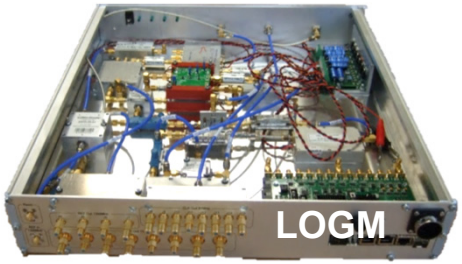
- Incoming inspection
- Device test
- Crate installation
- Rack installation

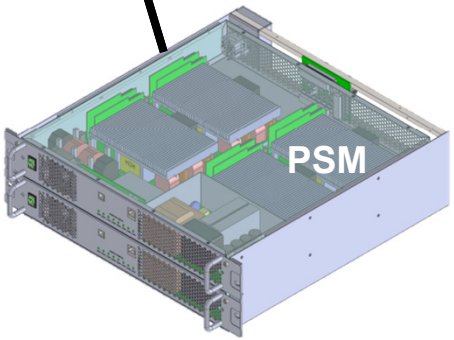


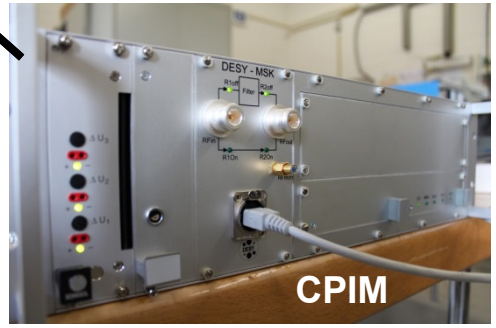






# INSTALLATION STEPS

- Incoming inspection
- Device test
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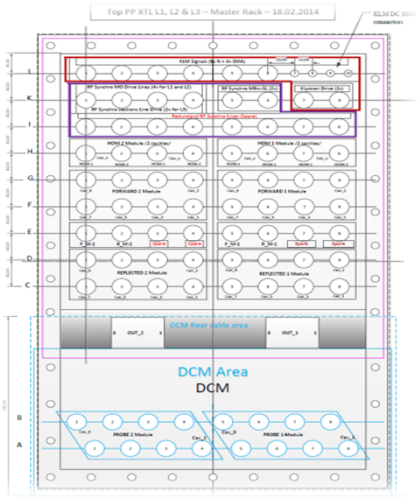
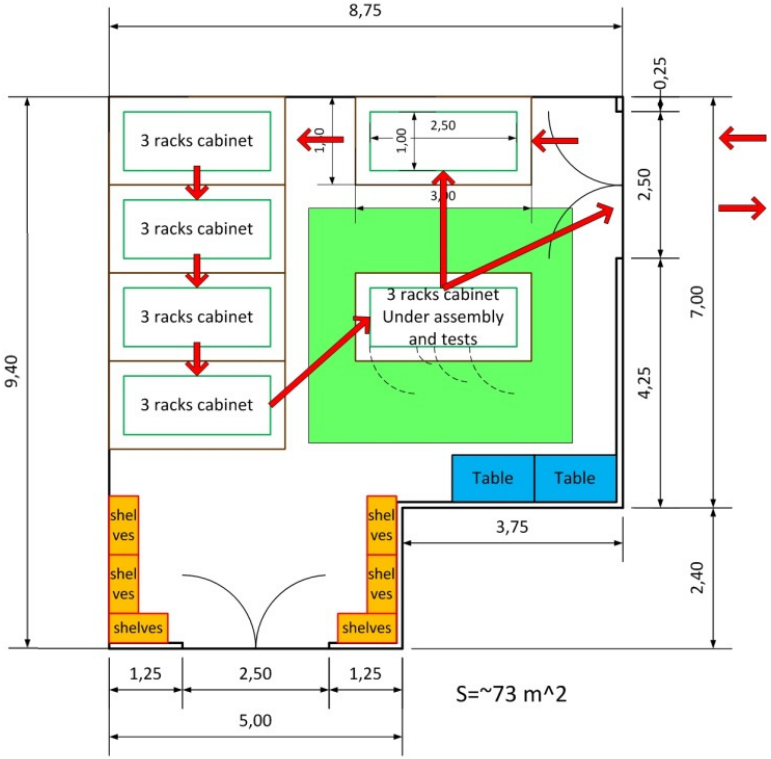
- Rack installation



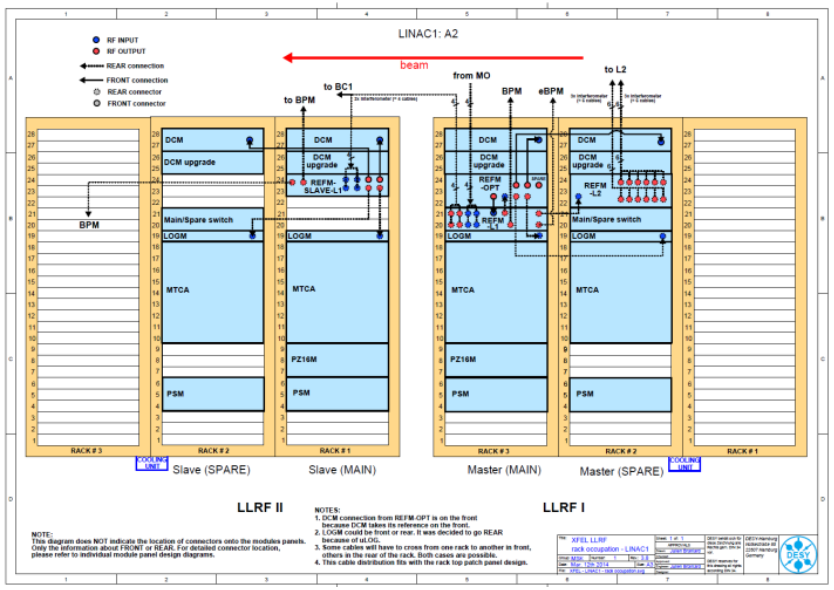

**LLRF rack assembly and test area (RATA)**




# INSTALLATION STEPS

- Incoming inspection
- Device test
- Crate installation
- Rack installation

a. **Installation of all 19” modules**
b. **Installation of MTCA crate**
c. Installation of all inner rack cabling
d. Installation of non-LLRF components
e. Connection to mains, to Ethernet, to water
f. Cabinet integral test (checklist)
g. Storage of cabinet in LLRF racks assembly facility
h. Ready for tunnel installation notification
i. KDS final documentation and EDMS upload of cabinet assembly checklist



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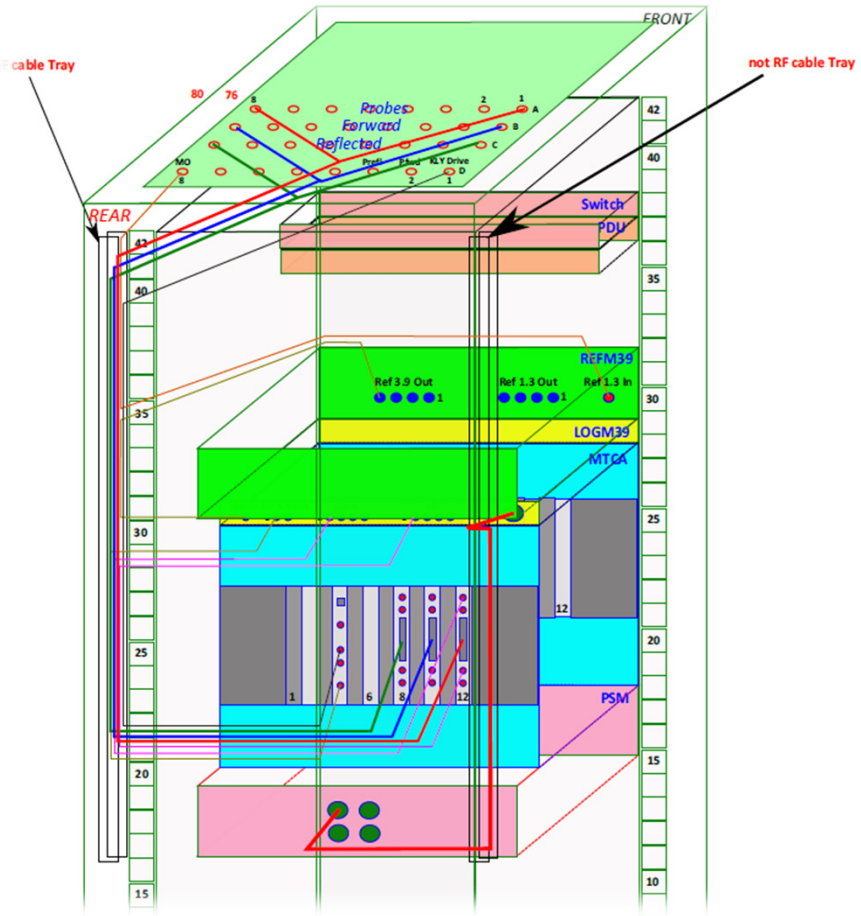


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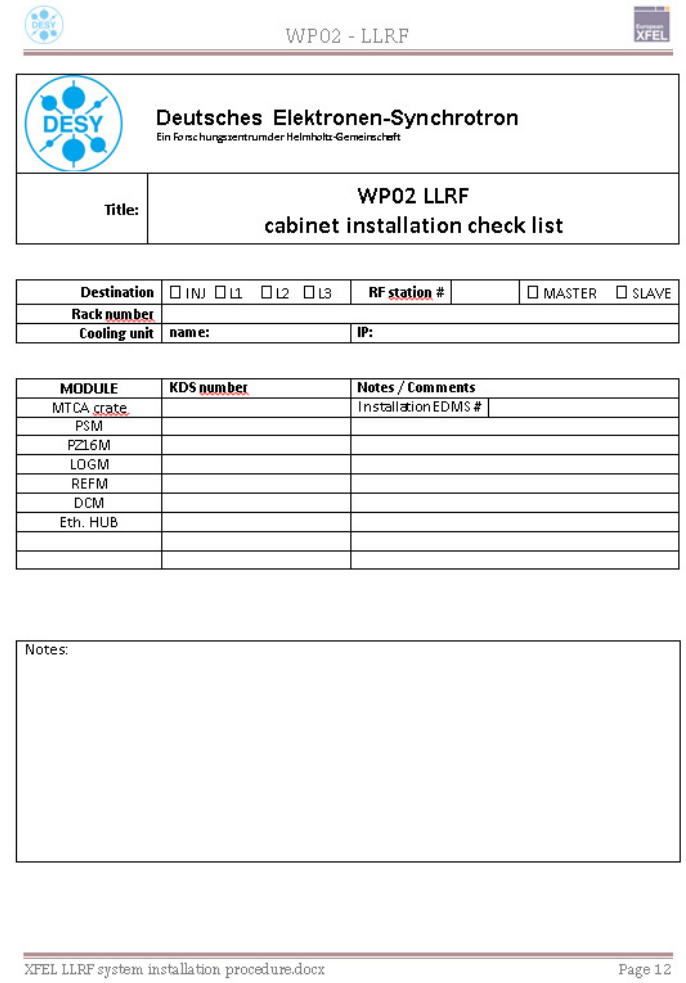


WP02 - LLRF

Deutsches Elektronen-Synchrotron
Ein Forschungszentrum der Helmholtz-Gemeinschaft

| Title: | WP02 LLRF<br>cabinet installation check list |
|---|---|

| Destination | ☐ INJ ☐ L1 ☐ L2 ☐ L3 | RF station # | | ☐ MASTER ☐ SLAVE |
|---|---|---|---|---|
| Rack number | | | | |
| Cooling unit | name: | IP: | | |

| MODULE | KDS number | Notes / Comments |
|---|---|---|
| MTCA crate | | Installation EDMS # |
| PSM | | |
| PZ16M | | |
| LOGM | | |
| REFM | | |
| DCM | | |
| Eth. HUB | | |
| | | |
| | | |

Notes:

XFEL LLRF system installation procedure.docx Page 12

# INSTALLATION STEPS

- Incoming inspe
- Device test
- Crate installati
- Rack installatio
  a. Installation of al
  b. Installation of M
  c. Installation of al
  d. Installation of n
  e. Connection to n
  f. **Cabinet integra**
  g. Storage of cabir
  h. Ready for tunne
  i. KDS final docum of cabinet asse

## At this point:

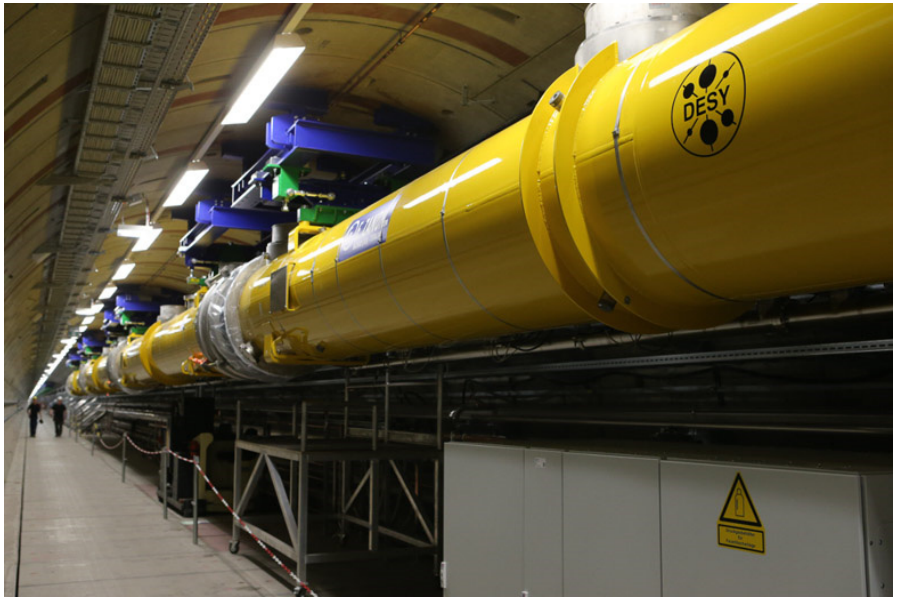
- ✓ Hardware checked
- ✓ Drivers installed
- ✓ Servers installed and configured
- ✓ Inner rack cabling checked
- ✓ Signal integrity verified
- ✓ Pre-commissioning DONE!

➔ **READY FOR TUNNEL INSTALLATION**

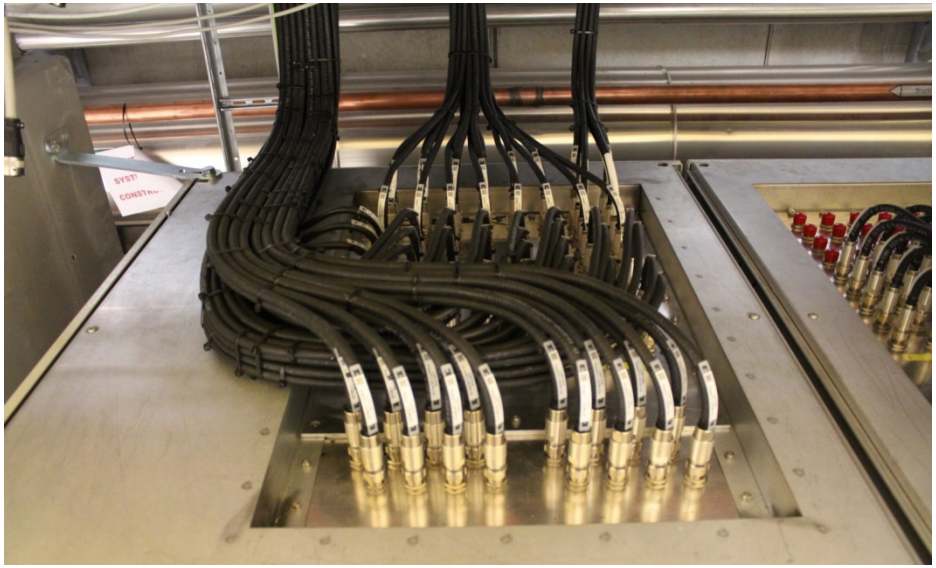
# INSTALLATION STEPS

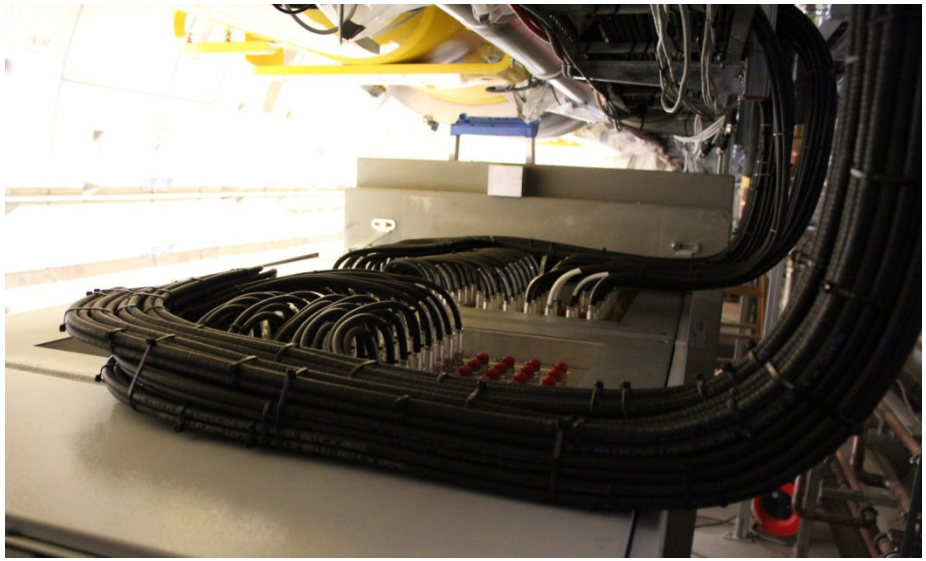
- Incoming inspection
- Device test
- Crate installation
- Rack installation
- Tunnel installation

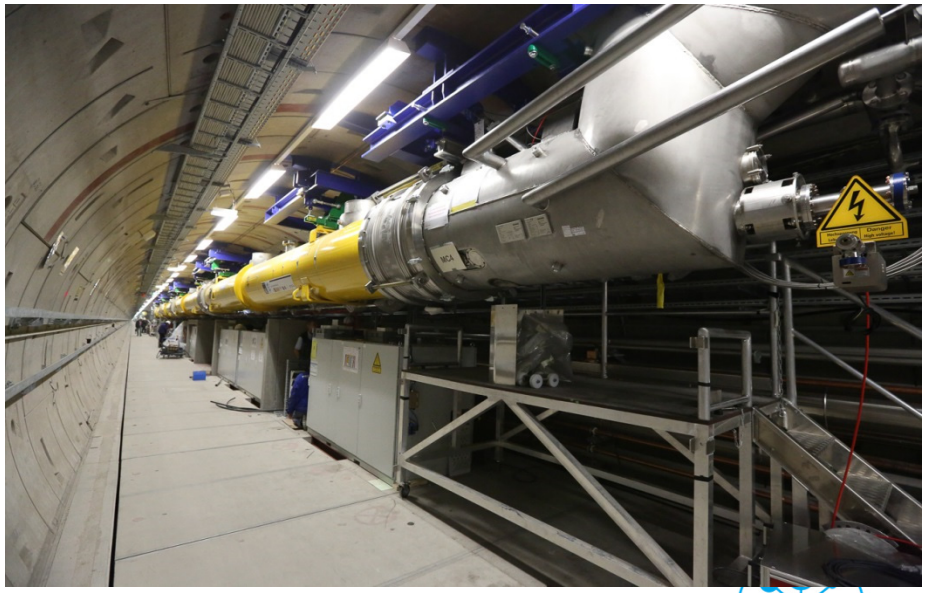
a. cabinet transport
b. RF cabling
c. Fiber optics connections
d. Connections to mains, water and Ethernet
e. Installation of shielding if applicable
f. Power ON
g. Installation complete checklist
h. Notification “system ready for commissioning”
i. Installation complete sign-off




# INSTALLATION STEPS



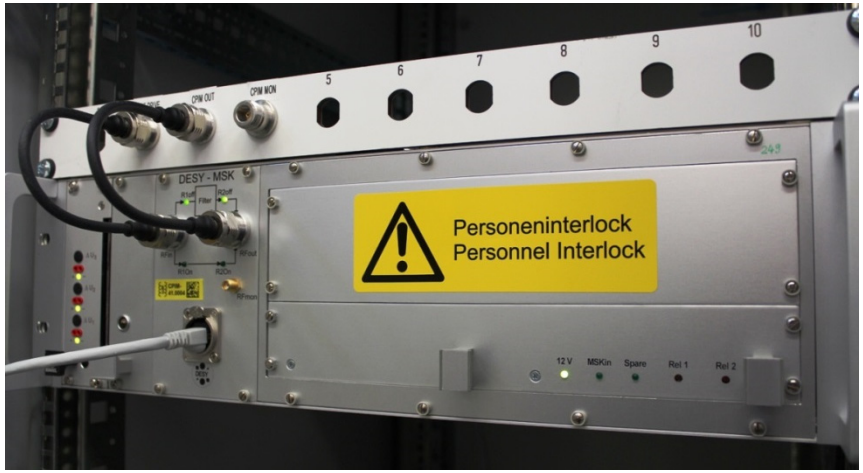


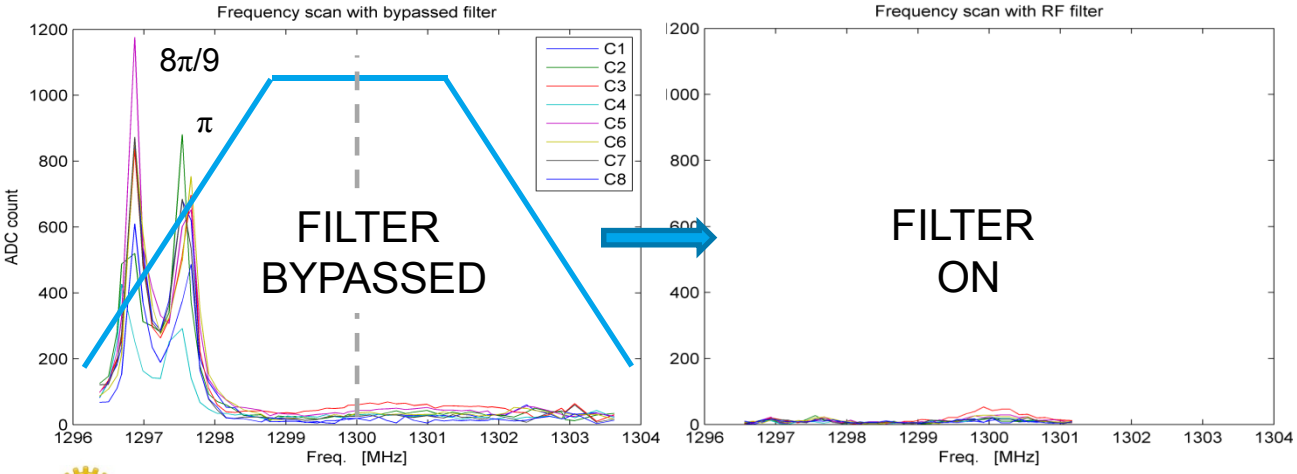
# COMMISSIONING

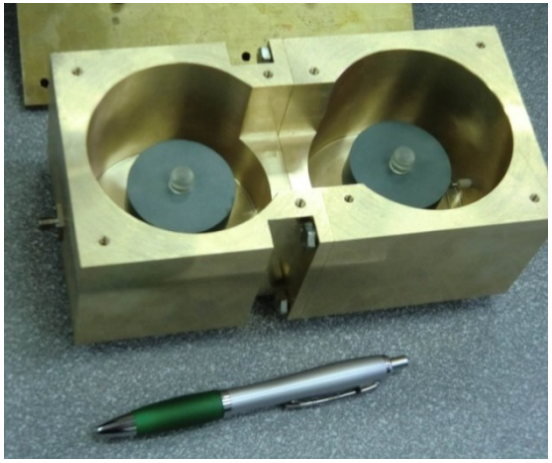
Official Approval for L1.A2 : **Apr. 20th 2015**





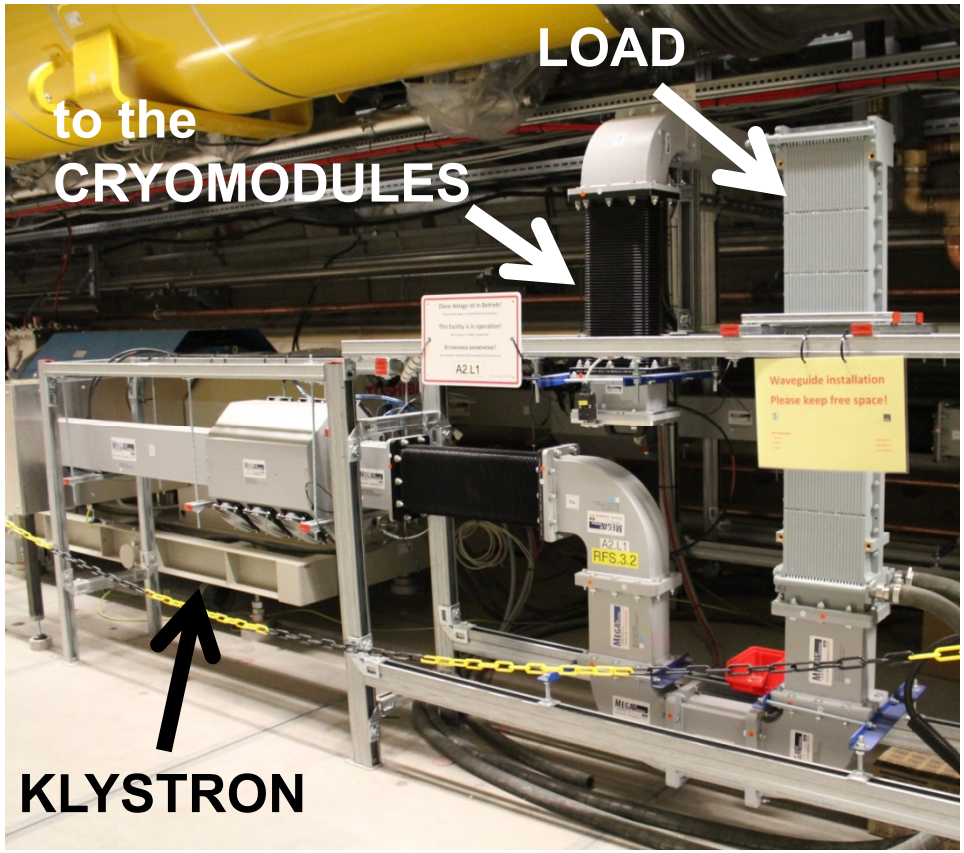

Coupler Processing Interlock Module



# COMMISSIONING

- Subsystem integration
  - LLRF, timing, MPS, klystron
  - synchronization of triggers, gates
- RF ON
  - load / modules
- Outer rack cabling verification
  - rack-rack + rack-module
- Power calibration
  - first time using power meter
  - 1 klystron, 4 cryomodules
- Coupler re-conditioning (warm)
  - automated using FSM




# COMMISSIONING REMARKS

- Installation work in parallel with RF station commissioning
  - No transport (scaffolding, modules, girders…) during klystron operation
  - Careful planning (schedule, shifts)


- Tunnel access
  - limited space next to installed cyromodules
  - keep access path free (equipment, tools, etc…)

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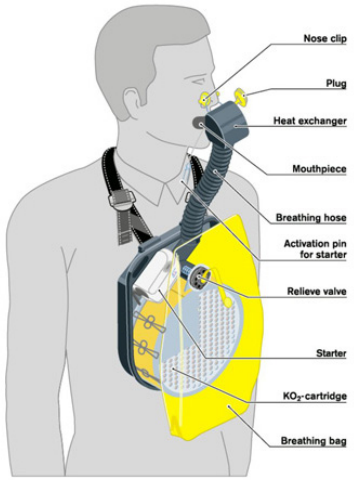
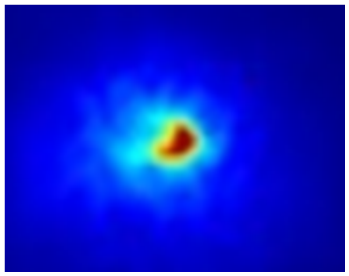
- Tunnel access
  - limited space next to installed cyromodules
  - keep access path free (equipment, tools, etc…)
  - oxygen packs
  - bicycle + trailer (L3: 0.5 – 1.5 km!)



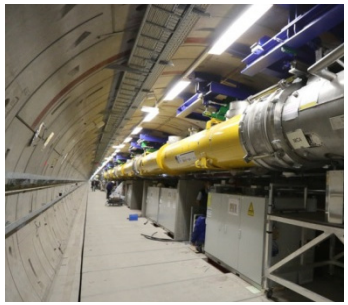

- Optimizing installation granularity

# SUMMARY

- Injector
  - Feb. 2015: first accelerated beam!
  - May-Aug. 2015: A1/AH1 installation
  - Oct. 2015: injector cool down and cold commissioning



- Main linac
  - May 2015: commissioning of first RF station: L1.A2
  - June 2015: commissioning of L3.A6-A8
  - Summer 2016: commissioning of the last RF station



- Quality control / pre-commissioning is essential
  - “check as much as you can, as early as you can”
- Optimizing installation based on experience acquired with first RF station




DESY

# SUMMARY

- Thanks to all my colleagues for the hard work before, during and after installation.

- Thank you to Dirk Noelle for the permission to use his pictures.

- **Thank you for you attention!**


- References:

IPAC 2012: “The European XFEL LLRF system”
MIXDES 2013: “MTCA.4 LLRF system for the European XFEL”
IPAC 2013: “Recent developments of the European XFEL LLRF system“
IPAC 2014: “The European XFEL RF gun commissioning and LLRF linac installation”