LHC Injectors Upgrade

# A new RF system for the PSB.


Wide working group involved including :

S.Albright, M.E.Angoletta, L.Arnaudon, M.Brugger, N.Chritin, A.Findlay, M.Haase, J.Hansen, M.Jaussi, A.Jones, J-M.Lacroix, D.Landre, J.Molendijk, M.Paoluzzi, D.Quartullo, B.Riffaud, C.Rossi, J.Sanchez Quesada, E.Shaposhnikova, ……

……and many more..


LIU-PSB Working Group Meeting, 10th December 2015



CERN

1. *Brief historical recall*
2. *Proven performances*
3. *System characteristics*
4. *Cavities arrangement.*
5. *Available space and layout in the ring.*
6. *Issue with pick up.*
7. *Layout in equipment rooms.*
8. *Required parts and installations.*
9. *Installation planning.*

# Brief historical recall

- *PSB RF system consolidation requires heavy interventions in existing RF systems :*
  - *→ intensity and energy increase → Linac 4.*
  - *→ consolidation of ageing equipment.*
- *Deep and costly interventions required on the C02 and C04 RF systems:*
  - *→ Finemet system studies launched to face new requirements and changes.*
- *Studies converged into a new approach which:*
  - *→ maximize the advantages of the wideband response of Finemet*
  - *→ use of solid-state amplifiers.*
- *A wide range of issues had to be addressed:*
  - *RF power production*
  - *Radiation hardness of solid-state devices*
  - *Dedicated low-level electronics for active cancellation of beam-induced voltages*
  - *Dedicated low-level electronics allowing multi-harmonic operation.*
  - *Beam stability issues*
- *New system performance finally also allow controlled blow-up:*
  - *→ abandon C16 upgrade.*

***The project study phase is now completed, results reported at the project review and full deployment plan endorsed by the management.***

# Proven performances

- ***Beam tests proved the system ability to produce intense beams equivalent to what achieved with standard operation.***
- ***System capable of operation at h1, h2 and h10.***
- ***All system components are largely within thermal and current limits even at high duty-cycles.***
- ***Effects of radiation on the amplifiers in the ring can be mitigated and re-adjustments needed every 10 years.***
- ***The LL digital electronics compensate beam loading and maintain beam stability.***
- ***Extrapolations indicate that operation will be possible at 2GeV and beam intensities as high as $2 \bullet 10^{13}$ ppp.***

# System characteristics.

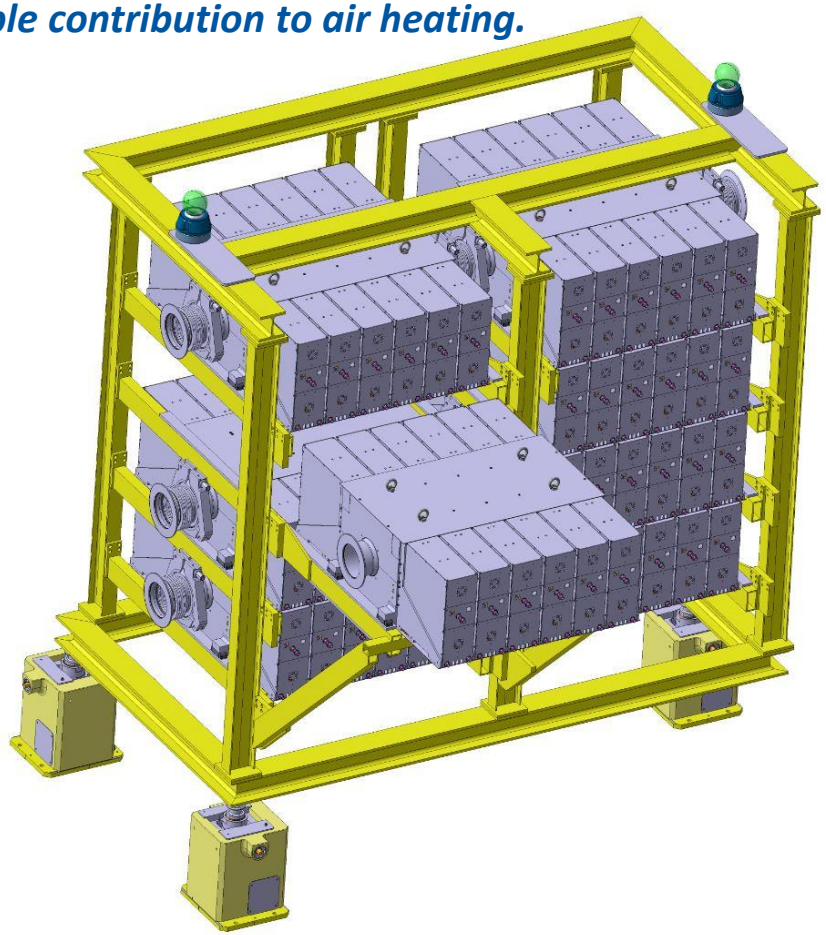
- *Modular system based on wideband, solid-state driven identical cells.*
- *High performance digital Low Level electronics:*
  - *→ Multi-harmonic operation (8, 12 or more beam revolution frequency harmonics)*
  - *→ Voltage allocation at the most appropriate frequency*
  - *→ Active cancellation of beam induced voltage.*
  - *→ Active gap impedance reduction*
- *Ample margins and reserves.*
  - *RF power amplifier designed to ensure operation with 2 broken RF Mosfets out of 16.*
  - *System designed to ensure operation with 6 broken cells per ring.*
- *PLC interlocks individually tracing the characteristics of the RF Mosfets, RF amplifiers, radiation effects, etc.*
- *PLC / Low Level electronics communication ensures best performance with available number of cells.*

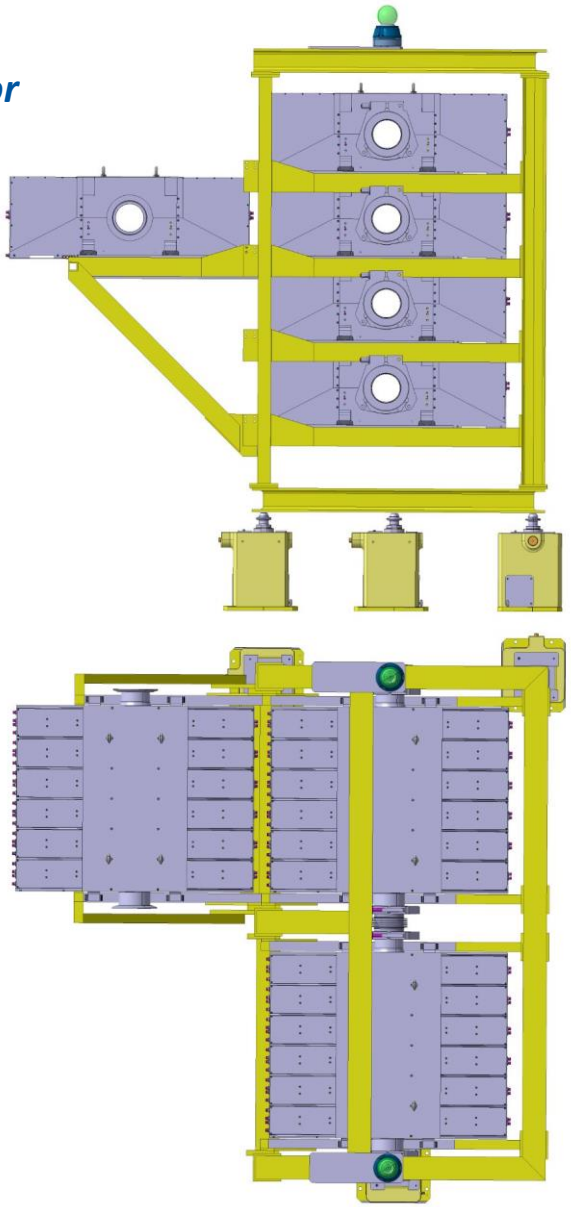
# System characteristics.

| Parameter | Value |
|---|---|
| Operation Frequency | 1 MHz to 18 MHz |
| Operation mode | Single frequency or multi-harmonic |
| Single cell voltage<br>Freq < 4 MHz<br>Freq > 4 MHz | <br>700 $V_{Pk}$<br>Linearly derate to 250 $V_{Pk}$ |
| Total nominal voltage<br>Freq < 4 MHz<br>Freq > 4 MHz | <br>24 $kV_{Pk}$<br>Linearly derating to 4 $kV_{Pk}$ |
| Cell length | 130 mm |
| Number of cells in a cavity | 6 |
| Number of cavities per ring | 6 |

# Cavities arrangement (preliminary).

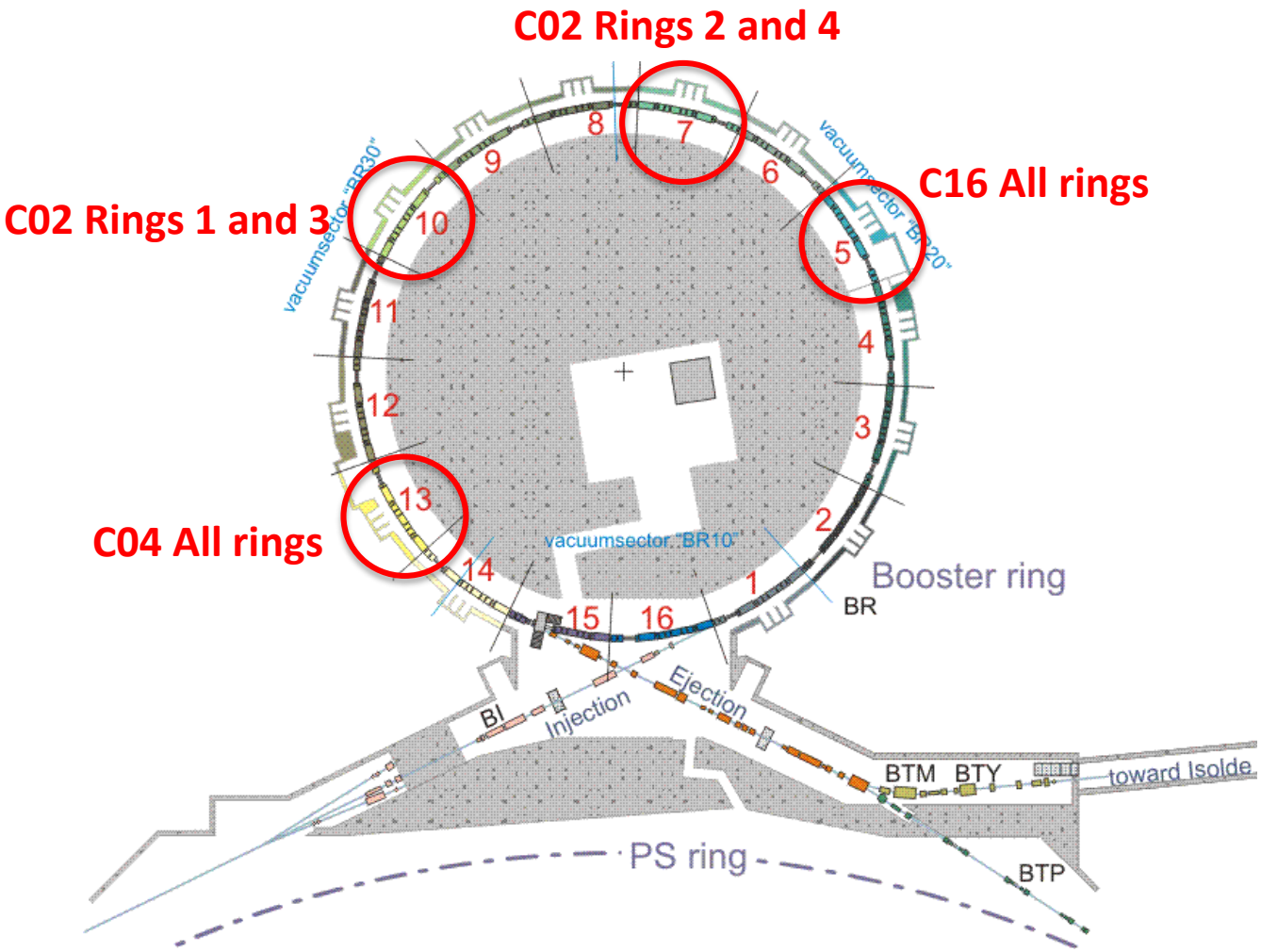
- *Two 6-gaps units can be installed in each section and ring.*
- *Amplifier installed on one side only. Other side available for future improvements.*
- *Cavities and power amplifiers cooled by demineralized water.*
- *Negligible contribution to air heating.*





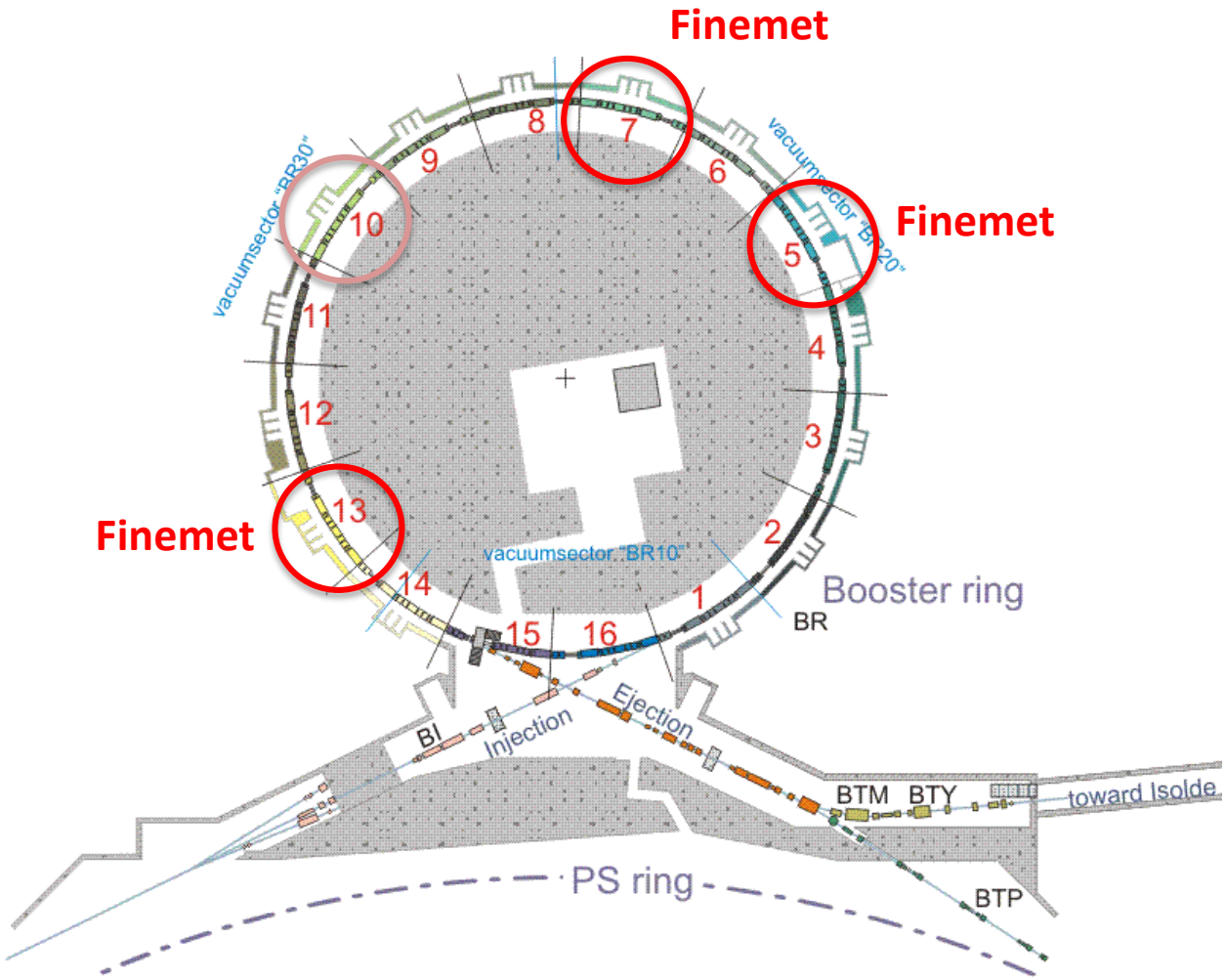
# Available space in the machine.

***Four sections presently attributed to RF systems: 5L1, 7L1, 10L1 and 13L1***

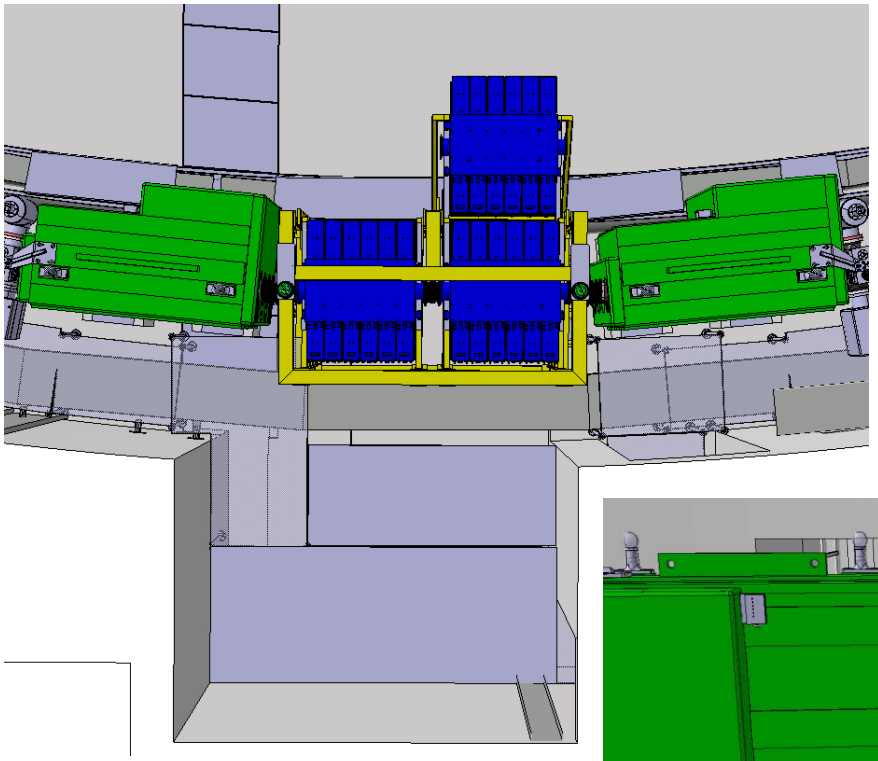


# Proposed layout in the ring.

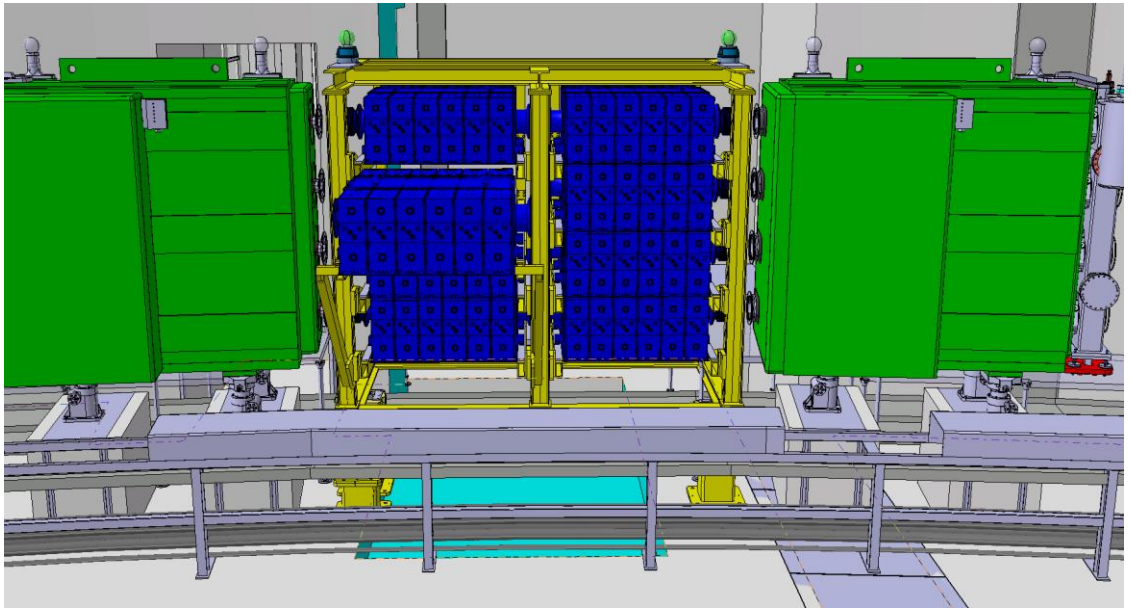
***Use of three sections for new RF systems: 5L1, 7L1 and 13L1. Section 10L1 in stand-by.***



# Proposed layout in the ring.

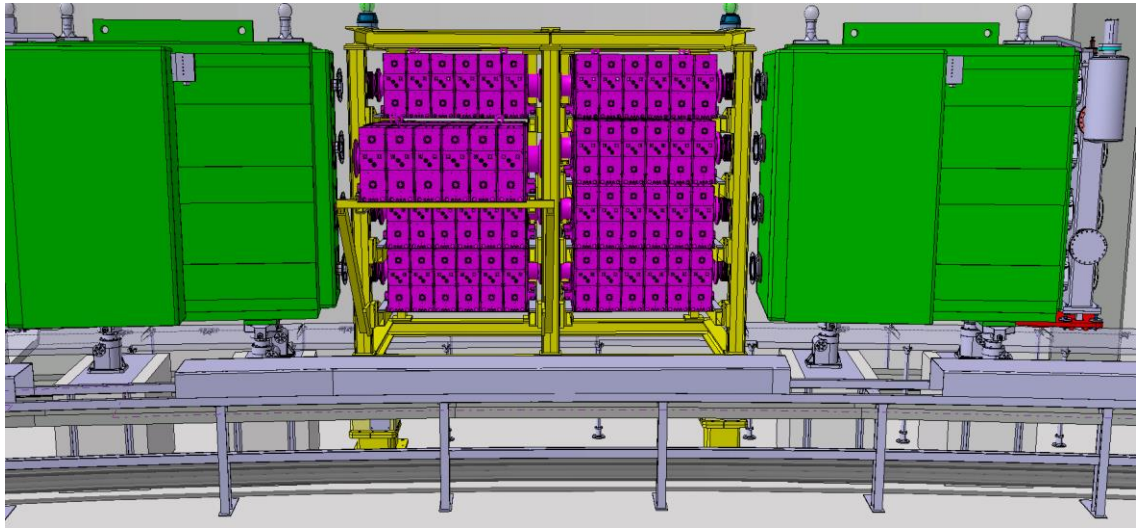


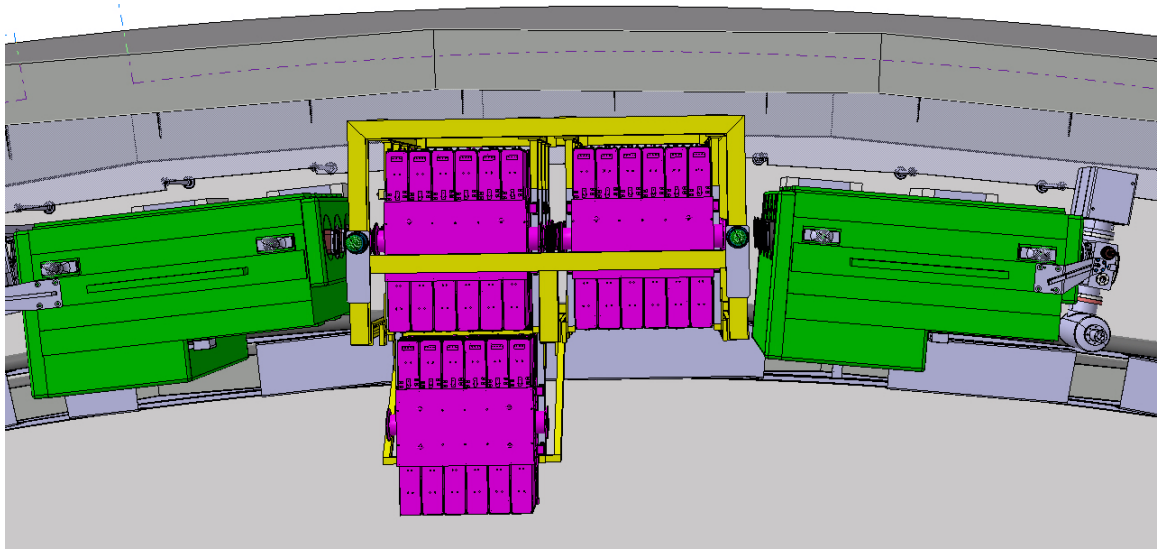
***13L1***



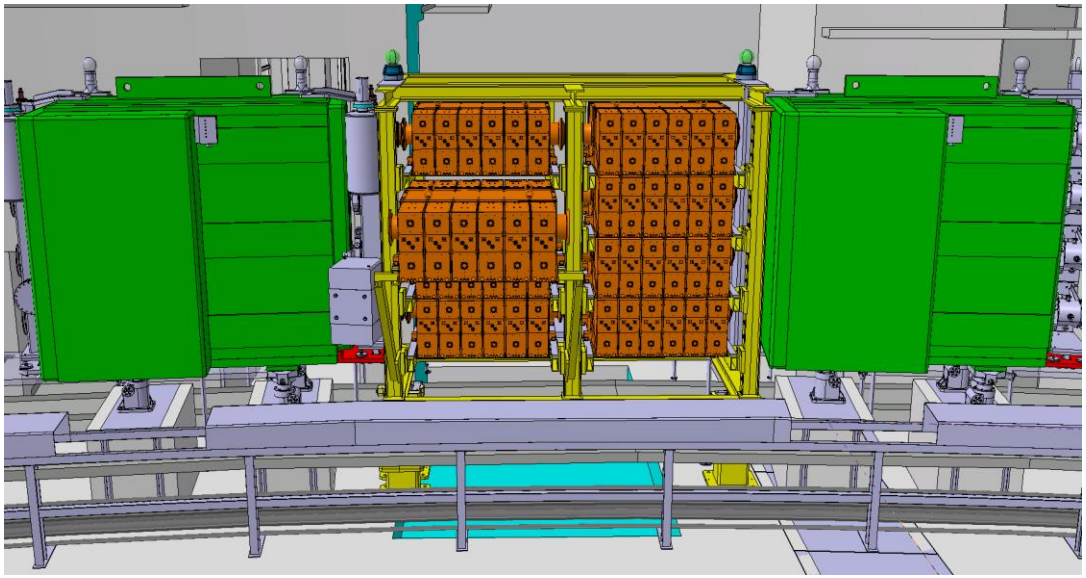
# Proposed layout in the ring.

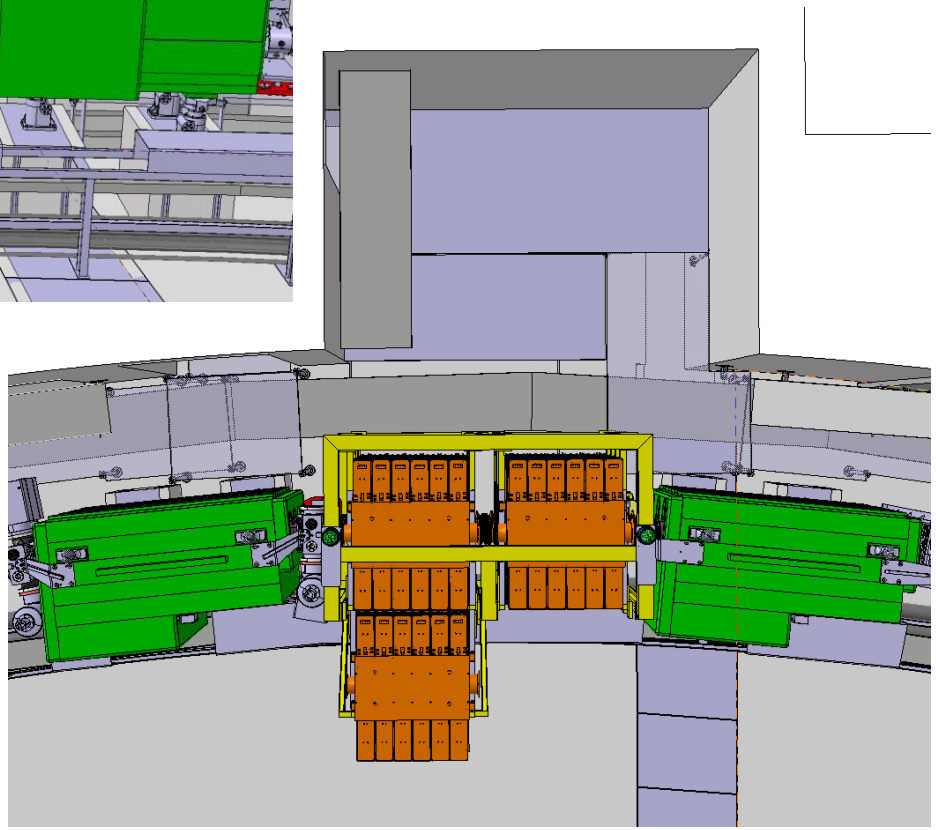
7L1





# Proposed layout in the ring.





***5L1***

# Issue with BPP5L1 pick-up.

*Section 5L1 presently filled with :*

- *The C16 RF system*
- *The pick-up BPP5L1*

*Both to be removed to allow the new installation.*

*Existing pick-up installed in sections:*

- *1L5, 8L1, 11L2 : not used*
- *5L1, 14L4 : 1 in use and 1 spare*

*Proposed future pick-up arrangement :*

- *1L5 : not used may be removed*
- *8L1, 11L2 : 1 in use and 1 spare*
- *5L1 : removed*
- *14L4 : not used may be removed*

*Proposed strategy agreed by*

- *RF : A. Blas and A. Findlay*
- *BI : L. Soby*
- *OP : B. Mikulec*

*During 2015-2016 YETS*

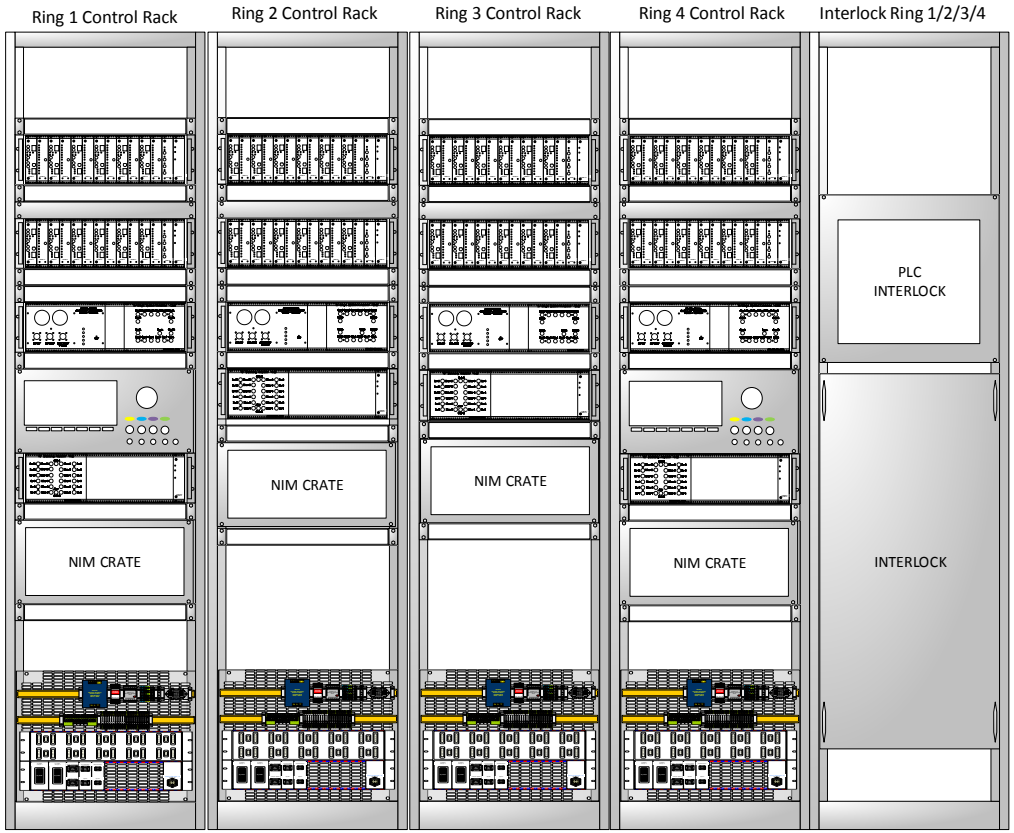
*Head amplifiers installed in 8L1 and tested during 2016.*

*During 2016-2017 EYETS*

*Head amplifiers will be installed in 11L2 and tested during 2017.*

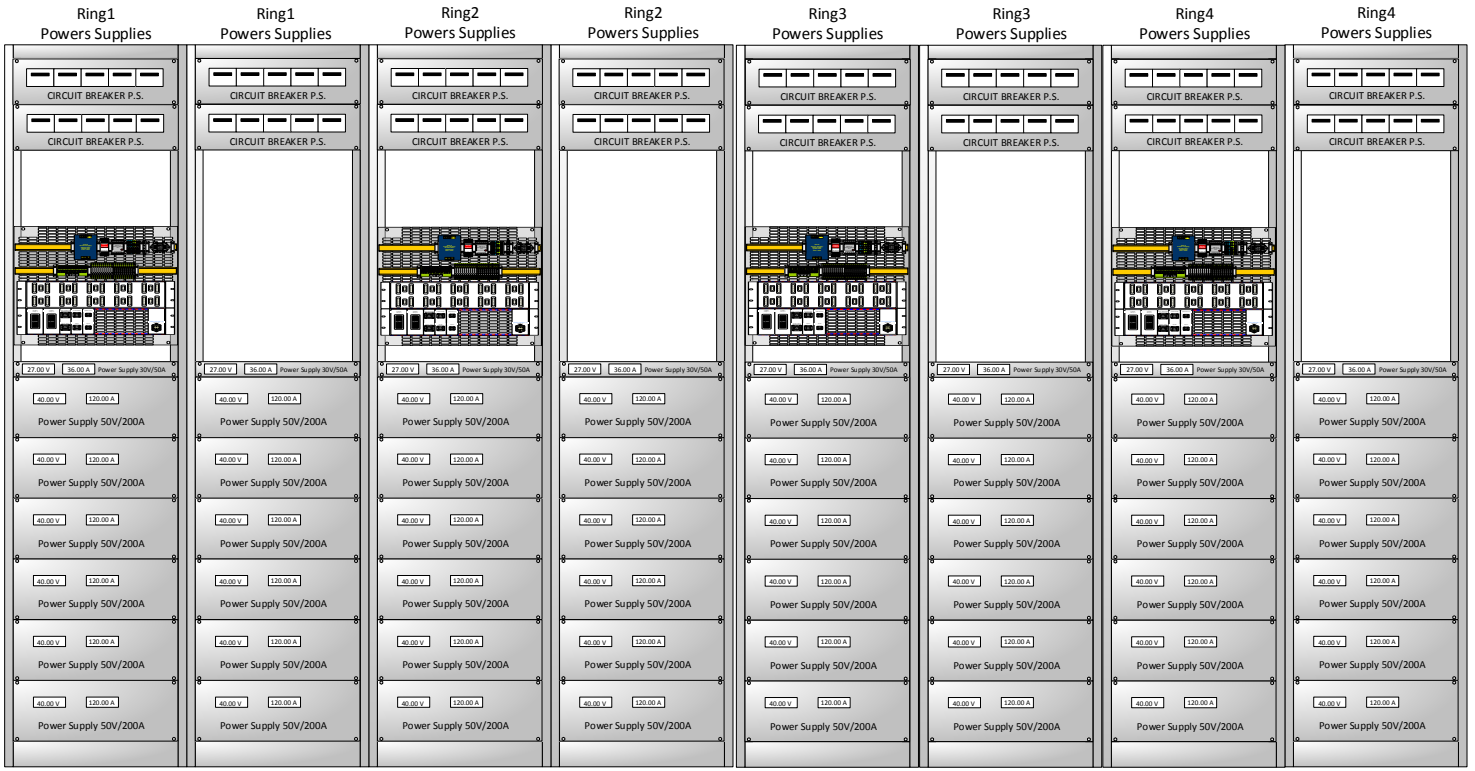
*Removals, changes etc. to be discussed with TE/VSC*

# Rack Layout: FINEMET control for one Section




- *Racks for control electronic and interlock: section 5L1, 7L1 and 13L1*
- *Each cavity 1 control rack*
- *For one section (4 cavities) 4 control racks plus one interlock rack*
- *Three systems 15 control racks*

# Rack Layout: Power Supplies for one Section

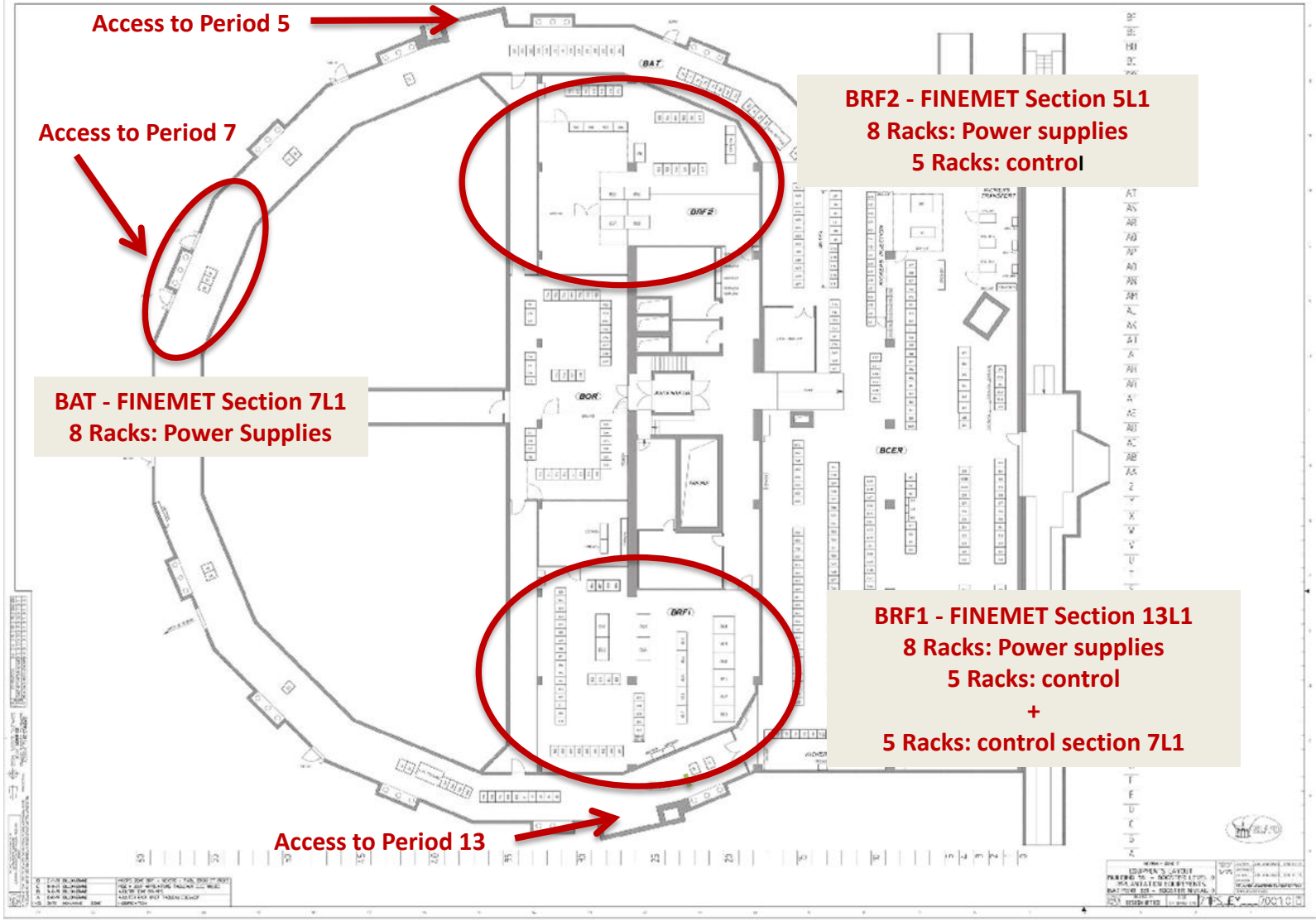



- ***Racks for power supplies: section 5L1, 7L1 and 13L1***
- ***Each cavity 2 racks with power supplies one section 8 racks***
- ***Three systems 24 racks with power supplies***


**M. Haase**

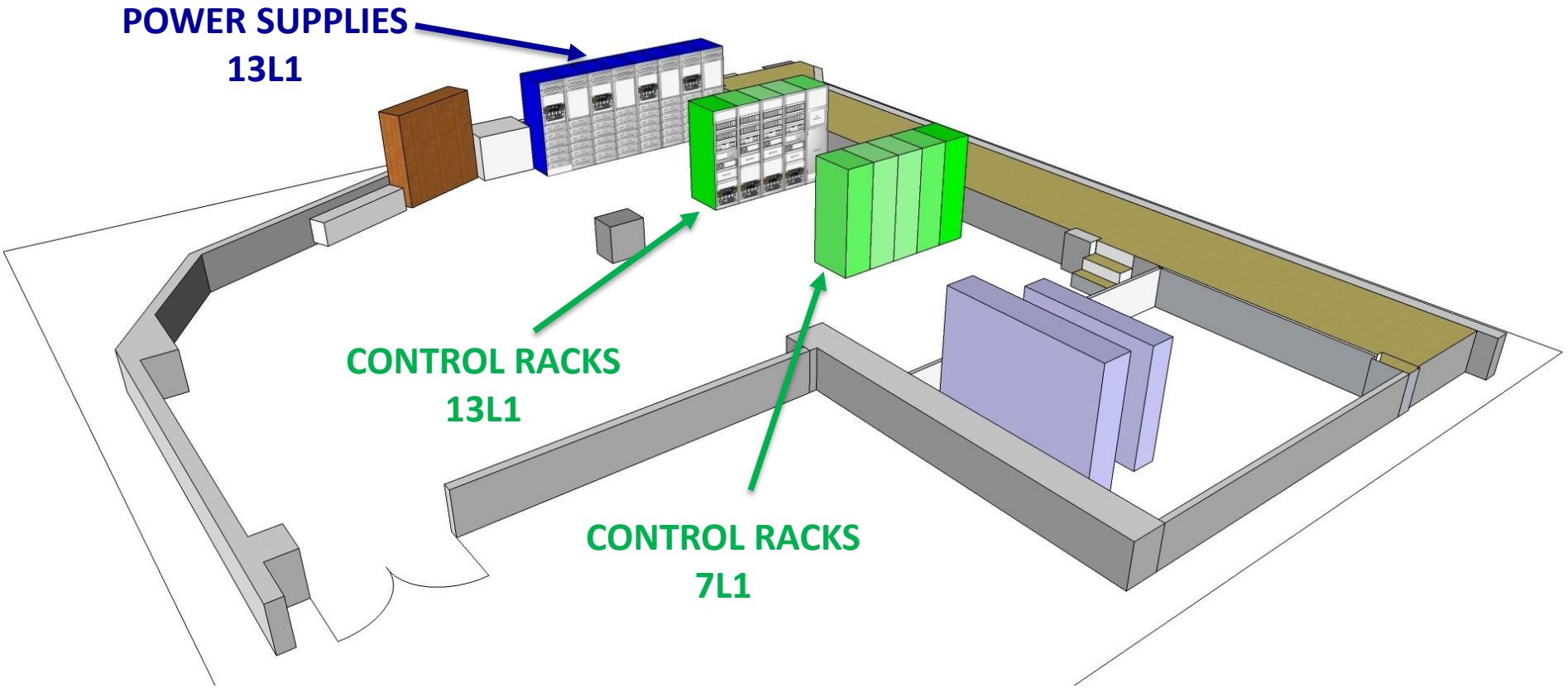
**December 10th 2015**

# Booster 361/1

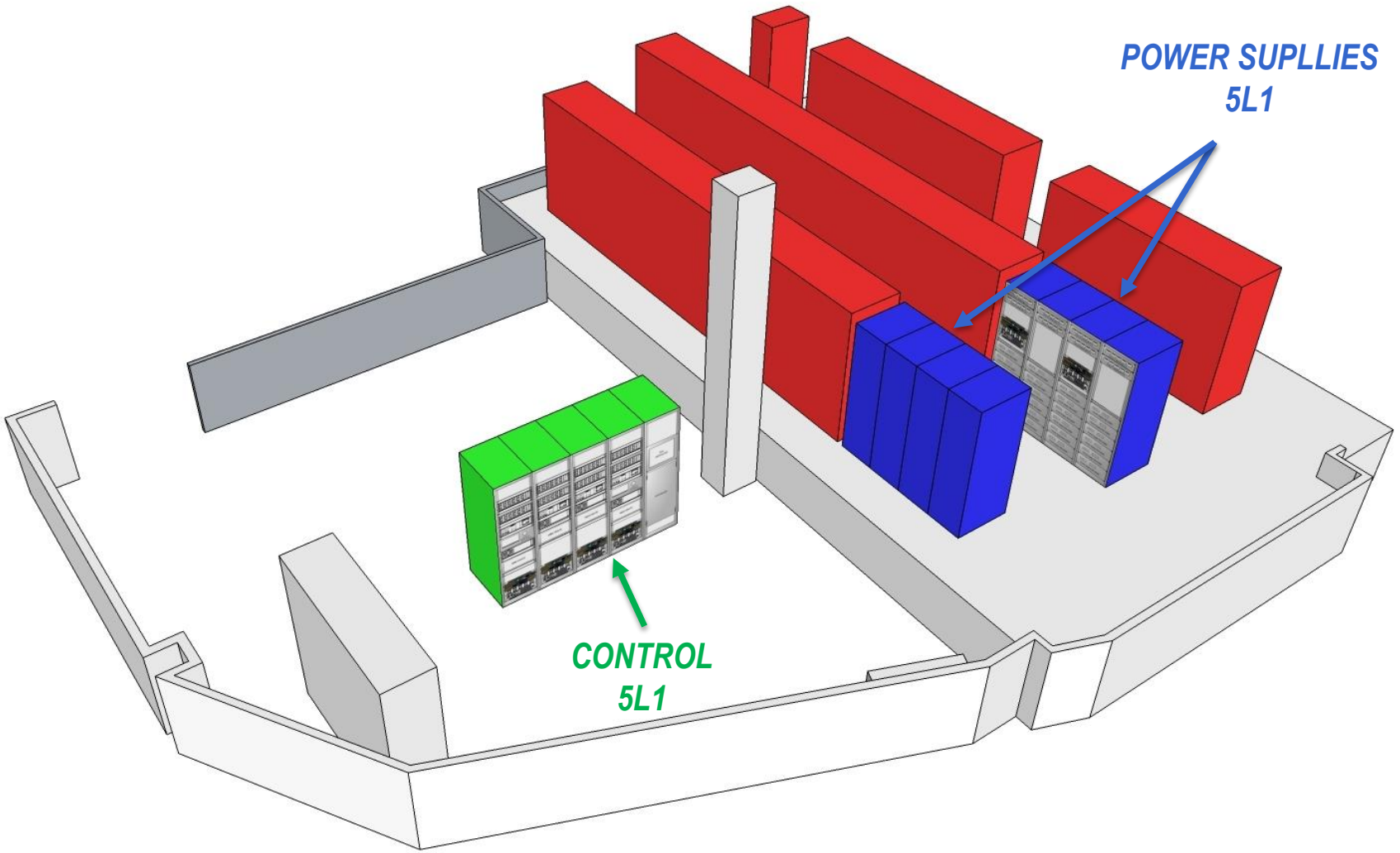



M. Haase
December 10th 2015

# BRF 1 LAYOUT LS2



# BRF2 LAYOUT LS2: FINEMET SECTION 5L1

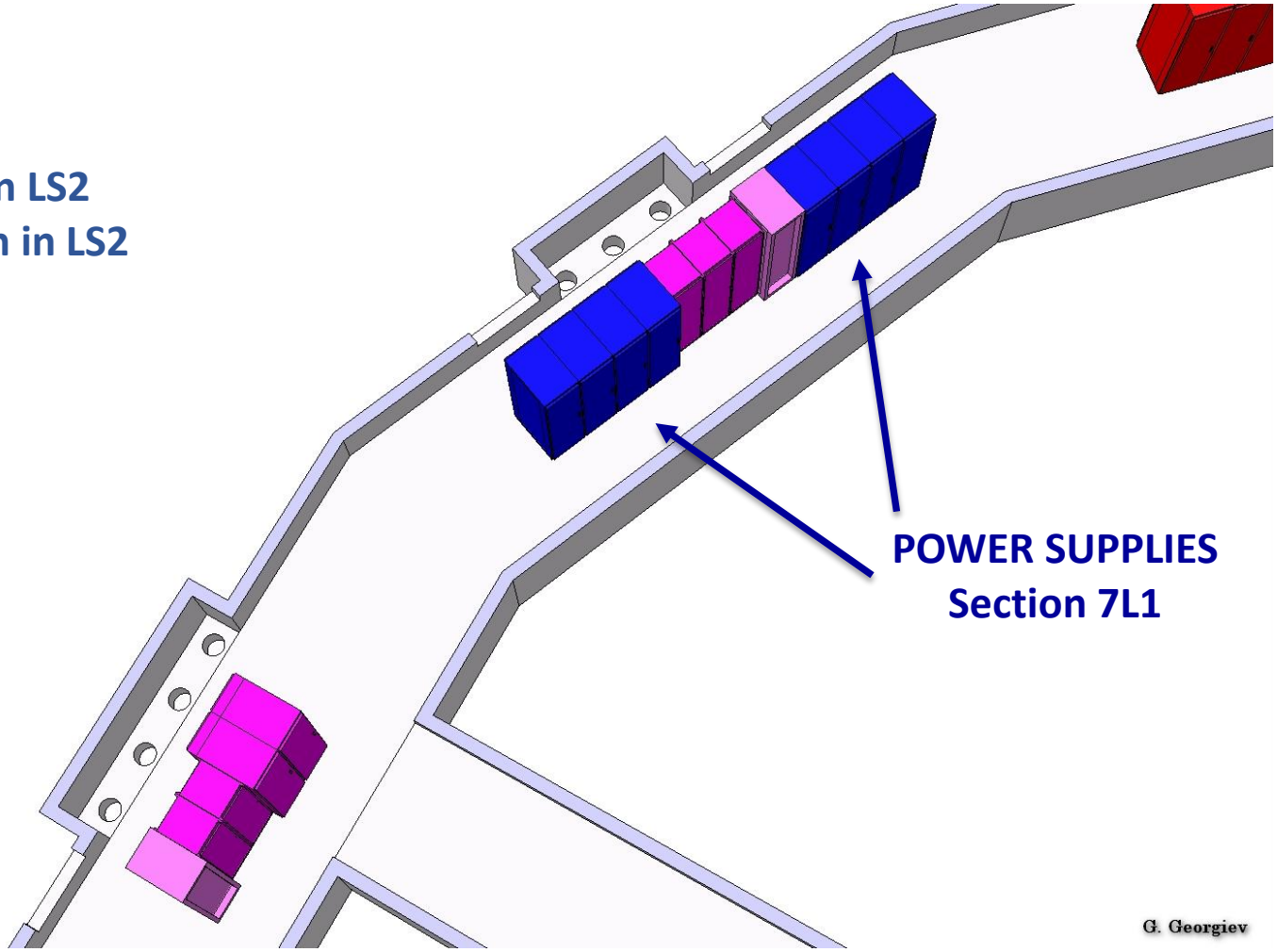





M. Haase
December 10th 2015

# BAT Layout LS2 Access Period 7L1

**Rack structure in LS2**
**Rack installation in LS2**



# Required parts and installations.

- *The modular system has the advantage of being mostly composed of standardized units:*
  - *The 6-gaps cavity* — *24 units + 2 spare*
  - *The RF amplifier* — *144 units + 20 spares*
  - *40V 200A power supply* — *144 units + 20 spares*
  - *30V 50A power supply* — *24 units + 3 spares*
  - *Ancillary electronics and RF drivers* — *24 units + 3 spares*
  - *PLC interlocks* — *24 units + 1 spares*
- *Additional components/contributions will be:*
  - *Cooling water distribution - S. Moccia informed (EN-CV) :≈ 48m$^3$/hr per section*
  - *Cabling - G. Minchev informed (EN-EL) : Remove≈ 2000 / install ≈ 1200 cables*
  - *Power distribution & cabling - J. Devine informed (EN-EL)*
  - *Timing and intranet*
  - *Rack integration BRF1 / BRF2 /BAT*
- *Dedicated test place for parts acceptance, test and maintenance.*

# Installation planning.

**All system elements will be assembled, tested in the test place and ready for installation before beginning of LS2.**