

**High
Luminosity
LHC**

SPS Crab Cavity Integration & Test Program

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On behalf of WP4



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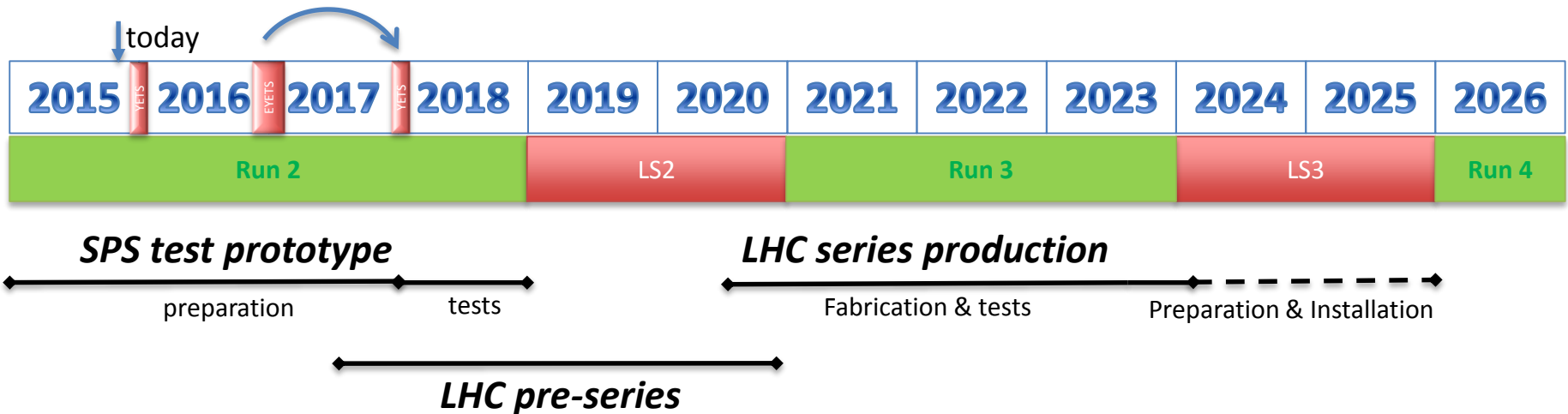


Scope

- *LHC-CC09, Action Item*
 - *Evaluate the difference between electrons & protons with crabs*
- *Performed actions so far*
 - CCinS & CCTC: *feasibility of testing 2-cavity cryomodule in SPS*
 - *LSS6 established as the SPS location*
 - *Ongoing SPS emittance growth studies to have a baseline*

HL-LHC Project Phases, v2

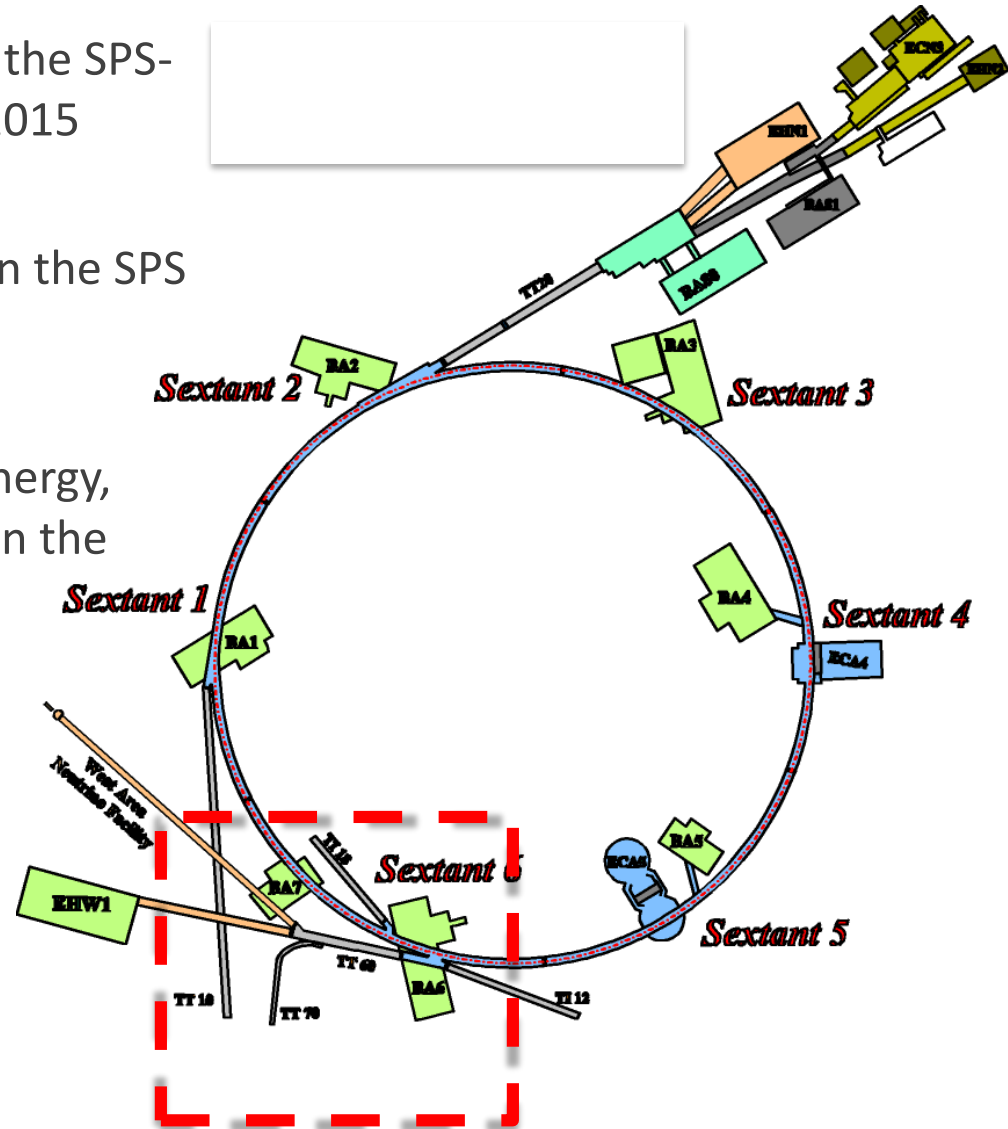
YETS – 8 weeks
EYETS – 14 weeks



- After C&S review: move the cryomodule installation to YETS-2017/18
 - Use 2015/16/17 technical stops for tunnel & surface preparation
 - Test 1 cryomodule in 2018, the 2nd after LS2
- Earlier cryogenic bottleneck solved with new scheme (thanks WP9)
- Space requirements almost clear

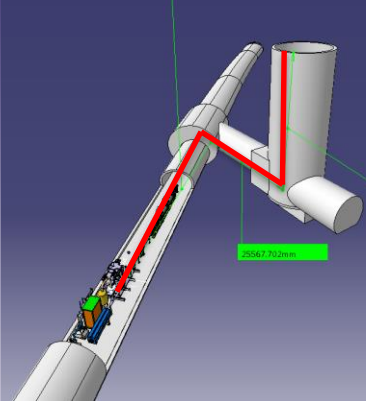
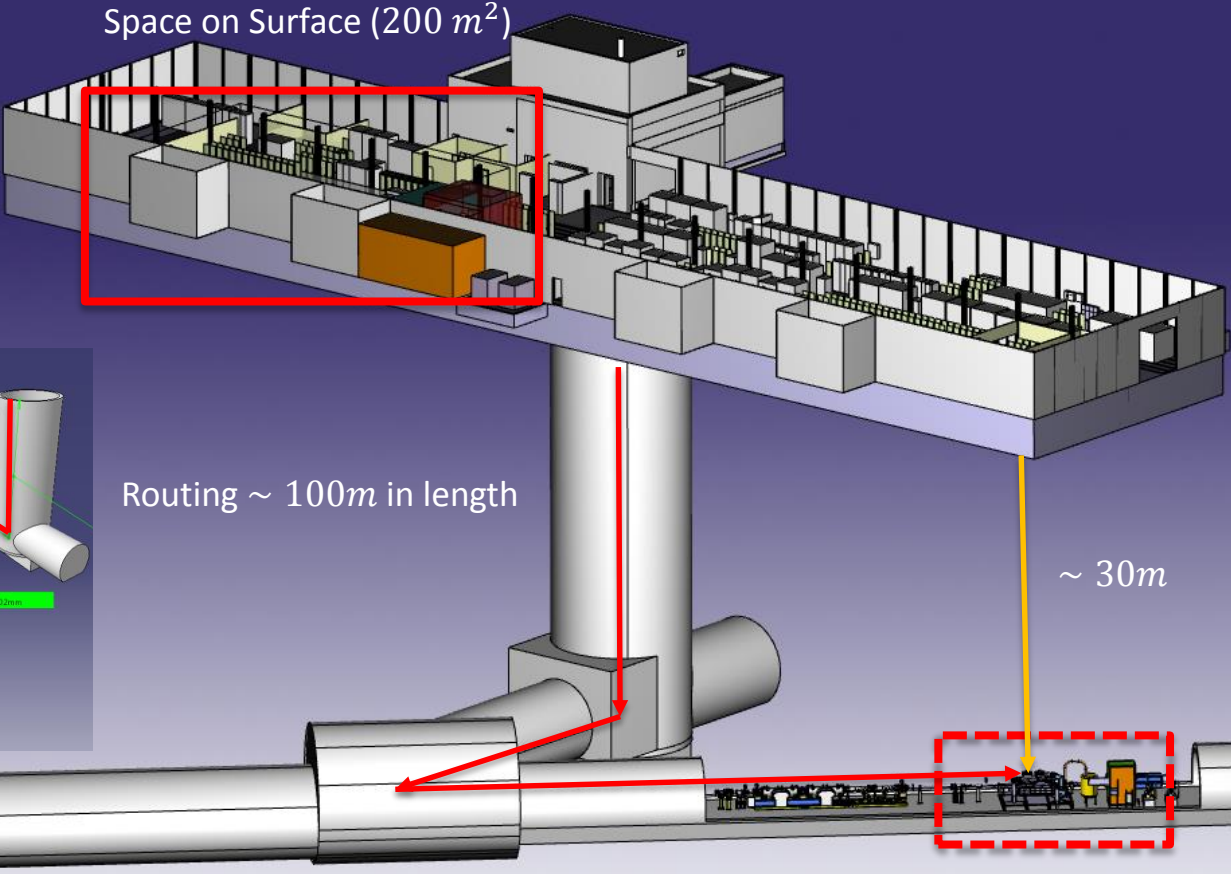
SPS-LSS6 Bypass

- Decision to place crab cavity testing in the SPS-LSS6 (in collaboration with LIU) – Jun 2015
- A more permanent SC-RF test station in the SPS (thanks Lucio!)
- When finished, it will be the highest energy, high current proton SC-RF test facility in the world.



3D Layout, Preliminary

Courtesy EN-MEF-INT



SPS-LSS6

Machine Parameters

Energy = 55, 120, 270 GeV

$\beta_{x,y} = 40, 80$ m

Dispersion = -50 cm

Available length ~ 9.5 m

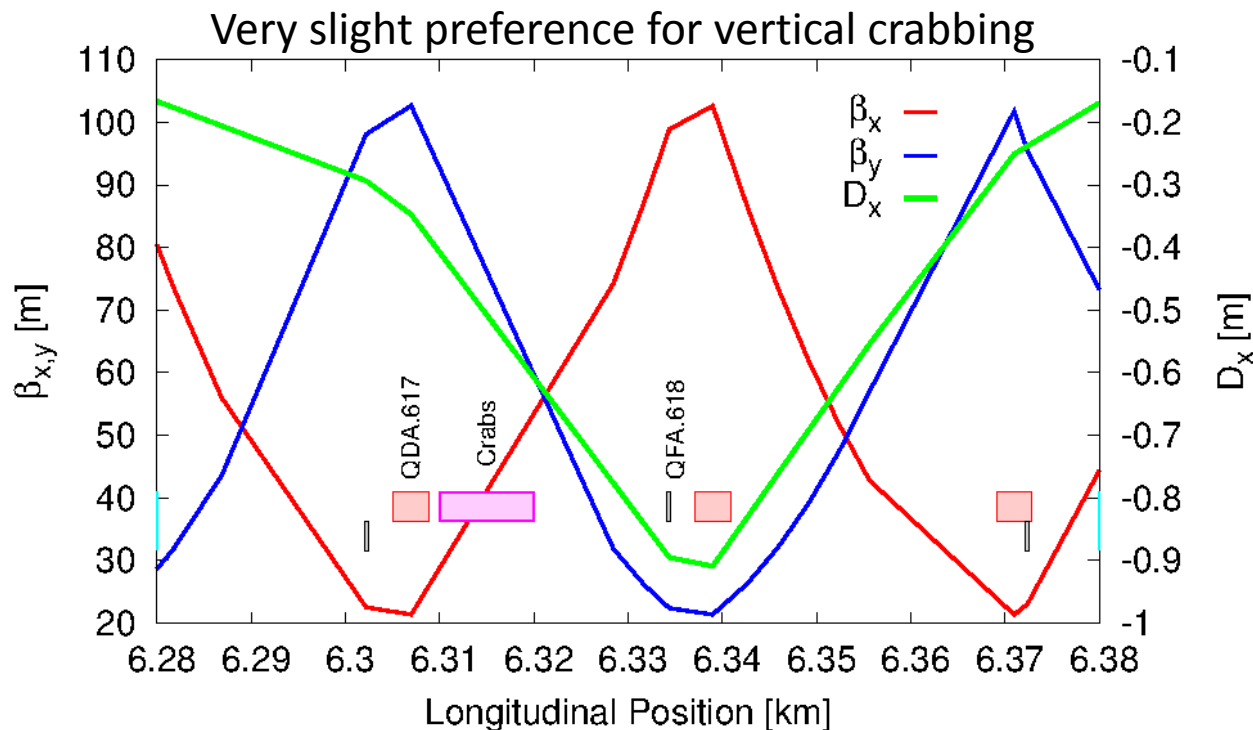
Instrumentation

Longitudinal: BCT, Fast BCT, BSRT

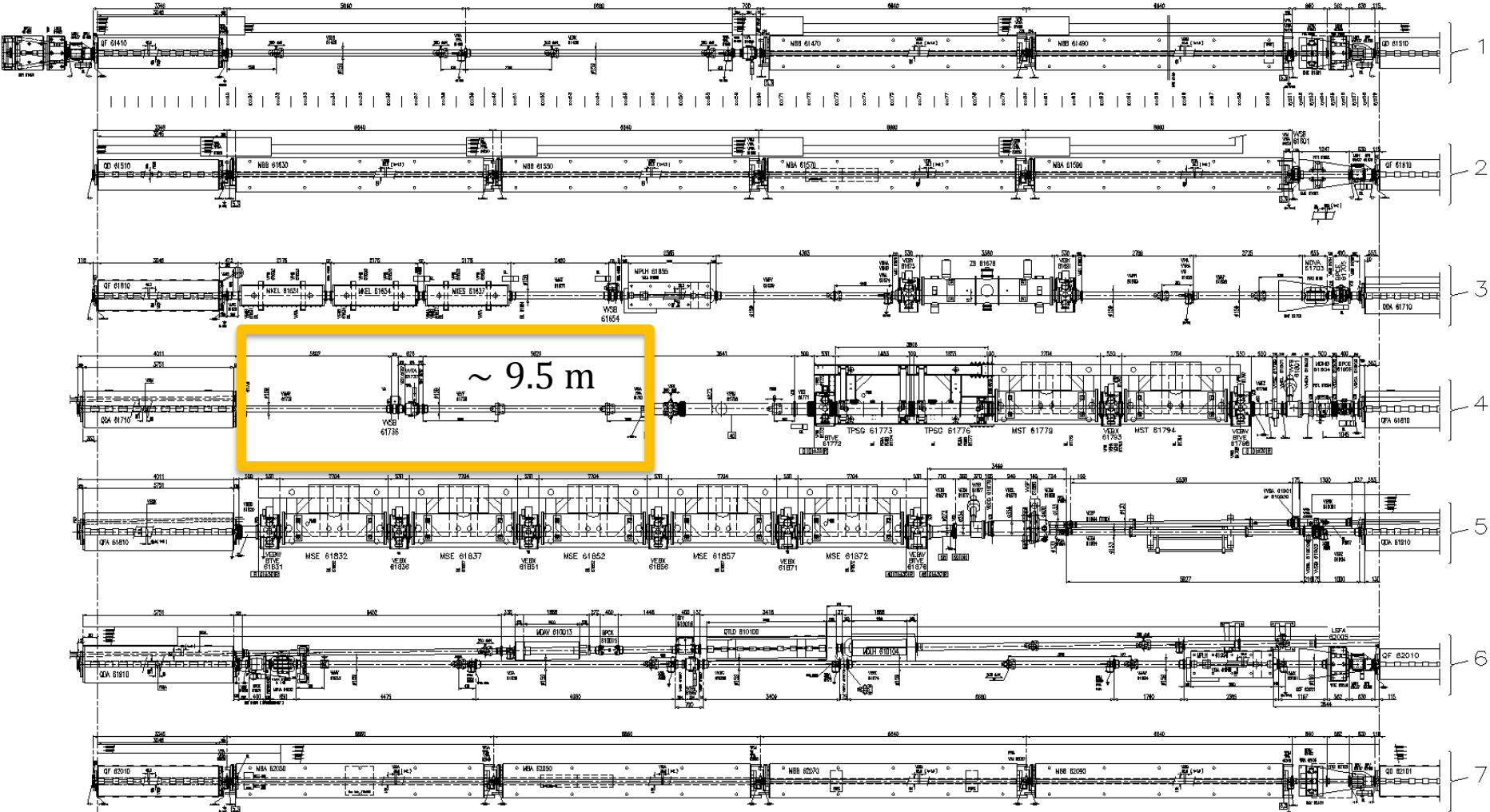
Transverse: Wire scanners, BGI

Trajectory: 216 BPMs, 4 LHC BPMs, Damper PUs

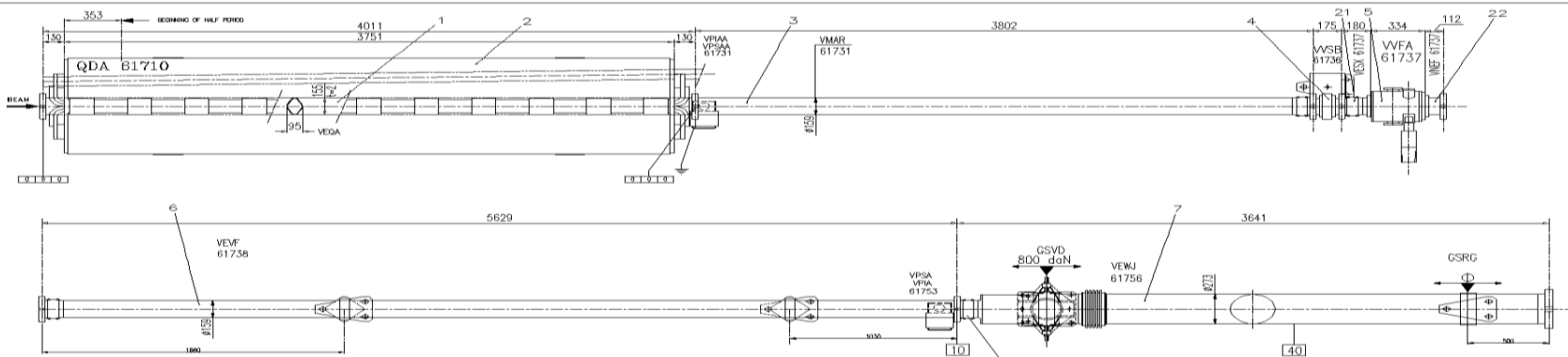
Intra-bunch: Head-tail monitors, Optical PU



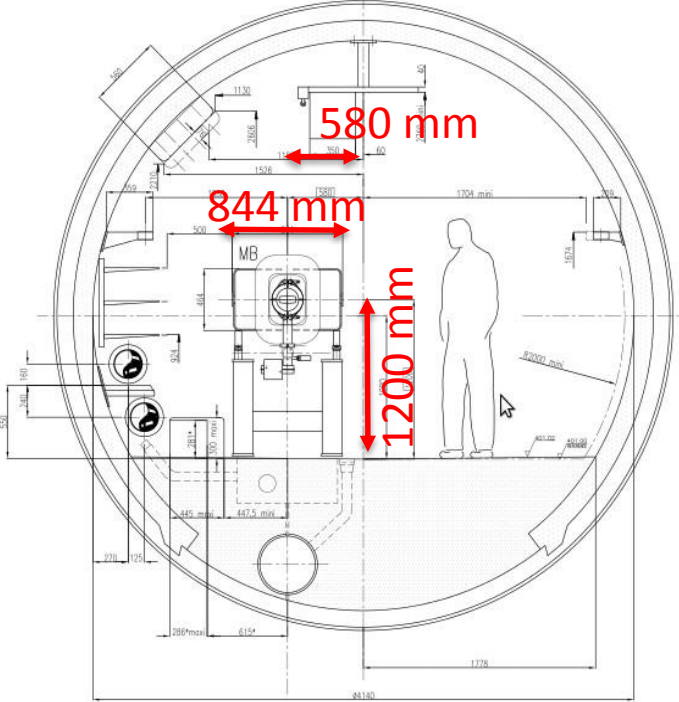
SPS Long Straight Section 6



SPS QDA617 – QFA618



Standard SPS Cross Section

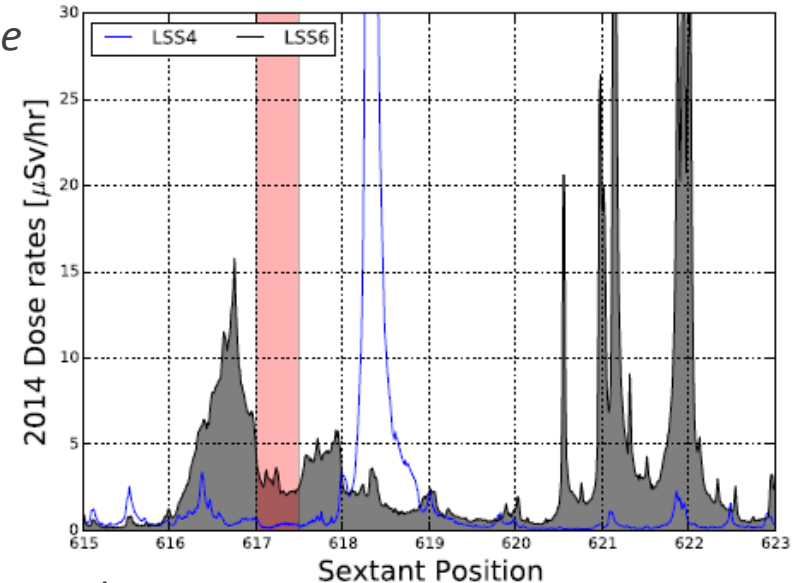


Present LSS6, “Crab Zone”

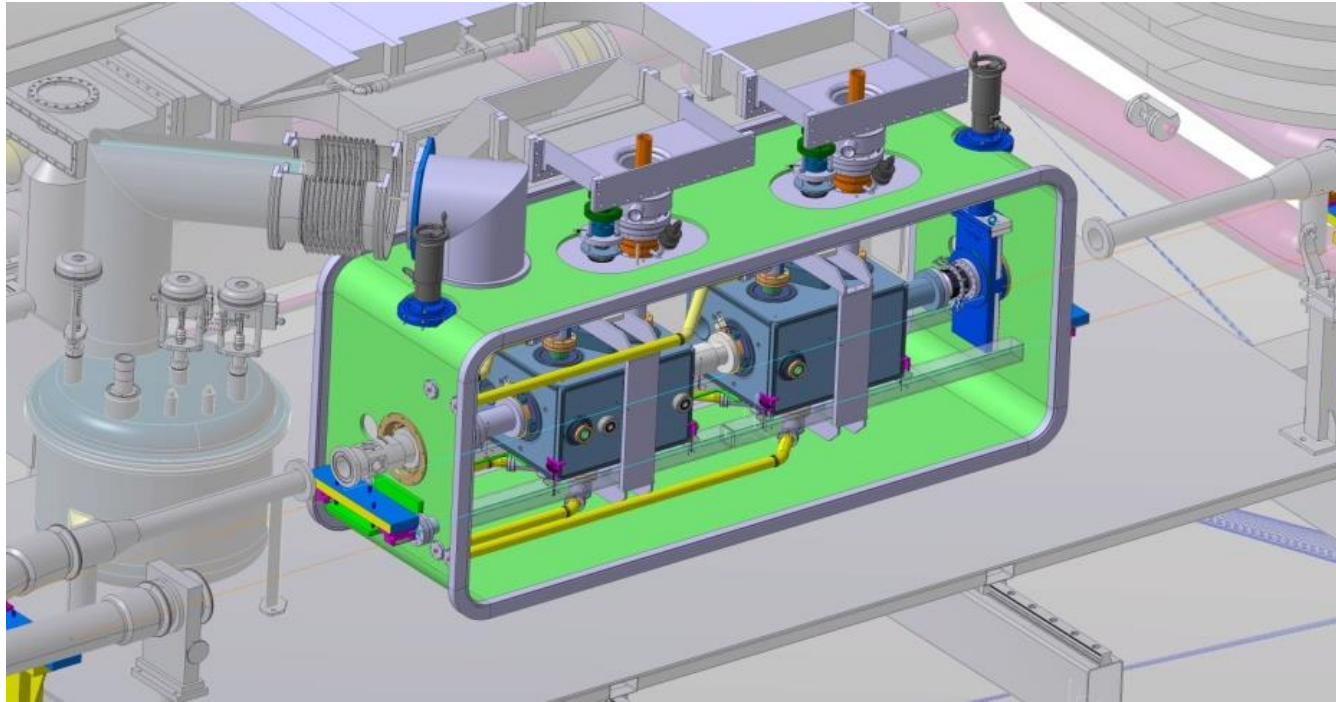


Radiation & Safety

- Classified as supervised area ($\leq 3\mu\text{Sv/h}$)
 - Compared to LSS4 it is higher, RP survey in coming YETS
 - Requires controlled area training to access the zone
- 2nd cryogenic area in the SPS tunnel
 - Buffer tank (150 L) & service module near crabs
 - Cold box in a near by “cavern” (TBD)
- Access to Cryomodule and RF equipment
 - Scheduled maintenance ($\sim 1/\text{yr}$, several hrs)
 - Intervention on Cryomodule, RF guides, etc.. of up to 1 day

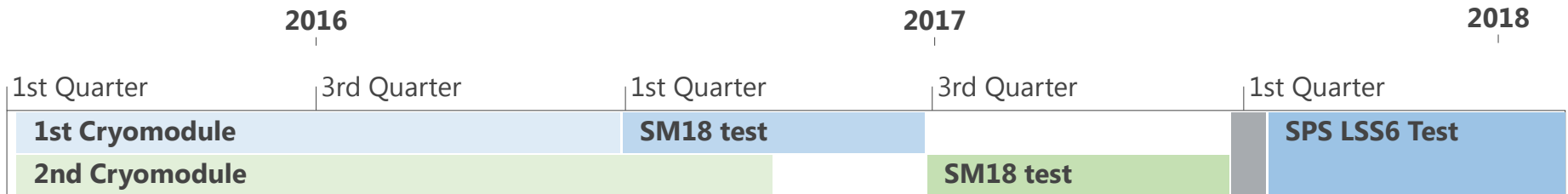


SPS Test Prototype, Design Evolution



Cryomodule Review (Nov 10-11, 2015) to finalize the conceptual designs
→ production phase SPS-LSS6 detailed integration launched

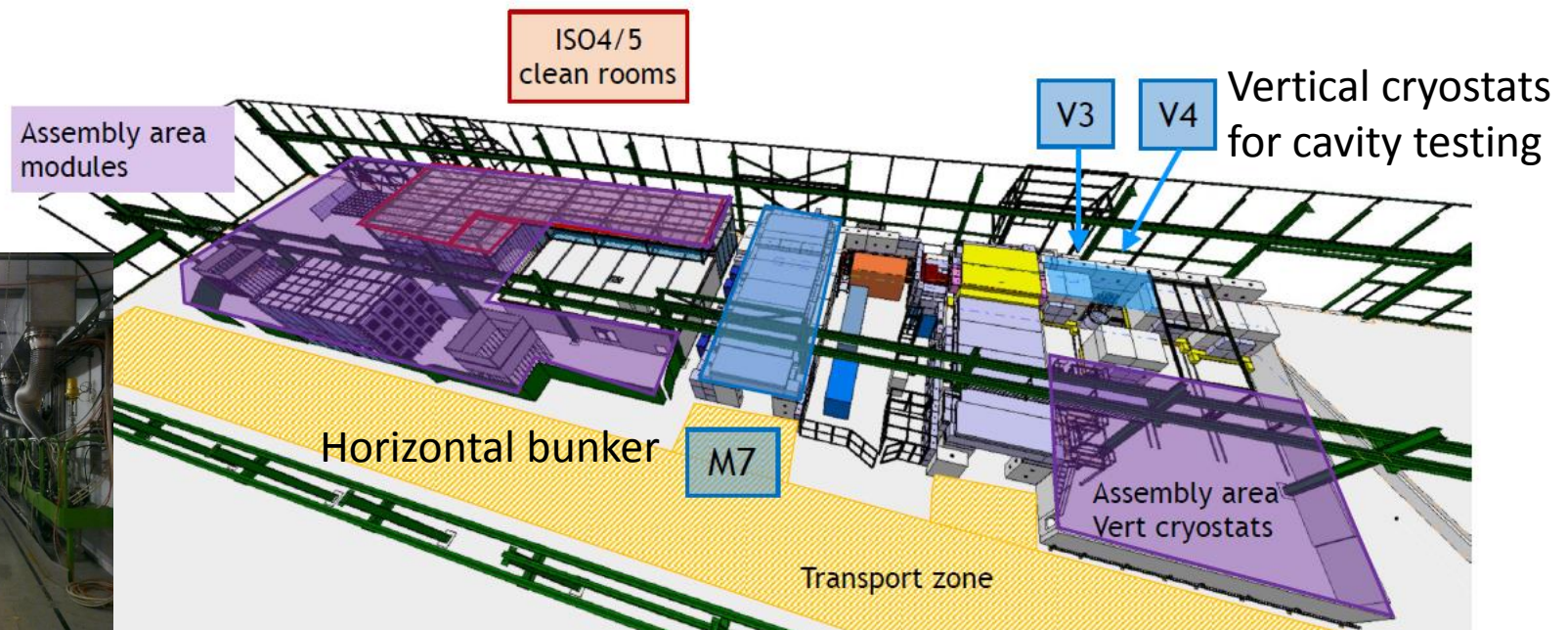
Cryomodule (Old) Schedule



- Cavity & He-Vessel Fabrication
 - *Cavity production delayed from the baseline delivery in spring 2016*
 - *Is now in the critical path – (see previous talks by G. Apollinari & O. Capatina)*
- HOM Couplers & Tuning
 - *8 couplers machined of DQW – assembly, RFD couplers will follow*
 - *Need to be ready by end-2016 (for one cavity type) - CERN*
- Cryostat & Ancillaries
 - *Conceptual design in the final stages – several sub-systems moving at the planned pace - UK-CERN*

SM18 Preparation

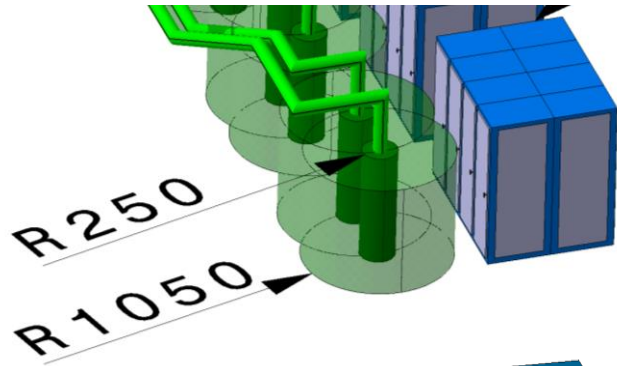
- Cavity testing & assembly
 - *Tooling for cleanroom and outside activities being prepared*
- M7 horizontal bunker for cryomodule testing
 - *Validation of cryogenic distribution of SPS (critical path)*



3D Drawing, courtesy EN-MEF-INT

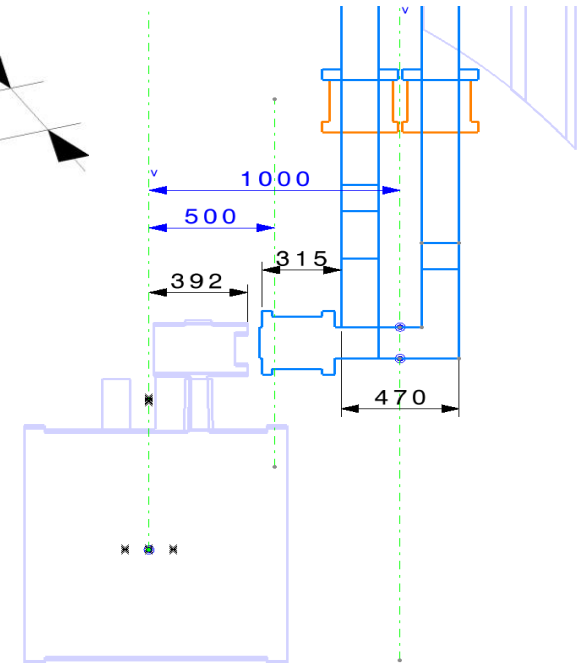
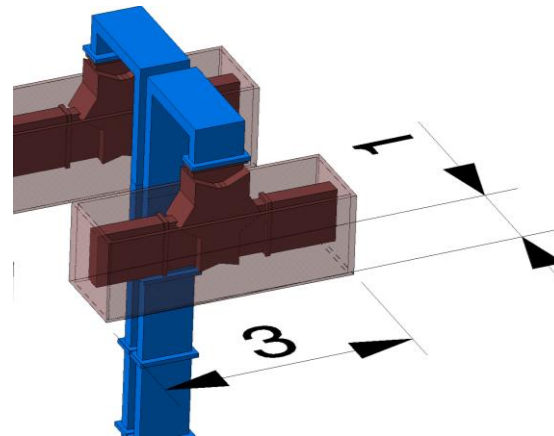
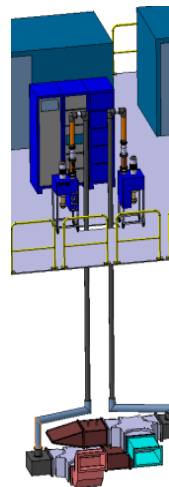
RF Distribution

Pics shown as in LHC, for illustration
Courtesy (S. Maridor et al.)



Surface/Cavern (Tetrode + HVPS)
3 LLRF (faraday cage), 1 SSA, 1 PLC, 1 spare racks

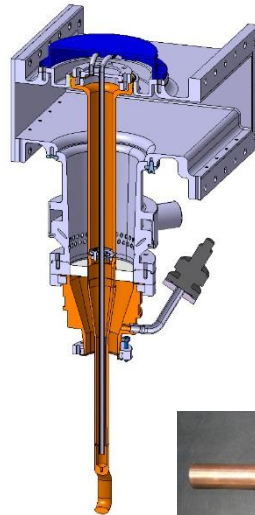
Circulator/load placement
TBD (**surface** or tunnel)



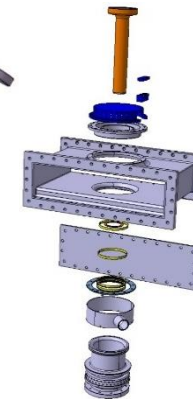
Cryomodule interface, transpose the
LHC concept with additional 0.5m
movement capability

RF Services

- High Power RF & FPC
 - *Amplifiers being tested (2+2 stations for SM18 & SPS)*
 - *Circulators and loads, new power supplies & SSA ordered, some received*



Coupler body

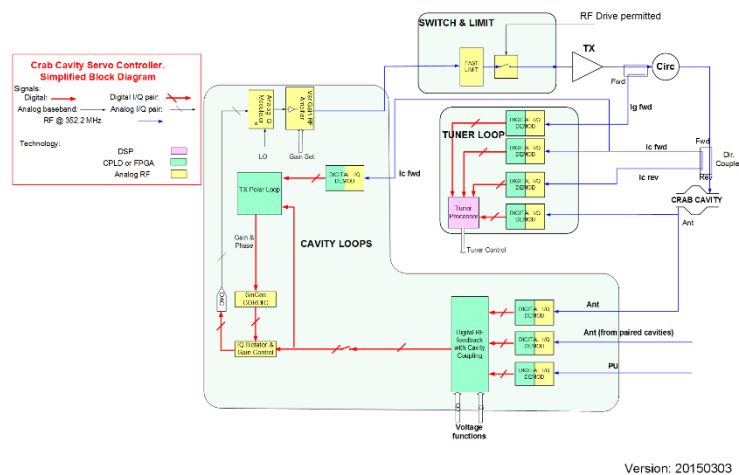


- *Coupler fabrication ongoing*
Brazing issues with ceramic window being solved

LLRF & Controls

Round trip delay is similar or bigger than LHC

Long delay cables between the cavities to simulate across IP like in LHC



Version: 20150303

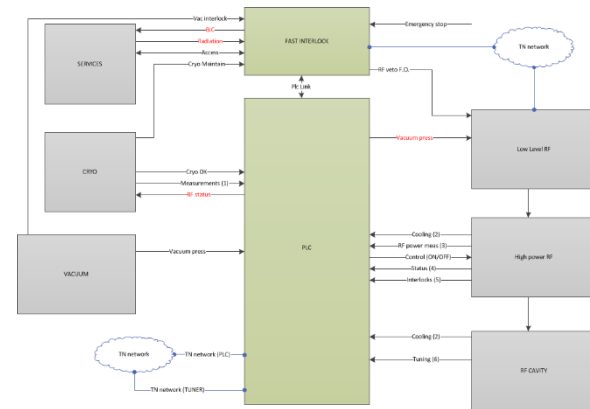
LLRF block diagram (Use LINAC4 like architecture)

- RF Feedback Loop for noise and beam loading control
- TX Polar Loop to reduce noise and stabilize gain/phase
- A Tuner Loop to shift cavity frequency
- A field Set Point for precise control of the cavity field.

PLC Slow Controls (*CERN standard PLCs*)

Expected PLC cycle time

2ms, Expected Fast Interlock cycle time 15us

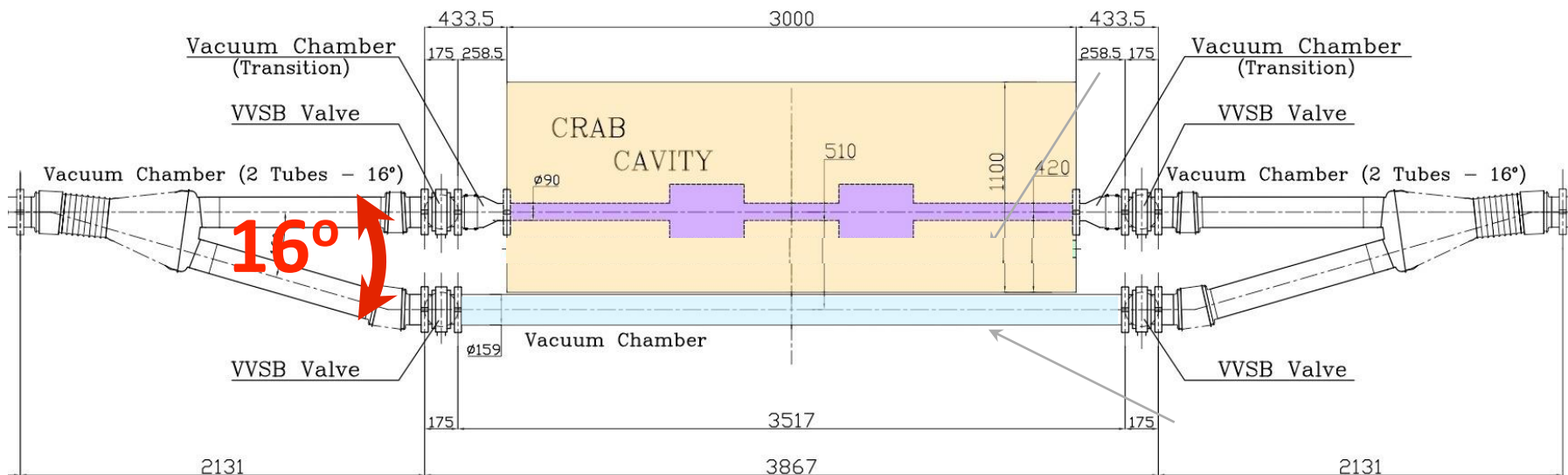


SM18 & SPS systems should be ready before EYETS

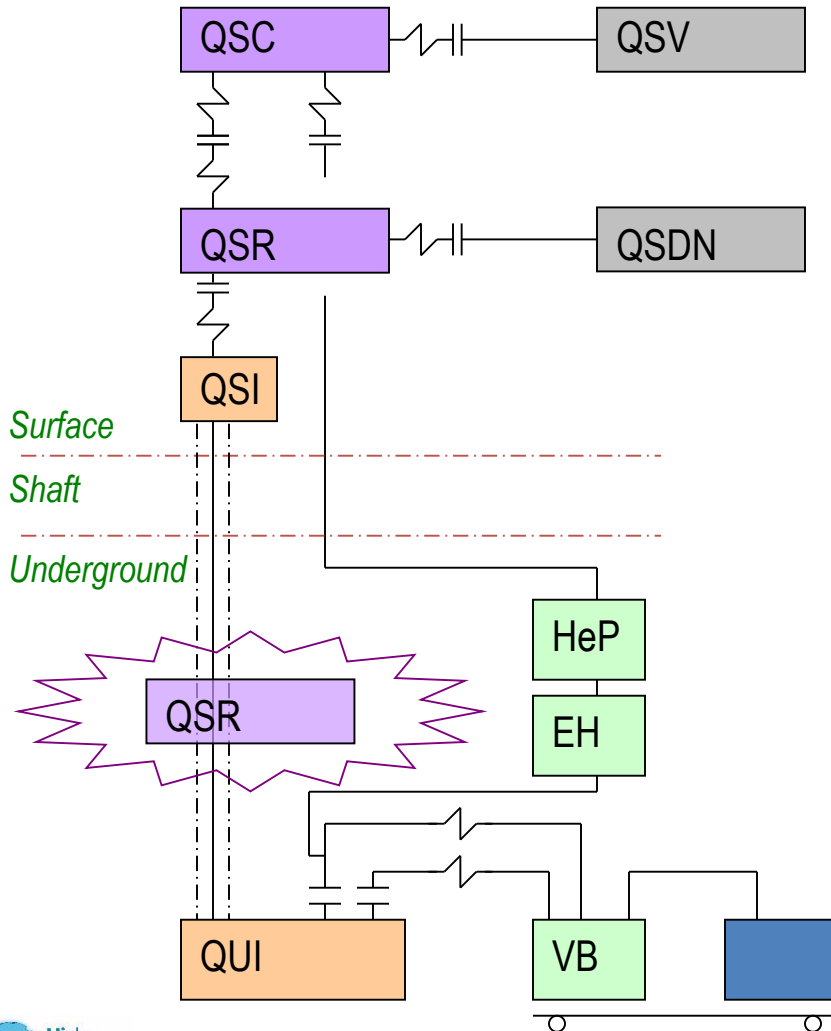
Beamline Vacuum

* Preliminary for illustration only

- 16°Y-chamber with multiple vacuum sectorization & NEG – ready for EYETS
 - NEG coating on either side of the module with differential pumping
 - Operating pressure $\sim 10^{-10}$ mbar
- Movable table – 510 mm transversely in ~ 20 min (EYETS ?)



Cryogenic Concept, LSS6



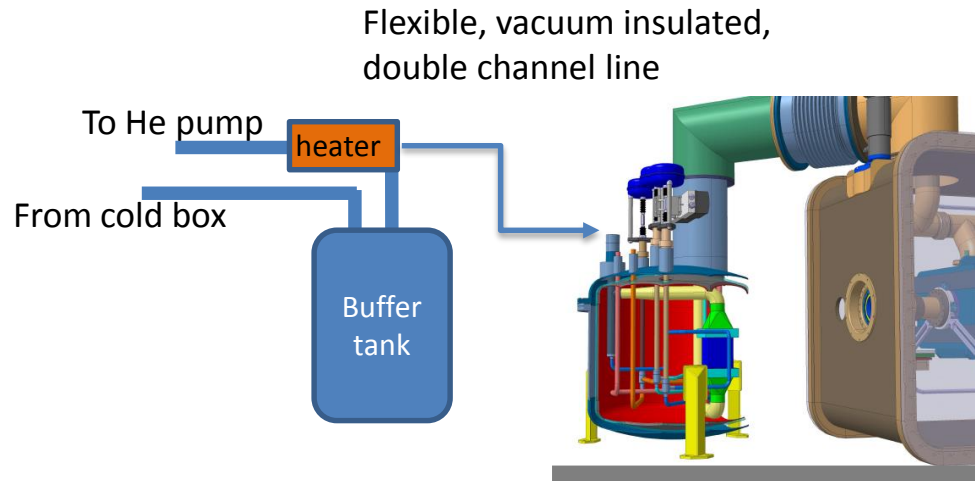
Since KEK meeting

New concept proposed with a **mobile cold box**
→ adopted as baseline

Studies launched for new refrigerator, distribution line, gas storage, valve boxes, ...(including technology validation in SM18 → critical path)

Locating the cold box underground is preferred solution for cryogenic distribution
→ Imminent decision **needed** (YETS2015)

Cryogenics Status



2K pumps installed at
BA4 already in LS1

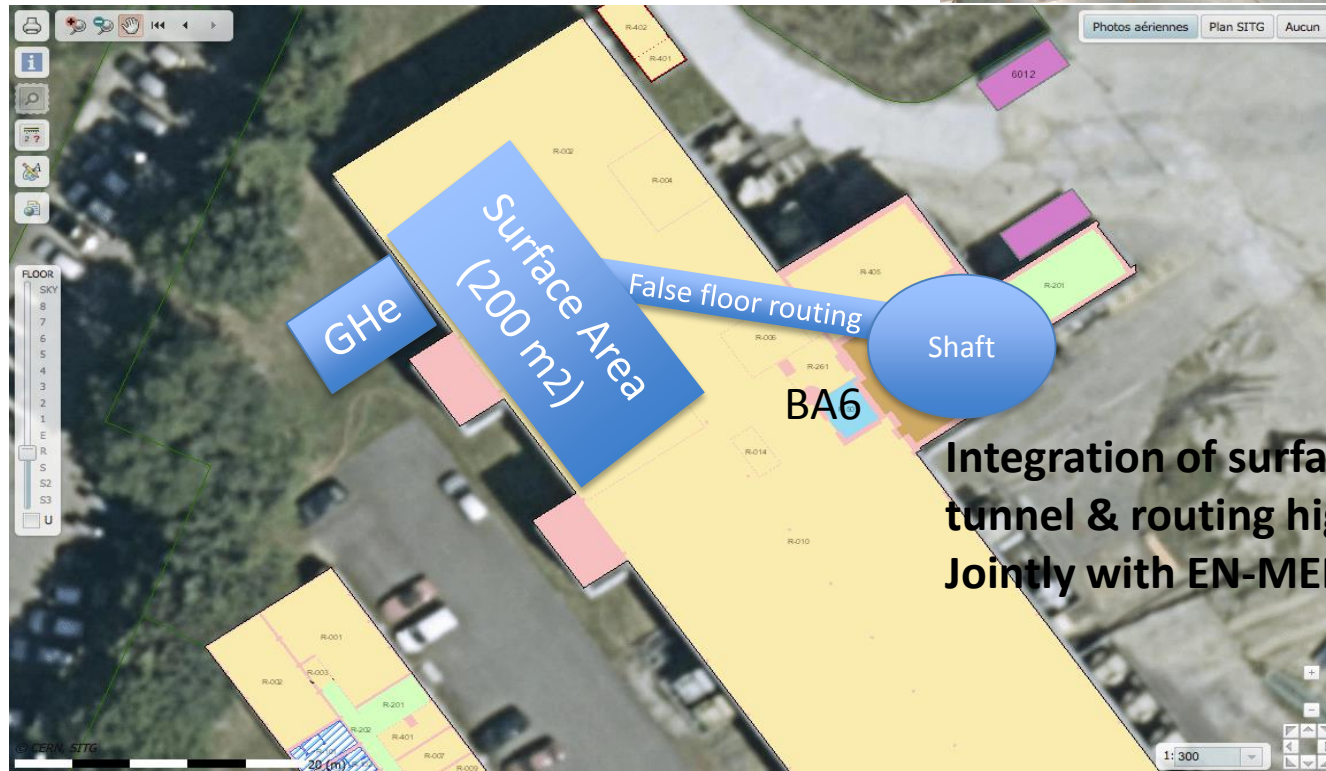


Service module, flex line, buffer tank and heater to be ordered soon
Hardware at CERN late 2016 for **SM18 test** and then installed in tunnel

Location of the cold box pending the SPS visit (YETS or before) and integration study after
Uninstall the pumps from BA4 during YETS → new location needs rapid decision

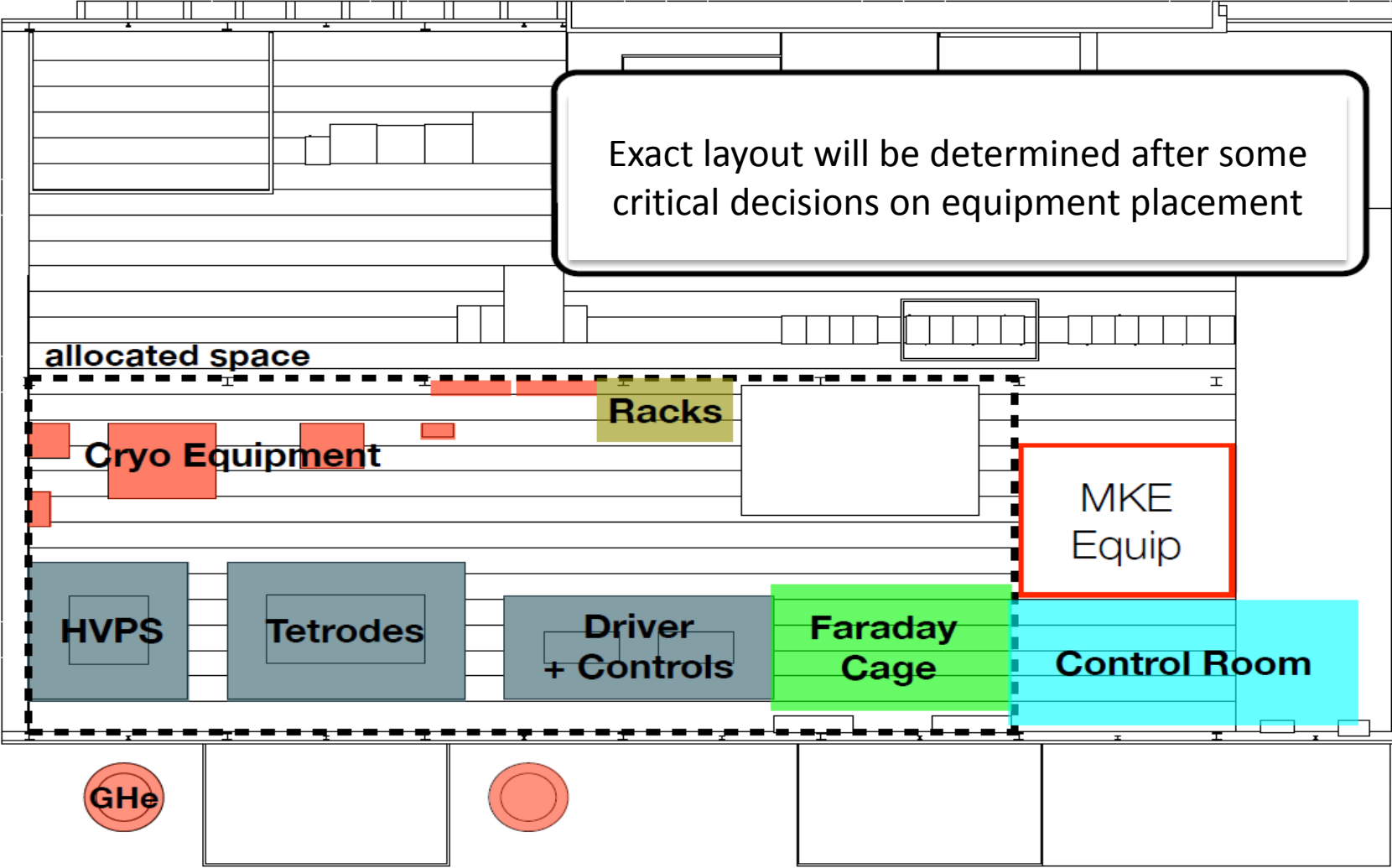
BA6 Surface Bldg.

Presently occupied by kicker equipment → to be moved
Coordinating with our TE-ABT colleagues
alternate storage space being identified



**Integration of surface equipment,
tunnel & routing highest priority
Jointly with EN-MEF**

Surface Layout, 1st Glance



Overall Activity Planning

SPS

2015 YETS	1 st – 2 nd Quarter	3 rd -4 th Quarter	2016 EYETS	1 st – 2 nd Quarter	3 rd -4 th Quarter	2017 YETS
False floor & reinforcement inspection	BA6 Surface clean up & Preparation for RF		Install: RF & Cryo Lines, Movable table, Cabling & Y-chamber+valves	RF, Cryo, Vacuum Tests Movable Table(?)		Install CM1 Vacuum commissioning
Uninstall 2K pumps from LSS4	Design of y-chamber and vacuum Cryo equipment procurement		Other services: Cooling, ventilation, water, electricity & Ethernet			DQW Cryomodule Cooldown + RF Commissioning + Movement

SM18

2015 YETS	1 st – 2 nd Quarter	3 rd -4 th Quarter	2016 EYETS	1 st – 2 nd Quarter	3 rd -4 th Quarter	2017 YETS
Cryo M7 Bunker Preparation	DQW String Assembly, 2 cavities + 2 FPCs	DQW CM1 Integration, 2-cavity cryomodule		DQW CM1 Hor Testing, M7 Bunker		
	High Power & Low level RF Prep SM18 Cryogenic validation		RFD String Assembly, 2-cavities + 2 FPCs, LLRF Preparation	RFD CM2 Integration, 2-cavity cryomodule	RFD CM2 Horizontal Testing, M7 Bunker	

Test Program Summary

- **In-situ cryomodule testing** in out-of-beam position
- **RF commissioning** with low-intensity beam, 1-12 bunches
 - *Establish proper RF parameters (operating frequency, amplitude, and phase)*
 - *Verify that CCs are transparent (cavity counter-phasing and detuning)*
- **High intensity** single bunch up to 4x72 trains
 - *Impact on cavity performance (including transient behavior), impedance, stability & machine protection as a function of beam current; interlocks*
 - *Verify cavity stability over many hours (relevant for LHC physics fill)*
- **Long-term behavior** of coasting beams in the SPS with 1-bunch
 - *Study the effects of cavity drifts, emittance growth, non-linear effects such as RF multipoles*

SPS Emittance Growth, 2015

Smallest emittance growth observed in vertical plane since 2010

