Crab Cavities in IR1 and IR5

Some considerations on tunnel integration

- What will be the situation in the tunnel after the LHC IR Phase-1 Upgrade.
- What are the space and services requirements for crab cavities and related equipment.

R. Ostojic,

LHC-CC09, 16-18 Sep 2009

sLHC projects and design studies

CMS/ATLAS Upgrade Phase-1

2014

sLHC

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UPGRADE PROJECTS

Linac4

LHC IR Upgrade Phase 1

UPGRADE STUDIES

SPL

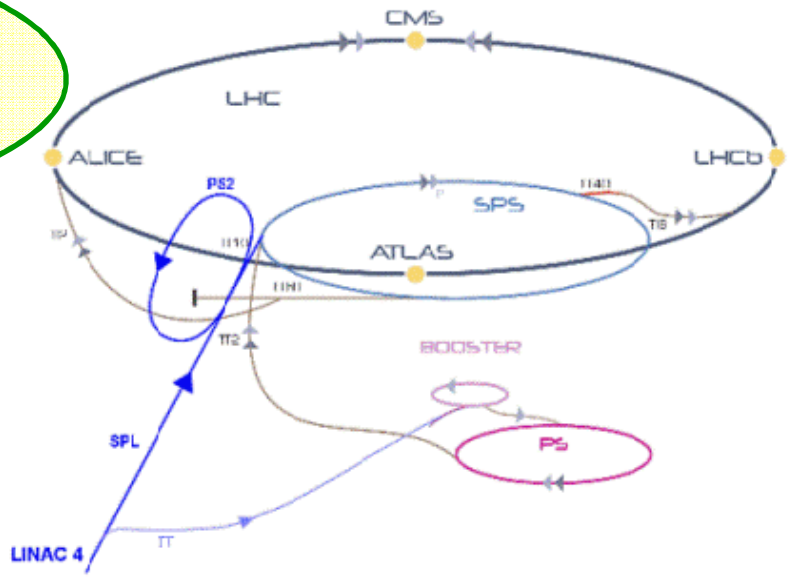
PS2

SPS Upgrade

RELEVANT E.U. PROGRAMMES (FP7)

EuCARD

SLHC-PP



LHC IR Upgrade – Phase-1

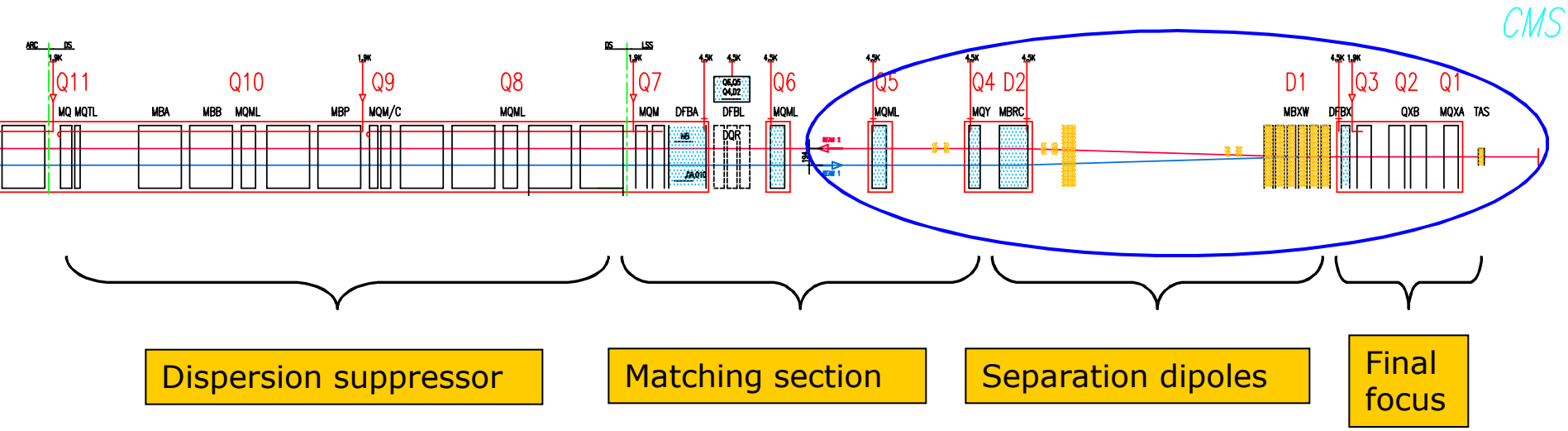
Goal of the upgrade:

Enable focusing of the beams to β^*=0.25 m in IP1 and IP5, and reliable operation of the LHC at 2 to 3 10^{34} $cm^{-2}s^{-1}$ on the horizon of the physics run in 2014.

Scope of the Project:

1. Upgrade of ATLAS and CMS interaction regions. The interfaces between the LHC and the experiments remain unchanged.
2. The cryogenic cooling capacity and other infrastructure in IR1 and IR5 remain unchanged and will be used to the full potential.
3. Replace the present triplets with wide aperture quadrupoles based on the LHC dipole (Nb-Ti) cables cooled at 1.9 K.
4. Upgrade the D1 separation dipoles, TAS and other beam-line equipment so as to be compatible with the inner triplets.
5. Modify matching sections to improve optics flexibility and machine protection, and introduce other equipment relevant for luminosity increase to the extent of available resources.

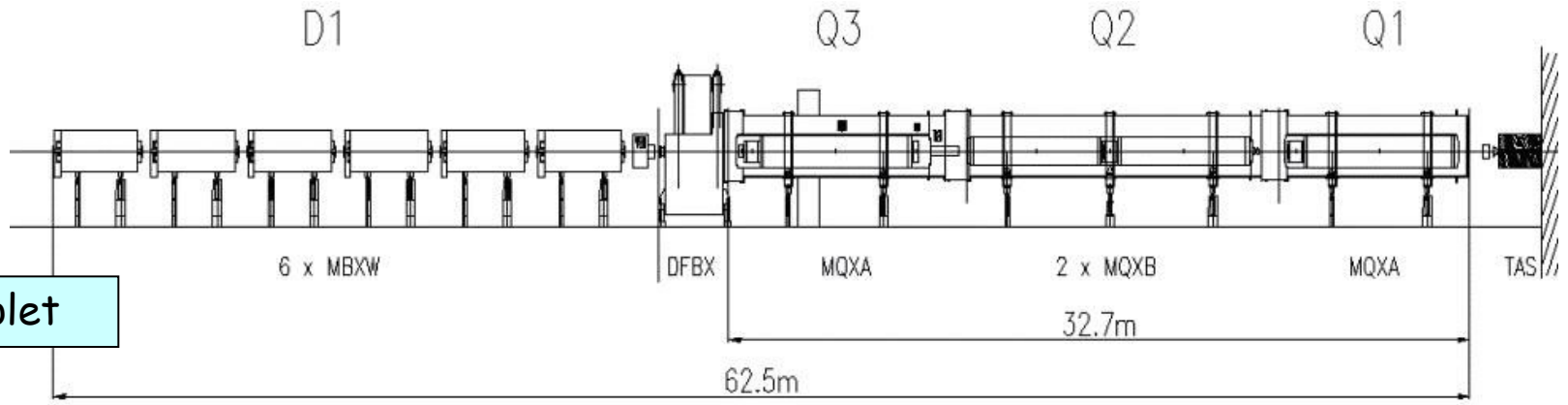
The ATLAS and CMS interaction regions



Triplet

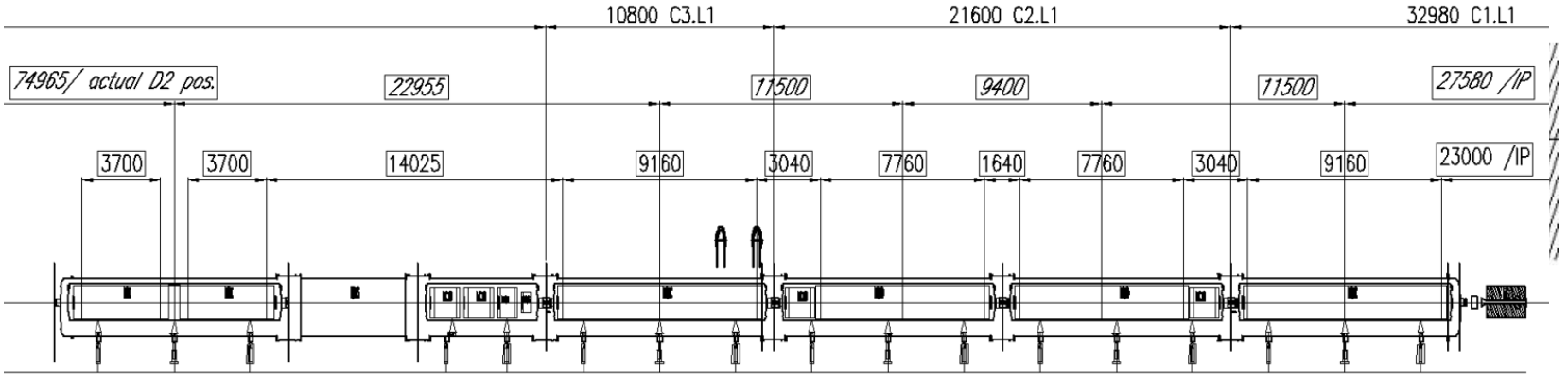
- Position — L* = 23 m
- Quad gradient — 120 T/m
- Coil aperture — 120 mm
- β^*, $\mathcal{L}$ — 25 cm, 2-3 $10^{34}cm^{-2}s^{-1}$
- Dissipated power — 500 W @ 1.9 K

Triplet layout



LHC triplet

~66m



Phase-I triplet

Constraints

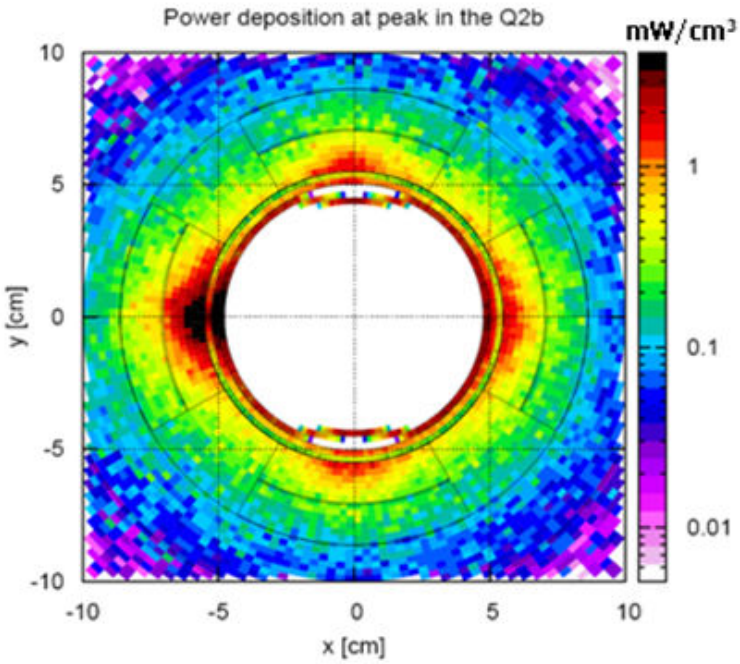
- Interfaces with the experiments: Very tight interfaces between the triplet, TAS, shielding, vacuum and survey equipment, and beam instrumentation; no possibility of reducing L* (23m).
- Cryogenics: Ultimate cooling capacity is 500 W@1.9K in each triplet. Replacement of triplets in IR1/5 requires at present warm-up of 4 sectors.
- Chromatic aberrations: Reduction of β^* drives chromatic aberrations all around the LHC. A new optics solution for all arcs and insertions is necessary.
- Accessibility and maintenance: All electronics equipment for the triplets should be located in low-radiation areas. Severe space constraints around IP1 and IP5 for any new equipment. New magnets must be similar in size to the LHC main dipole.
- Upgrade implementation: during the extended shutdown, compatible with CERN-wide planning (Linac4 commissioning, phase-1 upgrade of the experiments).

Protection against particle debris

Protection against particle debris is the single most serious issue of the upgrade.

- Energy deposition in the coils and magnet lifetime.
- Equipment protection in the tunnel (TAS, TAN).
- Protection of electronic equipment in underground areas.
- Maintenance and interventions …

Max power density = 4.3 mW/cm^3 (@2.5 10^{34})

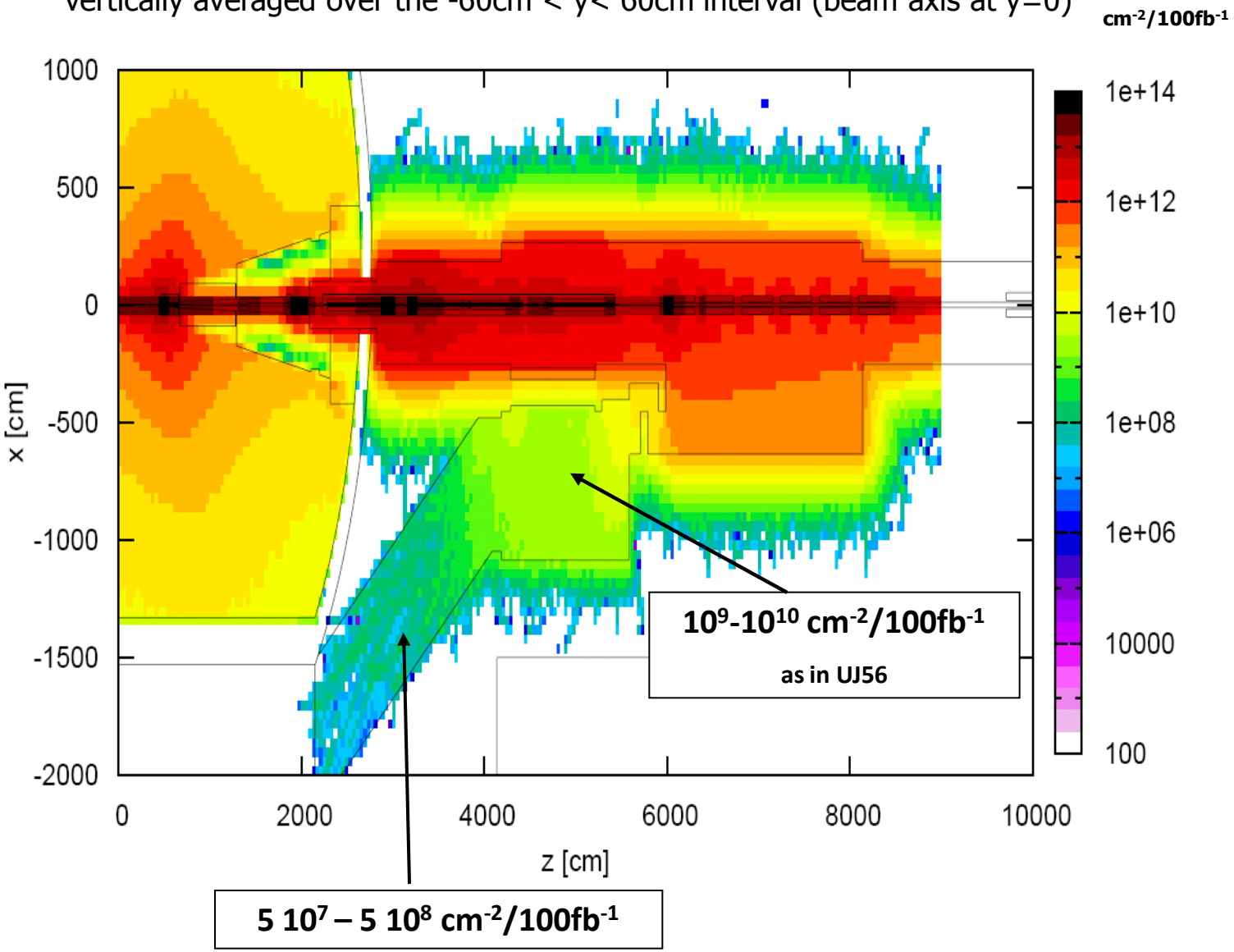


Average dose 1.5 MGy/100 fb^{-1}

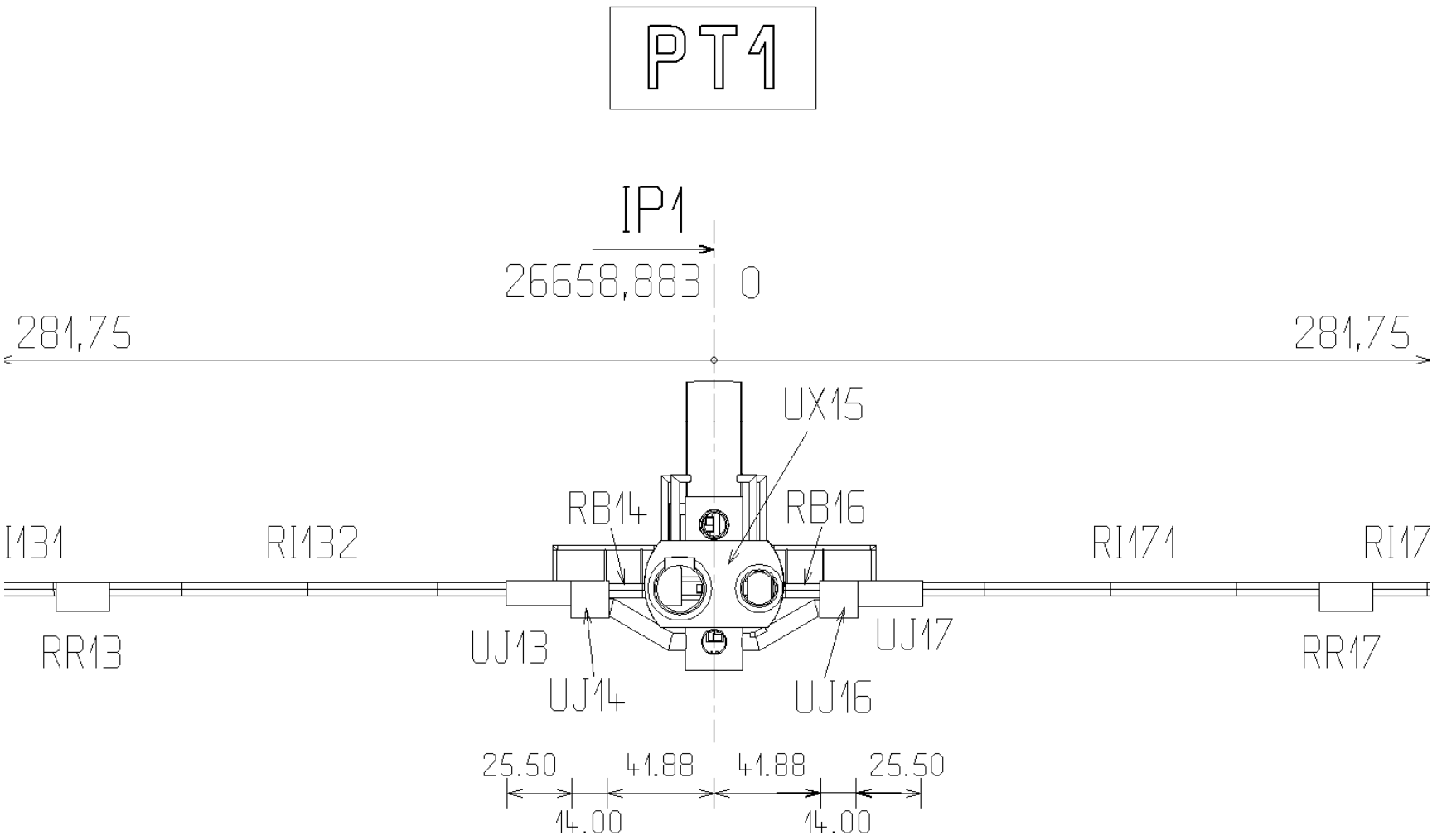
All magnets built for a lifetime ~ 1000 fb^{-1}, greater than the lifetime of ATLAS and CMS before their phase-2 upgrade.

Hadron fluence in IP1

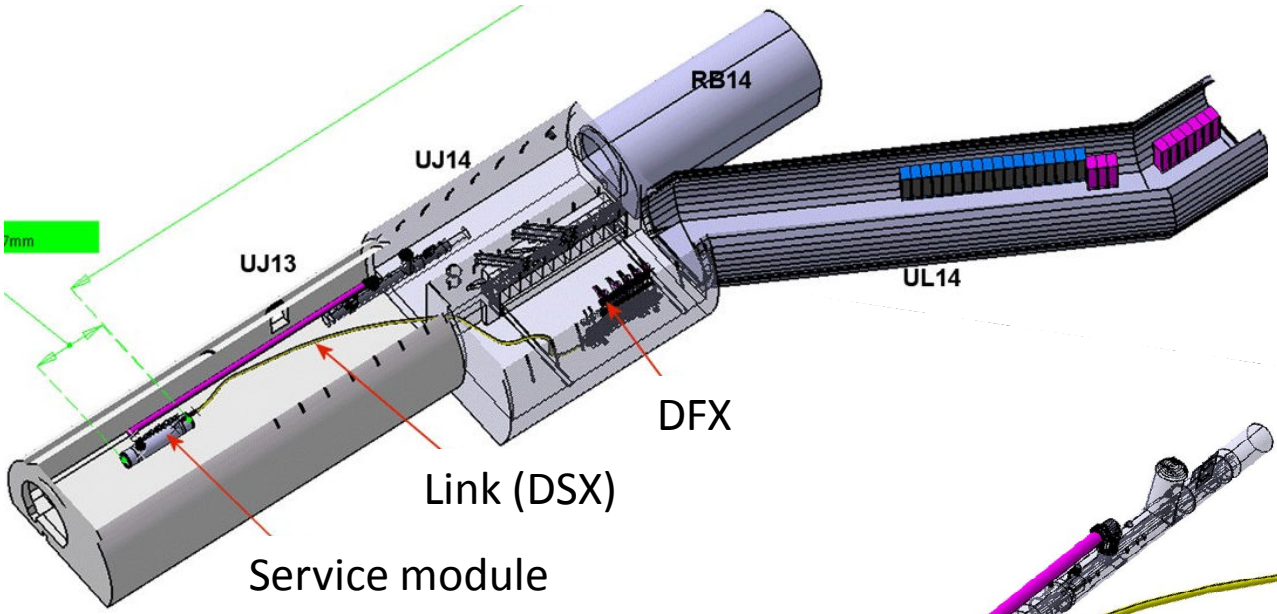
vertically averaged over the -60cm < y< 60cm interval (beam axis at y=0)

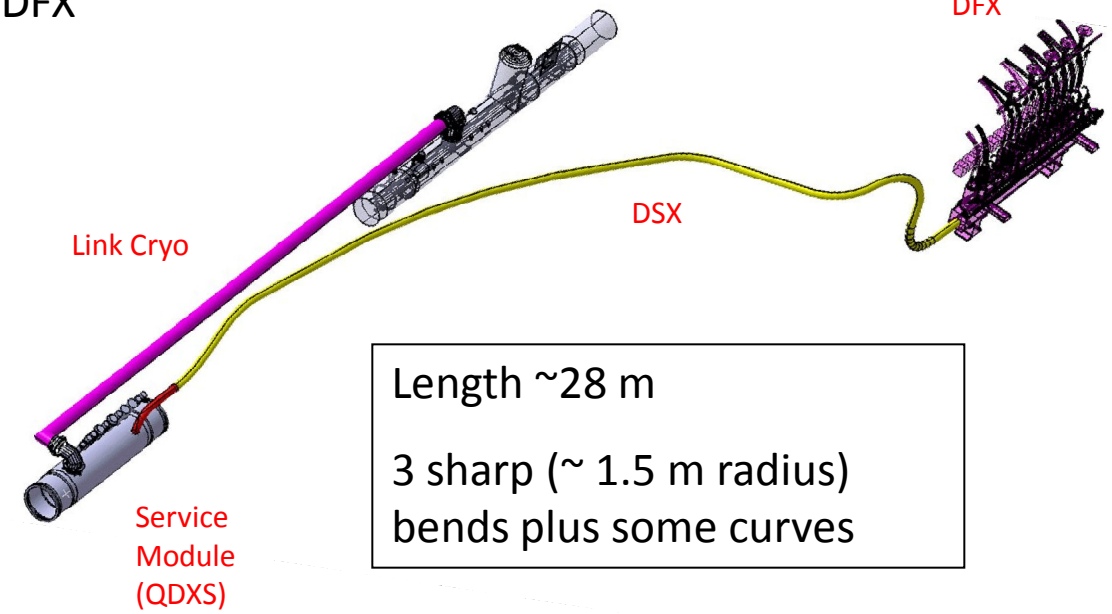


LHC tunnel in IR1



Phase-1 Upgrade Equipment in IR1

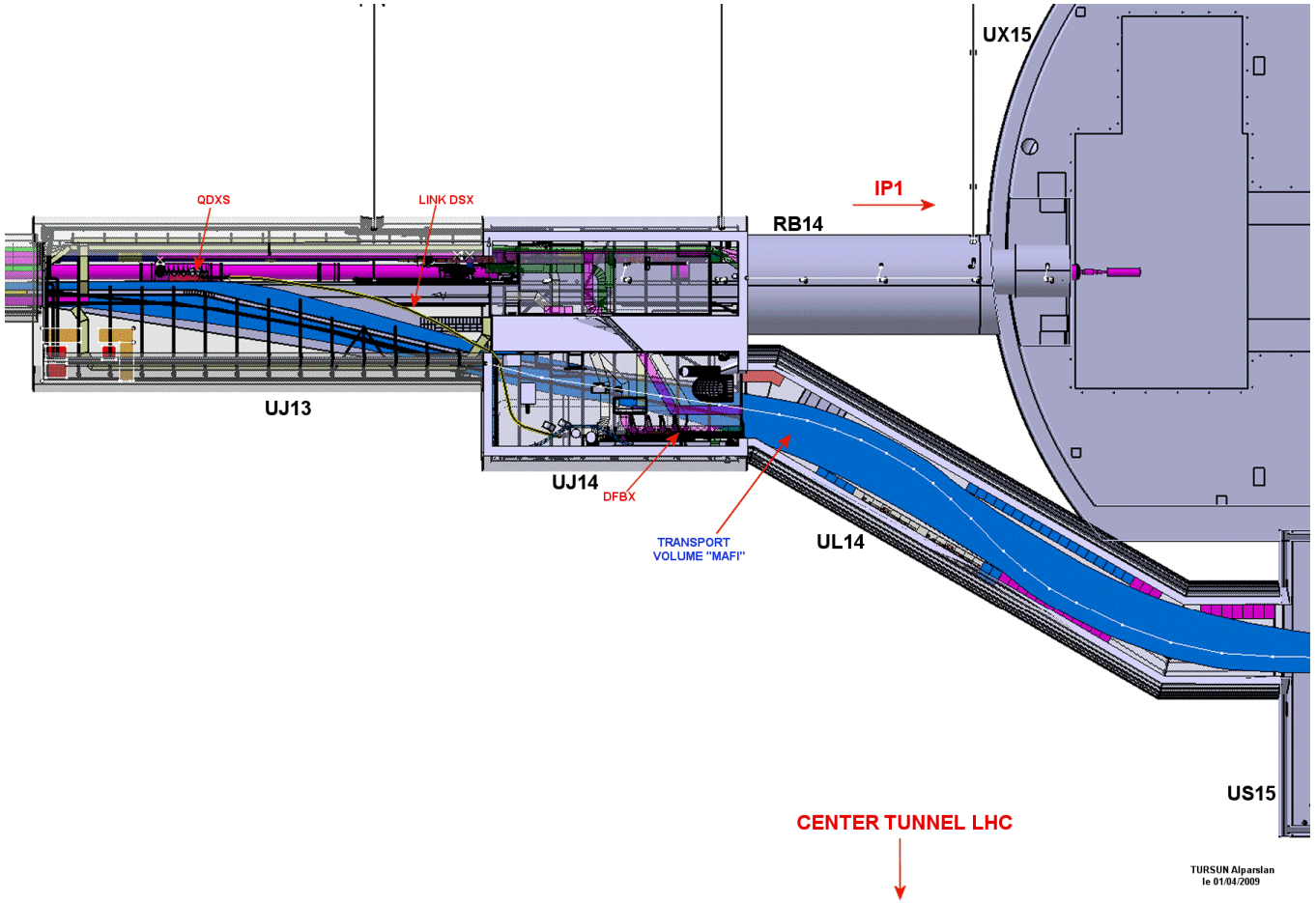




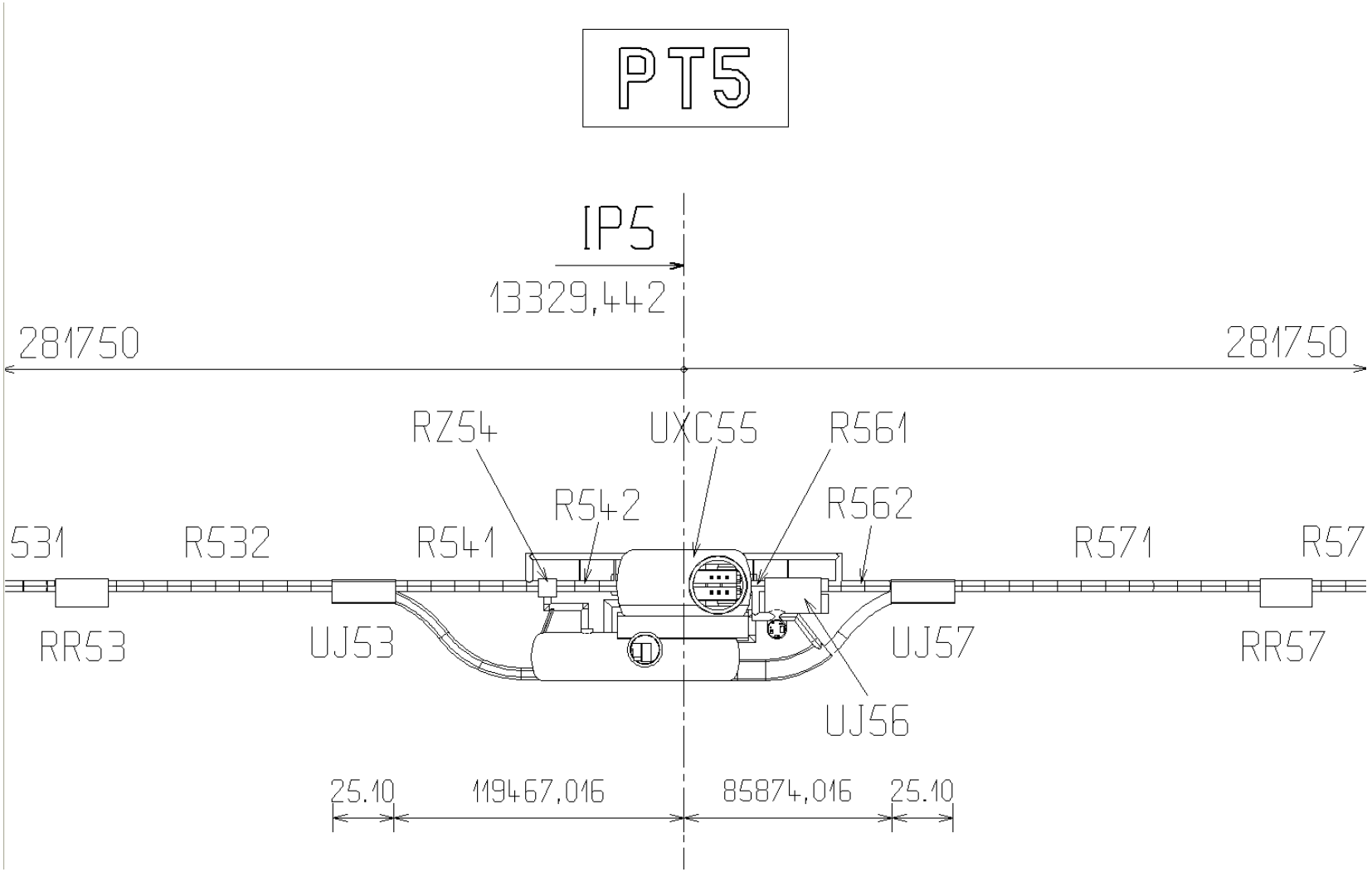
Length ~28 m

3 sharp (~ 1.5 m radius) bends plus some curves

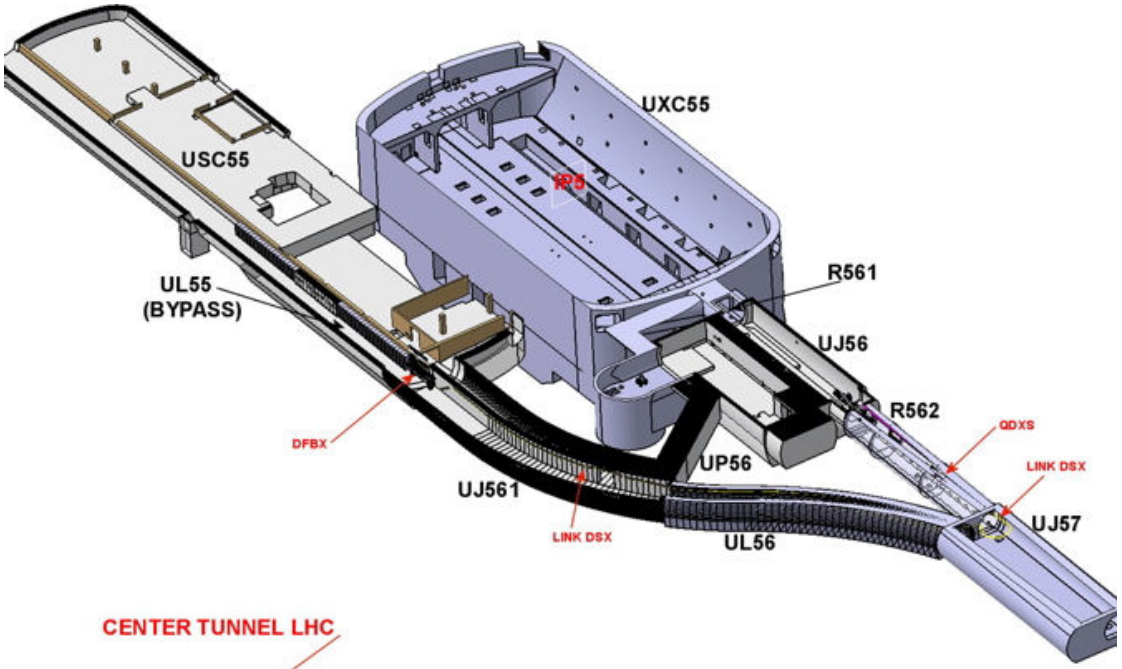
Phase-1 Upgrade Equipment in IR1

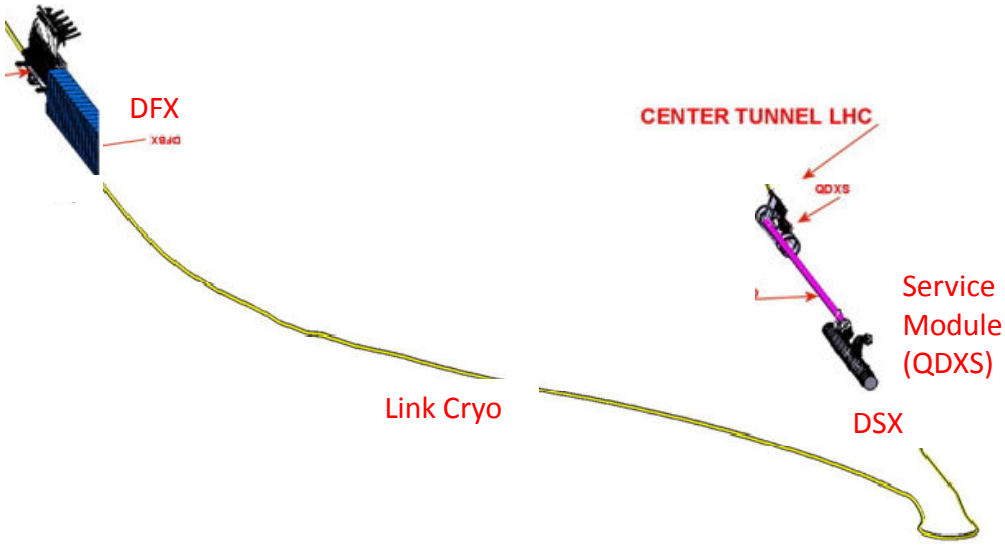


LHC tunnel in IR5



Phase-1 Upgrade Equipment in IR5

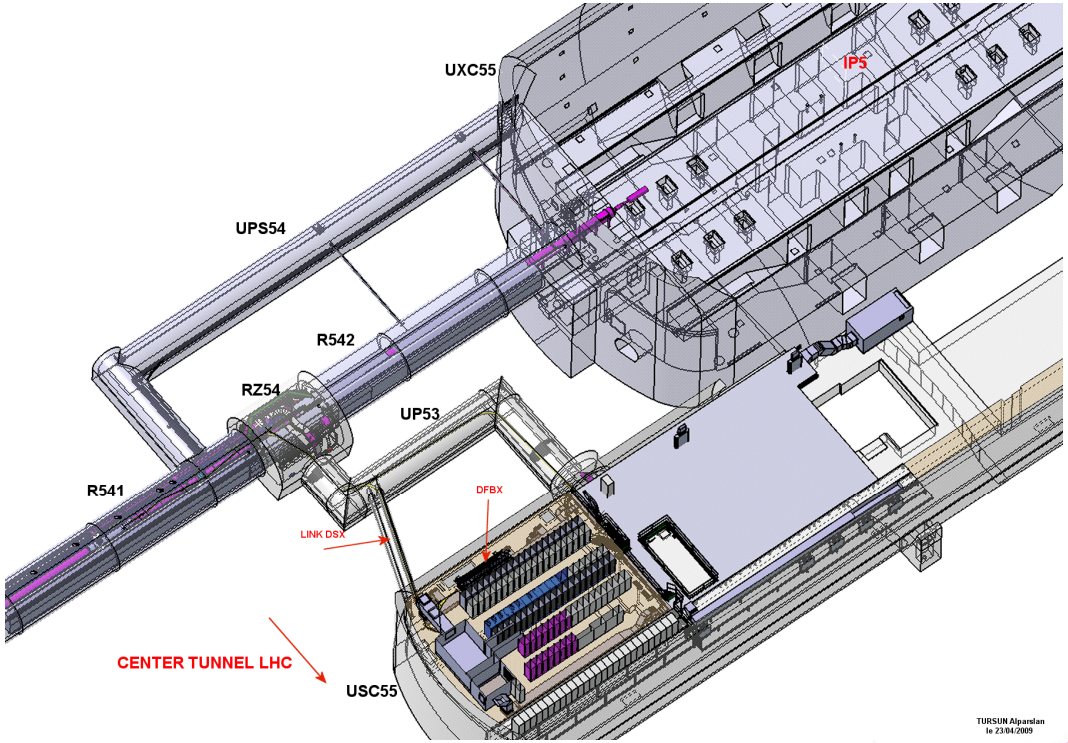




Length ~95 m

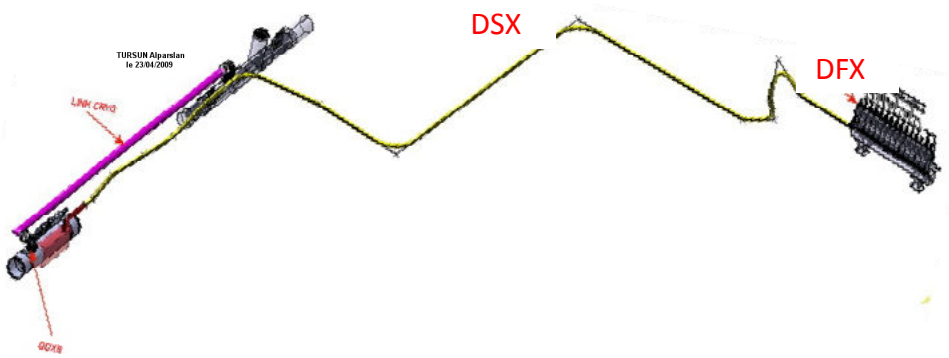
One 180 degree curve plus some longer curves

Phase-1 Upgrade Equipment in IR5



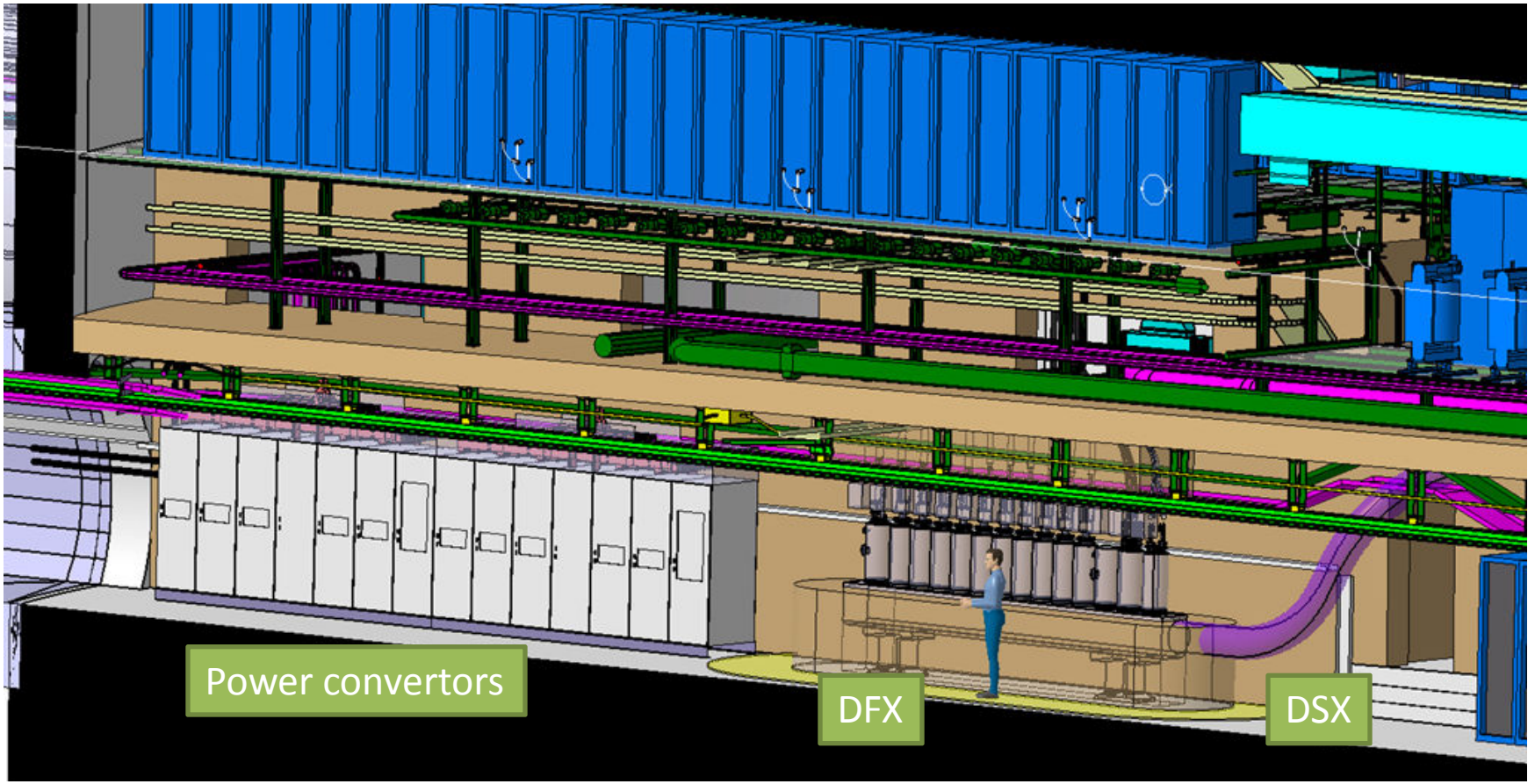
Length ~50m

5 sharp bends

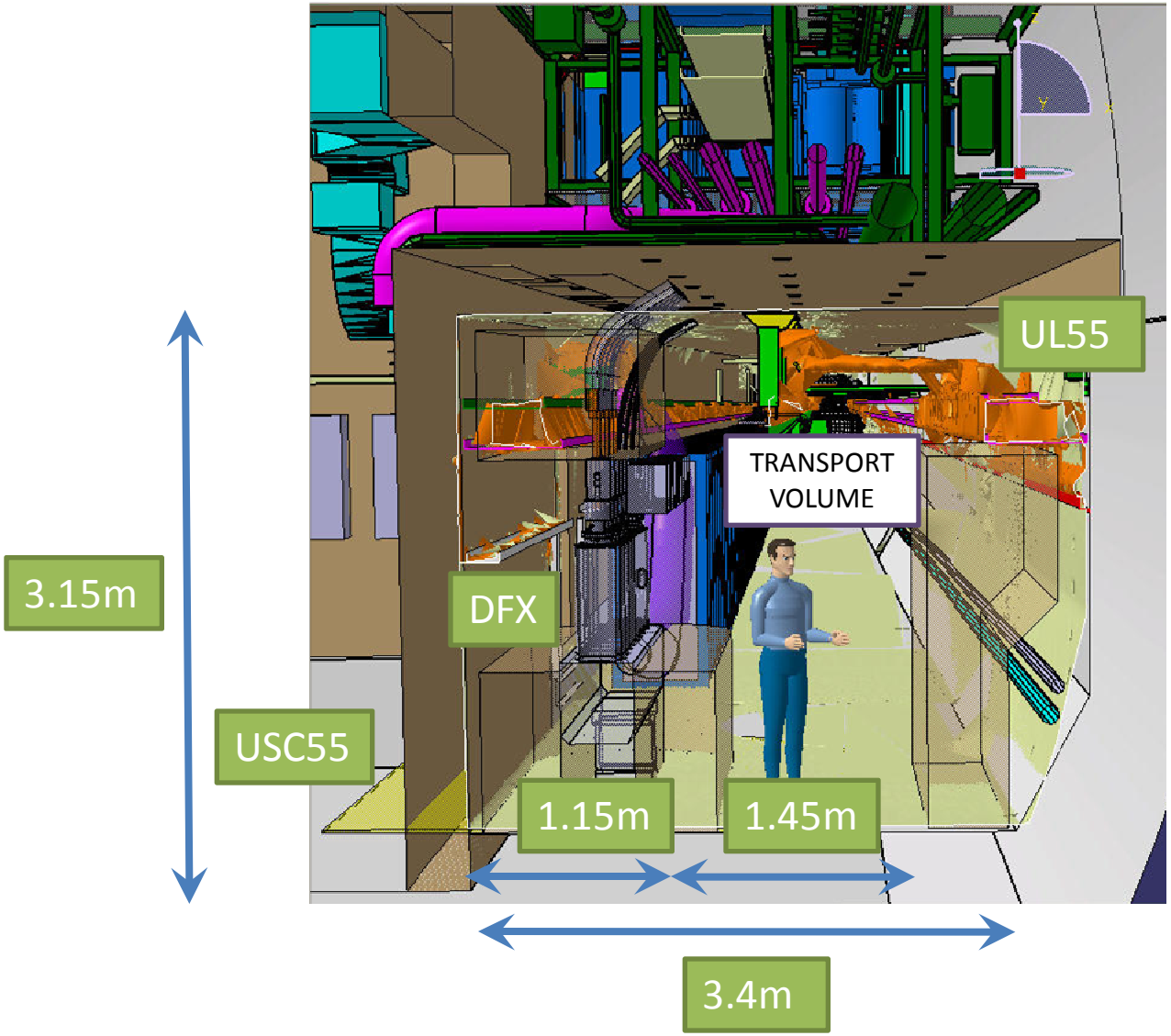


Service Module (QDXS)

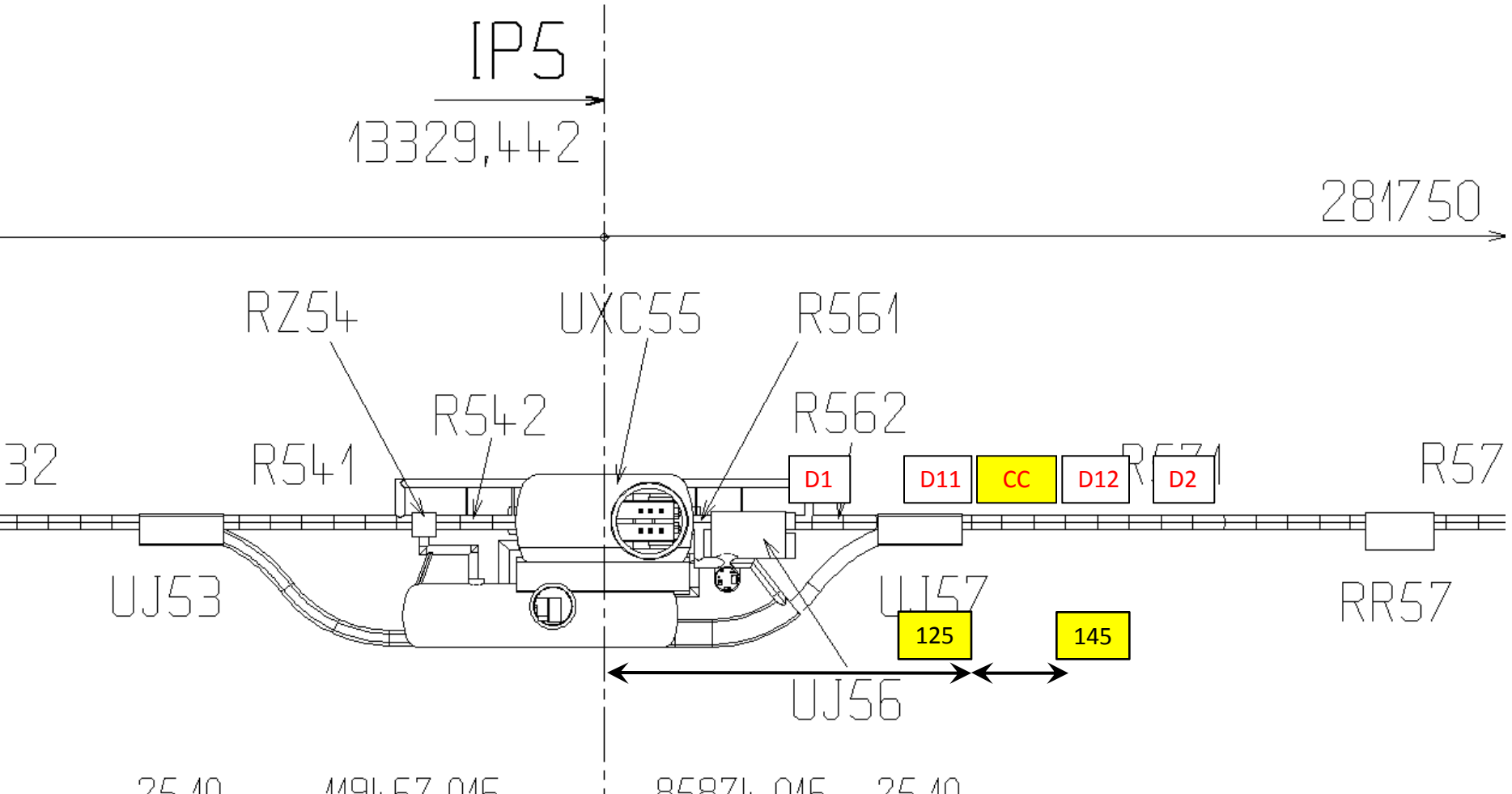
Phase-1 Upgrade Equipment in IR5



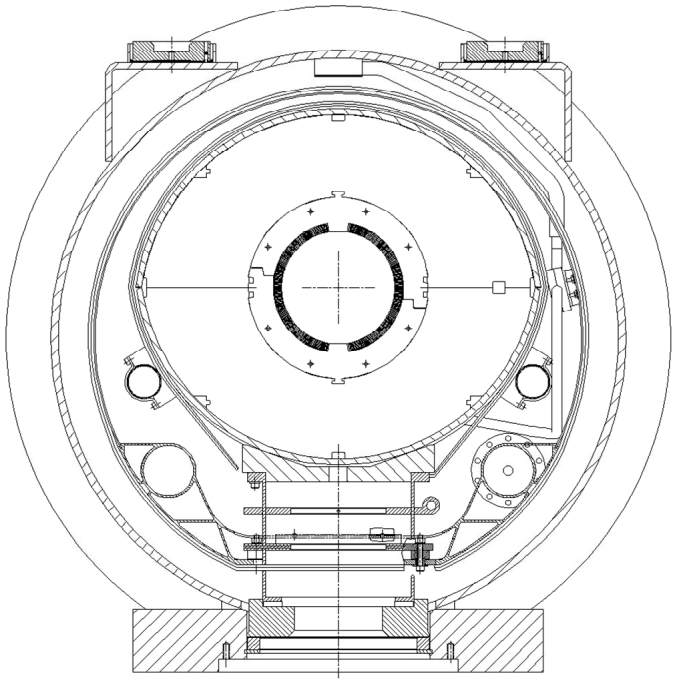
Phase-1 Upgrade Equipment in IR5



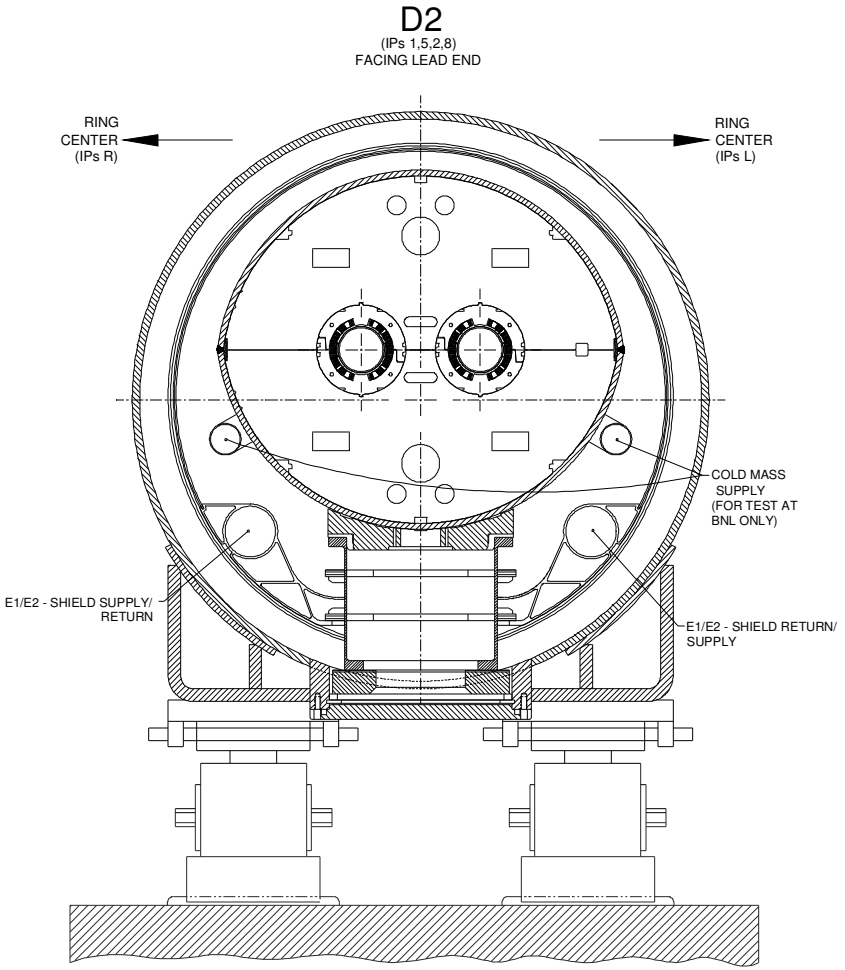
LHC tunnel in IR1



Separation dipoles



D1, Phase-1 Upgrade



Separation dipoles

	D1 Phase-1 (Phase-2)	D11	D12	D2 (nom LHC)
Strength (Tm)	30 (70)	70	40	38.7
Field (T)	4 (7)	7	4	4.1
Operating temp (K)	1.9	1.9	4.5	4.5
Beam stay-clear (mm)	140 (134)	106	78	69/53
Coil aperture (mm)	180	130	100	80
Beam separation (mm)	-	270	270	188
Eff. Coil-coil separation (mm)	-	40	70	48
Yoke diameter (mm)	645	940	910	645
Cryostat diameter (mm)	914	914	914	914

- Potential problem with beam separation (too small for separate aperture magnets)
- Yoke diameter too large

Crab cavity requirements

- Two strings of SC per IR side, about 20 m long.
- Cavities cooled at 2 K.
- Space for RF power tube and PS
  - In RF shielded zone
  - ~ 8 racks per system
  - Minimal footprint 1.8x2 m
  - Two systems per IR side
- Power tubes and controls in low-radiation areas
  - But less than 100 m from CC
- Radiation hardness of in-tunnel equipment

Some conclusions

- The Phase-1 Upgrade of the LHC interaction regions relies on the mature Nb-Ti magnet technology, while maximising the use of the existing infrastructure.
- Any new equipment in IR1 and IR5 (CC and separation dipoles) must conform in size with the transport zone.
- Phase-2 triplets will require new cryogenic plants in IR1 and IR5. Additional requirements from CC and separation dipoles need to be developed to optimize their design.
- It seems that additional tunnel alcoves in IR1 and IR5 for Phase-2 cryogenics and machine equipment (and moving power convertors from the RRs) is unavoidable.