Preliminary integration of Hollow e-lenses

EDMS No: **1764989 v.2 (V.1. Presented on 26th TCC 16/03/2017)**
References: 1765930.v.1

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Contributions

HEL conceptual design and parameters: D. Perini, C. Zanoni
Beam optics and HEL technical coordination: A.Rossi

HEL 3D Modelling: A. Kolehmainen

3D Integration Modelling: M. Gonzalez
QPS requirements: D. Wollmann, R. Denz, A. Verweij

Power Converters requirements: M. Martino & Y. Thurel
Vacuum requirements: P. Santos

Cryogenics requirements: S. Claudet

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2. Preliminary integration of HEL in HL-LHC machine and technical services in the tunnel of 4L
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REMARK

This is a preliminary integration study of the Hollow e-lenses in the machine lay-out for HL-LHC and its technical services in the tunnel and service caverns with the present conceptual design of the device (EDMS No: 1765930.v1). The conceptual design is subject to change due to further technical optimizations and definitions by the WPs involved in its design. In particular possible integration in the Hollow e-lenses of Beam Instrumentation that are not accounted here and for which the possible impact on the device and layout is not known.

Introduction to HEL

HEL- Components

Hollow Electron Lenses

Main solenoid
- Solenoid coils (2 or 3 sections)
- Corrector coils (3 sets)
- He tank
- Thermal screen
- Vacuum vessel
- Current leads
- He in and out
- Quench protection
- Power supply
- Supports

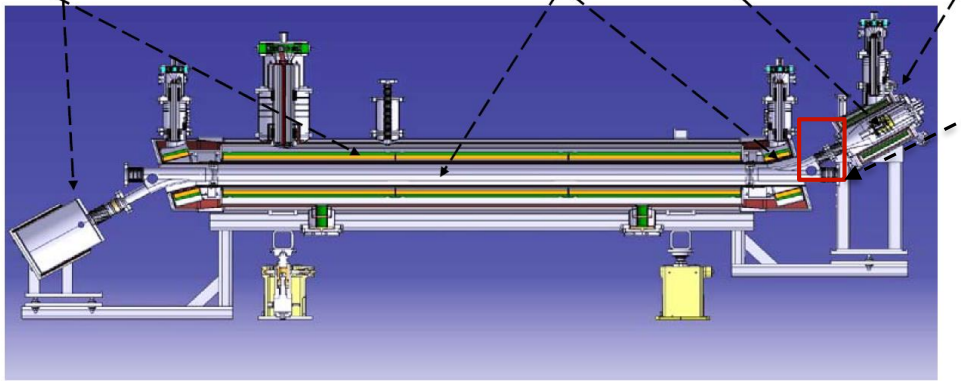
Collector
- Mechanical components
- Cooling system
- Power supply for electrods

Bending coils. Each side of the m.s.
- Solenoid coil
- Corrector coils
- He tank
- Thermal screen
- Current leads
- He in and out
- Quench protection
- Power supply
- Supports

Vacuum Chamber
Instrumentation

Gun
- Mechanical components
- Cathode
- Modulator
- Power supply

e-Gun coils
- Solenoid coils (2 indipendent coils)
- Corrector coils
- He tank
- Thermal screen
- Vacuum vessel
- Current leads
- He in and out
- Quench protection
- Power supply
- Supports



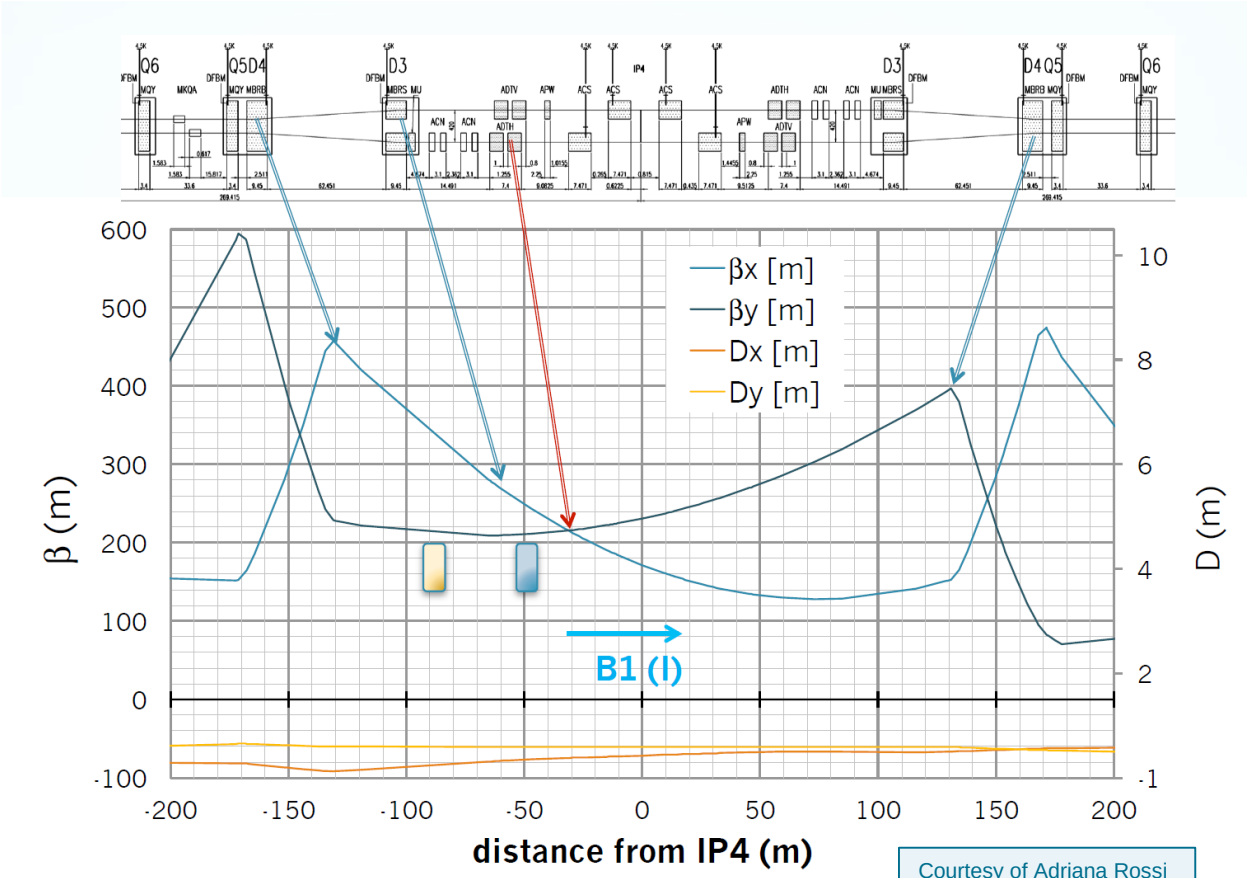
Sector valve for e-gun

HEL- Parameters

Nominal magnetic field of the main solenoid	4 T
Inner radius of the hollow electron beam @ nominal fields	0.9 mm (3 σ)
Outer radius of the hollow electron beam @ nominal fields	1.8 mm (6 σ)
Nominal magnetic field in the e-gun cathode	0.2 T
Inner diameter of the cathode	8.05 mm
Outer diameter of the cathode	16.10 mm
Inner radius of the hollow electron beam @ 4 T with 0.1 T @ cathode	0.635 mm
Outer radius of the hollow electron beam @ 4 T with 0.1 T @ cathode	1.275 mm
Nominal current at the cathode	5 A

Dimensions of the hollow electron beam and of the emitting cathode. As an example we give the dimensions that can be obtained changing the e-gun tuneable solenoid from the nominal level of 0.2 T to 0.1 T.

HEL- Optics

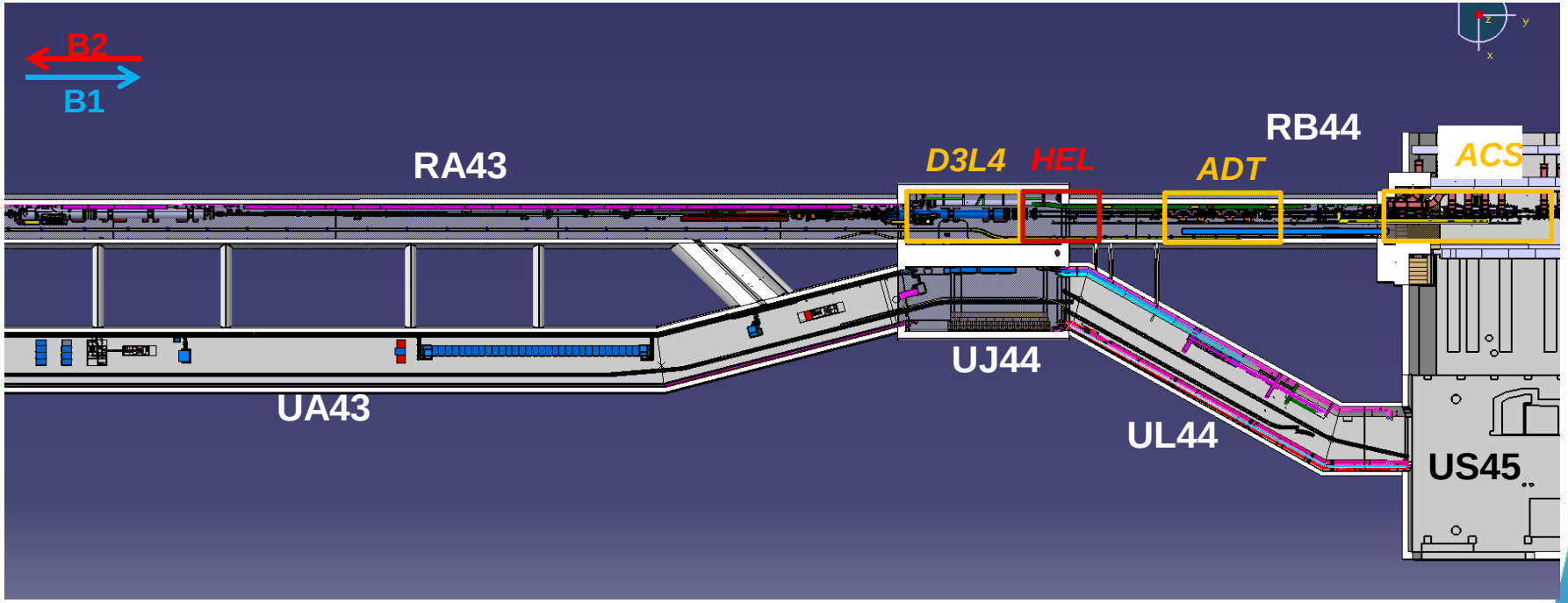


Courtesy of Adriana Rossi

Preliminary integration of HEL in HL-LHC machine and technical services in the tunnel of 4L*

**Please note that 4R is symmetric to 4L*

Overview of LSS4 P4L



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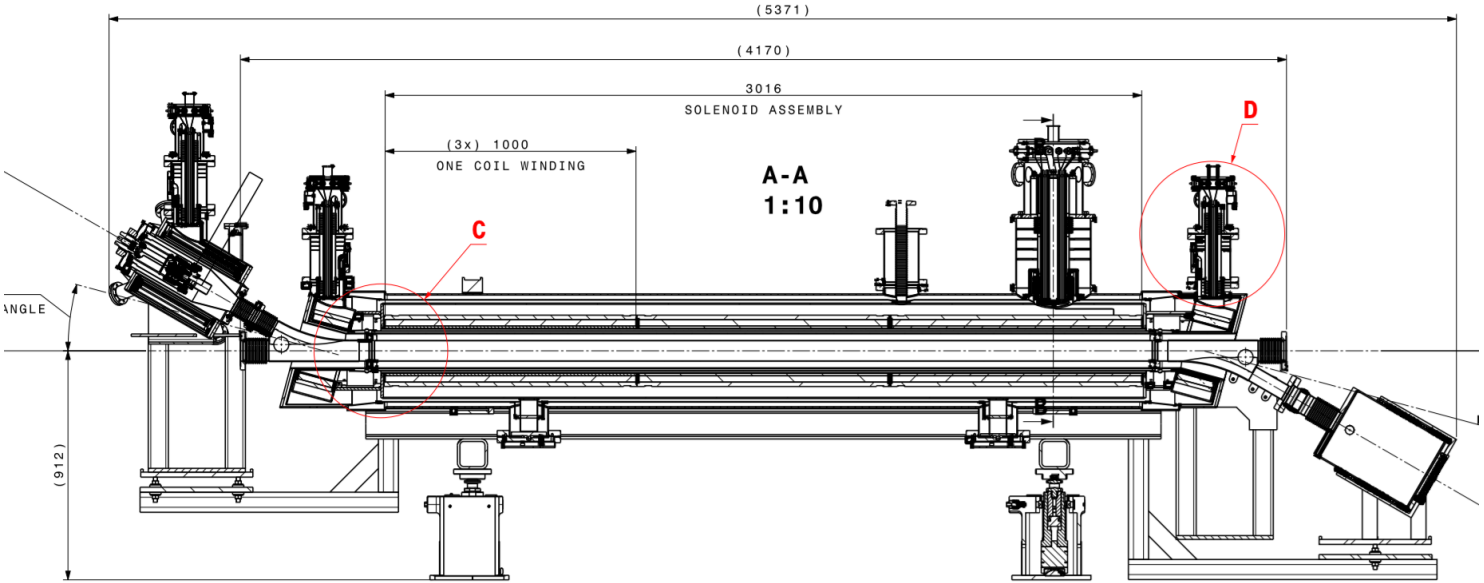
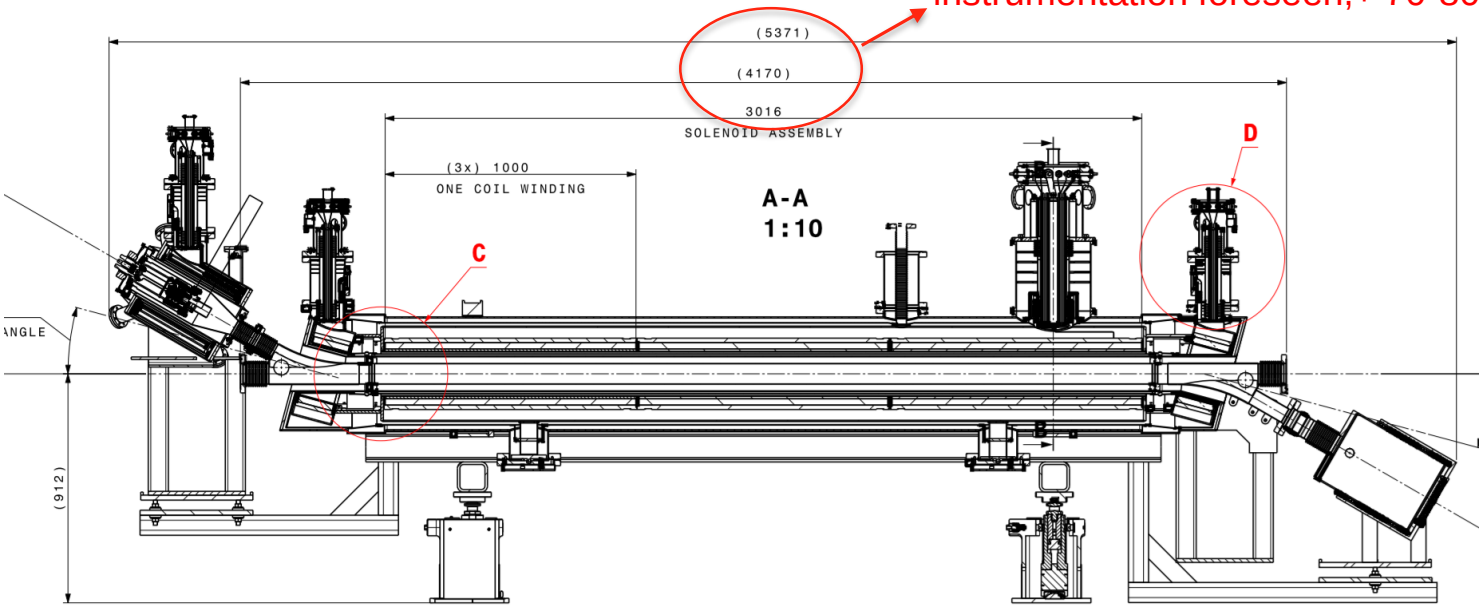
HEL - Dimensions



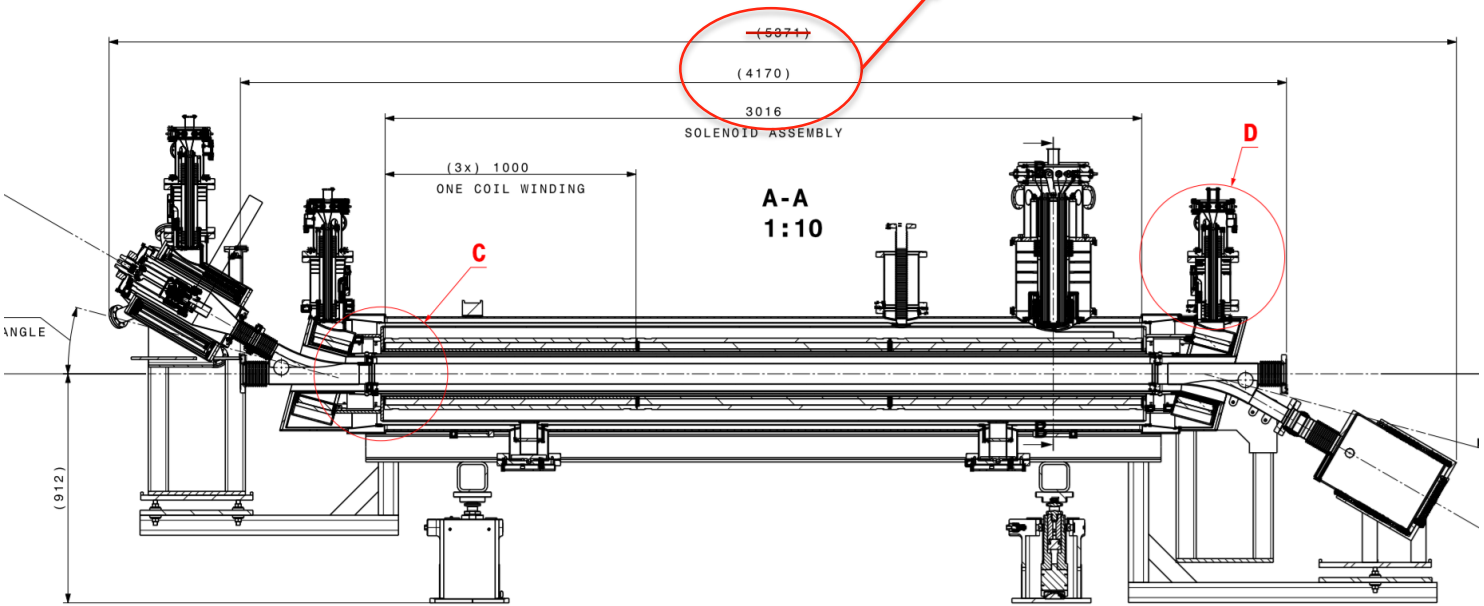
HEL - Dimensions

Conceptual design: Transverse profile instrumentation foreseen,+ 70-80 cm

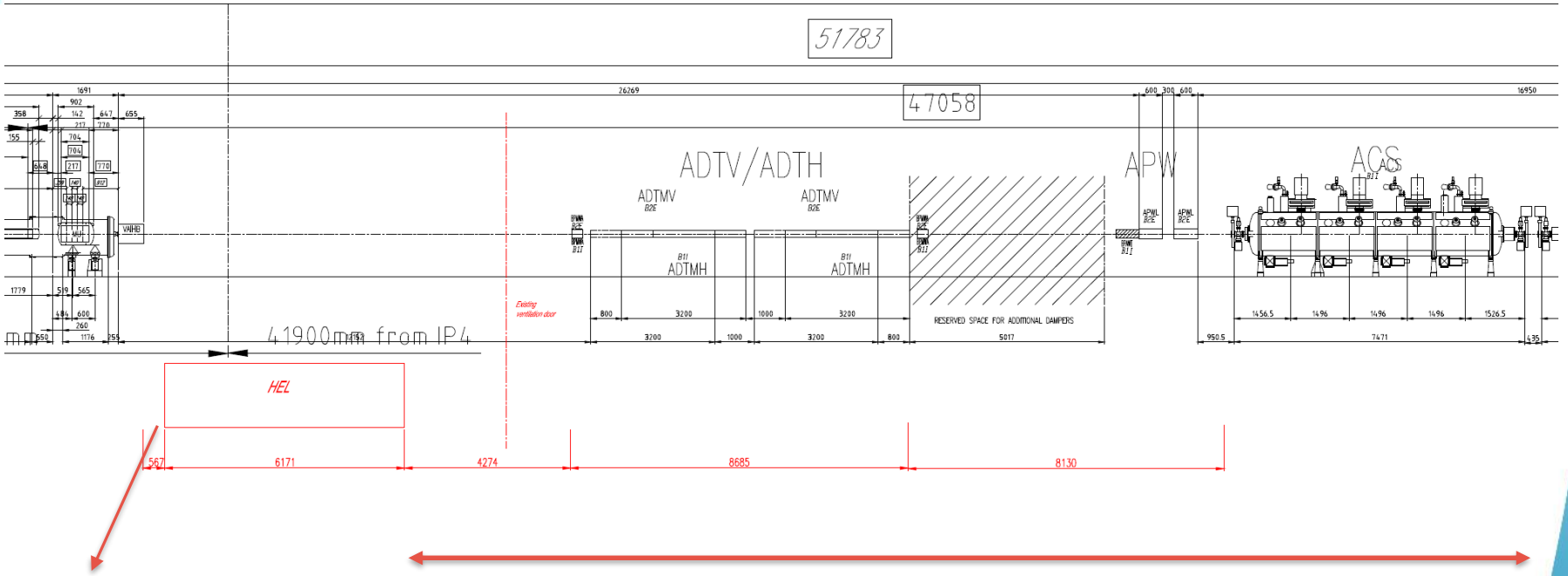


HEL - Dimensions

Total length used for this integration 6171 mm



Sketch layout with HEL - 4L

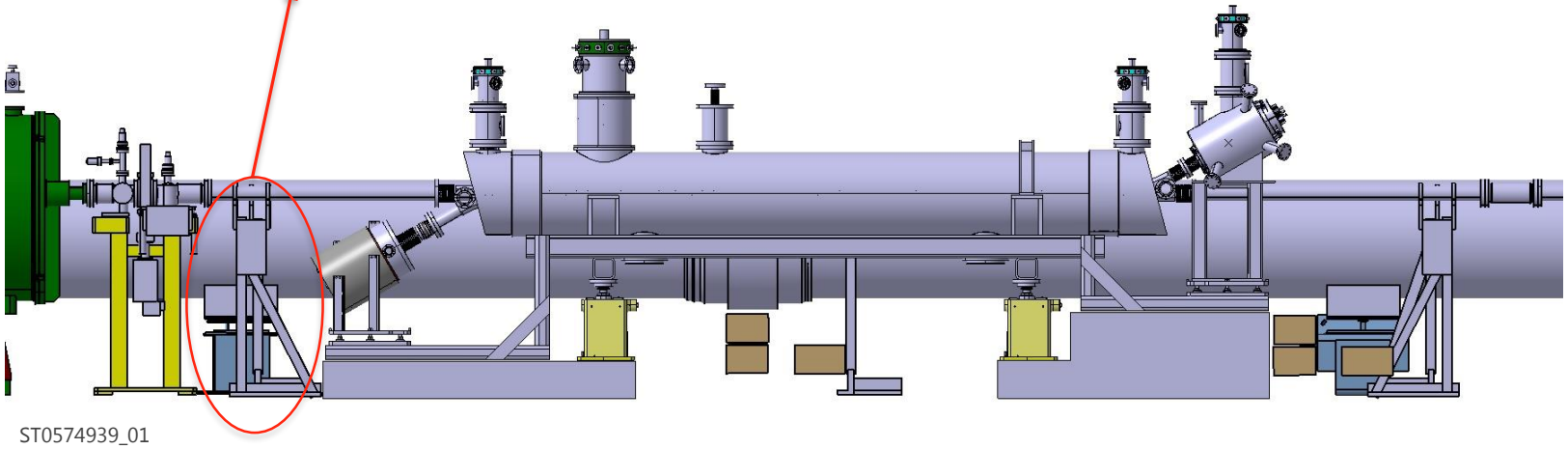


Distance from IP4: 43529 mm

Total length of RF zone (from HEL to IP): 37357 mm

Layout integration in HL-LHC machine

New design of vacuum chamber supports to gain some space



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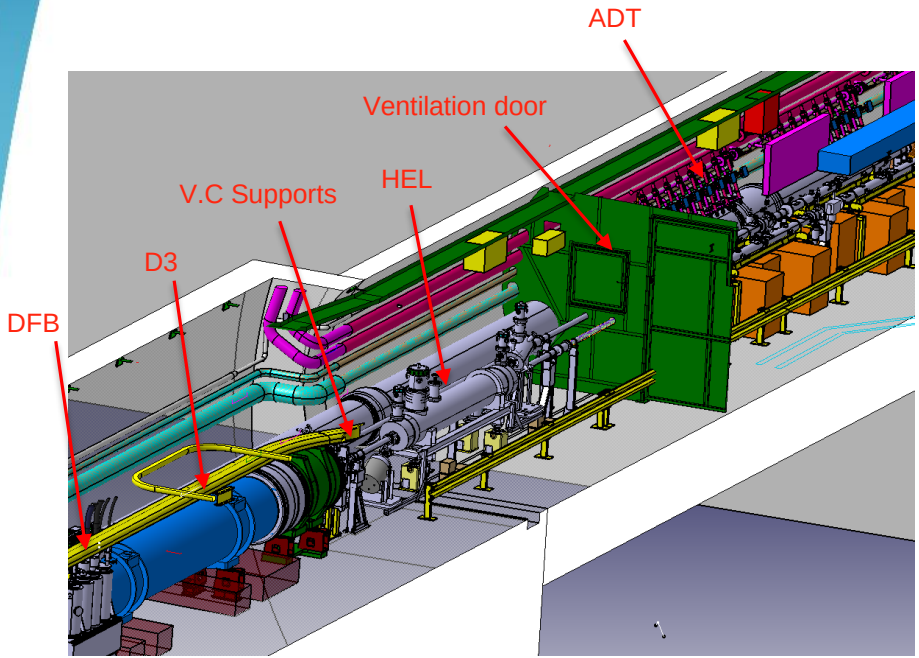
Layout integration in HL-LHC machine



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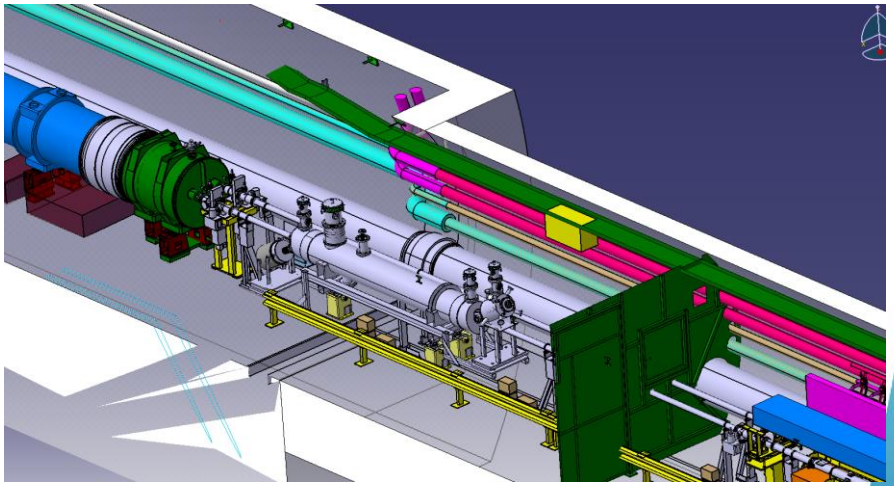

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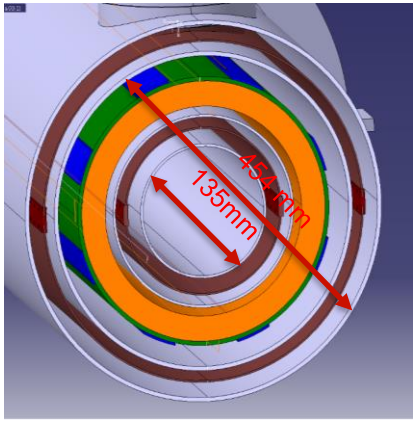
Interface of HEL with other equipment

Vacuum:



- Vacuum pressure during operation must be lower 10^{-11} mbar.
- Vacuum chamber NEG coated.
- Vacuum chamber inner diameter: 80 mm.
- Vacuum chamber material: cooper.
- Bake-out temperature: 250°C.
- 25 mm bake-out jacket.
- Sector valve for the e-gun:
  - Exchange procedure to be study.
- The design of the collector should avoid degassing.
  - In case of collector degassing, ion pumps or in worst case 1 m length NEG coated vacuum pipe on both sides of the HEL should be installed. (Not in present layout proposal) → to be studied by the HEL team and WP12.

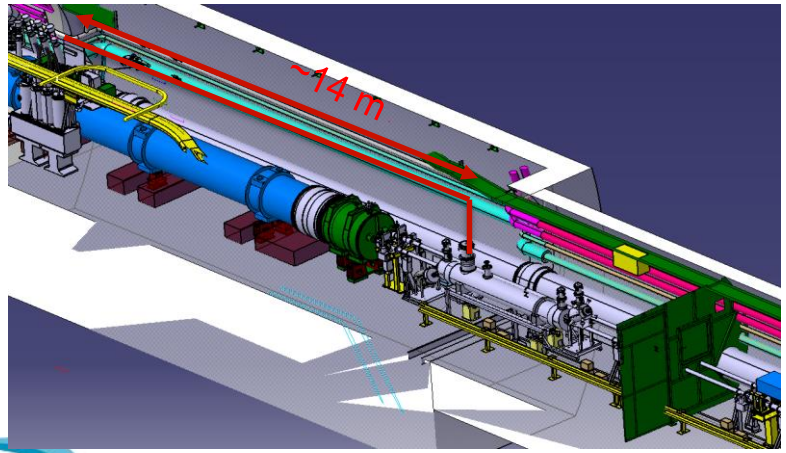
BI:

- 2 x Current Transformer
- 2 x Beam Position Monitor
- 2 x Gas Jet Monitor

Interface with other equipment in the tunnel

- Cryogenics supply:
  - Option 1: from existing jumpers coming from D3 or RF modules (first one to be checked but improbable)
  - Option 2: New dedicated service module and jumper
    - Possibility to install one dedicated service module for HEL leaving space for a future service module for new xxxMHz module or,
    - install a double service module with two jumpers for HEL and future xxxMHz module

Option 1



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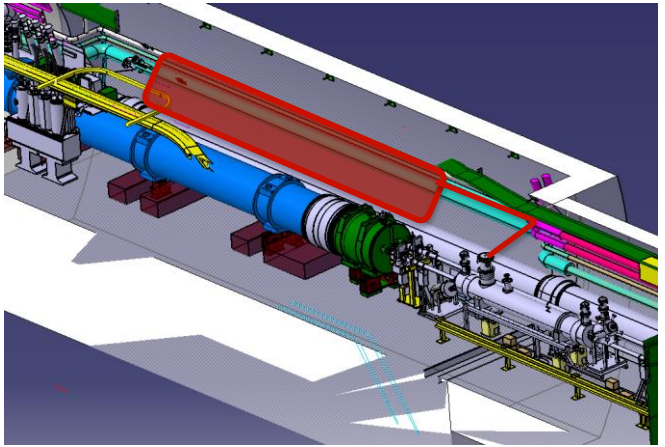
Option 2



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Tunnel general services

- Water cooling pick up for collector
- Services for e-gun powering:
  - to be identified

Preliminary integration of technical services in Service caverns of 4L*

**Please note that 4R is symmetric to 4L*

Power supplies - Circuit rating

	Main solenoid	Bending coils	e-gun coil 1	e-gun coil2	Correctors main sol.	Correctors bend coil	Correctors e-gun
Characteristics	3 coils 1m-long	2 coils 15-cm-long	1 coil 20-cm-long	1 coil 20-cm long	6 flat dipole coils	2 flat dipole coils	2 flat dipole coils
Numb. of indipendent circuits	3	2	1	1	6	2	2
Nominal current	330 A	330 A	106 A	54 A			
Maximum current	450 A	450 A	150 A	150 A	50 A	50 A	50 A
Inductance	3x3.71 H	2X0.66 H	0.09 H	0.09 H			

Power supplies - Circuit rating

	Main solenoid	Bending coils	e-gun coil 1	e-gun coil2	Correctors main sol.	Correctors bend coil	Correctors e-gun
Characteristics Numb. of indipendent circuits	3 coils 1m-long 3	2 coils 15-cm-long 2	1 coil 20-cm-long 1	1 coil 20-cm long 1	6 flat dipole coils 6	2 flat dipole coils 2	2 flat dipole coils 2
Nominal current	330 A	330 A	106 A	54 A			
Maximum current	450 A	450 A	150 A	150 A	50 A	50 A	50 A
Inductance	3x3.71 H	2X0.66 H	0.09 H	0.09 H			

- Total number of independent circuits: 17
  - 7 PC x HL-LHC600A-10V
  - 10 PC x Cancun 50
- Total number of racks: 6 PC racks + 1 control rack
  - Spare slots taken into account
  - Water cooling for HL-LHC600A-10V

Power supplies - Characteristics

Project Qty (Total 17 units)	Magnet Type / function	Magnet Differential Inductance Load Differential Inductance [H]	Magnet Resistance @ 25 °C Load Resistance [Ohm]	Magnet U max di/dt max + I max [V]	Cable Go-only Length (distance between Converter Race and Magnet) Load Cable Length [m]	Equivalent Cable Cross Section Load Cable Cross-Section [mm²]	Cable Resistance @ 45 °C (2x Cable-only length data computed) Load Cable Resistance [Ohm]	Circuit Resistance @ 45 °C for its load cable and @ 25°C for magnet Circuit Resistance [Ohm]	Energy Stored [J]	Circuit Ramp Time (from 0 to I max [s]	Circuit di/dt max [A/s]	Circuit U max di/dt max + I max [V]	Circuit I nom (operation) [A]	Circuit I max (operation) [A]	Circuit Op. Use (DC, Slow Pulsed, Pulsed) [ ]	Circuit Op. Use (Unipolar, Bipolar)	Converter Name / Model	Converter Cooling Water System Required [ ]
3	Main Solenoid	3.7100	0.000	5.57	50	240	0.01	0.01	375 638	300	1.50	9.14	330	450	DC	Unipolar	HL-LHC600A-10V	Yes
2	Bending Coil	0.6600	0.000	0.99	50	240	0.01	0.01	66 825	300	1.50	4.56	330	450	DC	Unipolar	HL-LHC600A-10V	Yes
1	E-gun Coil-1	0.0900	0.000	0.06	50	120	0.02	0.02	1 013	240	0.63	2.44	106	150	DC	Unipolar	HL-LHC600A-10V	Yes
1	E-gun Coil-2	0.0900	0.000	0.06	50	120	0.02	0.02	1 013	240	0.63	2.44	54	150	DC	Unipolar	HL-LHC600A-10V	Yes
6	Corrector Main Solenoid	0.0000	0.000	0.00	50	90	0.02	0.02	0.000	240	0.21	1.06		50	DC	Bipolar	Cancun.50	No
2	Corrector Bending Coil	0.0000	0.000	0.00	50	90	0.02	0.02	0.000	240	0.21	1.06		50	DC	Bipolar	Cancun.50	No
2	Corrector E-gun	0.0000	0.000	0.00	50	90	0.02	0.02	0.000	240	0.21	1.06		50	DC	Bipolar	Cancun.50	No

- Cabling characteristics:
  - Waiting for AC and DC cabling definition and integration
  - First check from EN-EL→ Installed power in UA43/47 should be enough

HEL – Other racks needs

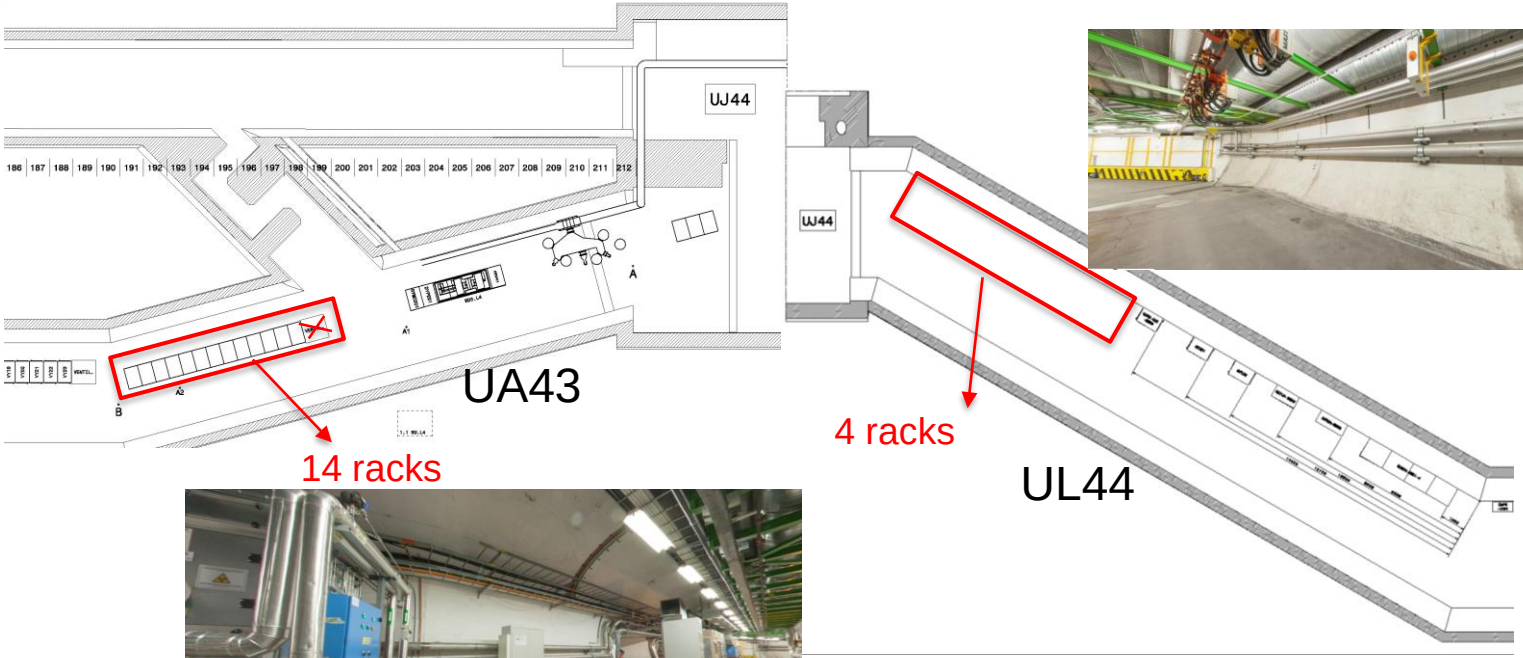
- QPS:
  - EE system needed?→ Study by WP7 to see if they are self protected
  - Racks → 2 min, 6 max (if EE needed)
  - Location: together with the PCs
- BI: 2 racks for control
- E-gun: sofisticated system, maybe in-kind contribution →reserve 2 racks for control

Racks needs summary

System	Min. racks	Max. racks
Power converters	7	8
QPS	2	6
BI	2	2
E-gun	1	2
Total	12	18

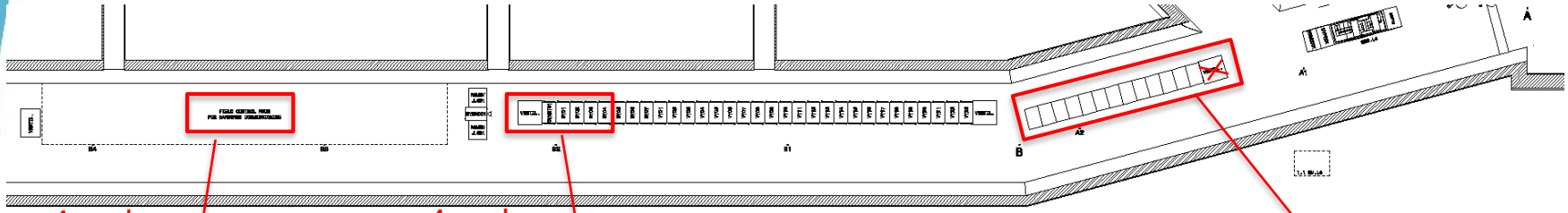
Racks- Location

Option 1: UA43 & UL44 (P4L) / UA47 & UL46 (P4R)



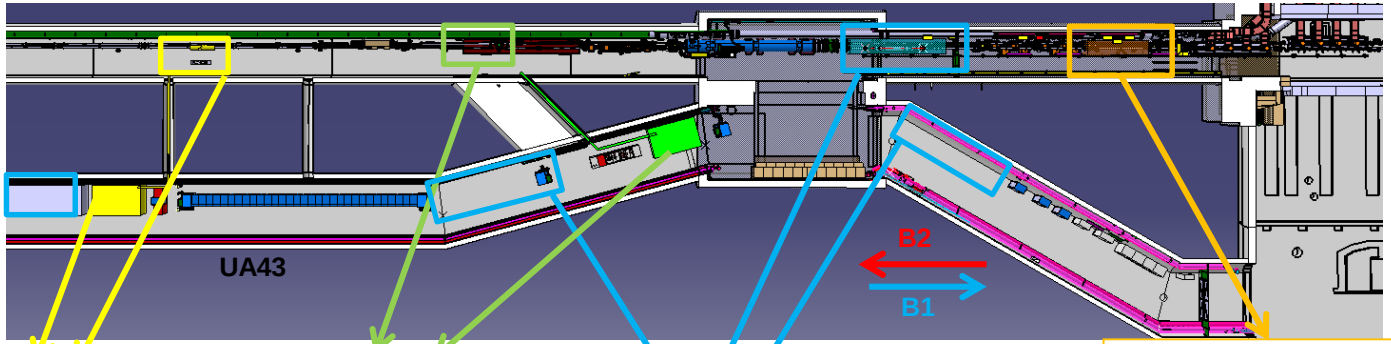
Racks- Location

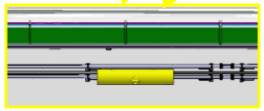
Option 2: UA43 (P4L) / UA47 (P4R)



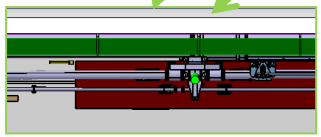
Conclusions

Overview of LSS4 P4L until D4 for HL-LHC



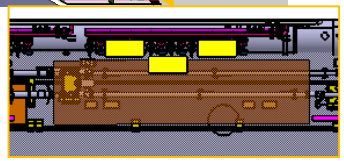


BSR - New extraction and hutch



BSR - Old extraction and hutch

HEL and racks



NEW ADT: existing reservation

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HEL – Conclusions

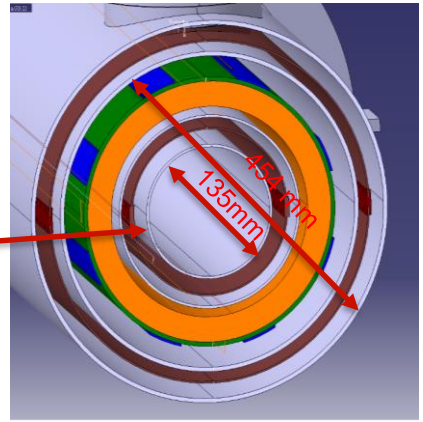
- In view of a possible technological and integration review in autumn this year the integration and service analysis should be updated taking into account:
  - Results of EE computation
  - Addition of Beam Instrumentation equipment and its impact on the HEL design and of the general services requirements
  - A detailed analysis of other ancillary equipment that should be placed in the LHC tunnel (e-gun ancillaries?)
  - Cabling routing from PC to HEL should be defined and integrated

Thank you

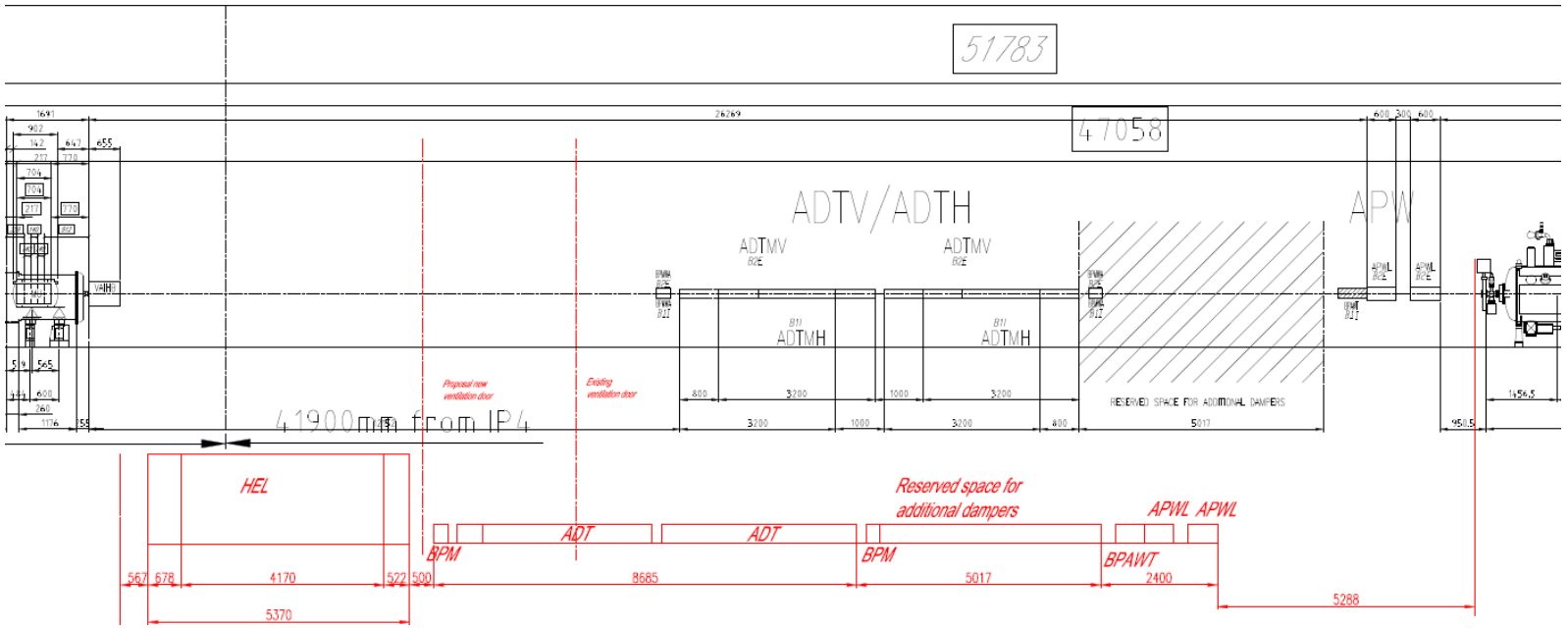
Extra slides

Interface of HEL with other equipment

From inside to outside in grey the room temperature vacuum tank, in brown the thermal screen, in grey the helium tank wall, in orange the main solenoid, in blue the corrector coils generating a horizontal and a vertical dipole. Then follow the helium tank wall, the thermal screen and the vacuum tank. The overall external diameter is 454 mm.

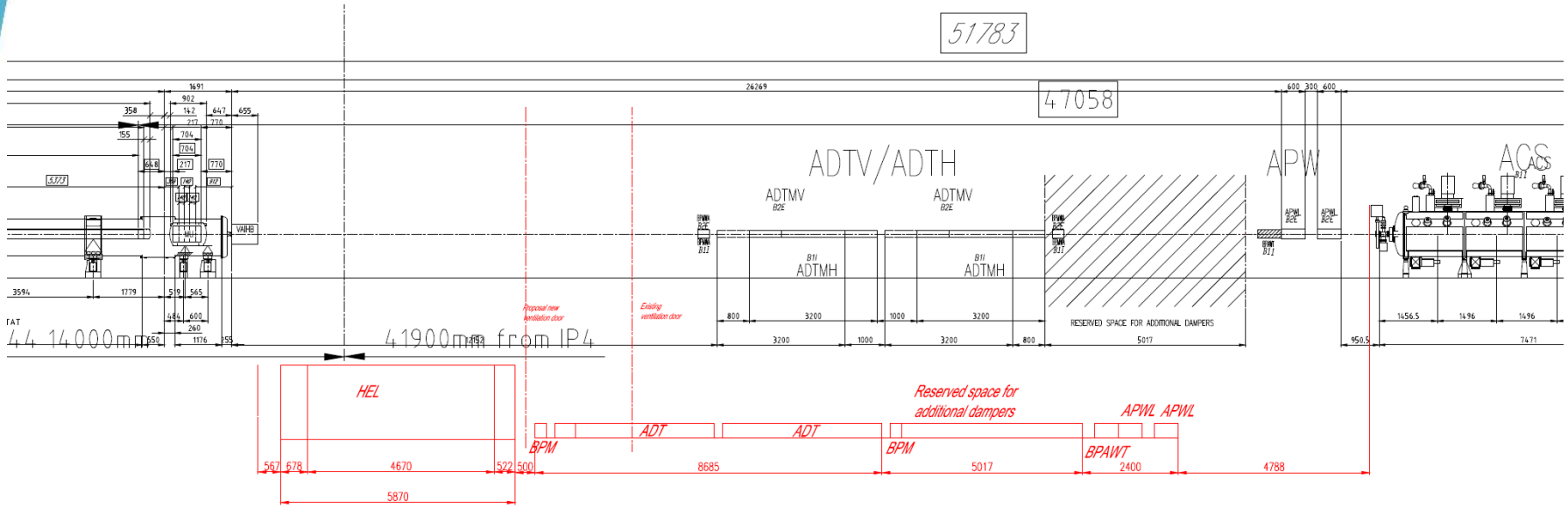


Sketch layout in case of possible RF upgrade



Sketch layout in case of possible RF upgrade with arbitrarily longer HEL

(+500 mm for instrumentation)



HEL – Conclusions

System	Type	Description	Actions
Gas Position Monitor	Open option	It will increase the length of the device, therefore decrease space between HEL and BPM after ADT	Wait to see if it is going to be included
Gun and collector degassing	Design optimization	Design of electrons gun and collector to avoid degassing, otherwise 1m of vacuum chamber in both extremes of HEL with NEG coating needed	Design of the collector avoiding degassing
Space for pumps	Design optimization	Not so much space for the ion pump in e-gun	Interaction with Vacuum for HEL design
Supports for vacuum chamber	Design optimization	Support of vacuum chamber between HEL and Valve takes space maybe needed	Design of new supports
Racks options	Integration study	Two options for racks, depending on total number of racks needed and space availability	Conduct integration studies
Cryogenic supply	Technical study	Two options for cryogenic supply	Conduct studies
EE	Technical study	On-going study to see if the coils are self-protected, it will save space for EE racks	Wait for results
DC Cabling	Study	DC cabling and integration has to be studied	Conduct studies