Initial considerations about the cross-section of a tunnel for CLIC

The aim of this work is to review considerations defining the diameter of a tunnel for CLIC, to collect comments and suggestions in the light of the experience from the LHC installation and to stimulate further work on the subject.

Initial considerations about the cross-section of a tunnel for CLIC

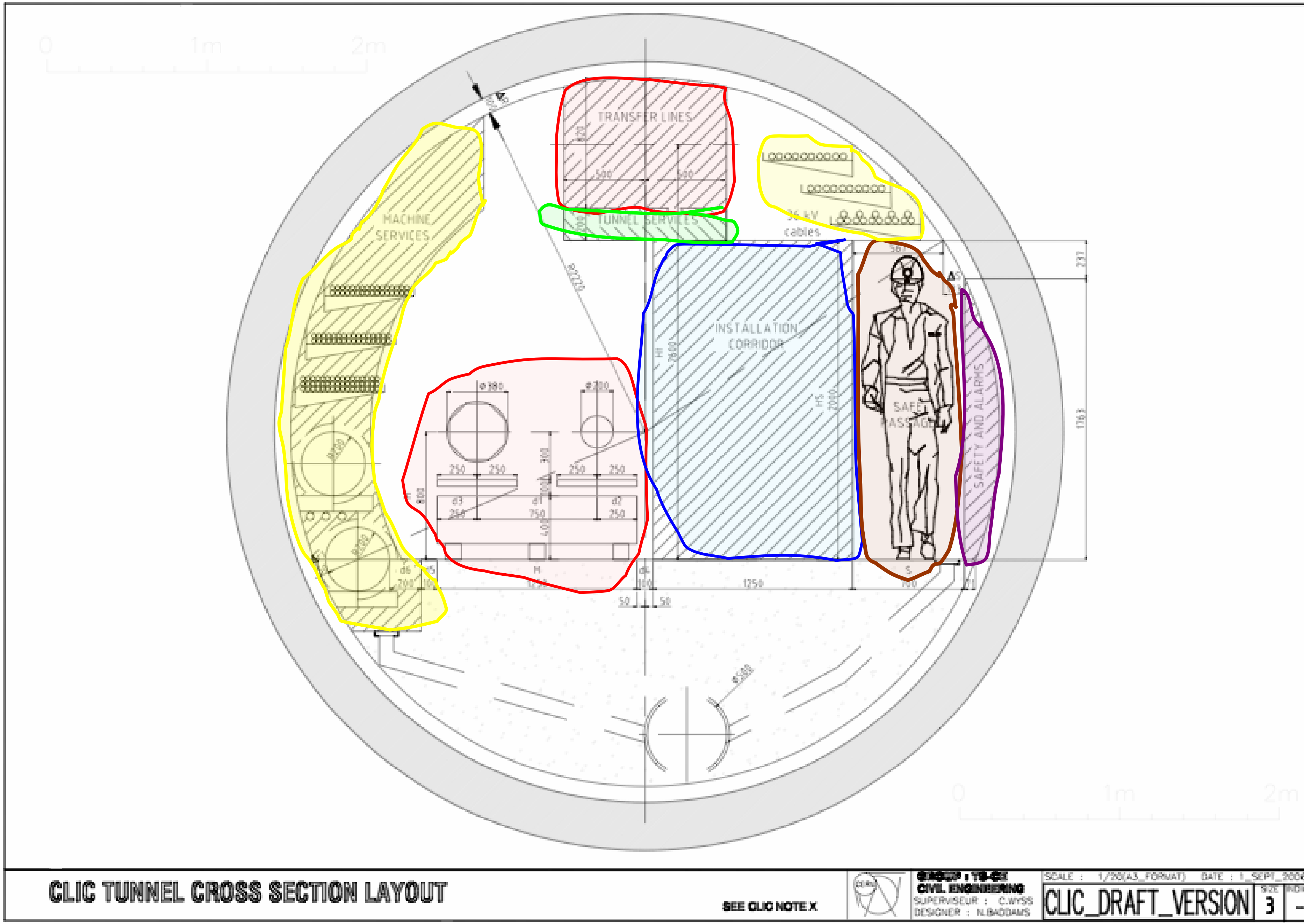
The tunnel diameter must be such that space is simultaneously provided in a safe and economically optimized way for the following items:

1. the CLIC machine, with its drive and main beam machine components.

2. the 2.4 GeV and 9 GeV transfer lines for the drive and main beams, respectively.

3. an installation corridor for the transportation of machine modules for installation or replacement.

4. a free section of at least 70 cm width and 200 cm height to allow a person to pass between a machine module being transported or installed and the tunnel wall.


TRANSFER LINES
TUNNEL SERVICES
MACHINE SERVICES
36 kV cables
INSTALLATION CORRIDOR
SAFE PASSAGE
SAFETY AND ALARMS
CLIC TUNNEL CROSS SECTION LAYOUT
SEE CLIC NOTE X
GROUP : TS-CE
CIVIL ENGINEERING
SUPERVISEUR : C.WYSS
DESIGNER : N.BADDAMS
SCALE : 1/20(A3_FORMAT)
DATE : 1_SEPT_2006
CLIC_DRAFT_VERSION
3
-

Machine services

- Supply and return manifolds for the demineralised water cooling RF structures, magnets and the drive beam dumps. Sufficient radial space forinstallation, welding, compensators, valves, local distribution manifolds is to be foreseen as well.
- Raw water supply and return tubes, in the tunnel invert.
- Drainage for ground water inleaks and machine cooling water leaks.

Machine services

- Compressed air distribution for the PETS on/off mechanism.

- Nitrogen distribution, if any.

- One or two 40-mm duct(s) for optical fibre links for communication and machine reference signals, as done for the LHC.

Machine services

- Two or three 500-mm wide cable trays for the dc power cables for the quadrupole magnets of the drive and main beams. Each sector contains some 600 independent quadrupoles for the drive beam. Should these magnets need a relatively high current density to minimize the overall coil long. and transverse dimensions, the necessary relatively high excitation current may limit the possibility of using multi-conductor cables feeding each several magnets.

LEP - regular lattice cell

LEP - DS cell

Machine services

- One 500-mm wide cable tray for low power and signal cables for the RF system.
- One 500-mm wide cable tray for beam instrumentation, survey and vacuum systems.
- One 300-mm wide cable tray for the power cables of the transfer lines.
- One 200-mm wide cable tray for the cables of the vacuum and beam instrumentation systems of the transfer lines.

Machine services

- the low-voltage (400 V) electricity distribution, with its outlet boxes.
- five (5) cables for the medium-voltage (36 kV) electricity supply [2]. These cables (one per surface area and one for the tunnels services) will bring power from the Prévessin central point to the CLIC surface areas (cooling and ventilation, lifting equipment, site services) and to the underground technical rooms (UTR's).

Machine services

- the secure low-voltage electricity distribution.

- the power rail for the transport vehicles for machine installation (battery operated vehicles instead ?).

Tunnel services

- Normal lighting.
- Leaky cable antenna for portable phones.
- Public address system.

Safety services

- Panels with emergency lightning, emergency stop buttons, red phones.
- Evacuation push-buttons of the break-glass type and sirens.
- Emergency radio communication for the fire brigade.
- Radiation monitors
- Oxygen deficiency monitors ?

Safety services

Items to be protected from the effect of fire:

- Leaky feeder cables (antennas) for radio and mobile phone communications
- The 36 kV power supply cables
- All cables whose function must be ensured in case of fire (ventilation control, rede phones, alarms L3,…) should be housed in a fire resistant duct

Alignement, tunnel tolerances

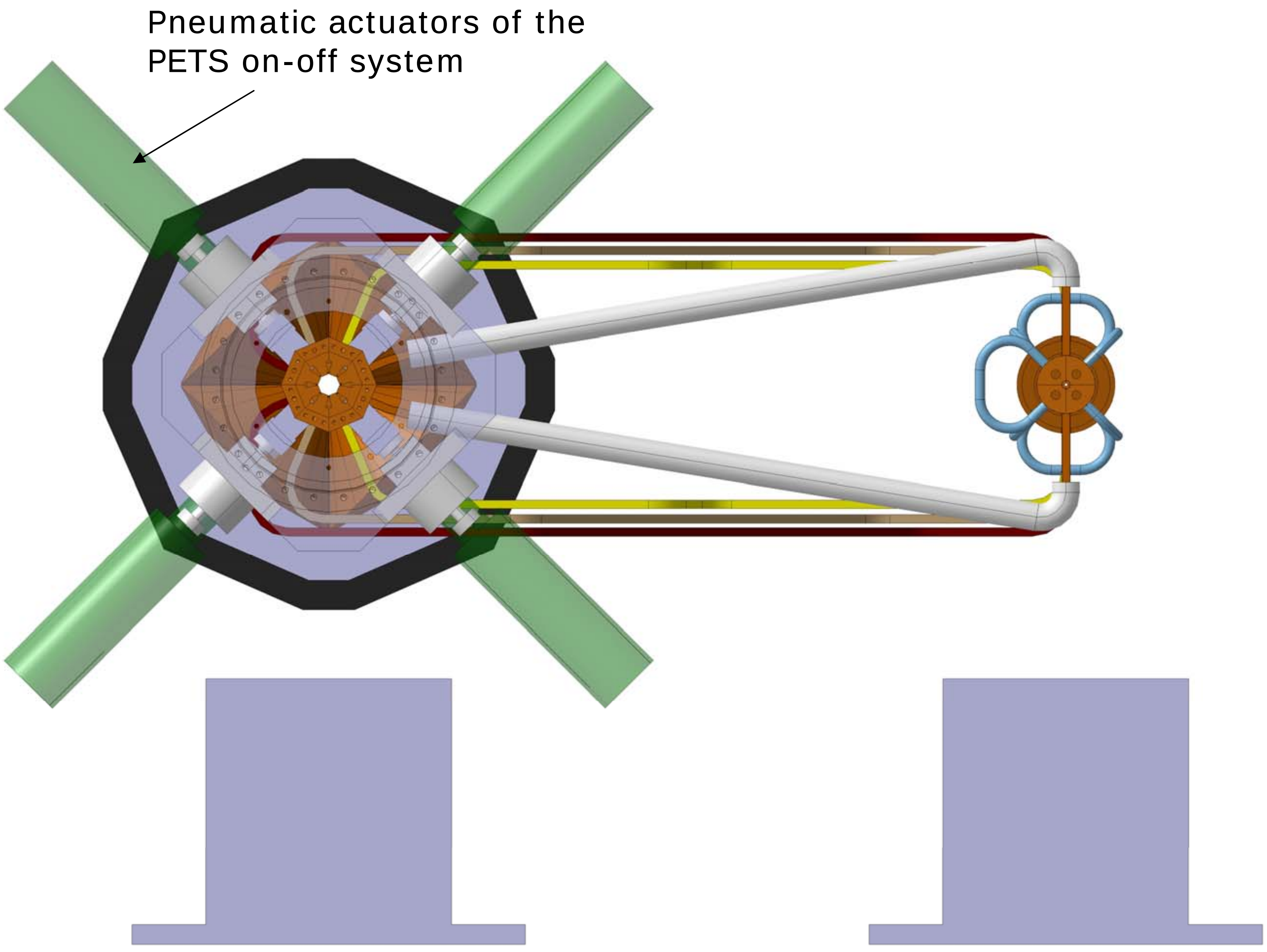
Further, and particularly important in the case of CLIC, sufficient space is to be provided for all machine alignment and survey operations, which will not be carried out at the same time than machine module transportation.

After having defined the tunnel radius from machine proper, machine services and safety requirements, a radial allowance is to be added for the accuracy of the tunnel geometry.

Initial dimensions

d1: distance between the drive beam and the main beam axis. For the time being this distance is assumed [3] to be 750 mm, it is defined by

- the half-widths of the HDS and PETS structures vacuum tanks. For the latter, the overall dimensions of the pneumatic actuators of the PETS on-off system shall be kept within limited boundaries.
- the half-widths of the main and drive beam quadrupole magnets.
- the dimensions and bending radius of the waveguides between PETS and HDS.
- the space needed by the main and drive beam alignment systems.


Pneumatic actuators of the
PETS on-off system

Initial dimensions

d2: width needed for machine components right of the main beam axis. For the time being this distance is assumed to be 250 mm, as observed on the CTF2 assembly in bldg. 18. This width it is defined by

- the half-width of the HDS structures vacuum tank.
- the half-width of the main beam quadrupole magnets.
- the space needed for the main beam alignment system.
- any other space needed for the waveguides from the HDS to the RF loads, for Beam Position Monitors (BPM) cabling and other machine equipment yet to be defined.

Initial dimensions

d3: width needed for machine components left of the drive beam axis. For the time being this distance is assumed to be 250 mm, as observed on the CTF2 assembly in bldg. 18. This width it is defined by

- the half-width of the PETS structures vacuum tank, and the overall dimensions of the pneumatic actuators of the PETS on-off system.
- the half-width of the drive beam quadrupole magnets.
- the space needed for the drive beam alignment system.
- any other space needed for BPM cabling and other machine equipment yet to be defined.

Initial dimensions

M: total machine width,

M = d1+d2+d3
= width of the installation corridor
= 1250 mm for the time being.

This dimension is likely to be the driving one for the tunnel diameter and cost, its definition will be the result of the careful engineering design of the CLIC machine modules.

Initial dimensions

d4: clearance between the right boundary of the installed machine and the left boundary of the installation corridor. This clearance, currently 100 mm, is meant to avoid damages to the installed machine by the loads moved during machine installation.

A mechanical protection, as it had been done for LEP, may be considered. In this case 100 mm may not be enough.

LEP - regular lattice cell

LEP - DS cell

Initial dimensions

d5: clearance between the edge of the trench (if the latter is needed for the cooling water manifolds) of the tunnel invert and the feet of the machine modules.

This clearance, [4] currently 100 mm, is necessary to avoid fissuring or breaking the invert edge by installation operations (e.g. hole drilling) or because of the stresses stemming by the installed loads.

Initial dimensions

d6: clearance between the edge of the trench and the cooling manifold.

This distance is currently assumed to be 200 mm, it is meant to reduce the risk of damages to the machine in case of interventions on the services with the machine already installed.

This distance may also be useful/needed to accommodate flexible connections for the machine services to the modules.

Initial dimensions

S: width of the safety passage between installation corridor and right tunnel wall.

According to the presentation by Prof. Haack [5] at CERN on 21 August 2006 about the safety considerations made for the TESLA and XFEL projects at DESY, this width is assumed to be nominally 700 mm.

This width is defined at § 19 of the German regulations (BOStrab) [6] concerning the construction and operation of metro/commuter railway system, adopted e.g. also for the driverless, fully automated Copenhagen metro.

Initial dimensions

S: width of the safety passage between installation corridor and right tunnel wall.

The above quoted § 19 stipulates further that in case that the tunnel is not of square dimensions, the width of the passage can slightly be reduced at its bottom and top parts.

This is our case, since we have a circular tunnel. We assume therefore that the passage width is reduced by ^2S at the top of the passage cross-section, ^2S being chosen so as to leave enough head room. Let us assume here that $^2S = 100$ mm.

Initial dimensions

Tunnel type	Standard	Width (m) *	Height (m)	Max. length (m)*
road	RABT	1.00	2.25	300
railway	DS 800 01	0.80 (0.40-0.50)	2.20	1000 (1.30)
	EBA Ril	1.20 (0.90)	2.20	1000 (2.0)
metro / ommuter railway	BOStrab (§ 19)	0.70 (0.50)	2.00	600 (6.0)
	DS 800 03	0.80 (0.50)	2.20	800 (1.0)

* in bracket exceptions for width over a limited length

Initial dimensions

r1: radius of the cooling water supply and return manifolds.

This radius is set at 200 mm for the time being, according to preliminary estimates [7] of the heat loads in each of the 21 linac sections and assuming that up to 4 sections are cooled from these manifolds.

Under this working hypothesis, the maximum distance between tunnel main shafts is equal to 2 x (4 x 670) = 5360 m.

Initial dimensions

N.B. The distance between main shafts will in practice be defined by the topography and by the land usage/allocation of the surface terrain (housing, industrial, agricultural, forest, natural reserve) defined by the host state local authorities, as well as by the geology of the underground.

This means that the distance between different shafts might well not be identical.

The diameter of the piping for cooling will have to be then defined according to the eventually chosen shaft locations.

Initial dimensions

²r1 : radial allowance for manifold welding and installation. This allowance is set at 50 mm for the time being.

The supports for the water manifolds are likely to be designed to damp vibrations induced in the manifolds by the turbulent water flow. As a consequence the space taken by the manifold supports is to be evaluated with the appropriate care.

The water flow will increase from 120 to some 900 m3/h along a manifold length, with regular small steps in water mass flow/ velocity stemming from the incremental flow distribution and collection to/from the modules.

Initial dimensions

^{2}R : radial allowance for tunnel geometry .

This allowance is set at 100 mm according to experience from the LEP tunnel and advice gained in the course of the 2006 international study about the ILC tunnel dimensions [9].

Initial dimensions

H: beam height above the tunnel invert, chosen at 800 mm for the time being. The actual height will depend on the dimensions of:

- the vacuum tanks for PETSs and HDSs.
- the mechanics of the supports of the drive and main beams.
- the active alignment systems of the main beam quadrupoles and accelerating structures.
- the active alignement system of the drive beam quadrupoles.
- the dimensions of the module base girder.

Initial dimensions

For information, the CTF2 set-up in building 18 features the following vertical dimensions:

- distance between beam axis and alignment plates: 270 mm.
- distance between beam axis and base support: 330 mm.
- height of the base support structure: 900 mm.
- distance between beam axis and floor: 1230 mm.

Initial dimensions

Ht: beam height of the transfer lines above the tunnel invert.

This height, given in first approximation by the transverse dimensions of the quadrupole magnets, is set at 2600 mm and is for the time being an educated guess, as no work has been made so far about the optics of these transfer lines

Initial dimensions

Hs: height of the safety passage S.

This height is set at 200 cm, according to Ref 3.

200 cm too low ?

Tentative tunnel diameter

$$R_1 = \sqrt{(M + \frac{d_4}{2} + d_5 + d_6 + r_1)^2 + H^2} + (r_1 + \Delta r_1)$$

$$R_2 = \sqrt{(M + \frac{d_4}{2} + (S - \Delta S))^2 + (H_s - H)^2}$$

Tentative tunnel diameter

With the parameters values listed above, the following figures are obtained:

R_1 = 2.219 m
R_2 = 2.347 m

We have a difference of 128 mm between the two above radii, which can be cancelled by increasing ^{2}S by 33 mm from 100 to 133 mm, as illustrated in Fig. 1, which shows that the required head room is essentially maintained.

We obtain finally a tunnel radius of 2.32 m (or a diameter of 4.64 m), once the radial allowance ^{2}R for the tunnel geometry is added.

Tentative tunnel diameter

For reference, the corresponding figures for the LEP/LHC tunnel are a radius of 1.88 m (i.e. 0.44 m less – 0.42 cm is the width of an A3 sheet- than the above 2.32 m) and a diameter of 3.76 m.

The axis of the LEP machine was at 350 mm distance from the tunnel axis, i.e. 300 mm less that the (1250+50)/2 = 650 mm currently assumed for the CLIC axis, and the LEP beam height was 650 mm, i.e. 150 mm less than the 800 mm assumed here.

Tentative tunnel diameter

For information, with the overall machine width

M = 1000 mm

of the CTF2 set up in Bldg 18, the evaluation of (1) plus the ²R allowance for tunnel geometry yields a tunnel radius of about 2.1 m.

Conclusion

An initial set of requirements has been used to tentatively define the diameter of the machine tunnel for CLIC.

Considering that the space allocated at one tunnel side for the secure passage of personnel is about equal to that needed at the opposite tunnel side for the machine services, the most important contribution to the definition of the tunnel diameter is the overall width of the CLIC machine modules.

Conclusion

To progress on the subject, further input is required about

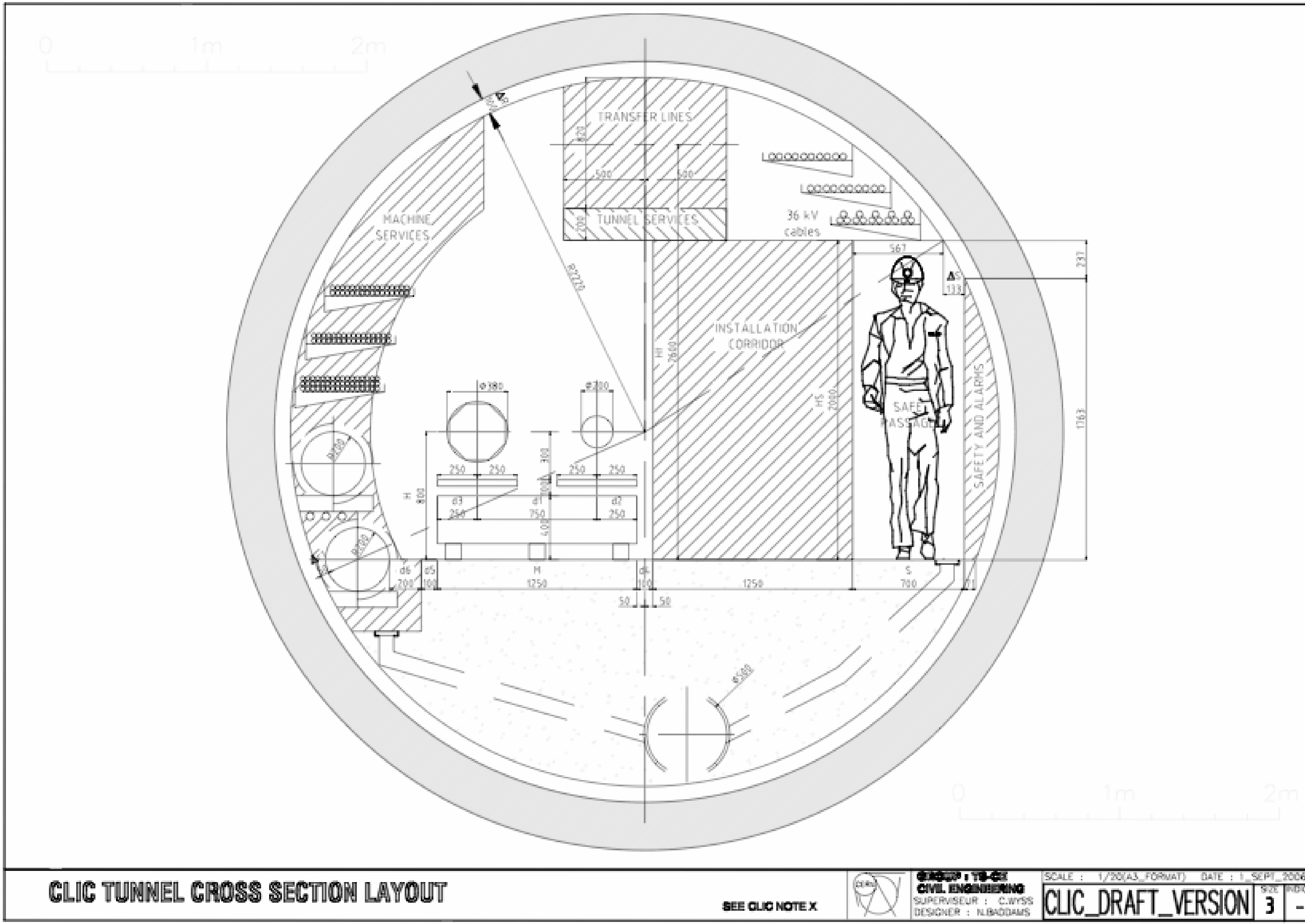
- the most likely overall width (RF-frequency dependent) and height of the CLIC machine modules.
- the space required for the beam transfer lines.
- a better estimation of the space required for machine, tunnel and safety services, following a first inventory of requirements and the experience from the LEP and LHC installation.

Acknowledgements

Helpful discussions with and input by

J-L.Baldy, H.Braun, P.Ciriani, F.Corsanego, C.Hauviller, J.Pedersen and M.Poehler are gratefully acknowledged.

Many thanks to N.Baddams for producing the draft tunnel cross-section drawing.


CLIC TUNNEL CROSS SECTION LAYOUT
SEE CLIC NOTE X
GROUP : TS-CE
CIVIL ENGINEERING
SUPERVISEUR : C.WYSS
DESIGNER : N.BADDAMS
SCALE : 1/20(A3_FORMAT)
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SIZE
3
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-
TRANSFER LINES
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INSTALLATION CORRIDOR
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0
1m
2m