XFEL – based HLRF scheme

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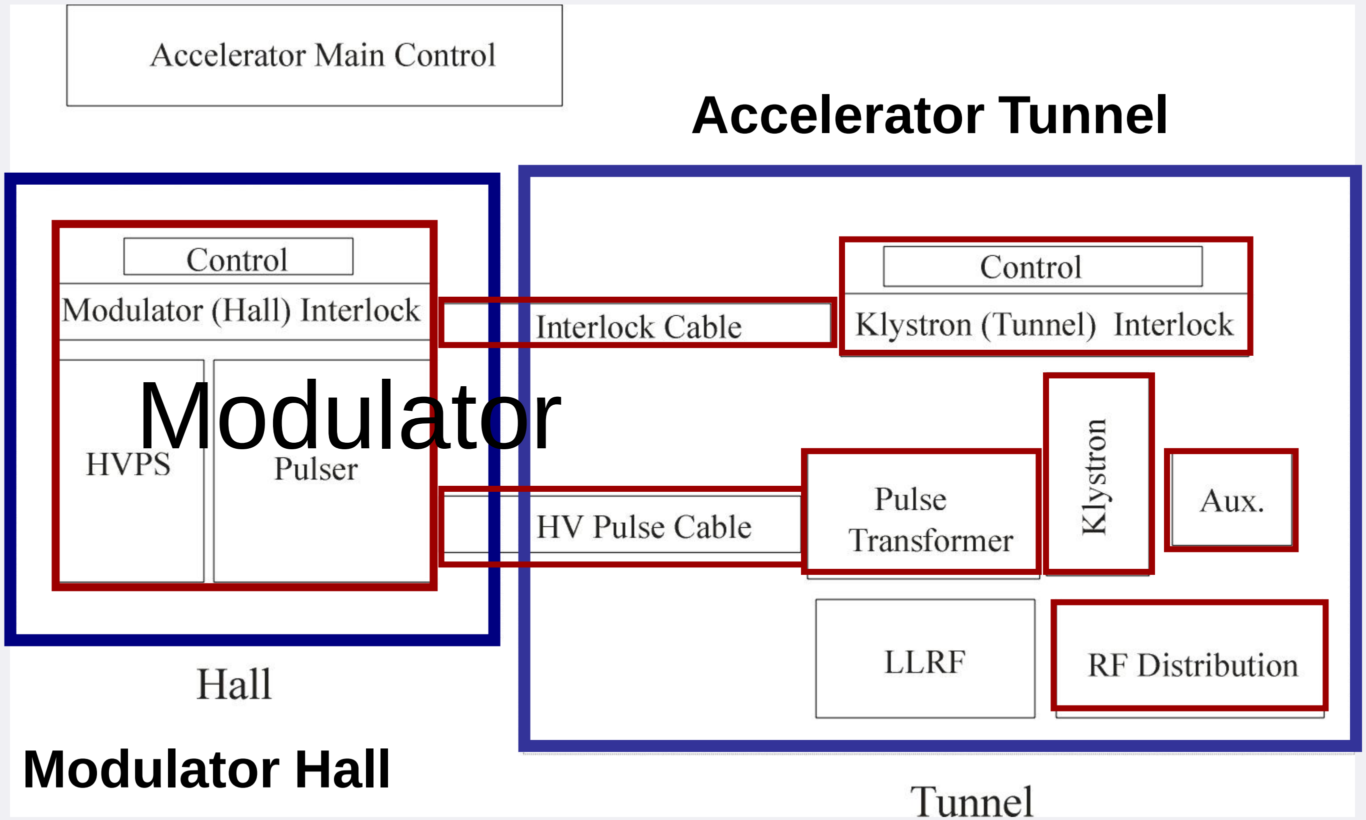
RF System Requiremets

Overview Layout of the RF Station



HV Pulse cable scheme (XFEL)

- The pulse forming units of the modulators will be installed in the modulator halls at the surface, whereas the pulse transformers will be installed inside the tunnel.
- Thus, pulse cables with a length of up to 1.7 km must be used for the connection. (XFEL)
- **In order to limit the ohmic power loss to 2%, on average, a current lead of 300 mm2 is required.**
- The wave impedance of the cable must match the impedance of the klystron transformed to the transformers primary side to avoid distortion of the pulse shape.
  - **In addition, the skin effect must be minimised.**
- **Therefore, four cables in parallel, each of 75 mm2 cross section, 25Ω impedance, and an outer diameter of 30 mm, will be used.**
- The cables are the triaxial type to minimise electromagnetic interference.
- The inner lead is at high potential (12 kV), the middle cylindrical lead at the potential of the bouncer circuit (±2 kV) and the outer cylindrical lead at ground potential.
  - **Additional line matching to the pulse transformer will be done via a RC network.**
- H.-J. Eckoldt, *Pulse Cables for TESLA, TESLA Report 2000-35*.

SYSTEM OVERVIEW

The modulator provides high voltage pulses to supply the klystron during the machine pulse. At XFEL the klystrons will be placed in the accelerator tunnel whereas all modulators will be placed in a central modulator hall at the beginning of the accelerator section. As the maximum length will be 1700 m, an impedance matched system is needed for the interconnection. This is achieved by using 4 coaxial cables, each with a nominal impedance of 28 ohms in parallel, resulting in an effective cable impedance of 7 ohms.

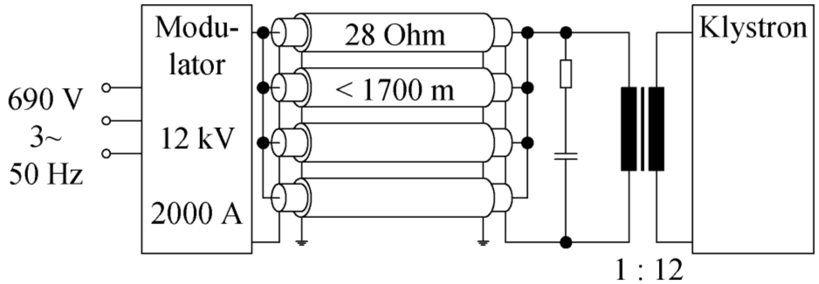


Figure 1: System overview.

Figure 1 shows a simplified block diagram of the overall system. More details are available in [1].

A NEW PROTOTYPE MODULATOR FOR THE EUROPEAN XFEL PROJECT IN PULSE STEP MODULATOR TECHNOLOGY
J. Alex, et al (PAC09)

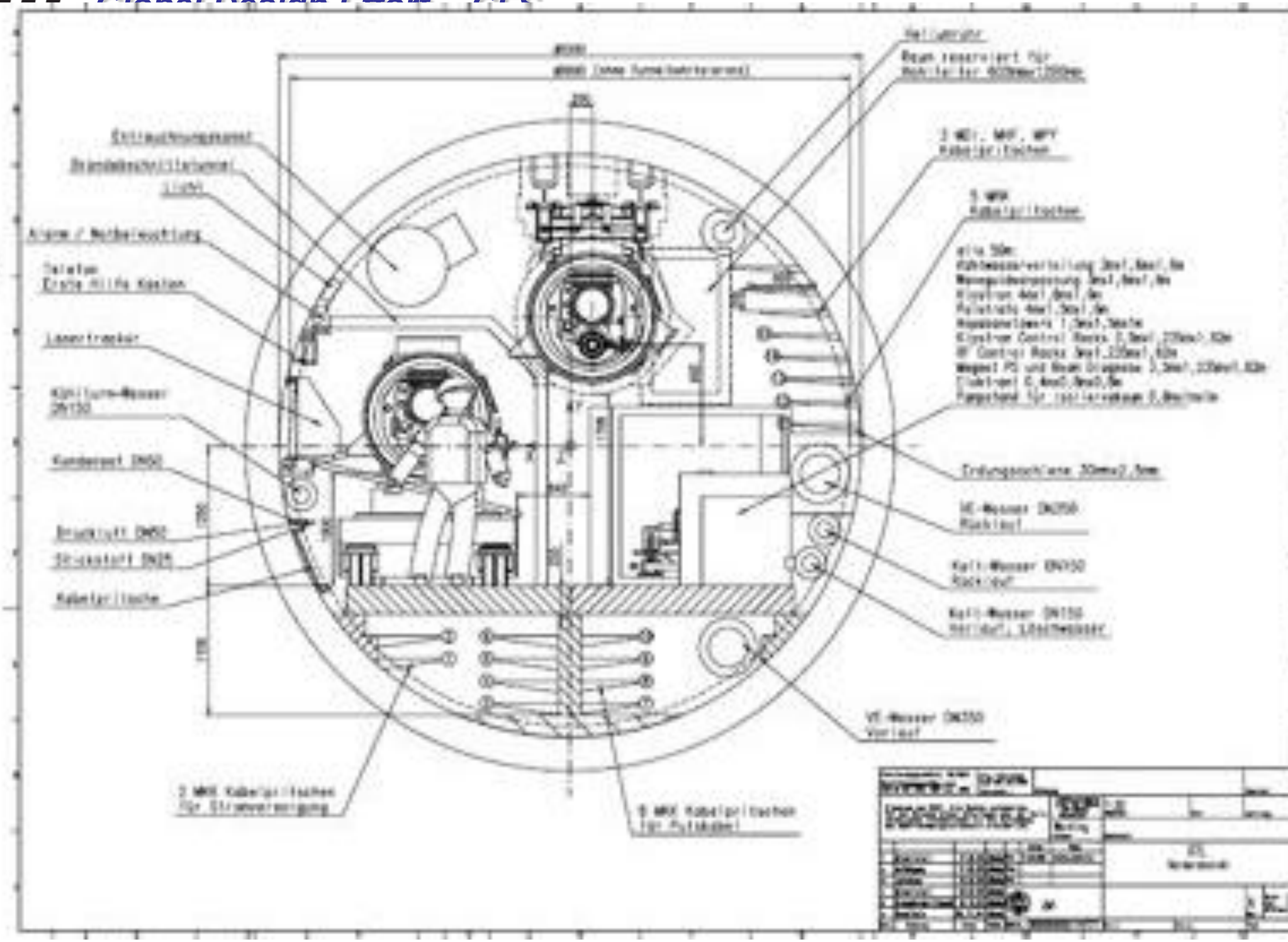


Figure 7.1.9 shows an aerial visualisation/simulation of the XFEL site DESY-Bahrenfeld.

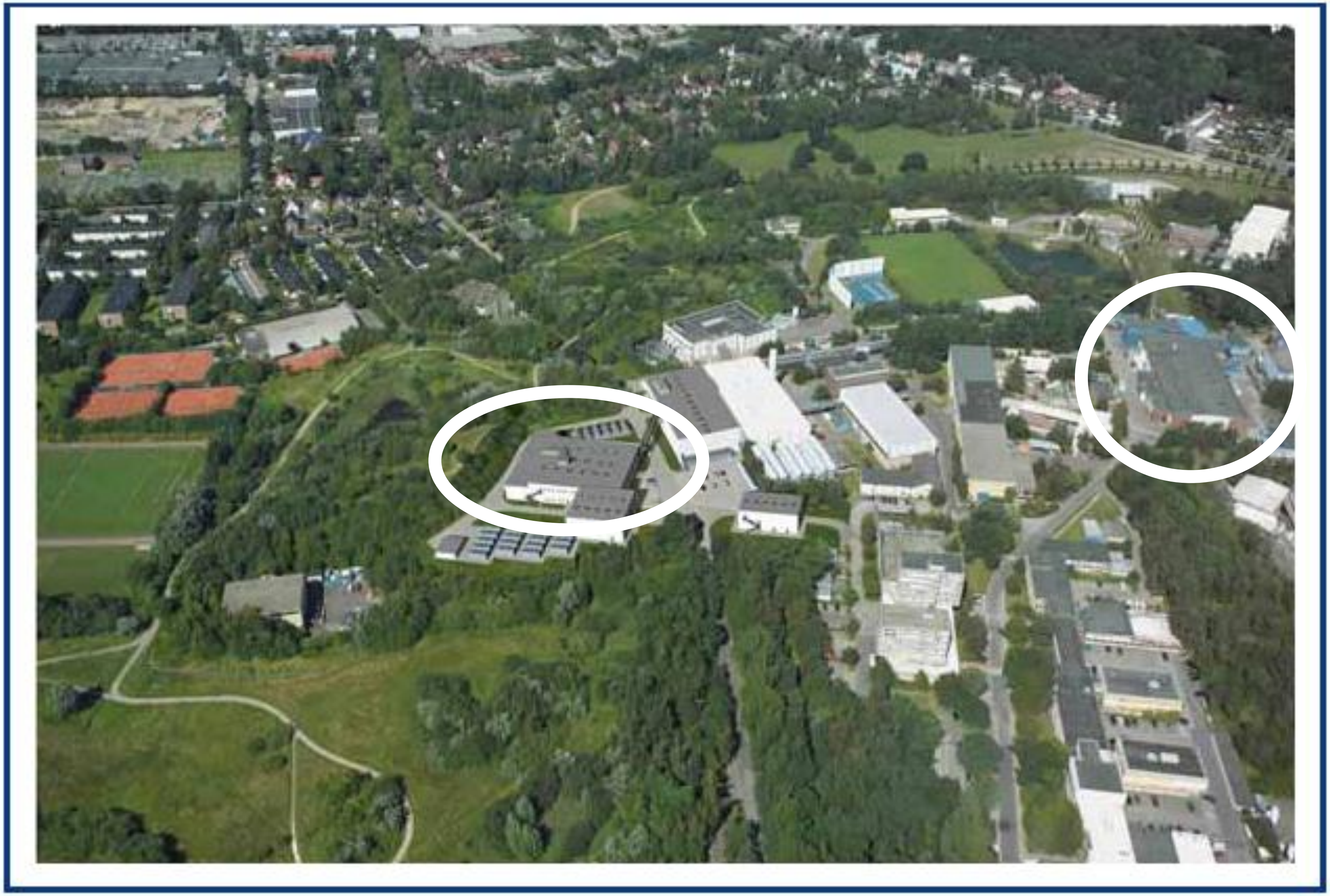
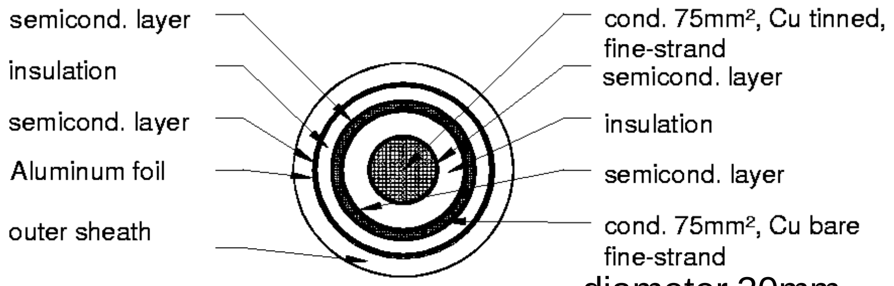


Figure 7.1.9 *Aerial visualisation/simulation of the XFEL site DESY-Bahrenfeld.*

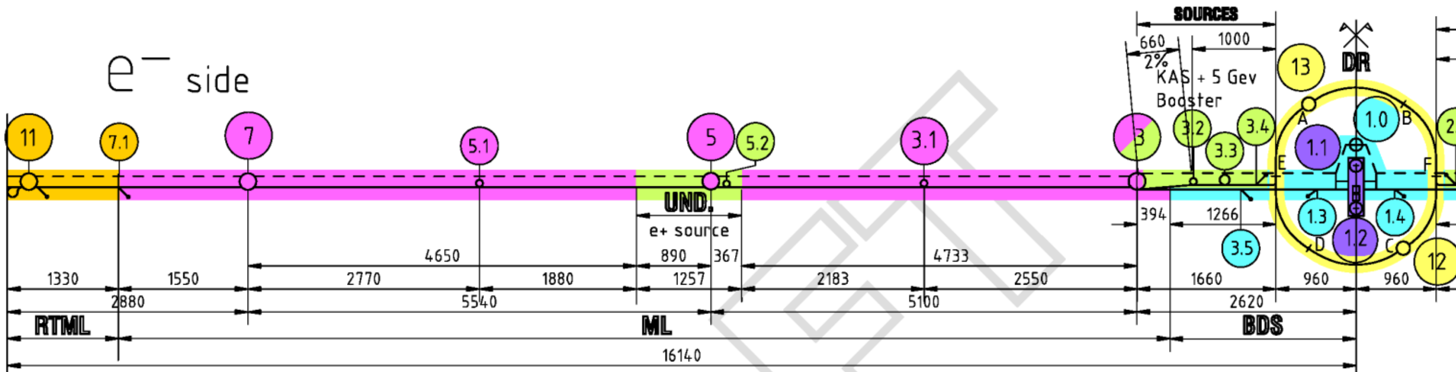
HV Pulse Cable

- Transmission of HV pulses (10kV, 1.6kA, 1.57ms, 10Hz (30Hz)) from the pulse generating unit (modulator hall) to the pulse transformer (accelerator tunnel)
- Maximum length 1.5km
- Impedance of 25 Ohms (4 cable in parallel will give 6.25 Ohms in total) to match the klystron impedance
- Triaxial construction (inner conductor at 10kV, middle conductor at 1kV, outer conductor at ground)

Average 25 (75) A shared between 4 parallel cables



diameter 30mm
dielectric material: XLPE

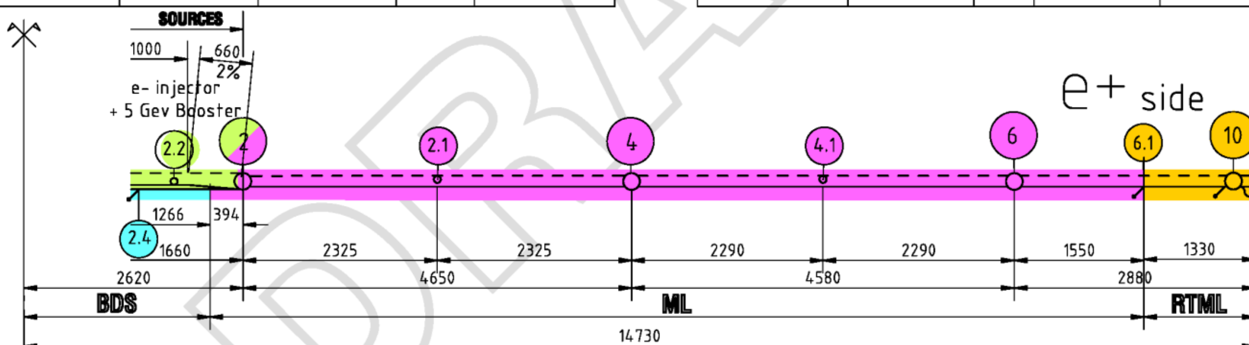


SITE / TUNNEL LENGTHS (m)

e– side + Undulator ML + RTML	e+ side ML + RTML	BDS + sources	DR	TOTAL
13 914 / 27 948	12 504 / 25 128	4452 / 12 236	0 / 6704	30 870 / 72 016

TUNNELS

Area	e- inject.,KAS beam + serv	DR	RTML beam + serv	ML beam + serv	BDS beam + serv	BDS Survey
ϕm	4.5	5.0	4.5 + 4.5	4.5 + 4.5	4.5 + 4.5	1.5 x 2.2



Legend :

- RTML
- ML
- DR
- Sources e- KAS
- BDS
- Detectors Area

SHAFTS

Point	1.0	1.1	1.2	2	3	3.3	5.2	4	5	6	7	10	11	12/C	13/A
ϕm	9	16	16	14	14	4	4	14	14	9	9	14	14	9	9

BORINGS

Point	2.1, 3.1, 4.1, 5.1	2.2, 3.2	1.3, 1.4, 2.4, 3.5
ϕm	1.50		

SHAFT BASE CAVERNS

Point	2, 3, 4, 5, 6, 7, 10, 11
(LxWxH) m	49 x 16 x 18 + 3 storeys

MUON WALL WIDENINGS

Point	1.3, 1.4
(LxWxH) m	25 x7x6 +15x7x6

SOURCES CAVERNS

Point	Undulator 5.2	KAS 3.3	2.2, 3.2
(LxWxH) m	21 161m3	6 574m3	7 X 15 X 7.5

DR ALCOVES

Point	12/C, 13/A	B, D, E, F
(LxWxH) m	75 x 10 x 10 + 1 storey	16 x 8 x 8

DETECTORS HALL

Point	1.1, 1.2	1.0
(LxWxH) m	120 x 25 x 39	40 x 15 x 15

BEAM DUMPS CAVERNS (↖)

Point	SOURCES 2.3, 3.4	RTML 6.1, 7.1, 10, 11	BDS 1.3, 1.4, 2.4, 3.5
(LxWxH) m	5 x 4 x 4		20 x 9 x 15 + 1 storey

BEAM DUMP SERVICE HALLS (↖)

Point	BDS 1.3, 1.4, 2.4, 3.5
(LxWxH) m	30x20x 10

ILC - UNDERGROUND STRUCTURES SCHEMATIC LAYOUT

AREA SYSTEM DIVISION **(2 mobile Detectors - Push Pull - modified CMS procedure)**

EUROPEAN REGION

CERN

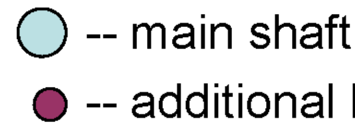
GROUP : TS-CE
CIVIL ENGINEERING
SUPERVISOR : JL.BALDY
DESIGNER : N.BADDAMS

SCALE : 1/50000(A3_FORMAT) DATE : 05_DEC_2006

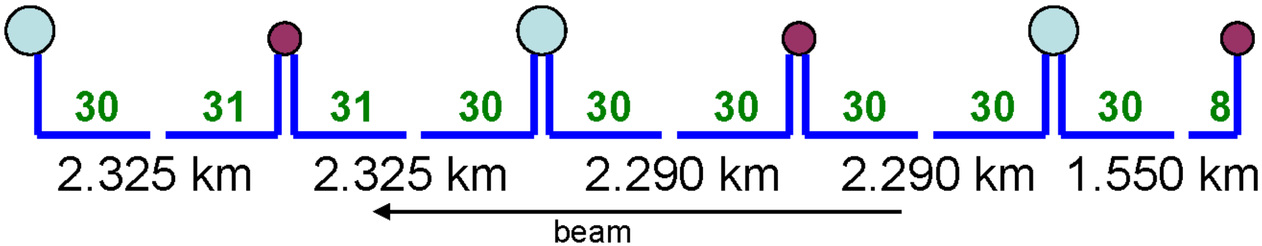
ILC–.CE–1.1649.0016 | SIZE 3 | INDICE G

Shaft Location

560 3-CM rf units, 280 per linac
31 per cluster → 9.03 clusters, 5 shafts per linac

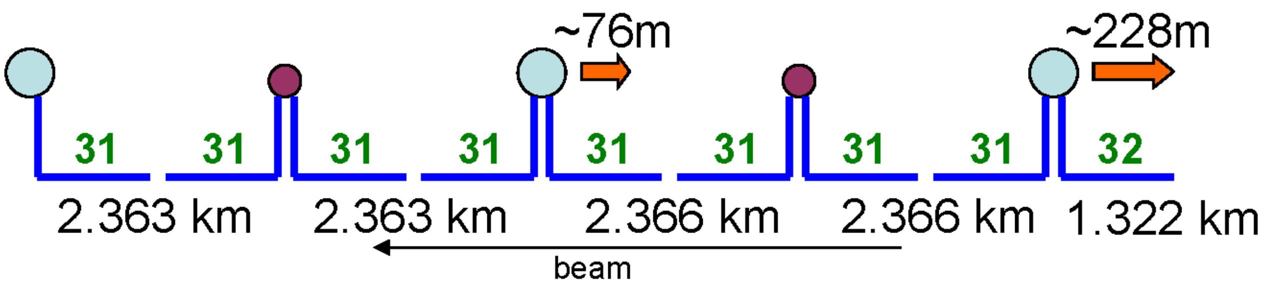


The RDR shaft location would require three additional shafts, for a total of 6, for the KCS.

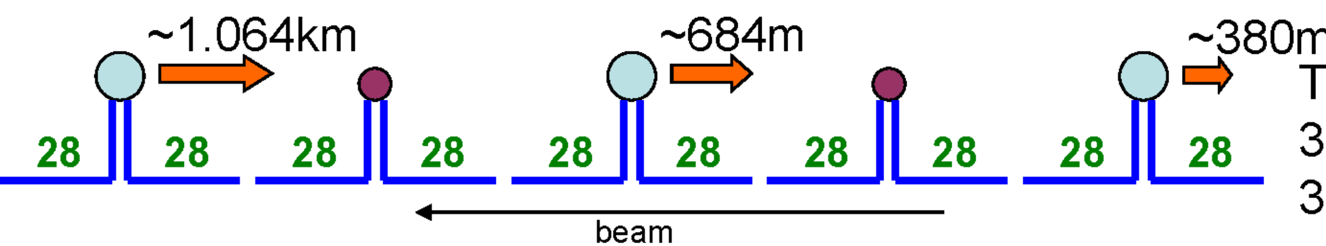


Typical KCS: 30 rf units,
32 klystrons worth of power,
34 klystrons/cluster

Shifting the main shafts would accommodate KCS implementation with only two additional shafts per main linac.



Typical KCS: 31 rf units,
33 klystrons worth of power,
35 klystrons/cluster



Typical KCS: 28 rf units,
30 klystrons worth of power,
32 klystrons/cluster

Pulse HV Cable length

Shaft (e+ ML only)	Total RF Units	Up side RF units	Down side	Max length
2	61	31	30	2325
4	121	60	61	2325
6	98	38	60	2290

- Maximum ~ 2455 m (45% > XFEL max 1700)
- Average 1265 m (27% > XFEL average)
- Total length triax: 2830 km (both ML);
  - **5.06 km/RF unit average**
  - **(4 cables per RF unit)**

Cable power loss

- 0.5 W/m → see Wilhelm's talk
- 1.4 MW for RDR-scheme
  - **(compared to 75.7 MW total)**
- Shaft 4: 484 x 150 m (max)
  - **36.3 KW (242 W/m)**
- Feasible

Cable installation

- 30 mm outer diameter
  - **cross section +20% = 1100 mm^2**
- Shaft 4 feeds 121 RF units: 484 cables
  - **~ one sq m total**
  - **(tray loading limits increase space requirement ~ factor 5 to 10)**

Conclusion

- Backup scheme –
  - *to be adopted if motivated by cost or R & D results*
- For Americas/EU RDR sample sites:
  - *** the cable based scheme is feasible ***
  - **Adding surface construction for modulators**
  - **Compensate for cable power loss**
  - **Adopt XFEL – like tunnel scheme**
  - **To study: tunnel cross section, availability, adaptation to different topography,…**

Proposed Baseline 'TLC'*

- Adopt 'forward-looking' view
- New HLRF schemes should provide flexible solutions – Technical criteria for linac CFS
- → motivation for R & D on KCS and DRFS
- → justification for * Top-Level Change of baseline

- BUT – just in case – the XFEL / TESLA scheme is a reliable backup