HELIUM-Experiment in the HERA-Tunnel

Test results of the Helium propagation mechanism after a sudden release of Helium from the cryogenic system of HERA's proton ring

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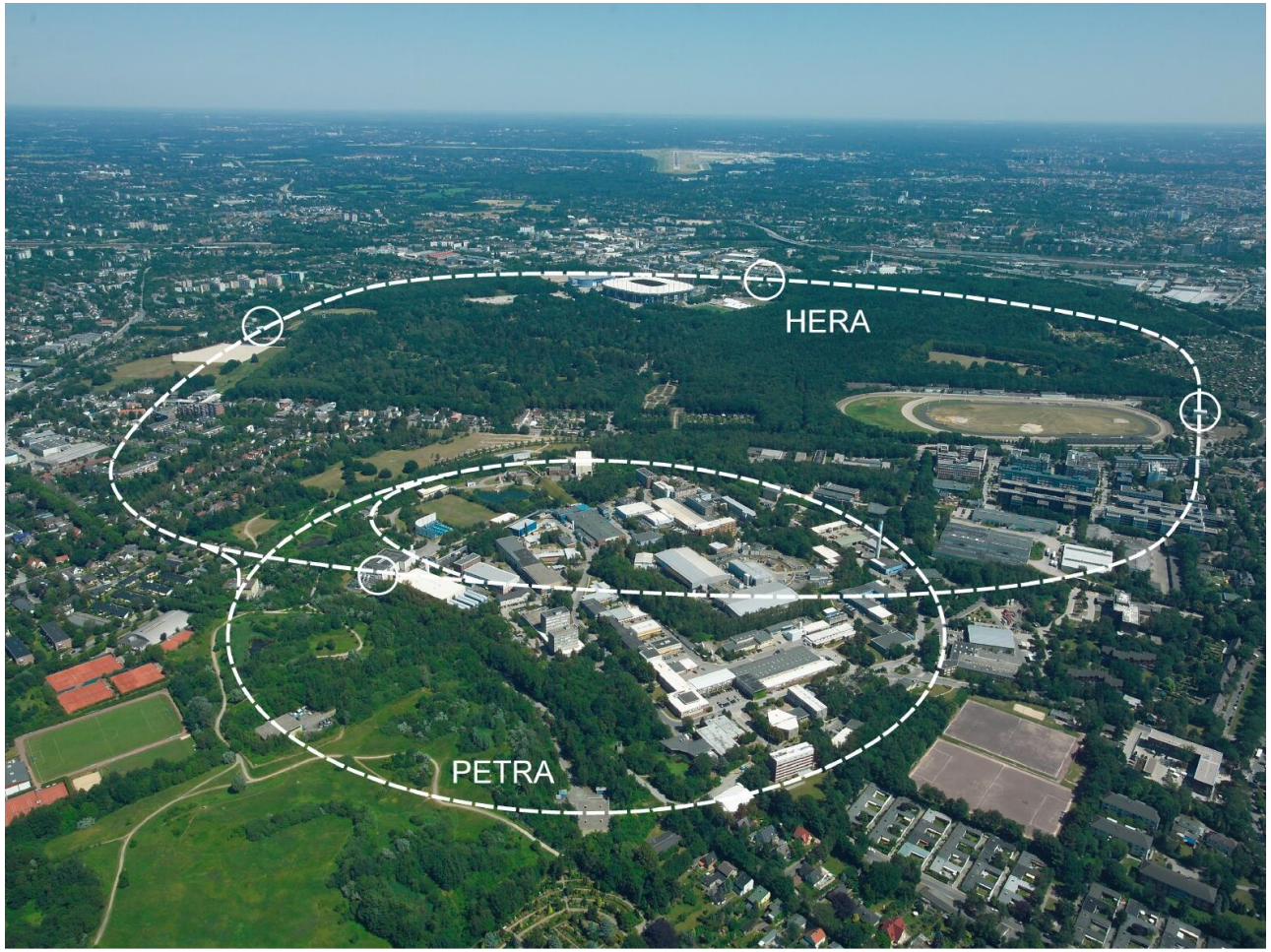
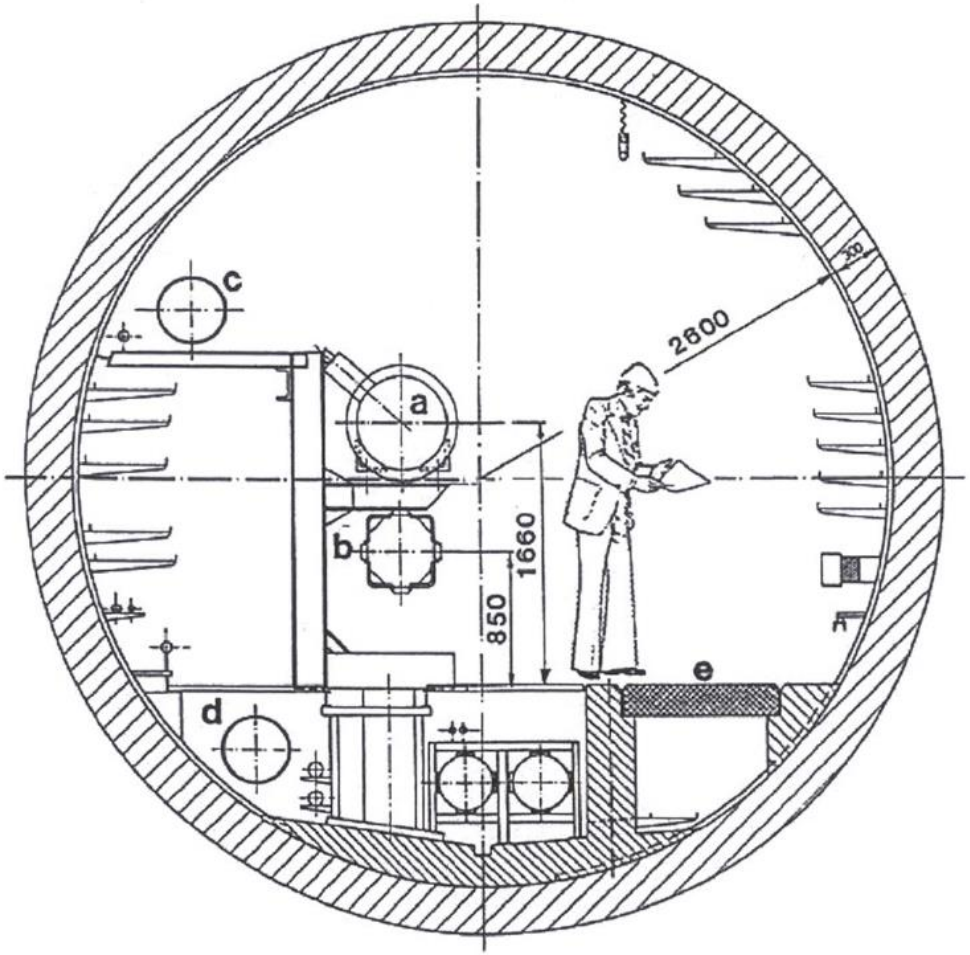
HERA AT DESY



Areal view of the DESY site. Indicated are the positions of the 2 storage rings HERA (length 6336 m) and PETRA (length 2604 m).

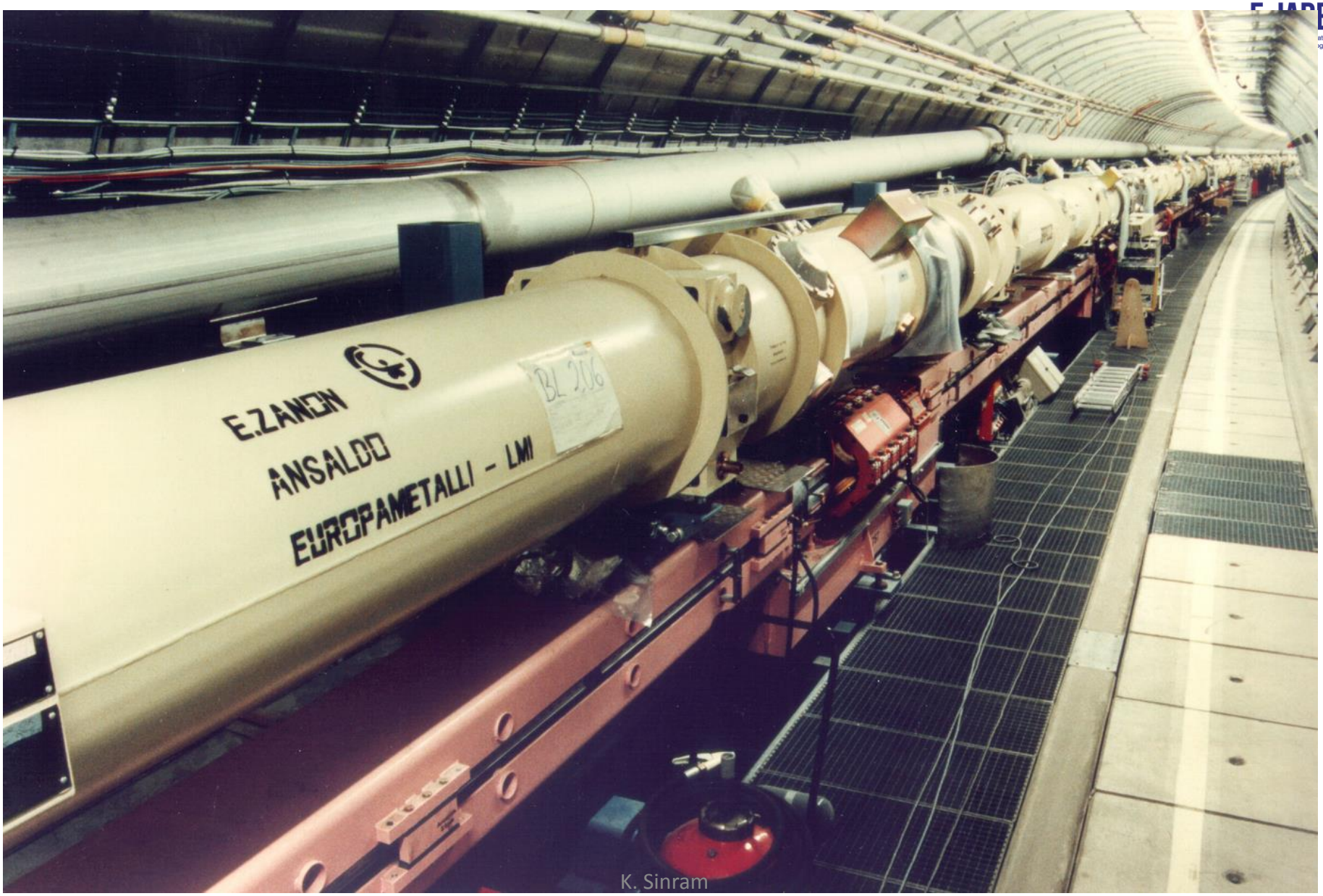
THE HERA TUNNEL



Radius 2.8 m

Standard cross section of the HERA-tunnel (arc-section) containing beamguidance-magnets of the proton-accelerator (a) and electron-accelerator (b), Helium-transfer-line(c), quench-line (d) and driveway (e).

THE HERA TUNNEL



Introduction

- Extensive installations for liquid Helium inside the HERA -tunnel for the operation of superconducting HERA proton accelerator magnets

- In case of damage: substantial flow-out (~ 120 kg liquid He) into the tunnel within 10 s
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  ➔ oxygen deficiency, extreme cold
  ➔ danger for persons in the tunnel

- Requires constant monitoring of oxygen levels and potentially the carrying of a respirator?
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  ➔ Necessity depends on propagation conditions of Helium inside the tunnel.

- Two tests to determine propagation properties carried out.

First test – setup

- **Aim:** Get a rough idea of the evaporated Helium propagation speed in the tunnel.

- **Setup:** Arbitrary selection of measuring sections 20m against and 100m towards tunnel ventilation.

- 10 measuring positions were specified at z = -20 m, -10 m, -5 m, -2 m, 2 m, 5 m, 10 m, 20 m, 50 m, 100 m.

- Measurements in three heights above driveway (h = 0.8, 1.6, 3.5 m)

- Technical details:

  - 30 electrochemical sensors for oxygen-level measurements
  - 30 NiCr-Ni thermal-elements for temperature measurements
  - Data-logger with 64 channels for recording

First test – procedure

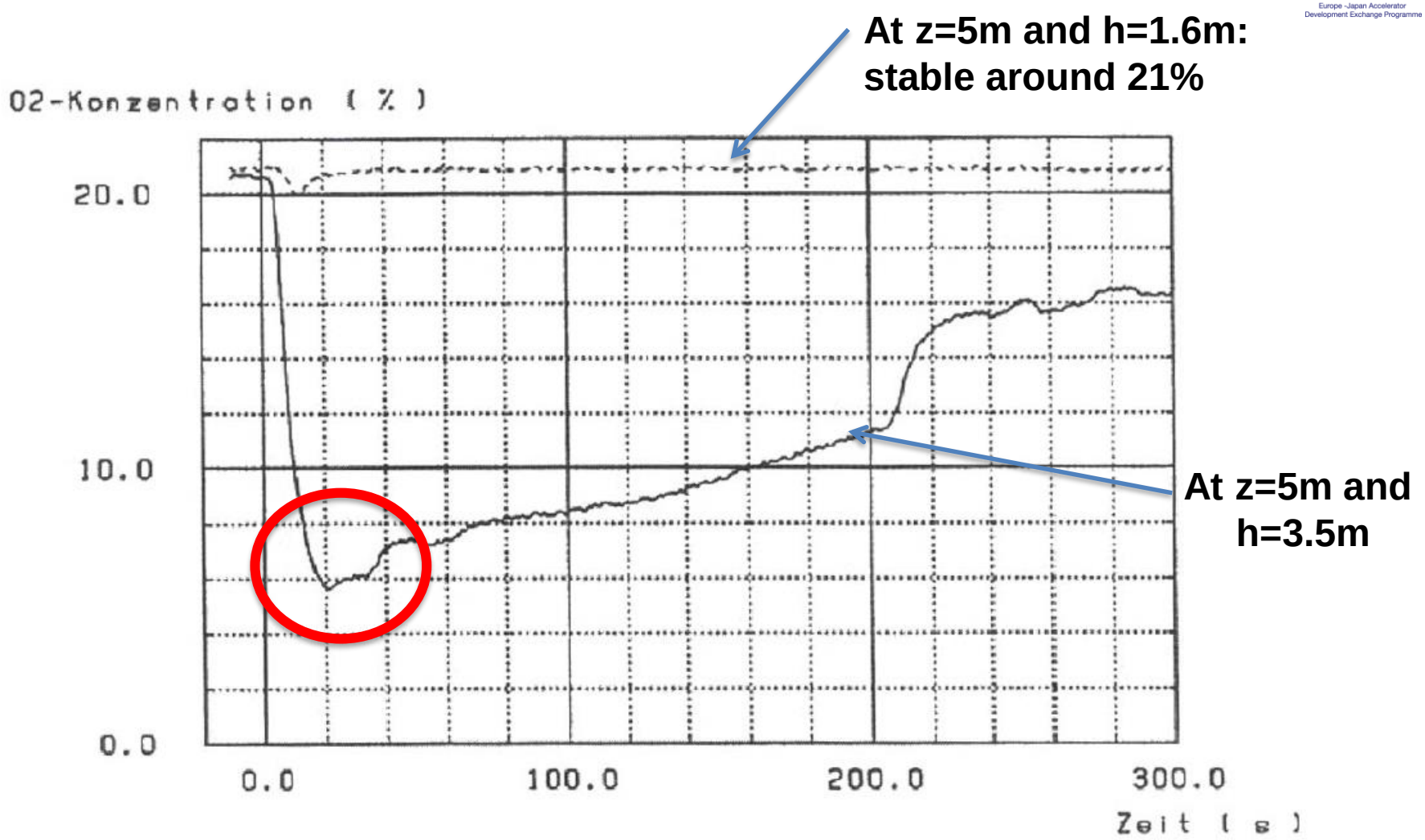
- The liquid Helium was brought in by a mobile Dewar-container with a capacity of 500 l at 6 bar.
  - Outflow controlled by electro-pneumatically controlled valve; outflow direction upwards up to 2.5 m, then free spreading out into the tunnel.
- Two camcorders (at 30 and 50 m) used to record speed and shape of propagation of Helium cloud.
  - Control of speed via distance marks
- The 500 l = 62.5 kg liquid He leaked out in 10s into a volume of ~370 m^3 after heating up to tunnel temperature
  - The air speed measured to be at 0.5 ± 0.1 m·s-1.
- Observations:
  - The Helium heats up quickly and immediately ascends towards the ceiling
  - The Helium does not mix with the tunnel air and expands far quicker than given by the tunnel ventilation
  - The Helium proceeds a lot further than 20 m against the airflow.
  - Substantial effects appeared only on the sensors at a height of 3.5 m.

First test – results

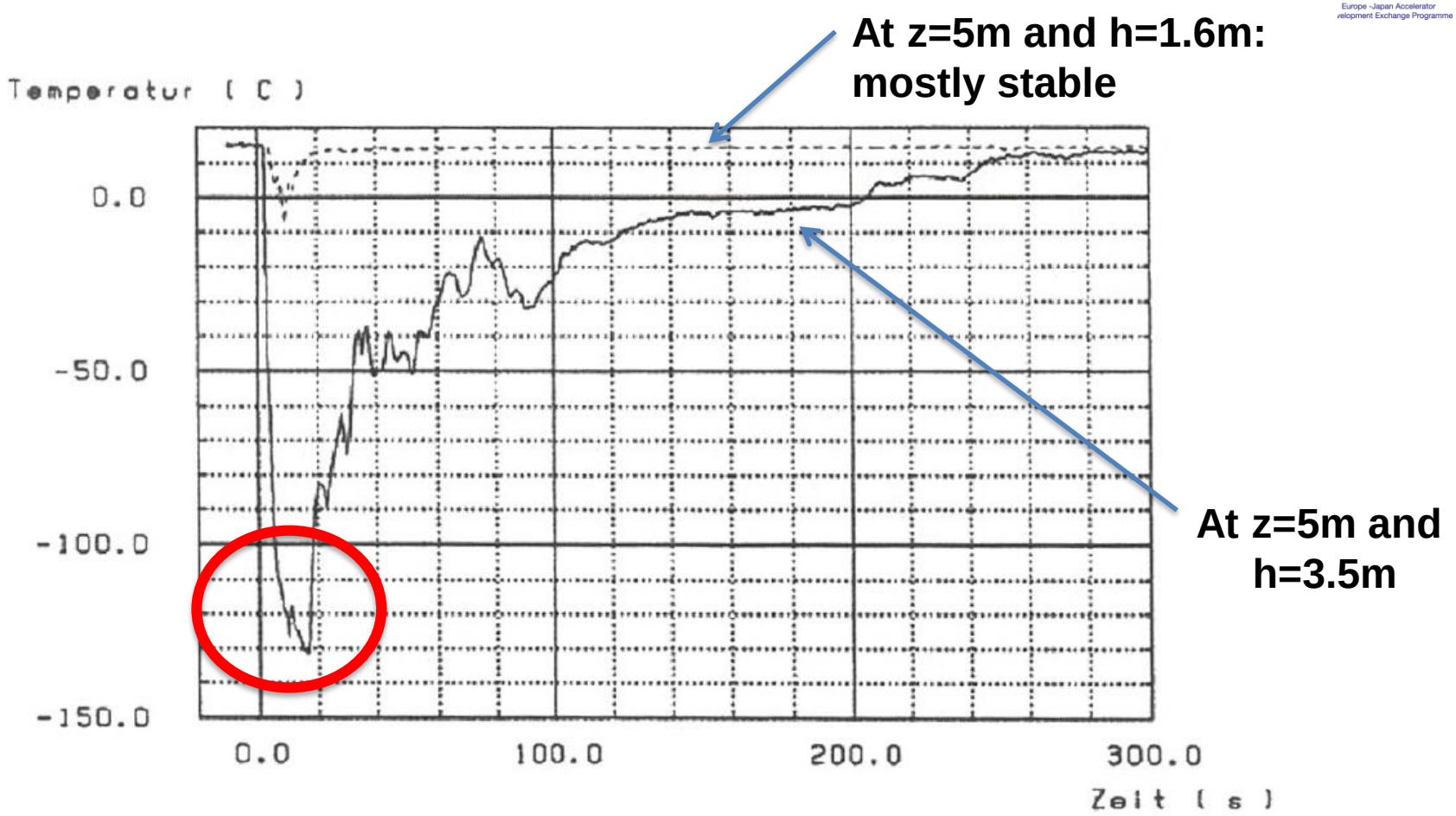
z	t	$v_{average}$	$V_{O2,min}$ (1.6 m)	T_{min} (1.6 m)	$V_{O2,min}$ (3.5 m)	T_{min} (3.5 m)
-20	13	1.5	(20.9)	(16)	6.3	-104
-10	6	1.7	(20.9)	(16)	5.6	-115
-5	3	1.7	(20.9)	14	4.9	-126
-2	1		20.6	0	4.7	-163
2	1		20.8	13	4.2	-156
5	2	2.5	20.0	-7	5.6	-131
10	4	2.5	20.8	6	6.4	-107
20	8	2.5	(20.9)	13	7.2	-97
50	23	2.2	(20.9)	15	8.8	-71
100	55	1.8	(20.9)	(16)	14.0	-6
[m]	[s]	[$m \cdot s^{-1}$]	[%]	[°C]	[%]	[°C]

Results of the first test for h = 1.6 m and 3.5 m

First test: O2 concentration vs time



First test: temperature vs time



Second test:

- Propagation speed established in first test
- Now extend measuring range from -100m to +200m with measuring stations at -100 m, -60 m, -30 m, -10 m, -5 m, -2 m, 2 m, 5 m, 10 m, 30 m, 100 m, 150 m, 200 m
- Simulate Helium out flow 1 m above driveway level facing downwards, according to the worst-case-scenario of the leakage of one of the lowest arranged superconducting magnets.
- Double amount of Helium to 1000 l with a second, identical Dewar-container
  - corresponds to the maximum possible amount of flow-out (one HERA octant).
  - Second container opened with a delay of 10 s and with a longer time of out-flow (~60 s)

Second Helium Test Video

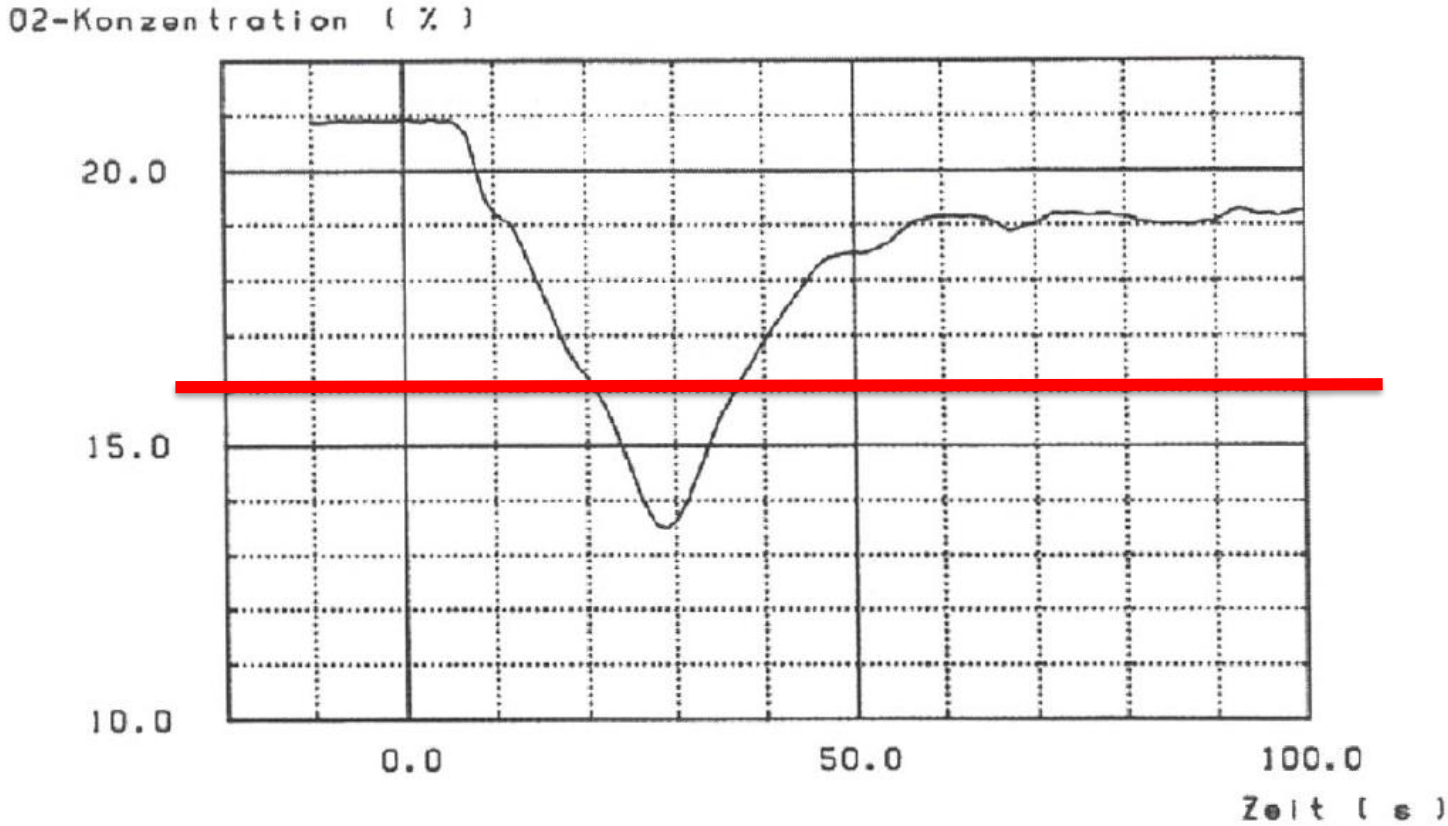
Second test: results

According to the changed test conditions, also in low heights near the outbreak, up to ±10 m the O2-levels and the temperature partially drop very strongly

z	h = 0.8 m		h = 1.6 m		h = 3.5 m	
	$V_{O2,min}$	T_{min}	$V_{O2,min}$	T_{min}	$V_{O2,min}$	T_{min}
-100			(20.9)	(18)	10.0	-27
-60			(20.9)	(18)	8.1	-38
-30			(20.9)	(18)	8.2	-51
-10			17.4	5	7.3	-53
-5	17.6	-37	12.6	-63	6.9	-63
-2	14.6	-99	13.3	-64	6.9	-66
2	9.0	-112	11.5	-111	7.1	-77
5	14.5	-25	12.9	-44	7.5	-72
10			13.5	-36	7.7	-60
30			19.5	8	8.7	-32
100			(20.9)	(18)	11.4	-22
150			(20.9)	(18)	12.6	-11
200			(20.9)	(18)	16.7	7
[m]	[%]	[°C]	[%]	[°C]	[%]	[°C]

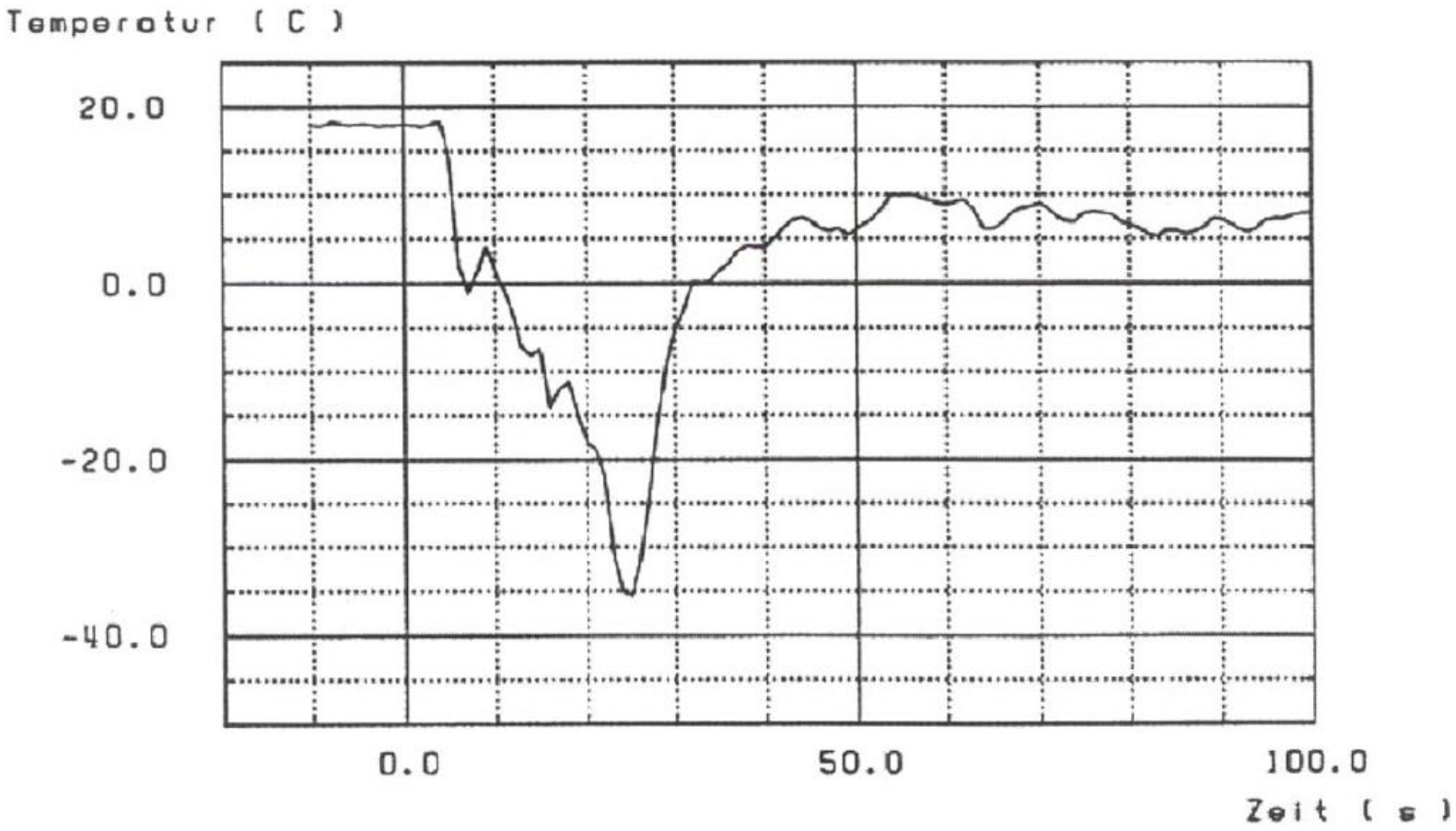
Also stronger mixing of Helium with air → reduced propagation speed of 1m/s.

Second test: O2 vs time



Temporal development of the O2-concentration at z = 10 m, h = 1.6 m

Second test: temperature vs time



Temporal development of the temperature at z = 10 m, h = 1.6 m

Conclusions

- Effects of dropping O2-levels and temperature restricted to a few 10 s.
- Endangerment of persons in the vicinity can be classified as not serious (except for direct contact at outflow),
  - appearance of dense fog cloud and heavy noise
  - ➔ compel people to immediately leave the hazardous area.
  - Those alarm flags can be seen as sufficient warning for persons working in the upper part of the tunnel cross section at a greater distance from the outbreak
- Second test also showed that a stationary system for monitoring the O2-content of the air is not necessary inside the HERA-tunnel.
  - The usage of oxygen rebreathers is not reasonable because the time needed to put on that equipment is sufficient to leave the hazardous area.

Lessons learned from the HERA HELIUM-test for the ILC:

- The worst case scenario in the case of the ILC corresponds to a maximum possible Helium flow-out of approximately 3 times the amount in the HERA case.

- Since the ILC-tunnel cross section and the height of the tunnel ceiling above driveway are substantially larger than in HERA the conclusions from the HERA tests can in principle be directly adopted for the ILC case.