Synchrotron Radiation at the ZEUS Interaction Region after Luminosity Upgrade.

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Overview over the Beam and the Experiment.

The Table below gives an overview of all magnets within ± 68 m from the IP for the electron case. The coordinate system has its origin at the electron- proton IP with the z-axis pointing along the electron direction (!), the x-axis horizontal and away from the HERA center (!) and the y-axis upwards. The positron-proton IP in this coordinate system is at -0.008, 0, 0 (all in m), and the center of the ZEUS detector is at 0.01, 0, 0.

	name	za	xa	ze	xe	B	G
1	start	-68.61	0.0000	-68.61	0.0000	0.000	0.000
2	DL10	-68.61	0.0000	-67.61	0.0000	0.000	0.000
3	QLL67	-67.61	-0.5146	-66.61	-0.5046	0.000	-17.471
4	DL9	-66.61	0.0000	-65.89	0.0000	0.000	0.000
5	BHL63	-65.89	-0.4961	-62.53	-0.4675	-0.088	0.000
6	DL8	-62.53	0.0000	-61.67	0.0000	0.000	0.000
7	QLL61	-61.67	-0.4627	-60.67	-0.4556	0.000	17.552
8	DL7	-60.67	0.0000	-55.43	0.0000	0.000	0.000
9	QLL55	-55.43	-0.4187	-54.43	-0.4117	0.000	-12.921
10	DL6	-54.43	0.0000	-43.50	0.0000	0.000	0.000
11	QLL43	-43.50	-0.3347	-42.50	-0.3276	0.000	6.422
12	DL5	-42.50	0.0000	-42.24	0.0000	0.000	0.000
13	BNL41	-42.24	-0.3261	-40.74	-0.3144	0.103	0.000
14	DL4	-40.74	0.0000	-11.18	0.0000	0.000	0.000
15	ALGM	-11.18	0.0000	-10.93	0.0000	0.000	0.000
16	BOL10	-10.93	0.0000	-10.43	-0.0485	-0.120	0.000
17	DL3	-10.43	0.0000	-10.18	0.0000	0.000	0.000
18	GJL9	-10.18	-0.0484	-8.30	-0.0341	0.000	-14.012
19	DL2	-8.30	0.0000	-7.93	0.0000	0.000	0.000
20	GIL7	-7.93	-0.0326	-6.05	-0.0181	0.000	24.918
21	DL1	-6.05	0.0000	-5.20	0.0000	0.000	0.000
22	GOL2	-5.20	-0.0111	-2.00	0.0020	-0.259	-13.467
23	DL0	-2.00	0.0000	0.00	0.0000	0.000	0.000
24	IP	0.00	0.0000	0.00	0.0000	0.000	0.000
25	DR0	0.00	0.0000	1.95	0.0000	0.000	0.000
26	GGR2	1.95	0.0200	3.25	0.0200	-0.277	0.000
27	DR1	3.25	0.0000	3.85	0.0000	0.000	0.000
28	QIR4	3.85	0.0077	5.73	-0.0036	0.000	-21.889
29	DR2	5.73	0.0000	6.25	0.0000	0.000	0.000

30	GIR7	6.25	-0.0185	8.13	-0.0333	0.000	26.085
31	DR3	8.13	0.0000	8.57	0.0000	0.000	0.000
32	GJR9	8.57	-0.0320	10.45	-0.0470	0.000	-11.891
33	AABS	10.45	0.0000	10.69	0.0000	0.000	0.000
34	EABS	10.69	0.0000	10.98	0.0000	0.000	0.000
35	ARGM	10.98	0.0000	11.18	0.0000	0.000	0.000
36	DR4	11.18	0.0000	40.74	0.0000	0.000	0.000
37	BNR41	40.74	-0.3202	42.24	-0.3319	0.134	0.000
38	DR5	42.24	0.0000	42.50	0.0000	0.000	0.000
39	QLR43	42.50	-0.3333	43.50	-0.3401	0.000	3.959
40	DR6	43.50	0.0000	54.42	0.0000	0.000	0.000
41	QLR55	54.42	-0.4242	55.43	-0.4210	0.000	-15.270
42	DR7	55.43	0.0000	60.67	0.0000	0.000	0.000
43	QLR61	60.67	-0.4565	61.67	-0.4633	0.000	18.020
44	DR8	61.67	0.0000	62.53	0.0000	0.000	0.000
45	BHR63	62.53	-0.4679	65.89	-0.4960	-0.096	0.000
46	DR9	65.89	0.0000	66.61	0.0000	0.000	0.000
47	QLR67	66.61	-0.5046	67.61	-0.5146	0.000	-17.950
48	DR10	67.61	0.0000	68.61	0.0000	0.000	0.000

Magnet position and strength for electron-proton running.
Names beginning with B are bending magnets,Q quadrupoles, G special magnets, D drift spaces.
za,ze,xa,xe are start/end coordinates of magnets in m, B field in T, G gradient in T/m.

The beam enters at z=-68m with an angle of 10 mr. The first bending magnet at 63m (BHL63) bends the beam by 3 mr to an angle of 7mr, the next one at 41m (BNL41) bends by 1.6mr back to 8.6mr, and the magnet at 10m (BOL10) bends by 0.6mr to 8 mr. The main and final deflection by 8mr occurs in the superconducting magnet GOL2 inside the detector. Downstream of the IP (in the electron direction) there is an (almost) symmetrical arrangement of magnets.
All of these magnets are strong sources of synchrotron radiation. In addition, synchrotron radiation from the quadrupoles has to be considered. The largest such background comes from quadrupoles GJL9 at 9m and GIL7 at 7m. By shifting these quadrupoles slightly off beam center the angular opening of the radiation fan from them can be reduced and then stays generally well within the beam pipe and its absorbers.
In the positron case the beam will be displaced by 8 mm towards the ring inside w.r.t. the electron beam. The Table below shows the corresponding list of magnets for the positron case.

	name	za	xa	ze	xe	B	G
1	start	-68.60	0.0000	-68.60	0.0000	0.000	0.000
2	DL10	-68.60	0.0000	-67.60	0.0000	0.000	0.000
3	QLL67	-67.60	-0.5155	-66.60	-0.5055	0.000	-18.151
4	DL9	-66.60	0.0000	-65.89	0.0000	0.000	0.000
5	BHL64	-65.89	-0.4972	-62.53	-0.4685	-0.086	0.000

6	DL8	-62.53	0.0000	-61.67	0.0000	0.000	0.000
7	QLL61	-61.67	-0.4636	-60.67	-0.4565	0.000	18.189
8	DL7	-60.67	0.0000	-55.43	0.0000	0.000	0.000
9	QLL55	-55.43	-0.4193	-54.43	-0.4122	0.000	-12.753
10	DL6	-54.43	0.0000	-43.50	0.0000	0.000	0.000
11	QLL43	-43.50	-0.3346	-42.50	-0.3275	0.000	4.756
12	DL5	-42.50	0.0000	-42.24	0.0000	0.000	0.000
13	BNL41	-42.24	-0.3260	-40.74	-0.3142	0.100	0.000
14	DL4	-40.74	0.0000	-11.18	0.0000	0.000	0.000
15	ALGM	-11.18	0.0000	-10.93	0.0000	0.000	0.000
16	BOL11	-10.93	-0.0500	-10.43	-0.0485	-0.135	0.000
17	DL3	-10.43	0.0000	-10.18	0.0000	0.000	0.000
18	GJL9	-10.18	-0.0482	-8.30	-0.0340	0.000	-13.229
19	DL2	-8.30	0.0000	-7.93	0.0000	0.000	0.000
20	GIL7	-7.93	-0.0363	-6.05	-0.0265	0.000	24.669
21	DL1	-6.05	0.0000	-5.20	0.0000	0.000	0.000
22	GOL4	-5.20	-0.0111	-2.00	0.0020	-0.084	-14.076
23	DL0	-2.00	0.0000	0.00	0.0000	0.000	0.000
24	IP	0.00	0.0000	0.00	0.0000	0.000	0.000
25	DR0	0.00	0.0000	1.95	0.0000	0.000	0.000
26	GGR3	1.95	0.0200	3.25	0.0200	-0.182	0.000
27	DR1	3.25	0.0000	3.85	0.0000	0.000	0.000
28	QIR5	3.85	0.0004	5.73	-0.0086	0.000	-22.666
29	DR2	5.73	0.0000	6.25	0.0000	0.000	0.000
30	GIR7	6.25	-0.0237	8.13	-0.0353	0.000	26.219
31	DR3	8.13	0.0000	8.57	0.0000	0.000	0.000
32	GJR10	8.57	-0.0294	10.45	-0.0429	0.000	-11.908
33	AABS	10.45	0.0000	10.69	0.0000	0.000	0.000
34	EABS	10.69	0.0000	10.98	0.0000	0.000	0.000
35	ARGM	10.98	0.0000	11.18	0.0000	0.000	0.000
36	DR4	11.18	0.0000	40.74	0.0000	0.000	0.000
37	BNR41	40.74	-0.3202	42.24	-0.3319	0.132	0.000
38	DR5	42.24	0.0000	42.50	0.0000	0.000	0.000
39	QLR43	42.50	-0.3333	43.50	-0.3401	0.000	2.779
40	DR6	43.50	0.0000	54.43	0.0000	0.000	0.000
41	QLR55	54.43	-0.4248	55.43	-0.4217	0.000	-13.614
42	DR7	55.43	0.0000	60.67	0.0000	0.000	0.000
43	QLR61	60.67	-0.4574	61.67	-0.4642	0.000	15.243
44	DR8	61.67	0.0000	62.53	0.0000	0.000	0.000
45	BHR64	62.53	-0.4688	65.89	-0.4971	-0.095	0.000
46	DR9	65.89	0.0000	66.60	0.0000	0.000	0.000
47	QLR67	66.60	-0.5055	67.60	-0.5155	0.000	-15.131
48	DR10	67.60	0.0000	68.61	0.0000	0.000	0.000

Magnet position and strength for positron-proton running.
Names beginning with B are bending magnets, Q quadrupoles, G special magnets,D drift spaces.
za,ze,xa,xe=start/end coordinates of magnets in m, B field in T, G gradient in T/m.

The total synchrotron power power emitted at 30 GeV Electron energy and a beam current of 58 mA is 28 kW (sum of both sides). It obviously scales proportional to the beam current, and depends on the electron energy like E^4 (at constant bending radius). The critical energy is proportional to E^3/R, where R is the bending radius. It is highest in the superconducting magnet GOL2, where it is 130 keV for 27.5 GeV beam energy. In the other bending magnets and the quadrupoles it is correspondingly smaller.
The elaborate shielding and absorber arrangements described below are driven by the fact, that the radiation level in the IR has to be well below 1 μW. This extreme demand equires a careful consideration of many details.

The radiation from the bending magnets at z=-63m and z=-41m will be absorbed by collimators at -50m and -19m, respectively. The main power coming from the superconducting magnets GO and GG hits a number of absorbers situated between z=11m and z=26m and a fraction of it is reflected back into the experiment. The experiment is protected from this radiation by a set of absorbers C5a, C5b, C5c in the IR. In addition the direct radiation is not allowed to hit anything near the IR down to a level of $< 10^{-6}$. It turns out that this can only be achieved if the detector is moved by 10 mm to the ring outside with respect to the line x=0, which coincides with the position of the electron beam in the IP (the positron beam is at x=-8 mm). The center of the beam pipe is displaced by another 13.5 mm towards the ring outside to accomodate the MVD. It also turns out that the magnet GG is at z=3.4 m in the way of the direct radiation and therefore its center has to be moved by x=20 mm towards the ring outside. Fig.1 shows the geometry of the detector after upgrade.

Upstream Bending Magnets.
Bremsstrahlung of the electron beam on the residual gas in the beam pipe is a problem, which will not be treated in detail here. It will lead to energy loss of the electrons, which will consequently be swept into the experiment by the bending magnets. There are two ways to reduce this background. First, there is the obvious measure to reduce the residual gas pressure as much as possible. Second, two bending magnets ('chicane') in the electron beam line will be used, which will reduce the distance over which the stray electrons will be accumulated. These magnets are of course relevant for the synchrotron radiation background.

The first magnet BHL63 at z=-63m produces about 1600 W of synchrotron radiation power at 30 GeV electron energy. To keep the radiation from this magnet away from the interaction region, one needs a collimator at the ring outside at z=-50 m . This collimator is at 20 σ (=8.6 mm) from the beam center and will require cooling. It will cast a shadow at z=0.8m, which keeps the synchrotron radiation away from the absorbers. Even if there is a deviation of the electron beam center by 3 s.d., the shadow will extend from -6 mm to 60 mm, which is acceptable, since the collimators at z=0.8 m are at x=-19 mm and x=68 mm, respectively.

The next magnet at z=-41m (BNL41) produces about 1000 W of synchrotron radiation power at 30 GeV electron energy. For shielding one needs a collimator at -19 m on the ring inside at 20 σ (=22mm). The power density on it will be about 30 W/ mm . This collimator is of vital importance, and it should be thick enough to completely stop the radiation from BNL41. Its thickness (along the beam) must therefore be at least $80 g/cm^2$. It will be made out of a combination of copper (for heat conduction) and tungsten.

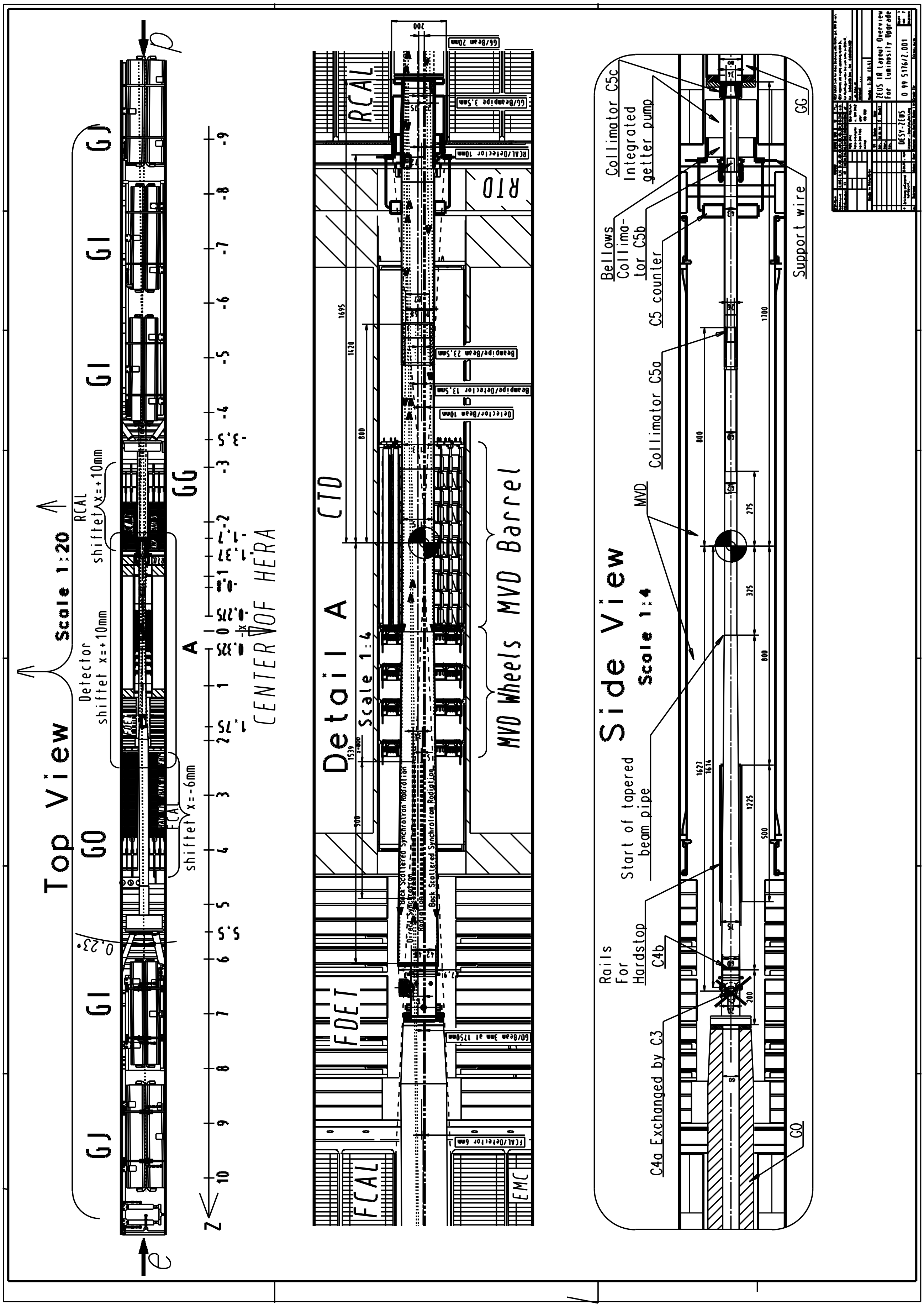

Top View
Scale 1:20
Detail A
Scale 1:4
Side View
Scale 1:4
CENTER OF HERA
RCAL
RTD
CTD
FDET
FCAL
EMC
MVD Barrel
MVD Wheels
Collimator C5c
Integrated getter pump
Bellows
Collimator C5b
C5 counter
Collimator C5a
Collimator
MVD
Support wire
Start of tapered beam pipe
Rails For Hardstop
C4b
C4a Exchanged by C3
GO
GG
GI
GJ
Detector shiftet x=+10mm
RCAL shiftet x=+10mm
FCAL shiftet x=-6mm
Back Scattered Synchrotron Radiation
ZEUS IR Layout Overview For luminosity Upgrade
DESY-ZEUS

Figure 1:

z-pos.	x-pos.	beamcenter	no. of σ	remarks	ring
-50.0	-0.372	-0.3806	20	synch.rad.	outside
-19.0	-0.1490	-0.1272	20	synch.rad.	inside
-14.6	-0.077	-0.0894	10	stray el.	outside

Table 1: Upstream Collimators, positions in m

Stray electrons, which have lost energy by bremsstrahlung, can be stopped by a collimator at at z=-14.6 m. This collimator on the ring outside, closed to 10 σ, will reduce the flux on the beampipe by a factor 2.3

Table 1 gives a summary of collimator positions. All numbers are in m in the HERA coordinate system (x=0 =electron beam center at the IP).

Horizontal Profile of the Synchrotron Radiation.
The power flux as a function of the horizontal coordinate x was computed at various values of z by tracing electrons through all magnets. The electron emmitance was assumed to be $\epsilon = 22 \cdot 10^{-9}\, m$. The horizontal electron beam profile was assumed to be gaussian out to 5 standard deviations, which seems to be supported by evidence from the machine group. At larger distances the density was assumed to drop linearly with distance out to 10 s.d., where it was assumed to be zero. Profiles were calculated at the position of the C5a collimator (z=0.8 m), and at the end of the GG magnet (z=3.4 m), which is the second critical position. These profiles are shown in Figs.2-5 for electrons and positrons, respectively. The radiation at the 10^{-7} level stays clear of the C5a collimator at x=68 mm, and of the edge of the GG magnet, which is effectively at x=81 mm. However, one has to allow that the electron beam may be off its normal orbit by up to 3 s.d. in σ_x. The resulting power flux is shown in Figs.6-9. For this calculation an arbitrary phase of the missteering has been assumed. It is still acceptable near the IP, but may be too high at z=3.4 m. Moreover, the calculation may still be on the optimistic side, if the beam profile deviates more strongly from a gaussian shape than has been assumed. A safe way to protect the C5a collimator under all circumstances is a collimator C3, situated inside the GO magnet. This collimator will cast a shadow of the radiation coming from the quadrupoles GI and GJ. The collimator will also shield the edge of the GG magnet for the positron case, but not be completely effective in the electron case.

Collimator Design and Background in the IR. The direct synchrotron radiation from the magnets is not allowed to touch anything in the IR. The limit is at the level of less than a fraction of 10^{-6} of the central power density.
This can be seen as follows: The backscattered flux is about 0.5% of $26\, kW/sr = 130\, W/sr$ at an effective distance of the main absorbers of 14 m. It hits the flange at the GO magnet, which has an area of $50\, cm^2$, with a power of $0.06\, mW/cm^2$ or a total power of 3 mW. Any other radiation on surfaces in the IR has to be keept well below this value. We shall adopt 1 mW as a limit. Now, at the IP the direct radiation beam has a power of 13 kW over a horizontal width of about 35 mm or a power density of about $400\, W/mm$. At the position of the detector surfaces it drops by a factor e over a distance of 2.5 mm. Therefore the allowed level of radiation is the fraction of $1\, mW/(2.5\, mm \cdot 400\, W/mm) = 10^{-6}$.

This requirement can be met, if the center of the detector is displaced by 10 mm w.r.t. the electron direction at the IP towards the ring outside, and the GG magnet is displaced by 20 mm

99/12/30 13.42

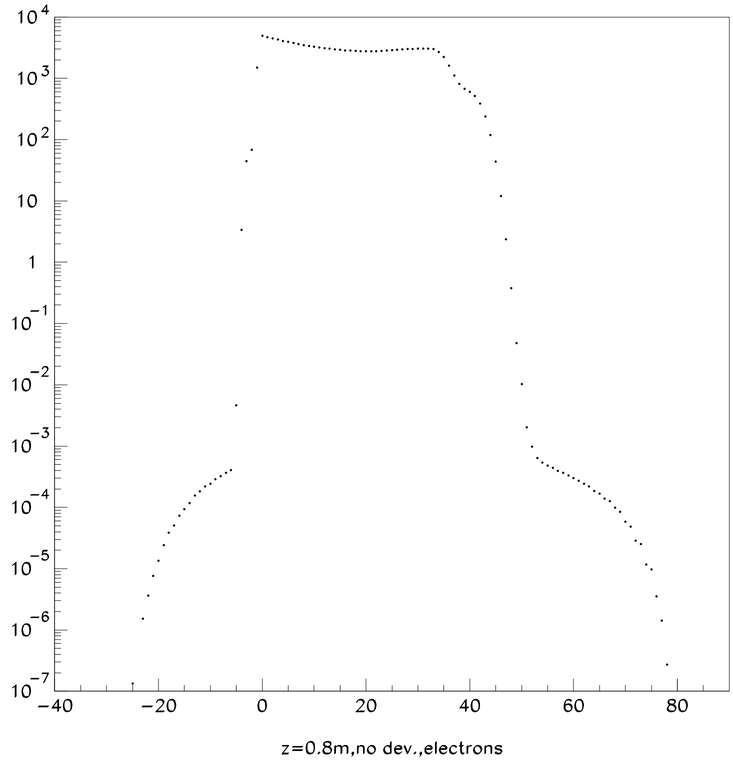


Figure 2:

99/12/30 14.15

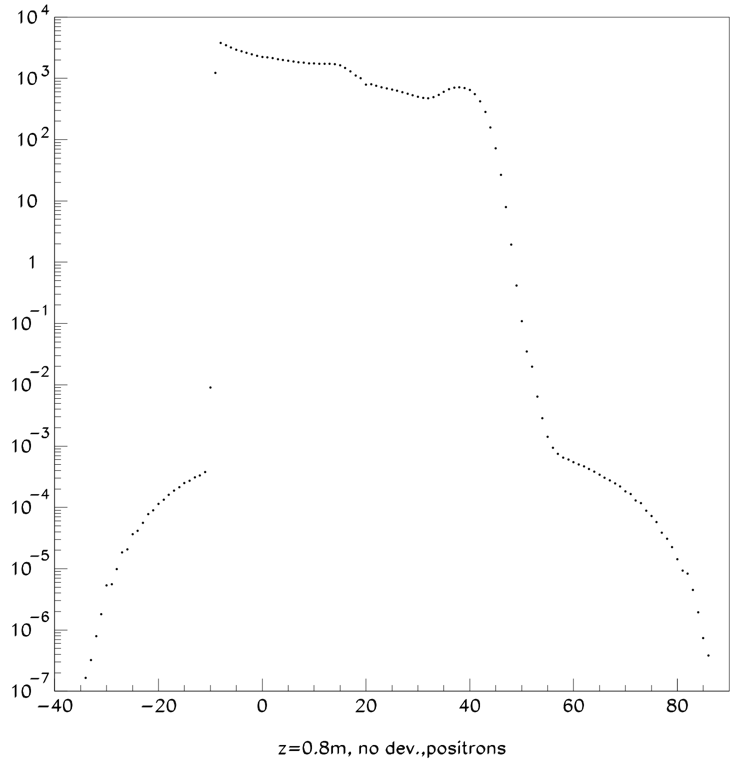


Figure 3:

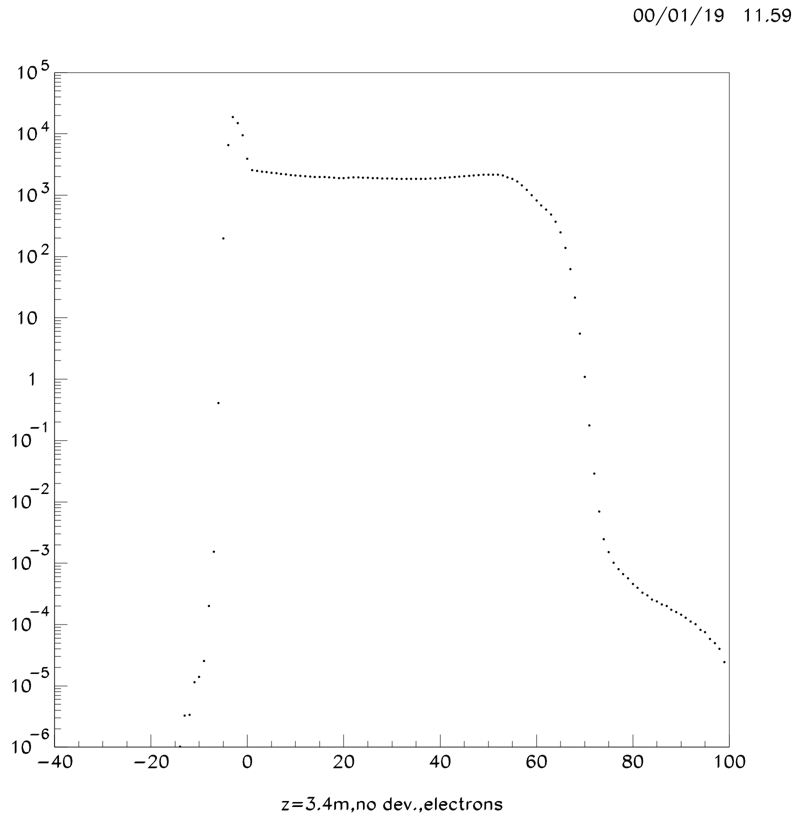
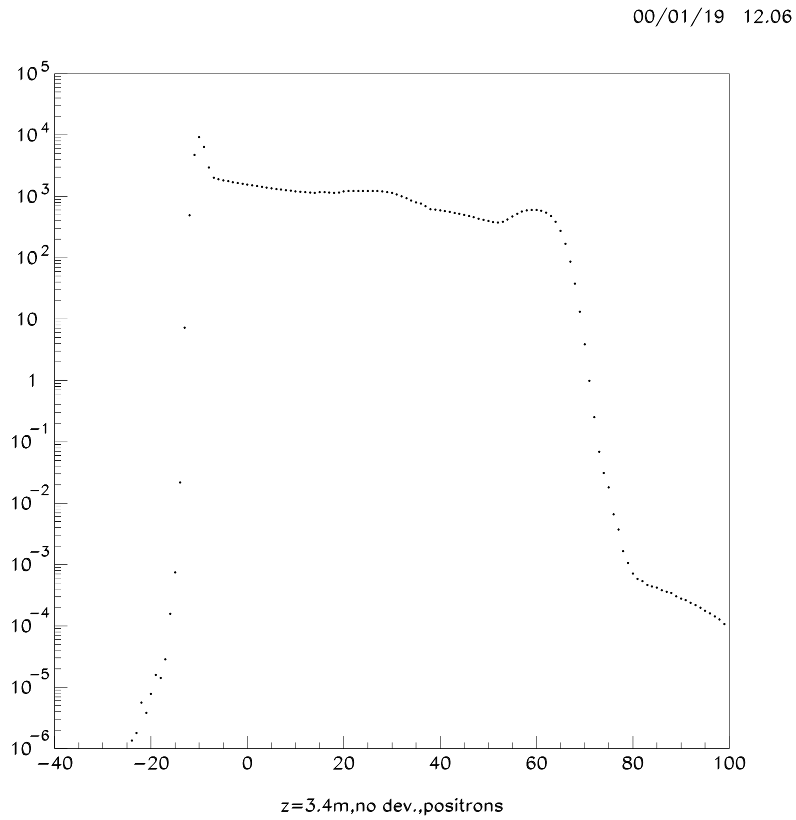


Figure 4:



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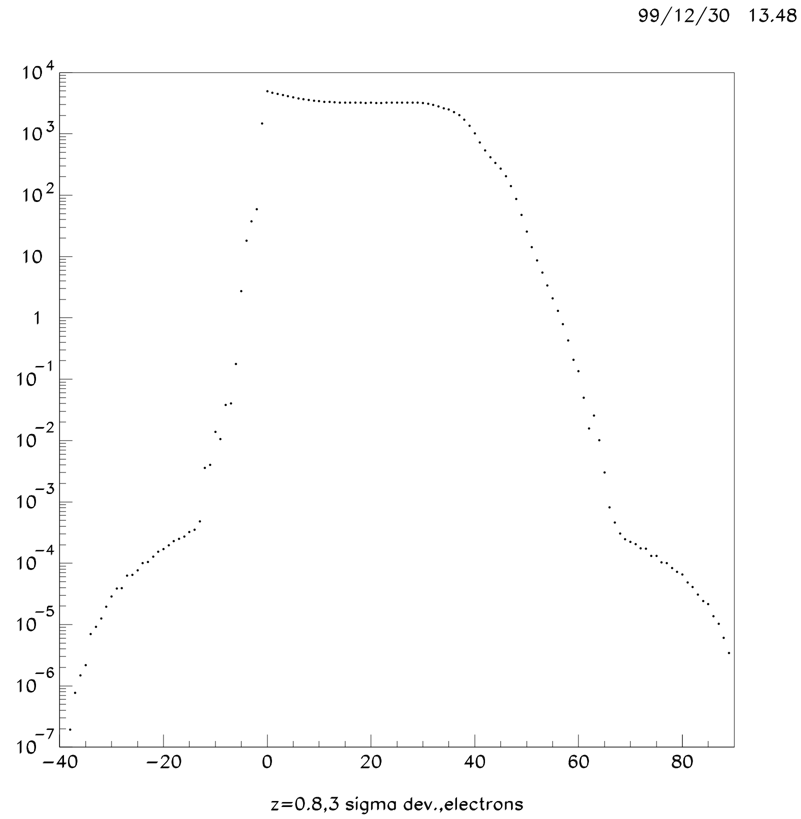

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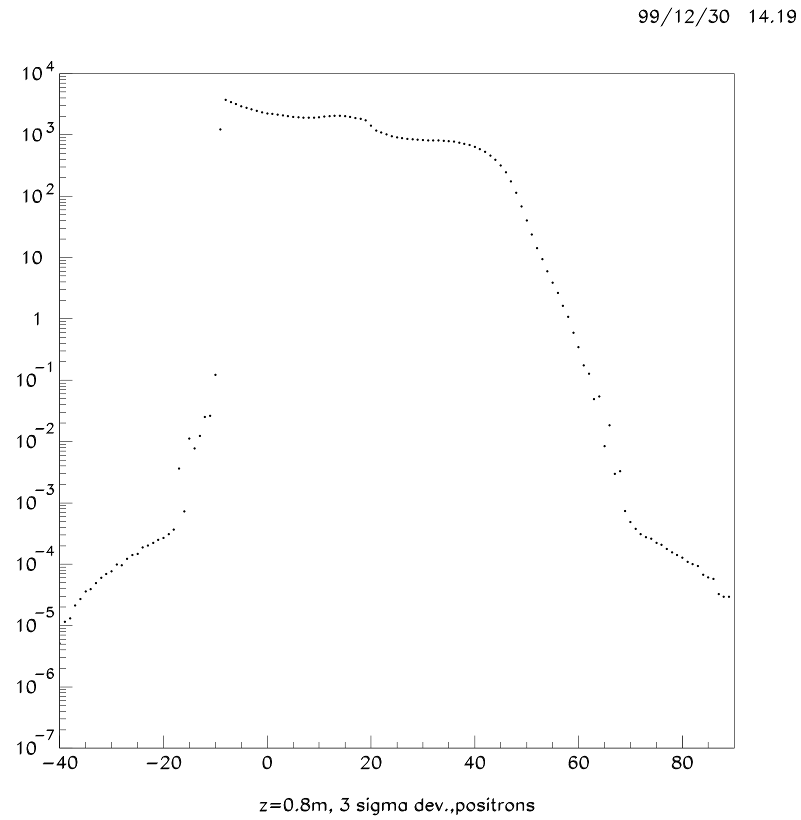

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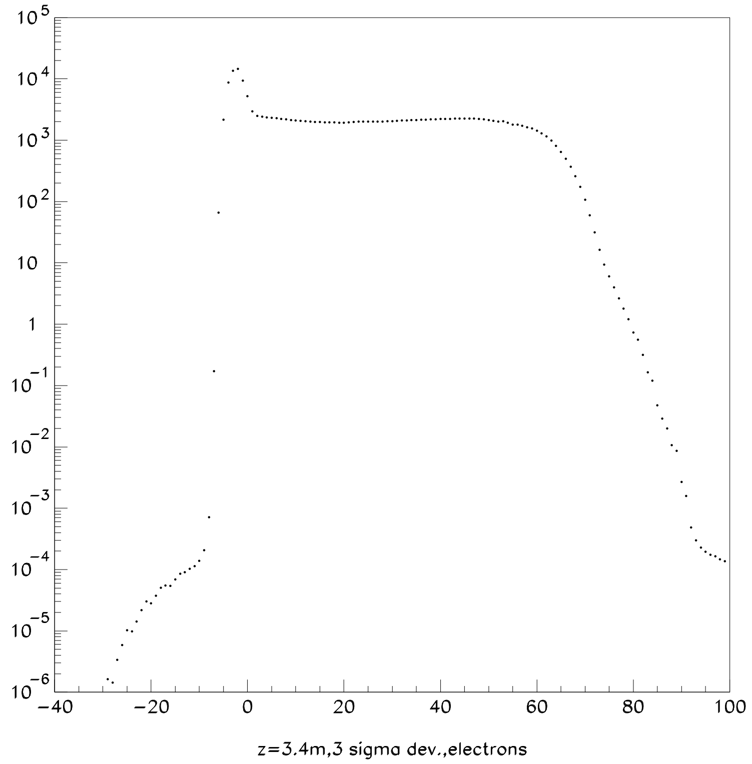

Figure 8:

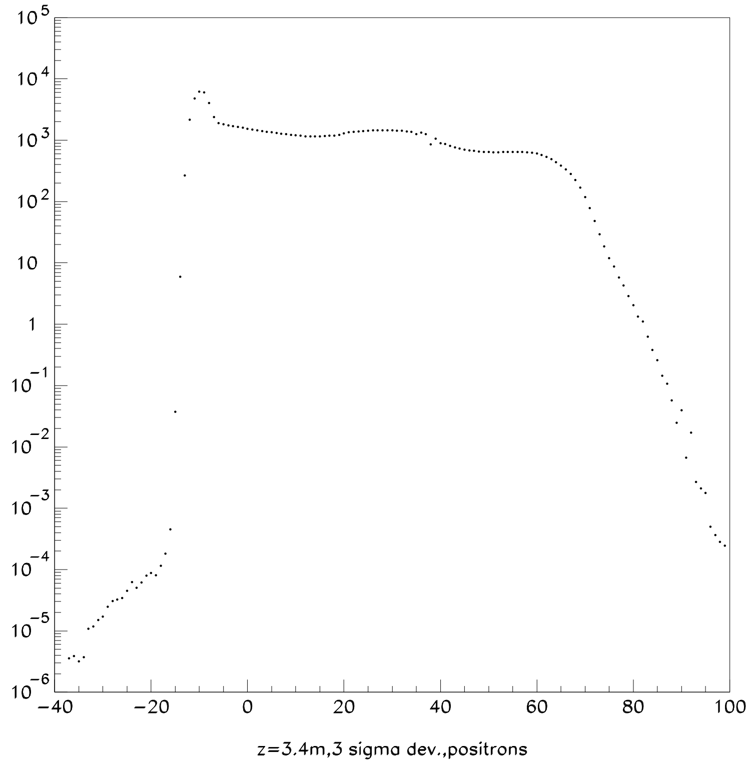

Figure 9:

Name	z-Position	x-Position	y-Position
C5a	0.80m	68mm/-19mm	± 13mm
C5b	1.42m	72mm/-	-
C5c	1.70m	75mm/-21mm	± 17mm

Table 2: Collimators in the IR.

Abs.Nr.	d	width	power	position	scaled power
1	11 m	5.1 cm	6.6 kW	19 to 70mm	30.1 kW
2	26 m	10.0 cm	6.9 kW	150 to 250mm	5.2 kW
3	11 m	1.8 cm	4.5 kW	-14 to -32mm	20.5 kW
4	18 m	2.9 cm	1.8 kW	-68 to -97mm	3.1 kW
sum			19.8 kW		58.9 kW

Table 3: Survey of incident power on the synchrotron radiation absorbers; d=distance from the IP; in the last column the power is scaled by a factor $(23.5\,m/d)^2$.

w.r.t. the electron direction at the IP. The main background comes then from the radiation, which is backscattered from the main absorbers, situated between 11 m and 27 m downstream from the interaction point.

This backscattered radiation has to be kept away from any detector components and from the beampipe. This is accomplished by collimators C5a,C5b and C5c at z=0.8m,1.42m and 1.7m. The main effect is made by C5a. The collimators C5b and C5c plug a gap in the shielding left by C5a. The thickness of these absorbers can be determined as follows:

The reflected radiation has a power density of about 60 μW/cm^2 at the IP. The experiment can stand a few nW/cm^2. One therefore needs an attenuation by a factor of about 10^4. For a critical energy of 140 keV a W absorber will give an attenuation by a factor 200 (2000) for a thickness of 2.5 cm (6 cm) in absorbed energy. The reason for these small factors is that the the absorber acts as a filter, passing only radiation at the compton window at about 1 MeV. However, this also means that the radiation is correspondingly weaker absorbed at the experiment by an estimated factor 30. Therefore, a thickness of 2.5 cm may suffice, considering the fact that the radiation cannot directly hit the CTD. However, the forward part of the vertex detector may be hit. Therefore, to be on the safe side, a collimator thickness of 5 cm should be chosen.

Table 2 gives an overview of these collimators in the IR.

The distance of the outer and inner C5a collimator from the center of the electron beam is 68 mm and 19 mm, respectively. In the case of positron running, the IP will be moved by 8 mm, and then the distance of the inner C5a collimator from the beam is reduced from 19 mm to 11 mm, which is still sufficient.
The collimator C5a has to be protected on either side by an antireflection coating.

In order to estimate the synchrotron radiation background, scaling from the present running conditions is the most accurate procedure. For this comparison we assumed the same electron energy, namely 30 GeV and the same current of 58 mA.

Table 3 gives a survey of the power reflected from the absorbers, including, in the last column, the equivalent power scaled to a distance of the absorbers from the IP of 23.5 m, which corresponds to the present situation.

Table 4 gives a summary of this comparison for the power incident on the absorbers. The first row of table 6 shows the total synchrotron radiation power, and the second row the power

	present	upgrade	factor
Total Power	9.7 kW	26.2 kW	
Power on absorbers	5.1 kW	19.8 kW	
normalized to 23.5 m	5.1 kW	58.9 kW	11.5

Table 4: Comparison of total synchrotron radiation power

reflection	anti-reflective coating	in 2π sr	reflected/sr	
90°, 40 keV	no	1.4%	0.6%	present
90°, 140 keV	no	3.3%	1.1%	upgrade
40-100 mr, 140 keV	no	18%	$0.56 \pm 0.13\%$	
40-100 mr, 140 keV	yes	10%	$0.27 \pm 0.06\%$	

Table 5: Ratio of reflected/incident synchrotron radiation power.

hitting the absorbers. (The rest of the power continues and its influence on the interaction region is neglected). To get a comparison of the present and upgrade situations, the radiation from the absorbers has been normalized to a distance of 23.5 m, assuming a $1/r^2$ law. Next one has to consider the change in the reflection coefficient due to the difference in critical energy, which is 40 keV now and will be 130 keV - 150 keV in the new setup. A second change is due to the different angle of incidence. Presently the angle of incidence is $\approx 90°$, whereas for the upgrade one needs grazing incidence at an angle of 40-100 mrad. Table 5 lists reflection coefficients, for the two reference cases, at critical energies of 40 keV and 140 keV (average), respectively.

Table 5 shows, that at grazing incidence a large fraction (18%) of the incident radiation is reflected. It must be taken care of by a proper design of the absorber region.

It is also seen, that an antireflection coating of 30 μm Cu, 30 μm Ag, and 500 μm W on Cu will reduce the albedo by about a factor 2.

Overall, the ratio of reflected/incident radiation seems similar for the present and upgrade schemes, because there is relatively less backward reflection for grazing incidence; this part of the comparison carries a factor 1.

The reflected radiation is not allowed to hit any detector parts. Only after one more reflection, radiation may be scattered into the detector. Here one gets a factor of 2 for the ratio of reflection coefficients, due to the difference of the mean reflected energy.

These absorbers are situated at the flange connecting the GO magnet with the ZEUS beam pipe (called collimator C4 in Fig.1). They are rather critical and must be covered by an antireflection coating of 130 μm Cu and 500 μm Ag on W. The same is true for collimator C5a. On the other side, the reflecting area of C4 is decreased from 91 cm^2 to 22 cm^2, i.e. by a factor 4.1, compared with the present situation, yielding an overall factor of 0.5 with respect to the present scheme.

There are still two more differences: In the present arrangement the collimators C1, C2 and C3 absorb about 50% of the power, decreasing the amount of power listed in the table. On the other hand these absorbers are scattering additional background into the experiment. Assuming that these two influences approximately cancel, one gets a factor of 1 with an upper bound of 2.

The overall ratio of radiation backgrounds is therefore (taking the upper bound): 11.5 (scaled total power) $\cdot$ 1 (reflection from main absorbers) $\cdot$ 0.5 (secondary reflection) $\cdot$ 2 (no upstream

12σ limit of p-beam x=	10σ limit of e-beam x=	coll.pos. x=	shade at z=0.8m at z=3.4m	beam
2.8mm	1.6mm	5 mm 7 mm 9 mm	61 mm 86 mm 64 mm 90 mm 67 mm 94 mm	electrons
-4.8mm	-3.0mm	-2.5 mm -0.5 mm 1.5 mm	48 mm 71 mm 51 mm 74 mm 54 mm 78 mm	positrons

Table 6: Shadow limits by C3.

collimators) = 11.5; i.e. we have to expect a level of radiation about 12 times larger than at present, normalized to the same electron beam current.

What are the consequences for the ZEUS detector?
The direct reflected synchrotron radiation delivers a dose rate of about 0.01 Gy/s, adding up to about 10^4 to 10^5 Gy/y. The vertex detector, which must of course be shielded from this radiation, receives a dose which is about 1000 times smaller. The background in the CTD under present running conditions is small and hard to measure. One finds for the average number of background hits, which are more or less uniformly distributed through the chamber:

$$N_{hit} = 1.75 + (0.037 \pm 0.016)\frac{I}{\mathrm{mA}} \tag{1}$$

With an electron current of I=58 mA, and a factor of 11.5, one expects 27 ± 10 hits, which appears tolerable.

Collimator C3

The previous section shows, the the synchrotron radiation background should be tolerable. However, this will only be the case for normal running conditions with well adjusted beams. It is quite possible, that occasionally the electron beam is misadjusted horizontally by about 3 sigma. As figures 6-9 show, this may lead to a large background. If the tail of the electron beam has been underestimated, the situation could be worse. The detector has therefore to be protected by a provision to dump the electron beam if a large radiation background is sensed. For the CTD this may not be fast enough. A safe way is to cast a shadow with an absorber C3 situated at z=-5 m inside the superconducting magnet GO. It blocks the offending radiation from the quadrupoles GJL and GIL, irrespective of the beam profile.

Table 6 shows the shadow limits cast by a C3 collimator positioned at z=-5 m.

The table shows, that collimator C5a is perfectly shielded, and the critical region around z= 3.4m is perfectly protected for the positron case and at least improves the situation for the electron case.
Fig.10 shows collimator C3. The absorber is supported by a 60 cm long stainless steel tube of 8 mm OD and can be moved horizontally close to the beam at a pivot point at the flange of the GO magnet at z=-5.6 m. Therefore it is completely decoupled from the cold part of the GO magnet. Higher order mode losses amount to 20 W, if the collimator is close to the electron beam, otherwise they are negligible. The cooling will be done by an air stream of 50 m/s. The heat load of this device on the cold surface of the GO magnet will be about 1 W by radiation if it is close to the beam, else much less. Direct contact with the beam pipe must be avoided by a mechanical stopper; as a safety device a thin pin could be fixed to the absober to keep it away from the beam pipe wall. A pin of 10mm length and 1 mm^2 cross section would lead to

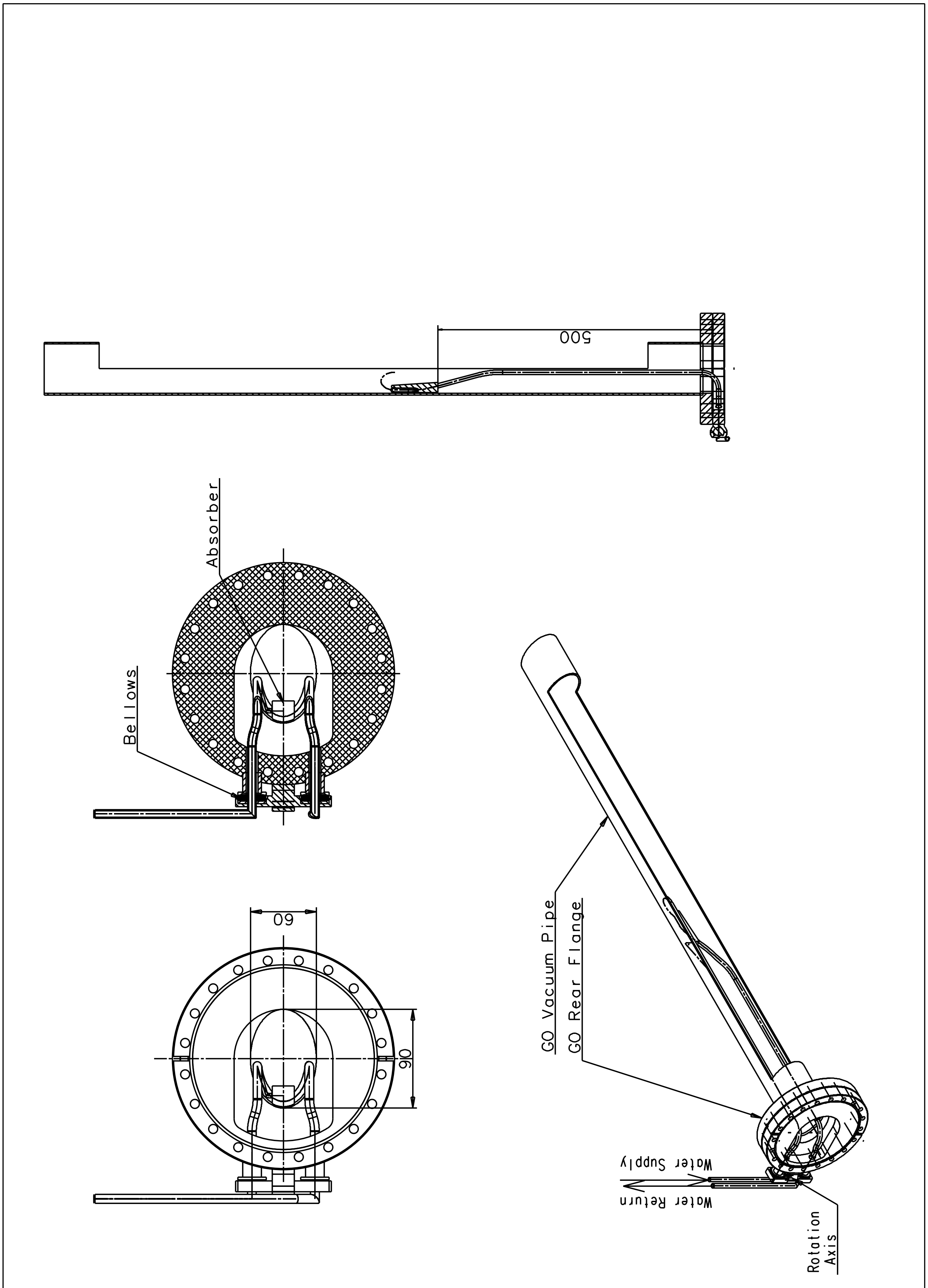
500
Absorber
Bellows
60
90
GO Vacuum Pipe
GO Rear Flange
Water Supply
Water Return
Rotation
Axis

Figure 10:

a heat leak of about 0.4 W.
What happens if there is no beam and the air cooling (heating) fails? In this case the absorber and its support will cool down. At the temperature of liquid nitrogen the heat flow by radiation will be negligible, and (worst case) heat flow through the pin will be 60 mW. On the other hand the heat flux from the flange along the support will be 0.3 W; therefore it will not be possible to cool the absorber down to the temperature of liquid nitrogen.

Exit Window for Synchrotron Radiation

There is an exit window at z=92.5 m in the direction tangent to the electron beam at the IP. It will be hit by direct synchrotron radiation, which is a problem.The window should be as thin as possible in terms of radiation lengths, on the other hand it should be thick enough to allow cooling of the delivered synchrotron radiation power.
In the present conditions this window consists of CuBe2 with a thickness of 1.5 mm, corresponding to 10 % of a radiation length. It is water cooled and its temperature for an electron beam of 40 mA is estimated to be a few 100 degrees. After upgrade the power delivered at this window is about 2.5 times as large, leading to an unacceptable temperature increase.
Therefore the new exit window will be made of Aluminum with a thickness of 10 mm, corresponding to 11 % of a radiation length. An electron beam of 58 mA at 28.5 GeV will deliver a power of about 700 W in this window. With a proper cooling by water its temperature will be about 120 degrees.

It should be noted, that the machine group (K.Wittenburg,MDI) plans to install a screen of Al_2O_3 immediately behind this window, in order to monitor the profile of the synchrotron radiation.