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# EHNL_5N

# Design of T8 Line (DIRAC Experiments) for EHNL

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## INDEX

# 1. Introduction

In the context of the **EHNL** project (East Hall New Look, ref. 1), a big experiment called ***DIRAC*** will be set up at the end of the South branch of the PS East Area.

This experiment will be devoted to lifetime measurement of $\pi^+ \pi^-$ atoms to test low energy QCD predictions (ref.2). A specific beam line called ZT8 has been projected to fulfil DIRAC requirements; this paper describes its features, constraints and needs.

The strict requirements for DIRAC experiments in the context of the EHNL project have imposed to study the whole chain of transfer lines from the PS ring down to the ZT8 line. This explains why additional information relative to the upstream part of ZT8 is given in the next section.

# 2. Features

*Transfer lines terminology from PS to ZT7 and ZT8 lines*

In this paper the names of the ejection lines FT61, E17_s and E17_n are changed respectively to **F61**, **F61_s** and **F61_n** (ref. 3). Consequently, all the elements have been renamed (see Appendix 1).

*Geographical configuration*

The F61 ejection line splits into two branches: the North branch and the South branch. The North one will feed the secondary lines ZT9, ZT10 and ZT11. The South one is shared by the secondary line ZT7 and the primary line ZT8 (see the drawing of the East Hall).

*Beam sharing at the splitter magnet*

The extracted beam from PS during the two cycles, is shared by the North and South branches at the splitter magnet on the F61 line. The beam can be split into two or three parts. For the latter, the upper and lower parts feed the North branch, while the central part is deflected to the South branch. When only one branch is in operation, no splitting is applied by shaping the whole beam to fit the acceptance of the gap between the two blades of the splitter (nominal setting 20 mm). The intensity ratio (North/South) can be set by adjusting the beam parameters at the splitting magnet.

*Beam sharing within the PS super cycle (time wise)*

Since the antiproton program in LEAR was completed at the end of 1996, protons are no longer required for antiproton accumulation. Therefore, the PS machine can now feed the East Area with two spills within a PS super cycle. In this paper they are arbitrarily named **Cycle 1** and **2.**

*Beam switching between ZT7 and ZT8 line:*

The fraction of the beam from the splitter reaching the South branch is then deflected to the targets of ZT8 or ZT7 alternatively by a switching magnet (F61_s.BH2). The doublet F61_s.QF1, F61_s.QD2 and the bending magnets F61_s.BH2, ZT7_BH1 will operate in *Pulse to Pulse Modulation* (ref.4) mode. Table 1 gives the operational settings of the active elements to switch the beam to ZT7 or ZT8 line. In this table Cycle 1 and 2 are respectively assigned to ZT8 and ZT7.

| | Cycle 1 ( beam for ZT8) | Cycle 2 (beam for ZT7) |
|---|---|---|
| **F61_s.QF1**<br>**F61_s.QD1** | Nominal current to focus on ZT8 target | Nominal current to focus on ZT7 target |
| **F61_s.BH2** | No current | Nominal current to deflect the beam to ZT7 target |
| **ZT7.BH1** | No current | Nominal current to feed ZT7 |
| **ZT8.BH1 & BH2** | Nominal current to feed ZT8 | No current (for power saving purpose) |

**Table 1. Setting of the magnetic elements involved in the switching ZT7/ZT8**

It is obvious that this ZT7/ZT8 switching is optional. Hence, both cycles may be allotted to one of the two lines for a given period.

## 3. Safety aspects

They have been presented to the "PS Safety Committee" which meets every Tuesday morning. The opportunity is taken here to enumerate the list of points which have been discussed and acknowledged at first step. They can be considered as valid in the absence of contradictory notices.

For safety reasons, the ZT8 line is divided into three zones named **ZT8a**, **ZT8b** and **ZT8c** (see drawing of the East Hall). ZT8a is the primary zone upstream the shielding wall. This wall, located just downstream the bending magnets ZT8.BH1 and ZT8.BH2, is made out of iron and is 6 m thick and acts as a beam dump. ZT8b and ZT8c, located downstream this wall, are separated by a grid. A safety door (**n° 154**) will permit to pass the grid in controlled access when requested. The use of equipment in the chain of safety, such as a Hall probe in the magnetic field of F61_s.BH1, is still under investigation (ref.5).

The drawing in Appendix 2 gives the required clearance under the roof of the ZT8 tunnel to house the set-up of the experiment, as well as the amount of shielding for radiation safety (ref.6-7). A more accurate computation has to be made to validate the size and shape of the beams and walls to stand the weight load of the roof.

**Proposed safety system to have access to ZT8c, ZT8b and ZT8a zones** :

**Access to ZT8c:**

Accessing in this zone is possible via **door 115** using a 'control access card'.

| **Controlled Access Requested to Get in ZT8c** | | |
|---|---|---|
| | **CYCLE 1 (for ZT8)** | **CYCLE 2 (for ZT7)** |
| **F61_s.BH2** | Nominal current to feed ZT7 (**static setting**) (1) | |
| **ZT8.BH1 & BH2** | No current (2) | |
| **Beam Stopper ZT8** | IN beam | |
| **Door 115** | Status : door passed to get in ZT8c | |
| **Door 154** | Status : zone safe, nobody in ZT8b | |

**Table 2.**

(1) the beam is deflected to the target of ZT7 whether the beam is used by ZT7 or not.

(2) the non-deflected beam will hit the wall (dump) which separates ZT8a to ZT8b.

**Access to ZT8b:**

It is possible to enter this zone by the **doors 115** and **154.** The key of **door 154** is to be taken from **MCR** (Main Control Room of PS). Exiting the zone ZT8b imposes a patrol to ensure nobody is present in this zone, to locking the door 154 and to bringing back the key to MCR before releasing the veto.

| **Access Requested to Get in ZT8b** | | |
|---|---|---|
| | **CYCLE 1 (for ZT8)** | **CYCLE 2 (for ZT7)** |
| **F61_BH1 & BH 2** | Fixed setting to deflect the beam to the Test Beam Dump of PS | |
| **F61_s.BH2** | Don't care | |
| **ZT8.BH1 & BH2** | Don't care | |
| **Beam Stopper F61** | IN beam | |
| **Door 115** | Status : ZT8c in free OR controlled access | |
| **Door 154** | Status : zone not safe, since the key is missing in MCR and the patrol has not been performed in ZT8b | |

**Table 3.**

**Access to ZT8a:**

Accessing to this zone is possible via **door 152 or 151** and with the agreement of the operator in **MCR.** In this case the beam is preliminarily stopped in F61 line by setting the elements F61.BH1 and BH2 which deflect the proton beam to the Test Beam Dump. In addition the two stoppers in F61, just downstream the splitter, are moved in beam.

## Access to beam lines and areas other than ZT8:

*Procedures*

**ZT9, ZT10, ZT11** are considered as secondary beam areas and can be reached using the same procedure as today in the East Hall. Namely, using 'control access cards' to pass the door while entering into the zone during operation. Before entering, the beam stoppers are moved in beam position.

**ZT7a** and **ZT7b** will respectively stick to the same procedure as for **ZT8a** and **ZT8b**. While **ZT7c** has an additional element in the security chain. It consists in the **ZT7.BH1** which have to be set at **0 current** during the access to ZT7c.

| **Controlled Access Requested to get in ZT7c** | | |
|---|---|---|
| | **CYCLE 1 (for ZT8)** | **CYCLE 2 (for ZT7)** |
| **F61_s.BH2** | Don't care | |
| **ZT7.BH1** | No current (**static setting**) (*) | |
| **Beam Stopper ZT7** | IN beam | |
| **Door PPE _ZT7** | Status : door passed to get in ZT7c | |
| **Door 153** | Status : zone ZT7b safe | |

**Table 4.**

(*) The beam hits the shielding wall separating ZT7c and ZT7b.

The access in **ZT7b** is possible via **door 153** and the key has to be taken from **MCR.**

| **Controlled Access Requested to get in ZT7b** | | |
|---|---|---|
| | **CYCLE 1 (for ZT8)** | **CYCLE 2 (for ZT7)** |
| **F61_BH1 & BH2** | Fixed setting to deflect the beam to the Test Beam Dump of PS | |
| **F61_s.BH2** | Don't care | |
| **ZT7.BH1** | Don't care | |
| **Beam Stopper ZT7** | IN beam | |
| **Door PPE _ZT7** | Status : ZT7c in free OR controlled access | |
| **Door 153** | Status : zone ZT7b not safe, since the key is missing in MCR and the patrol has not been performed | |

**Table 5.**

**Length of the beam stoppers on all beam lines in the hall**

| Beam lines | Copper block (mm) | Frame (mm) |
|---|---|---|
| **F61 (2 elements)** | 150 x 2 | 158 x 2 |
| **ZT7** | 600 | 680 |
| **ZT8** | 500 | 700 |
| **ZT9 (2 elements)** | 600 x 2 | 680 x 2 |
| **ZT10** | 600 | 680 |
| **ZT11** | 600 | 680 |

**Table 6.**

## 4. Characteristics of the extracted proton beam from the PS ring

The DIRAC experiments will make use of the primary proton beam extracted from the PS by slow extraction with the following parameters (ref.8):

1. Nominal momentum of 24 GeV/c .
2. One or two cycles per 19.2 sec or 14.4 sec depending on whether the PS programme is in Ion production or not .
3. Spill length of 300 ms .
4. Primary beam intensity limited to 4 x $10^{11}$ protons per PS super cycle, due to radiation safety constraints in the hall.
5. A mean momentum change, inherent in the extraction mechanism of 0.3 % along the spill. Programmed magnets dynamically compensate the trajectory drift.
6. An instantaneous momentum spread close to 0.08% ($2\sigma$).
7. Vertical and horizontal beam emittances are both taken to be 2.0 $\pi$ mm mrad ($2\sigma$)

## 5. ZT8 beam line optics

ZT8 line will be equipped with the following optical elements :

- Two bending magnets (ZT8.BH1, ZT8.BH2) to deflect the beam towards the Dirac final straight section. These magnets are MCB type with a deflection angle of 38 mrad, each. Their location has been chosen to minimise the bending power required. It is possible to set them on *Pulse to Pulse Modulation* if necessary.
- Two corrector magnets (ZT8.DH1, ZT8.DV1) that, with the help of the elements F61_s.DH1 and F61_s.DV1, perform the horizontal and vertical steering. These magnets should be equipped with a feedback-control system to tune the proton beam location onto the target. Their positions have been chosen to optimise the vertical and horizontal steering of the beam.
- Two quadrupole magnets (ZT8.QF1, ZT8.QD2) that, together with the doublet QF1/QD2 on F61_s line, determine the focus on the target and the design spot dimensions.

The requested dimensions of the beam spot at the nominal focus are the following (ref.9) :

$x = 0.2$ cm $x' = 1$ mrad $\quad\quad$ $y = 0.3$ cm $y' = 0.66$ mrad

Fig.1 shows the proposed optics starting from the middle of the splitter magnet SMH1 (on the F61 ejection line) to the DIRAC target. All the simulations have been done with the TRANSPORT program. The optics upstream the splitter is the standard optics used to feed both the North and South branches using the splitter magnet (ref. 10).

Correction of the horizontal broadening of the beam due to the mean momentum drift ($\Delta p/p=0.3\%$) over the total duration of the spill, can be done by the element F61_s.DH1 connected to a GFA (Analog Function Generator) system. The correction angle is estimated to be 0.16 mrad or ~50 Ampere amplitude.

Figs. (2-3) show the action of the horizontal and vertical correctors . In Fig.2, a kick of 1 mrad in the horizontal plane is generated at the splitter. Kicks of -0.4 mrad at the F61_s.DH1 and 0.424 mrad at the ZT8.DH1 compensate the trajectory error. In Fig.3, a vertical kick of 0.5 mrad at the splitter is corrected at the F61_s.DV1 with -0.1688 mrad and 0.486 mrad at the ZT8b.DV1.

In Table 7 the main parameters of the beam line are summarised. Table 8 supplies the geometry of the line in the "2000" CERN standard co-ordinates.

| ZT8 LINE PARAMETERS | |
|---|---|
| **Design momentum** | 24 GeV/c |
| **Distance from the splitter magnet centre to the reference focus** | 81.97 m |
| **Beam height from the ground** | 1.28 m |
| **Transversal dimensions of the beam at the ref. Focus** | $x = 0.2$ cm , $x' = 1.0$ mrad<br>$y = 0.3$ cm, $y' = 0.66$ mrad |
| **Beam emittances** | $\varepsilon_H = \varepsilon_V = 2.0\ \pi$ mm mrad |
| **Instantaneous momentum spread** | $\Delta p/p = 0.08\%$ |
| **Momentum drift over spill time** | $\Delta p/p = 0.3\%$ |

**Table 7. Main ZT8 Line parameters.**

```
Reported by TRANPLT/SRV program   [std units: L(m), S(m), Field(kG)]
 Initial coord. at Sx=Sy=Sz=0, Ax=pi/2, Ay=0, Az=-pi/2
 Bend coord. given at Xing point of straight lines
 Z axis stands as the altitude
 Program version 1.2 - J-Y.Hemery (CERN)
```

Start Ax,Ay,Az (radians)= 1.7981 -.2273 -1.5708

| Name | dSl | S.lgth | S.x(*) | S.y(*) | S.z(*) | B.pos | Length | Field | deg | rad |
|---|---|---|---|---|---|---|---|---|---|---|
| >SMH1 | 1.090 | 1.090 | 2054.195 | 2187.320 | 2433.68 | 1.090 | 2.180 | -6.6101 | -1.0313 | -.0180 |
| _TV3 | 3.500 | 4.590 | 2057.590 | 2186.470 | 2433.68 | 4.590 | | | | |
| >sBH1 | 5.300 | 9.890 | 2062.731 | 2185.183 | 2433.68 | 9.890 | 2.600 | -13.2399 | -2.4637 | -.0430 |
| _TV1s | 12.450 | 22.340 | 2074.668 | 2181.643 | 2433.68 | 22.340 | | | | |
| *sQF1 | 1.050 | 23.390 | 2075.675 | 2181.345 | 2433.68 | 23.390 | 1.240 | 6.7498 | | |
| *sQD2 | 2.000 | 25.390 | 2077.592 | 2180.776 | 2433.68 | 25.390 | 1.240 | -6.4703 | | |
| _sDH1 | 1.700 | 27.090 | 2079.222 | 2180.293 | 2433.68 | 27.090 | | | | |
| _sDV1 | 1.200 | 28.290 | 2080.373 | 2179.951 | 2433.68 | 28.290 | | | | |
| >sBH2 | 2.300 | 30.590 | 2082.578 | 2179.297 | 2433.68 | 30.590 | 2.600 | .0000 | .0000 | .0000 |
| _SC1s | 2.100 | 32.690 | 2084.591 | 2178.700 | 2433.68 | 32.690 | | | | |
| >8BH1 | 13.460 | 46.151 | 2097.495 | 2174.873 | 2433.68 | 46.150 | 2.600 | 11.7004 | 2.1772 | .0380 |
| >8BH2 | 3.500 | 49.651 | 2100.887 | 2174.006 | 2433.68 | 49.650 | 2.600 | 11.7004 | 2.1772 | .0380 |
| _8DV1 | 10.180 | 59.831 | 2110.839 | 2171.861 | 2433.68 | 59.830 | | | | |
| _8DH1 | 1.780 | 61.611 | 2112.579 | 2171.486 | 2433.68 | 61.610 | | | | |
| *8QD1 | 2.080 | 63.691 | 2114.612 | 2171.048 | 2433.68 | 63.690 | 2.160 | -7.7589 | | |
| *8QF2 | 4.560 | 68.251 | 2119.070 | 2170.087 | 2433.68 | 68.250 | 2.160 | 7.1559 | | |
| _8Foc | 13.720 | 81.971 | 2132.481 | 2167.196 | 2433.68 | 81.970 | | | | |
| _ENDP | 6.000 | 87.971 | 2138.347 | 2165.932 | 2433.68 | 87.970 | | | | |

Final Ax,Ay,Az (radians)= 1.7831 -.2123 -1.5708

**Table 8. Geometry of T8 Line.**

(*) The CERN coordinate system is a three-dimensional Cartesian system (ref.11).It has its origin in the center of the PS machine(Point $P_0$). The $P_0$ coordinates are X=2000.00000, Y=2097.79265, Z=2433.66000.

## 6. Needed magnetic resources and power supplies.

Table 9 shows the necessary currents and powers of the magnets used for the operation of the ZT8 line. The quoted powers take into account the DC resistance of the magnets at a mean coil temperature of 35°C. It neglects wiring losses. The water flow is given for a 20°C temperature rise.

| | MAGNET | RESISTANCE R (OHM) | CURRENT I (A) | POWER P (KW) | NOMINAL FLOW (L/MIN) |
|---|---|---|---|---|---|
| **F61_s.QF1** | Q120.04 | 0.175 | 327 | 19 | 68 |
| **F61_s.QD2** | Q120.06 | 0.175 | 313 | 17 | 68 |
| **F61_s.DH1** | M105.01 | for 1.5 mrad (maximum correction angle)<br>I = 230 A, P = 4. 3 kW | | | 14 |
| **F61_s.DV1** | Mnpa30.09 | for 1.5 mrad (maximum correction angle)<br>I = 350 A, P = 12 kW | | | 18 |
| **ZT8.BH1** | MCB | 0.172 | 380 | 25 | 60 |
| **ZT8.BH2** | MCB | 0.172 | 380 | 25 | 60 |
| **ZT8.DH1** | Dipole corrector magnet (*) | Requested strength: 0.12 T m for 1.5 mrad of correction angle<br>(they have to be laminated) | | | 14 |
| **ZT8.DV1** | Dipole corrector magnet (*) | Requested strength: 0.12 T m for 1.5 mrad of correction angle<br>(they have to be laminated) | | | 14 |
| **ZT8.QD1** | Q200 | 0.2 | 503 | 50 | 54 |
| **ZT8.QF2** | Q200 | 0.2 | 459 | 42 | 54 |
| | | | | | |
| **Experimental Magnet** (**) | MNP21-3 | Requested current<br>I = 2500 A | Requested voltage<br>V = 500V | Requested power<br>P = 1250 kW | Requested water flow<br>540 l/min |

**Table 9. Magnet, powers and required water flow**

(*) These magnets are not available and have to be bought.

(**) This magnet is part of the DIRAC apparatus (ref.12)

## 7. Line vacuum.

The line is expected to be under a primary vacuum level of approximately 1Pa ($10^{-2}$ mbar). This pressure is sufficient enough for the energy of the proton beam used.

## 8 Monitoring devices

The control of the beam characteristics, as requested by the DIRAC experiments (ref.9), needs special monitoring devices. The choice of these devices is under discussion with the Beam Diagnostic Group at CERN-PS.

## 9. Halo beam

The DIRAC experiments is expected to be sensitive to particles outside the beam core in the vertical plane (halo). The production of these particles, which are expected to have the same momentum as the main beam, is mostly due to the scattering of protons on the blades of the splitter. The maximum tolerable limit of the halo intensity is defined to be $4 \times 10^7$ protons per spill (ref.13) in the acceptance of their *co-ordinate detectors* (ref.14-15) placed about 2m downstream the target with a lower edge of ~19.4 cm above the beam . The sensitive area of these detectors is about 10 $cm^2$.

Measurements of the halo distribution are described in ref.13. The transversal dimensions of the halo at the splitter exit extrapolated from these measurements are expected to be: x = .197 cm, x' = 1.015 mrad , y = 0.2 cm, y' = 2. 0 mrad ($2\sigma$ level). The halo intensity is estimated to be 4.9 % of the proton beam.

Taking into account these values and assuming the beam halo has the same optical functions as the proton beam, a simulation has been done with the TRANSPORT program to study the halo behaviour. Fig. 4 shows the result of this simulation. The halo coming from the splitter is collimated in the first two quadrupoles. The particles within the acceptance of the quadrupoles are transported downstream and are defocused by the final doublet. The vertical amplitude of the halo at the *co-ordinate detectors* is expected to be y = 12.234 cm, y' = 5,322 mrad at $2\sigma$ level. Assuming a gaussian distribution of the halo integrated over the sensitive surface of the detectors, it is possible to give an estimation of the fraction of halo hitting the *co-ordinate detectors*. The number of particles reaching the detectors is computed to be ~ $7 \times 10^6$ protons per spill. Even if this value is in agreement with DIRAC requirements (ref.13), it should be more convenient to reduce as much as possible the halo production at the splitter level. This is possible using a modified optics upstream the splitter as described in the next section.

## 10. Proposed optics to reduce the halo .

To reduce halo production at the splitter level, a special optics has been studied for the F61 ejection line. The purpose of this new optics is to reduce the transversal dimensions of the proton beam at the entrance of the splitter and to pass through the central gap of the magnet avoiding the scattering on the splitter blades. In this case the two spills could be allotted this way :

- cycle 1 shared between ZT7 and the North branch;
- cycle 2 for ZT8 only (full intensity on the ZT8 target).

Fig. 5 shows the modified optics from the extraction point of PS to the end of ZT8 line. In Table 10 are given the values of the currents of the quadrupoles magnets involved.

| | MAGNET | CURRENT I(A) |
|---|---|---|
| **F61.QF1** | Q74.03 | 600 |
| **F61.QD2** | Q12.03 | 248 |
| **F61.QF3** | QFL 08 | 388 |
| **F61.QD4** | Q610 | 330 |
| **F61_s.QF1** | Q120.04 | 385 |
| **F61_s.QD2** | Q120.06 | 396 |
| **ZT8.QD1** | Q220 | 417 |
| **ZT8.QF2** | Q220 | 479 |

**Table 10 . Current magnets for the modified optics upstream the splitter**

The application of the optics discussed above, implies that the quadrupoles of F61 line could work on *Pulse to Pulse Modulation* to pass from the dedicated optics for ZT8 (beam within splitter gap) to the standard optics for secondary lines (beam shared by North target and ZT7 target using the splitter). Since all the quadrupoles of the ejection line have solid yokes, it is not possible for cost reasons to substitute them with laminated ones. Further studies are needed to confirm the application of these optics using the quadrupoles on *Pulse to Pulse Modulation.*

## 11. Halo behaviour with the modified optics upstream the splitter

Fig. 6 shows the halo behaviour with the modified optics upstream the splitter. It should be noted that the expected transversal dimensions of the proton beam at the splitter are x = 0.3 cm, x' = 0.88 mrad , y = 0.88cm , y' = 0.023 mrad , and the splitter aperture diameter is 20 mm = 4.5 $\sigma_y$ , so only a little part of the beam will be scattered on the splitter blades. For convenience the dimensions of the halo at the splitter are supposed to be the same as in the previous case, that is to say: x = 0.197 cm, x' = 1.015 mrad, y = 0.2 cm, y' = 2. 0 mrad at 2$\sigma$ level.

The particles falling into the acceptance of the line are transported downstream and naturally collimated at the quadrupoles QF1/QD2 on F61_S. line. The remaining particles are focused by the last doublet of ZT8 line. At the co-ordinate detectors the expected dimensions of the halo are quite small (x = 0.2 cm, x ' = 1. 0 mrad, y = 2.7 cm, y' = 0.3 mrad ) and fully contained into the vacuum pipe of the main beam.

## 12. Muon zone

It was originally suggested (ref.16) to locate such a zone downstream the beam dump of the ZT8 line. This zone could be used for free while DIRAC is running. This explains the presence of a muon zone on the drawings up to version EHNL_5L. In this configuration, a flux of 10 muon.$s^{-1}$.$cm^{-2}$ is expected for a primary beam of 4E11 at 24 GeV/c every 15 seconds. This dose rate is acceptable to keep this part of the hall "Access Free" but nevertheless as a "Restricted Area".

Enquiries were made to ensure this facility was of some use for the experiments. The ALICE representative stated a request for a higher flux (from 500 down to 50 muon.$s^{-1}$.$cm^{-2}$). Such a dose rate can be obtained from 4 to 6 m inside the dump along the beam axis [see Appendix 3]. This would have imposed to split the dump into two sections to insert a dedicated muon zone. The latter would have had to be a "Controlled Access Area", and consequently DIRAC experiments should have stopped taking data during access to this muon zone. Hence, the "exclusive OR" would have penalised DIRAC experiments as far as duty cycle is concerned. Facing this problem, the representative of ALICE experiments (ref.17) has withdrawn the request of having such a facility. The Physics co-ordinator (ref.18) has accepted the vanishing of this facility.

## 13. Irradiation block house

The volume, of 3 x 4.5 x 4 $m^3$ (length x width x height) just upstream the beam dump, is the 'catcher' requested by DIRAC experiments. Its purpose is to trap the back scattered particles from the interaction of the 24 GeV/c primary beam with the dump. Opportunity is taken here to use this volume for irradiation tests. Small items (10x10 $cm^2$) can be put in 'In beam position' using a 'shuttle device' to travel into or out of this volume. Large items are to be introduced by opening the roof which requires a day of work. Insertion or extraction of all elements (solid, liquid, gas) require the permit of the TIS representative.

## 14. Environmental background due to induced radioactivity

Measurements have been performed for two sources of potential background for the DIRAC experiments:

1) The area (~18 x 3 $m^2$, drawn in red) underneath the left hand side wall of the ZT8c zone corresponds to an old dump in the ground of a proton primary beam line. The measurements spreads between 0.18 and 1.6 uSv.$h^{-1}$ at 40 cm from the ground (ref.19). Hence, this low level may be tolerable for the DIRAC experiments.

2) The iron blocs which shield the inner part of the ZT8c zone were requested to radiate less than 10 uSv.$h^{-1}$ or ~500 photons per $cm^2$ per second (ref.9). The measurements of the residual radioactivity of the blocs commonly used spread between 0.1 Sv.$h^{-1}$ and 7 uSv.$h^{-1}$ at 10 cm (ref.20). The blocs will be measured and classified according to their level of residual radioactivity in 5 categories. Obviously, the blocs of low level will be mounted in the region of the detectors of the experiments to guarantee the minimum achievable and for sure below the threshold quoted by DIRAC experiments.

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15. H. Herr (PPE) - Private communication dated 27/02/97.
16. L. Danloy - Expérience DIRAC - Calcul des blindages - PS/PA Note 95-18.
17. F. Piuz (PPE) - Private communication.
18. E. Tsesmelis (PPE) - Private communication.
19. Conan N. (TIS) - Rapport de surveillance Radiation. RSR/PS/97-8
20. Conan N. (TIS) - Rapport de surveillance Radiation. RSR/PS/97-12

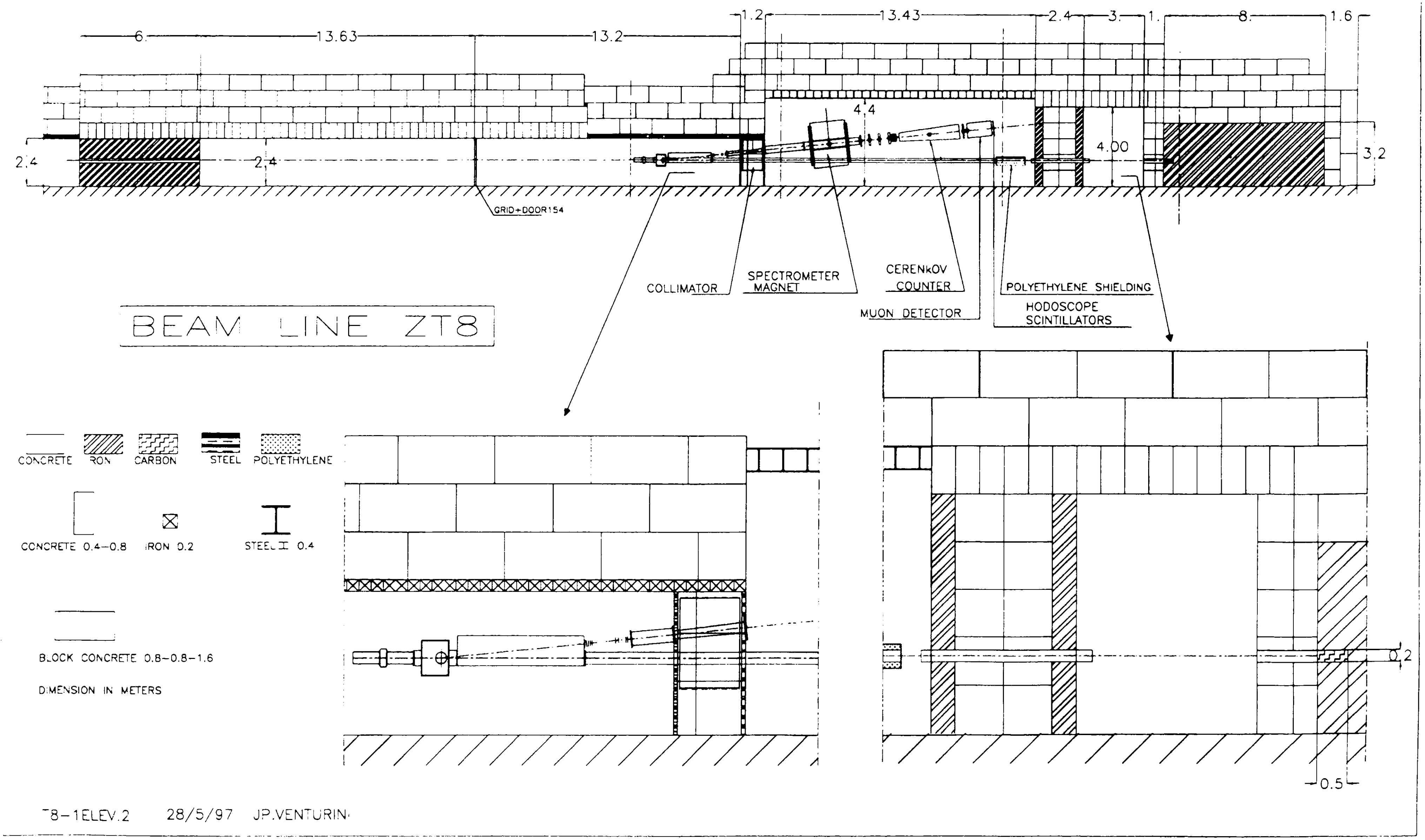
Appendix 1

**MAGNETIC ELEMENTS ON F61, F61_n AND F61_s LINES .**

| ACTUAL NAMES | EHNL NAMES |
|---|---|
| | |
| FT61.QFO01 | F61.QF1 |
| FT61.DHZ01 | F61.DH1 |
| FT61.QDE02 | F61.QD2 |
| FT61.DVT01 | F61.DV1 |
| FT61.DVT02 | F61.DV2 |
| FT61.QFO03 | F61.QF3 |
| FT61.BHZ01 | F61.BH1 |
| FT61.BHZ02 | F61.BH2 |
| FT61.QDE04 | F61.QD4 |
| FT61.SMH01 | F61.SMH1 |
| | |
| E17_n.QDE05 | F61_n.QD1 |
| E17_n.QFO06 | F61_n.QF2 |
| E17_n.DVT03 | F61_n.DV1 |
| E17_n.DHZ02 | F61_n.DH1 |
| E17_n.BVT01 | F61_n.BV1 |
| | |
| E17_s.BHZ03 | F61_s.BH1 |
| E17_s.QFO07 | F61_s.QF1 |
| E17_s.QDE08 | F61_s.QD2 |
| E17_s.DHZ03 | F61_s.DH1 |
| E17_s.DVT04 | F61_s.DV1 |
| E17_s.BHZ04 | F61_s.BH2 |

**CAMERAS, SECONDARY EMISSION CHAMBERS (SEC) AND TELESCOPES ON F61, F61_n AND F61_s LINES.**

| ACTUAL NAMES | EHNL NAMES |
|---|---|
| | |
| FT61.MSC01 | F61.SC1 |
| FT61.MTV02 | F61.TV1 |
| FT61.MTV03 | F61_d.TV1 |
| FT61.MTV04 | F61.TV2 |
| FT61.MTV05 | F61.TV3 |
| | |
| FT61_n.MTV06 | F61_n.TV1 |
| FT61_n.MTV07 | F61_n.TV2 |
| FT61_n.MSC02 | F61_n.SC1 |
| FT61_n.TEL1 | F61_n.TEL1 |
| | |
| FT61_s.MTV08 | F61_s.TV1 |
| FT61_s.MSC03 | F61_s.SC1 |
| FT61_s.MTV09 | F61_s.TV2 |
| FT61_s.TEL2 | F61_s.TEL1 |


6.
13.63
13.2
1.2
13.43
2.4
3.
1.
8.
1.6
4.4
4.00
3.2
2.4
2.4
GRID+DOOR154
COLLIMATOR
SPECTROMETER MAGNET
CERENKOV COUNTER
MUON DETECTOR
POLYETHYLENE SHIELDING
HODOSCOPE SCINTILLATORS
BEAM LINE ZT8
CONCRETE
IRON
CARBON
STEEL
POLYETHYLENE
CONCRETE 0.4–0.8
IRON 0.2
STEEL I 0.4
BLOCK CONCRETE 0.8–0.8–1.6
DIMENSION IN METERS
0.2
0.5
T8-1ELEV.2 28/5/97 JP.VENTURINI

## Appendix 3

### Muon flux computation

The computations below evaluates the $\Phi_{mu}$ muon flux observed at **1** [m] away from the rear face of a splitted dump bloc (made of **iron**). Its depth (**thick**) varies from **1 to 8** [m]. The incoming primary beam is **nb_pps** [protons.s-1] of **Ek** [GeV] kinetic energy. One should notice that no concrete is taken into account for this study.

*References:*

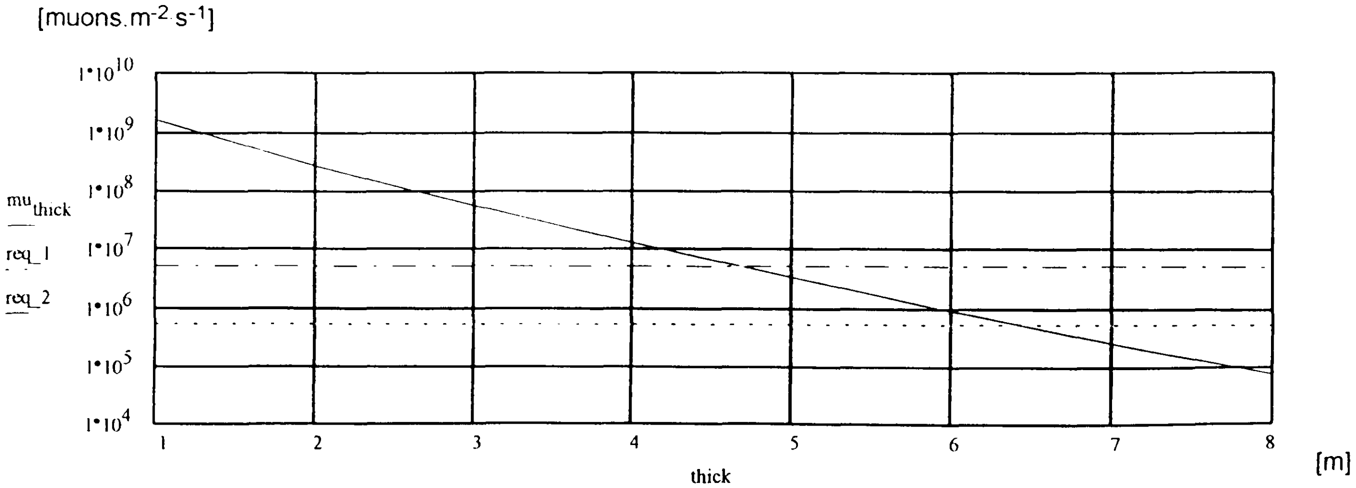
*A.H.Sullivan - Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators*

*L. Danloy - Expérience DIRAC, Calcul de Blindages - PS/PA Note 95-18*

| | **Formulae & constants definition** | | **Units** |
|---|---|---|---|
| Avogadro ($N_A$) | $N \equiv 6.02 \cdot 10^{23}$ | | $mole^{-1}$ |
| Muon production (analytical formula) | $\Phi mu(Ek, q, \lambda, X, \alpha, t) \equiv \frac{.085 \cdot Ek \cdot q(\lambda)}{X^2} \cdot \left( e^{\frac{-\alpha \cdot t}{Ek}} - e^{-15} \right)$ | | $muons.m^{-2}.proton^{-1}$ |
| Incident kinetic energy of proton beam | $Ek \equiv 23.08$ | | GeV |
| Atomic mass for iron (A) | $A\_iron \equiv 55.85$ | | $g.mole^{-1}$ |
| Density for iron (A) | $d\_iron \equiv 7.4$ | | $g.cm^{-3}$ |
| Interaction cross section ($\sigma$) | $\sigma(A) \equiv 42 \cdot A^{0.7} \cdot 10^{-27}$ | | $cm^2$ |
| Hadron nuclear interaction mfp ($\lambda$) | $\lambda\_iron \equiv \frac{A\_iron}{N \cdot \sigma(A\_iron)} \cdot \frac{10^{-2}}{d\_iron}$ | $\lambda\_iron = 0.179$ | m |
| Average path length of secondary pions | $q(\lambda) \equiv 1.8 \cdot \lambda$ | | m |
| Average muon energy loss | $\alpha\_iron \equiv 23$ | | $GeV.m^{-1}$ |
| Beam population per second | $nb\_pps \equiv \frac{4 \cdot 10^{11}}{15}$ | $nb\_pps = 2.667 \cdot 10^{10}$ | $protons.s^{-1}$ |
| Flux limits required for ALICE: | $req\_1 \equiv 50 \cdot 10^4$ | $req\_2 \equiv 500 \cdot 10^4$ | $muons.m^{-2}.s^{-1}$ |

### Computation

| | | | | |
|---|---|---|---|---|
| Range of iron depth | $thick := 1 .. 8$ | Location of exposure | $X_{thick} := thick + 1$ | m |
| Muon flux at the location of exposure | | $mu_{thick} := \Phi mu(Ek, q, \lambda\_iron, X_{thick}, \alpha\_iron, thick) \cdot nb\_pps$ | | $muons.m^{-2}.s^{-1}$ |



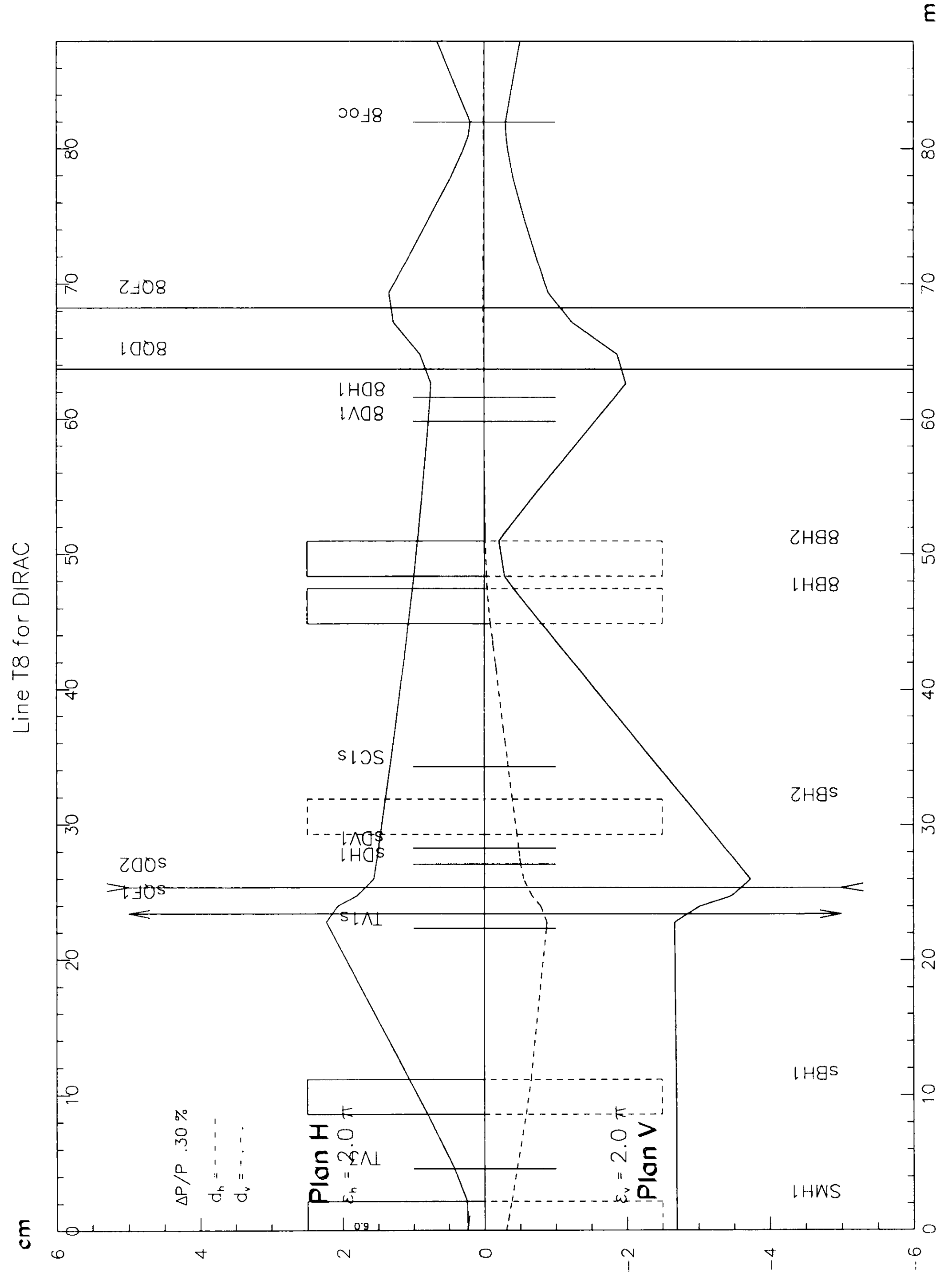



**Fig. 1 ZT8 optics from the splitter magnet centre to the DIRAC target.**

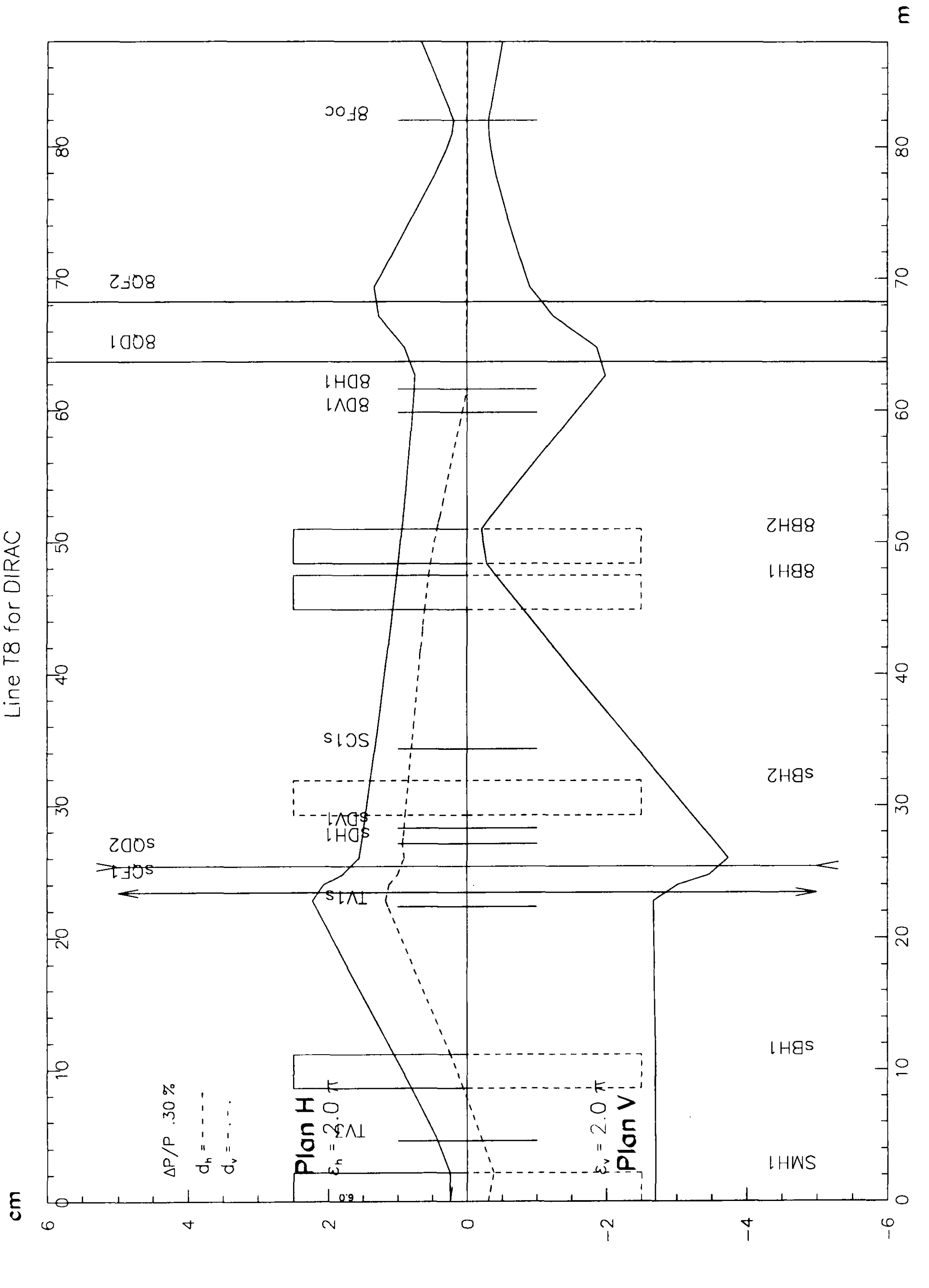



**Fig. 2 An horizontal kick at the splitter compensated by F61s. DH1 and ZT8b.DH1 correctors.**

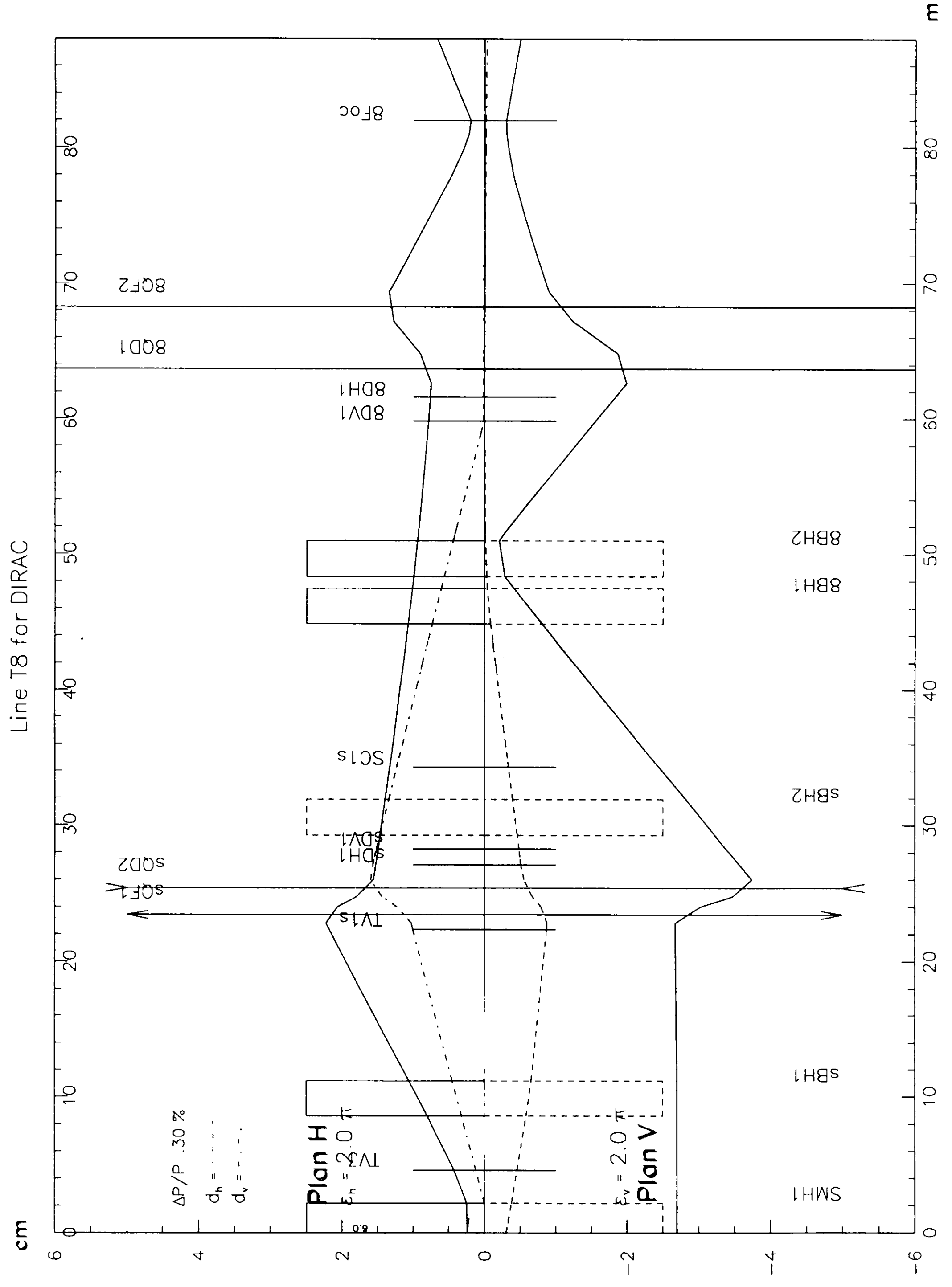



Fig. 3 A vertical kick at the splitter compensated by F61s.DV1 and ZT8b.DV1 correctors.

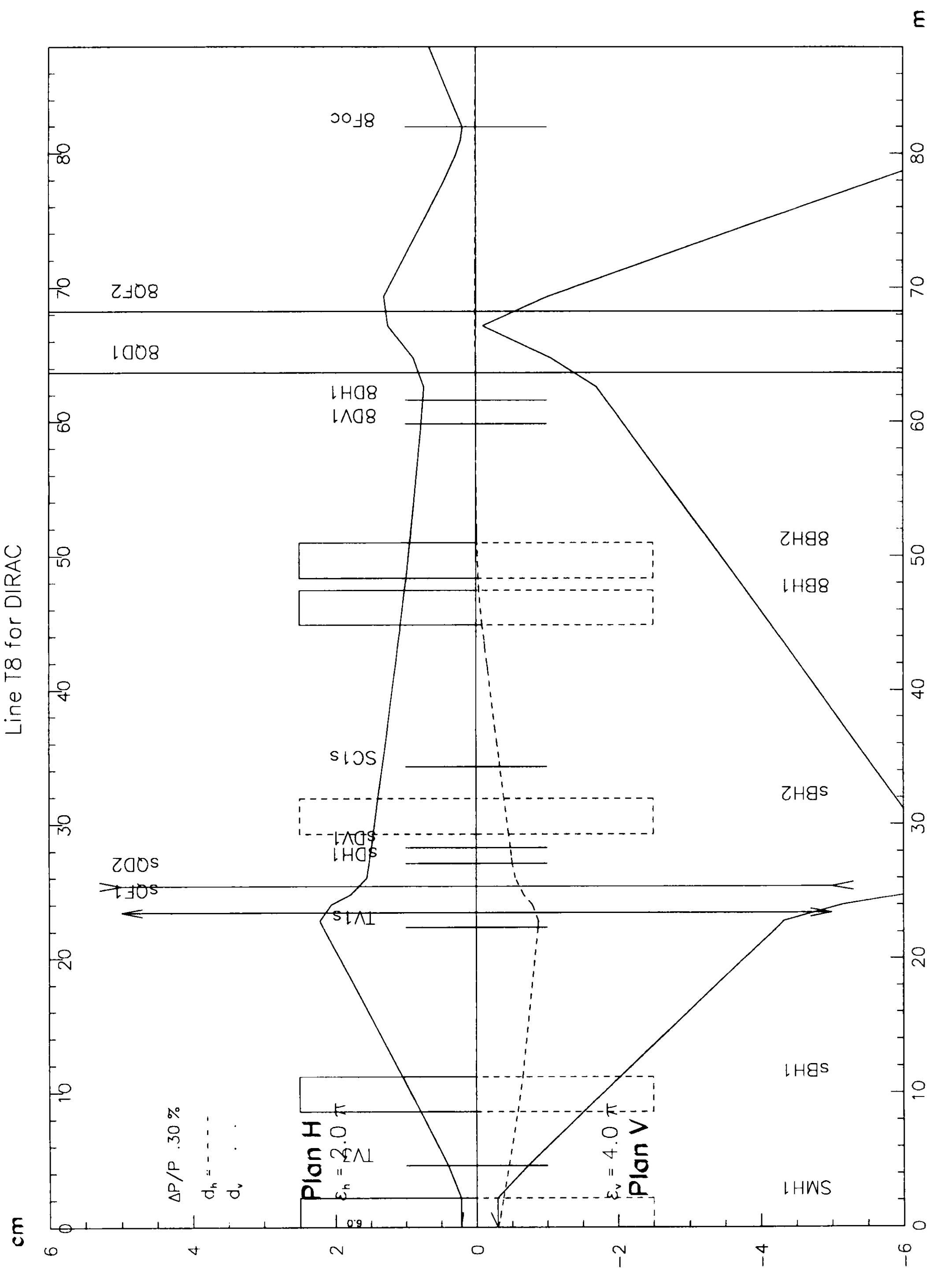



**Fig. 4 Halo optics model**

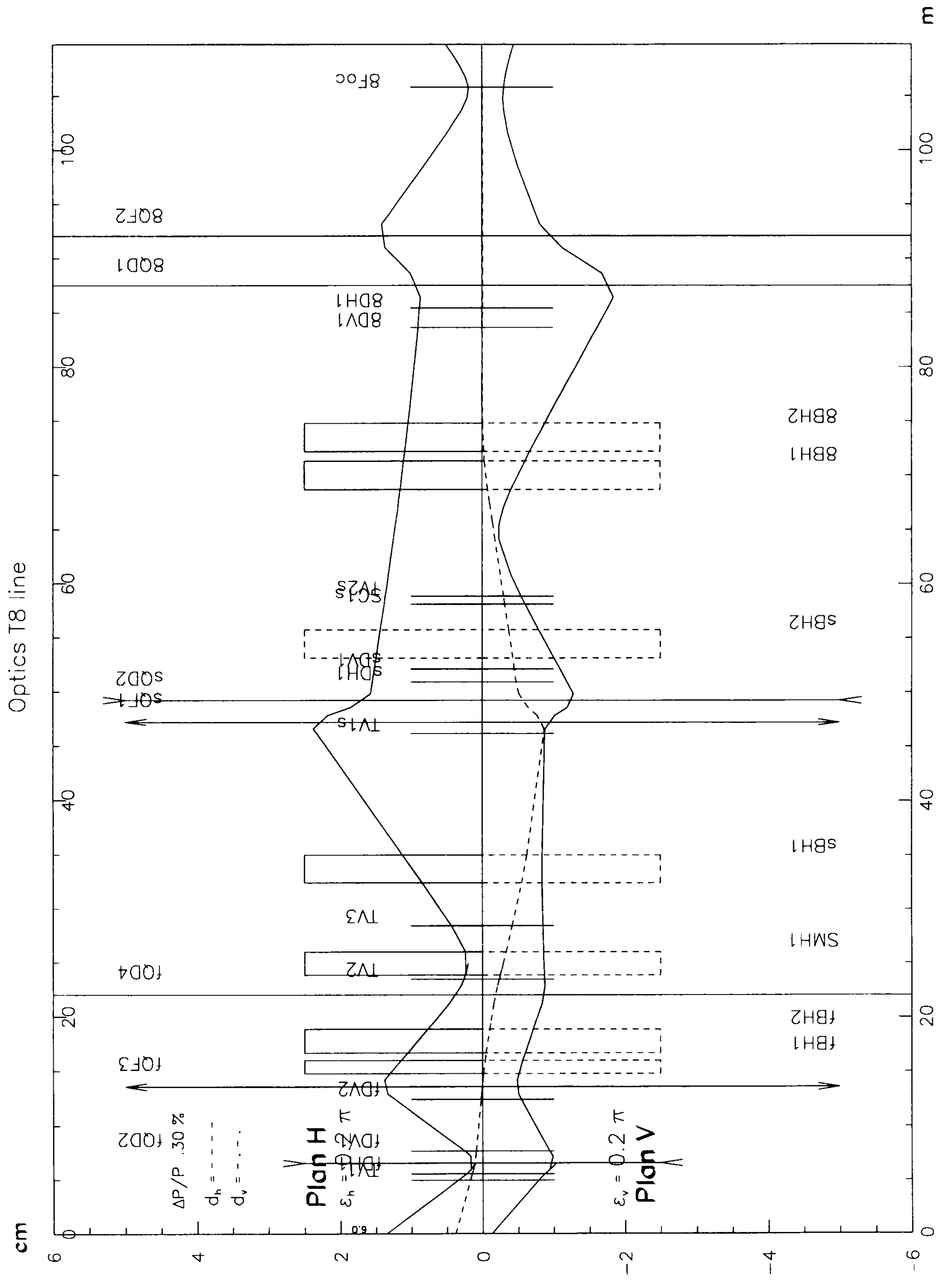



**Fig. 5 ZT8 optics from the PS exit to the DIRAC target for a modified model upstream the splitter magnet.**
(In this figure emittances units are taken to be mm crad)

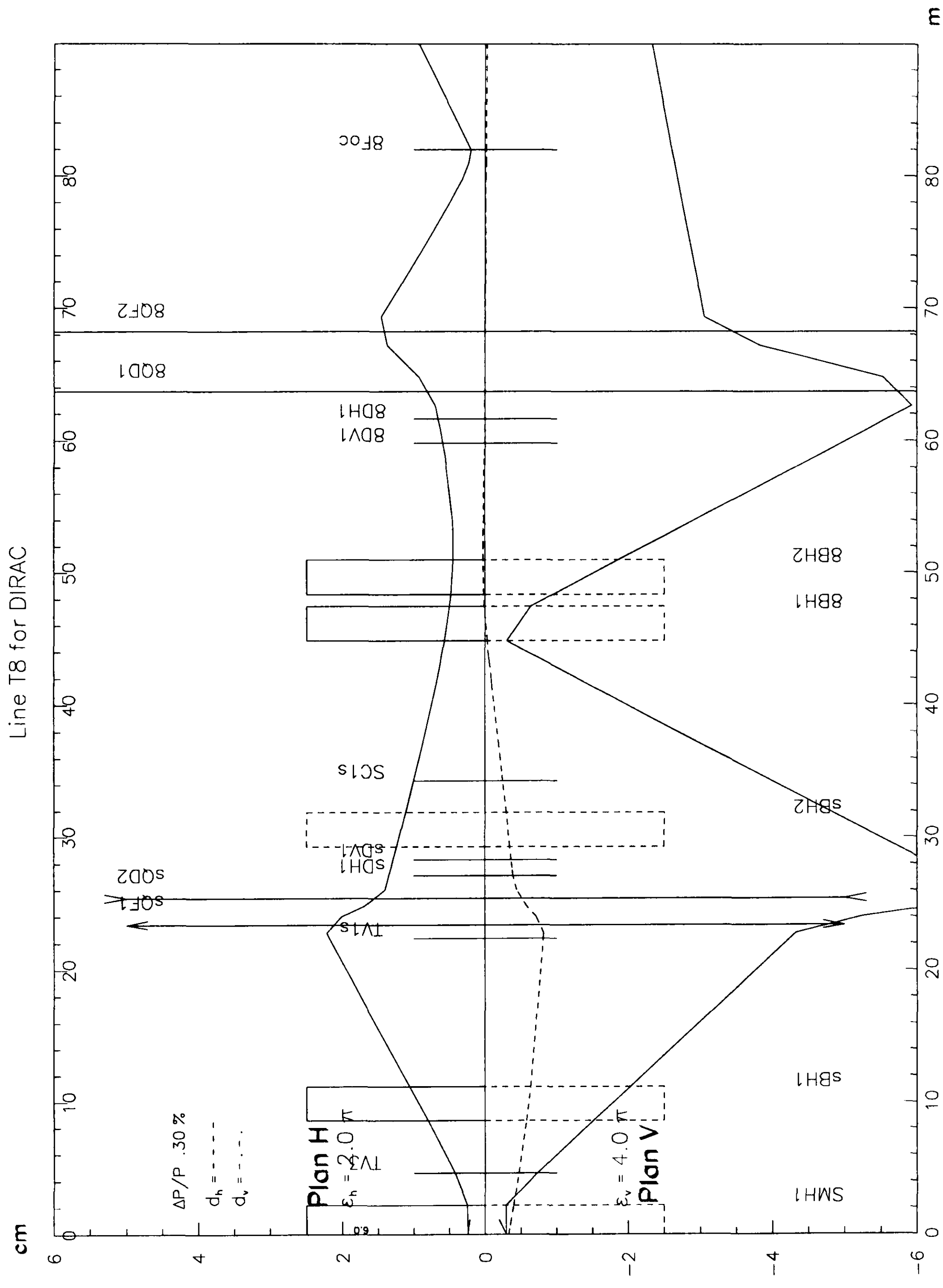


**Fig. 6 Halo optics model for the modified optics upstream the splitter.**

**List of distribution :**

| | |
|---|---|
| Lemeilleur F. | /ECP-MIC |
| Lasseur C. | /EST-SU |
| Brouet M. | /LHC-VA |
| Bosser J. | /PS-BD |
| Chohan N. | /PS-BD |
| Koziol H. | /PS-BD |
| Daems G. | /PS-CO |
| Frammery B. | /PS-CO |
| Allardyce B. | /PS-DI |
| Bouthéon M. | /PS-DI |
| Simon D.J. | /PS-DI |
| Cappi R. | /PS-CA |
| Coccoli R. | /PS-CA |
| Delaprison J. | /PS-CA |
| Durieu L. | /PS-CA |
| Ferrando O. | /PS-CA |
| Giovannozzi M. | /PS-CA |
| Gueugnon D. | /PS-CA |
| Hémery J-Y. | /PS-CA |
| Martini M. | /PS-CA |
| Metzger C. | /PS-CA |
| Metzmacher K. | /PS-CA |
| Riunaud J-P. | /PS-CA |
| Scheffre C. | /PS-CA |
| Thivent M. | /PS-CA |
| Bellone R. | /ST-HM |
| Bonzano R. | /ST-MC |
| Carlod M. | /ST-HM |
| Genolin M. | /ST-HM |
| Guillaume J-C. | /ST-IE |
| Kuhnl-Kinel J. | /ST-CV |
| Cambarrat R. | /TIS-GS |
| Conan N. | /TIS-RP |
| Tavlet M. | /TIS-CFM |
| Tuyn J. | /TIS-RP |
| Dekkers D. | /PS-HP |
| Buttkus J. | /PS-PO |
| Grüber J. | /PS-PO |
| Boillot J. | /PS-OP |
| Bencze G. | /PPE-CMO |
| Doser M. | /PPE-XB |
| Ferro-Luzzi M. | /PPE-JET |
| Henriques A.M. | /PPE-ATO |
| Herr H. | /PPE-DED |
| Leroy C. | /PPE-LE |
| May J. | /PPE-ALD |
| Nemenov L. | /PPE-LR |
| Piuz F. | /PPE-ALI |
| Tsesmelis E. | /PPE-NOE |