Presentation 43

Machine Implications of Moving LEP 5 to a Low Beta Insertion

By M. Placidi

43.1 Introduction

The agreement for the LEP-5 Experiment (Figure 43.1) to be installed in IP1 to test the feasibility of detecting single-bremsstrahlung photons as a fast luminosity monitor has been settled in a Memorandum [1] between CERN and INFN (National Institute for Nuclear Physics), Rome, Italy.

The Experiment was installed on the right side of IP1 in the 1989-1990 shut down and has been taking data during the 1990 LEP run.

After the Cogne meeting and following the results of the test experiment [2] "*interest has been expressed by the LEP-5 and L3 collaborations in the installation of a version of the LEP-5 Single-Arm bremsstrahlung Monitor in IP2*" (meeting on LEP-5 installation in L3, Jan. '91).

The implications for LEP deriving from this proposal, already analyzed at the time of the LEP-5 project (1988) in terms of layout modifications, engineering for new components, manpower and costs, are illustrated in the figures and commented in the following.

43.2 The present situation

At present the LEP-5 Experiment in IP1 straight section makes use of the same modifications to the machine layout approved and realised for the installation of the laser polarimeter on the e^- side, namely the enlarged vacuum chamber in the B4/1 dipole with the built-in $50 \times 20\,\mathrm{mm}^2$ Al window, the reversed B4/2 dipole and the modified external coils of quadrupole QL13.R1, providing a 20 mm vertical clearance for the bremsstrahlung photons to reach the detector installed behind the B4/3 dipole, about 340 m downstream IP1 (Figure 43.2).

43.2.1 Beam divergence and diaphragms

In the absence of spurious dispersion the beam divergence at the IP can be written:

$$\sigma'_h = \sqrt{\epsilon_h/\beta_h} = \sqrt{k_\beta\,\epsilon_h/\beta_v}\ , \qquad \sigma'_v = \sqrt{\epsilon_v/\beta_v} = \sqrt{k_c\,\epsilon_h/\beta_v} \qquad (43.1)$$

where $k_\beta = \beta_v/\beta_h$ is the β-ratio at the IP and $k_c = \epsilon_v/\epsilon_h$ the coupling factor.
In the particular case $k_c = k_\beta$ (*optimum coupling*) one clearly has $\sigma'_h = \sigma'_v$.
For the optics adopted in the 1990 runs the situation at IP1 is :

$$\beta_h = 20\,\mathrm{m}\ , \qquad \beta_v = 1.4\,\mathrm{m} \rightarrow k_\beta = 0.07.$$

Assuming for the horizontal emittance at the Z^0 resonance a value $\epsilon_h = 34.9\,\text{nm}$ and a coupling factor $k_c = 0.01 - 0.04$ the rms beam divergences are:

$$\sigma'_h = 41.8\,\mu\text{rad}\,, \qquad \sigma'_v = 15.8 - 31.6\,\mu\text{rad}$$

The $50 \times 20\,\text{mm}^2$ window at ~ 293 m from IP1 defines an angular diaphragm of $\pm 85\,\mu$rad (H-plane) and $\pm 34\,\mu$rad (V-plane) i.e. an angular transmission to the detector :

$$A_h \leq \pm 2\,\sigma'_h\,, \qquad A_v \leq \pm(1 - 2)\,\sigma'_v \qquad (43.2)$$

which represents a relatively comfortable situation taking into account the constraints imposed by the LEP straight section layout.

43.3 The situation next to an even IP

43.3.1 Beam divergence and diaphragms

In each of the four interaction points we have

$$k_\beta = 0.04\,, \qquad \beta^*_v \geq 0.04\,\text{m}$$

With the previous assumptions for ϵ_h and the coupling factor k_c the r.m.s. beam divergences become :

$$\sigma'^*_h \leq 187\,\mu\text{rad}\,, \qquad \sigma'^*_v \leq 93 - 187\,\mu\text{rad}$$

The maximum angular aperture provided by the ring structure at both sides of the even interaction points (Figure 43.3) is limited to :

- V-plane : $\pm 117\,\mu$rad (70 mm vacuum chamber internal height in B4/1 dipole, 300 m from IP);
- H-plane : $\pm 200\,\mu$rad (100 mm vacuum chamber diameter at QS11, 248 m from IP). This figure can be further reduced to $\pm 100\,\mu$rad by the horizontal collimator COLH.QS6, 121.4 m from IP, usually set at ± 12 mm aperture.

The angular transmission to the detector is then limited to (Figures 43.4, 43.5) :

$$A^*_h \leq \pm 1\,\sigma'^*_h \ (\leq \pm 0.5\,\sigma'^*_h \text{ with collimation}) \qquad A^*_v \leq \pm(1.2 - 0.6)\,\sigma'^*_v \qquad (43.3)$$

i.e. **a much less comfortable situation** with respect to the situation (43.2).

43.3.2 Required modifications

A *single-arm monitor* would require modifications to the original LEP layout on only one side of the IP. Nevertheless, it is clear from the following considerations that some of the changes have to be made to both sides of the straight section of interest (Figures 43.6, 43.7).

Vacuum chamber and window - The LEP vacuum chamber in the B4/1 dipole and in the QS13 quadrupole has to be completely re-designed to provide a path for the bremsstrahlung photons to the detector through a window of $120 \times 70\,\text{mm}^2$ to assure the aperture for the largest of the two horizontal diaphragms (without collimation) required for the calibration of the device.

Quadrupole QS13 : Coils and PC - A vertical clearance of at least 75 mm has to be provided between the external coils of QS13 to be consistent with the vertical diaphragm represented by the vacuum chamber which can be accommodated in the gap of the B4/1 dipole. **The 8 coils of both QS13 quadrupoles** (series connected to the same power converter) have to be rebuilt. Even if this is possible in the present LEP optics configuration without increasing the current density in the reduced conductor volume too much, **new QS13 quadrupoles** are likely to be needed for the LEP200 project.

It has to be noticed that with the present design of the iron core for QS13 the transmission of the bremsstrahlung photons to the detector is still affected by the interference of the pole tips with the aperture provided by the coil modification (Figure 43.6).

A new power converter has to be foreseen anyhow for the two quadrupoles.

Repositioning of dipole B4/2 - As in the LSS1 layout, this dipole has to be pulled out and realigned in the reversed position (yoke inside tunnel). The electrical connections to the coils have to be modified accordingly.

Miscellaneous - Other interventions requiring qualified manpower are : **the water connections to the dipoles B4/2 and B4/3** and to the **main vacuum chamber**, together with **the return legs of the horizontal corrector CHA.QS13.**

43.3.3 Cost considerations

A "shopping list" concerning the modifications for both sides of the interaction region is shown in Figure 43.7. The estimated expenditure ("1988 prices") is in the range 540 – 600 KCHF and **does not include the acquisition of new QS13 quadrupoles** Figure 43.8.

It should be noted that the cost for a *single-arm monitor* is still of the order of 2/3 of the above figure allowing for one spare vacuum chamber and the considerations about the QS13, valid for both quadrupoles.

43.4 Conclusions

The interest of an experiment like LEP-5 or any other one providing the possibility of "looking" directly into the interaction region is, in the case of LEP, mitigated by the intrinsic difficulties connected with the dimensions of the ring.

The reduced β-functions and the consequent strong divergences at the IP drastically limit the angular aperture to the apparatus even if the considerable engineering efforts envisaged to design, build and install the important modifications to the existing ring layout are supported.

In several discussions about the feasibility of equipping the LEP experimental regions with a LEP-5-like facility it has been stressed that, even if the cost involved in the modifications should not in any case be underestimated, the main problems are the availability of qualified engineering support and manpower in the context of the present and future commitments of the SL Division.

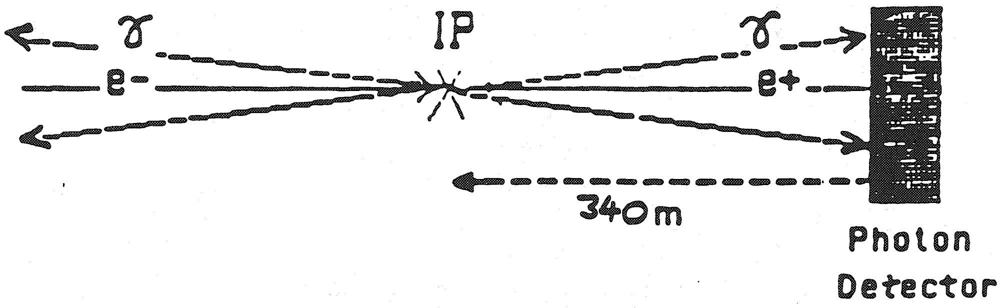
References

[1] Memorandum of understanding for the execution of experiment LEP-5 (PLP) to develop a new luminosity and polarisation monitor at LEP, between CERN and INFN (July 1989).

[2] C. Bini, G. De Zorzi, G. Diambrini Palazzi, G. Di Cosimo, A. Di Domenico, P. Gauzzi, D. Zanello, Fast measurement of luminosity at LEP by detecting the single bremsstrahlung photons. To be submitted to NIM.

Monitor for Measurement of Luminosity and Beam Divergence at Interaction Point.

$$e^+ e^- \longrightarrow e^+ e^- \gamma$$



For $L = 10^{31}\ cm^{-2}\ s^{-1}$ and

$0.01 < \frac{K}{E} < 0.99$ we get

$\dot{N} = 3.4 * 10^{6}$ photons/sec

85 photons/crossing

@ $\mathcal{L} = 10^{29}\ cm^{-2} s^{-1}$

LEP bhabha	$\dot{n} = 1$ Hz
Single bremsstr.	$\dot{n} = 3 \cdot 10^{4}$ Hz

Figure 43.1: The L5 luminosity monitor scheme

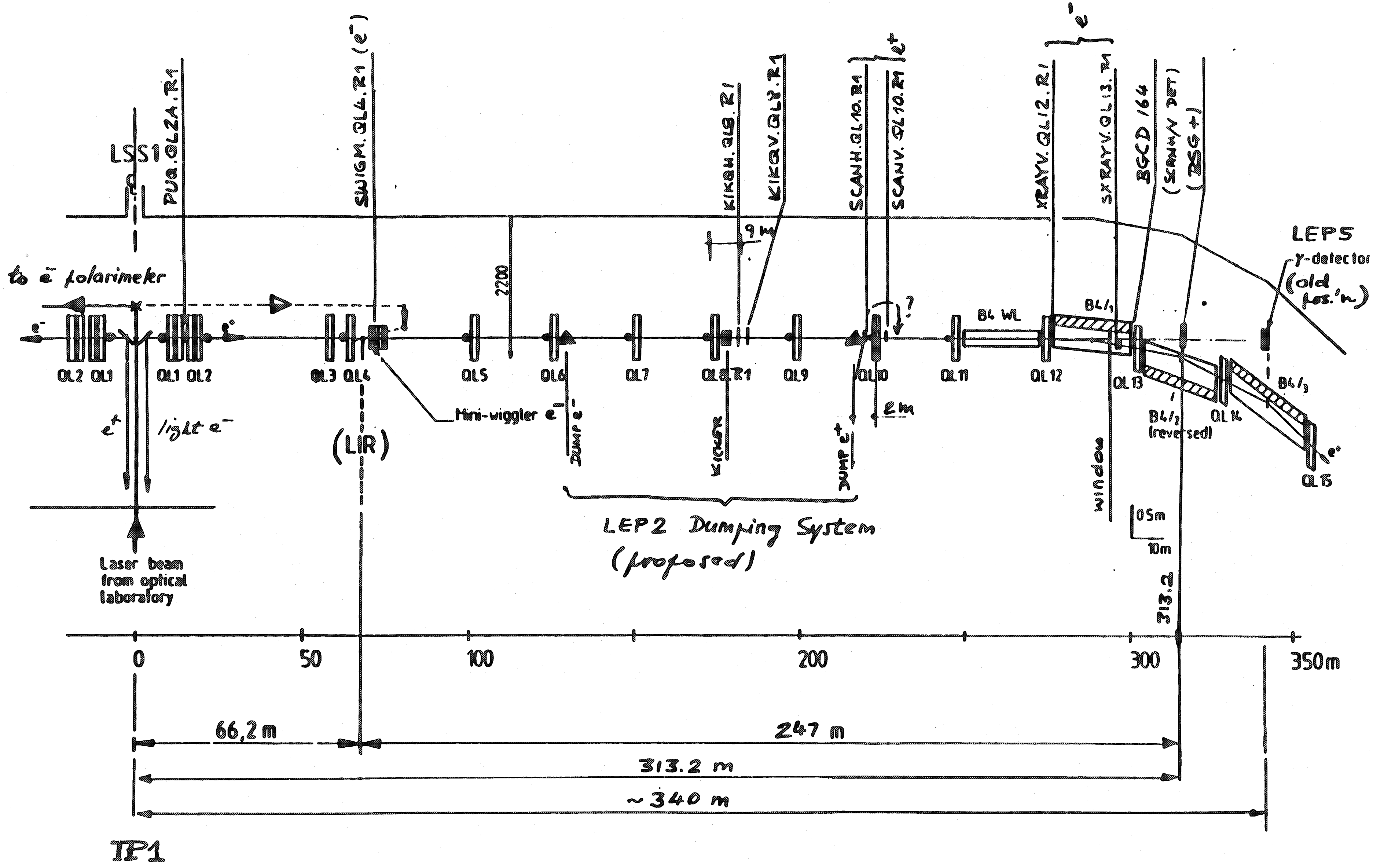


Figure 43.2: Layout of LEP right of IP 1

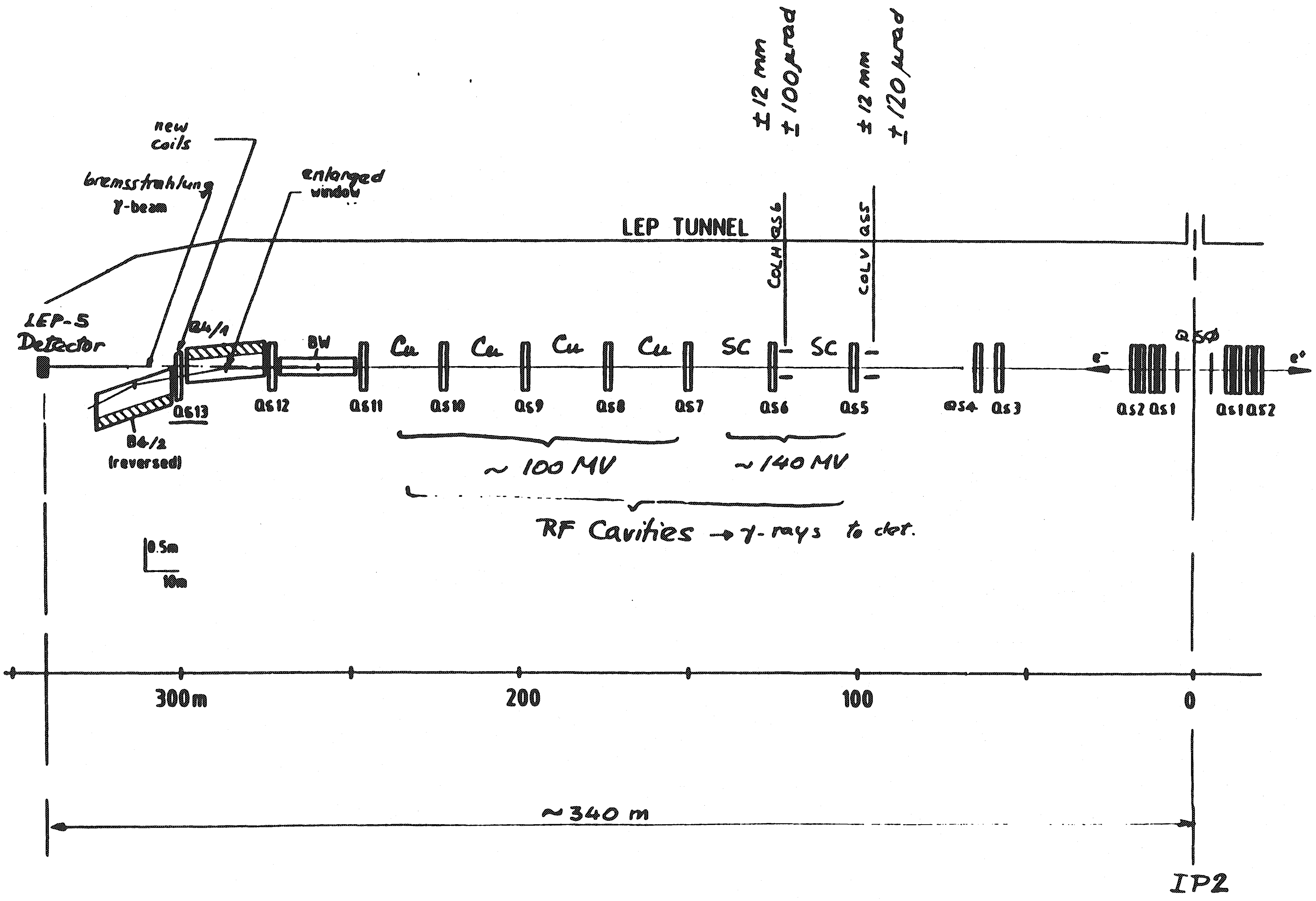


Figure 43.3: Possible Layout for LEP 5 -type of experiment left of IP 2

Angular Acceptance (vacuum chamber)

- ϕ 100 mm → @ QS11 (248 m from IP) $\qquad \theta_{H,V} \leq \pm 200\ \mu rad$
- h = 70 mm in B4/1 (299 m from IP) $\qquad \theta_V \leq \pm 117\ \mu rad$

Nominal rms beam divergence @ IP

$$\sigma_H'^{*} = \sqrt{K_\beta\, \varepsilon_H / \beta_V^*}$$

$$K_\varepsilon = \varepsilon_V / \varepsilon_H \,, \quad K_\beta = (\beta_V/\beta_H)^*$$

$$\sigma_V'^{*} = \sqrt{K_\varepsilon \varepsilon_H / \beta_V^*}$$

→ For E = 45.625 GeV, $\beta_V^* = 4$ cm, $K_\beta = 1/25$, $K_\varepsilon = 1 \div 4$ %

$\varepsilon_H = 34.9$ nm (scaled)

$\sigma_H'^{*} = 187\ \mu rad$, $\sigma_V'^{*} = $ 93 μrad ($K_\varepsilon = 1$%) / 187 μrad (4%)

	Diaphragms Position	D/mm	$\theta_{H,V}/\mu rad$	$A = \theta/\sigma'^*$		
	QS11	100	$\leq \pm 200$	$\leq \pm 1.07$		H
	B4/1	70	$\leq \pm 117$	$\leq$ ±1.25 ±0.62	K = 1% 4%	V
with collim.	HC / QS6	±12	± 100	$\leq \pm 0.53$		H
	VC / QS5	±12	± 120	$\leq \pm$ 1.3 0.64		V

Figure 43.4: Angular acceptance for the possible scheme

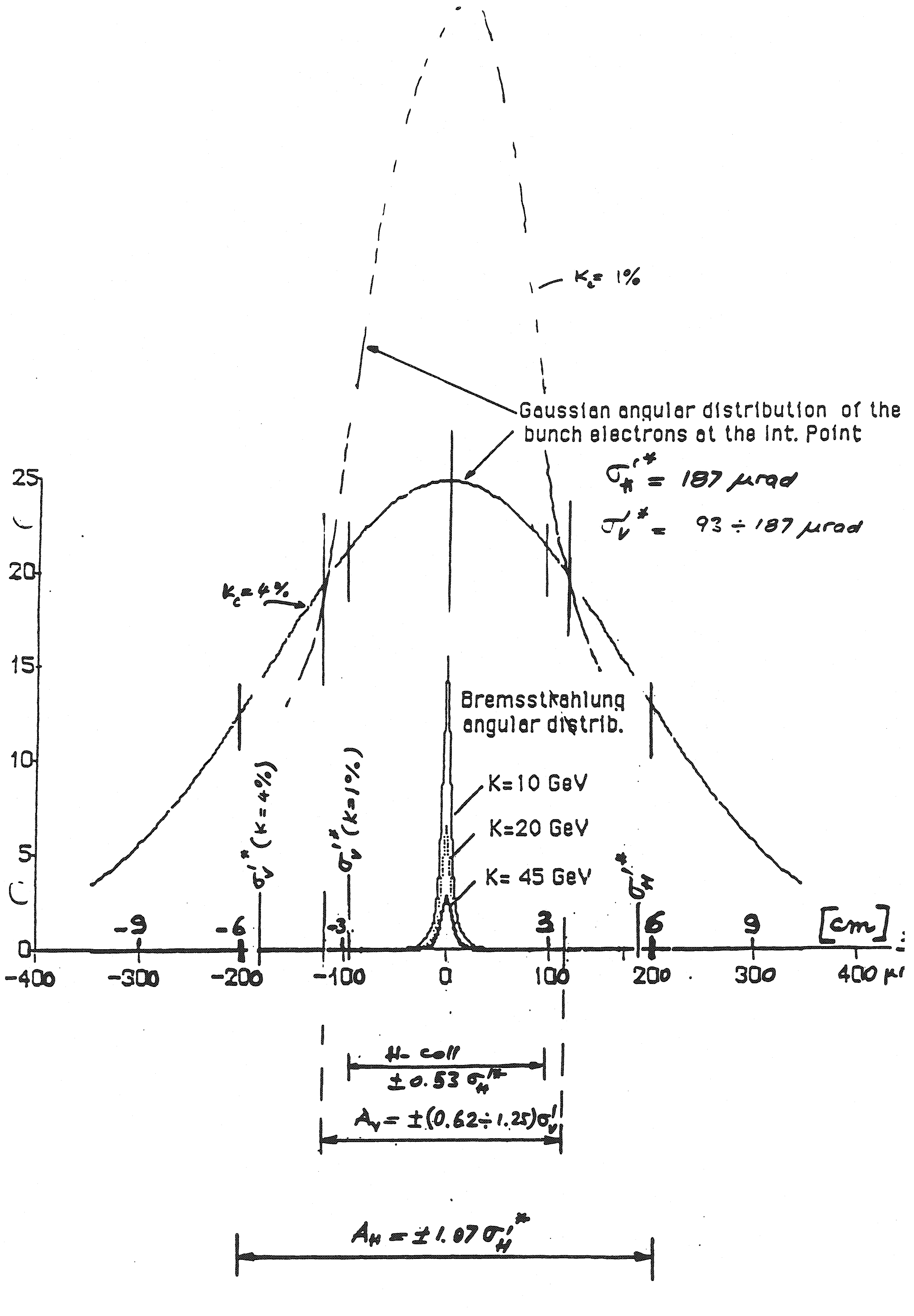


Figure 43.5: Cut off of the radiation distribution

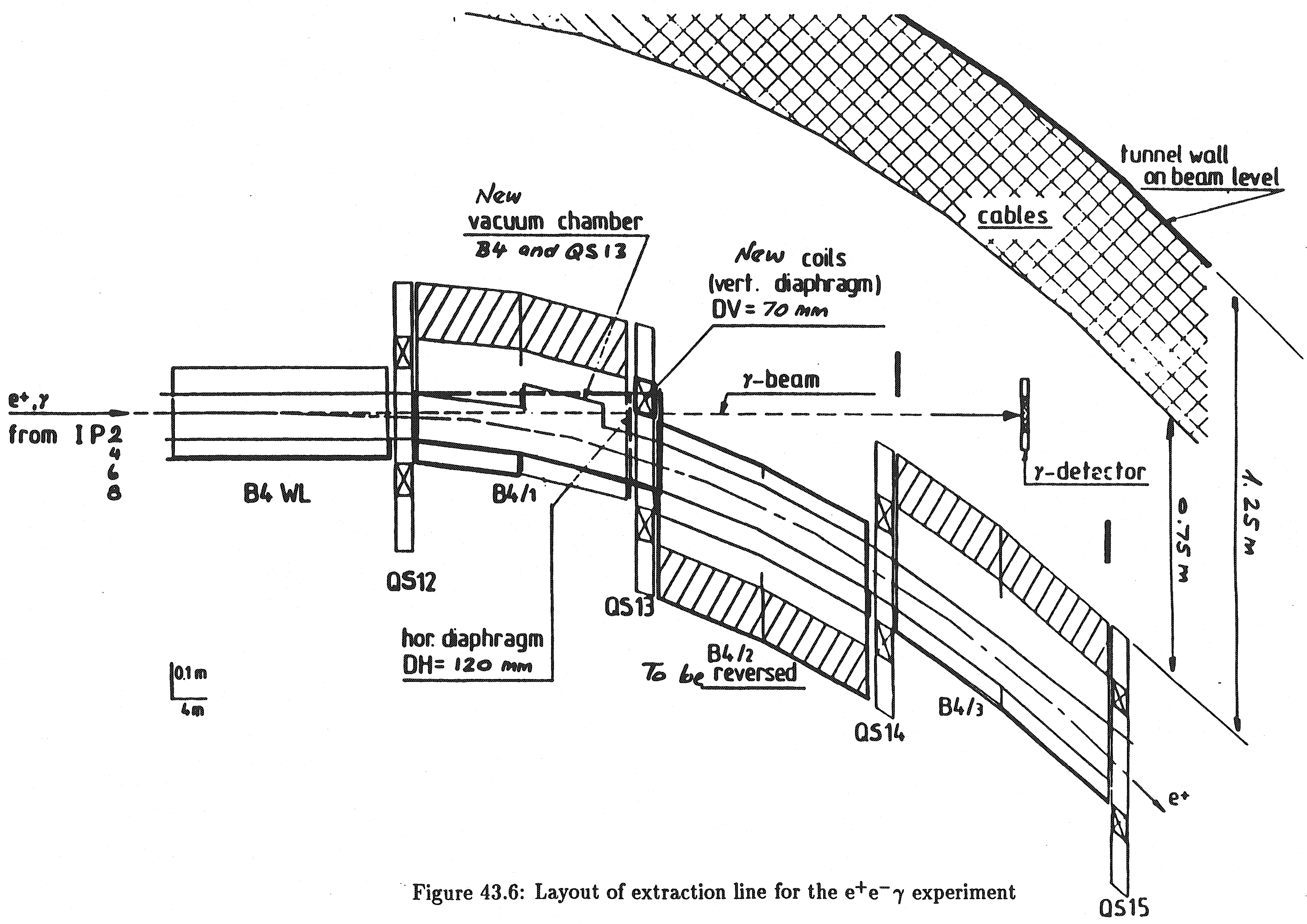
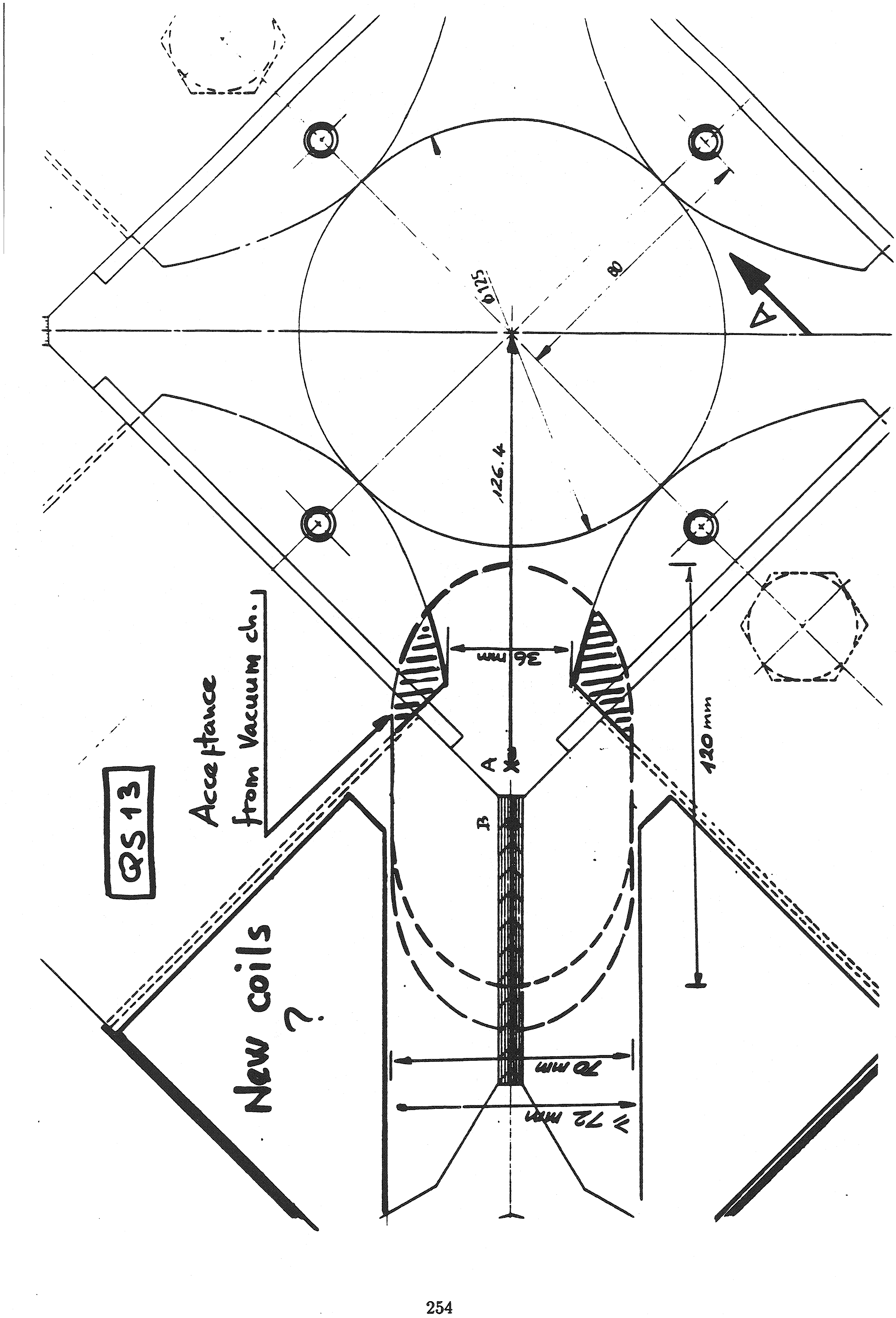


Figure 43.6: Layout of extraction line for the $e^+e^-\gamma$ experiment


QS13
Acceptance from Vacuum ch.
New coils ?
36 mm
120 mm
126.4
ø125
80
A
B
70 mm
≥ 72 mm

"SHOPPING LIST" FOR WINDOWS ON EVEN IP's

Costs listed below are per interaction region (2 γ channels)

	Items	kCHF
1)	New vacuum chamber in B4/1 (2 installed + 1 spare) -> Aperture 70 x 120 mm^2 (end B4/1) centered w.r.t γ's line of flight	350 - 400
2)	QS13 New coils & PS (new Quads??) (two quads in series on same PS)	
	8 coils	80 - 100
	1 PS	100
3)	Reversed B4/2 magnets (one at each side of IP)	
	Modified coil connections (made at CERN)	10
	Total per int. Region	**540 - 600 kCHF**
		400 kCHF, 1 side

Figure 43.8: Estimated expenditure