# 1 Muon trigger system for the DVCS data taking

For the DVCS measurements we aim for a minimum bias trigger, thus it was chosen to use an inclusive trigger system which selects events with a scattered muon with a minimum $Q^2$ of about 0.5 $(\mathrm{GeV}/c)^2$. In a second step, this trigger might be extended to include e.g. the proton recoil detector. For efficiency determination the fully inclusive could then run on a lower rate.
For the inclusive muon trigger we will make use of the existing hodoscope based trigger system for inclusive events which is operated since 2002 at the COMPASS experiment and which was continuously improved during the recent years. A further upgrade is planned for next year's transverse data taking.
Due to the large variation of the counting rates, different trigger systems are being used for different kinematic regions (see fig.1). These parts are:

- the **Ladder trigger** covering low $Q^2$ and high $y$,
- the **Middle trigger** covering intermediate $Q^2$ and low $y$
- the **Outer trigger** covering high $Q^2$ and all $y$
- the **LAS trigger** covering highest $Q^2$ and high $x$ (will be set up for 2010).

Details on the hodoscopes are given in Tab.1 and a sketch of the positions is shown in fig.2.

## 1.1 Ladder trigger

The ladder trigger selects muons with small scattering angles but high energy losses. To achieve this selection, both hodoscopes are located behind the spectrometer magnets bending particles in the horizontal plane. Both hodoscopes consist of short vertical strips. Using a coincidence of the two hodoscope strips, muons with a large deflection in the magnets but a small scattering angle are selected, a so-called energy loss trigger. In the previous years the ladder system had to be combined with a calorimeter trigger to reduce the trigger rate.
For the DVCS running this compromise will not work, thus the ladder sytsem has to make use of the full veto system to reduce the trigger rate. In addition, the more central strips with the highest trigger rates could be excluded from the trigger if necessary as they mainly cover events with $Q^2 < 1$ $(\mathrm{GeV}/c)^2$ *(has to be checked).*

## 1.2 Middle trigger

The middle trigger combines the features of an energy loss trigger using vertical elements with a more standard target pointing trigger in the non-bending vertical direction using a second layer of horizontal strips for each of the two hodoscopes. As it is closer to the beam it reaches lower $y$.

## 1.3 Outer trigger

The outer system consists of a horizontal hodoscope plane at the exit of the second spectrometer magnet and a second one behind the hadron absorber in the SAS to obtain vertical target pointing. It is divided into two halfes to avoid very long strips. It covers all $y$ and large $Q^2$ up to 10 $(\mathrm{GeV}/c)^2$.

## 1.4 LAS trigger

The LAS trigger system will be set up for the 2010 transverse data taking. It consists of the two horizontal hodoscope planes, H1 in front of the RICH and H2 after the first hadron absorber in between the muon wall 1 modules. The second hodoscope is split into two halfes to avoid too long strips. Similar to the outer system it makes use of vertical target pointing. The main purpose of this system is the extension of the muon trigger system to the largest $Q^2$ and high $x_{Bj}$.

Fig.4 shows the event distribution in $Q^2$ and $y$ for the individual trigger systems and the total inclusive acceptance that will be reached with the whole system.

Table 1: The trigger hodoscopes and their main parameters, the last column also indicates whether the strips are read out on one or both ends. The overlaps between neighbouring strips guarantee high trigger efficiency.(*the column with the PM types should be excluded*)

| system | hodoscope | # of strips | width (mm) | overlap (mm) | $z$–Pos. (m) | area ($x \times y$) ($cm^2$) | photomultiplier type |
|---|---|---|---|---|---|---|---|
| inner | H4I (up) | 32 | 6 | 0.6 | 32 | 17.34×32 | 1 × R7400 |
| | H4I (dn) | 32 | 6 | 0.6 | 32 | | 1 × R7400 |
| | H5I (up) | 32 | 12 | 1 | 51 | 35.3×51 | 1 × XP2900 |
| | H5I (dn) | 32 | 12 | 1 | 51 | | 1 × XP2900 |
| ladder | H4L | 32 | 22 – 67 | 1 – 3 | 40.65 | 128.2×40 | 2 × XP2900 2090,2020 |
| | H5L | 32 | 27 – 87 | 1 – 3 | 48.05 | 168.2×47.5 | 2 × XP2900 2090,2020 |
| middle | H4MV (up) | 20 | 62 | 1.5 | 40.3 | 120×102 | 1 × XP2072B |
| | H4MV (dn) | 20 | 62 | 1.5 | 40.3 | | 1 × XP2072B |
| | H4MH | 32 | 21.5 – 25 | 1.5 | 40.4 | | 2 × XP2900 |
| | H5MV (up) | 20 | 77 | 1.5 | 47.7 | 150×120 | 1 × EMI9954B |
| | H5MV (dn) | 20 | 77 | 1.5 | 47.7 | | 1 × EMI9954B |
| | H5MH | 32 | 25 – 30 | 1.5 | 47.8 | | 2 ×XP2900 |
| outer | H3O | 16 | 70 | 5 | 23 | 200×100 | 2 × EMI9813B |
| | H4O | 2×16 | 150 | 10 | 40.0 | 480×225 | 2 × XP2020, EMI9813B |
| LAS | H1 | 32 | 52 | 0 | 8.0 | 160×80 | 2 × XP2900 |
| | H2 | 2×32 | 100 | 10 | 16.0 | 490×400 | 2 × EMI9813B, |

## 1.5 Veto system

Due to the sizeable muon beam emittance and the halo of about 25% (near plus far halo) at 160 GeV beam energy many triggers in the hodoscope systems are caused by muons no interacting in the target. They are being rejected using a system of veto counters in front of the target. It consists mainly of two segmented scintillation counters of roughly 30m diameter upstream of the target with a central hole of about 3 cm leaving the central region around the beam uncovered. They allow to veto tracks with a slope greater than 8 mrad. A third counter, $\mathrm{Veto}_{BL}$, 20 m upstream of the target (not shown in fig.3) allows to reach smaller slopes. The first veto counter is supplemented by additional strips covering an area of about 250 cm × 320 cm to veto also the far muon halo.

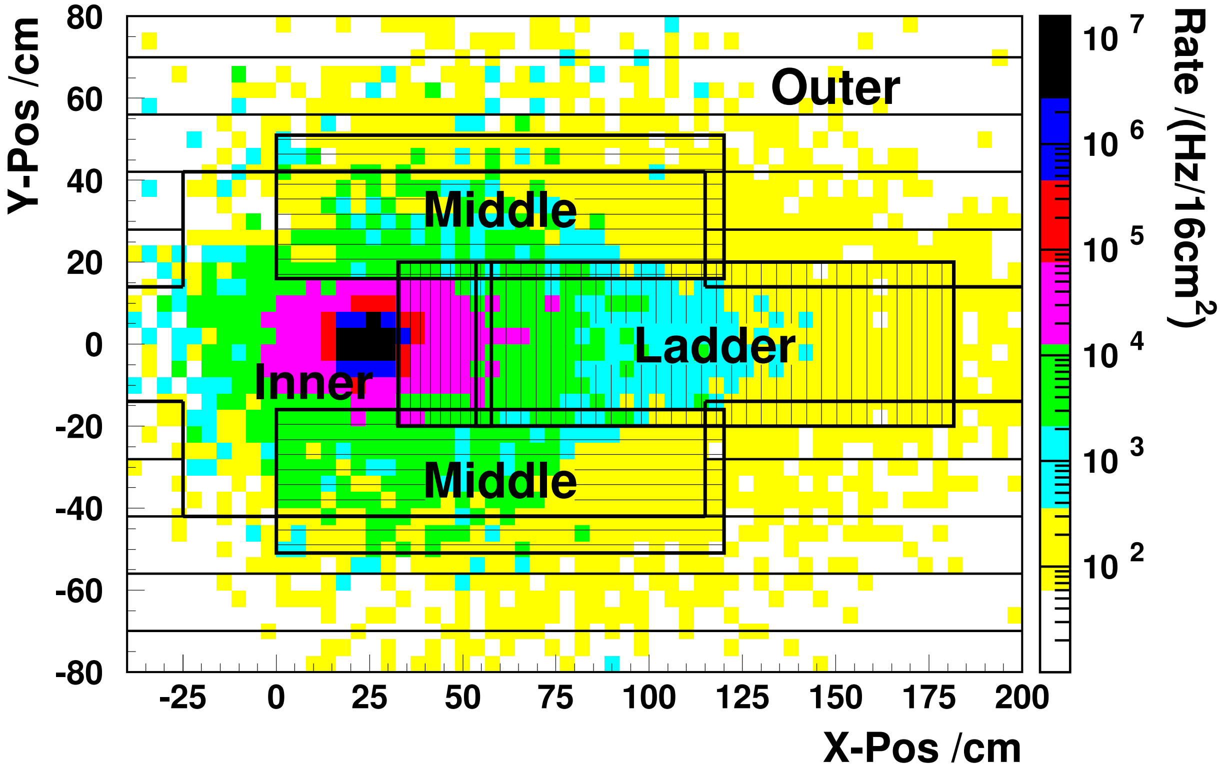



Figure 1: MC-simulation of the muon rates per 16 cm$^2$ and s behind the muon filter 2 ($z = 40$ m). The sizes of the different hodoscope subsystems are indicated.

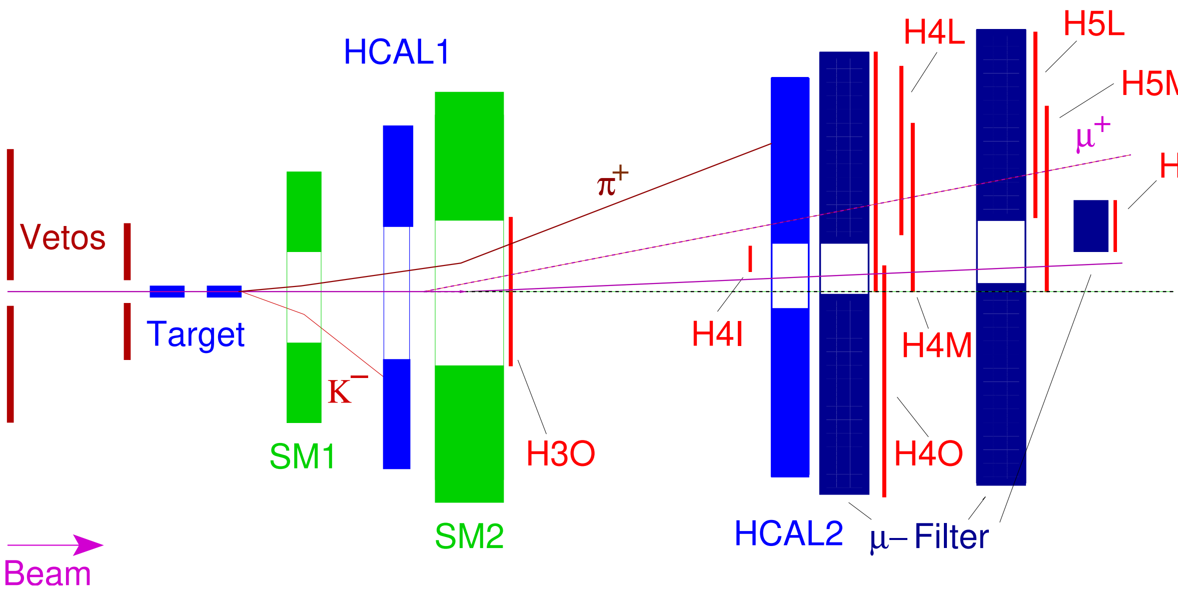
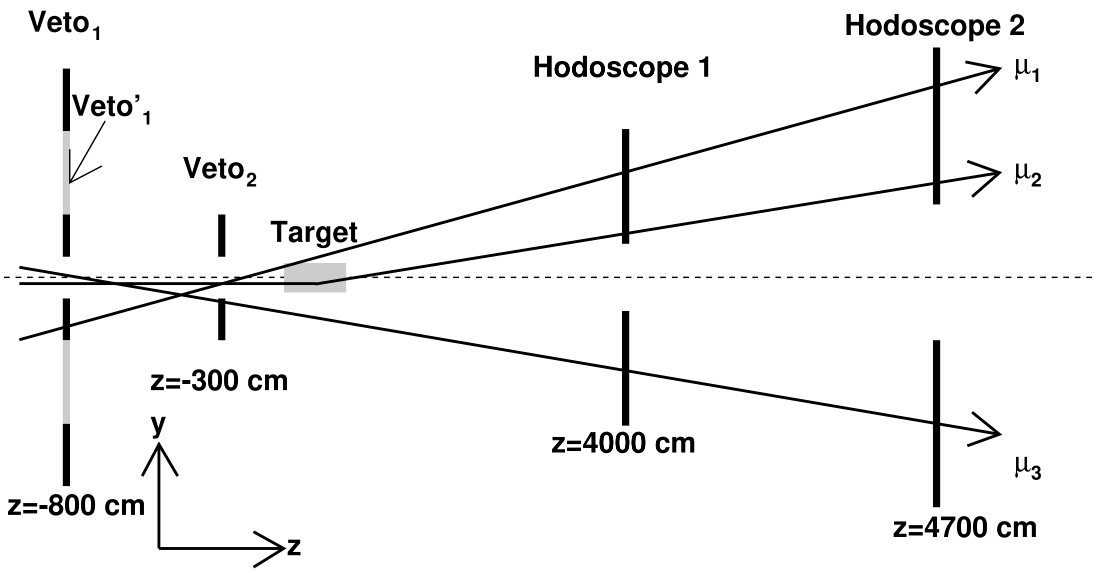



Figure 2: Location of the components relevant for the trigger (schematically) (see also tab. 1).

The drawback of a veto system is the dead time associated to it. The dead time of the full veto system which has to be applied to all inclusive triggers is about 20% at the nominal beam intensity of $2 \cdot 10^8$ muons per 5 s spill. Up now the ladder system was used together with a calorimeter trigger, thus requiring only part of the veto system. For the DVCS data taking the ladder system has to run as an inclusive trigger. The performance of the ladder system under these conditions will be studied in detail during the 2009 DVCS test beam time.
For the future it would be desireable to run with a lower veto dead time, also in view of the possibility to use a 100 GeV muon beam with the associated higher halo. For this a more modular veto system is needed which allows to veto only the regions around the muon causing an inclusive trigger. For this purposes the central veto counters need a higher granularity and coincidence matrices similar to the ones used in the hodoscope system, Here we plan to make use of the new trigger electronics using FPGAs as they are currently developed in Freiburg for the LAS trigger and the recoil detector.




| | Dimensions/ cm | $z$-pos./ cm | no. of elements | dead time/ % | Rate/ MHz |
|---|---|---|---|---|---|
| single Hodoscopes | | | | | |
| Veto$_1$ | 250×320, ∘ 4 | -800 | 34 | 16 | 8.2 |
| Veto'$_1$ | 250×120 ,□ 30×30 | -800 | 24 | 1.7 | 4 |
| Veto$_2$ | 30×30, ∘ 4 | -300 | 4 | 5.9 | 9 |
| V$_{\rm bl}$ | 50×50, □ 10×10 | -2000 | 4 | 1.9 | 4 |
| combinations | | | | | |
| V' = Veto'$_1$ + $V_{\rm bl}$ | | | | 6 | 2.9 |
| V$_{\rm tot}$ =Veto$_1$ + Veto$_2$ + $V_{\rm bl}$ | | | | 21 | 14.7 |

Figure 3: Schematical layout of the veto system. The tracks $\mu_1$ and $\mu_3$ are vetoed, whereas the track $\mu_2$ fulfills the inclusive trigger condition. In column 2 the outer dimensions and the diameters/sizes of the inner holes are given. The symbol ∘ stands for a circular, □ for a quadratic hole. V$_{\rm bl}$ is the additional veto hodoscope placed further upstream in the beam line to veto tracks passing through both holes in Veto$_1$ and Veto$_2$, Veto$_1$' is part of Veto$_1$.

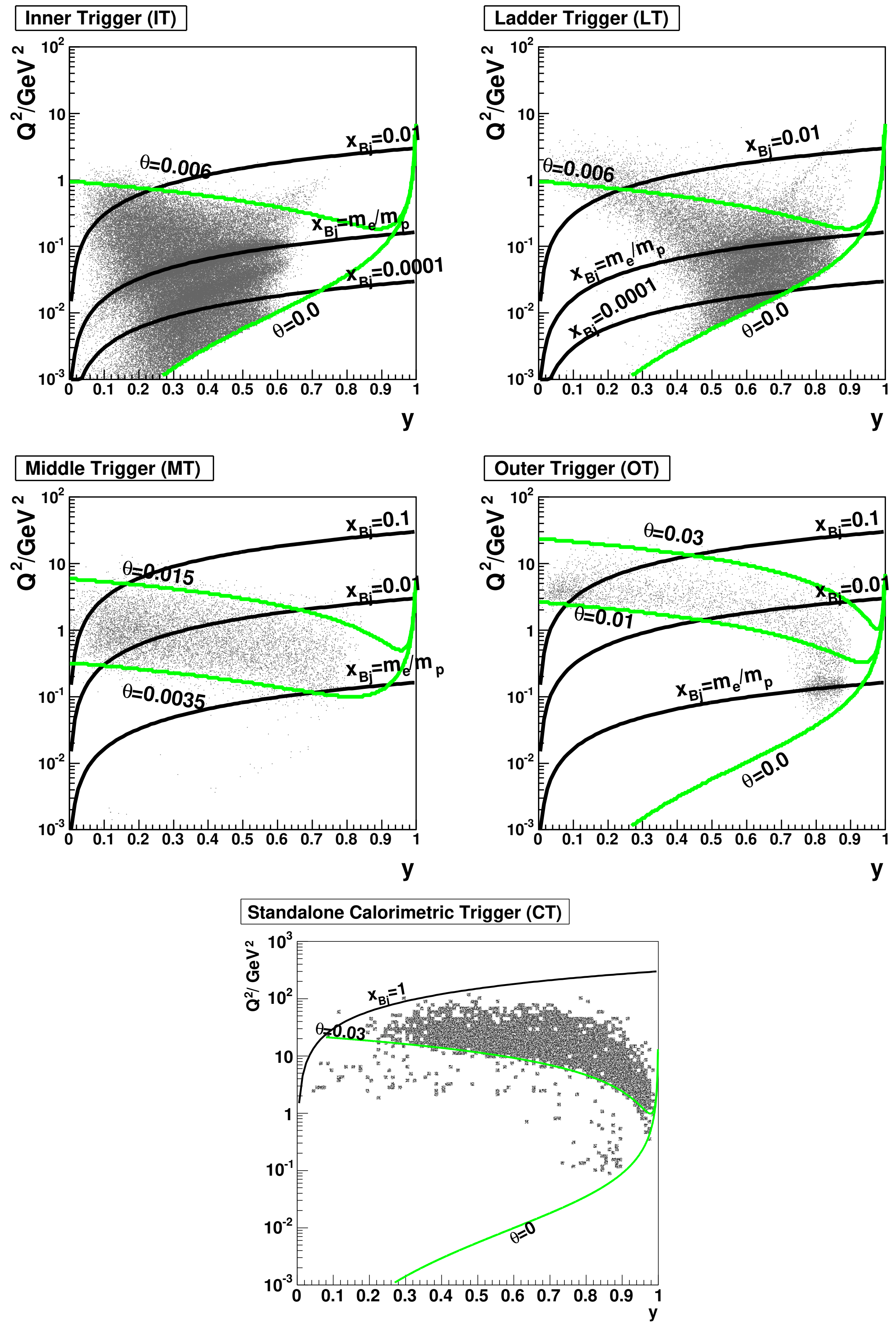



Figure 4: Event distribution in $y$ and $Q^2$ for the four hodoscope trigger subsystems and the standalone calorimetric trigger, $\theta$ is the muon scattering angle in the laboratory system. Here, the inner, ladder and middle trigger were used with calorimeter condition, events with an additional hodoscope trigger were excluded for the calorimetric trigger.