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Physics Processes and the GEM Trigger

Ken McFarlane, Henk Uijterwaal
SSC Laboratory

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This note starts with an overview of the physics processes and their typical signatures that should be accepted by the GEM trigger and the background processes that should be rejected by the trigger. The next section gives an (incomplete) list of the trigger data (the so-called *trigger primitives*) available at the three trigger levels. The signatures of the physics events can be written in terms of the trigger primitives. This has been done for the Level 1 trigger. The result is a list of 12 trigger conditions. A logical "OR" of these conditions will accept all physics processes listed in this note and is a starting point for the study of the physics acceptance and background reduction of the Level 1 trigger system. We used our trigger conditions, as an example, to select $H^0 \rightarrow \gamma\gamma$ and minimum bias events. Our preliminary results show a physics acceptance of $O(90)\%$ and a background reduction to $O(20)$ kHz. These values are close to what one expects from the Level 1 trigger. The appendix of this note contains a calculation of the interaction rate between the proton-beams and the residual gas in the Beam pipe.

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The signatures of the physics events can be written in terms of the trigger primitives. This has been done for the Level 1 trigger. The result is a list of 12 trigger conditions. A logical "OR" of these conditions will accept all physics processes listed in this note and is a starting point for the study of the physics acceptance and background reduction of the Level 1 trigger system. We used our trigger conditions, as an example, to select $H^0 \rightarrow \gamma\gamma$ and minimum bias events. Our preliminary results show a physics acceptance of $\mathcal{O}(90)\%$ and a background reduction to $\mathcal{O}(20)$ kHz. These values are close to what one expects from the Level 1 trigger.

The appendix of this note contains a calculation of the interaction rate between the proton-beams and the residual gas in the Beam pipe.

1 Introduction.

The goal of this document is to give an overview of which physics processes should be accepted or rejected by the GEM-trigger and how this (in principle) can be accomplished.

Section 2 gives an overview of the physics program for GEM, see also [1, 2], and the signatures of the interesting physics events. The second half of section 2 lists the possible non-physics background events and their signatures.

Every physics process can be characterized by one or more typical features or *signatures*. Section 3 lists the signatures and the signals they give in the detector.

Unfortunately, the trigger won't provide us with the signatures but only with so-called *trigger primitives*. There is a many-to-many relation between the event signatures and the trigger primitives. Section 4 lists the primitives that will be provided by the trigger at the 3 trigger levels. The list of primitives is not yet complete: the information for some components is missing and for other components more details have to be provided.

Section 5 contains a first attempt to define Level 1 trigger criteria for the various physics processes in terms of the trigger primitives. Trigger criteria for the higher-level trigger systems still have to be developed.

The next step for the Level 1 trigger is to simulate the trigger system, as well as the detector itself, in a Monte Carlo program and to study the physics acceptance and background rejection of the Level 1 trigger criteria. This document can be used as a starting point for these studies.

We tested our trigger conditions, as an example, on $H^0 \to \gamma\gamma$ and minimum bias background events. Our preliminary results on $H^0 \to \gamma\gamma$ acceptance and minimum bias background reduction are discussed in section 5.1.

2 Physics and background processes.

2.1 Events that should be accepted by the trigger.

The following physics program for GEM can be extracted from [1, 2].

The trigger should accept all (or at least a reasonable fraction) of these events. The acceptance in terms of ϕ, η, particle masses, etc, has to be studied with a Monte Carlo simulation.

2.1.1 Standard Model Higgs.

1. $H^0 \to \gamma\gamma$ ($m_H \approx 80 - 150\ GeV$). The (primary) event signature is a pair of isolated γ's.

2. $t\bar{t} + H^0 \to l\gamma\gamma + X$ ($m_H \approx 80 - 150\ GeV$). These events can be tagged by looking for a pair of γ's plus a lepton.

3. $H^0 \to Z^0Z^0 \to l^+l^-l^+l^-$ or $H^0 \to Z^0Z^* \to l^+l^-l^+l^-$ with $l = e, \mu$ ($m_H \approx 140 - 800\ GeV$). Look for 2 lepton-pairs.

4. $H^0 \to Z^0Z^0 \to l^+l^-$jet jet with $l = e, \mu$ ($m_H \approx 800\ GeV$). Look for a lepton-pair plus 2 jets.

5. $H^0 \to Z^0Z^0 \to l^+l^-\nu\bar{\nu}$ with $l = e, \mu$ ($m_H \approx 800\ GeV$). Look for a lepton-pair plus $\not{E}_T$.

6. $H^0 \to Z^0Z^0 \to l^+l^-\tau^+\tau^-$ with $l = e, \mu$ ($m_H \approx 800\ GeV$). Look for a lepton-pair plus τ-decays (jets or leptons plus $\not{E}_T$).

2.1.2 Extended Standard Model Higgs.

1. H^+H^- production. These events can be recognized by looking for any pair of the $H^\pm$ decays:

- $H^+ \to t\bar{b}$. Look for a t- and b-decay (refer to section 2.1.3).
- $H^+ \to c\bar{s}$. Look for 2 jets.
- $H^+ \to \tau^+\nu_\tau$. Look for a τ-decay (jet or lepton) plus $\not{E}_T$.

2.1.3 Heavy Flavor Physics.

1. $t\bar{t}$-production ($m_t = 140\ GeV$ or $250 - 300\ GeV$) through various production modes and with the following t-decay modes:
   - $t \to W^+b$. Look for a W^+- and b-decay.
     - ◇ $W^+ \to l\nu_l$. Isolated lepton plus $\not{E}_T$.
     - ◇ $b \to$ jet, the jet may include a μ.
   - $t \to H^+b$, $m_{H^+} \approx 150\ GeV$.
     - ◇ $H^+ \to c\bar{s}$. Look for 2 jets.
     - ◇ $H^+ \to \tau^+\nu_\tau$. Look for a τ-decay (jet or lepton) plus $\not{E}_T$.

   The $t\bar{t}$-events can be tagged by looking for any pair of these decay modes. There might be other t-decay modes of interest, these should be included in the trigger as well.

2. Leptoquark pair-production $gg, q\bar{q} \to \pi_{\bar{L}Q}, \pi_{\bar{Q}L}$, with decays to heavy flavors like $\pi_{\bar{L}Q} \to \tau^+b$ or μ^+b. Look for a τ-decay (jet or lepton) or μ and a jet.

3. Technicolor. $gg, q\bar{q} \to \pi_{Q\bar{Q}}\pi_{Q\bar{Q}}$, with technipion decays to heavy quarks: $\pi_{Q\bar{Q}} \to b\bar{b}$, $t\bar{t}$ or $t\bar{b}$.

2.1.4 Jet Physics.

1. Quark substructure from jets with $P_T \gtrsim 4\ TeV$.

2. Color-octet technirho production and similar processes, decays into 2 jets: gg, $q\bar{q} \to \rho_T^8 \to$ jet jet.

3. Technicolor. $gg, q\bar{q} \to \pi_{Q\bar{Q}}\pi_{Q\bar{Q}}$, with technipion decays to light quarks: $\pi_{Q\bar{Q}} \to$ jet jet.

4. $\tilde{g}\tilde{g}$ into jets (this is also an $\not{E}_T$ process).

All these categories of events can be recognized by looking for jets and determining the jet parameters.

2.1.5 Physics at $\mathcal{L} = 10^{34} cm^{-2} s^{-1}$.

1. Quark substructure: $q\overline{q} \rightarrow \mu^+\mu^-$. Look for a muon pair. (Some cuts must be applied to reduce the physics background).
2. Quark substructure: $\overline{q}q' \rightarrow \mu^{\pm}\nu$. Look for a muon pair plus $\not{E}_T$.
3. $Z'^0 \rightarrow l^+l^-$ with $l^{\pm} = e^{\pm}, \mu^{\pm}$. Look for a lepton-pair, apply cuts to reject $Z^0 \rightarrow l^+l^-$.
4. $W'^{\pm} \rightarrow l^{\pm}\nu_l$. With $l^{\pm} = e^{\pm}, \mu^{\pm}$. Look for a isolated lepton and $\not{E}_T$, with a cut to reject $W^{\pm} \rightarrow l^{\pm}\nu_l$.
5. Color singlet $\rho_T^{\pm} \rightarrow Z^0W^{\pm} \rightarrow l^+l^-l^{\pm} + \not{E}_T$. Look for 3 leptons and $\not{E}_T$.
6. Color singlet $\rho_T^{\pm} \rightarrow Z^0W^{\pm} \rightarrow l^+l^-$jet jet. Look for a lepton-pair and 2 jets.

2.1.6 $\not{E}_T$ Physics / Supersymmetry.

1. Events with large $\not{E}_T$.
2. $\tilde{g}\tilde{g}$ via the $\not{E}_T$ signature.
3. Squark detection via the $\not{E}_T$ signature.

2.1.7 Other Physics Processes.

There are more physics processes of interest at the SSC but these are not studied in this note.

2.2 Events that should be rejected by the trigger.

The following categories of events can be considered uninteresting (or non-physics) background and should be rejected by the trigger. There can also be a physics background (an event from one interesting process is misidentified as an event from another physics process) but for the trigger this is not relevant.

1. Minimum Bias (pp at $\sqrt{s} = 40\ TeV$). At a luminosity of $10^{33} cm^{-2} s^{-1}$ each bunch-crossing, regardless whether one of the physics interactions mentioned above occurs, will produce an average of 1.6 minimum bias interactions. The trigger should reject the bunch-crossings that contain *only* minimum bias events, not the bunch-crossings that contain minimum bias *and* physics events.
2. Interactions between the proton beams and the residual gas in the Beam pipe ("Beam-Gas" or pp at $\sqrt{s} = 200\ GeV$). A rough estimate (see appendix A) shows that 1% to 5% of the bunch-crossings will contain a Beam-Gas interaction. Beam-Gas interactions will generally deposit energy around the beam-pipe and affect physics processes at high η-values. This has to be studied in more detail.

3. Beam-Scraping. Interactions between the beam-halo and off-momentum protons and the detector elements close to the beam like quadrupoles, field-shapers, magnets, collimators etc. The rate depends on the quality of the beam and is hard to estimate at this stage. However the effect on physics processes, in particular at high η-values, has to be studied.
4. Cosmic rays. (Mainly cosmic muons traversing the detector through the interaction point).

The trigger rejection for background events has to be studied with a simulation.

3 Overview of event signatures.

Summarizing the previous section in terms of event signatures gives the following list of signatures.

1. γ. An (isolated) γ can be recognized from
   - Energy in a cluster of the EM-calorimeter cells.
   - Little or no energy in the HA-calorimeter cells behind the EM-calorimeter cells. $(E_{HA} \leq x\% \times E_{EC})$.
   - Little or no energy in the neighbouring calorimeter cells.
   - No track pointing to the cluster of EM-calorimeter cells.
2. $e^{\pm}$. Electrons and positrons can be recognized by looking at:
   - Energy in a cluster of the EM-calorimeter cells.
   - Little or no energy in the HA-calorimeter cells behind the EM-calorimeter cells. $(E_{HA} \leq x\% \times E_{EC})$.
   - Little or no energy in the neighbouring calorimeter cells.
   - A track pointing to the cluster of EM-calorimeter cells.
3. $\mu^{\pm}$. Muons can be recognized by looking at:
   - A track in the CT pointing to
   - a track in the MUon system and
   - energy consistent with a Minimum Ionizing Particle (MIP) in the calorimeter.
4. Jet. Jets can be recognized by looking at:
   - Energy in a cluster of EM- and HA-calorimeter cells. The cluster radius and energy should be consistent.
   - Little or no energy in the neighbouring cells.

- Tracks pointing to the cluster.

5. ν_l, $\overline{\nu_l}$. Neutrinos can be detected by looking for $\not{E}_T$.

6. $\not{E}_T$. The vector sum of calorimeter energy deposits. $\not{E}_T$ can be determined by looping of all calorimeter cells or from the jet-, electron- and photon-cluster energies and positions.

7. $\gamma\gamma$-pair. Any pair of 2 γ's.

8. e^-e^+-pair. A pair of 2 e's with opposite charge.

9. $\mu^+\mu^-$-pair. A pair of 2 μ's with opposite charge.

The trigger should not only find these signatures, especially at the higher trigger levels it should also determine the parameters of the signatures like: position (in (η, ϕ)), energy, charge, invariant mass of pairs of particles, ... before cuts on the various quantities can be made.

Not mentioned in the list of physics processes is:

1. E_T. If $\not{E}_T$ cannot be calculated online, an E_T-cut might be an alternative. (Besides that: an E_T-cut might be useful to reject minimum bias events with little or no energy outside the beam-pipe region).

Possible veto-signals are (data cannot be from physics-events if one of these veto-conditions is fulfilled).

1. Vertex position of a track outside the interaction region.

2. Timing of the signals incompatible with the beam-crossing structure. *This assumes that the electronics at some trigger level can assign the event to a particular bunch-crossing.* However, if the timing of the signals is available, it can be a very powerful cut for rejecting cosmics and Beam-Gas interactions.

4 Trigger primitives.

At present the following trigger primitives are foreseen. For some of the components the information is still missing and for other components the trigger primitives should be defined in more detail.

The current version of the trigger simulation of the Monte Carlo program `gemfast` [3] calculates the trigger primitives for the digital version of the calorimeter level 1 trigger, the level 1 trigger primitives for the other components and the calorimeter level 2 electron/γ trigger.

4.1 Level 1 trigger.

1. Central Tracker (CT). The CT will presumable not participate in the Level 1 trigger.
2. Electromagnetic Calorimeter (EC).
   - Number of "EM-Trigger Towers" (areas of $\approx 0.16 \times 0.16$ in (η, ϕ)) with:
     (a) Most energy in the electromagnetic section of the calorimeter. In the digital (processor) option for the calorimeter level 1 trigger [4], this can be implemented as: $(0.1 \times E_{T,EC} > E_{T,HC})$. In the analog option for the calorimeter level 1 trigger [5], a slightly different condition has to be used.
     (b) Isolated from other energy deposits in the calorimeter. In case of the digital processor option for the calorimeter level 1 trigger: Sum of E_T in 8 neighbouring cells minus the E_T in the neighbouring cell with the highest energy less than 7.5 GeV). A slightly different isolation condition has to be used in the analog calorimeter level 1 trigger.

     Threshold values are currently 8.0, 16.0, 50.0 and 80.0 GeV (but this is programmable and still open for discussion). The trigger towers consist of 6×6 EM-cells in the barrel region. In the endcap regions, areas of roughly the same size in (η, ϕ) will be defined. Because the cells are larger in this region, these trigger towers contain less cells than the ones in the barrel region.
   - Position (in (η,ϕ)) and E_T of the 4 towers with the highest E_T.
   - Global sums like E_T, $\not{E}_T$, P_X, P_Y.
3. Hadronic Calorimeter (HC).
   - Global sums like E_T, $\not{E}_T$, P_X, P_Y.
4. Electromagnetic and Hadronic Calorimeter combined (CA).
   - Position (in (η,ϕ)) and E_T of the 4 "CA-trigger towers" with the highest E_T. The trigger towers correspond to non-overlapping areas of $\approx 0.64 \times 0.64$ in (η, ϕ) (or 24×24 EM-cells in the barrel region) for the analog calorimeter level 1 trigger design or overlapping areas of $\approx 0.48 \times 0.48$ in (η, ϕ) (or 18×18 EM-cells in the barrel region) for the digital calorimeter level 1 trigger design. These towers can be identified with jets.

     If the electromagnetic section of a trigger-tower is already identified as an isolated electron or γ, the tower is not included in the list of CA-trigger towers.
   - The number of "CA-trigger towers" above programmable thresholds. Overlapping towers (a jet spread out over two or more trigger-towers) are only counted once.
   - Global sums like E_T, $\not{E}_T$, P_X, P_Y.
5. Scintillating Calorimeter. At the moment it is not known whether the scintillating calorimeter will participate in the trigger or not.

6. Forward Calorimeter (FC).

   - P_X and P_Y for $\not{E}_T$ measurement.

7. Muon system (MU).

   - Number of tracks in the muon chambers above a P_T-threshold. Several threshold values are being considered 10, 20 GeV/c and some value high enough (30 GeV/c?) so that a single muon trigger can work at $\mathcal{L} = 10^{34}\ cm^{-2}s^{-1}$ [6].

4.2 Level 2 trigger.

1. Central Tracker (CT).

   - The highest momentum tracks.

2. Electromagnetic Calorimeter (EC).

   - Isolated electrons and γ's. The algorithm calculates the E_T-sum in all possible towers of 3×3 and 5×5 EM-cells and then selects the towers with:

     (a) $\frac{\sum_{3\times3\ cells}}{\sum_{5\times5\ cells}} > 0.9$ and

     (b) $\sum_{3\times3\ cells} >$ threshold.

     There are 4 thresholds. The number of towers above each threshold is counted. Threshold values are currently 8.0, 16.0, 50.0 and 80.0 GeV (but this is programmable).

   - Position and energy of the 4 electrons or γ's with the highest energy.

3. Electromagnetic and Hadronic Calorimeter combined (CA).

   - Jets. A jet finding algorithm is currently being tested [7].

4. Scintillating Calorimeter. At the moment it is not known whether the scintillating calorimeter will participate in the trigger or not.

5. Forward Calorimeter (FC).

   - Level 2 trigger primitives for the FC have not yet been defined.

6. Muon system (MU).

   - Momentum of the muons found in L1.

4.3 Level 3 trigger.

At level 3 it is expected that the full event data is available for triggering. No special trigger primitives are foreseen.

5 Relation between the trigger primitives and event signatures.

This section defines trigger criteria in terms of the trigger primitives listed in the previous section for the *Level 1 trigger*. Trigger criteria for the higher level triggers have not yet been defined.

The (boolean) primitives are denoted by the following symbols (see section 4.1).

E_X = (E_T in an EM trigger tower is >X).

H_Y = (E_T in a calorimeter trigger tower >Y).

M_P = (p_T of muon >P).

P_W = (Vector sum of $\not{E}_T > W$). W is of order of 100 GeV.

T_n = (No. of tracks in some $\Delta\phi\Delta\eta$ 'tower' of the central tracker is >n).

The primitives E_X, H_Y and T_n (if such a quantity is created) exist for the η and ϕ coverage of the calorimeter and tracker, so that these are many such quantities (an array of each) corresponding to the segmentation of the detectors in the trigger electronics. One could then denote a neutral EM trigger as $(E_{X,i} \wedge T_{0,i})$, where i denotes a 'tower' or segment in η and ϕ.

Referring to the numbers of the reactions in section 2, we have the list of suggested triggers given in table 1. Note that many of the thresholds suggested are tentative.

The global level 1 trigger decision could be the logical "OR" of the triggers given in table 1. However, there is some overlap between the triggers. If we remove the overlapping trigger modes, the list of trigger from table 1 can be reduced to a shorter list given in table 2. Again, the thresholds are just suggestions.

A logical "OR" of the 12 triggers from table 2 will accept all physics processes listed in section 2. Both lists of triggers have been coded into Fortran and are included in the trigger simulation for the Monte Carlo Program `gemfast`.

Some other open questions that should be answered with a simulation are:

- Do we need a special τ trigger. And if so, how should this trigger be implemented? A possibility is a trigger on a low multiplicity hadronic jet.
- Should some triggers be restricted to the barrel or the endcap?
- Are there triggers which should use the tracker at Level 1?

Reaction No	Reaction	Trigger/Comment
0.1	single W	trigger on most W to lepton.
		$(E_{16} \vee M_{10} \vee H_{16}) \wedge P_{50}$
0.2	single Z	trigger on most Z to 2 leptons.
		$(2 \text{ of} E_{16}) \vee (2 \text{ of} M_{10}) \vee ((2 \text{ of } (E_{16} \vee M_{10} \vee H_{16})) \wedge P_{50})$
Higgs		
1.1	$H^0 \rightarrow \gamma\gamma$	$(2 \text{ of} E_{16}) \vee E_{50}$
1.2	$t\bar{t} + H^0$	$(2 \text{ of} E_{16}) \wedge (3rd\ E_{16} \vee M_{10})$
1.3	$H^0 \rightarrow 4l$	$(4 \text{ of} M_{10}) \vee ((2 \text{ of} E_{16}) \wedge (2 \text{ of} M_{10})) \vee (4 \text{ of} E_{16})$
1.4	$H^0 \rightarrow 2l$ 2jets	$((2 \text{ of} E_{16}) \vee (2 \text{ of} M_{10})) \wedge (2 \text{ of} H_{16})$
1.5	$H^0 \rightarrow 2l2\nu$	$((2 \text{ of} E_{16}) \vee (2 \text{ of} M_{10})) \wedge P_{100}$
1.6	$H^0 \rightarrow 2l2\tau$	$((2 \text{ of} E_{16}) \vee (2 \text{ of} M_{10})) \wedge ((2 \text{ of } (E_{16} \vee M_{10} \vee H_{16})) \wedge P_{50})$
Extended Higgs		
Heavy Flavor Physics		
3.1	$t\bar{t} \rightarrow W^+b$	$(E_{50} \vee M_{30})$
	$t\bar{t} \rightarrow H^+b$	$(E_{50} \vee M_{30} \vee (4 \text{ of} H_{50}))$
3.2	Leptoquark	$(4 \text{ of} H_{50}) \vee ((M_{10} \vee E_{16}) \wedge (3 \text{ of} H_{50})) \vee (((2 \text{ of} E_{16}) \vee$
		$(2 \text{ of} M_{10})) \wedge (2 \text{ of} H_{50}))$
3.3	Technicolor	$(4 \text{ of} H_{50})$
Jet Physics		
4.1	Quark substructure	H_{80}
4.2	Technirho	$(3.1) \vee ((2 \text{ of} H_{50}) \wedge M_{10})$
4.3	Technicolor	(4.2)
Physics at high Luminosity		
5.1	Quark substructure	$(2 \text{ of} E_{80}) \vee (2 \text{ of} M_{20})$
5.2	Quark substructure	$M_{40} \vee E_{80}$
5.3	Z'^0	(5.1)
5.4	$W'^{\pm}$	$(E_{80} \vee M_{40}) \wedge P_{100}$
5.5	$\rho_T^{\pm}$	$(3 \text{ of } (E_{80} \vee M_{40})) \wedge P_{100}$
5.6	$\rho_T^{\pm}$	(1.4)
$\not{E}_T$ Physics – Supersymmetry		
6.1	$\not{E}_T$	P_{100}
6.2	$\tilde{g}\tilde{g}$	$P_{100} \vee (3 \text{ of} H_{80})$
6.3	$\tilde{q}\tilde{q}$	(6.2)

Table 1: List of suggested Level 1 trigger criteria for the physics processes listed in section 2. The symbols E_X, H_Y, M_P, P_W and T_n are defined in section 5. The logic symbols used are: $\sim$ (not), $\wedge$ (and), $\vee$ (or) and $\underline{\vee}$ (exclusive or).

No.	Trigger	Comment
1	H_{80}	High P_T-jet.
2	(4 of H_{50})	Multi jet event.
3	E_{50}	High P_T electron or γ.
4	M_{30}	High P_T μ.
5	(2 of E_{16})	Two electrons or γ's.
6	(2 of M_{10})	Two μ's.
7	P_{100}	$\not{E}_T$
8	$E_{16} \wedge P_{50}$	Electron and $\not{E}_T$ ($W^\pm$, τ)
9	$M_{10} \wedge P_{50}$	Muon and $\not{E}_T$ ($W^\pm$, τ)
10	$H_{16} \wedge P_{50}$	Tau and $\not{E}_T$
11	$M_{10} \wedge$ (3 of H_{50})	Muon and 3 jets.
12	$E_{16} \wedge$ (3 of H_{50})	Electron and 3 jets.

Table 2: Reduced list of suggested Level 1 trigger criteria. A logical "OR" of these criteria will accept all physics processes listed in section 2. The same notation as in table 1 has been used.

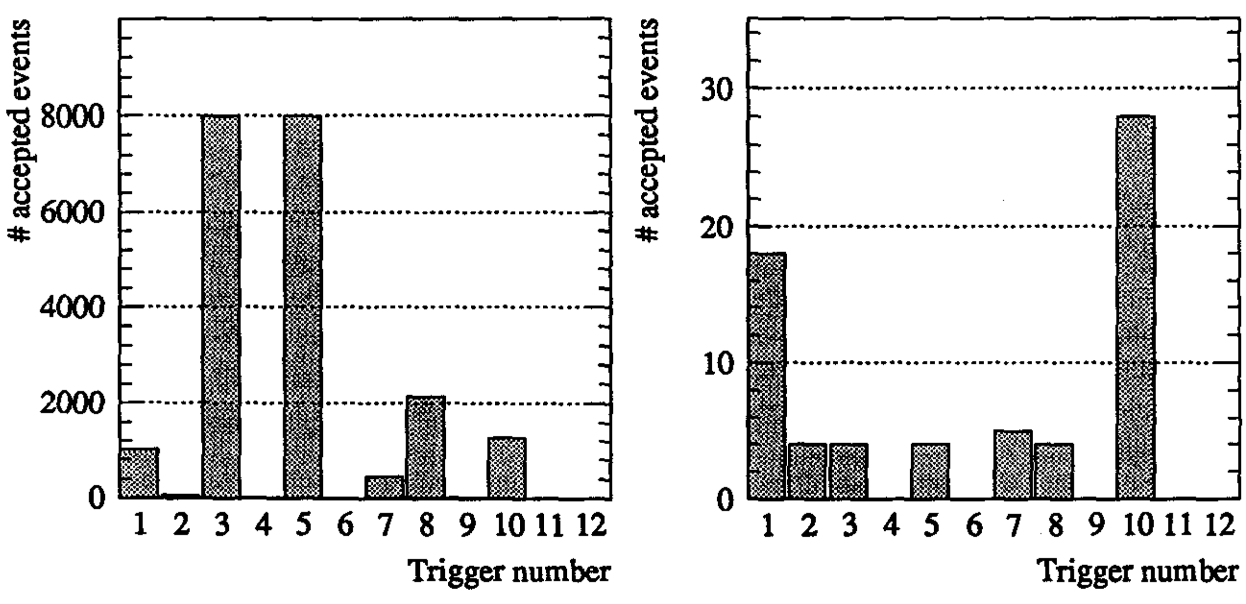

Figure 1: Number of accepted events by each of the 12 trigger modes from table 2 for $H^0 \to \gamma\gamma$ (left hand plot) and minimum bias (right hand plot).

Process	m_H	# Events Generated	Accepted	Efficiency
$H^0 \to \gamma\gamma$	80 GeV	10000	7566	75.66%
$H^0 \to \gamma\gamma$	110 GeV	10000	8811	88.11%
$H^0 \to \gamma\gamma$	140 GeV	10000	9464	94.64%
Minimum bias only	–	100000	38	–

Table 3: Total trigger efficiencies for the $H^0 \to \gamma\gamma$ and minimum bias events for the logical "OR" of the 12 triggers presented in table 2.

5.1 A first look at trigger efficiencies.

We used the trigger criteria from table 2 to select $H^0 \to \gamma\gamma$ and minimum bias background events.

The standard `gemfast` setup, with two `Pythia` event generators to generate the signal and minimum bias events for each bunch crossing, was used to generate two samples of detector output: one for 10000 $H^0 \to \gamma\gamma$ events and one for 100000 events with only minimum bias interactions. For $H^0 \to \gamma\gamma$, the η-range of the two γ's was limited to ± 3, the geometrical acceptance of the detector.

The `gemfast` output for each event was fed into the trigger simulation and the number of accepted events by at least one of the 12 trigger criteria was counted. The results are listed in table 3. For $H^0 \to \gamma\gamma$ both γ's are within the acceptance of the detector so dividing the number of accepted events by the number of generated events gives the trigger efficiency. The minimum bias reduction corresponds to a reduction of the event-rate from 60 MHz to 23 kHz.

The number of events accepted by each individual trigger condition is plotted in figure 1. This figure shows clearly that most of the $H^0 \to \gamma\gamma$ events are accepted by the EM-triggers #3 and #5. These are, see table 1, the two trigger criteria intended for this process.

The same figure also shows the distribution for the events from the minimum bias sample which survive. Most of the events are accepted by either trigger condition #1, a high P_T jet, or #10, a $\tau^\pm$ decaying to a $\pi^\pm$ and neutrinos. Since the physics events only contain τ-pairs, the background reduction might be improved by replacing this trigger by a τ-pair trigger instead of single τ-trigger.

This example shows that our trigger criteria have an acceptance for $H^0 \to \gamma\gamma$ of $\mathcal{O}(90)$% and reduce the background to $\mathcal{O}(20)$ kHz. These values are close to what one would expect from the Level 1 trigger: acceptance $\gtrsim$ 95% and background reduction to 10 kHz.

Work is in progress to study the efficiency for more physics processes and improve the background reduction. Both subjects will be discussed in more detail in a next note.

References

[1] B. Barish; "Responses to the December 1991 PAC report", GEM TN–92–131.

[2] K. Lane; "Outline of GEM TDR Chapter 2", December 1992.

[3] T. Skwarnicki; `gemfast`, fast simulation of the GEM-detector, version 1.02.
H. Uijterwaal; `libtrf`, trigger simulation for `gemfast`, version 1.01.

[4] D. Crosetto; GEM TN–92–248.

[5] B. Cleland; Results presented at the Electronics and DAQ meeting at SSCL, February 1993.

[6] P. Dingus; Private communication.

[7] H. Uijterwaal; Results presented at the Calorimeter Simulation Workshop at SSCL, December 1992.

[8] H. Uijterwaal; Ph.D.Thesis, University of Amsterdam, 1992.

A An estimate of the Beam-Gas interaction rate.

The number of interactions between one of the proton-beams and the residual gas in the beam-pipe (dN) per unit of length (dL) and time (dt) can be written as [8]:

$$\frac{d^2N}{dL\,dt} = F\,\frac{\rho}{M}\,N_A\,\sigma \tag{1}$$

F is the incoming proton flux. ρ is the density of the rest-gas, M its molecular weight and $N_A = 6 \times 10^{23} mol^{-1}$ is Avogadro's number. σ is the cross-section for proton-gas molecule interactions.

The flux of incoming protons F is equal to:

$$F = \frac{N_p}{\left(\frac{R_{SSC}}{c}\right)} = 6 \times 10^{17} s^{-1} \tag{2}$$

N_p is the number of protons stored in the ring, the SSC design value is $\approx$ 17500 bunches with 10^{10} protons per bunch. R_{SSC} is the circumference of the ring.

The mass-density per molecule of rest-gas (ρ/M) can be calculated from:

$$\frac{\rho}{M} = \frac{mp}{MkT} \tag{3}$$

With k Boltzman's constant. T the temperature of the warm beam-pipe (300 K). The molecule mass m equals Mm_p, with m_p the proton mass. The pressure in the beam-pipe is a function of z and fluctuates between 5×10^{-9} and 10^{-7} $torr$, here the average (5×10^{-8} $torr$) of these two extremes is used. Substituting all these values gives:

$$\frac{\rho}{M} = 2.74 \times 10^{-9} \frac{g}{m^3} \tag{4}$$

The proton-gas molecule cross-section is equal to:

$$\sigma = A^{\frac{2}{3}} \sigma^{pN} \tag{5}$$

With A the atomic number of the gas molecules and σ^{pN} the cross-section for proton-nucleon interactions. This cross-section, at $E_{cms} = 200\ GeV$, is taken to be equal to:

$$\sigma^{pN} = 50\ mb = 5 \times 10^{-30}\ m^2 \tag{6}$$

If the rest-gas is a mixture of gasses, in (5) the average over the different molecules has to be taken. Formula (5) then has to be extended to:

$$\overline{\sigma} = \sum n_i \sigma_i = \sum n_i A_i^{\frac{2}{3}} \sigma^{pN} = \sigma^{pN} \sum n_i A_i^{\frac{2}{3}} \tag{7}$$

With n_i the fraction of atoms with an atomic number A_i in the rest-gas.

Substituting all this into (1) leads to:

$$\frac{d^2N}{dL\,dt} \approx 5\,\frac{kHz}{m} \tag{8}$$

If the rest-gas consists of only a light gas like H_2 or

$$\frac{d^2N}{dL\,dt} \approx 18\,\frac{kHz}{m} \tag{9}$$

If the rest-gas consists of a mixture of 90% H_2 and 10% of heavier gasses like CO_2, O_2 or CO.

This rate has to be multiplied by the length of the warm beam-pipe (35 m to each side of the interaction point) and a factor 2 (as there are 2 proton beams). This gives, depending on the rest-gas composition, rates between:

$$\frac{dN}{dt} \approx 0.7\,MHz \tag{10}$$

and

$$\frac{dN}{dt} \approx 2.5\,MHz \tag{11}$$

Given the bunch-crossing rate of 60 MHz, between 1% and 5% of the bunch-crossings will contain a Beam-Gas interaction.