A Fast Triple-GEM Detector for High-Rate Charged-Particle Triggering

G. Bencivenni1, W. Bonivento2, C. Bosio3, G. Cardini4, G. Felici5, A. Lai6, F. Murta7, D. Pinc1, B. Saltatt8, L. Satta9 and P. Valente1

(1) Laboratori Nazionali di Frascati - INFN, Frascati, Italy (2) Sezione INFN di Cagliari - Cagliari, Italy (3) Università degli Studi di Cagliari, Italy (4) Sezione INFN di Roma I, Italy (5) CERN EP Division, Geneva, Switzerland

9th Vienna Conference on Instrumentation, Vienna, Austria, February 19 - 23, 2003

Abstract

Detectors made of three cascaded Gas Electron Multiplier with pad readout have been tested at the CERN PS TII Hadron Beam Facility. A time distribution RMS of 6 ns has been obtained with an Ar/CO2/CF4 mixture, achieving a substantial improvement with respect to Ar/CO2/CF4 mixture, where an RMS of 10 ns was obtained. This resulted in an efficiency of about 96% in a 25 ns time window, suggesting that these detectors could be interesting devices for triggering at the typical LHC interaction rate.

GEM: Principle of Operation

A Gas Electron Multiplier (GEM) is a thin (50 µm) kapton foil, copper clad on each side, perforated by a high density of holes acting as electron multipliers in the gas where the GEM is immersed in a gas mixture.

Typical holes are one of the smallest dimensions of 70 µm, internal at 50 µm and a pitch of 140 µm. Voltages of 400-600 V are applied between the two copper sides, giving fields of 1000-1500V/cm into the holes, resulting in a GEM electron gain of 20-30.

Very high rate capability (up to 1 kHz/cm2) and low noise (0 to 3 MeV) have been measured in other groups with these detectors, when operating under Ar/CO2/CF4.

Time Performances

The intrinsic time spread of a GEM based detector is given by T ∝ √P, where P is the number of clusters per unit length and v is the drift velocity of the drifts, which is typically about 1 km/s.

To achieve a good time resolution, both field and gas mixtures are required. Indeed, a GEM is an efficient detector for primary electron electronics, as the time resolution is determined by the time走了 to the first GEM, which dominates the time resolution. To reduce this effect it is important to adjust the electric field to maximize the GEM gain, as explained in the following section.

- The efficiency of detecting primary electrons into the holes, which decreases more rapidly than the intrinsic time of the electric field, because the defocusing of the field lines (some electrons could hit the GEM anode)
- The electron multiplication into the holes, which increases exponentially with the voltage applied to the GEM.

- The high rate capability: high gain (up to 1 kHz/cm2) and low noise (0 to 3 MeV) have been measured in other groups with these detectors, when operating under Ar/CO2/CF4.

Detector Prototypes and Test Setup

The tests were performed with a GEM consisting of three cascaded gas mixtures, which have a high yield (CO2:40% in 3 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

Gas Mixtures

Ar/CO2/CF4 at 30% to STP

The detector efficiency in the gas mixtures was tested with a gas mixture, which has a high yield (CO2:40% in 3 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

Fields Optimisation

A scan at 687 V/cm was performed with the purpose of maximizing the detector efficiency as a function of the electric field.

Ar/CO2/CF4 at 30% to STP

The detector efficiency in the gas mixtures was tested with a gas mixture, which has a high yield (CO2:40% in 3 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

V_gem Optimisation Ar/CO2/CF4 (60/20/20)

As in the previous case we kept the second and third GEMs at modern values of 2700 V.

The detector efficiency in the gas mixtures was tested with a gas mixture, which has a high yield (CO2:40% in 3 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

Time Distributions

These are the time distributions for the Ar/CO2/CF4 gas mixtures, which have a high yield (CO2:40% in 5 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

V_gem Optimisation Ar/CO2/CF4 (60/20/20)

The detector efficiency in the gas mixtures was tested with a gas mixture, which has a high yield (CO2:40% in 5 M/s) and a good electron drift velocity (600 V/cm at 3 M/s).

Future Tests and Developments

Tests to be performed during 2003

- High intensity (1 MHz/cm²) hadron beam test at PSI to study the detector behavior (and improve the energy resolution) when using fast C6 detection at low intensity
- Tests with high intensity X-ray source: the plan is to integrate about 5 C6/cm²
- Fast timing to improve GEM detector time performances

Conclusions

Triple-GEM detector prototypes equipped with pad readout and supplied with a gas mixture of Ar/CO2/CF4 (60/20/20) at STP have shown very good time performances, resulting in a time distribution RMS of 6 ns and an efficiency of 96% in a 25 ns time window. Studies aiming to investigate the stability of these detectors under high charged-particle rate and their ageing properties are in progress. A fine tuning of gas mixtures, electric field configuration and detector geometry might allow additional improvements on the time resolution.