Test beam results of the precision gaseous detectors for the LHCb inner tracker

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Talk summary

- Requirements for the LHCb inner tracker
- Microwire detector
- Micromegas detector
- Triple GEM detector
- Conclusion

LHCb spectrometer

- LHCb has a 10 tracking stations spectrometer
 - * Each station is able to determine an accurate track space point
 - * Each station is divided in an outer part with relatively low particle density and an inner part with finer granularity

LHCb inner tracker

- The LHCb Inner Tracker
 - * Covers an area of $60 \times 40 \text{ cm}^2$ around the beam pipe
 - * Has a rate capability up to 50 KHz/mm^2
 - * About 100 MHz hadron in each stations (mostly from target)
 - * About three times more electrons (mostly from beam pipe)
 - * Needs to be as thin as possible
 - * The occupancy should be kept below a few %
 - * A spatial resolution below $100 \mu\text{m}$ is enough
 - * Two bunches crossing time resolution
- Many technologies have been proposed
 - * All have been tested with X-rays and have the rate capability
 - * All suffer from a severe gas amplification limit due to discharges occurring in hadron environment

Microwire detector

- The micro slit gas detector. NIM A430(1999)54
- It is made by etching out of a simple kapton foil 50 μm in thickness and metallized on both faces with 5 μm copper
- It can be very thin only 0.037% of a radiation length
- A $10 \times 10\text{cm}^2$ prototype has been constructed and tested at PSI in a low energy pion beam
- The detector is completed by a drift electrode located at 3 mm on the mesh side

- Electric field configuration for one cell perpendicular to the anode direction

Results

- For this test anode strips were grouped on a width of 12 mm and coupled to a single amplifier
- MIP Landau distributions (gains of 15000, 10000 and 8100)

- Time resolution better than 21 ns
- Spark probabilities of 2×10^{-8} (gain 1400) and 1.1×10^{-6} (gain 4400)
- The detector was exposed for 9 hours in a 20 KHz/mm^2 beam (charge of 0.15C in 12cm^2) and no damages have been observed

Micromegas

- NIM A376 (1996) 29
- A $15 \times 15 \text{ cm}^2$ detector has been tested at PSI in a low energy hadron beam and at CERN PS with $10 \text{ GeV}/c \pi^+$
 - * $100 \mu\text{m}$ amplification gap, $317 \mu\text{m}$ strip pitch

- At PSI a very high discharge probability per particle was observed
 - * With $\text{Ar} - \text{CO}_2$ (60-40) at a gain of 6000 $P = 1.1 \times 10^{-5}$
 - * With $50 \text{ KHz}/\text{mm}^2$ proton beam the sparking rate was as high as 3 KHz and the current was 2 mA
- No damage to the chamber has been observed

Discharges study with α

- A small prototype was built with 8 mm diameter anode
 - * The amount of charge released in the conversion gap is precisely controlled
 - * The number of incident α can be counted at low gain

- * The discharge limit does not depend very much on the noble gas but isobutane gives better results than CO_2
- * Higher limits are obtained with less quencher
- * The question of the optimum gap is under study

Effect of spark to aging

- 5.5 millions sparks at a rate of 40 Hz in 16mm^2
- Average charge 26 nC ($1.6 \cdot 10^{11}$ e or 10^6 MIP at a gain of 10000)
- Integrated charge 150 mC
- Only a loss in gas gain of about 35 %

- Microscope view of the anode disk and the mesh after irradiation

Current pulse shape

- With an amplification gap of $120\text{ }\mu\text{m}$
- The Fe^{55} pulse exhibit a very fast peak due to electrons the rest of the signal correspond to the drift of ions through the amplification gap
- For α particles the rise time is given by the electrons drift time in the conversion gap
- In the He case the ion mobility is faster and the signal is shorter than for Ne

Discharge probability in hadron beam

- The discharge probability has been measured with different gases in high and low energy pion beams but with the same conversion gap of 3 mm
- To compare the data the discharge probability is plotted as a function of the product:
MIP primary charge x gain
- Helium gas mixture allows the highest avalanche charge

Primary charge distribution

- Events with very large primary ionization (HIP) are typical in hadron beams
- The primary charge distributions for two gases and the same geometry was measured
- The distributions have very long tails orders of magnitude larger than for MIP
- The He end point is 10 times lower than for CF_4
- This explains at least qualitatively why helium is so much better

Test with 10 GeV/c π^+

- For He-isobutane (90,10) mixture an average of only 8 primary charges (3.6 clusters) is expected
- Plateau with an average efficiency of 0.97 start at 405 V
- Gas gain of 6500 at the beginning of plateau
- For about 20 V (factor 2 in gain) the discharge probability per incident π^+ remains below 10^{-8}

Test with 10 GeV/c π^+ cont'

- Landau distribution at 420 V
- Average cluster size 1.97

Micromegas for COMPASS

- The Saclay group has developed a new chip including a 80 ns peaking time charge amplifier and discriminator
- A $30 \times 40 \text{ cm}^2$ detector was tested at 10 GeV and 190 GeV
- Noise less than 1500 e rms for 50 pF detector capacity

- 99% efficiency is reached at low gas gain (1500 with Ar and 2300 with Ne)
- Using leading and trailing edges very good performances are obtained
 - * Time resolution 8.5 ns rms
 - * Spatial resolution 50 μm rms
- The chamber was exposed to rates up to 120KHz/strip mainly hadron from the beam and target halos in the 190 GeV Compass muon beam
- The average discharge rate per 2s burst reaches 1
 - * At a gain of 1200 for the Ar – iC₄H₁₀ (89/11) mixture
 - * At a gain of 5200 for the Ne – C₂H₆ – CF₄ (79-11-10) mixture

Triple GEM prototype

- The idea is to distribute the amplification over three GEM foils (NIM A386(1997)) to reduce discharges
- A 23 cm $\times$ 25 cm prototype was built and tested in a low energy hadronic beam at PSI
- GEM foils characteristics
 - * pitch 140 μm
 - * copper hole diameter 95 μm
 - * kapton hole diameter 55 μm
- After the last GEM charges are collected by a simple printed circuit board with strips at a pitch of 500 μm
- Readout of a few strips by fast current amplifiers

- In a first detector a short developed in one foil after one single spark and the detector couldn't be used anymore
- Careful conditioning of a second detector allowed to withstand at a gain of 18000 a proton rate of 40 KHz/mm^2 during 8 hours without spark

Gain measurement

- The gas gain is measured with a Fe^{55} source
- For two identical detector the difference by a factor 2 in gain is not yet well understood
- The gain as measured from the anode current indicates a gain about a factor of two higher than the Fe^{55} source

Signal shape

- The current signal from the Fe^{55} source
- This current is induced by the movement of the cloud charge between the last GEM and the anode. Its duration agrees with the 40 ns drift time at the expected velocity of $7.5\text{cm}/\mu\text{s}$

- For MIP one sees overlapping contributions arising from clusters of primary ionization dispersed within 40 ns, the drift time in the conversion gap

Cluster size and time resolution

- The waveforms for a sample of 200 events have been recorded
- They are folded with a gaussian function to simulate the transfer function of the preamplifier to be designed
- The time of maximum pulse height with respect to the scintillator trigger is taken to evaluate the time resolution
- The amplitude at 60 ns for cluster size evaluation
- An increase in shaping time results in a decrease of both the time resolution and the cluster size
- For a 20 ns shaping time the results are
 - * Time resolution $\sigma = 8\text{ ns}$
 - * Cluster width $\sigma = 0.6$

Double GEM for COMPASS

- A double-GEM prototype with an active area of $31 \times 31 \text{ cm}^2$ and a two-coordinate read-out printed circuit board has been constructed for COMPASS
- Good gain uniformity
- In COMPASS hadron beam (10MHz) less than one spark per hour at a gain of 1.2×10^4

- Nice correlation of the cluster charge measured in two directions

CONCLUSION

- Many progresses have been achieved this year for both GEM and Micromegas detectors
- Detectors with sizes fulfilling the LHCb requirements have been constructed and tests in beam have just started
- Many points need still to be clarified
 - * Effect of discharges
 - * Real aging test involving a large detector area
 - * Behavior in 1.1 T magnetic field
- It is time also to define the final electronics