Development and tests of a large area CsI-TGEM-based RICH prototype

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In the framework of the ALICE upgrade program we are investigating the possibility to build a new RICH detector allowing to extend the particle identification for hadrons up to 30GeV/c. It is called VHMPID.

The VHMPID should be able to identify, on a track-by-track basis, protons enabling to study the leading particles composition in jets (correlated with the π0 and/or γ energies deposited in the electromagnetic calorimeter).
The suggested detector will consist of a gaseous radiator (for example, CF$_4$ or C$_4$F$_{10}$) and a planar gaseous photodetector.
There are **two** options for planar photodetectors which are currently under evaluation:

- **TGEMs/RETGEMs**

  For TGEM see: L. Periale et al., *NIM* A478, 2002, 377, S. Chalem et al., *NIM* A558, 2006, 475

- **MWPC** (similar to one used in ALICE RICH)

  or

- **TGEMs/RETGEMs**

  or

  Cherenkov photons
The aim of this work is to build a CsI-TGEM based RICH prototype, perform it beam test and compare to the MWPC approach.
TGEM

TGEM is a hole-type gaseous multiplier based on standard printed circuit boards featuring a combination of mechanical drilling (by a CNC drilling machine) and etching techniques.

Thickness: 0.45 mm
Hole d: 0.4 mm
Rims: 10 μm
Pitch: 0.8 mm
Active area: 77%

100mm
The operation principle of the CsI coated triple TGEM (CsI-TGEM)

TGEMs have several attractive features compared to ordinary GEMs:
1) ~10 times higher gains
2) robustness - capability to withstand sparks without being destroyed
3) it is a self-supporting mechanical structure making their use convenient in large detectors
CsI-TGEMs, have some advantages, over MWPC for example:

- CsI-TGEM can operate in badly quenched gases as well as in gases in which are strong UV emitters. This allows to achieve high gains without feedback problems. This also opens a possibility to use them in unflammable gases or if necessary using windowless detectors (as in PHENIX).
- In some experiments, if necessary CsI-TGEMs, can operate in “handron blind mode” with zero and even reversed electric field in the drift region which allows strongly suppress the ionization signal from charged particles (PHENIX).
Design of the CsI-TGEM based RICH prototype
Pad plain (each pad 8x8mm)

TGEMs

CsI

Drift mesh

Electronics

Acquisition

Beam particles

Cherenkov light

$C_6F_{14}$ radiator

PC

PC
The top view of the RICH prototype (from the electronics side)
View from the back plane
Csl side
Drift meshes (three independent grids)
Voltage dividers

There was a possibility to independently observe analog signals from any of electrodes of any TGEM and if necessary individually optimize voltages on any TGEM.
Six triple TGEMs were assembled using a glow box inside the RICH prototypes gas chamber.
The RICH prototype has windows in front of each triple TGEM allowing to irradiate the detectors either with the radioactive sources such as $^{55}\text{Fe}$ or $^{90}\text{Sr}$ or with UV light from a Hg lamp.
Laboratory tests
Before the installation to the RICH detector, each TGEM was individually tested in a separate small gas chamber.

In these tests we mainly identified the maximum achievable gains when the detectors were irradiated with the $^{55}$Fe source and with the UV light.
Summary of **single** TGEMs performance

**Performance of TGEMs (gold electrodes)**

- **A_{\text{max}}**
- Theoretical vs Observed max

**Performance of TGEM (copper electrode)**

- **A_{\text{max}}**
- Theoretical vs Observed max
Typical results of gas gain measurements for triple CsI-TGEMs

Gains in the range $3 \times 10^5$-$10^6$ were achieved

Measurements were performed when the detectors were simultaneously irradiated with $^{55}$Fe and UV light and $^{90}$Sr source
Stability?

See, for example: V. Peskov et al., JINST 5 P11004, 2010
We have solved the stability problems by constantly keeping some voltages over TGEMs.

PS. The variations above correlated to the atmospheric pressure changes.
QE measurements before CsI-TGEM installation into the RICH prototype

The QE value is about 16% less than in the case of the best CsI-MWPC
Beam test
Our proximity focusing TGEM-based RICH prototype installed at CERN T10 beam test facility (mostly ~6 GeV/c pions)
Some results
Single events display

Run: 3689 Event: 10

Run: 3689 Event: 43

Run: 3689 Event: 197

Run: 3689 Event: 242

MIP
Ne+10%CH$_4$
(Overlapping events, radiator thickness 10mm)

November 2010 beam test. Noise was removed offline
Ne+10%CF$_4$ (overlapping events, rad. thickness 15 mm)

May 2011 beam test. Raw data, no noise removal
Some examples of data

Main conclusion: ~1 p.e. per TGEM
Four triple TGEMs together

After corrections on geometry and nonuniformity of the detector response the estimated mean total number of photoelectrons per event is about 10.2
How much p.e one can expect in “ideal conditions”: full surface (without holes) and CH₄ gas:
Corrections: 0.9 (extraction) x 0.75 = 0.68
10 p.e/0.68 ~ 15 pe
What was achieved in the past with the CsI-MWPC (radiator 15mm)?

F. Piuz et al., NIM A433, 1999, 178
Overall TGEM gas gain $\sim 1.4 \times 10^5$
Conclusion from the scan: the QE of the CsI layer on the top of TGEMs is practically the same as before our tests - about 16% less than in the case of good MWPC - so corrected on this the total number of expected p.e. will be around 16-17-close enough to the MWPC data.
Developing the simulation program
Some details, how simulation was done.
Input parameters: geometry, n-index, gas (ionization, diffusion), E-field, Average Gas Amplification, FEE parameters,...

- Primary ionization: track, Fe55 (position in a space of each e-), single photo-electron from CsI on a top of a first foil (GEANT-3 for UV production, transport and CsI QE)
- Transport of each e- to nearest hole in first foil (probability and position in a hole)
- Gas amplification; Polya distribution and “some special parameters”.
- Transfer of each e- after gas amplification step to next foil (hole selection)
- Repeat GA and Transport steps for second and third foil.
- Collect electrons on pad (strip) structure
- Add FEE noise and response for each (“active”) pad
- Threshold to select “active” pads.
- Cluster finding and reconstruction.

- NO Background (for the moment)
Some preliminary results of the simulation

Number of reconstructed clusters per trigger (assumption QE=0.66QE in CH$_4$), so ~35% accuracy
Conclusions:

- **For the first time** Cherenkov rings were detected with CsI-TGEMs.

- The mean number of detected photoelectrons is the same as expected from estimations.

- Thus, preliminary it looks that TGEM is an attractive option for the ALICE VHMPID: it can operate in inflammable gases with a relatively high QE, it has a fast signals and cetera.

- Of course, the final choice of the photodetector for VHMPID will be based on many considerations, for example MWPC approach has its own strong advantage: it is a well proven technology.
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Spare
The main advantages of MWPC - it is a proven technology

The current ALICE/HMPID Detector

- 7 modules:
- total area 11 m²

First Cherenkov rings candidates at 7TeV proton-proton collisions at LHC
Rate dependance

Triple TGEM is inside this general limit!.. So at the beam test we should not expect an unlimited gain
Measurements with 55Fe

The gas flow at the beam test was 27/3
Measurements with 55Fe

Gain 2x10E5

UV signal

Ne+8%CH4

10000 1000 100 10 1
580 600 620 640 660 680 700 720

18/1.6
9/0.8
No flow dependence in the given region