Very High Momentum Particle Identification Detector at CERN LHC ALICE

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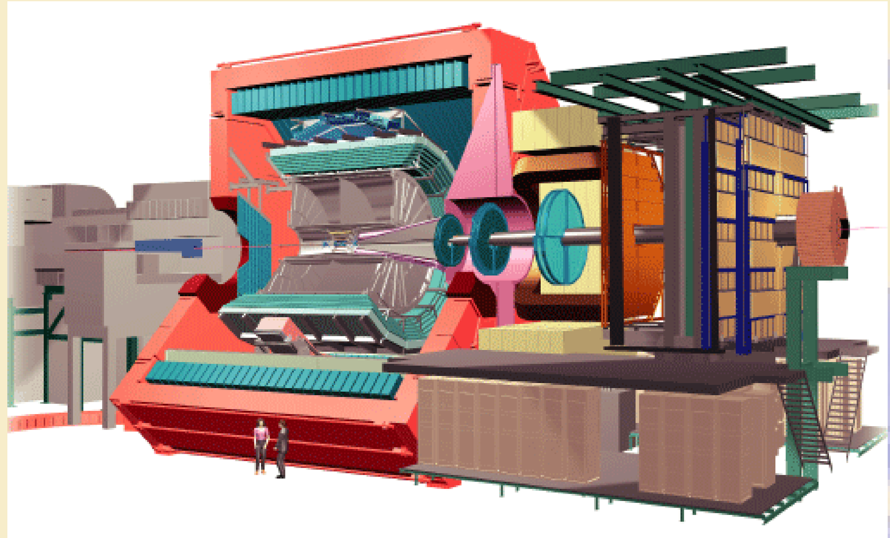
ALICE at LHC

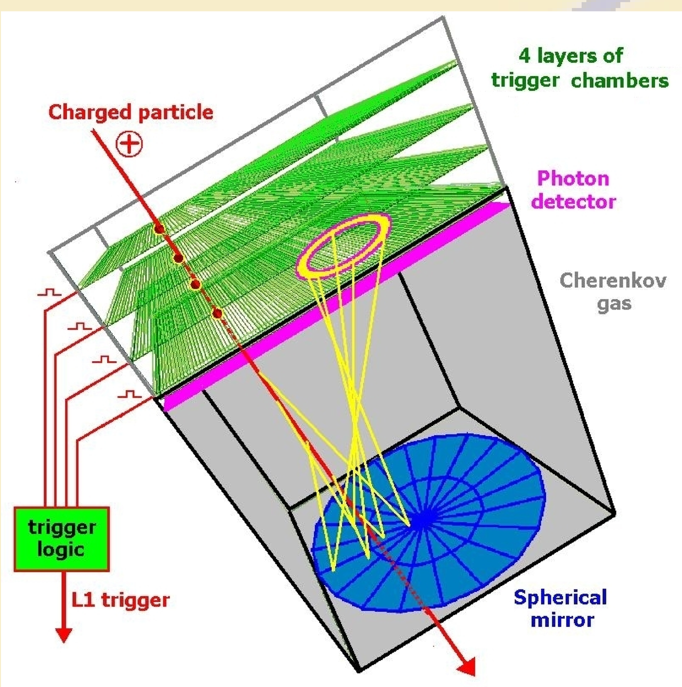
ALICE [1] is the dedicated experiment at CERN LHC to investigate heavy ion collisions and search for the new state of matter, the quark-gluon plasma (QGP). The strongly coupled deconfined matter formed in the early stage of heavy ion collisions will expand and rehadronize into hadrons. The proper identification of these hadrons, especially at high transverse momenta, could shed light on the properties of the hot dense phase and the features of the QGP state.



Detailed view on the ALICE experiment

ALICE has an excellent particle identification capability up to 5 GeV/c via its various detector system. The Very High Momentum Particle Identification Detector [2] (VHMPID) will extend this range up to 25 GeV/c.

VHMPID



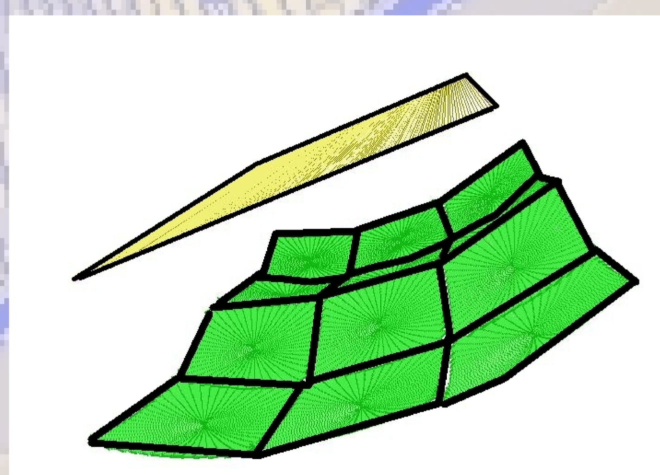
A simple scatch of one segment of the VHMPID detector.

VHMPID is a gaseous ring imaging Cherenkov detector. The radiator gas have been choosen to make the detector able to separate pions/kaons/protons in the 5-25 GeV/c momentum range track by track. Spherical mirrors are focusing the Cherenkov light onto the photo sensitive detector forming a ring. The radius of this ring is correlated with the Cherenkov angle and the particle's velocity as well.

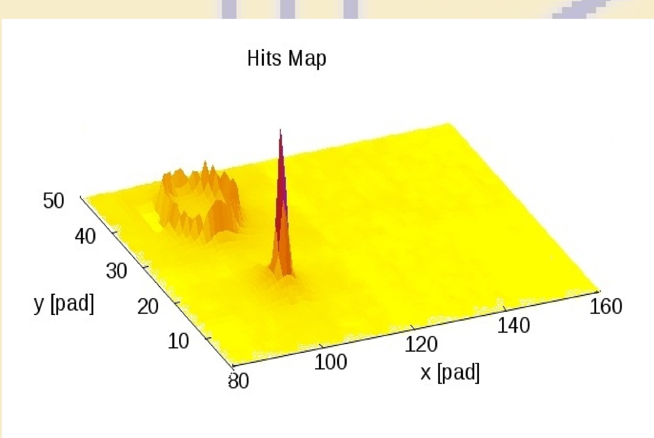
VHMPID will be an excellent tool to analyse jet structure, near side baryon-meson and baryon-antibaryon correlations. One can study multi-hadron fragmentation functions and medium modified fragmentation as well. HMPID and PHOS located in ALICE opposite side as the VHMPID opening the opprtunity to measure away-side hadron-hadron and photon-hadron correlations.

Research and development

Focusing geometry will put the center of the rings independently of the incoming particle allowing us to reduce the photo detector's area. Mirrors are tilted to focus at the same spot or near each other, reducing further the cost and area of the photon detection part. However this feature makes mirror alignment a more important task. Online mirror aligment information will be served by an alignment measuring laser system inside the detector.



Tilted mirror structure to improve the ring-geometry.

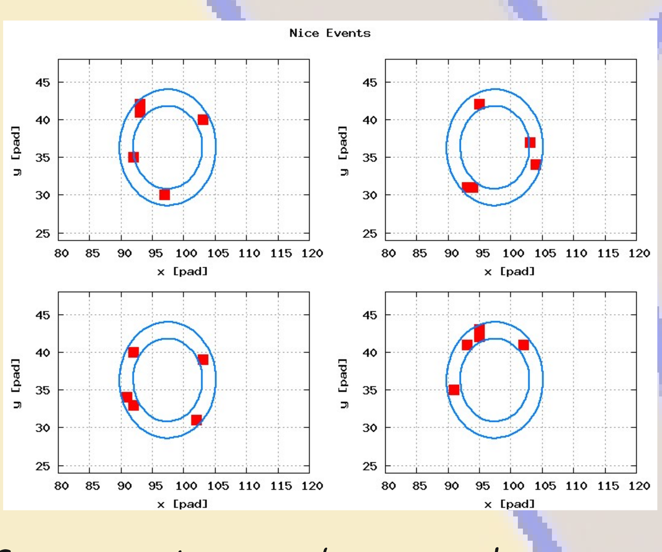


The MIP and the Cherenkov ring from the 100 GeV/c pions at CERN SPS in 2010.

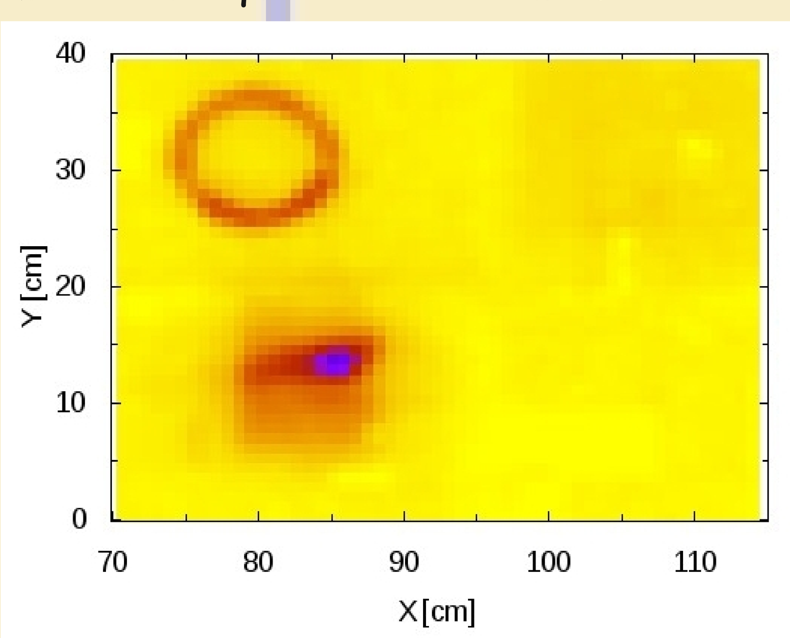
The very low number of Cherenkov photons forces us to use state of the art technoloy for photon detection. Besides the classic CsI coated MWPC (like in HMPID [3]), TGEM based [4] and TGEM+CCC based detectors are studied and tested. The purity of the Cherenkov gas is a crusial question, both H_2O and O_2 levels should be kept under ~5-10ppm to avoid photon absorption inside the radiator gas volume.

VHMPID beam test at SPS

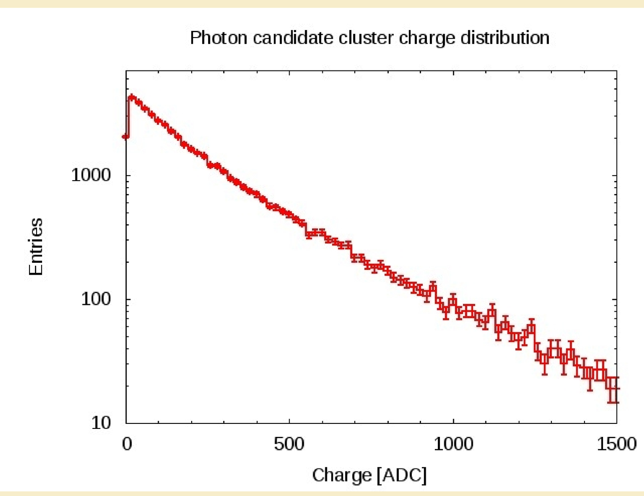
We had tests at both CERN PS and SPS with various energy beams and could done many important studies. After gas purufication workable O_2 and H_2O levels could be reached. Mirror focusing, and tiltedness were excellent, as the plots show it. Ring studies and identification capabilities could be tested.
Radiator lenghts studies were made experimentally with an aluminium plate to absorb the Cherenkov light made at the entrance of the particle. Photon detection was made by CsI coated MWPC with strip cathodes on the separation window.
Tests have also been carried out with ThickGEM based photon detectors with Cherenkov light obtained from solid and liquid radiators as well.



Some events can be seen here: the squares are the detected photon hits, the blue ring correspondes to the theoretical circle of the 100 GeV/c pions, where the mirror should focus it.



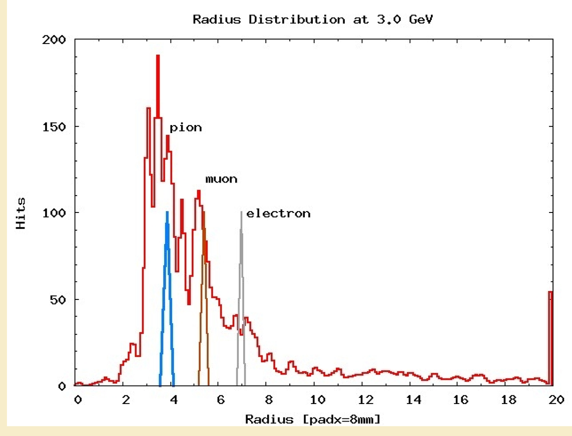
Focusing geometry places the ring and its center at the same splot independently from the particle's position.



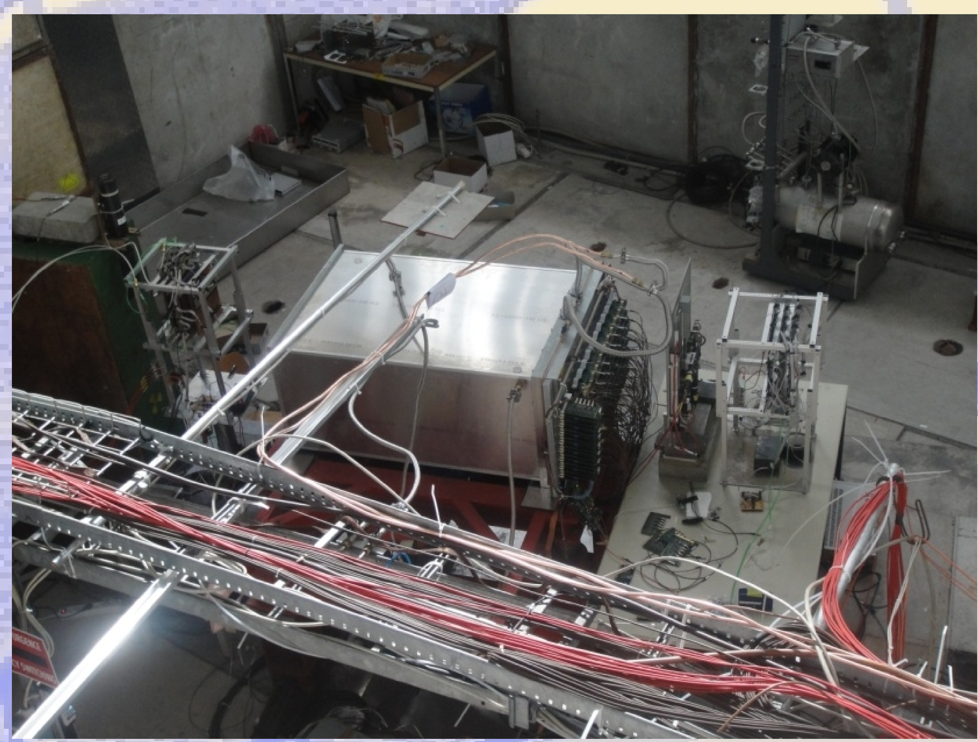
Charge disrtibution of the one photon candidate clusters shows the desired exponential shape.

VHMPID beam test at PS

At PS T10 energies (1-6 GeV/c) one can study how pions start to radiate the Cherenkov photons. Ring radius dependencies, photon detection and radiator length studeis have been made. Using a secondary beam, which contains electrons and muons as well, the identification capabilities could be studied. A still noisy but impressive plot can be seen on the right side.



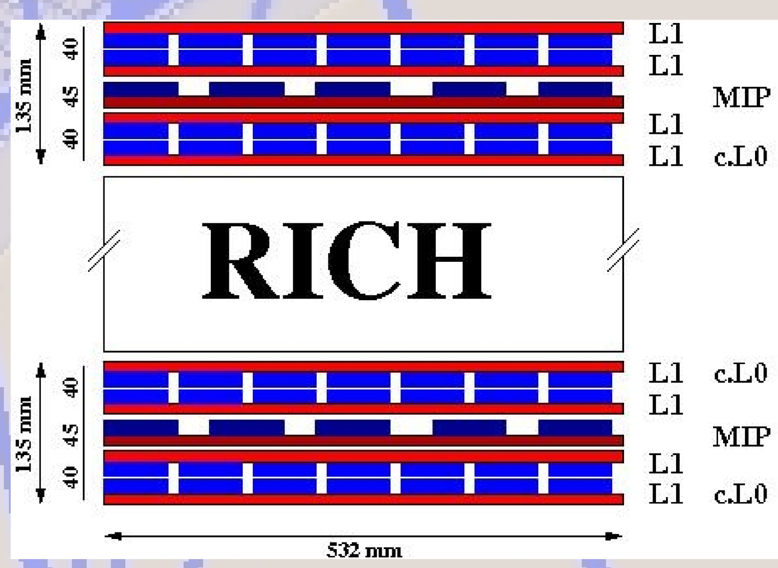
The three different rings at 3.0 GeV from pions, muons and electrons. The coloured peaks show the theoretically calculated radii.



Combined VHMPID+HPTD beam test at PS. 3+4 layers of CCCs are before+behind the Cherenkov detector.

We could test how the Cherenkov and the trigger parts can work together. This close to final setup can be easily compated to the AliROOT simulations. Material budget effects, MIP measurements and especially before+behind pattern appearance were studied.

High p_T triggering



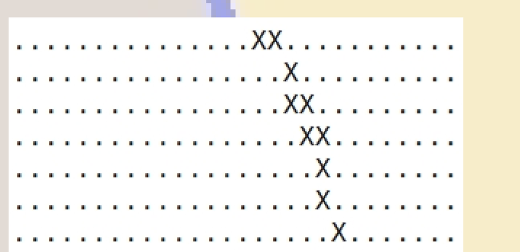
Five + five layers of the HPTD will be surrounding the Cherenkov detector to give L1, L0 triggers and MIP information

High p_T particles are extremely rare therefore a good trigger could highly increase the recorded interesting data. The High P_T Trigger Detector [5] (HPTD) will serve three functions:

1. Tracking before and behind the RICH module.
2. L1 triggering at high p_T in PbPb and pp collisions.
3. L0 triggering at pp collisions.

HPTD consist of 5+5 layers of gaseous detectors around the Cherenkov part. Each layer should have good spatail resolution and low material budget.

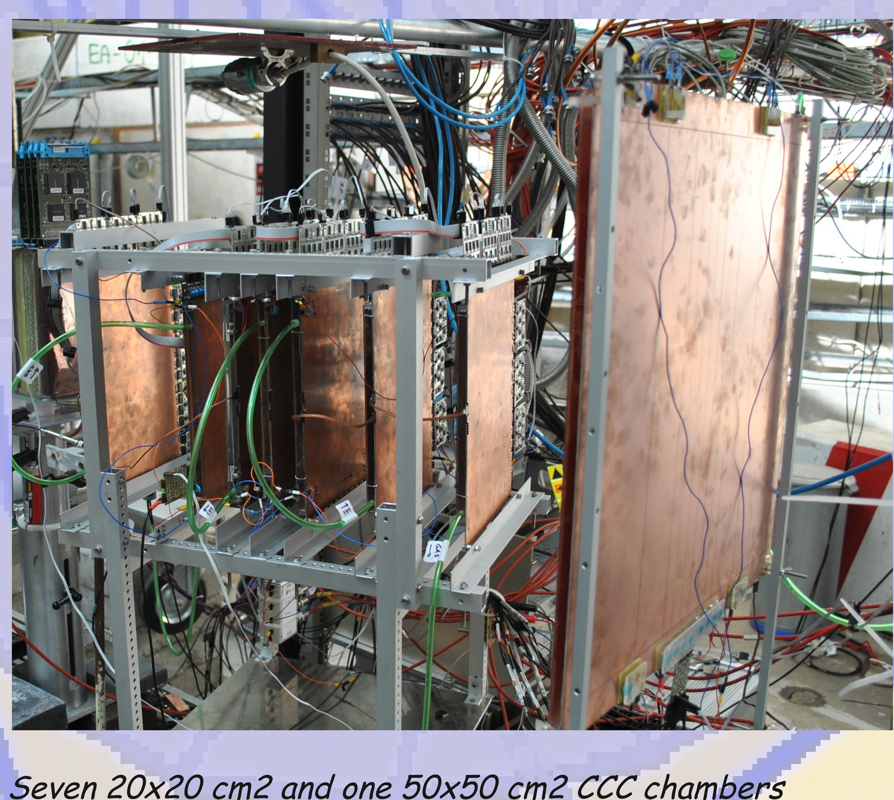
Inside the ALICE magnet charged particles' tracks are bent according to their transverse momenta. Precise measurement of the tracklets allows us to define a set of certain tracklet patters that are generated by the high p_T particles. Due to the high multiplicities in heavy ion collision and the low yield of interesting particles background suppression is extremely important, one has to filter out decays, seconday particles and specially combinatoric fake patterns. Detector readout, patter recognition, and L1 decition is made by FPGAs within 5 us required by the ALICE L1 trigger system.



A typical patterns form last years beam setup with seven chambers can be seen. The digital bits are visualised with "X" and "." for a better visual contrast.

For L0 at pp collions we use some of the same detectors as for L1. Here large superpads are made to decrease the number of channels, their digital one bit signals go to a purely hardware logic gate system to achive the 800 ns response for decision.

HPTD beam tests



Seven 20x20 cm2 and one 50x50 cm2 CCC chambers at HPTD's beam test at CERN PS in 2010.

HPTD does not need to measure the energy loss of the charged particles it only have to detect its tracklet. This simplifies the used electronics into a preamplifier and a discriminator which output is only one bit per channel making it really cost effective. Therefore the detector layers should have narrow pad response function to achive low enough occupancy with the same number of channels. The Hungarian REGARD Group developed a newish multi wire chamber, the "Close Cathode Chamber" [6] with narrow pad respons, low material budget and large mechanictal tolerance. Several chambers are working for years now, and have prooven their reliability in labor, cosmic and beam tests as well.

Summary

VHMPID is a gaseous Cherenkov detector for hadron identification in the 5-25 GeV/c momentum range. This extension is necessary for detailed jet and medium studies in ALICE. HPTD will serve as L0 and L1 trigger for high momentum particles for VHMPID. Both detectors are in R&D phase with several successful beam tests done.

References

[1] JINST 3 (2008), S08002
[2] NIM A 617 (2010), p 424-429
[3] NIM A 553 (2005) p 345-350
[4] JINST 5 (2010) P11004
[5] Nucl.Phys. B (P.S.) 197 (2009) p 296-301
[6] NIM A D11 (2011) 00130 (accepted)

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