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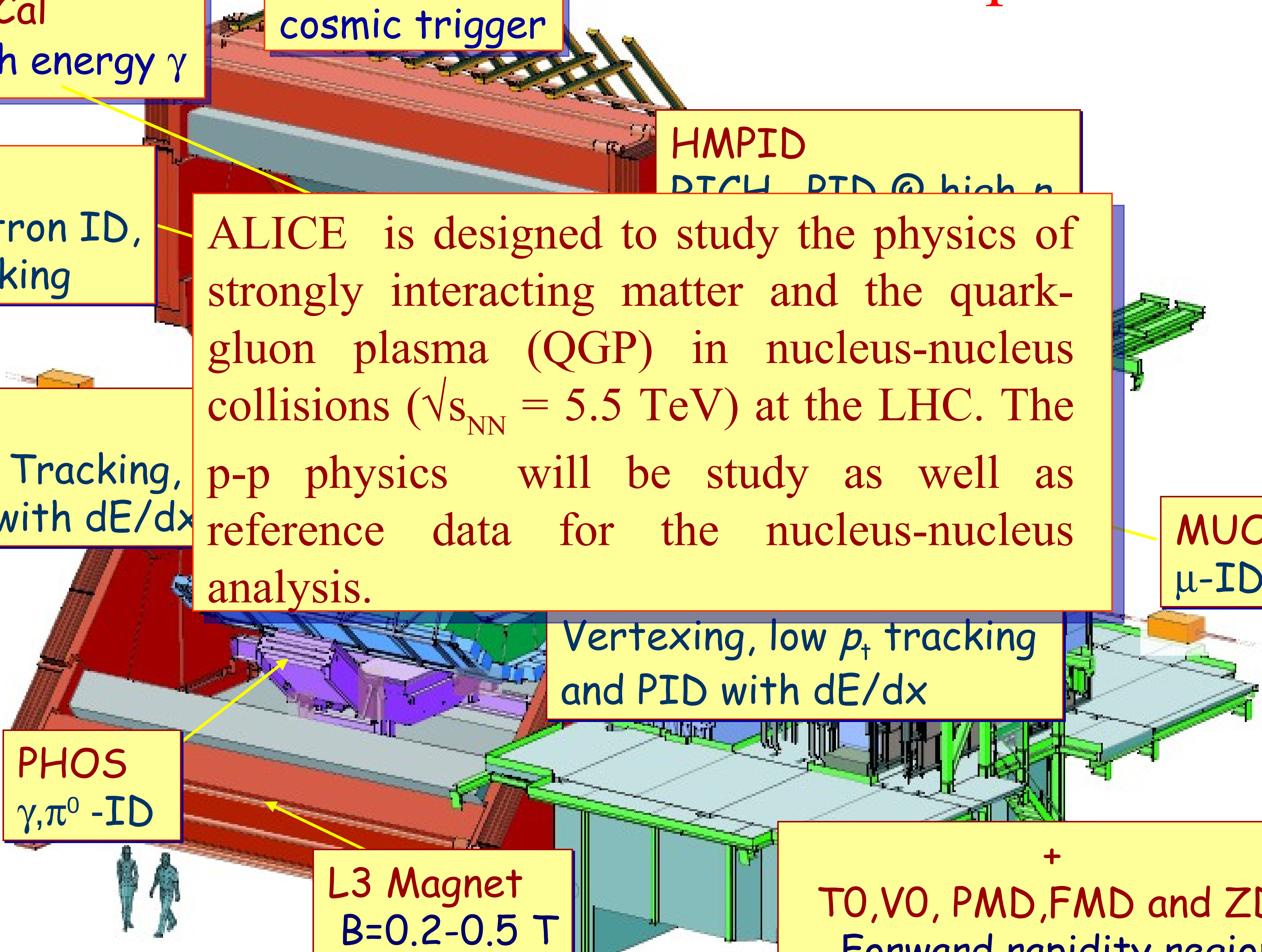
Cherenkov detectors in the ALICE experiment at LHC

Giacomo Volpe[a,b]
for
ALICE-HMPID group and VHMPID protocollaboration

[a]*INFN, Sezione di Bari, Italy.*
[b] *Dipartimento Interateneo di Fisica "M. Merlin", Bari, Italy.*

ALICE experiment

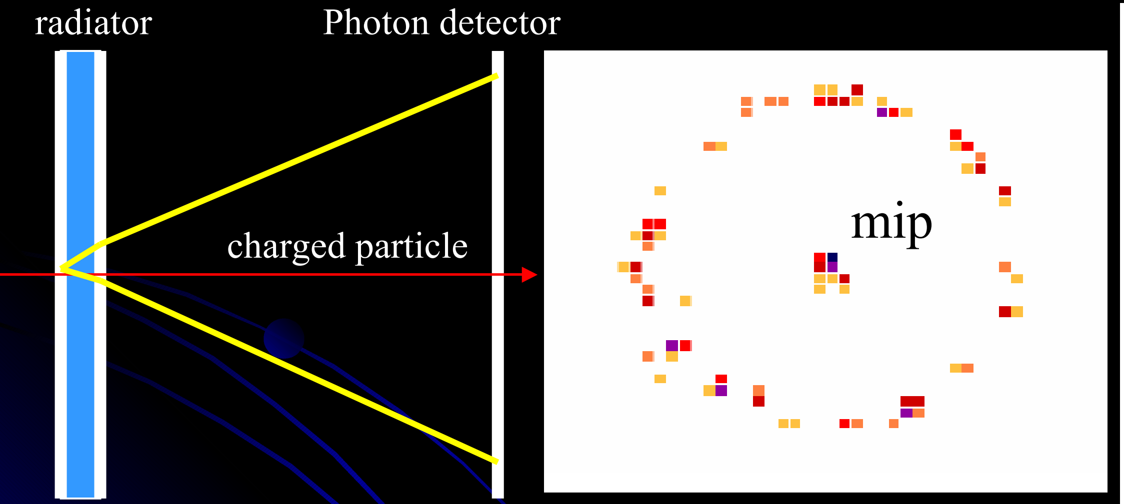


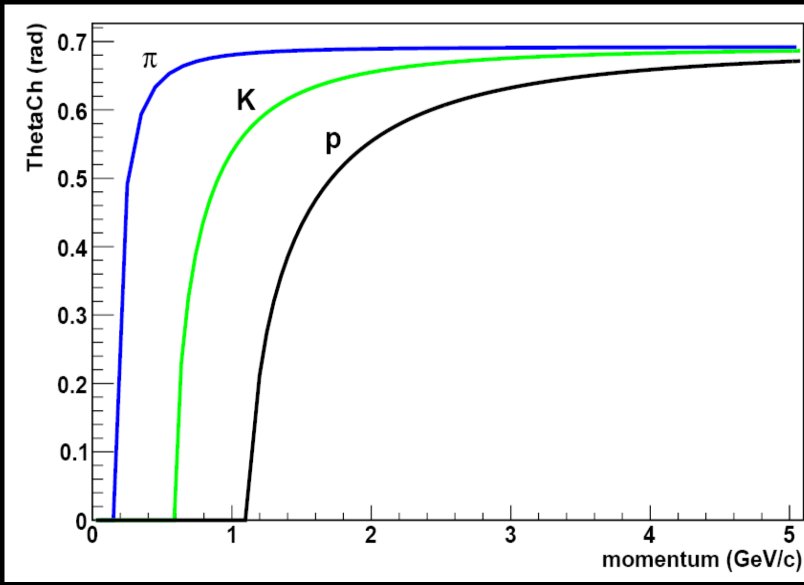
ALICE is designed to study the physics of strongly interacting matter and the quark-gluon plasma (QGP) in nucleus-nucleus collisions ($\sqrt{s_{NN}}$ = 5.5 TeV) at the LHC. The p-p physics will be study as well as reference data for the nucleus-nucleus analysis.

HMPID detector description

- ALICE-HMPID (High Momentum Charged Particle Identification Detector) performs charged particle track-by-track identification by means of emission Cherenkov angle measurement and of the momentum information provided by the tracking devices.

- It consists of seven identical proximity focusing RICH (Ring Imaging Cherenkov) counters





- HMPID is the only Cherenkov detector in the ALICE apparatus;

- Physics goals: particle ratios, HBT interferometry, meson production;

HMPID detector description

PID RANGE

- $1<p<3$ GeV/c π-k

- $2<p<5$ GeV/c p

RADIATOR

15 mm liquid C_6F_{14},
n ~ 1.2989 @ 175nm, $\beta_{th} = 1.21$

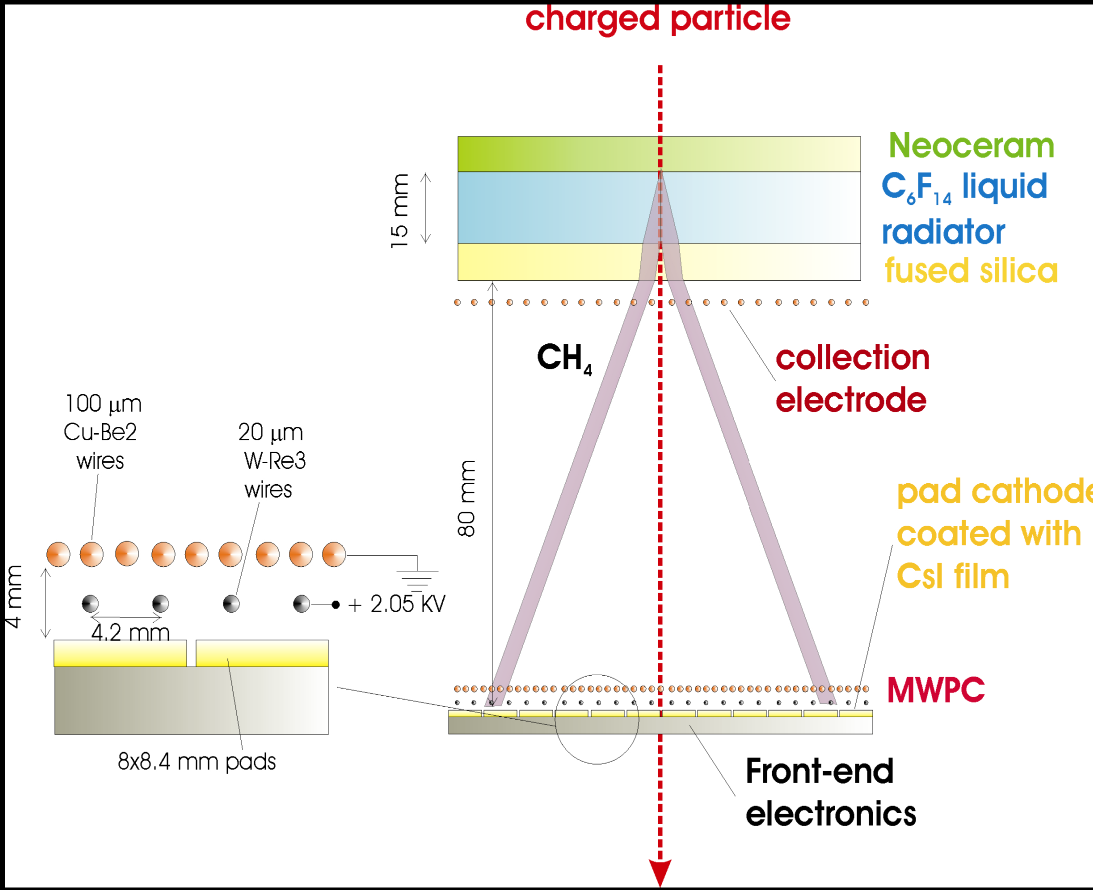
PHOTON CONVERTER

Reflective layer of CsI
QE ~ 25% @ 175 nm.

PHOTOELECTRON DETECTOR

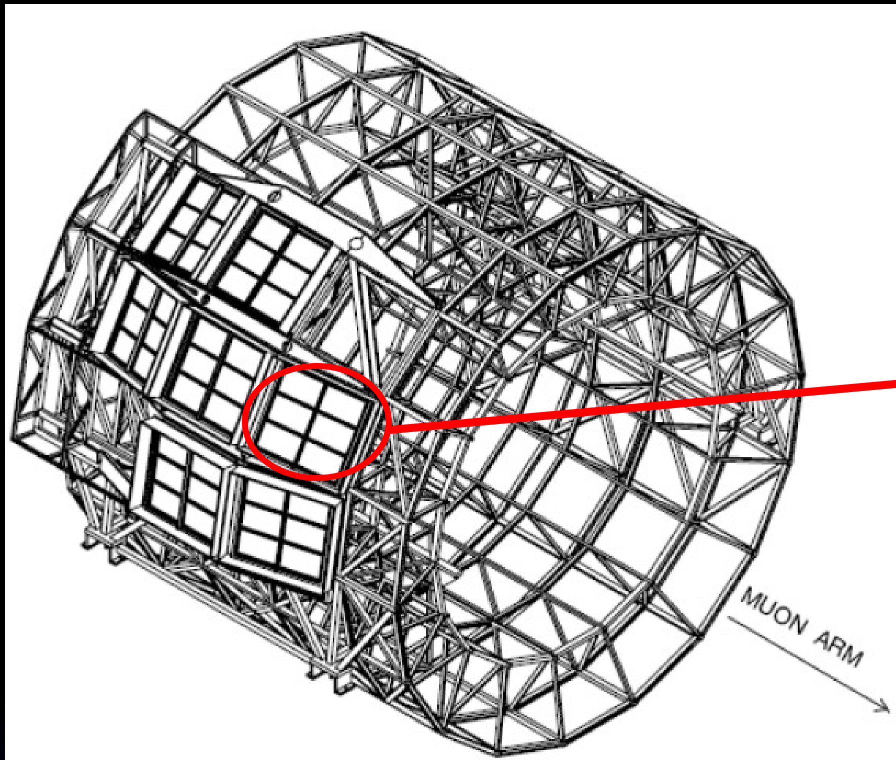
- MWPC with CH_4 at atmospheric pressure (4 mm gap) HV = 2050 V.

- Analogue pad readout

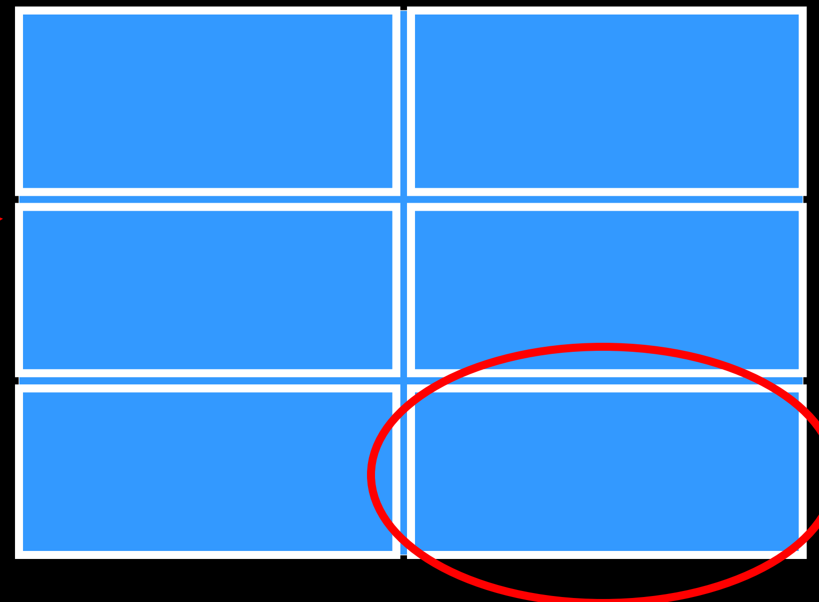


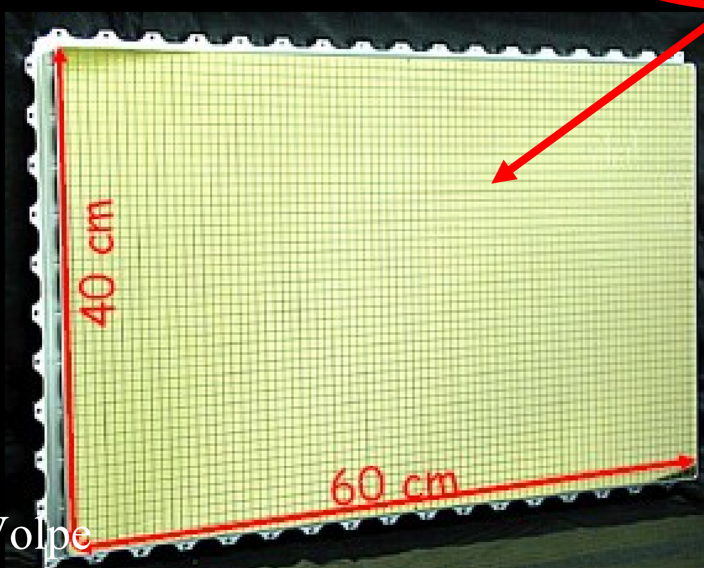
The largest scale (11 m²) application of CsI photo-cathodes in HE/HI-P!

HMPID detector description



Six photo-cathodes per module





CsI photo-cathode is segmented in 0.8x0.84 cm pads

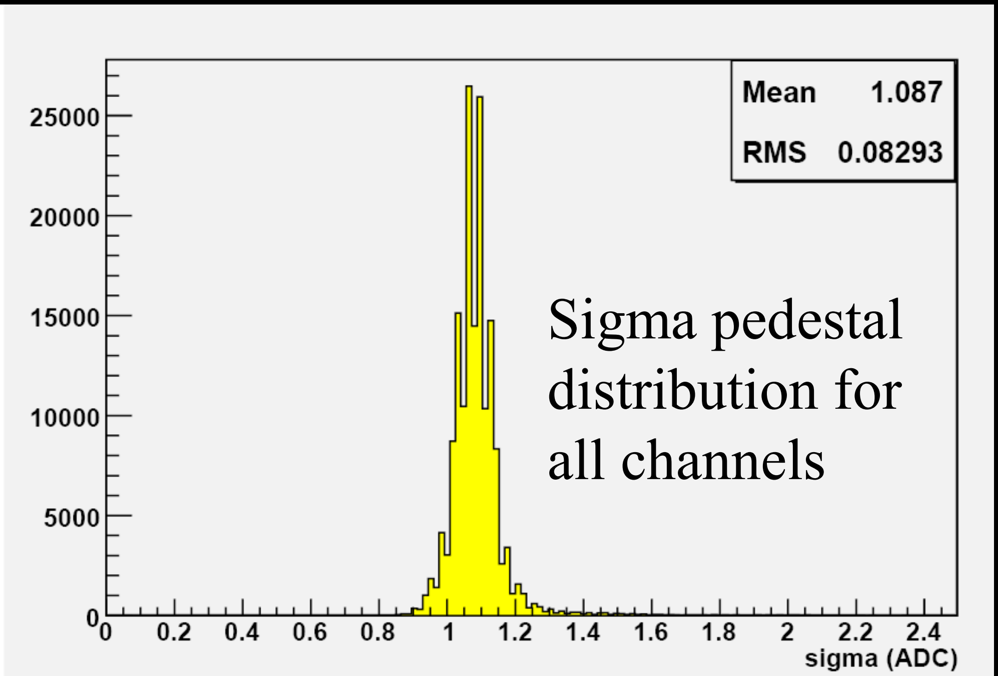
HMPID detector description

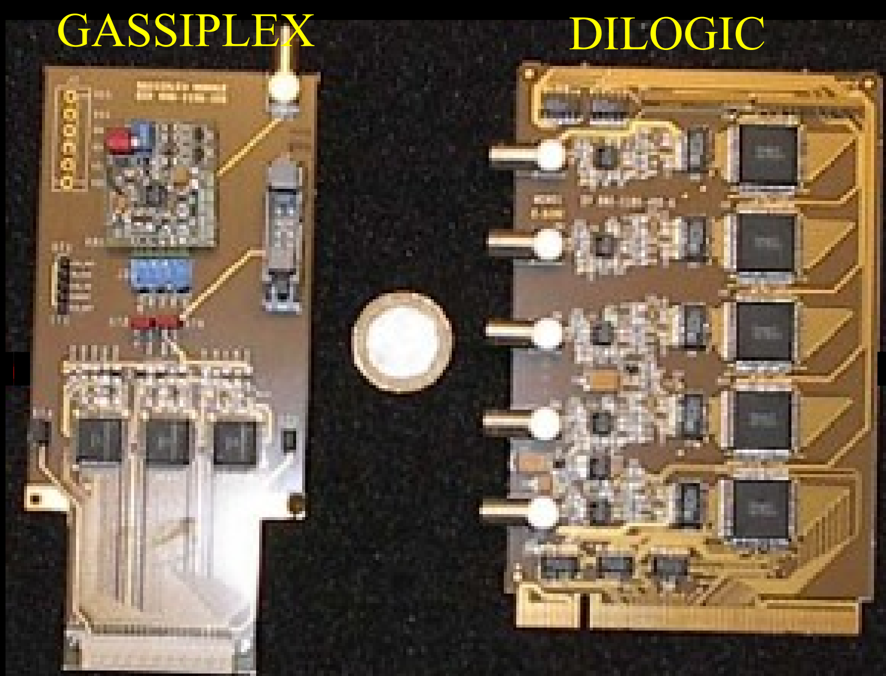
- FEE and RO electronics is based on GASSIPLEX and DILOGIC chips developed within the HMPID project

- GASSIPLEX: 16-channel analogue multiplexed low-noise signal processor, the noise level is 1000 *e*⁻, dead/noisy pads are less than 200 out of 161280

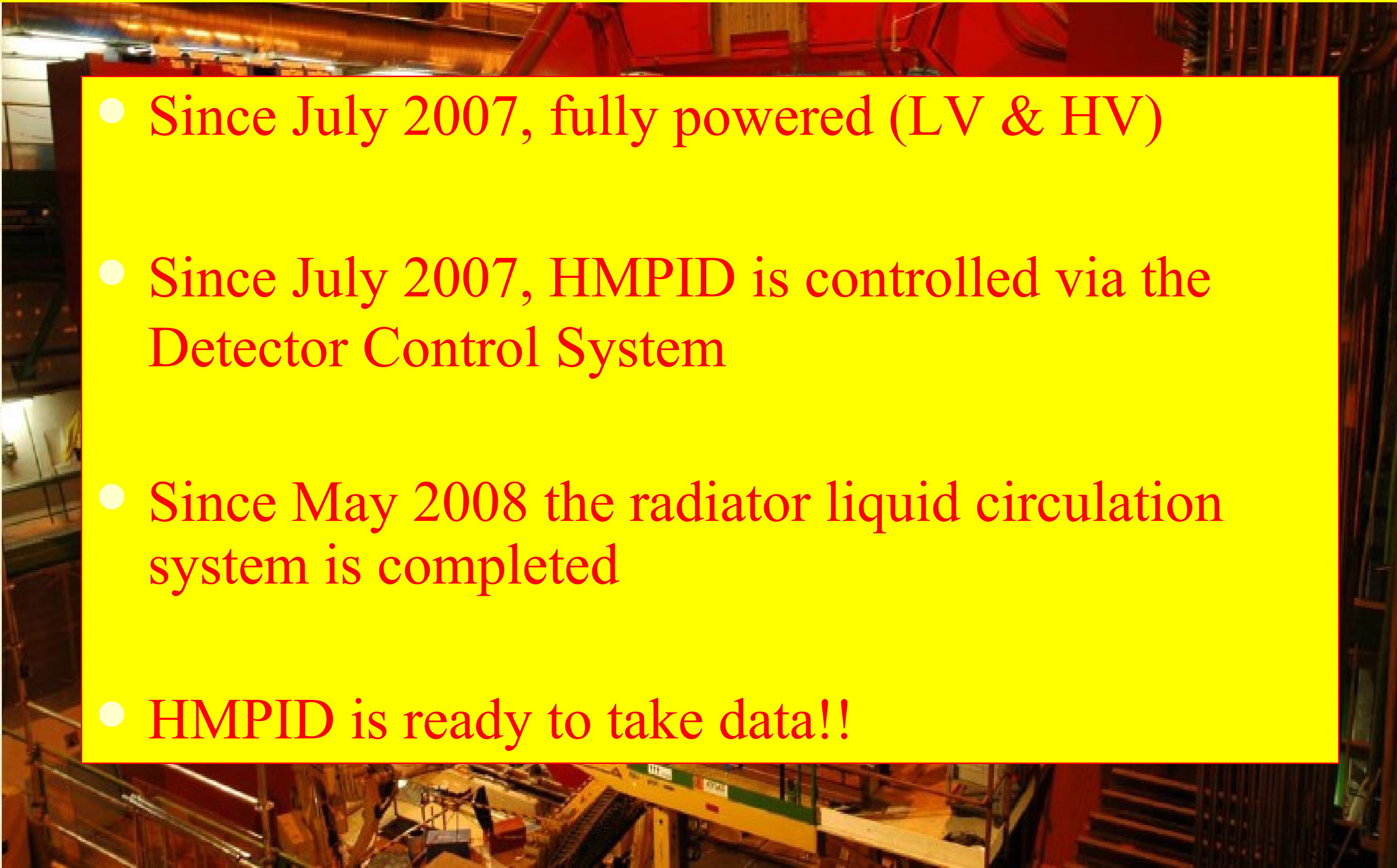
- DILOGIC: individual threshold and pedestal setup

- 42 photo-cathodes are segmented into 3840 pads with individual analog readout.





HMPID is installed in the ALICE magnet since September 2006



- Since July 2007, fully powered (LV & HV)
- Since July 2007, HMPID is controlled via the Detector Control System
- Since May 2008 the radiator liquid circulation system is completed
- HMPID is ready to take data!!

ALICE data taking

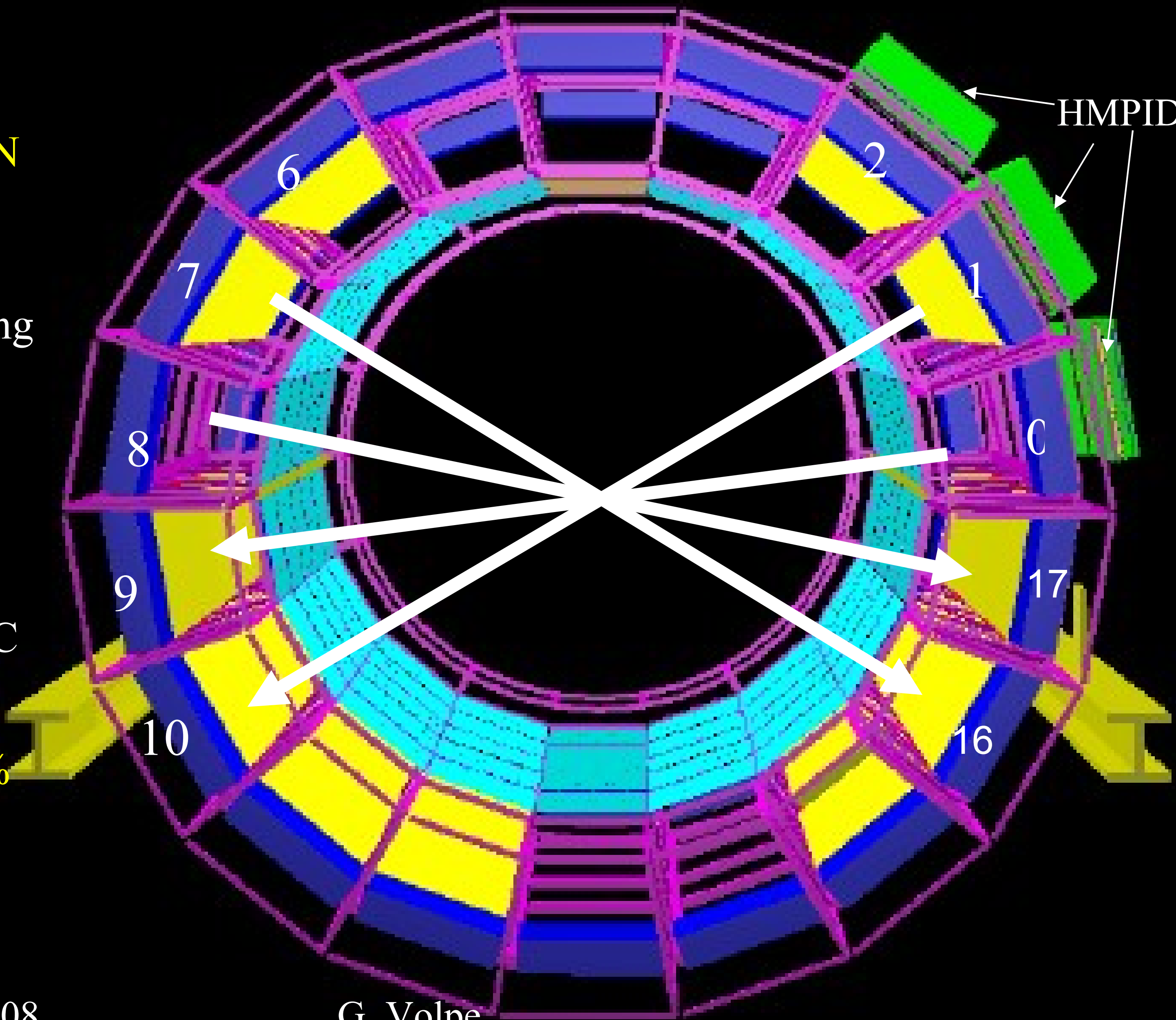
- Global Run I: December 2007 (2 weeks)
  - Start system commissioning
- Global Run II: February/March 2008 (3 weeks)
  - global commissioning, magnet commissioning, cosmics.
- Global Run III: from May, foreseen until 12th of October
  - global commissioning, calibration and alignment with cosmics
  - First beams

Results from cosmics

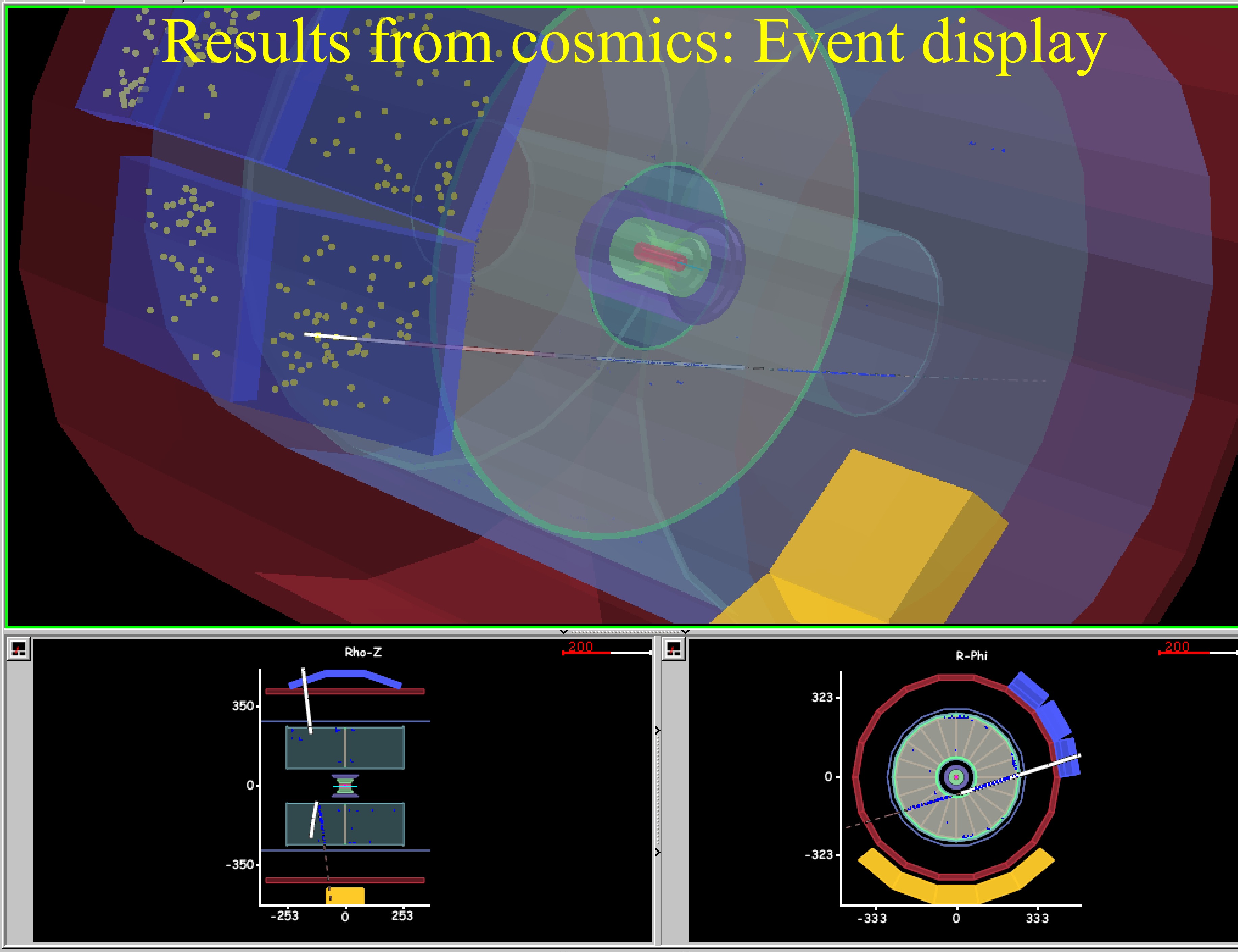
TOF TRIGGER CONFIGURATION

HMPID got interesting data using trigger provided by the TOF detector, which match good with its geometry acceptance!! Tracking in the TPC is available.

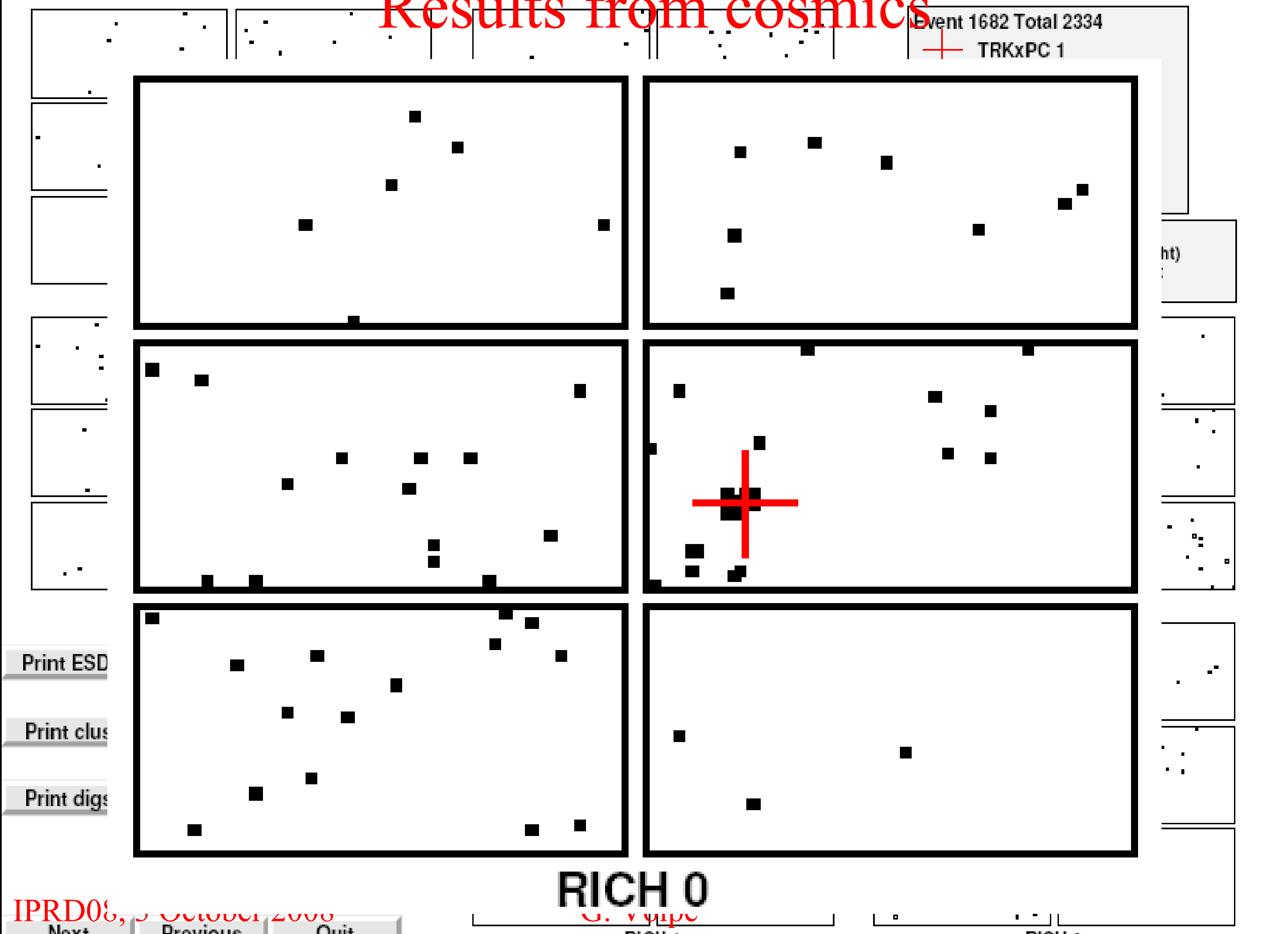
Trigger purity ~ 2%



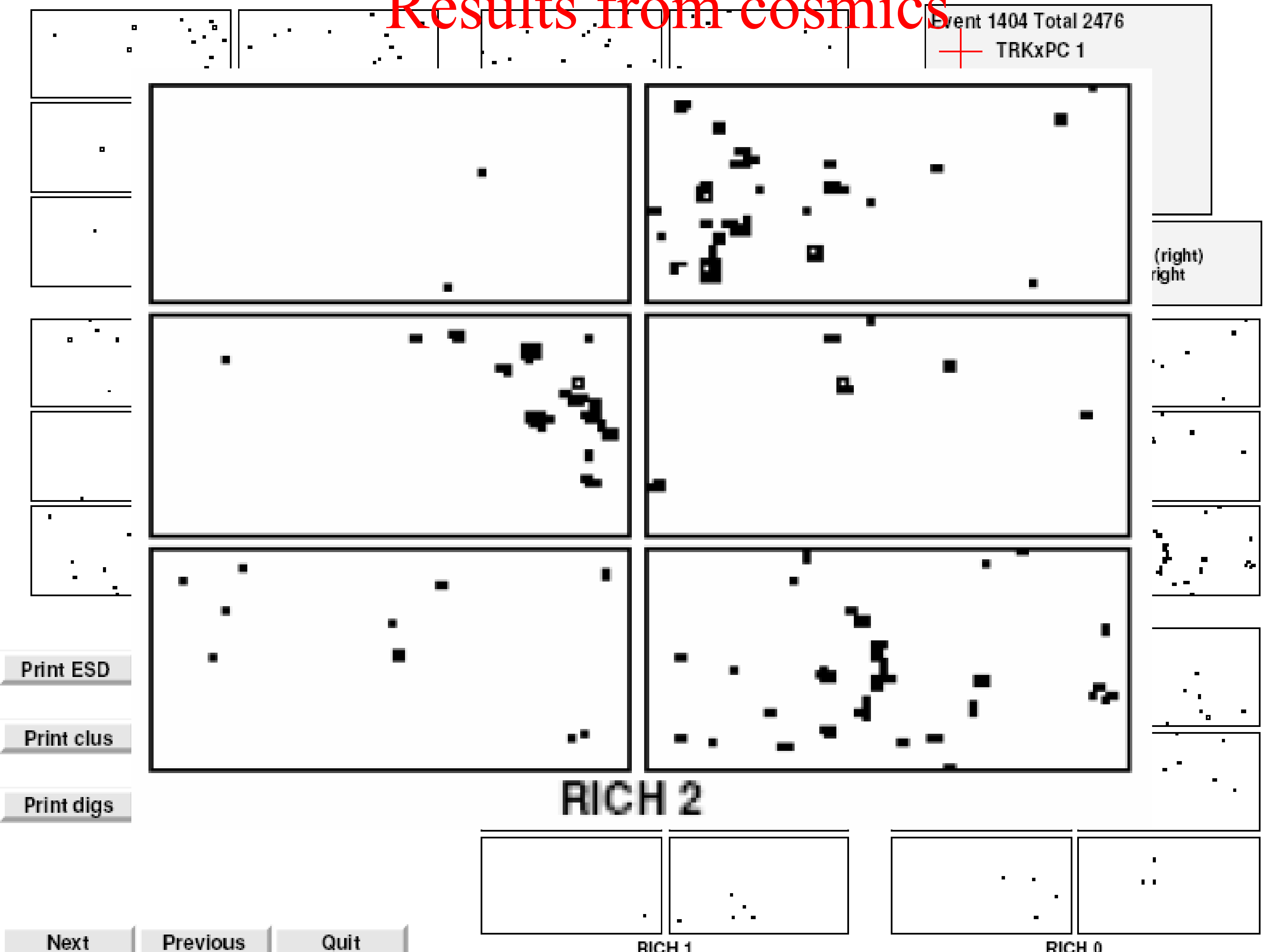
Results from cosmics: Event display



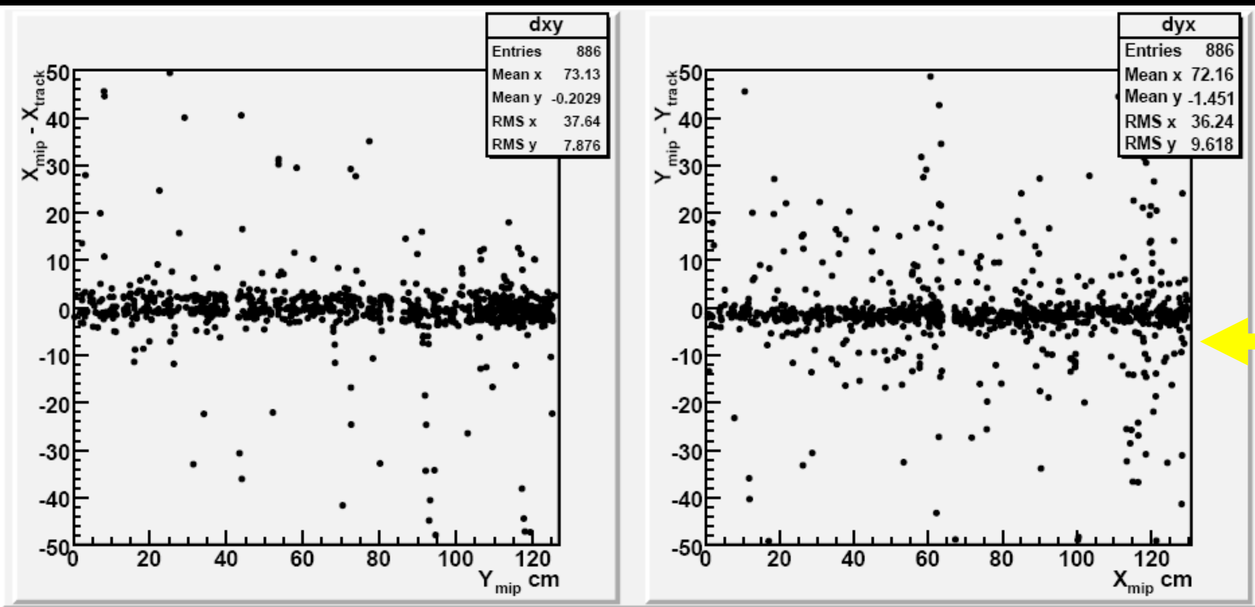
Results from cosmics



Results from cosmics

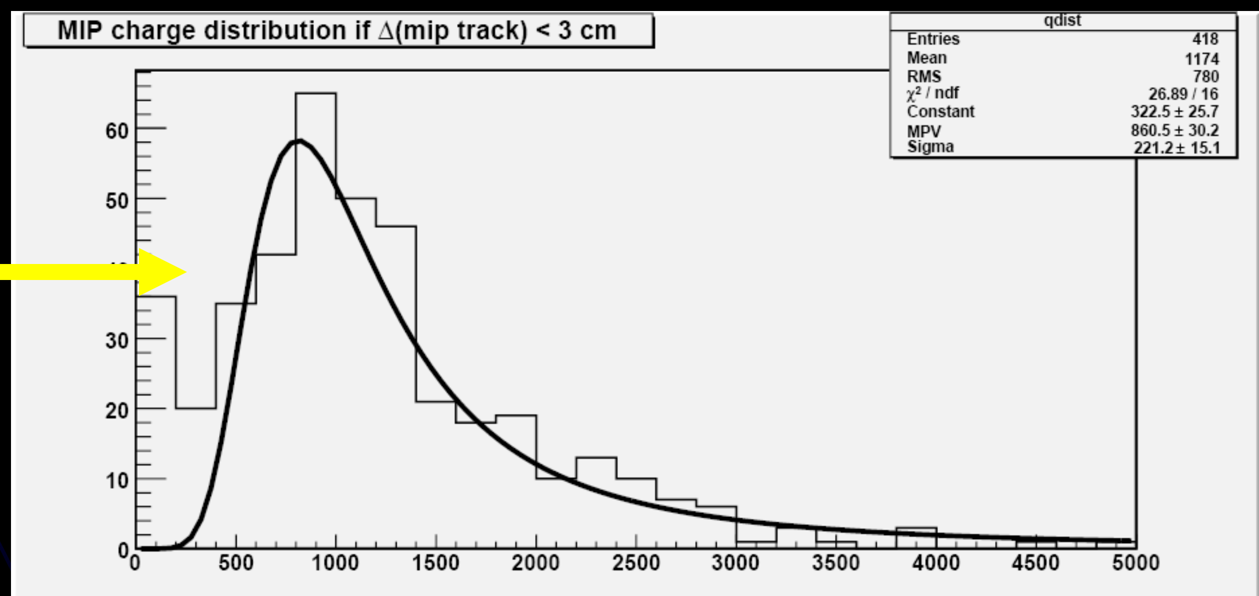


Results from cosmics



Track matching HMPID-TPC, no alignment

Clusters charge distribution selecting clusters corresponding to a track in the TPC

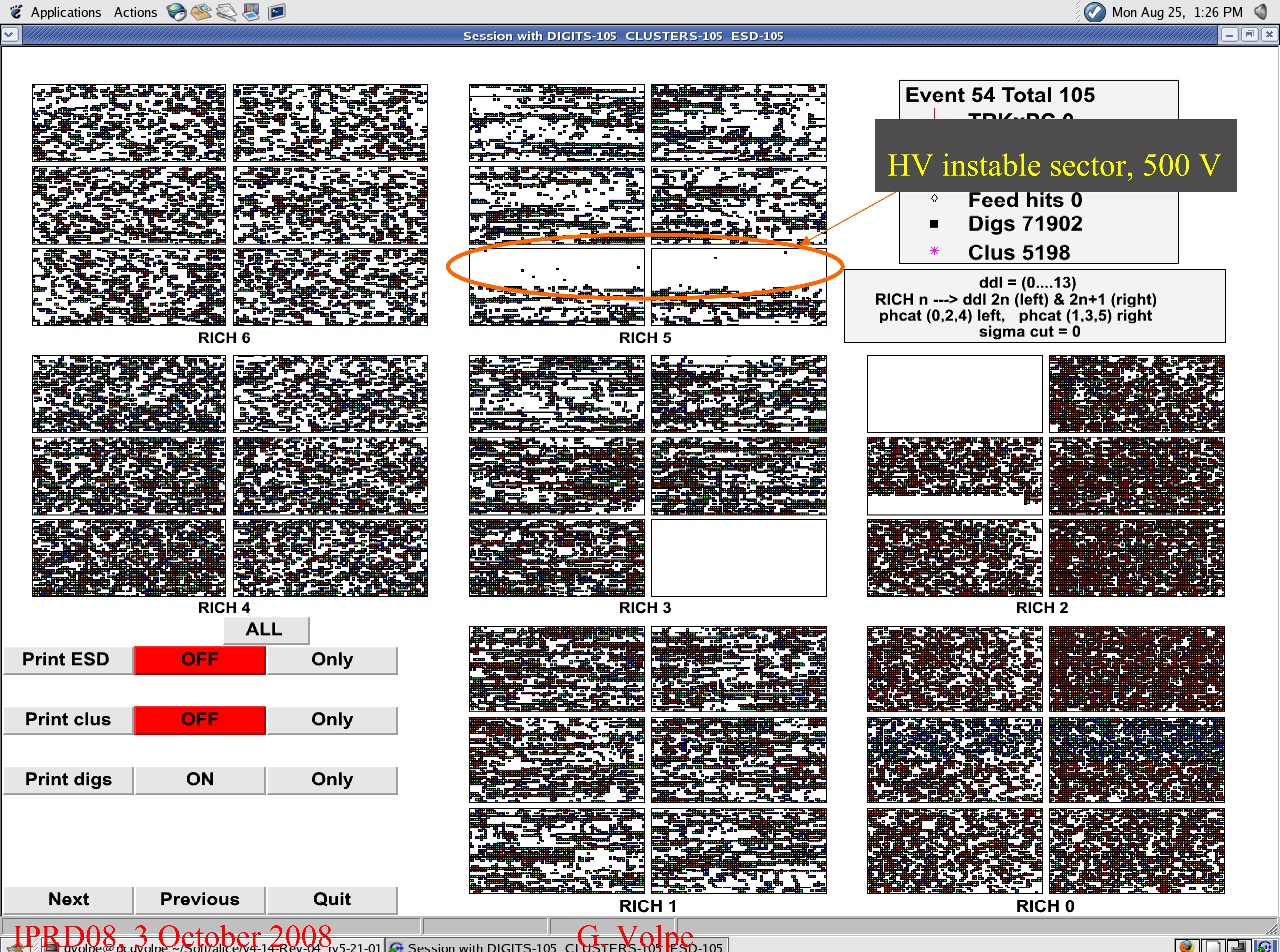


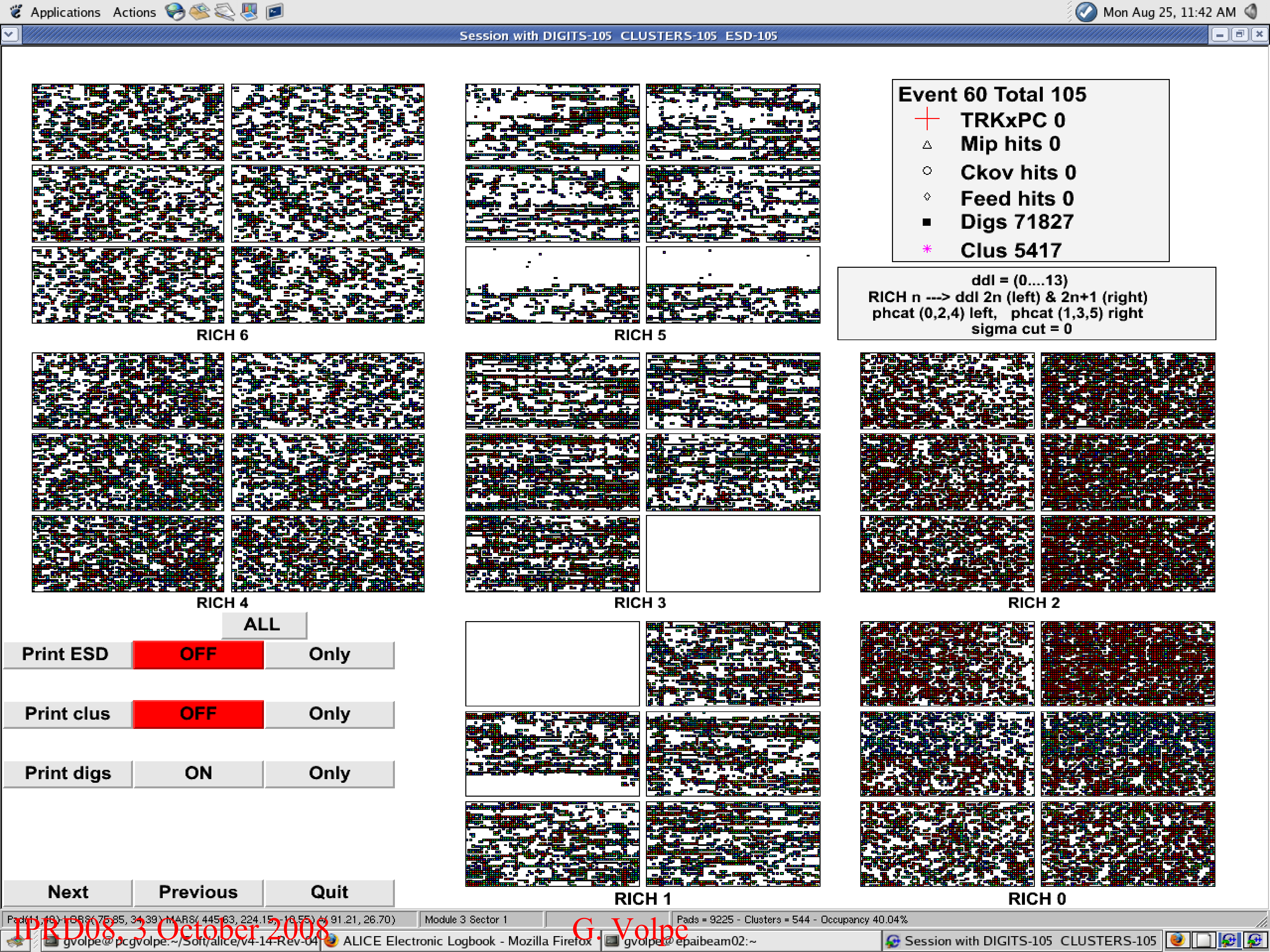
G. Volpe

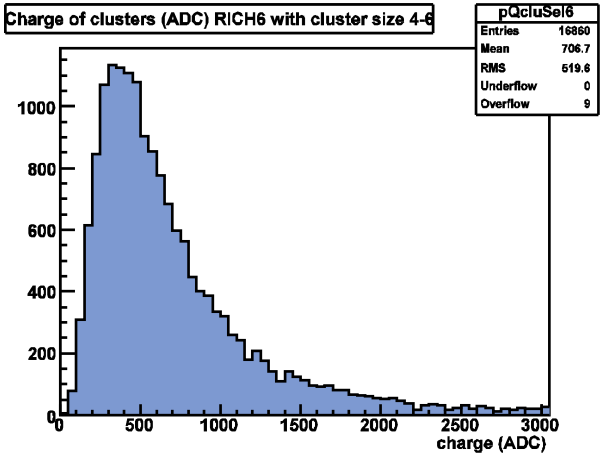
Results from beam injection test dump on TED

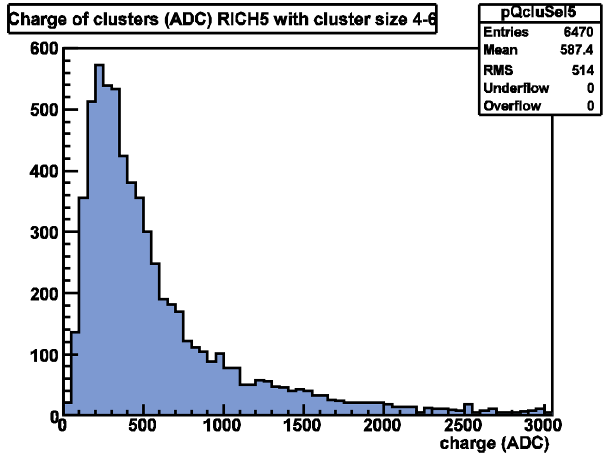
RICH6 1800 V	RICH5 1800 V	
RICH4 1800 V	RICH3 1800 V	RICH2 1860 V
	RICH1 1860 V	RICH0 1860 V

Because of the large flux of particle foreseen, to prevent trips in the chambers HV has been set to value lower than the usual.

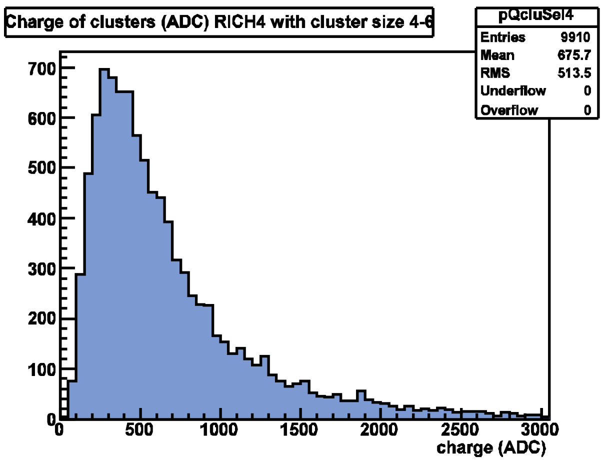

Session with DIGITS-105 CLUSTERS-105 ESD-105
Event 54 Total 105
HV instable sector, 500 V
Feed hits 0
Digs 71902
Clus 5198
ddl = (0....13)
RICH n ---> ddl 2n (left) & 2n+1 (right)
phcat (0,2,4) left, phcat (1,3,5) right
sigma cut = 0
RICH 6
RICH 5
RICH 4
RICH 3
RICH 2
RICH 1
RICH 0
ALL
Print ESD
OFF
Only
Print clus
OFF
Only
Print digs
ON
Only
Next
Previous
Quit

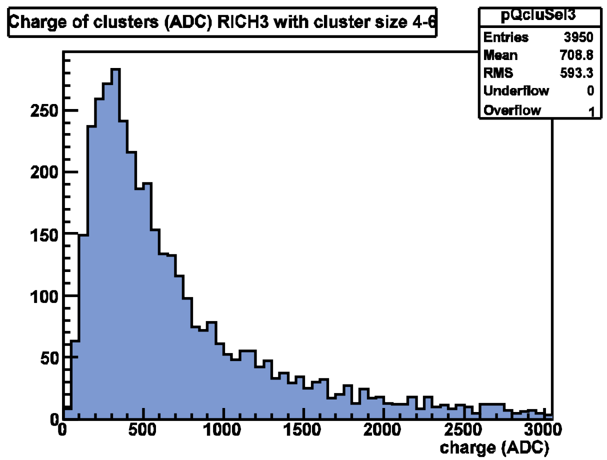

Applications Actions
Mon Aug 25, 11:42 AM
Session with DIGITS-105 CLUSTERS-105 ESD-105
Event 60 Total 105
TRKxPC 0
Mip hits 0
Ckov hits 0
Feed hits 0
Digs 71827
Clus 5417
ddl = (0....13)
RICH n ---> ddl 2n (left) & 2n+1 (right)
phcat (0,2,4) left, phcat (1,3,5) right
sigma cut = 0
RICH 6
RICH 5
RICH 4
RICH 3
RICH 2
RICH 1
RICH 0
ALL
Print ESD
OFF
Only
Print clus
OFF
Only
Print digs
ON
Only
Next
Previous
Quit
Module 3 Sector 1
Pads = 9225 - Clusters = 544 - Occupancy 40.04%
ALICE Electronic Logbook - Mozilla Firefox
Session with DIGITS-105 CLUSTERS-105

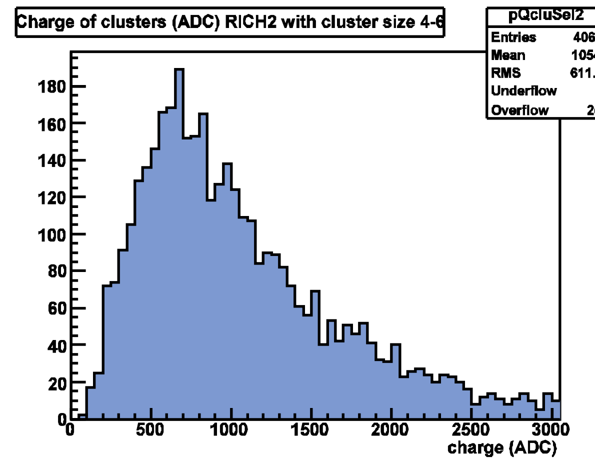


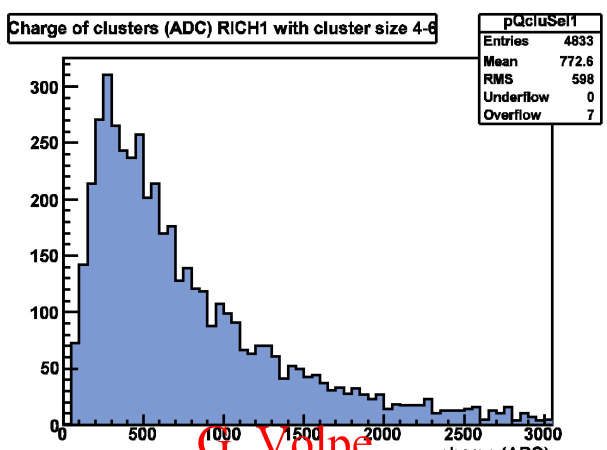


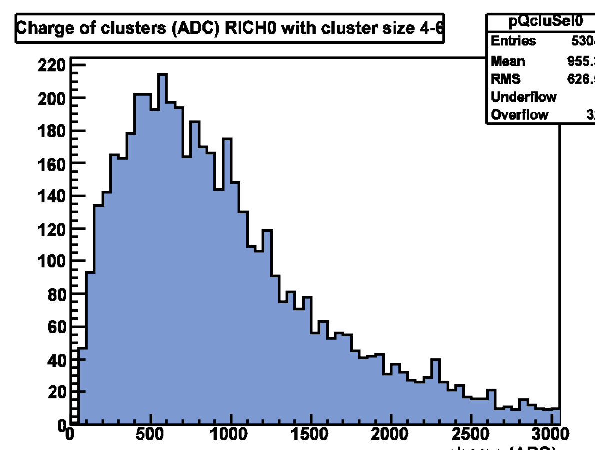
Cluster charge distribution selecting cluster with size between 4-6.





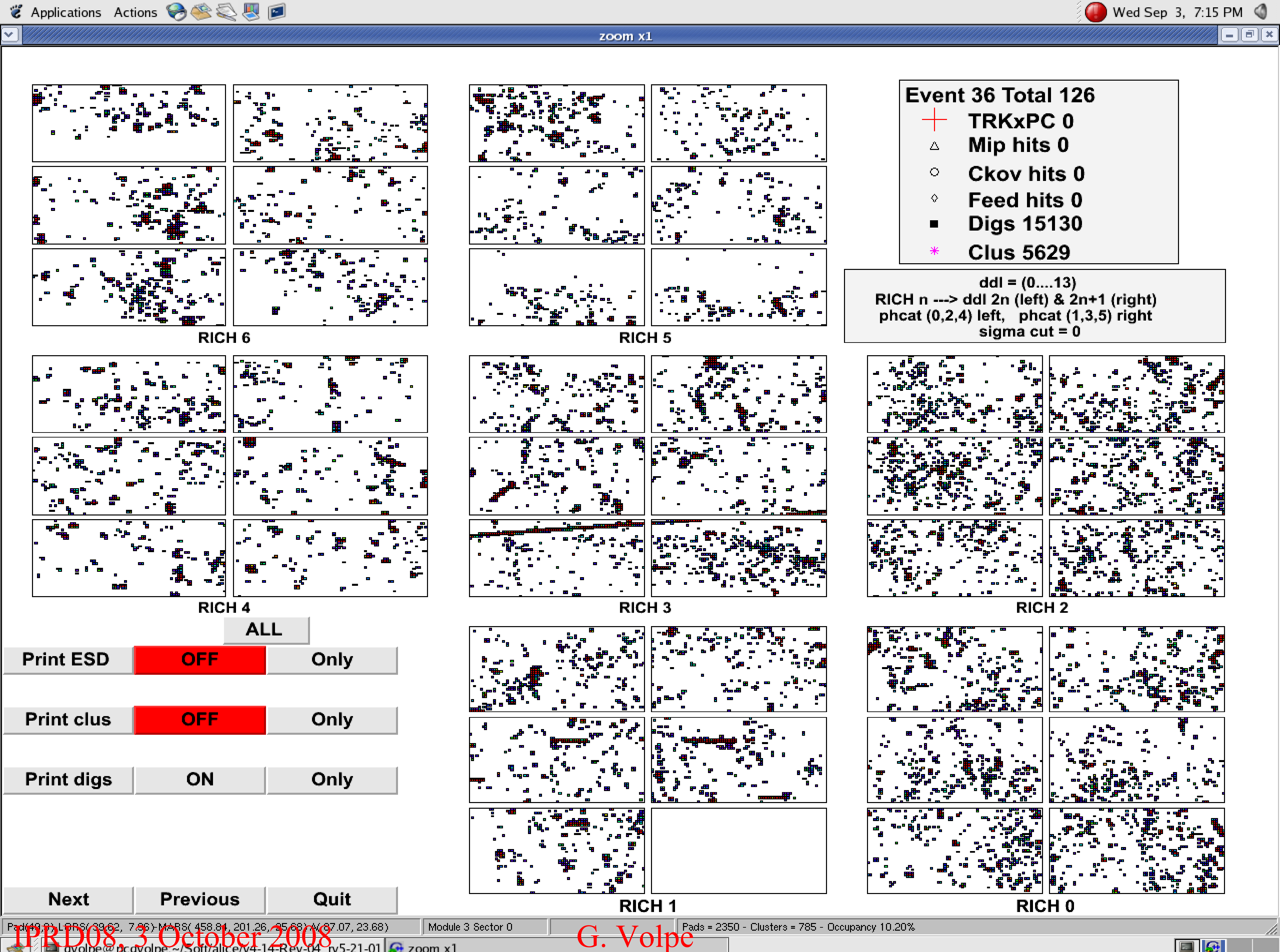




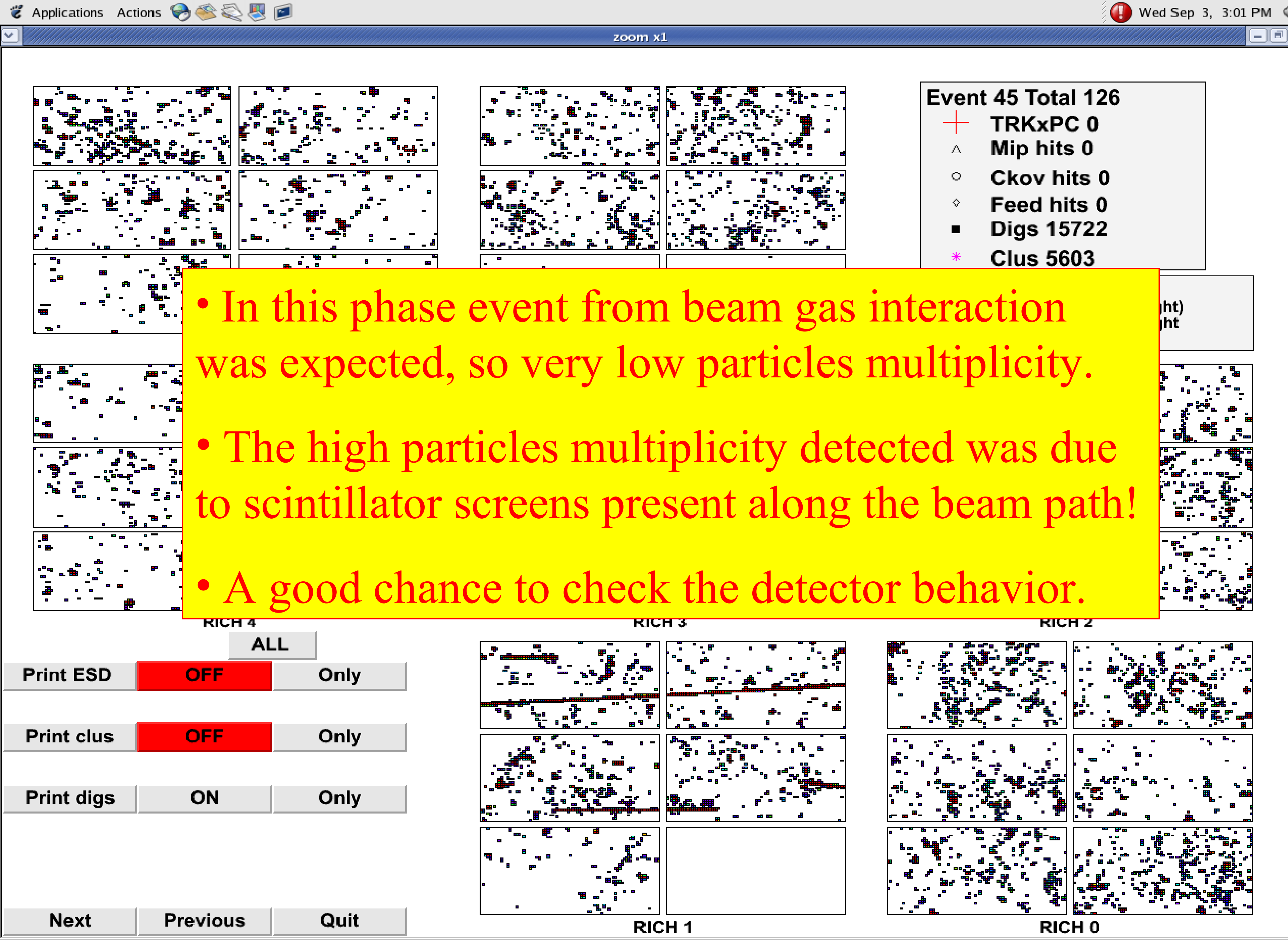


Results from beam injection test
Beam through ALICE

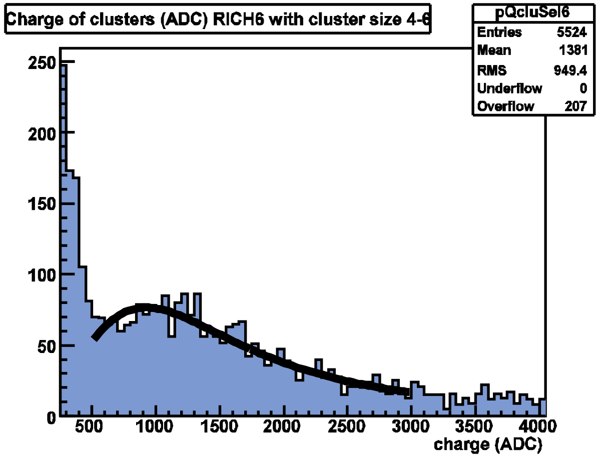
RICH6 2050 V	RICH5 2050 V	HV has been set to the nominal value.
RICH4 2050 V	RICH3 2050 V	RICH2 2050 V
	RICH1 2050 V	RICH0 2050 V

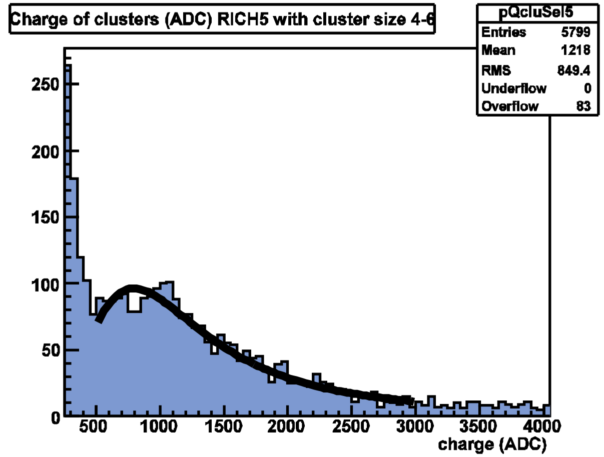


Applications Actions
Wed Sep 3, 7:15 PM
zoom x1
Event 36 Total 126
TRKxPC 0
Mip hits 0
Ckov hits 0
Feed hits 0
Digs 15130
Clus 5629
ddl = (0....13)
RICH n ---> ddl 2n (left) & 2n+1 (right)
phcat (0,2,4) left, phcat (1,3,5) right
sigma cut = 0
RICH 6
RICH 5
RICH 4
RICH 3
RICH 2
RICH 1
RICH 0
ALL
Print ESD
OFF
Only
Print clus
OFF
Only
Print digs
ON
Only
Next
Previous
Quit
Module 3 Sector 0
Pads = 2350 - Clusters = 785 - Occupancy 10.20%
zoom x1

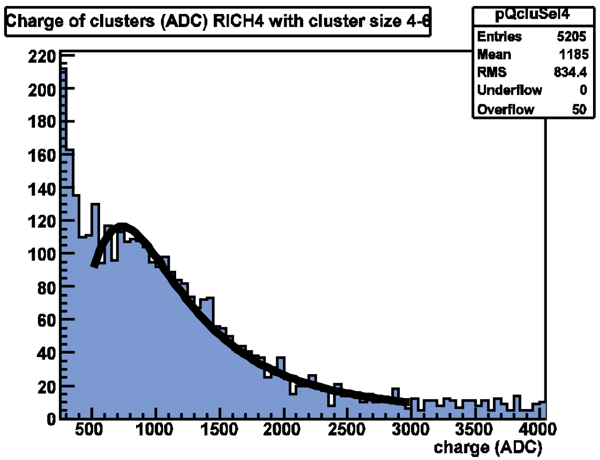


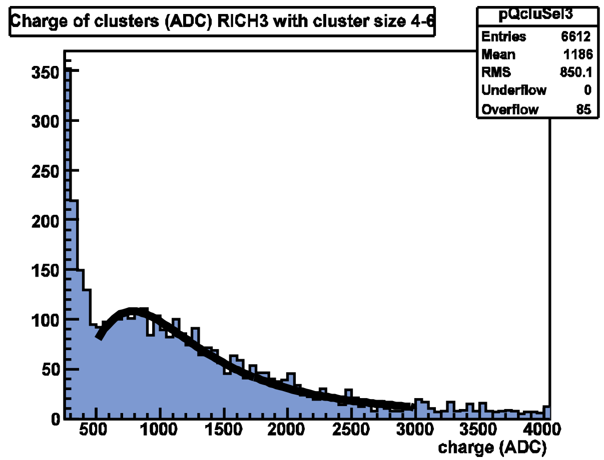
- In this phase event from beam gas interaction was expected, so very low particles multiplicity.
- The high particles multiplicity detected was due to scintillator screens present along the beam path!
- A good chance to check the detector behavior.

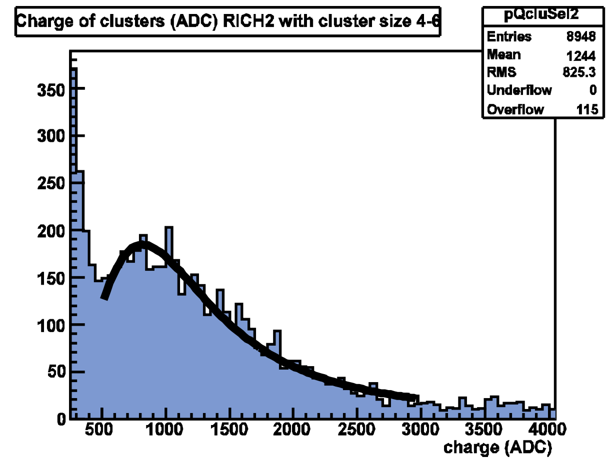


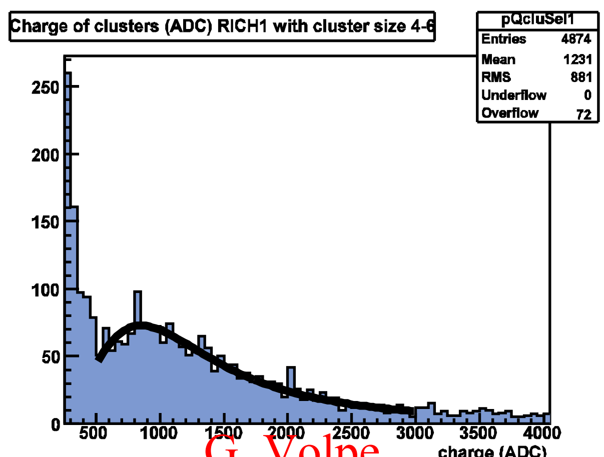


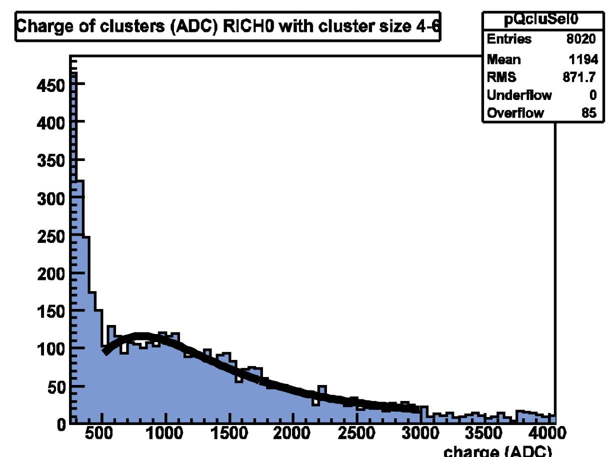
Cluster charge distribution selecting cluster with size between 4-6.







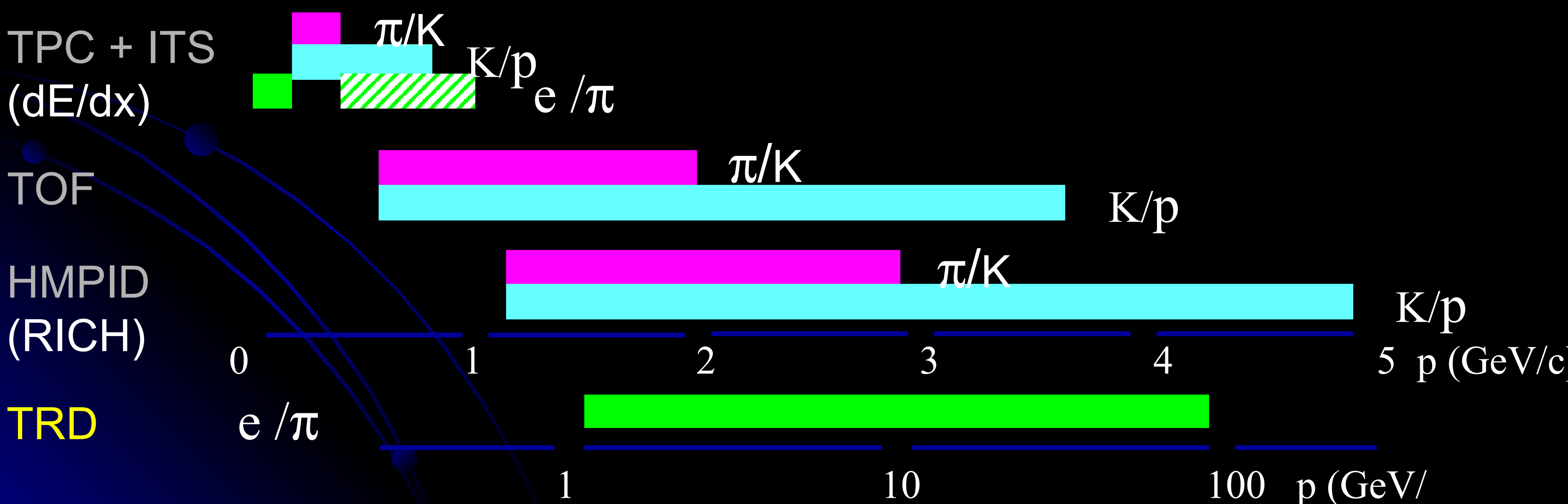




PID in ALICE

ALICE has a very good capability of charged particle identification, due to the exploiting of different types of detectors:

- ITS + TPC : low p_T identification (up to p = 600 MeV/c).
- TOF : covers intermediate p_T region.
- TRD : electrons identification.
- HMPID : high p_T region (1÷5 GeV/c).



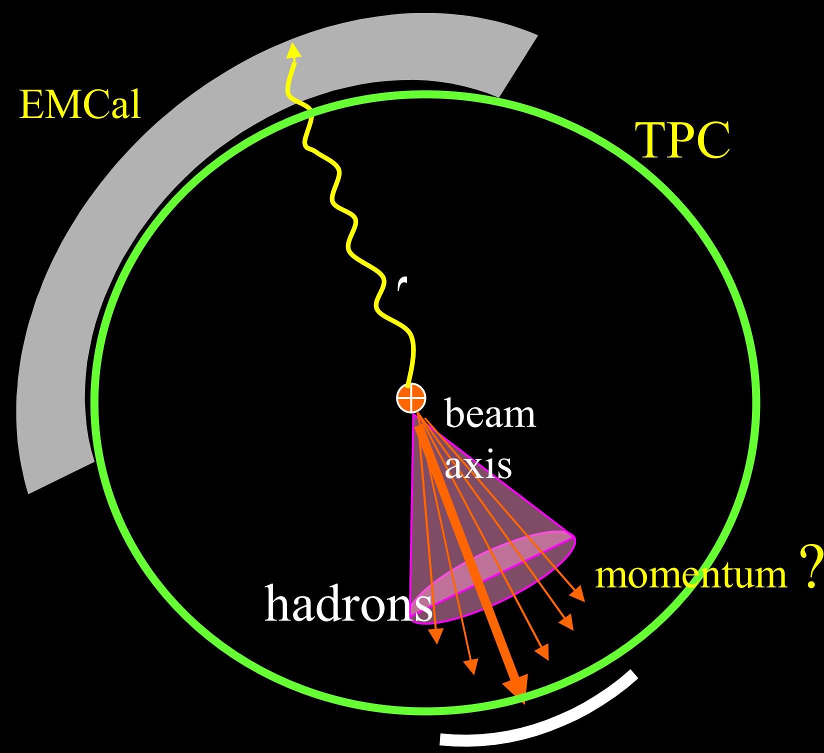
ALICE PID upgrade

• At RICH baryons – mesons ratio anomaly has been observed.

•According to the present theoretical studies, at LHC is expected a substantial increase of baryon production in the momentum range p = 10-30 GeV/c.

• The track-by-track identification of charged hadrons in such momentum range will be very important to have insights in the hadronization mechanism at LHC energies.

• The use of the Electromagnetic Calorimeter opens interesting possibility to distinguish quark and gluon jets in gamma - jet events and subsequently the study of the probability of fragmentation in pions, kaons or protons.



VHMPID

- ALICE-HMPID collaboration is studying the possibility to built a new detector to identify charged particles with momentum p > 10 GeV/c → VHMPID (Very High Momentum Particle Identification Detector).
- Energy loss or Time of Flight measurements don't allow to identify track-by-track in such momentum range.
- Since the given space in the ALICE detector and the physics requirements it seems inevitable to use gas Cherenkov counters.
- To use a gas Cherenkov detector in a magnetic field environment brings about the following key problems: the choice of radiator gas, the photon detection and the detector geometry.
- A combination of a gas with low value of refractive index, with the proven concept of large area CsI photo-cathodes, has been considered.
- Depending on the particle momentum values, with VHMPID will be possible to have PID by means pattern recognition method or by threshold counters technique.
- Simulation results will be presented.

VHMPID

Radiator gas

• CF_4 (n ≈ 1.0005, γ_{th} ≈ 31.6) has the drawback to produce scintillation photons (N_{ph} ≈ 1200/MeV), that increase the background.

• C_5F_{12} (n ≈ 1.002, γ_{th} ≈ 15.84) has a boiling point T_b = 28° C at 1 atm, implying a difficult use of it in ALICE setup, where the internal temperature could be more or less the same (heating plant is needed).

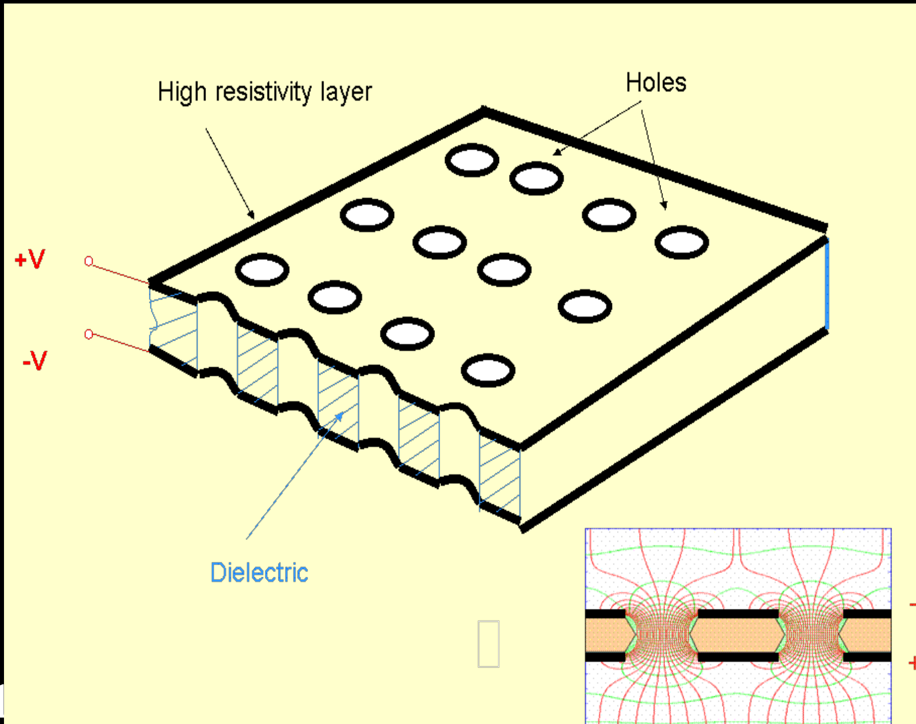
• C_4F_{10} (n ≈ 1.0014, γ_{th} ≈ 18.9) has been chosen.

Photon detector

• The same used in the HMPID detector.

• GEM-like detector combined with a CsI photo-cathode (higher gain, photons feedback suppression).

• The chamber is separated from the radiator by a SiO_2 window (4 mm of thickness).

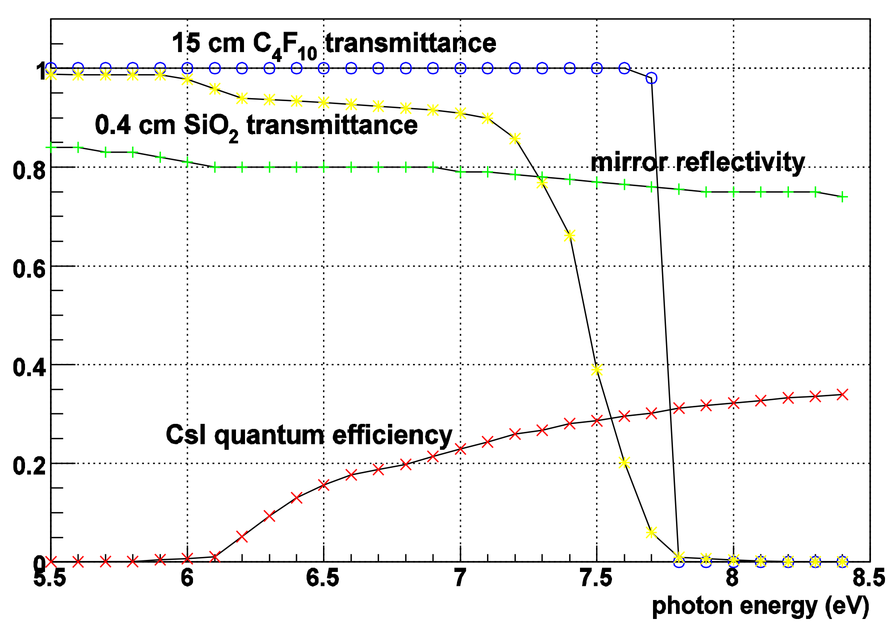


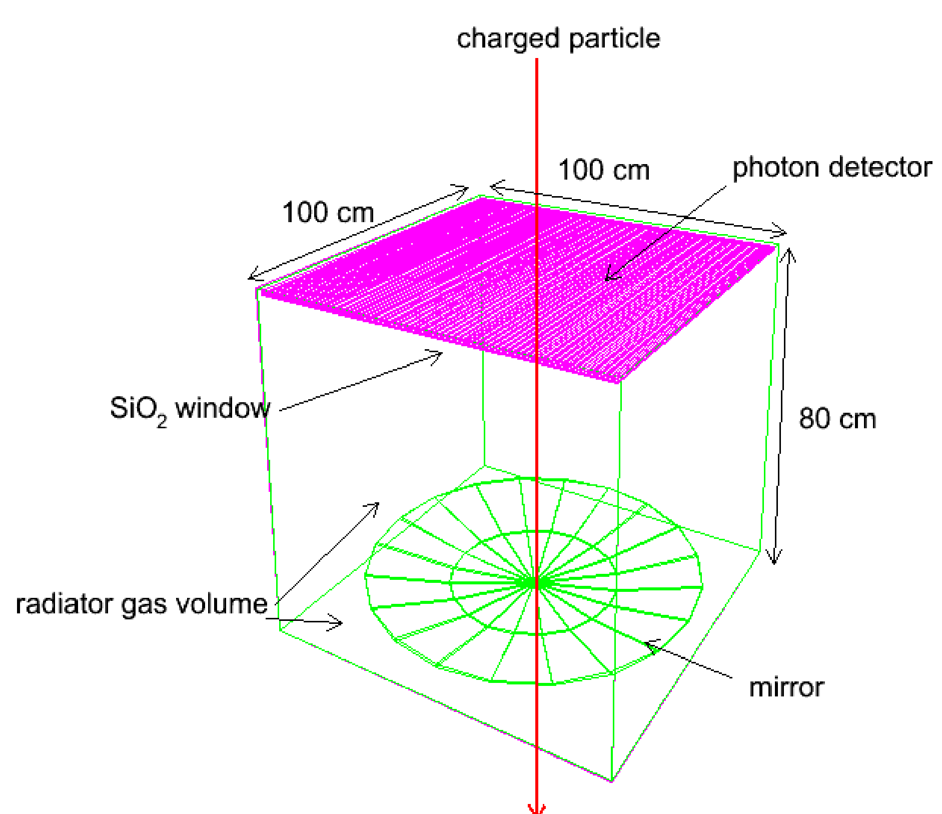
Studied setup

• The available space in the ALICE apparatus is not too much. The goal is to decrease much as possible the detector dimension.

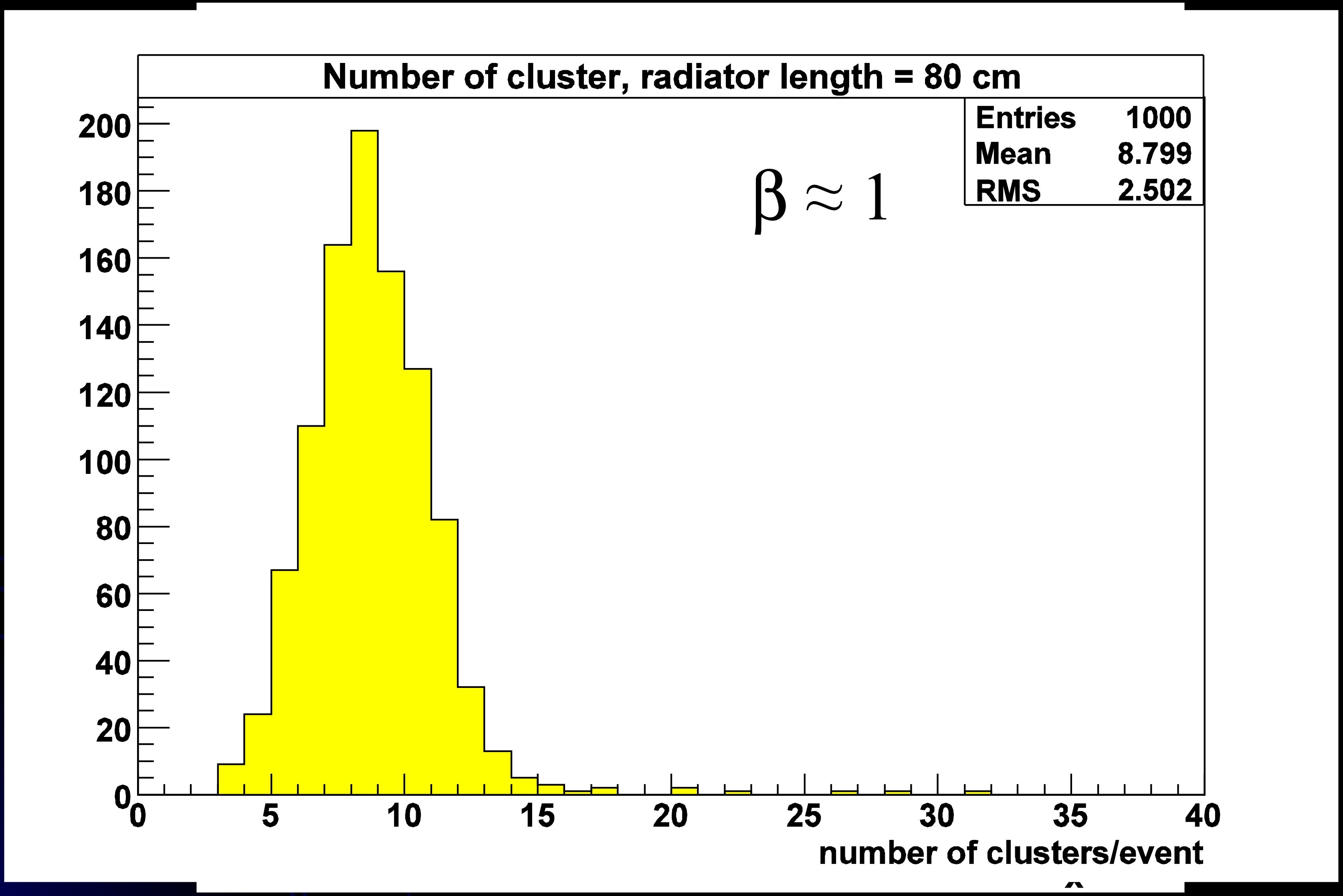
• The simulation has been executed using AliRoot, the official simulation framework of the ALICE experiment.

• The focusing properties of a spherical mirror of radius R = 160 cm, are exploited. The photons emitted in the radiator are focused in a plane that is located at R/2 from the mirror center, where the photon detector is placed.





Simulation results: Cherenkov angle

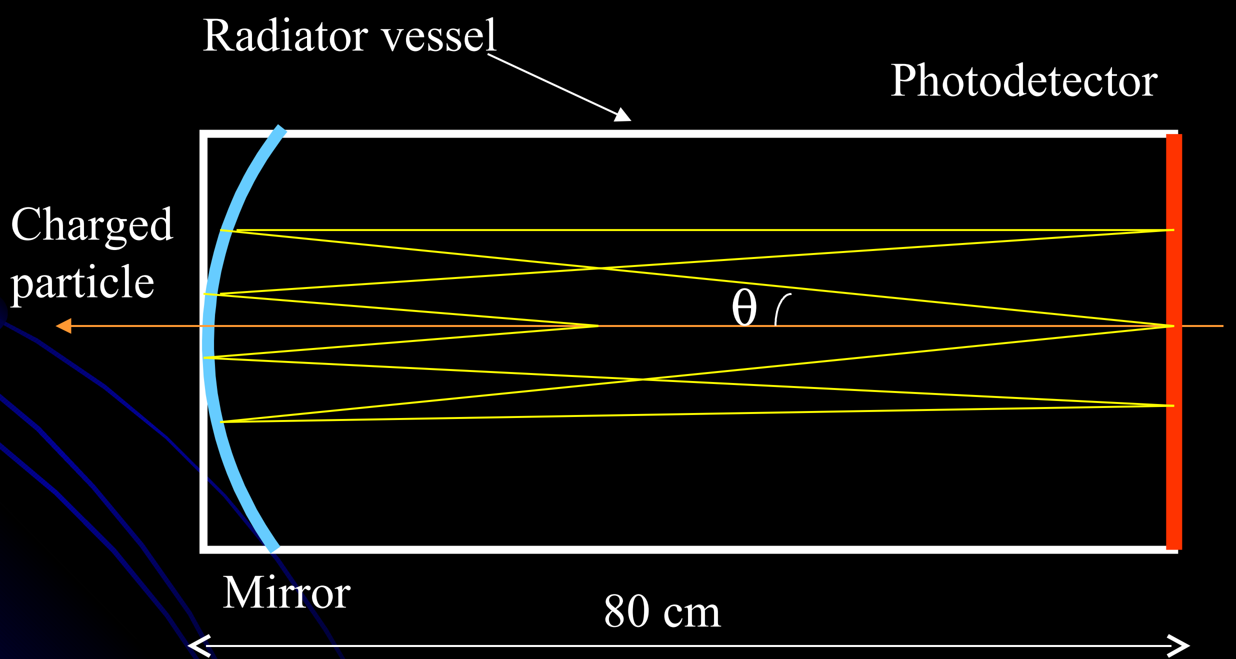


Study of the detector response

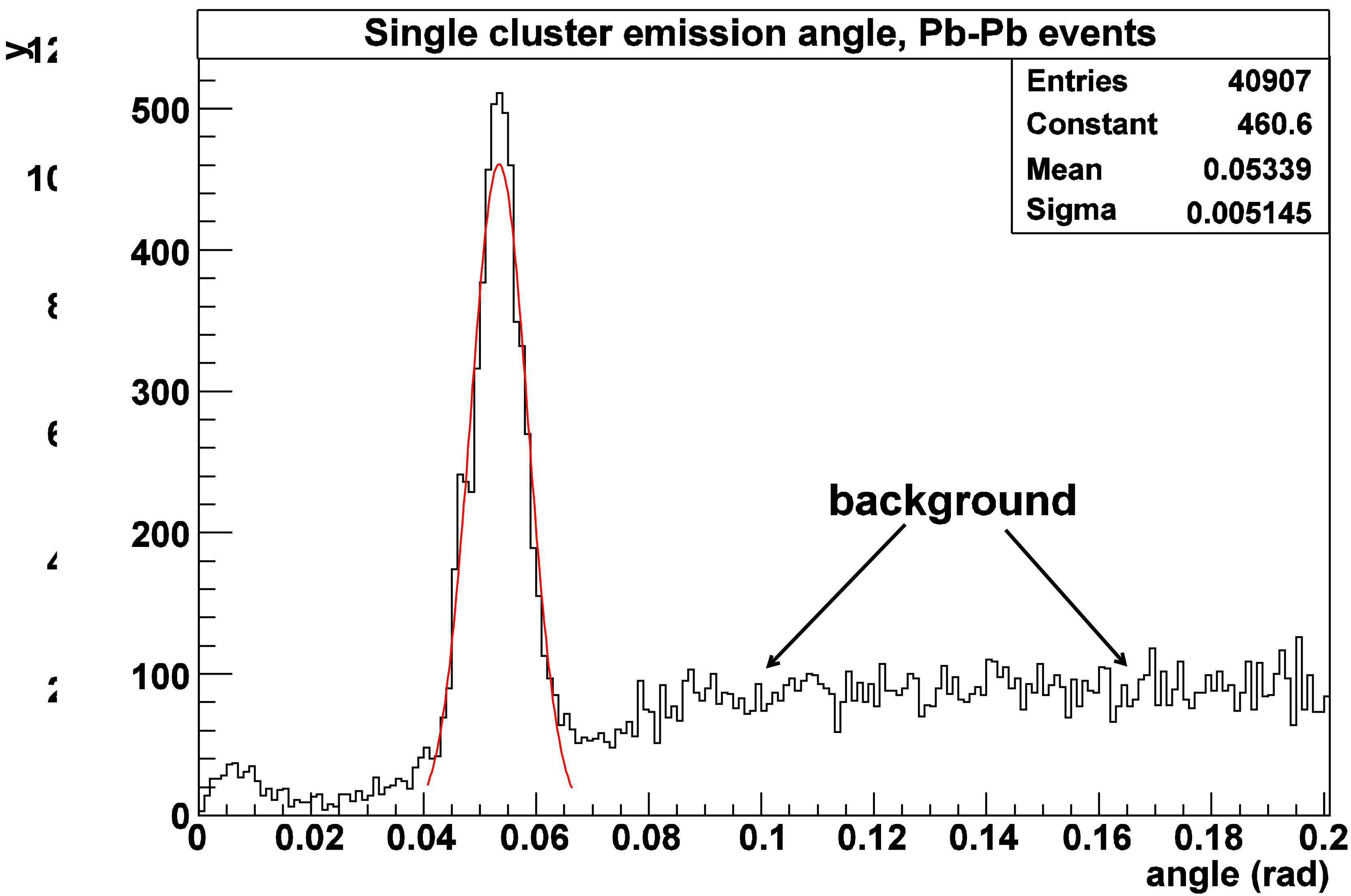
• With a focusing setup the determination of Cherenkov emission angle is possible.

• Pattern recognition algorithm is needed to retrieve the emission angle.

• A back-tracing algorithm has been implemented to retrieve the Cherenkov emission angle. It calculates the angle starting from the photon hit point coordinates, on the photon detector.



Simulation results: Pb-Pb background



Background subtraction algorithm
Hough transform method

• The Hough Transform Method (HTM) is an efficient implementation of a generalized *template matching* strategy for detecting complex patterns in binary images.

• In the case of the Cherenkov pattern recognition, the starting point of the analysis is a bidimensional map with the impact point (x_p, y_p) of the charged particles, hitting the detector plane with known incidence angles (θ_p, φ_p), and the coordinates (x, y) of hits due to both Cherenkov photons and background sources.

• A "Hough counting space" is constructed for each charged particle, according to the following transform:

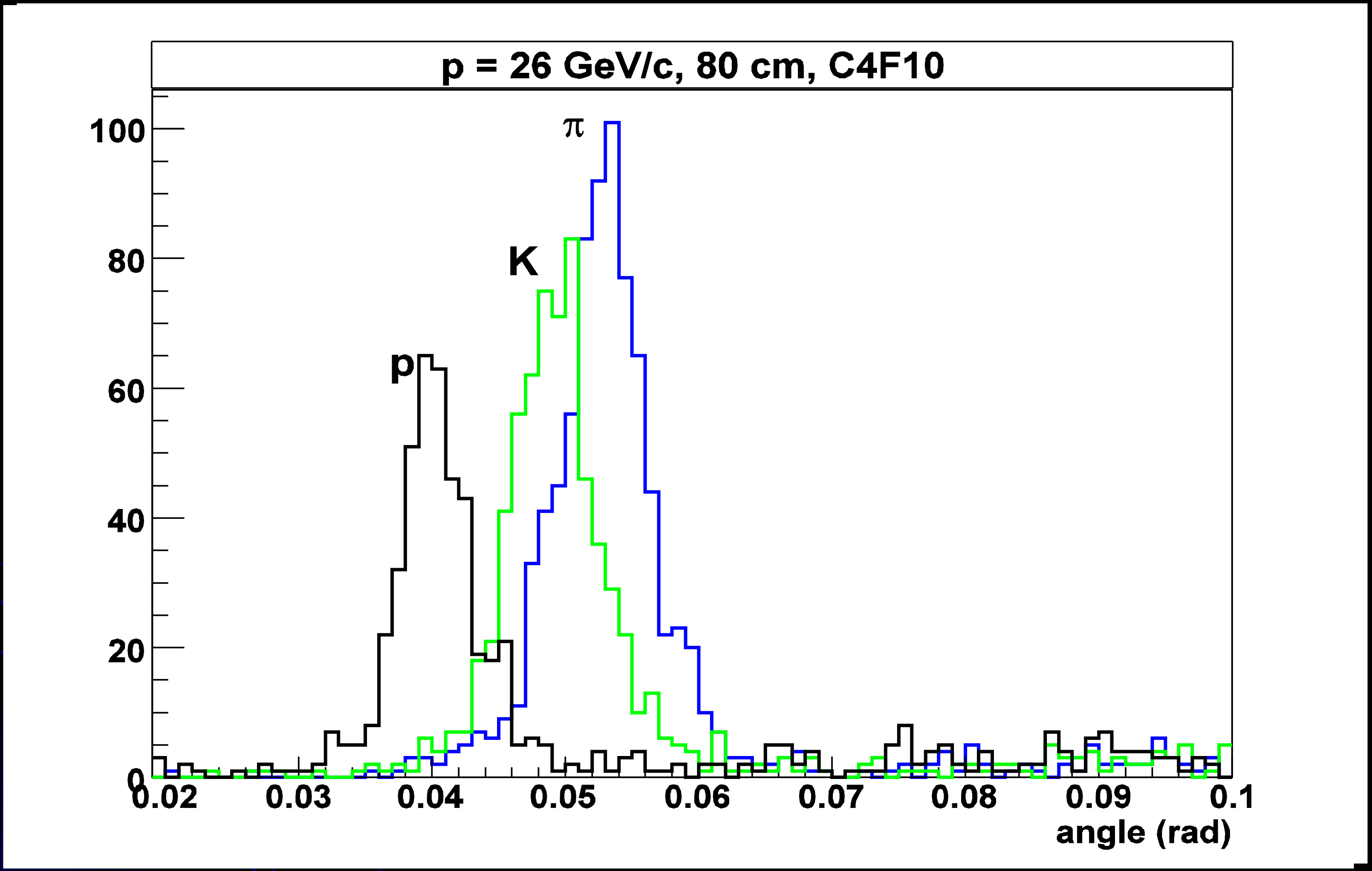
$$(x, y) \rightarrow ((x_p, y_p, \theta_p, \varphi_p)\ ,\ \eta c)$$

• (x_p, y_p, θ_p, φ_p) is provided by the tracking of the charged particle, so the transform will reduce the problem to a solution in a one-dimensional mapping space.

• A η_c bin with a certain width is defined.

• The Cherenkov angle θ_c of the particle is provided by the average of the η_c values that fall in the bin with the largest number of entries.

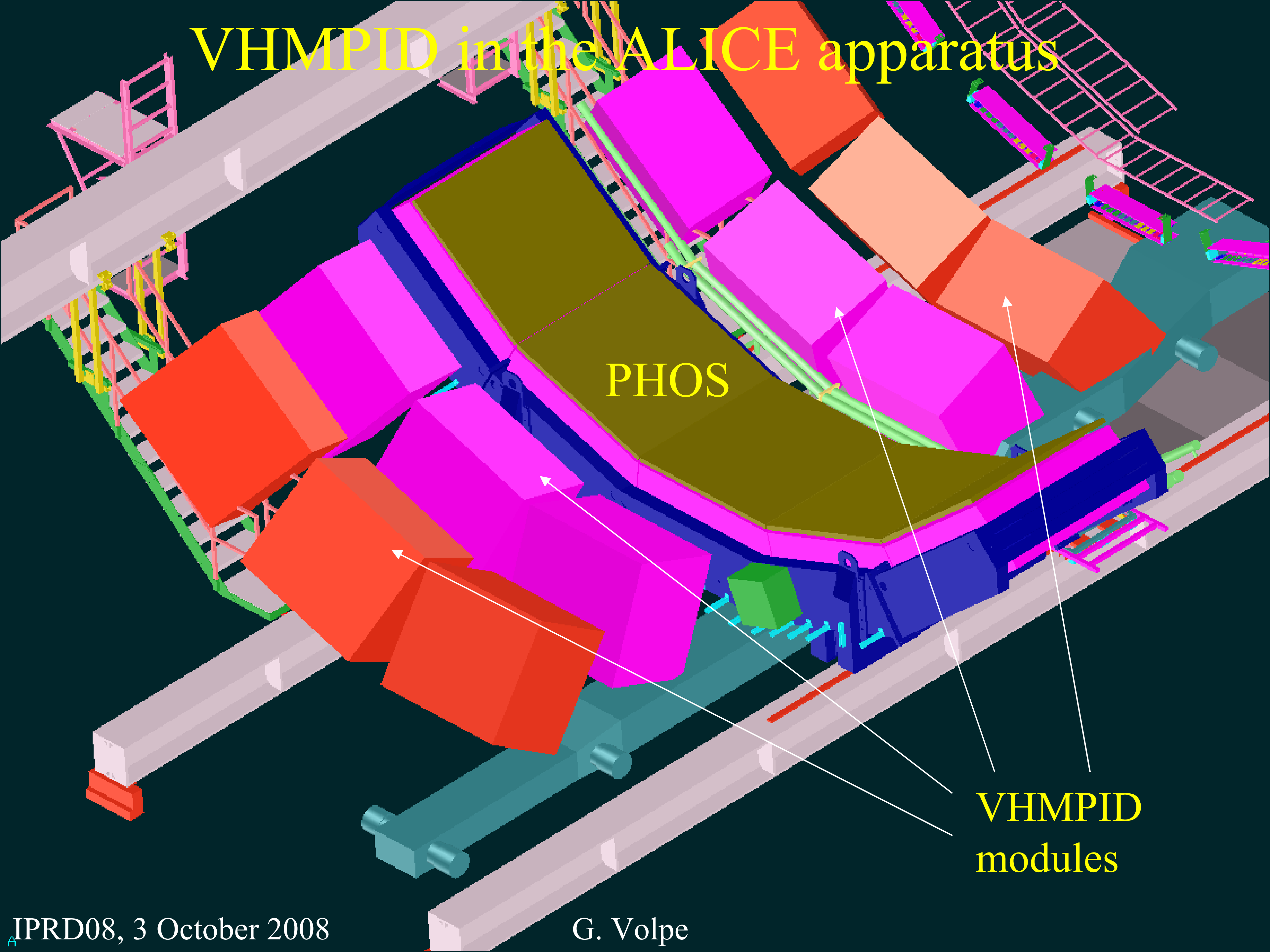
Simulation results: Cherenkov angle



Momentum range for π, K and p identification in Pb-Pb collisions environment.

Momentum	C_4F_{10}	Particle Id.
< 3 GeV/c	0	?
3< p < 9 GeV/c	1	π
3 < p < 9 GeV/c	0	K, p
9 < p < 14 GeV/c	1	π, K
9 < p < 17 GeV/c	0	p
17 < p < 26 GeV/c	1	p

VHMPID in the ALICE apparatus



Conclusions & Outlook

• The results obtained from the cosmics and beam injection test have proven that HMPID works as expected.

• Nevertheless calibration (chambers gain, refractive index) and alignment with cosmics are not possible since high tracks statistic is necessary.

• HMPID is waiting for collisions!!!

• Simulation studies show that it is possible to improve the PID capability of the ALICE apparatus by means of a new Cherenkov detector.

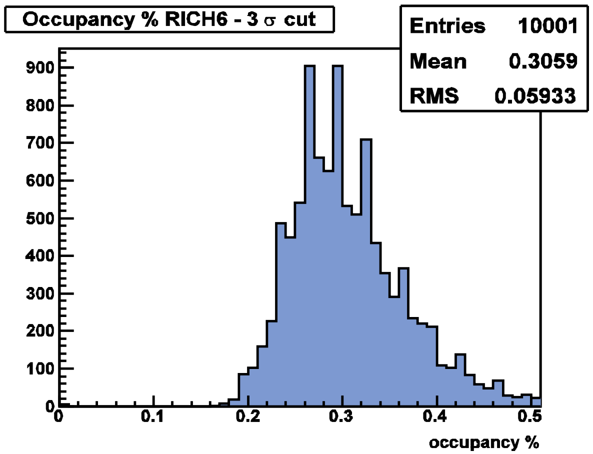
• Test beam on the first prototype of VHMPID are foreseen already for November of this year at CERN.

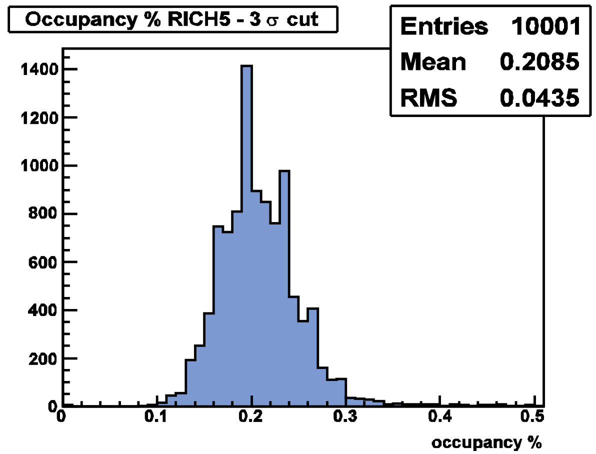
• To enrich the sample with interesting event, triggering option for VHMPID has been also considered, using a dedicated trigger (see L. Boldizsar talk) and/or photons in the EMCal.

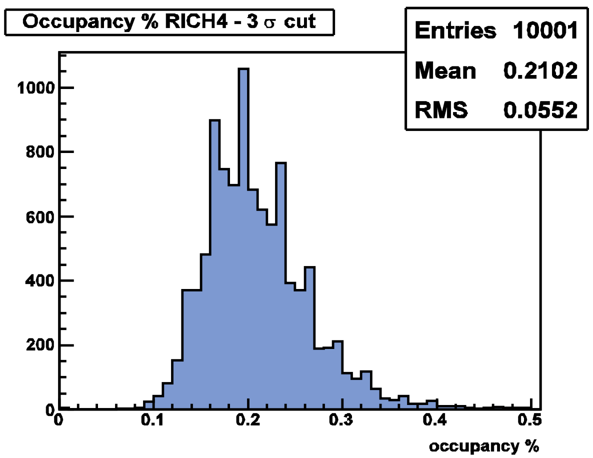
backup

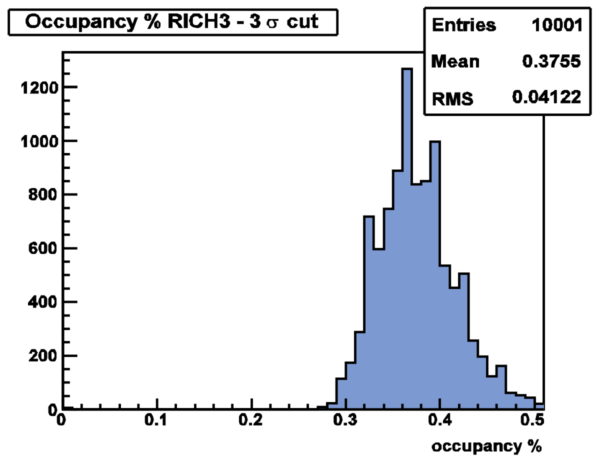
3σ cut

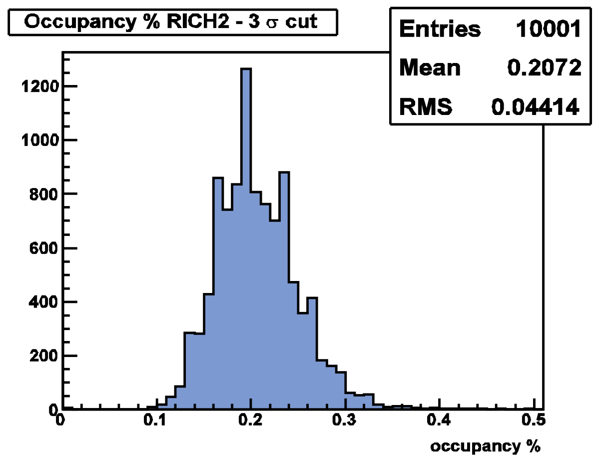
Run 47522

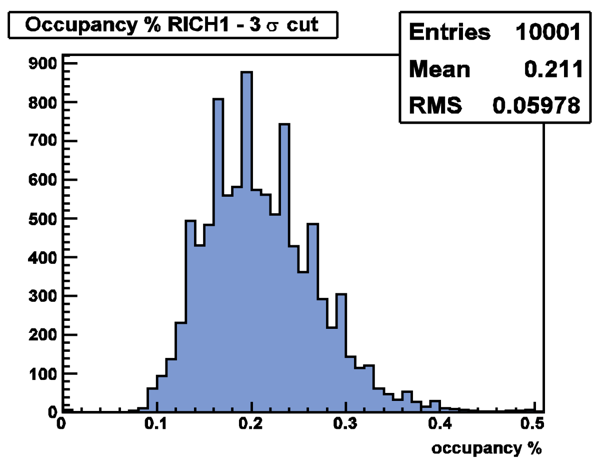


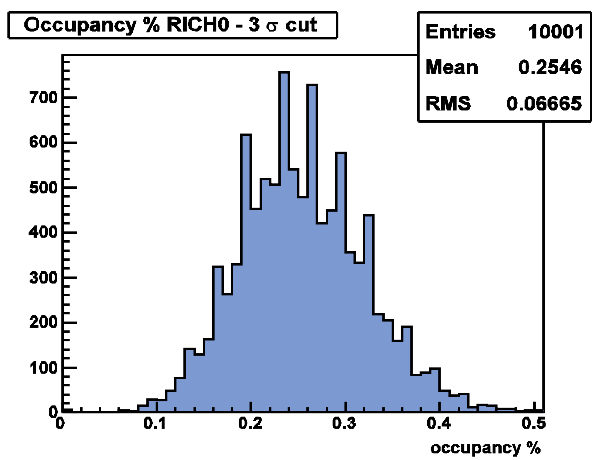






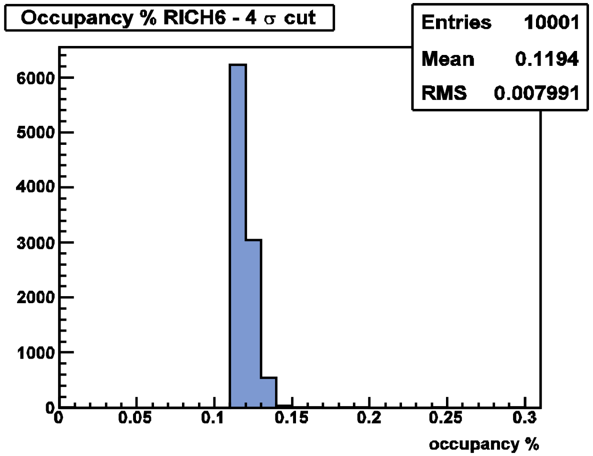


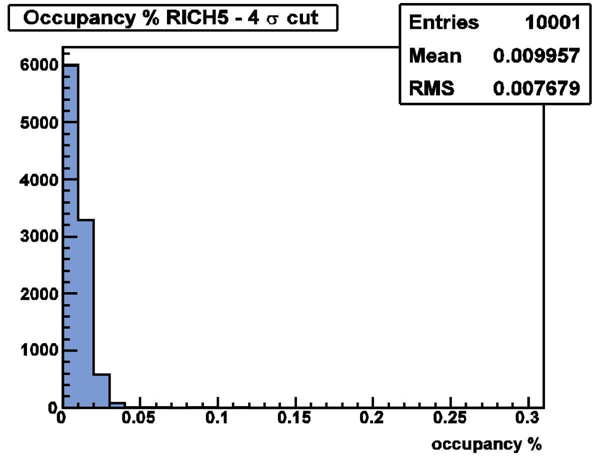


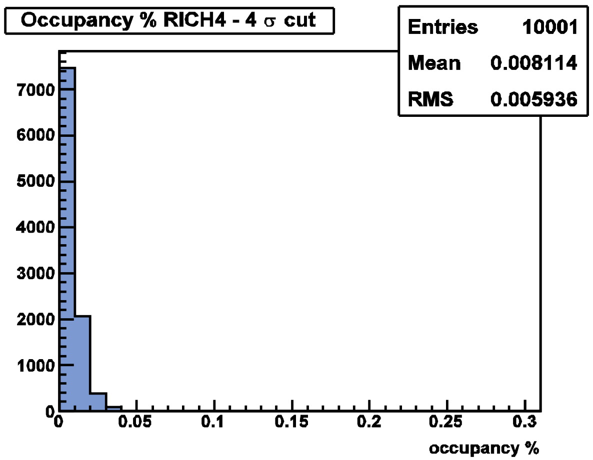


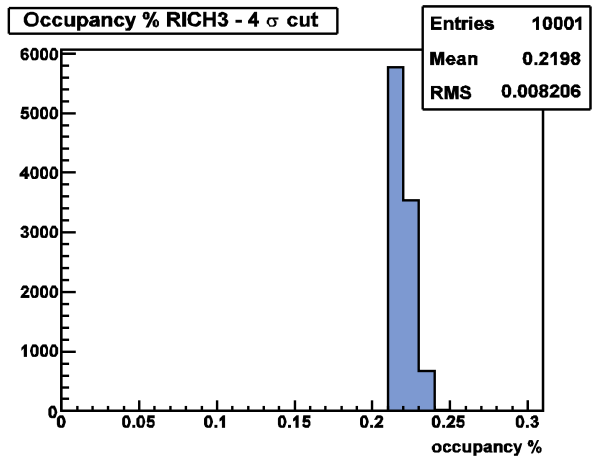
4σ cut

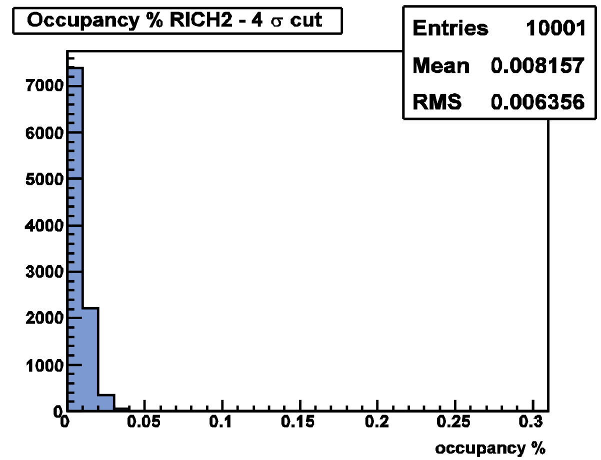
Run 47530

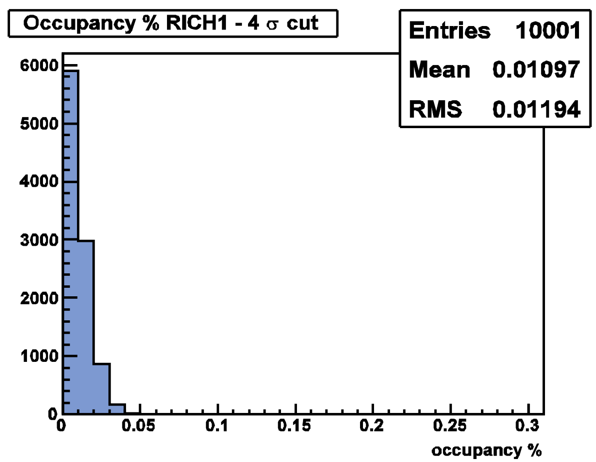


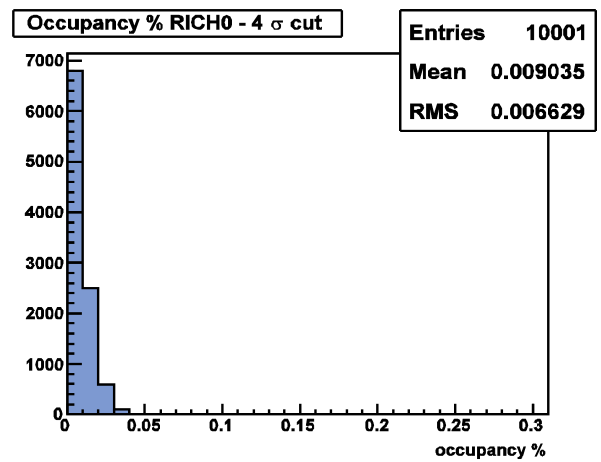


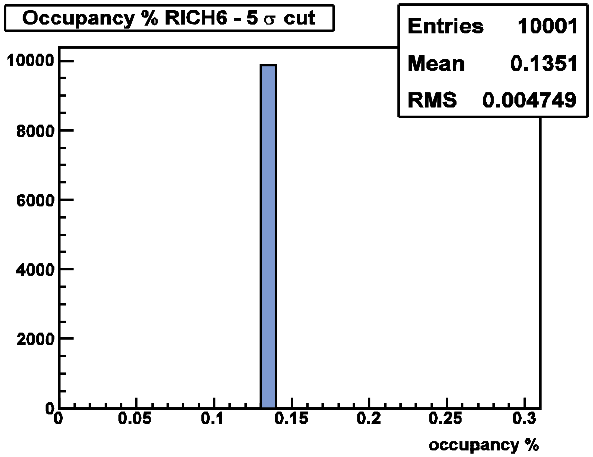


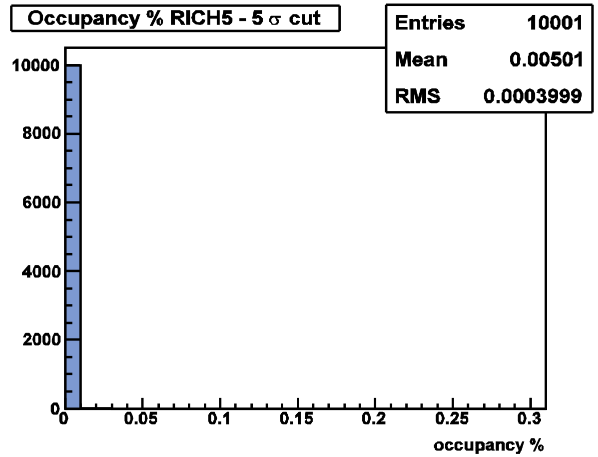






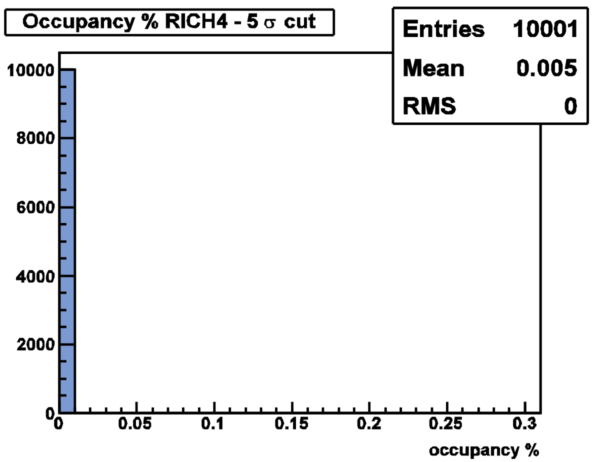


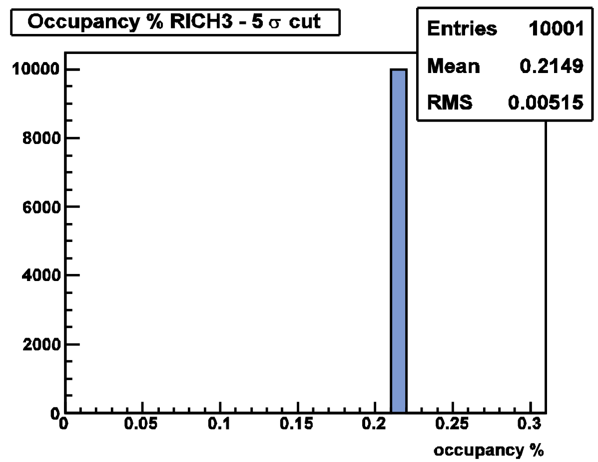


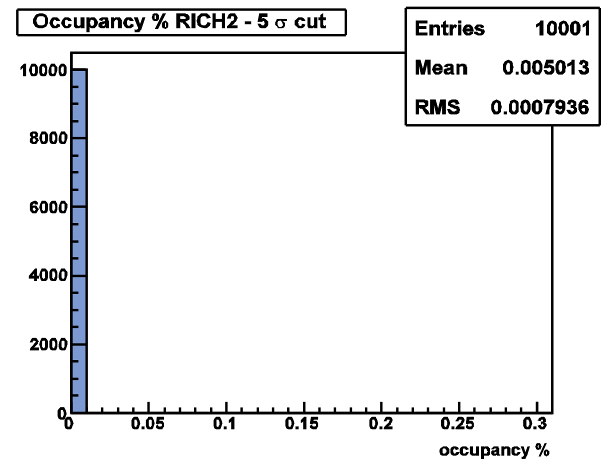


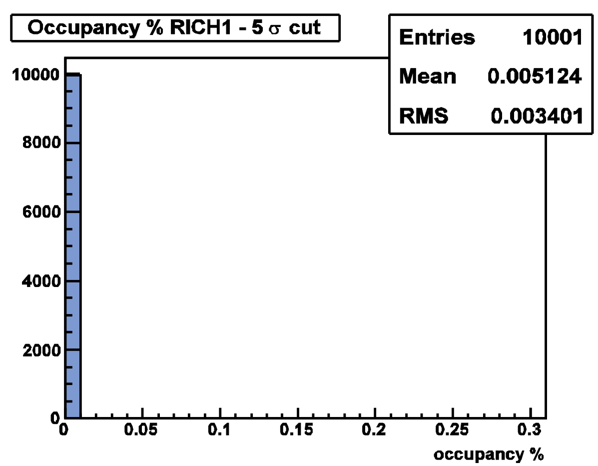
5σ cut

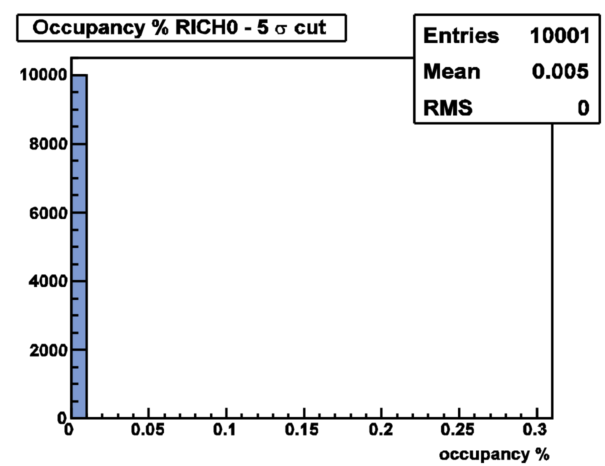
Run 47533

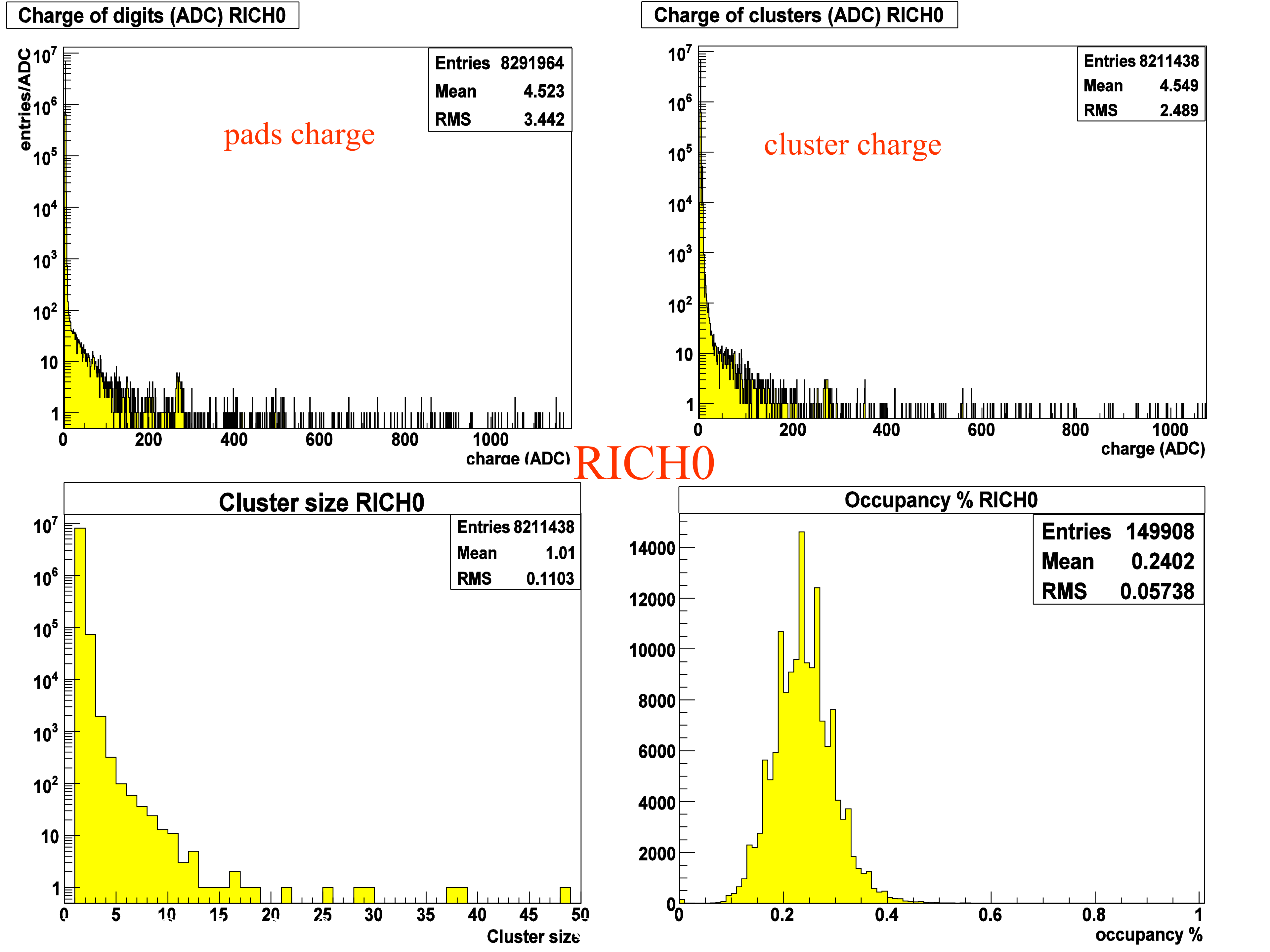


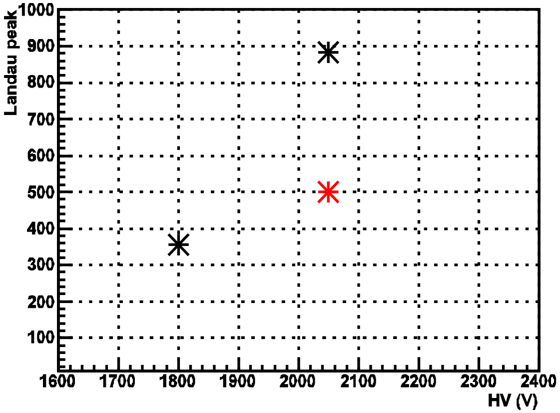


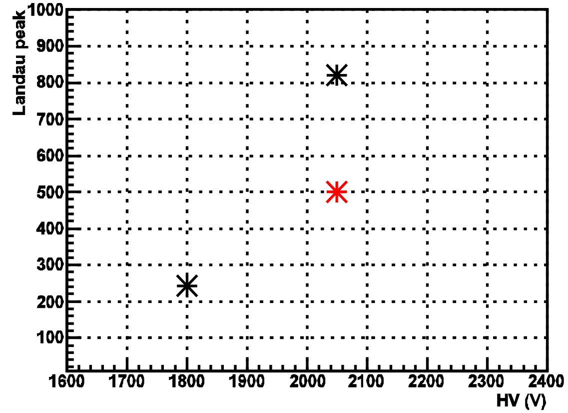




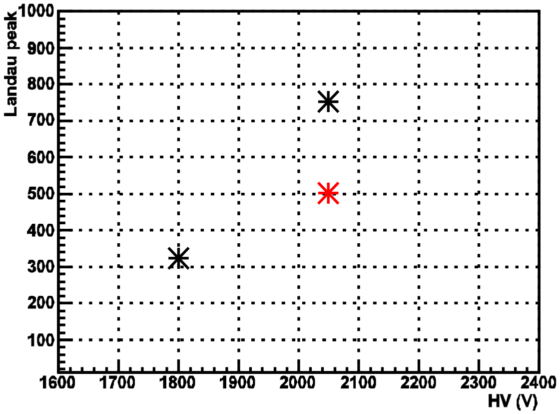


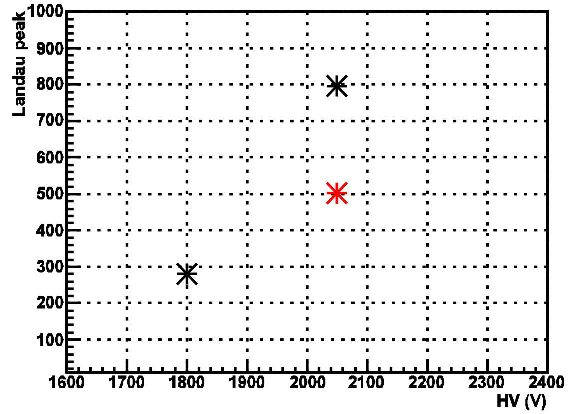

Charge of digits (ADC) RICH0
Entries 8291964
Mean 4.523
RMS 3.442
pads charge
entries/ADC
charge (ADC)
Charge of clusters (ADC) RICH0
Entries 8211438
Mean 4.549
RMS 2.489
cluster charge
charge (ADC)
RICH0
Cluster size RICH0
Entries 8211438
Mean 1.01
RMS 0.1103
Cluster size
Occupancy % RICH0
Entries 149908
Mean 0.2402
RMS 0.05738
occupancy %

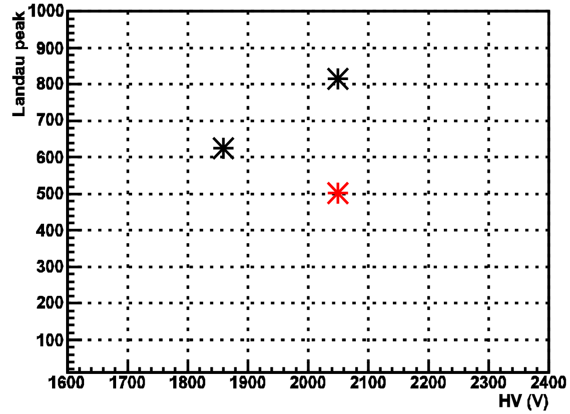


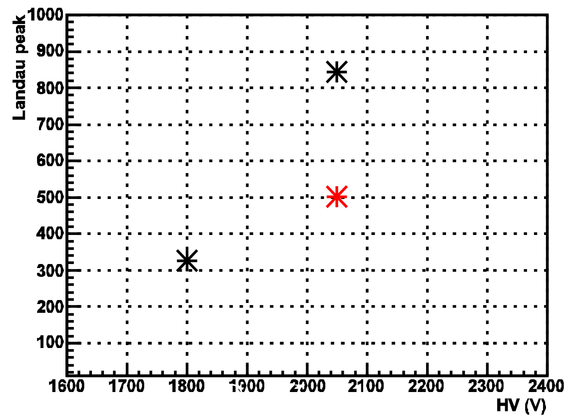


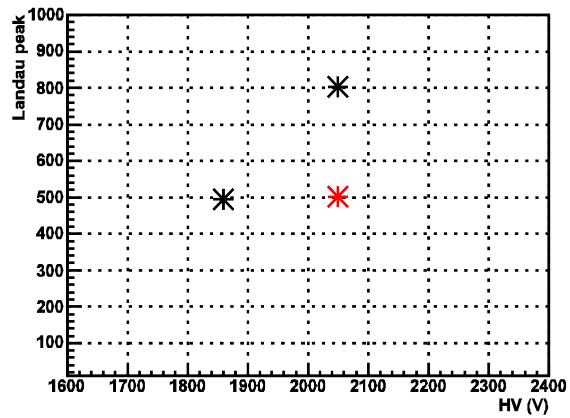
* test beam data (orthogonal tracks, less charge)

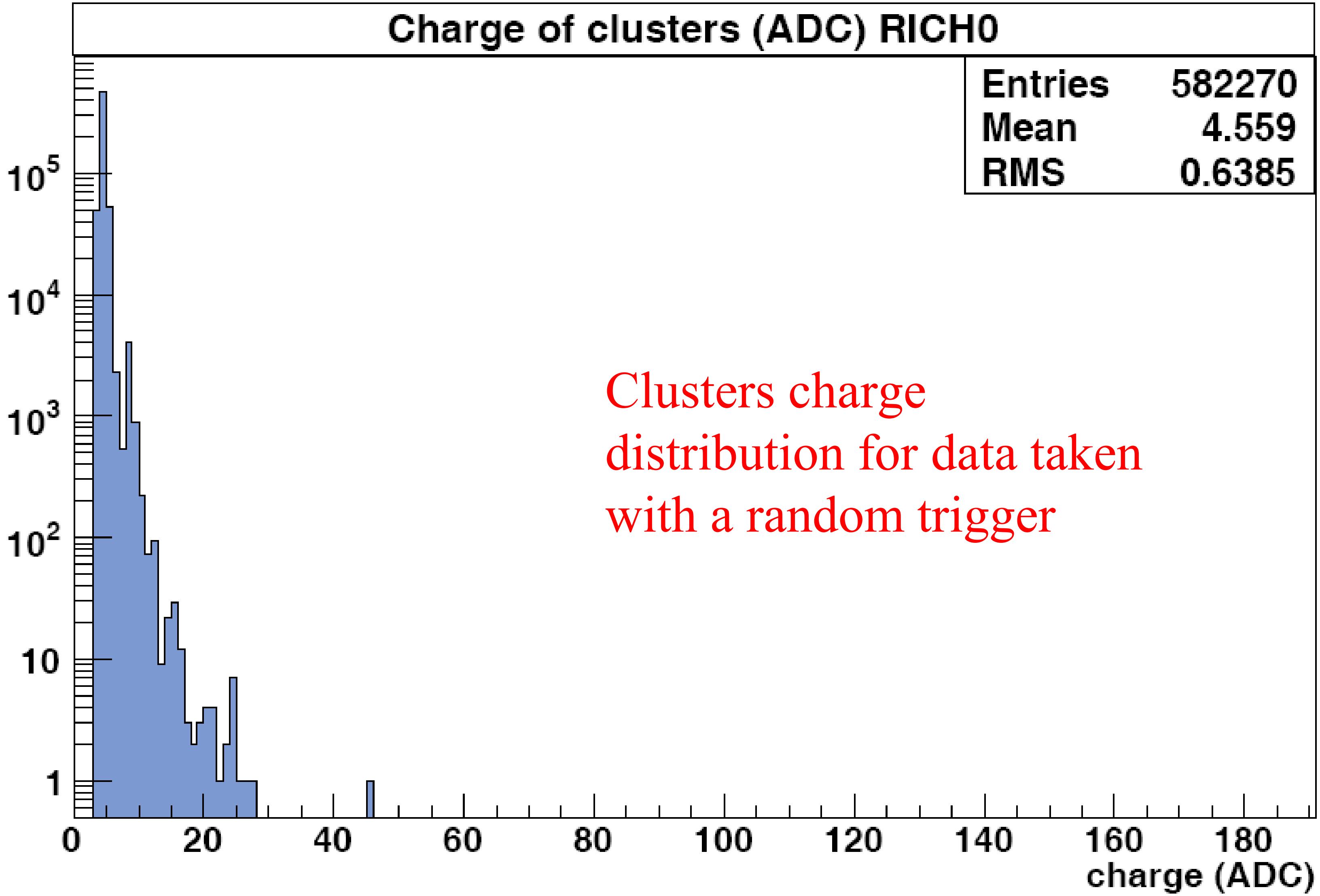








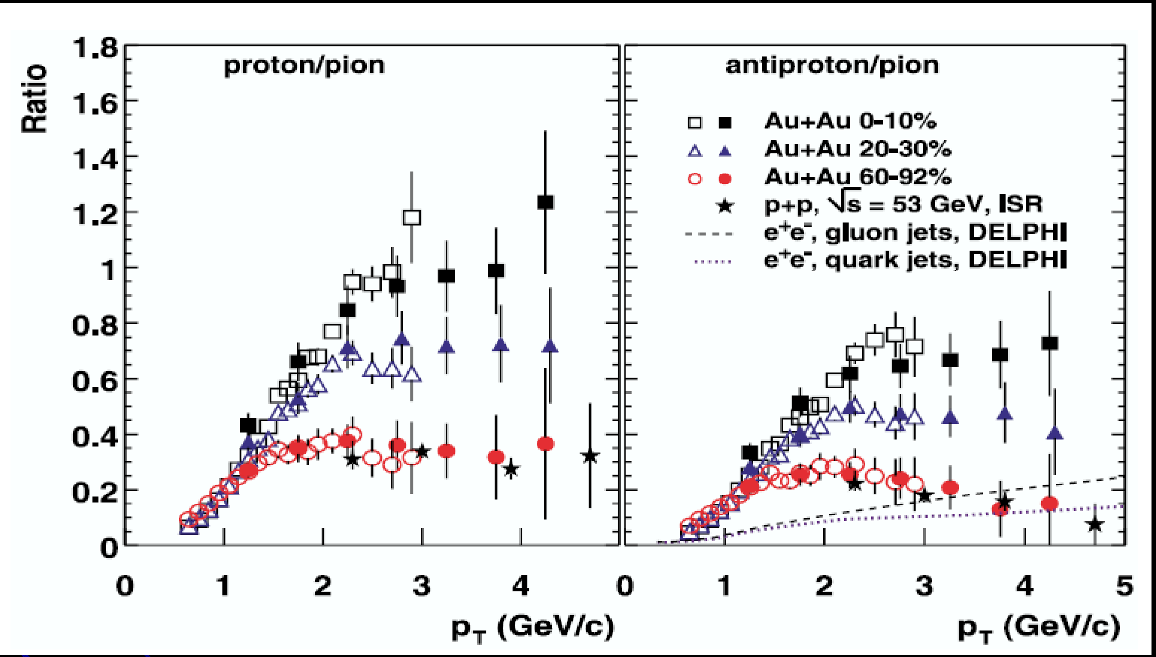




Clusters charge distribution for data taken with a random trigger

ALICE PID upgrade

RICH results: At RHIC has been observed a large enhancement of baryons and antibaryons relative to pions at intermediate $p_T \approx 2$ - 5 GeV/c, while the neutral pions and inclusive charged hadrons are strongly suppressed at those p_T.



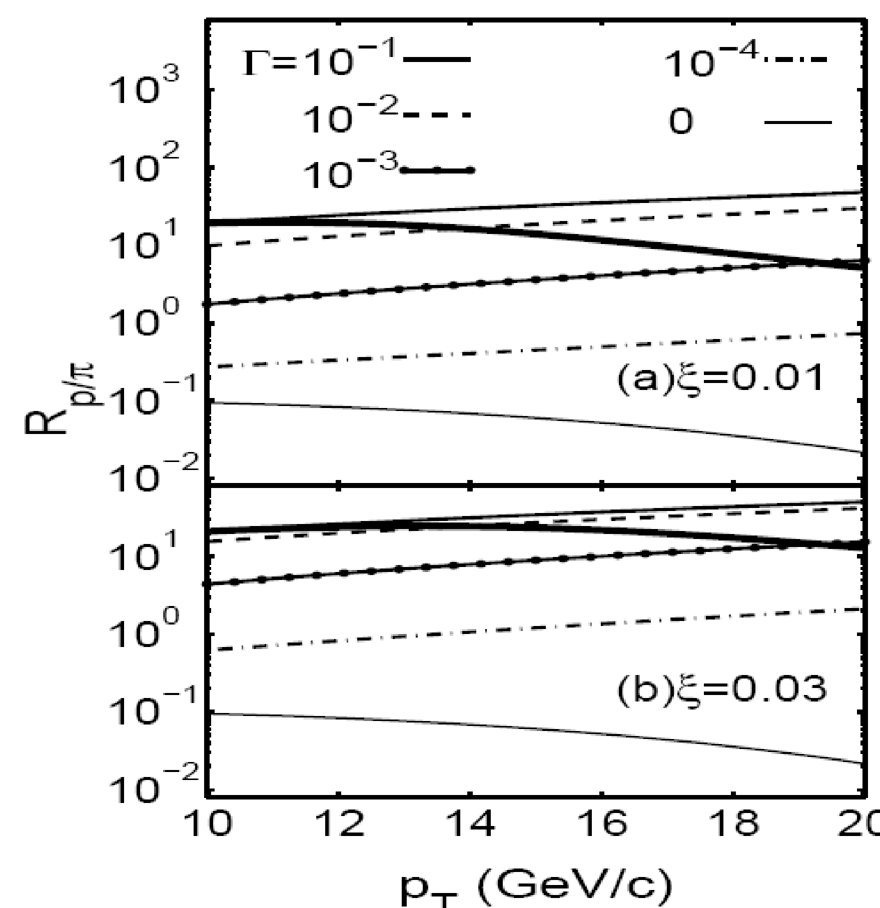
• The key issue is to understand what is the mechanism of the hadronization and the influence of this mechanism on the spectra of baryons and mesons.

ALICE PID upgrade

• The baryon puzzle observed at RICH can be interpreted with the "partons recombination" or "coalescence" mechanism.

• In the recombination scenario quark-antiquark pair close in the phase space can form a meson at hadronization, while three (anti)quark can form an (anti)baryon.

At LHC where the density of jets is very high, a new phenomenon originates where the recombination of shower partons in neighboring jets can make a significant contribution. It is foreseen that the baryon enhancement will be present in a momentum range higher than at RHIC, p_T = 10 ÷ 20 GeV/c. (ref. Rudolph C. Hwa, C. B. Yang, arXiv:nucl-th/0603053 v2, 21 Jun 2006)

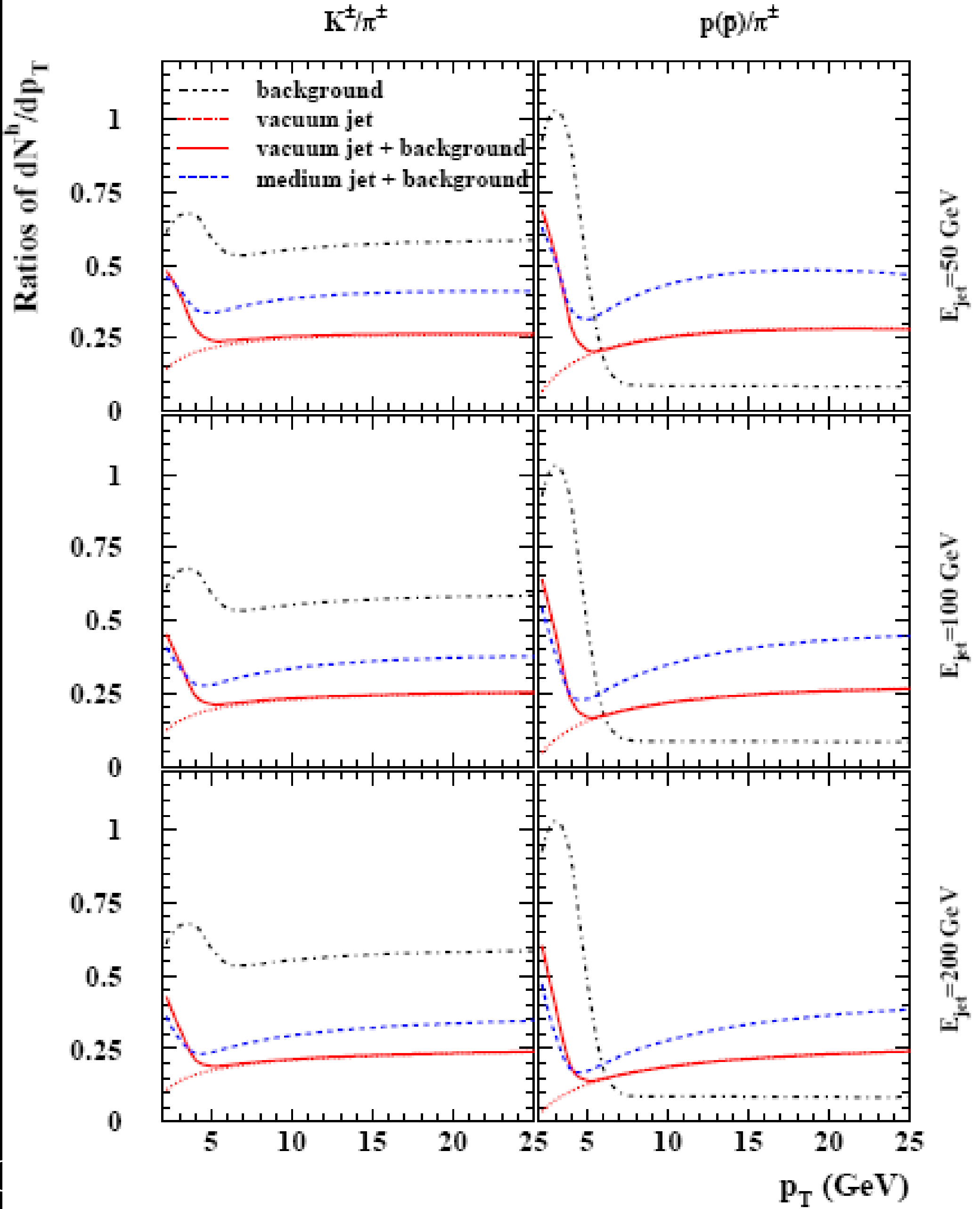


ALICE PID upgrade

Other authors using different arguments foresee also change in meson-baryon ratio for p_T > 10 GeV/c.

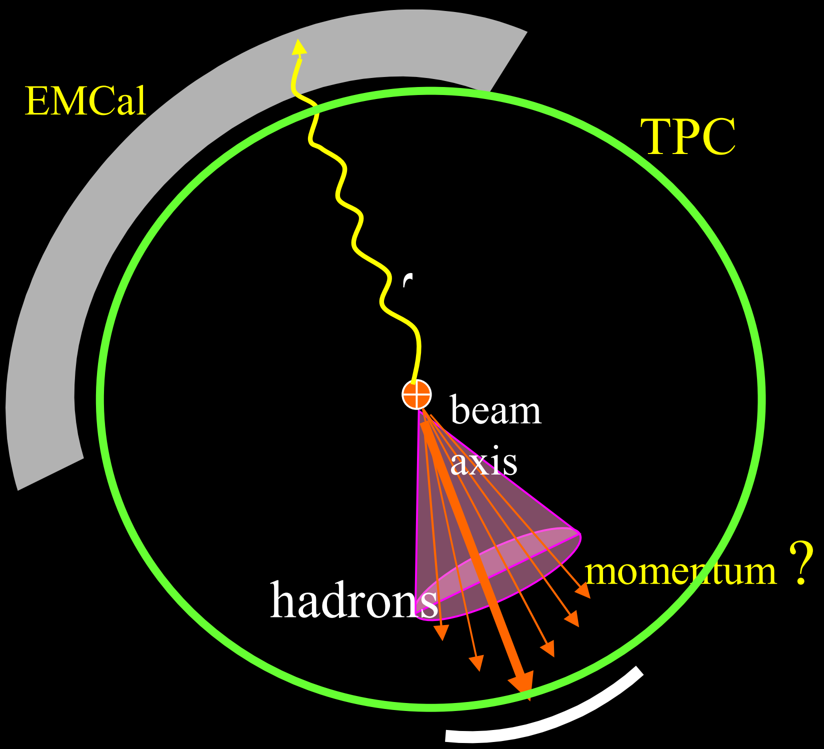
Jet quenching can leave signatures not only in the longitudinal and transverse jet energy and multiplicity distributions, but also in the hadrochemical composition of the jet fragments.

S. Sapeta and U. A. Wiedemann, arXiv:0707.3494 [hep-ph], July 2007.



ALICE PID upgrade

• The use of the Electromagnetic Calorimeter opens interesting possibility to distinguish quark and gluon jets in gamma - jet events and subsequently the study of the probability of fragmentation in pions, kaons or protons.



• Regardless of the theoretical interpretations it seems important to have the possibility to measure the meson-baryon ratio up to momenta well above the current limits of ALICE for a track-by-track identification.