Status of the Micromegas SDHCAL project

LCWS, Arlington, October 24th 2012

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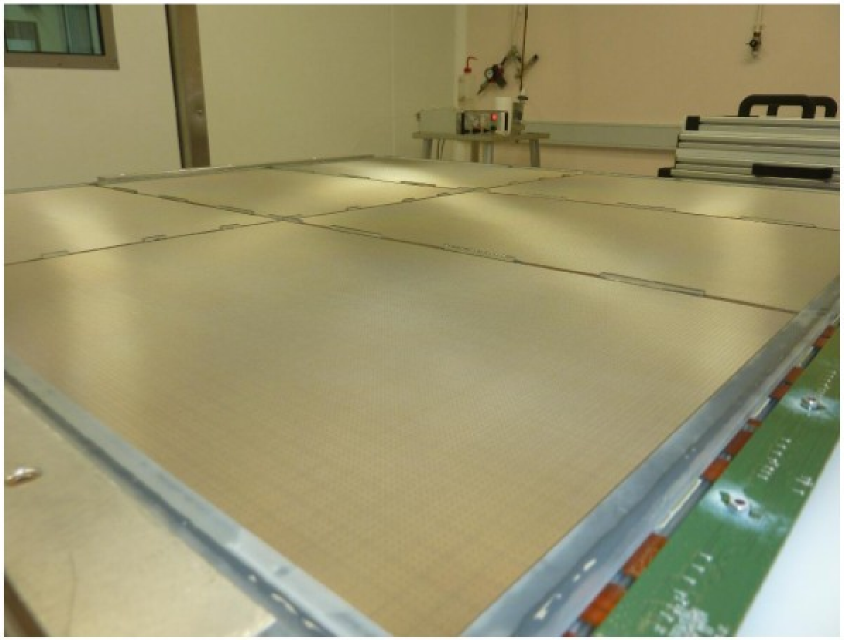
on behalf of the LC group of LAPP, Annecy

Overview

- Introduction
- 1x1 m^2 Micromegas chamber
- Test beam activity
  - Results in CALICE SDHCAL
  - November 2012 tests
- Protection against discharges
- Conclusion



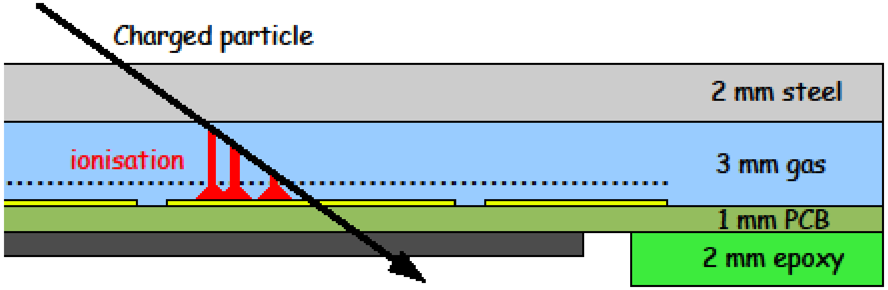
Micromegas SDHCAL project

Particle Flow calorimetry at a LC

Calorimeter granularity more important than its single particle energy resolution
→ sampling gaseous hadron calorimeter with 1x1 cm^2 cells and 8 mm thin active layers

In CALICE, 4 gaseous HCAL projects

1-bit readout: RPC and GEM DHCAL (US);
2-bit readout: RPC and Micromegas SDHCAL (EU).



The 2-bit readout should allow to correct for the saturation in the dense part of showers and thus to improve the energy resolution (→ lower constant term).

Advantage of Micromegas (and GEM) over RPCs

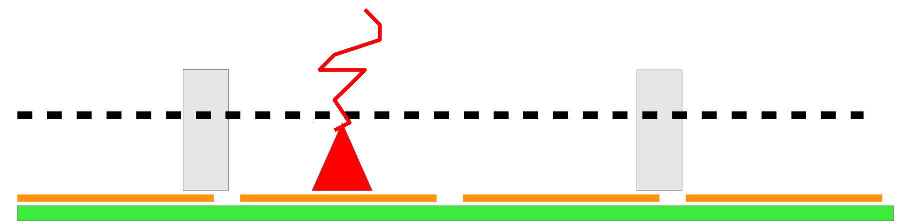
No space charge effects → High rate capability & proportionality (better use of semi-digital information)

Simple gas mixtures (Ar/CO2), no ageing, low operating voltages (< kV), low hit multiplicity (~1.2)

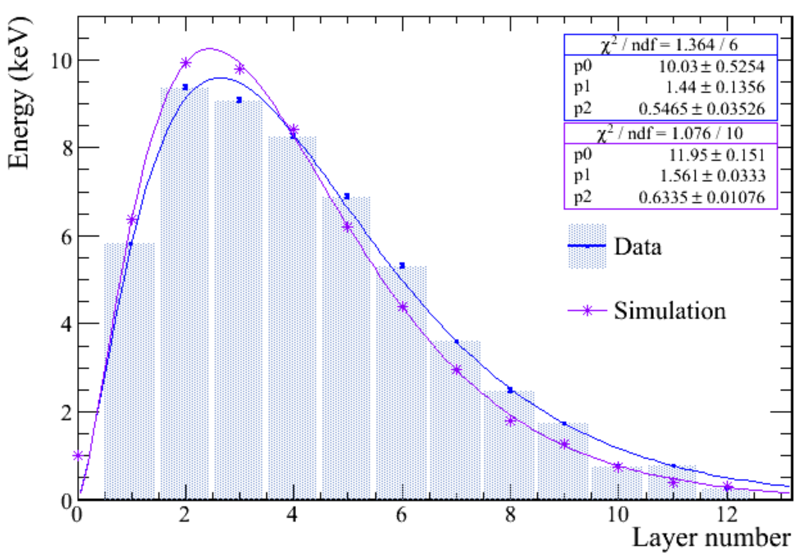
Bulk Micromegas

Our Micromegas detectors are fabricated using the Bulk technology
The fabrication consists in the lamination of a steel woven mesh and photo-sensitive layers on a PCB

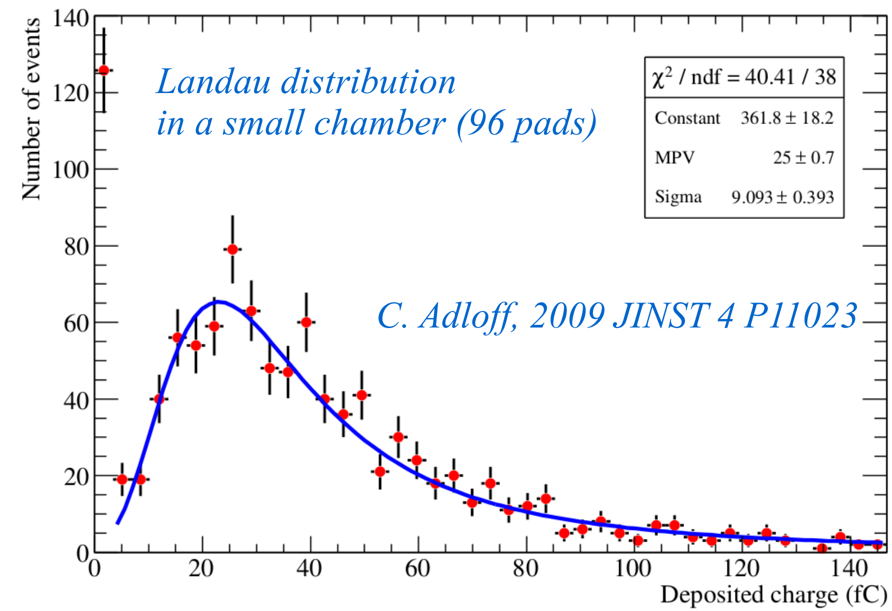
Geometry
Detector : 128 μm amplification gap, 3 mm drift gap
Woven mesh : 80 μm pitch, steel wire diameter 20 μm
Pillars : 300 μm diameter, 2 mm pitch
Pads : square pattern, 1 cm pitch



Average number of primary electrons of ~ 30 e-, Gas gain up to a few 10^4, MIP charge of 5-20 fC in 150 ns



2 GeV e- profile in a virtual ECAL, C. Adloff 2010 JINST 5 P01013

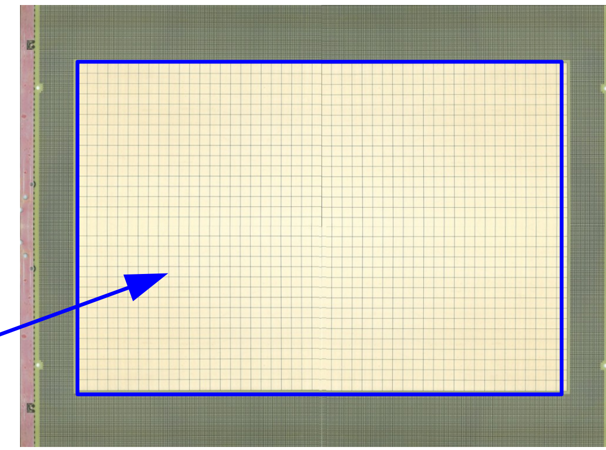


Micromegas boards (ASU)

The basic building block of our large area Micromegas chamber is an 8 layer PCB of 32x48 cm^2

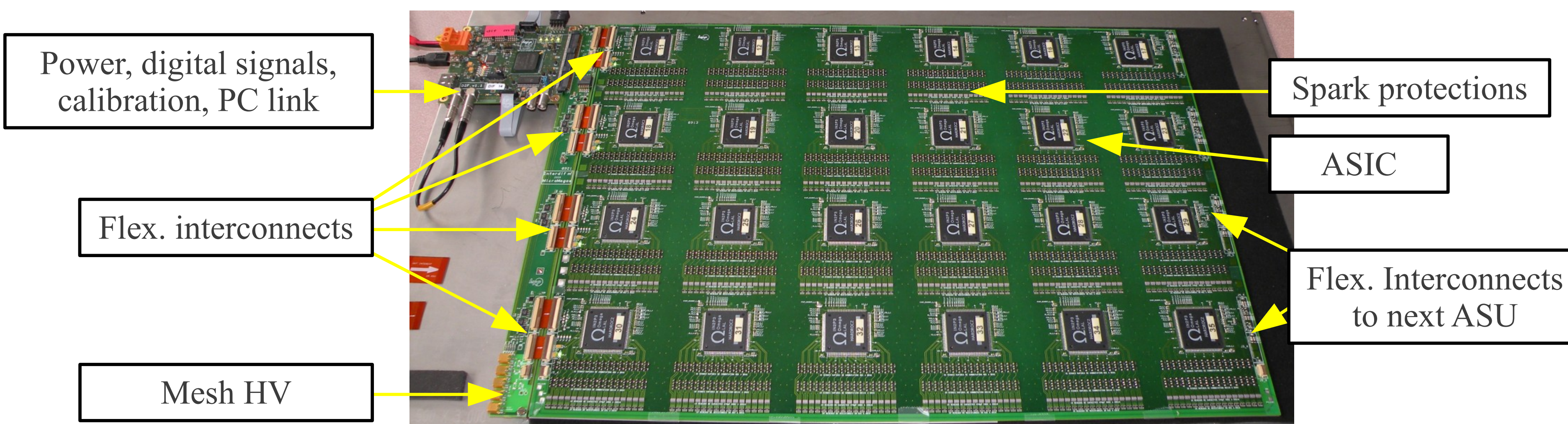
It is equipped with 24 ASICs, 1536 pads and a Bulk mesh
It is called an Active Sensor Unit (ASU)

ASU can be chained thanks to flexible inter-connections
They are also equipped with spark protections (diodes)
They are read out by 2 boards: DIF & interDIF (cf. photograph)



32x48 pads of 1 cm^2 on mesh side

24 ASIC + spark protections on back side

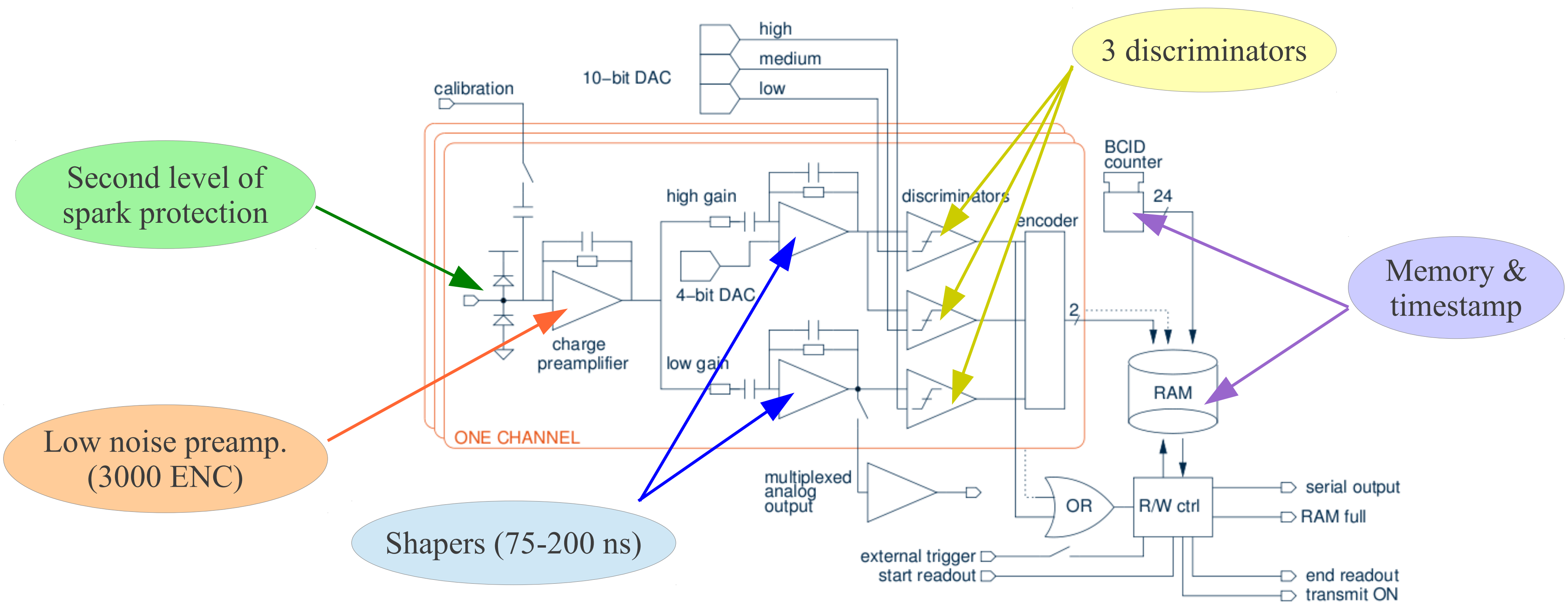


Front-end electronics

Following the ILC beam time structure, the front-end electronics:

- is off between bunch trains → power-pulsing of analogue part;
- is on during trains → self-triggering capability + memory with 200 ns timestamping;

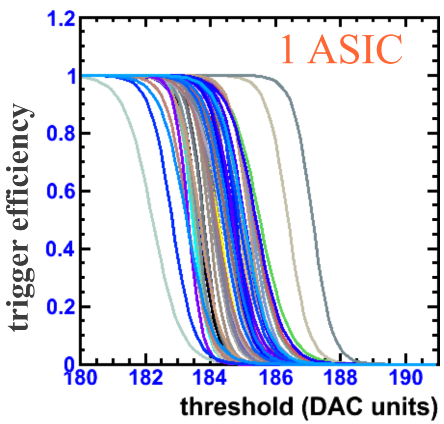
The MICROROC is a 64 channel chip developed with LAL/Omega

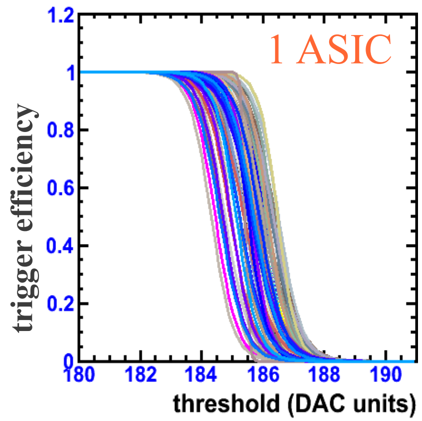


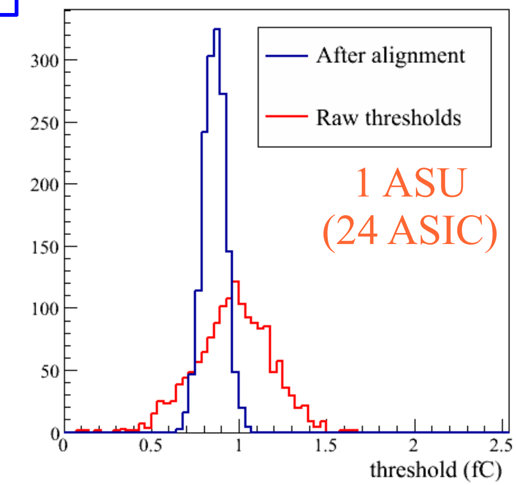
It is well suited for both Micromegas and GEMs → Will be used with THGEM during Nov. test beam

ASU characterisation

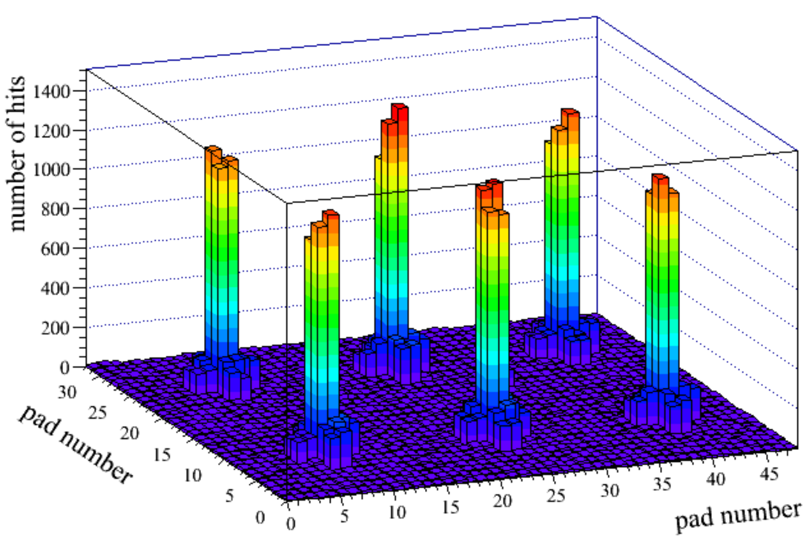
Electronics calibration: align pedestals to reduce threshold dispersion to ~ 1 fC

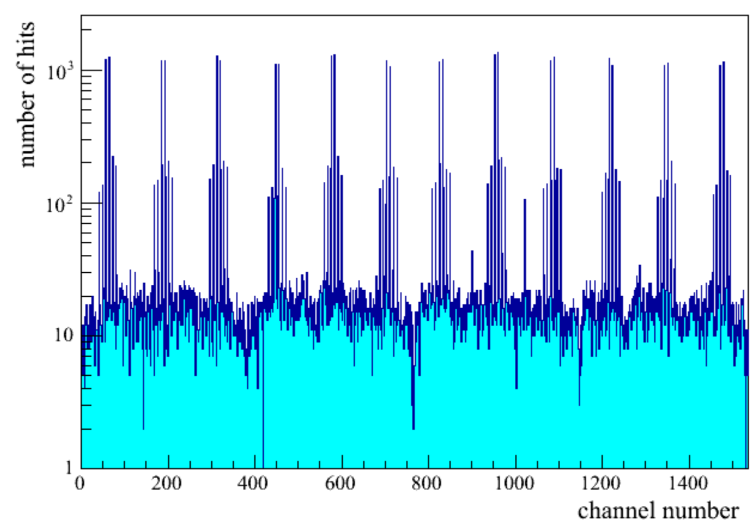






Operation inside a gas chamber: ^{55}Fe quanta peaks above flat (cosmic) background: no noise!





Design of the 1 m^2 chamber

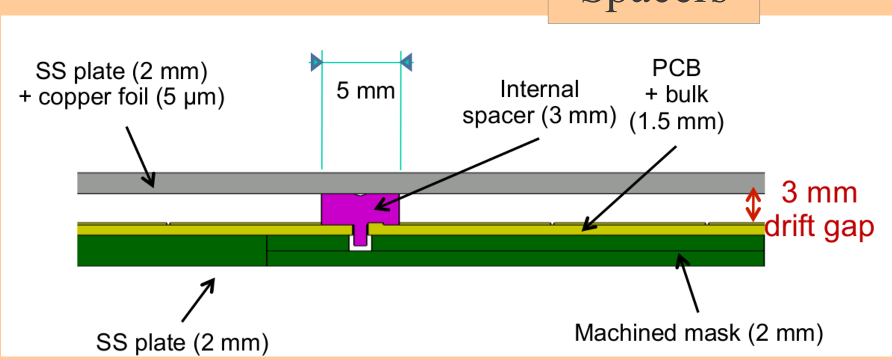
The 1 m^2 chamber consists of 3 slabs with DIF + interDIF + ASU + ASU

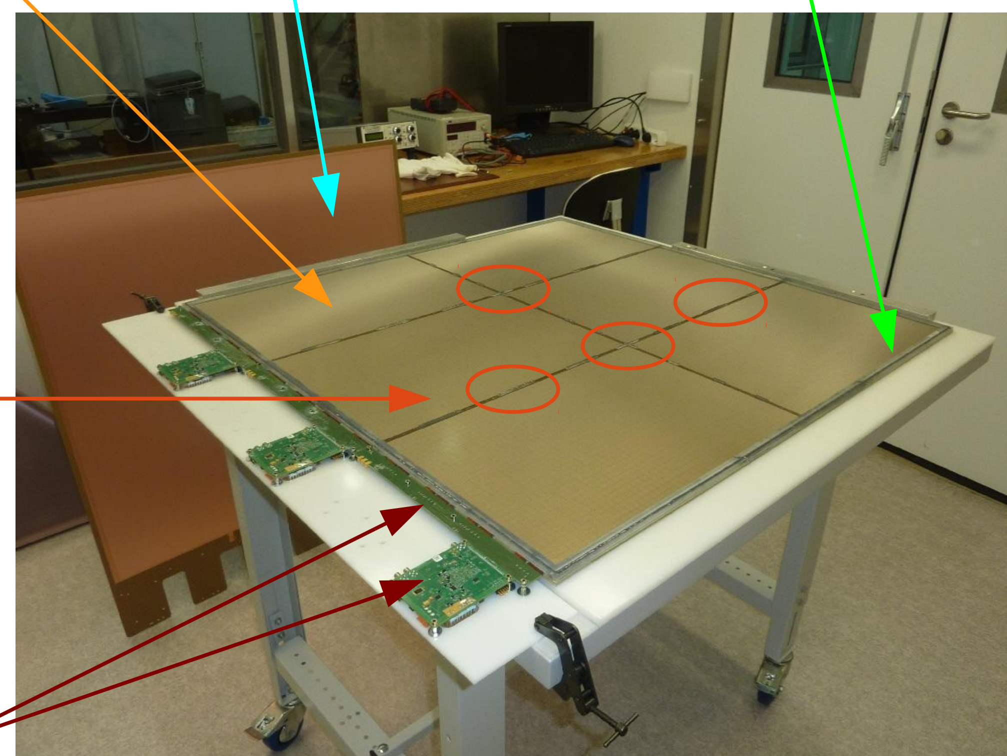
This design introduces very little dead zone (below 2%) and is fully scalable to larger sizes

The drift gap is defined by small spacers and a frame

The final chamber thickness is 9 mm

Spacers



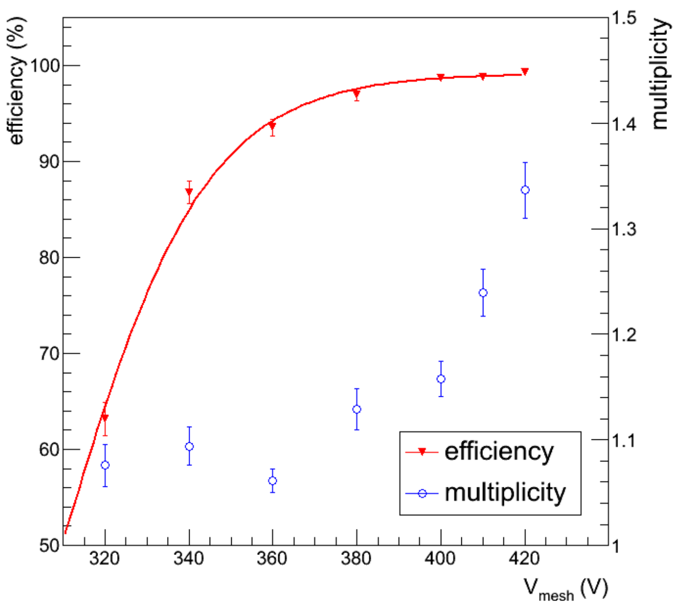


Performance to MIPs

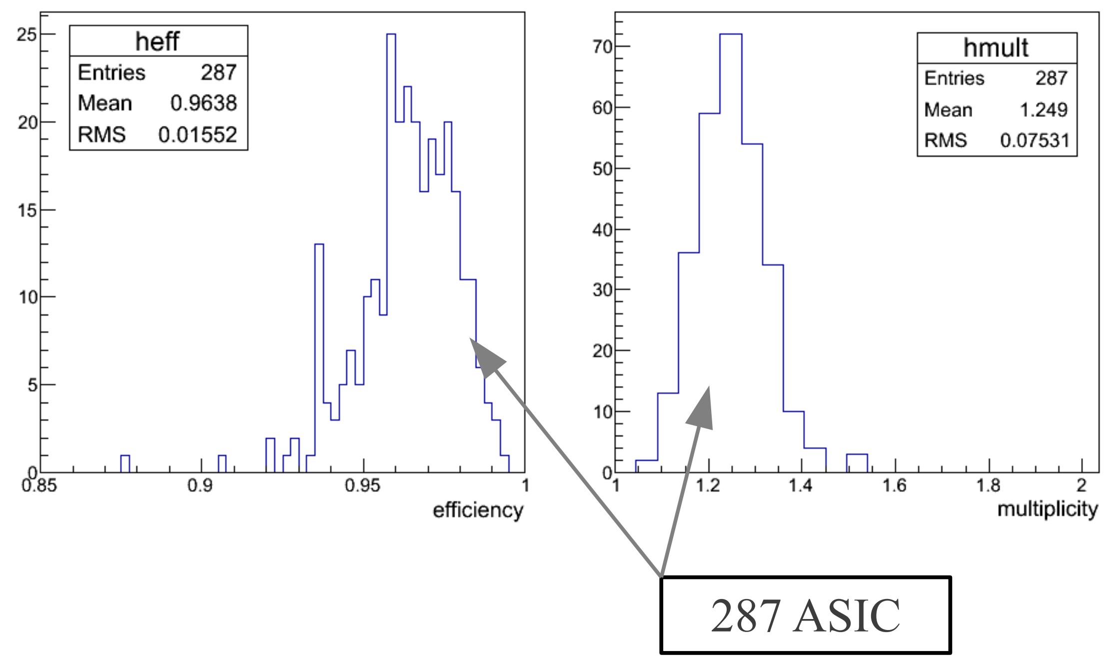
A high efficiency to MIPs is reached at a gas gain of 3000 (390 V)

Due to the small spread of charge in the Micromegas, the hit multiplicity is between 1.1-1.2 at 90° incidence

Efficiency & multiplicity VS mesh HV (Standalone test)



Efficiency and multiplicity – 2 prototypes inside SDHCAL



The efficiency variation over 287 ASIC (8x8 cm^2 regions) is 2% RMS, for an average of 96%

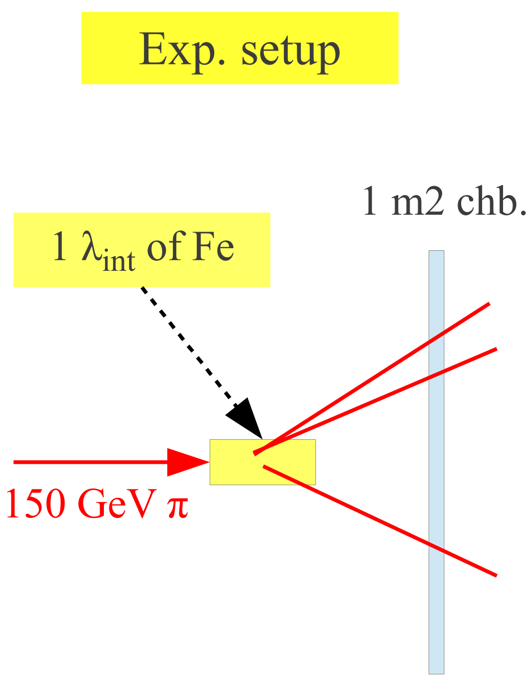
→ Very good control of the chamber dimension and thresholds

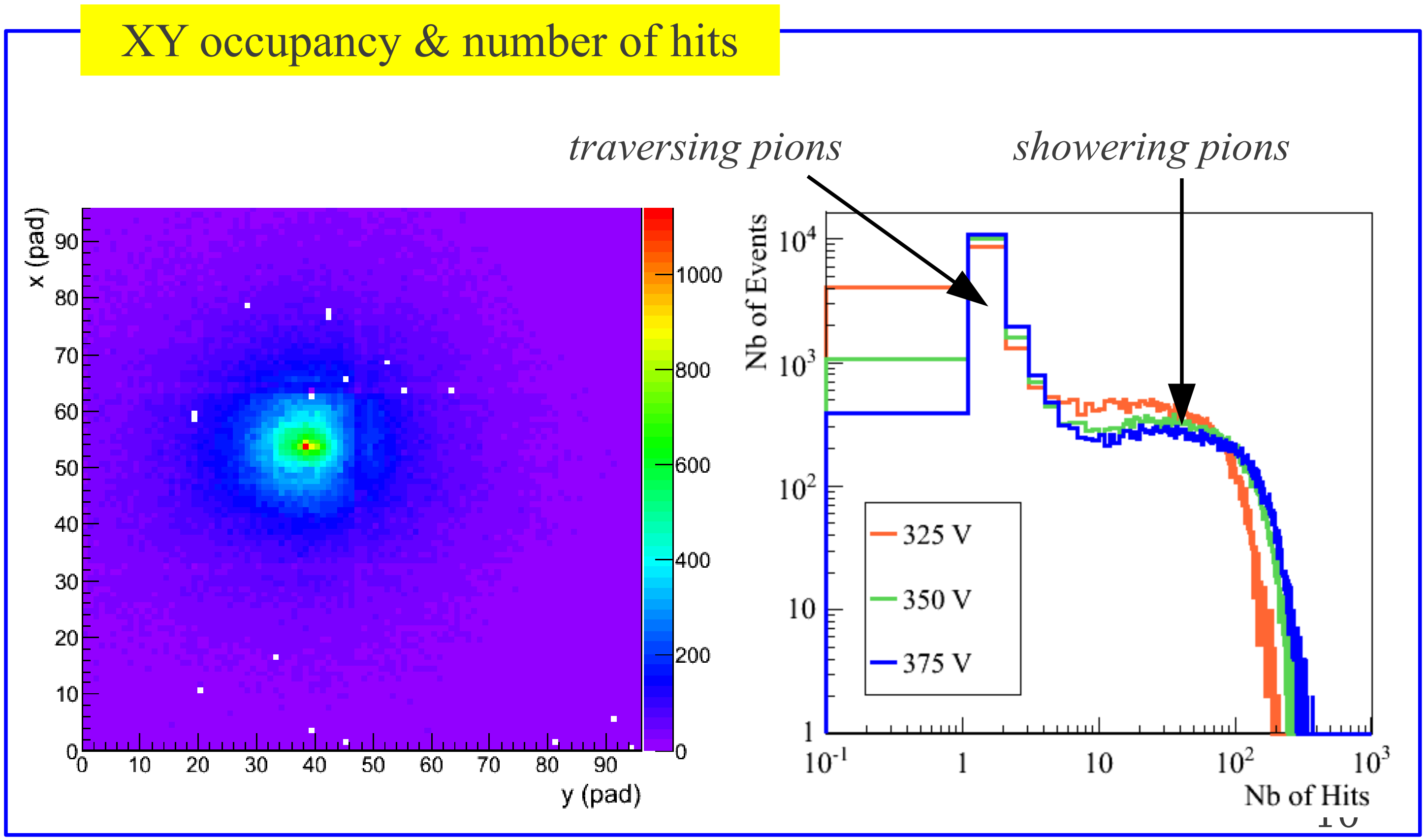
Performance to hadrons

Hadron showers contain heavily ionising particles (& a few MIPs) → what is the necessary gas gain?

From the distribution of the number of hits at various voltages... **probably less than 1000!**

Indeed, the tails of the distributions at 350 V and 375 V are very similar.



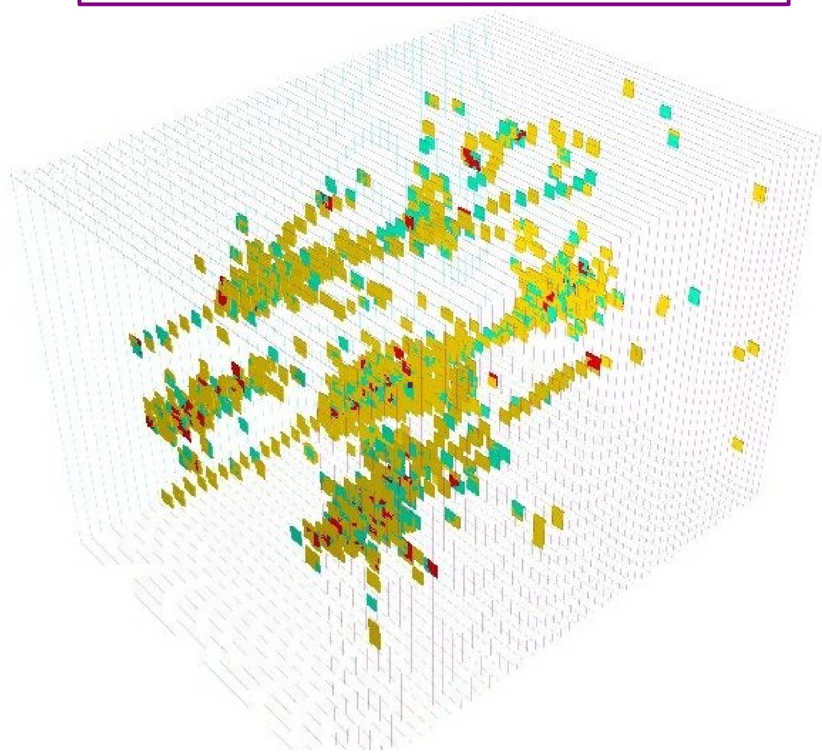


Performance inside CALICE/SDHCAL

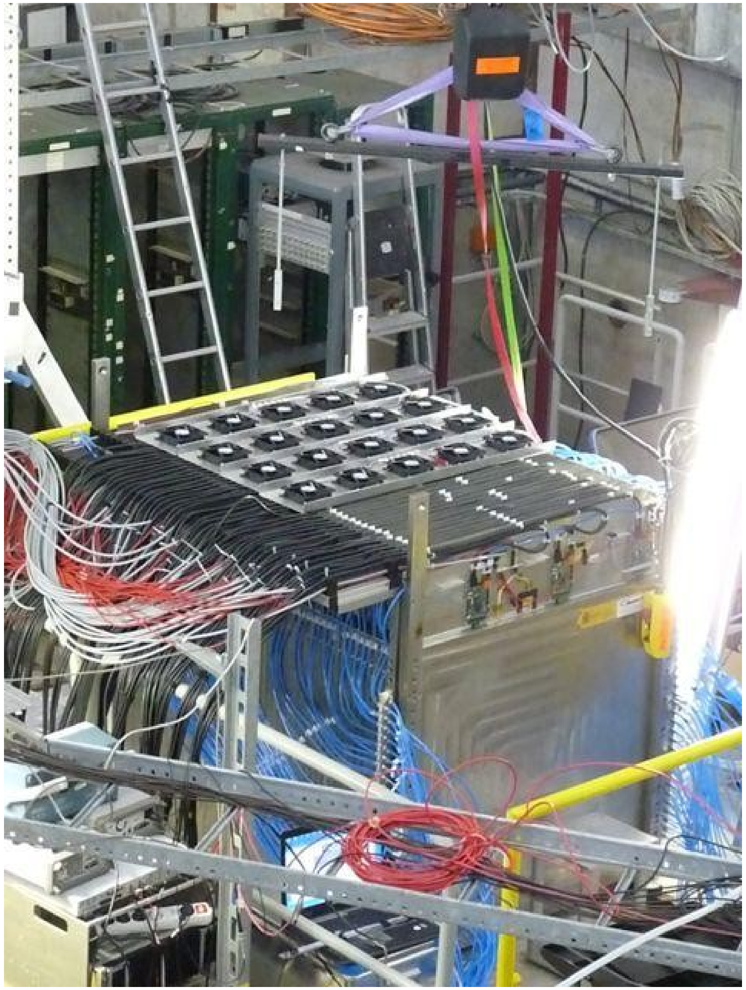
The SDHCAL is a 50 layers sampling calorimeter (~ 6 λ_{int}) of steel absorbers and 1 m^2 active layers

During a test beam in May, the SDHCAL was equipped with 48 RPCs and 2 Micromegas
All detectors were all read out by a common DAQ (cf. next slide)

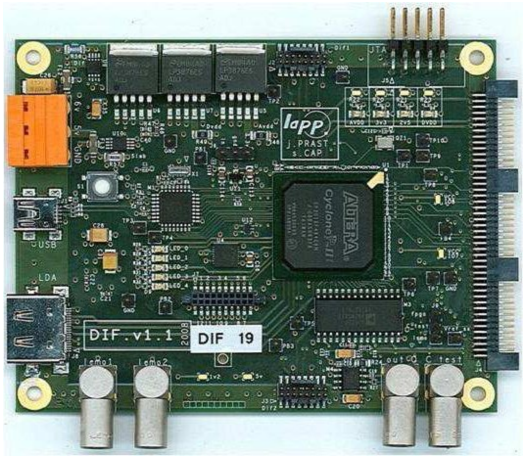
About 500 thousands channels in 1 m^3



Pions simultaneously showering in the SDHCAL
Colors stand for the 3 thresholds



LAPP contributions to the SDHCAL

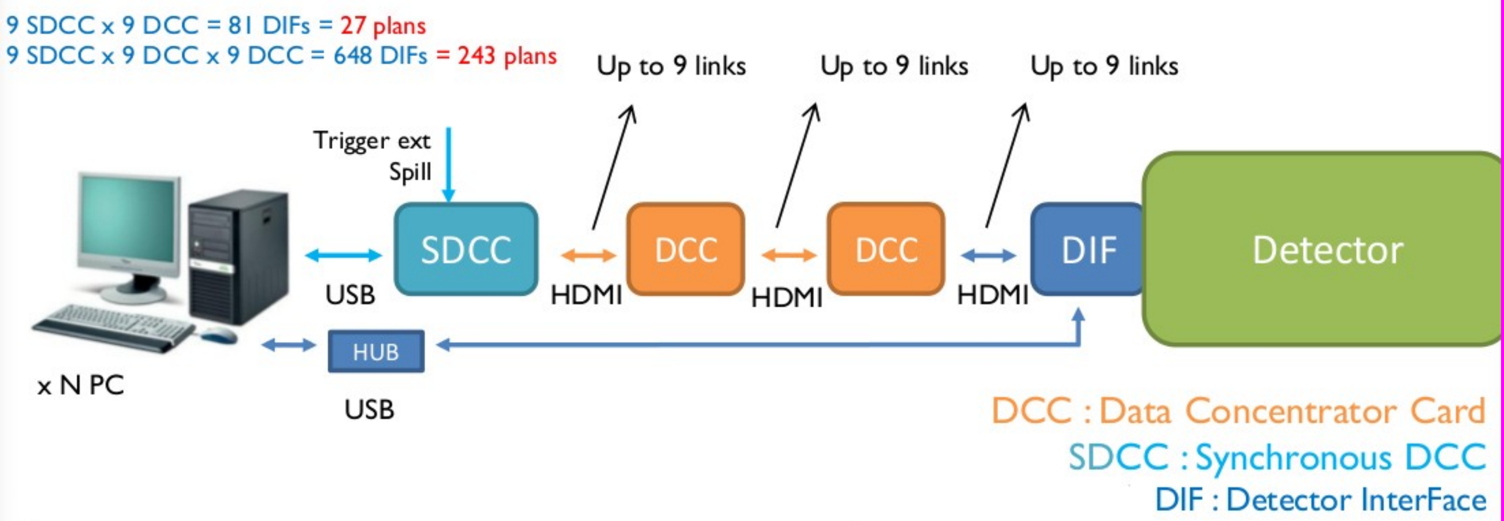


LAPP designed and programmed (firmware) the Detector Interface boards (DIF) that equip the 1x1 m^2 RPCs and Micromegas (3 DIFs / chamber)

In November 2011, it was decided to postpone the development of the CALICE DAQ in favour of an "intermediate" DAQ that would be operational for the 2012 test beams of the SDHCAL.

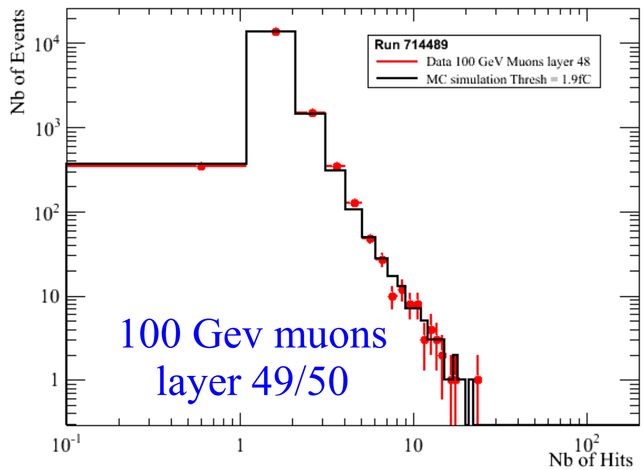
LAPP developed the firmware for the DIF & DCC boards.

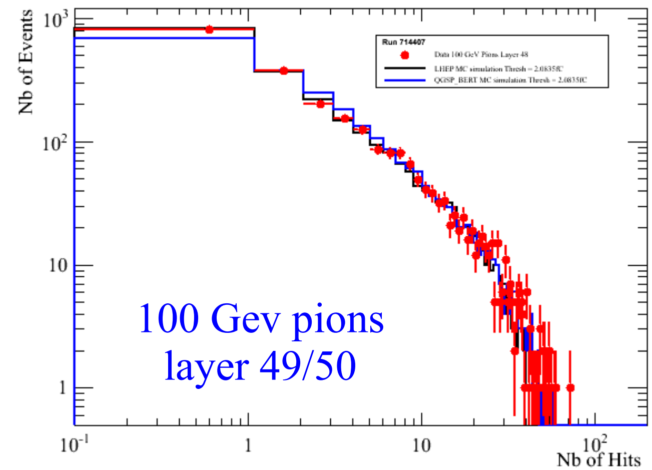
The "intermediate" DAQ was fully functional for the first test beam in May 2012



Performance inside CALICE/SDHCAL

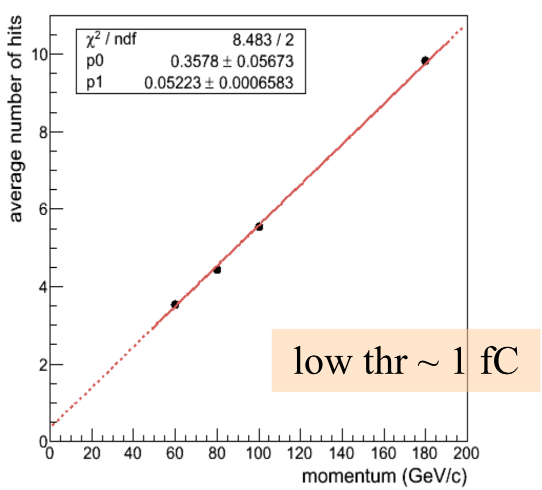
The distributions measured in the Micromegas chambers are well reproduced by MC simulation

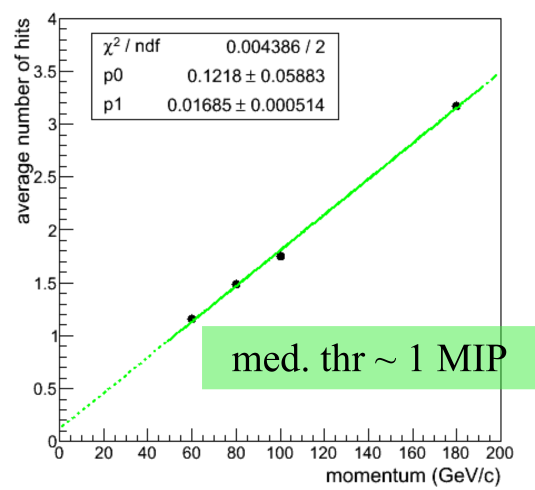


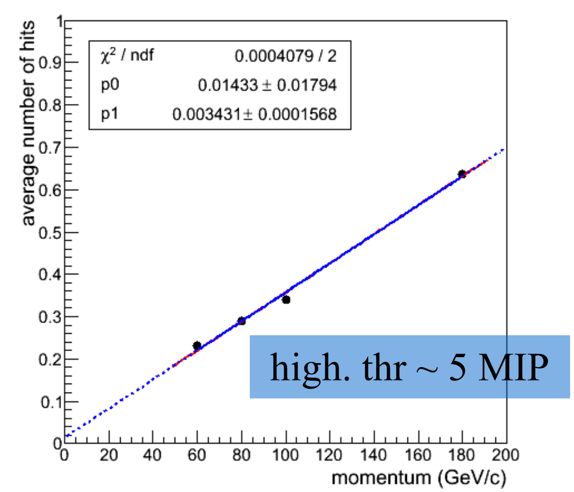


Average Nhit versus pion energy

No saturation at the back of SDHCAL → <u>linear response of 3 thresholds</u>







Future plans inside CALICE/SDHCAL (1/2)

Novembre 2012 test beam inside the SDHCAL

The calorimeter will be equipped with 46 RPCs and 4 Micromegas at layers 10-20-35-50

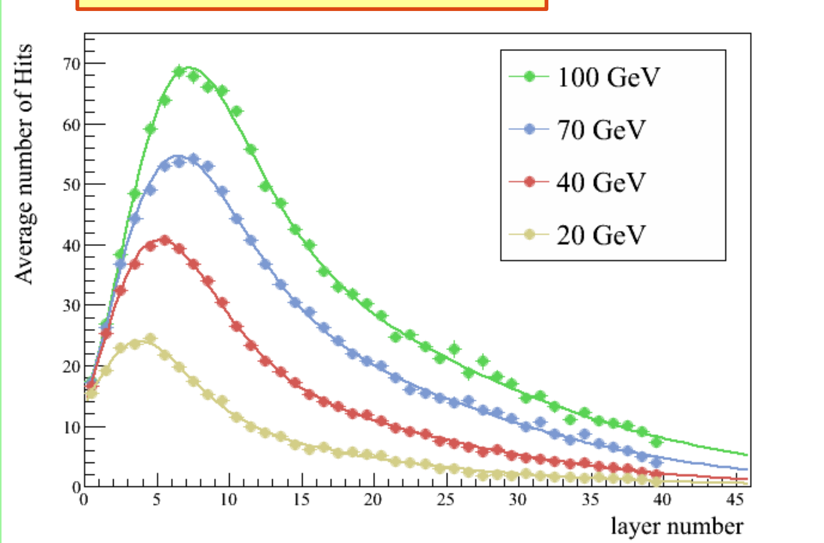
Identify shower start z_0 with RPCs
and measure Nhit in Micromegas chambers w.r.t. z_0

In this way the shower longitudinal profile w.r.t. z_0 can be obtained

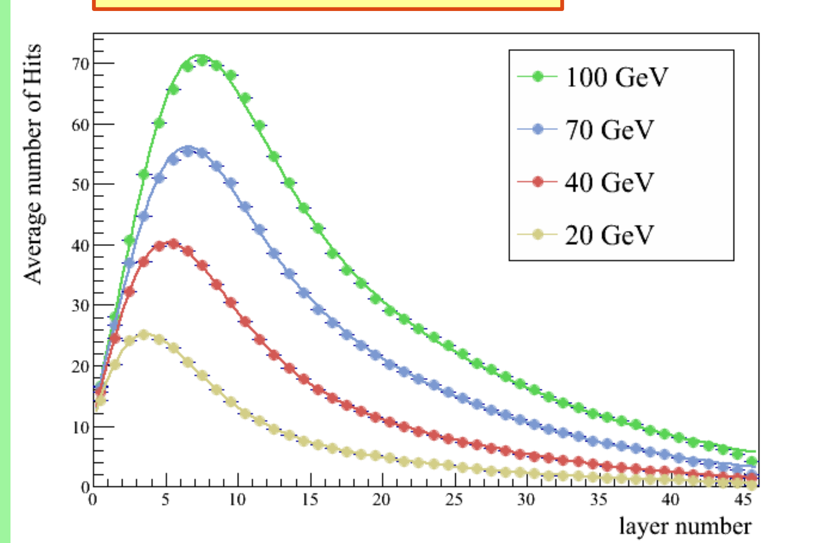
Proof of principle demonstrated with SDHCAL May data using RPCs only

We used 3 chambers at layers 10, 25 & 40 and compared with the results with 45 chambers

Data - 3 RPCs



Data - 45 RPCs

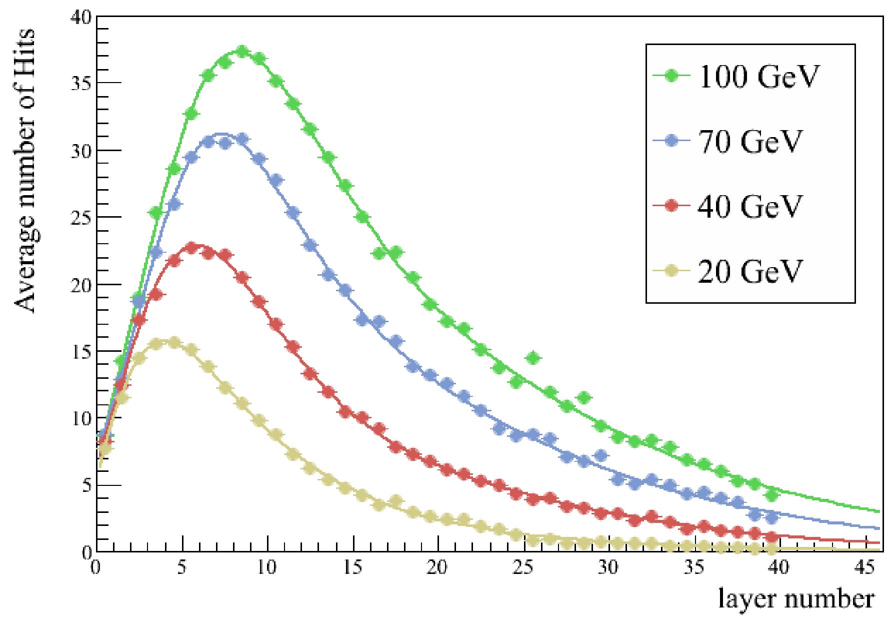


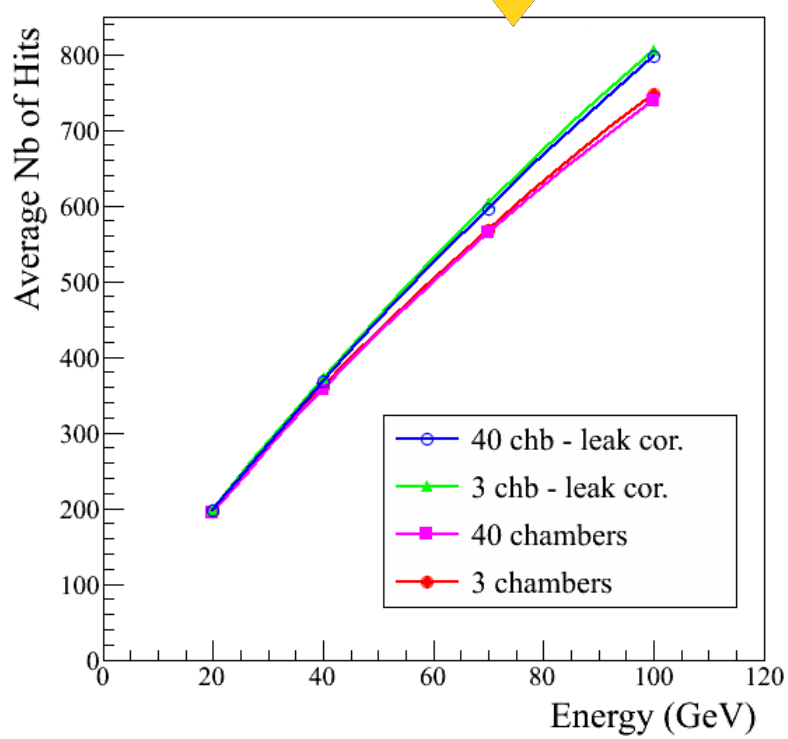
Future plans inside CALICE/SDHCAL (2/2)

From a fit of the longitudinal profile:
Integral yields the average number of hits, the leakage can be calculated and corrected for

Measuring the profiles at various pion energies
will lead to the response of a virtual 50 layer Micromegas SDHCAL
Maybe we can also learn about the semi-digital readout...

Simu – 3 VS 40 RPCs





Spark protection in Large Area Micromegas

SPLAM project within CEA/IRFU and CNRS/IN2P3 laboratories
to investigate different protection strategies against gas discharges in Micromegas detectors.

Eventually: reduce PCB cost by replacing the (so far efficient) protection diodes
by a resistive layer on the anode surface

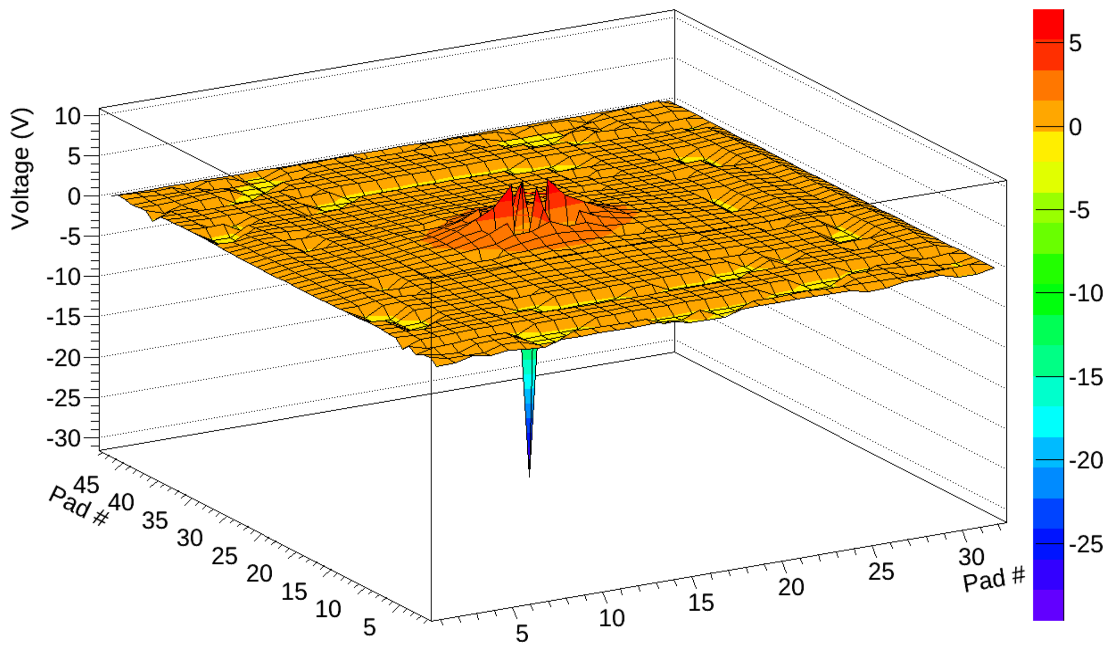
2012

Simulations with different configurations:

- standard (bare anode pads);
- resistive + dielectric layer on pads.

Resistive VS standard config.
→ max. voltage drop reduced from -400 to -30 V

Maximum voltage drop on pads during a spark with a resistive configuration



2013: fabricate and test prototypes based on our current ASU design (32x48 cm^2)

Conclusion and future plans

- Micromegas chambers of 1 m^2 are a nice piece of R&D
  - Excellent performance so far
  - **Exciting measurement to come** inside GRPC-SDHCAL during November test beam

    We are getting organised with our RPCs colleagues from IN2P3/IPNL

    1) Start as tail catcher during 1st week

    2) Insertion inside the calorimeter at fixed positions during 2nd week

- During LHC shut-down
  - Hopefully, lot of data to keep us busy on analysis/publication
  - **Continue R&D**: resistive Micromegas, thinner chambers with smaller pads (possibly ECAL)

- With the discovery of a Higgs-like particle at CERN and Japan interest on hosting a LC
  - Reinforce efforts on **physics analyses** within LAPP LC group