Micromegas for sampling calorimetry

M. Chefdeville pour le groupe LC du LAPP

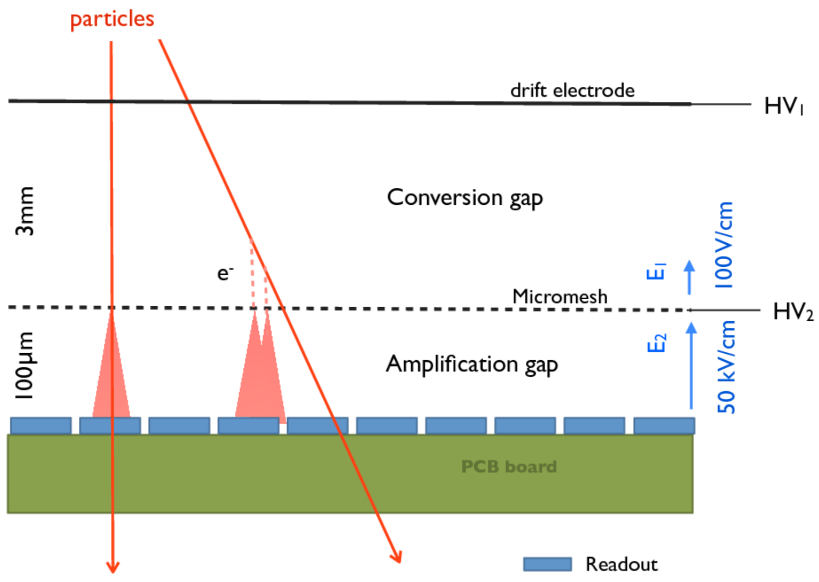
Conseil scientifique IN2P3, 30/01/2014

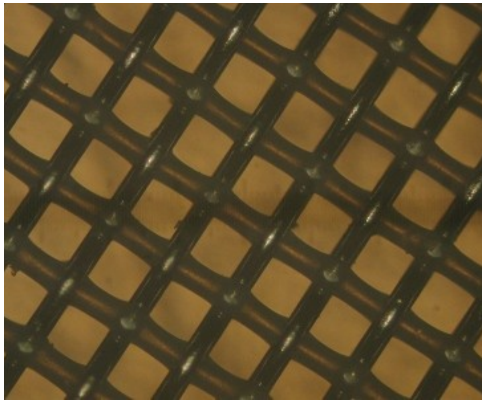
- ✗ *Micromegas & gaseous calorimetry*
- ✗ *Group expertise & resources*
- ✗ *Achievements*
- ✗ *Future*

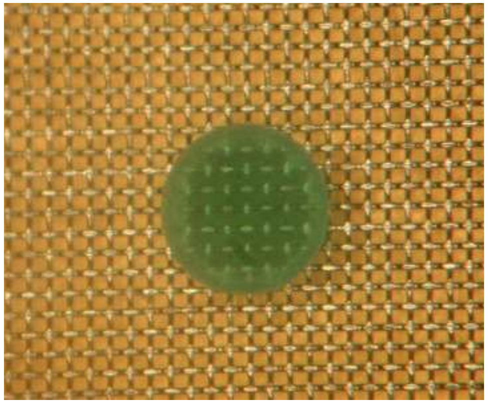
Micromegas & gaseous calorimetry

Low multiplication factor – Narrow avalanche – Fast ion collection → Space charge field ~ 0

→ Signal are proportional to the energy deposited in the gas ↔ ***linear response***







Mesh lies on pillars (1% dead zone) → uniform E-field → *Small constant term & easy calibration*

High rate capability of tens of MHz/cm^2 → *Barrel/endcap/forward region-compatible*

Simple gas (e.g. Ar/CO_2) & low voltages (500 V, 40 kV/cm) → *No ageing*

Gas gain dependence on P/T/V well known → *Response stable with time*

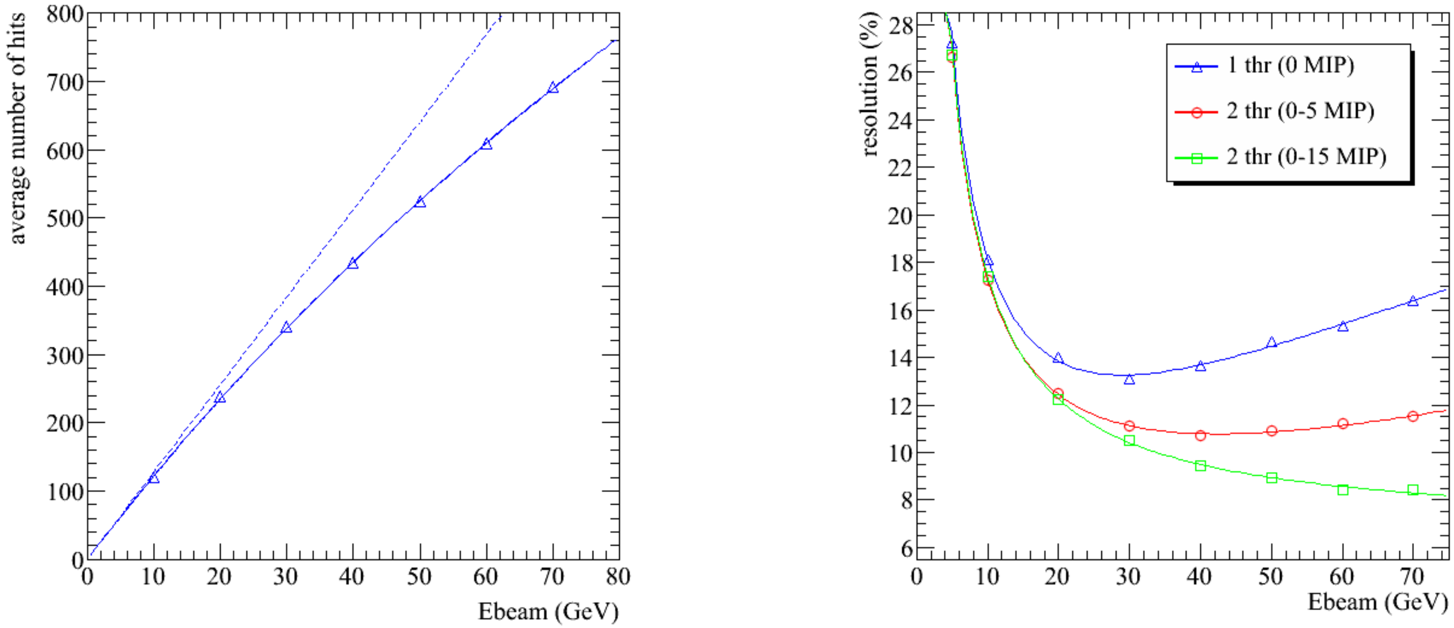
Semi-digital hadron calorimetry

Micromegas suitable for EM & H calorimetry. In the case of Particle-Flow calorimetry:

✗ Alternative to Si for W-ECAL but with larger Molière radius & worse energy resolution;

✗ *Candidate for a Fe-DHCAL (ILC)* and W-DHCAL (CLIC).

Expected response & resolution to pions of an 11 λ_{int} HCAL with 1-bit & 2-bit readout (Geant4)



The response of a DHCAL is saturated (cell size VS R_M) with consequences on the energy resolution.

But off-line compensation techniques can be used to correct for it, e.g. 2- bit readout.

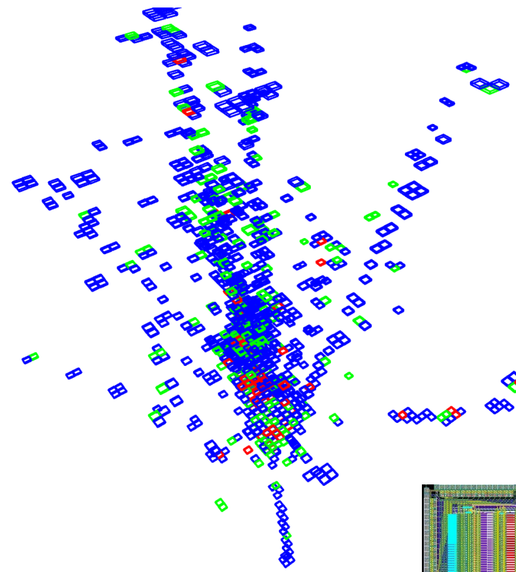
Group expertise

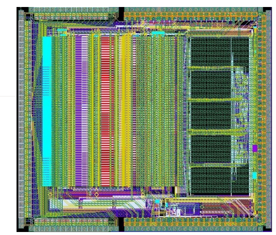
Prototyping

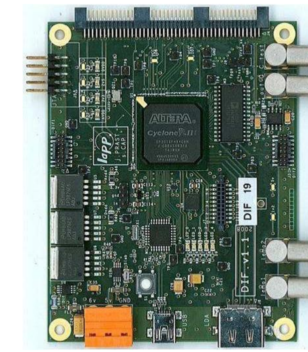
Large area Micromegas with embedded ASICs

Spark protection with resistive coatings

Micro-electronics (MICROROC ASIC with Omega)





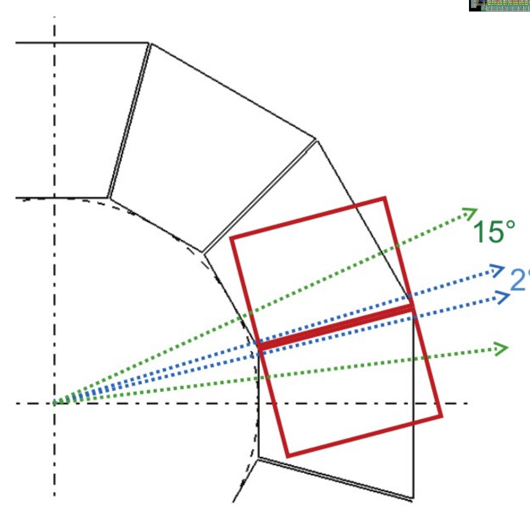


Detector optimisation (simulation)

Analogue/digital performance

Compensation algorithms

Geometry optimisation (SDHCAL & SiD barrel)



Data acquisition for SDHCAL

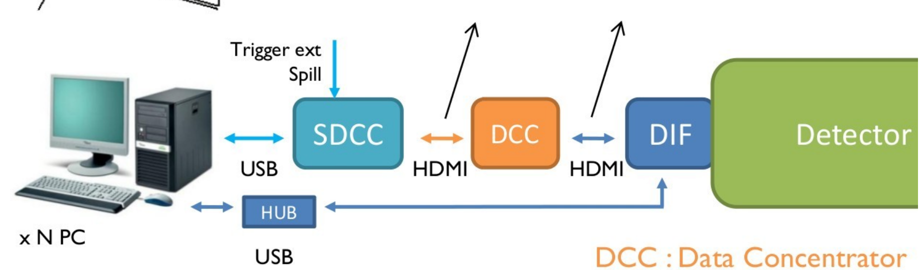
Design of front-end board (DIF)

Firmware of all readout boards

Software

Acquisition for Micromegas (Labview)

Reco & analysis of SDHCAL (C++ framework)



Physics studies

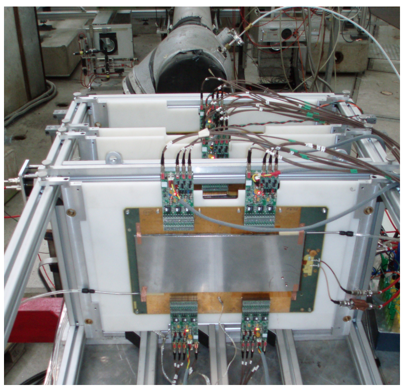
Z' & SUSY particles @ CLIC

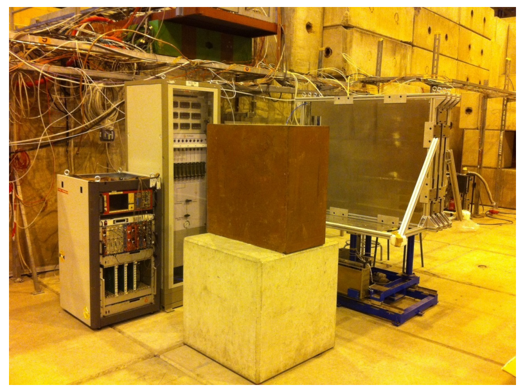
Collaborations, resources & chronology

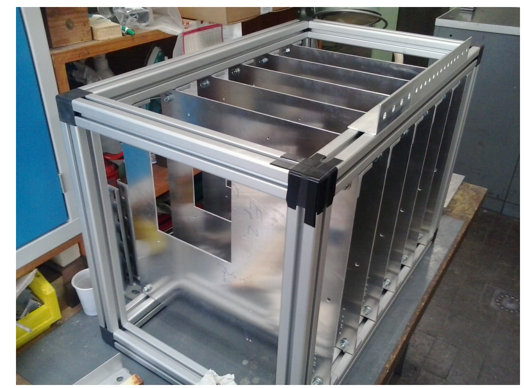
Strong implication in CALICE (SDHCAL), RD51 (large MPGD), CLIC (det. & phys.)

Collaborators: IN2P3 groups, Irfu, Athens NTUA, Weizmann institute

Funds: IN2P3, ANR (SDHCAL & SPLAM), AAP

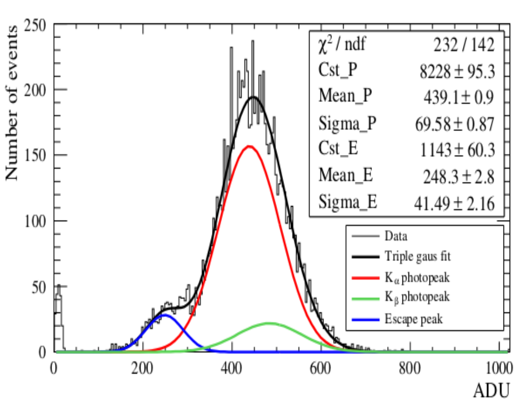


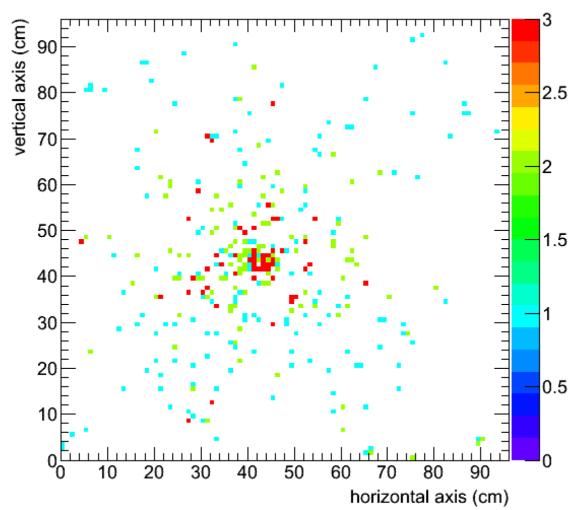


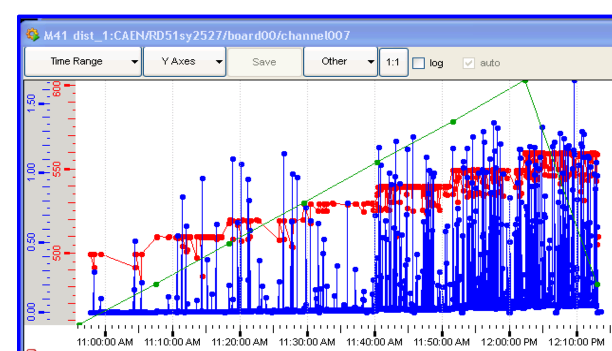


2006-2009 *2009-2012* *2012-2013*

Proof-of-principle *Large area (SDHCAL)* *Spark protection (SPLAM)*







Micromegas prototype of 1x1 m^2

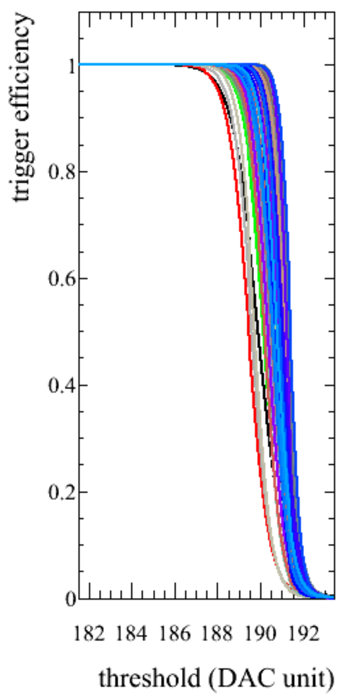
ASIC (MICROROC) with noise of ~ 1500 e^- RMS

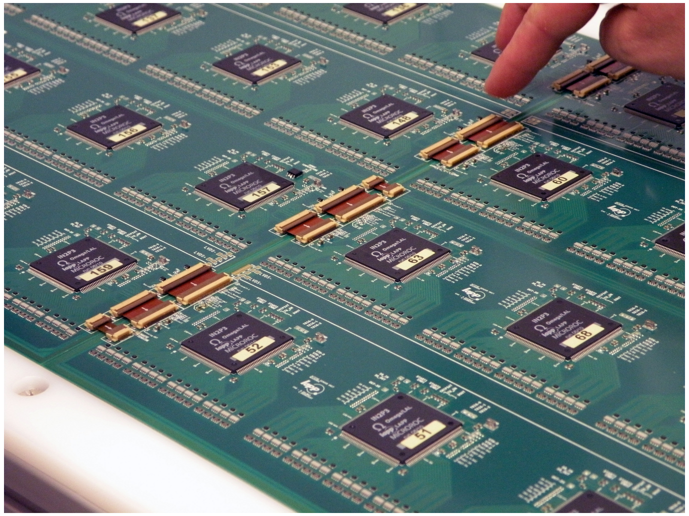
Threshold of 1 fC (S/N~25) with a dispersion of 0.2 fC RMS

Active Sensor Units (24 ASIC) with flexible interconnects + spark protections

(+ calibration inputs, analogue readout & T sensor)

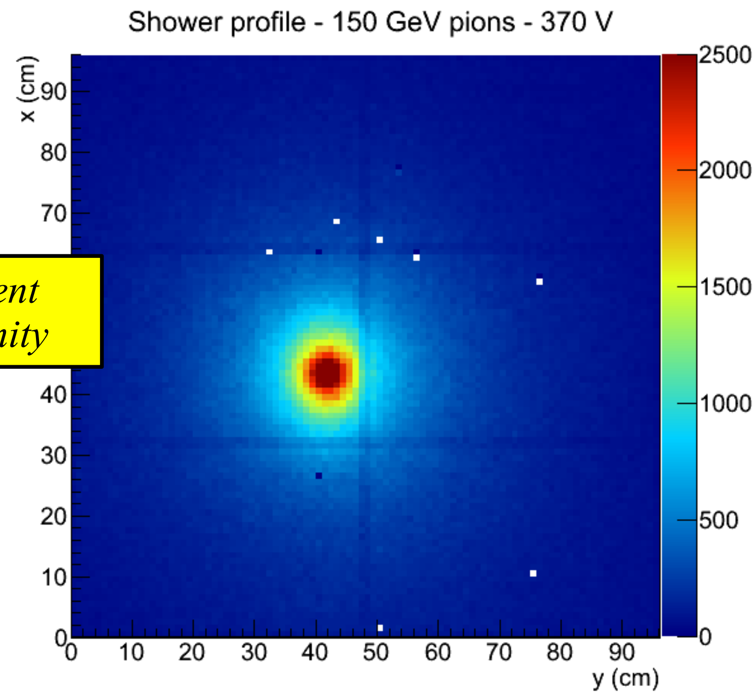
Modular mechanical design based on 6 ASU: thickness <1 cm, 2% dead zones



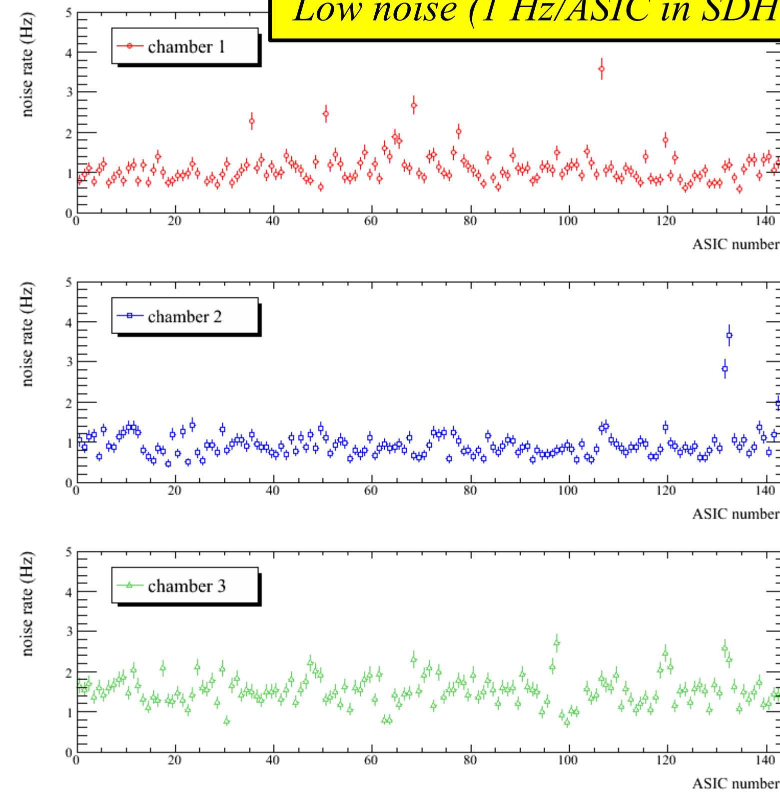


Highlights of testbeam results (characterisation)

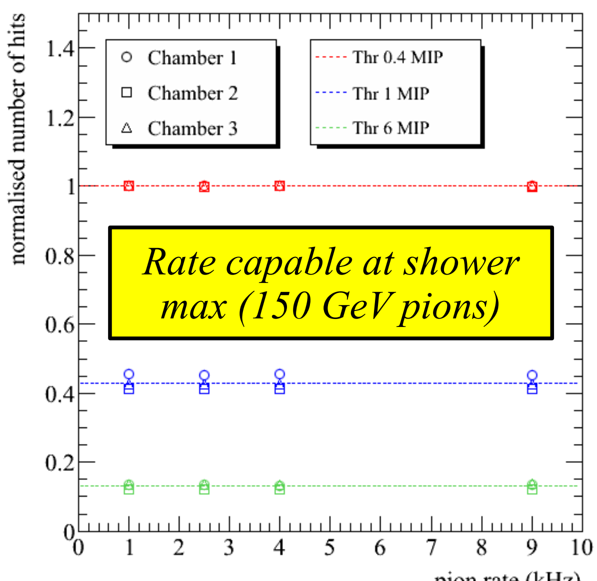
Excellent uniformity



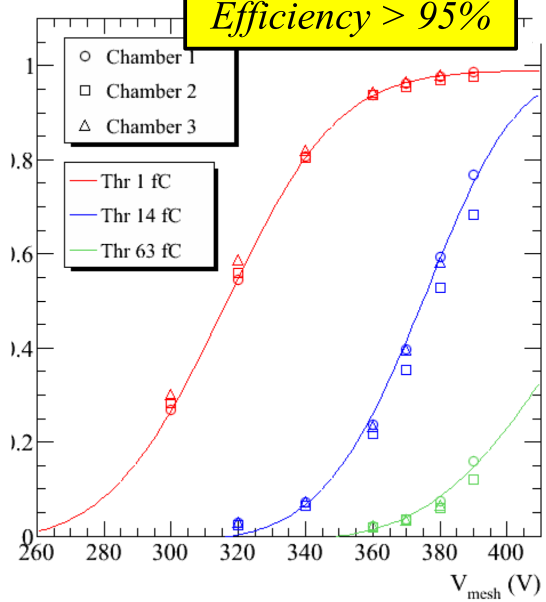
Low noise (1 Hz/ASIC in SDHCAL)



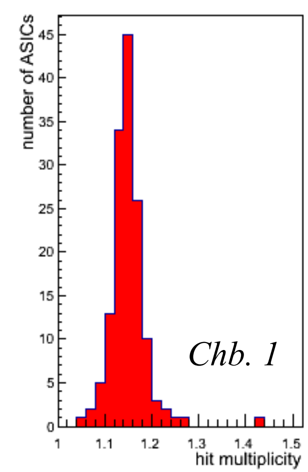
Rate capable at shower max (150 GeV pions)

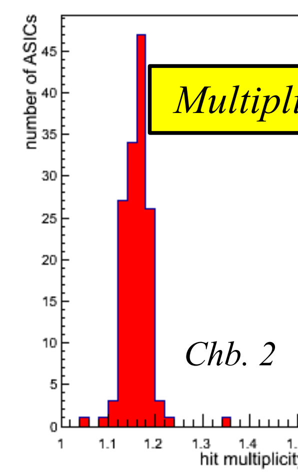


Efficiency > 95%



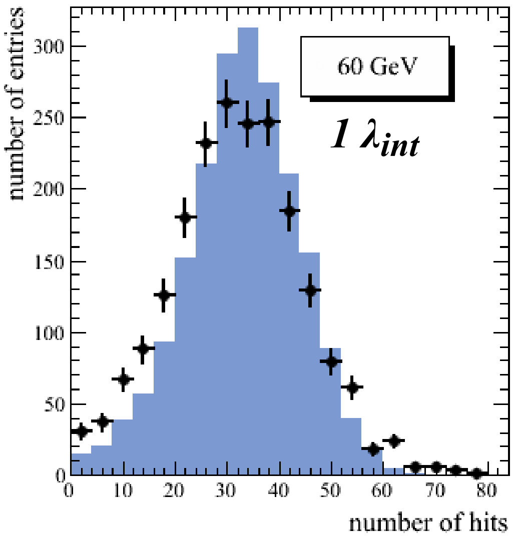
Multiplicity ~ 1.15





Highlights of testbeam results (calorimetry 1/2)

1. we measured the number of hits behind various Fe-absorber thickness...



Pions (SPS) 20-150 GeV

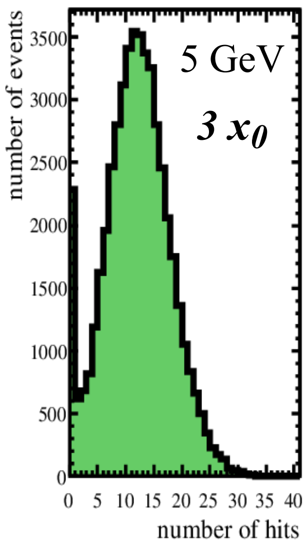
SDHCAL (46 RPC + 4 Micromegas)

→ Shower start ID

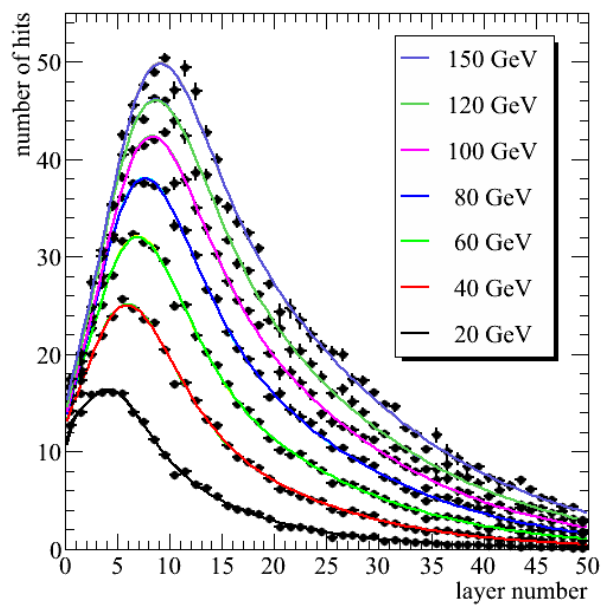
Electrons (DESY) 1-5 GeV

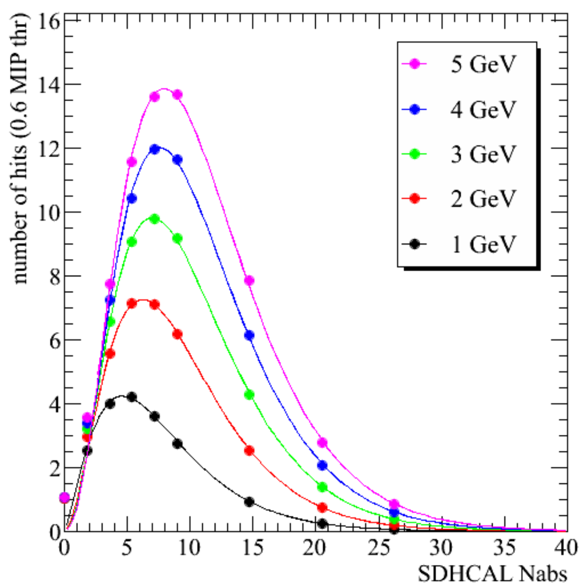
1 Micromegas + N absorbers

No shower start ID but little fluctuations



2. and determine the shower longitudinal profile in a SDHCAL at various energies...

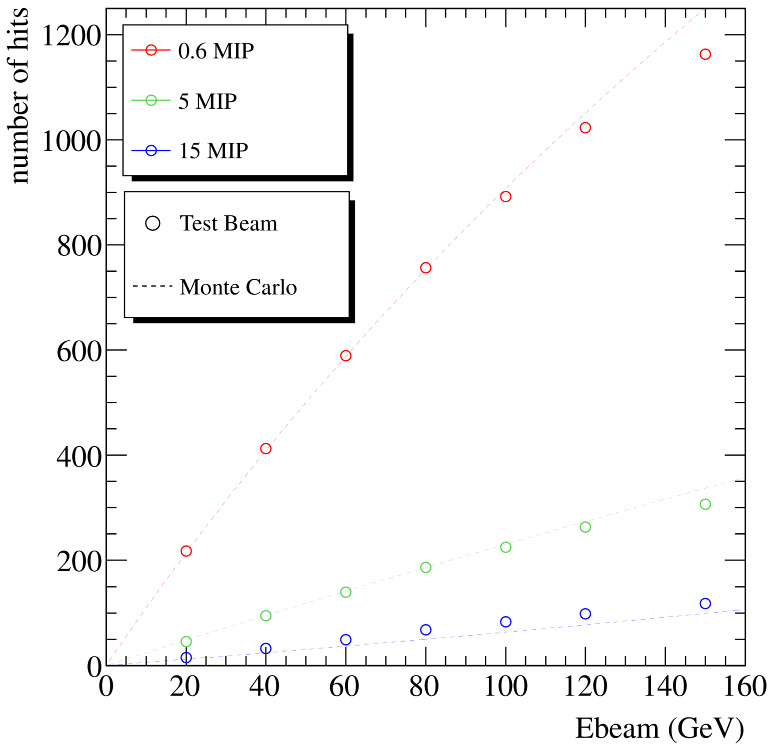




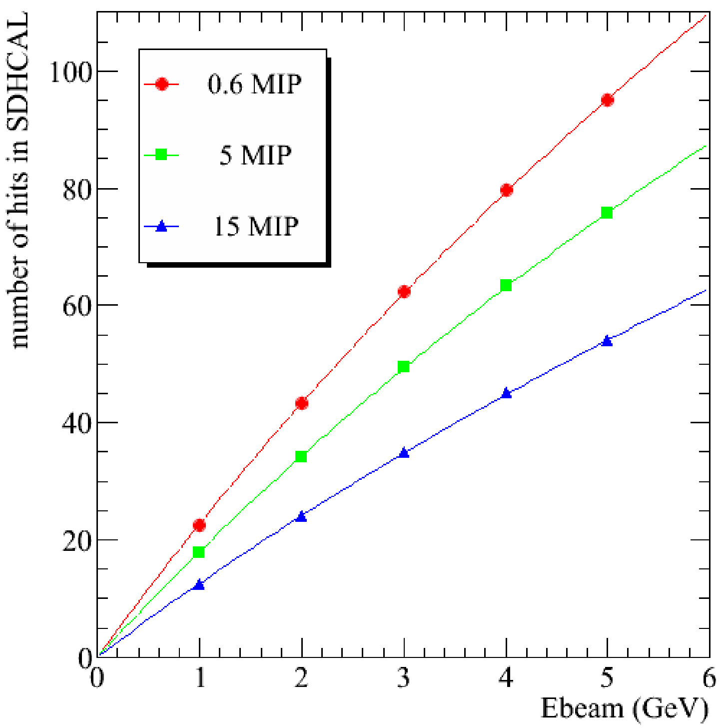
Highlights of testbeam results (calorimetry 2/2)

3. by integration of the profile, we obtain the response of a virtual Micromegas SDHCAL...

pions (CERN)



electrons (DESY)



4. and start testing Monte Carlo (so far for pions only)

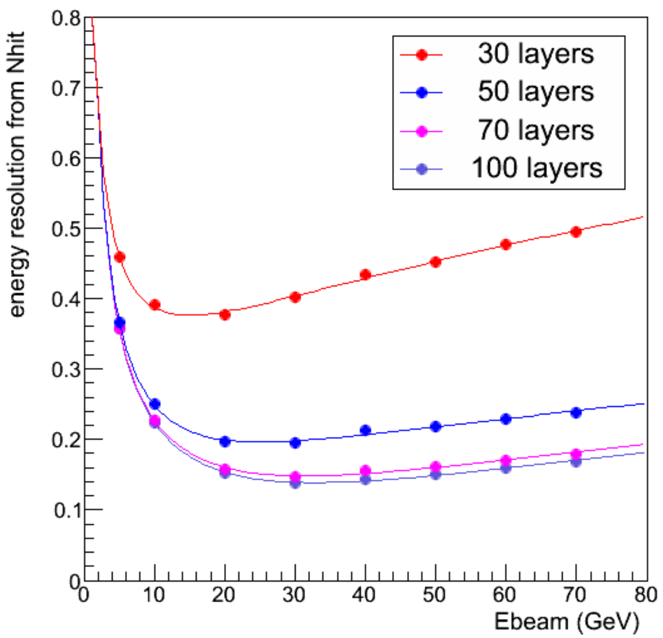
→ Lots of (shower) physics with a few layers!

Highlights of simulation work (1/2)

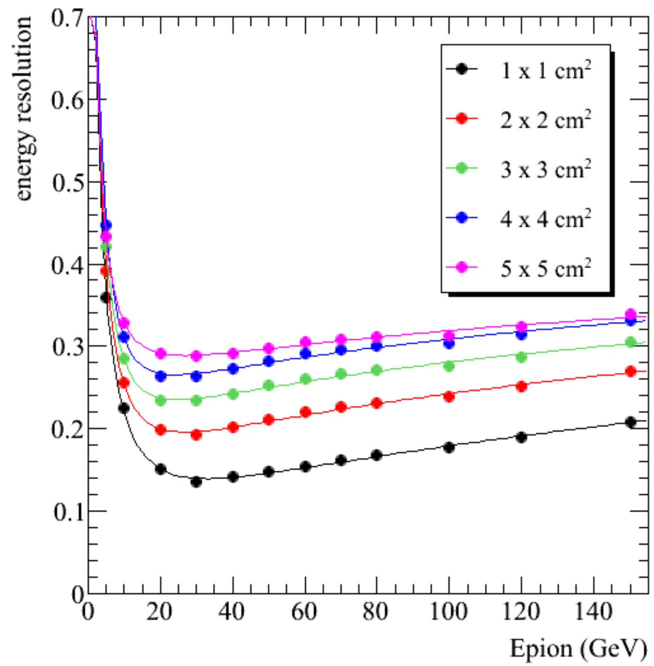
Our model of Micromegas SDHCAL fits well the measured pion response

It is used to investigate the energy resolution of a SDHCAL to single pions (before studying jets)

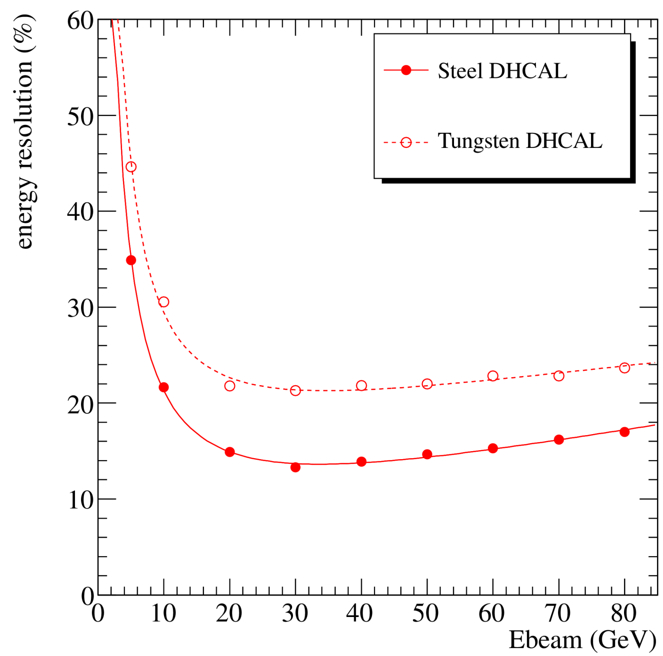
Raw DHCAL response needs corrections for leaks & saturation



Rear leakage (Fe)
Number of layer



Saturation (Fe)
Pad size



Saturation
Absorber Fe-W

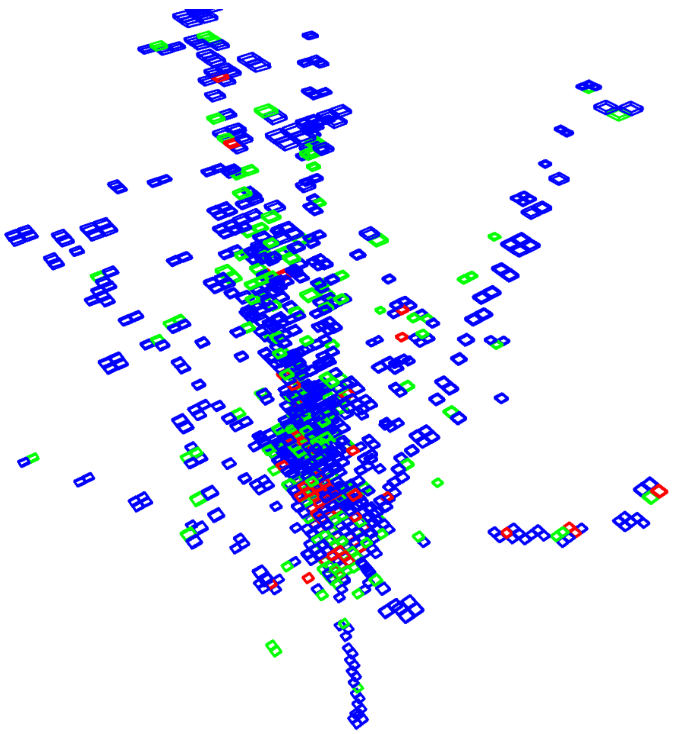
Highlights of simulation work (2/2)

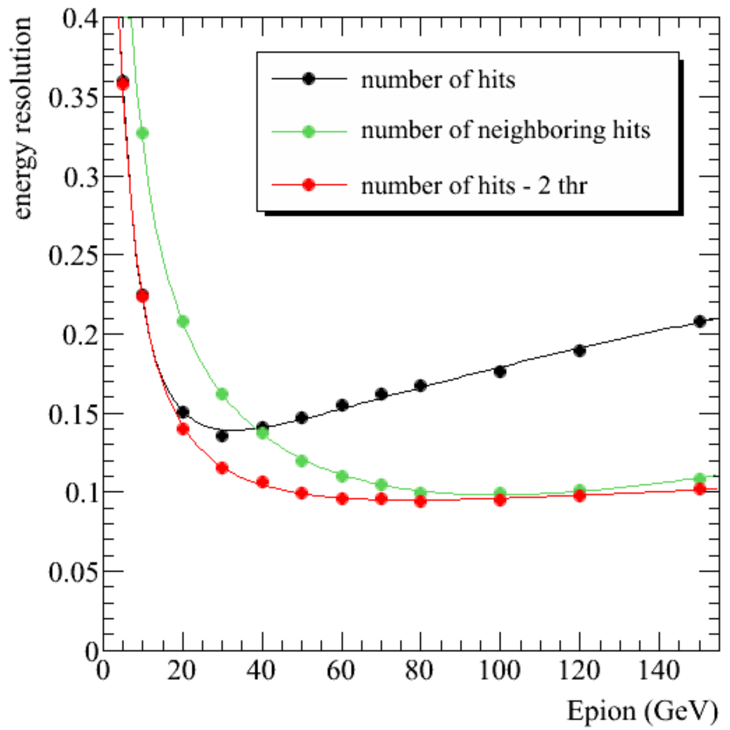
Compespensation

= equalisation of response to EM and H part of hadron showers improves linearity & resolution

→ EM energy is concentrated in a small volume (Molière radius) → geometric saturation

→ In a (S)DHCAL, it can be tagged with **hit density** or with **multi-threshold** readout



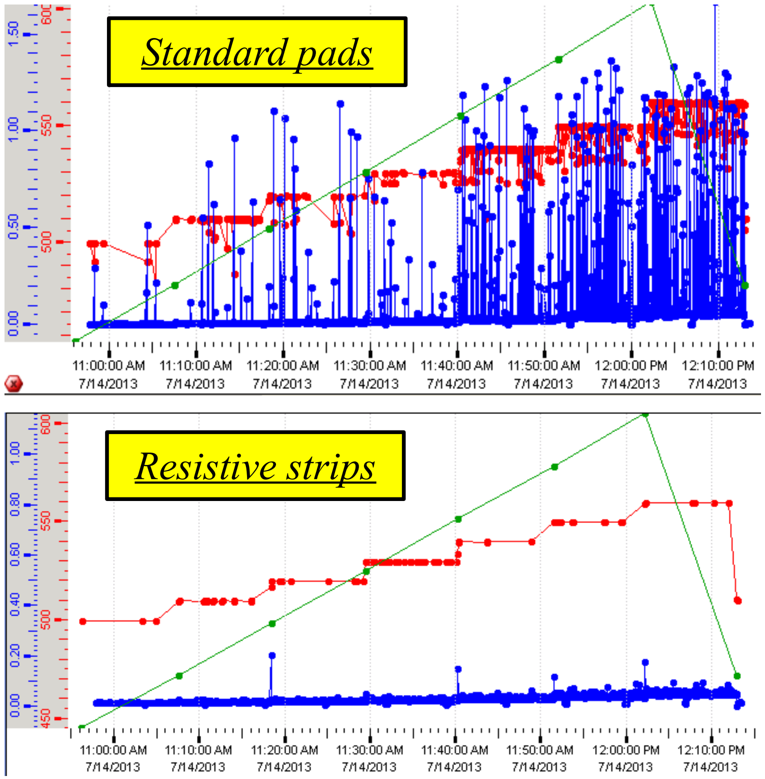


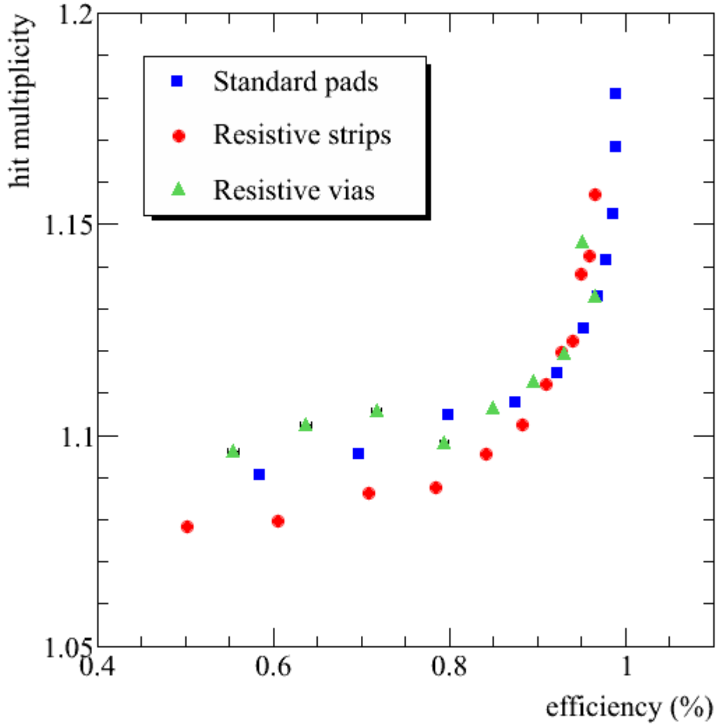
Resistive Micromegas (1/2)

Improvements of existing large prototypes

Avoid discharges (measured probability = 10^{-6} / showering pion / m^2) with resistive layers

Simplify PCB by removing current-limiting diodes

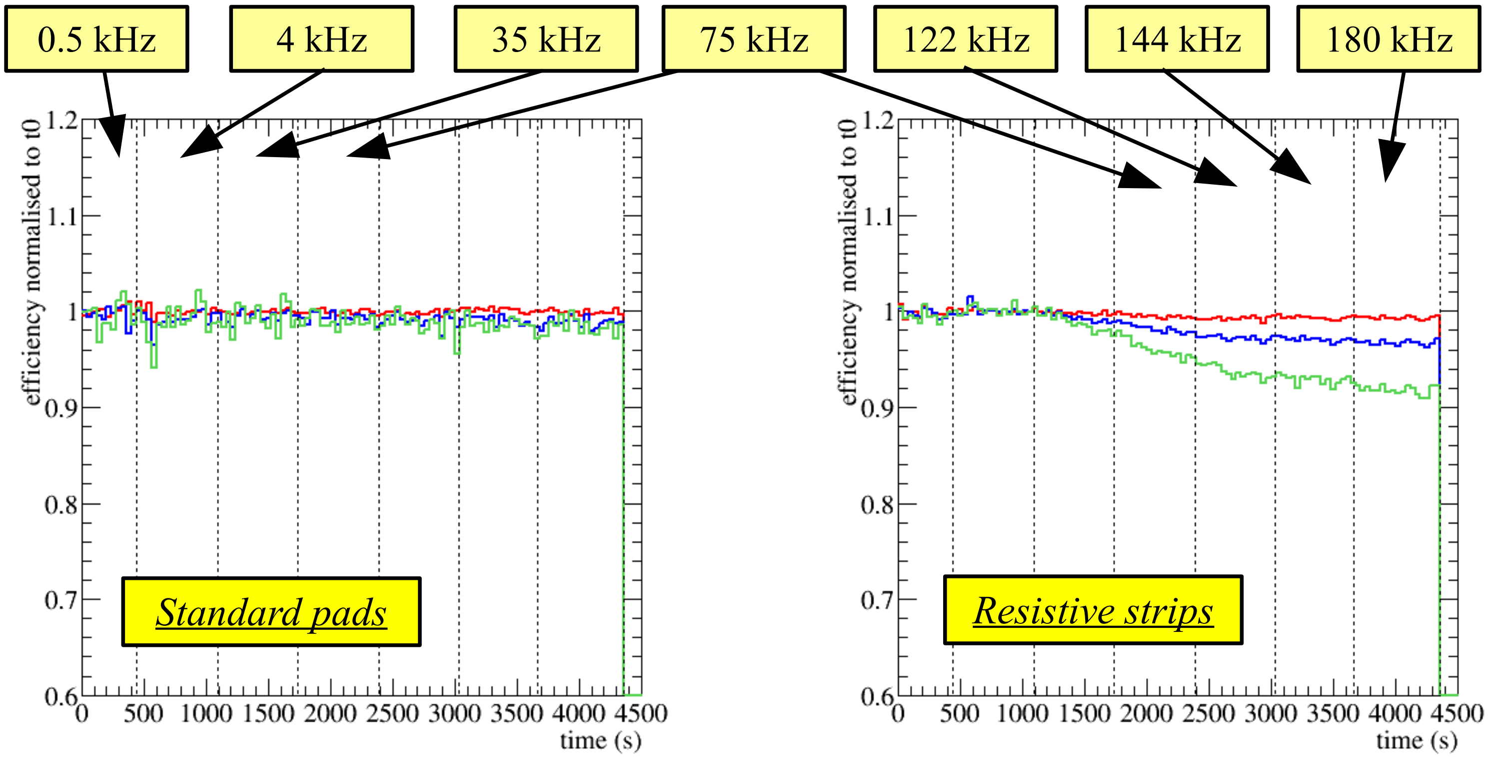




Challenge 1: do not change efficiency/multiplicity → specific R-strip patterns

Resistive Micromegas (2/2)

Challenge 2: Maintain rate capability as high as possible



Rate scan

5 GeV e⁻ beam

Collim. 2x2 cm^2

Thr0 = 0.5 MIP

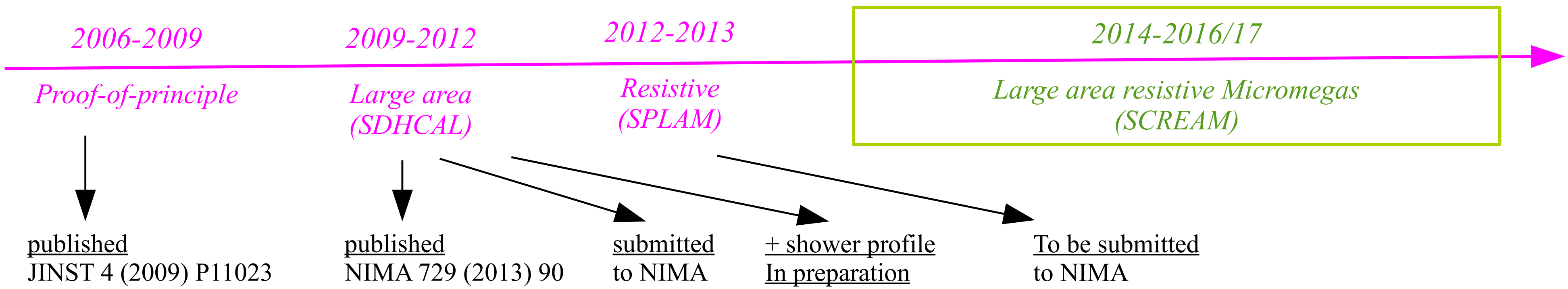
Thr1 = 5 MIP

Thr2 = 15 MIP

Rate effects in resistive prototypes seen but remain small

Analysis on-going to understand & model the underlying mechanisms

Future plans (and publication)



Two R&D phases completed: large area Micromegas (SDHCAL) & resistive Micromegas (SPLAM)

→ Next is : * Medium size calorimeter prototype with simplified mechanics for HCAL and ECAL combined effort with LHC experiments

* Study of a hybrid electronics digital/analogue to remedy saturation effects

*ANR proposal called Sampling Calorimetry with Resistive Anode Micromegas (**SCREAM**)*

ANR = 0

Validate resistive large area Micromegas

→ Enlarge PCB size to 48x48 cm^2

→ Modify 1x1 m^2 chamber design (4 ASU)

ANR = 1

Validate Micromegas calorimetry

→ 50 layers of 48x48 cm^2

→ Full characterisation completed in 2017

Conclusions

✗All tests carried out so far prove that Micromegas is a very good choice for a SDHCAL

We expect that a Micromegas calorimeter would out-perform other gaseous technologies

✗Good and improving understanding of the SDHCAL possibilities

Sustained analysis effort of RPC-SDHCAL testbeam data & Geant4 simulation

✗LAPP group gained a strong expertise in R&D on gaseous detectors used for calorimetry

✗Fruitful interaction with IN2P3 groups (ASIC, DAQ, software)

✗With/without ANR support: well defined road map till a possible positive decision of Japan