The Micromegas SDHCAL project,
Status and Future

CALICE collaboration meeting
Annecy Sept. 9th-11th 2013

M. Chefdeville, CNRS/IN2P3/LAPP Annecy

The 1x1 m^2 Micromegas prototype

First paper: NIMA 729 (2013) 90–101

→ http://lappweb.in2p3.fr/~chefdevi/Work_LAPP/NIMA/

Design

Embedded electronics → total thickness of 1 cm (incl. 2 mm of steel)

Modular (6 meshes / m2) → XY scalability to larger size

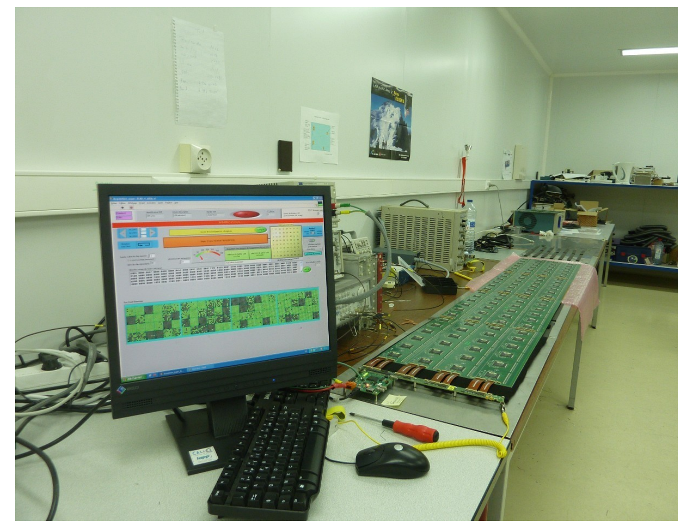
Electronics (*MICROROC*, LAPP/Omega)

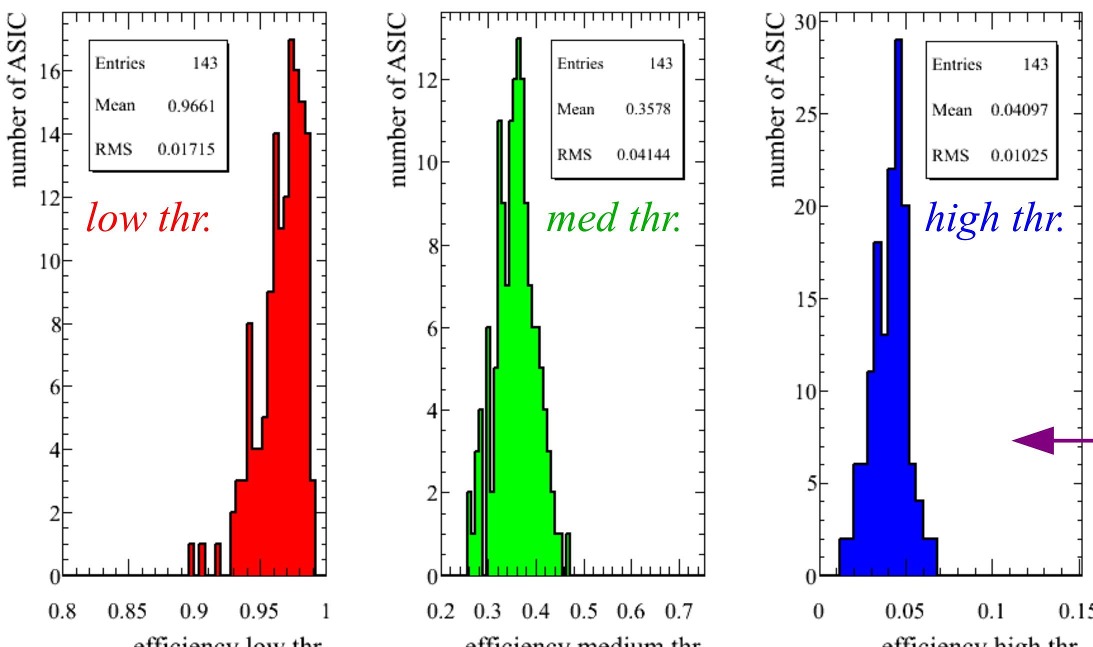
Low noise preamp → 1-2 fC threshold over 1x1 m^2 area!

3 thresholds → semi-digital readout (linearity up to 40 and 100 MIPs)

Readout boards can be chained → successful test up to 4 → 2 m!

ILC features: power-pulsing, self-trigger + memory, timestamping





Performance

Low threshold → high efficiency (> 95%)

Precise MICROROC calibration
→ good response uniformity over 1x1 m^2

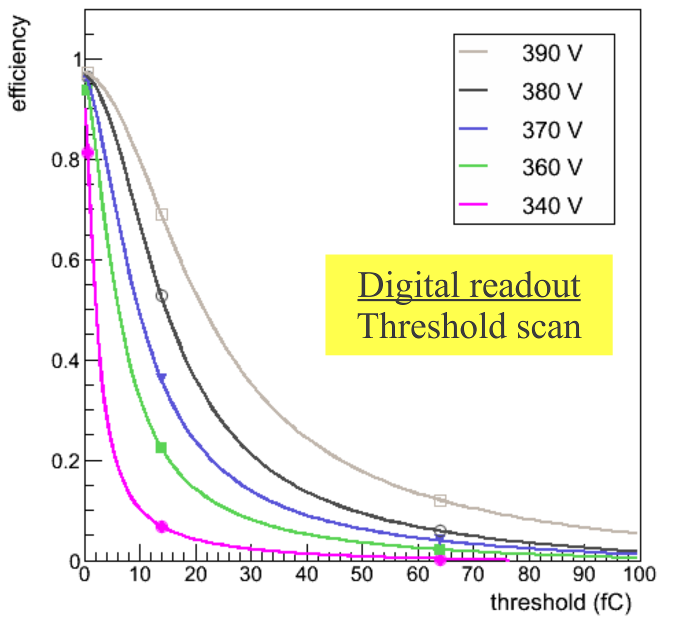
The 1x1 m^2 Micromegas prototype, *on-going analysis*

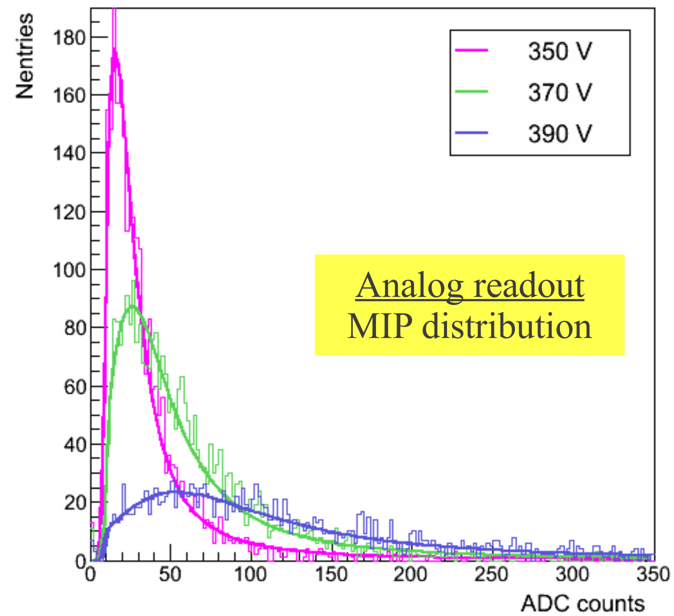
From 2011 to 2012, 4 prototypes were constructed and tested in particle beams

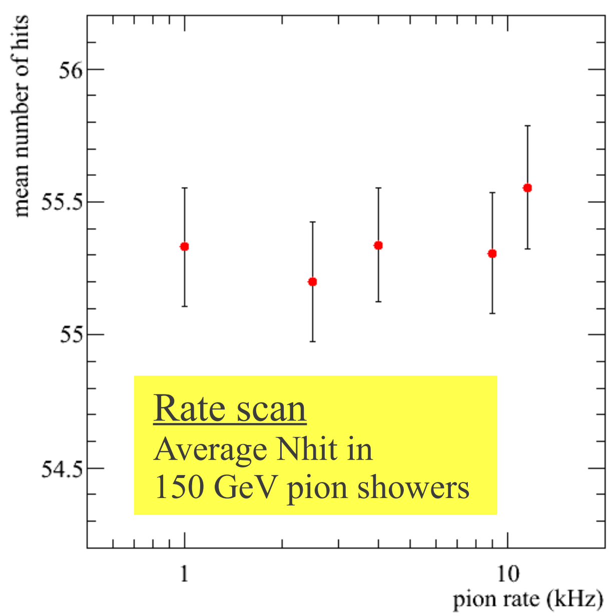
Nov. 2012 testbeam, standalone (SPS/H4)

Analysis mostly done: HV scan, threshold scan, rate scan, Landau distributions...

Paper in preparation: "***Test in beam of large area Micromegas chambers for calorimetry***"







Nov. 2012 testbeam, inside SDHCAL (SPS/H2)

Measurement of the pion response of a virtual Micromegas SDHCAL *over 20-150 GeV energy range*

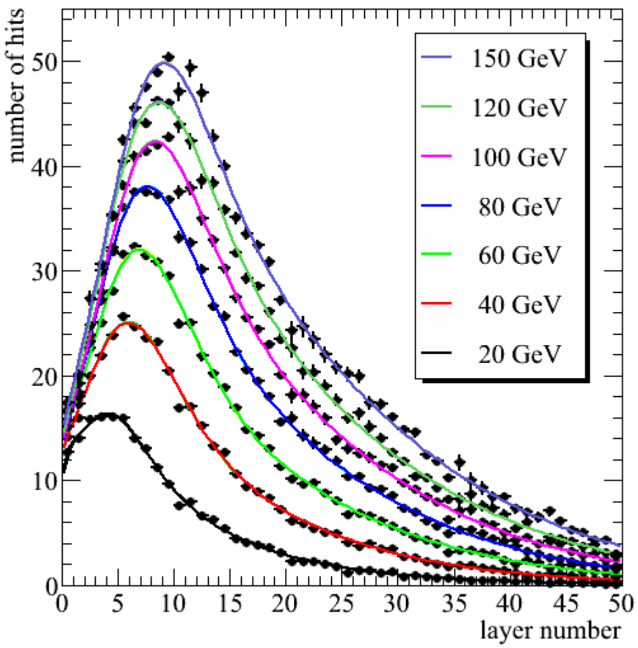
On-going : testbeam / Monte Carlo data comparison, CAN in preparation, if accepted, submit to journal

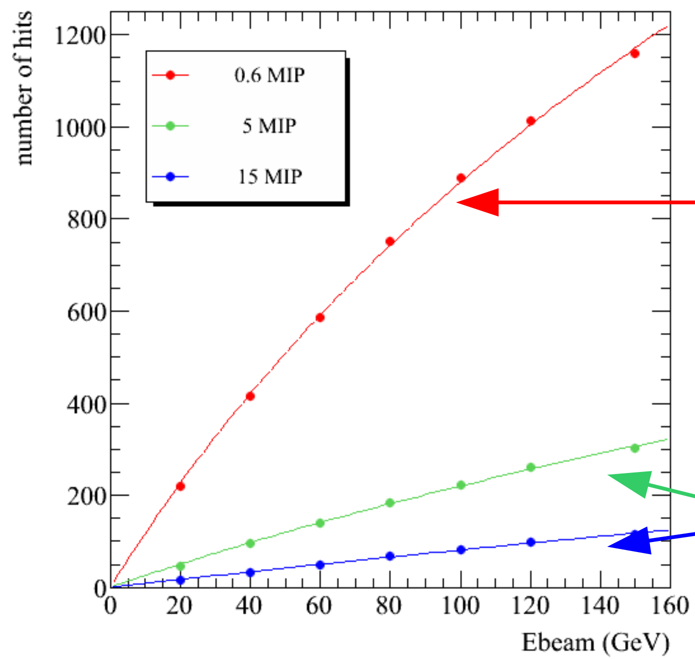
The pion response of a virtual Micromegas SDHCAL (1/3)

4 Micromegas at layers 10, 20, 35, 50; remaining slots occupied by RPCs

Find shower starting layer ($\sigma z_0 = \lambda_{int} \sim 17$ cm) & measure Nhit in Micromegas

→ shower profile → pion response with rear leakage correction





Saturated response

$N_0 = A/B . \log(1+BE)$

$A = 12.3$ hit/GeV

$B = 0.009$ / GeV

Linear response between 5-15 MIP...

What's new since Hamburg?

→ More realistic digitisation: low threshold = 0.6 MIP (instead of U_i(Ar))

→ Identify shower start layer, algorithm has been optimised with Monte Carlo data

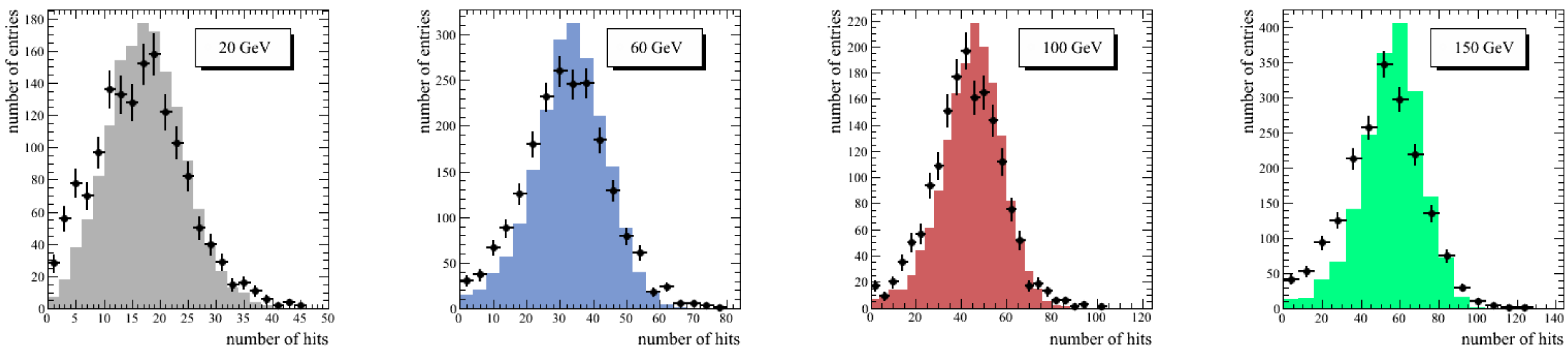
→ Simulated energy range extended from 70 to 150 GeV (10k evt / E, Geant4 v9.5 QGSP_BERT)

→ Data/Monte Carlo comparison → N_{hit} distribution per layer, profile and response for 3 thresholds

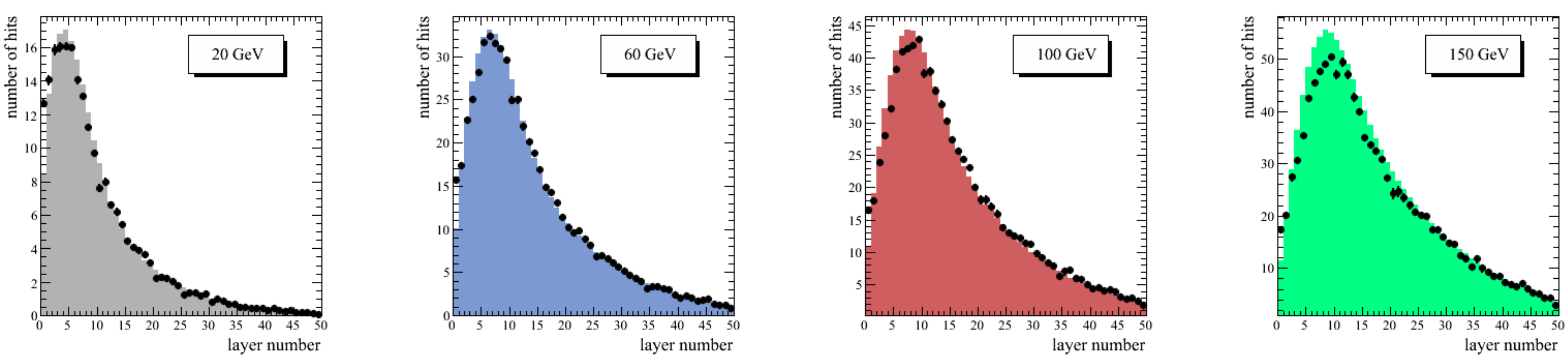
The pion response of a virtual Micromegas SDHCAL (2/3)

Data/Monte Carlo comparison, reasonably good agreement up to 100 GeV

Nhit distribution at shower max at 20, 60, 100 & 150 GeV (available for any layer)



Longitudinal profile at 20, 60, 100 & 150 GeV (each point is the mean of N_{hit} distribution)

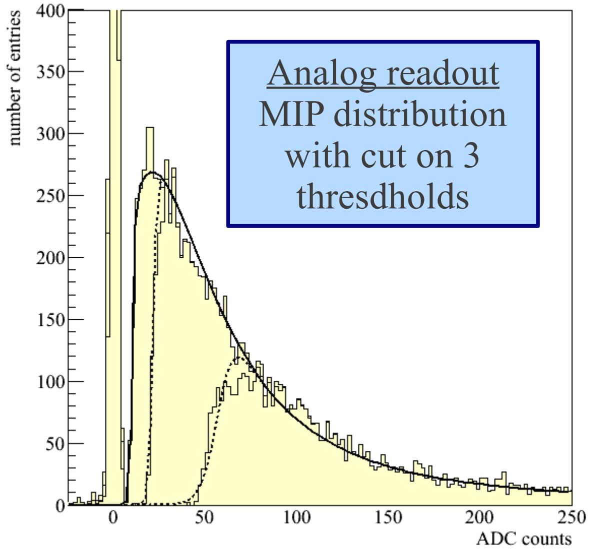


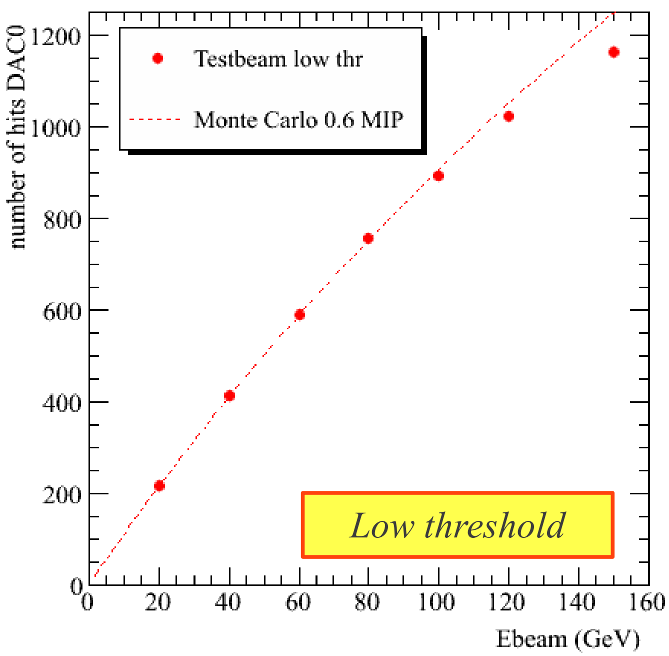
The pion response (3/3)

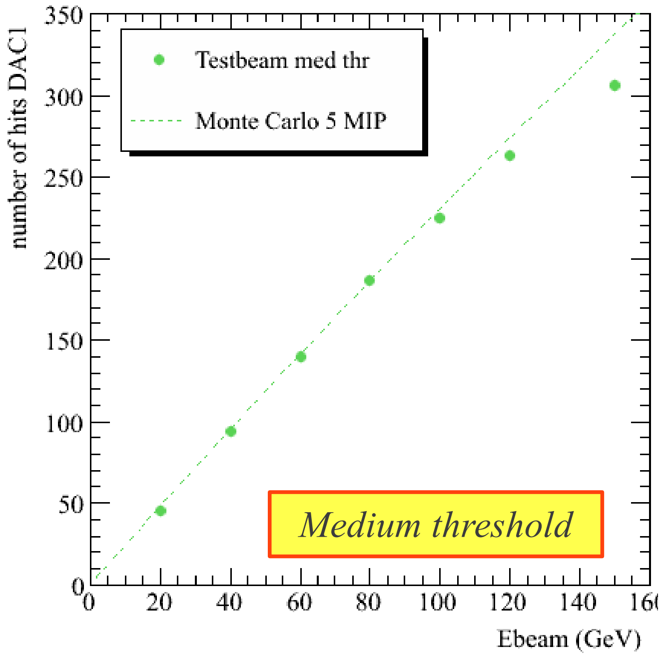
Low threshold (0.6 MIP) response well reproduced up to 100 GeV
That's good!

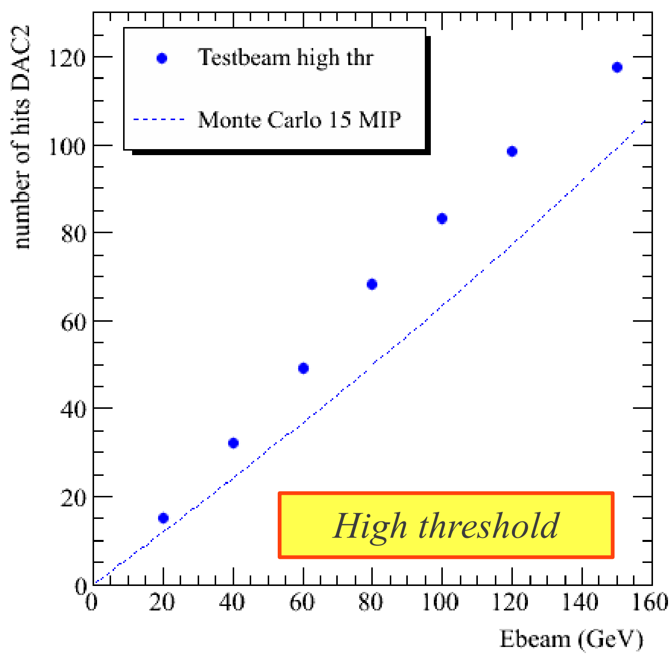
Medium threshold (5 MIP) not bad either
The detector was tuned well ← analogue readout

High threshold (15 MIP) not reproduced
High energy deposit = delta-rays → Is G4 reliable?









Above 100 GeV Micromegas signal saturation unlikely → G4 physics list discontinuity? Radial distrib.?

Below 100 GeV We have a good model of the calorimeter → Can be used for compensation studies (cf. Iro's talk in Analysis session)

Resistive Micromegas (1/2)

Successful beamtest of small prototypes this summer at DESY (see Jerome's talk in this session)

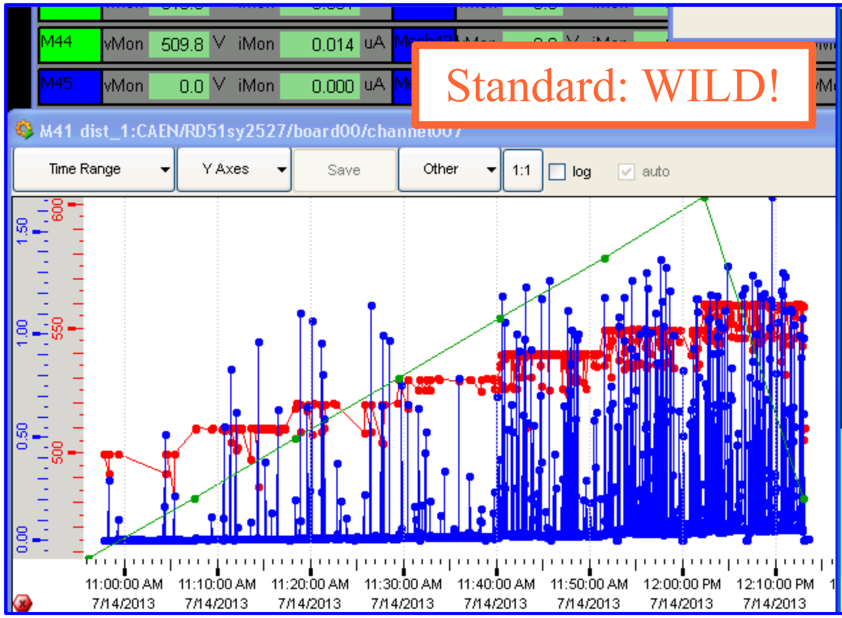
Let's repeat it!

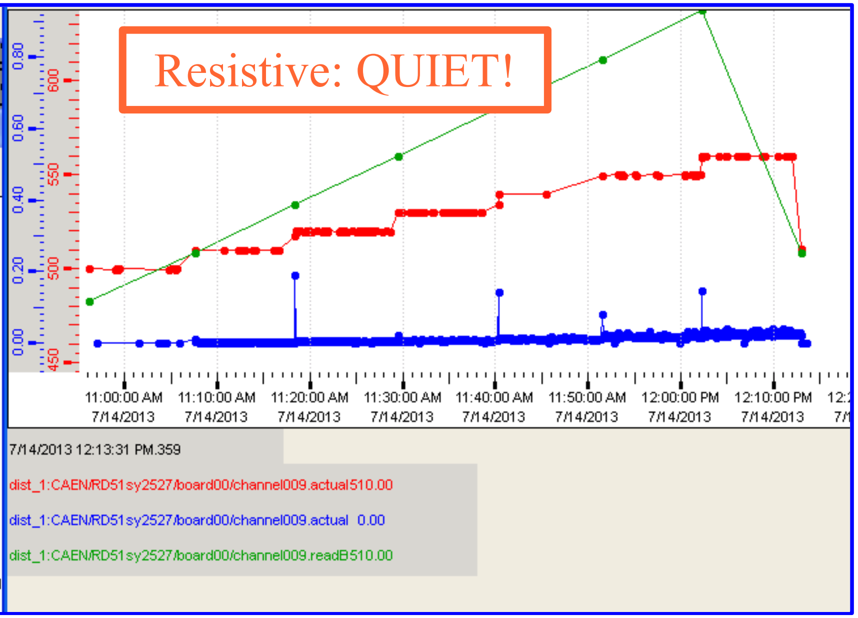
→ Sparks are gone

→ The rate capability is maintained (at least up to 50 kHz/cm^2)

→ We officially switched to non-flammable gas mixture (Ar/(CF_4)/iC_4H_{10} → Ar/CO_2)

Mesh voltage and current in a 1 kHz/cm^2 electron beam while ramping up the voltage





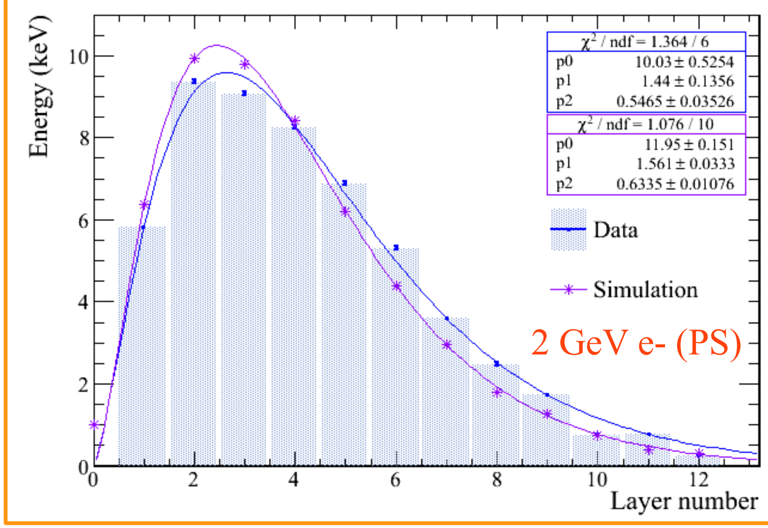
Resistive Micromegas (2/2)

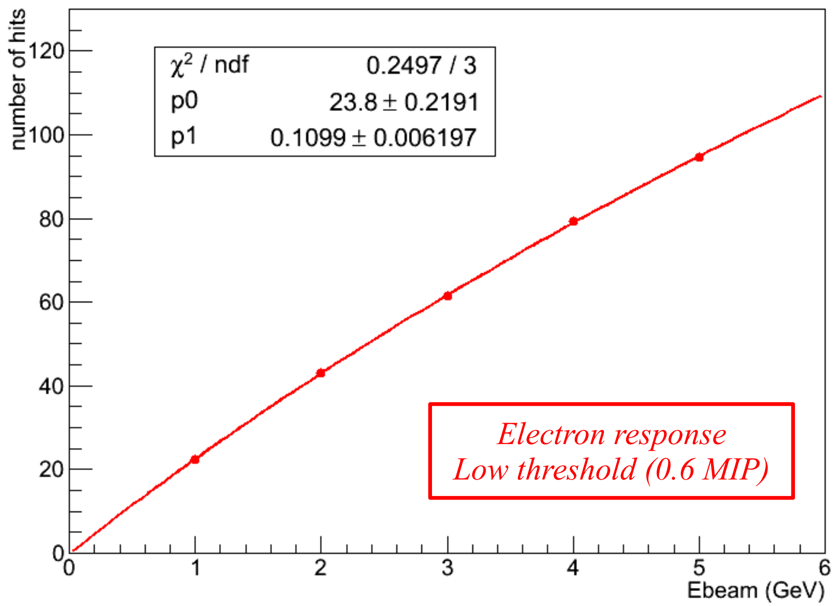
Small size (16x16 cm^2) but good enough to study the EM response over small E range

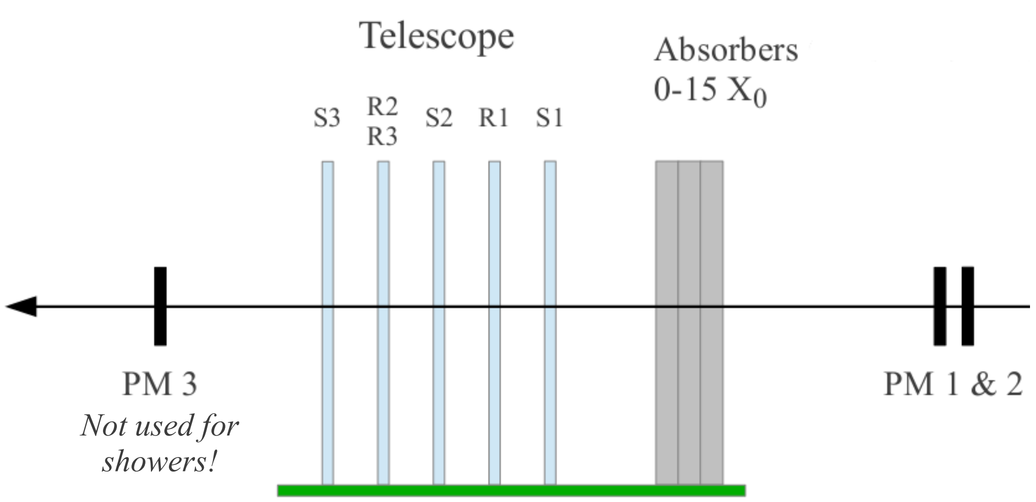
Variable number of absorbers upstream of the detector stack

→ Now we know both the
<u>pion & electron response of a Micromegas SDHCAL</u>

Method validated in 2009 with small Gassiplex prototypes but at only 1 energy







Next step → *Validate the resistive technology on a large area prototype*

Future: Validate the resistive technology on a large area prototype

But what large area prototype?

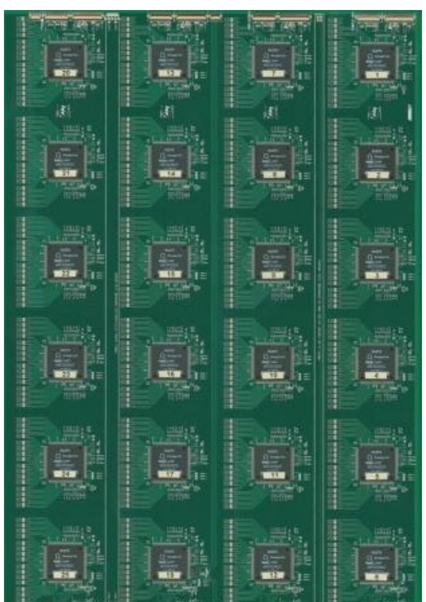
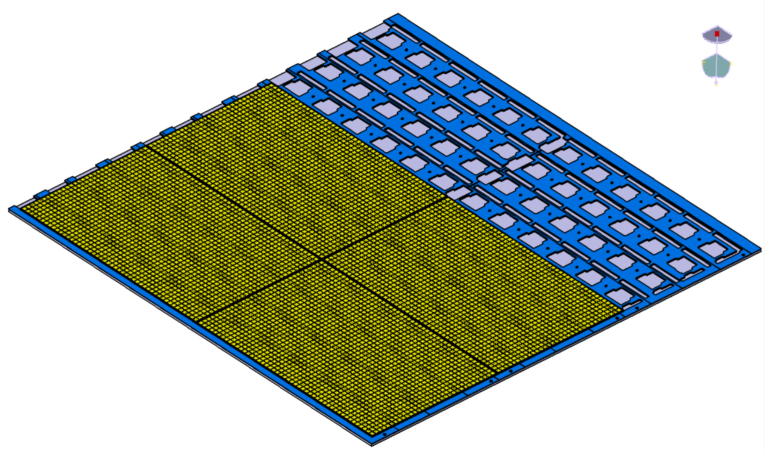
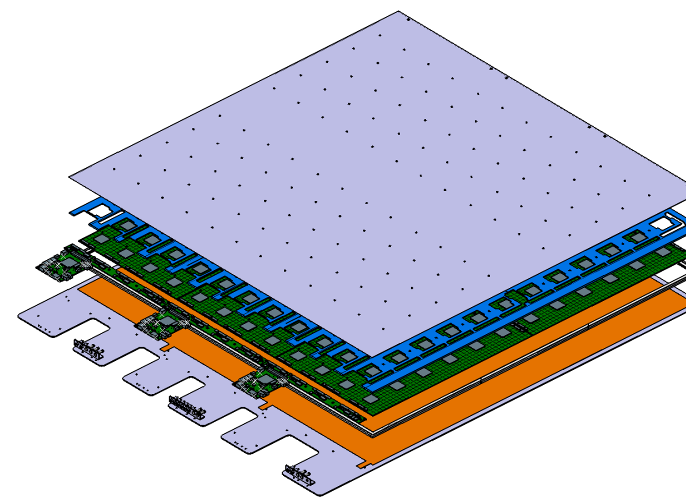
1. → Keep the same 1x1 m^2 design: a resistive ASU of 32x48 cm^2

2. → Enlarge the ASU size

   A resistive ASU of 32x96 cm^2 → 3 Bulk meshes instead of 6 / m^2

   A resistive ASU of different size suited for beamtest of a Micromegas SDHCAL

3. → Modify the mechanical design: attach a single mesh to the cathode cover → 1 mesh / m^2
   (in this case, the mesh does not belong to the ASU anymore → keep 32x48 cm^2 ASU)

Current 1x1 m^2 prototype design based on 6 ASU of 32x48 cm^2

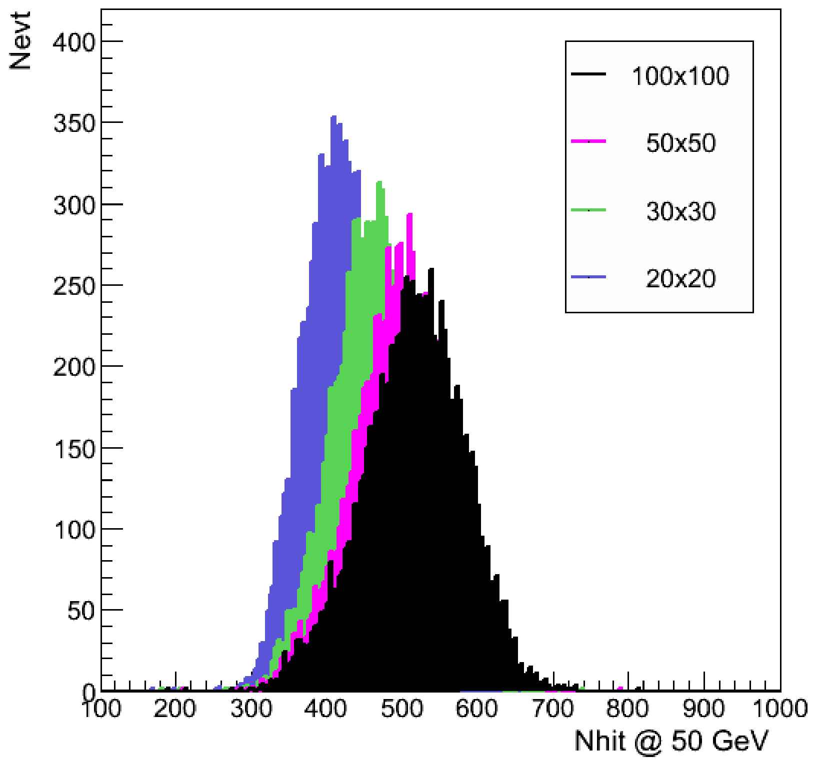
A small Micromegas SDHCAL (1/4)

What is the minimal size of an active layer for testbeam characterisation of a SDHCAL?
→ How much are we willing to give up on energy resolution compared to a 1 m^3? Let's say below 1% absolute.

More slides available @ http://lappweb.in2p3.fr/~chefdevi/Work_LAPP/Small_sdhcal/

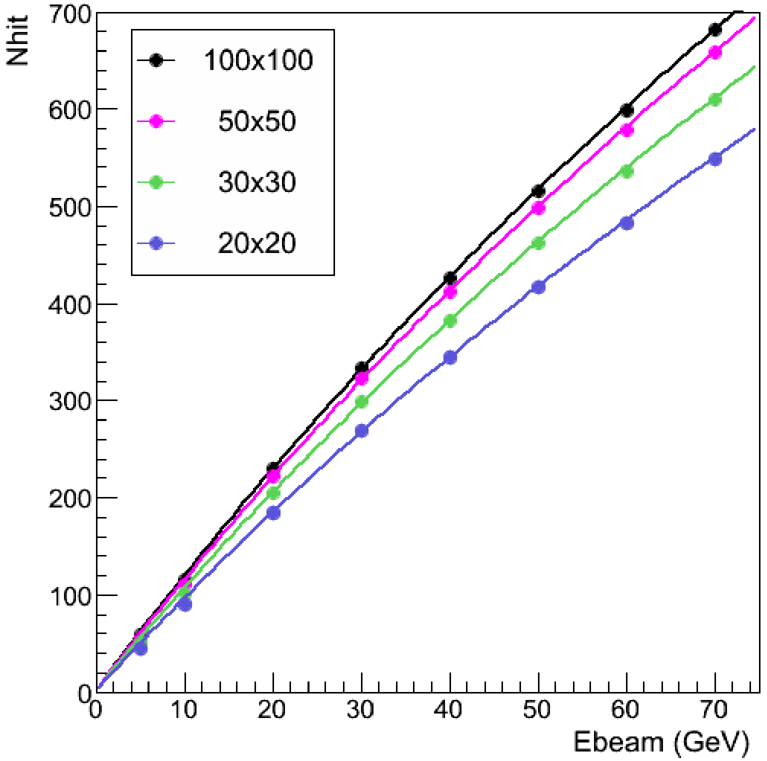
The Monte Carlo (pions) sees no big difference between 1x1 m^2 and 50x50 cm^2

50 GeV pions - 100 layers



N_{hit} distribution @ 50 GeV

N ~ log (E) → E ~ exp(N)



Pion Response

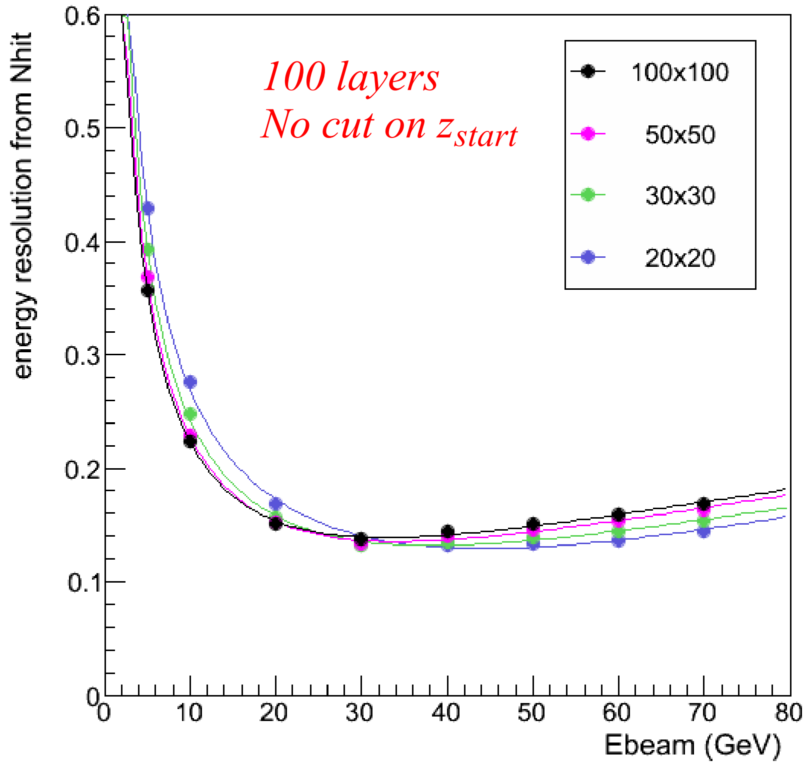
A small Micromegas SDHCAL (2/4)

Impact of transverse size on energy resolution

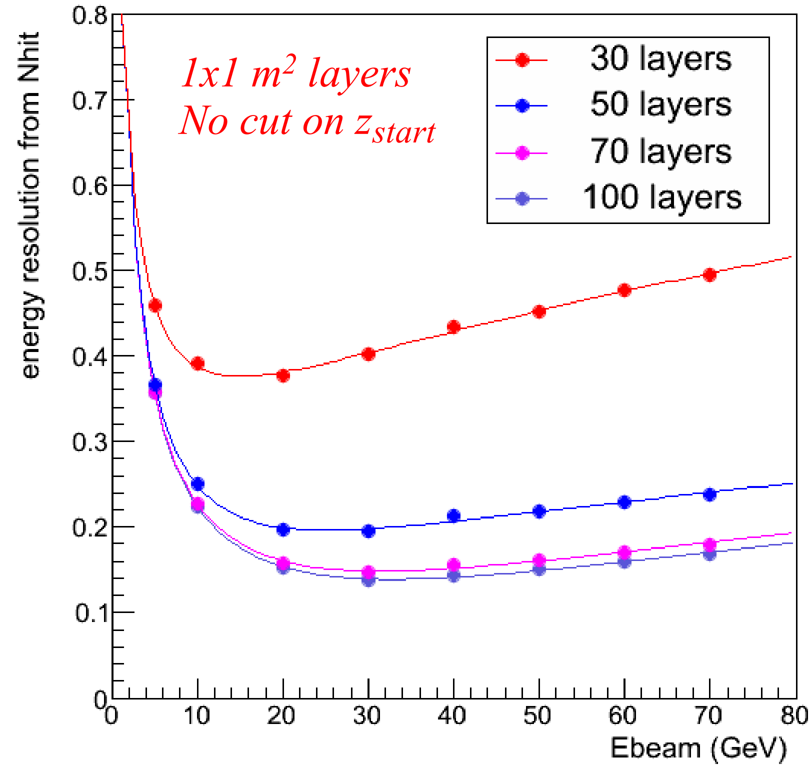
More important at low energy (< 30 GeV) probably because of lower *fem* → more MIP (i.e. tracks)

Improvement with smaller size at high energy (>30 GeV) not yet understood

The resolution is much more dependent on the thickness than on the transverse size



Resolution – XY dependence

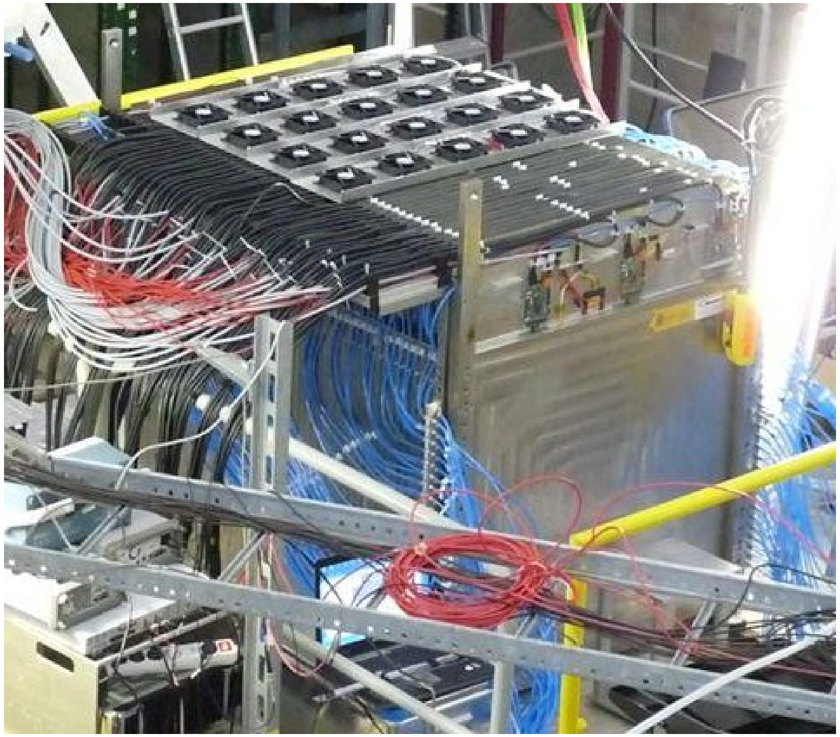


Resolution – Z dependence

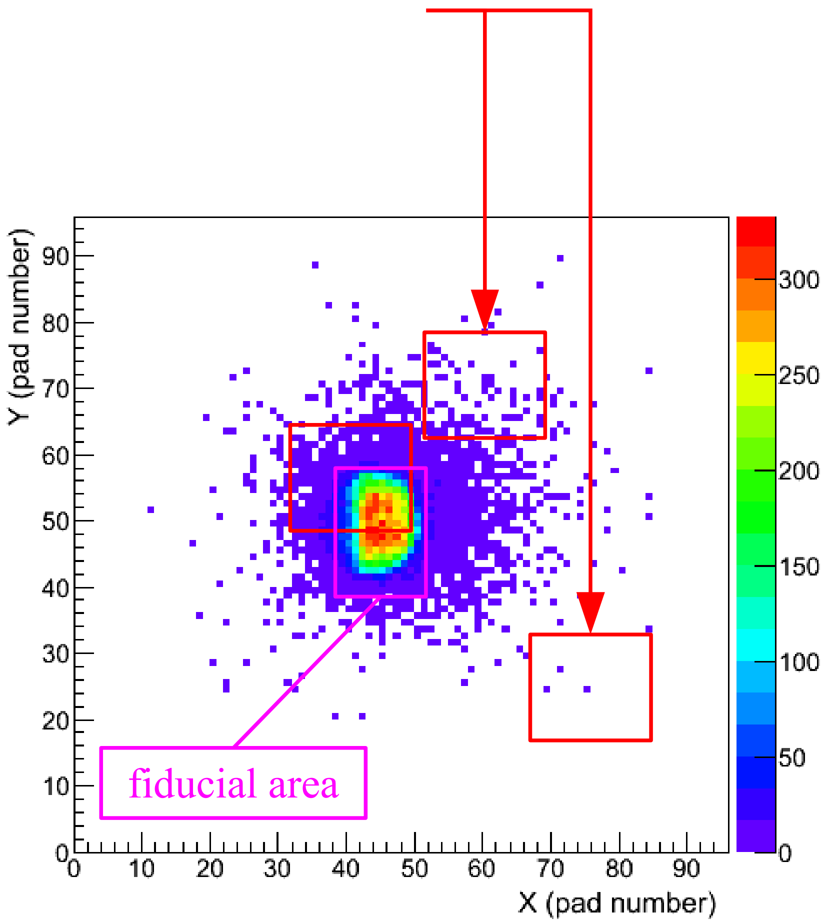
A small Micromegas SDHCAL (3/4)

Testbeam data: selected pion runs from August 2012 RPC-SDHCAL campaign

"Crop box" centred around pion impact on first layers
(i.e. varies from event to event)
+ fiducial cut



The GRPC-SDHCAL at the SPS
(Only the first threshold is used: pure digital)

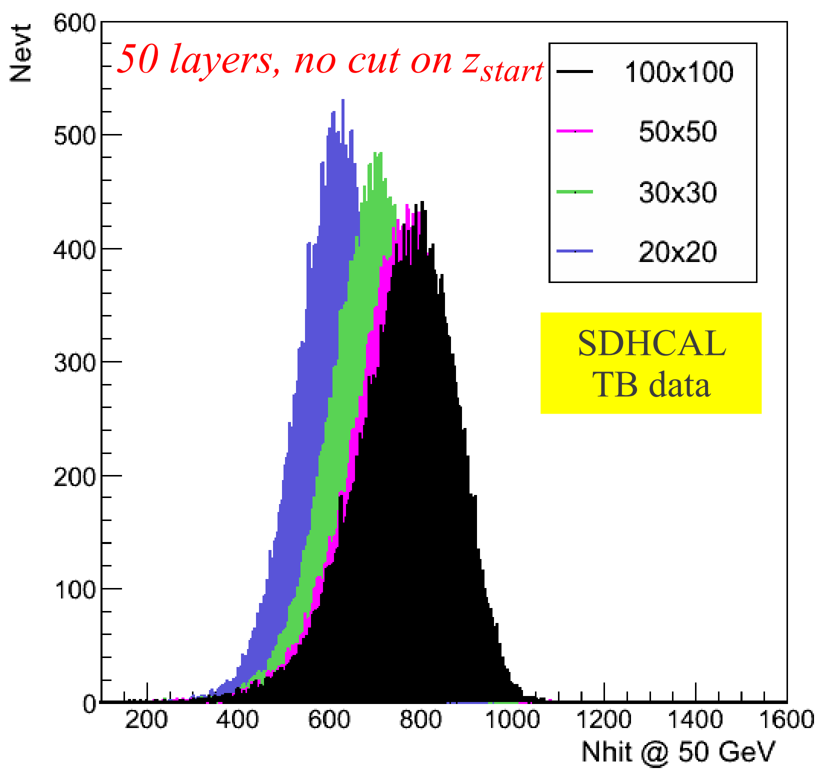


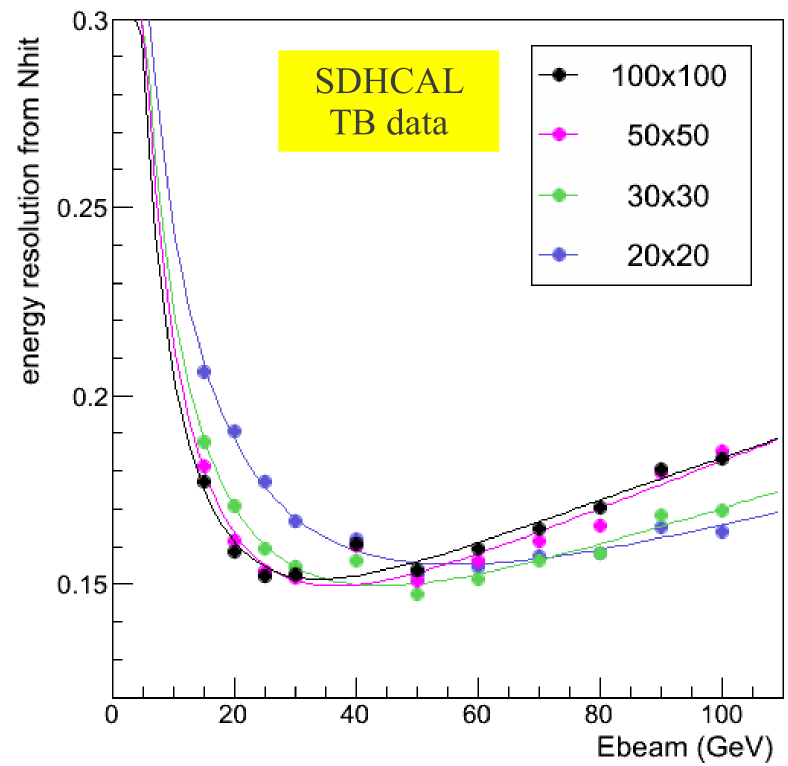
HITS IN FIRST LAYERS

A small Micromegas SDHCAL (4/4)

Conclusion from Monte Carlo and testbeam data analysis

There is no degradation of hadron resolution when changing the transverse dimension of a (S)DHCAL from 100x100 cm^2 to 50x50 cm^2





→ Resistive ASU size of 48x48 cm^2 (current size is 32x48 cm^2)

→ Little R&D involved: new PCB & inter-DIF design + MICROROC available

Conclusions

1x1 m^2 Micromegas prototype

Calorimetry results with 4 layers inside RPC-SDHCAL

Finish analysis and publish (one paper already published in NIM, 2 more to come)

Semi-digital readout of a gaseous HCAL

Optimisation of thresholds with Monte Carlo and testbeam data

On-going work to understand source of saturation and how to correct for it

Results with steel absorbers, new dataset available with tungsten

Resistive Micromegas

Beautiful testbeam results

Next: validation on large area

Micromegas SDHCAL

Would need to be long but not too wide (50x50 cm^2 layers seem fine)

But will not be for free → submit proposal to funding agency