Pion calorimetry with 1x1 m^2 Micromegas chambers (latest testbeam results)

RD51 mini-week, Dec. 4th 2012, CERN

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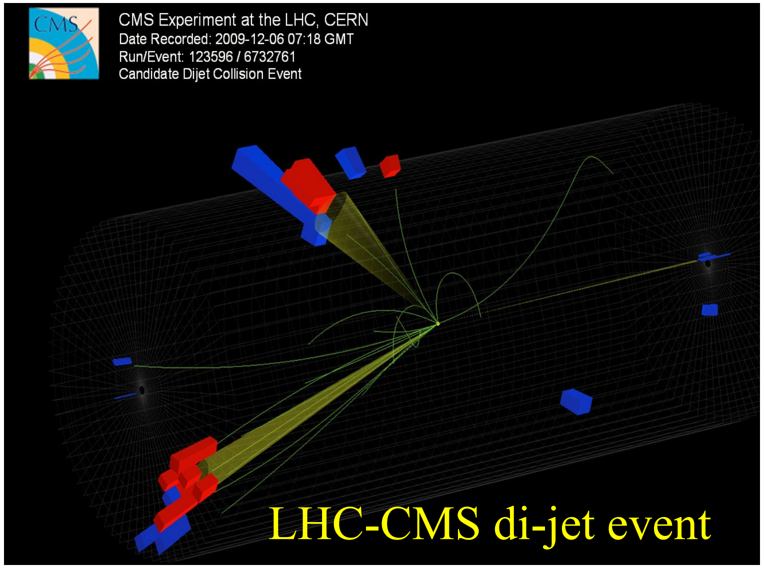
Overview

- Calorimeter prototypes for Particle Flow at a LC
- The Micromegas SDHCAL
- Thresholds and voltages for hadron calorimetry, the RD51 testbeam
- Response to pions inside a 6 λ_{int} HCAL, the CALICE testbeam
- Conclusion, future plans

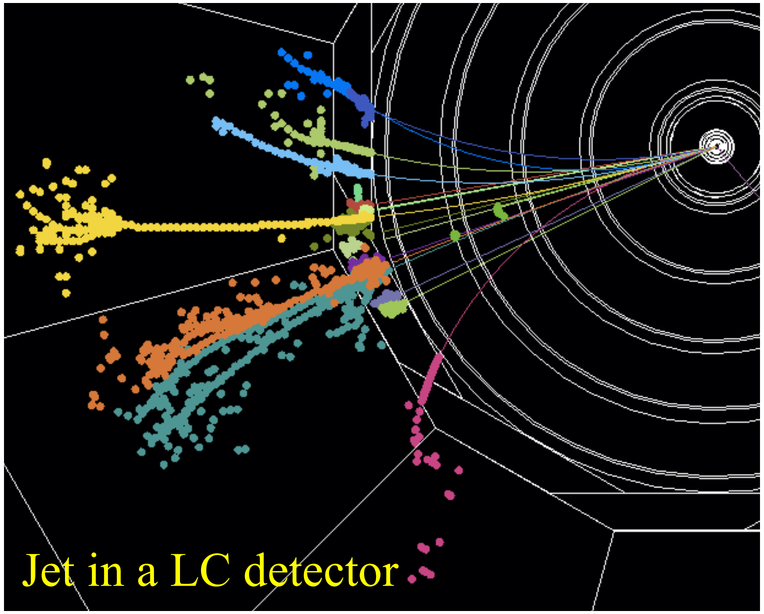
Introduction

- **Particle Flow** (PF) for jet reconstruction
  - Use tracker to measure the charged particles
    Use ECAL/HCAL for photons and neutrals hadrons
  - Jet energy resolution dominated by *confusion* more than calorimeter resolution



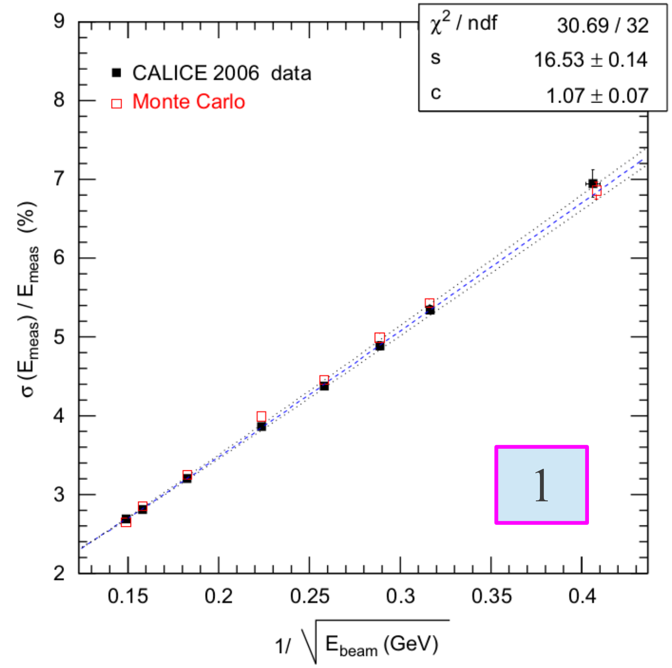
- PF calorimeters are highly granular,
  both in transverse and longitudinal directions.
  They have been adopted as baseline for ILD & SiD.

- PF calorimeters are sampling calorimeter
  using Fe or W absorbers and
  scintillators, silicon and gas as sensing medium.
  Many R&D projects well on track (CALICE).



ECALs

1. European Si/W
   - First physics prototype, first performance results
2. Sc/W in Japan
   - Uses strips instead of pads
3. Si/W US prototype, at the extreme of integration
   - ASIC bounded directly on Si sensors
4. Si/W Digital ECAL from UK
   - Count particles in EM showers thanks to a MAPS readout



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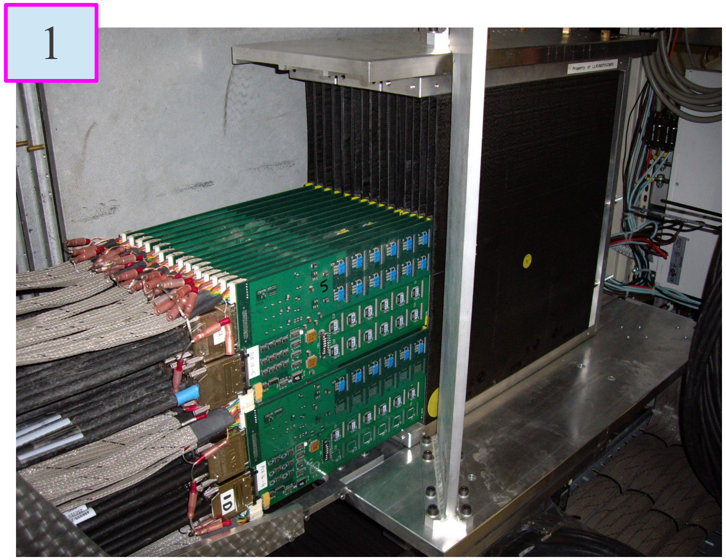

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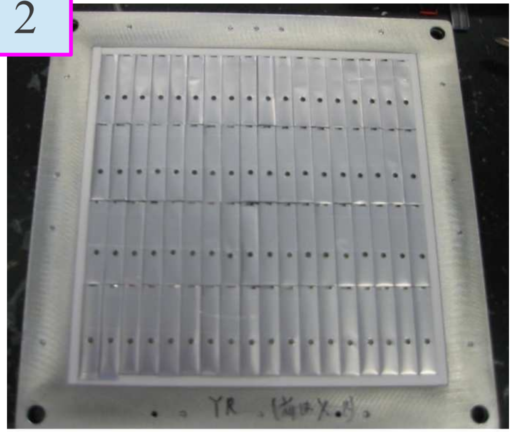

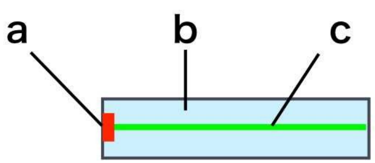

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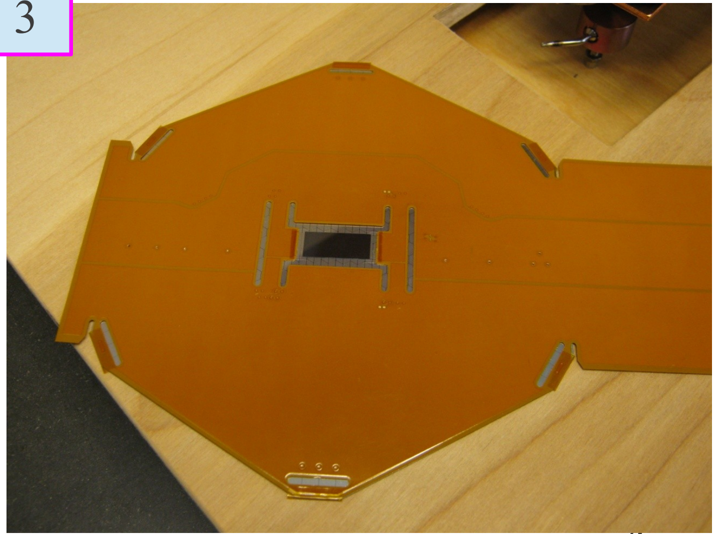
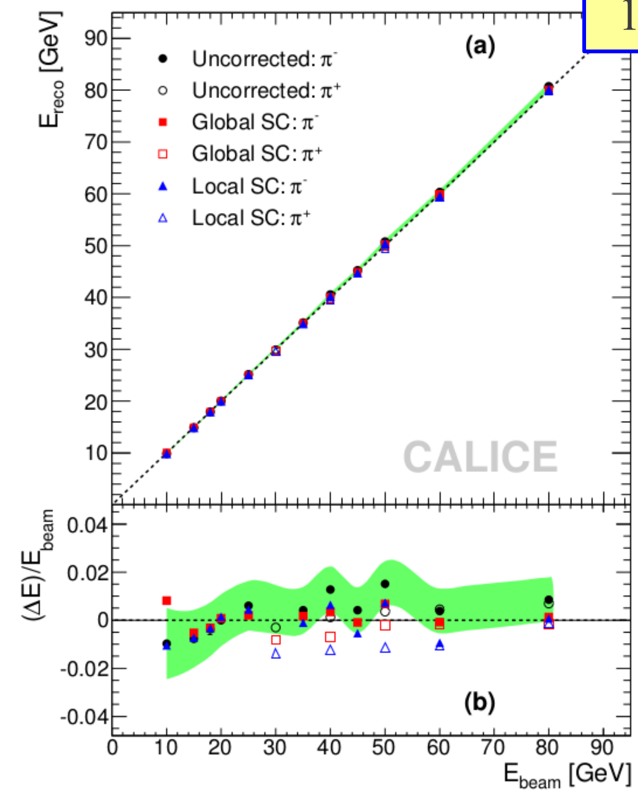
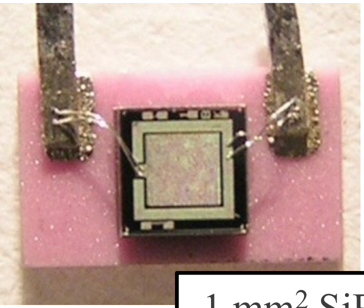


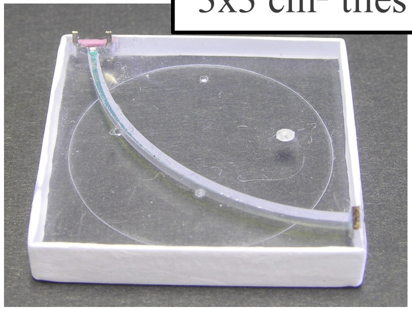
HCALs

1. European Analogue HCAL (**AHCAL**)
    - Scintillating tiles of 3x3 cm2 readout by SiPM (DESY)
2. US Digital HCAL (**DHCAL**)
    - Uses RPCs with 1-bit readout electronics and 1x1 cm2 pads (ANL)
    - An alternative using GEMs exists (UTA)
3. European **SDHCAL**, lot in common with US DHCAL
    - Correct for saturation in the shower core by using 3 readout thresholds
    - Gaseous detectors: Glass-RPCs and Micromegas

- 3 mechanical structures: 2 in steel and 1 in tungsten (CLIC)

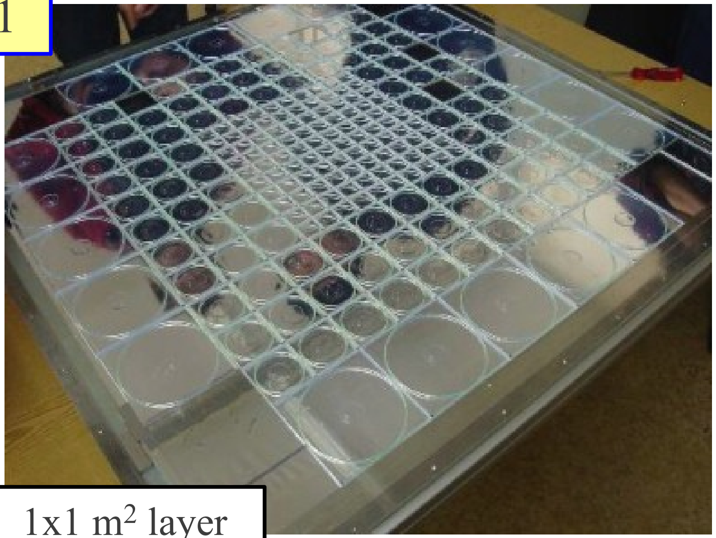




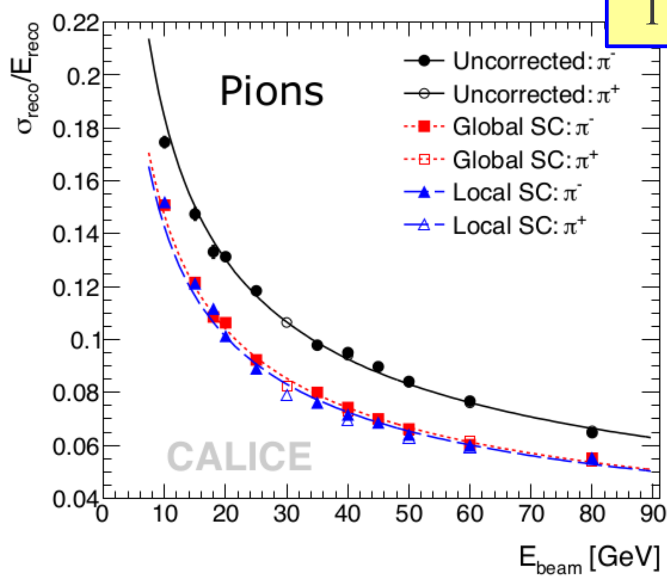


1 mm^2 SiPM
3x3 cm^2 tiles

1



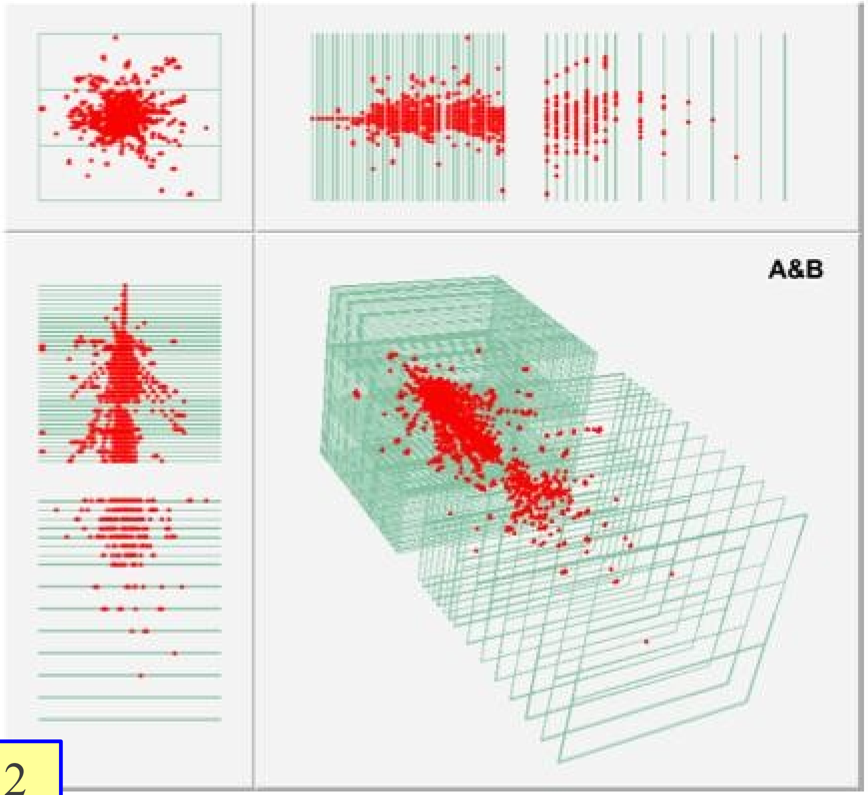
1x1 m^2 layer



$\sigma/E = 45.1\%/\sqrt{E} \oplus 1.7\% \oplus 0.18/E$

Semi-digital hadron calorimetry

30 GeV pion shower inside DHCAL



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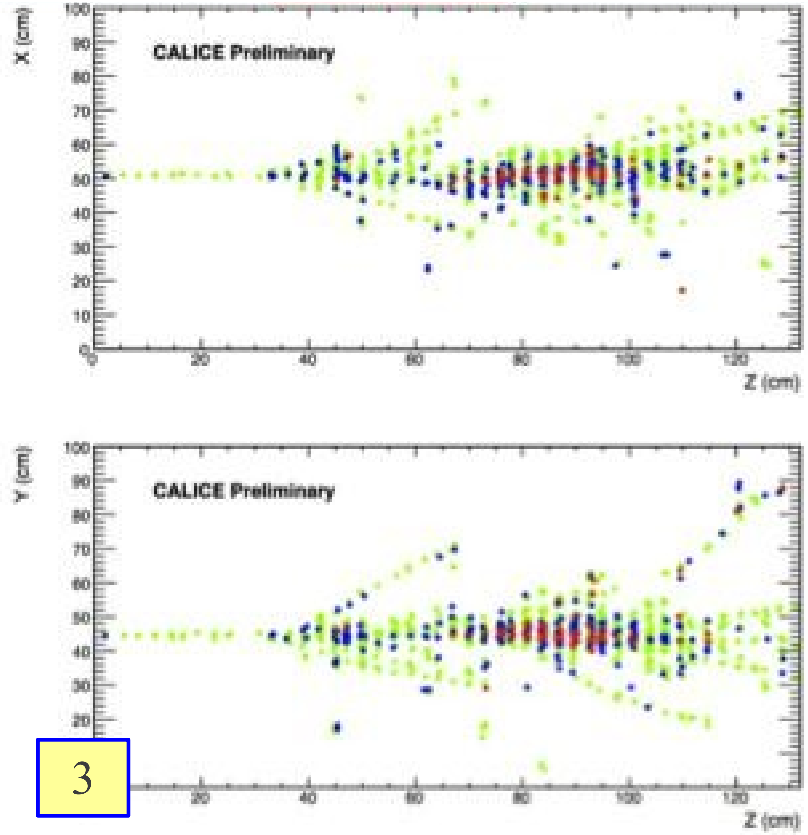
80 GeV pion shower inside SDHCAL



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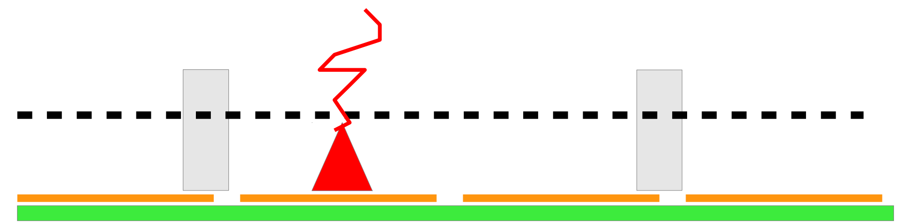
With a digital readout, the EM sub-showers are responsible for the saturation of the response.

Additional thresholds may be used to identify the EM parts and correct for the non-compensation of the HCAL ($e/h \neq 1$). This, in principle, should result in improved linearity and energy resolution.

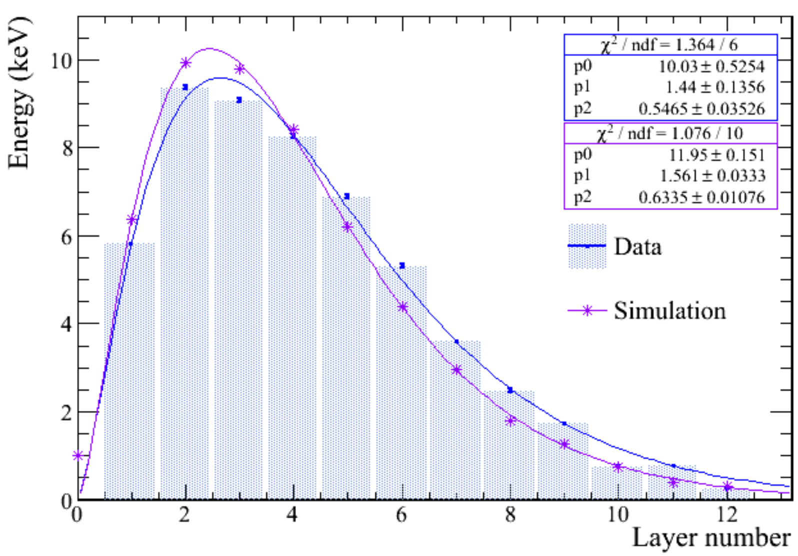
Micromegas chambers for a SDHCAL

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

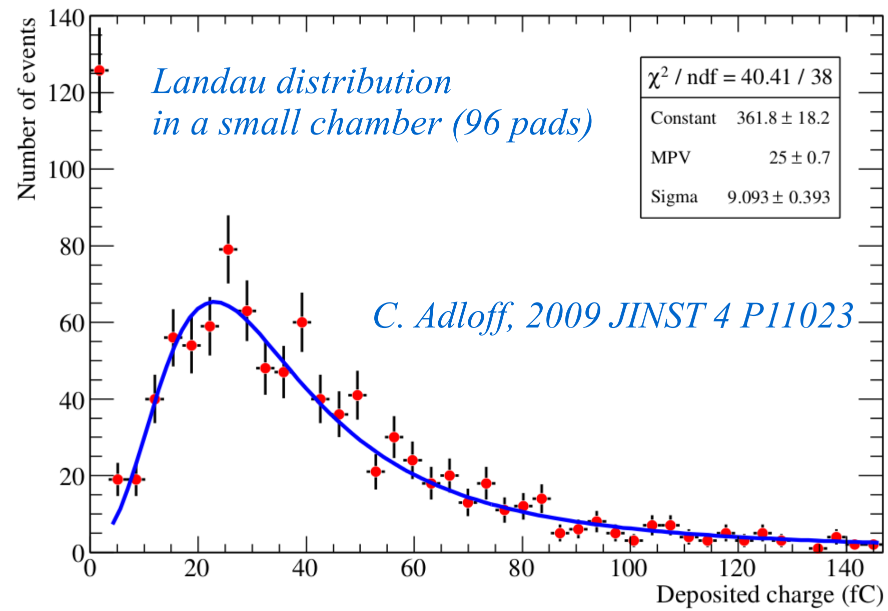
<u>Geometry</u>
Detector : 128 µm amplification gap, 3 mm drift gap
Woven mesh : 80 µm pitch, steel wire diameter 20 µm
Pillars : 300 µm diameter, 2 mm pitch
Pads : square pattern, 1 cm pitch



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



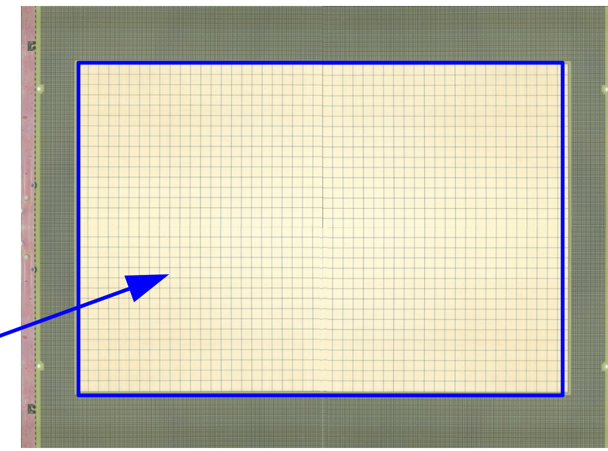
Micromegas boards (ASU)

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

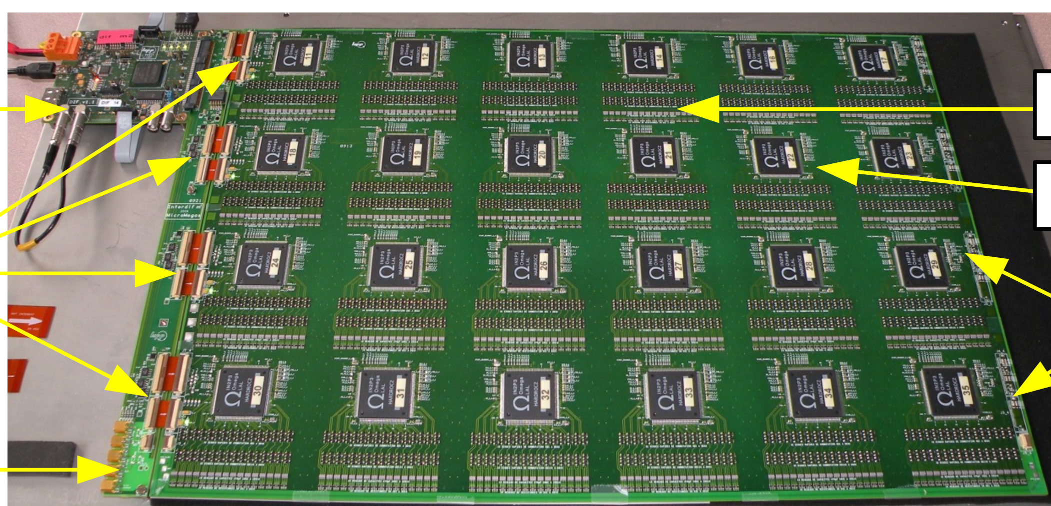
It is equipped with 24 ASICs, 1536 pads and a Bulk mesh
It is called an Active Sensor Unit (ASU)

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



Power, digital signals, calibration, PC link

Flex. interconnects

Mesh HV

Spark protections

ASIC

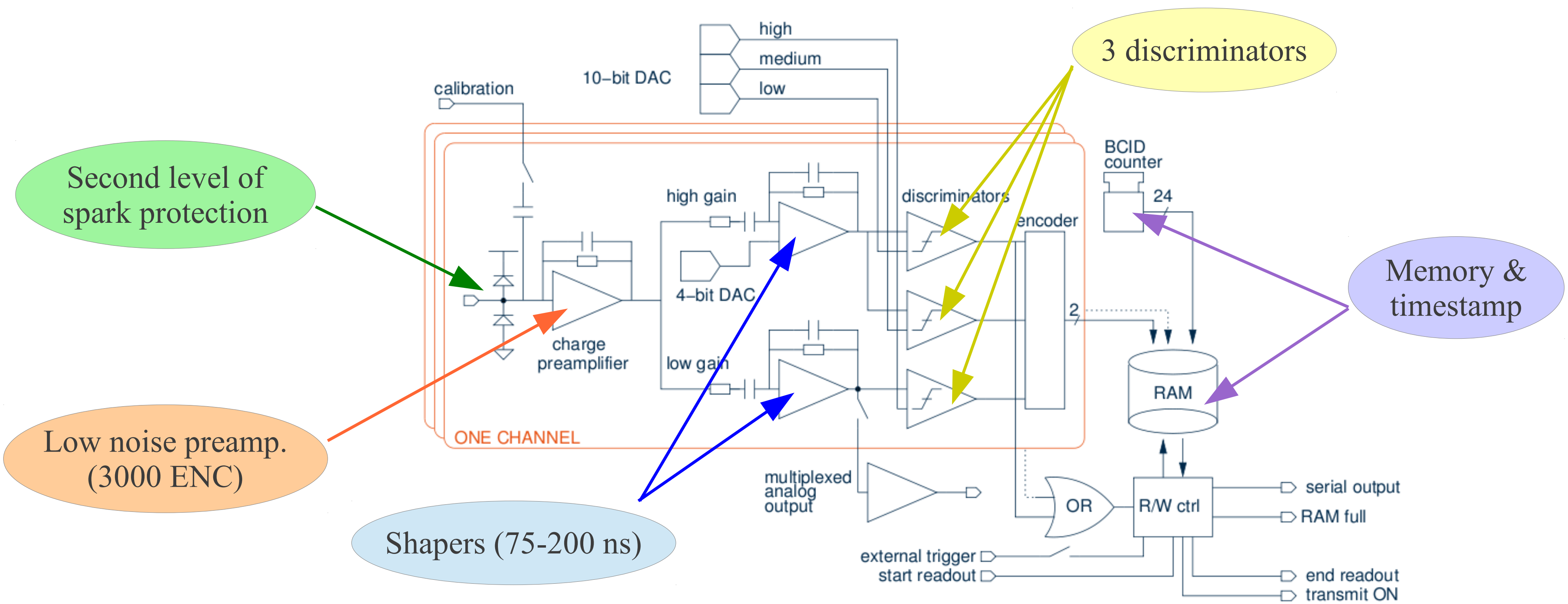
Flex. Interconnects to next ASU

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

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

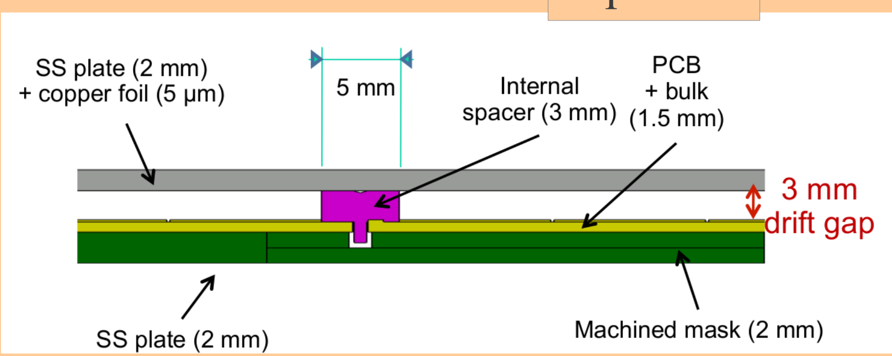
The final chamber thickness is 9 mm

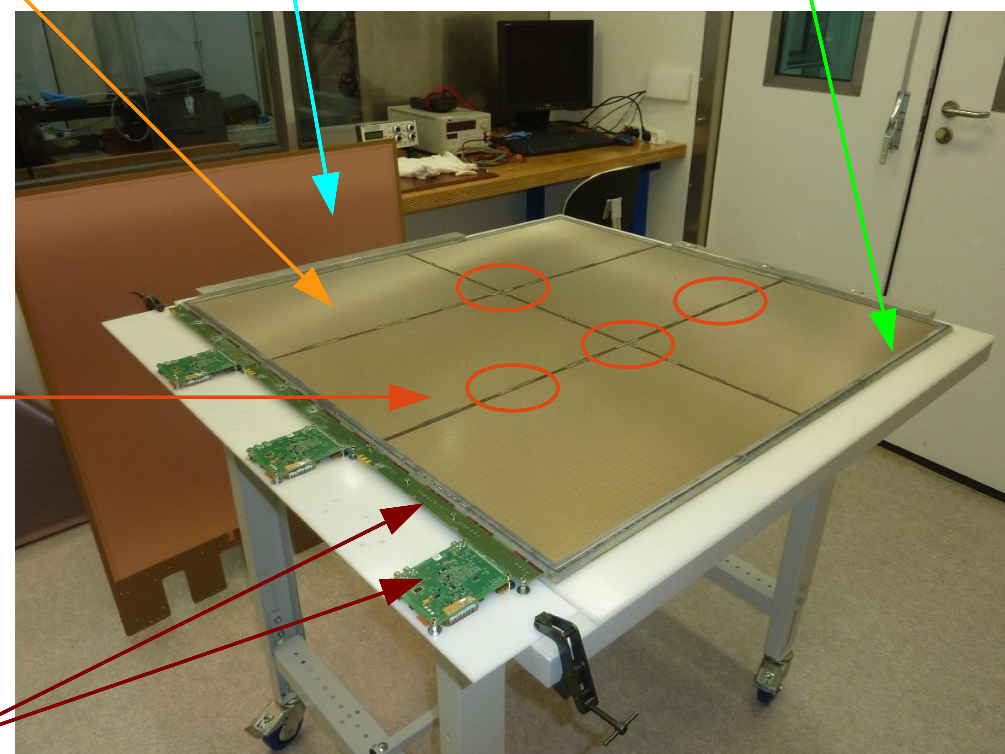
Drift cover

Frame with 2 gas pipes

ASU (mesh)

Spacers



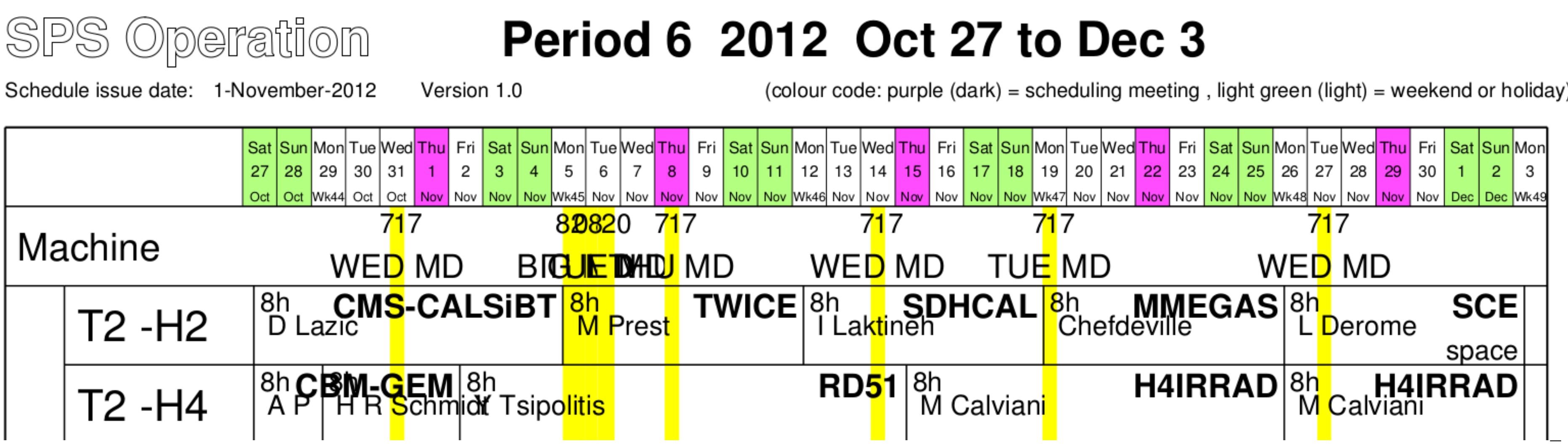


Readout boards (DIF+interDIF)
Also provide ASIC LV & mesh HV

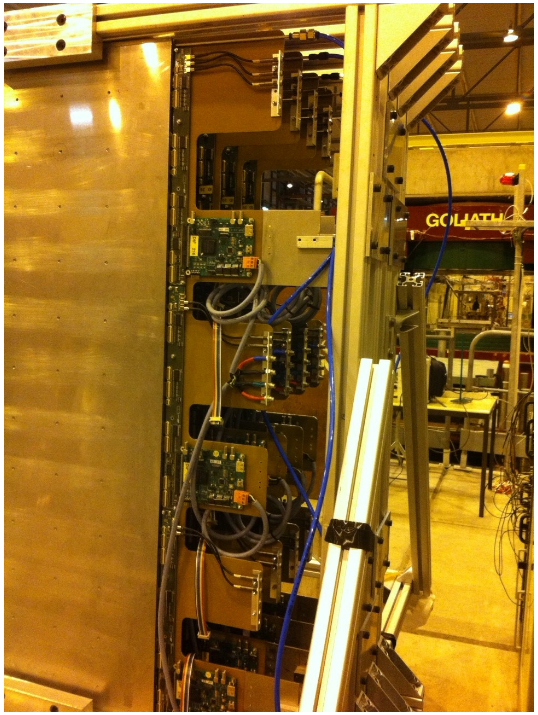
2012 test beams

- May: joined GRPC-SDHCAL test
  - 2 Micromegas chambers in 2 last layers

- November
  - RD51 period in H4: standalone test of 4 chambers
  - CALICE/GRPC in H2: outside SDHCAL as tail catcher
  - CALICE/Micromegas in H2: inside SDHCAL at layers 10,20,35,50



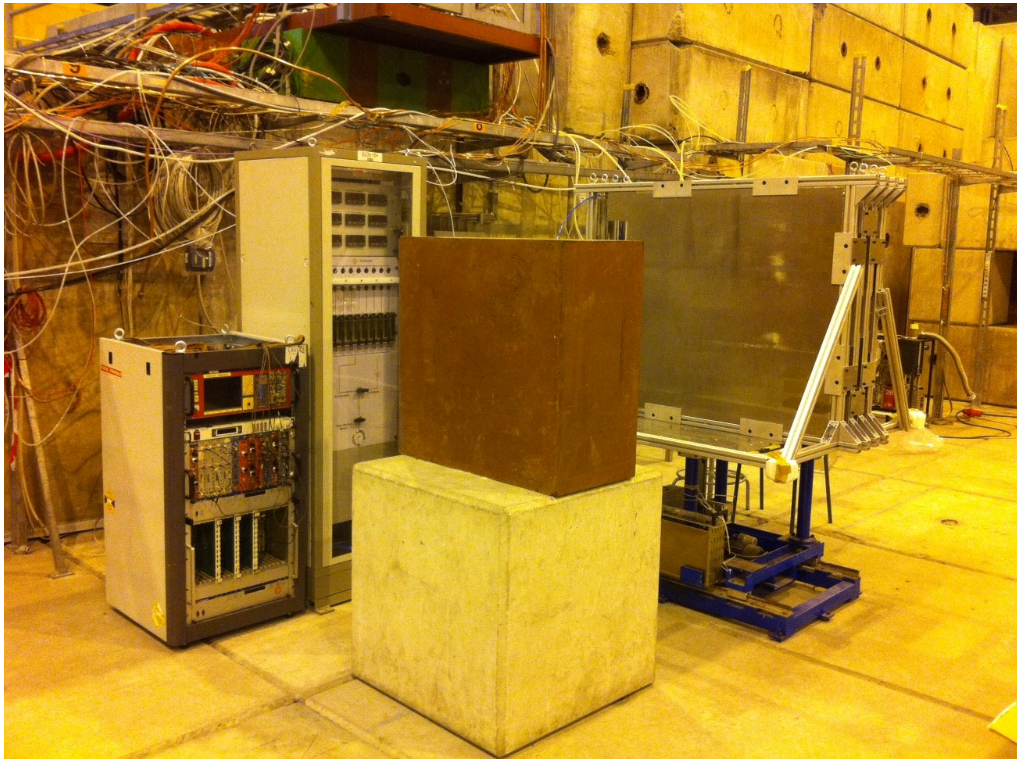
RD51 period



- Questions to answer:
  - At what voltage (or gas gain) to operate inside SDHCAL?
  - How to fix the 3 thresholds in a reliable way?
  - What values for the medium and high thresholds?
  - And some others on stability, rates, sparks etc...

- Detectors: 4 chambers
  Mostly all nicely efficient & noise free
  - #1: all efficient
  - #2: 1 chip missing
  - #3: HV problem on 1 ASU
  - #4: 1 chip missing

- Setup: **PMT - 2 λ_{int} Fe block- 4 chambers**



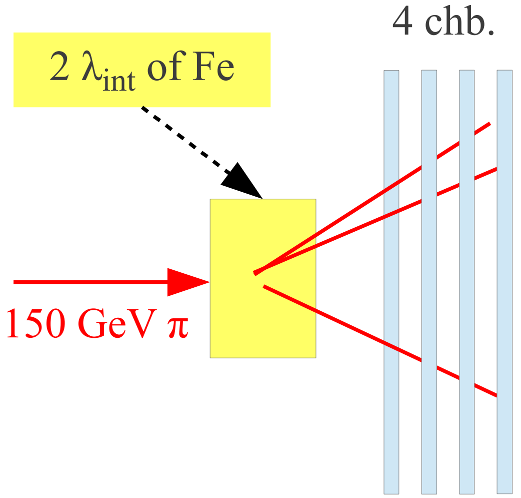
What mesh voltage in showers?

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

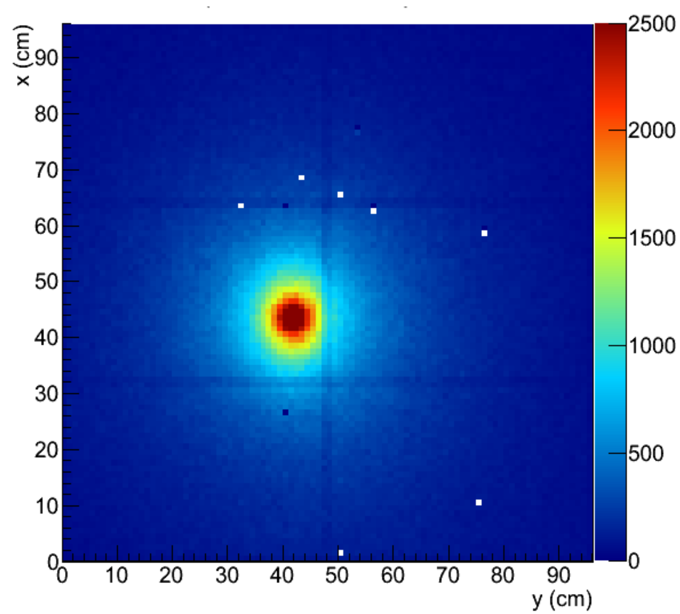
From the distribution of the number of hits at various voltages… **probably less than 1000!**

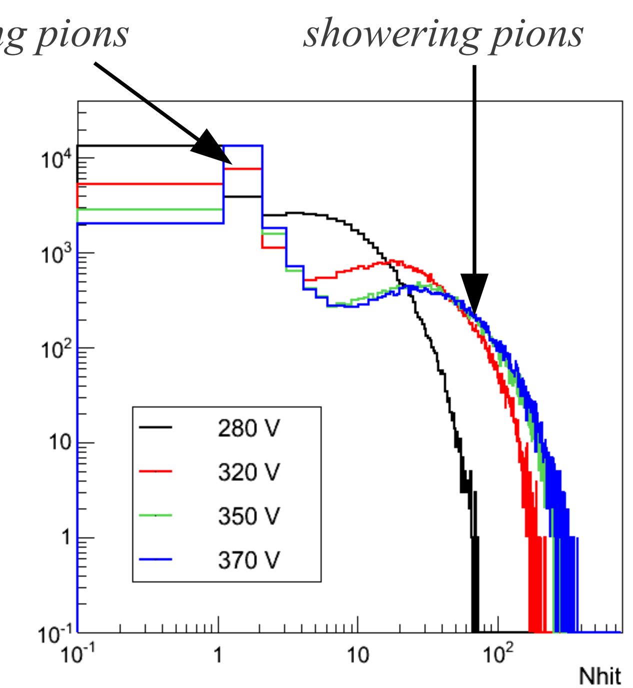
Indeed, the tails of the distributions at 350 V and 375 V are very similar.

Exp. setup



XY occupancy & number of hits





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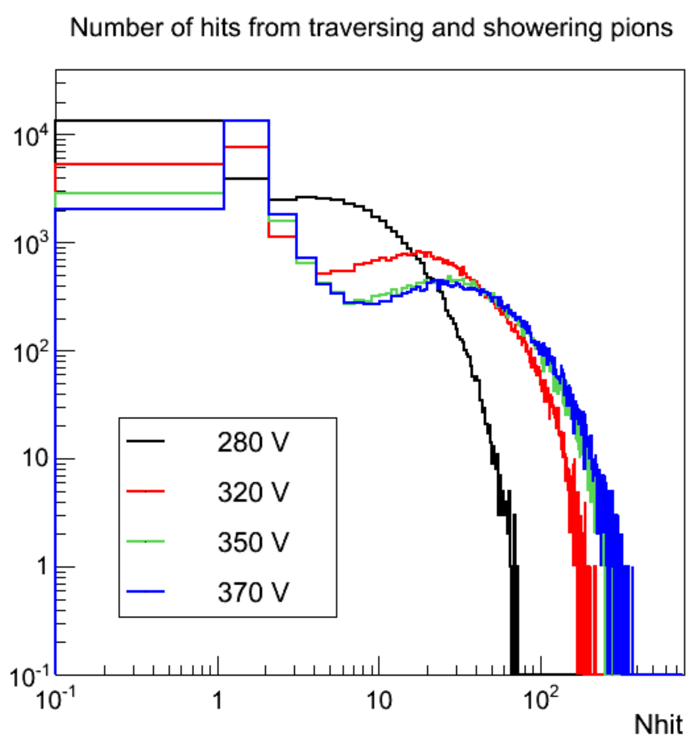
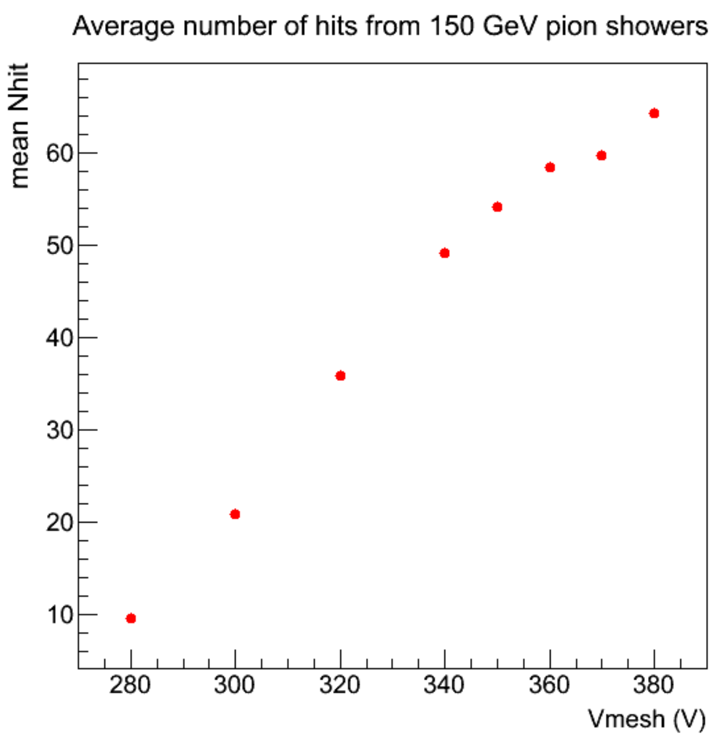




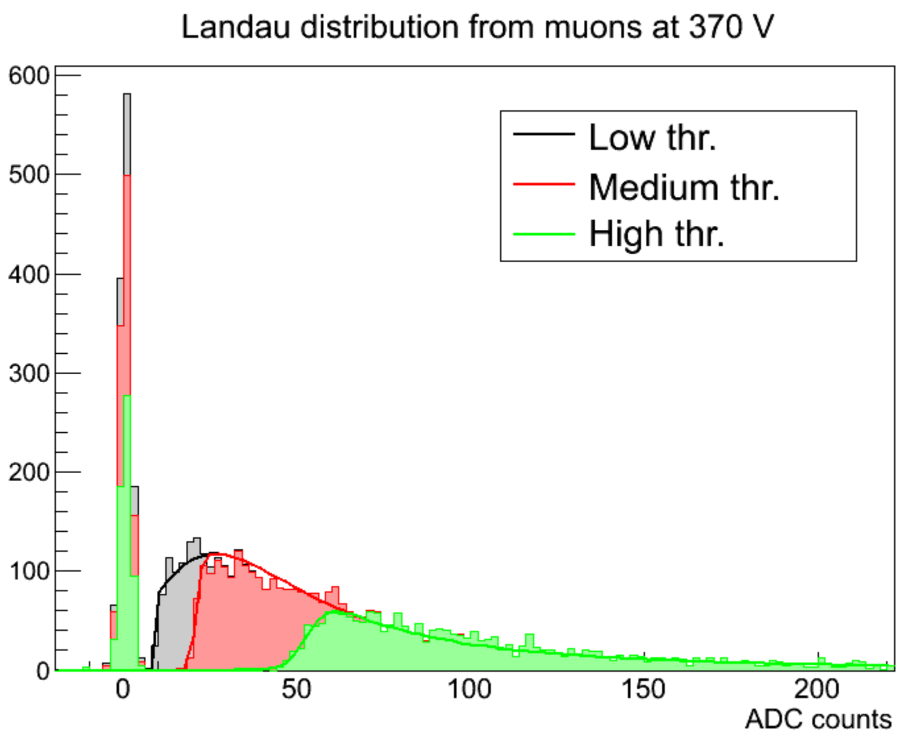
The number of hits from 150 GeV pions measured after 2 λ_{int} reaches a plateau at 360 V

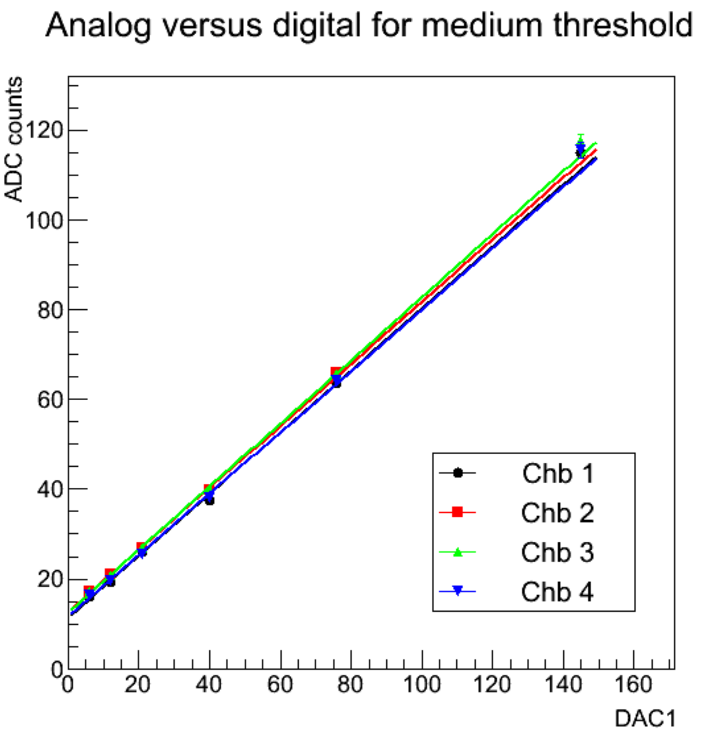
The penetrating MIPs can be identified with the 4 chambers
They are removed from the average calculation (right plot)

We chose 370 V. Above, the average increases due to the increased hit multiplicity.

How to set the thresholds?

We make use of the analogue readout to set the thresholds directly in units of MIP.
No calibration constant involved!





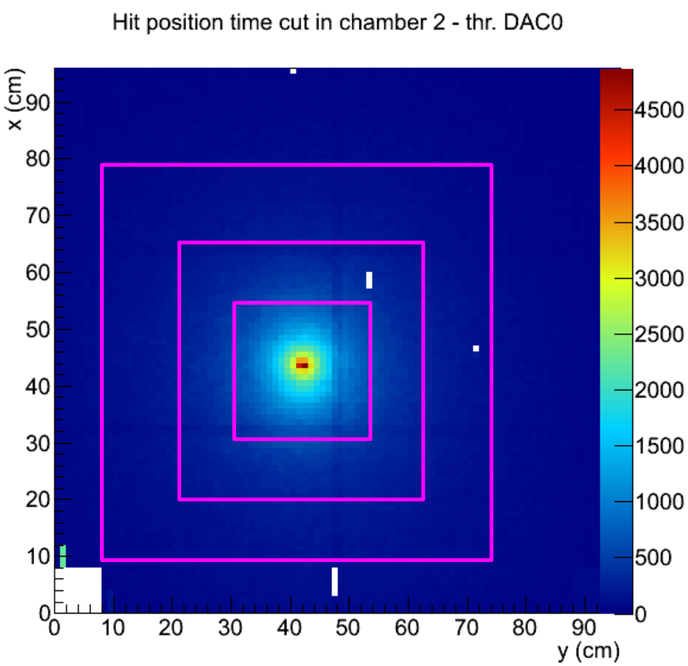
We "see" where the thresholds are by cropping the Landau distribution.

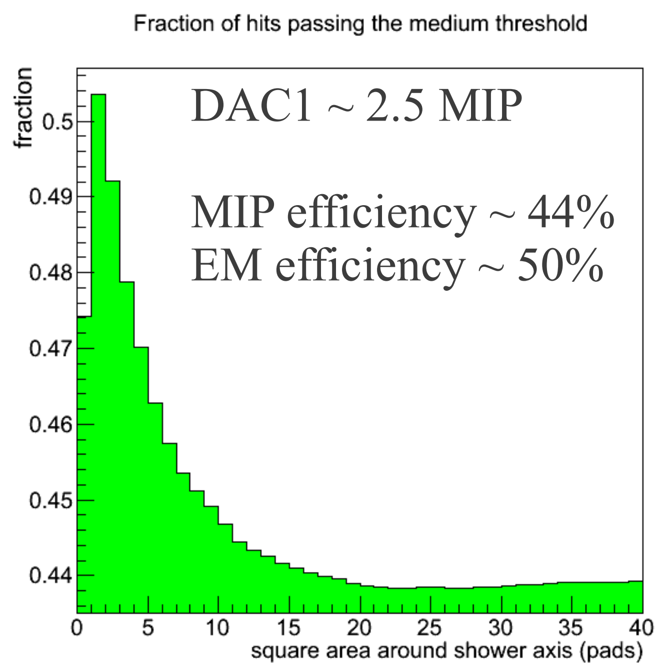
From which we obtain the DAC to ADC relation.

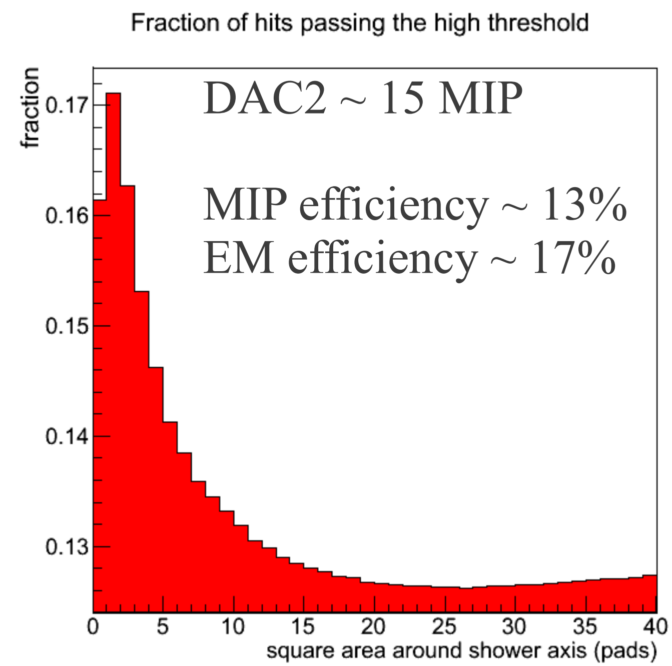
We measured the MIP @ various Vmesh and can set the medium and high threshold at will.

What value for the thresholds?

NO DEFINITIVE ANSWER YET... BUT SOME IDEAS







Records profile from 150 GeV pion showers
Sum up hits in a square window and look at fraction of hits N1/N0, N2/N0 → EM & MIP parts

Want large difference between EM & MIP fractions but still some efficiency to EM core

Trade-off: we chose 5 MIP and 15 MIP finally.

CALICE period

- First week in tail catcher
  - SDHCAL + 1 uM + 40 cm Fe + 1 uM + 40 cm Fe + 1 uM + 80 cm Fe + 1 uM
  - Goal: improve event selection for energy resolution measurement with GRPCs

- Second week inside SDHCAL at layers 10,20,35,50
  - Goal: measure linearity of a 50 layers Micromegas SDHCAL from the longitudinal profile of hadron showers at various energies (20-150 GeV)

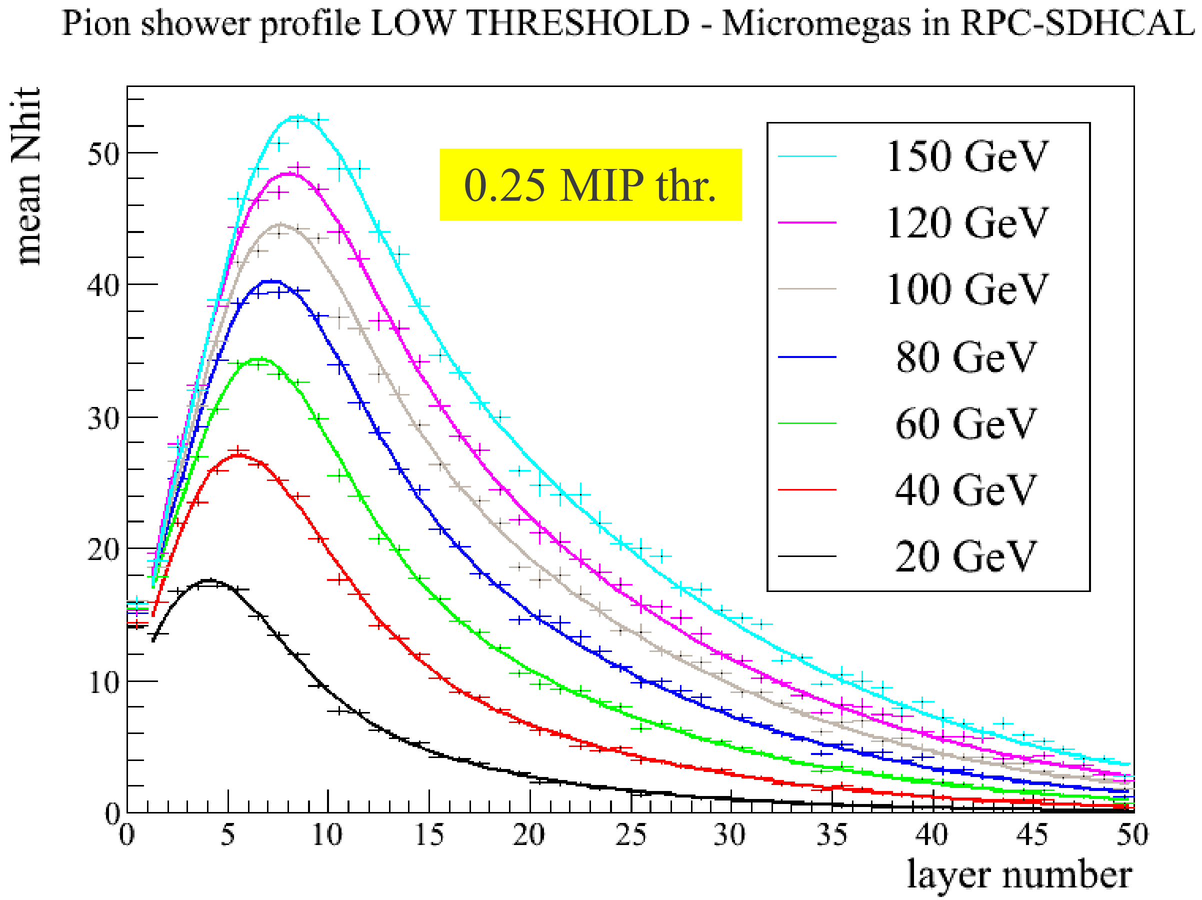
Pion E(GeV)	Nshower
20	21580
30	21049
40	20149
60	20433
80	20750
100	17500
120	16000
150	12500

Longitudinal profiles

Still some systematics in finding the shower starts

+ very simple analysis so far (simple cut on Nhit, no fiducial cut...)

But already some nice profiles! (these profiles include 2/3 of the statistics)

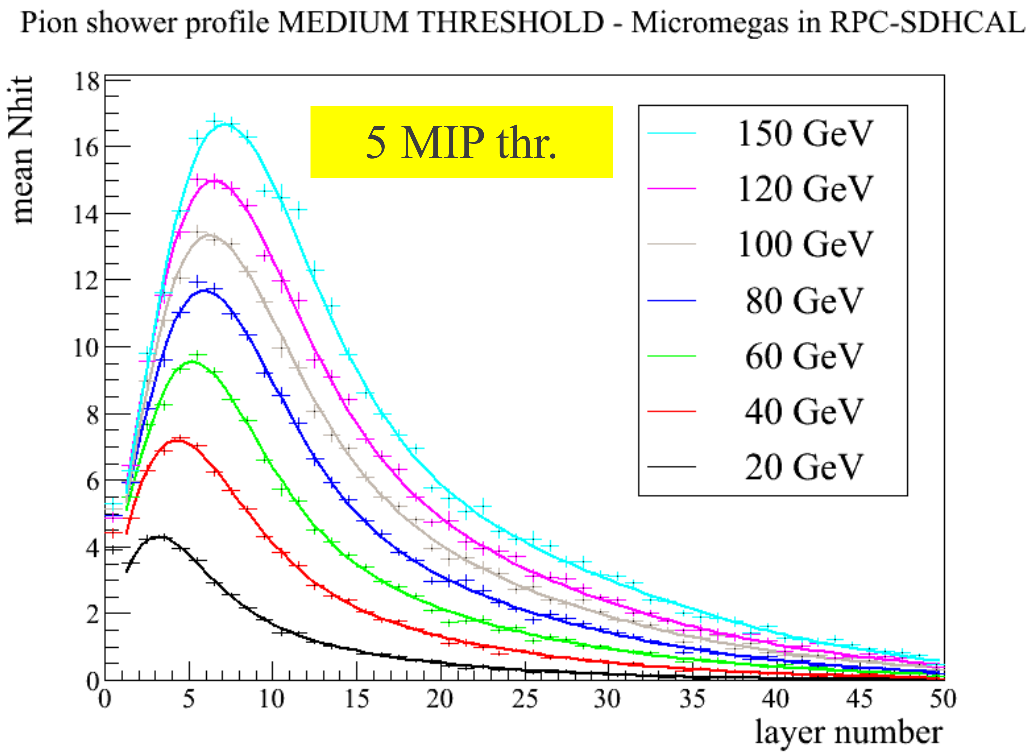


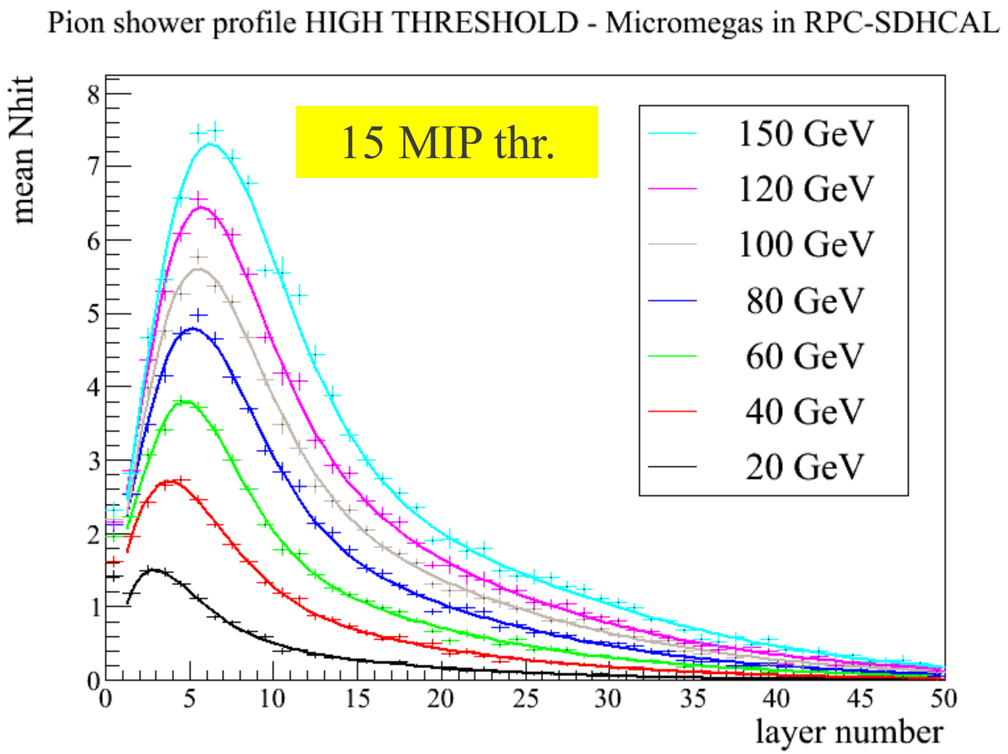
Longitudinal profiles

Still some systematics in finding the shower starts

+ very simple analysis so far (simple cut on Nhit, no fiducial cut...)

But already some nice profiles! (these profiles include 2/3 of the statistics)
Available for the 3 thresholds.





Response to hadrons

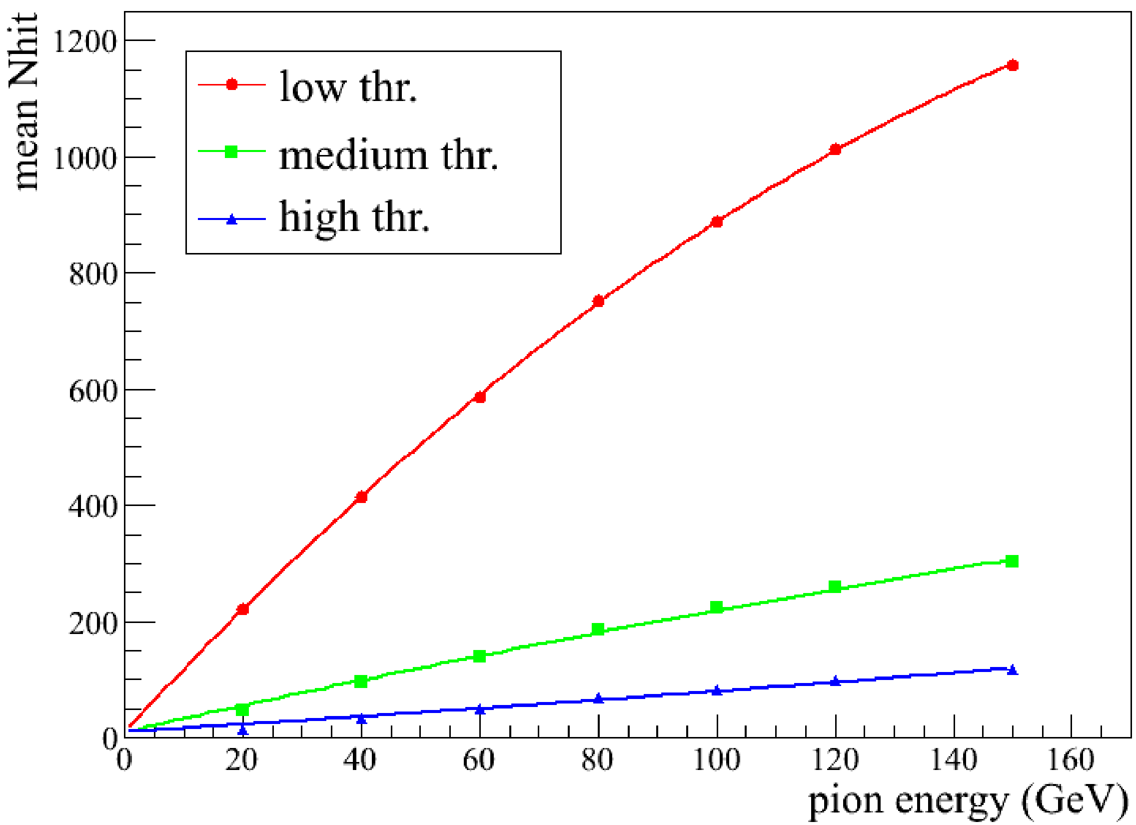
Use fit to calculate the integral, correct for leakage and get rid of small deviations.

Expected saturation seen.

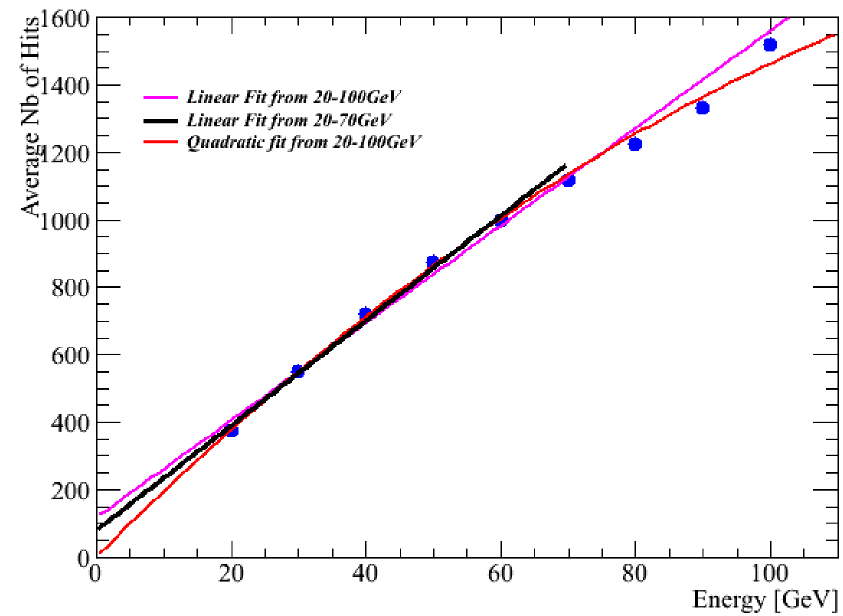
The low threshold data are well described by aE^2+bE, the curve nicely goes through 0.

The number of hits compared to GRPC scales roughly with the ratio of the MIP multiplicity.

Micromegas response for 50 chambers measured with 4 chambers only!



GRPC response (48 chambers)



Conclusion and plans

- We are approaching the end of a the second phase of the project, namely the construction and characterisation of large area Micromegas chambers for hadron calorimetry
  - Complete set of measurements (RD51 + CALICE)
  - Lot of results to analyse and publish next year

- The next steps
  - Improve the chamber design by e.g. replacing the PCB spark protections by a resistive layer **SPLAM project** (ANR funds: Spark Protection of Large Area Micromegas)

    → Set of resistive prototypes in 2013
  - Investigate the possible use of Micromegas for EM calorimetry

    → simulation of physics performance

    → possibly small prototype with analogue readout and smaller pad size

PS1: many thanks to Kostas for the RD51 PVSS slow control
PS2: many thanks to Eraldo for the PMT and scintillators