RD51

# Micromegas for a SDHCAL, status and perspectives

*CALICE collaboration meeting*
*Cambridge, 16-19 Sep. 2012*

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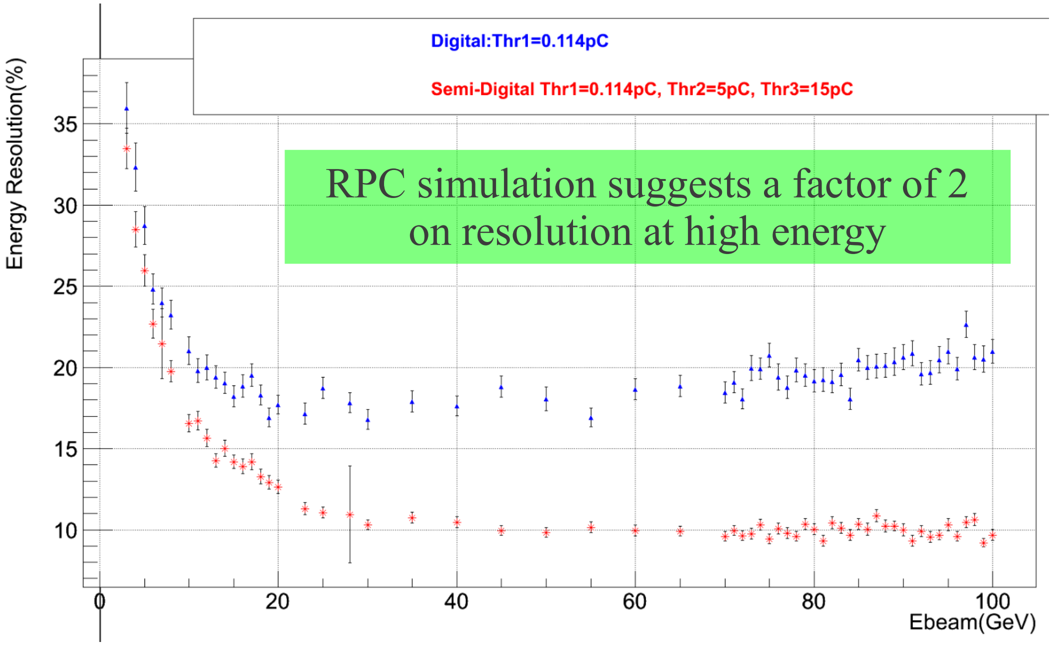
# Overview

- Introduction
  - Micromegas for gaseous calorimetry
  - Characteristics of constructed chambers
  - First look at behaviour in hadron showers
- Experience and plans in the GRPC-SDHCAL
- Conclusion

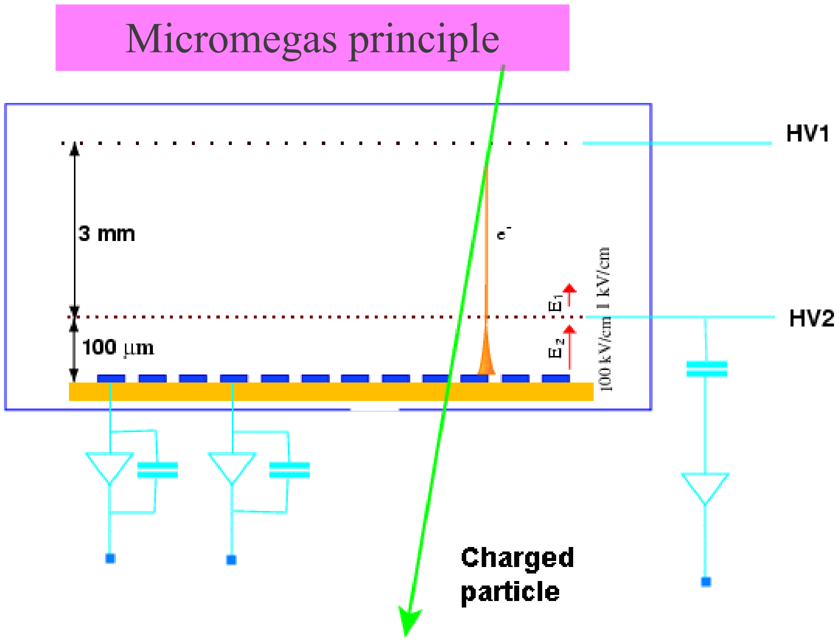
# Micromegas for gaseous calorimetry

- Jet energy resolution at a future LC
  - Granularity → minimize confusion
  - Energy resolution → measure neutral hadrons
- Digital HCAL: small cells to minimize confusion
  - Saturation (core, $\pi^0$) → tail in Nhit distribution

- Semi-digital approach
  - **Require some proportionality**
    **→ Micromegas**
  - Real improvement on resolution?
    → Simulation: says yes, data will tell soon

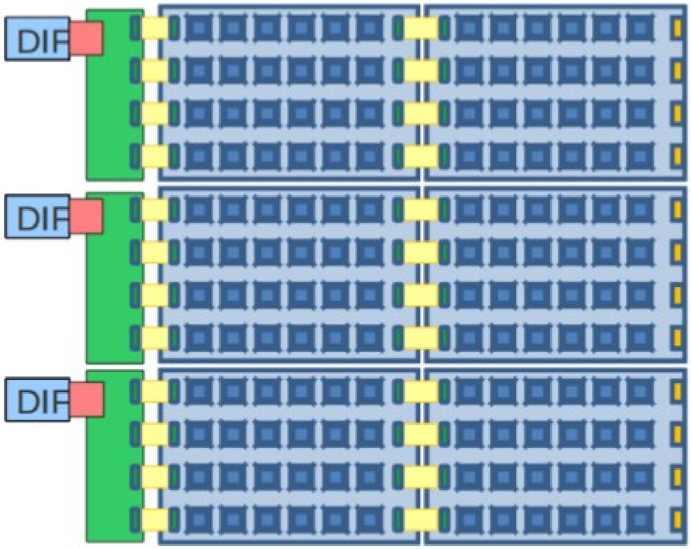



*Simulation from S. Mannai, UCL Louvain, GRPC/SDHCAL group*

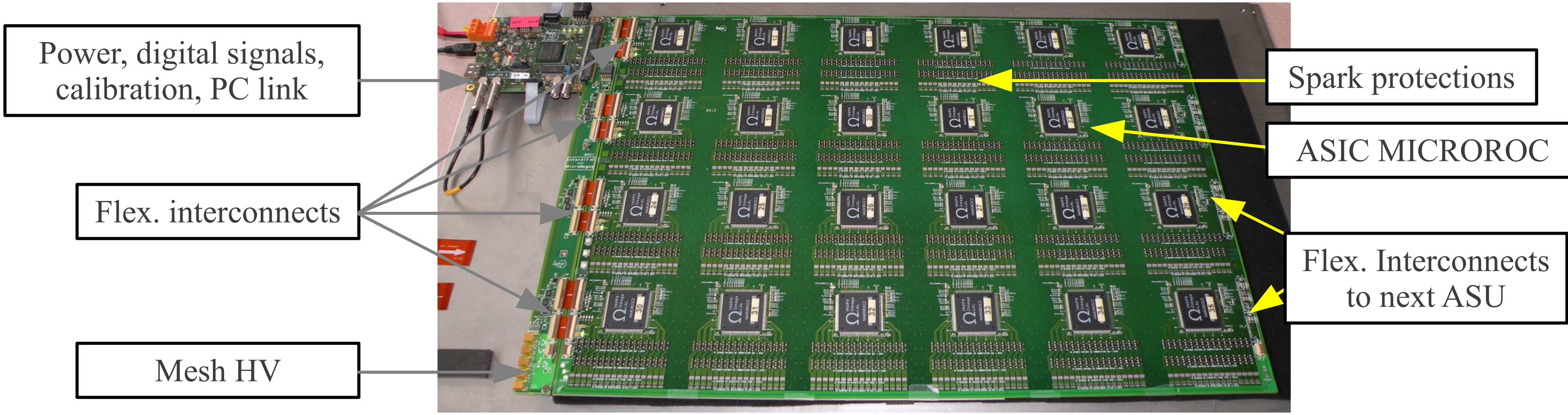


# Constructed chambers: design

- Modular approach: 1 $m^2$ = 6 * (32*48) $cm^2$
  - Dead zones below 2 %, easily scalable to larger sizes
- Quite thin for a Micromegas of that size: 9 mm
  - Active Sensor Unit = 4 mm (PCB with pad and mesh & ASICs)
  - Gas = 3 mm
  - Cathode steel cover = 2 mm (also part of the absorber)




32x48 pads of 1 $cm^2$ on back side



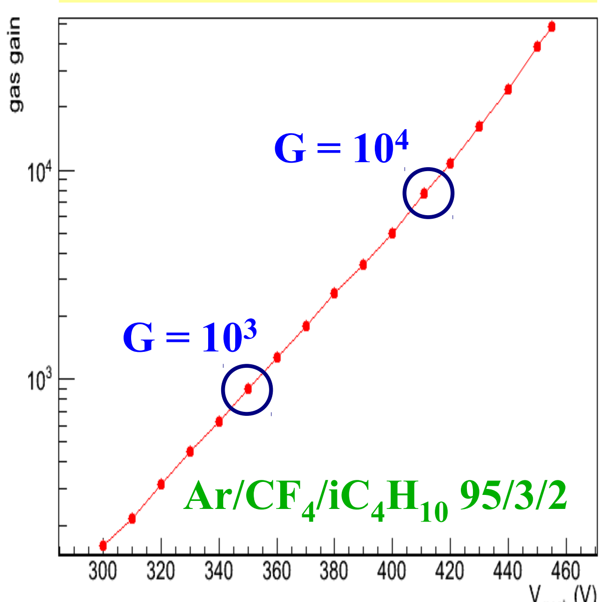
# Constructed chambers: operational characteristics

- Signal, noise and thresholds
  - Gas gain up to some $10^4$ (Ar mix.)
  - MICROROC noise of 1500 e- → 5 sigma threshold is 6000 e- only

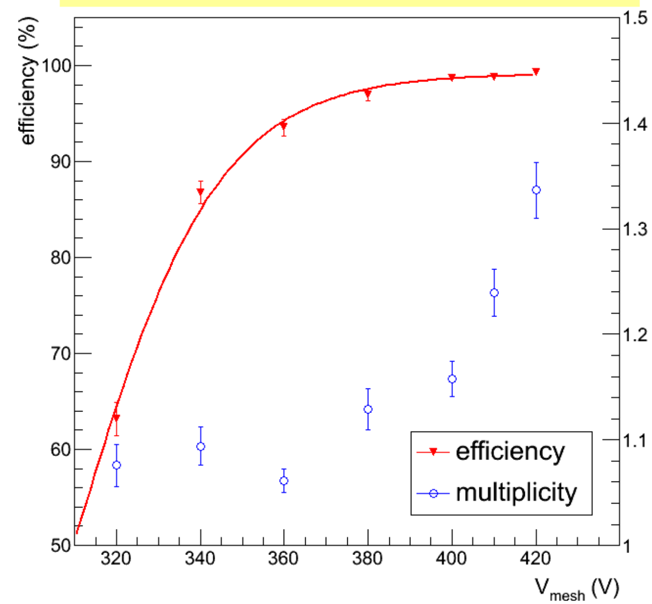
- **Performance to MIPs** (in $Ar/CF_4/iC_4H_{10}$ but any mixture providing a gain of $3.10^3$ is fine)
  - Efficiency > 95% @ a gain of $3.10^3$, with 2% variation over whole chamber
  - Multiplicity between 1.1-1.2 (depending on angle)

- Stability: 99.98% of channels operational; No lost ASIC → efficient spark protections

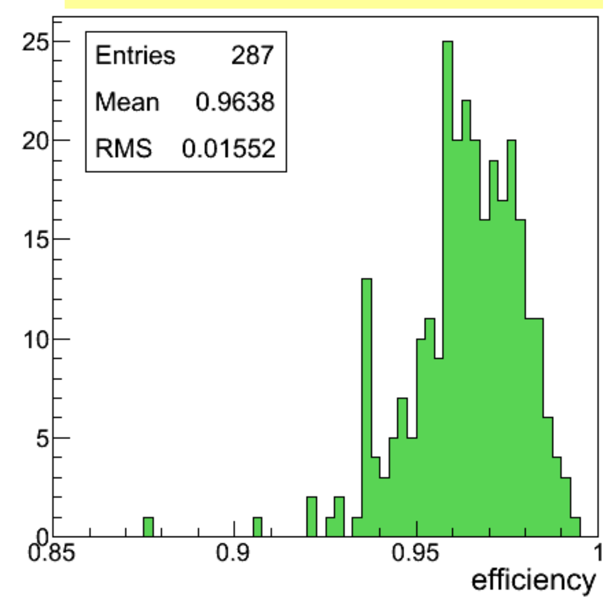
Gas gain VS mesh voltage




Efficiency & multiplicity VS HV



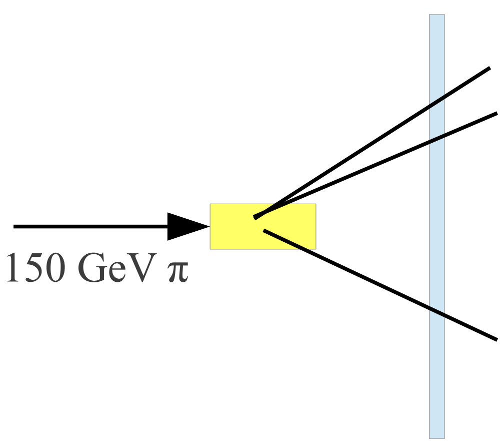

Efficiency uniformity (2 $m^2$)

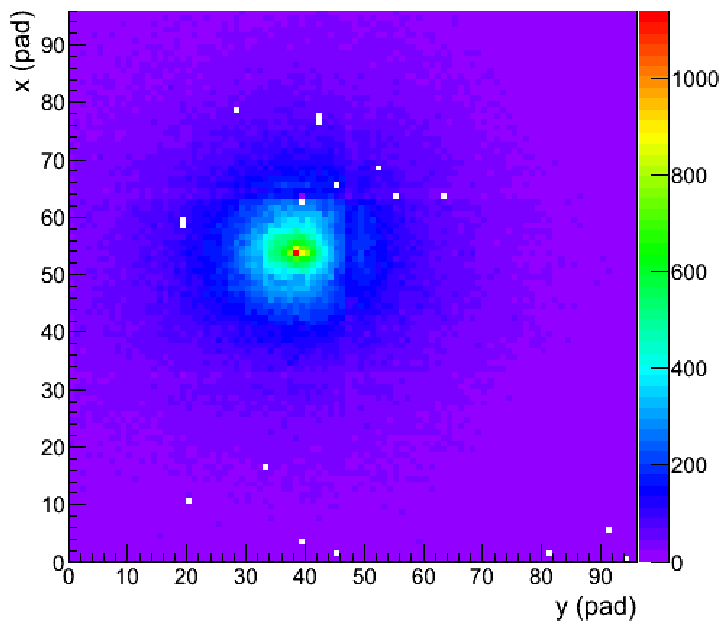


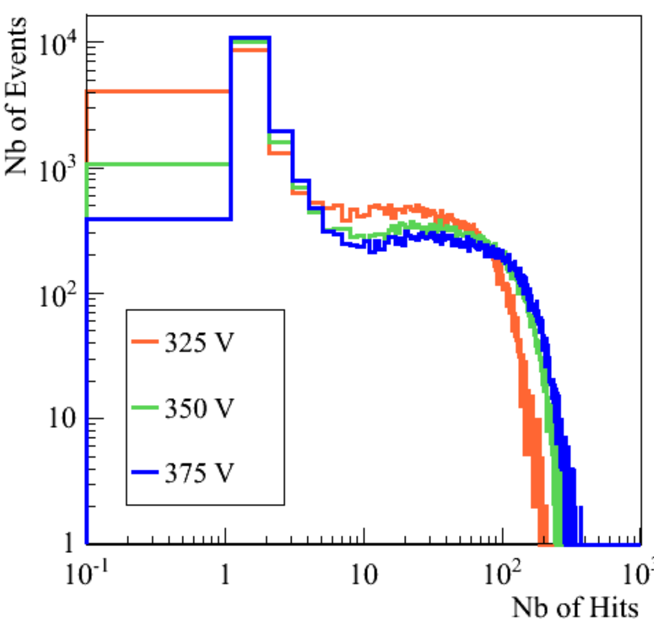
# Spark rate and working gas gain

- Spark rate so far very manageable but no precise number yet
  → RD51 test beam in November, counting setup with μ, π and showers
- Spark rate depends on the total avalanche charge
  - Broad dE/dx spectrum in hadron showers (MIPs, X-rays, hadrons, alpha's...)
  - But what gas gain is needed for a Micromegas SDHCAL?
- Data from June 2011 test beam suggests that a high MIP efficiency is not necessary

**Number of hits after 1 $\lambda_{int}$ of Fe:** <u>tails at 350 and 375 V are similar</u> (~ a factor of 2 in gas gain)



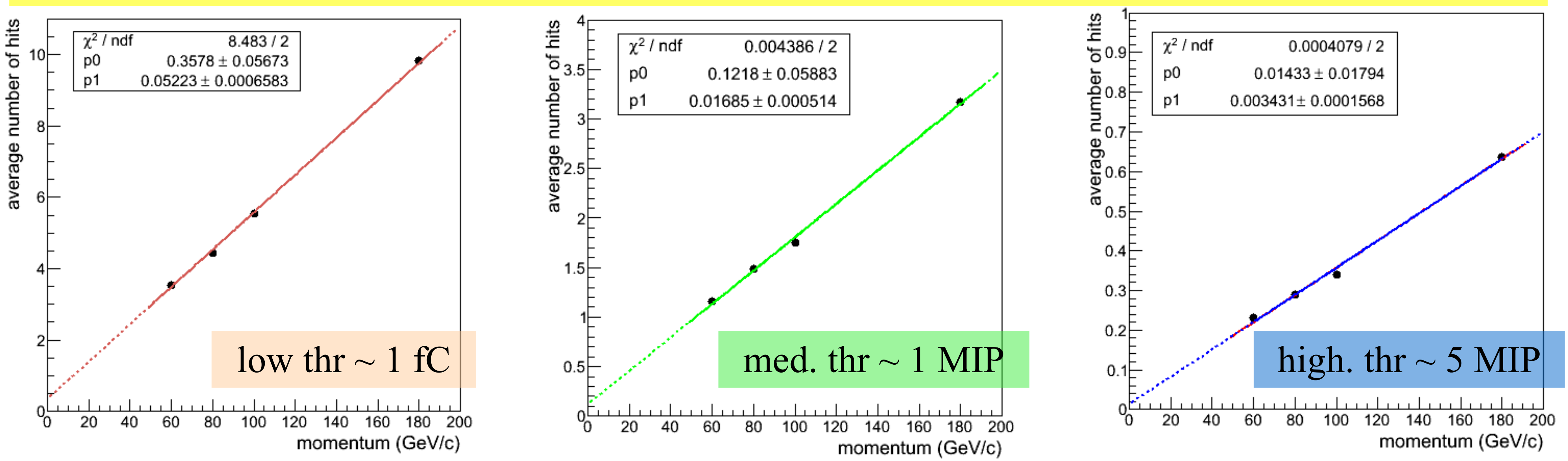



# Experience in the SDHCAL

- SDHCAL is a collective achievement
  - SDHCAL structure consists of 51 Fe layers of 1.5 cm thickness with 1.3 cm gaps (~ 5.5 $\lambda_{int}$) → CIEMAT
  - Chambers, ASIC, DAQ → participation of several IN2P3 groups (IPNL, LAL, LLR, LAPP)
- First test with GRPCs + 1 Micromegas inside, slot 47/50: October 2011
  - No common DAQ, standalone USB running with external PMT triggers, ~ 1 million events at various energies
- At the back of the calorimeter, there is no saturation and 3 thresholds show linear behaviour

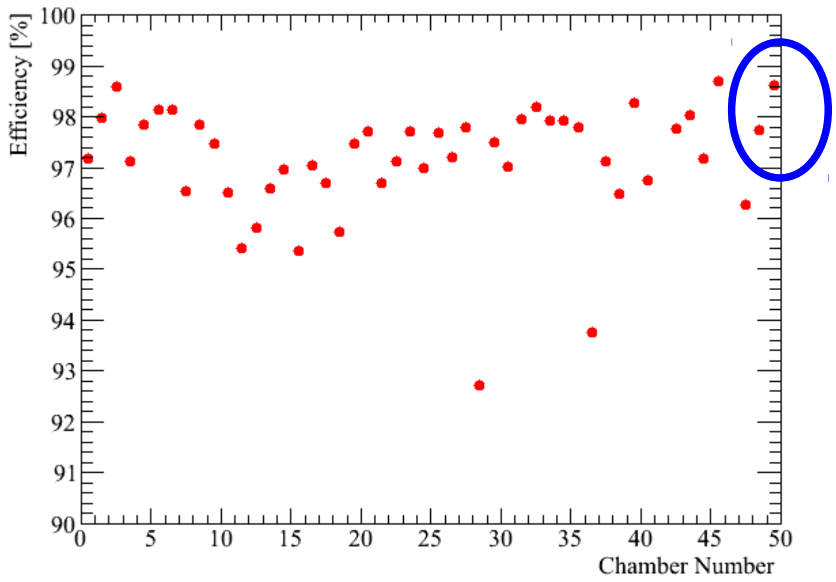
  → need to get closer to shower maximum to learn about the semi-digital readout

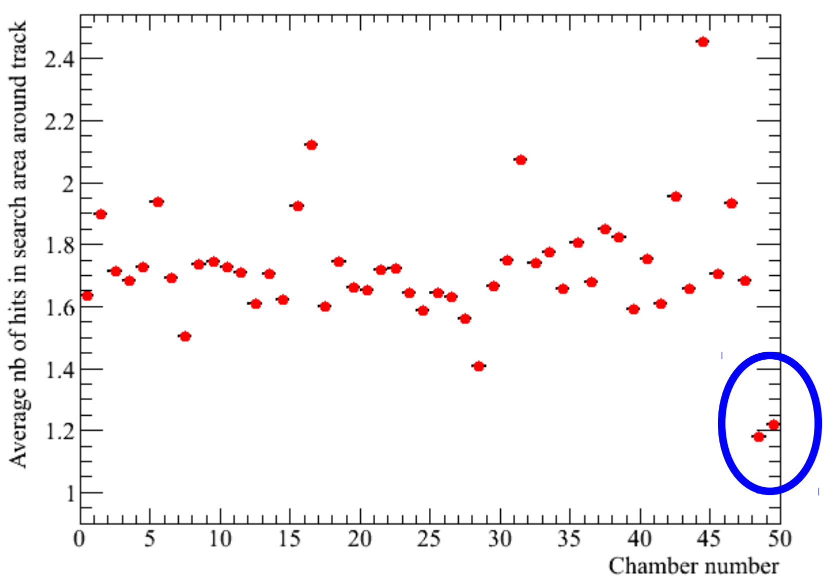
**Average Nhit @ layer # 47 VS π momemtum**, 50-100k events / point, 60,80,100,180 GeV/c



# Micromegas running in GRPC-SDHCAL, 2012

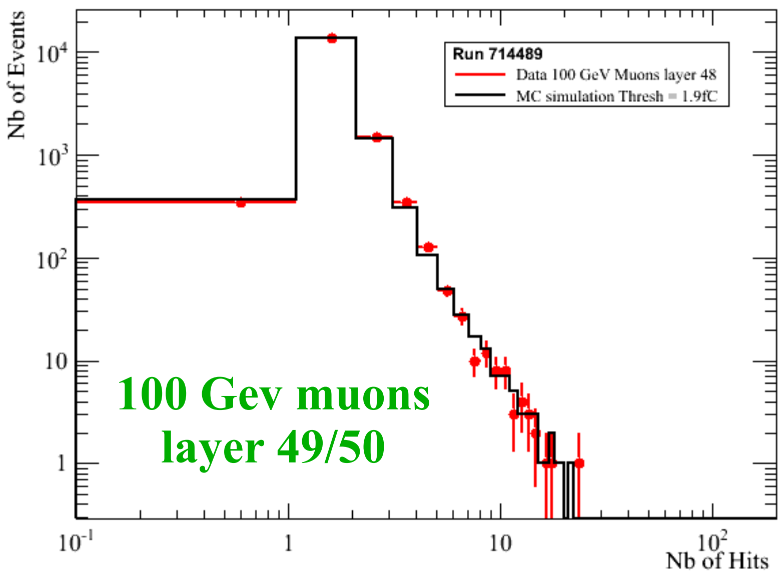
- "Intermediate" CALICE DAQ to allow running of SDHCAL in 2012
  - DIF / DCC : Control signals from DCCs through HDMI, data from DIFs through USB
  - LAPP contribution: DIF design + DIF and DCC firmware (G. Vouters)
- Micromegas running, 2 chambers at slot 49 & 50 / 50
  - Common DAQ operated in RAMFULL mode (internal trigger when 1 ASIC memory is full)
  - Sometimes, noisy ASIC in Micromegas chambers saturates the DAQ (see next slides)
    → Most of the time, we were out of the DAQ but there are some runs with both RPCs and Micromegas
- Penetrating muons were used to monitor chamber performance
  - We are doing good, high efficiency and low multiplicity



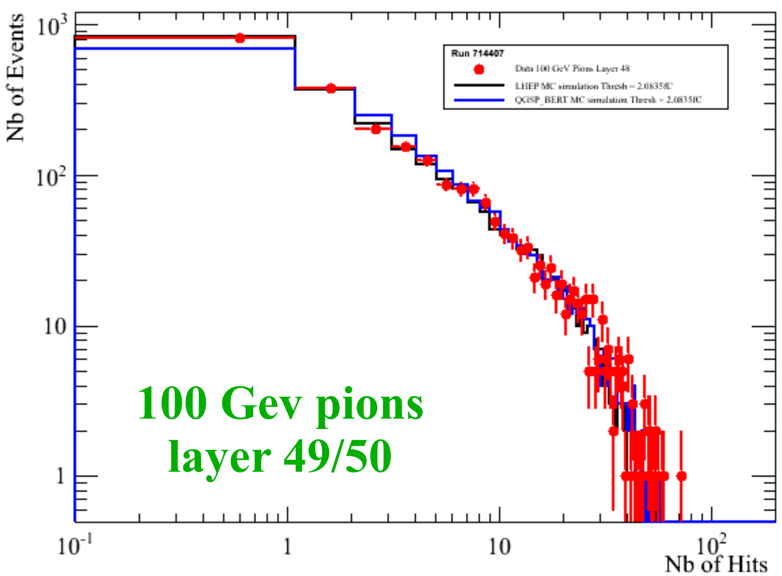



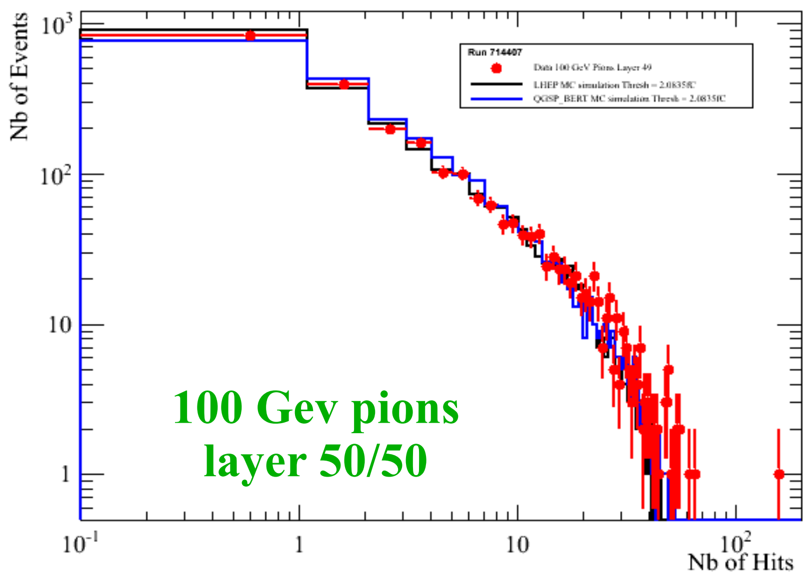
# Monte Carlo / data comparison

- Straight-forward digitisation
  - Compare Geant4 energy to threshold
    + Add known multiplicity from diffusion
  - Tune threshold to reproduce inefficiency to muons




- Number of hit from pions
  - Apply threshold tuned with muons
  - LHEP and QGSP reproduce distribution well
  - Next step: space distributions



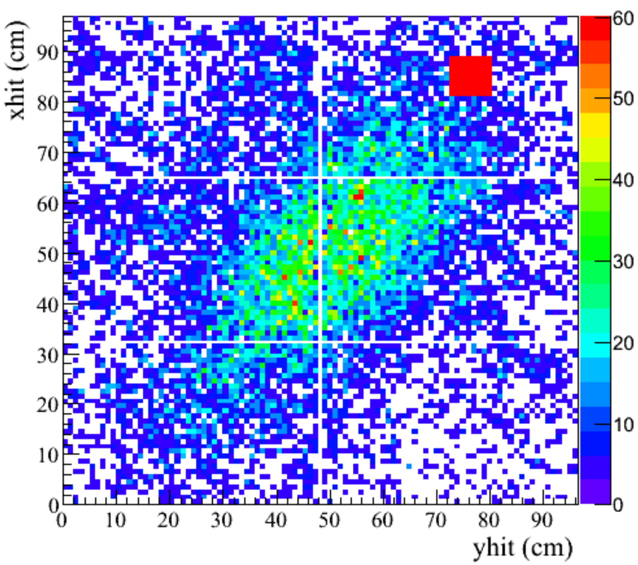



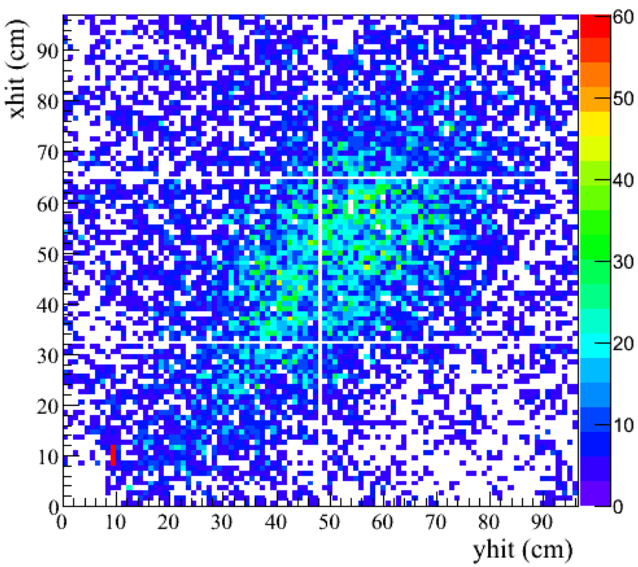
# Noisy ASICs - troubleshooting

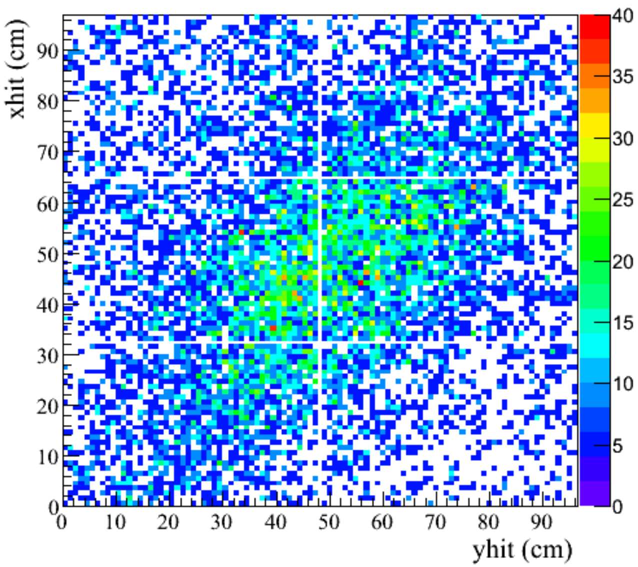
- What we observed: suddenly a quiet ASIC becomes noisy and send many RAMFULL triggers
  - Keeps the DAQ busy, happened 20 times in 14 days at SPS
  - Data previously recorded are not lost → No real time loss
- We have reproduced this effect in a systematic way at LAPP
  - It occurs above a certain working voltage → certainly linked to sparks
  - Reading the slow control of ASICs, it appears that thresholds bits are modified

- Solutions
  - Seem to be always the same ASIC → possible replacement but little spares
  - Working at low gas gains (< 350 V), but maybe we don't want that
  - Sending a slow control periodically (e.g. between SPS spills) WORKS

Cosmic run at LAPP
Scintillator shadow on 3 chb.



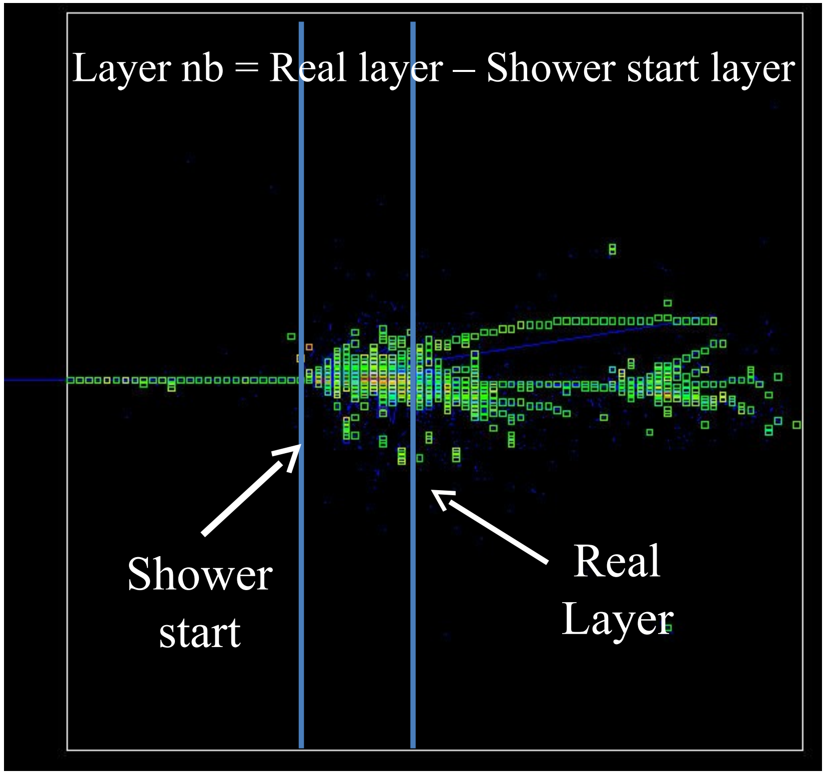



# Near-future test beam inside SDHCAL

- We have a strong physics case:
  - Measure linearity of a 50 layer Micromegas SDHCAL from longitudinal shower profiles with 4 Micromegas and 46 RPCs (proposed by C. Adloff)
  - Use RPCs to identify the shower starting layer
  - Measure Nhit in Micromegas chambers which virtually move inside the calorimeter

- From a fit of the longitudinal profile
  - Integral yields the average number of hit
  - Effect of leakage on linearity can be corrected for
  - With various sets of thresholds, **improvement using semi-digital readout can be assessed**



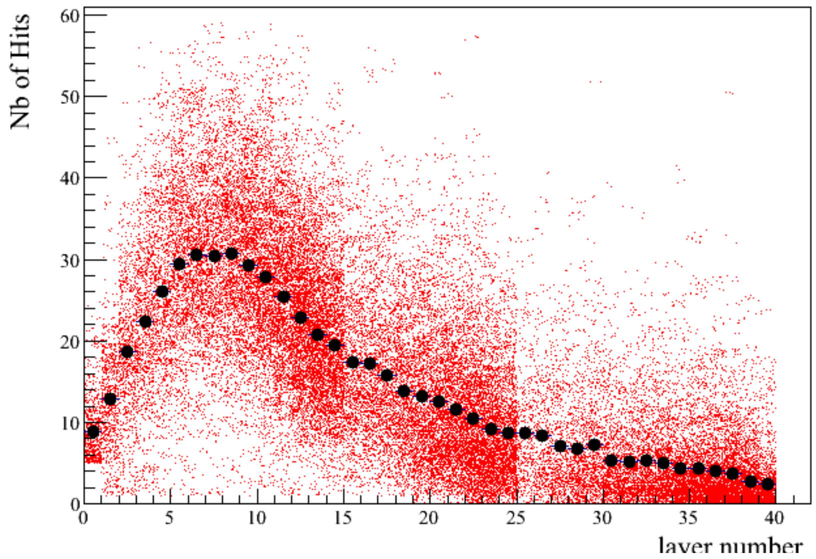

Proof of principle? Statistics? Beam time?
→ Simulation & testbeam data

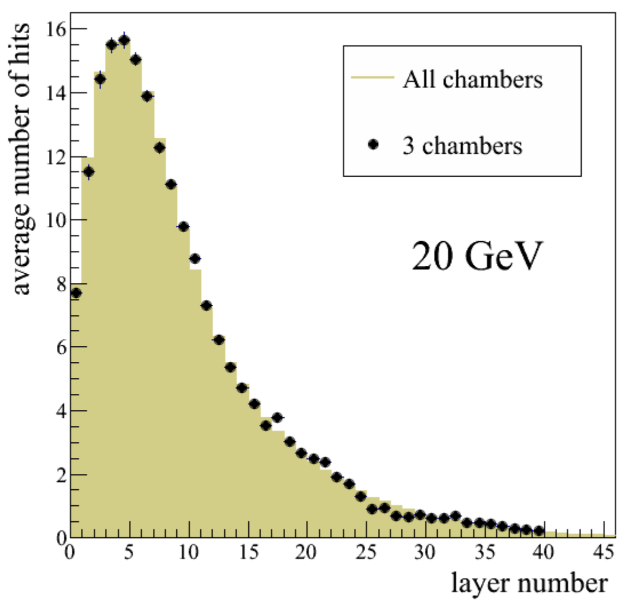
# Linearity from shower profile – simulation (1/2)

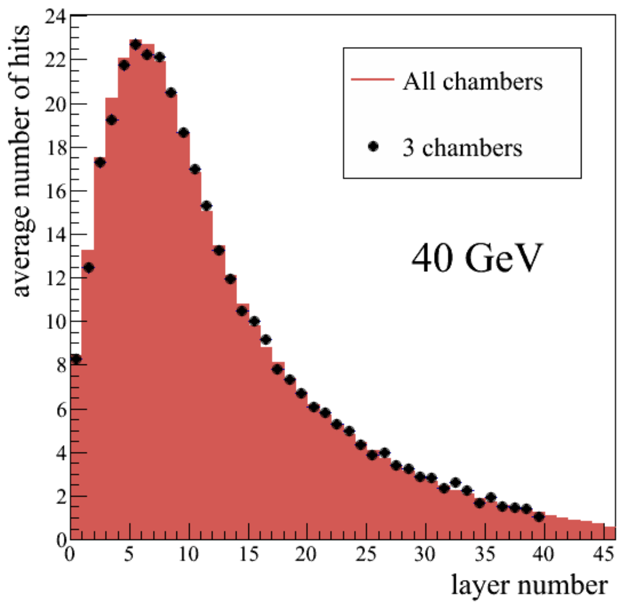
- Simulation
  - We use the geometry of the 48 layers RPC/SDHCAL
  - We do 4 energy points at 20, 40, 70 and 100 GeV
  - At each energy: 20000 pion events
  - We consider 3 test chambers at layer 15, 25 and 40

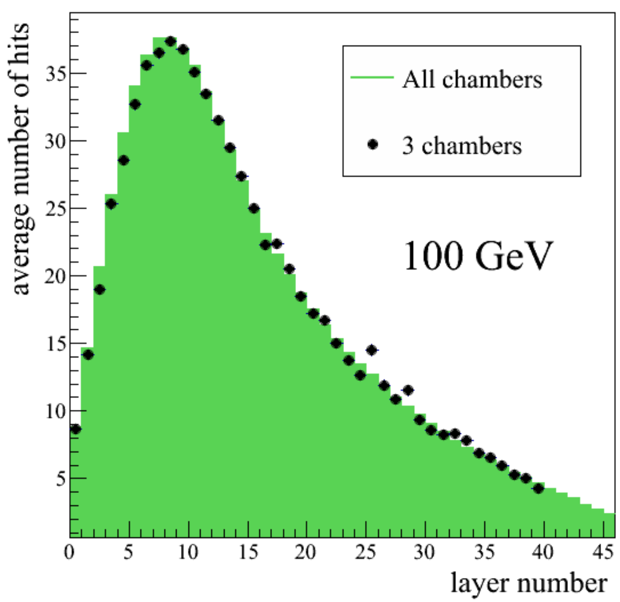
- Analysis
  - Find shower starting layer z0
  - Measure **Nhit in 3 test chambers**
  - Measure **Nhit in all chambers w.r.t. z0**

Profile at 70 GeV from 3 chambers at 15-25-40



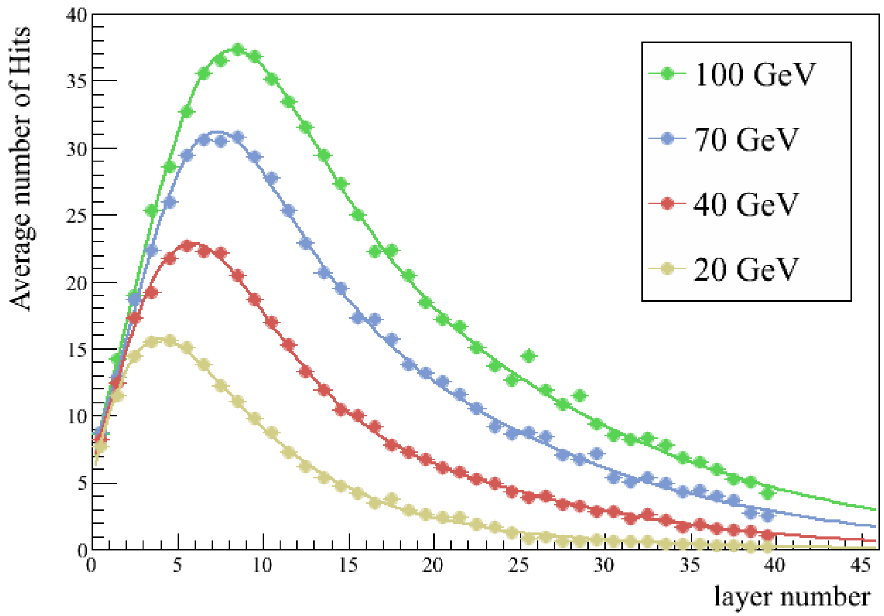
# Linearity from shower profile – simulation (2/2)

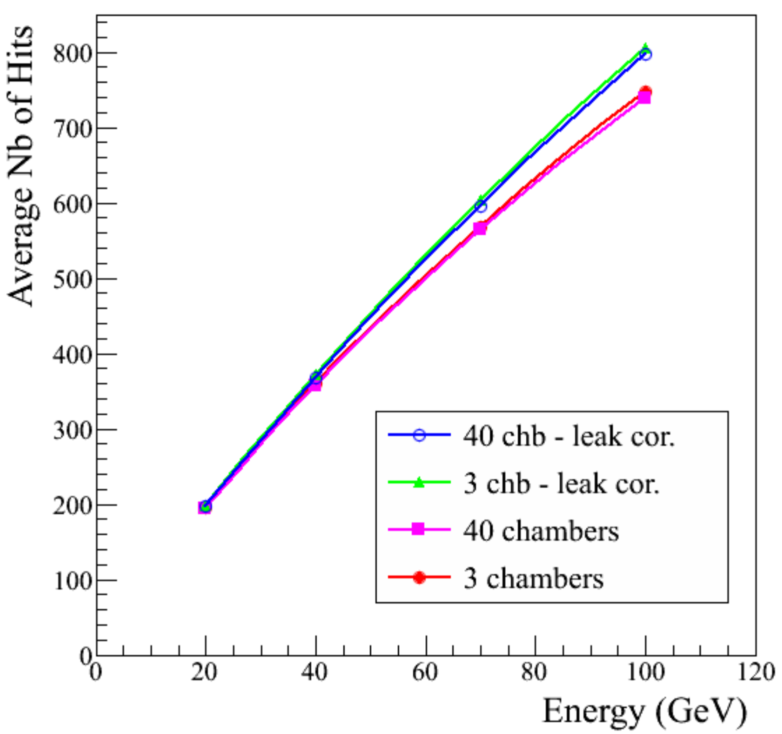
- Fit of the longitudinal profile
  - We use the function from R.K. Bock et al., NIM 186 (1981) 533

    Combination of 2 Power laws and Exponential decays for EM and H part of shower + some e/h ratio

$$dE = k\,[w s^{a-1}\, e^{-bs} + (1 - w)\, t^{c-1}\, e^{-dt}]\, dx$$

- Results
  - Profiles obtained with 3 chambers compare well to the one obtained with the calorimeter
  - It is possible to correct the average Nhit for leakage → significant correction above 40 GeV



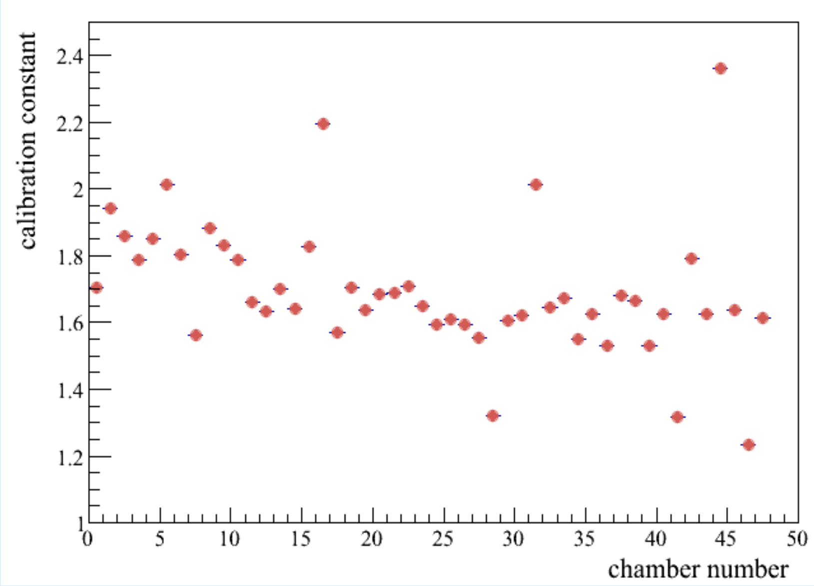

Proof of principle OK, what about with test beam data?

# Linearity from shower profile – TB data (1/2)

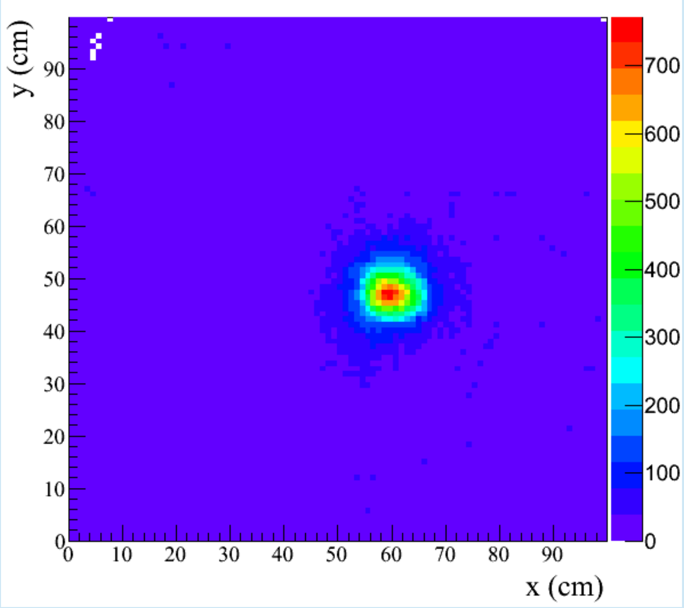
- Data set from May 2012 TB at SPS/H2
  - Selection of pion events (very similar to the one of Y. Karyotakis explained in the Analysis session)
  - We use runs at 20, 40, 70 and 100 GeV of small statistics: 4500, 25300, 8700 and 7850 events respectively
  - 3 test chambers are the “visually best” RPCs at layer 15, 25 and 40.

- Analysis
  - Essentially the same as in simulation BUT
  - We apply chamber to chamber calibration constants given by (ε . m), measured with beam muons

Calibration constants 48 GRPC/SDHCAL



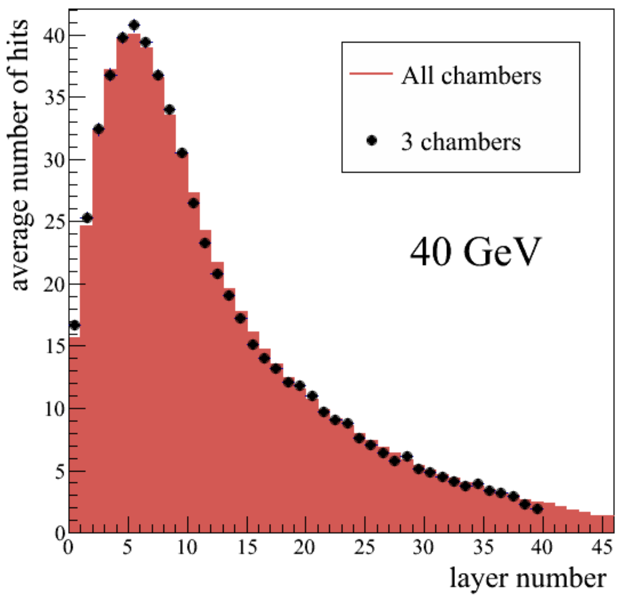

Occupancy at layer 15 (after time cut)

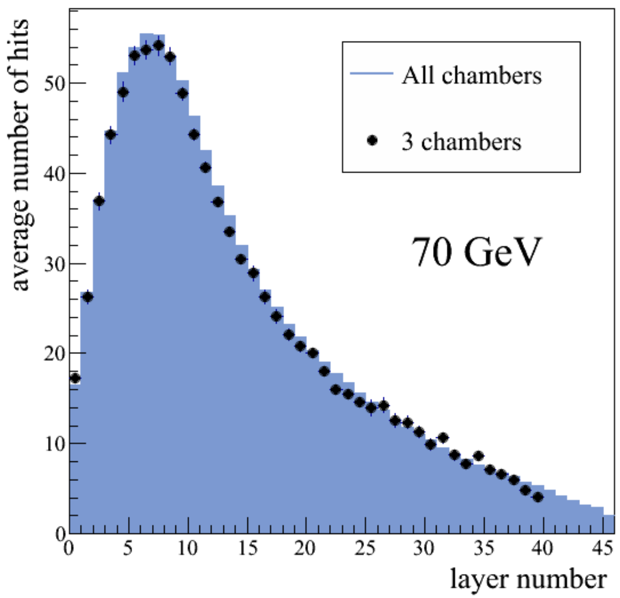


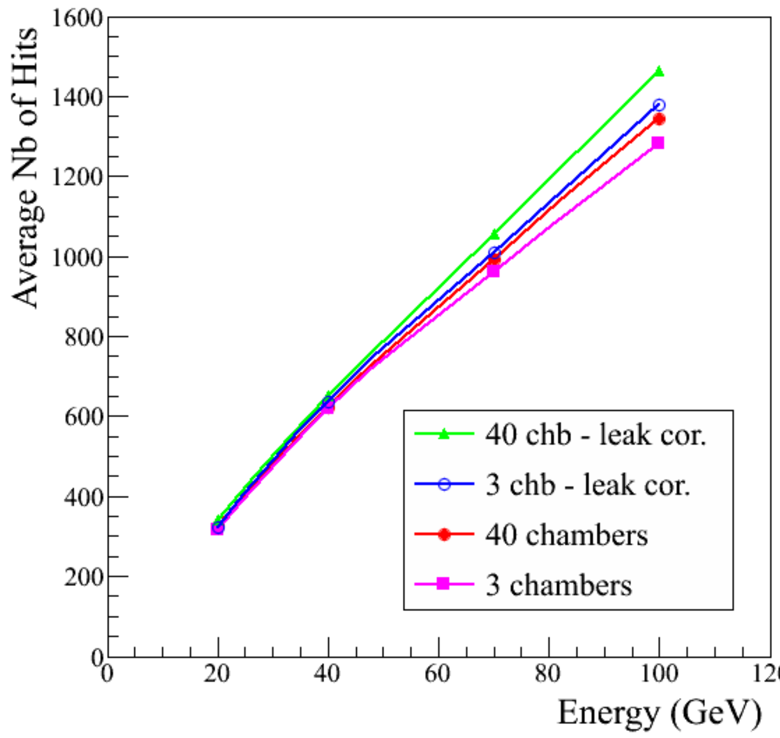
# Linearity from shower profile – TB data (2/2)

- Results
  - Good agreement with profiles obtained with 3 and 40 chambers at 20 and 40 GeV
    Less good at 70 and 100 GeV, difference of 3% and 5% respectively

- Conclusions
  - Monte Carlo shows that the method works
  - Discrepancies in data at high energy to be understood
  - We are confident that the method works



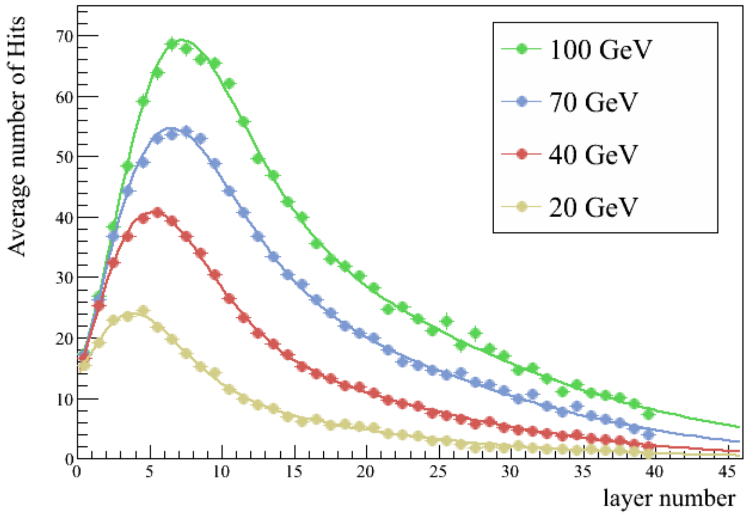



# Conclusion of the study

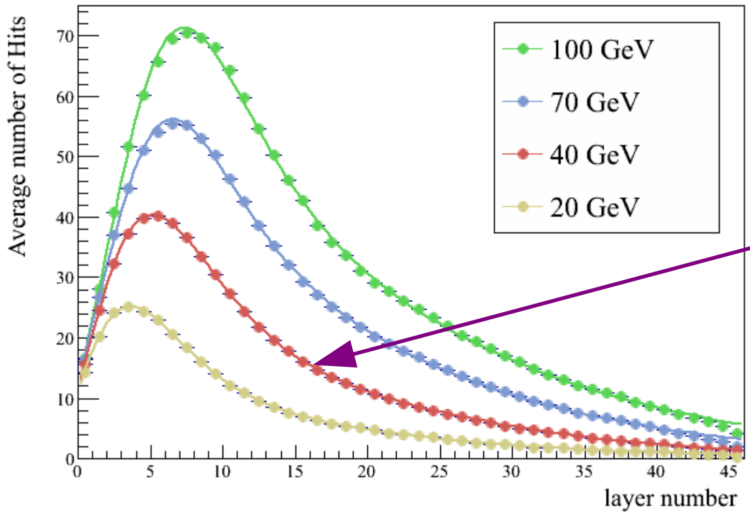
- We are confident that the method works and can be applied during next TB
  - 4 chambers should be available by October, final positions to be defined, probably 10, 20, 35 and 50

- Needed statistics / energy point
  - Best profile fit is with 45 chambers at 40 GeV (25 k events), let's define this as our goal
    → with 4 chambers: 45 / 4 *25 k ~ 250 k events per energy point
- Number of energy points during the CALICE/Micromegas period of 1 week
  - With an acquisition rate for pions of 10 Hz → 24 energy points
  - Taking into account the unexpected, we should be able to complete 10 points between 5 and 150 GeV

With 3 chambers




With 45 chambers




Best fit @ 40 GeV
25 k events

# 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 Lyon colleagues

    1) Start as tail catcher during GRPC master week

    2) Insertion inside the calorimeter at fixed positions during Micromegas master 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