Micromegas SDHCAL

CALICE collaboration meeting
Argonne National Laboratory, 19-21 March 2014

M. Chefdeville on behalf of the LC group of CNRS/IN2P3/LAPP, Annecy

Overview

- ✗ What's new since CALICE meeting in Annecy ?
- ✗ Resistive Micromegas – rate effects & linearity
- ✗ SDHCAL – rate effects & calibration
- ✗ Project overview & future plans

What's new?

- ✗ Second paper submitted to NIM
  (http://lappweb.in2p3.fr/~chefdevi/Work_LAPP/NIMA/m2prototype2_nim.pdf)
  Test in a beam of large-area Micromegas chambers for sampling calorimetry

- ✗ ANR post-doc left in November 2013 (J. Samarati)
  Myself: joined LAPP/LHCb group (part time with LC)

- ✗ Strengthened collaboration with Weizmann, invitation by S. Bressler in January
  Installation with G. Vouters of 2 THGEM-MICROROC setups

- ✗ Proposal (to ANR) to build a Micromegas calorimeter not accepted :(

- ✗ Presented here: finished & on-going analyses:
  - ✗ Standalone DESY 2013 testbeam analysis (finished)
    Rate capability & linearity of resistive prototypes
  - ✗ SDHCAL SPS 2012 testbeam (in progress)
    Rate effects in RPCs & calibration

Standard VS Resistive Micromegas

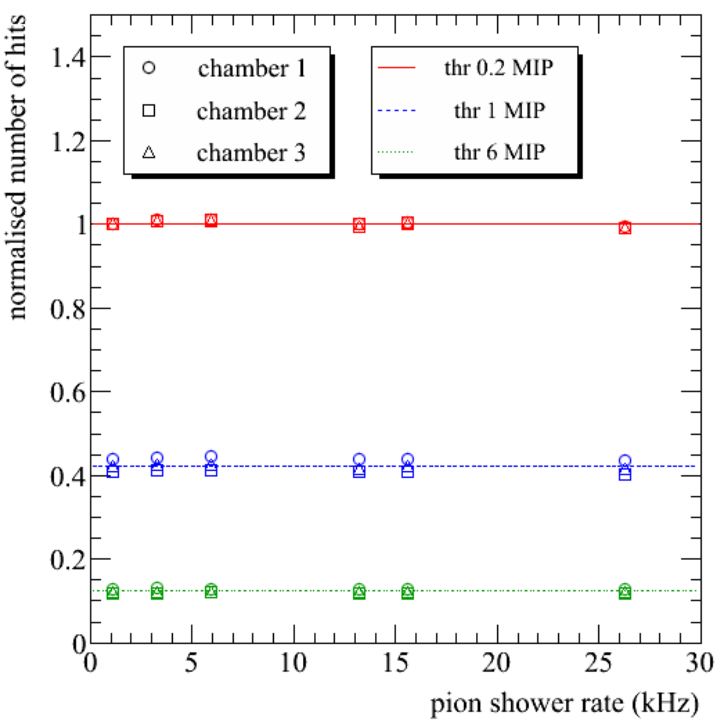
Standard Micromegas: high rate-capability but sparks from time to time

150 GeV pion beam with 2 λ_{int} Fe aborber (shower max) & 3 1x1 m^2 prototypes

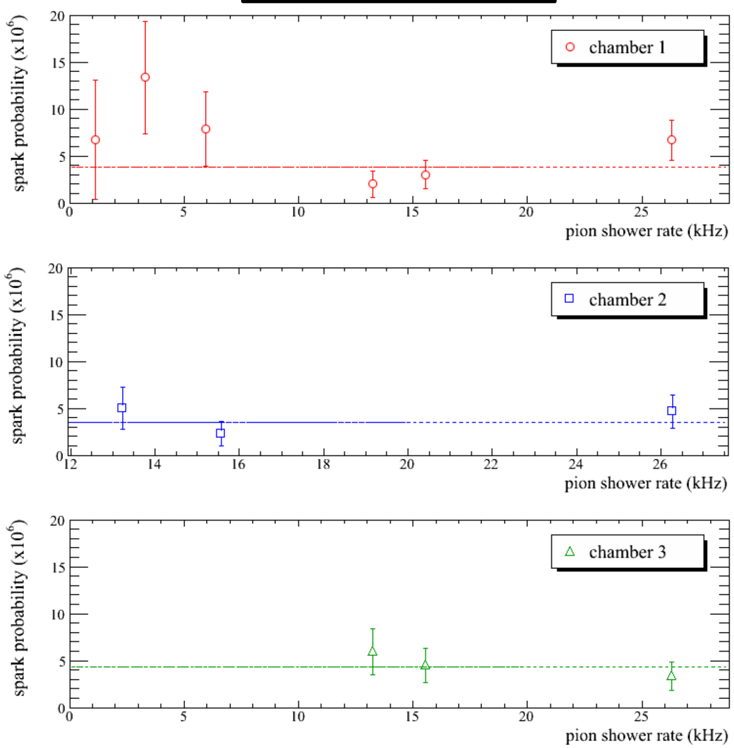
→ No effect on efficiency up to 25 kHz shower rate & Spark probability per shower of ~ 5.10^{-6}

Resistive Micromegas: high-rate friendly (quench sparks) + no diode protection (simpler PCB)

Response VS Rate



Sparks VS Rate



Resistive prototypes

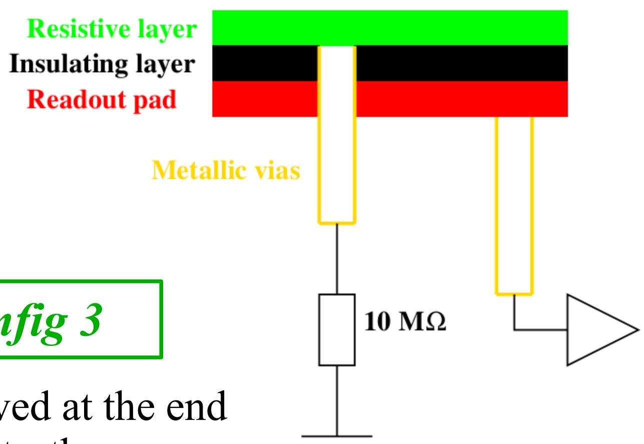
Three configurations implemented on 16x16 cm² MICROROC ASU

1. Resistive strips on insulating layer laminated on anode PCB, grounded on PCB side
2. Resistive pad connected to anode pad with a resistor buried in the insulating layer
3. Resistive pad connected to ground with a via going through the insulating layer & PCB

DESY testbeam setup

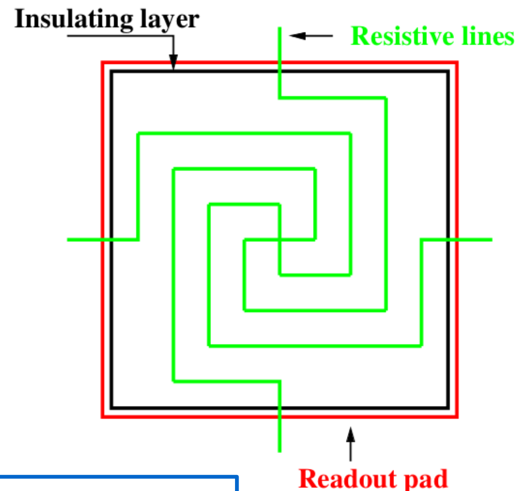
Air stack of 3 standard prototypes (*S1,S3,S5*) interleaved with 2 resistive prototypes (*R2,R4*)

Usual 3 threshold digital readout + slow analogue readout



Config 3

Received at the end of the testbeam



Config 1

Config 2

Did not work,
(processing issues)

Old & new results

Calibration
Resistive layers do not change the noise at the MICROROC preamp inputs

Voltage scan 1
Standard & resistive prototypes show similar efficiency & multiplicity to MIPs
(necessary voltage for given efficiency varies by 20-30 V from chb. To chb.)

Position scan
Spatial-uniformity of efficiency better than 2%

Voltage scan 2
No sparks were observed in resistive prototypes,
while a spark probability of 10^{-7} / electron was measured in standard prototypes

Rate scan
At low threshold (0.2 MIP), no significant effects of rate on the efficiency

See J. Samarati talk, CALICE, Annecy

NEW

Rate-induced loss of efficiency (depends on threshold value)

Signal linearity in resistive and standard uM (inferred from shower profiles)

Rate study

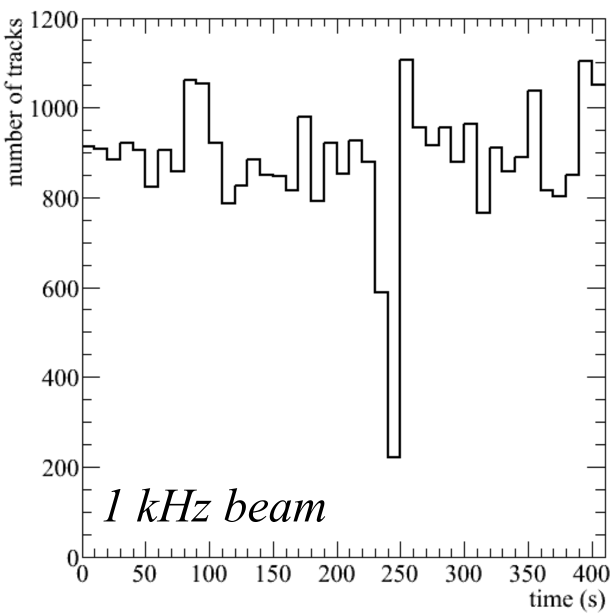
Monitor beam activity with telescope = chamber S1 (upstream) and S5 (downstream)

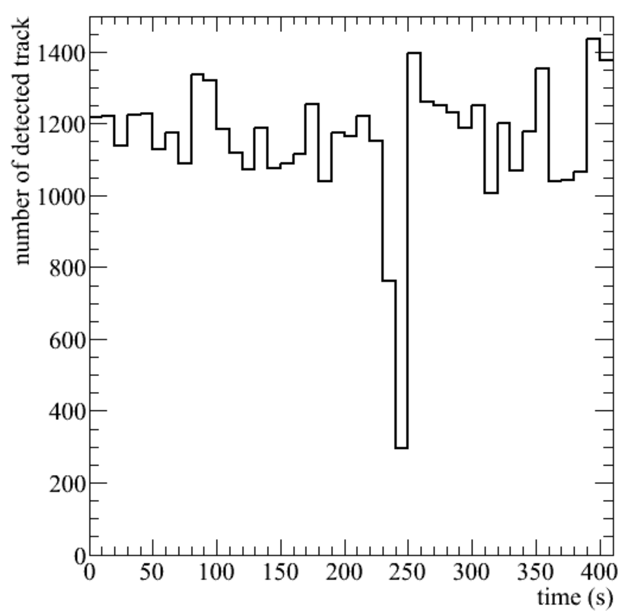
→ request single aligned hits

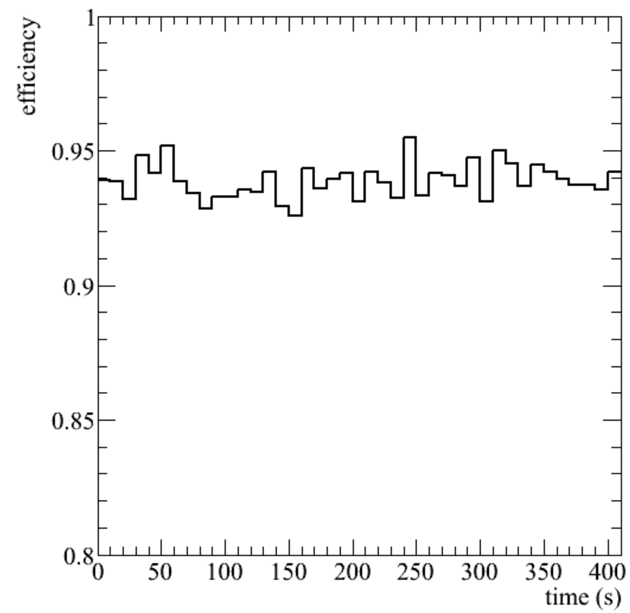
→ probe chamber 2 (R2), chamber 3 (S3) and chamber 4 (R4)

Rate varies from 1 to 180 kHz / 4 cm^2 in 1.2 hour

N_{track} telescope	***N_{hot} chb4***	***Efficiency chb4***





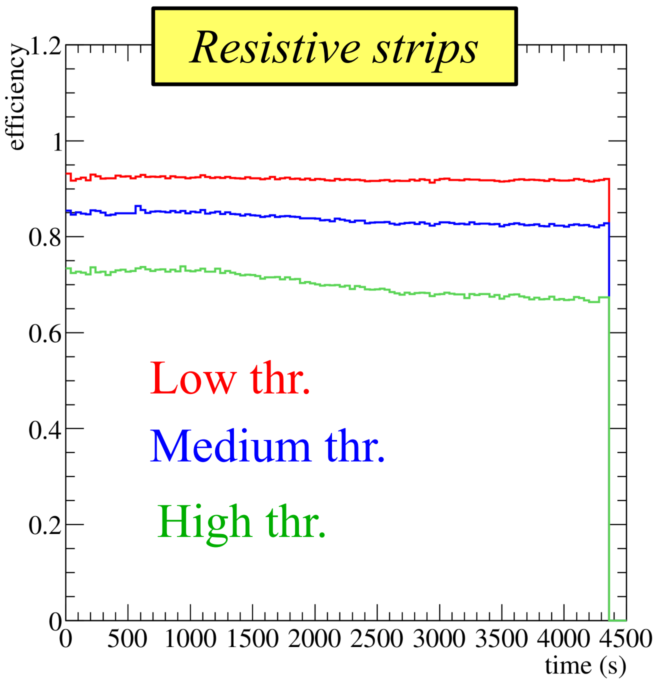


Efficiency variations over time

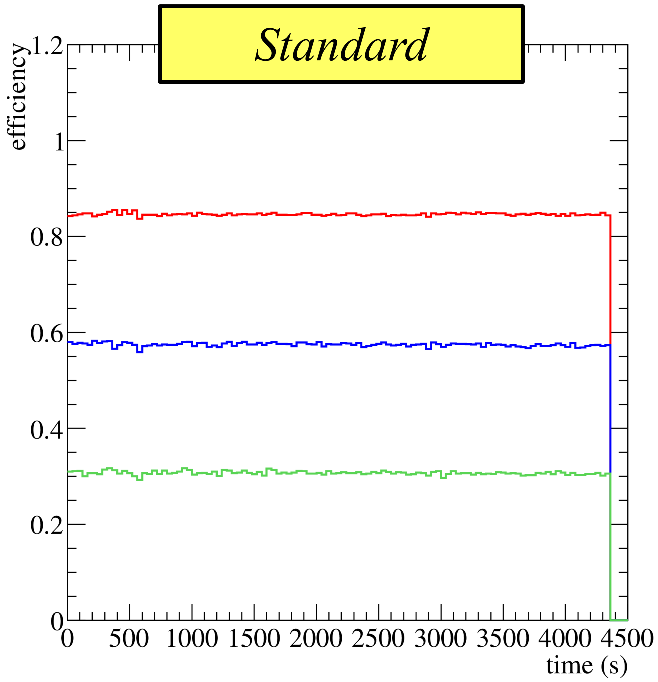
Due to a poor knowledge of the Landau distribution during the testbeam (long-lasting bug of the analogue readout), the resistive prototypes were operated at slightly different gas gain.

→ *the efficiency @ t_0 and @ given threshold is different from prototype to prototype*

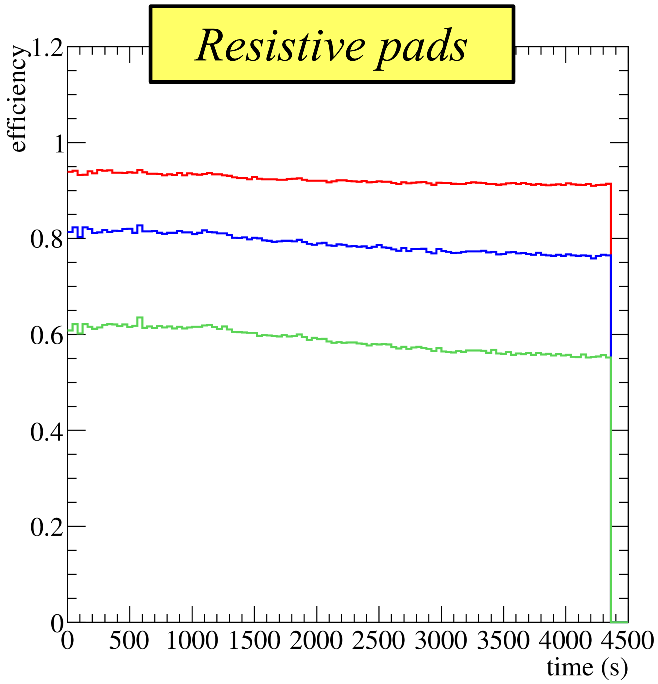
Also, the voltage of the standard prototypes was deliberately lowered to avoid sparks at high rates



Vmesh = 530 V



Vmesh = 475 V

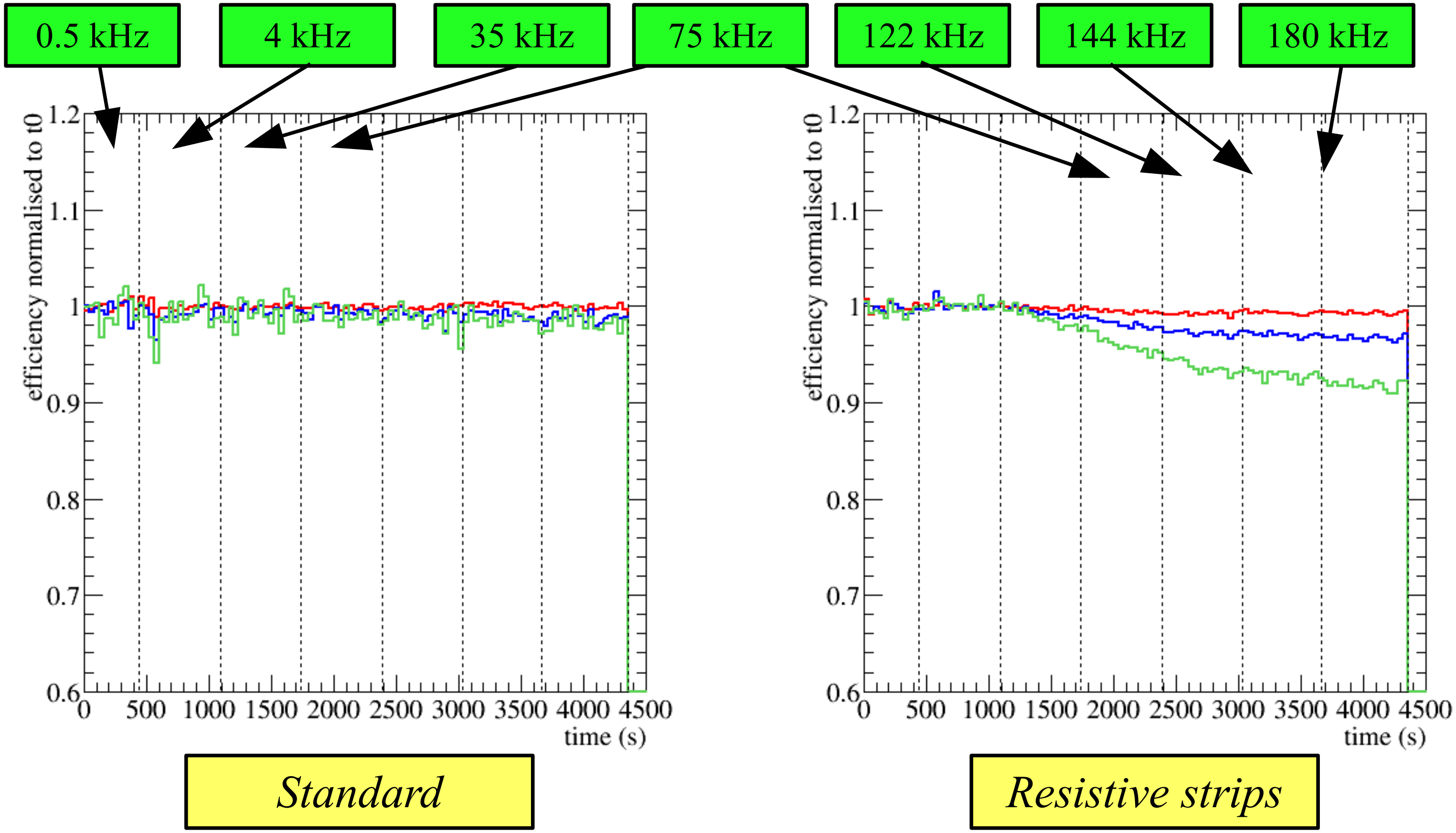


Vmesh = 510 V

R2: Variations normalised to t_0

For the resistive strip prototype,

rate-induced voltage (and efficiency) losses observed around 10 kHz/cm²



Rate scan

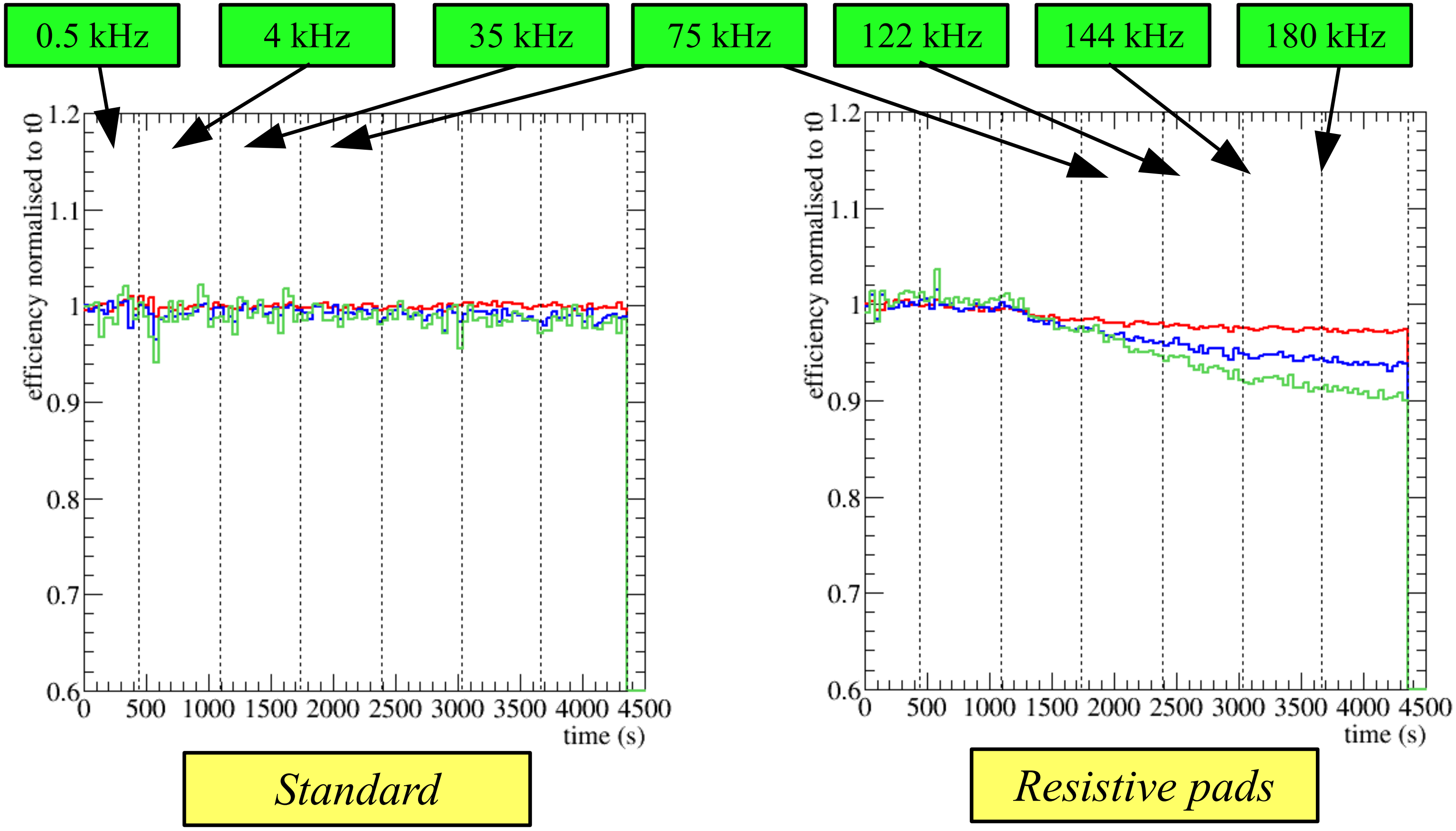
5 GeV e^- beam

Collim. 2x2 cm²

R4: Variations normalised to t_0

Despite the different design,

very similar behaviour is observed for the resistive pad prototype



Rate scan

5 GeV e^- beam

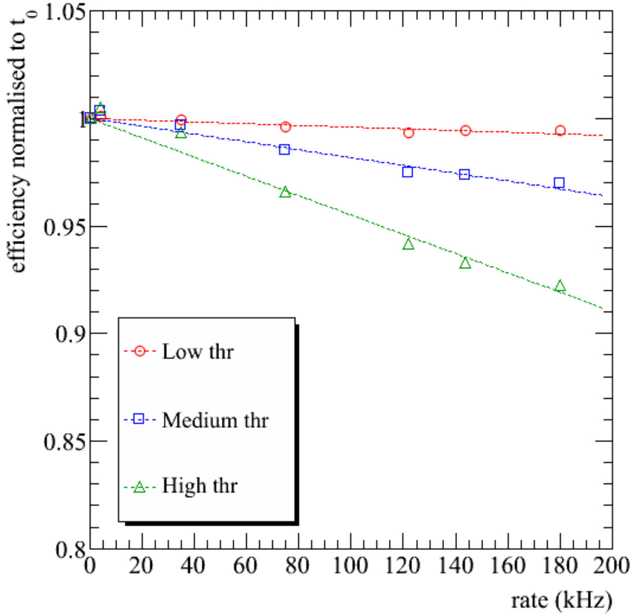
Collim. 2x2 cm^2

Efficiency variations versus rate

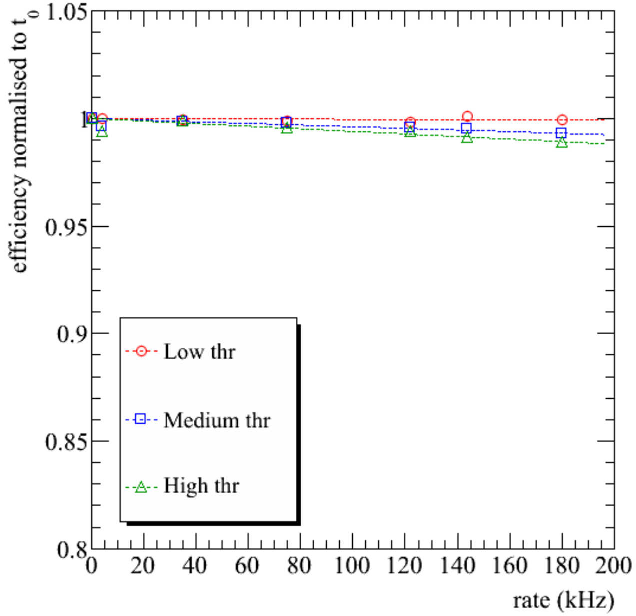
Standard prototype response is flat within 1%

Prototypes R4 shows larger drop than R2 because its signal to threshold ratio are higher.

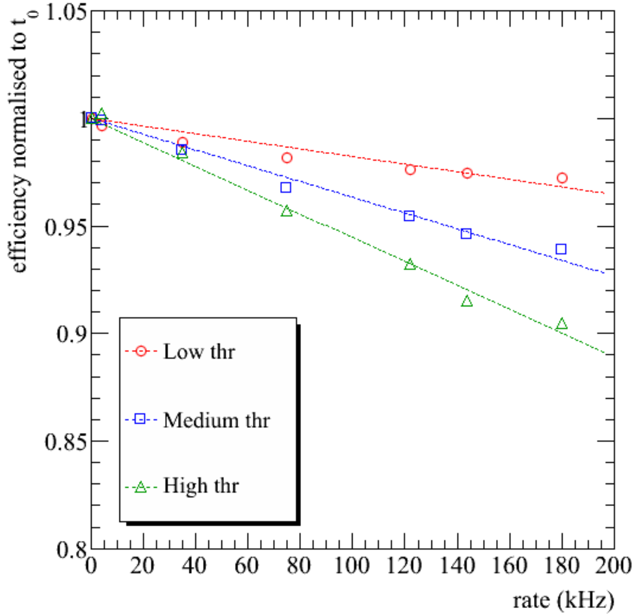
Resistive strips



Standard



Resistive pads



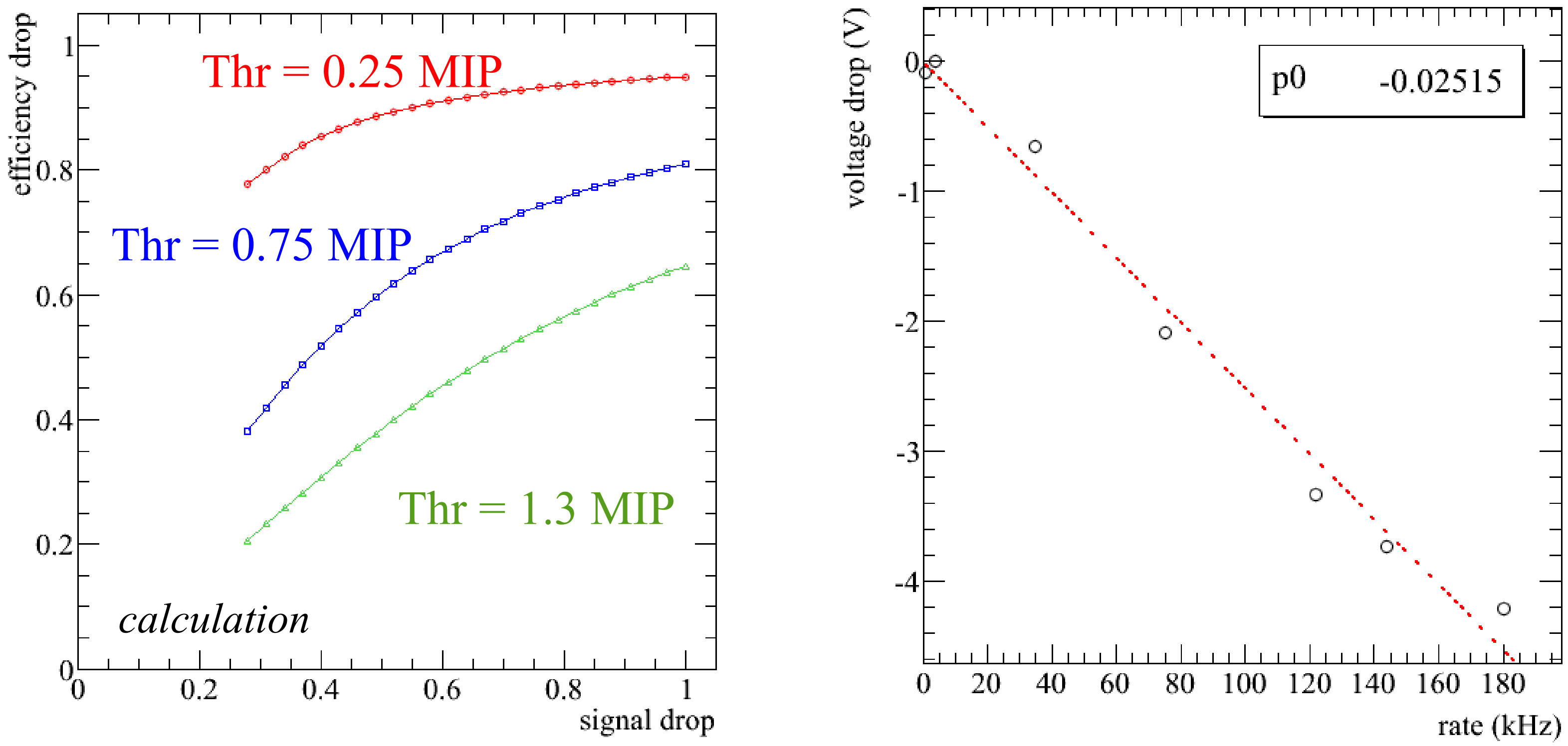
Gas-gain variations versus rate

The loss of efficiency depends on the Landau distribution and threshold value

Knowing the threshold and the efficiency loss,
one can infer the variations of the Landau MPV and thus of voltage.

Plotting versus rate, one sees the <u>Ohmic law</u> → R value of the prototypes of ~ 2 GΩ!

PS: 1 kHz beam → $10^3 * 30\ e^- * 1.6.10^{-19}\ C * 3.10^3 \sim 1.6.10^{-2}$ nA



Linearity study in electron showers

Is the nice proportionality of Micromegas spoiled by the resistive layer?

→ measure the analogue response of standard & resistive prototypes

(loss of proportionality → saturated response)

Getting the response with one sampling layer

1. Add absorbers in front of the stack (0, 1.8 cm, ... 26 cm of steel)
2. Measure the signal distribution (N_{hit} or ADC_{sum})
3. Build the longitudinal profile (Signal mean VS Absorber thickness)
4. Integrate the profile
5. Do it at several beam energies
6. Extract response (Profile fit function integral VS E_{beam})

To compare different prototypes (S/R) and different readouts (D/A)

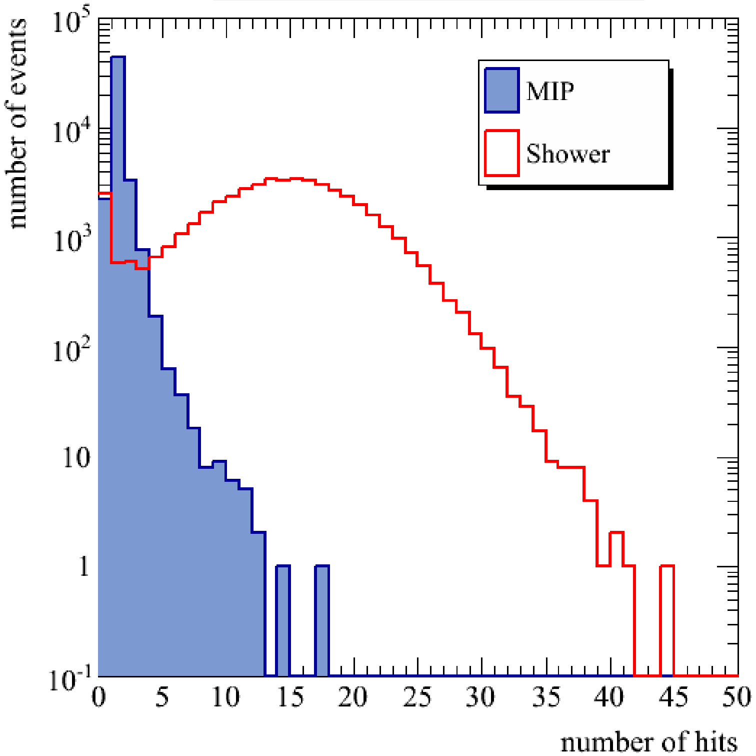
→ normalised signal in units of MIP

PS: for this measurement, only 1 resistive prototype was operational (R2-strips)

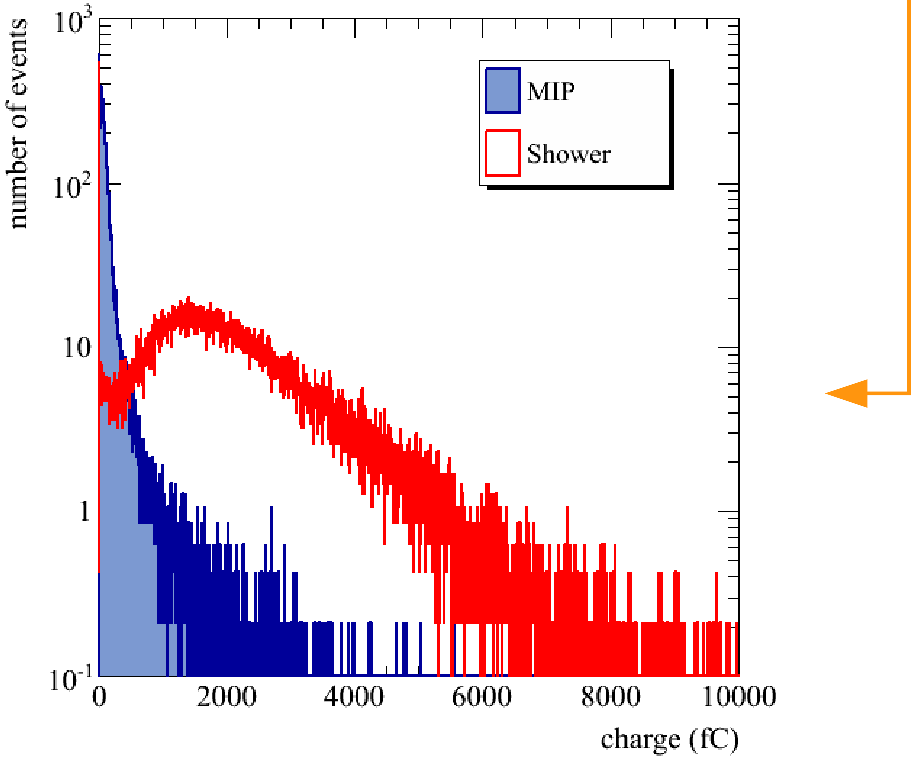
MIP & shower signal distributions

Highest energy and shower max run is at 5 GeV and with 7 cm of steel

Number of hits, S1



ADC sum, S1



<u>The "MIP" normalisation</u>

Done using the *mean signal at 1 GeV and with no absorber*

Normalisation of ADC distribution

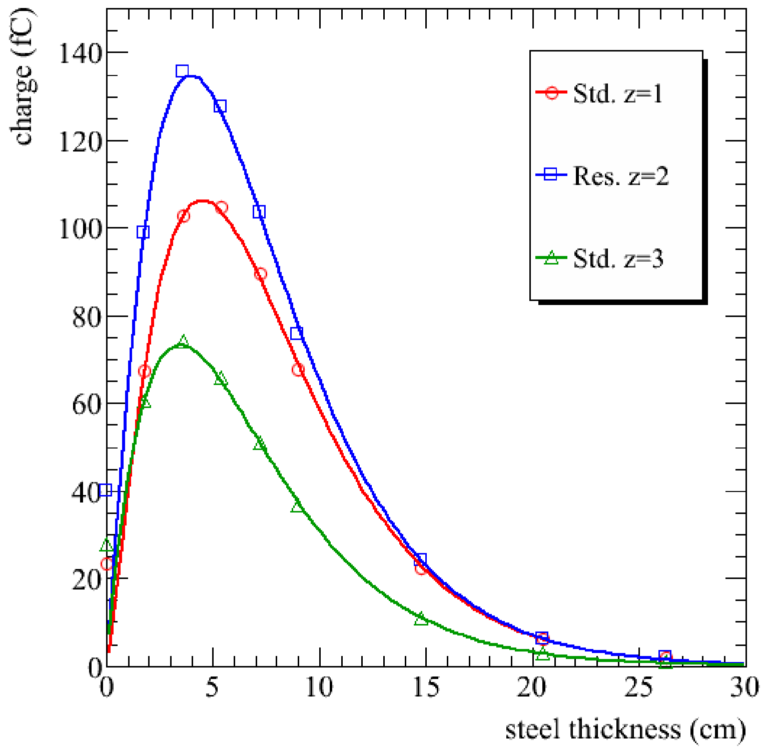
Resistive prototype R2 at z = 2 operated at higher gas gain

→ Can be seen from data points with no absorber (0 cm of steel)

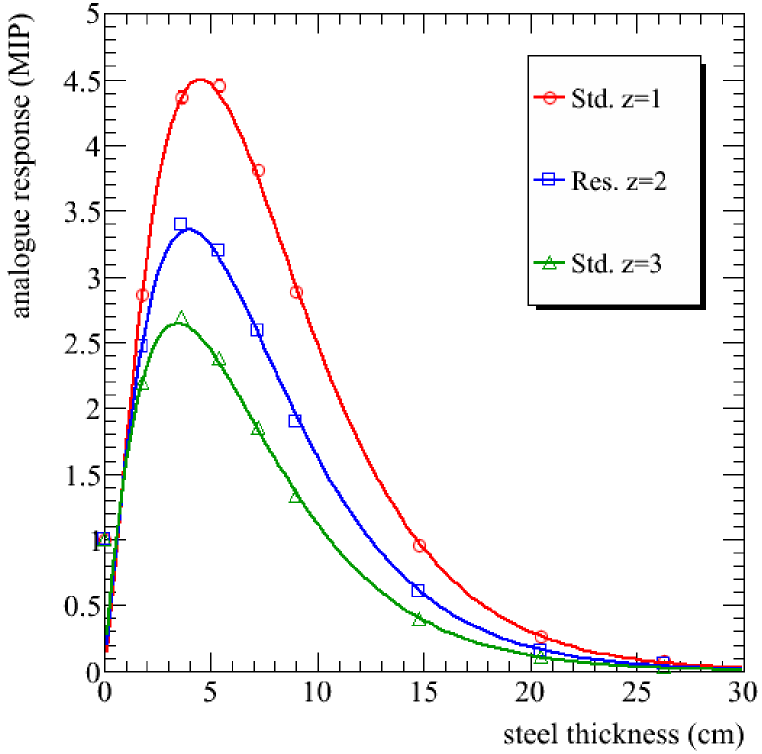
After MIP normalisation,

the analogue response decreases with the prototype position along the beam line as expected from the *increased material traversed by the showers*.

1 GeV, fC unit, S1-R2-S3



1 GeV, MIP unit, S1-R2-S3



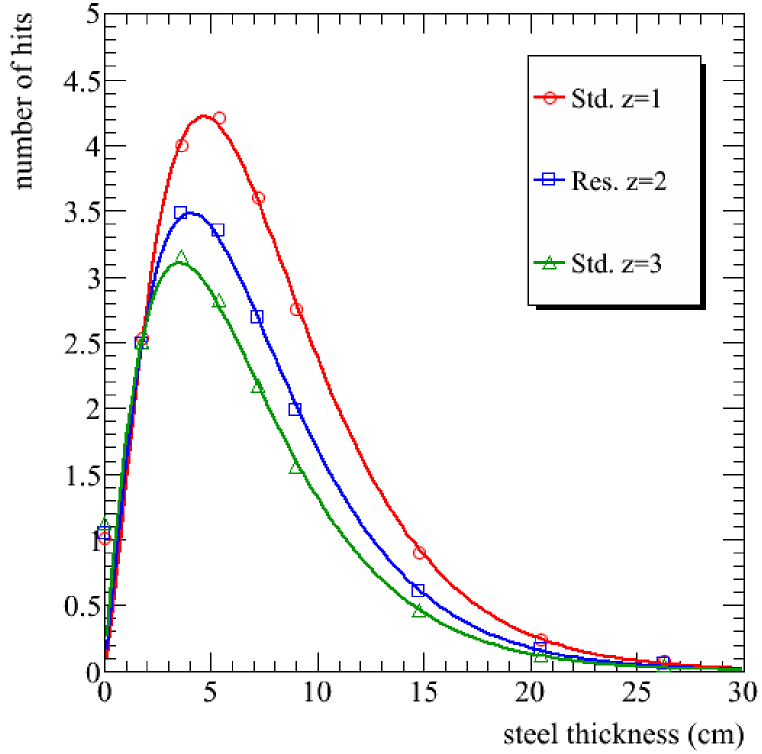
Normalisation of N_{hit} distribution

The number of hits from 1 GeV electrons is close to 1

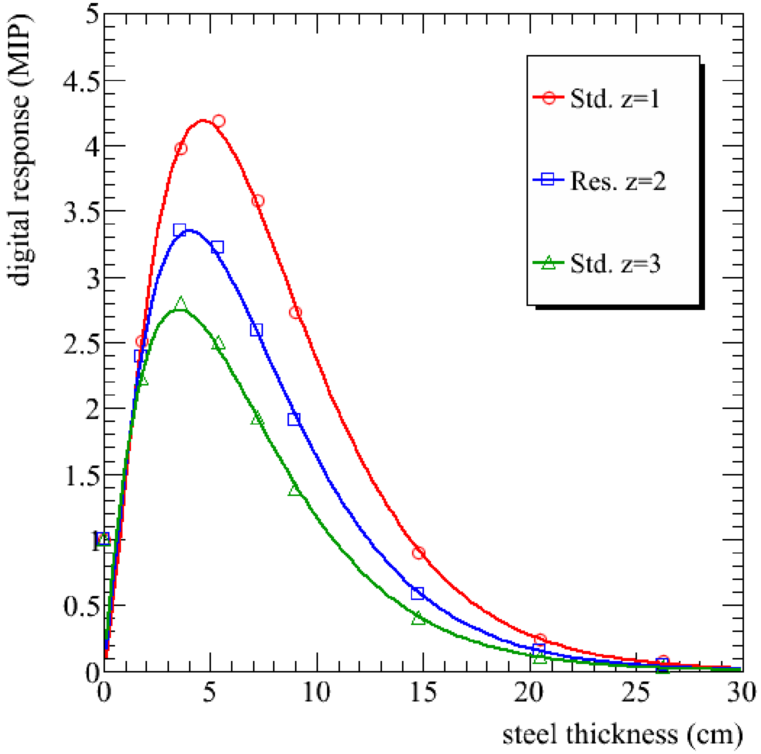
and depends weakly on the gas gain

→ Very little effect of MIP normalisation on the distribution of the number of hits

1 GeV, N_{hit} unit, S1-R2-S3



1 GeV, MIP unit, S1-R2-S3

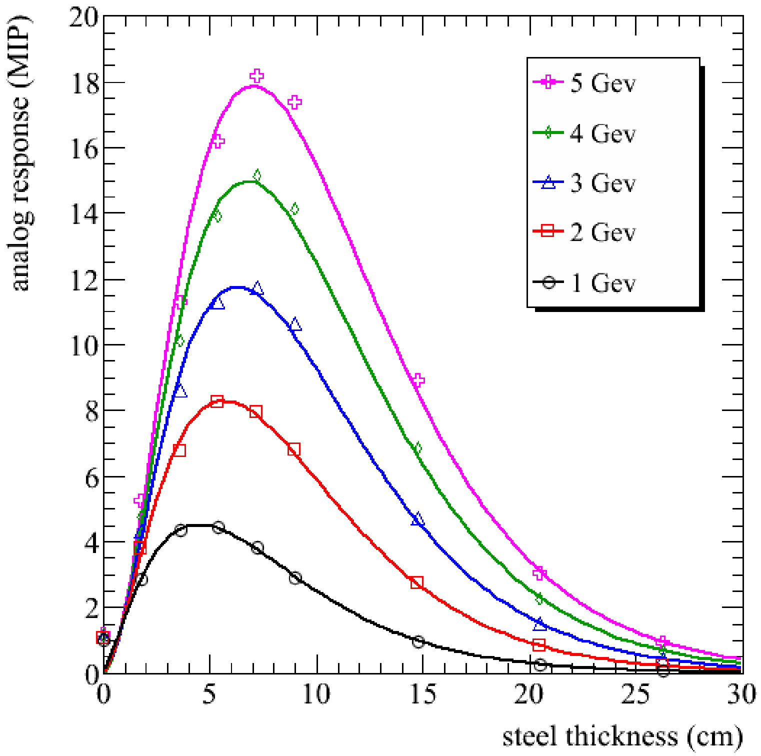


Longitudinal profiles

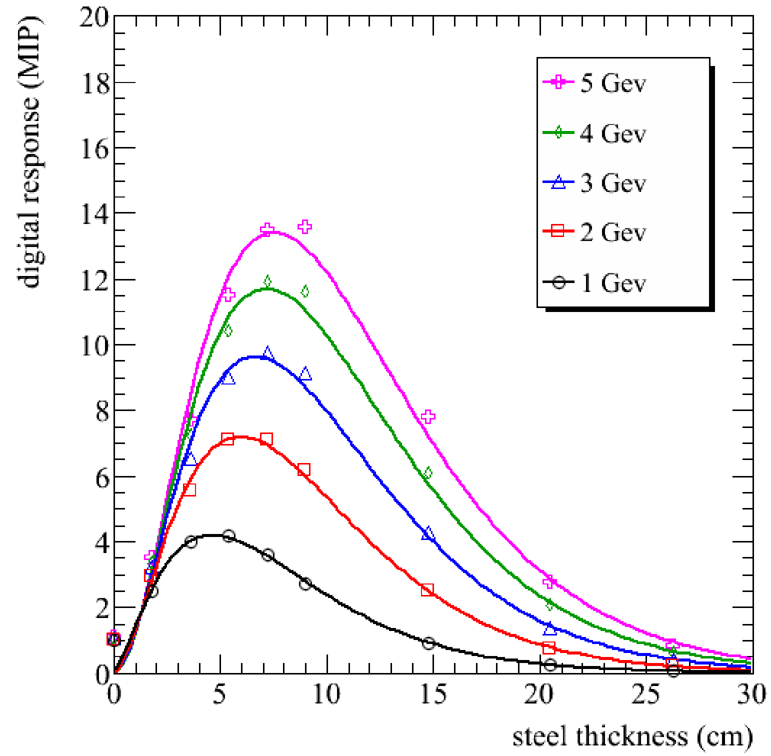
As expected from geometrical saturation,

the shower profiles in digital mode are attenuated compared to analogue mode.

Analogue, S1



Digital, S1



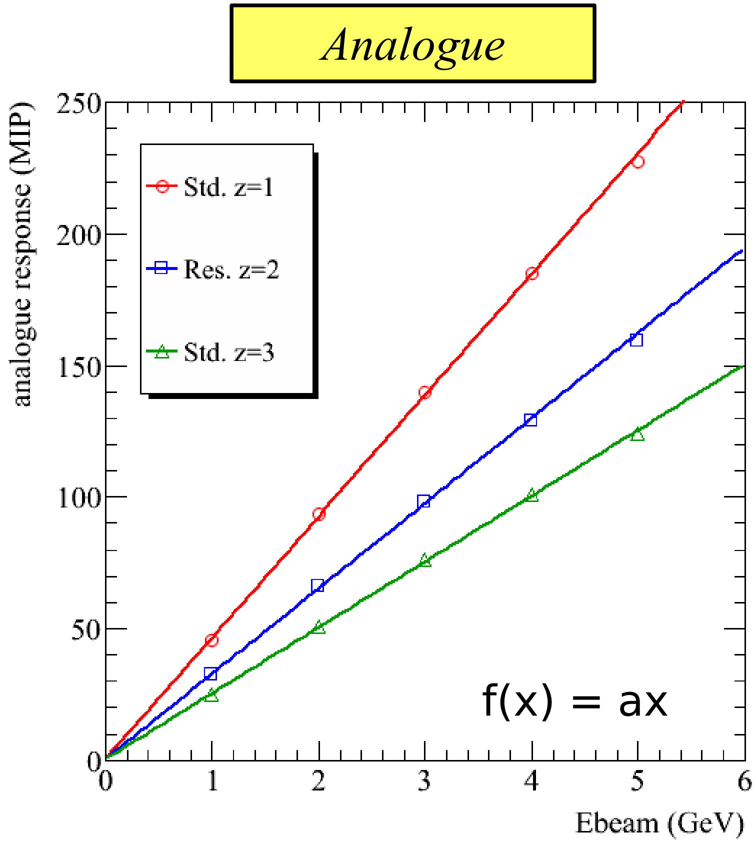
EM response, finally

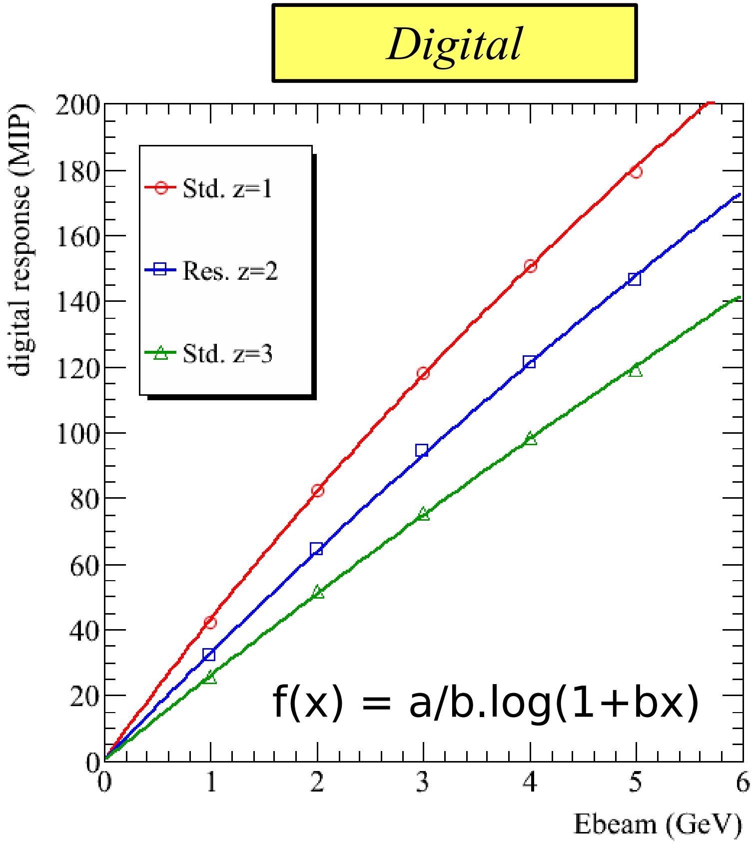
The electron response is a function of the position in the stack and

→ is saturated in digital mode

→ In analogue mode, it is close to linear for both standard & resistive prototypes

Small drop observed in all chambers at 5 GeV probably not related to R-layer...





Deviations from linearity

2 suspects

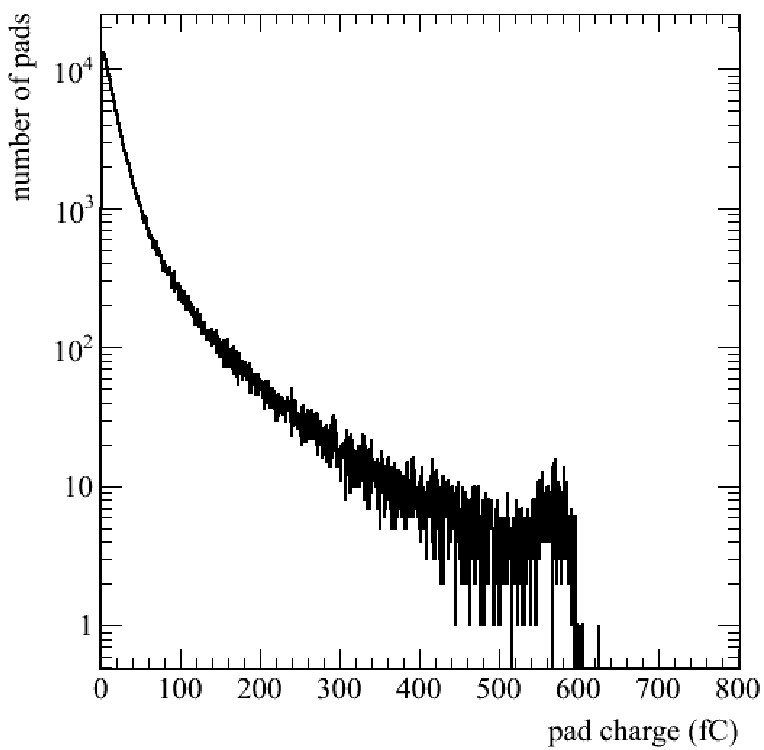
ADC saturation is most pronounced at 5 GeV

Can not reject the events without biasing the sample

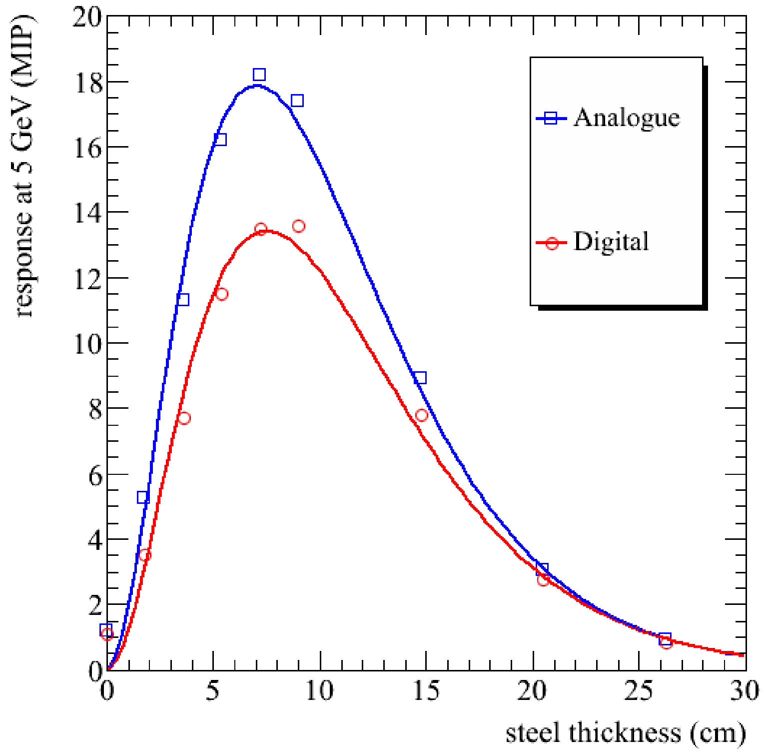
Fit function is constrained to zero @ x=0: $f(x) = A \cdot x^B \cdot \exp(-x / C)$

+ fit gets worse with energy, fails to describe the profile maxima well above 4 GeV

Pad charge in S1 @ 5 GeV & shw. max.



Shower profile in S1 @ 5 GeV



Compensation of the SDHCAL response

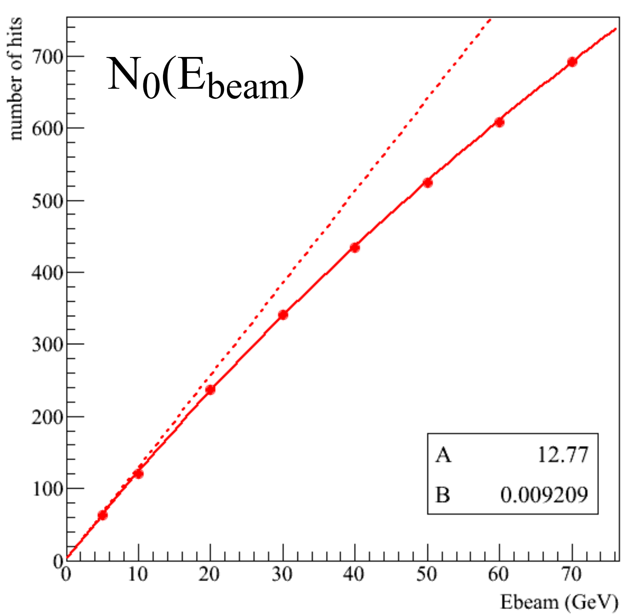
Based on Monte Carlo, we developed multi-threshold compensations techniques

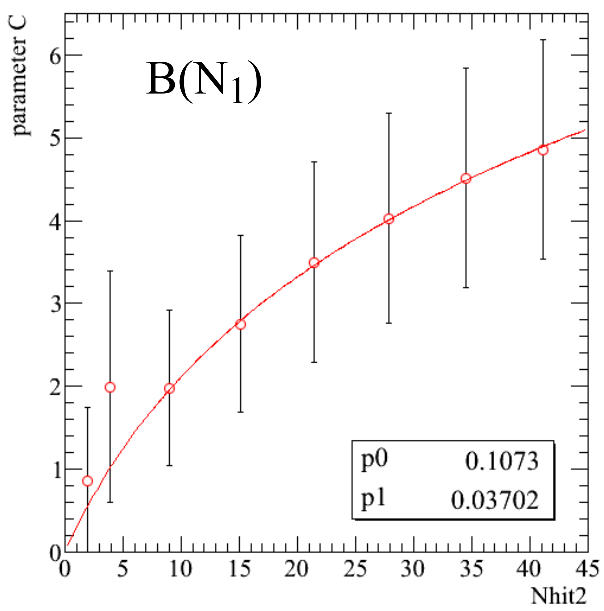
See I. Koletsou talk, CALICE, Annecy.

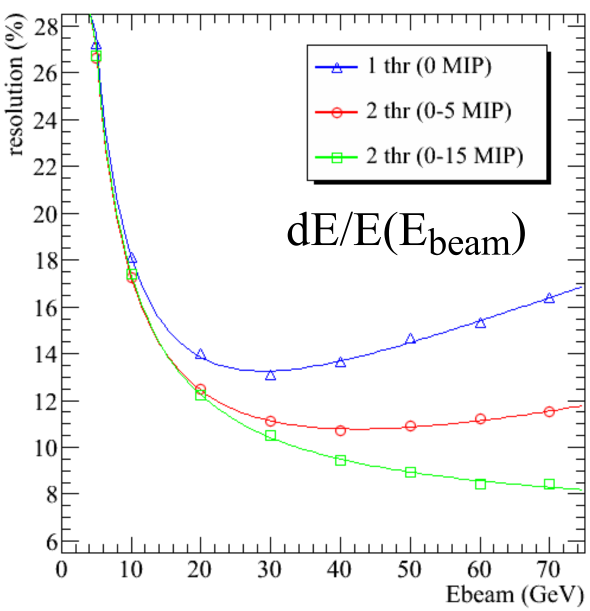
The simplest uses 2 thresholds → $E_{rec} = A\,(N_0 + B.N_1)$

Takes as input the following relations: $N_0(E_{beam})$ and $N_1(E_{beam})$

From which are deduced the parametrisation of the weight B





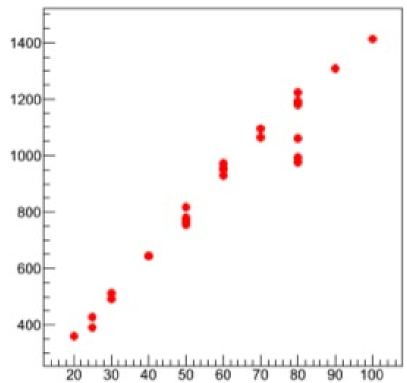


And of course, we dream of applying it to real data!

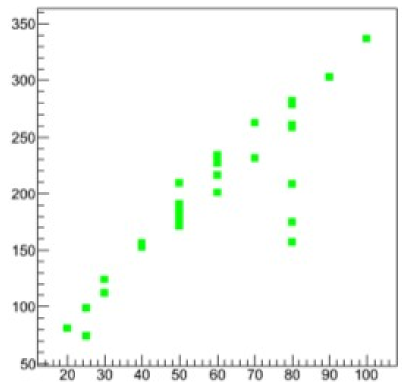
Un-calibrated RPC-SDHCAL response

<u>Data from August 2012 SPS/H6 testbeam</u>

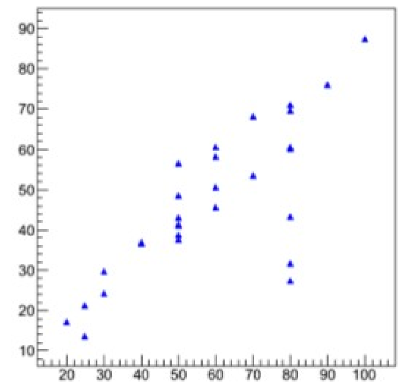
The raw response shows significant deviations from a continuous log. function. Especially for medium (5 MIP) and high thresholds (15 MIP).



Nhit0 VS Ebeam



Nhit1 VS Ebeam



Nhit2 VS Ebeam

Run	Ebeam
715747	30
715748	40
715751	50
715753	60
715754	70
715756	80
715757	90
715758	100
715759	110

Large deviations are due to a wrong beam settings (too high rates).

Small deviations are still present in official best runs. →
They are probably due to rate effects as well

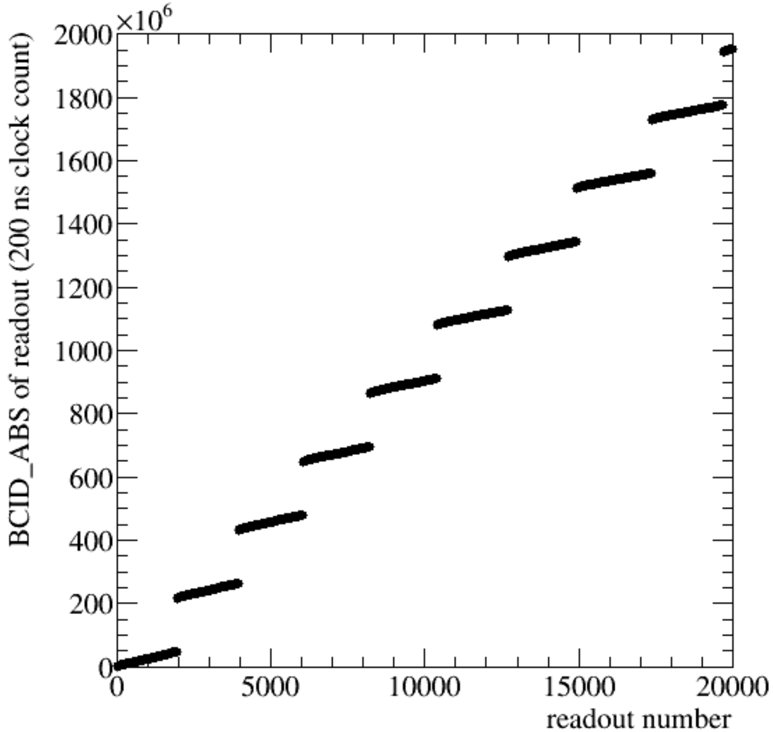
→ Investigate SDHCAL response dependence on time in spill
<u>And work out possible corrections</u>

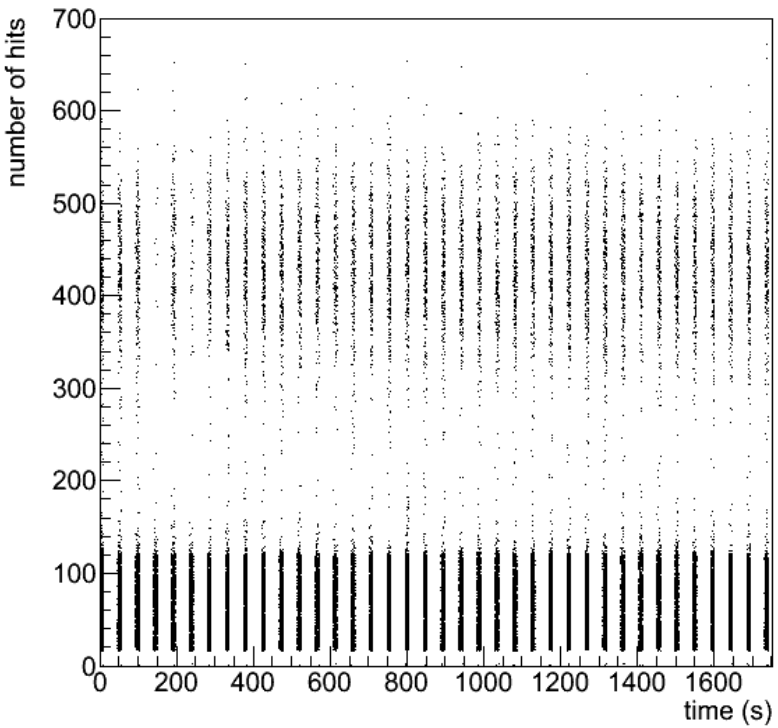
Time-ordering of events

Acquisition & reconstruction:

ASU → DIF → DCC → SDCC → 4 PC → 4 slcio files
Data from 2 consecutive RAMFULL readouts may be written on ≠ PCs
→ merging & time-ordering of events

Left: timestamp VS readout number → spill structure
Right: number of hits versus time → showers and tracks (beam + cosmics)





Beam conditions (shower rate)

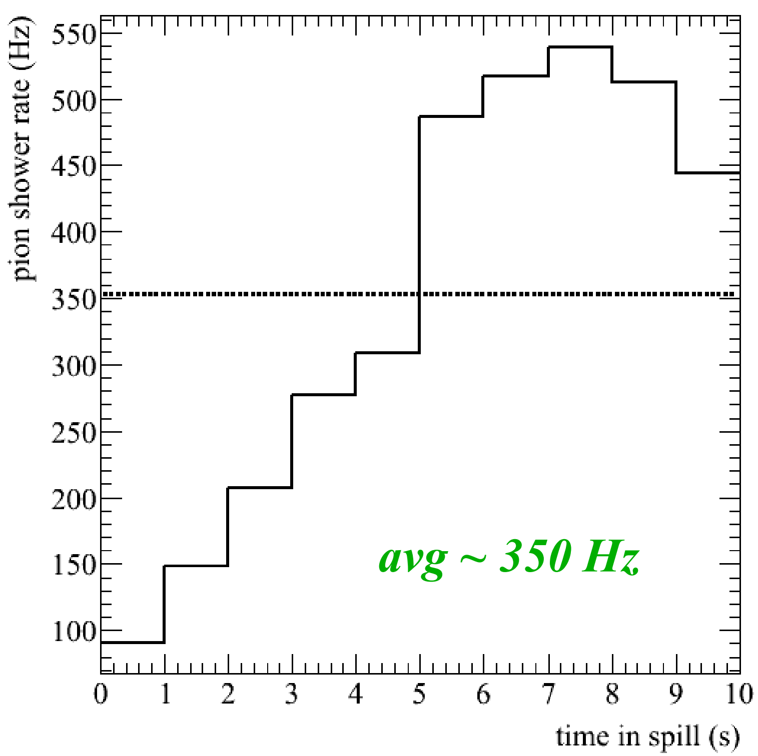
Rate calculated as sum of hit and time in RAMFULL readouts.

ALL SPILL INTO 1: the pion rate is not constant, large increase during the spill

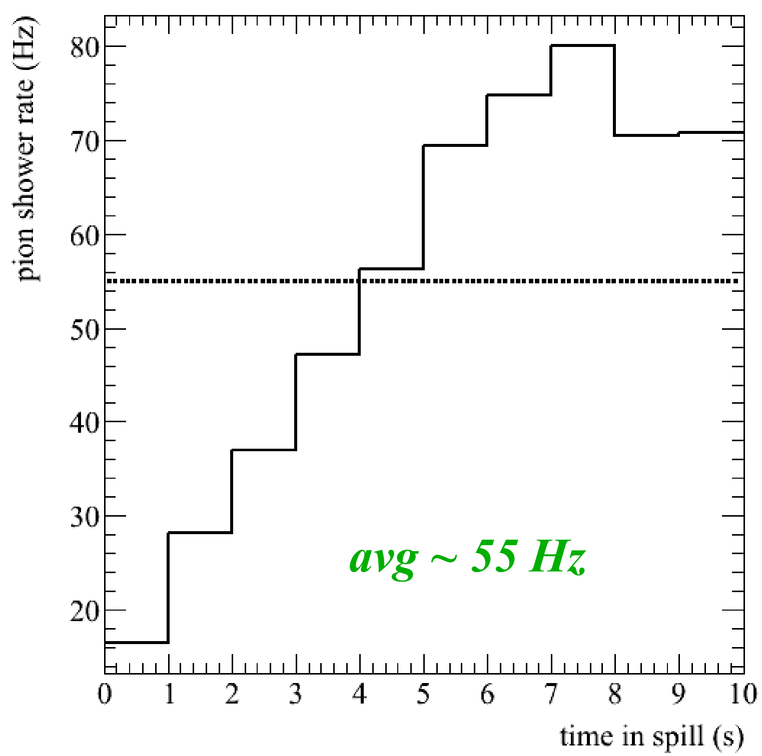
Taking a bad & a good 80 GeV run, it reaches at most ~ 550 Hz & 80 Hz resp.

For most of the "good runs" the average shower rate is around 50 Hz

"High" shower rate @ 80 GeV



"Low" shower rate @ 80 GeV



Number of hits versus time

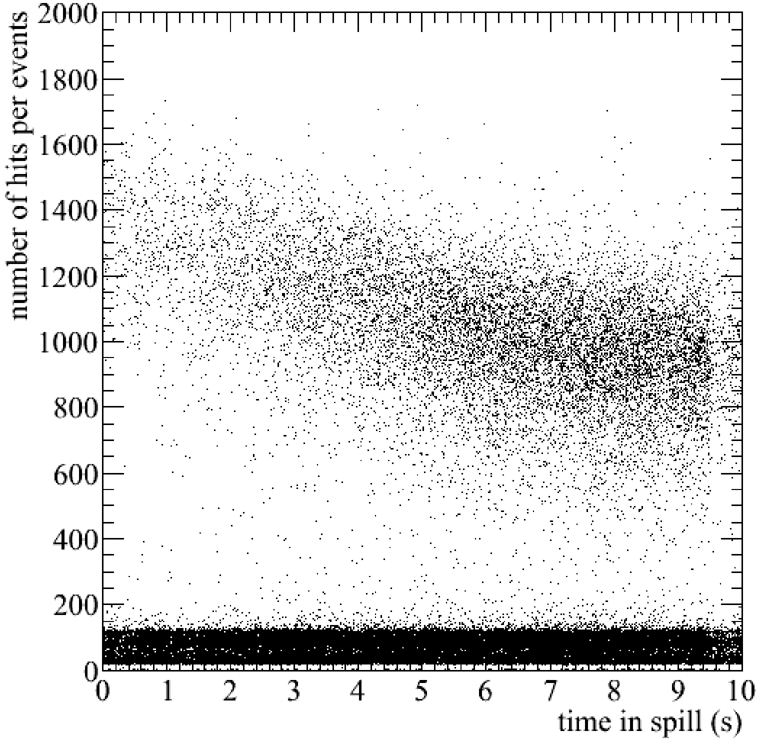
After superposition of all spills into 1:

Muon cloud is flat at both energies

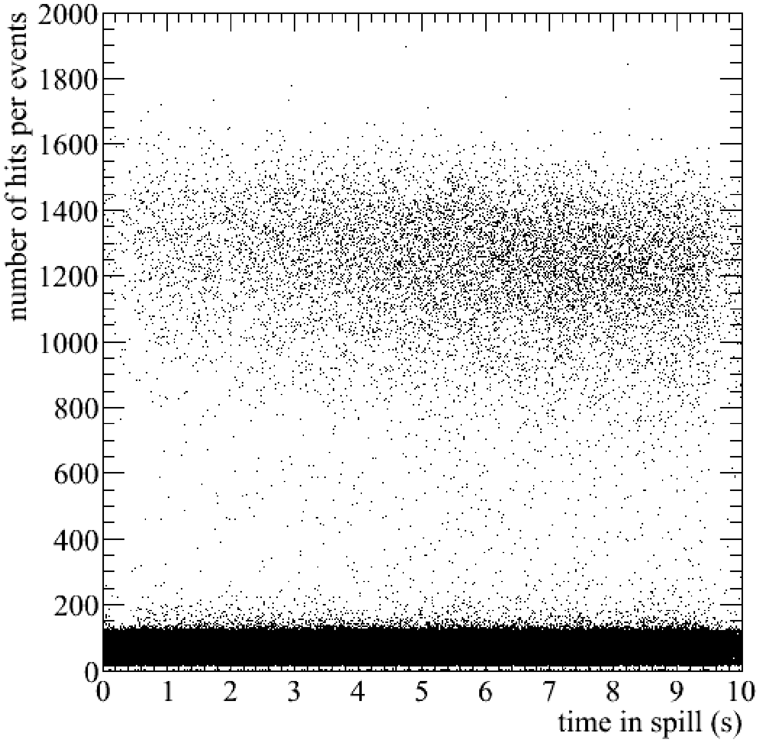
Shower cloud is more populated by the end of the spill (pion rate ≠ constant)

+ is not flat ← depends on energy, rate and threshold

"High" shower rate @ 80 GeV



"Low" shower rate @ 80 GeV

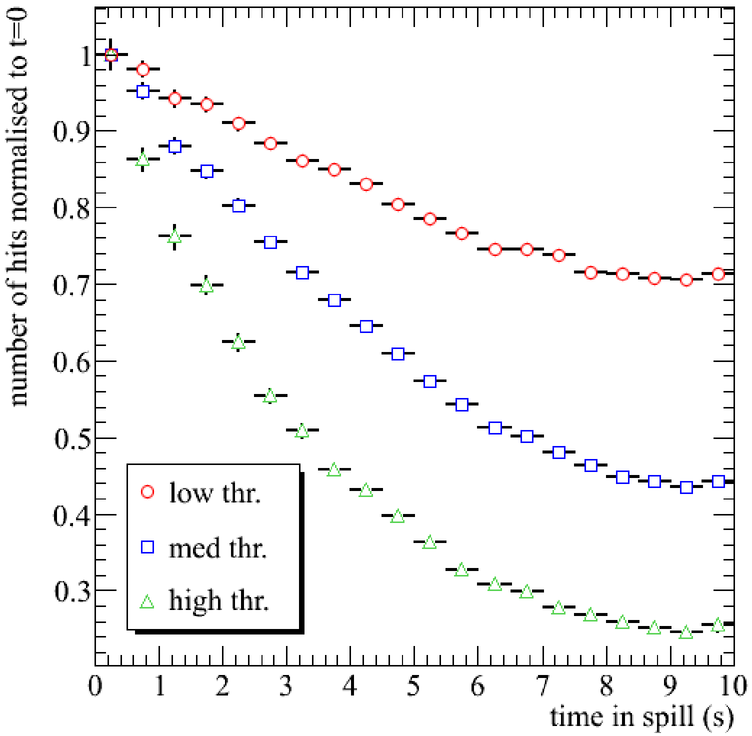


Number of hits in showers versus time

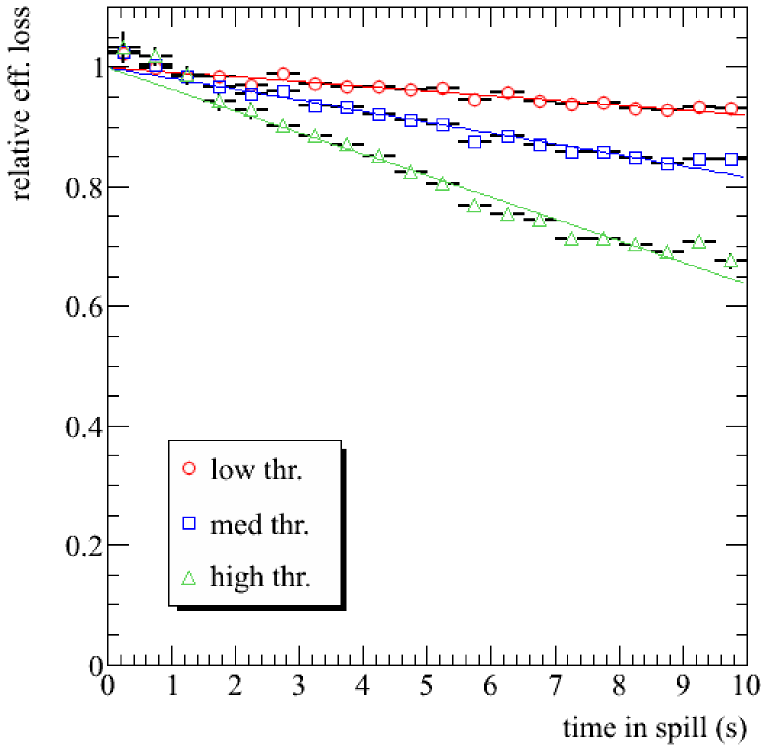
If the voltage decreases and the signal distribution is not uniform:

→ the response of the 3 thresholds (low, medium 5 MIP, high 15 MIP) are affected differently by a given voltage drop

“High” shower rate @ 80 GeV



“Low” shower rate @ 80 GeV



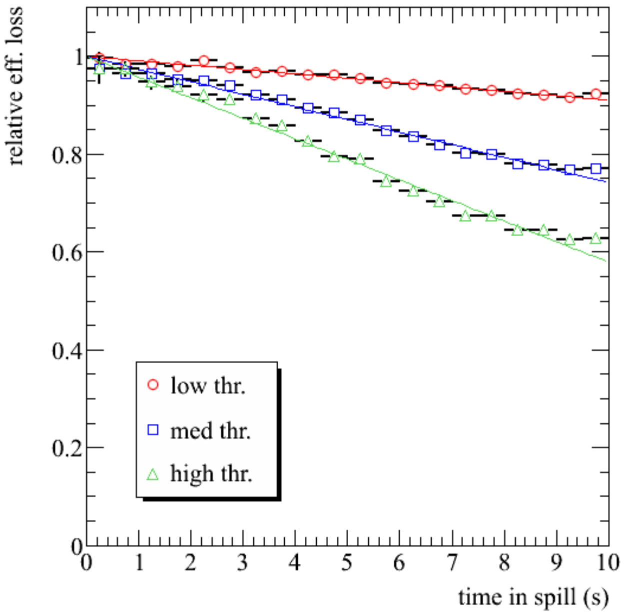
Normalised number of hits in showers versus time

For good runs, typical relative losses of N_{hit} in pion showers are of the order of

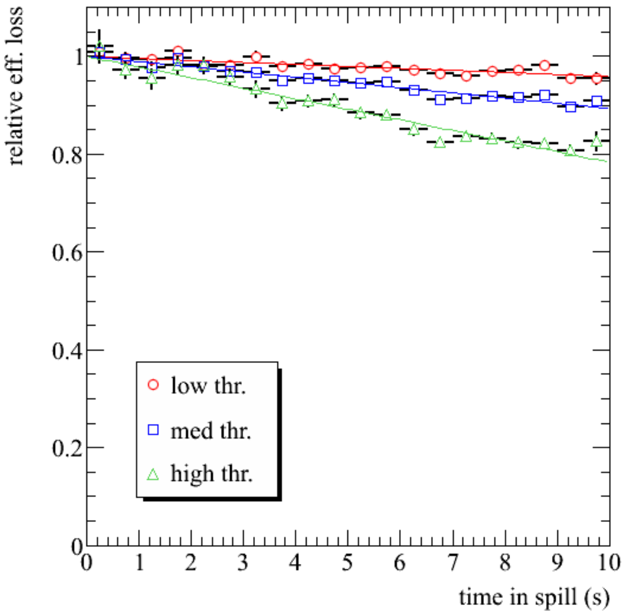
5-10% @ low threshold, 10-20% @ medium threshold and 20-40% @ high threshold

<u>The fitted trends can be used for correcting the measured number of hits</u>

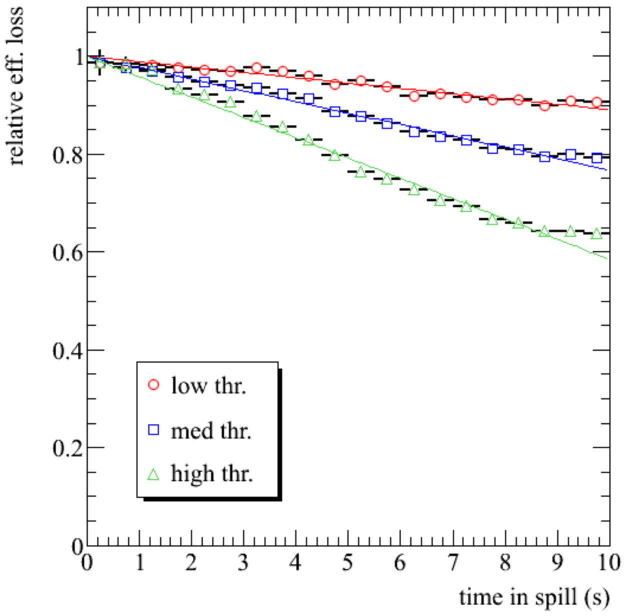
30 GeV



60 GeV



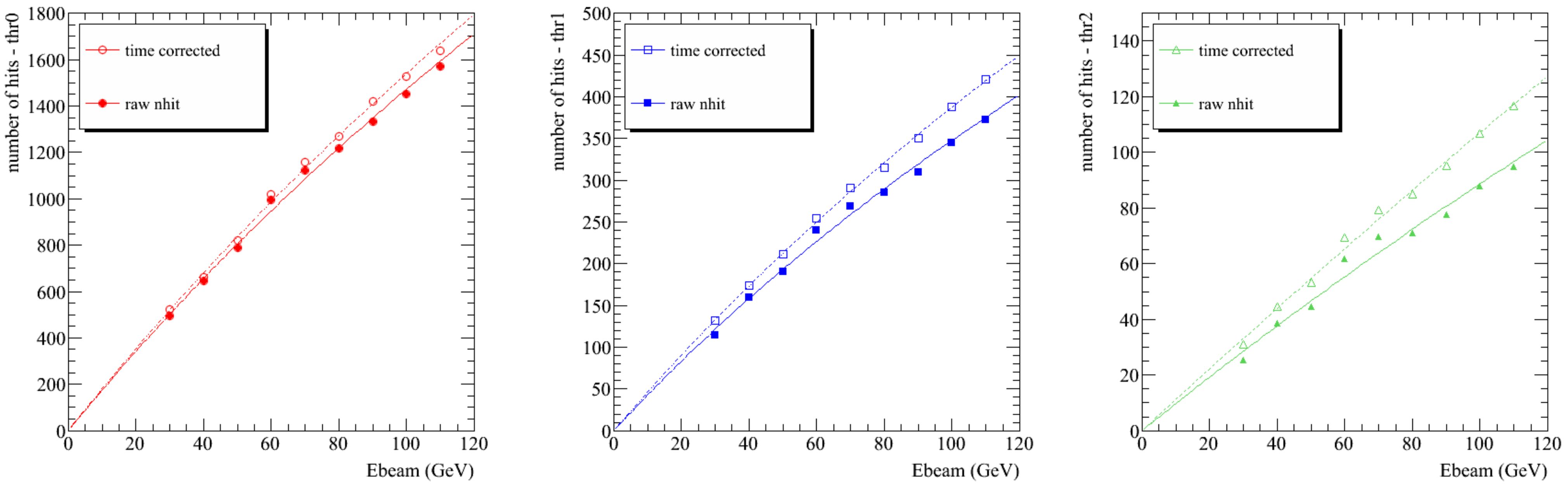
90 GeV



Time-calibrated response

The spread of the data points along the fitted log. function is reduced.

The effect is *particularly striking for medium and high thresholds.*



Still, some spread remains → full calibration not trivial.

Other effects are investigated (P/T, MIP, threshold, spatial uniformity) by the SDHCAL group.

Micromegas Project Overview (1/2)

→ *1x1 m^2 large-area prototype "phase-space" explored (2nd paper submitted)*

The construction of an even larger prototype is not justified.
(functional chaining test of 4 un-Bulked MICROROC ASUs (2 m long SLAB) successful)

→ *Sparks can be suppressed with R-layers*

Signal linearity seems preserved up to 5 GeV (for electrons) but...
Is linearity preserved at higher energies?

Consequence on rate capability observed & understood.
What is the minimum resistivity necessary to insure protection against sparks?

→ Further prototyping (lower resistivity) & testbeams necessary.

Roadmap 2014-2015

Complete the resistive Micromegas R&D: optimise R-layer for calorimetry.

Prototyping (2014), testbeam (2015).

Micromegas Project Overview (2/2)

In addition: construction of a Micromegas calorimeter prototype

THE project to keep us busy until a positive Japanese decision: 2014 – 2017.
Unfortunately, proposal to French funding agency not accepted.

Built so far: 4 layers of 1x1 m^2, each equipped with 6 ASU of 32x48 cm^2

Is recycling possible?
→ 24 small layers + couple of new resistive ASUs (200 ASIC left) = 30 layer stack

If yes, we have a physics case: (analogue) study of EM showers (2015-2016).
If not, we'll build 1 or 2 1x1 m^2 resistive prototypes (2015), depending on funding.

In parallel

Publish papers (shower profiles & response, resistive prototypes)

Continue collaboration with Weizmann's THGEM (MR setup, common testbeam?)

Continue analysis effort of RPC-SDHCAL testbeam data

Follow CMS HG-CAL developments for forward upgrades (GEM/uM for backend)
→ common R&D with Saclay & Demokritos on R-Micromegas

Micromegas Project Overview

→ *1x1 m^2 large-area prototype "phase-space" explored (2nd paper submitted)*

The construction of an even larger prototype is not justified.
(functional chaining test of 4 un-Bulked MICROROC ASUs (2 m long SLAB) successful)

→ *Sparks can be suppressed with R-layers*

Signal linearity seems preserved up to 5 GeV (for electrons).
Is linearity preserved at higher energies?

Consequence on rate capability observed & understood.
What is the minimum resistivity necessary to insure protection against sparks?

→ Further prototyping & testbeams necessary.