Digital versus semi-digital readout

Simulation and energy reconstruction
First trial on SDHCAL-RPC TB data

07/02/2013

Simulation

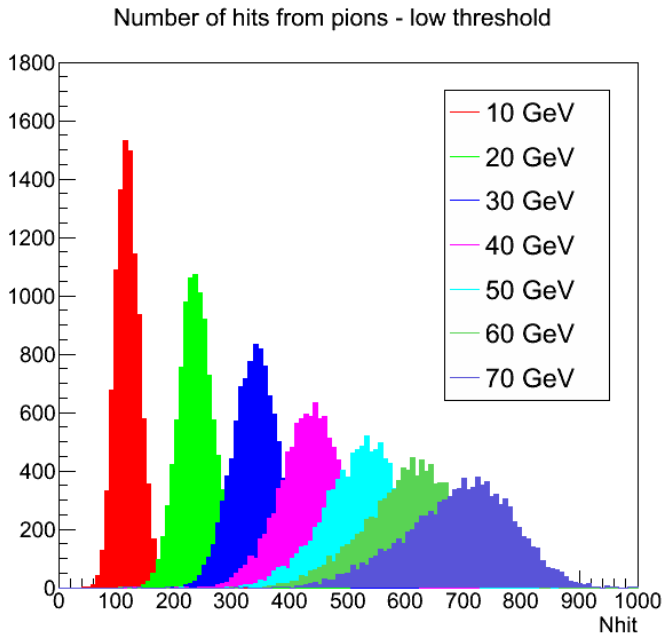
- Geometry
  - 100 Micromegas layers of 1x1 m2
  - SDHCAL absorbers
- Data set
  - 10000 pion events from 10 to 70 GeV, every 10 GeV
- Digitisation
  - Low threshold at 15 eV (gas ionisation potential)
  - Medium threshold at 5 MIP (set in keV from muon Landau distribution)
  - High threshold at 15 MIP (set in keV from muon Landau distribution)

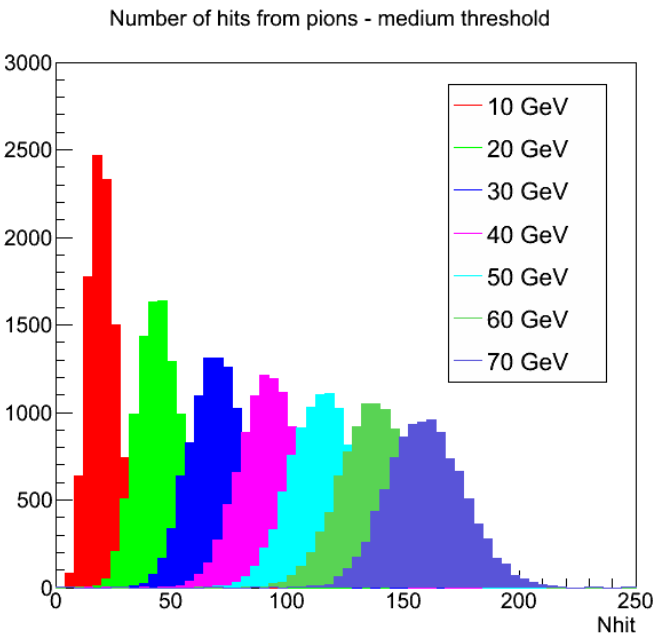
Nhit distributions – 3 thresholds

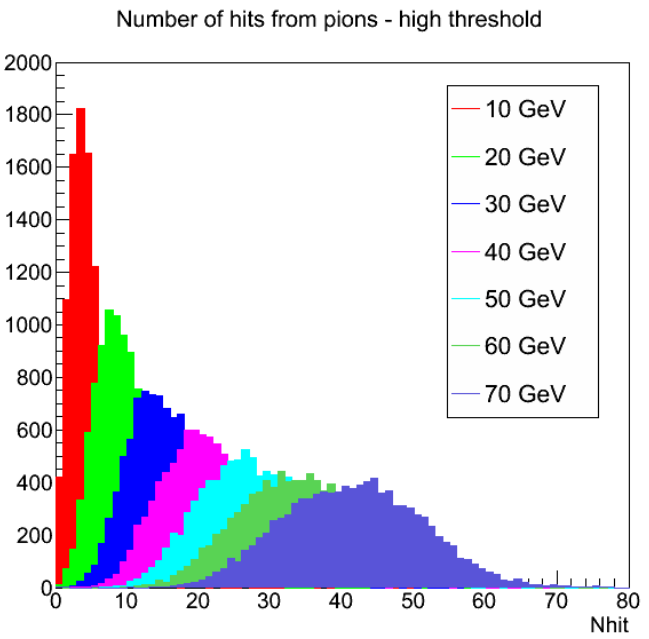
Low thr.

Medium thr.

High thr.







~ 0 MIP

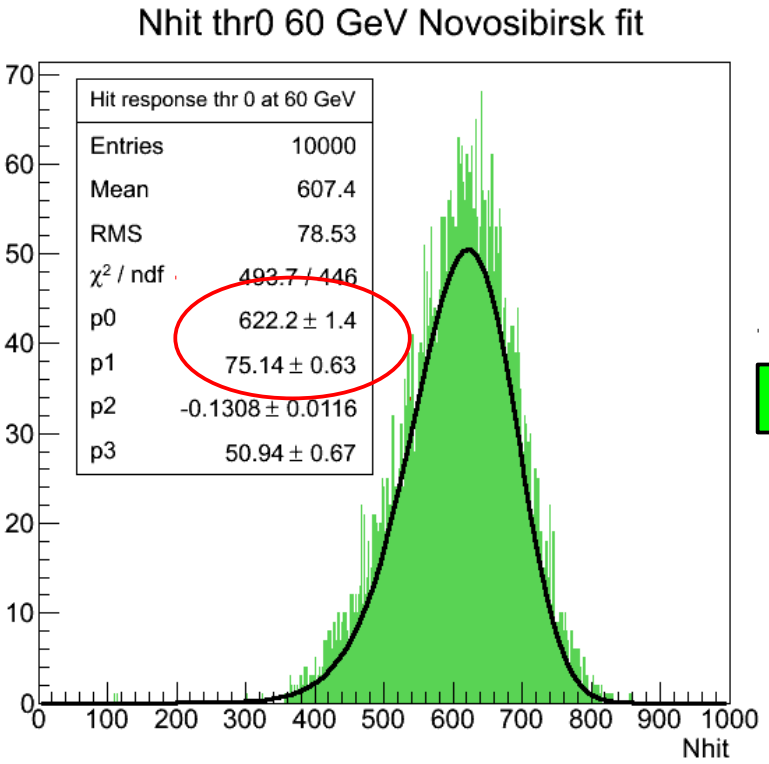
5 MIP

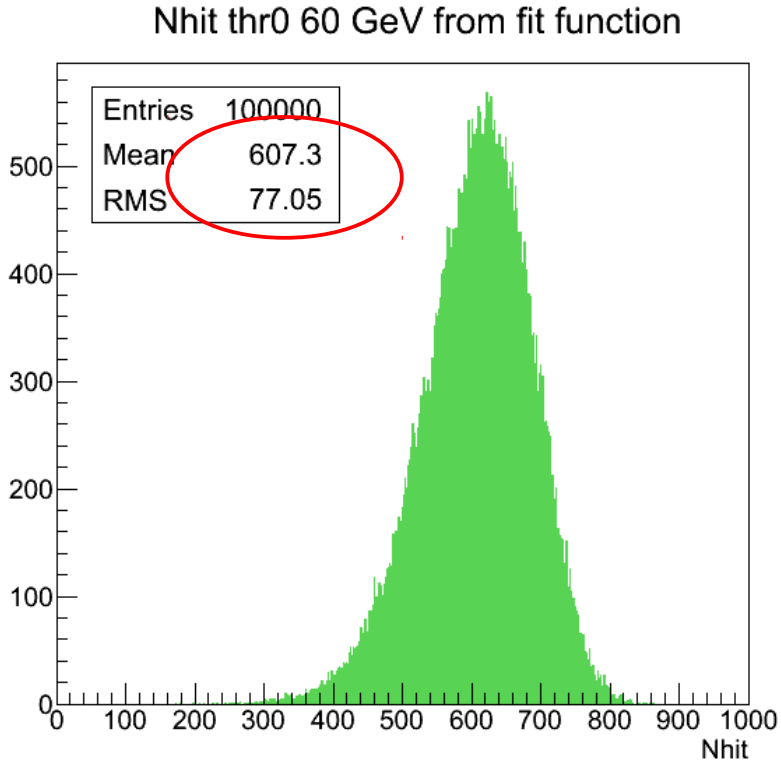
15 MIP

Distribution moments

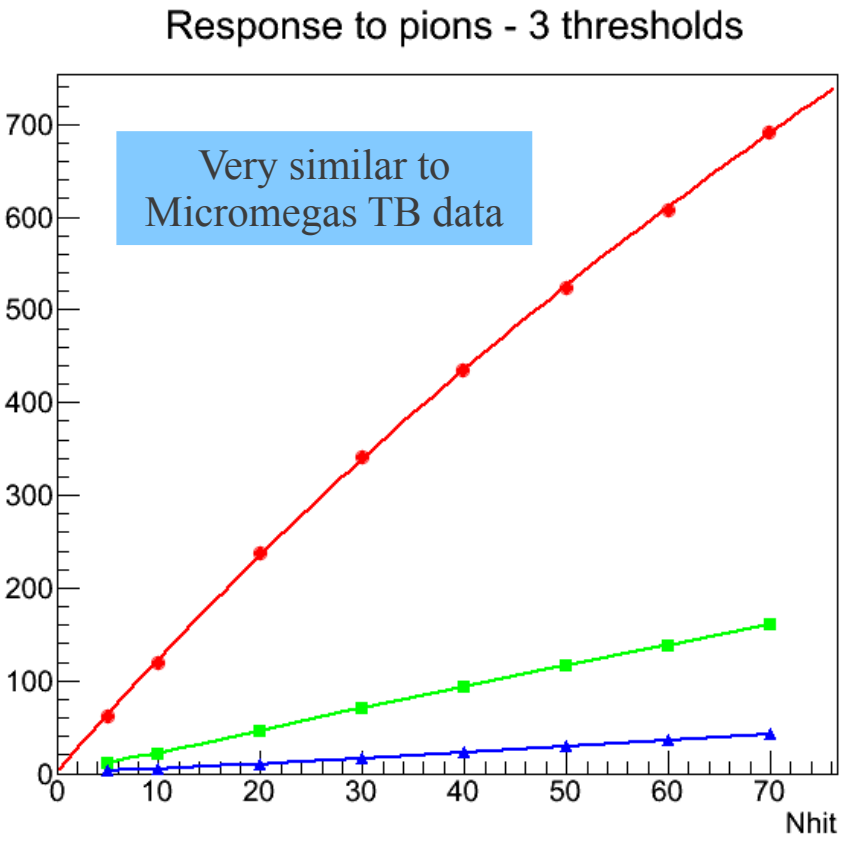
Get RMS and MEAN from smoothed distribution instead of fit parameters
→ MEAN not over-estimated
→ RMS not under-estimated

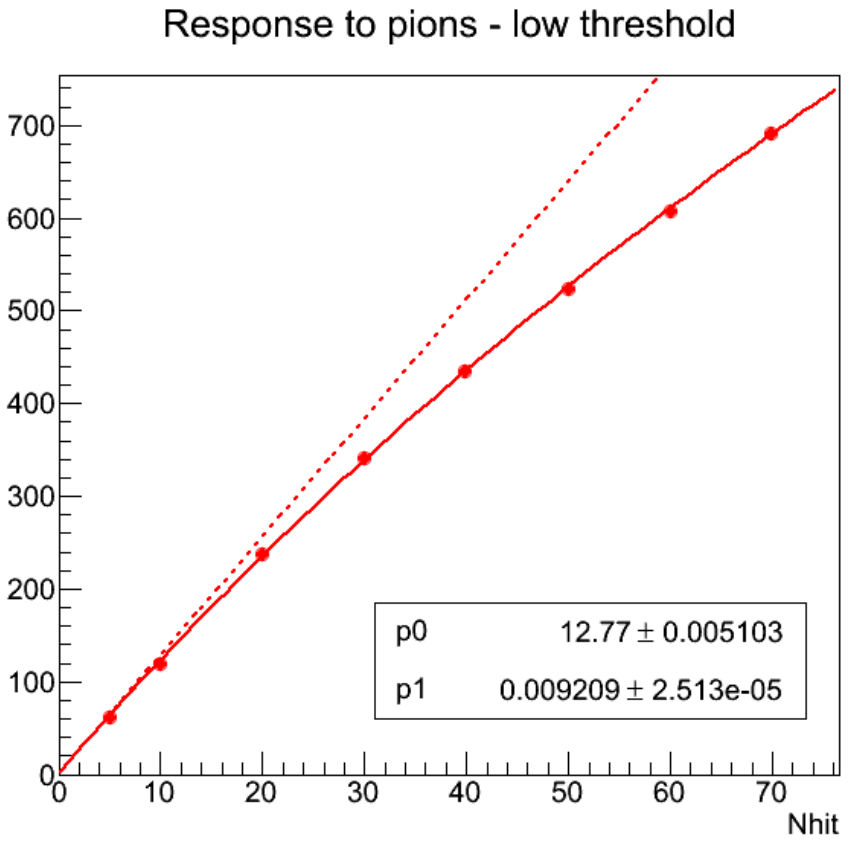
1. Fit Novosibirsk function to histo1
2. Fill histo2 from fit function (10^5 entries for a smooth histo)
3. Get MEAN and RMS of histo2





Response to pions in Nhit

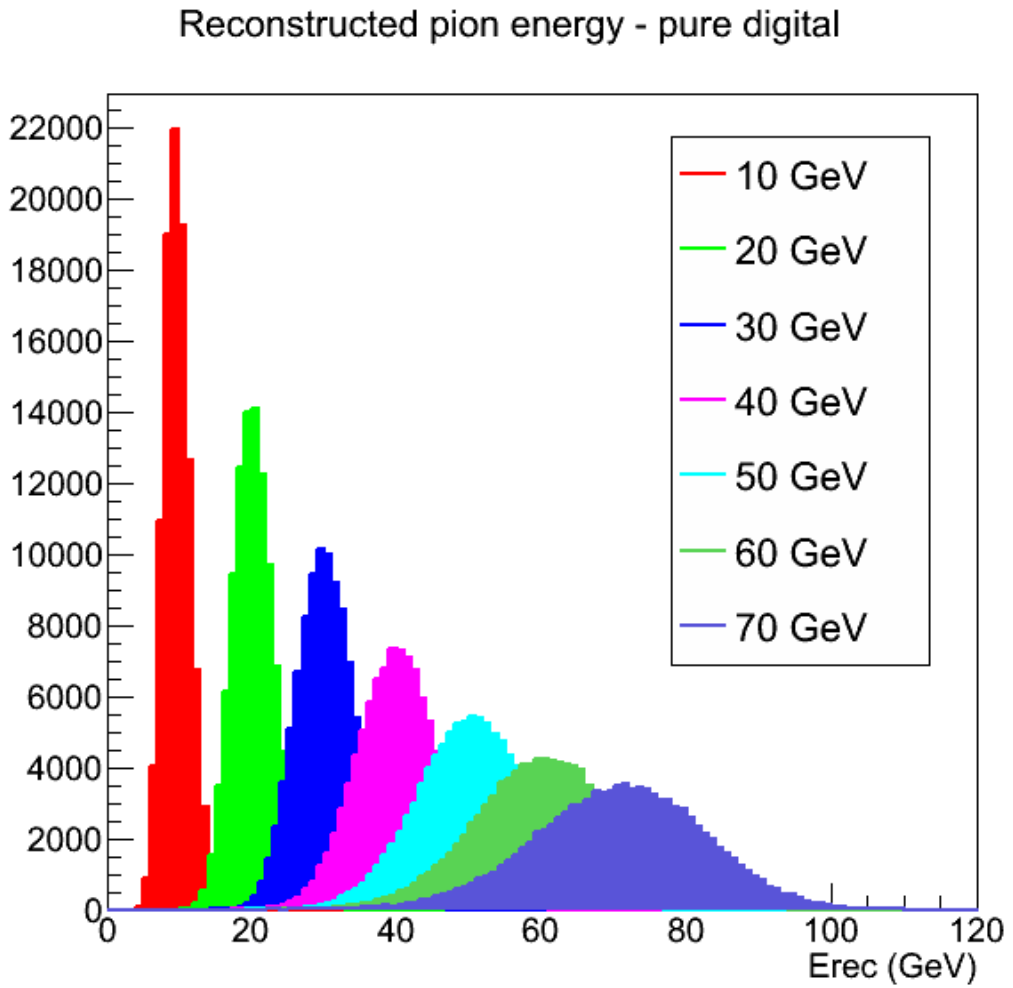




Fit function: N0 = [0]/[1] * log(1 + [1] * E)
Work only for the low threshold: medium thr. ~ linear
while high thr. rises faster than linear

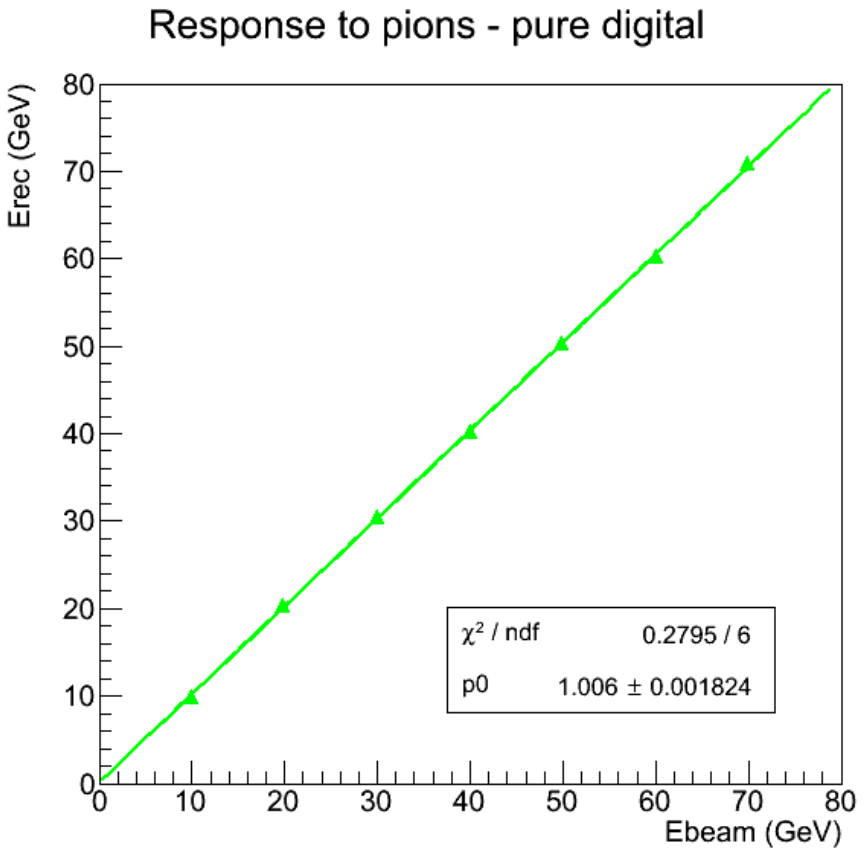
Energy reconstruction - pure digital

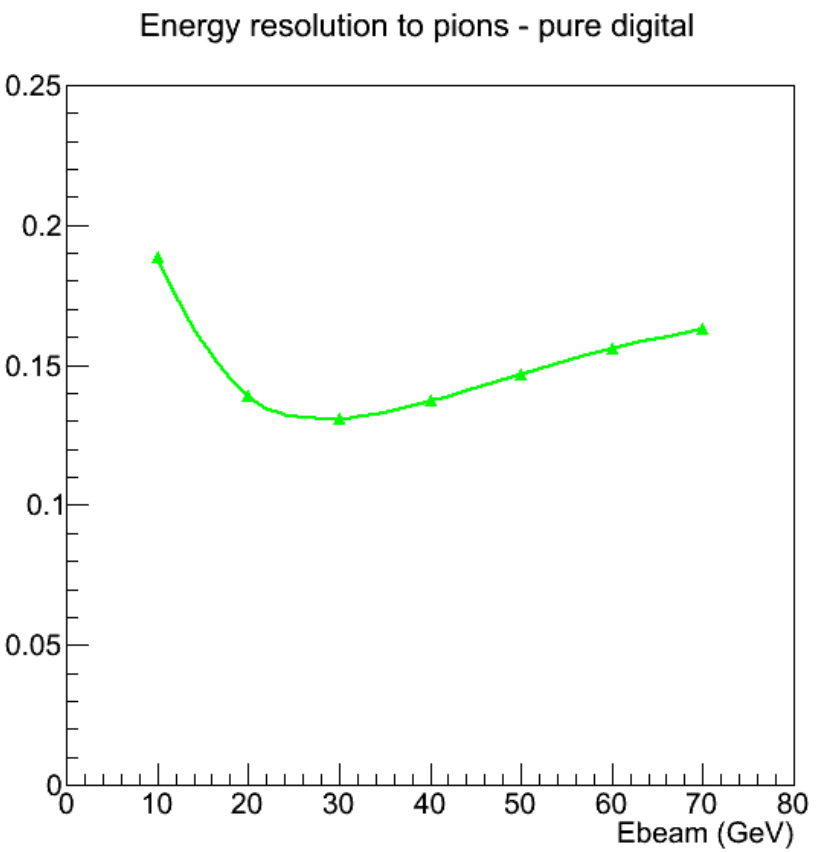
Inverse fit function: E = exp([1] / [0] * N0 – 1) / [1]



Performance for pure digital

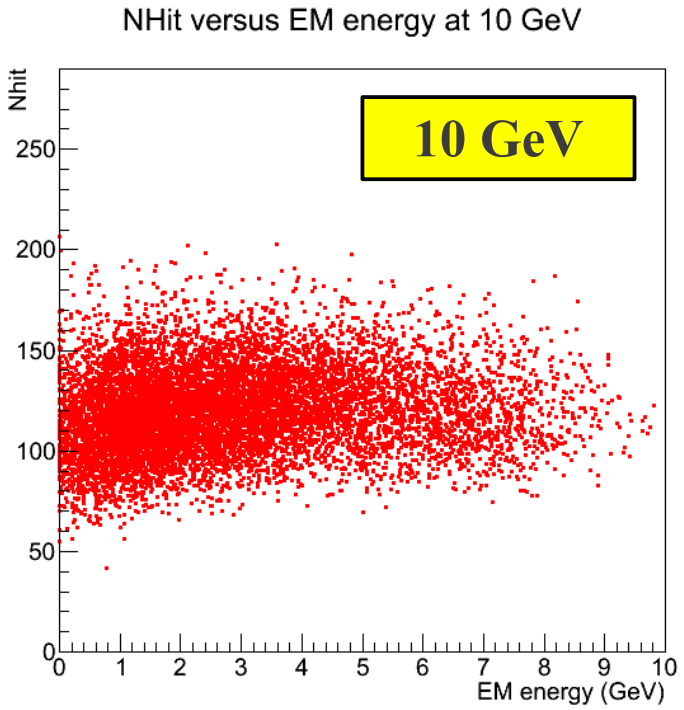
Linearity almost perfect (no surprise, we used the inverse of the response)
However, corrections degrade the energy resolution above at 30 GeV

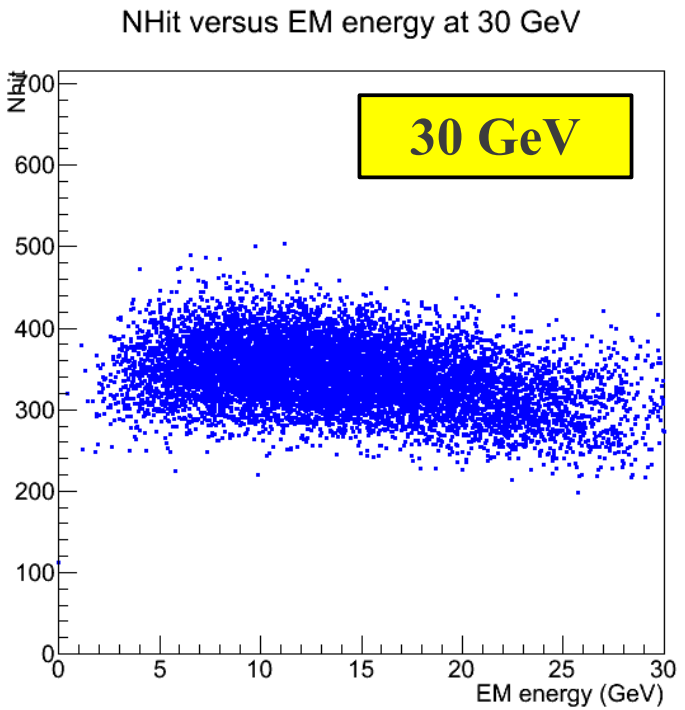




Degradation of the resolution

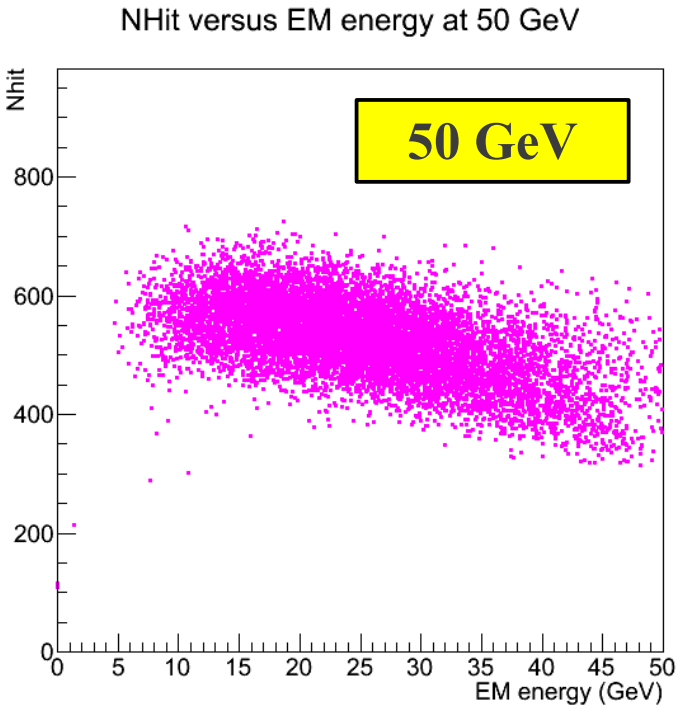
The EM fraction of hadron showers increases with energy.
With a digital readout → saturation of Nhit → worse resolution.

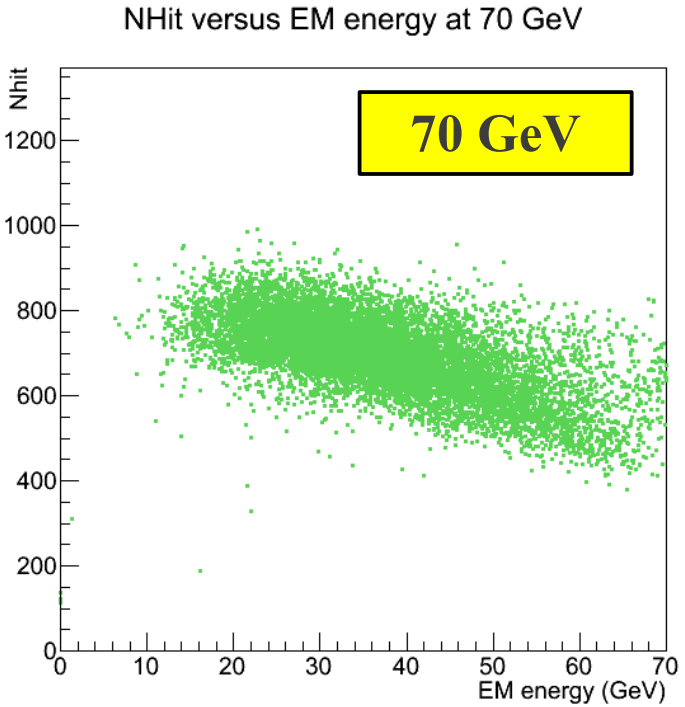




Degradation of the resolution

The EM fraction of hadron showers increases with energy.
With a digital readout → saturation of Nhit → worse resolution.





Energy reconstruction - semi-digital

Maximum likelihood method

Calculate at each energy, the probability to observe (N0,N1,N2)
The best estimate of the energy is then the one for which the probability is maximum

Hypothesis

N0, N1, N2 are not correlated
(verified in 2D plots and with correlation coef. centred at 0)

→ p(N0,N1,N2) = p(N0) * p(N1) * p(N2)

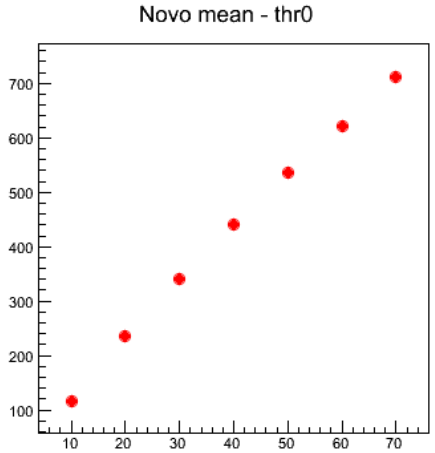
Calculation of probability

Parametrise the energy dependence of Novosibirsk fit parameters (mu,sig,tail,norm)
Normalised distributions → p(Ni,E) at any energy in the parametrisation range

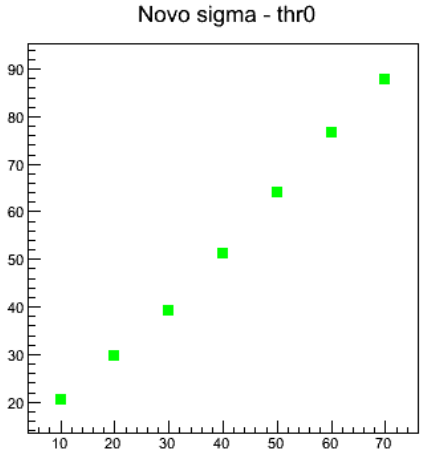
Energy parametrisation - thr0

Calculation of probability

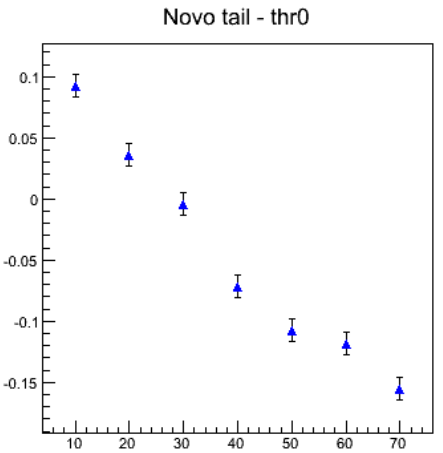
Parametrise the energy dependence of Novosibirsk fit parameters (mu,sig,tail,norm)
Normalised distributions → p(Ni,E) at any energy in the parametrisation range



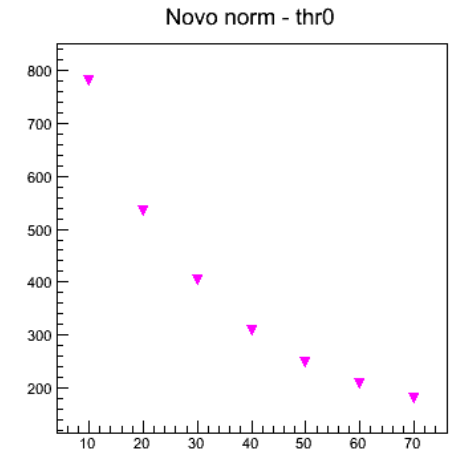
Mean



Sigma

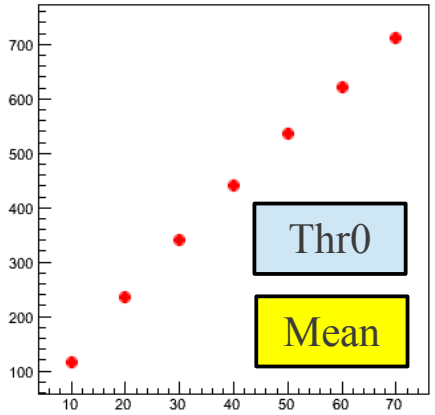


Tail

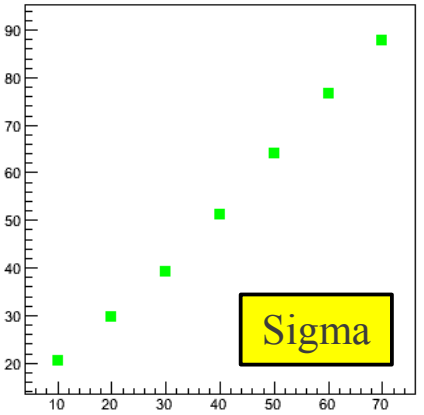


Norm

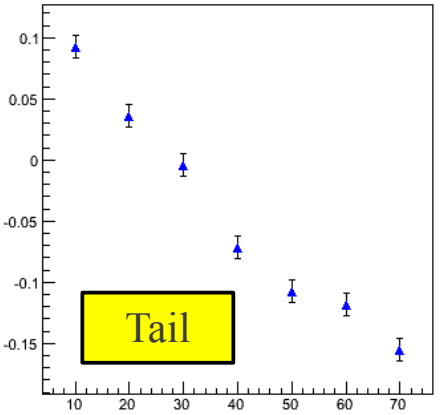
Novo mean - thr0



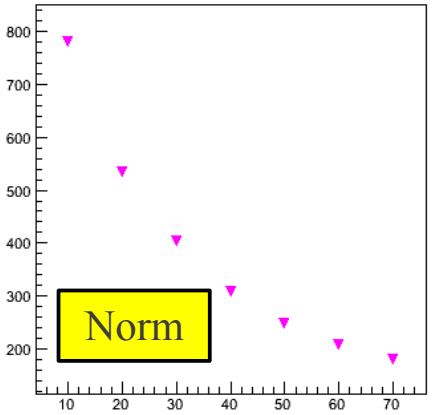
Novo sigma - thr0



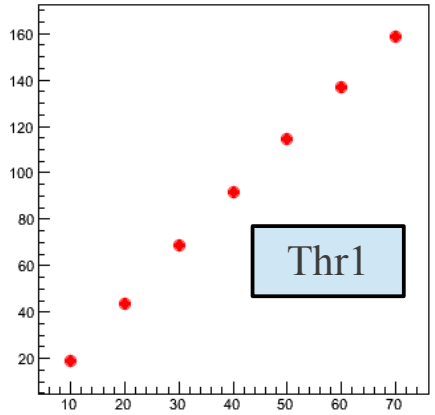
Novo tail - thr0



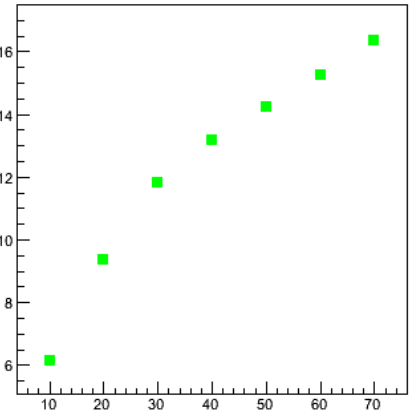
Novo norm - thr0



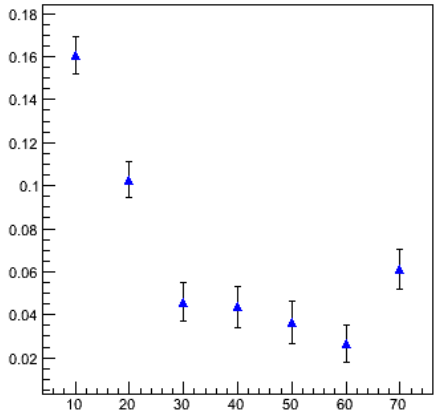
Novo mean - thr1



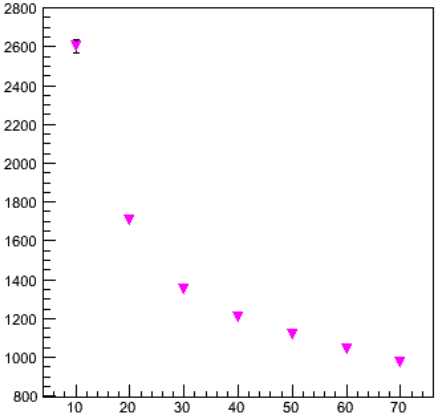
Novo sigma - thr1



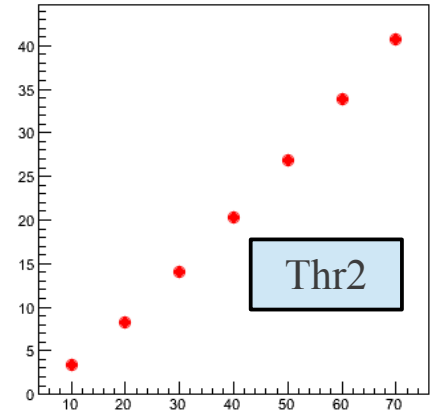
Novo tail - thr1



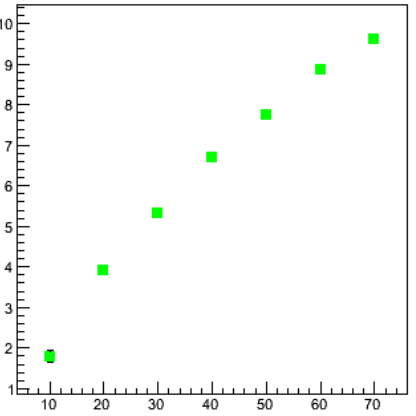
Novo norm - thr1



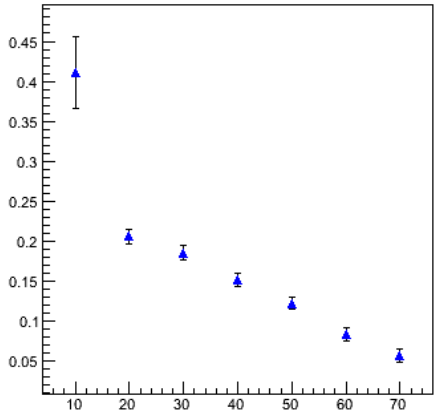
Novo mean - thr2



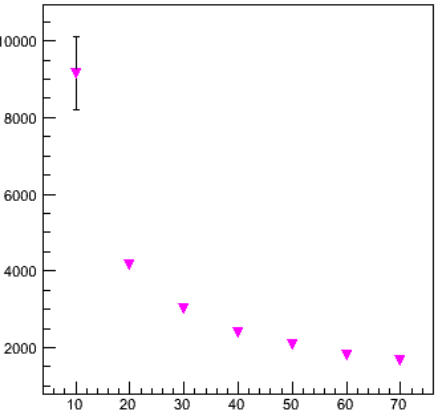
Novo sigma - thr2



Novo tail - thr2



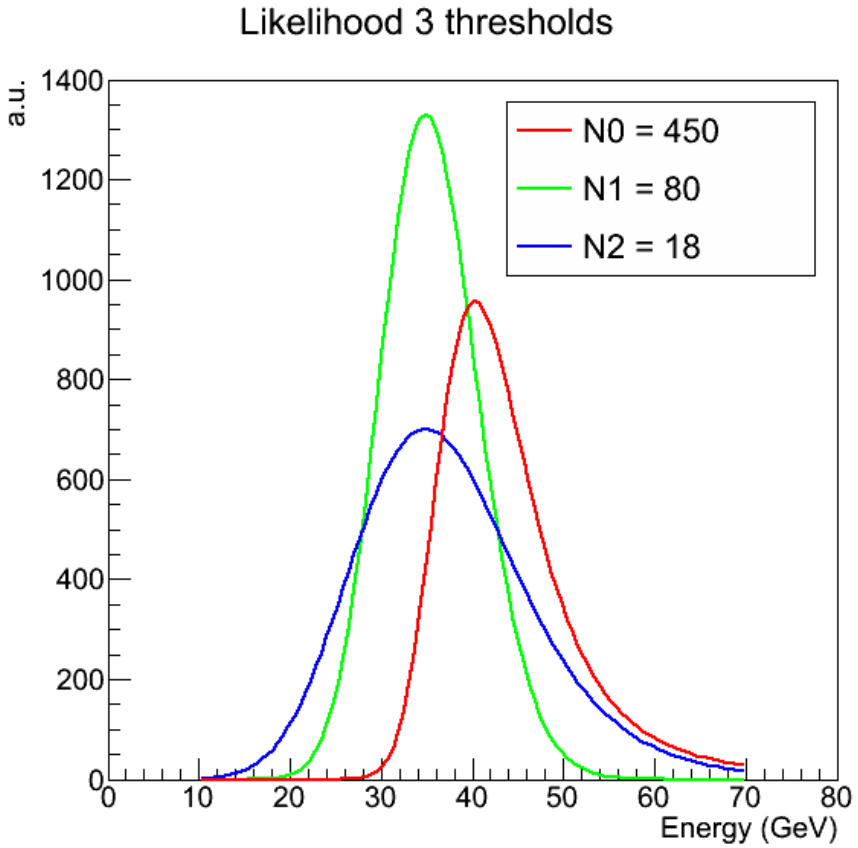
Novo norm - thr2



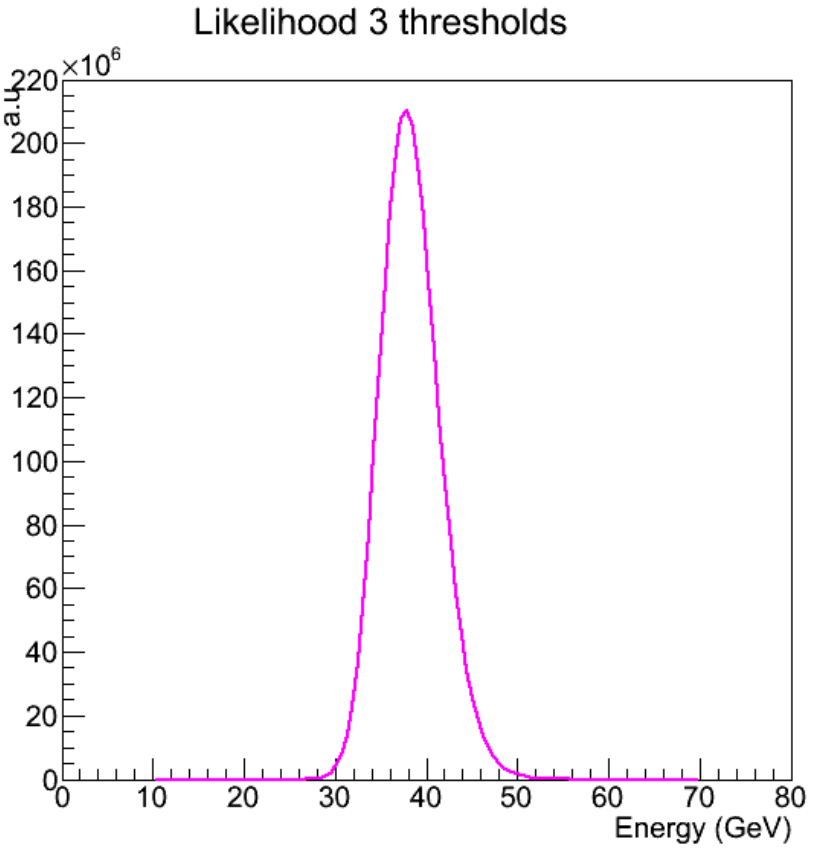
Energy parametrisation - thr0

Calculation of probability

Parametrise the energy dependence of Novosibirsk fit parameters (mu,sig,tail,norm)
Normalised distributions → p(Ni,E) at any energy in the parametrisation range

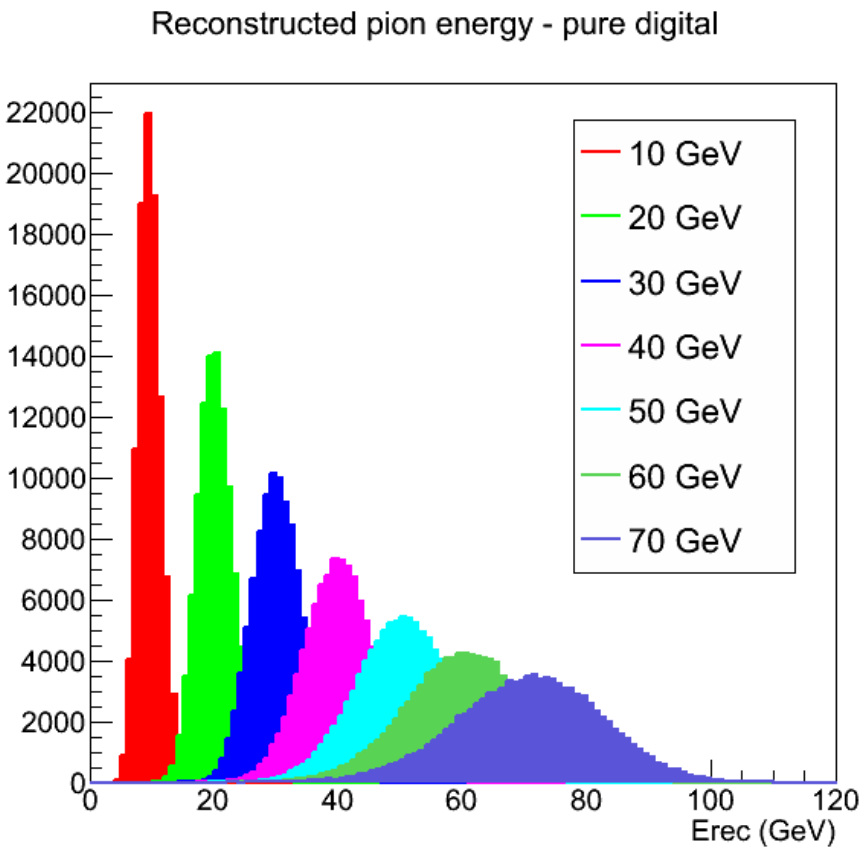


product

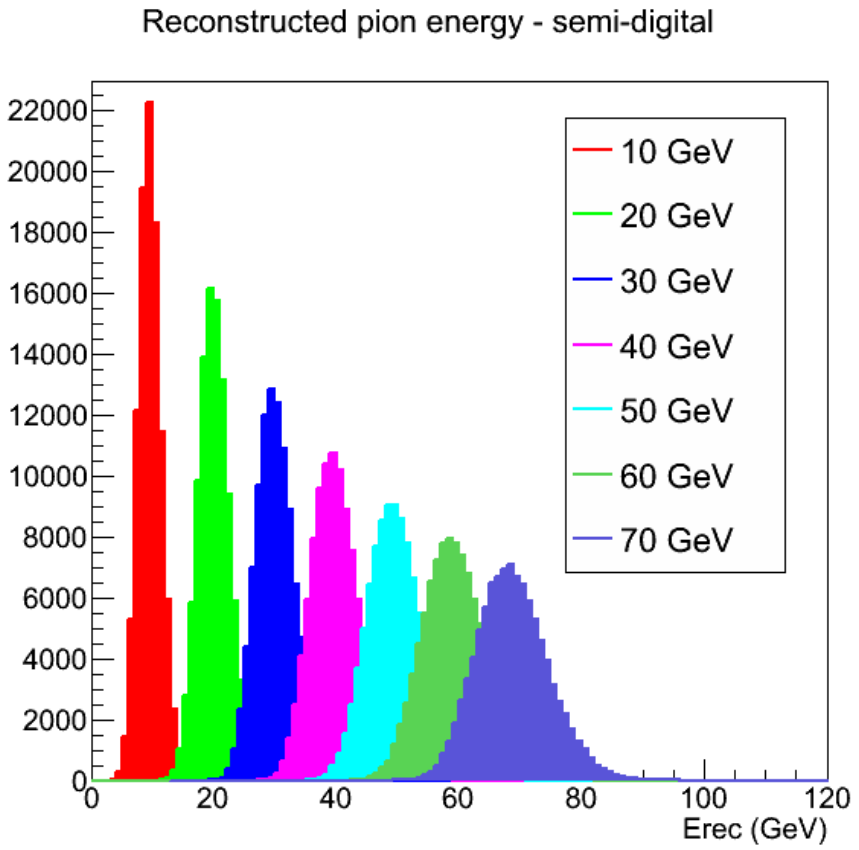


Energy reconstruction - semi digital

Pure digital



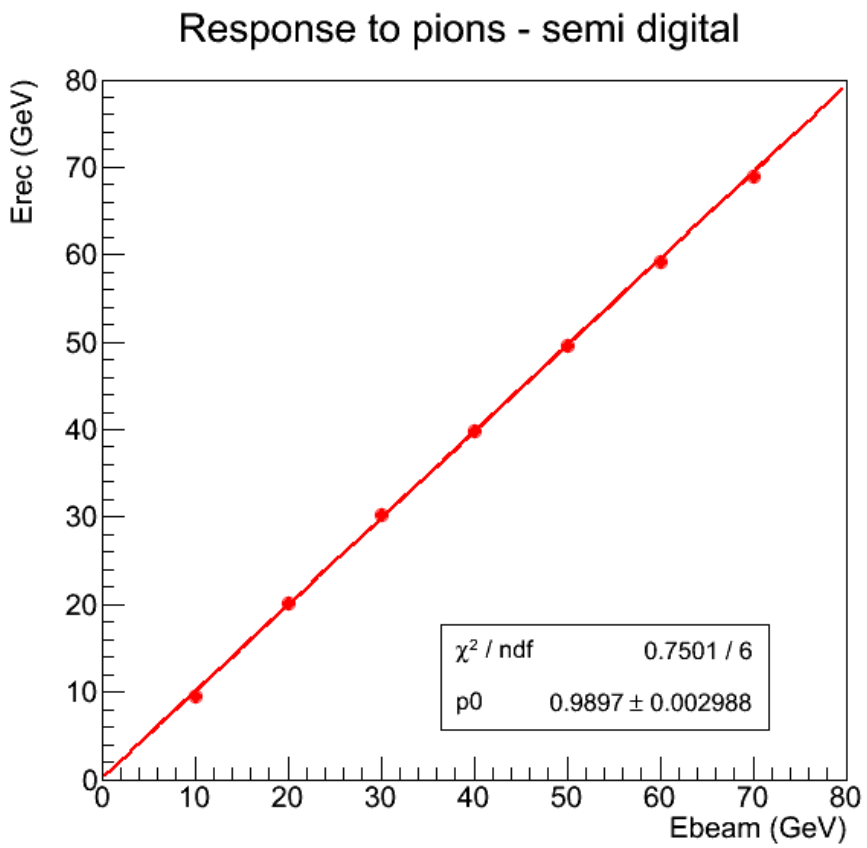
Semi digital

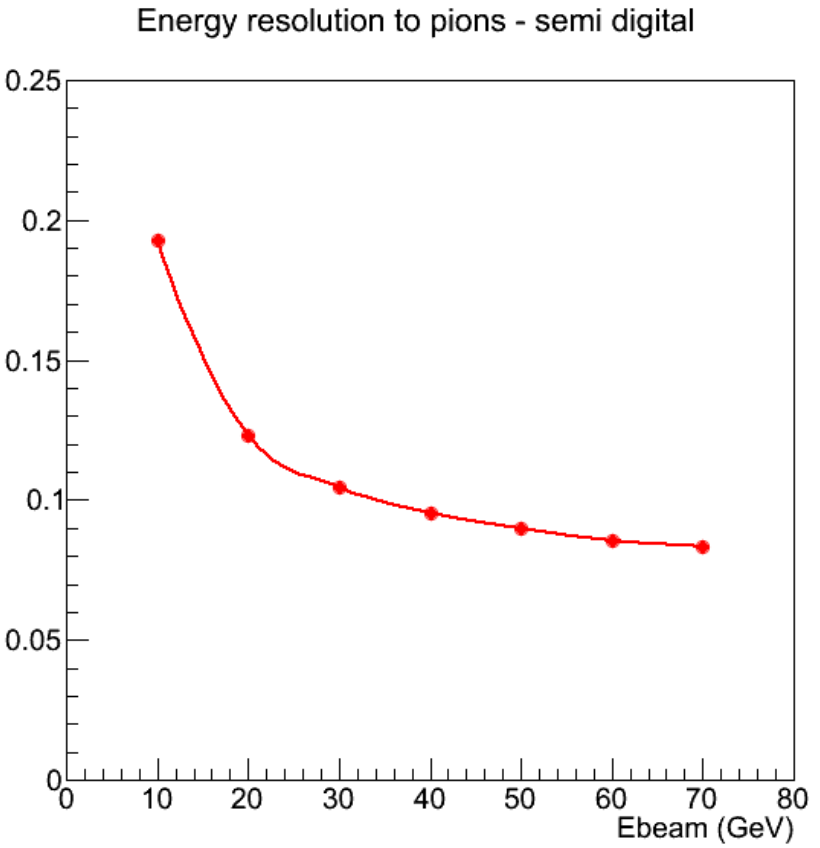


Distributions are more symmetrical!

Performance semi-digital

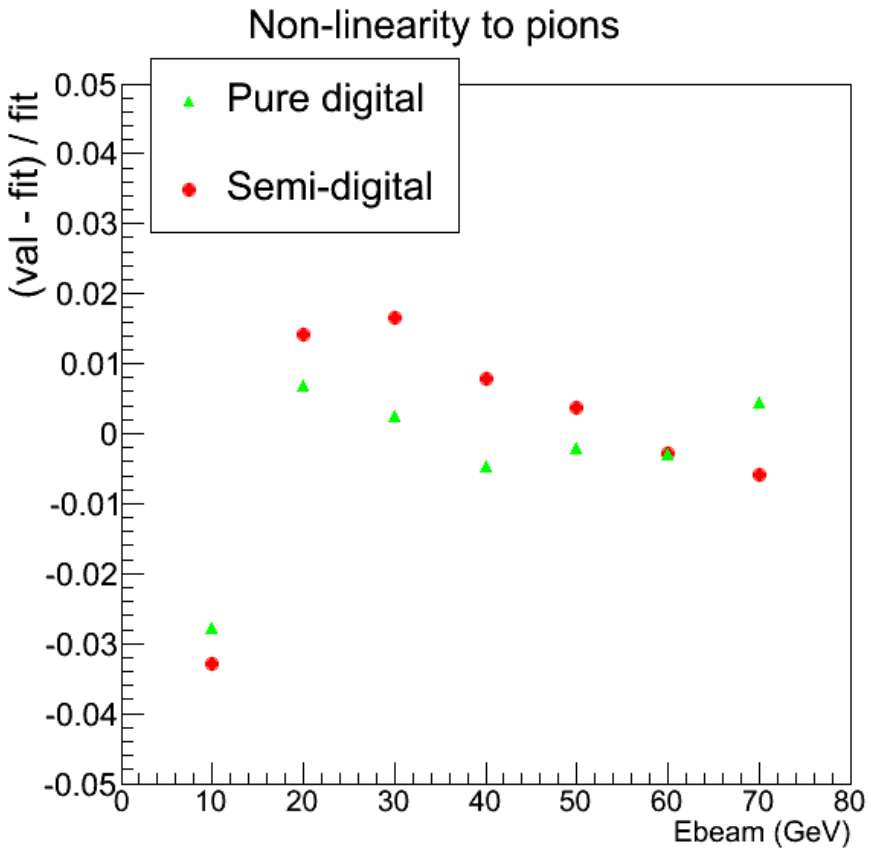
Linearity slightly worse than with pure digital (for which it had to be ~ perfect)
No degradation of resolution: OFFLINE COMPENSATION works!

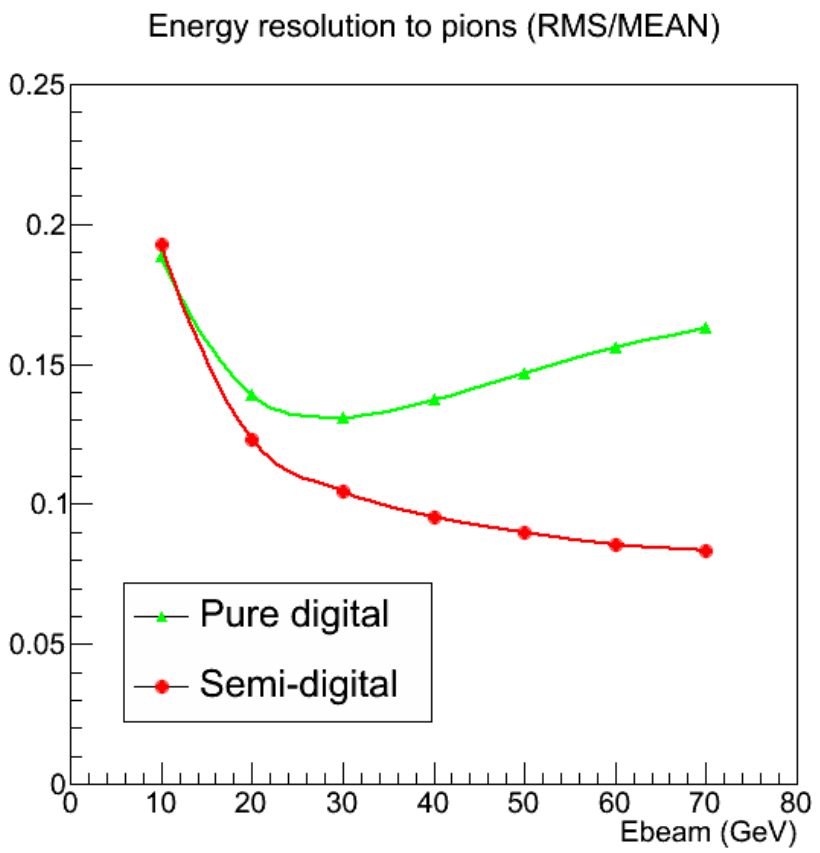




Comparison pure/semi digital

Semi-digital non linearity below 4% at 10 GeV, below 2% in 20-70 GeV
Energy resolution: improvement already at 20 GeV





Next steps

Apply semi-digital energy reconstruction method to RPC testbeam data (hoping the detector is proportional...)

Add more discrimination power to likelihood method

→ barycentre of hits along beam axis is correlated to the beam energy

→ also: radial position of hits?

SDHAL/RPC testbeam data

August-Sept. Period: H6, better beam conditions claimed by RPC group

Difference with simulation:
100 perfect layers → 47 layers → leakage (in addition to geom. saturation)
Environmental variations → systematics
Proportional signals → saturated signals (?)
Pure samples → electrons, pions, cosmics, muons → PID

Before parametrisation of Novo. function with energy for 3 thresholds
→ many checks!

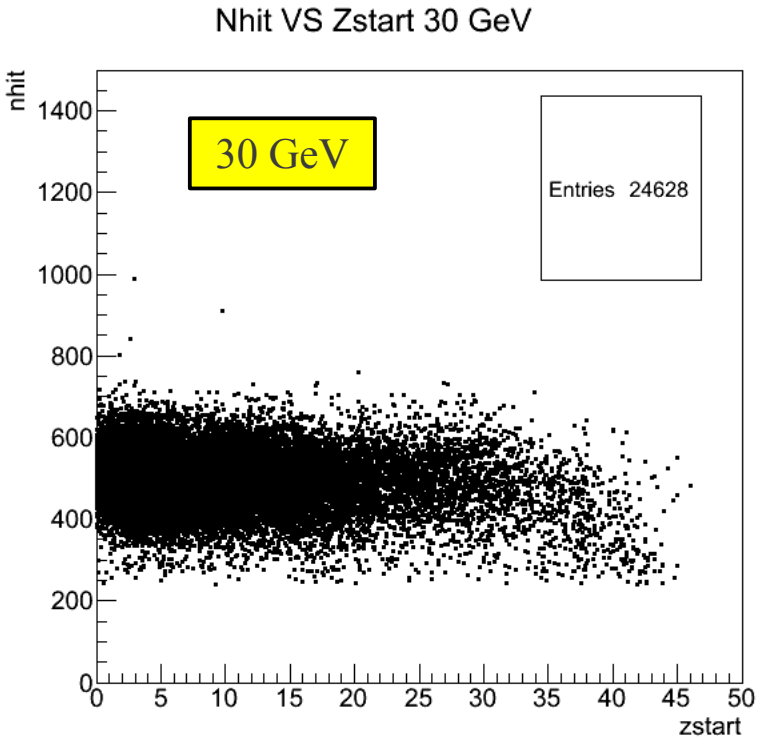
SDHAL/RPC testbeam data

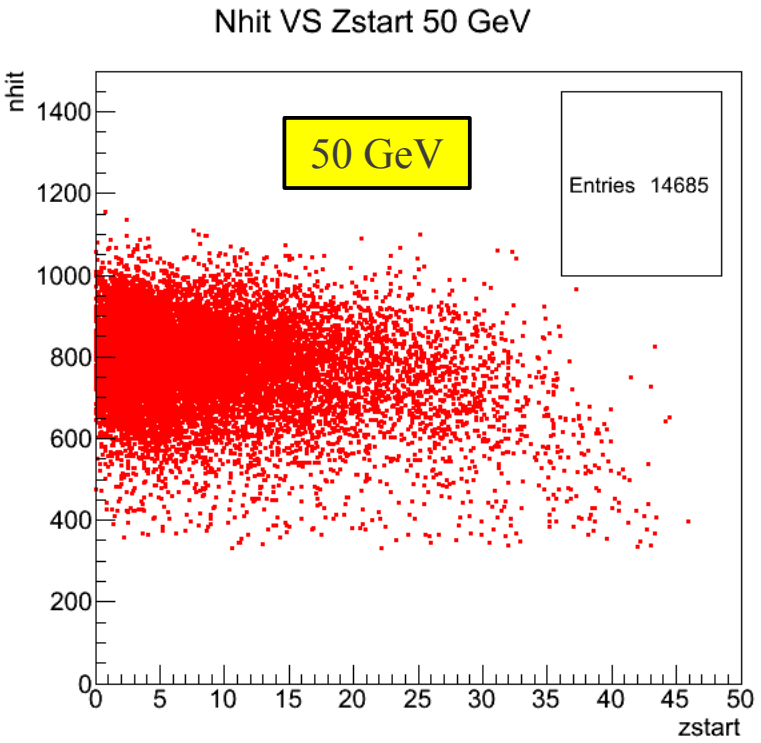
August-Sept. Period: H6, better beam conditions claimed by RPC group

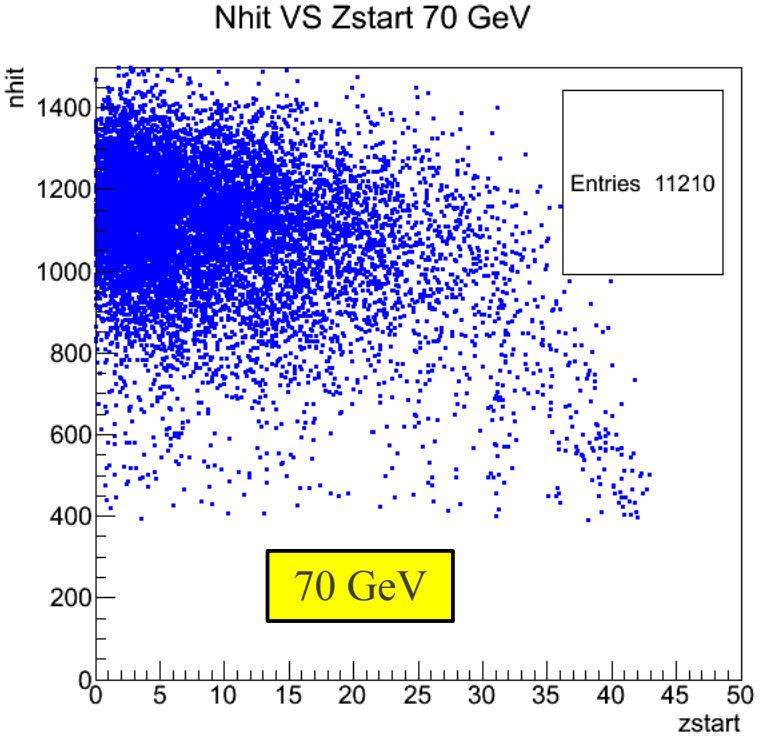
Difference with simulation:
100 perfect layers → 47 layers → leakage (in addition to geom. saturation)
Environmental variations → systematics
Proportional signals → saturated signals (?)
Pure samples → electrons, pions, cosmics, muons → PID

Before parametrisation of Novo. function with energy for 3 thresholds
→ many checks!

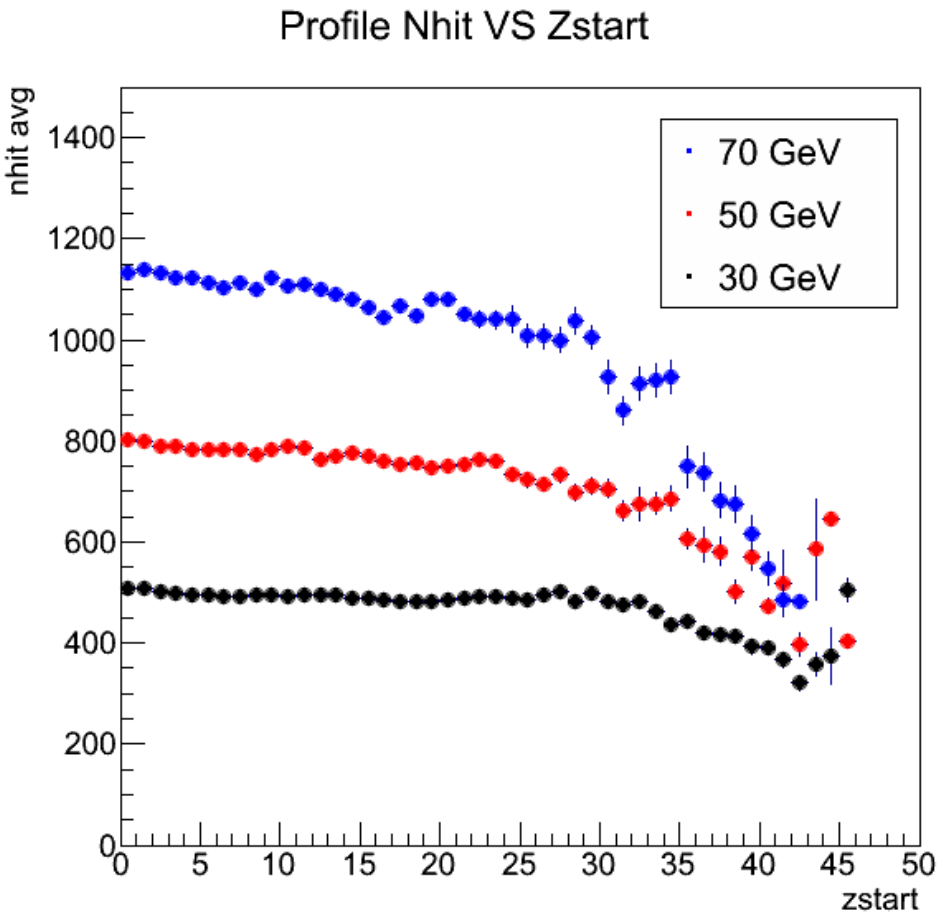
Leakage


Nhit VS Zstart 30 GeV
nhit
30 GeV
Entries 24628
zstart


Nhit VS Zstart 50 GeV
nhit
50 GeV
Entries 14685
zstart

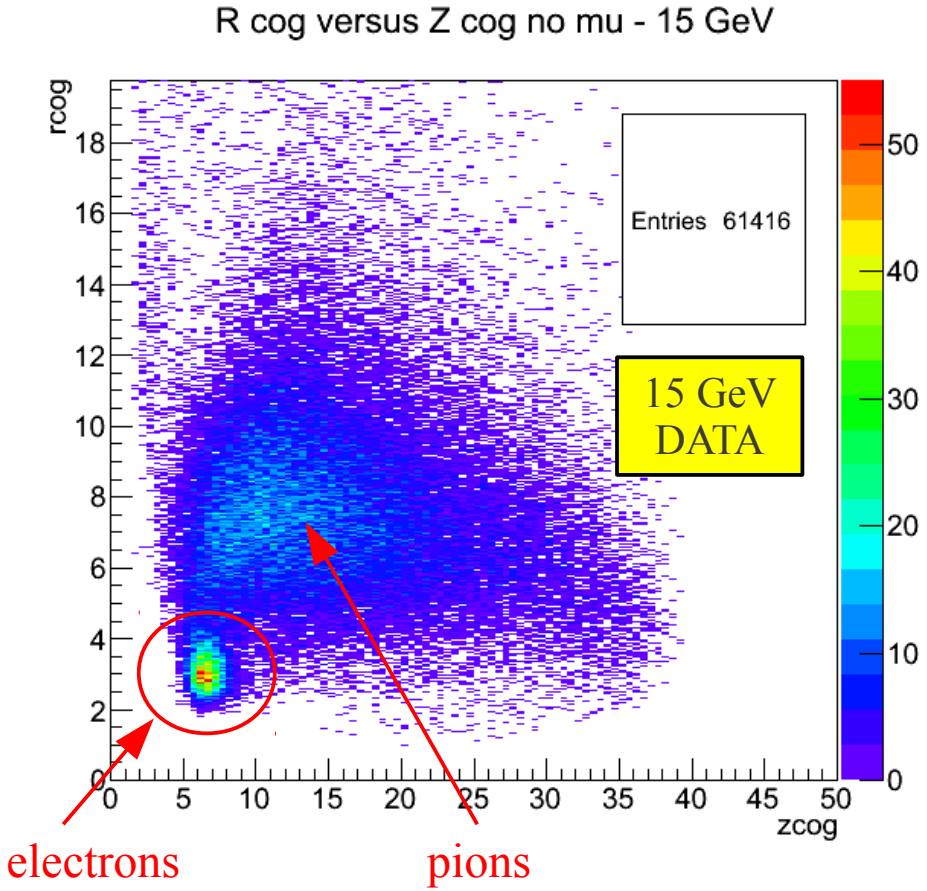

Nhit VS Zstart 70 GeV
nhit
Entries 11210
70 GeV
zstart

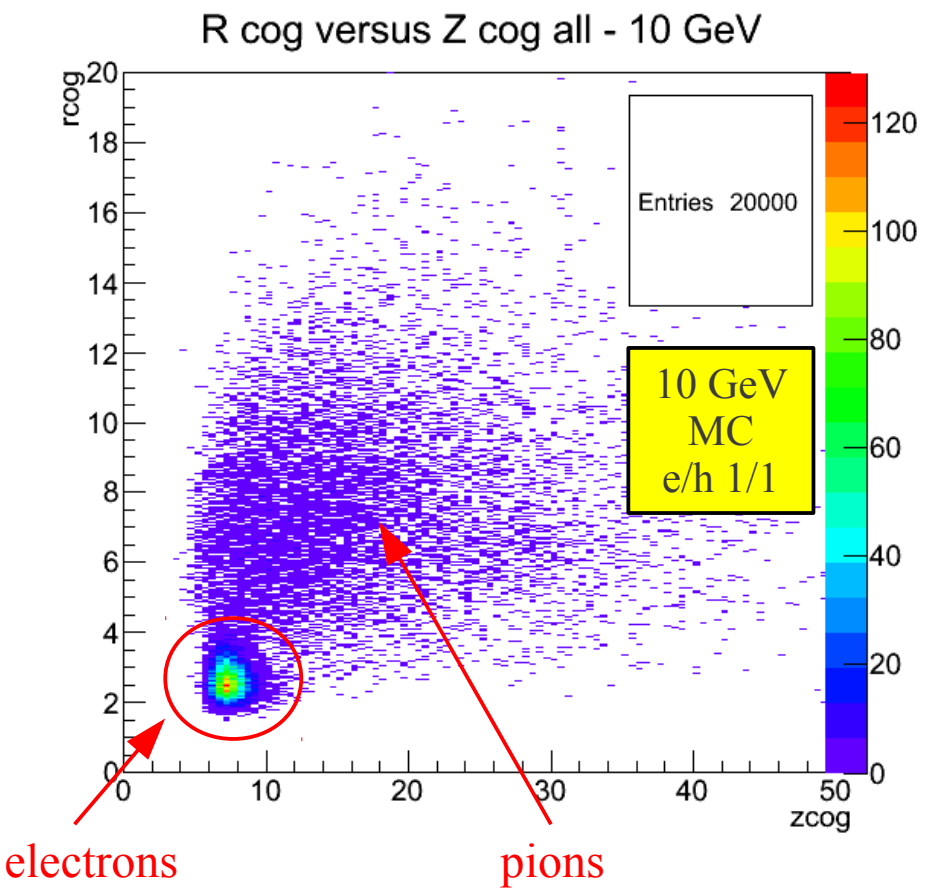
Leakage



→ Select shower starting in 12 first layers
(cut on Nhit in last layers not allowed, would bias the sample)

Sample purity

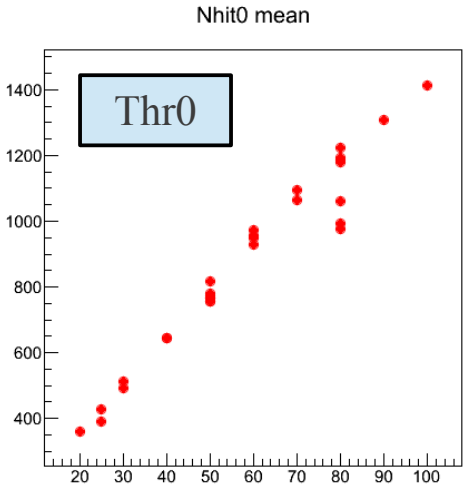


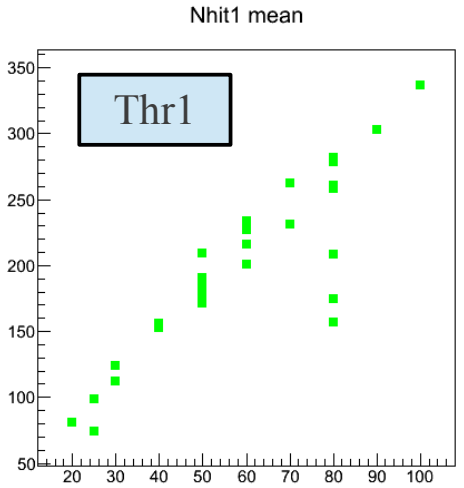


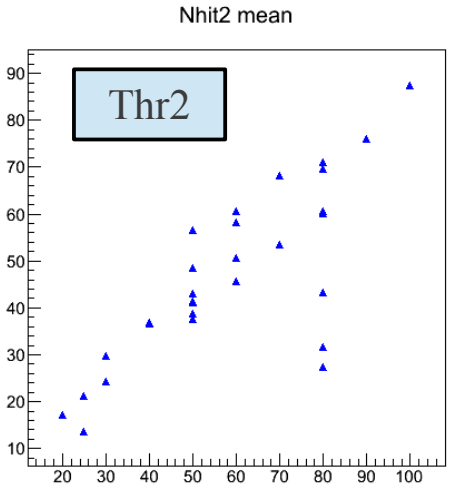
SDHCAL is ~ compensated at low energy → PID e/h based on Nhit useless.
→ Use transverse and longitudinal information
→ Centre of gravity radial and along Z
(proved to work in simulation too)

Systematics

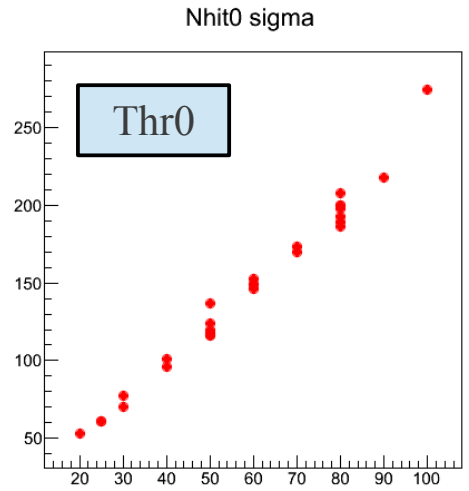
Mean

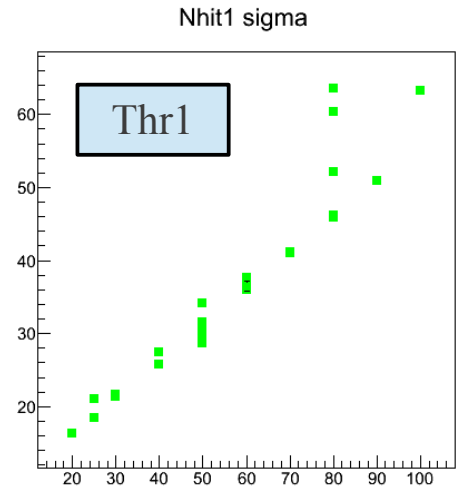


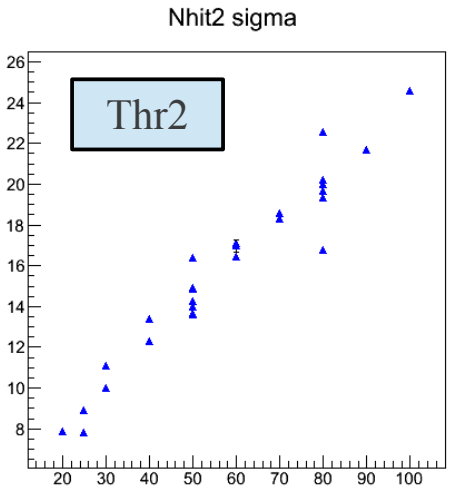




Sigma







At a given energy, the Novosibirsk parameters show some spread for 3 thr.
The trends with energies are to be understood...

Conclusion

It seems that we have a method that improves the energy resolution by using the semi-digital information.

Lot of work still to understand the RPC data...
… hoping it is possible.