Semi-digital Analysis of AHCAL data

Testbeam CERN 2010

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CALICE Collaboration Meeting 2013
Annecy, 10.09.13

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- Multi-threshold combination methods
- Implementation of the RPC SDHCAL group method
- Results
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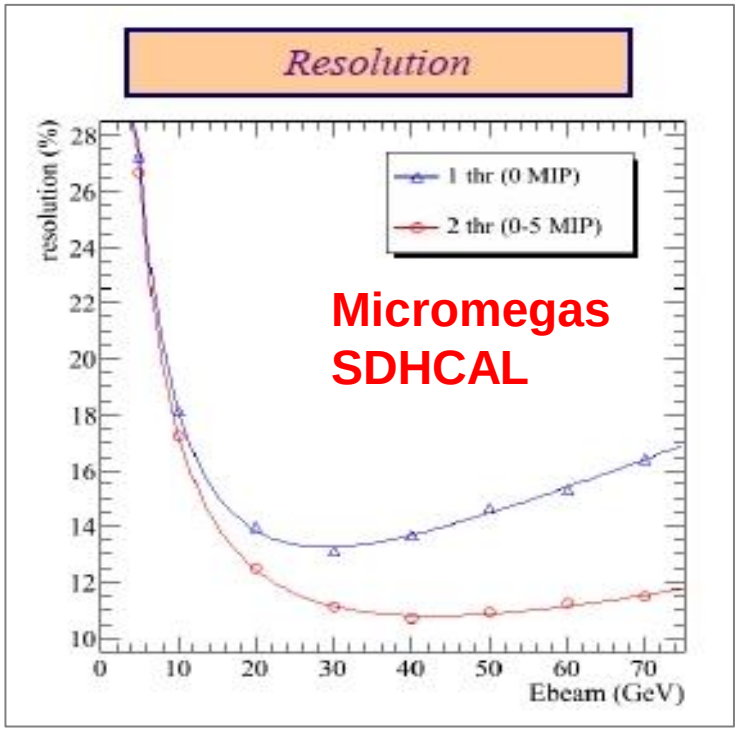
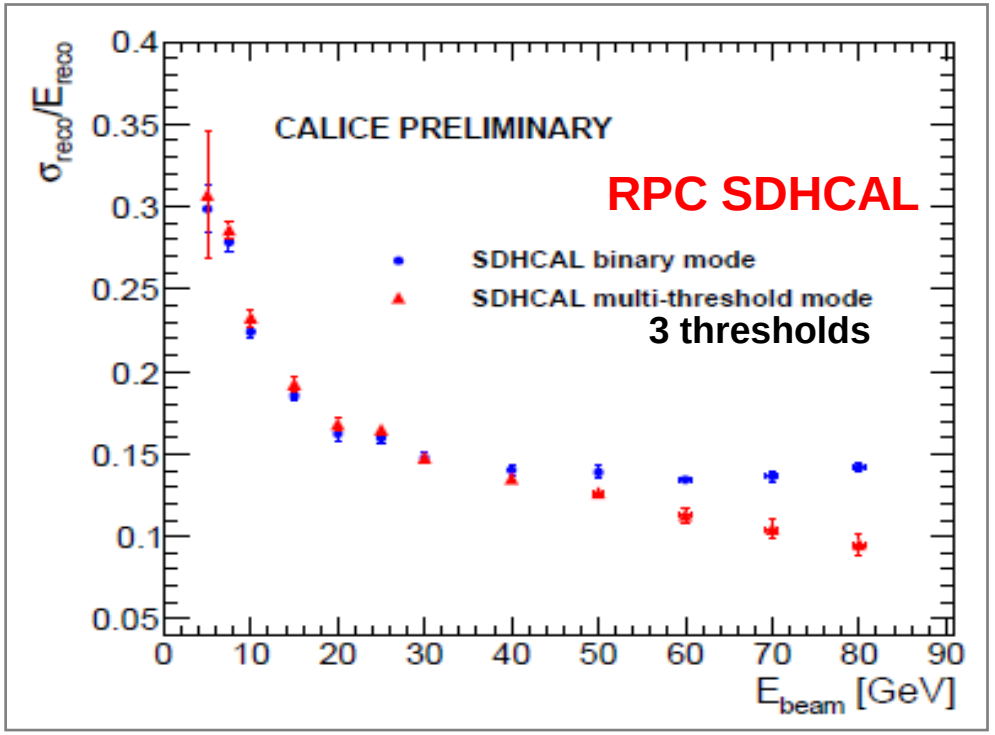
Motivation

- Understanding of comparability of AHCAL and DHCAL approach
- Personal: analog principle and digital Analysis
- Influence of “thresholding” on AHCAL resolution



“Off-line compensation of a SDHCAL a MC study”, CALICE collaboration meeting Hamburg 2013, M.Chefdeville, I. Koletsou, Y.Katyotakis



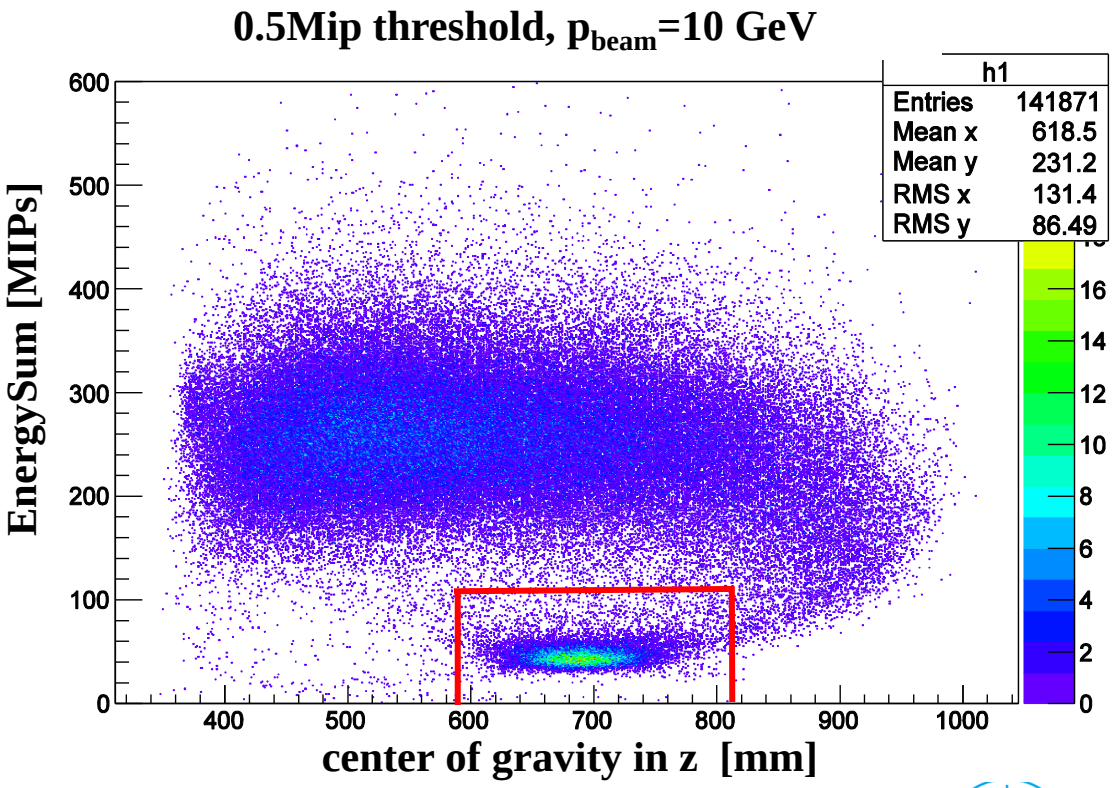
CALICE Analysis Note CAN-037, G. Grenier, Nov. 2012

TB CERN 2010 – pion selection

RunNumbers: 360463, 360774, 360771, 360767, 360737

- TB provided beam momenta 2-10 GeV, Absorber: Tungsten, 30 layer of ScHCAL (3x3cm^2)
- Pion selection: BeamBit, BadLedCut, VetoRegion Cut, List of noisyCells, Cherenkov Counter
- Muon rejection:
  Different cuts on the energy sum and number of hits for different energies

P_{beam} [GeV]	Pion events
2	16.2%
4	32.8%
6	35.6%
8	37.1%
10	41.1%

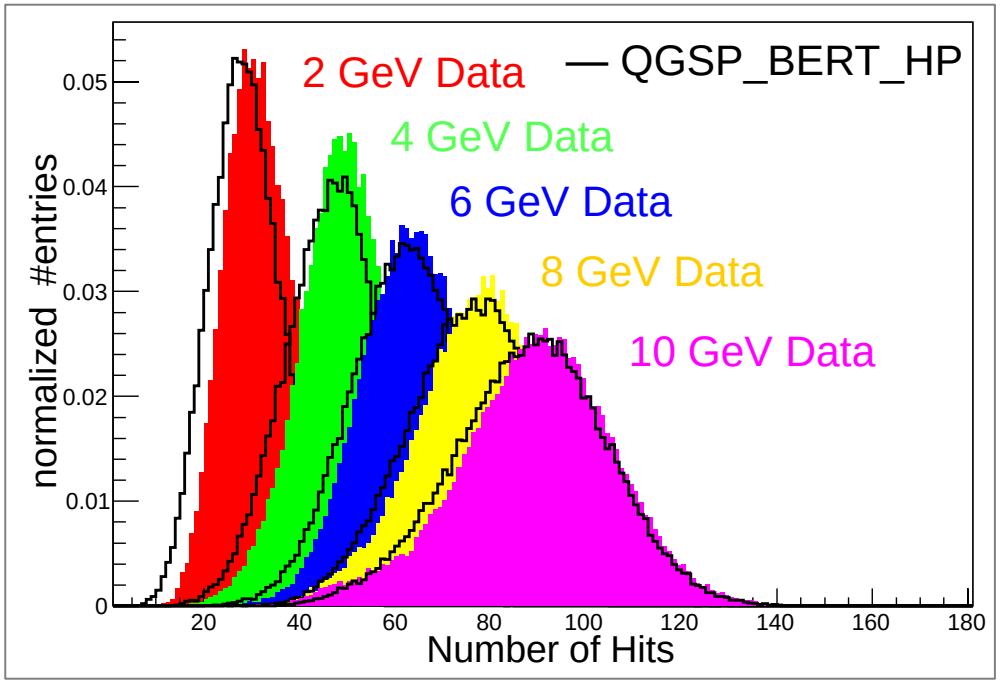


TB CERN 2010 – number of Hits

- Additionally a Monte Carlo Sample was generated:
  - Particle gun position directly (3mm) in front of the HCAL (punch through pions/muons seen)
  - Cuts: preShowerCut, VetoRegionCut, BadLED and MuonRejectionCut

0.5 MIPs threshold

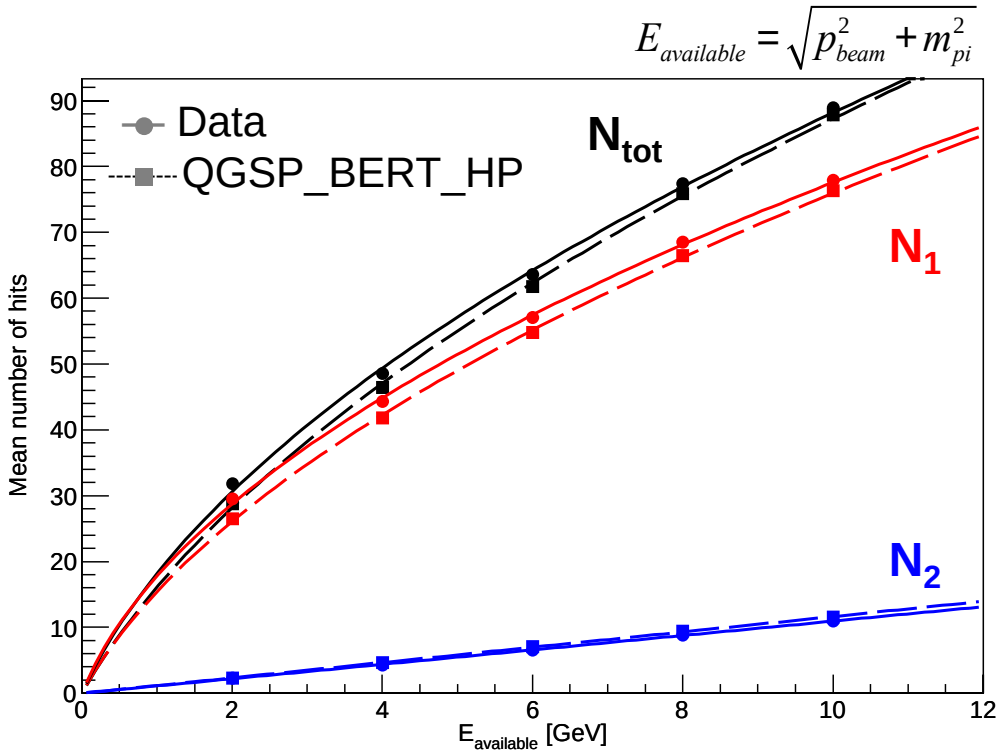
- Data is shifted to higher number of hits
- nHit distributions do not follow a Gaussian
- 2 GeV pions highly difficult to select and susceptible to uncertainties
- In the following the response is always taken from the mean



TB CERN 2010 – mean number of hits

Towards implementation “multi thresholds”

1. Mean of response:
   - **N_{tot}** – all hits above 0.5 Mip threshold (N_1+N_2)
   - **N_1** – 0.5 < hits < 5 Mip threshold
   - **N_2** – hits above 5 Mip threshold



> N_2 shows linear behaviour, while N_1 and N_{tot} saturate
   - MC and Data disagree on a few per cent level
   - Different methods to linearize

Multi threshold methods

Micromegas-SDHCAL (MC)	RPC-SDHCAL (data)
Binary (1 threshold) **mode**	
1. Hits described by log function $N(E) = \frac{A}{B} \times \log(1 + B \times E)$	1. Hits described by root function $N(E) = -\frac{A}{2B} + \sqrt{\frac{A^2}{4B^2} + \frac{E}{B}}$
1. Energy reconstructed by exponential function $E_{rec,1thr} = \frac{1}{B} \times \left(e^{(B/A \times N_{1thr})} - 1 \right)$	2. Energy reconstructed by quadratic function $E_{rec,1thr} = A \times N_{1thr} + B \times N_{1thr}^2$
Multi (2 thresholds) **threshold mode**	
3. Hit Combination: $E_{rec,2thr} = a\left(N_{tot} + b \times N_2\right)$	3. Hit Combination: $E_{rec,2thr} = aN_1 + bN_2$
α constant with beam energy, β follows log function $B = f(\log N_{tot})$	$a = a_1 + a_2 N_{tot} + a_3 N_{tot}^2, b = b_1 + b_2 N_{tot} + b_3 N_{tot}^2$
	4. Parameter characterisation by minimization of: $c^2 = \sum_i^{events} \frac{\left(E_{rec,2thr} - E_{true}\right)^2}{E_{true}}$

- Mathematical considerations lead us to chose **RPC-SDHCAL group method**

TB CERN 2010 – binary mode

Implementation of RPC-SDHCAL group method

2. Reconstruction of the energy:
   - **N_{tot} – all hits above 0.5 Mip threshold**
   - N_1 – 0.5 < hits < 5 Mip threshold
   - N_2 – hits above 5 Mip threshold

$$E_{rec,tot} = \left(A + B \times N_{tot}\right) N_{tot}$$

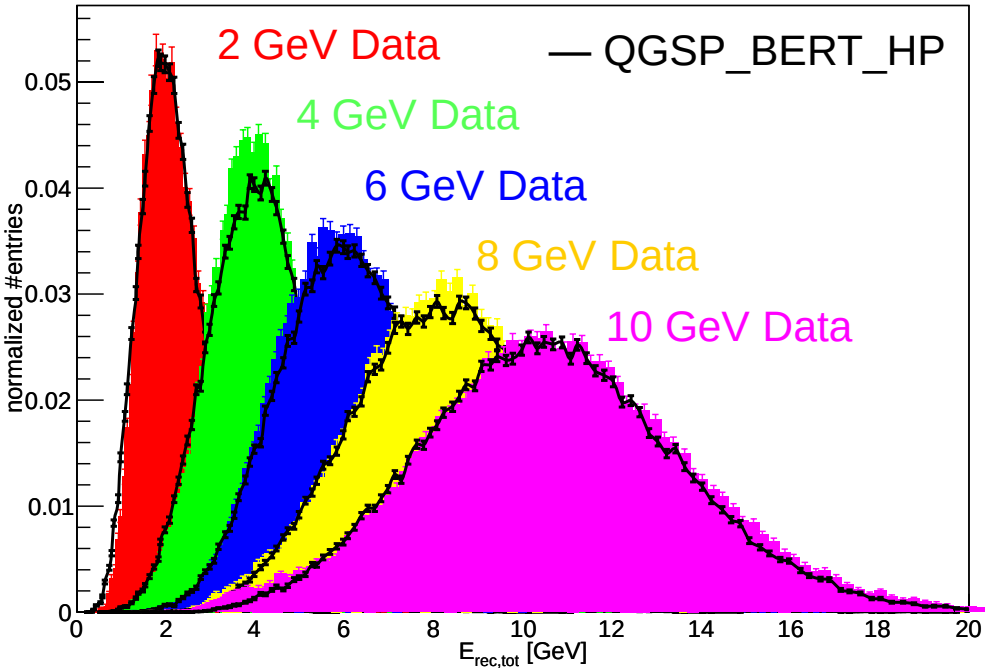
$$A = 0.0398 GeV / hit$$

$$B = 0.0008 GeV / hit$$

> Linearization of E_{rec}

1 threshold / binary mode:

> Leads to pretty broad distributions
   - Mean value of peaks tending to higher values
   - Width broadening with increasing energy
   - MC and Data in agreement



TB CERN 2010 – multi threshold mode

Implementation of RPC-SDHCAL group method

$$c^2 = \sum_{i}^{events} \frac{\left(E_{rec} - E_{true}\right)^2}{E_{true}}$$

3. Minimization of χ^2 for

2 thresholds:

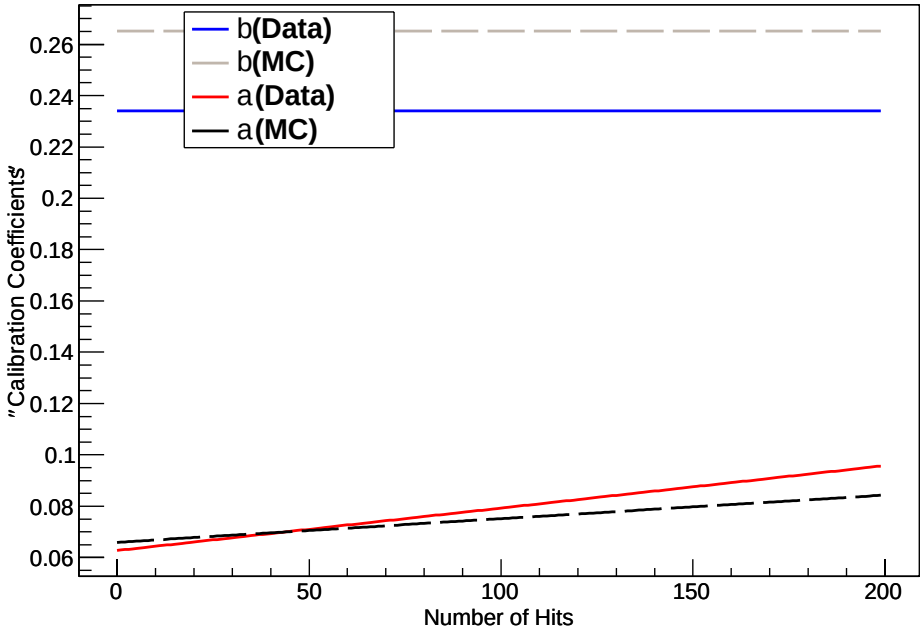
- With $\mathbf{E_{rec}=\alpha N_1 + \beta N_2}$
- 6 constant Parameters:

$a_1, a_2, a_3, b_1, b_2, b_3$

$$a = a_1 + a_2 N_{tot} + a_3 N_{tot}^2$$

$$b = b_1 + b_2 N_{tot} + b_3 N_{tot}^2$$

- Calculated for 20000 pion events each energy in data and 50000 events in MC



> a_3, b_2 and $b_3 = 0$ due to low energy, small number of hits above 5Mip threshold

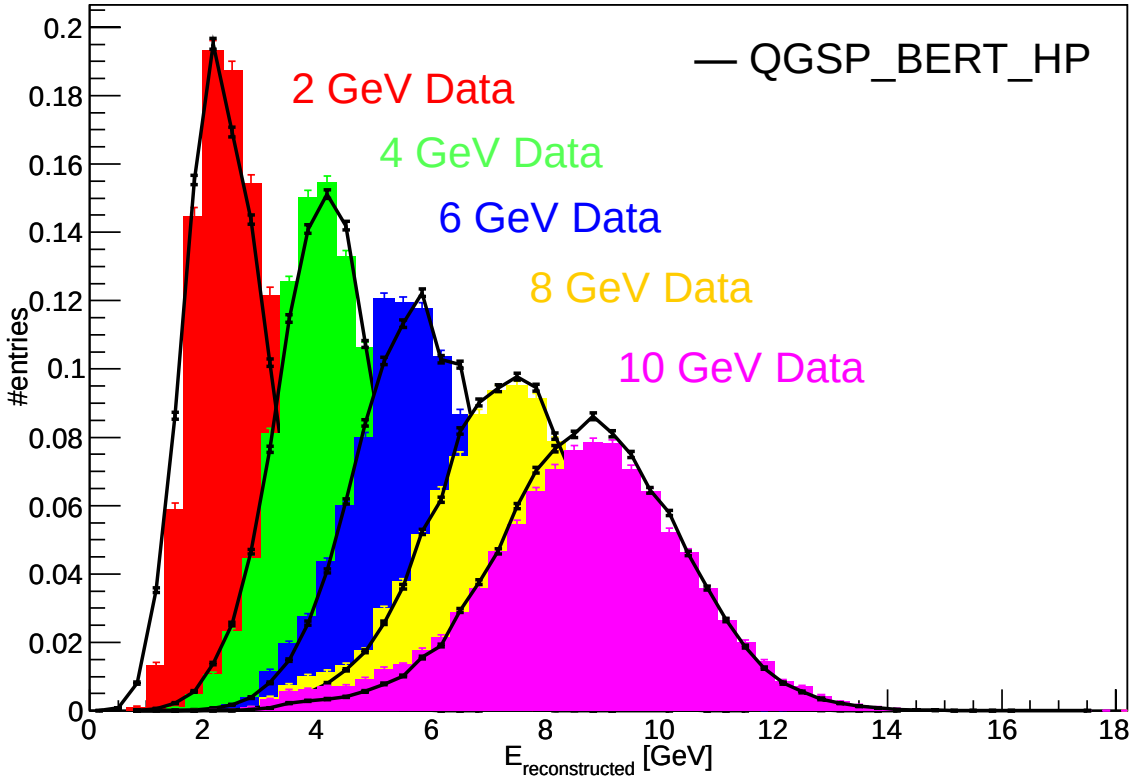
TB CERN 2010 – multi threshold mode

Implementation of RPC-SDHCAL group method

3. Reconstruction of the energy

$$E_{rec,2thr} = aN_1 + bN_2$$

- Peaks much less broad than in binary mode
- 8 and 10 GeV peaks shifted to smaller energies
- Nice agreement between MC and data

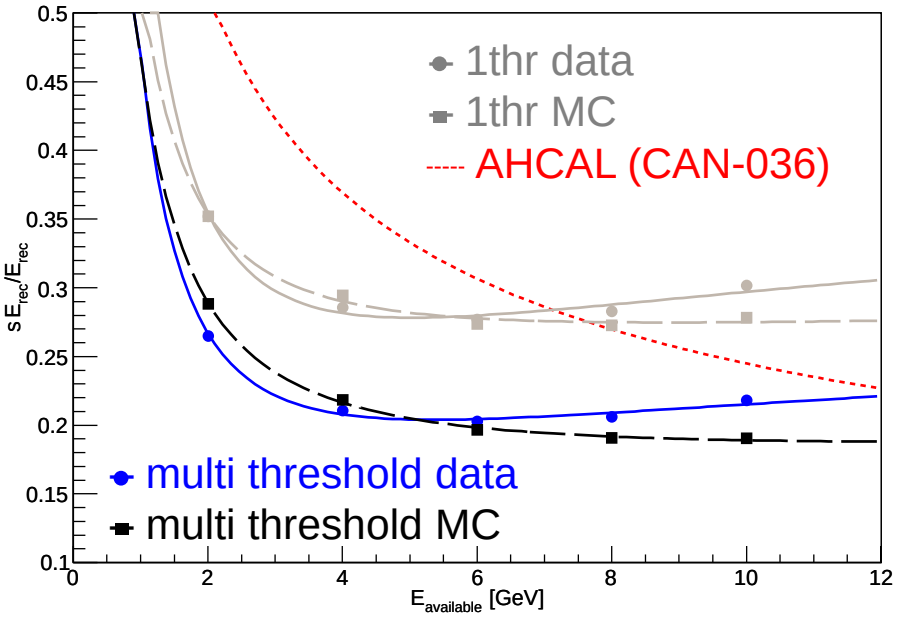


TB CERN 2010 – multi threshold mode

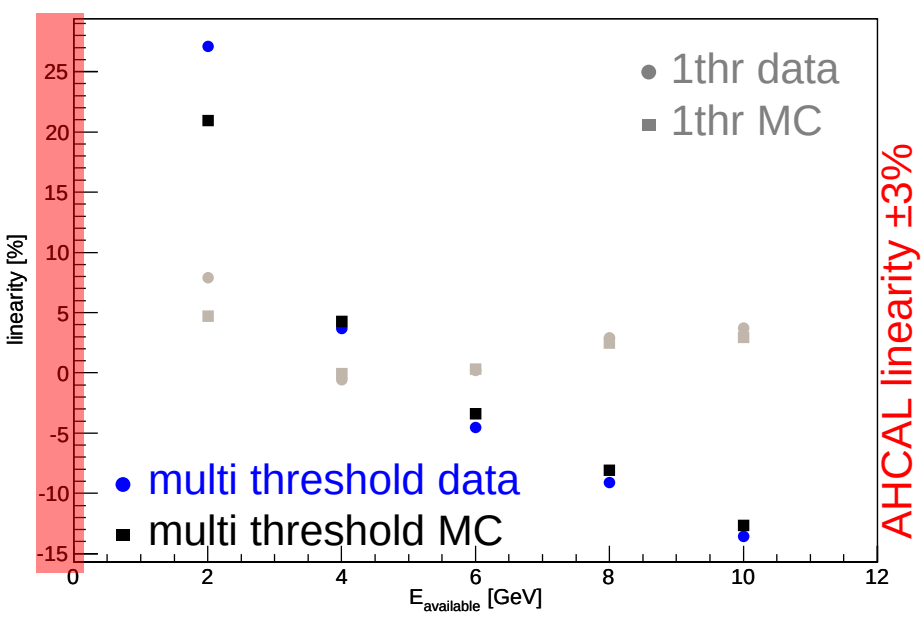
Implementation of RPC-SDHCAL group method

3. Reconstruction of the energy ➔ Resolution & Linearity

WORK IN PROGRESS



WORK IN PROGRESS



- **Binary mode**: Resolution for energies < 8GeV better than AHCAL
- **Multi threshold mode**: Bad linearity -> Resolution can not be trusted
  - **Idea:** overlapping energy distributions influence χ^2 performance

TB CERN 2010 – multi threshold mode

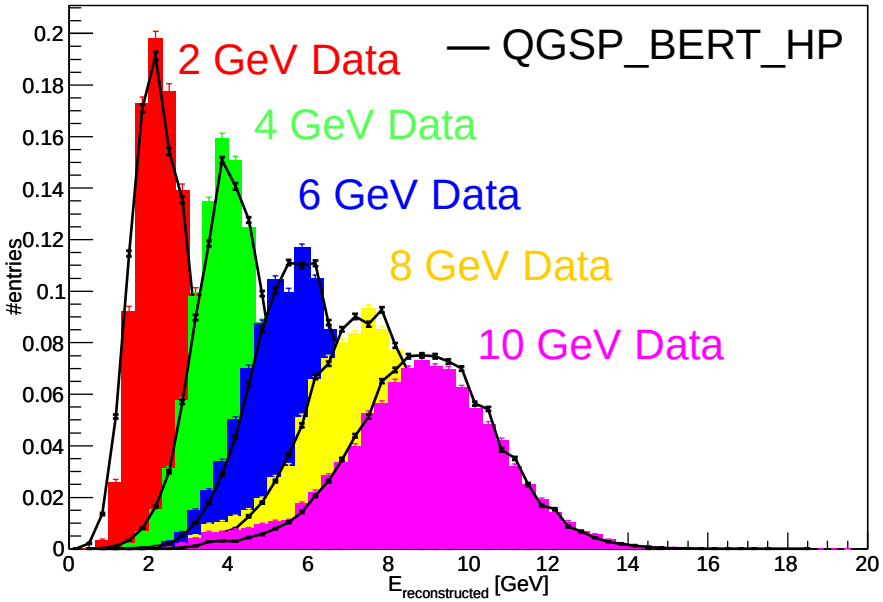
Implementation of RPC-SDHCAL group method

3. Linearity (only 2 ,6 and 10 GeV data used for minimization of χ^2)

WORK IN PROGRESS

Data for χ^2	α	β
All energies	$0.0627+0.0002 \cdot N_{tot}$	0.234
2+6+10 GeV	$0.0535+0.0003 \cdot N_{tot}$	0.247

$$E_{rec,2thr} = aN_1 + bN_2$$

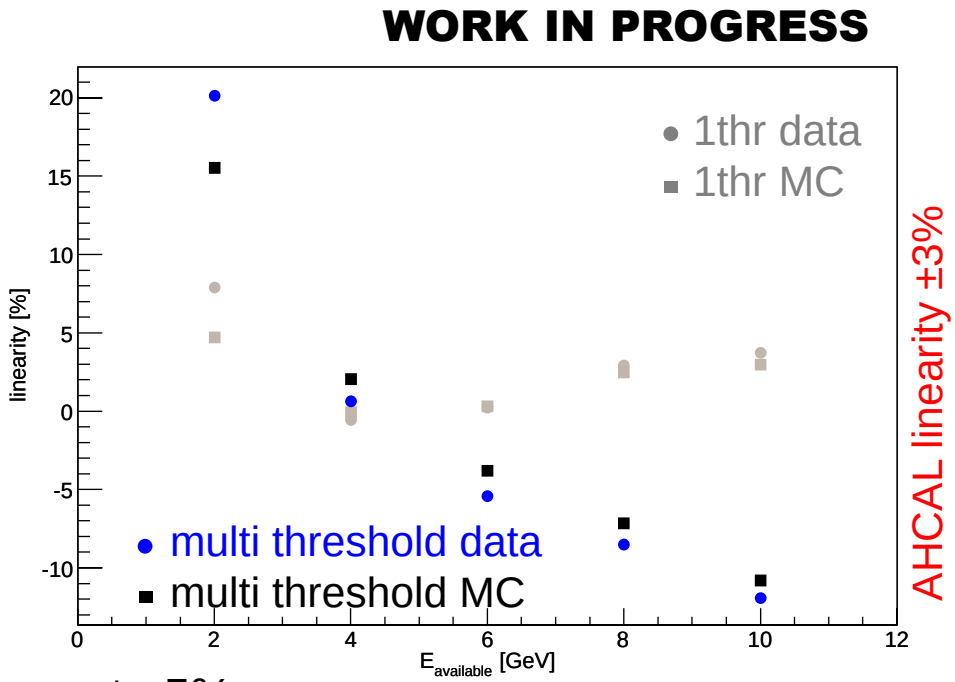


- Increasing contribution from N_2, decreasing N_1 dependence
- Peaks become broader

TB CERN 2010 – multi threshold mode

Implementation of RPC-SDHCAL group method

3. Linearity (only 2 ,6 and 10 GeV data used for minimization of χ^2)



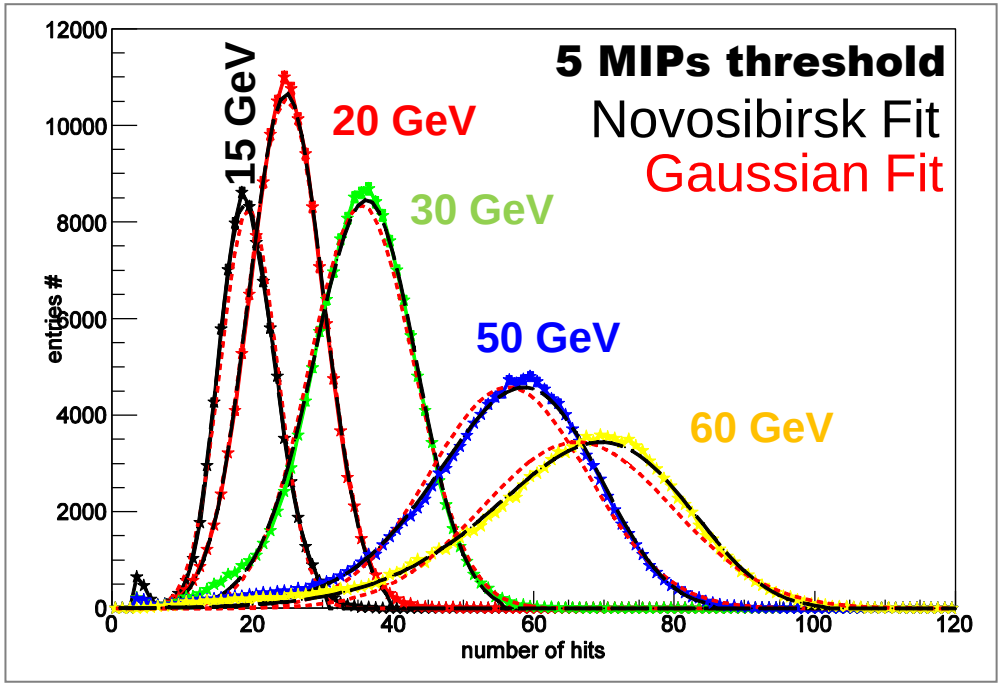
- Linearity improves up to 5%
  - **BUT from that no conclusion should be drawn**
  - χ^2 needs to be changed!

Summary & Outlook

- Binary mode (hits > 0.5Mip):
  - Resolution achieved 28%, looks better than AHCAL with a little worse linearity

- **Next steps**:
- Implementation of a 3rd threshold ($E_{rec}=\alpha N_1+\beta N_2+\gamma N_3$)
- Implementation of this multi threshold mode to higher energy TB data:

- CERN 2011 WHCAL, 38 ScHCAL layers of 3x3cm^2
- Hit distributions fitted with Novosibirsk function
- Further improvement of pion selection:
  MC samples needed



Pion Selection Cuts: Chrenkov counter + muon rejection(energySum 45-150 Mips)

Summary & Outlook

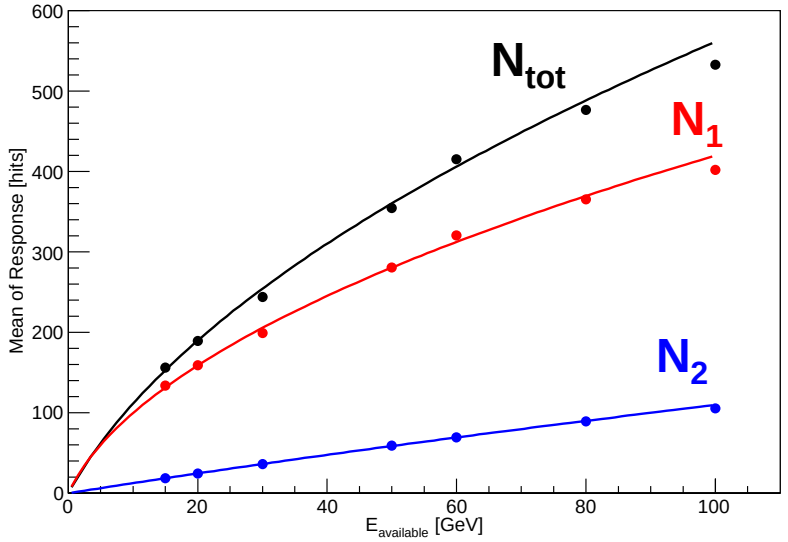
> Thank You for Your Attention!

Summary & Outlook

- Mean of response:

$$N = -\frac{A}{2B} + \sqrt{\frac{A^2}{4B^2} + \frac{E_{available}}{B}}$$

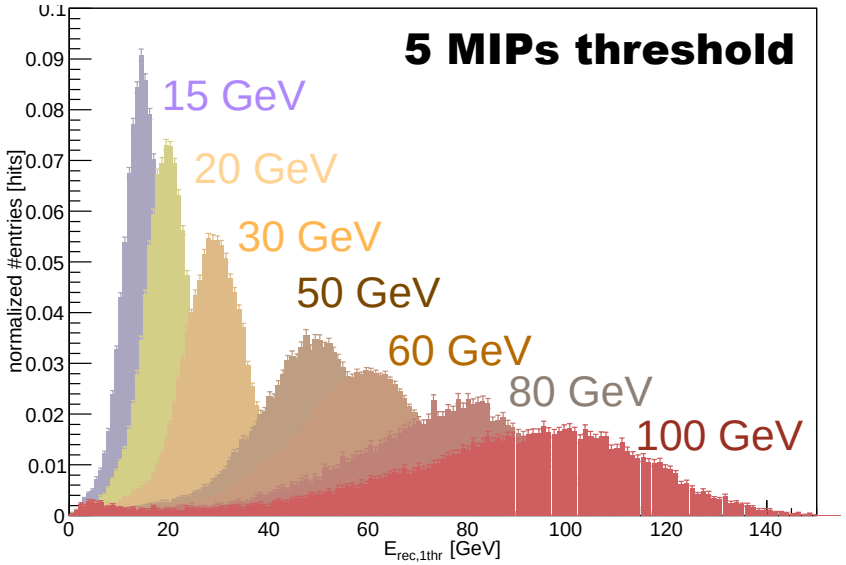
  - All hits >0.5 Mip (N_{tot}) and 0.5 > hits < 5 Mip (N_1) show clearly no linear response
  - Hits >5 Mip (N_2) pretty linear



- Reconstructed energy:

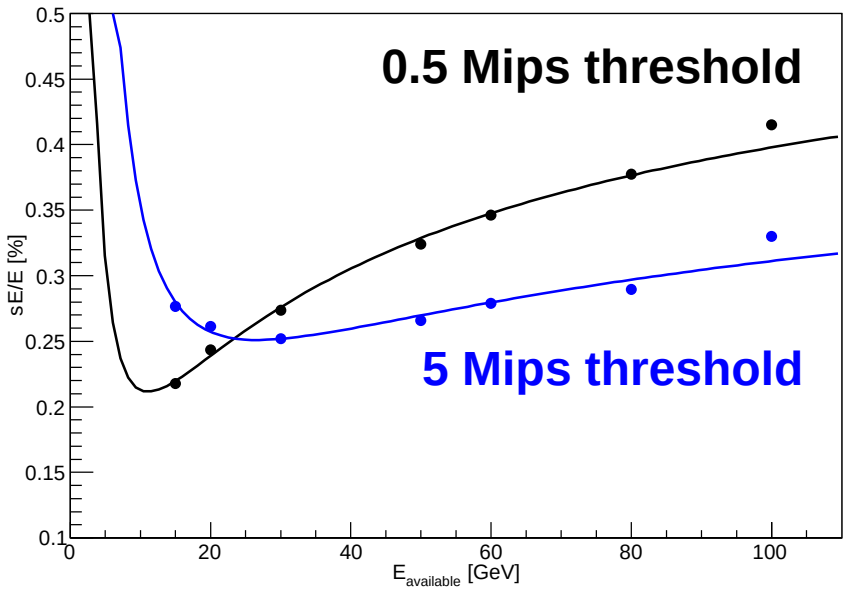
$$E_{rec,tot} = \left(A + B \times N_{tot}\right) N_{tot}$$

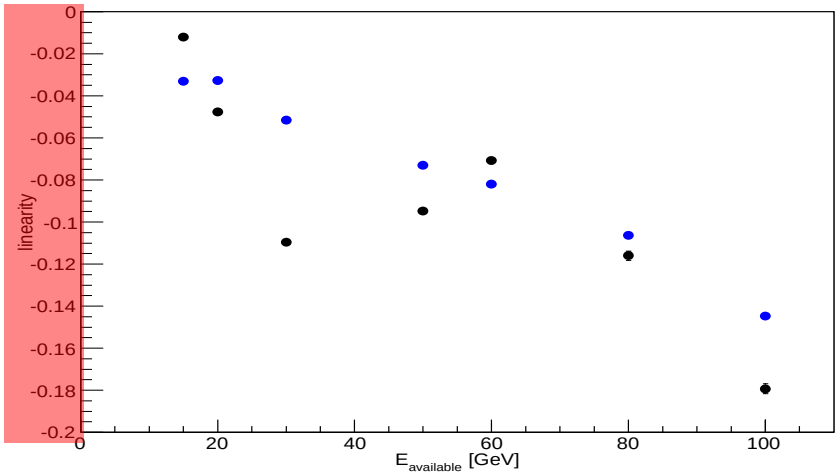
  - Higher energies >50 GeV show very broad peaks



Summary & Outlook

- Resolution:
  - Until 20 GeV 0.5Mip cut shows better resolution, while 5Mip threshold becomes better at high energies (like expected)
- Linearity:
  - Always negative
  - Reaches 18% for high energies

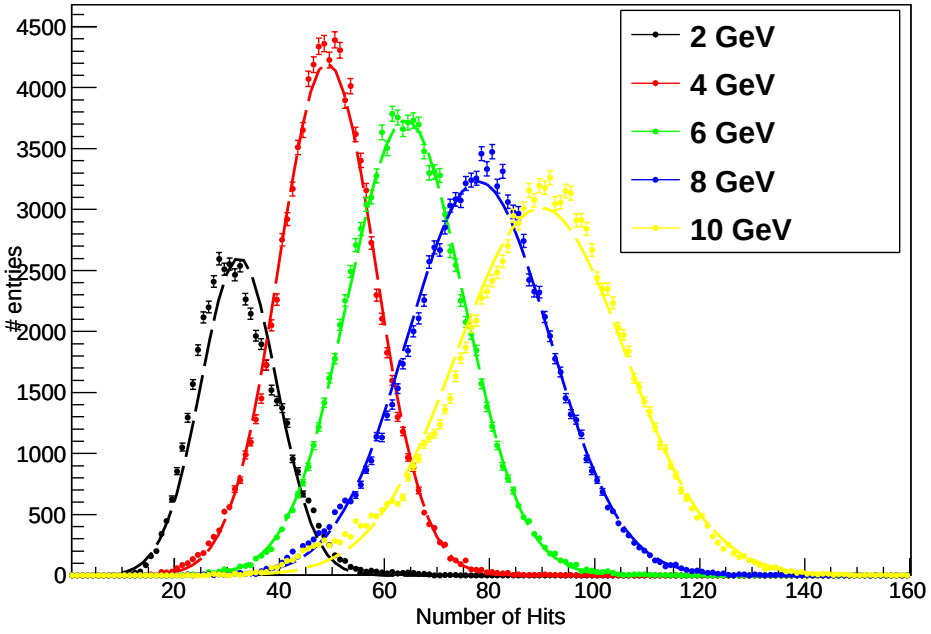


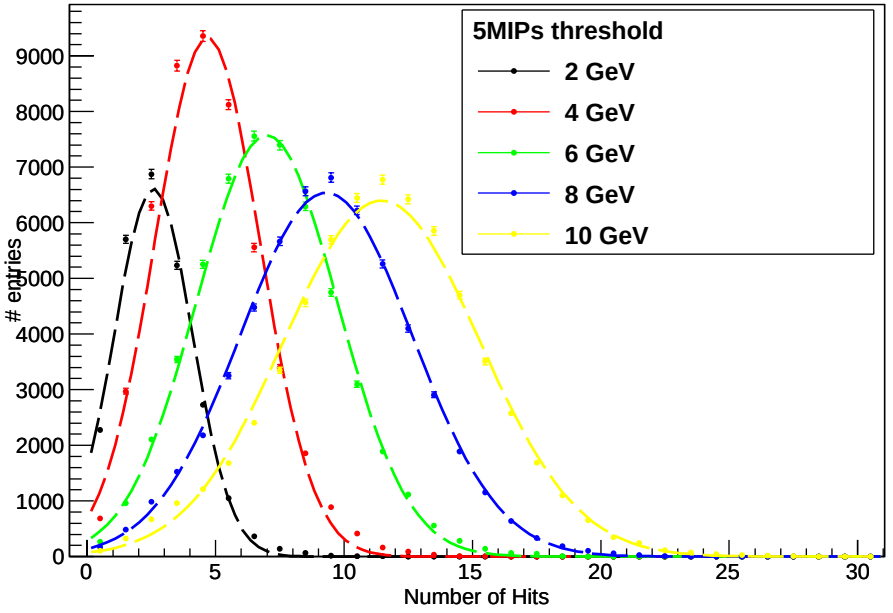


- All shown results indicate more careful pion selection
- MC sample needs to be generated!
- Expect: real improvement by implementing multi threshold mode

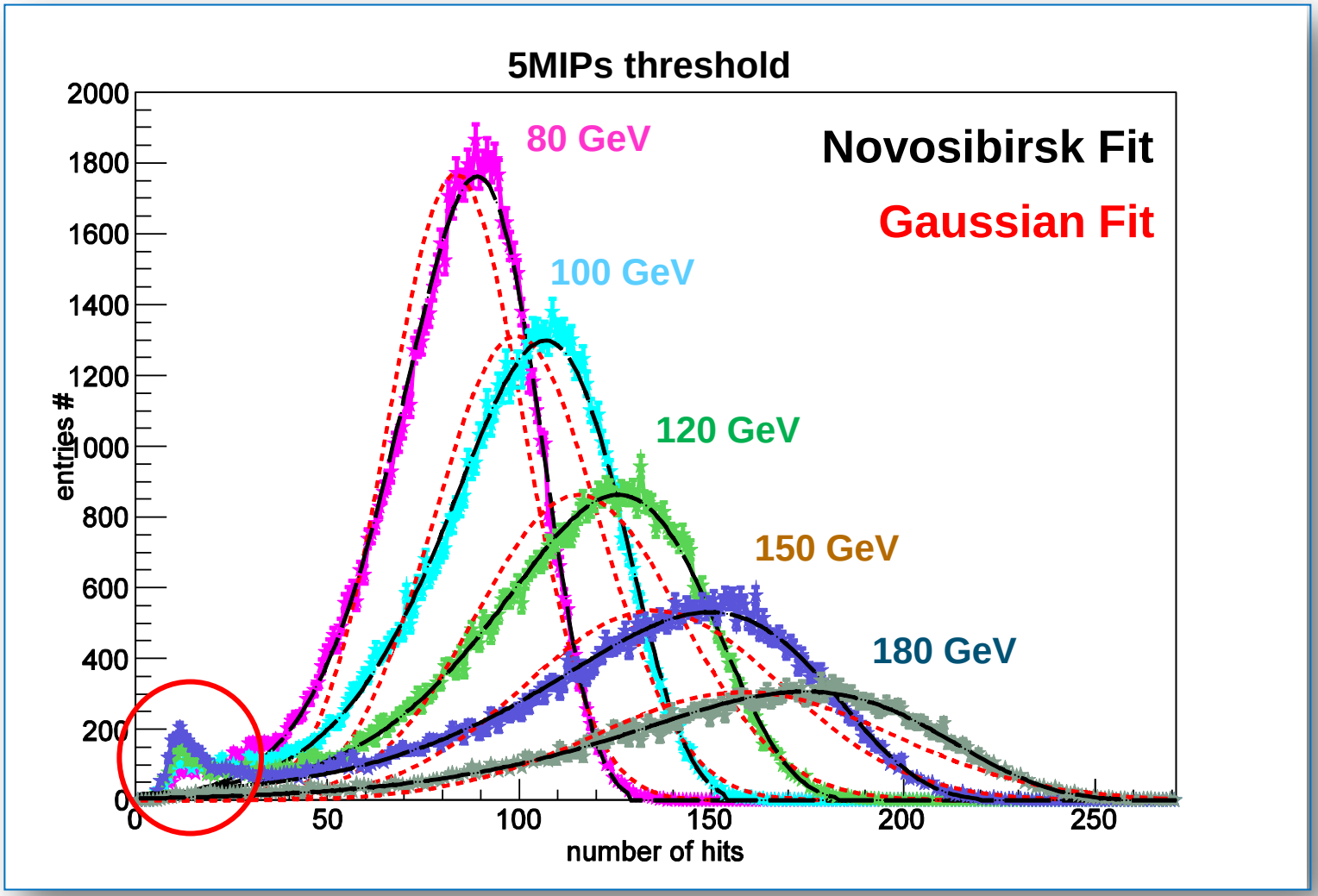
TB CERN 2010 – Number of Hits

- nHit distribution does not follow a Gaussian
- Visible at 2 GeV
- In the following the response is taken by the mean value





High energy TB CERN 2011

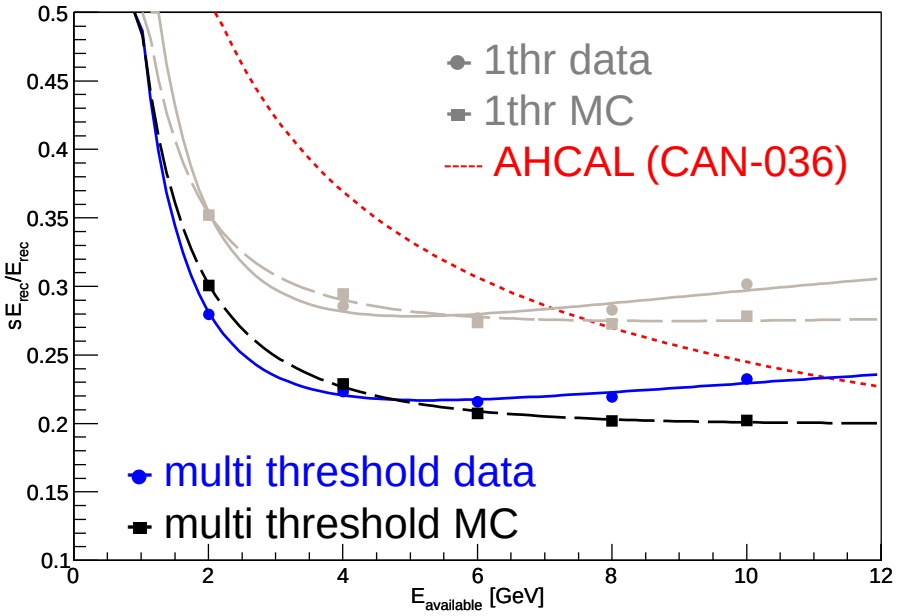


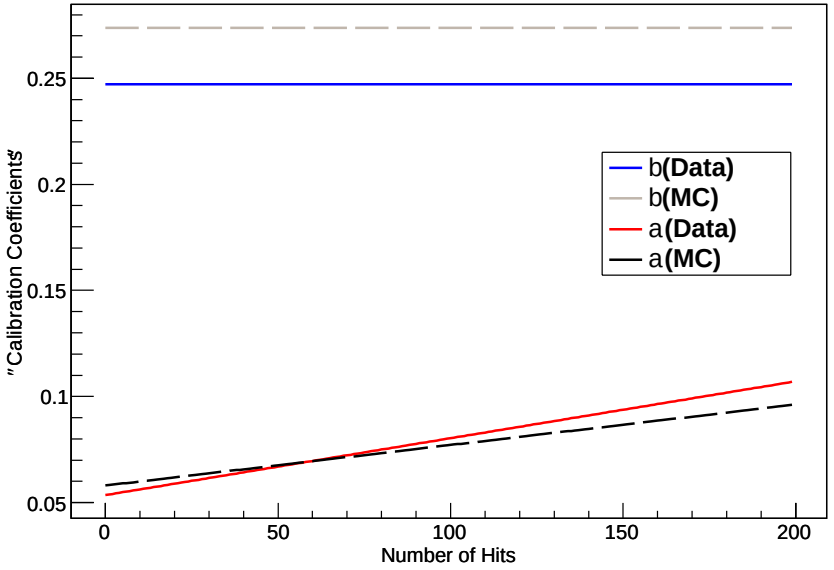
Selection Cuts: Chrernkow counter + muon rejection(energySum 45-150MIPS) [see upcoming CAN-044]

New reconstructed energy

- Parameters calculated only with 2,6 and 10 GeV data

WORK IN PROGRESS



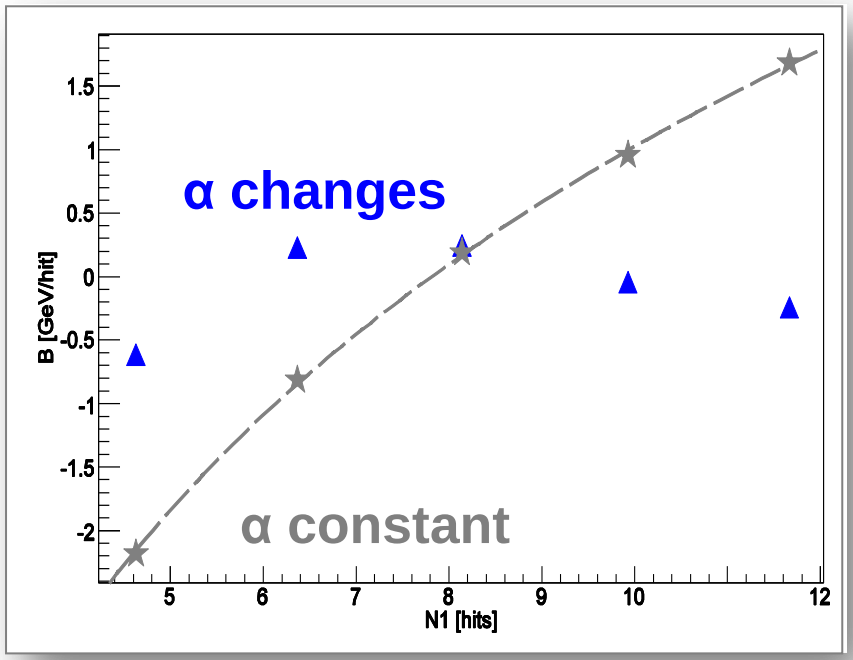


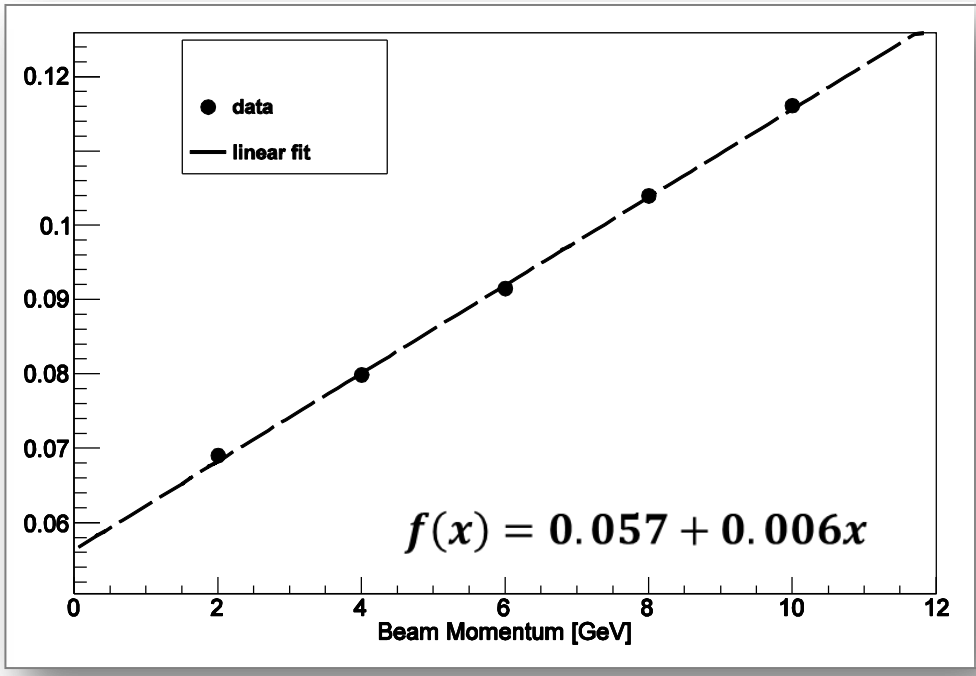
MC data for χ^2	α [%]	β [%]
All energies	$0.0663+0.0001 \cdot N_{tot}$	0.265
2+6+10 GeV	$0.0580+0.0002 \cdot N_{tot}$	0.274

Micromega Approach with A const

- α is not constant

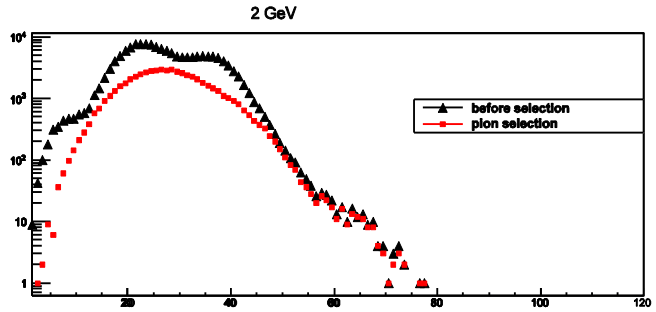
$$E_{rec,2thr} = a\left(N_{tot} + b \times N_2\right)$$

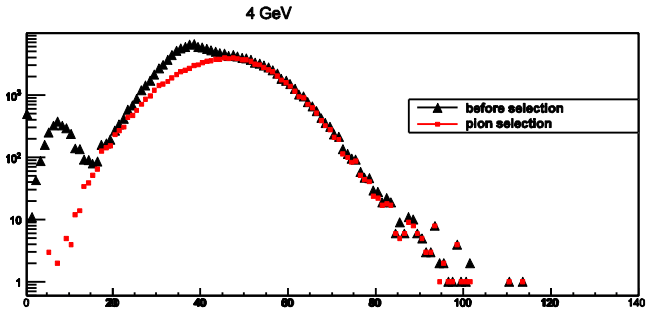


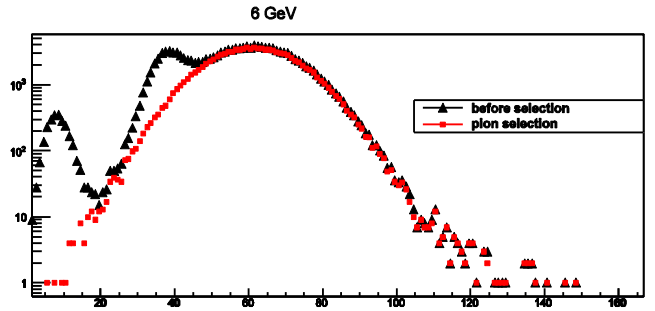


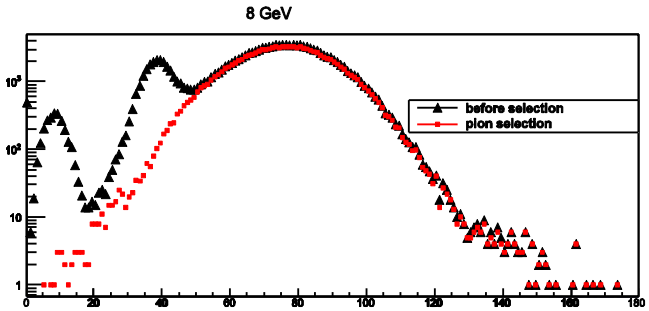
Pion selection

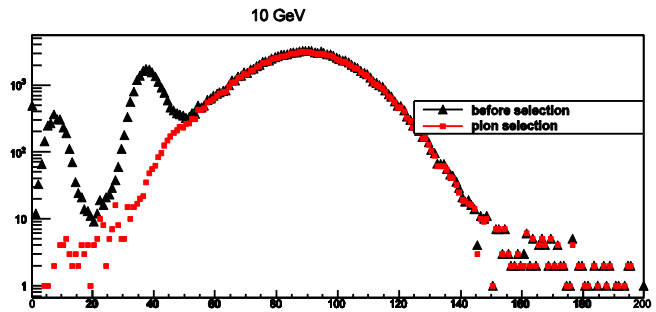
Hits before & after pion selection (0.5 MIPs)











Pion data set is not completely clear.

Other cuts have to be applied!
(Noise cut)