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Muon Walls Performance in 1998 and 1999 Tilecal Beam Tests

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Abstract

Muon walls setup for beam test of the TILECAL barrel module 0 in June–July 1998 and July 1999 is described. The walls are remotely operated and their setting for hadronic shower leakage detection is described. The low energy tail suppression for events without leakage is illustrated.

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1 Introduction

ATLAS hadron calorimeter TILECAL module 0 undergos tests on H8 beam of the SPS accelerator at CERN, accompanied with five Tilecal prototype modulesas depicted on Fig. 1. At the module's back and lateral side scintillator detectors are placed for a detection of hadronic showers leakage. The detectors are configured into two remotely operated walls, so called Back and Side Muon walls. For the June–July 1998 tests the walls were reconfigured in respect to previous beam tests [1]; the back wall movement range was enlarged and the side wall had to be fixed further from the module 0 newly equipped with "fingers".

The back wall slides parallel to the modules' girders and the side wall slides perpendicular to them. Both muon walls can together fully cover leaking particles for η around -0.5, when the beam axis passes close to the corner of module 0. The back wall, see Fig. 2, is composed of 2 rows of 7 pieces of scintillator detectors, the so called 'Prague' counters [2] with the total active area 80×132 cm^2.

The side muon wall, see Fig. 3, consists of 5 Michigan State University (MSU) scintillator pairs [3]. The MSU counters are fixed with 2 cm overlaps and their active area 92×102 cm^2 has no dead zones. The horizontal axis of the wall is parallel to the middle plane of the module 0,

A group of three scintillator pairs of the side wall can be folded to allow the drawer insertion into the girder.

At the end of July-98, before the tests with new DIRAC digitisers placed inside the drawer, the side muon wall was dismantled enabling easier access to drawer and test of a new tool for drawer insertion.

The same configuration without side muon wall was used also for the July 1999 beam test period.

The muon walls cabling and the data acquisition labels are summarised in Table 1.

The walls are moved with the use of engines and their position is electronically read. The walls positioning may be operated either remotely from the control room with the help of PC or locally on the scanning table as explained in Section 2. The recommended positions for different test beam geometries are summarised in Section 3 .

The typical shape of muon wall counters response to muons is depicted in Section 4 and the standard ntuple variables describing muon walls counters are summarised in Appendix A.

Usage of the variable MuBackHit to suppress low tail of reconstructed pion energy by selecting events without longitudinal leakage is illustrated also in Section 4.

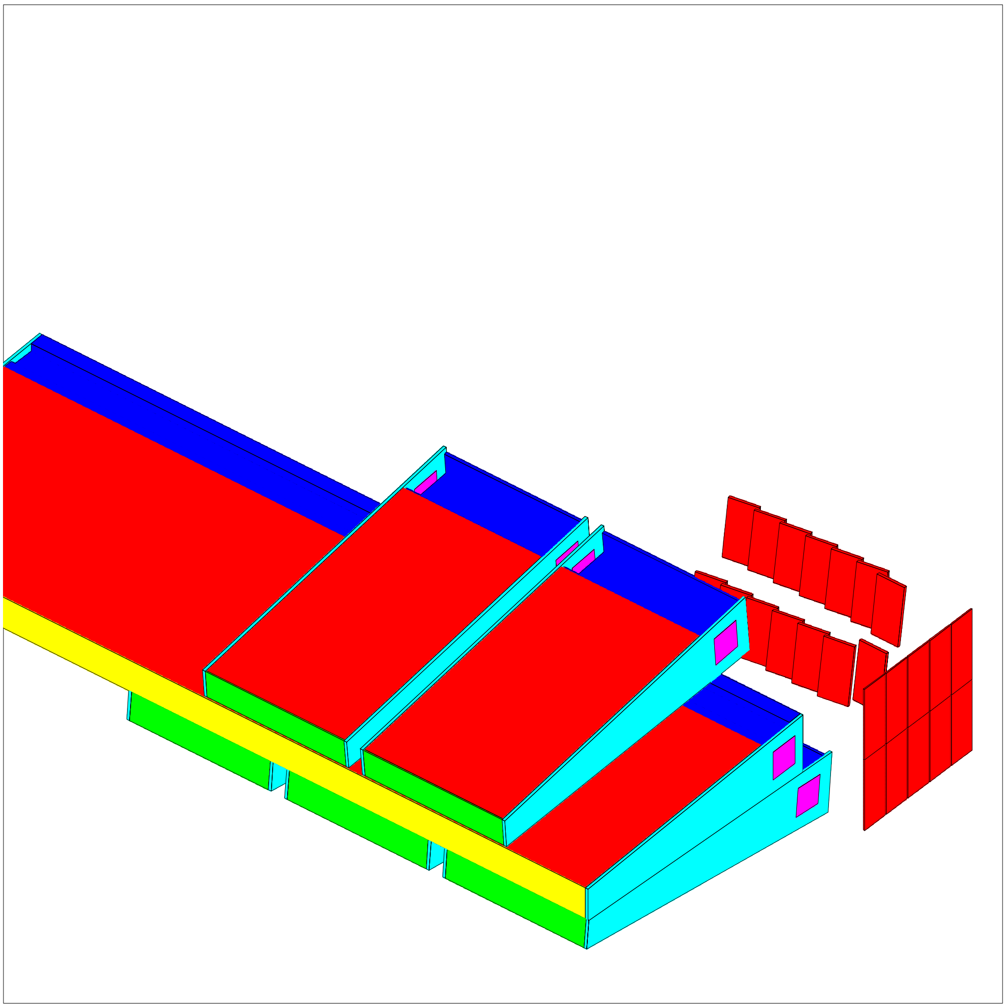

Figure 1: The 1998 beam test setup with the remotely controlled muon walls. The walls are in the position for the pseudorapidity scan at $\eta = -0.45$.At the end of July 1998 the side muon wall was dismantled and was not present during 1999 beam test period.

```
     BACK MUON WALL
     ==============


           |-|  |-|  |-|  |-|  |-|  |-|  |-|
           | |  | |  | |  | |  | |  | |  | |
           |_|  |_|  |_|  |_|  |_|  |_|  |_|
           / \  / \  / \  / \  / \  / \  / \
   ......./___\/___\/___\/___\/___\/___\/___\
     .    |    |    |    |    |    |    |    |
     .    |    |    |    |    |    |    |    |
     .    | 2  | 4  | 6  | 8  | 10 | 12 | 14 |
     .    |    |    |    |    |    |    |    |
   80 cm |____|____|____|__x_|____|____|____|
     .    |    |    |    |    |    |    |    |
     .    |    |    |    |    |    |    |    |
     .    | 1  | 3  | 5  | 7  |  9 | 11 | 13 |
     .    |    |    |    |    |    |    |    |
   ......|____|____|____|____|____|____|____|
         :                                  :
         :                                  :
         :              132 cm              :
        >:==================================:<
```

Figure 2: The back muon wall for the beam test of barrel module 0 in June−July 1998. The beam entrance for pseudorapidity scan at $\eta = 0$ is marked by x. All detectors are positioned with PMTs up. The same configuration of back muon wall was used at July 1999 test beam period.

```
SIDE MUON WALL
==============


         ......._________________________.
          .     |    |    |    |    |    |
          .     | 2  | 4  | 6  | 8  | 10 |
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
        102 cm  |.x.......................|
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
          .     |    |    |    |    |    |
          .     | 1  | 3  | 5  | 7  |  9 |
         ......|____|____|____|____|____|
                :                        :
                :                        :
                :         92 cm          :
               >:========================:<
```

Figure 3: The side muon wall for the June–July 1998 beam test as seen by the beam at $\theta = -90$ deg. Beam entrance is marked by x for the test of tile number 10 in the right-most wall position. The wall was removed at end of July 1998 and was not present for the July 1999 test beam.

# counter see Fig.2,3		HV cable	Signal cable	ADC channel	#DET	# PMT case	HV [V]	CAEN Crate 04 channel	# PM in DATA-BASE	Comment
	1	211	246	246	1	4279	1850	19	1	Prague
	2	219	233	233	12	4277	1830	27	8	Prague
	3	212	226	226	2	4315	1790	20	2	Prague
	4	214	228	228	13	4294	1850	35	9	Prague
B	5	213	227	227	3	4316	1820	21	3	Prague
A	6	220	234	234	14	4385	1820	28	10	Prague
C	7	215	229	248	7	4262	1850	23	4	Prague
K	8	221	235	235	15	4261	1750	29	11	Prague
	9	216	230	230	8	4282	1850	24	5	Prague
W	10	222	236	236	16	4311	1740	30	12	Prague
A	11	217	231	249	10	4289	1730	25	6	Prague
L	12	223	240	240	17	4317	1830	31	13	Prague
L	13	218	232	232	11	4290	1770	26	7	Prague
	14	224	242	242	18	4293	1750	32	14	Prague
	1								15	test
	2								16	test
	3								17	test
S	1	201	215	215	1down	1	1650	08	22	Michigan
I	2	206	220	220	1up	6	1450	13	29	Michigan
D	3	202	216	216	2down	2	1548	09	23	Michigan
E	4	207	221	221	2up	7	1497	14	30	Michigan
	5	203	217	217	3down	3	1648	10	24	Michigan
W	6	208	222	222	3up	8	1675	15	31	Michigan
A	7	204	218	218	4down	4	1625	11	25	Michigan
L	8	209	223	223	4up	9	1646	16	32	Michigan
L	9	205	219	219	5down	5	1575	12	26	Michigan
	10	210	224	224	5up	10	1649	18	33	Michigan

Table 1: The muon walls and DAQ labels for the June–July 1998 beam test. The second column contains the counter logical numbers for the back and the side walls as marked in Fig. 2 and Fig. 3. The sixth and seventh columns give the production serial numbers of Prague counters and PMT's, respectively. For the Michigan State University PMT's, the number in the seventh column is the label attached to the PMT-case. The values of back muon wall stay valid also for July 1999 test beam period.

2 Remote control of muon walls

2.1 Description

The walls are moved by 220 V engines. Each wall has its own steering electronics box fixed either directly on the back wall or just under the side wall. The box contains display that shows the position in some local relative units and knobs for display operation. The box further contains main switch ON/OFF and a toggle switch REMOTE/LOCAL. An operation box with a yellow light and 2 green push buttons for manual wall movement in respective directions is located close to the steering box. Manual operation can be used only in the toggle position LOCAL. For a remote control the toggle must be in the REMOTE position.

The back wall is moved by DC 220 V engine over a chain fixed to the scanning table floor. The engine is controlled with the help of relay. The relay is steered via simple diodes logic directly by pushing green knobs on the steering box. For the remote control the relay is operated by steering electronics. The position is measured by an IRC element. The element precision is 0.05 mm, the wall positioning precision due to gear box, chain and steering system is on the level of 15 mm.

The side wall is moved by AC asynchronous 220 V engine over long screw. The control is practically the same as for the back wall. The position is measured with the IRC method, but the element is realised by mechanical switches. The positioning precision is similar to that of the back wall.

Remote control personal computer located in the control room sets two target position values for each wall. The steering electronics will start the engine motion in correct direction to move the wall between the set target positions. The target position values are sent from the personal computer over serial line RS422 (2x twisted pair). One cable connects both walls, because each wall has its own address. C-language program resides on PC and sends the target position values, computed from requested η values for projective scan or from θ and z values for non-projective scan. It is also possible to set directly the walls positions in Atlas coordinates. The final walls positions can be displayed on the PC.

Each wall has two sets of end switches. First switch stops the wall movement in current direction and enables to move it in the opposite one. The second end switch is an emergency switch that switches off the engine but the relay logic still remains operational. A technical intervention is required when the second emergency end switch is activated. Both walls have manual emergency switches that switch off the whole wall. They may be used for emergency stop of the walls and complete electronics switch off. Moreover, one emergency switch stopping and switching off both walls is located on the fence of the experimental zone close to the control room entrance.

2.2 Operation

Remote control is provided by PC-Olivetti placed in the control room of H8 test beam with the program 'muonwall.exe' placed in directory `C:\muonwall`. The values of parameters necessary for program initialisation are read from the file 'muonwall.ini'. All distances are given in Atlas reference system coordinates in cm.

The control electronics system of muon walls has to be initialised in the beginning by means of steering and operation boxes:

- Release the red emergency stop buttons.
- Flip main switch to 'ON' position.
- Flip toggle to 'REMOTE' position. Remark: The wall may automatically begin to move to some previously set position!
- Start the program muonwall.exe.
- Send the command "o" to origin the positions of both walls. The walls start to move and each wall will automatically stop in its limit position.The Back wall is moved in the direction of side wall (to the highest Atlas z) and the side wall in the direction of back wall (to the highest Atlas r).
- Press the red emergency stop to switch off both walls.
- After few seconds release this emergency stop to switch on. Both displays will be set to 0.
- Now the walls are ready to be set to desired positions.

The program is operated from the keyboard by single character commands with the following meanings (see also a hint inside the program window on the screen):

g GO - both walls start to move to positions which can be set by 'e', 's', 'b' or 't'+'z' commands

q QUIT the program

e ETA - set a value of pseudorapidity. Type 'enter' after delivering η value. Program will calculate positions of walls. Then you can press button 'g' and walls start to move to computed positions. You can check the position of walls by pressing 'r'.

r READ - the program will continuously read and display the positions of the walls. To stop reading press any key.

s SIDE - set the position of the sidewall separately. After typing a number press 'enter'.

b BACK - set the position of the back wall separately. After typing a number press 'enter'.

Pseudorapidity of test beam	η_{min}	η_{centre}	η_{max}	z_{min} [cm]	z_{centre} [cm]	z_{max} [cm]
≤ -0.5	-0.36	-0.48	-0.59	191.	256.	323.
-0.4	-0.28	-0.40	-0.51	148.	214.	280.
-0.3	-0.18	-0.30	-0.42	92.	158.	224.
-0.2	-0.07	-0.20	-0.32	39.	105.	171.
-0.1	0.03	-0.10	-0.23	$-14.$	52.	118.
0.0	0.13	0.00	-0.13	$-66.$	0.	66.
0.1	0.23	0.10	-0.03	$-118.$	$-52.$	14.
0.2	0.32	0.20	0.07	$-171.$	$-105.$	$-39.$
≥ 0.3	0.39	0.27	0.15	$-210.$	$-144.$	$-78.$

Table 2: The correspondence between the beam test pseudorapidities and the η and z values of the edges and centre of the BACK MUON WALL for the η scan values.

t THETA - set the angle theta for non-projective scan. After typing a number press 'enter'.

z ZETA - set z-coordinate for non-projective scan (Atlas z-coordinate of the beam entrance into the extended barrel 0). After typing a number press 'enter'.

3 Muon wall positioning

The active surface centre of either wall is normally positioned against the beam spot. If it is not possible respective wall remains in its limit position.

3.1 Pseudorapidity scan

For barrel module 0 beam test the back muon wall can detect secondary particles with Atlas pseudorapidities from -0.48 to 0.27. The side muon wall covers range -0.77 to -0.65.

Tabs. 2 and 3 show the real coverage possibilities of either wall by means of the three values of pseudorapidities corresponding to the edges (η_{max} and η_{min}) and to the centre (η_{centre}) of the wall for several pseudorapidities planned for the test beam. Further they show position of wall edges and centres in the Atlas coordinates z and r for back and side muon walls, respectively. For positive η values the side wall is positioned to its maximum r value.

3.2 Scan at $\theta = -90$ deg

During the scan at $\theta = -90$ degrees by electron beams the side muon wall must be outside the beam trajectory. This can be simply achieved by the same wall

Pseudorapidity of test beam	η_{min}	η_{centre}	η_{max}	r_{min} [cm]	r_{centre} [cm]	r_{max} [cm]
≤ -0.8	-0.85	-0.77	-0.70	349.	395.	441.
-0.7	-0.77	-0.70	-0.64	397.	443.	489.
≥ -0.6	-0.71	-0.65	-0.60	439.	485.	531.

Table 3: The correspondence between the test beam pseudorapidities and the η and r values of the edges and centre of the SIDE MUON WALL for the η scan values.

θ [deg]	z_{in} [cm]	z_{centre} [cm]	r_{centre} [cm]
20.	37.	226.	485.
20.	61.	250.	485.
20.	87.	256.	485.
20.	141.	256.	485.
20.	201.	256.	395.
20.	233.	256.	395.

Table 4: The setting of the muon walls for the non-projective scan defined by the beam input θ angle and the z_{in} input point. The z_{centre} describes the position of the back muon wall centre and the r_{centre} describes the position of the side muon wall centre.

position as for rapidity scan with $\eta = -0.476$. (Side wall will be in the position closest to the back muon wall).

The side muon wall can detect muon and pion beams only for the test of tiles number 10 and 11 if it is positioned to its limit upstream position. Alternatively, for a fine scan, the desired side wall position may be set by 's' SIDE command.

3.3 Non-projective scan

The non-projective scan is defined by two variables θ and z_{in} (on computer display marked as 'z'). The z_{in} is Atlas z coordinate of the beam entrance to the extended barrel module 0 face and θ is an angle between this face normal and the beam axis. For negative θ values the side muon wall is positioned as for projective positive η scan values. Table 4 shows the corresponding muon walls centres setting for specified beams.

3.4 Manual positioning

As a backup solution the walls can be moved manually (the toggle on steering box in 'LOCAL' position). The position labels are marked on the scanning table along the muon walls rails. Table 5 shows the correspondence between the Position Labels and η, z, r values of muon wall centres in the Atlas coordinates.

Backward wall						Side wall		
P.L.	z_{centre}	η_{centre}	P.L.	z_{centre}	η_{centre}	P.L.	r_{centre}	η_{centre}
1	-153.	0.29	7	82.	-0.16	1	395.	-0.77
2	-114.	0.22	8	121.	-0.23	2	418.	-0.74
3	-75.	0.14	9	160.	-0.30	3	441.	-0.70
4	-38.	0.07	10	199.	-0.37	4	464.	-0.67
5	5.	-0.01	11	238.	-0.44	5	485.	-0.65
6	43.	-0.08						

Table 5: Manual positioning the back resp. side muon walls. The correspondence between the Position Labels (P.L.) and z and η values resp. r and η values of muon wall centre in the Atlas coordinates.

4 Response to the muons

The response of the muon wall scintillation counters to charged particles was tested using muon beams and using selected events with muon contamination of pions beams. Fig. 4 and Fig. 5 illustrate the typical muon response spectra for the detector of the back resp. side muon wall. Energy losses in the scintillator correspond to the Landau theory and were fit by the convolution of Landau and Gaussian distribution [4] to determine a peak position.

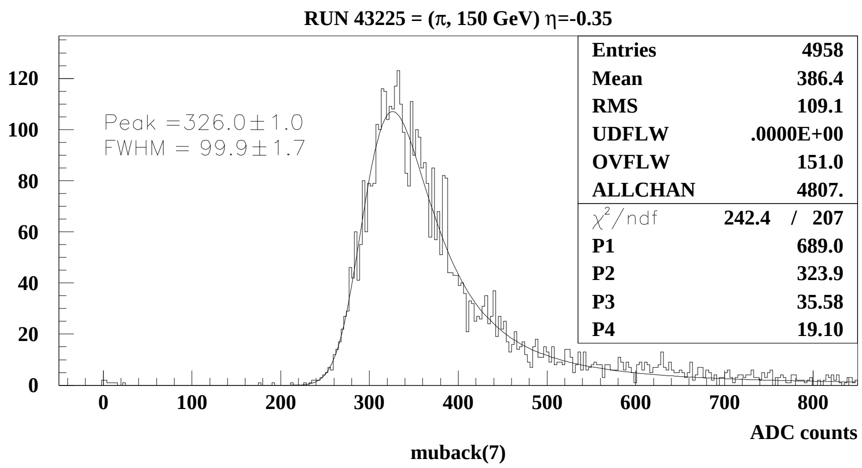

Figure 4: The ADC spectra of muon response for the Prague's counters placed in back muon wall (muons were extracted as a contamination from the pion beam). The convolution of Landau and Gaussian distributions was fit to the data.

Peak positions for all counters of both muon walls are summarised in the Table 6.

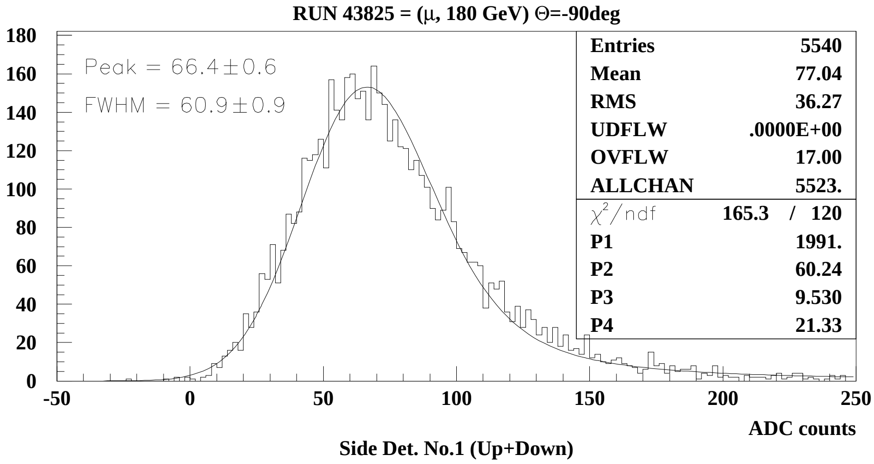

Figure 5: The Michigan State scintillator pair response to the muon beam at $\theta = -90$ degrees impinging Tile 10. The detector is read by two PMTs, both upper and down counters are optically connected, therefore the output of both PMTs is plotted in one spectrum and fit by G-L convolution.

Backward wall				Side wall	
'Prague' counters				'MSU' counters	
# det	Peak_position	# det	Peak_position	# det	Peak_position
1	200	11	292	1	25
2	214	12	185	2	26
3	258	13	229	3	21
4	250	14	195	4	51
5	340			5	18
6	189			6	22
7	326			7	32
8	187			8	22
9	361			9	38
10	249			10	44

Table 6: The peak position of the muon response for all counters in ADC counts for 'Prague' counters and in Amplified ADC counts for the 'MSU counters.

Values of fitted peak position are used for the standard ntuple production in the following manner : We define that the counter was hit by at least one charged particle if the signal obeys the relation

$$ADC > 0.7 \times \text{Peak\_position} \tag{1}$$

The number of counters with charged particle hits is given for the back and side muon walls separately. The sum of the normalised signals from all counters is also calculated for the back and side muon walls separately using the formulae

$$MuBackSum = \sum_{i=1}^{14} MuBack(i)/\text{Peak\_position}(i) \tag{2}$$

$$MuSideSum = \sum_{i=1}^{10} MuSide(i)/\text{Peak\_position}(i) \tag{3}$$

The standard ntuple variables of muon walls are summarised in Appendix A.

The events without longitudinal leakage are characterised by all counters of muon wall without hit. The influence of the cut: MuBackHit=0 on the reconstructed energy spectrum for 300 GeV pion beam at $\eta = -0.15$ is illustrated on the Fig. 6, where low energy tail suppression is clearly seen.

5 Summary

The muon wall scintillation counters and their correspondence to the DAQ system is described for the June–July 1998 barrel module 0 beam test period in Table 1. Starting from RUN No. 44330 the configuration without side muon wall is used, the values of back muon wall stay valid also for July 1999 test beam period.

The remote control is explained and the suitable positions of the movable muon walls for the beam test of the Tilecal barrel module 0 are given in Tabs. 2,3.

The response of muon wall counters to the muon beam is listed in Table 6 and the typical spectra are shown on Fig. 4 and 5.

The usage of standard Ntuple variable MuBackHit to select events without longitudinal leakage is demonstrated on Fig. 6.

6 Acknowledgements

Financial support of Prague group by grant RP-4210/69 of the Ministry of Industry and Trade of the Czech Republic is acknowledged.

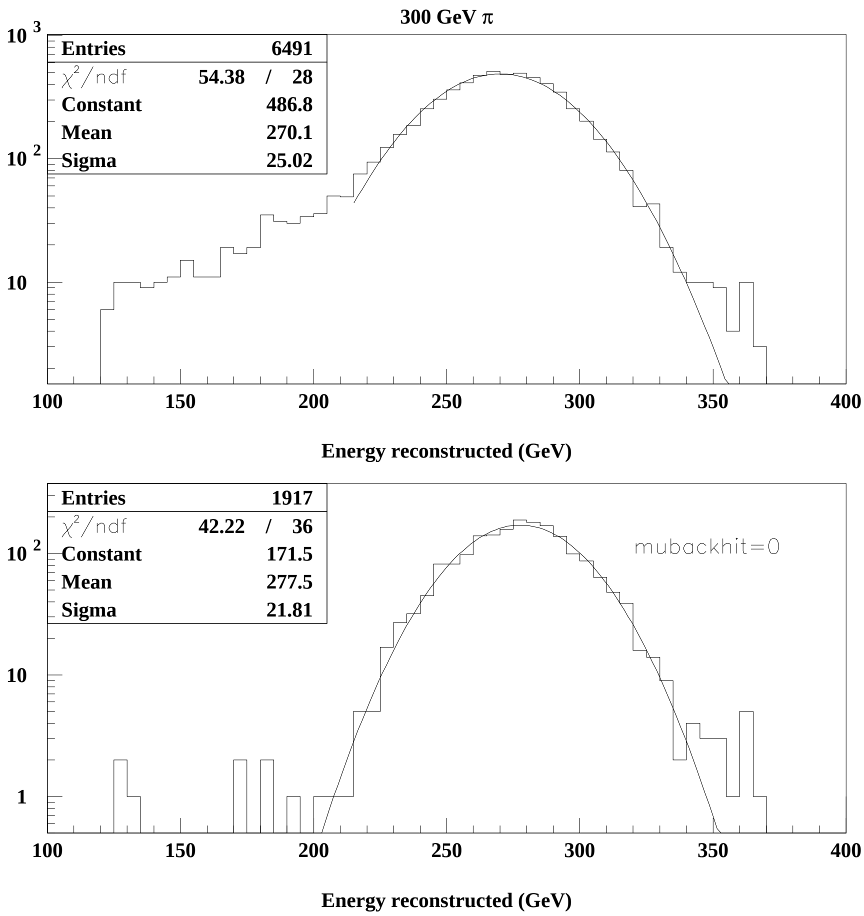

Figure 6: Low energy tails in the 300 GeV pion spectrum before (upper plot) and after (lower plot) rejecting events with a hit in the muon wall.

References

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[3] R. Miller et al.: *Midsampler Scintillator Planes for LArCal + Tilecal Combined Tests*, TILE-TR-060, June 24, 1996.

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A Muon wall data in the standard NTUPLEs

The Muwall information in the standard N–tuple has the following structure:

```
*      1   * R*4  *        *        * MUWALL   * MuBackSum
*      2   * R*4  *        *        * MUWALL   * MuBackHit
*      3   * R*4  *        *        * MUWALL   * MuSideSum
*      4   * R*4  *        *        * MUWALL   * MuSideHit
*      5   * R*4  *        *        * MUWALL   * dummy
*      6   * R*4  *        *        * MUWALL   * MuBack(14)
*      7   * R*4  *        *        * MUWALL   * MuSide(10)
```

- MuBackSum contains the normalised sum of the 14 counters of the back muon wall.
- MuBackHit is the number of counters detecting at least one charged particle (m.i.p.) in the back muon wall.
- MuSideSum and MuSideHit are equivalent values for the side muon wall.
- The muon walls are described by 4 words and two vectors MuBack(14) and MuSide(10). The vectors contain ADC output for each counter (the vector sequence numbers correspond to the logical numbers shown in the Figs. 2,3).

  For the 'Prague' counters the values given are **NON-AMPLIFIED ADC** counts, for the 'MSU' counters the values are **AMPLIFIED ADC** counts.