Partículas de muy bajo pT en el *Combined TestBeam* 2004 de ATLAS

Carmen Iglesias

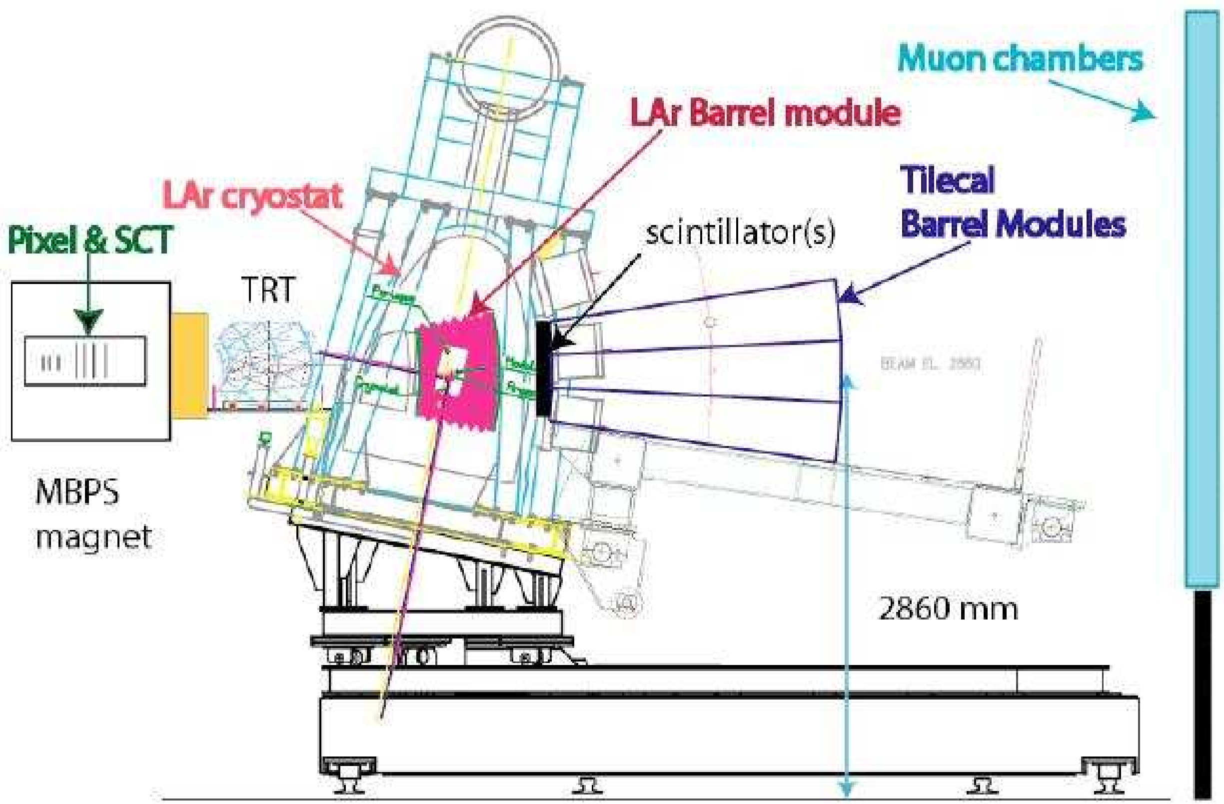
Dpto. Física Atómica y Nuclear

IFIC-Universidad de Valencia

XXX Reunión Bienal de la Real Sociedad Española de Física

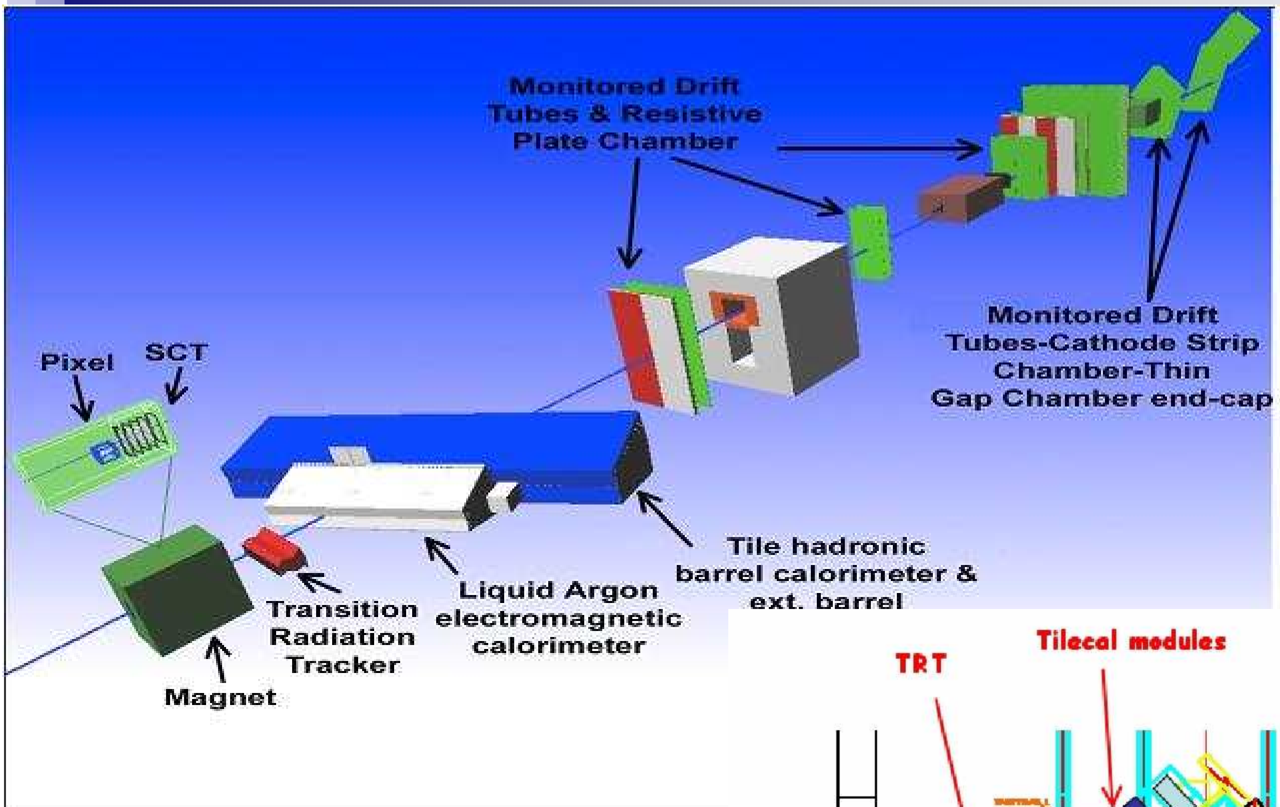
Campus Universitario de Ourense de la Univ de Vigo, 12-16 Septiembre de 2005.

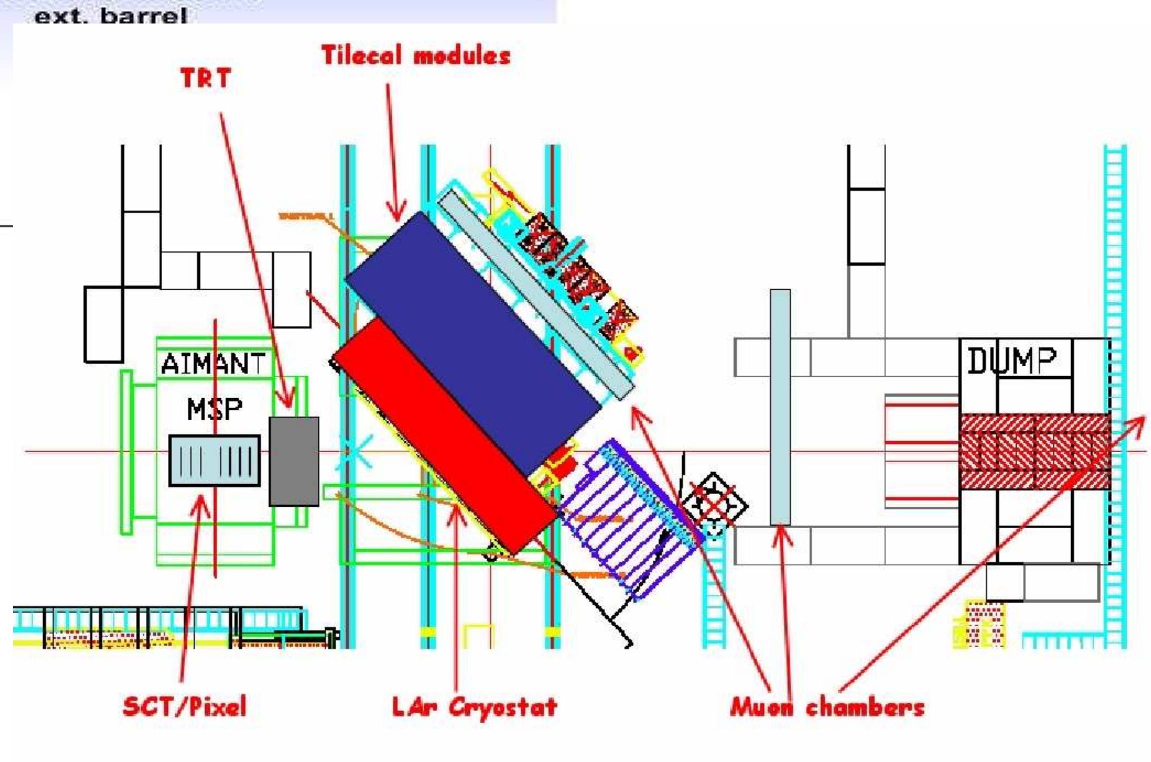
Combined Test Beam: setup



A full slice of the ATLAS experiment has been tested with beams of different particles (π's, μ's, γ, electrons and protons), at different energies (1-350 GeV) and polarities.

- **Inner Detector**: 3 layers of Pixel, 4 layers of SCT and 2 modules-barrel slice of TRT
- **Barrel EM and HAD calorimeter**: 2 barrel modules of EM LAr calo and 3 barrel modules of HAD TileCal + 3 extended barrel modules of HAD calo
- **Muon spectrometer**:


Monitored Drift
Tubes & Resistive
Plate Chamber
Monitored Drift
Tubes-Cathode Strip
Chamber-Thin
Gap Chamber end-cap
Pixel
SCT
Tile hadronic
barrel calorimeter &
ext. barrel
Liquid Argon
electromagnetic
calorimeter
Transition
Radiation
Tracker
Magnet


TRT
Tilecal modules
AIMANT
MSP
DUMP
SCT/Pixel
LAr Cryostat
Muon chambers

Physics sample

- events from 1 to 9 GeV at eta=0.35, with Calo info (LAr+Tile) and the tracks info from TRT only (pixels have problems)
- 100 k events for each point
- Mixture of e, π and μ
- Reconstruction with release 9.1.1
  - Separate the different kind of particles
  - Evaluate the fraction of e, π and μ
  - Apply clustering algorithms

Ntuples were generated by Vincent with the default values of RecExTB:

castor/cern.ch/atlas/ctb/test/real_data/reconstruction/Combined/

Energy	#Run
1 GeV	2101077
2 GeV	2101078
3 GeV	2101079

Energy	#Run
4 GeV	2101080
5 GeV	2101047
6 GeV	2101084

Energy	#Run
7 GeV	2101085
8 GeV	2101048
9 GeV	2101049

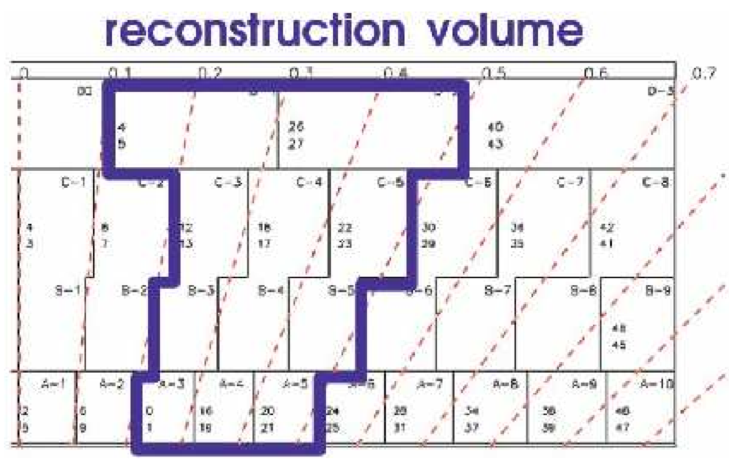
Energy Reconstruction

- E = Sum of cells with $|E_{cell}| > \sigma_{pedestal}$

Level of noise per cell

	σ_{noise} in MeV
Presampler	60 for eta < 1.4
Front	32
Middle	60
Back	70
TileCal A	25
TileCal BC	25
TileCal D	25

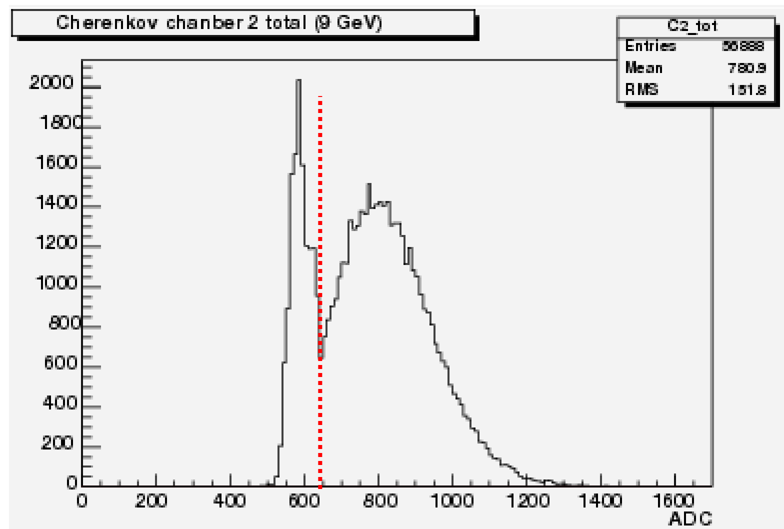
- Only cells in a small volume around the beam axis
  - For LAr
    $0.25 < \eta < 0.45$
    $-0.15 < \varphi < 0.15$
  - For TileCal
    $0.20 \leq \eta \leq 0.50$
    $-0.1 < \varphi < 0.1$
    (cells A3, A4, A5, BC3, BC4, BC5, D1, D2)

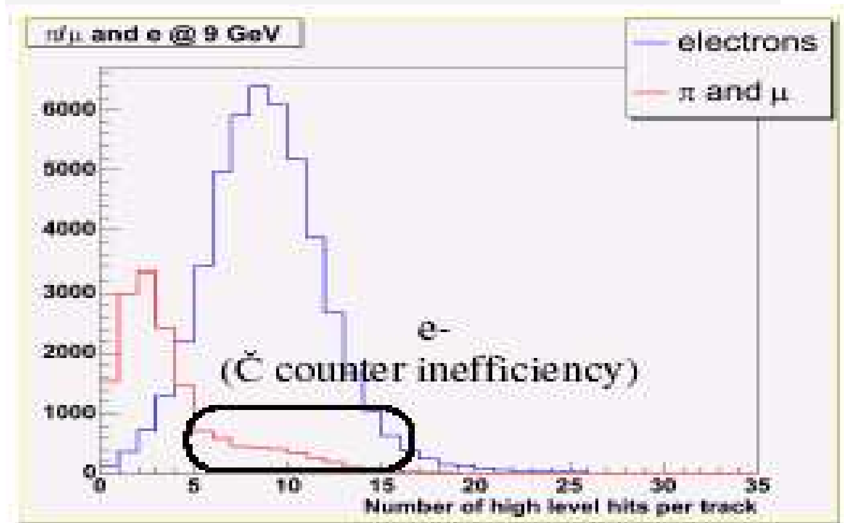


Because the hadronic shower is wider than the electronic one, and the most of the deposition comes from pions in Tile.

Beam definition

- **Selection of good tracks**
  - trk_nTracks==1Only 1 track
  - trk_nTrtHits[0]≥20 More than 20 hits per track
- **to separate e from π/μ**
  - Cherenkov2 counter cut
    - for electrons: sADC_C2>650
    - for π/μ: sADC_C2<650
  - high-level hits (improves the Cherenkov efficiency)
    - for π/μ: nHL>5
    - for π/μ: nHL≤2

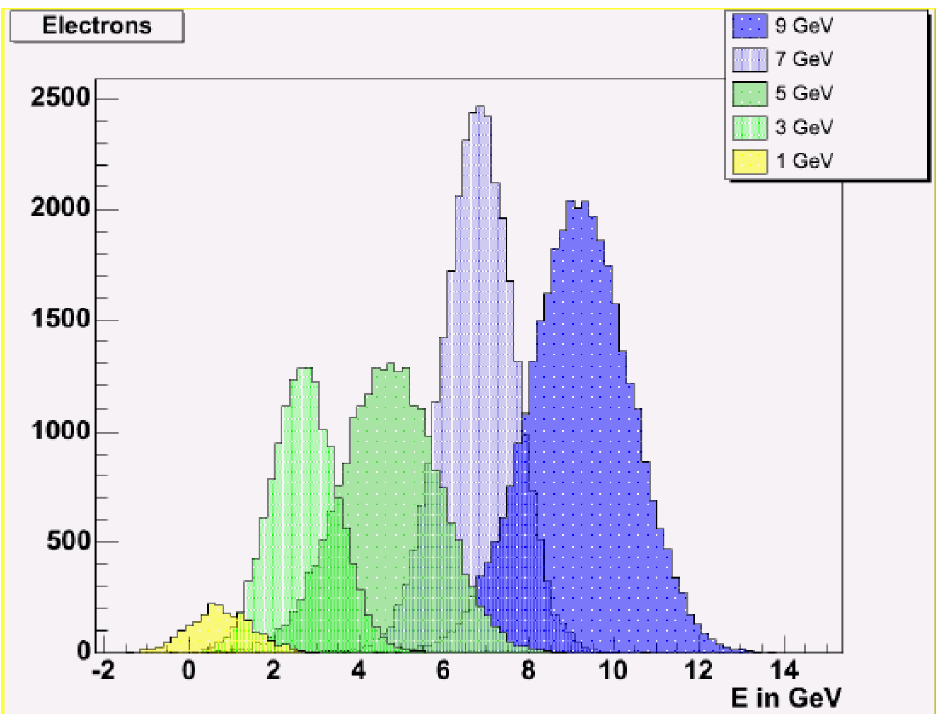




The Electron sample

Electrons are selected requesting:

- ❑sADC_C2>650 Cherenkov2 counter cut
- ❑nHL>5 number of high-level hits
- ❑No energy in TileCal sample D : to remove the μ contamination



Energy in GeV	Events with 1 track	Electrons
1	82 k	1.8 k
2	78 k	7.7 k
3	74 k	14 k
4	65 k	13 k
5	31 k	21 k
6	66 k	28 k
7	64 k	29 k
8	56 k	29 k
9	63 k	34 k

Separate pions from muons

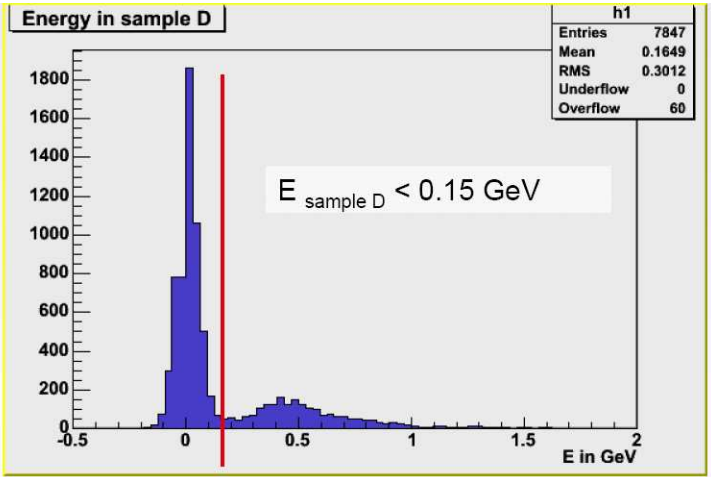
Both **pions and muons** are:

- ❑ sADC_C2<650 Cherenkov2 counter cut
- ❑ nHL≤2 number of high-level hits

First method: using sample D as a muon veto

Assuming that only muons can reach sample D and π signal is only coming from pedestal, we put the cut:

$$E_{SampleD} < 0.15 \text{ GeV}$$



ADVANTAGE: method very efficient and easy to reproduce with MC
DISADVANTAGE: we can reject pions that reach the sample D, getting a bias.

In order to avoid it, different strategies are followed depending on ET:

a) below 6 GeV : using TileCal last sample as a muon veto. It is supposed that there is no ET in Sample D from pions (only pedestal)

b) above 6 GeV : use another method→ longitudinal profile in Tilecal

Second method: Using the longitudinal profile

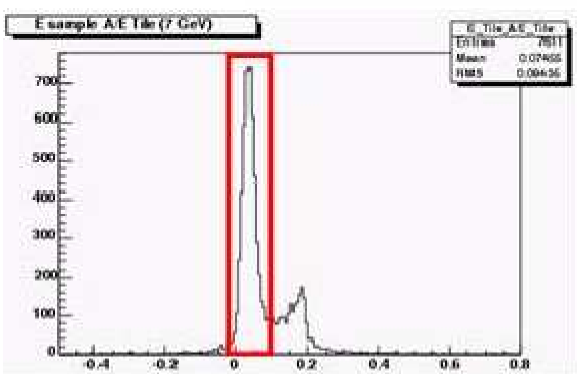
Using the fact tha muons leave their ET uniformly (normalizing by the path lenght)

E $\propto$ path in matter

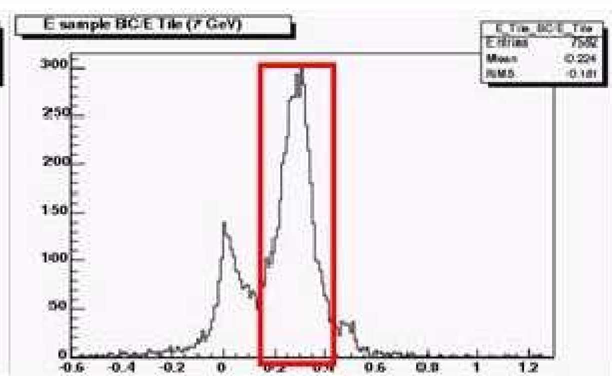
Sample	Depth	D(Sample)/ D(Tot)
A	30 cm	0,19
BC	84 cm	0,54
D	42 cm	0,27
Total	156 cm	

For E_T>6GeV, different conditions are applied to $\frac{E_{SampleA}}{E_{Tile}}$, $\frac{E_{SampleBC}}{E_{Tile}}$ and $\frac{E_{SampleD}}{E_{Tile}}$

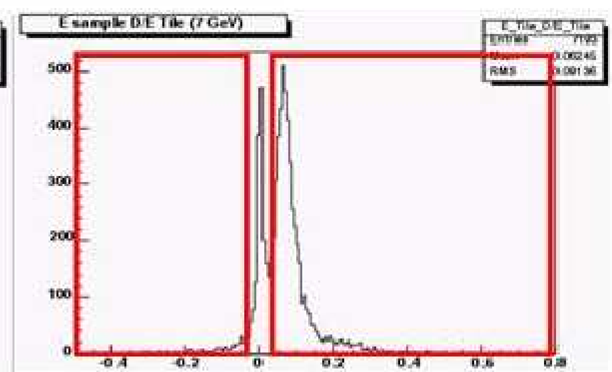
E_T	$\frac{E_{SampleA}}{E_{Tile}} \equiv x_A$	$\frac{E_{SampleBC}}{E_{Tile}} \equiv x_{BC}$	$\frac{E_{SampleD}}{E_{Tile}} \equiv x_D$
7 GeV	$0.0 < x_A < 0.1$	$0.15 < x_{BC} < 0.45$	$\lvert x_D \rvert > 0.05$
8 GeV	$0.0 < x_A < 0.1$	$0.20 < x_{BC} < 0.40$	$\lvert x_D \rvert > 0.05$
9 GeV	$0.0 < x_A < 0.1$	$0.22 < x_{BC} < 0.37$	$\lvert x_D \rvert > 0.05$



$0.0 < E_{sampleA}/E_{Tile} < 0.1$



$0.15 < E_{sampleBC}/E_{Tile} < 0.45$



$|E_{sampleD}/E_{Tile}| > 0.05$

Number of Particles

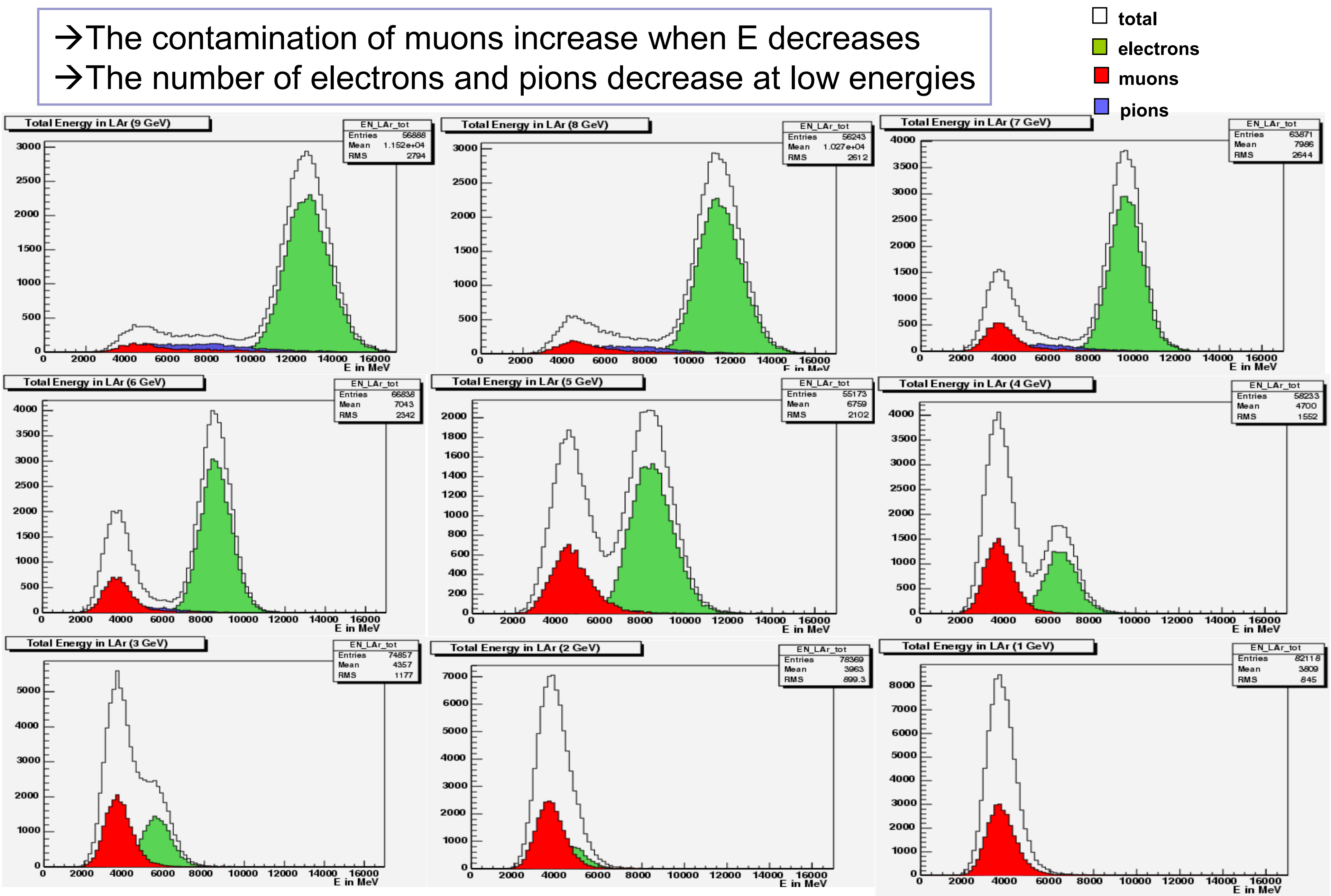
E_T particles	Total particles	Electrons # in LAr	Electrons (%)	Pions # in LAr	Pions (%)	Muons # in LAr	Muons (%)
9 GeV	50599	31618	62.48	2687	5.31	779	1.54
8 GeV	49948	30521	61.10	1983	3.97	1404	2.81
7 GeV	51150	27318	53.40	1459	2.85	3279	6.41
6 GeV	53440	26988	50.50	1098	2.05	5878	11.00
5 GeV	55173	22475	40.73	651	1.18	8914	16.16
4 GeV	58233	58233	23.70	176	0.30	14668	25.18
3 GeV	59870	12131	20.26	227	0.38	15902	26.56
2 GeV	62625	6753	10.50	96	0.15	19581	31.27
1 GeV	65711	1918	2.92	71	0.11	23614	35.94

- For **electrons**, the conditions used seems to be good to select them, and they decreases at lower E_T at the same time that increase the **muon** contamination.

- **Pions** in LAr also decrase at smaller E_T. In TileCa, it is more difficult to select them due to the large contamination of **high energy muons**, coming from the high E line.

In LAr

- →The contamination of muons increase when E decreases
- →The number of electrons and pions decrease at low energies



Clustering info in CBT ntuples

- **Emcluster**: clusters from the sliding window algorithm

- **Tbemclusters**: clusters from an algorithm used in previous test beam. It has been added to allow comparison. It's a window of 3x3 cells.
  - Emclusters and tbemclusters use only cells from the LAr calorimeter.

- **Cmbclusters**: sliding window clusters but they are done on towers (larg+tile) and not anymore on cells. It is not working for the moment because of a coordinate problem between LAr and Tile.
  - LAr is shifted with respect to Tile by "half module" :
    - TileCal has just 3 modules -0.15 < eta < +0.15
    - LAr has -0.2 < eta < 0.2,

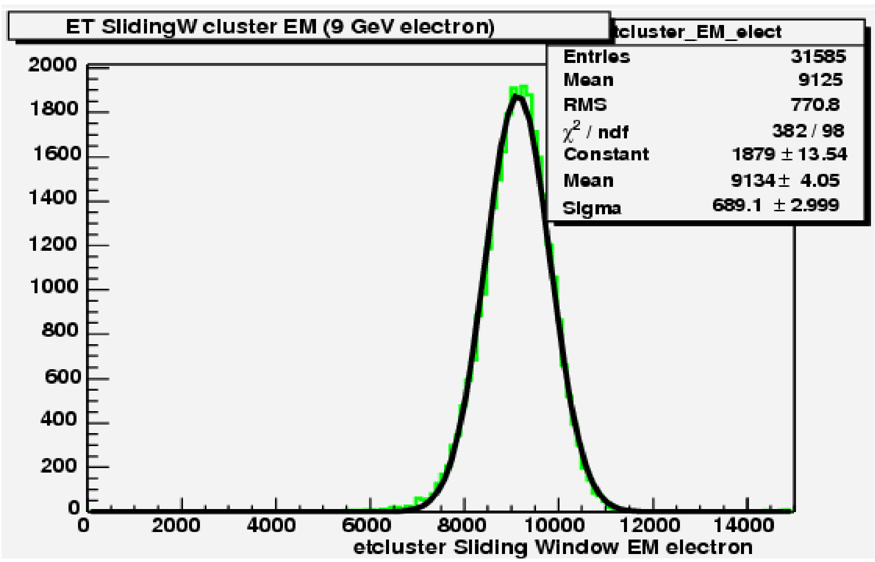
    i.e. there are 3 slices with $\Delta\phi$=0.1 in Tile and 4 slices in LAr, shifted by half of the slice

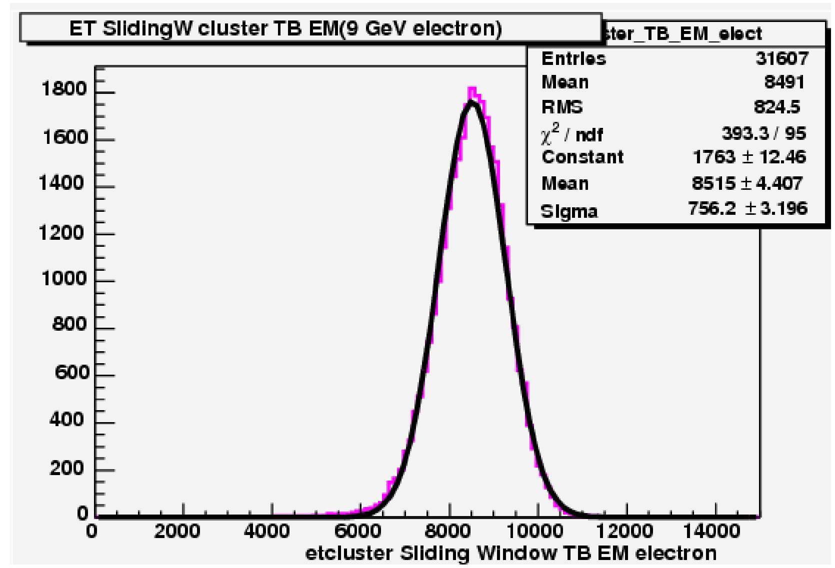
- **Topo_EM cluster and Topo_Tile cluster**: Finds a seed cell, then cluster expands by checking energy in neighboring cells. Thresholds for defining seed and including neighbors can be changed. The default values are:
  - seed threshold is $E/\sigma_{noise}>6$
  - neighbor threshold is $E/\sigma_{noise}>3$

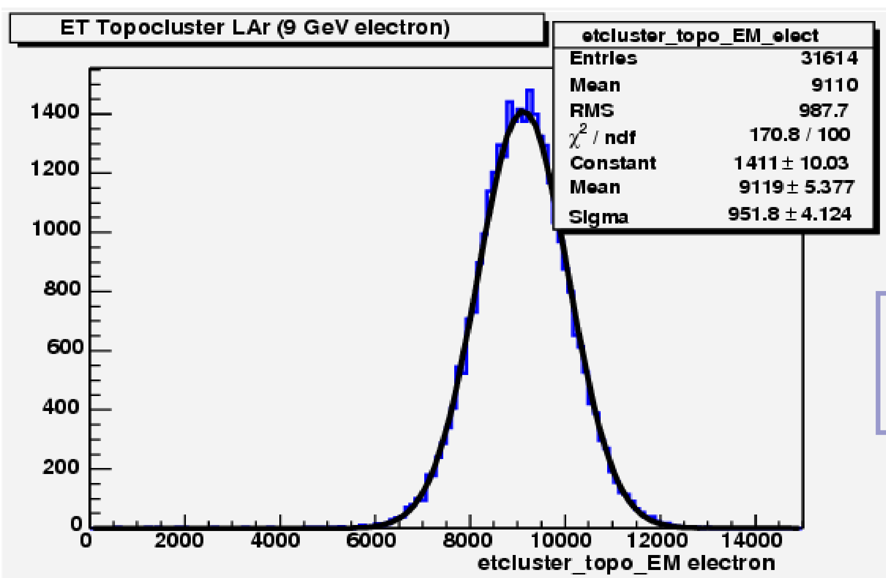
  (Hadronic TopoCluster is the sum of Topo_EM and Topo_Tile)

e- in Lar: Energy distribution

For electrons at **9 GeV**







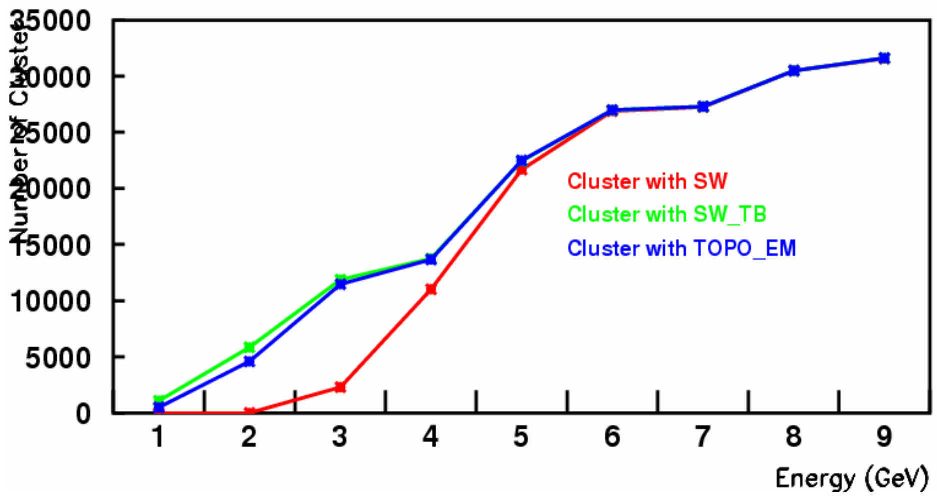
→For electron it seems as the cuts on TRT works good

e^- in LAr: Number of Clusters

E_T particles	# particles electrons	# Clusters SW cluster	SW_TB cluster	Topo_EM cluster
9 GeV	31618	31585	31607	31614
8 GeV	30521	30475	30506	30514
7 GeV	27318	27252	27303	27292
6 GeV	26988	26878	26969	26961
5 GeV	22475	21689	22446	22464
4 GeV	58233	10994	13751	13670
3 GeV	12131	2292	11869	11472
2 GeV	6753	—	5853	4574
1 GeV	1918	—	1093	482

→#particles and #cluster is very similar → #clusters is very similar between them for each ET value.

#clusters is very low



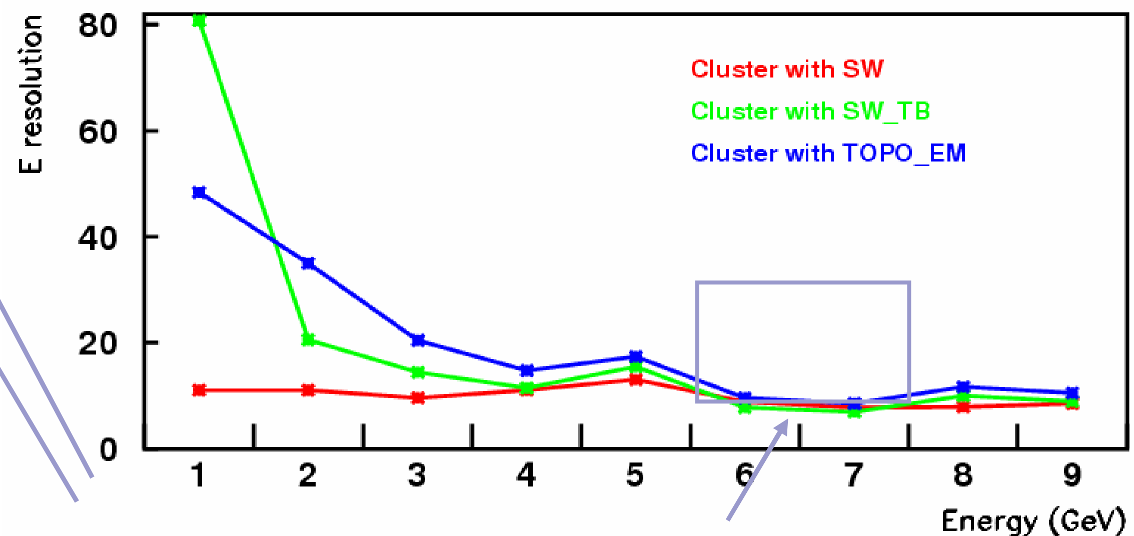
→ #clusters defined increase with the energy.

(*) There is a cut (E>2 GeV) in this algorithm by definition

e⁻ in LAr: Resolutions

→In general, the E resolution is better when E increases

	SW	SW_TB	TOPO_EM
9 GeV	7.57	8.92	10.48
8 GeV	8.51	10.04	11.64
7 GeV	7.85	6.93	8.51
6 GeV	8.83	7.81	9.62
5 GeV	13.07	15.47	17.34
4 GeV	11.04	11.47	14.78
3 GeV	9.59 (*)	14.38	20.39
2 GeV	---(*)	20.51	34.99
1 GeV	---(*)	80.75	48.38



E resolution slightly better than it's expected, **WHY?**
Maybe problems in the reconstruction chain

→The best resolution is for **SW**, but all the algo present very similar results.

→**TOPO** obtain the worst resolutions

→maybe it will be needed to change the thresholds for seed and neighbor cells.

→In my previous analysis of <u>clustering in VLE in simulation:</u> the best resolution with seed threshold E/σnoise>4 and neighbor threshold E/ σnoise>2 (but they have been done without noise and pile-up)

(*) There is a cut (E>2 GeV) in this algorithm by definition

Improvement in the resolution of electrons

New release of Athena is used:

- ❑Optimal Filtering is applied in LAr signal
- ❑Problems in the reconstruction chain have been solved.

Only samples with 9, 7, 5 and 3 GeV have been posible to generate

Now the TopoCluster is the global cluster for Lar+Tile calo:"super3D", as well as new values are used for the thresholds:

- seed threshold is $E/\sigma_{noise} > 4$
- neighbor threshold is $|E/\sigma_{noise}| > 3$

E_T particles	Energy resolution SW cluster	SW_TB cluster	Topo cluster
9 GeV	4.81	4.41	5.04
7 GeV	5.32	4.62	5.46
5 GeV	6.61	5.97	6.90
3 GeV	—	8.67	10.15

→There is a importan improvement of the resolution

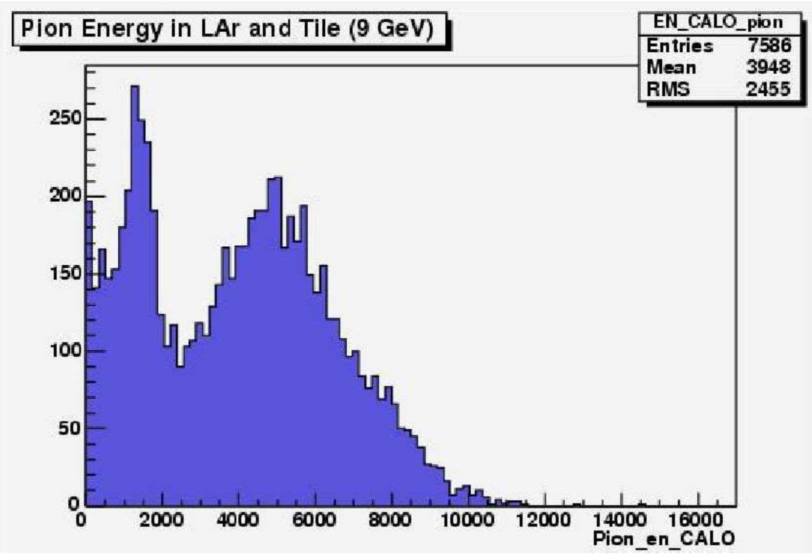
→The values are of the order that are expected for VLE particles (Calorimeter Performance π's at 9GeV ~4-5%)

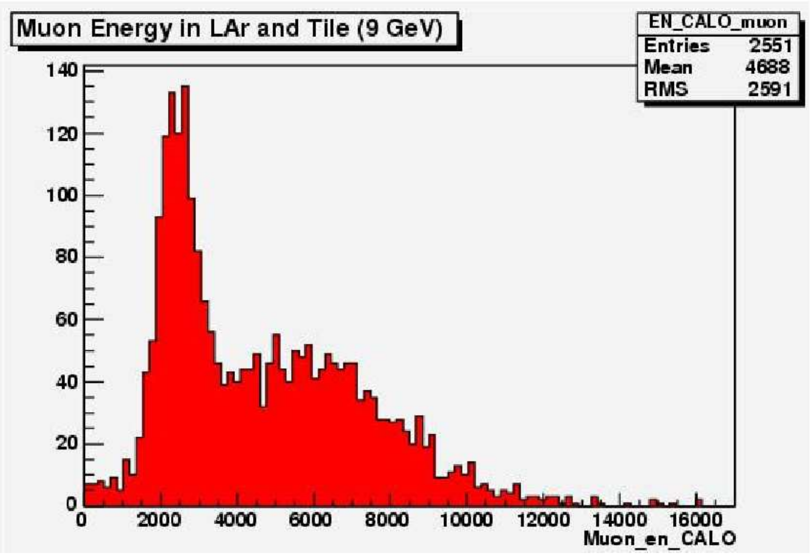
Results for pions and muons

E_T particles	# particles Pions	# particles Muons	# TopoClusters Pions	# TopoClusters Muons
9 GeV	5089	2551	5019	2481
7 GeV	3194	5170	3109	5120
5 GeV	1077	8723	1018	8673
3 GeV	344	13562	291	13546

E_T particles	E_T resolTopoClusters Pions	E_T resolTopoClusters Muons
9 GeV	21.05	—
7 GeV	21.55	10.19
5 GeV	23.78	12.02
3 GeV	27.86	16.65

Results are very difficult to interpert, because there is still a mixing of μ's and π's at energies above 7 GeV

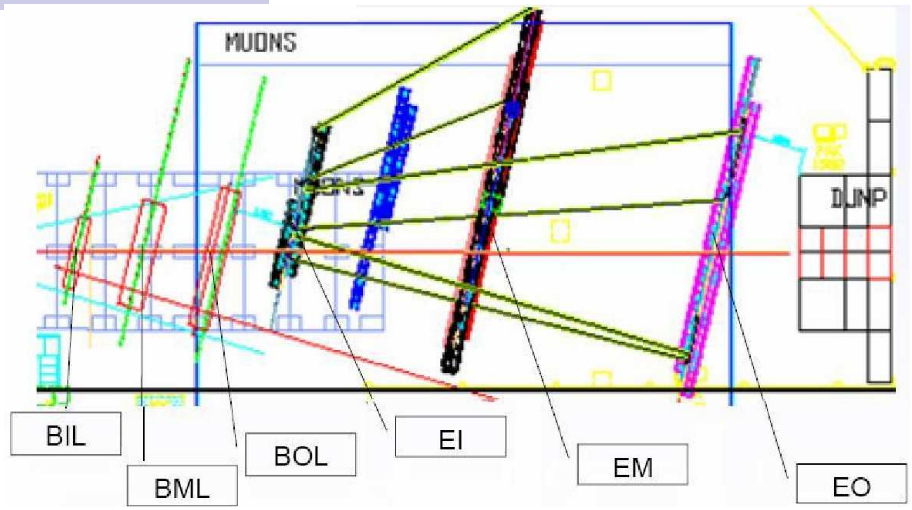




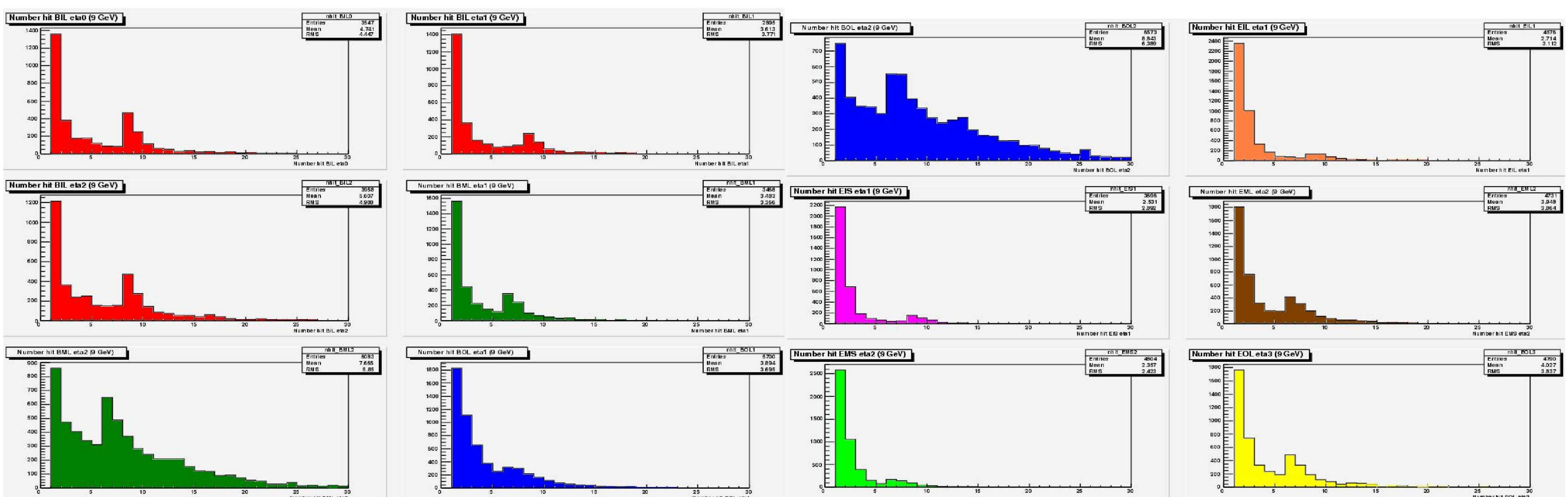
New method to separate μ's and π's

Third method: using MDT information

Using the variable *nMDTdig* to count the number of hits in the different MDT stations

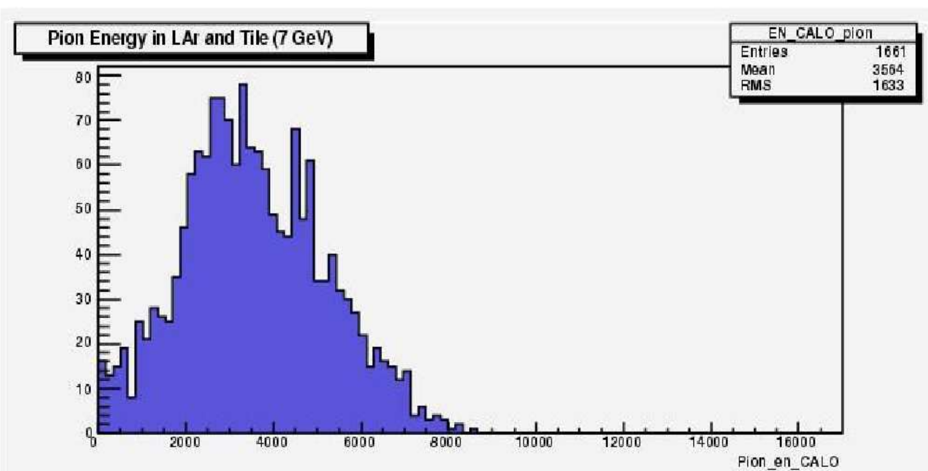


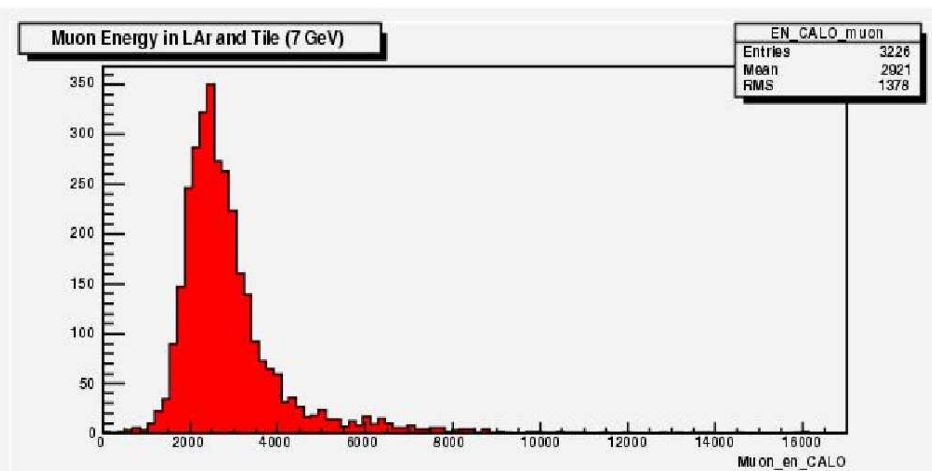
We can assume that events with **more than 8 digits** in a MDT stations are muons (because we have 8 plans tubes per station)



Station	Eta region	Cut to remove muons
BIL	0	Number of hits < 8
	1	No difference between μ and e-
	2	Number of hits < 6
BML	1	No difference between μ and e-
	2	Number of hits < 6
BOL	1	No difference between μ and e-
	2	Number of hits < 6
EIL	1	No difference between μ and e-
EIS	1	No difference between μ and e-
EML	2	Number of hits < 6
EMS	2	No difference between μ and e-
EOL	3	Number of hits < 6
EOS	3	No difference between μ and e-

After applying these cuts, the correct separation of π's from μ's above 7 GeV it's possible





E_T particles	# particles Pions	# particles Muons	# TopoClusters Pions	# TopoClusters Muons
9 GeV	2663	700	2638	697
7 GeV	1661	3226	1636	3204
5 GeV	572	7822	548	7796
3 GeV	278	12671	249	12857

→#TopoClusters is very similar to #particles, so the **clustering method** seems to **works well**.

The resolution from π's is rather similar, nevertheless the most important results is the **improvement in resolution for μ's.**

E_T particles	E_T resolution (Topo) Pions	E_T resolution (Topo) Muons
9 GeV	21.15	6.54
7 GeV	22.42	7.13
5 GeV	23.08	9.45
3 GeV	30.30	15.05

- For $E_{beam} > 7$ GeV, the use of MDT cuts to reject muons is more satisfactory than using a cut on TileCal last sample (No bias).
- For energies bellow 7 GeV, there are too much muons, and the cut on the 3rd TileCal sample is justified here (negligible energy expected for pions)

Conclusions

- The reconstruction of very low energy particles it's possible with the tools available in the reconstruction package for the Combined TestBeam inside Athena.

- For the recostruction of 1-9 GeV e-, the two Sliding Windows algo are usefull, and the Topocluster results are very competivie with them. The energy resolutions obtained are of the order that it is expected
  - Nevertheles, it will be necessary to apply some changes in the ET thresholds of SW to can apply them at 1-3 GeV e.m. particles

- The reconstruction of π's and μ's, first nedeed of a very accuracy separation of them. We conclude to use the muon veto ($E_{SampleD}$<0.15GeV) for E<6GeV and the MDT cuts for larger energies. The values of E resolutions obtained are inside the expected ones.
  - However, it will be interesting a tunning work to adapt the E threshold more properly to VLE particles (as in the previous simulation analysis)