Pion contamination in Muon beam

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Data

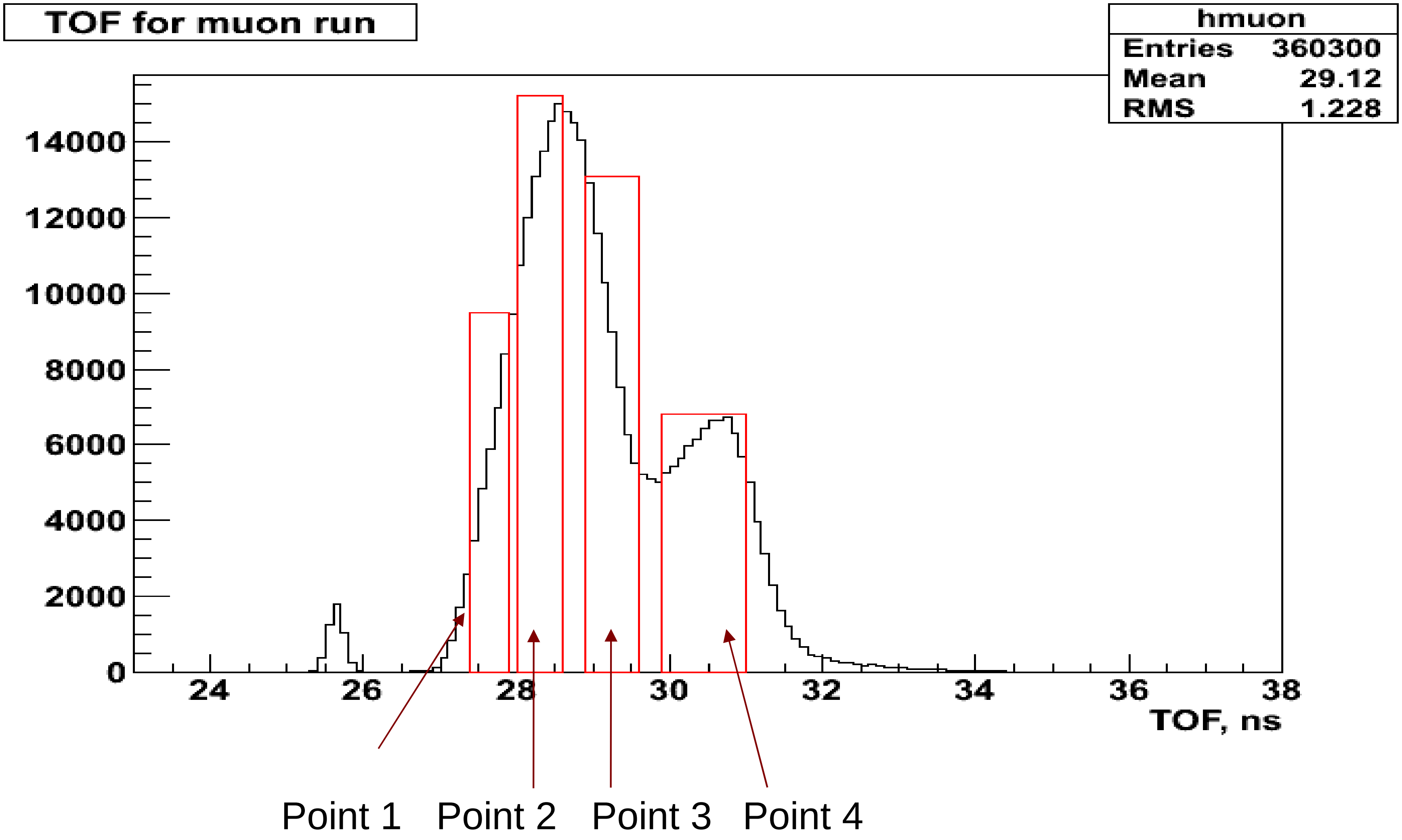
Muon runs with full statistics:
Muon1:
200 MeV/c, nominal (P(D2) = 237 MeV/c) => 3407, 3506, 3507, 3514, 3515, 3516
Muon2:
140 MeV/c, 6pi (P(D2) = 188.86 MeV/c) => 3419, 3420, 3495, 3499

Pion runs with full statistics:

	TOF1-TOF0, ns	Muons		Pions	
		from run	with P(D2), MeV/c	from run:	with P(D2), MeV/c
Point 1	27.4 - 27.9	3253	294	3426	341
Point 2	28.0 - 28.6	3252, 3250	258	3261	320
Point 3	28.9 - 29.6	3256	222	3454	280
Point 4	29.9 - 31.0	3364, 3373, 3375	195	3252, 3250	258

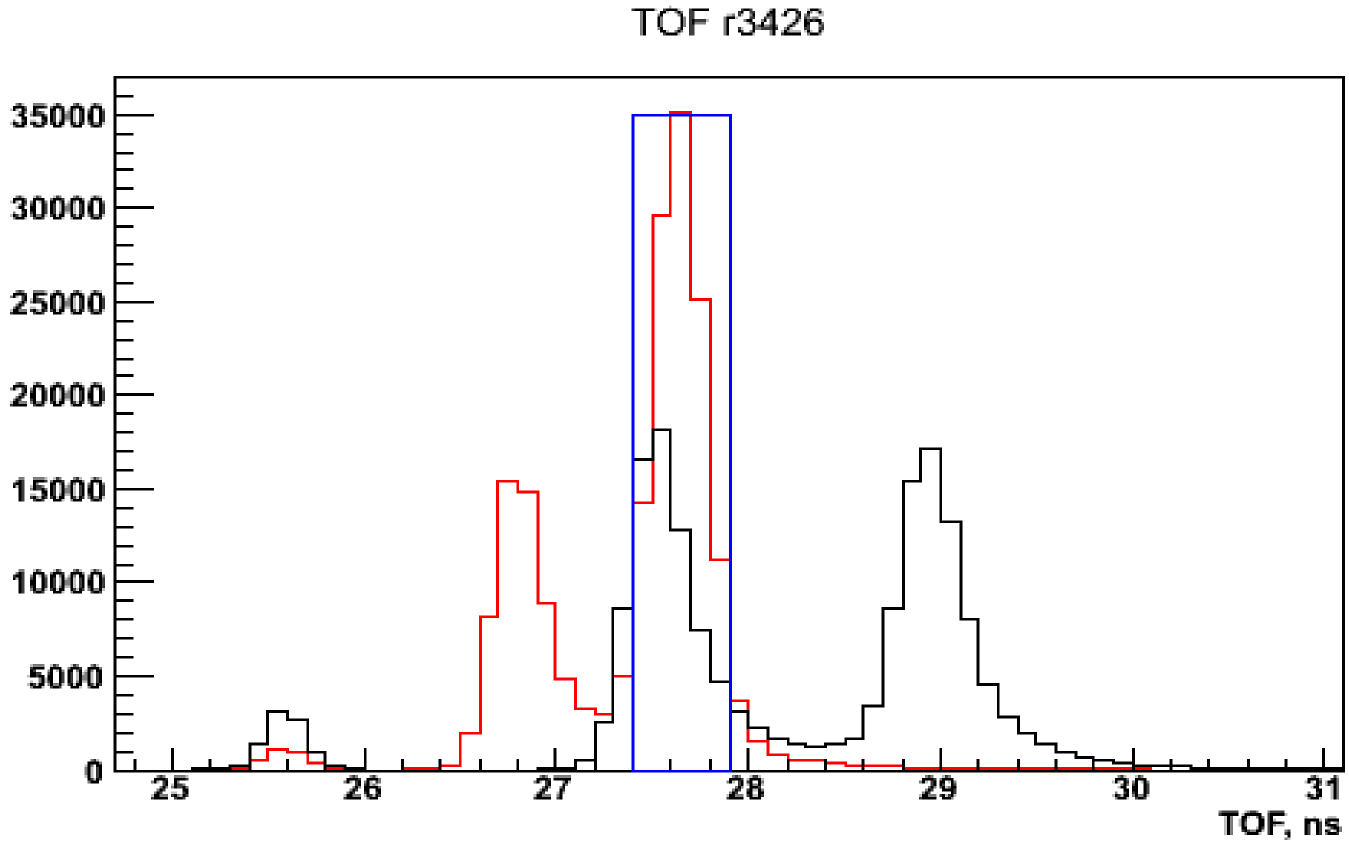
Covered points

POINT == TOF window



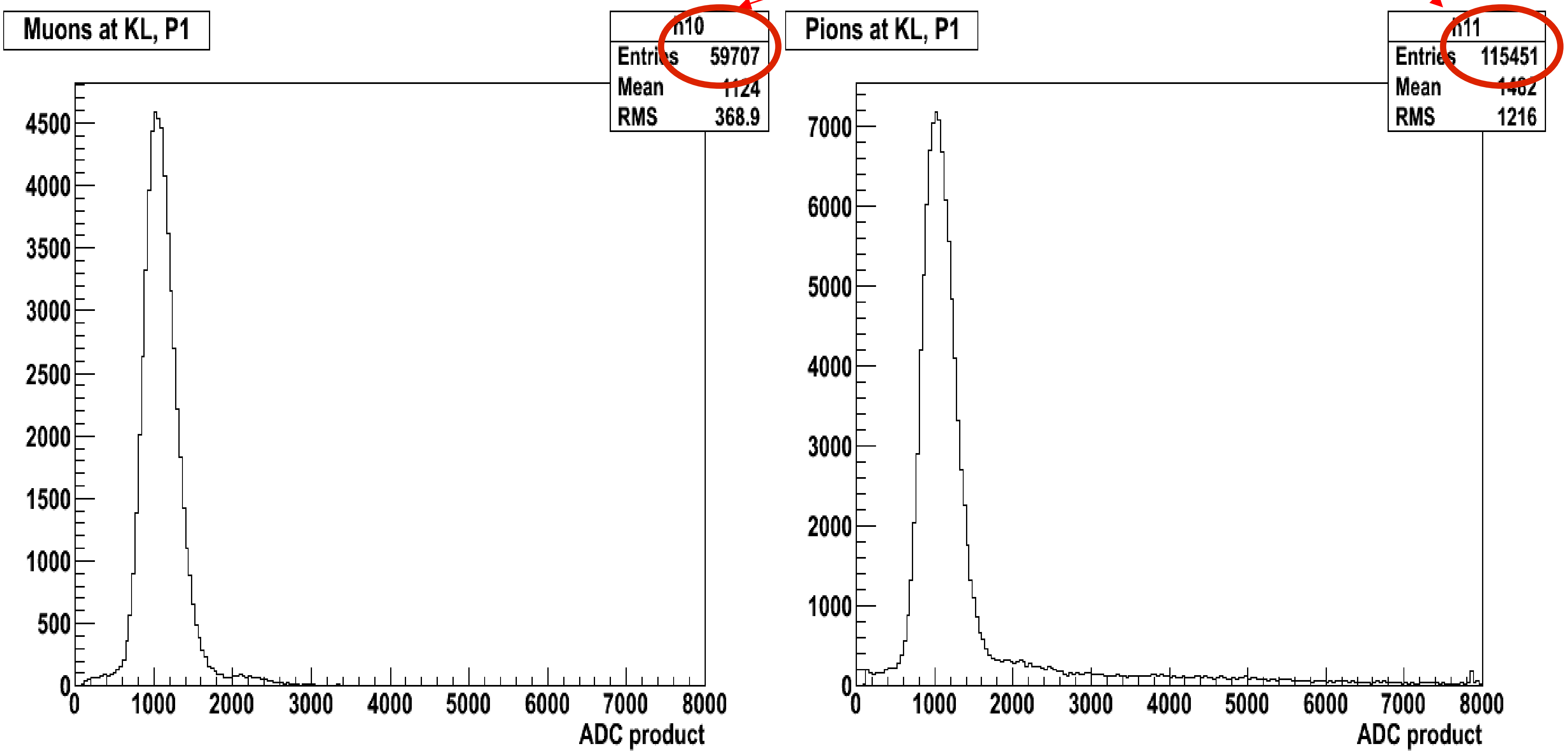
Procedure

1. Select TOF slot. It is determined mainly by the overlap region between muon and pion peak in **pion runs**.



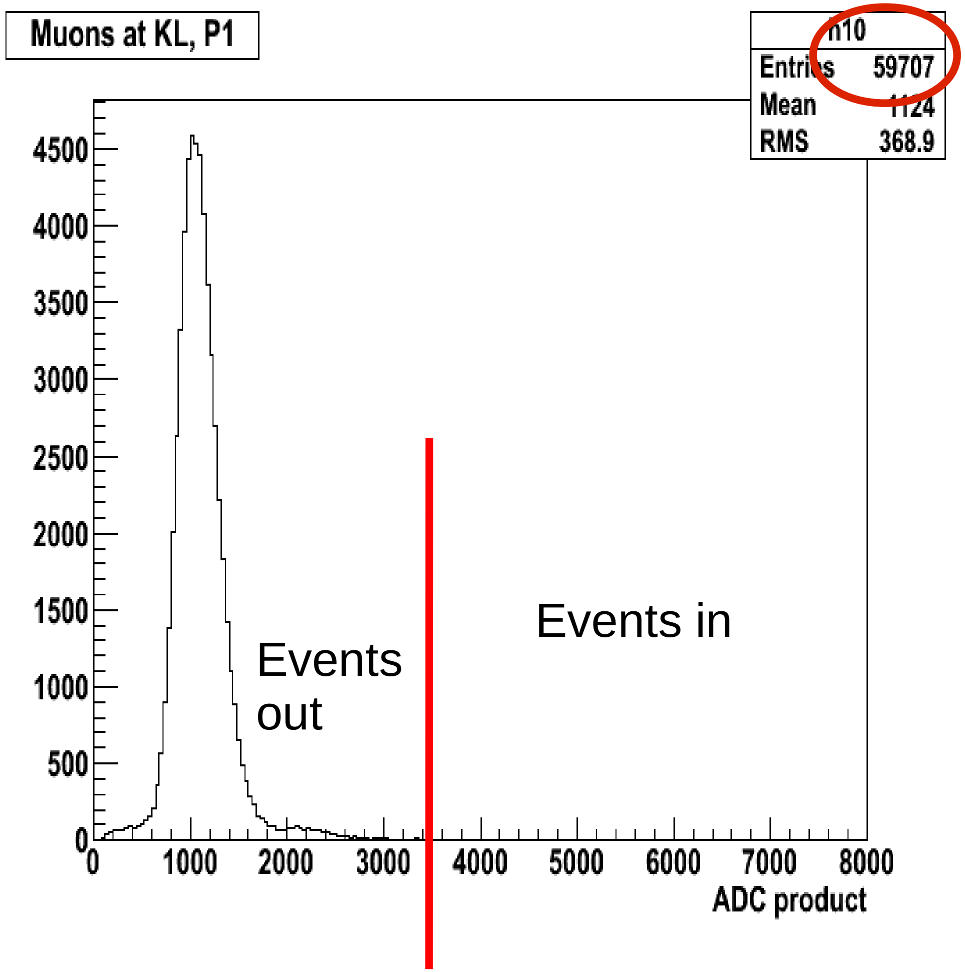
Procedure

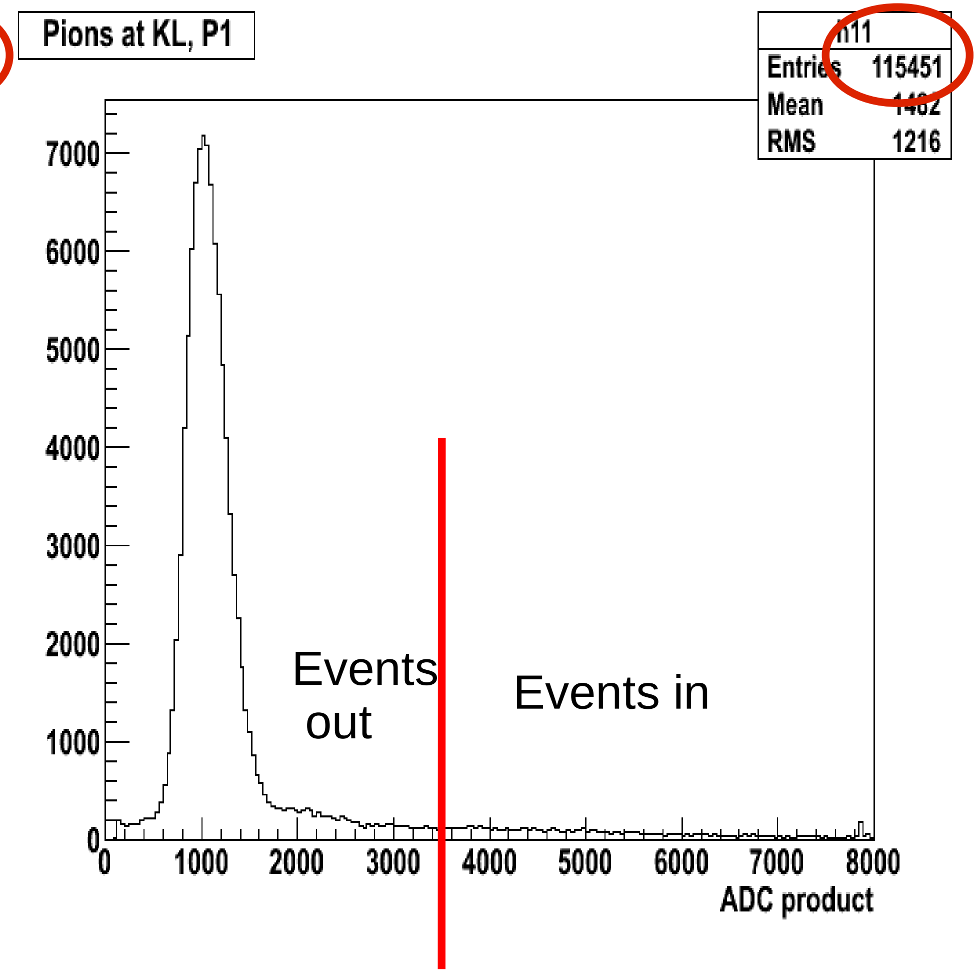
2. For the given slot count the number of muons **Tμ** in muon peak and pions **Tπ** in pion peak.



Procedure

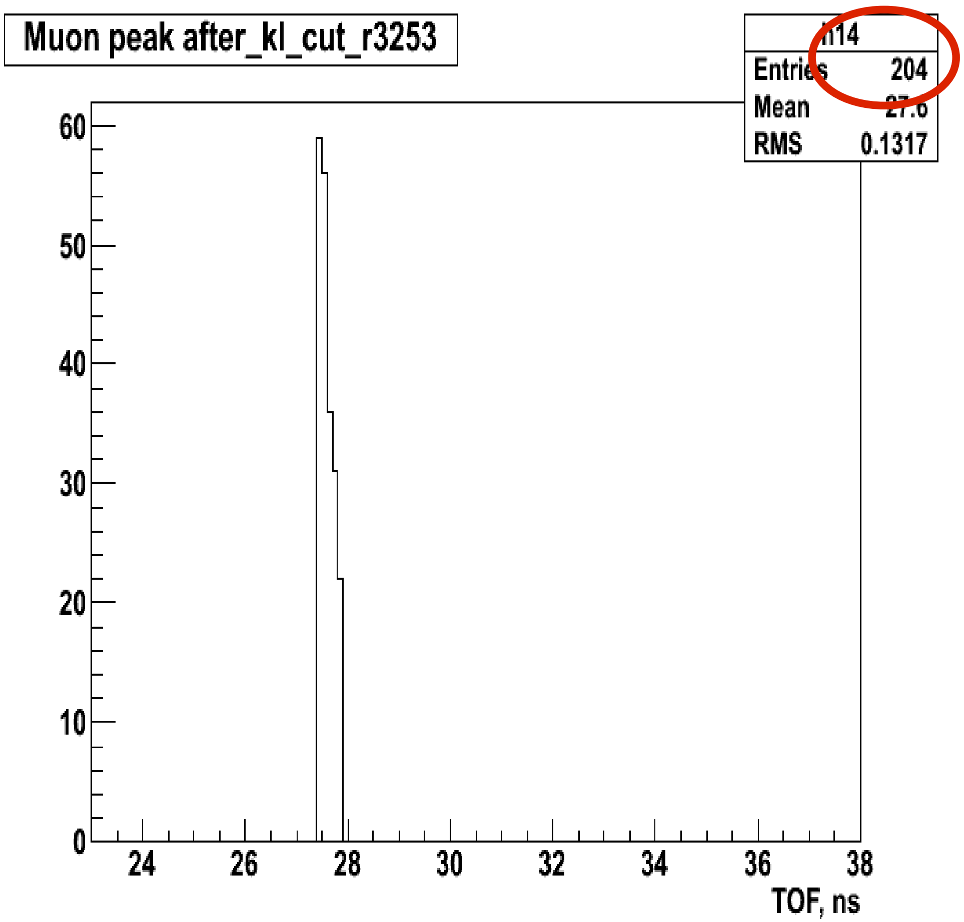
3. For the same TOF slot, apply a cut on KL ADC counts for muons and pions in **pion run.** The cut must be **the same** for muons and pions. We can vary it in order to check for some cut dependence of results.

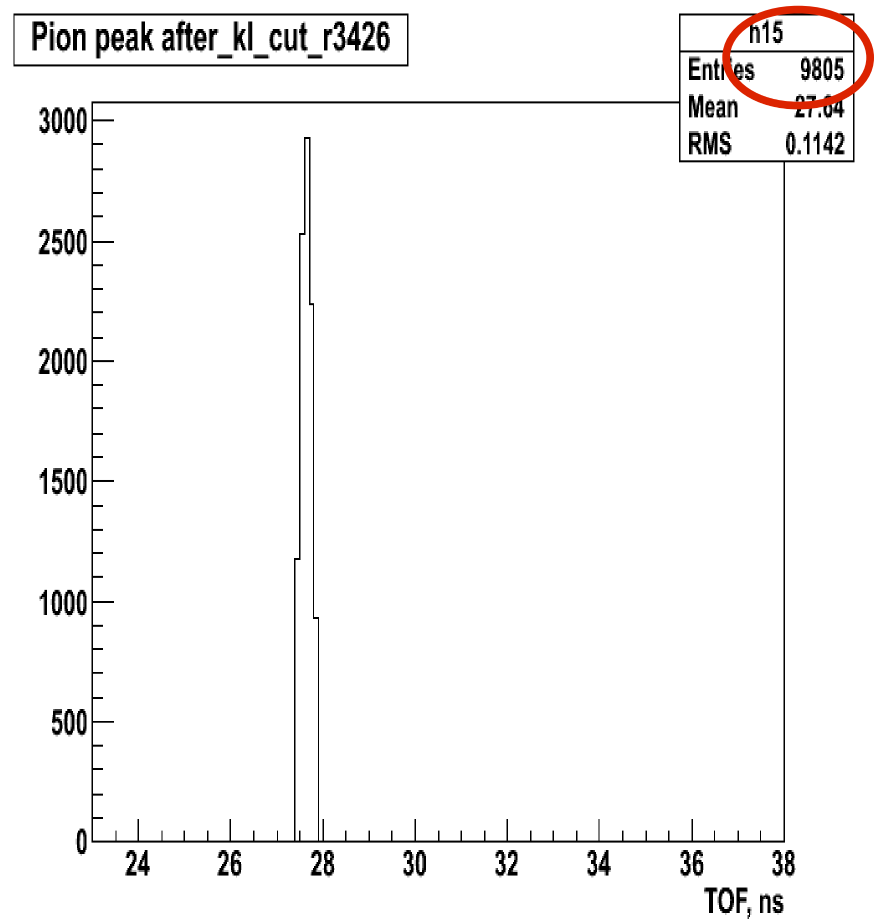




Procedure

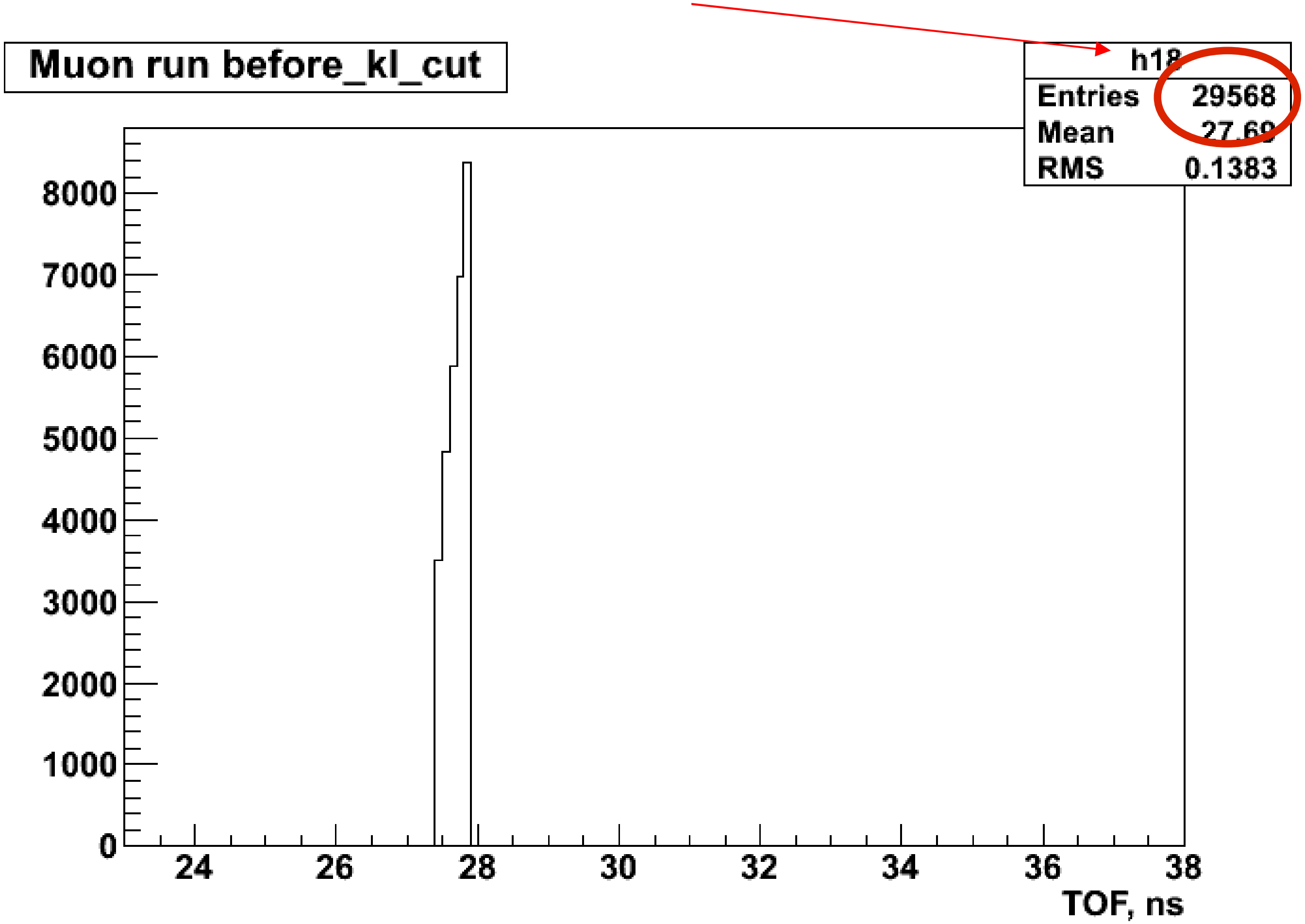
4. Count again the number passed the cut muons **Cμ** and pions **Cπ**.
5. Calculate the fraction of passed the cut muons **Kμ = Cμ/Tμ** and pions **Kπ = Cπ/Tπ**.





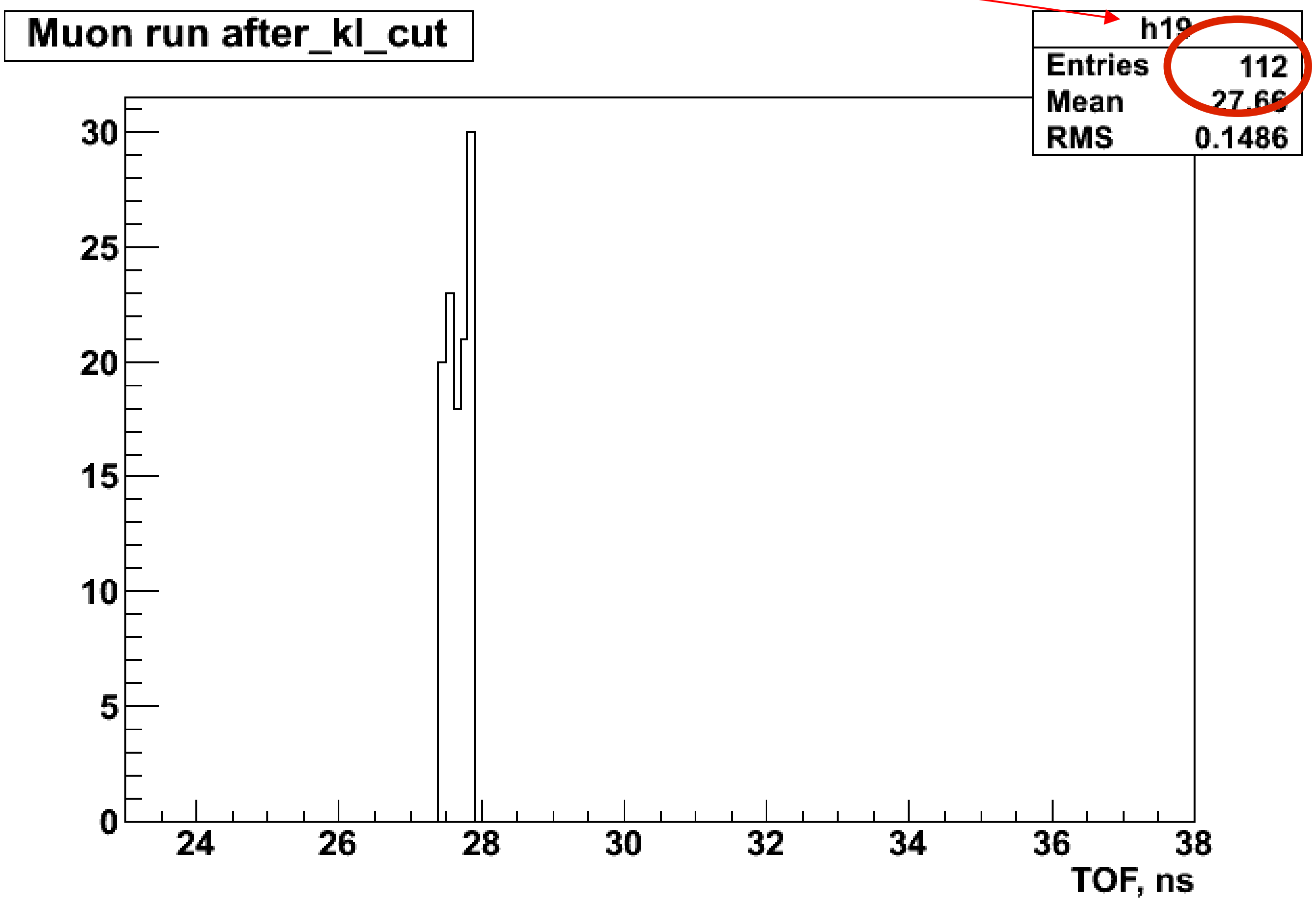
Procedure

6. For the **same TOF** slot count the number **N** of particles in both **muon runs separately**. We believe there are muons and pions, i.e. **N = Nμ + Nπ**.



Procedure

7. Apply **absolutely the same cut** on KL ADC (as it is in p.3 up) for muon runs and count survived particles **Ncut**.



Procedure

8. Our main assumption is that the same fraction of muons **$K\mu$** and pions **$K\pi$** after the cut will survive, i.e. **$Ncut = K\mu * N\mu + K\pi * N\pi$**.
9. Solve the equations (6) and (8) and determine number of muons **$N\mu$** and pions **$N\pi$** in **muon runs:**

   $N = N\mu + N\pi$
   $Ncut = K\mu * N\mu + K\pi * N\pi$.

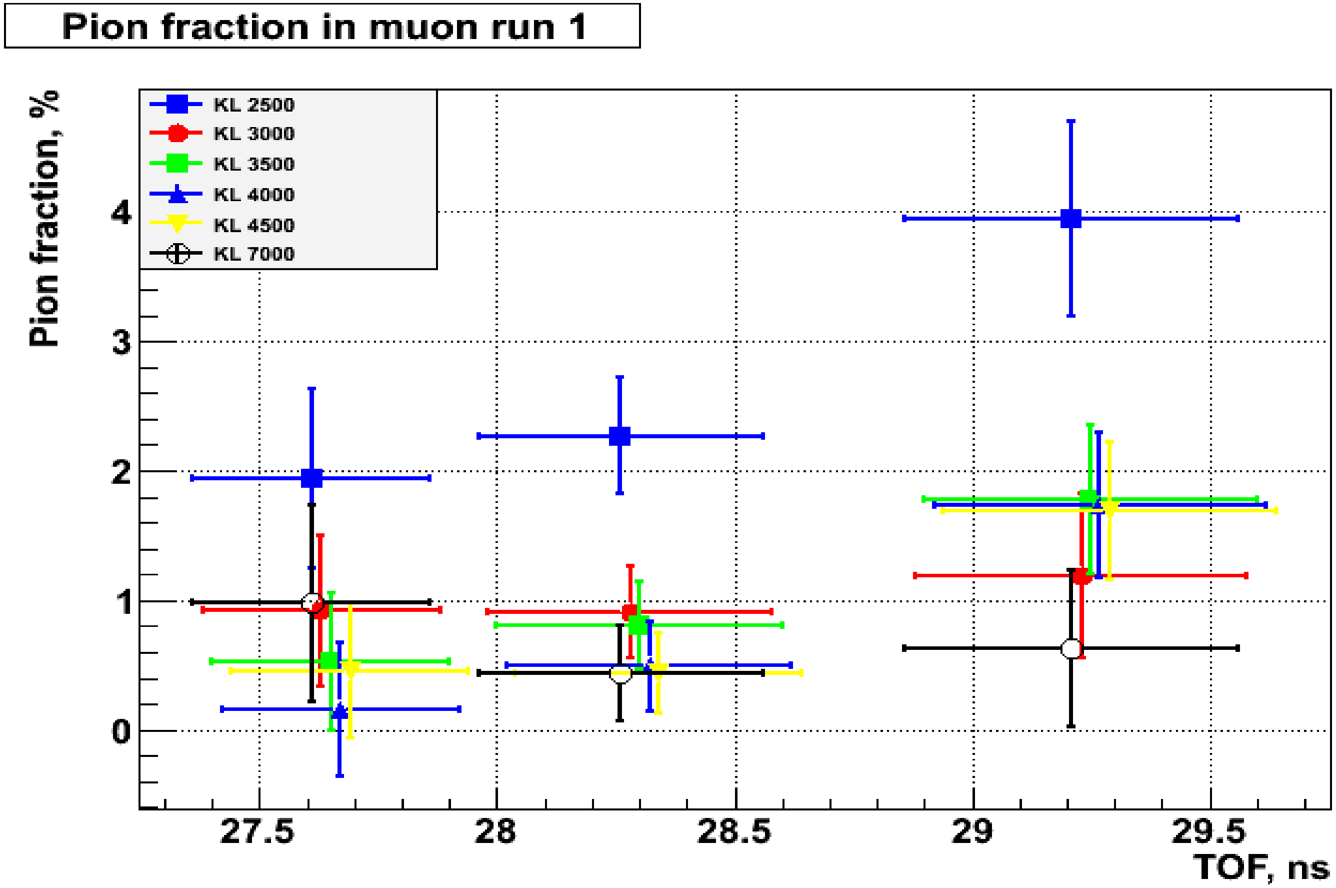
10. Determine their fractions **$N\mu/N$** and **$N\pi/N$.** Calculate statistical uncertainties .

Pion fraction in muon run 1 (table)

The table represents the fraction of pions in % as a function of KL cut and TOF windows (P1, P2, P3). The errors are statistical sigma's.

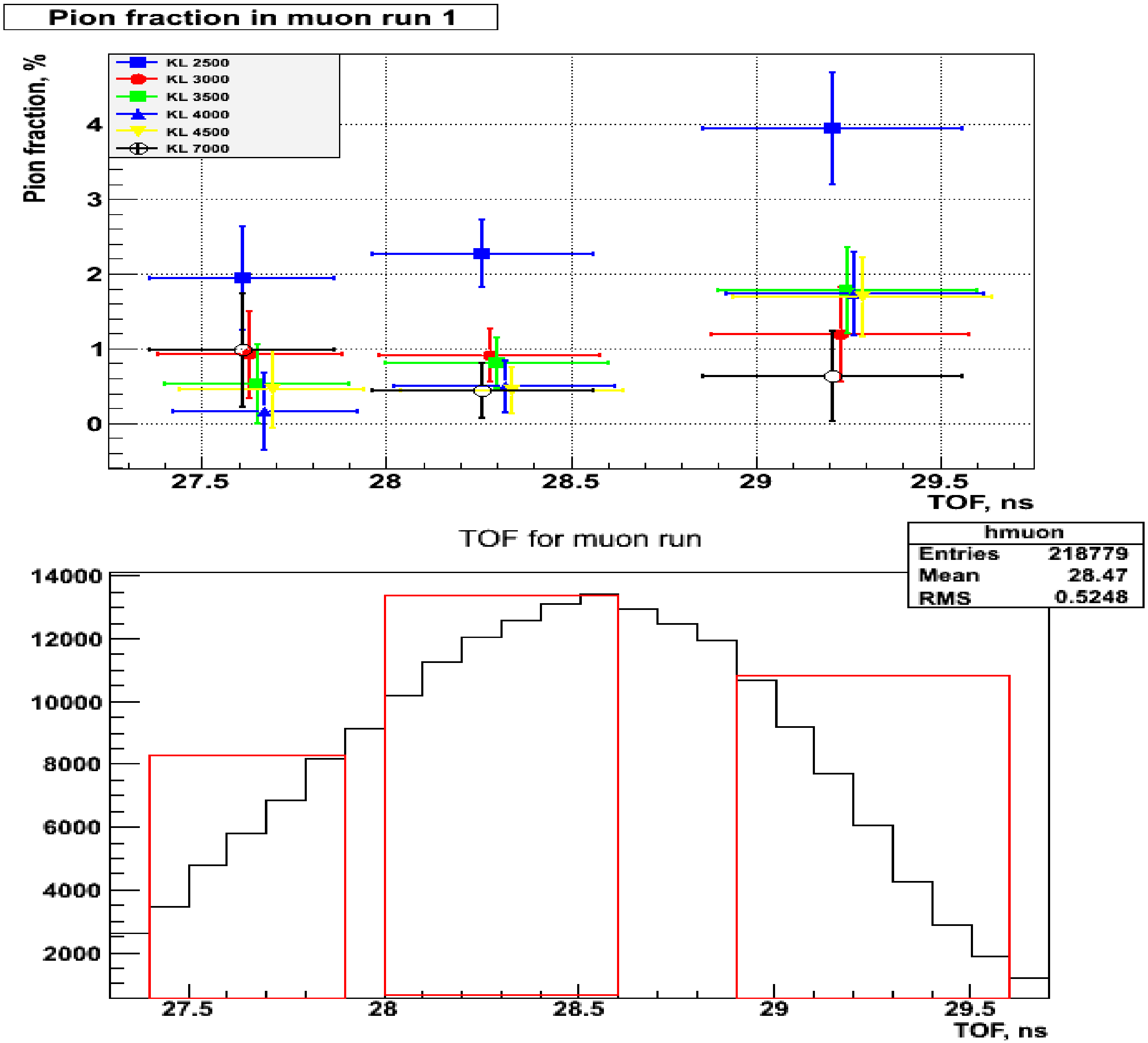
KL cut	P1	P2	P3
2500	1.94±0.69	2.27±0.45	3.95±0.75
3000	0.92±0.58	0.91±0.36	1.19±0.63
3500	0.53±0.53	0.81±0.34	1.78±0.57
4000	0.16±0.52	0.49±0.34	1.47±0.56
4500	0.46±0.52	0.44±0.31	1.69±0.53
7000	0.98±0.76	0.44±0.37	0.63±0.60

Pion fraction in muon run 1 (graphics)

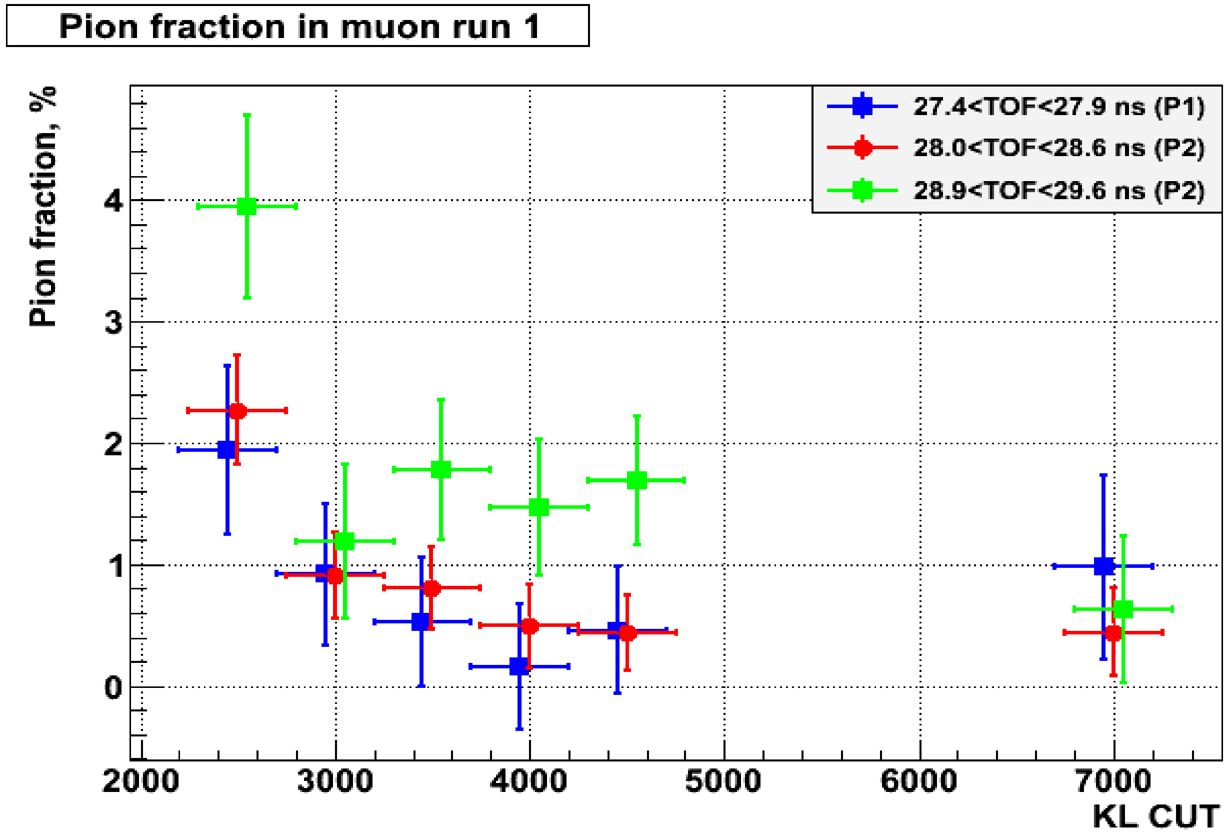


- The lowest KL cut (blue squares) shows higher pion contamination.
- The number of pions into muon run increases with increasing TOF.

Results for muon run 1 (graphics)



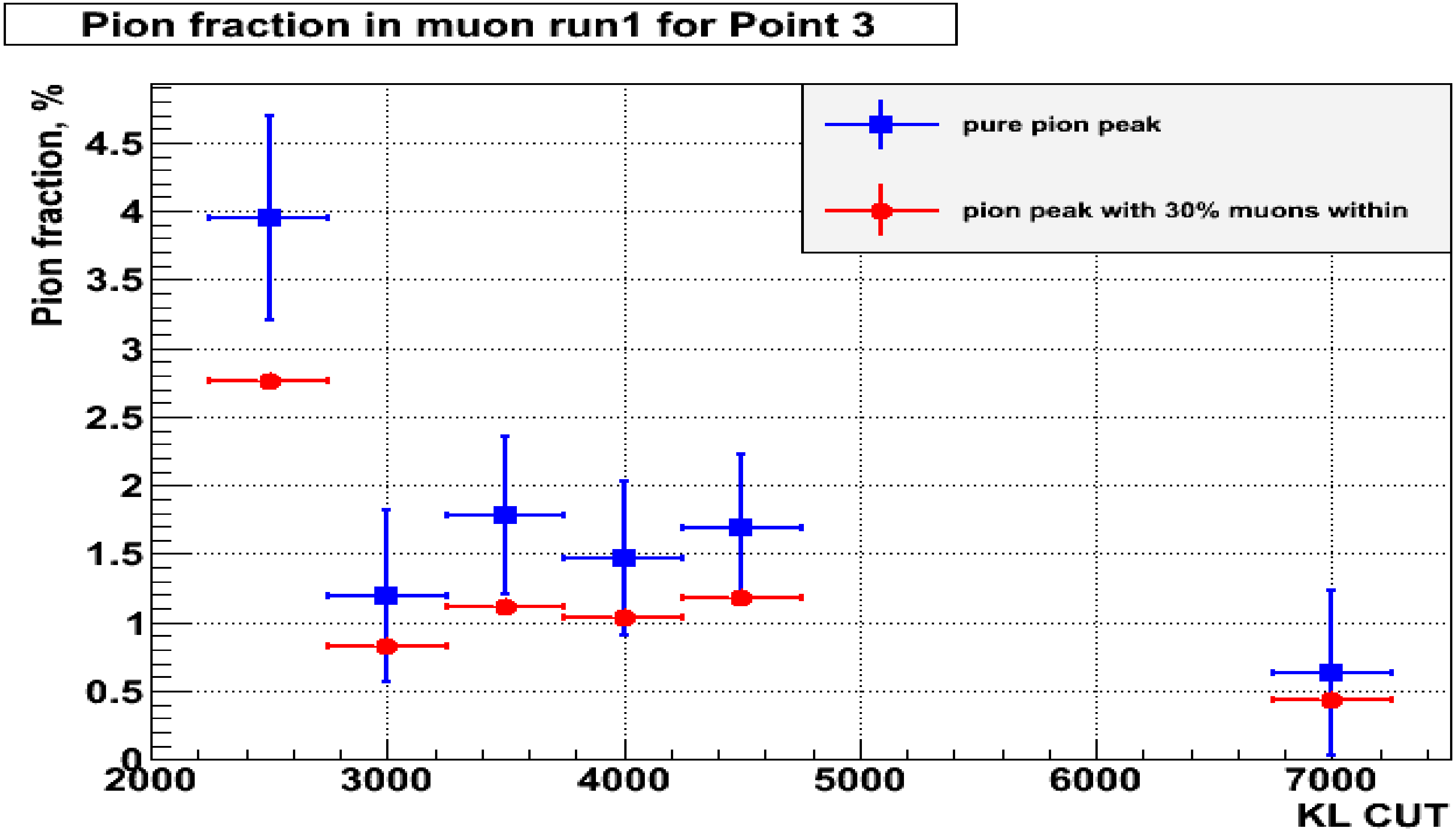
Pion fraction muon run 1 (another representation)



At KLCUT=7000 the pion fractions for all three time windows are the same in practice. Does the other cuts suffer from some systematics?

Systematics (one source for now)

Assuming that the pion peak is not pure but lies on a background of muons. An overestimated number is 30%.
There is an effect on the ratio, but it is negligible.
And again highest KL cut gives lowest systematics.

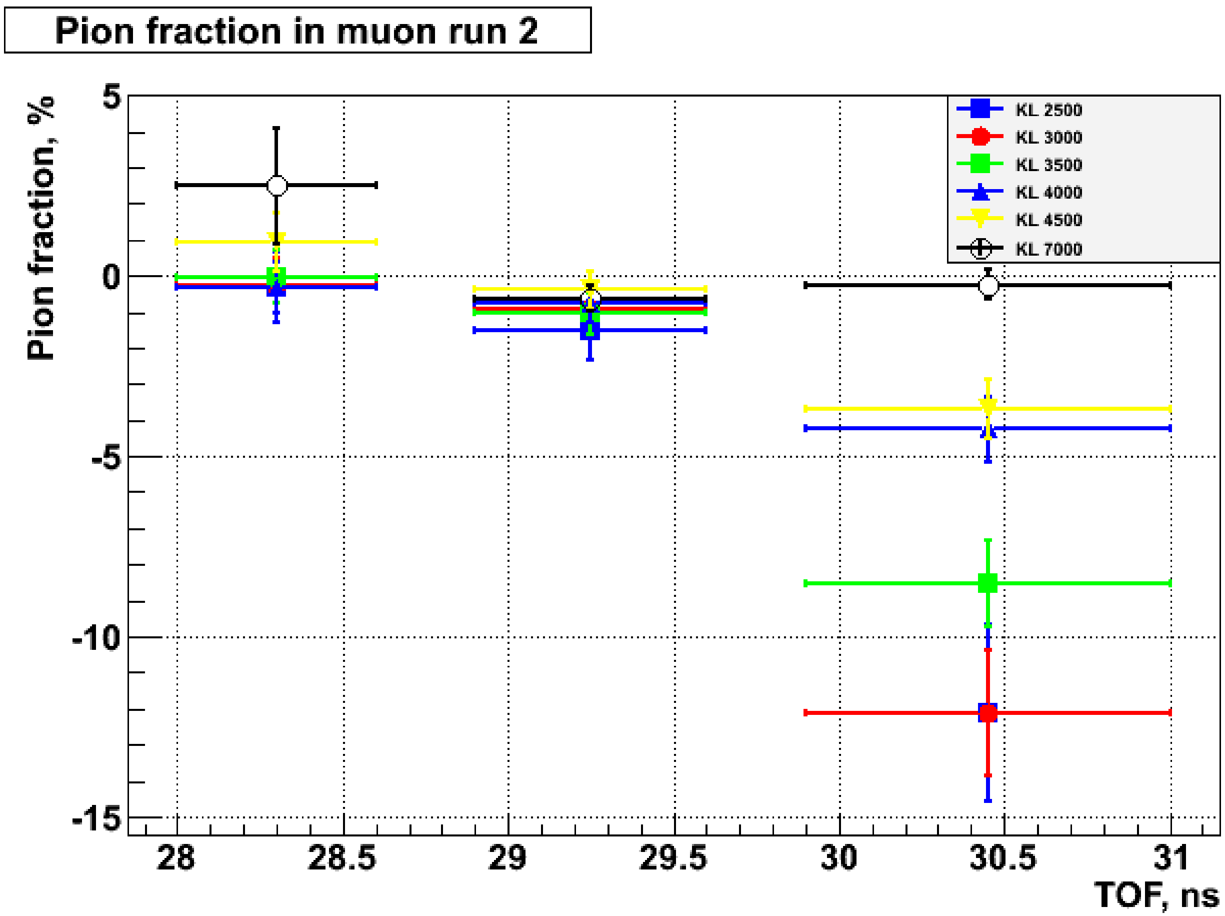


Pion fraction in muon run 2 (table)

TOF windows are P2, P3 and P4. The procedure fails, we get negative number of pions, but still can be informative.

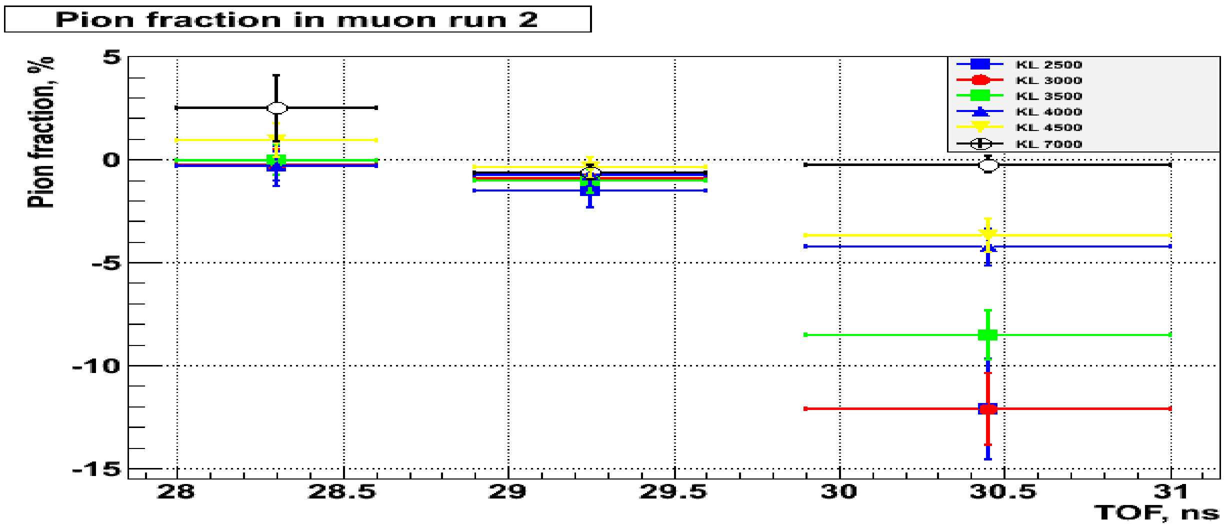
KL Cut	P2	P3	P4
2500	-0.32±0.97	-1.53±0.82	-12.13±2.44
3000	-0.27±0.77	-1.92±0.68	-12.33±1.73
3500	-0.03±0.75	-1.05±0.58	-8.54±1.20
4000	-0.33±0.71	-0.73±0.57	-4.52±0.91
4500	0.94±0.83	-0.40±0.51	-3.69±0.84
7000	2.49±1.60	-0.63±0.36	-0.25±0.40

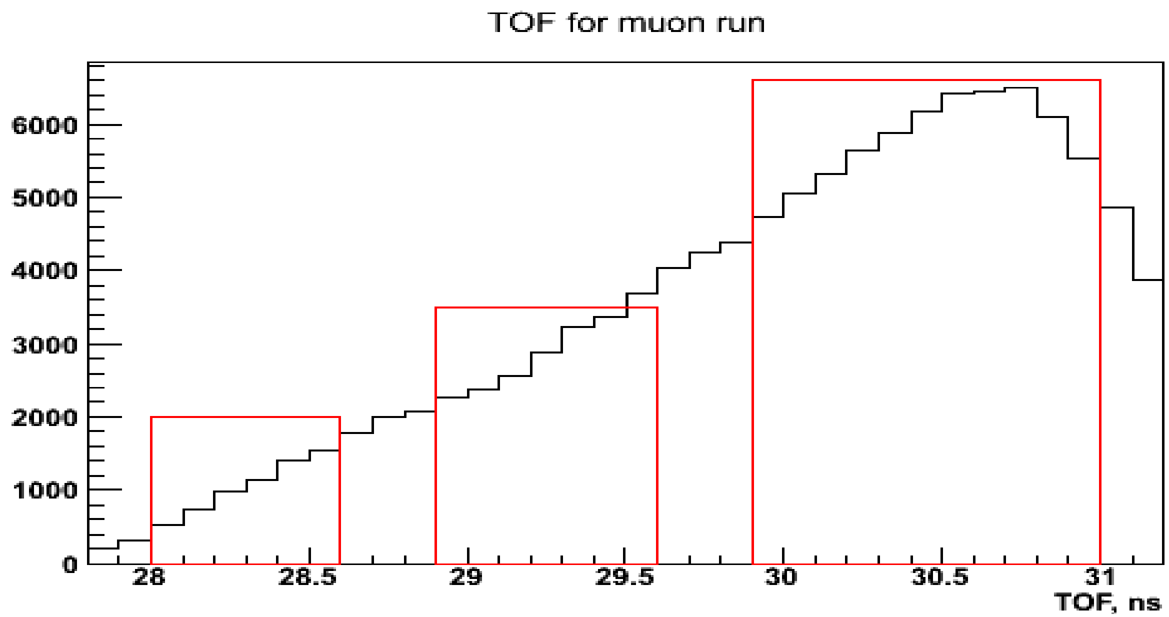
Pion fraction in muon run 2 (graphics)



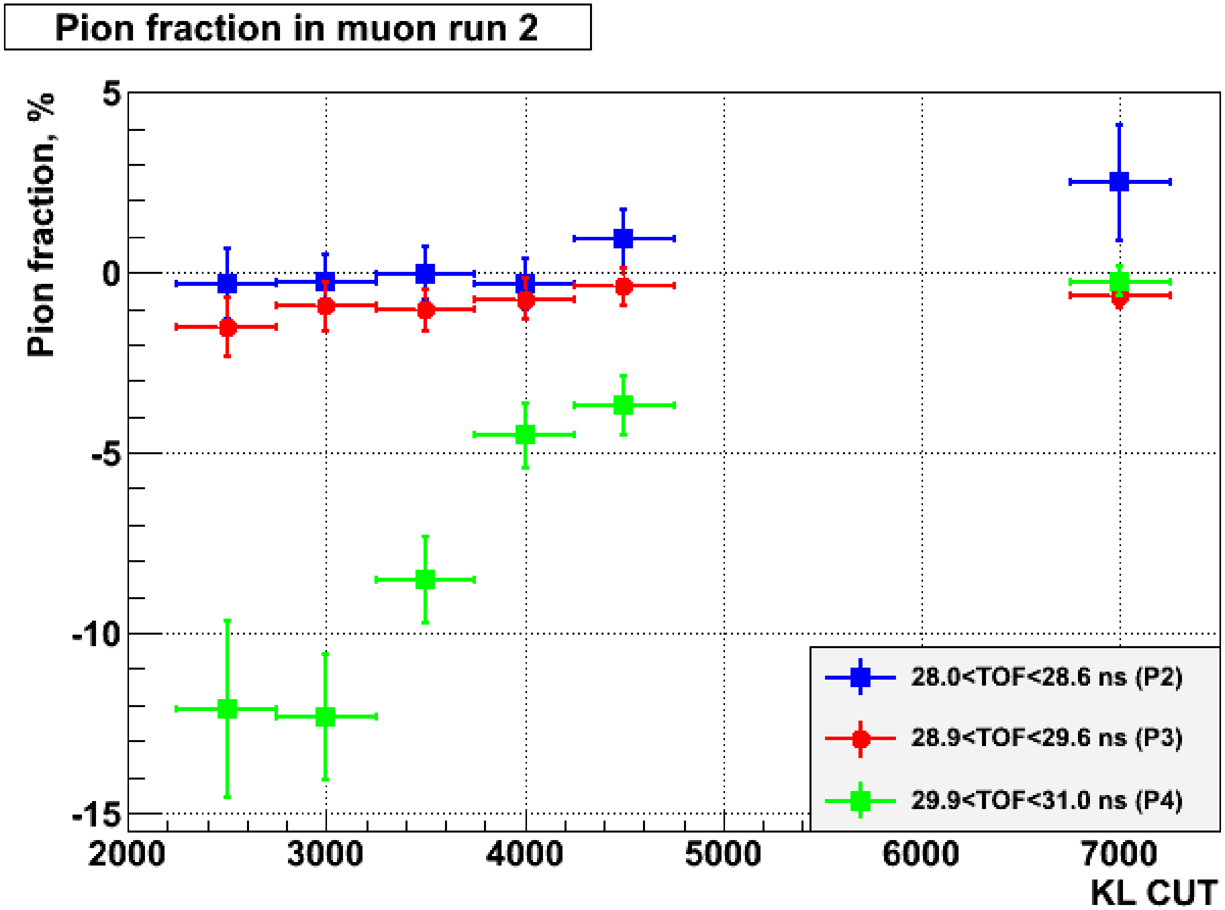
The pion fraction is “almost” compatible with zero for P2 and P3.
P4 shows large discrepancies between different KL cuts.

Pion fraction in muon run 2 (graphics)





Pion fraction in muon run 2 (another view)



The pion fraction trend for P4 (green squares) is to converge to “0” with cutting harder and harder. Probably there is systematic effect too.

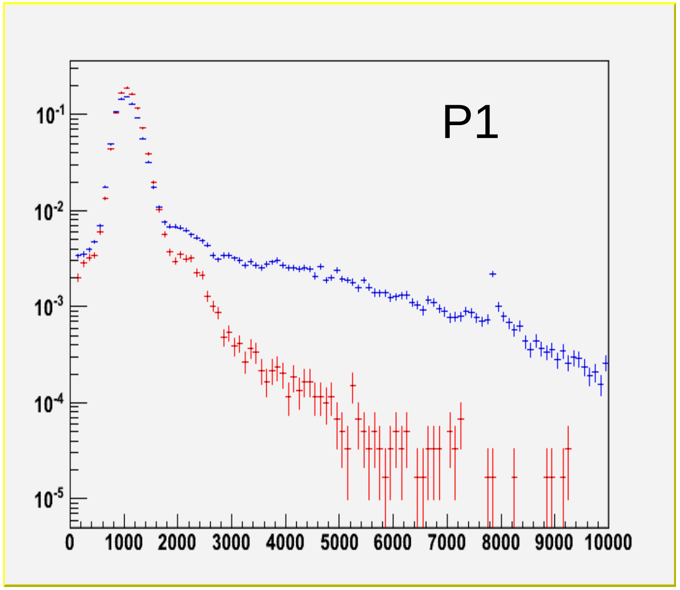
Second approach to the problem

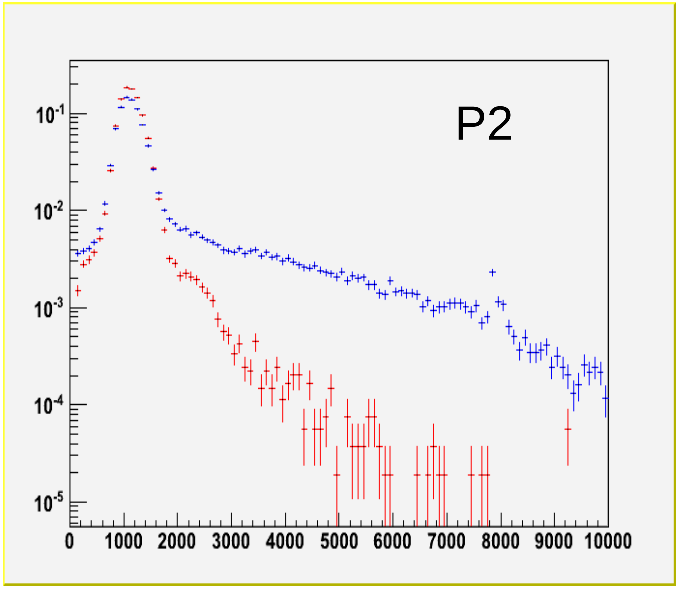
by Domizia Orestano

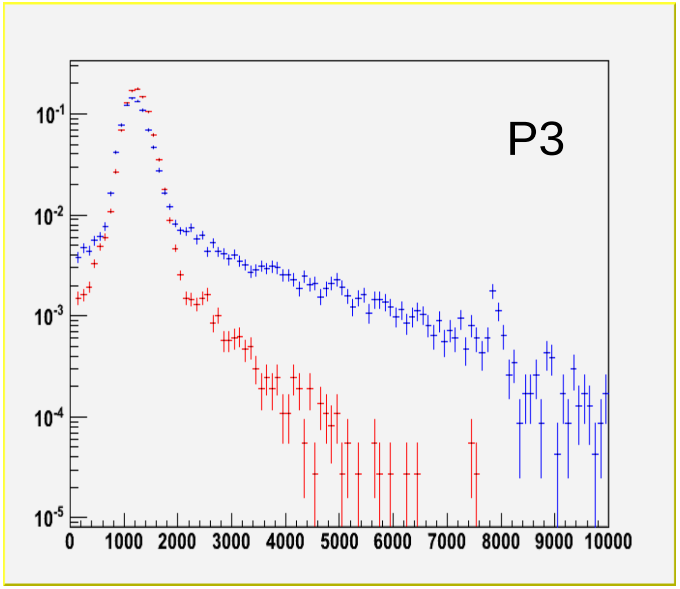
Method

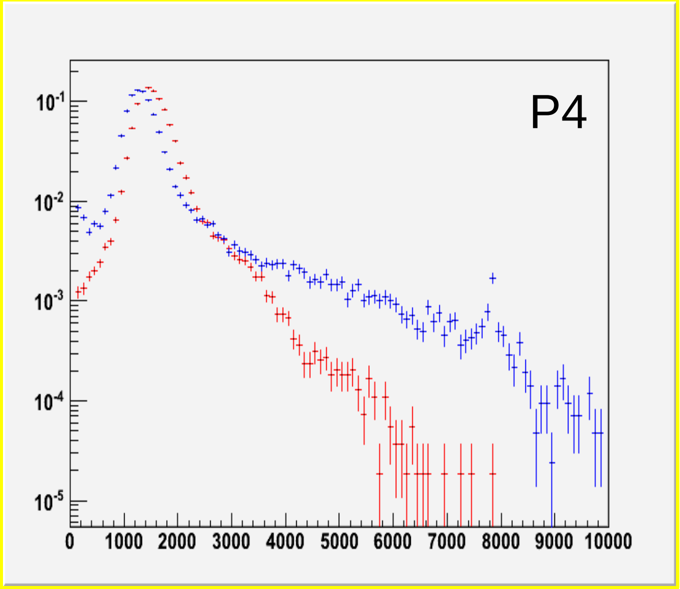
- Extract from pion runs templates for muons and pions in fixed TOF windows
- Use the same 4 points defined above + 1 additional
- Fit the fraction of muons and pions in muon runs data within the same TOF window using ROOT TFractionFitter method
- TFractionFitter takes into account both data and templates statistical uncertainties. The way in which this is done is through a standard likelihood fit using Poisson statistics; however, the template predictions are also varied within statistics

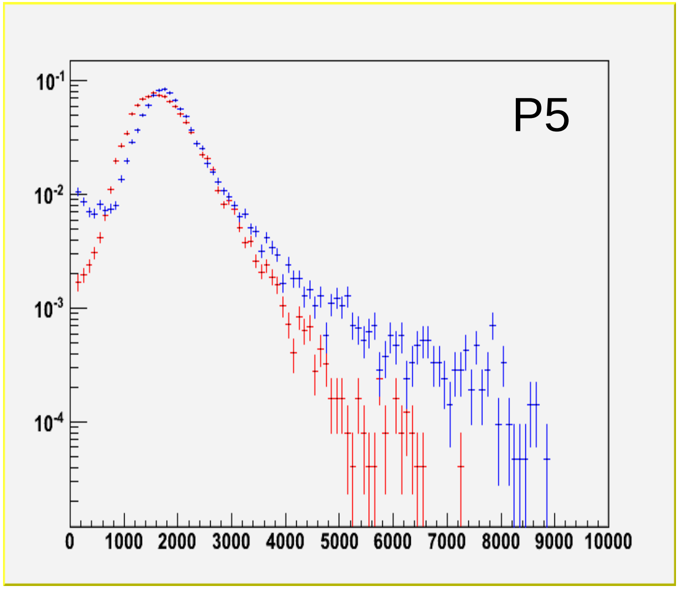
Templates







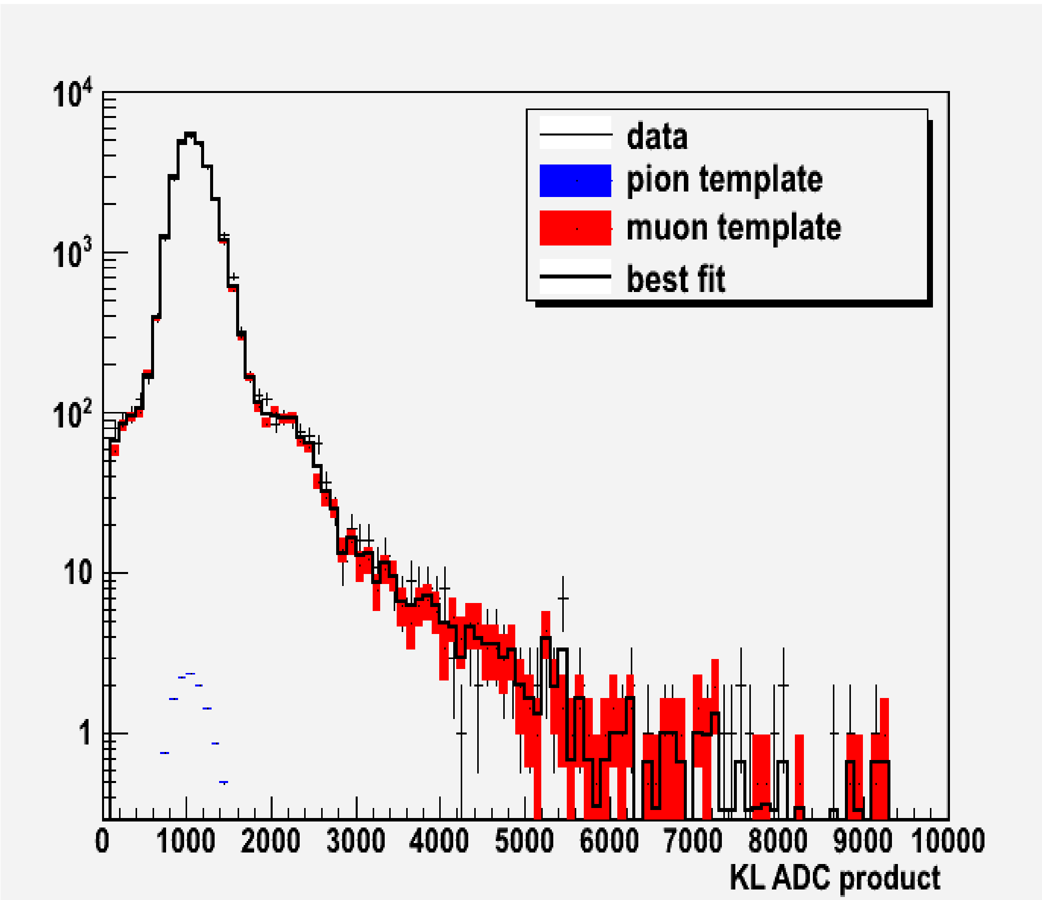


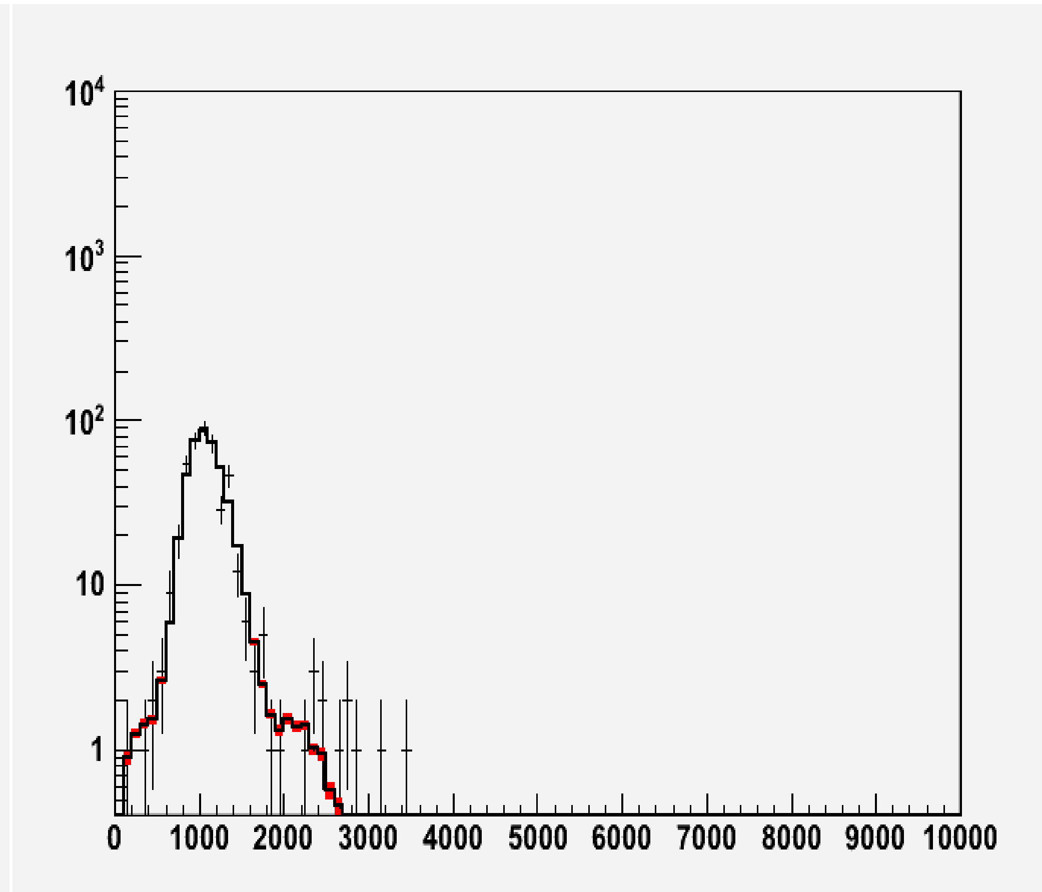


Pion

Muon

Point P1



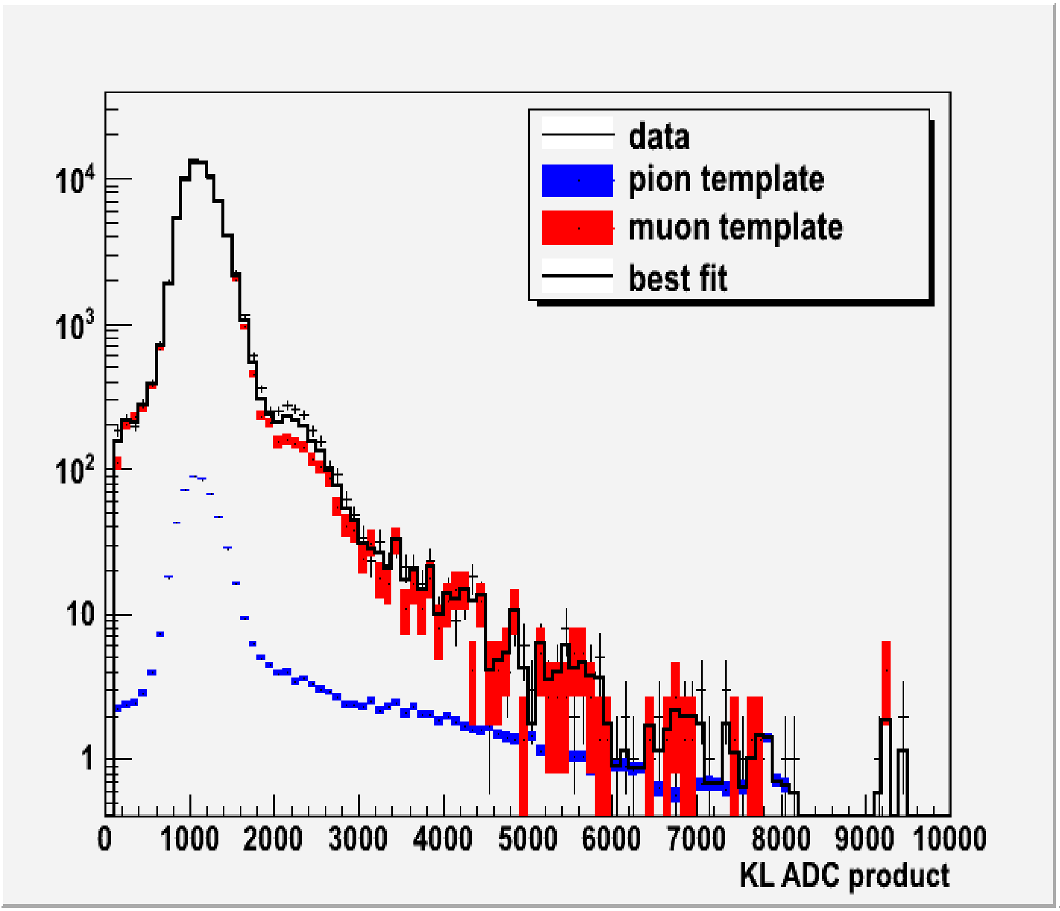


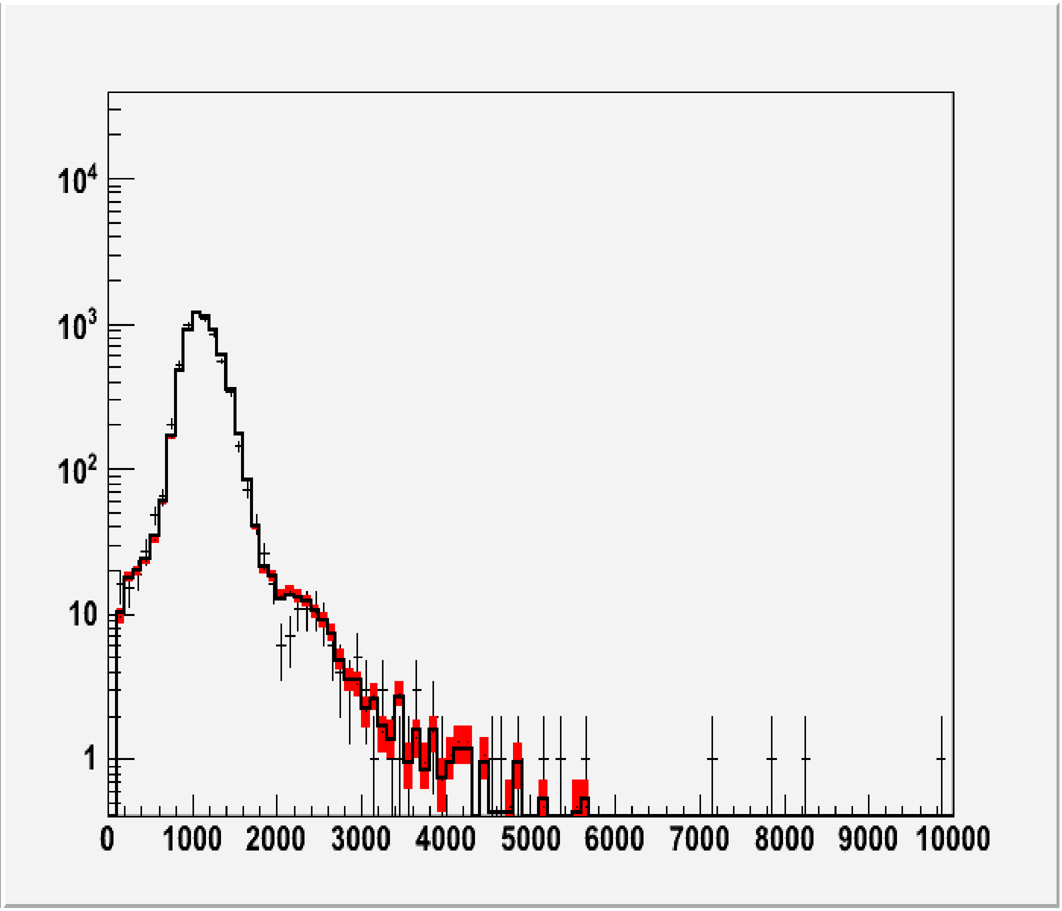
Muon fraction: (100 pm 1) %
Pion fraction: (0 pm 0.5) %

Muon fraction: (100 pm 8) %
Pion fraction: (0 pm 3) %

P1 described in both muon settings by the muon template alone

Point P2



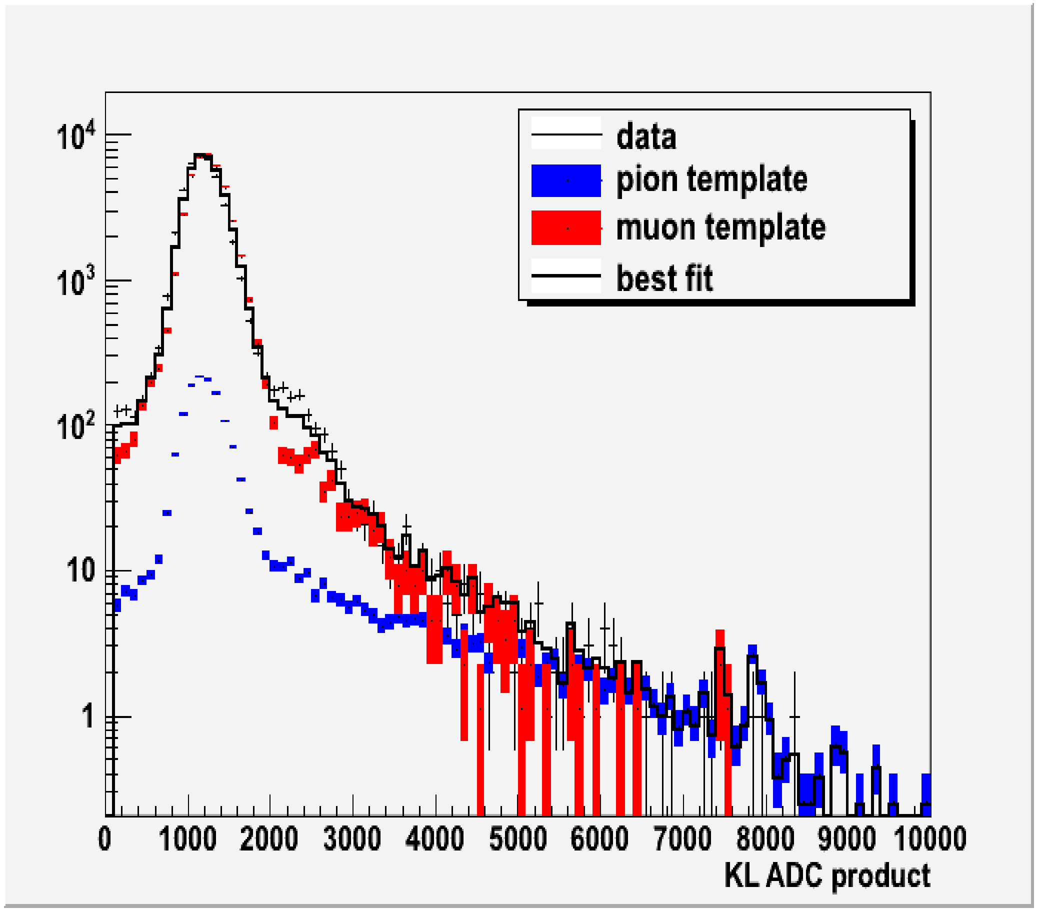


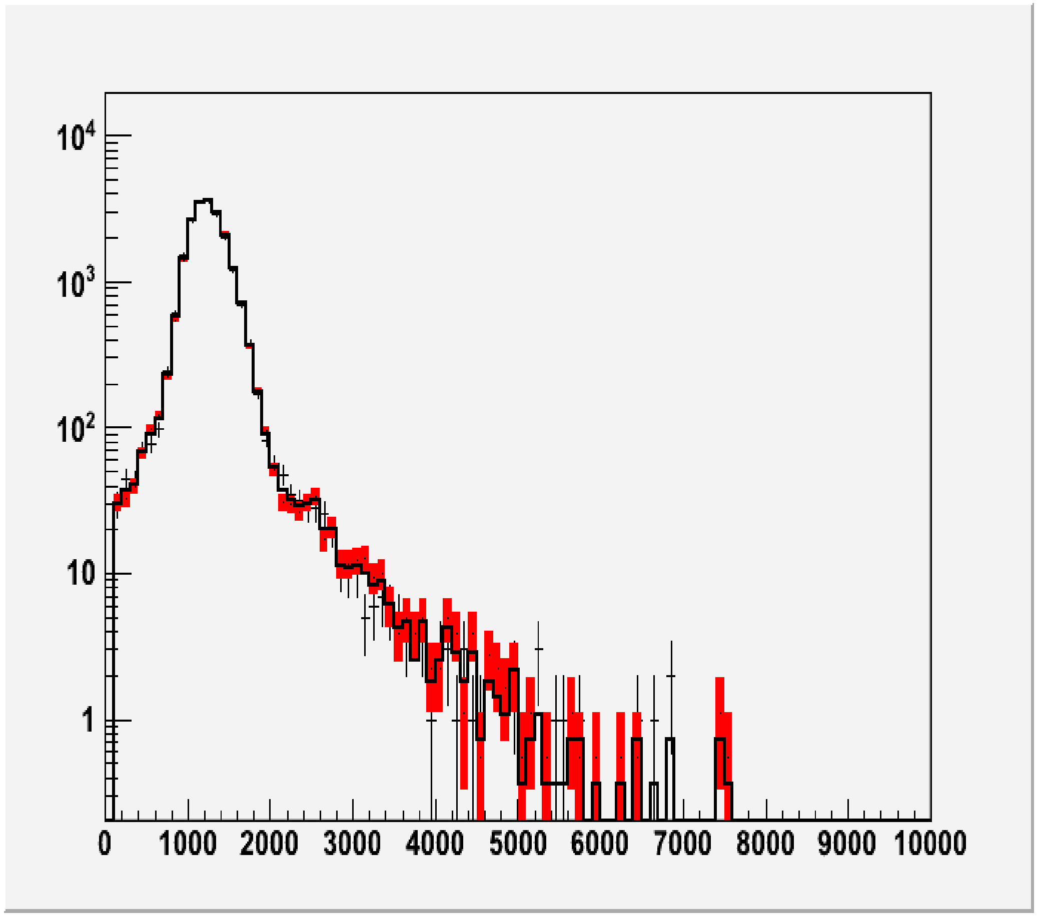
Muon fraction: (99.2 pm 0.6) %
Pion fraction: (0.8 pm 0.3) %

Muon fraction: (100 pm 4) %
Pion fraction: (0 pm 0.7) %

P2 described in both muons runs by the muon template alone

Point P3





Muon fraction: (96 pm 1) %
Pion fraction: (3.6 pm 0.6) %

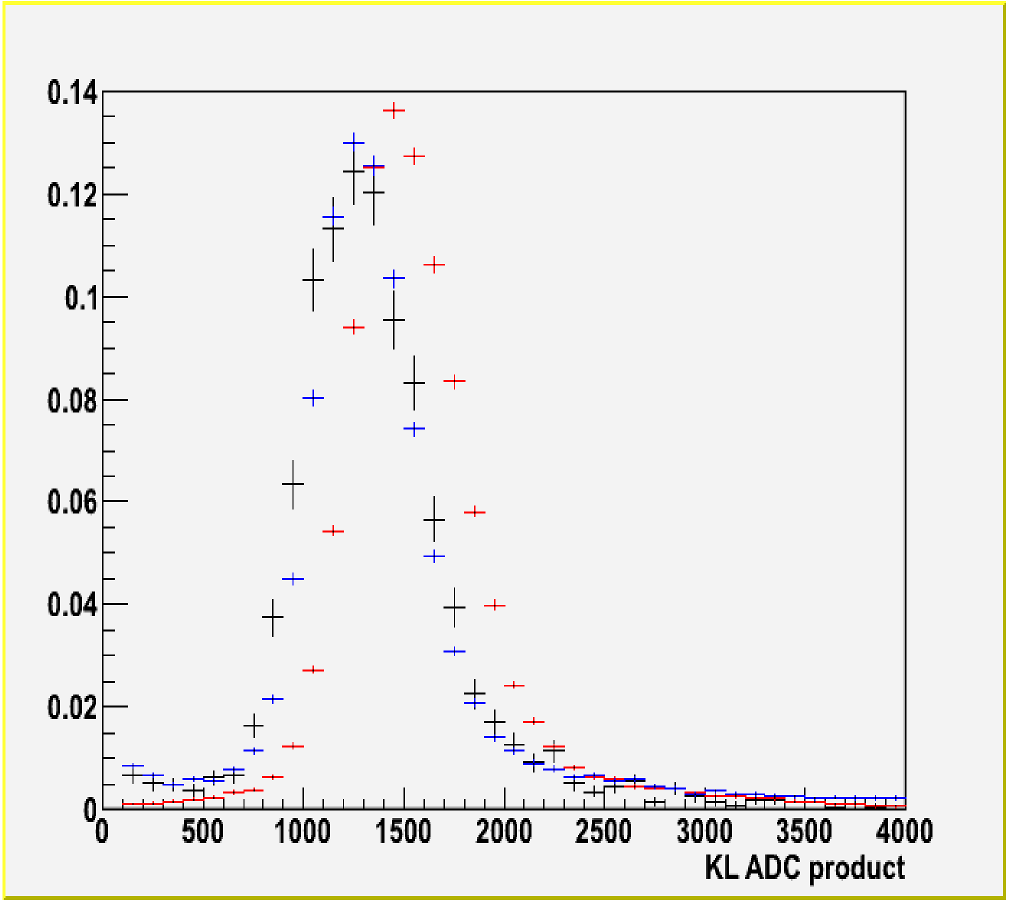
Muon fraction: (100 pm 2) %
Pion fraction: (0 pm 0.1) %

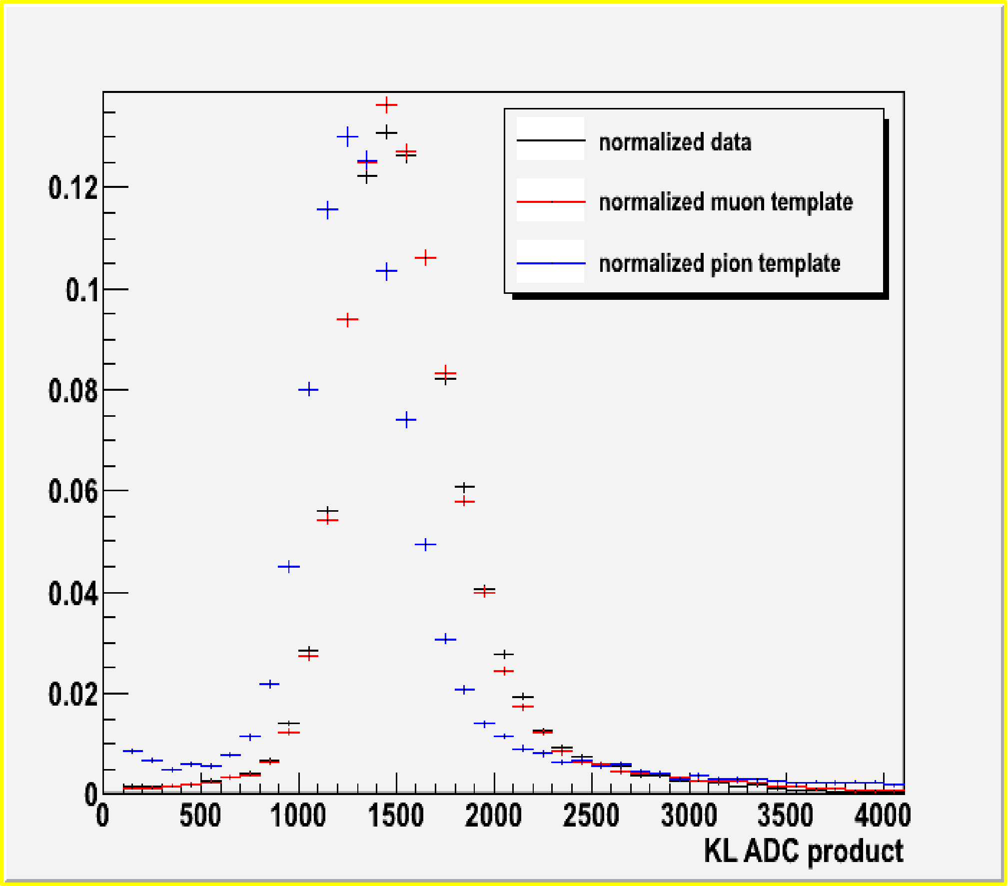
Some room for pions in P3, not enough statistics in muon settings 2 to see them

Points P4 and P5

- Up to point 3 the muon and pion templates show a MIP peak in the same position and differ only for the tails
- The muon run data display a MIP peak at the same position, so the fits focuses on getting the pion fraction needed to reproduce the tails
- In points P4 and P5 we see a different behavior which needs to be understood before blindly using the templates

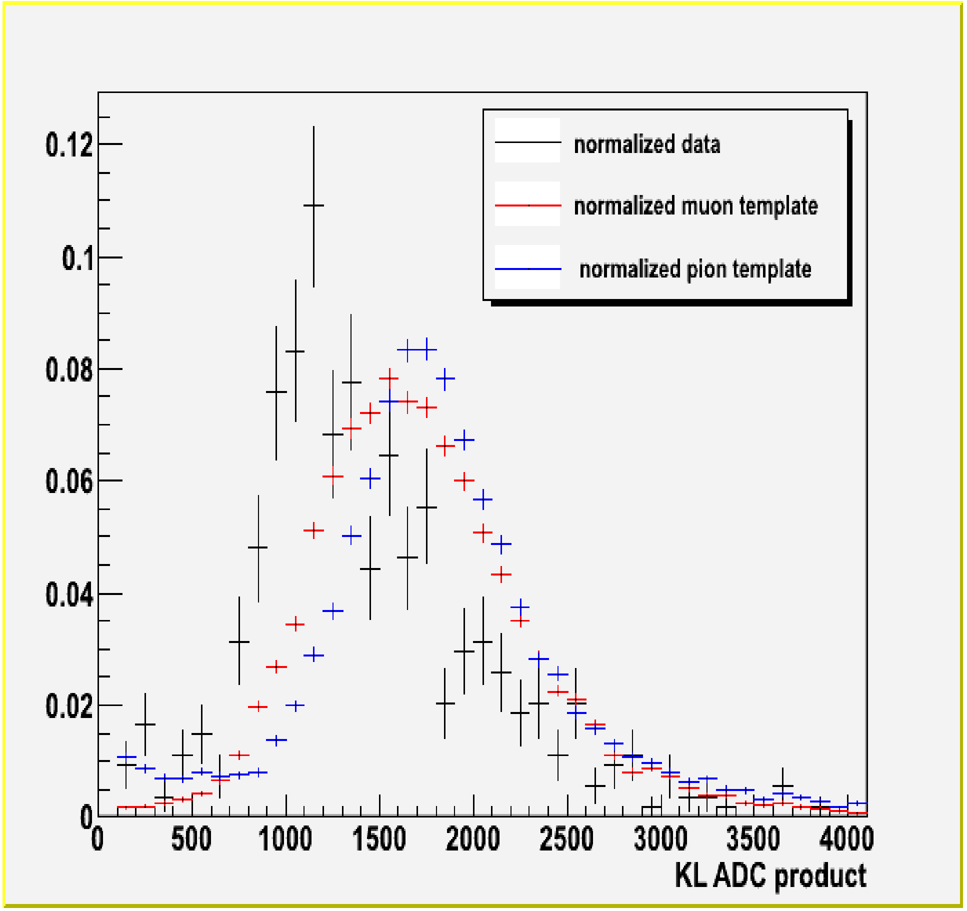
P4 problems

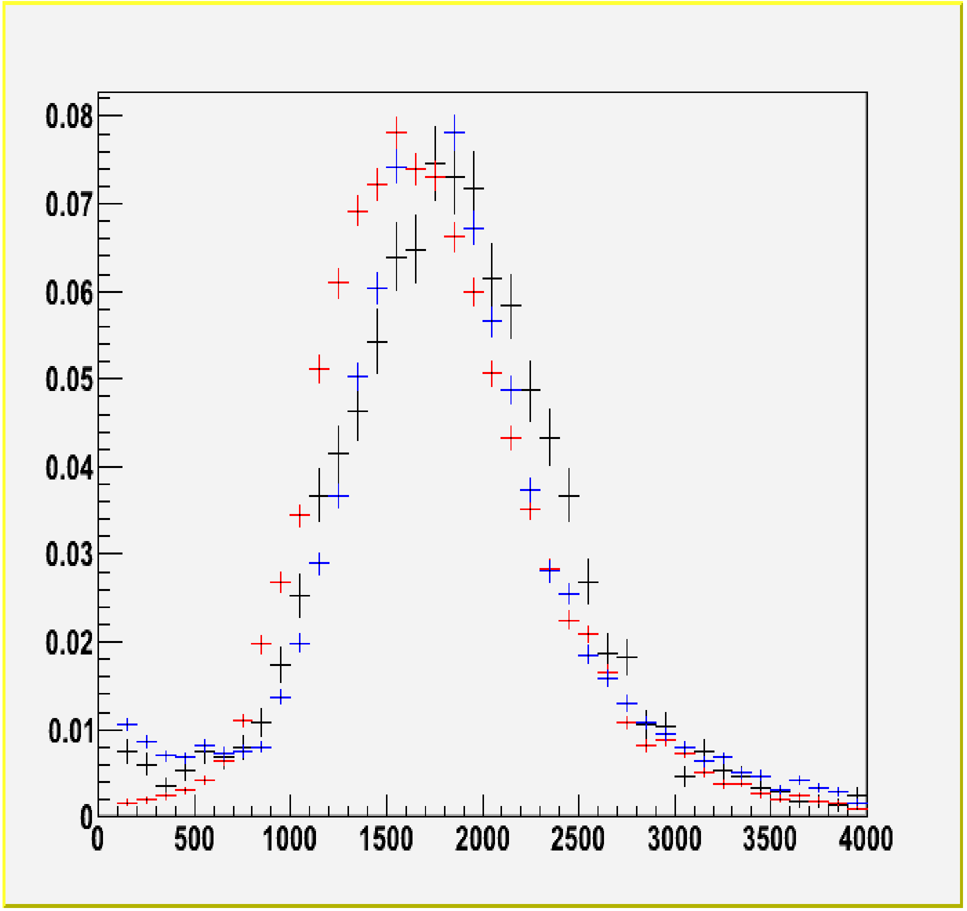




MIP peaks in pion and muon template do not coincide: moreover data from the two muon settings differ: the first set of data is pion like, the second is muon like!

P5 problems





MIP peaks in pion and muon template do not coincide: moreover data from the two muon runs differ: the first set of data is incompatible with both muon and pion templates while the second is pion-like!

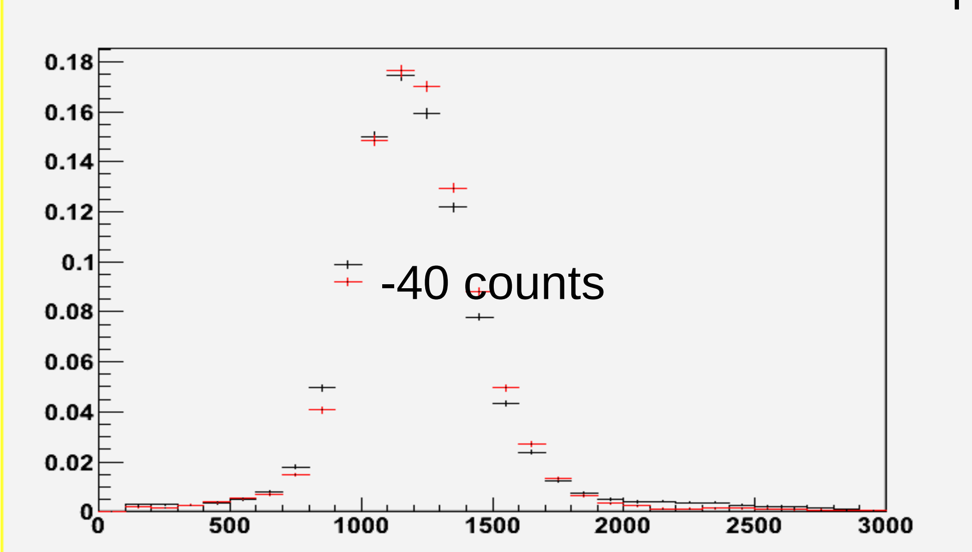
Systematics

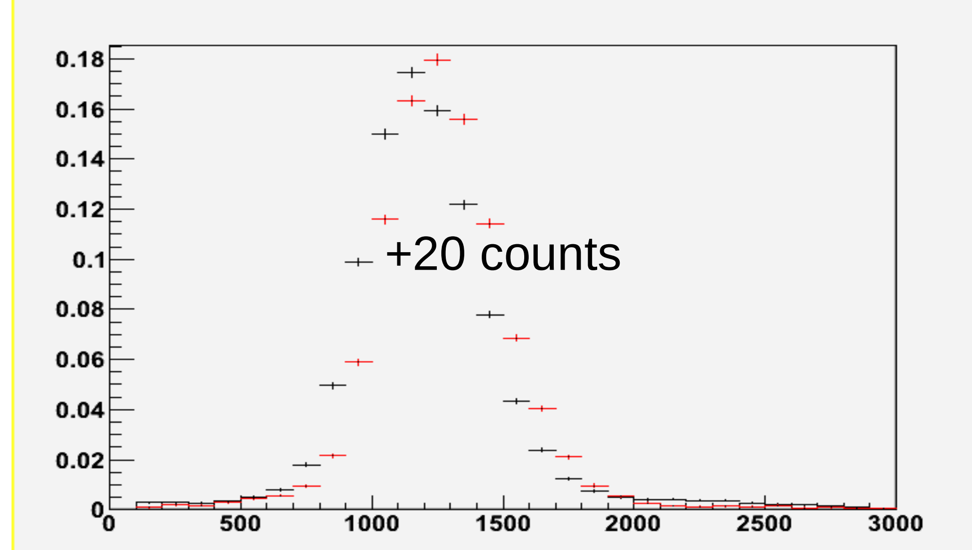
- Explore the effect of
  - Unconstraining the fitted fractions (currently bounded between 0 and 1)
  - Changing the binning
  - Slightly shifting the templates (within a reasonable agreement with MIP peak in data)
  - Changing the TOF window boundaries

Systematics at P3

	Muon fraction	Pion fraction
default	(96 pm 1) %	(3.6 pm 0.6) %
unconstrained	(96.5 pm 1.0) %	(3.6 pm 0.6) %
Double Nbins (200)	(96.5 pm 1.0) %	(3.5 pm 0.7) %
Half Nbins (50)	(96.5 pm 1.0) %	(3.5 pm 0.6) %
Shift muon template +20	(95 pm 1) %	(5.2 pm 0.7) %
Shift muon template -40	(97.3 pm 0.8) %	(2.7 pm 0.5) %
Shift TOF window -0.2	(97.4 pm 0.8)%	(2.6 pm 0.5) %
Shift TOF window +0.2	(95.5 pm 1.0) %	(4.6 pm 0.8)%
Enlarge TOF window (+0.4)	(97.7 pm 0.7) %	(2.3 pm 0.5)%

Muon template shift





Conclusion

- It is studied what is pion contamination in two muon runs: 200 MeV/c nominal and 140 MeV/c.
- The detectors used fo for this study are TOF0, TOF1 and KL.
- The analysis is based on the assumption that muons and pions in muon and pion runs have the same detector response for given TOF window.
- For the nominal run and TOF windows P1 and P2 the pions are less than 1% , while in P3 are about 1%.
- For 140 MeV/c the procedure fails, but gives an indication that there are no pions.
- There is some KL cut dependence.
- An alternative approach is studied which take into account whole distribution.
- Both methods give similar results.