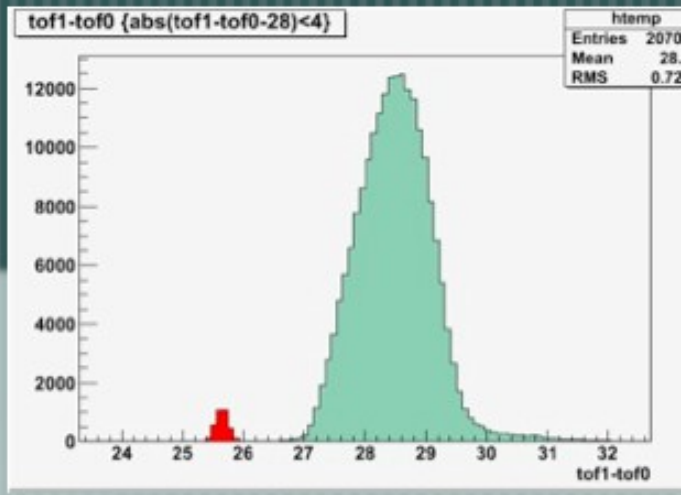
Pion contamination paper

Domizia Orestano

CM39

Analysis principle (I)



- we measure TOF for MICE beam particles
- we will measure momentum, but we currently don't
- therefore our MICE beam is an unknown mixture of muons and pions - while **electrons** are easy to spot
- statistical estimate of the pion contamination in the MICE beam (as already presented in CM 32): to characterize the beam now (not for the emittance measurements!)

Analysis principle (II)

- Different interaction probability in KL for muons and pions
- Can statistically separate two populations with the same TOF but different PID (and different KL interactions)
  - But interactions in KL can depend on particle momentum
  - Treat separately different TOF intervals, i.e. different momenta for a given particle mass

Calibration runs

Need "pure" samples of pions and muons with well defined TOF: these are obtained from different runs (different p_{D2})

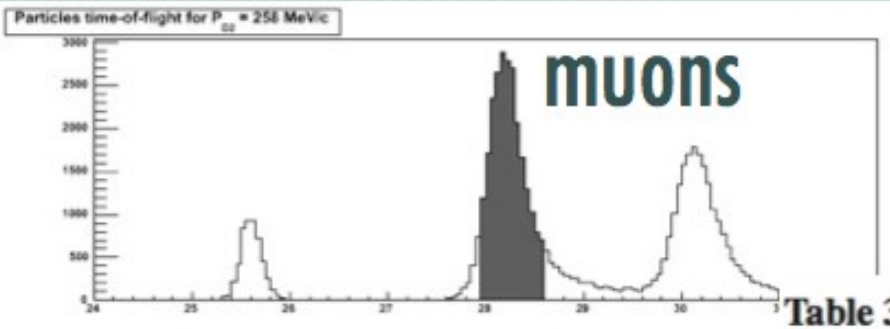


Table 3. Paired beam settings for three time–of–flight intervals (also called points).

	TOF interval, ns	muons from runs with P_{D2} (MeV/c)	pions from runs with P_{D2} (MeV/c)
Point 1	27.4 – 27.9	294	362
Point 2	28.0 – 28.6	258	320
Point 3	28.9 – 29.6	222	280

POINT2

	TOF interval, ns	muons from run:	pions from run
Point 1	27.4 – 27.9	3253	3426
Point 2	28.0 – 28.6	3250, 3252	3261
Point 3	28.9 – 29.6	3256	3454

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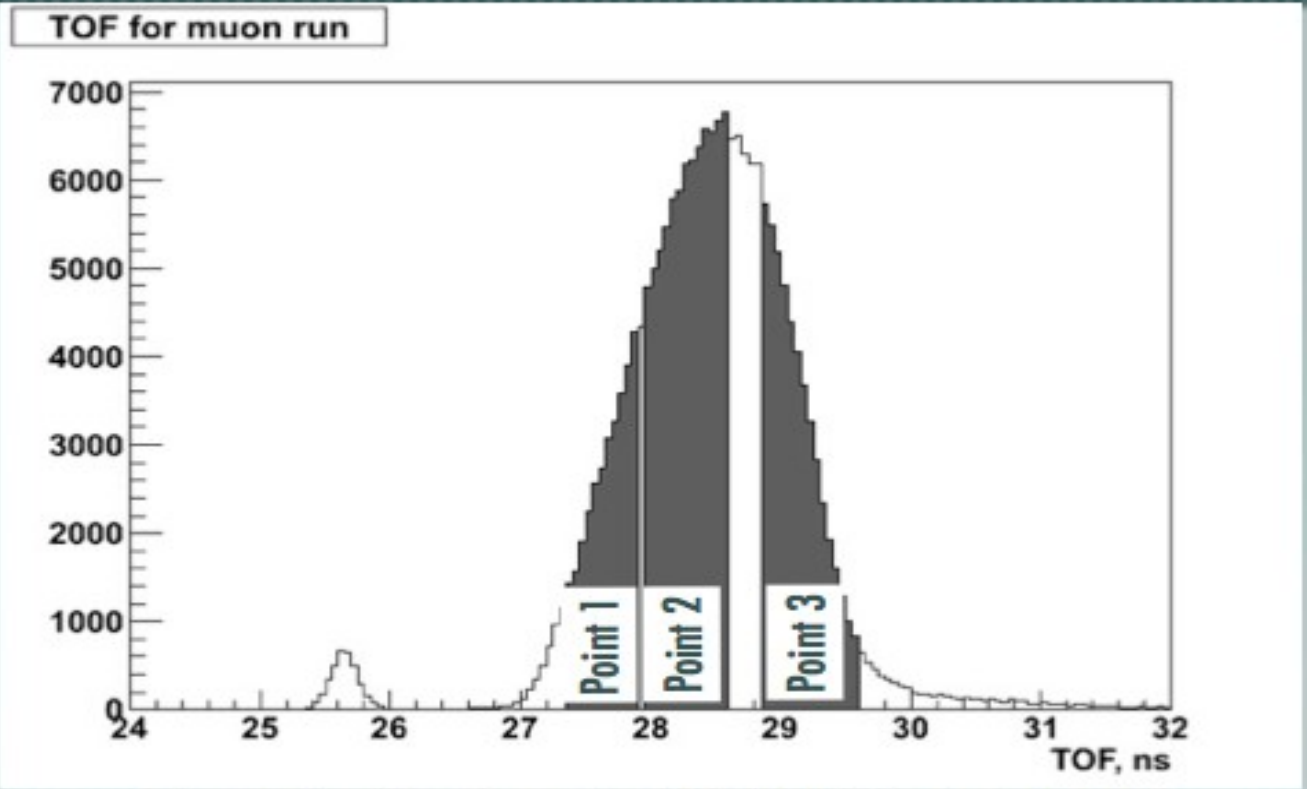
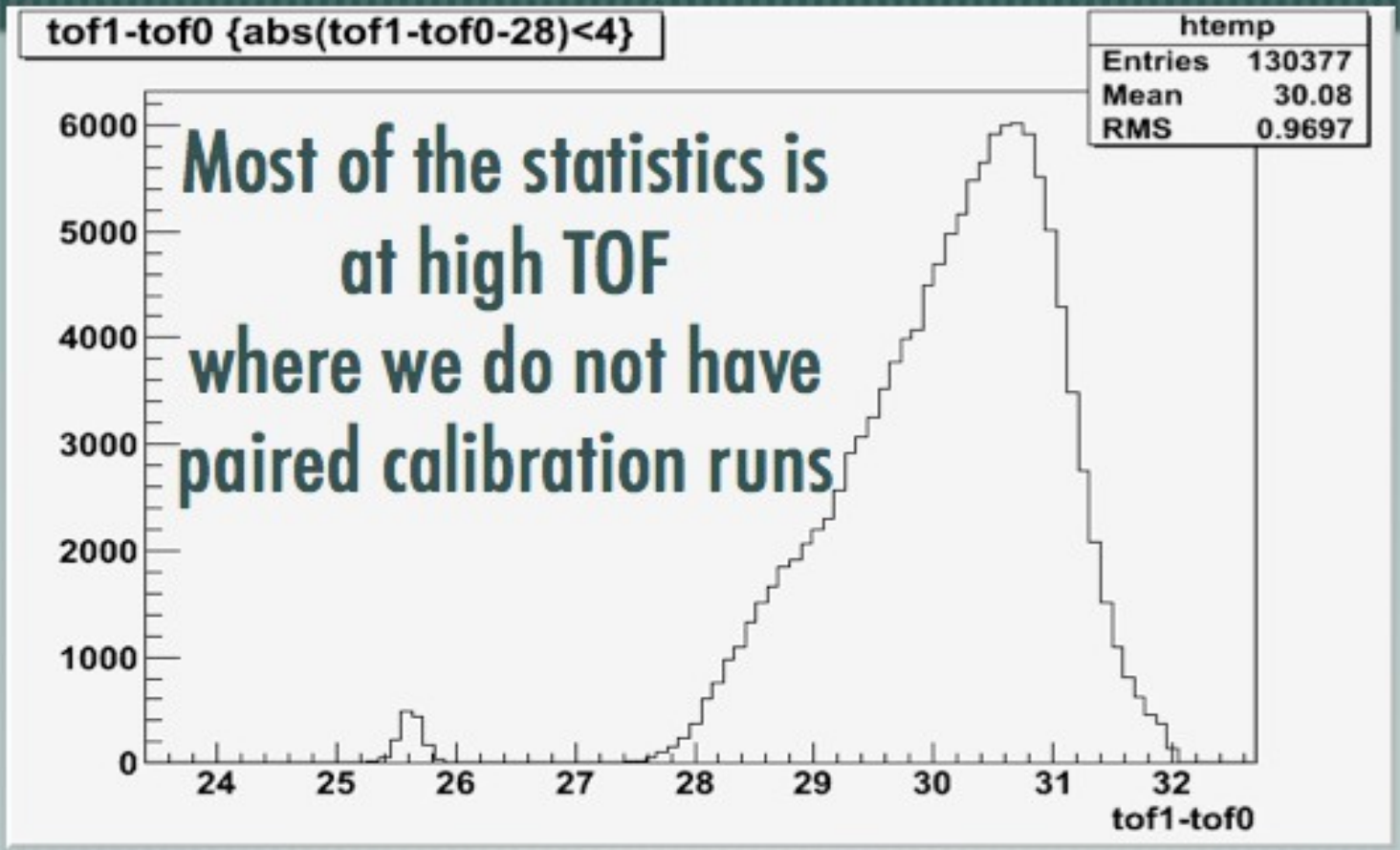
MICE beam sample I



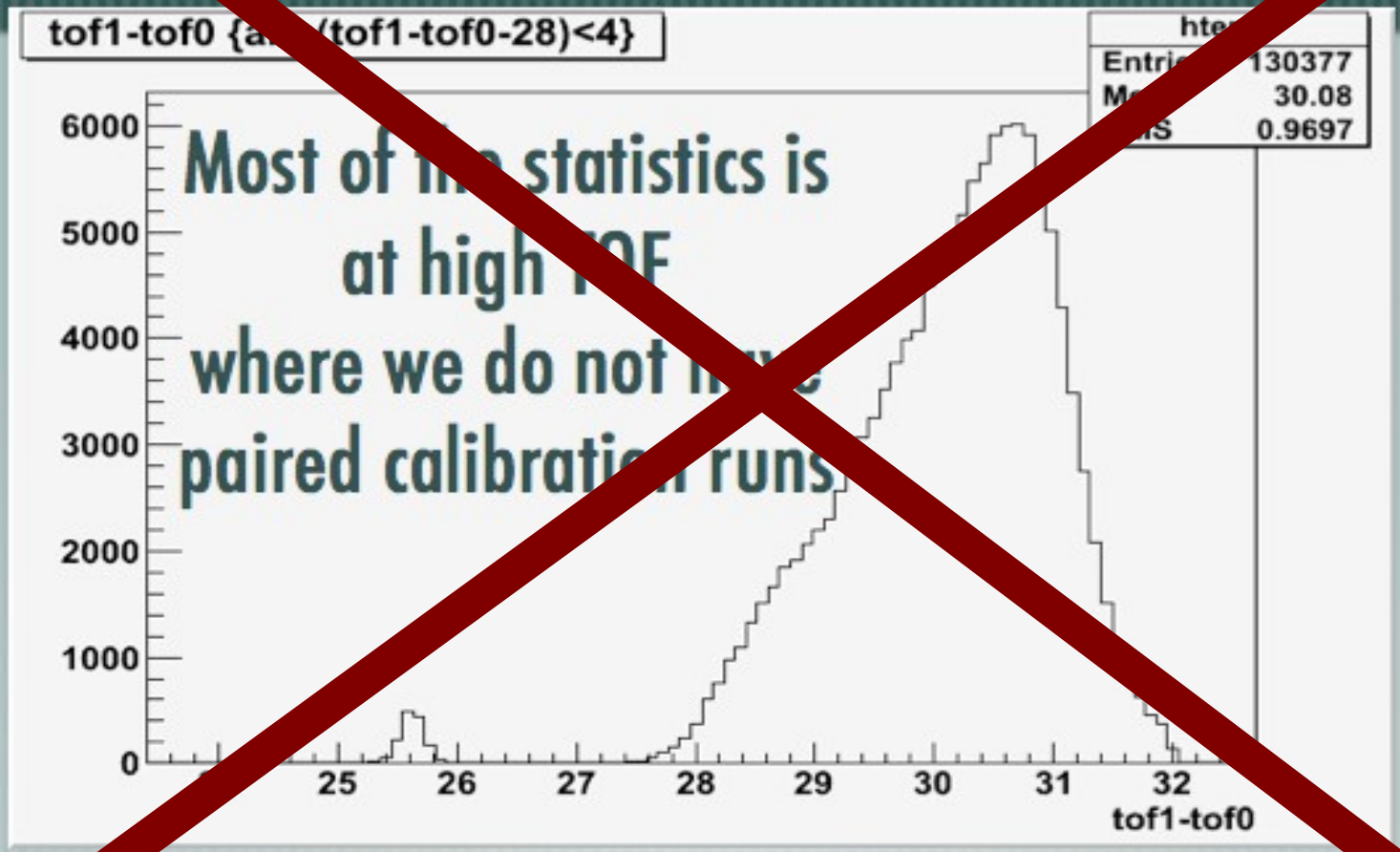
run number	beamline species	P_{D2} (MeV/c)	collected pulses
3407	μ^+	240, nominal	1691
3506	μ^+	240, nominal	1386
3507	μ^+	240, nominal	1383
3514	μ^+	240, nominal	2184
3515	μ^+	240, nominal	2346
3516	μ^+	240, nominal	676

MICE beam sample II



run3419, 3420, 3495, 3499 188.86 MeV @D2
(settings 140 MeV, 6 pi)

MICE beam sample II



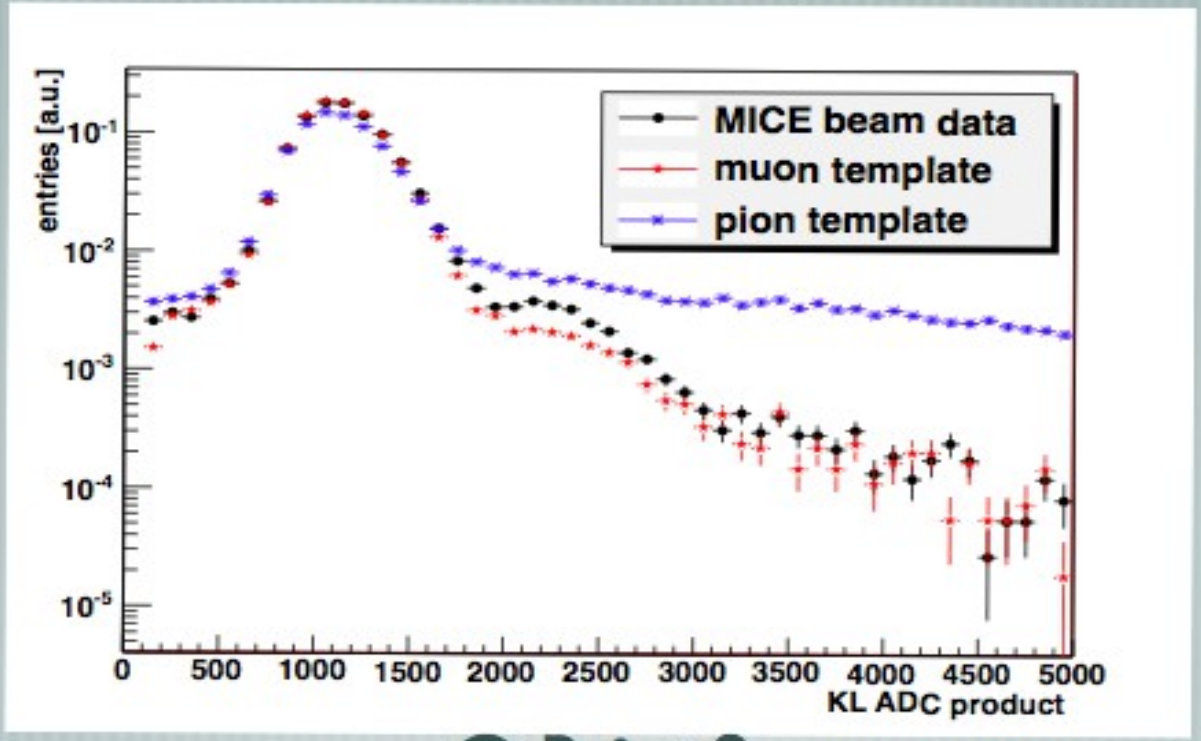
Most of the statistics is at high TOF where we do not have paired calibration runs

Run3419, 3420, 3495, 3499 188.86 MeV @D2

(settings 140 MeV, 6 pi)

KL response

KL ADC product: geometrical average of signals from the 2 PMTS (reduced position dependence)



@ Point 2

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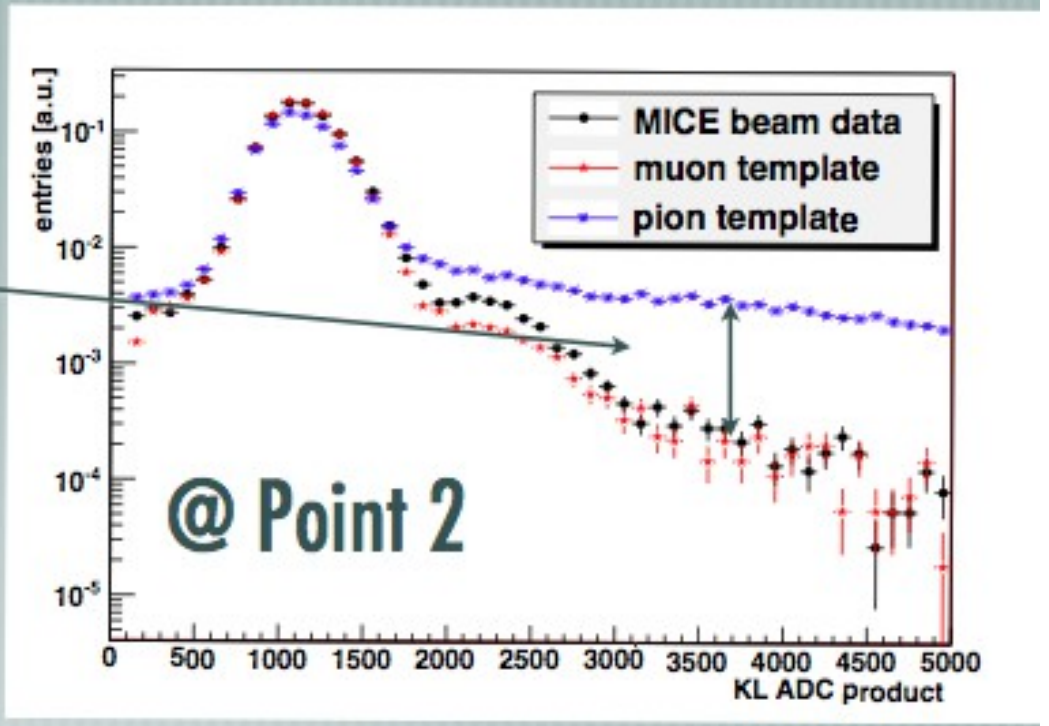
Method

- exploit difference in KL to estimate pion contamination



A bit of history

- Draft 0 circulated in March 2013
  - Both a cut&count and a template based fit of KL tails
  - Included Ckov based analysis
  - Included truth based beam composition anf TOF information
- But TOF & Ckov measurements not independent
- New draft for EB in May 2013
  http://mice.iit.edu/pc/pc542/pc542_bonesini_piddraft1.pdf
- A MICE note summarizing where we were
  http://mice.iit.edu/micenotes/public/pdf/MICE0416/MICE0416.pdf

Analysis issues (I)

- **In moving from Point 1 to Point 3 (lower momenta) we measure an increased contamination in data (but large errors!) and expect a lower one from MC**

Table 6. Summary of results on pion contamination. The average of the results for Point 1 to 3 takes into account the fraction of particles in each interval. Statistical (for both data and Monte Carlo) and systematic (for data only) errors are reported.

Method	$\pi(\%)$ at Point 1	$\pi(\%)$ at Point 2	$\pi(\%)$ at Point 3 (%)	average π cont. (%)
analysis	$0.65 \pm 0.46 \pm 0.30$	$0.84 \pm 0.27 \pm 0.34$	$1.87 \pm 0.35 \pm 0.80$	$1.11 \pm 0.19 \pm 0.32$
cross-check	$0.46 \pm 0.52 \pm 0.57$	$0.44 \pm 0.31 \pm 0.57$	$1.69 \pm 0.53 \pm 1.04$	$0.81 \pm 0.24 \pm 0.44$
MC	0.78 ± 0.07	0.13 ± 0.02	0.28 ± 0.04	0.33 ± 0.03

Analysis issues (II)

- There is a large discrepancy between MC expected contamination and what we see in data
- We do see a second muon peak in data which could affect the population in the tails as well
- The chi2/ndof of the fits is poor (ranges from 51/38 to 125/38)

Activities in past year

- John Nugent working on G4beamline simulations

Possibility to check the effect of DS on/off (the available data were acquired in different conditions)

- Mariyan Bogomilov introducing KL digitisaton in MAUS

Possibility for John to simulate the full chain and aim at a direct data/MC comparison

Status

- A lot of nice progresses
  - Tracked in https://micewww.pp.rl.ac.uk/issues/1473
- But
  - Beam line simulation is not yet in agreement with data

TOF plots

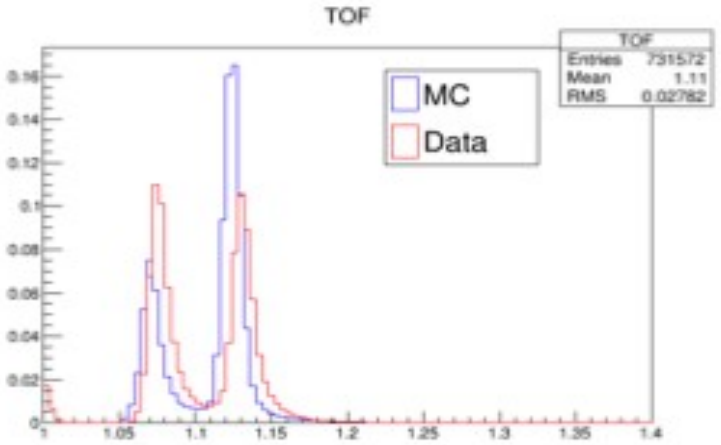


Figure: Pion beam 3253

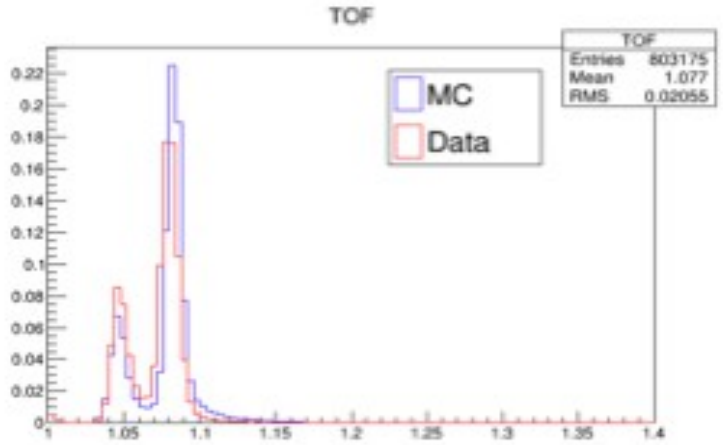
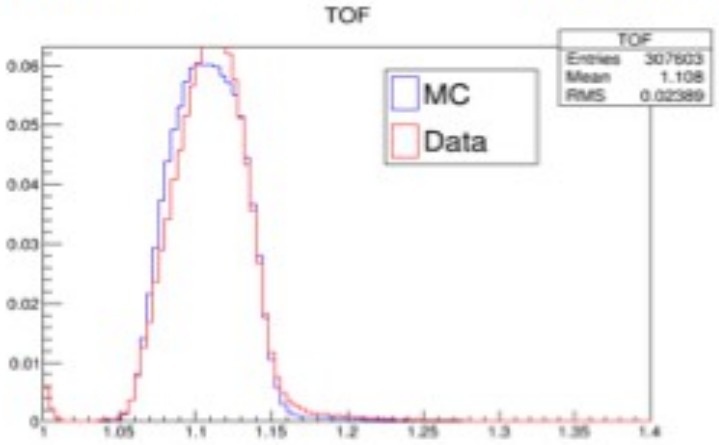


Figure: Pion beam 3426



Status

- A lot of nice progresses
  - Tracked in https://micewww.pp.rl.ac.uk/issues/1473
- But
  - Beam line simulation is not yet in agreement with data
  - KL digitisation needs tuning
    - Smearing of the MIP peak (photoelectrons stat+?)
    - Modeling of the tails (G4 thresholds)

KL Product Spectrum

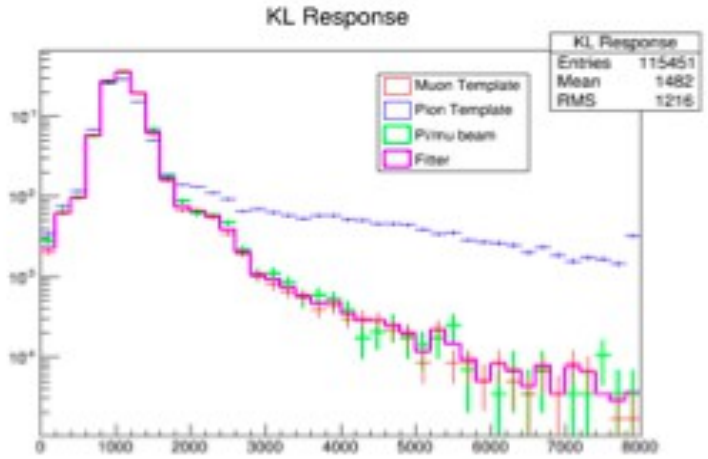


Figure: Data (6, 200) μ^+ beam

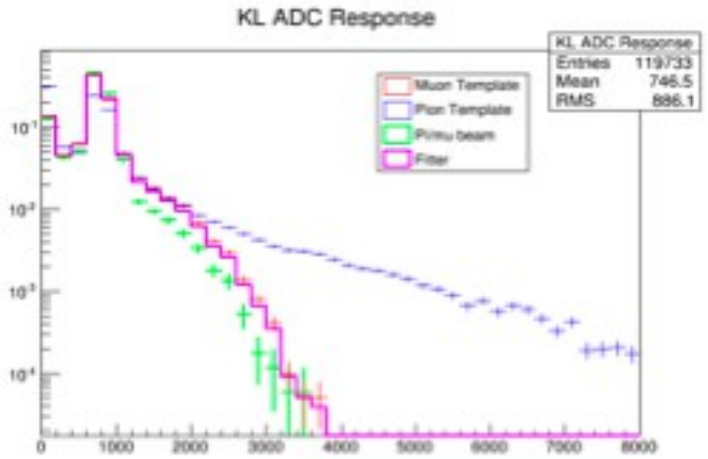
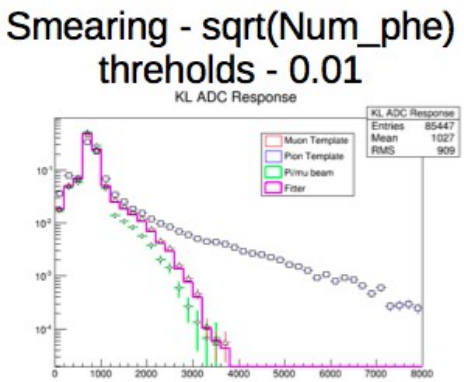


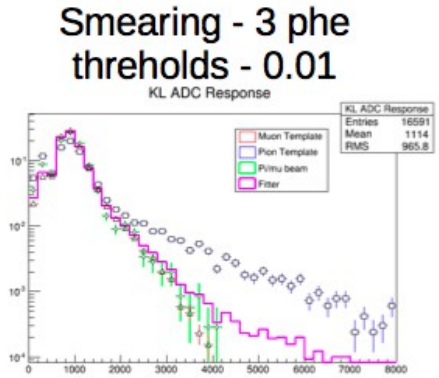
Figure: MC MAUS (6, 200) μ^+ beam

KL digitisation studies

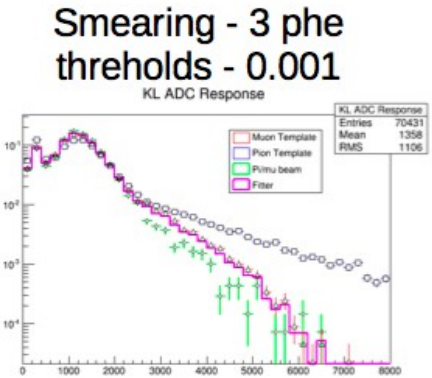
- **Ongoing...**



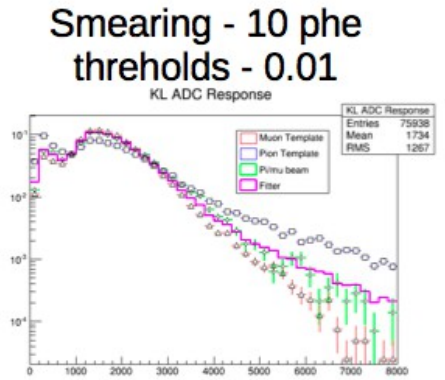
Despite the change of smearing factor and reduced threshold this is nearly identical to the plot shown at the meeting.



The width of the peak is increased with the increased smearing factor however the tails remain absent for the template and muon run.



Further reducing the thresholds increases the tails and also widens the peak



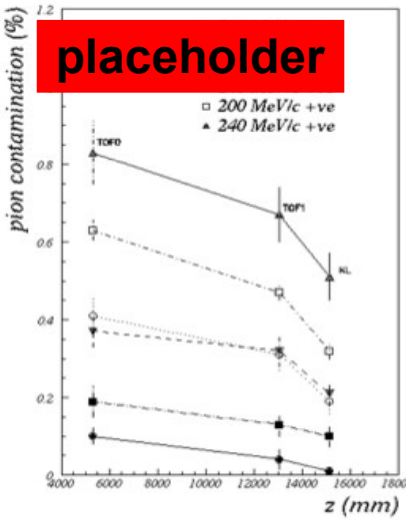
Increasing the smearing to this level clearly overestimates the width of the peak.

Analysis plans

- Assuming KL digitisation will be tuned soon
- Still need to
  - Improve TOF agreement (i.e. Beam momentum distribution) if possible
  - Address the double MIP peak – can it be obtained from double hits?

Paper plans (I)

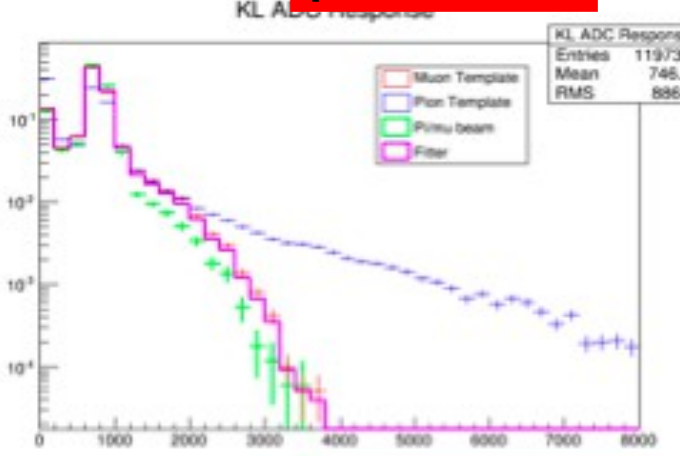
- In the paper we would like
  - To describe the beam [(6,200)? all?]:
    - momentum spectrum from MC
    - evolution of the composition with Z
  - To show agreement with data:
    - direct comparison both for muon (6,200) beam and for calibration runs
      - TOF distributions with data and MC overlayed
      - KL distributions in TOF windows with data and MC overlayed



Paper plans (II)

- **Prove the method on MC only**
  - **Fit MC templates to MC muon beam KL spectrum and extract a pion contamination to be compared to MC truth**
    - **For the contamination provided**
    - **For extra contamination values**

placeholder



Paper plans (III)

- **Provide the contamination measurement from data (as it is now)**
  - **Using full MAUS based analysis**
  - **Eventually dropping point 3**

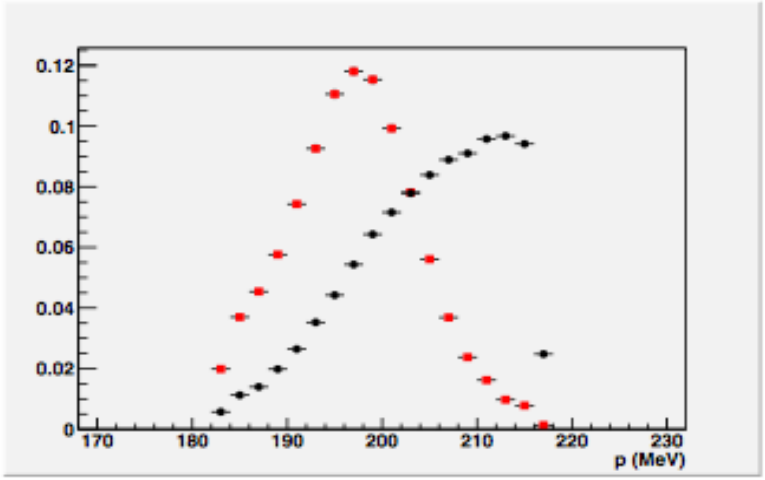


Figure 9. The muon momentum estimated from time–of–flight measurements for MICE beam data (black dots) and for the muon template (red squares) at Point 3.

Plans

- All these analysis updates should first go to a MICE note
- Only afterwards we can finalize a paper draft, hopefully for CM40

Proposed paper index

- Introduction
- MICE muon beam and 2011 data taking
- Pion contamination measurement
  - Description of the method
  - TOF and KL distributions in data and MC
  - Proof of the method with MC only
  - Results with data