PID Detectors & Emittance Resolution

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MICE CM17

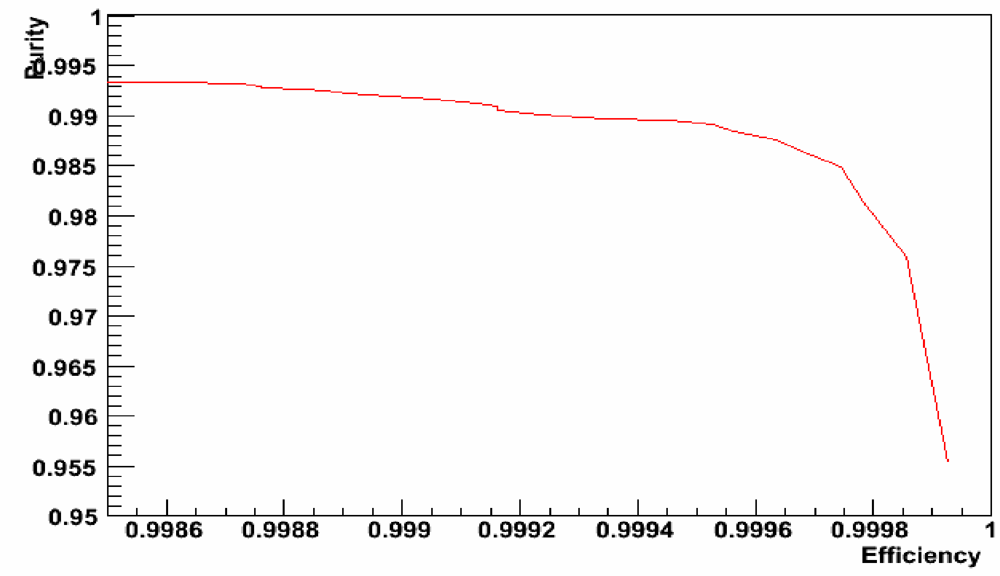
Two talks in one

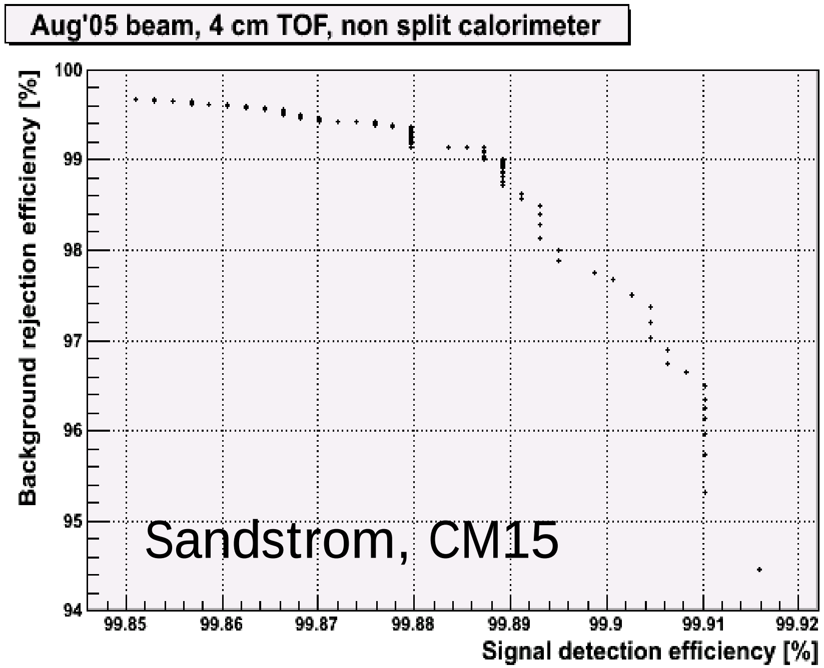
- A first look at emittance resolution vs downstream PID
- Second look at longitudinal emittance resolution that comes from TOF1/2 timing measurement

Downstream PID input sample

- I am using an input sample from Rikard with
  - ~ 30,000 events, of which ~280 are background
  - ~10 MeV rms energy spread
  - Input emittance 4 pi mm rad transverse
  - 0.035 c^2 pi ns longitudinal
  - Input energy 176 MeV, Output energy 173 MeV
  - Output emittance 7.5 pi mm rad transverse
  - 0.11 c^2 pi ns longitudinal
  - Note that the beam is not matched so there is considerable heating
  - I guess there is no RF/Absorbers but I am not sure of the details
- Rikard may show some new samples in the Analysis session

Purity Vs Efficiency

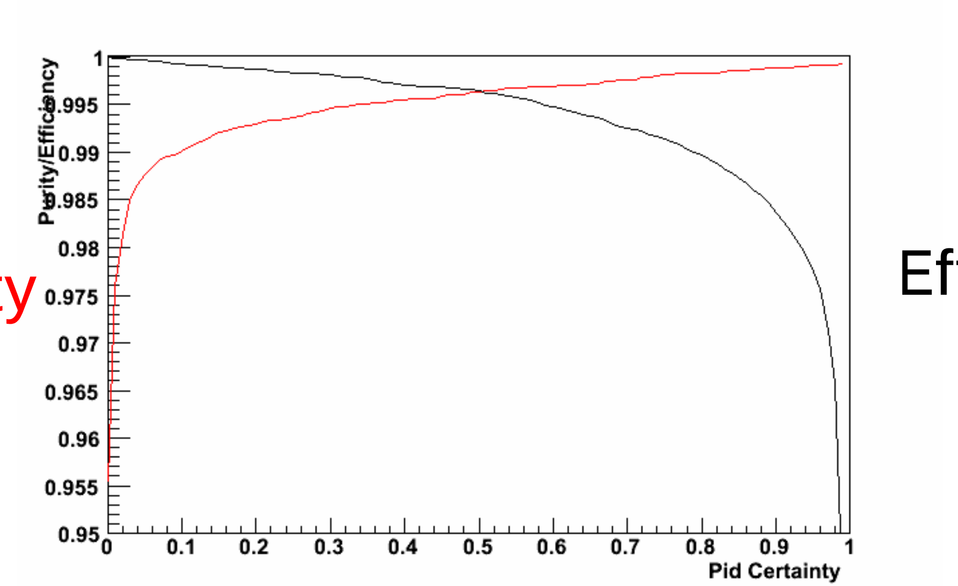




- I show a plot of purity vs efficiency
  - For comparison I also show one of Rikard's from June 06
  - Two different beams, so don't expect them to be identical - but at least looks reasonable
  - Purity = N(truth reconstructed good hits)/N(reconstructed good hits)
  - Efficiency = N(truth reconstructed good hits)/N(good hits)

Downstream PID Performance

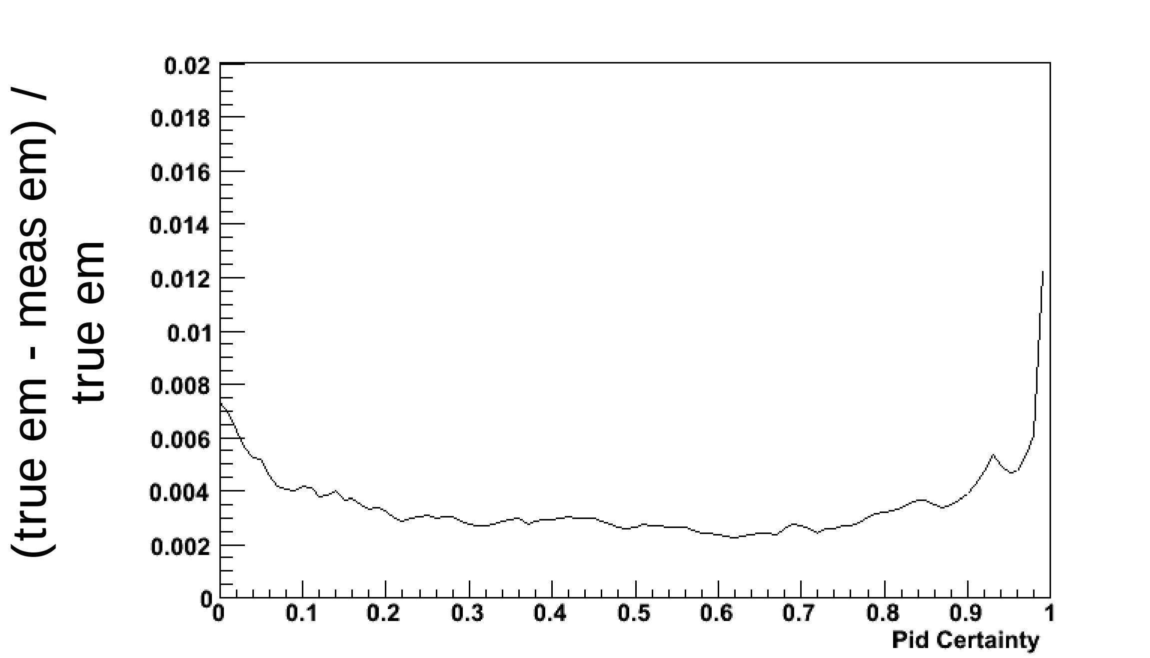
Purity



Efficiency

- Introduce new variable "PID Certainty"
  - Output from PID software giving an *estimate* of the probability that a particle is a muon
  - 0~definitely not a muon and 1~definitely a muon
- Show a plot of purity and efficiency after a cut to discard events with PID Certainty < x
- Demanding greater certainty that a particle is a muon improves purity and worsens efficiency

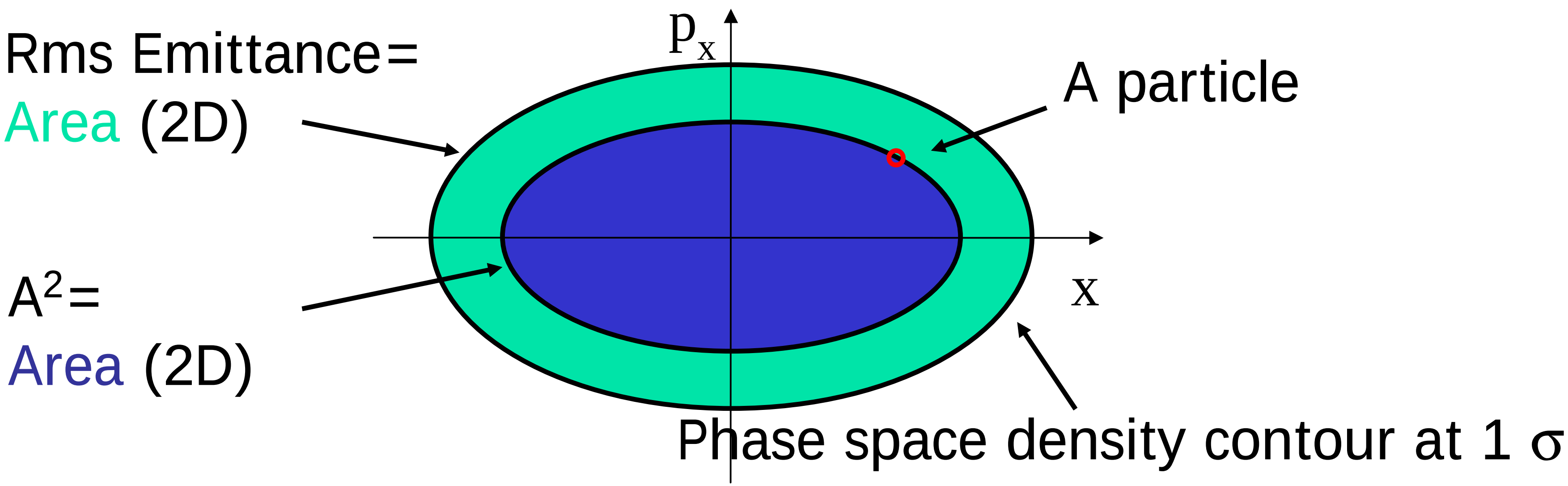
Emittance vs PID Certainty Cut



- This is fractional offset in emittance as a function of PID Certainty Cut due to mis ID
- *Underestimating* downstream emittance by about 2-3 per mil
  - This means the mis-identified events are in the centre of the beam
  - Statistical error >~ 10 %
    - Subtracting mean of 29900 events from mean of 30000 events
- Confirm this by looking at particle amplitude

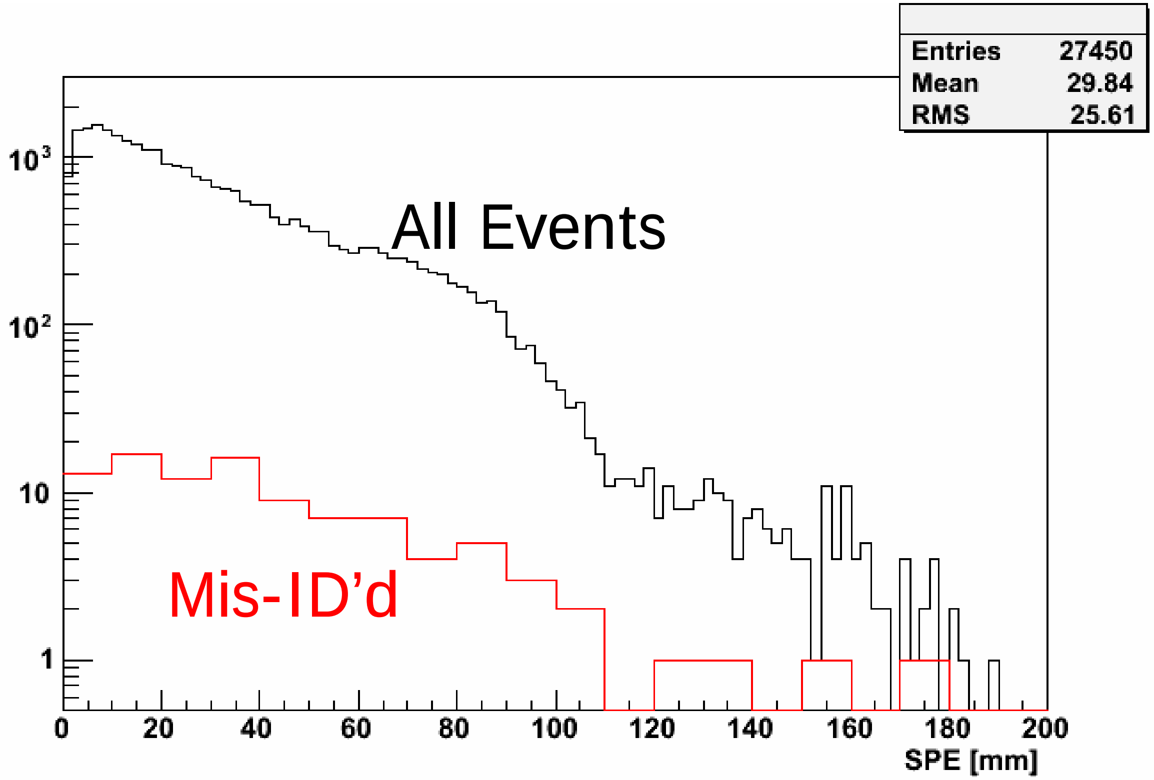
Amplitude (slide from 2004!)

- We can see the heating as a function of emittance without using many beams of different emittance
  - Define Amplitude squared A^2 by



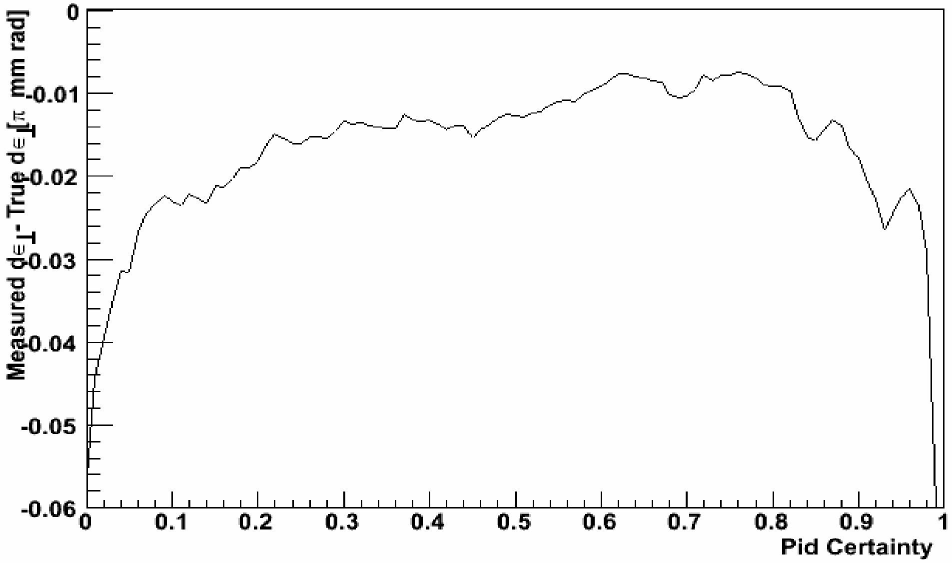
- Emittance is the mean of amplitude squared

Amplitude for PID Certainty cut of 0.5



- Discard events with PID certainty < 0.5 and look at amplitude
  - (Note log y axis)
  - Not a massive difference between the signal distn and the particle distn of mis-identified particles
  - I.e. mis-ID'd events have typical amplitudes

Emittance Change



- In MICE we are interested in emittance change
  - Look at the bias in emittance change rather than just emittance
  - If mis-identified particles start and end at the same amplitude, mis-PID does not bias emittance change
- Plot shows bias vs PID Certainty
  - Smallest bias is -0.0075 pi mm rad

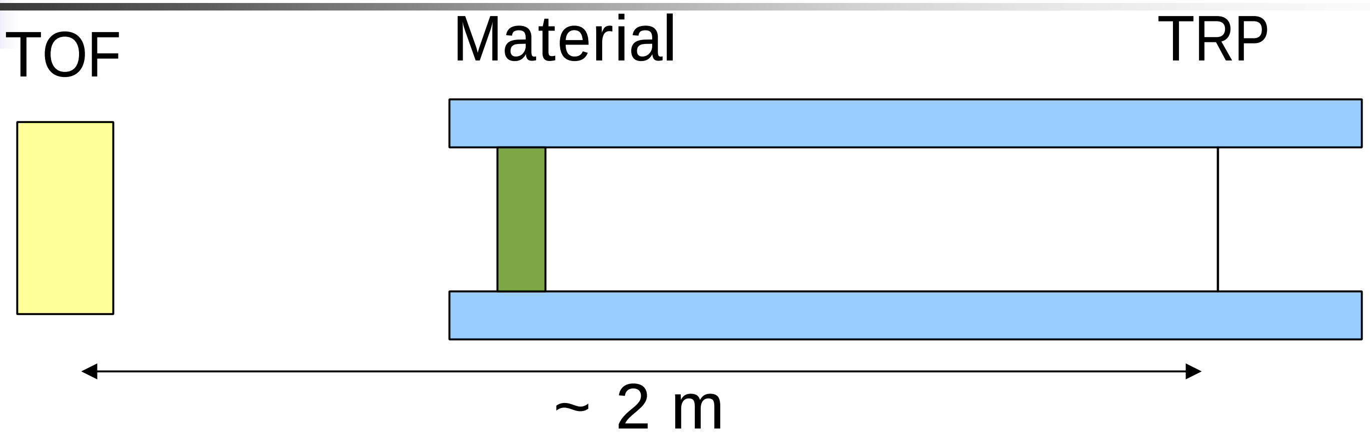
Summary One

- A first look at downstream PID indicates an emittance offset of about 0.2-0.3%
- Bias in the emittance change measurement of about 0.0075 pi mm rad transverse
  - This is roughly what we need for MICE
- The study should be repeated for a matched beam with cooling elements included
  - It is possible that the reported biases will be very different in this case
  - Some further consideration of which MICE stages, momenta & emittances to study is also desirable
  - Some further consideration of the statistical errors which may be large
- The code for this is public (just ask) and I encourage keen PIDers to take up the work load as I may not have time

Timing measurement for emittance

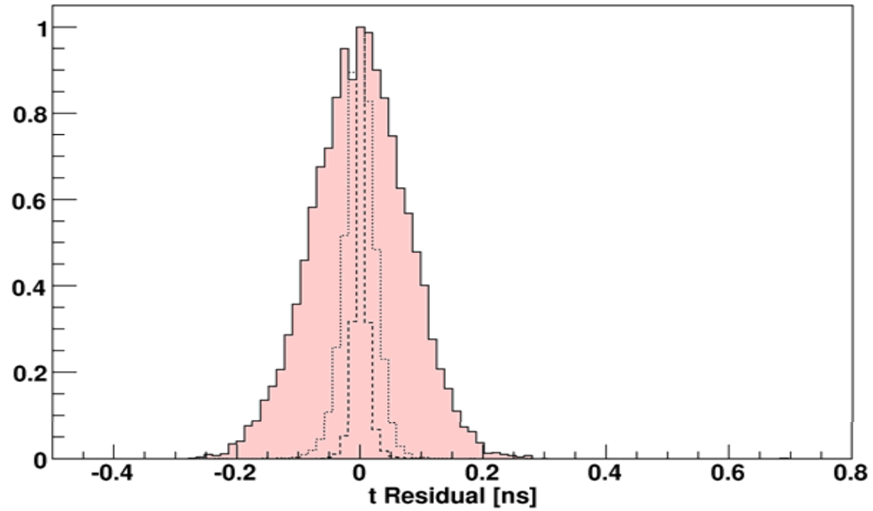
- For longitudinal emittance calculation, I require a timing measurement at the Tracker Reference Plane (TRP)
- Technique is to extrapolate timing measurement from TOF1 to the TRP using energy measurement in the SciFi
- Repeat for TOF2
- At CM14 I showed the error introduced by this extrapolation at TOFII based on the tracker resolution of that version of G4MICE
  - Errors dominated by tracker resolution
  - But tracker resolution was poor due to software problems
- Here I repeat the study but using a ~Gaussian smearing to model the tracker
  - Designed to mimic the tracker resolution detailed in MICE note 90
- I also consider the resolution upstream of MICE, where the diffuser has a detrimental effect

Algorithm



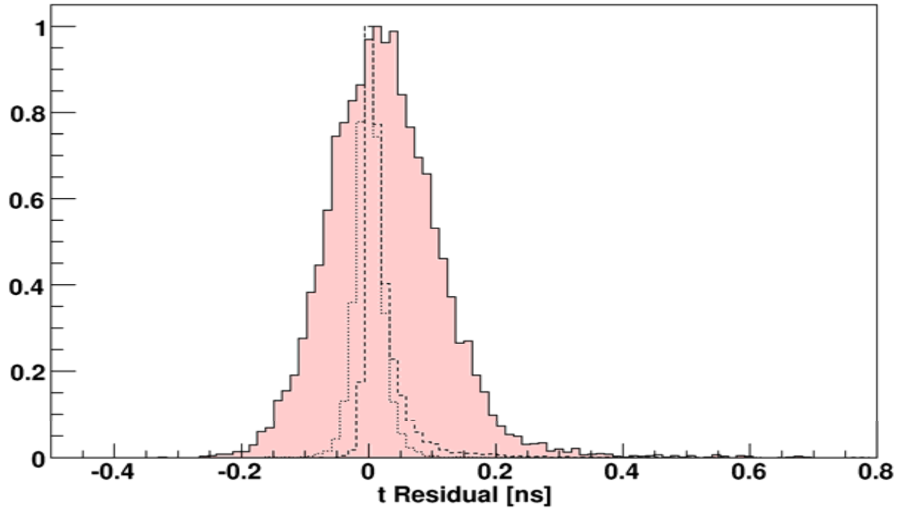
- I have x,y,px,py,pz for a particle at the TRP and t at the TOF
  - Track muons back from TRP to TOF1 and remember the time of flight
    - If material gets in the way, assume mean dE/dz and no multiple scatter
  - Assign time measurement to the muon from TOF1
  - Add simulated time of flight of muon to get time measurement at TRP
- I take TOF at +/- 6611 mm, TRP at +/- 4690 mm, diffuser 7.6 mm, ignore Helium and vacuum windows
  - I have not been careful about the solenoid bore, light fibres etc on the edge of the beam which will have a further detrimental effect

Downstream



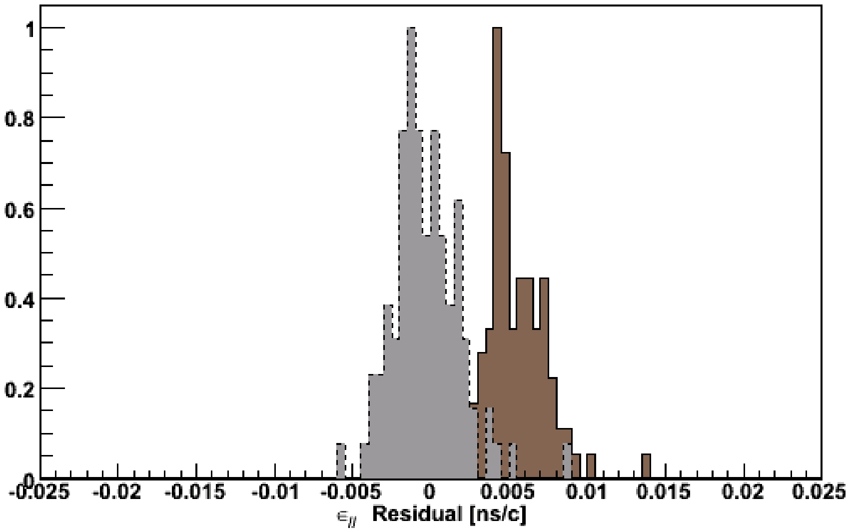
- Timing residuals downstream are shown
  - Full resolution = 76.7 ps RMS
  - Error introduced from material in beamline = 12.6 ps RMS (dashed)
    - Include tracker planes but no Helium, vacuum windows, etc
  - Error introduced from tracker resolution = 26.3 ps RMS (dotted)
  - Taking TOF resolution to be 70 ps RMS, distributed as a Gaussian

Upstream



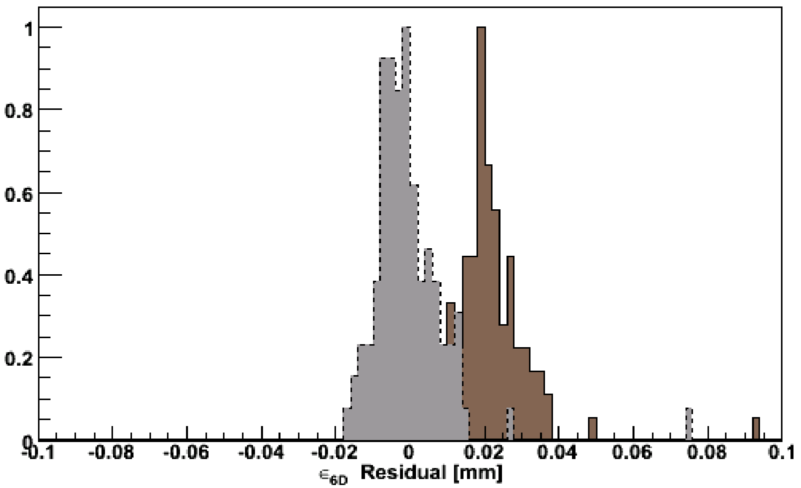
- Timing residuals upstream are shown -
  - Full resolution = 89.9 ps RMS
  - Error introduced from material in beamline = 49.9 ps RMS (dashed)
    - 7.6 mm lead diffuser
  - Error introduced from tracker resolution = 24.3 ps RMS (dotted)
  - Note the long tail and mean offset of 26.1 ps due to multiple scattering
    - Muons which scatter a lot have a shorter path length upstream of the diffuser which I do not model correctly

Longitudinal emittance



- Show the longitudinal emittance residual ($\delta\varepsilon_{//} = \varepsilon_{//}^{meas}-\varepsilon_{//}^{long}$) for 100 samples of 1000 muons measured at upstream TRP
  - Brown is natural distribution
  - Grey is distribution after the “deconvolution” algorithm is applied to remove the systematic bias (cf Rogers & Ellis MICE Note 122)
  - Compare with actual longitudinal emittance of ~0.26 ns

6D Emittance



- Repeat the procedure for 6D emittance
  - Again, brown is natural distribution and grey is distribution after "deconvolution"
  - Compare with actual 6D emittance ~2.3 [$mm^{2/3}$ $ns^{1/3}$]

Summary Two

- Summary of timing resolutions:

	$\sigma(t)$ Downstream [ns]	$\sigma(t)$ Upstream [ns]
Material	12	26
Tracker	24	50
TOF	70	70
Combined	77	90

- Summary of emittance resolutions
  - Upstream tracker, 70 ps TOF resolution, ε_{6D} = 2.3, $\varepsilon_{//}$ = 0.26 ns, 1000 muon samples:

	$\sigma(\delta\varepsilon_{//})$	$<\delta\varepsilon_{//}>$	$\sigma(\delta\varepsilon_{6D})$	$<\delta\varepsilon_{6D}>$
Uncorrected	0.00205	0.00528	0.0101	0.0222
Corrected	0.00213	-0.00029	0.0106	-0.00043