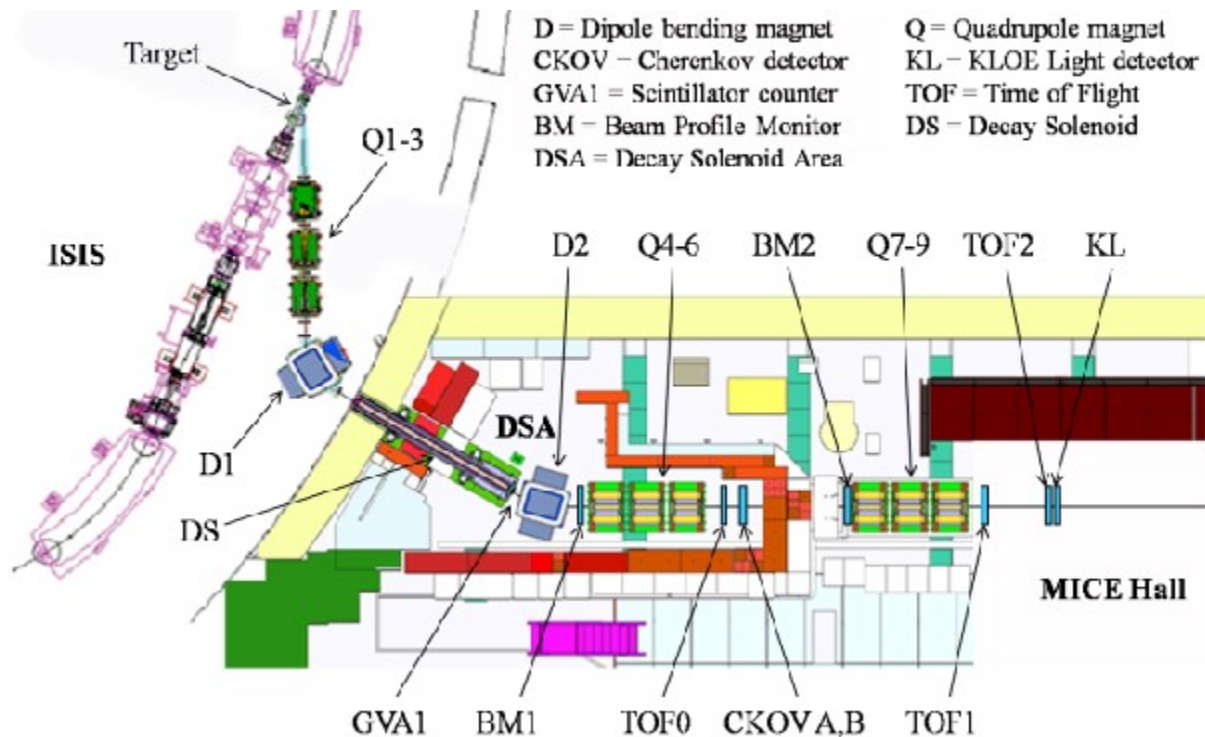
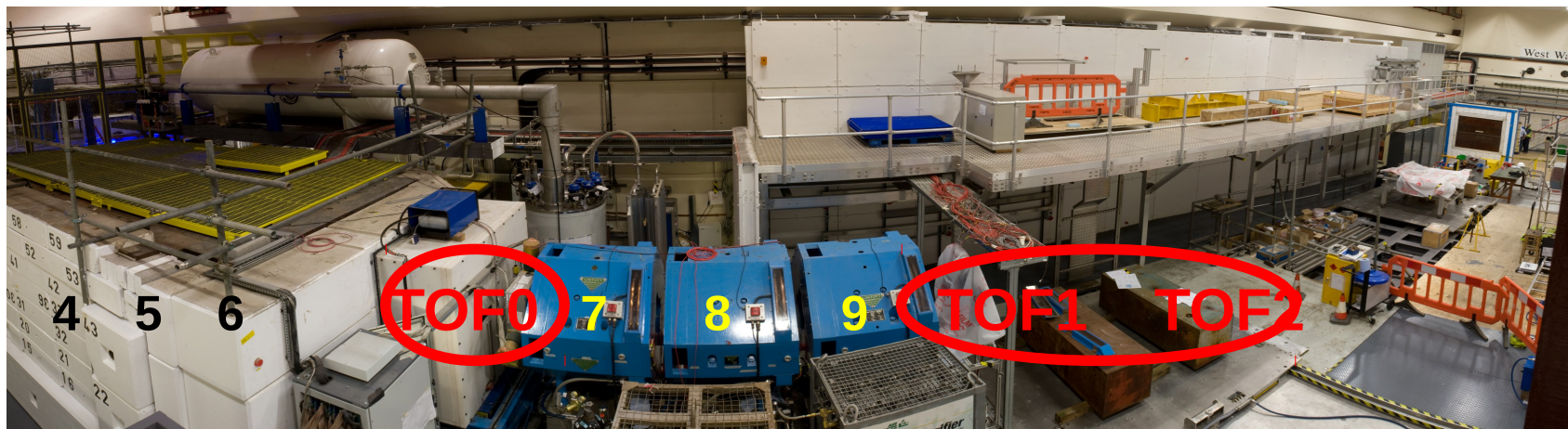
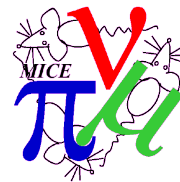




# Data Quality Check



Summer Blot  
University of Chicago  
M.I.C.E.

# Motivation

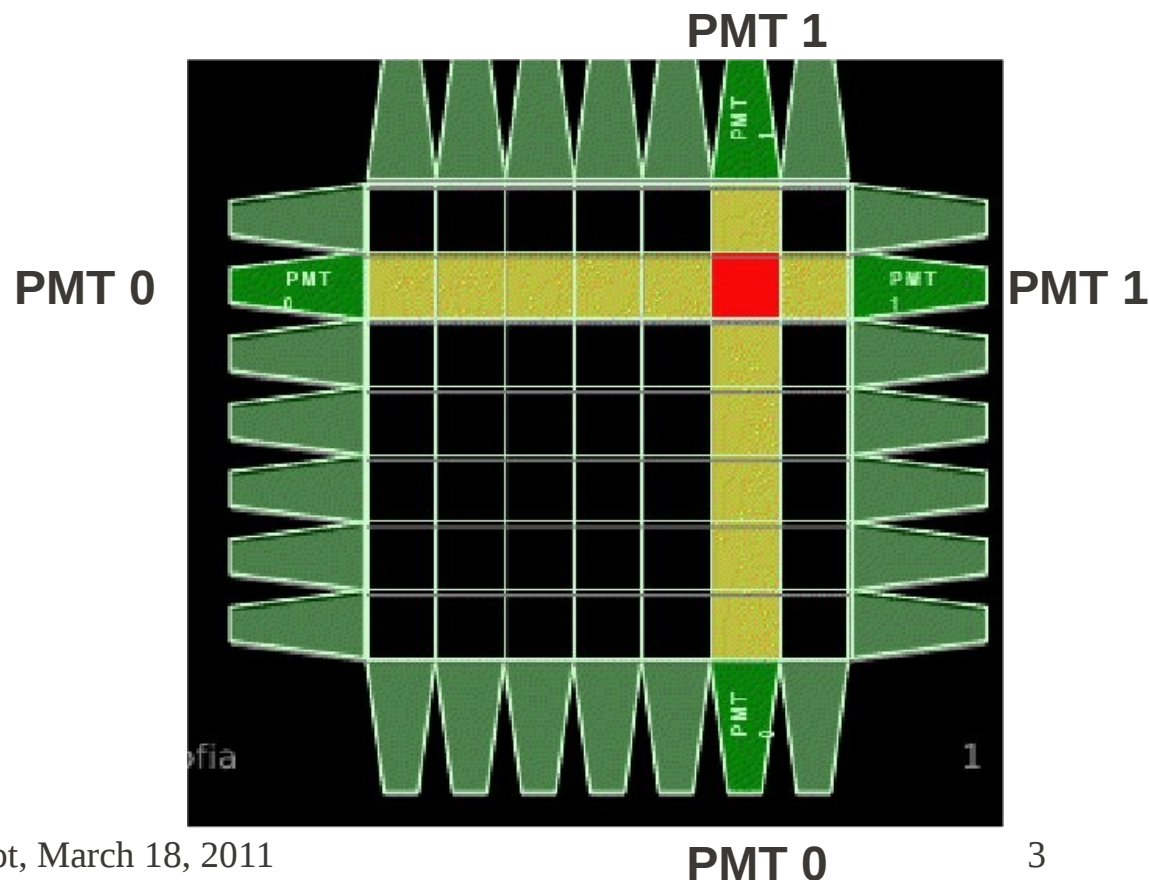
- Aim of the **Muon Ionization and Cooling Experiment (MICE)** is to demonstrate transverse beam emittance reduction for a muon beam
  - Fast/effective/low cost cooling method is necessary component of Neutrino Factory of **Muon Collider!**
- Data was taken over the summer of 2010 for **Step I** of MICE, in which we altered the configuration of the upstream magnets and measured the effects on the beam.
- To ensure stability of the beam line, **reference runs** were taken throughout running period
  - Fixed target configuration
  - Magnets set to give **6pi-200MeV/c** muon beam
- Important to analyze this data to ensure consistency of beam dynamics so that further analysis can be carried out and the beam prepared for downstream matching and cooling

# Time of Flight Detectors

- 2 planes (X and Y) of fast 1-in scintillator counters fitted with R4998 Hamamatsu fast photomultipliers
- TOF0
  - 40x40 cm coverage
  - 10 slabs in each plane – each is 4 cm wide
- TOF1
  - 42x42 cm coverage
  - 7 slabs in each plane – each is 6 cm wide
- TOF2
  - 60x60 cm coverage
  - 10 slabs in each plane -each is 6 cm wide
- TDC and ADC signals are read out at both ends of each slab



TOF 0 in the beamline between Q6 and Cerekov detectors



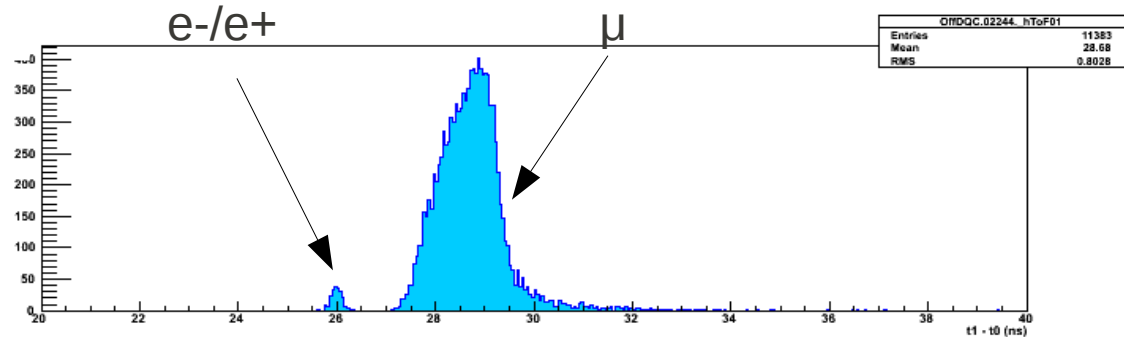
# Delta bravo 10-4, Roger that!

- Some quick definitions so that you don't get lost in the lingo
- A “run” for MICE corresponds to many target actuations (for reference runs ~200 pulses into the ISIS beam)
- A “hit” in a TOF corresponds to coincidence between PMT0 and PMT1 at EACH end of a slab, in BOTH X and Y planes (see previous slide)
- NOTE: when I get to the analysis about specific slab hits, the definition of “hit” changes. In that part of the study, “hit” refers to a coincidence between PMT0 and PMT1. I look at the X and Y planes *separately* for this part of the analysis.
- G4MICE is the analysis software we use – I did not write any of the applications used in the analysis, I simply modified them to fit my needs

# Data Quality Check

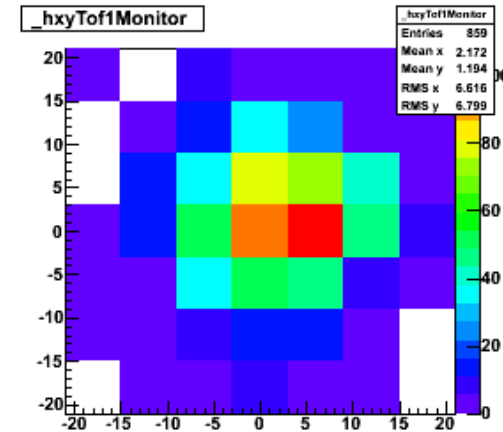
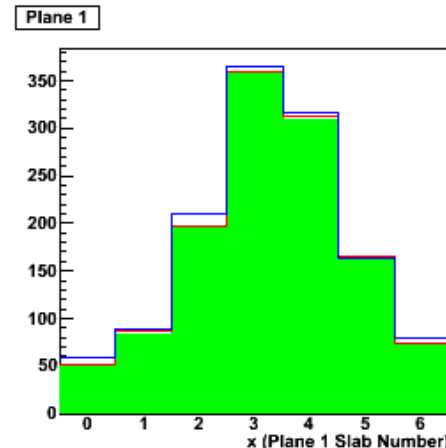
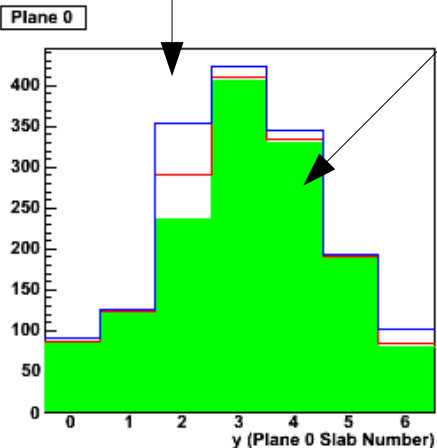
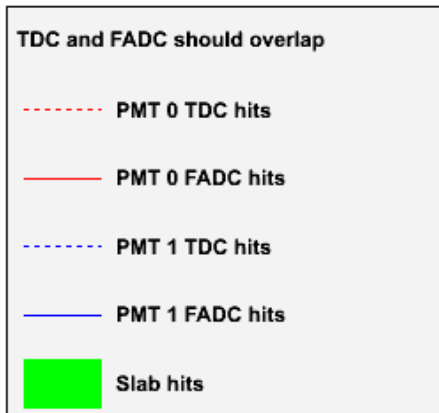
- G4MICE Application
  - Is run ONLINE while taking data – available for off line analysis (me)
  - converts TDC information from TOF detectors to precision timing measurements between TOF stations
  - Creates ROOT histograms of hits/slab in both X and Y plane

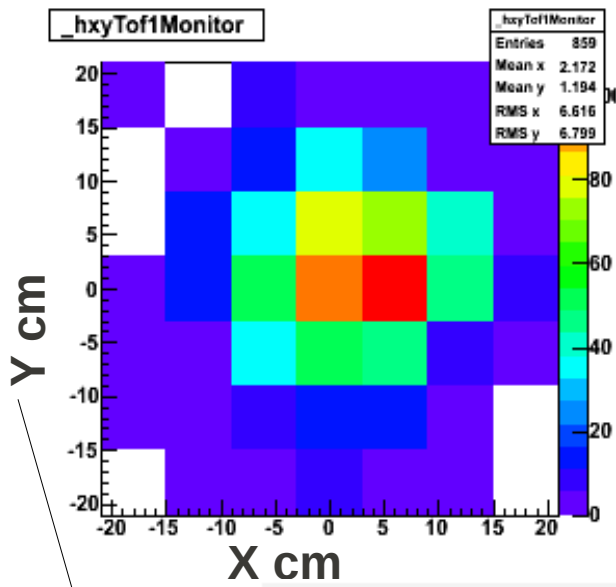
TOF 0-1



PMT 0 vs 1

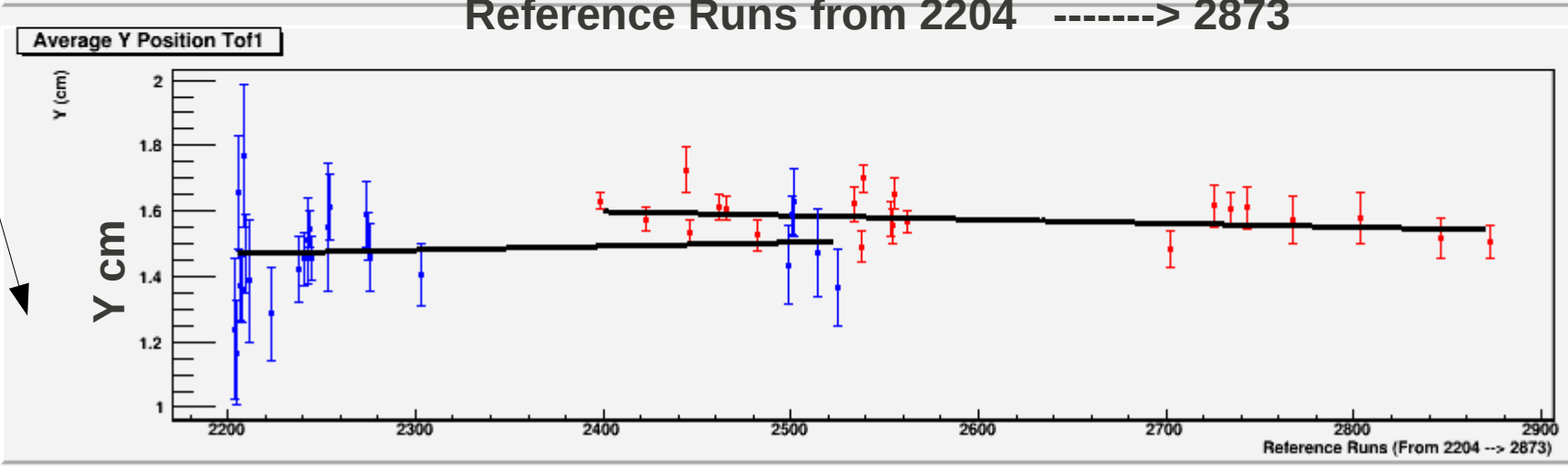
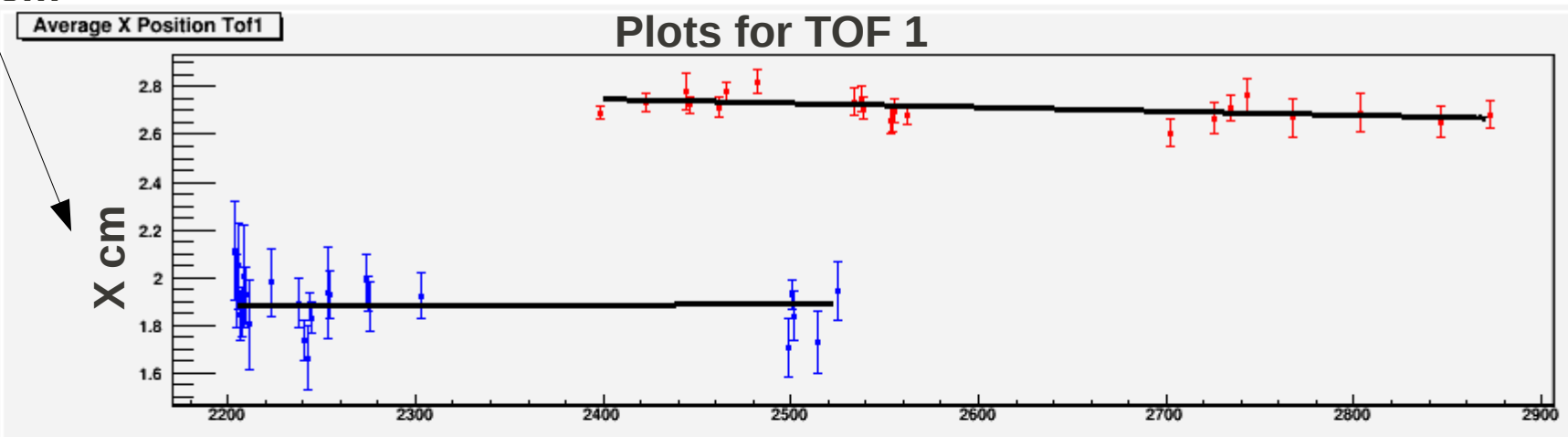
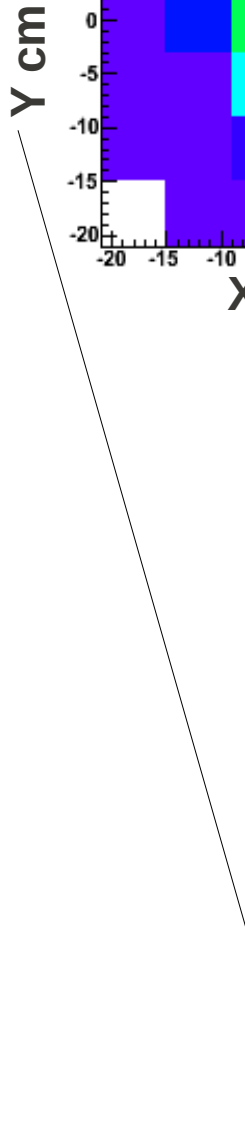
Green = slab hit  
(pmt coincidence)





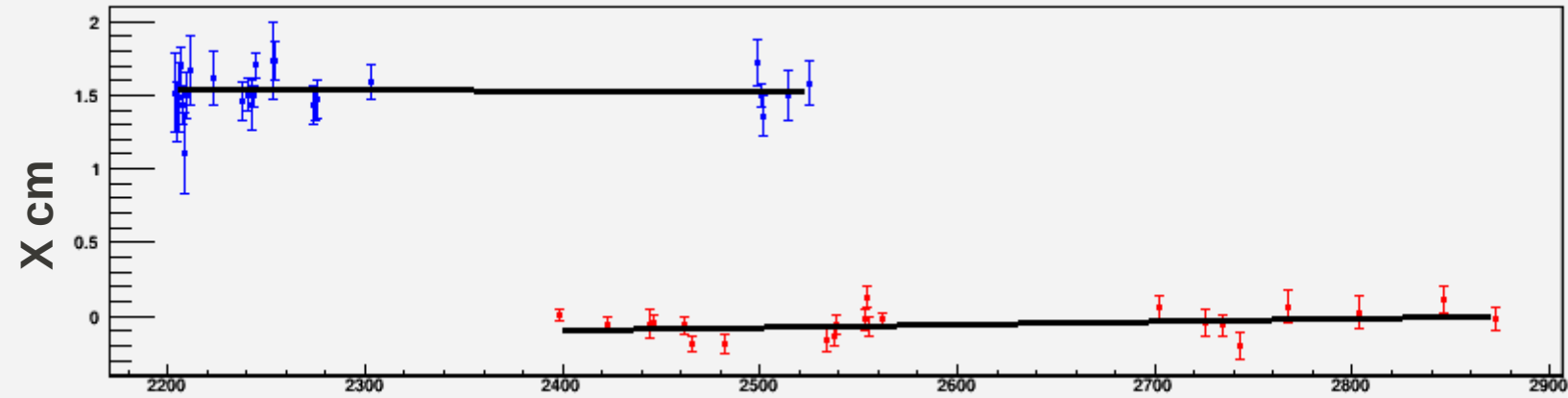
# Average X and Y Positions

(Red is positive polarity beamline, Blue is negative)



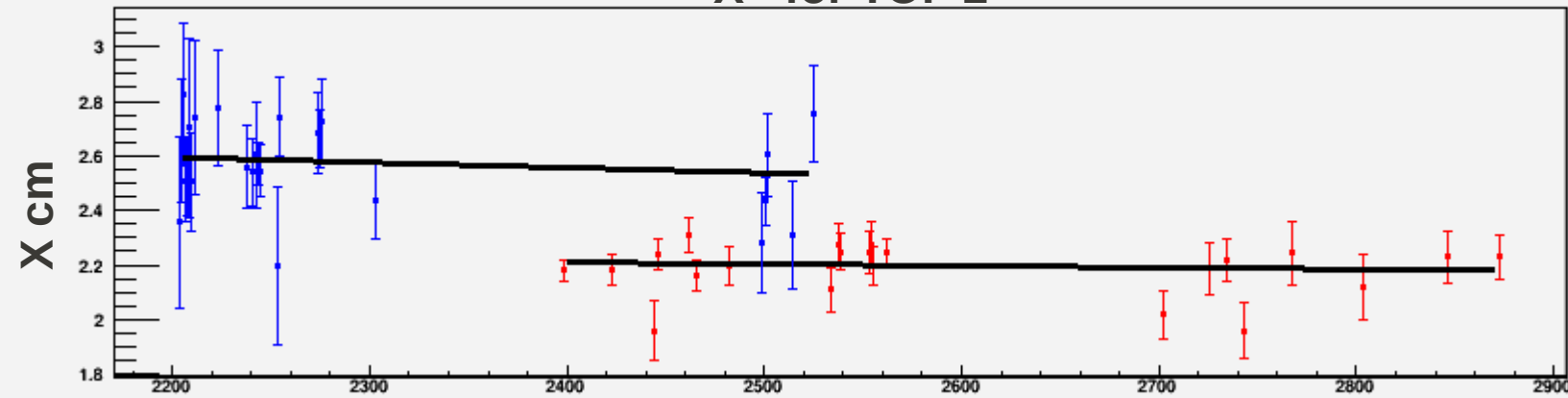
Average X Position Tof0

<X> for TOF 0



Average X Position Tof2

<X> for TOF 2



- Separation between positive and negative <X> is
  - ~1.5 cm for TOF0
  - ~1.0 cm for TOF1
  - ~0.2 cm for TOF2

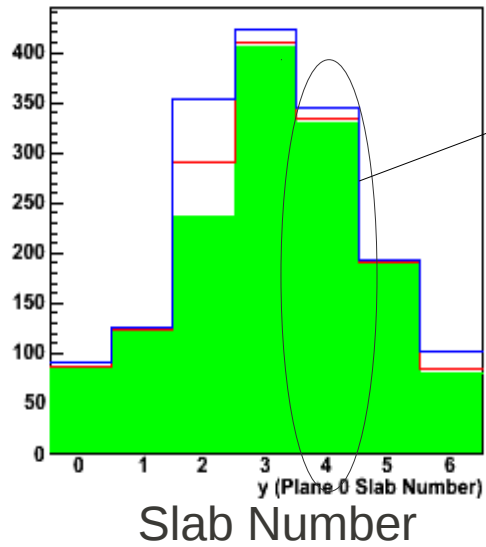
-Overall, great consistency among reference runs!  
 (Slopes ~0.0, and  $\chi^2 \sim 1.0$  for both <X> and <Y>)

	Average X Position					
	POSITIVE			NEGATIVE		
	<X>	Slope	$\chi^2$	<X>	Slope	$\chi^2$
TOF0	-0.067	2.03E-4	1.858	1.526	-7.87E-6	0.782
TOF1	2.724	-1.68E-4	1.222	1.895	2.70E-5	0.681
TOF2	2.188	-6.34E-5	1.147	2.584	-1.91E-4	0.776

	Average Y Position					
	POSITIVE			NEGATIVE		
	<Y>	Slope	$\chi^2$	<Y>	Slope	$\chi^2$
TOF0	-0.171	1.59E-4	1.659	0.105	-1.24E-4	0.780
TOF1	1.580	-1.19E-4	1.453	1.461	1.17E-4	1.054
TOF2	2.320	-6.36E-5	0.922	2.022	1.49E-4	1.008

Plane 0

Y Plane

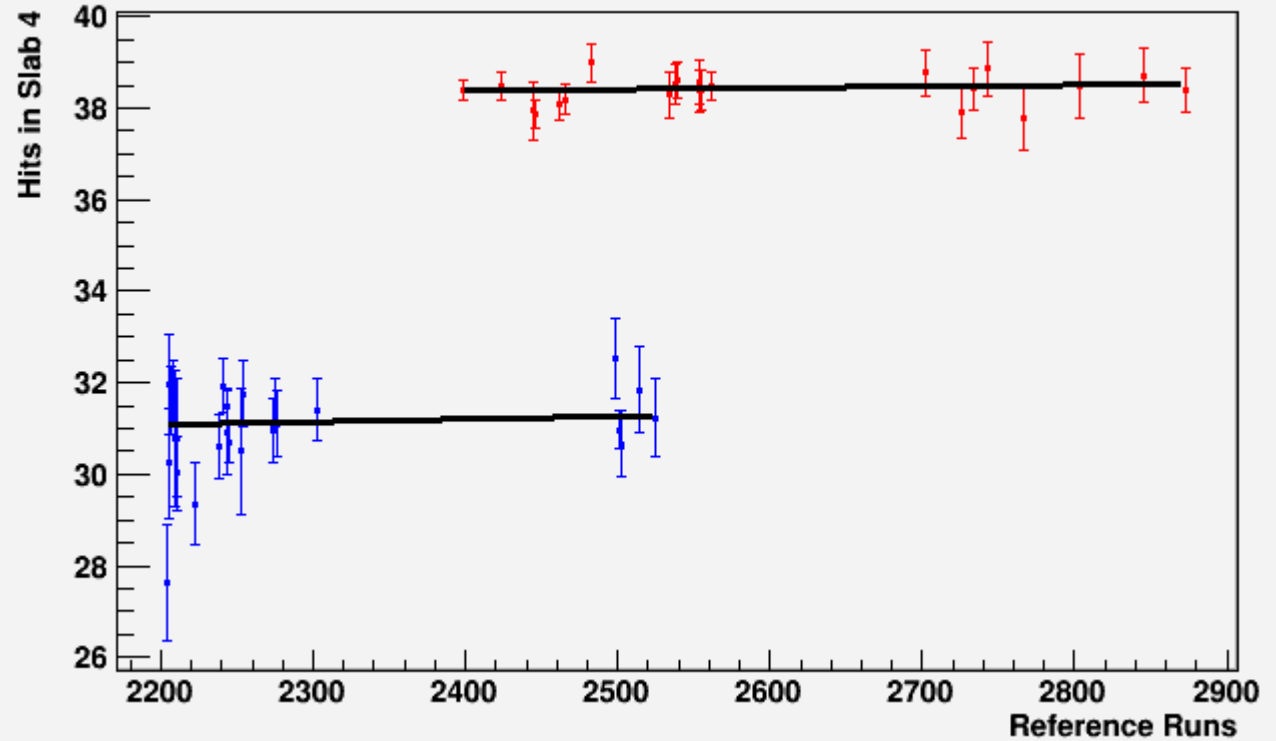


# TDC Hits in Slab

## Total TDC hits in plane

(For each run)

Tof1, Y Plane, Hits in Slab 4



- This is slab 4, so it is essentially right in the middle of TOF1. Thus, we'd expect this slab to be highly uniform and this is indeed what we observe

-Discrepancy between positive and negative still present



# Slab Hit Results

Fraction of Hits in Slabs for TOF0								
Horizontal Plane					Vertical Plane			
POS		NEG			POS		NEG	
Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2	
Slab 0	-	-	-	-	-	-	-	-
Slab 1	-3.07E-4	1.432	5.46E-4	0.897	-9.94E-5	1.635	-1.40E-6	0.716
Slab 2	-3.70E-4	0.652	4.28E-4	0.863	-2.13E-4	1.126	-1.73E-4	1.056
Slab 3	-1.40E-4	0.396	-6.87E-4	0.662	-2.94E-4	0.720	6.46E-4	0.647
Slab 4	-3.08E-4	1.042	-2.26E-3	1.174	-5.78E-4	0.686	-3.96E-4	0.565
Slab 5	3.18E-4	1.347	6.39E-4	0.520	8.00E-4	0.531	1.00E-3	1.093
Slab 6	-2.33E-4	1.183	2.92E-3	0.649	-6.62E-5	0.891	-1.79E-3	0.784
Slab 7	1.98E-4	0.722	-4.98E-4	1.389	2.59E-4	0.992	1.34E-3	0.646
Slab 8	5.62E-4	1.187	-1.34E-3	1.033	5.95E-4	1.647	-4.18E-4	0.899
Slab 9	8.32E-6	1.127	2.36E-5	0.863	-3.02E-4	0.622	-6.14E-5	0.825

Fraction of Hits in Slabs for TOF1								
Horizontal Plane					Vertical Plane			
POS		NEG			POS		NEG	
Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2	
Slab 0	-	-	-	-	-	-	-	-
Slab 1	-1.82E-4	1.065	5.95E-4	2.148	1.86E-6	1.622	-1.13E-4	2.151
Slab 2	1.04E-4	0.744	1.01E-4	0.684	-3.52E-4	2.391	-1.96E-3	1.108
Slab 3	7.28E-4	1.042	-1.00E-3	1.224	7.93E-4	0.959	8.33E-4	0.600
Slab 4	7.43E-5	0.433	2.19E-3	0.576	3.11E-4	0.674	5.72E-4	1.018
Slab 5	-7.29E-4	0.626	-1.61E-5	1.003	-1.20E-4	0.462	3.07E-3	1.292
Slab 6	-7.05E-5	1.399	-8.49E-4	0.722	-4.70E-4	0.969	-1.48E-3	1.354

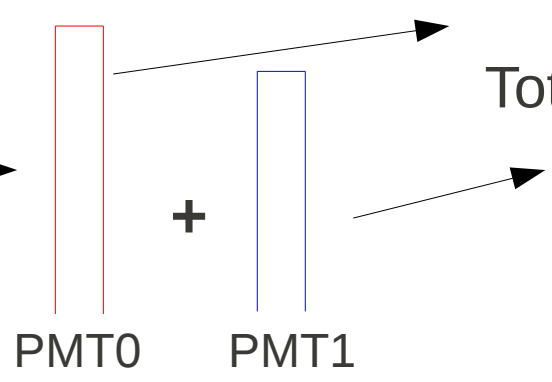
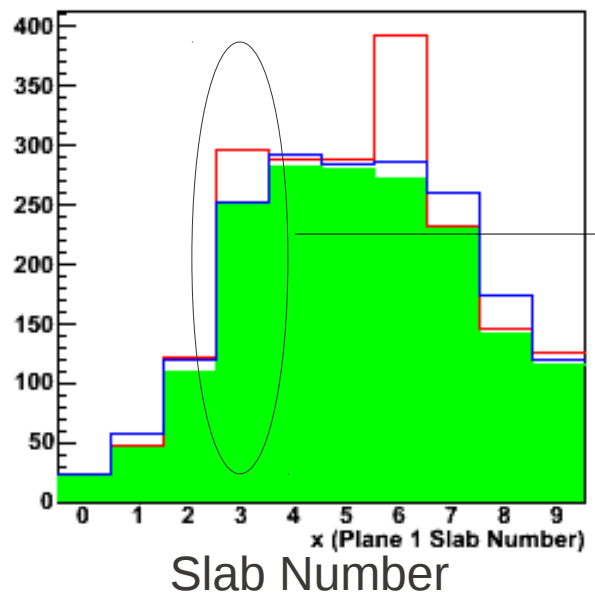
# Slab Hit Results (cont'd)

Fraction of Hits in Slabs for TOF2								
Horizontal Plane					Vertical Plane			
POS		NEG			POS		NEG	
Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2	
Slab 0	-	-	-	-	-	-	-	-
Slab 1	9.62E-5	1.558	-2.49E-4	2.394	1.15E+0	0.000	7.10E-1	0.000
Slab 2	-3.92E-4	0.756	2.35E-4	1.427	4.32E-1	0.000	8.17E-1	0.000
Slab 3	4.78E-4	1.118	6.48E-4	0.997	7.26E-1	0.000	8.39E-1	0.000
Slab 4	3.97E-6	1.243	-1.38E-3	1.548	8.68E-1	0.001	1.38E+0	-0.001
Slab 5	-7.61E-4	1.347	5.58E-4	0.918	8.61E-1	0.000	7.48E-1	-0.002
Slab 6	2.23E-4	0.909	2.55E-3	0.571	6.47E-1	0.000	9.33E-1	0.000
Slab 7	6.80E-4	0.890	-2.98E-3	0.737	6.74E-1	0.000	4.96E-1	0.002
Slab 8	-2.93E-4	0.560	9.60E-4	1.001	7.50E-1	-0.001	1.19E+0	0.000
Slab 9	-2.72E-4	0.744	-3.77E-4	0.308	9.60E-1	0.000	8.07E-1	0.000

- All of the slopes for linear fit are  $\sim 0$  (largest slope is  $10^{-3}$ )
- $X^2$  values are all  $\sim 1 \rightarrow$  good fit
- Based on this analysis, there seems to be excellent consistency among reference runs, which again is what we would expect given the consistency of  $\langle X \rangle$  and  $\langle Y \rangle$

Plane 1

X Plane

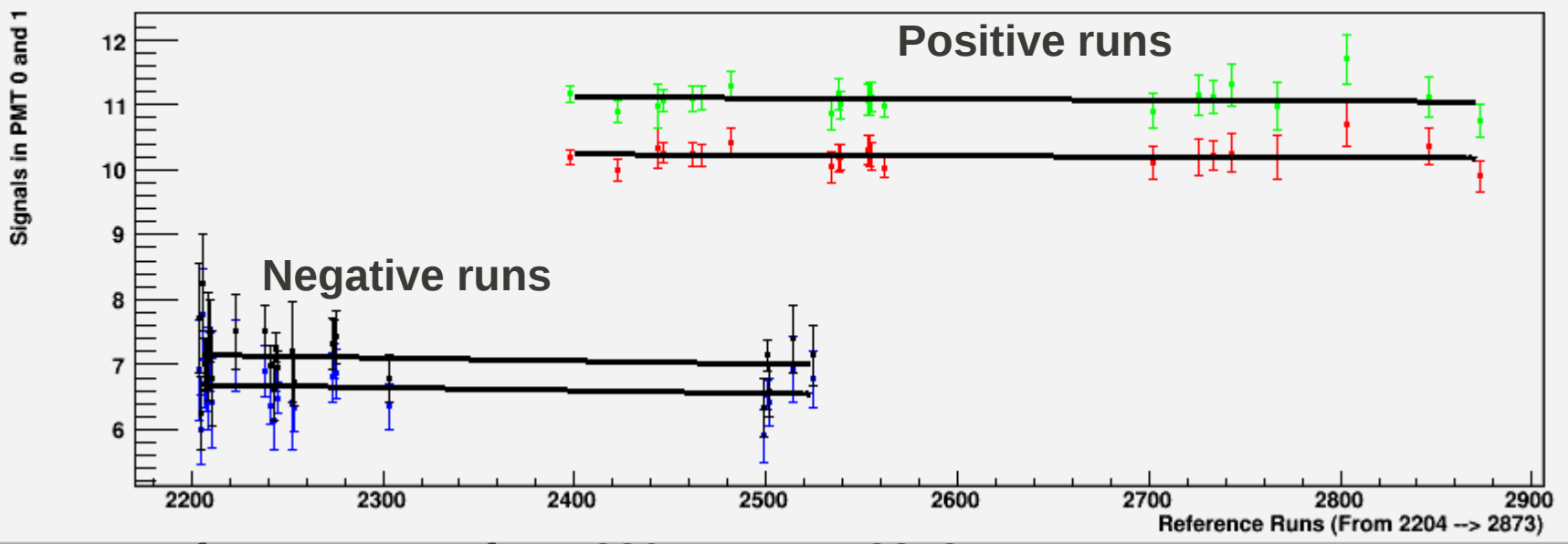


$\frac{\text{PMT0(or 1) TDC counts}}{\text{Total TDC counts in 0}^{\text{th}} \text{ (or 1) plane}}$

(Change of color code...)

- **GREEN** and **BLACK** = PMT 0
- **RED** and **BLUE** = PMT 1

Tof0, X Plane, Signals in PMT0 and PMT1 Slab 3



Reference Runs from 2204 -----> 2873  
S. Blot, March 18, 2011

# PMT coincidence Results

TOF0

Fraction of Hits in PMT 0 and 1 for TOF0								
Horizontal Plane								
	PMT0				PMT1			
	POS		NEG		POS		NEG	
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2
Slab 0	-	-	-	-	-	-	-	-
Slab 1	-2.84E-4	1.524	5.11E-4	0.975	-2.78E-4	1.365	5.44E-4	0.710
Slab 2	-3.17E-4	0.539	4.71E-4	0.936	-4.43E-4	0.684	2.99E-4	0.870
Slab 3	-1.28E-4	0.506	-4.49E-4	0.700	-1.56E-4	0.464	-4.74E-4	0.721
Slab 4	-1.46E-4	1.121	-2.57E-3	1.108	-2.73E-4	1.059	-1.82E-3	1.119
Slab 5	2.90E-4	1.567	3.99E-4	0.609	2.54E-4	1.329	4.31E-4	0.686
Slab 6	-2.89E-4	1.046	2.59E-3	0.633	-2.93E-4	1.281	2.91E-3	0.693
Slab 7	1.47E-4	1.315	-2.75E-4	1.846	1.07E-4	0.782	-1.21E-4	1.454
Slab 8	4.86E-4	1.243	-1.19E-3	0.994	5.13E-4	1.479	-1.24E-3	1.235
Slab 9	-1.75E-5	1.319	3.37E-4	1.239	3.07E-4	0.941	-8.38E-4	1.158

X  
plane

Fraction of Hits in PMT 0 and 1 for TOF0								
Vertical Plane								
	PMT0				PMT1			
	POS		NEG		POS		NEG	
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2
Slab 0			-	-	-	-	-	-
Slab 1	-1.28E-4	1.637	-6.94E-5	0.769	-1.24E-4	1.753	-4.07E-5	1.000
Slab 2	-1.95E-4	1.109	-1.79E-4	1.086	-2.01E-4	1.075	-1.87E-4	1.090
Slab 3	-2.56E-4	0.716	5.97E-4	0.654	-2.37E-4	0.765	5.86E-4	0.649
Slab 4	-5.81E-4	0.676	-3.37E-4	0.564	-6.60E-4	0.696	-3.63E-4	0.585
Slab 5	7.92E-4	0.533	1.04E-3	1.081	8.58E-4	0.519	1.12E-3	1.172
Slab 6	-8.66E-5	0.853	-1.83E-3	0.782	-1.87E-4	0.842	-2.06E-3	0.780
Slab 7	2.85E-4	1.051	1.37E-3	0.654	2.70E-4	1.052	1.39E-3	0.680
Slab 8	6.17E-4	1.737	-3.35E-4	0.926	6.49E-4	1.684	-3.45E-4	0.925
Slab 9	-3.00E-4	0.584	-5.88E-5	0.847	-2.67E-4	0.663	2.55E-4	0.824

Y  
plane

# PMT coincidence Results (cont'd)

TOF1

Fraction of Hits in PMT 0 and 1 for TOF1								
Horizontal Plane								
	PMT0				PMT1			
	POS		NEG		POS		NEG	
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2
Slab 0	-	-	-	-	-	-	-	-
Slab 1	-1.73E-4	1.195	6.25E-4	2.213	-2.09E-4	1.149	6.88E-4	1.816
Slab 2	1.17E-4	0.697	4.67E-5	0.712	1.38E-4	0.720	1.69E-4	0.797
Slab 3	7.71E-4	1.052	-9.34E-4	1.222	7.57E-4	0.924	-8.76E-4	1.151
Slab 4	1.73E-5	0.426	2.28E-3	0.613	-4.06E-5	0.417	2.28E-3	0.587
Slab 5	-7.92E-4	0.639	-5.21E-5	1.027	-6.19E-4	0.708	-2.26E-4	0.990
Slab 6	-2.39E-5	1.409	-9.56E-4	0.726	-1.02E-4	1.366	-9.68E-4	0.726

X  
plane

Fraction of Hits in PMT 0 and 1 for TOF1								
Vertical Plane								
	PMT0				PMT1			
	POS		NEG		POS		NEG	
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2
Slab 0	-	-	-	-	-	-	-	-
Slab 1	-1.72E-5	1.704	-1.30E-4	2.2596400	-4.12E-5	1.907	-5.14E-5	2.478
Slab 2	-4.08E-4	2.607	-1.84E-3	1.1745000	-3.37E-4	2.432	-1.82E-3	1.388
Slab 3	1.62E-3	1.767	4.37E-4	0.9305610	1.69E-3	2.034	2.19E-3	1.217
Slab 4	-2.54E-4	0.759	6.64E-4	0.9852590	-2.43E-5	0.808	8.54E-4	0.969
Slab 5	-3.60E-4	0.518	3.16E-3	1.3607900	-1.72E-4	0.513	3.19E-3	1.247
Slab 6	-4.06E-4	0.917	-1.63E-3	1.2968200	-4.01E-4	1.199	-1.49E-3	0.971

Y  
plane

# PMT coincidence Results (cont'd)

TOF2

Fraction of Hits in PMT 0 and 1 for TOF2									
Horizontal Plane									
	PMT0				PMT1				
	POS		NEG		POS		NEG		
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2	
Slab 0	-	-	-	-	-	-	-	-	-
Slab 1	9.23E-5	1.970	-5.89E-4	2.291	1.07E-4	1.506	-1.67E-4	1.670	
Slab 2	-4.37E-4	0.789	1.36E-4	1.234	-3.79E-4	0.769	1.82E-4	1.383	
Slab 3	4.82E-4	1.079	6.51E-4	1.087	4.15E-4	1.175	6.57E-4	1.089	
Slab 4	-5.31E-5	1.215	-1.26E-3	1.554	-2.93E-5	1.210	-1.30E-3	1.609	
Slab 5	-7.88E-4	1.456	7.11E-4	0.937	-7.36E-4	1.380	4.78E-4	0.902	
Slab 6	2.13E-4	0.938	2.52E-3	0.635	2.87E-4	0.936	2.73E-3	0.586	
Slab 7	6.93E-4	0.923	-3.03E-3	0.609	6.99E-4	0.903	-3.24E-3	0.724	
Slab 8	-2.03E-4	0.609	1.03E-3	0.958	-2.60E-4	0.552	9.67E-4	1.046	
Slab 9	-2.38E-4	0.760	-2.14E-4	0.804	-3.33E-4	0.761	-3.18E-4	0.737	

X  
plane

Fraction of Hits in PMT 0 and 1 for TOF2									
Vertical Plane									
	PMT0				PMT1				
	POS		NEG		POS		NEG		
	Slope	X ^2	Slope	X ^2	Slope	X ^2	Slope	X ^2	
Slab 0	-	-	-	-	-	-	-	-	
Slab 1	-1.89E-5	1.199	4.23E-4	0.645	-4.80E-5	1.052	2.91E-4	0.762	
Slab 2	-1.63E-4	0.402	-1.66E-5	0.863	-1.30E-4	0.438	-4.62E-5	0.919	
Slab 3	-4.20E-4	0.740	3.25E-4	0.823	-4.52E-4	0.726	2.95E-4	0.874	
Slab 4	9.91E-4	0.941	-9.20E-4	1.382	8.40E-4	0.927	-7.33E-4	1.422	
Slab 5	3.90E-4	0.917	-1.60E-3	0.768	3.10E-4	0.837	-1.72E-3	0.759	
Slab 6	-1.37E-4	0.633	5.21E-4	0.926	-1.07E-4	0.683	5.48E-4	0.917	
Slab 7	2.60E-4	0.731	2.25E-3	0.551	4.42E-4	0.657	2.10E-3	0.539	
Slab 8	-5.39E-4	0.702	2.74E-4	1.186	-6.08E-4	0.750	1.61E-4	1.072	
Slab 9	-3.79E-4	1.037	1.76E-4	0.884	-3.22E-4	0.982	1.09E-4	0.911	

Y  
plane



# Conclusions



- Overall, beamline looks stable – the slopes for linear fits are all approximately 0.0 (indicating little fluctuation) and the fits are good (chi-sq values  $\sim 1.0$ )
- There were a few “reference” runs that were outliers in the first round of fitting. Further investigation showed that these were due to
  - Improper markings in run summary spreadsheet/logbook
    - \_ Runs 2498 and 2500 were ISIS trip – not analyzable
  - Low statistics
  - UNKNOWN: 2255, 2256
- Not bad, only 2 runs were strange for unaccounted for reasons. Given the number of reference runs, its likely that something was just not marked in the spreadsheet/logbook
- Difference in PMT0 – PMT 1 was small for most slabs. However, large discrepancy for:
  - Tof0: X plane: slab 4, slab 5, slab 8, slab 9 :: Y plane: none
  - Tof1: X plane: none :: Y plane: slab 3, slab 4 (positive runs only), slab 5 (positive only)
  - Tof2: X plane: none :: Y plane : none
- **Positive vs Negative polarity beam is still not understood. Efforts are underway to find the cause**
  - Personally I am looking at the effect of the proton absorber (only in the beam for positive polarity runs) effects the muon/pion/electron populations.

# Thank you!



R.R. Fletcher (U.C. Riverside) and I helping take data for Step I of M.I.C.E. during the summer 2010 (TOF2 can be seen in the background)

S. Blot, March 18, 2011