



# UCNA Background Analysis



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Caltech

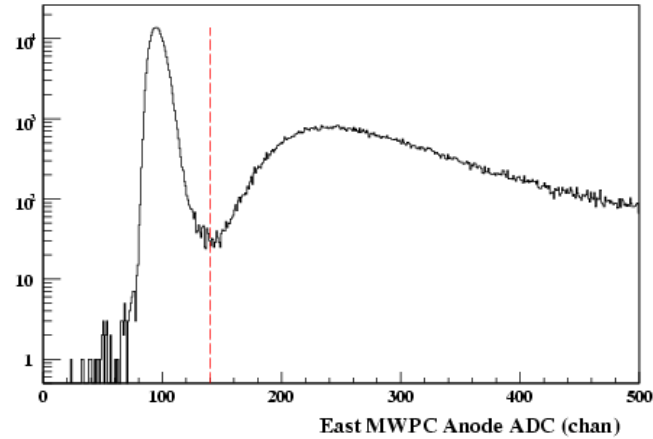
Data taken in November, 2006

Run	Configuration	Time (s)
4123	Beam off	2049.2
4124	Beam off	3667.5
4125	Beam off	3712.5
4127	Beam off	3598.0
4128	Beam off	9573.6
4133	Beam on, GV closed	3594.4
4135	Beam on, GV closed	3593.4
4141	Beam on, GV closed	4119.2
4143	Beam on, GV closed	2382.5
4145	Beam on, GV closed	3598.6
4138	Sn calibration	1197.6

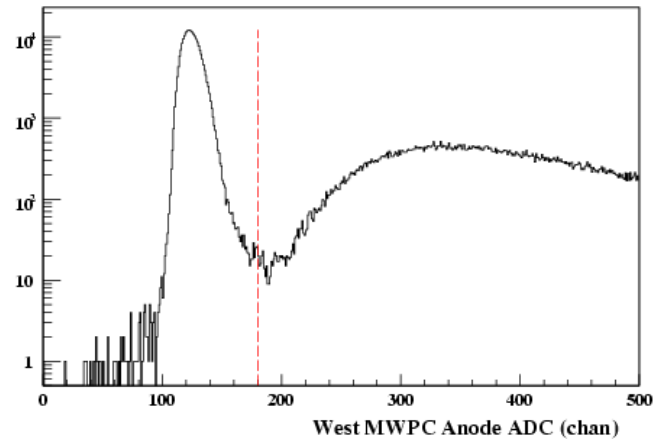
# Basic Data Cuts

# MWPC

MWPC  
Anode ADC

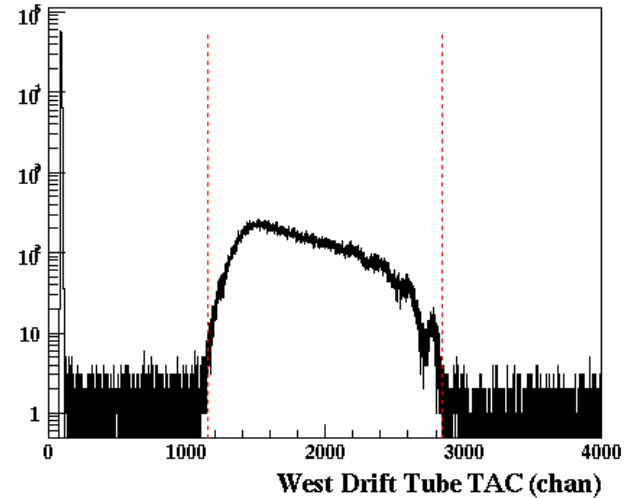
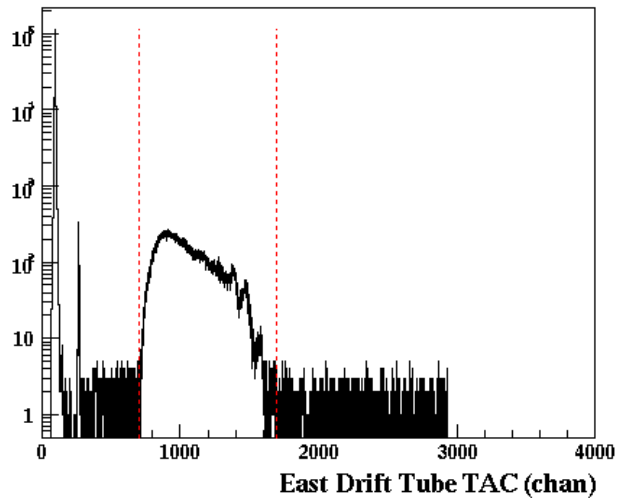
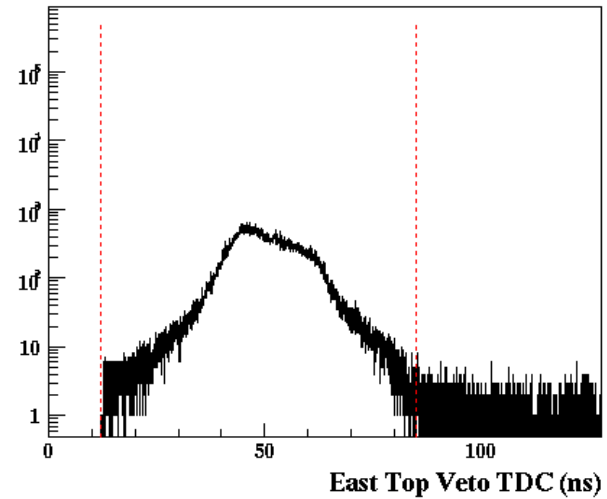
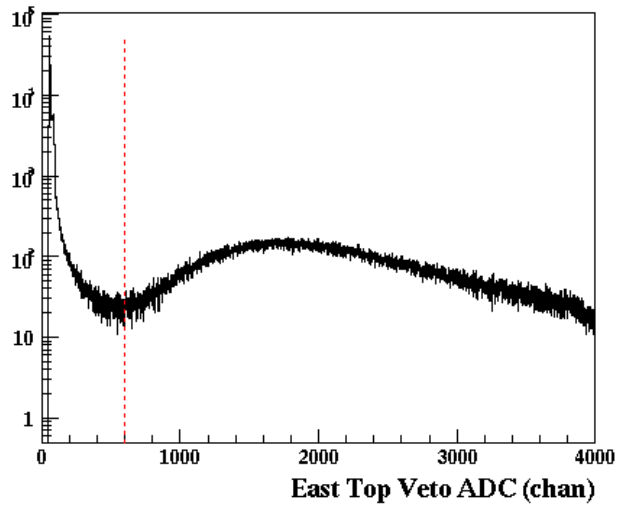


*Data from the Sn  
calibration run.*



Further applied fiducial cut: ( $r_{\text{MWPC}} < 41.5$  mm @ spectrometer center)

# Top and Side Veto

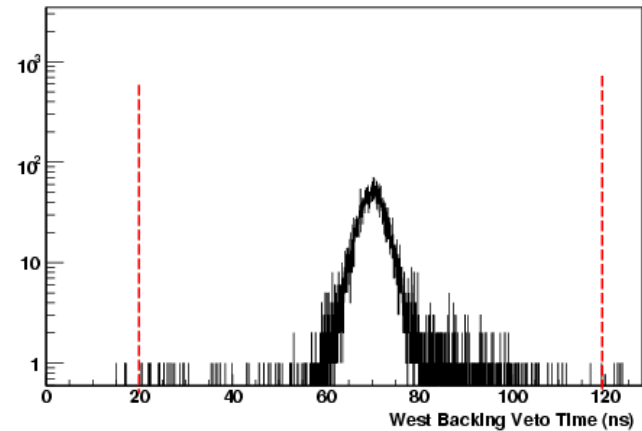
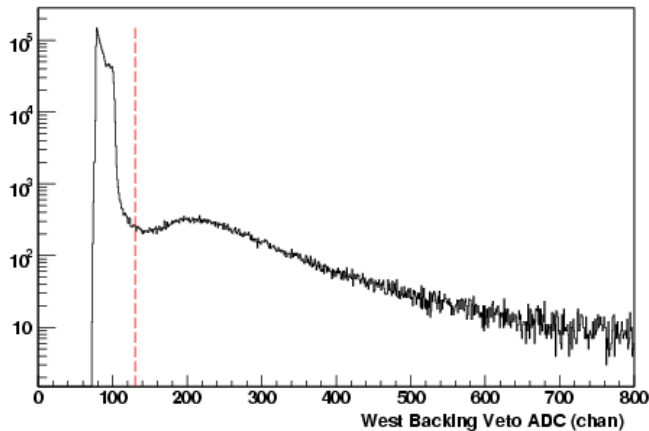
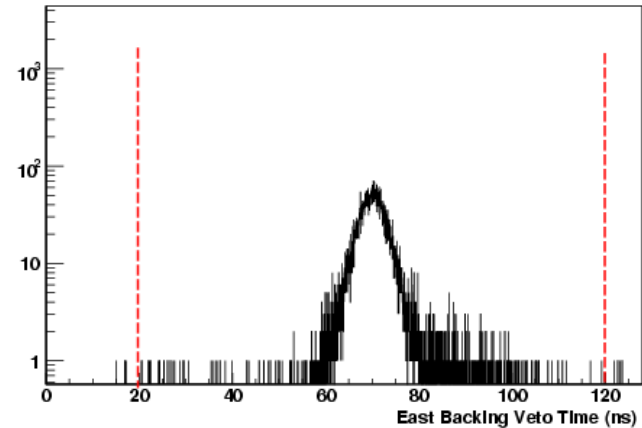
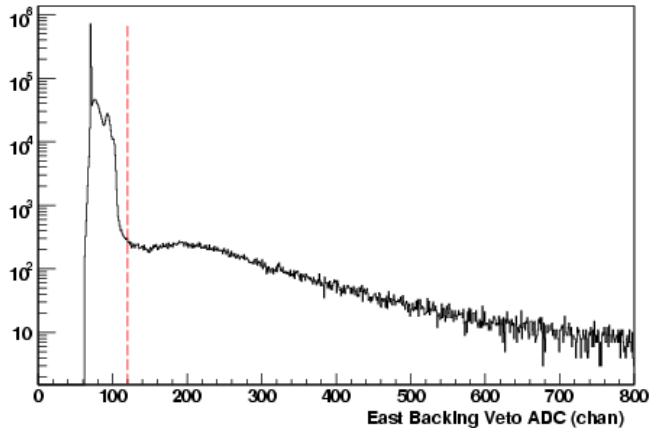


Data from background run.

# Backing Veto

ADC cuts: “best guess”

Timing cuts: [20,120] ns



Conservatively (to cut background “harder”), Cut = ADC **OR** TDC  
Data from background run.

# Event Selection

## Measured Background:

- East:  $\beta$  scintillator & MWPC (with fiducial cut)  
& ((Backing ADC OR TDC) OR (Tito ADC OR TDC) OR Drift TAC)
- West:  $\beta$  scintillator & MWPC (with fiducial cut)  
& ((Backing ADC OR TDC) OR Drift TAC)

## Residual background in “signal”:

- East:  $\beta$  scintillator & MWPC (with fiducial cut)  
& **NOT** ((Backing ADC OR TDC) OR (Tito ADC OR TDC) OR Drift TAC)
- West:  $\beta$  scintillator & MWPC (with fiducial cut)  
& **NOT** ((Backing ADC OR TDC) OR Drift TAC)

# Correlated and Uncorrelated Background Rates

# Muon Detector Singles

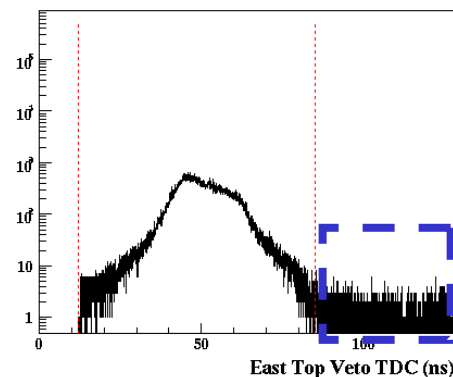
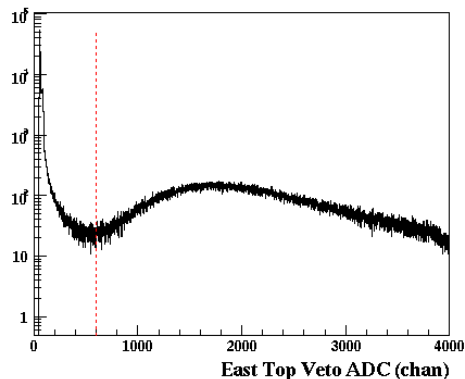
Take the total hits in individual outer veto detectors  
**(within cuts, NO coincidence with MWPC!)**

Run	Raw Trigger rate (Hz)	East top paddle (Hz)	East side drift tubes (Hz)	West drift tubes (Hz)
4123 (bkg)	79.7	27.7	9.7	18.9
4128 (bkg)	79.5	27.7	9.8	19.0
4138 (Sn)	314.4	28.6	10.1	19.7

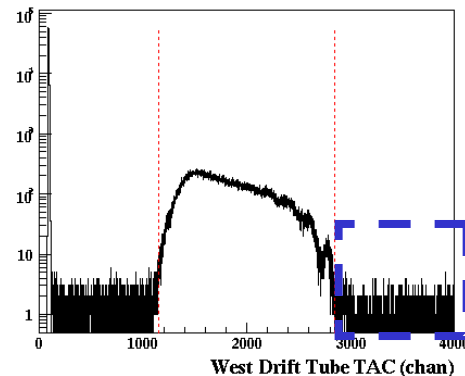
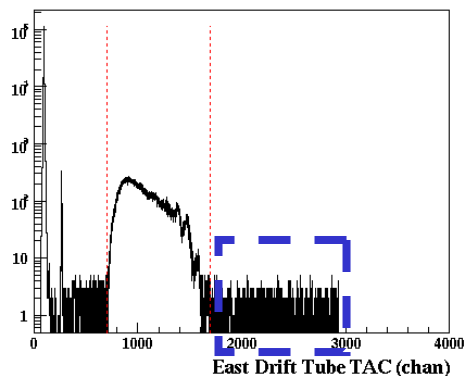
Since raw triggers are set by the beta scintillators, the fact that the veto hits within cuts are independent of the trigger rate is a solid proof that those hits are mostly correlated hits!

# Estimated of Uncorrelated Muon Rates

Recall timing spectra for Tito's paddle and drift tubes



"hair"



$$\frac{\text{"hair"}}{\text{"bump"}} \text{ (normalized by gate width)} \approx \frac{R_{trigger} R_{veto}^{uncorr} \tau}{R_{bump}}$$

Background run 4123, see table on page 8

Veto DET	Raw Trigger rate (Hz)	$R_{\text{bump}}$ (Hz)	$\tau$	Hair/bump	$R_{\text{uncorr}}$ (kHz)
East top paddle	79.7	27.7	100 ns	9.8E-3	34.1
East side drift tubes	79.7	9.7	6 $\mu$ s	1.1E-2	0.22
West top&side drift tubes	79.7	18.9	6 $\mu$ s	9.1E-3	0.36

Sn run 4138, see table on page 8

Veto DET	Raw Trigger rate (Hz)	$R_{\text{bump}}$ (Hz)	$\tau$	Hair/bump	$R_{\text{uncorr}}$ (kHz)
East top paddle	314.4	28.6	100 ns	0.011	10.0
East side drift tubes	314.4	10.1	6 $\mu$ s	0.043	0.23
West top&side drift tubes	314.4	19.7	6 $\mu$ s	0.032	0.33

Note,  $\tau = 6 \mu$ s might be shorter. Not sure about TAC scale.

## Drift tube bench test: from my log book entry, Oct. 27, 2006

*We took measurements of drift tubes with magnet on/off. Below is a summary (rates in Hz):*

<i>current</i>	<i>top</i>	<i>bottom</i>	<i>coinc</i>
<i>62 A</i>	<i>823.1</i>	<i>839.7</i>	<i>454.2</i>
<i>62 A</i>	<i>824.0</i>	<i>833.8</i>	<i>455.0</i>
<i>0 A</i>	<i>824.6</i>	<i>852.4</i>	<i>454.4</i>

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No actual scaler measurement of the drift tube single rate in the final “ganged” configuration, but we know:

- West > East simply due to geometrical coverage
- Total rate of the order of kHz from bench test

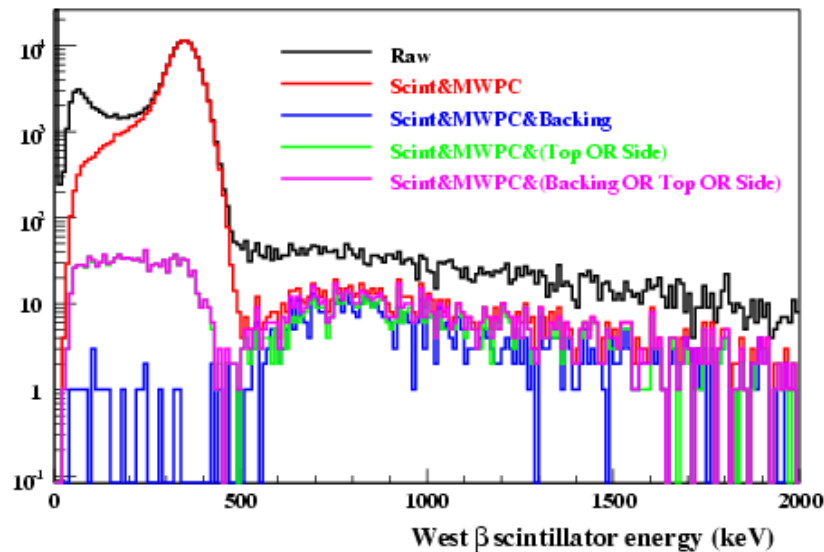
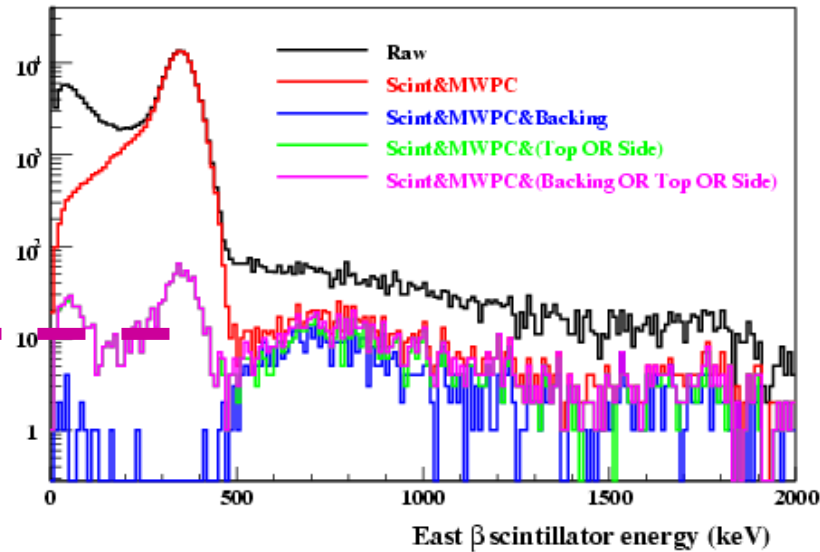
■ Randoms in drift tubes in the two runs agree, but seems much lower than actual rates (~kHz). Likely  $6\mu\text{s}$  is too long.

■ Scintillator noise changed in between two runs by a factor of 3. Perhaps a real change in room background?

# Background Energy Spectra and Rates

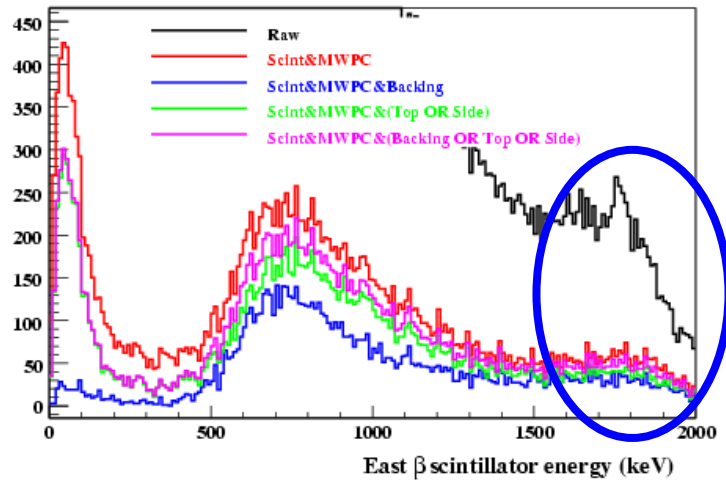
# E Spectra for Sn

Random  
caused by  
noisy  
scintillator  
paddle

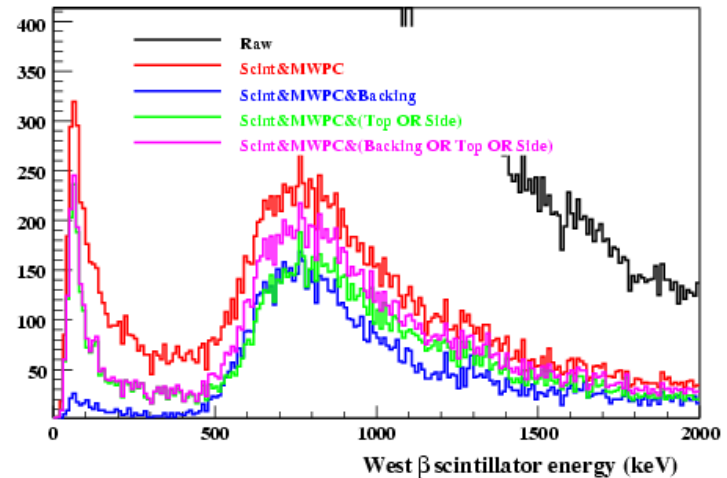
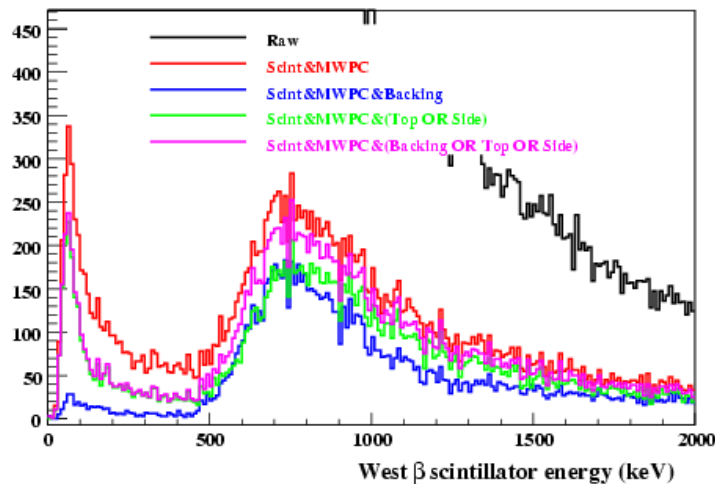
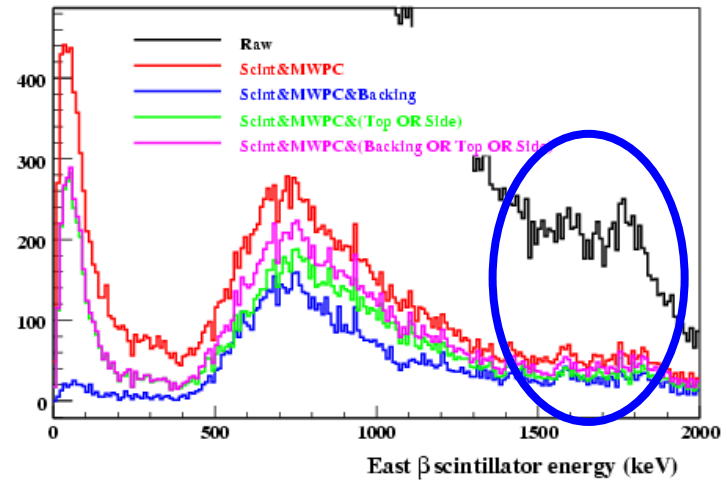


# E spectra for background

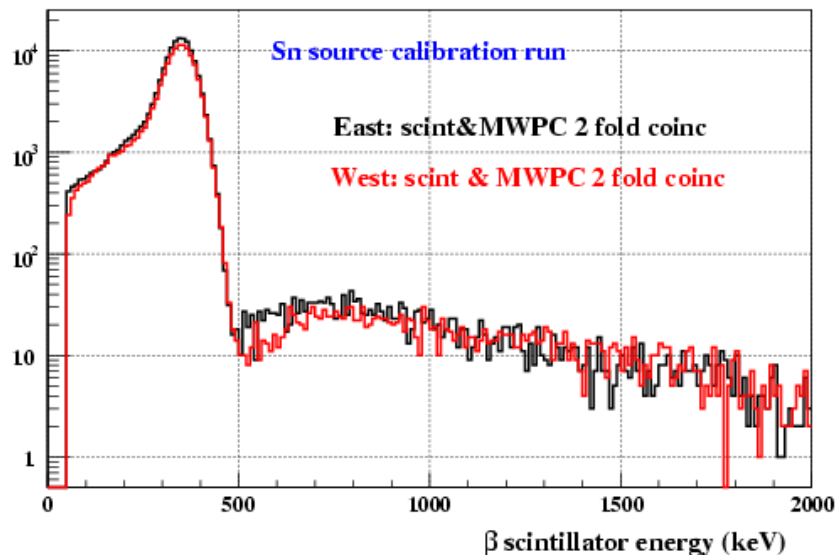
## Beam off background



## Beam on background



# Sn Rates for different veto cuts



Raw trigger rate: 314.4 Hz

Rates in [50,1000] keV

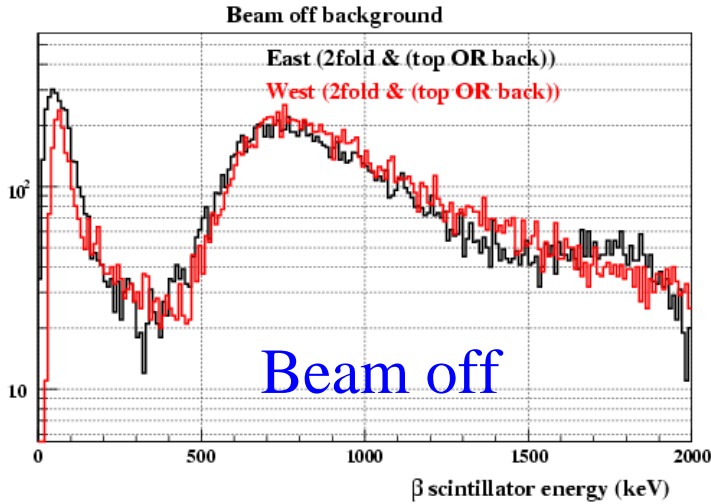
Background spectrum (around 500 keV) different!

Cuts	East (Hz)	West (Hz)
Raw	156.7(0.4)	126.4(0.3)
2fold	120.1(0.3)	105.8(0.3)
2fold&back	0.31(0.02)	0.30(0.02)
2fold&(top+side)	1.07(0.03)	1.20(0.03)
2fold&((top+side) OR back)	1.15(0.03)	1.28(0.03)

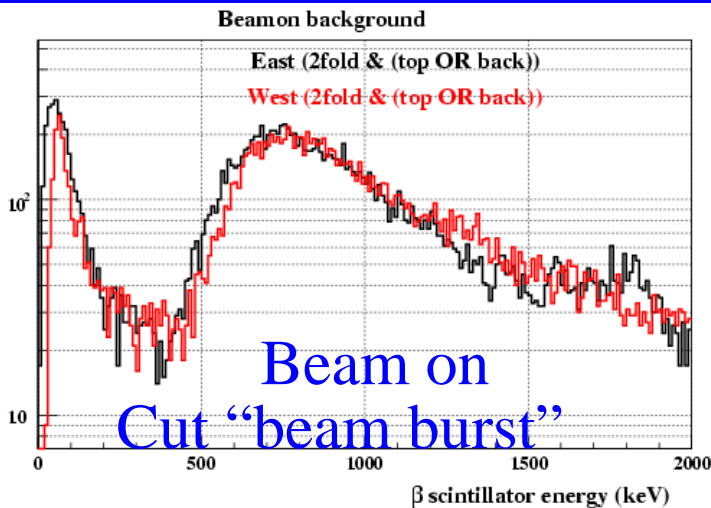
# Background Rates for Different Veto cuts

Rates in [50,1000] keV

Raw trigger rate: 79.4 Hz



Cuts	East (Hz)	West (Hz)
Raw	35.2(0.04)	20.9(0.03)
2fold	0.76(0.01)	0.74(0.01)
2fold&back	0.28(0.004)	0.33(0.004)
2fold&(top+side)	0.50(0.01)	0.46(0.01)
2fold&(any veto)	0.56(0.01)	0.56(0.01)



Raw trigger rate: 105.27

Cuts	East (Hz)	West (Hz)
Raw	34.21(0.05)	18.78(0.03)
2fold	0.76(0.01)	0.68(0.01)
2fold&back	0.30(0.004)	0.31(0.004)
2fold&(top+side)	0.49(0.01)	0.43(0.01)
2fold&(any veto)	0.57(0.01)	0.52(0.01)

"Muon rate" lower compared to the last row in table on page 9.

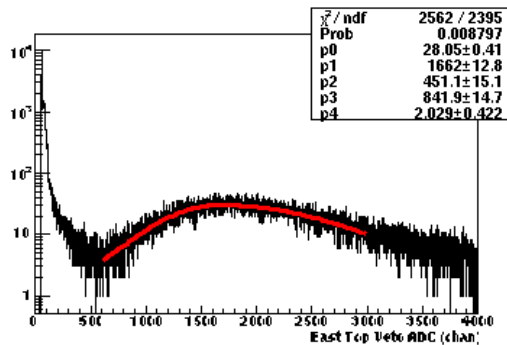
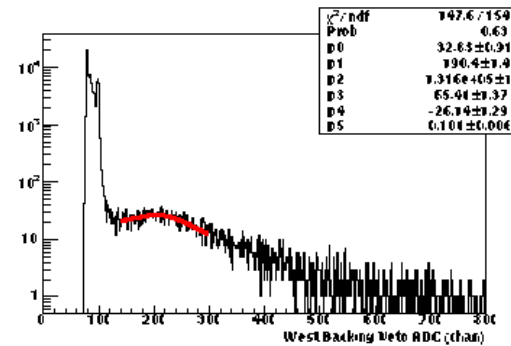
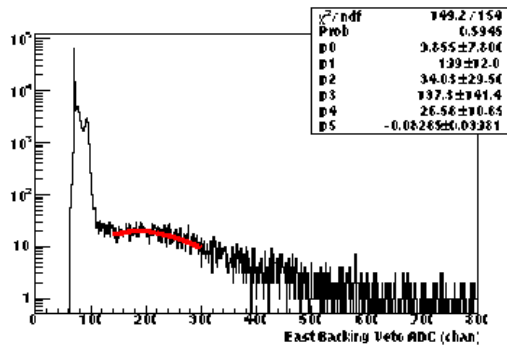
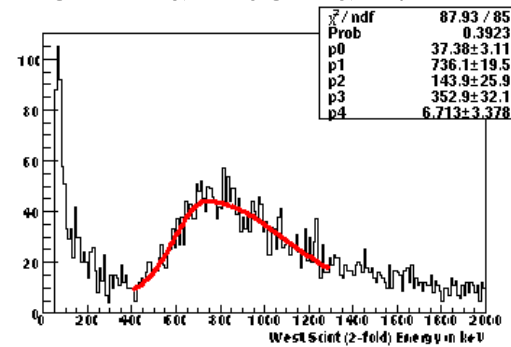
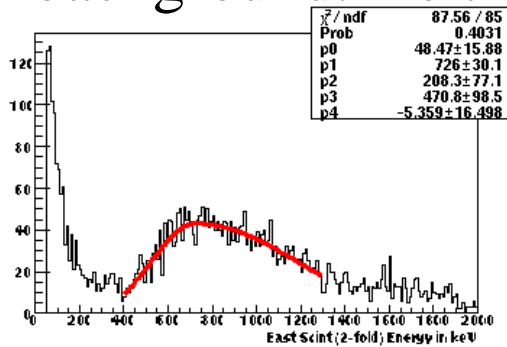
# Background Tagging Efficiency

From previous page, if we combine all veto components, the veto efficiency is only 75%. The impact of this will be discussed later on.

# Background Fluctuation

# Estimate of Scintillator Gain Fluctuation

Method: fit the cosmic peak with asymmetric Gaussian + linear background. Do this from run to run.



Run	E scint (keV)	W scint (keV)	E backing (chan)	W backing (chan)	E "Tito" (chan)
4123	726(30)	736(20)	200(12)	190(1)	1662(13)
4124	666(18)	692(12)	188(7)	197(5)	1644(10)
4125	663(15)	692(14)	179(10)	213(12)	1679(10)
4127	699(18)	716(13)	190(7)	209(5)	1655((9)
4128	685(10)	712(9)	202(10)	204(3)	1644(6)
Std. Dev.	26	18	9	9	15


 Pedestal located ~ channel 100

Using the std. dev. to estimate the fluctuation of gain is not very fair, since the stat. precision is poor. Just to set the scale ...

- Beta scintillator: 3% from run to run
- Backing veto scintillator: 10% from run to run
- Tito's paddle: 1% from run to run

# Background Rates Fluctuation

Take the rate in [50,1000] keV in the scintillator requiring **scint&MWPC&(a given veto component)**. Rates in Hz.

Run	E drift tubes	E backing	E "Tito"	W drift tubes	W backing	
4123	0.13(0.01)	0.26(0.01)	0.39(0.01)	0.45(0.01)	0.33(0.01)	Beam off
4124	0.09(0.01)	0.28(0.01)	0.42(0.01)	0.47(0.01)	0.33(0.01)	
4125	0.13(0.01)	0.30(0.01)	0.45(0.01)	0.45(0.01)	0.31(0.01)	
4127	0.14(0.01)	0.27(0.01)	0.41(0.01)	0.48(0.01)	0.36(0.01)	
4128	0.13(0.01)	0.27(0.01)	0.42(0.01)	0.46(0.01)	0.33(0.01)	
4133	0.13(0.01)	0.29(0.01)	0.42(0.01)	0.43(0.01)	0.30(0.01)	Beam on
4135	0.13(0.01)	0.30(0.01)	0.42(0.01)	0.43(0.01)	0.30(0.01)	
4141	0.13(0.01)	0.30(0.01)	0.42(0.01)	0.44(0.01)	0.31(0.01)	
4143	0.13(0.01)	0.31(0.01)	0.41(0.01)	0.43(0.01)	0.32(0.01)	
4145	0.13(0.01)	0.31(0.01)	0.40(0.01)	0.42(0.01)	0.31(0.01)	
Std. Dev.	0.01	0.02	0.02	0.02	0.02	

From previous version of the note, where I have not applied the fiducial cut ...

## Background Rates Fluctuation

Take the rate in [50,1000] keV in the scintillator requiring **scint&MWPC&(a given veto component)**

(Rates in Hz)

Run	E drift tubes	E backing	E "Tito"	W drift tubes	W backing
4123	0.30(0.02)	0.36(0.01)	0.72(0.02)	0.92(0.02)	0.64(0.02)
4124	0.20(0.01)	0.40(0.01)	0.77(0.01)	0.95(0.02)	0.65(0.01)
4125	0.31(0.01)	0.45(0.01)	0.83(0.02)	0.89(0.02)	0.63(0.01)
4127	0.31(0.01)	0.41(0.01)	0.77(0.02)	0.93(0.02)	0.69(0.01)
4128	0.28(0.01)	0.38(0.01)	0.75(0.01)	0.91(0.01)	0.67(0.01)
Std. Dev.	0.05	0.03	0.04	0.02	0.02

# Impact of Background Rate Fluctuation

$\sigma R_{\text{bkg}}$  = the fluctuation of the Measured background rate from run to run.

- If the **true background rate is a constant over time**,  $\sigma R_{\text{bkg}}$  = fluctuation of residual background in the “signal” sample (due to fluctuation of the veto efficiency)
- If the **veto efficiency is a constant over time**, then  $\sigma R_{\text{bkg}}$  reflects the fluctuation of the true background  $\Rightarrow$  fluctuation of residual background in the “signal” sample =  $\varepsilon/(1-\varepsilon) \sigma R_{\text{bkg}}$ .
- The truth has to lie in between. For now, let us conservatively take the former, and take  $\sigma R_{\text{bkg}} = 0.02$  Hz based on the previous table

*Project to the desired 10 Hz  $\beta$  run:*

- Signal rate = 10 Hz  $\Rightarrow$  in an hour-long run, get **10 Hz  $\pm$  0.05 Hz** (statistics)
- Background rate = 2 Hz, and we veto 75% of it. So residual background = **0.5  $\pm$  0.02 Hz** for a given run (point-point systematical uncertainty from run to run)
- Since 0.02 Hz (pt-pt sys) is less than 0.05 Hz (stat), we do not take a big hit in our final (statistical) precision.

# Background Asymmetry Fluctuation

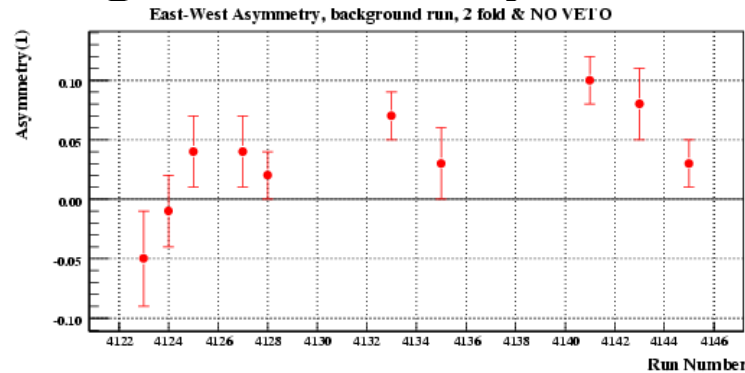
Calculate East-West Asymmetry (in unit “1”) for  $\beta$  scint rate with different level of veto

Run	Scint&MWPC (2-fold)	2-fold & back	2-fold & (top+side)	2-fold & (any veto)	2-fold & NO veto
4123	-0.02(0.02)	-0.11(0.03)	0.02(0.02)	-0.01(0.02)	-0.05(0.04)
4124	0.06(0.01)	-0.08(0.02)	-0.04(0.02)	-0.04(0.02)	-0.01(0.03)
4125	0.05(0.01)	-0.02(0.02)	0.08(0.02)	0.06(0.02)	0.04(0.03)
4127	-0.01(0.01)	-0.14(0.02)	0.01(0.02)	-0.03(0.02)	0.04(0.03)
4128	0.01(0.01)	-0.10(0.01)	0.04(0.01)	0.00(0.01)	0.02(0.02)
4133	0.06(0.01)	-0.02(0.02)	0.08(0.02)	0.05(0.02)	0.08(0.02)
4135	0.06(0.01)	0.01(0.02)	0.08(0.02)	0.06(0.02)	0.03(0.03)
4141	0.05(0.01)	-0.01(0.02)	0.06(0.02)	0.05(0.01)	0.08(0.02)
4143	0.06(0.01)	-0.03(0.02)	0.07(0.02)	0.05(0.02)	0.09(0.03)
4145	0.06(0.01)	-0.01(0.02)	0.06(0.02)	0.06(0.02)	0.04(0.02)
Std. Dev.	0.03	0.05	0.04	0.04	0.04

Beam off

Beam on

# Impact of Background Asymmetry Fluctuation



Measured residual background asymmetry have no statistical but point-point fluctuation  $\equiv \sigma A_{\text{bkg}} \sim 0.04$ .

Residual background rate in the signal =  $1.5 \times 25\% = 0.38$  Hz (assuming 75% veto efficiency)

■ Assume 10 Hz beta rate, stat precision of beta asymmetry in an hour-long run is **0.005**

■ Systematic run-by-run fluctuation due to fluctuation of background difference = background rate/signal rate  $\times \sigma A_{\text{bkg}} = 0.38 \text{ Hz}/10\text{Hz} \times 0.04 = \mathbf{0.002}$  (point-point systematic)

■ So once again, the point-point systematic uncertainty is small compared to the stat. uncertainty.

# Background and False Asymmetry

# Generic Background Systematics for Beta Run

The raw measured rate during GV **OPEN** run, with only MWPC&scint cut:

$$R_{raw}^{open} = R_{\beta} + R_{bkg}$$

Apply veto cuts on the GV **OPEN**: MWPC&scint&No Veto

$$R_m^{open} = R_{\beta} - R_{\beta} f_{mis} + R_{bkg} f_{ineff}$$

■  $f_{mis}$ : fraction of beta being identified as muon due to uncorrelated muon or random rate (see page 7) in the veto:  $f_{mis} = R_{\mu}^{uncorr} \times \tau$

■  $f_{ineff}$ : background tagging inefficiency (e.g. due to low gain of backing veto)

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The raw measured rate during GV **CLOSED** run, with only MWPC& scint cut:

$$R_{raw}^{close} = R_{bkg}$$

Apply veto cuts on the GV **CLOSED**: MWPC&scint&No Veto

$$R_m^{close} = R_{bkg} f_{ineff}$$

So the “signal” rate

$$R_s = R_m^{open} - R_m^{close} = R_\beta (1 - f_{mis})$$

if  $R_{bkg}$  and  $f_{ineff}$  are the same for **OPEN** and **CLOSED** runs

NOTE:

■ If muon inefficiency are the same for GV OPEN and CLOSED runs, it only deteriorate the precision **statistically** by the counting stat of the “inefficient” muons. For 10 Hz of beta and 1.5 Hz of background rate (veto by ~75% eff.), tiny contribution to uncertainty!

■ Otherwise, there is a component of point-point systematic uncertainty, which has been discussed earlier, and is relatively small.

■ If background level different for GV OPEN/CLOSE, e.g. UCN induced background, will have a nasty effect. Perhaps should perform runs with SCS off.

**For now, ignore this effect ...**

Now let  $R_\beta$  and  $f_{mis}$  all have east-west asymmetry, then

$$A_s = \frac{1}{1 - f_{mis}} A_\beta - \frac{f_{mis}}{1 - f_{mis}} A_{mis}$$

# Estimate

$$A_s = \frac{1}{1 - f_{mis}} A_\beta - \frac{f_{mis}}{1 - f_{mis}} A_{mis}$$

■ Take random rate in the veto detector be 300 Hz (page 10),  $f_{mis} = 300 \text{ Hz} \times 6\mu\text{s} = 0.2\%$ .

Take  $A_{mis} = 10\%$  based on the east-west backing veto asymmetry.

■  $A_\beta = 4\%$

1<sup>st</sup> term deviates from  $A_\beta$  by 0.2%. 2<sup>nd</sup> term is about 0.5% of  $A_\beta$ .

**Furthermore, 2<sup>nd</sup> term goes away one we flip the neutron spin!**

So the real remaining issue is to study how different are the true backgrounds with GV open and close!