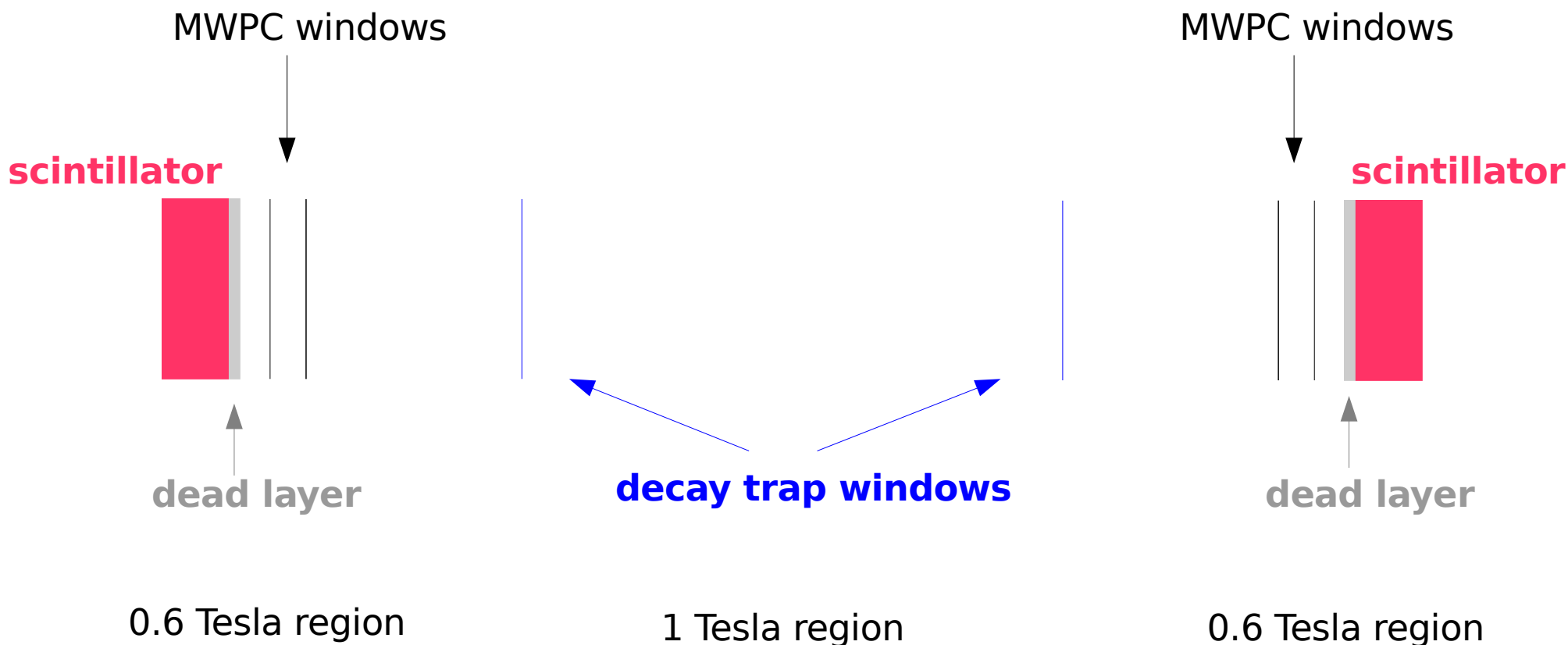


# GEANT4 simulation of UCN betas

## backscattering from spectrometer windows



- Decay trap window = 2.5 micron mylar
- MWPC windows = 25 micron (front) + 25 micron (back)

# Details of the simulation

- Generate neutron decay betas isotropically in the fiducial tube:  
 $r = [0,4]$  cm,  $z = [-1.5,1.5]$  m
- Use simplified geometries as shown on the previous page
- Record the hit time sequence to reconstruct electron trajectory
- Enable optical photon simulation in the beta scintillator with 360 PE/MeV light yield, a quenching constant (Birks constant) of 0.02 cm/MeV, and a dead layer with thickness of 3 micron. [J. Yuan thesis, Sec. 3.2.1.3]
- Trigger = any side of the scintillator with  $\geq 2$  PE
- **NO angular asymmetry embedded so far**

# Classification Events

Without going too much into details, first simply classify events into correct/misidentified

```
IF
  Only one of the 2 scintillators fires ( $\geq 2PE$ )
THEN
  IF the correct side that fires
    THEN correct
  ELSE
    Misidentified
  ENDIF
ELSE IF
  Both scintillators fires ( $\geq 2PE$ )
THEN
  Find the earlier hit scintillator
  IF the earlier side is the correct side
    THEN correct
  ELSE
    Misidentified
  ENDIF
ENDIF
```

# Gross Backscattering Fractions

	Total Triggered	Correct (1-side)	Misidentified (1-side)	Correct (2-side)	Misidentified (2-side)
Left	406674	376906	21965	7369	434
Right	406728	376852	21965	7447	464
Total	813402	753758	43930	14816	898

$$f_{mis} = \text{Misidentified fraction} = \frac{\text{Number of misidentified triggers}}{\text{Total number of triggered events}} = 5.51 (0.03) \%$$

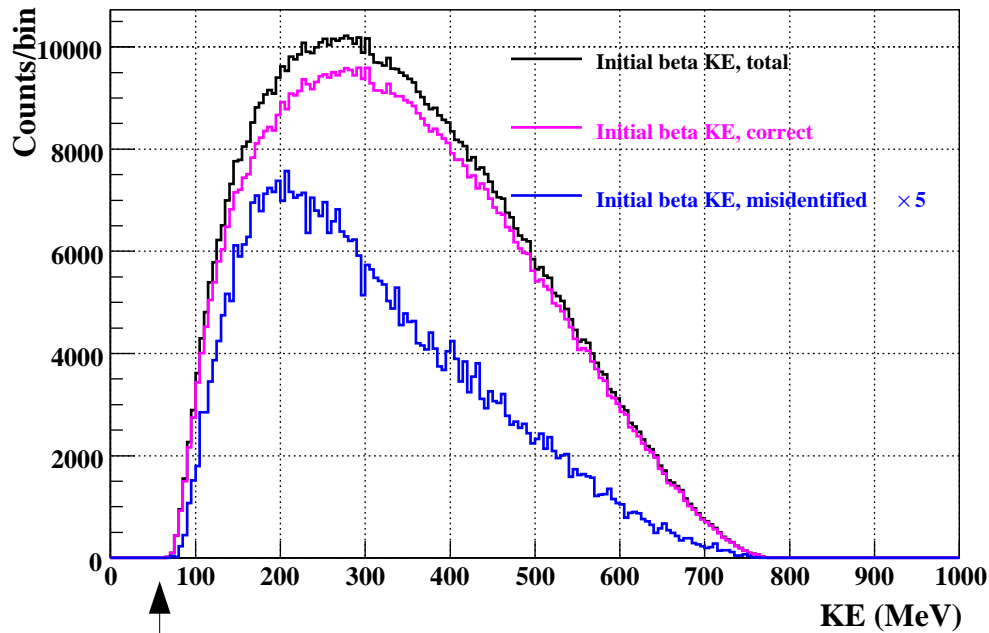
- The trigger condition above, as described, **is  $\geq 2$  PE**
- If “relax” the trigger condition to purely geometrical (i.e. as long as the electron hit the active scintillator volume), the resulting table is

	Total Triggered	Correct (1-side)	Misidentified (1-side)	Correct (2-side)	Misidentified (2-side)
Left	407498	377559	21992	7502	445
Right	407547	377482	21021	7575	469
Total	815045	755041	43013	15077	914

This practically does not change the misidentified fraction.

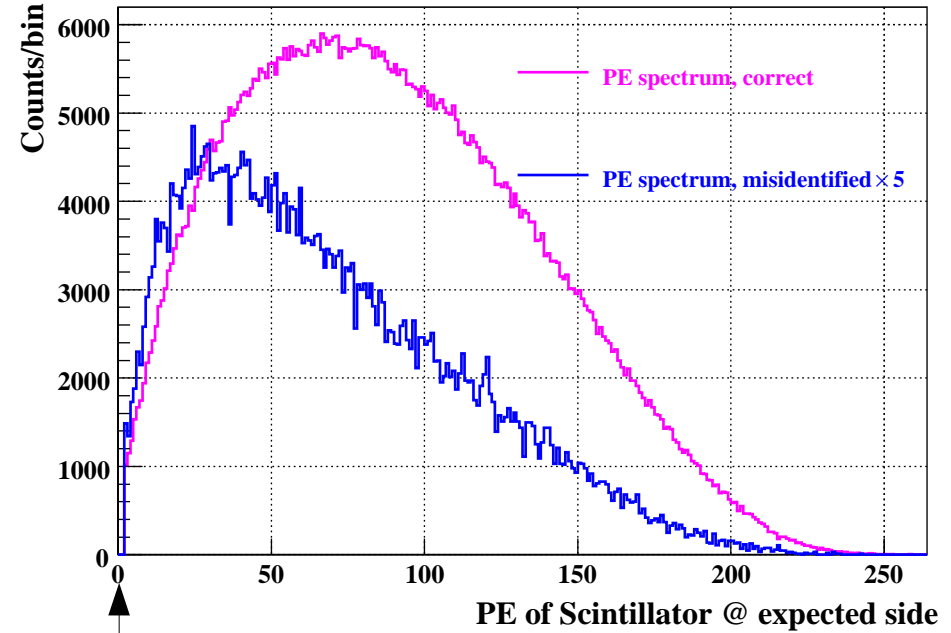
# Energy and PE spectra for Different Types of Events

Beta energy spectra for different types of events



Effective energy threshold due to energy loss in the windows

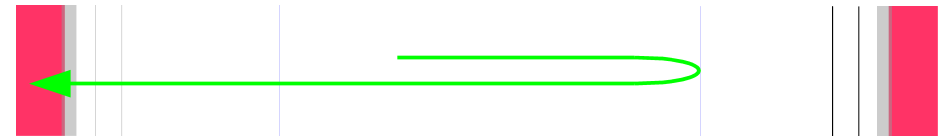
PE spectra (scintillator on the expected side)

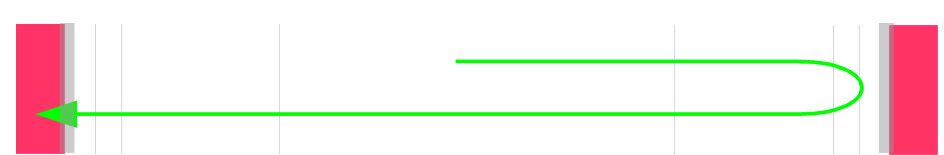


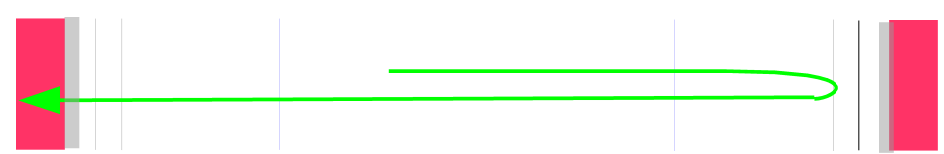
2 PE cut

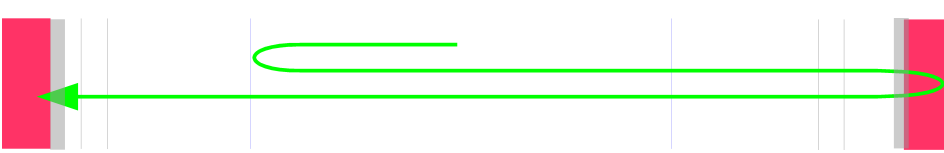
The misidentified events has overall lower energy spectrum, however one sees that raising the PE cut does not suppress the misidentified events significantly

# More detailed classification of misidentified events

From decay trap  
window = **type A**  4.63(0.02)%

From MWPC outer  
window = **type B**  0.40(0.01)%

From MWPC inner  
window = **type C**  0.25(0.01)%

2-side: From decay  
trap window inner  
then from beta  
scintillator = **type D**  0.097(0.003)%

**Others** 0.133(0.003)%

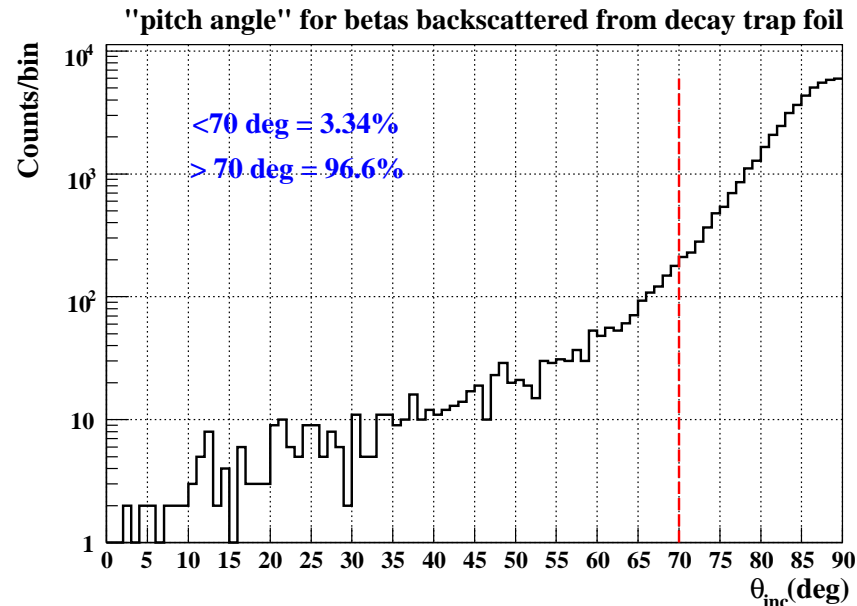
---

Total 5.51(0.03)%<sup>6</sup>

# More on Misidentified Events

Q: Why so many electrons back-scatters from the decay trap window?

It is located in the 1- Tesla region, therefore incident angle can be up to 90 deg!



- Betas backscattered from the outer MWPC windows (0.41%) are “Brad's type II events”. Most of them can be identified by additional MWPC cuts
- Beta backscattered from the inner MWPC windows (0.24%) are “Brad's type IV events”. Like the ones from the decay trap windows, they can NOT be tagged.

# Systematics on Big A due to backscattering I

Take all “misidentified events” (5.51%), including ones scattered off from the back windows (Brad's Type II).

- For a given energy and angle, the true left/right asymmetry is  $A\beta\cos(\theta)$ .
- The overall true asymmetry is an average of the above over energy and acceptance

$$A_{true} = \frac{\int A\beta\cos(\theta)d\Omega dE}{\int d\Omega dE}$$

With backscattering, the measure asymmetry is modified into

$$A_{meas} = \frac{\int_{corr} A\beta\cos(\theta)d\Omega dE - \int_{mis} A\beta\cos(\theta)d\Omega dE}{\int_{corr} d\Omega dE + \int_{mis} d\Omega dE}$$

# Systematics on Big A due to backscattering II

If asymmetry is flat over angle and energy, then the raw measured asymmetry is

$$A_{meas} = A_{true} (1 - f_{mis}) - A_{true} f_{mis} = (1 - 2f_{mis}) A_{true}$$

**For  $f_{mis} = 5.51\%$ , this is a 11% systematics on  $A_{true}$  !**

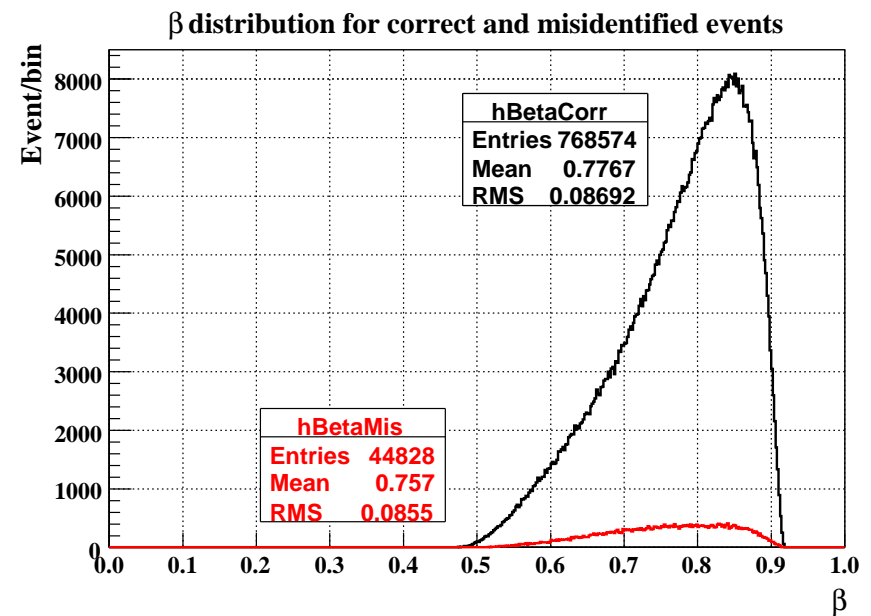
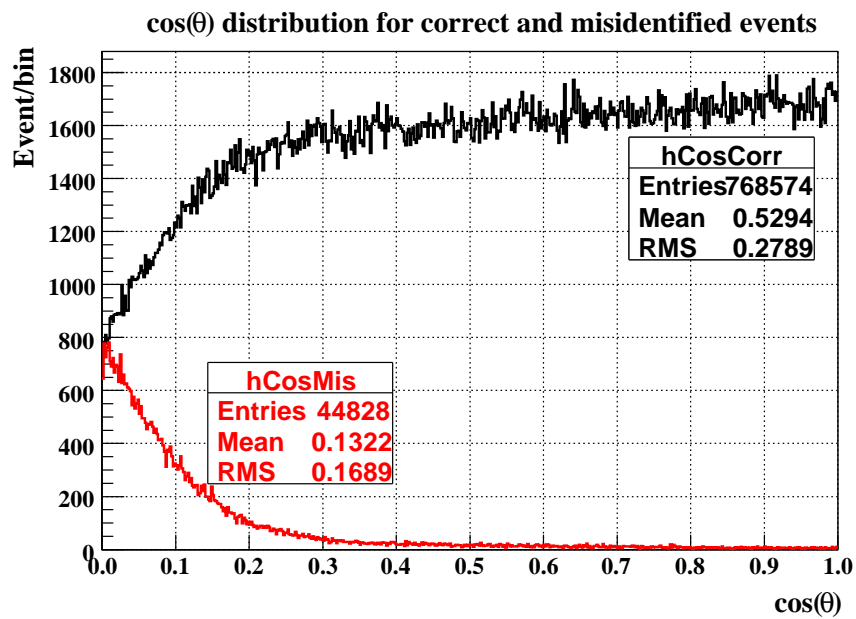
Fortunately, as shown earlier,  $\theta$  is peaked at large angle for backscattered events, which carries smaller asymmetry.

Use Monte Carlo to evaluate  $A_{true}$  and  $A_{meas}$

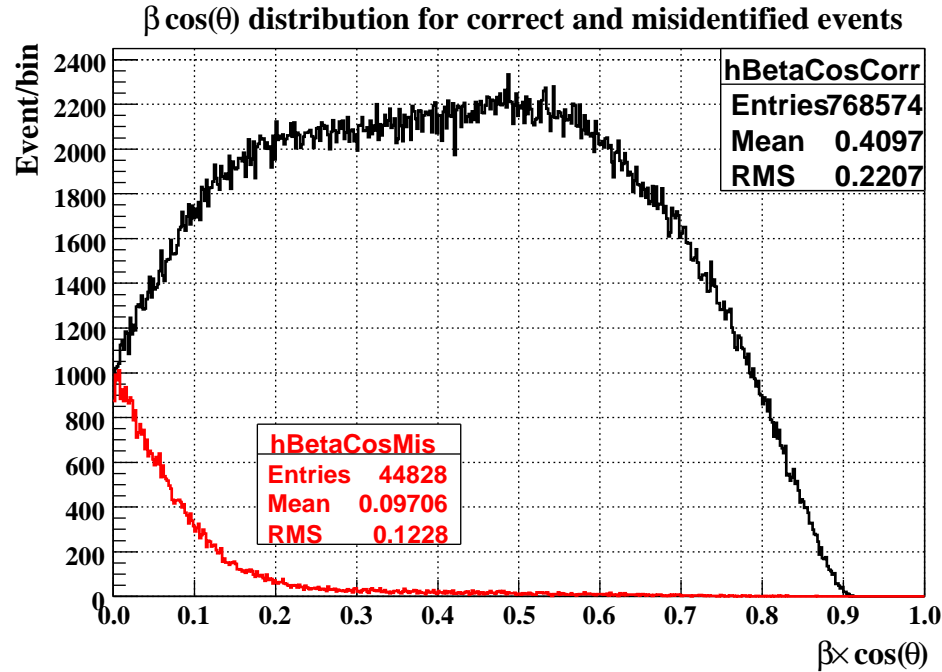
$$A_{true} = \frac{\sum_{corr} A \beta \cos(\theta) + \sum_{mis} A \beta \cos(\theta)}{\sum_{corr} 1 + \sum_{mis} 1}$$

$$A_{meas} = \frac{\sum_{corr} A \beta \cos(\theta) - \sum_{mis} A \beta \cos(\theta)}{\sum_{corr} 1 + \sum_{mis} 1}$$

# Systematics on Big A due to backscattering III



# Systematics on Big A due to backscattering IV



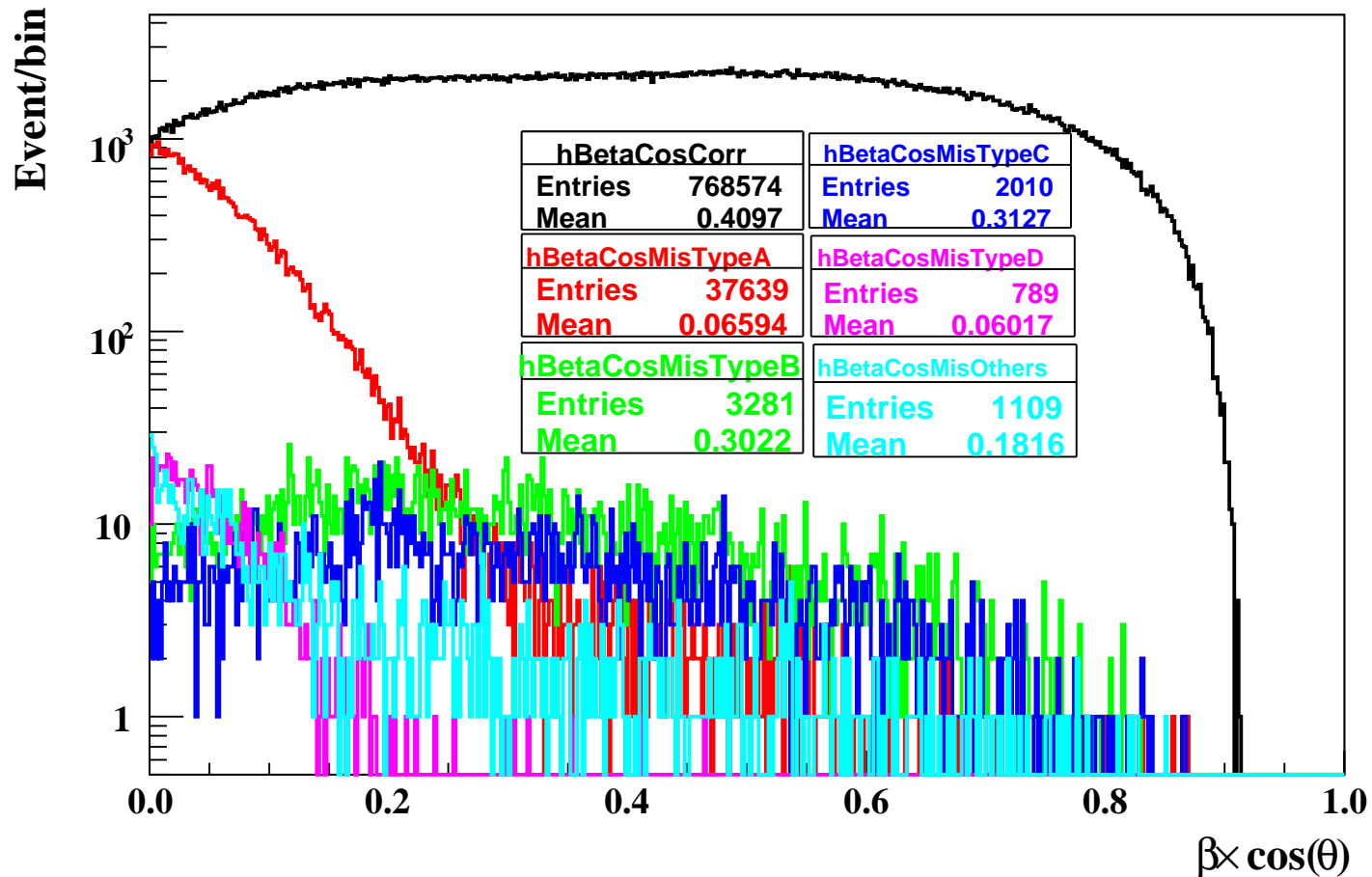
$$A_{true} = A \frac{\langle \beta \cos(\theta) \rangle N_{corr} + \langle \beta \cos(\theta) \rangle N_{mis}}{N_{corr} + N_{mis}} = A \frac{0.4097 \times 768574 + 0.09706 \times 44828}{768574 + 44828} = 0.39247 A$$

$$A_{meas} = A \frac{\langle \beta \cos(\theta) \rangle N_{corr} - \langle \beta \cos(\theta) \rangle N_{mis}}{N_{corr} + N_{mis}} = A \frac{0.4097 \times 768574 - 0.09706 \times 44828}{768574 + 44828} = 0.38177 A$$

$$\frac{A_{true} - A_{meas}}{A_{true}} = 2.7\%$$

# Systematics due to different types of events I

$\beta \cos\theta$  distribution for various types of events



**See page 6 for definition of different “types”.**

- Initial decay angle distribution for types A and D electrons peaked at much larger angle since they backscatter from the foil
- Initial decay angle distribution for types B and C tends to be at larger angle compared to the correct events, but not by much.

# Systematics due to different types of events II

Event types	MC events	$\langle\beta\cos\theta\rangle$	rate fraction(%)	$\Delta A(\%)$
Correct	768574	0.41	94.49	
Type A = from decay trap foil	37639	0.07	4.63	-1.55
Type B = from MWPC back win	3281	0.30	0.40	-0.62
Type C = from MWPC front window	2010	0.31	0.25	-0.39
Type D = from trap window, 2 scints	789	0.06	0.10	-0.03
Other misidentified events	1109	0.18	0.14	-0.13
Total	813402			-2.73

Summary table obtained from the figures from the previous page.