

# Time-Dependent Point Source Analysis Study

Patrick Berghaus  
MPI-K Heidelberg

IceCube Meeting  
Wisconsin, April 2007



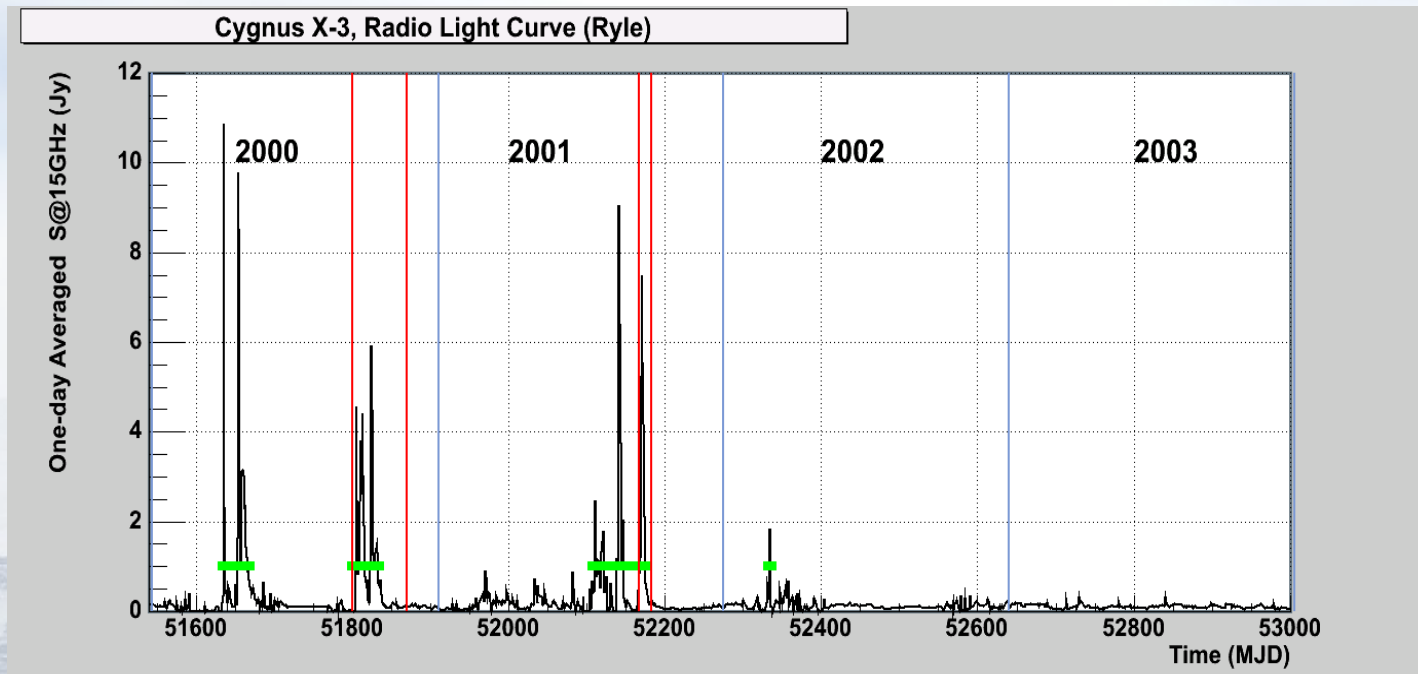
# Outline

- Time-dependent Analysis Overview
- Likelihood Ratio Method
- (Toy) Case Studies
- **Method, not Model!**

# Time Information in PS searches

- No Prior Knowledge (->RodinP., Konstancja S.)
- EM behavior as input (“multi-wavelength”)
  - More Information
  - Model-dependent (assumptions about gamma-nu connection)

# Multi-Wavelength (Zeuthen)

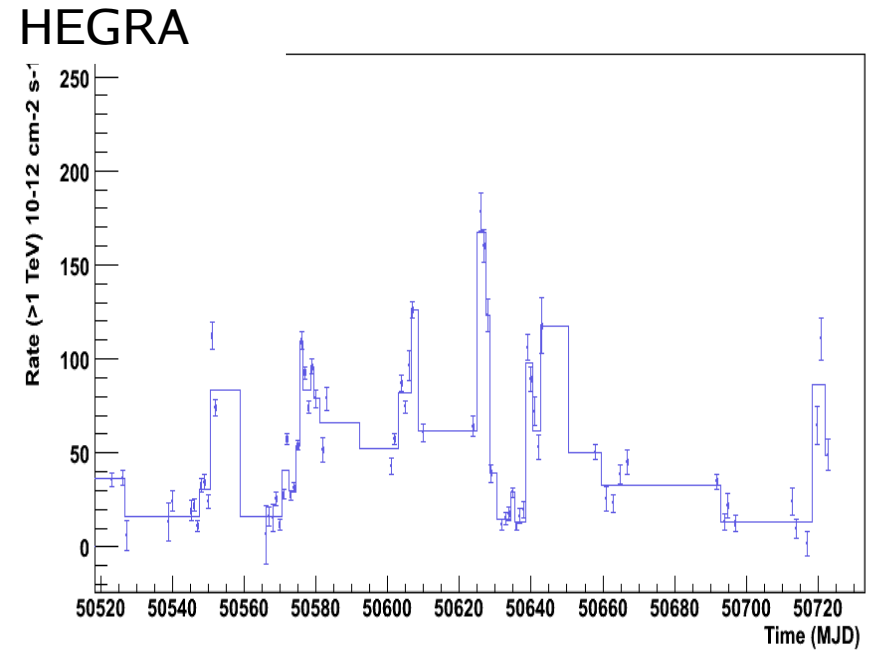
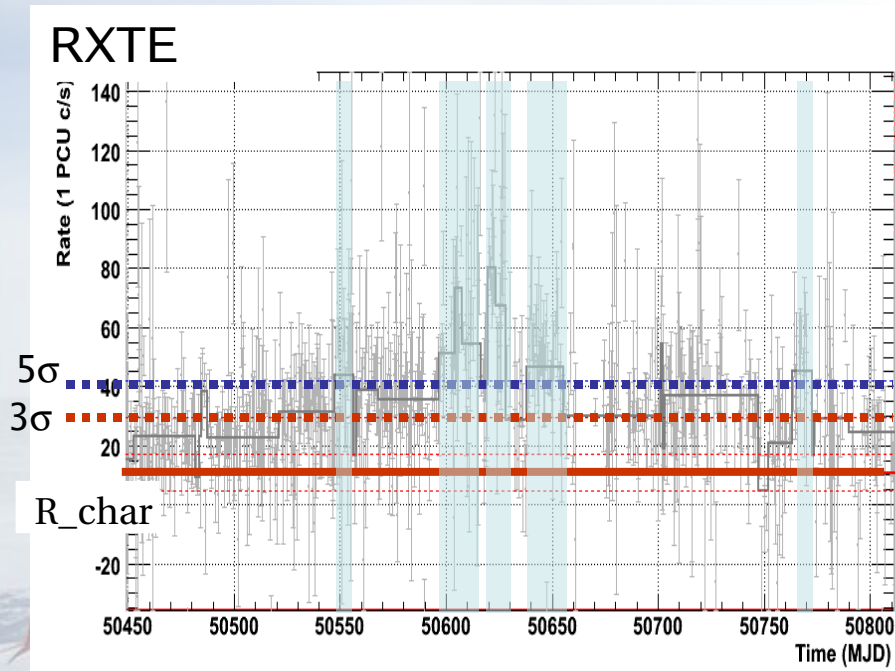


Selection of periods based on photon flux

Plot by M. Ackermann, E. Bernardini, T. Hauschildt

# Likelihood Block Method

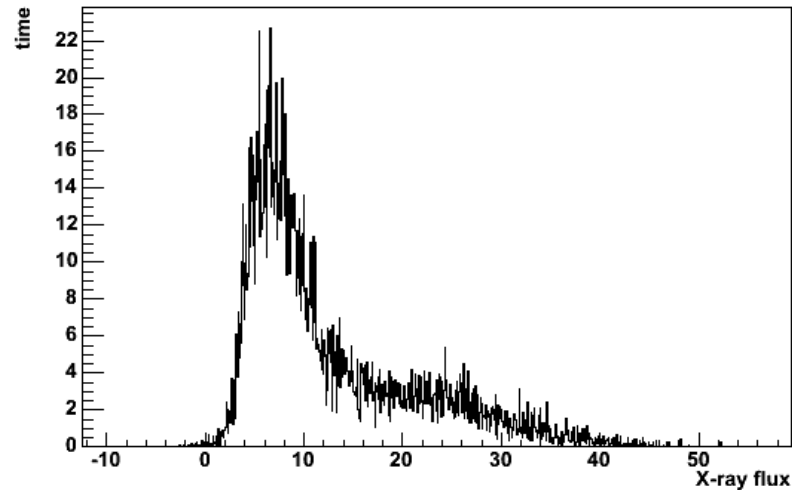
Mkn 501 (BL Lac)



Plots by Elisa Resconi, Luigi Costamante

# Toy Flux Model

Cyg X-3 likelihood blocks



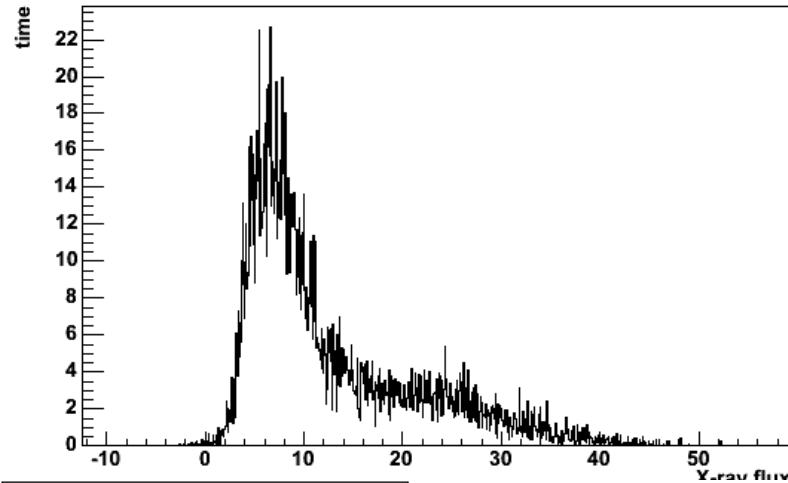
Why Cyg X-3?

Because it looks good and has strong X-Ray flux.

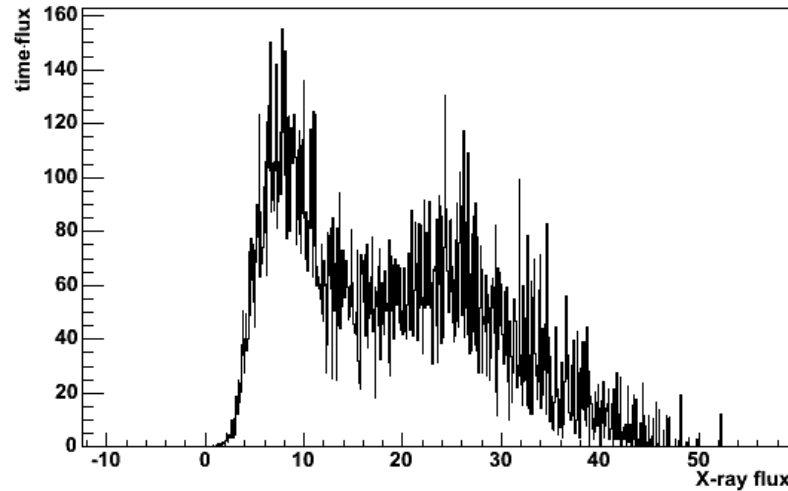
Just an example!

# Toy Flux Model

Cyg X-3 likelihood blocks



Cyg X-3 flux-weighted blocks

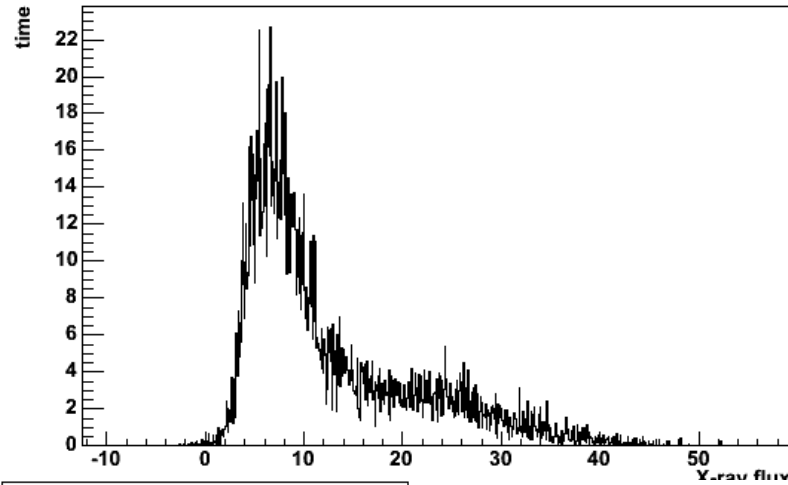


Simplest (Toy) Assumption:

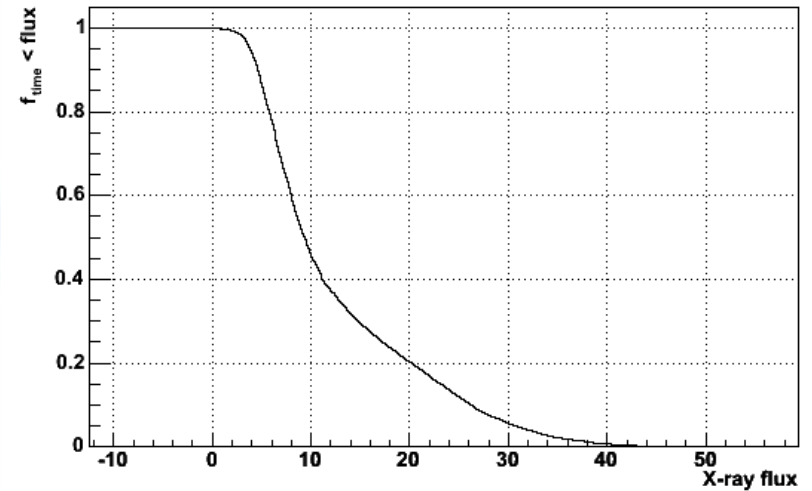
$$f_{\gamma} \propto f_{\nu}$$

# Toy Flux Model

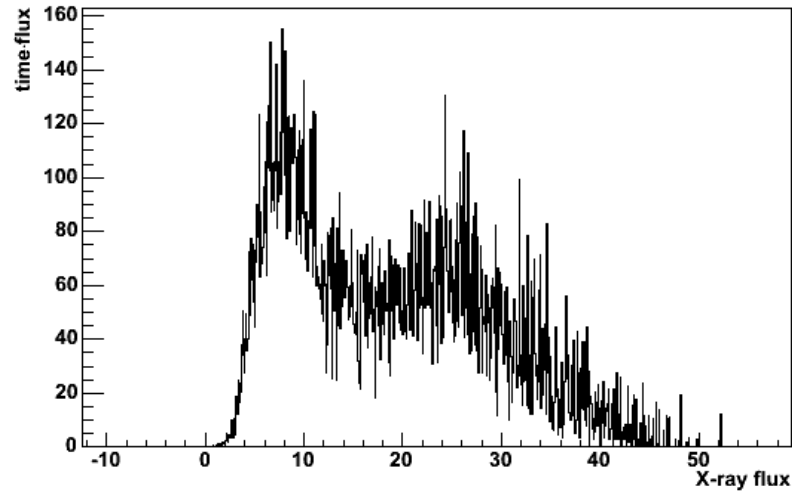
Cyg X-3 likelihood blocks



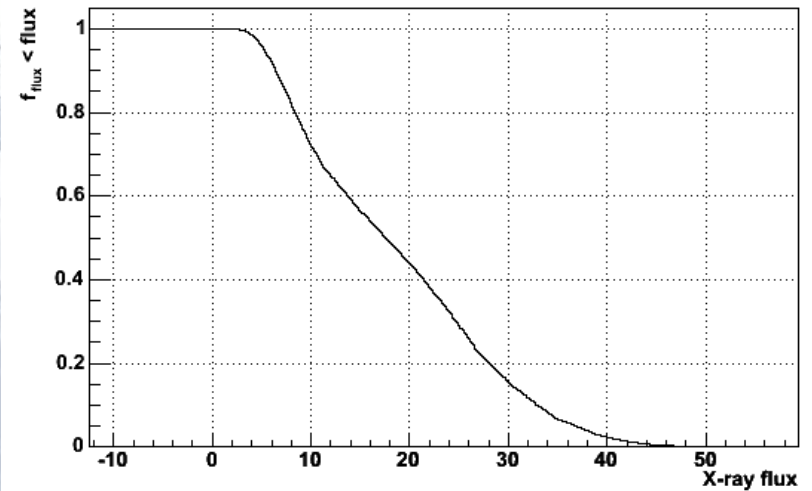
Cyg X-3 time above flux level



Cyg X-3 flux-weighted blocks



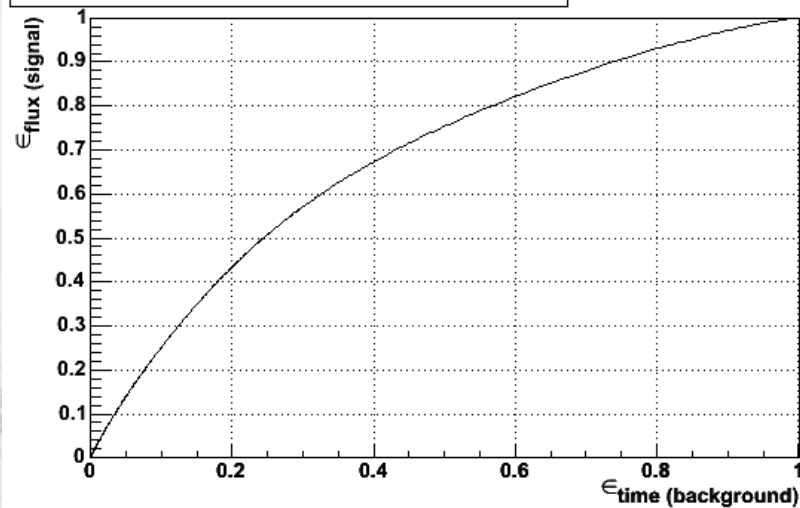
Cyg X-3 flux above flux level



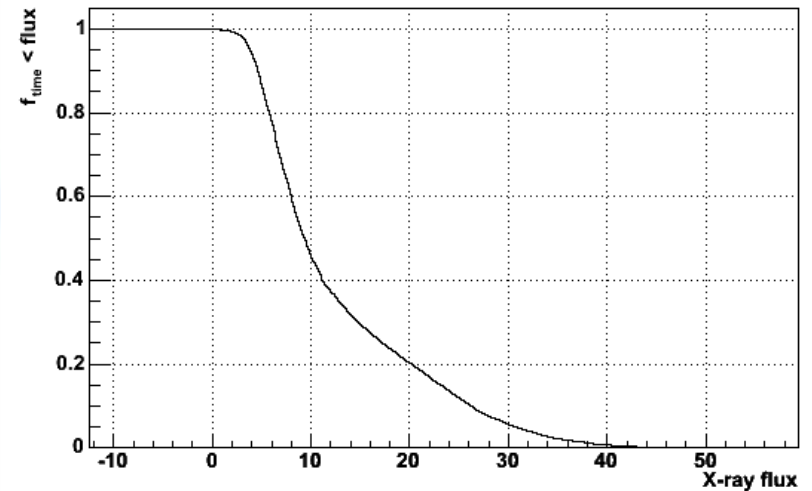


# Toy Flux Model

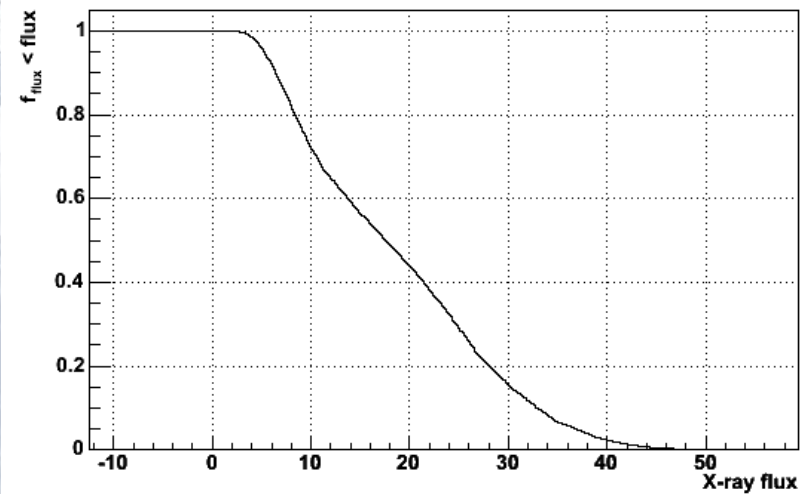
Cyg X-3 Signal vs. Background Efficiency



Cyg X-3 time above flux level



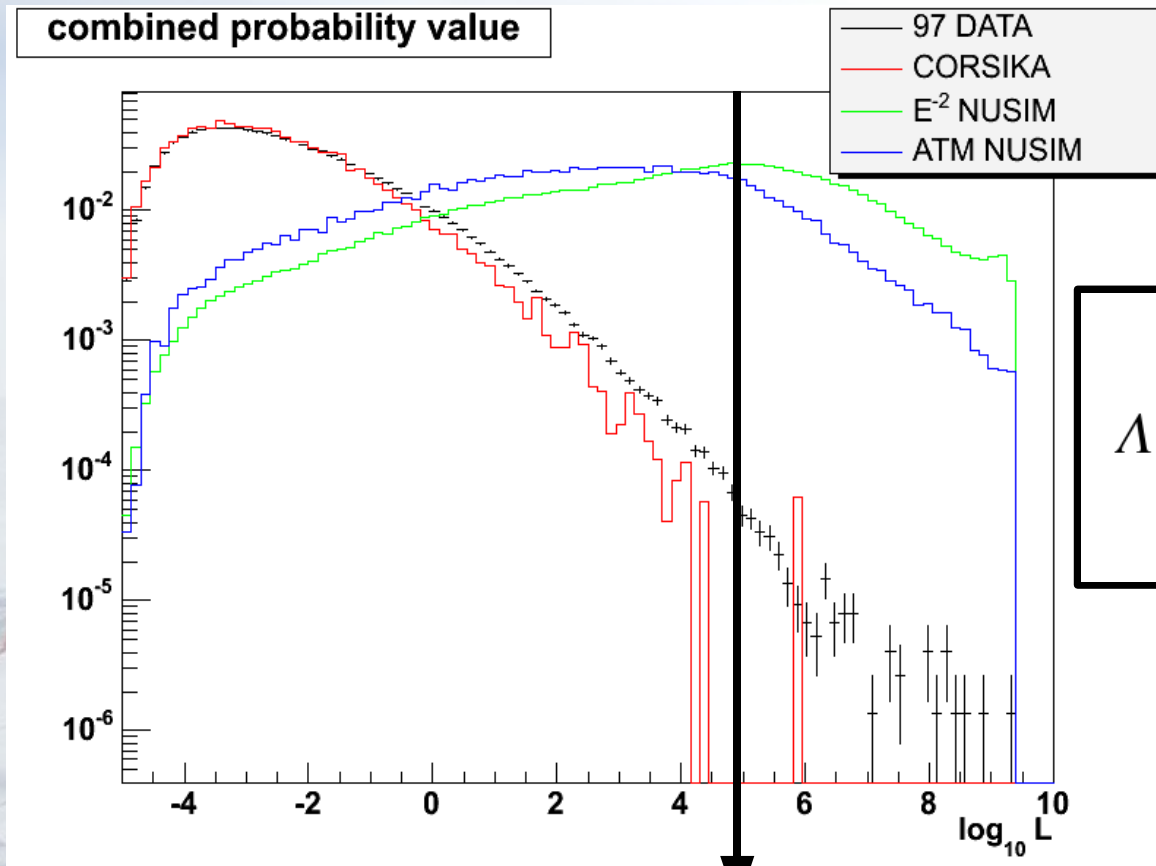
Cyg X-3 flux above flux level



# Implementation

- All based on 1997 data, PS analysis
- Methods of including time information
- Detection and Sensitivity

# Neyman-Pearson Parameter



$$\Lambda(\vec{x}) = \frac{pdf(\vec{x}|S)}{pdf(\vec{x}|B)} \approx \prod_{i=1}^{N_{obs}} \frac{pdf(x_i|S)}{pdf(x_i|B)}$$

See also: My talk about  
B10 Point Sources,  
Daan Hubert's talk in Zeuthen

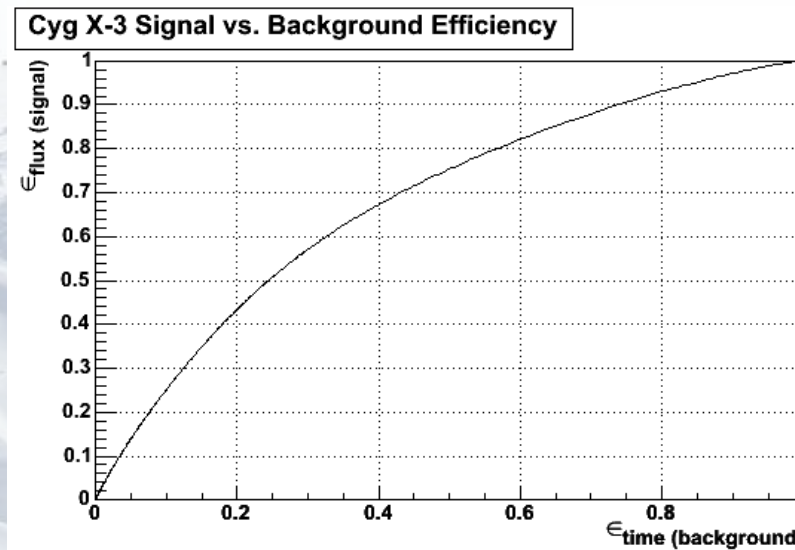
Typical steady PS cut

# Separate Time Cut

Naive assumption: Another cut will always do good if it improves  $\frac{S}{\sigma(B)} = \frac{S}{\sqrt{B}}$   
But:  $\sigma(B) \rightarrow const$  for low event numbers!

$$\Rightarrow cut_{max} \neq \max\left(\frac{S}{\sqrt{B}}\right)$$

Consequence:

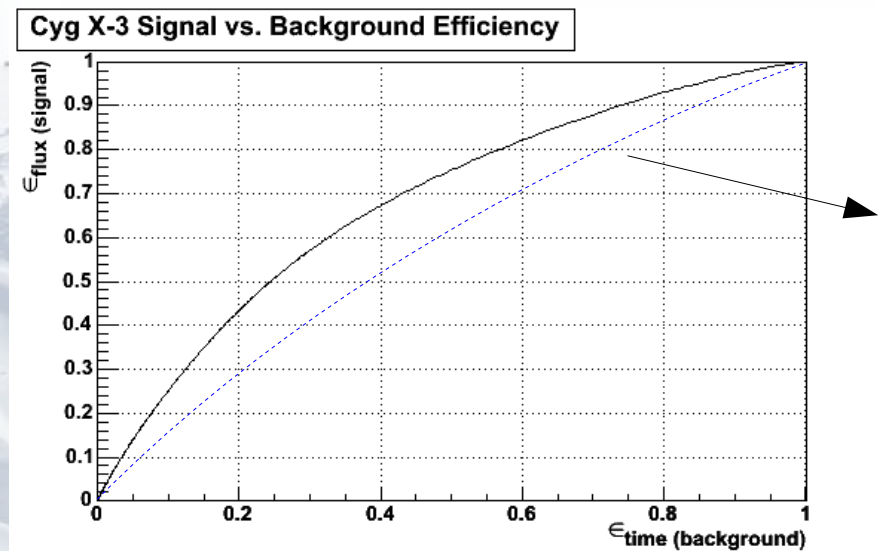


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For given  
quality cut level  
< optimum

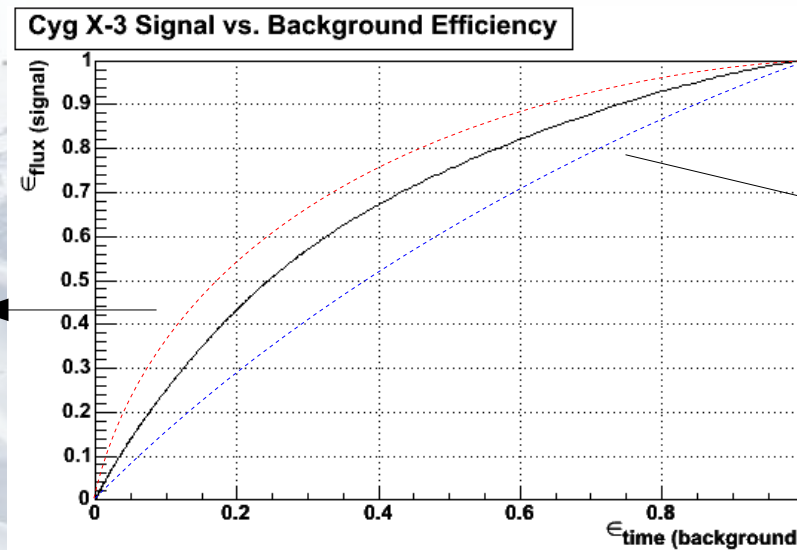


Time Cut better  
than quality cut

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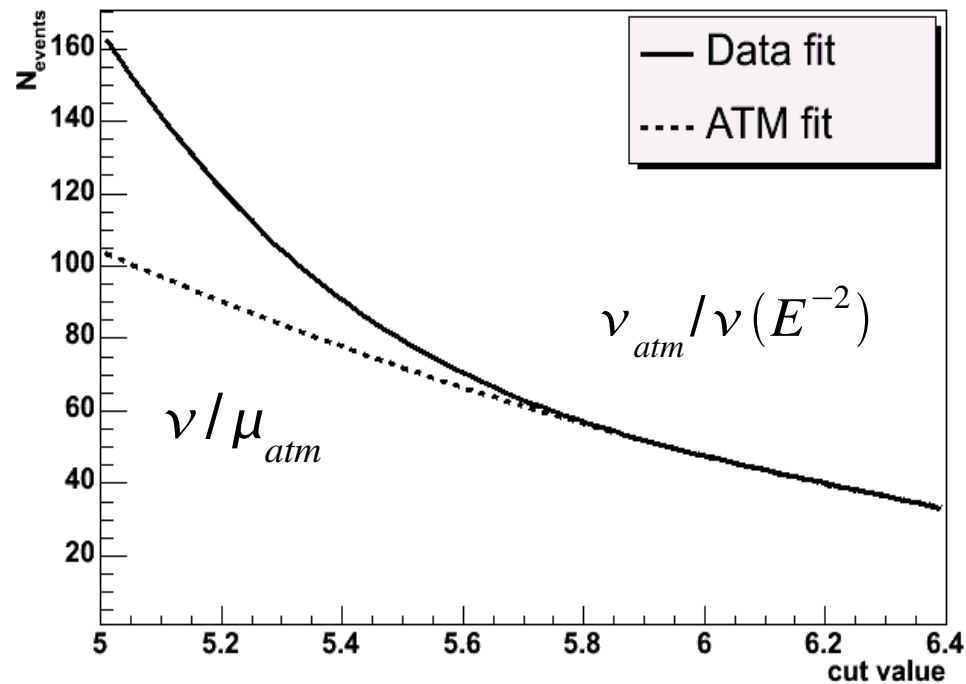


Time Cut worse than quality cut

Time Cut better than quality cut

# Caveats

1997 all angles

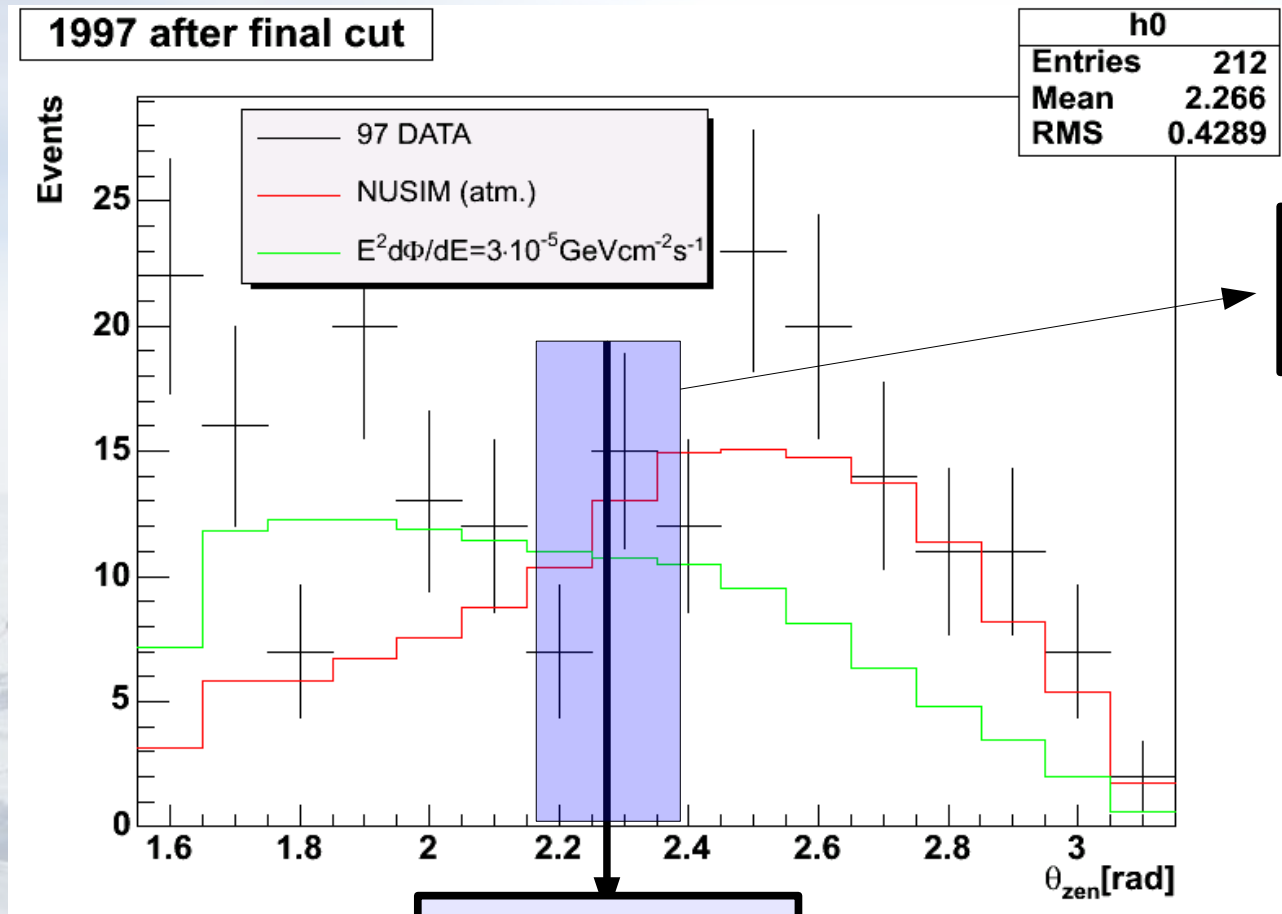


Tightening of quality cuts:  
elimination of low-E neutrinos

Time-dependent cut  
preserves them!

Quiescent states (zero flux) will  
of course always lead to time cut  
advantage

# Case Studies: Toy Source Position



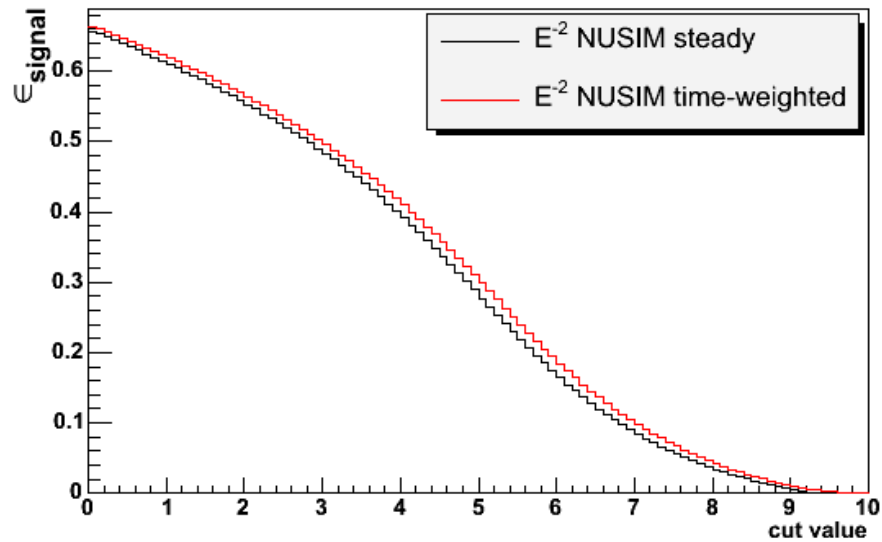
Data, MC used in Model

Mkn501: 2.264rad  
 Mkn421: 2.242rad  
 Cyg X-3: 2.284rad

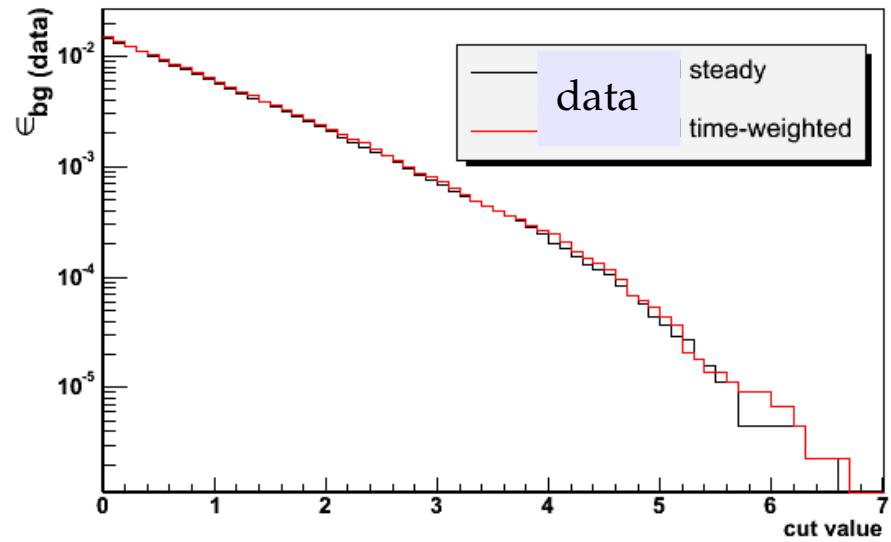


# Inclusion of time into NP

Cyg X-3 signal efficiency

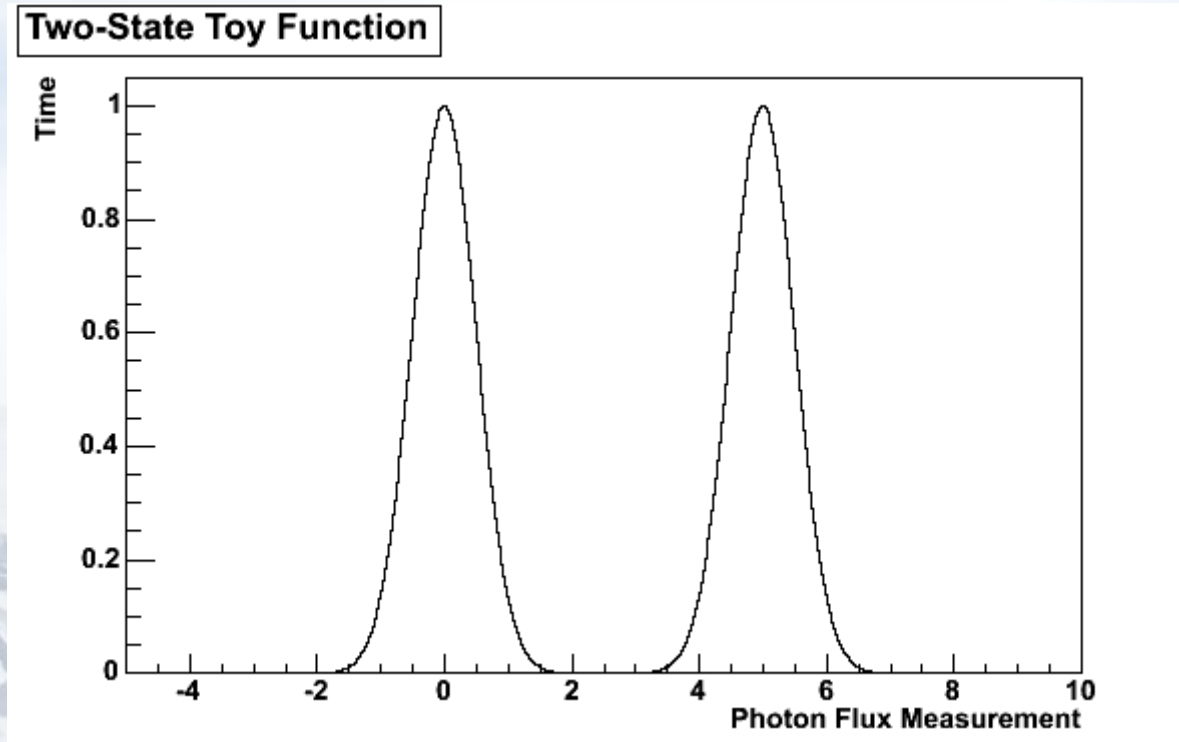


Cyg X-3 Background Efficiency



$$\Lambda_{tot} = \frac{p(\vec{x}_{quality}|S)}{p(\vec{x}_{quality}|B)} \times \frac{p(t|S)}{p(t|B)}$$

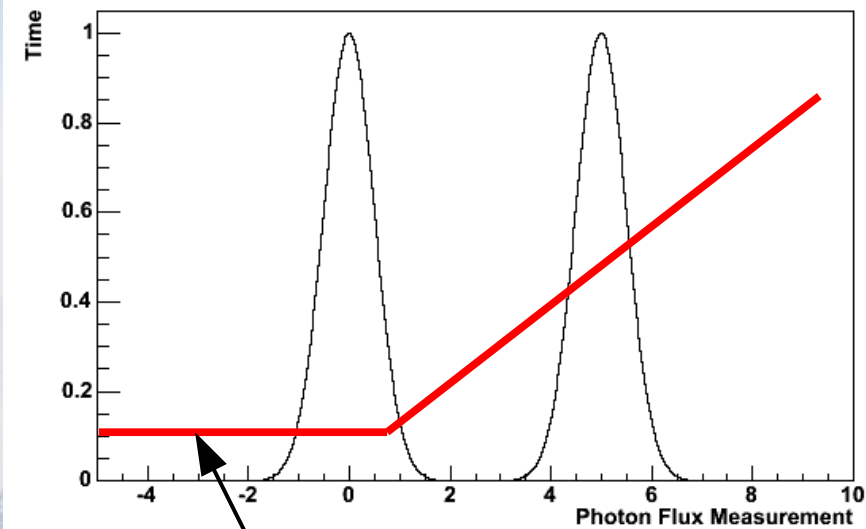
# Example Function



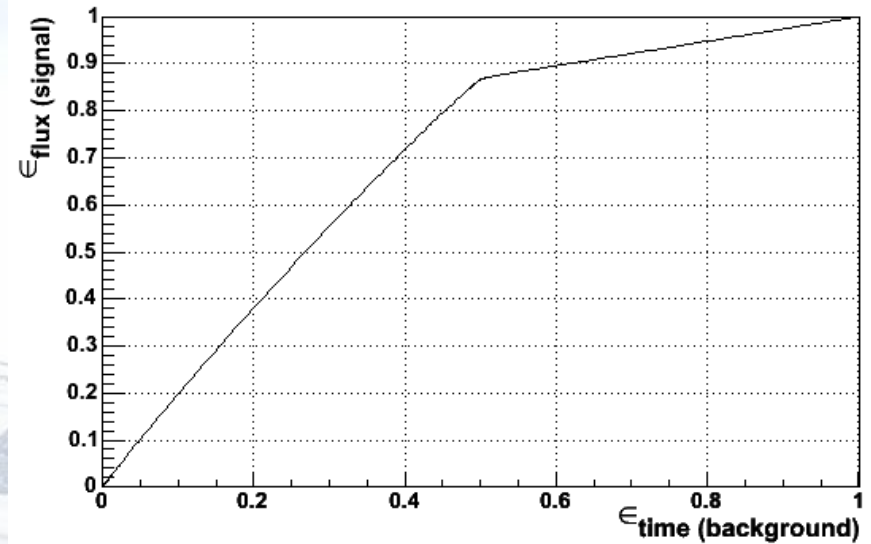
Classical case for time-dependent analysis: One quiescent, one active state

# Example Function

Two-State Toy Function

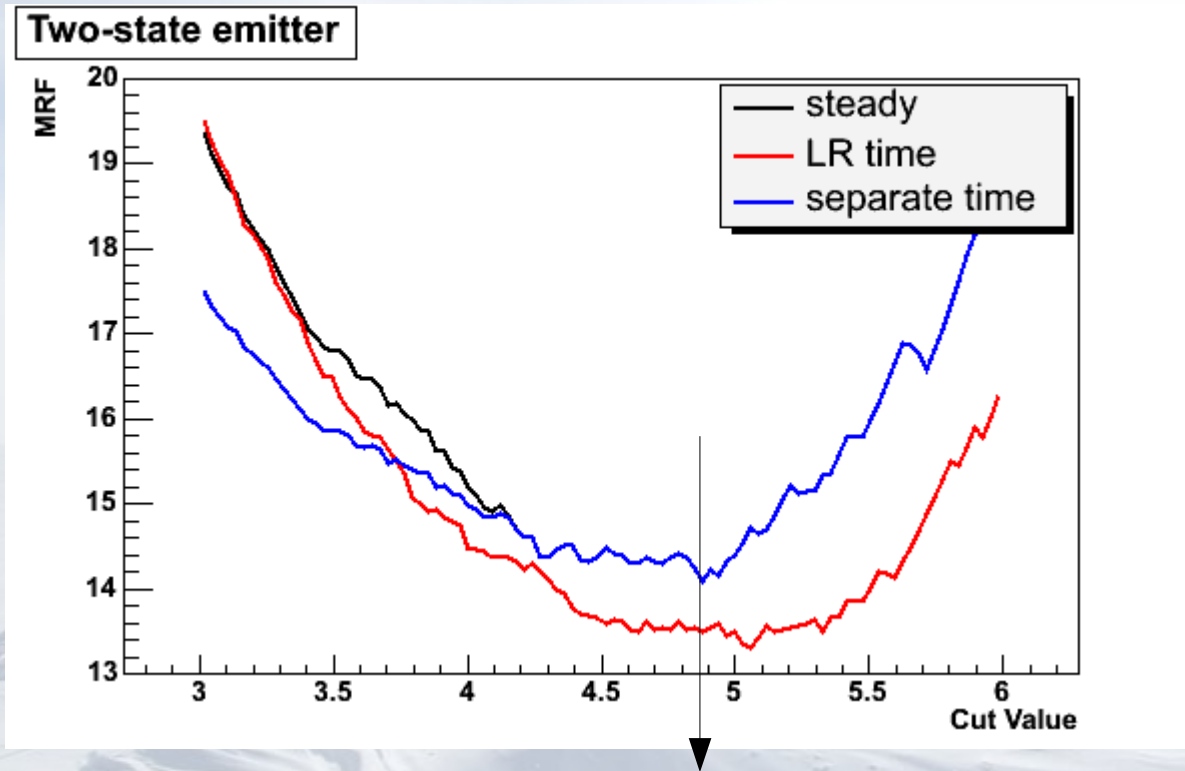


Two-State Signal vs. Background Efficiency



Conservative Flux Model: Constant neutrino flux up to threshold, linear above

# Example MRF

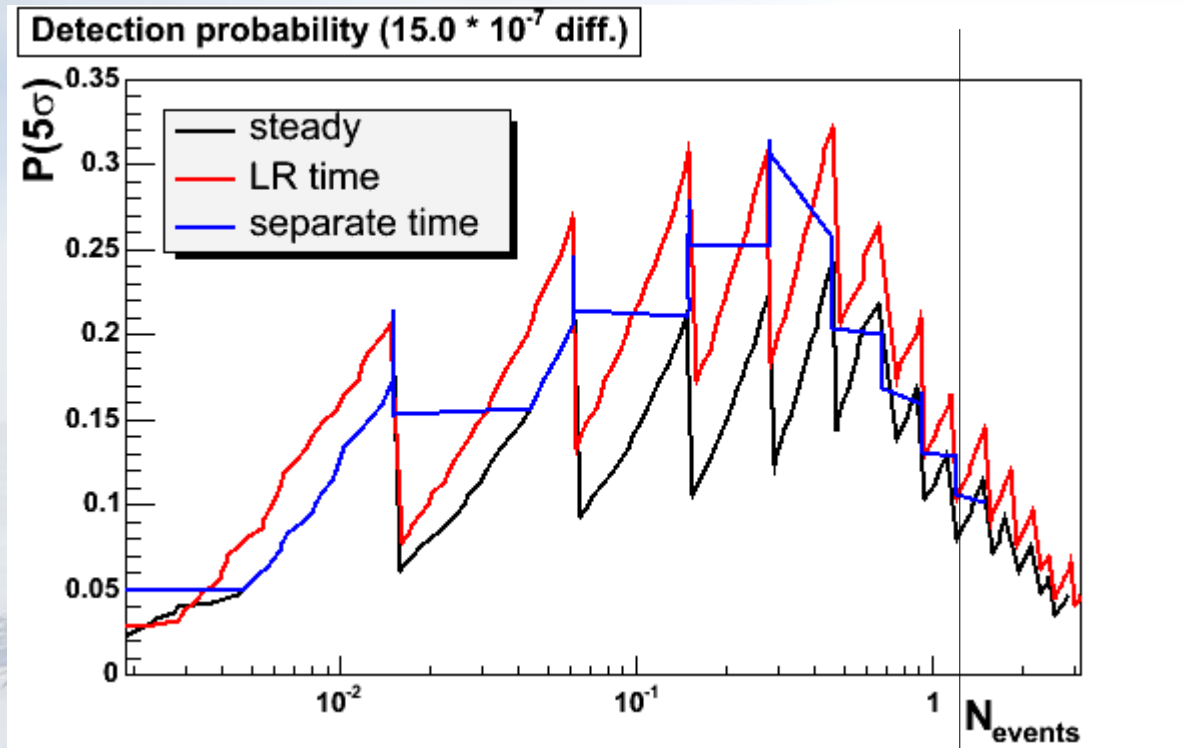


≈ 10% improvement with LR method

No improvement with separate cut

Steady PS search cut

# Example Detection Probability

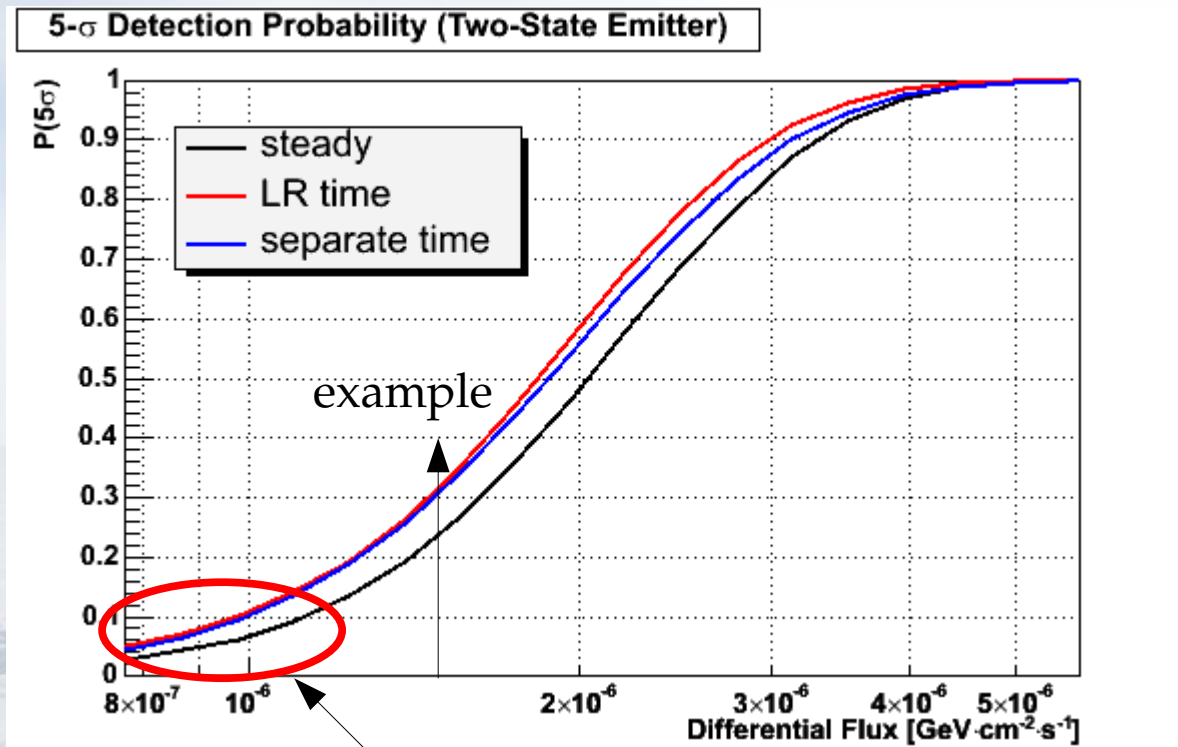


Hard cut, all events are neutrinos

Including  $N(\text{channel})$  cut would reduce time cut benefit

Steady PS Search Cut

# Example Detection Probability

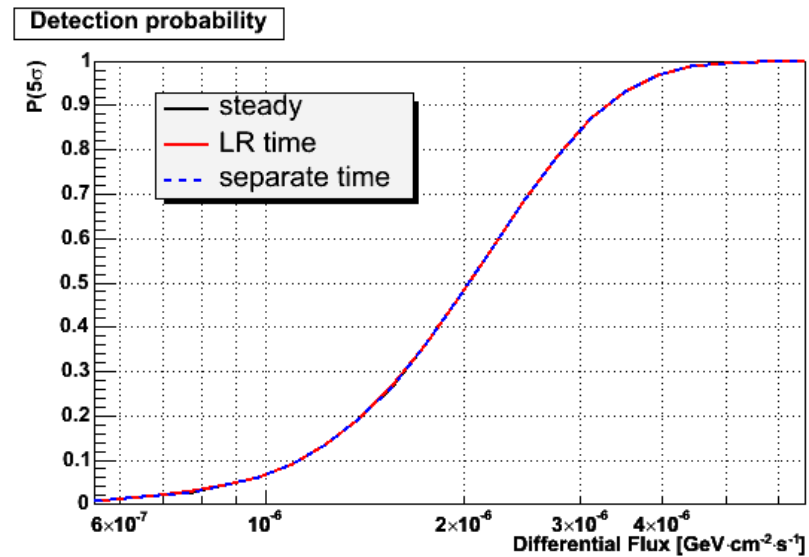
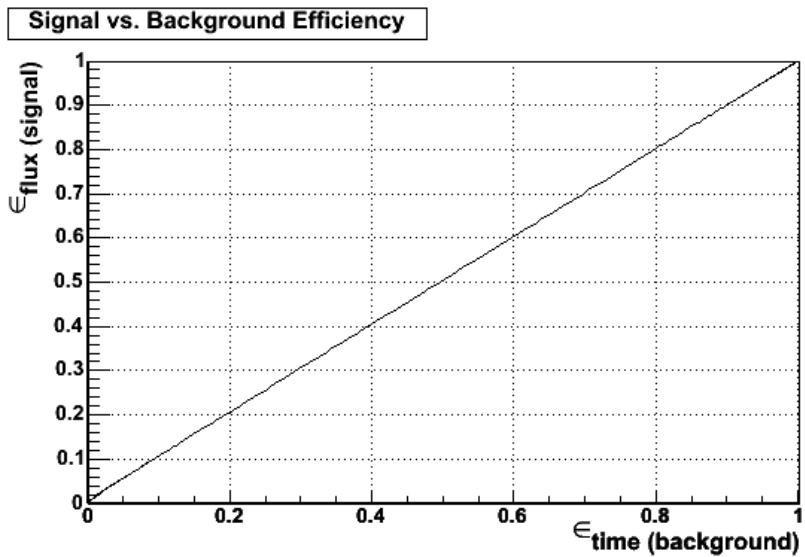
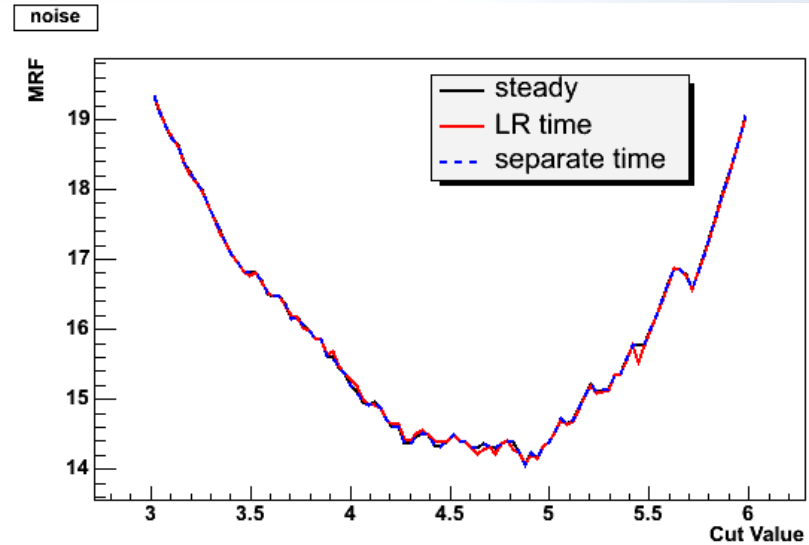
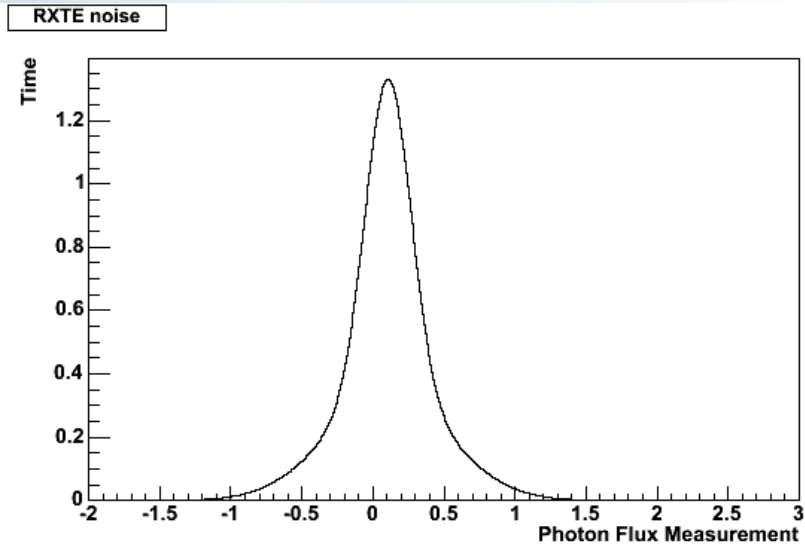


Cuts optimized for detection of given flux

Advantage up to factor of 2

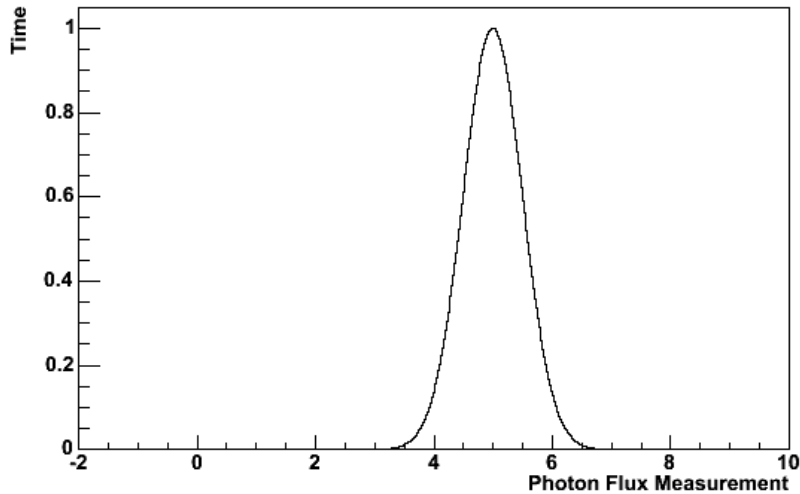
Could make difference between indication and detection

# (RXTE) Noise

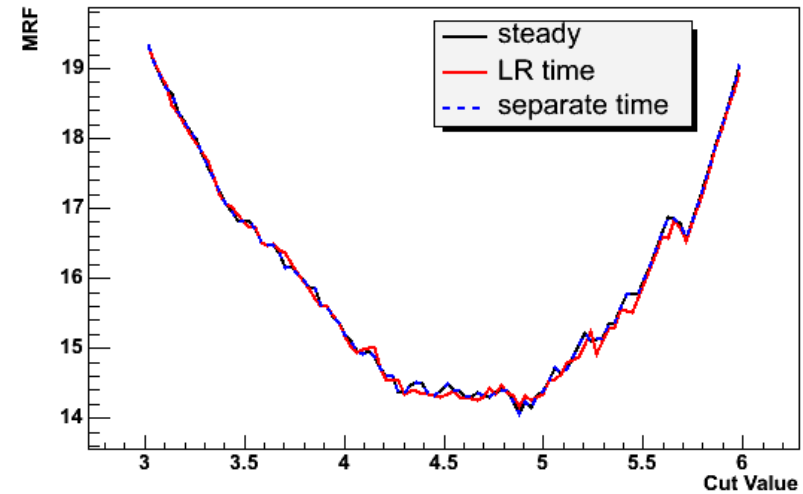


# Steady Source

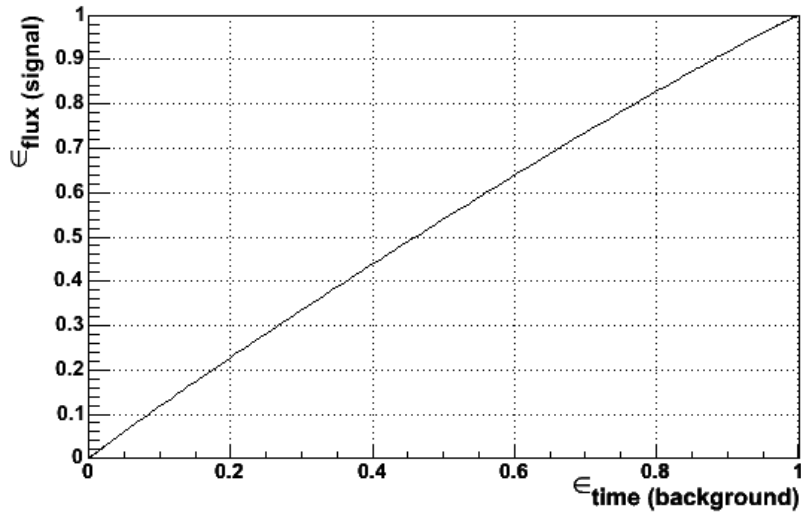
Steady Source



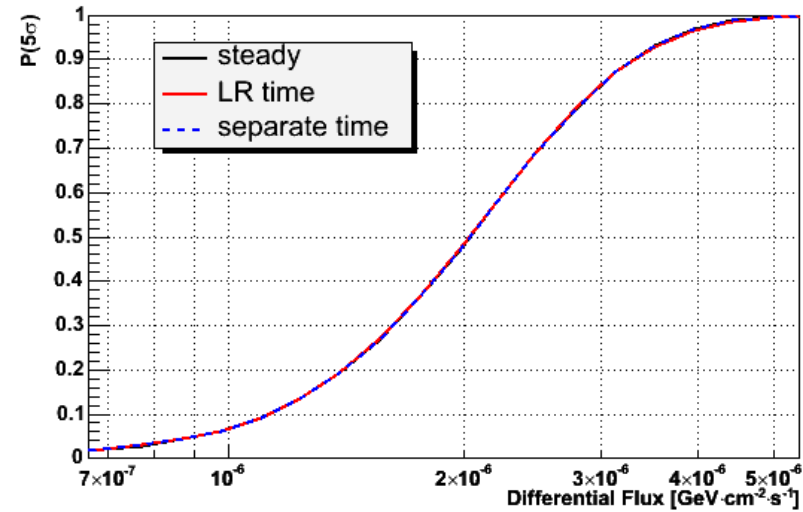
steady



Signal vs. Background Efficiency



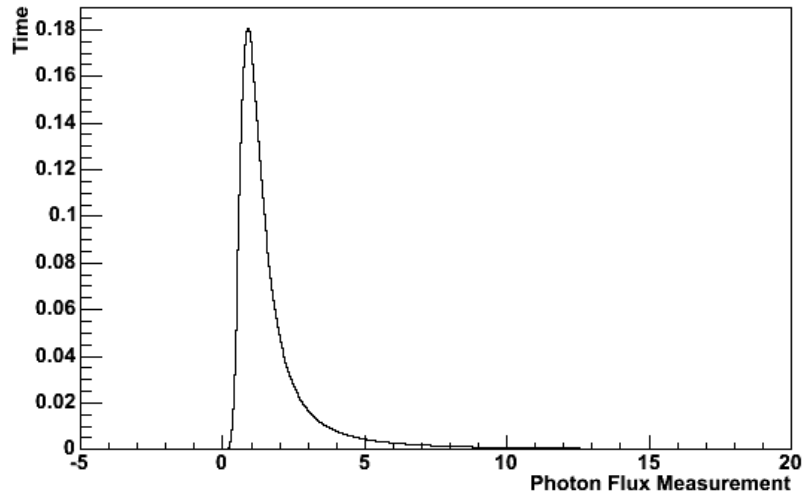
Detection probability



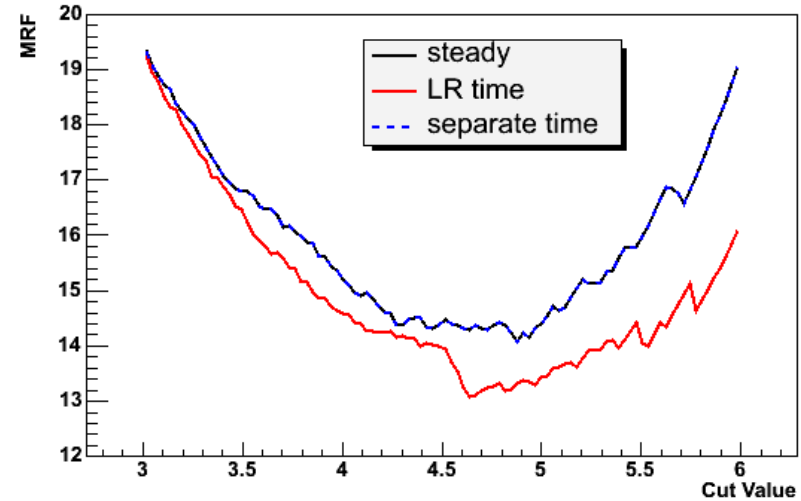


# Landau Fit to Mkn 501 RXTE (1997)

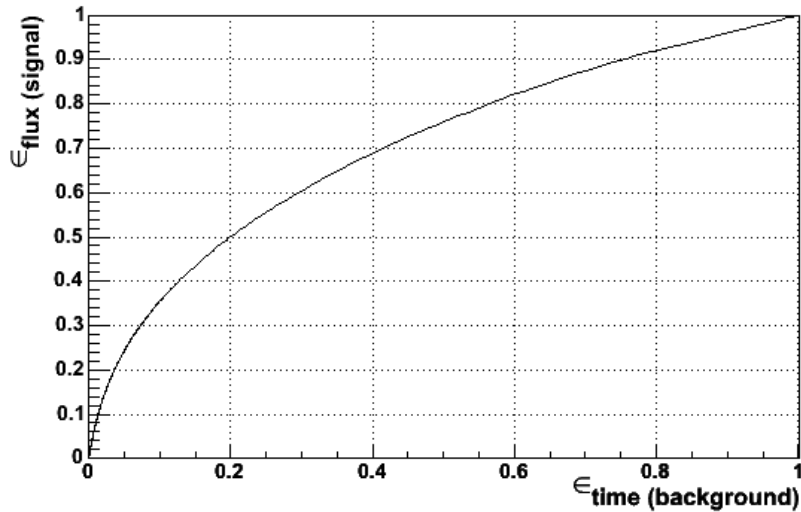
Landau Fit to Mkn 501 RXTE data (1997)



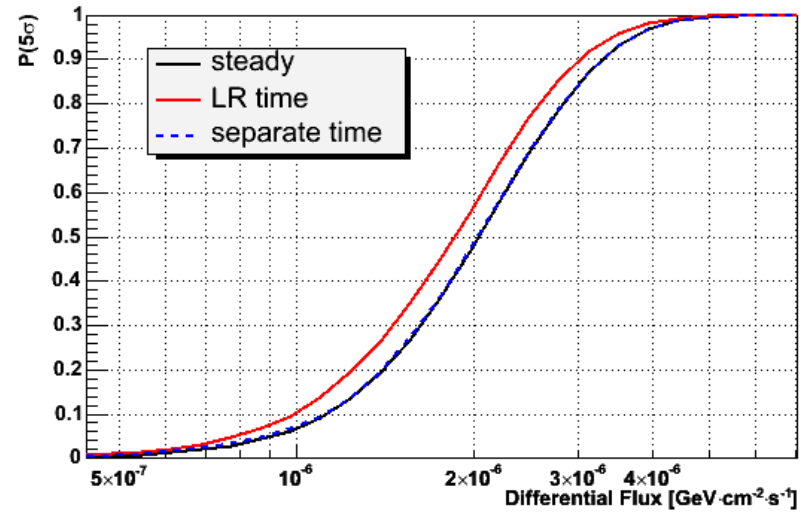
landau\_501\_97



Signal vs. Background Efficiency



Detection probability



# Conclusion

- Method to estimate advantage of time-dependent analysis
- Likelihood Ratio probably the way to go
- Careful Phenomenological Modeling essential