Search for Point Sources with AMANDA-B10

1. Introduction (data sets, types of reconstruction)
2. Comparison with Scott Young's results
3. Objective method to optimize the cuts
4. Preliminary results (my filter and skymap)
5. Angular resolution and binning choice
6. Still to do

1. Introduction

- 10% of 1997 data set
- BG MC : downgoing muons
  version: ama.loh.bas.mass00v004.b10
- Signal MC : upgoing neutrino-induced muons (up to 10^5 GeV)
  version: ama.loh.nusim.numu.mass00v005_test.b10
- New version of recoos

Hit cleaning: same as Scott Young

Types of reconstruction (same as Scott Young)

(1) Line fit
(2) Likelihood fit
(3) Hit probability topological likelihood fit
(4) Cascade first guess fit
(5) Cascade time likelihood fit
(6) Muon iterative time likelihood reconstruction

2. Comparison with Scott Young's results

Same discriminating variables, same cuts (UCI filter)

ε = cut efficiency , $R = \varepsilon_{signal}/\varepsilon_{bg\ or\ data}$

Cut level	ε_{data} Scott 97	ε_{data} Jan 97	ε_{data} Thierry 97	ε_{bg-MC} Thierry 97	$\varepsilon_{signal-MC}$ Thierry 97	ε_{data} Othmane 99
1 LBNL	1	1	1	1	1	1
UCI 2a : zenith(2)>90	0.642	0.820	0.861	0.853	0.905	0.807
UCI 2b : 0.43<smootallrl(2) <0.3	0.357	0.440	0.401	0.457	0.744	0.403
UCI 2c : ldirc(2)>75	0.356	0.430	0.398	0.385	0.752	0.468
UCI 2d : jkrchi(2)/jkrchi(1)<4.10^{-6}	0.518	0.490	0.449	0.520	0.802	0.610
UCI 2e : zenith(6)>90	0.550	0.850	0.985	0.985	0.998	0.913
2 UCI filter	0.0232	0.0646	0.061	0.077	0.405	0.0849

R values for the UCI filter

R_{data} Scott 97	$R_{background}$ Scott 97	R_{data} Thierry 97	$R_{background}$ Thierry 97
22.990	18.954	6.69	5.26

→ With the same cuts and reconstruction: different results between Scott and Jan/this work !

→ As suggested by Othmane (Berkeley 2002), would be due to recent recoos version (warning: certain important variables like *jkprob* and *jkchi* not reconstructed any more !)

→ The data seems to be better reconstructed !

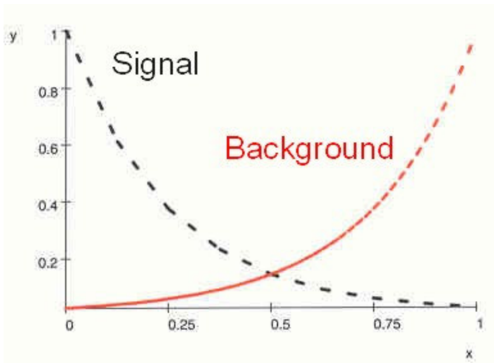
3. Objective method to “optimize” the cuts

- 1 upgoing muon for 10^6 downgoing muons !

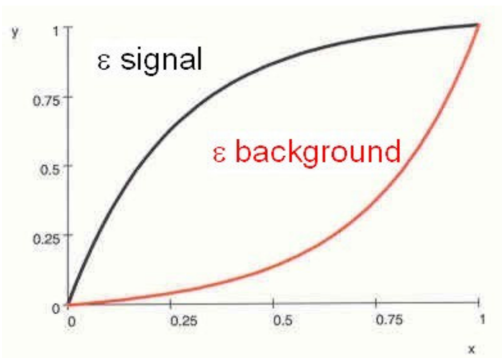
→ reject that background as much as possible while keeping most of the signal…

→ apply cuts with the highest R and ε_{signal} AT THE SAME TIME

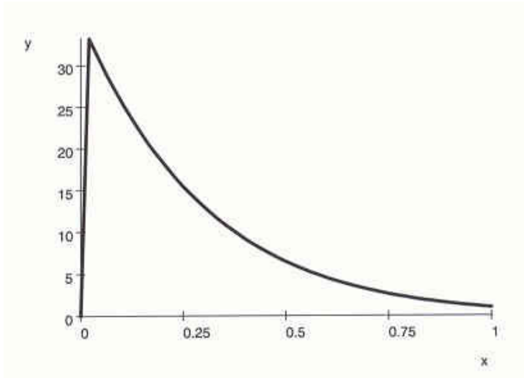
- Graphical method (simple example)



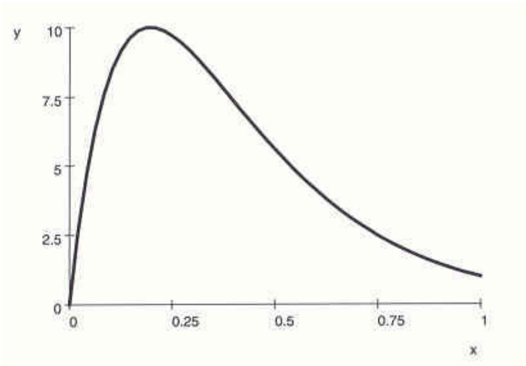
Distribution of signal and background vs a certain variable



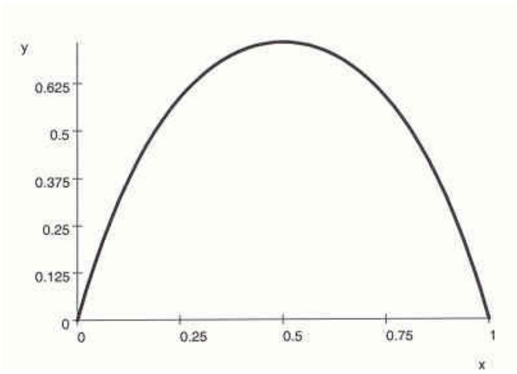
Integrated curves → cut efficiencies vs the cut



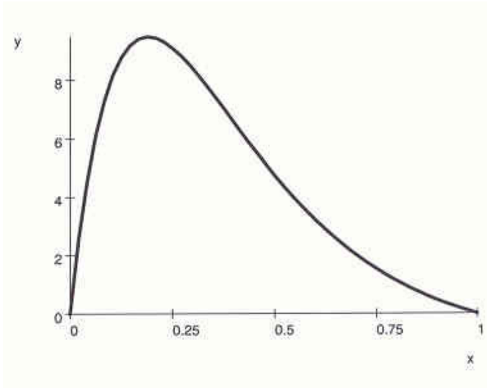
R vs the cut



$R \cdot \varepsilon_{signal}$ vs the cut



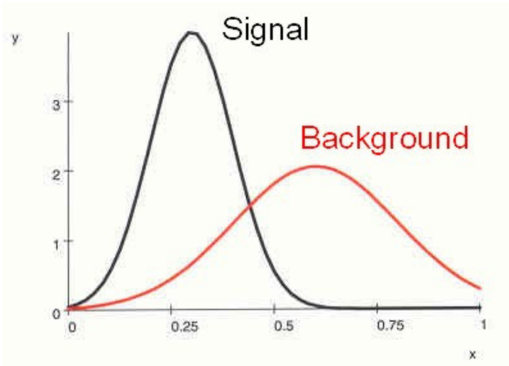
$\varepsilon_{signal} - \varepsilon_{background}$ vs the cut



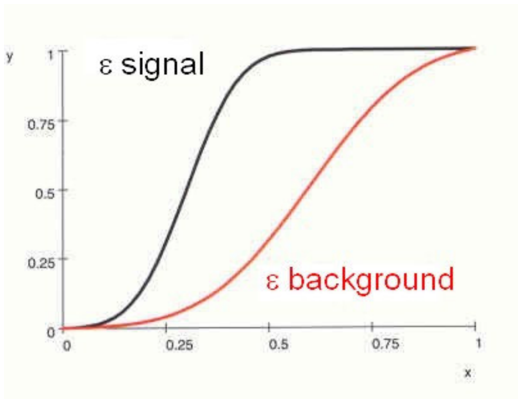
$R \cdot (\varepsilon_{signal} - \varepsilon_{background})$ vs the cut

Maximum of	X	ε_{signal}	$\varepsilon_{background}$	R
$\varepsilon_{signal} - \varepsilon_{background}$	0.5	0.866	0.134	6.45
$R(\varepsilon_{signal} - \varepsilon_{background})$	0.189	0.526	0.028	19.0
$R\varepsilon_{signal}$	0.1965	0.540	0.029	18.5

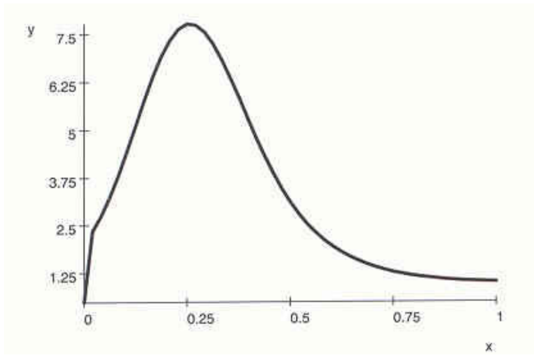
Simulation of a real example (smootallrl)



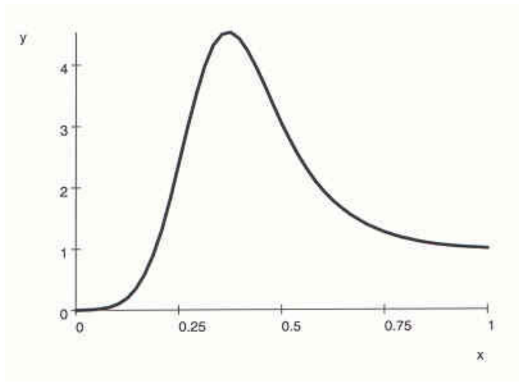
Distribution of signal and background vs smootallrl



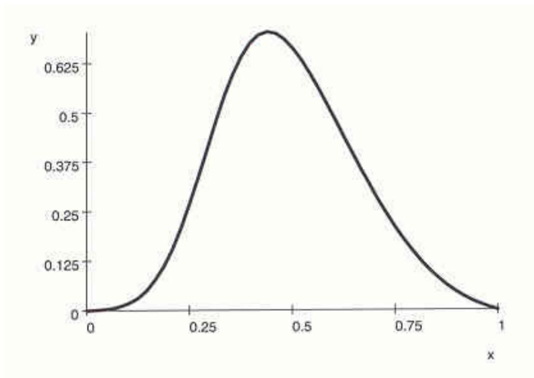
Integrated curves → cut efficiencies vs the cut



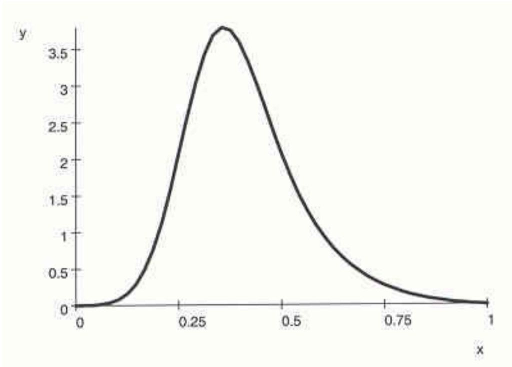
R vs the cut



$R \cdot \varepsilon_{signal}$ vs the cut



ε_{signal} - $\varepsilon_{background}$ vs the cut



$R \cdot (\varepsilon_{signal} - \varepsilon_{background})$ vs the cut

Maximum of	X	ε_{signal}	$\varepsilon_{background}$	R
$\varepsilon_{signal} - \varepsilon_{background}$	0.44	0.919	0.216	4.26
$R(\varepsilon_{signal} - \varepsilon_{background})$	0.256	0.329	0.04	7.77
$R\varepsilon_{signal}$	0.37	0.758	0.127	5.98

In many realistic cases:

high R, but low ε_{signal}
or
high ε_{signal}, but low R
or
R artificially high

For point sources search, apply the cut at the maximum of $(\varepsilon_{signal} - \varepsilon_{background})$

→ gives the best compromise between ε_{signal} and R
→ always a maximum in the distribution curve

→ "Maximum Difference Method"

- <u>First trial: "optimization" of the UCI filter</u>

UCI filter on new reconstructed data :

Cut level	ε_{signal} (%)	ε_{data} (%)	$\varepsilon_{background}$ (%)	R_{data}	$R_{background}$
LBNL	100	100	100	1	1
1. Zenith(2)>90	90.5	86.1	85.3	1.05	1.06
2. –0.43<smootallrl(2)<0.3	74.4	40.1	45.7	1.86	1.63
3. ldirc(2)>75	75.2	39.8	38.5	1.89	1.95
4. Jkrchi(2)/jkrchi(1)<4.10^{-6}	80.2	44.9	52.0	1.79	1.54
5. Zenith(6)>94	99.8	98.5	98.5	1.01	1.01
Total	40.5	6.1	7.7	6.69	5.24

UCI filter "optimized" with the "maximum difference method" :

Cut level	ε_{signal} (%)	ε_{data} (%)	$\varepsilon_{background}$ (%)	R_{data}	$R_{background}$
LBNL	100	100	100	1	1
1. Zenith(2)>90	90.77	86.06	85.37	1.05	1.06
2. Ldirc(2)>100	52.18	21.95	22.67	2.38	2.30
3. -0.25<smootallrl(2)<0.28	73.70	26.24	32.14	2.81	2.29
4. Jkrchi(2)/jkrchi(1)<3.10^{-6}	73.95	31.31	35.71	2.36	2.07
5. Zenith(6)>94	97.50	95.73	96.21	1.02	1.01
Total	25.17	1.49	2.14	16.90	11.67

- <u>Then: optimization for 3 different parts of the sky</u>

  Nadir : -1<cos(zenith(6))<-0.666
  Centre : -0.666<cos(zenith(6))<-0.333
  Horizon : -0.333<cos(zenith(6))<0

→ no significant differences

- <u>Search for Point Sources</u>

Use the "Maximum Difference Method" with a set of variables that present BEFORE ANY CUT (> LBNL) :

- a good agreement between data and BG MC - a good discrimination between signal and background

<u>Procedure :</u>

Optimise the cut for each variable, apply the optimized cut for the variable that presents the best R value and so on…

List of variables used :

ldirb(2) ; ldirb(6)
ldirc(2) ; ldirc(6)
ndira(2) ; ndira(6)
ndirb(2) ; ndirb(6)
ndirc(2) ; ndirc(6)
ndirc(6) - ndirc(5)
jkrchi(3)
smootallrl(2) ; smootallrl(6)
smootallphit(3)

4. Preliminary results

- Filter obtained with the maximum difference method :

Cut level	ε_{signal} (%)	ε_{data} (%)	$\varepsilon_{background}$ (%)	R_{data}	$R_{background}$
1. Zenith(2)>90	90.77	86.06	85.37	1.05	1.06
2. ndirb(2)>4	61.70	21.19	13.71	2.91	4.50
3. ndirc(6)>8	71.07	40.43	23.36	1.76	3.04
4. ldirb(6)>90	62.47	15.63	17.54	4.00	3.56
5. –0.24<smootallrl(6)<0.26	76.47	21.59	20.81	3.54	3.67
6. ndira(2)>5	59.28	22.26	17.59	2.66	3.37
7. –0.13<smootallphit<0.23	80.69	24.43	34.21	3.30	2.36
8. –100<cogz<170	100	96.74	100	1.03	1.00
9. zenith(6)>90	99.93	97.60	92.31	1.02	1.08
Total	9.1	~ 0.01	~ 0.01	~ 910	~ 910

- Skymap :

- Include 203 data events

- By comparison with signal events, BG events are more confined to the horizon

5. Angular resolution and binning choice

- Rectangular bins (Δ zenith ; Δ azimuth)

Complete sky	FWHM (°) zenith(6)-truezenith(3)	FWHM (°) azimuth(6)-trueazimuth(3)
After 1 cut	8.2	10.8
After 2 cuts	7.6	10.1
After 3 cuts	7.0	9.5
After 4 cuts	5.7	8.9
After 5 cuts	5.7	8.9
After 6 cuts	5.1	8.2
After 7 cuts	4.4	7.6
After 8 cuts	4.4	7.6
After 9 cuts	4.4	7.6

Nadir -1<cos(zenith(6))<-0.666	FWHM (°) zenith(6)-truezenith(3)	FWHM (°) azimuth(6)-trueazimuth(3)
After 1 cut	7.6	14.6
After 2 cuts	7.0	12.0
After 3 cuts	6.3	10.1
After 4 cuts	5.1	10.1
After 5 cuts	5.1	9.5
After 6 cuts	4.4	8.9
After 7 cuts	3.8	8.9
After 8 cuts	3.8	8.9
After 9 cuts	3.8	8.9

Centre -0.666<cos(zenith(6))<-0.333	FWHM (°) zenith(6)-truezenith(3)	FWHM (°) azimuth(6)-trueazimuth(3)
After 1 cut	8.9	11.4
After 2 cuts	7.6	10.1
After 3 cuts	7.0	9.5
After 4 cuts	6.3	8.2
After 5 cuts	6.3	8.2
After 6 cuts	5.1	7.6
After 7 cuts	5.1	7.0
After 8 cuts	5.1	7.0
After 9 cuts	5.1	7.0

Horizon -0.333<cos(zenith(6))<0	FWHM (°) zenith(6)-truezenith(3)	FWHM (°) azimuth(6)-trueazimuth(3)
After 1 cut	8.9	10.1
After 2 cuts	7.6	8.9
After 3 cuts	7.0	8.2
After 4 cuts	6.3	7.6
After 5 cuts	6.3	7.6
After 6 cuts	5.1	7.0
After 7 cuts	5.1	7.0
After 8 cuts	5.1	7.0
After 9 cuts	5.1	7.0

Bin width :

Complete sky (after 9 cuts)	Zenith	Azimuth
1.0 HWHM	2.2° = 61% of signal	3.8° = 56% of signal
1.5 HWHM	3.3° = 77% of signal	5.7° = 69% of signal
2.0 HWHM	4.4° = 86% of signal	7.6° = 77% of signal
2.5 HWHM	5.5° = 91% of signal	9.5° = 82% of signal
3.0 HWHM	6.6° = 94% of signal	11.4° = 86% of signal
3.5 HWHM	7.7° = 96% of signal	13.3° = 89% of signal
4.0 HWHM	8.8° = 97% of signal	15.2° = 90% of signal

NADIR (after 9 cuts)	Zenith	Azimuth
1.0 HWHM	1.9° = 60% of signal	4.5° = 52% of signal
1.5 HWHM	2.9° = 75% of signal	6.7° = 65% of signal
2.0 HWHM	3.8° = 84% of signal	8.9° = 72% of signal
2.5 HWHM	4.8° = 90% of signal	11.1° = 77% of signal
3.0 HWHM	5.7° = 93% of signal	13.4° = 81% of signal
3.5 HWHM	6.7° = 95% of signal	15.6° = 84% of signal
4.0 HWHM	7.6° = 97% of signal	17.8° = 86% of signal

CENTRE (after 9 cuts)	Zenith	Azimuth
1.0 HWHM	2.6° = 66% of signal	3.5° = 61% of signal
1.5 HWHM	3.8° = 81% of signal	5.3° = 75% of signal
2.0 HWHM	5.1° = 89% of signal	7.0° = 83% of signal
2.5 HWHM	6.4° = 94% of signal	8.8° = 89% of signal
3.0 HWHM	7.7° = 96% of signal	10.5° = 92% of signal
3.5 HWHM	8.9° = 98% of signal	12.3° = 94% of signal
4.0 HWHM	/	/

HORIZON (after 9 cuts)	Zenith	Azimuth
1.0 HWHM	2.6° = 63% of signal	3.5° = 59% of signal
1.5 HWHM	3.8° = 78% of signal	5.3° = 74% of signal
2.0 HWHM	5.1° = 87% of signal	7.0° =82% of signal
2.5 HWHM	6.4° = 92% of signal	8.8° = 88% of signal
3.0 HWHM	7.7° = 95% of signal	10.5° = 91% of signal
3.5 HWHM	8.9° = 97% of signal	12.3° = 94% of signal
4.0 HWHM	/	/

Remark : azimuth distributions

- Circular bins

Space angle (between the reconstructed track and the true track)

$$\psi = \mathrm{acos}[\cos(\theta_{rec}) \cos(\theta_{true}) + \sin(\theta_{rec}) \sin(\theta_{true}) \cos(\phi_{rec} - \phi_{true})]$$

Bin opening :

Percentage of signal	Bin opening (COMPLETE SKY)	Bin opening (NADIR)	Bin opening (CENTRE)	Bin opening (HORIZON)
50% ("median")	3.4° (SY= 3.9°)	3.1°	3.5°	4.1°
75%	5.8°	5.4°	5.8°	6.6°
90%	9.2°	8.9°	9.0°	9.9°
95%	11.8°	11.8°	11.1°	12.4°

Open the bin = increase signal but background too

→ find the good compromise

6. Still to do

- Include 100% of data
- Compute effective areas, S/N ratios, flux limits (whole sky and candidate sources)
- See the influence of the binning choice
- Further improvement of the cuts
- Investigate the “errors” issue