Quality parameters for atmospheric neutrino separation

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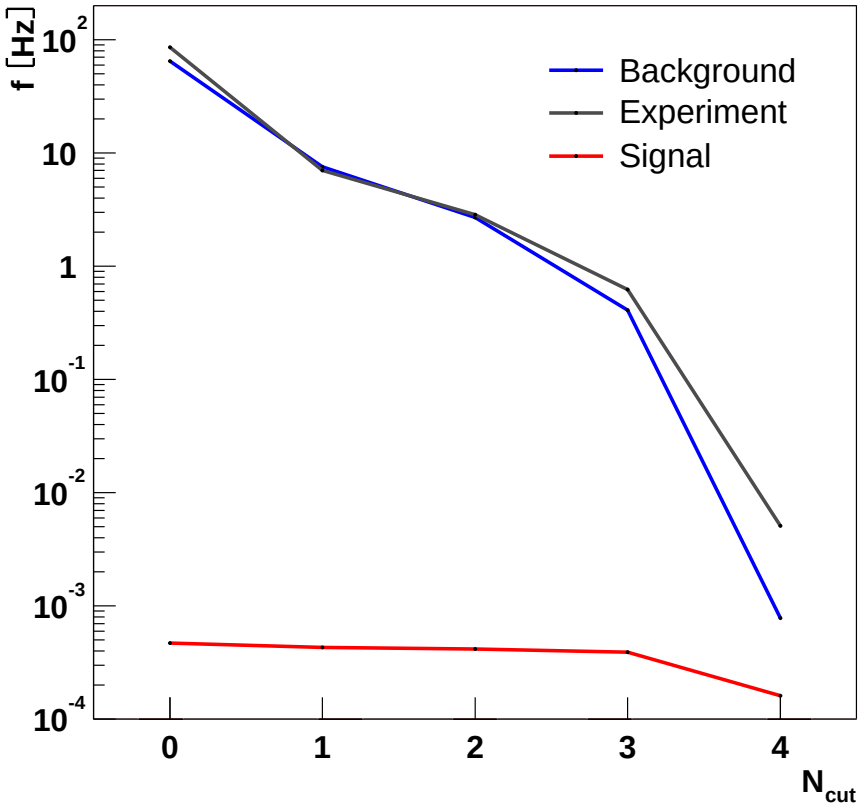
Stockholm

Overview

- Analysis
  - Standard analysis
  - Topological parameters
  - Quality parameters
- Final sample
  - Background extrapolation
  - Energy reconstruction
  - Comparison to AMANDA-B10

Standard analysis



Data samples

Experimental data : 43.2 days

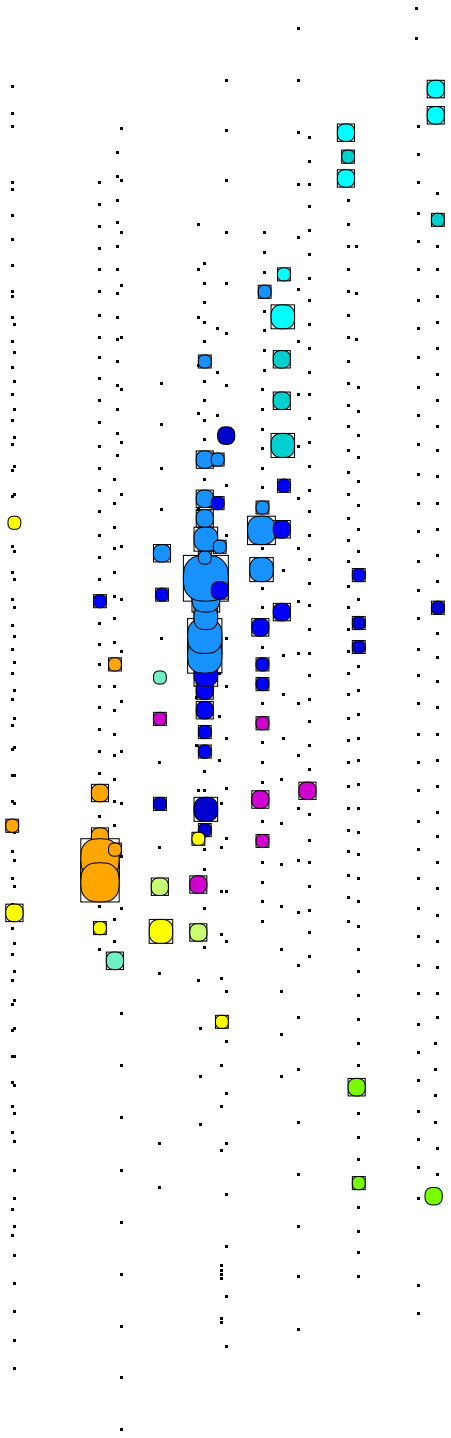
Background simulation : 1.16 days

Signal simulation : 110 days

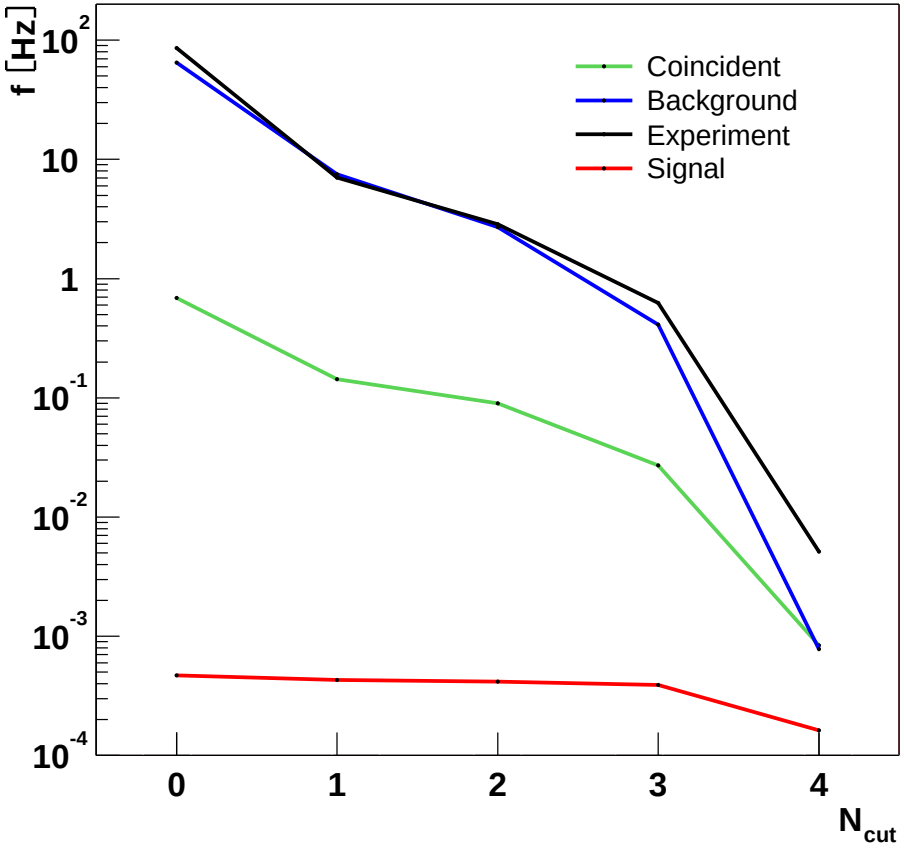
Zenith angle selections

1. $\max\left(\theta_{DW}, \theta_{LF}\right) > 70^\circ$
2. $\max\left(\theta_{LK}^{[1]}(DW), \theta_{LK}^{[1]}(LF)\right) > 80^\circ$
3. $\theta_{LK}^{[16]} > 80^\circ$
4. $\theta_{bayes} > 90^\circ$

Coincident muon candidate



Coincident muons



⇒ difficult to handle : ~~θ_{bayes}~~ - Cut

Simulation

- air shower
- muon propagation
- merge events ($\Delta t = \pm 5\,\mu\mathrm{s}$)
- detector response

Rate calculation

$$f_{\text{coinc }\mu} \approx f^2_{\text{atm. }\mu} \cdot \Delta t$$

$$f_{\text{coinc }\mu} = 0.69\,\mathrm{Hz}$$

Data sample

Coincident simulation : 18.6 days

Topological parameters

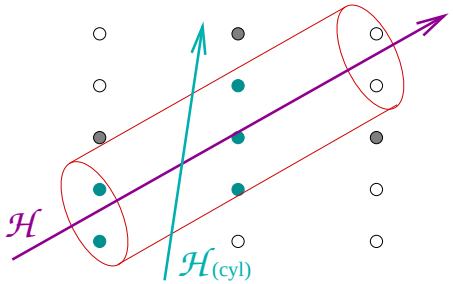
Investigate hit pattern $\mathcal{T}$ relative to the track hypothesis $\mathcal{H}$

Cylinder

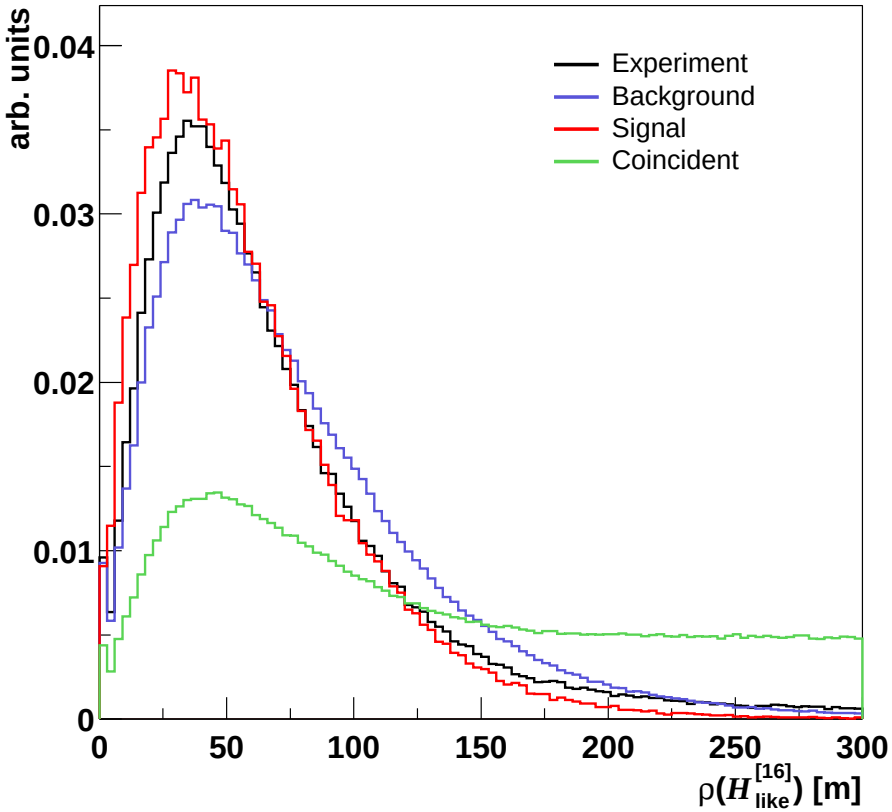
$$\rho = 50\,\mathrm{m}$$

Parameters

- number of hits in cylinder
- fraction of hits in cylinder
- *smoothness* of hits



Reconstruction
Full reconstruction using *only* hits in the cylinder



$\rightsquigarrow$ Suppression of coincident muon events by a factor of ~ 10

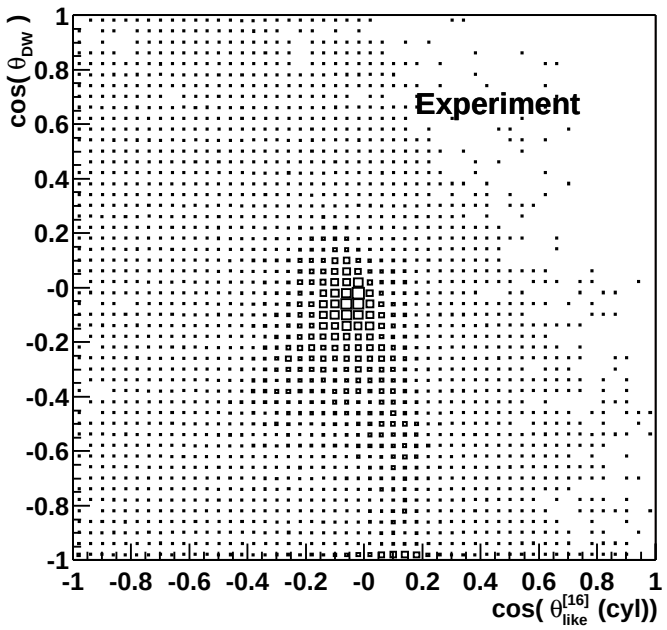
Quality parameters

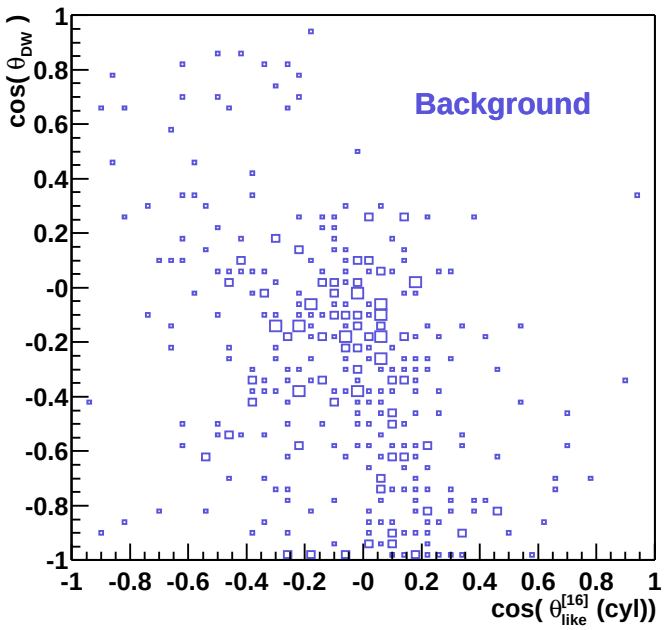
À Low number of simulated background events
  ⇝ combine observables into **one** quality parameter
    ⇝ background extrapolation possible

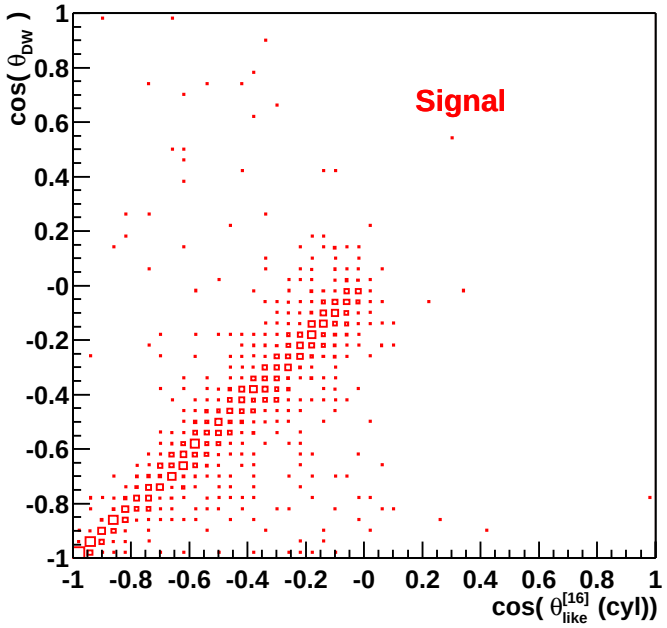
` Simulations and experimental data do not match for many observables
  ⇝ use correlations of observables which are **equally** affected.

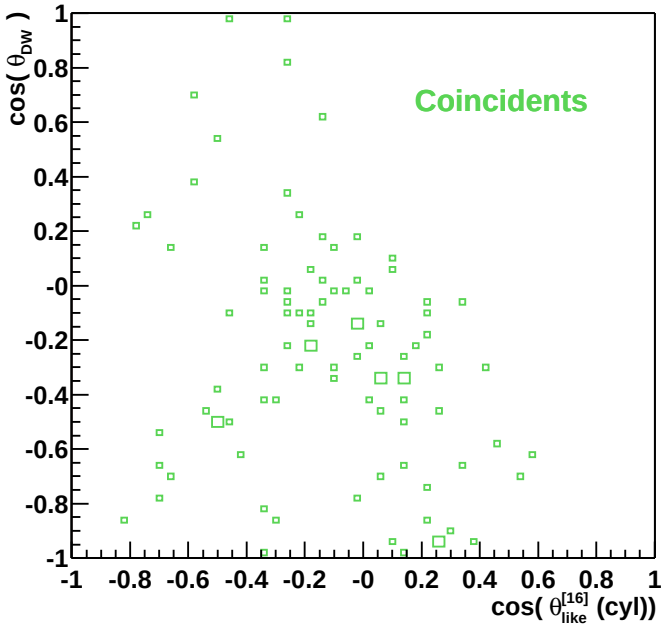
´ Minimize influence of systematic effects
  ⇝ systematic checks using well reconstructed **downgoing** muon events.

Correlations



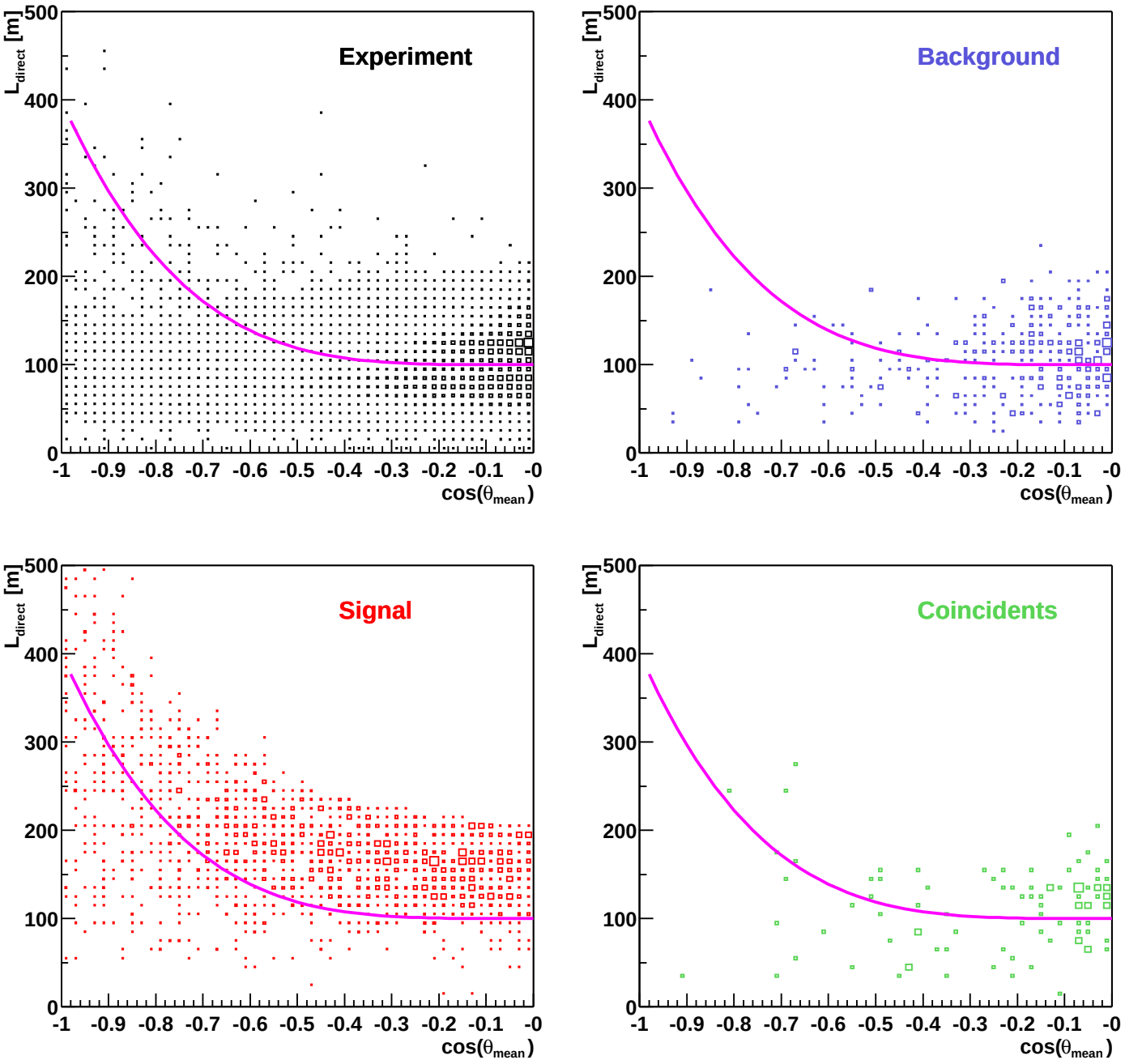






Correlation of different track reconstructions

Correlations



Correlation of track length and incident angle

Systematic checks

Reference $\theta_{mean} > 90^\circ$

Signal : good events

Upward tracks $\theta_{mean} > 90^\circ$

Background : fake events

Experiment : mostly fake events

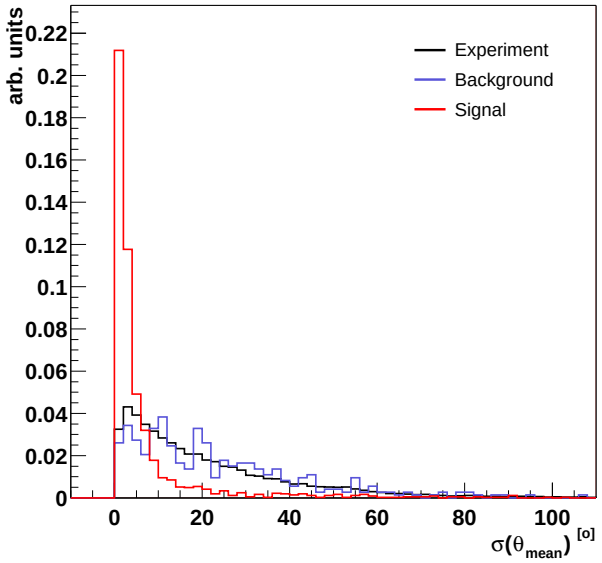
$\rightsquigarrow$ only background and experiment match

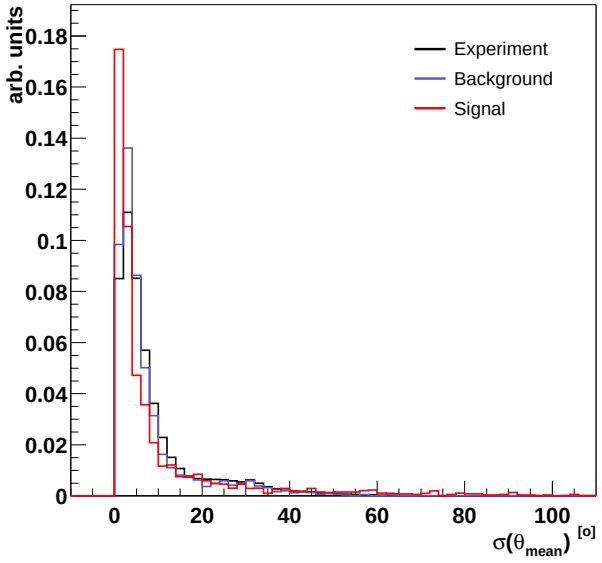
Horizontal tracks $\theta_{mean} = 80^\circ \pm 5^\circ$

Background : good events

Experiment : mostly good events

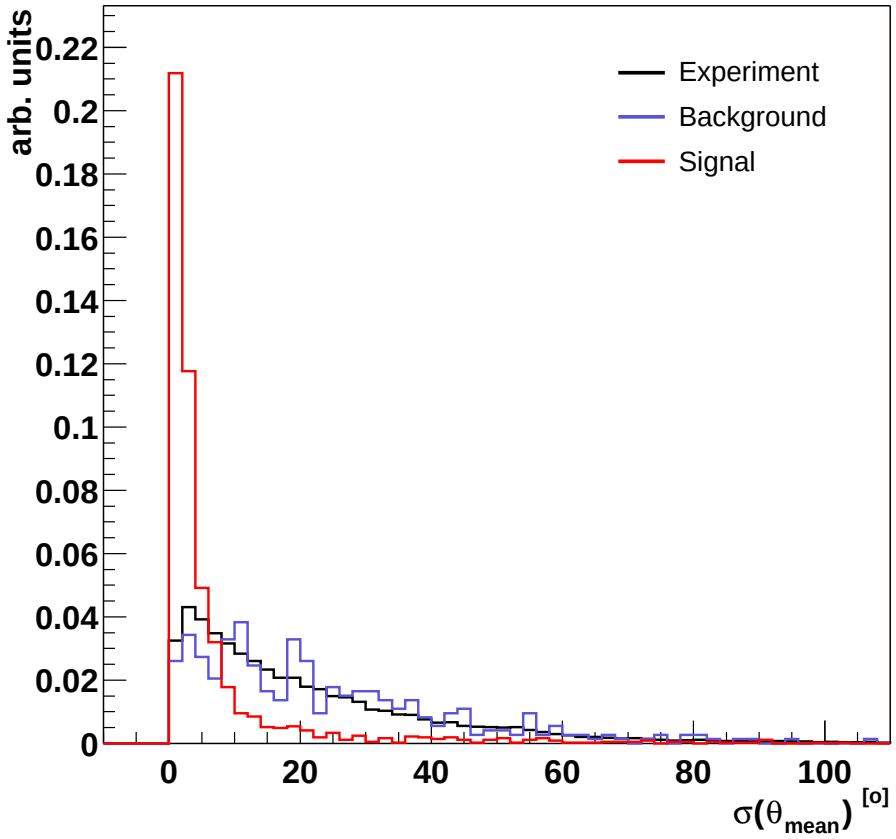
$\rightsquigarrow$ matching of background, experiment and signal





Final variables

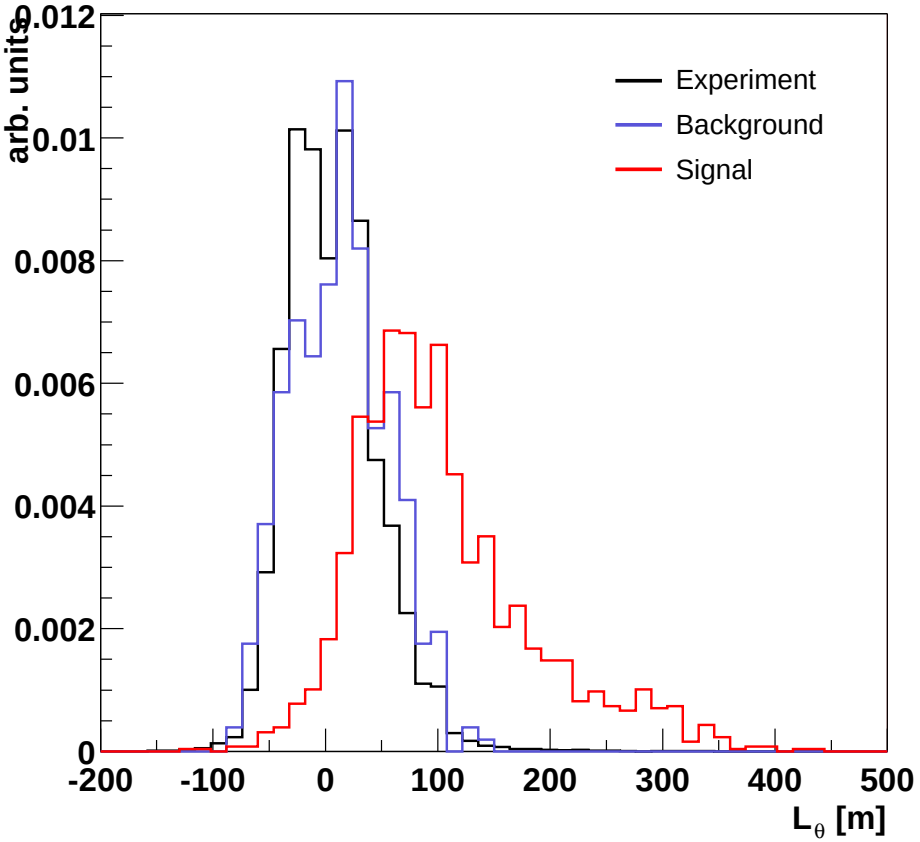
Stability of reconstruction



$$\sigma(\theta_{mean}) := \sqrt{\langle\theta_j^2\rangle - \langle\theta_j\rangle^2}$$

$j \in \left\{ DW, Lk^{[1]}, Lk^{[16]}, Lk^{[16]}_{(cyl)} \right\}$

Detector aspect ratio

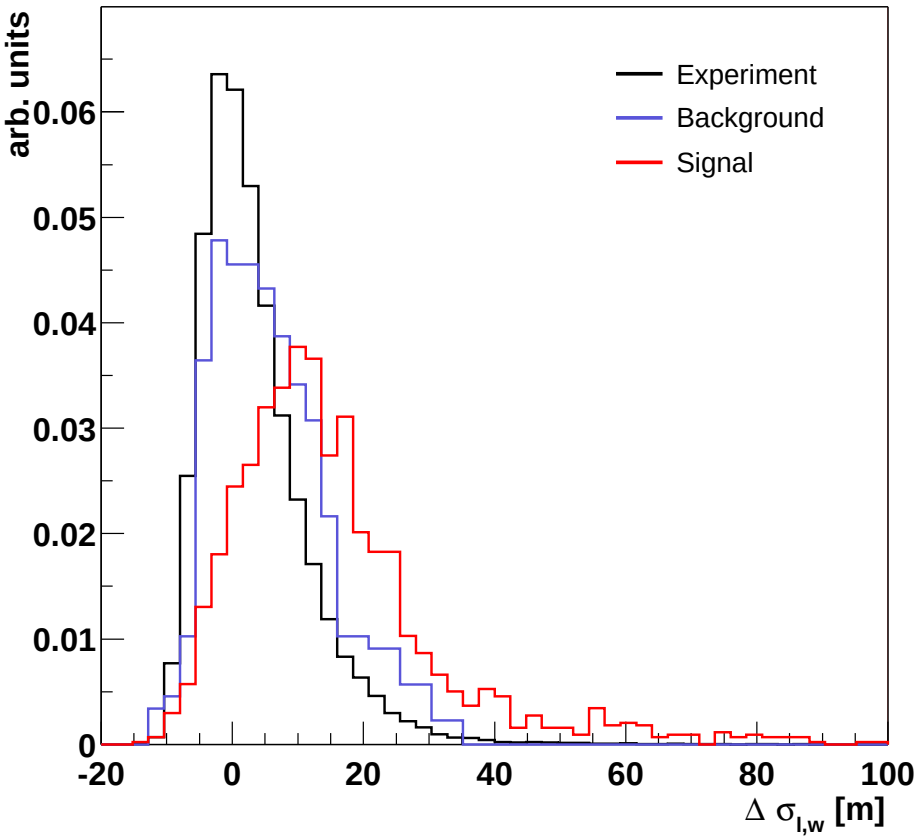


$$L_\theta := L_{direct} - \left(a \cdot \cos(\theta_{mean})^4 + b\right)$$

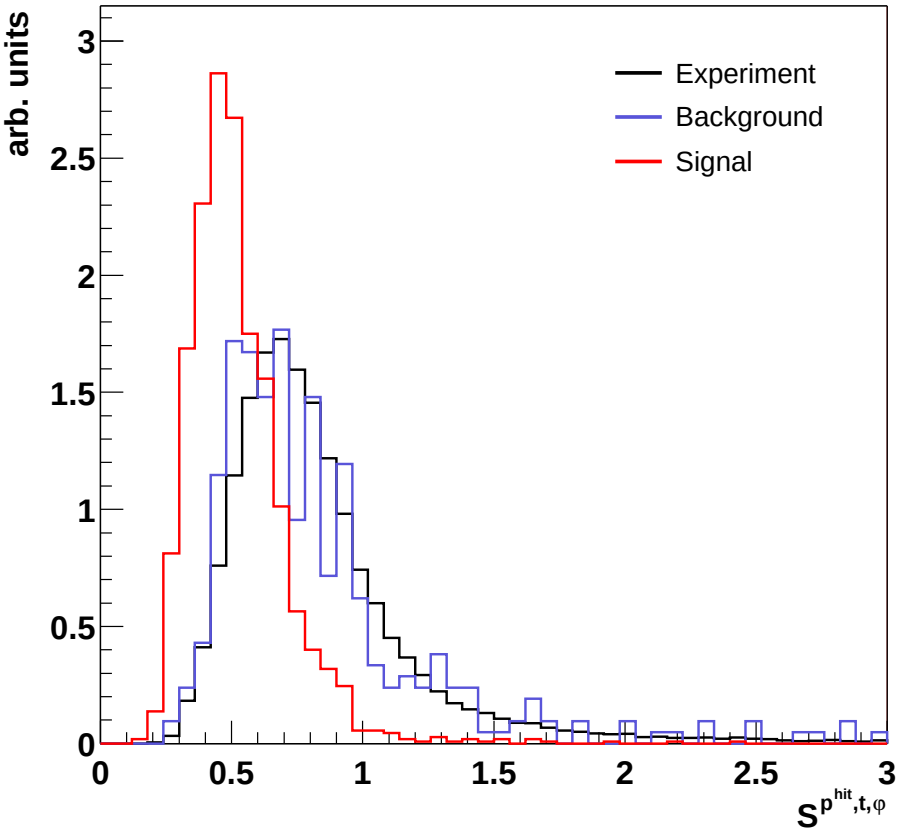
a,b=const

Final variables

Spread of hits



Smoothnesses



$$\Delta\sigma_{l,w} := \sqrt{\sum z^2} - \sqrt{\sum x^2 + y^2}$$

x,y,z in TOI system

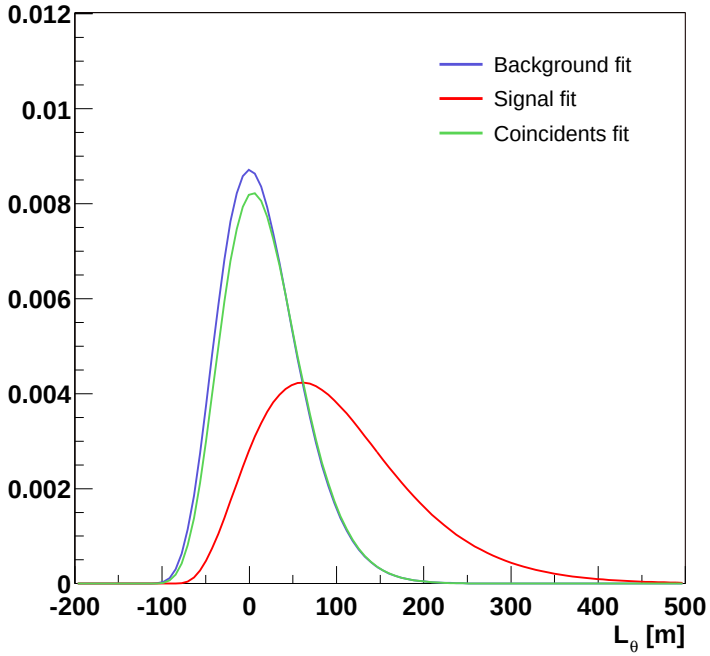
$$S := \sqrt{\left(S^{phit}_{direct}\right)^2 + \left(S^{\phi}(cyl)\right)^2 + \left(S^{t}_{direct}\right)^2}$$

along around time

Parameter probability

Fit distributions

$$f(x)^{(j)} = \alpha\,(x+\delta)^{\beta}\cdot e^{-\gamma x} \qquad j \in \text{sig, back, coinc}$$



Bayes theorem

$$P(j|x) = \frac{P(j)\cdot P(x|j)}{P(x)}$$

- $P(j) = 1 \quad \forall j$
- $P(x) = \sum_j P(x|j)$
- $P(x|j) = f(x)^{(j)}$

Probability density

$$P(j|x) = \frac{f^{(j)}(x)}{\sum_k f^{(k)}(x)} \qquad j,k \in \text{sig, back, coinc}$$

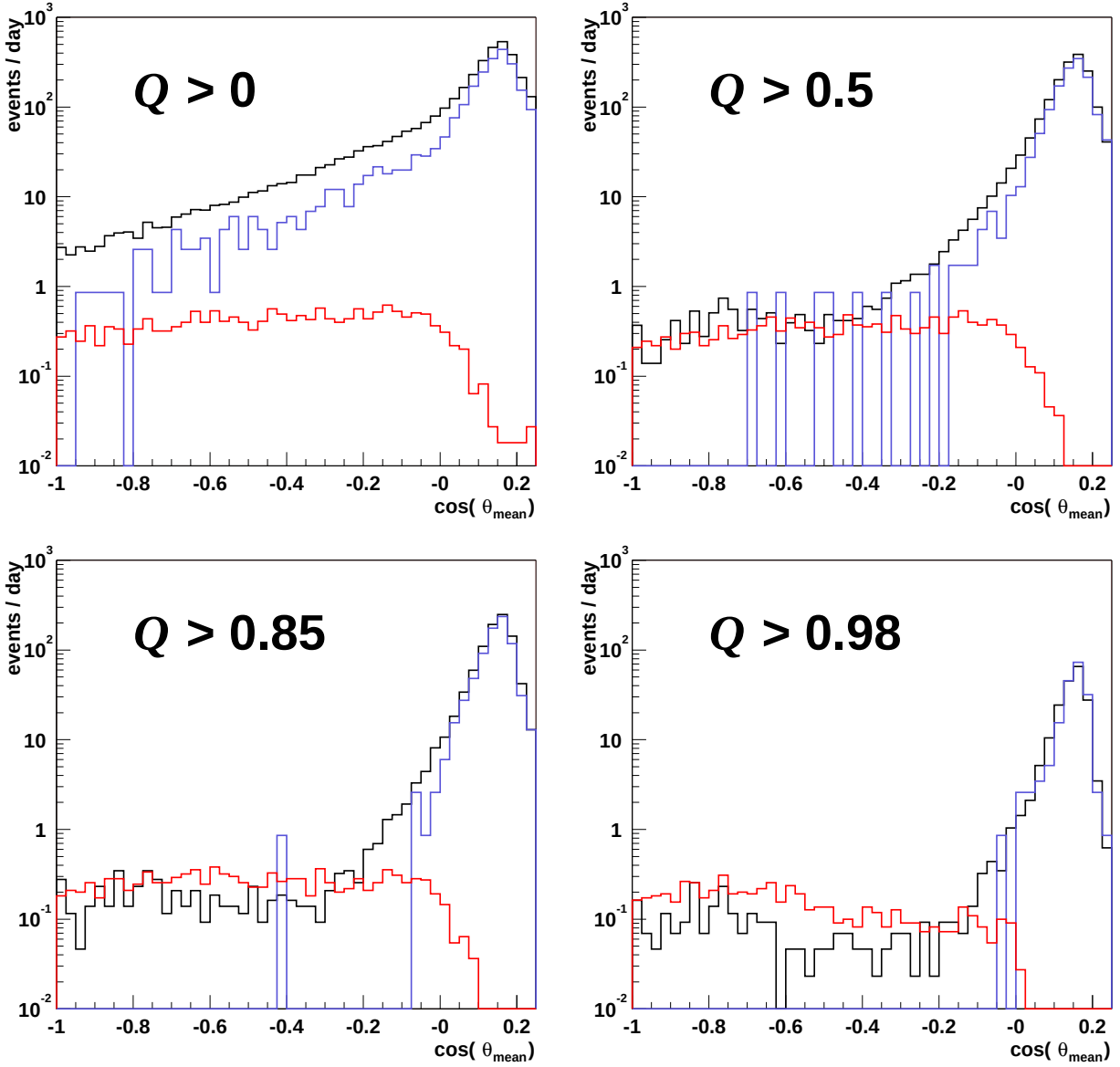
Quality parameter

Combine parameters

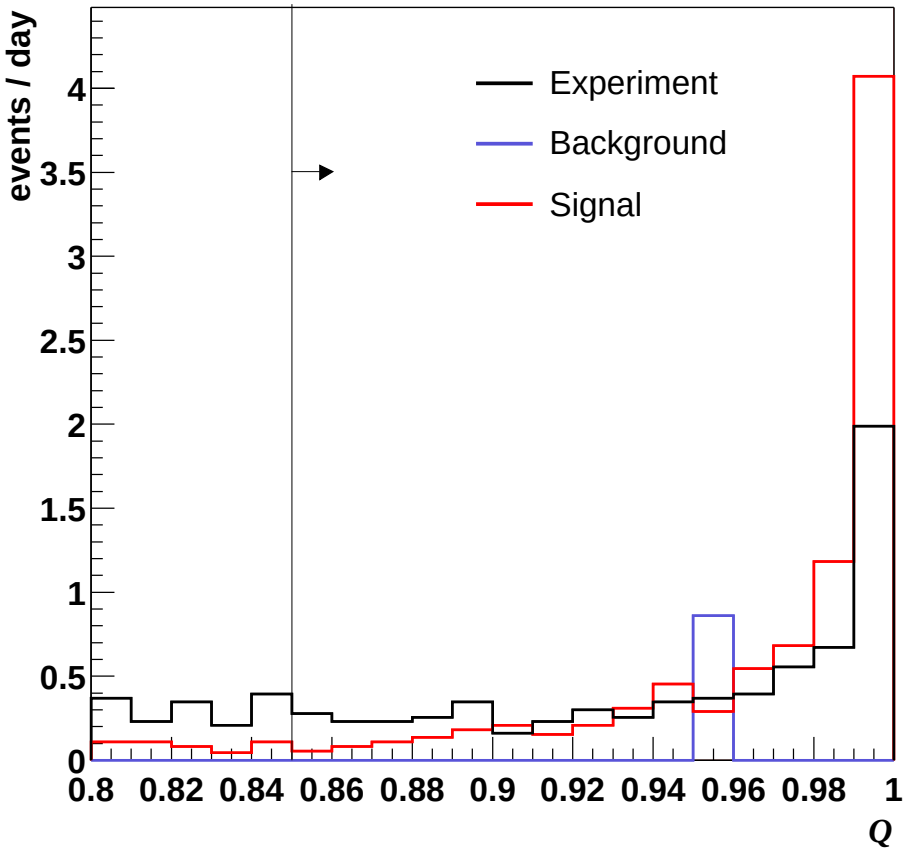
$$\mathcal{Q}(\vec{x}) = \frac{\prod_i P_i(sig|\vec{x})}{\sum_j \prod_i P_i(j|\vec{x})}$$

$i \in \{1, 2, 3, 4\}$

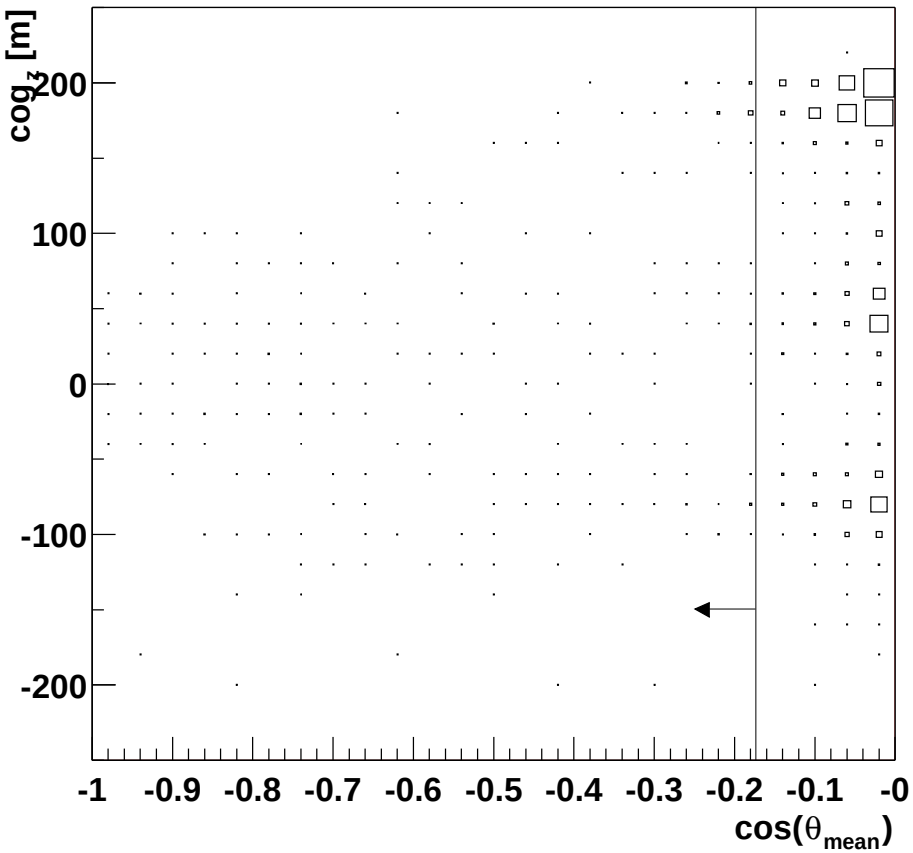
$j \in$ sig, back, coinc



Final Cuts



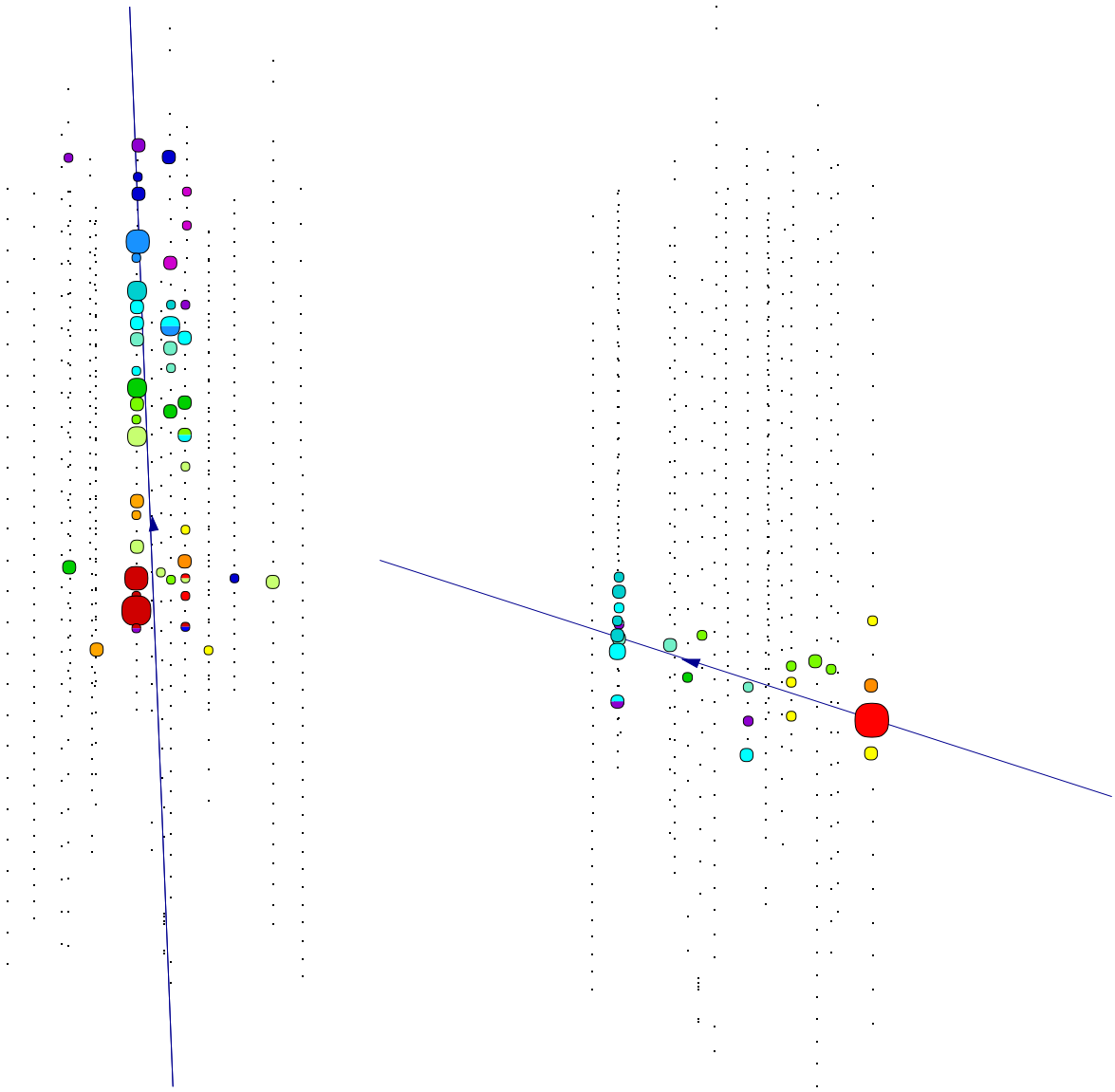
$\mathcal{Q} > 0.85$



$\theta_{mean} > 100$

Results

Neutrino candidates



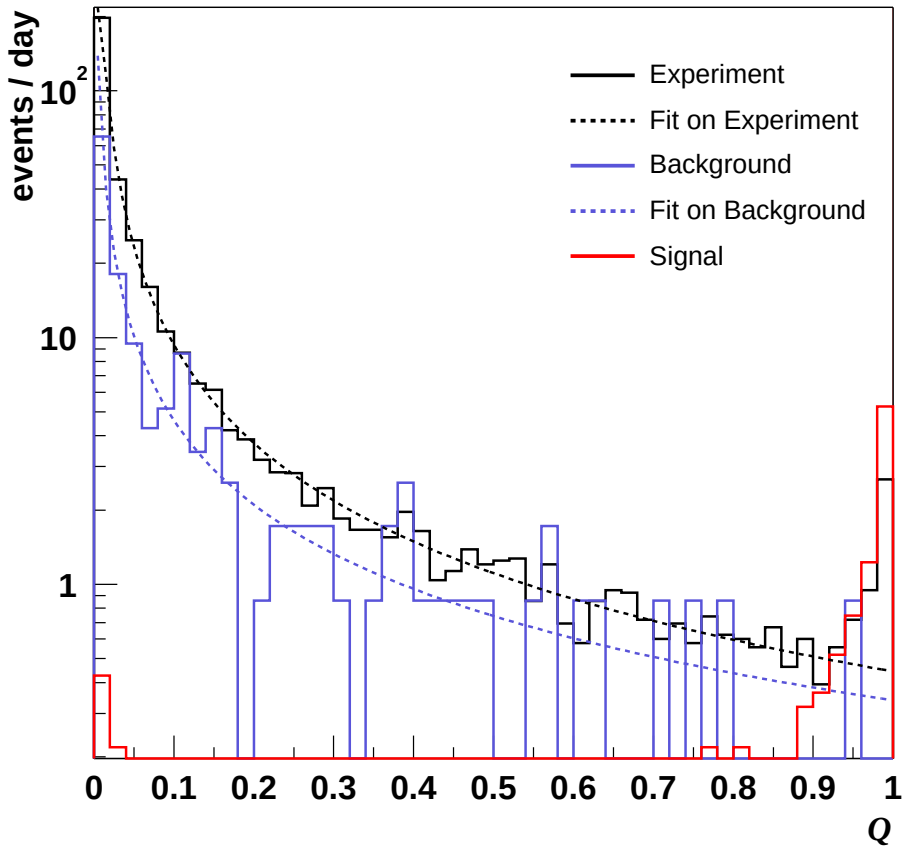
Background extrapolation

Fit

$$N^{BG}(\mathcal{Q}) = N_0^{BG}\frac{1}{\mathcal{Q}^{\alpha}}$$

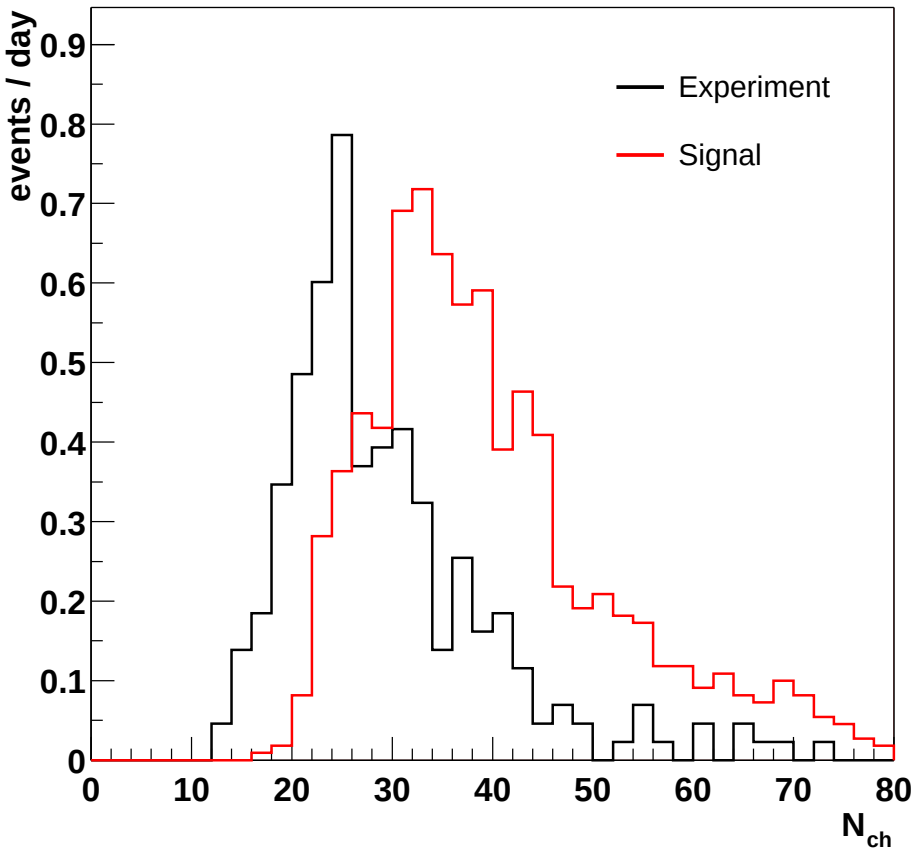
Event rates

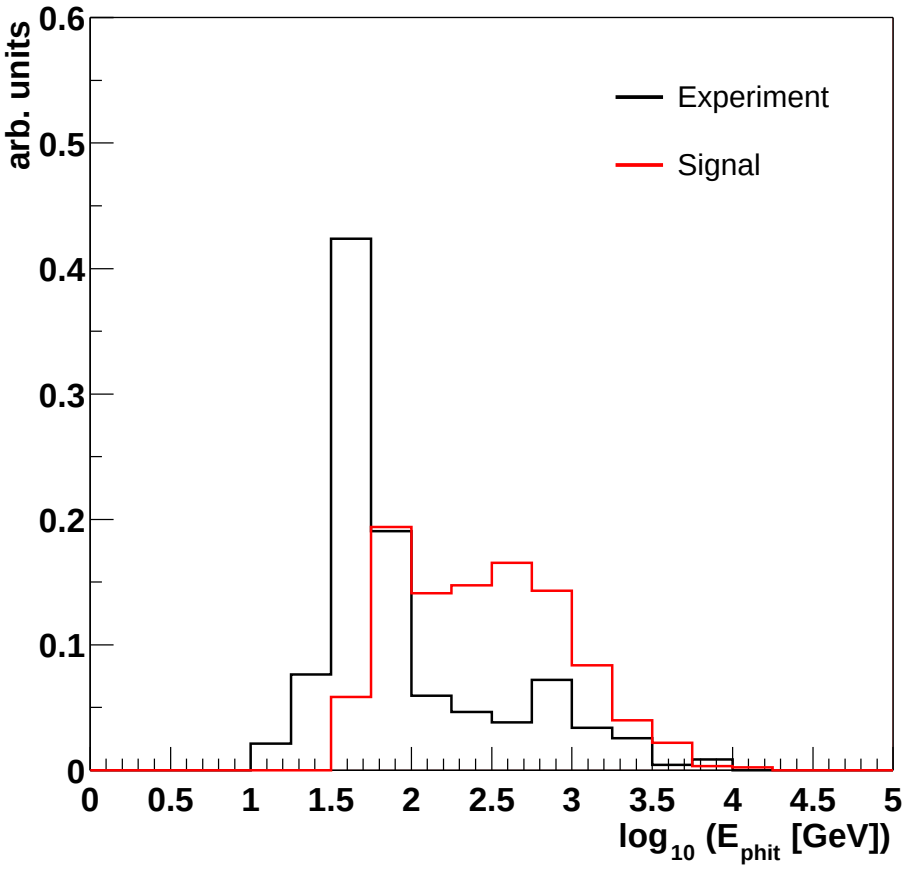
	N_{events}	$f\,[\mathrm{day}^{-1}]$
Signal	908	8.25
Background	1	0.9
Fit background	(120)	2.8
Fit experiment	(160)	3.7
Experiment	236	5.45
Coincident	4	0.2



75% deficit in neutrino rate

Energy reconstruction





Problem: Filewise OM-selection $\rightsquigarrow$ $\mathbf{N}_{ch}$ systematically lower
but shape seems okay

Energy spectrum

Neural Network *by Heiko Geenen*

- 6 input - 3 hidden - 1 output neurons
- trained with flat spectrum
- six input parameters

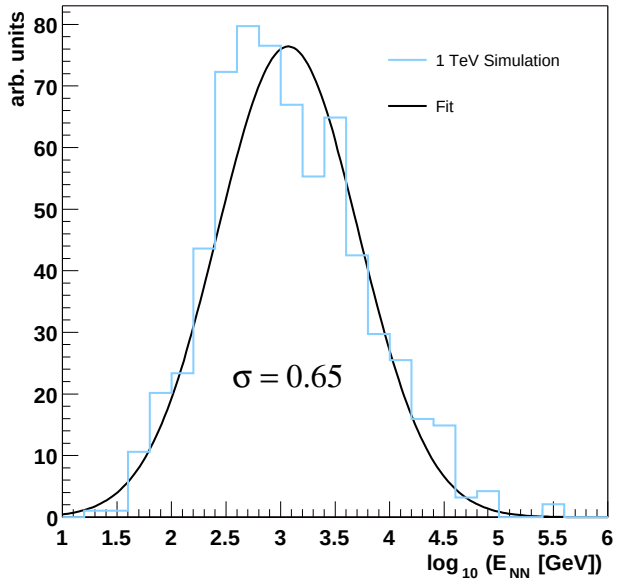
$$\begin{array}{cc} \langle A_{calib} \rangle & N_{ch}^{[1]} \\ \langle LE \rangle & N_{ch} \\ \sigma\,(LE) & \underbrace{\log_{10}\,(N_{hit})} \end{array}$$

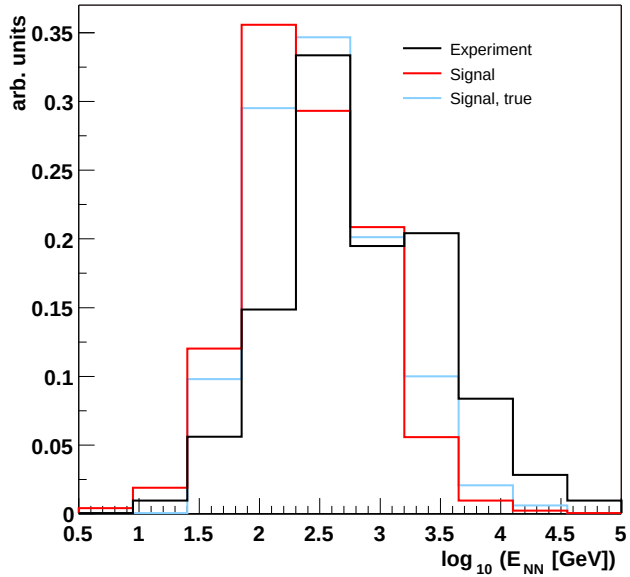
fudge factor $\times$ 1.25

- Energy resolution

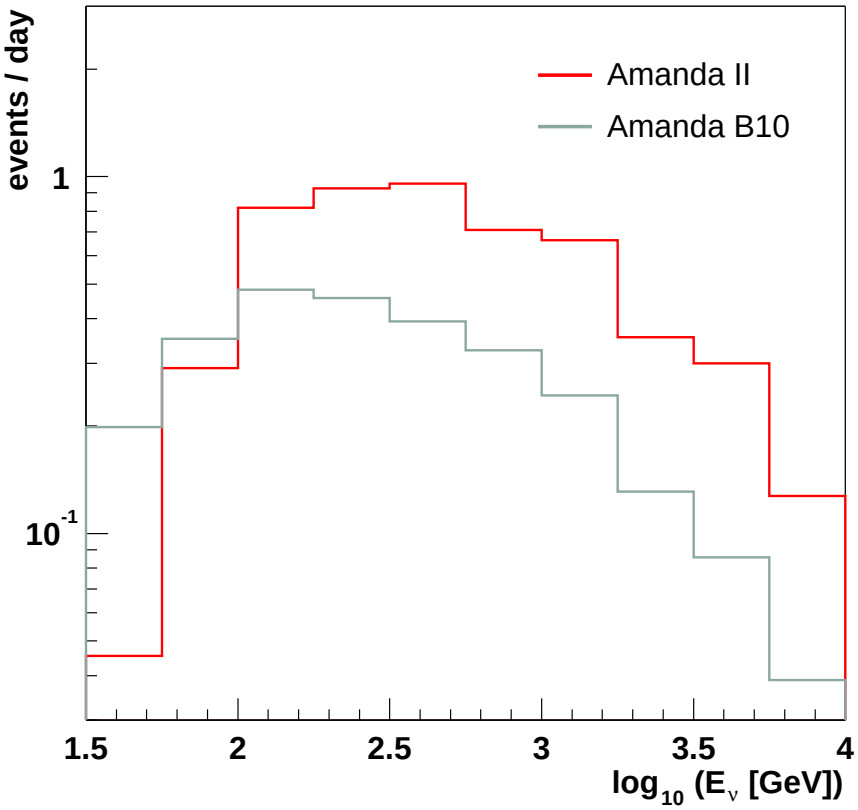
E_{mono}	100 GeV	1 TeV	10 TeV	100 TeV
$\sigma\left(\log_{10}(E_{NN})\right)$	0.53	0.65	0.65	0.61

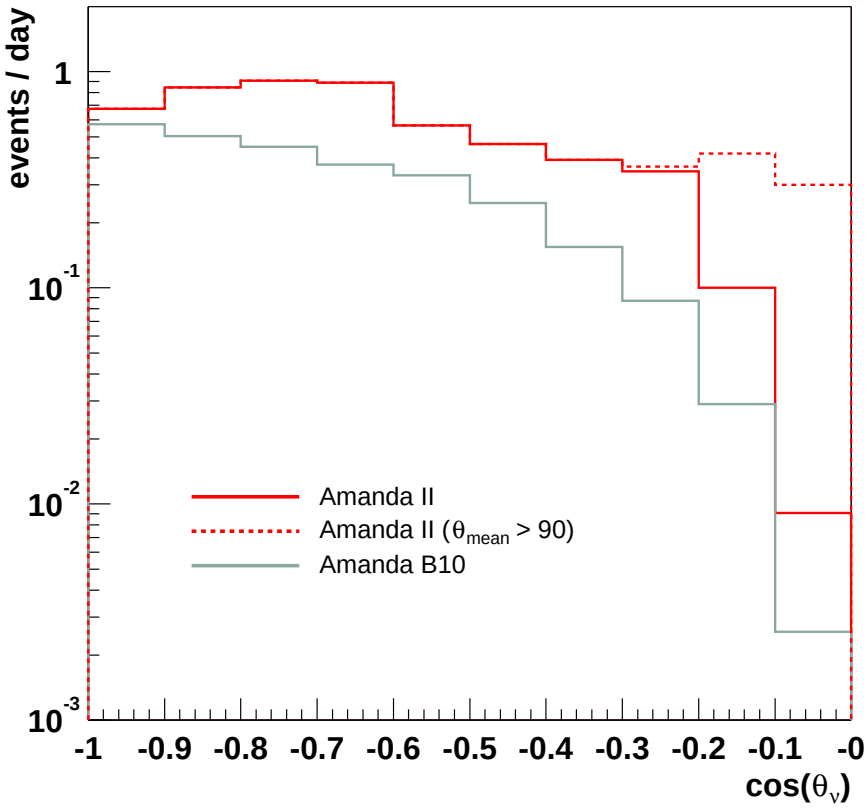
à energy estimate possible





Comparison to AMANDA-B10





Different systematics $\rightsquigarrow$ compare signal at same background level ($< 15\%$)

Increased sensitivity to **higher energies** and to the **horizon**

Summary

- **Coincident muons**
  - 4 identified
  - 4 simulated
  - 4 suppressed
- Small number of parameters
  Ù **Simplification** of analysis
- Quality parameter
  Ù Background **extrapolation**
- Neural network
  Ù Energy **estimate**

Needs more investigation

- 8 Poorly described variables
- 8 Neutrino deficit

Diploma thesis
http://www.ifh.de/∼sboeser/