

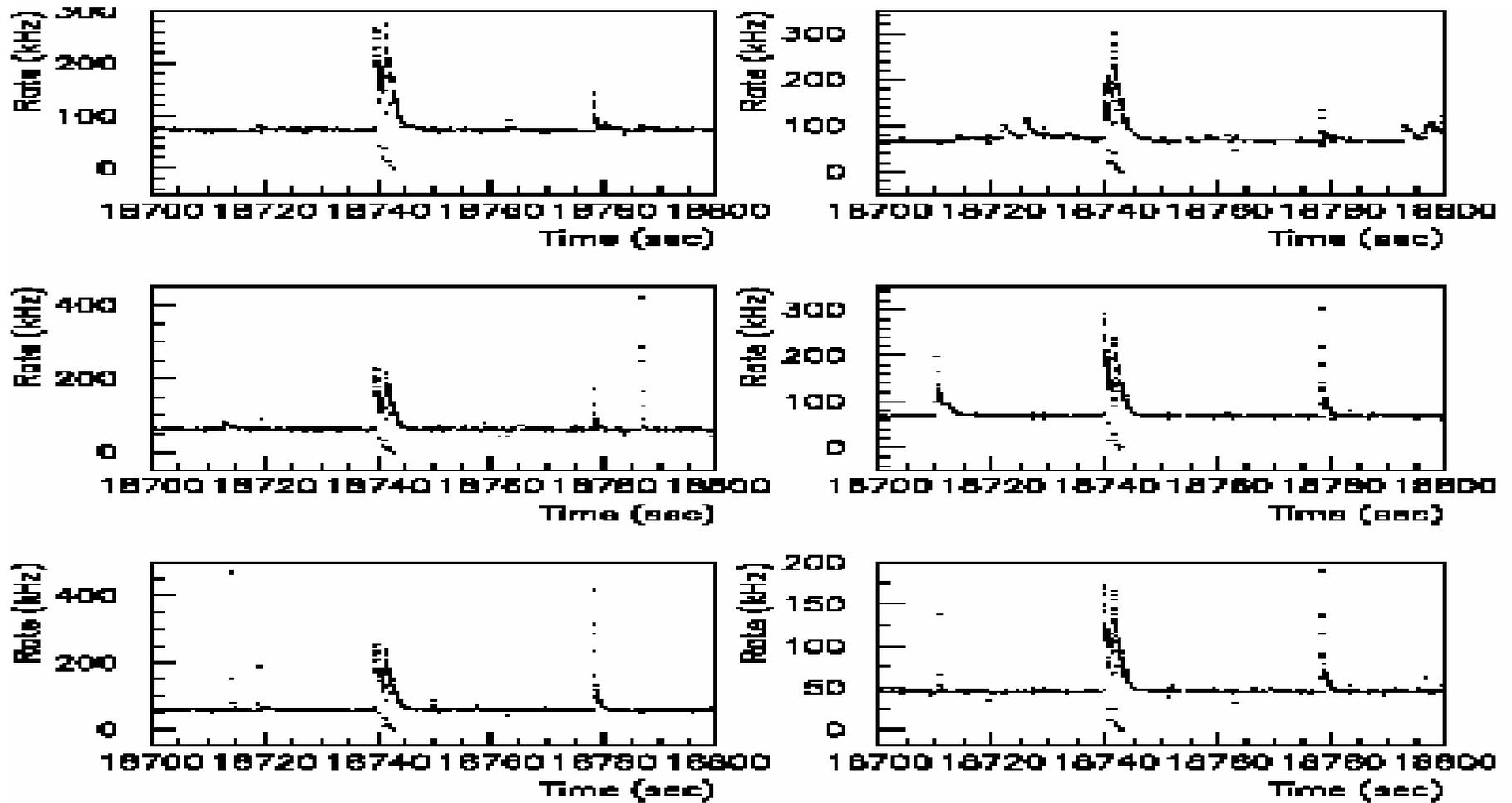
NESTOR

Neutrino **E**xtended **S**ubmarine **T**elescope with **O**ceanographic
Research

**Reconstruction, Background Rejection
Tools and Methods**

Background Sources

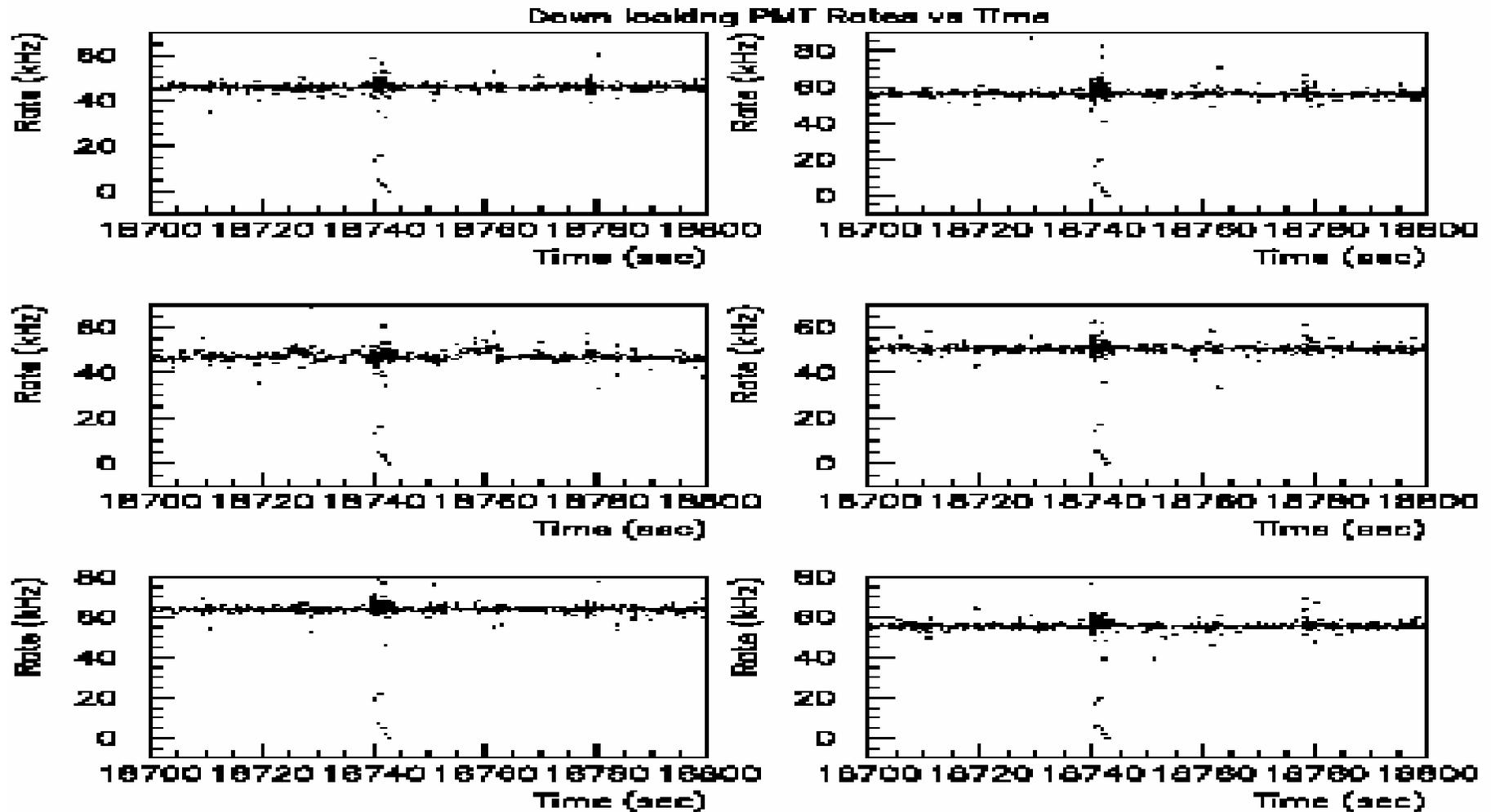
Bioluminescence Activity



PMT Rates vs Time : Up-Looking PMTs

Background Sources

Bioluminescence Activity



PMT Rates vs Time : Down-Looking PMTs

Background Sources

Bioluminescence Activity

- Light Bursts with duration 1-10sec
- Site depended
- Decreases exponentially with depth
- Seasonal variations
- Correlated with water currents
- Contributes to detector dead time

Background Sources

Bioluminescence Activity

Emitted light at the single photoelectron level

Number of Collected P.E.s

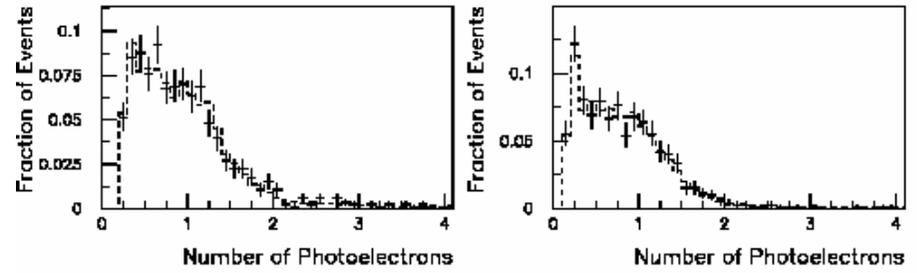
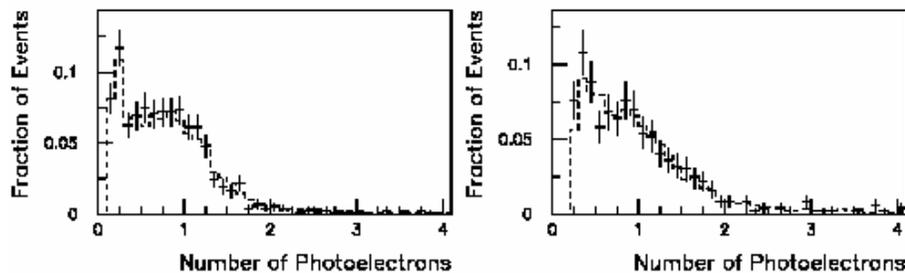
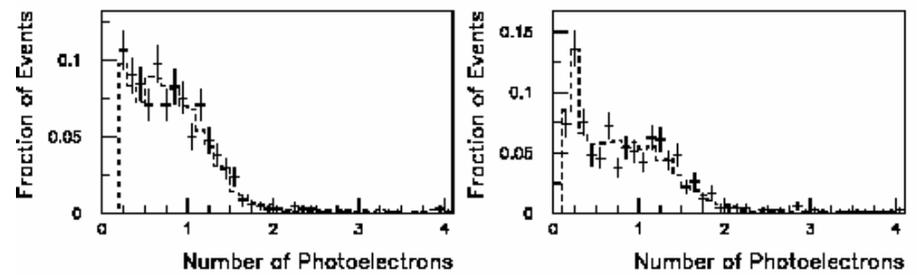
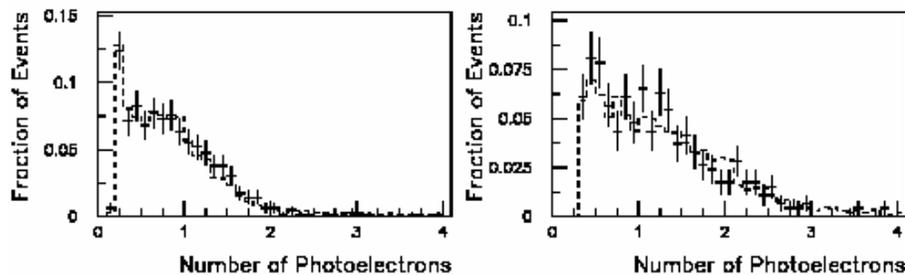
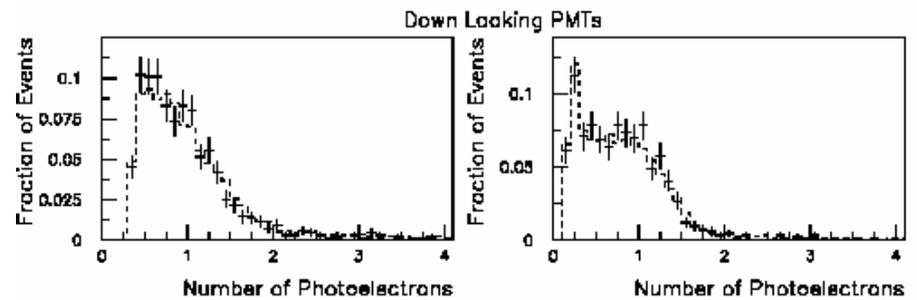
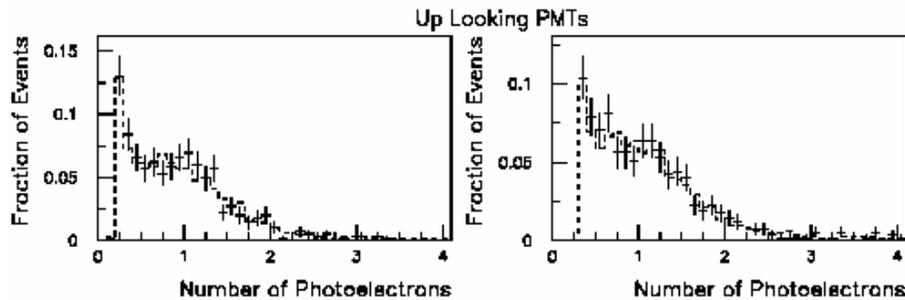
Trigger: = 4fold Coincidence



During Bioluminescence Activity



Bioluminescence Activity Excluded



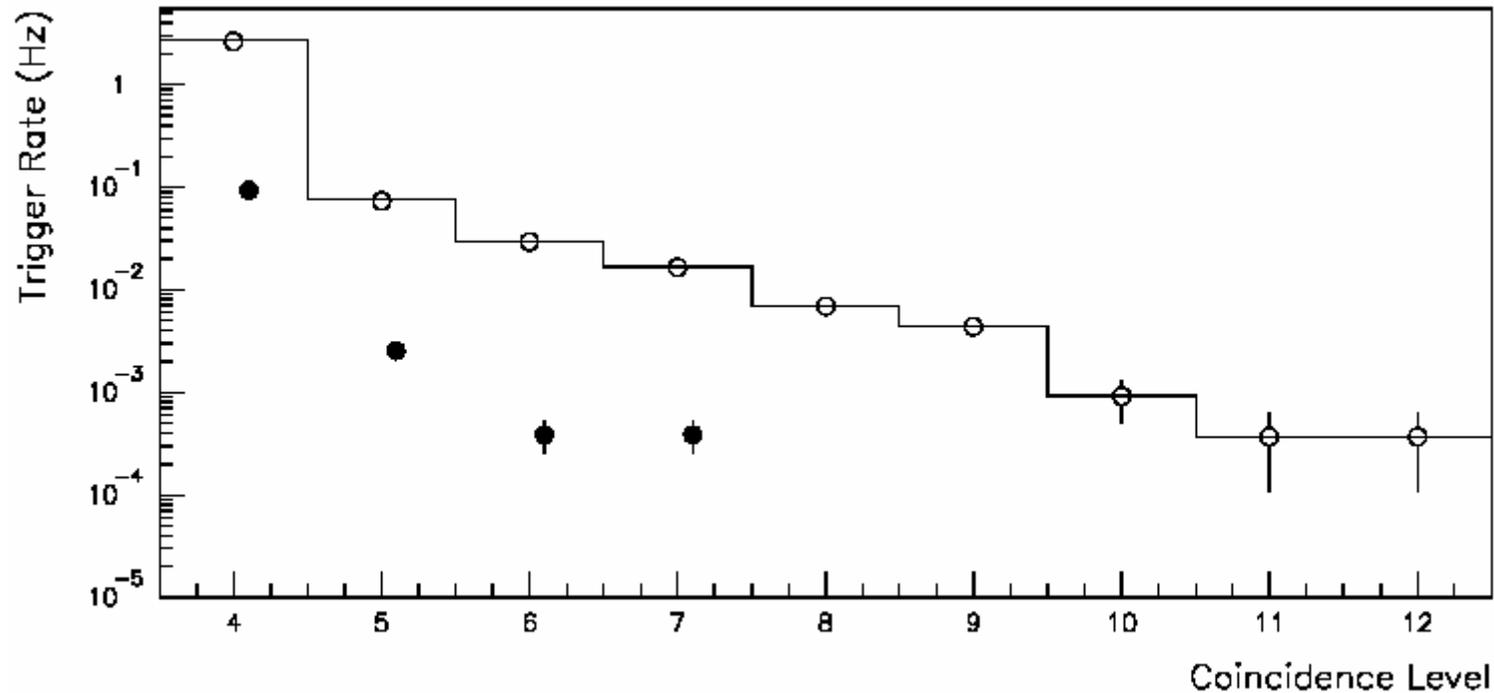
Background Sources

Bioluminescence Activity

Bioluminescence Contribution to the Total Trigger Rates

Bioluminescence Occurs for the $1.1\% \pm 0.1\%$ of the Active Experimental Time

- Total Trigger Rates
- Bioluminescence Contribution to the Total Trigger Rates
- Experimental Trigger Rates from Periods Without Bioluminescence



Background Sources

K^{40} beta decay

Increasing Thresholds does not affect seriously the detection efficiency

Data Collected with 4fold Majority Coincidence Trigger

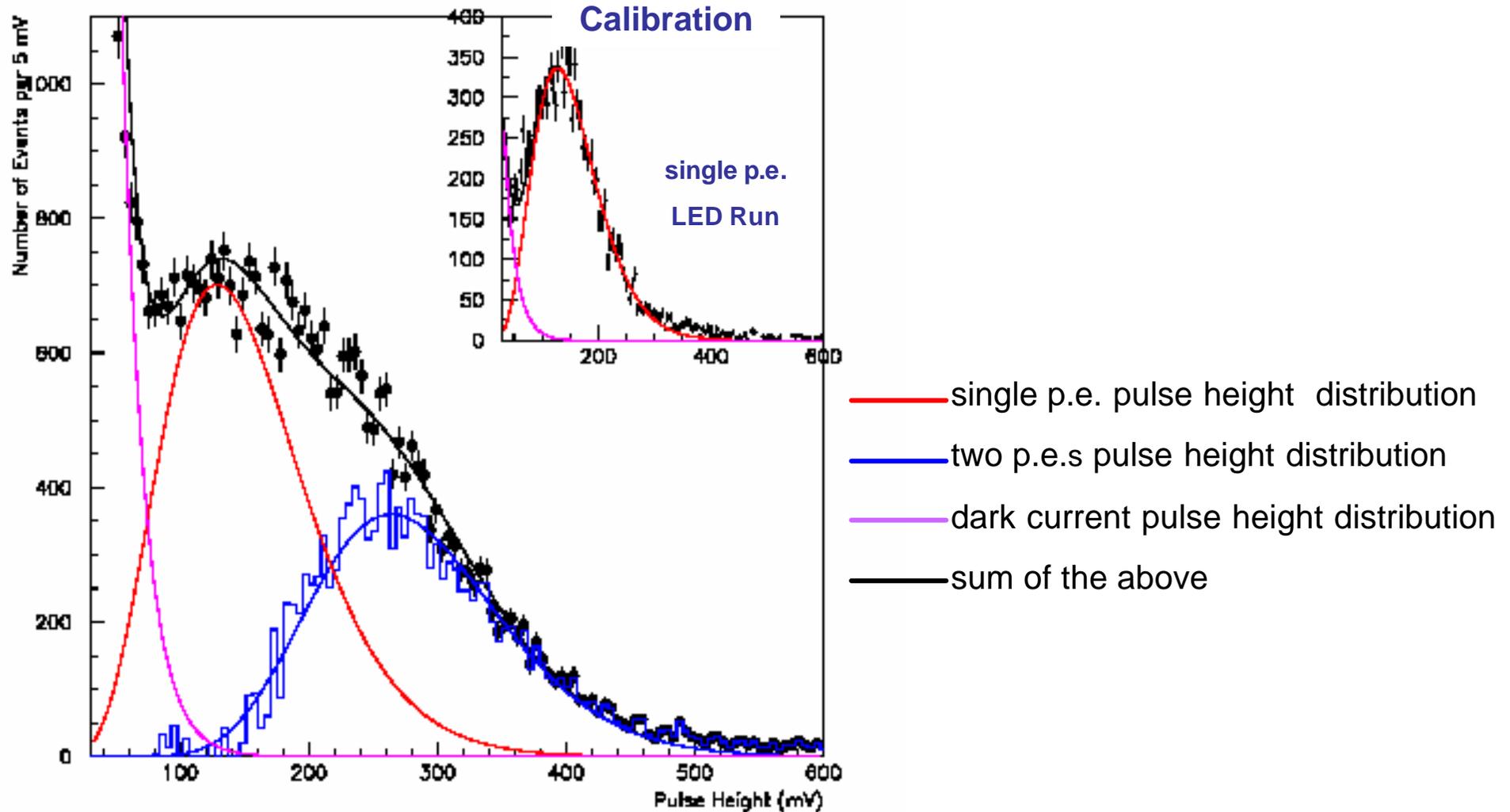
	Thresholds at 30 mV	Thresholds at 120 mV
Measured Total Trigger Rates (greater or equal to 4fold)	2.61 ± 0.02 Hz	0.12 ± 0.01 Hz
M.C. Prediction (atmospheric muons only)	0.141 ± 0.005 Hz	0.12 ± 0.01 Hz

Background Sources

K^{40}

K^{40} radioactivity can be used for calibration purposes in deep sea

Data from a depth of 4000 m: PMT Pulse Height Distribution

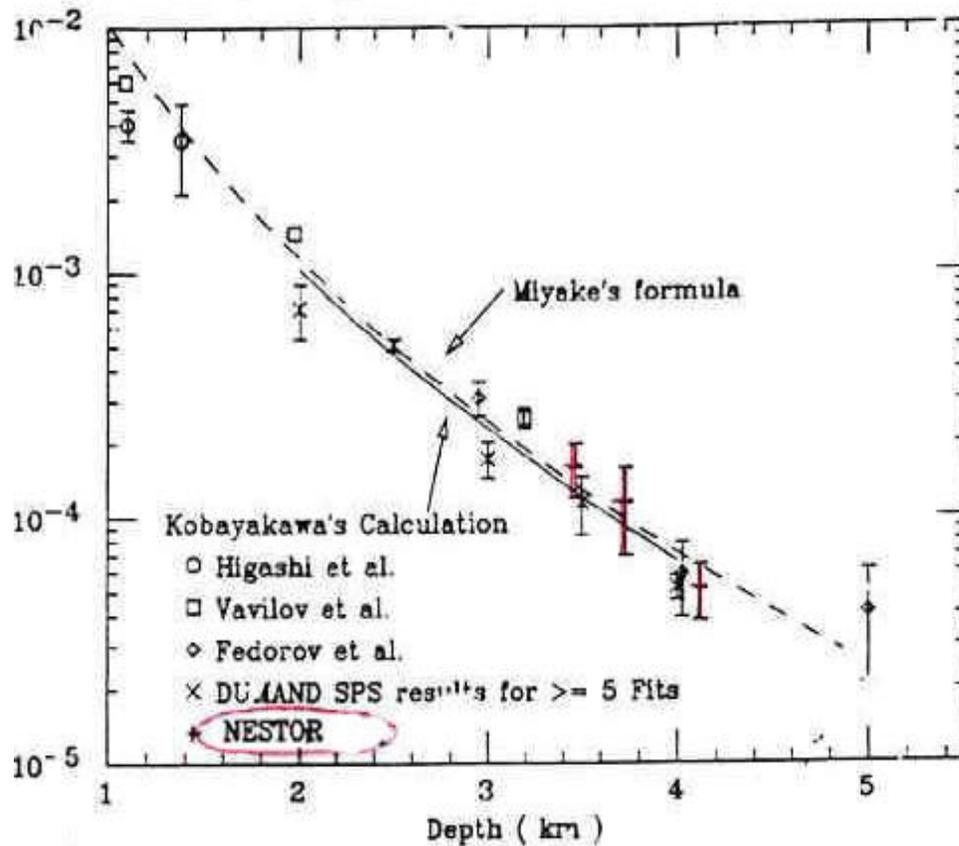


Background Sources

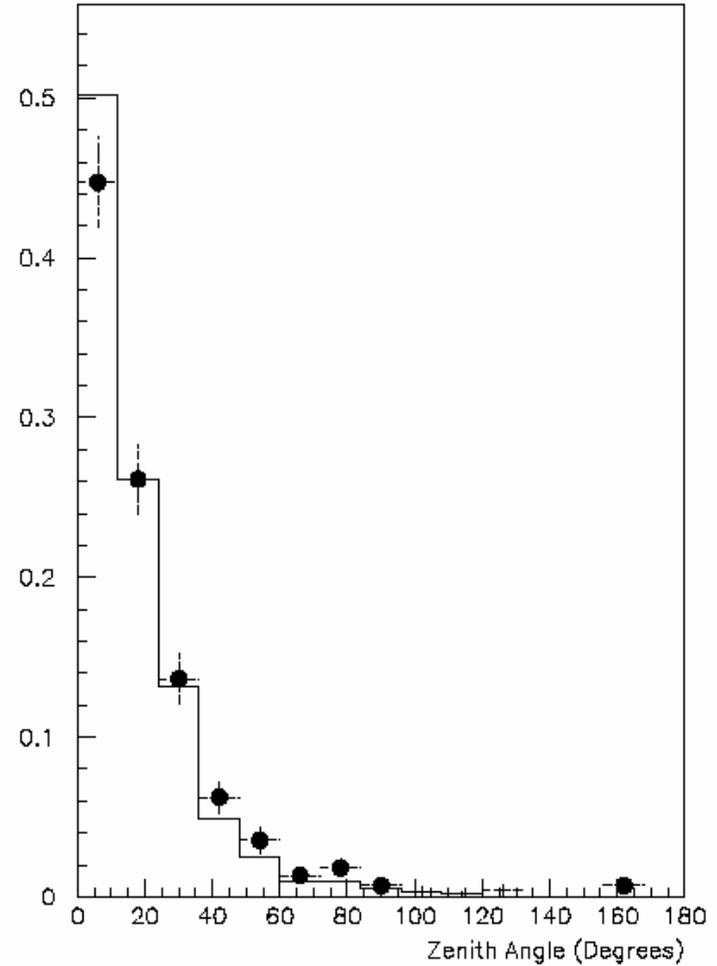
Cosmic ray muon background

Atmospheric muon angular distribution
Okada parameterization

Depth intensity curve



Zenith Angular Distribution



Background Sources

Cosmic ray muon background

**Down coming atmospheric muons can be misreconstructed as
upcoming neutrino induced muons (mirror tracks)**

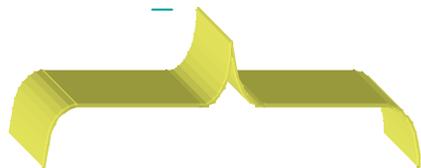
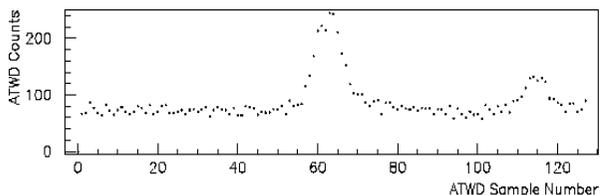
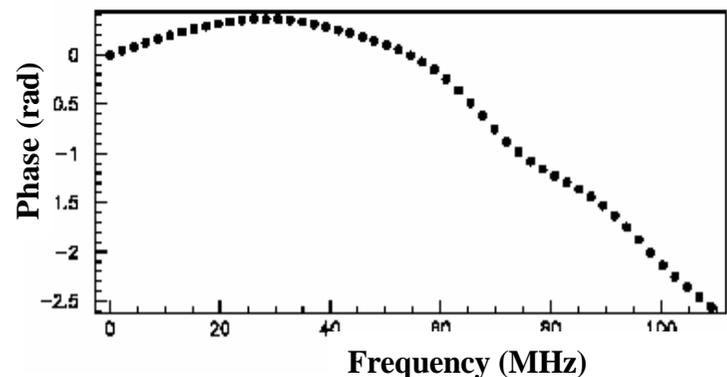
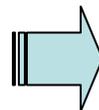
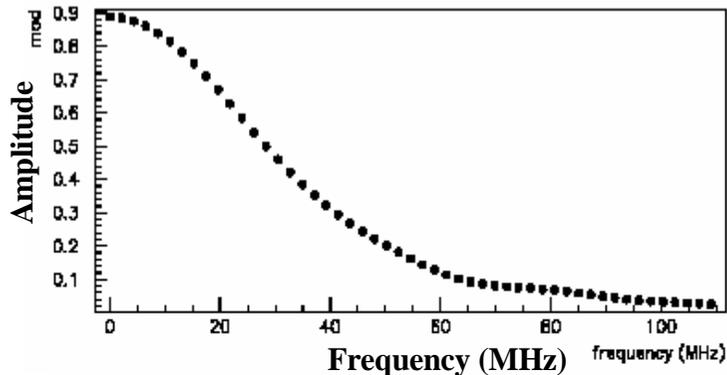
**By using the accumulated charge on each PMT we can reduce the
mirror track background**

(the reduction depends on the available degrees of freedom)

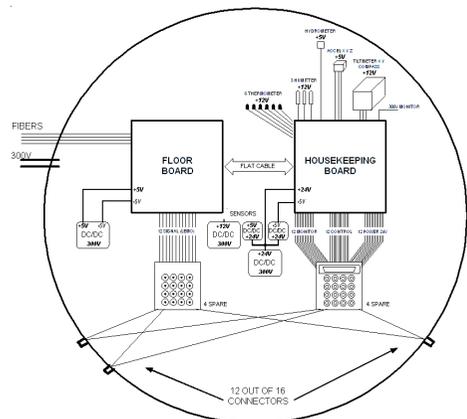
Detector Preparation

Attenuation Correction

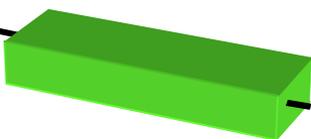
Fourier Transform-Comparison



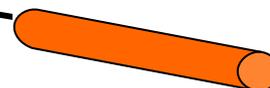
Reference waveform



Electronic delay lines and amplifier

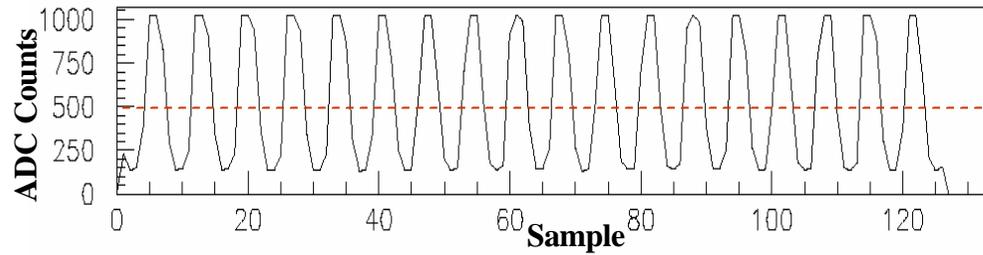


Coaxial cable

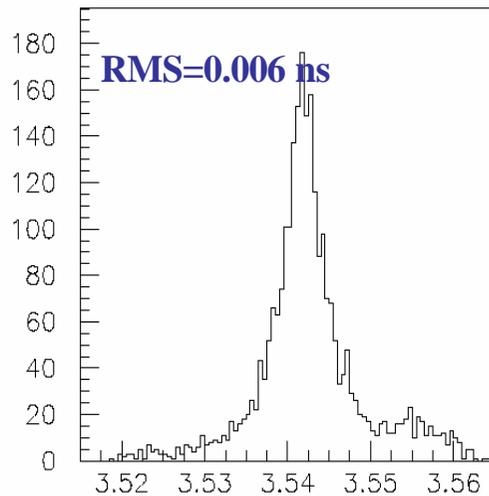


Signal processing

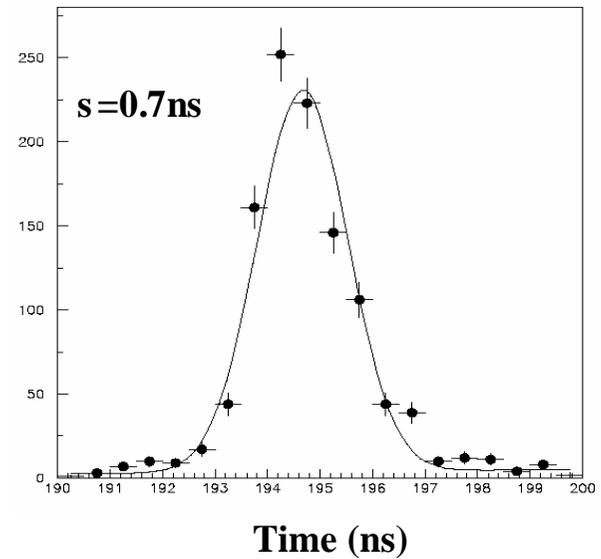
40 MHz Clock Waveform Capture



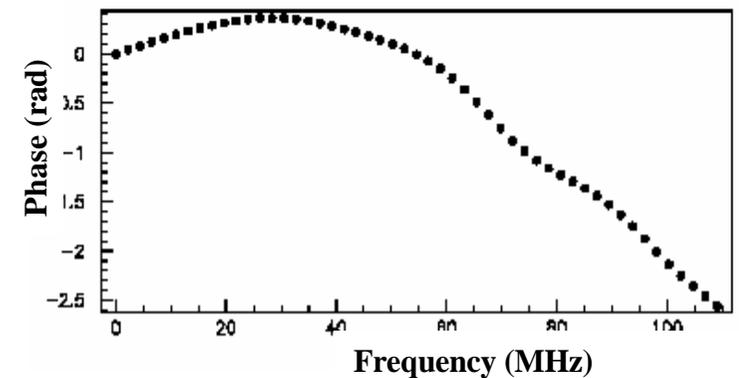
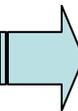
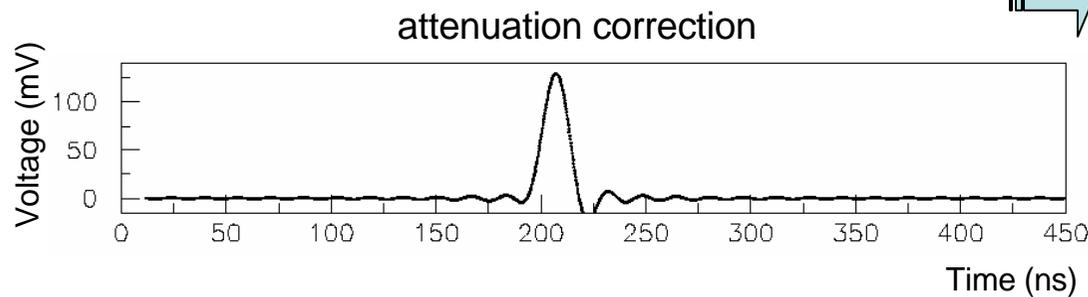
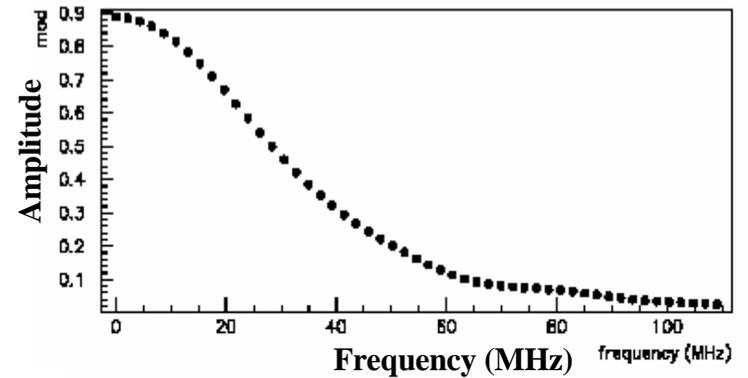
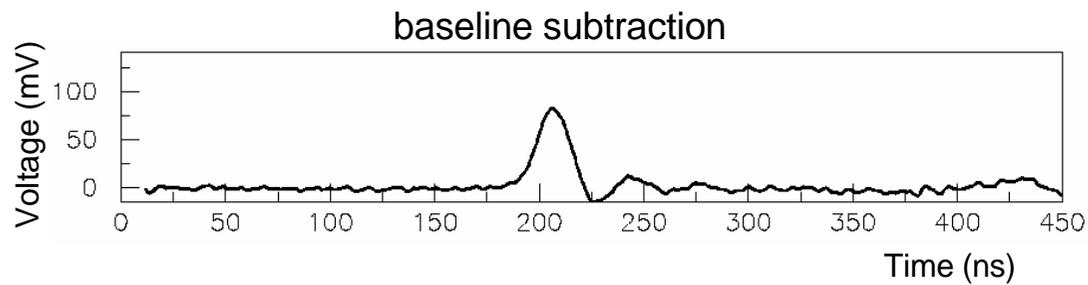
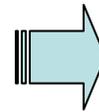
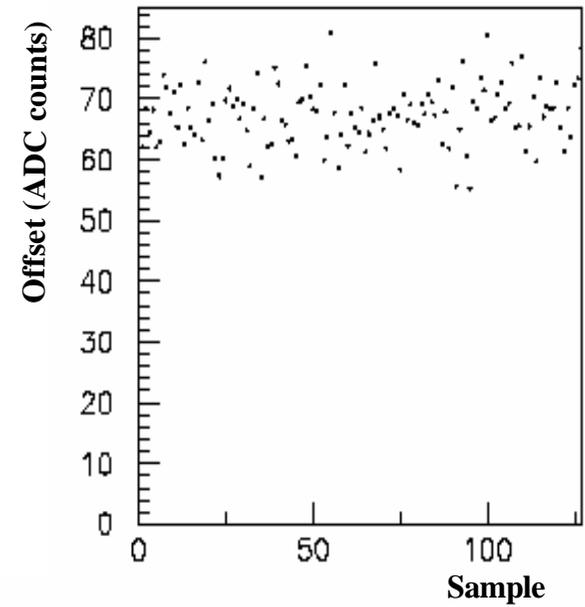
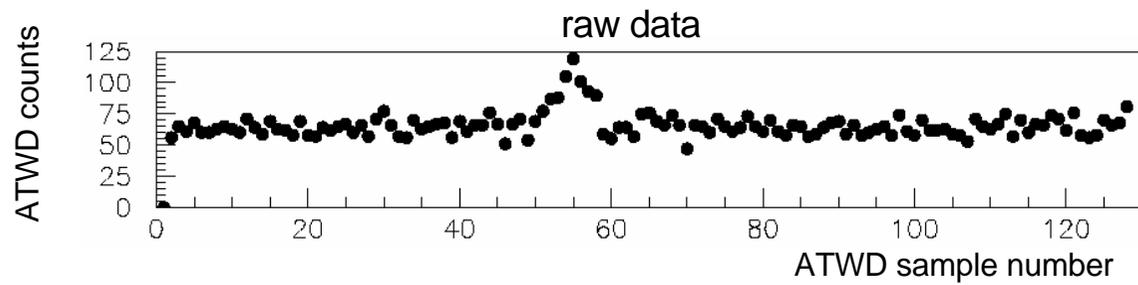
Event by Event Sampling Interval Variation (Constant Temperature)



Software to Hardware Trigger Time Difference (arbitrary time offset)



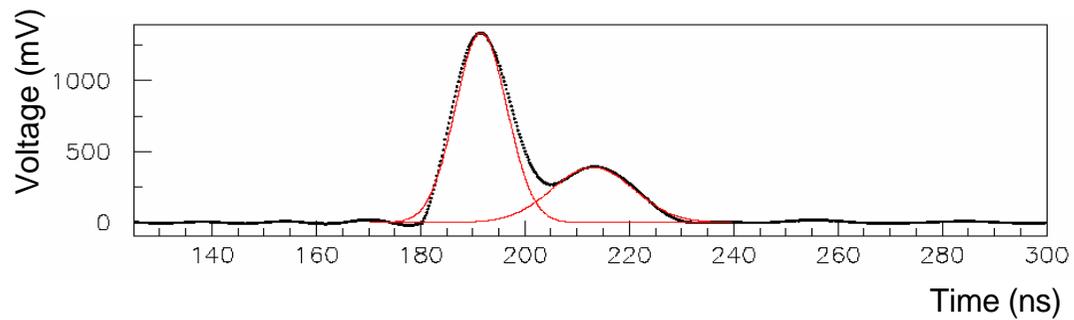
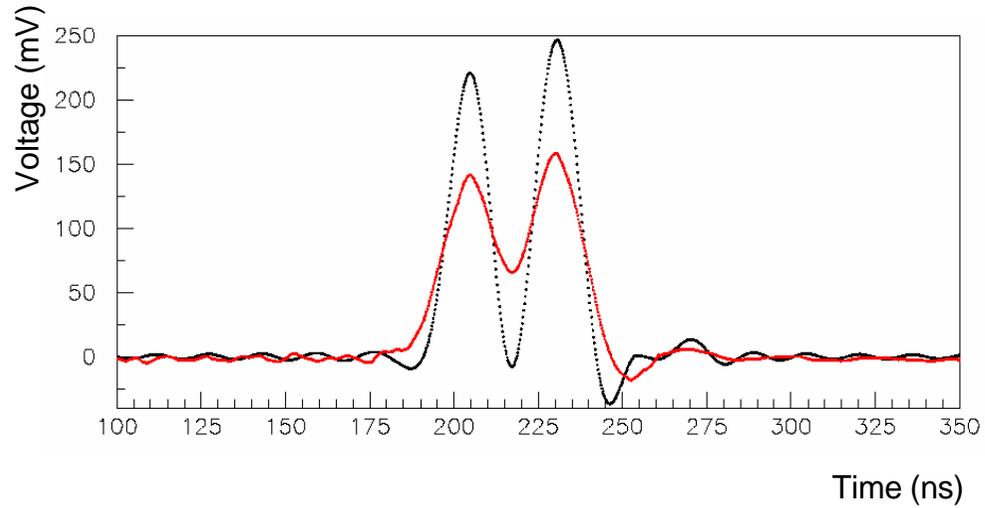
Signal processing



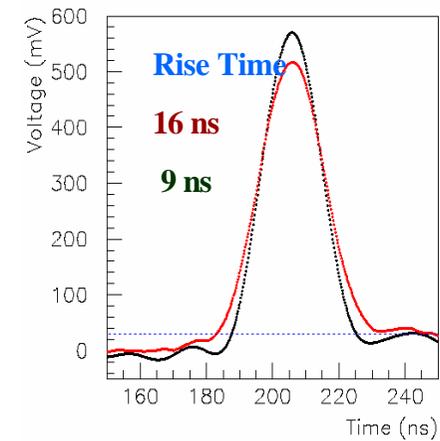
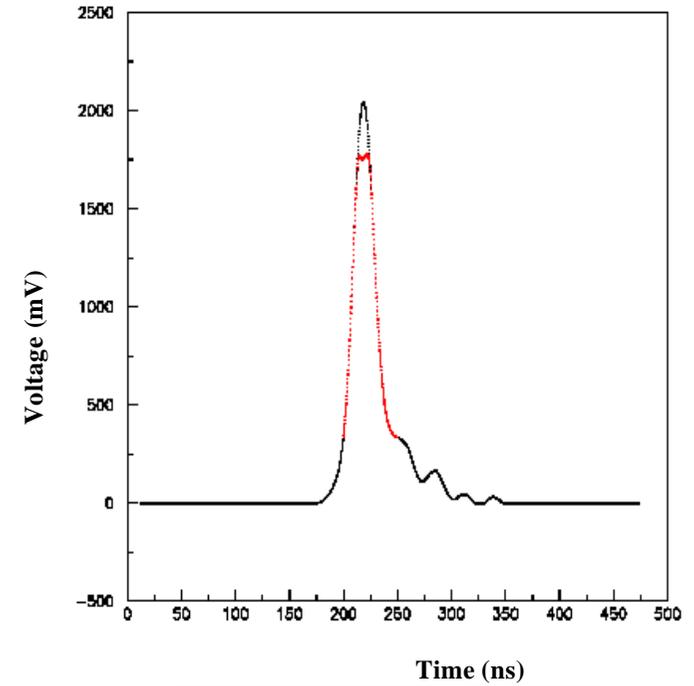
Signal processing

Double pulse disentangling

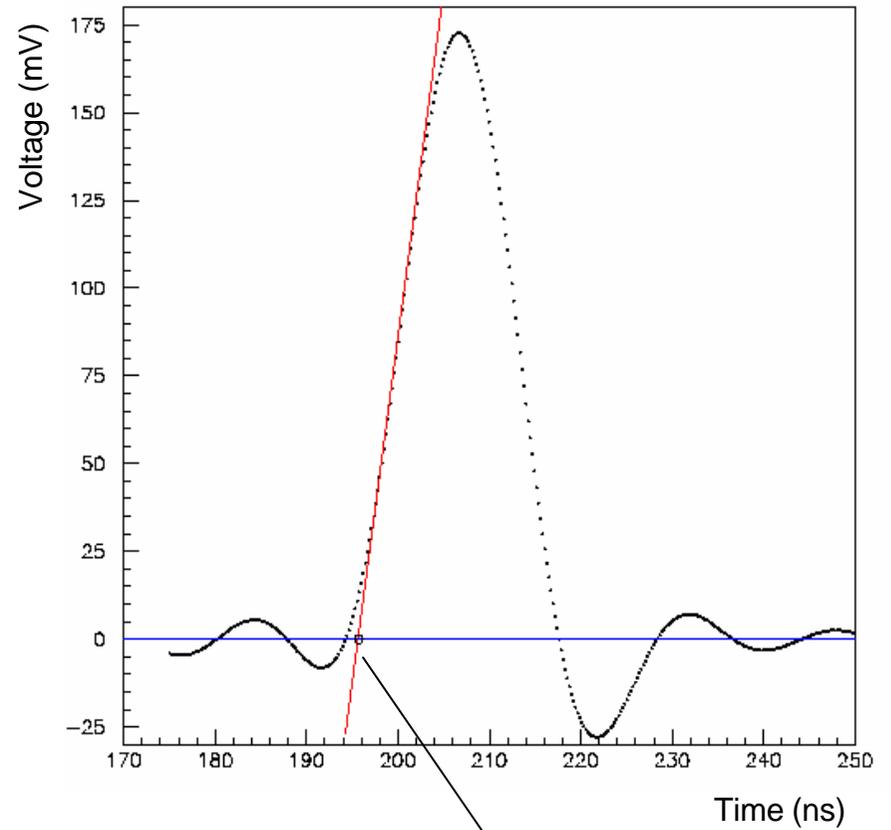
- Before the F.F.T and the attenuation corrections
- After the F.F.T and the attenuation corrections



Correction for overflow



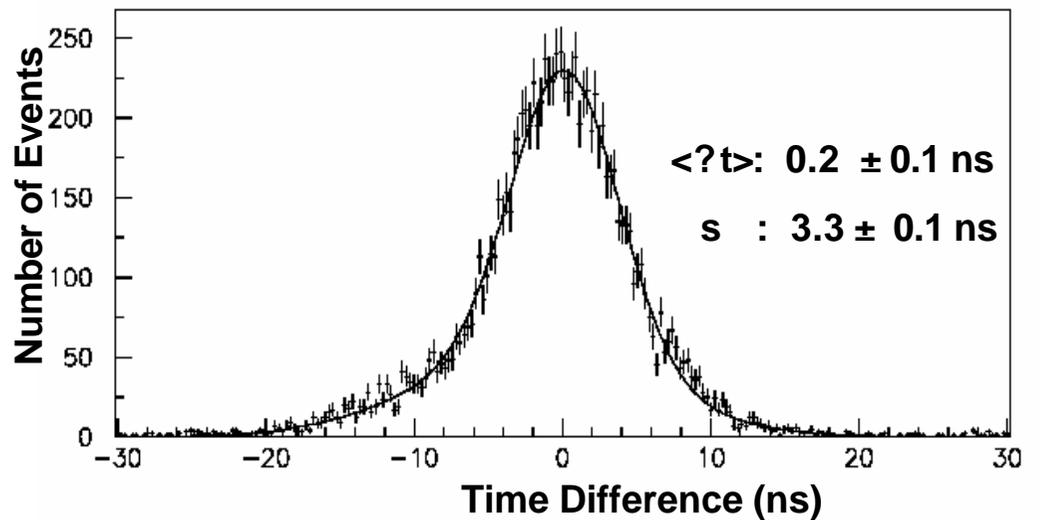
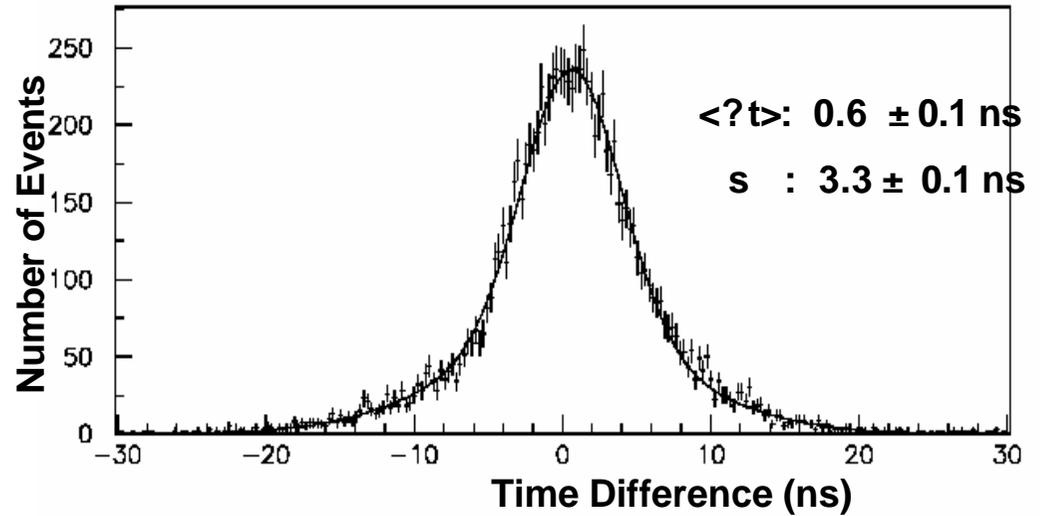
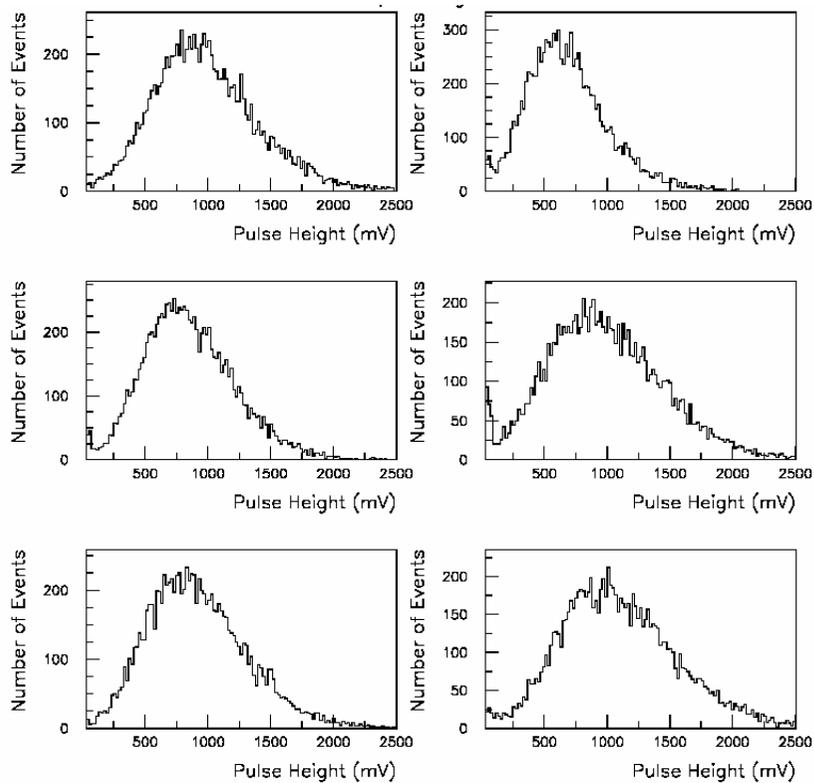
Arrival time definition...



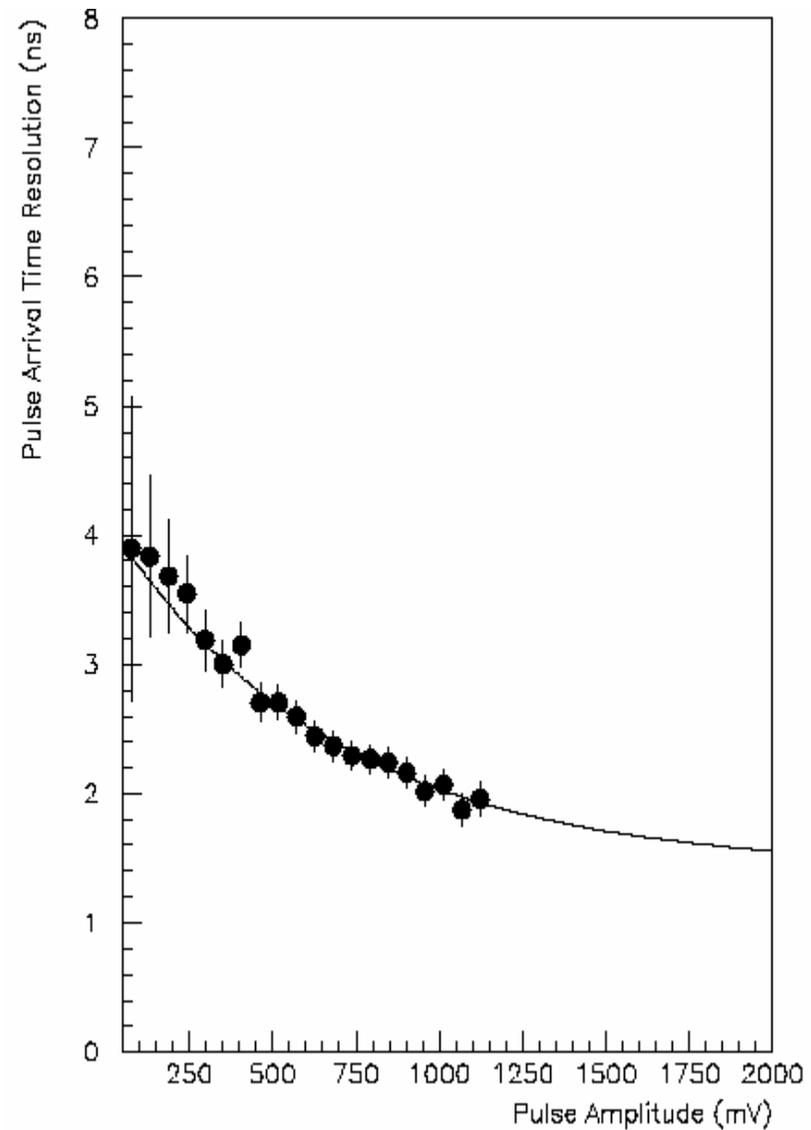
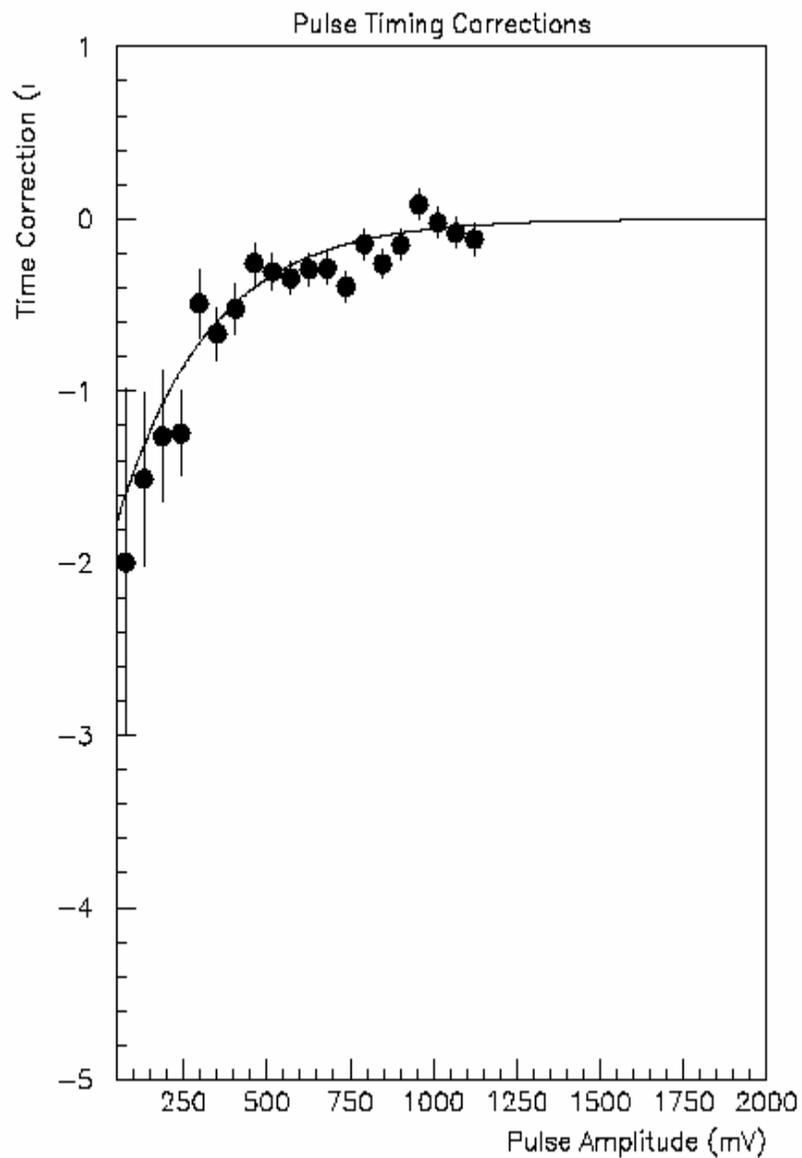
Arrival time

Data from a depth of 4000 m

Calibration Run



Data from a depth of 4000 m: Calibration Run

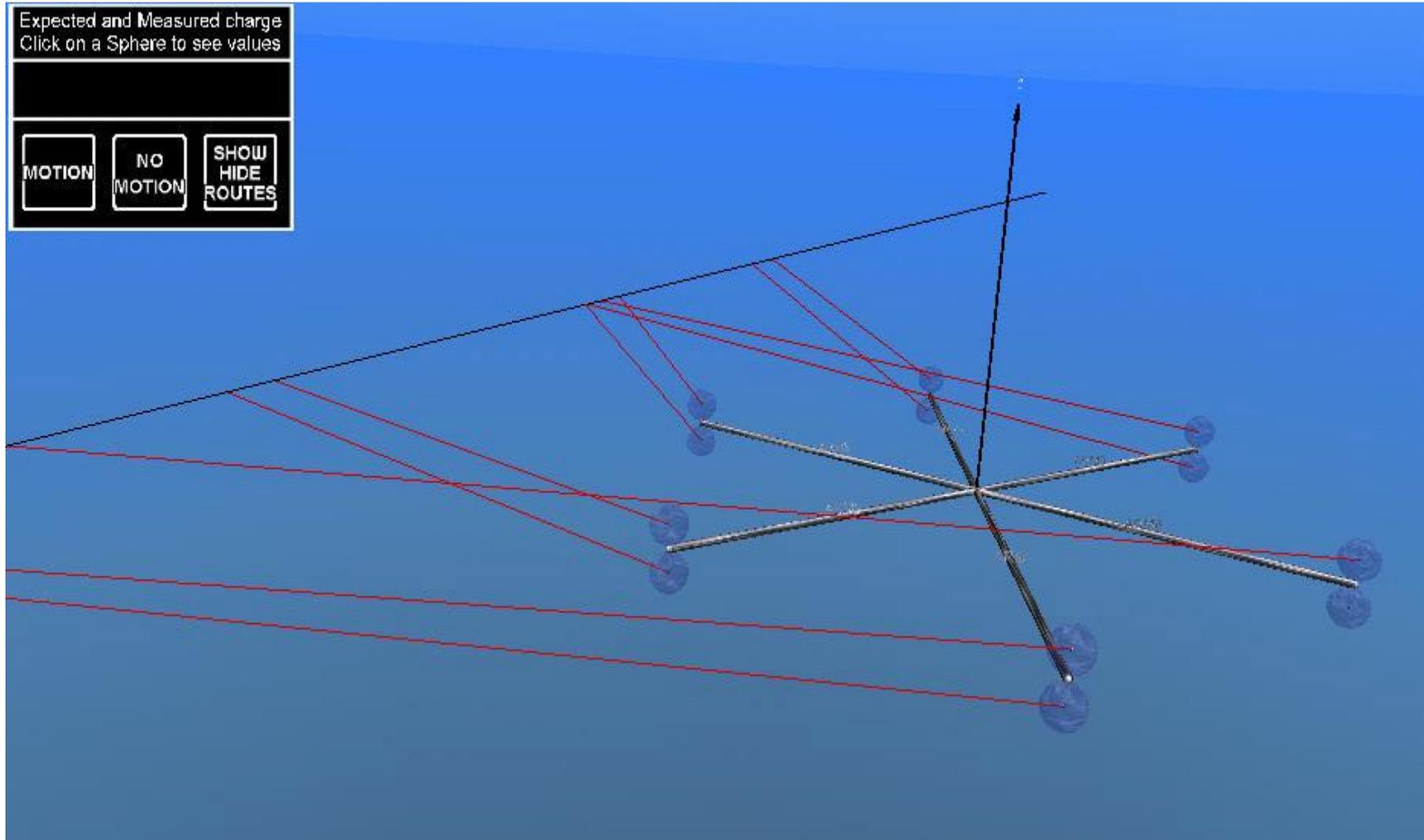


Reconstructed Waveforms

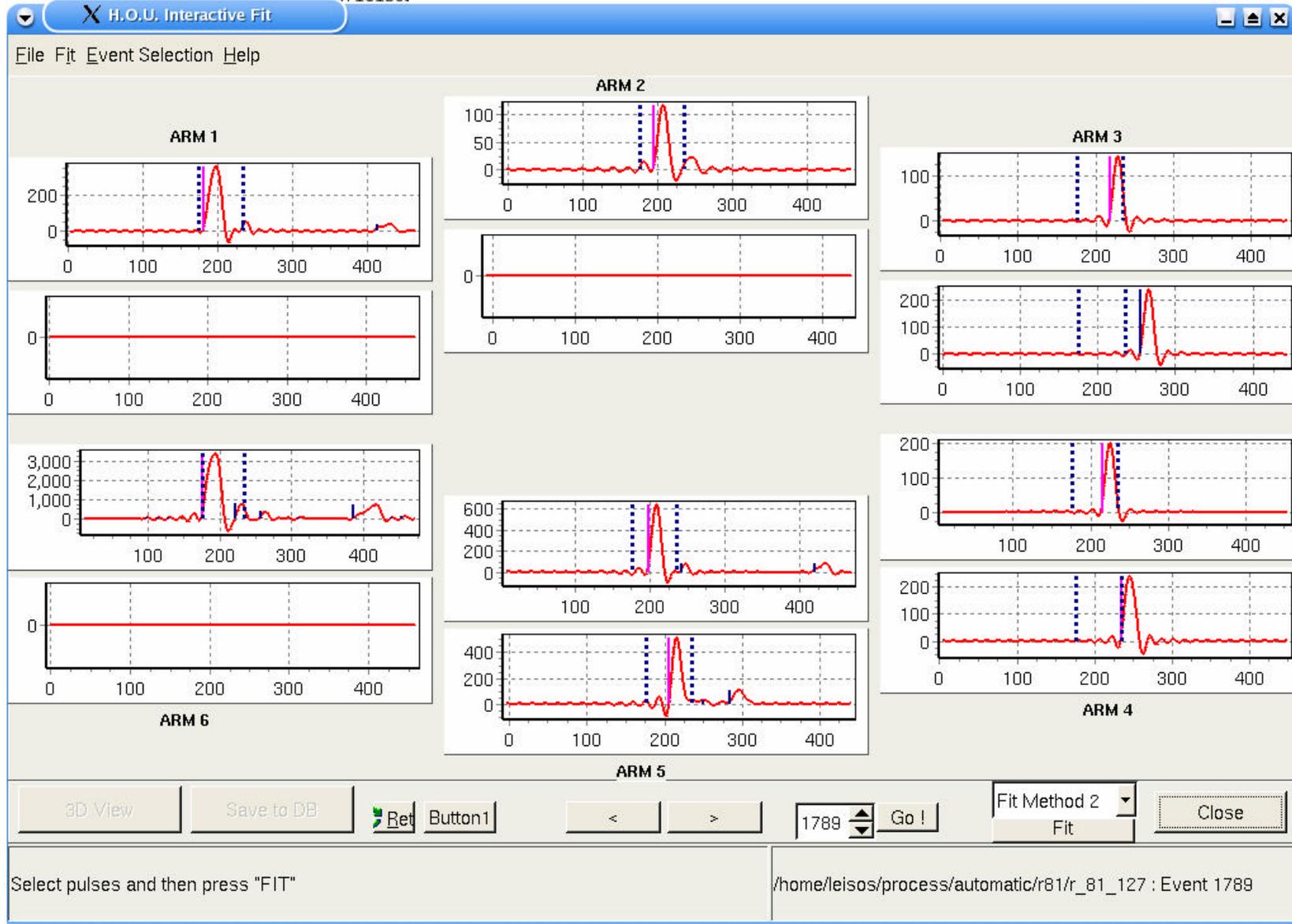
Input to the Fitter



Track Reconstruction...



Input to the Fitter



Best fit

Fit Results

X Fit Results
_ ▲ X

Page 1 | Page 2 |

Candidate Track 1

Number of Selected Pulses : 8		Number of Used Pulses : 7		x[*]: 2.579		Qx[*]:310.800		QL : 64.600	
Theta 12.32	+/- 26.40	Phi 58.47	+/- 144.50	d 22.50	+39.40	-2.89			
Vx 24.91	+/- 33.52	Vy 15.07	+/- 10.28	Vz 33.56	+/- 41.01				

Correlation Matrix				
Vx	Vy	Vz	Theta	Phi
1.00	0.38	-0.99	-0.33	-0.36
0.38	1.00	-0.49	0.72	0.70
-0.99	-0.49	1.00	0.22	0.24
-0.33	0.72	0.22	1.00	0.96
-0.36	0.70	0.24	0.96	1.00

[Show Details](#)

Candidate Track 2

Number of Selected Pulses : 8		Number of Used Pulses : 7		x[*]: 2.402		Qx[*]:173.500		QL : 49.160	
Theta 91.86	+/- 9.99	Phi 11.22	+/- 28.55	d 17.50	+24.97	-5.32			
Vx 43.21	+/- 21.44	Vy 14.33	+/- 15.05	Vz 12.82	+/- 19.76				

Correlation Matrix				
Vx	Vy	Vz	Theta	Phi
1.00	-0.72	-0.95	0.56	-0.58
-0.72	1.00	0.50	-0.83	0.98
-0.95	0.50	1.00	-0.28	0.33
0.56	-0.83	-0.28	1.00	-0.81
-0.58	0.98	0.33	-0.81	1.00

[Show Details](#)

Candidate Track 3

Number of Selected Pulses : 8		Number of Used Pulses : 7		x[*]: 6.313		Qx[*]:892.100		QL : 47.910	
Theta 83.93	+/- 6.24	Phi 24.69	+/- 25.34	d 14.00	+9.58	-6.04			
Vx 44.28	+/- 10.76	Vy 21.04	+/- 13.04	Vz -5.78	+/- 10.82				

Correlation Matrix				
Vx	Vy	Vz	Theta	Phi
1.00	-0.65	0.83	-0.03	-0.80
-0.65	1.00	-0.21	-0.22	0.97
0.83	-0.21	1.00	0.19	-0.40
-0.03	-0.22	0.19	1.00	-0.16
-0.80	0.97	-0.40	-0.16	1.00

[Show Details](#)

Candidate Track 4

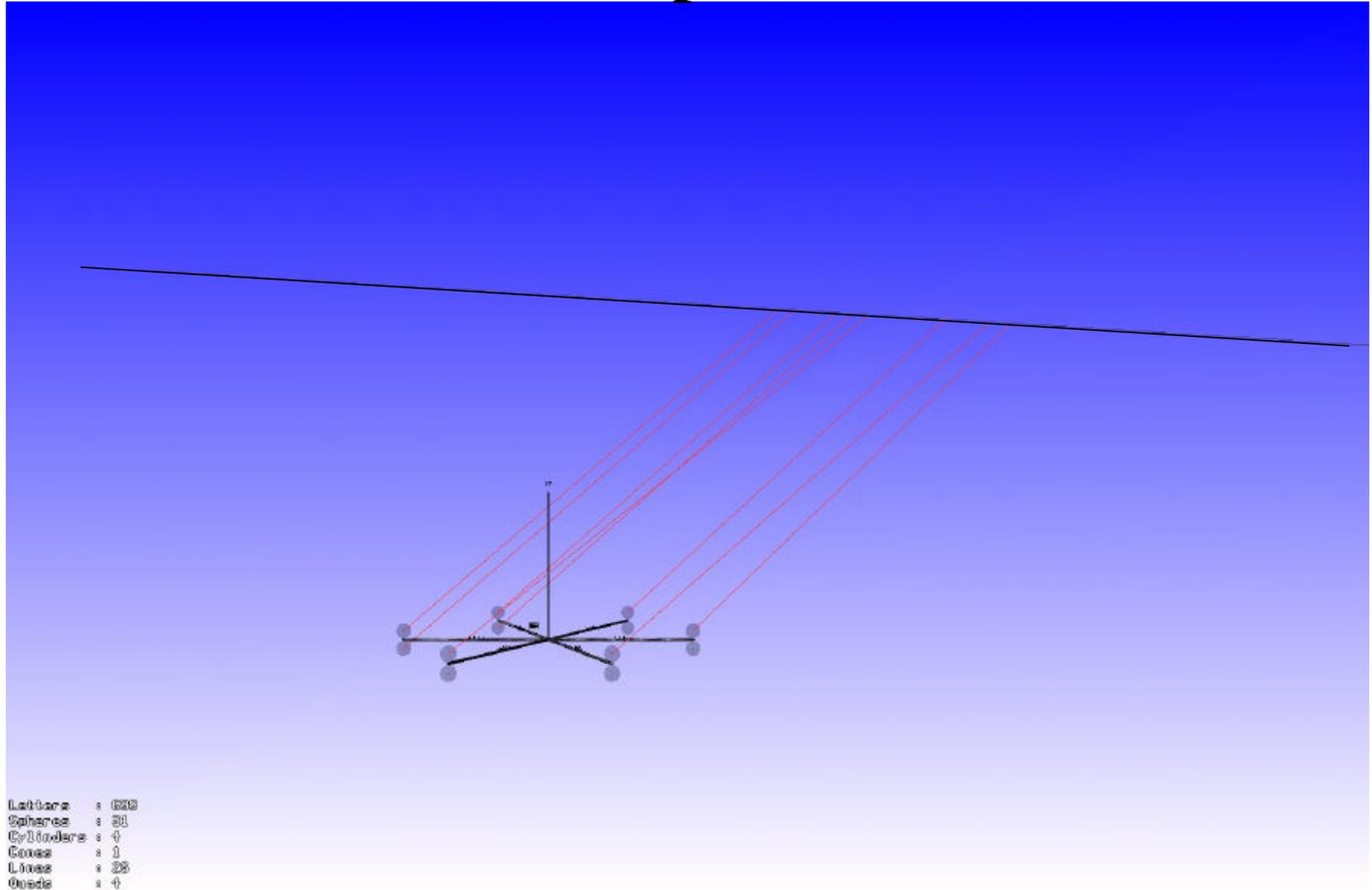
Number of Selected Pulses : 8		Number of Used Pulses : 7		x[*]: 6.343		Qx[*]:666.500		QL : 48.540	
Theta 161.30	+/- 23.58	Phi 341.80	+/- 56.43	d 12.00	+ 27.66	- 1.29			
Vx 24.06	+/- 12.71	Vy 3.97	+/- 13.39	Vz -41.27	+/- 14.25				

Correlation Matrix				
Vx	Vy	Vz	Theta	Phi
1.00	-0.33	0.89	-0.88	-0.75
-0.33	1.00	0.08	0.73	0.79
0.89	0.08	1.00	-0.59	-0.51
-0.88	0.73	-0.59	1.00	0.93
-0.75	0.79	-0.51	0.93	1.00

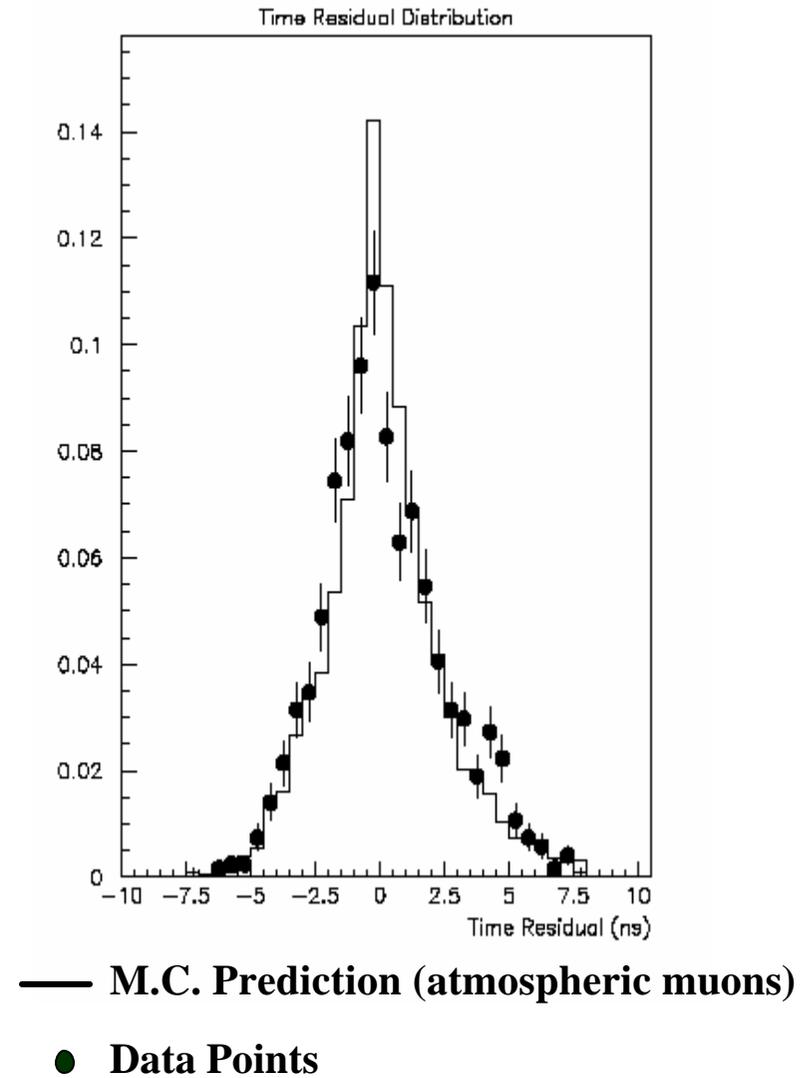
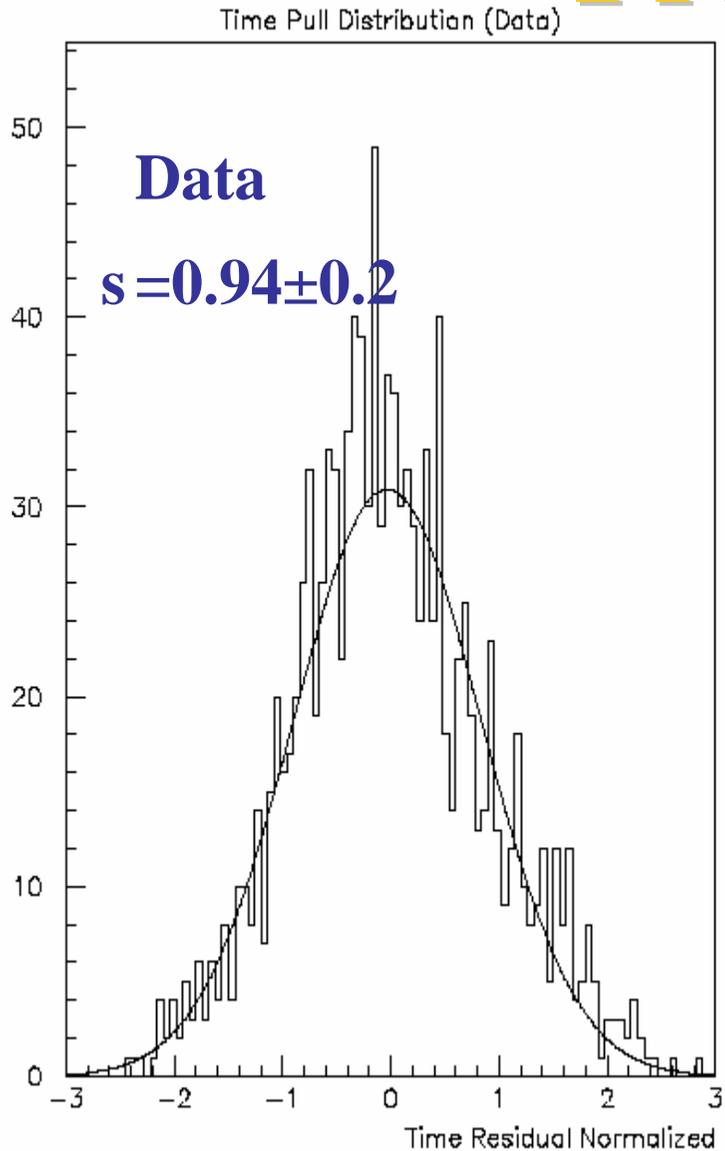
[Show Details](#)

Run: 81_127 Event: 1789

Pictorial Representation



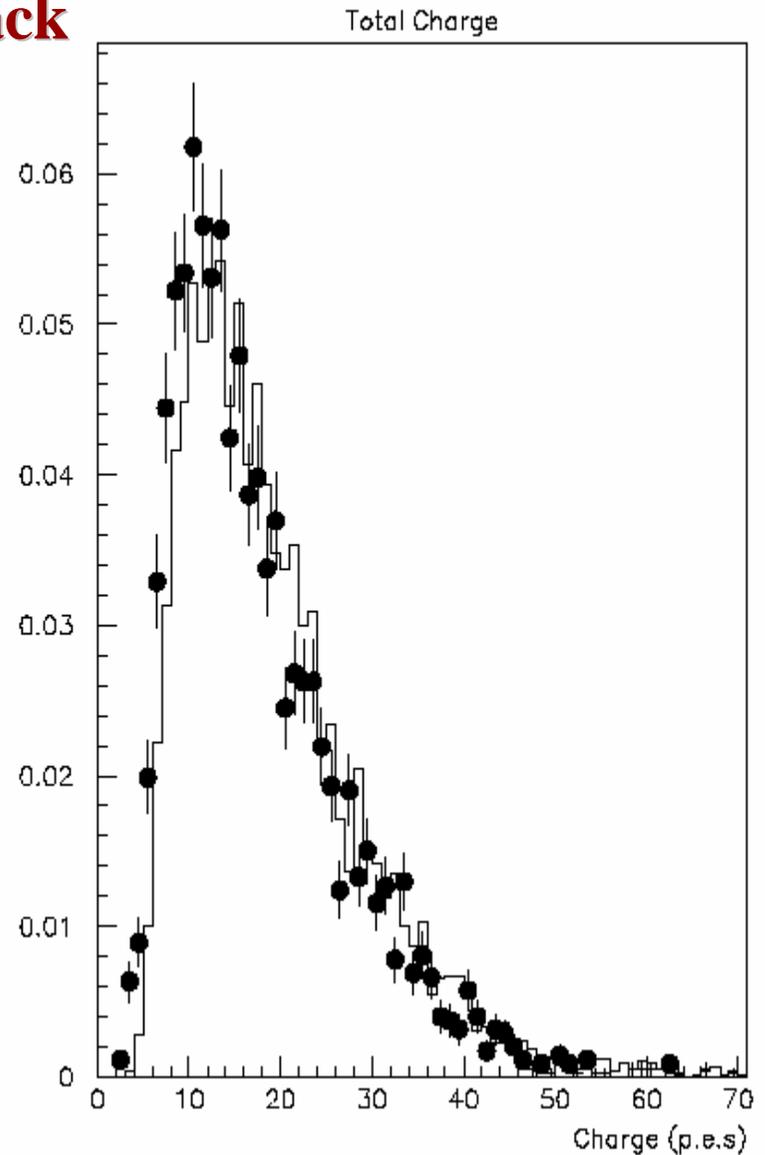
Preliminary



Preliminary

Total number of p.e.s per Track

- M.C. Prediction (atmospheric muons)
- Data Points



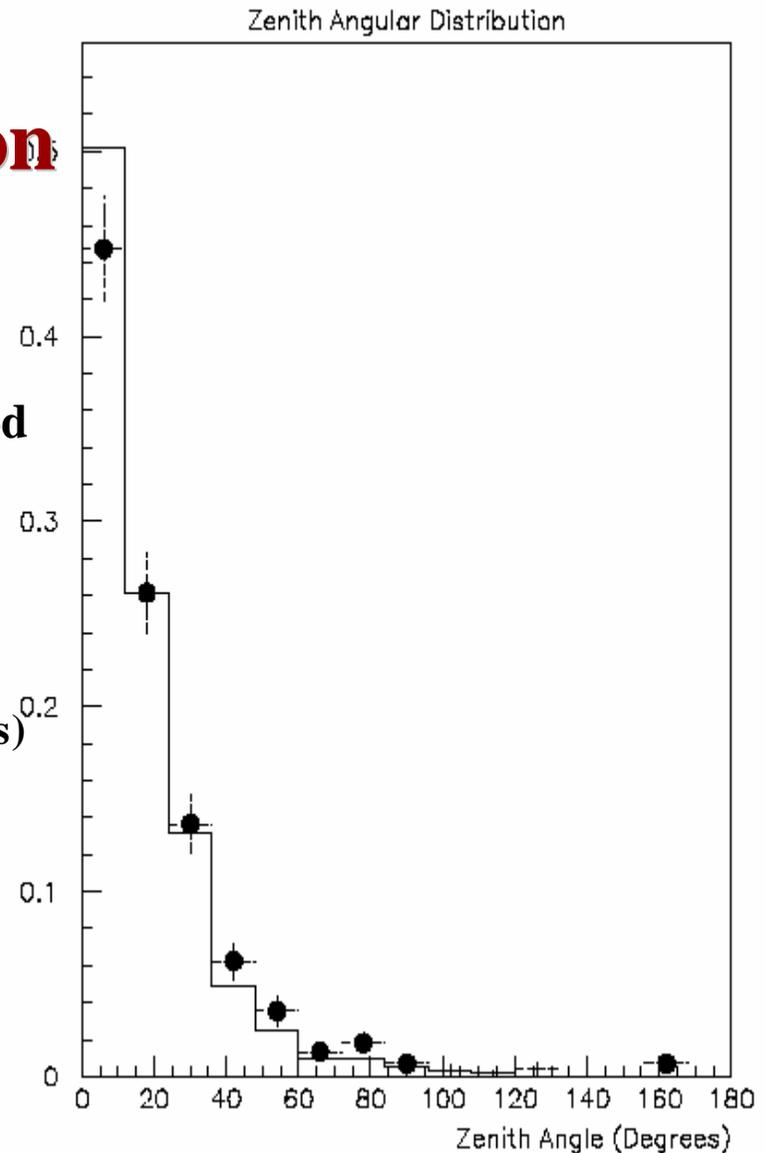
Preliminary

Zenith Angular Distribution

- χ^2 probability > 0.1
- track selection according to the charge-likelihood
- more than 4.5 p.e.s per hit per track

— M.C. Prediction (atmospheric muons)

● Data Points



Extension to many floors

One Tower

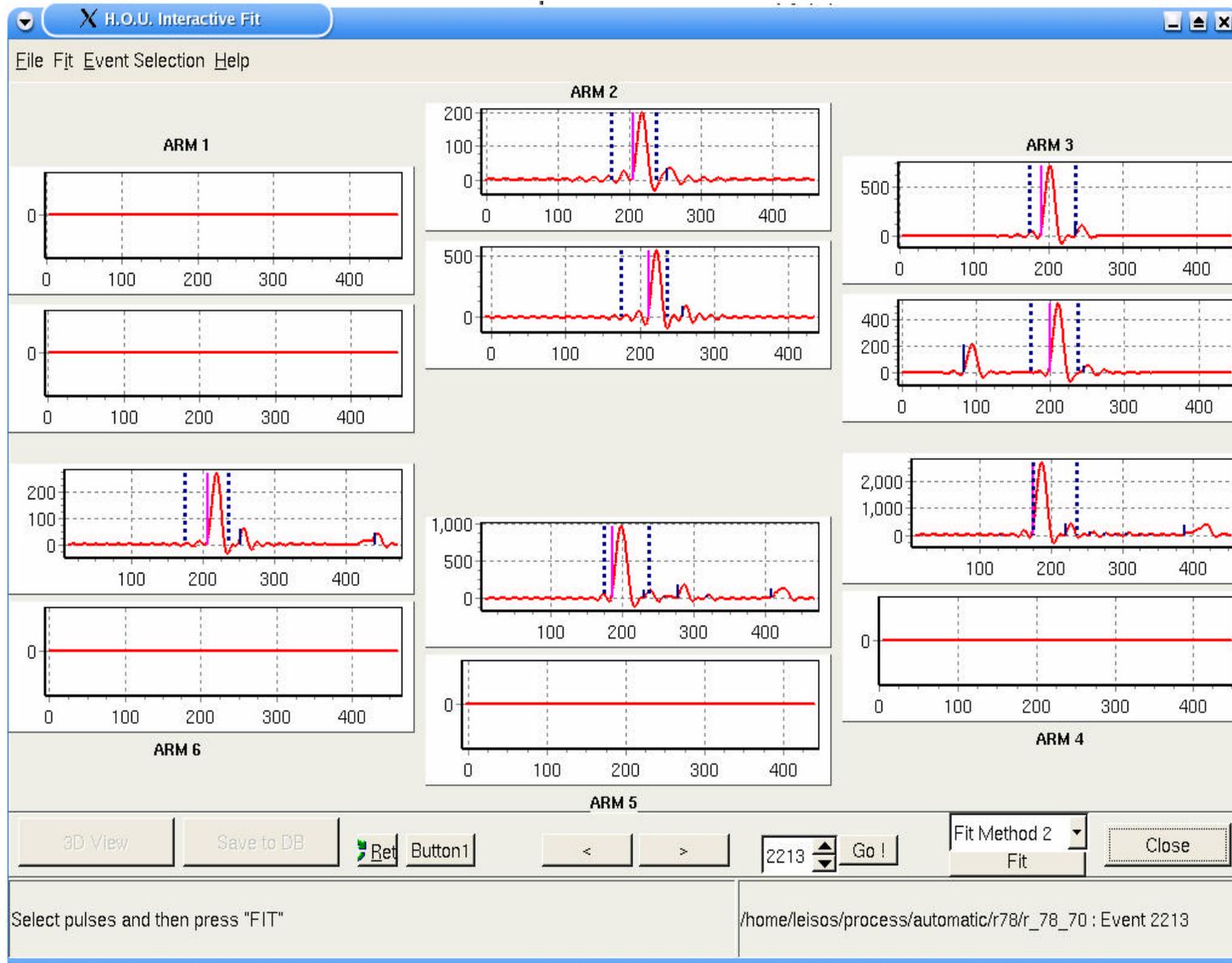
- Each floor runs independently (floor sub-event)
- An event is a collection of several floor sub-events when certain requirements (e.g. timing) are fulfilled
- Online event-building
- Offline track reconstruction

Many Towers

- Track segment fit: using the PMT's of each Tower
- Global fit: using matched track segments.
- Second iteration to collect more points

Trivially the best strategy is to use all the PMT's independent of tower
This is depended on the trigger, data transmission (e.g. optoelectronics)
and DAQ architecture

Event 2213 – Run 78 – BFile 70



Event 2213 – Run 78 – BFile 70

Best Fit



Fit Results

Page 1 | Page 2

Candidate Track 1

Number of Selected Pulses : 7 Number of Used Pulses : 7 χ^2 : 2.287 Qx:16.620 QL : 30.550

Theta	92.53 +/- 13.82	Phi	148.50 +/- 36.31	d	7.00	+16.47	-0.90
Vx	-47.83 +/- 10.76	Vy	24.52 +/- 29.48	Vz	1.64	+/- 6.32	

Correlation Matrix

Vx	Vy	Vz	Theta	Phi
0.00	0.99	0.57	0.91	-1.00
0.99	0.00	0.53	0.92	-1.00
0.57	0.53	0.00	0.81	-0.54
0.91	0.92	0.81	-0.04	-0.91
-1.00	-1.00	-0.54	-0.91	1.00

Show Details

Candidate Track 2

Number of Selected Pulses : 7 Number of Used Pulses : 7 χ^2 : 3.014 Qx:16.450 QL : 29.040

Theta	25.97 +/- 218.40	Phi	212.60 +/- 71.31	d	10.00	+194.00	--3.90
Vx	-25.19 +/- 111.30	Vy	-9.33 +/- 91.16	Vz	45.00	+/- 31.91	

Correlation Matrix

Vx	Vy	Vz	Theta	Phi
0.00	1.00	1.00	1.00	0.98
1.00	0.00	1.00	1.00	0.97
1.00	1.00	0.00	0.99	0.96
1.00	1.00	0.99	0.90	0.97
0.98	0.97	0.96	0.97	1.00

Show Details

Candidate Track 3

Number of Selected Pulses : 7 Number of Used Pulses : 7 χ^2 : 7.307 Qx:1954.000QL : 77.210

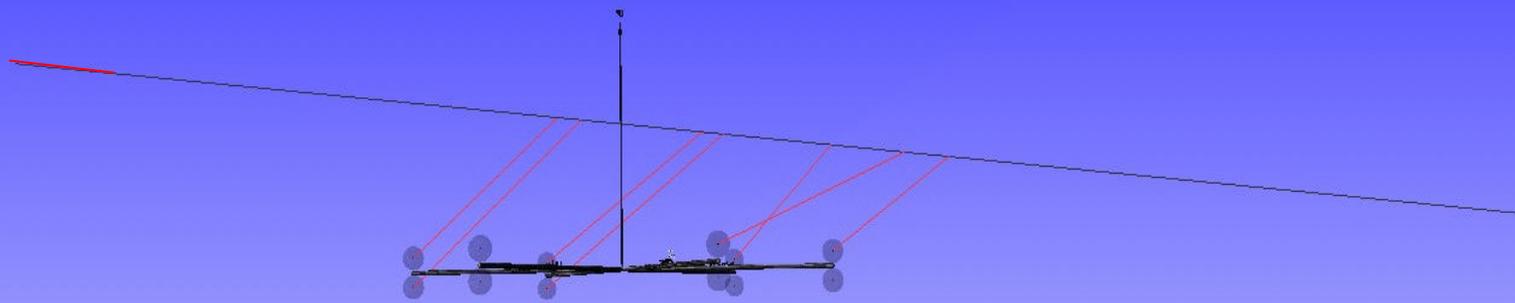
Theta	98.77 +/- 11.93	Phi	164.30 +/- 68.77	d	43.50	+42.85	-10.84
Vx	-37.18 +/- 30.45	Vy	3.83 +/- 19.49	Vz	22.49	+/- 50.92	

Correlation Matrix

Vx	Vy	Vz	Theta	Phi
0.00	-0.99	1.00	-0.29	0.03
-0.99	0.00	-0.99	0.32	-0.02
1.00	-0.99	0.00	-0.29	0.03
-0.29	0.32	-0.29	-0.15	-0.79
0.03	-0.02	0.03	-0.79	1.00

Show Details

Event 2213 – Run 78 – BFile 70



Letters : 686
Spheres : 31
Cylinders : 4
Cones : 1
Lines : 26
Quads : 4