Measuring linear and nonlinear couplings between channels

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Overview of Talk

- Frequency domain statistics
- 4 different algorithms/statistics used
  - Coherence
  - Phase Coupling
  - Amplitude Coupling
  - Bicoherence
- Computing false alarm probabilites
- Operational parameters
- Results

Coherence

$$c(f_1, f_2) = \frac{\Sigma_1^N \tilde{A}_i(f_1)\tilde{B}_i^*(f_2)}{\left[\Sigma_1^N |\tilde{A}_i(f_1)|^2 \Sigma_1^N |\tilde{B}_i(f_2)|^2\right]^{1/2}}$$

Amplitude Coupling

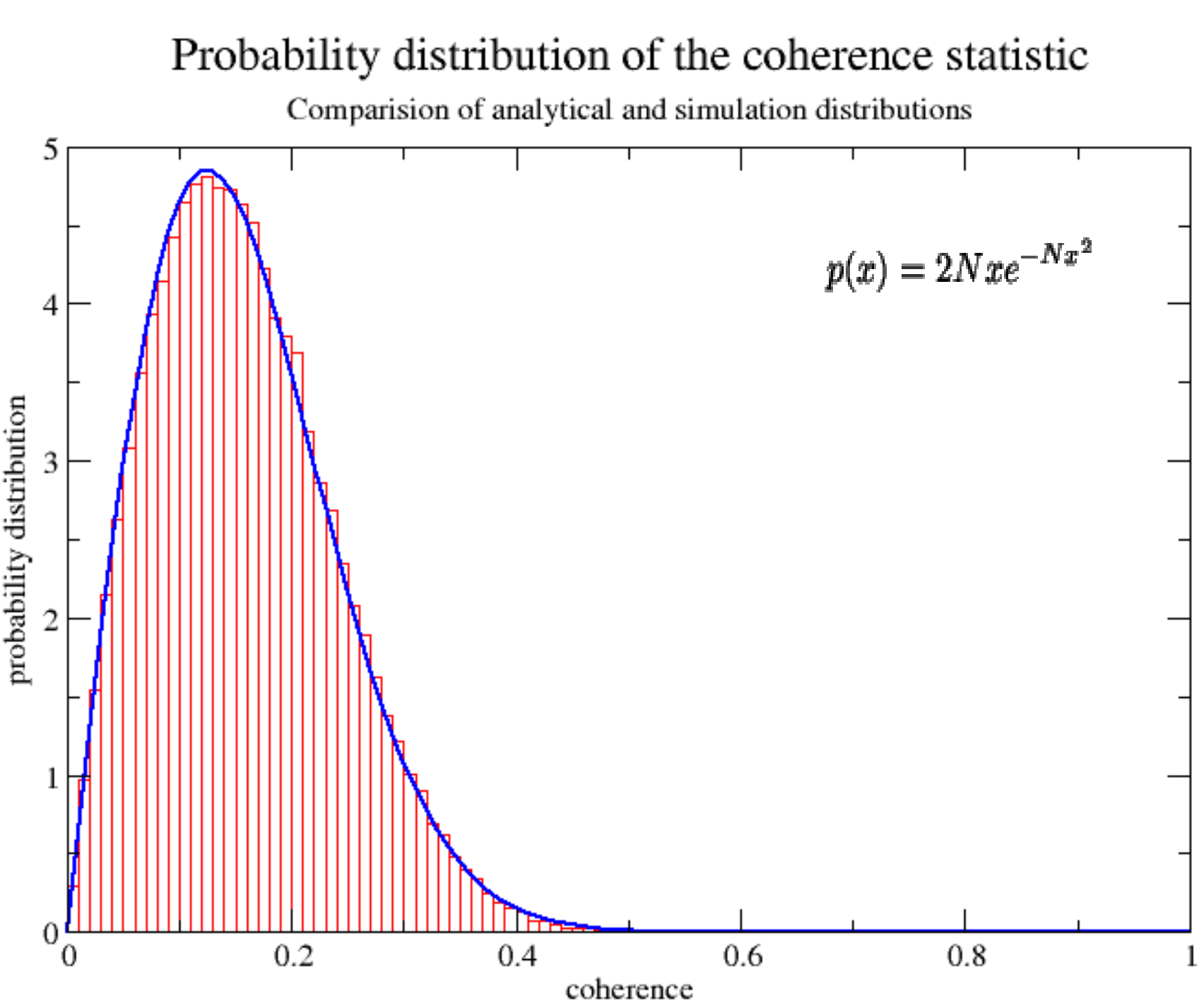
$$c(f_1, f_2) = \frac{\Sigma_1^N |\tilde{A}_i(f_1)\tilde{B}_i^*(f_2)|}{\left[\Sigma_1^N |\tilde{A}_i(f_1)|^2 \Sigma_1^N |\tilde{B}_i(f_2)|^2\right]^{1/2}}$$

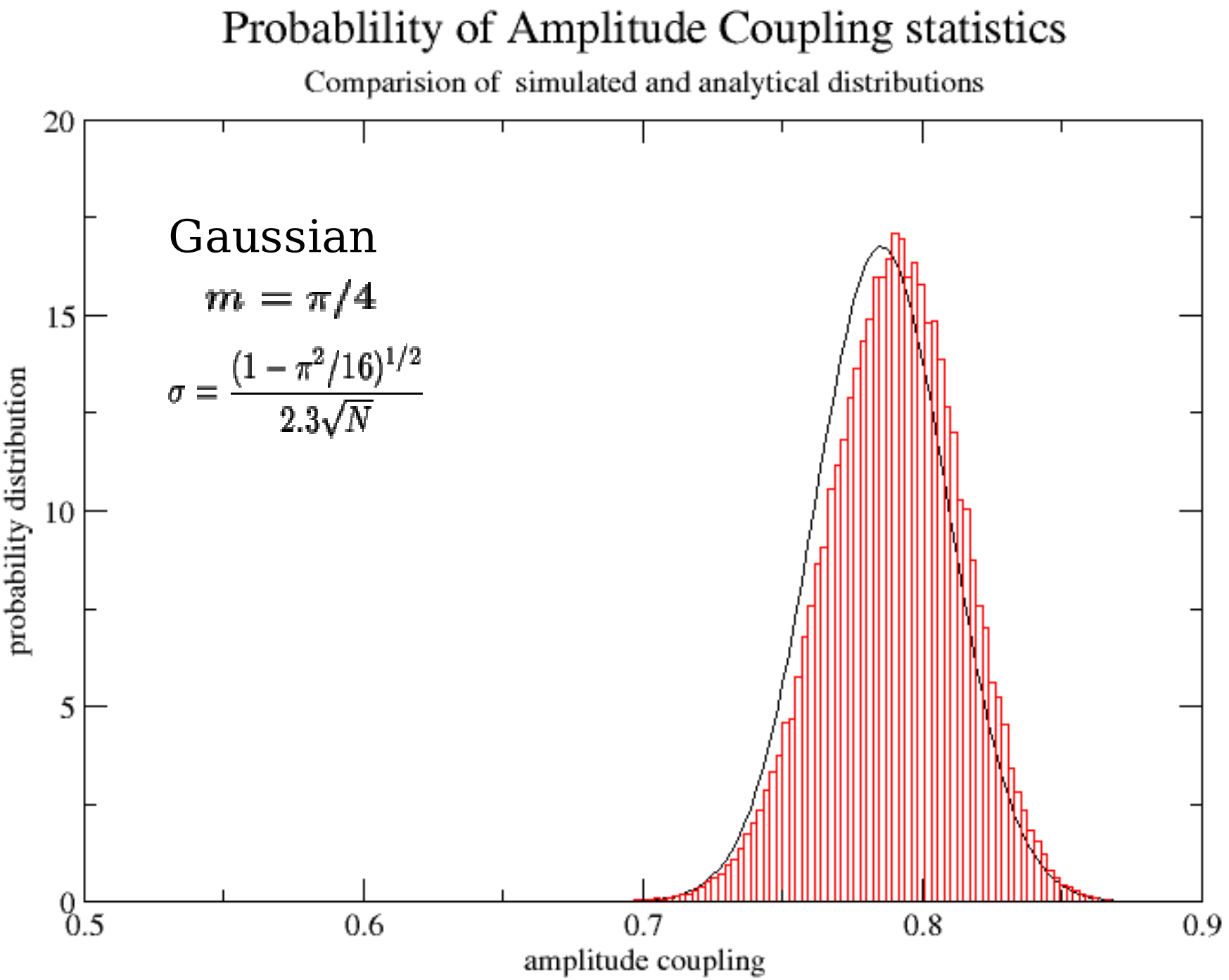
Phase Coupling

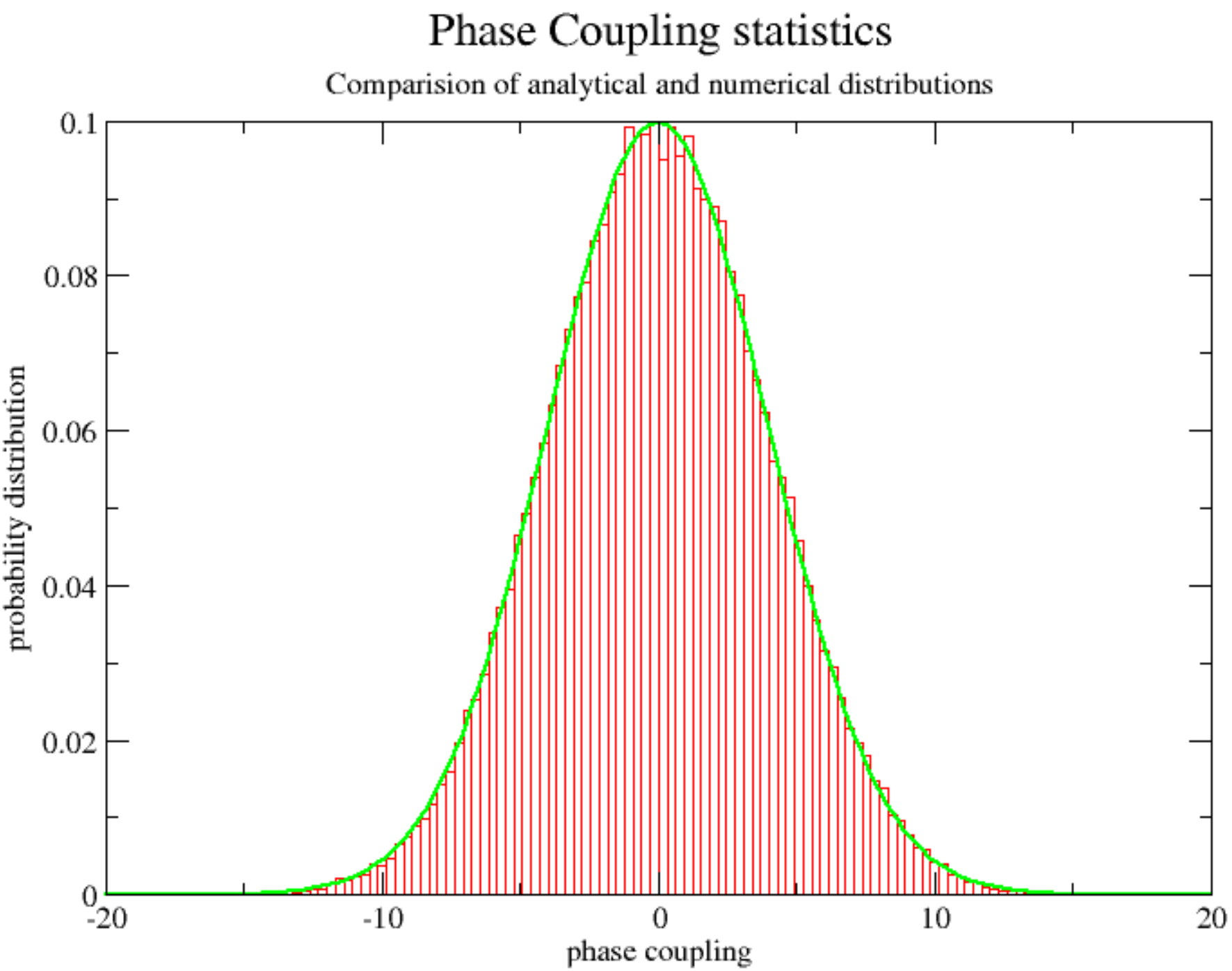
$$c(f_1, f_2) = \Sigma_1^N \frac{\tilde{A}_i(f_1)\tilde{B}_i^*(f_2)}{|\tilde{A}_i(f_1)||\tilde{B}_i(f_2)|}$$

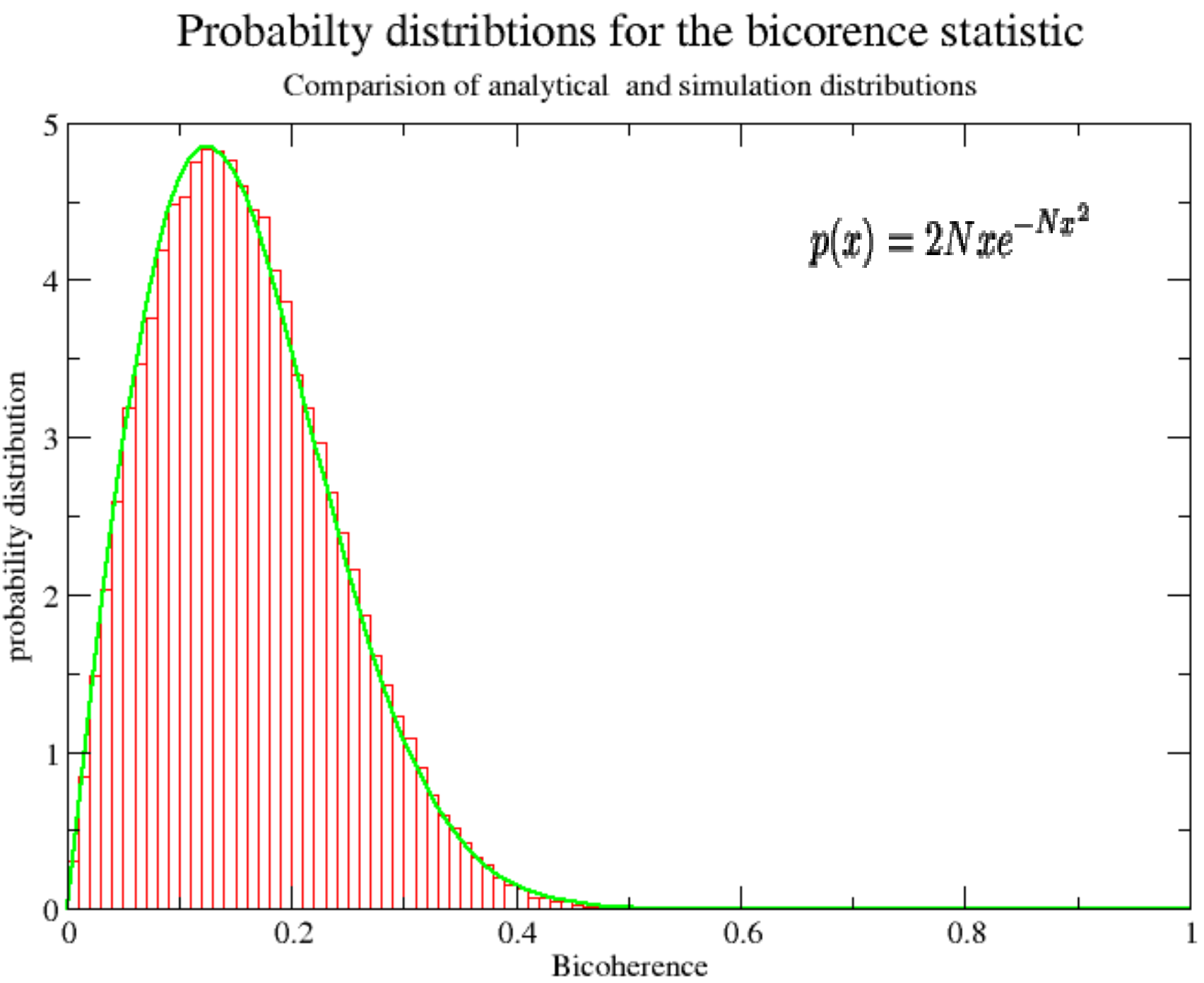
Bicoherence

$$b(f_1, f_2) = \frac{\Sigma_1^N \tilde{A}_i(f_1)\tilde{B}_i(f_2)\tilde{B}_i(f_1 + f_2)}{\left[\Sigma_1^N |\tilde{A}_i(f_1)\tilde{B}(f_2)|^2 \Sigma_1^N |B_i(f_1 + f_2)|^2\right]^{1/2}}$$


Probability distribution of the coherence statistic
Comparision of analytical and simulation distributions
$p(x) = 2Nxe^{-Nx^2}$
probability distribution
coherence
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1


Probablility of Amplitude Coupling statistics
Comparision of simulated and analytical distributions
Gaussian
$m = \pi/4$
$\sigma = \frac{(1-\pi^2/16)^{1/2}}{2.3\sqrt{N}}$
probability distribution
amplitude coupling
0
5
10
15
20
0.5
0.6
0.7
0.8
0.9

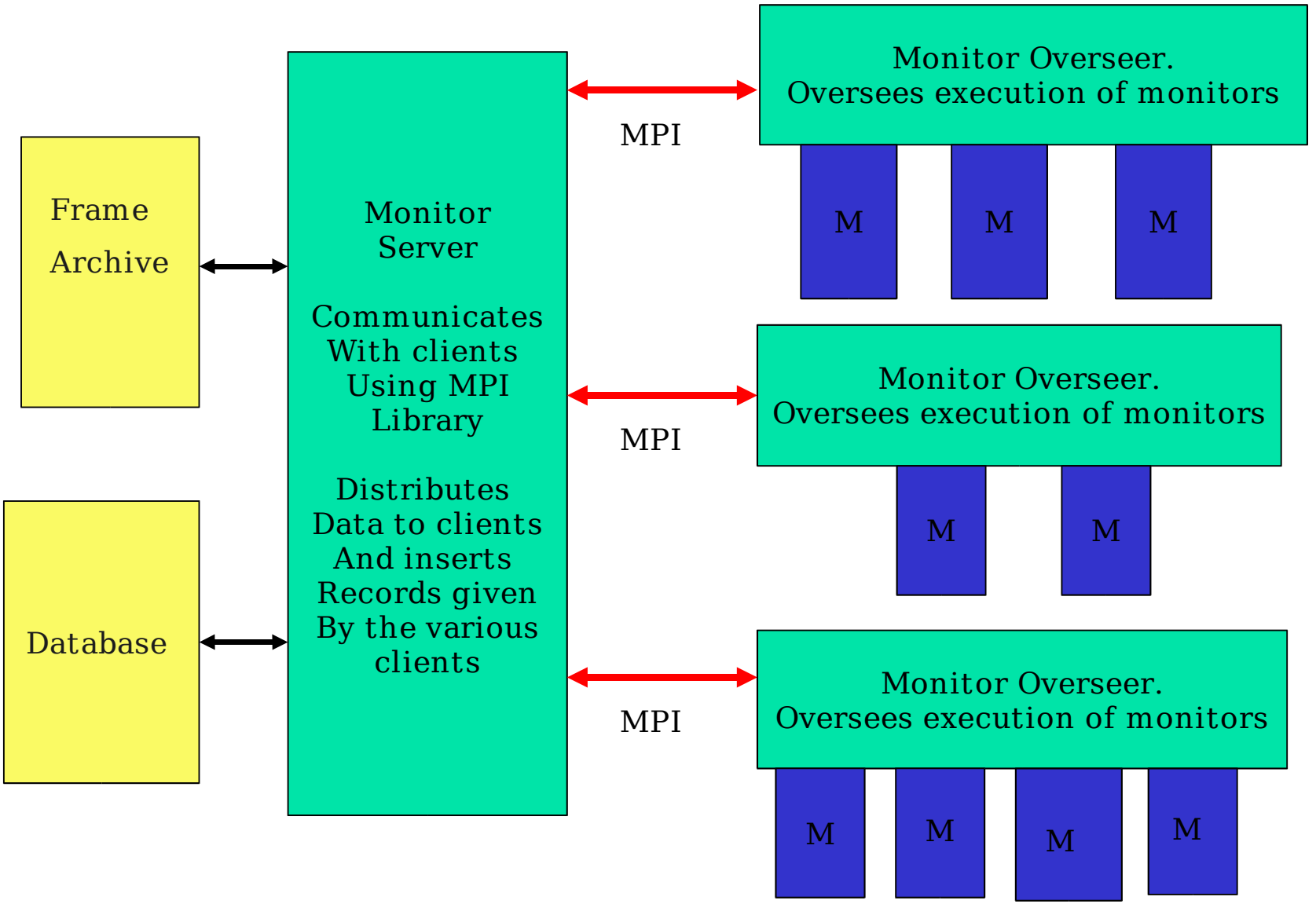

Phase Coupling statistics
Comparision of analytical and numerical distributions
probability distribution
0.1
0.08
0.06
0.04
0.02
0
-20
-10
0
10
20
phase coupling


Probabilty distribtions for the bicorence statistic
Comparision of analytical and simulation distributions
$p(x) = 2Nxe^{-Nx^2}$
probability distribution
Bicoherence
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1

Implementation details

- All statistics implemented as monitors in GODCS
- Developed just before S3 and running currently
- Typically segments are 10 seconds long to get afreq resolution of 0.1 Hz
- Averages are carried out for N=32 or 64
- Statistically significant “events” are written the relevant tables in the MySQL database
- Operate at a false alarm rate of about 1.e-6
- Currently looking at results between seismometers and the “main” channel.

GEO Online Detector Characterization System



Results

- Have looked at and followed up only part of the results
- The various statistics are fairly consistent but also saw significant differences.
- Observe interesting coupling events between the microseismic noise and the line frequencies in the LSC channels
- Some of these lines correspond to calibration lines
- Coupling for these has been verified and explained (Martin/Josh) . The optical gain has been observed to be coherent with the microseismic noise
- In the process of looking at other results. Bicoherence monitor generates a huge number of events. Still to understand the results.