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Search for short duration gravitational waves  
coincident with S2 GRBs  
(parallel work within External Triggers group)

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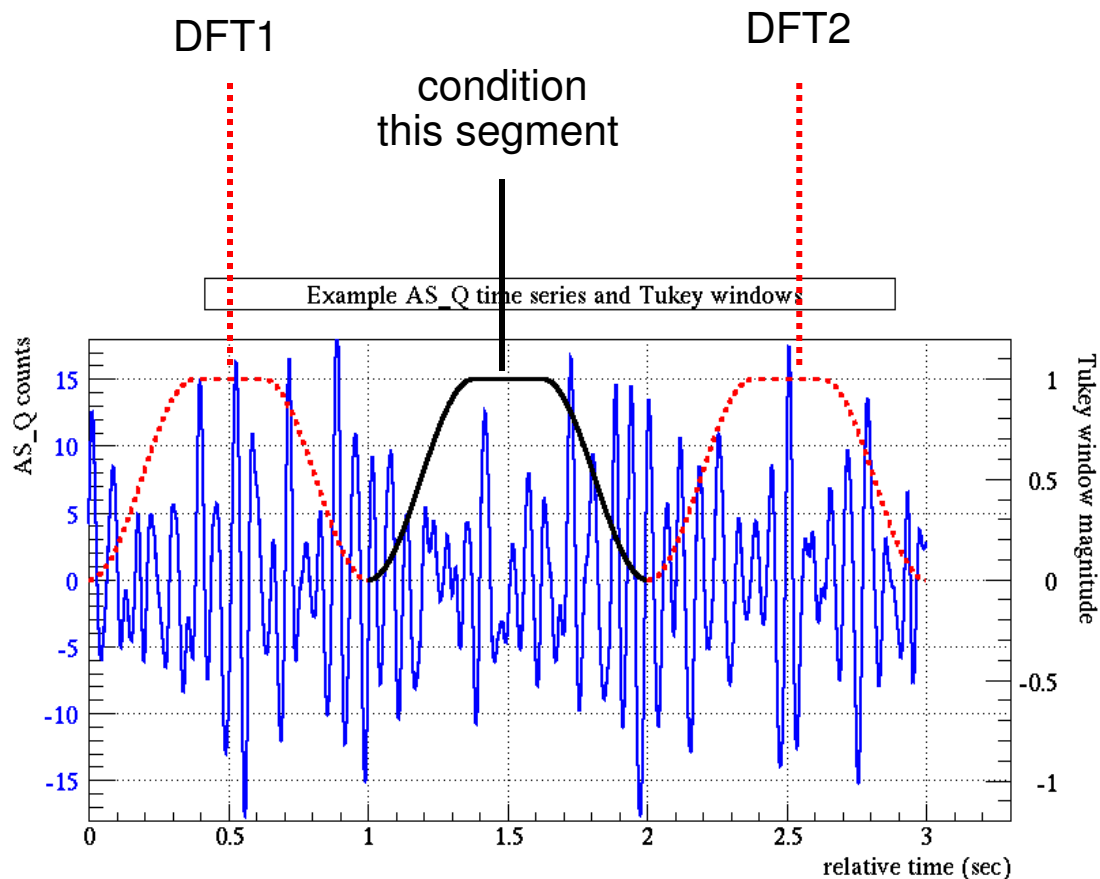
Isabel Leonor  
University of Oregon

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## What has been done

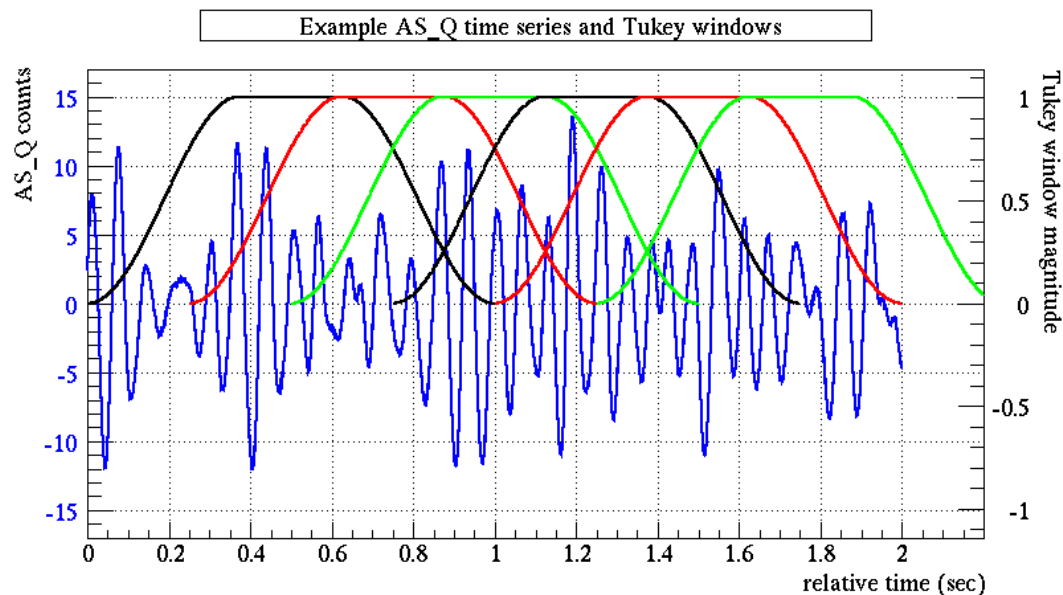
- ❖ searched **25 S2 GRBs** for coincident G-waves of duration  **$\sim 1 - 10$  ms**
- ❖ used crosscorrelation method
- ❖ explored data conditioning in the frequency domain, included whitening and phase correction – luxury of limited on-source and off-source data to analyze
- ❖ injected signals to study sensitivity of pipeline
- ❖ used playground data with no GRB trigger
- ❖ data analysis code (standalone), injection and calibration scripts, written using Matlab

# Data conditioning - whitening



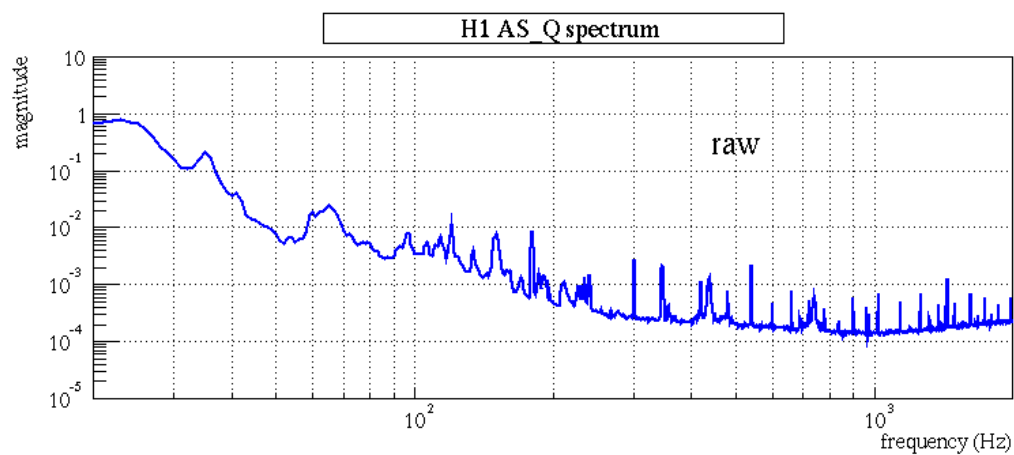
- ❖ data conditioning done in frequency domain
- ❖ data DFTed using 1-second Tukey windows
- ❖ adjacent 1-sec segments DFTed to determine factor for whitening in frequency domain
- ❖ whitening factor =  $\max(\text{DFT1}, \text{DFT2})$

# Data conditioning – overlapping Tukey windows, and “stitching”

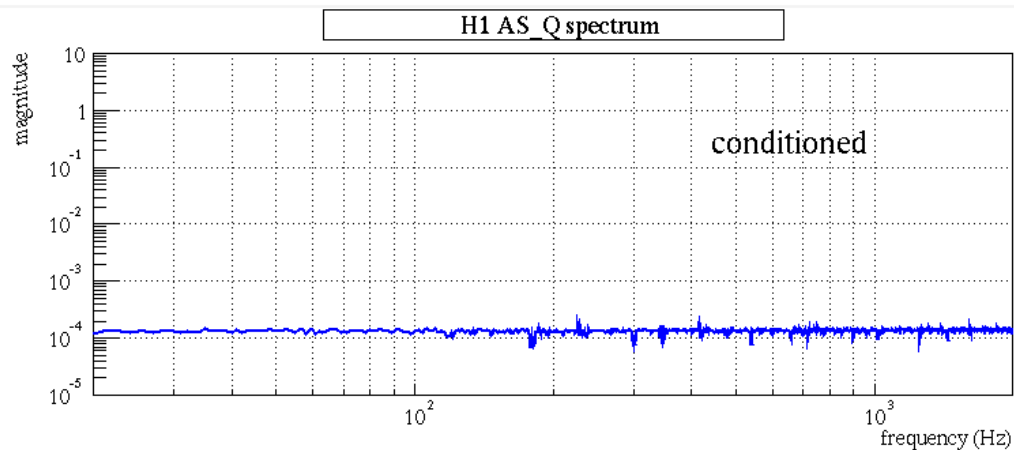


- ❖ data conditioning process repeated for each second
- ❖ perform inverse DFT to convert back to time domain
- ❖ keep only time segment corresponding to unattenuated section of window
- ❖ crosscorrelation calculated in time domain

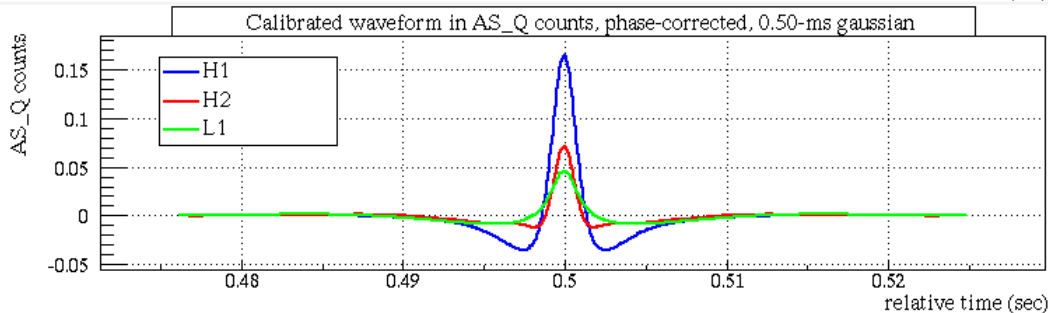
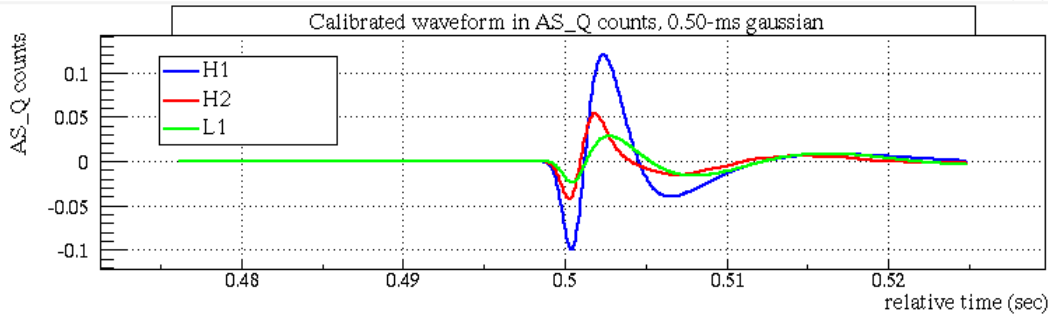
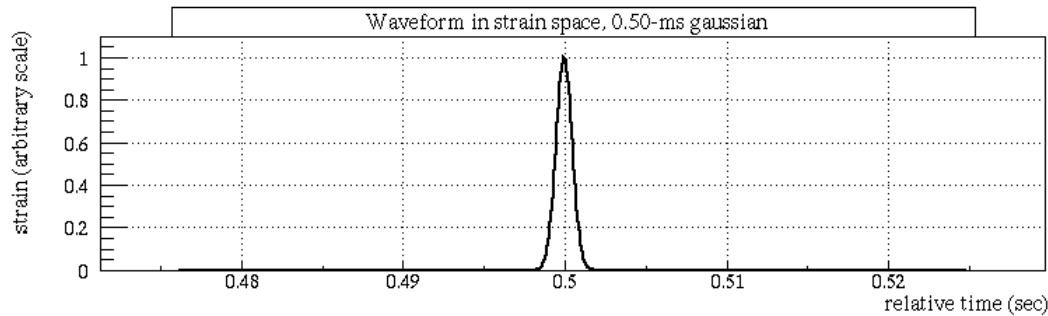
# Whitened data example



❖ average over 160 seconds

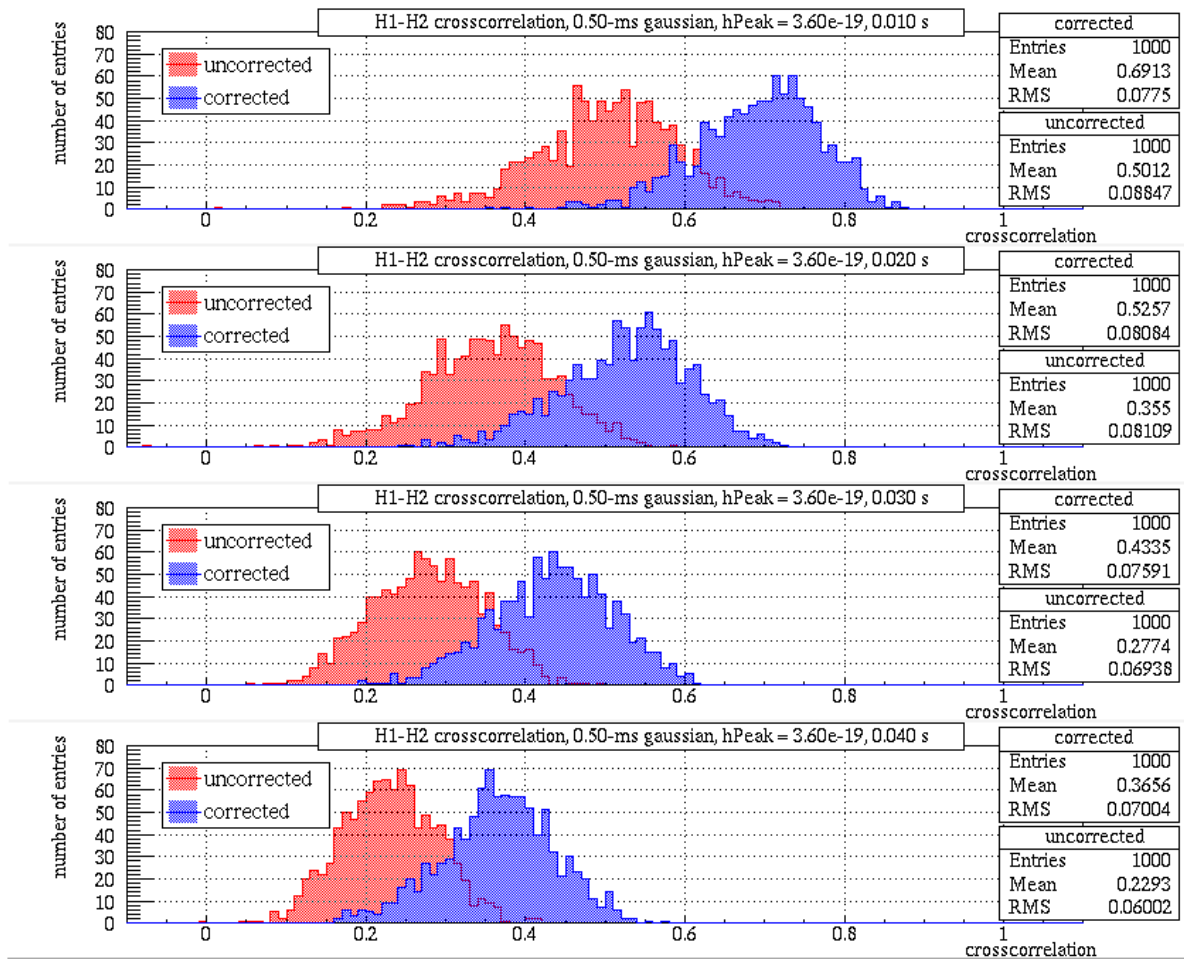


# Phase correction



- ❖ IFO response function results in out-of-phase AS\_Q signal
- ❖ decreases value of crosscorrelation
- ❖ time-domain calibration to correct would be great (S. Marka, S. Mohanty, X. Siemens, others)
- ❖ explored phase correction in frequency domain
- ❖ applied phase calibration after whitening stage
- ❖ calculate inverse DFT to go back to time domain

# Effect of phase correction on crosscorrelation



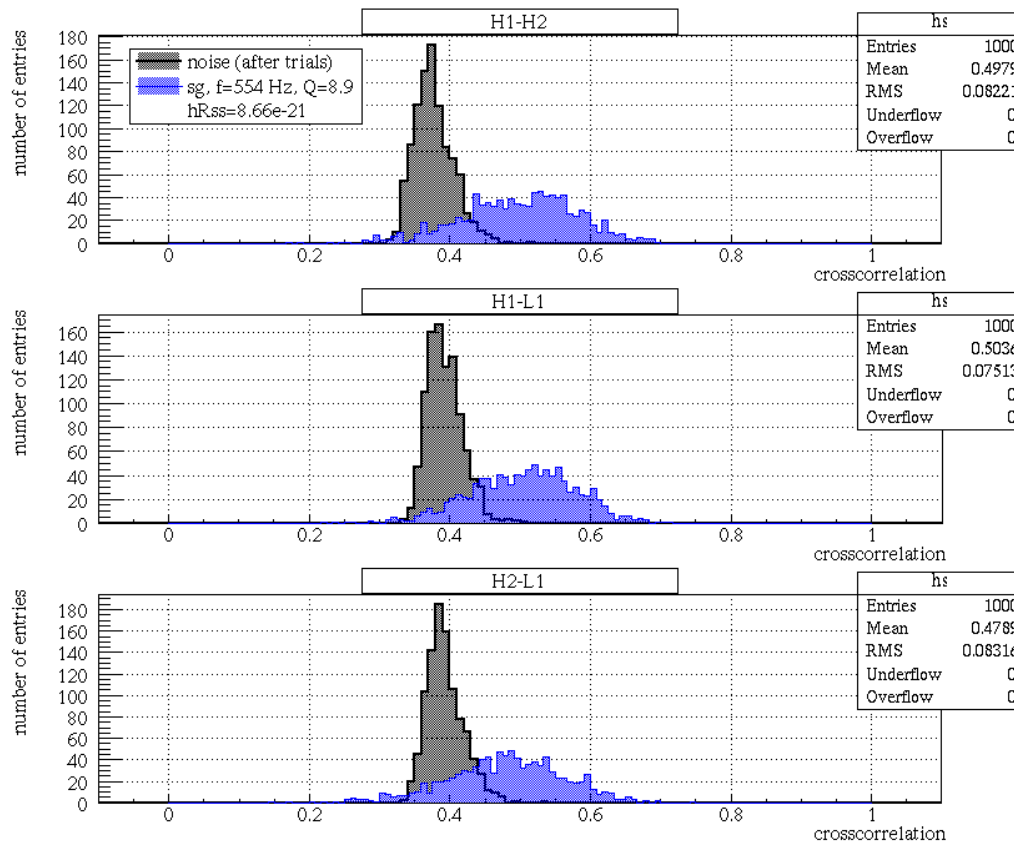
❖ phase correction increases crosscorrelation significantly for all IFO pairs

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## Search method

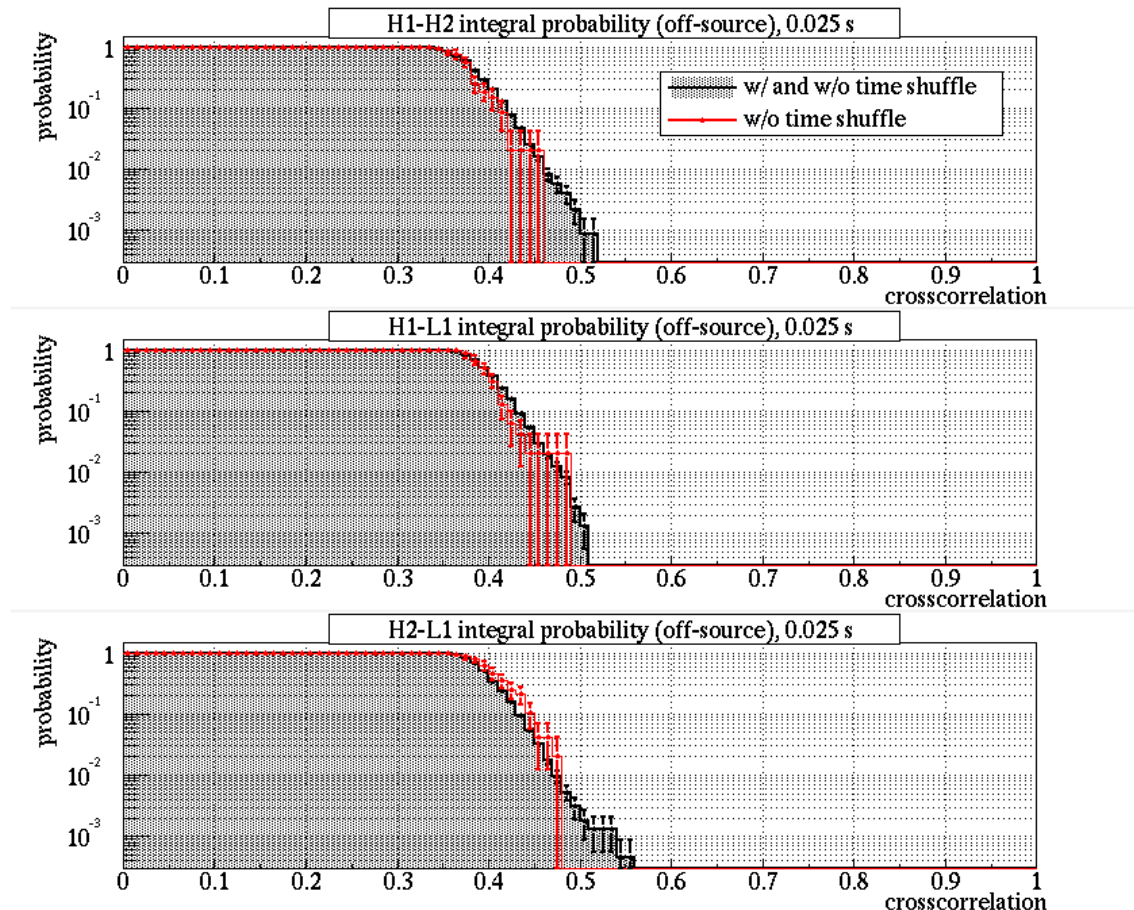
- ❖ each search segment is **160-seconds** long (less ~1.5 seconds at ends of segment)
- ❖ each 160-second segment pre-conditioned
- ❖ use crosscorrelation windows of length **25 ms** each, windows overlapping by half a window length
- ❖ calculate normalized crosscorrelation for each 25-ms second
- ❖ find **largest crosscorrelation** within each 160-second search segment; find **largest abs(cc)** for H1-L1 and H2-L1 due to unknown polarization
- ❖ use playground data to test pipeline and estimate sensitivity – playground data was long science segment not coincident with any GRB trigger

# Crosscorrelation distributions – ‘off-source’ and ‘on-source’ examples

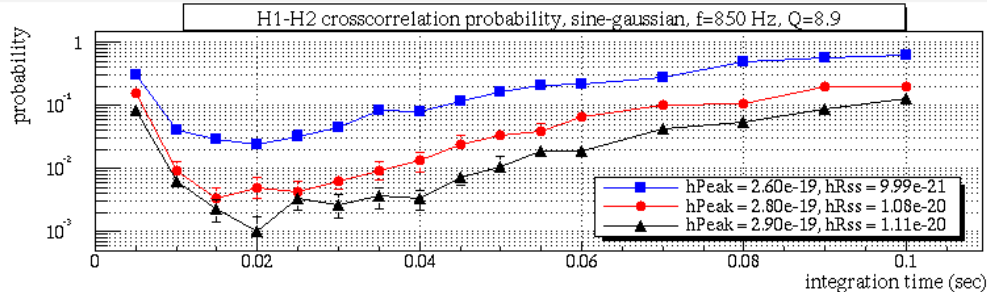
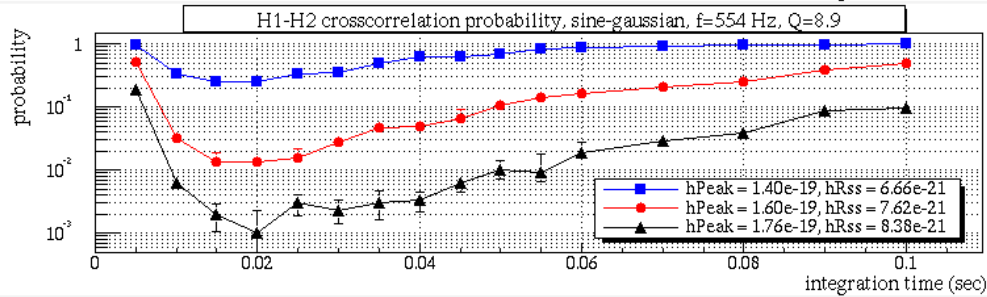
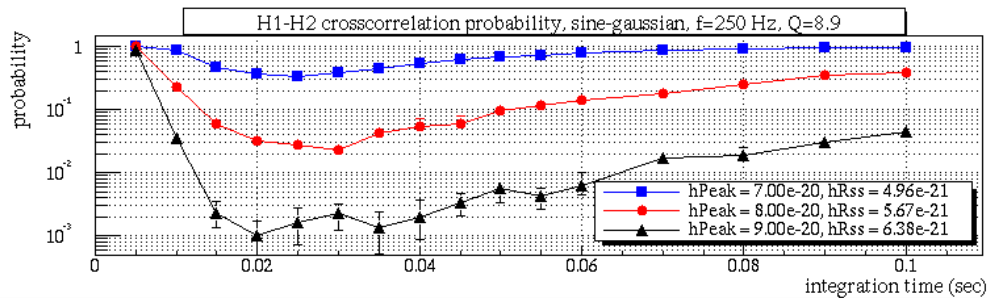


- ❖ on-source distributions derived from playground data with injections
- ❖ off-source segments were **shuffled** – each search segment from one IFO paired with all segments from other IFO

# Estimation of probabilities from off-source distributions (playground data)

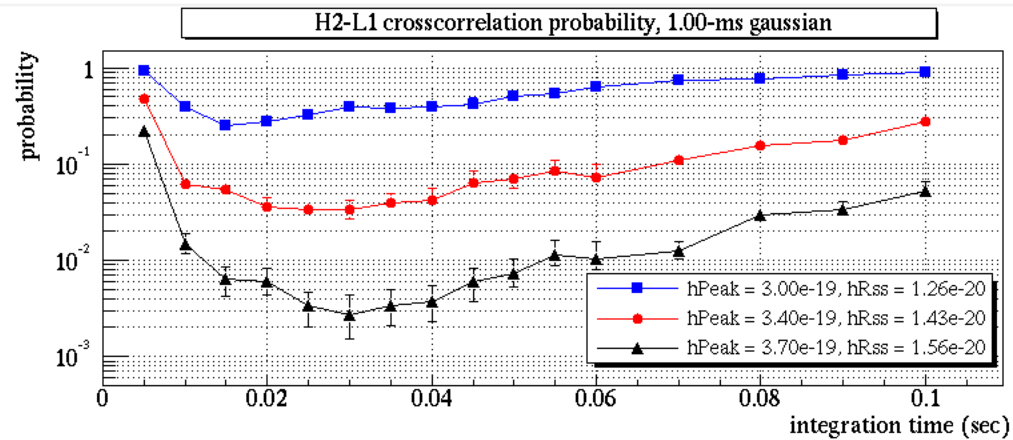
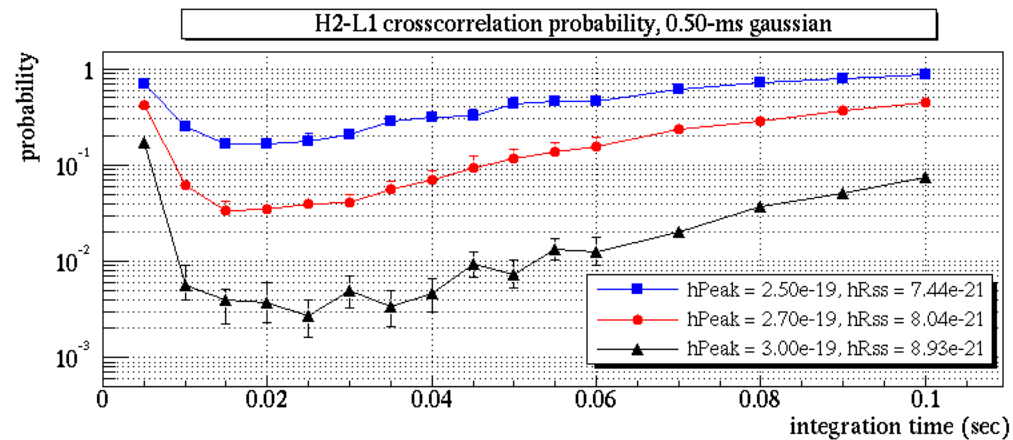


# Optimal integration lengths for short duration signals ( $\sim 1 - 10$ ms)

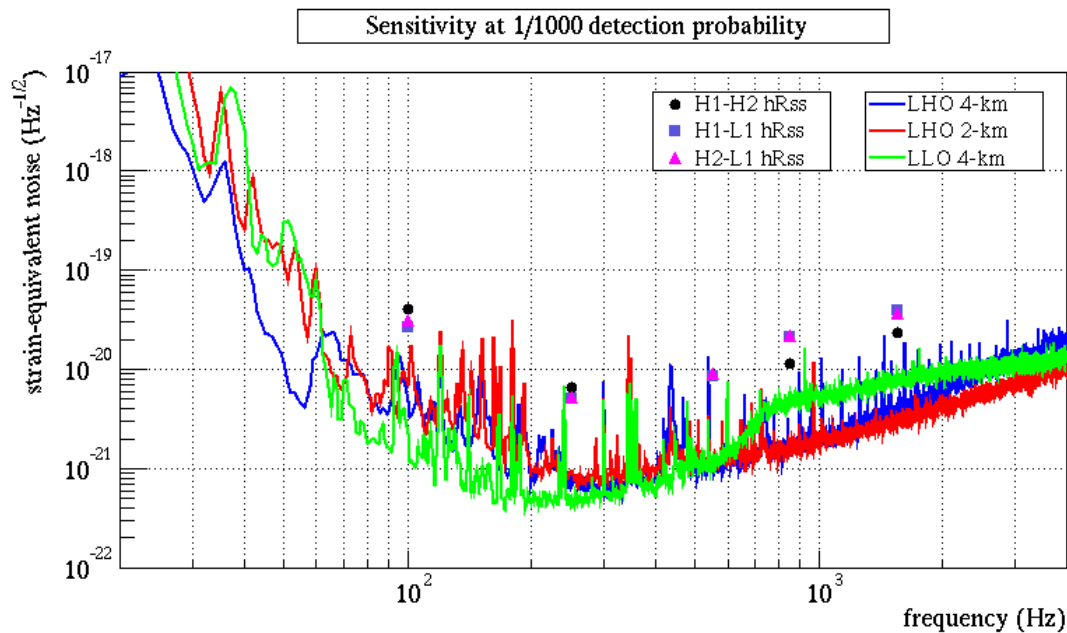


- ❖ probability for getting median of on-source distribution, given off-source distribution
- ❖ probability takes into account trials in search
- ❖ probability is function of length of crosscorrelation window
- ❖ small window:  $1/\sqrt{N}$ , more trials
- ❖ large window: more noise integrated

# Optimal integration lengths - gaussians



# Sensitivity to sine-gaussians at detection probability 1/1000 (after trials)

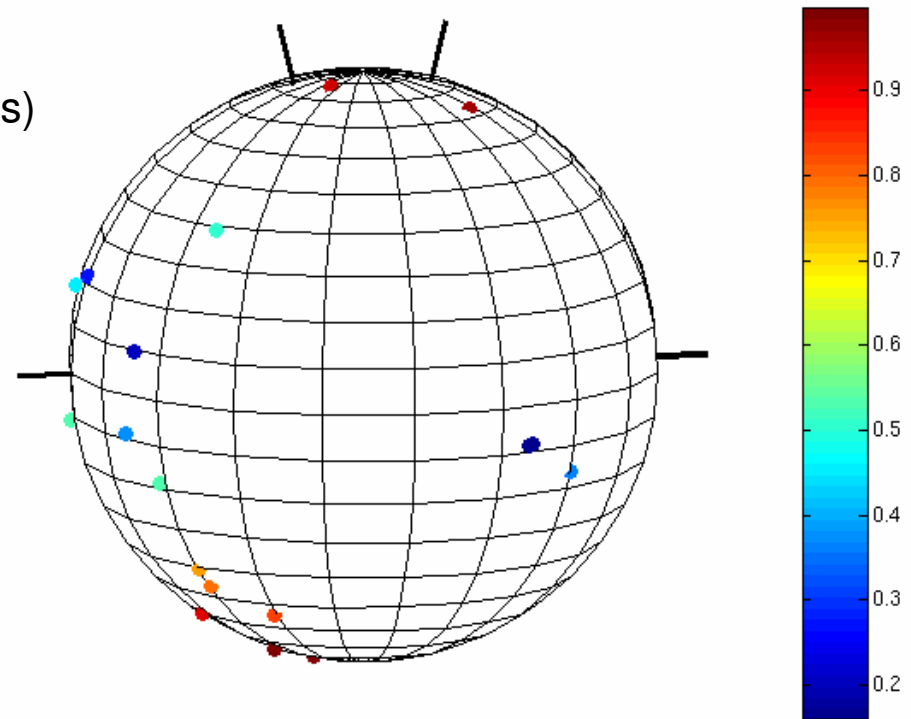


- ❖ valid for 160-second search segments, 25-ms crosscorrelation window
- ❖ playground data
- ❖  $Q = 8.9$
- ❖ sensitivity to gaussians:

$\sigma$	H1-H2	H1-L1	H2-L1
0.5 ms	1.10e-20	8.56e-21	9.47e-21
1.0 ms	2.02e-20	1.49e-20	1.66e-20

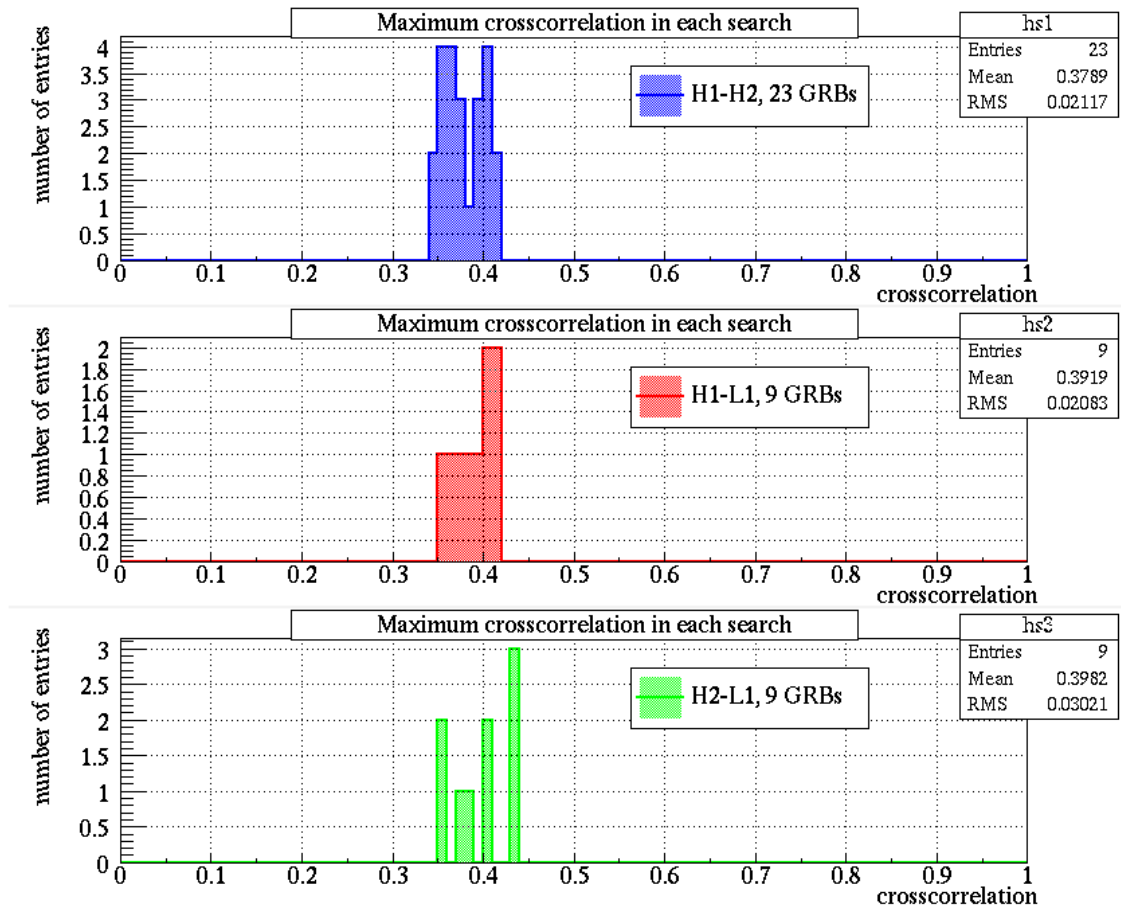
# The GRB sample

- ❖ **25 GRB** triggers used
  - ❖ 23 for H1-H2 (includes 4 HETE GRBs)
  - ❖ 9 for H1-L1
  - ❖ 9 for H2-L1
- ❖ H1-L1, H2-L1 search did not include non-localized IPN triggers (separate search)
- ❖ **time delay** taken into account for H1-L1, H2-L1 search
- ❖ GRB durations ranged from 0.3 – 200 s
- ❖ all on-source segments were clean (no error codes)



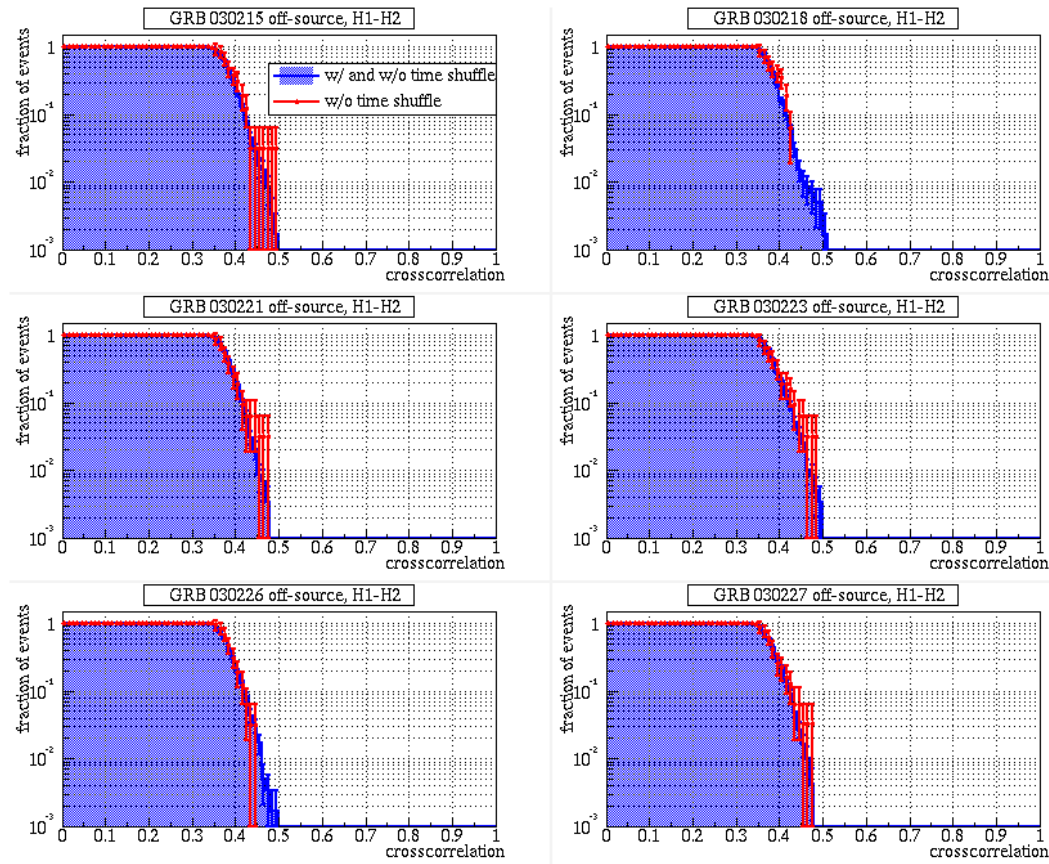
Local coordinates of GRB triggers and rms antenna factors for LHO

# Largest crosscorrelation found in each GRB on-source segment



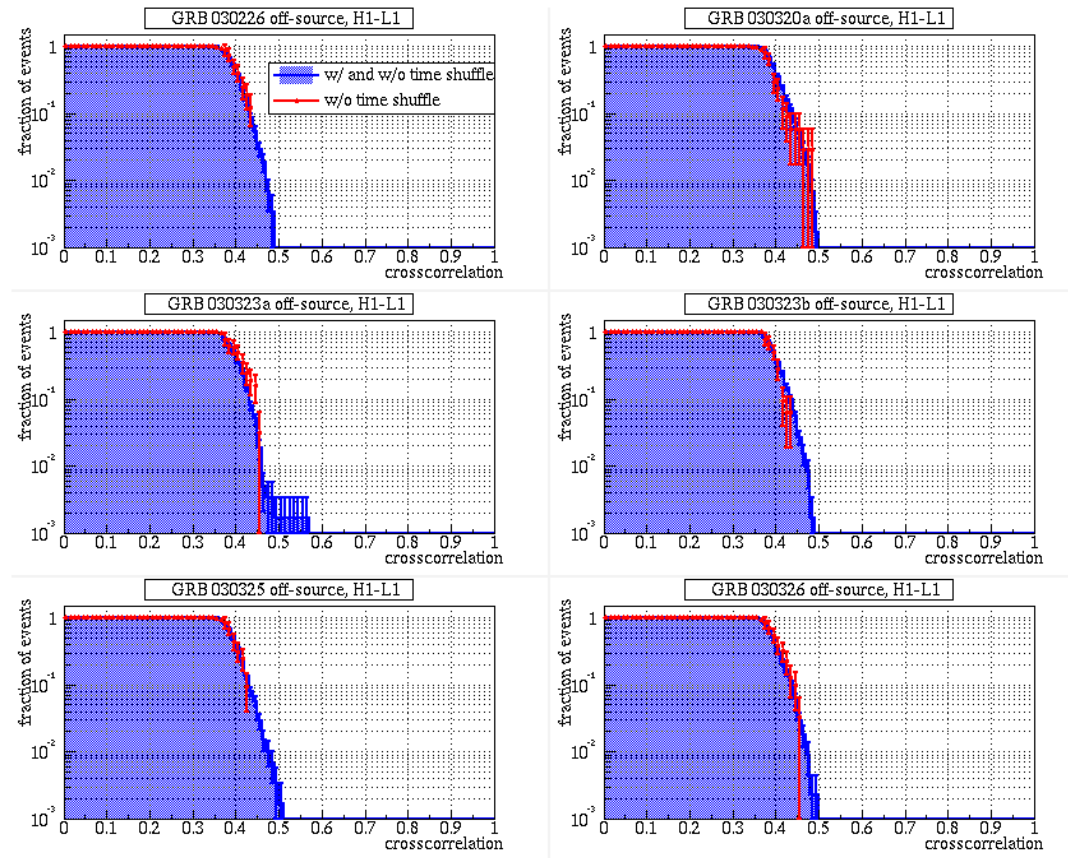
- ❖ find largest cc for H1-H2
- ❖ find largest  $\text{abs}(\text{cc})$  for H1-L1, H2-L1

# Off-source distribution examples – H1-H2

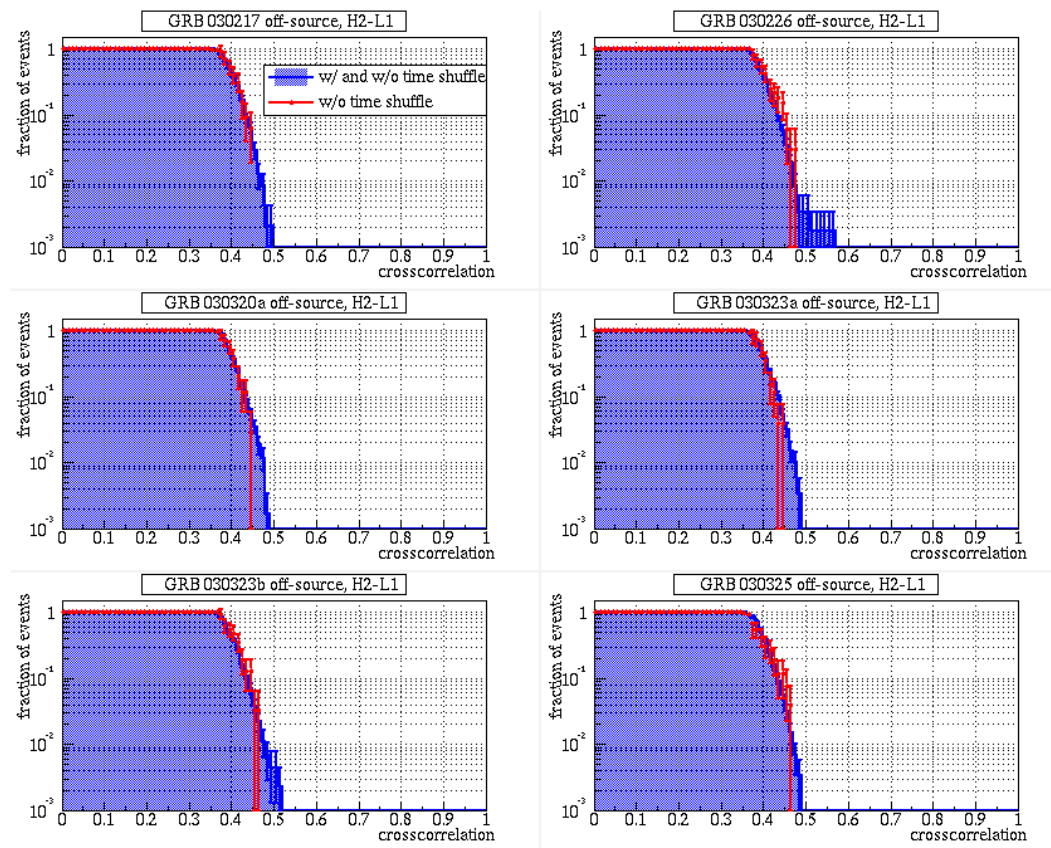


- ❖ local off-source distribution determined for each GRB trigger
- ❖ each distribution determined from searches within science segments occurring within a few hours of GRB trigger
- ❖ largest crosscorrelation found in each search included in distribution
- ❖ used data segments defined by burst group (J. Zweizig), with last 10 seconds of each segment excluded

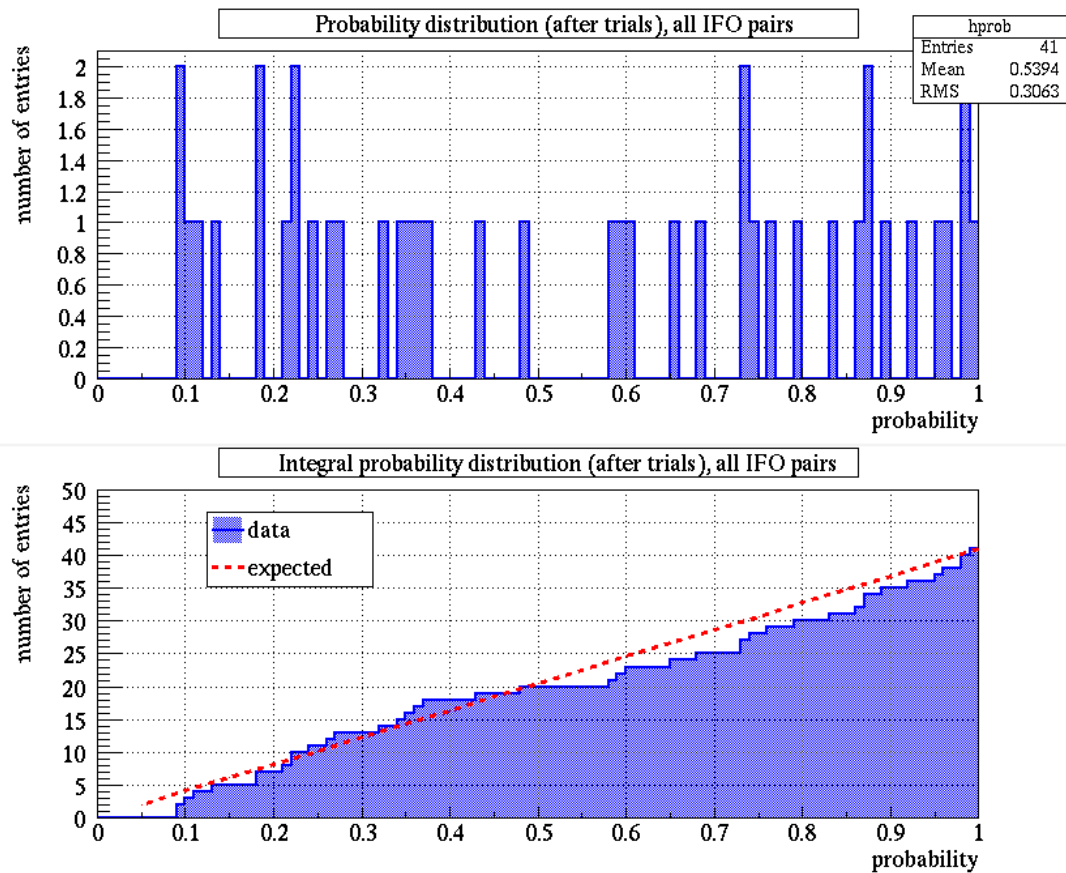
# Off source distribution examples – H1-L1



# Off-source distribution examples – H2-L1



# What are the odds?



- ❖ calculate probability for largest cc found, given off-source distribution
- ❖ measured probability distribution consistent with random distribution
- ❖ no evidence of outliers, significant excess
- ❖ consistent with null hypothesis