THE EFFECT OF NETWORK CONFIGURATION ON PARAMETER ESTIMATION

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OVERVIEW

- Introduction
- Parameter Estimation
- 3rd Generation Network Configurations
- Simulations
- Conclusions

INTRODUCTION

- Parameter estimation is a necessity for extracting maximum science potential from 3rd generation detectors.
  - Measurement of parameters, in particular masses, distances, angular orientation (GRBs), sky location.
- What effect does our choice of network topology have on parameter estimation?
  - Accuracy
  - Precision
  - Breaking degeneracies

REQUIREMENTS

- Require a framework to perform these and other investigations robustly and efficiently.
- Use the network coherently, as a single instrument.
- Infer physical parameters of the signal.
- Incorporate known prior information.

PARAMETER ESTIMATION

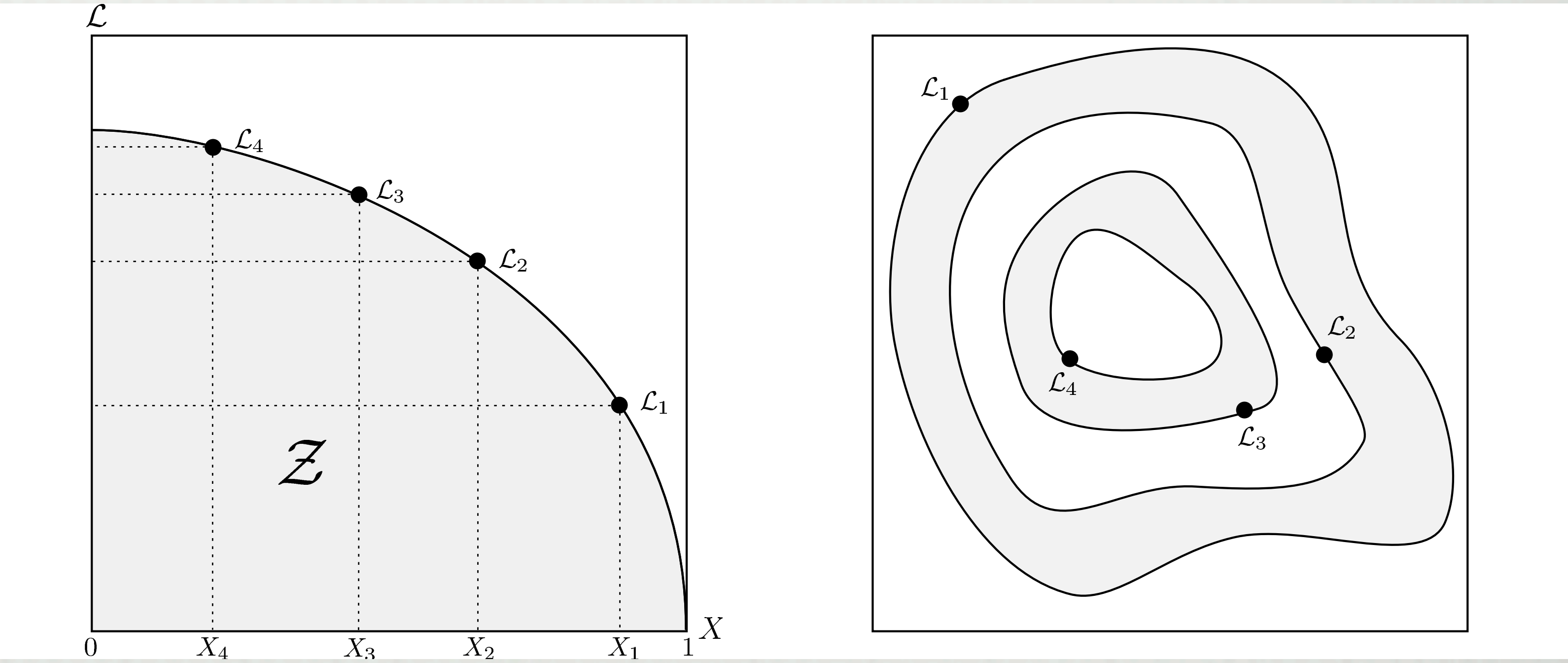
- Compute the full posterior probability density function on the parameter space θ of the signal model H, given data $\{d\}$.

$$p(\vec{\theta}|\{d\}, H) = \frac{p(\theta|H)p(\{d\}|\theta, H)}{p(\{d\}|H)}$$

- Want to examine the full PDF, and calculate means & variances, but integrating the distribution analytically is tricky.
- Use Monte Carlo Integration: approximate integrals by sampling the distribution.

NESTED SAMPLING

- Nested Sampling[1] designed to perform difficult likelihood integrals by mapping onto a 1-D integral over prior.
- Use a collection of N_{Live} samples from prior. At each iteration replace outermost sample with one drawn from within the contour.
- At each iteration the volume enclosed shrinks by factor $\sim e^{1/N_{Live}}$.
- Calculates:
  - Marginal likelihood: fit of data to a model
  - Posterior samples: parameter estimation



J. Skilling, "Nested Sampling for General Bayesian Computation" Bayesian Analysis **1** (4) 2006

NETWORK CONFIGURATIONS

- We consider two network configurations, with ET built as a triangular detector, or as 4 L-shaped detectors at two sites.

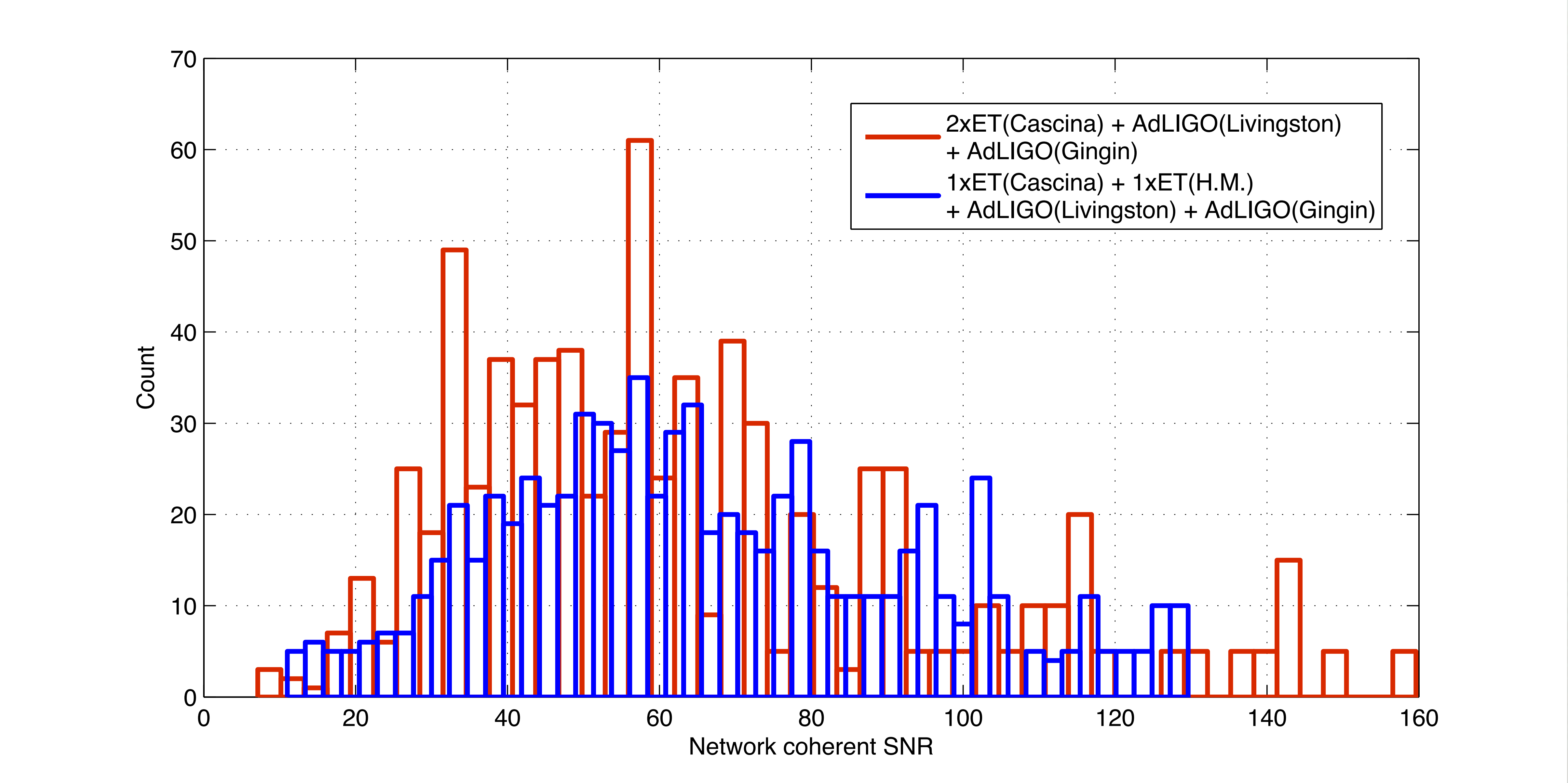
Network 1 ET + LIGO(South)	Network 2 ET (2 sites) + LIGO(South)
2x 10.6km @ Cascina equiv. 7.5km triangle	1x 10.6km @ Cascina
	1x 10.6km @ Homestake Mine S.D.
Advanced LIGO (4km) @ Livingston	Advanced LIGO (4km) @ Livingston
Advanced LIGO (4km) @ Gingin	Advanced LIGO (4km) @ Gingin

SIMULATIONS - DETAILS

- Use the ET_B noise curve for all ET-detectors.
- Binary neutron star systems, 2PN.
- Inject in grid over RA, declination, inclination, polarisation to cover range of possibilities.
- As a first approach to the problem, make some simplifying assumptions
  - Gaussian noise with known power spectral density (ET_B).
  - 2-PN inspiral-only waveforms.
  - 30Hz lower frequency cutoff (to shorten length of signals)

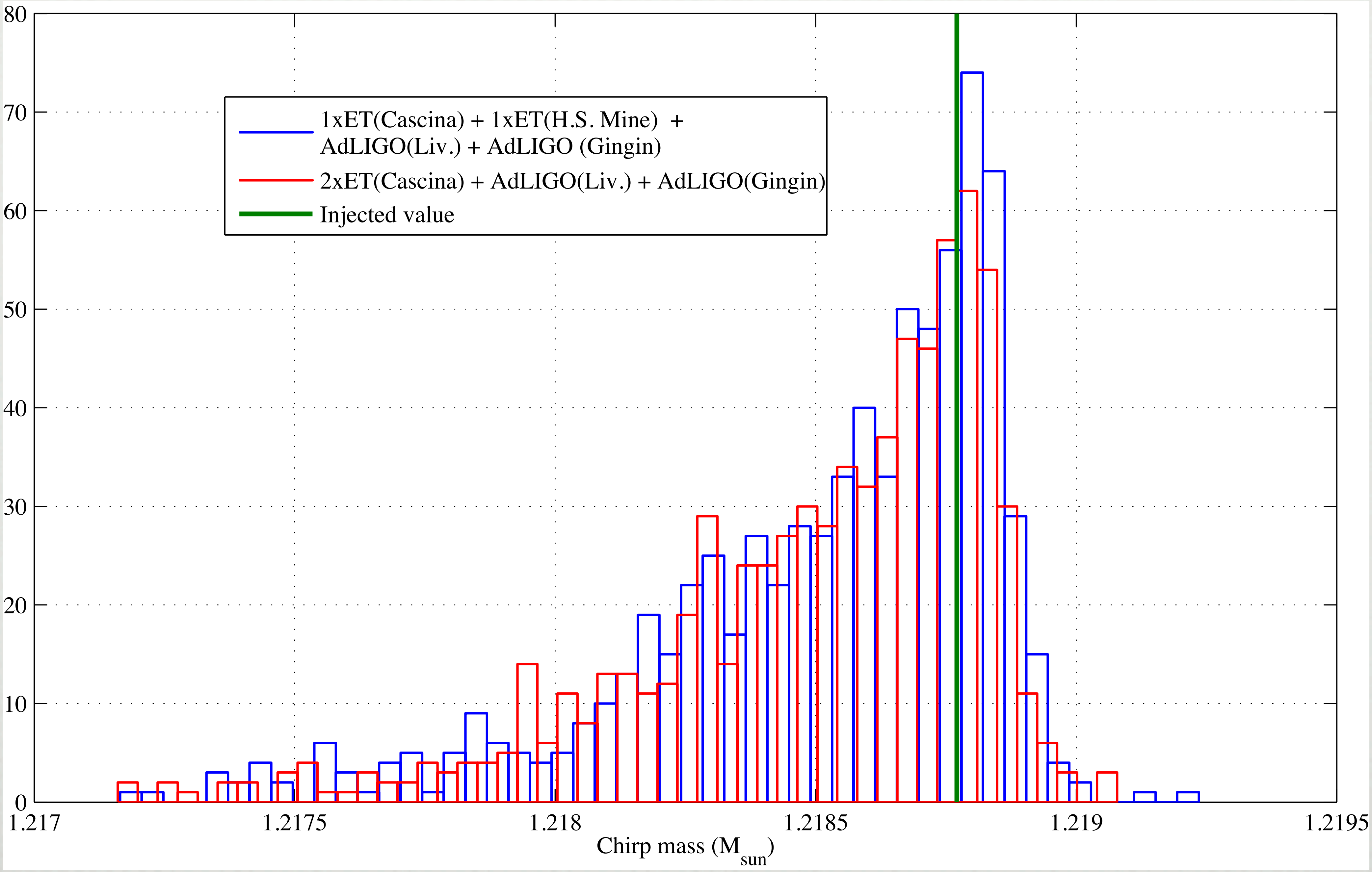
INJECTIONS - DETAILS

- Injections have broadly similar SNR distributions in each network



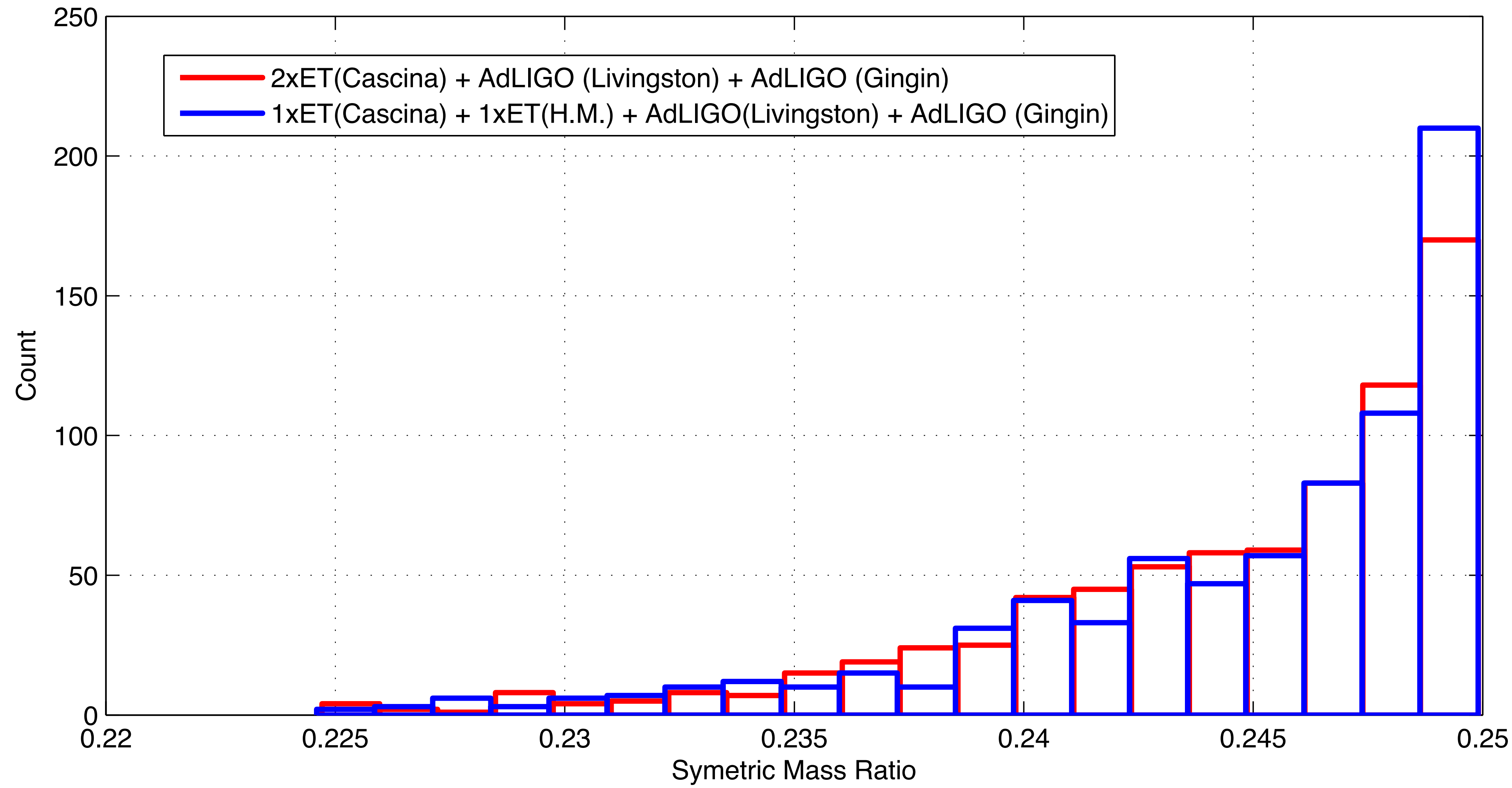
ACCURACY - CHIRP MASS

Mean value of recovered Chirp Mass estimate

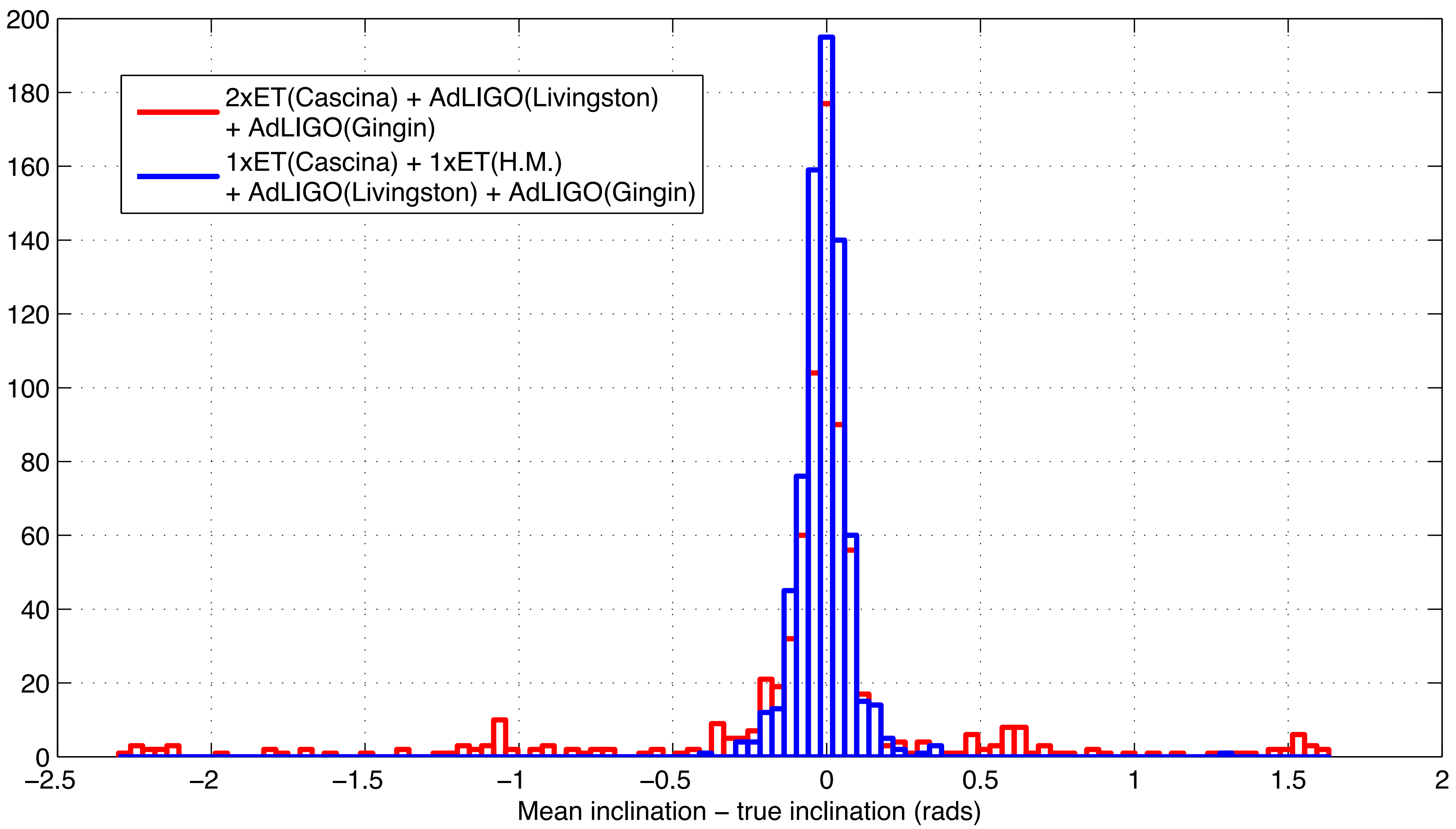


ACCURACY - MASS RATIO

Mean value of recovered Symmetric Mass ratio estimate

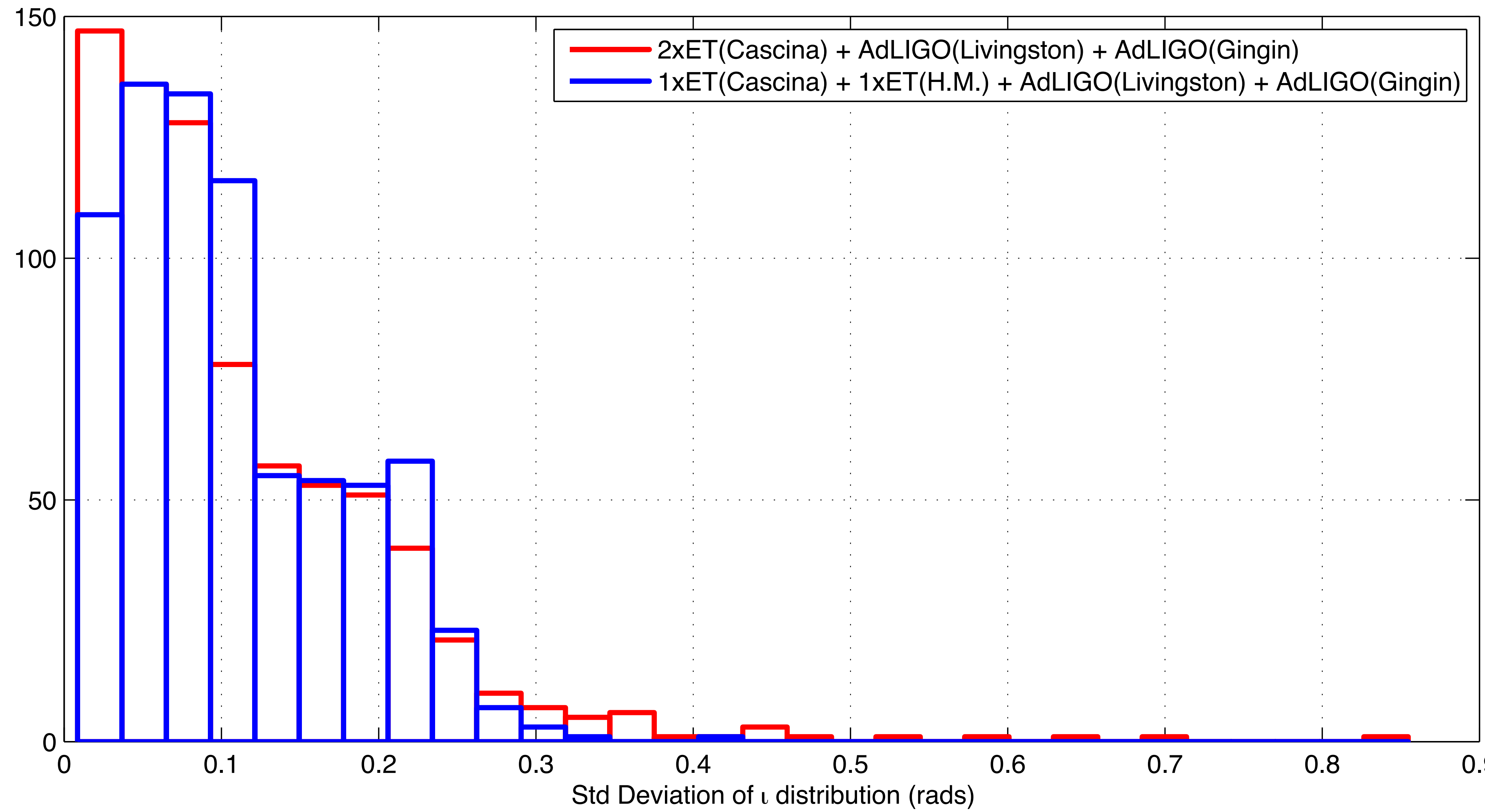


ACCURACY - INCLINATION

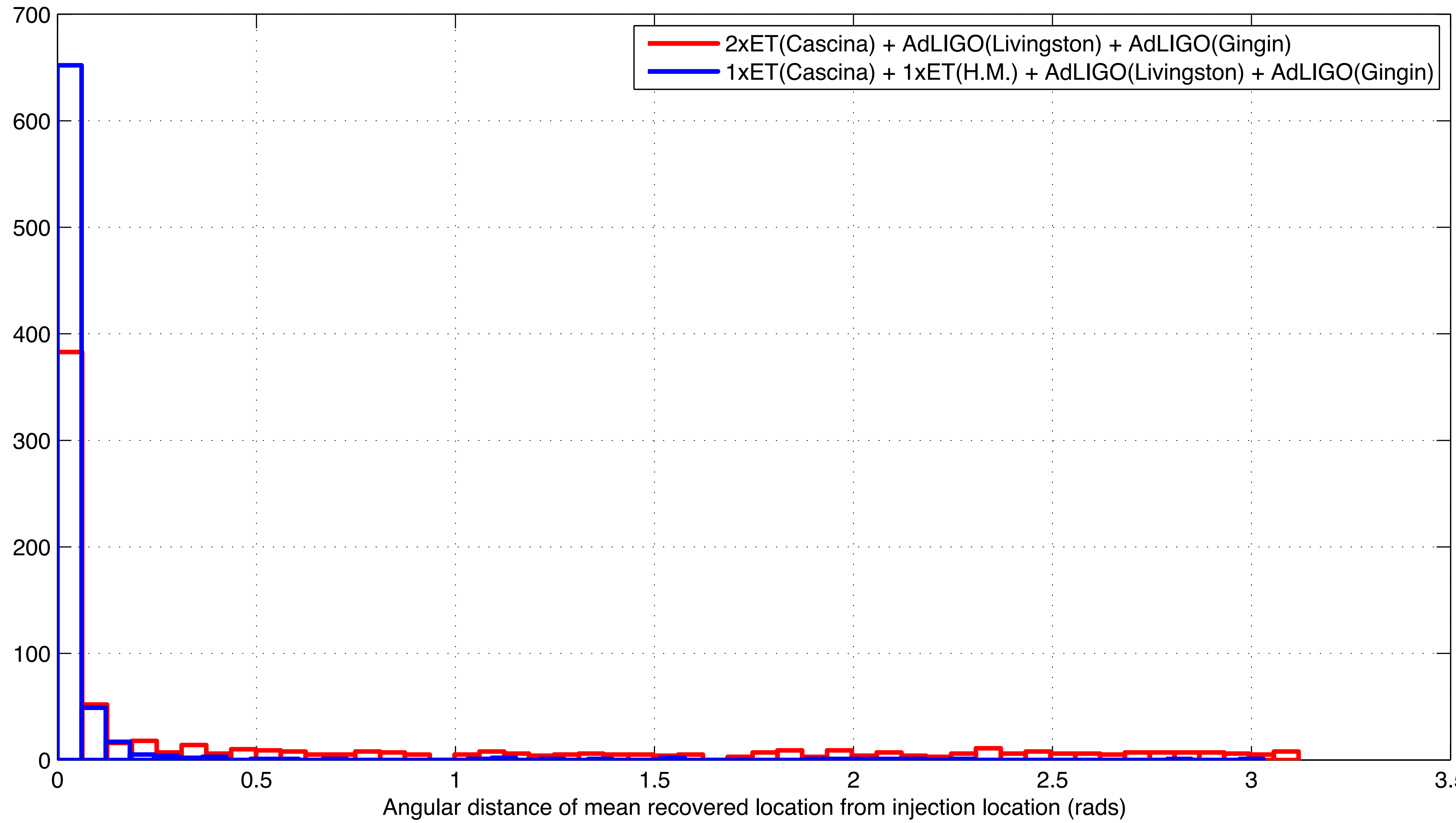


- We start to see the difference a fourth site makes.

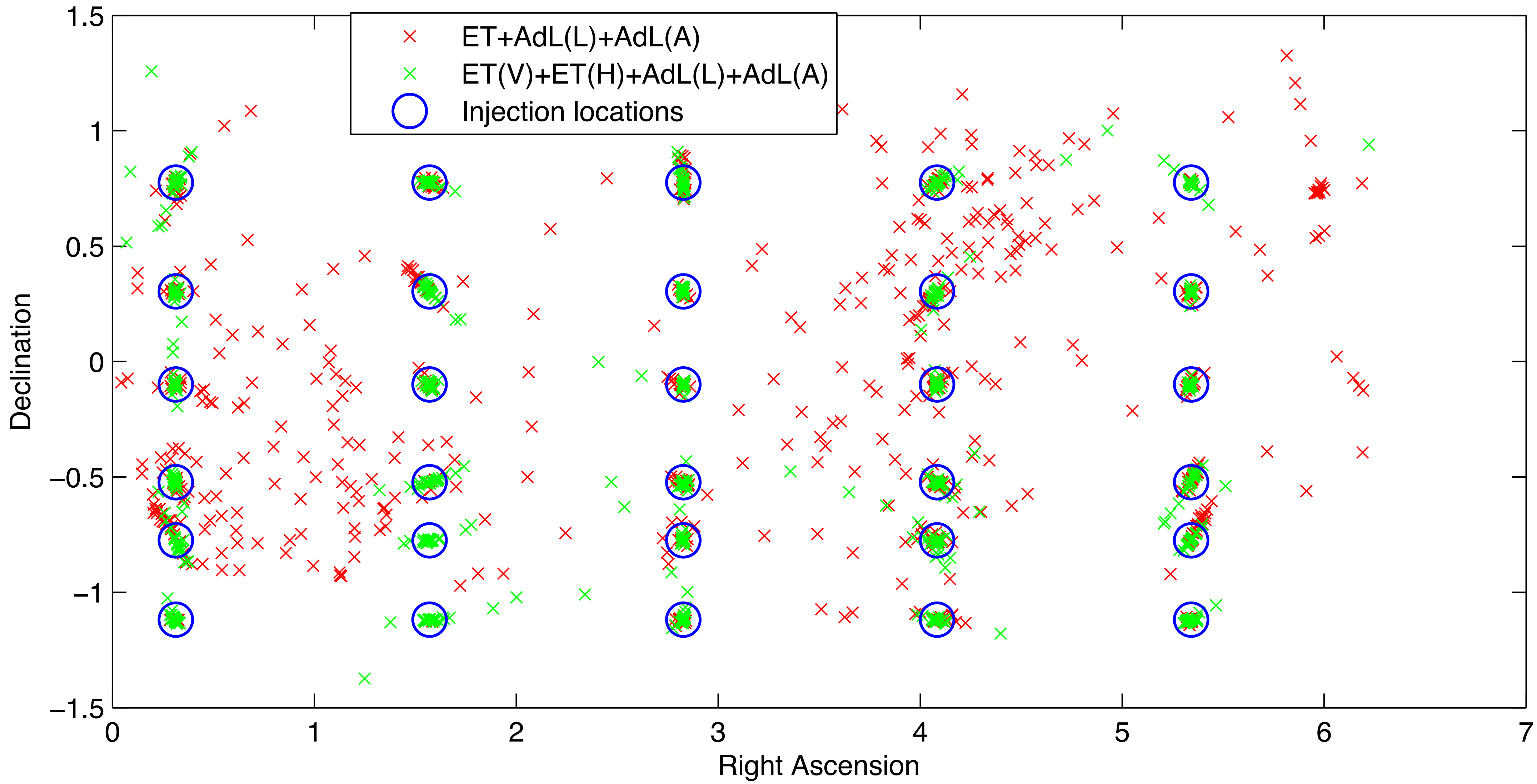
PRECISION - INCLINATION



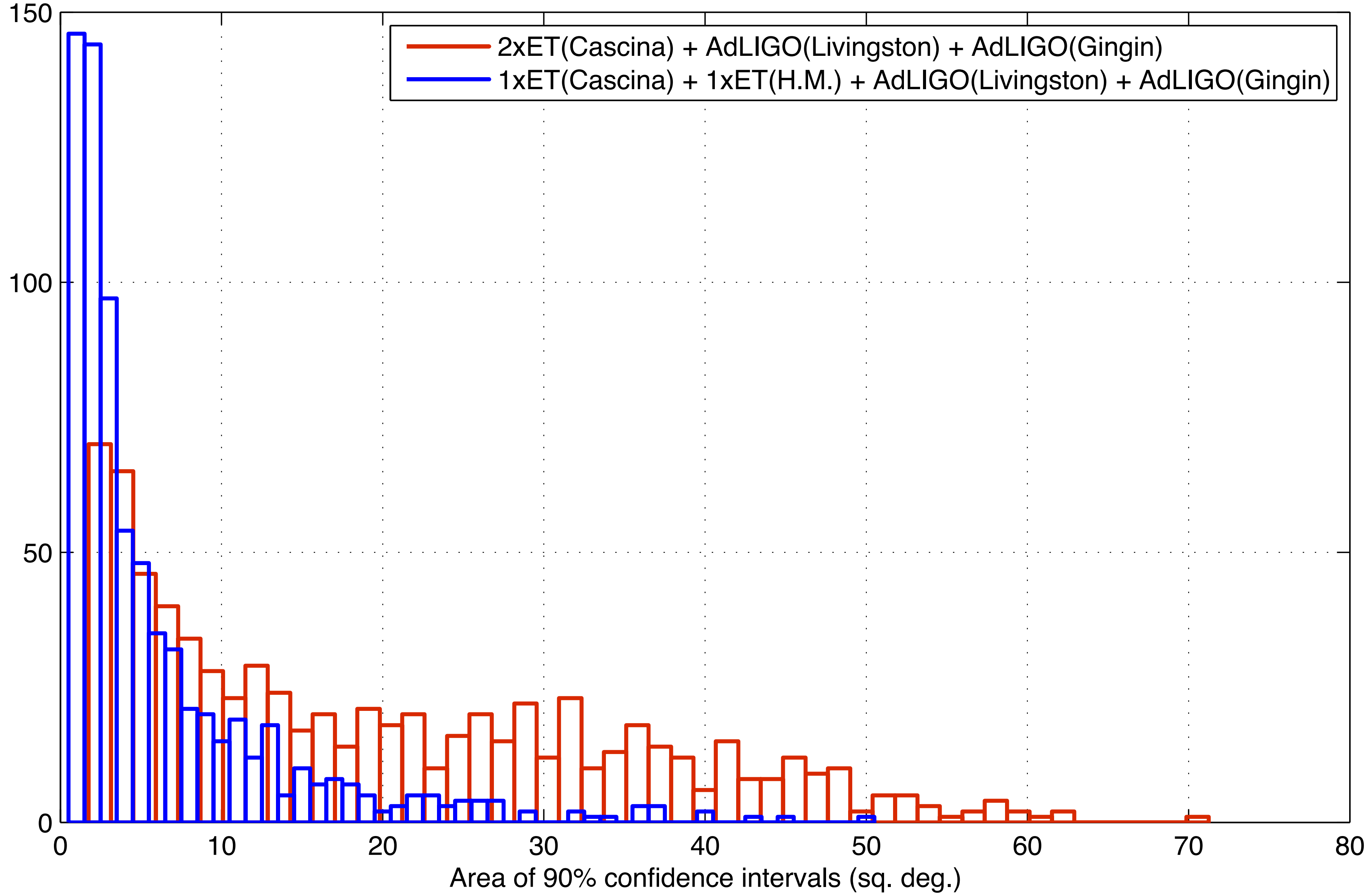
ACCURACY - SKY POSITION



ACCURACY - SKY LOCATION

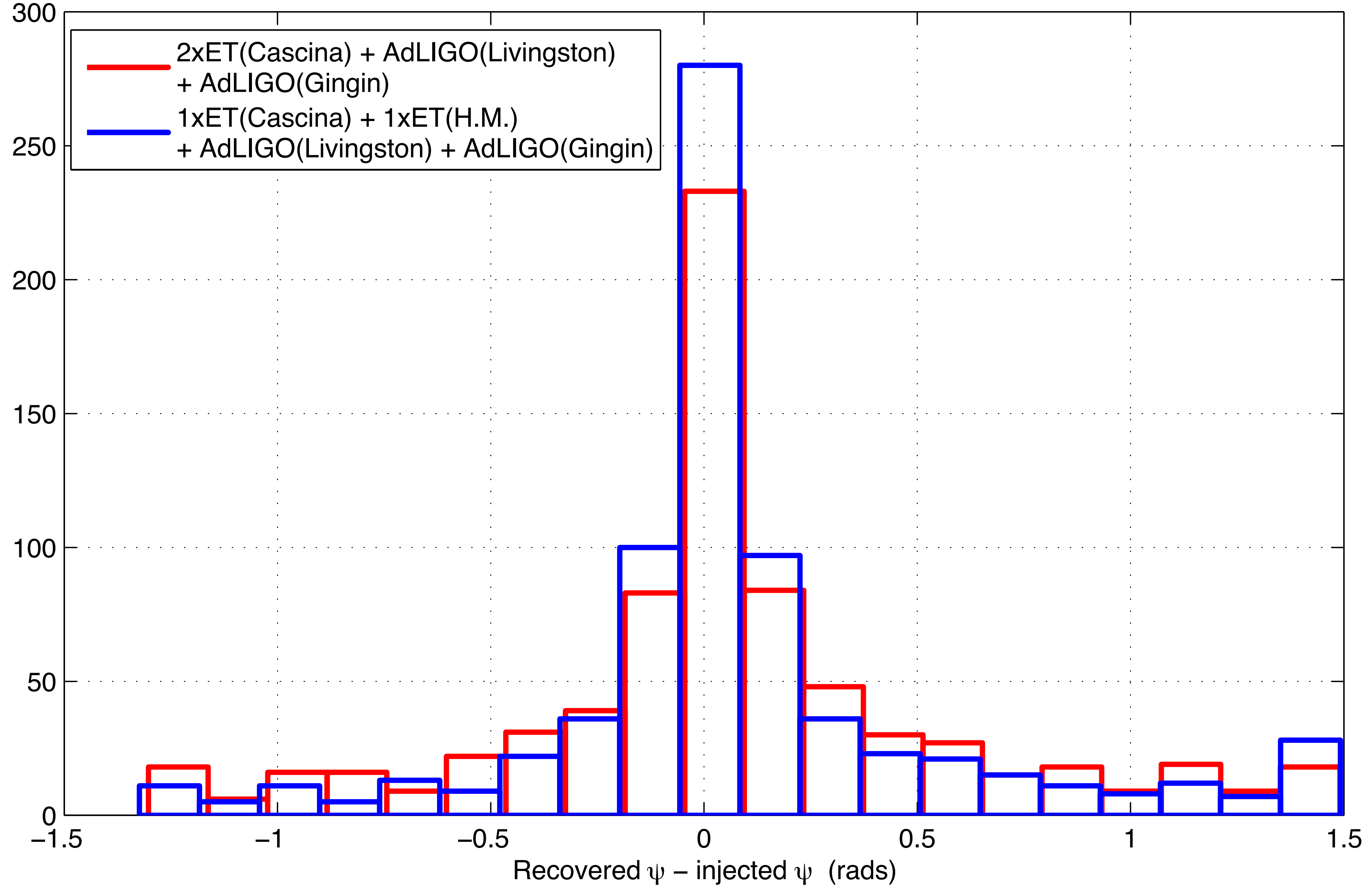


PRECISION - SKY LOCATION



- Length of baselines dominates ability to resolve sky location.

ACCURACY - POLARISATION

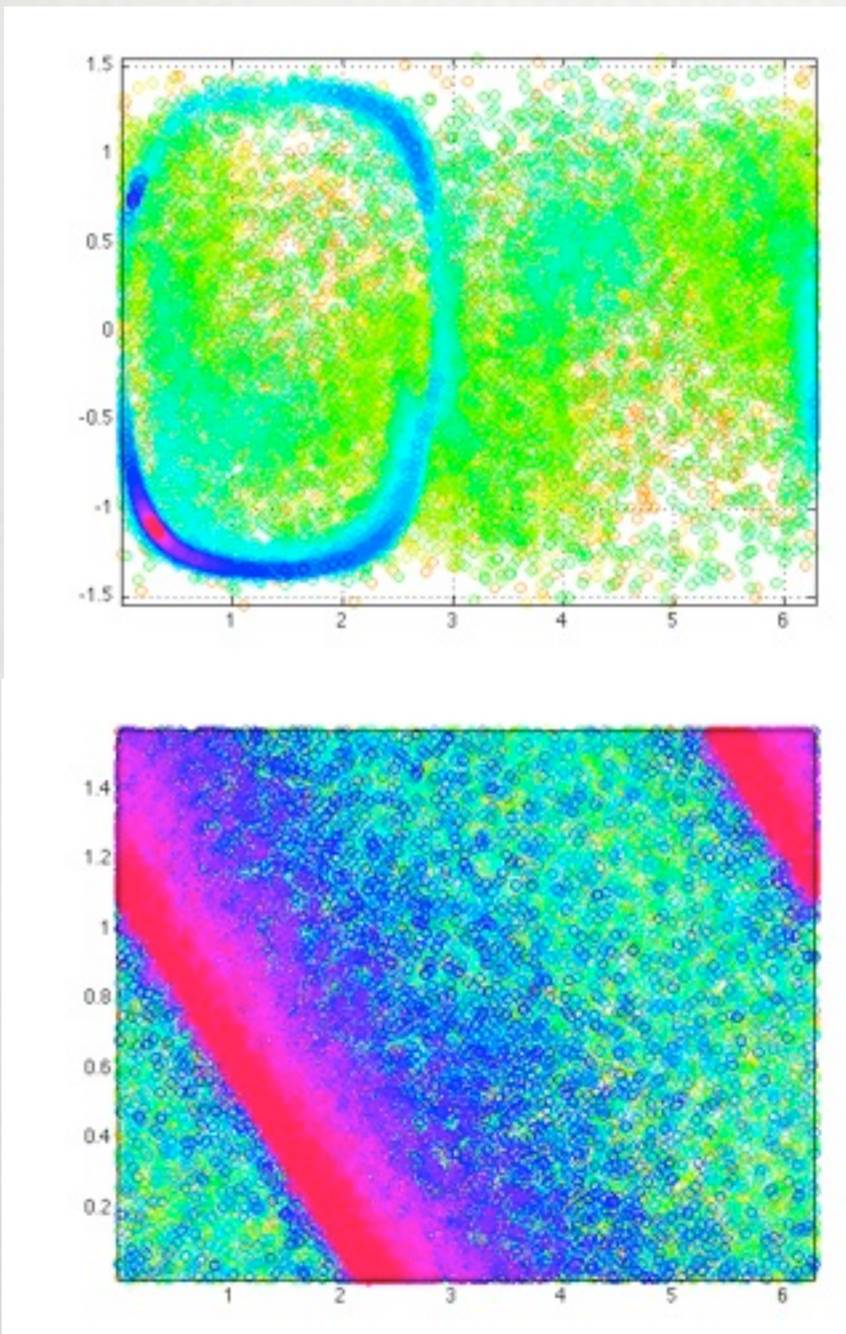


- Both network configurations have the ability to resolve the polarisation angle of the source

POLARISATION - DEGENERACY

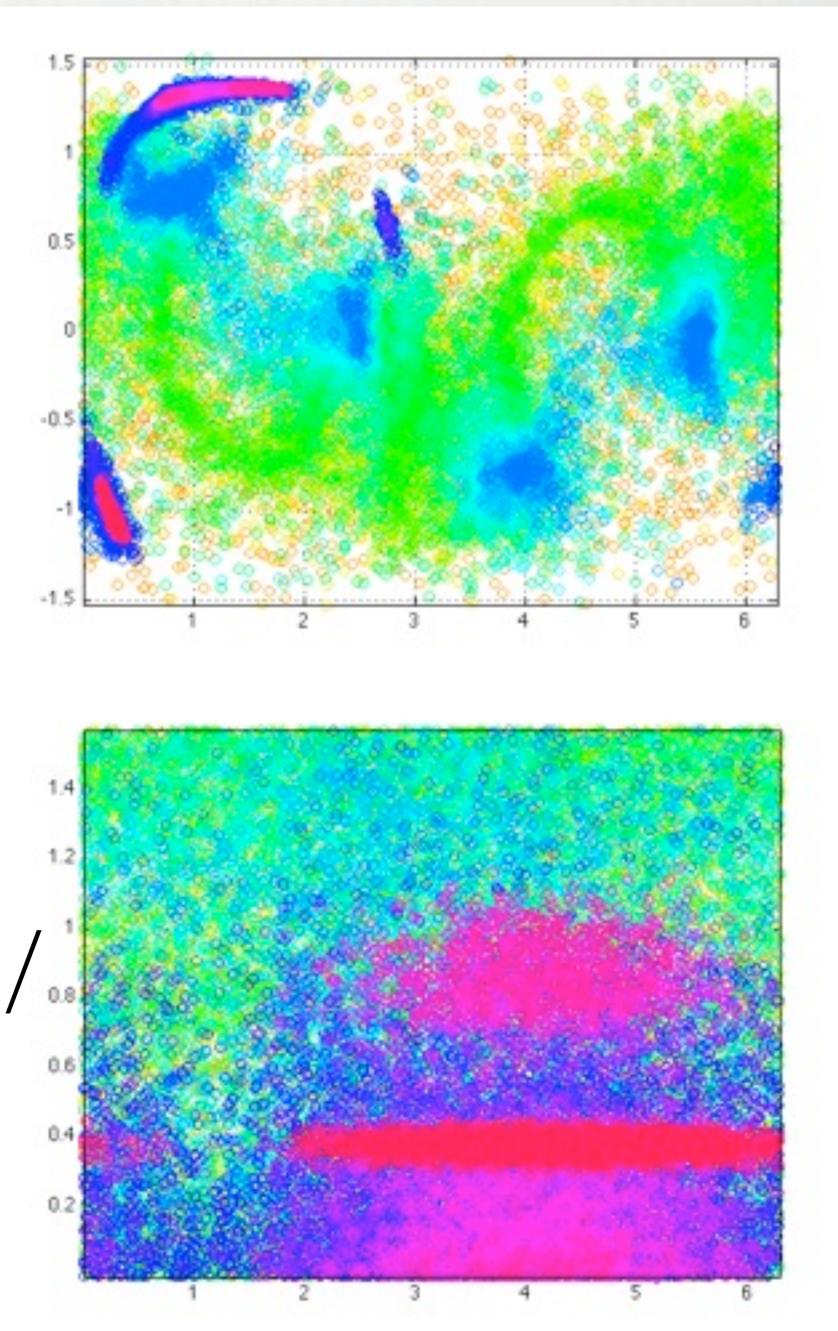
Face-on

Edge-on

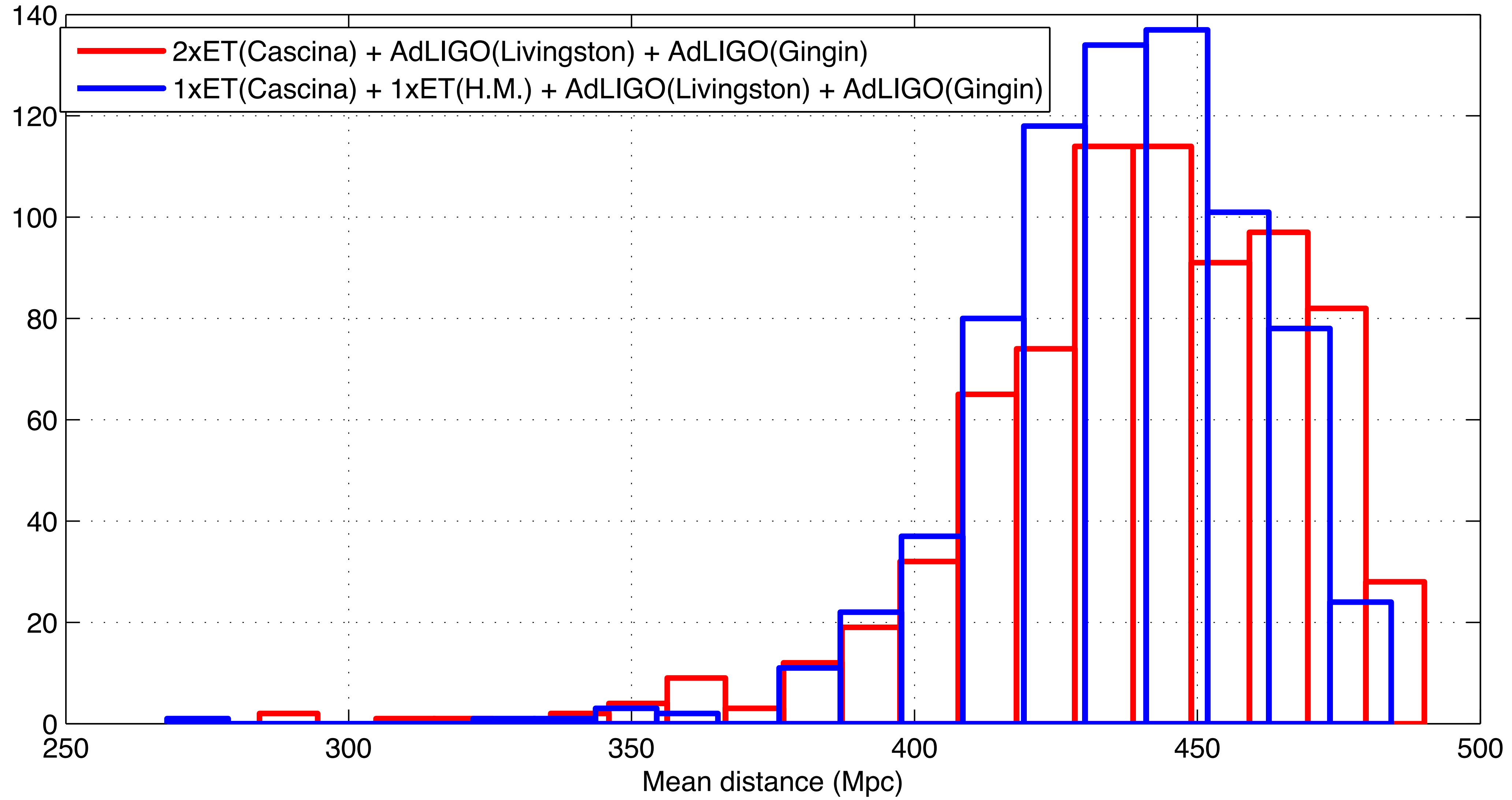


Sky location

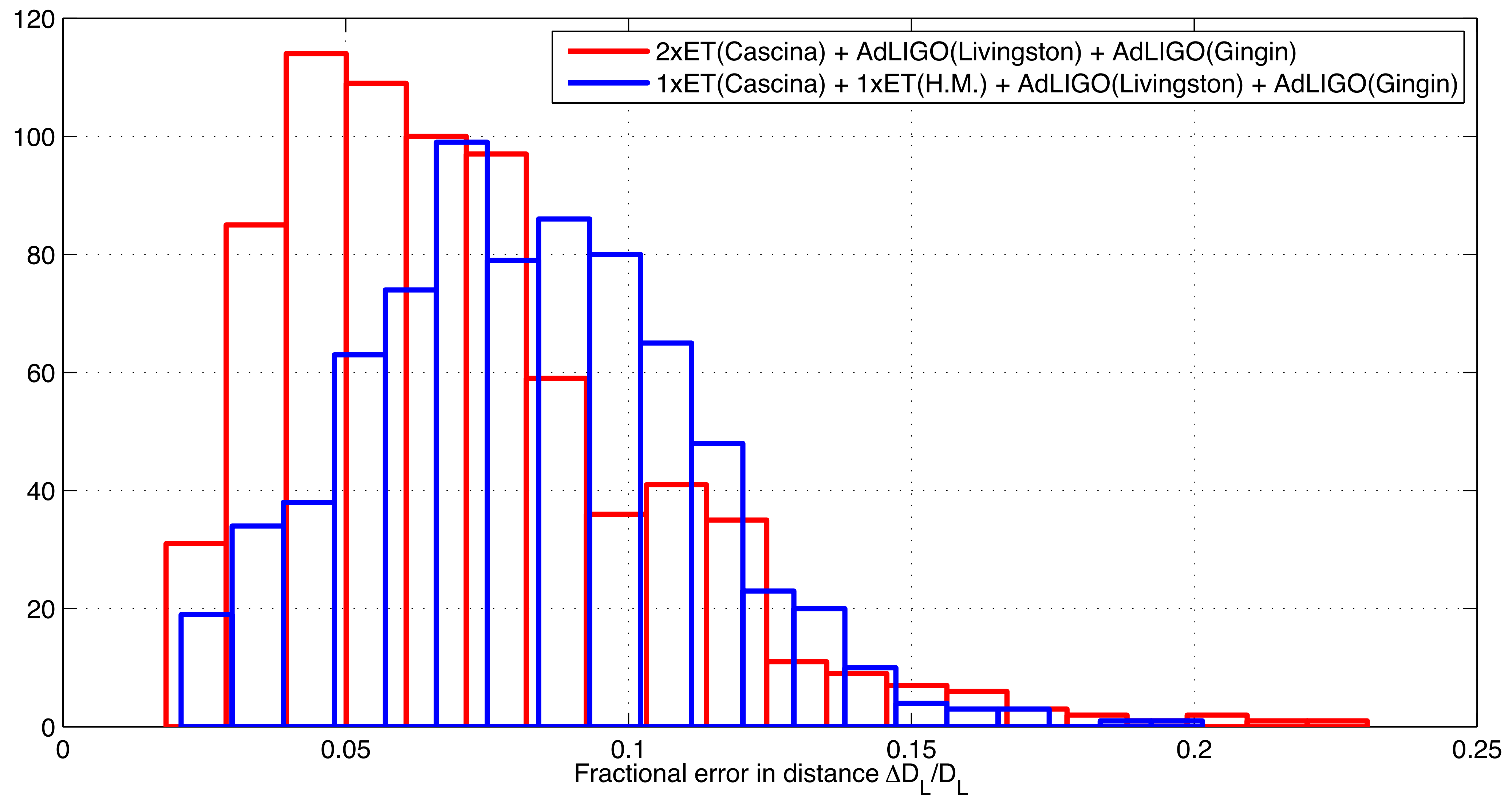
Polarisation / phase



DISTANCE - ACCURACY



DISTANCE - PRECISION



FOR THE FUTURE

- Increase realism of the simulations:
  - Amplitude corrected waveforms
  - A wider range of masses
  - Inspiral/Merger/Ringdown waveforms
- What effect does having multiple signals in-band have on parameter estimation?
  - Do we need to estimate the noise curve at the same time?
- ET Mock Data Challenge!

CONCLUSIONS

- 3rd generation detectors should be able to pinpoint estimates of progenitor masses, irrespective of network configuration
- Polarisation states and inclination can be measured very well in either case – and can probably be done even better with amplitude corrected waveforms.
- Accuracy of sky localisation depends primarily on baseline length of the network, and also number of sites – the bigger the better!