

SEARCH INPUTS

(different for each multi-messenger trigger)

GW

1 GW trigger

- Skymap (Ω)
- Mean distance (r_{GW})
- SNR (ρ)
- Time

Neutrino

Multiple neutrino triggers

- Sky position mean (RA, Dec)
- Sky position std. dev. (σ)
- Energy
- Time

SEARCH PARAMETERS

(constants used for many triggers)

- GW signal-noise ratio (SNR) background distribution
- Background neutrino triggers
- Effective IceCube area
- Integration bounds
- Empirical constants

BACKGROUND

Adjust neutrino energy window so that it matches enough background triggers

Find similar neutrinos in empirical background data

Calculate background (BG) rate

CHANCE COINCIDENCE

Real GW, BG neutrinos

$$P_{E_{GW}} \left(\frac{r_{GW}^2 \rho^2}{k_0^2} \right) r_{GW}^2$$

Real neutrinos, BG GW

$$\int A_{eff} \Omega_\nu d\Omega \times \int r^2 Poiss.(n, \langle n_\nu(E_\nu, r) \rangle) dr dE_\nu$$

Calculate chance coincidence likelihood

SIGNAL

Calculate spatial overlap:

$$\int_{allsky} A_{eff} \Omega_\nu \Omega_{GW} d\Omega$$

Combine real GW, real neutrino probabilities with overlap integrals to get signal likelihood:

$$\int Poiss.(n, \langle n_\nu(E_\nu, r) \rangle) P(E_\nu) dE_\nu \times P_{E_{GW}} \left(\frac{r_{GW}^2 \rho^2}{k_0^2} \right) r_{GW}^2 \times (t_\nu, t_{GW} \text{ overlap integral}) \times (spatial \text{ overlap})$$

ODDS RATIO For any GW+HEN detection on this GW trigger (decomposed into partial fractions)

$$\sum_{i=1}^N \frac{P(H_S | x_{GW}, x_{\nu,i})}{P(H_0 | x_{GW}, x_{\nu,i}) + P(H_C | x_{GW}, x_{\nu,i})} + \sum_{i,j} \frac{P(H_S | x_{GW}, x_{\nu,i}, x_{\nu,j})}{P(H_0 | x_{GW}, x_{\nu,i}, x_{\nu,j}) + P(H_C | x_{GW}, x_{\nu,i}, x_{\nu,j})} + \dots$$

(SINGLE NEUTRINO) (DOUBLE NEUTRINO) (...)