Simulation Study for Cross-Talk Noise between Two Detectors of LCGT on Detection of GW

Nobuyuki Kanda
Osaka City University
for *the LCGT collaboration*

The 9th Gravitational Wave Data Analysis Workshop
12/16/2004, Annecy, France

Plan of Talk

Brief Introduction to LCGT

Motivation

- Coincidence and Cross Talk Noises

Simulation

- Model of Cross Talk Noises
- Generation of Noise

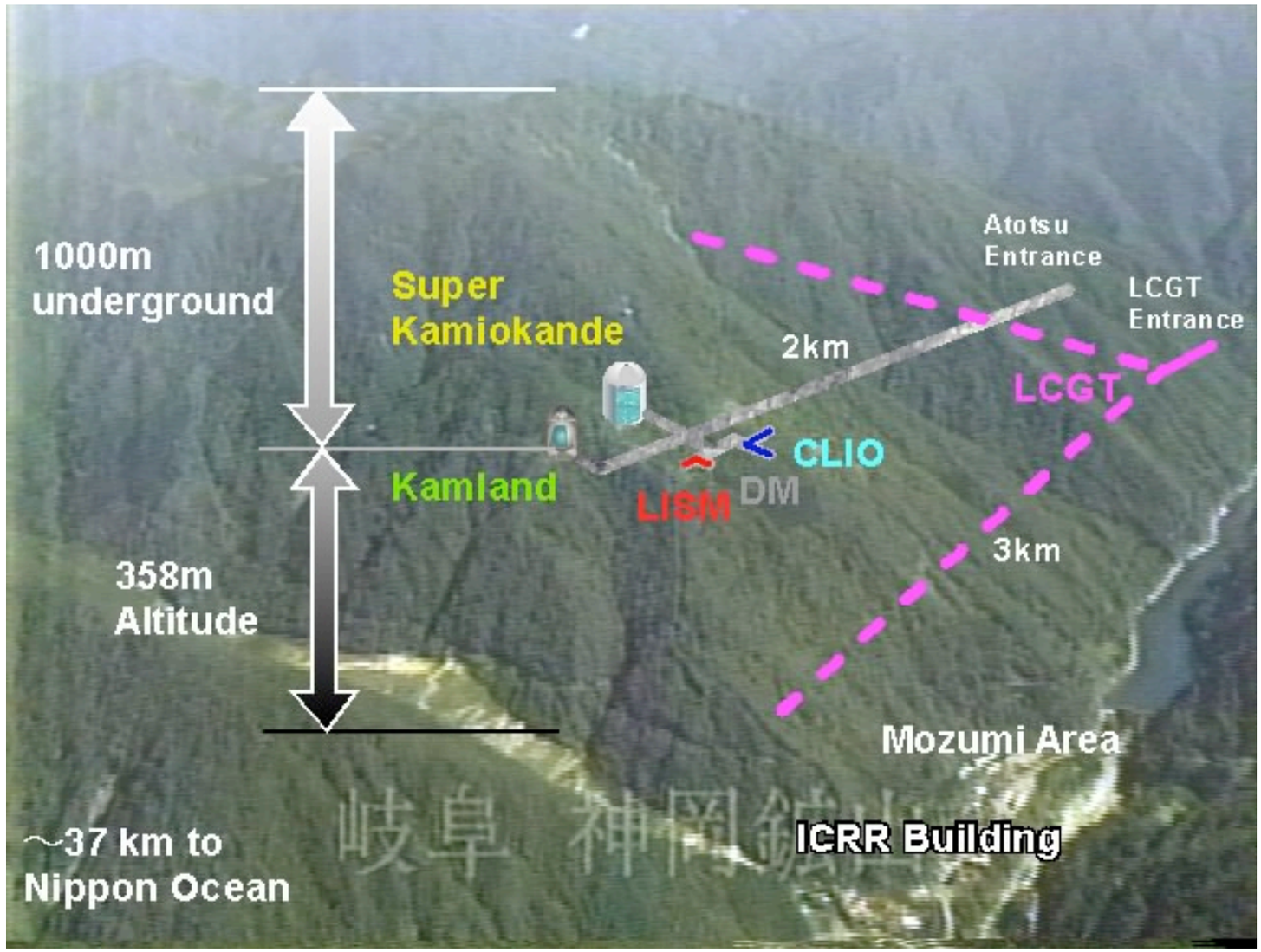
Process Noise by Matched Filter for GW event search

- Evaluate the fraction of Accidental Coincidence

LCGT

Large-scale Cryogenic Gravitational Telescope

(near!) Future Plan in Japan



Cryogenic interferometer

Mirror temperature: 20K

- Reduce thermal noise

Underground site

Kamioka mine,

1000m underground

- Reduce seismic noise

stable operation

Large-scale interferometer

Two interferometers

Baseline length: 3km

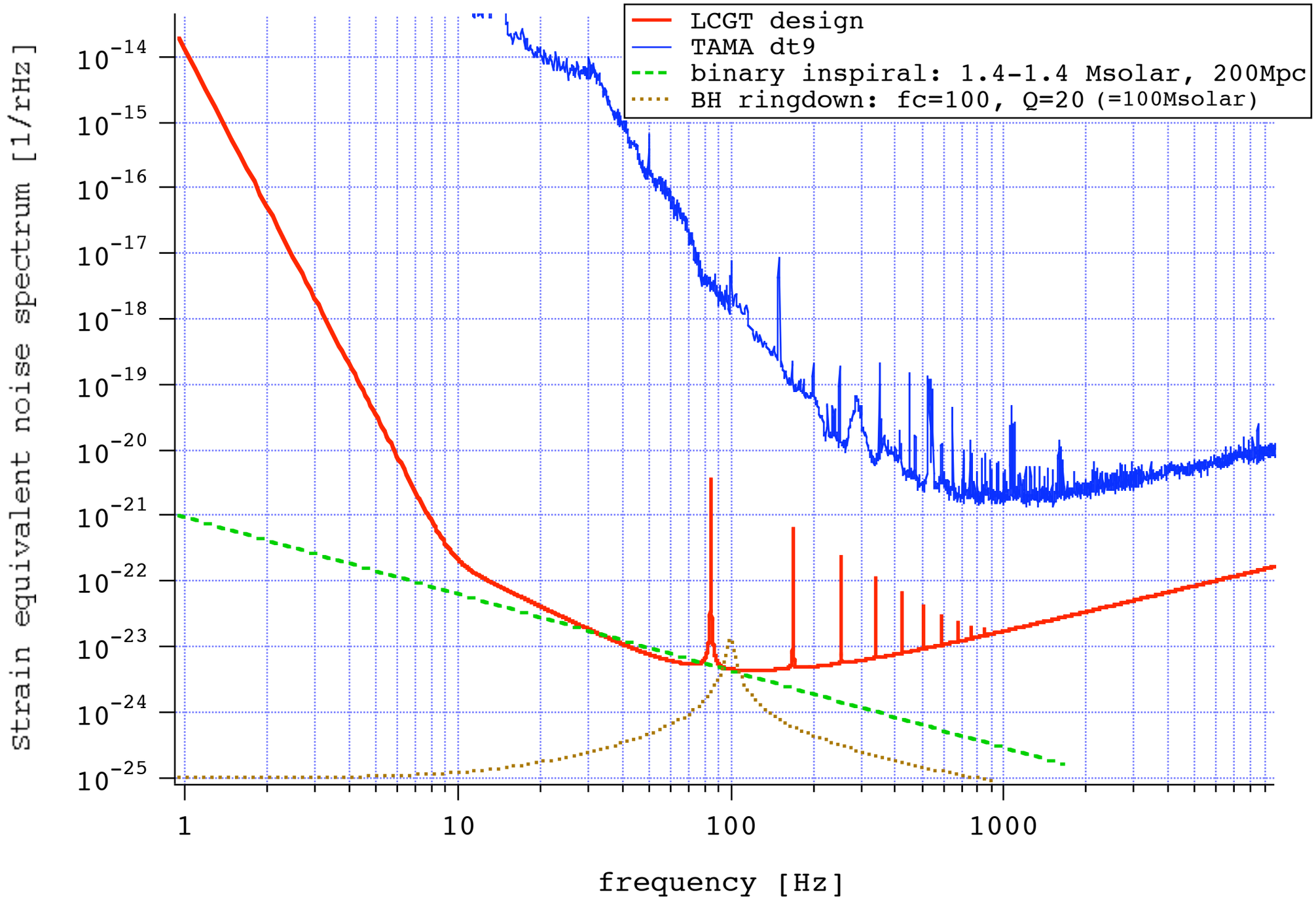
High-power laser

- Better sensitivity

Fake-reduction

with coincidence

LCGT design sensitivity



Single detector of LCGT will reach to 200Mpc for binary inspiral.

LCGT Board

Institute for Cosmic Ray Research, University of Tokyo (ICRR)
High Energy Accelerator Research Organization (KEK)
National Astronomical Observatory JAPAN (NAOJ)
Department of Physics, University of TOKYO
Department of Advanced material Science, University of TOKYO
Earthquake Research Institute, University of TOKYO
National Institute for Advanced Industrial Science and Technique
Kyoto University
Osaka University
Osaka City University
Communication Research Laboratory
Electrical Telecommunication University
Waseda University
Niigata University
Ochanomizu University

Reason of two detectors :

Coincidence for Fake Event Reduction

Fake events due to noise from complete independent detectors will be accidental coincidence only.

Requirement of the coincidence between GW candidates triggers
---> Reject Fakes

example:

TAMA -LISM(Kamioka20mIFO)

Reduction Rate ~ 10^{-4}

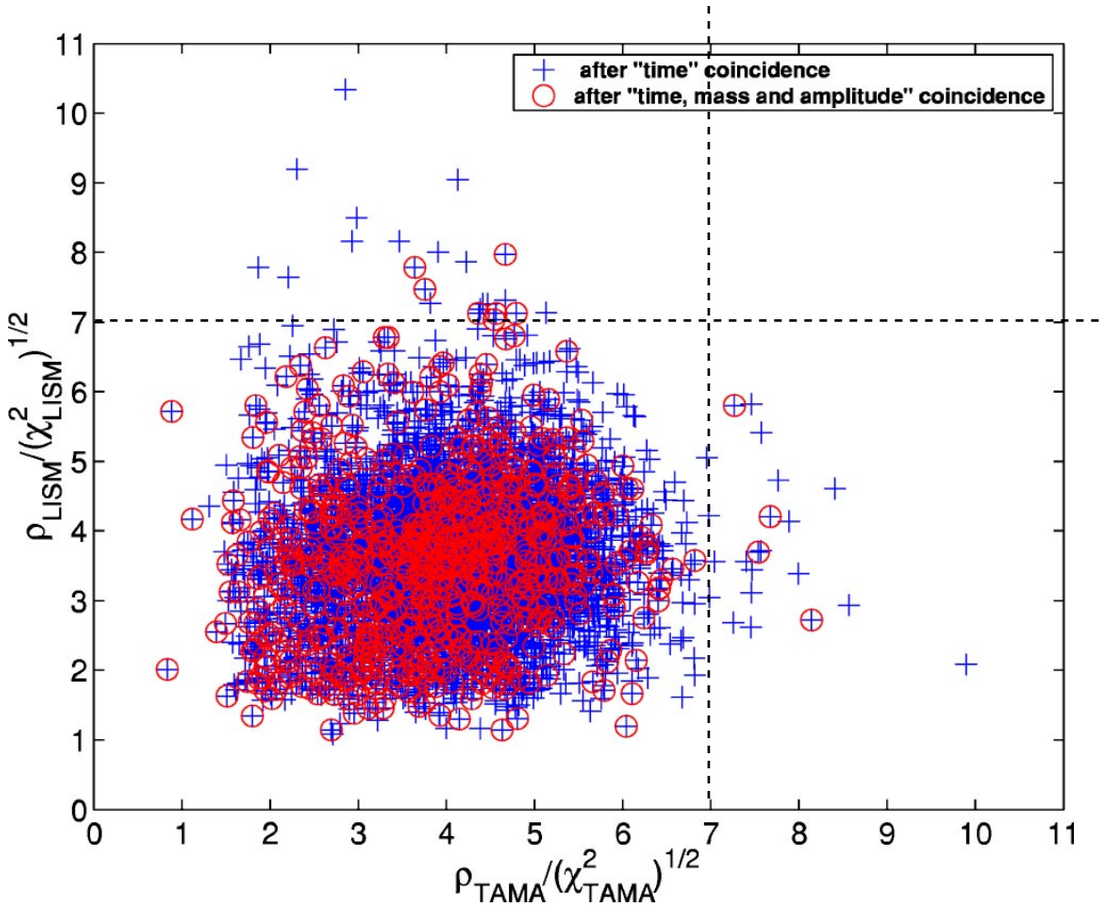


FIG. 10. $(\rho_{\mathrm{TAMA}}/\sqrt{\chi^2_{\mathrm{TAMA}}},\ \rho_{\mathrm{LISM}}/\sqrt{\chi^2_{\mathrm{LISM}}})$ scatter plots. The crosses $(+)$ are the events survived after the time selection, and the circled crosses $(\oplus)$ are the events survived after the time, mass and amplitude selections.

H.Takahashi et. al., PRD70, 042003

Possible Problem: Cross Talk between two Detectors

However, closed detectors have

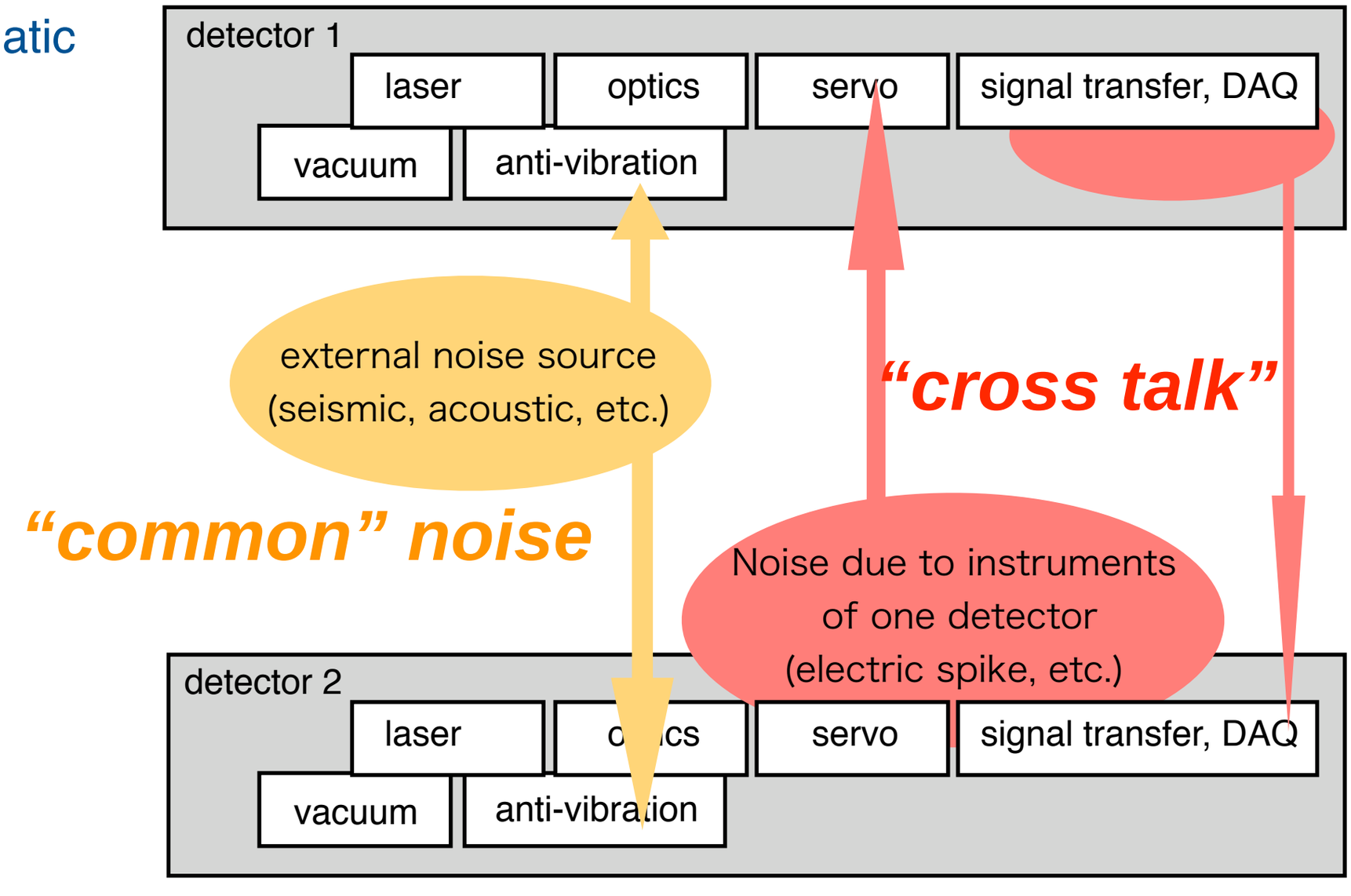
common source of noise,

cross talk of electric signal

mechanical coupling

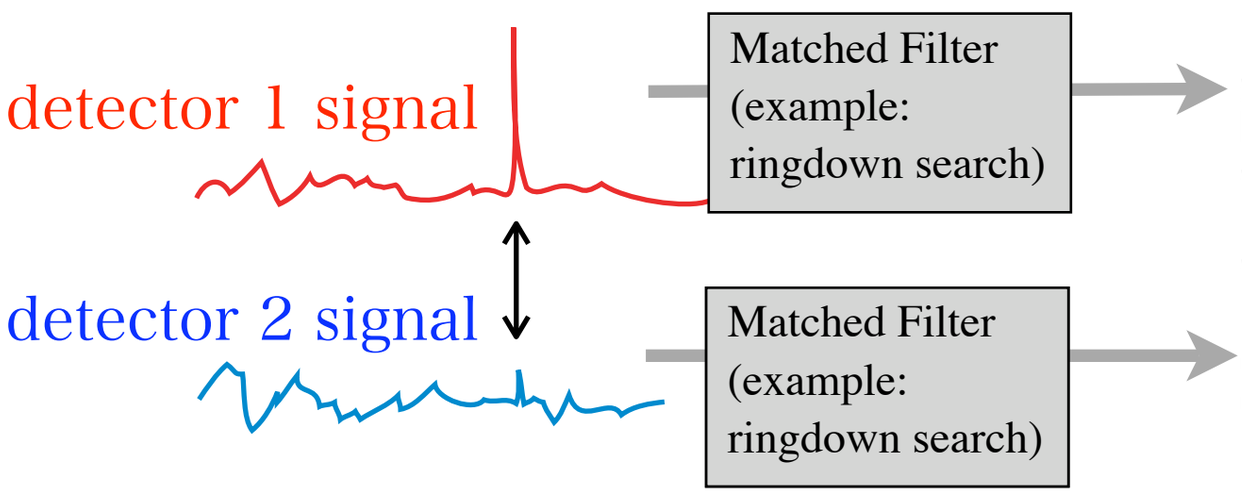
--> cross talk (common component) of noise be contains in the data.

Schematic

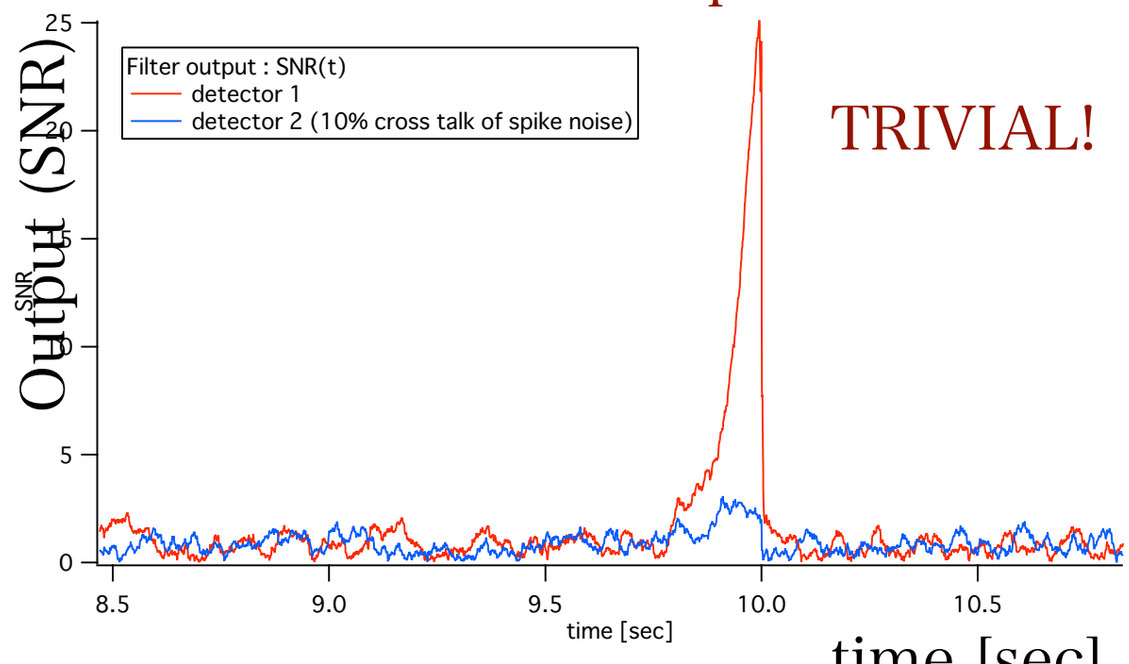


Spike like noise cross talk

--> generate fake which amplitude be proportional to the coupling



simulation example



TRIVIAL!

- However, it is possible to reject with the requirement of GW amplitude consistency.
- Even same spike in electric raw data, it might be not equal in h(f) or h(t).

Stationary bulk components of cross talk /common source of noise

--> How appear after event selection ?

inspiral GW search, Black-Hole ringdown GW search : easy to understand, but the quantity of fake coincidence is not trivial <u>after Matched filtering</u>.

Aim of this study: to evaluate the influence of cross talk noise in GW event search (= check the statistical characteristics of cross talk.)

Simulation of Cross Talk Noise

Noise model:

two detectors, each signal s_1 and s_2

bulk noise cross talk (stationary noise)

all frequency band

common only seismic noise

$$s_1^2 = s_{1,independ}^2 + s_{common}^2$$

$$s_2^2 = s_{2,independ}^2 + s_{common}^2$$

$$\text{cross talk} : R = \frac{s_{common}^2}{s^2}$$

spike noise

coupling factor : R

$$s_1 = s_{1,independ} + s_{spike}$$

$$s_2 = s_{2,independ} + R\ s_{spike}$$

Monte-Carlo

use LCGT design spectrum

generate noise in Fourie domain

amplitude <-- design average, PDF

phase <-- random

LCGT expected power spectrum : $Sh(f)$

Randomize (amplitude<- spectrum, phase<-uniform)

$\tilde{S}_{1,independ}(f)$

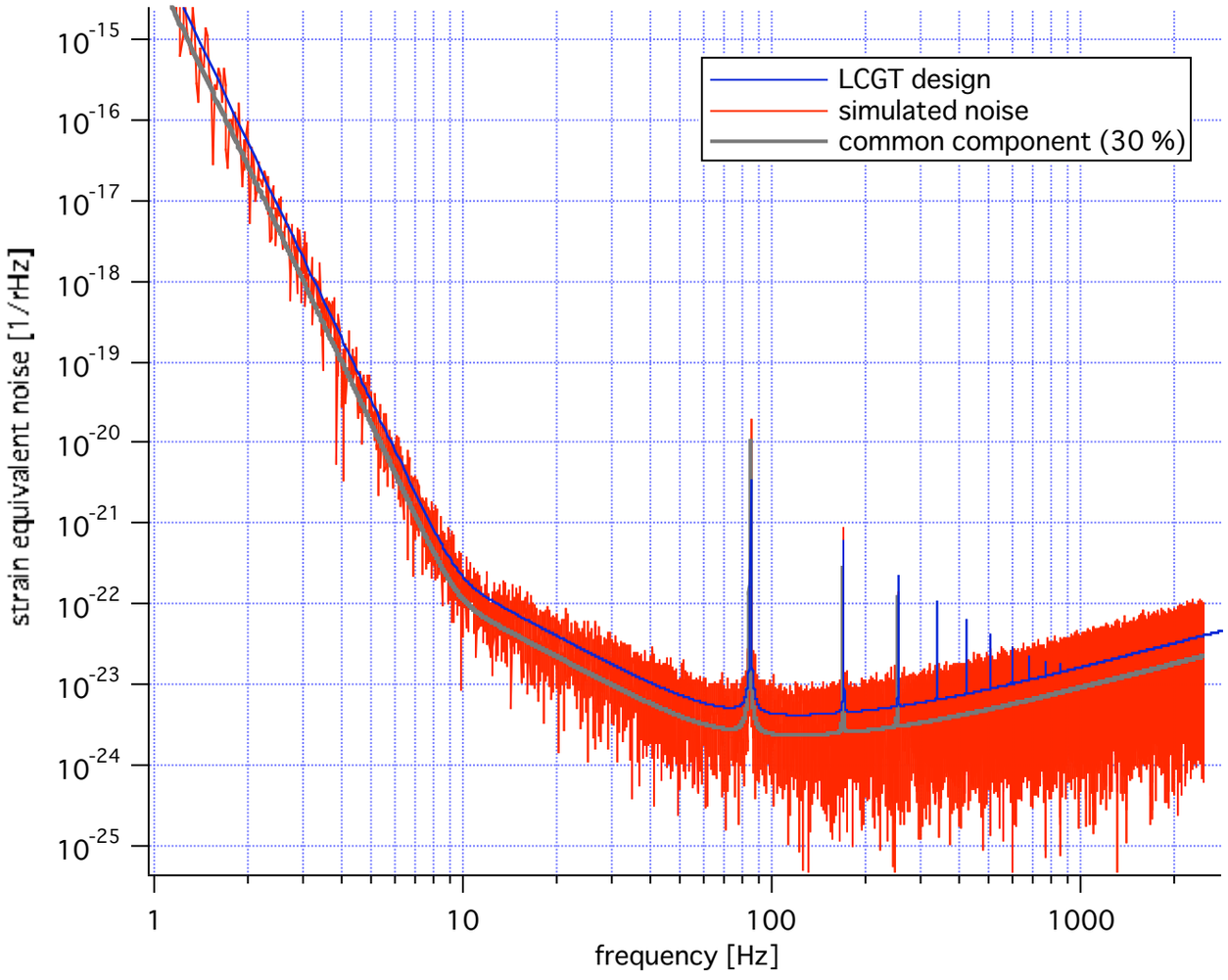
$\tilde{S}_{common}$

$\tilde{S}_{2,independ}(f)$

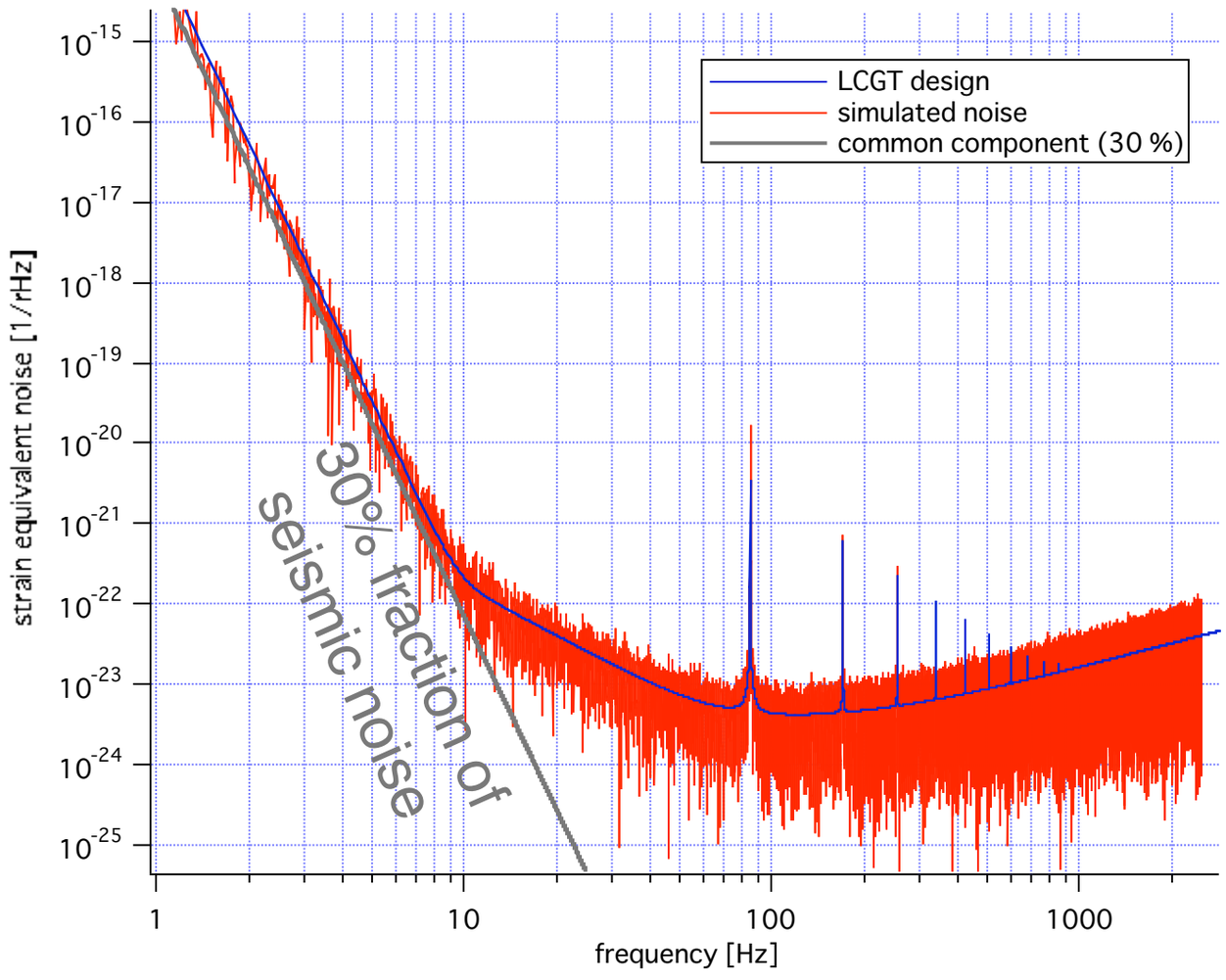
$\tilde{S}_1 = \sqrt{1-R}\ \tilde{S}_{1,independ} + \sqrt{R}\ \tilde{S}_{common}$

$\tilde{S}_2 = \sqrt{1-R}\ \tilde{S}_{2,independ} + \sqrt{R}\ \tilde{S}_{common}$

example of simulated noise (Bulk)



All frequency region



Seismic component only

Matched filter processing for simulated noise

detector 1 signal : $s_1(f)$

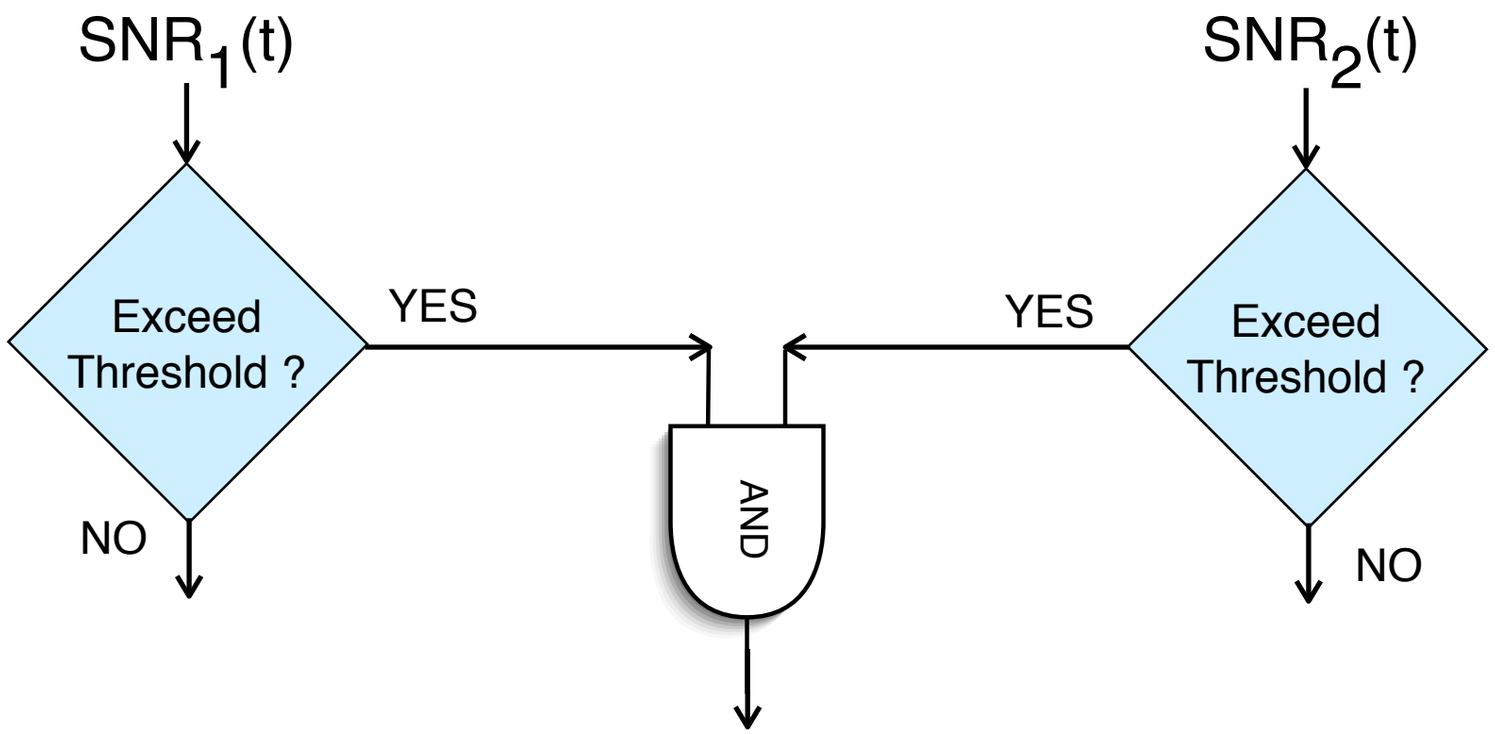
Matched Filter
inspiral GW
ringdown GW

$$(h,s) = \int \frac{\tilde{h}^*(f)\cdot\tilde{s}(f)}{Sh(f)} e^{i2\pi t} df$$

$$\mathrm{SNR(t)} = \sqrt{(h_+,s)^2 + (h_\times,s)^2}/\sqrt{2}$$

detector 2 signal : $s_2(f)$

Matched Filter

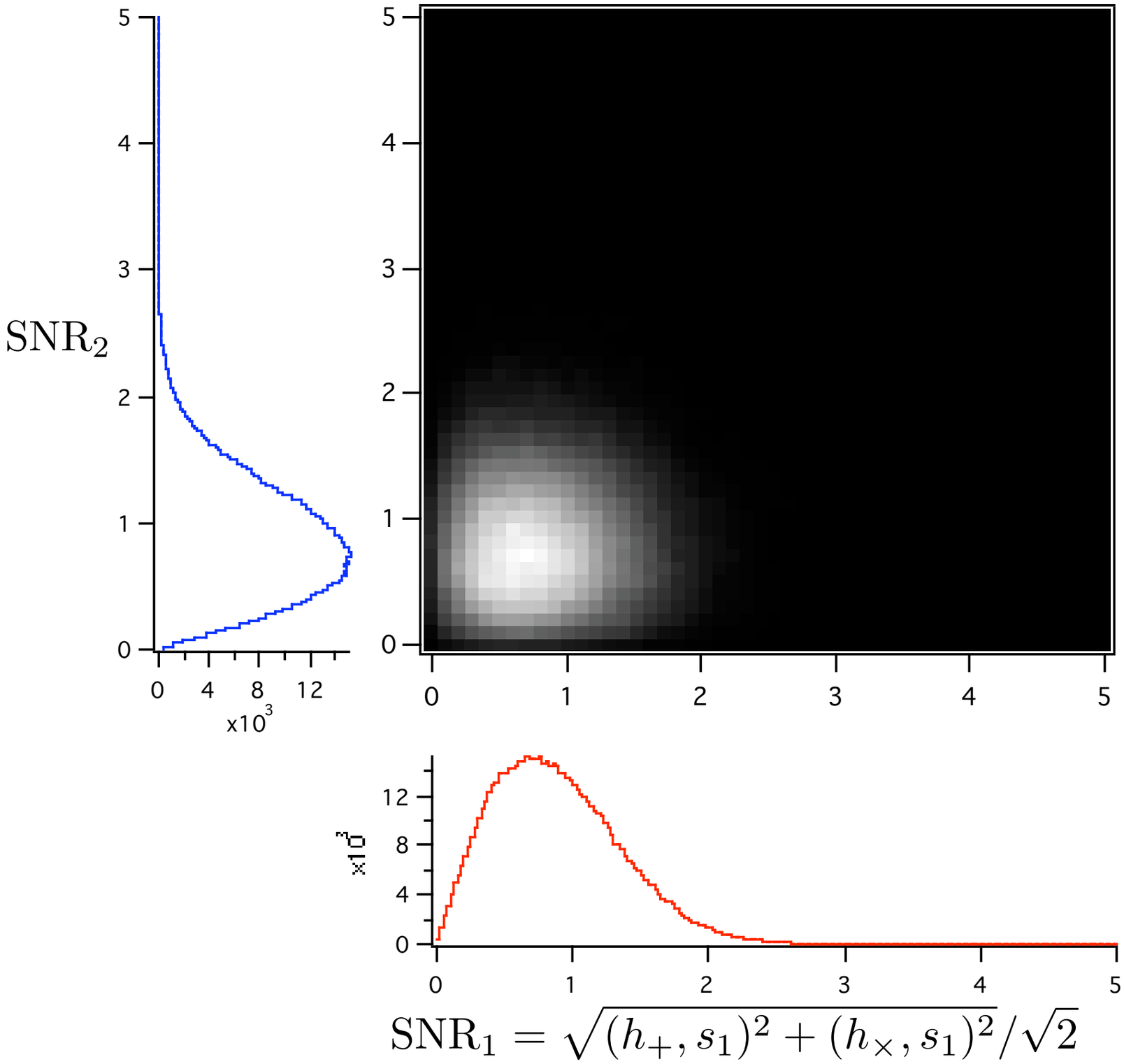


Accidental Coincidence

Check the fraction of accidental coincidence for the variance of cross talk amount !

Example of simulation: Accidental coincidence of Fake Event

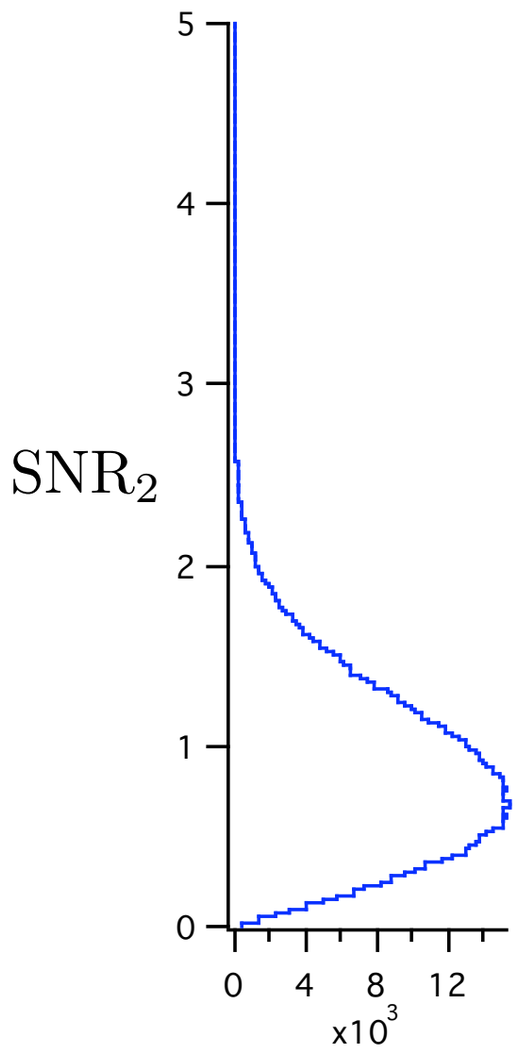
complete independent two detectors

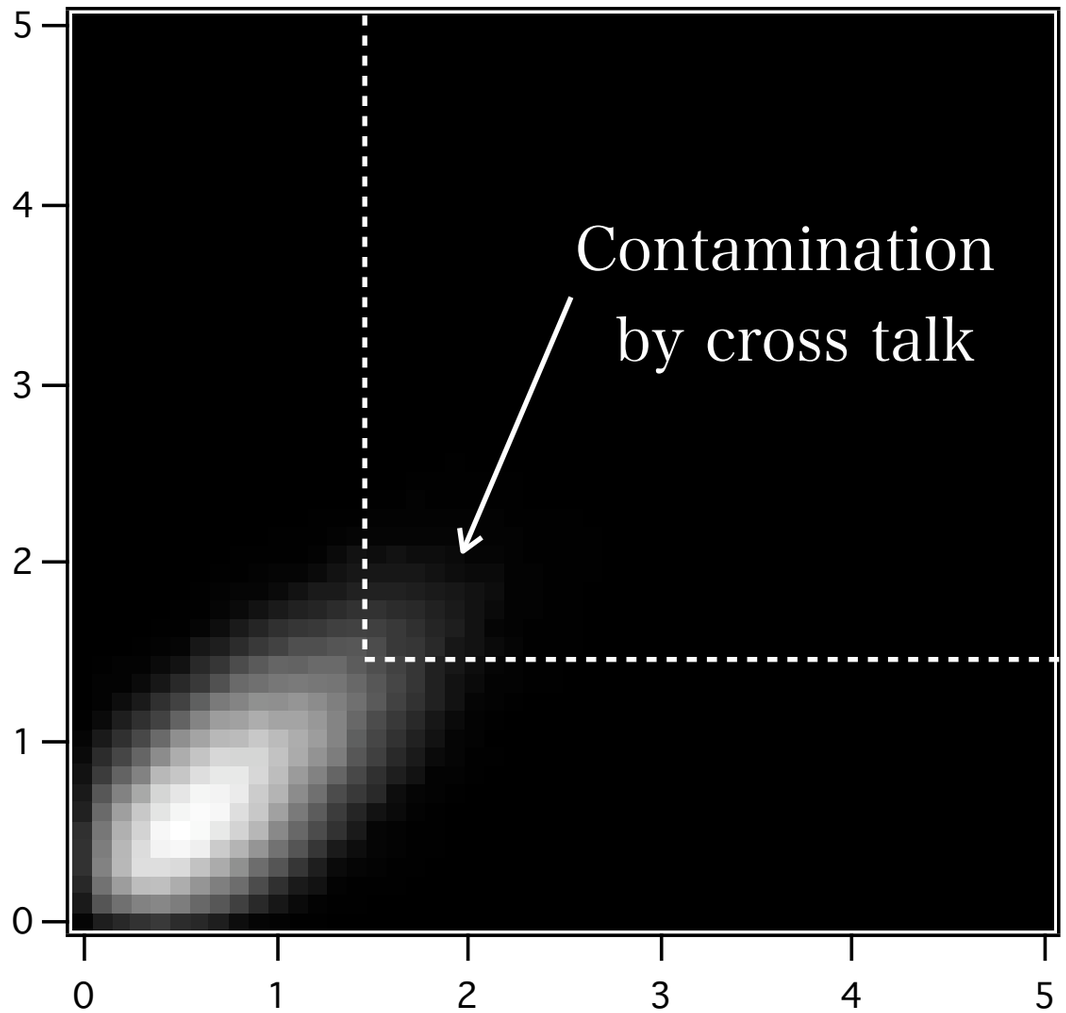


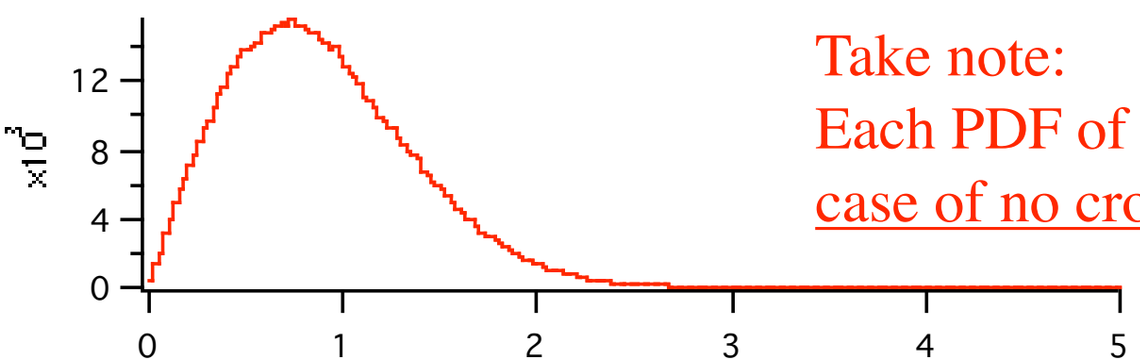
$$\mathrm{SNR}_1 = \sqrt{(h_+, s_1)^2 + (h_\times, s_1)^2}/\sqrt{2}$$

Example of simulation: Accidental coincidence with Huge cross talk

cross talk with 80% (so much!)





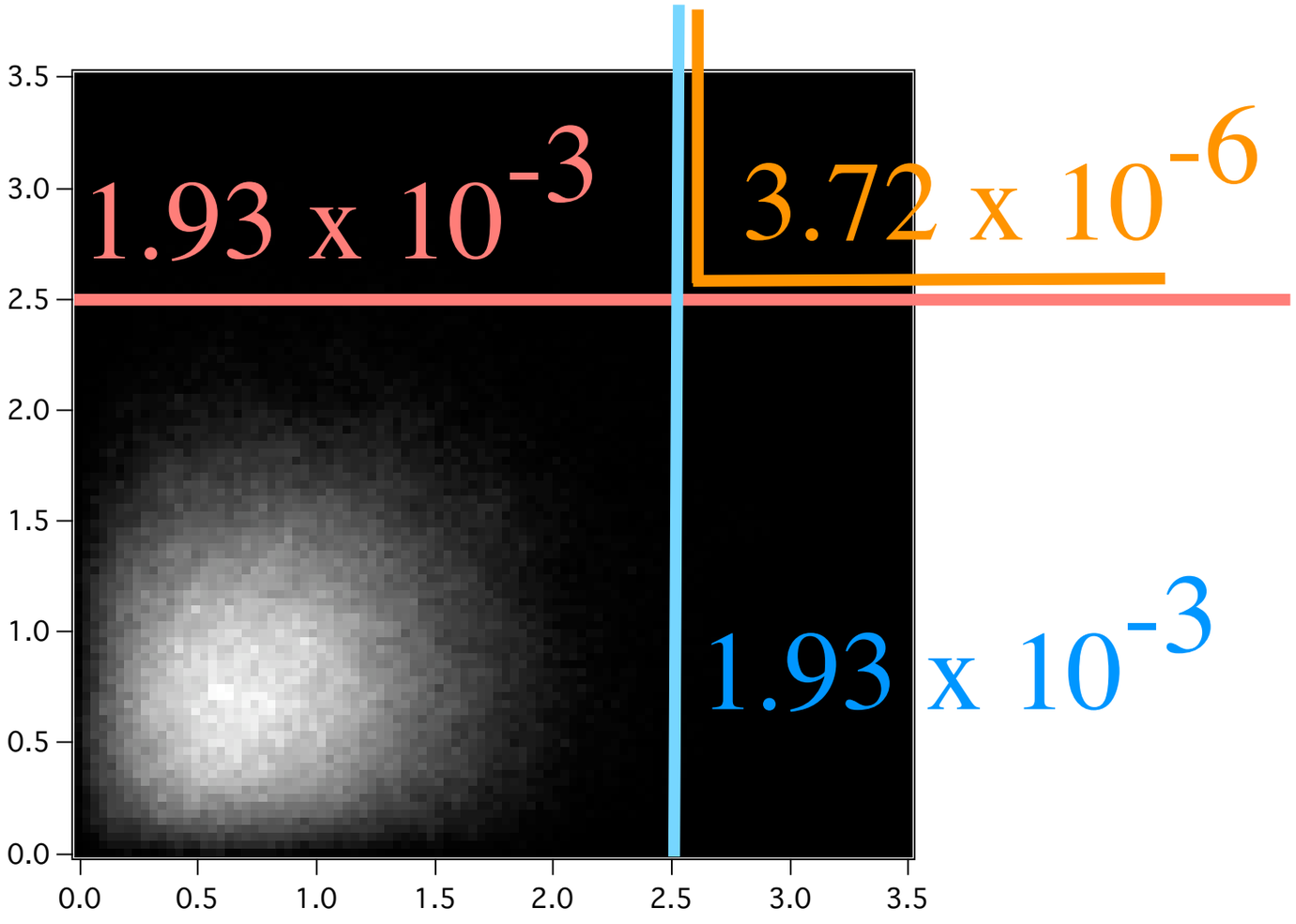


Take note:
Each PDF of SNR looks same as the case of no cross talk !

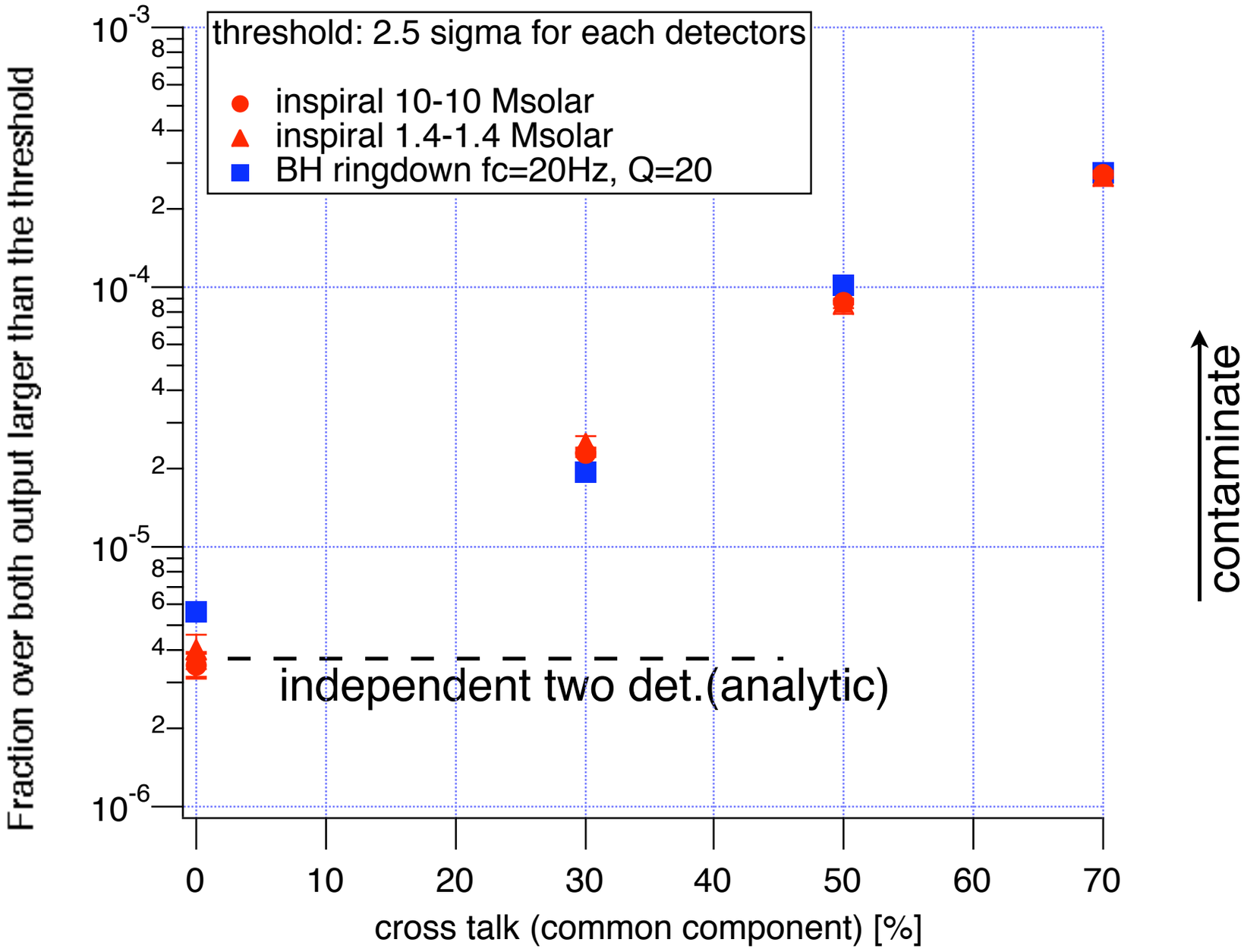
$$\mathrm{SNR}_1 = \sqrt{(h_+, s_1)^2 + (h_\times, s_1)^2}/\sqrt{2}$$

Note:

fraction for the case of independent detectors (analytic expectation)



Results 1: Cross talk VS contamination



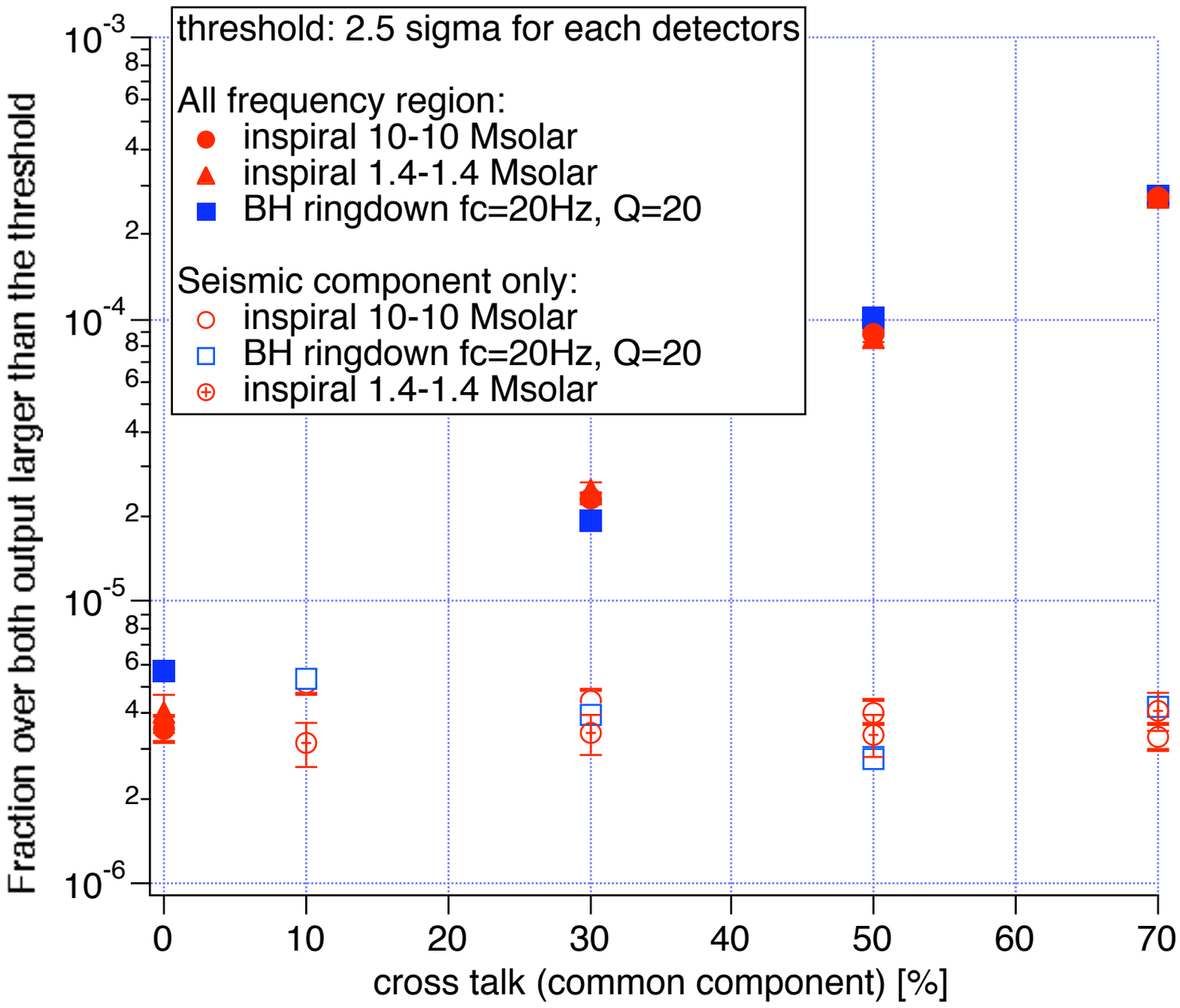
30% cross talk complicate 10 times accidental coincidence.

Results 2:
Seismic component cross talk VS contamination

Seismic component is biggest concern.

inspiral search : assume larger mass source -> integrate from $f_{low} < 10Hz$

BH ringdown : source near seismic cutoff



If the cross talk is seismic only, no significant contamination !

Summary and Future

We tried practical study of cross talk between two LCGT detectors.

- Even stationary bulk noise, 30% cross talk contaminate 10 times for accidental coincidence.
- Seismic component looks as no problem.

		GW source		
		inspiral 1.4-1.4 Msol	inspiral 10-10 Msol	BH ringdown (20Hz,Q2=0)
cross talk model	all frequency band	30% -> x 10	30% -> x 10	30% -> x 10
	seismic component only	no effect	no effect	no effect
	spike	proportional to cross talk	proportional to cross talk	proportional to cross talk

Future and More...

- Consider instrumental mechanism more (e.g. up-conversion of seismic trough the servo system, scattering light, etc.)
- Study for stochastic GW