E-thinca: An improved method for coincidence analysis

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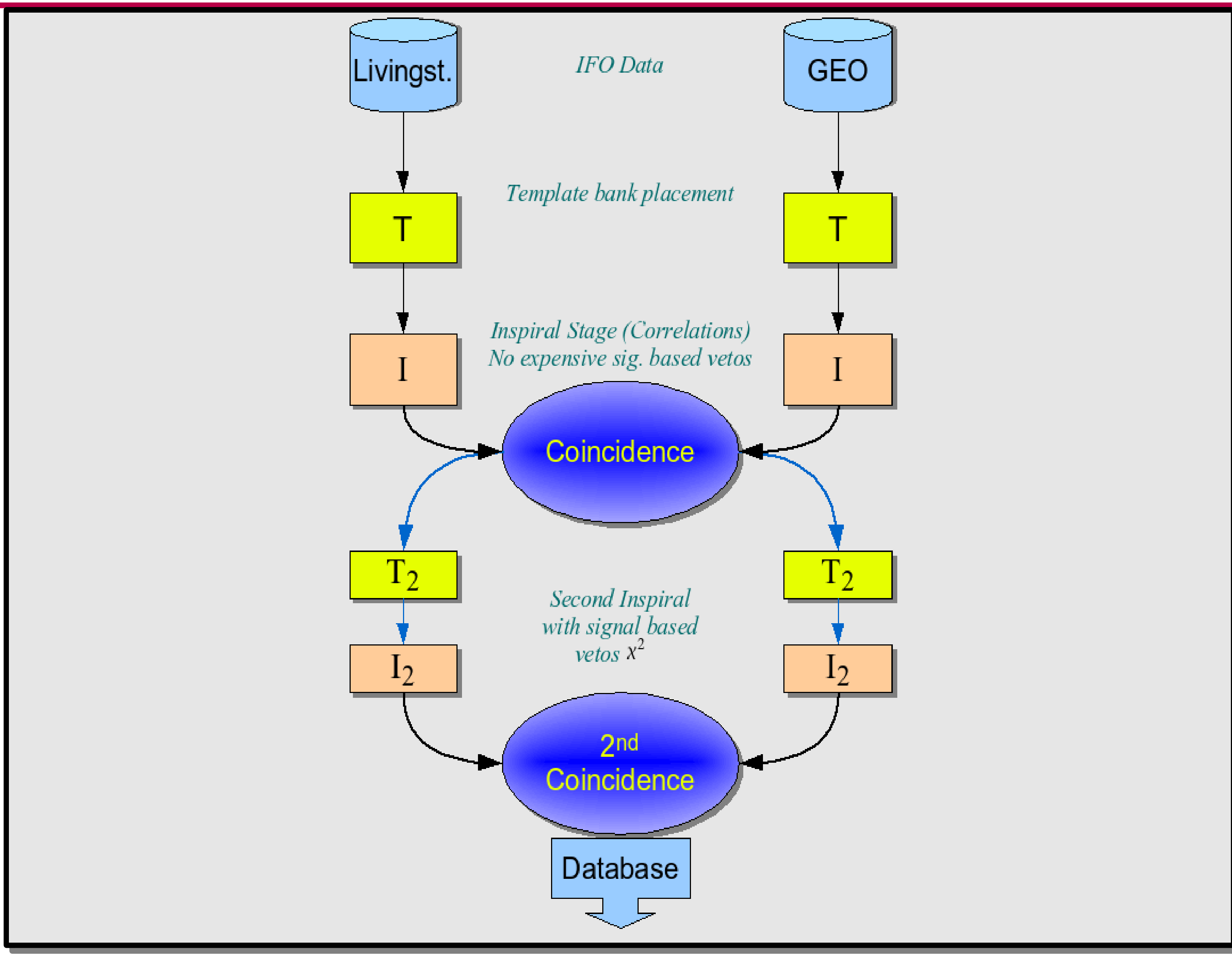
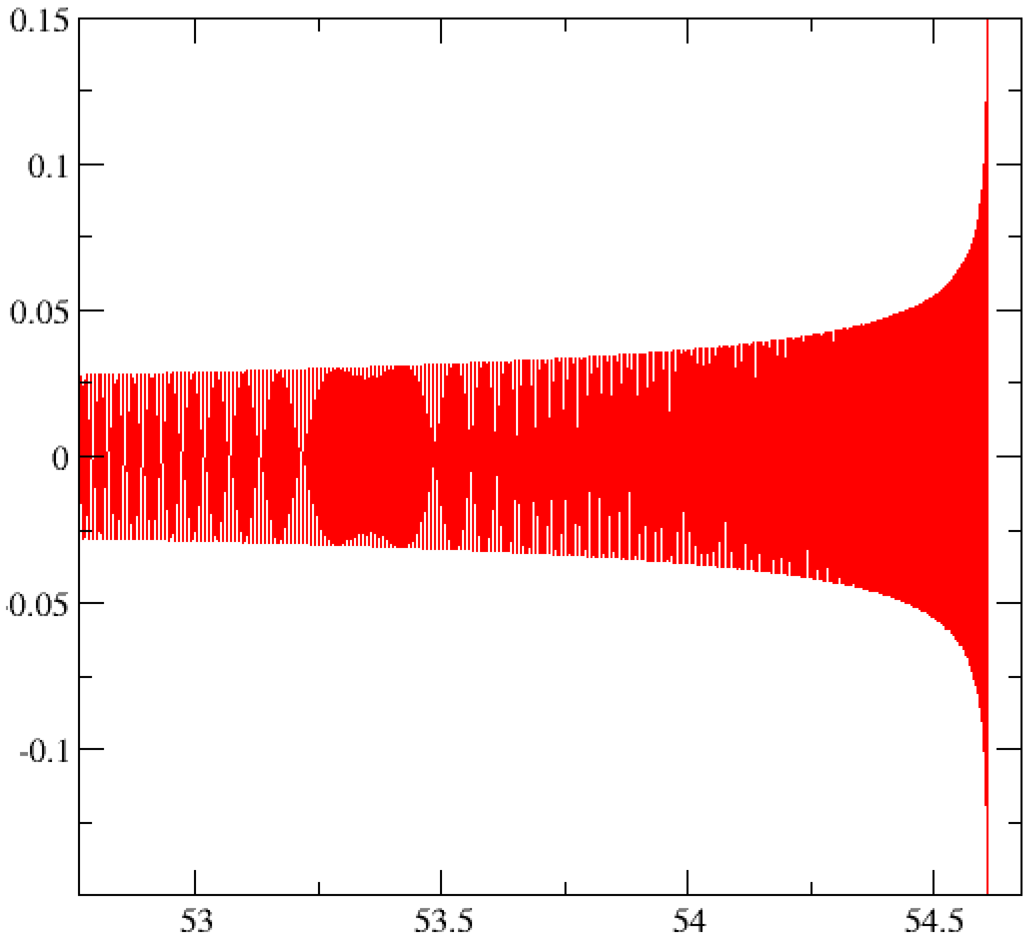
Outline

- Typical methodology for coincidence analysis
- Motivation for parameter-dependent tuning of coincidence windows
- Description of the e-thinca method
- Current status
- Future work

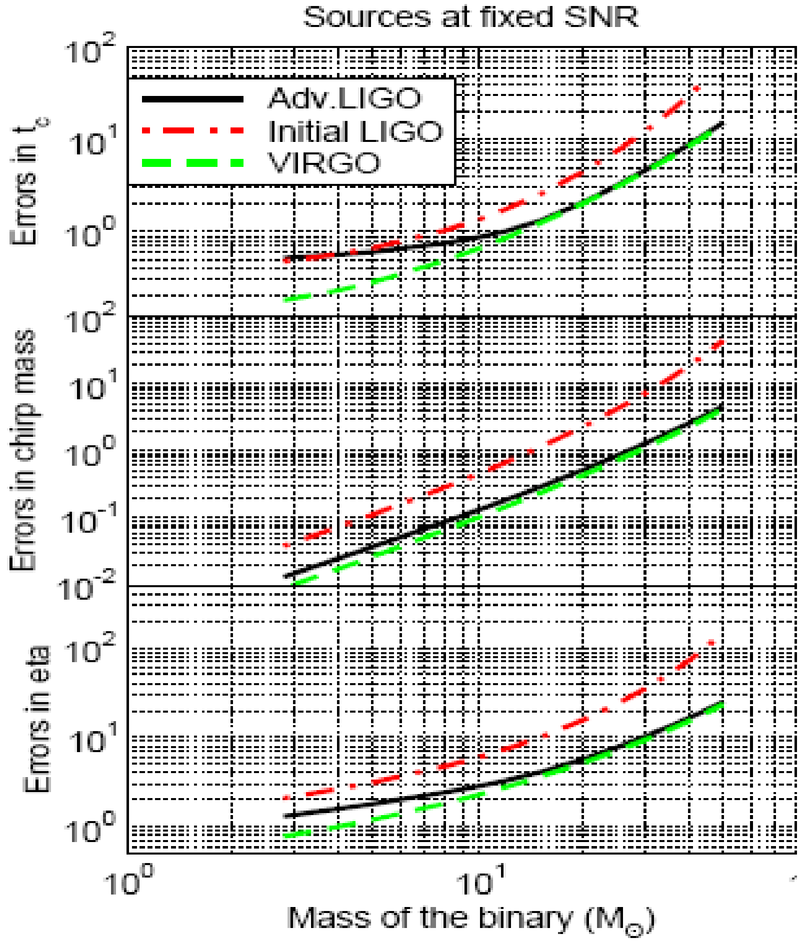

Livingst.
IFO Data
GEO
Template bank placement
T
T
Inspiral Stage (Correlations)
No expensive sig. based vetos
I
I
Coincidence
T2
T2
Second Inspiral
with signal based
vetos χ2
I2
I2
2nd
Coincidence
Database

Coincidence Analysis

- Following single-ifo analysis, list of triggers from each IFO
- Look for coincident events between IFO's
- Typically, fixed windows on differences in parameters e.g $t_c, \mathscr{M}, \eta$



Motivations for parameter-dependent approach



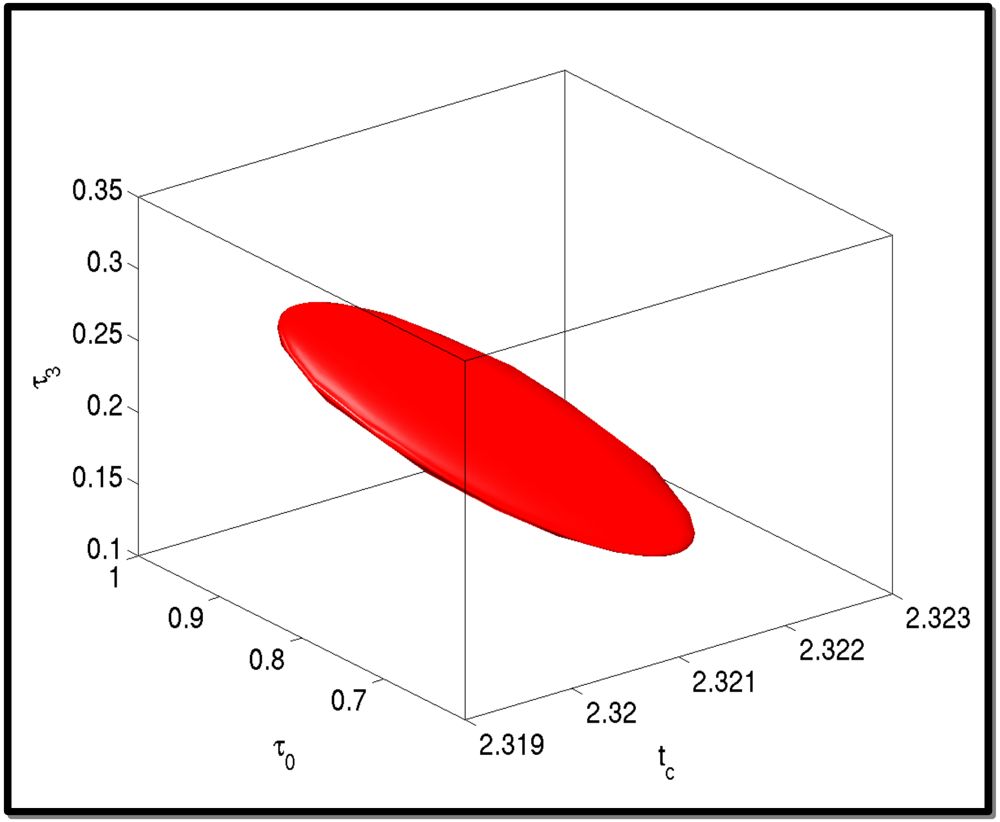
- Error in measurement of parameters vary widely across BBH parameter space.
- Suggests fixed-window coincidence method is not optimal for BBH searches.
- Motivated the development of analysis using parameter-dependent windows.

K.G. Arun, B. R Iyer, B.S. Sathyaprakash, P.R. Sundararajan, 2004

Ellipsoid coincidence analysis method

- Coincidence windows replaced by error ellipsoids associated with each trigger
- Error ellipsoids determined by the metric
- One tunable parameter:
  - *ellipsoid scaling factor*, e_p
- Introduces parameter dependence,
  - but also uses information about correlation
  - Volume of ellipsoid ~30x less than equivalent standard windows

Ellipsoid model for the triggers



Metric codes in correlation between parameters.

- Ellipsoids
  - Position vector of the centre $\vec{r} \in \Lambda$
  - Shape matrix $\mathcal{G}$
- Mathematical definition of the ellipsoids

$$\mathscr{E}(\vec{r},\mathscr{G}) = \left\{ \vec{x} \in \Lambda \mid (\vec{x}-\vec{r})^T \,\mathscr{G}\, (\vec{x}-\vec{r}) \leqslant 1 \right\}$$

- Where, $\mathscr{G} = \dfrac{\Gamma}{1-e_p}$

Overlap of ellipsoids

- Contact function to test overlap of ellipsoids

$$F_{(i,j)=\max_{0\le\lambda\le 1}\mathcal{F}_{(i,j)}}$$

where,

$$\mathcal{F}_{(i,j)} = \left\{\lambda(1-\lambda)\ \vec{r}^{\,T}_{(i,j)}\left[\lambda\mathcal{G}_j^{-1}+(1-\lambda)\mathcal{G}_i^{-1}\right]^{-1}\vec{r}_{(i,j)}\right\}$$

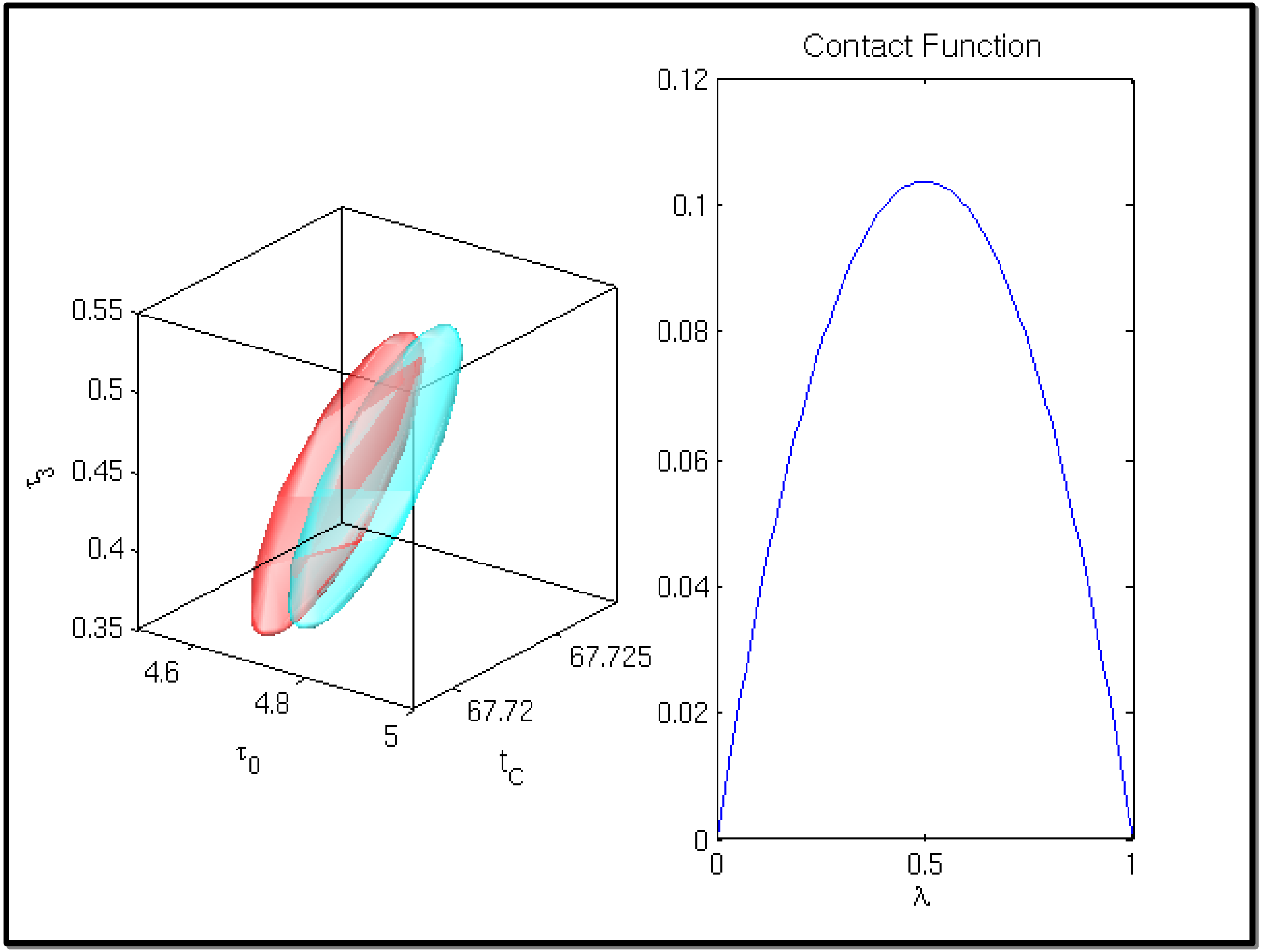
Perram & Werthiem, 1985,
Journal of Computational Physics

- Function is bound between $0 \le \lambda \le 1$

- Second derivative of contact function $\mathcal{F}_{(i,j)}$ w.r.t parameter λ is negative definite. This implies a unique maximum in the above interval.

- Ellipsoids labeled i and j are deemed to overlap if $F_{(i,j)}$ is less than 1.

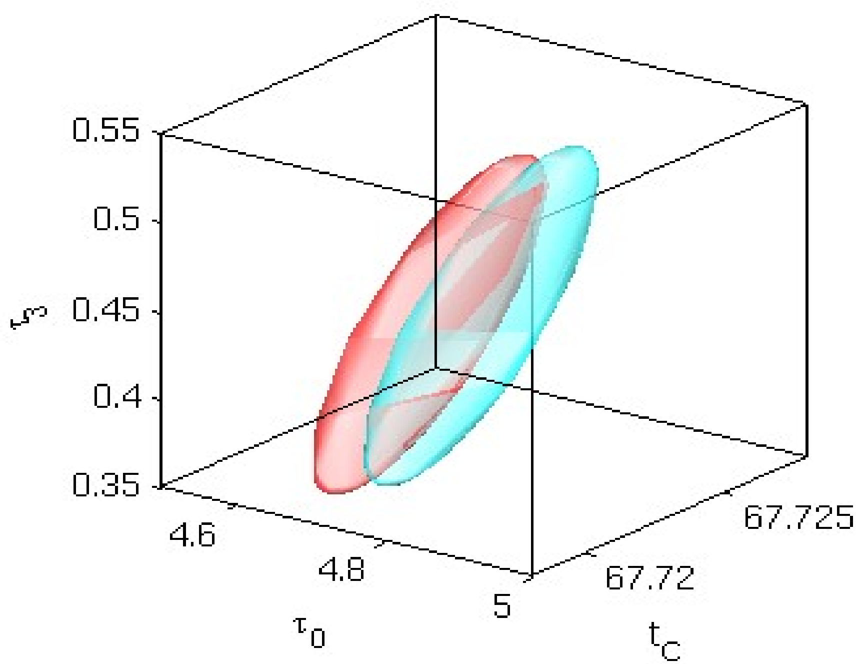
Overlap of ellipsoids-2



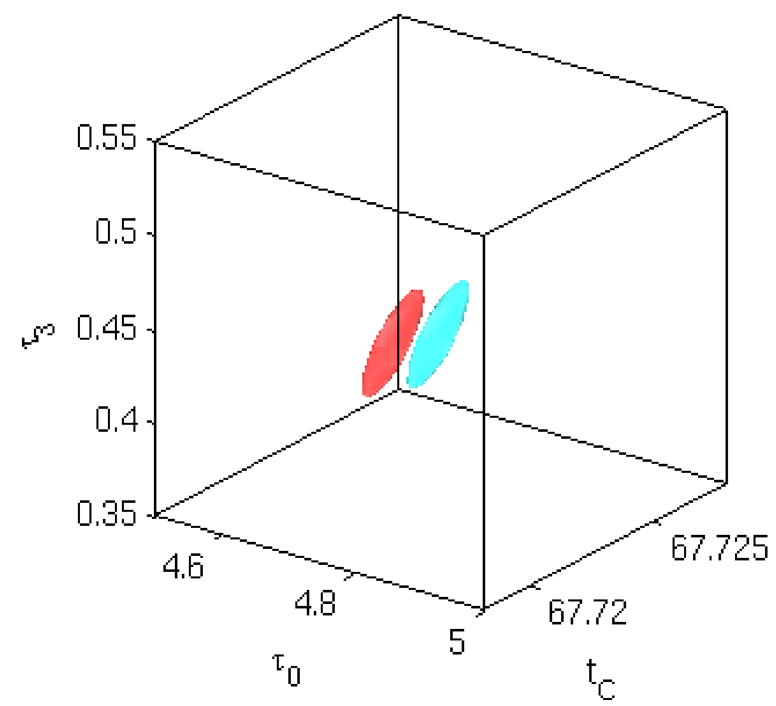
Ellipsoid coincident analysis method

- If ellipsoids of triggers in different IFO's overlap, they are deemed coincident

Coincident

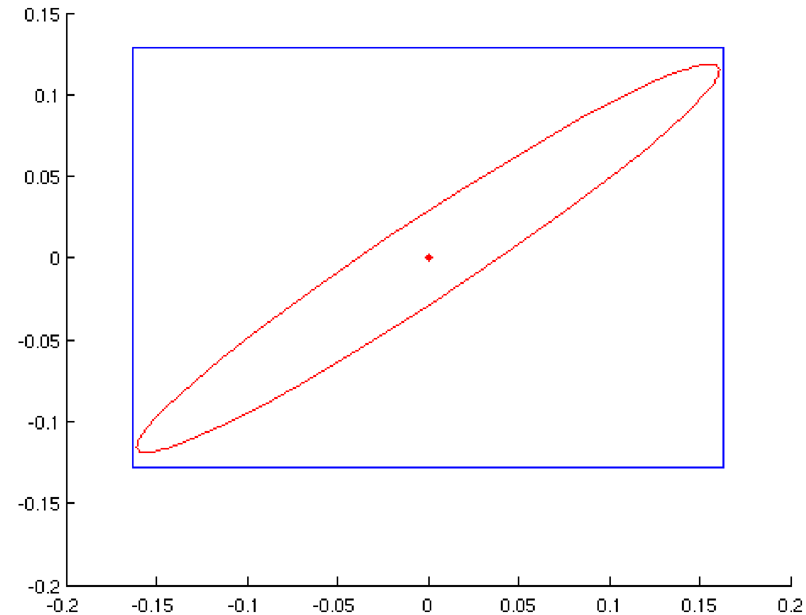


Not coincident



Status of the method

- Algorithm as described implemented for two- and multi-ifo cases
- Preliminary tests run, comparing ellipsoid method with 'bounding box'
- Huge reduction (> x 10) in (unclustered) background rate, for insignificant (< ~1%) reduction in found signal injections
- Many loud background events removed, but some still remain

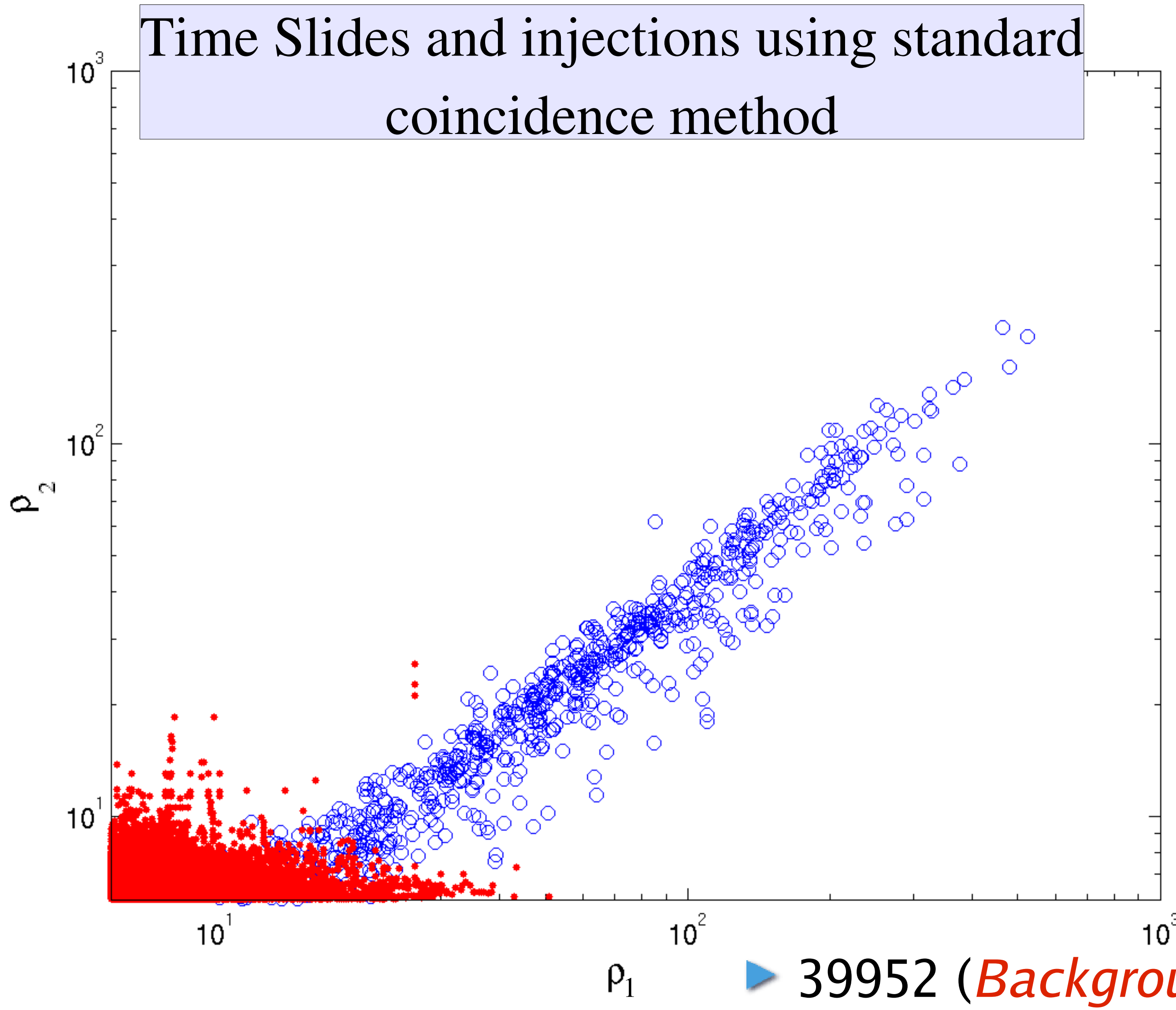


Projection onto $_0$ $_3$ space of ellipsoid with greatest volume, and box which bounds all ellipsoids

LIGO

Monte-Carlo Injections

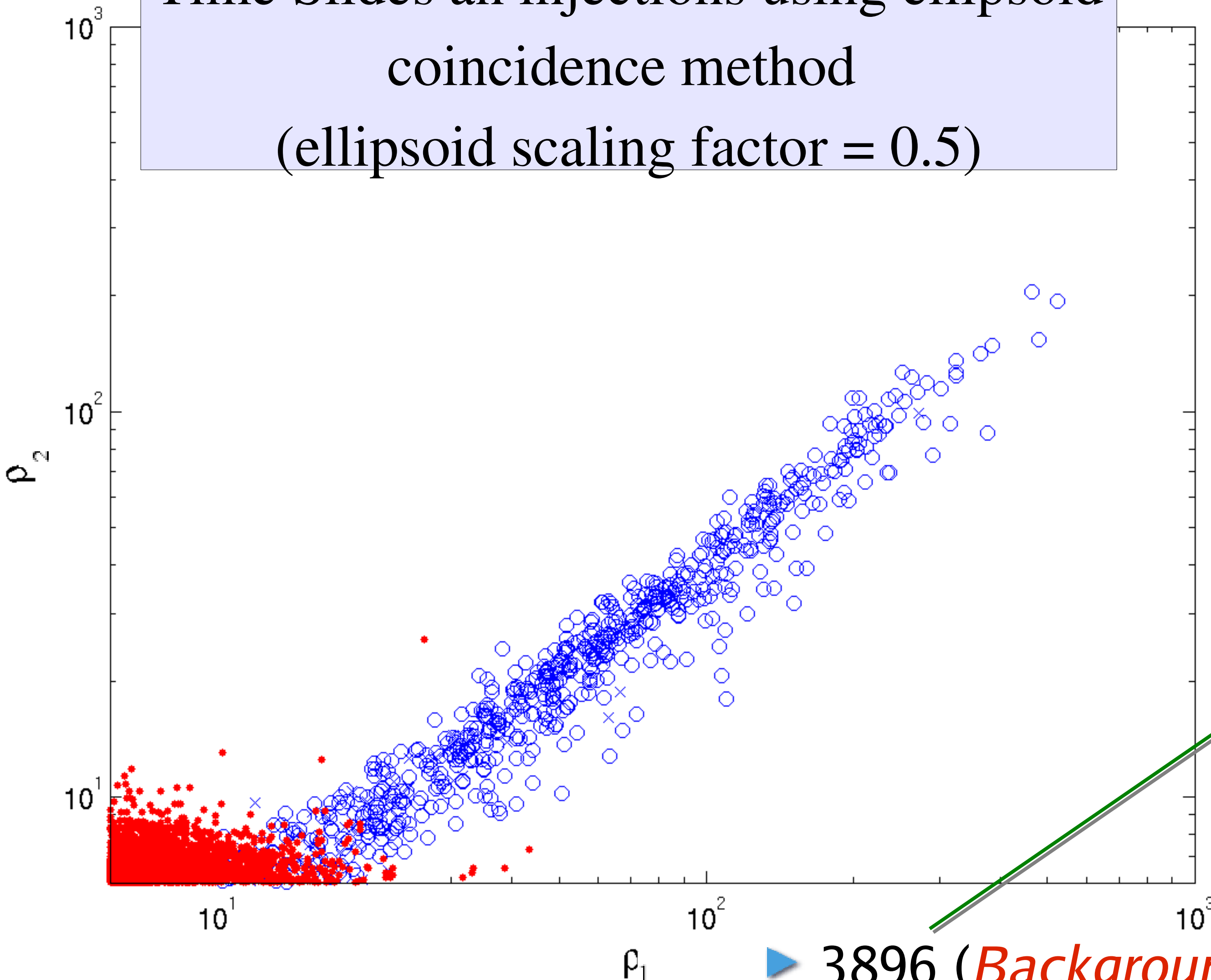
LSC



- 39952 (*Background*)
- 883 found out of 1925 (*Injections*)

Monte-Carlo Injections

Time Slides an injections using ellipsoid coincidence method
(ellipsoid scaling factor = 0.5)



X10 reduction

- 3896 (*Background*)
- 878 found out of 1925 (*Injections*)

Extension – SNR-dependent tuning

- Although a reduction in loud background events, some still remain
- In reality, parameter errors depend on SNRs. We may do better by introducing SNR dependence.
  - Due to the coarseness of the template bank, we are limited in the reduction of ellipsoid size we can make. Would be unsafe to use ellipsoid 'match' parameter $e_p > MM$
- It may be unsafe even approaching this limit, due to clustering of single-IFO triggers
  - This may limit the use of SNR dependent tuning in the current pipeline.

Conclusions

- An improved method for coincidence analysis has been developed
- Inspiral triggers modelled using error ellipsoids
- Coincidence determined by checking for overlaps of ellipsoids
- Substantial reduction in number of background triggers, while not greatly affecting found injections
- Potential further improvements from using SNR dependence; however, may be issues due to template bank coarseness