E7 Analysis: Burst Group Report

Sam Finn, for the Burst Group

Overview

- Analysis Goals
- Data processing pipeline
- Event triggers & generation
- Diagnostic triggers & vetoing
- Interpretation
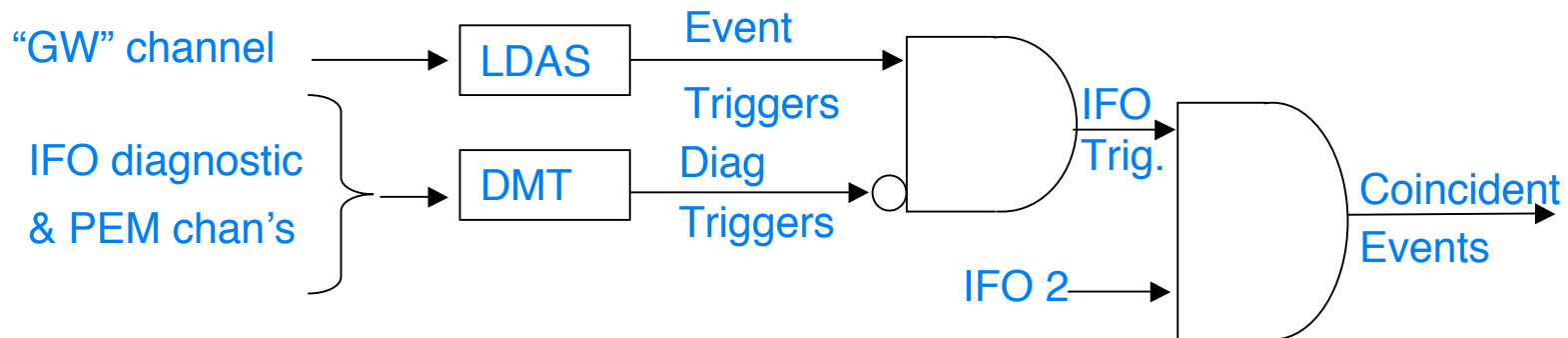- Preliminary results
- Triggered analysis
- Open Issues

Goals

- Search for gravitational wave bursts of unknown waveform, spectrum

- Bound rate of strain events v. strength

- Bound rate of cosmic gravitational wave bursts (v. strength)

- Bound gravitational wave burst strengths coincident with gamma-ray bursts

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Data processing pipeline

- *Processing + Interpretation = Analysis*
- Nomenclature
  - » Diagnostic trigger/generator: indicator for instrumental artifacts
  - » Event trigger/generator: indicator for gravitational wave events
  - » IFO trigger: event triggers not vetoed
  - » Coincident events: "simultaneous" IFO triggers
- Methodology
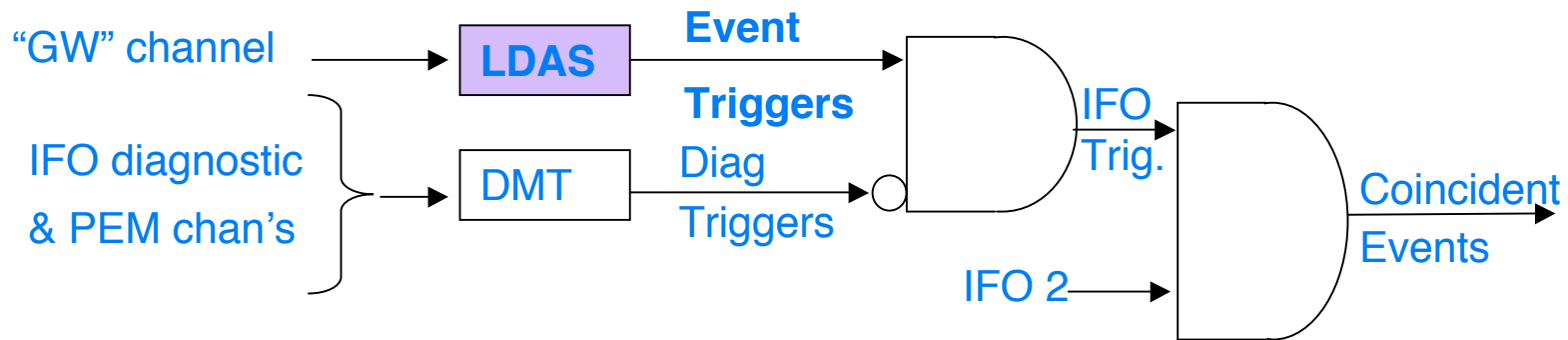 - » Learn on playground, execute on remainder

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Tools & Tools

- ### Diagnostic trigger investigation & generation
  - » Featuring: Adhikari, Gonzalez, Ito, Raab, Rahkola, Schofield, Shoemaker, Zweizig
- ### Event trigger generation
  - » Featuring: Daw, Sylvestre
- ### Clustering and Coincidence (Event Tool)
  - » Featuring: Ito, Sigg
- ### Veto efficacy and ifo coincidence studies
  - » Featuring: Ballmer, Cadonati, Katsavounidis
- ### Interpretation
  - » Featuring: Brady, Finn, Kalogera, Katsavounidis, Saulson, Weinstein, Zweizig
- ### Simulations
  - » Featuring: Weinstein
- ### Triggered Search
  - » Featuring: Marka, Rahkola
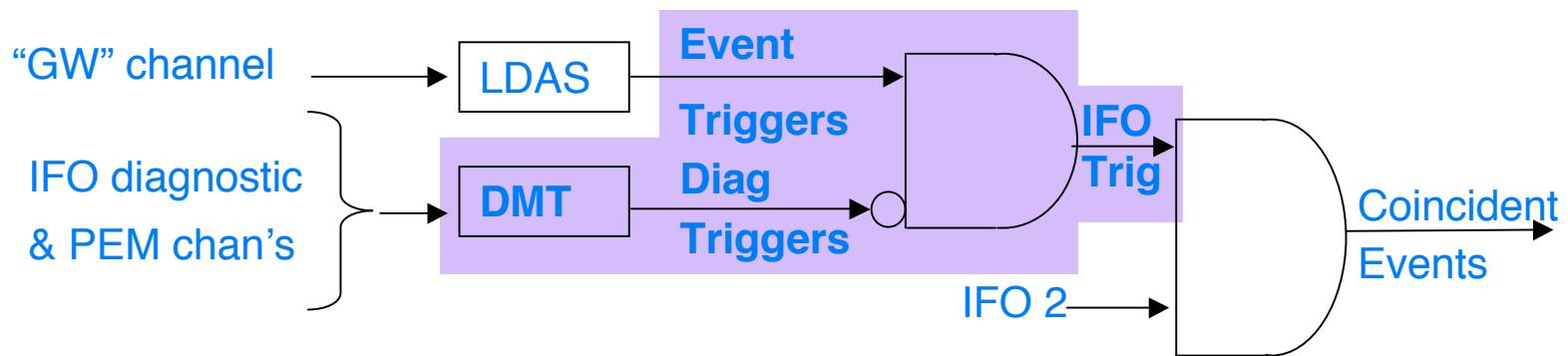
Event triggers and their generation

"GW" channel → **LDAS** → **Event Triggers**

IFO diagnostic & PEM chan's → DMT → Diag Triggers

IFO Trig.

IFO 2

Coincident Events

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Event triggers and their generation

- **"TFClusters"**
  - » Identify extended regions of high-power in spectogram

- **"Slope"**
  - » Identify large "time-averaged" slope in "strain"
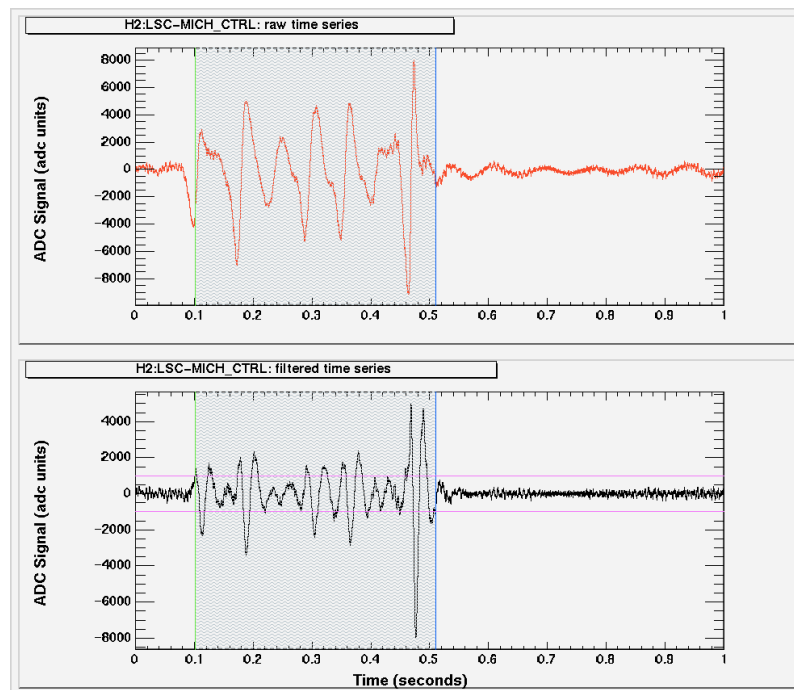

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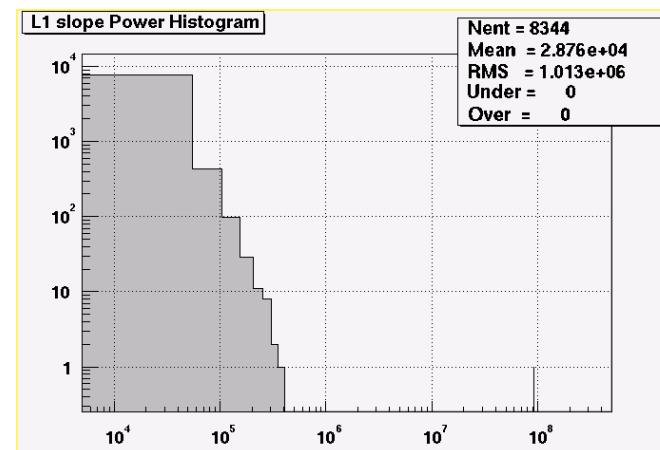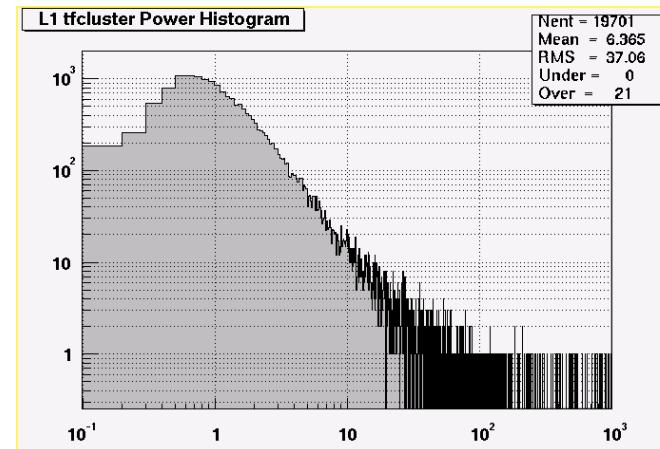
Diagnostics and Vetoing

Diagnostic trigger generation

- **Investigations suggested commissioning new diagnostic trigger generator**
 - » absGlitch, based on glitchMon

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Tuning & Pruning

- ## Tension
  - » Maximize identification of non-gw event triggers
  - » Minimize false identification

- ## E7 Tuning Strategy
  - » Live time: duration exclusive of vetoes
  - » Efficacy η: ratio of "effective" to "accidental" vetoes
  - » Residual rate ζ: ratio of events not vetoed to live time
  - » Choose parameters to minimize ζ / η (residual rate to efficacy)

- ## E7 Pruning Strategy
  - » Veto, event triggers characterized by start time, duration
 - » IFO triggers are event triggers that don't overlap with veto triggers

Tuning: L1

- **Channels investigated**
  - » PSL, CARM, MICH, REFL
- **Efficiency vs. deadtime**
  - » Aim for upper left corner
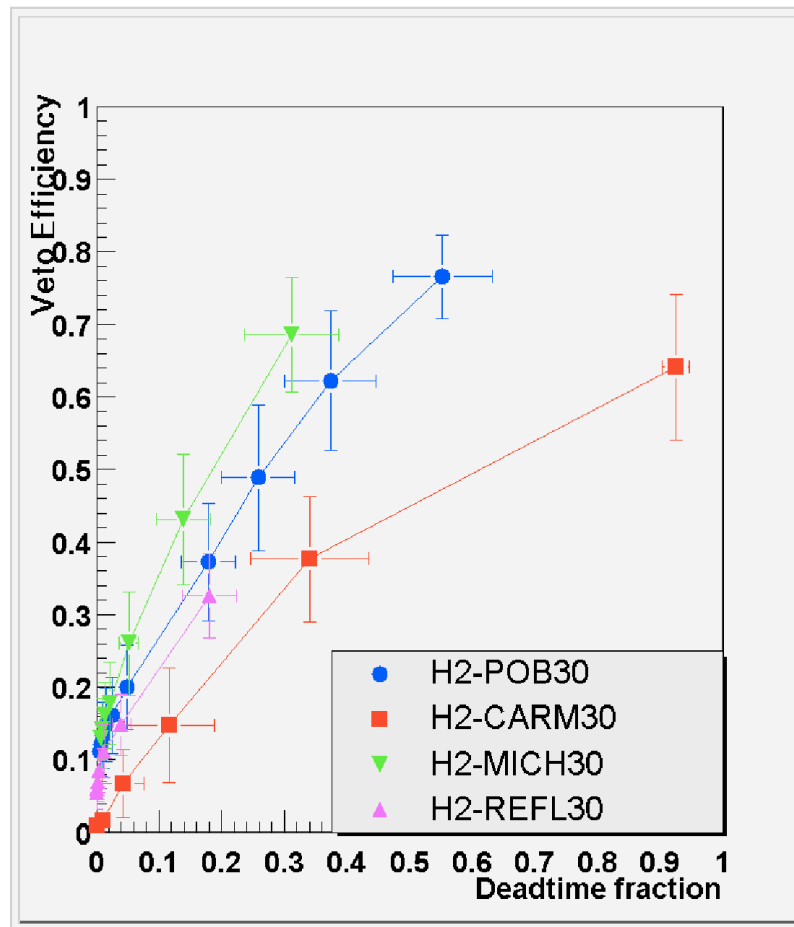- **PSL is "tall pole"**
  - » Nothing added by including other channels

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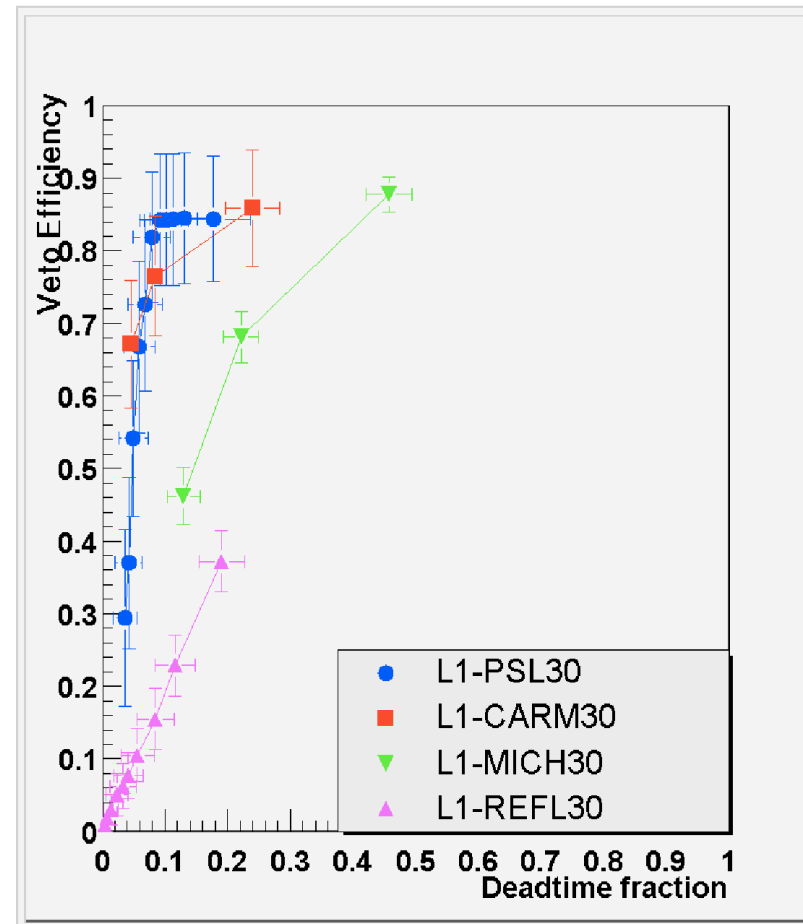
Tuning & Pruning: L1

- **Channels investigated**
  - » PSL, CARM, MICH, REFL
- **Efficiency vs. deadtime**
  - » Aim for upper left corner
- **PSL is "tall pole"**
  - » Nothing added by including other channels
- **Time-delay histogram**
  - » Events vetoed vs. time delay btwn event & diag triggers
  - » Shows veto doing something real
 - » Peak to tail ration is measure of veto efficacy
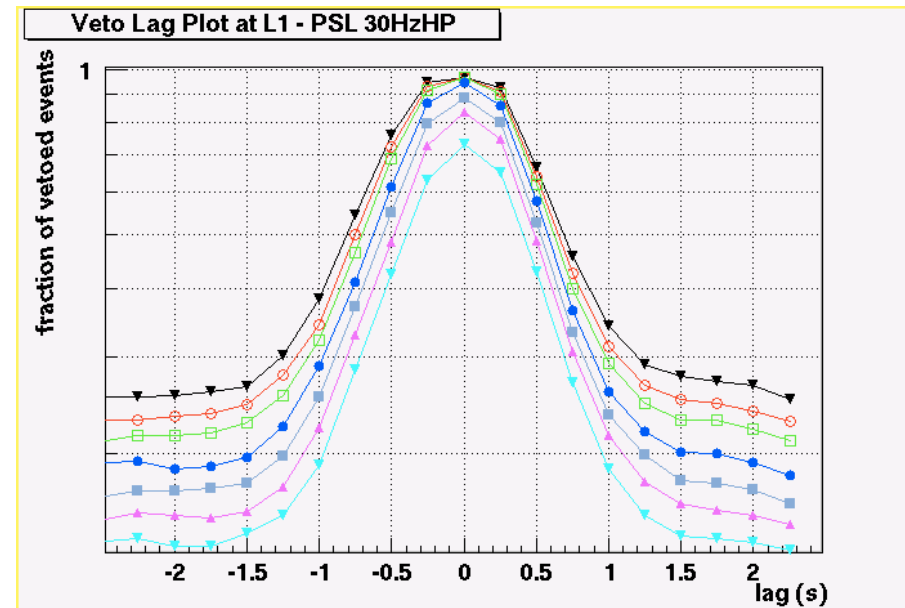
Veto Lag Plot at L1 - PSL 30HzHP

Tuning & Pruning: H2

- **Channels investigated**
  - » POB, CARM, MICH, REFL
- **MICH is "tall pole"**
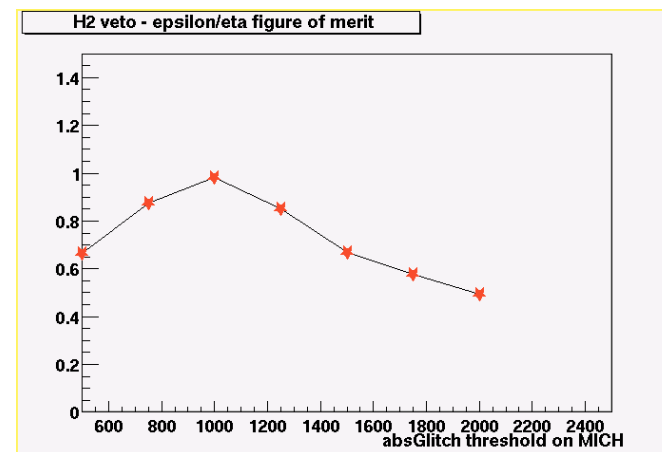 - » … but none particularly good
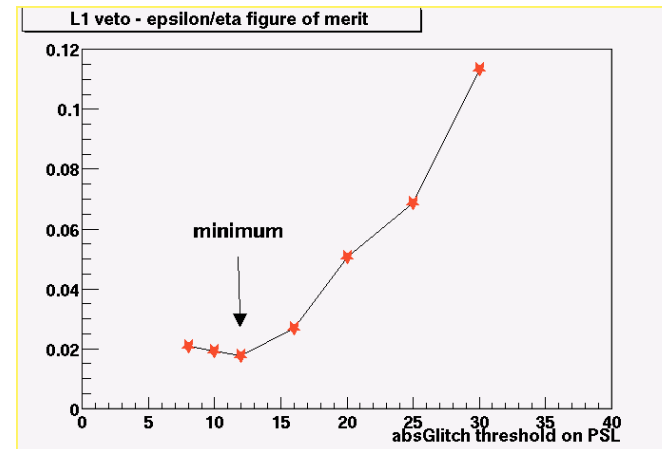

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Tuning & Pruning: H2

- ## Channels investigated
  - » POB, CARM, MICH, REFL
- ## MICH is "tall pole"
  - » … but none particularly good
- ## Time-delay histogram
  - » Efficacy low and messy!

Veto Lag Plot at H2 - MICH 30HzHP
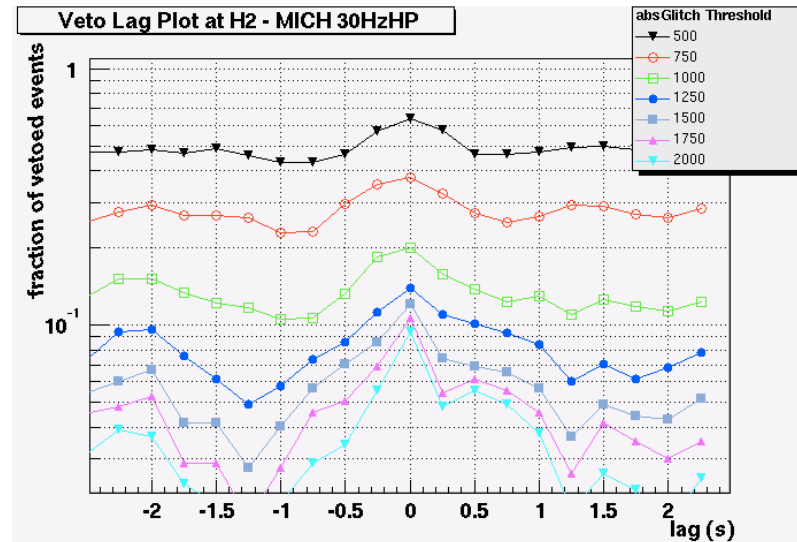
Tuning & Pruning

- **L1**
  - » Figure of merit ζ/η has broad minimum

- **H2**
  - » No ζ/η minimum!
  - » FOM needs re-thinking
  - » Used highest threshold

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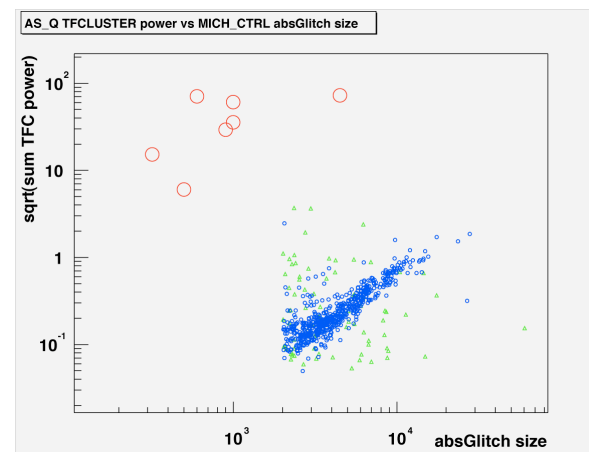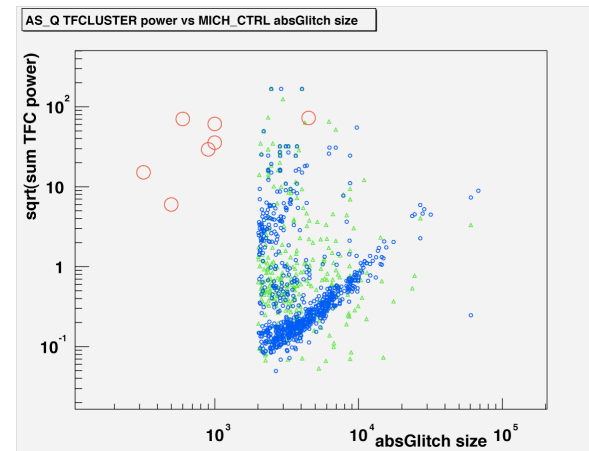
Tuning & Pruning

- ## L1 veto
  - » Decimation in event rate with only 10% loss in live time
  - » *But note:*
    - – Distribution shape approximately unchanged
    - – Conjecture event triggers still dominated by same instr. noise
    - – Message: Bad data, not good veto!

- ## H2 veto
  - » Prunes outliers, leaves bulk of events unchanged

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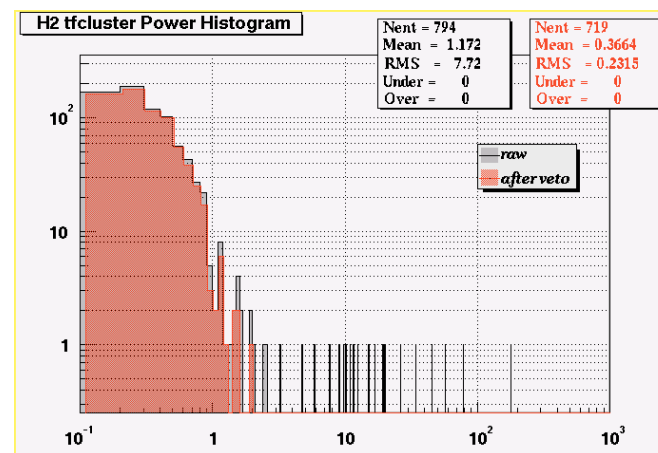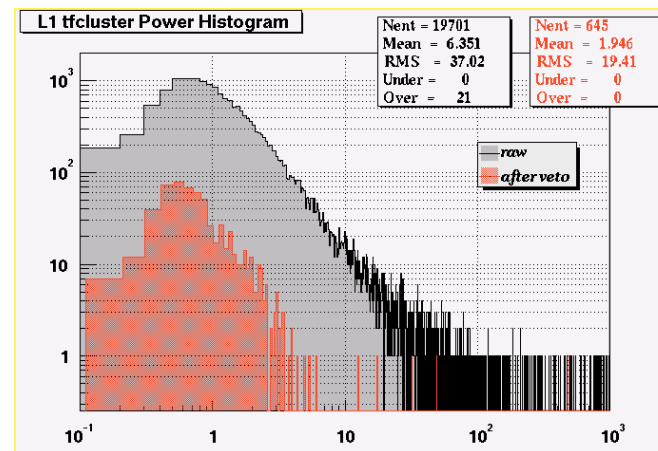
MICH_CTRL v. AS_Q

- MICH, AS_Q both sensitive to differential mode
  - » "At risk" of pruning gw events?
- Scatter plot coincident event, diagnostic trigger energy
  - » Expect larger event/veto energy ratio for GW source than non-GW source
  - » Red: h/w injected "GW-type" events
  - » Blue: observed coincident events
  - » Green: "accidentals" (coincidence after veto/event time shift)
- Can distinguish gw, non-gw
- Non-GW branches separate in frequency
  - » Lower branch events below 100Hz in TFClusters
  - » Upper branch events above 100 Hz

AS_Q TFCLUSTER power vs MICH_CTRL absGlitch size

AS_Q TFCLUSTER power vs MICH_CTRL absGlitch size

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Tuning & Pruning: Summary

		L1	H2
TFClusters	# Bursts	19701	794
	# Vetoed	19056	75
	Residual (rate)	645 (0.07 Hz)	719 (0.07 Hz)
Slope	# Bursts	9000	1827
	# Vetoed	8873	341
	Residual (rate)	127 (0.013 Hz)	1486 (0.14 Hz)

Data processing pipeline

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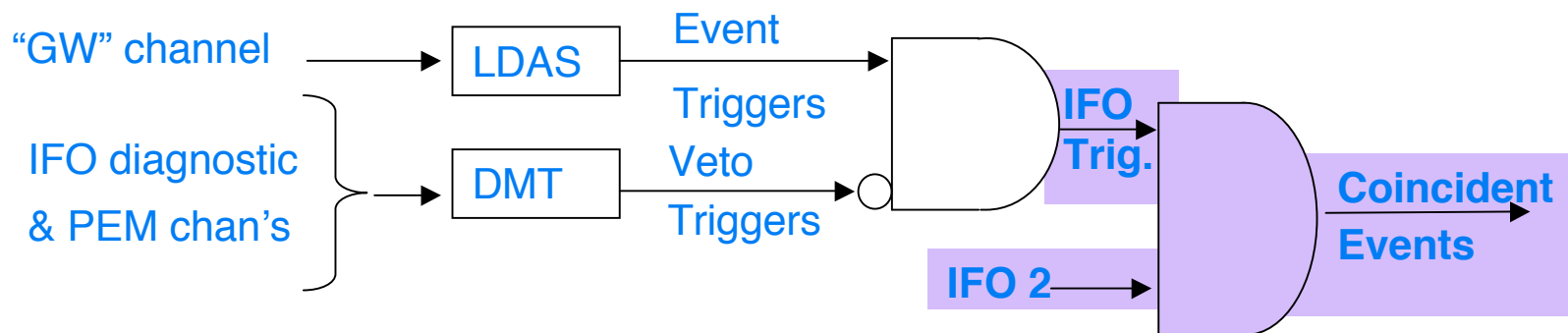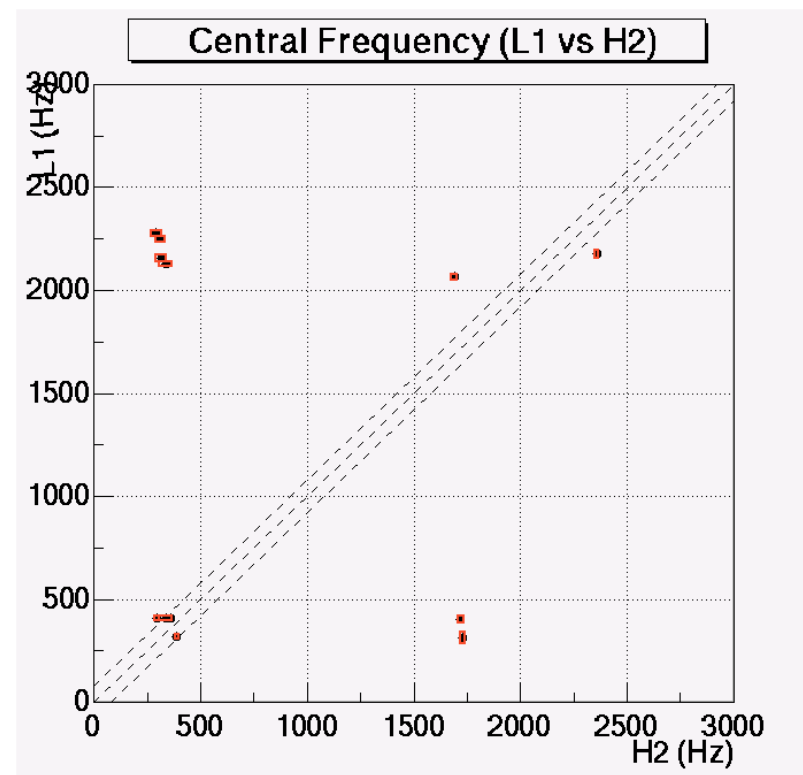
Coincidence?

- **Require agreement between IFO trigger characteristics**
- **Time window**
  - » TFClusters: +/- 0.5s
    - – Based on jitter
  - » Slope: +/- 0.5 s
    - – Can be much tighter
- **Strain amplitude agreement *(not implemented)***
  - » Requires calibration, obtained from simulation
- **Other characteristics**
  - » TFClusters: frequencies agree

Central Frequency (L1 vs H2)

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TFClusters frequency histograms
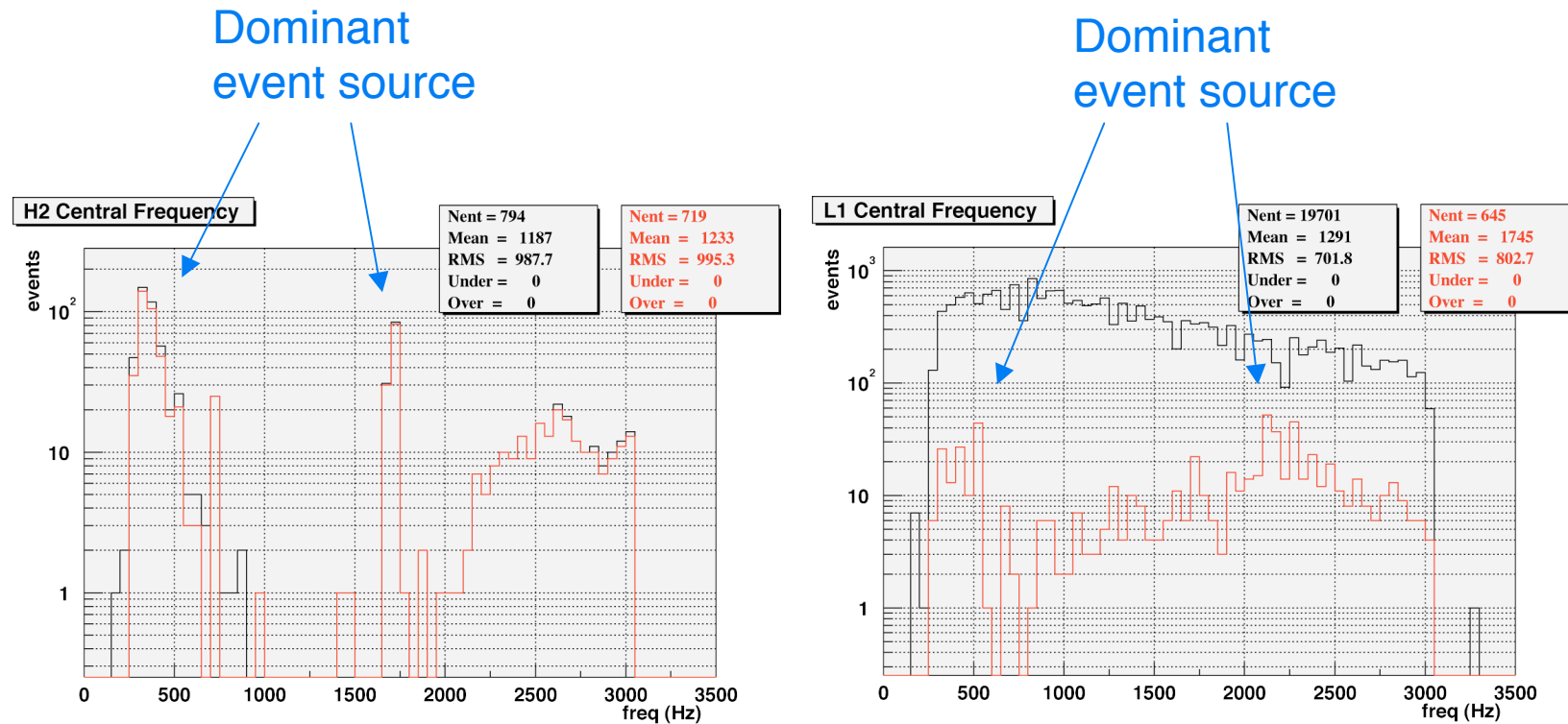
*Focus attention on "clean band": 500 to 1600 Hz*

Science interpretation

- "Raw" excess events
  - » Events unexpected (inexplicable?) owing to background
  - » *Requires estimate of background rate*

- "Instrumental" interpretation
  - » Calibrated strain events rate vs. strength
  - » *Requires simulation to obtain efficiency to characteristic strain*

- "Astrophysical" interpretation
  - » Characteristic sources distributed in space
    - – Also relative orientation source, detector
  - » *Different simulations for efficiency*
    - – Source, detector orientation, polarizations
    - – Convolution with spatial distribution
  - » Characteristic source choice?

- "Triggered" analysis
  - » Measure power in x-corr among ifos proximate to astrophysical events (e.g., GRB)
  - » Separate pipeline!

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Raw excess events (Playground results)

- **Background rate estimation**
  - » Time-delay histogram
    - – Assumes that no non-GW common-cause events in zero-delay coincidence window: *not investigated*
  - » TFClusters: 18 μHz
    - – Clean band
  - » Slope: 190 μHz
- **Zero-lag events**
  - » TFClusters: 0
  - » Slope: 0
- **Upper limit (90% CL)**
  - » TFClusters: 240 μHz
  - » Slope: 130 μHz
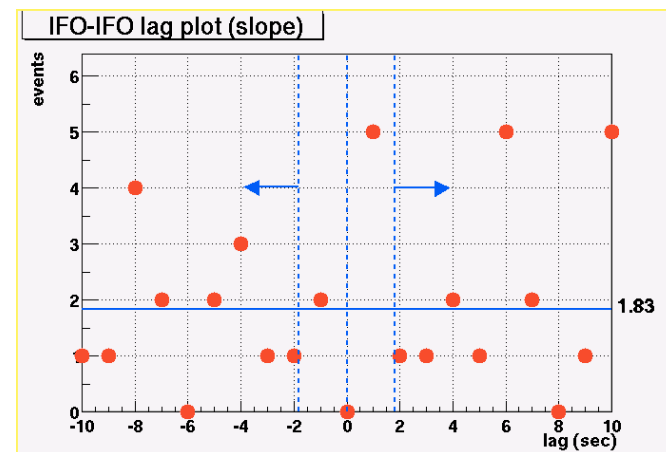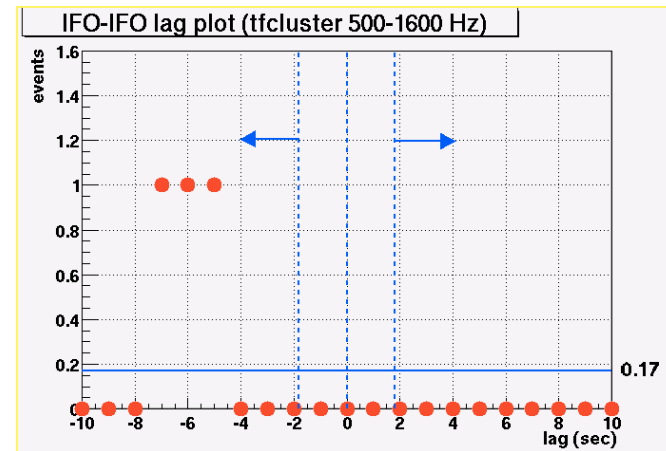
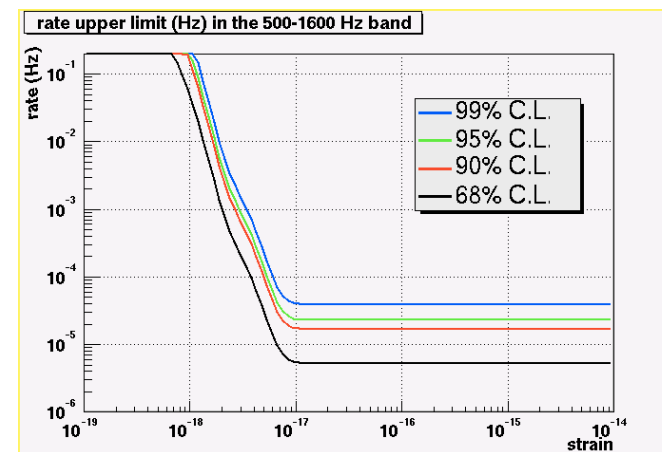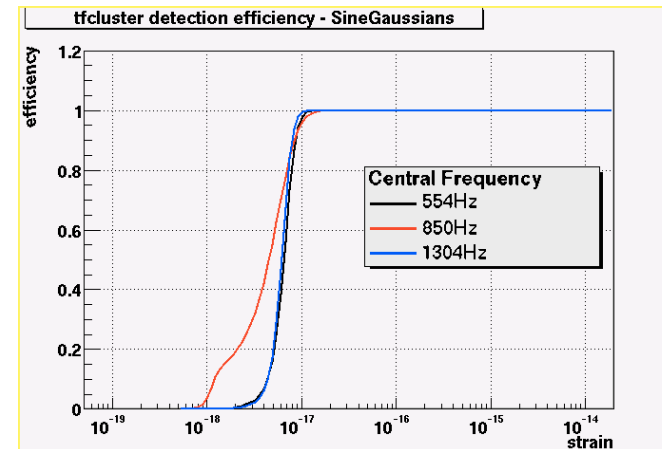IFO-IFO lag plot (tfcluster 500-1600 Hz)

IFO-IFO lag plot (slope)

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Instrumental interpretation (*Preliminary* E7 Final results)

- Limit rate of fixed-strain events
  - » Limit? Bound in rate v. strength
  - » Characteristic strain event? Gaussian modulated sine
    - – 10 Hz bandwidth
- Efficiency
  - » Preliminary: simulations in playground
  - » 850 Hz fit small number statistics problem: need more simulations
- Rate v. strength
  - » Exclude combinations of rate v. strength in upper right
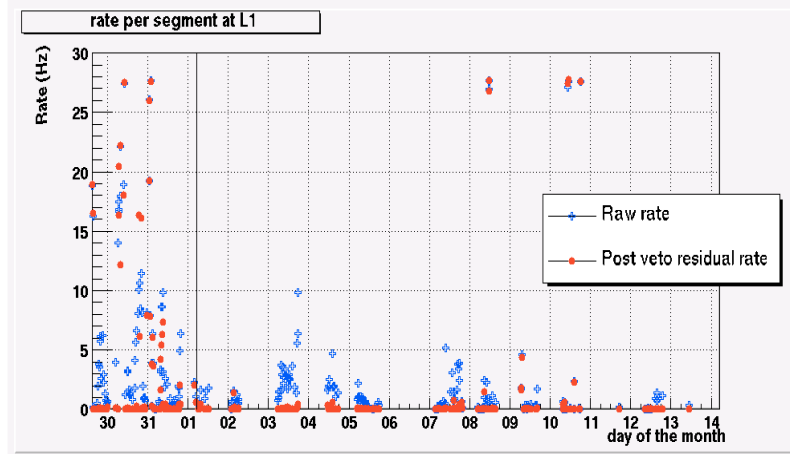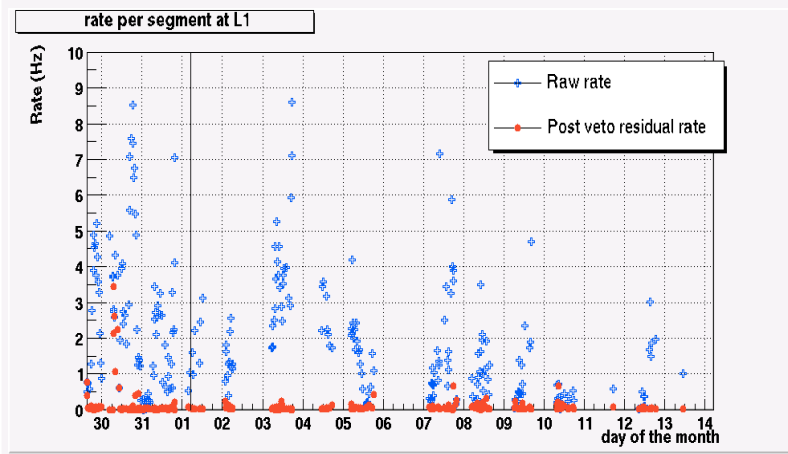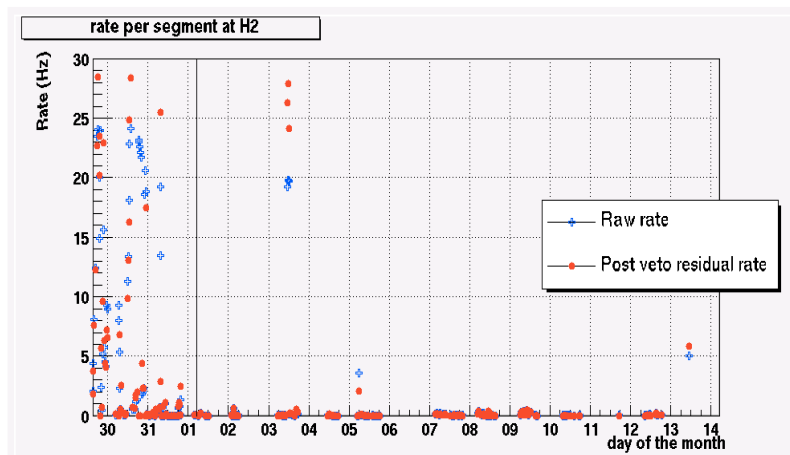 - » (Didn't use first two days …)

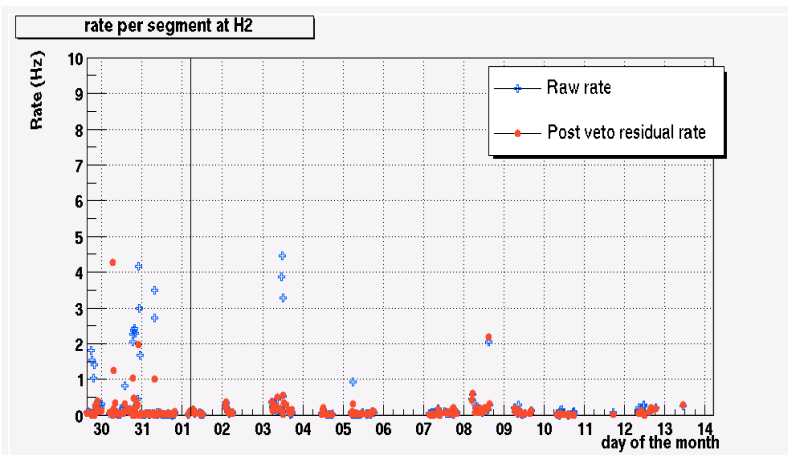tfcluster detection efficiency - SineGaussians

Central Frequency
554Hz
850Hz
1304Hz

rate upper limit (Hz) in the 500-1600 Hz band

99% C.L.
95% C.L.
90% C.L.
68% C.L.

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The First Two Days ...

TFClusters

Slope
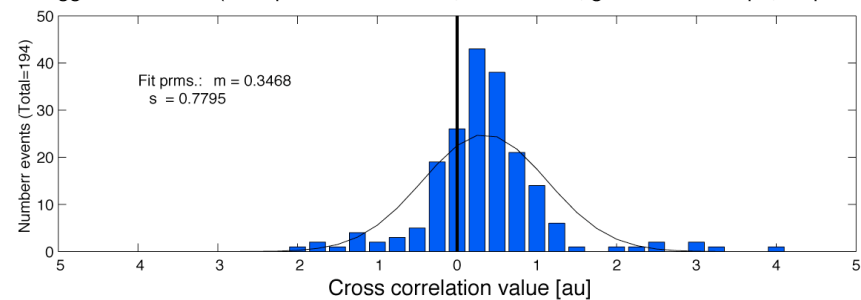
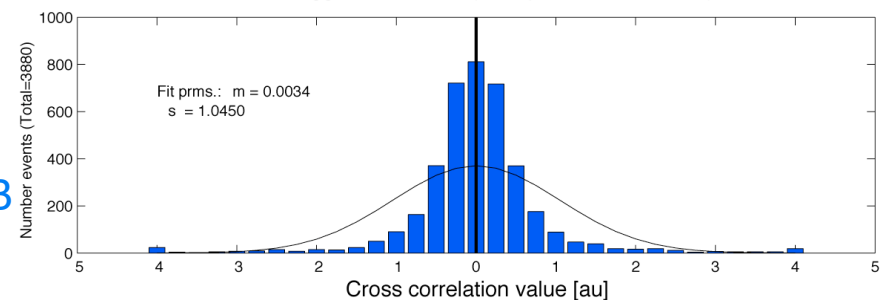Sam Finn/Penn State/Burst Group

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Triggered Analysis

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- **Data**
  - » Five events from GCN during E7
  - » Eleven events from IPN during E7
    - – Limited to poor directional information
  - » *Two events coincident with clean L1/H2*

- **Analysis follows FMR 1999**

- **Tuning**
  - » Pointing uncertainty, GRB/GWB lag, number GRB events, GWB signal character, data conditioning

ON trigger distribution (Bandpass 300Hz   4kHz, White noise, gaussian envelope, amp. = 1.0)

Fit prms.: m = 0.3468
            s = 0.7795

Numberr events (Total=194)

Cross correlation value [au]

OFF trigger distribution (Bandpass 300Hz   4kHz)

Fit prms.: m = 0.0034
            s = 1.0450

Number events (Total=3880)

Cross correlation value [au]

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Open Issues

- Diagnostic trigger generation: *Dealing with non-stationarity*

  » Adaptive veto triggers?

  » Qualifying data segments?

- Event trigger generation

  » How to handle multiple event trigger generators?

- Coincidence criteria: Implementing amplitude match

- Interpretations

  » "Astrophysical interpretation": needs work!

  » Multiple "sources": an upper limit, or multiplicity of upper limits?

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