GRAVITATIONAL WAVE LOCALIZATIONS, ERROR BOXES AND TIMESCALES

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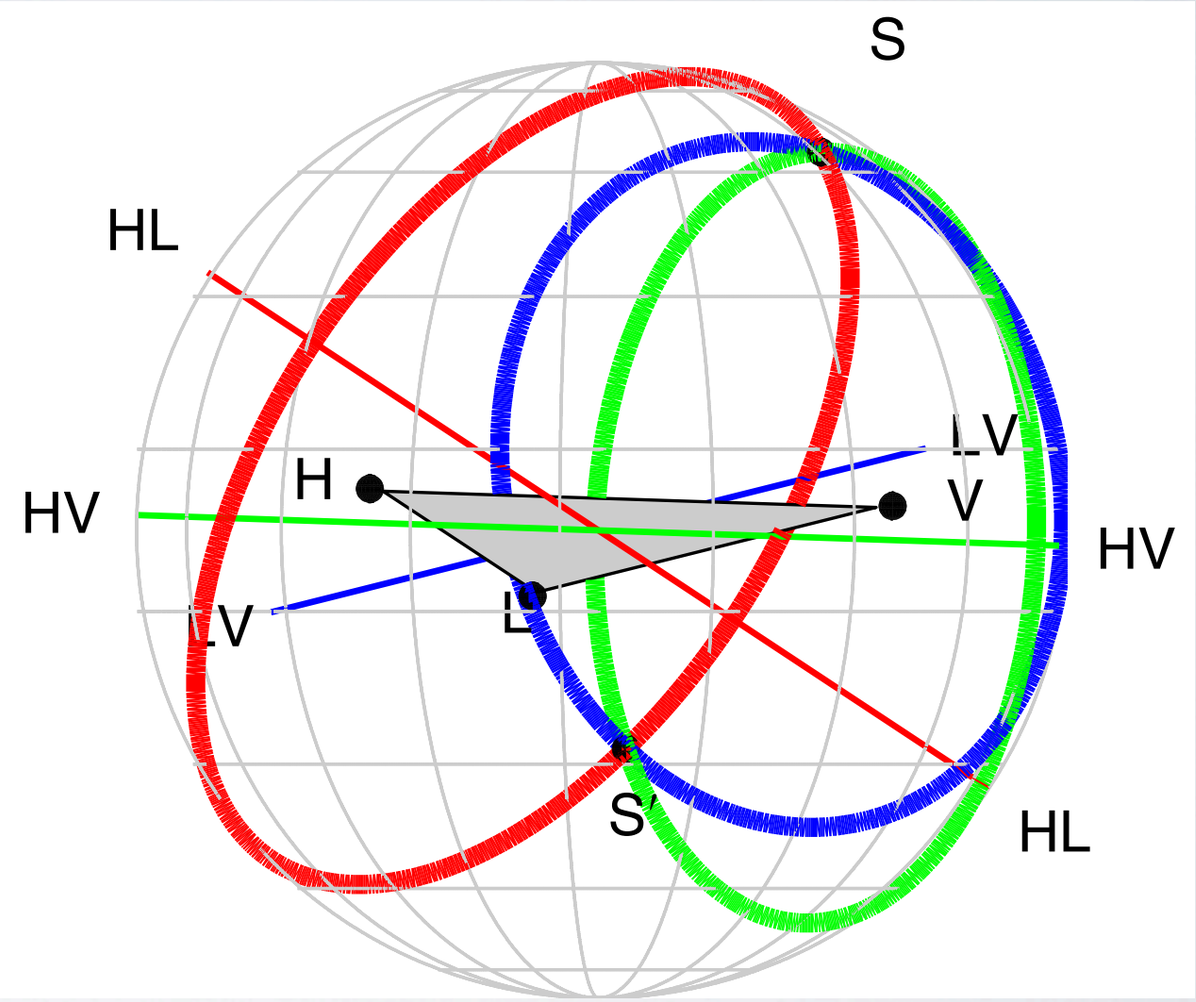
LOCALIZATION FROM TIMING

- A pair of detectors localizes to a ring on the sky



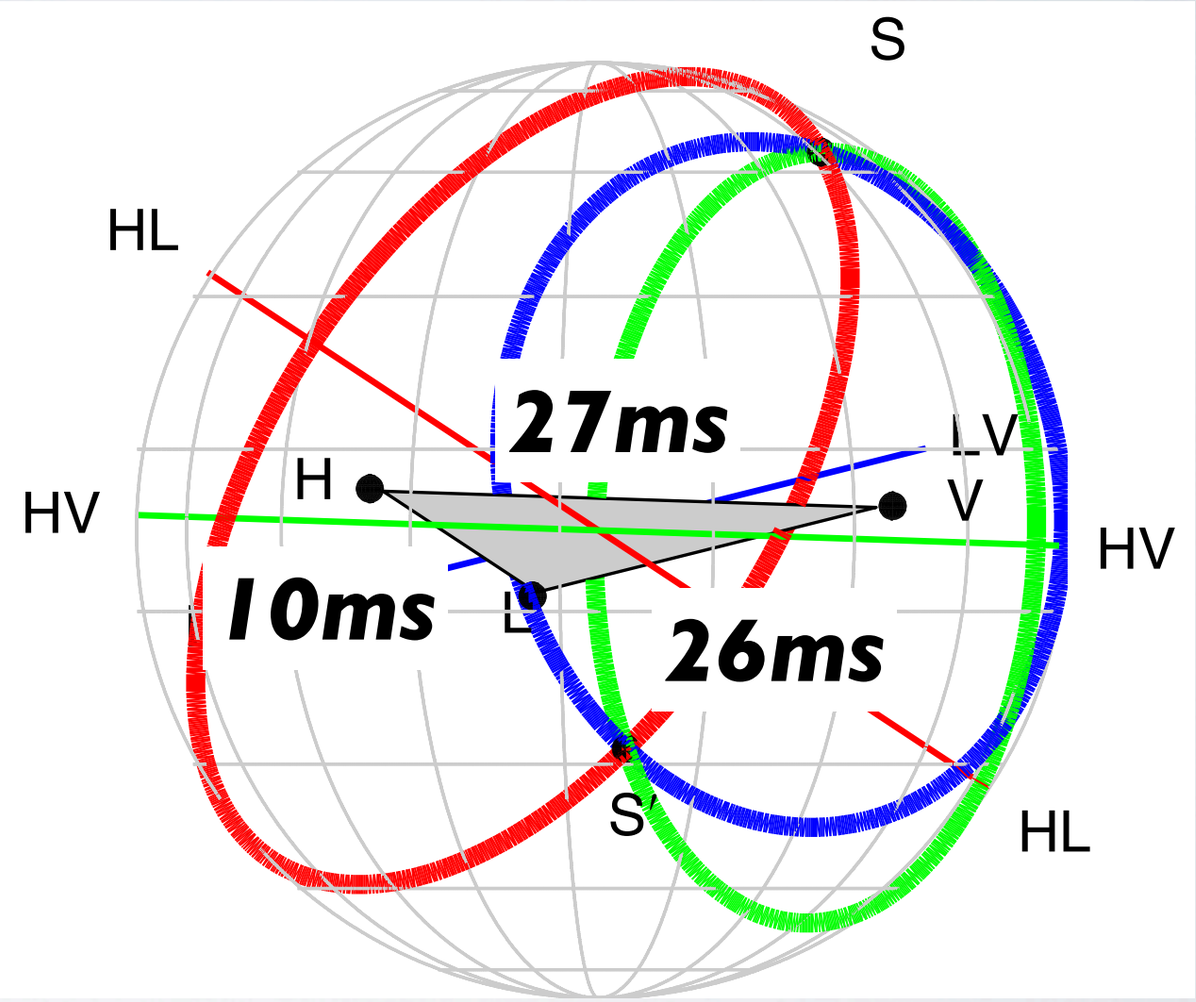
LOCALIZATION FROM TIMING

- A pair of detectors localizes to a ring on the sky
- Width of rings given by

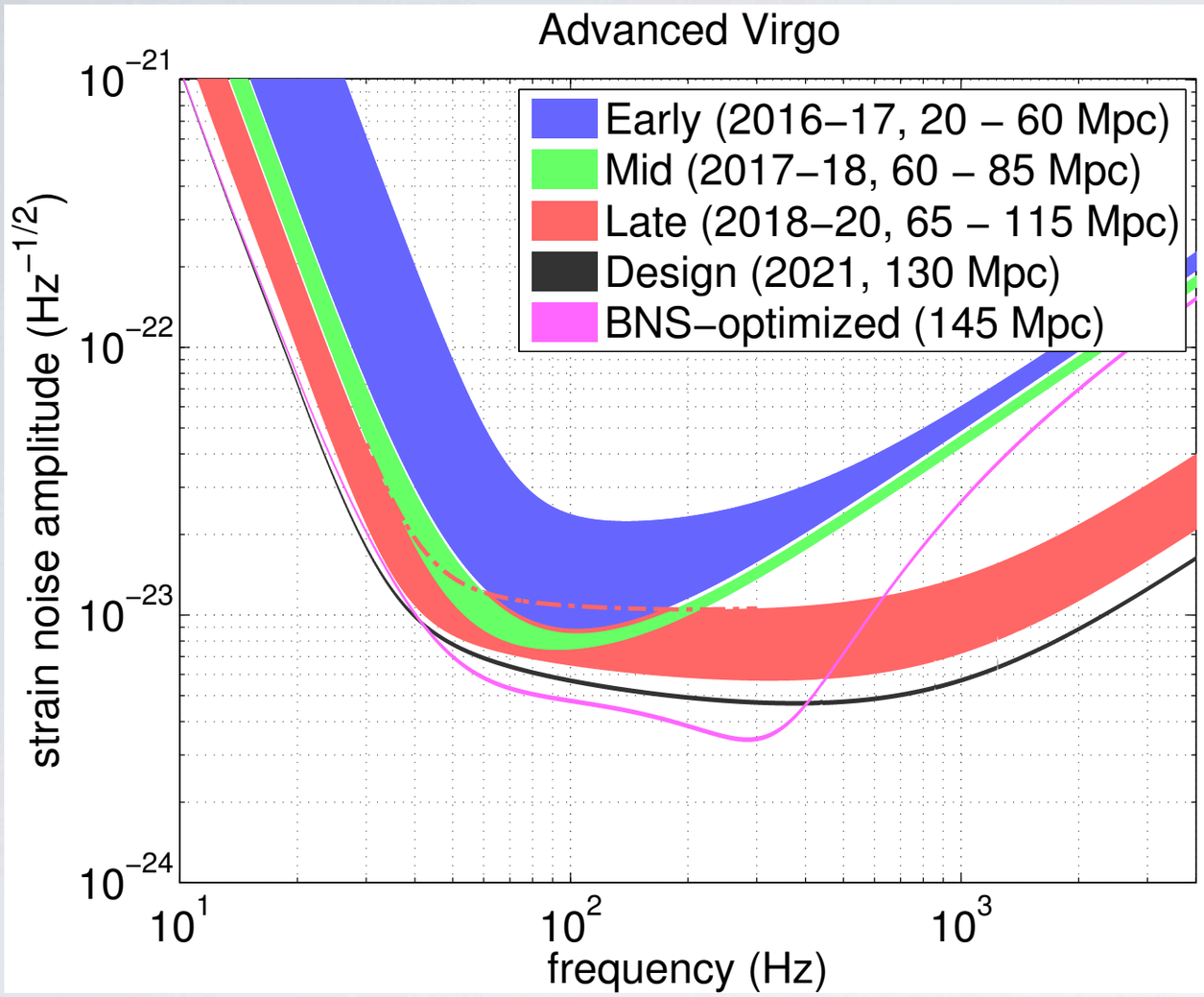
$$\sin\theta\, d\theta = \frac{\sqrt{\sigma_1^2 + \sigma_2^2}}{\Delta t}$$

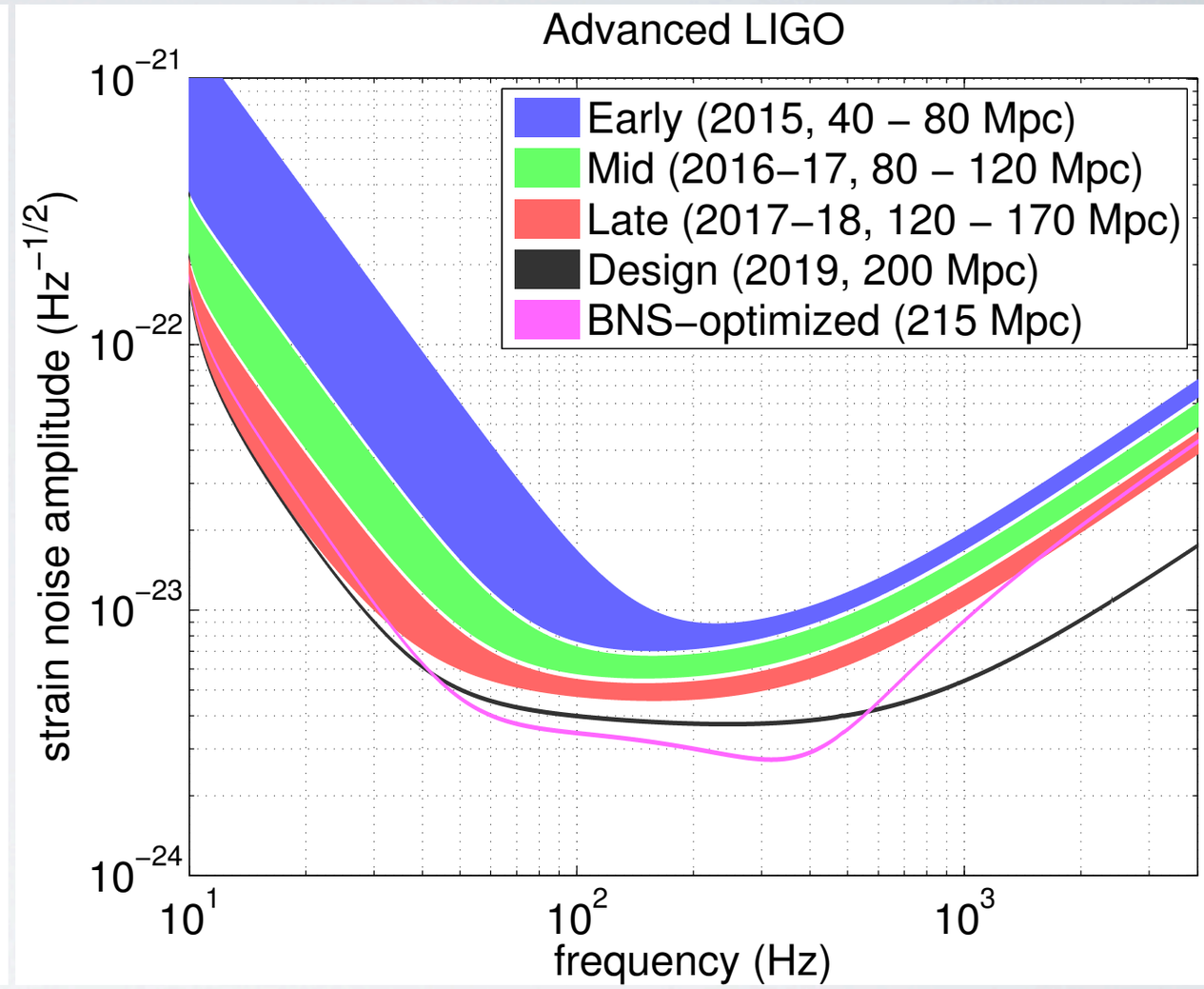
- where $\sigma_t = \dfrac{1}{2\pi\rho\sigma_f}$

Δt detector baseline



SF NJP 2009; CQG 2011



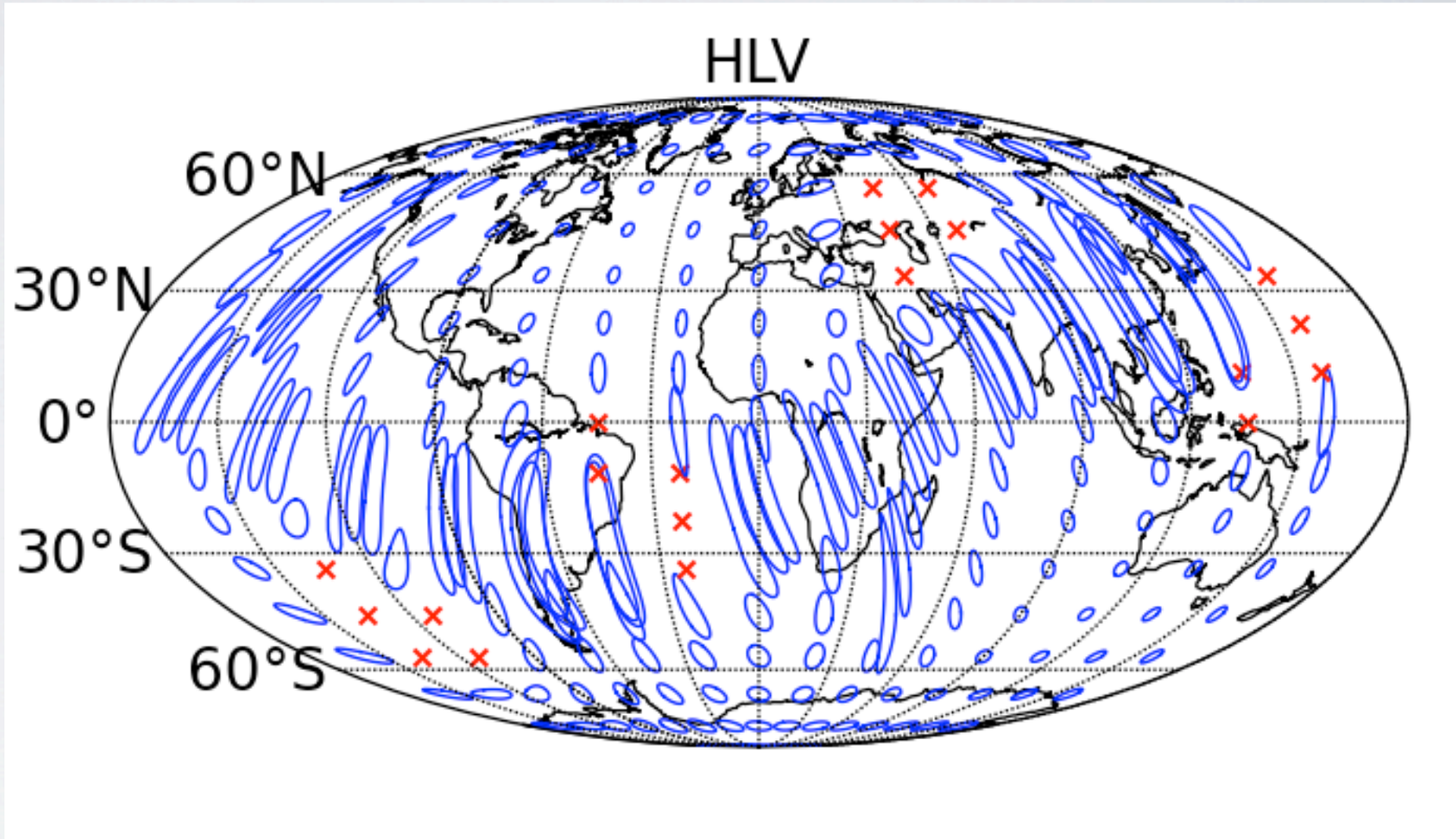


DETECTOR SENSITIVITIES

From Aasi et al, arXiv:1304.0670

2016-17

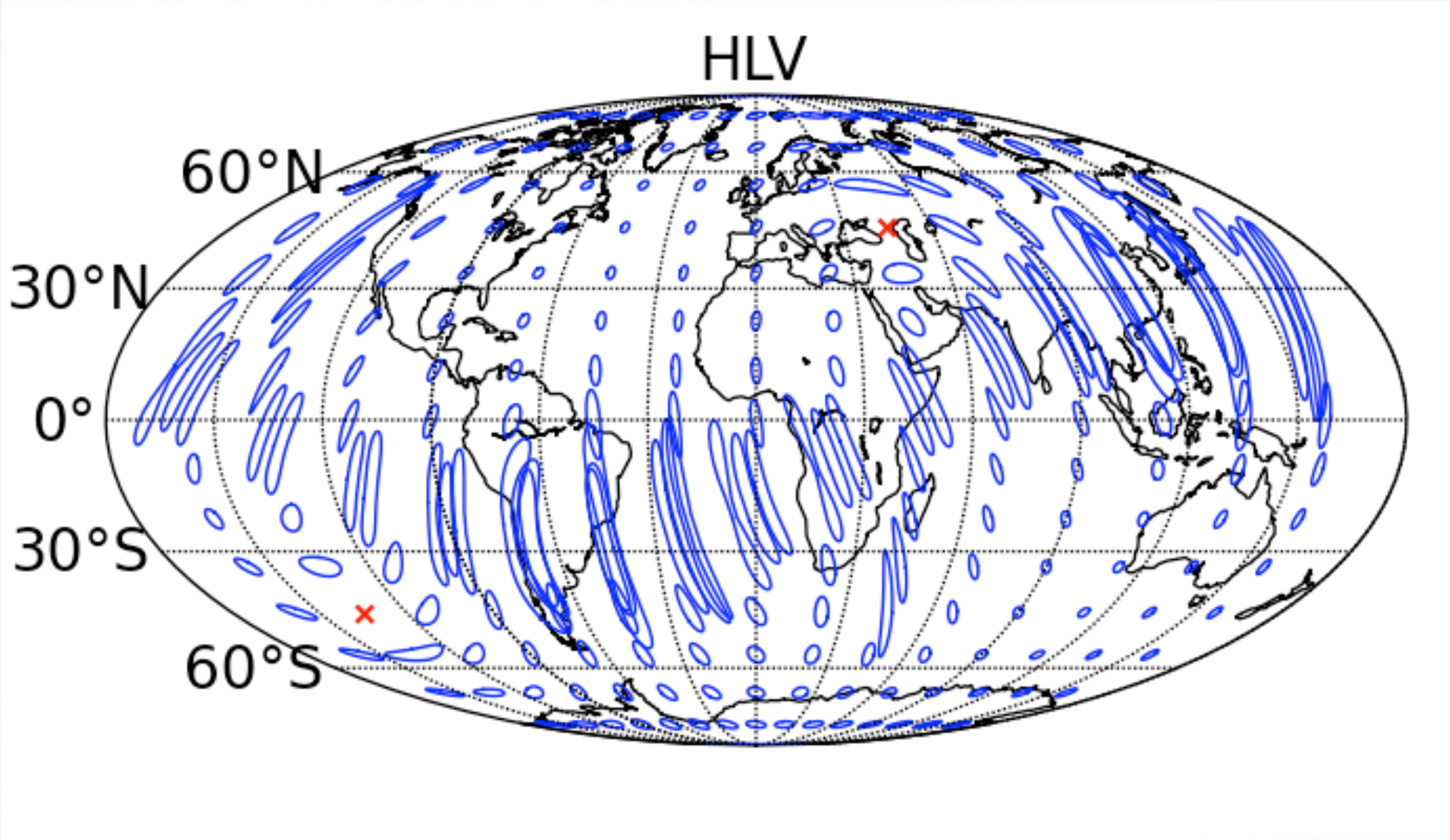
- LIGO 80 -120 Mpc
- Virgo 20 - 60 Mpc
- Assume 80% duty cycles
- 0.006 - 20 BNS signals in 6 month run



Face on BNS @ 80 MPc
90% confidence regions

2017-18

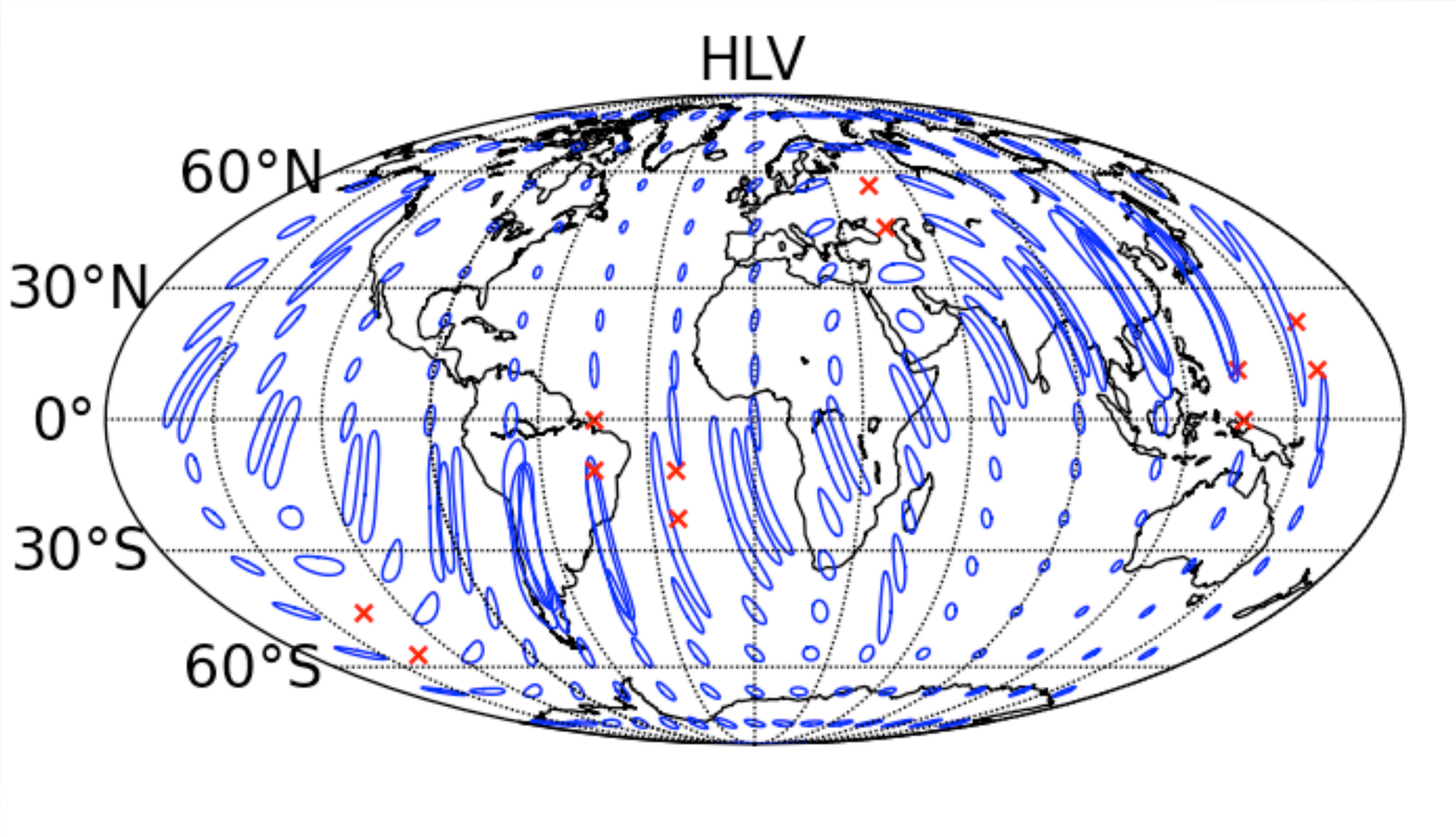
- LIGO 120-170 Mpc
- Virgo 60-85 Mpc
- Assume 80% duty cycles
- 0.04 - 100 BNS signals in 9 month run



Face on BNS @ 80 MPc
90% confidence regions

2019+

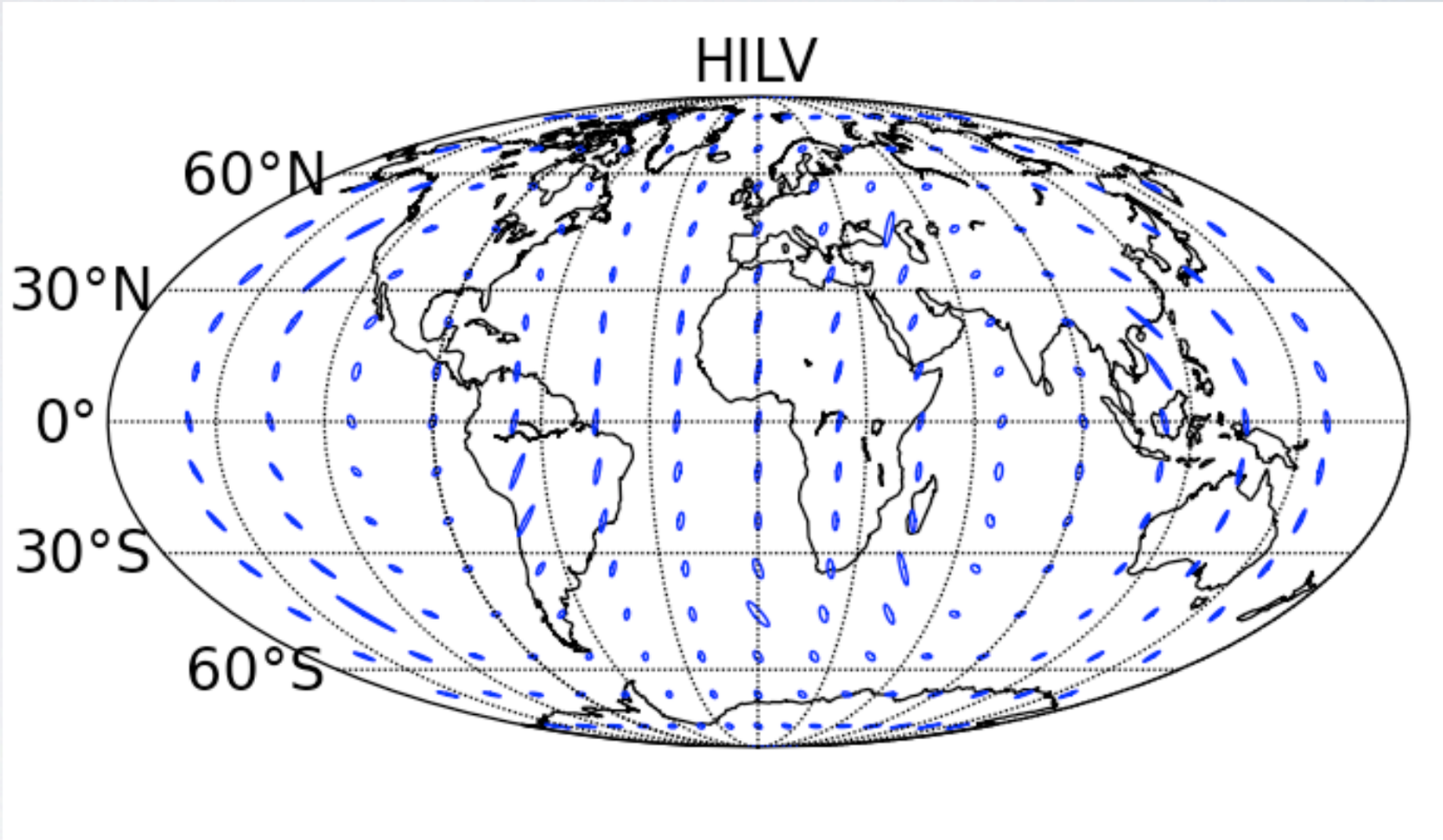
- LIGO 200 Mpc
- Virgo 65-130 Mpc
- Assume 80% duty cycles
- 0.2 - 200 BNS signals per year



Face on BNS @ 160 MPc
90% confidence regions

2022+ WITH INDIA

- LIGO 200 Mpc
- Virgo 130 Mpc
- LIGO India 200 Mpc
- Assume 80% duty cycles
- 0.4 - 400 BNS signals per year

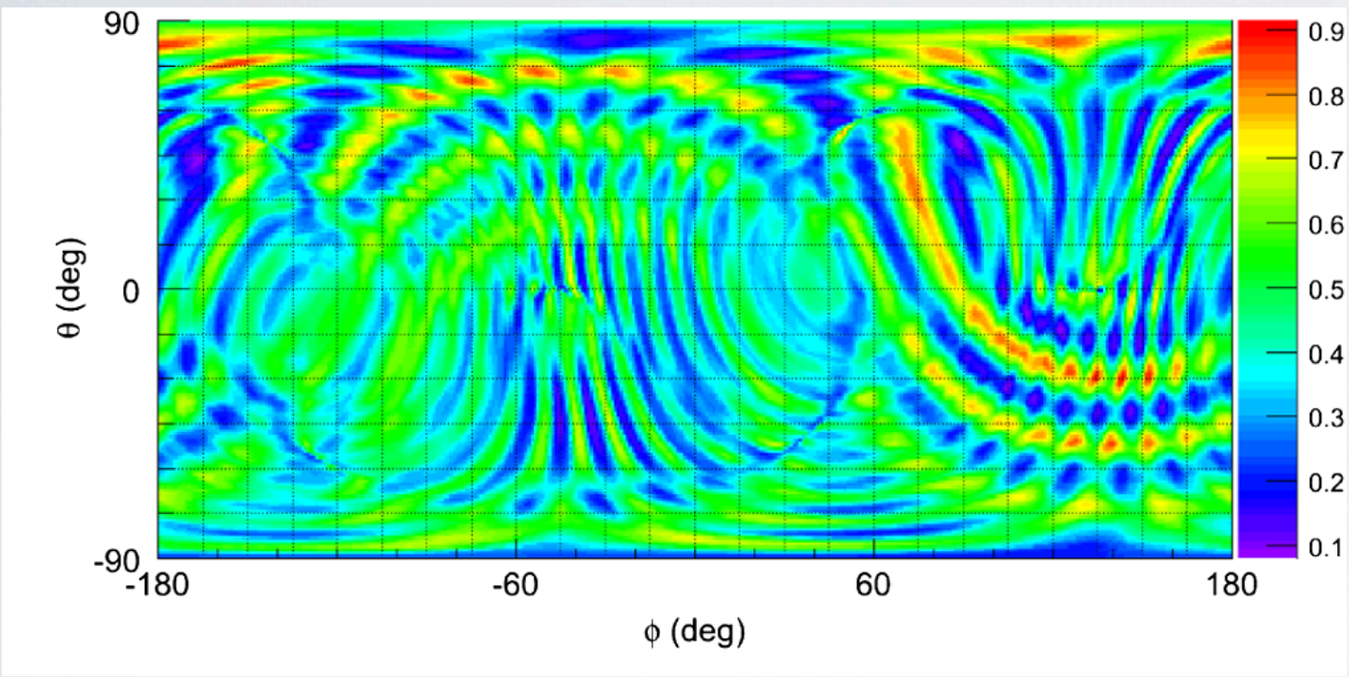


Face on BNS @ 160 MPc
90% confidence regions

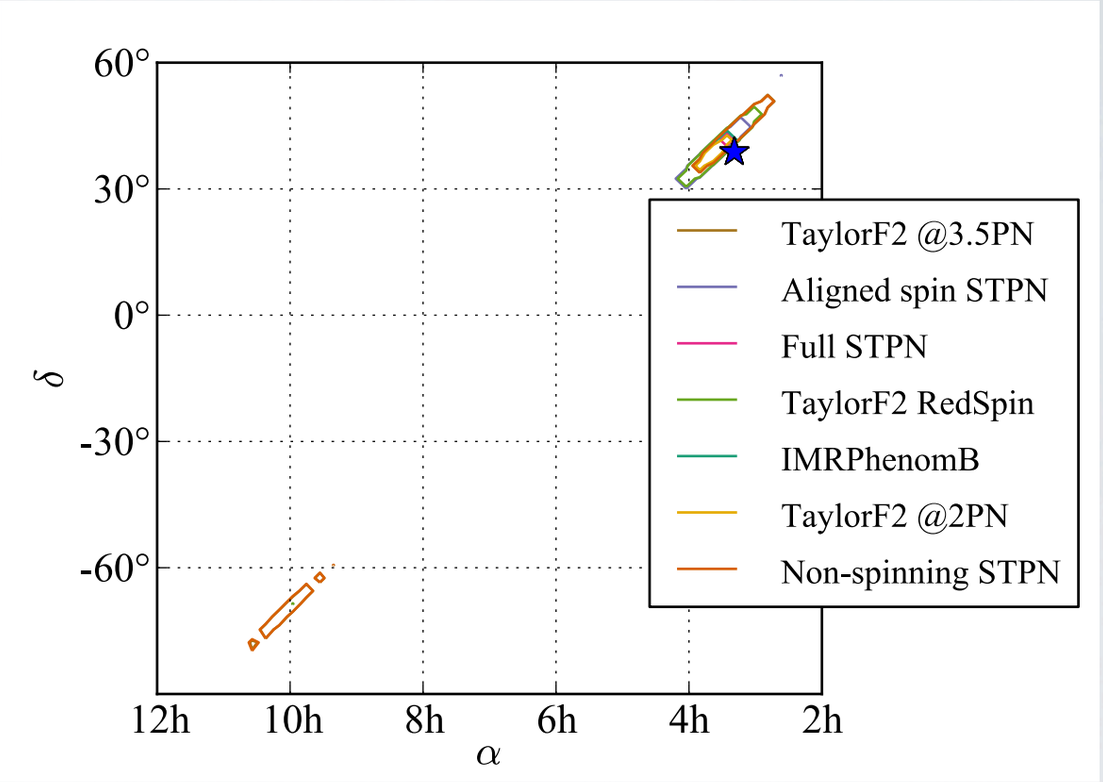
CAVEATS & IMPROVEMENTS

- Results use only timing information.
  - We assume we can break reflection degeneracy for 3 sites.
  - Can do better using amplitude/phase consistency between sites.
- Use Gaussian approximation to localization.
  - Leads to overly optimistic results at low SNR - tend to get rings.
  - Error boxes approximated as ellipses
- Have neglected spin (precession) effects.

LOCALIZATION EXAMPLES

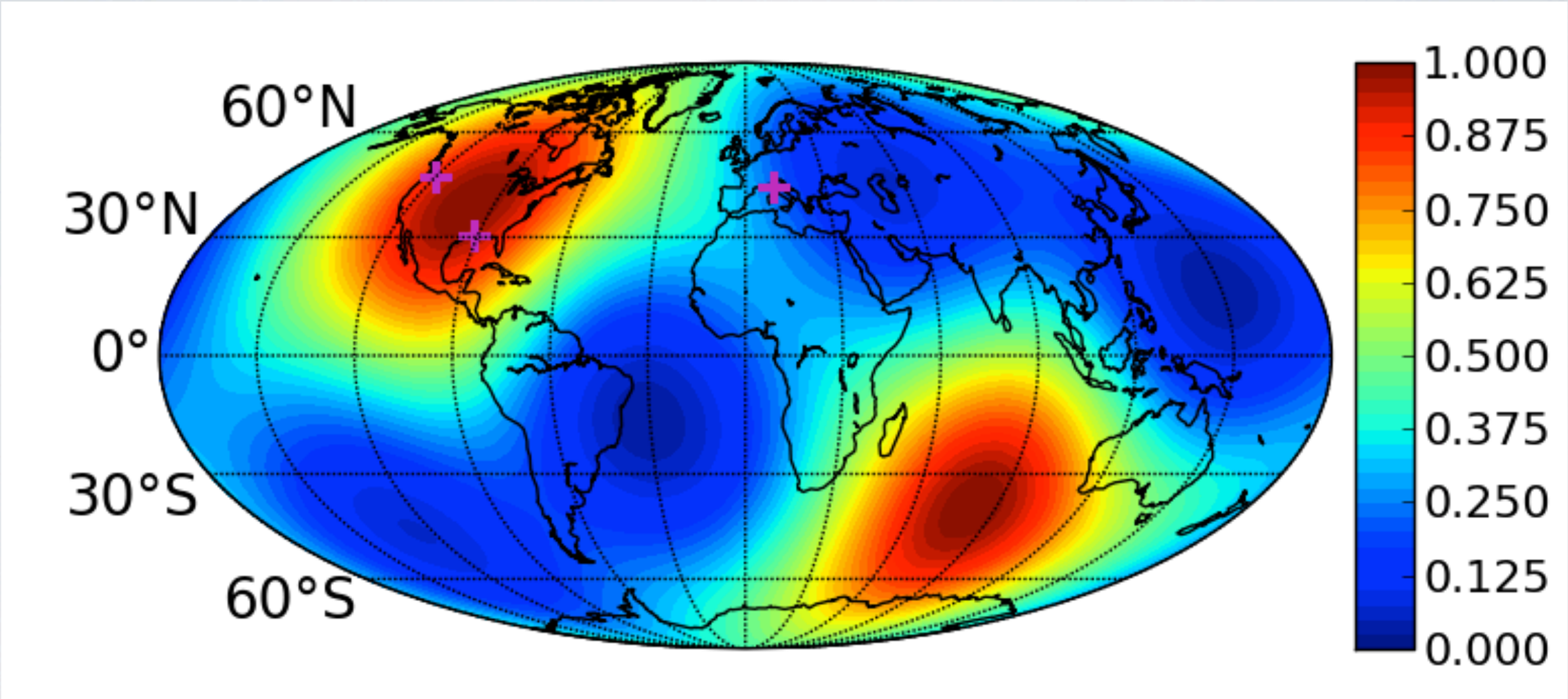


From Klimenko et al, PRD 2011
Burst source localization



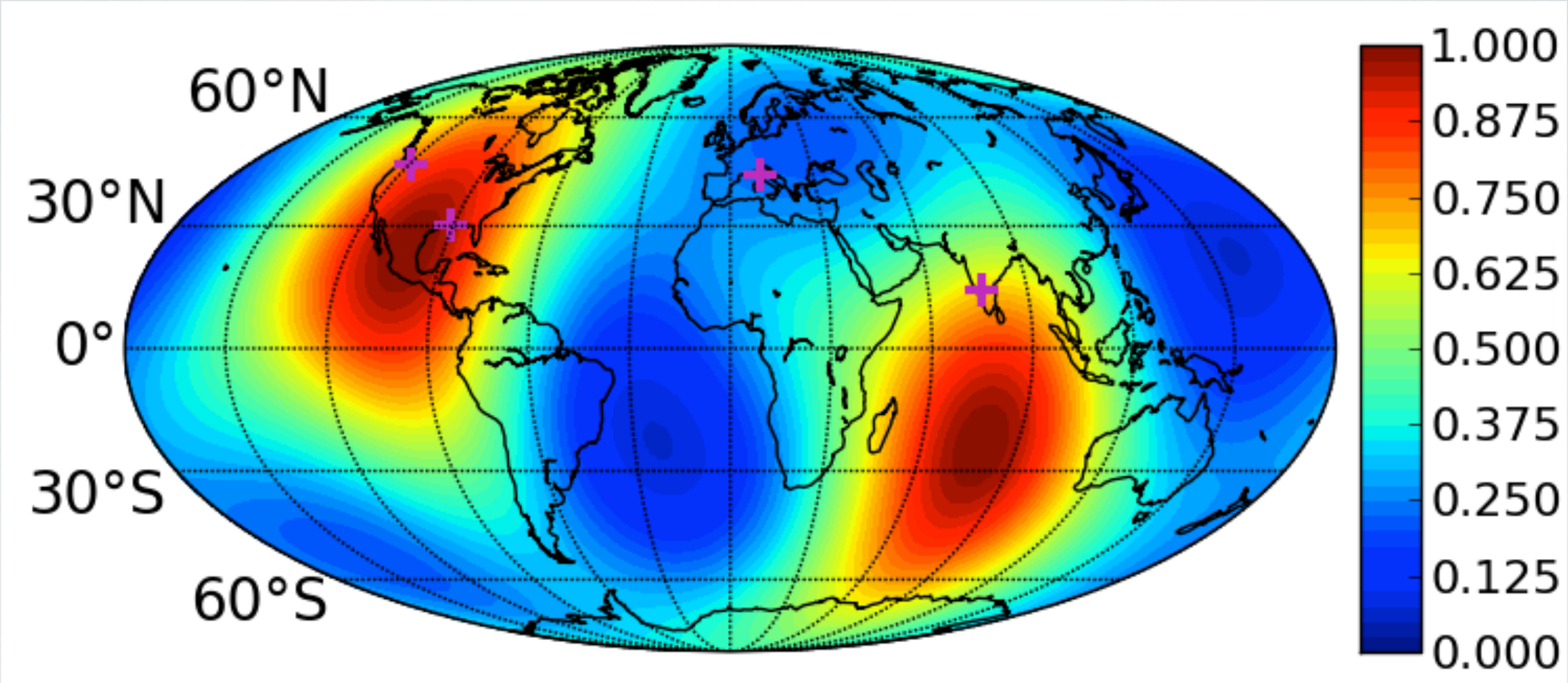
From Abadie et al, arXiv:1304.1775
BNS source localized to two sky patches

LIKELY SKY LOCATIONS



Relative rate of sources from different sky positions
LIGO taken to be twice as sensitive as Virgo

LIKELY SKY LOCATIONS

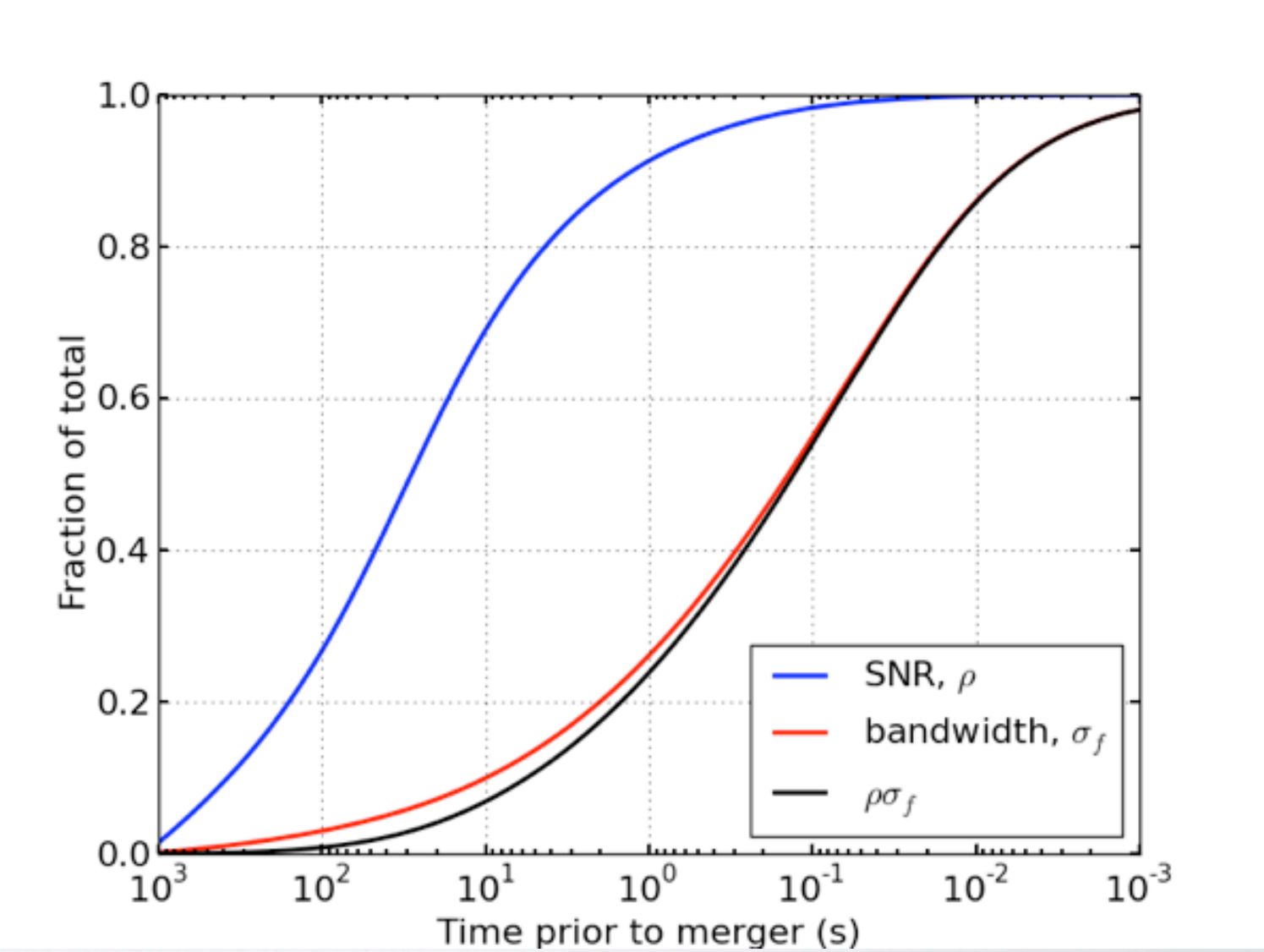


Relative rate of sources from different sky positions
2022+ configuration with LIGO India

LATENCY

LOCALISATION BEFORE MERGER?

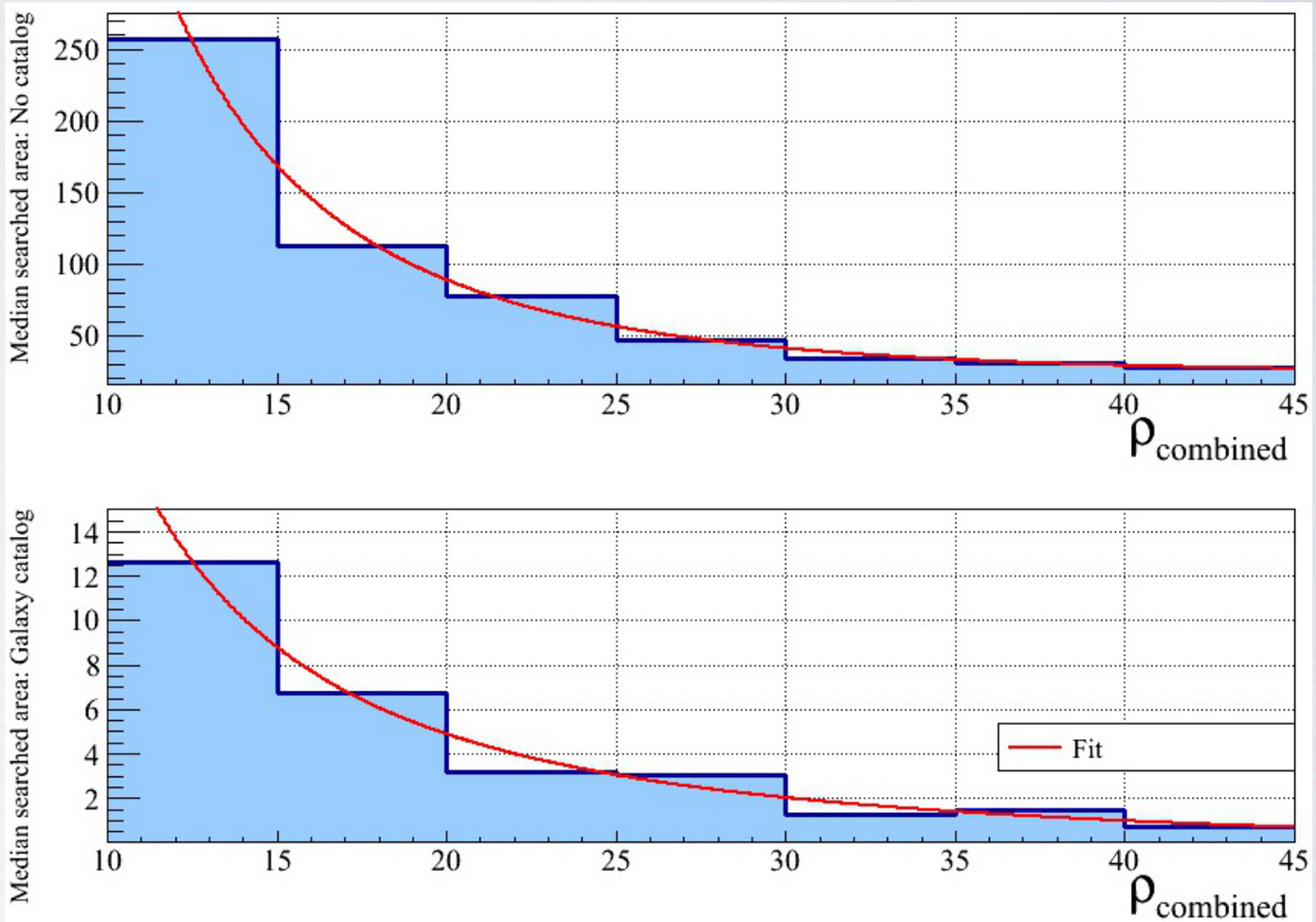
- In advanced detectors, BNS signals spend minutes in band
- Might detect a loud signal a minute ahead.
- But localisation comes in the last second.



SF NJP 2009

S6-VSR3 LOW LATENCY

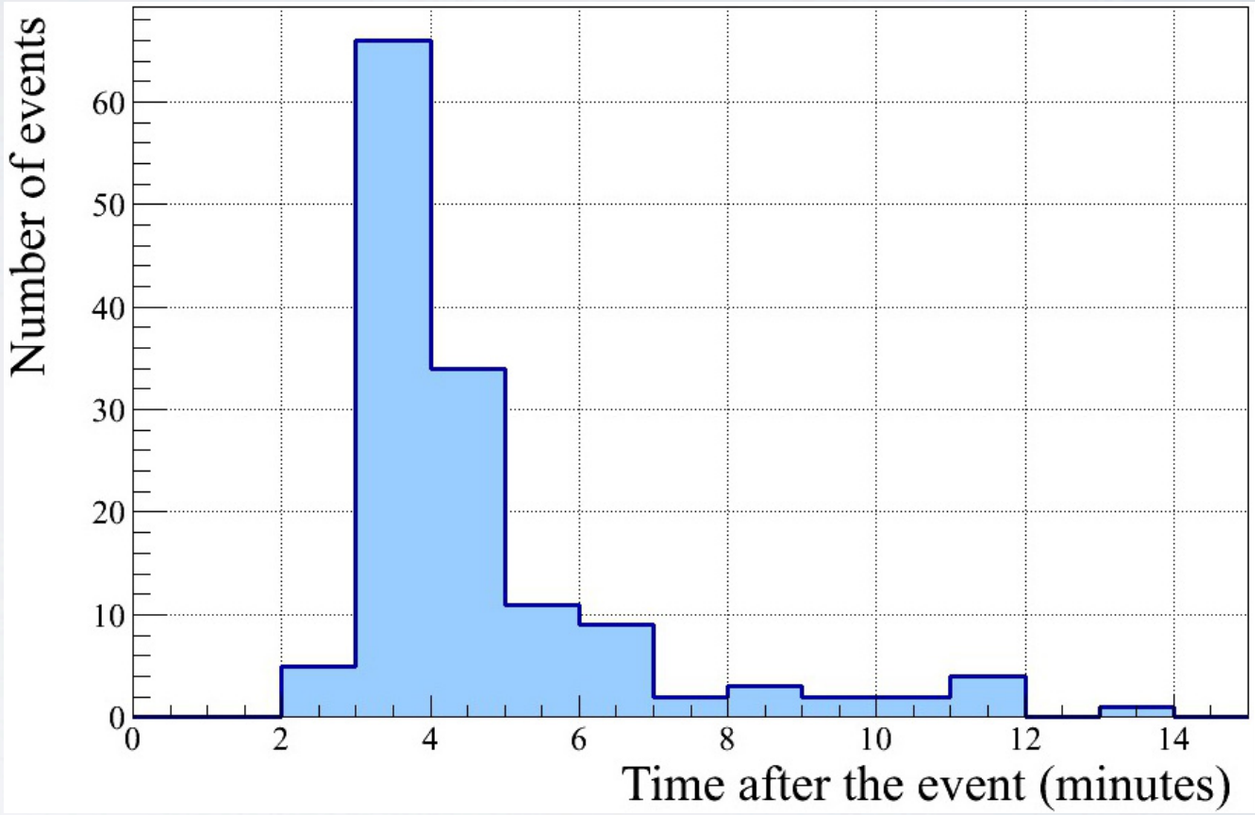
- Low latency search was done in S6-VSR2/3
- Used timing and amplitude information for rapid localization
- Areas comparable to theoretical predictions
- Also used galaxy calatogue to refine locations



Abadie et al, A&A 2012

S6-VSR3 LOW LATENCY

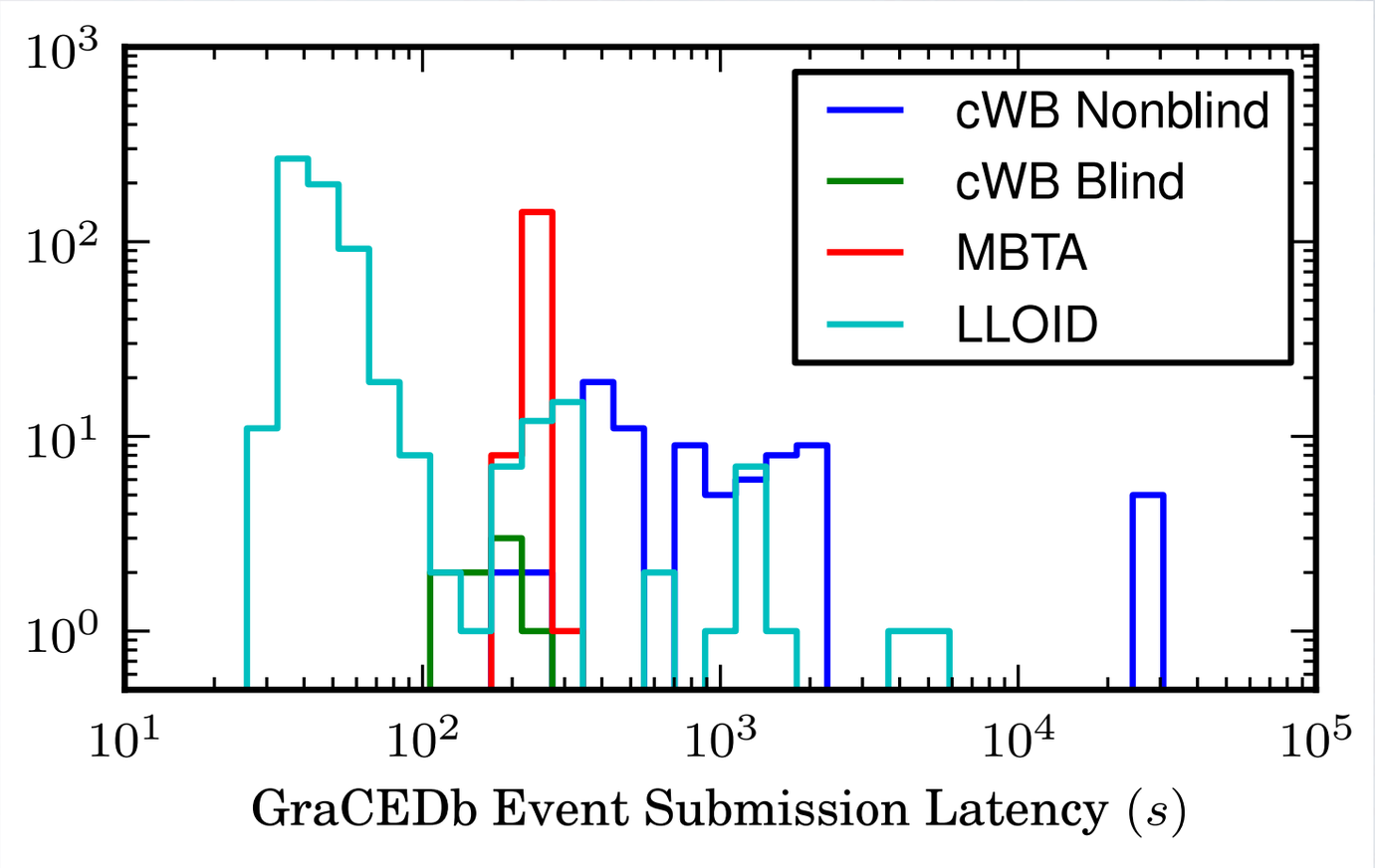
- Latencies of minutes for the analysis were achieved
- There was then a human check of instrumental performance



Abadie et al, A&A 2012

ADVANCED DETECTOR LATENCY

- Low latency much harder
  - 10x longer templates
  - 10x as many templates
- Significant effort to achieve minutes latency
- Achieved in recent "engineering runs" using simulated data at advanced detector design



Keppel for the LSC and Virgo, GWPAW 2012 poster

SUMMARY

Epoch	Estimated Run Duration	$E_{\rm GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		$5\,\mathrm{deg}^2$	$20\,\mathrm{deg}^2$
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48