

Search for joint sources of gravitationnal waves and high energy neutrinos with the LIGO-Virgo and ANTARES detectors



LIGO
Scientific
Collaboration



VLVnT 2015, Rome, 15/09/2015



B. Baret for the LIGO-Virgo and ANTARES collaborations

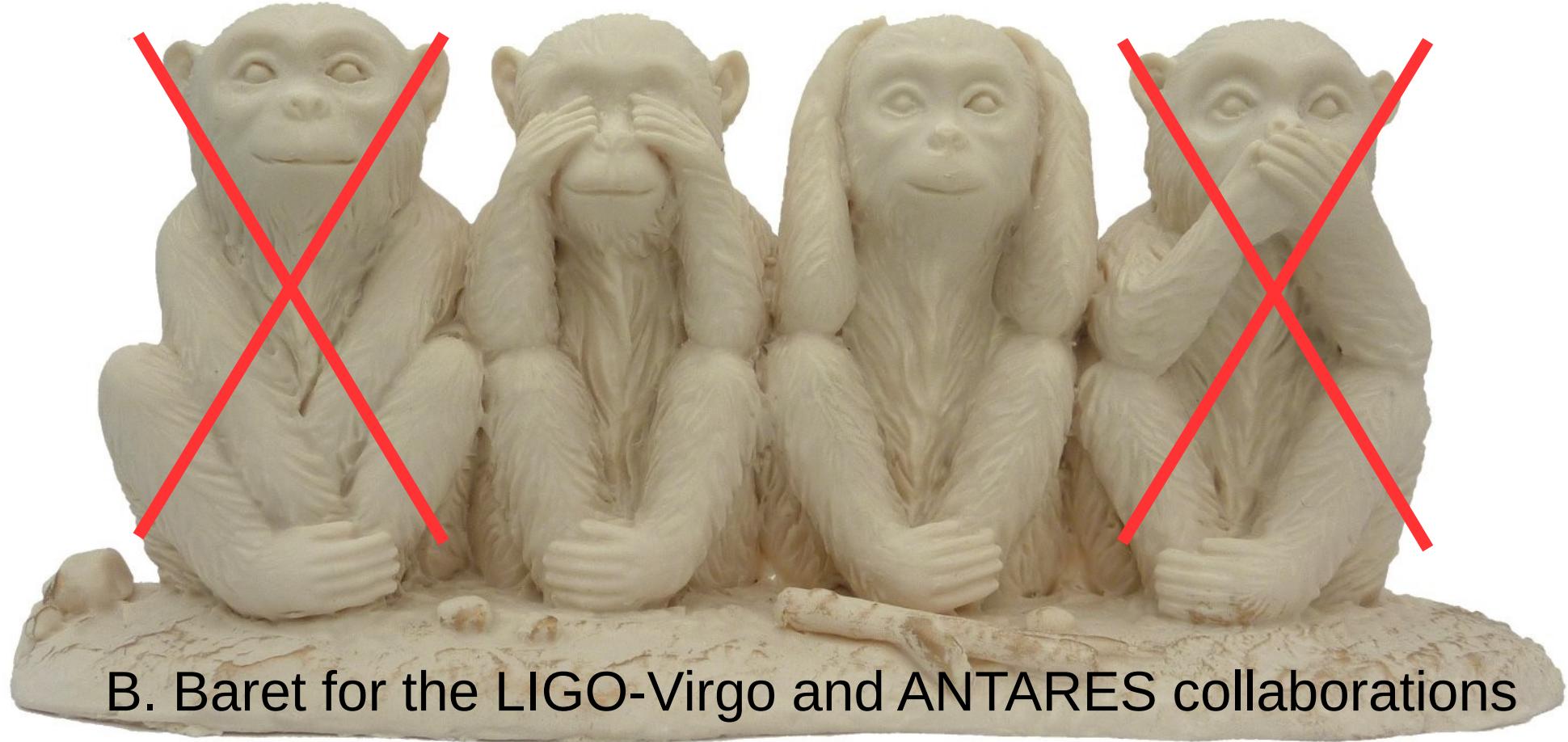
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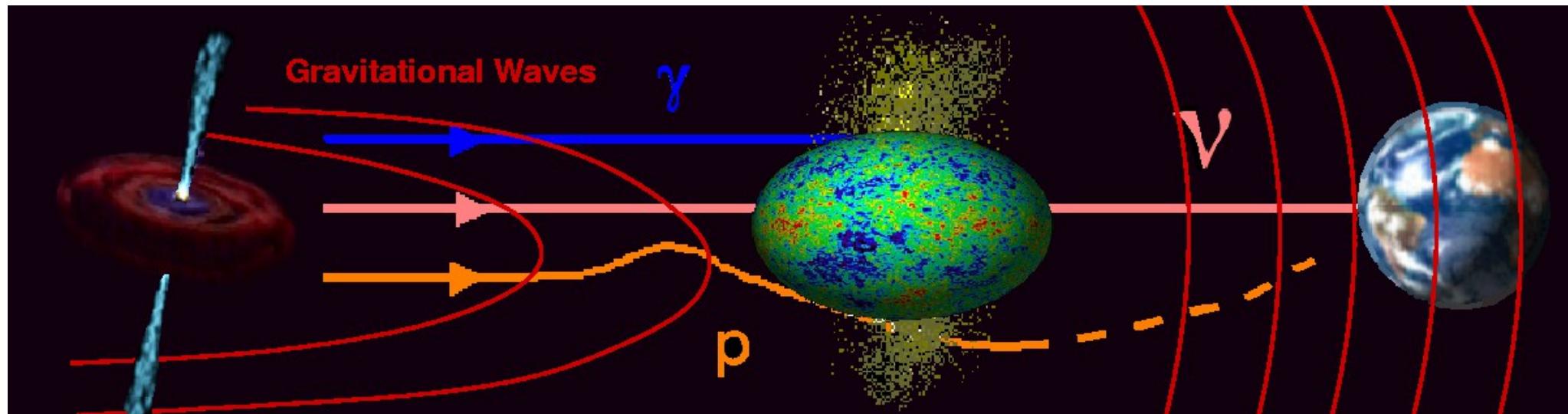


50th Rencontres de Moriond, La Thuile, 25/03/2015



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Why GW+HEN ?



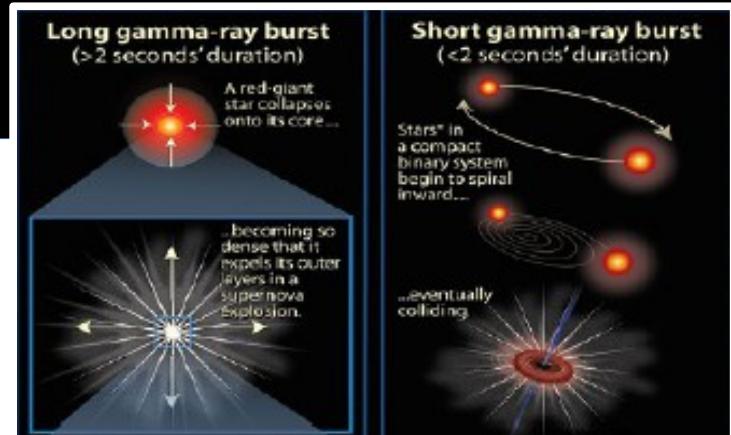
- 1 - Sources invisible in photon ? : Dark Bursts
- 2 - Coincident Detection validate both detections
- 3 - Unique Information on internal processes : accretion-ejection...
- 4 - Fundamental Physics ? : LVI

GWHEN

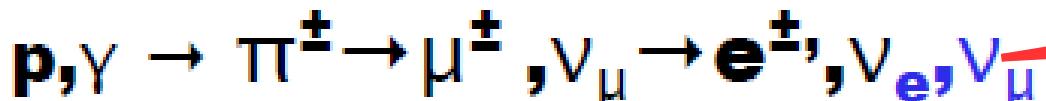
« Joint venture » of people from LIGO, Virgo, ANTARES, IceCube
Data exchange MOUs

Target Sources

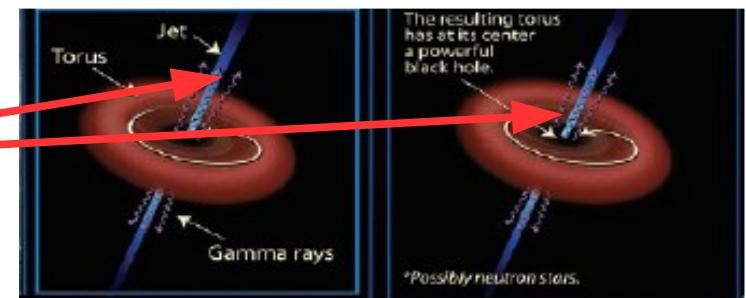
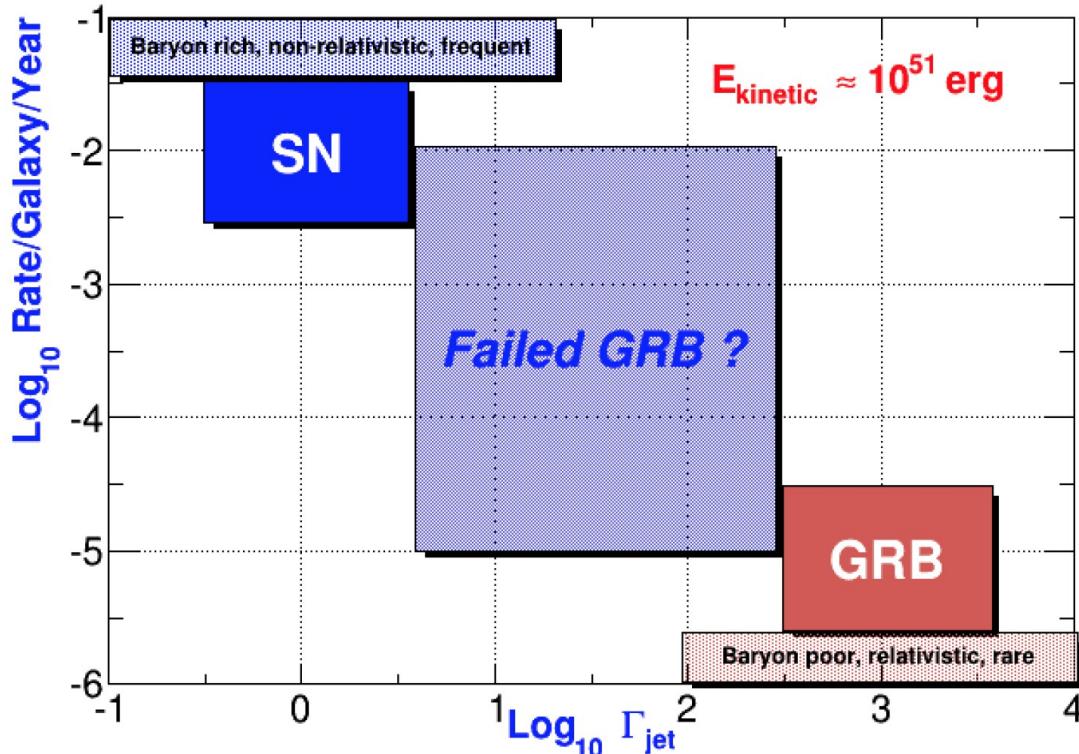
GW emission:
Collapse or binary mergers



HEN emission:
Acceleration of protons, followed by pp
and py interactions



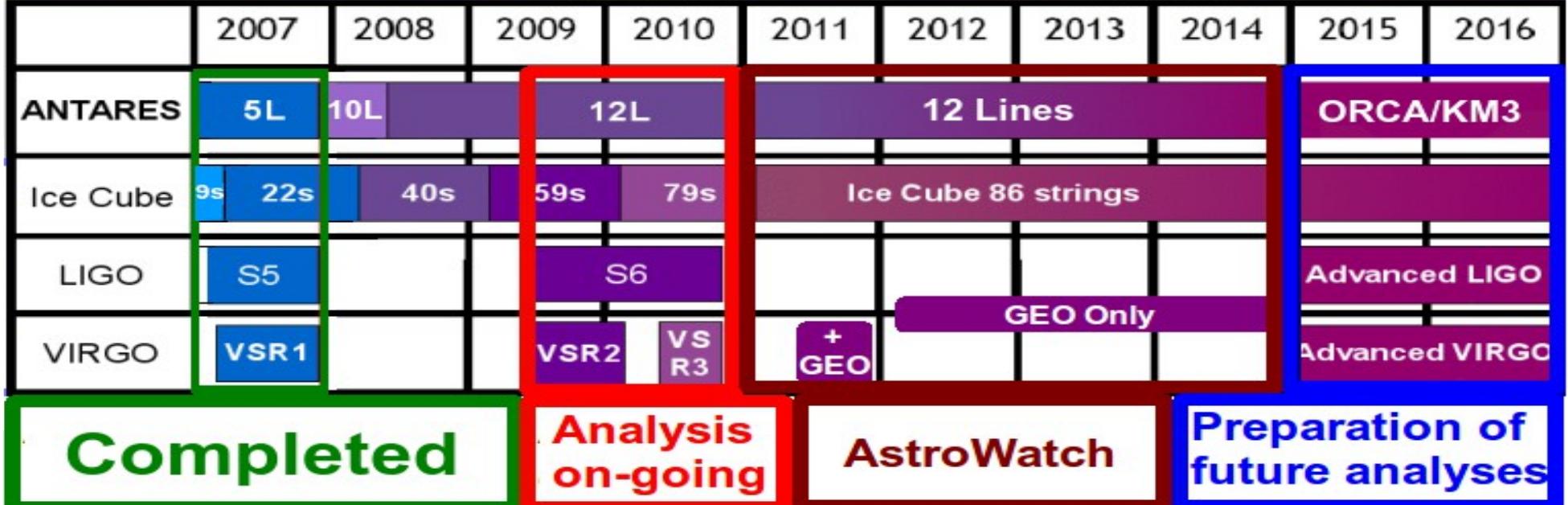
From SN to GRBs (Ando, 2009)



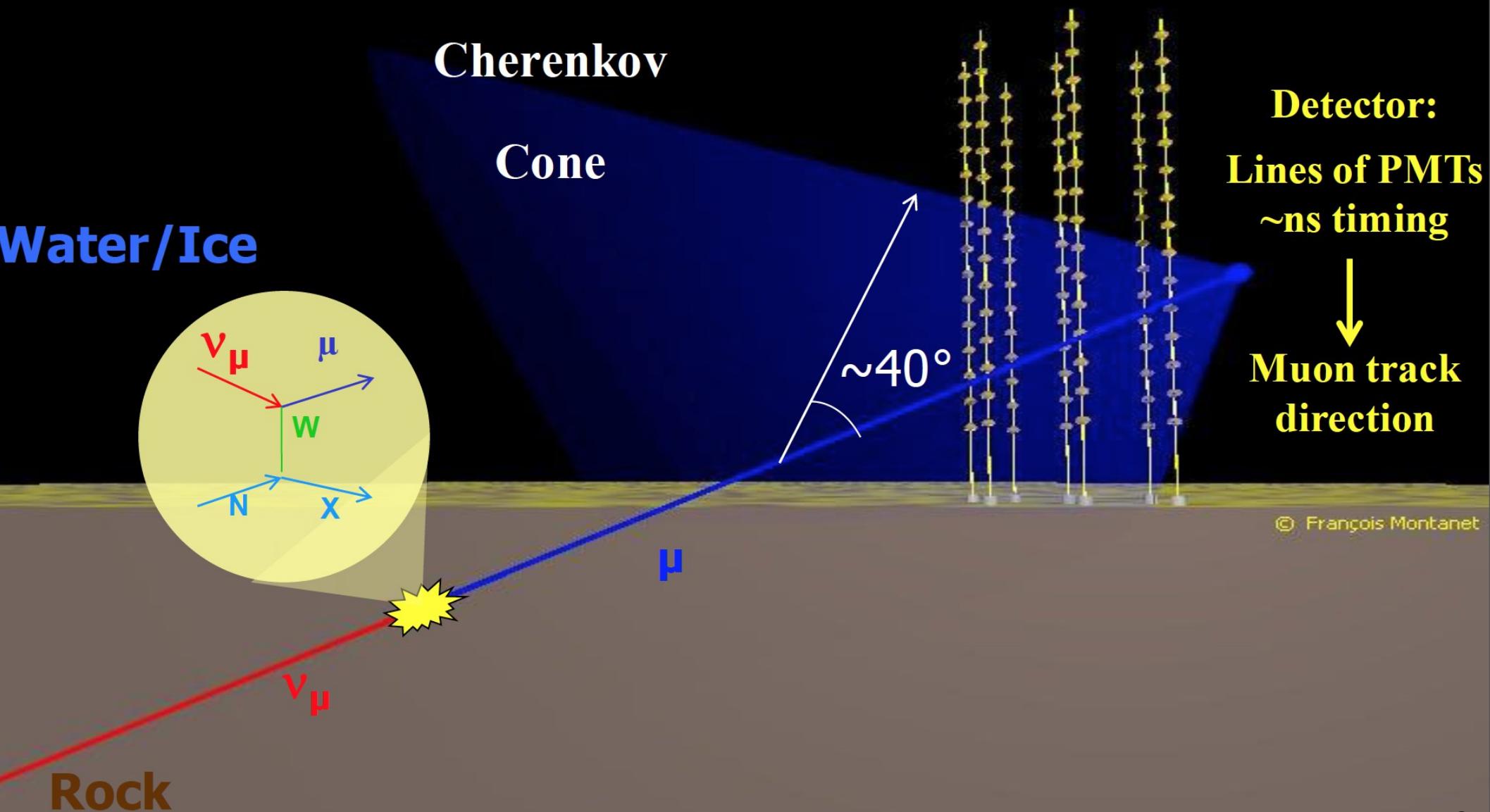
“Failed” GRB:

- ▶ Optically thick media:
no or weak γ -ray emission
- ▶ Possibly detectable by
GW+HEN

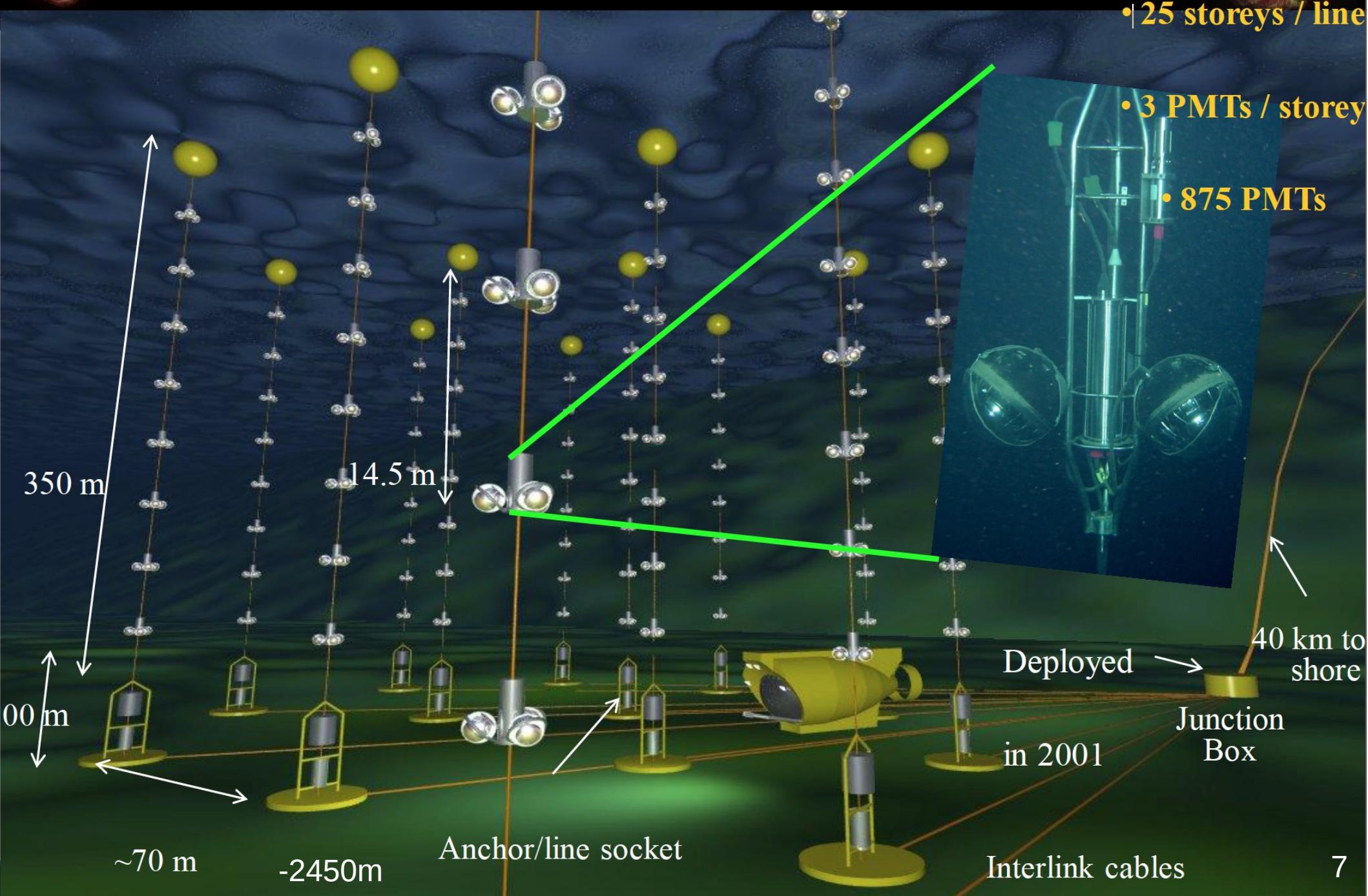
The space-time experimental landscape



HEN detection principle

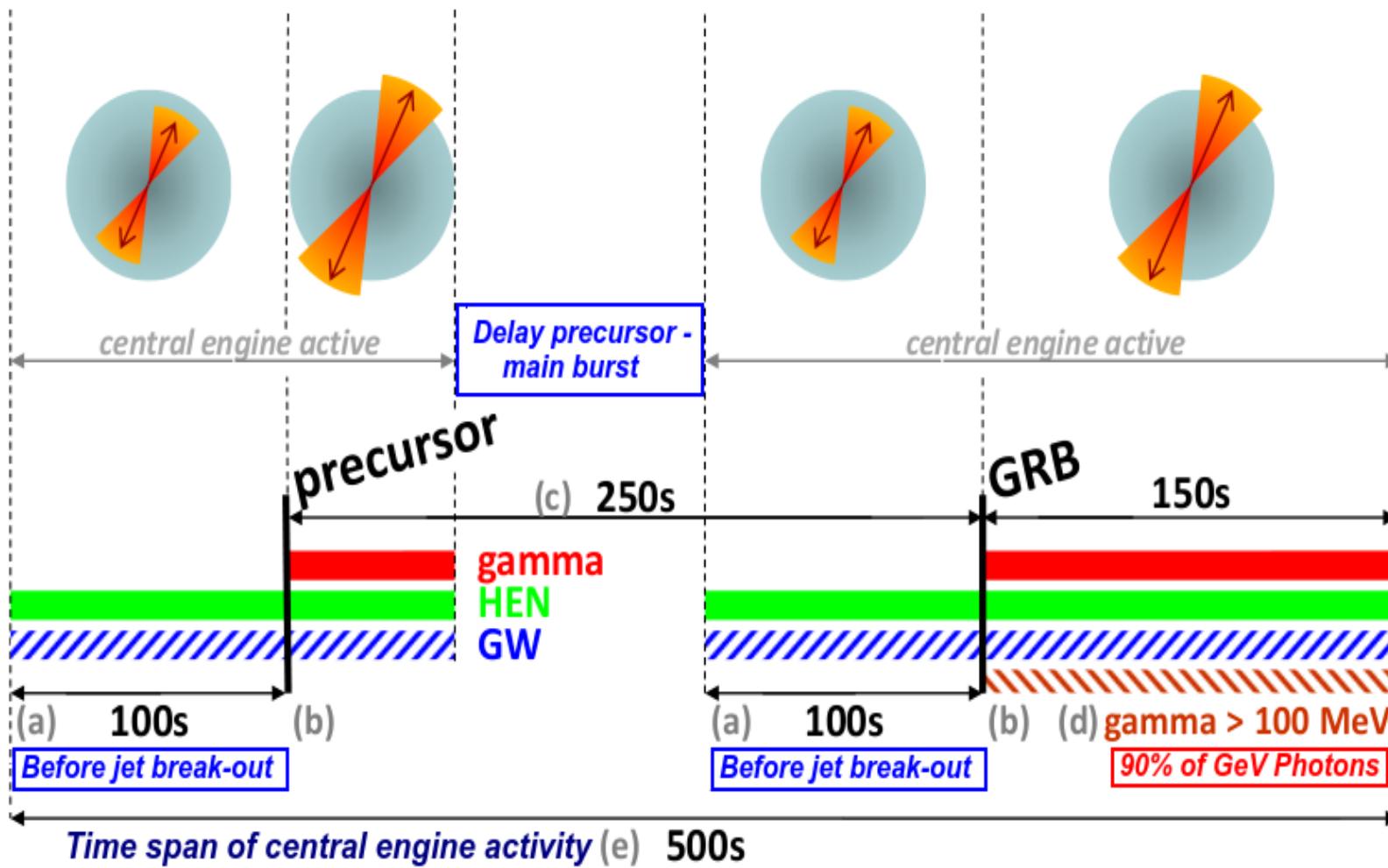


ANTARES H.E. neutrino telescope

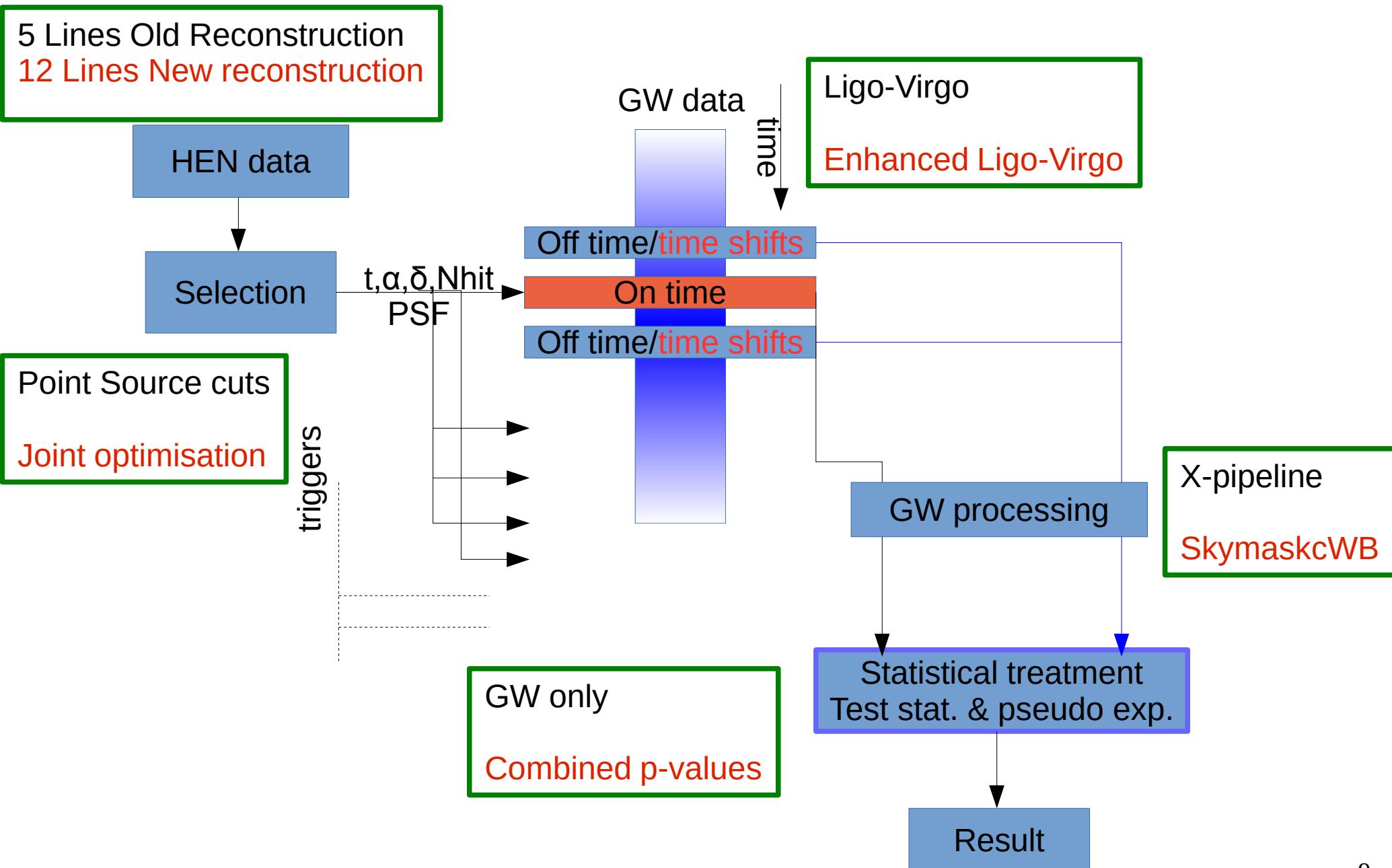


Which time coincidence window ?

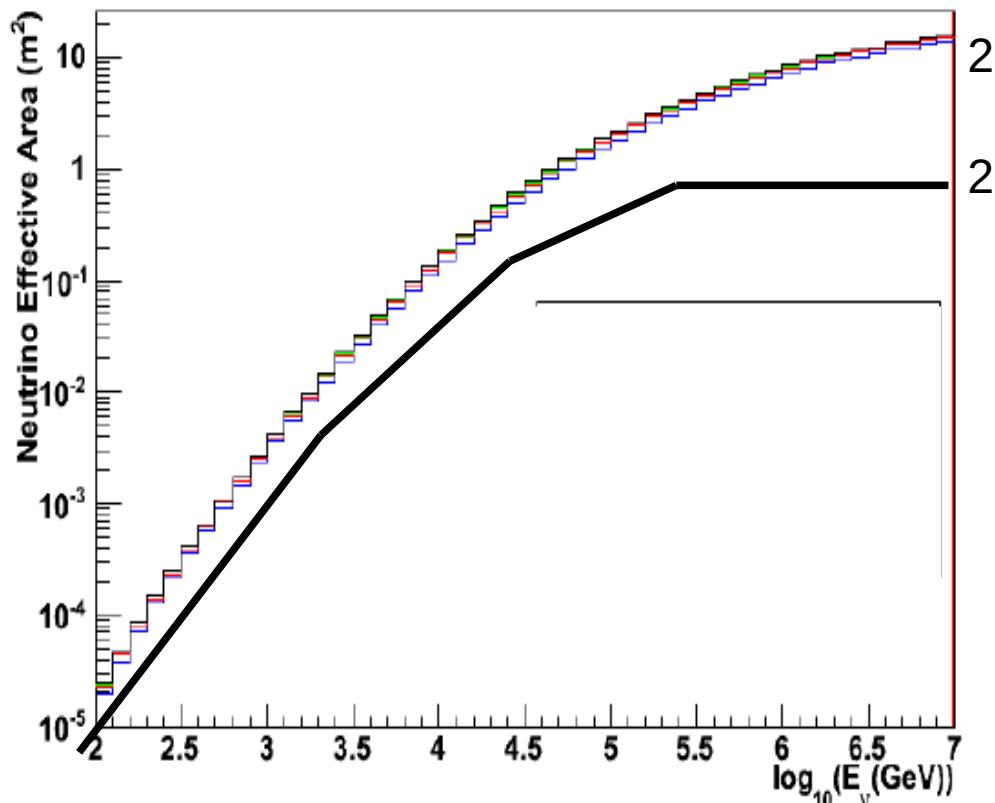
B. Baret et al., Astroparticle Physics 35 (2011) 1-7
 $T = \pm 500s$ [arXiv:1101.4669]



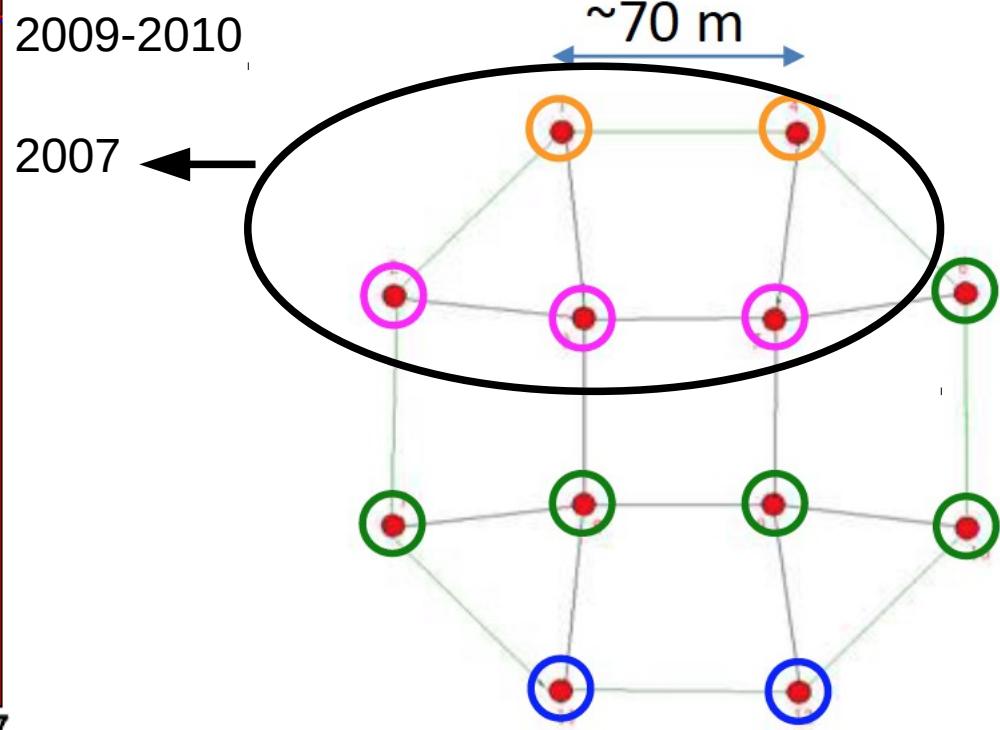
2007 vs 2009-2010



HEN data and pipeline



max(HEN signal test flux)



- 2L : 2006
- 5L : 01/2007
- 10L : 12/2007
- 12L : 05/2008

New reconstruction+ better detector:

Search box : $10^\circ \rightarrow 2^\circ$

Efficiency to HEN signal x 2-3

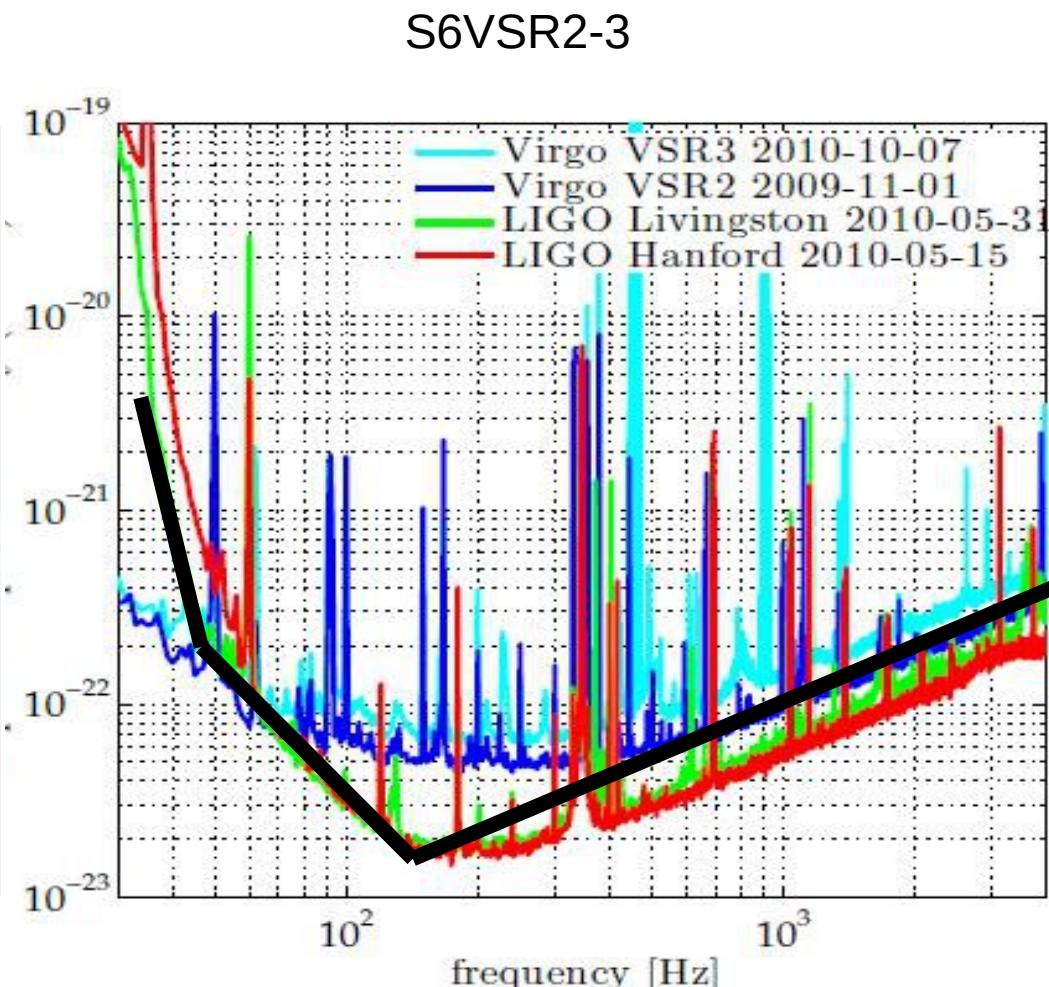
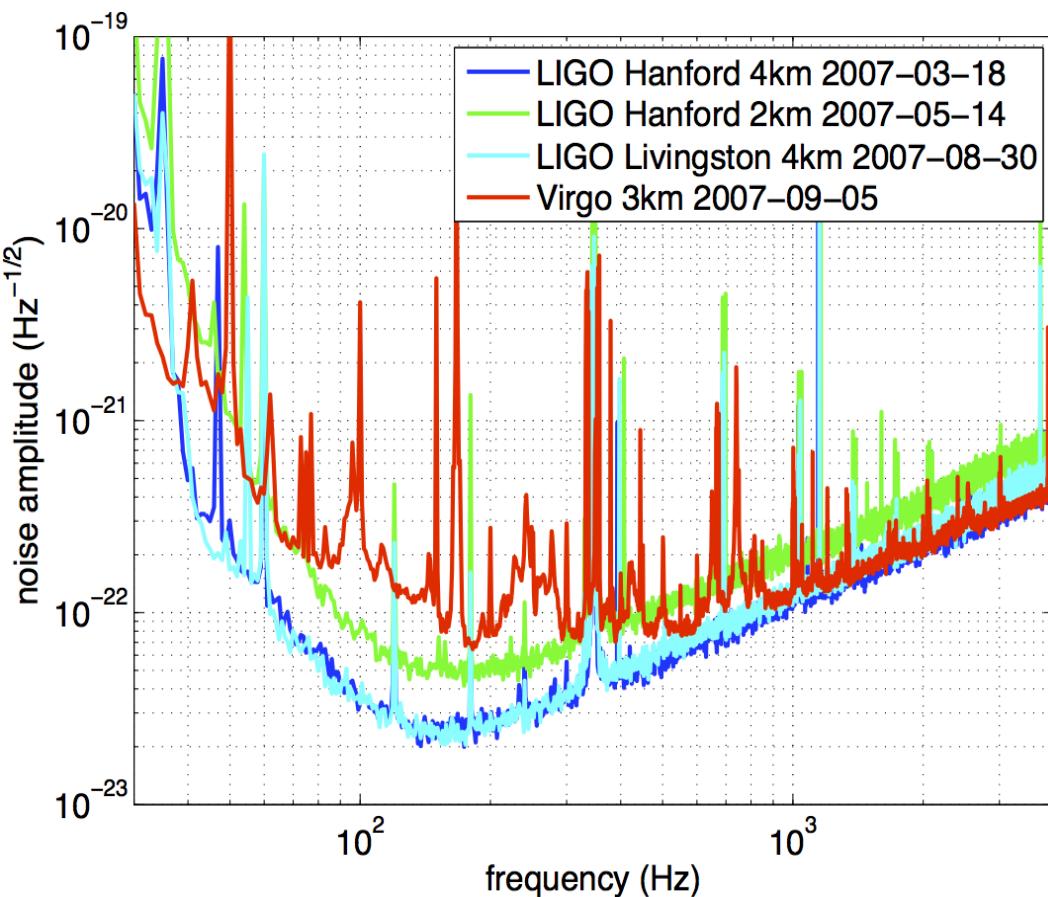
GW data

1rst version detectors => enhanced LIGO+VIRGO

104 days => 129 days

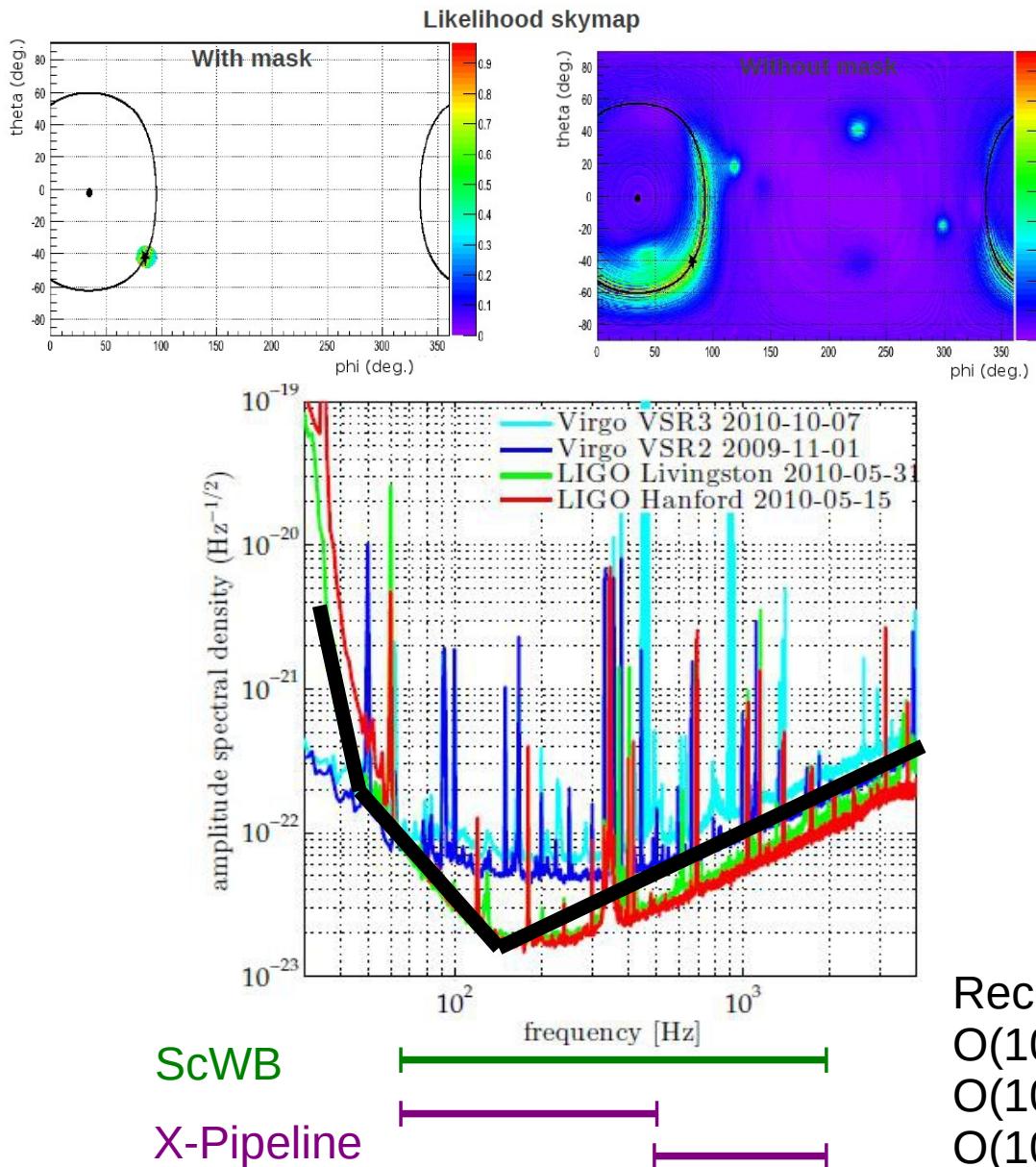
3 IFOs => 2 (65%) or 3 (35%) IFOs

Better sensitivity at High frequencies



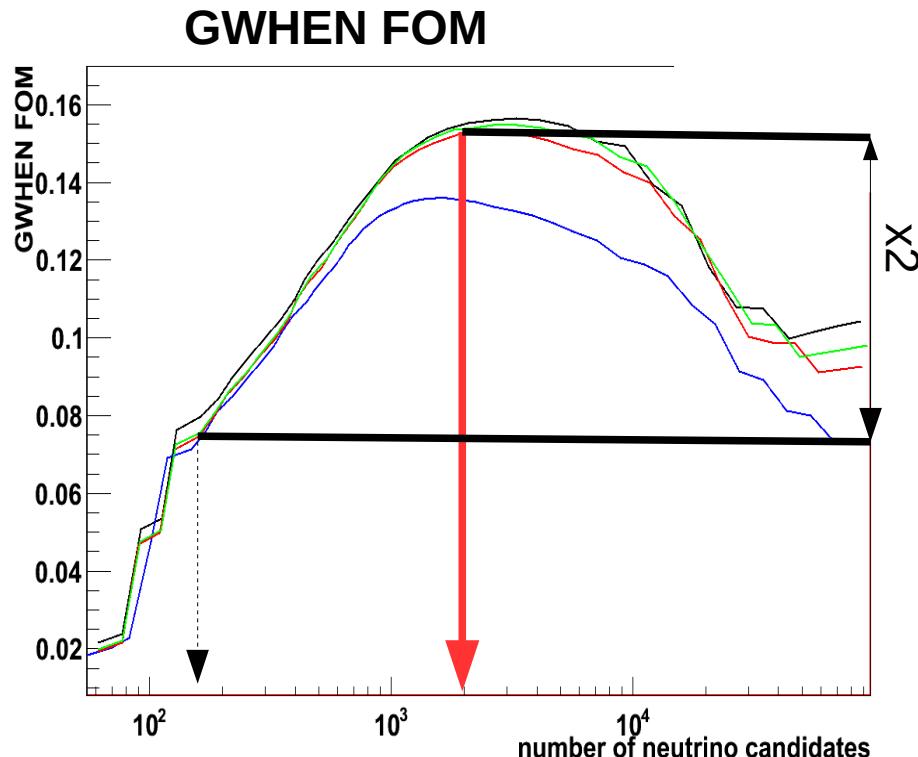
GW pipeline : SkyMask coherentWaveBurst

Adapted from cWB : S. Klimenko et al. *Class.Quant.Grav.* 25 (2008) 114029

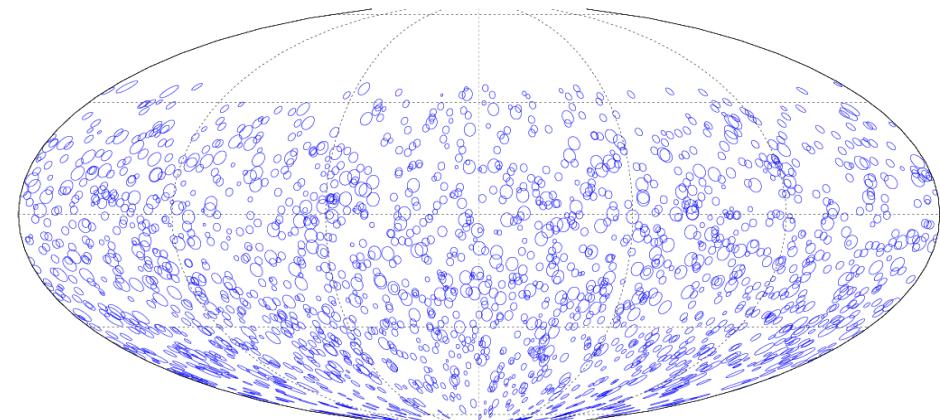


Joint optimisation

- ANTARES+S5 , IceCube+S5-S6 : No optimisation, Point Source search HEN sample
- **This search** : maximise the number of observable common sources keeping the False Alarm Probability constant
(Efficiency to HEN $\nearrow \Rightarrow$ number of HEN $\nearrow \Rightarrow$ FAP $\nearrow \Rightarrow$ Efficiency to GW \searrow)



1986 HEN candidates, 773 in coincidence with L-V



How to combine data ?

Method :

B. B., I. Bartos et al. Phys. Rev.D 103004(2012)

Same spirit as LIGO-Virgo +IceCube

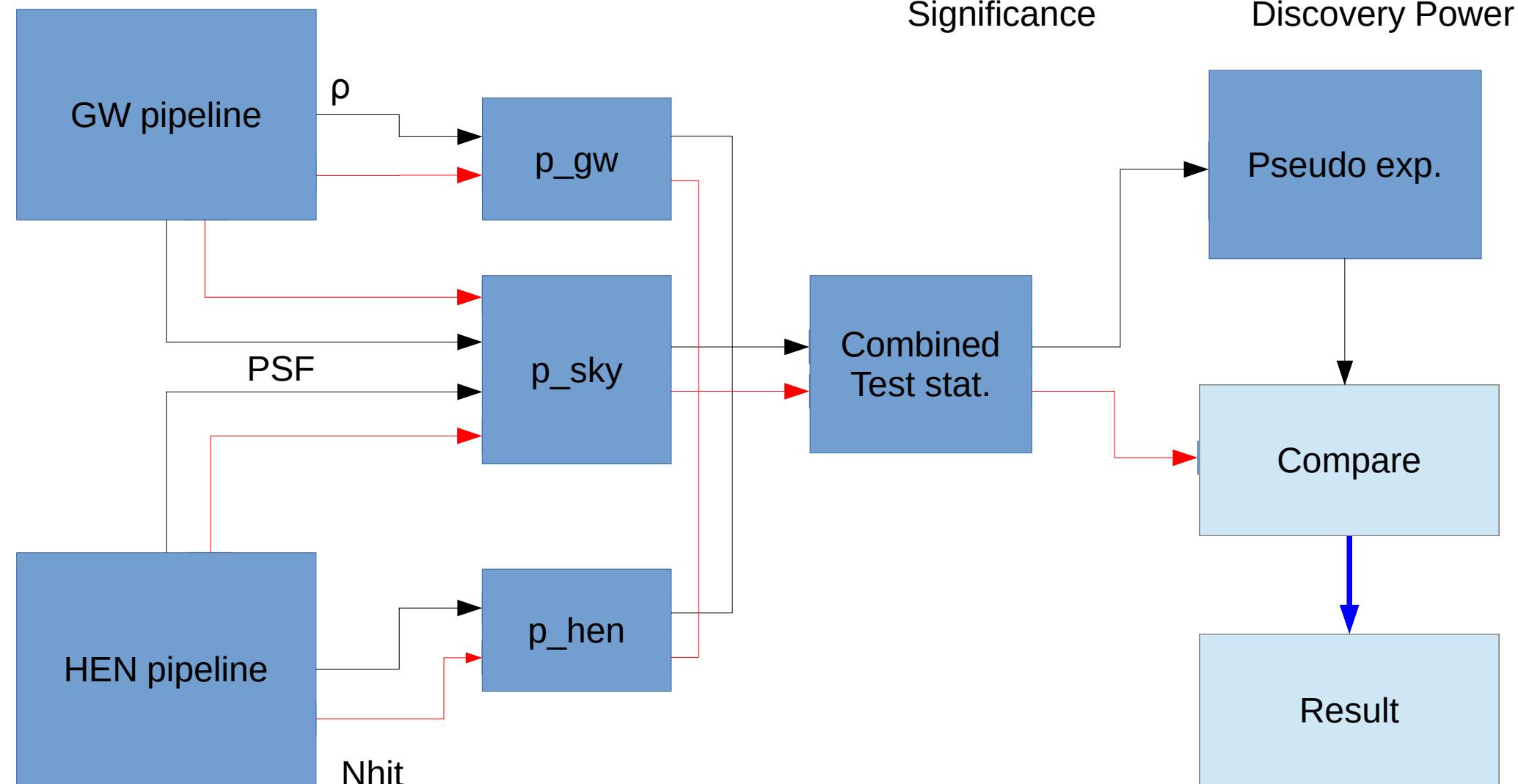
Phys. Rev. D 90, 102002

— Real data

— Background distribution OR signal injections

Significance

Discovery Power



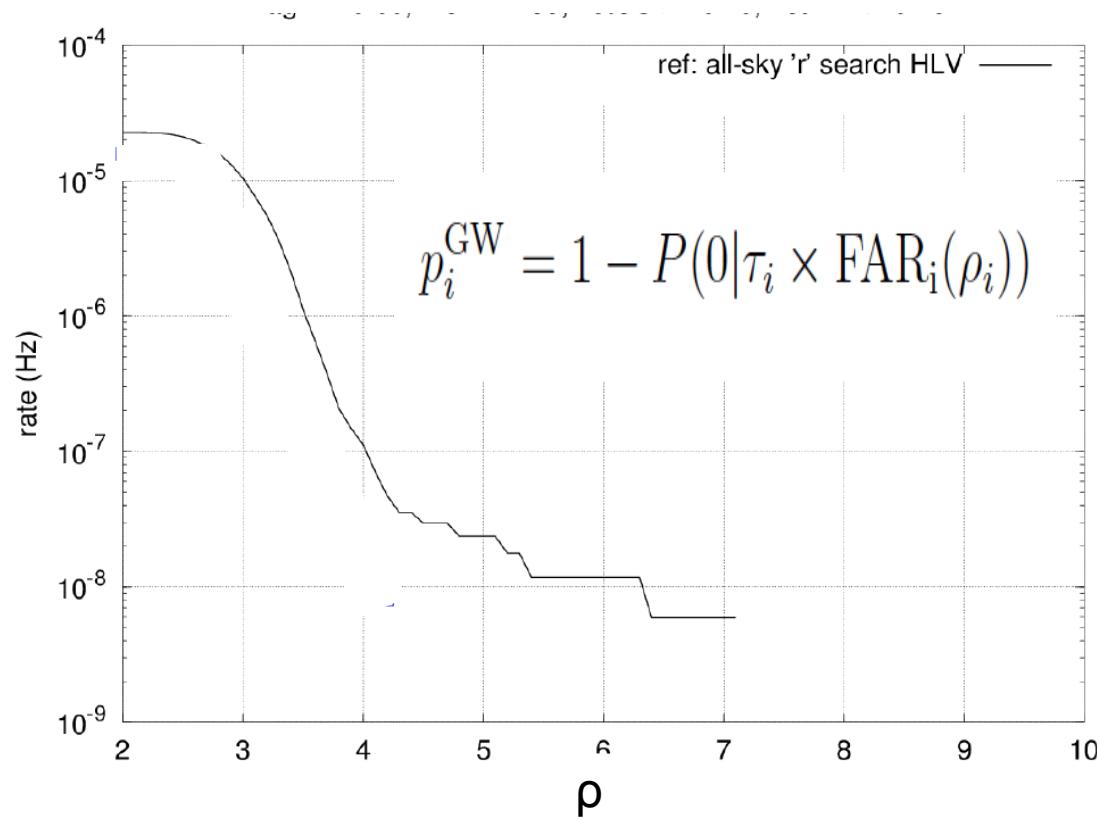
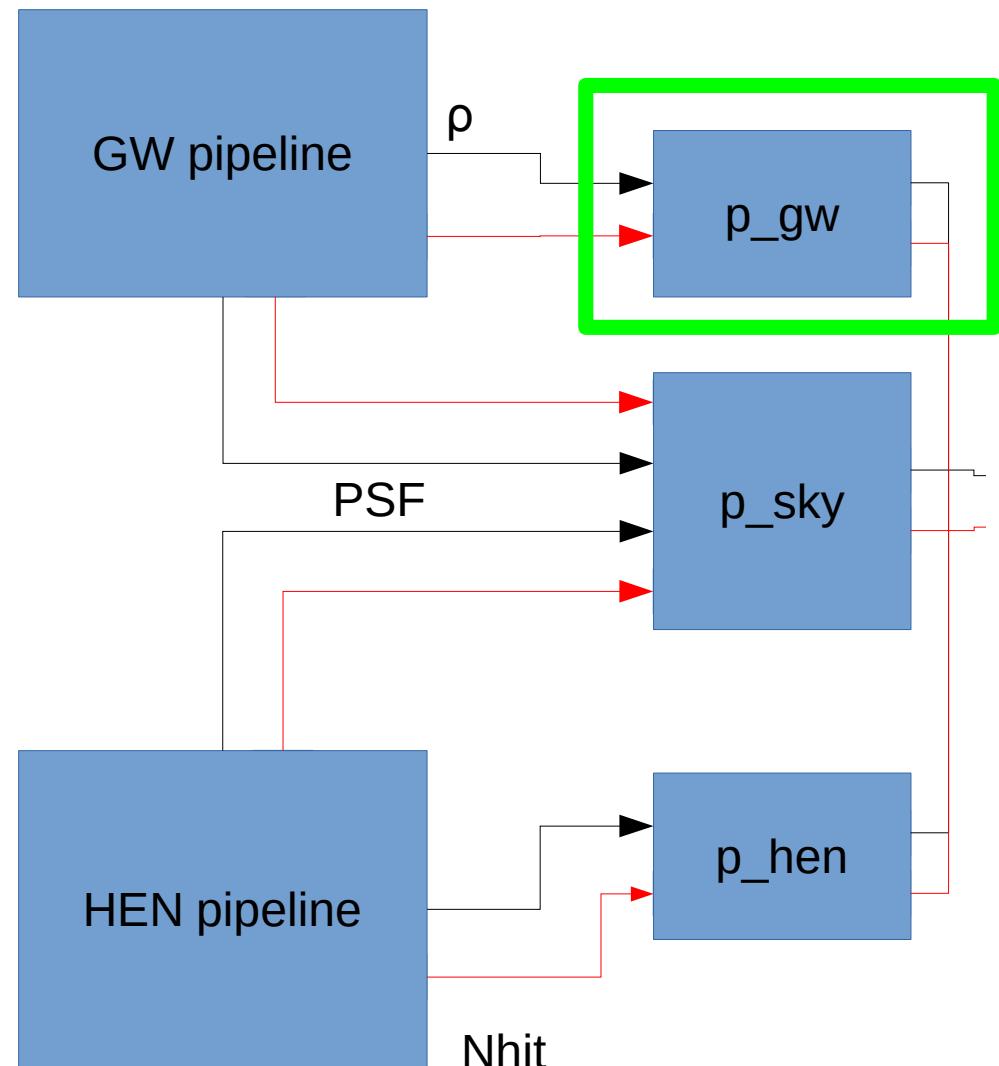
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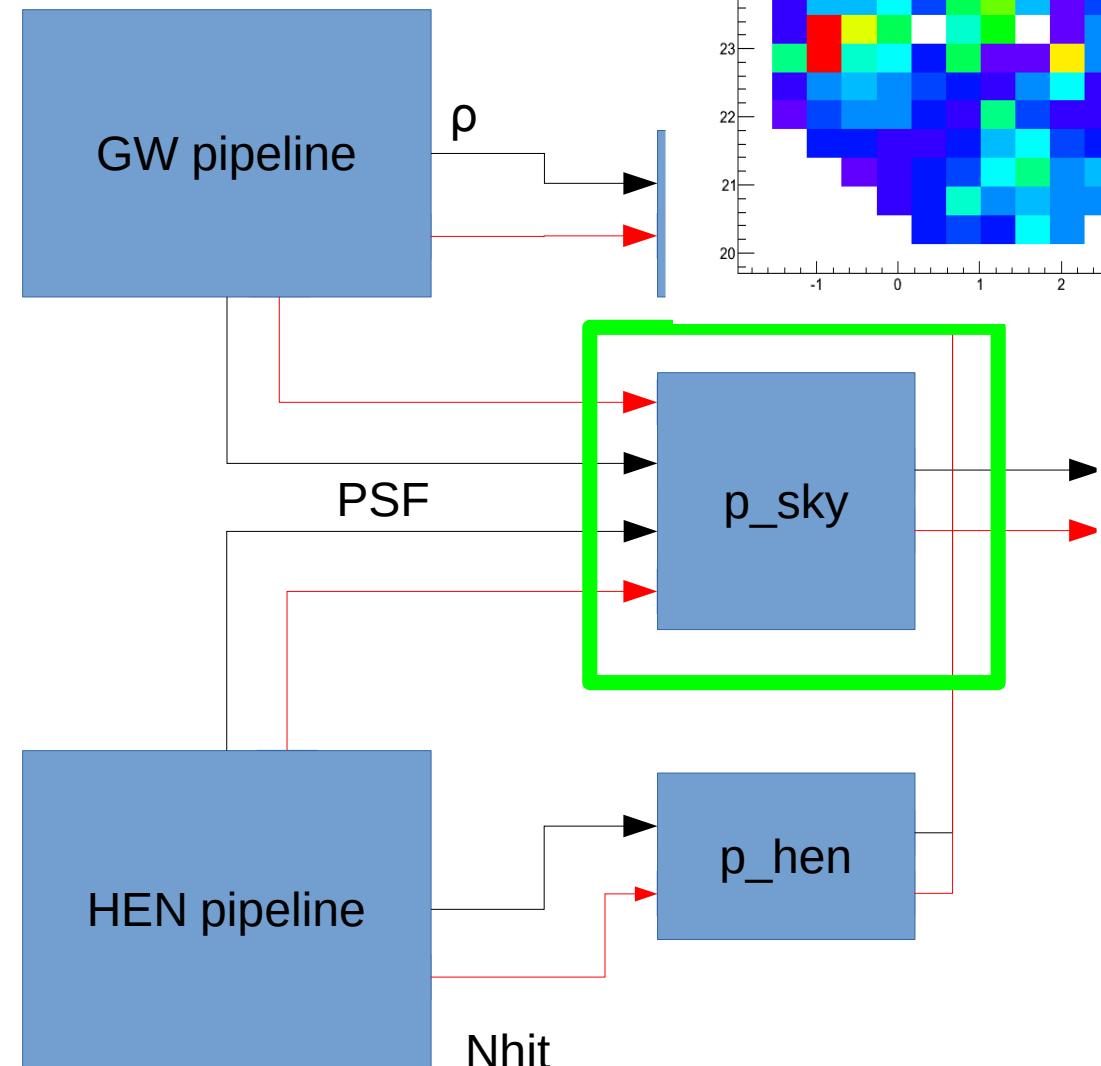
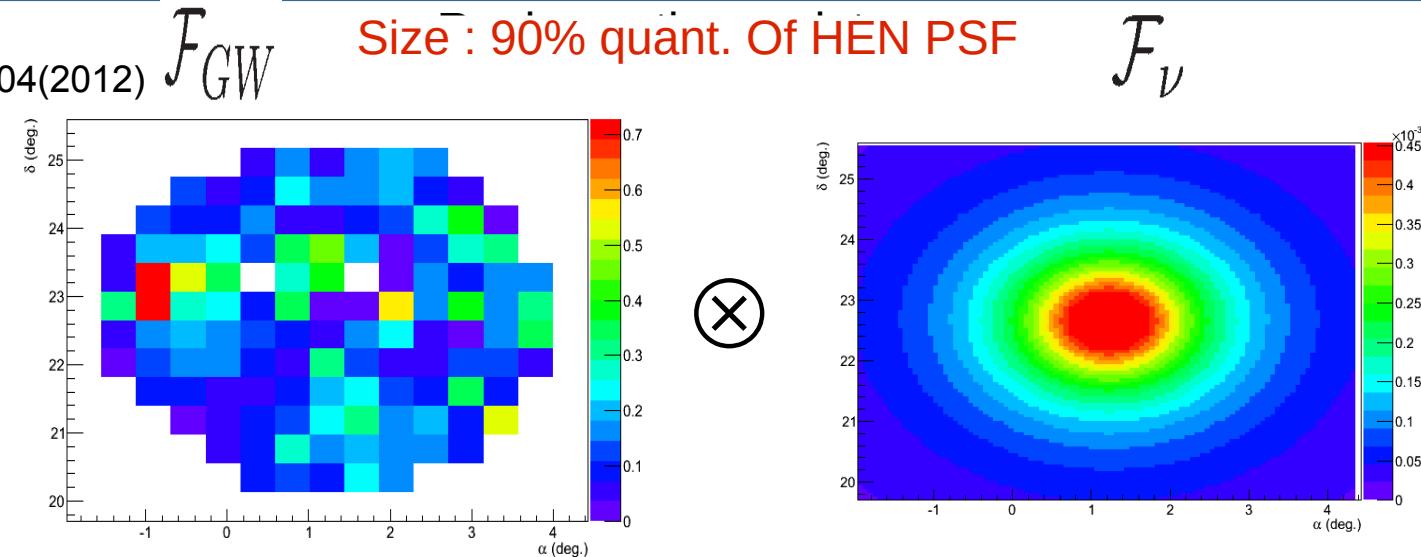
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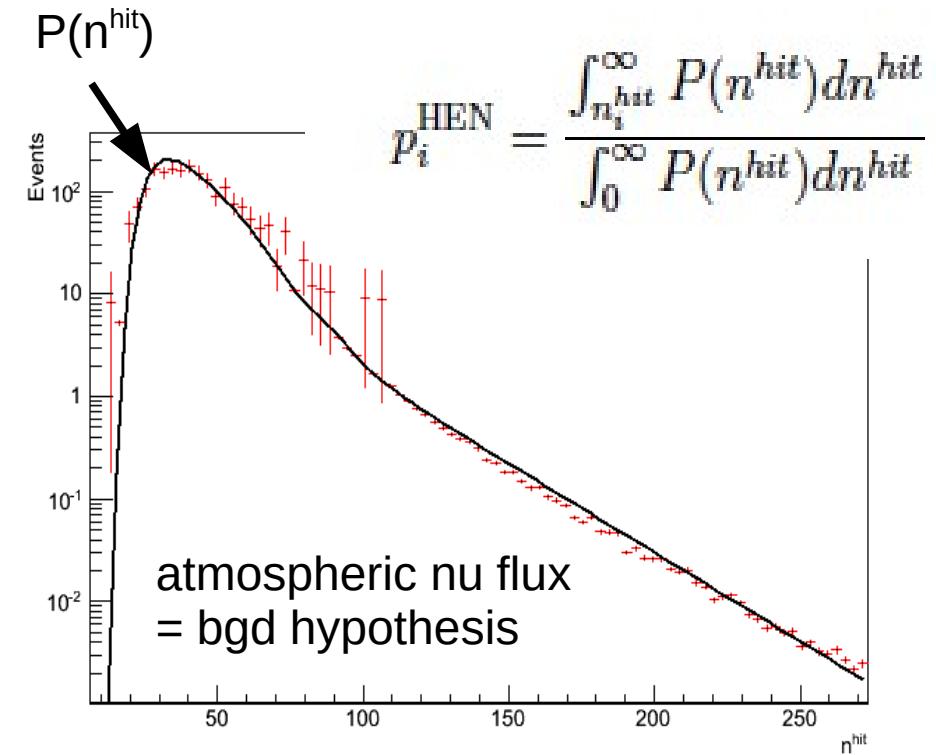
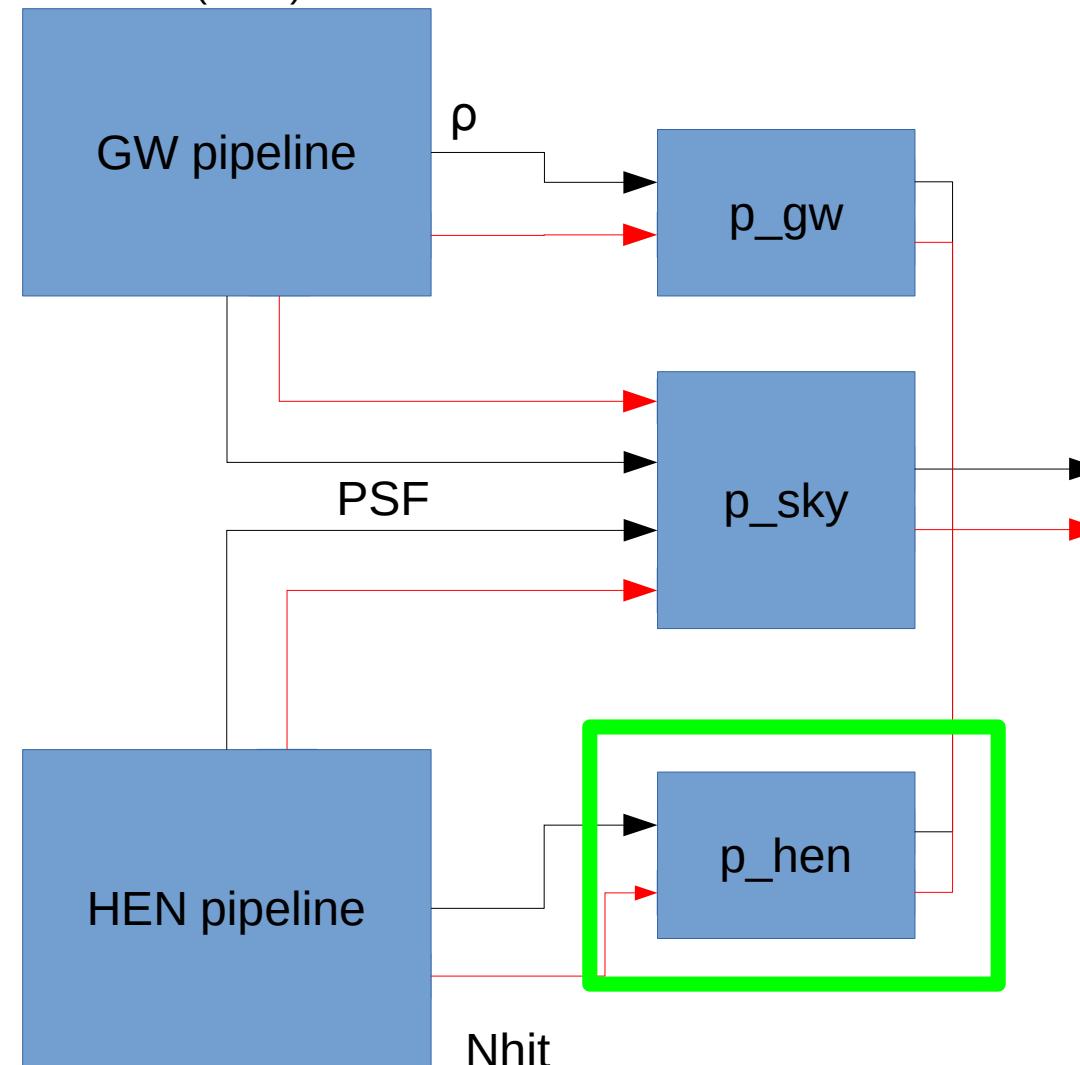


$$\mathcal{L} = \int d^3\vec{x} \mathcal{F}_{GW}(\vec{x}) \mathcal{F}_\nu(\vec{x})$$

$$p_i^{sky} = \int_{\mathcal{L}_i}^{\infty} P_{bg}(\mathcal{L}) d\mathcal{L}$$

How to combine data ?

Same spirit as LIGO-Virgo
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Baret et al. Phys. Rev.D
103004(2012)

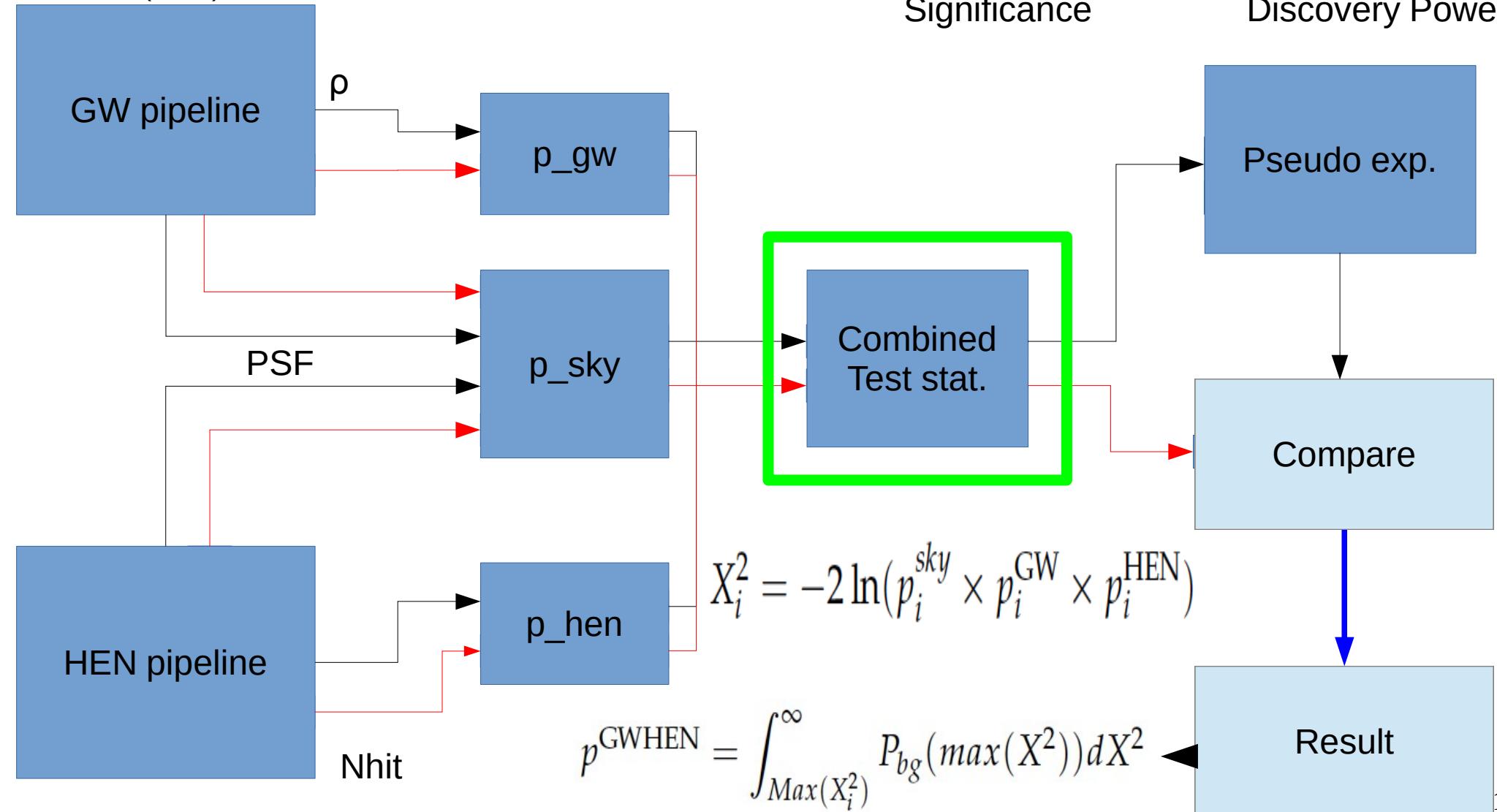


n^{hit} = number of hits on muon track
neutrino energy proxy

How to combine data ?

Same spirit as LIGO-Virgo
+IceCube
Baret et al. Phys. Rev.D
103004(2012)

— Real « on time » data
— Background distribution OR signal injections
↓
Significance
↓
Discovery Power

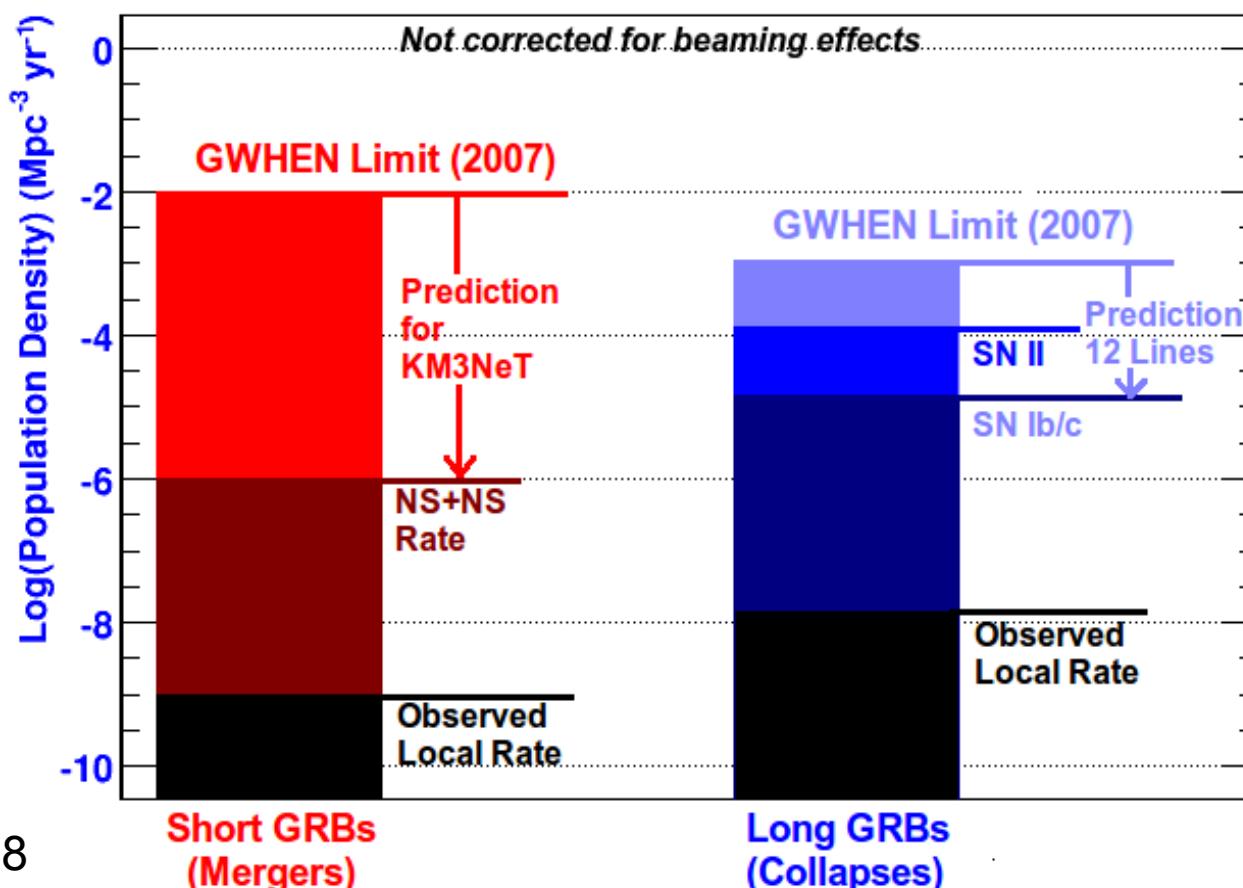


2007 : First Results

$$R_{\text{UL}} = \frac{2.3}{V_{\text{GWHEN}} T_{\text{obs}}} \quad \longleftarrow \quad N_{\text{GWHEN}} = R_{\text{GWHEN}} \times V_{\text{GWHEN}} \times T_{\text{obs}}$$

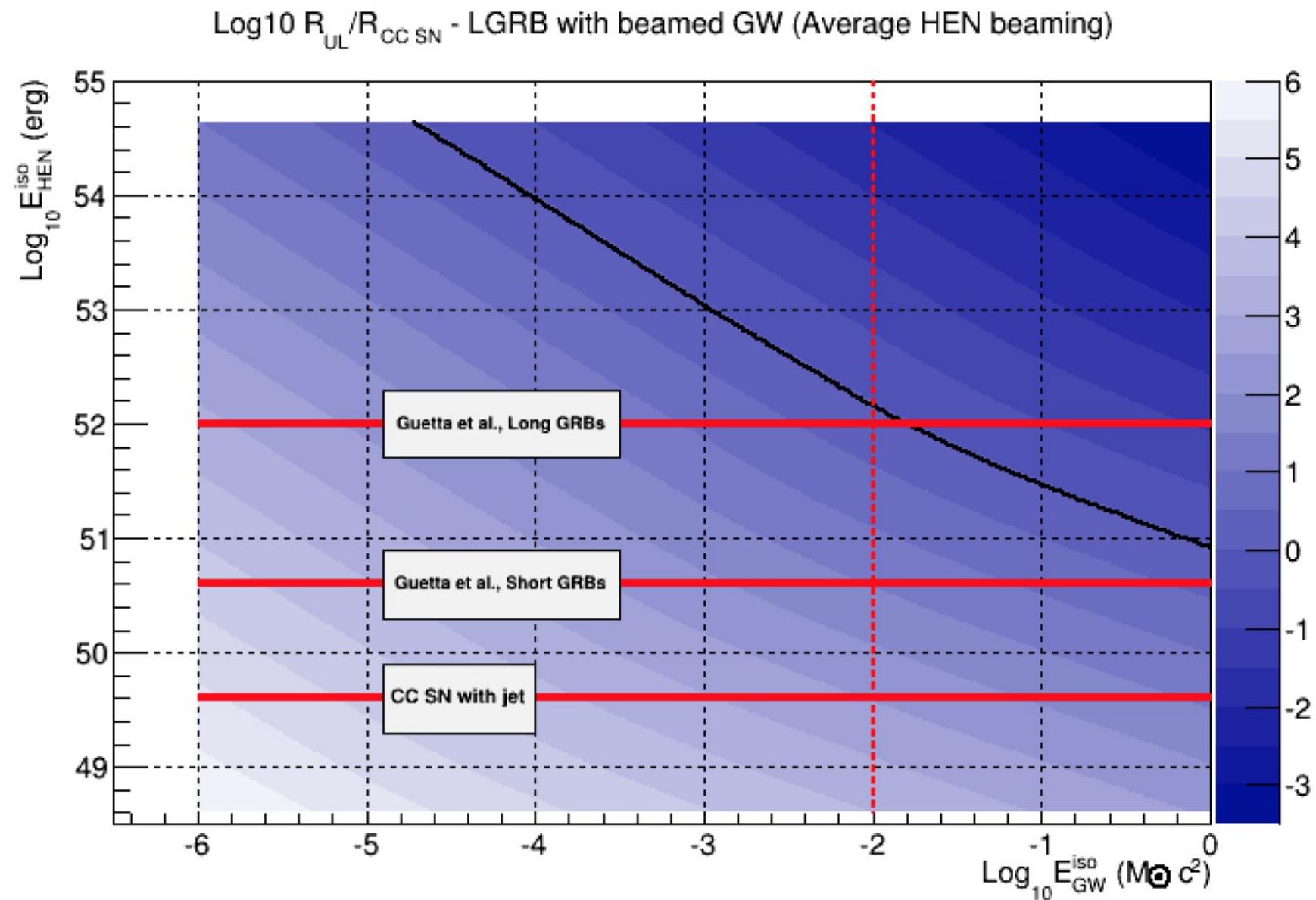
GWHEN horizon limited by HEN typically 1-10Mpc

**Results of the first GWHEN Search : 2007 data
VSR1-S5 Virgo/LIGO + Antares 5 Lines**



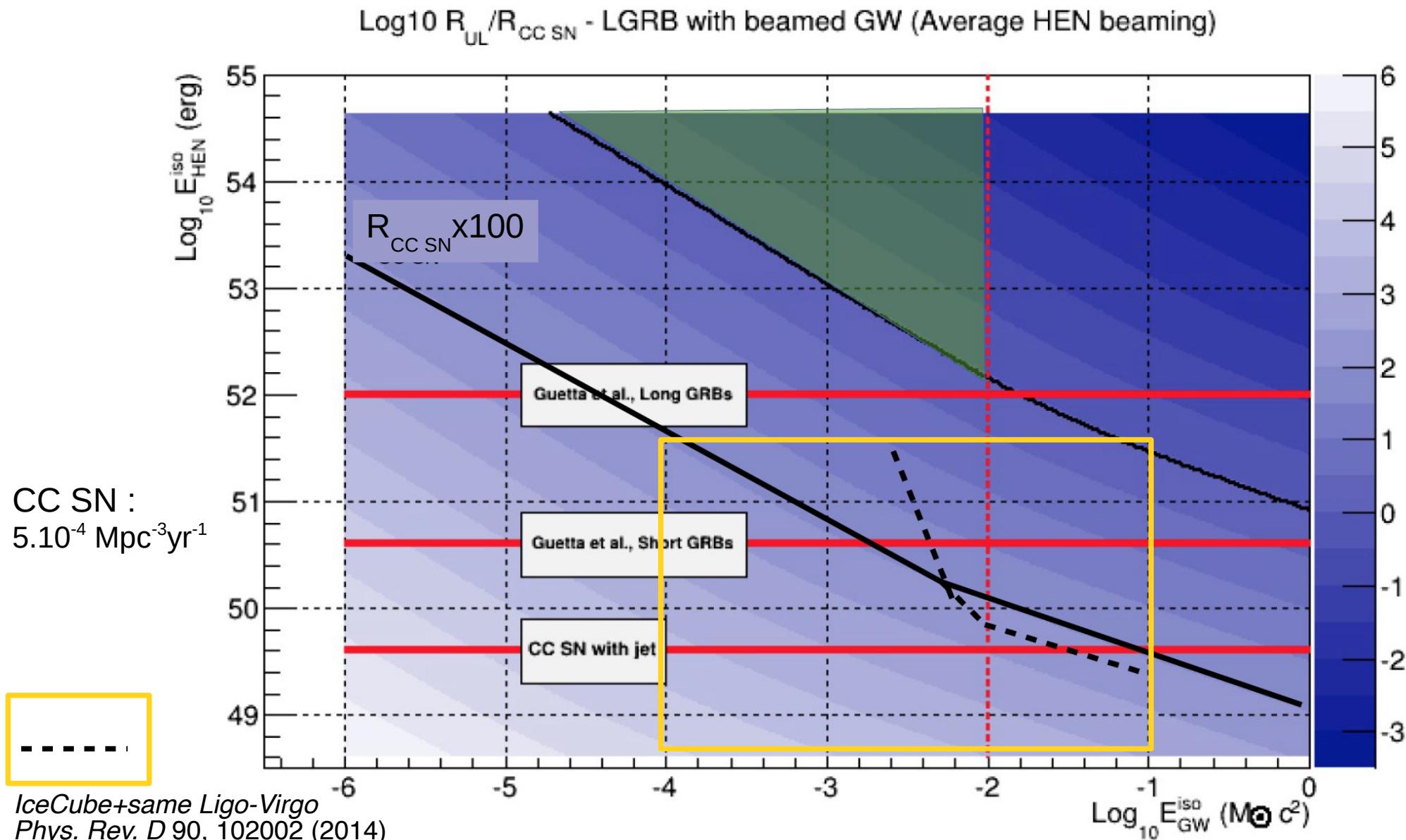
Constraints on population density estimate

with all sky GW efficiencies from Phys. Rev. D 85, 122007 (2012) → conservative



Constrains on population density estimate

with all sky GW efficiencies from Phys. Rev. D 85, 122007 (2012) → conservative



Take Home Message

- ▶ Still have to open the box
 - ▶ Getting closer to the physically interesting region thanks to :
 - ▶ better detectors (enhanced 1rst gen)
 - ▶ better reconstruction pipelines
 - ▶ joint optimisation
 - ▶ real multimessenger interpretations
 - ▶ Ready for next gen. (sensitivity x 10):
 - ▶ aLIGO (2015-16 →) & aVirgo (2016-17 →)
 - ▶ ANTARES(→ 2016) & KM3NeT (2016-17 →)
- 
- Sensitivity x 8

Stay tuned !