



# Search for high energy neutrinos from bright GRBs with ANTARES

**Matteo Sanguineti**

**Università degli Studi di Genova – INFN Genova**

*Silvia Celli (GSSI, INFN Roma) – Damien Turpin (Aix-Marseille U.)*

*on behalf of the ANTARES collaboration*



**UNIVERSITÀ DEGLI STUDI  
DI GENOVA**



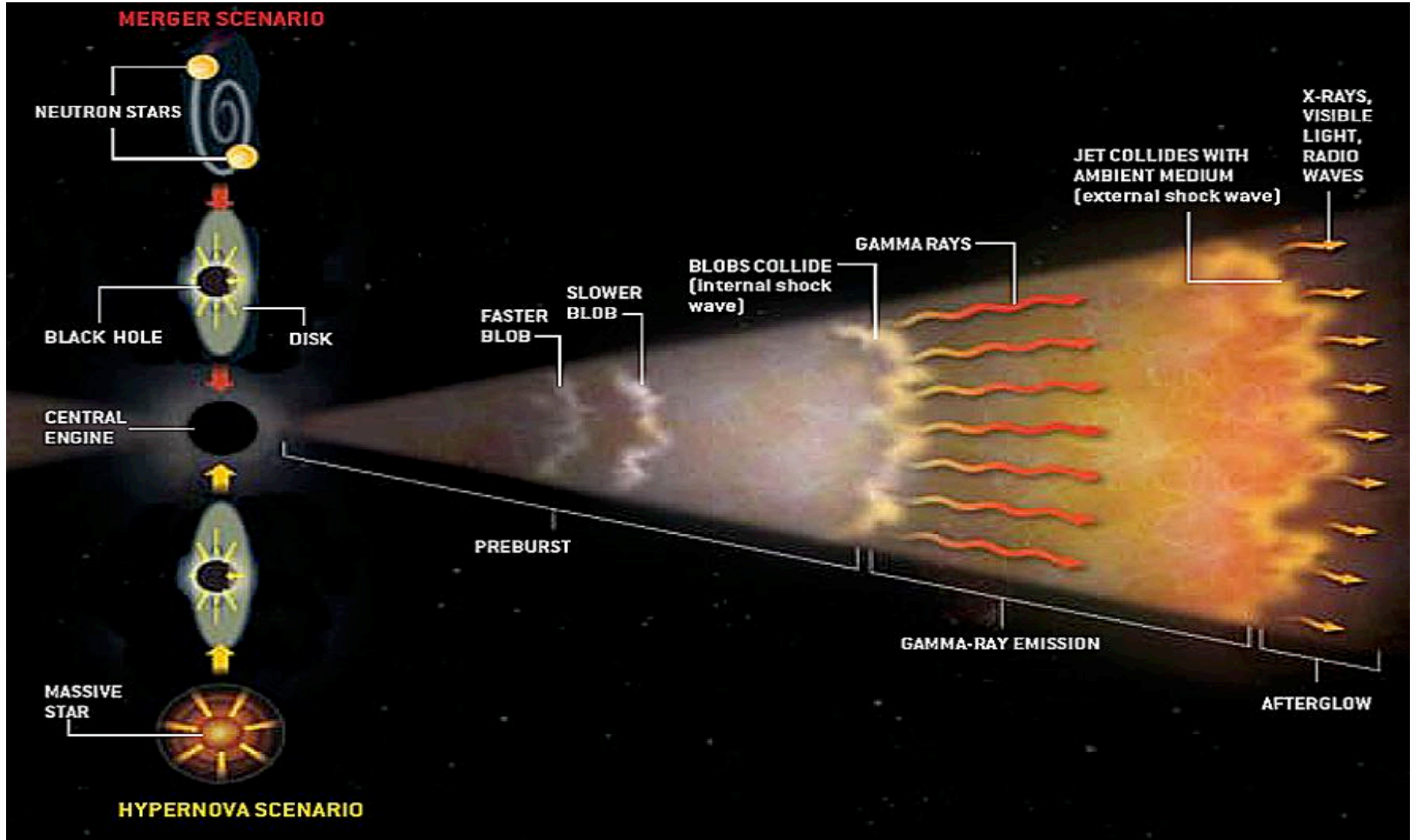
**Istituto Nazionale  
di Fisica Nucleare**

# Outline

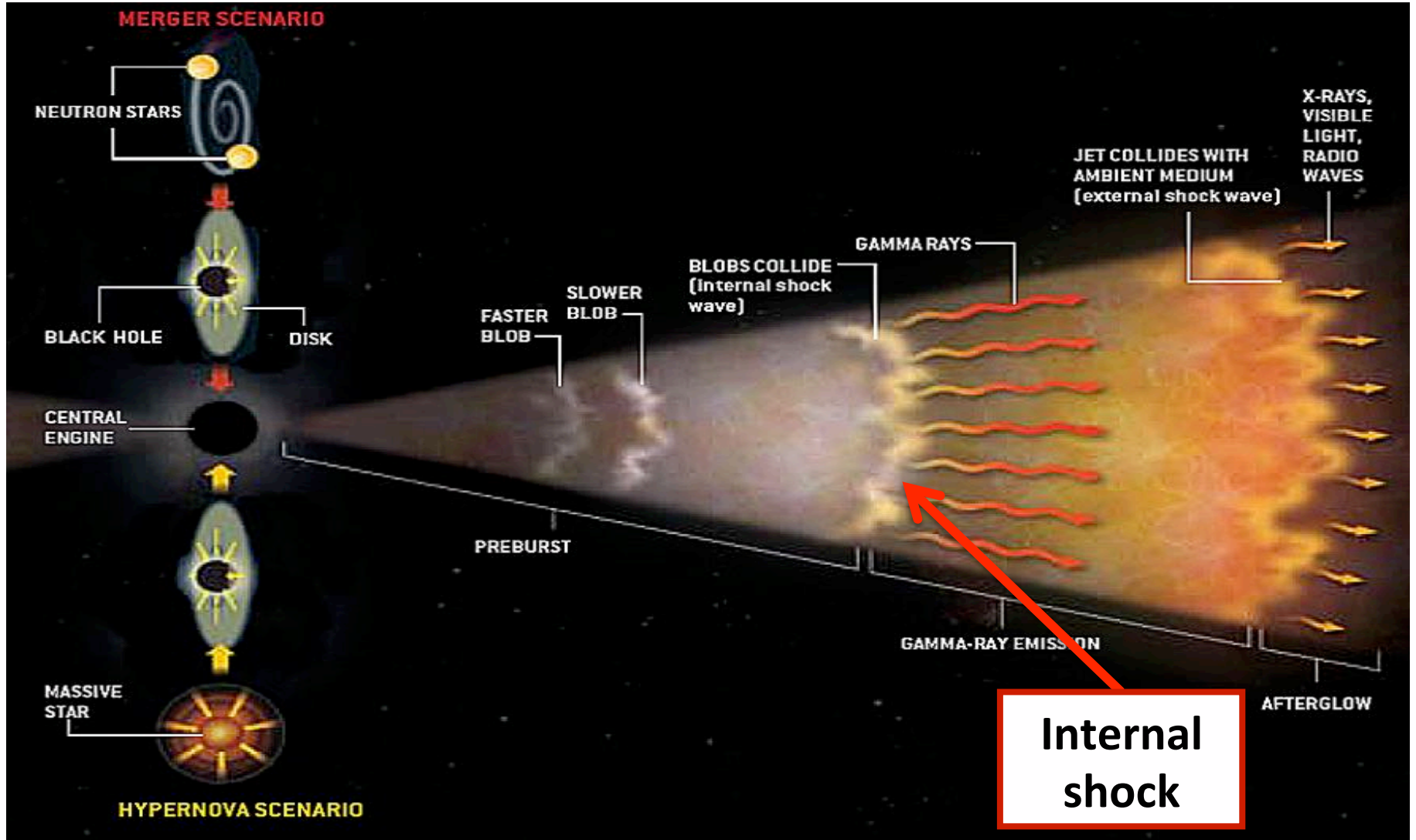


- **Gamma ray burst emission models**
- **ANTARES detector**
- **Study of the internal shock model**
- **Study of the photospheric model**
- **GRB constraints**
- **Conclusions**

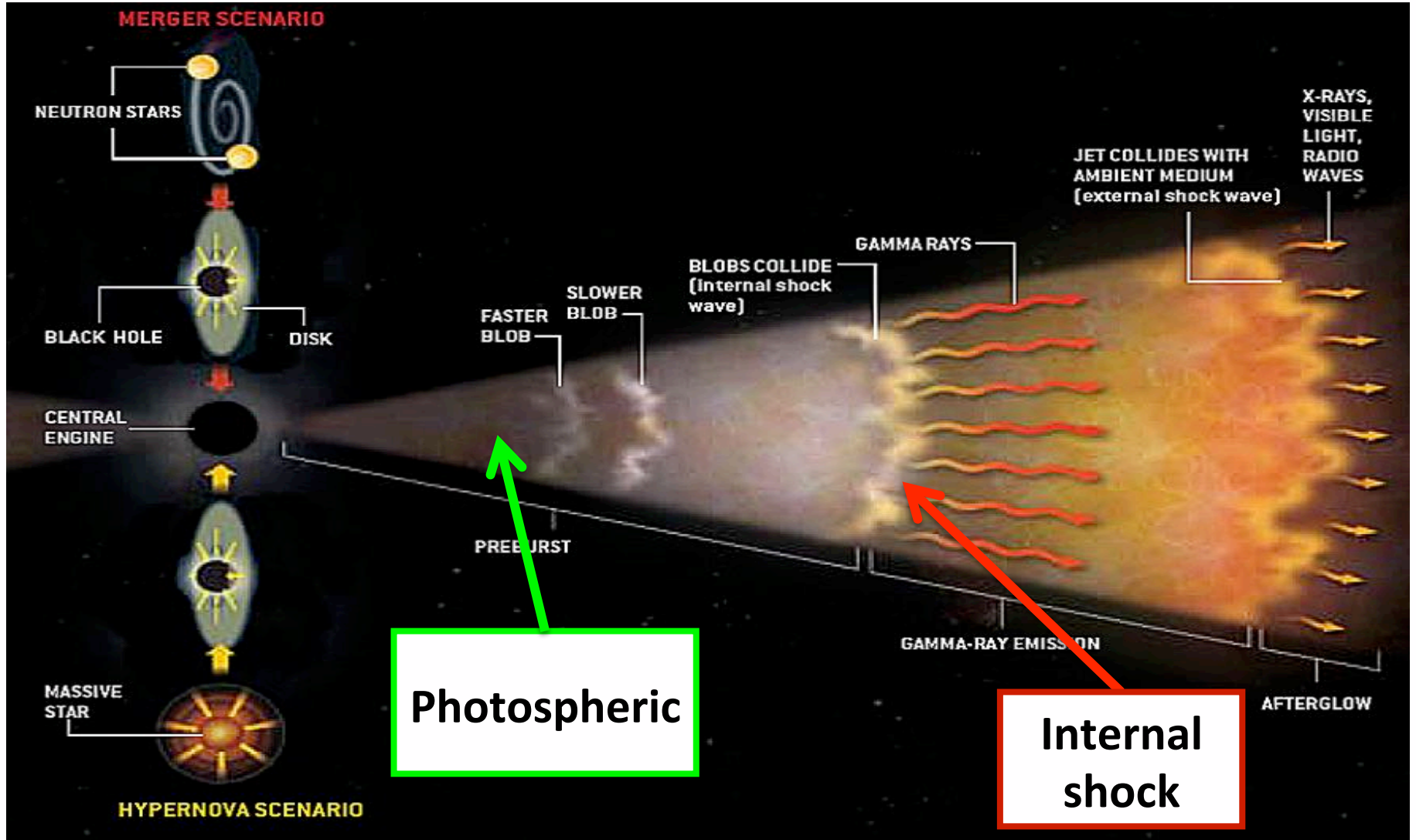
# Gamma ray bursts



# Gamma ray bursts



# Gamma ray bursts





# Interaction radius

**Photospheric model (Zhang & Kumar):**

$$R_{ph} \propto 10^{11} L_{iso,52} \Gamma_{2.5}^{-3} cm$$

**Internal shock model (NeuCosmA):**

$$R_{is} \propto \frac{10^{13} c \Gamma_{2.5}^2 t_{var,-2}}{1+z} cm$$

$L_{iso,52}$  (isotropic  $\gamma$ -ray luminosity) =  $L_{iso}/10^{52}$  erg s<sup>-1</sup>,

$\Gamma_{2.5}$  (bulk Lorentz factor) =  $\Gamma/10^{2.5}$

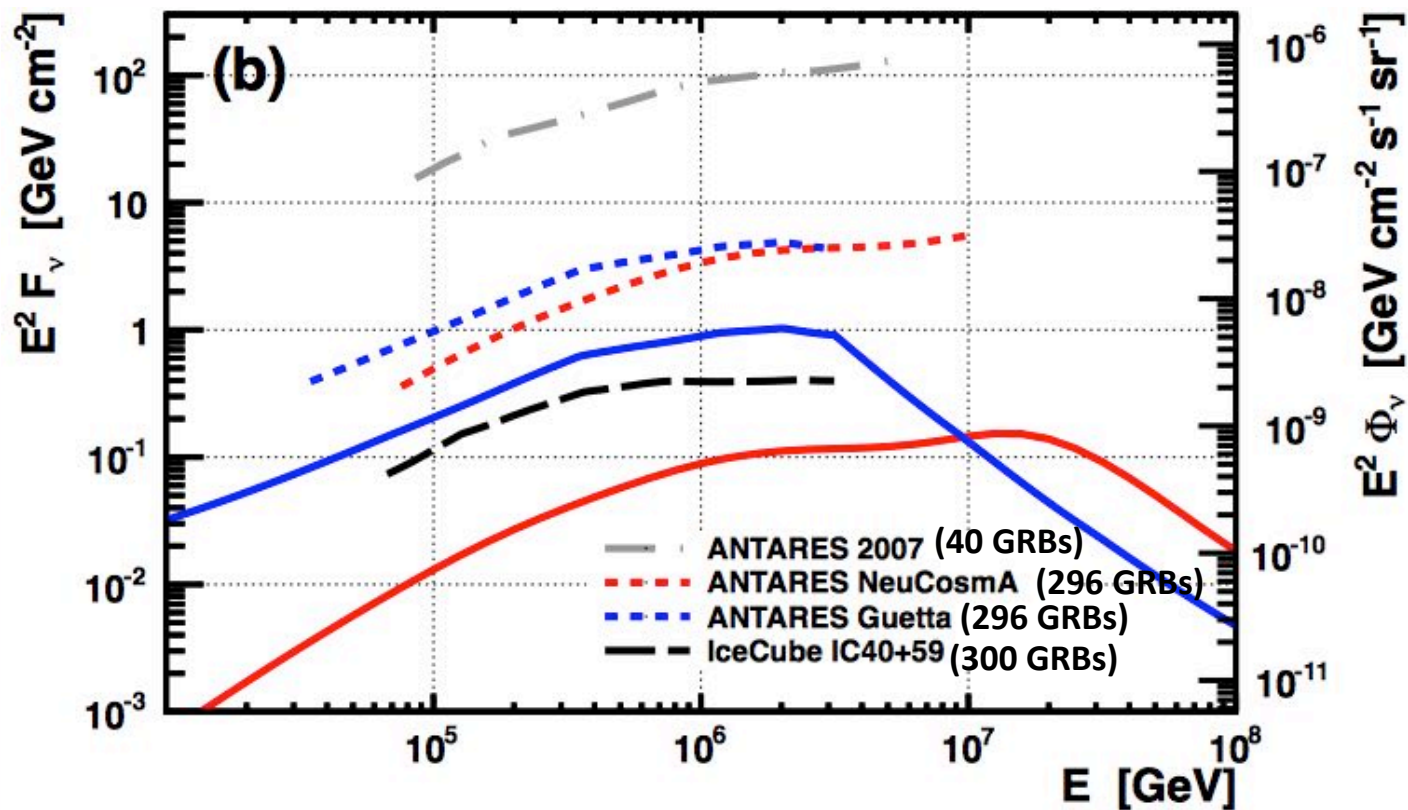
$t_{var,-2}$  (variability time scale) =  $t_{var}/0.01$  s

$z$  (redshift)

# Previous ANTARES GRB analysis

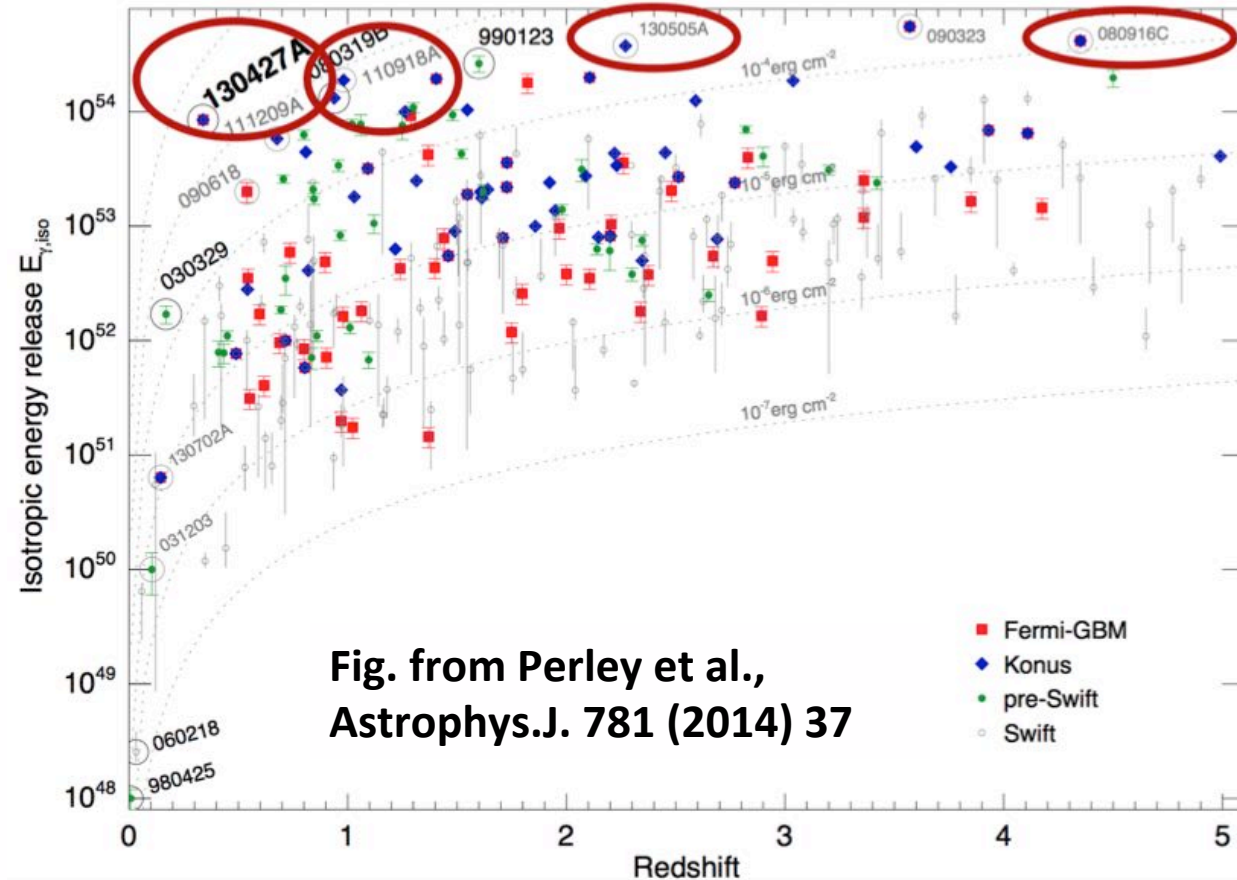


Stacking analysis of 296 GRBs detected from end of 2007 to 2011.



Adrian-Martinez S. et al., *Astron. Astrophys.* 559 (2013) A9

# Bright GRB selection



- Measured redshift
- High gamma-ray fluence ( $F > 1 \times 10^{-4}$  erg/cm<sup>2</sup>)
- Time dependent gamma-ray parameters available
- Below ANTARES horizon at trigger time
- ANTARES is in Physics run



# Selected GRBs



GRB NAME	080916C	110918A	130427A	130505A
Fluence ( $\times 10^{-4}$ erg/cm <sup>2</sup> )	1.16	7.66	27.7	3.13
Duration (s)	100.9	28.4	18.7	7.0
RA (deg)	119.87°	32.58°	173.14°	137.06°
DEC (deg)	-56.59°	-27.58°	27.71°	17.49°
z (redshift)	4.35	0.982	0.3399	2.27



# Expected neutrino flux

*Interaction radius :  $R_{ph} < R_{is}$*

*Neutrino flux cut off :  $E_{cut\ off} \propto R \longrightarrow E_{cut\ off\ PH} < E_{cut\ off\ IS}$*

*Optical depth :  $\tau \propto R^{-1} \longrightarrow \tau_{PH} > \tau_{IS}$*

$$\int dE_{\nu} F(E_{\nu}) E_{\nu} \propto f_p \left( 1 - \left( 1 - \langle x_{p \rightarrow \pi} \rangle \right)^{\tau} \right) \int dE_{\gamma} F(E_{\gamma}) E_{\gamma}$$

*where*

*$f_p =$  barionic loading*

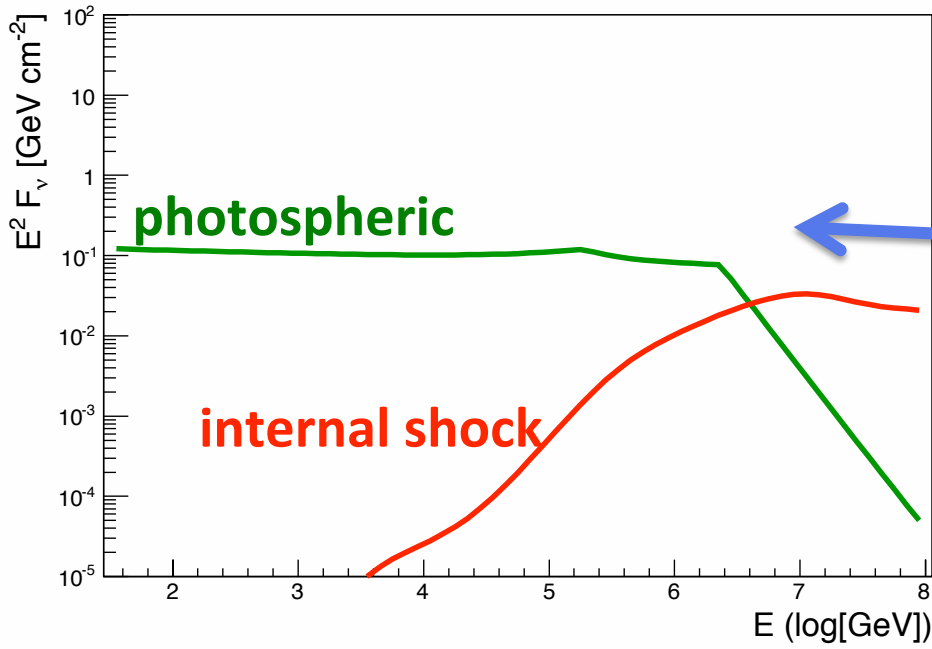
*$x_{p \rightarrow \pi} =$  fraction of proton energy transferred to a pion*

*$F(E_{\nu}) / F(E_{\gamma}) =$  gamma / neutrino fluence*

**$\tau_{ph} > \tau_{is} \rightarrow$  larger neutrino flux is expected in the photospheric picture w.r.t. internal shock model**

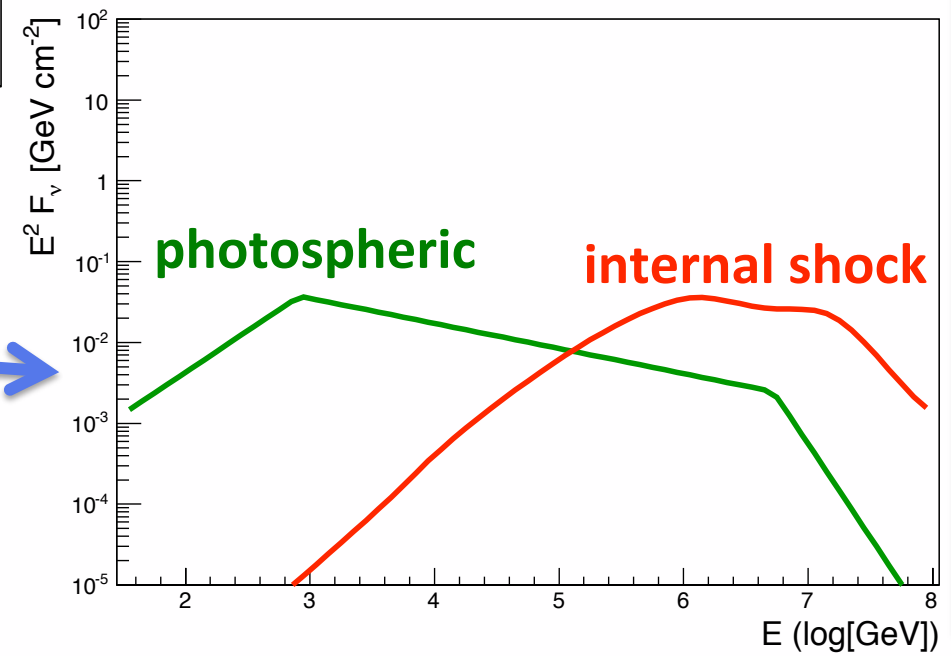


# Expected neutrino flux

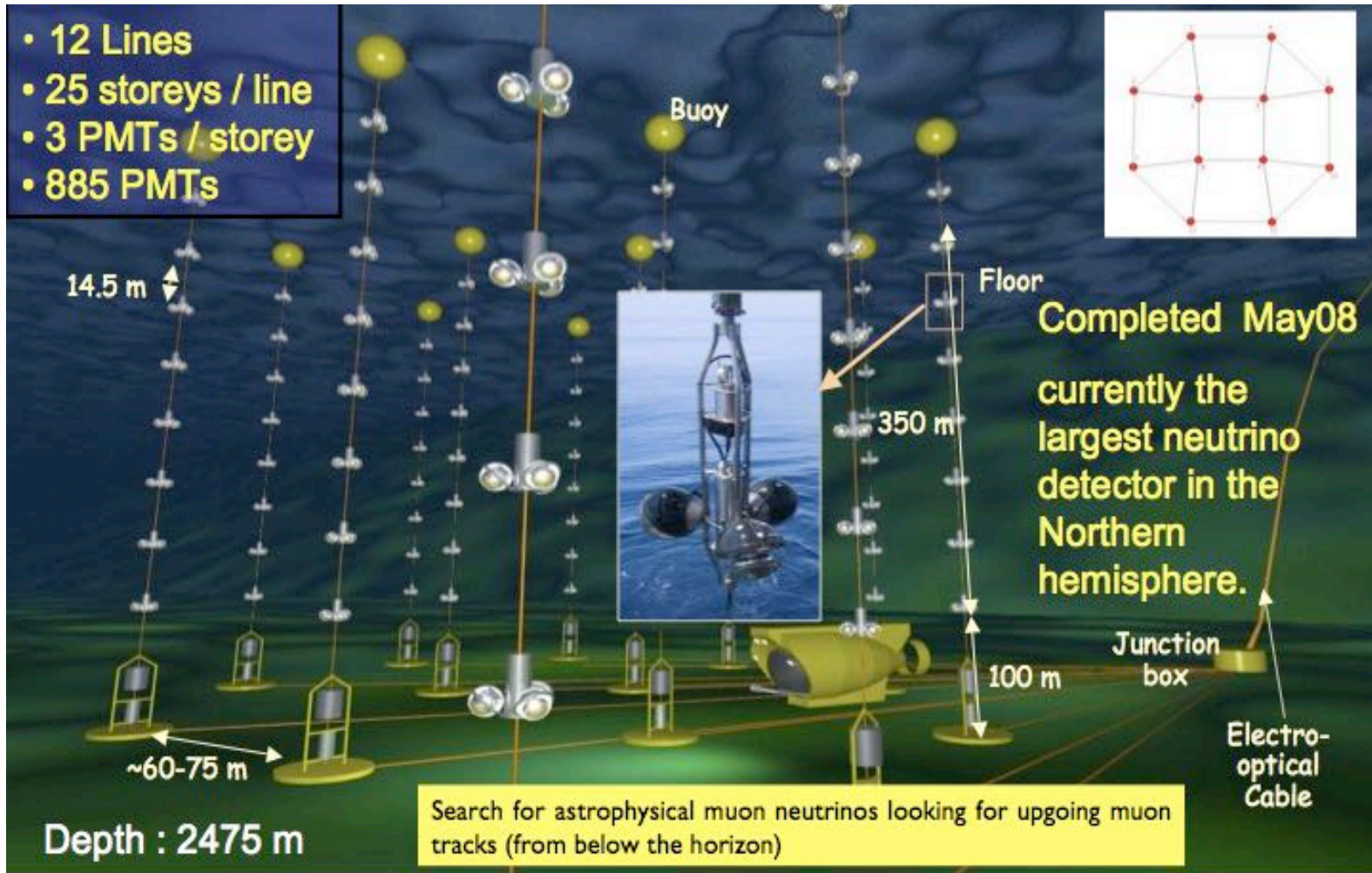


**GRB 130427A**

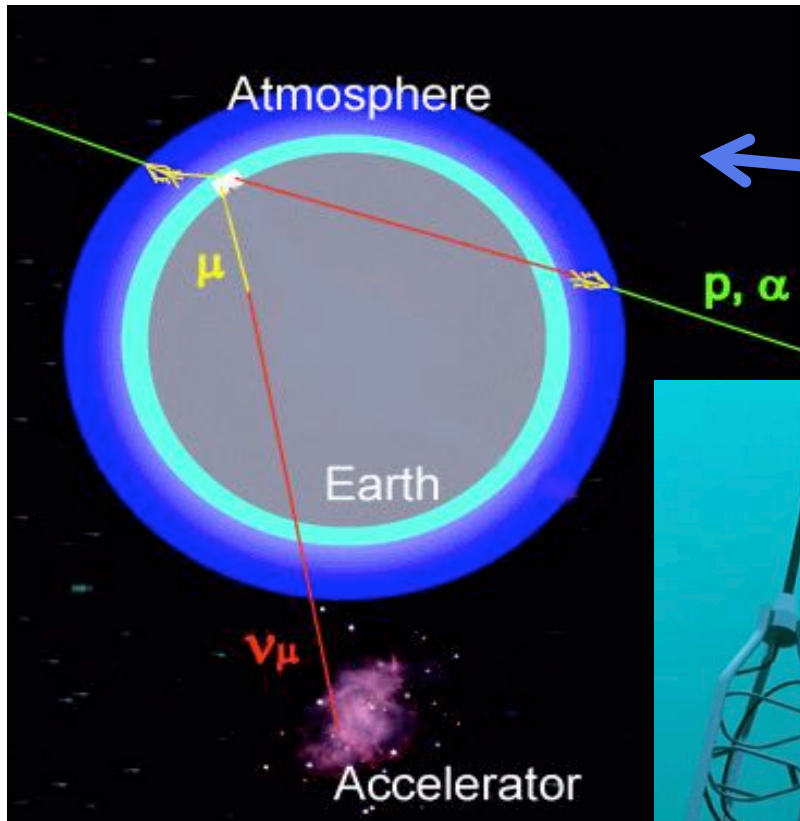
**GRB 130505A**



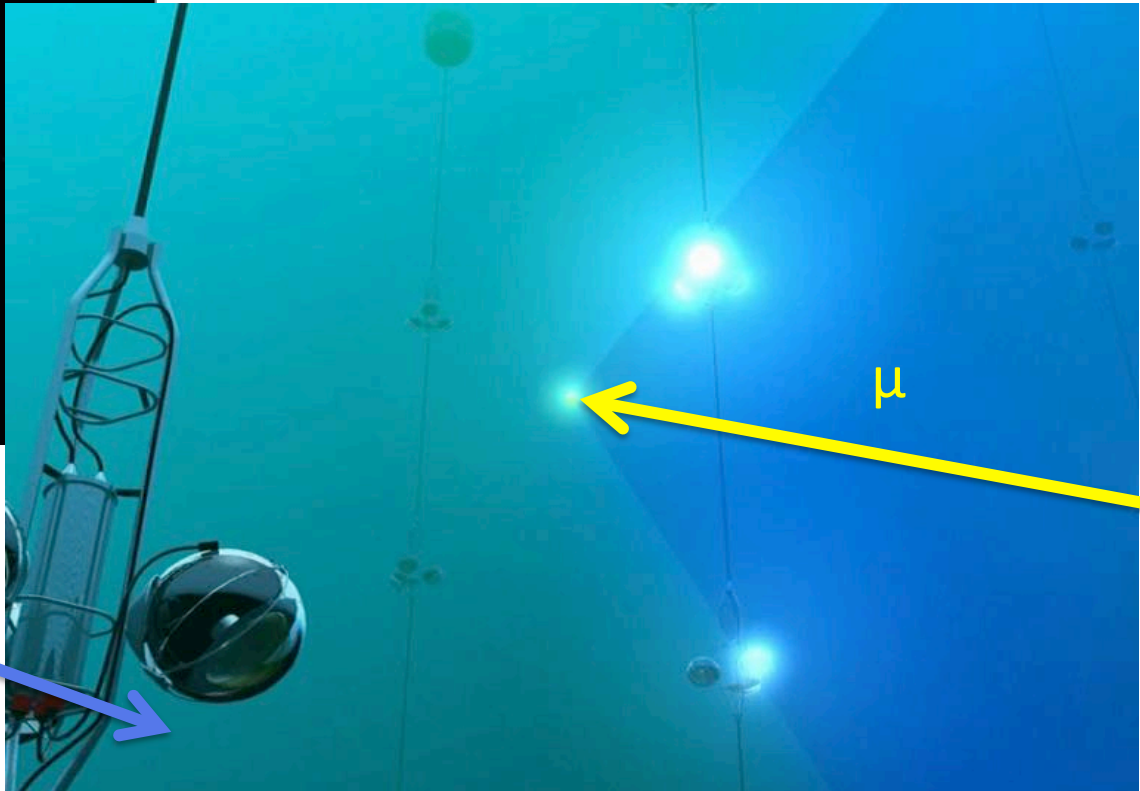
# The ANTARES telescope



# Detection principle



Signal and background contribution



Photon detection

# Internal shock model: study

See S. Celli poster

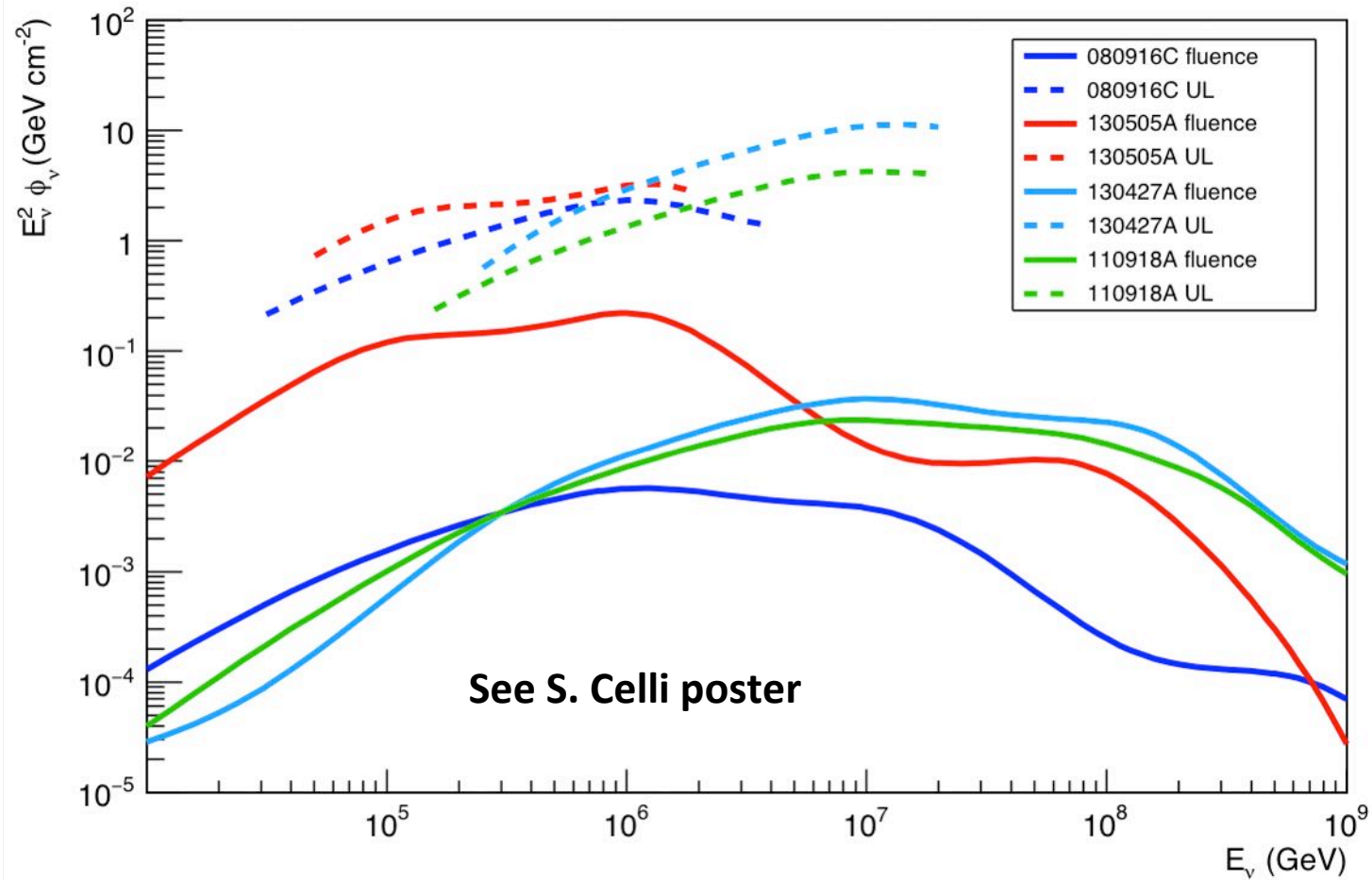


- **Per burst signal Monte Carlo simulations**
- **Per burst background evaluation using off-time data**
- **Reconstruction of the track with a linear fit algorithm (Heijboer PhD thesis (2004))**
- **10° search window**
- **Time dependent search**
- **Optimization through computation of extended maximum likelihood**
- **Maximization of model discovery potential**

# Internal shock model: results



## No neutrino detected in correspondence of GRB



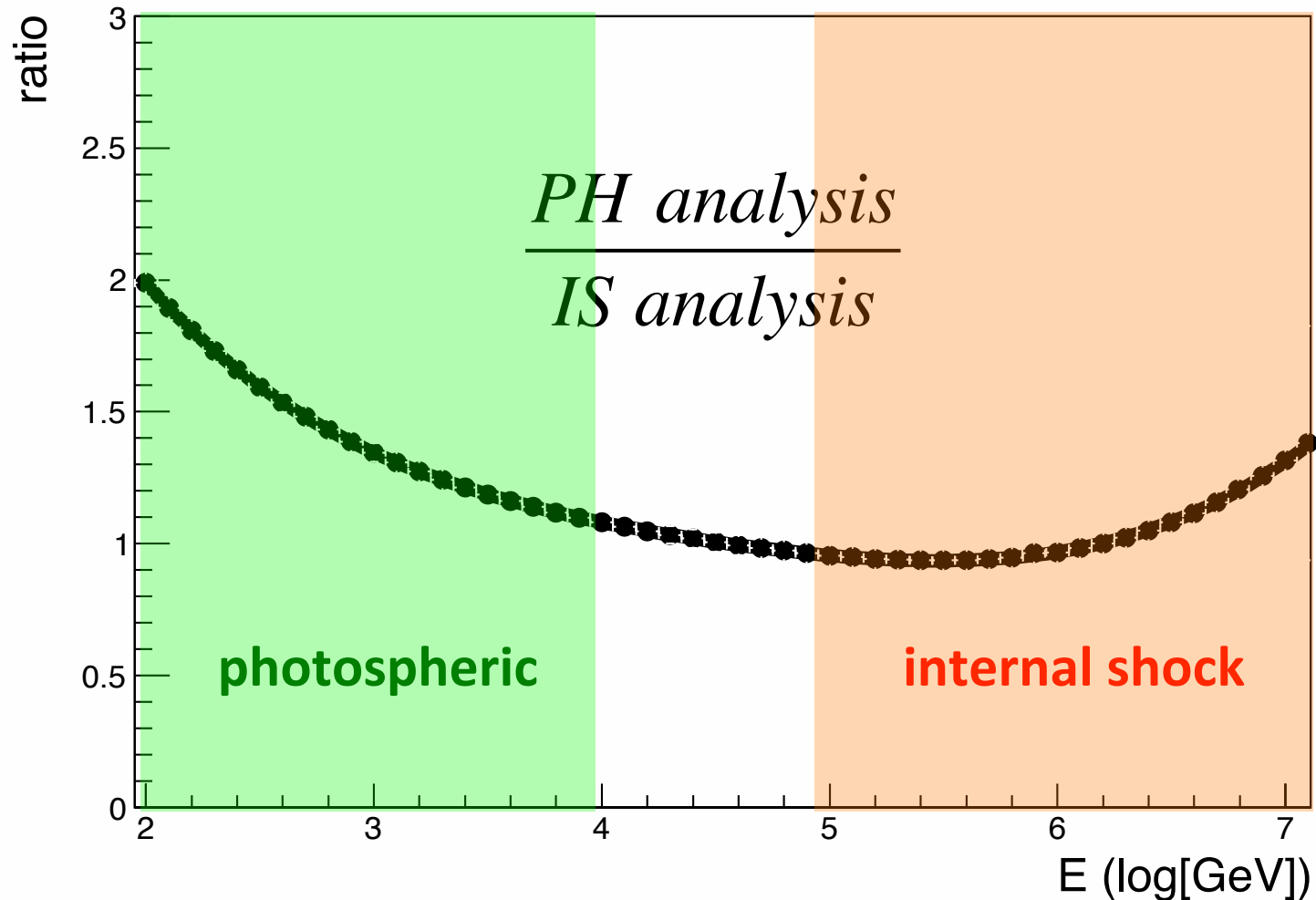
# Photospheric model: study



- **Same optimization as in the internal shock model study**
- **Sample of untriggered data has been used instead of the standard filtered data**
- **Offline triggering with a special directional filter**
- **Reconstruction with a low energy optimized algorithm (Visser PhD thesis (2015))**
- **No time dependent search**



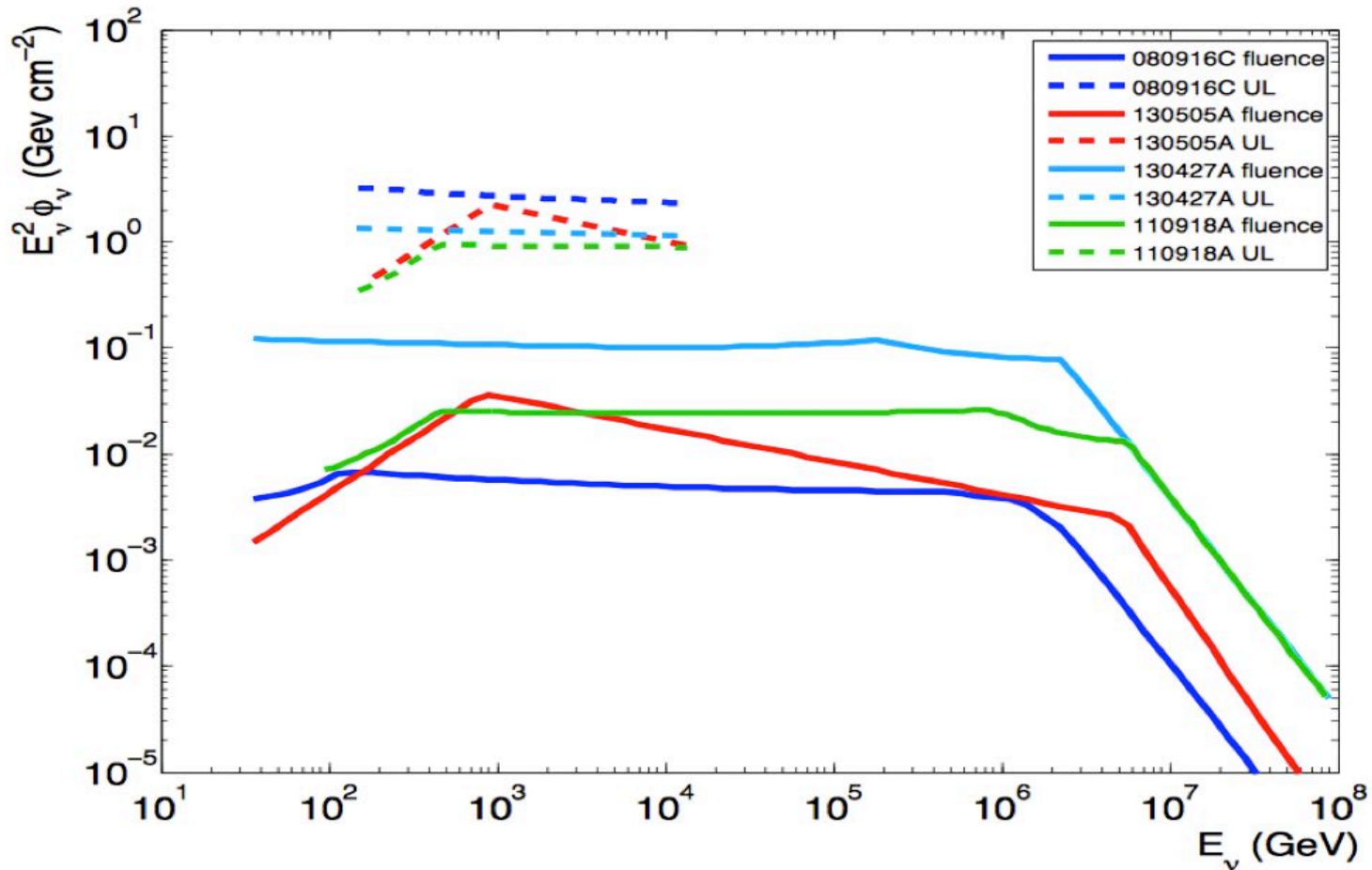
# Signal efficiency improvement



# Photospheric model: results



No neutrino detected in correspondence of GRB





# GRB constraints

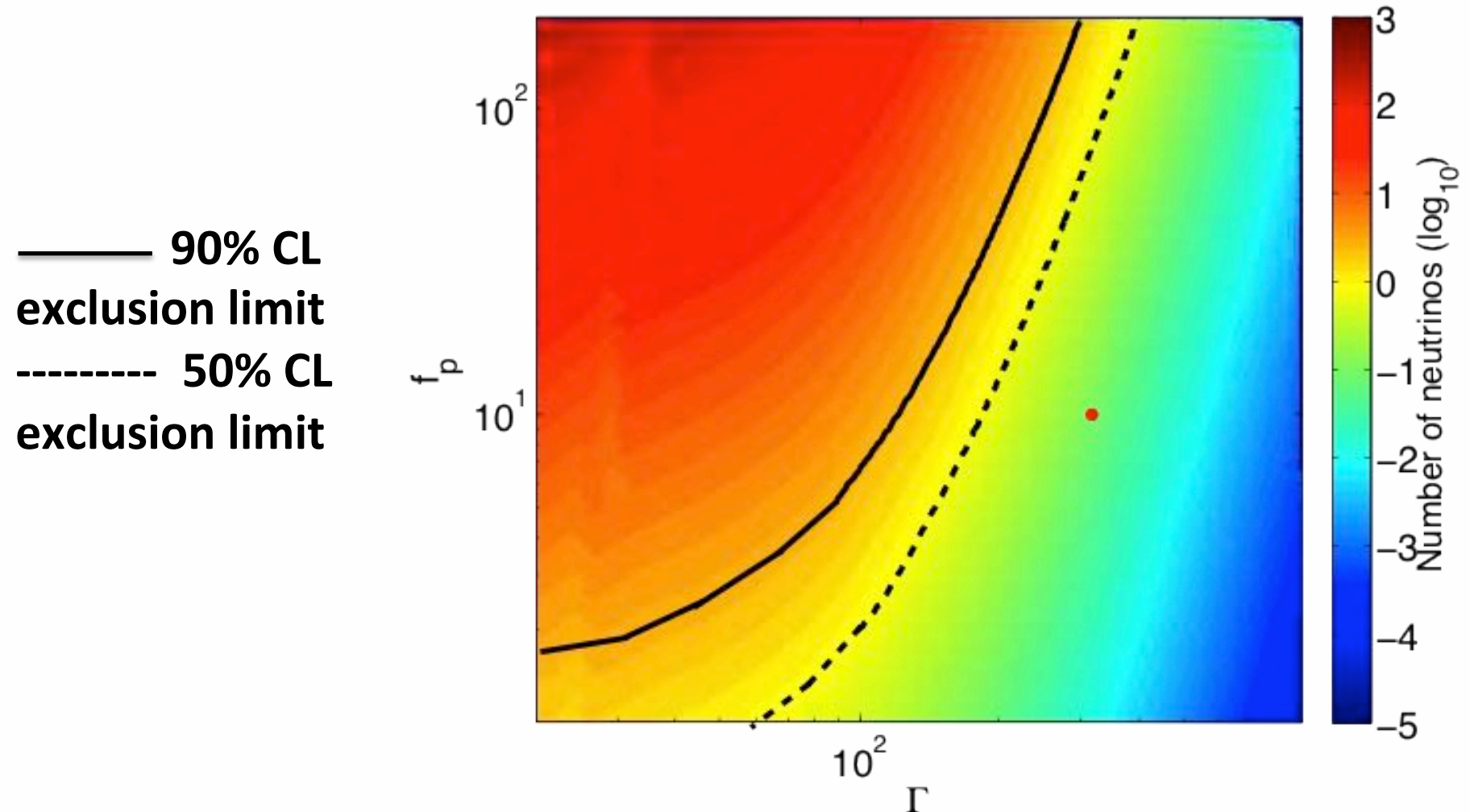
- **No neutrino events were spatially and temporally found in coincidence with one of the four bright GRBs**



- **90% C.L limits on the neutrino fluence allow to constrain the parameter space of the free parameters that significantly impact the neutrino flux: the baryonic loading factor  $f_p$  and the bulk Lorentz  $\Gamma$**

# Internal shock constraints

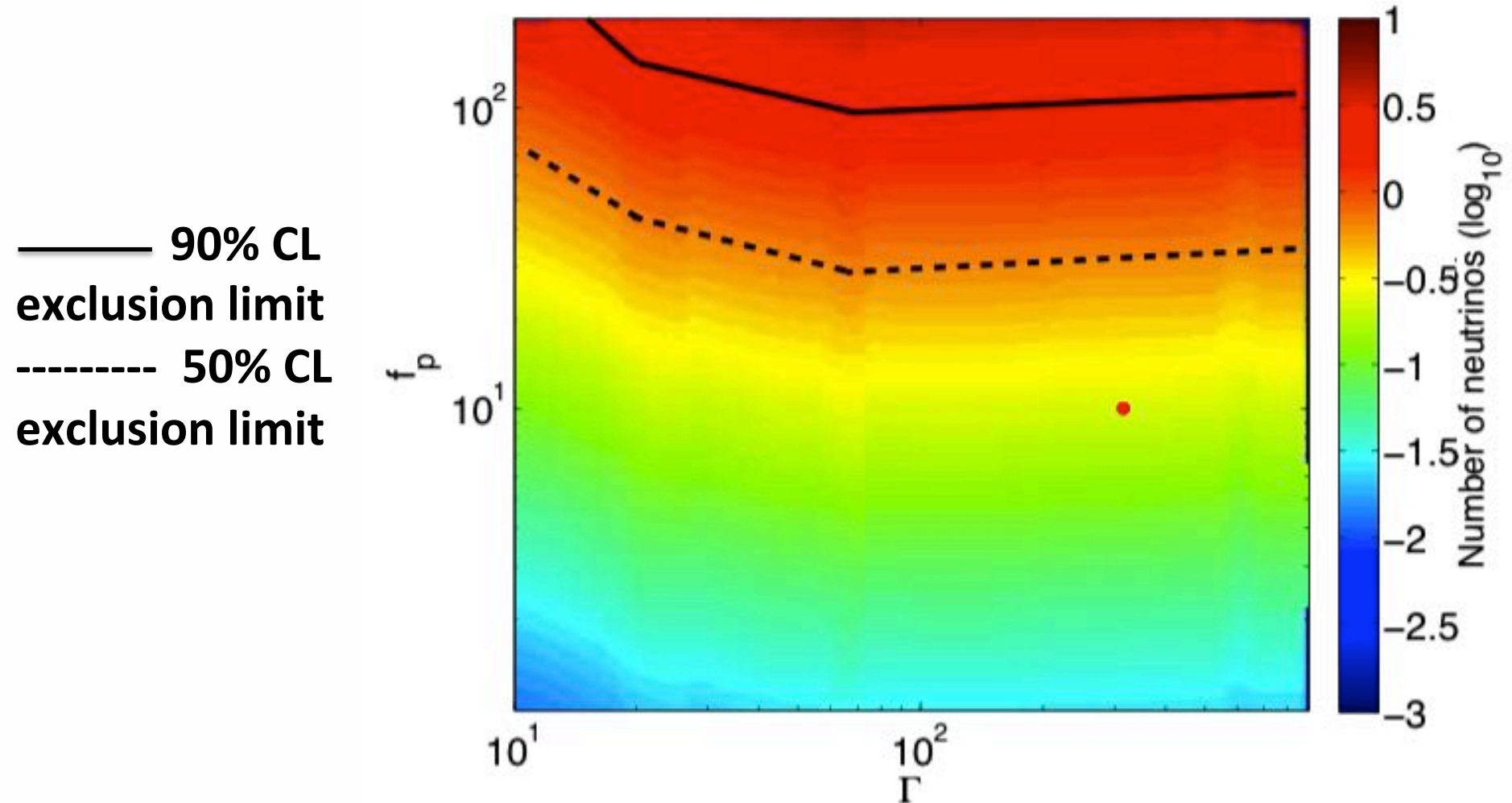
GRB130505A



# Photospheric constraints



GRB130427A





# Conclusions

- A search for muon neutrinos in space and time coincidence with the prompt emission of 4 bright GRBs has been performed through ANTARES data.
- Internal shock and photospheric models tested and constrained
- No events detected  $\rightarrow$  upper limit derived
- Constraints computed on the baryonic loading factor  $f_p$  and the bulk Lorentz  $\Gamma$



***Thank you  
for your  
attention***

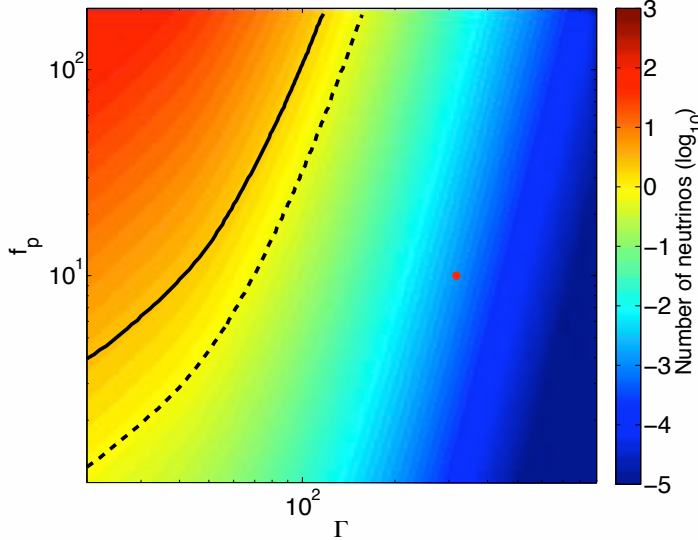
# Backup



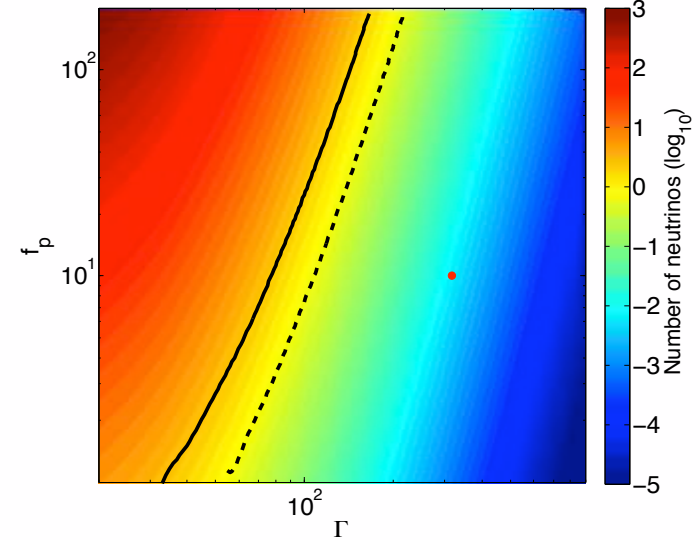


# Internal shock constraints

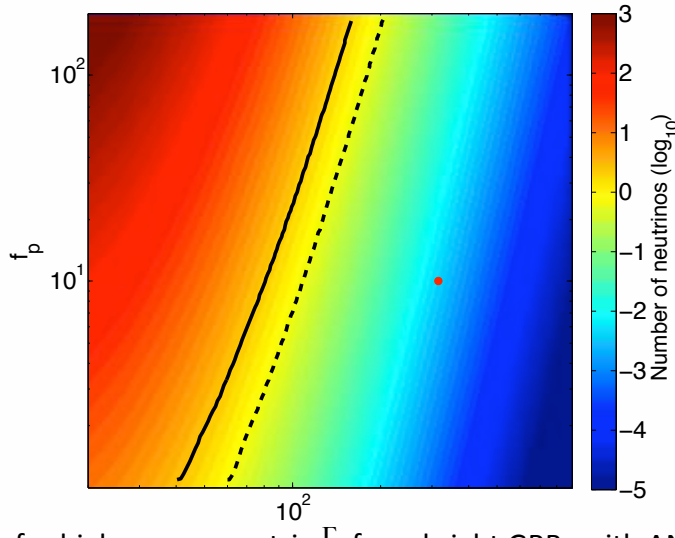
## GRB080916C



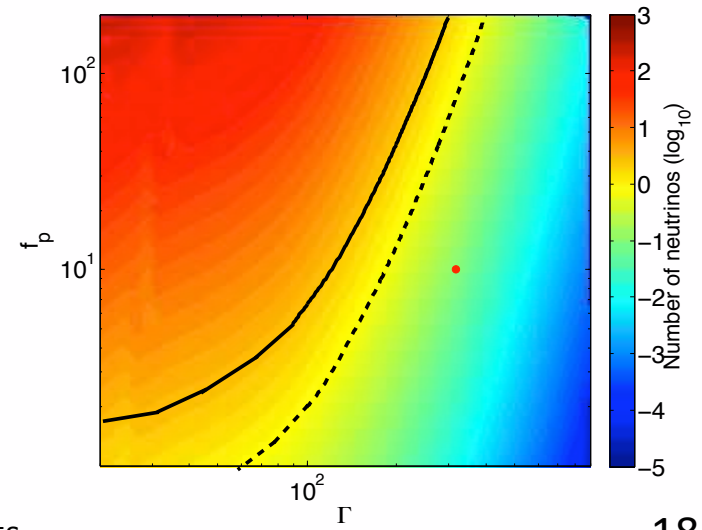
## GRB110918A



## GRB130427A



## GRB130505A

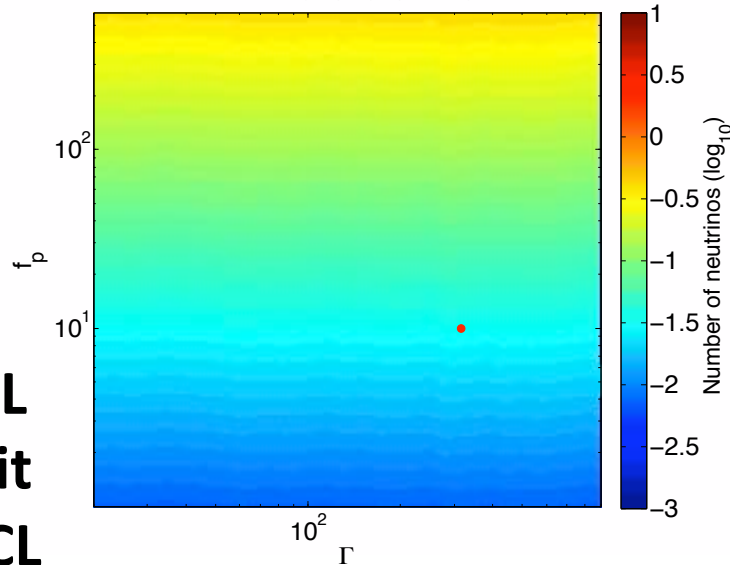


— 90% CL  
exclusion limit  
- - - - 50% CL  
exclusion limit

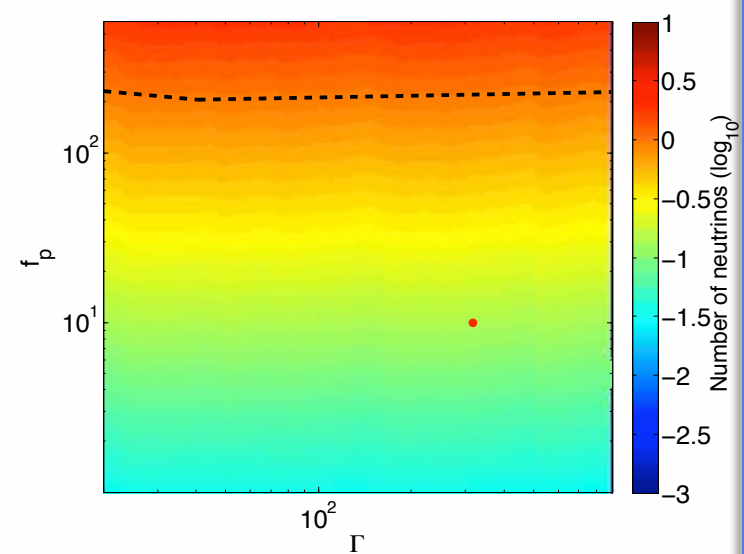
# Photospheric constraints



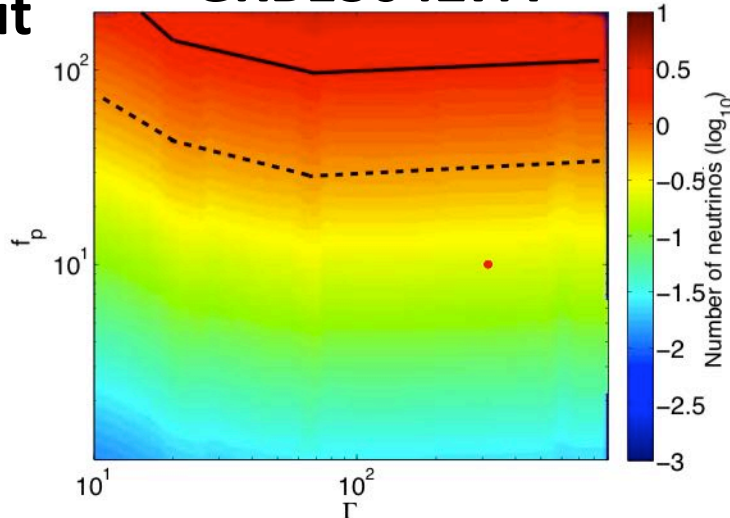
## GRB080916C



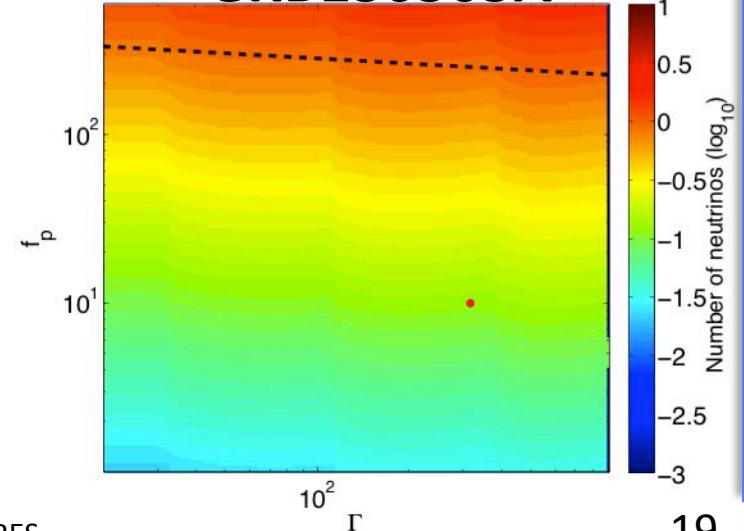
## GRB110918A



## GRB130427A



## GRB130505A



— 90% CL  
exclusion limit  
- - - - 50% CL  
exclusion limit