KM3NeT and Fermi bubbles: some predictions

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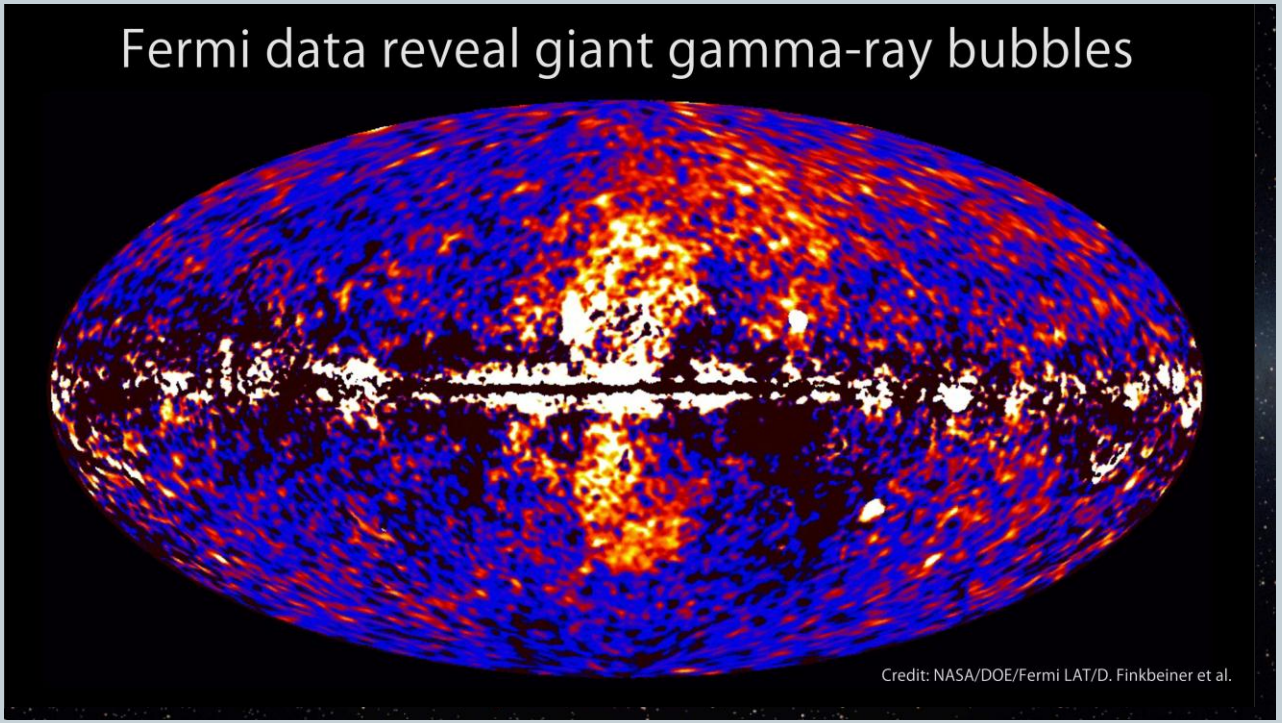
The bubbles

The observation of high energy gamma from two well shaped giant Bubbles in the Milk Way is one of the recent most exciting discoveries

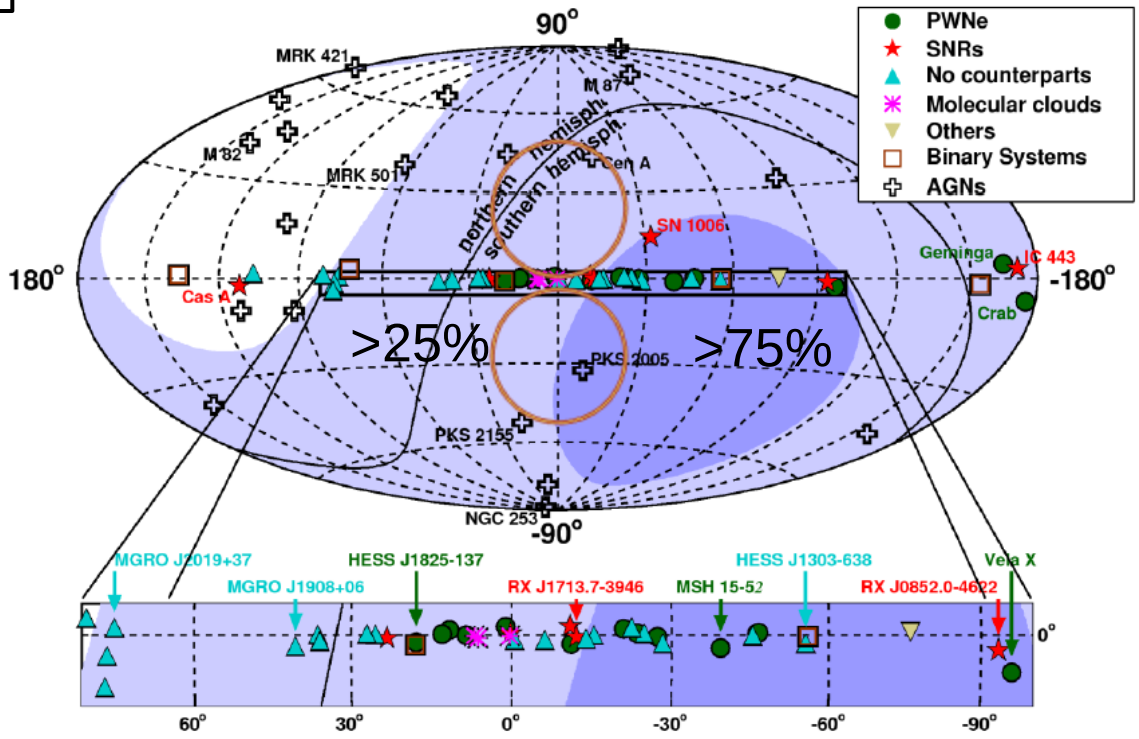


- ✓ What mechanism can produce high energy gamma rays?
- ✓ Are also high energy neutrinos produced?

Sky view of the Mediterranean sea telescopes

FOV for up-going neutrinos

From Mediterranean
24h per day visibility
up to declination δ ~-50°



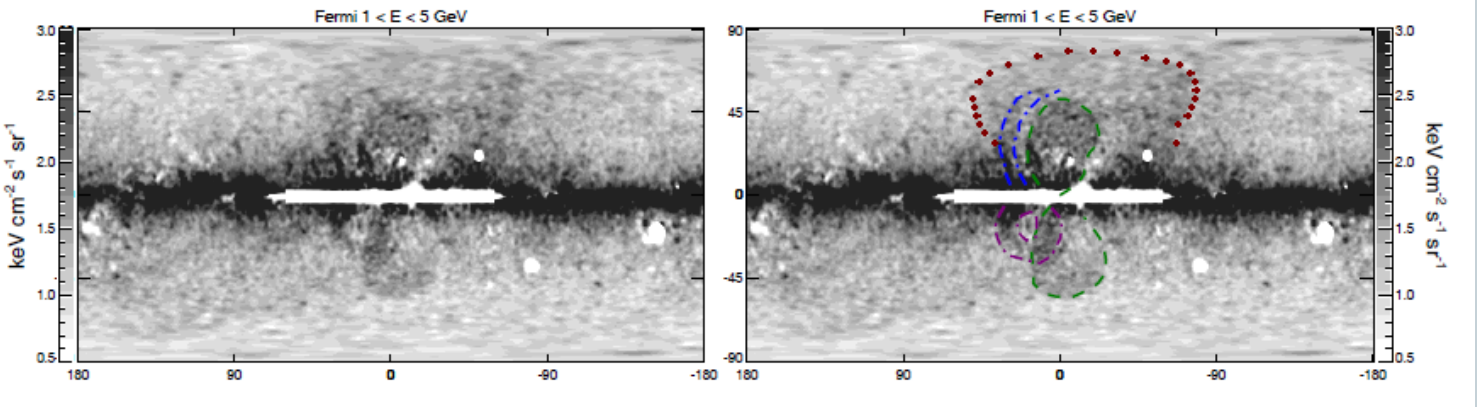
- Coverage of most of the sky (87%) including the Galactic Centre

The Fermi bubbles observation

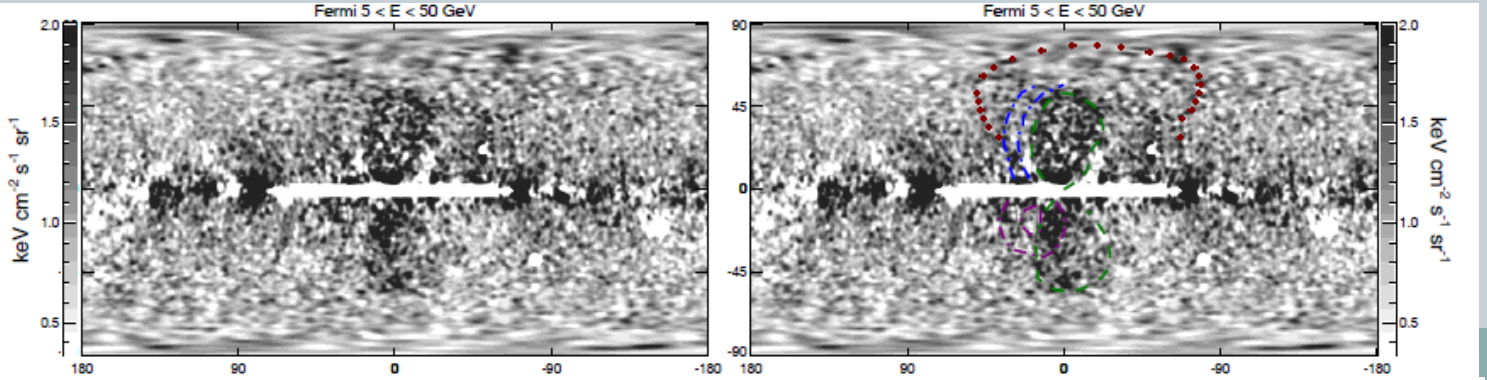
Fermi LAT observation

Meng Su, Tracy R. Slatyer, Douglas P. Finkbeiner, Astrophys. J. 724 1044-1082, 2010

1 <Eγ<5 GeV



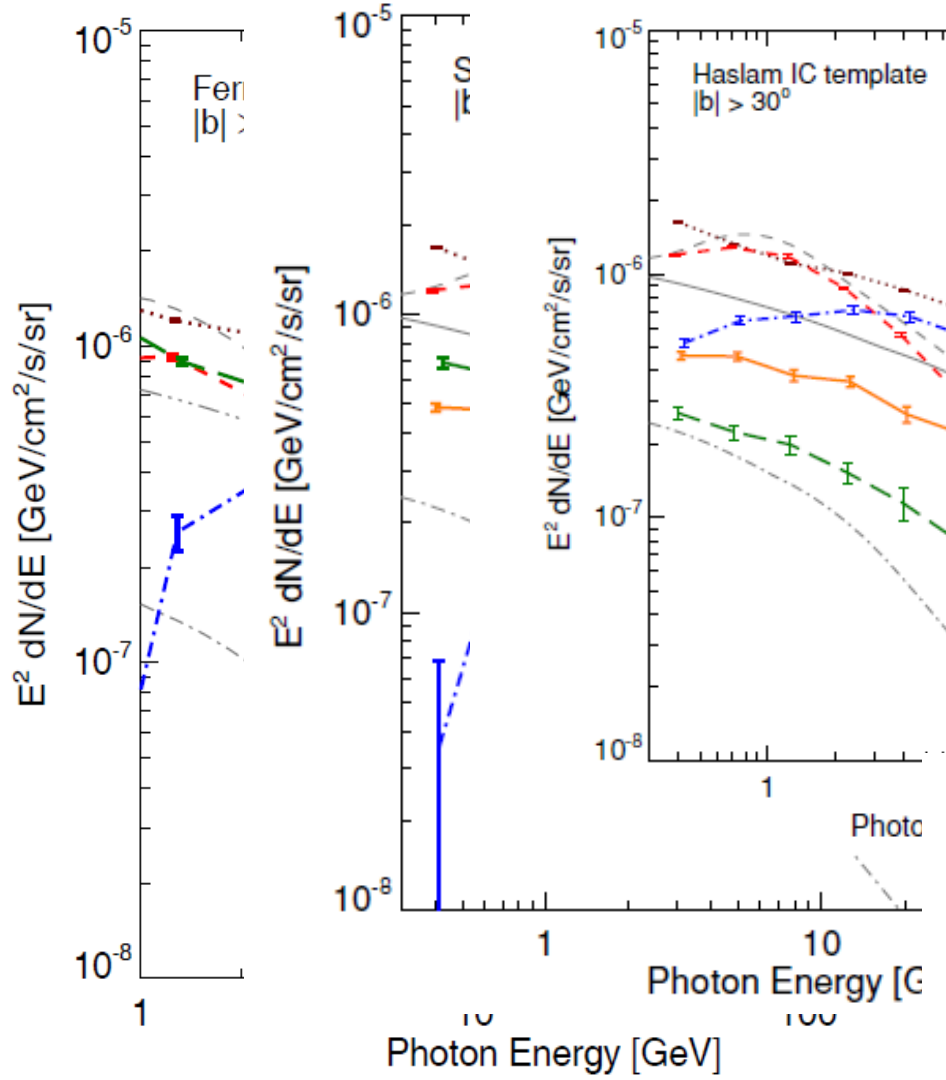
5 <Eγ<50 GeV



no spatial and intensity variation in the γ spectrum

Solid angle single bubble 0.35 sr

γ spectrum



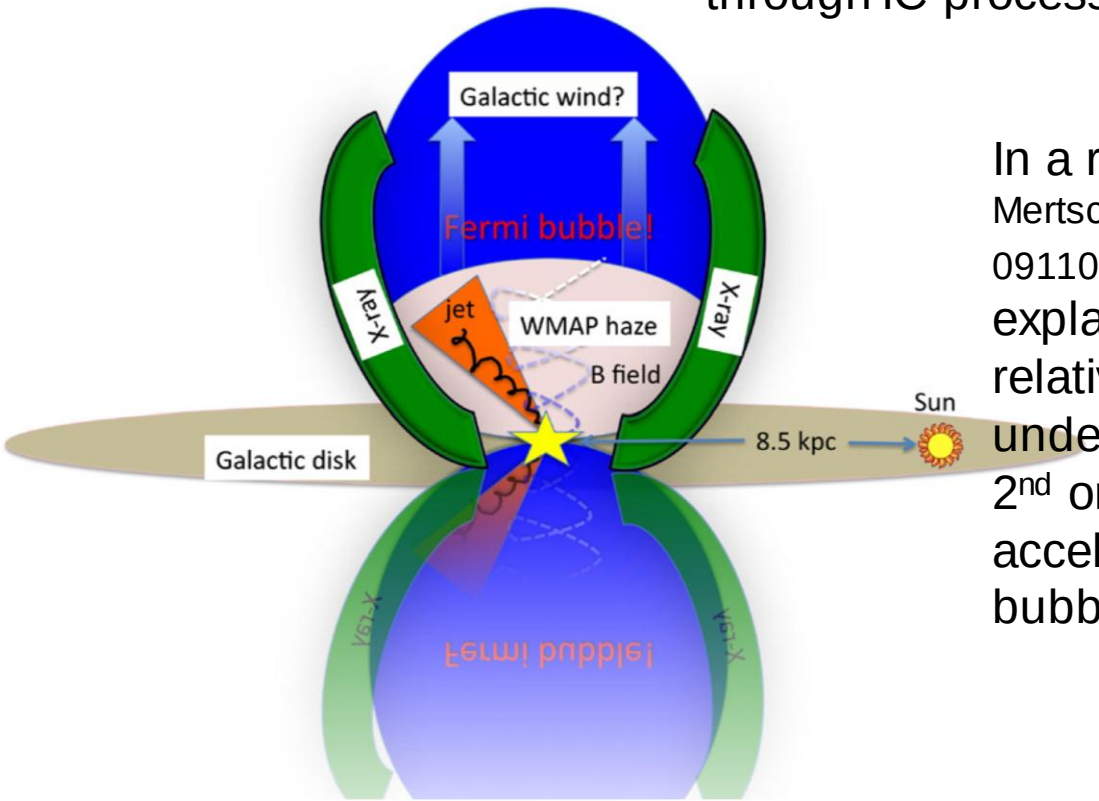
The γ spectrum is flat in E^{-2} dN/dE and of high intensity ($10^{-7} \div 10^{-6}$ GeV/cm²/s/sr)

Mesured up to 100 GeV

A cartoon picture

Bubbles observed also in X-ray and Microwaves

In *Meng Su et al.* bubbles are explained as due to relativistic CR electrons that produce gamma through IC process



In a recent paper Mertsch & Sarkar PRL 107 091101(2011) bubbles explained as due to relativistic electrons undergoing stochastic 2nd order Fermi acceleration in all the bubble volume

Figure 27. Schematic illustration to summarize the observations of the *Fermi* bubble structures. Two blue bubbles symmetric to the Galactic disk indicate the geometry of the gamma-ray bubbles observed by the *Fermi*-LAT. Morphologically, we see corresponding features in *ROSAT* soft X-ray maps, shown as green arcs embracing the bubbles. The *WMAP* haze shares the same edges as the *Fermi* bubbles (the pink egg inside the blue bubbles) with smaller extension in latitude. These related structures may have the same physical origin: past AGN activities or a nuclear starburst in the GC (the yellow star).

A hadronic model: gammas from a "reservoir" of CR protons and heavy ions in the Galactic Center

From M. Crocker and F. Aharonian Phys. Rev. Lett. 106 (2011) 101102

Gammas from a relic CR protons and heavier ions injected by processes associated with extremely long time scale (10^{10} years) and high density star formation in the Galactic Center

✓protons confined in bubbles ($t_{acc} << t_{pp} < t_{esc}$) ➔the gamma spectrum has the same slope of proton spectrum

✓A strong wind removes most of the CR from the GC

.....

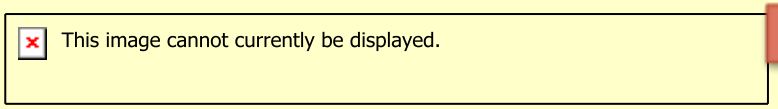
"...Finally, we predict that there should be a region of extended, TeV γ radiation surrounding the Galactic nucleus on similar size scales to the GeV bubbles with an intensity up to $E^{-2} F_{\gamma}(TeV) \sim 10^{-9}$ TeV cm^{-2} s^{-1} sr^{-1} which should make an interesting target for future γ-ray studies. Likewise, the region is a promising source for future, Northern Hemiphere, km3-volume neutrino telescope: we estimate (assuming a γ=2.0 proton spectrum cut-off 1 PeV)....

Is the neutrino flux visible with a high energy neutrino detector ?

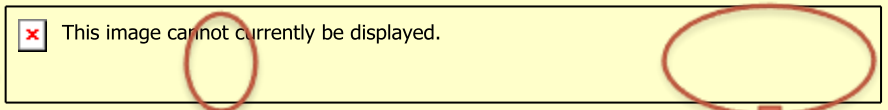
Neutrino flux estimate

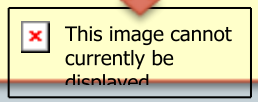
If the source is transparent to its γ radiation and the high energy γ spectrum is of hadronic origin from the measured γ spectrum can be estimated the ν spectrum (F. L. Villante and F. Vissani PRD 8 103007 (2008))

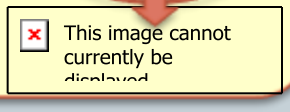
γ spectrum



ν spectrum







For the Fermi bubbles

$E^{-2} F_\nu(TeV) \sim \underbrace{5\ 10^{-7}\ GeV\ cm^{-1}\ s^{-1}\ sr^{-1}}_{\text{Gamma flux}} * \underbrace{0.34 * 2\ sr}_{\text{bubbles solid angle}} / \underbrace{2.5}_{\text{From } \gamma \text{ spectrum to } \nu \text{ spectrum}} \sim 1 \div 2\ 10^{-7}\ GeV\ cm^{-1}\ s^{-1}$

If protons are accelerated up to ≈ PeV ➔ expected neutrino cut-off 50 ÷ 100 TeV

KM3NeT detector lay-out

Artist impression of KM3NeT

The Storey

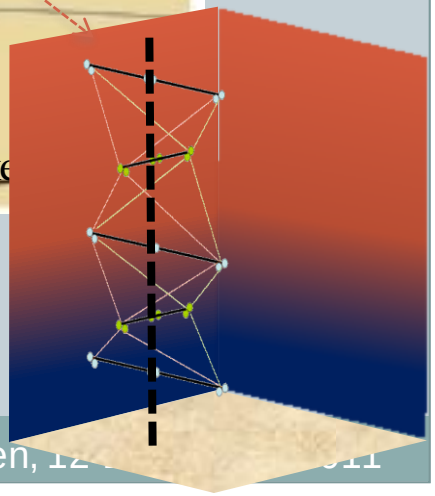
The OM

Primary Junction box

Secondary Junction boxe

Electro-optical cable

Detection Units



KM3NeT in numbers (full detector)

- ~ 300 DU
- 20 storey/DU
- 40m storey spacing
- ~ 1 km DU height
- ~ 180m DU distance
- ~ 5 km^3 volume

All the technical information in http://www.km3net.org/KM3NeT-TDR.pdf

The MC simulations

Monte Carlo Simulations

ANTARES code modified for km3 detector and multi-PMT

- Neutrino generation and interaction (CC & NC) + ν_{atm} generation (Bartol flux) and interaction (CC & NC) (GENHEN) + μ_{atm} (Mupage parameterization)
- Light simulation (optical water properties)
- Hit generation (PMT simulation)
- K40 Background and electronics
- Track reconstruction based on likelihood

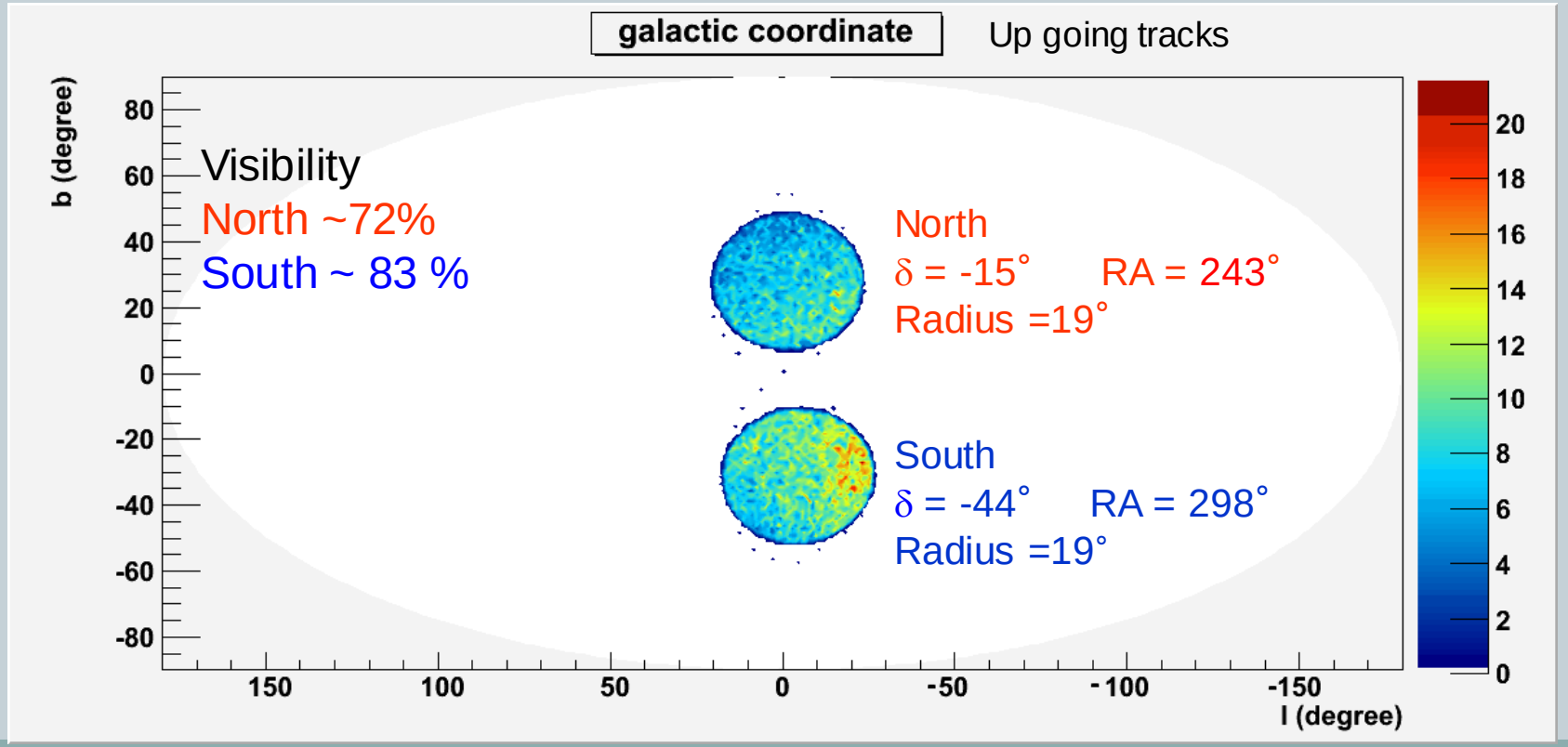
Discovery flux calculation

- Minimization of the Model Discovery Potential (MDP)

Cuts on Λ (related to the reconstruction quality), #hits (related to the muon energy), R_{bin} search cone

The neutrino generation

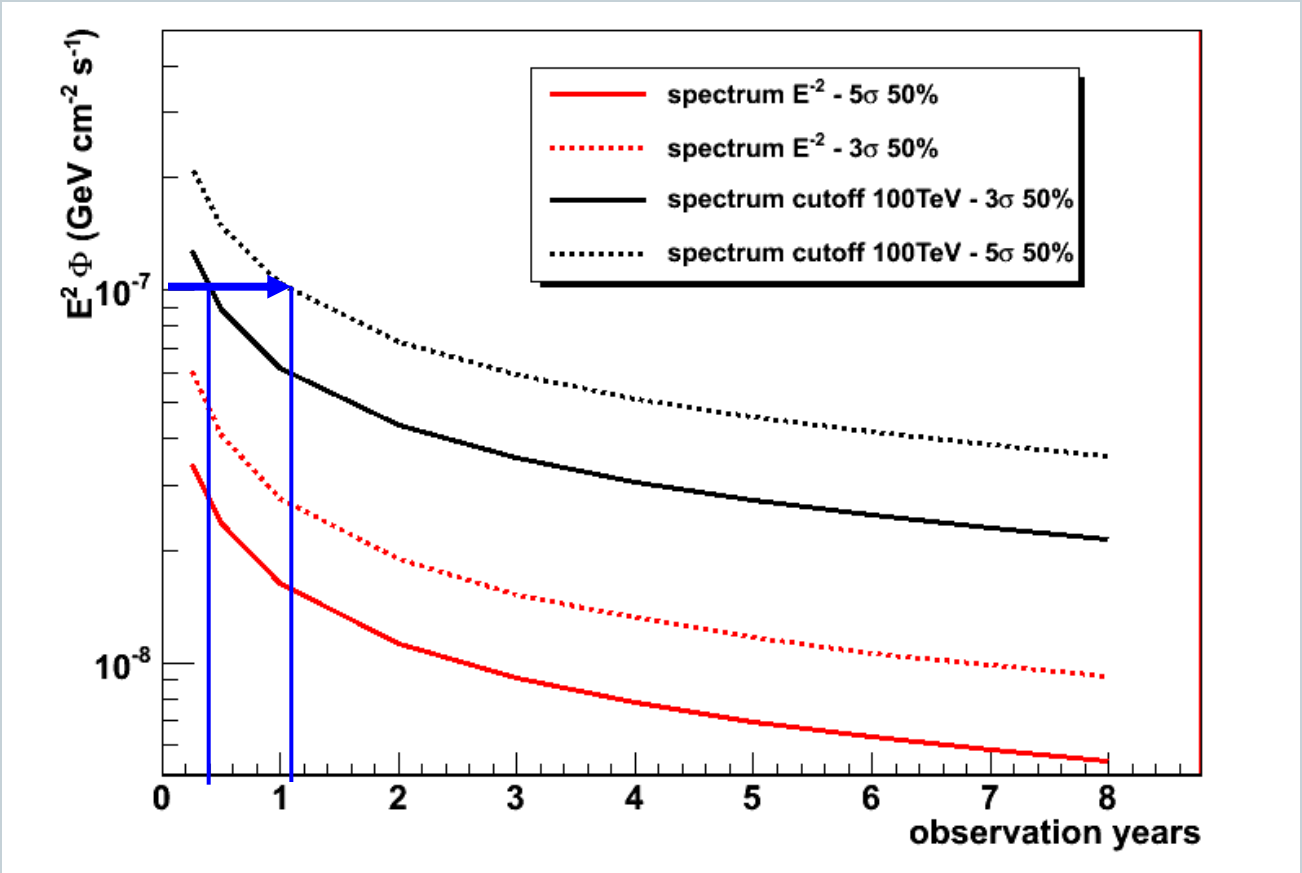
Homogeneous generation in a circular region around fixed points (modified version of GENHEN code)



Discovery flux

Full KM3NeT detector
≈ 310 towers

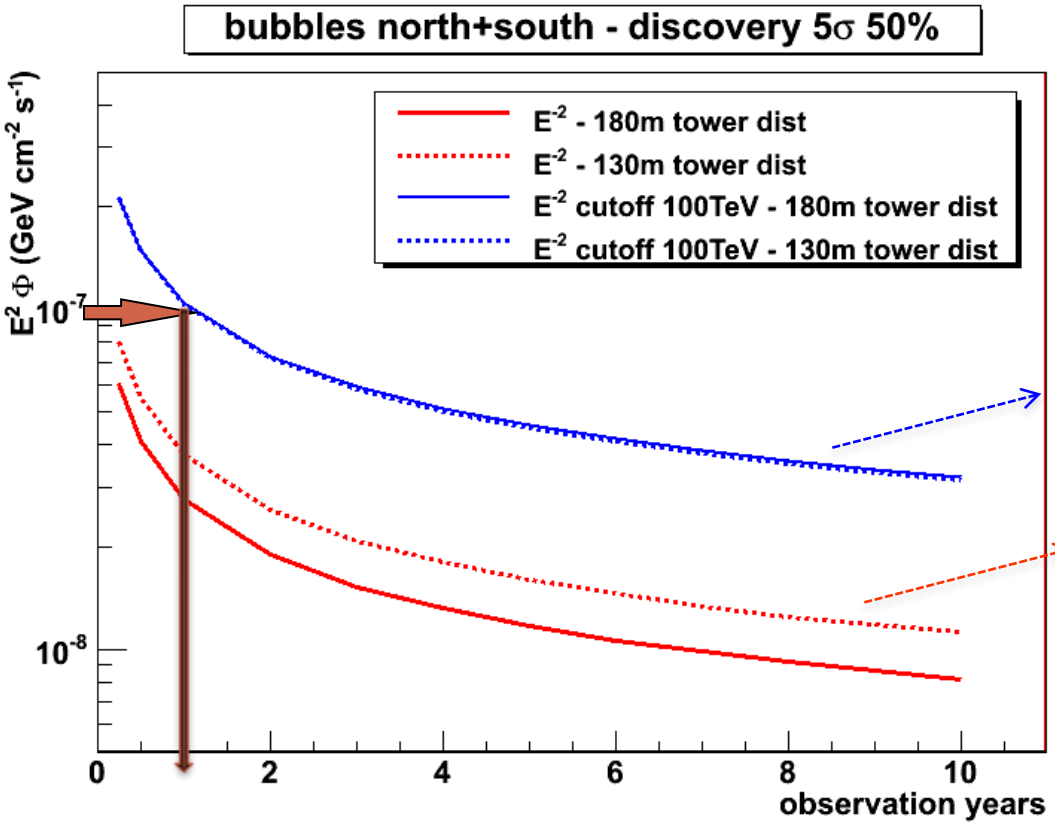
Bubbles north + south



- ~ months for the evidence (3σ)
- ~ 1 years to claim the discovery (5σ)

Discovery flux: dependence on the detector footprint

Detectors with different tower distances:
----- 130m tower distance V≈ 3.1 km^3
——— 180m tower distance V≈ 5.8 Km^3

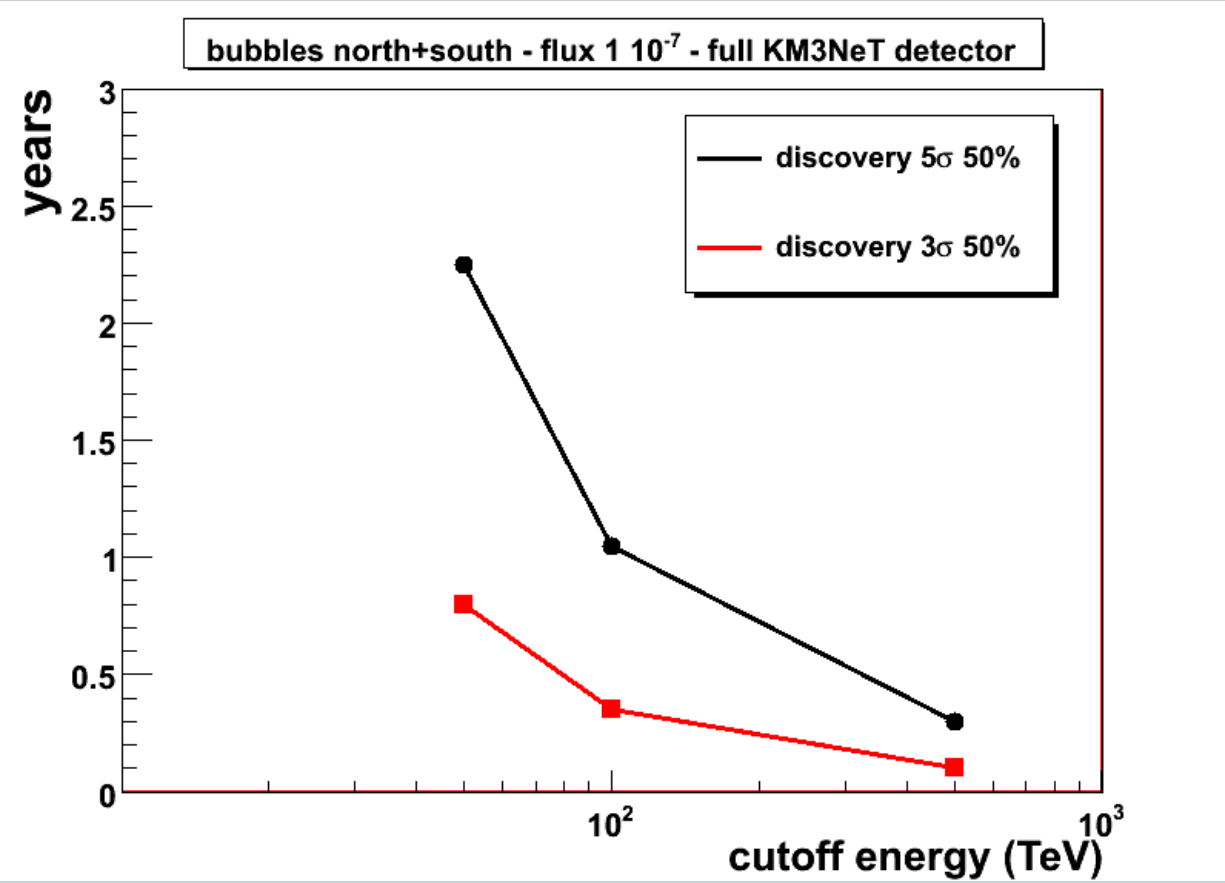


cut off 100 TeV

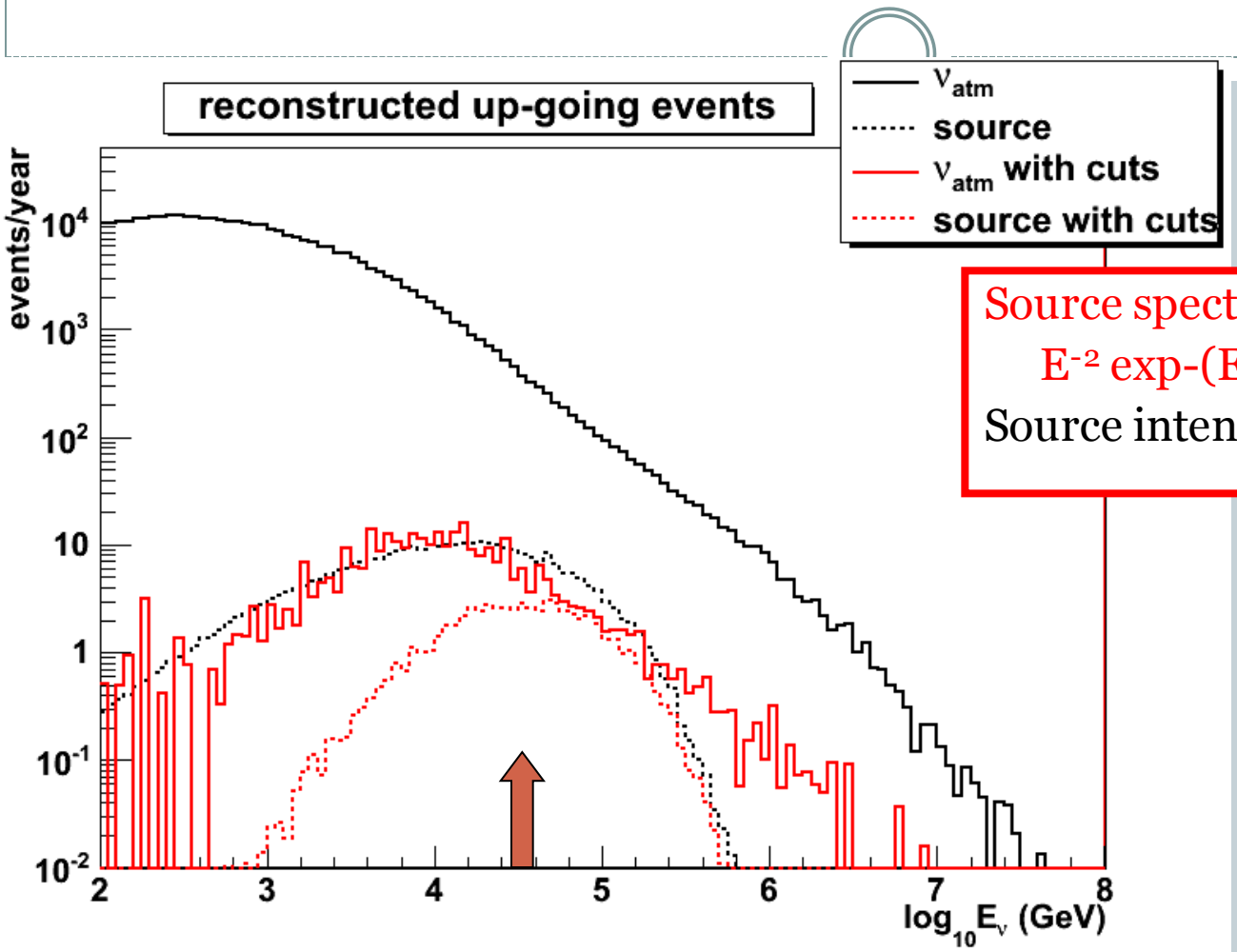
E^{-2}

Years for discovery as a function of energy cutoff

Number of years needed to claim the discovery (5σ 50%) if a flux of 1 10^{-7} GeV cm^{-2} s^{-1} is assumed



Energy spectra



Source spectrum

$E^{-2} \exp-(E_\nu/100\ \text{TeV})$

Source intensity $1.7\ 10^{-7}\ \text{GeV cm}^{-2}\ \text{s}^{-1}$

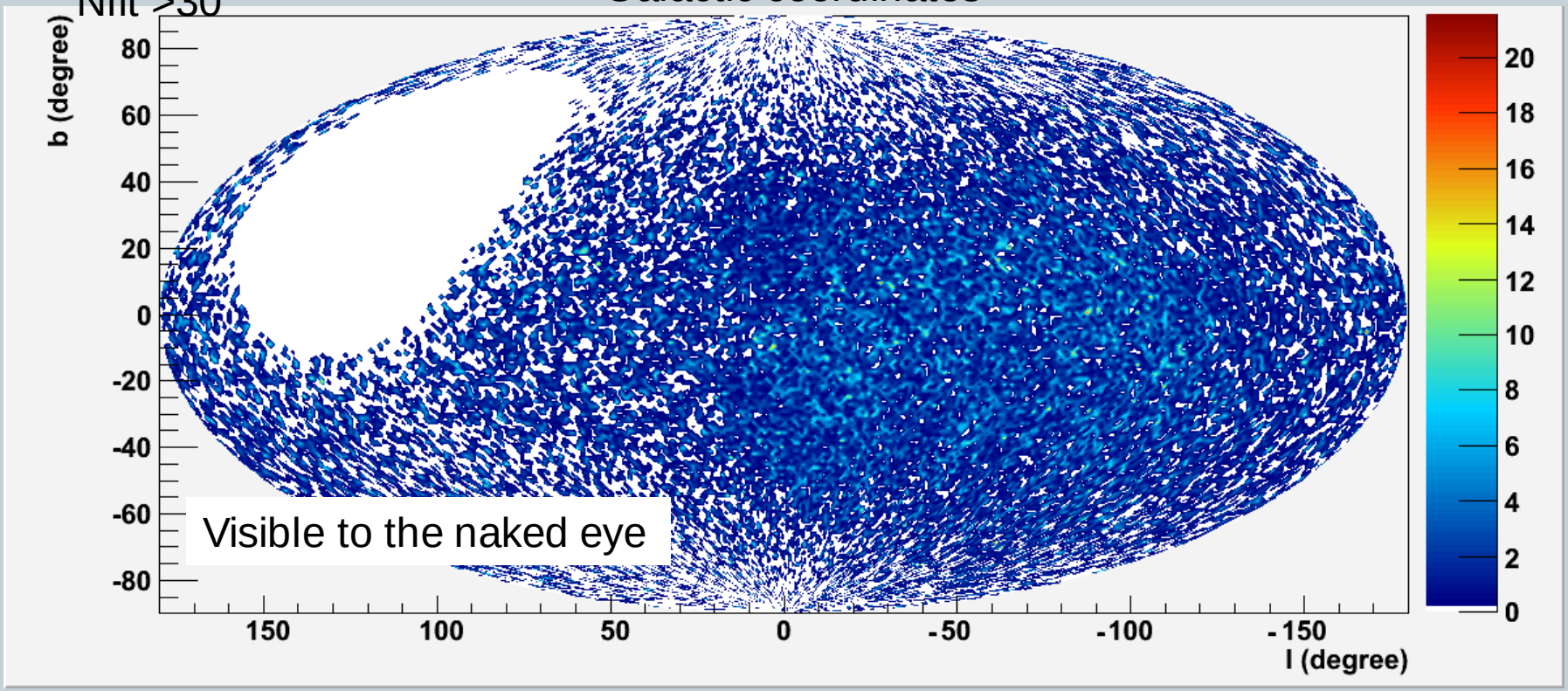
Neutrino energy of around 30 TeV

Sky map of reconstructed events

Up - going events
Soft cut applied
Λ>-5
Nfit >30

E^{-2} spectrum

Galactic coordinates



Conclusions

- ✓ Analysis similar to the diffuse flux analysis
- ✓ Fermi bubbles predictions very sensitive to the shape of the neutrino spectrum ➔ high energy gamma measurements needed
- ✓ Good chance to see neutrinos from Fermi Bubbles with a KM3NeT detector