ANTARES constraints on the neutrino flux from the Milky Way

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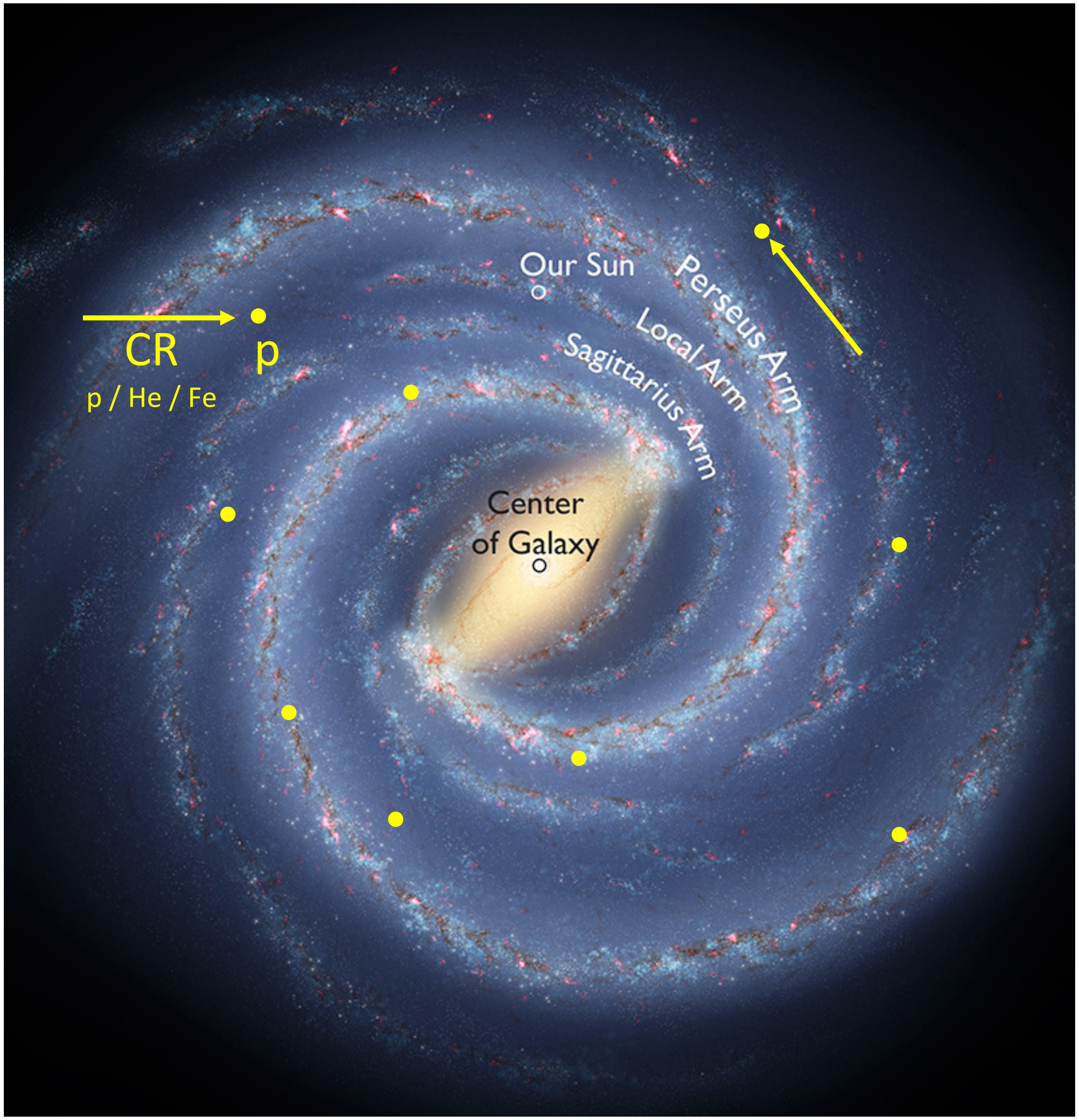
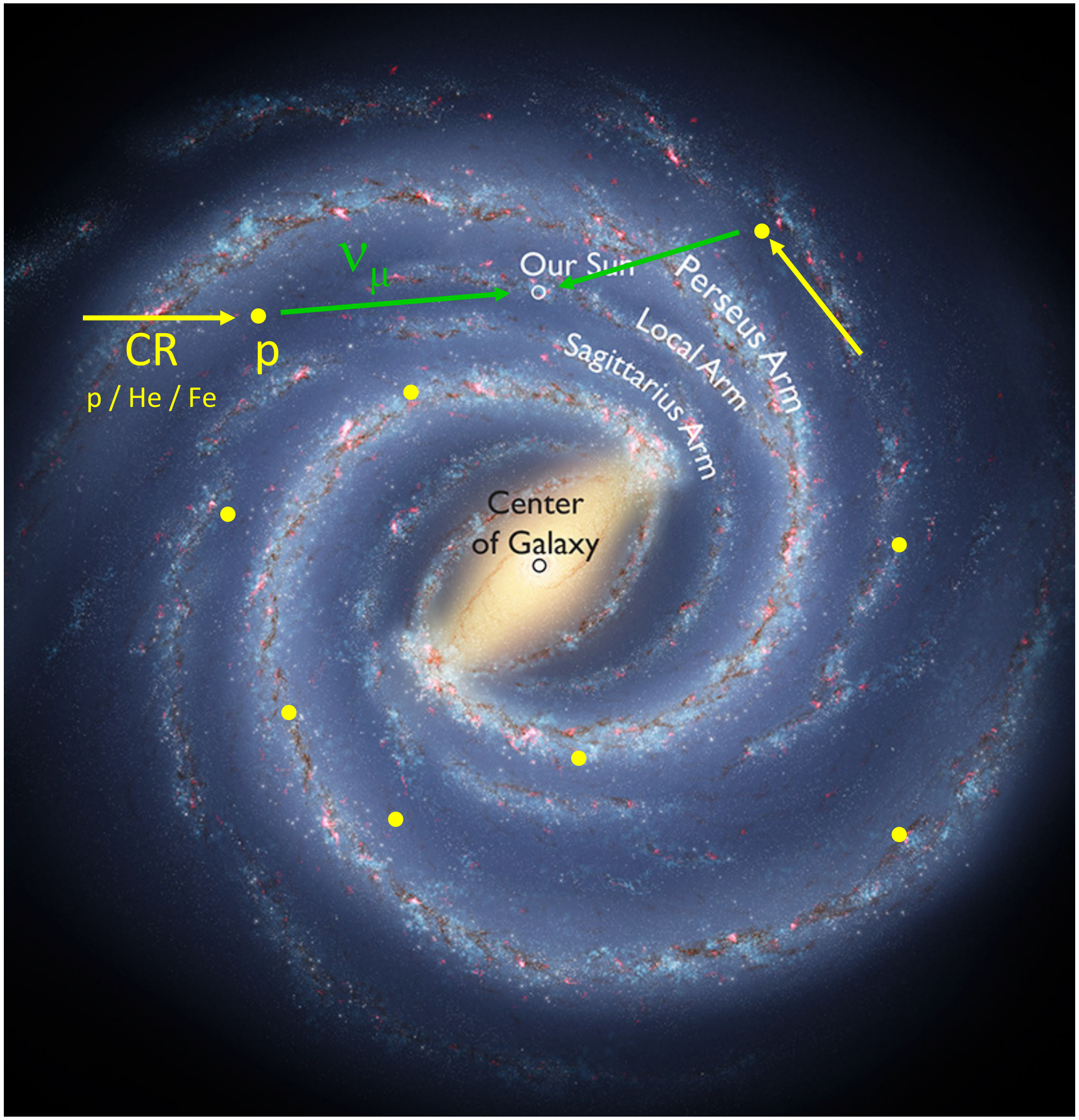
Outline

- Neutrino signal from the Milky Way
- Estimating the neutrino flux
- Description of the analysis method
- ANTARES results

Neutrino signal from the Milky Way



Neutrino signal from the Milky Way



- Cosmic rays interact with interstellar gas
- Neutrinos produced mainly via charged pion decay
- Pions do not interact before decay
  - Neutrino spectrum follows CR spectrum
- Guaranteed signal
- IceCube excess could be caused by this mechanism
  - Neronov et al. Phys. Rev. D, 89 (103002), 2014

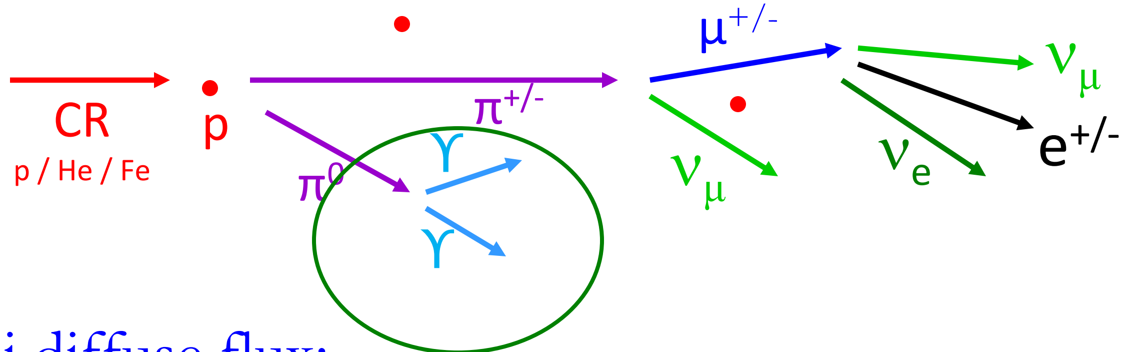
Estimating the neutrino flux

1. Theoretical models

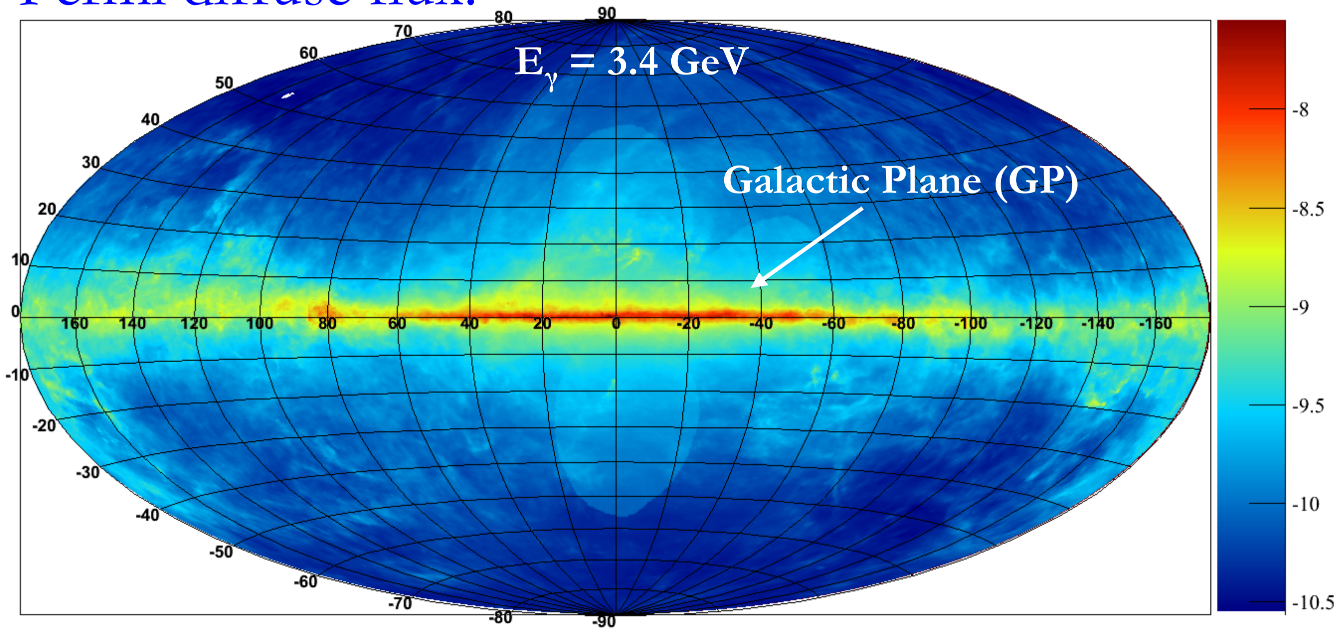
Model name	**Reference**	**Matter density**	**Cosmic ray flux**
NoDrift_simple	Ingelman and Thunman arXiv:hep-ph/9604286	constant: 1 nucleon / cm^3	constant
NoDrift_advanced	Candia and Roulet JCAP09(2003)005	constant: 1 nucleon / cm^3	constant
Drift	Candia JCAP11(2005)002	Radially dependent	Higher in GC due to drift of CRs

Estimating the neutrino flux

2. Use experimental data

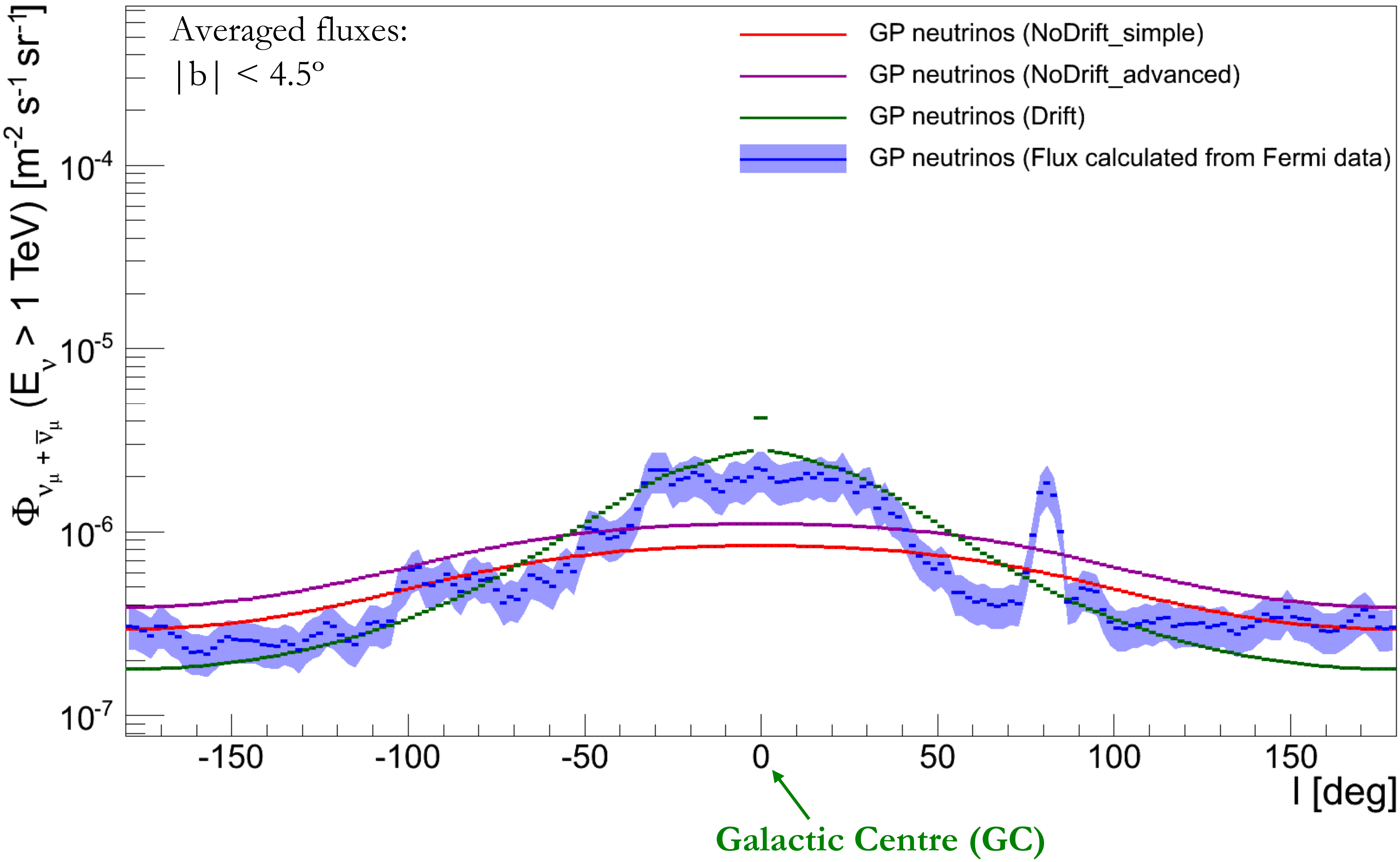


Fermi diffuse flux:

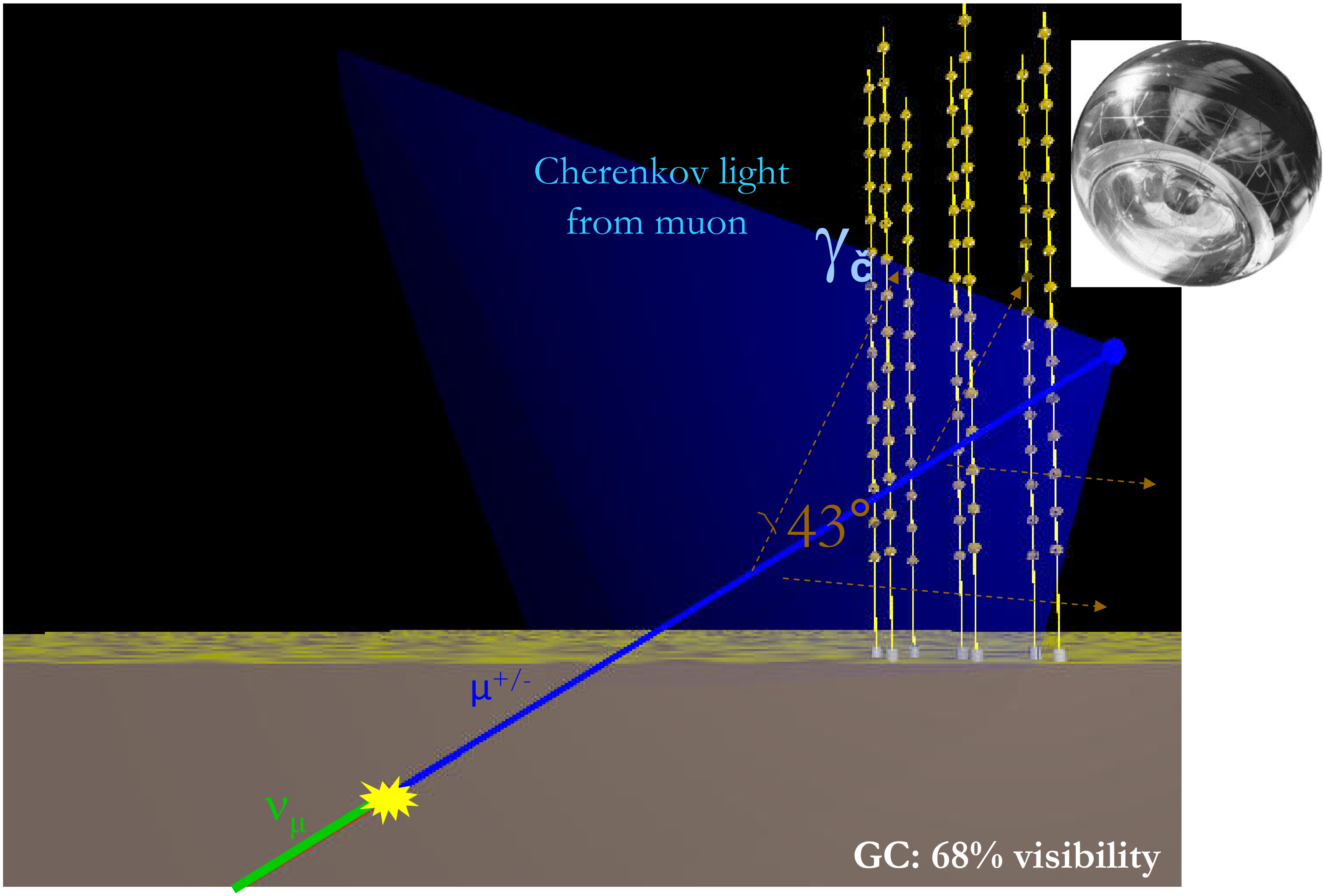


- Use GALPROP to estimate fraction of γ's from neutral pion decay and IC scattering
  - Ackermann et al. ApJ, 750 (3), 2012
- Uncertainty of neutral pion contribution is estimated from range in models
- Convert neutral pion to charged pion flux

Estimating the neutrino flux



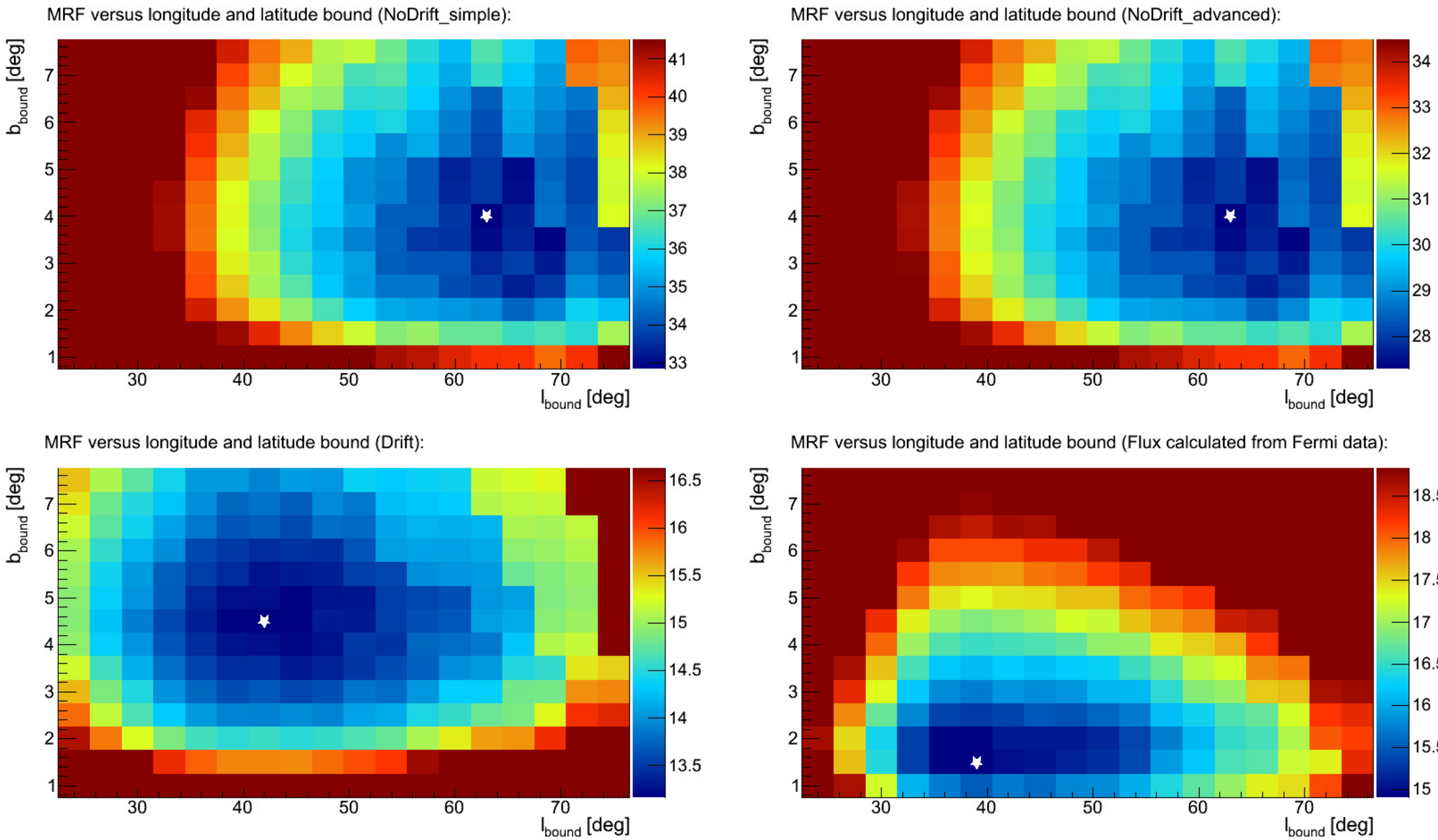
The ANTARES neutrino telescope



The analysis

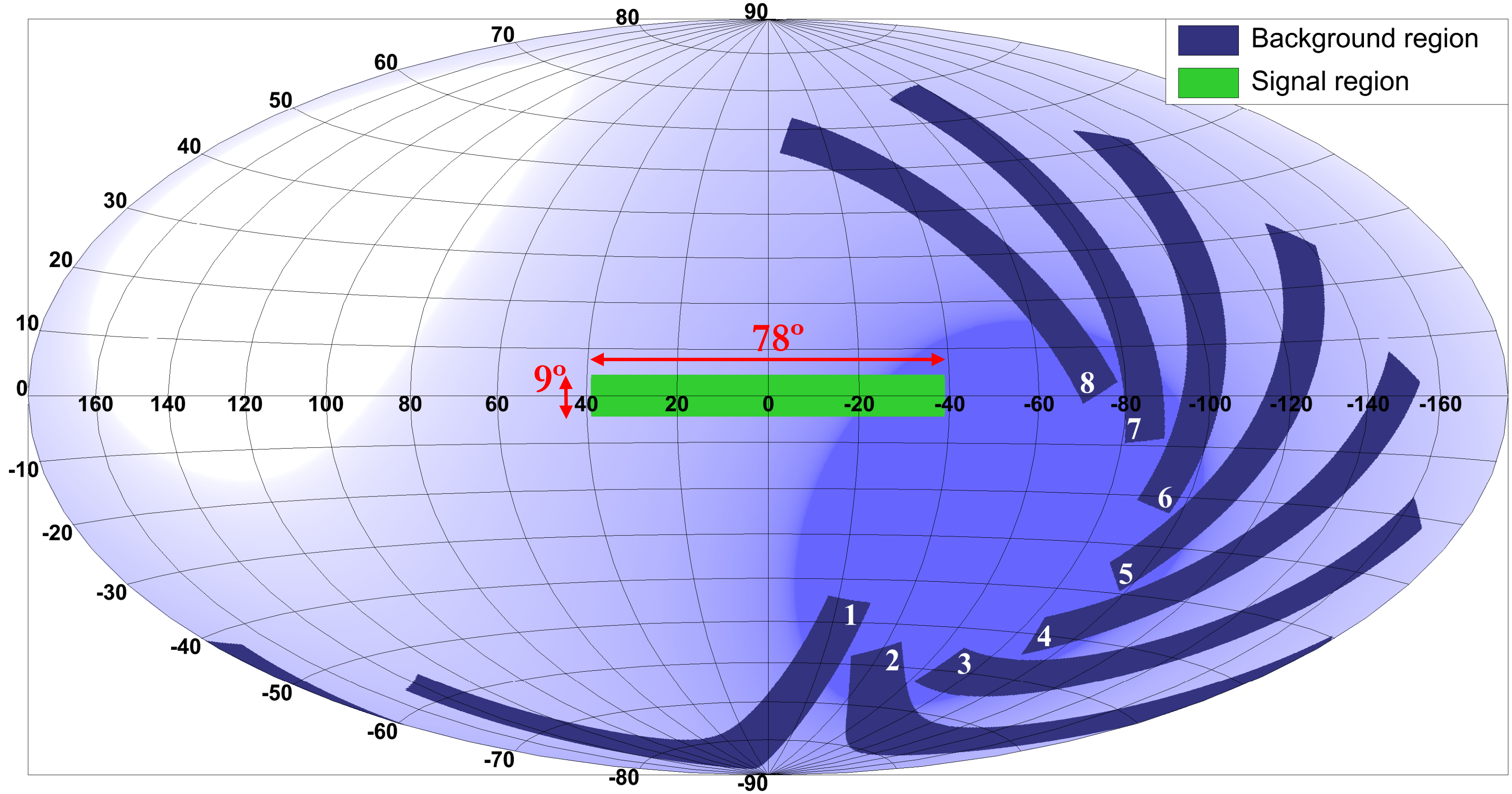
90% neutrino purity

- Optimise size of signal region for best flux limit (MRF method)



The analysis

Size of each region is 0.214 sr



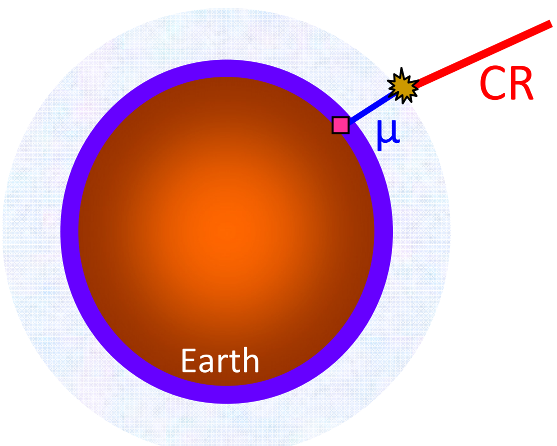
- Background is measured from the data and compared to number of events from the signal region

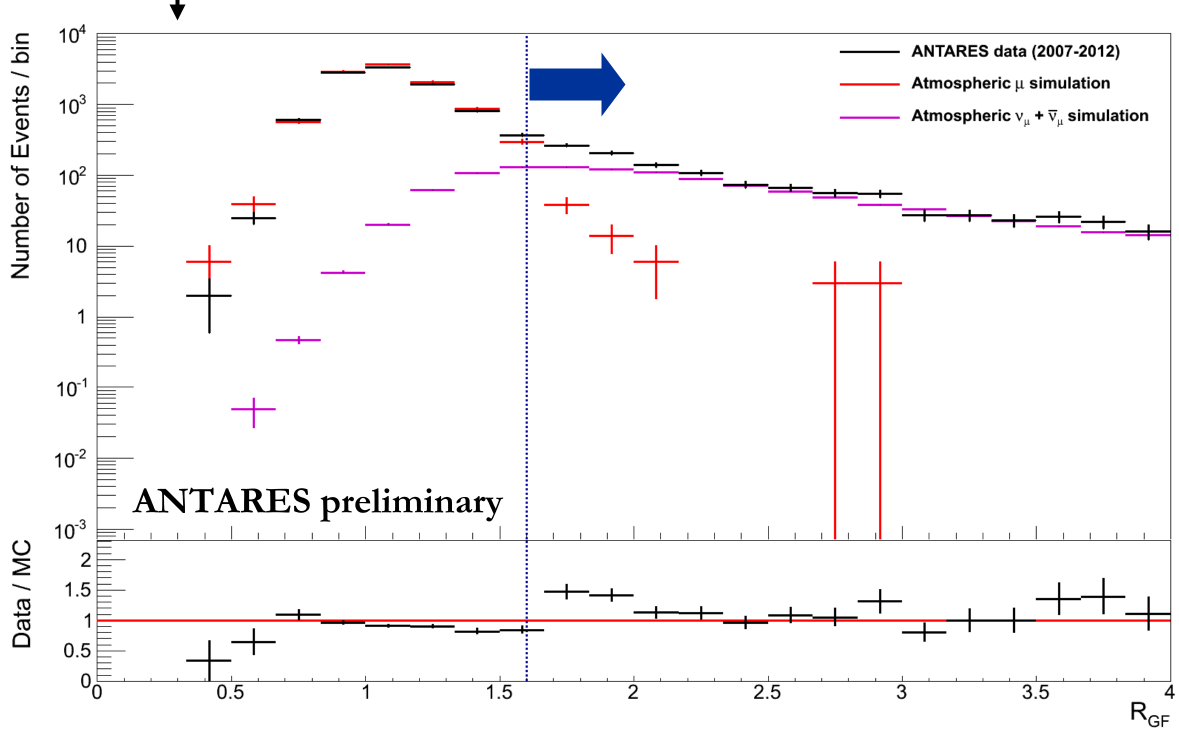
The background

1. Atmospheric muons

- Reducible background
- Only consider high quality, upgoing events

Parameter	Description	Cut value
β	angular error estimate	< **8.0°**
R_{GF}	event topology	> **1.6**
Λ (default trigger)	fit quality	> **-5.62**
Λ (low energy trigger)	fit quality	> **-5.57**





The background

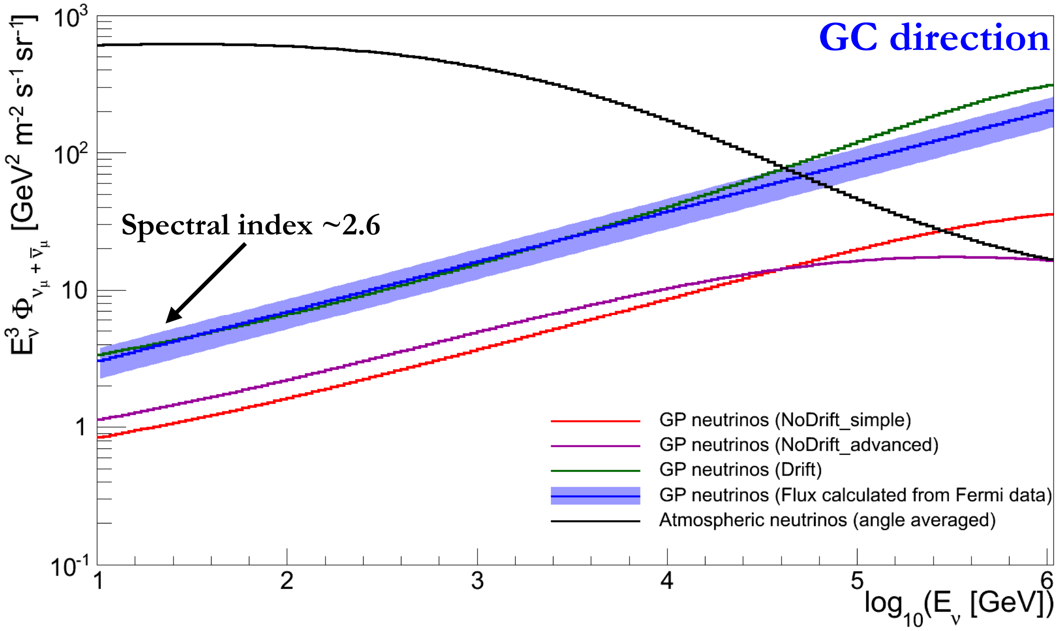
1. Atmospheric muons

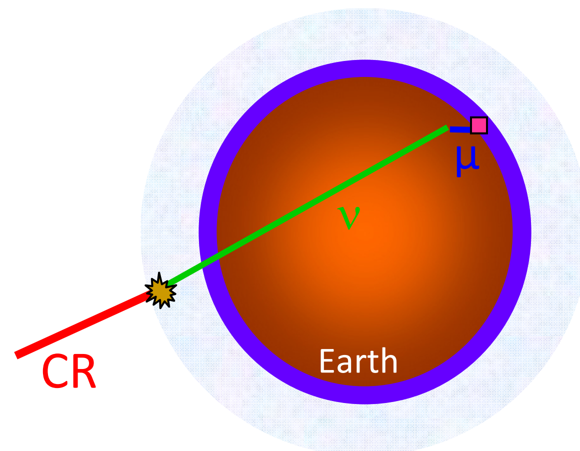
- Reducible background
- Only consider high quality, upgoing events

2. Atmospheric neutrinos

- Irreducible background
- Use energy estimator to suppress

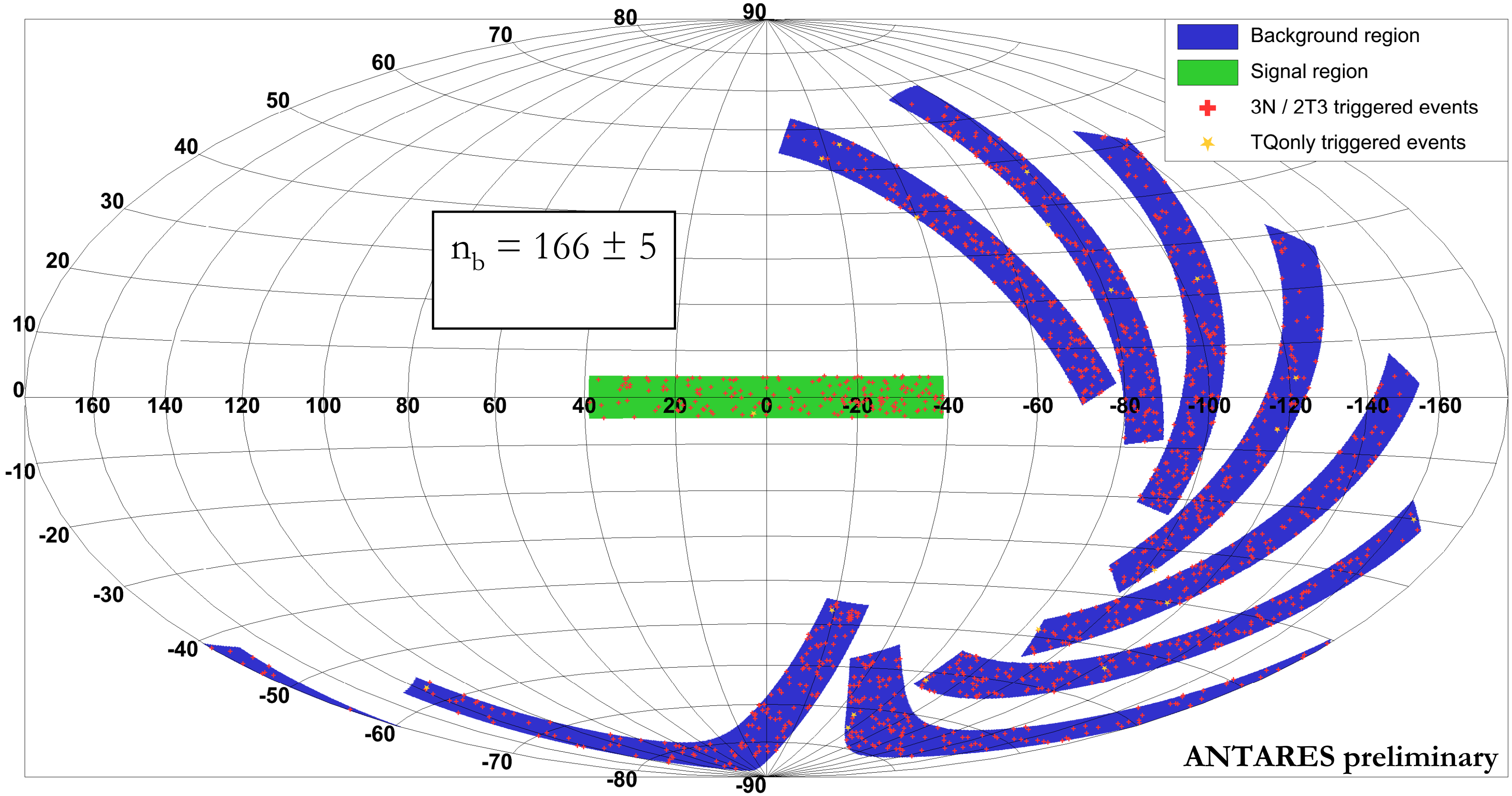
Trigger	E_{rec} [GeV]
Default trigger	> **350**
Low energy trigger	**> 250**





ANTARES results

Used data: 2007 – 2012



- Signal prediction: ~0.6 – 1.8 events

ANTARES results

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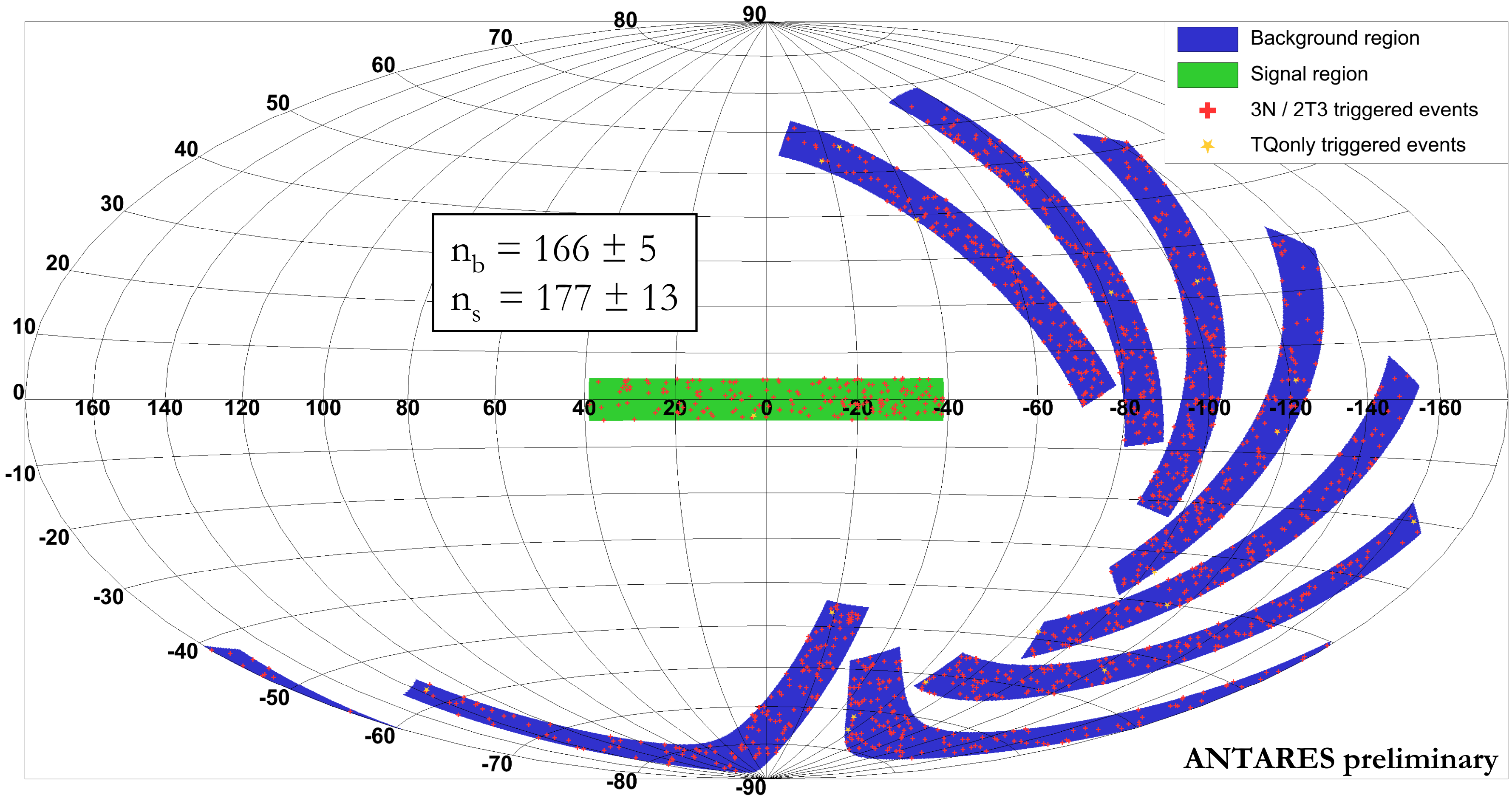
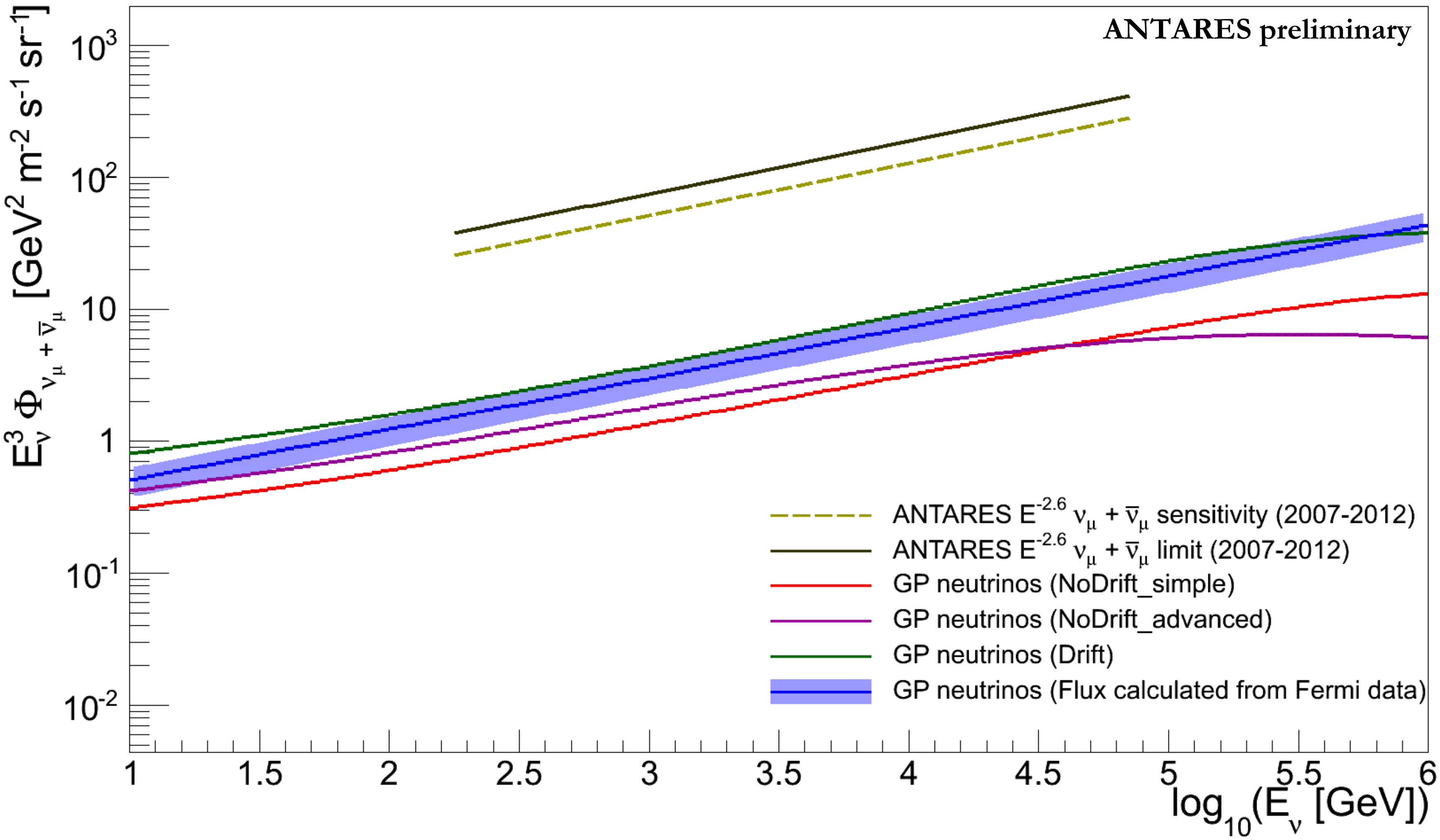


- Signal prediction: ~0.6 – 1.8 events
- Excess corresponds to 0.8σ

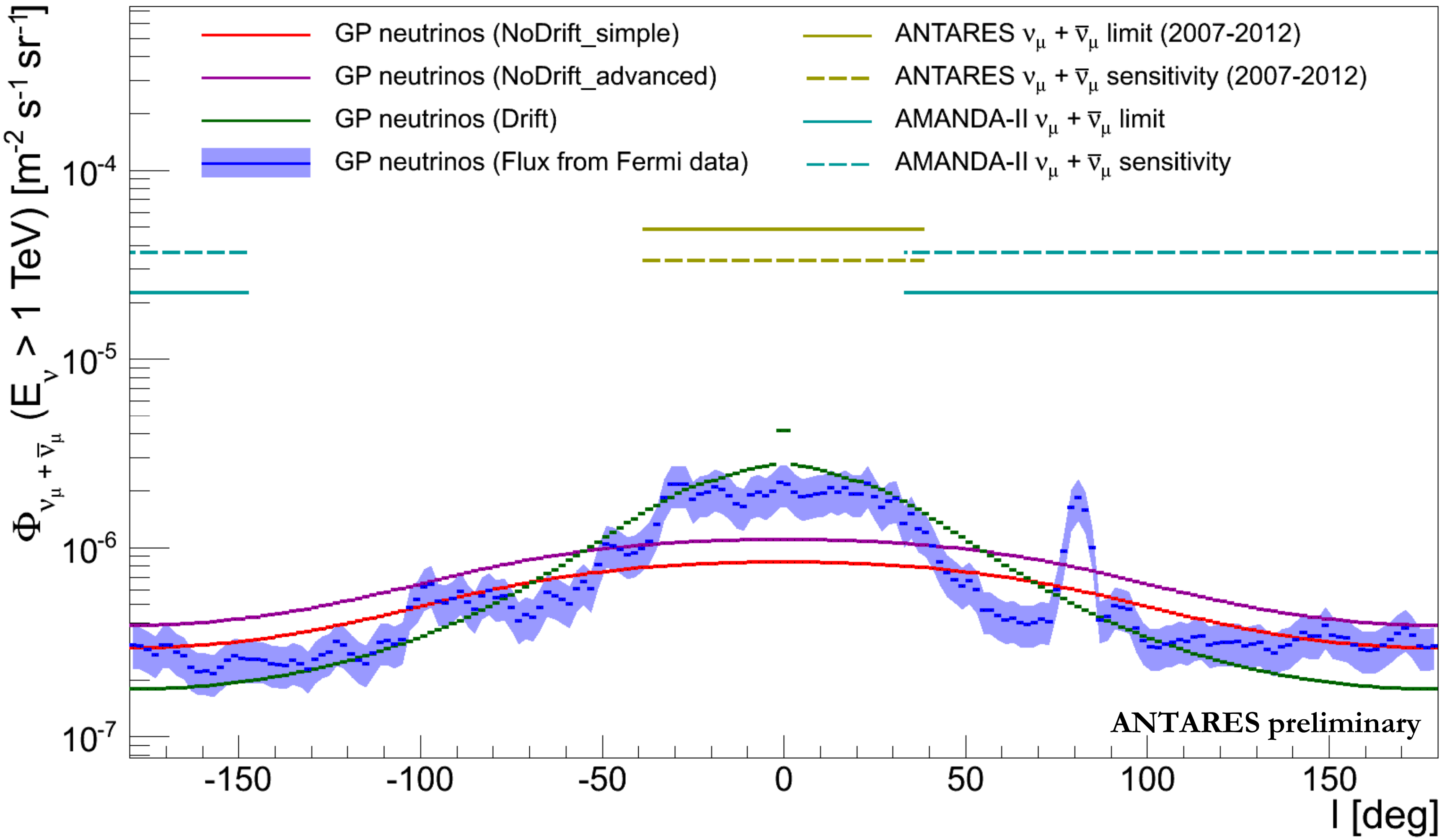
ANTARES results: flux upper limits



- Flux limit: $\Phi_{\nu_\mu + \bar{\nu}_\mu} < 4.61 \, E^{-2.6} \, \mathrm{GeV}^{-1} \, \mathrm{m}^{-2} \, \mathrm{sr}^{-1} \, \mathrm{s}^{-1}$ (178 GeV < E < 70.8 TeV)

  central 90% of the signal

ANTARES results: flux upper limits



- Flux limit: $\Phi_{\nu_\mu + \bar{\nu}_\mu} < 10.18\ E^{-2.7}\ \mathrm{GeV}^{-1}\ \mathrm{m}^{-2}\ \mathrm{sr}^{-1}\ \mathrm{s}^{-1}$ (153 GeV < E < 52.1 TeV)

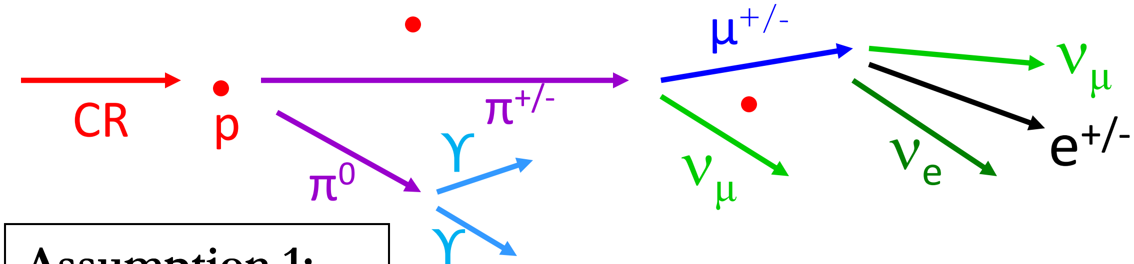
central 90% of the signal

Conclusions and outlook

- Measurement of (muon) neutrino flux from cosmic ray interactions in the Milky Way has been performed
- Small excess seen, compatible with background fluctuation (0.8σ)
- Flux upper limits have been set
- KM3NeT will be able to improve limits

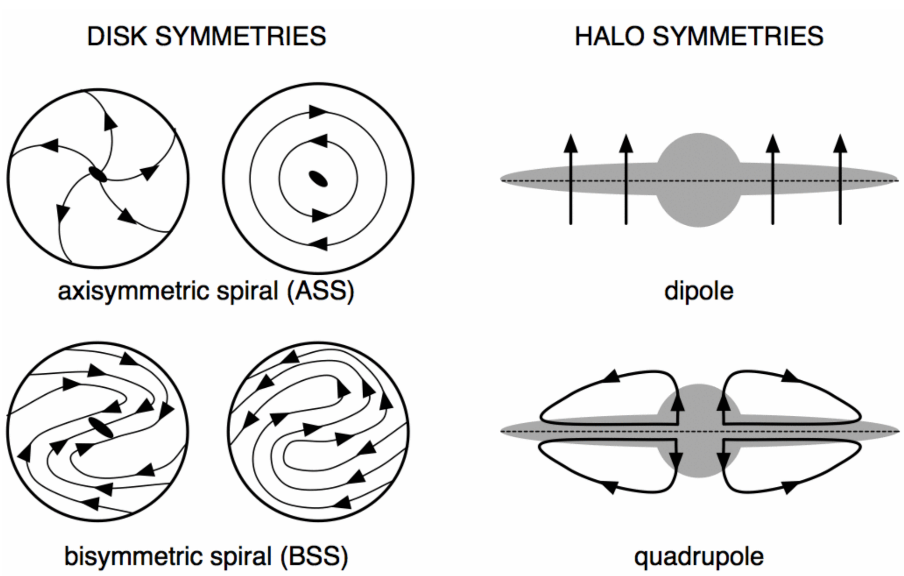
Backup

Theoretical models

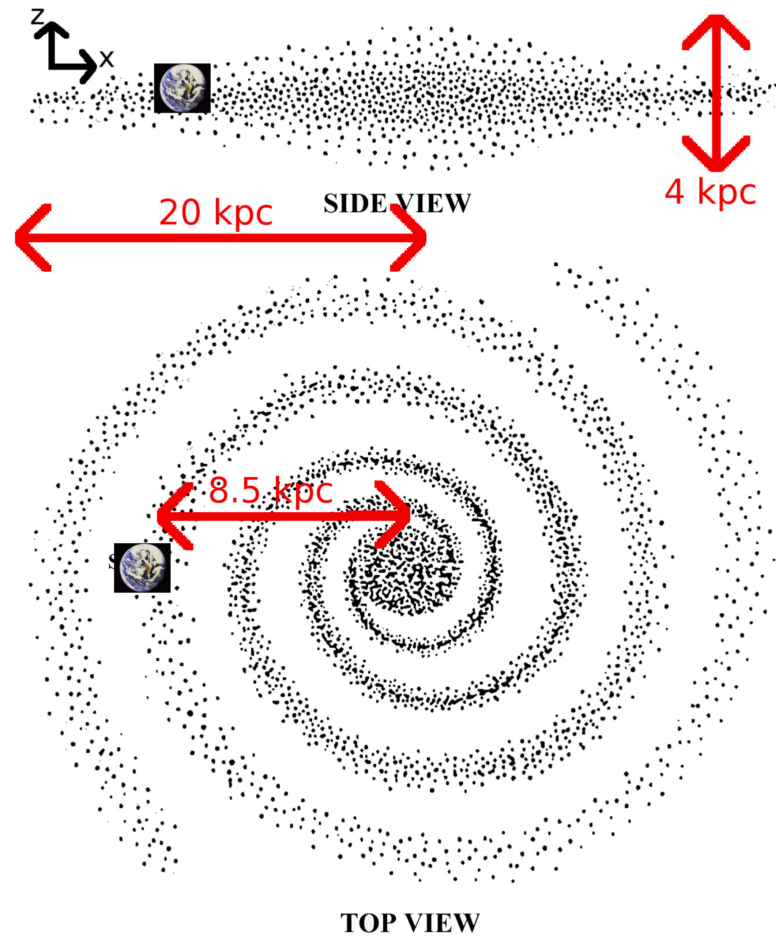


Assumption 1: cosmic ray flux

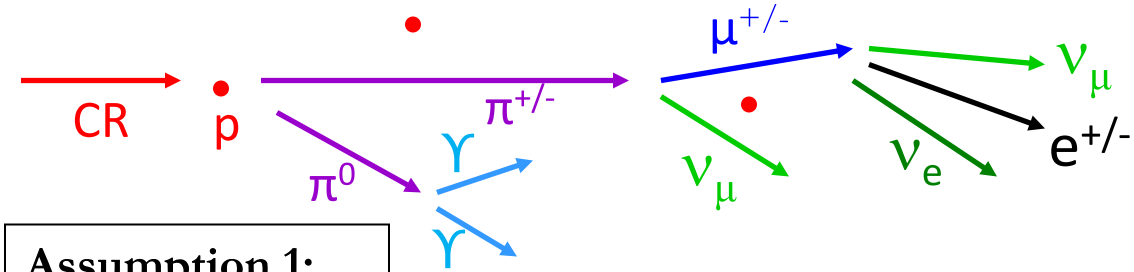
Assumption 2: matter density



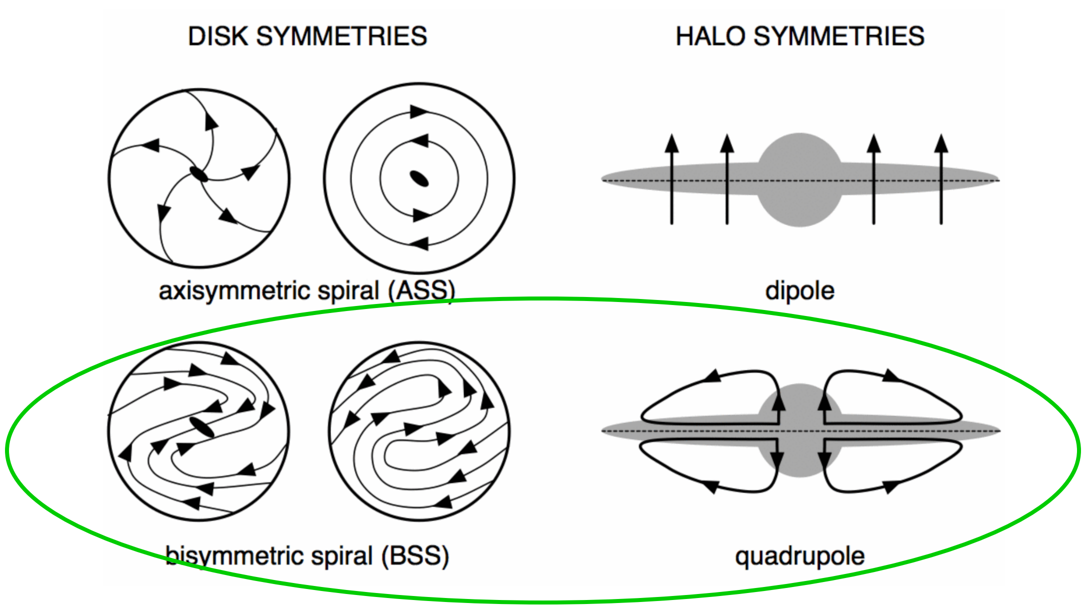
Assumption 3: magnetic field



Theoretical models



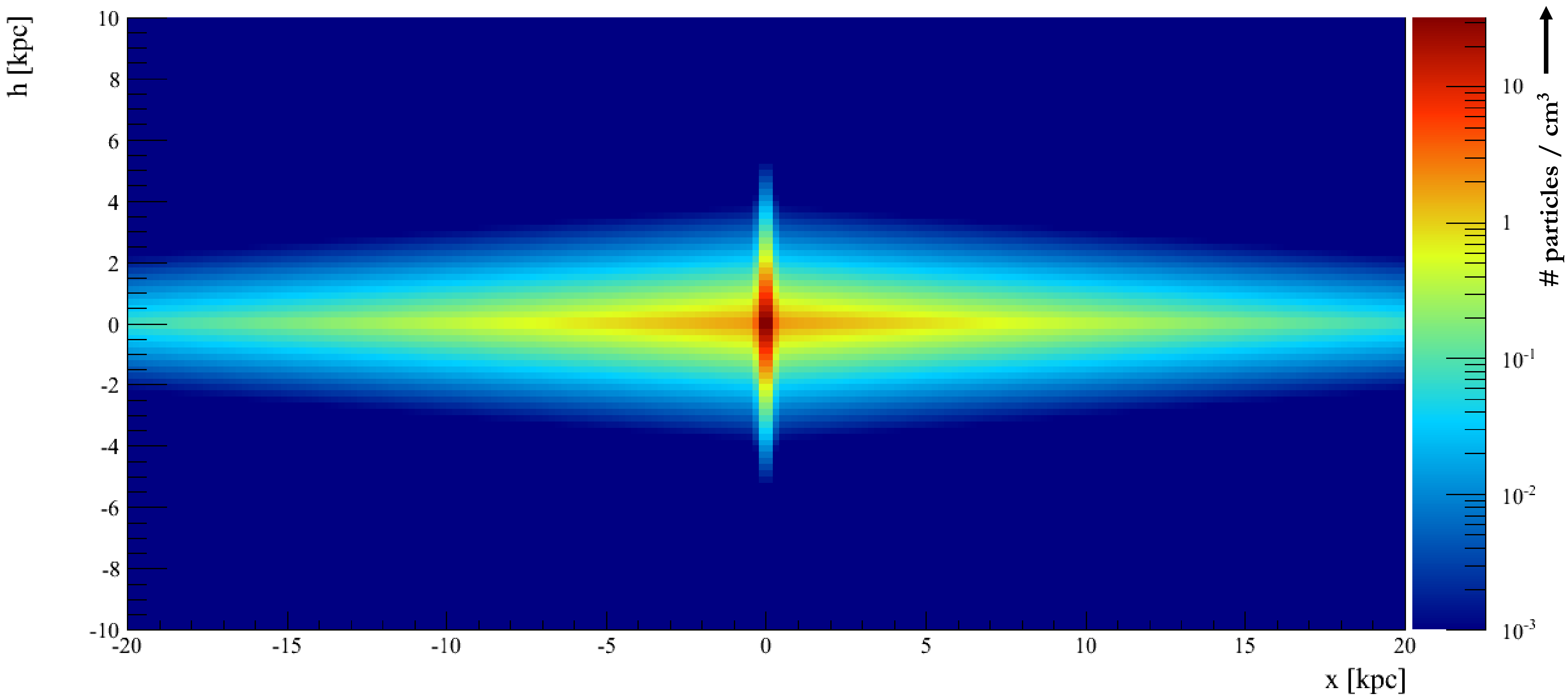
Assumption 1:
cosmic ray flux



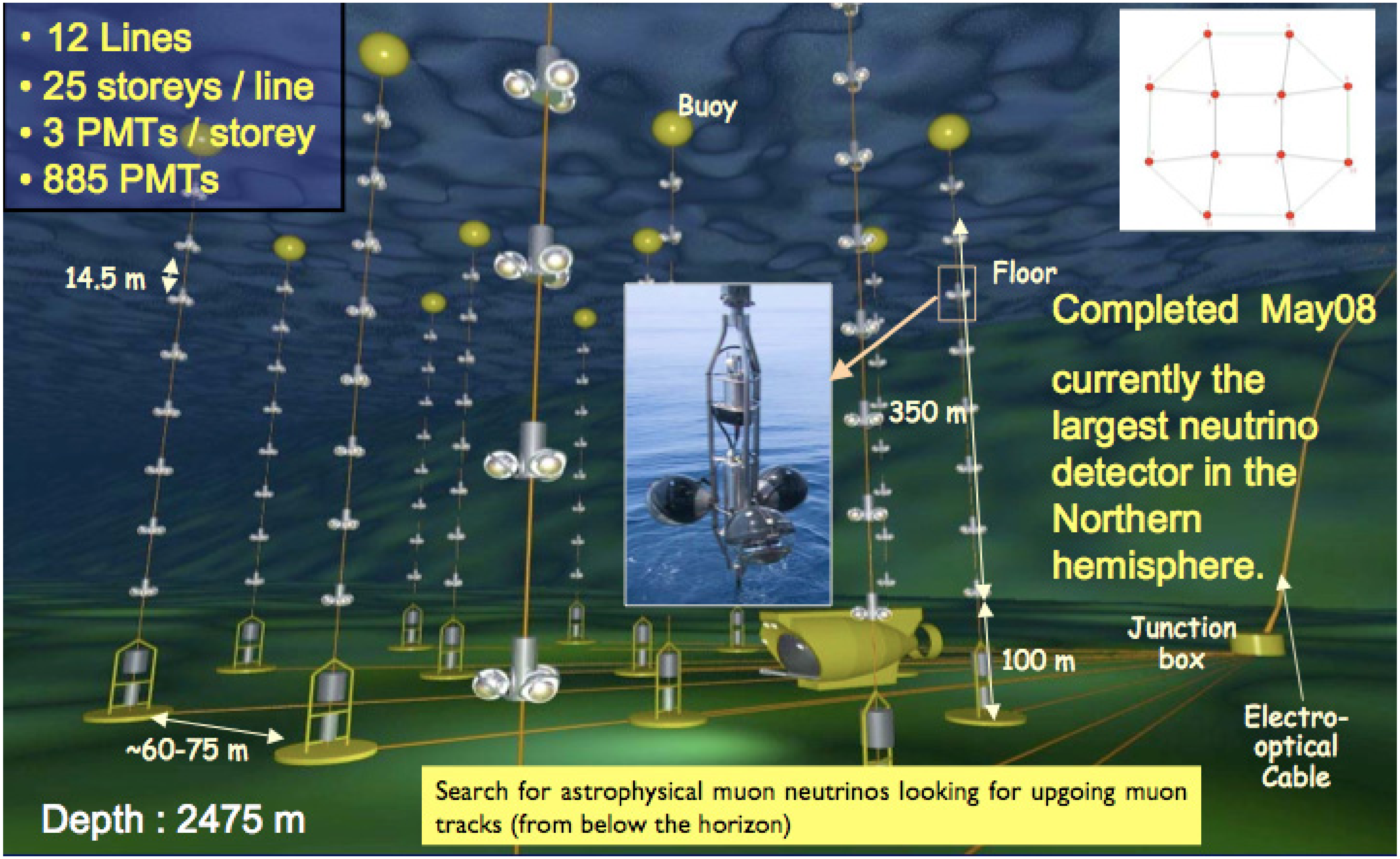
Assumption 3:
magnetic field

- NoDrift_simple model
  - Constant matter density
  - Neglect magnetic field
- NoDrift_advanced model
  - Take CR composition into account
- Drift model
  - Magnetic field gives drift of CRs to GC
  - Model the matter density

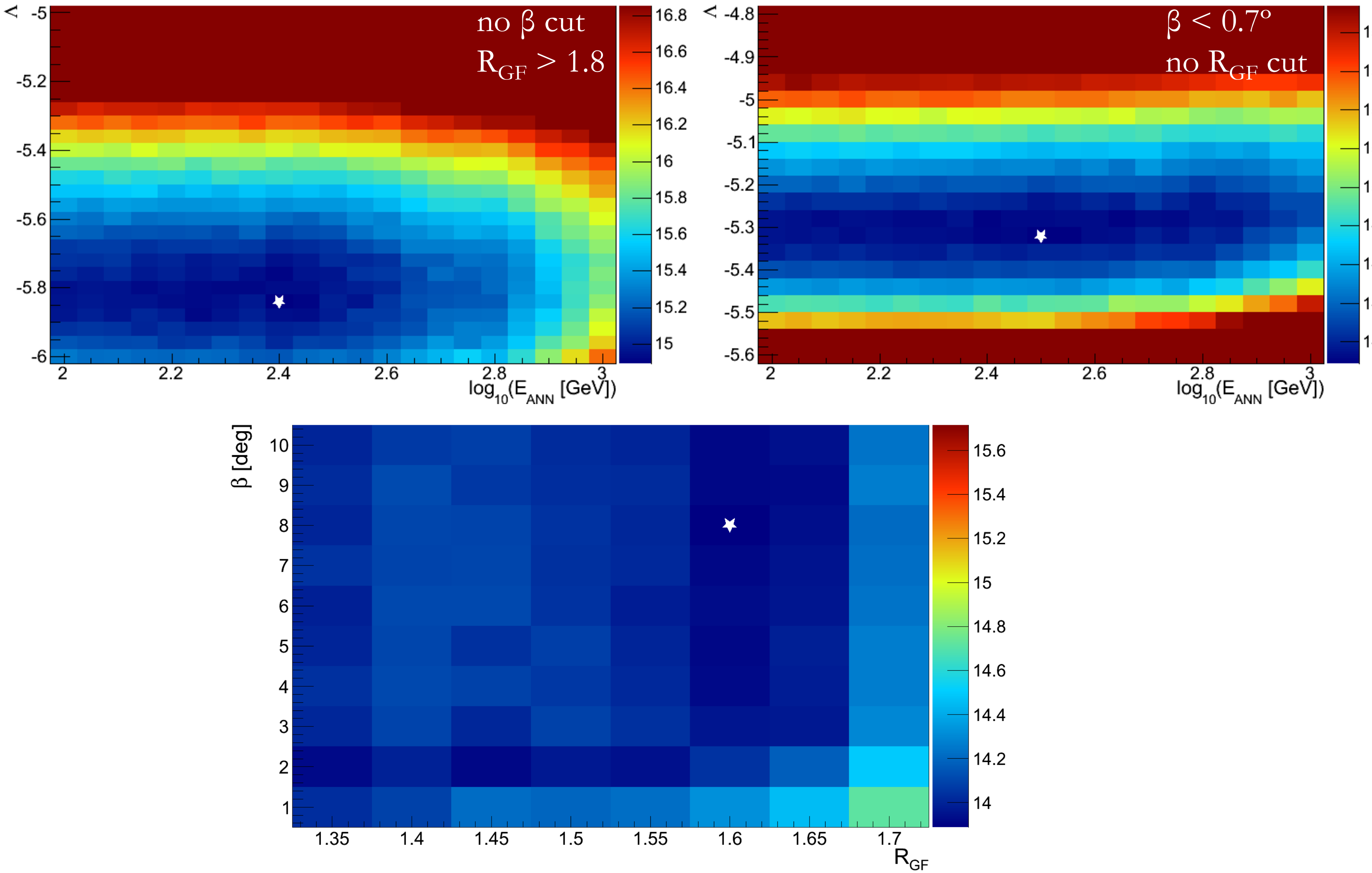
Matter density in the galaxy (Drift)



The ANTARES detector

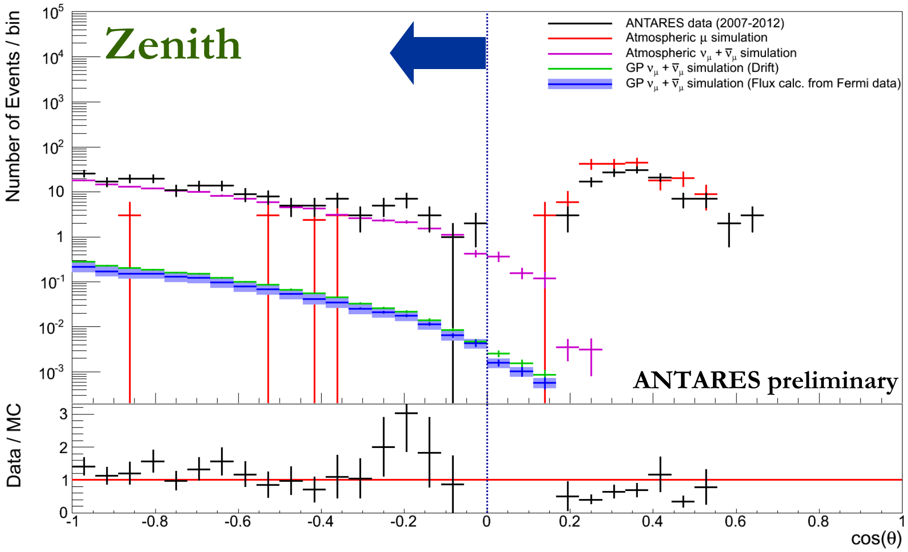


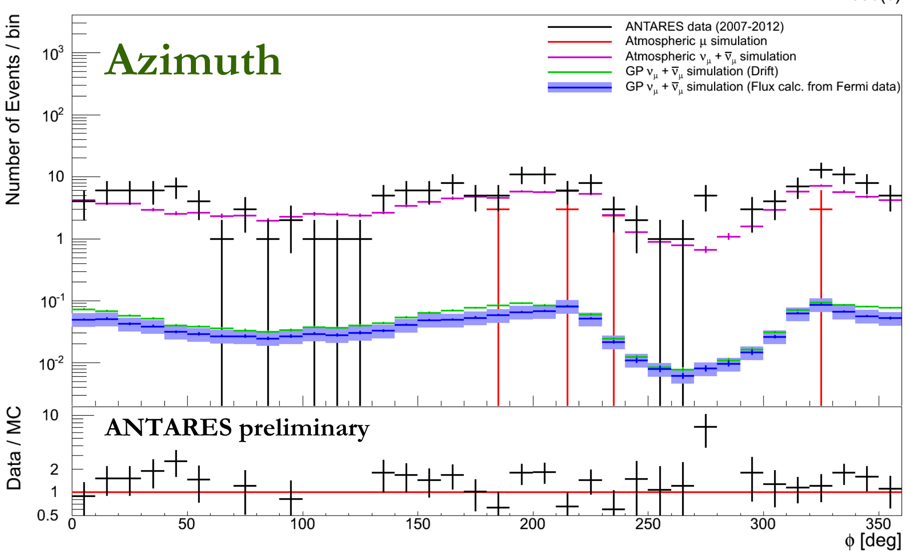
Cut optimisation



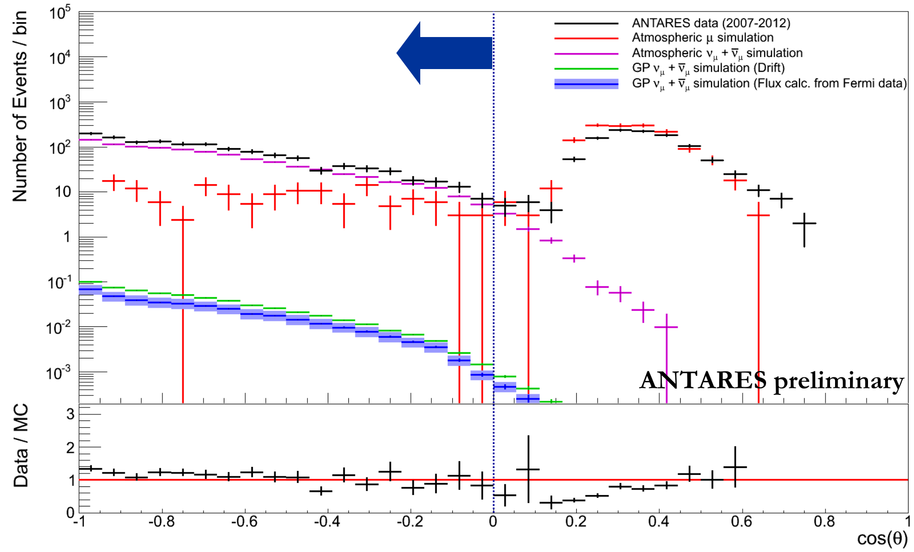
Data-MC comparison

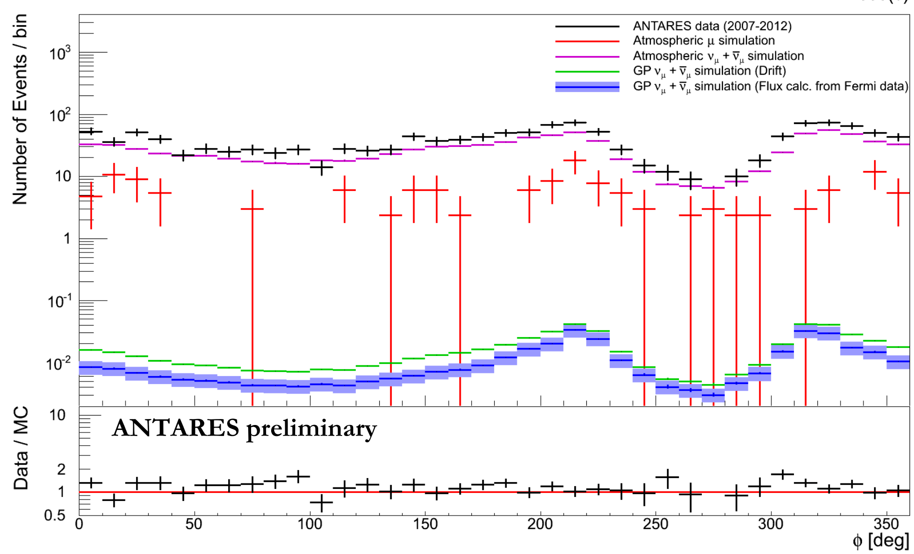
Signal region:





Sum of 8 background regions:





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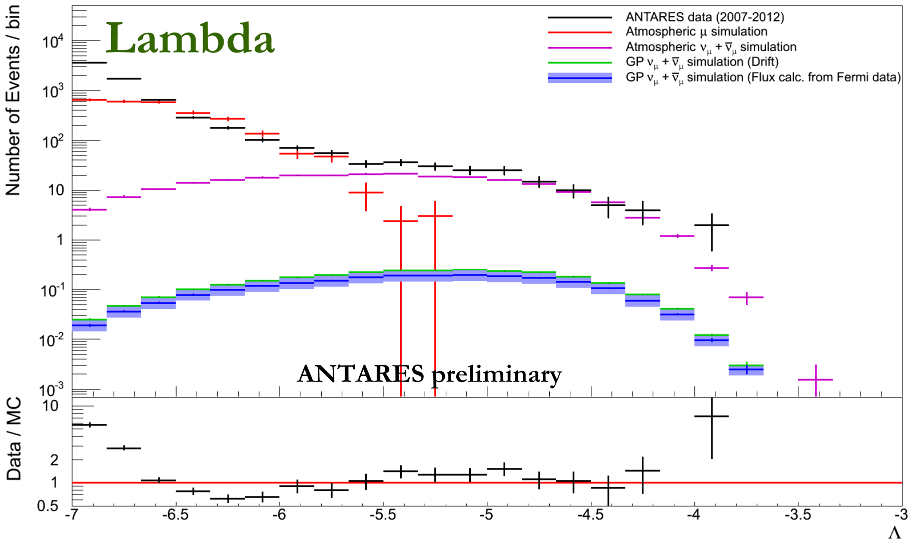

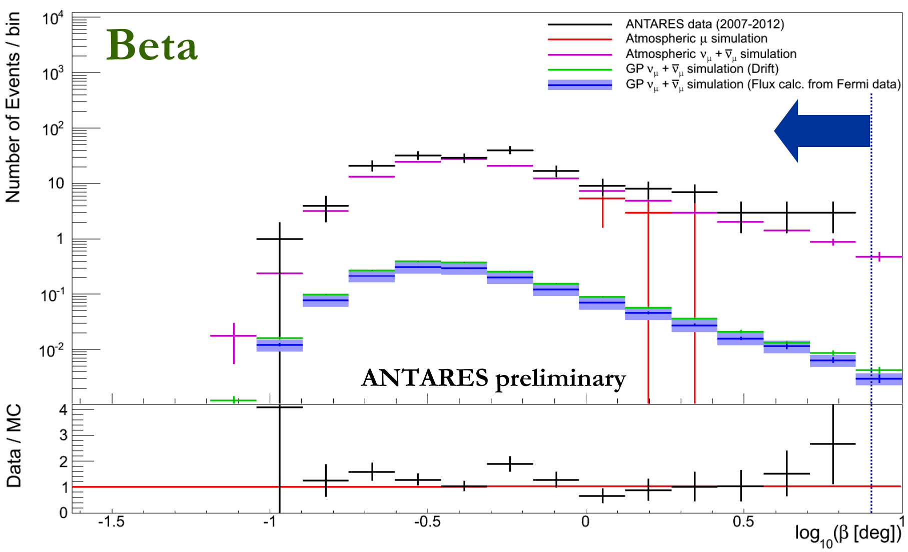

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