Search for GeV neutrinos associated with solar flares
IceCube Neutrino Observatory
South Pole, Antarctica
IceCube

- 1km³ of instrumented ice
- 1.5km below the South Pole surface
- 5160 optical modules
- Modules detecting Cherenkov radiation
- Completed in 2010
Astrophysical neutrino

PeV neutrino
Since 2013, we kept pushing the detection limits, with e.g.:

- sterile neutrino limits
- WIMP-nucleon cross section limits
- neutrino oscillation measurements
- multimessenger and realtime analyses
GeV neutrino
You might be thinking:

- GeV neutrinos, where could they come from?
- How can you even see this kind of events?
- IceCube? Neutrino? I thought I was at Fermi Symposium.
You might be thinking:

- GeV neutrinos, where could they come from?
- How can you even see this kind of events?
- IceCube? Neutrino? I thought I was at Fermi Symposium.
Sun

GeV neutrino
Solar flare $\nu$, what?

- $\nu$ hadron acceleration (up to several GeV)
- $p + p \rightarrow \nu$ atm
- $\nu$ Solar Energetic Particles

\[
\begin{align*}
\pi^+ &\rightarrow \mu^+ + \nu_\mu \\
\mu^+ &\rightarrow e^+ + \nu_e + \bar{\nu}_\mu \\
\pi^0 &\rightarrow 2 \gamma \\
\pi^- &\rightarrow \mu^- + \bar{\nu}_\mu \\
\mu^- &\rightarrow e^- + \bar{\nu}_e + \nu_\mu
\end{align*}
\]
You might be thinking:

- GeV neutrinos, where could they come from?
- How can you even see this kind of events?
- IceCube? Neutrino? I thought I was at Fermi Symposium
Astrophysical neutrino

Atmospheric muon

Pure noise

GeV neutrino
Let’s do the event selection together!
Astrophysical neutrino

Atmospheric muon

Difference?

Pure noise

GeV neutrino
Astrophysical neutrino

Atmospheric muon

Pure noise

GeV neutrino

Difference?
Astrophysical neutrino

Pure noise

Atmospheric muon

GeV neutrino

Rate = 0.02 Hz
You might be thinking:

✓ GeV neutrinos, where could they come from?
✓ How can you even see this kind of events?

• IceCube? Neutrino? I thought I was at Fermi Symposium
Solar flare $\nu$, what?

hadron acceleration (up to several GeV)

\[ p + p_{\odot} \text{ atm} \rightarrow \gamma, \mu, \nu, \pi^+, \pi^-, \mu^+, \mu^- \]

\[ p, \alpha... = \text{Solar Energetic Particles} \]

\begin{align*}
\pi^+ &\rightarrow \mu^+ + \nu_\mu \\
\mu^+ &\rightarrow e^+ + \nu_e + \bar{\nu}_\mu \\
\pi^0 &\rightarrow 2\, \gamma \\
\pi^- &\rightarrow \mu^- + \bar{\nu}_\mu \\
\mu^- &\rightarrow e^- + \bar{\nu}_e + \nu_\mu
\end{align*}
Solar flare $\nu$, how?
Solar flare $\nu$, how?

Sun

Fermi

IceCube
2 possible approaches:

1. Use IceCube archival data (2011-now) and study solar flares seen by Fermi-LAT

2. Trigger IceCube based on realtime Fermi observations
2 possible approaches:

1. Use IceCube archival data (2011-now) and study solar flares seen by Fermi-LAT
   - Mar 7th 2012
   - Feb 25th 2014
   - Sep 1st 2014

2. Trigger IceCube based on realtime Fermi observations
Solar flare ν, how?

Fermi light curve for March 7th, 2012
Ajello et al., 2014
Solar flare $\nu$, how?

20 minutes

Fermi light curve for March 7\textsuperscript{th}, 2012
Ajello et al., 2014
2 possible approaches:

1. Use IceCube archival data (2011-now) and study solar flares seen by Fermi-LAT
   - Mar 7th 2012
   - Feb 25th 2014
   - Sep 1st 2014

2. Trigger IceCube based on realtime Fermi observations
   - HitSpool data -> SFNews
Solar flare \( \nu \), how?
Solar flare $\nu$, how?
- Sep 6$^{th}$ 2017
- Sep 10$^{th}$ 2017
- ...

Sun

Fermi

IceCube
Beam of protons: \[ F(E) = A E^{-\delta} H(E_{\text{max}} - E) \]

A and \( \delta \) derived from observations

Fixed \( \delta = 3.2 \)
Beam of protons: \[ F(E) = A \ E^{-\delta} \ H(E_{\text{max}} - E) \]

A and \( \delta \) derived from observations

Fixed \( \delta = 3.2 \)

Together, we can constrain proton acceleration in solar flares!
Take-home messages

- **IceCube** is sensitive to **GeV neutrinos** from transient sources
- **Fermi** is an **essential** partner in this search
- Together, we can constrain **solar flare** physics and much more!

Thanks!
IceCube

- 1km$^3$ of instrumented ice
- 1.5km below the South Pole surface
- 5160 optical modules
- Modules detecting Cherenkov radiation
- Completed in 2010