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Mind the Gap on IceCube

Cosmic neutrino spectrum and muon anomalous magnetic moment

Toshihiko Ota

Saitama University
埼玉大学

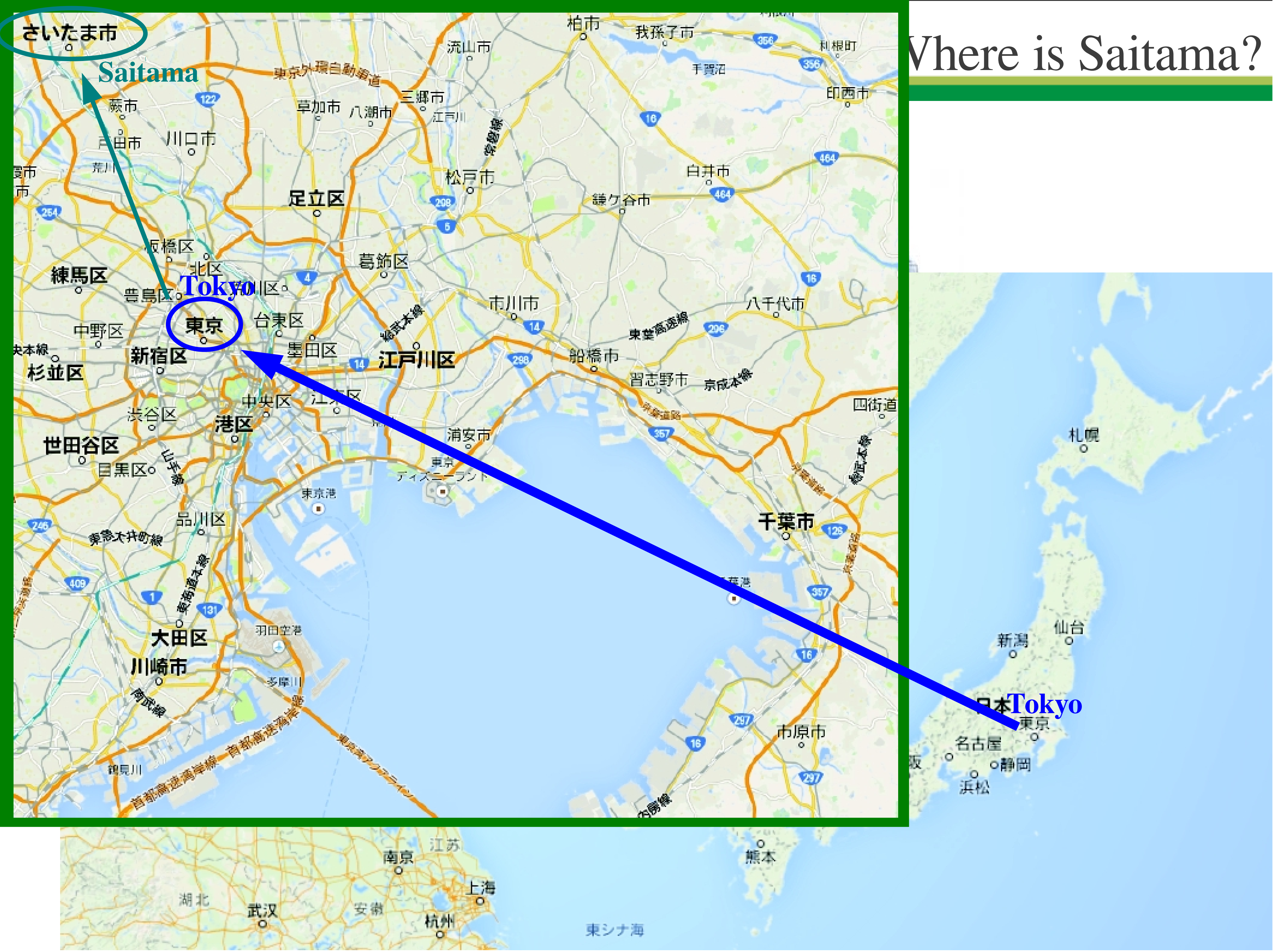
based on

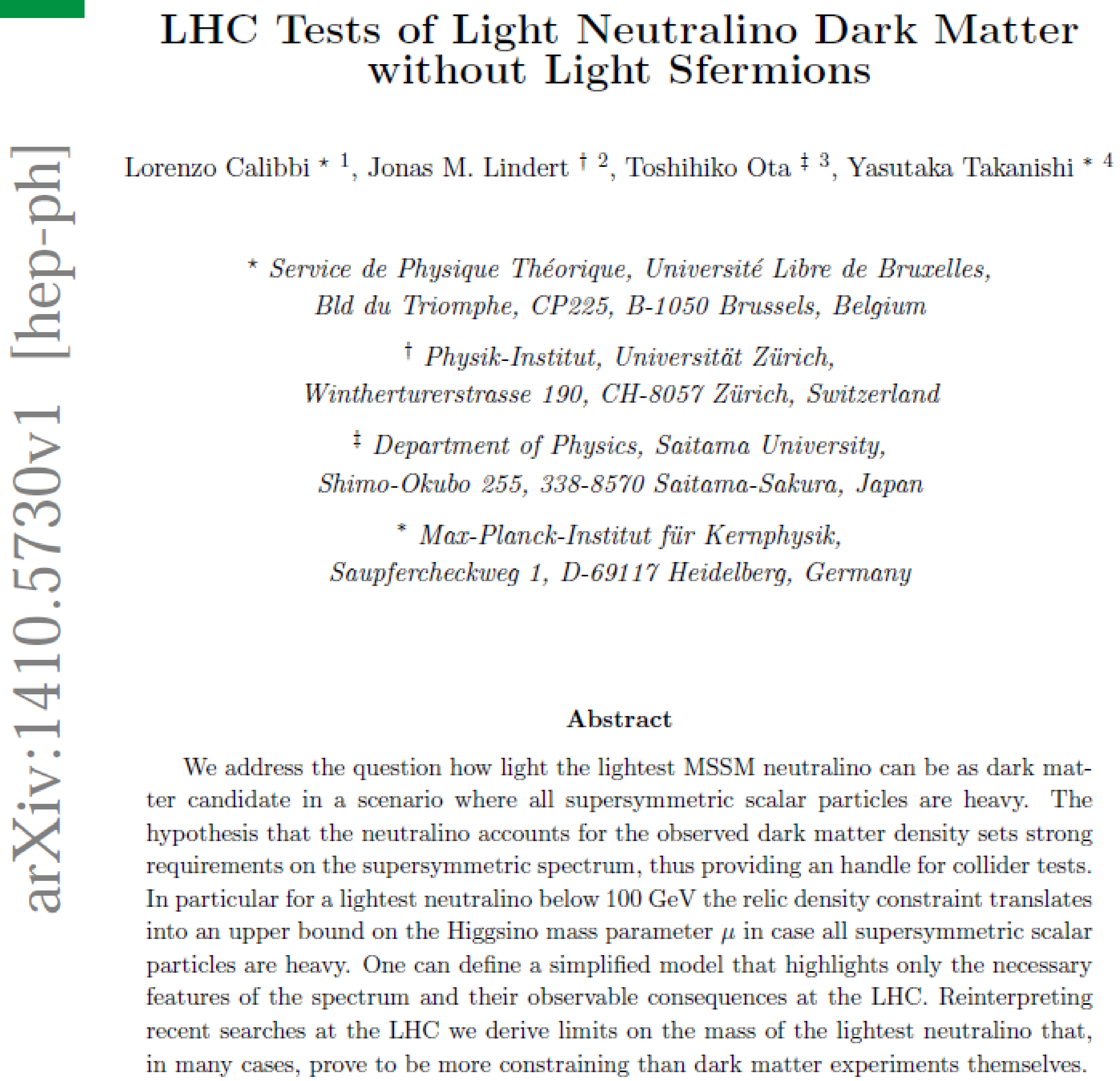
T.Araki, Y.Konishi, F.Kaneko, TO, J.Sato, T.Shimomura

ArXiv.1409.4180v2

Where is Saitama?

Vhere is Saitama?





LHC Tests of Light Neutralino Dark Matter without Light Sfermions

Lorenzo Calibbi [⋆] [1], Jonas M. Lindert [†] [2], Toshihiko Ota [‡] [3], Yasutaka Takanishi [*] [4]

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Abstract

We address the question how light the lightest MSSM neutralino can be as dark matter candidate in a scenario where all supersymmetric scalar particles are heavy. The hypothesis that the neutralino accounts for the observed dark matter density sets strong requirements on the supersymmetric spectrum, thus providing an handle for collider tests. In particular for a lightest neutralino below 100 GeV the relic density constraint translates into an upper bound on the Higgsino mass parameter μ in case all supersymmetric scalar particles are heavy. One can define a simplified model that highlights only the necessary features of the spectrum and their observable consequences at the LHC. Reinterpreting recent searches at the LHC we derive limits on the mass of the lightest neutralino that, in many cases, prove to be more constraining than dark matter experiments themselves.


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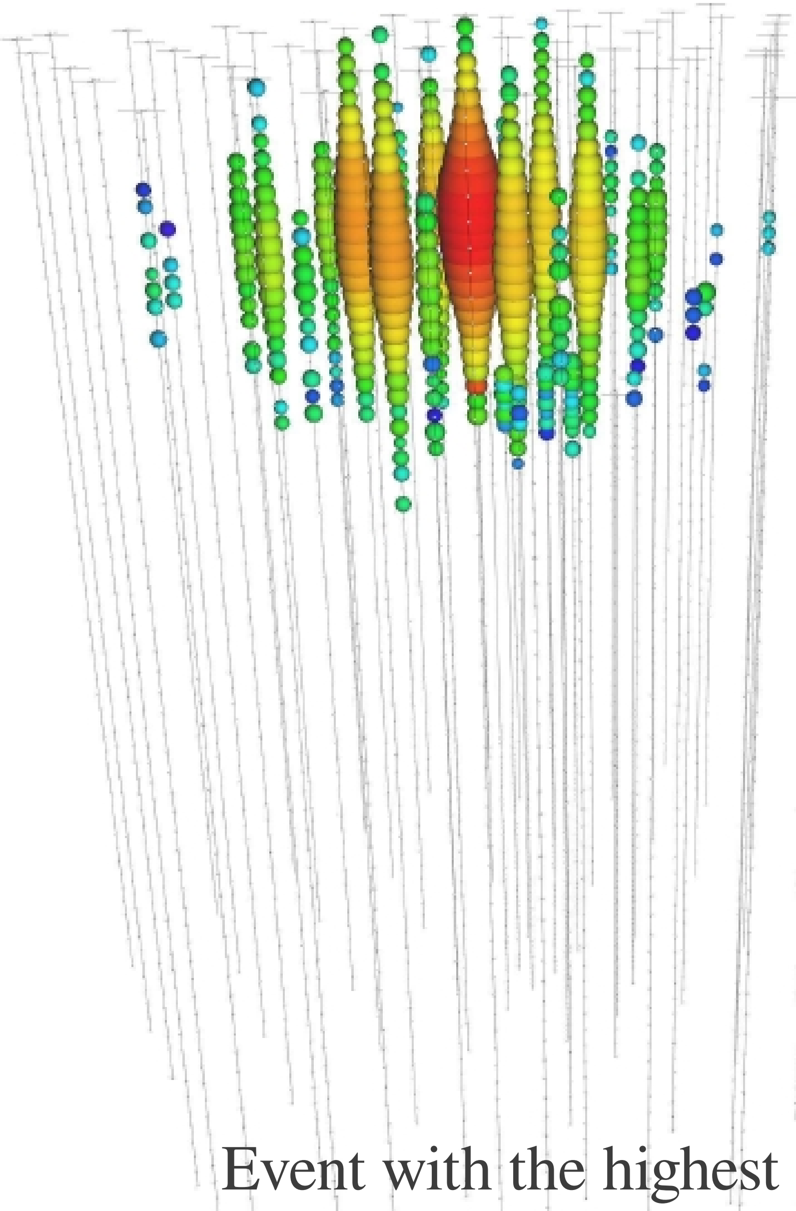
Preface

- PeV cosmic neutrino spectrum
  IceCube collaboration PRL **113** (2014) 101101



Event with the highest deposit energy~2 PeV

ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

Preface

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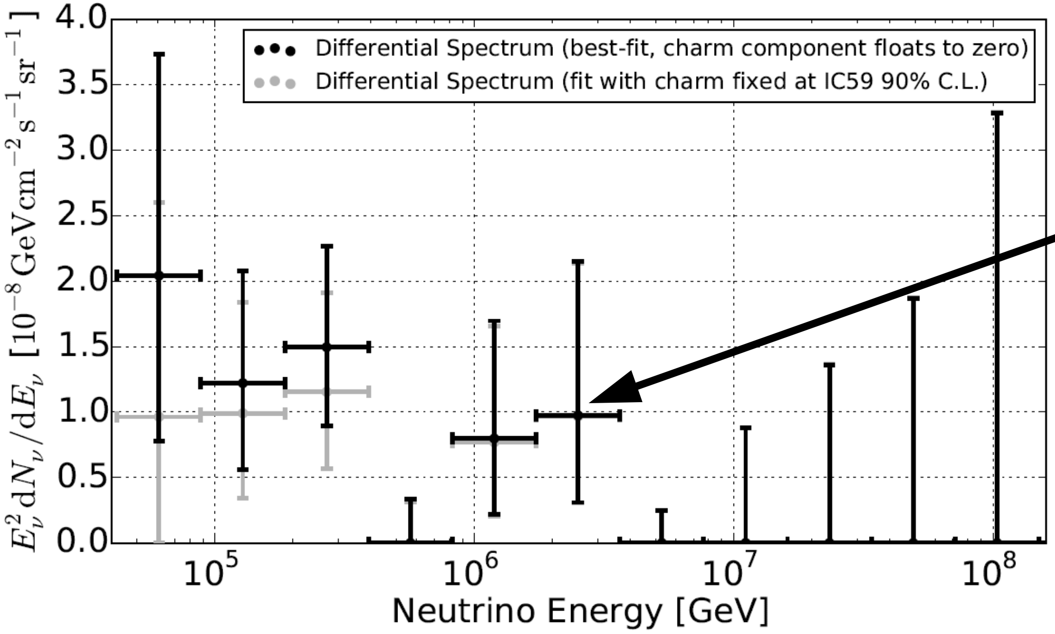
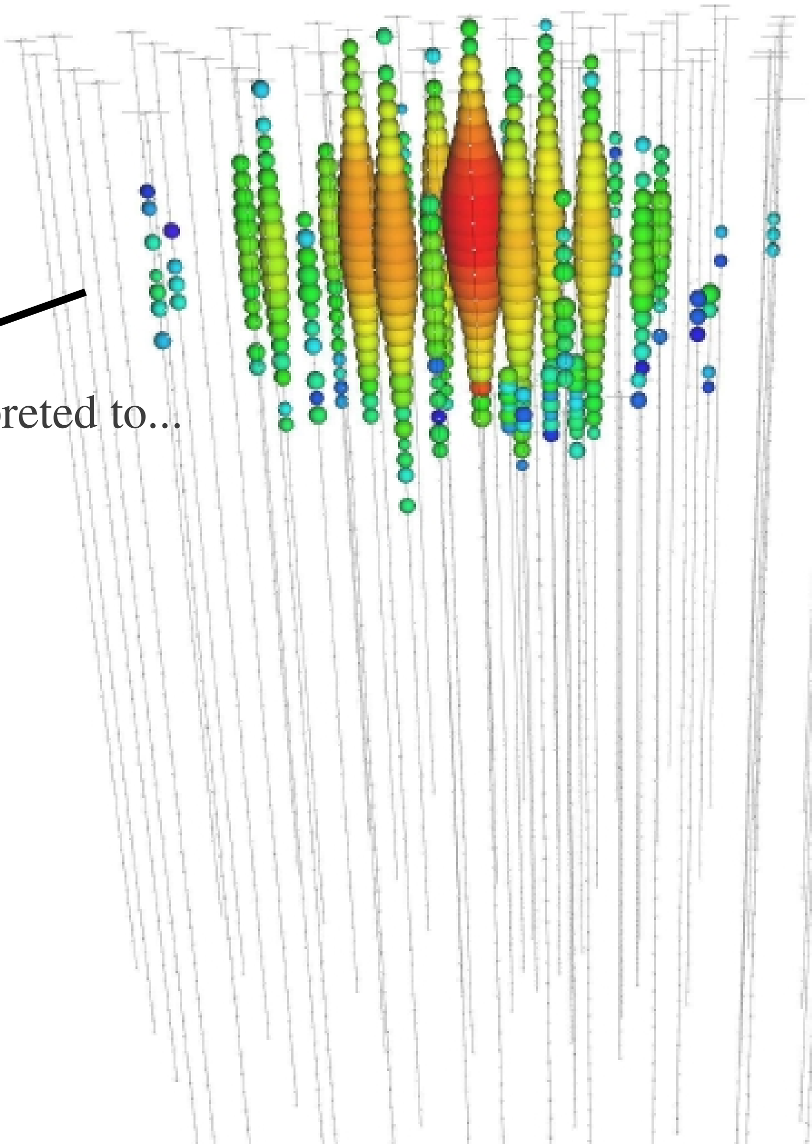


Interpreted to...



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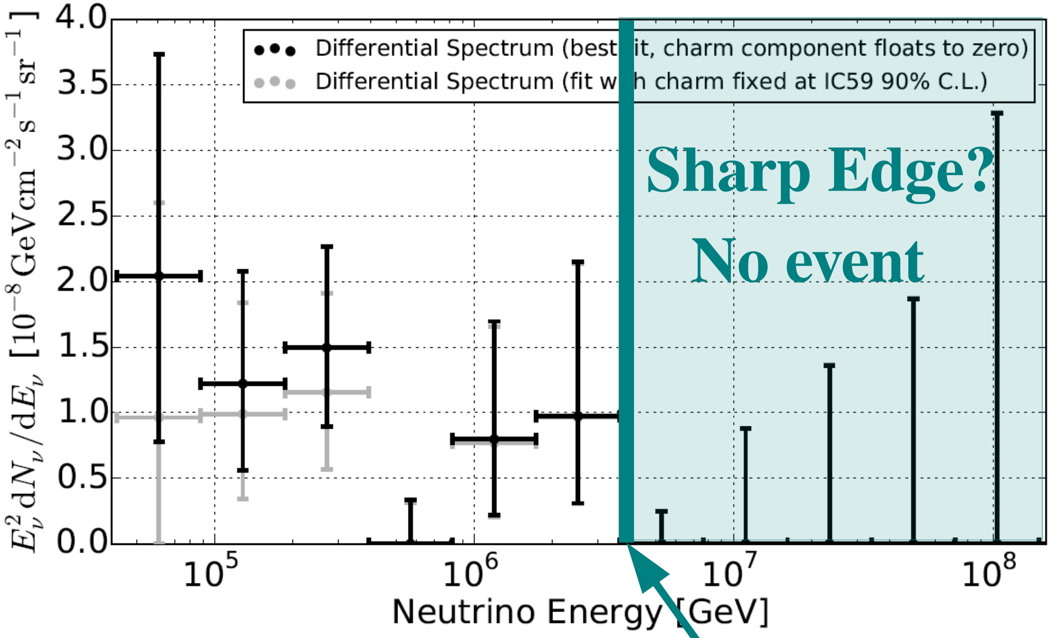


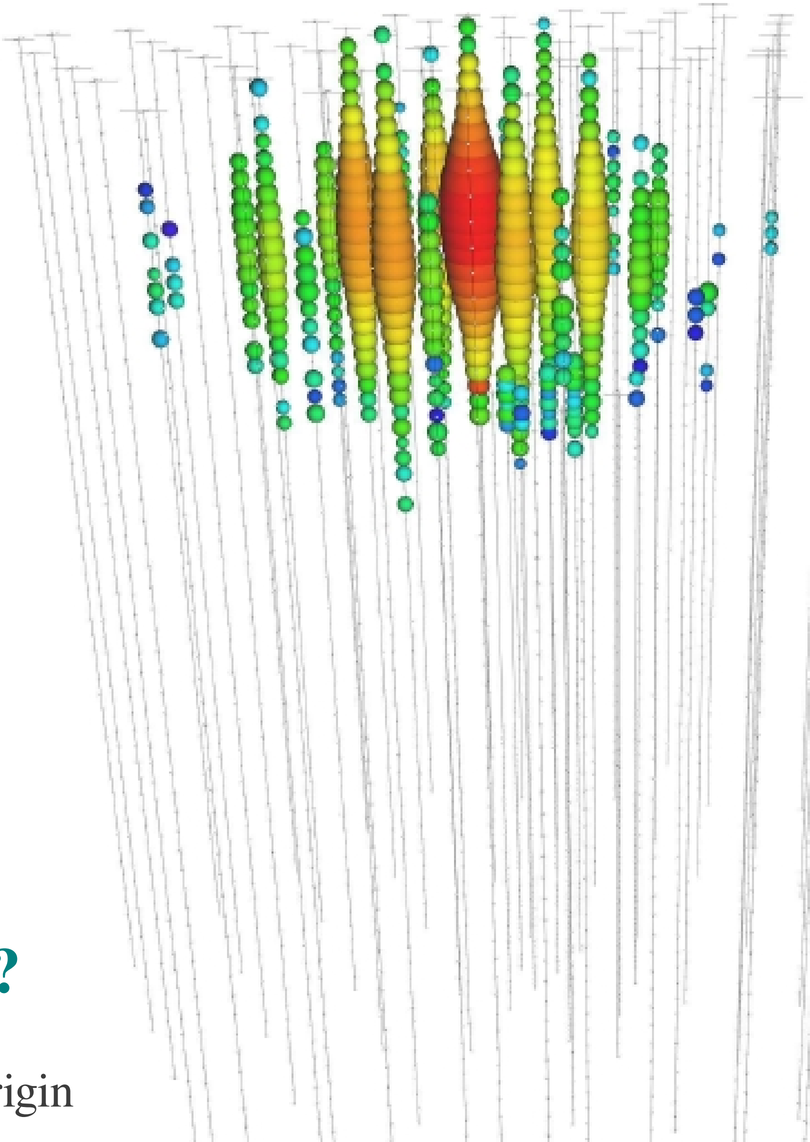
Sharp Edge?

No event

IceCube Edge?

at 3 PeV

may be astrophysical origin



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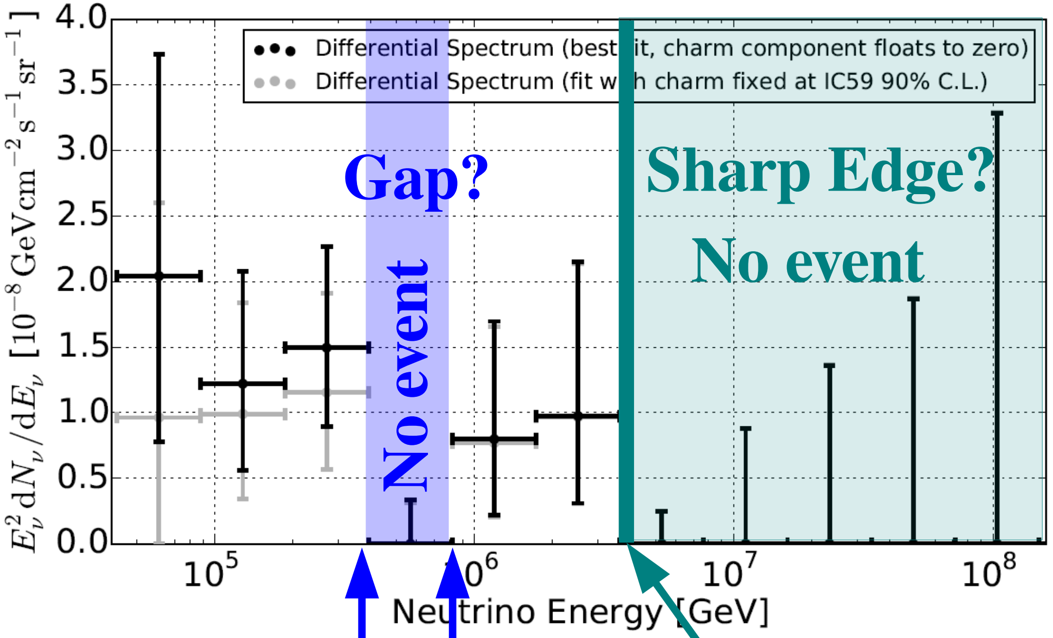

IceCube Gap

No event at 0.4-1 PeV

IceCube Edge?

at 3 PeV

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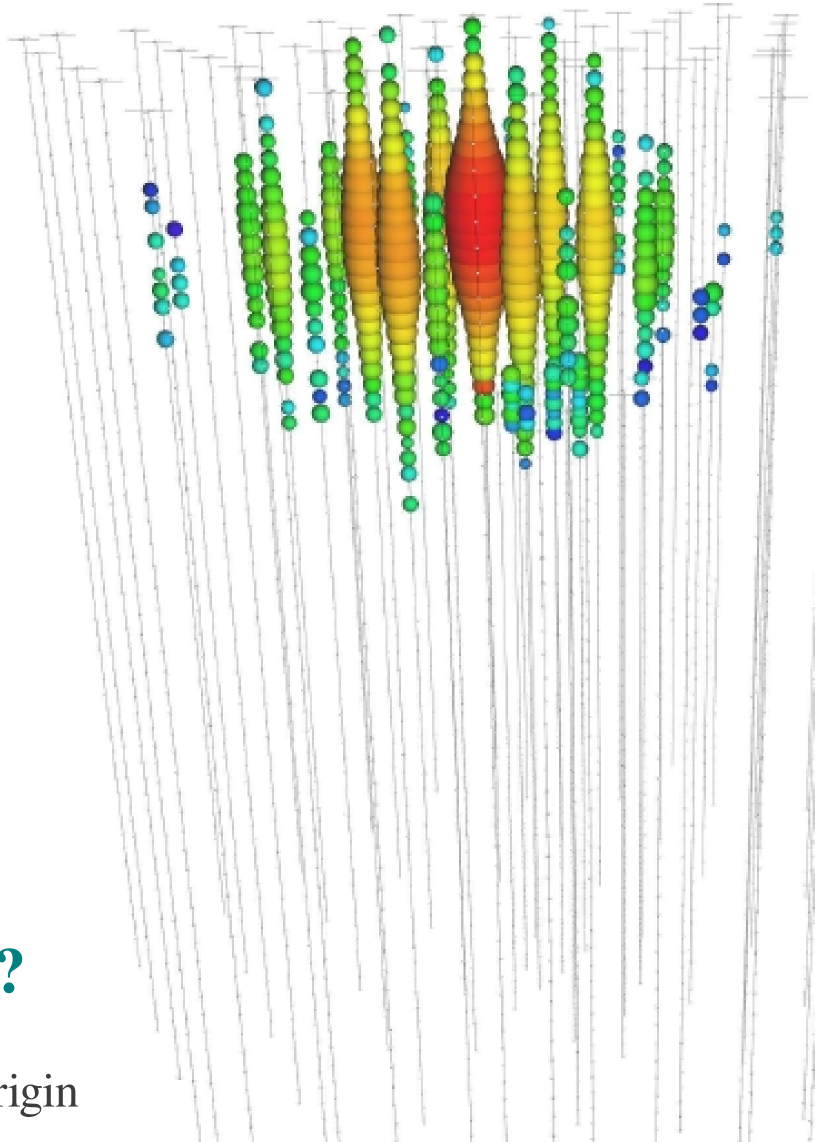

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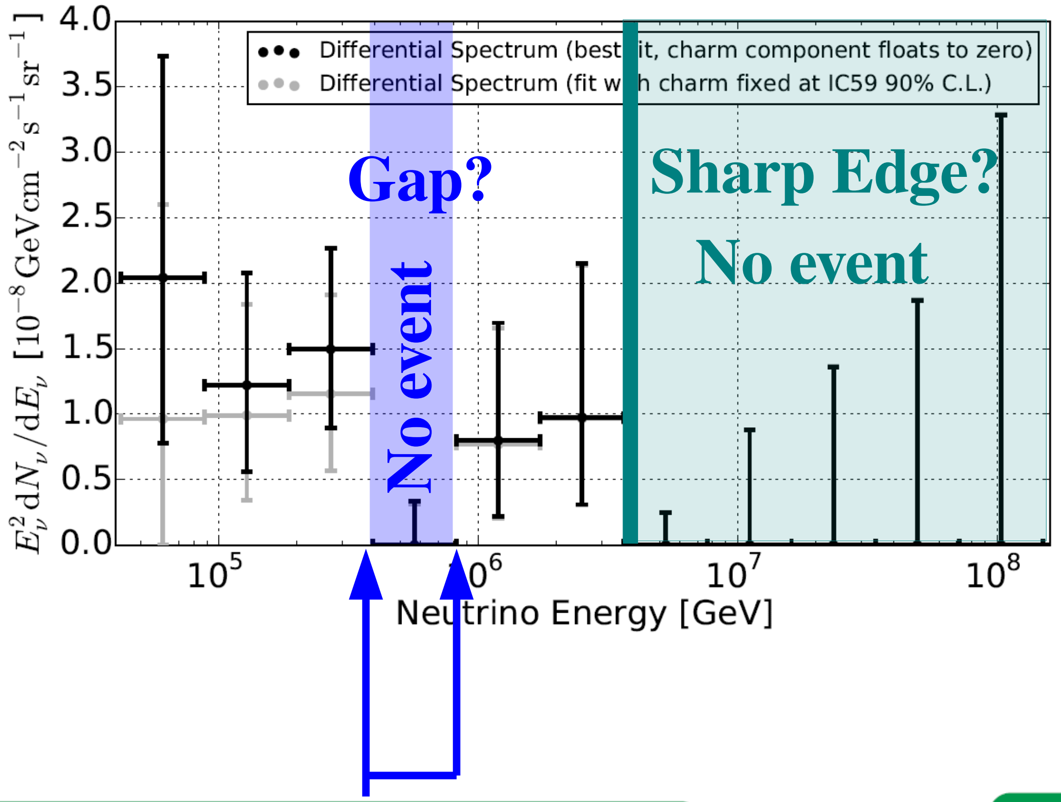
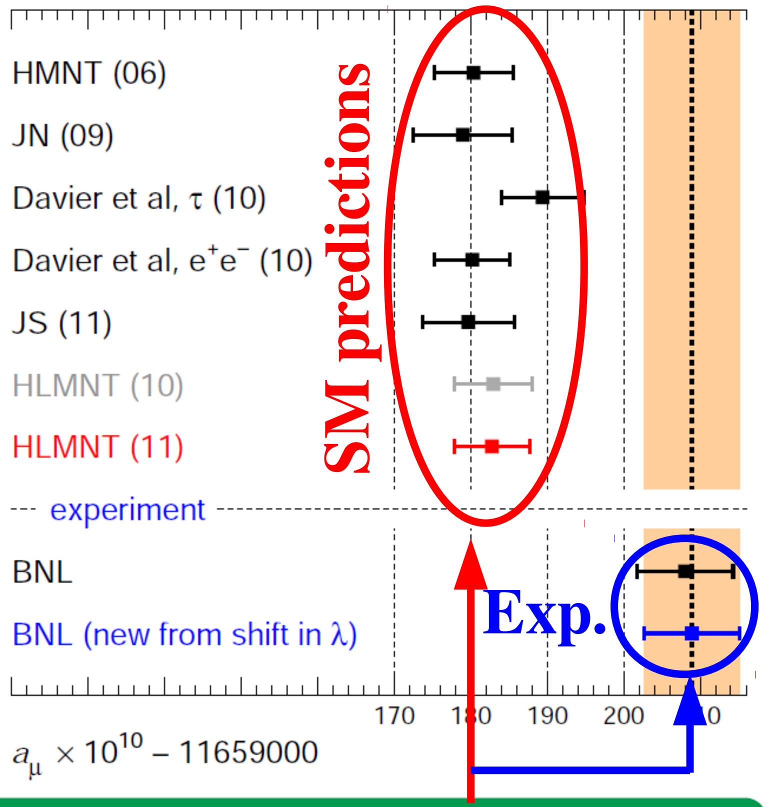


IceCube Gap

No event at 0.4-1 PeV

- Muon g-2

Hagiwara et al., J.Phys. **G38** (2011) 085003



$g_\mu - 2$ Gap

$$a_\mu^{\mathrm{Exp}} - a_\mu^{\mathrm{SM}} = (26.1 \pm 8.0) \cdot 10^{-10} \; (3.3\sigma)$$

New physics at the MeV scale

may explain both the gaps

Outline

1 IceCube gap

- Attenuation of cosmic neutrino by secret neutrino interaction
- Gauged leptonic force $L_\mu - L_\tau$ as secret interaction

2 Muon anomalous magnetic moment

- Gauged leptonic force as a contribution to g-2
- Constraints from colliders and neutrino trident process

3 A solution to the gaps

- Reproduction of IceCube gap → distance to the neutrino source
  → neutrino mass spectrum

① IceCube gap

If the **IceCube Gap** is explained by some **New Physics (NP)**...

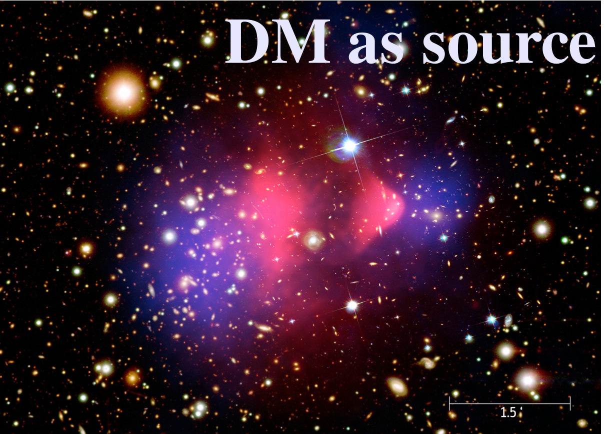
① IceCube gap

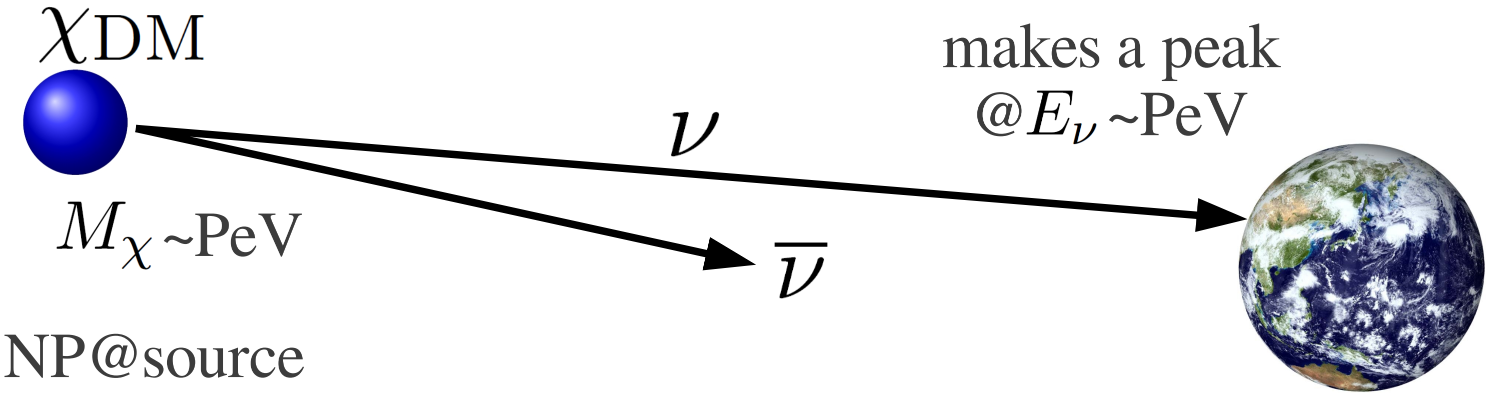
If the **IceCube Gap** is explained by some **New Physics (NP)**...

NP at Source: PeV Dark matter decay

Feldstein Kusenko Matsumoto Yanagida, PR**D88** (2013) 015004. Zabala PR**D89** (2014) 123514.
Ibarra Tran Weniger Int.J.Mod.Phys. **A28** (2013) 1330040.
Esmaili Serpico JCAP **1311** (2013) 054, Esmaili Kang Serpico, 1410.5979.
Ema Jinno Moroi PL**B733**(2014) 120, JHEP **1410** (2014) 150. Rott Kohri Park 1408.3799.
Higaki Kitano Sato JHEP **1407**(2014) 044. Fong Minakata Panes Zukanovich-Funchal 1411.5318.

NASA:Chandra X-ray observatory





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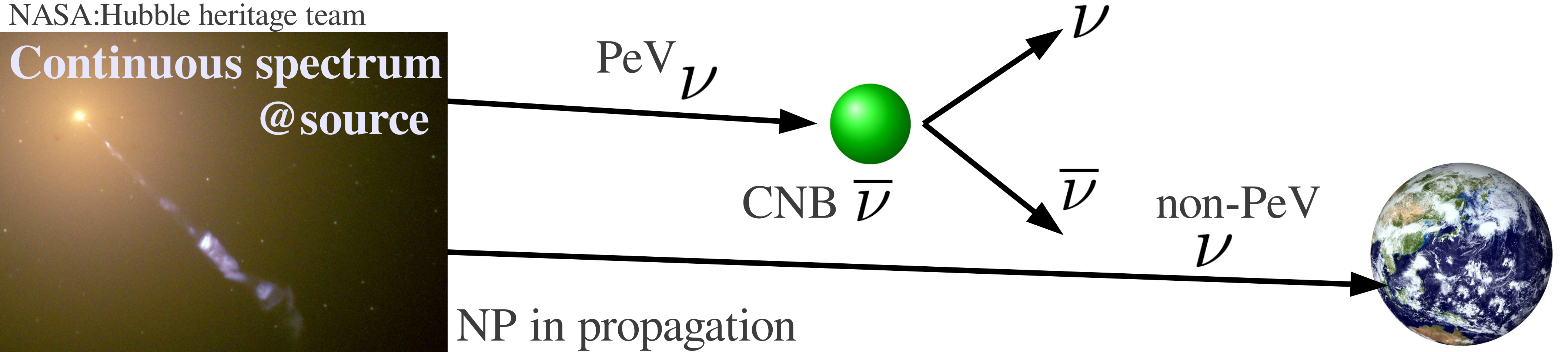
- **NP in Propagation: Scattering with CNB with a MeV mediator**

  As an effective int.: Ng Beacom PR**D90** (2014) 065035, Ioka Murase PTEP **6** (2014) 061E01
  With neutrino mass model: Ibe Kaneta PR**D90** (2014) 053011, Blum Hook Murase 1408.3799


NASA:Hubble heritage team

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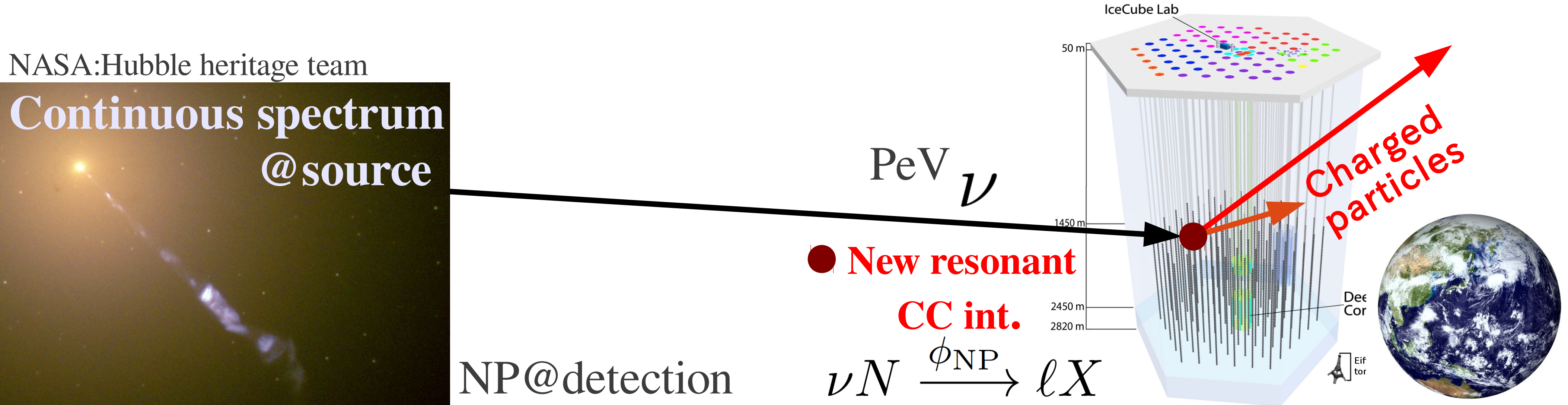
- **NP at Detection: CC int. mediated by a new TeV field**

  Barger Keung PL**B727** (2013) 190…



NASA:Hubble heritage team

Continuous spectrum @source

PeV ν

● **New resonant CC int.**

Charged particles

NP@detection

$$\nu N \xrightarrow{\phi_{\mathrm{NP}}} \ell X$$

New Physics in propagation

- In this talk, we pursue the possibility of

➡ **NP in propagation**, namely **Resonant scattering with CNB**

- We set **3 assumptions** for cosmic neutrino sources

New Physics in propagation

① **IceCube gap**

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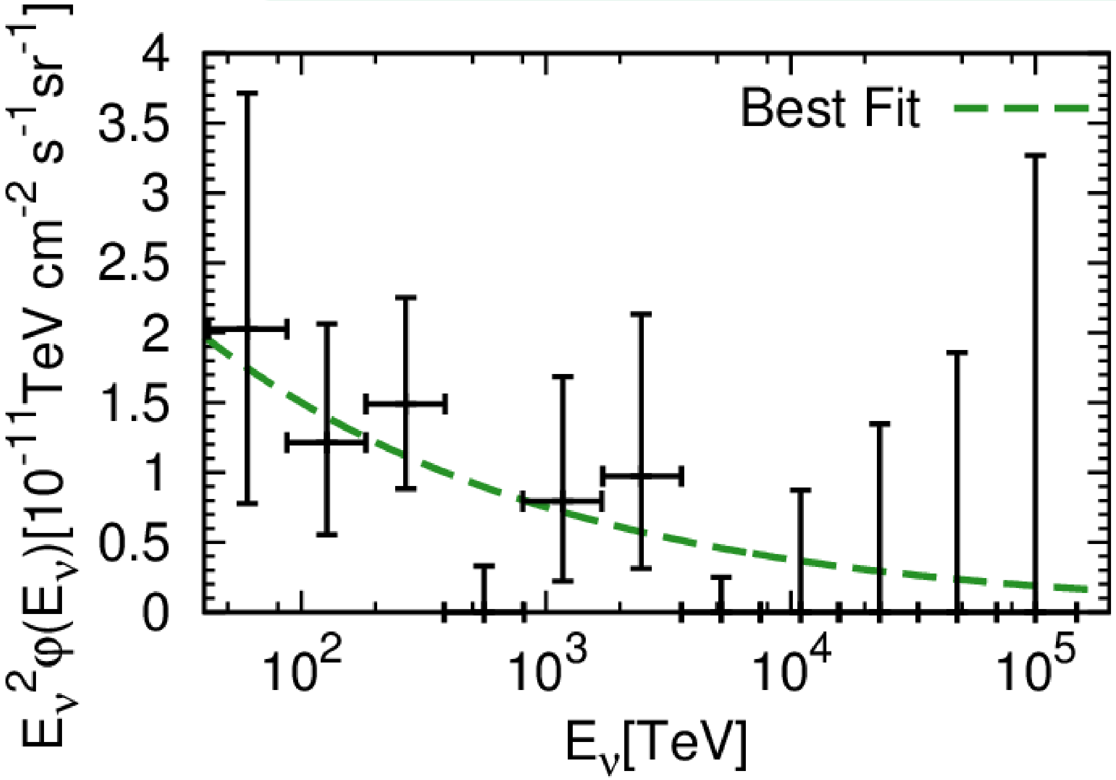
① Continuous (power-law) spectrum



① The spectrum shown with the **green curve** is reproduced, **if there is no NP**.

New Physics in propagation

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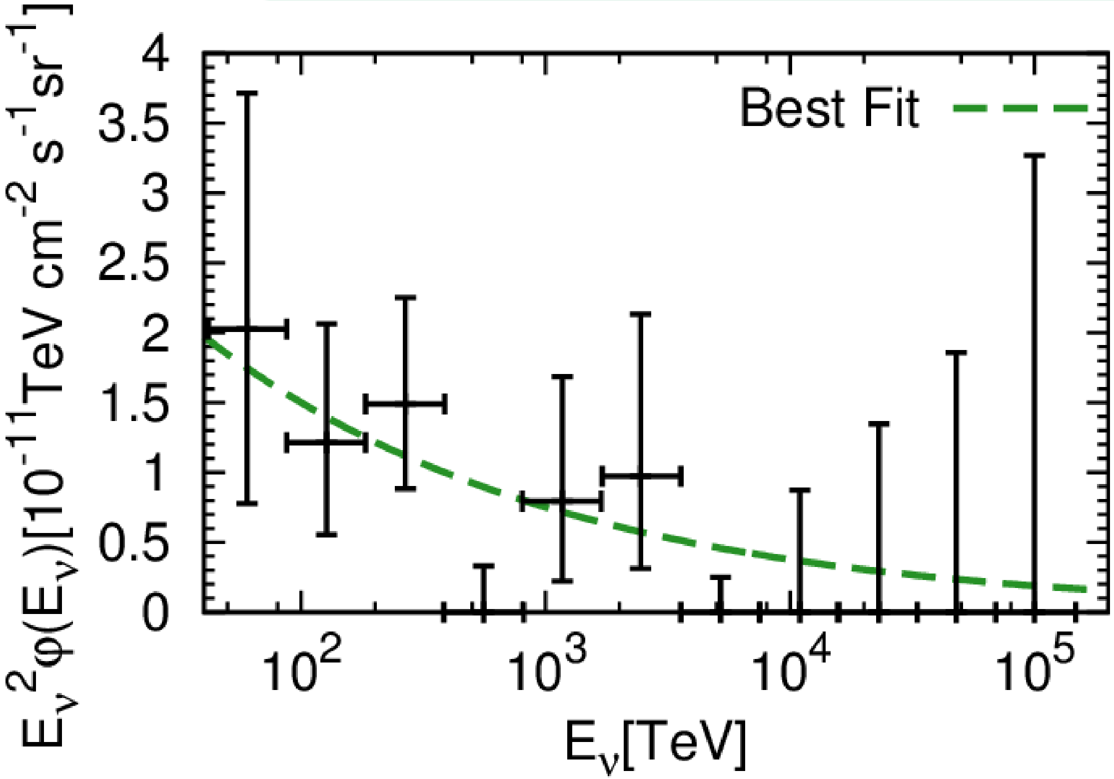
① Continuous (power-law) spectrum

② Flavour ratio ~1:1:1 after leaving sources



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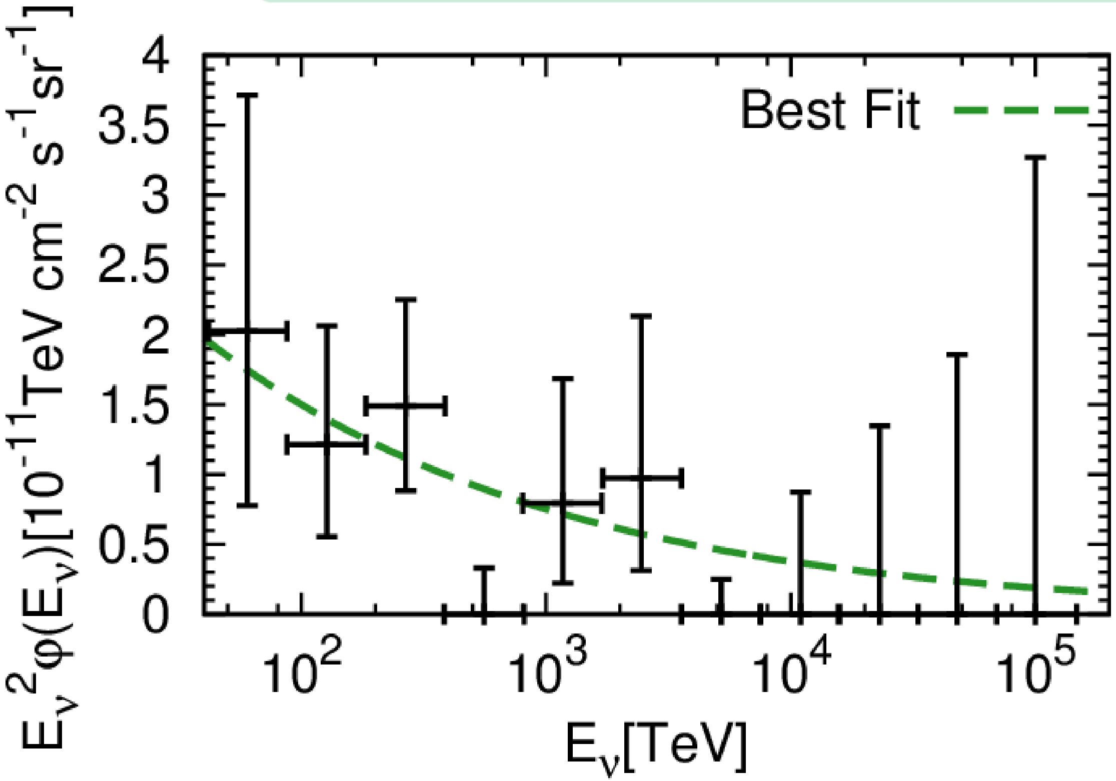
① Continuous (power-law) spectrum

② Flavour ratio ~1:1:1 after leaving sources

③ Sources distribute around a particular redshift z_{source}



① The spectrum shown with the **green curve** is reproduced, **if there is no NP**.

② is not crucial. We will see…

③ for simplicity.

→ z-dependence of source distribution

e.g., The star-formation rate has a peak at z =1~2.

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“A sharp gap” → “Cosmic neutrino with a particular energy is scattered off”

The key idea is...“Resonant interaction with Cosmic Neutrino Background (CNB)”

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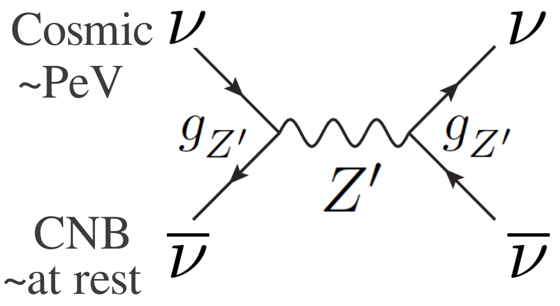
$$s \simeq 2E_{\nu_{\text{Cosmic}}} m_{\nu_{\text{CNB}}} \overset{!}{=} M_{Z'}^2$$



Why CNB? → $n_{\text{CNB}} \gg n_{\text{Baryon}}$

$n_{\text{CNB}} = 56.8$ [/cm^3] for each dof

New Physics in propagation

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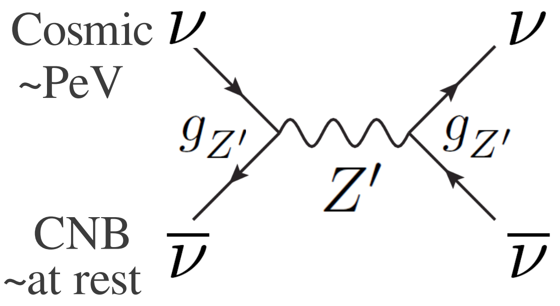

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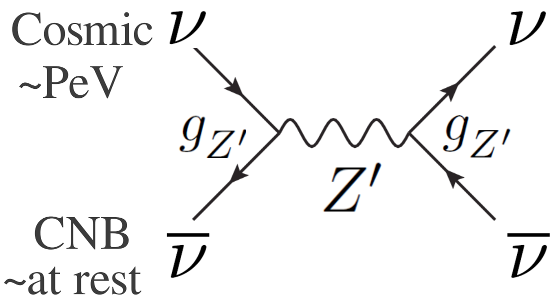
NP @MeV scale



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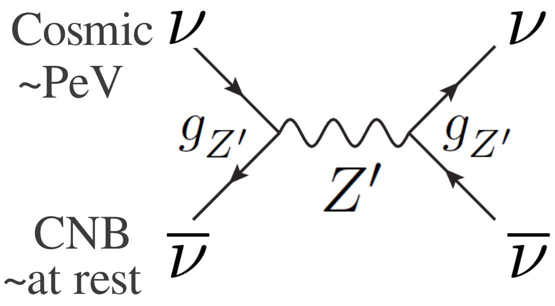

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- **How far can cosmic neutrinos travel in CNB?** → Mean free path: λ

$$\lambda \simeq 1/n_{\text{CNB}}\sigma_{\text{@Res.}}$$

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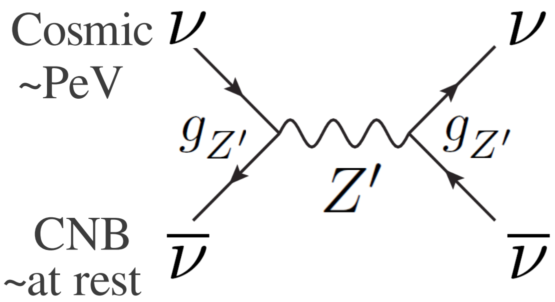

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Extra galactic source

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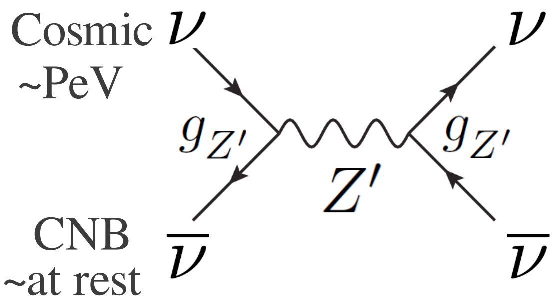

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Extra galactic source

$$\rightarrow \sigma_{\text{@Res.}} \simeq 10^{-30}\ [\text{cm}^2]$$

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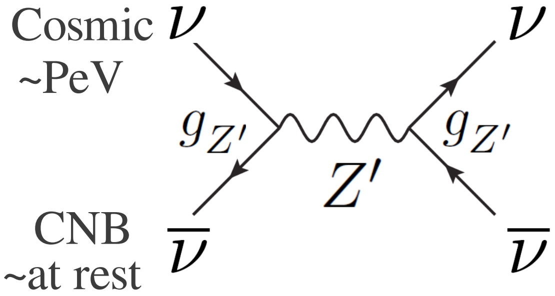

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Extra galactic source

$$\to \sigma_{\text{@Res.}} \simeq 10^{-30}\ [\text{cm}^2]$$

IceCube Gap requires

$M_{Z'} \sim$MeV, $\sigma_{\text{@Res.}} \gtrsim 10^{-30}$ [cm^2].

Let us calculate the cross-section in a particular model...

Model

- Gauged $U(1)\,L_\mu - L_\tau$ force as **a benchmark model**

Charge assignments

$$Y(L_\mu) = +1, Y(L_\tau) = -1,$$
$$Y(\mu_R) = +1, Y(\tau_R) = -1, Y(\text{others}) = 0.$$

$$\begin{aligned}\mathscr{L}_{L_\mu - L_\tau} = \; & g_{Z'}\overline{L}_\mu\gamma^\rho L_\mu Z'_\rho - g_{Z'}\overline{L}_\tau\gamma^\rho L_\tau Z'_\rho \\ & + g_{Z'}\overline{\mu_R}\gamma^\rho\mu_R Z'_\rho - g_{Z'}\overline{\tau_R}\gamma^\rho\tau_R Z'_\rho\end{aligned}$$

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Neutrino secret int.

Constrained! but...

Contribute to muon *g-2*

We discuss it in **Sec.** ②

Coupling in mass eigenbasis

$$g_{ij} = g_{Z'}(U^\dagger_{\text{PMNS}})_{i\alpha}\text{diag}(0,1,-1)_{\alpha\beta}(U_{\text{PMNS}})_{\beta j}$$

* Cosmic neutrino is produced as a flavour eigenstate= a coherent sum of mass eigenstates. But the coherence is lost in its travel.

Model

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Neutrino secret int.

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Coupling in mass eigenbasis

$$g_{ij} = g_{Z'}(U^\dagger_{\mathrm{PMNS}})_{i\alpha}\mathrm{diag}(0,1,-1)_{\alpha\beta}(U_{\mathrm{PMNS}})_{\beta j}$$

* Cosmic neutrino is produced as a flavour eigenstate= a coherent sum of mass eigenstates.
But the coherence is lost in its travel.

- **Motivated from...**
  - (almost) Maximal mixing Choubey Rodejohann Eur.Phys.J C40 (2005) 259
  - Gauge anomaly free Foot Mod.Phys.A6 (1991) 527, He et al., PRD43 (1990) R22

- In this talk, we do not go into the details of the spontaneous breaking of the $L_\mu - L_\tau$ sym. →

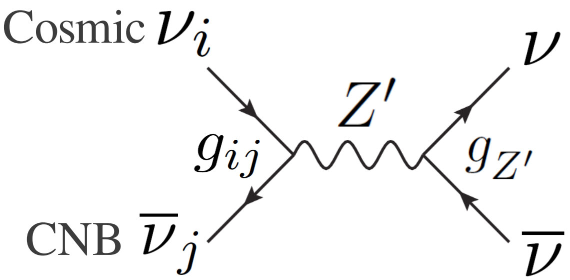
Model parameters

$g_{Z'}$ and $M_{Z'}$

① IceCube gap

Cross-section of the neutrino scattering proc.

$$\sigma(\nu_i\overline{\nu}_j \to \nu\overline{\nu}) = \frac{|g_{ij}|^2\, g_{Z'}^2}{6\pi}\frac{s}{(s-M_{Z'}^2)^2+M_{Z'}^2\Gamma_{Z'}^2}$$



Decay rate

$$\Gamma_{Z'} = \frac{g_{Z'}^2 M_{Z'}}{12\pi}$$

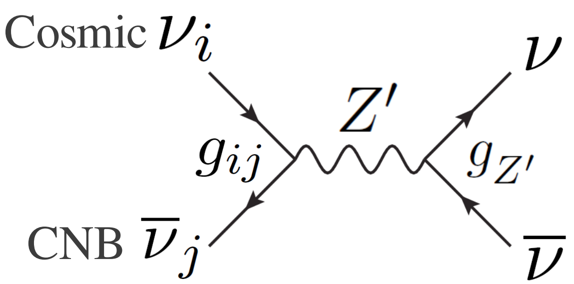
Cross-section@Resonance

$$\sigma_{\text{@Res.}} = \frac{4\pi\,|g_{ij}|^2}{M_{Z'}^2}\delta\left(1-\frac{M_{Z'}^2}{s}\right)$$

Model

- **Cross-section of the neutrino scattering proc.**

$$\sigma(\nu_i\overline{\nu}_j \to \nu\overline{\nu}) = \frac{|g_{ij}|^2\, g_{Z'}^2}{6\pi}\frac{s}{(s-M_{Z'}^2)^2 + M_{Z'}^2\Gamma_{Z'}^2}$$



- **Decay rate**

$$\Gamma_{Z'} = \frac{g_{Z'}^2 M_{Z'}}{12\pi}$$

- **Cross-section@Resonance**

For IceCube Gap

$$\sigma_{\text{@Res.}} = \frac{4\pi\,|g_{ij}|^2}{\boxed{M_{Z'}^2}}\delta\left(1-\frac{M_{Z'}^2}{s}\right) \overset{!}{=} 10^{-30}\ [\text{cm}^2]$$

$M_{Z'}$ ~MeV

Model

① IceCube gap

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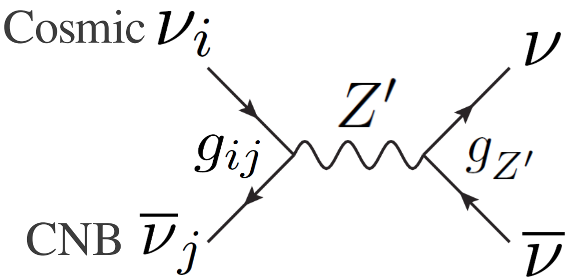

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$M_{Z'}$ ~MeV

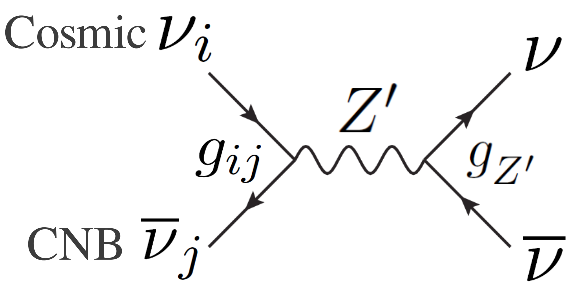
$$\to g_{Z'} \simeq 10^{-3}$$

Saitama University 埼玉大学 Model

① IceCube gap

Cross-section of the neutrino scattering proc.

$$\sigma(\nu_i\overline{\nu}_j \to \nu\overline{\nu}) = \frac{|g_{ij}|^2\, g_{Z'}^2}{6\pi}\,\frac{s}{(s-M_{Z'}^2)^2+M_{Z'}^2\Gamma_{Z'}^2}$$



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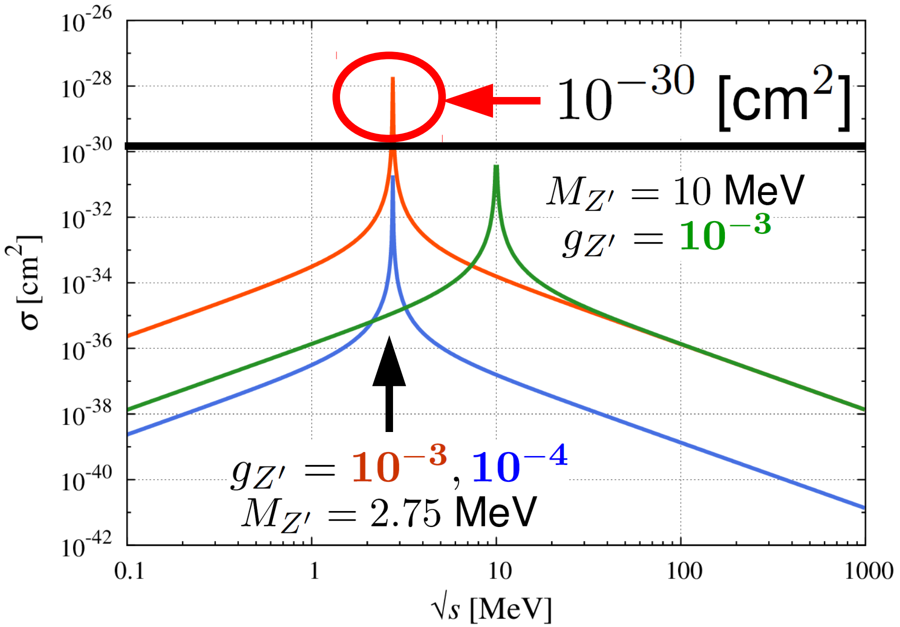
$M_{Z'}$ ~MeV $\to g_{Z'} \simeq 10^{-3}$



IceCube Gap requires

$M_{Z'}$ ~MeV, $\quad g_{Z'} \gtrsim 10^{-4}$.

- The width might be **too narrow** for the **IceCube Gap** **(0.4-1PeV)**.
- We can ask the help to m_ν and z

→ **Sec.** ③

Before going into the details of the cosmic neutrino spectrum, let's check muon g-2.

Outline

1 IceCube gap

- Attenuation of cosmic neutrino by secret neutrino interaction
- Gauged leptonic force $L_\mu - L_\tau$ as secret interaction

2 Muon anomalous magnetic moment

- Gauged leptonic force as a contribution to g-2
- Constraints from colliders and neutrino trident process

3 A solution to the gaps

- Reproduction of IceCube gap → distance to the neutrino source
  → neutrino mass spectrum

Z' contribution to $g_\mu - 2$

$$\mathscr{L}_{L_\mu - L_\tau} = \underbrace{g_{ij}\overline{\nu}_i\gamma^\rho \mathrm{P}_L \nu_j Z'_\rho}_{\text{Neutrino secret int.}} + \underbrace{g_{Z'}\text{diag}(0,1,-1)_{\alpha\beta}\overline{\ell}_\alpha\gamma^\rho\ell_\beta Z'_\rho}_{\text{Contribute to muon } g\text{-}2}$$

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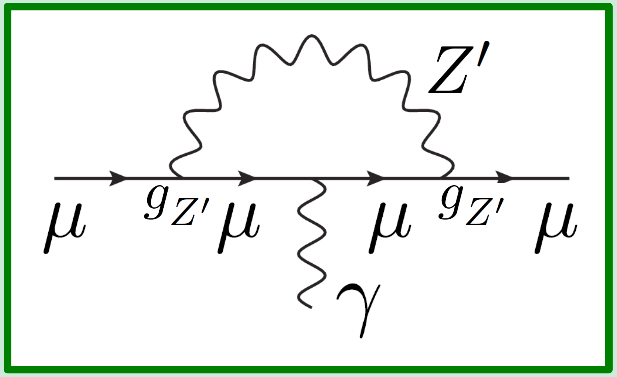
- $M_{Z'} \gg m_\mu \quad \rightarrow \Delta a_\mu^{Z'} = \frac{\boxed{g_{Z'}^2}}{12\pi^2}\frac{m_\mu^2}{\boxed{M_{Z'}^2}}$
- $M_{Z'} \ll m_\mu \quad \rightarrow \Delta a_\mu^{Z'} = \frac{\boxed{g_{Z'}^2}}{8\pi^2}$



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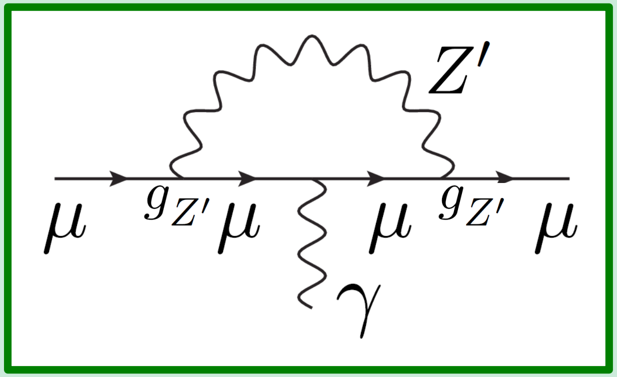
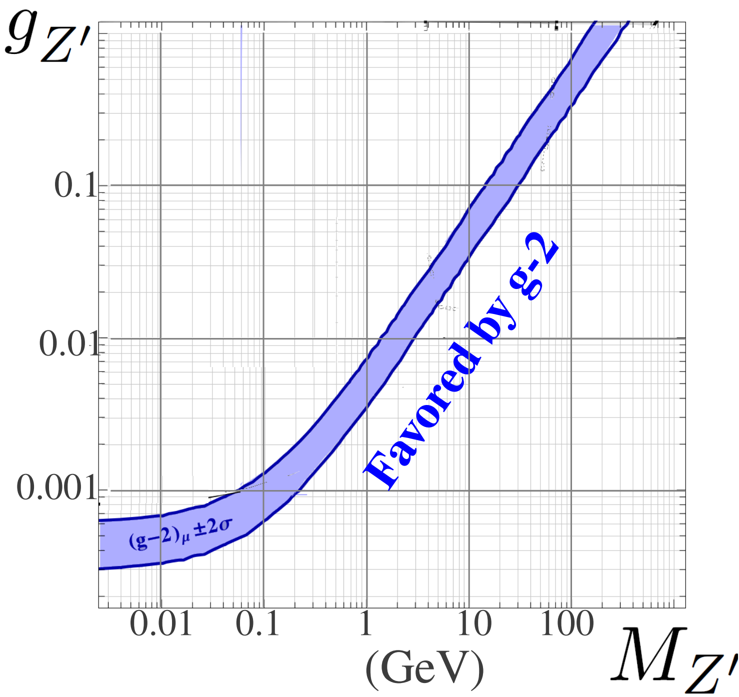


$g_\mu - 2$ Gap

$$a_\mu^{\text{Exp}} - a_\mu^{\text{SM}} = (26.1 \pm 8.0)\cdot 10^{-10} \;(3.3\sigma)$$

→ We need $\Delta a_\mu^{\mathrm{NP}} \simeq (20\text{-}30)\cdot 10^{-10}$



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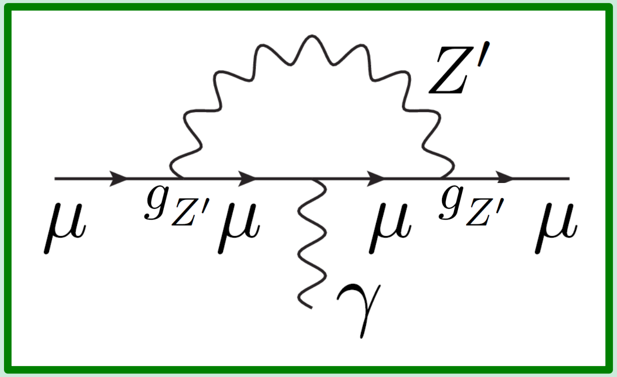

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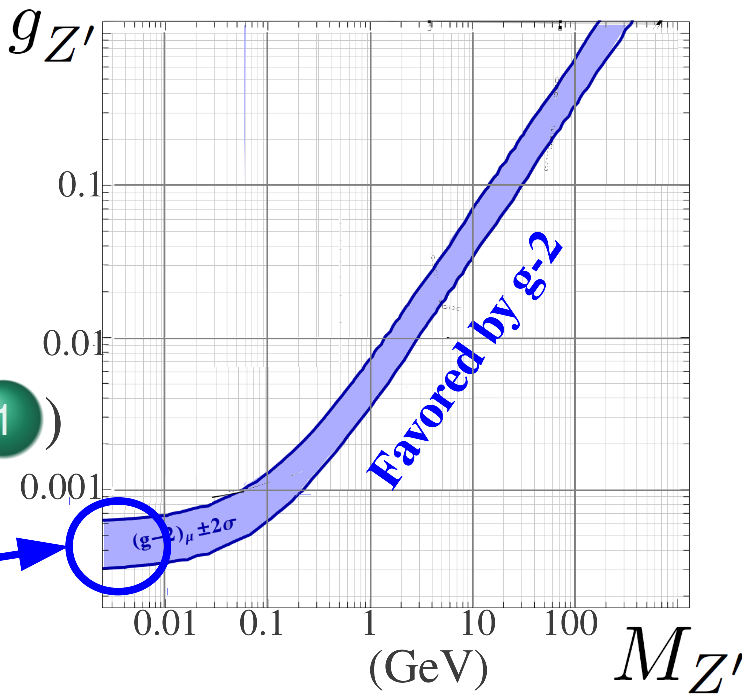
- Let me remind (back-of-the envelope calc. in **Sec.①**)

IceCube Gap requires

$M_{Z'} \sim$MeV, $\quad g_{Z'} \gtrsim 10^{-4}$.



Constraints

Collider bounds

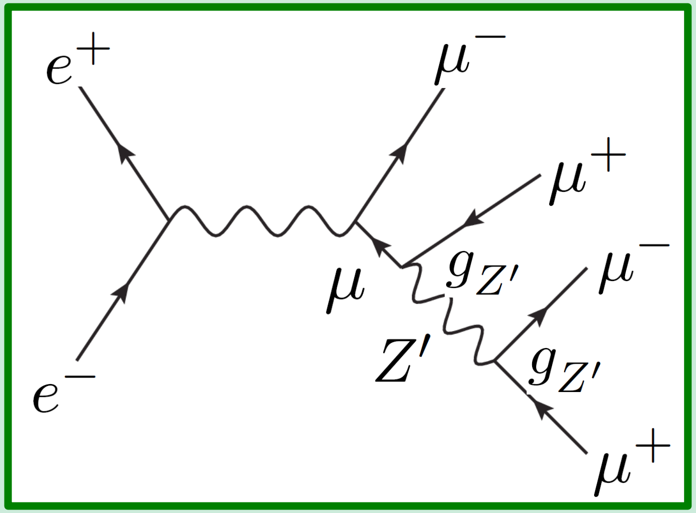
Harigaya et al., JHEP **1403** (2014) 105.

- Process: $e^+e^- \to 4\mu$

  $PP(P\bar{P}) \to 4\mu/2\mu 2\tau$

  only constrain relatively heavy Z'

→ LEP, LHC: $g_{Z'} \lesssim 0.1$ at $M_{Z'} \simeq 100$ GeV



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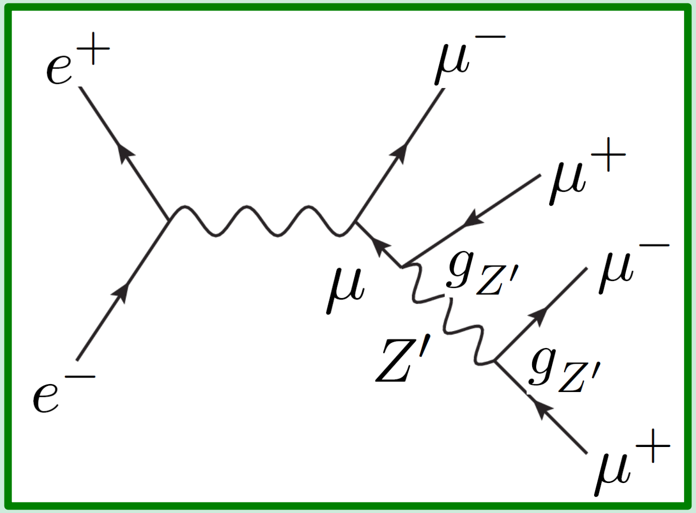

Rare meson decays

Lessa and Peres, PRD**75** (2007) 094001

- Process: $\pi^+/K^+ \to \mu^+\nu_\mu Z'$

  Bound from Kaon decay → $g_{Z'} \lesssim 0.01$ at $M_{Z'}$ ~MeV

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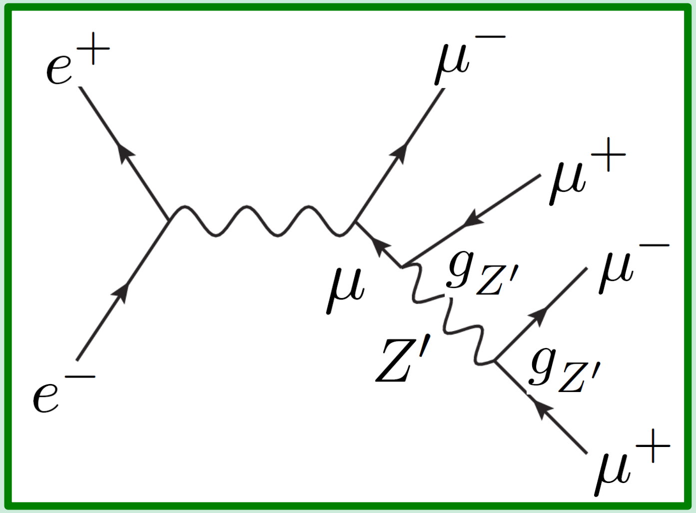

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- Process: $\pi^+/K^+ \to \mu^+\nu_\mu Z'$

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- The most relevant bound from lab. experiments is **Neutrino trident process** in neutrino-nucleon scattering

  Altmannshofer Gori Pospelov Yavin, PRL **113** (2014) 091801

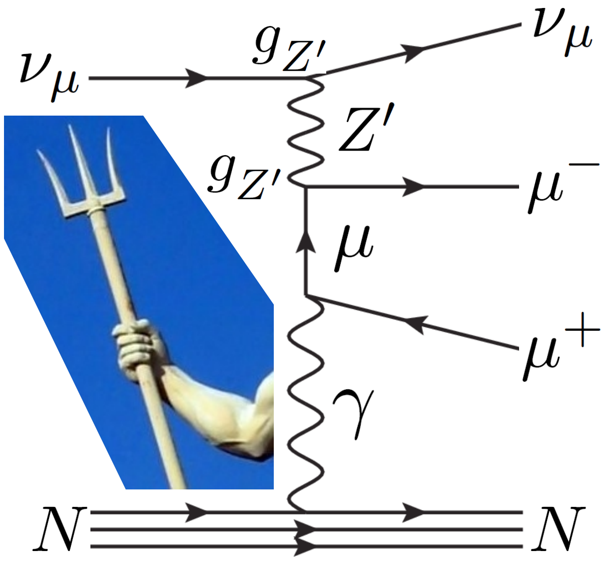
- Bounds from CMB, BBN, and also from SN1987A → References in Ng Beacom

Constraints: Neutrino Trident Process

- **Neutrino trident process**
  in neutrino-nucleon scattering events
  - Available **data** reported by CCFR in 1991!

37 events (±12.4)

CCFR collaboration, PRL **66** (1991) 3117
excavated recently (only cited 18 times)



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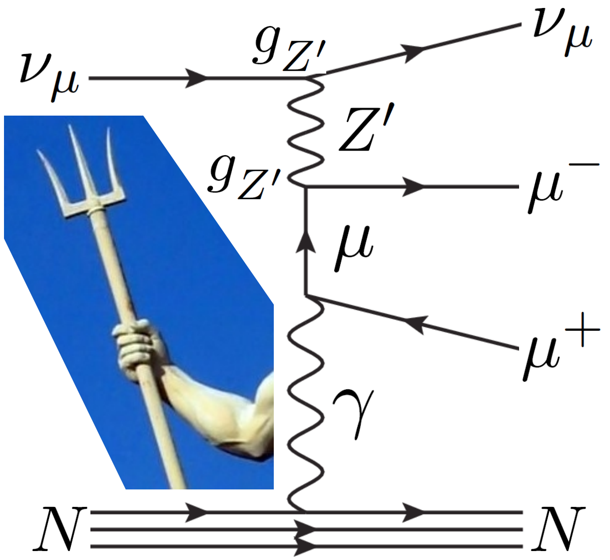
Consistent → constrains $g_{Z'}$ and $M_{Z'}$



Altmannshofer et al., PRL **113** (2014) 091801

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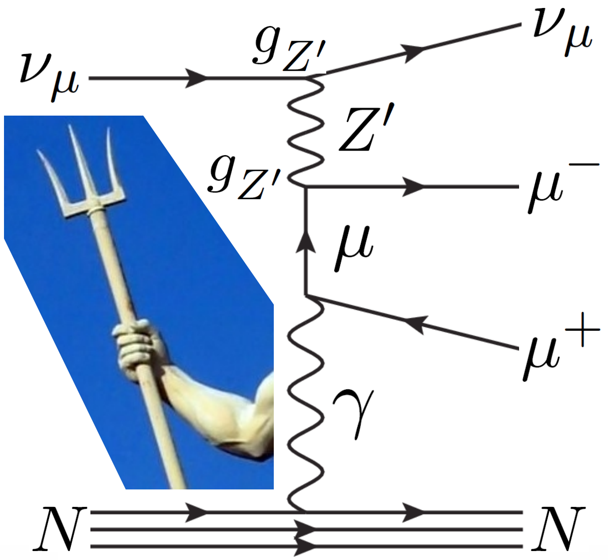

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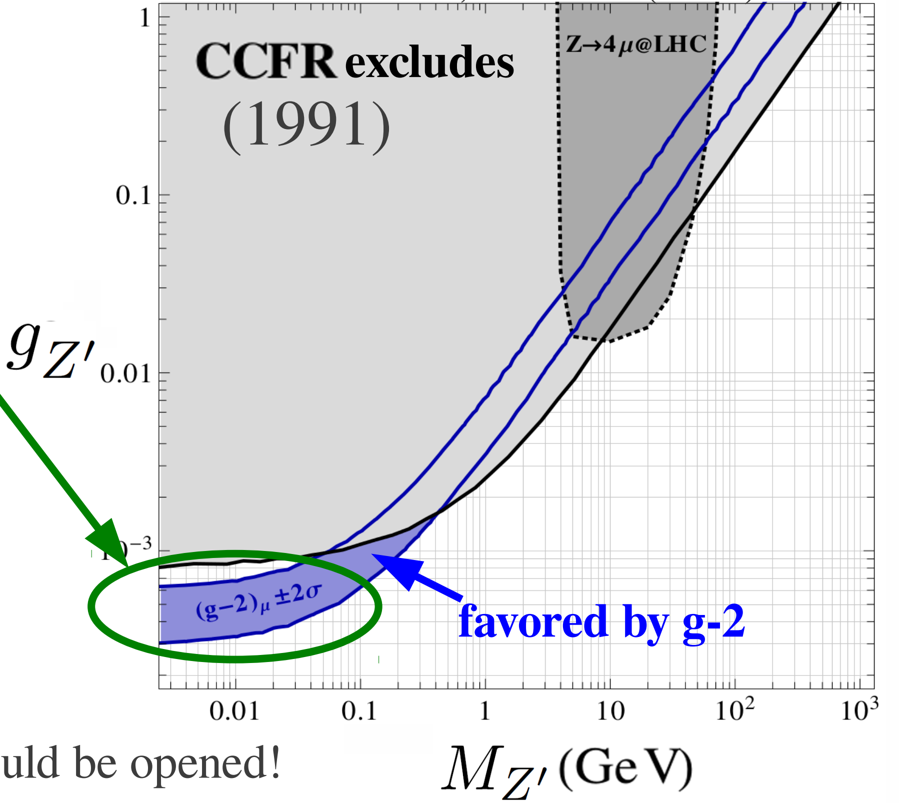
→ **Consistent** → constrains $g_{Z'}$ and $M_{Z'}$

$g_\mu - 2$ favored - Trident excl.

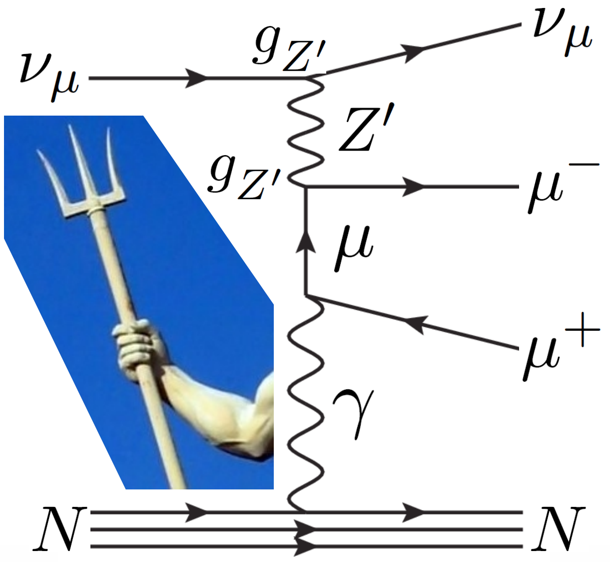
$M_{Z'} \lesssim 100$ MeV, $g_{Z'} \simeq$ several $\cdot 10^{-4}$.

Altmannshofer et al., PRL **113** (2014) 091801



*The trident process must be recorded on the hard disks of the near detectors in modern oscillation experiments. They should be opened!

Constraints: Neutrino Trident Process



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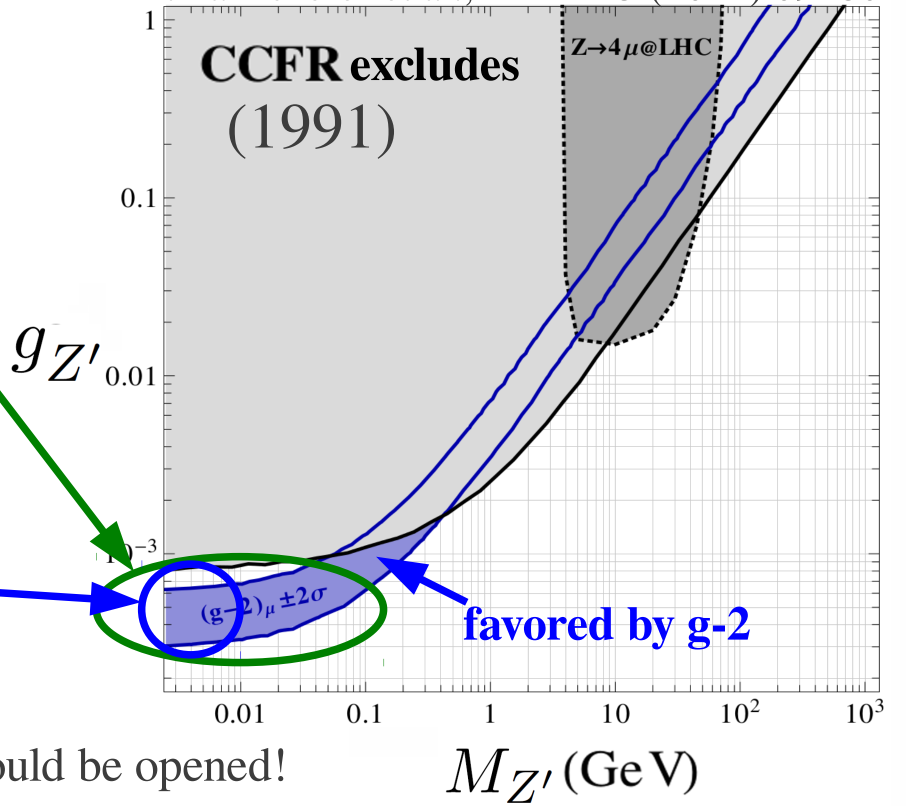

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Coincide!

IceCube Gap requires

$M_{Z'}$ ~MeV, $\quad g_{Z'} \gtrsim 10^{-4}$.

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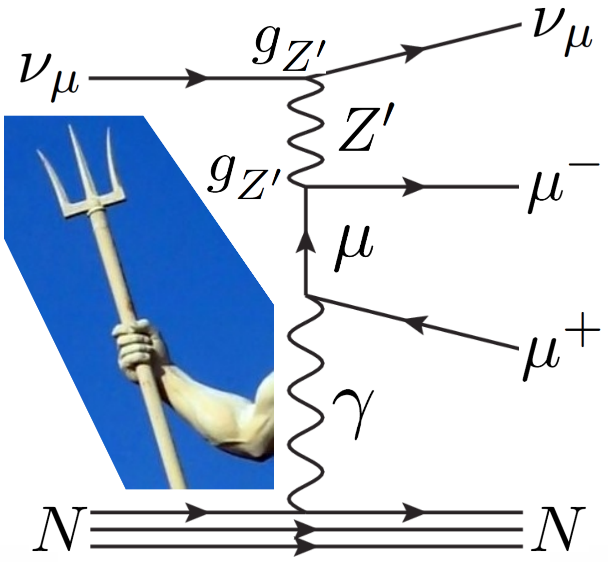
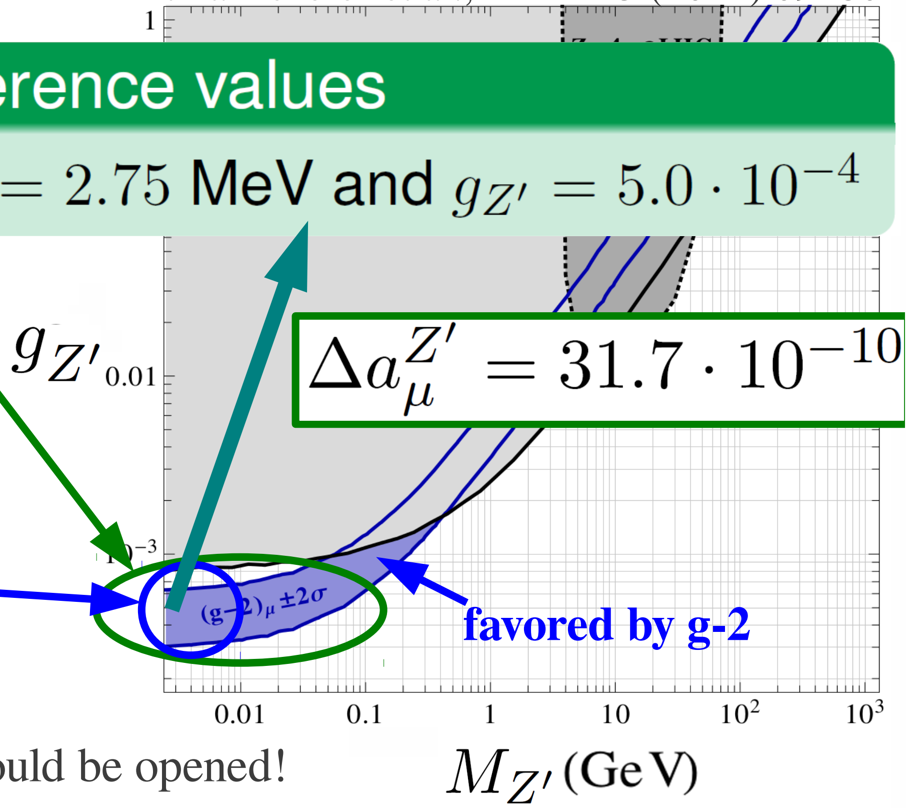


Altmannshofer et al., PRL **113** (2014) 091801



Reference values

$M_{Z'} = 2.75$ MeV and $g_{Z'} = 5.0 \cdot 10^{-4}$

$$\Delta a_\mu^{Z'} = 31.7 \cdot 10^{-10}$$

favored by g-2

$g_\mu - 2$ favored - Trident excl.

$M_{Z'} \lesssim 100$ MeV, $g_{Z'} \simeq$ several $\cdot\, 10^{-4}$.

Coincide!

IceCube Gap requires

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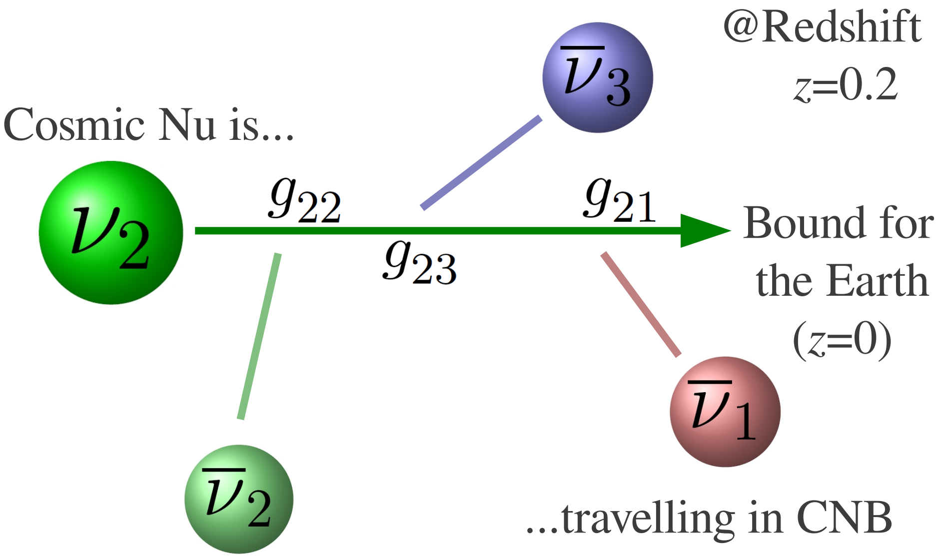
- Constraints from colliders and neutrino trident process

3 A solution to the gaps

- Reproduction of IceCube gap → distance to the neutrino source
  → neutrino mass spectrum

③ Cosmic neutrino spectrum

- $M_{Z'} = 2.75\ \text{MeV}, g_{Z'} = 5.0 \cdot 10^{-4}$ → Favored by ***g-2*** and allowed by **Trident**
- We fix $m_{\nu_{\text{lightest}}} = 3.0 \cdot 10^{-3}\ \text{eV}$ and take IH $m_{\nu_3} \ll m_{\nu_1} < m_{\nu_2}$
- Let us calculate the mean free path (for 2nd neutrino) at *z*=0.2.



Working example ③ Cosmic neutrino spectrum

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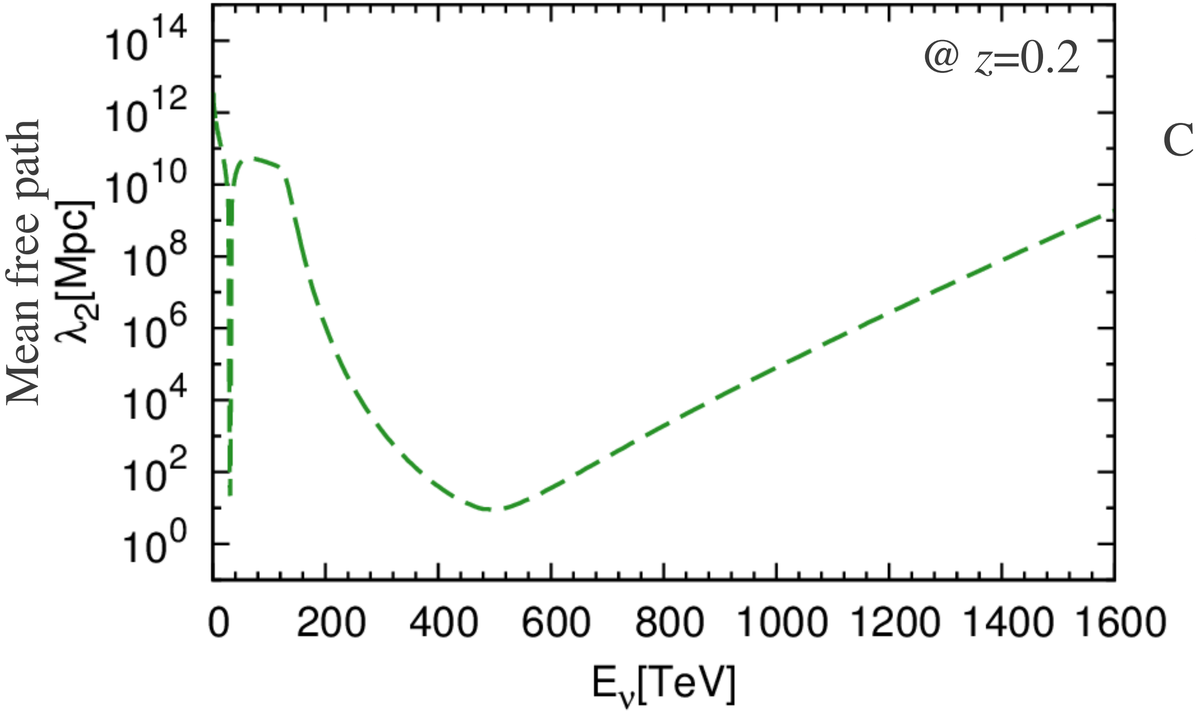
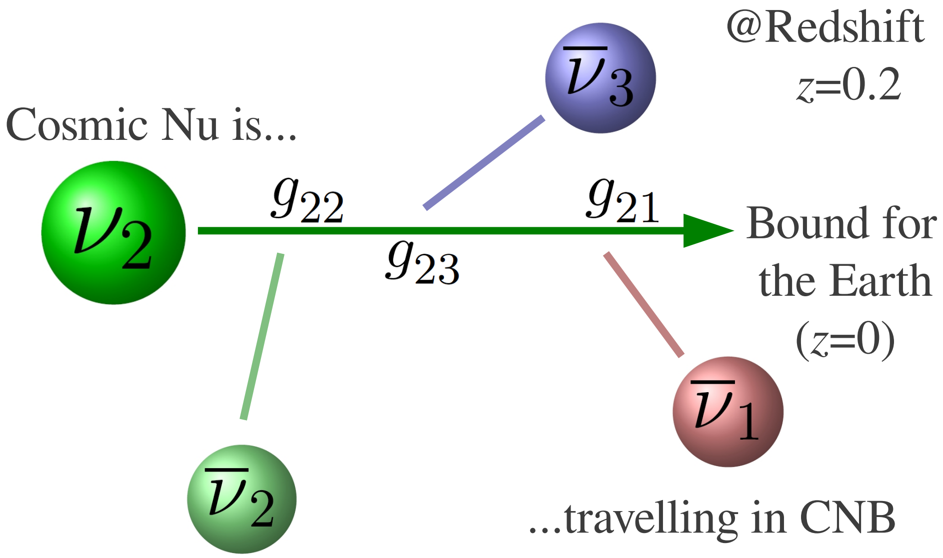


Neutrino energy observed at IceCube



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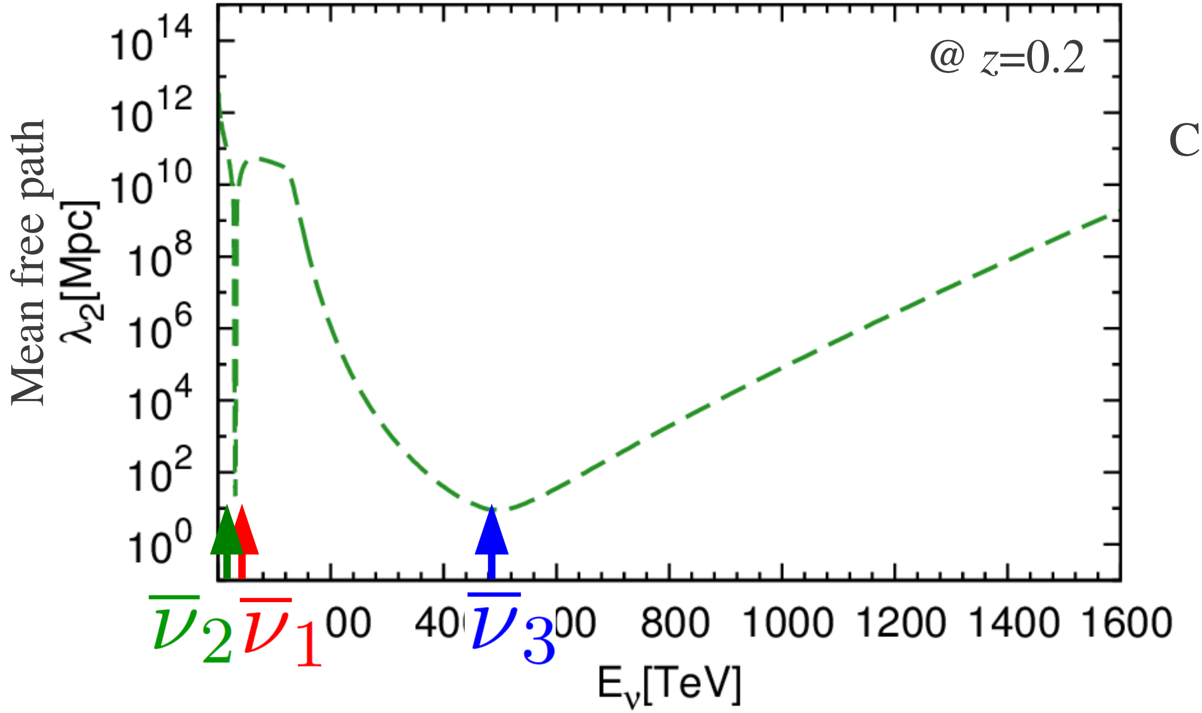

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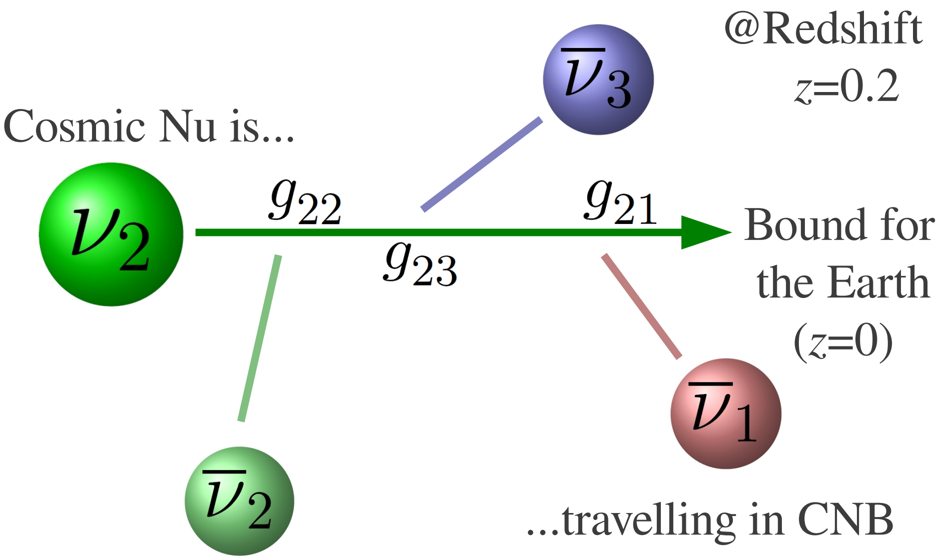

- **Resonant condition w. CNB distribution**

$$s \simeq \underset{\text{Neutrino energy }@z}{\underline{2E_{\nu_{i=2}}(1+z)}}\left[\sqrt{|\boldsymbol{p}|^2 + m_{\nu_j}^2} - |\boldsymbol{p}|\cos\theta\right] \overset{!}{=} M_{Z'}^2$$

$|\boldsymbol{p}|$: **CNB momentum** follows Fermi-Dirac dist. $\lesssim (1+z)T_{\nu 0} \sim 2.0\cdot 10^{-4}\,[\text{eV}]$ $@z = 0.2$

Working example ③ Cosmic neutrino spectrum

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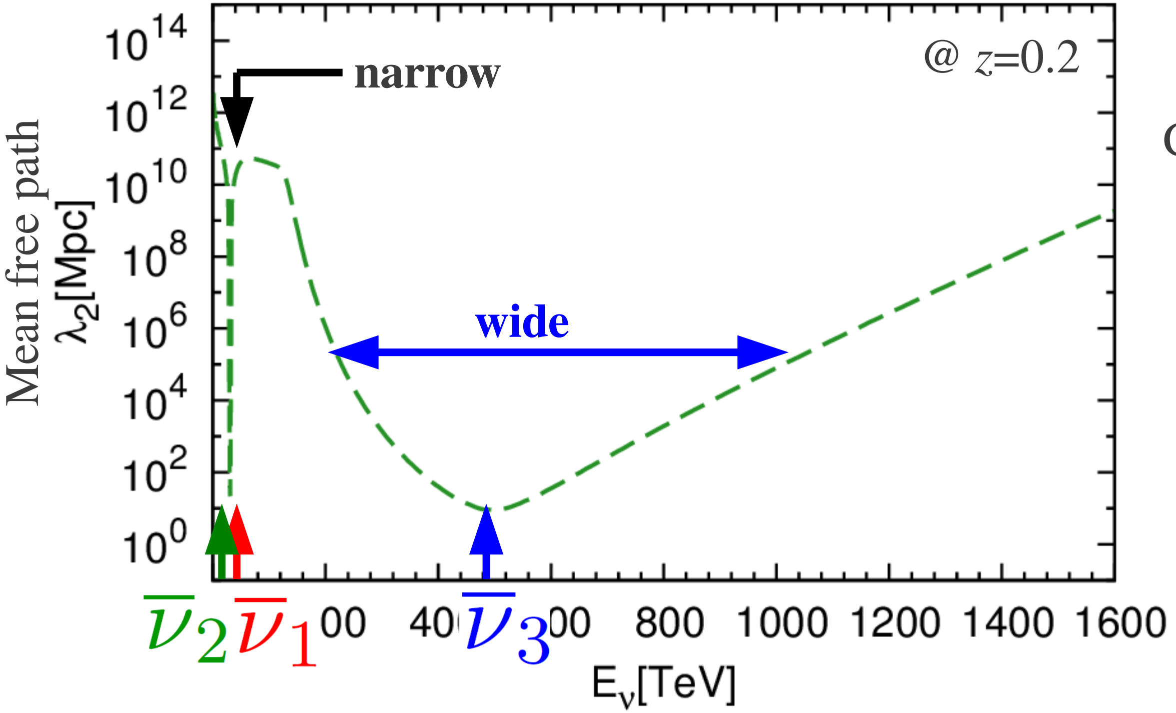
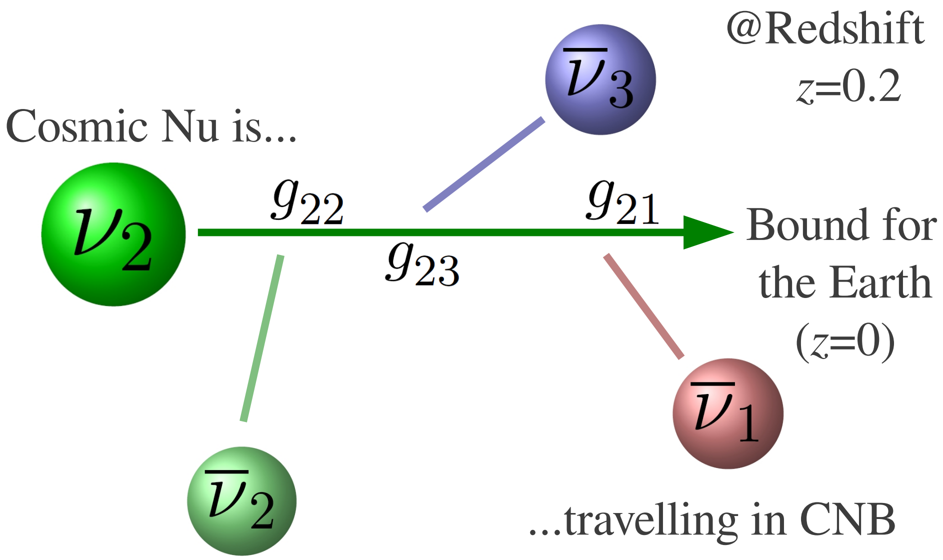


Neutrino energy observed at IceCube



$$\boxed{\begin{array}{l} m_{\nu_3} \sim |\boldsymbol{p}| \\ m_{\nu_{1,2}} \gg |\boldsymbol{p}| \end{array}}$$

- **Resonant condition w. CNB distribution**

$$s \simeq \underline{2E_{\nu_{i=2}}(1+z)}\left[\sqrt{|\boldsymbol{p}|^2 + m_{\nu_i}^2} - |\boldsymbol{p}|\cos\theta\right] \overset{!}{=} M_{Z'}^2$$

Neutrino energy @*z*

$|\boldsymbol{p}|$: **CNB momentum** follows Fermi-Dirac dist. $\lesssim (1+z)T_{\nu 0} \sim 2.0\cdot 10^{-4}$ [eV] @$z=0.2$

Working example ③ Cosmic neutrino spectrum

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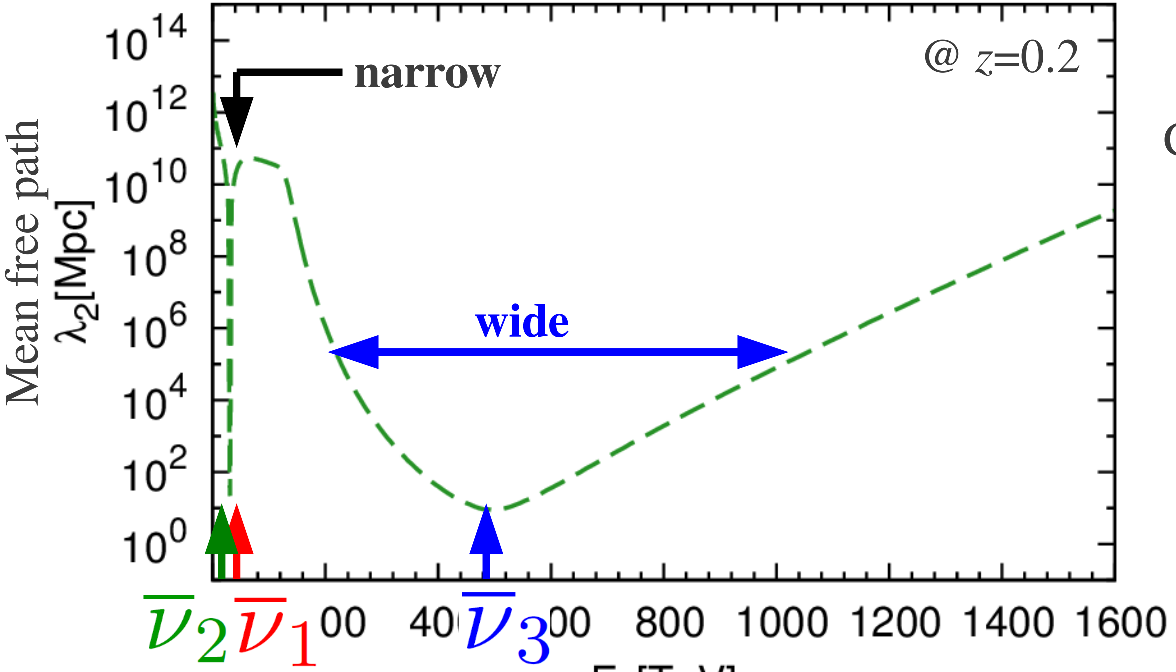
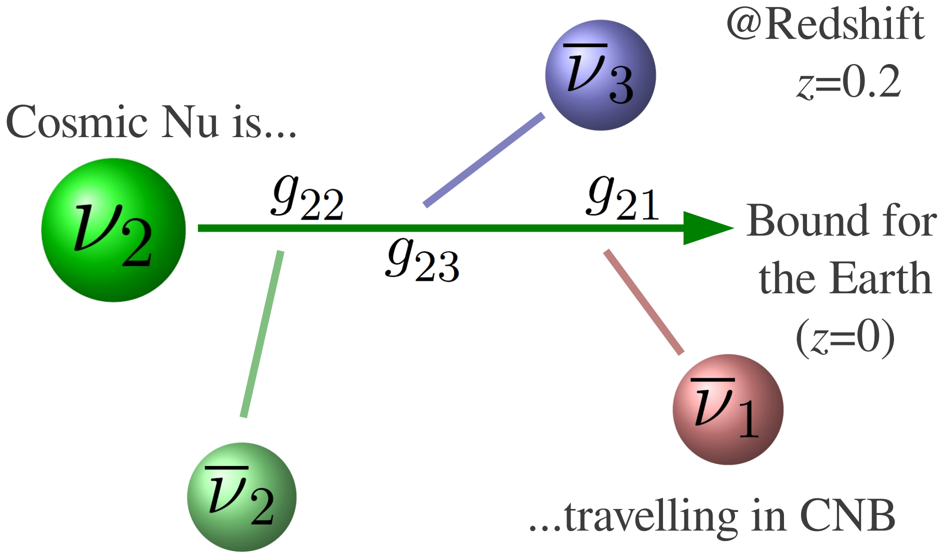


Neutrino energy observed at IceCube



$$\boxed{\begin{aligned} m_{\nu_3} &\sim |\boldsymbol{p}| \\ m_{\nu_{1,2}} &\gg |\boldsymbol{p}| \end{aligned}}$$

- **Resonant condition w. CNB distribution**

$$s \simeq \underbrace{2E_{\nu_{i=2}}(1+z)}_{\text{Neutrino energy @}z}\left[\sqrt{|\boldsymbol{p}|^2 + m_{\nu_i}^2} - |\boldsymbol{p}|\cos\theta\right] \overset{!}{=} M_{Z'}^2$$

_z_ shifts resonant _E_

Small _mNu_→ wide width

Large _z_ → wide width

$|\boldsymbol{p}|$: **CNB momentum** follows Fermi-Dirac dist. $\lesssim (1+z)T_{\nu 0} \sim 2.0 \cdot 10^{-4}$ [eV] $@z = 0.2$

- $M_{Z'} = 2.75\ \text{MeV}, g_{Z'} = 5.0 \cdot 10^{-4}$
- We fix $m_{\nu_{\text{lightest}}} = 3.0 \cdot 10^{-3}\ \text{eV}$ and take IH $m_{\nu_3} \ll m_{\nu_1} < m_{\nu_2}$
- Let us have a closer look at ***z* dependence** of MFP

Cosmic neutrino spectrum

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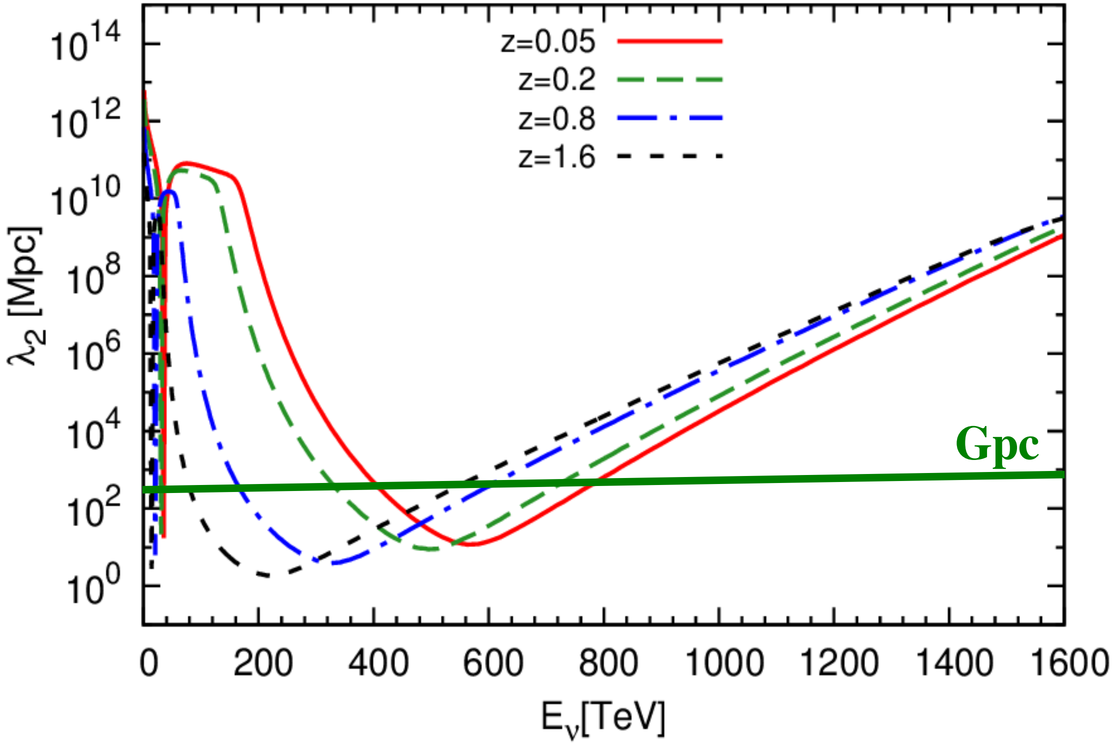

③ Cosmic neutrino spectrum

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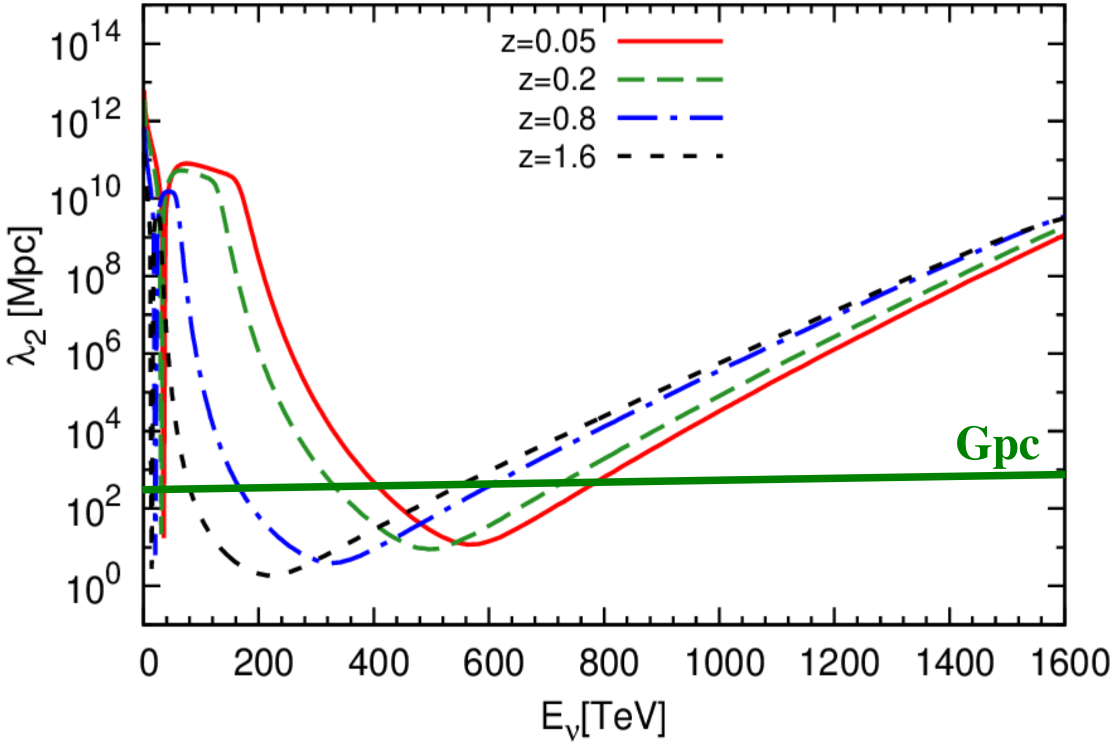

- Cosmic neutrinos travel from z_{source} to $z = 0$ (Earth)

$\downarrow$

- The resonance energy shifts along the travel path.

To keep the width of the gap appropriate, the source should not be so distant from the Earth.

Working example ③ Cosmic neutrino spectrum

- $M_{Z'} = 2.75\ \text{MeV}, g_{Z'} = 5.0 \cdot 10^{-4}$
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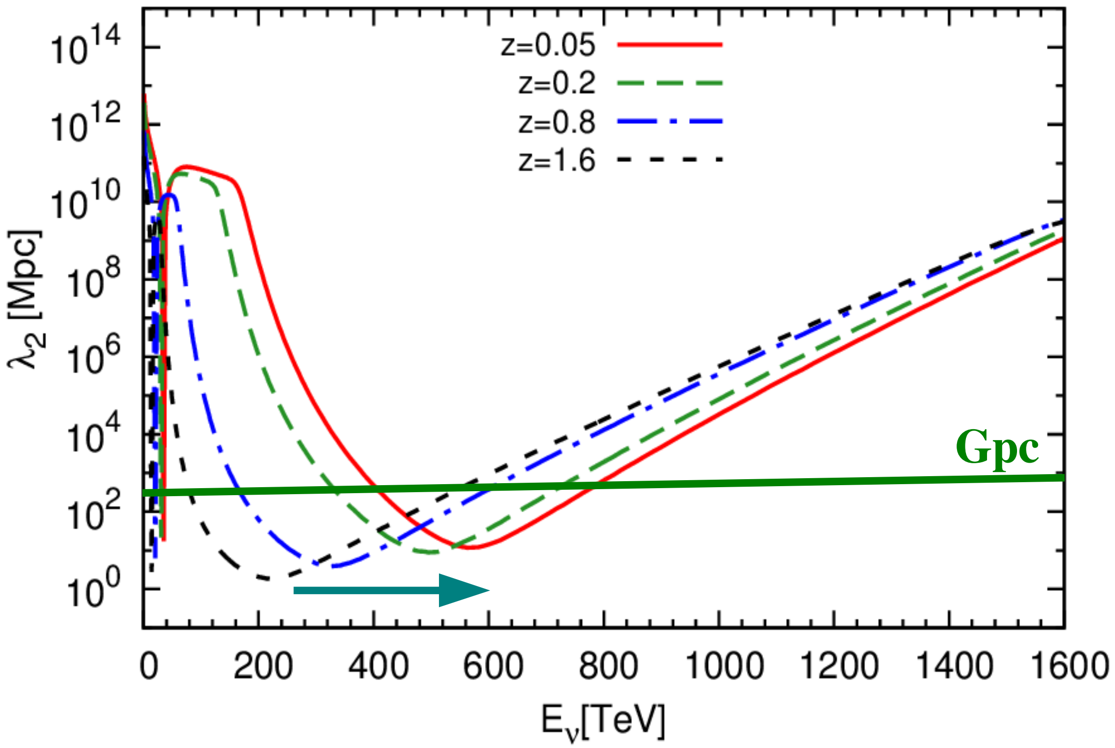

Peak position moves

$z_{\text{source}} \longrightarrow z = 0$

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↓

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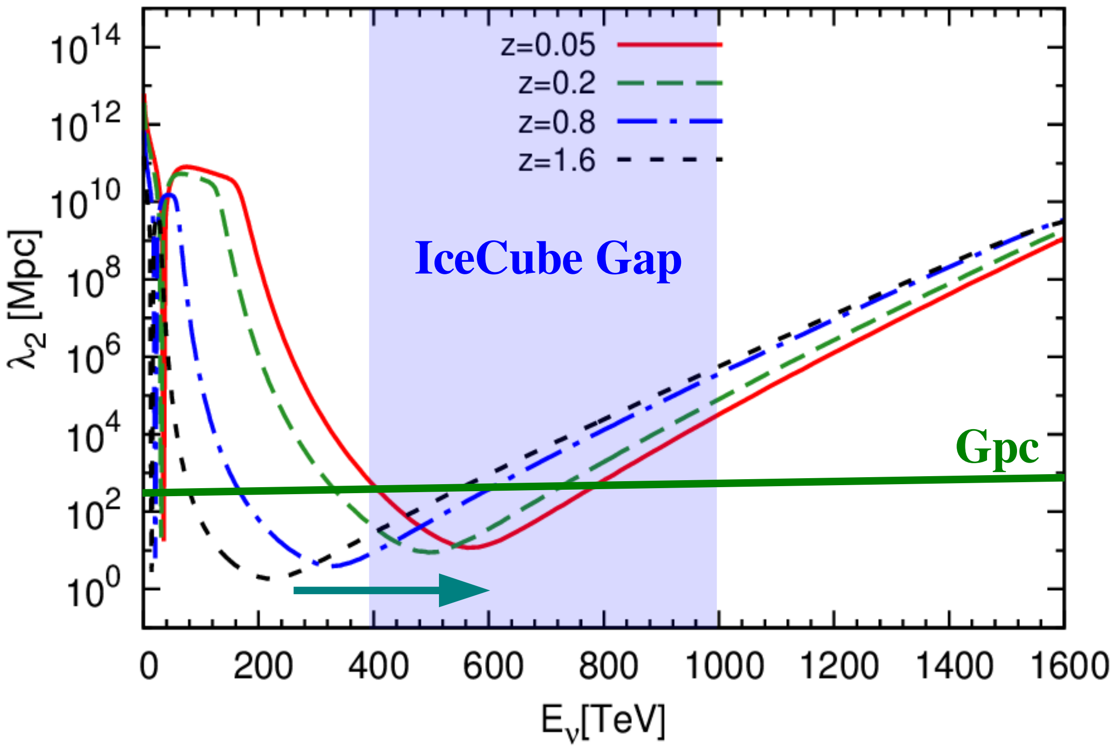

Peak position moves

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- Cosmic neutrinos travel from z_{source} to $z = 0$ (Earth)

  ↓

- The resonance energy shifts along the travel path.

To keep the width of the gap appropriate, the source should not be so distant from the Earth.

- We set z_{source}=0.2 so that the IceCube Gap is reproduced.

In reality, sources of cosmic neutrinos are distributed following some distribution function (e.g., the star formation rate)

③ Cosmic neutrino spectrum

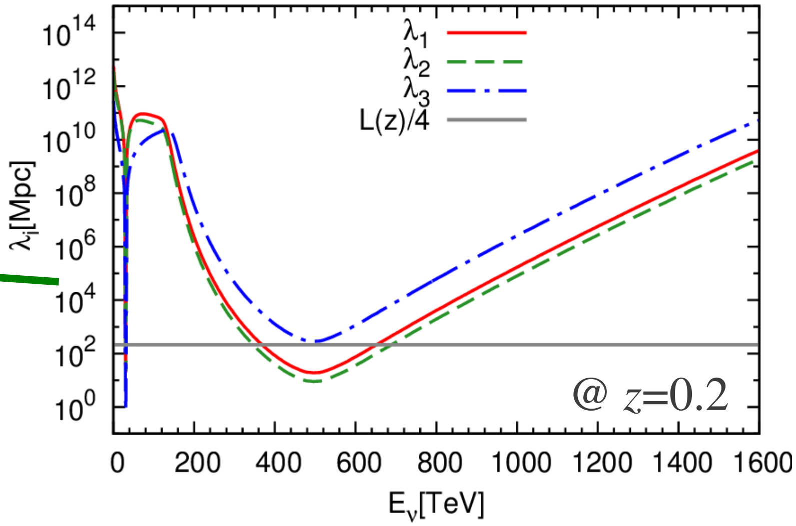
Mean free path → Spectrum

Following the approximation adopted in Ibe Kaneta PRD...

$$\varphi_i(E_\nu) = \varphi_i^{\text{original}}(E_\nu) \exp\left[-\int_0^{z_{\text{source}}} \frac{1}{\boxed{\lambda_i(E_\nu)}} \frac{\mathrm{d}L}{\mathrm{d}z} \mathrm{d}z \right]$$

MFP

Same for 3 cosmic Nu's...



The resulting gap does not depends on the initial flavour composition.

Saitama University 埼玉大学

Working example ③ Cosmic neutrino spectrum

- **Mean free path → Spectrum**

Following the approximation adopted in Ibe Kaneta PRD...

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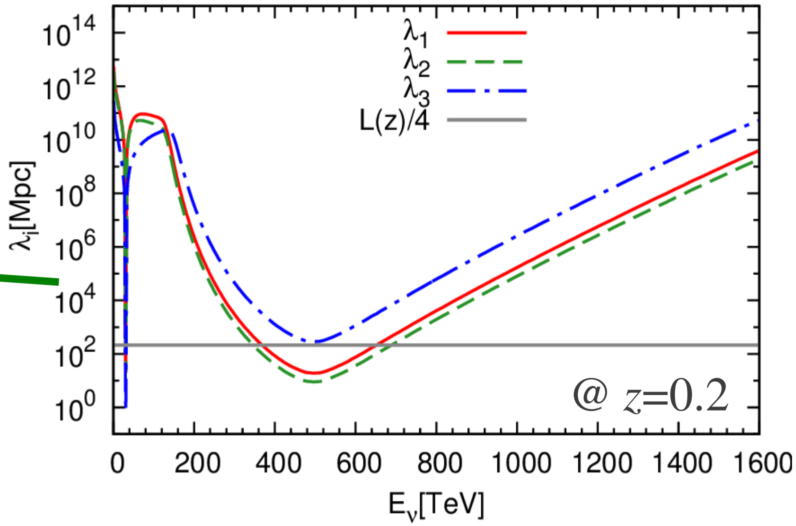
Resulting spectrum

Continuous (power-law) spectrum

MFP

Same for 3 cosmic Nu's...



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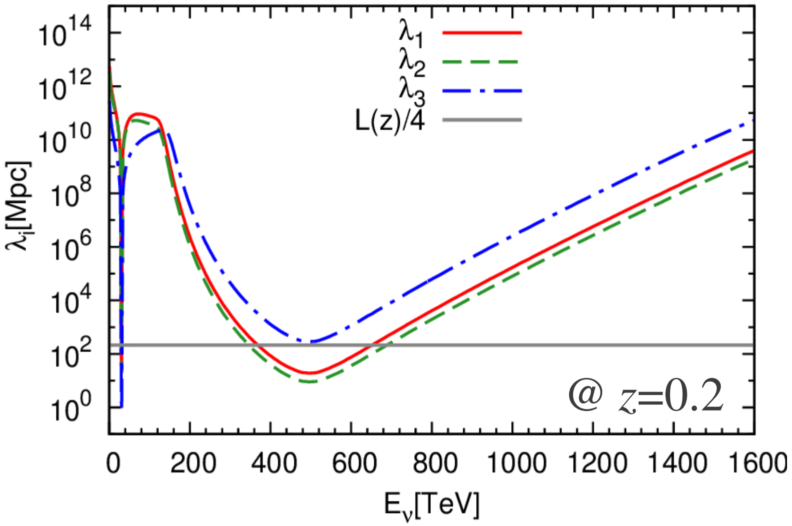
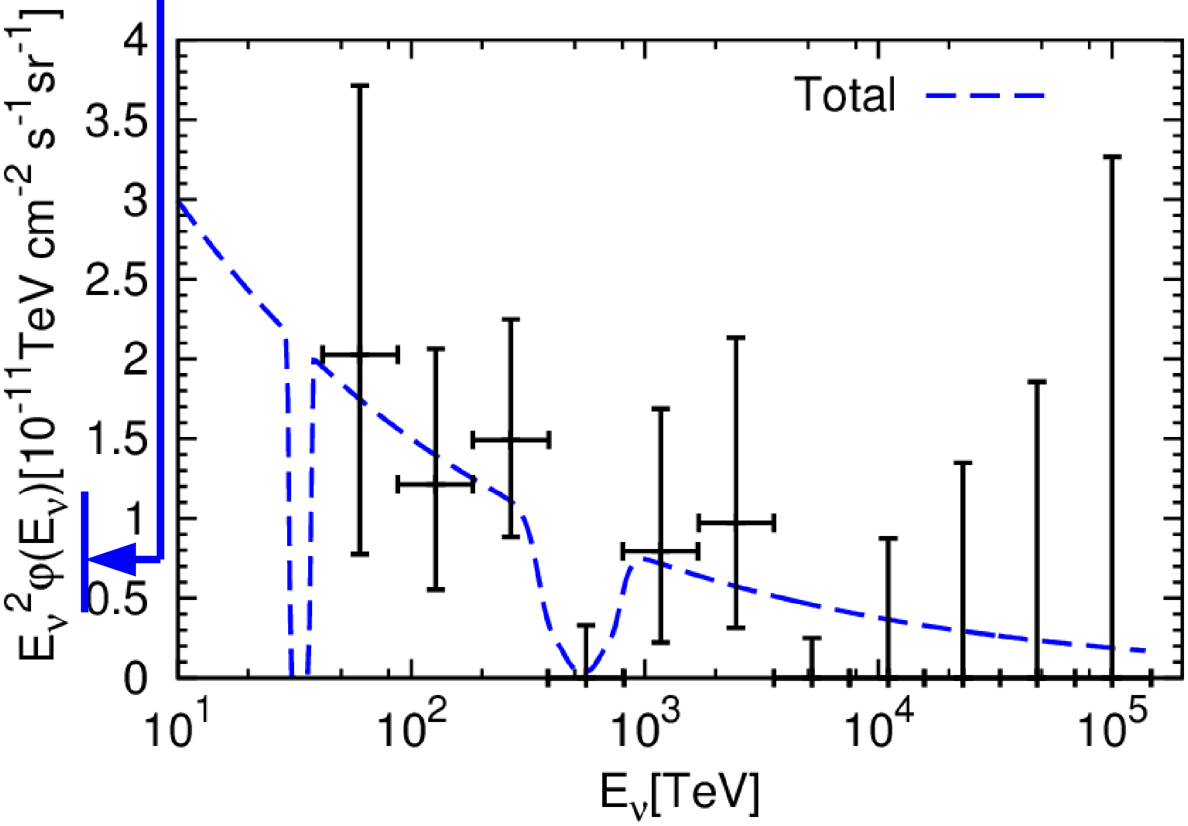
Resulting spectrum

$$\varphi(E_\nu) = \sum_i \varphi_i(E_\nu)$$

assuming flavour universal $\varphi_i^{\text{original}}(E_\nu)$

Same for 3 cosmic Nu's...





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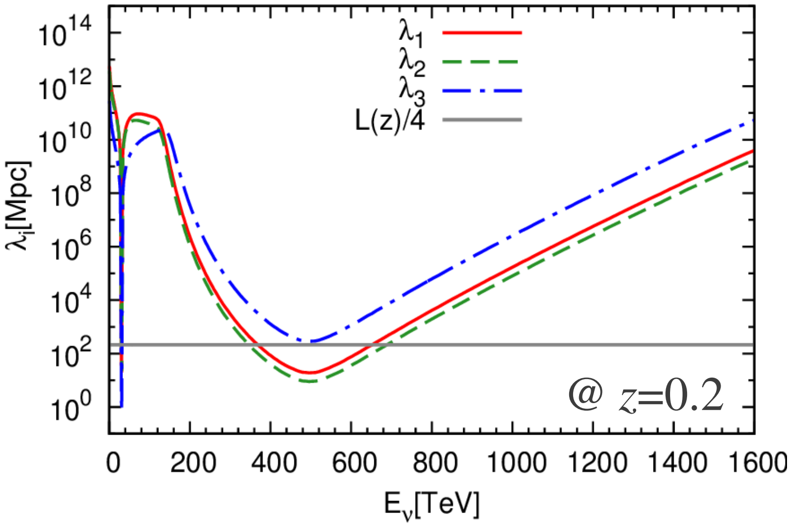

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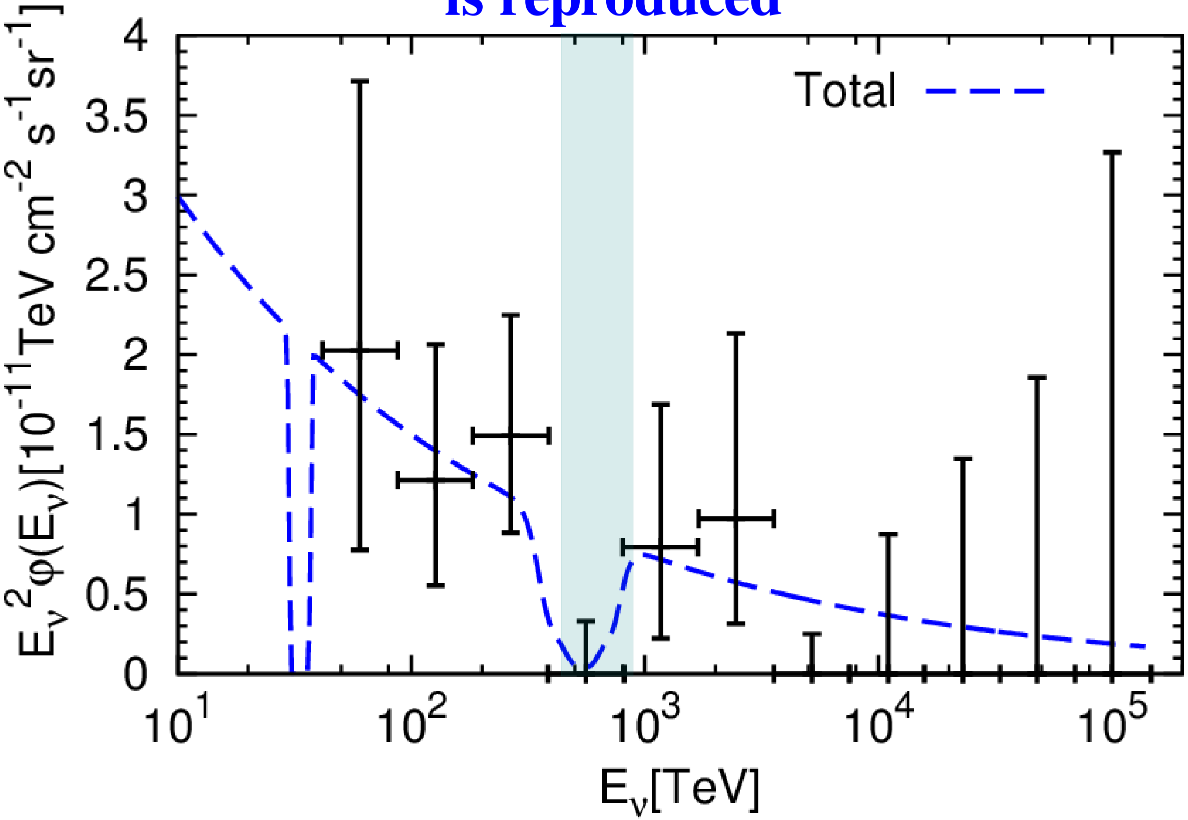
IceCube Gap is reproduced



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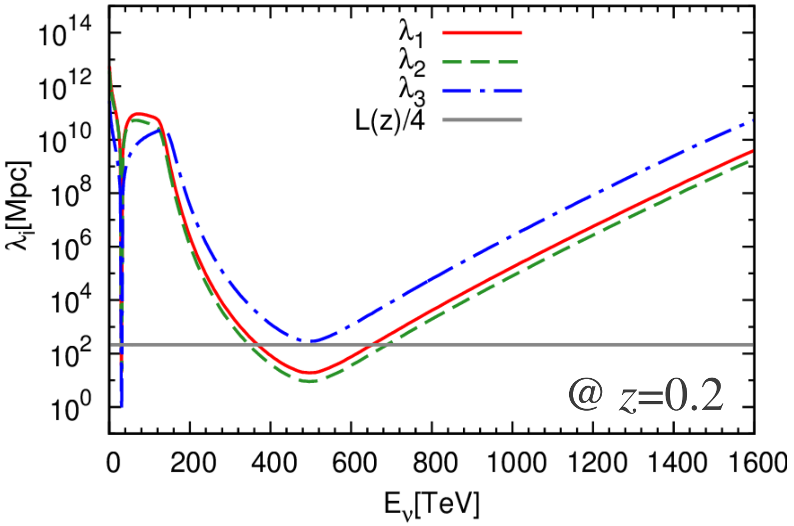

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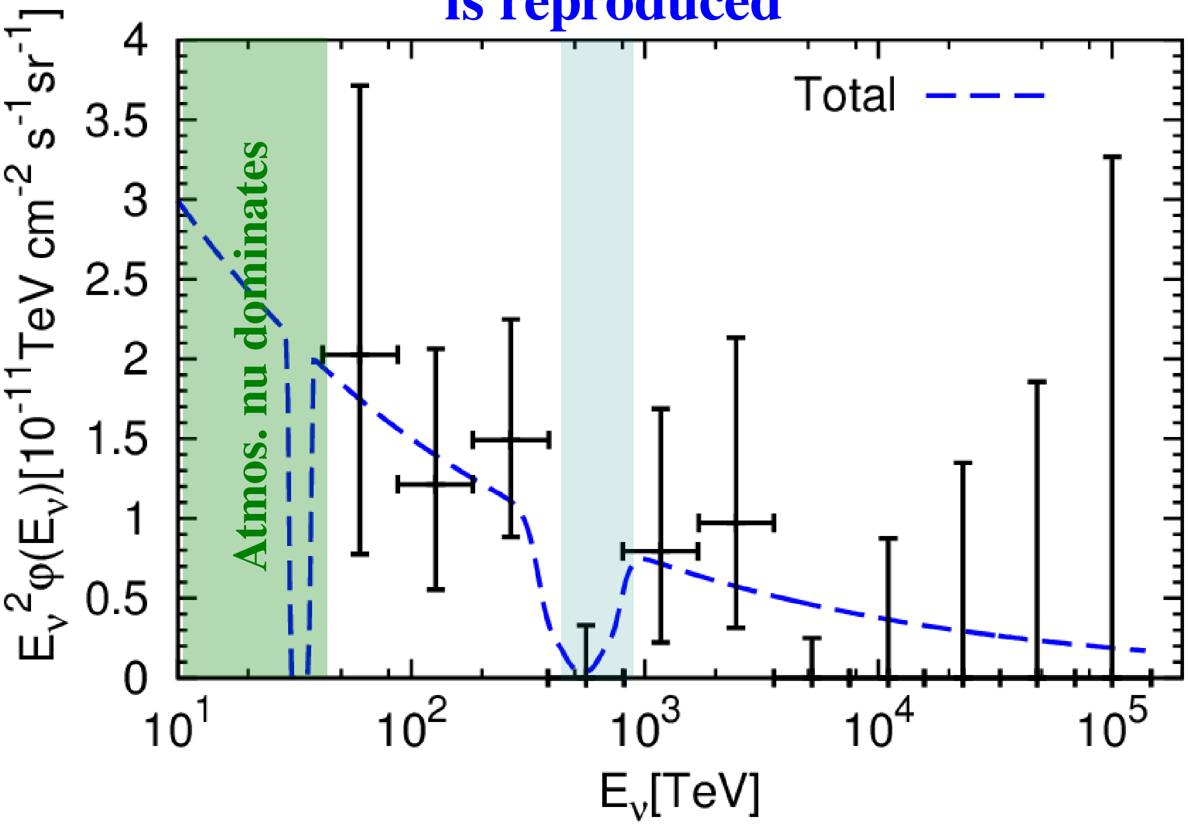

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Working example ③ Cosmic neutrino spectrum

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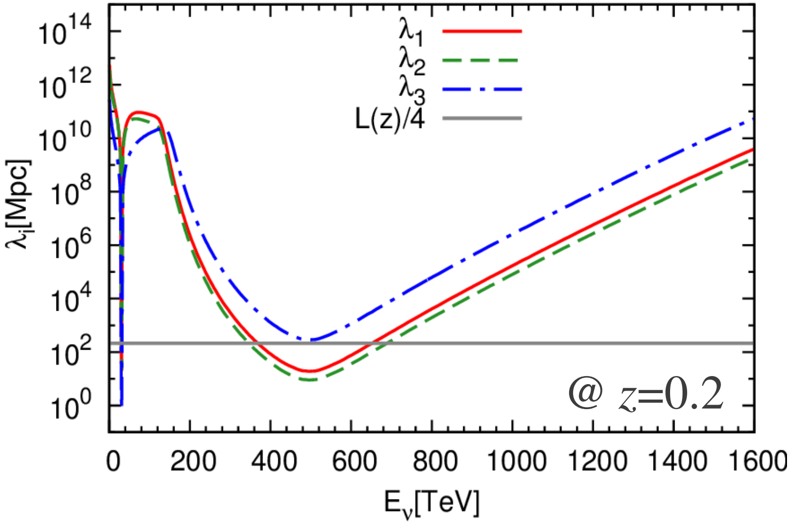

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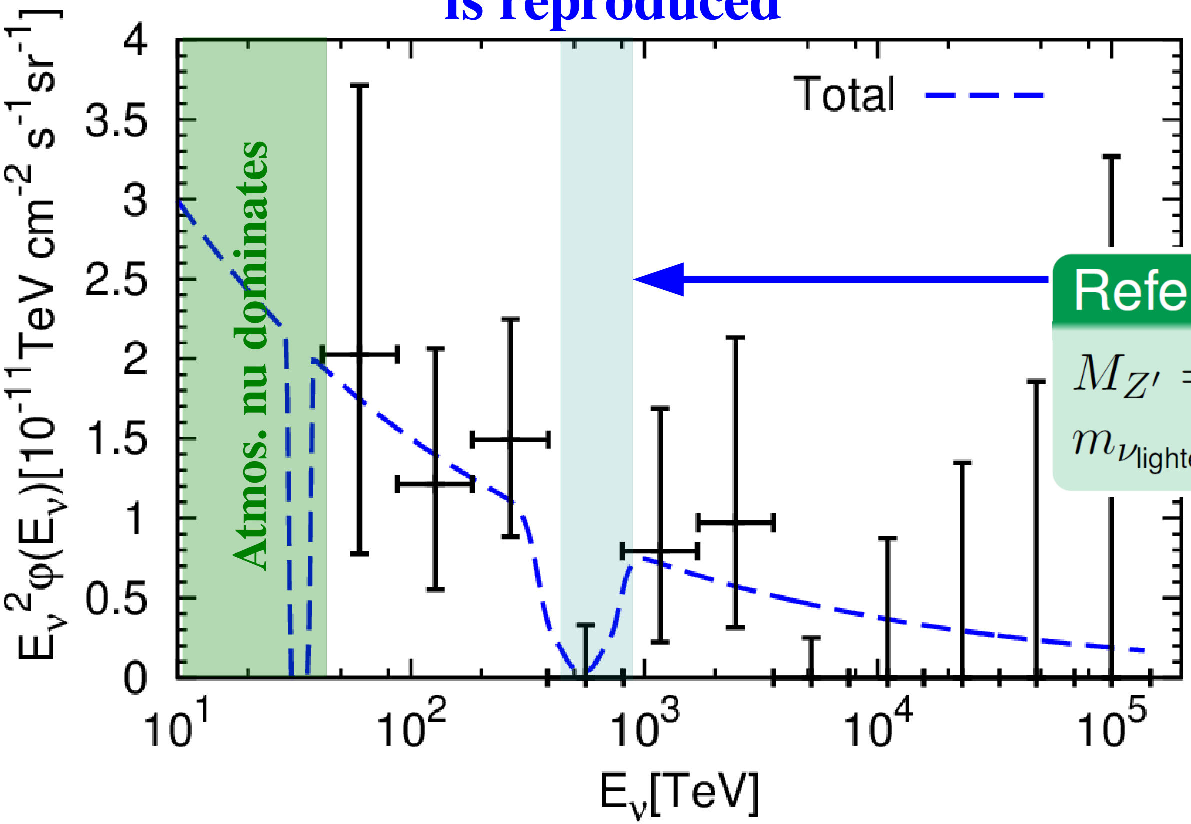


The resulting gap does not depends on the initial flavour composition.

Reference values

$M_{Z'} = 2.75$ MeV, $g_{Z'} = 5.0\cdot 10^{-4}$,
$m_{\nu_{\text{lightest}}} = 3.0\cdot 10^{-3}$ eV (IH) and $z_{\text{source}} = 0.2$.

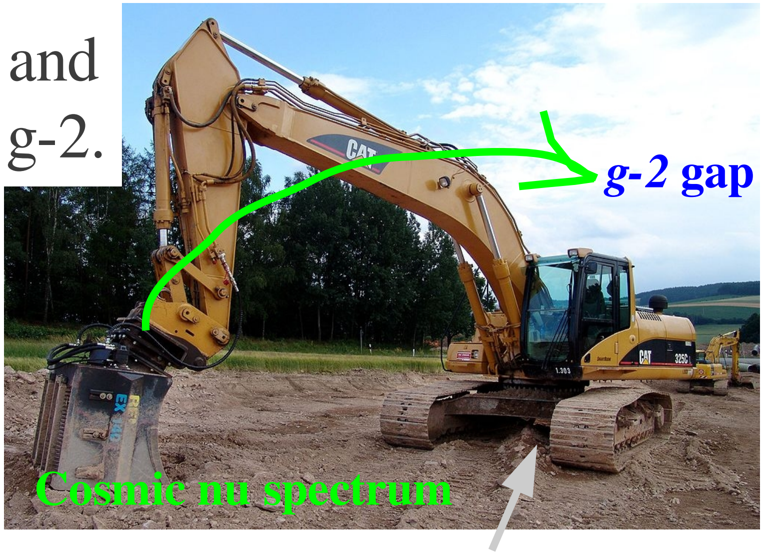
Z' contribution to muon g-2

$$\Delta a_\mu^{Z'} = 31.7\cdot 10^{-10}$$

***g-2* Gap is filled**

Summary and future prospects

We dig the cosmic neutrino spectrum to make a gap and swing around the surplus soil to fill the gap in muon g-2.



This tool is called as
“*U(1)* leptonic force Lmu-Ltau”

Reference values

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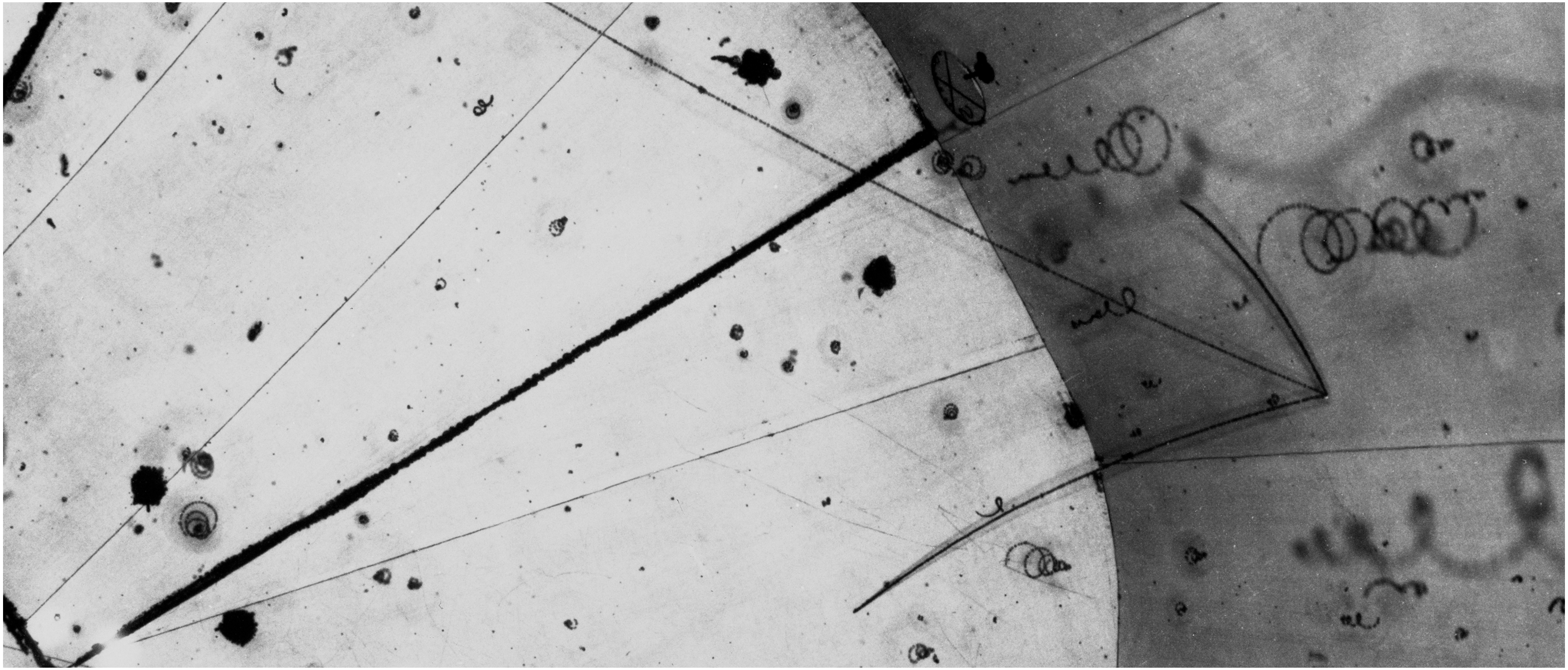
- IceCube Gap is reproduced.
- $\Delta a_\mu^{Z'} = 31.7 \cdot 10^{-10}$

But we did not...

- ...take into account distribution of neutrino source.
- ...also take into account secondary neutrino effect.
- ...discussed details of the model.

This small try shows that the idea works!
More precise, detailed, and sophisticated study may be worth to be done.

Back up slides



Back up slides

Distribution: star formation rate z=1-2.

P gamma (photohadronic)→ IceCube edge

An astrophysical explanation:
P gamma (photohadronic) (Enu<Gap) + PP (Enu<Gap)

Z vs distance (pc and light year)

Lambda on the Mnu-vs-Enu plane @z=0 (with various mZ')

Normal hierarchy

Discussion on Spontaneous breaking of Lmu-Ltau → some reference…?
Check Gori et al…or Harigaya et al…Spires

Relation to Neutrino Frontier

Precision measurement of neutrino int.

The most relevant bound
is **neutrino trident proc.**

Ask a favor (or two)
to experimentalists

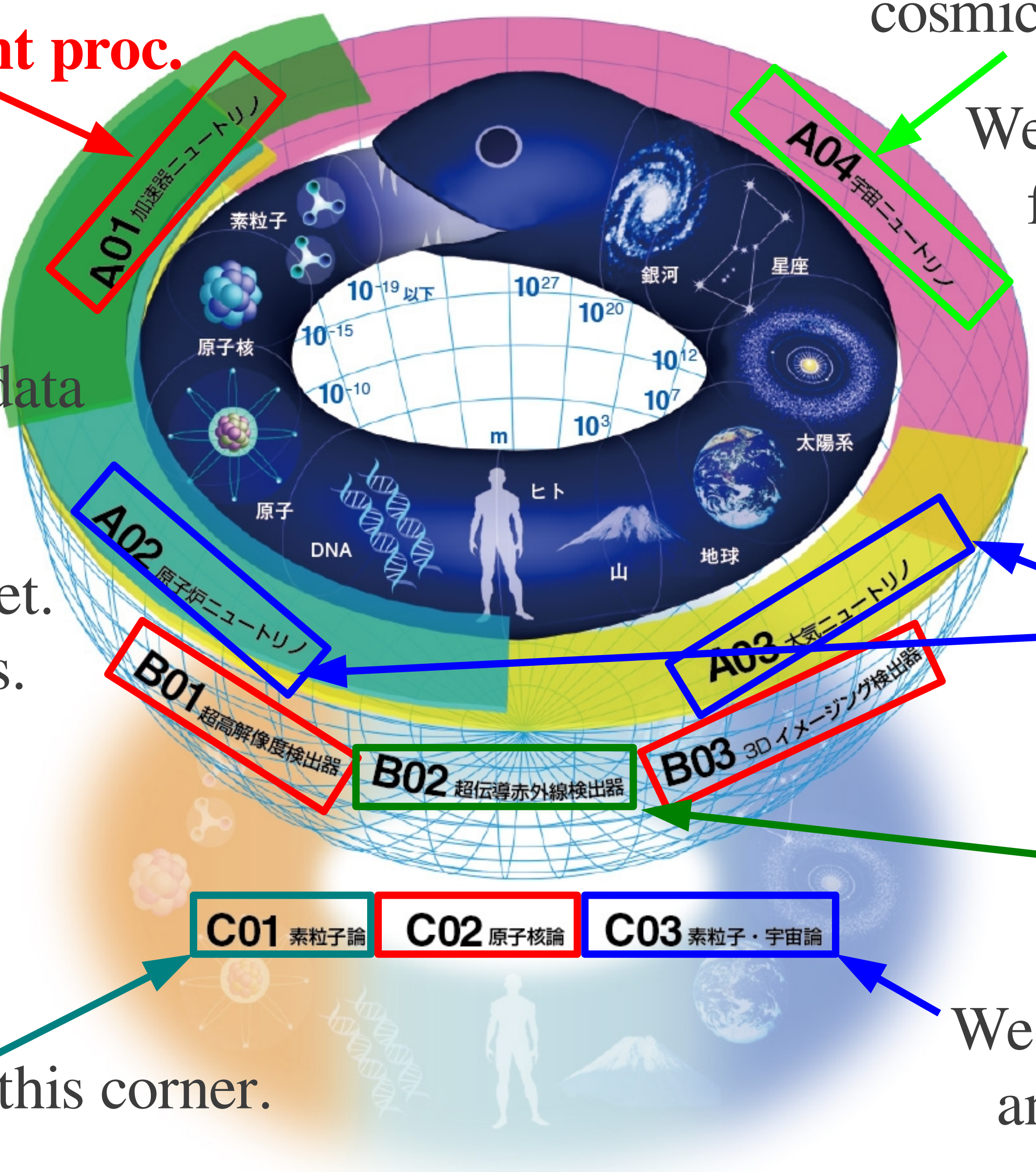
Please provide new data
(to feed theorists)

Please check near det.
events in your HDs.

We **mind the gap** on
cosmic neutrino spectrum

We are also motivated
from **muon *g*-2**

Charged Lepton



The model is
inspired by...

CNB int.

We share interest
and ideas with...

I belong to this corner.