IceCube実験による超高エネルギーニュートリノ探索

石原安野(千葉大学)

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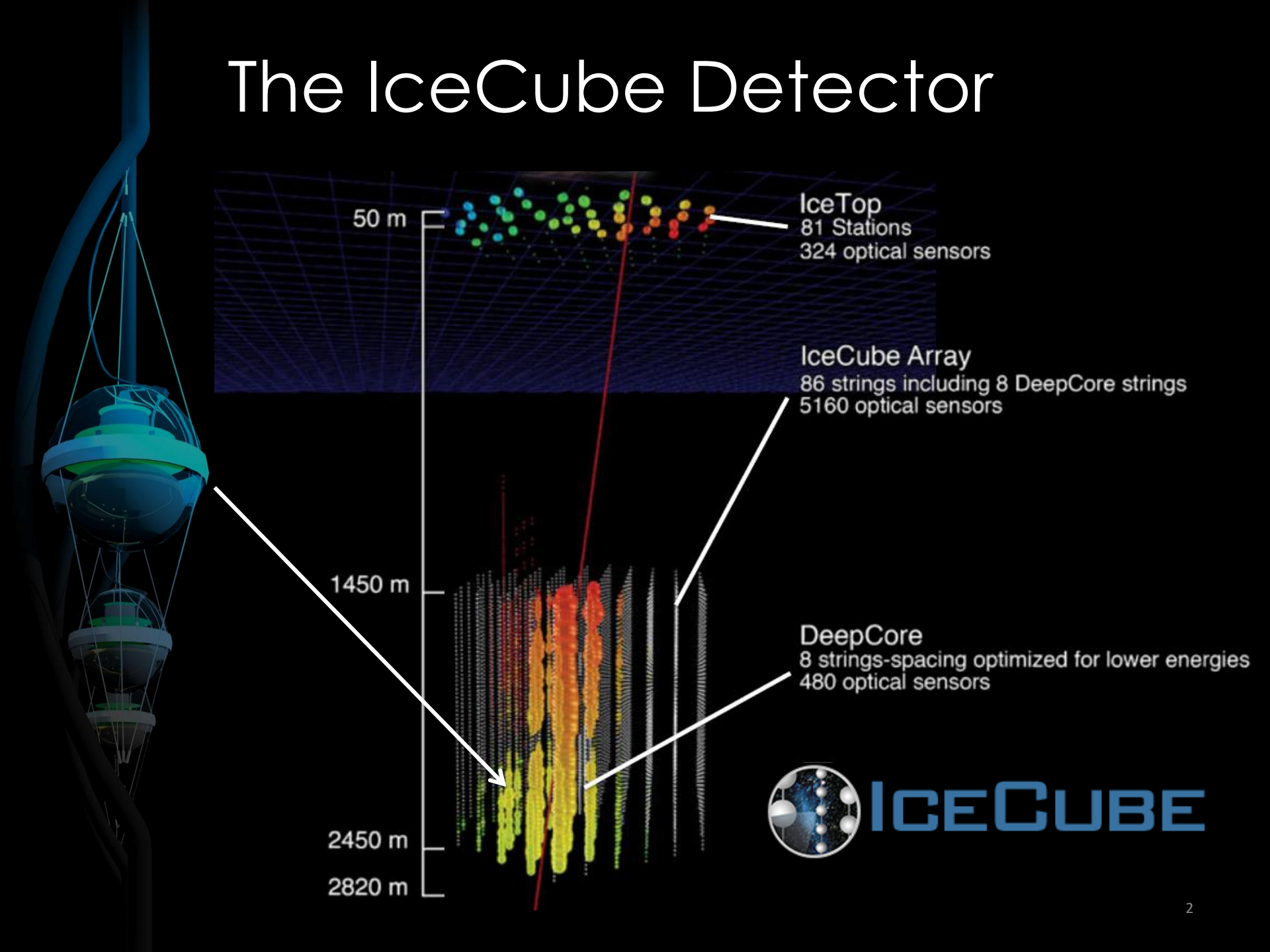
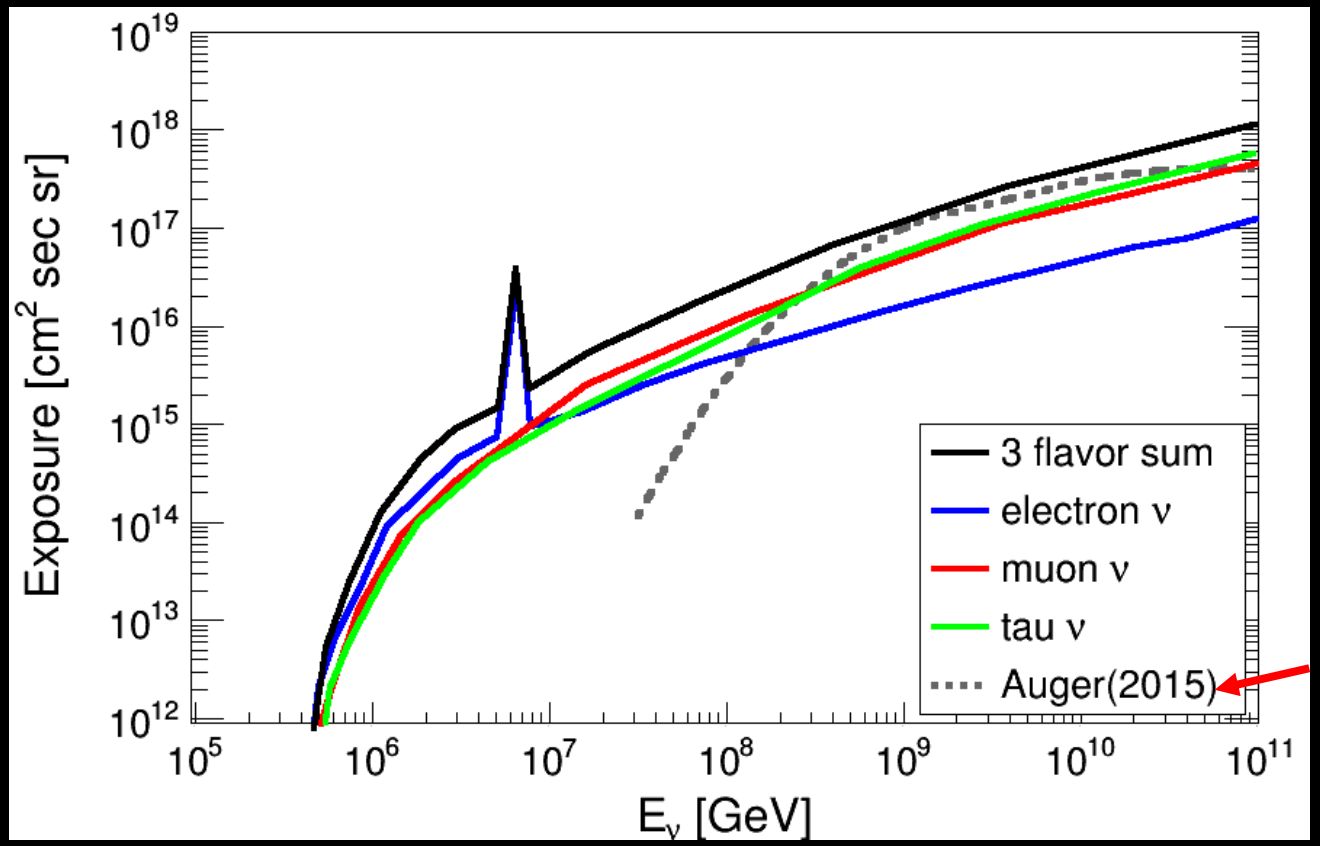
The IceCube Detector



Event sample and detector exposure

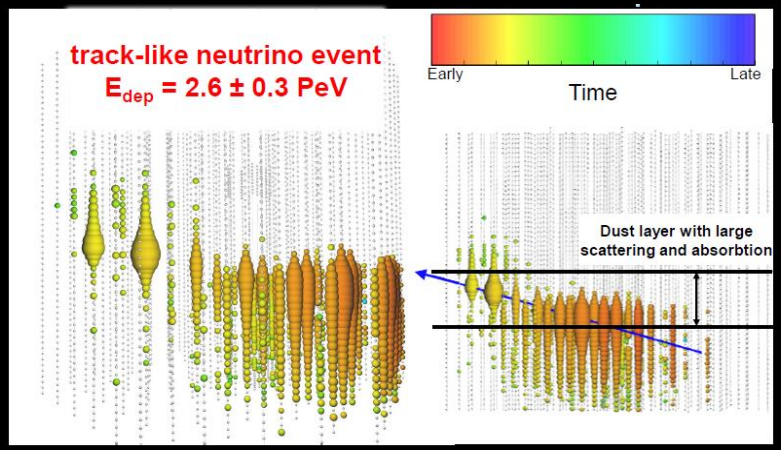
- EHE neutrino search with IceCube have been updated with 7 years of IceCube sample (data since IceCube half completed)
- Effective livetime of 2426days from April 2008-May 2015
- Exposure has increased more than a factor of 2.5 from the previous study

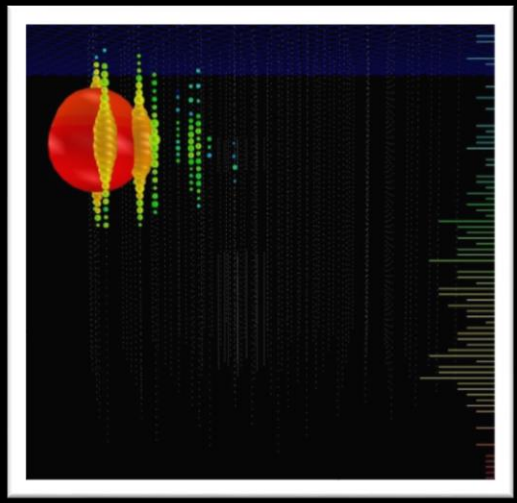


Auger 9yrs (2004–2013)

Observation after signal selection

- Multi-channel analysis looking for any type of events with a large energy deposit
- One partially contained upward-going cascade recorded at Nov 16, 2012
  - Energy deposit: 770 TeV
  - Vertex position close to the outer most layer of optical sensors
- One upward-going muon track observed at June 11, 2014
  - Energy deposit of 2.6 PeV





- **Atmospheric background only hypothesis test: p-value of 0.014% and rejected at 3.6σ**
- **Observation is not consistent with GZK hypothesis with p-value of 0.3%**
- **E^{-2} signal model is compatible with p-value of 92%**

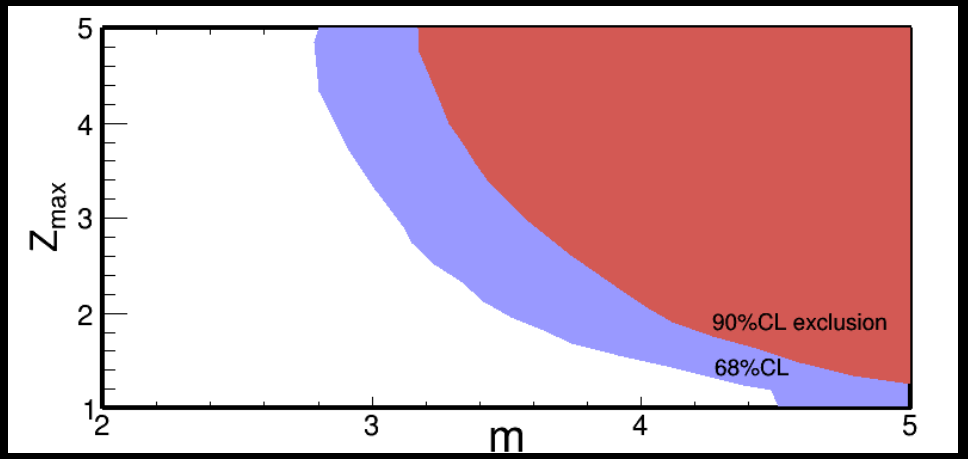
Constraints on the highest energy CR sources

- Non observation of higher energy event places sever constraints
- Cosmogenic neutrino limits disfavor the sources for UHECRs of which the cosmological evolution stronger than the star formation rate (SFR), such as AGN and GRB etc... assuming proton dominant composition

cosmogenic neutrino model	Event rates	p-value	upper limit 90% CL
Ahlers Fermi best fit, 3EeV	4.4	2.2%	0.61
Ahlers Fermi best fit, 10EeV	5.3	0.7%	0.41
Kotera SFR	3.6	22.3%	1.2
Kotera FRII	14.7	<0.1%	0.32
Aloisio SFR	4.8	7.8%	0.93
Aloisio FRII	24.7	<0.1%	0.19

exclusion region for cosmological evolution parameters

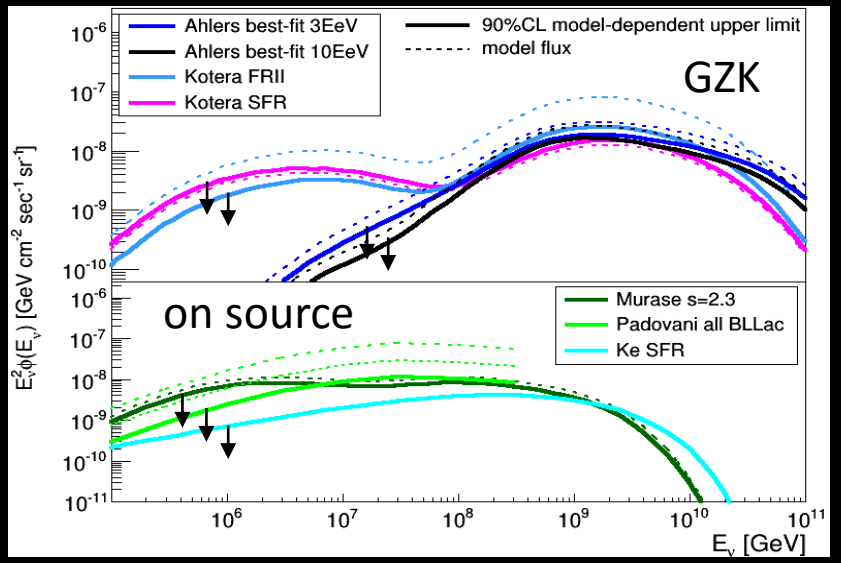
$(1+z)^m$ for $z \leq z_{max}$

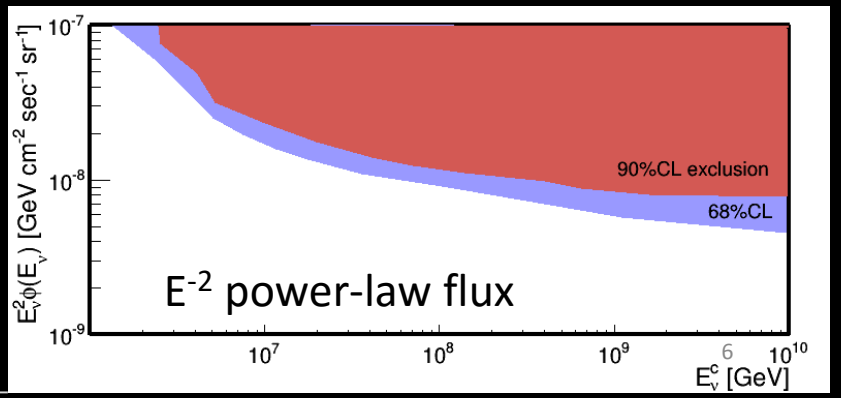


Constraints on the UHE CR sources

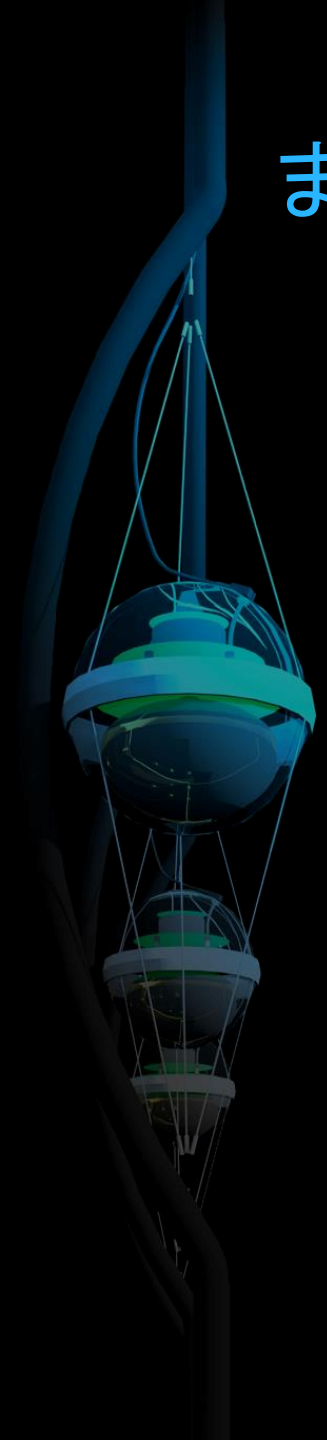
- UHECR composition independent constraints can placed
- Many models of on-source neutrino production from UHECR sources, such as blazers and new born pulsars, are onstrained

on-source neutrino	Event rates	p-value	upper limit 90% CL
Murase AGN s=2.3, ξ_{CR}=100	7.4	2.2%	0.73 (ξ_{CR}<73)
Murase AGN s=2.0, ξ_{CR}=3	4.5	20%	1.21 (ξ_{CR}<3.6)
Ke Pulser SFR	5.5	7.8%	0.99
Ke Pulser uniform	1.2	54.8%	4.6
Padovani Blazer $Y_{\nu\gamma}$=0.8	37.8	<0.1%	0.15 ($Y_{\nu\gamma}$<0.12)





exclusion region for E^{-2} power-law flux parameters



まとめ

- 7年分のIceCubeデータを解析
- 10PeVを超えるようなニュートリノ事象候補を探したが見つからなかった
- 最高エネルギー宇宙線が陽子だとすると、SFRより強い進化を持つ天体を起源天体とすることは難かしくなりつつある
- on-sourceモデルに対する制限からはcomposition-independentにUHECRのAGNモデルなどに制限がつきつつある
- 本解析から(CRだけでなく)ニュートリノからも10^{18}eVを超えるエネルギーの宇宙線源に対する、より現実的な制限がついた
- 最高エネルギー領域におけるマルチメッセンジャーによる天体クラス同定へ進んでいる

宇宙線研のクラスターを使い、背景事象の理解を進めました