

Kosmische Teilchenbeschleuniger und ihre Spuren in der Antarktis

Annika Rudolph, Anatoli Fedynitch



Discovery of a Cosmic-Ray Source Is a Triumph of 'Multimessenger Astronomy'

By Harrison Tasoff, Space.com Contributor | July 12, 2018 06:29pm ET

The New York Times

It Came From a Black Hole, and Landed in Antarctica

For the first time, astronomers followed cosmic neutrinos into the fire-spitting heart of a supermassive blazar.

Origin of Mystery Space Radiation Finally Found

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BUSINESS INSIDER
INDIA

A ghostly particle detected in Antarctica has led astronomers to a super-massive spinning black hole called a 'blazar'

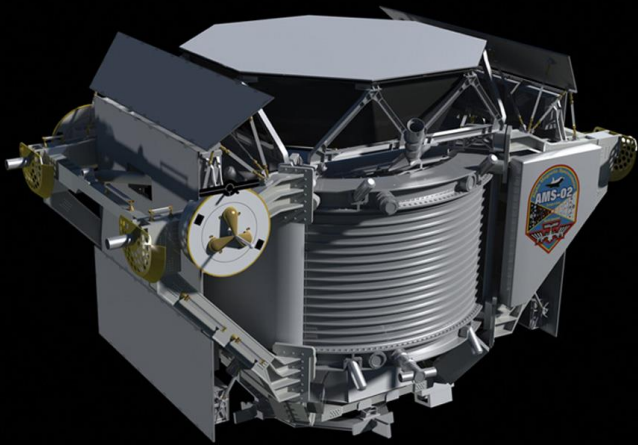
Neutrino observation points to one source of high-energy cosmic rays

1912, Victor Hess und die Höhenstrahlung



[B2] [R1, R2]

Nachweis kosmischer Strahlen heute



Niedrige Energien:
Satelliten (AMS)

[B3] [R3]

Hohe Energien: Luftschauere

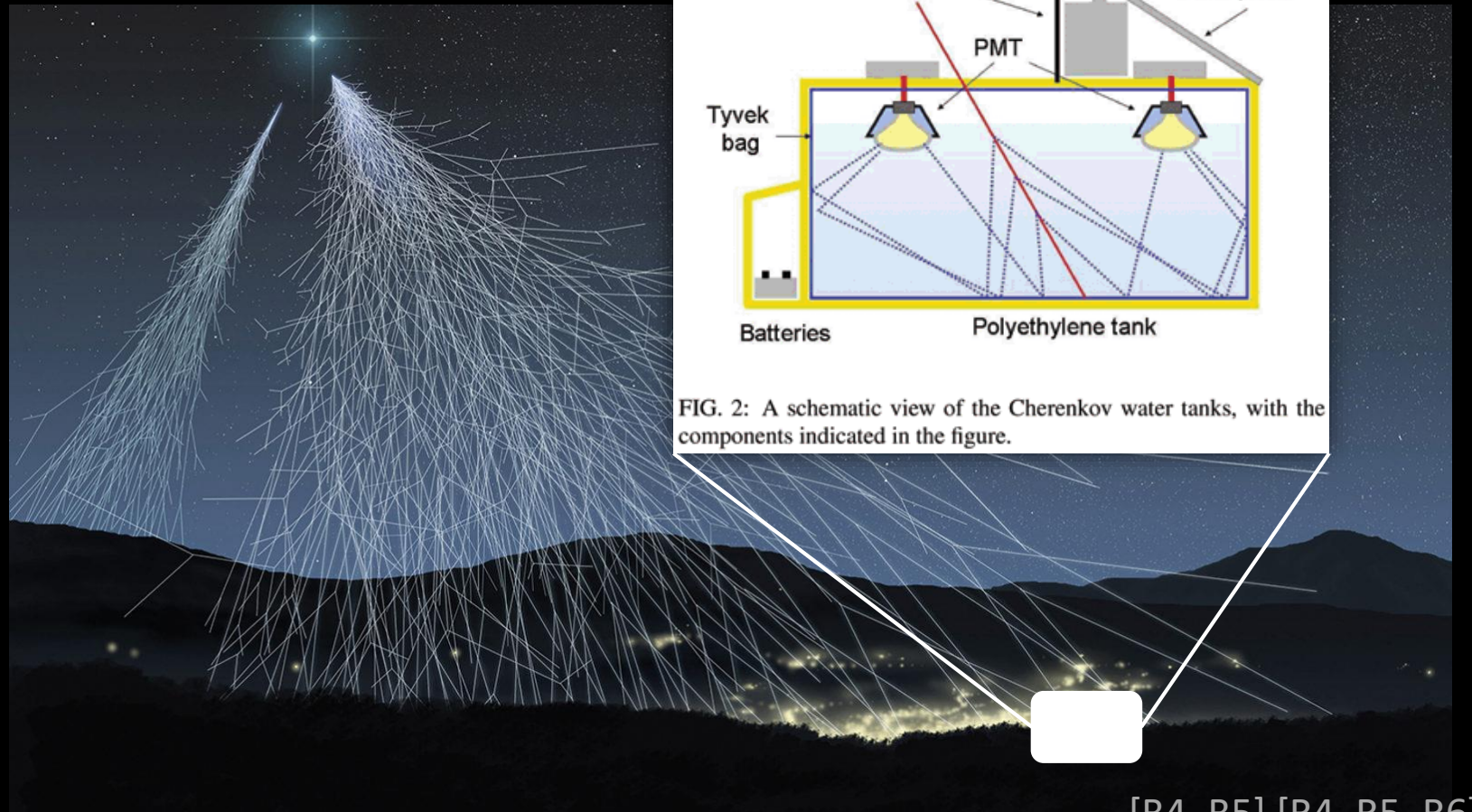
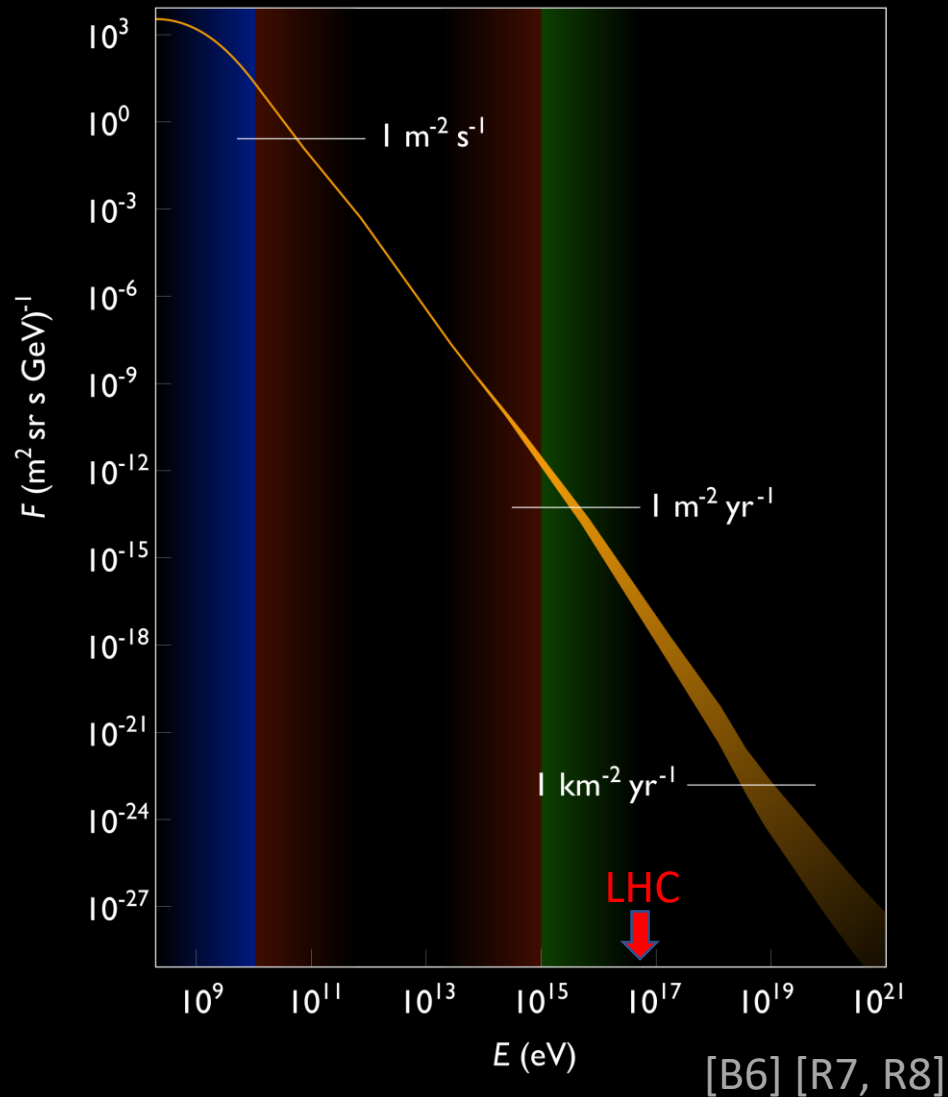


FIG. 2: A schematic view of the Cherenkov water tanks, with the components indicated in the figure.

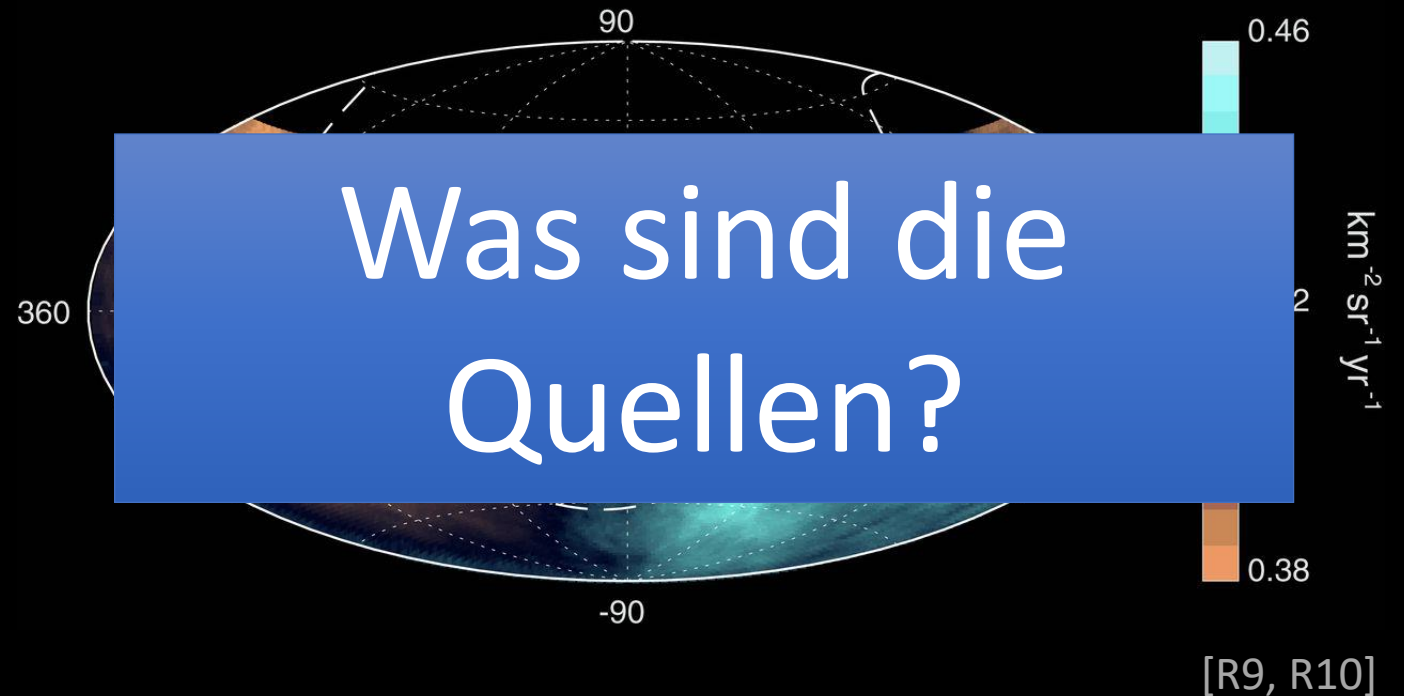
[B4, B5] [R4, R5, R6]

Was wissen wir über kosmische Strahlen?

Teilchenfluss



Ankunftsrichtung

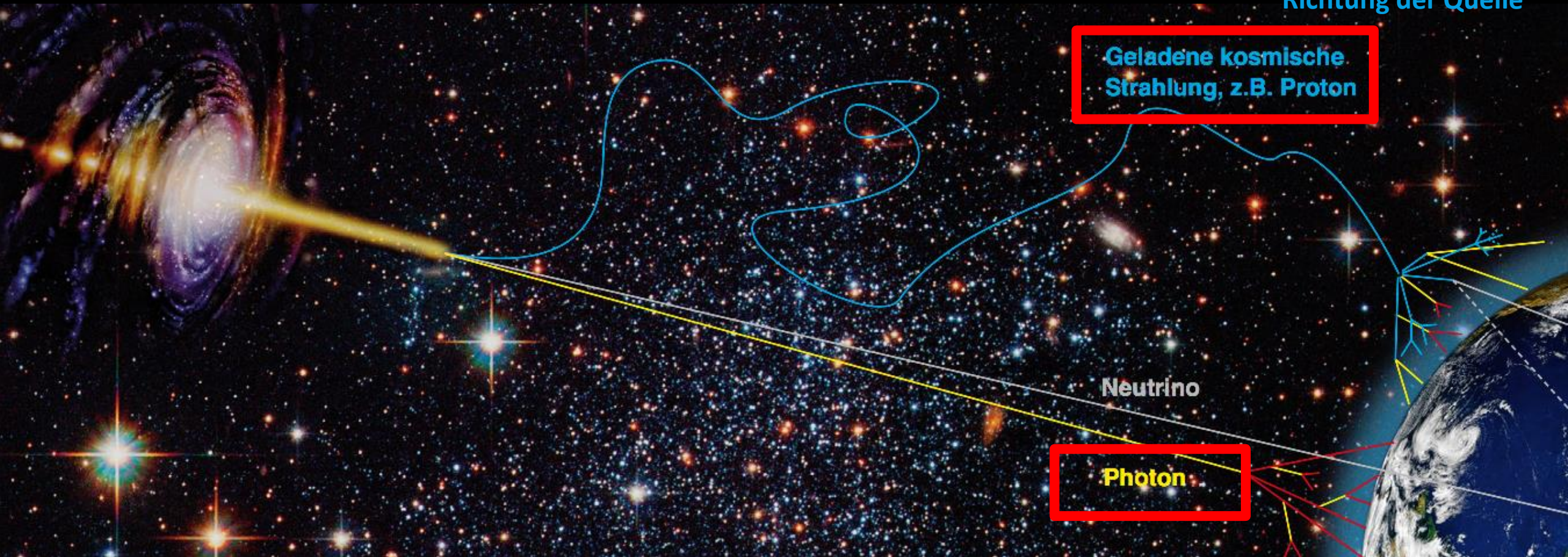


Problem: Beschleuniger nicht direkt bekannt



Kosmische Boten

... kommt nicht aus Richtung der Quelle

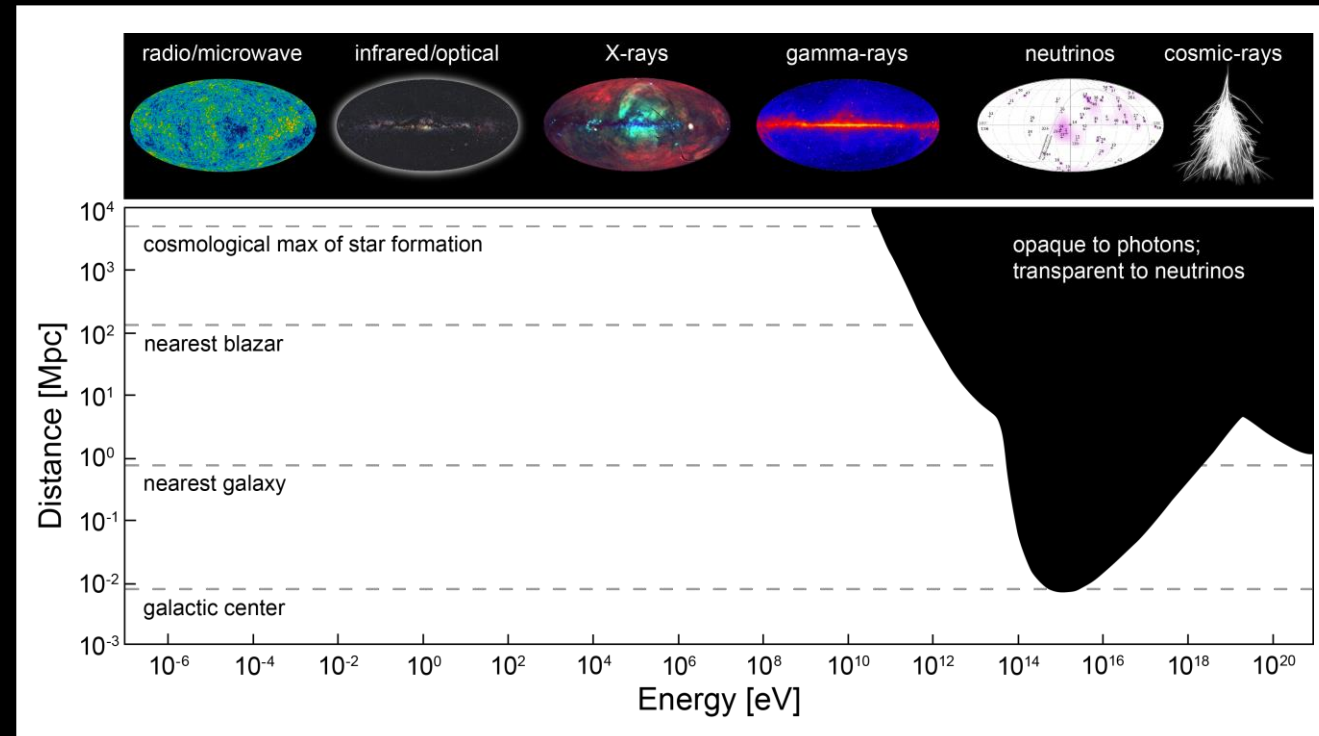


Licht als Informationsträger



Aber: Licht als Informationsträger nicht ausreichend

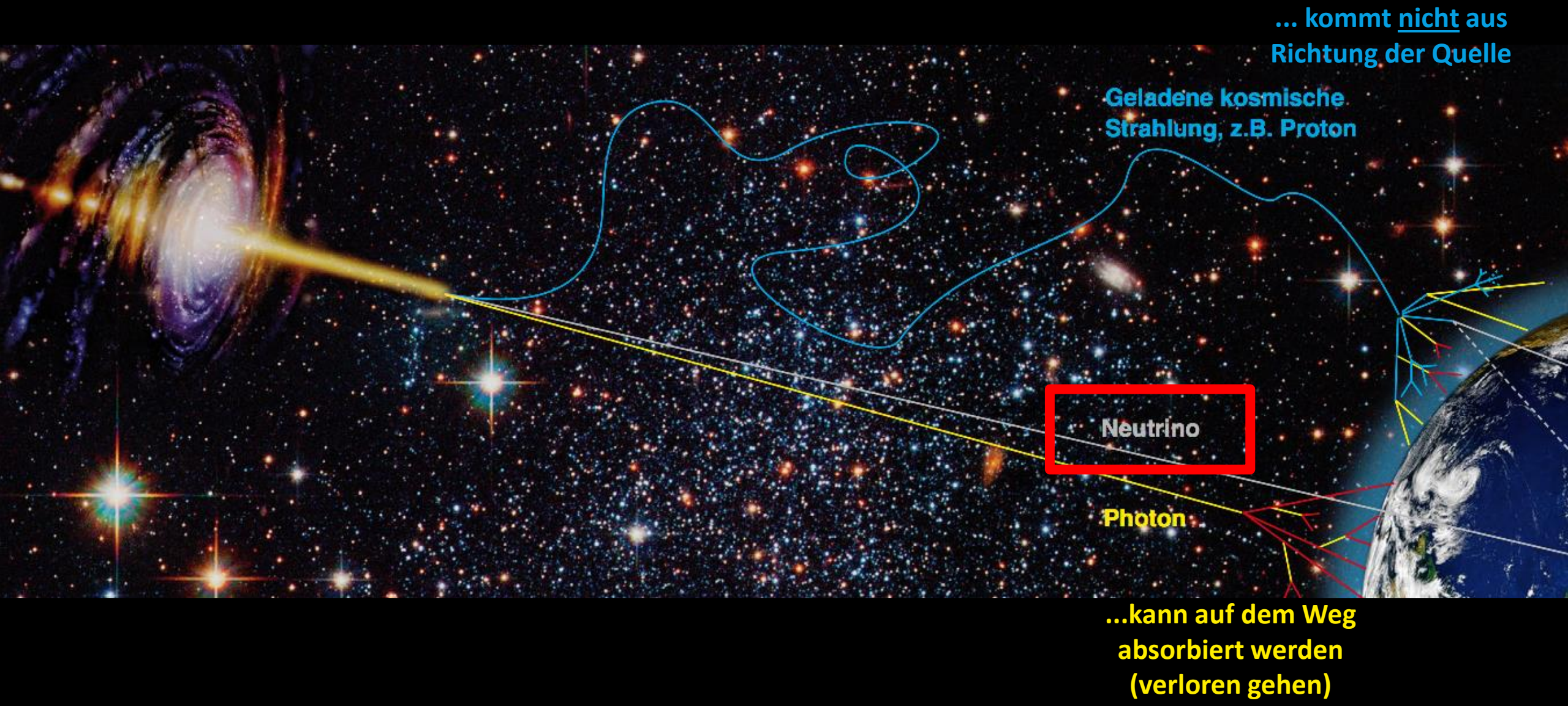
1. Begrenzter Horizont:
Gammastrahlung wird auf dem Weg absorbiert
2. Mehrdeutigkeit: Nicht (immer) unterscheidbare Ursachen für Abstrahlung
3. Abdeckung: Messung funktioniert nur Nachts oder im Weltraum und Teleskop muss ausgerichtet sein



[B9] [R11]

Andere Informationsträger?

Der dritte Bote – Neutrinos



... kommt nicht aus Richtung der Quelle

Geladene kosmische Strahlung, z.B. Proton

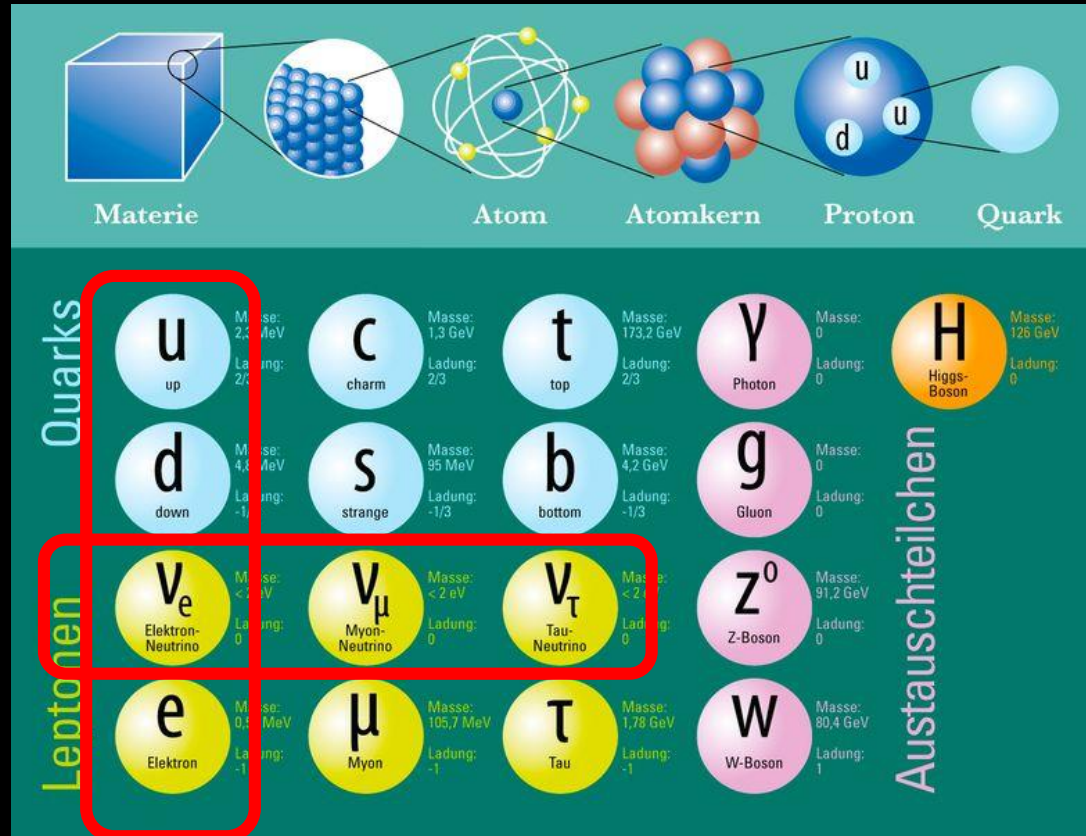
Neutrino

Photon

...kann auf dem Weg absorbiert werden (verloren gehen)

Moment, was waren nochmal Neutrinos?

Das Standardmodell der Teilchenphysik



Eigenschaften von Neutrinos:

- Keine Ladung
- Fast keine Masse
- Interagieren nur über die schwache Wechselwirkung



Moment, was waren nochmal Neutrinos?

In astrophysikalischen Quellen und deren Umgebung:

- Kosmische Strahlen interagieren mit anderen Teilchen und/ oder Licht
- Als Sekundärprodukte entstehen unter anderem Neutrinos (tragen ca 5% der Primärenergie)

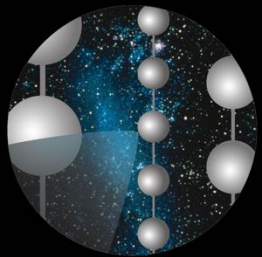
Neutrinos sind ein direkter Nachweis für kosmische Strahlen!

Eigenschaften von Neutrinos:

- Keine Ladung
- Fast keine Masse
- Interagieren nur über die schwache Wechselwirkung

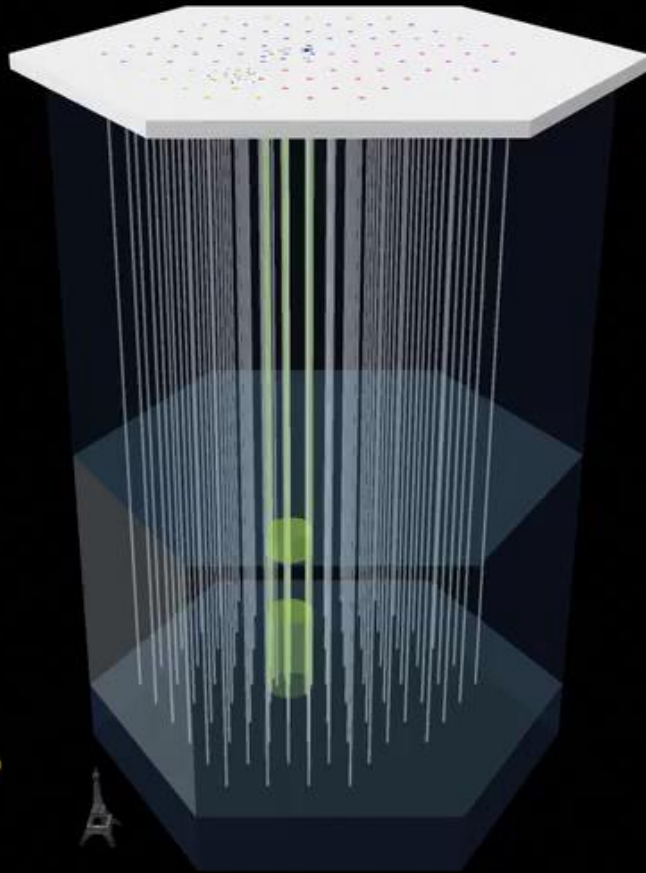


Messung astrophysikalischer Neutrinos



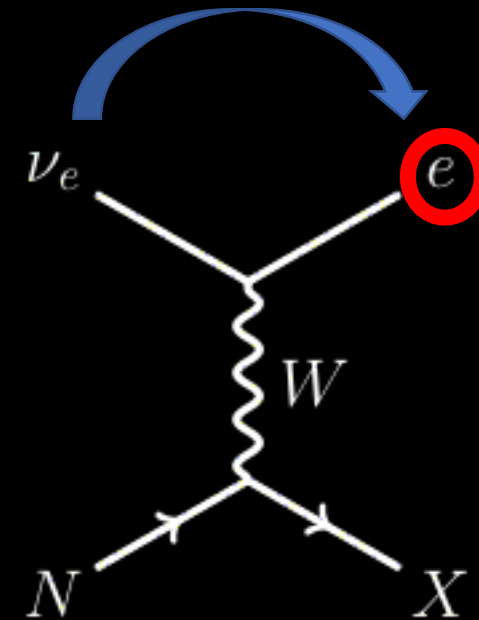
IceCube

Der IceCube Detektor



- 1 km³ Detektorvolumen im antarkt. Eis
- Über 250 Wissenschaftler weltweit beteiligt
- Detektion von Cherenkovstrahlung wechselwirkender Neutrinos

Konvertierung
von Neutrinos
in Leptonen



Protonen und
Neutronen im Eis

[B11]

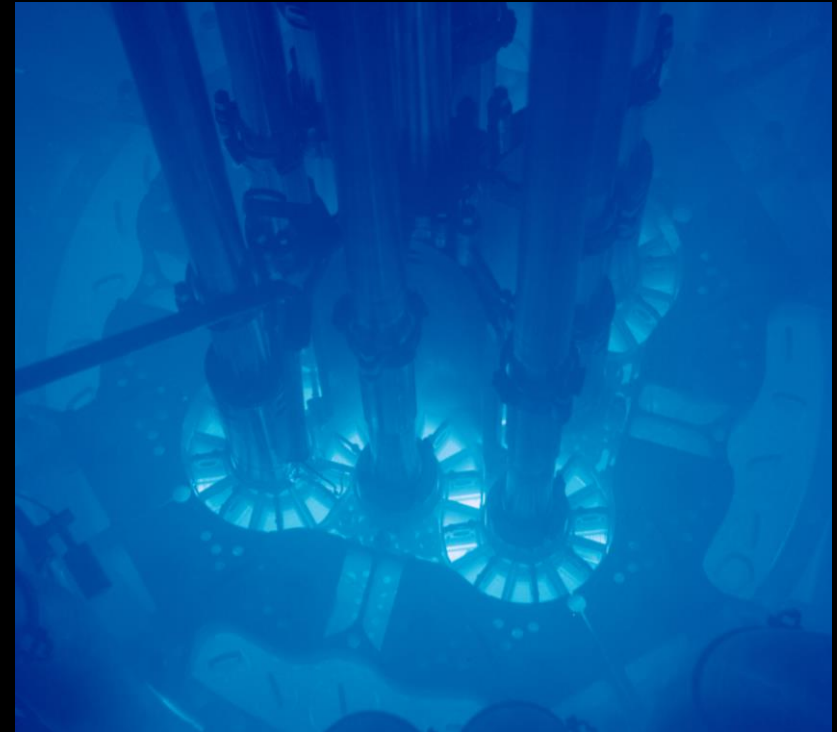
[R11, R12, R13]

Messprinzip

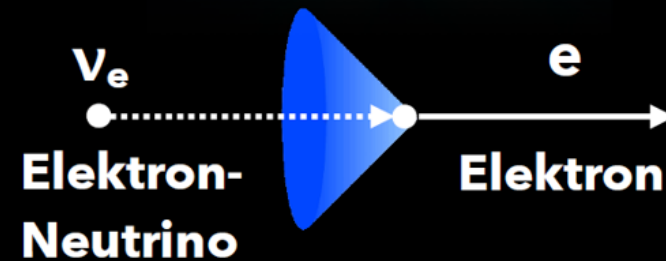
Cherenkov – Strahlung: entsteht wenn Teilchen sich (im Medium) schneller als Licht bewegen



[B14]



[B15]



[B16]



ICECUBE

SOUTH POLE NEUTRINO OBSERVATORY

50 m

Ice Top



IceCube Laboratory

Data is collected here and sent by satellite to the data warehouse at UW-Madison

1450 m

86 strings of DOMs, set 125 meters apart



Amundsen-Scott South Pole Station, Antarctica

A National Science Foundation-managed research facility



Digital Optical Module (DOM)

5,160 DOMs deployed in the ice

2450 m

IceCube detector

DeepCore

DOMs are 17 meters apart

60 DOMs on each string

Antarctic bedrock



2.5 km tiefe Bohrungen



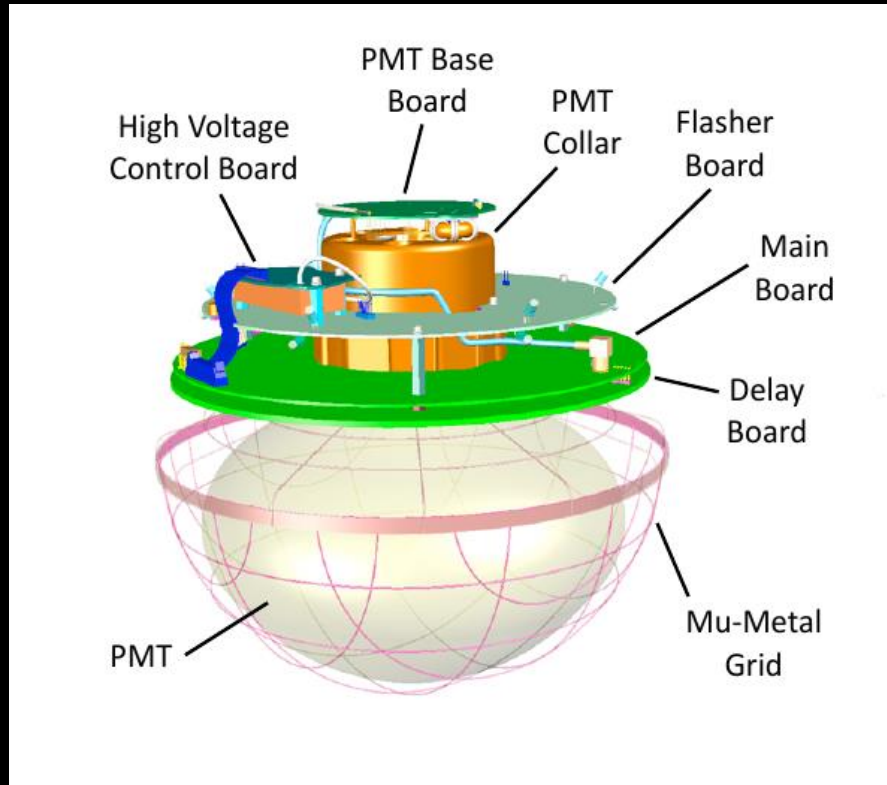
Verkabelung (mal anders)



Optische Module im Eis



Digitale Optische Module (DOM)

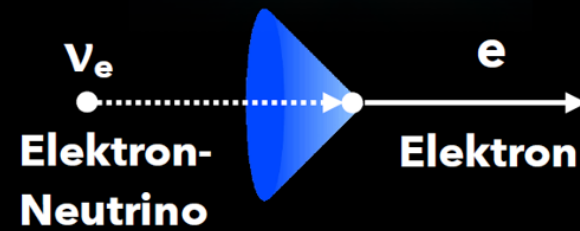
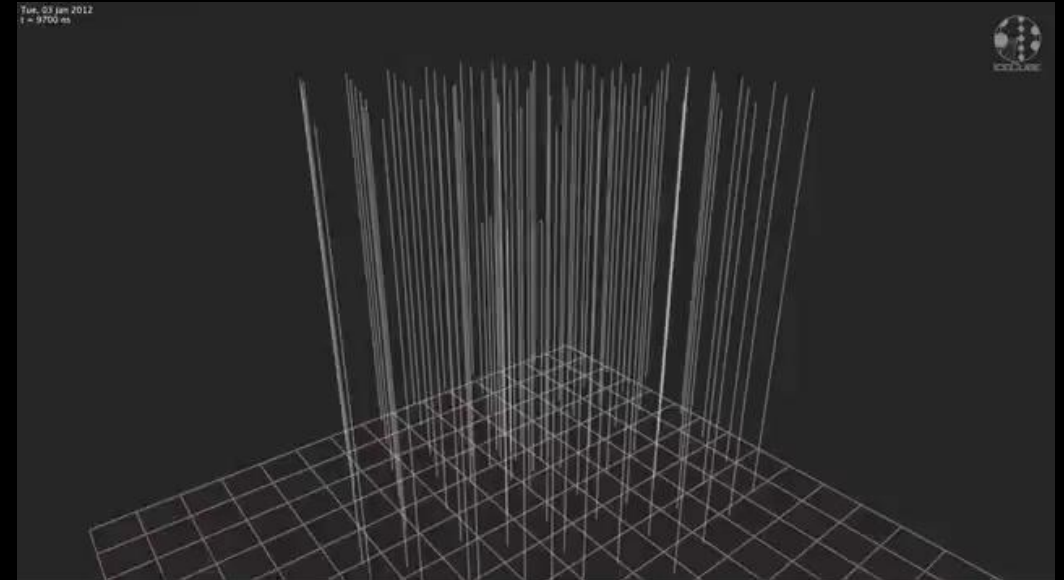
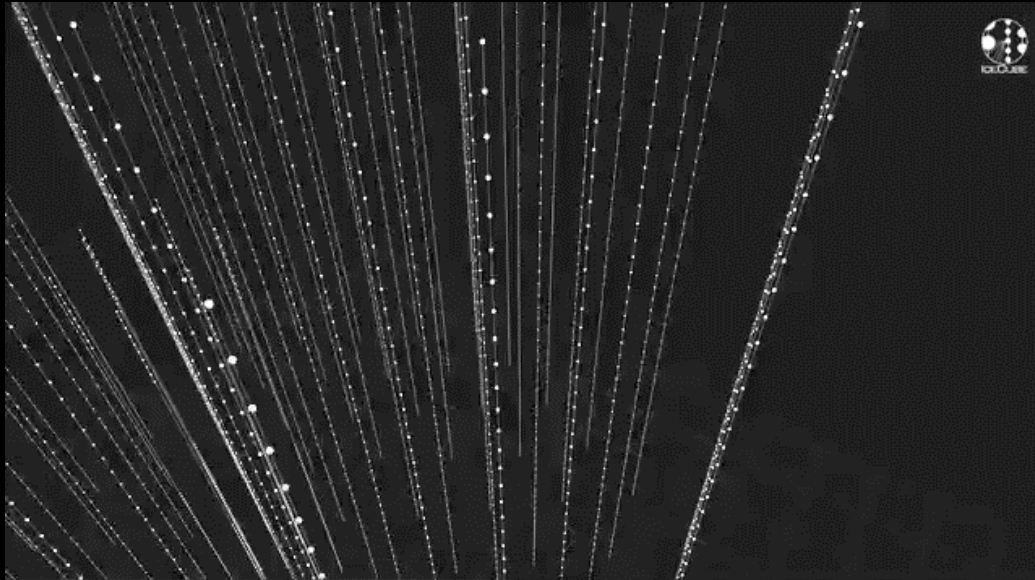


[R14]

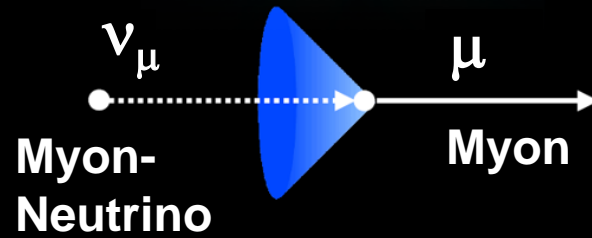
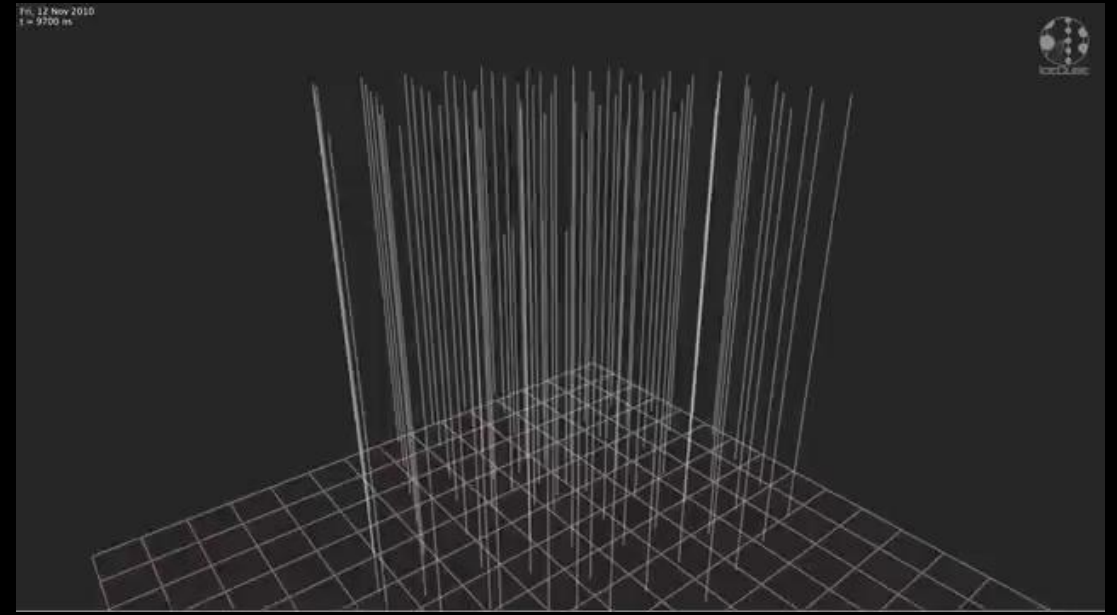
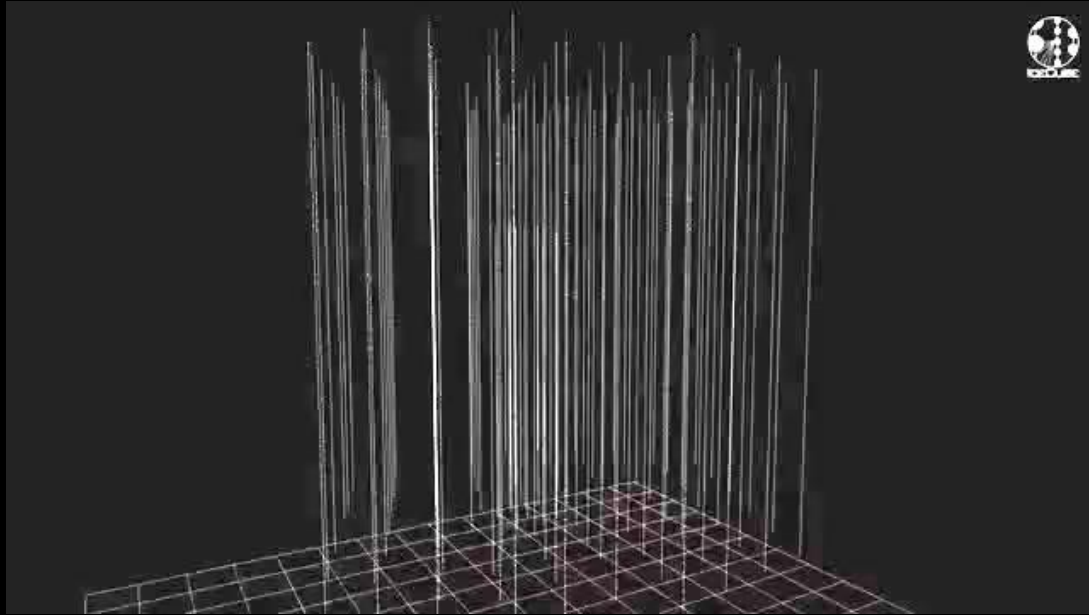


DOM = Kamera für blaues Licht

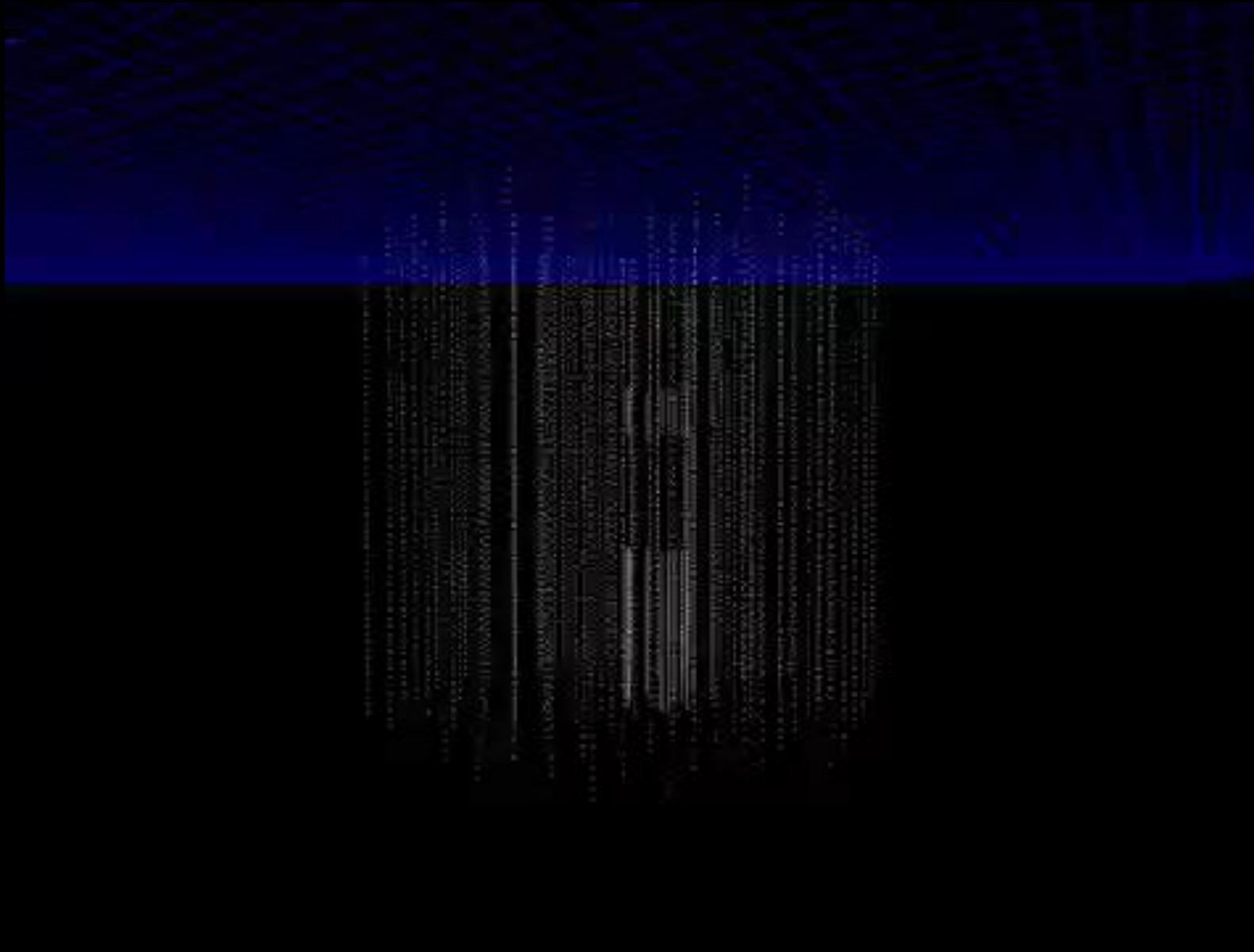
Elektron-Neutrino



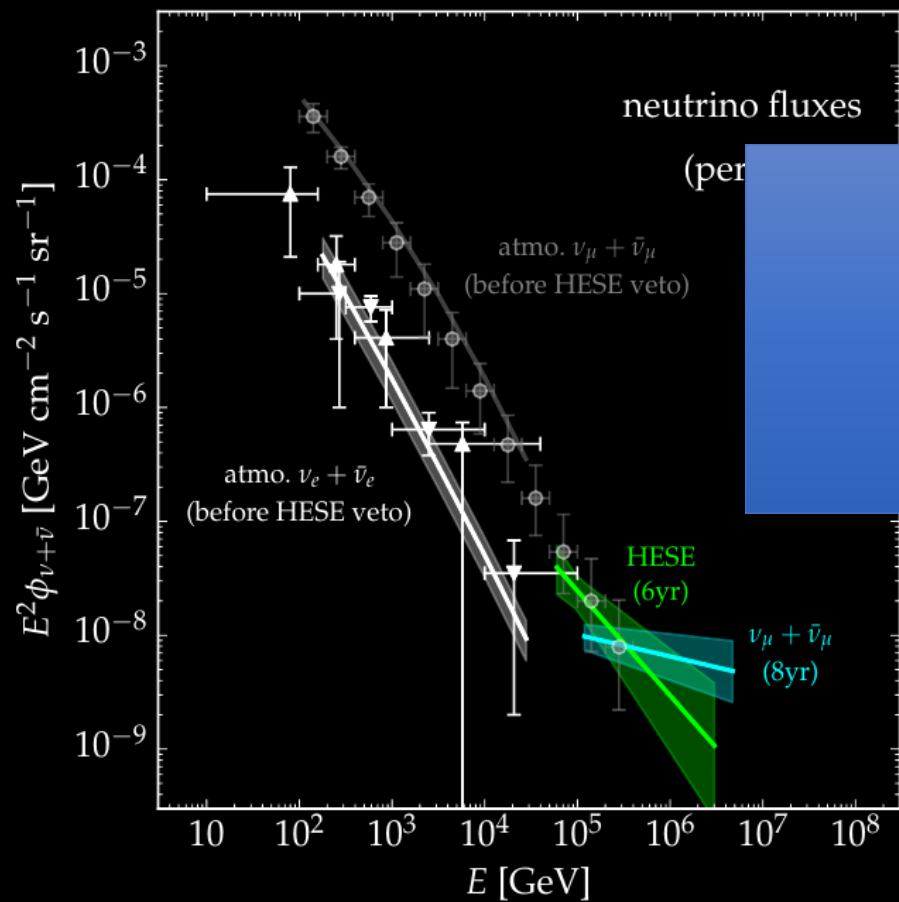
Myon-Neutrino



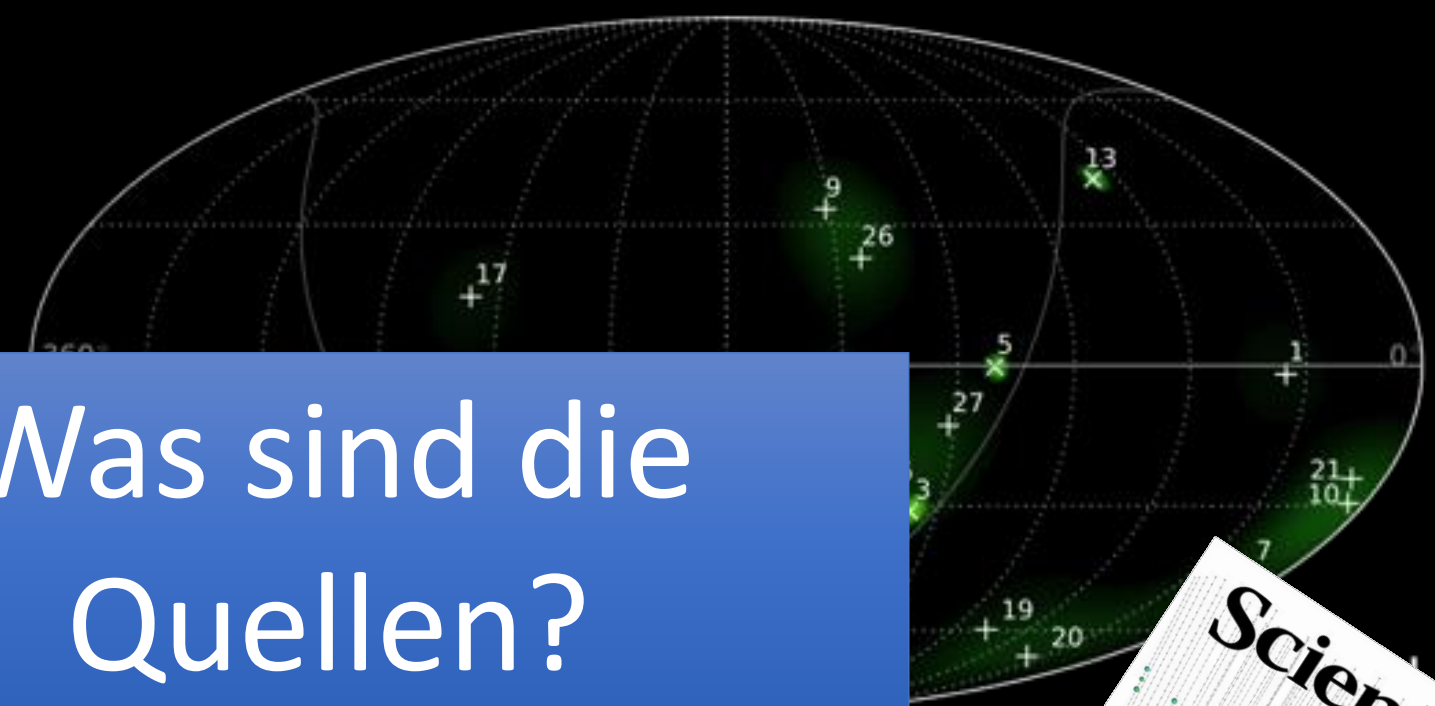
10ms aus der Sicht von IceCube



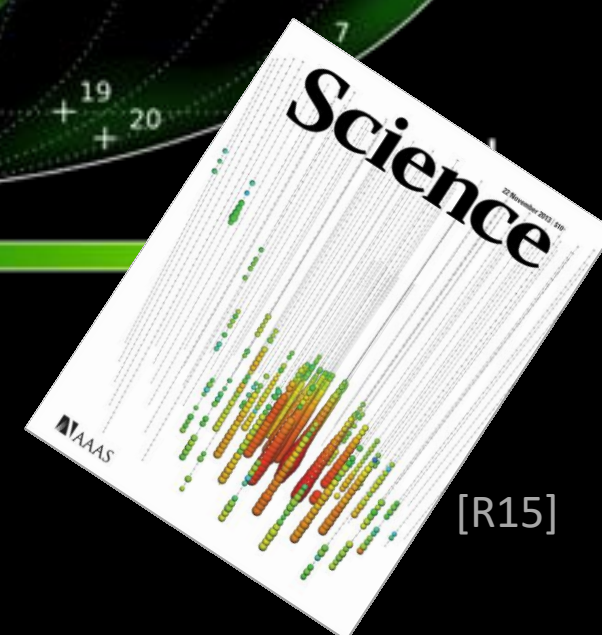
Entdeckung astrophysikalischer Neutrinos



Was sind die Quellen?



0 TS=2log(L/L0)



[R16]

[R15]

Diesen Sommer...

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Was Wissenschaftler sehen

RESEARCH ARTICLE

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube Collaboration, *Fermi*-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S., INTEGRAL, Kanata, Kiso, Kapteyn, Liverp...

[R17]

+ See all authors and affiliations

RESEARCH ARTICLE

Science 13 Jul 2018:
Vol. 361, Issue 6398, eaat1378
DOI: 10.1126/science.aat1378

Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert

[R18]

IceCube Collaboration^{*,†}

+ See all authors and affiliations

Science 13 Jul 2018:
Vol. 361, Issue 6398, pp. 147-151
DOI: 10.1126/science.aat2890

nature
astronomy

Letter | Published: 05 November 2018

Modelling the coincident observation of a high-energy neutrino and a bright blazar flare

Shan Gao, Anatoli Fedynitch , Walter Winter & Martin Pohl

Nature Astronomy (2018) | [Download Citation](#) ↓

Und viel mehr davon...

[R19]

Was ist ein Blazar?

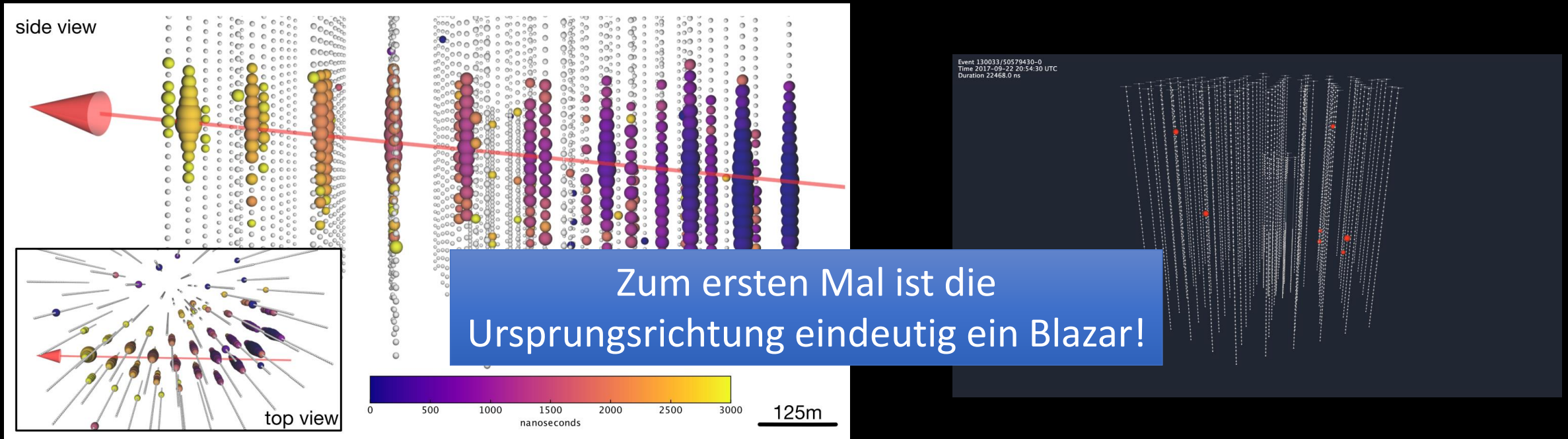
- Aktiver Kern einer entfernten Galaxie
- Supermassives Schwarzes Loch im Zentrum treibt einen Jet an
- Der Jet ist in Richtung Erde/Milchstraße orientiert
- An charakteristischer Strahlung erkennbar
- Blitzt alle paar Jahre auf (flares) und bleibt für einige Wochen oder Monate angeregt

Aktiver Galaktischer Nukleus aus der „Nähe“



- Schwarzes Loch treibt Akkretionsscheibe an
- Die Strahlung der Scheibe heizt die Umgebung; BLR und Torus
- Akkretion von Materie generiert den Jet (galaktische Dimension \sim kpc!!!!)
- Turbulenz im Jet formiert Strahlungszone (blobs)
- Elektronen und Protonen beschleunigen auf extrem hohe Energien
- Die Strahlung dieser Teilchen resultiert im beobachteten Spektrum

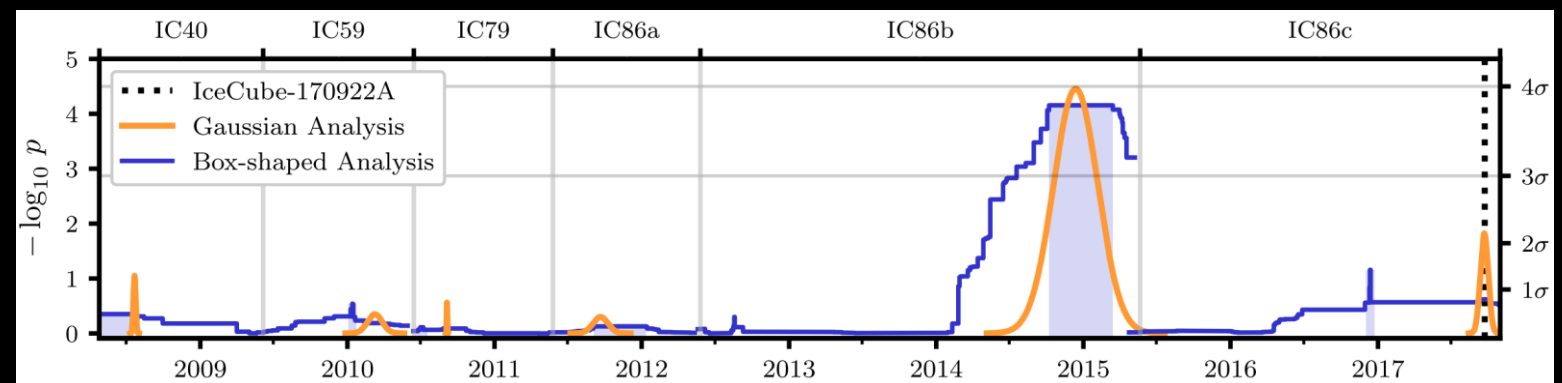
Die entscheidende Beobachtung



[R17, R19]

TXS durch historischen Daten
als Neutrinoquelle
klassifiziert

[R18, R22, R23]



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Bibliografie / Referenzen (englisch, falls nicht explizit anders vermerkt)

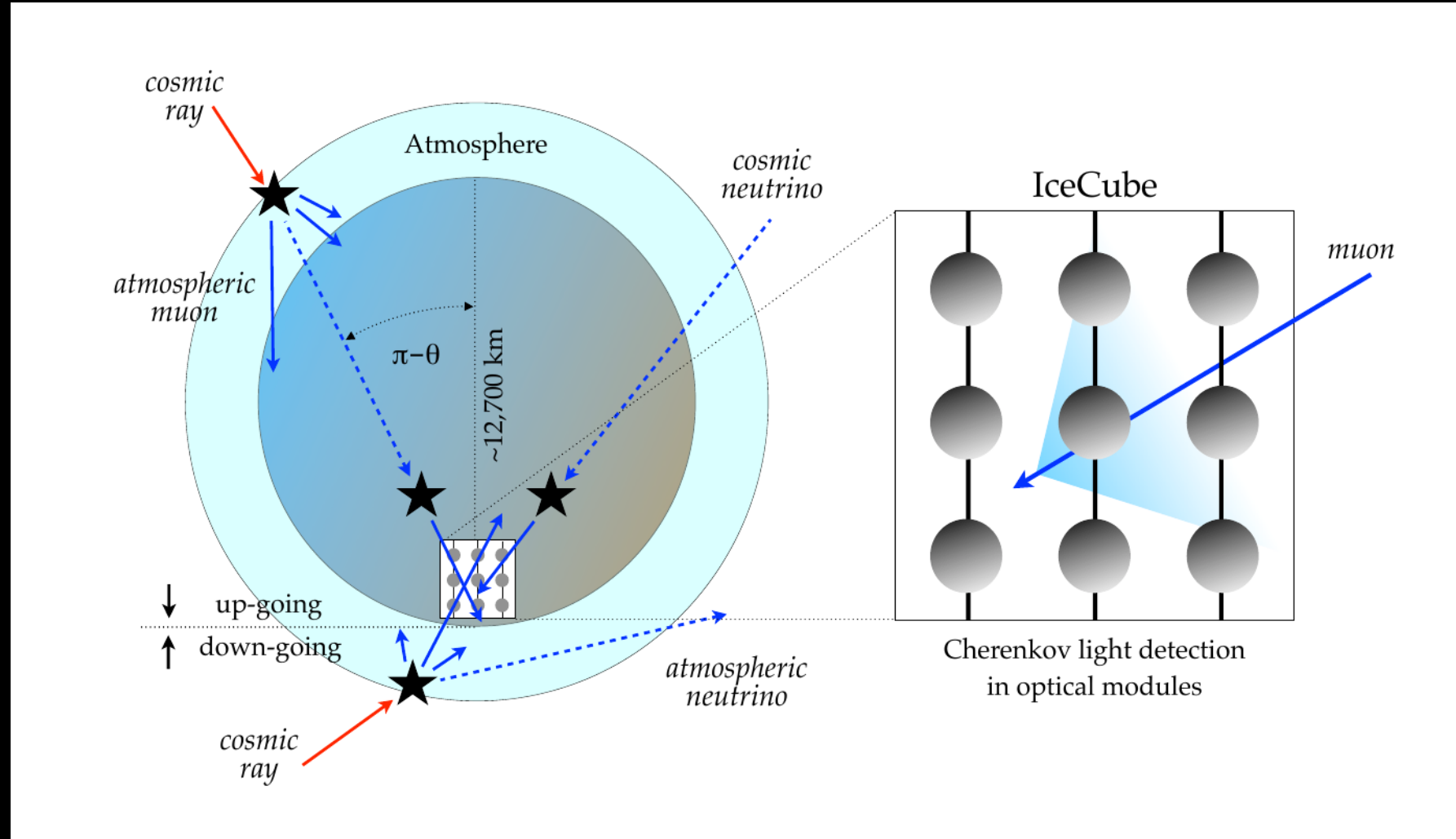
Slide	Tag	
3	R1	https://www.mpi-hd.mpg.de/hfm/HESS/public/vfHess.pdf (DE) ausführliche Diploma-Thesis
	R2	https://arxiv.org/abs/1808.02927 Original-Paper inkl. Kommentare
4	R3	https://arxiv.org/abs/1701.07305 Proceedings on electron positron fluxes (AMS Coll.)
	R4	https://arxiv.org/abs/astro-ph/0609060 Auger Observatory
	R5	https://arxiv.org/abs/1502.01323 ausführliche Detektorbeschreibung
	R6	https://arxiv.org/abs/1604.03637 AugerPrime Design Report, ohne AERA Radio Det.
5	R7	https://arxiv.org/abs/1311.7346 Galactic Cosmic Rays Review
	R8	https://arxiv.org/abs/1804.02331 Galactic CR from young massive stars
	R9	https://arxiv.org/abs/0711.2256 2008 Correlation of UHECR with AGN (Auger Coll.)
	R10	https://arxiv.org/abs/1709.07321 2017 large scale UHECR anisotropy (Auger Coll.)
13	R11	https://arxiv.org/abs/0812.3809 High Energy Neutrino Detectors overview
	R12	https://arxiv.org/abs/1412.5106 IceCube Gen2
	R13	https://arxiv.org/abs/1607.02671 PINGU extension for IceCube
19	R14	https://arxiv.org/abs/1612.05093 IceCube Instrumentation and Online Systems (DOM)
24	R15	http://science.sciencemag.org/content/342/6161/1242856.full (https://arxiv.org/abs/1311.5238)
	R16	https://arxiv.org/abs/1805.11112 Neutrino Astronomy focus IceCube
26	R17	http://science.sciencemag.org/content/361/6398/eaat1378 (open access: https://arxiv.org/abs/1807.08816)
	R18	http://science.sciencemag.org/content/361/6398/147 (open access: https://arxiv.org/abs/1807.08794)
	R19	https://arxiv.org/abs/1807.04275 modeling TXS
28	R20	http://adsabs.harvard.edu/abs/1993ARA%26A..31..473A AGN Unification scheme 1993
	R21	https://arxiv.org/abs/1107.5576 AGN UHECR
29	R22	https://arxiv.org/abs/1812.05939 Historical flare conventional models
	R23	https://arxiv.org/abs/1809.00601 Gas - Jet interaction model for historical flare

Image / Video Credits

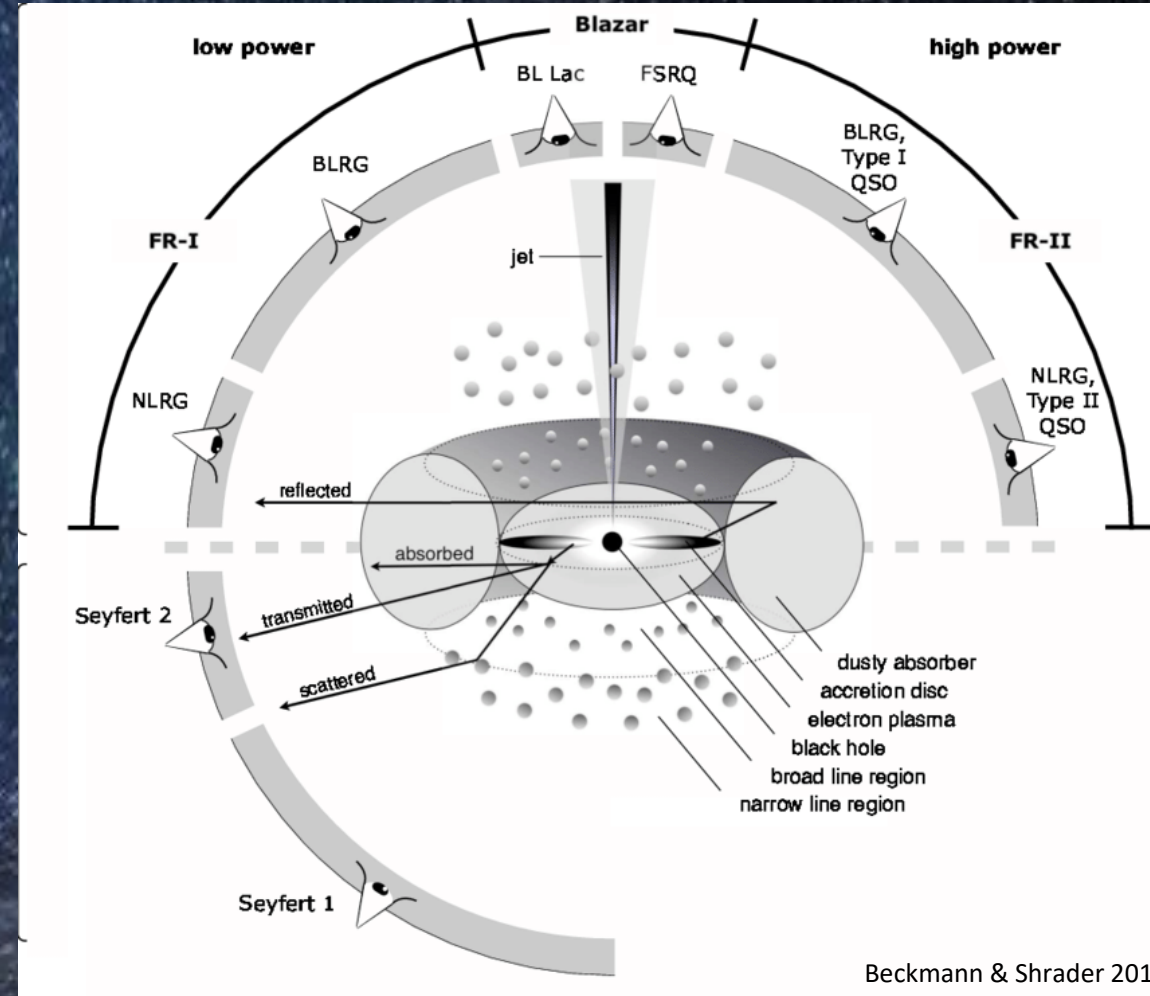
Slide	Tag	
1		Titelbild: NASA
3	B2	Uni Wien
4	B3	NASA
5	B4	CERN / LHC
	B5	Auger Collaboration
	B6	Sven Lafebvre
6	B7	NASA
7	B8	A. Fedynitch DESY
9	B9	IceCube Observatory
11	B10	freier-grafiker.de
13	B11	IceCube Collaboration
14	B12	https://military.id.me/
	B13	Argonne National Laboratory
	B14	IceCube Collaboration
18	B15	IceCube Collaboration
19	B16	DESY (Renderbild)
21	B17	IceCube Collaboration
22	B18	IceCube Collaboration
23	B19	IceCube Collaboration
27	B20	<u>Science Communication Lab</u> und DESY (https://multimessenger.desy.de/)
28	B21	<u>Science Communication Lab</u> und DESY (https://multimessenger.desy.de/)

Backup

IceCube Veto System

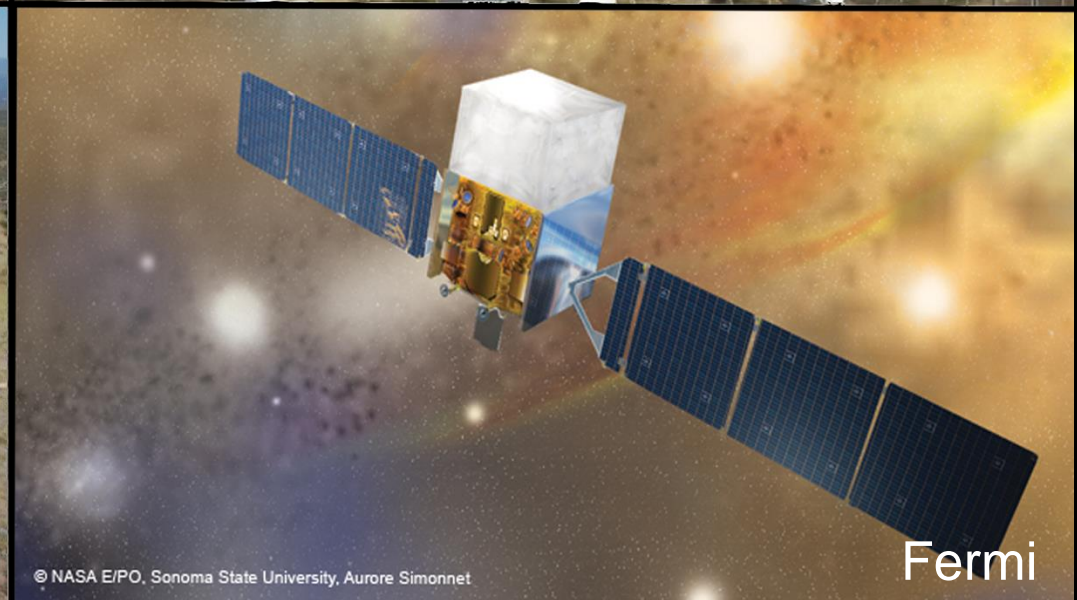


Aktive Galaktische Kerne (AGN)



Beckmann & Shrader 2012

Aktive Gammastrahlen-Teleskope



Cosmic Ray Detektoren (Satelliten)

