
Neutrinos
Unsichtbare Botschafter
aus dem Mikrokosmos
und dem fernen Universum


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Neutrino Carabiner

by Black Diamond Equipment

Original Price: 8.50

Volume Discount: 6 for 7.83 each.

Named for a subatomic particle with almost zero mass, this is the lightest, full-service carabiner made. That means it's the best choice for anyone who demands super lightweight carabiners without a compromise in strength. The mere 36 grams provide a large rope-bearing surface, a nose hood to protect against "gate rub", and a basket very similar to a Quicksilver 2.

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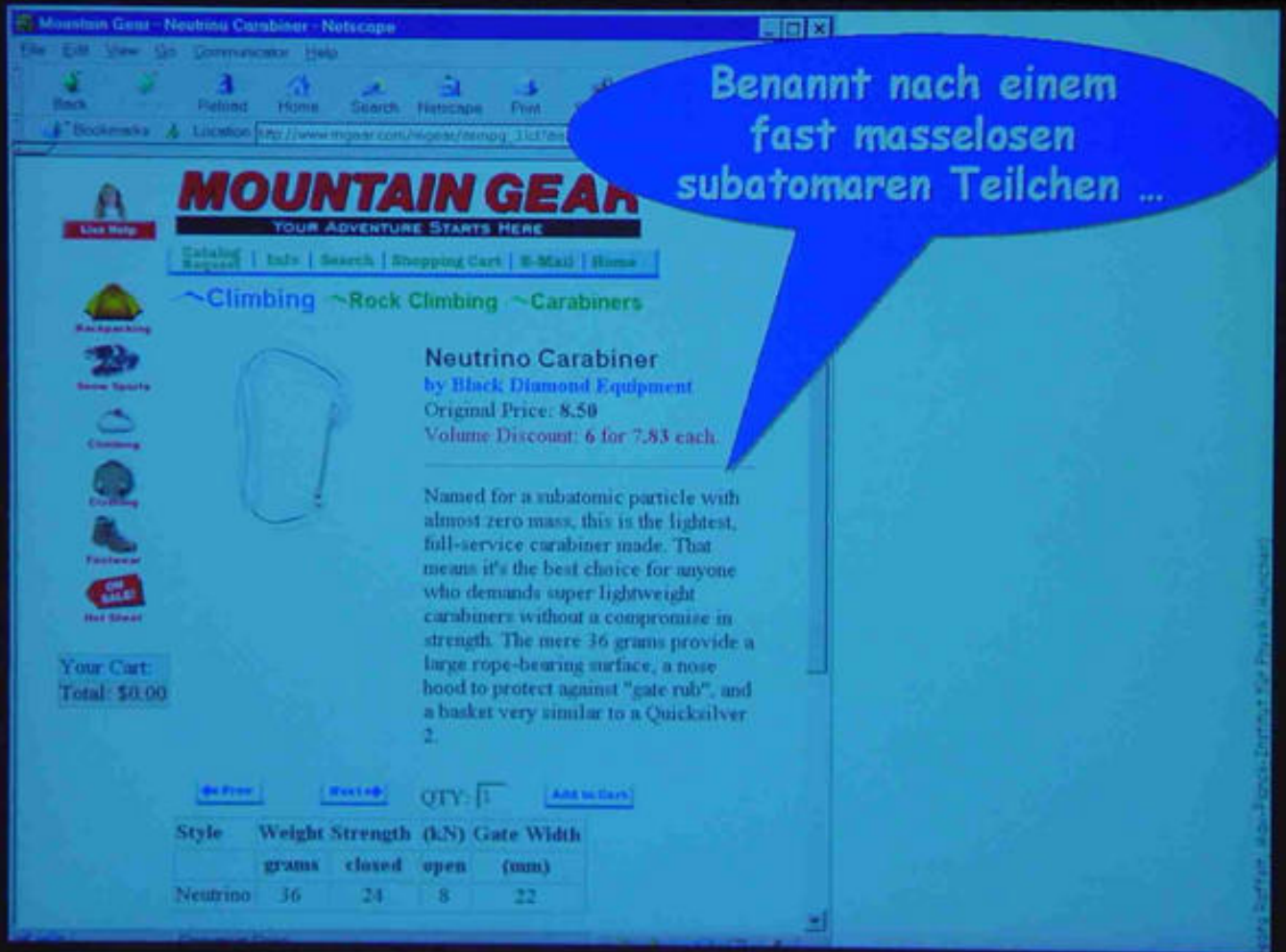
Style	Weight	Strength (kN)		Gate Width
	grams	closed	open	(mm)
Neutrino	36	24	8	22


Benannt nach einem fast masselosen subatomaren Teilchen ...
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Mountain Gear - Neutrino Carabiner - Netscape

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Your Cart Total: $0.00

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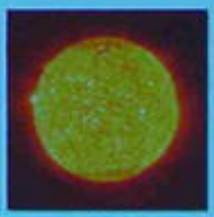
Benannt nach einem fast masselosen subatomaren Teilchen ...

Griechisch „Nü"

ν

Wo treten Neutrinos in der Natur auf?

✓ Kernreaktoren

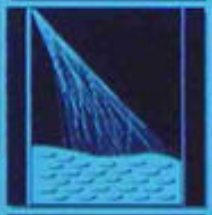


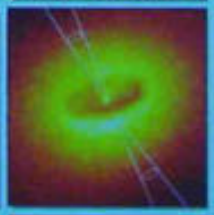
Sonne ✓

✓ Teilchen-beschleuniger

Supernovae (Sternkollaps)
SN 1987A ✓

✓ Erdatmosphäre (Kosmische Strahlung)



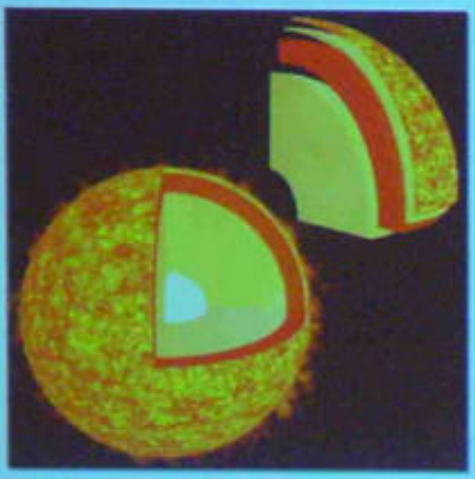


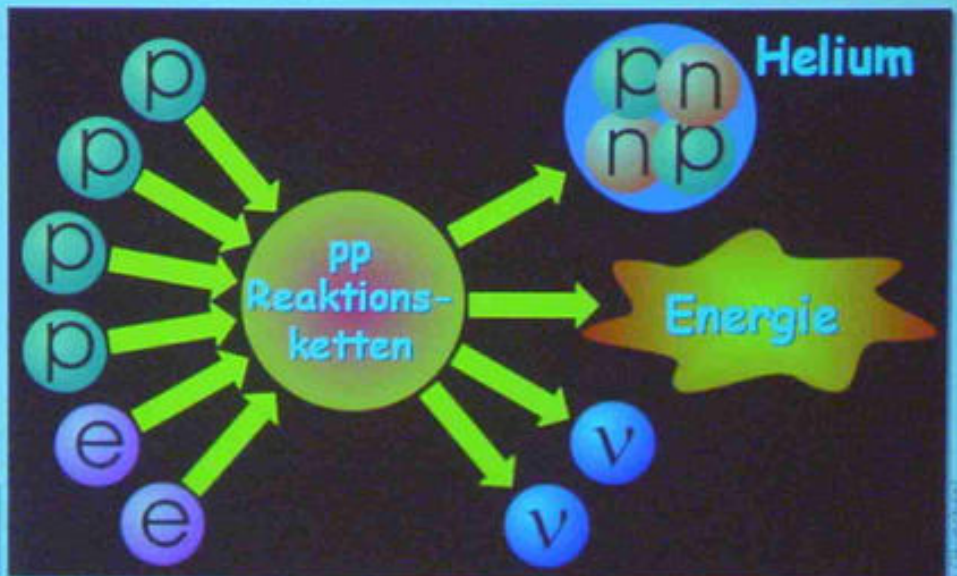
Astrophysikalische Beschleuniger
Schon bald?

Noch 2002? Erdkruste (Natürliche Radioaktivität)

Urknall des Universums (heute 330 ν/cm^3)
Indirekte Evidenz

Neutrinos aus der Sonne

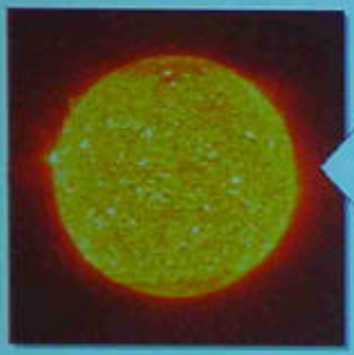




Sonnenabstrahlung: 98 % Licht
2 % Neutrinos
(Hier 66 Milliarden Neutrinos/cm² sec)

Hans Bethe (geb. 1906, Nobelpreis 1976)
pp Reaktionsketten (1938)

Sonnenbrille für Neutrinos?

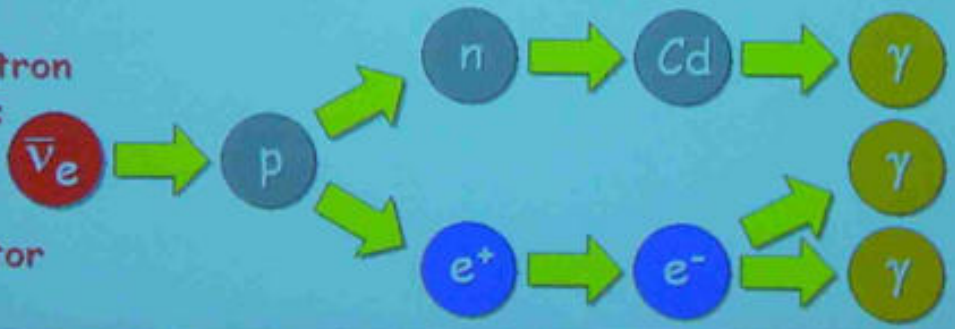


8,3 Lichtminuten

Eine Bleischicht der Dicke von etwa 1000 Lichtjahren nötig

Erster Nachweis (1954 - 1956)

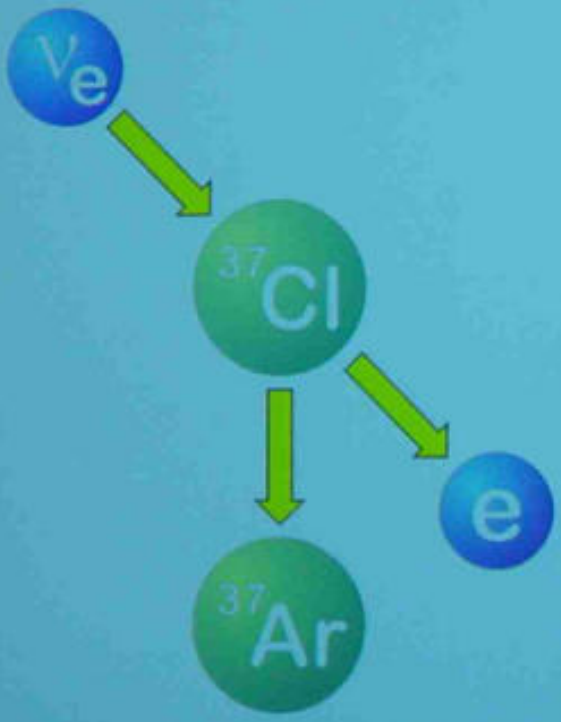
Anti-Elektron Neutrinos von Hanford Kernreaktor



3 Gamma Quanten in Koinzidenz

Erste Messung der Sonnenneutrinos

Inverser Beta-Zerfall („Neutrino-Einfang")

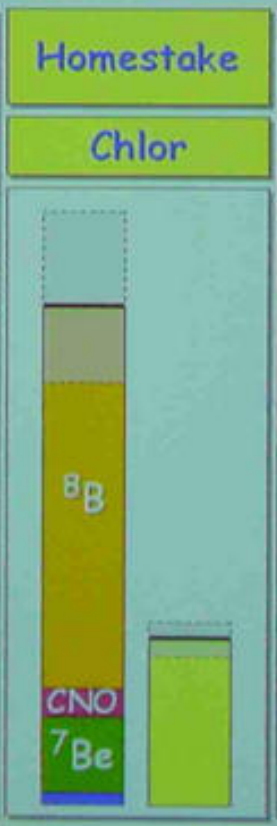


Homestake Sonnen-Neutrino Observatorium (seit ca. 1967)

Das Problem der fehlenden Sonnenneutrinos

Berechnung der Nachweisrate der Sonnenneutrinos aus verschiedenen Quellreaktionen

John Bahcall

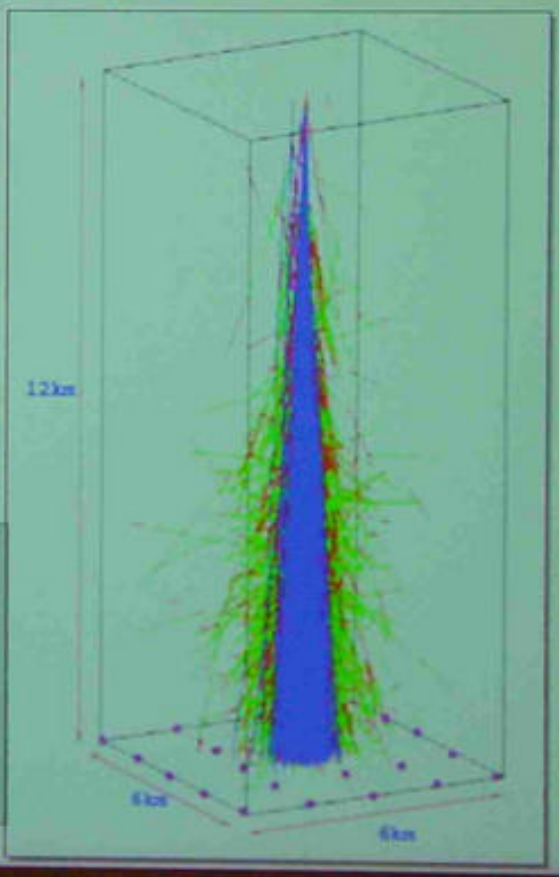


Messung (1967 - 1995)

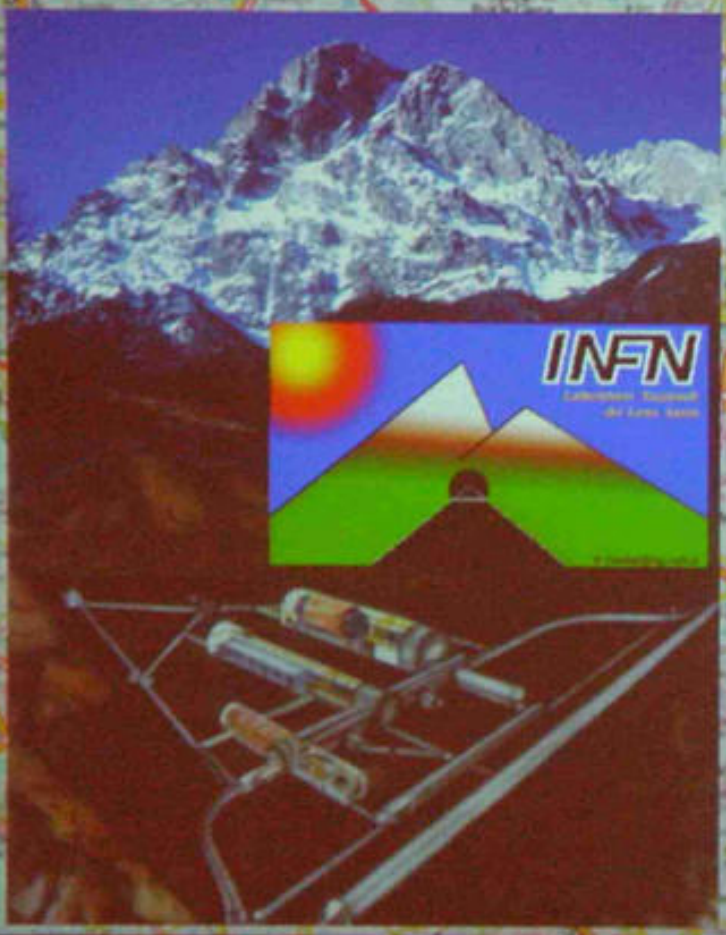
Raymond Davis Jr.

Kosmische Strahlung („Höhenstrahlung")

Luftschauer:
10^{19} eV primäres Teilchen
100 Milliarden sekundäre Teilchen
auf Meereshöhe

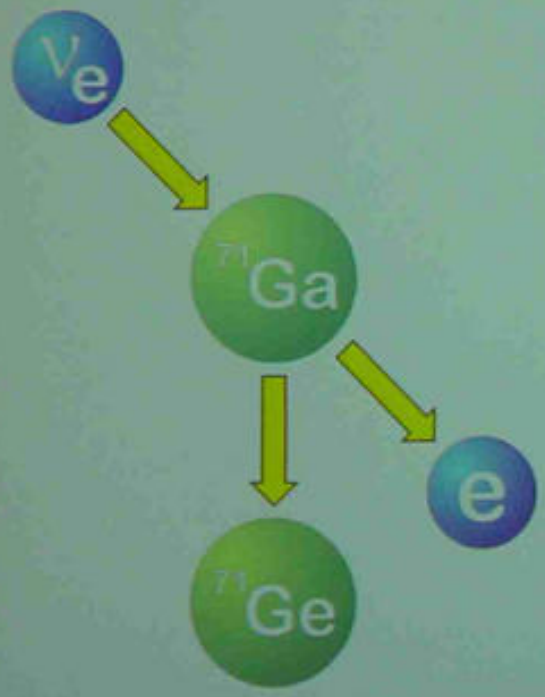


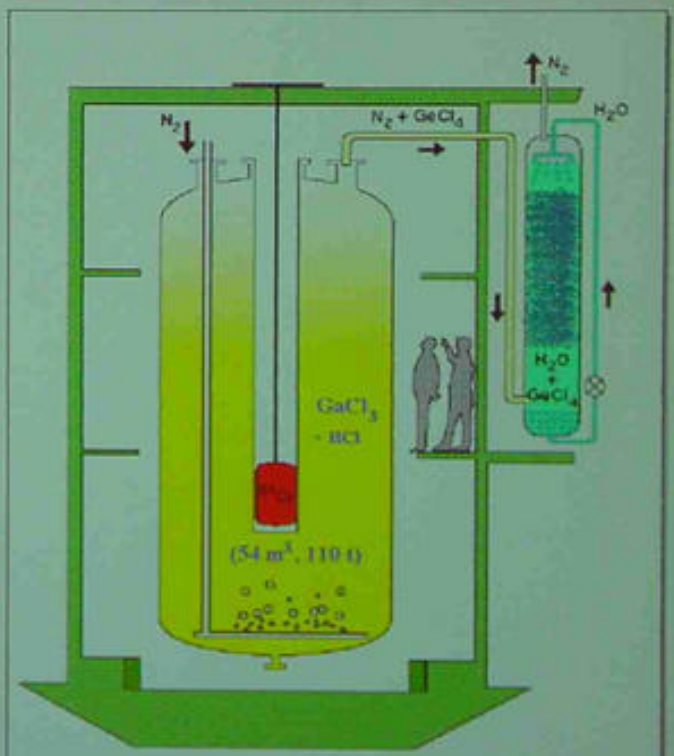
Neutrinophysik im Gran Sasso



Gallium Experimente Gallex/GNO und SAGE

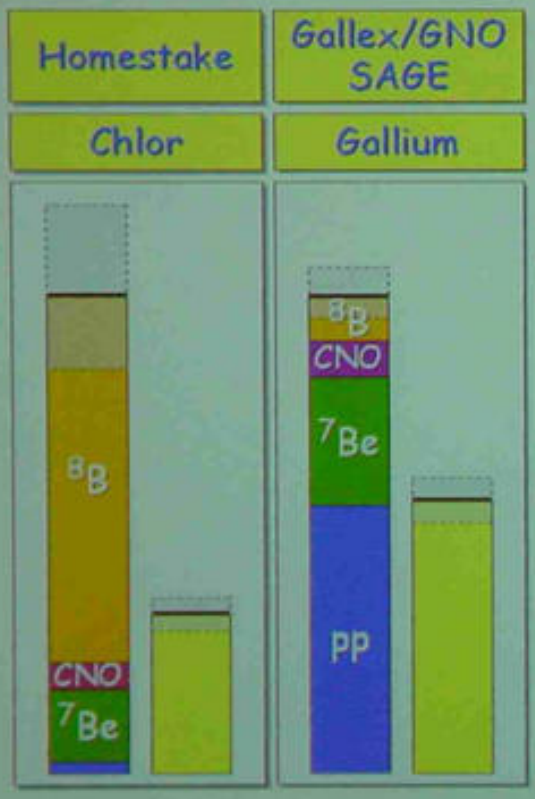
Inverser Beta-Zerfall
Gallium → Germanium





GALLEX/GNO (seit 1991)

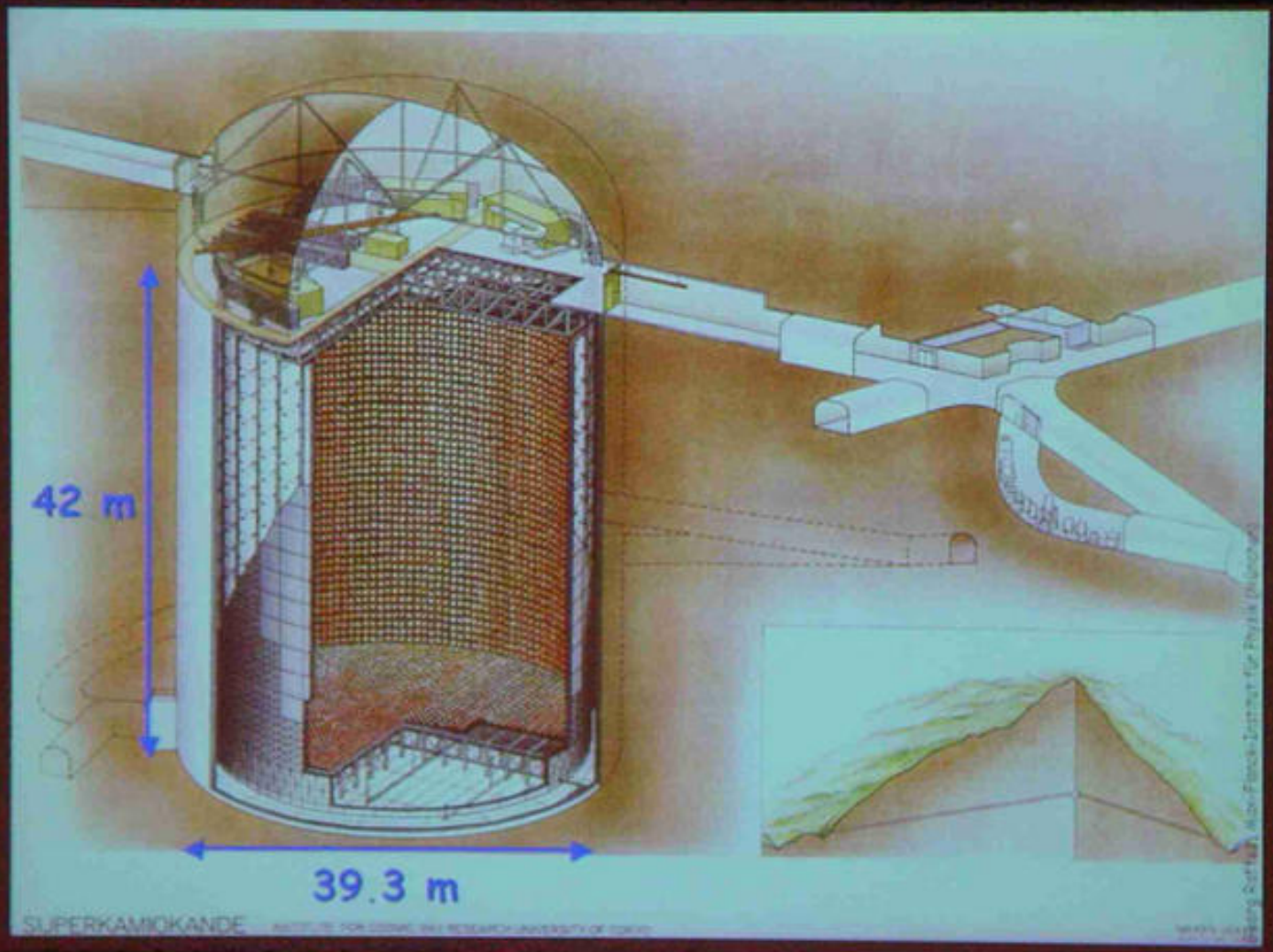
Das Problem der fehlenden Sonnenneutrinos

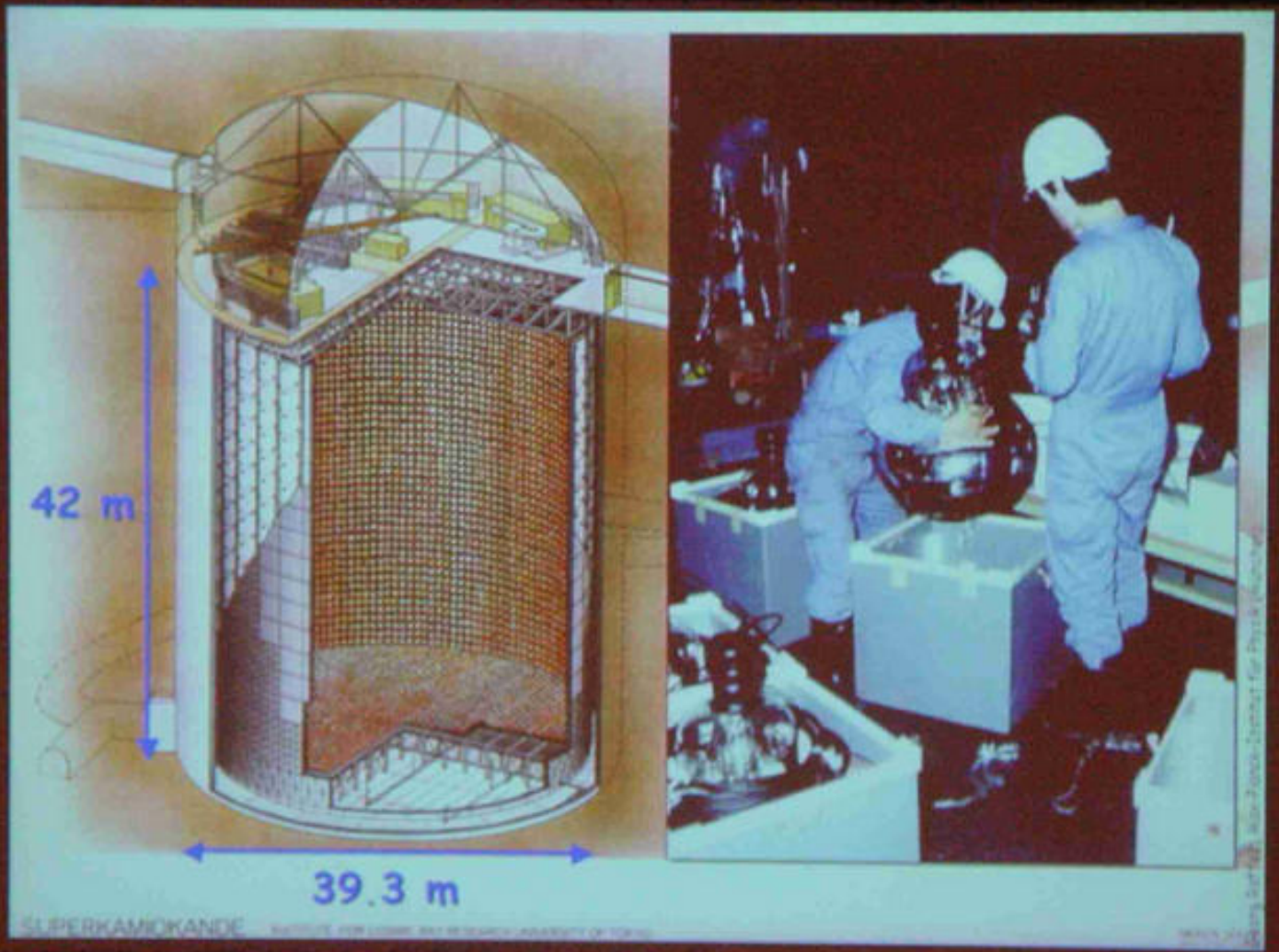


GALLEX
INTERNATIONAL
SOLAR NEUTRINO RESEARCH
COLLABORATION

GNO 30

Gallium-Experimente mit deutscher Beteiligung (MPI Kernphysik, Heidelberg, TU München)


42 m
39.3 m
SUPERKAMIOKANDE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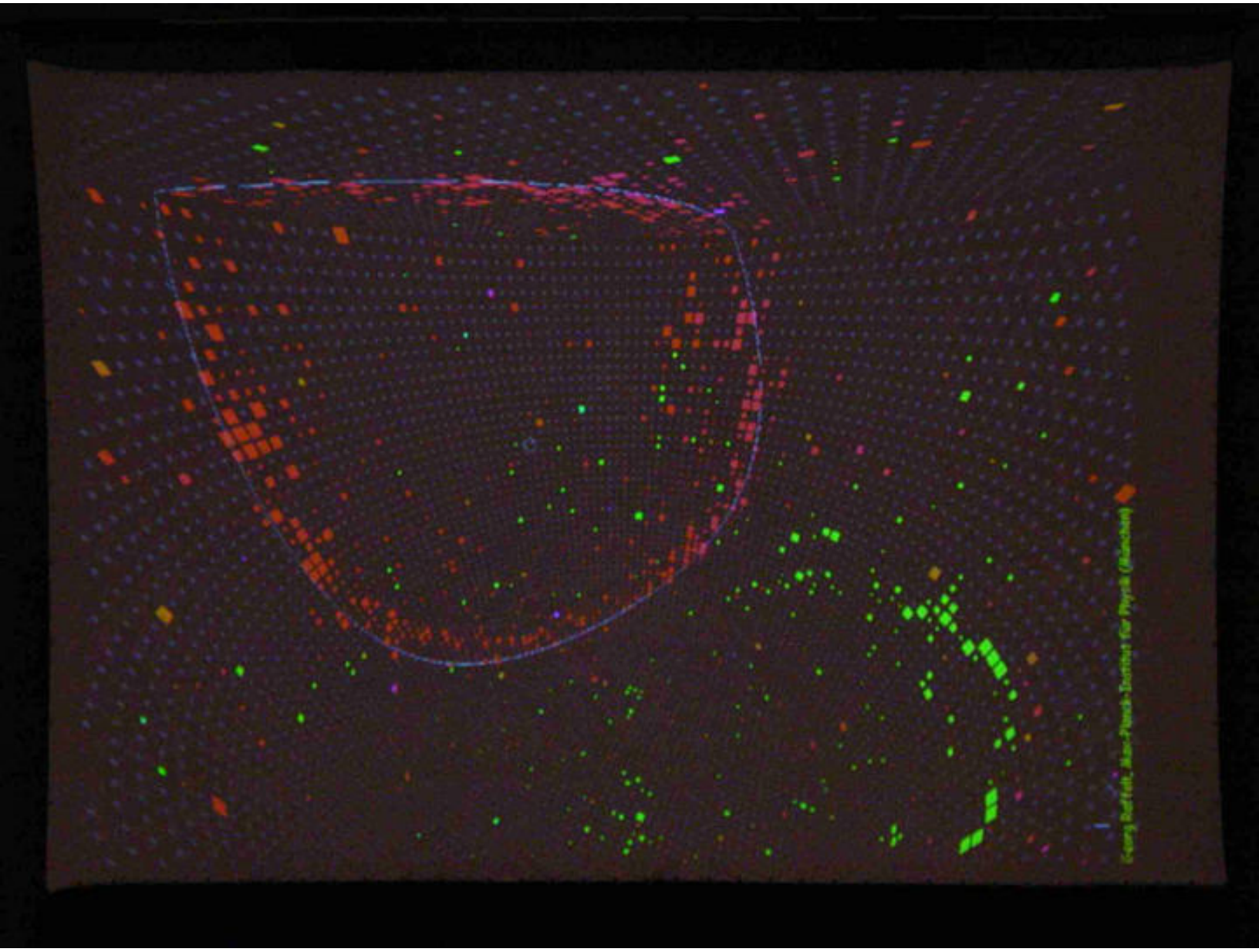
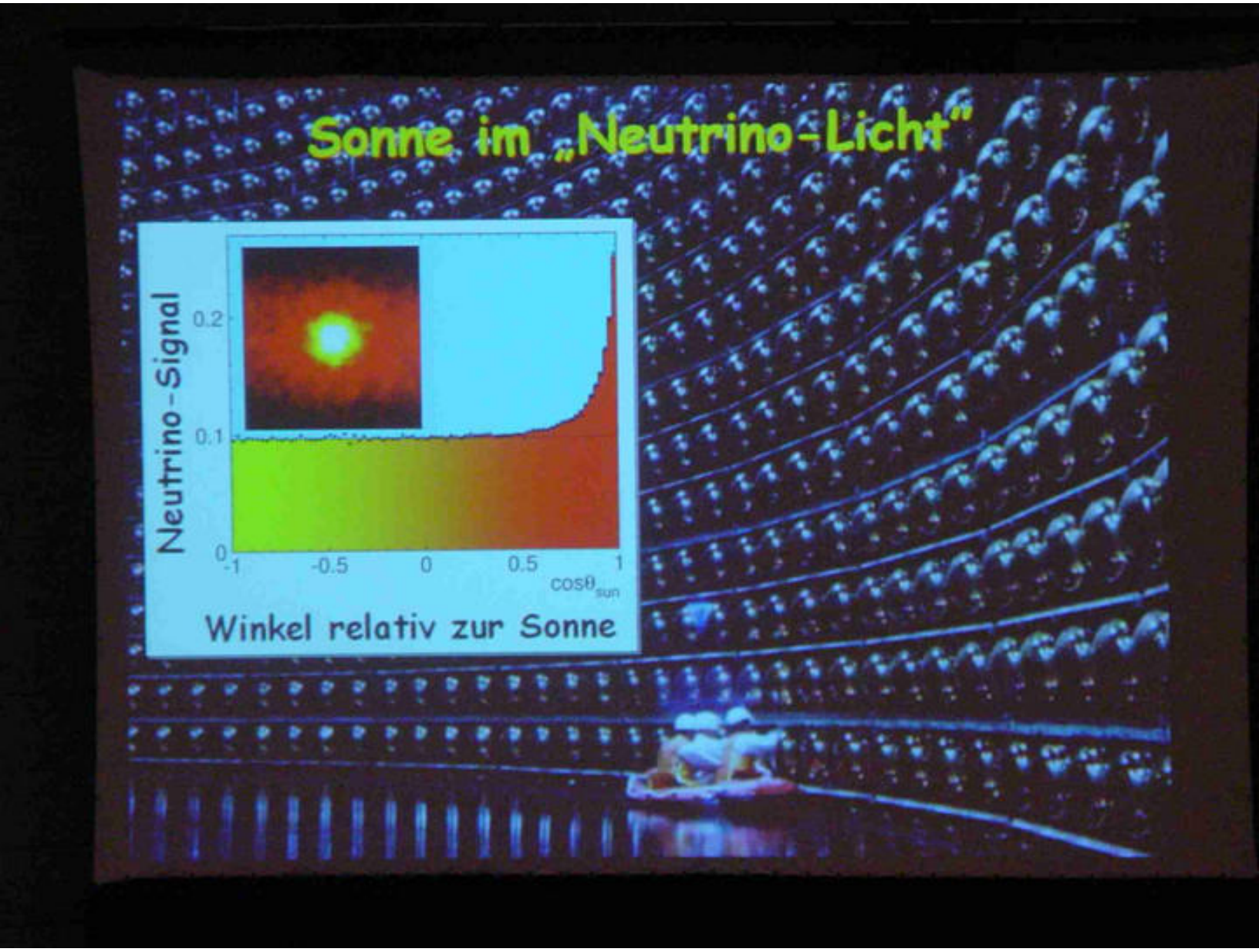
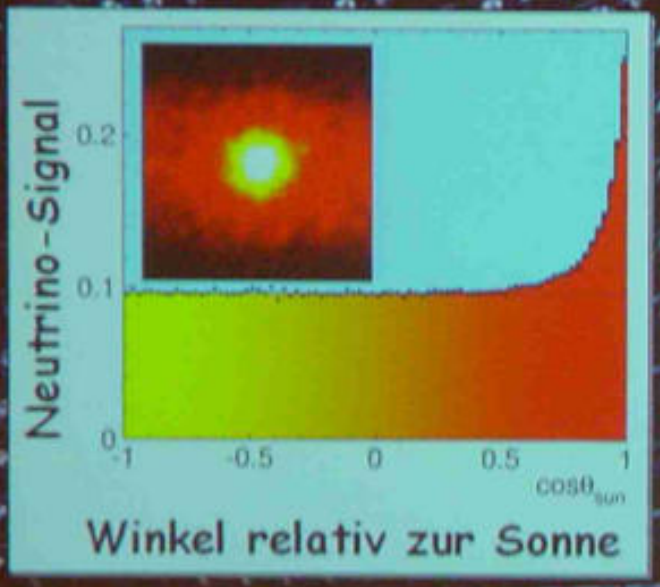
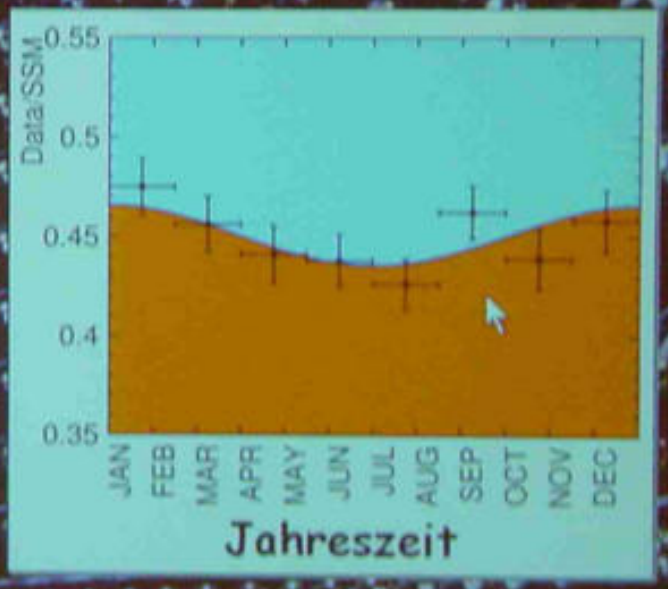


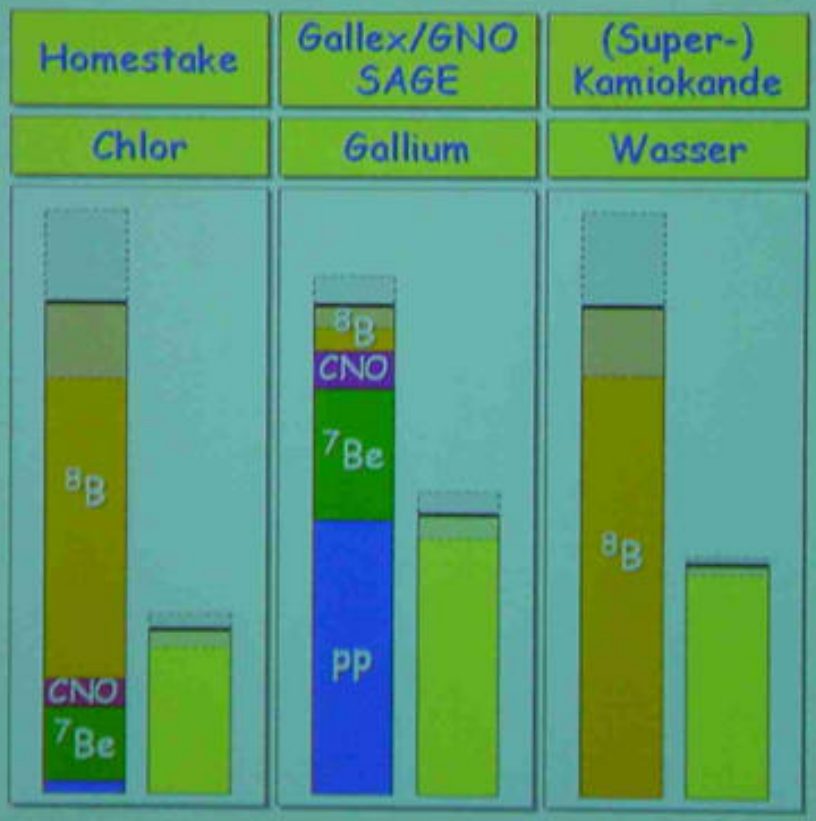

Sonne im „Neutrino-Licht"
Neutrino-Signal
0.2
0.1
0
-1
-0.5
0
0.5
1
cosθsun
Winkel relativ zur Sonne

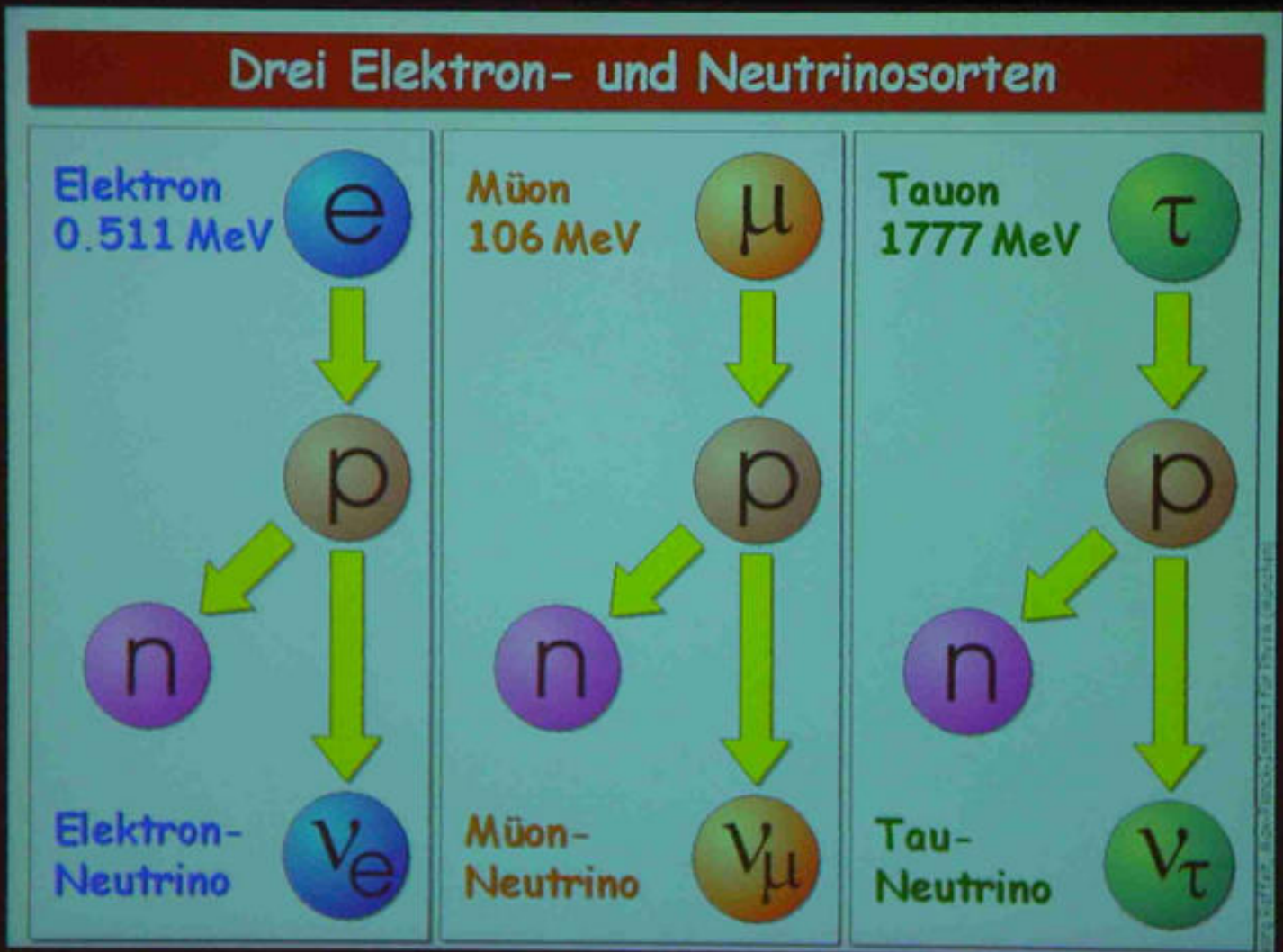
Sonne im „Neutrino-Licht"

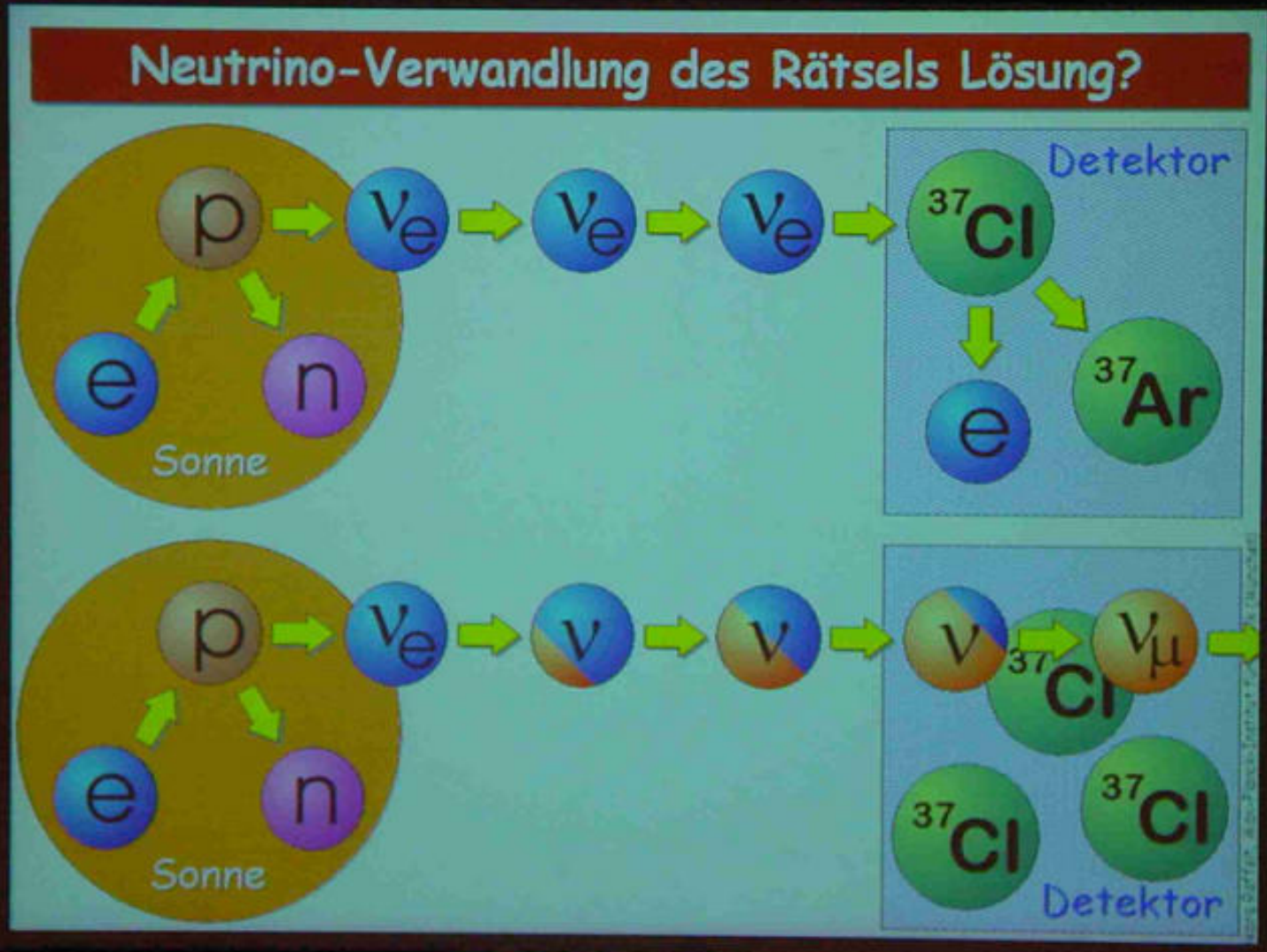




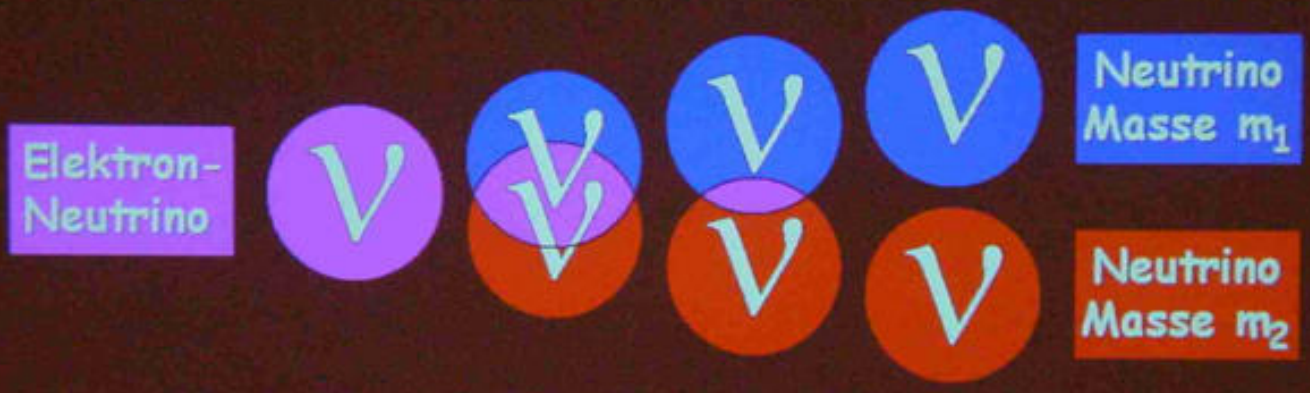
Das Problem der fehlenden Sonnenneutrinos




Drei Elektron- und Neutrinosorten
Elektron
0.511 MeV
e
p
n
Elektron-
Neutrino
ν_e
Müon
106 MeV
μ
p
n
Müon-
Neutrino
ν_μ
Tauon
1777 MeV
τ
p
n
Tau-
Neutrino
ν_τ

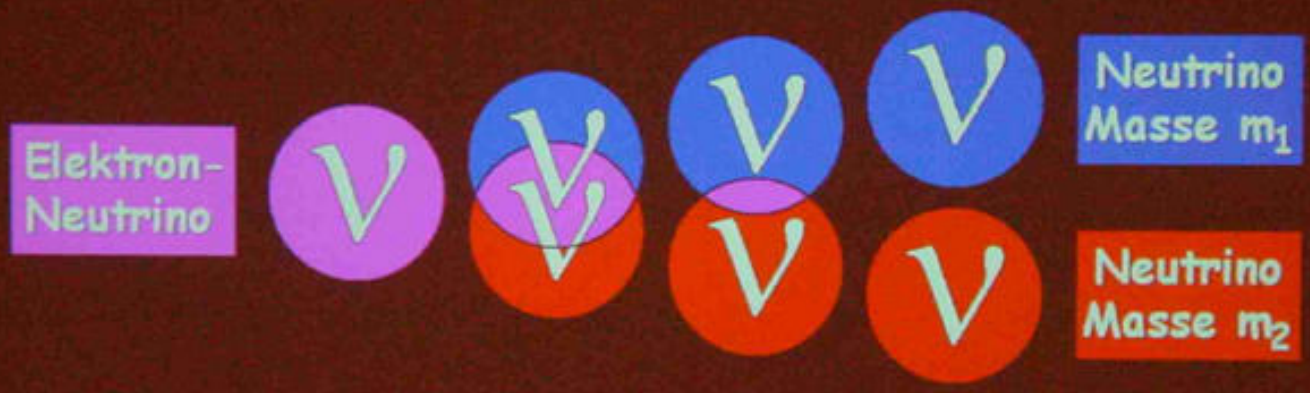

Neutrino-Verwandlung des Rätsels Lösung?
p
e
n
Sonne
ν_e
ν_e
ν_e
Detektor
^{37}Cl
e
^{37}Ar
p
e
n
Sonne
ν_e
ν
ν
ν
^{37}Cl
ν_μ
^{37}Cl
^{37}Cl
Detektor

Mischung von Neutrinos verschiedener Masse

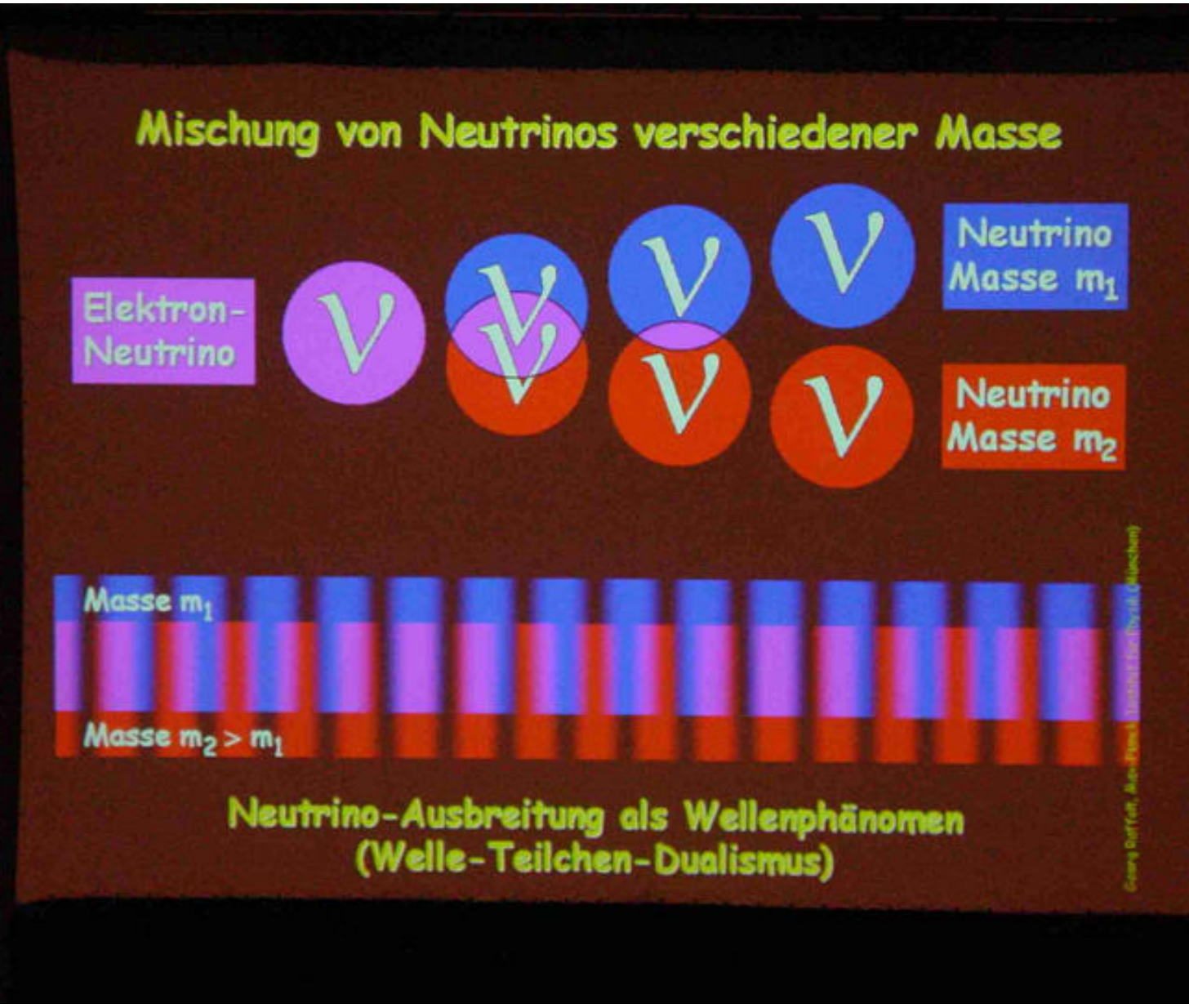


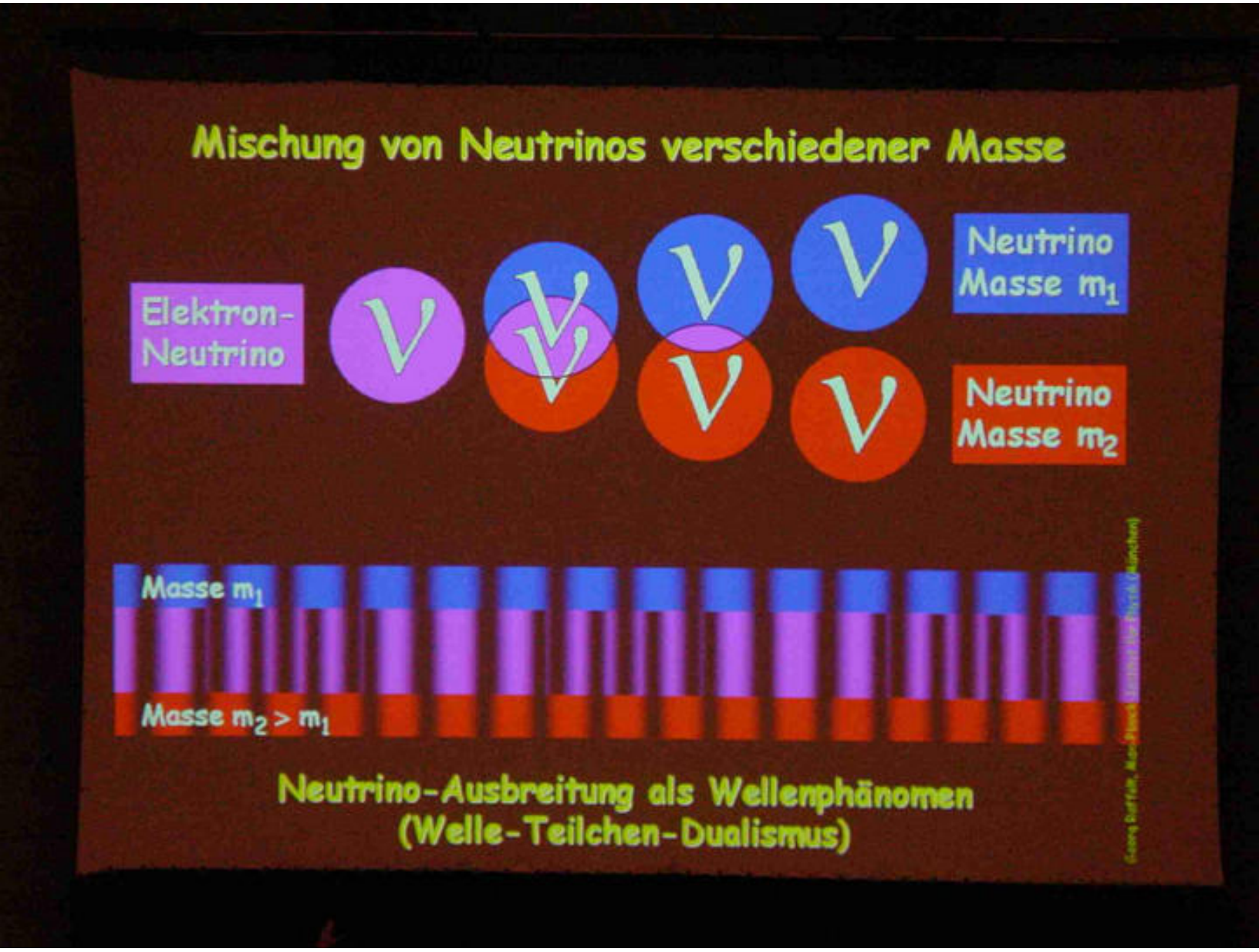
Neutrino-Ausbreitung als Wellenphänomen
(Welle-Teilchen-Dualismus)

Mischung von Neutrinos verschiedener Masse



Neutrino-Ausbreitung als Wellenphänomen
(Welle-Teilchen-Dualismus)


Mischung von Neutrinos verschiedener Masse
Elektron-Neutrino
Neutrino Masse m_1
Neutrino Masse m_2
Masse m_1
Masse $m_2 > m_1$
Neutrino-Ausbreitung als Wellenphänomen
(Welle-Teilchen-Dualismus)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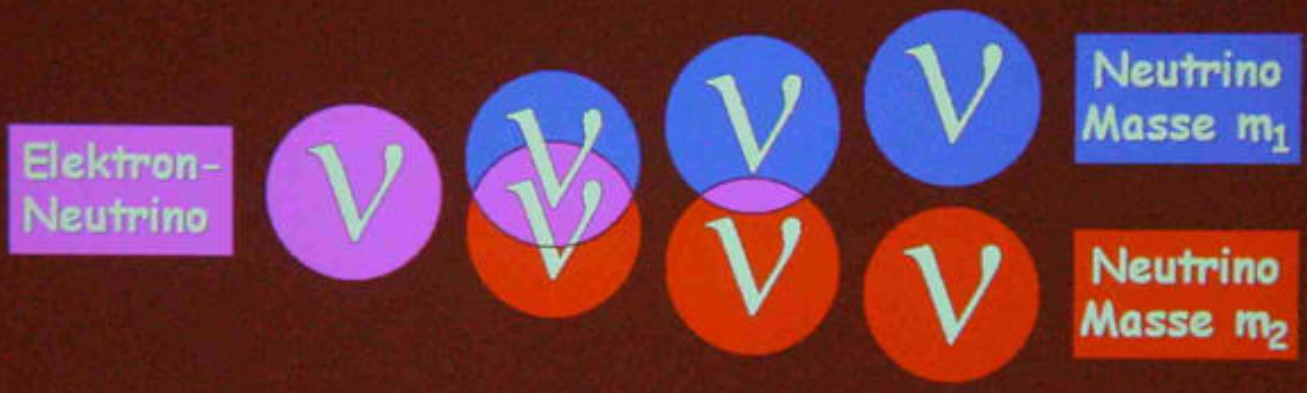

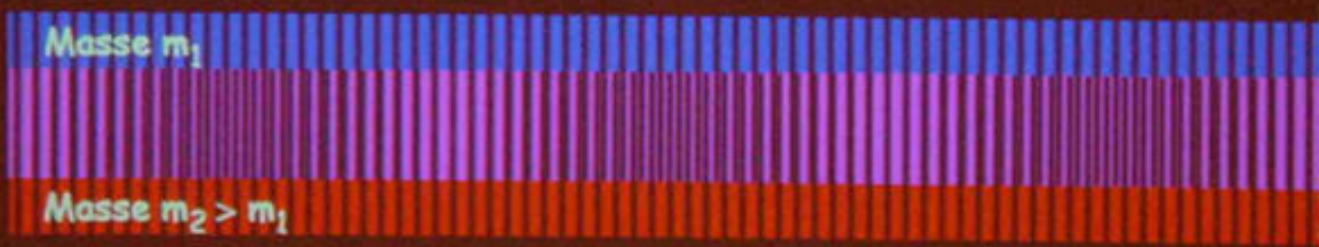

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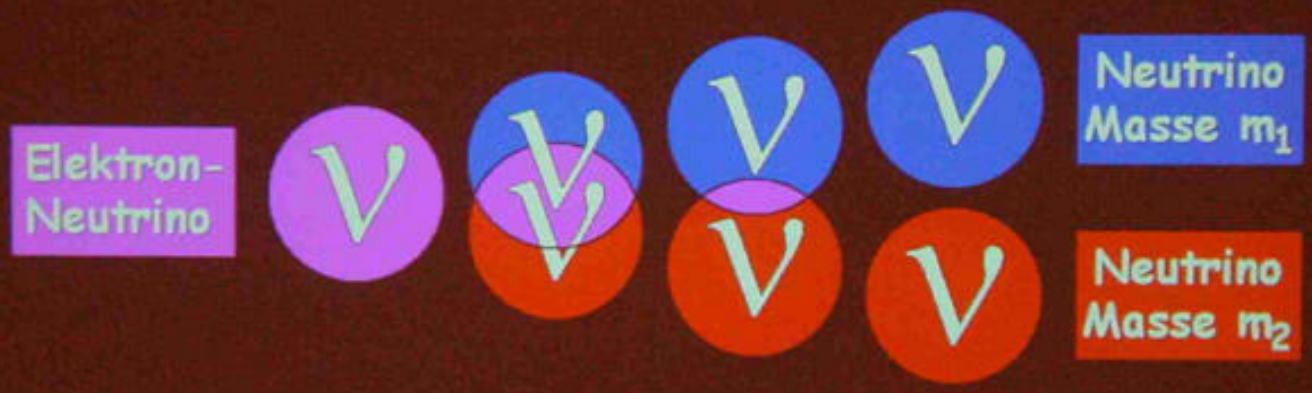
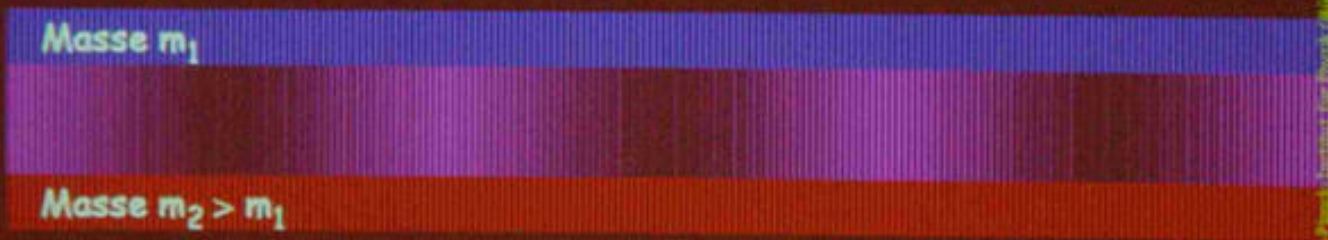
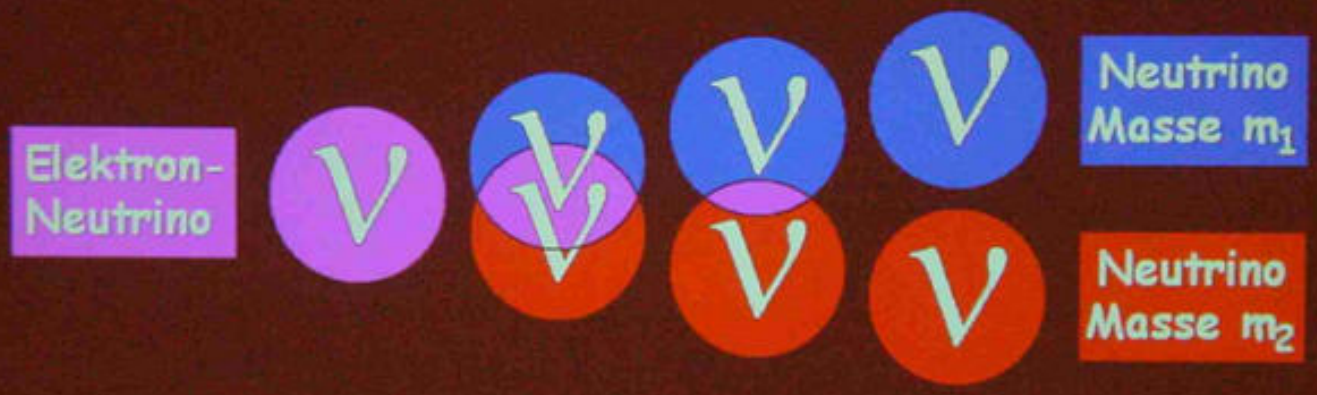
Mischung von Neutrinos verschiedener Masse





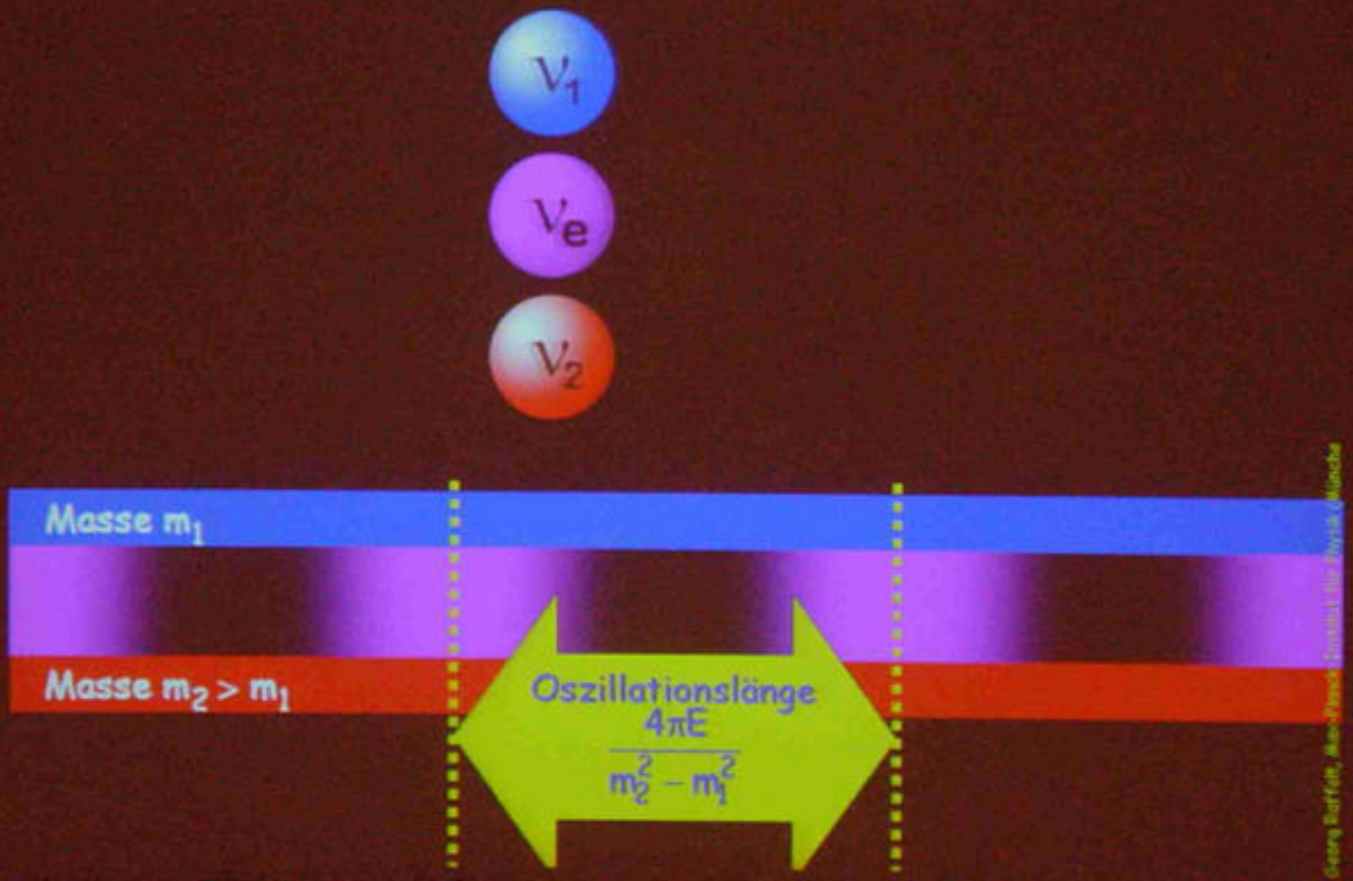
Neutrino-Ausbreitung als Wellenphänomen (Welle-Teilchen-Dualismus)

Mischung von Neutrinos verschiedener Masse

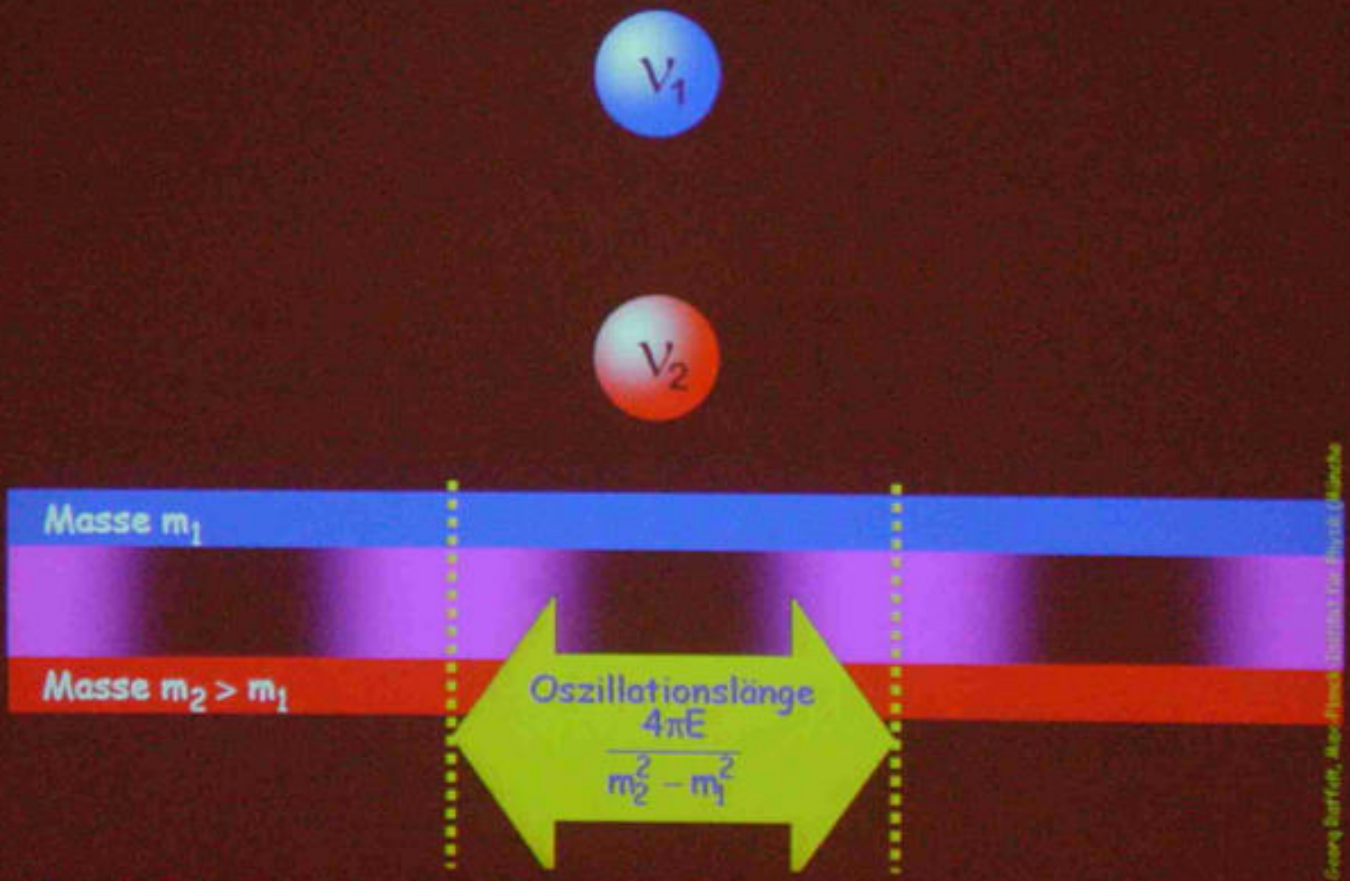


Neutrino-Ausbreitung als Wellenphänomen (Welle-Teilchen-Dualismus)

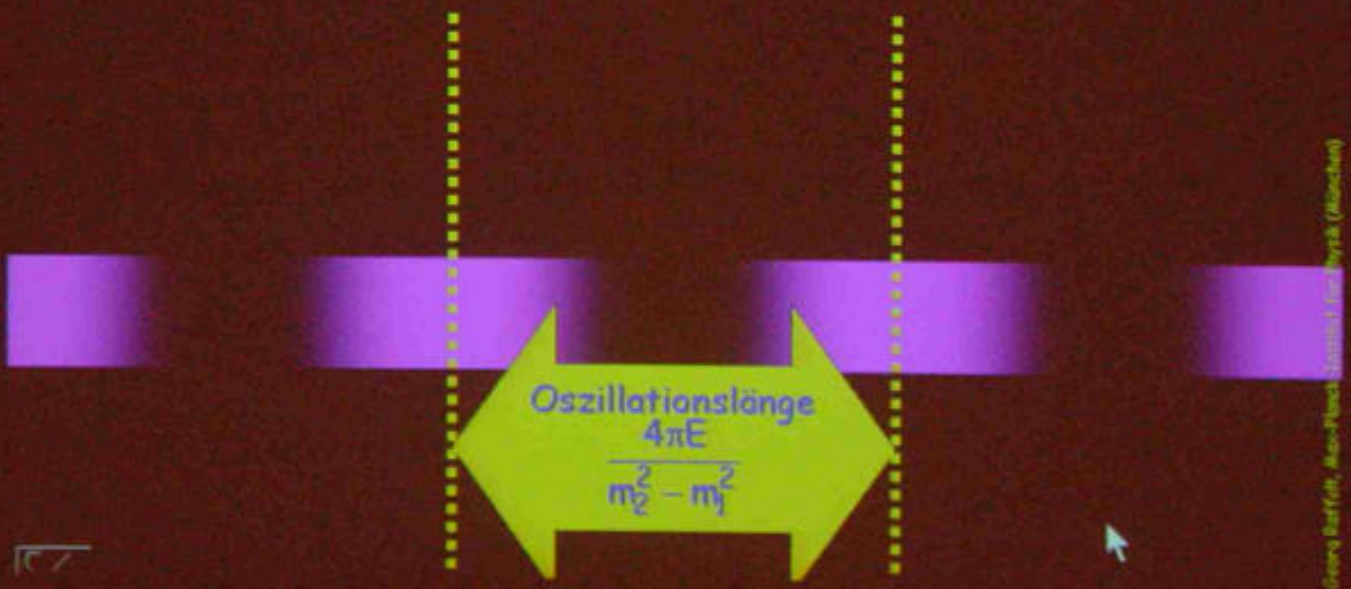
Neutrino-Oszillationen



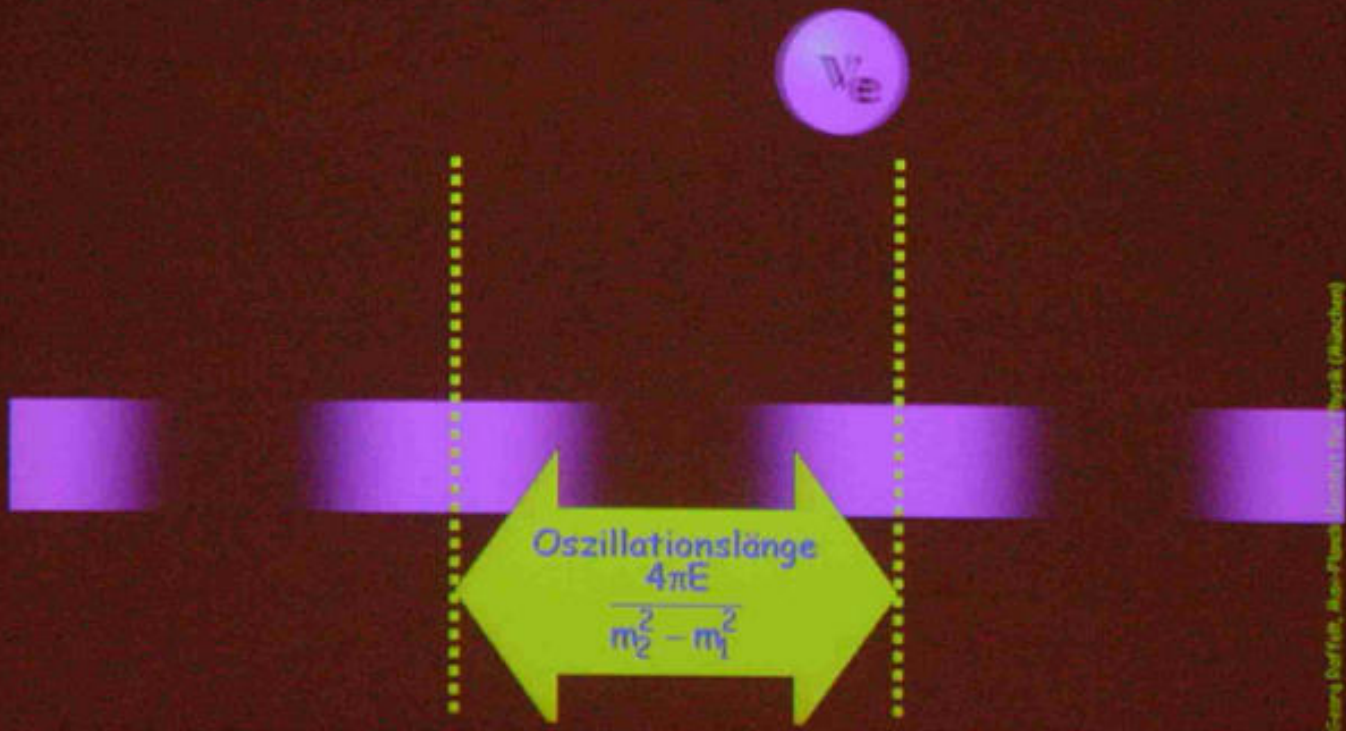
Neutrino-Oszillationen



Neutrino-Oszillationen



Neutrino-Oszillationen



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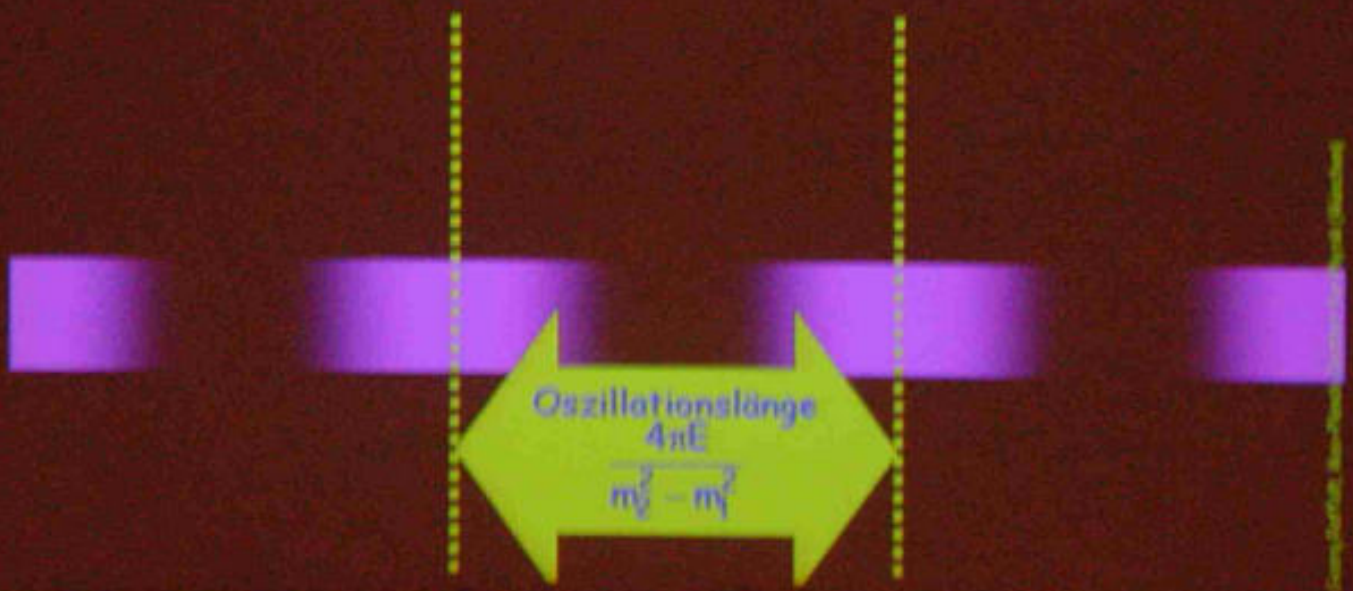
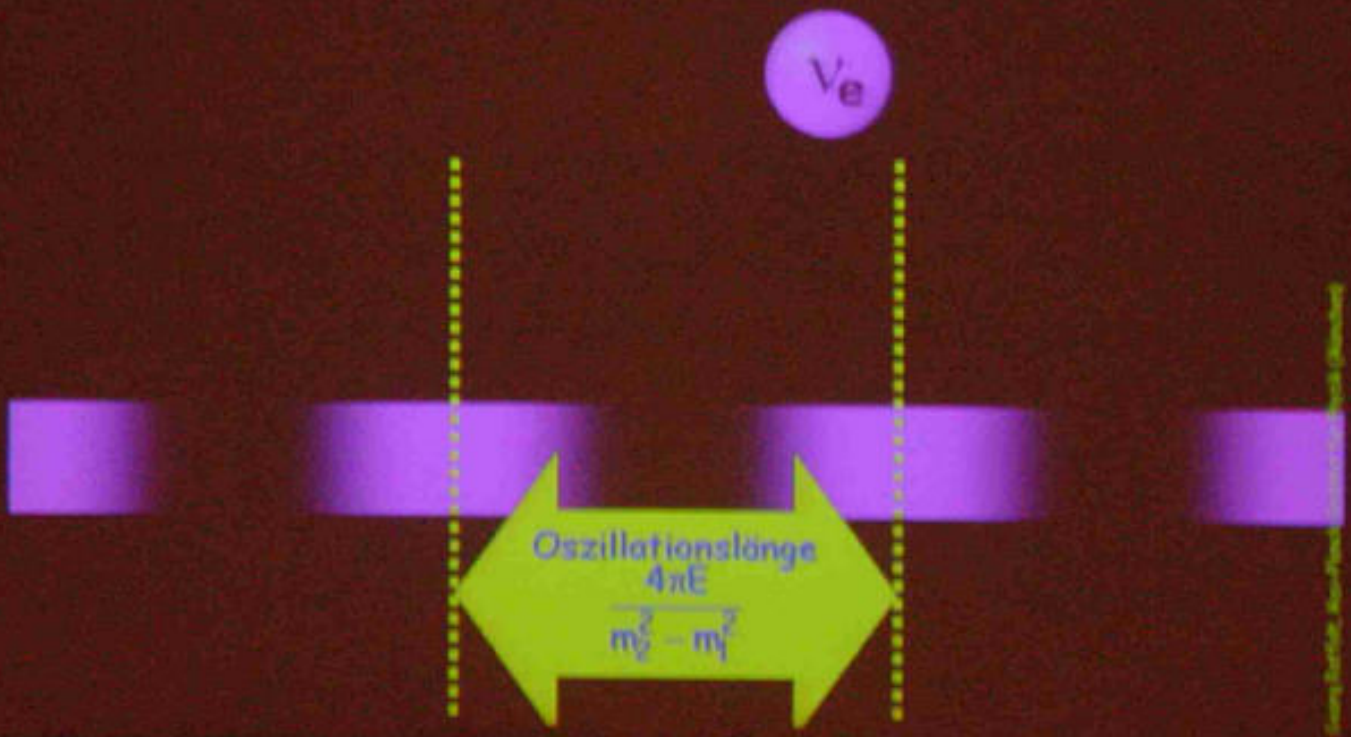
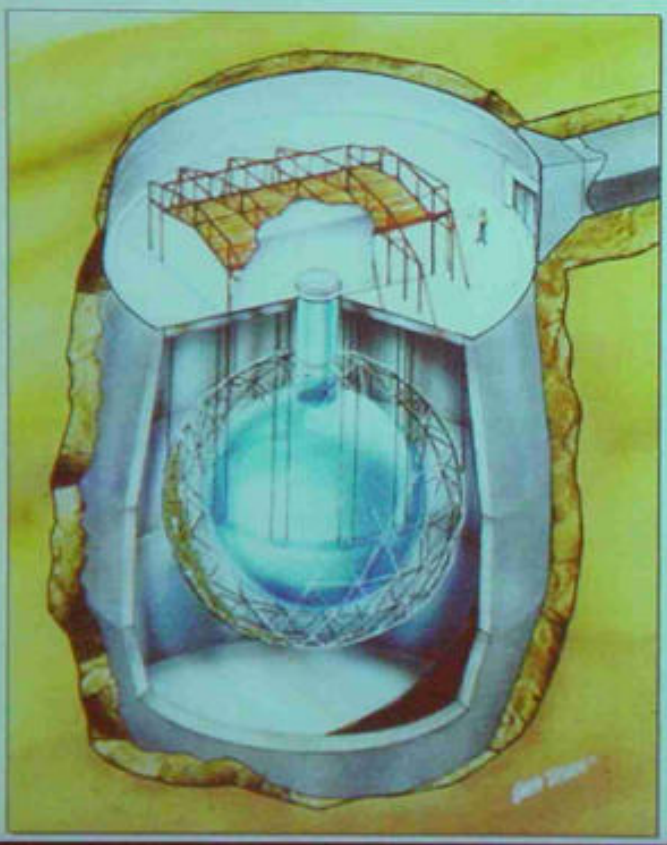


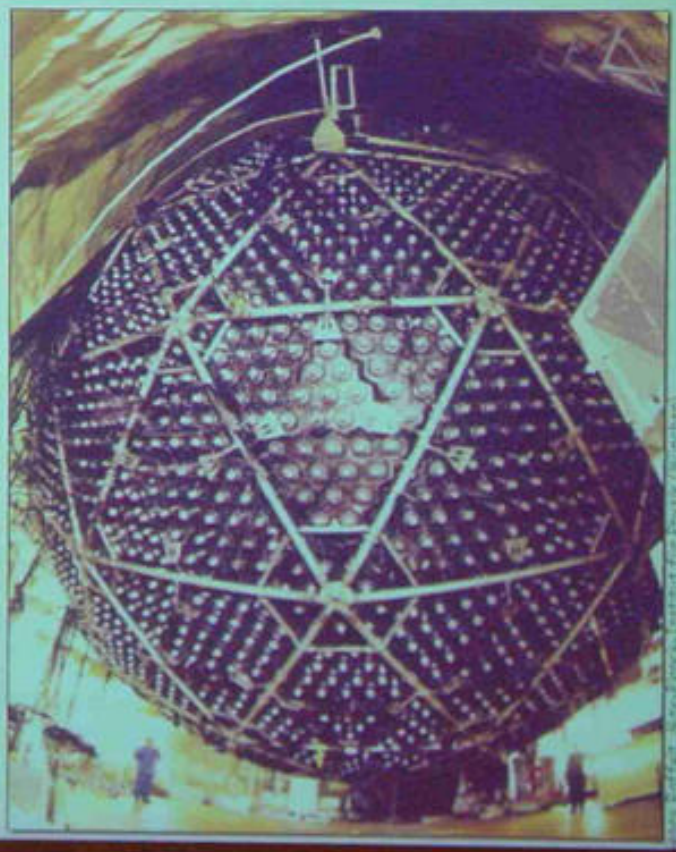
Neutrino-Oszillationen



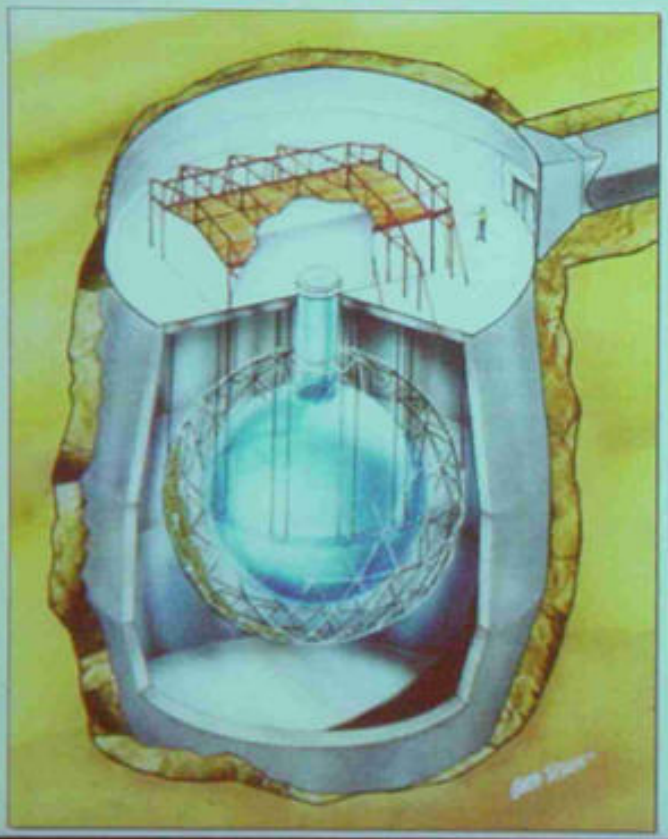
Bruno Pontecorvo
(1913 – 1993)
„Erfinder" der Neutrinooszillationen

Sudbury Neutrino Observatory (SNO)
(1000 Tonnen schweren Wassers)





Sudbury Neutrino Observatory (SNO)
(1000 Tonnen schweren Wassers)

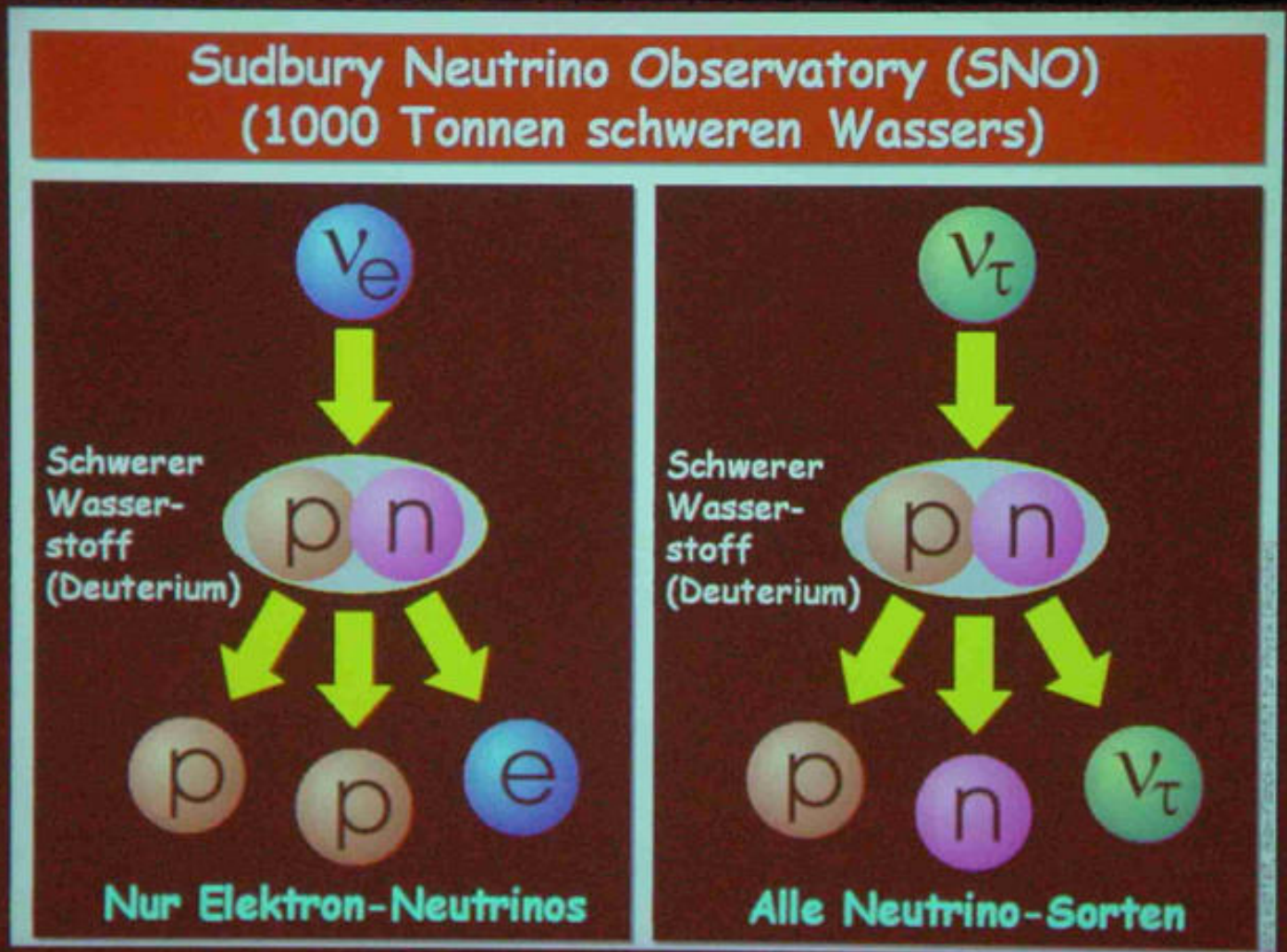


Normales (leichtes) Wasser:
H_2O

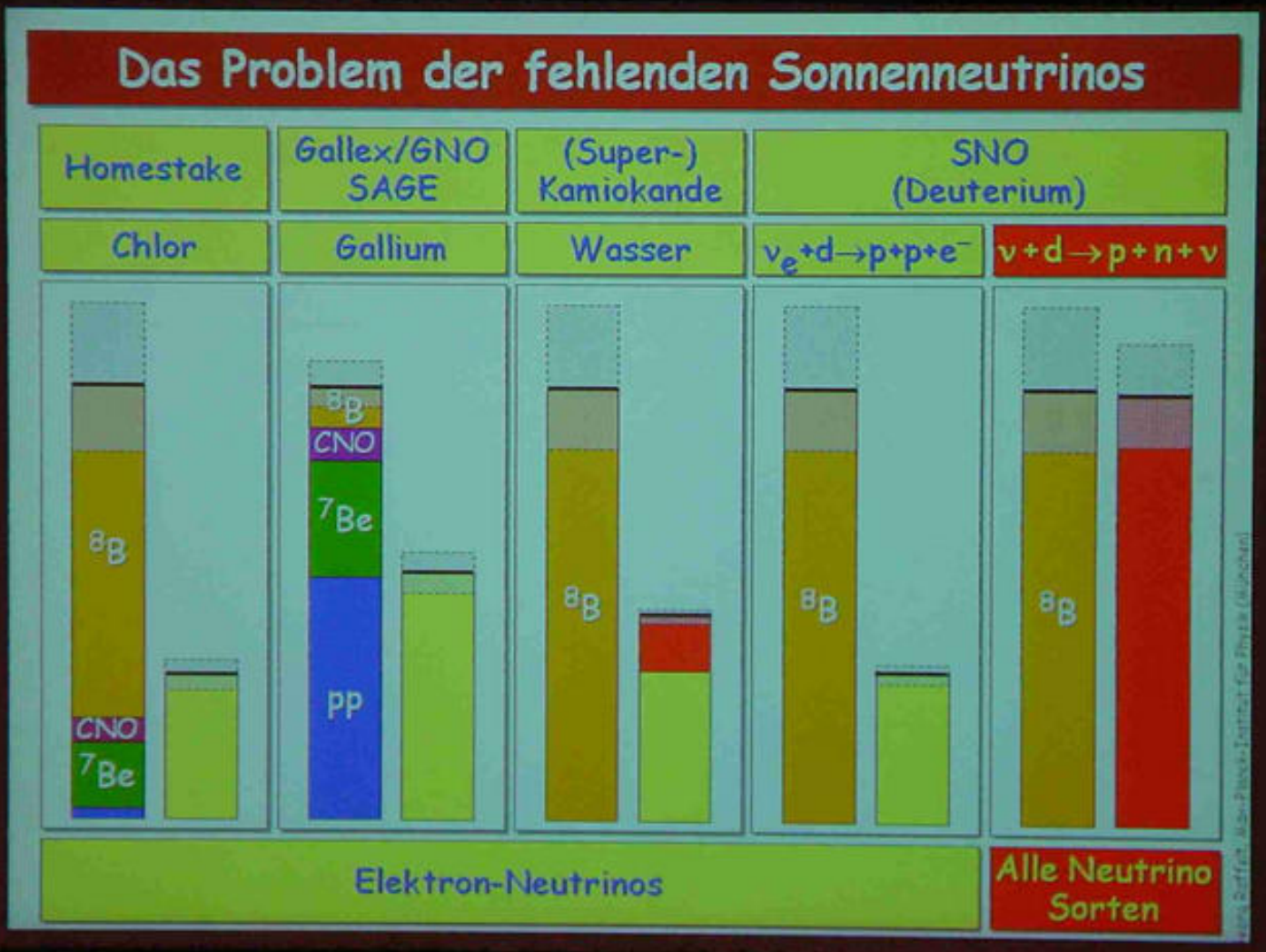
Schweres Wasser:
D_2O

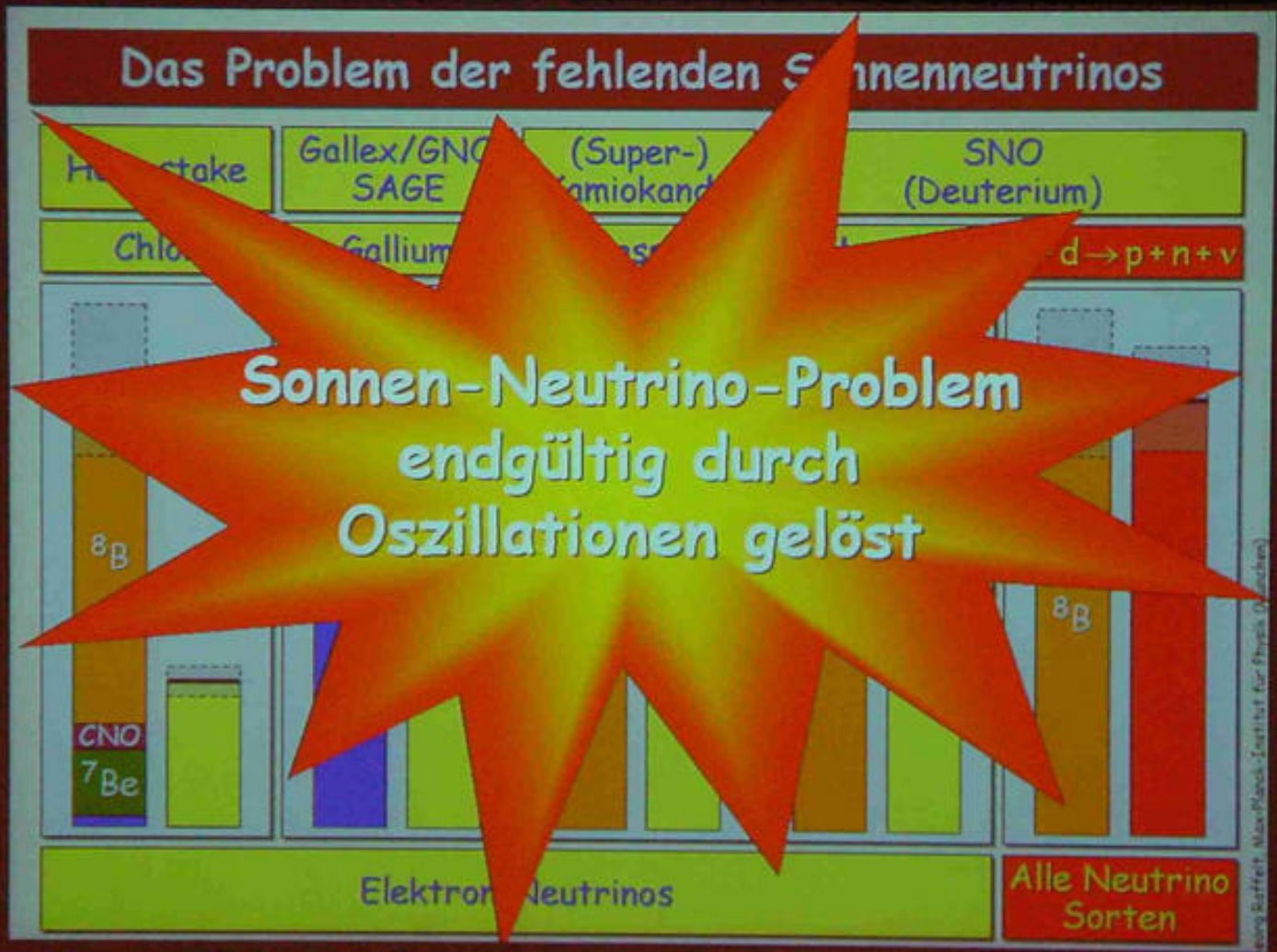
Kern des Wasserstoffs (Proton)

Kern des schweren Wasserstoffs (Deuterium)

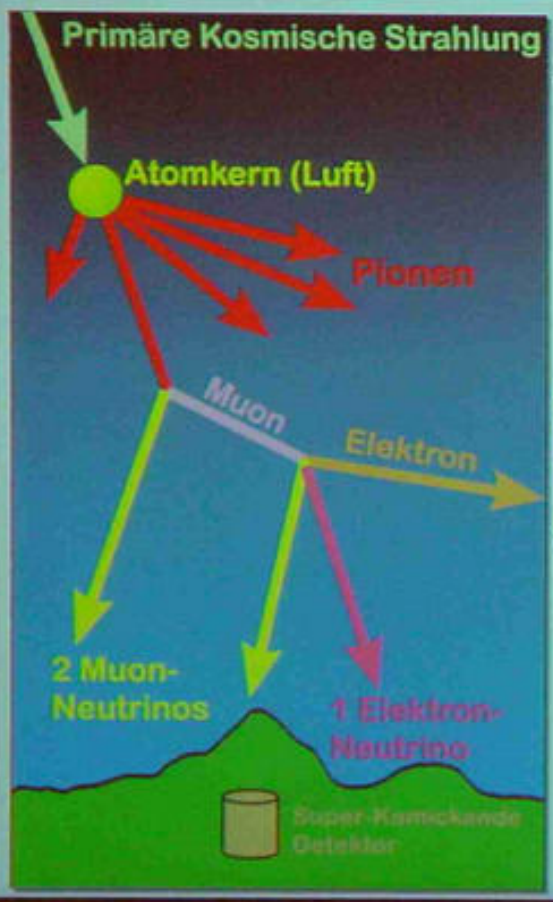

Sudbury Neutrino Observatory (SNO)
(1000 Tonnen schweren Wassers)
ν_e
Schwerer Wasser-stoff (Deuterium)
p n
p p e
Nur Elektron-Neutrinos
ν_τ
Schwerer Wasser-stoff (Deuterium)
p n
p n ν_τ
Alle Neutrino-Sorten

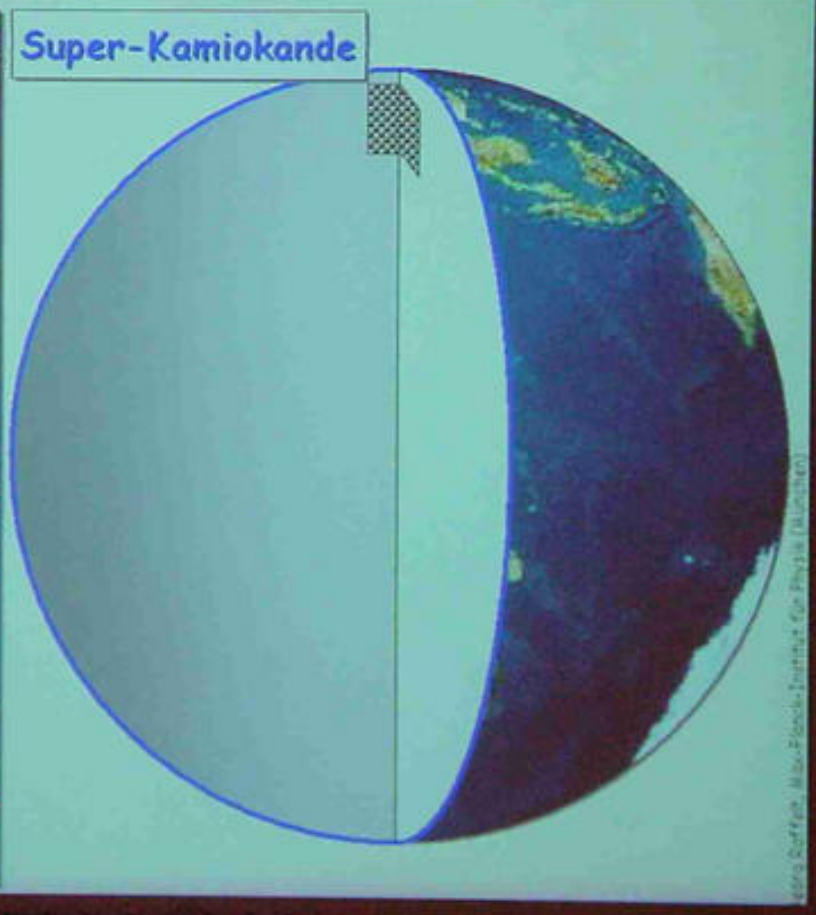
Das Problem der fehlenden Sonnenneutrinos



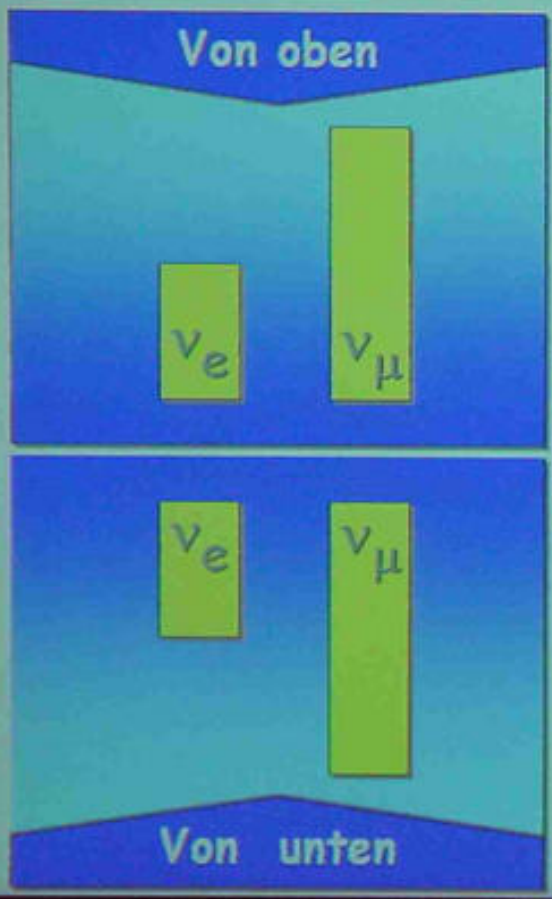

Das Problem der fehlenden S nnenneutrinos
Gallex/GNO
SAGE
(Super-)
SNO
(Deuterium)
Chlo
Gallium
d→p+n+v
Sonnen-Neutrino-Problem
endgültig durch
Oszillationen gelöst
8B
CNO
7Be
8B
Elektron Neutrinos
Alle Neutrino
Sorten

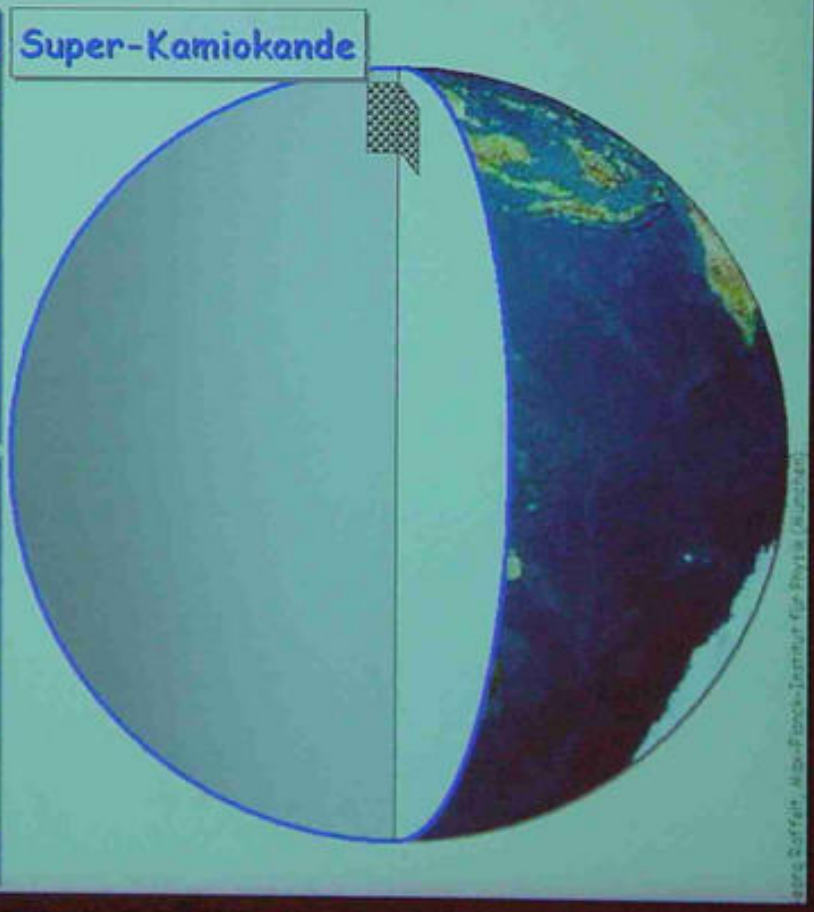
Atmosphärischer Neutrinofluss



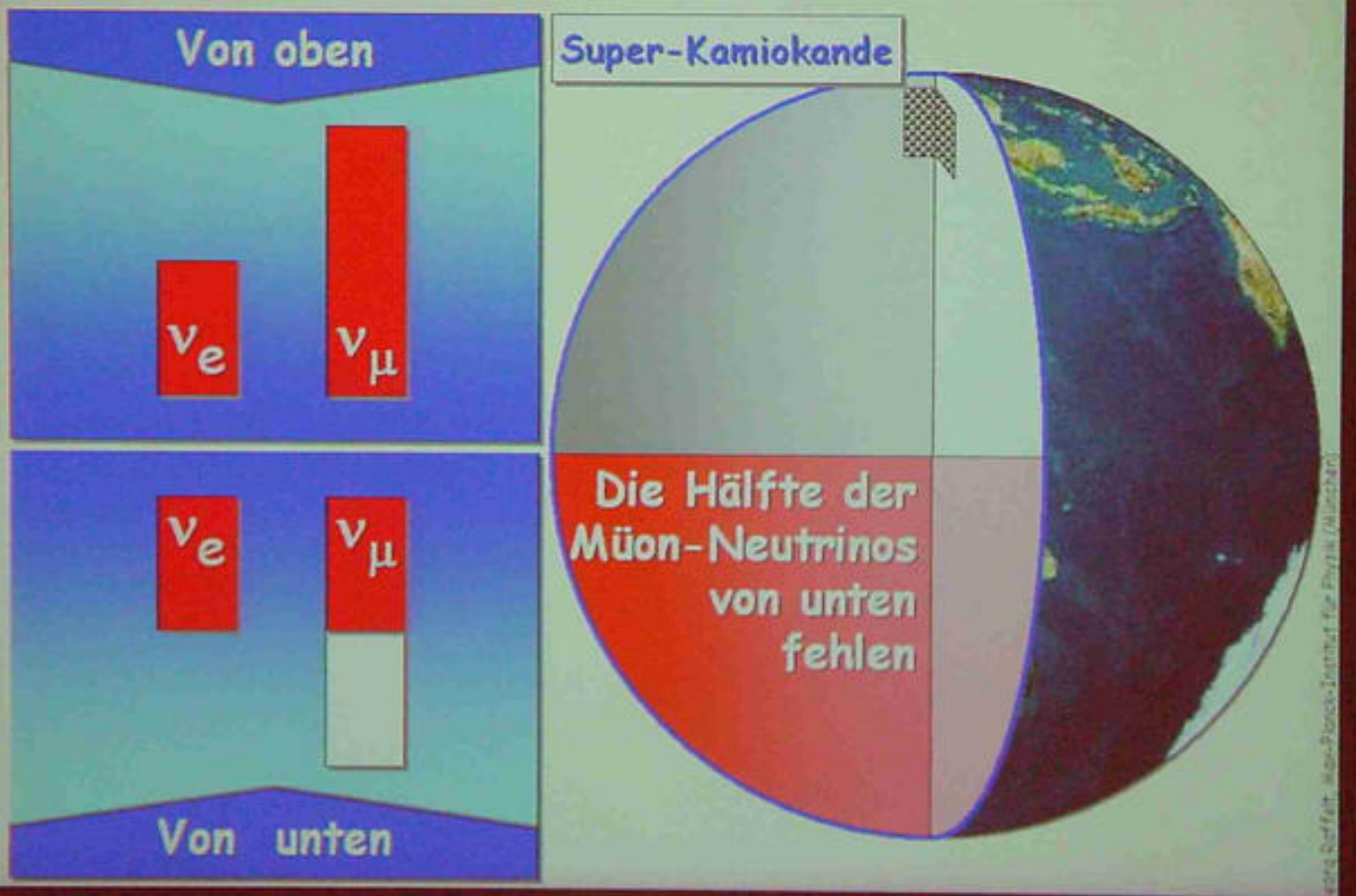


Atmosphärische Neutrino-Anomalie

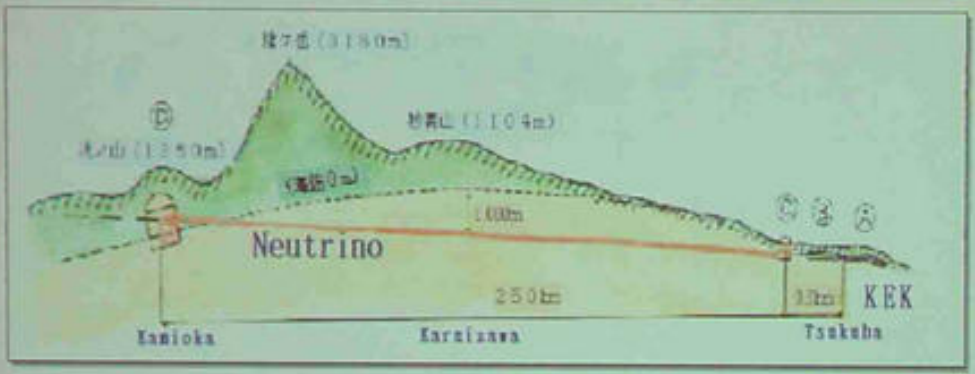




Atmosphärische Neutrino-Anomalie



„Long-Baseline" Experimente



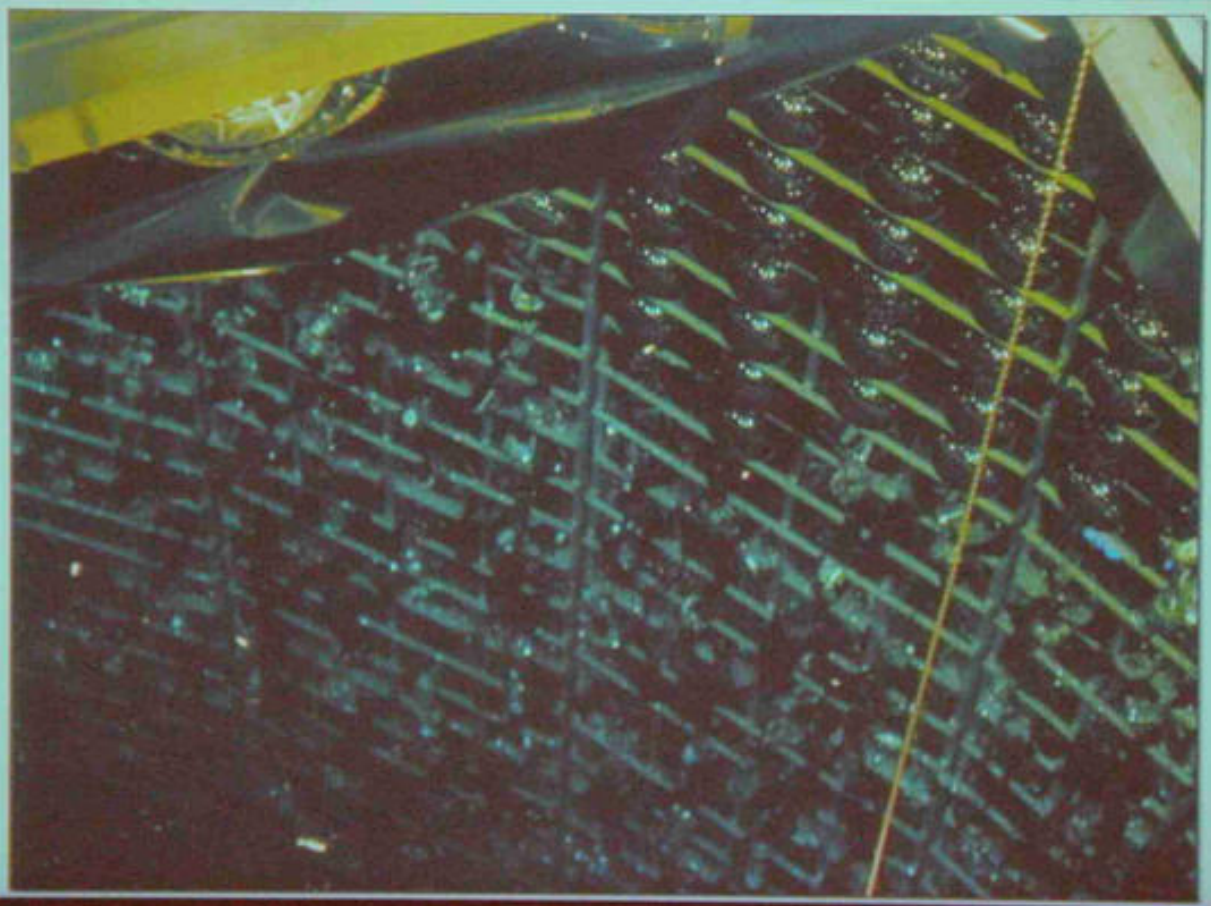
K2K Experiment

KEK to Kamiokande

Erste Daten bestätigen Neutrino-Oszillationen.

Derzeit keine Messungen wegen Unfall in Super-Kamiokande.

Super-Kamiokande Unfall am 12. Nov. 2001



„Long-Baseline" Experimente

CERN - Gran Sasso

FermiLab-Soudan (MINOS)

Materie-Inventar des Universums

Hubble Deep Field

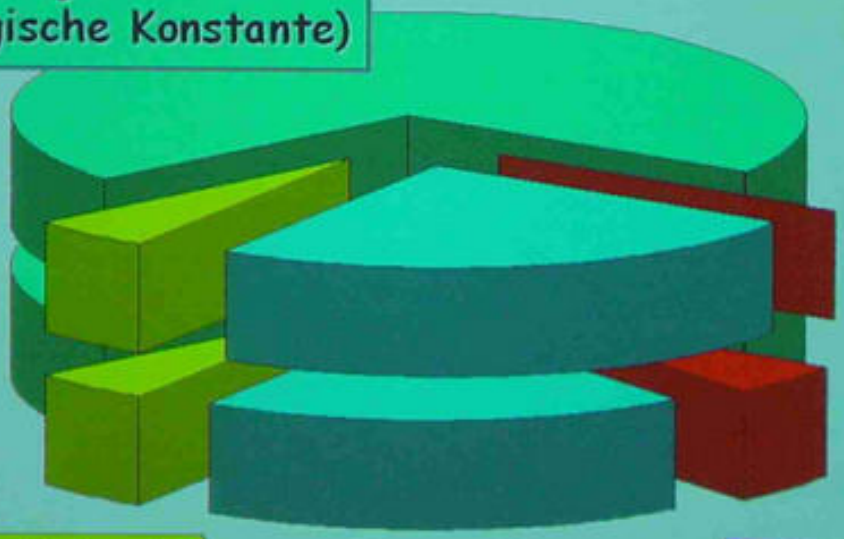
„Leuchtende Materie":
Entspricht im Mittel
ca. 1 H-Atom / 50 m^3
(0,3% kritischer Dichte)

„Dunkle Materie":
Entspricht im Mittel
ca. 6 H-Atome / m^3
(„kritische Dichte")

Relikt-Neutrinos aus dem Urknall:
110 Neutrinos & Anti-Neutrinos pro Sorte und pro cm^3
Neutrinomasse 30 eV entspricht kritischer Dichte

Materie-Inventar des Universums

Dunkle Energie
(Kosmologische Konstante)

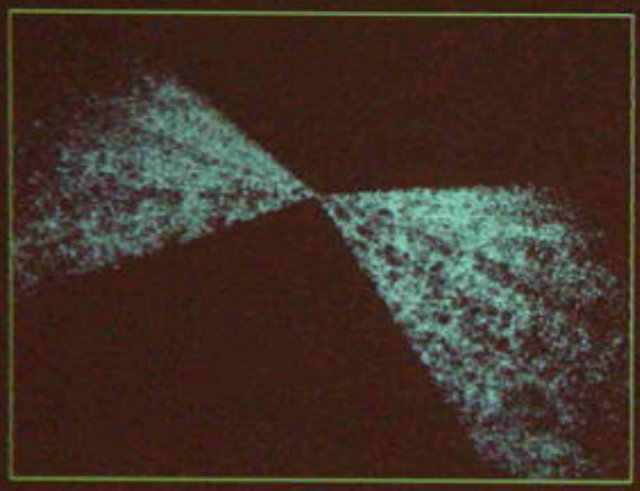


Normale Materie
(davon nur ca.
10% leuchtend)

Dunkle
Materie

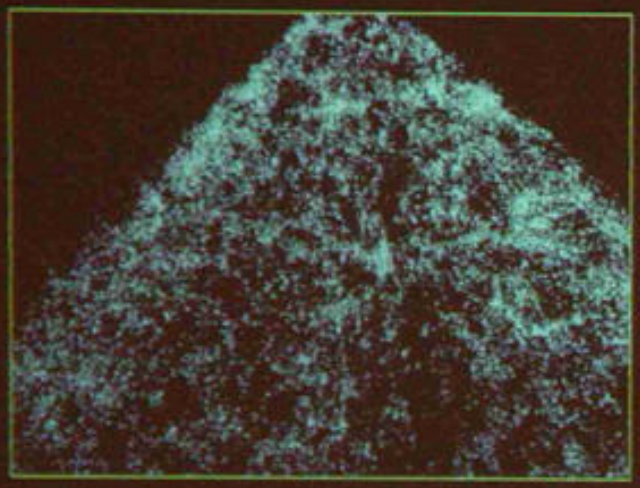
Neutrinos
min. 0,1%
max. 6%

Neutrinomasse aus der Galaxienverteilung



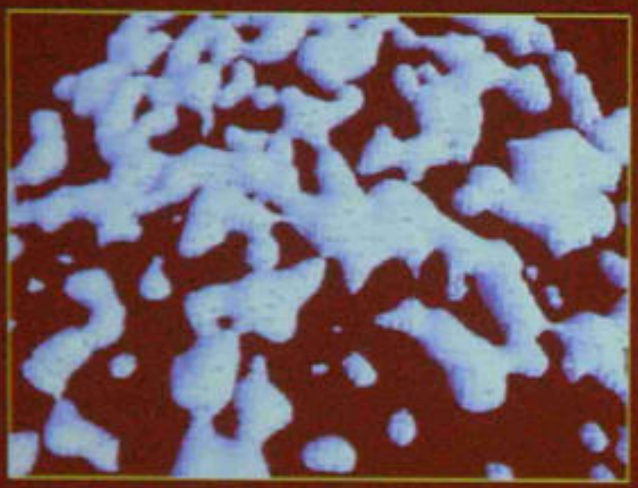
Animationen von 2dFGRS Homepage http://www.mso.anu.edu.au/2dFGRS/

Neutrinomasse aus der Galaxienverteilung



Animationen von 2dFGRS Homepage http://www.mso.anu.edu.au/2dFGRS/

Neutrinomasse aus der Galaxienverteilung



Animationen von 2dFGRS Homepage http://www.mso.anu.edu.au/2dFGRS/

Das Mass der „Galaxienklumpung" besagt, dass Neutrinos weniger als 6% der kritischen Dichte ausmachen

Neutrinomasse kleiner als ca. 1 eV


Sanduleak -69 202
Tarantel Nebel
Grosse Magellan'sche Wolke
Entfernung 50 kpc
(160.000 Lichtjahre)

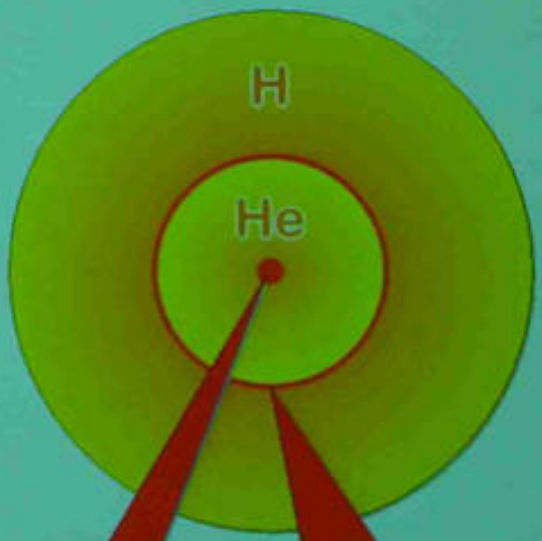

Sanduleak -69 202
Supernova 1987A
23. Februar 1987

Sternkollaps und Supernovaexplosion

Hauptreihenstern

Wasserstoffbrennen

Roter Riesenstern

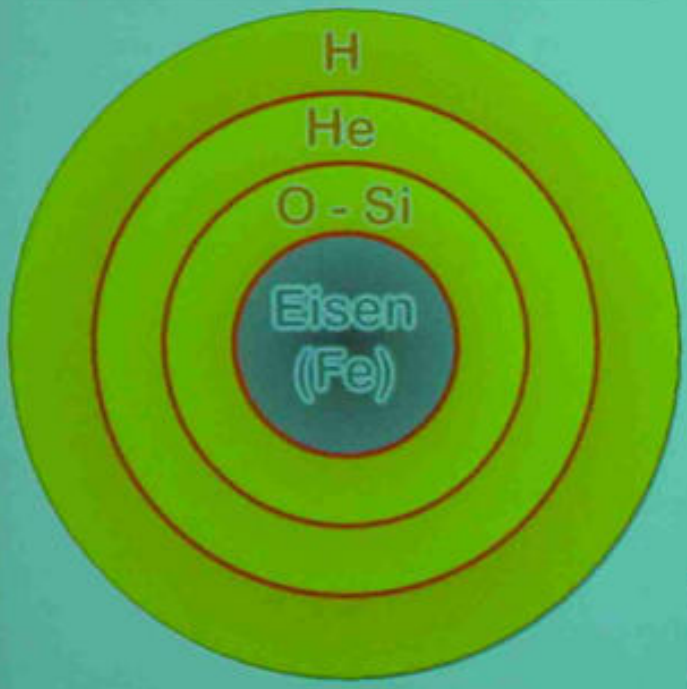


Helium-brennen

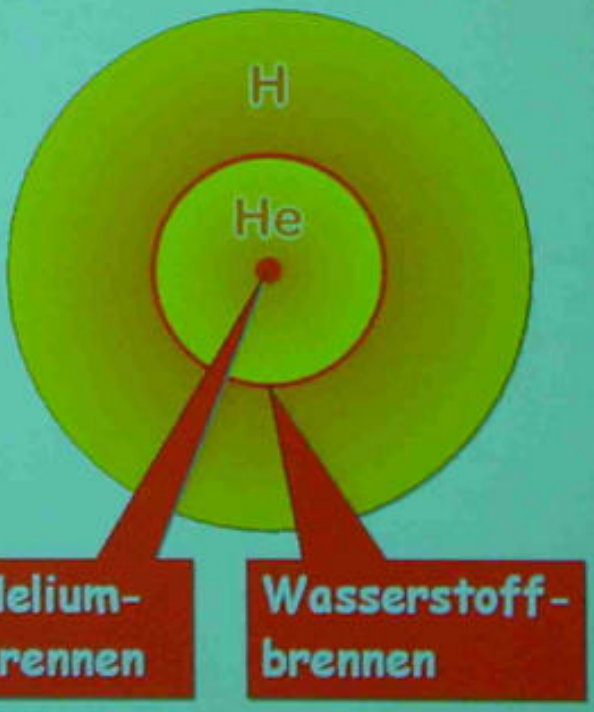
Wasserstoff-brennen

Sternkollaps und Supernovaexplosion

Zwiebelschalenstruktur



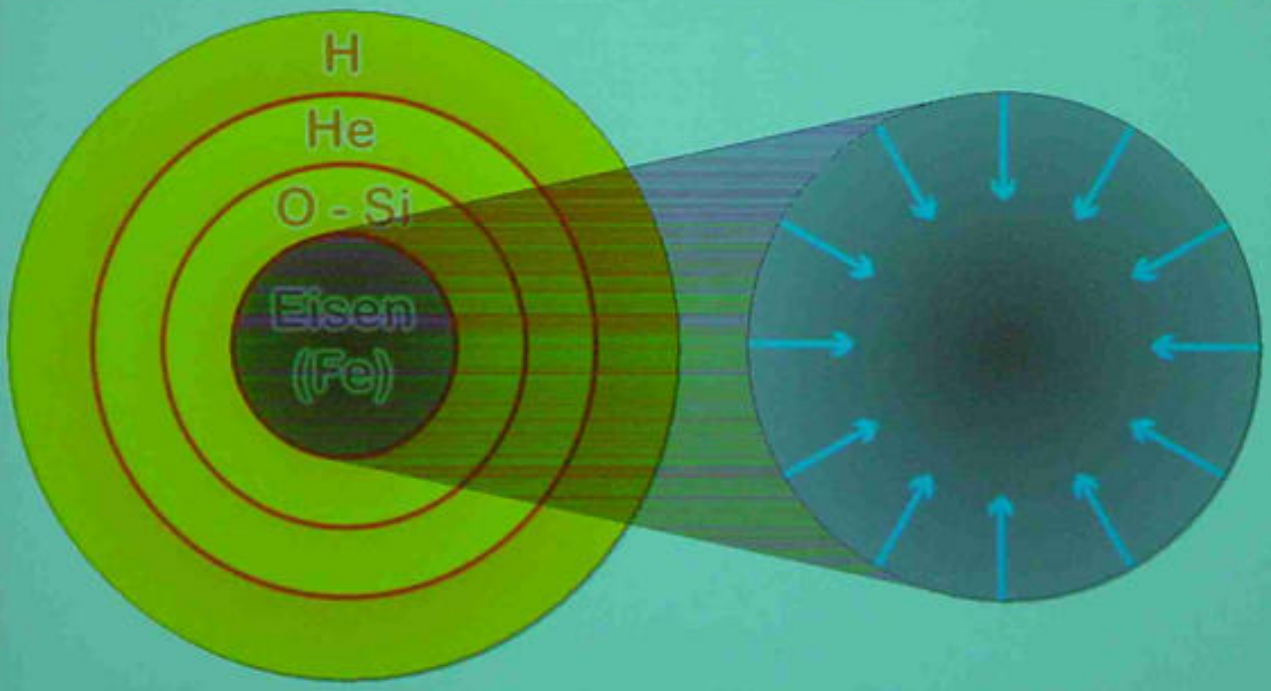
Roter Riesenstern



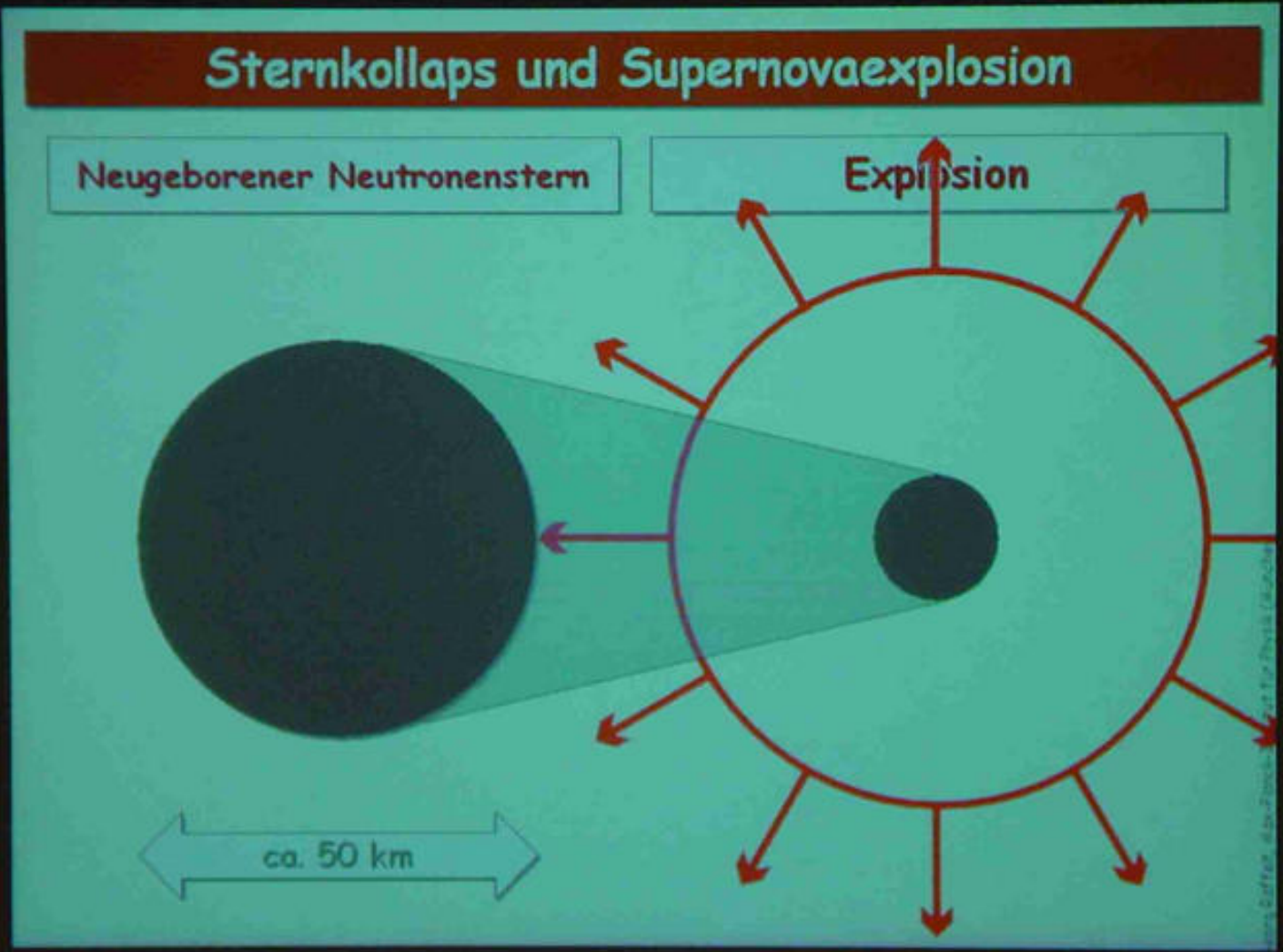
Sternkollaps und Supernovaexplosion

Zwiebelschalenstruktur

Kollaps (Implosion)

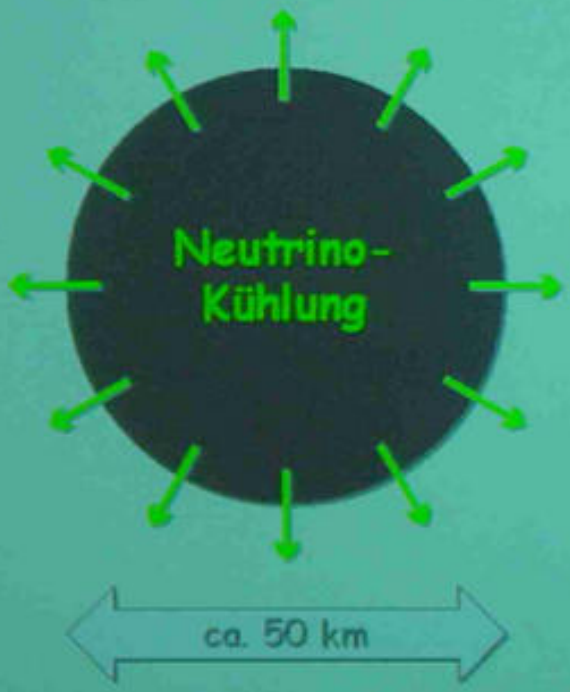


Sternkollaps und Supernovaexplosion



Sternkollaps und Supernovaexplosion

Neugeborener Neutronenstern



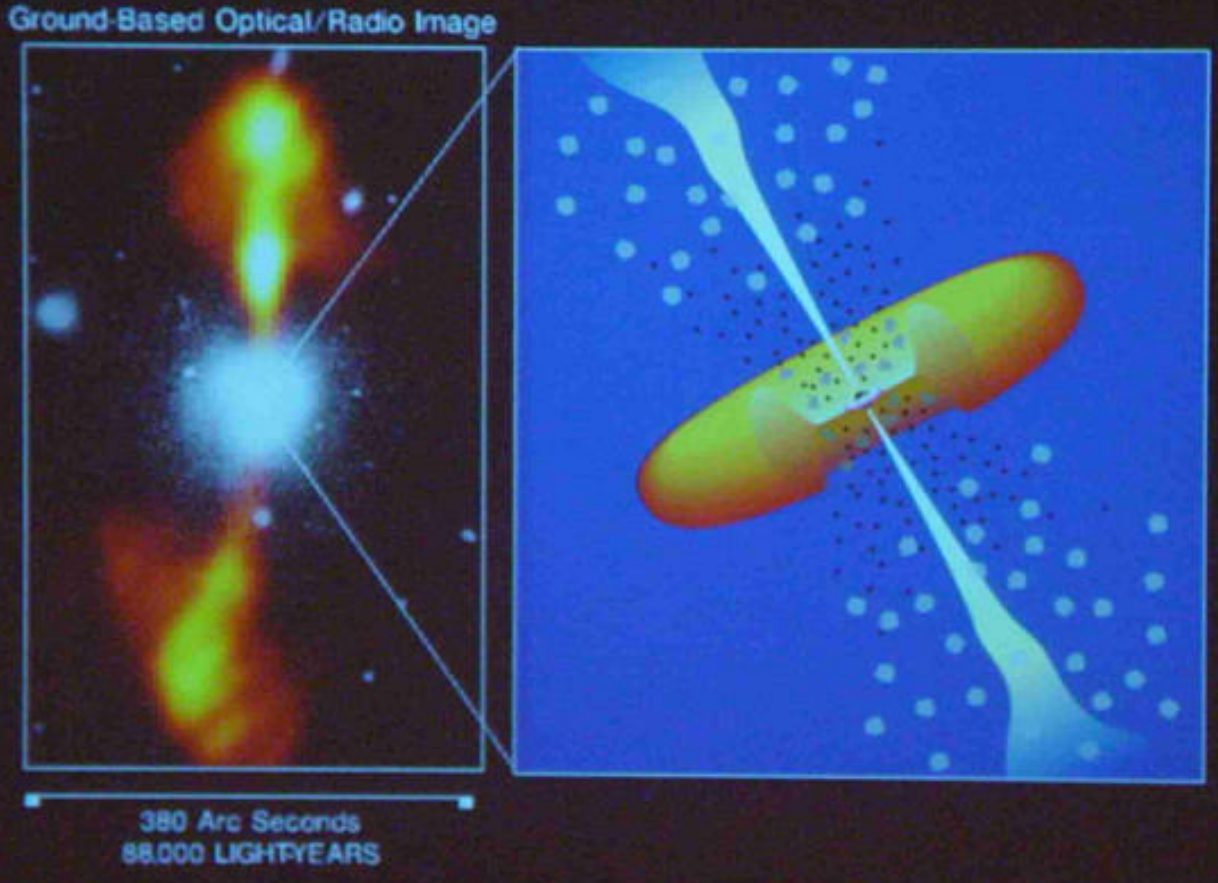
- Dichte ungefähr 300 Millionen Tonnen /cm³
- Neutrinos sind „gefangen"
- Kühlung durch Neutrinos in ca. 10 Sekunden
- Energiemenge entspricht ca. dem 100-fachen dessen, was die Sonne während ihrer ganzen Lebensdauer umsetzt

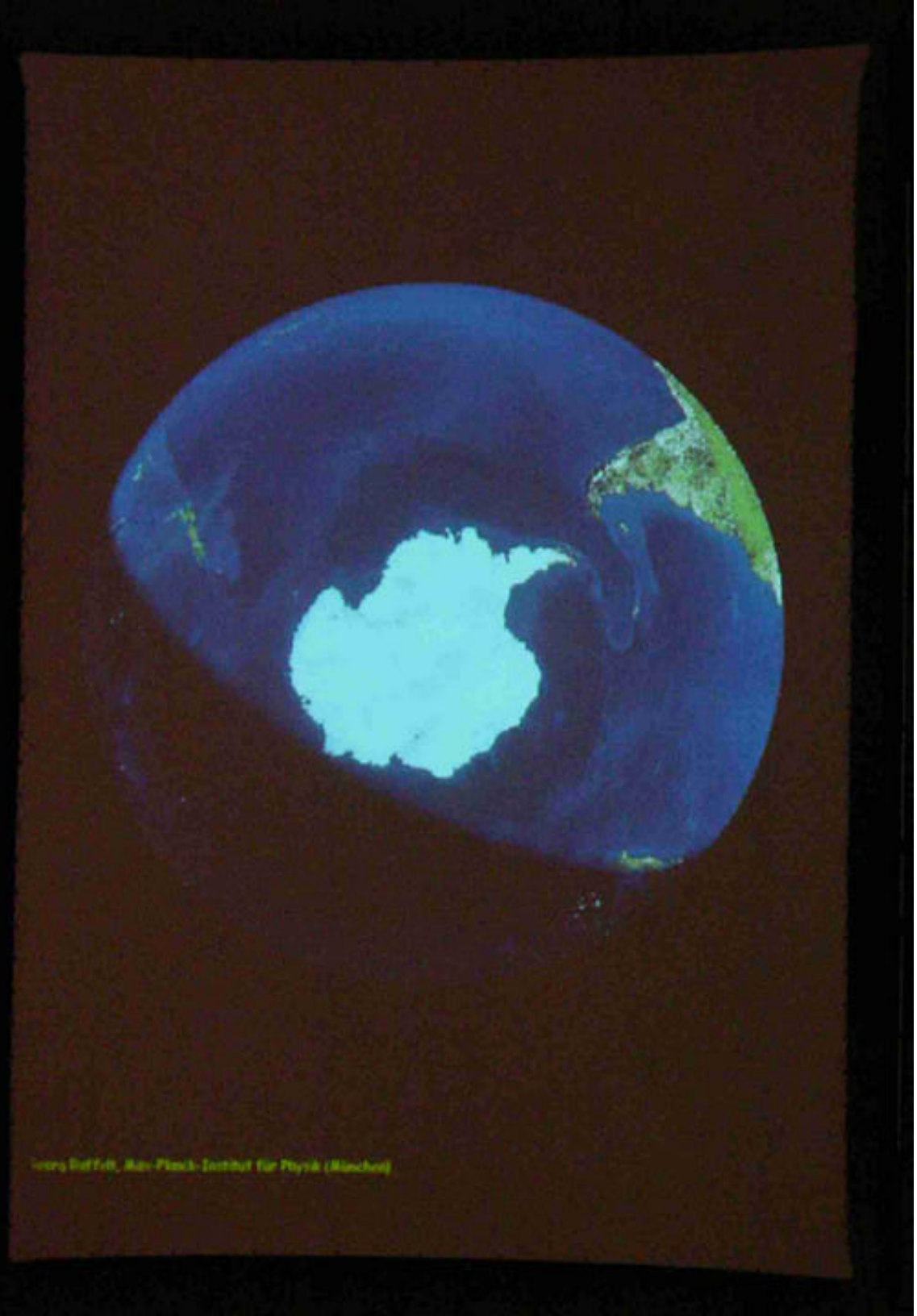
Kosmische Strahlung ("Höhenstrahlung")

Victor Hess (1911)

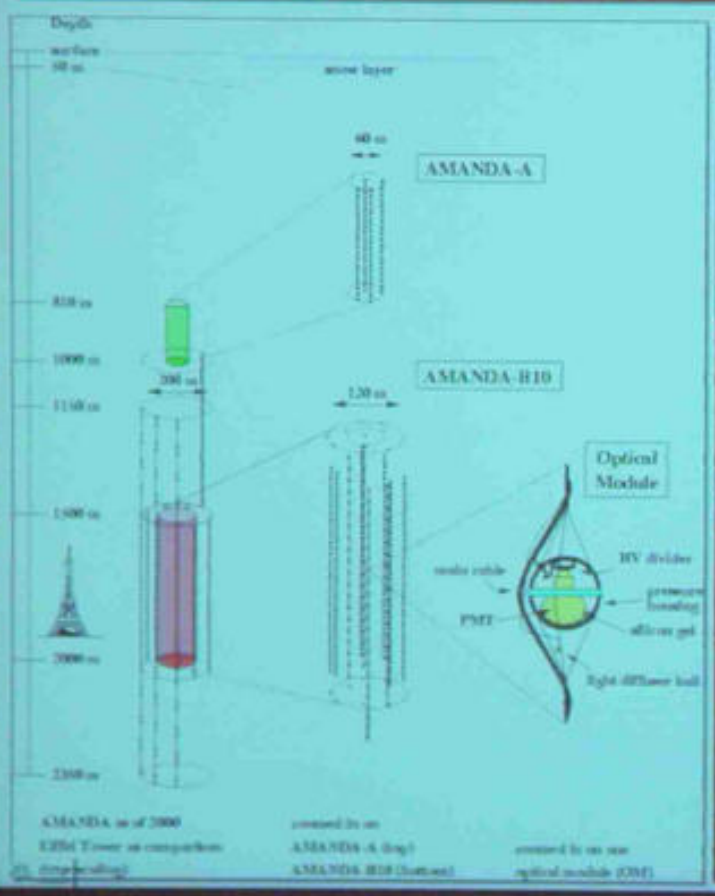
Woher kommt die primäre kosmische Strahlung?

Kern der Galaxie NGC 4261

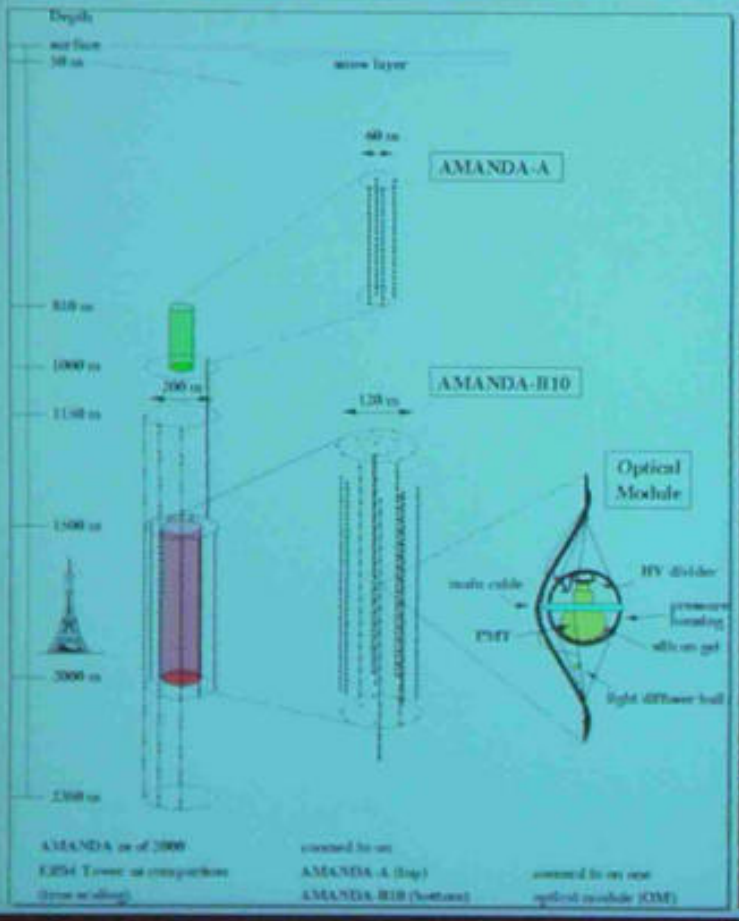


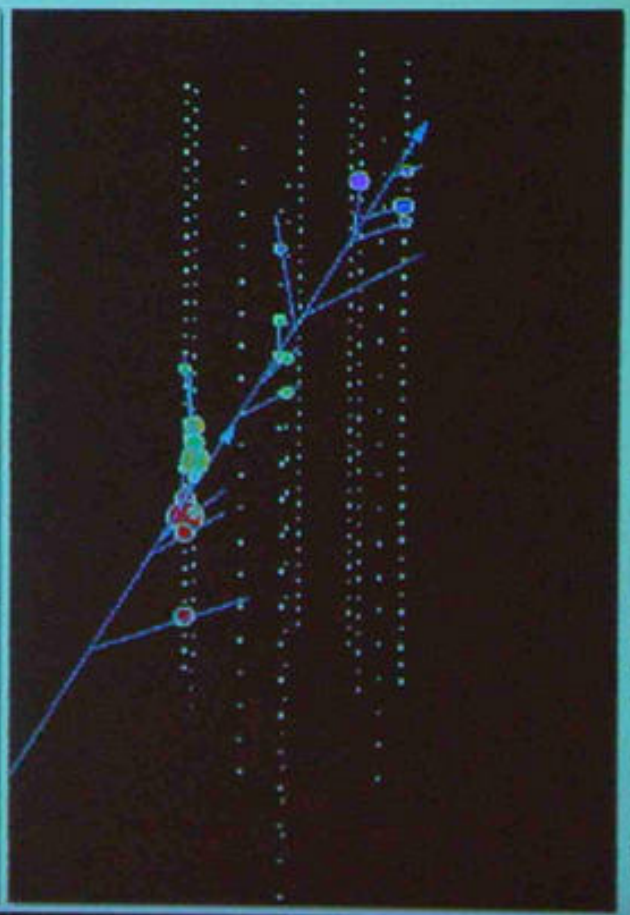


AMANDA - Neutrinoteleskop am Südpol

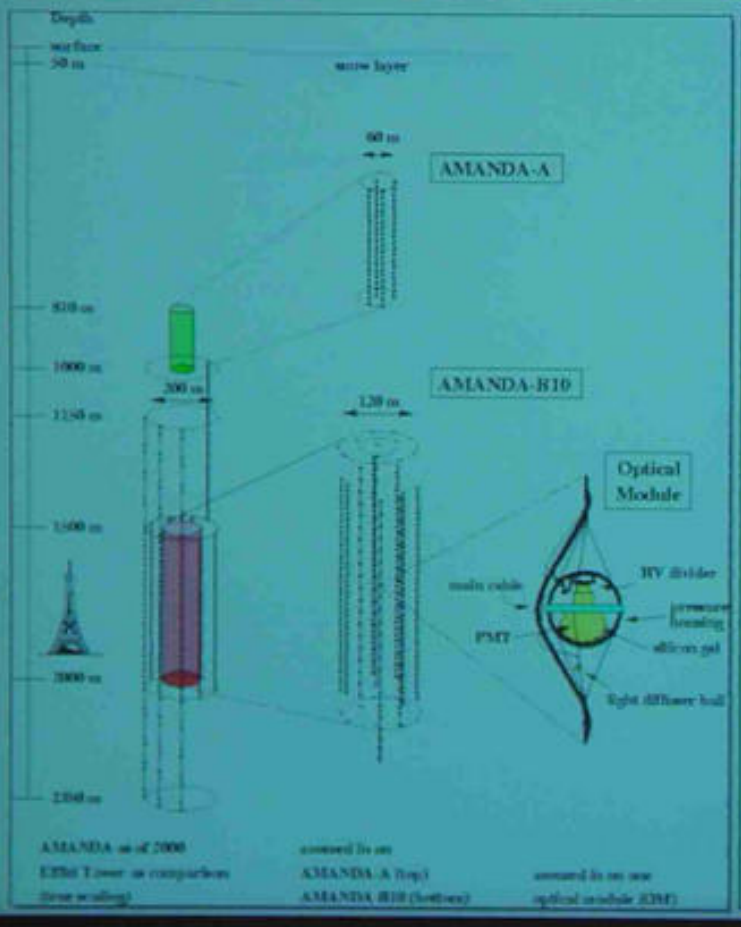


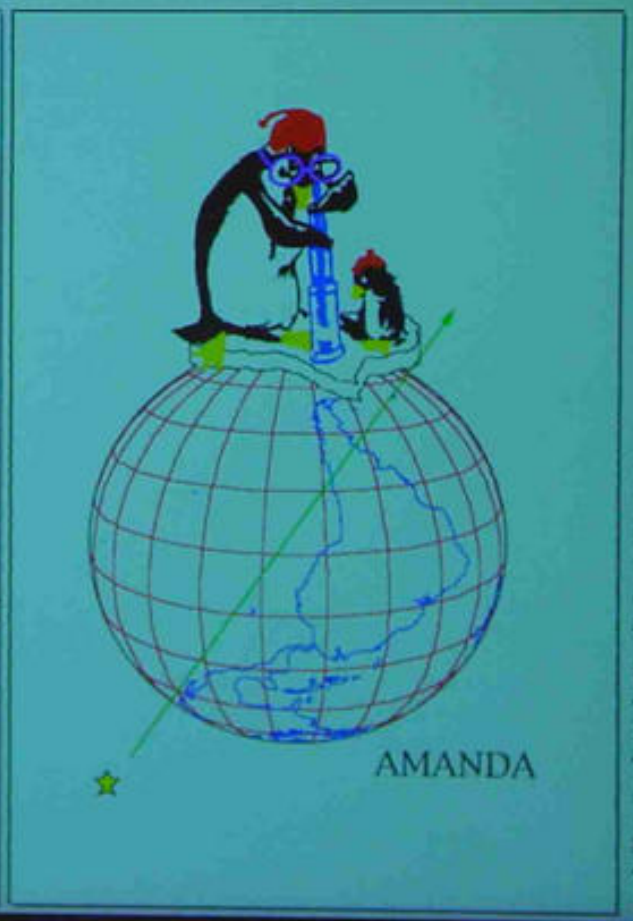
AMANDA - Neutrinoteleskop am Südpol



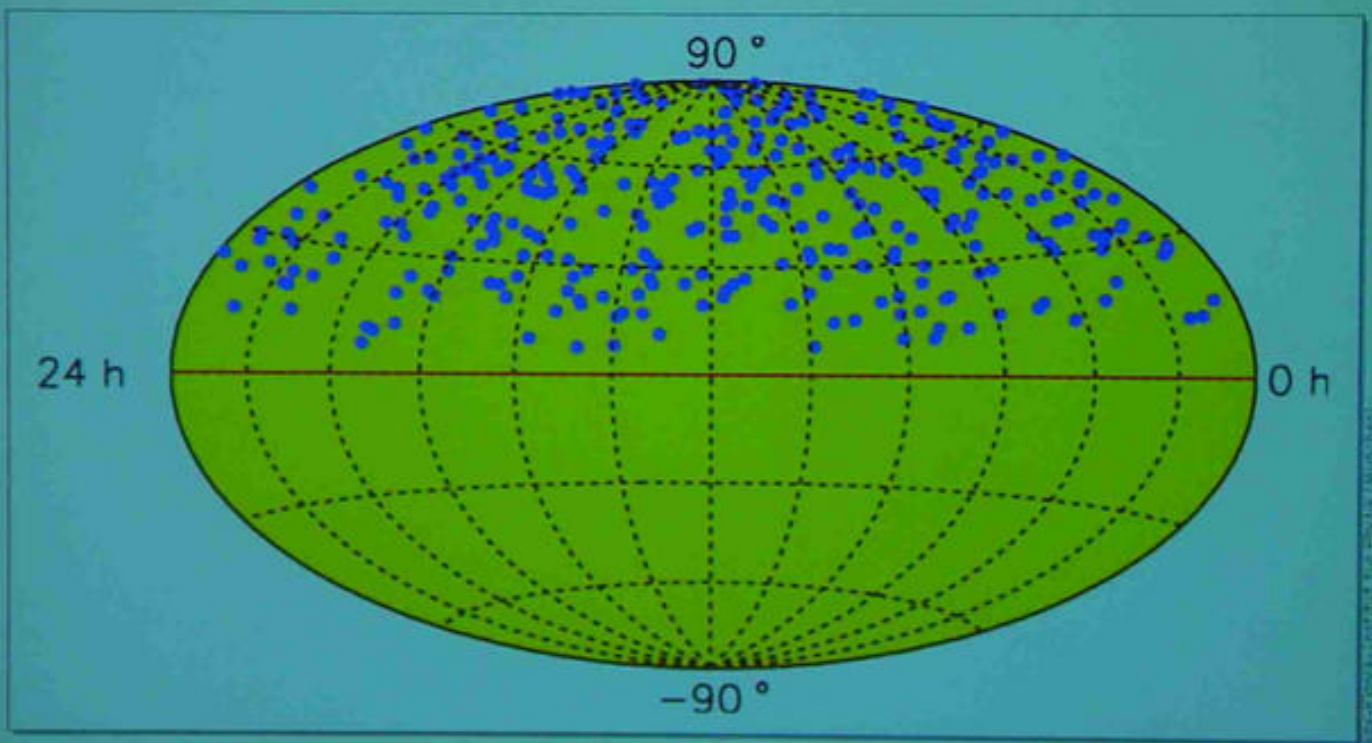


AMANDA – Neutrinoteleskop am Südpol

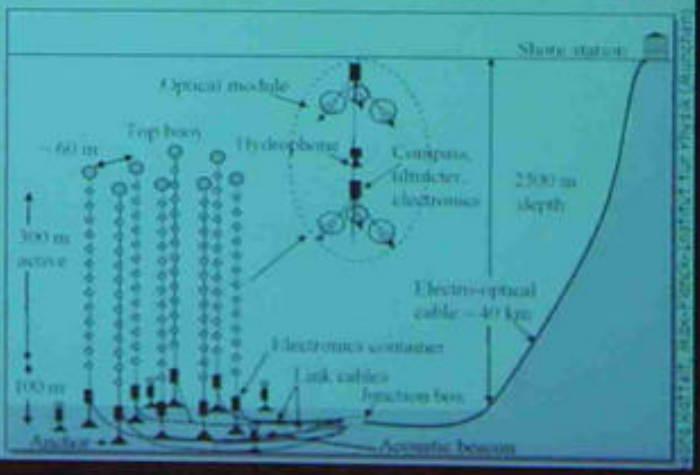


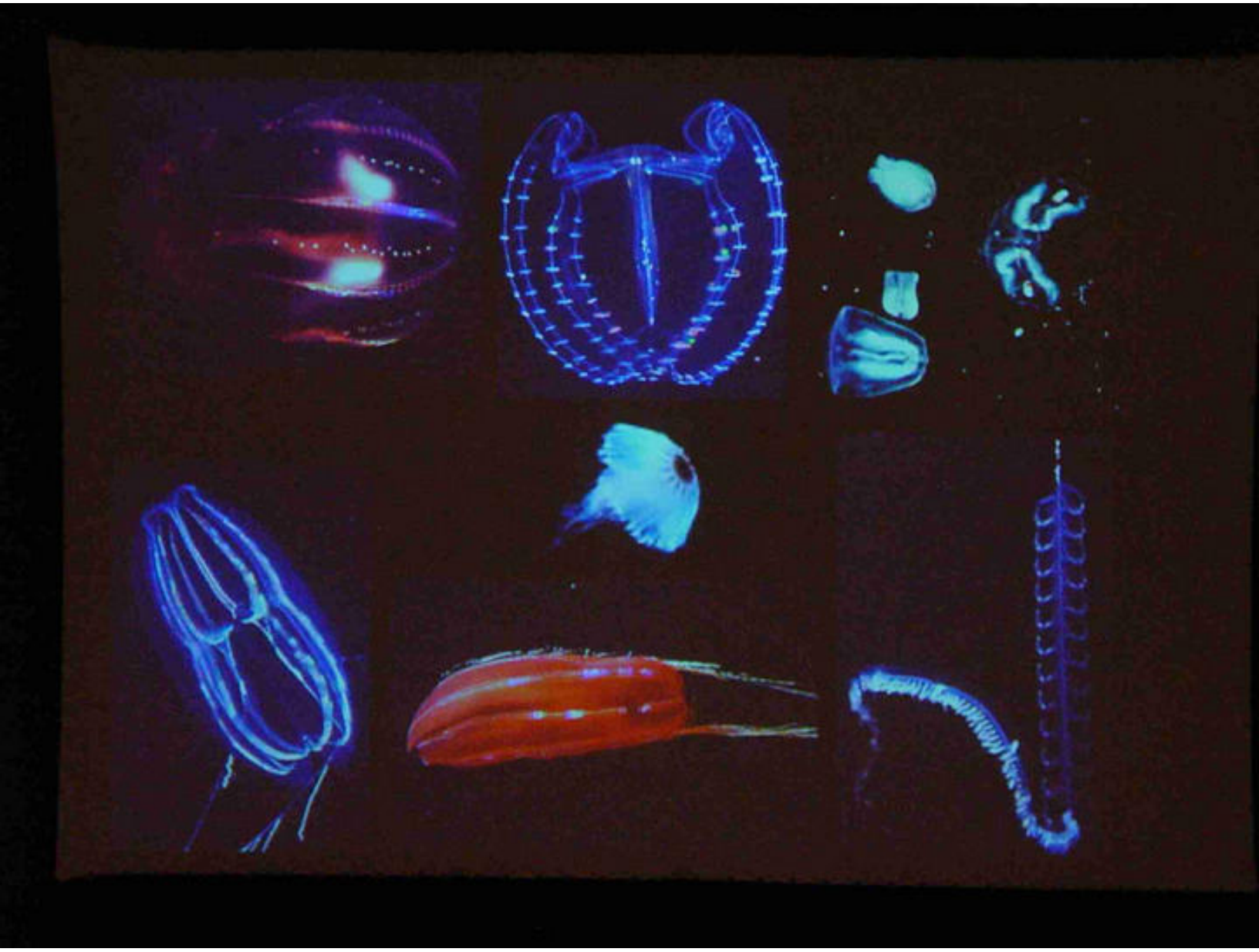


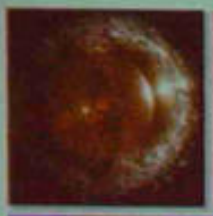
AMANDA - Erste Neutrinobeobachtungen



ANTARES - Neutrinoteleskop im Mittelmeer







- Sonnenneutrino-rätsel
- Atmosphärische Neutrino-Anomalie

Neutrinooszillationen

- Neutrinomassen etabliert (Sehr kleine Differenzen)
- Grosse „Mischungen"

Absolutwert der Neutrinomassen

2dFGRS

Präzisionskosmologie

Karlsruhe Tritium Neutrino Experiment

Doppel-Beta-Zerfalls Experimente (z.B. Heidelberg-Moskau, Genius)

Präzisionsvermessung der „Massen- & Mischungsmatrix"

Asymmetrie zwischen Neutrinos & Antineutrinos?

Himmel im „Neutrino-Licht"

Kosmische Beschleuniger? Hochenergie-Phänomene?

Galaktische Supernova?


Neutrinos
Unsichtbare Botschafter
aus dem Mikrokosmos
und dem fernen Universum