Astrofisica, Astronomia e l'esperimento Borexino

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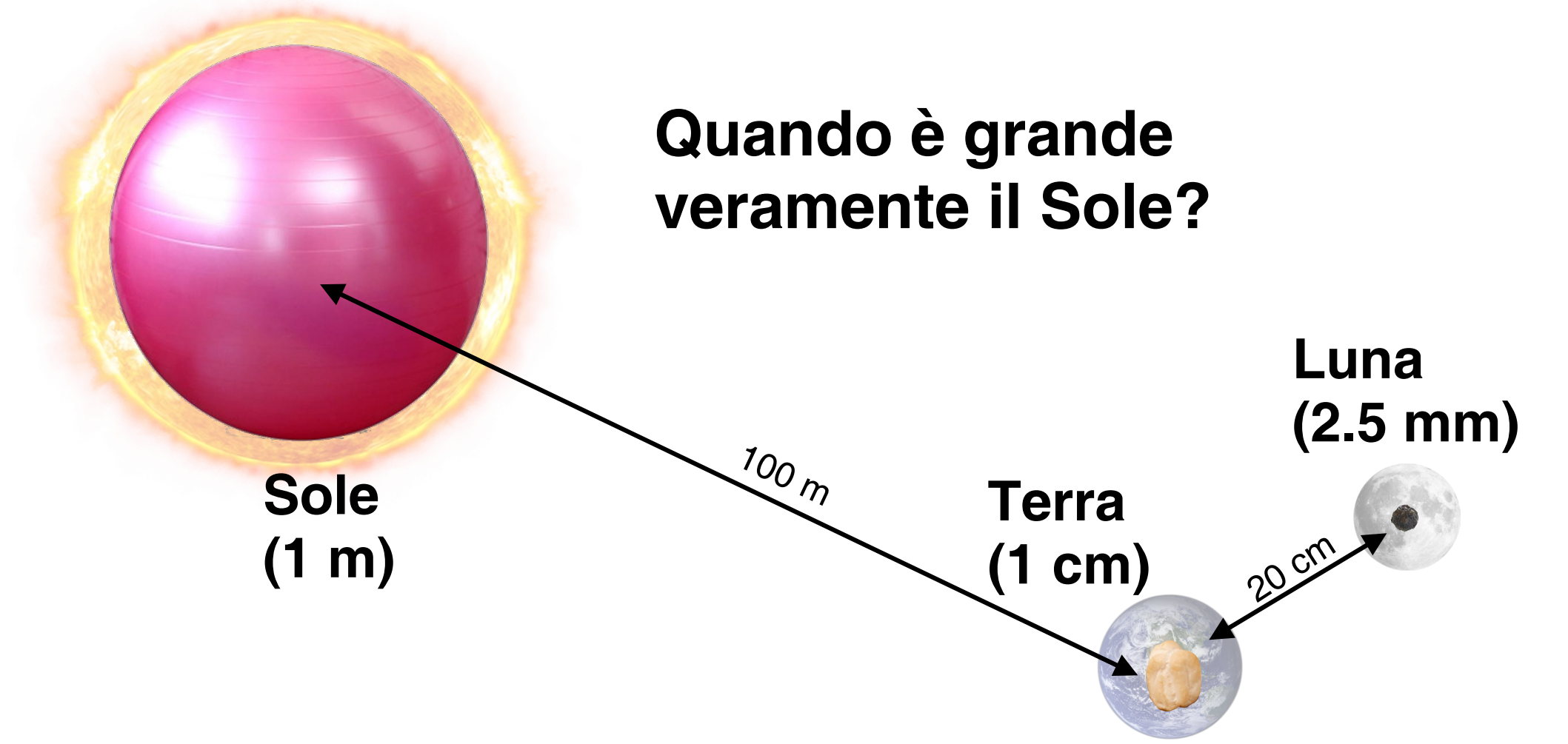
NEUTRINI SOLARI E MASSIMI SISTEMI
LNGS, 22 febbraio 2023

Circa 60 miliardi di neutrini per centimetro quadro al secondo

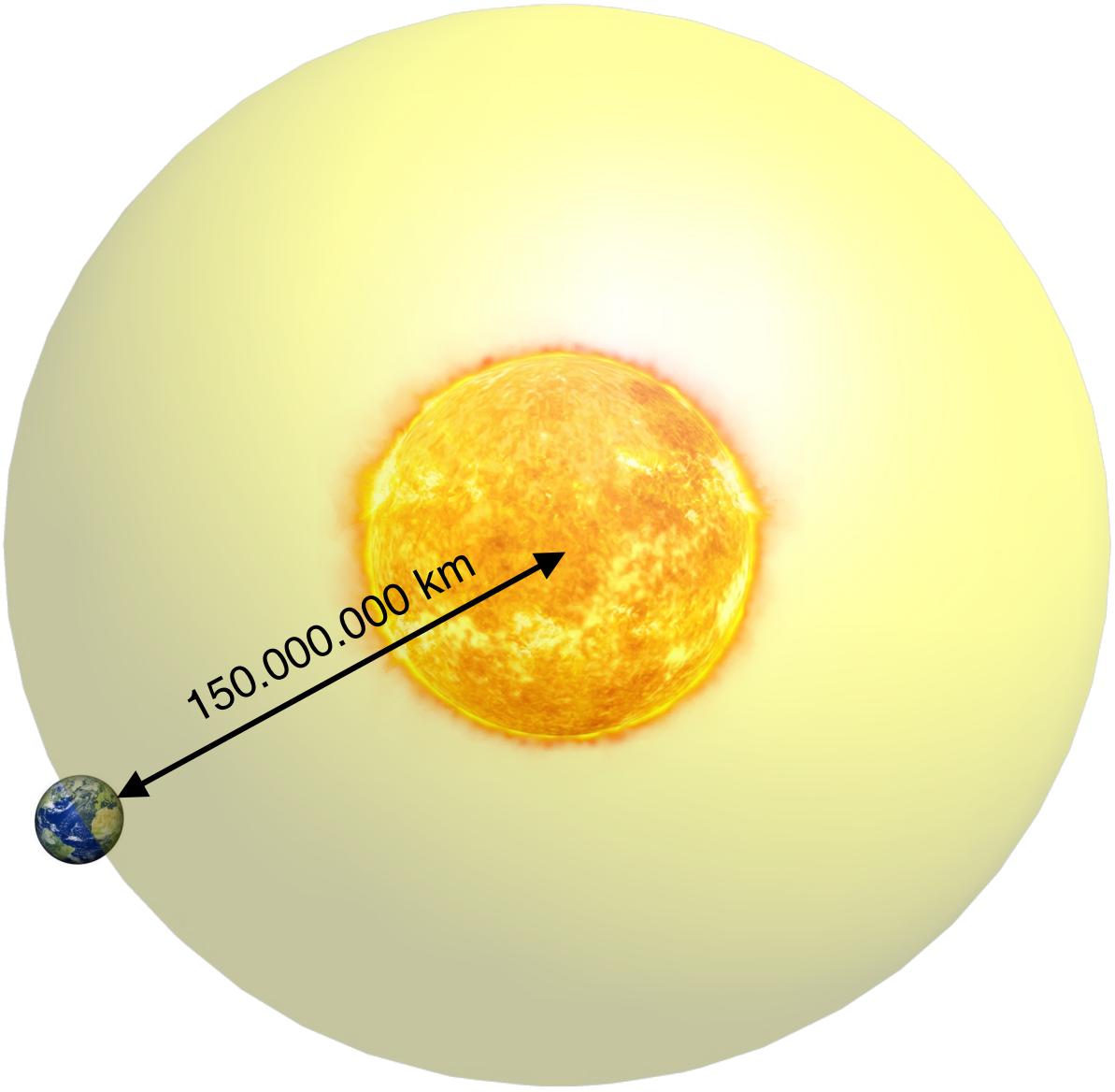
Quando è grande veramente il Sole?



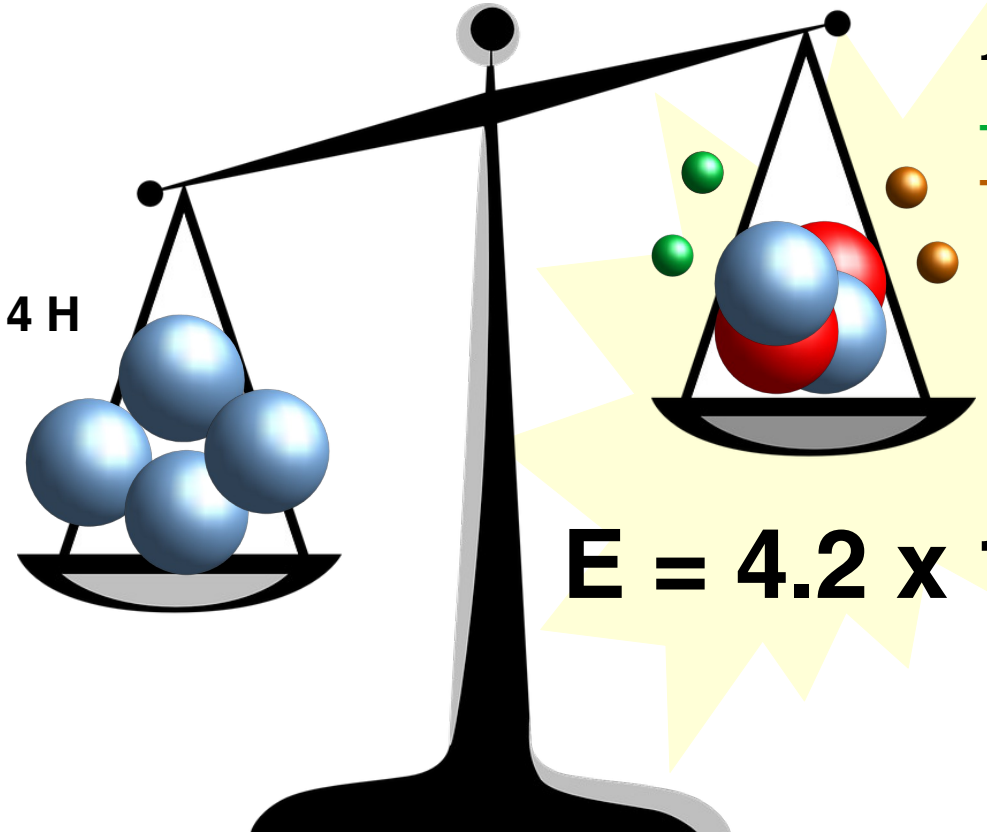

Il sole irraggia sulla terra
circa 1.3 kW/m²

Potenza generata dal Sole:

1300 W x [sfera] =
4×10^{26} W!

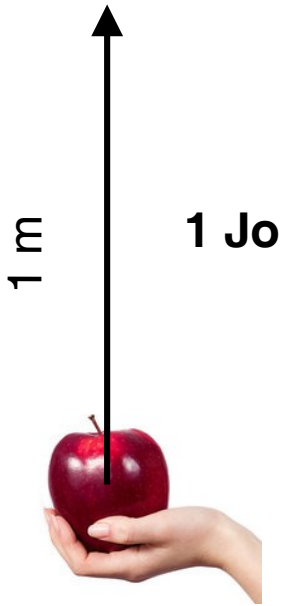


La fusione dell'idrogeno



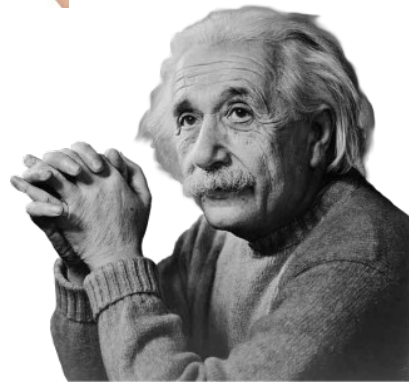
1 He
+ 2 positroni
+ 2 neutrini

$E = 4.2 \times 10^{-12}$ J



1 Joule

$E = mc^2$!



A che velocità brucia il sole?

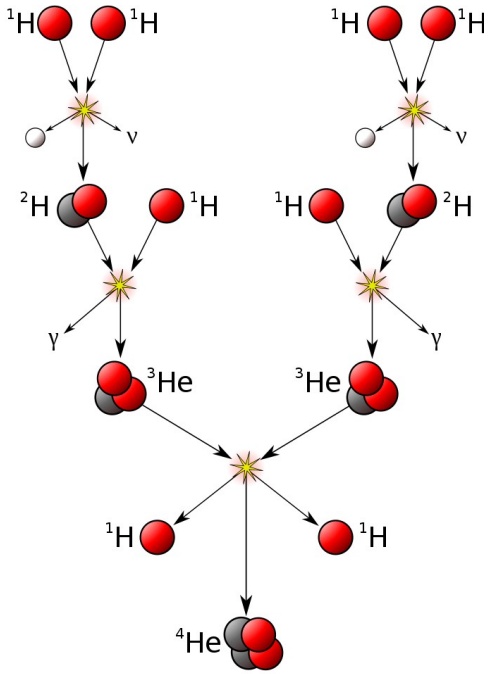
$$\frac{\text{potenza totale}}{\text{energia singola}} = \frac{4 \times 10^{26} J/s}{4.2 \times 10^{-12} J} \approx 10^{38} \frac{\text{fusioni}}{\text{secondo}}$$

600.000.000 tonnellate/sec di idrogeno

Quanti neutrini arrivano sulla terra?

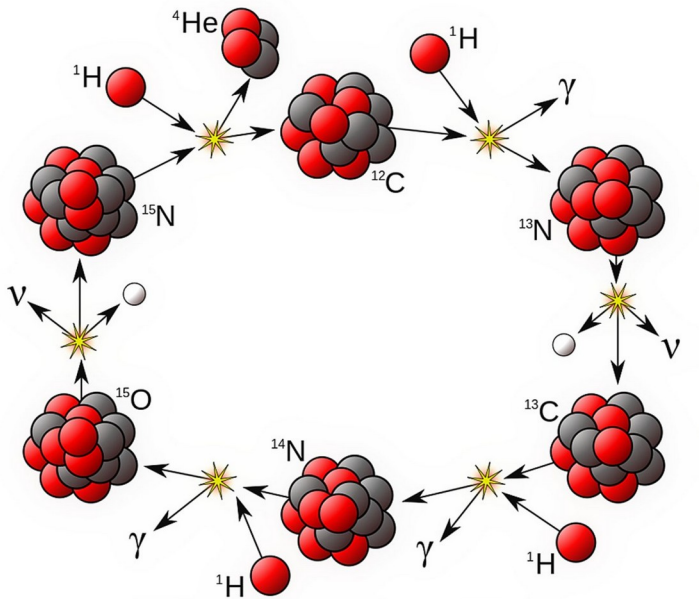
$$\frac{2 \times 10^{38}}{[\text{sfera}]} \approx 60 \times 10^{9} \frac{\text{neutrini}}{\text{secondo} \times \text{cm}^2}$$

Catena protone-protone



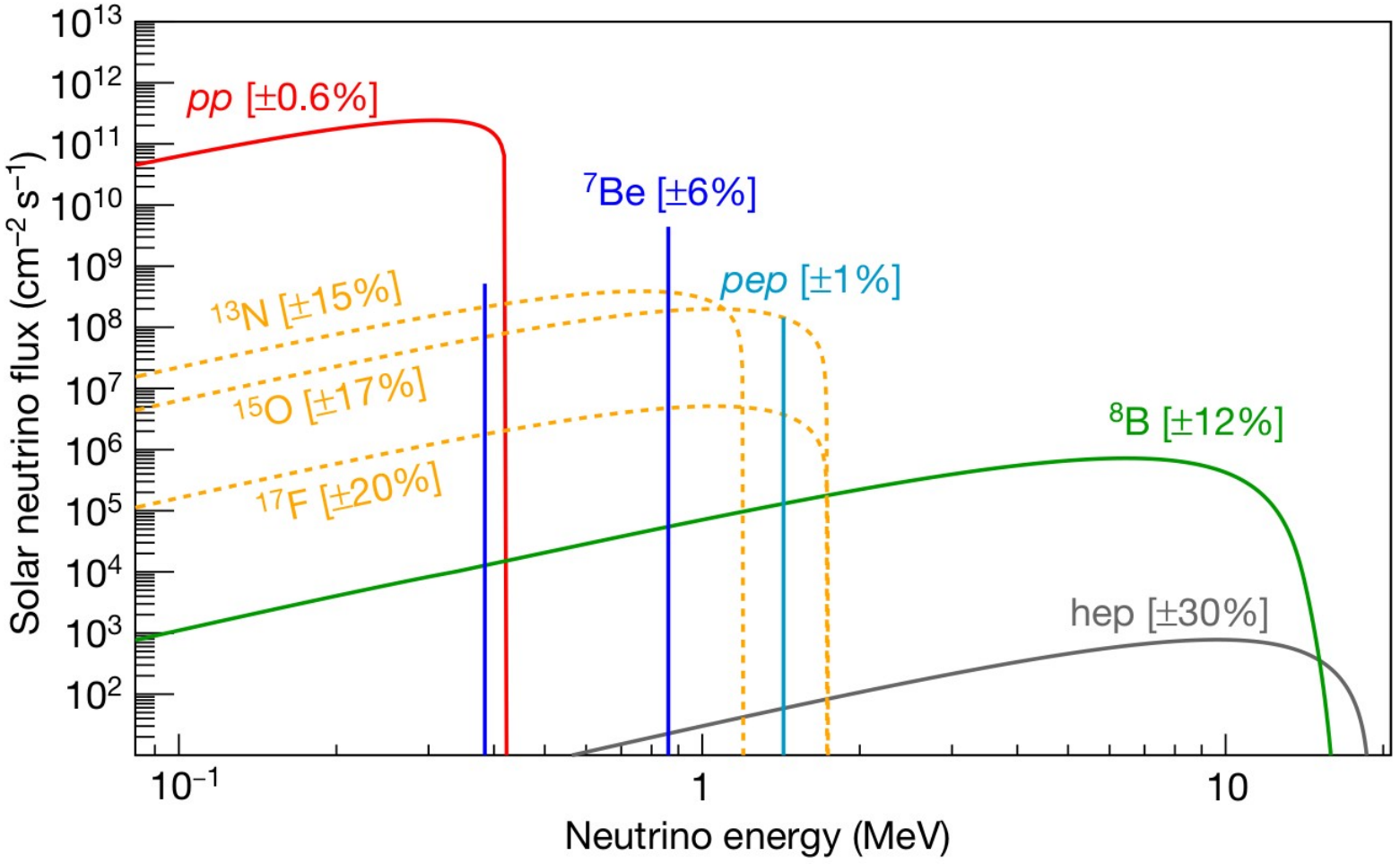
99%

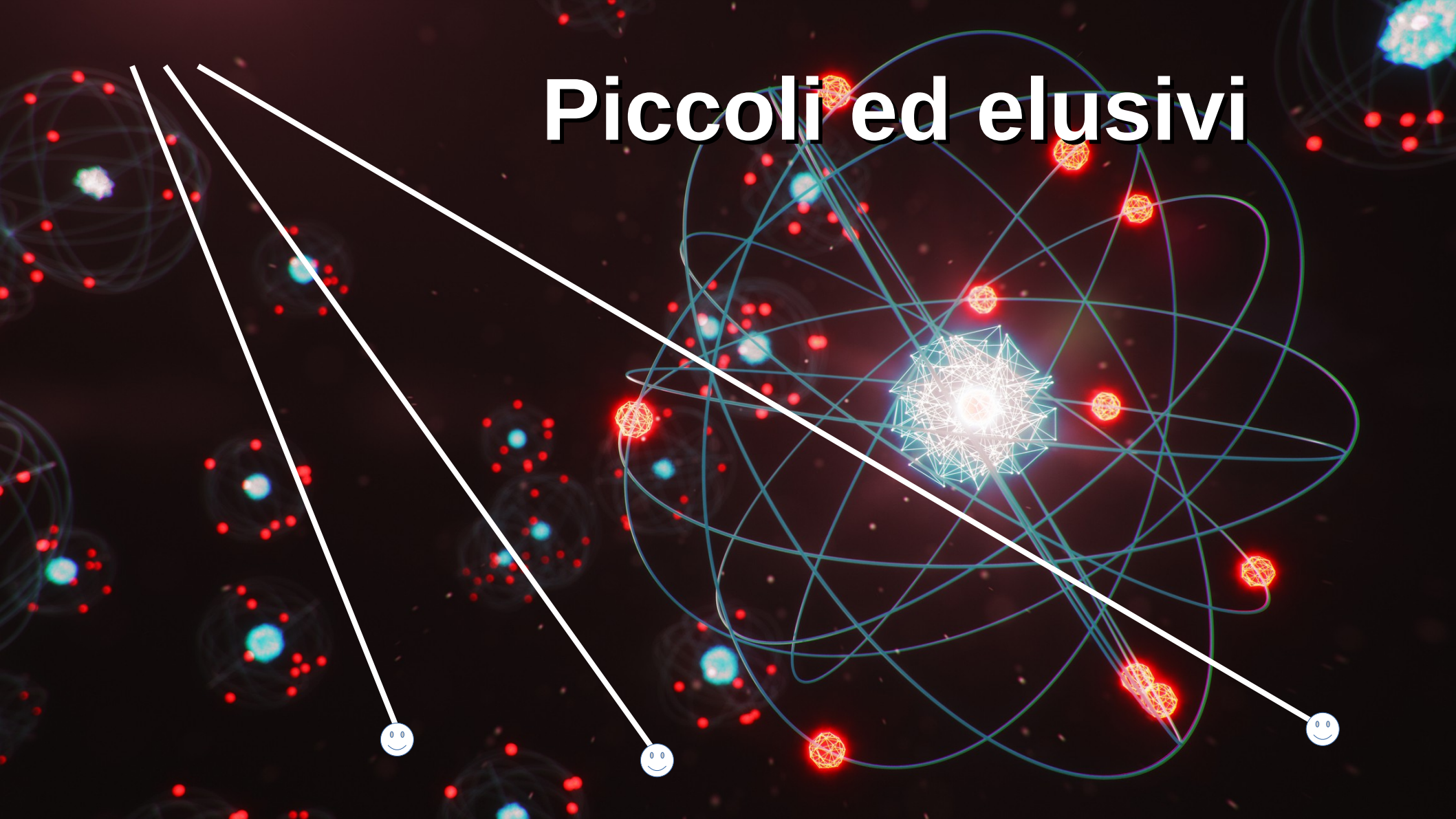
Ciclo CNO

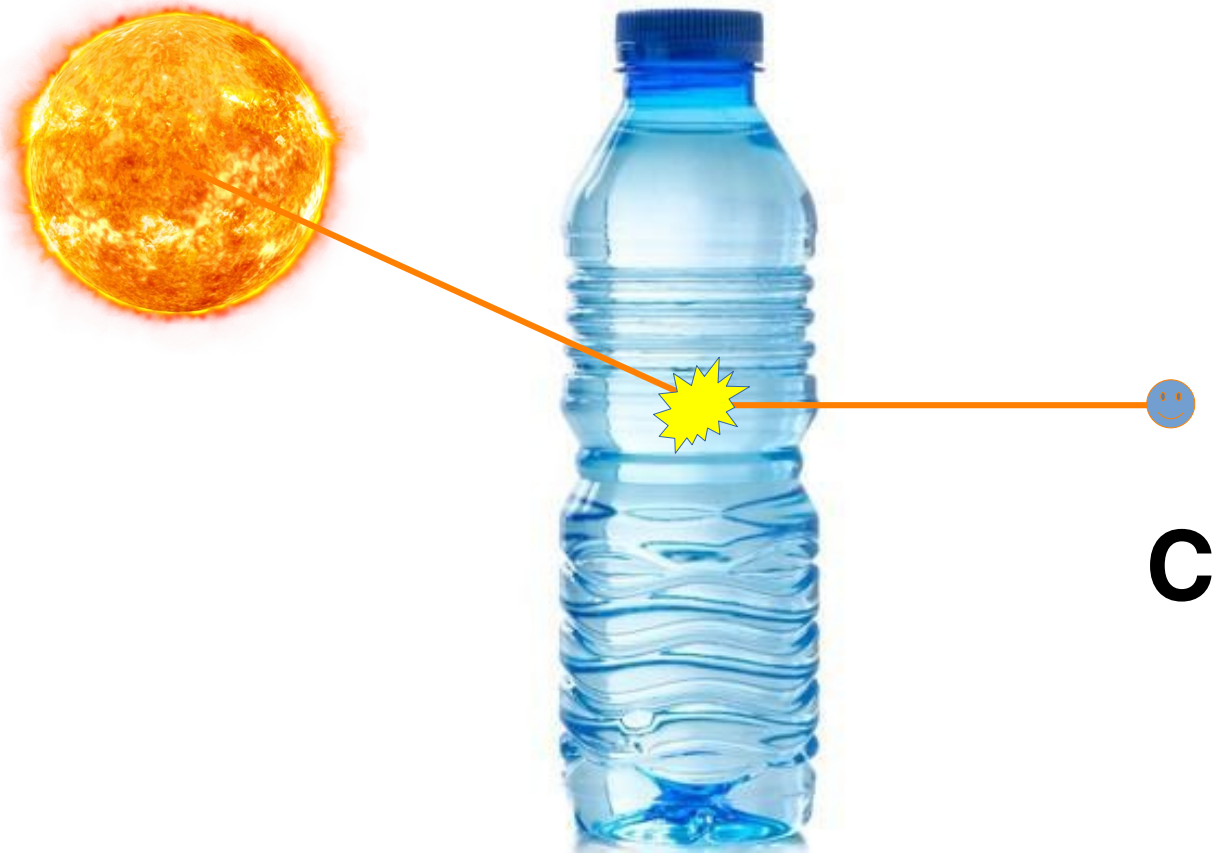


1%

Neutrini solari




Piccoli ed elusivi



Che probabilità ha un neutrino di interagire in un litro di acqua?

$$60 \cdot 10^9 \frac{\nu}{\mathrm{cm}^2} \times 3 \cdot 10^{26} \times 10^{-45} \mathrm{cm}^2 \times 3 \cdot 10^7 \mathrm{s} \approx \boxed{1 \frac{\nu}{\mathrm{y}}}$$

Flusso di neutrini sulla Terra

Quanti elettroni in un litro di acqua?

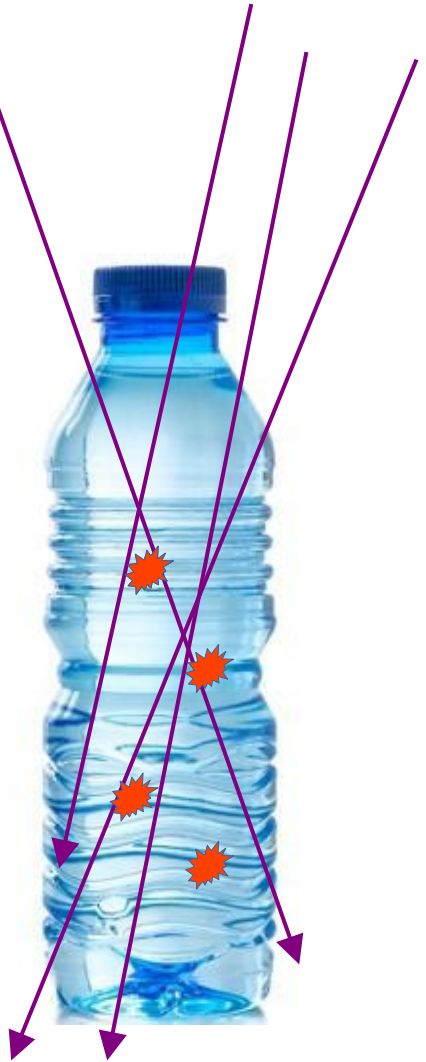
"dimensione" dei neutrini

Secondi In un anno

Solo un neutrino all'anno fermato da un litro di acqua!

Pioggia incessante di raggi cosmici

Un litro di acqua minerale contiene parti per miliardo di impurezze
(una disintegrazione al secondo)



Un neutrino su 100.000.000 eventi di fondo:
Cercare l'ago nel pagliaio!

Un rivelatore di neutrini solari deve essere

1. Protetto dalla roccia
2. Un miliardo di volte più puro di una buona acqua potabile
3. Di grandissimo volume

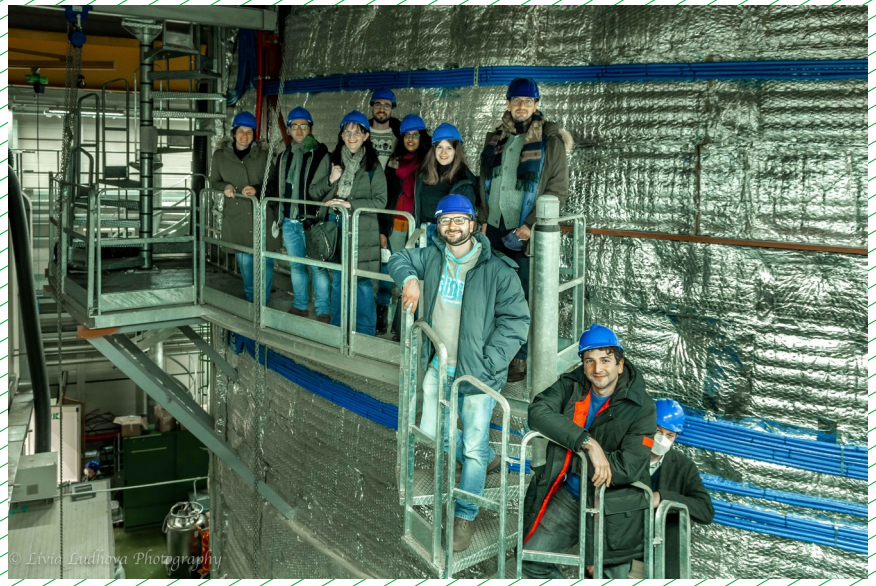
→ BOREXINO

x100000
centinaia di neutrini
al giorno

BOREXINO
Un'avventura lunga pù di 30 anni

Gianpaolo Bellini
Frank Calaprice
Raju Ragavan

Sardegna 2015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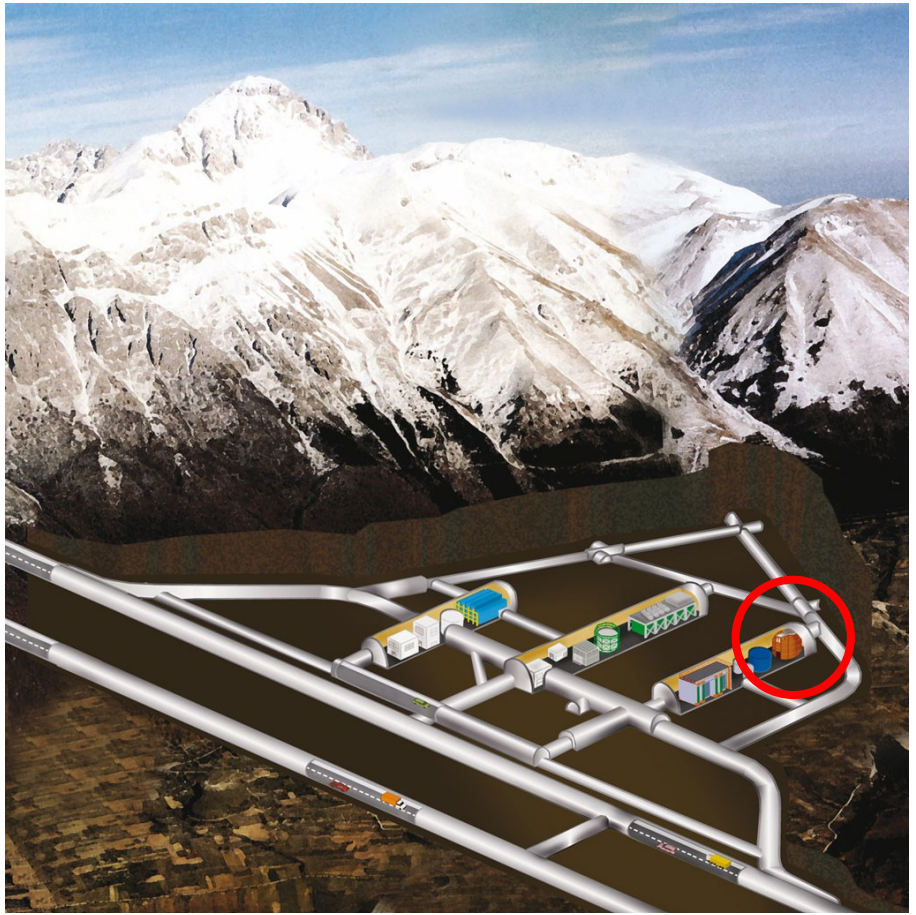
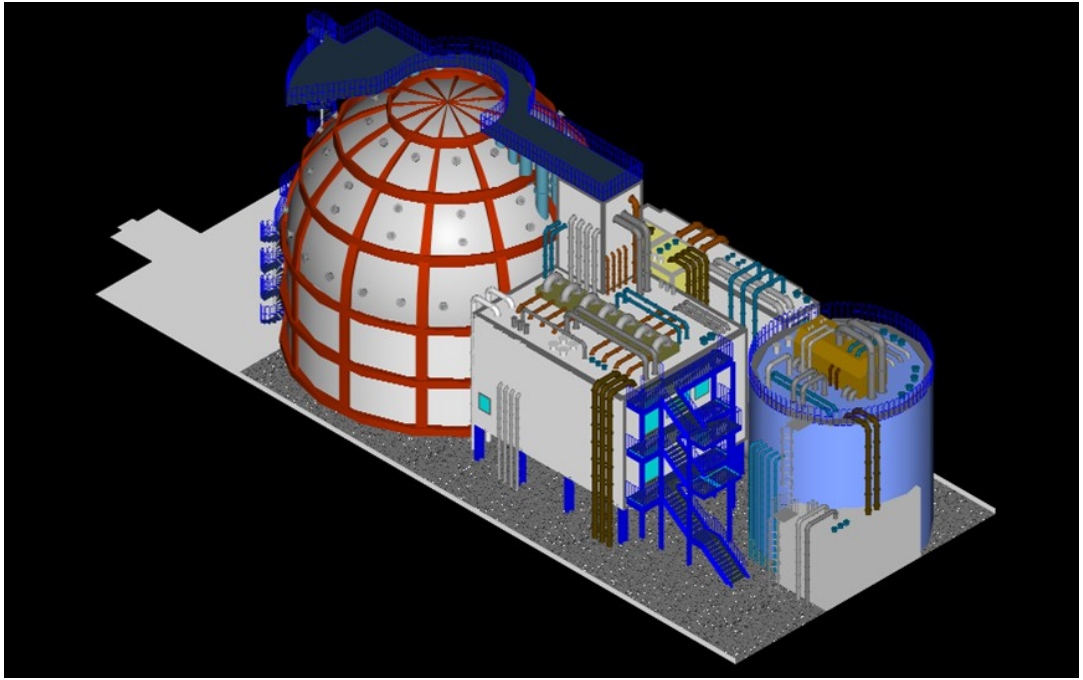
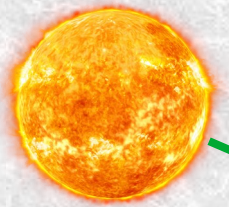
Dic. 2021

Il rivelatore Borexino ai LNGS



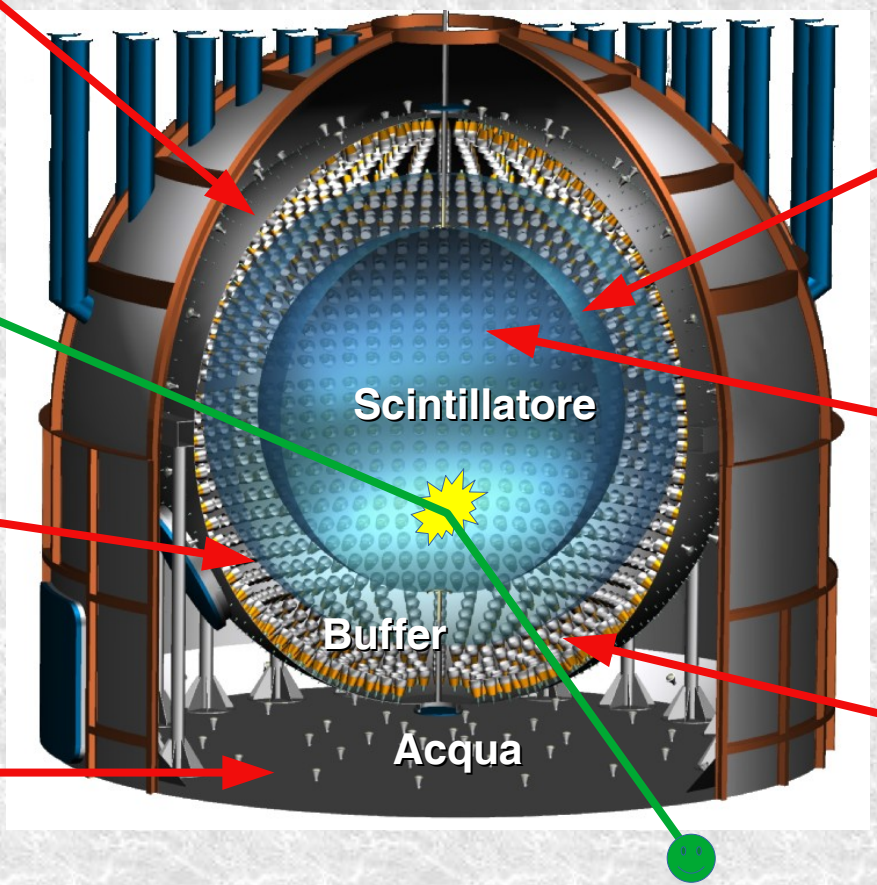


Sfera di acciaio



Pallone esterno di nylon

Acqua ultra-pura



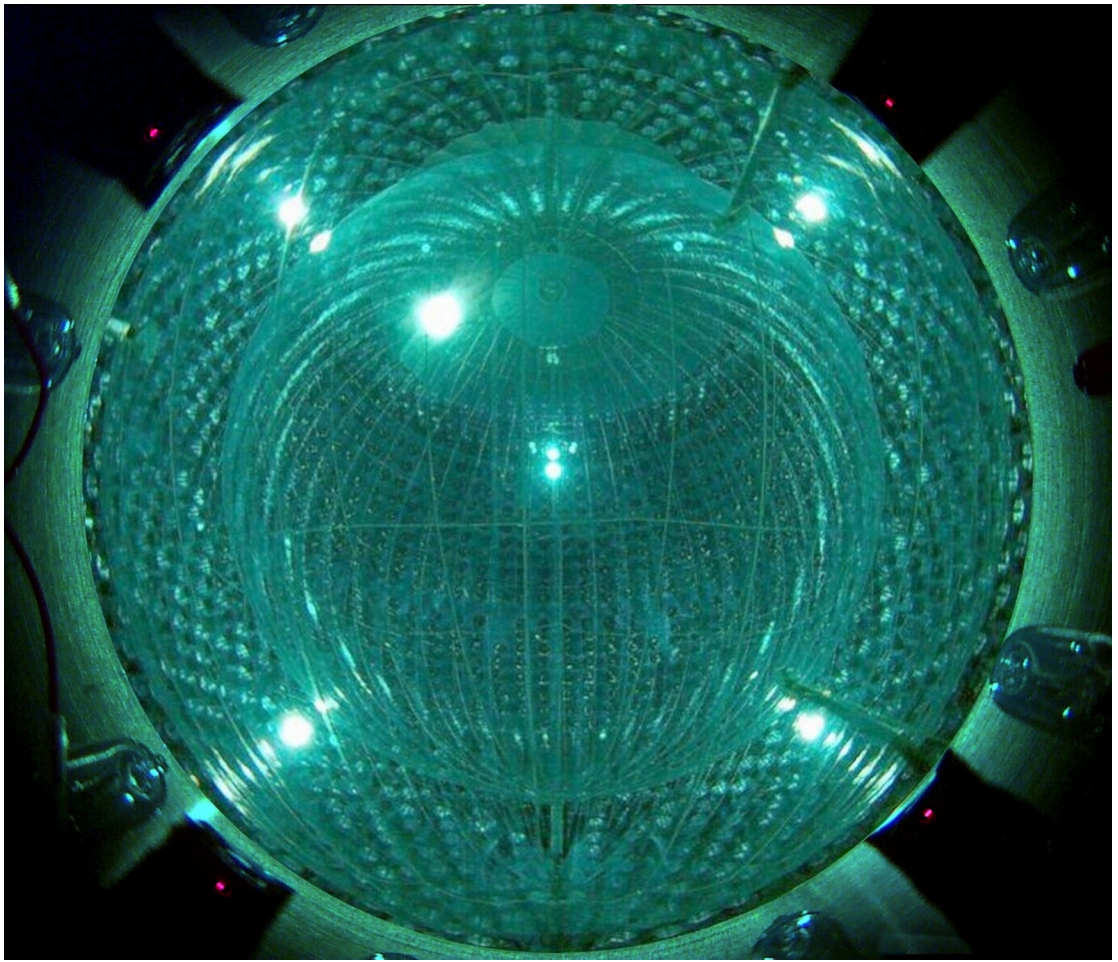
Pallone interno di nylon

Scintillatore

Tubi fotomoltiplicatori

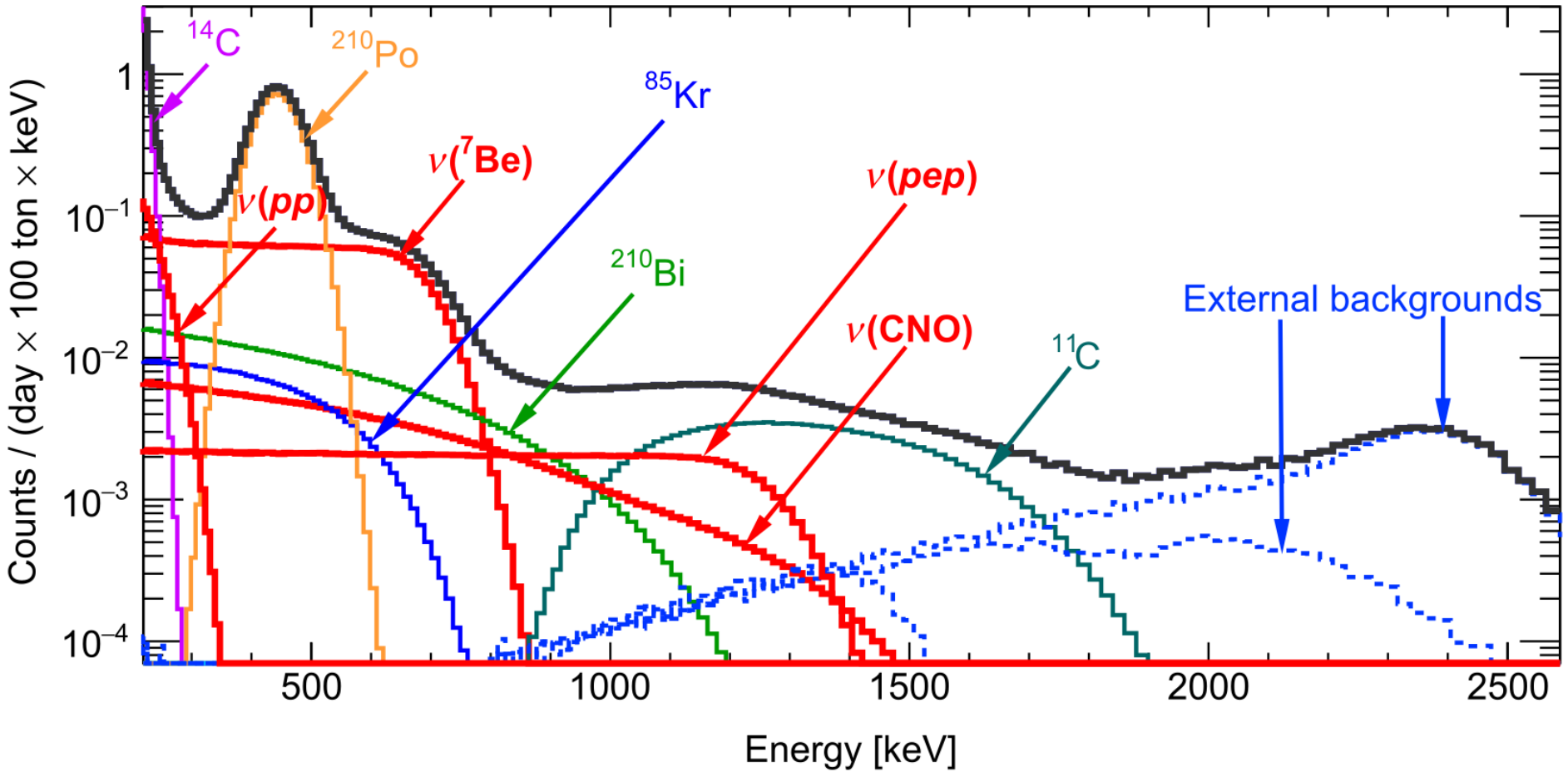
Prima del riempimento

Nella Sala C



Dalla telecamera

Distribuzione energetica degli eventi rivelati da BOREXINO



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Article | Published: 24 October 2018

Comprehensive measurement of *pp*-chain solar neutrinos

The Borexino Collaboration

Nature **562**, 505–510 (2018) | Cite this article

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Abstract

About 99 per cent of solar energy is produced through sequences of nuclear reactions that convert hydrogen into helium, starting from the fusion of two protons (the *pp* chain). The neutrinos emitted by five of these reactions represent a unique probe of the Sun's internal working and, at the same time, offer an intense natural neutrino beam for fundamental physics. Here we report a complete study of the *pp* chain. We measure the neutrino–electron elastic-scattering rates for neutrinos produced by four reactions of the chain: the initial proton–proton fusion, the electron-capture decay of beryllium-7, the three-body proton–electron–proton (*pep*) fusion, here measured with the highest precision so far achieved, and the boron-8 beta decay, measured with the lowest energy threshold. We also set a limit on the

catena pp

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Article | Published: 25 November 2020

Experimental evidence of neutrinos produced in the CNO fusion cycle in the Sun

The Borexino Collaboration

Nature **587**, 577–582 (2020) | Cite this article

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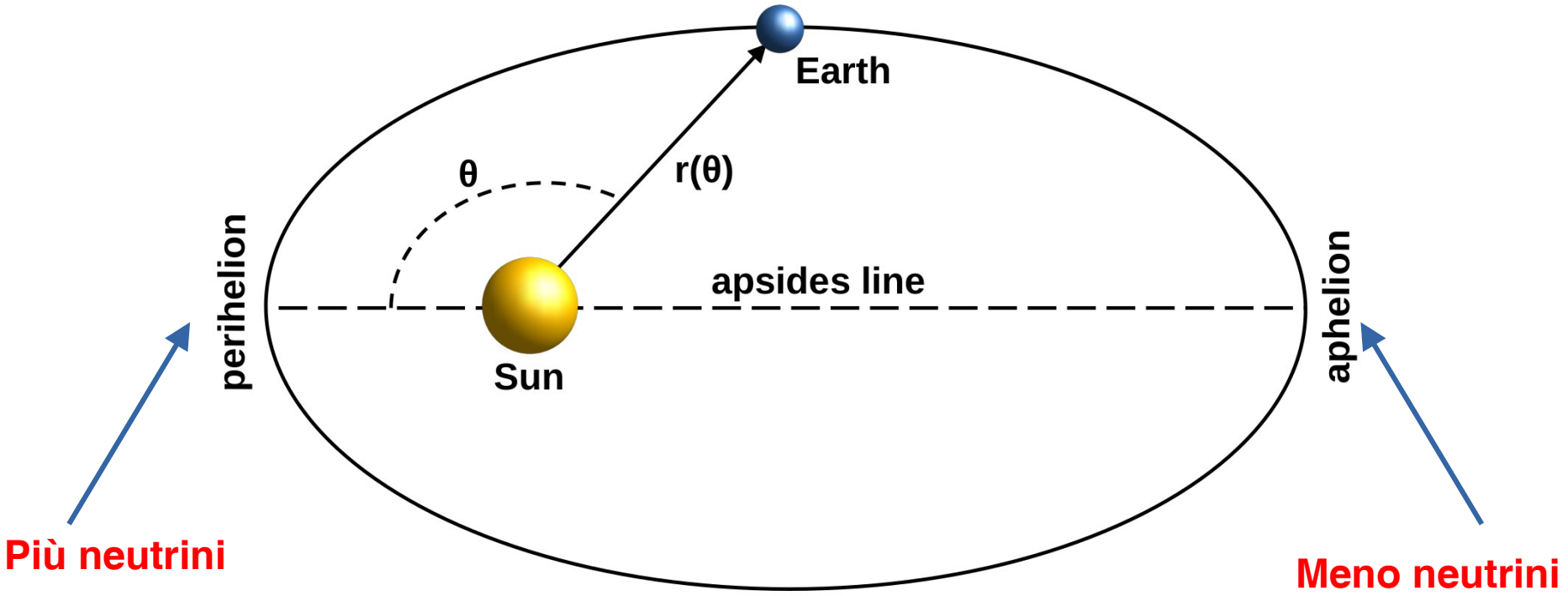
Abstract

For most of their existence, stars are fuelled by the fusion of hydrogen into helium. Fusion proceeds via two processes that are well understood theoretically: the proton–proton (*pp*) chain and the carbon–nitrogen–oxygen (CNO) cycle[1,2]. Neutrinos that are emitted along such fusion processes in the solar core are the only direct probe of the deep interior of the Sun. A complete spectroscopic study of neutrinos from the *pp* chain, which produces about 99 per cent of the solar energy, has been performed previously[3]; however, there has been no reported experimental evidence of the CNO cycle. Here we report the direct observation, with a high statistical significance, of neutrinos produced in the CNO cycle in the Sun. This experimental evidence was obtained using the highly radiopure, large-volume, liquid-scintillator detector of Borexino, an experiment located at the underground Laboratori

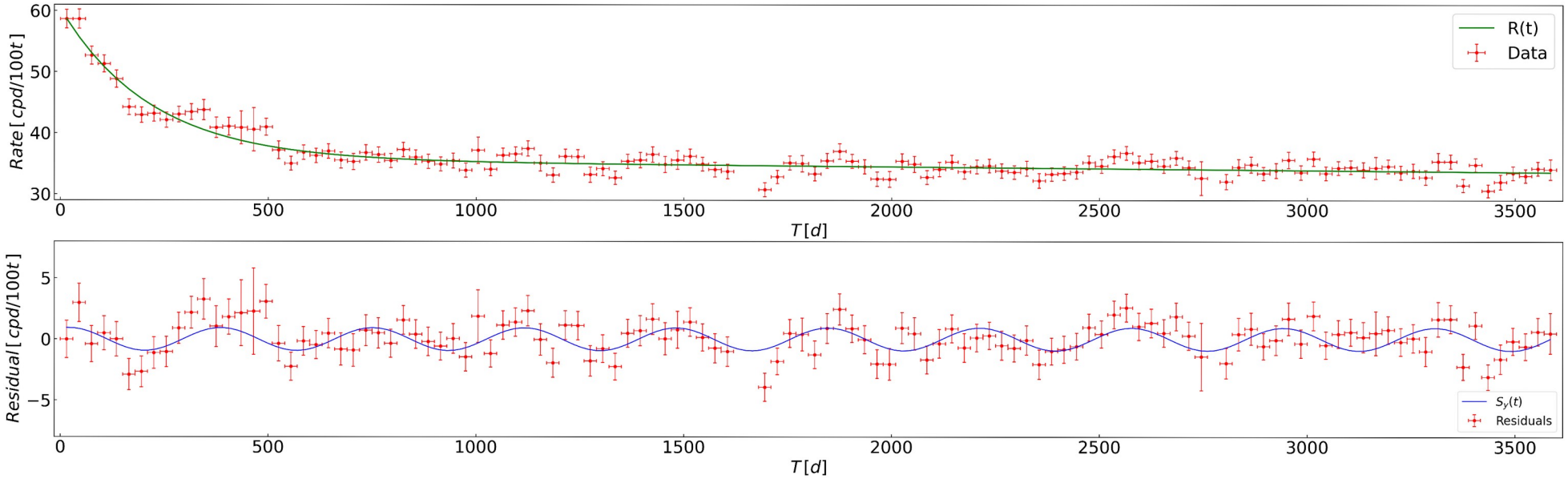
CNO

Cosa c'entra BOREXINO con l'astronomia?

Variazione annuale del flusso di neutrini rivelati da BOREXINO



Prima misura dei parametri orbitali terrestri fatta con i neutrini!



Eccentricità = 0.0184 ± 0.0032 (0.0167)

→ **Presentazione di Riccardo Biondi**

Grazie!

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physicsworld TOP 10 BREAKTHROUGH 2014

Premio Pontecorvo 2015 G. Bellini

physicsworld TOP 10 BREAKTHROUGH 2020

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Ministerstwo Edukacji i Nauki

Award of Polish Science Minister 2022

APS Advancing Physics

Bethe Prize 2023 F. Calaprice