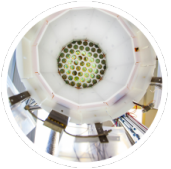
Bem vindos (remotamente …) ao LIP !

Experimental particle and **astroparticle physics**



Development of **new instruments** and **methods**

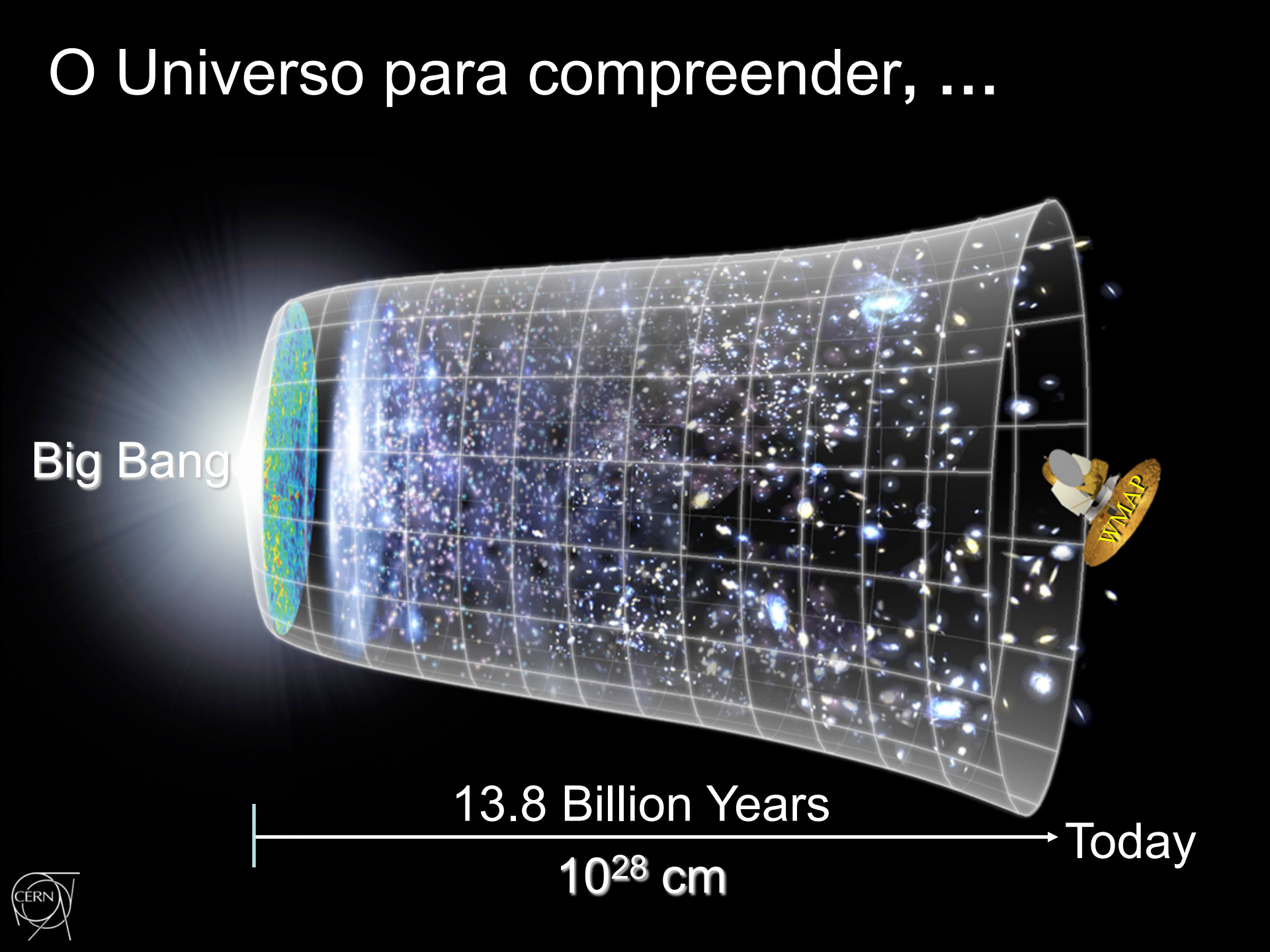
Scientific computing

Knowledge transfer, education and **outreach**

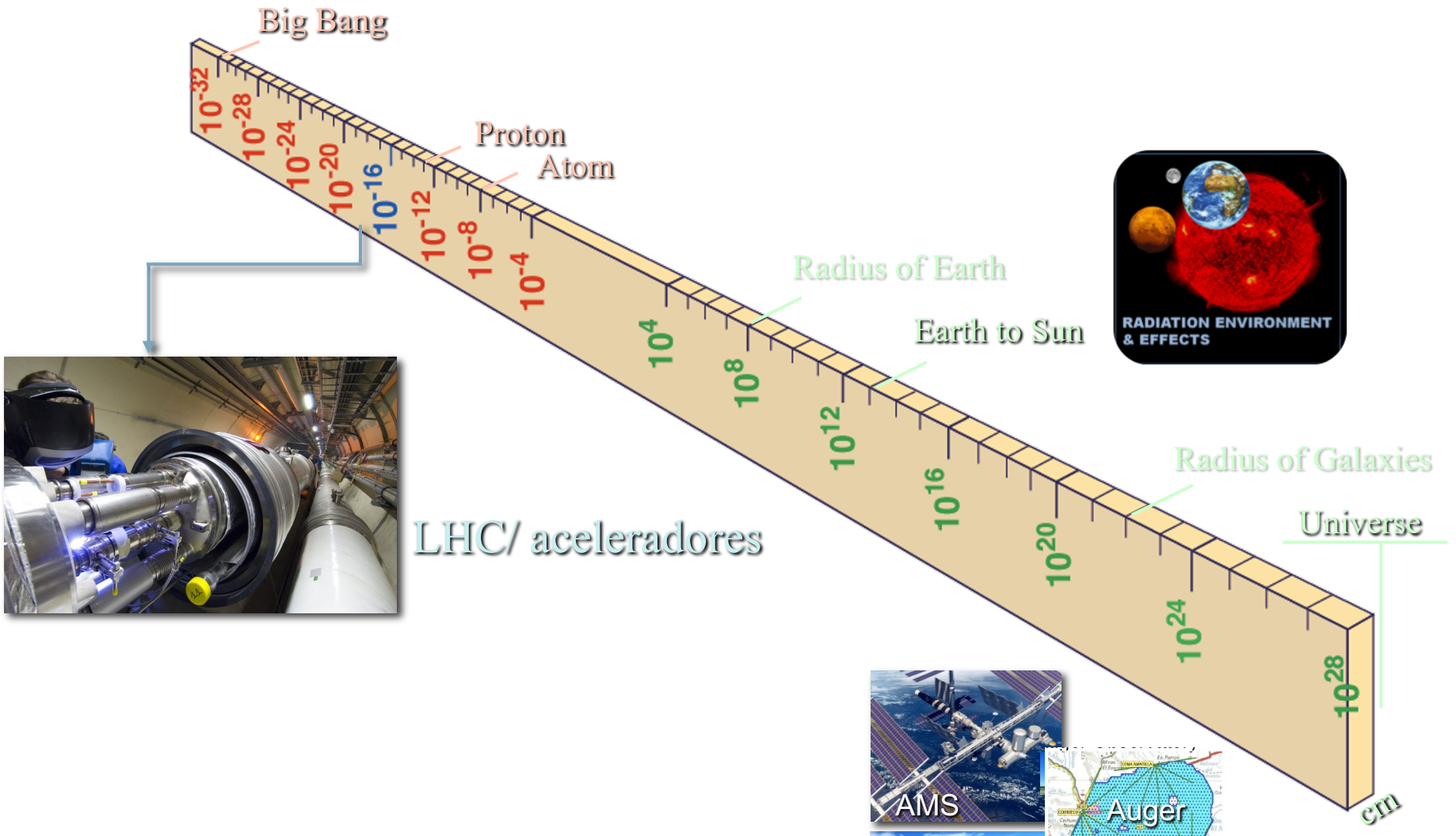
A aventura da Física de Partículas e Astropartículas

Mário Pimenta
Lisboa, Julho 2021

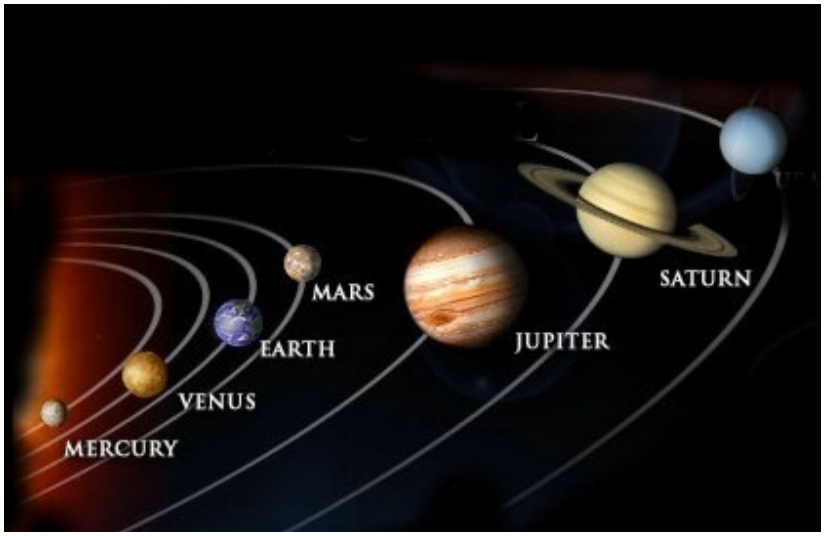
O Universo para compreender, ...



Escalas, ...


Big Bang
Proton
Atom
Radius of Earth
Earth to Sun
Radius of Galaxies
Universe
10^{-32}
10^{-28}
10^{-24}
10^{-20}
10^{-16}
10^{-12}
10^{-8}
10^{-4}
10^{4}
10^{8}
10^{12}
10^{16}
10^{20}
10^{24}
10^{28}
cm
RADIATION ENVIRONMENT & EFFECTS
LHC/ aceleradores
AMS
Auger
SWGO
Malargüe
m

Da maçã ao Universo



I. Newton

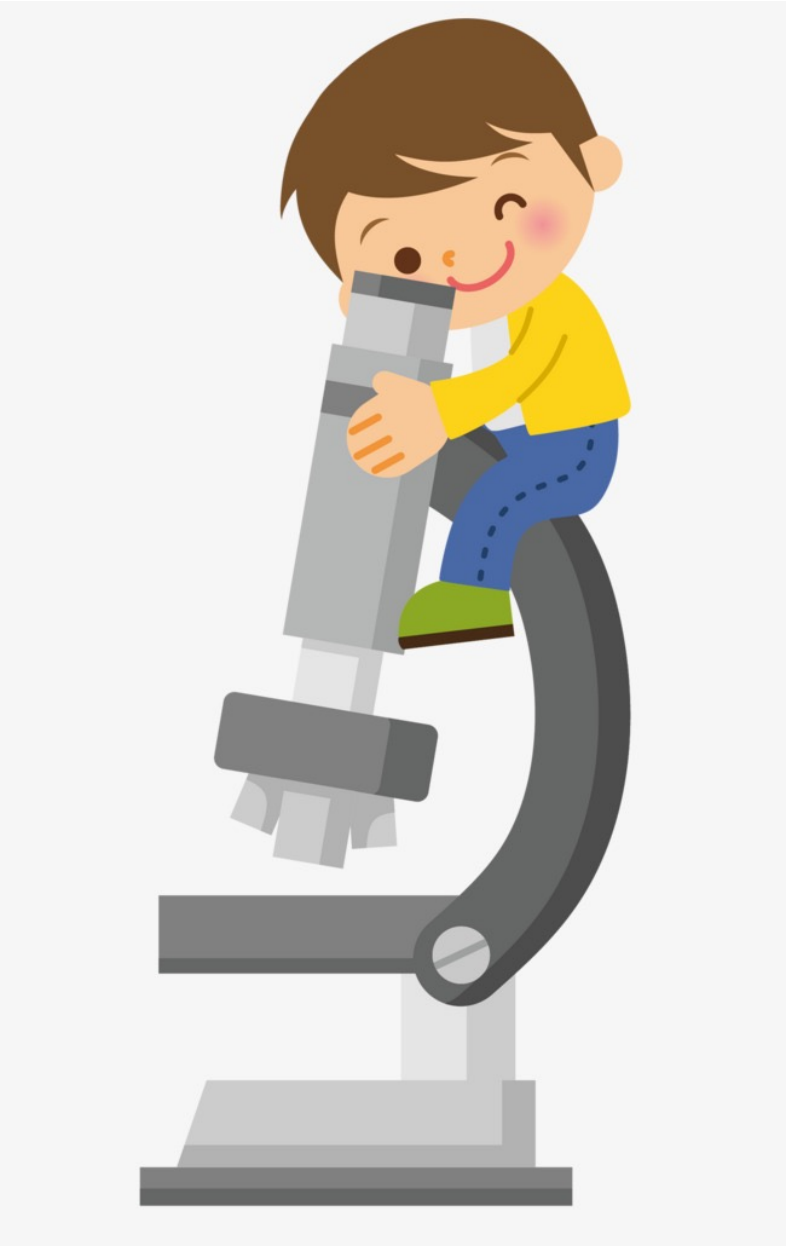
Lei da atracção Universal:

$$F = G \frac{m_{1g}\, m_{2g}}{r_{12}^{\,2}}$$

A gravidade !

Será que a maçã é elementar?

Ver o interior da maçã ???



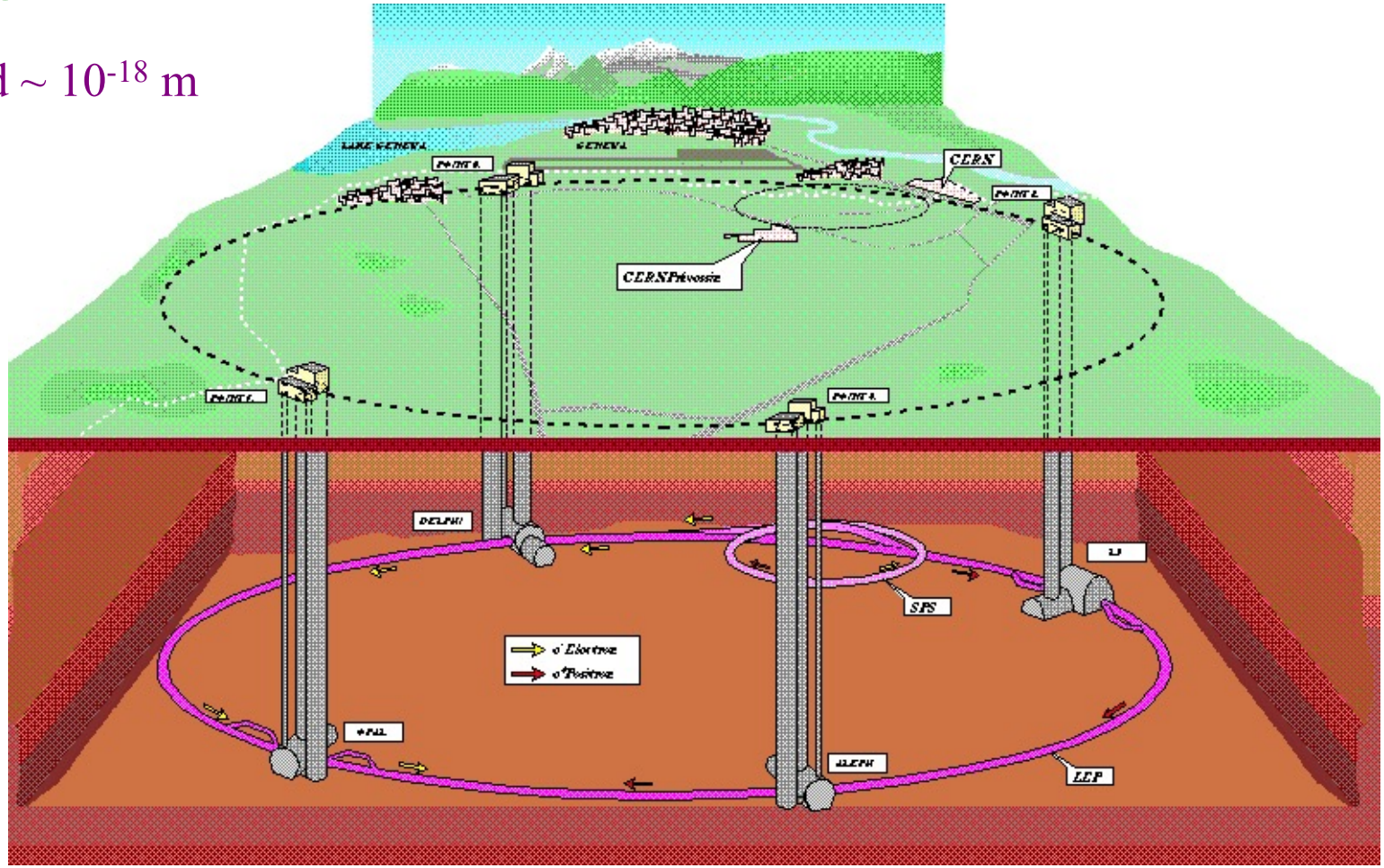
Ver com partículas

Louis de Broglie

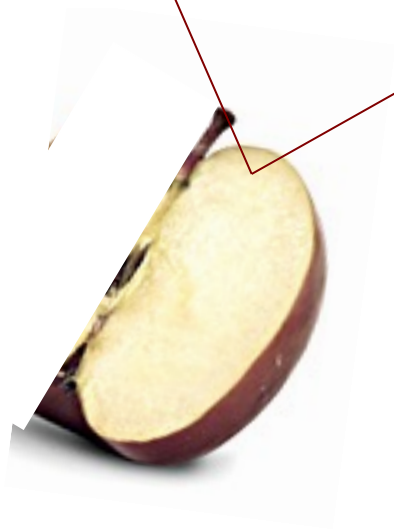
$$\lambda = \frac{h}{p}$$

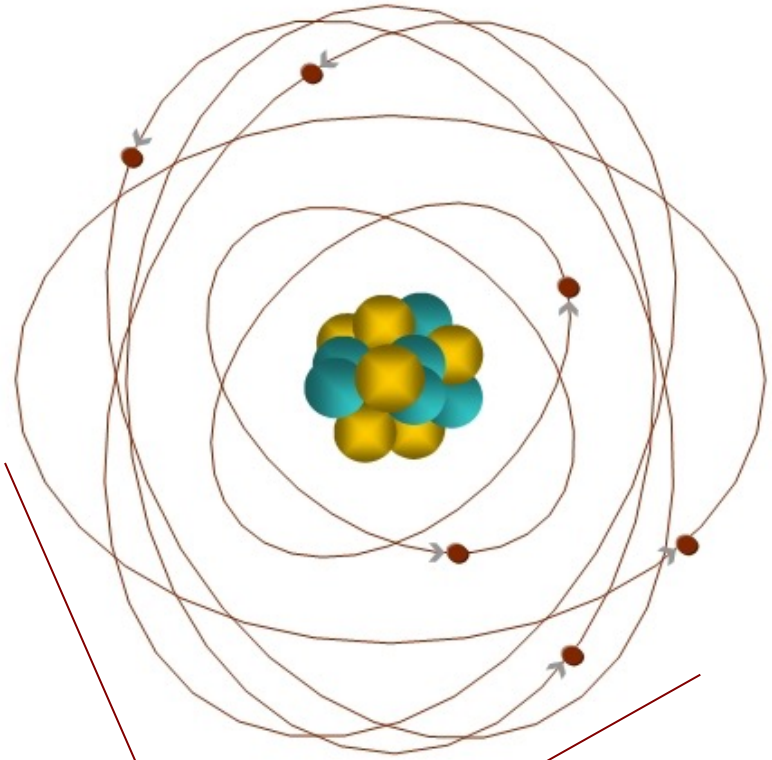
CERN

d ~ 10^{-18} m



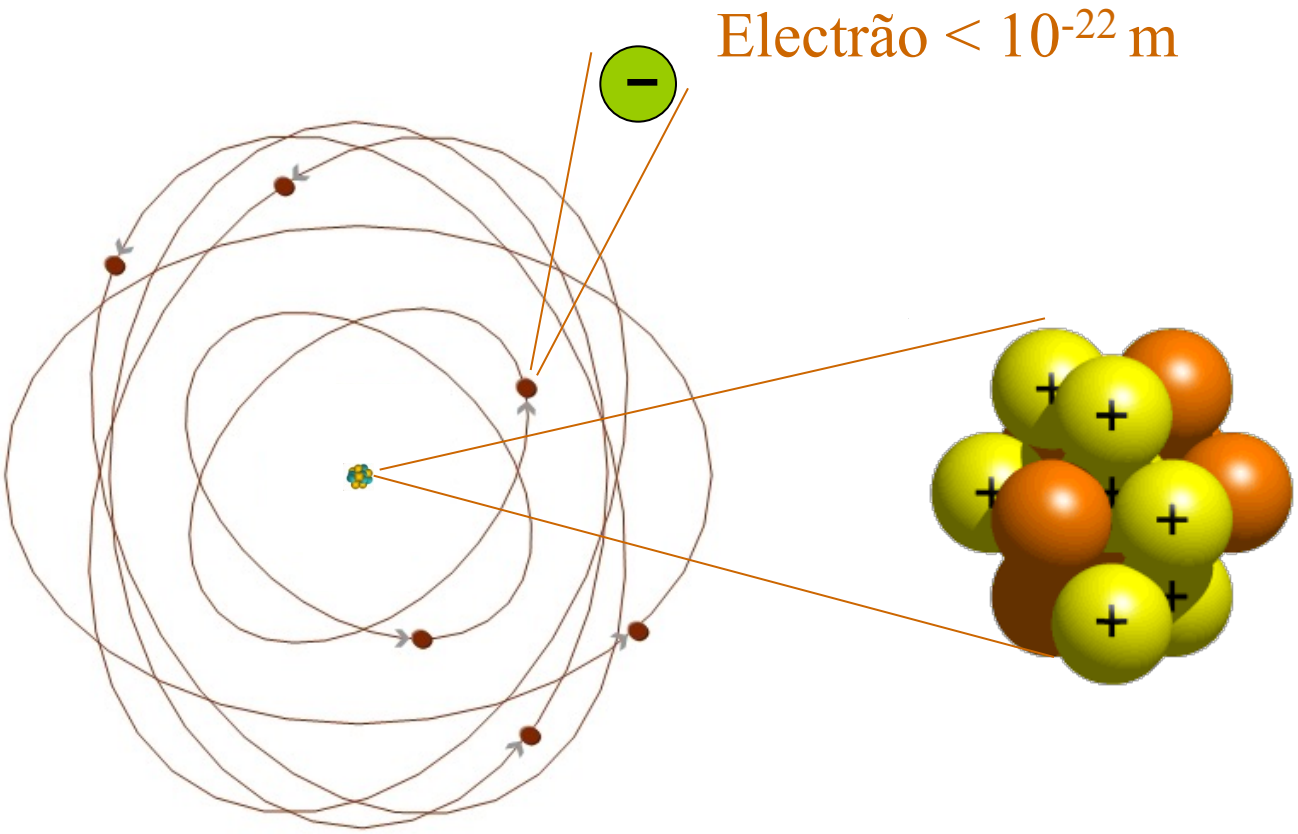
Será que a maçã é elementar?



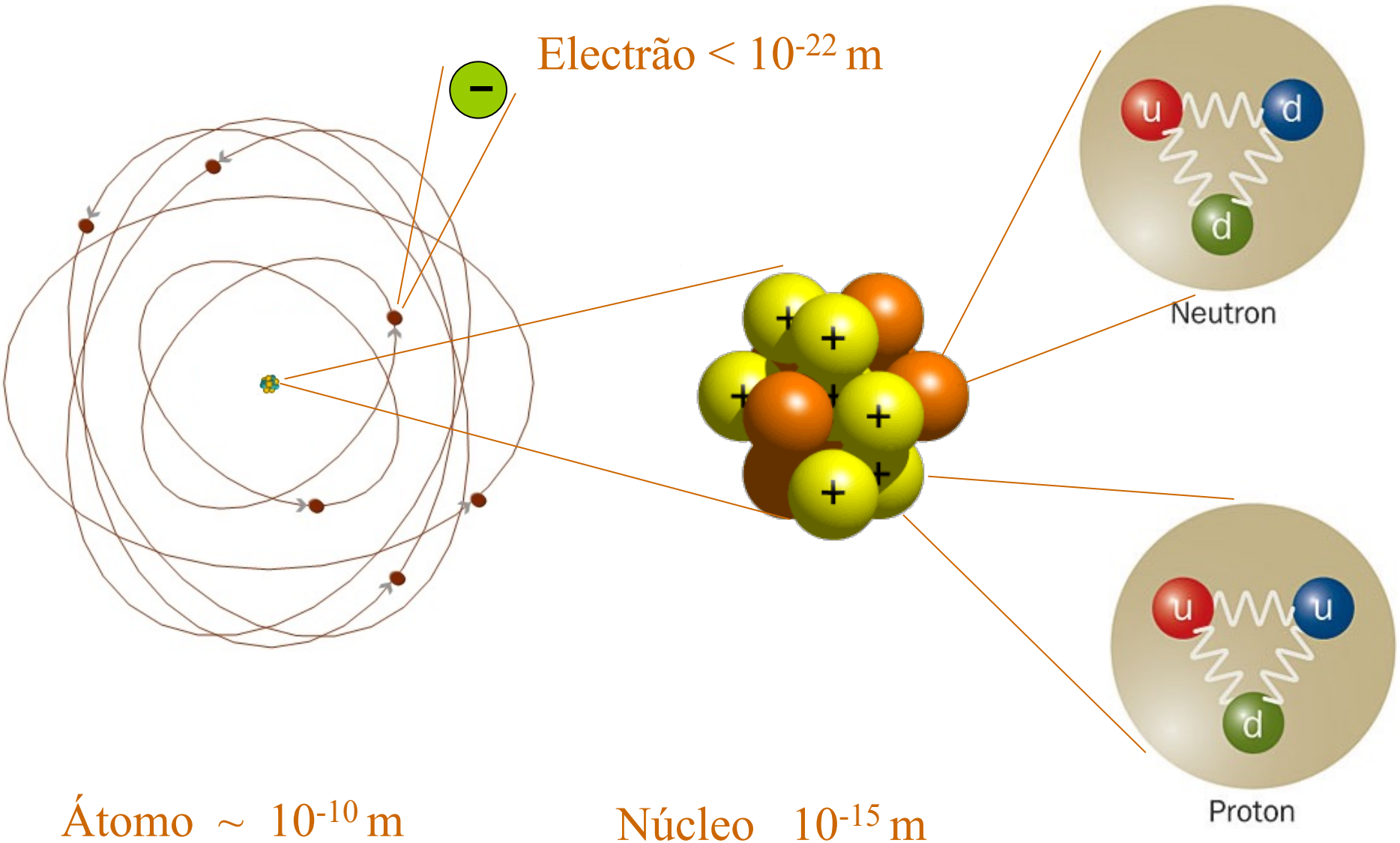


Átomo ~ 10^{-10} m

No interior dos átomos



No interior dos átomos



Vários quarks, muitas partículas !!!

Quarks:

$$\begin{pmatrix} u \\ d \end{pmatrix}$$

$Q = +\ 2/3$

$Q = -\ 1/3$

Vários quarks, muitas partículas !!!

Quarks:

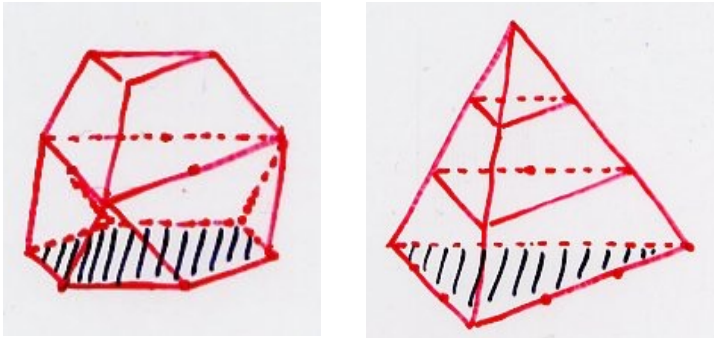
$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix} \quad \begin{pmatrix} ? \\ ? \end{pmatrix}$$

Q = + 2/3

Q = - 1/3

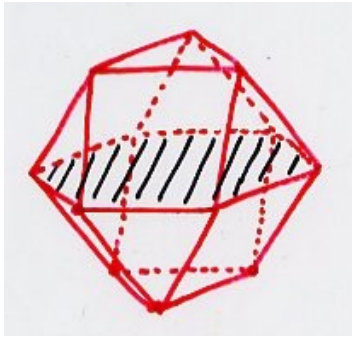
Combinar

$q_i q_j q_k$



$p\ ,n\ ,\Sigma\ ,\lambda\ ,\Xi\ ,\Delta\ ,\ldots$

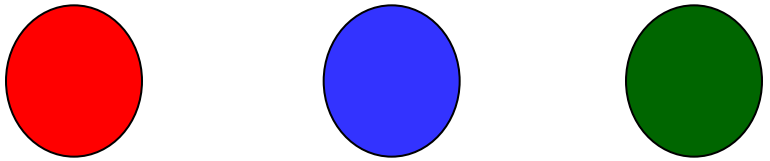
$q_i \bar{q}_i$



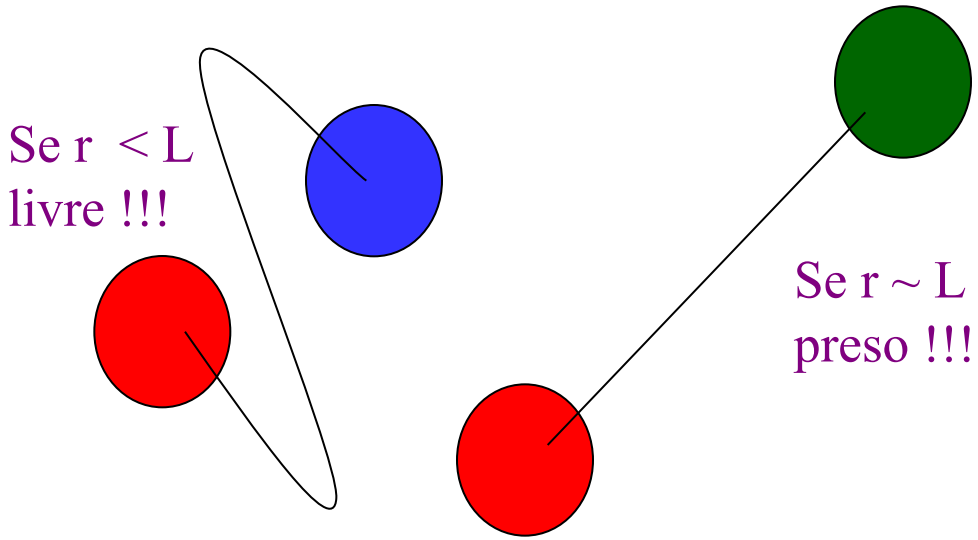
$\pi\ ,k\ ,\eta\ ,\rho\ ,\psi,\ldots$

A força forte

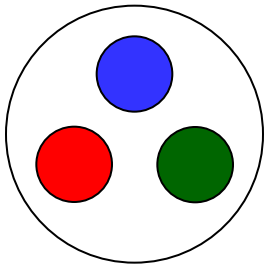
Quarks de três cores:



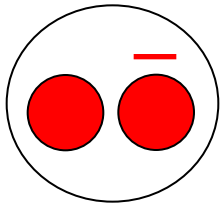
Ligados por “cordas”



Partículas “sem cor”

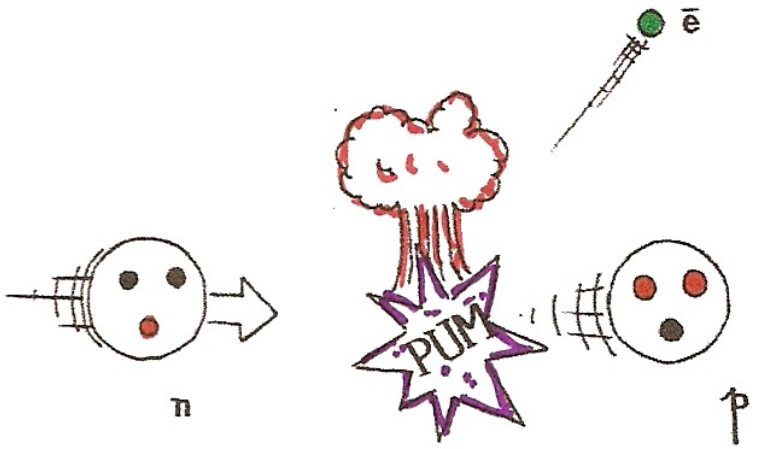


Bariões

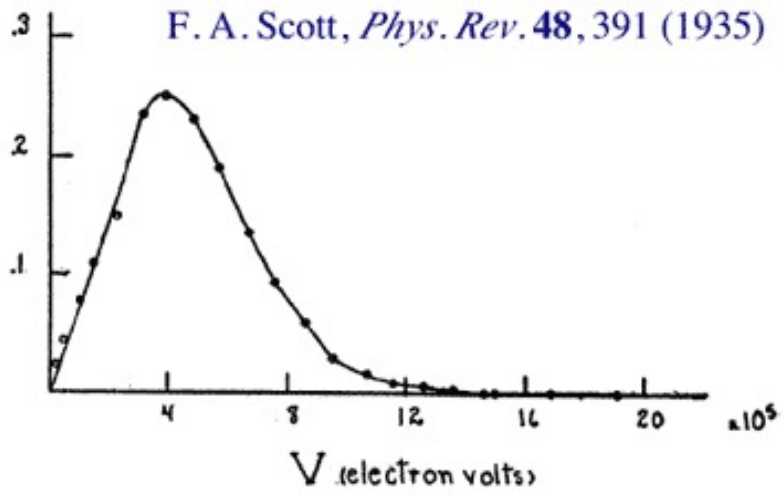


Mesões

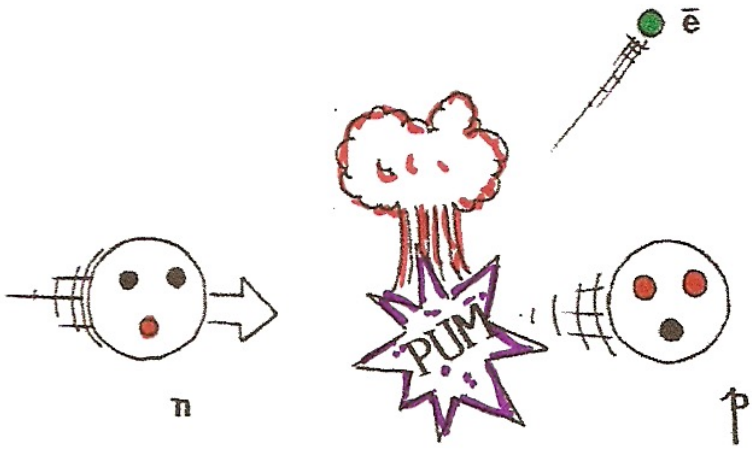
O neutrão decai…



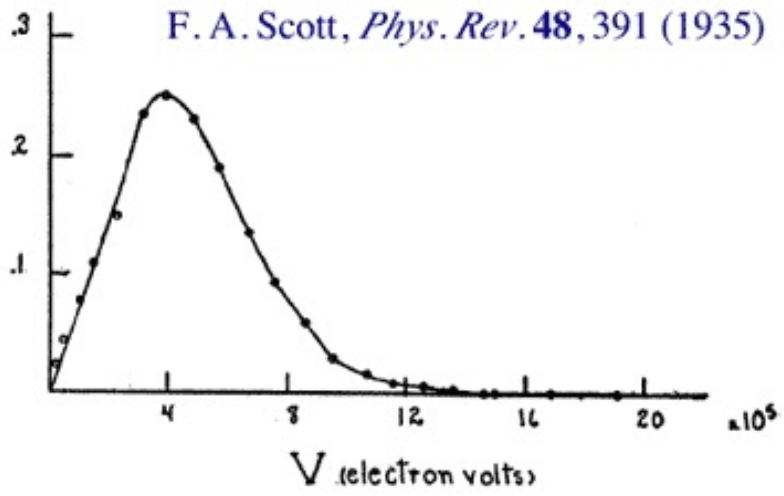
conservação E e $\vec{P}$???



O neutrão decai…



conservação E e $\vec{P}$???

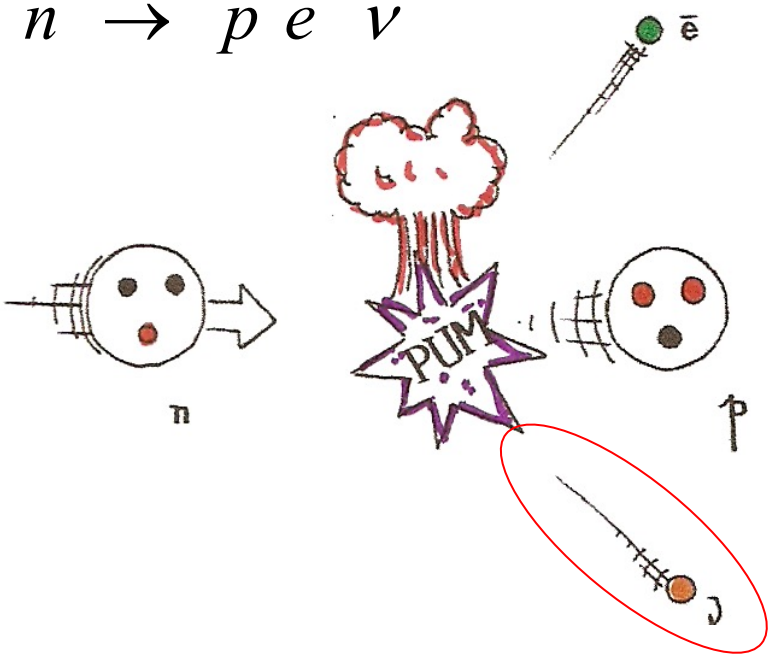


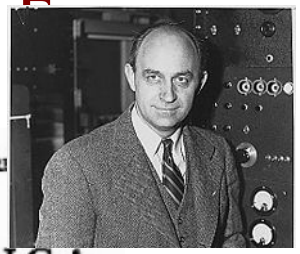
Pauli (1930)

O neutrino !!!

A força fraca

$$n \rightarrow p\, e^{-}\, \bar{\nu}$$





ANNO IV - VOL. II - N. 12 QUINDICINALE 31 DICEMBRE

LA RICERCA SCIENTIFICA

ED IL PROGRESSO TECNICO NELL'ECONOMIA NAZIONALE

Tentativo di una teoria dell'emissione dei raggi "beta"

Nota del prof. ENRICO FERMI

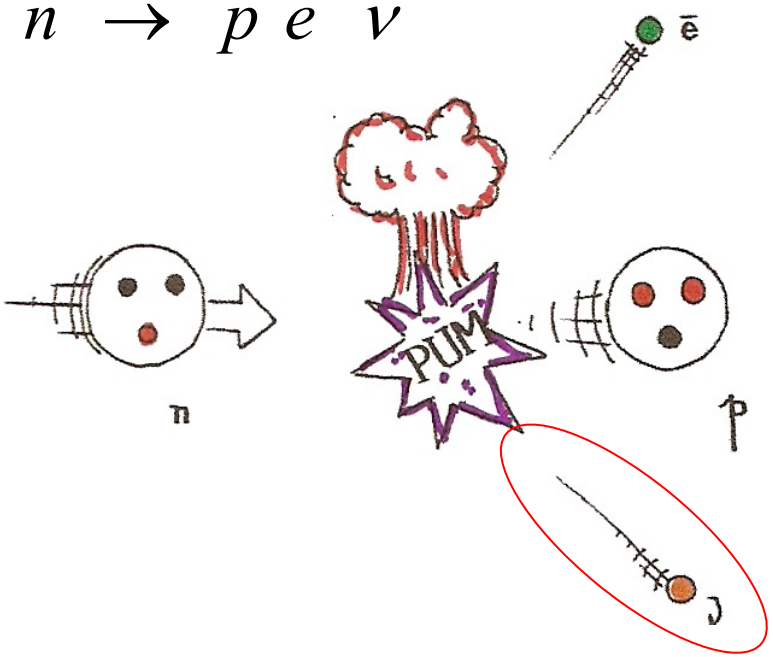
Riassunto: Teoria della emissione dei raggi β delle sostanze radioattive, fondata sull'ipotesi che gli elettroni emessi dai nuclei non esistano prima della disintegrazione ma vengano formati, insieme ad un neutrino, in modo analogo alla formazione di un quanto di luce che accompagna un salto quantico di un atomo. Confronto della teoria con l'esperienza.

Letter Submitted to Nature (1933)
REJECTED

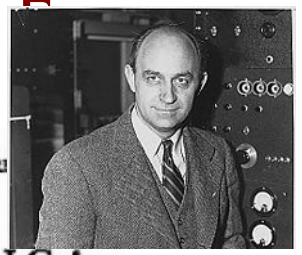
Nuovo Cimento and Zeitschrift fur Physik

A força fraca

$$n \rightarrow p\, e^{-}\, \bar{\nu}$$



E



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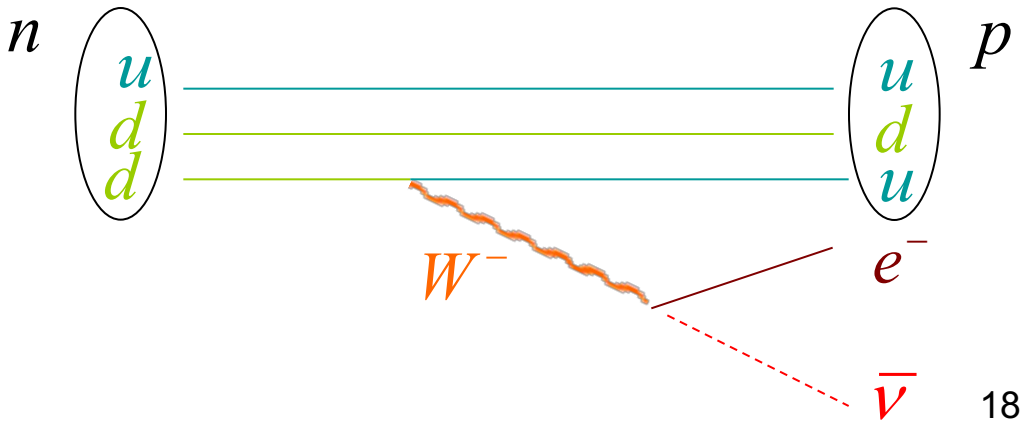
Letter Submitted to Nature (1933) REJECTED

Nuovo Cimento and Zeitschrift fur Physik

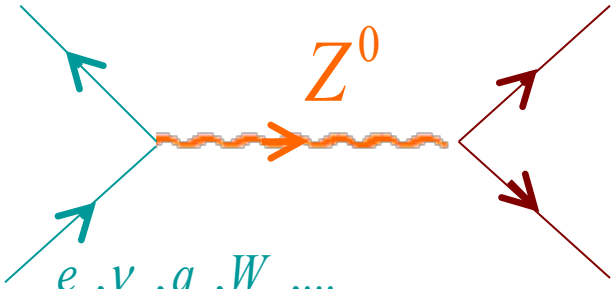
A visão moderna !

Um quark d transforma-se num quark u emitindo um bosão W que "decai" num par electrão, anti-neutrino

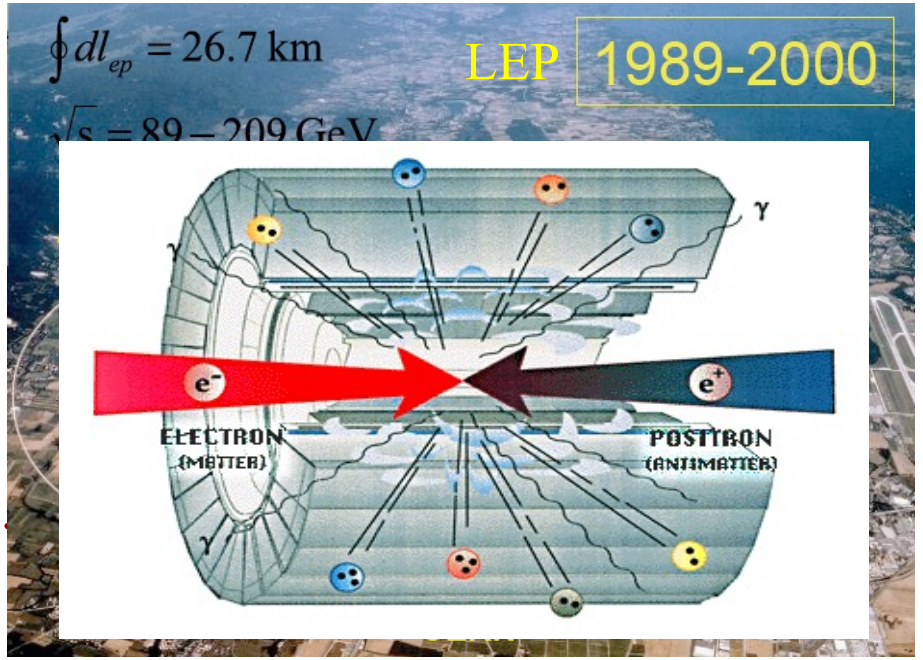


O Z^0

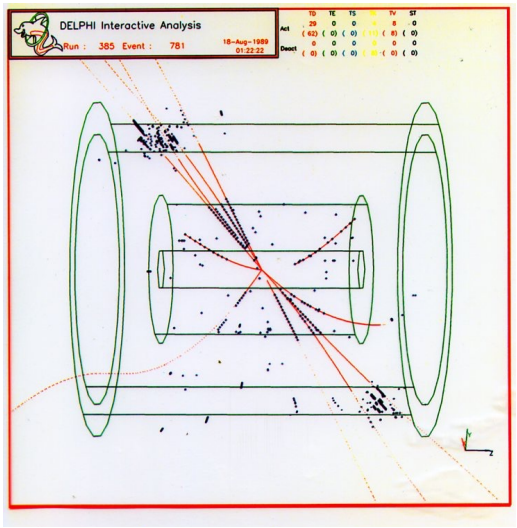
Parceiro neutro dos W´s

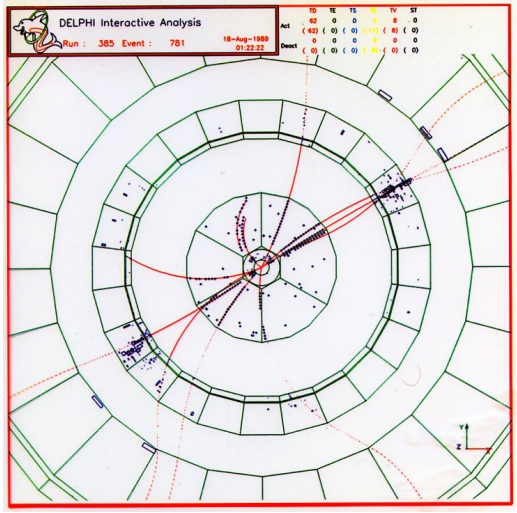


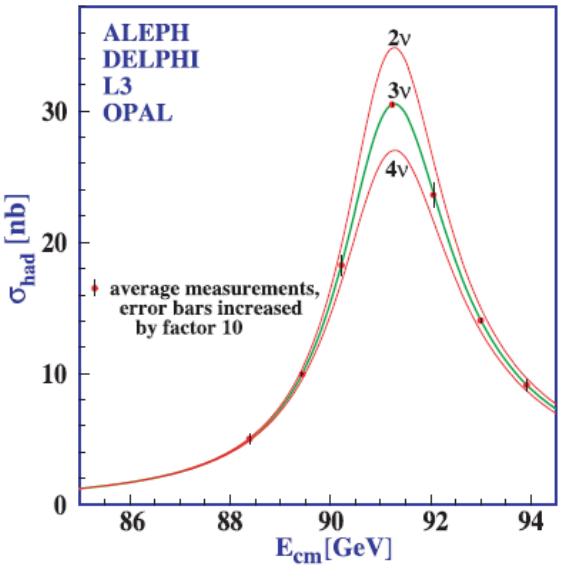
$e, \nu, q, W, \ldots$



$e^+e^- \rightarrow q\bar{q}$



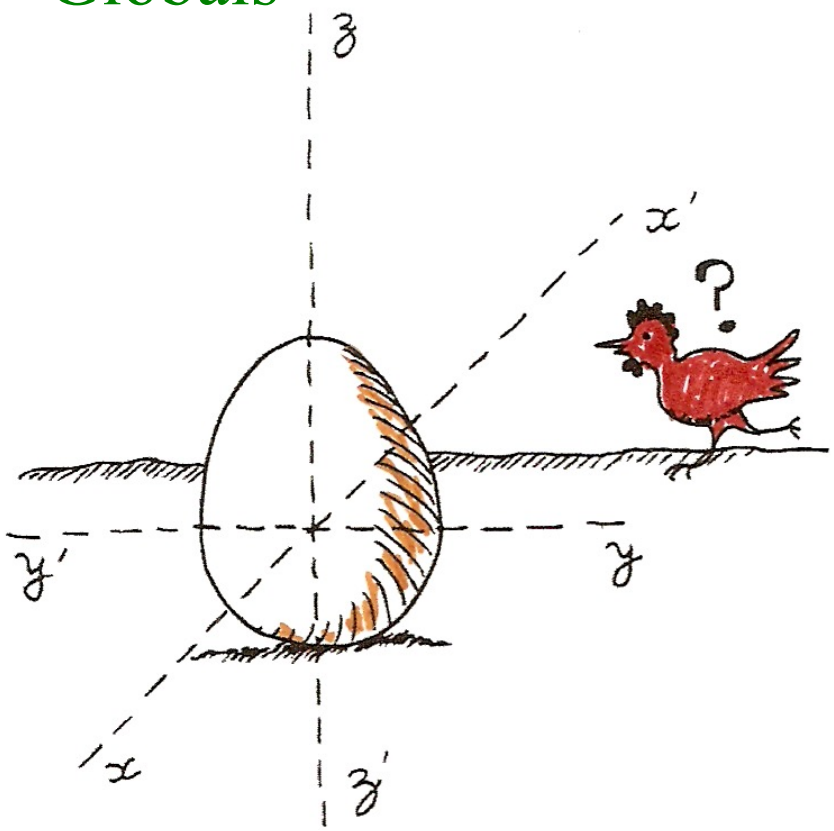




$M_z = 91.1875 \pm 0.0021$ GeV/c^2

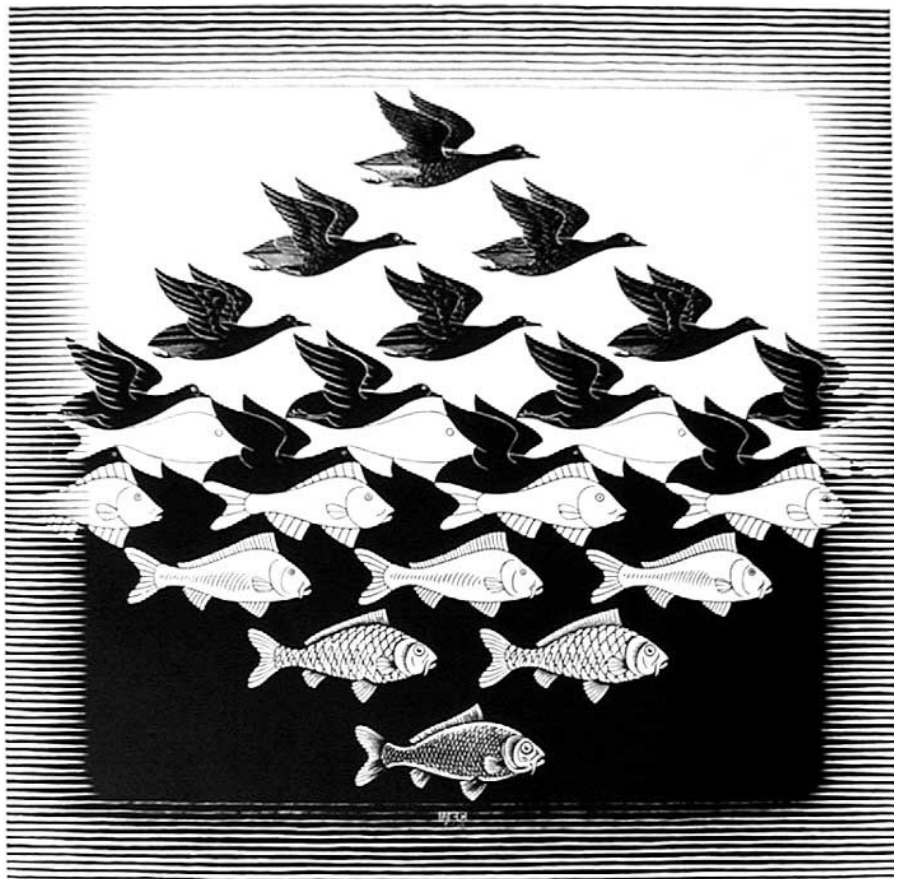
Simetrias !!!

Globais



Locais

M.C.Escher



Leis de conservação:
Energia, Momento linear,
Momento Angular

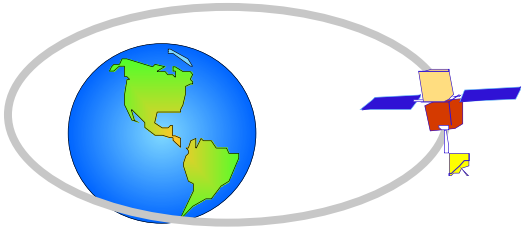
Campos de interacção:
Electromagnético,fraco,forte,
gravítico???,

As interações

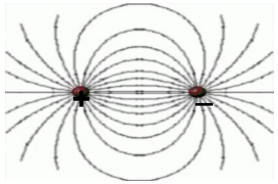
Unificação e Simetrias (locais)

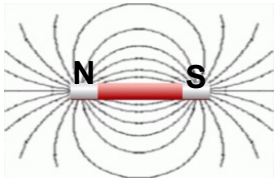
?

gravíticas

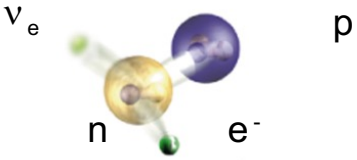


electromagneticas

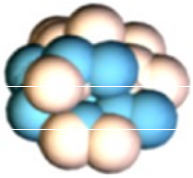




fracas



fortes



Mas as Partículas têm massa

em eV/c^2

$m_\nu \sim 10^{-1}$

$m_e \sim 500\ 10^{3}$

$m_u \sim 5\ 10^{6}$

$m_t \sim 174\ 10^{9}$

…

$m_\gamma = 0$

$m_W \sim 80\ 10^{9}$

$m_Z \sim 91\ 10^{9}$

$m_H \sim 125\ 10^{9}$

Como é que as massas são geradas ???

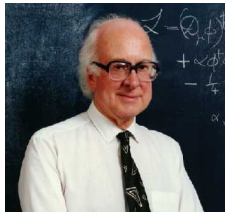
Por é que são tão diferentes ???

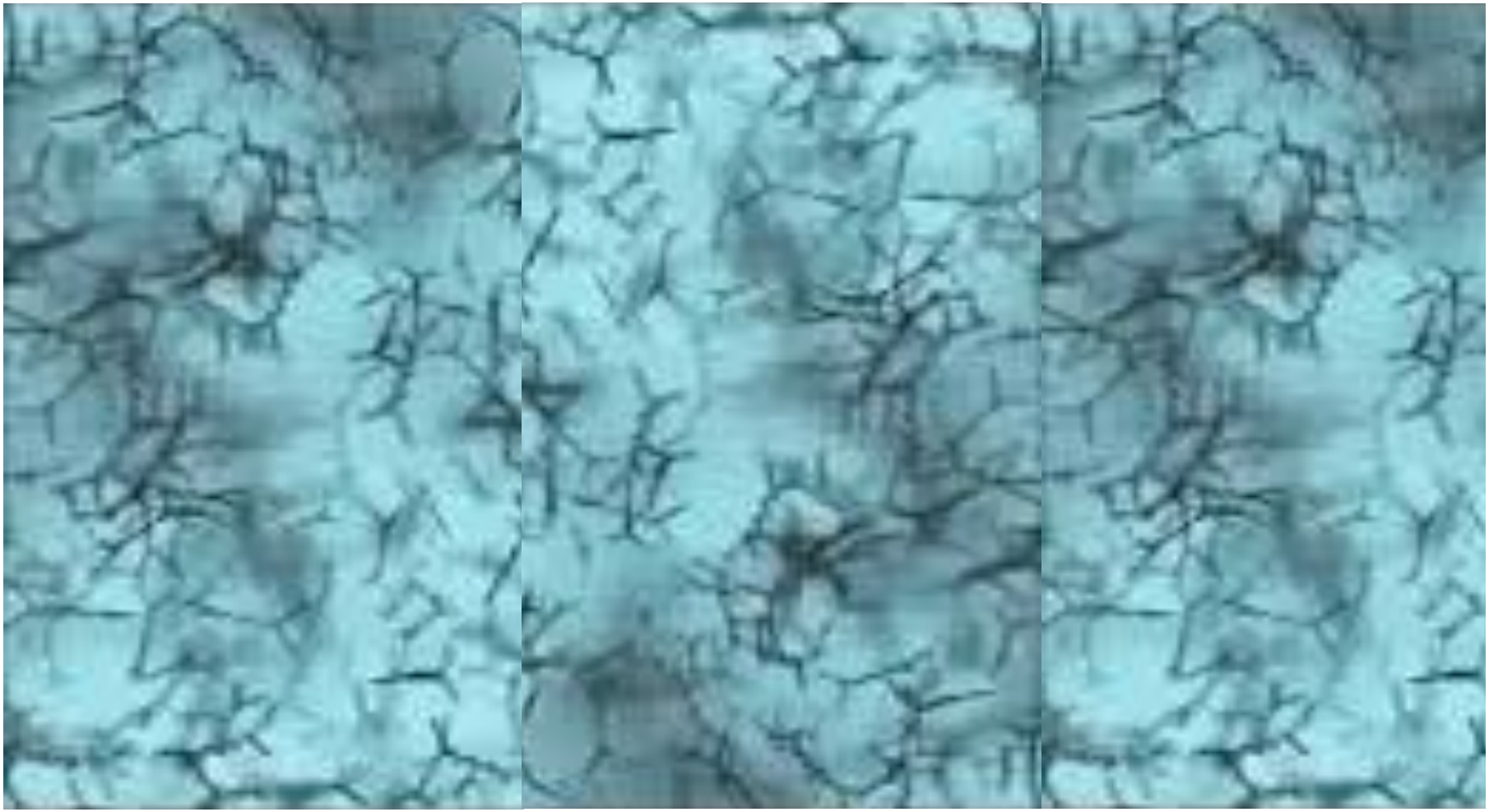
$1\ eV \sim 1.8\ 10^{-36} Kg$

O campo de Higgs

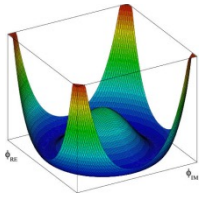
Higgs, Englert, Brout - 1964

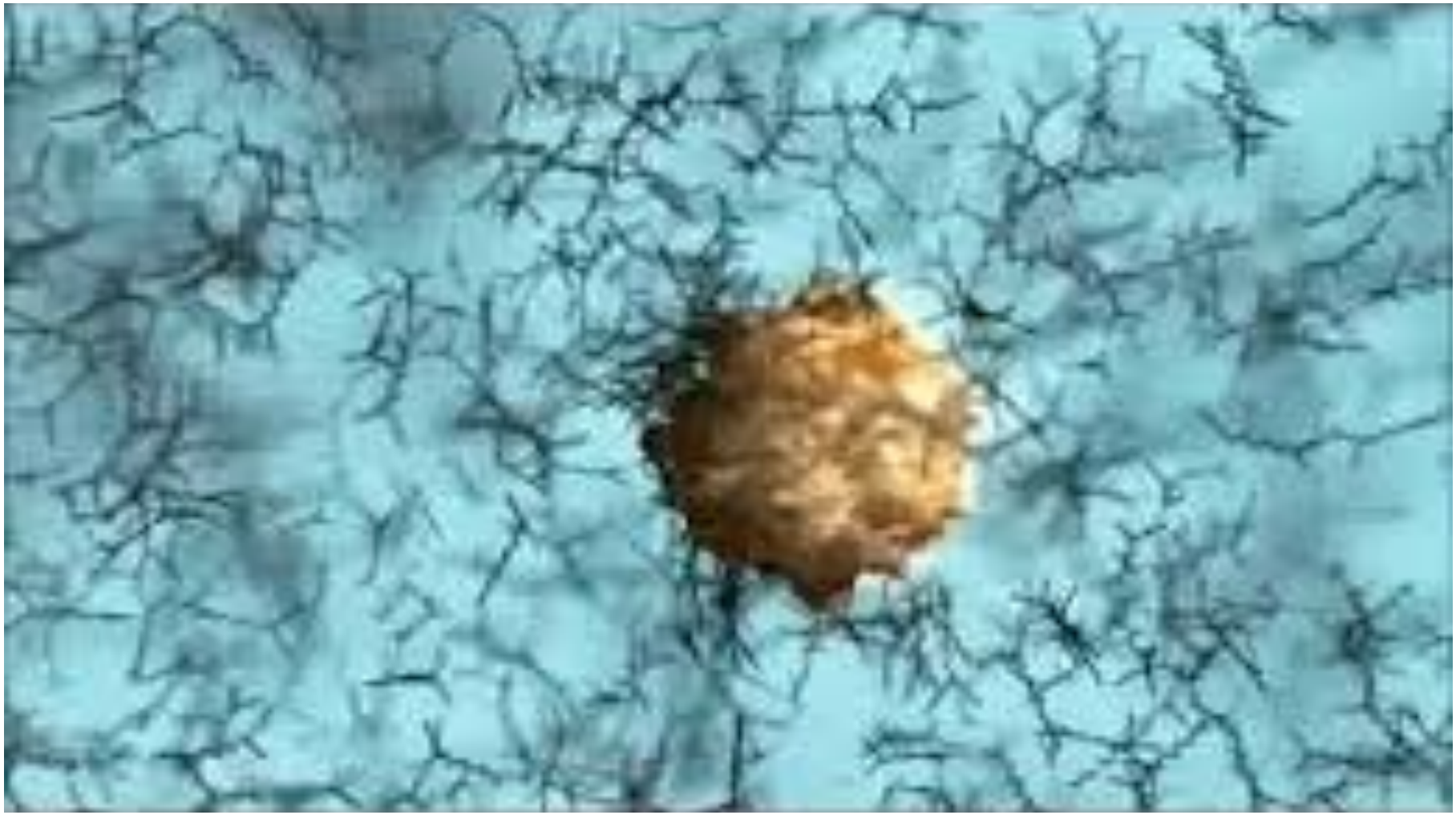
Peter Higgs





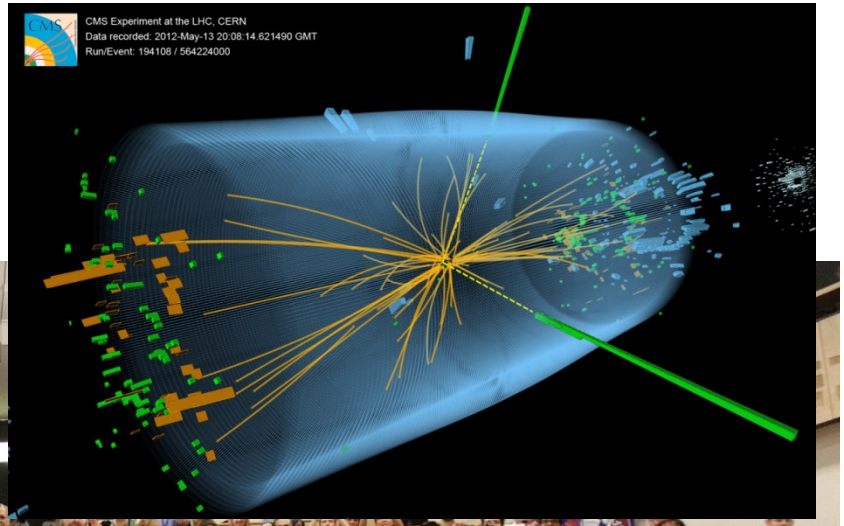
O mecanismo de Higgs





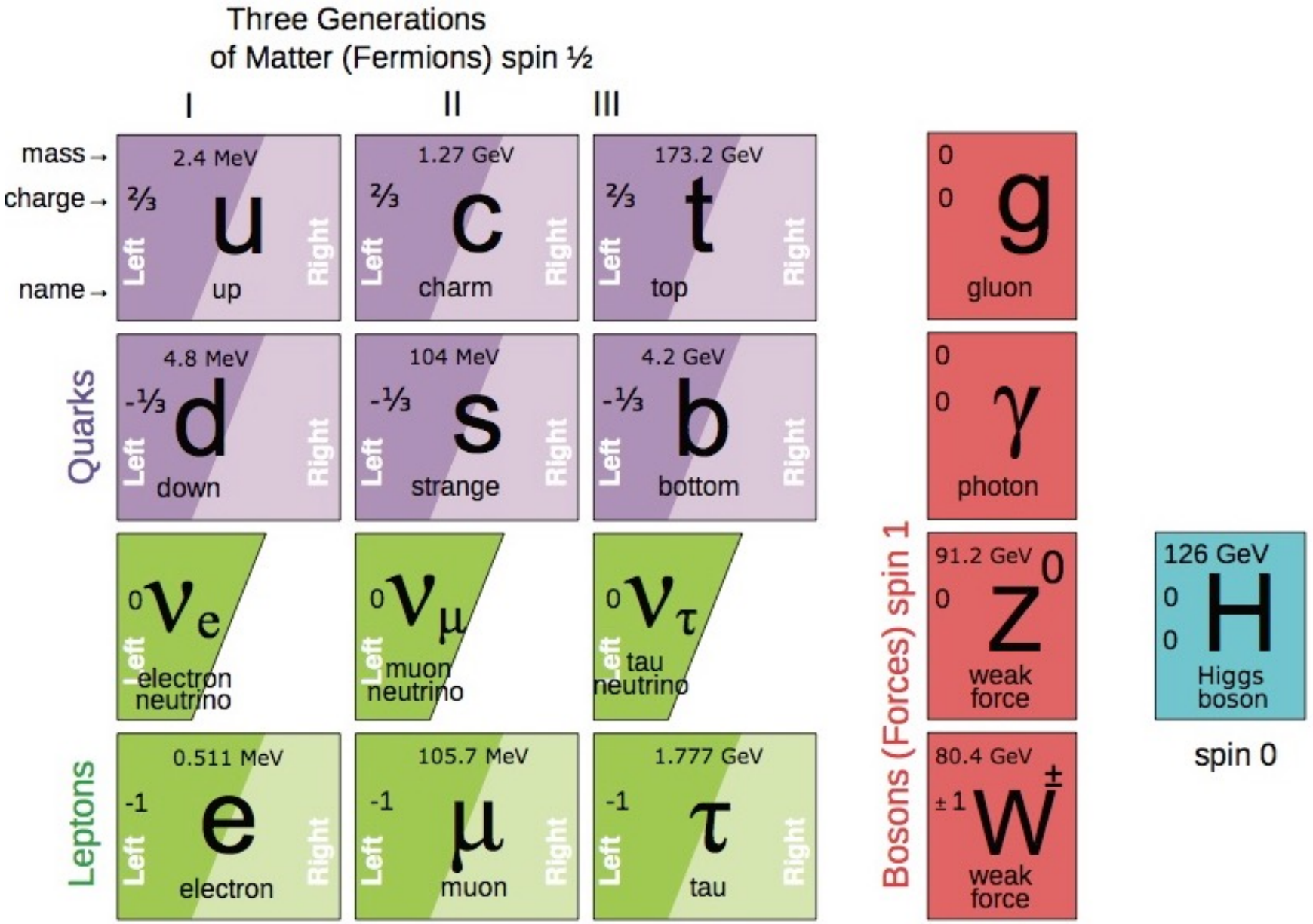
A massa é gerada na interacção com o campo

O bosão de Higgs

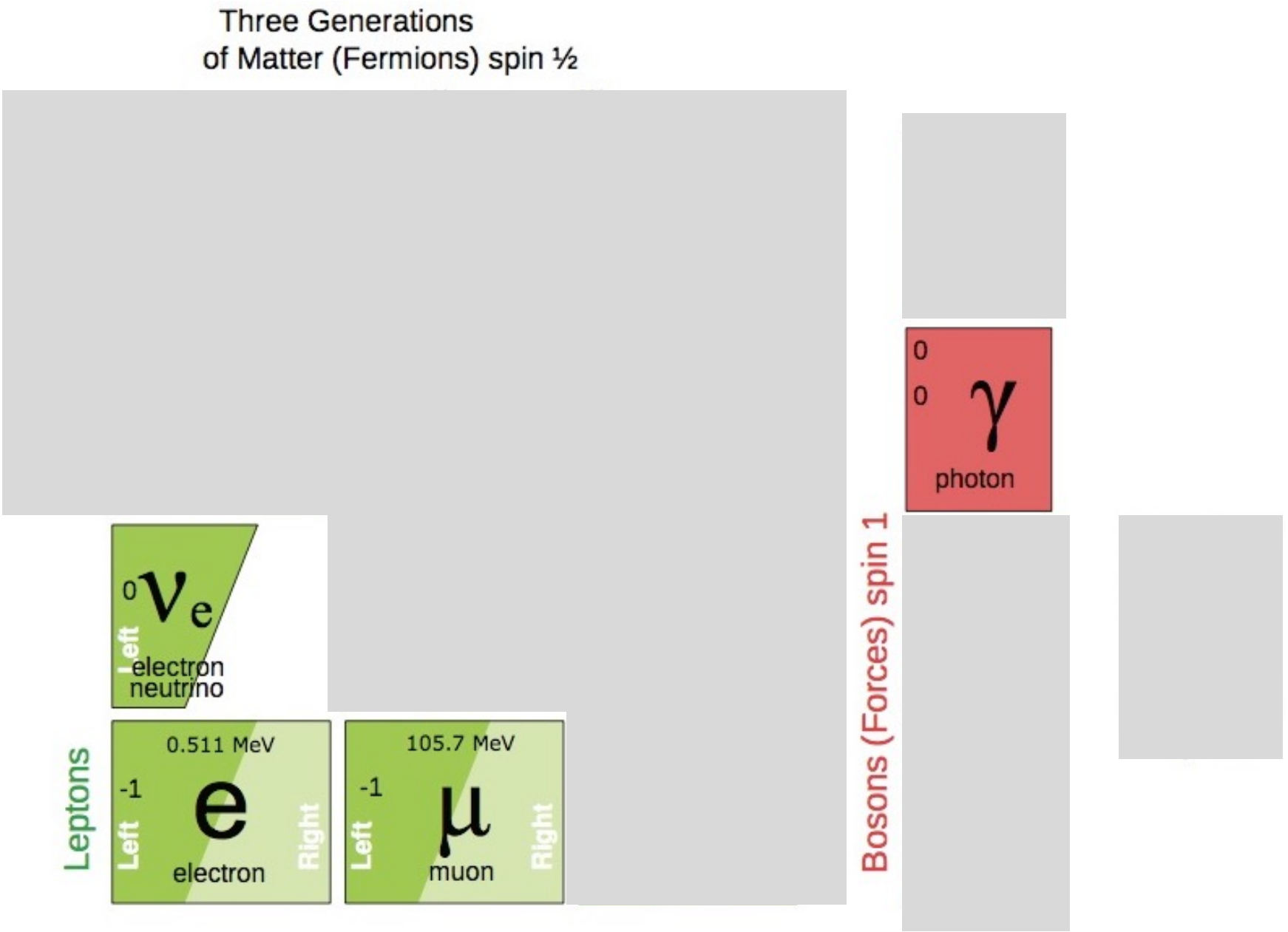


4 Julho 2012: CERN

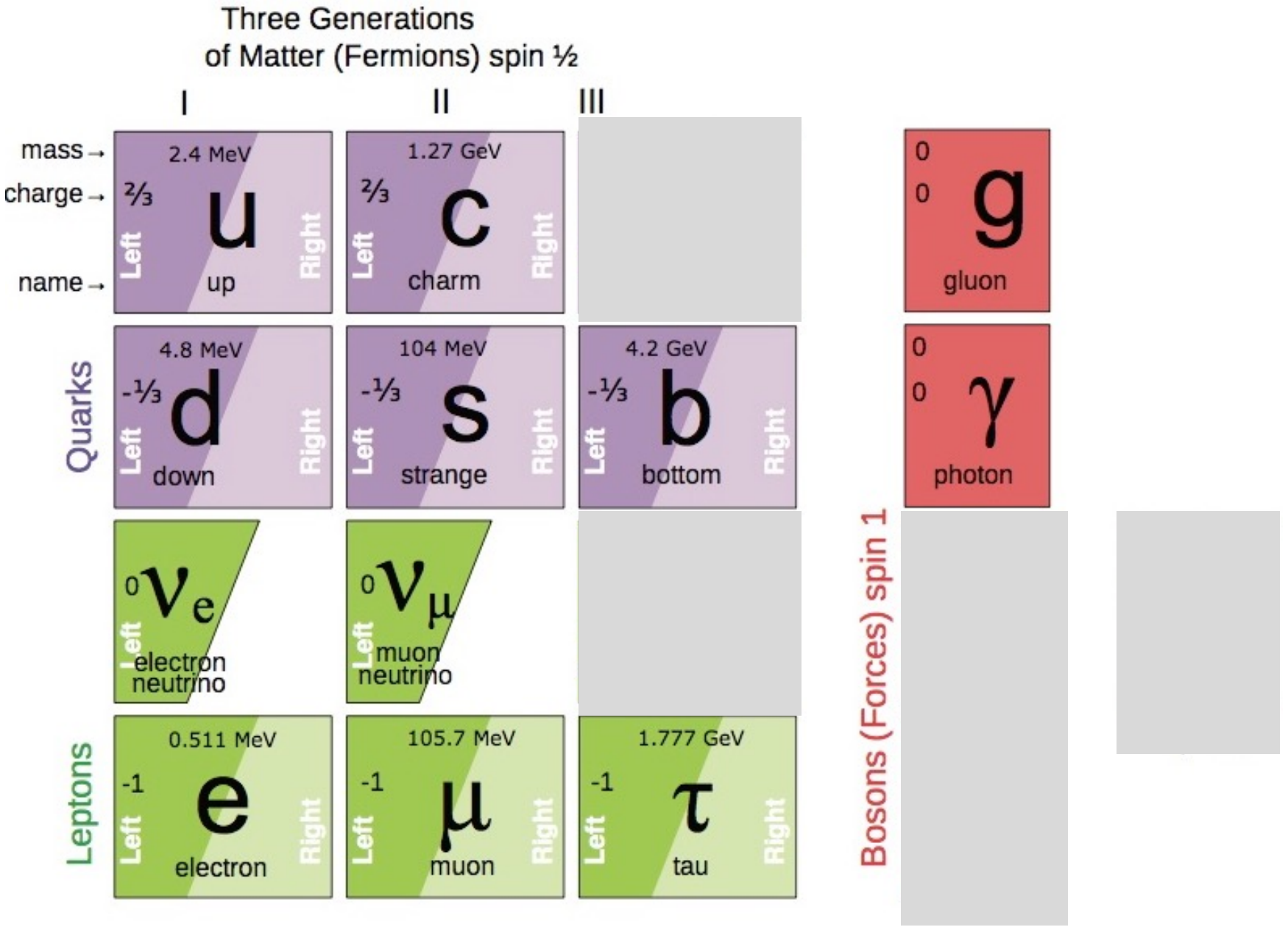
As partículas elementares hoje!



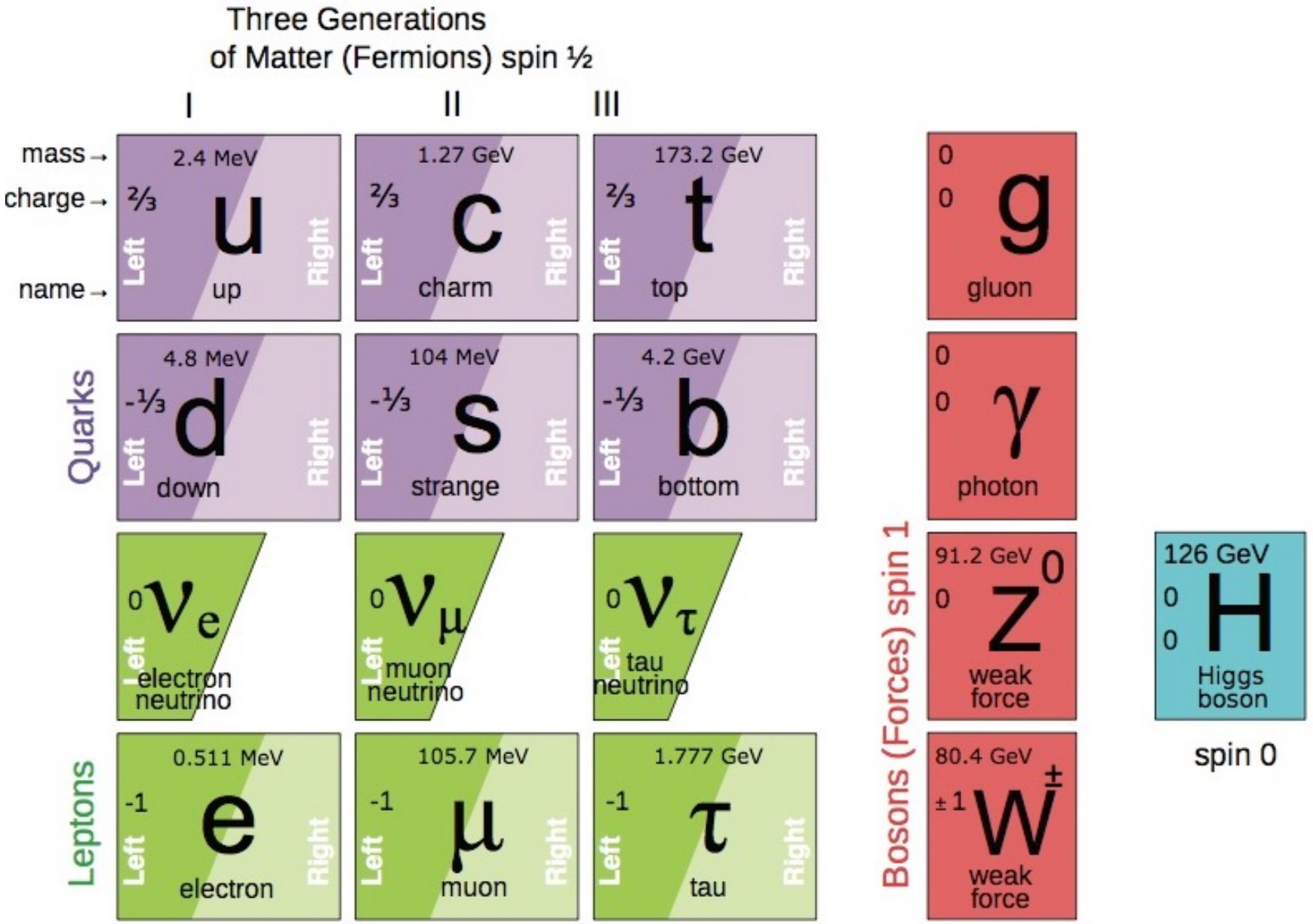
As partículas elementares em 1957



As partículas elementares em 1980

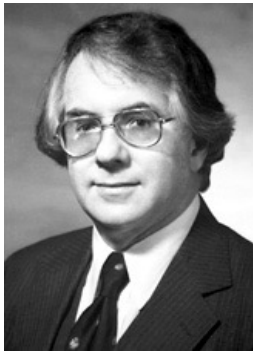


As partículas elementares hoje!



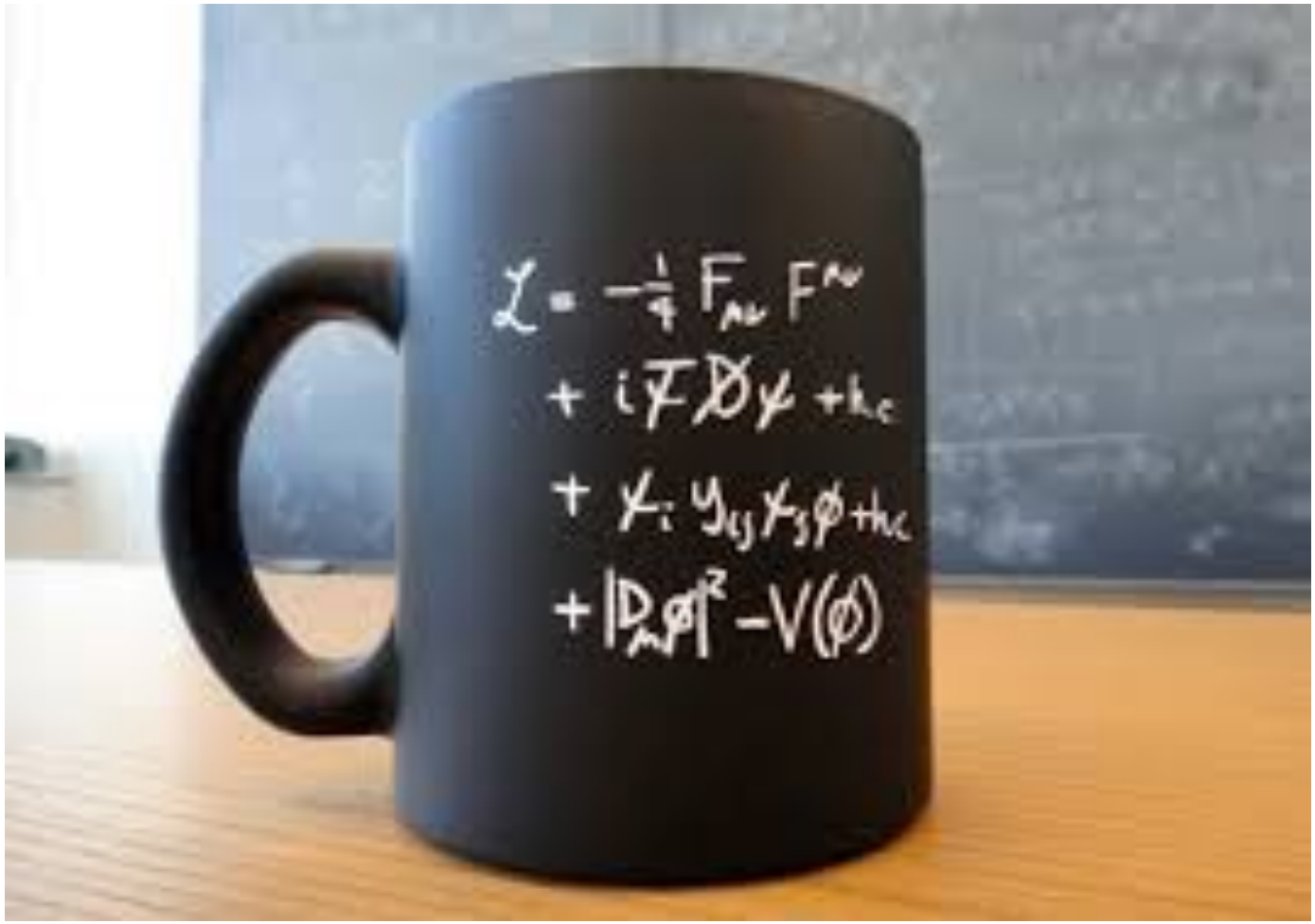
O Modelo Padrão: $SU(2)_L \otimes U_1$

Glashow

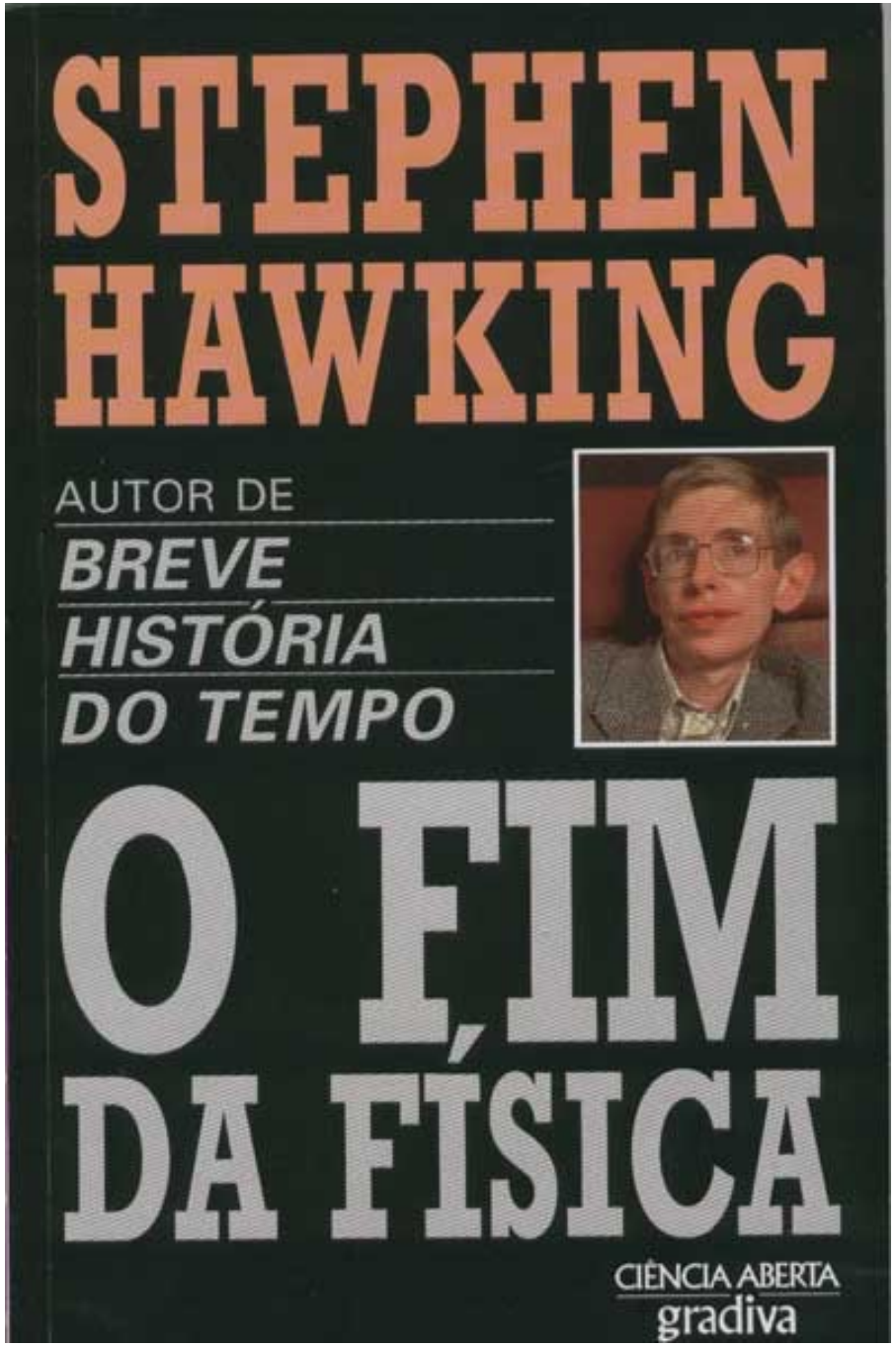


Salam

Weinberg



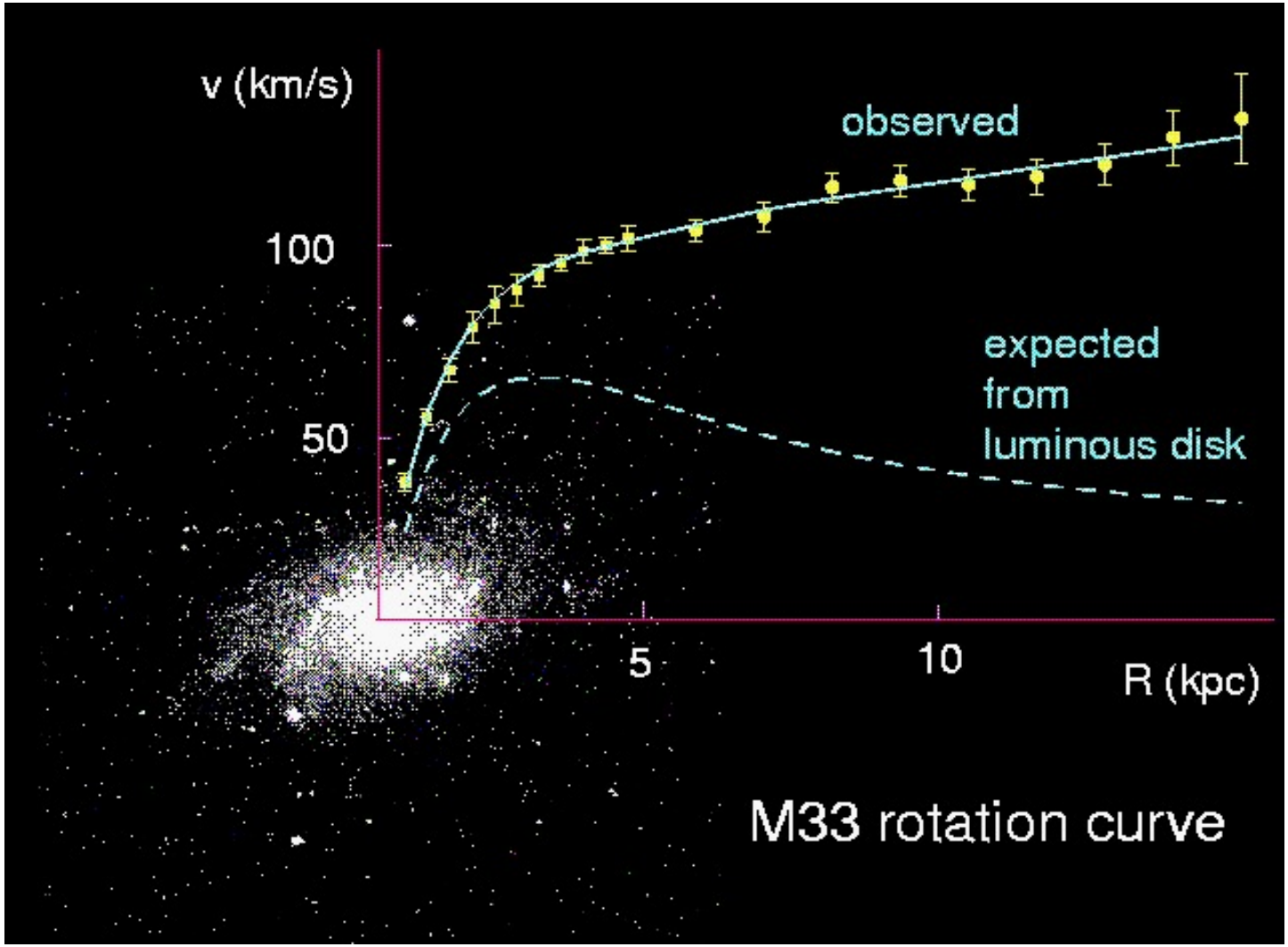
O fim da Física ?



A matéria luminosa

A velocidade de rotação das estrelas periféricas

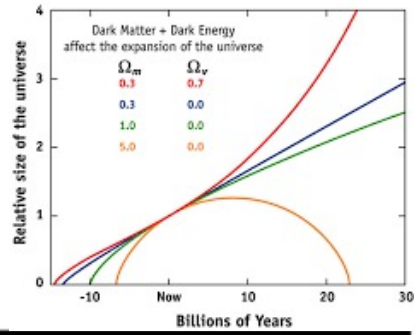
Rodar em torno do centro da galáxia

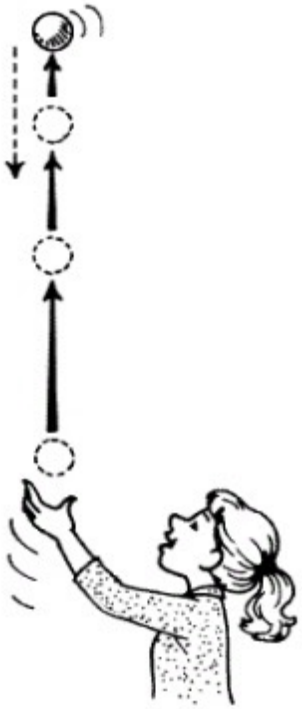


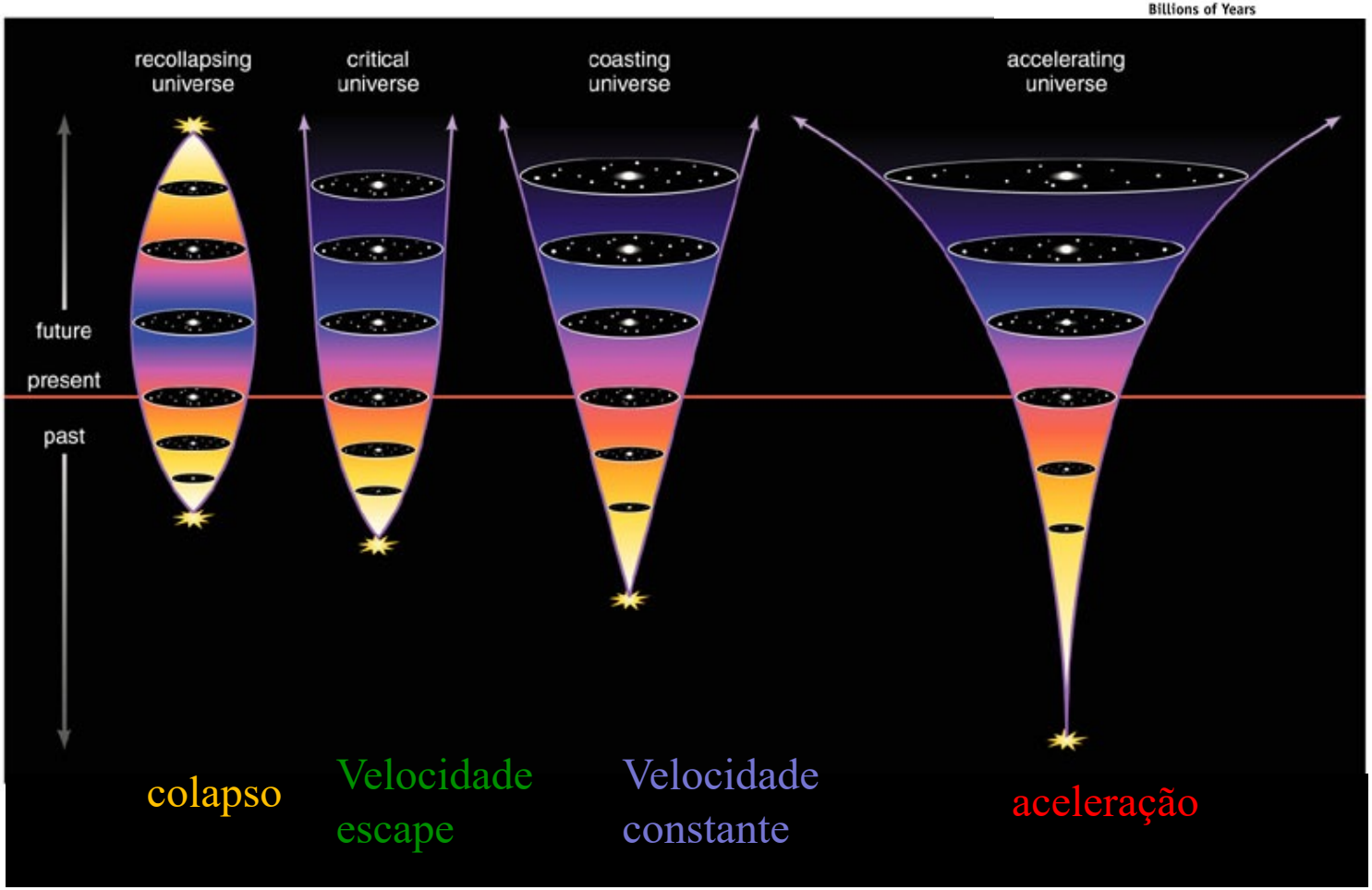
Um halo de matéria escura!

A matéria escura

A expansão do Unverso

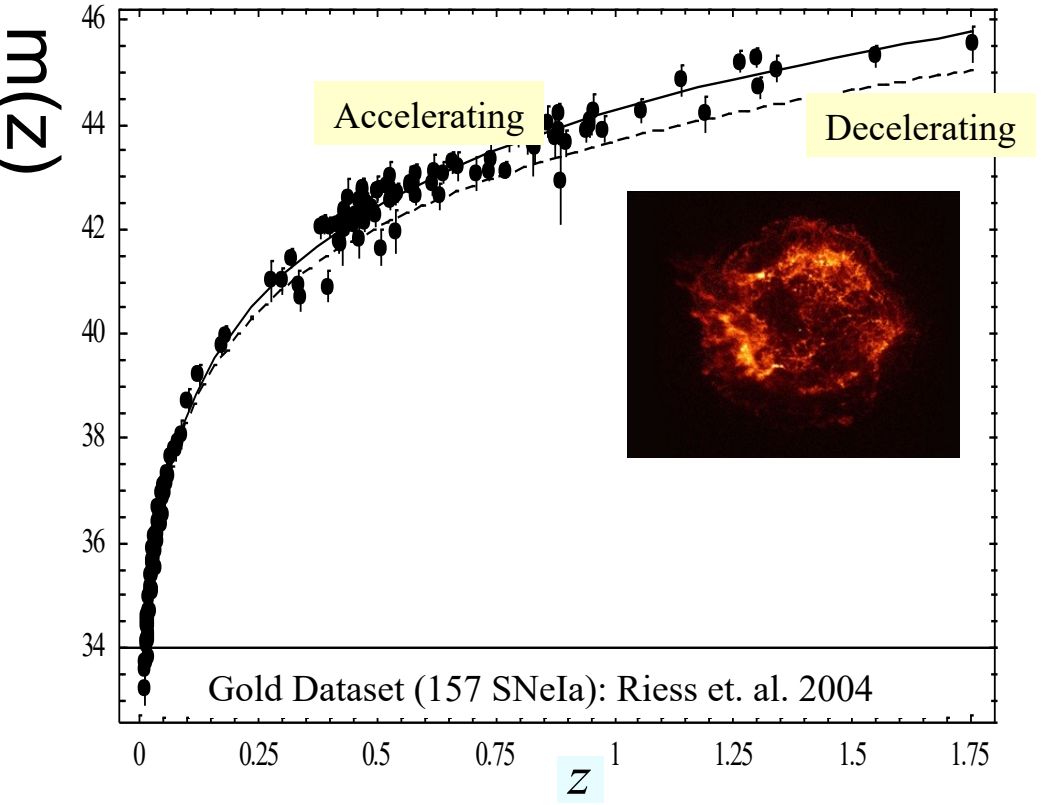


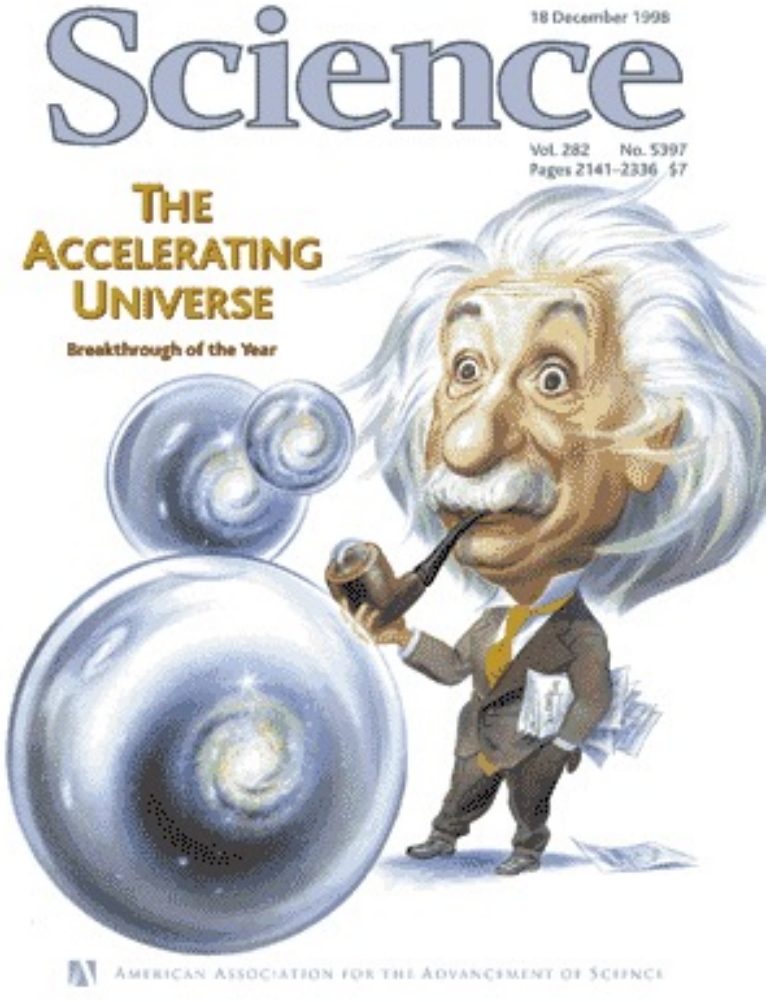




A energia escura !

Diagrama de Huble

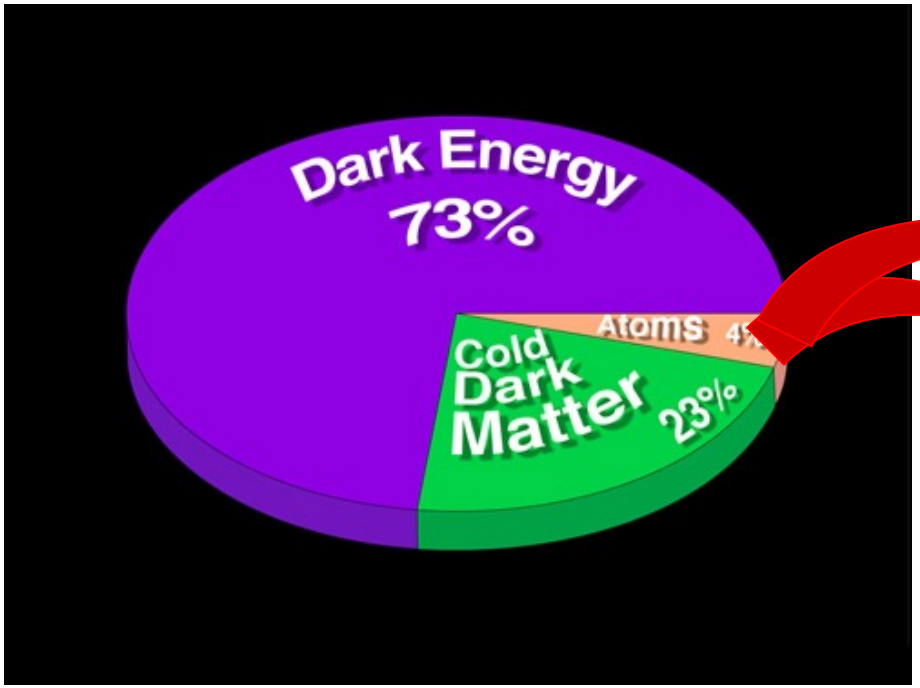




O Universo encontra-se numa expansão acelerada !!!

Energia escura – anti-gravítica

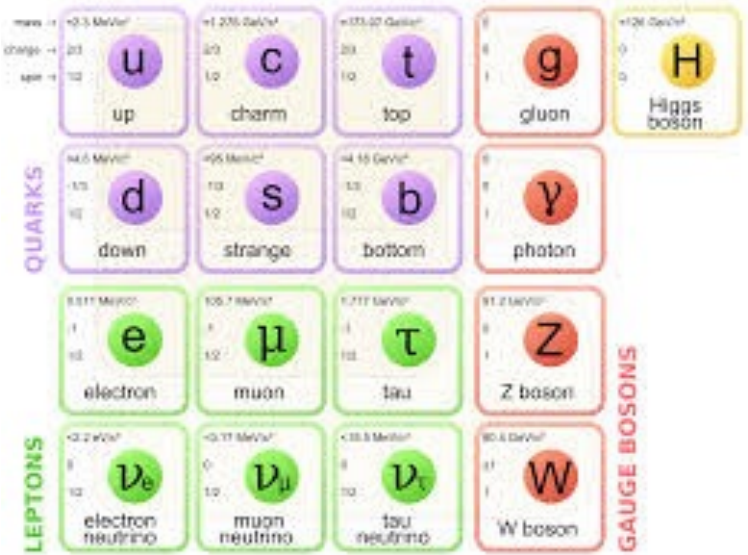
Fronteiras do nosso (des)conhecimento

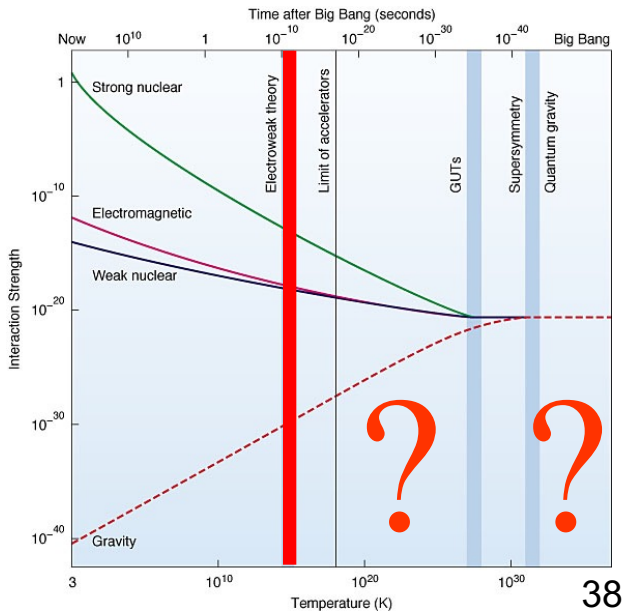


O modelo padrão

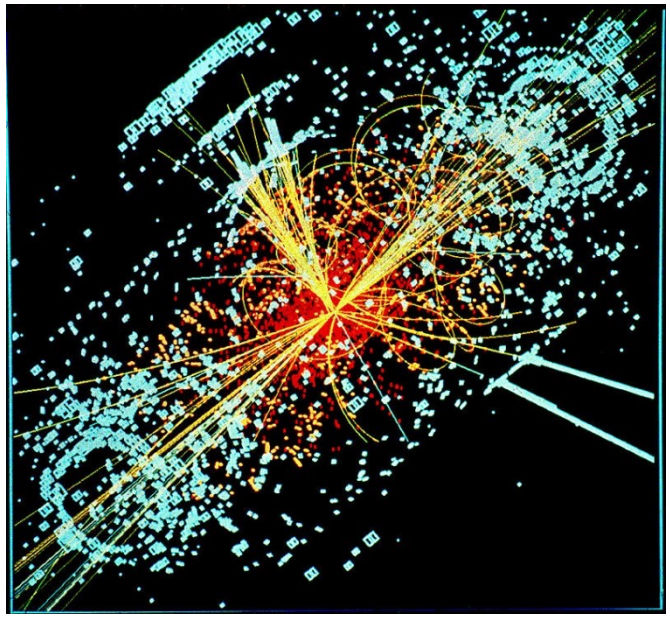
E_{CM} ~ 1 TeV

R ~ 10^{-18} m



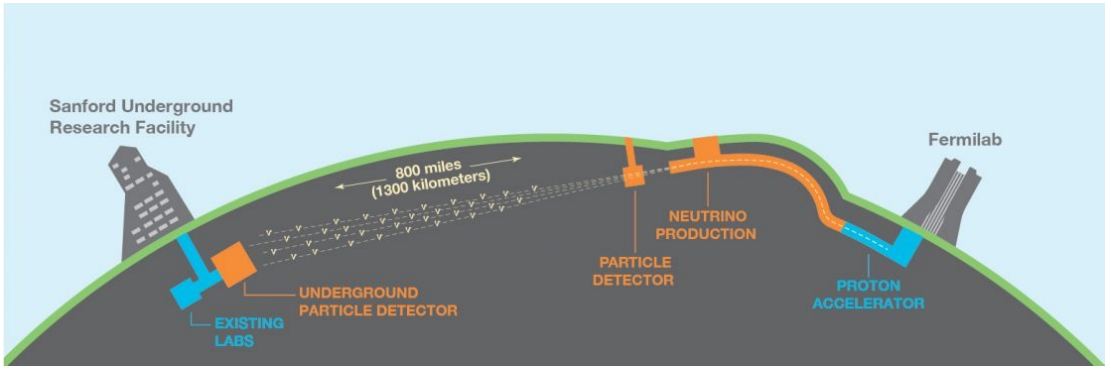


Olhar o Universo no sec. XXI

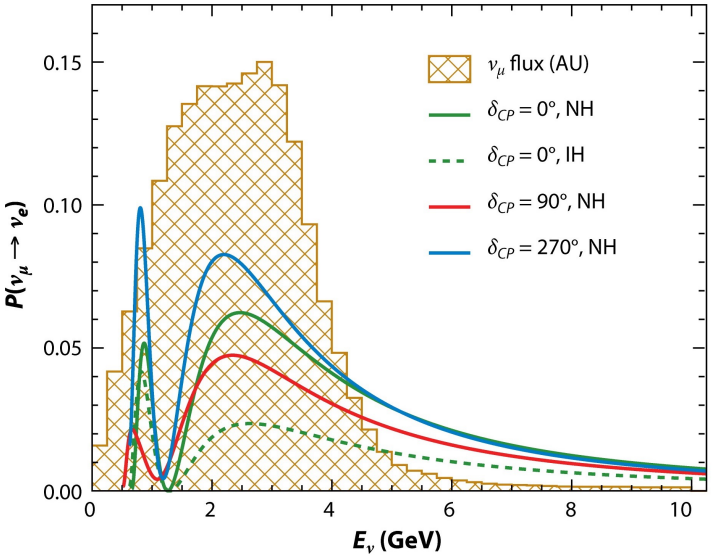


DUNE

violação de CP no
sector dos neutrinos ???



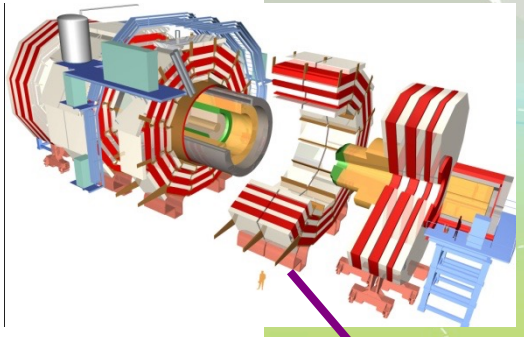
Padrões de Oscilação



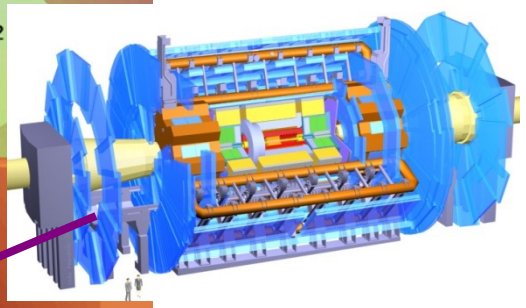
Proto-DUNE @ CERN

O LHC no CERN

CMS

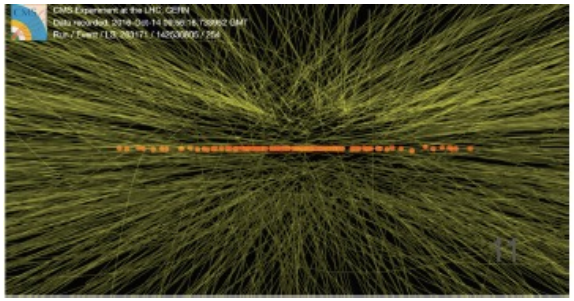


ATLAS



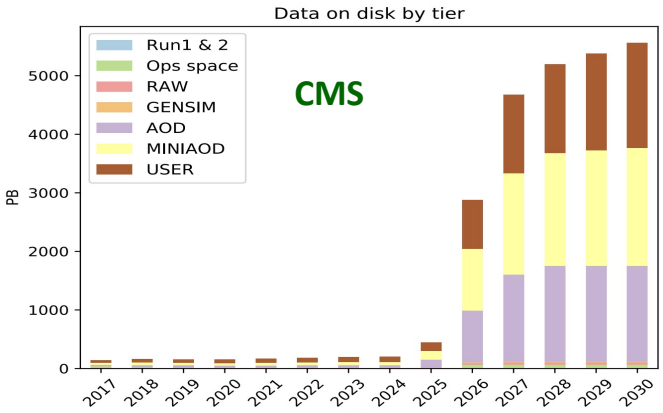
Os próximos 50 anos no CERN!

Até 2038 - LHC – alta intensidade

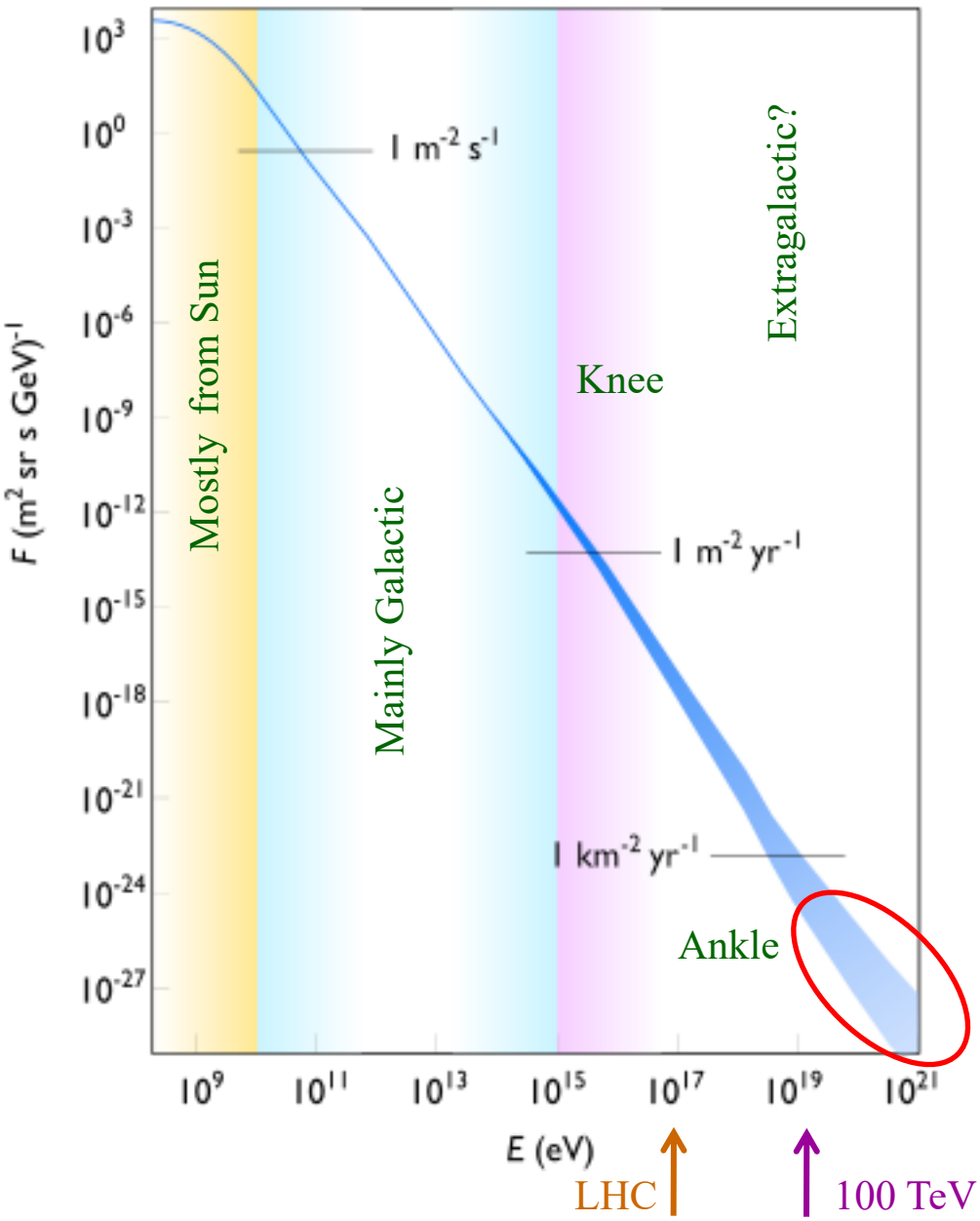


Inicia-se agora o caminho para novos aceleradores (em estudo o FCC)

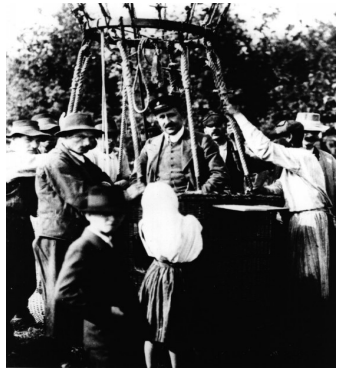
E muito R&D e desafios tecnológicos a vencer !

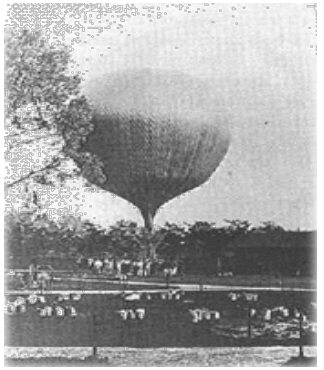


Raios cósmicos carregados



Viktor Hess, 1912



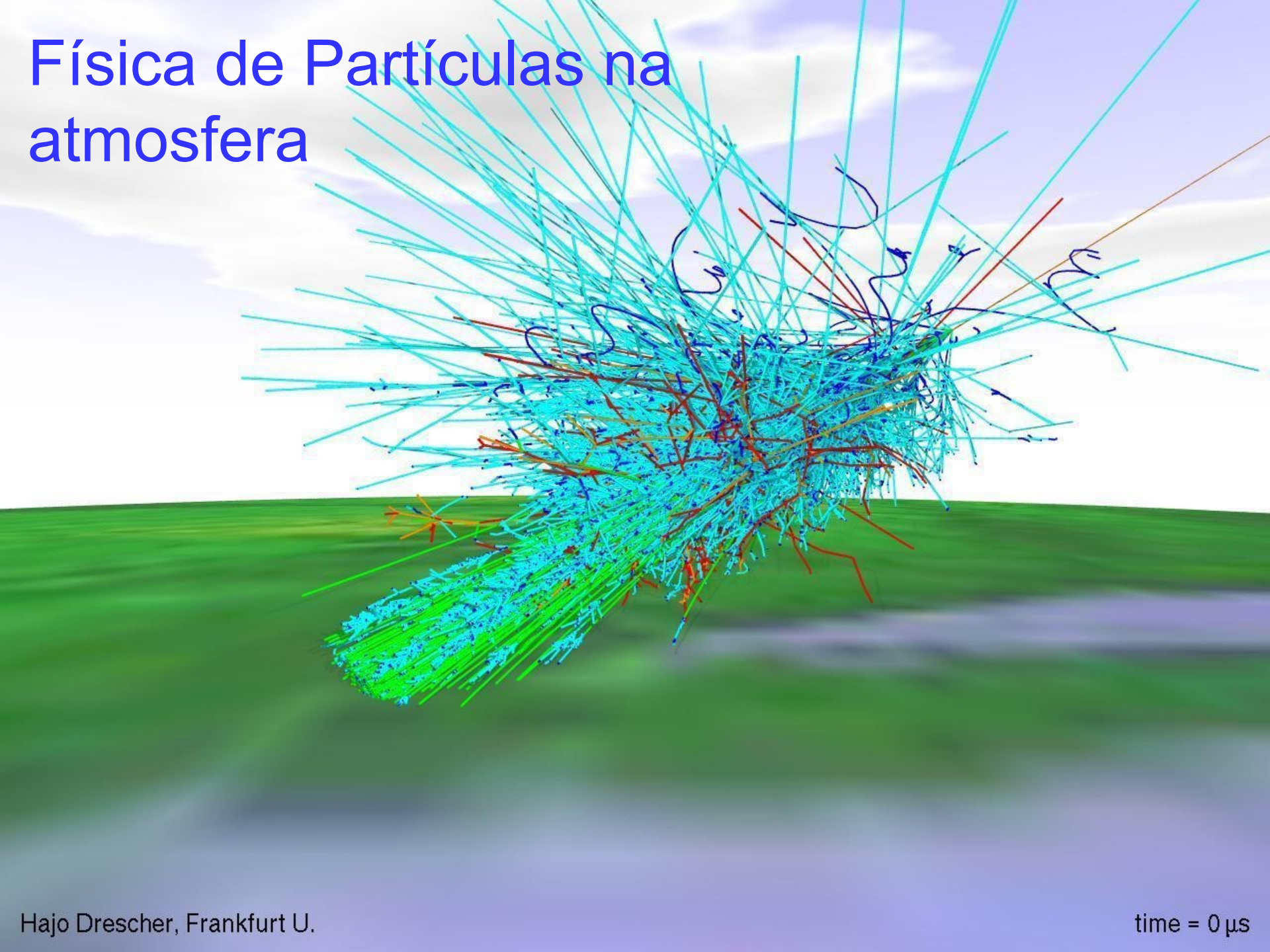


$$\frac{dN}{dE} \propto E^{-\alpha}$$

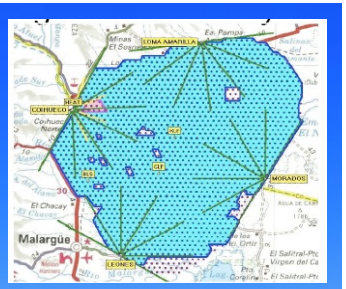
$$\alpha = \begin{cases} 2.7 & E < 10^{16} \\ 3.0 & 10^{16} < E < 10^{18} \\ 2.7? & E > 10^{18} \end{cases}$$

Um LHC do tamanho da órbita de Mercúrio !!!

Física de Partículas na atmosfera

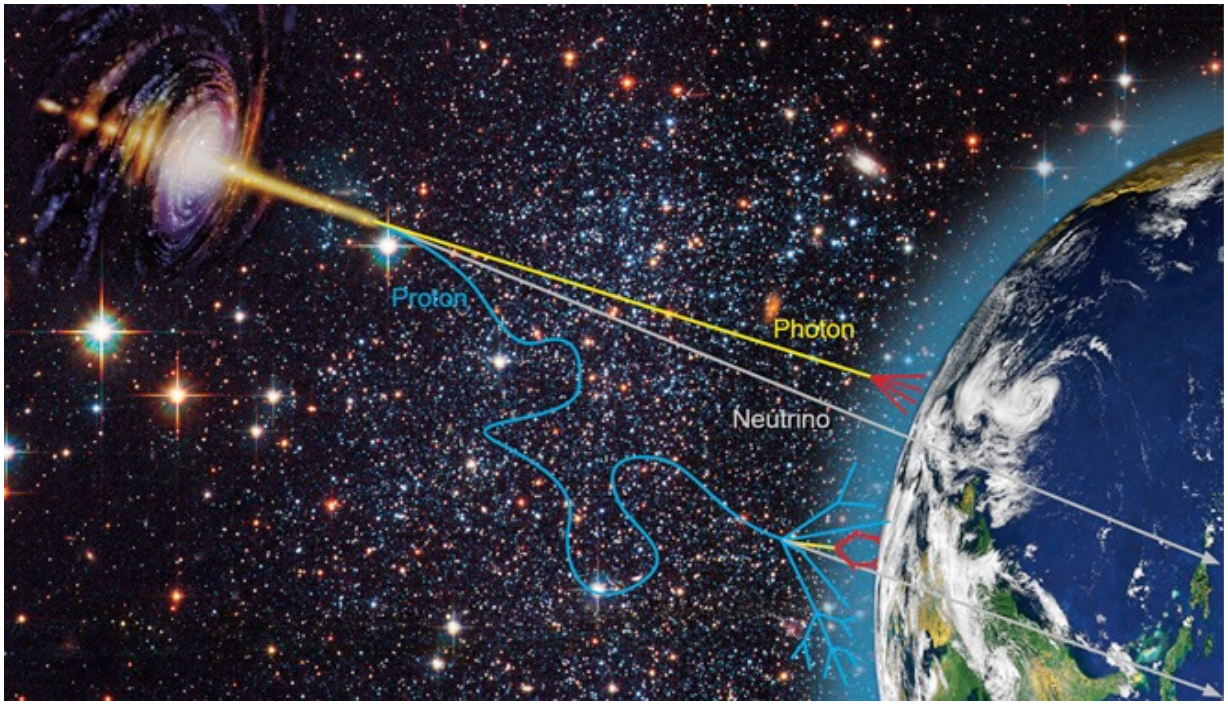


Na pampa argentina

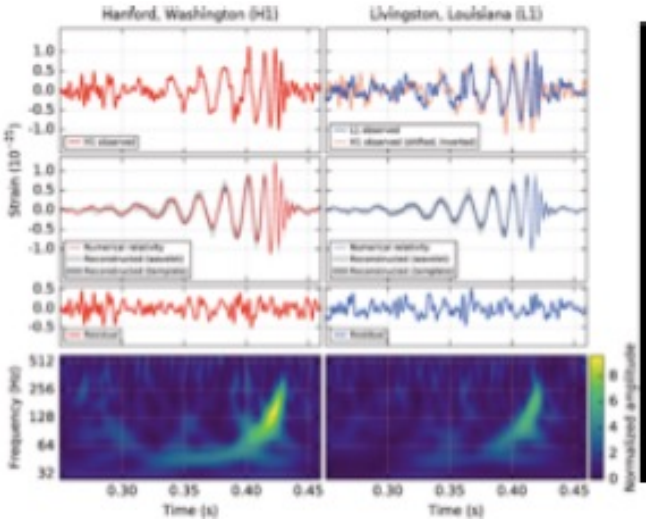


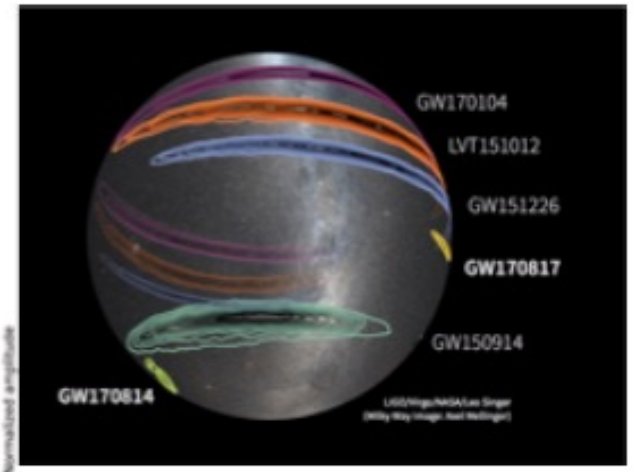
Mensageiros do Universo

γ, p, nuclei, ν

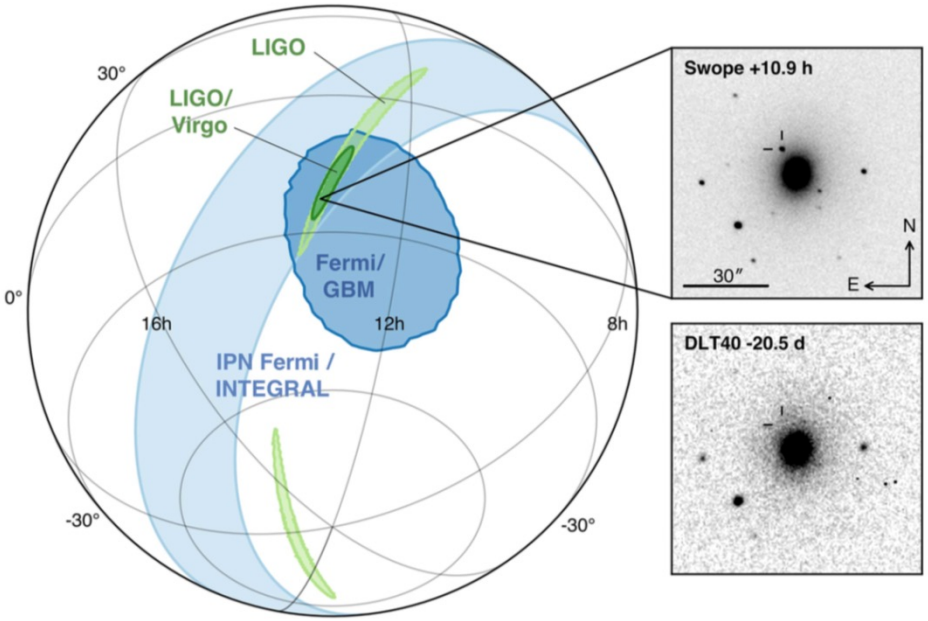


GW

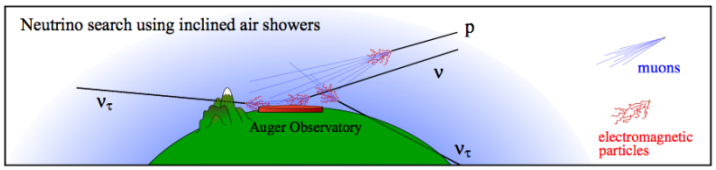


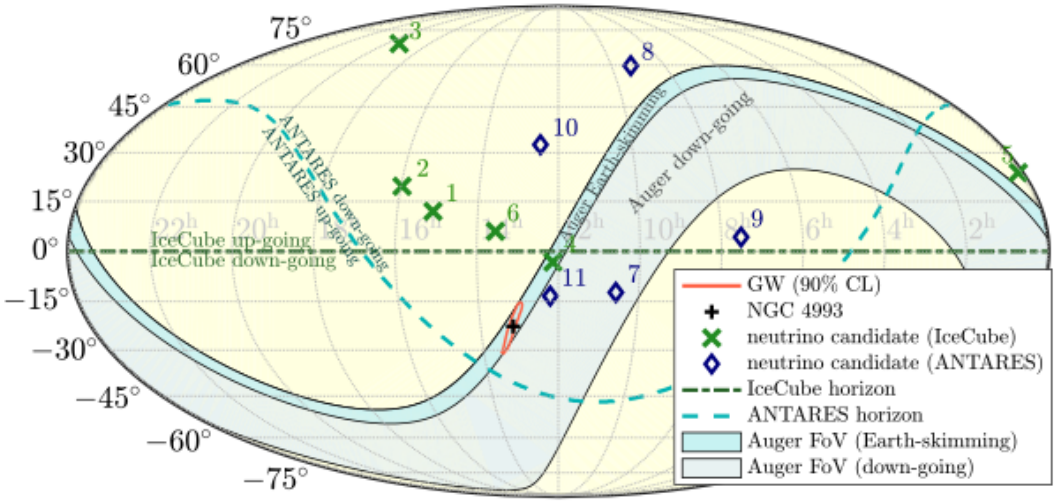


GW170817

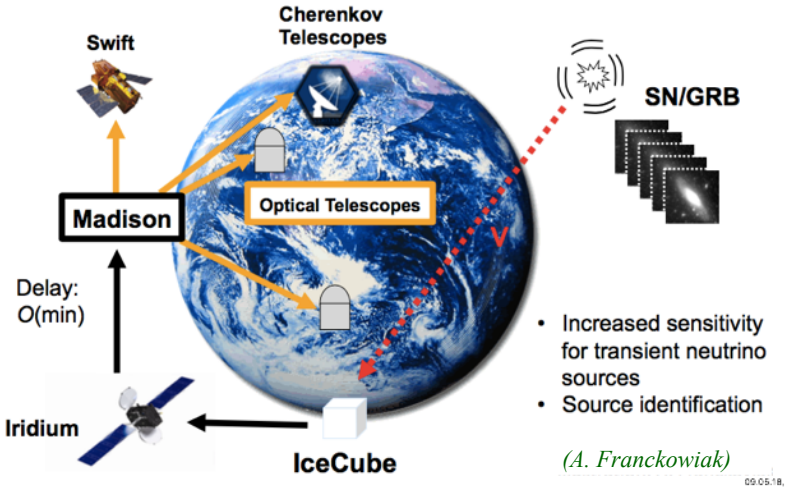


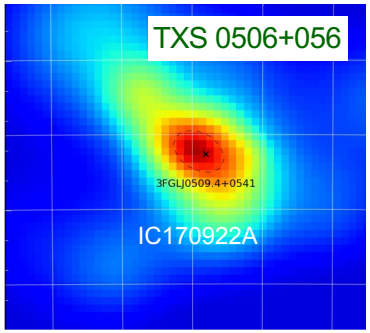
A primeira observação "multimessenger" da fusão de duas estrelas de neutrões



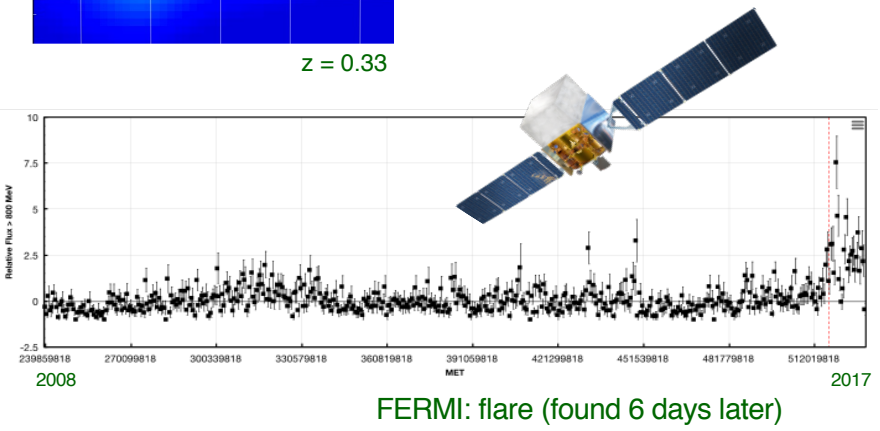


A primeira fonte de neutrinos astrofísicos de alta energia





MAGIC: flare E > 100 GeV

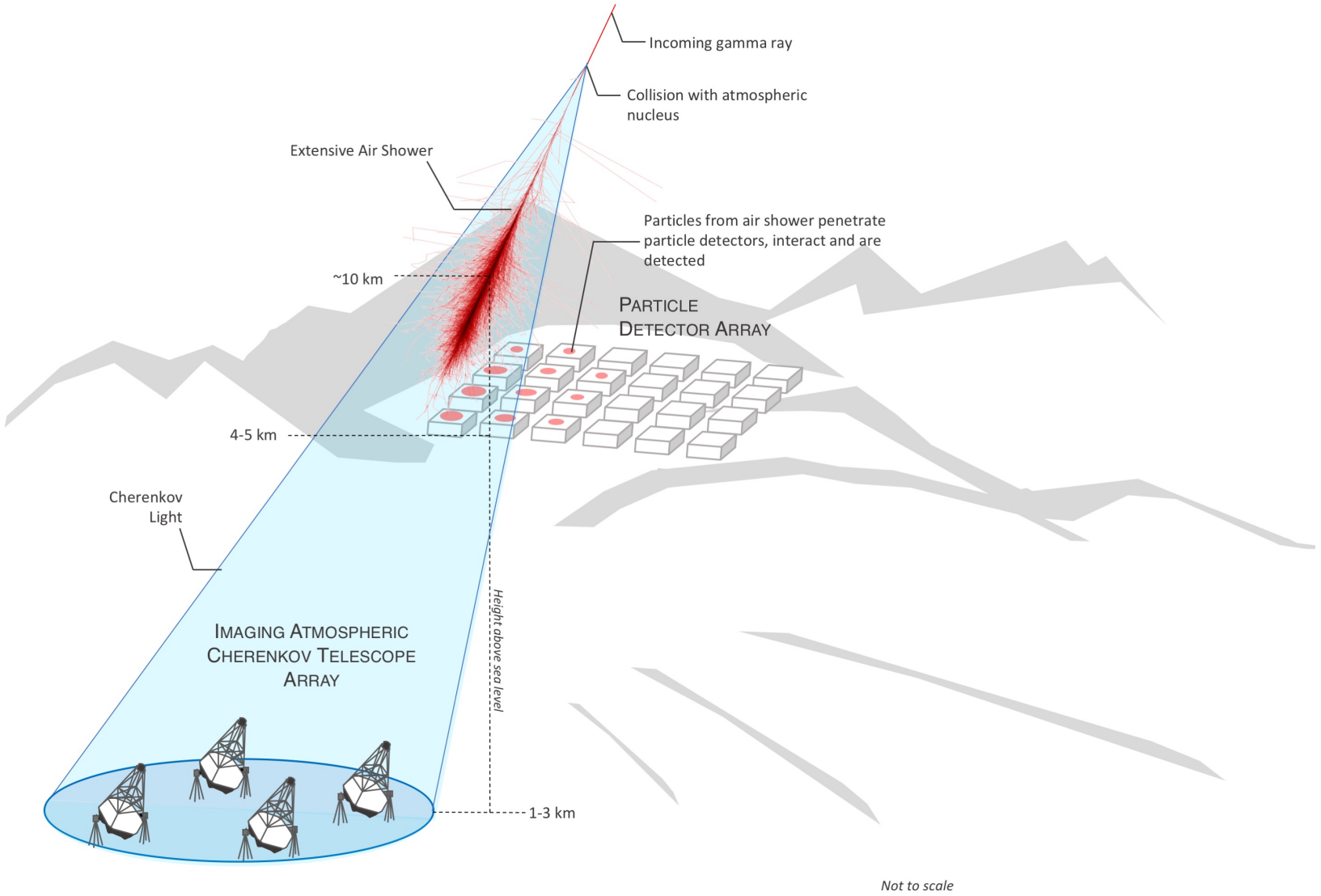


FERMI: flare (found 6 days later)

```
TITLE:   GCN CIRCULAR
NUMBER:  21916
SUBJECT: IceCube-170922A - IceCube observation of a high-energy neutrino candidate event
DATE:    17/09/23 01:09:26 GMT
FROM:    Erik Blaufuss at U. Maryland/IceCube  <blaufuss@icecube.umd.edu>

Claudio Kopper (University of Alberta) and Erik Blaufuss (University of  Maryland) report on
behalf of the IceCube Collaboration (http://icecube.wisc.edu/).

On 22 Sep, 2017 IceCube detected a track-like, very-high-energy event with a high probability
of being of astrophysical origin. The event was identified by the  Extremely High Energy
(EHE) track event selection. The IceCube detector was in a normal operating state. EHE events
typically have a neutrino interaction vertex that is outside the detector, produce a muon
that traverses the detector volume, and have a high light level (a proxy for energy).

After the initial automated alert
(https://gcn.gsfc.nasa.gov/notices_amon/50579430_130033.amon), more
sophisticated reconstruction algorithms have been applied offline, with the direction refined
to:

Date: 22 Sep, 2017
Time: 20:54:30.43 UTC
RA: 77.43 deg (-0.80 deg/+1.30 deg  90% PSF containment) J2000
Dec: 5.72 deg (-0.40 deg/+0.70 deg 90% PSF containment) J2000

We encourage follow-up by ground and space-based instruments to help identify a possible
astrophysical source for the candidate neutrino.
```

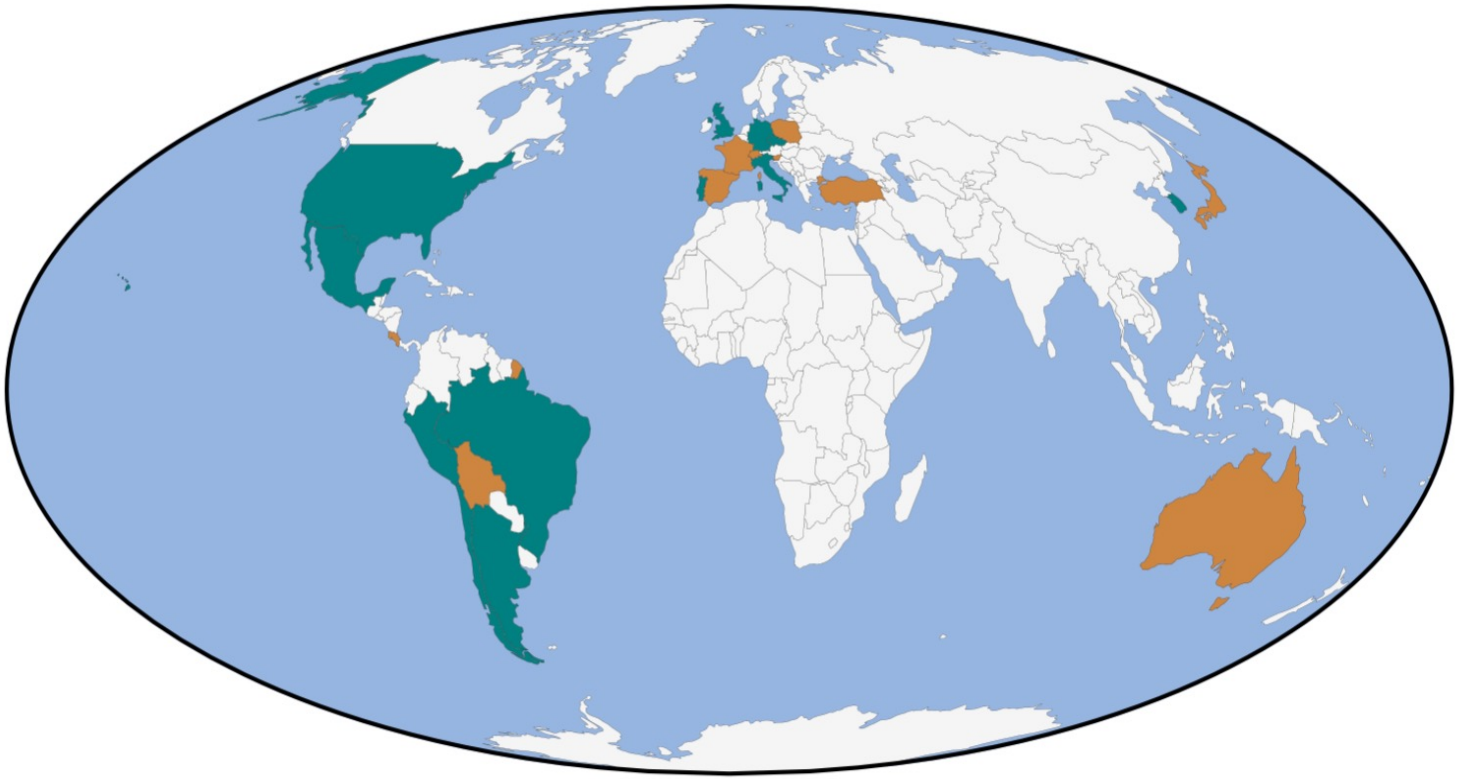
IceCube 1709922A, publications in preparation

Detectar fotões no alto das montanhas ..



SWGO

Southern Wide-field Gamma-ray Observatory



Countries in SWGO

Institutes

Argentina*, Brazil, Chile, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

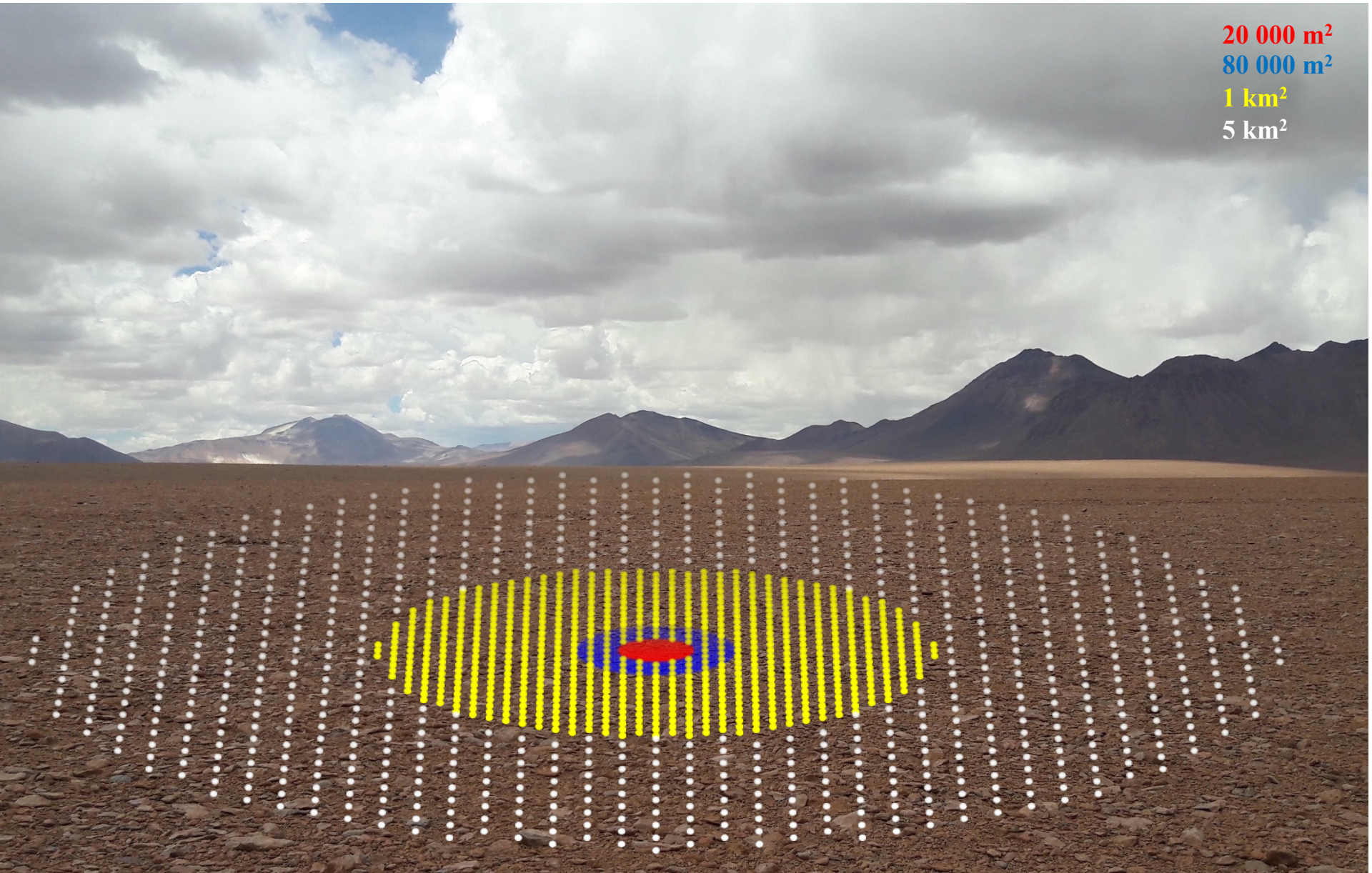
Supporting scientists

Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland, Turkey

**also supporting scientists*

100 + 32 cientistas, 53 institutos, 13 países

Olhar para o centro da galáxia e para o Universo a 4500-5000 m de altitude na América do Sul com um detector de fotões energéticos

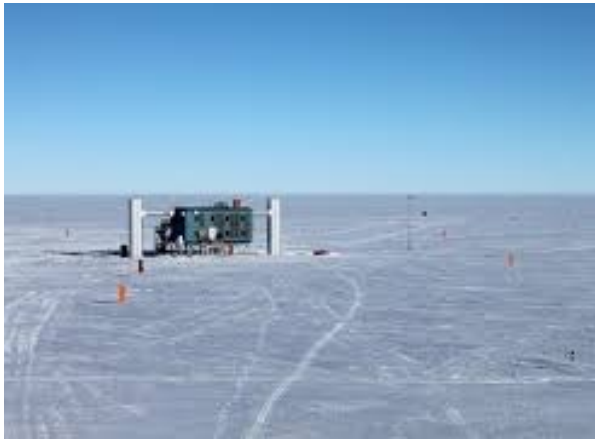


Da Terra aos Céus ...

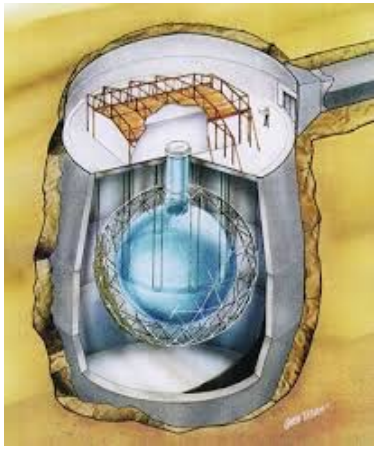
AMS

Fermi

LIGO



Ice Cube

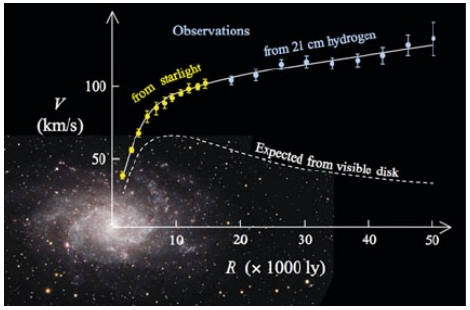


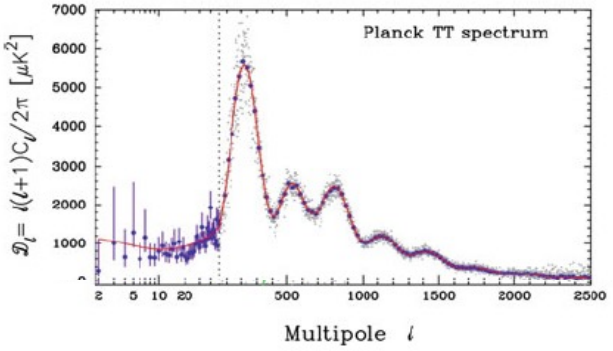
SNO^{+}

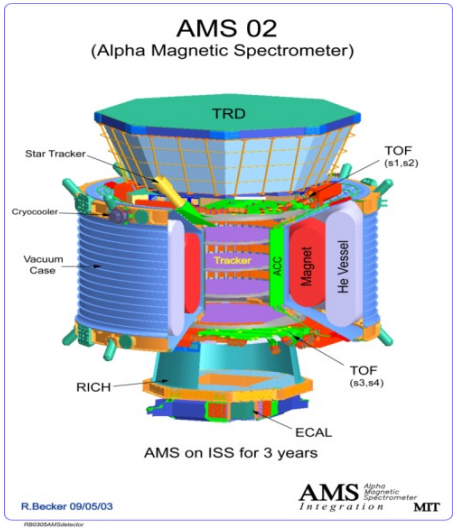
LST - CTA

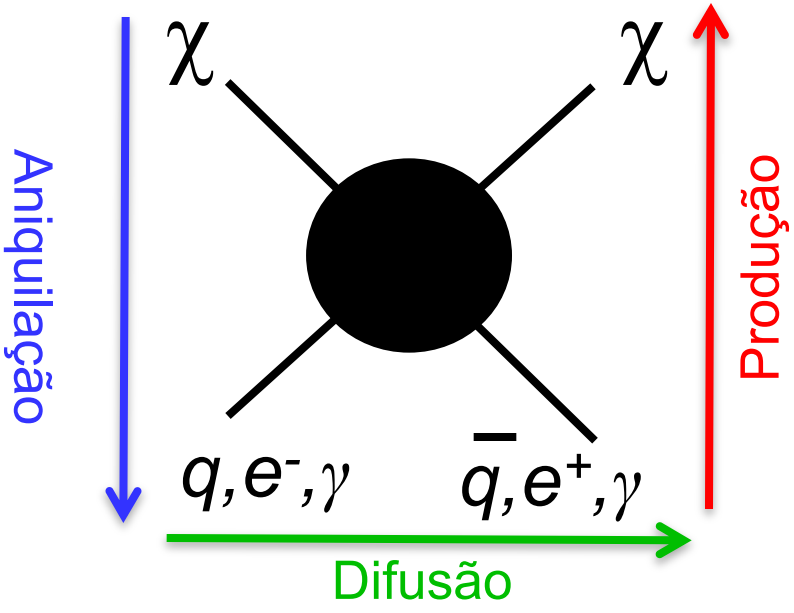
E muitos mais .....

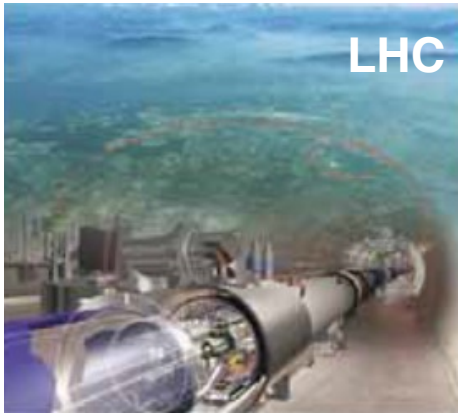
Matéria Escura



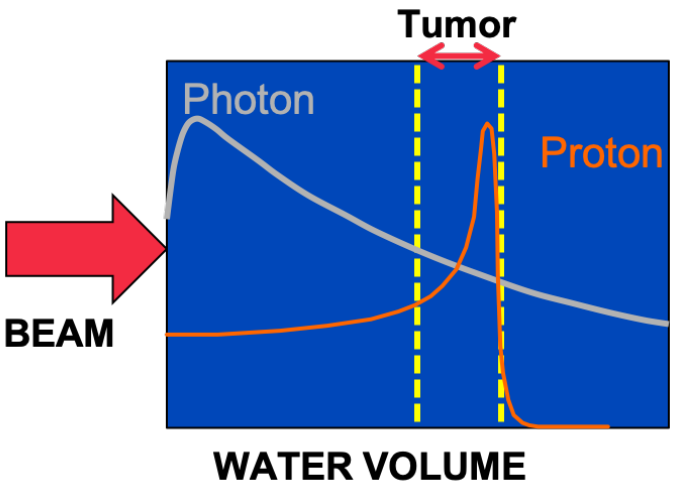








Terapia com Protões

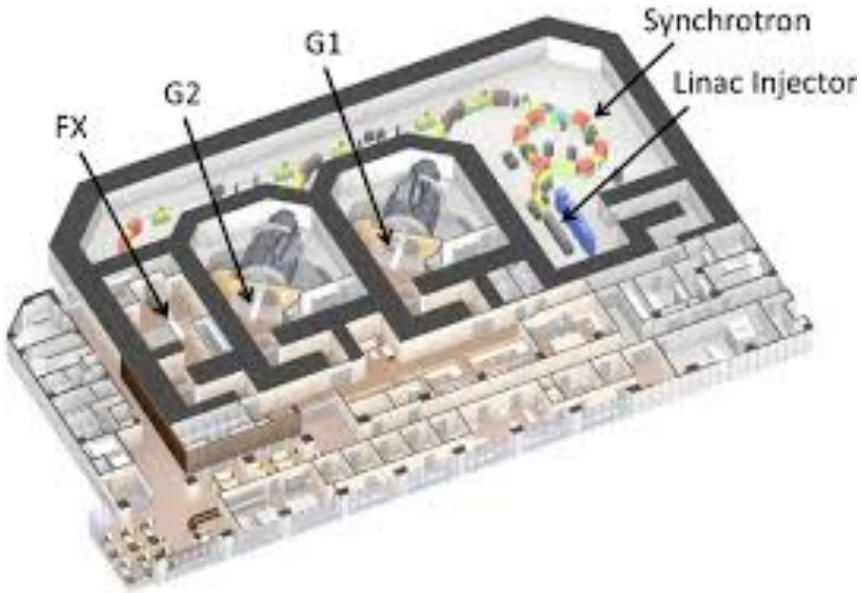


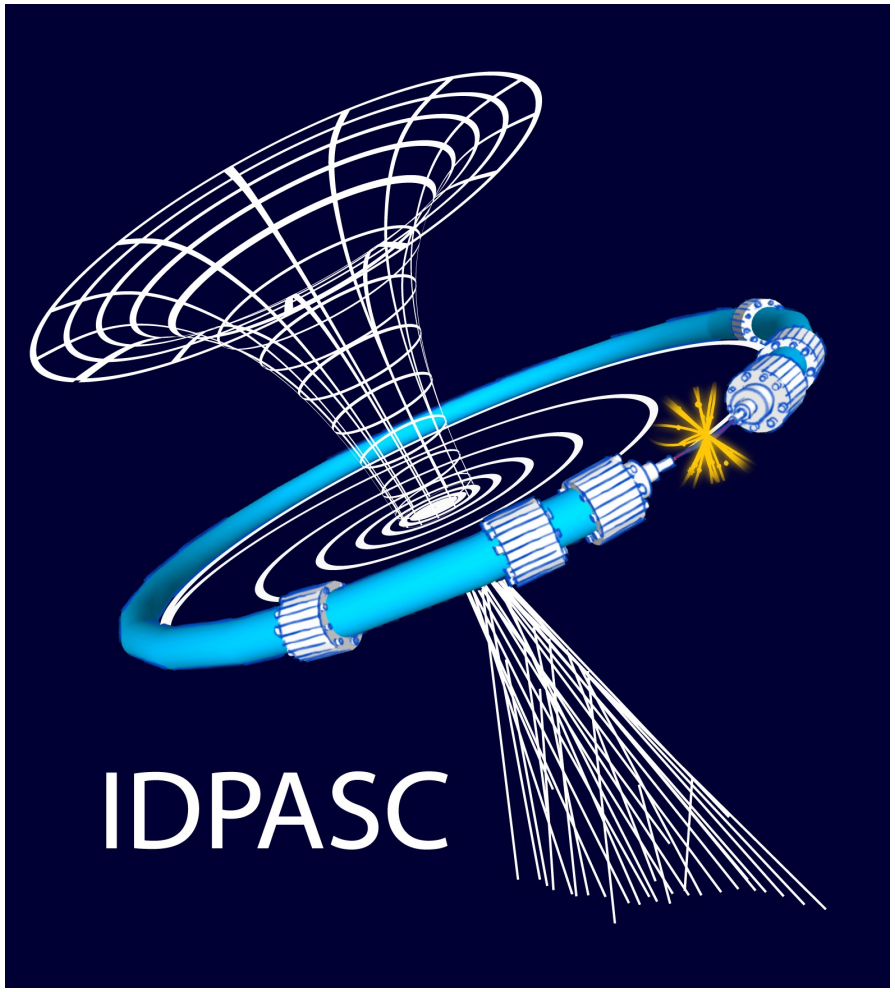
Grupo Hospitalar IPO, IST, LIP, ICNAS (UC)

Associação Portuguesa de Proto-Terapia e Tecnologias Avançadas para a Prevenção e Tratamento do Cancro (ProtoTera)

Loures (CTN): ciclotrão de 250 MeV com duas salas de tratamento e uma sala dedicada a desenvolvimento tecnológico, industrial e científico

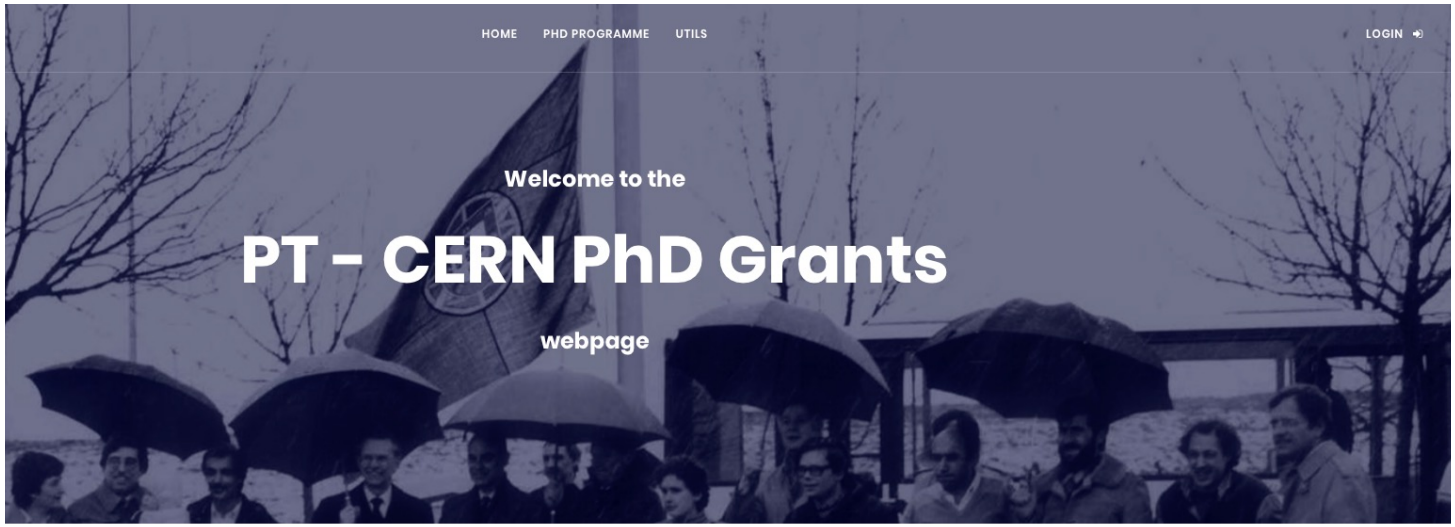
Coimbra (ICNAS): ciclotrão de 30 MeV + LINAC 70 MeV, com uma sala de tratamento para tumores oculares e produção de radioisótopos e radio fármacos para diagnóstico e terapia





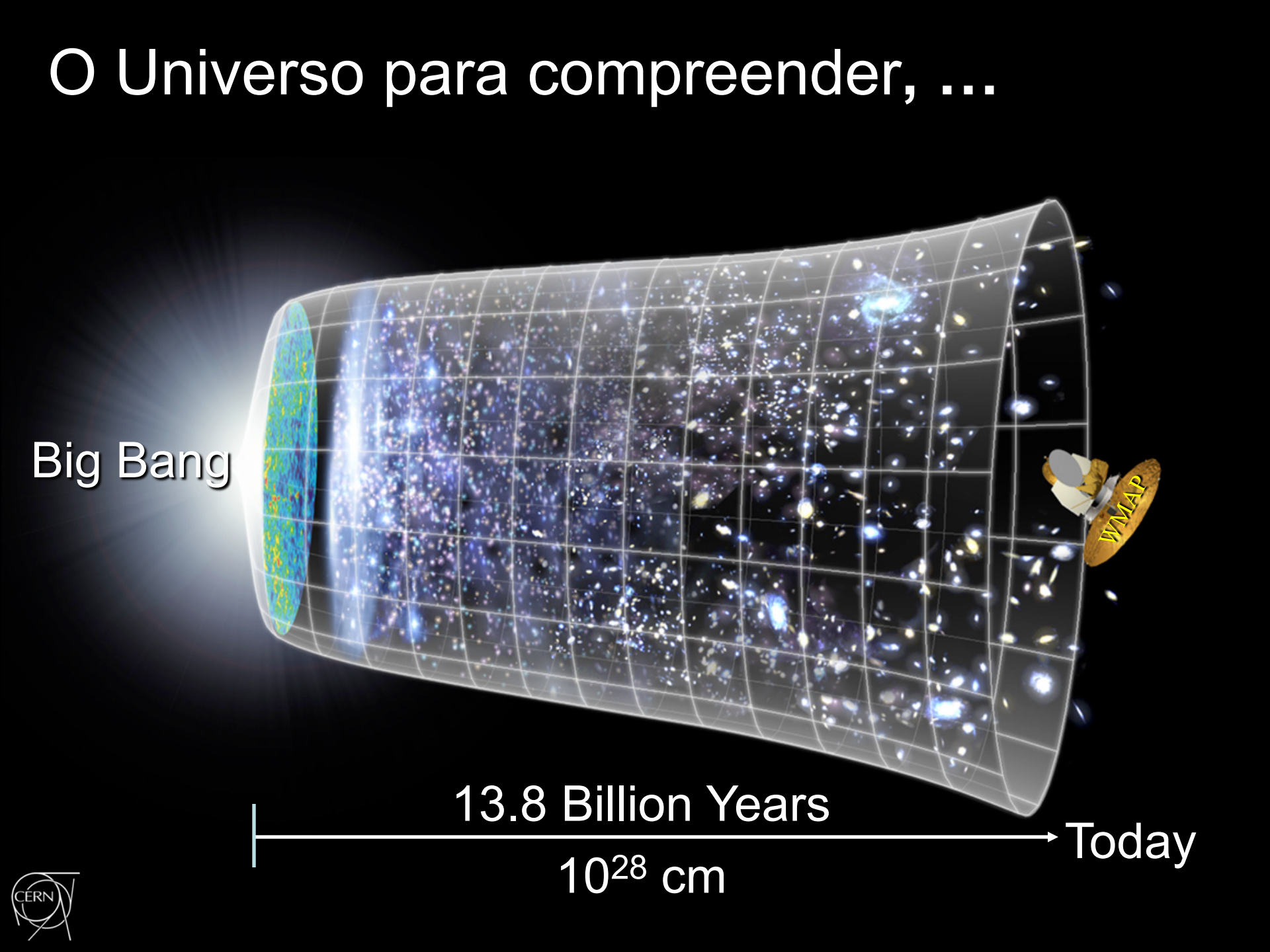
International Doctorate Network in Particle Physics, Astrophysics and Cosmology

Bolsas de Doutoramento



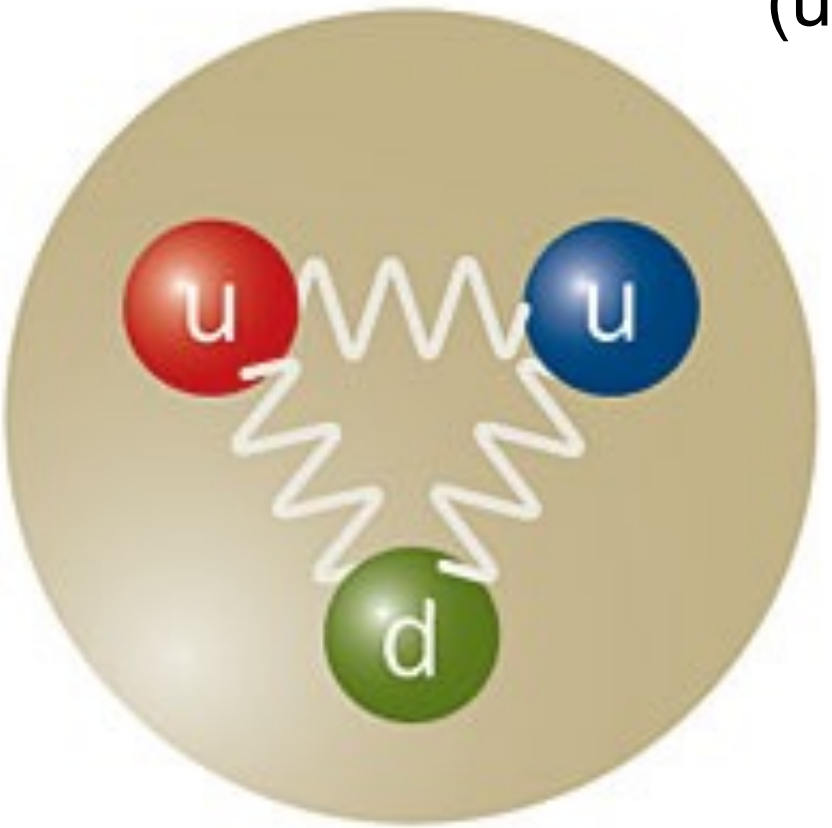
FCT – ProtoTera PhD Grants

O Universo para compreender, ...



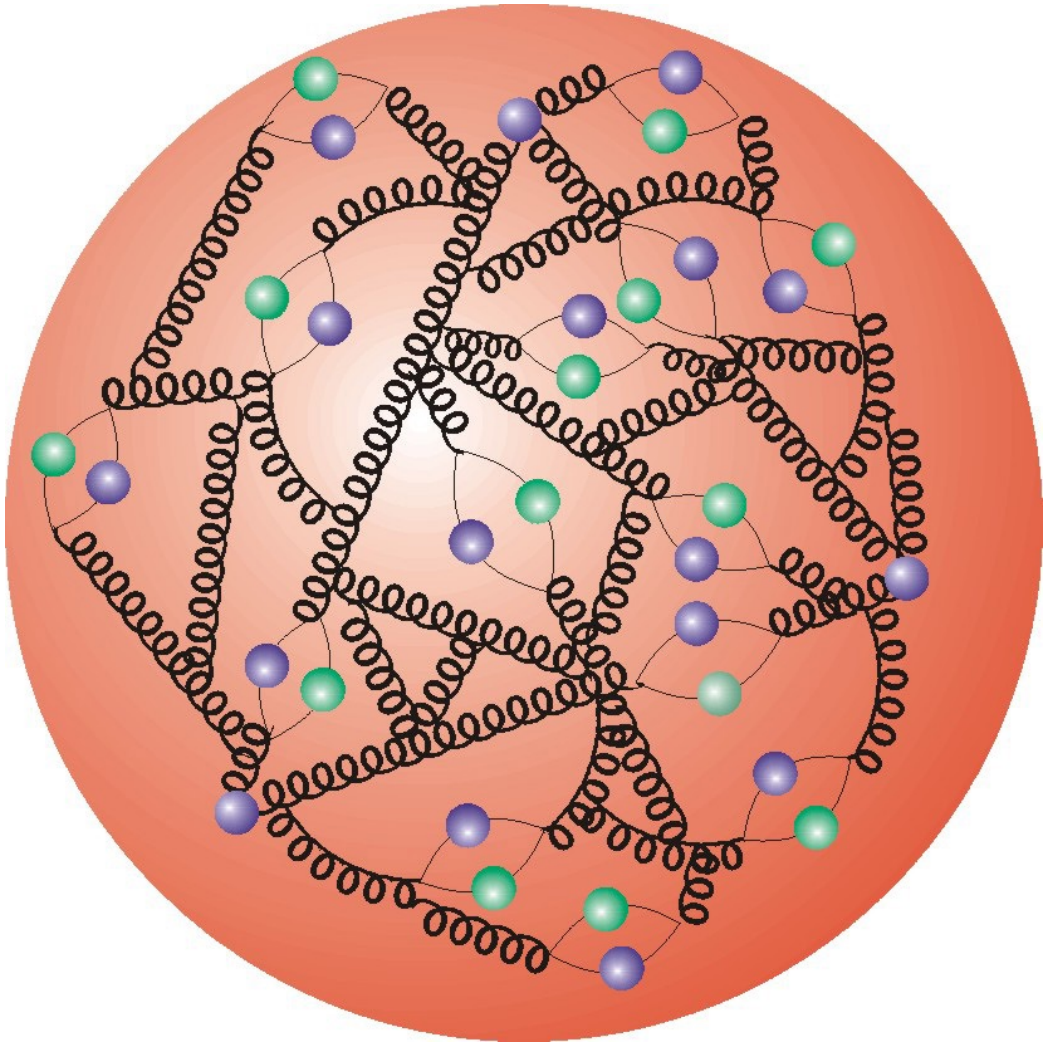
O Protão

(uud)



10^{-14} m

O Protão



A massa do Protão

$$M = \sum m_{quarks} + E_{campo}/c^2$$

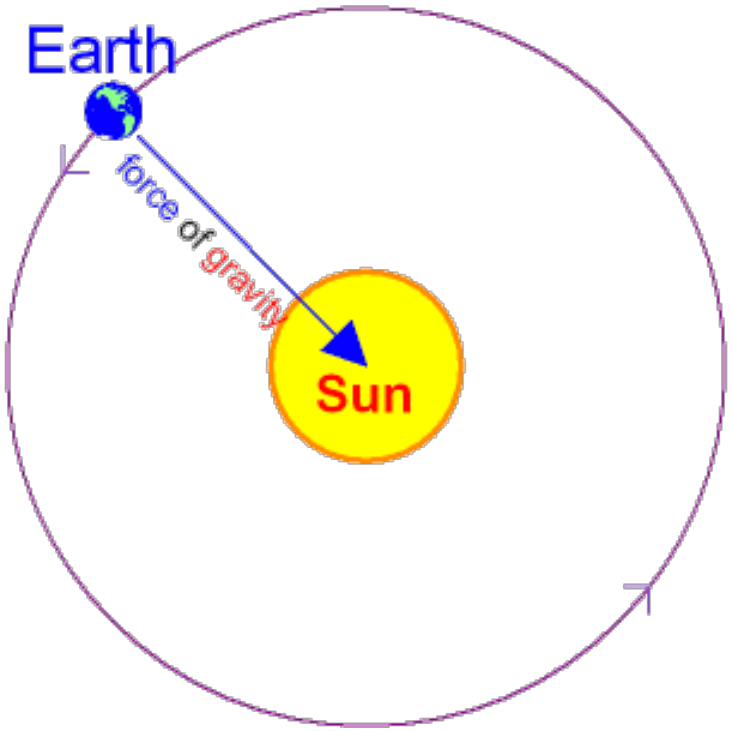
A massa do Protão

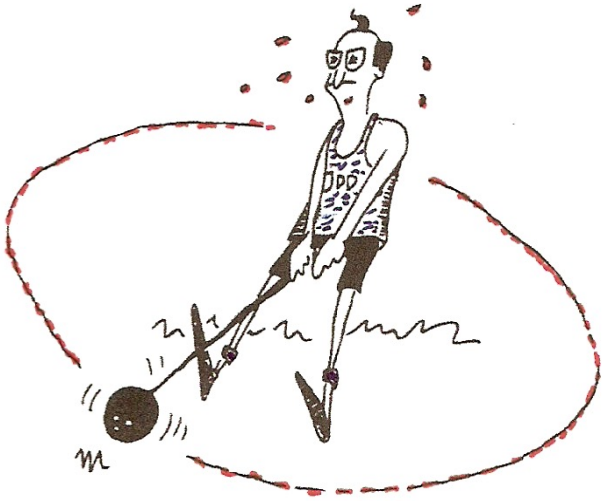
$$M = \sum m_{quarks} + E_{campo}/c^2$$

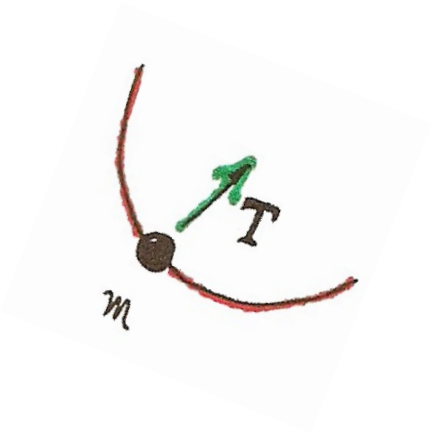
$$938 \sim (\quad 15 \quad + \quad 925)\ MeV/c^2$$

$$1\ MeV/c^2 \sim 1.8\ 10^{-30} Kg$$

A massa do Sol





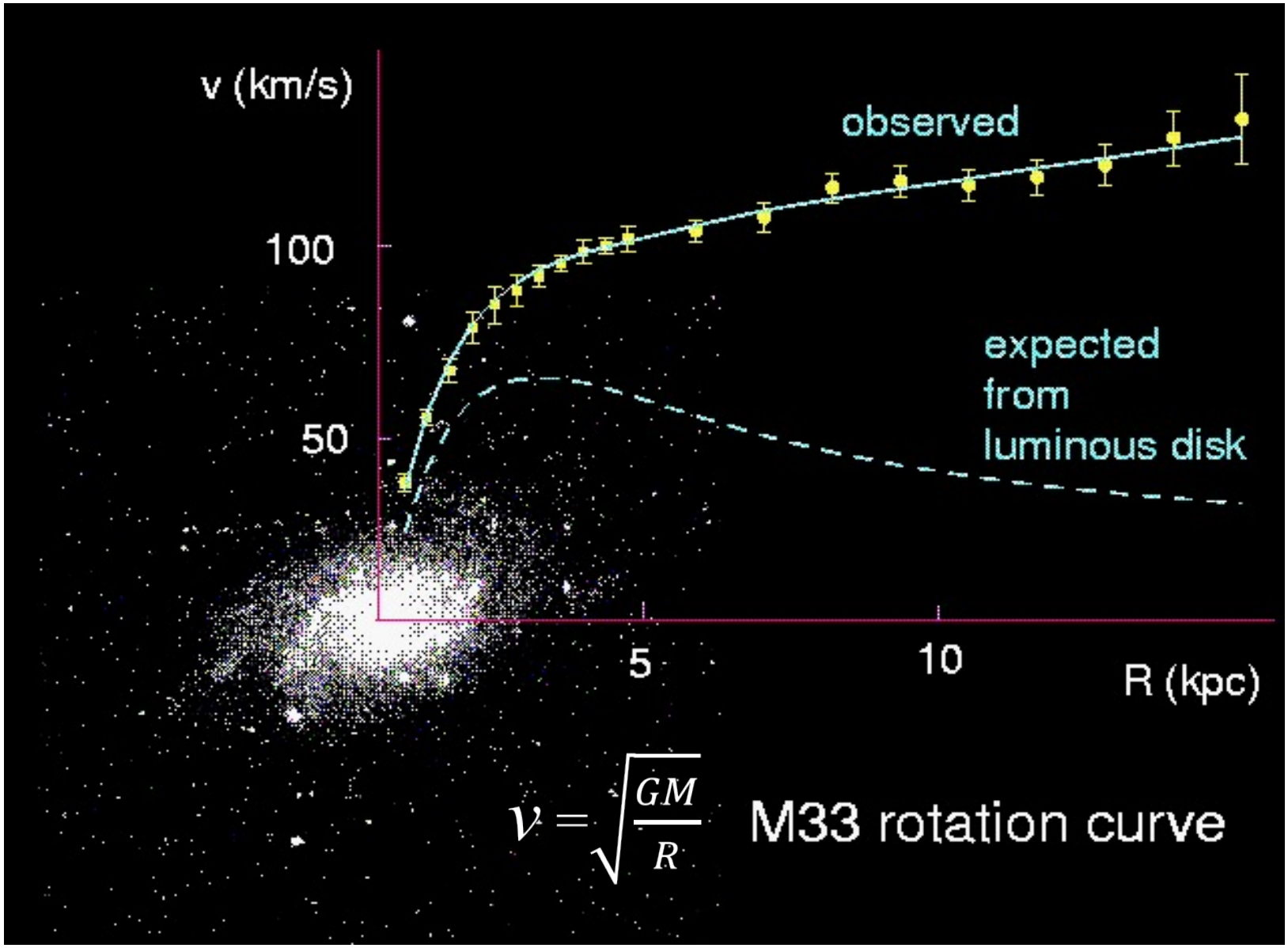


$$F_c = \frac{m\ v^2}{r}$$

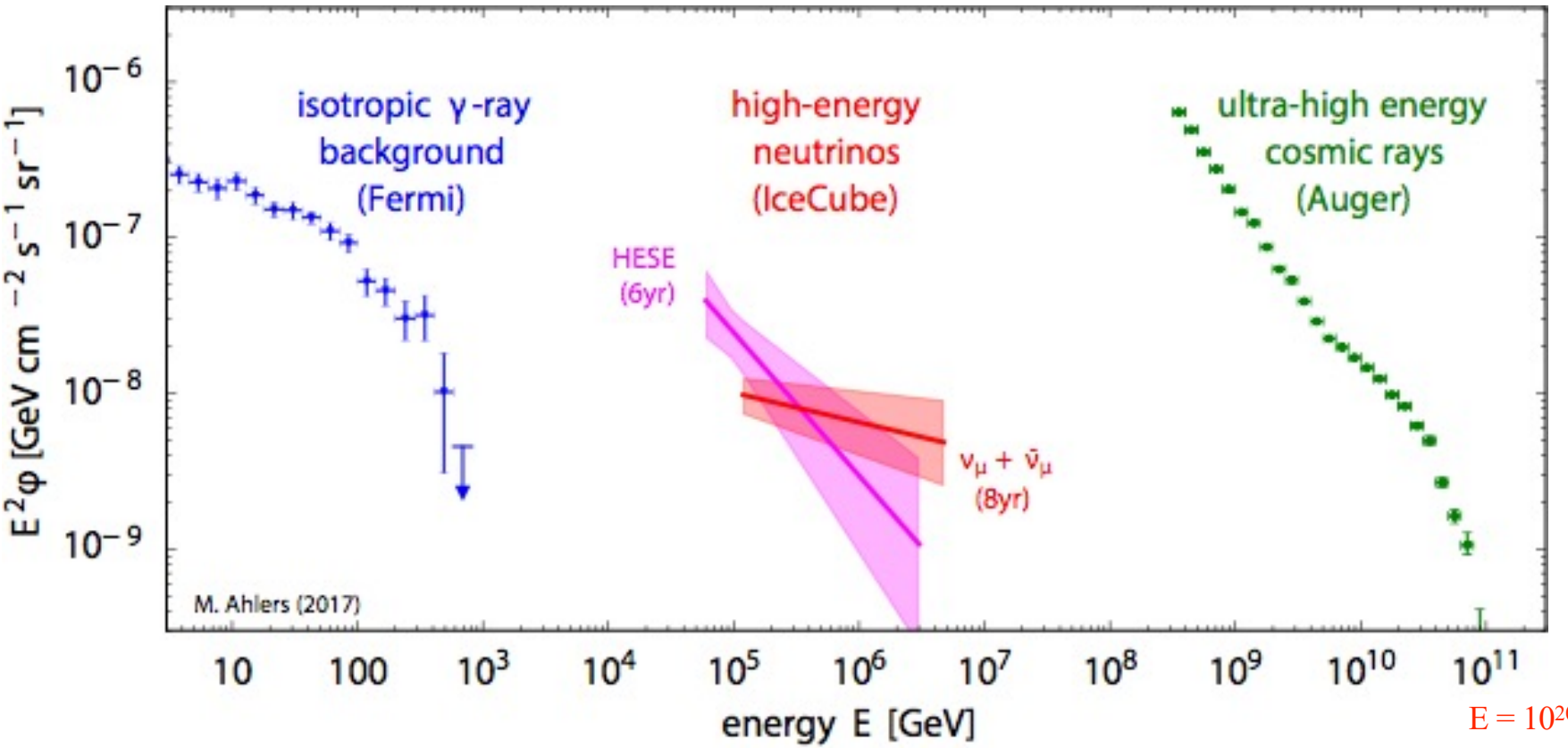
$$\frac{m_T\ v^2}{R} \approx G\ \frac{m_T\ M_S}{R^2}$$

$$M_S \sim 1.98\ 10^{30}\ kg$$

A velocidade de rotação das estrelas periféricas

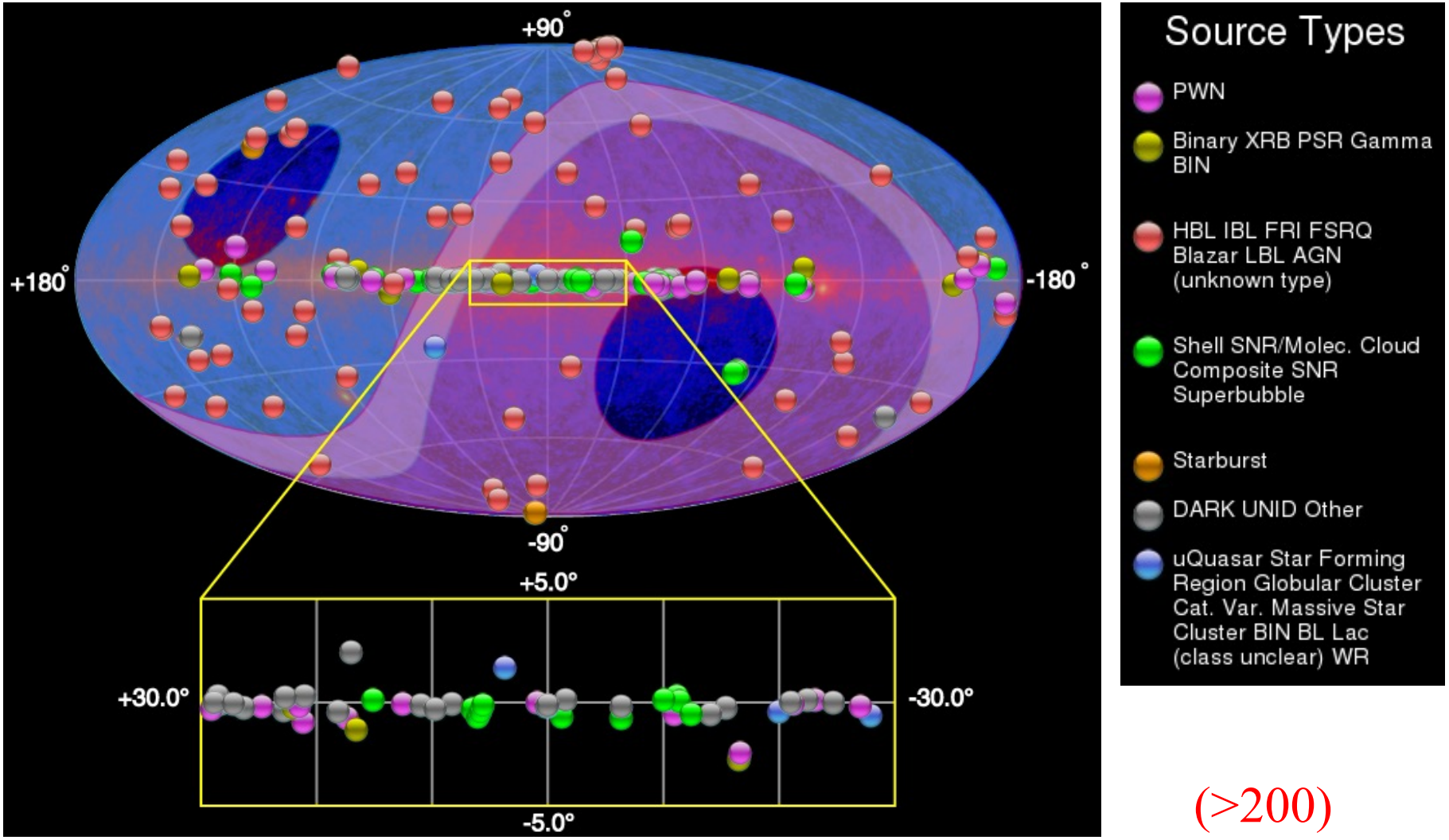


The Universe at the highest energies !



Energy density per decade similar in all three messenger particles

Fontes raios gamma de alta energia (TeV)



(>200)

As bolhas de Fermi