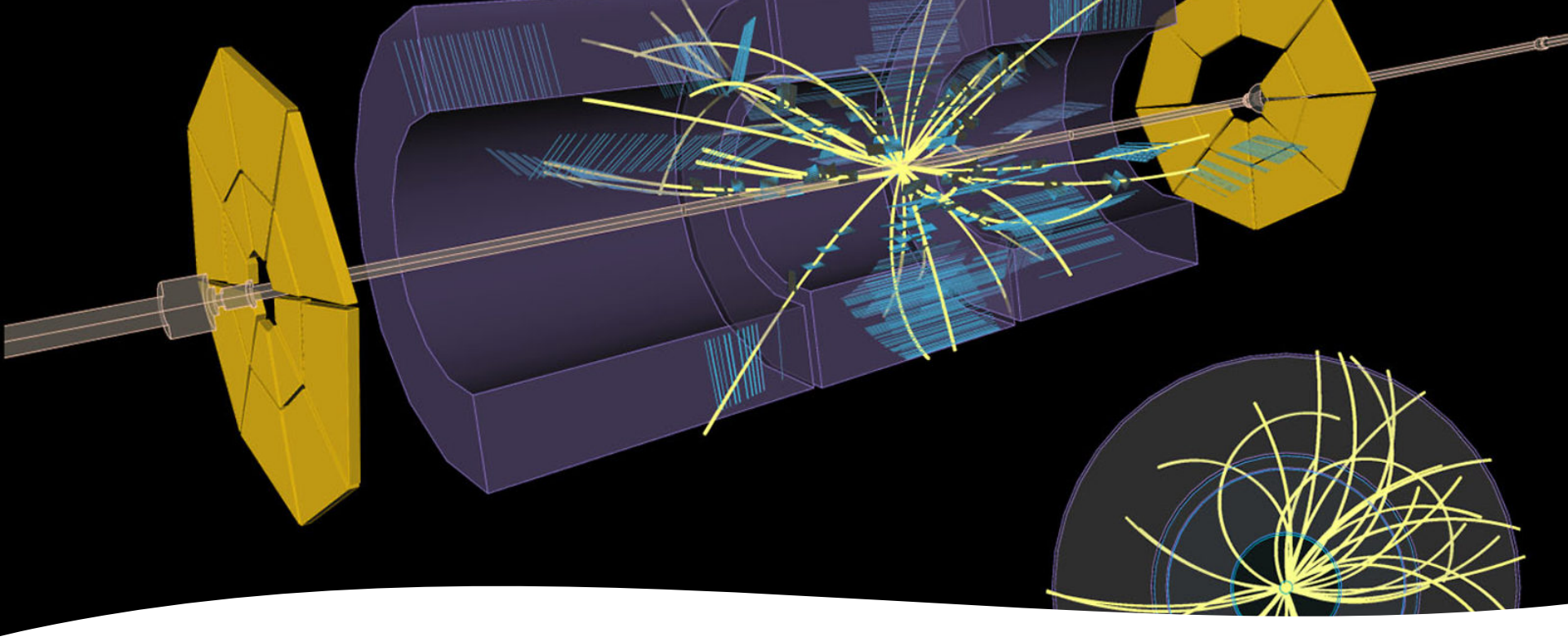


Particule în detector

Detecting Particles

Paul Gravila

Universitatea de Vest din Timisoara

High School Students Internship Programme
CERN 2021

Cuprins

- O cursă a energiilor înalte de (aproape) 100 de ani.
- Detectorul de particule. Procese în avalanşă.
- Detectorul modern şi era digitală.
- LHC şi bilanţul de energie.
- Virtual şi real.

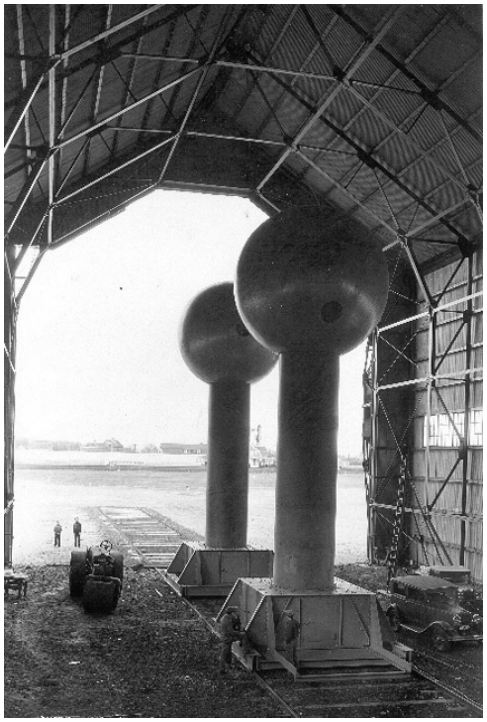
Ideea initiala:

1927: E. Rutherford “este necesar sa construim o sursa care sa furnizeze din abundenta proiectile cu energii mai mari decat sursele naturale alfa si beta”

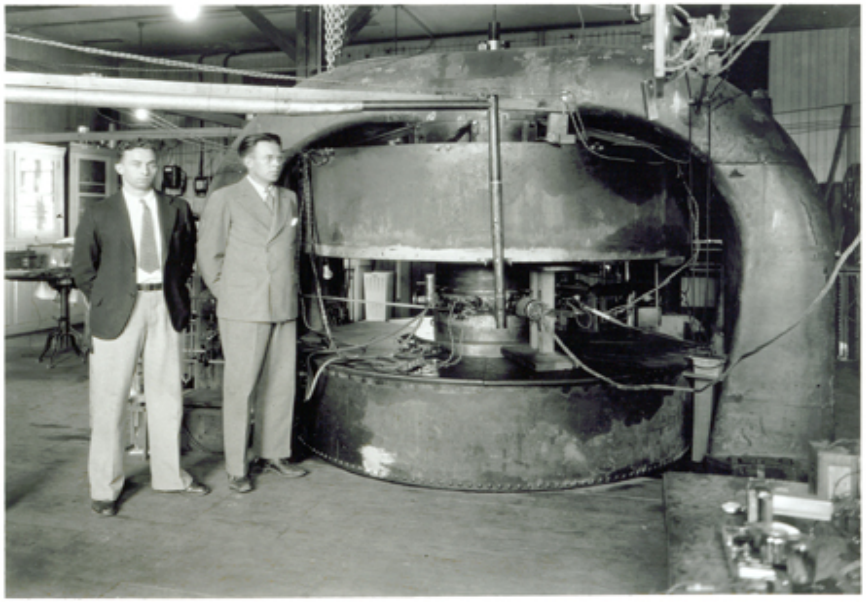
What we require is an apparatus to give us a potential of the order of 10 million volts which can be safely accommodated in a reasonably sized room and operated by a few kilowatts of power. We require too an exhausted tube capable of withstanding this voltage… I see no reason why such a requirement cannot be made practical.

O cursă a energiilor înalte de (aproape) 100 de ani.

1930

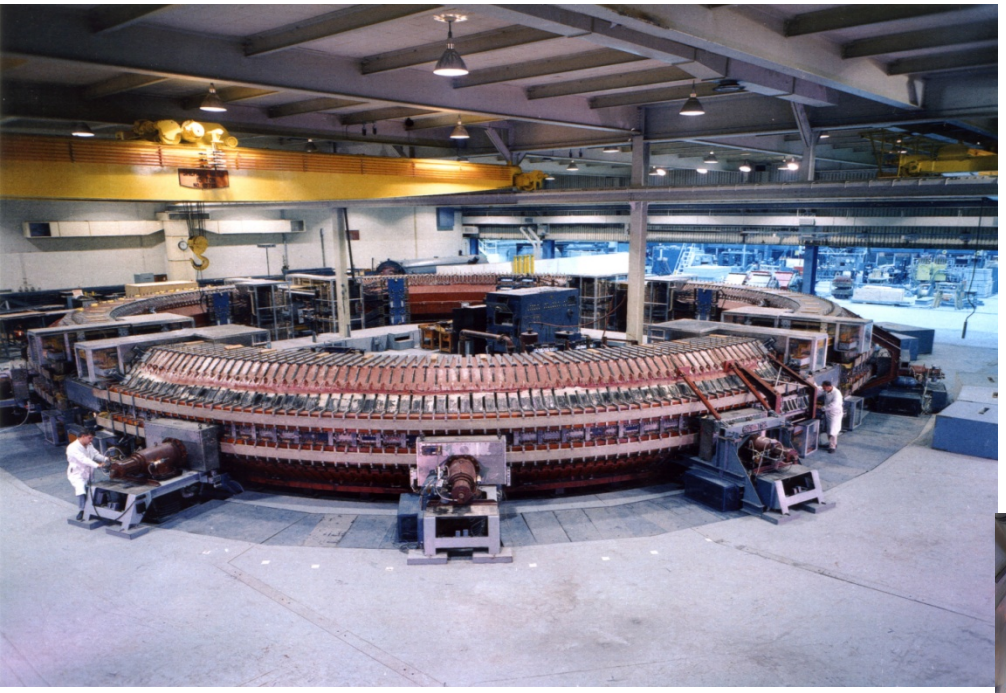


A.D.	Energie in unităţi uzuale pentru particule	Unităţi macro-scopice (S.I)
1930	1 MeV	10^{-13} J
1950	1 GeV	10^{-10} J
1980	1 TeV	10^{-7} J
Prezent	10 TeV	10^{-6} J

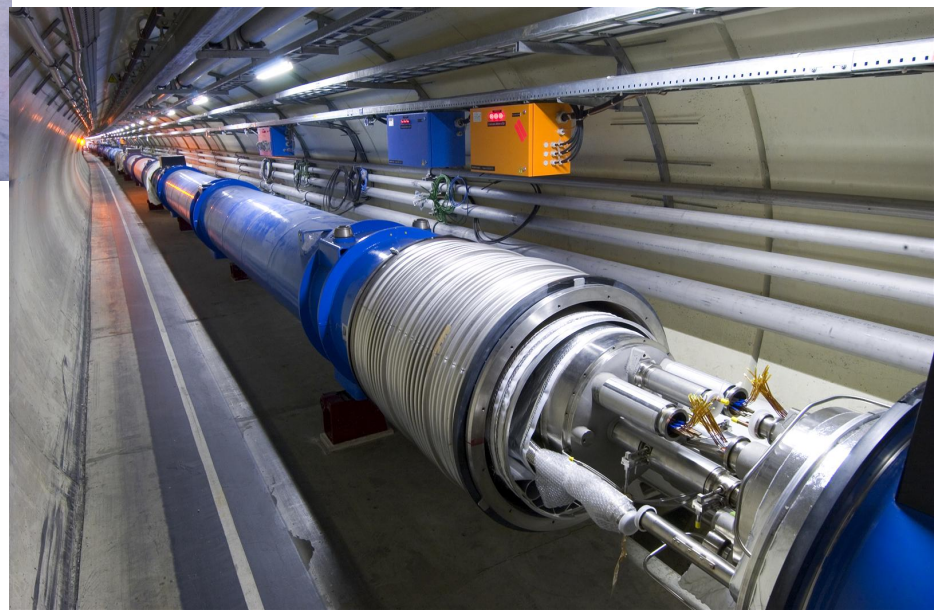


1940

Sincrotroane de protoni, la 70 de ani si patru ordine de marime diferenta.

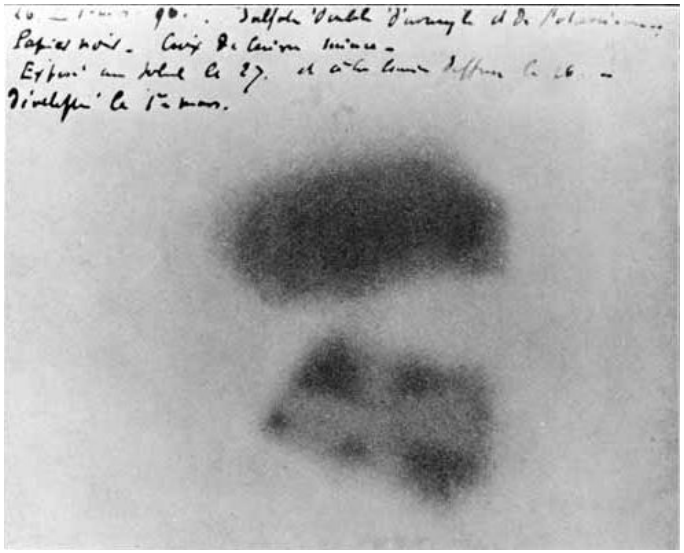


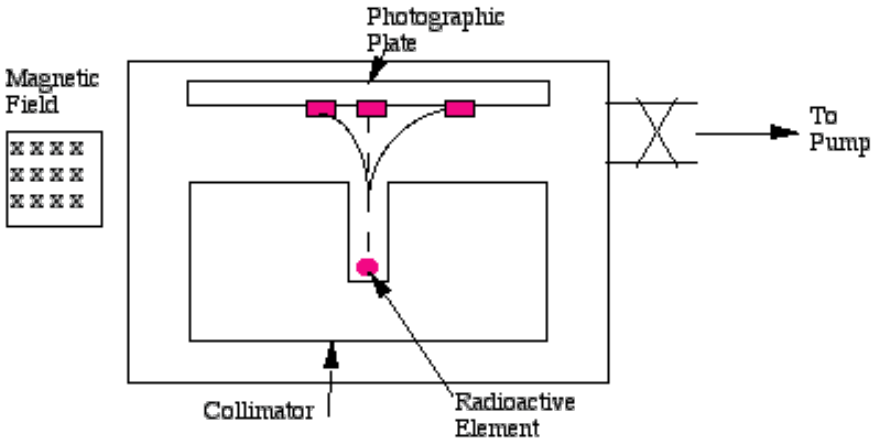
“Cosmotron” (Brookhaven 1952, 3 GeV)

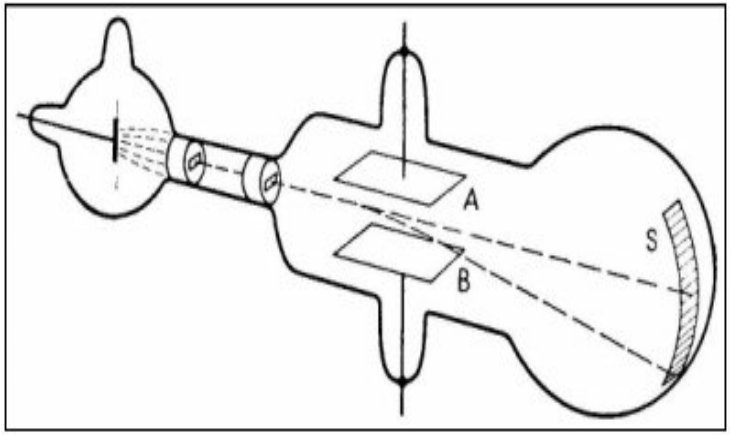


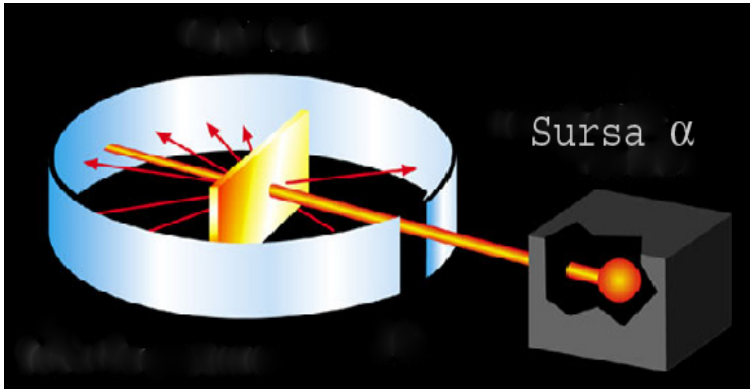
LHC (13000 GeV)

Detectarea particulelor. "Proto"-detectoare:
descoperirea radioactivităţii (Bequerel 1896),
descoperirea electronului (Thomson 1897),
descoperirea nucleului (Rutherford 1912)





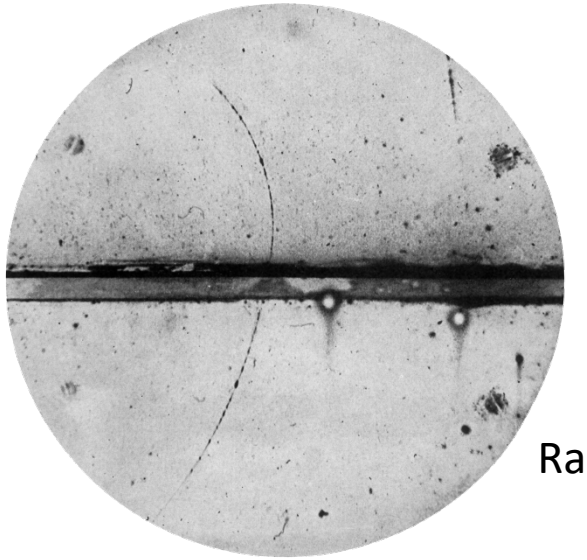




Medii supracritice.

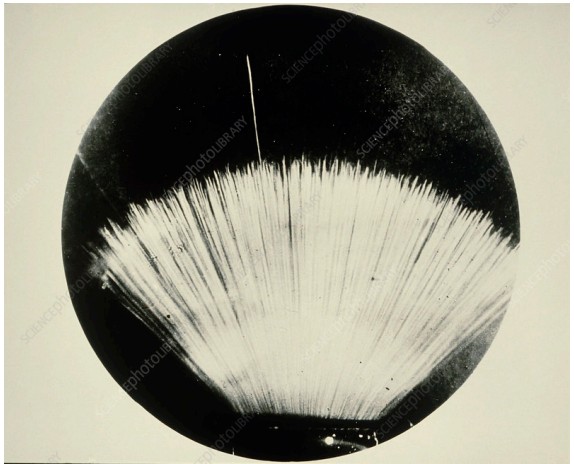
Detectoare capabile sa puna in evidenta particule individuale!
Stabilesc o punte de legatura intre lumea micro- si macroscopica

Camera cu ceaţă (Wilson)
1911 – 1950 (Nobel 1927)



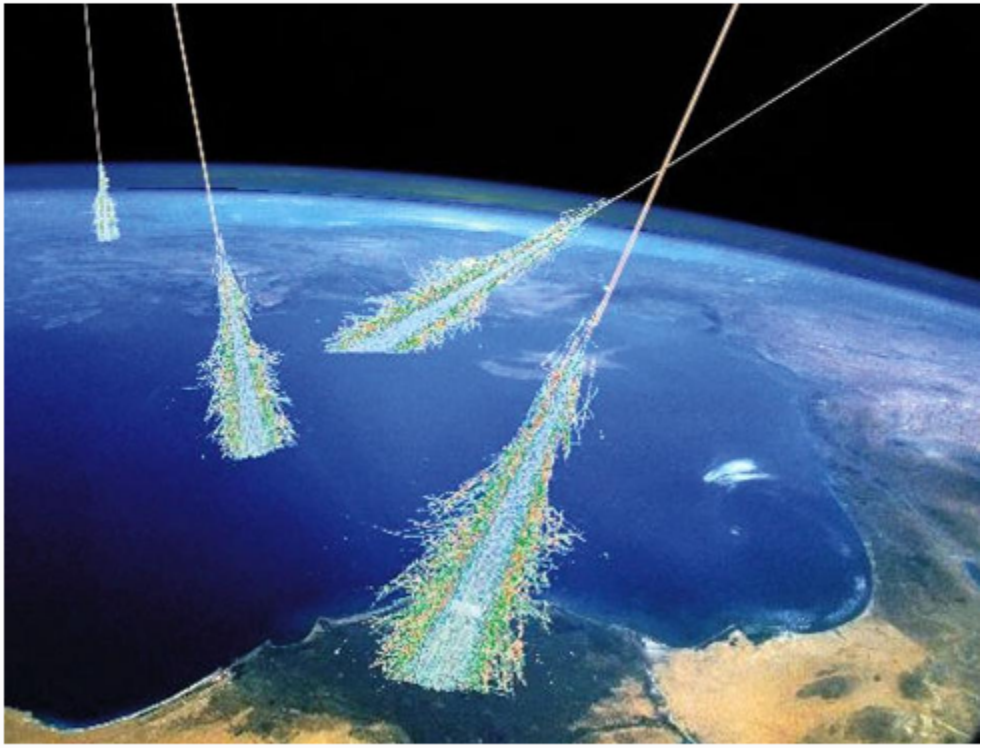
Radiatii alfa, beta. Traim cu radiatii!

Descoperirea pozitronului
(Dirac 1928, Anderson 1932)
Descoperirea miuonului (1936)



Why The Unexpected Muon Was The Biggest Surprise In Particle Physics History

Ethan Siegel Senior Contributor
Starts With A Bang Contributor Group
Science
The Universe is out there, waiting for you to discover it.



Cosmic rays, which are ultra-high energy particles originating from all over the Universe, strike ... [+] SIMON SWORDY (U. CHICAGO), NASA

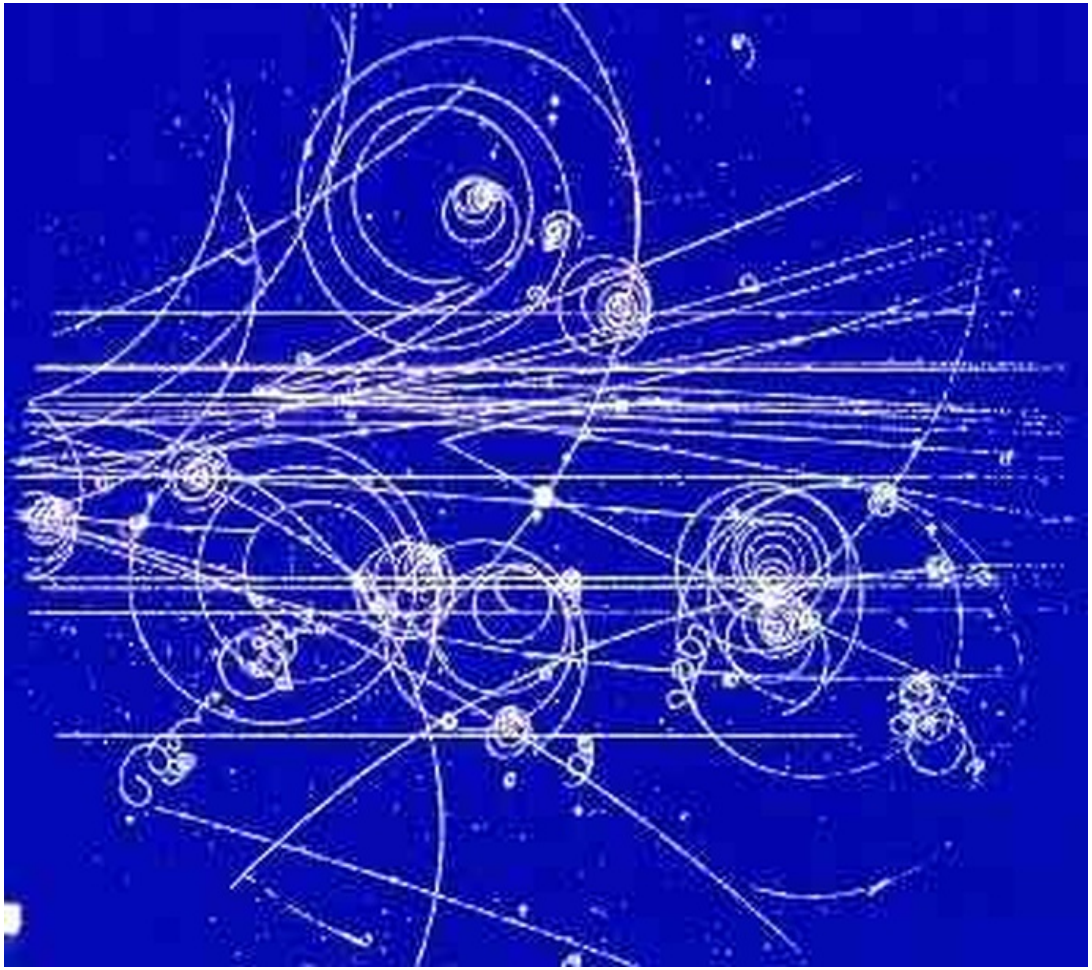
Back in the early 1930s, there were only a few known fundamental particles that made up the Universe. If you divided up the matter and radiation we observed and interacted with into the smallest possible components we could break them up into at the time, there were only the positively charged atomic nuclei (including the proton), the electrons that orbited them, and the photon. This accounted for the known elements, but there were a few anomalies that didn't quite line up.

https://www.forbes.com/sites/startswithabang/2021/02/03/why-the-unexpected-muon-was-the-biggest-surprise-in-particle-physics-history/?sh=87c9caf71519

Apogeul detectorilor analogici

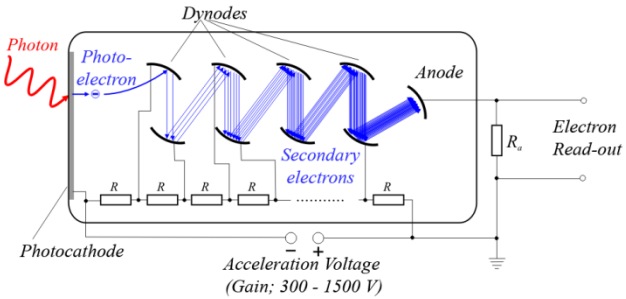
Camera cu bule (Glaser, 1952, Nobel 1960)
Big European Bubble Chamber (Cern, 1970-1984)

Apogeul detectorilor analogici

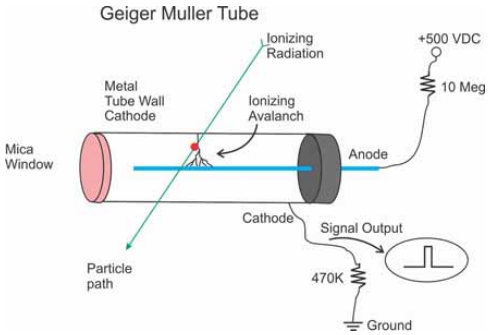


Apogeul detectorilor analogici

Alte detectoare care folosesc efecte de avalansa

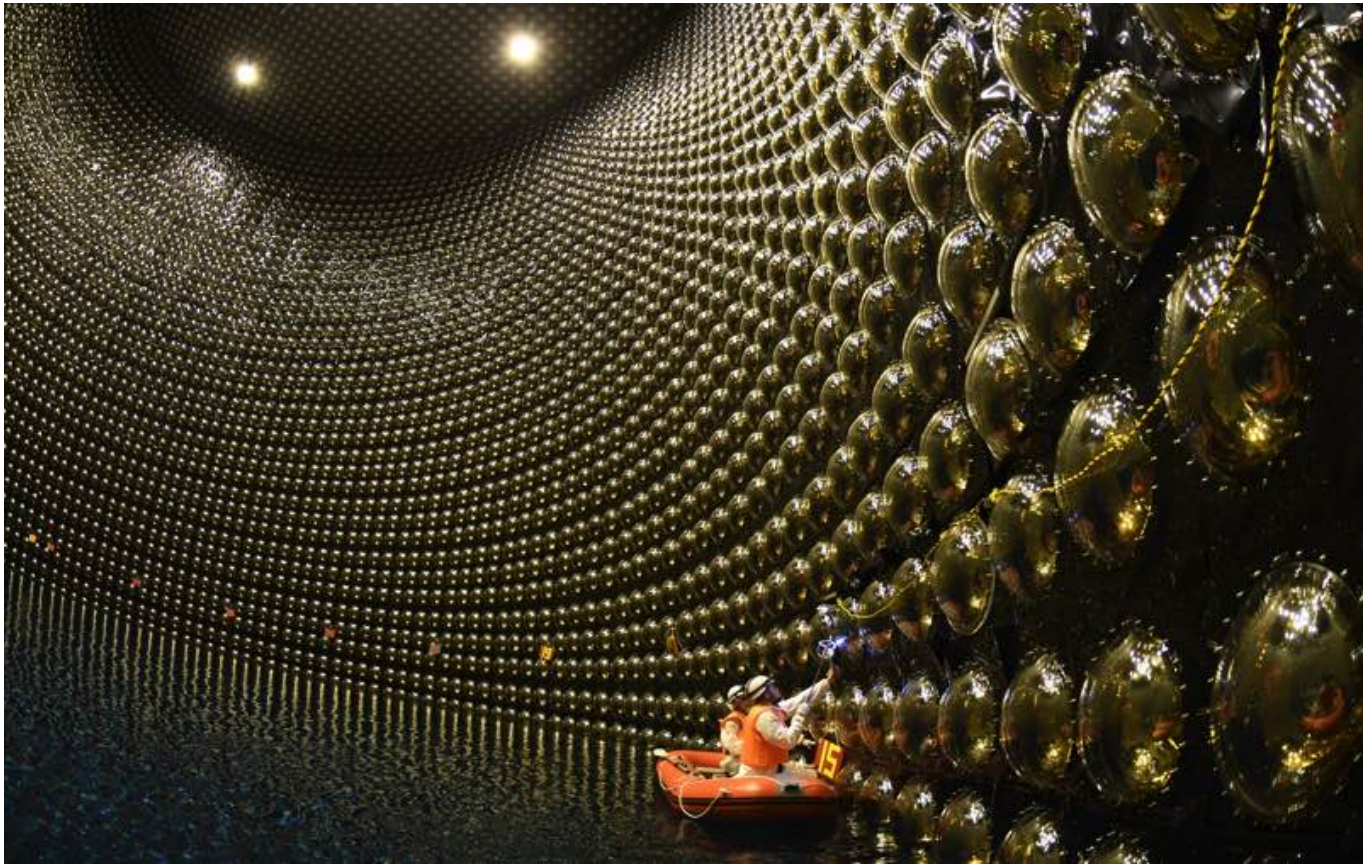


Tub fotomultiplicator



Contor Geiger Muller

Detector de neutrini
Kamiokande



Era digitală

Detectorul modern *plus* computere

(din toata lumea)

- Creșterea energiei. Este nevoie de calorimetre masive pentru a stopa particulele.

- Începe vânătoarea de evenimente rare. Creşterea luminozitătii, a ratei evenimentelor - chiar şi de un milion de ori,

- Trecerea de la descoperiri pe baza analizării câtorva evenimente, la statistica a milioane de evenimente,

- Tehnologii solid state in constructia detectorului,

- Dezvoltarea incredibilă a puterii de calcul si a rețelelor de computere.

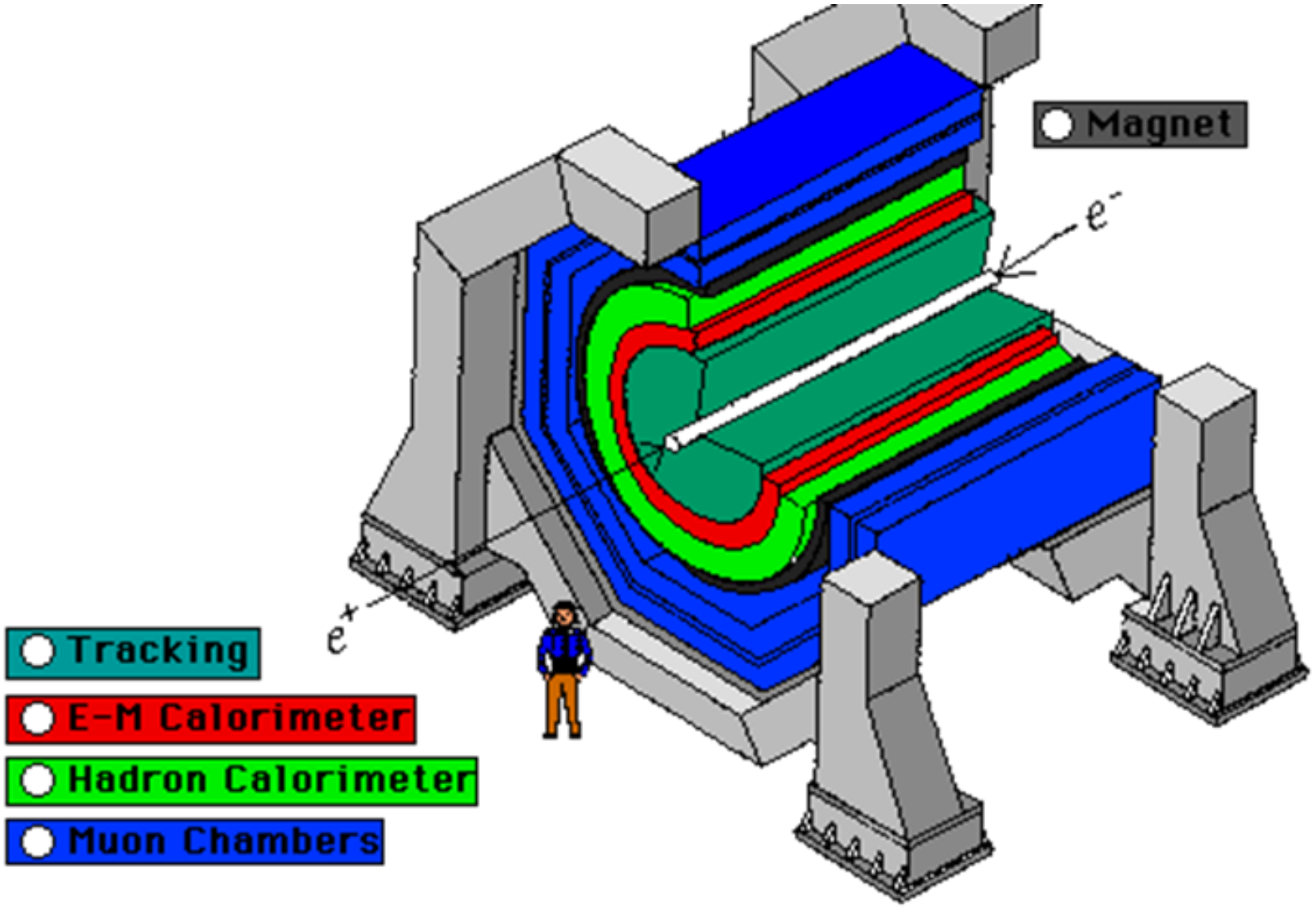
- Experimentul devine global (participăm şi noi!)

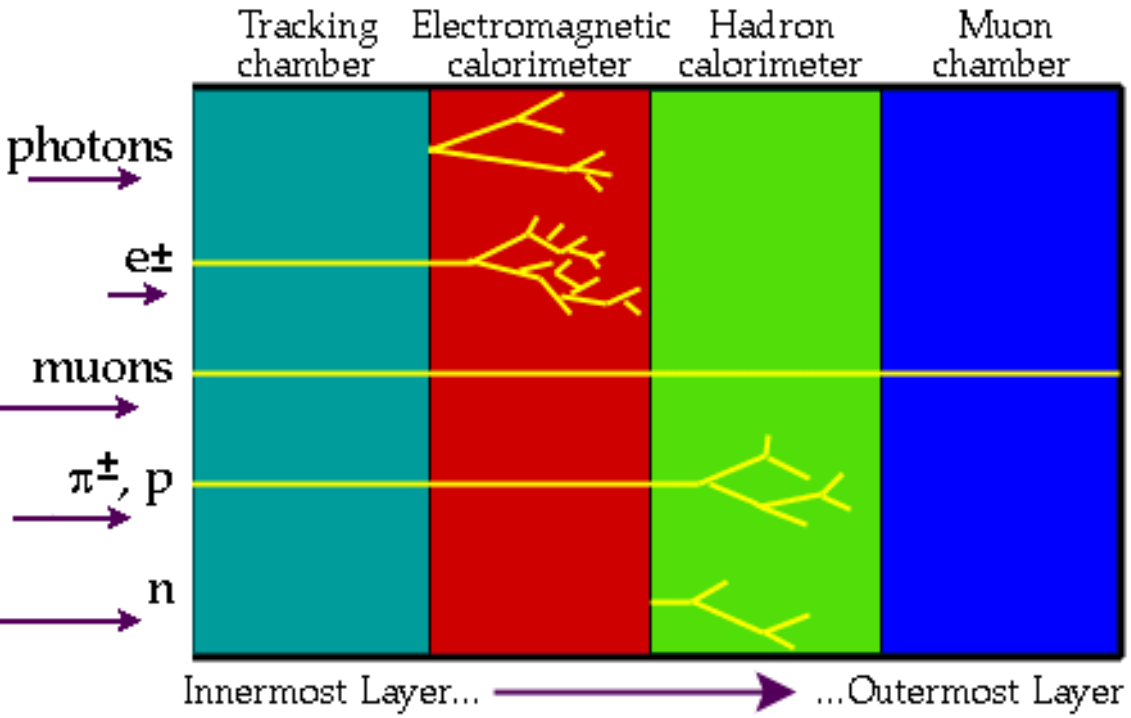
Evenimentele NU mai sunt vizualizate direct. Nu mai vedem traiectoriile particulelor.
Semnalele electrice de la detector sunt digitalizate si prelucrate de algoritmi computerizati.

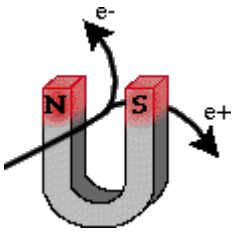
https://home.cern/news/news/experiments/seeing-invisible-event-displays-particle-physics

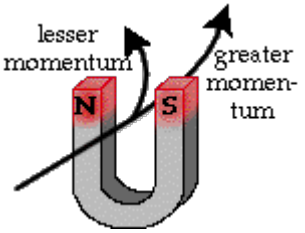
Detectorul modern, schema de principiu

www.particleadventure.org

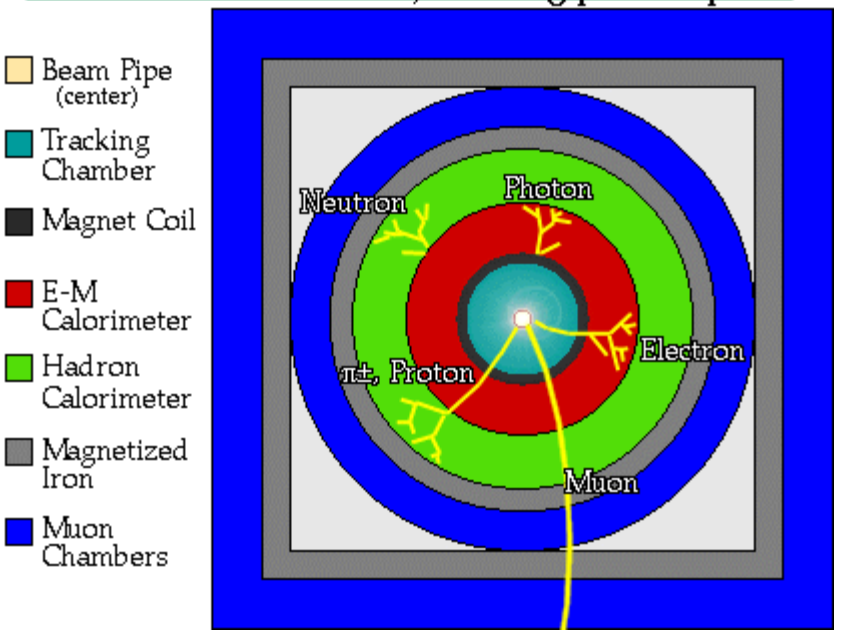






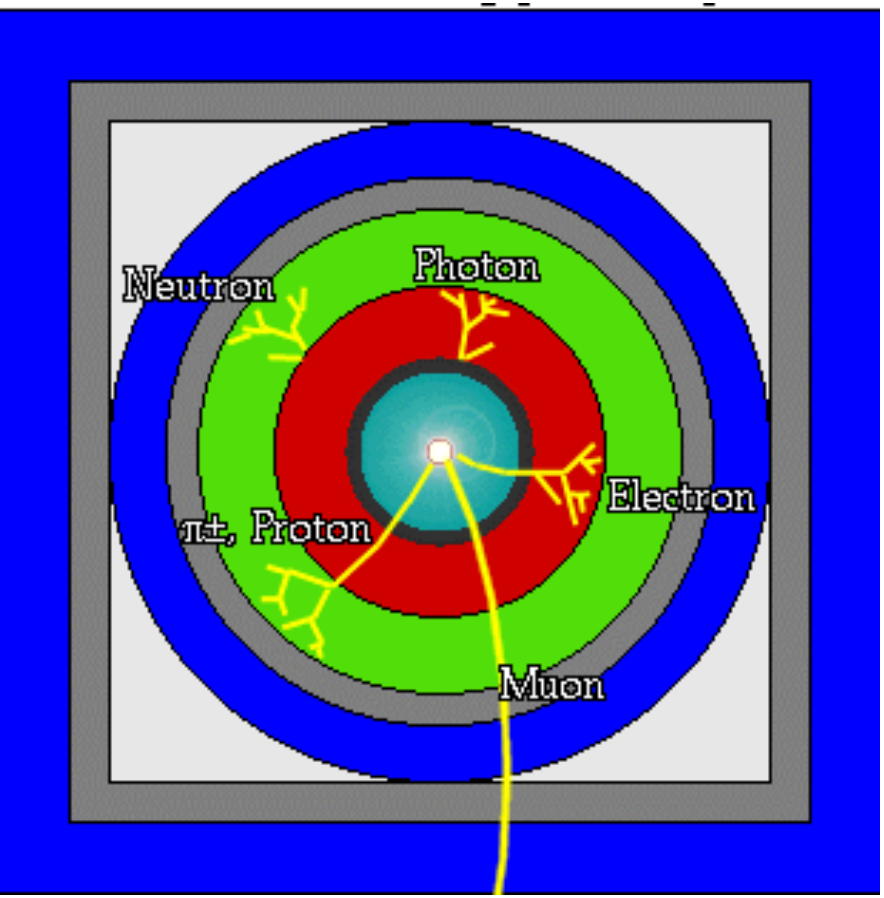


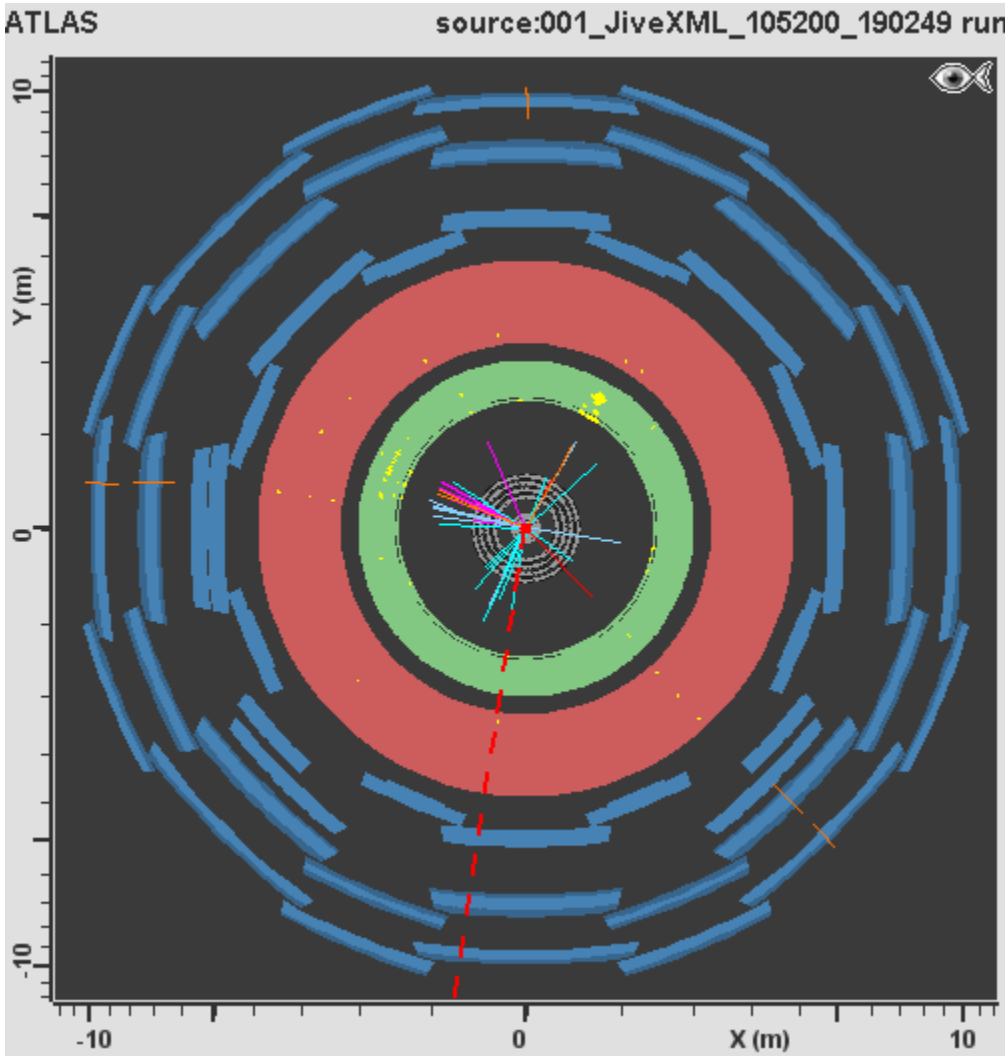
A detector cross-section, showing particle paths

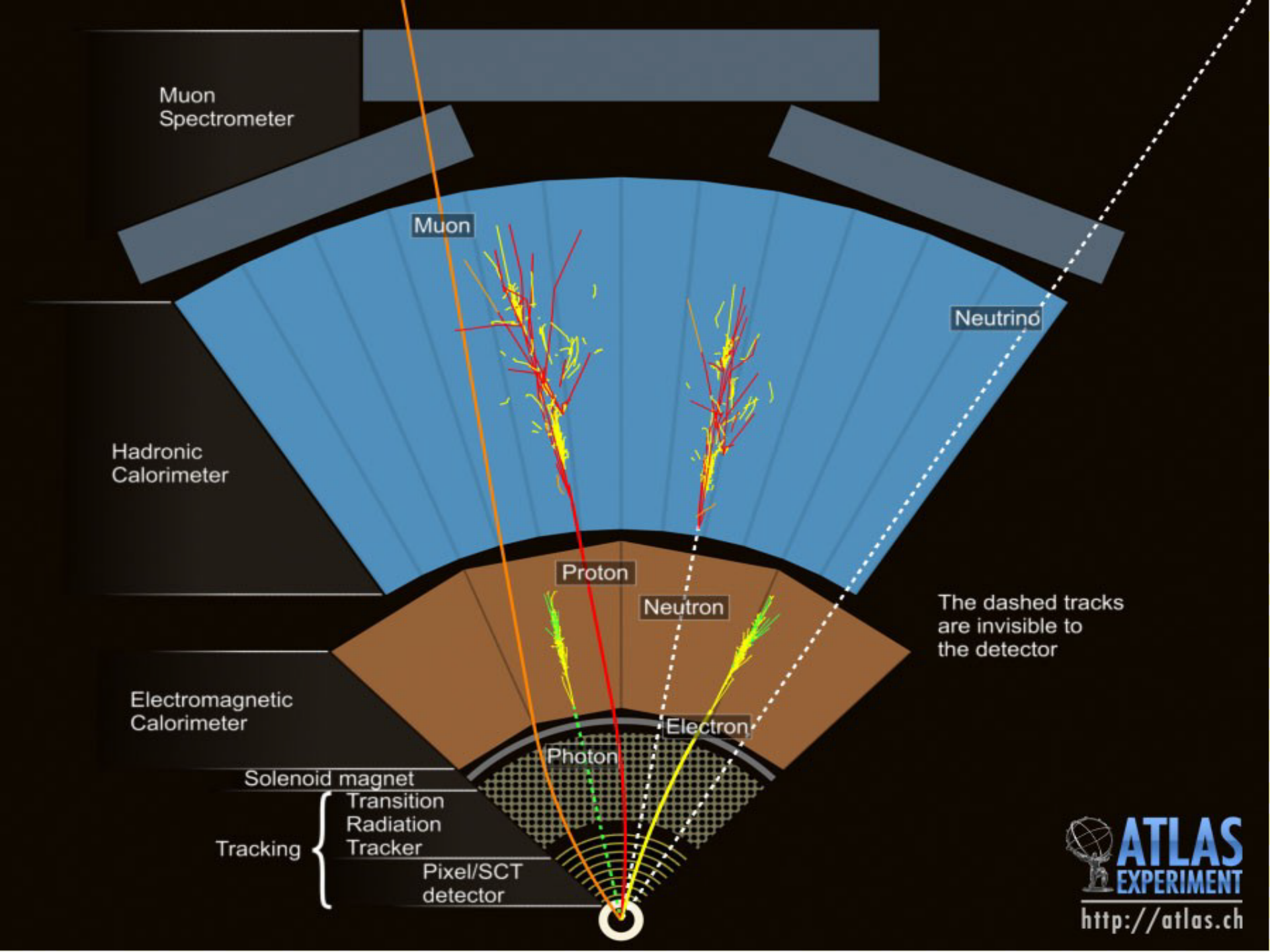


http://particleadventure.org/component_detector.html

Schema de principiu
versus
o reprezentare mai fidelă a detectorului, cu un eveniment real!






Muon Spectrometer
Muon
Neutrino
Hadronic Calorimeter
Proton
Neutron
The dashed tracks are invisible to the detector
Electromagnetic Calorimeter
Electron
Photon
Solenoid magnet
Tracking
Transition Radiation Tracker
Pixel/SCT detector
ATLAS EXPERIMENT
http://atlas.ch

Programul de vizualizare ATLANTIS

(în versiunea MINERVA = Masterlass Involving Event Recognition Visualised with Atlantis)

De ce mai avem nevoie de vizualizare?

1. Profesional. Ajutor pentru scrierea de algoritmi, vizualizarea unor evenimente individuale.
Rulează pe monitoare in camera de control ATLAS
Preparare de imagini pentru publicații științifice

2. Comunicare știință - societate: **IPPOG = Intl. Particle Physics Outreach Group**
Evenimente Masterclass pentru elevi (buni!) de liceu.

Un exercițiu fantastic pentru a ne apropia de cel mai mare experiment de fizica fundamentală din toate timpurile!

Programul de vizualizare rulează pe monitoare in camera de control ATLAS

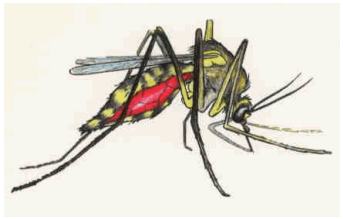
Energii in LHC: numere mari si mici

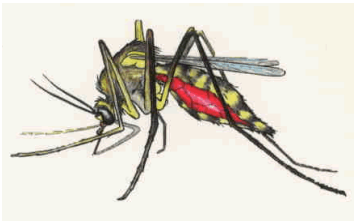
Energia de accelerare LHC:

7 + 7 TeV ~ **$2 \cdot 10^{-6}$ J** /coliziune

Factor Lorentz ~ 7000,

viteza ~ 99,999999% din c



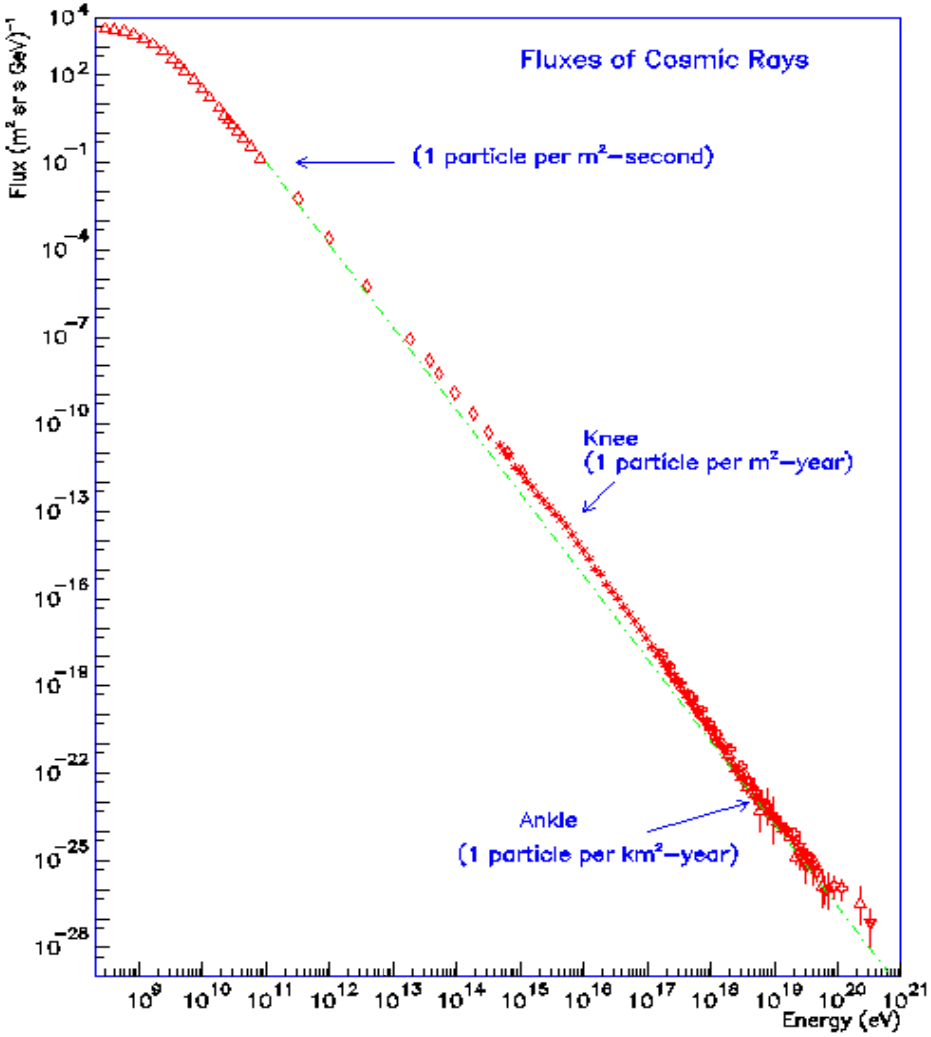


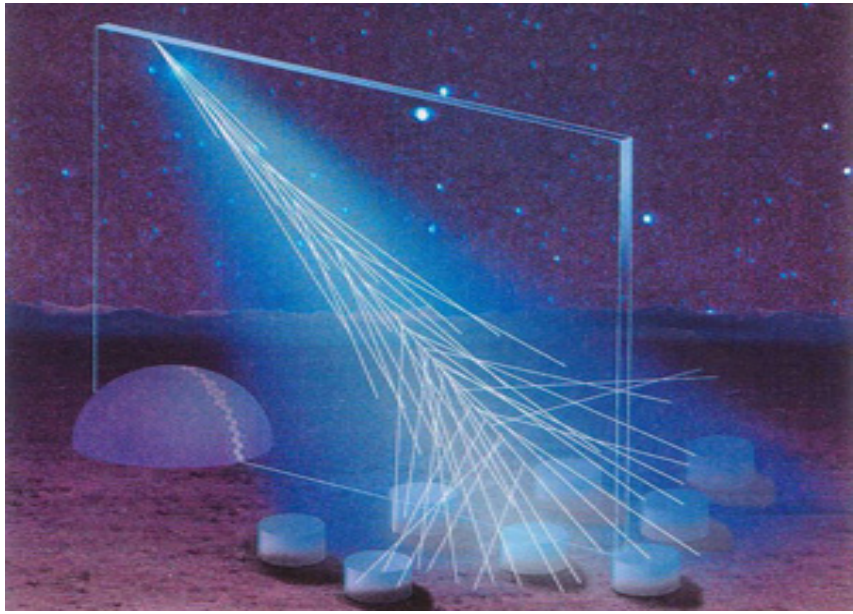
Dar: avem **$3 \cdot 10^{14}$** protoni in fascicul:

Total: **600 MJ** (cca 100 kg TNT)

concentrati pe **10^{-10}** g de materie (H+)

Particule cosmice de ultra-inalta energie (1 EeV = 1 exa-eV = 1.000.000 TeV)





Energia disponibila pentru reactie (CM):

LHC: E_{CM} = E1 + E2 = 14 TeV

Particule cosmice*:*

E_{CM} = = max. 200 TeV

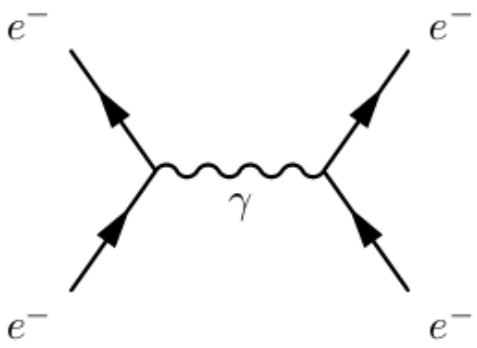
Fortele fundamentale

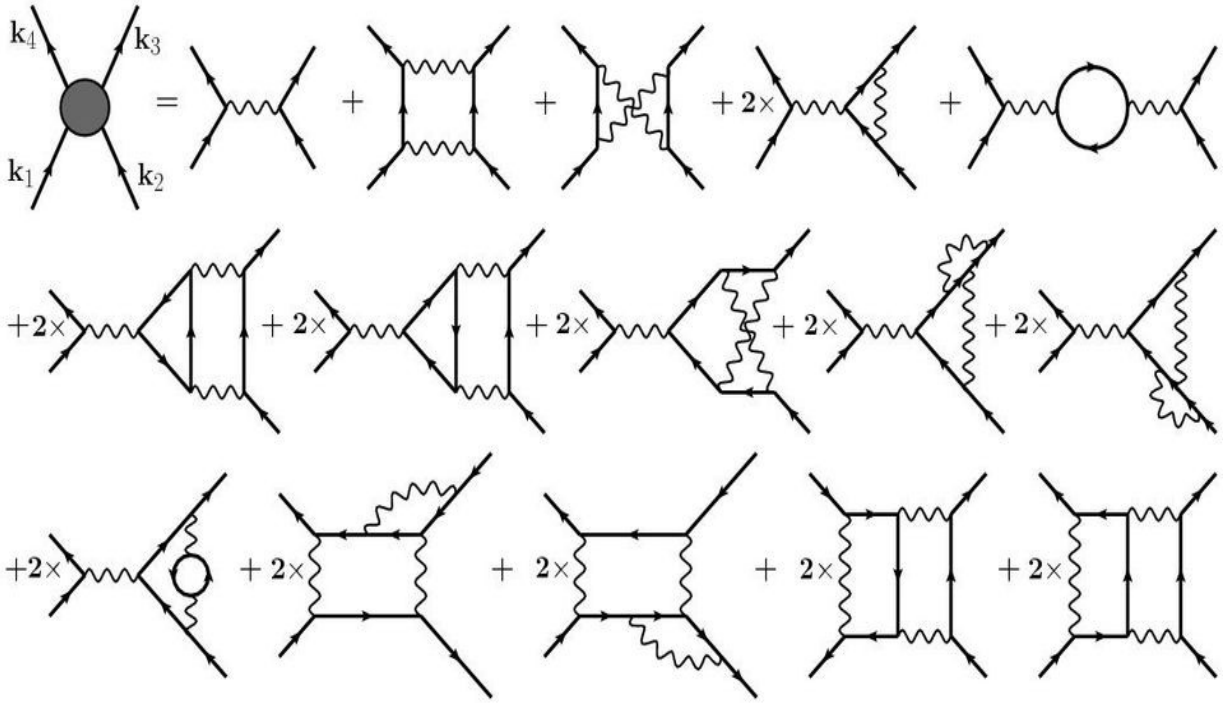
Forta	Cuplaj (tărie)	R (m)	Bozon de interactiune	Sarcina fortei	Actiune asupra:
Nucleară Tare	1	10^{-15}	8 x gluon (g) m=0, s=1, Q=0	"Culoare" RGB	Quarkuri, hadroni
EM (Electro-magnetică)	10^{-2} (1/137)	∞	Foton (γ) m=0, s=1, Q=0	Sarcina electrica +/-	Particule incarcate electric
Nucleară Slabă	10^{-5}	10^{-18}	3 bozoni Weinberg: W^+, W^- m=80 GeV* Z^0 m=91 GeV; s=1	Izospinul slab	Universal
Gravitatie	10^{-40}	∞	Graviton (?) M=0, s=2, Q=0	Masa	Universal

* Obs. In Fizica Particulelor masuram atat energii, cat si impulsuri si mase, in multipli de eV (MeV, GeV, …)

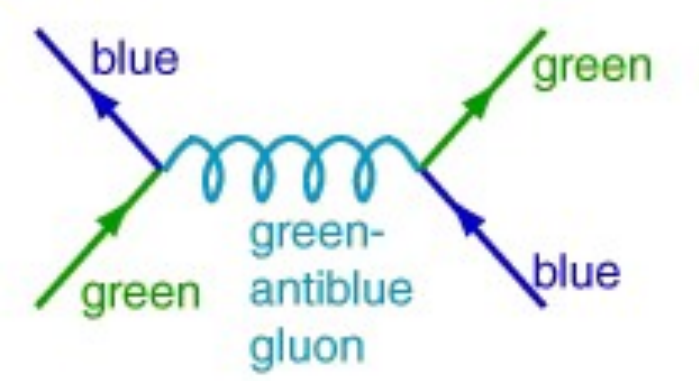
Imagini: http://particleadventure.org/standard_model.html

Diagrame Feynman ale interactiunilor





Interactiune **EM**
intre doi electroni
intermediată de ***foton.***
Teorie:
Electrodinamica cuantică (QED)

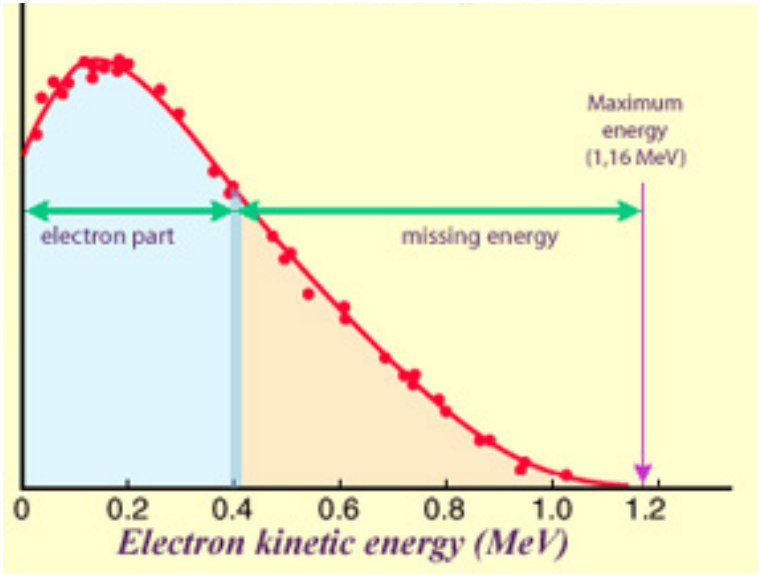


Interactiune **nucleară tare** intre doua quarkuri
intermediată de ***gluon.***
Teorie: Cromodinamica cuantică (QCD)

Ipoteza neutrinului (Pauli 1930). Energie lipsă!

$$^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + e^- + \bar{\nu}_e$$

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



Ipoteza neutrinului – W. Pauli (1930)
"Energie lipsă"

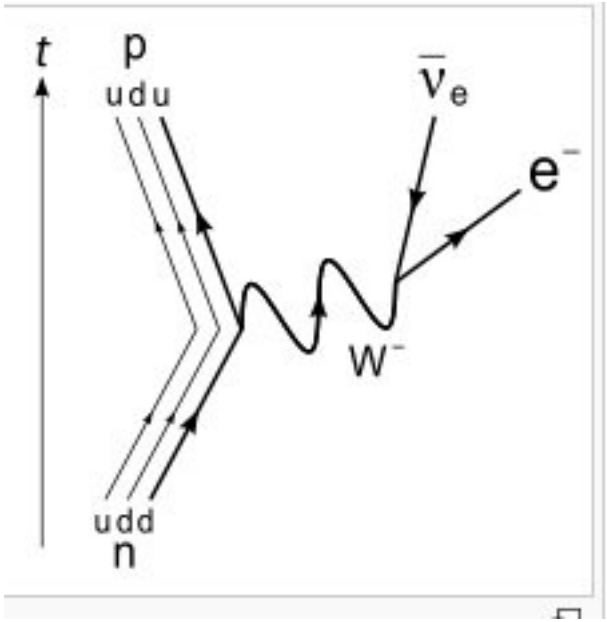
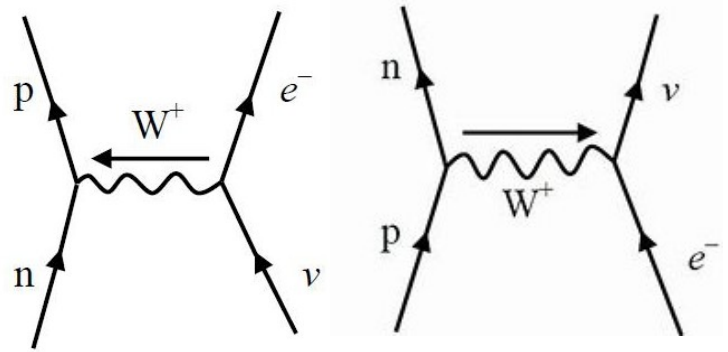


Diagrama dezintegrării. Forta nucleară slabă.



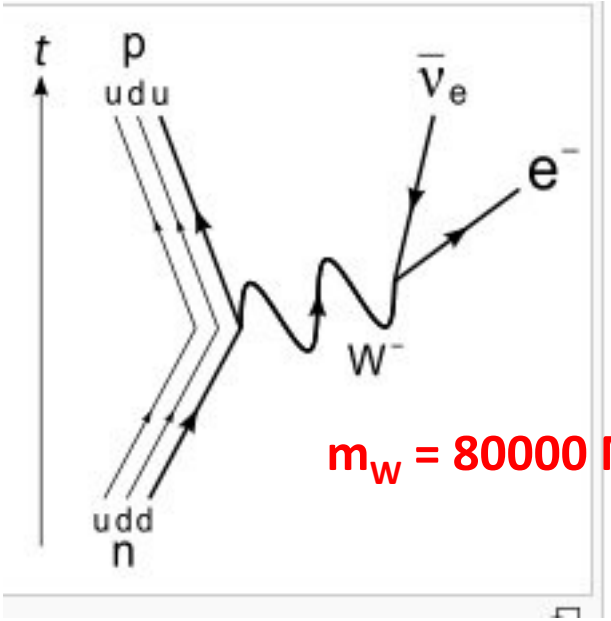
Captura de neutrin / electron

Bozonul W(einberg) ca particulă (extrem de-) virtuală

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

$m_p = 938.2$ MeV

$m_\nu = 0$



$m_e = 0.5$ MeV

$m_W = 80000$ MeV !!!

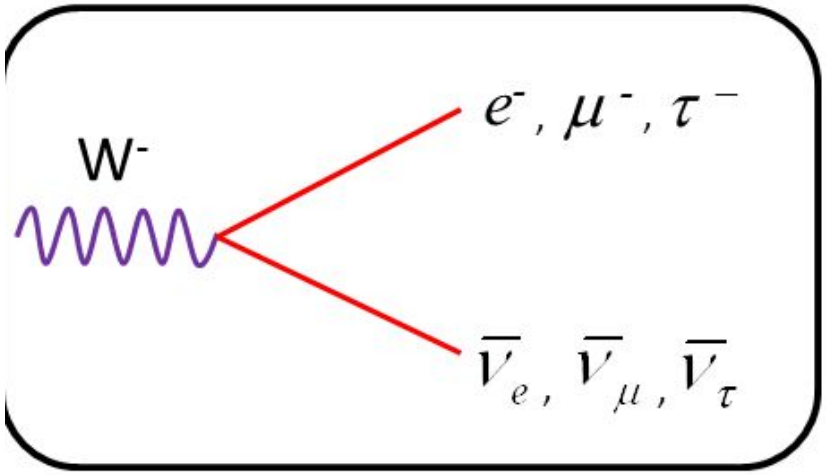
$m_n = 939.5$ MeV

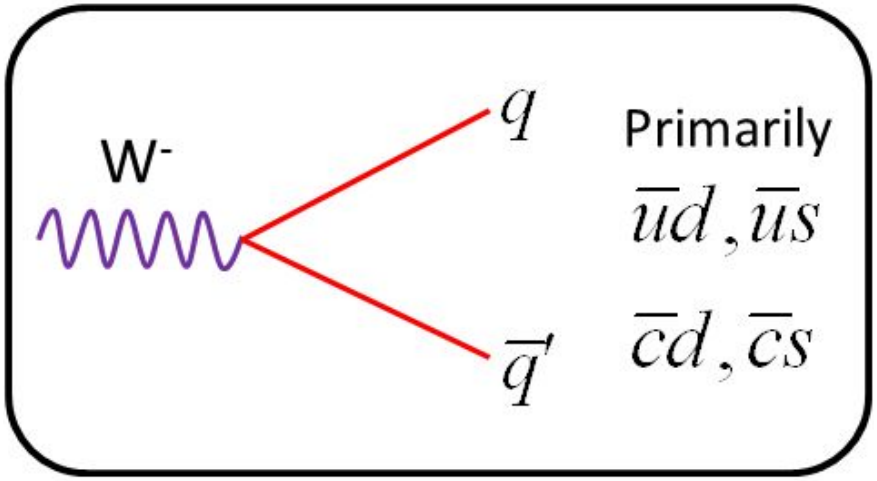
$$\Delta E \, \Delta t \geq \frac{\hbar}{2}$$

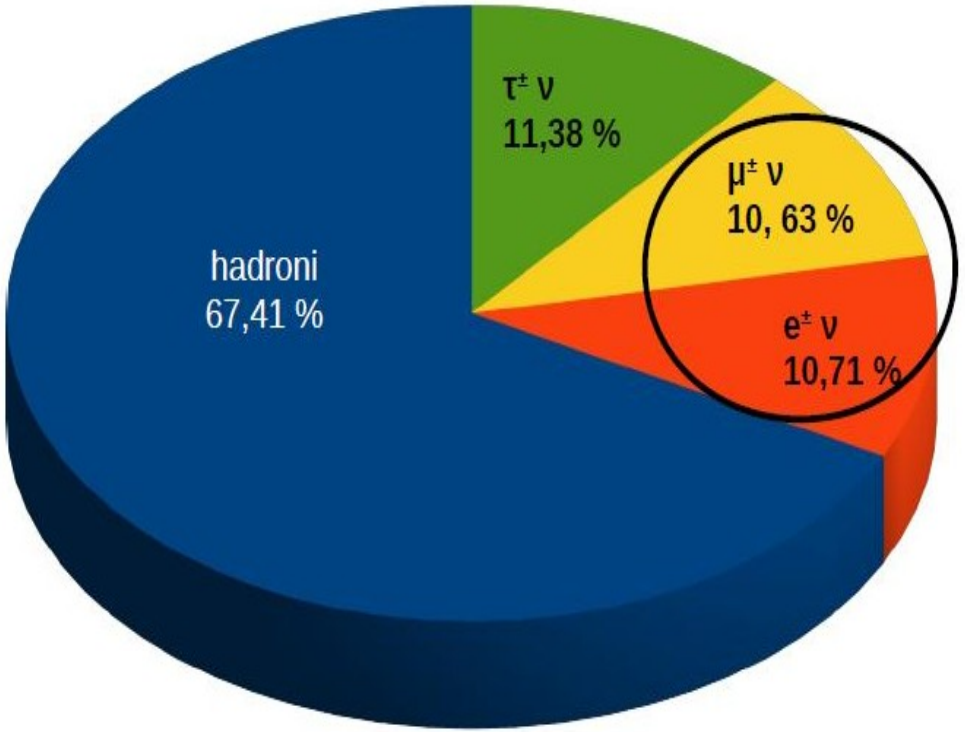
Relatia de nedeterminare Heisenberg

Bozonul de interactiune W este **virtual**

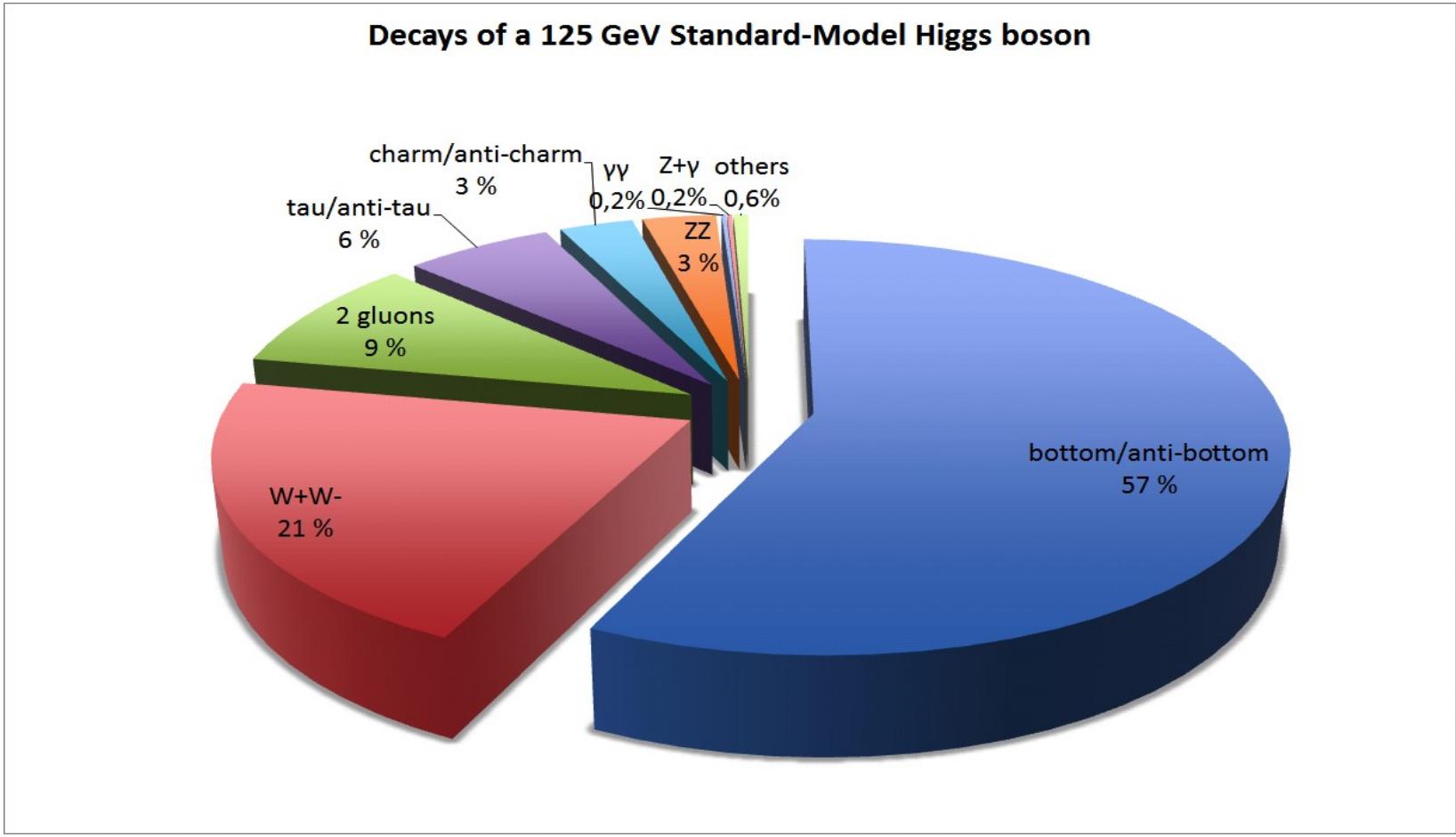
Bozonul Weinberg (W^+, W^-) ca particulă reală
(SPS - CERN 300 GeV, 1983)

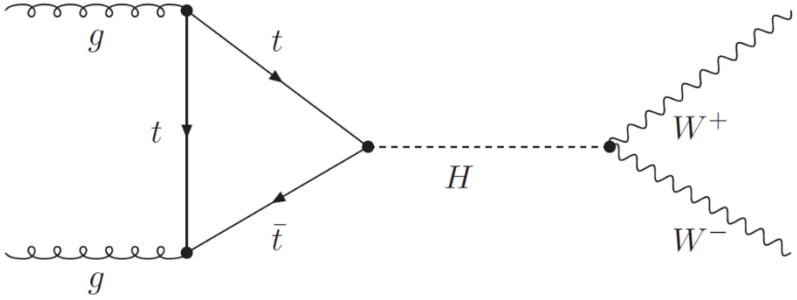






Descoperirea bozonului Higgs si legatura cu W^+, W^-



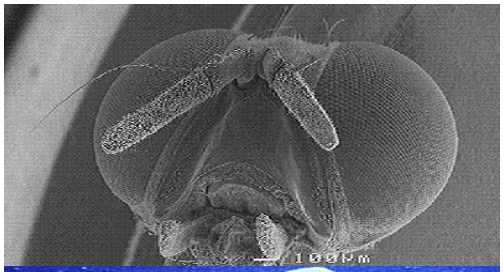


http://www.scholarpedia.org/article/The_Higgs_Boson_discovery

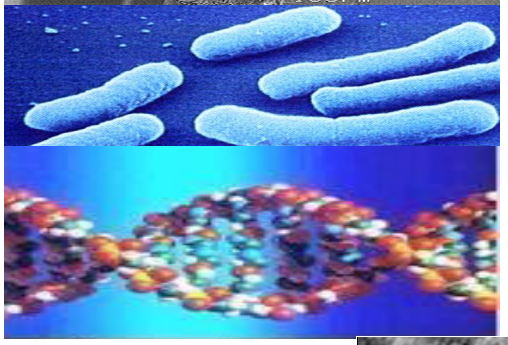
Backup slides…

Scara dimensiunilor mici

- 10^{-4} = 0.1mm

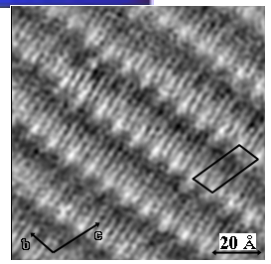


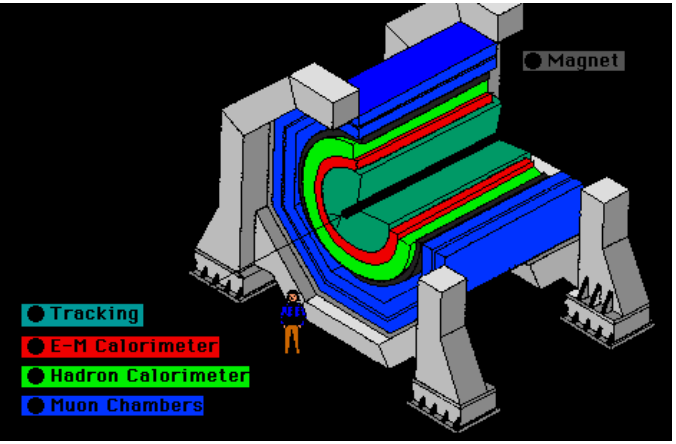
- 10^{-6} = 1µm



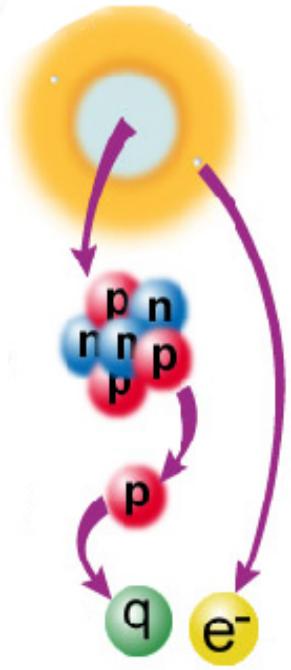
- 10^{-8} = 10nm

- 10^{-10} = 1Å





- 10^{-12} = 1pm



- 10^{-15} = 1fm

- 10^{-18} = 1am

10^{-19} LHC

$$L = L_1 + L_0 + L_{1/2}$$

$$L_1 = \frac{1}{8g^2}F^2(V) + \frac{1}{8g^2}tr\ F^2(W)$$

$$= tr[\frac{1}{2}(\nabla\phi)^\dagger(\nabla\phi) + \frac{1}{4}\lambda^2(\phi^\dagger\phi - \frac{1}{2}m^2)^2]$$

$$\nabla\psi) + tr\left[\begin{pmatrix} \Lambda_+ & 0 \\ 0 & \Lambda_- \end{pmatrix} q_R^T q_L \phi + \Lambda l_R^T l_L \phi \begin{pmatrix} 1 \\ 0 \end{pmatrix} +$$

Ce particula sunt?

- Ocup spatiu?
  - DA
    - Sunt particula de materie. Am spin 1/2 *(fermion)* Sunt sensibil la Forta Tare?
      - DA
        - Sunt QUARK Sarcina?
          - 2/3 — up, charm, top *(c: SLAC 1971) (t: Fermilab 1995)*
          - -1/3 — down, strange, bottom *(b: Fermilab 1977)*
      - NU
        - Sunt LEPTON Sarcina?
          - 0 — neutrini
          - -1 — electron, muon, tau *(τ: SLAC-LBL 1977)*
  - NU
    - Intermediez o forta fundamentala?
      - DA
        - Sunt un BOZON vectorial Am spin 1 Ce forta intermediez?
          - TARE — GLUON
          - EM — FOTON (γ)
          - SLABA — W+, W-, Z0 *(CERN-LEP 1983)*
      - NU
        - HIGGS! S=0 *(CERN-LHC 2013)*

	1st gen.	2nd gen.	3rd gen.
QUARK	u *up*	c *charm*	t *top*
	d *down*	s *strange*	b *bottom*
LEPTON	ν_e *e neutrino*	ν_μ *μ neutrino*	ν_τ *τ neutrino*
	e *electron*	μ *muon*	τ *tau*

Strong Force

g *Gluon*

Electro-Magnetic Force

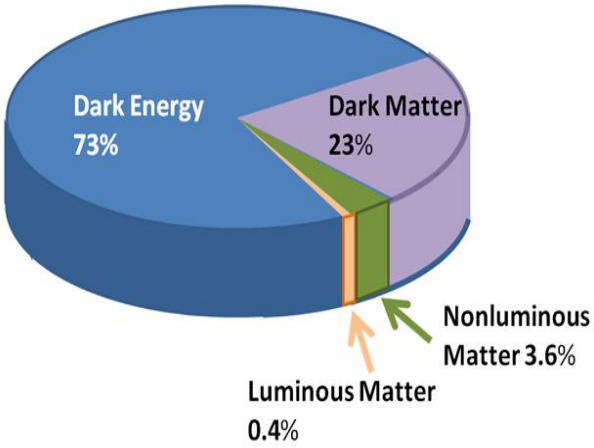
γ *photon*

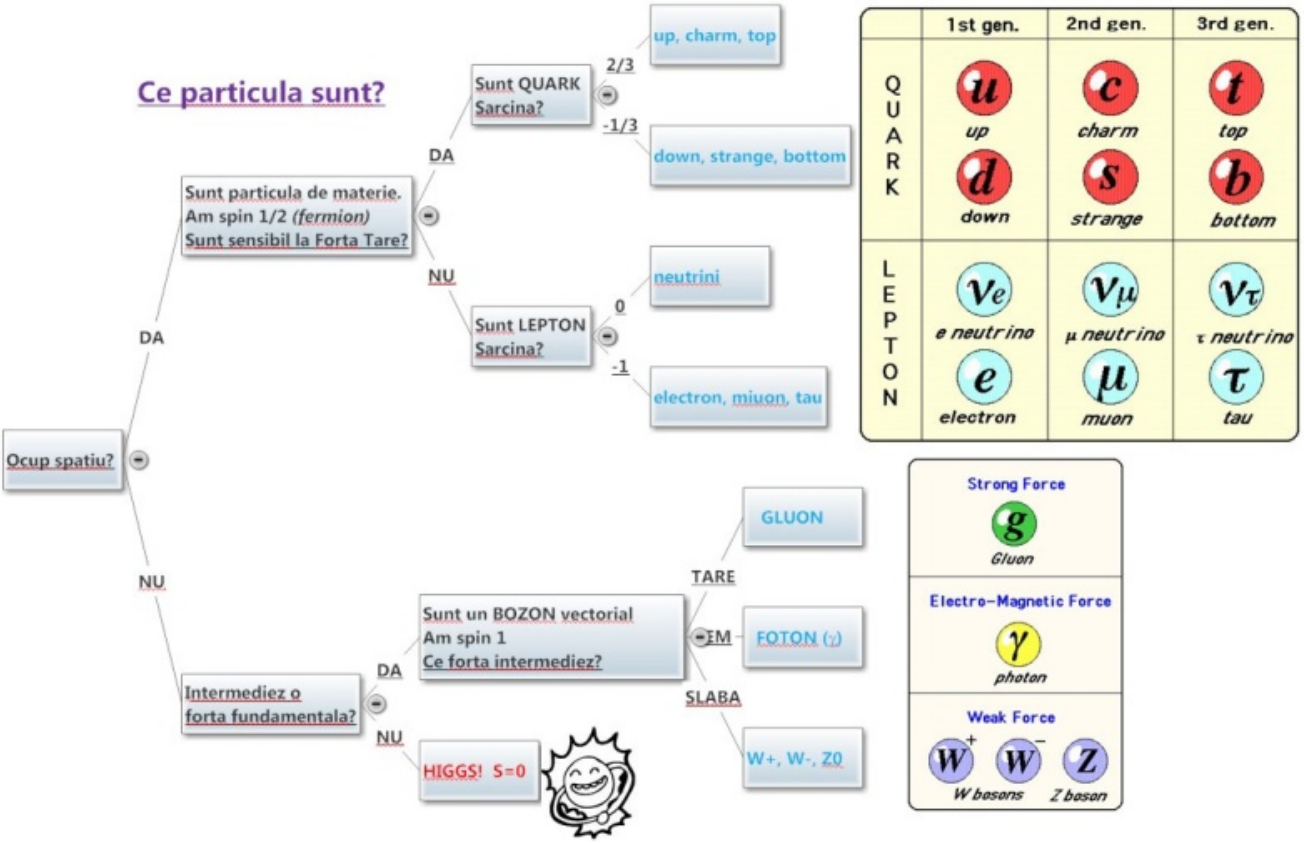
Weak Force

W^+ W^- Z

W bosons *Z boson*

Nu cunoastem decat o mica parte!





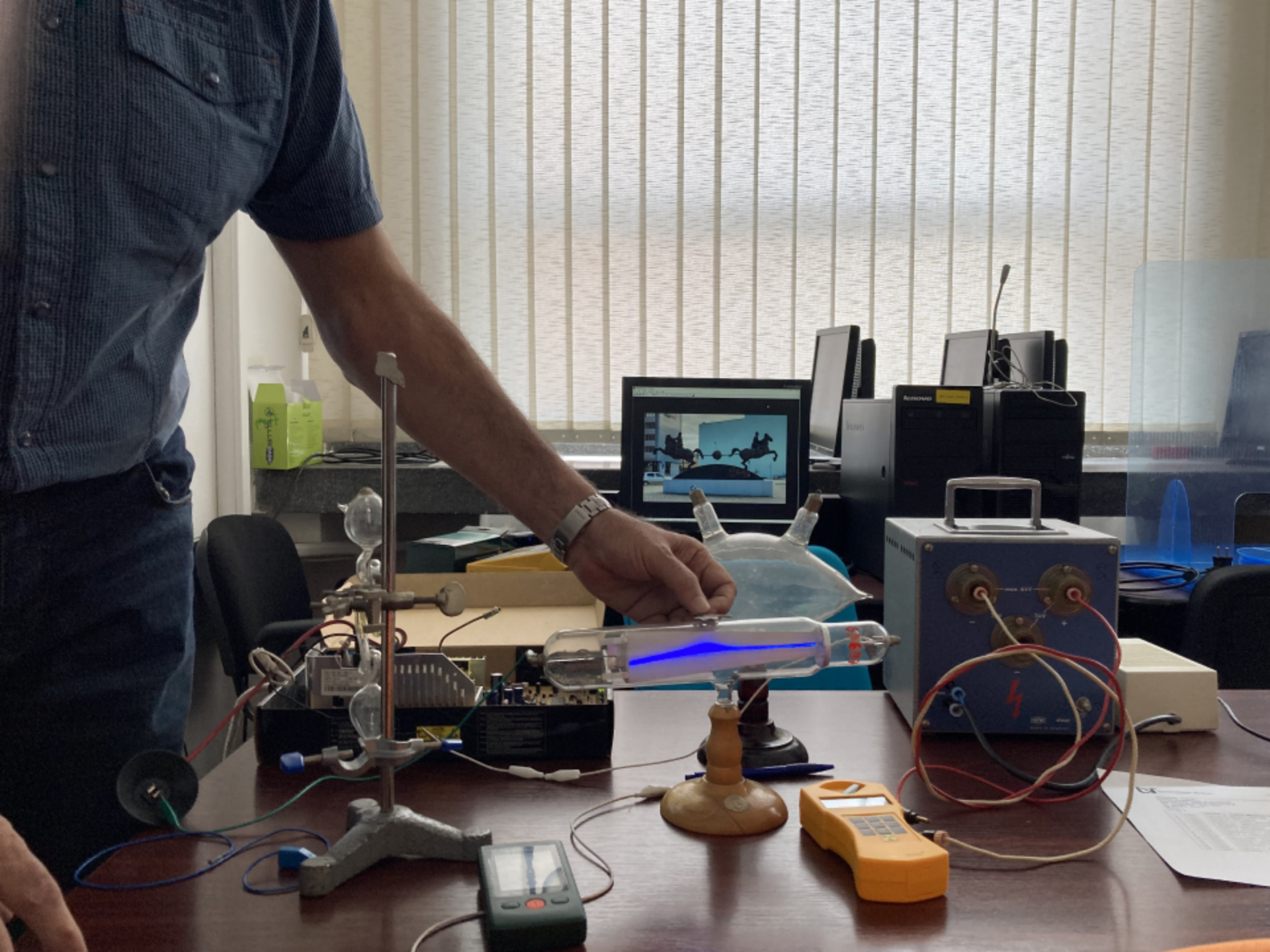
Dark Energy?

?

Gravitatie?

Dark Matter?

Inflatie?



V. *A Letter from Monſ.* Du Fay, *F. R. S. and of the Royal Academy of Sciences at* Paris, *to his Grace* CHARLES *Duke of* Richmond *and* Lenox, *concerning* Electricity. *Tranſlated from the* French *by* T. S. *M D.*

Paris, December 27, 1733.

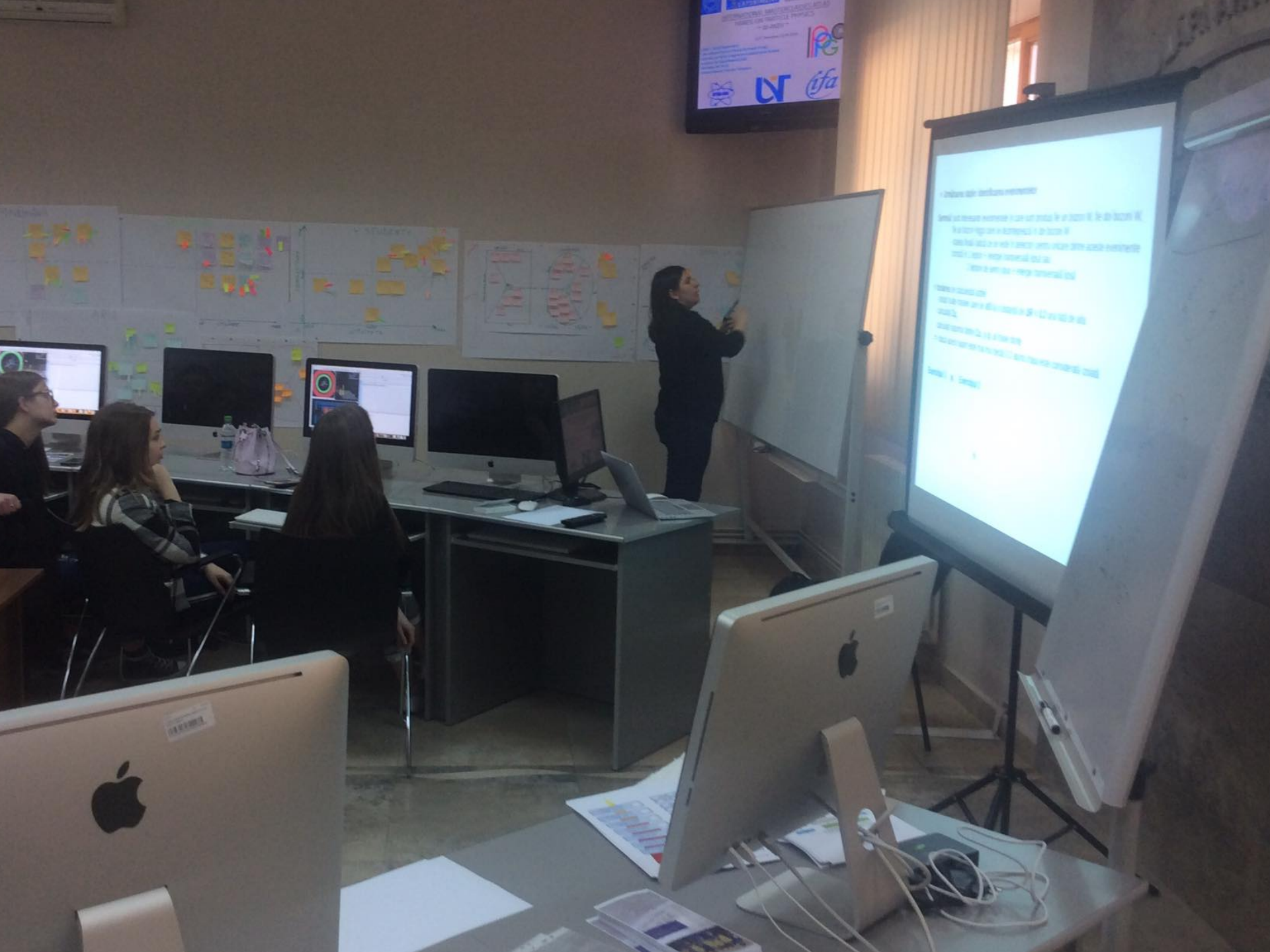
My LORD,

I Flatter my ſelf your Grace will not be diſpleaſed with an Account of ſome extraordinary Diſcoveries I have made in the *Electricity* of Bodies, nor refuſe the Favour I have to aſk, that it may be communicated to the *Royal Society*. I owe this Homage to that Illuſtrious Body, not only as a Member thereof, but in this reſpect as a Debtor to their Works; for the Writings of Mr. *Gray*, and the late Mr. *Hauksbee*, both of that *Society*, firſt put me upon the Subject, and furniſh'd me with the Hints that led me to the following Diſcoveries.

Firſt, I have found that all Bodies (metallick, ſoft or fluid ones excepted) may be made Electrick, by firſt heating them more or leſs, and then rubbing them on any ſort of Cloth. So that all kinds of Stones, as well precious as common, all ſorts of Wood, and in general every thing that I have made Trial of, became Electrick, by heating and rubbing; except ſuch Bodies as grow ſoft by Heat, as the Gums, which diſſolve in Water, Glue, and ſuch other Subſtances. 'Tis alſo to be remark'd, that the hardeſt

Raze X !!


ATPAS

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Astrophysics, Elementary Particles and Computational Physics

Responsabil program de studii: Conf. Dr. Paul Gravilă

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Semestrul I	**Semestrul II**
Complements of Theoretical Physics	Standard Model
Complements of Solid State Physics	Gravitation and cosmology
Complements of Atomic and Molecular Physics	Optional course 2 **(chose 1 of 2)** 1.Particle physics at accelerators 2.**Quantum fields**
Ethics and academic integrity. Methodology of scientific work	Introduction in astronomy
Optional course 1 **(choose 1 of 3)** 1. Magnetic active materials **2. Symmetries in physics** 3. Complements of biophysics with applications in medicine	Computational Physics
Anul II	
Semestrul I	**Semestrul II**
Quantum fields II	Specialization practice (projects, etc)

https://www.facebook.com/Experimentarium-Tm-497290843655283/

Linkuri

https://particleadventure.org/ un site de popularizare, excelent!

https://atlas.physicsmasterclasses.org/en/index.htm

https://home.cern/news/news/experiments/seeing-invisible-event-displays-particle-physics

Instalare Atlantis / Minerva:

https://java.com/en/download/uninstalltool.jsp
(pentru verificare/reinstalare java)

https://atlas.physicsmasterclasses.org/downloads/Minerva.zip
(despachetaţi si lansaţi programul (MINERVA_Windows.bat, pentru Windows)

paul.gravila@e-uvt.ro

Masterat in Astrofizica si Particule elementare la UVT

https://physics.uvt.ro/astrophysics-elementary-particles-and-computational-physics/