CERN ve Parçaçık Fiziği

Kaya Tatar

CERN

Türkiye @ CERN – Halka Açık Toplantı

1 Ekim 2022

CERN

Conseil **E**uropéen pour la **R**echerche **N**ucléaire : Avrupa Nükleer Araştırma Merkezi

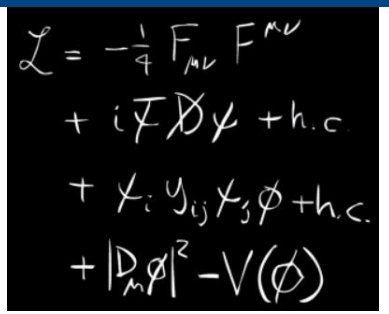
1945-1950 : Avrupa'ya ait üst seviye fizik araştırma merkezi
Bilimde önderlik ve birleşme

Bugün :
15000+ insan, 110+ ulus, 70+ ülke

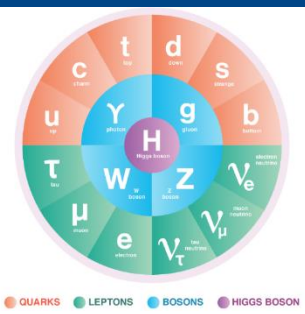
Kaynak : CERN

Amaç

Doğanın yapıtaşlarını ve işleyişini anlamak



Kaynak : CERN



Kaynak : US DOE

Bu bağlamda

- Parçacıkları ve etkileşimlerini inceleyen kuramlar ve deneyler
- Parçacık hızlandırıcı tesisleri geliştirmek
- Dünya'nın her yerinden insanları bir araya getirmek

Ve ötesinde

- Teknolojik buluşlar ve sanayiye bilgi aktarımı
- Geleceğin bilim insanı ve mühendislerini yetiştirmek
- İnsanları bilim hakkında bilinçlendirmek

Kaynak : CERN

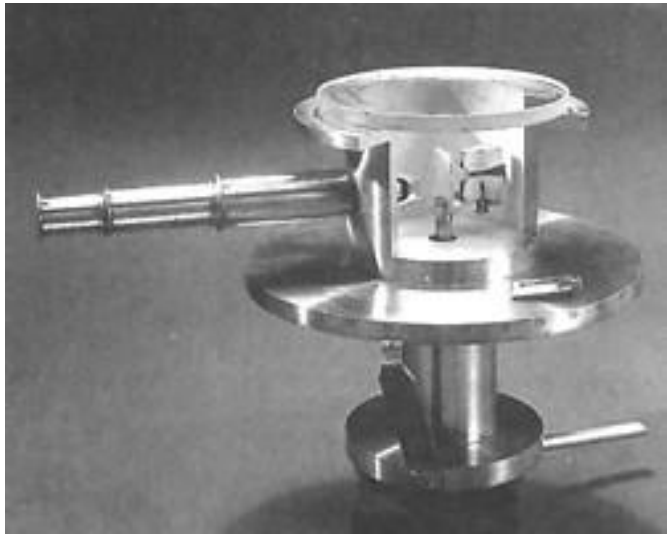
Geçmişte maddenin yapısı

- 19. yy : Atomlar (ör : hidrojen, karbon, oksijen, bakır, demir)

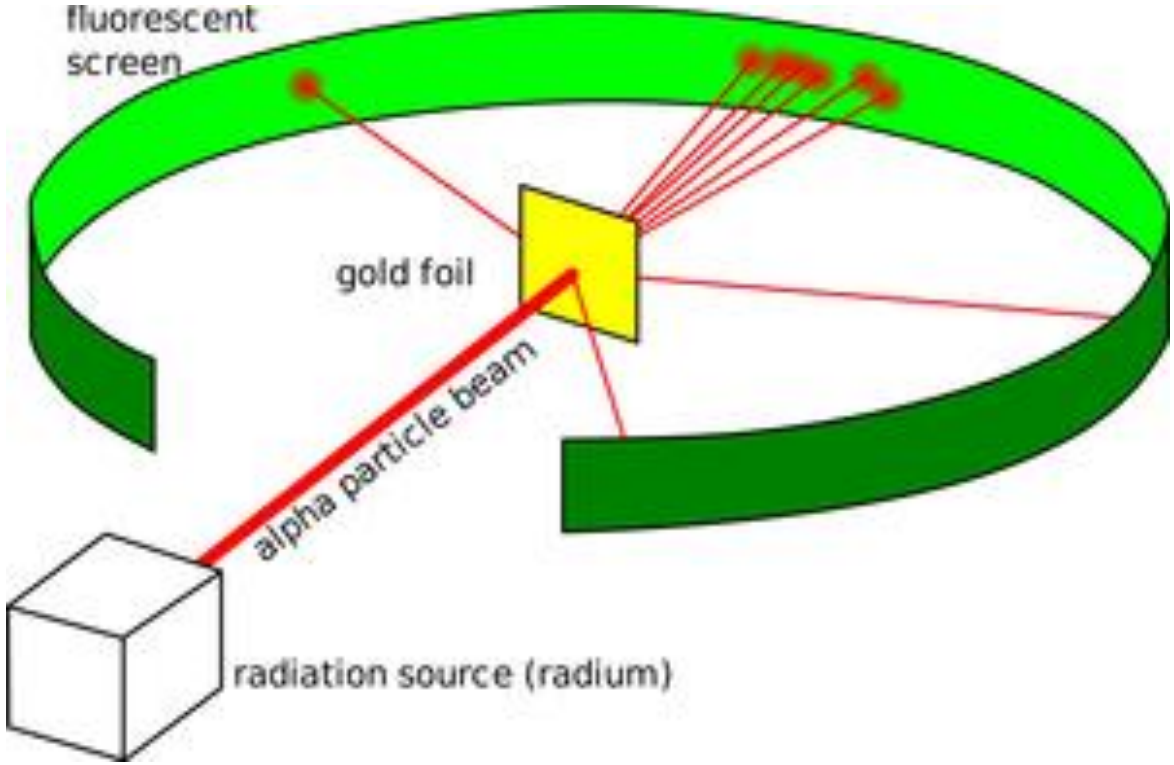
1897 : Elektron keşfediliyor. Atom artık temel parçacık değil.

- 19.yy sonu : Elektron ve karşıt yüklü parçacık(lar) atomu oluşturuyor.

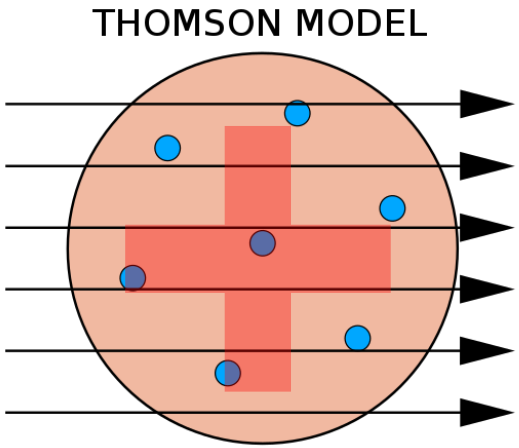
Atomun yapısı nedir ?

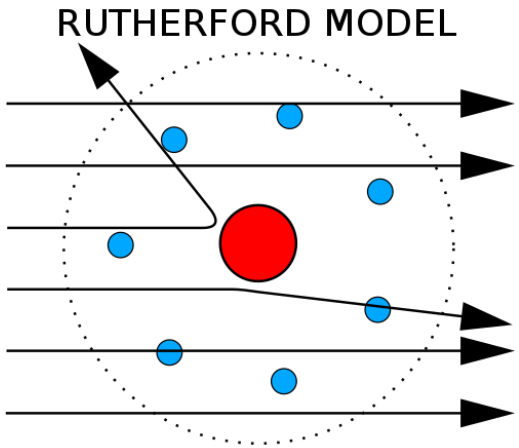


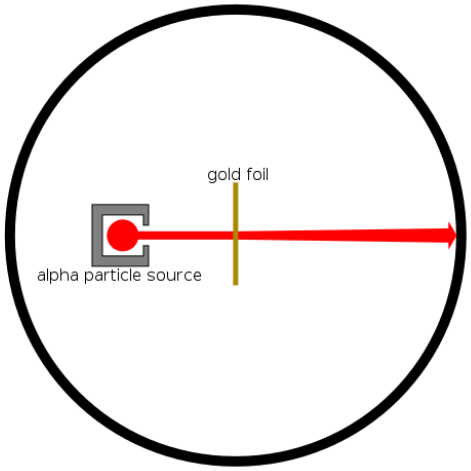
Geiger-Marsden deneyleri, 1908-13

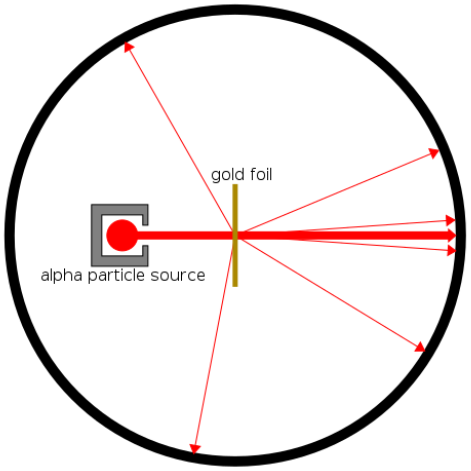


20. yy başı : Atomun yapısı









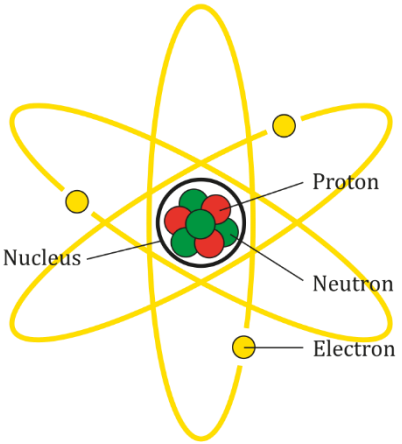
observed result

“Üzümlü kek” modeli

Gözlenmedi

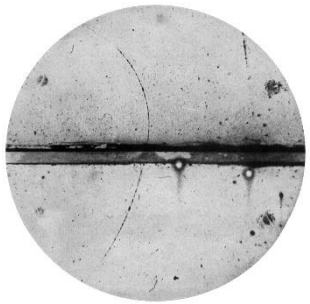
Atomun çekirdekli yapısı

Gözlenen

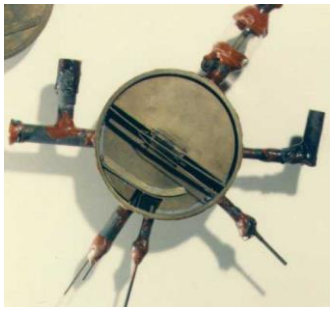


20. yy boyunca

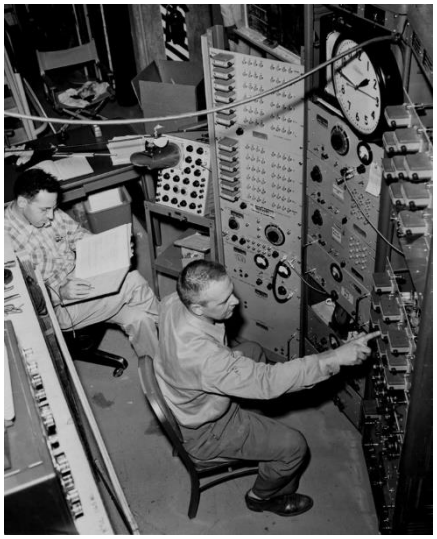
Çok sayıda teknolojik atılım, kuramsal gelişmeler, ve deneysel keşifler



Pozitron keşfi, 1932



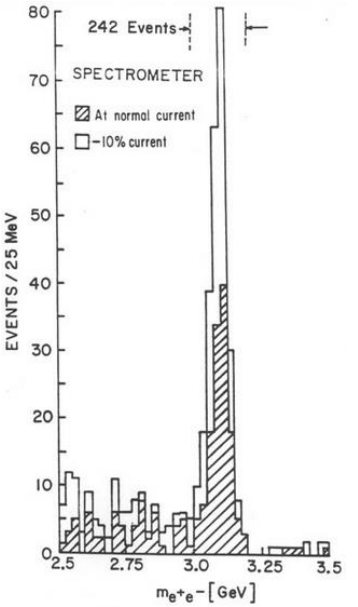
Küçük siklotron



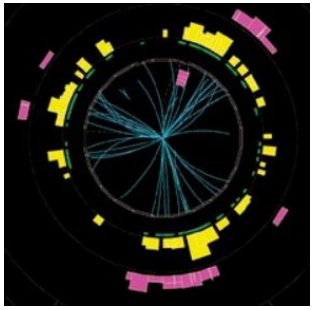
Cowan-Reines nötrino deneyi, 1956

Big European Bubble Chamber, CERN

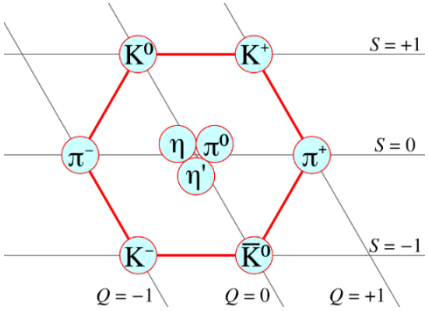
Derin inelastik saçılım deneyleri, SLAC, 1968



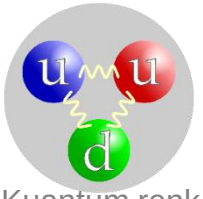
Tılsım (charm) kuark keşfi, 1974



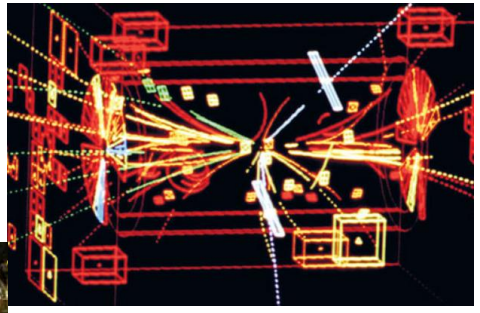
Doğrudan gluon gözlemi



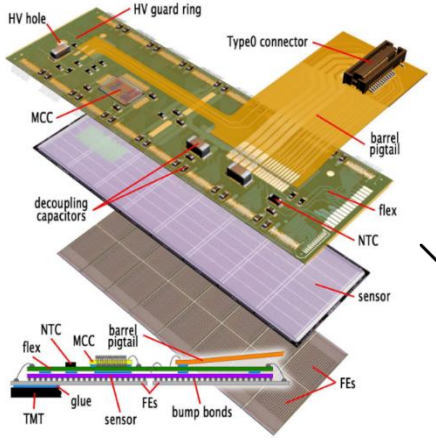
Kuark Modeli, 1964



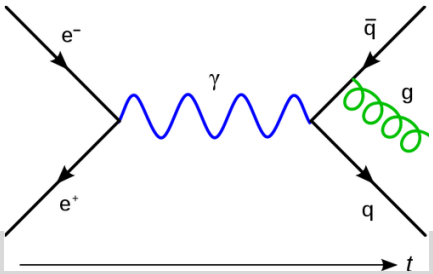
Kuantum renk dinamiği, 1973



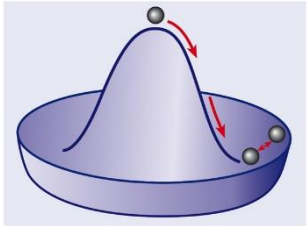
Z boson keşfi, CERN, UA1, 1983



Silikon detector modülü, CERN, ATLAS



Kuantum alan teorisi

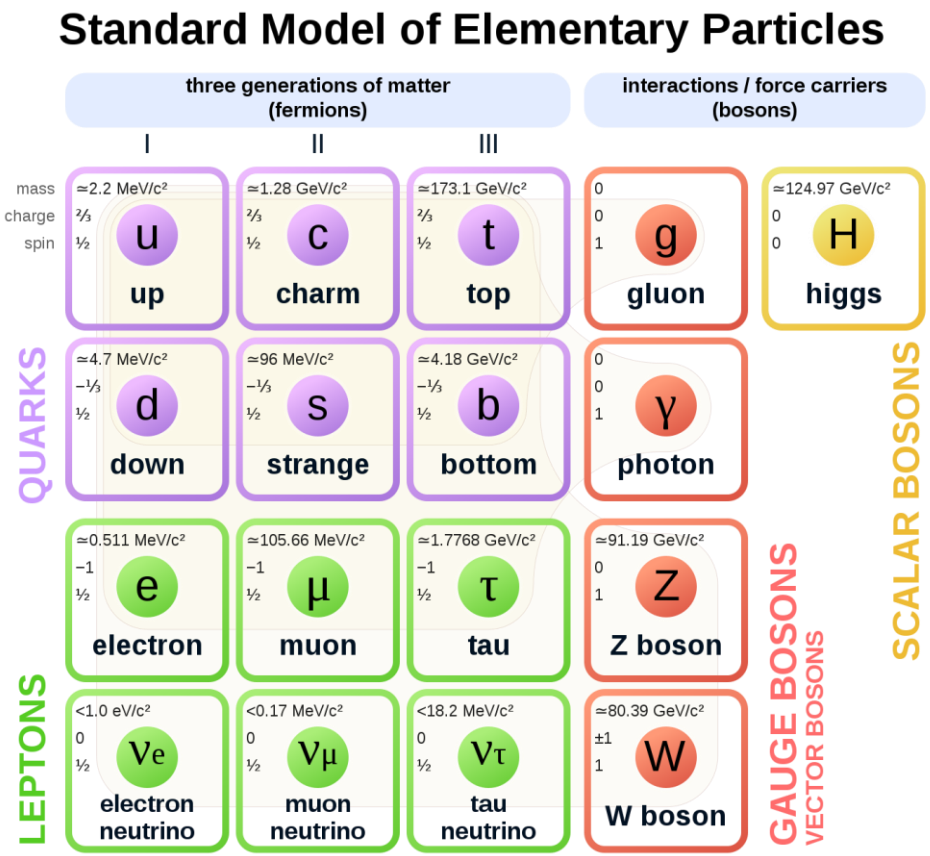


Higgs mekanizması

Super-Kamiokande deneyi

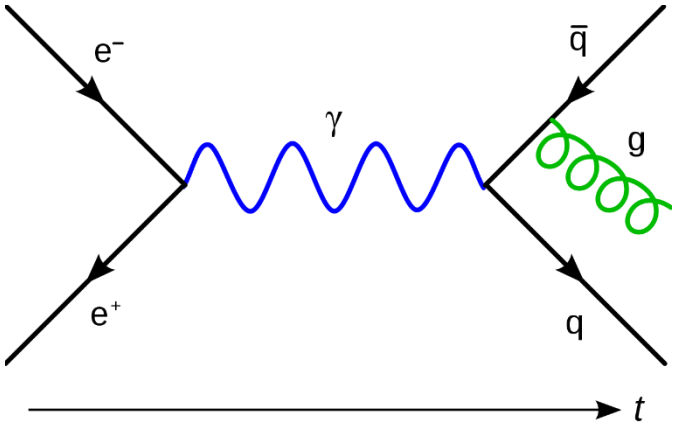
2000'ler : Standart Model

Temel parçacıklar



ve etkileşimleri

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\Psi}\not{D}\psi + D_\mu\Phi^\dagger D^\mu\Phi - V(\Phi) + \bar{\Psi}_L\hat{Y}\Phi\Psi_R + h.c.$$

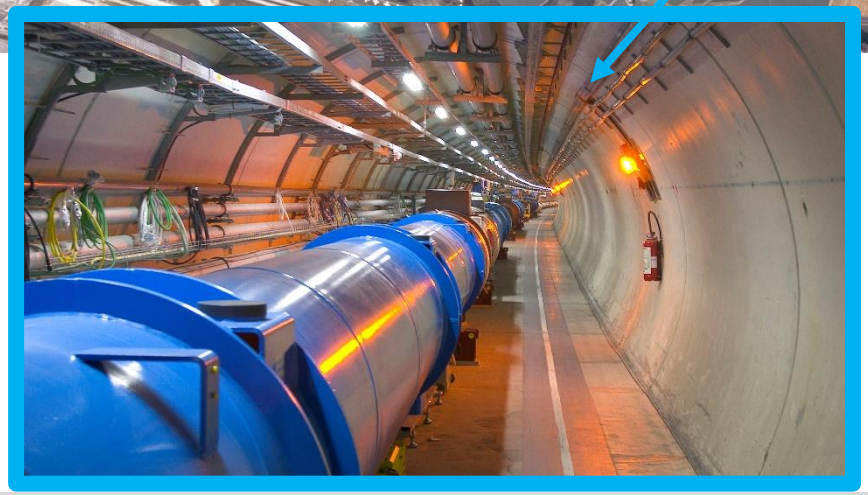


Higgs bozonu
Diğer parçacıkları ile etkileşimi onlara kütlelerini veriyor
Modelin teyit edilen **son** parçası (2012)

Deney aletleri : 1. Hızlandırıcı

Hızlandırıcı → “İlginç” olaylar **yüksek** enerjilerde ve **çok nadiren** gerçekleşiyor

Ör : Large Hadron Collider (LHC) (*Büyük Hadron Çarpıştırıcısı*)



LHC tüneli

LHC

1 demet ~ 10^{11} proton
Proton enerjisi ~ 5 TeV
Demet kesişimi ~ 40 MHz

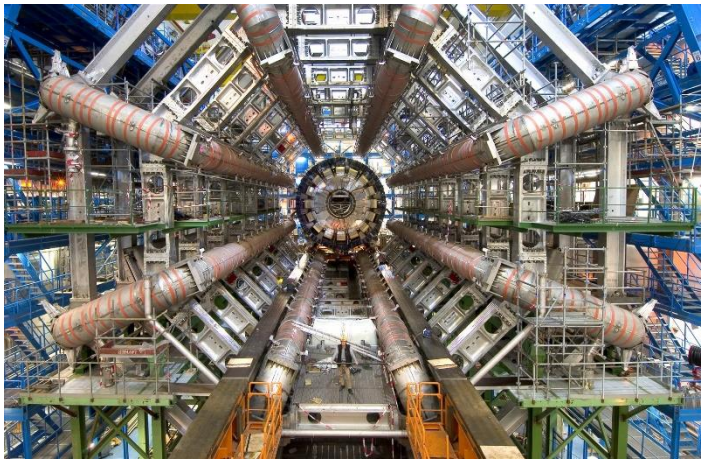
27 km uzunluk
Yerin ~100 m altında

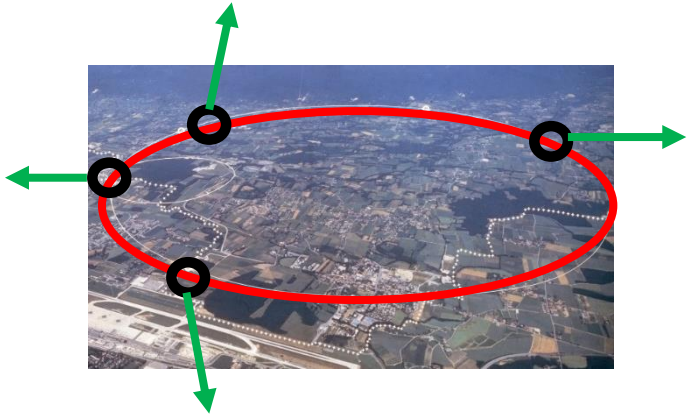
Deney aletleri : 2. Algıç

"İlginç" etkileşimlerin **izlerini** tespit eden ve onları incelemekte kullanılan aletler

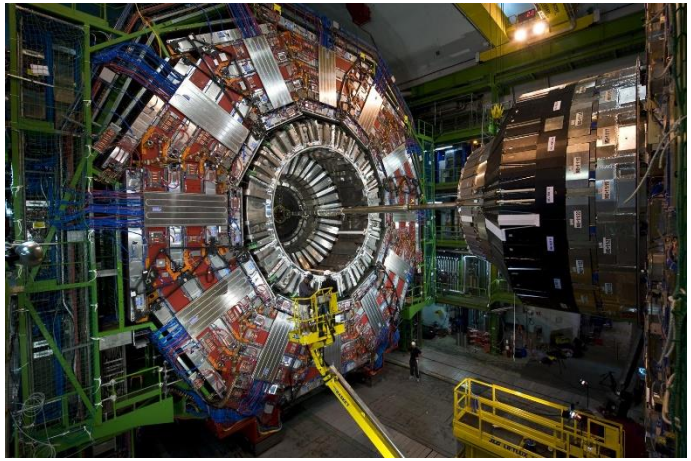
ALICE
(A Large Ion Collider Experiment)

ATLAS
(A Toroidal LHC Apparatus)



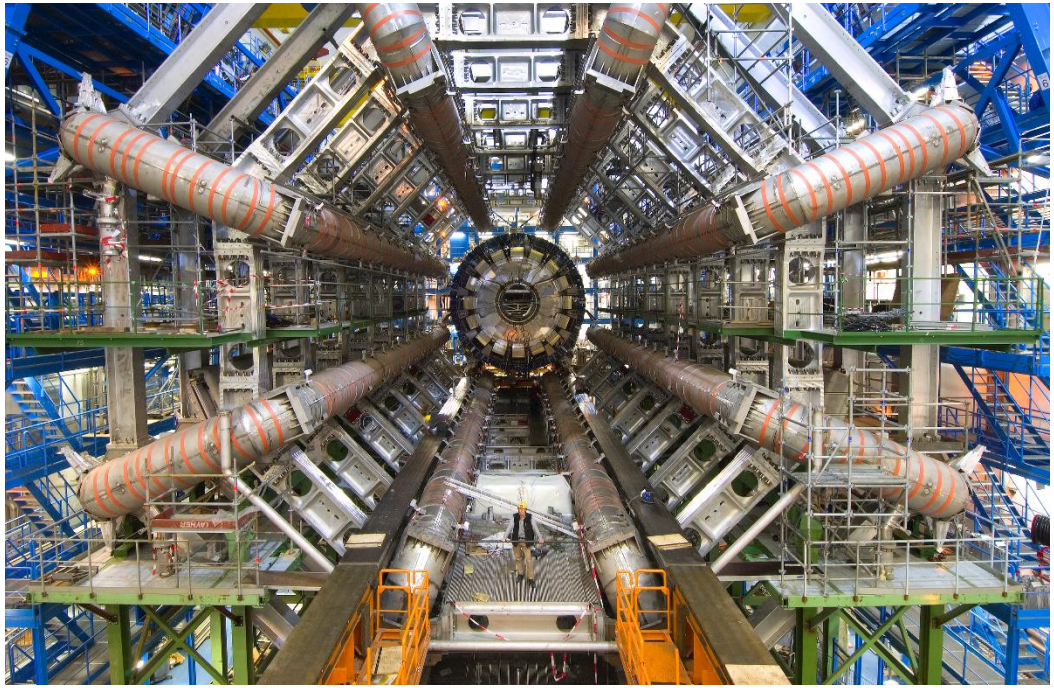


CMS
(Compact Muon Solenoid)

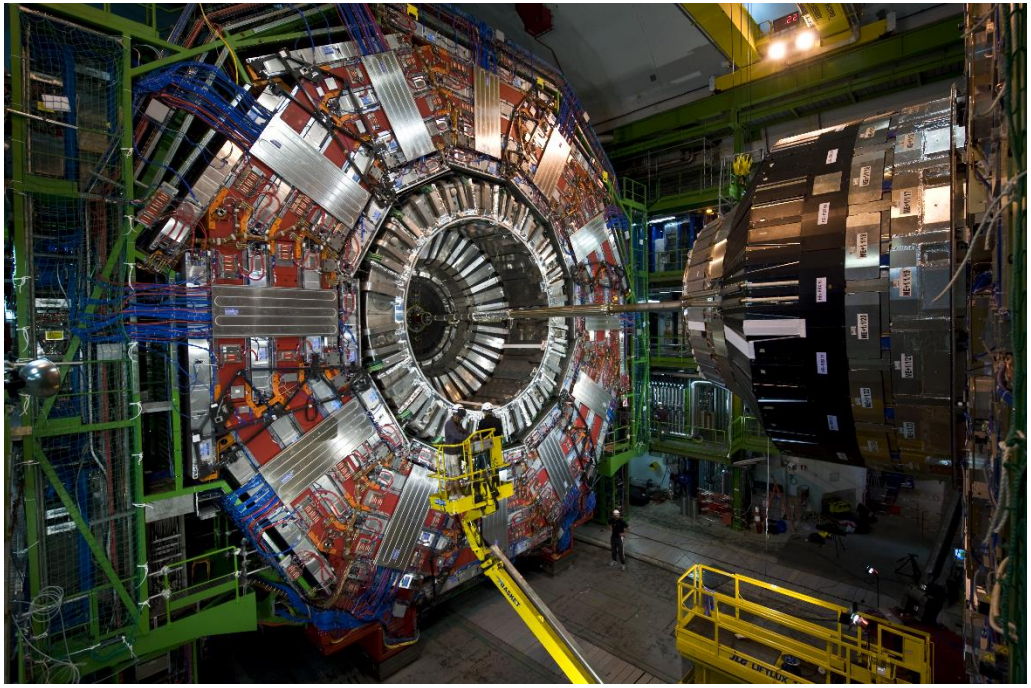


LHCb
(Large Hadron Collider beauty)

LHC algıçları devasa aletler



ATLAS
46m x 25m x 25m boyut, 7000 ton
5500+ insan (245 kurum)



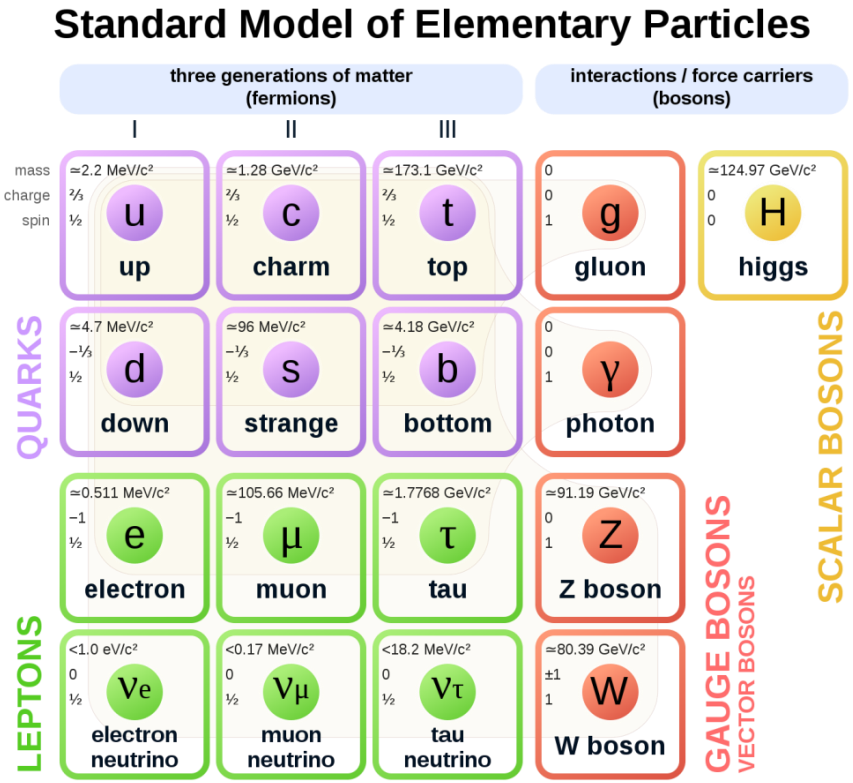
CMS
21m x 15m x 15m boyut, 14000 ton
5500 insan (241 kurum)

Parçaçıkların algıçtaki izleri çok kısa süreli (~1 μs-ms)
Algıçlar çok amaçlı (2800 bilimsel makale [1])
Veriyi **aktaracak** ve **saklayacak** kaynaklar kısıtlı

→ Olaylar (çarpışmalar) **çabucak ayıklanmalı** ve incelenmek üzere **kayıt edilmeli**.
→ Sonuçta : saniyede ~100 olayın verisi → Günde ~1 Petabyte veri

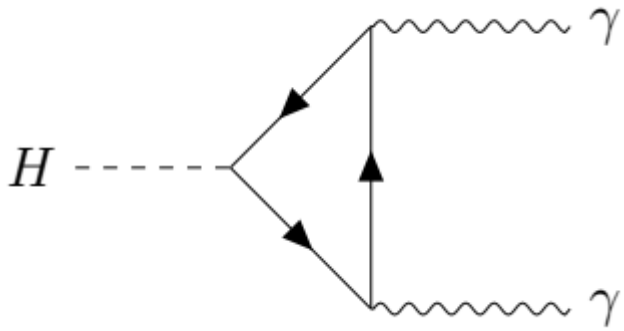
[1] : CERN Courier, Ocak 2021 itibariyle

Veri analizi I : Parçacık izleri

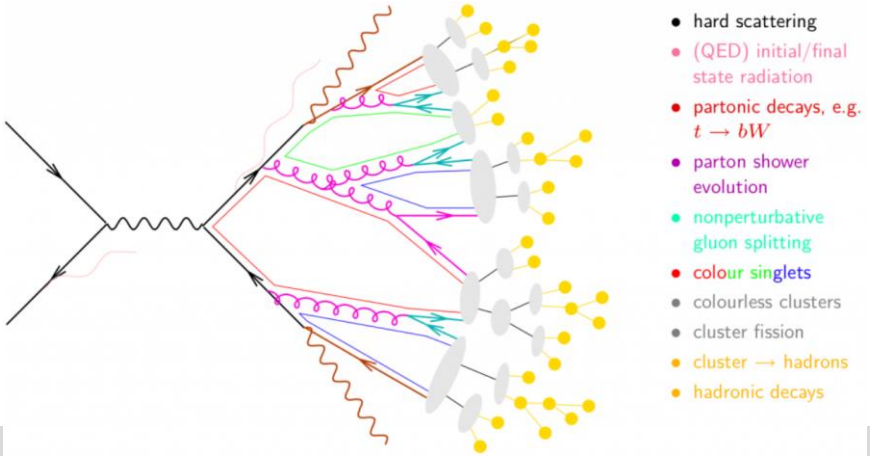


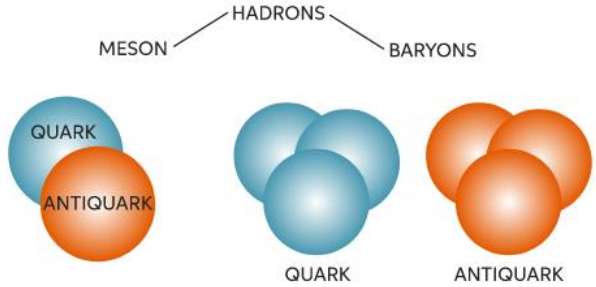
Temel parçacıkların büyük kısmı “**kararsız**”dır

1) Başka parçacıklara dönüşürler.
Algıca Higgs bozonu değil, bozunma ürünleri ulaşır.

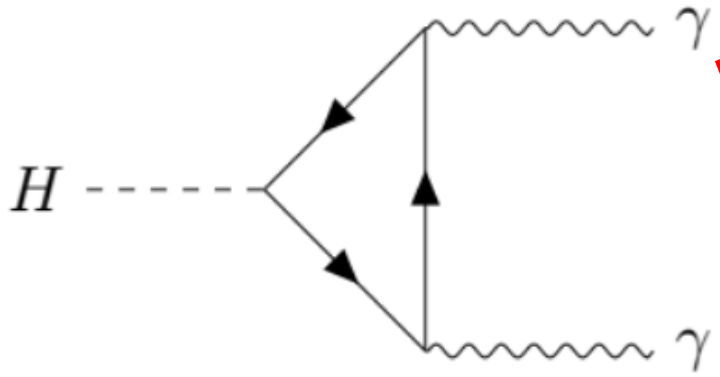


2) **Veya başka parçacıklar birleşmek isterler, yeni parçacık üretimi tetiklenir**
Kuark renk hapsi, ve hadron enkazı



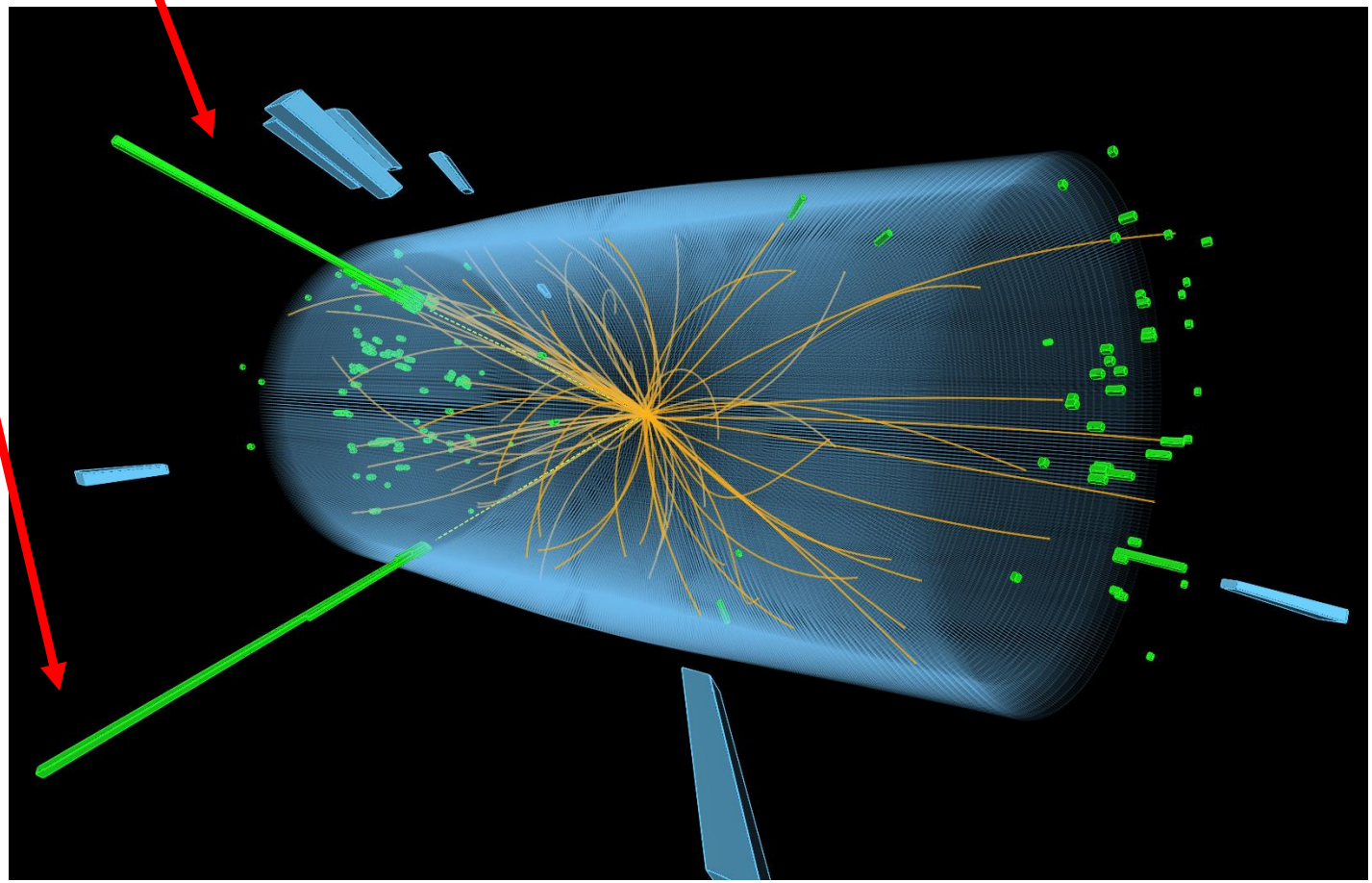


Verideki izler - I



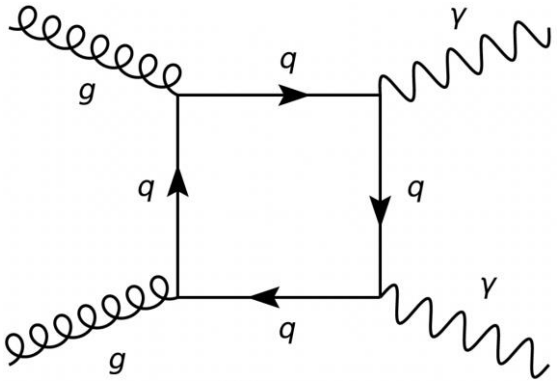
Algıç iki tane yüksek enerjili photon “adayı” buldu.
Bu bir Higgs bozonu olayı mı ?

Sinyal (İlginç olan) ?



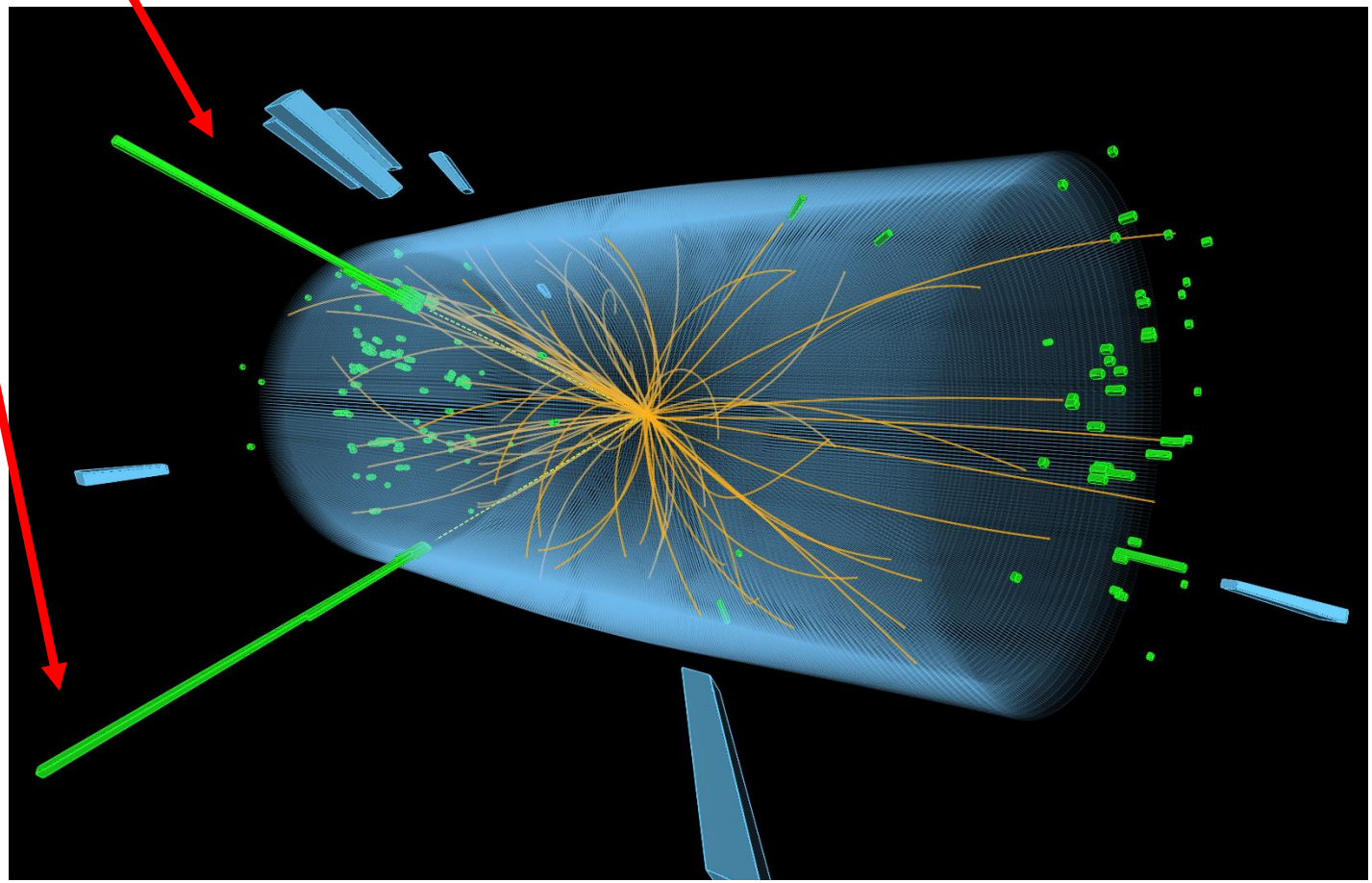
Kaynak : CERN, CMS event displays of Higgs to two photon candidates

Verideki izler - II



Ama aynı izle sonuçlanan farklı olaylar da olabilir.
Yoksa sıradan bir olay mı ?

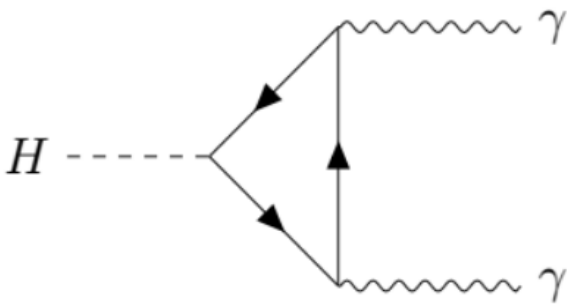
Arkaplan (Sıradan) ?



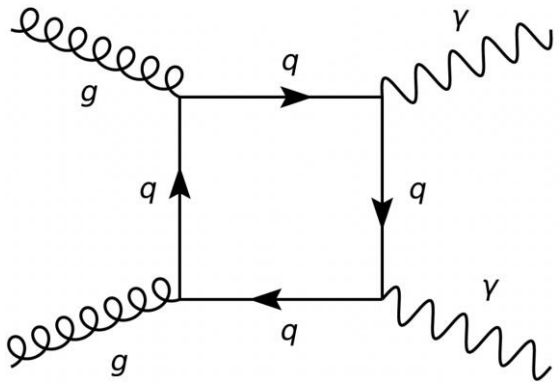
Kaynak : CERN, CMS event displays of Higgs to two photon candidates

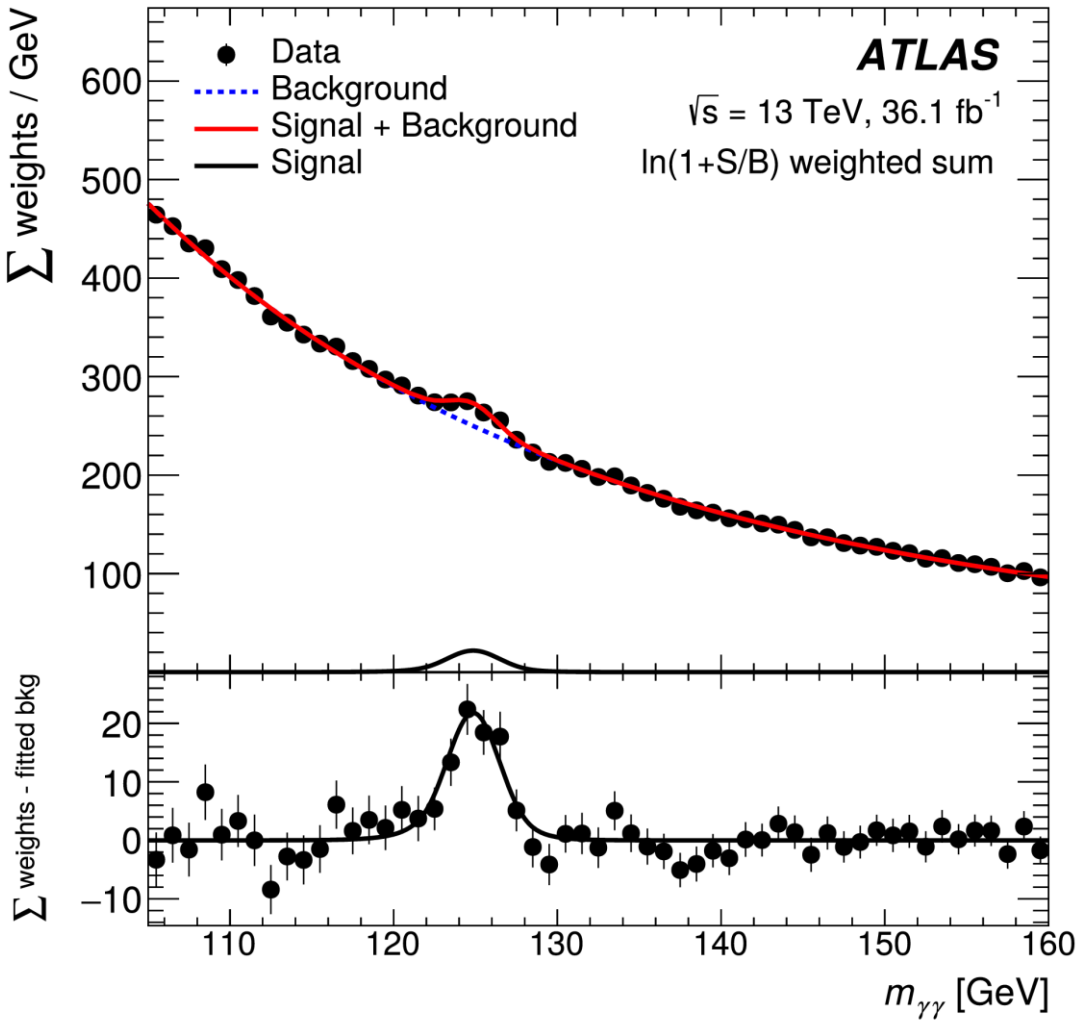
Higgs bozonu gözlemi

Sinyal (İlginç)



Arkaplan (Sıradan)





PLB 784 (2018) 345

Sinyali ortaya çıkarmak için hassas bir ölçüm gerekli.

Samanlıkta ~~iğne aramak~~, **birbirine benzeyen samanları saymak** !!

Standart Modelin son parçası

Kaynak : CERN

Temmuz 2012'de
ATLAS vs CMS deneyleri
yeni bir bozon (Higgs) gözlemini duyurdular.

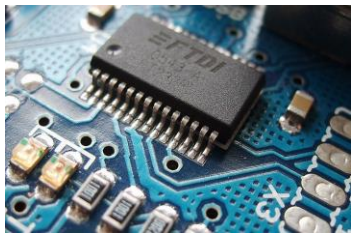
François Englert ve Peter Higgs
CERN, 4 Temmuz 2012

2013 Nobel Fizik Ödülü
François Englert ve Peter Higgs
"Parçacıkların kütlesini edinmesini açıklayan ve deneylerle teyit edilen kuram için"

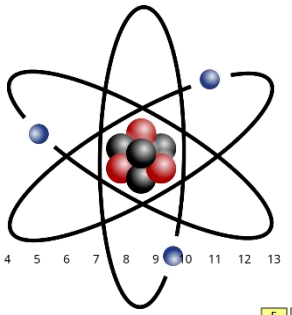
Temel Fizik ve CERN

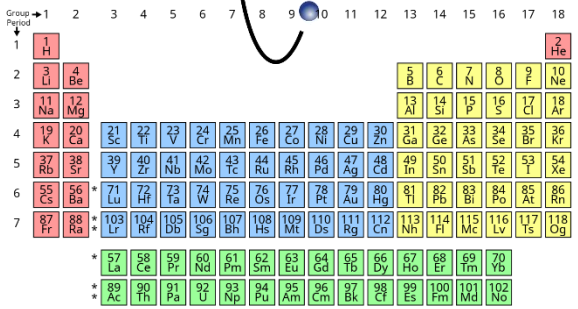
Dört temel etkileşim

Elektromanyetizma

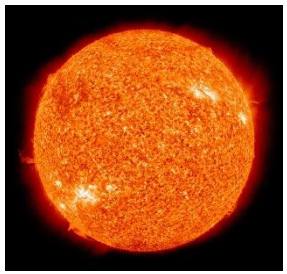


Güçlü etkileşim

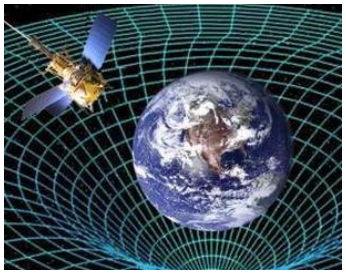




Zayıf etkileşim



Kütleçekimi



Genel Görelilik

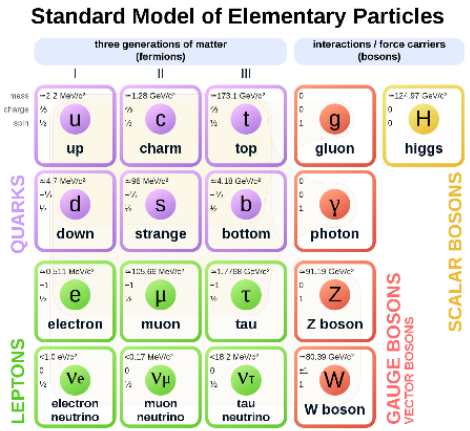
Standart Model

Gözlenen doğanın “**neredeyse**” hepsinin temel seviyede açıklaması
Gittikçe daha da sağlam (deneysel araştırmalar ile)
Eksikleri : Kara madde, kara enerji, Madde-karşıt madde dengesizliği

CERN katkısı

Deneysel keşifler, modellerin sınanması, teknolojik atılımlar, insan yetiştirme
Ör. Nobel fizik ödülleri : Yapılan çalışmalar (1984, 1992, 2013), yetişen insanlar (1976, 1988)

Kapatırken



Neden bunları yapıyoruz ?

Merak

Doğayı anlamak

Bir şeyleri çözme ve yanıt bulma isteği

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\Psi}\not{D}\psi + D_\mu\Phi^\dagger D^\mu\Phi - V(\Phi) + \bar{\Psi}_L\hat{Y}\Phi\Psi_R + h.c.$$

Neden parçacık fiziği ve CERN ?

En temel seviyeye inmek

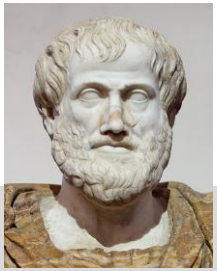
Yararı nedir ?

Doğanın parçasıyız, onu anlamak bizim faydamıza

Geleceğin ve günümüzün teknolojisi

Yan/Beklenmedik uygulamalar
(iletişim, tıp, tarih, enerji vs)

Zihinsel gelişim

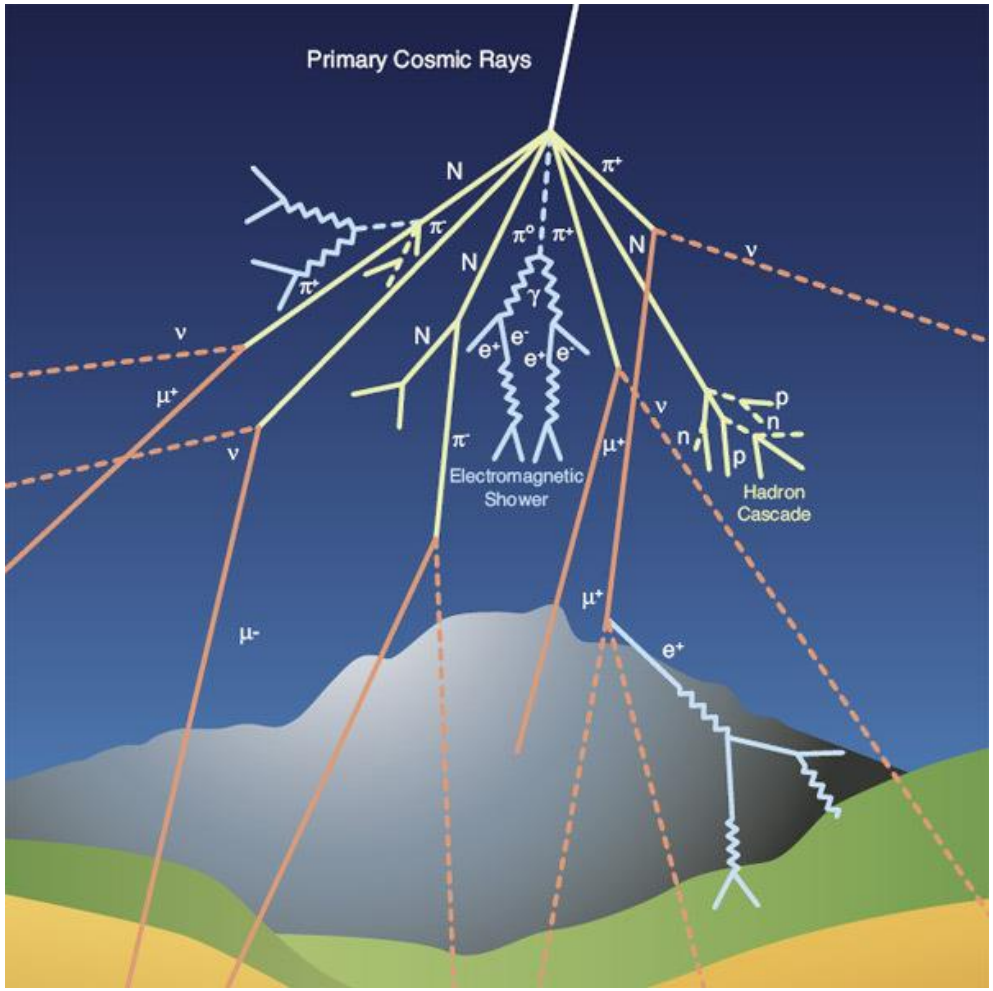


YEDEKLER

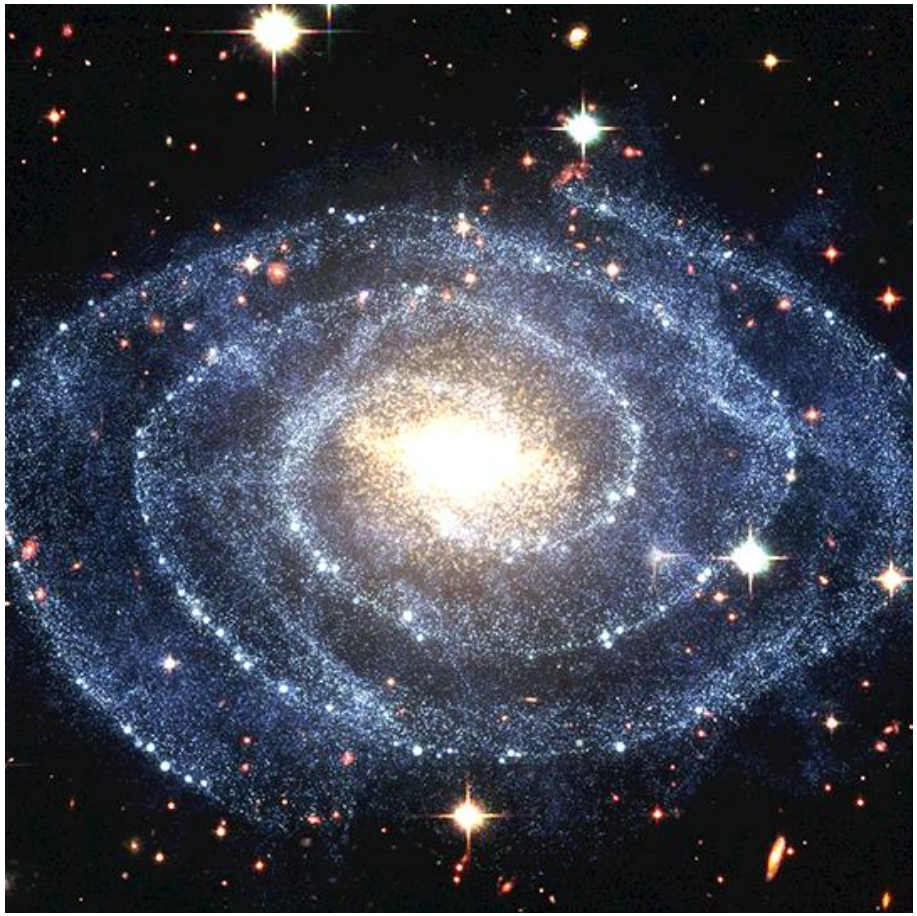
Parçacıklar bozunur

proton > 10^{34} yıl, elektron > 10^{28} yıl,
nötron ~ 15 dk, yüklü pion ~ 10^{-8} s,
Z boson ~ 10^{-25} s

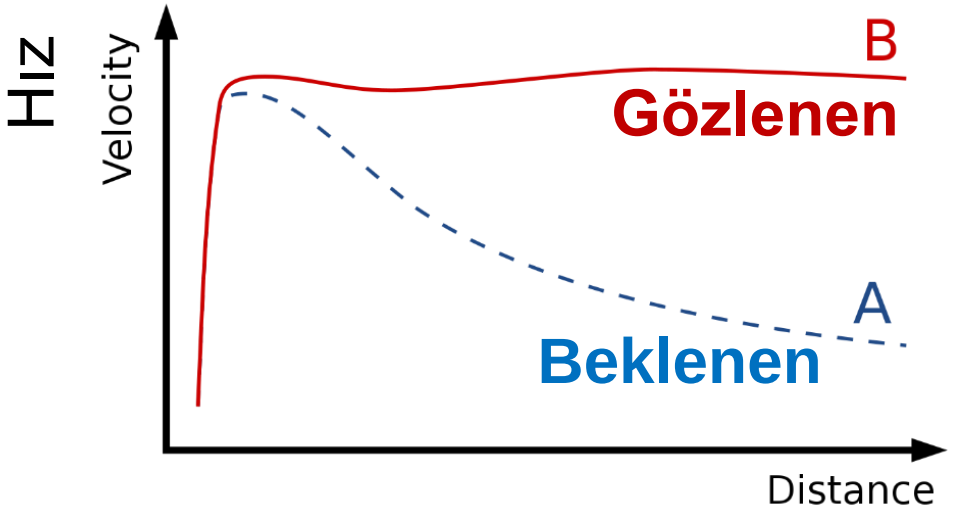
Deteköre ulaşamaz.
Nasıl tespit edeceğiz ?



Kara madde



Vera Rubin, Kent Ford, Ken Freeman,
1960-1970

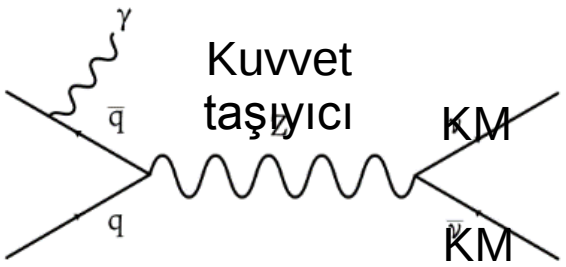


Merkezden uzaklık

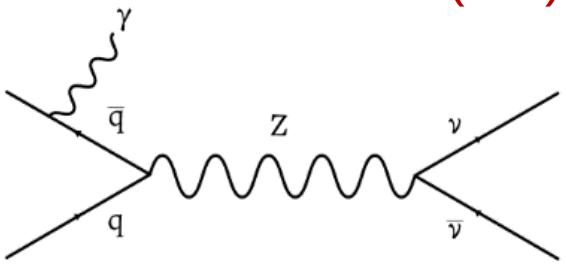
Tespit edilen, ama görülemeyen bir kütle
Karanlık madde

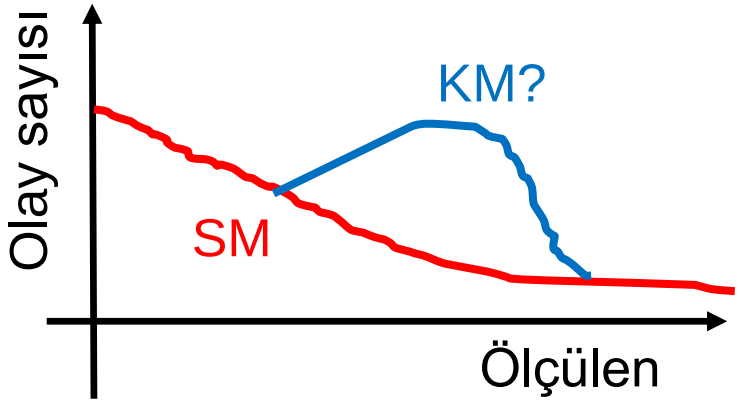
BHÇ'de Kararanlık Madde Arayışı

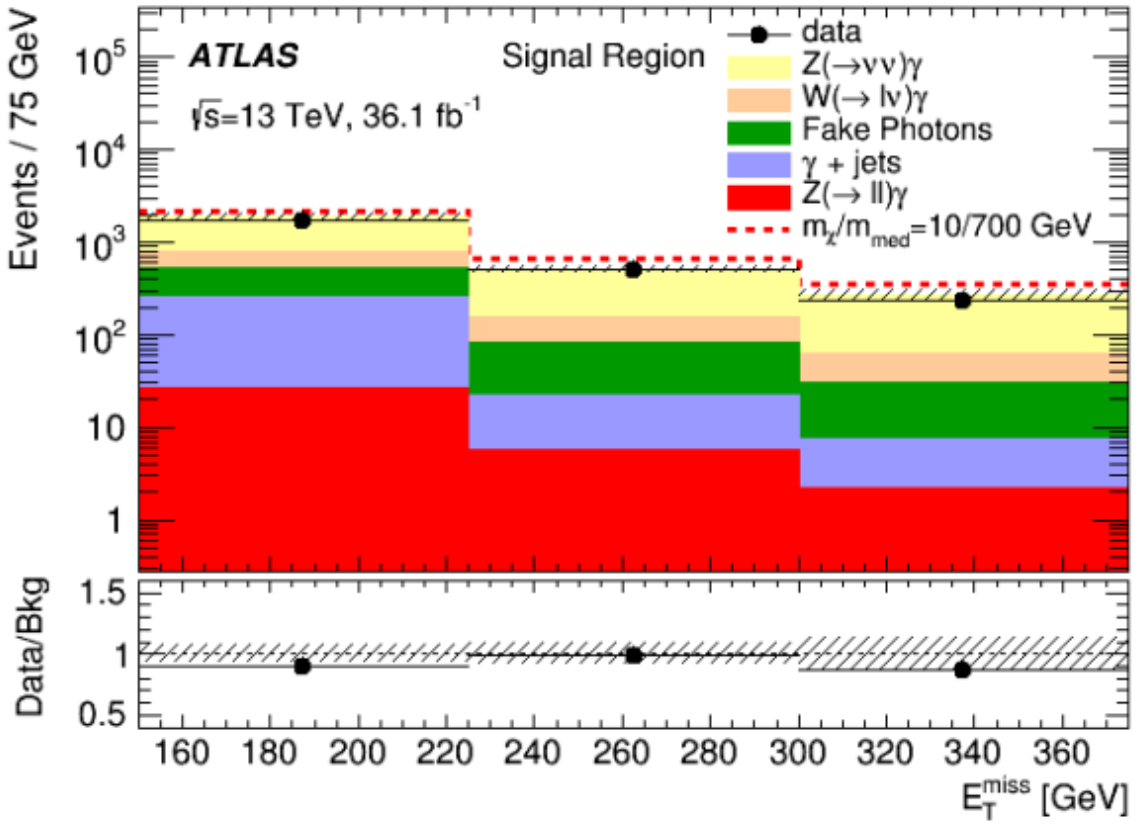
Varsayımsal Karanlık Madde (KM) etkileşimleri



Benzer son ürünlü Standard Model (SM)

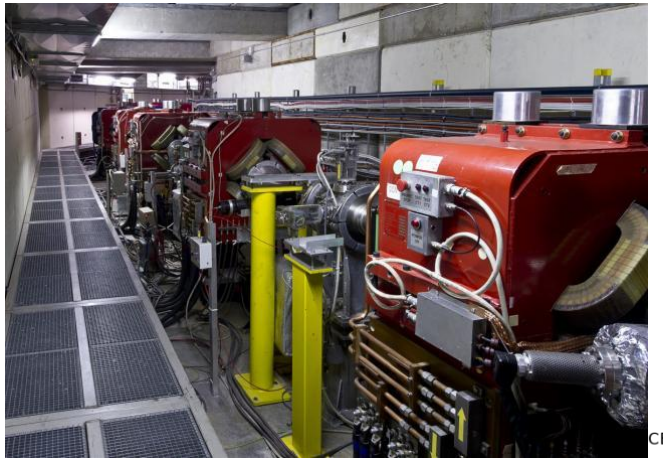




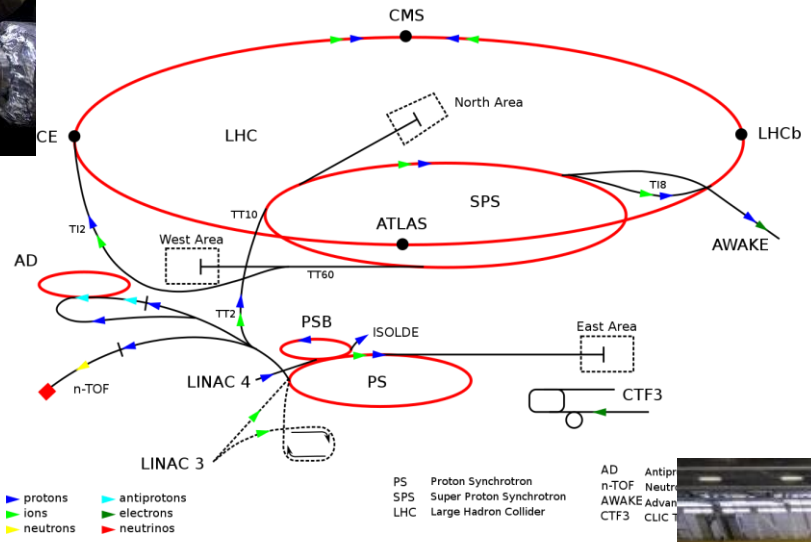


Sonuçlar SM beklentisi ile uyumlu
Bu veri hassasiyeti "SM dışında bir şey buldum" diyemiyor

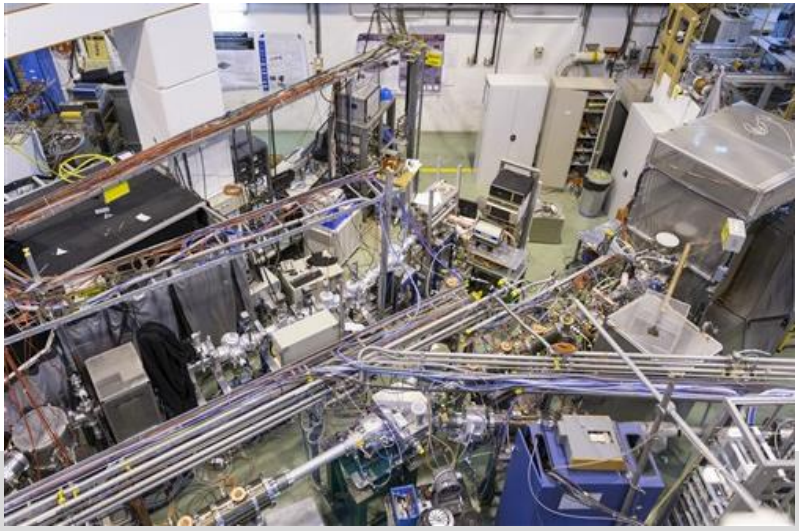
LHC dışındaki deneyler



Antiproton Decelerator
Antimadde özellikleri
Kütleçekimi



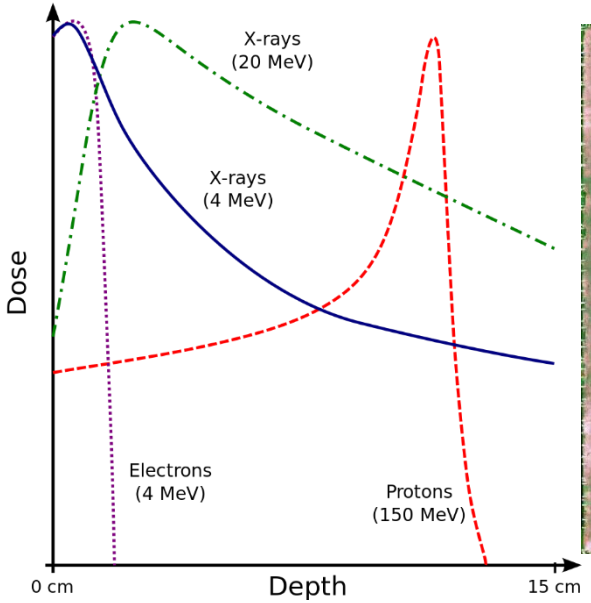
CLOUD
Bulut oluşumu



ISOLDE
Nükleer
spektroskopi

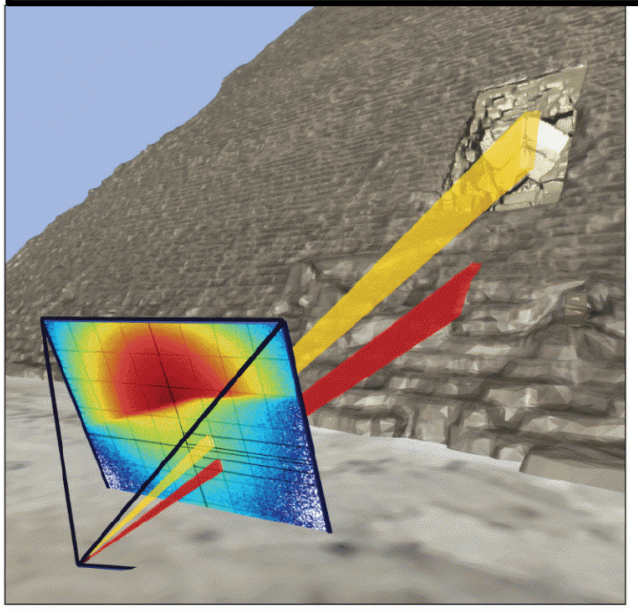
Teknoloji

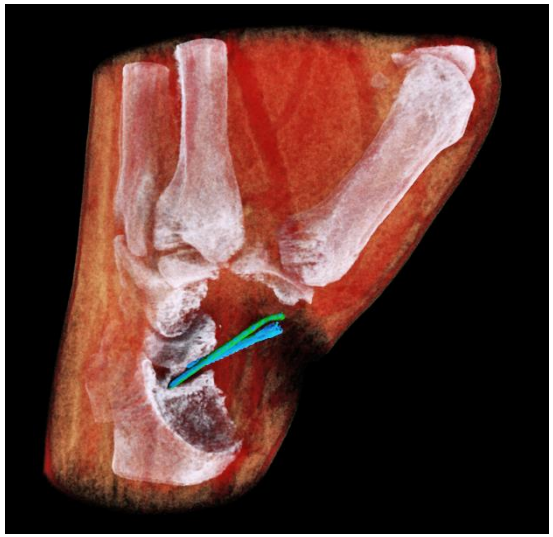
Hadron terapi



Altta yatanı ortaya çıkarma

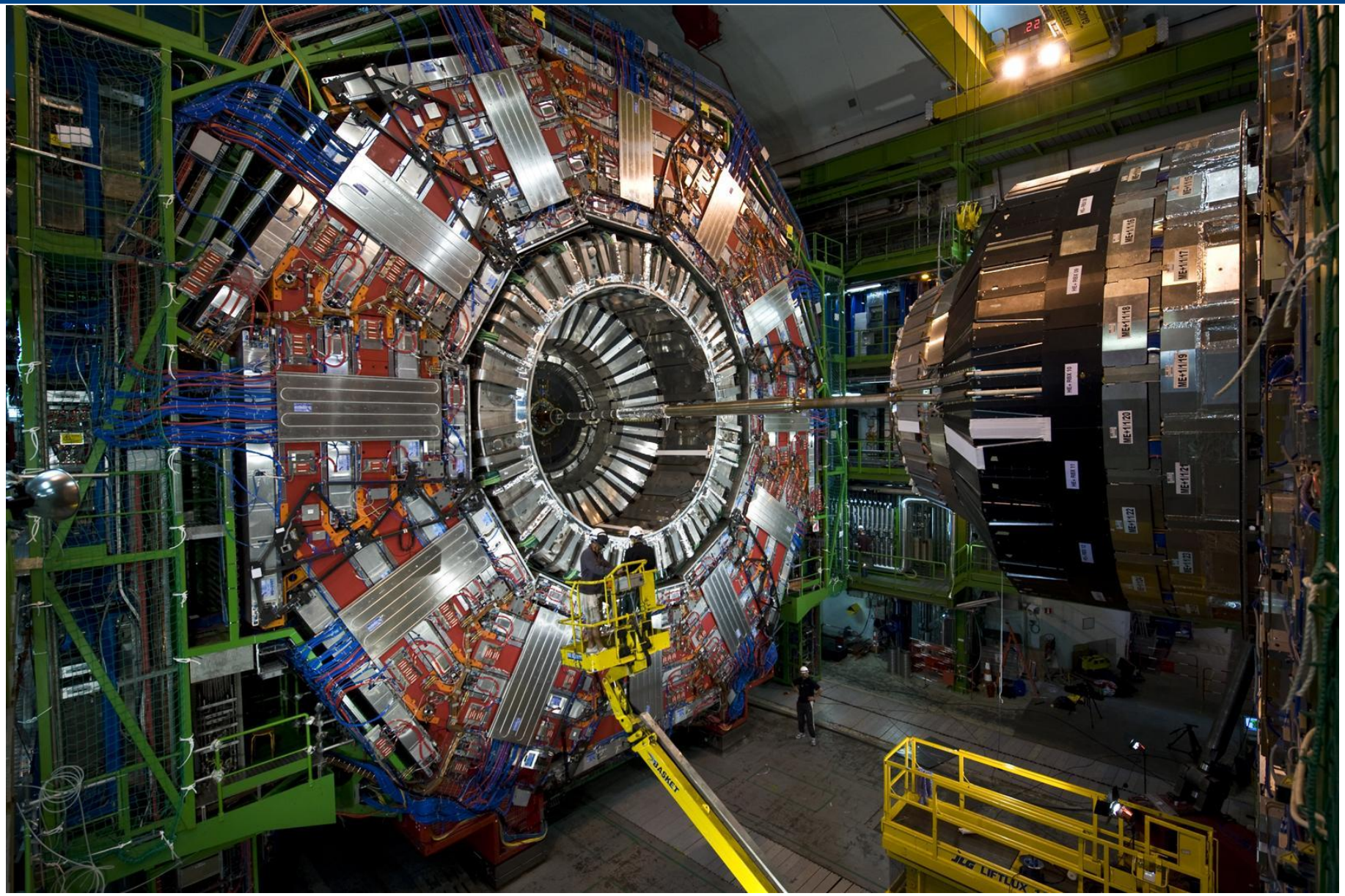
Arkeoloji ve muon detektörler



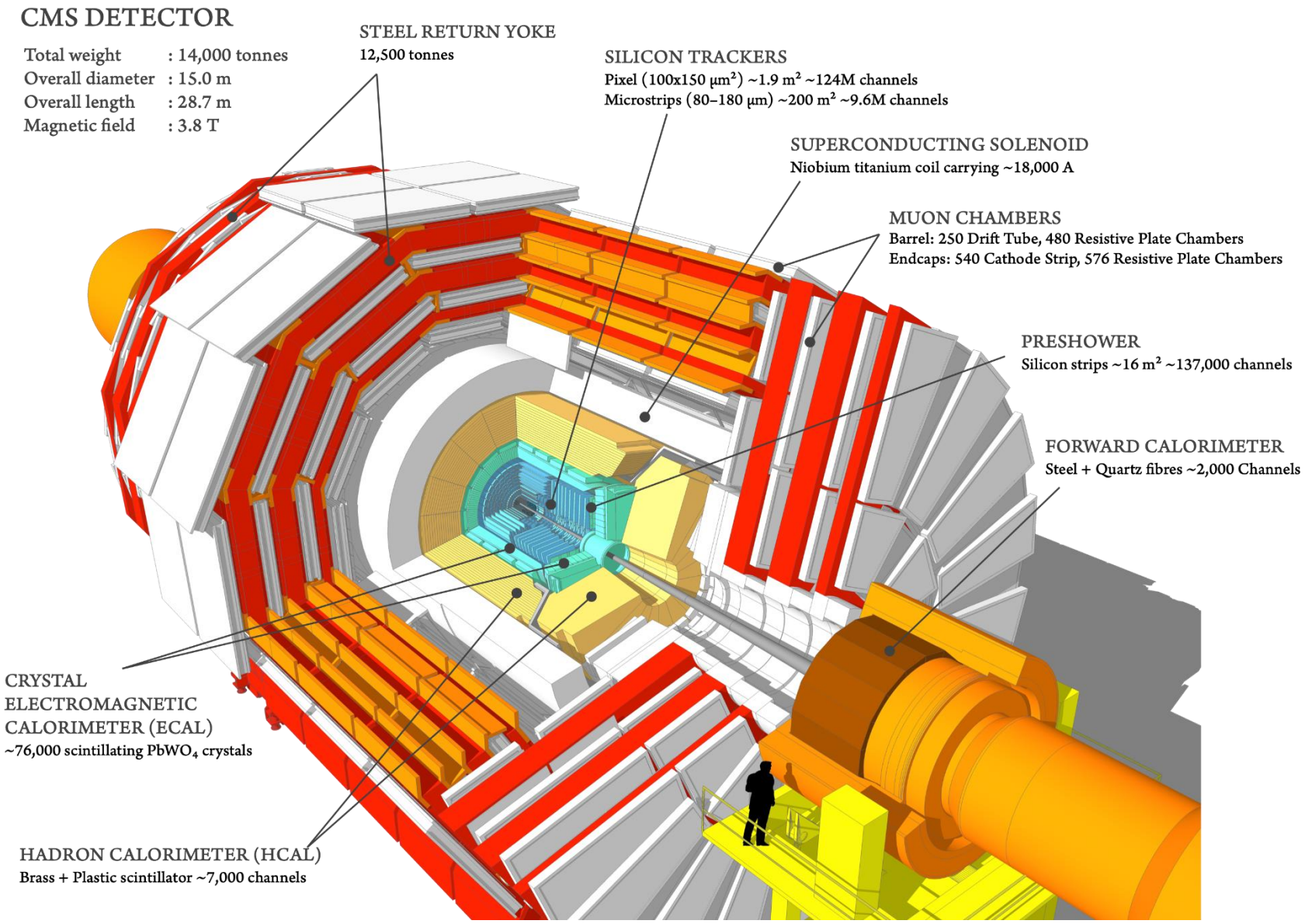


Medipix

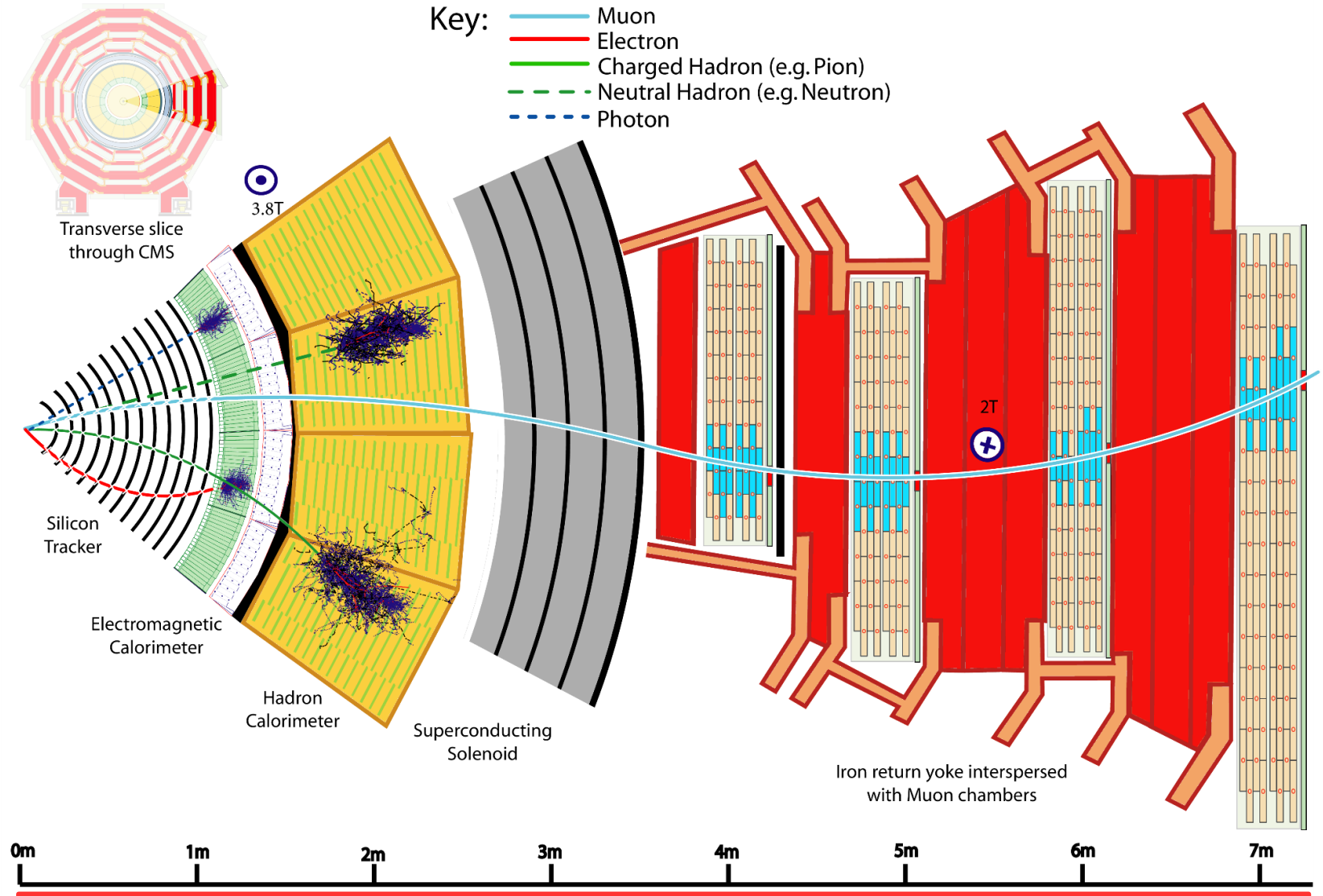
Compact Muon Solenoid



Compact Muon Solenoid - II



Compact Muon Solenoid - III



Farklı parçacıklar detektörde farklı iz bırakırlar.

(Neutrino ve erken bozunanlar hariç)