Compact Muon Solenoid

M.Numan Bakirci

**Slaytlarin bircogu David Barney tarfindan Temmuz 2007'de verilen sunumdan alinmistir*

Compact Muon Solenoid (CMS)

Physics Goals

CMS in 3 mins

CMS Detector
- Tracker
- ECAL
- HCAL
- Solenoid
- MUON
- Lowering

Point 5
- Outside
- Inside
- Gallery
- Underground

Resources

Q & A

- **CMS ve fizik**
- **CMS nedir?**
  - Compact
    - Ne demek?
  - Muon
    - Muonlara neden ihtiyacimiz var?
  - Solenoid
    - Nedir, Ne yapar, Neden cok ozeldir?
- **CMS dedektoru bilesenleri**
  - Bilgiler, resimler, vs..
- **The visit to Point 5**
  - SX5 hangar disi
  - SX5 hangar ici
  - Cavern
- **Bazi sorular ve cevaplari**

CMS ve Fizik

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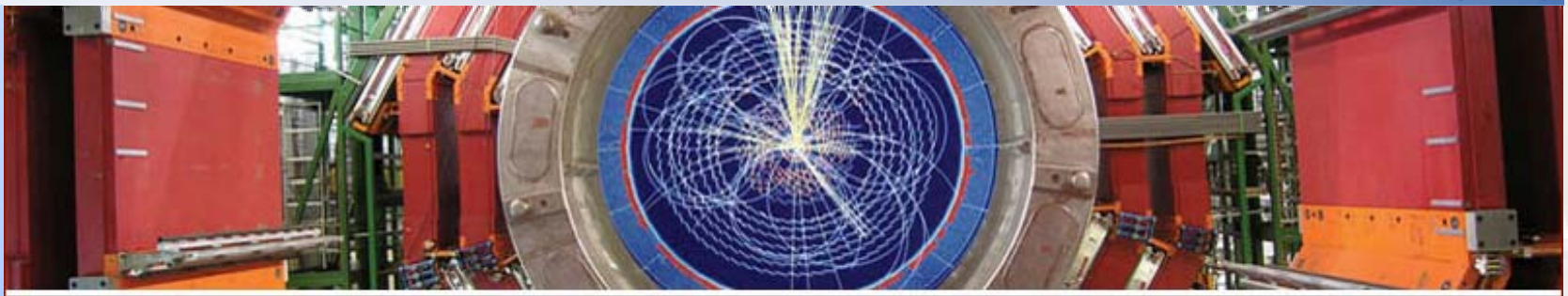
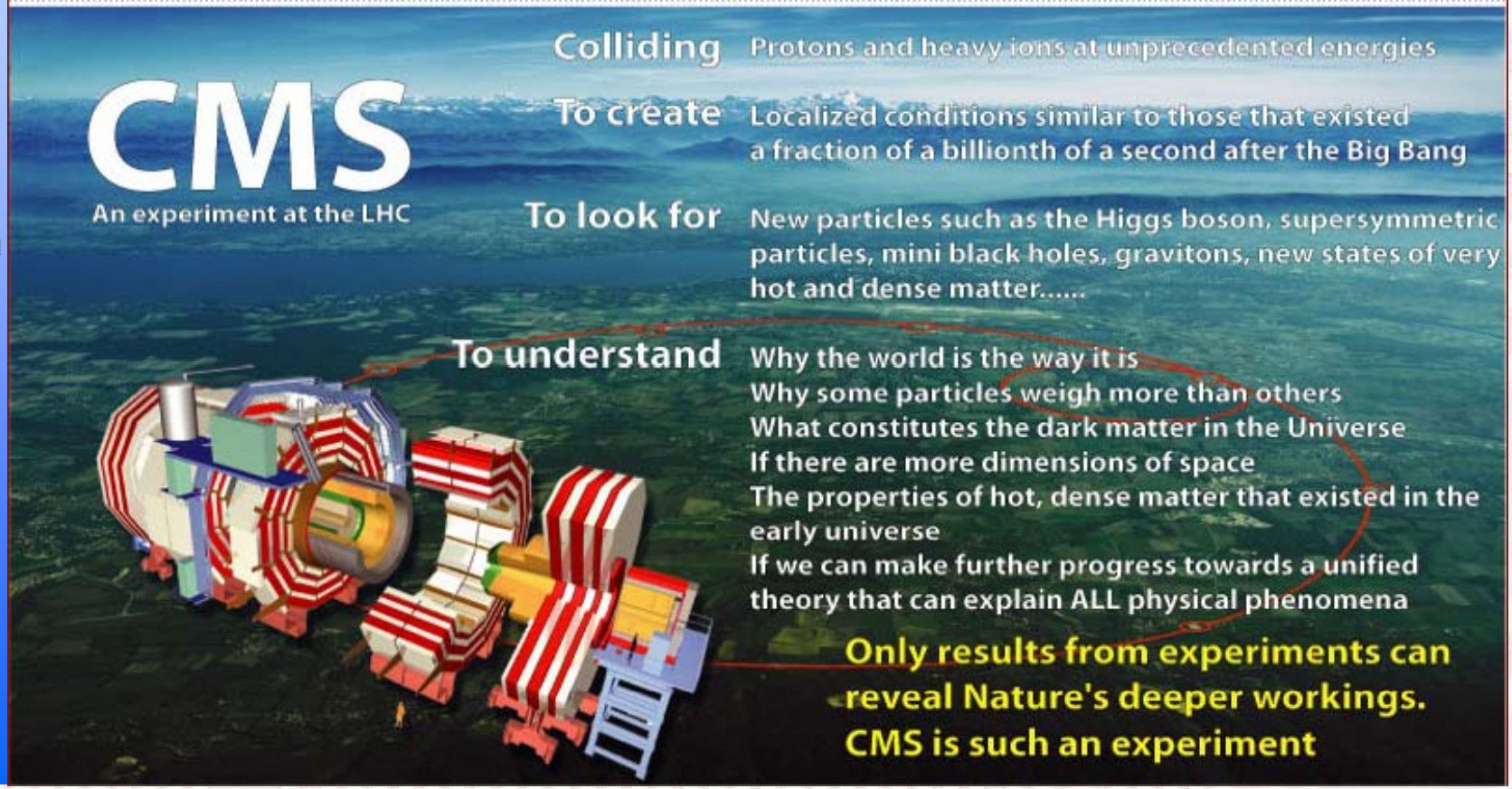
Q & A





CMS-Tarihce

Physics Goals
CMS in 3 mins
CMS Detector
Tracker
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HCAL
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MUON
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Outside
Inside
Gallery
Underground
Resources
Q & A

- **Ilk dusunce 1990'larda basladi**
- **Buyuk bir magnet icerisinde tum izleyici ve kalorimetre dedektorleri…**
- **Ana parcalarin yeryuzeyinde insa edilmesi ve sonra yeraltina indirilmesi**
- **17 yilda bazi degisikler oldu..**
- **Colaborasyon su an 38 ulkedeki 178 enstituden 2000 den fazla bilimadamindan olusmaktadir.**
- **Buyuk parcalarin insasina 5 yil once baslandi**
- **2008 yili ortalarinda ilk carpismalarin gozlenmesi beklenmektedir.**

Compact kucuk demek degil!

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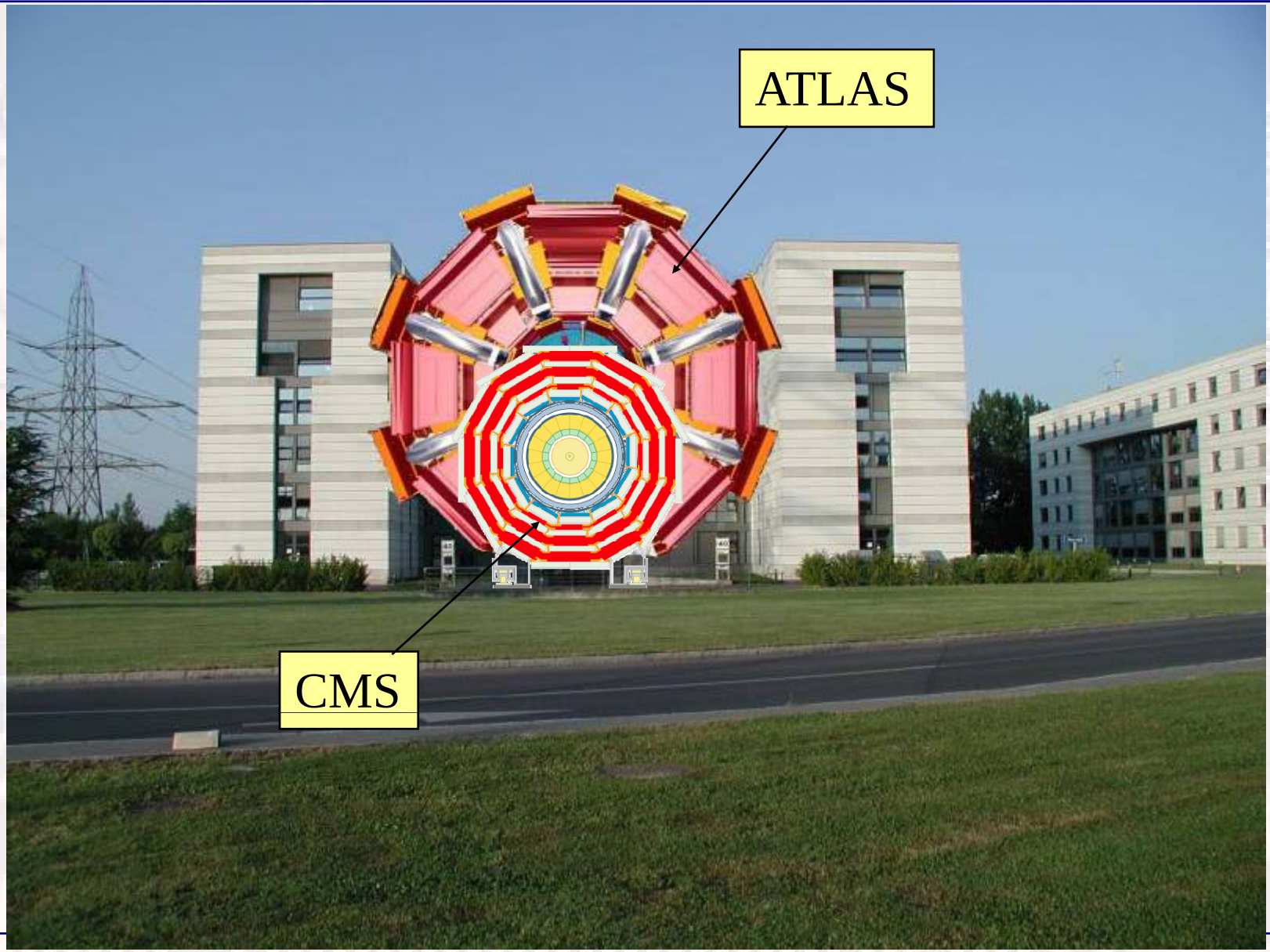
Q & A



Muonlar onemlidir

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Q & A

- **Varlanmalari cok kolaydir**
  - Carpismadan elde edilen verinin saklanip saklanmamasina cabuk karar verilemsini saglar
- **CMS cok katmanli muon dedektorleri kullanir**

Solenoid nedir?

Physics Goals

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Q & A

- Solenoid silindir halinda sarilmis iletkenlerden olusur. Iletkenlerden elektrik akimi gecirilmesi ile manyetik alan olusur.
- CMS solenoidi silindirinekseni boyunca 4 tesla'lik manyetim alan olusturacaktirs
  - dunyaninkinden yaklasik olarak 100000 kat daha buyuk..
- Gerekli olan akim ~20 k amper.
  - -- superiletken kullanilmasi gerekiyor (0 direnc)
- Superiletken olarak bakira sarilmis halde Niobium Titanium (NbTi) kullanilacaktir
  - ~4K'e kadar sogutulacak
- CMS solenoidi 13m uzunlugunda ve ic capi 5.9m'dir.
- Solenoid icine izleyici ve merkezi kalorimetreleri alacak kadar buyuktur
- **80 milyon CHF!**

ATLAS vs CMS (magnetler!)

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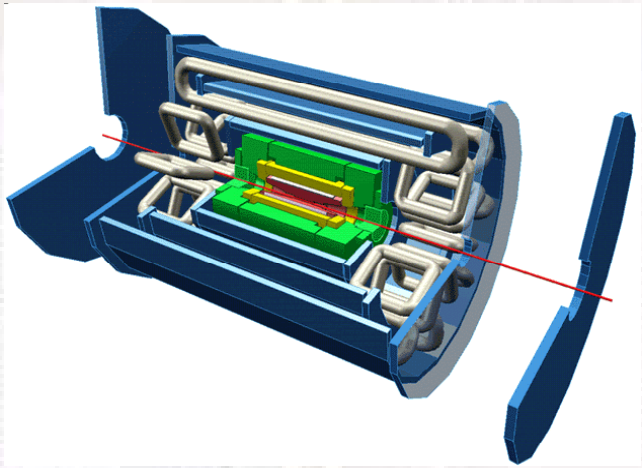
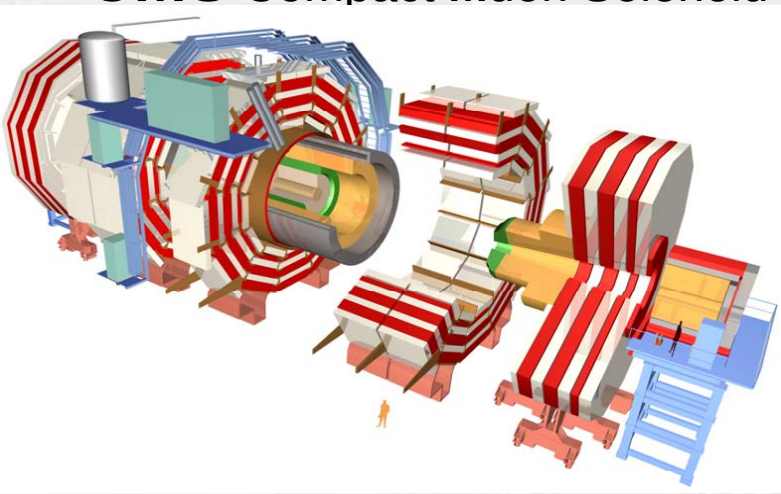
Resources

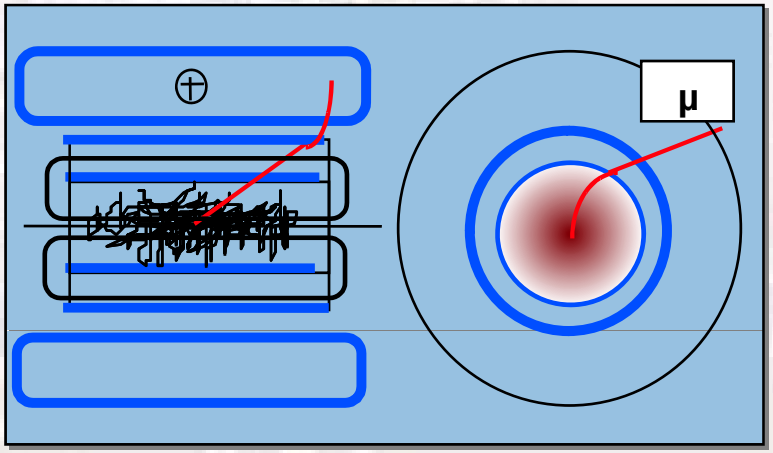
Q & A

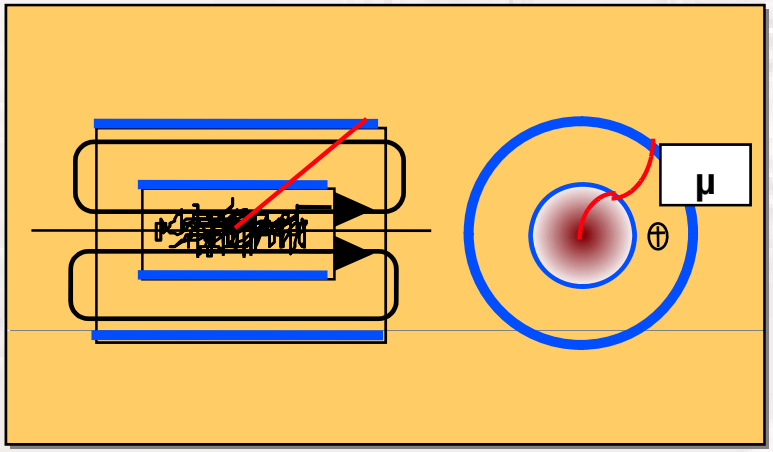
ATLAS A Toroidal LHC Apparatus



CMS Compact Muon Solenoid







Yuklu parcaciklar manyetik alanda sapacaklardir;sapma miktari bize ne kadar hizli olduklari hakkinda bilgi verecektir

CMS BROSURU

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Q & A

Dedektör ve detektifler

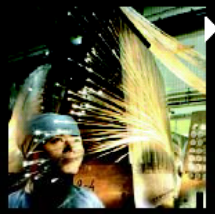
CMS, herbiri belirli bir amaç için tasarlanmış, birçok katmandan oluşan gelişmiş teknolojiye sahip büyük bir dedektördür. CMS'yi oluşturan bütün bu katmanlar, CMS araştırmacılarının CERN'ün Büyük Hadron Çarpıştırıcısındaki (BHÇ) çarpışmalarda oluşacak tüm parçacıkların kimliklerini belirlemelerini, enerji ve momentumlarını hassas olarak ölçmelerini sağlarlar.

İz bulucu

Çok küçük bölümlere (şerit ve kutucuklara) ayrılmış silikon algılayıcılar elektrik yüklü parçacıkların izlenmesini ve momentumlarının ölçülmesini sağlarlar. Ayrıca uzun ömürlü kararsız parçacıkların bozunduğu yerleri gösterirler.

Elektromanyetik Kalorimetre

Elektron ve fotonların enerjilerini hassas olarak ölçmek için yaklaşık 80.000 kurşun-tungstat ($PbWO_4$) kristali kullanılmaktadır. Silikon algılayıcılara dayalı bir "parçacık sağanağı öncesi" dedektör, uçlardaki kapaklarda parçacıkların kimliklerinin belirlenmesine yardımcı olur.



Hadron Kalorimetresi

Yoğun malzeme (pirinç veya çelik) katmanlarının arasına yerleştirilmiş plastik ışıldayıcı ya da kuvartz fiber katmanları hadronların, yani proton, nötron, pion ve kaon gibi taneciklerin enerjilerini belirlememizi sağlar.

Müon Dedektörleri

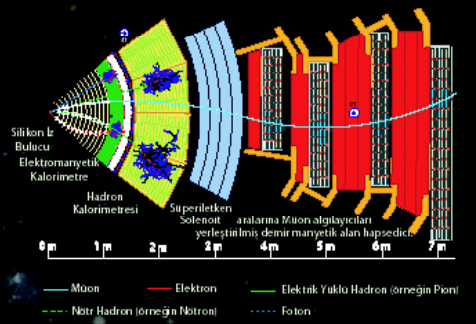
CMS, müonları (ağır elektronlar diye de tanımlanabilir) saptamak ve momentumlarını ölçmek için üç tip dedektör kullanmaktadır: sürüklenme tüpleri, şerit katod odacıkları ve dirençli plaka odacıkları.

Süperiletken Solenoit

13 m uzunluğunda ve 6 m çapında -270°C'ye soğutulmuş süperiletken niyobyum-titanyum sarımdan geçen 20.000 amper; 4 Tesla büyüklüğünde (dünyanın manyetik alanının yaklaşık 100.000 katı) bir manyetik alan üretir. Bu alan elektrik yüklü taneciklerin yörüngelerini eğerek birbirlerinden ayrılmalarını, ve momentumlarının ölçülmesini sağlar.

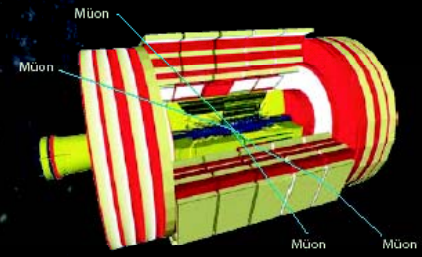
Örüntü Tanıma

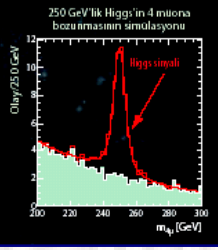
CMS'de keşfedilecek yeni parçacıklar çoğunlukla kararsız ve hemen daha hafif, daha kararlı ve daha iyi anlaşılmış parçacıklar çağlayanına dönüşen türde olacaktır. CMS'den geçen parçacıklar değişik katmanlarda onların tanınmasını sağlayan kendilerine özgü örüntüler ya da "imzalar" bırakırlar. Herhangi yeni bir parçacığı bulduğumuzu (ya da bulmadığımızı) bu imzalardan anlarız.



Tetikleme Sistemi

Higgs bozonu gibi çok ender olan parçacıkların üretilme olasılığını artırmak için BHÇ'nda parçacık demetleri saniyede 40 milyon kere çarpışırlar. Aşağıdaki şekilde görünen dört müona bozunmuş Higgs parçacıkları gibi sadece yeni fizik içerme olasılığı yüksek olayları (yaklaşık olarak saniyede 100 tane) kaydetmek (ya da bu tip olaylar oluştuğunda veri alımını tetiklemek) için parçacıkların imzalarını hızlı elektronik birimlerde inceleriz. Böylece veri akış hızı baş edilebilir düzeylere iner. Yalnızca seçilmiş bu ilginç olayları daha sonraki ayrıntılı çözümleme için kaydederiz.





Veri Çözümleme

Dünyanın her bir yanından fizikçiler, CMS'de kaydedilmiş milyonlarca olayı inceleyip solda görülen (simülasyon) gibi yeni parçacıkların ya da yeni olguların varlığını gösteren grafikler elde etmek için en son bilgi işlem yöntemlerini (GRID gibi) kullanırlar.

CMS bilesenleri: IZLEYICI

Physics Goals

CMS in 3 mins

CMS Detector
- **Tracker**
- ECAL
- HCAL
- Solenoid
- MUON
- Lowering

Point 5
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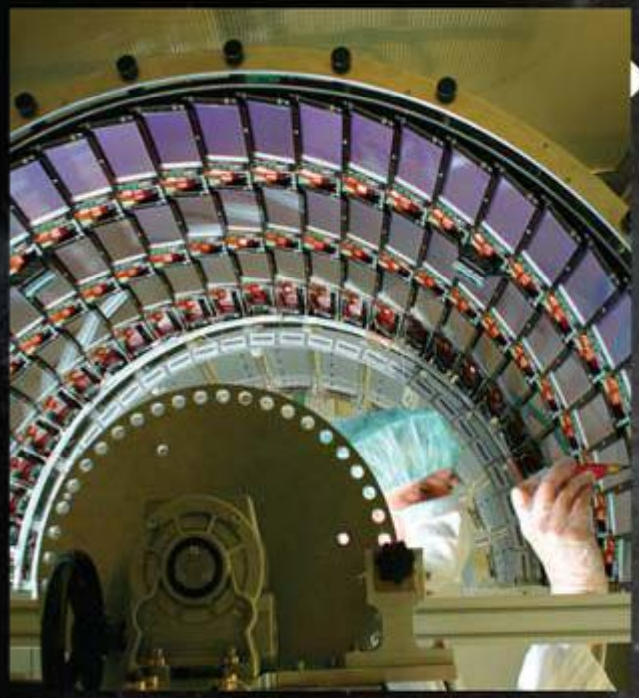
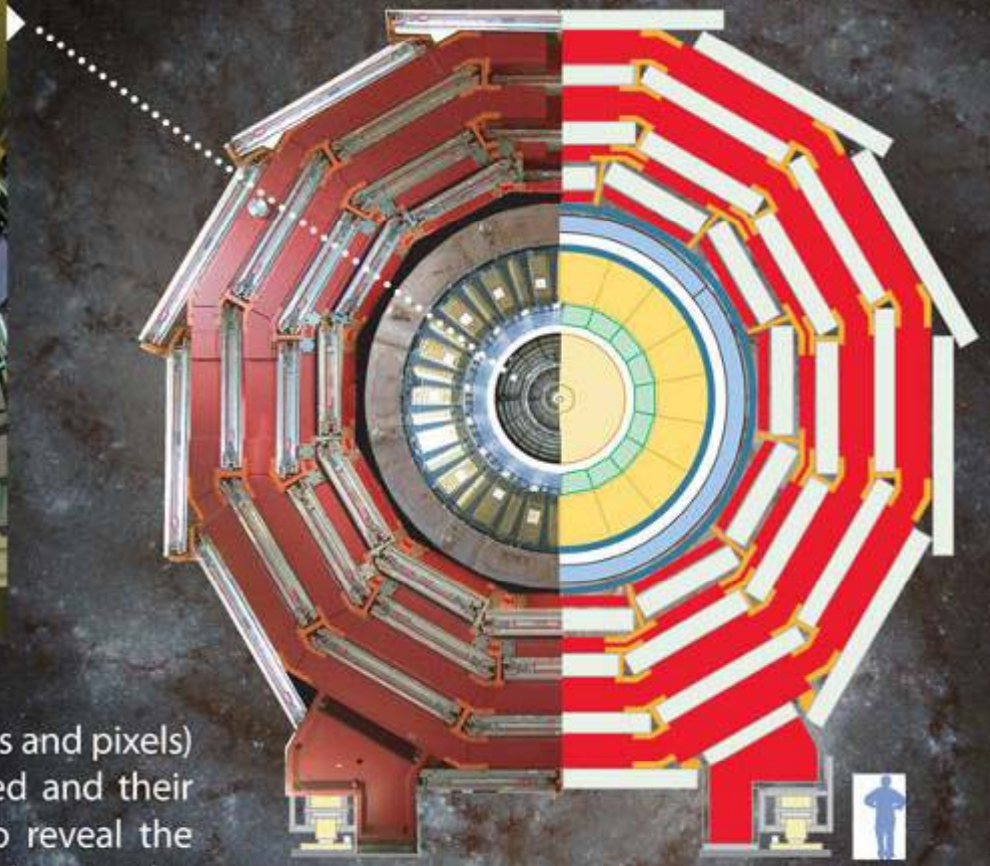
- Underground

Resources

Q & A





Tracker

Finely segmented silicon sensors (strips and pixels) enable charged particles to be tracked and their momenta to be measured. They also reveal the positions at which long-lived unstable particles decay.

Izleyici Yerlesimi

Physics Goals

CMS in 3 mins

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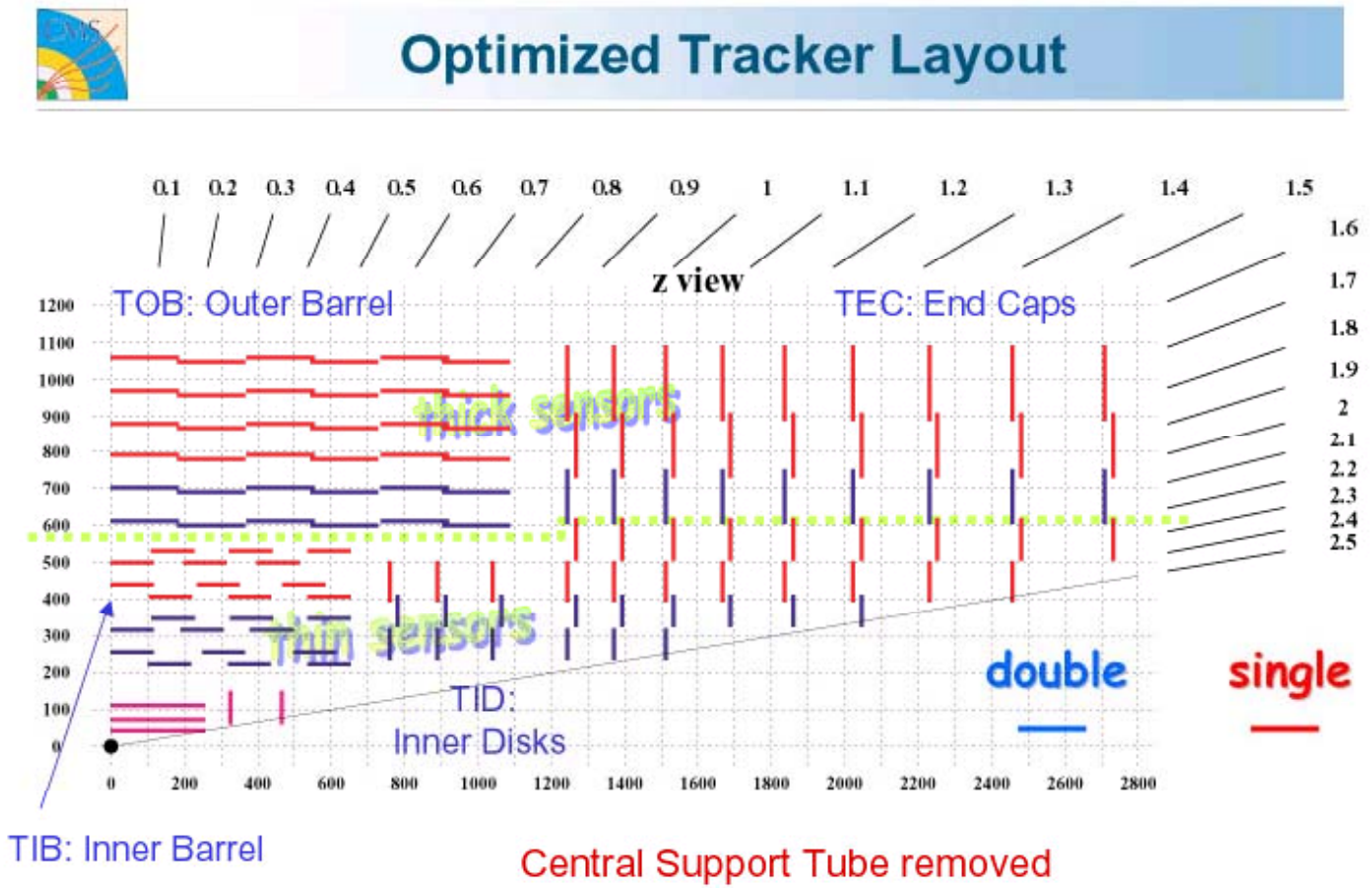

Bilgiler ve durum: Izleyici

Physics Goals
CMS in 3 mins
CMS Detector
Tracker
ECAL
HCAL
Solenoid
MUON
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Q & A

- **Dunyada su ana kadar yapilan en buyuk silicon-sensor sistemi**
  - 220m^2'den fazla sensor alani
  - 60 milyondan fazla elektronik kanal(pixeller and microstripler)
  - 6m uzunlugunda, ~2.2m capinda, -15^{o}C'de calisacak
- **Durumu**
  - Strip tracker tamamiyla insa edildi; testleri 186'da yapilmakta; onumuzdeki aylarda CMS'e yerlestirilmesi planlaniyor 2007
  - Pixel varlayicilar hemen hemen bitmek uzere; 2008'in baslarinda CMS'e yerlestirilmesi planlaniyor

CMS bilesenleri: ECAL

Physics Goals

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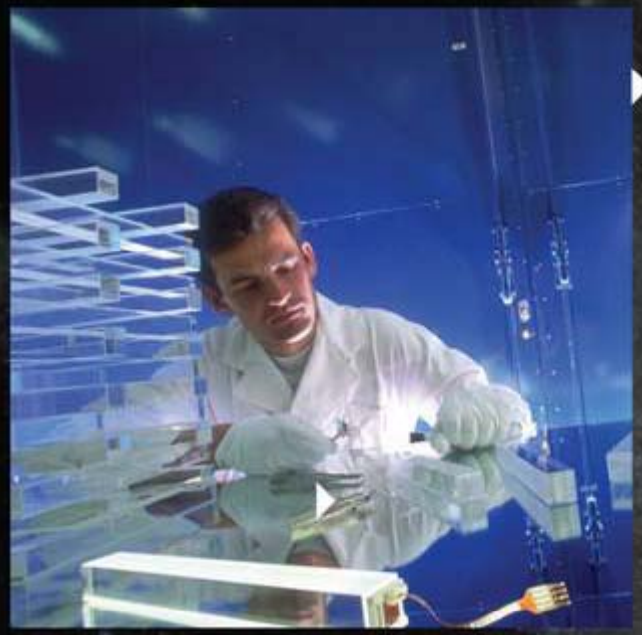
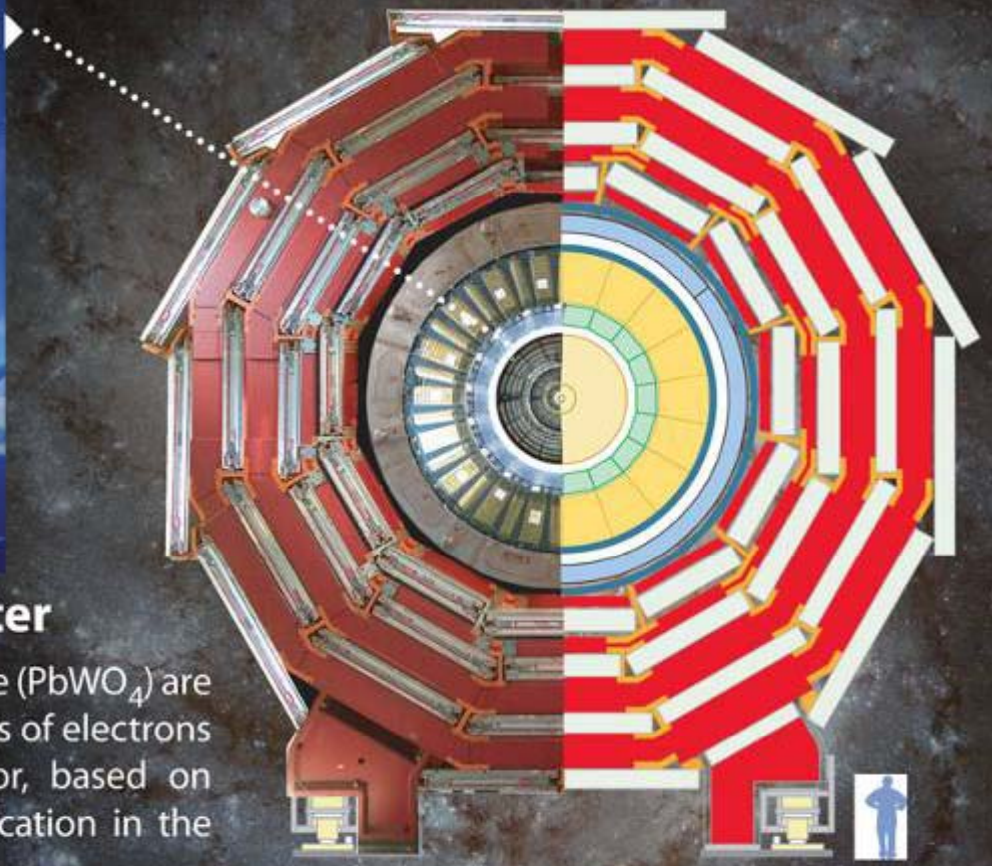
Q & A





Electromagnetic Calorimeter

Nearly 80 000 crystals of lead tungstate ($PbWO_4$) are used to measure precisely the energies of electrons and photons. A 'preshower' detector, based on silicon sensors, helps particle identification in the endcaps.

ECAL Yerlesimi

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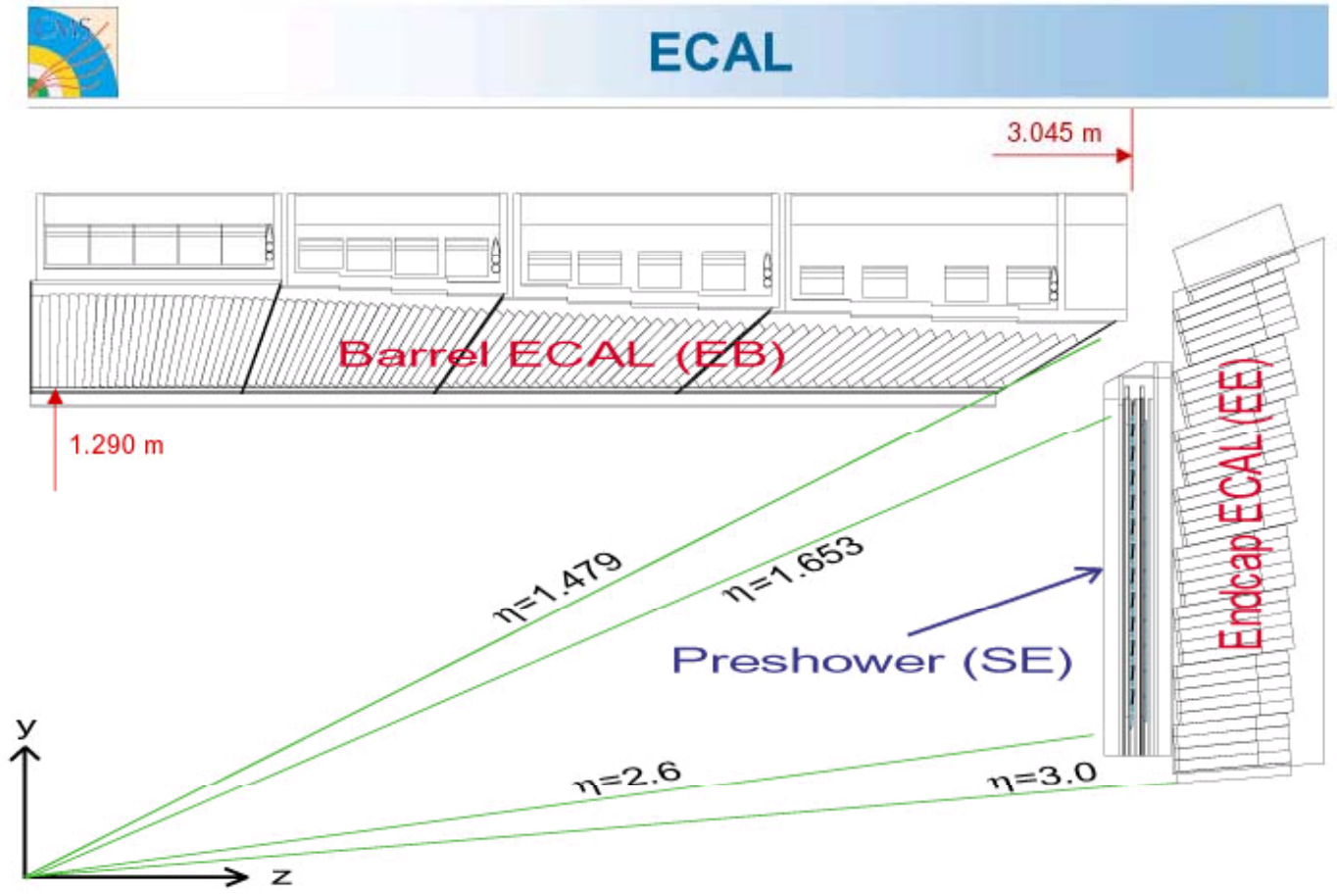
Q & A



Bilgiler ve durum: ECAL

Physics Goals

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Resources

Q & A

- **Homojen kalorimetre**
  - Kursun-Tungsten ($PbWO_4$) kristaller elektromenyetik dus ve sintilasyon isigi uretir
  - Fici: 36 “supermodules” icerisinde ~64000 kristal bulunur (herbirinde 1700 kristal vardir); isik,avalanche photodiodes ile varlanacaktir
  - Kapak: ~16000 crystals constructed as “supercrystals” – 5x5 matris seklinde ~16000 kristalden olusur; isik vacuum phototriodes ile varlanacaktir
- **Durum**
  - Butun fici supermoduller CMS’e yerlestirildi
  - Kapak superkristalleri ise (“Preshower” dahil) 2008 ortalarinda bitirilmis olacaktir

CMS bilesenleri: HCAL

Physics Goals

CMS in 3 mins

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- Tracker
- ECAL
- **HCAL**
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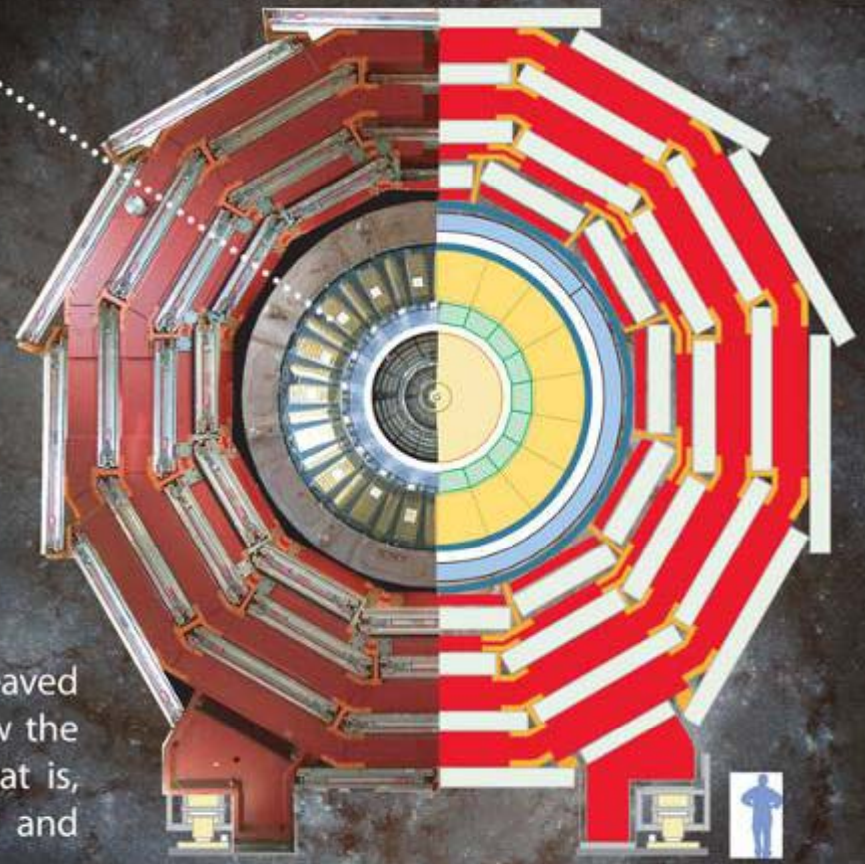
Resources

Q & A



Hadron Calorimeter

Layers of dense material (brass or steel) interleaved with plastic scintillators or quartz fibres allow the determination of the energy of hadrons, that is, particles such as protons, neutrons, pions and kaons.

HCAL Yerlesimi

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CMS in 3 mins

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Resources

Q & A

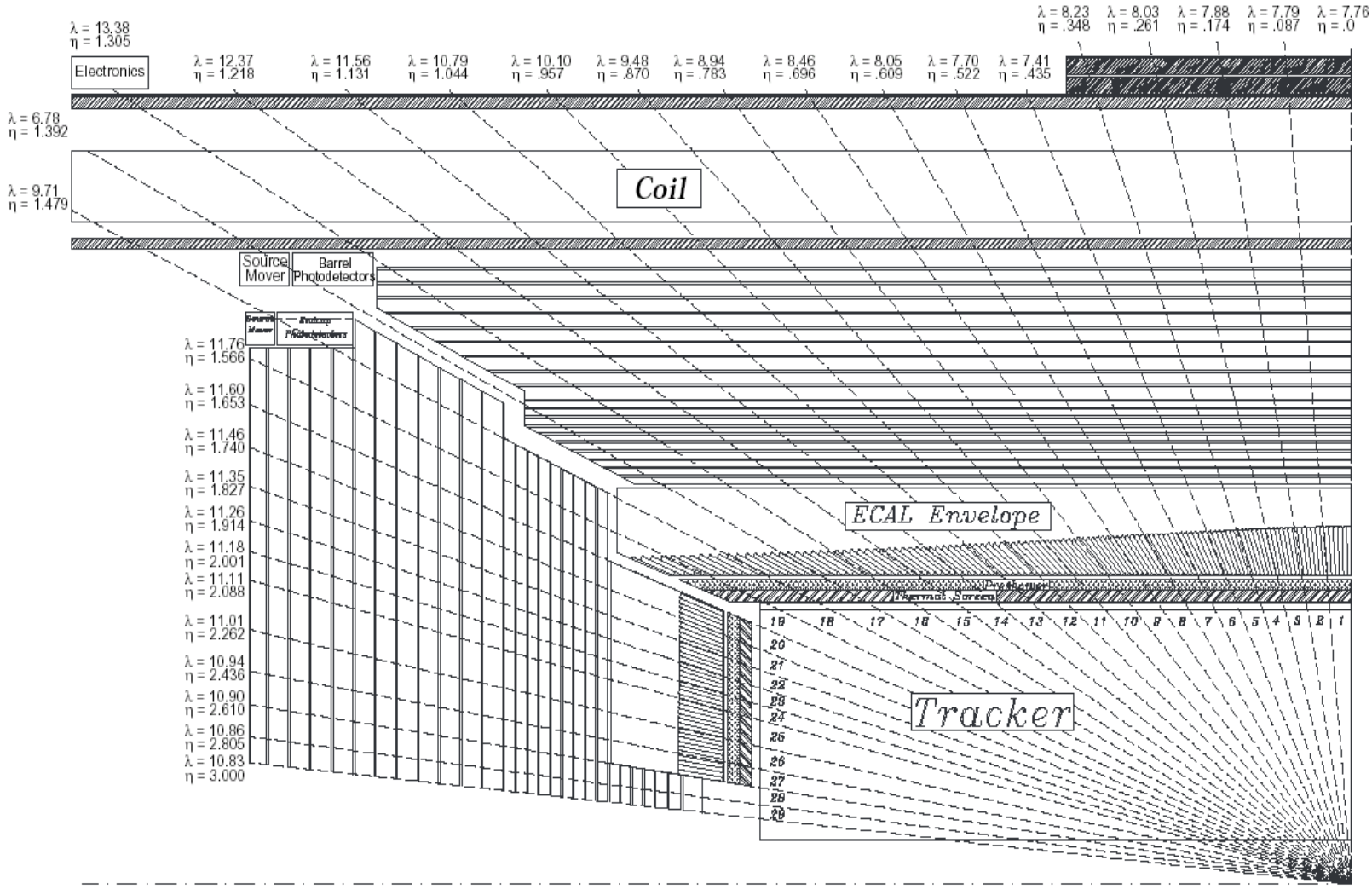

Fig. 5.2: The tower structure of HCAL, for the barrel and endcap regions (side view)

Bilgiler ve Durum: HCAL

Physics Goals

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Resources

Q & A

- **Uc parcali bulmaca**
  - Fici HCAL(HB) 36 brass sectorden olusmustur, herbirinin agirligi ~35 tonnes
  - Kapak HCAL(HE) atil durumdaki Rus savas gemilerinin elde edilmistir
  - Ileri HCAL (HF) celige gomulu kuartz fiberlerden olusmustur
- **Durum**
  - HB ve HE tamamlanmis ve (HE- haric) yeraltina indirilmistir
  - HF+ HB ve HE+ kalite kontrol testleri bitirilerek calisir hale getirilmistir

CMS bilesenleri: SOLENOID

Physics Goals

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- HCAL
- **Solenoid**
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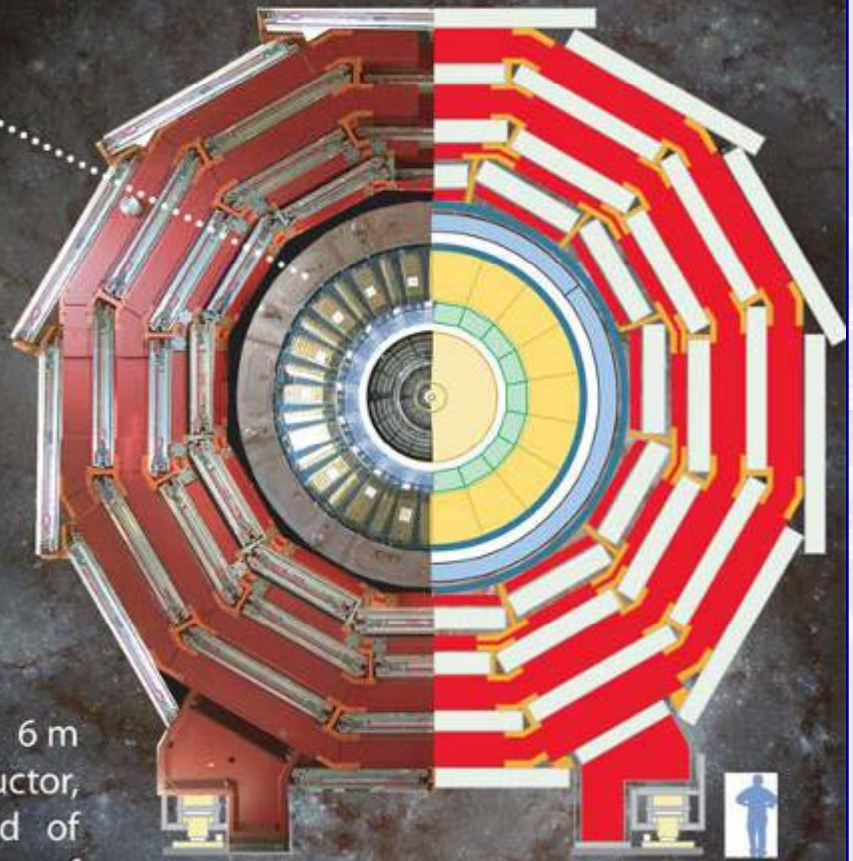
Q & A



Superconducting Solenoid

Passing 20 000 amperes through a 13 m long, 6 m diameter coil of niobium-titanium superconductor, cooled to –270°C, produces a magnetic field of 4 teslas (about 100 000 times stronger than that of the Earth). This field bends the trajectories of charged particles, allowing their separation and momenta measurements.

Bilgiler & Durum: Solenoid (1)

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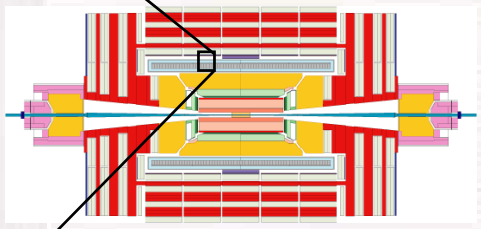
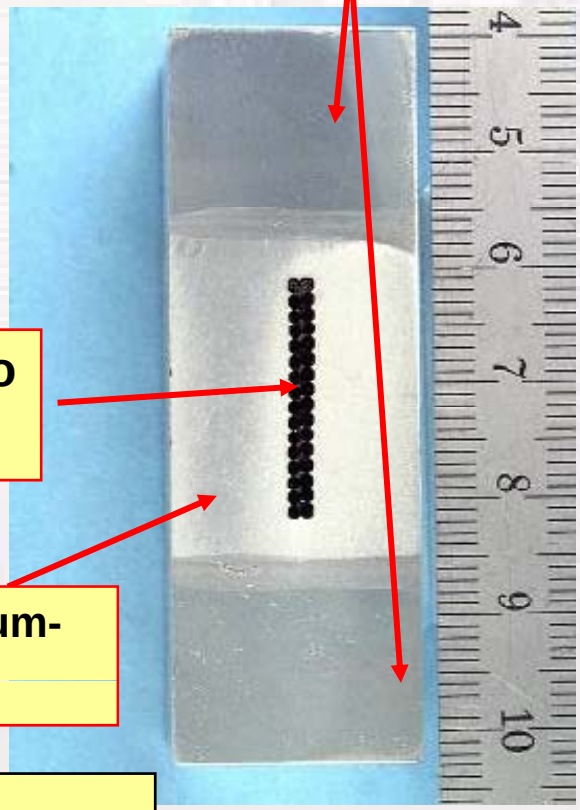
Q & A

Solenoid parcasi



Aluminyum alasim - mekanik sabitleyici

Superiletken kablo - NbTi



Ultra – saf Aluminyum-Magnetik sabitleyici

Yaklasik olarak 1 million km of NbTi flament kullanilmistir!

http://cmsinfo.cern.ch/outreach/CMSdocuments/MagnetBrochure/MagnetBrochure.pdf

Construction of the Solenoid

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- **7 ana parca:**
  - Dis vakum tanki: 3 parcadan olusmustur ve CERN'de insa edilmistir
  - Ic vakum tanki: tekparca halindedir
  - Solenoid : 5 sarmalin birlestirilmesiyle olusturulmustur
- **"return yoke"(Boyunduruk)**
  - ~10500 tonluk celik parcalar manyetik alani kontrol etmek icin Solenoidi cevreler
  - Ayrica CMS'in iskeleteni olusturur
  - Yoke 5 Fici halkasi ve 6 kapak diskinden (her iki tarafta 3'er tane) olusur

Solenoidin tasinmasi ve kurulmasi

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Resources

Q & A

“Sarmalin dondurulmesi”

Physics Goals

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Resources

Q & A

Coil is constructed vertically but needs to be horizontal!

Sarmalin yerlestirilmesi

Physics Goals

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Resources

Q & A

Bilgiler ve Durum: Solenoid (2)

Physics Goals

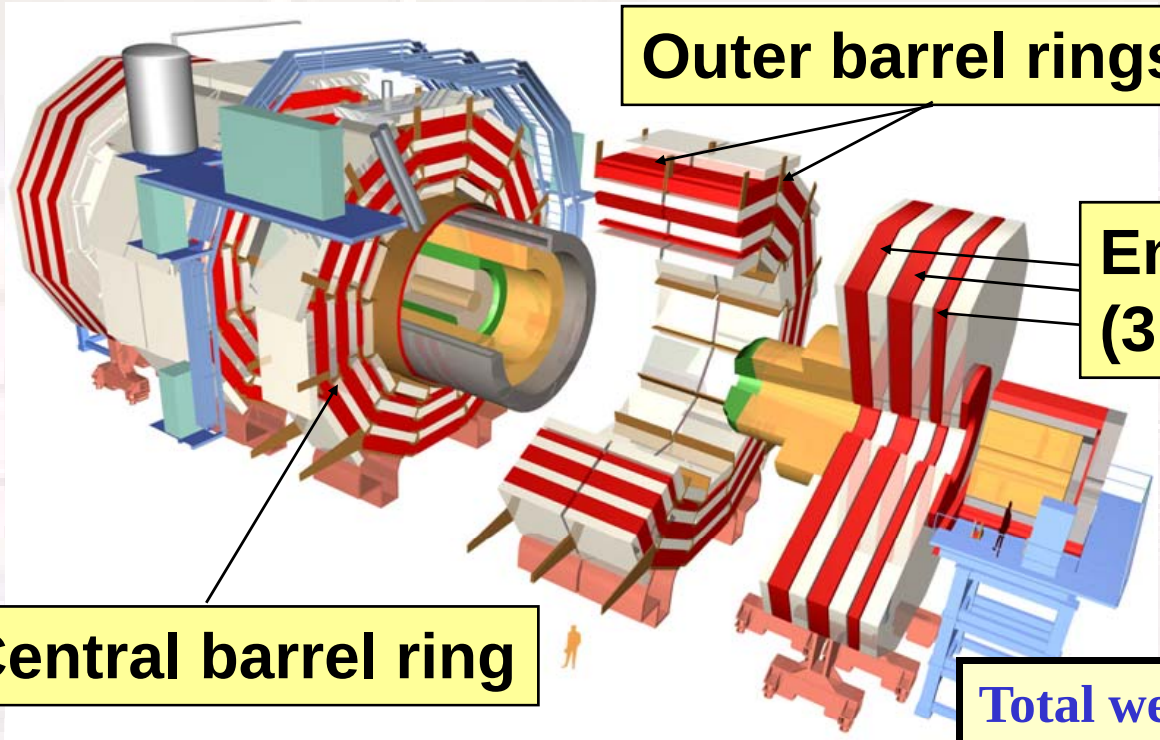
CMS in 3 mins

CMS Detector
- Tracker
- ECAL
- HCAL
- Solenoid
- MUON
- Lowering

Point 5
- Outside
- Inside
- Gallery
- Underground

Resources

Q & A



Outer barrel rings x 4 – 2 per side

Endcap disks x 6 (3 per endcap)

Central barrel ring

	Central Ring	*Outer Rings*
Barrel ring	1250 tonnes	1174 tonnes
Vacuum vessel	264 tonnes	-
Superconducting coil	234 tonnes	-
Support feet	72 tonnes	66 tonnes
Cabling on vacuum vessel	150 tonnes	-
Support for racks and cables	10 tonnes	10 tonnes
Total	**1980 tonnes**	**1250 tonnes**

Total weight	**12500 tonnes**
Diameter	**15m**
Length	**21.6m**
Magnetic field	**4 Tesla**

Endcap disk 1 (YE1)	~730 (disk) + 90 (cart) tonnes
Endcap disk 2 (YE2)	~730 (disk) + 90 (cart) tonnes
Endcap disk 3 (YE3)	~300 (disk) + 90 (cart) tonnes

Components of CMS: the MUON system

Physics Goals

CMS in 3 mins

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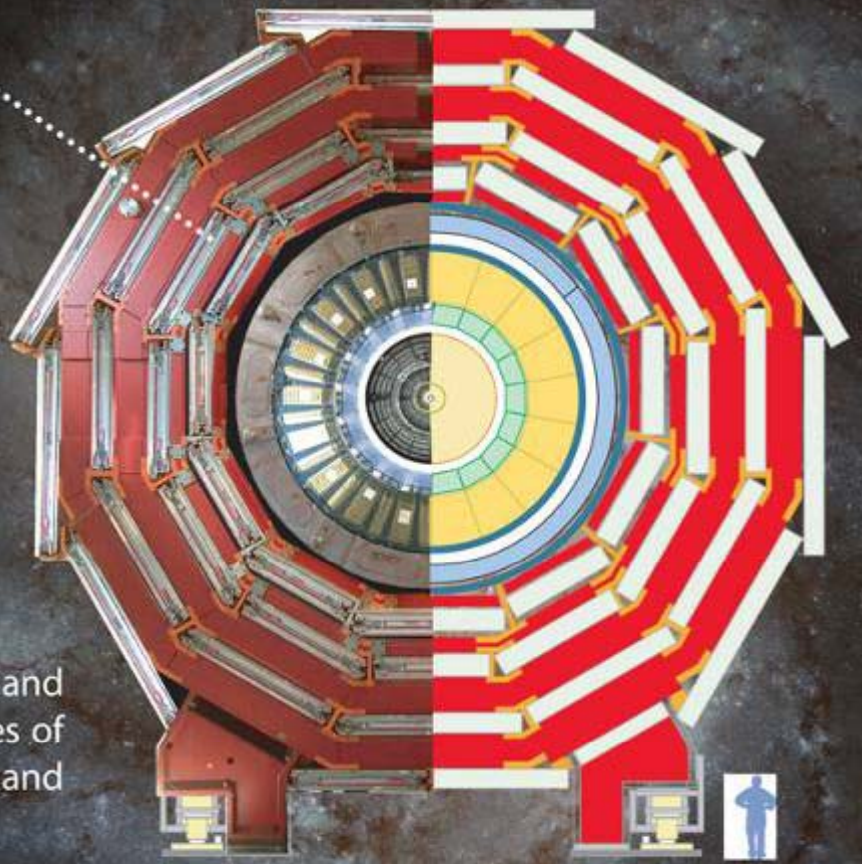
Resources

Q & A



Muon Detectors

To identify muons (essentially heavy electrons) and measure their momenta, CMS uses three types of detector: drift tubes, cathode strip chambers and resistive plate chambers.

Numbers & Status: MUON system

Physics Goals

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Resources

Q & A

- **Konum olcumu**
  - Fici: Drift Tubes (DT)
  - Kapak: Cathode Strip Chambers (CSC)
- **Trigger**
  - Fici ve kapakta bulunan Resistive Plate Chambers (RPCs)
- **Durum**
  - Butun Muon Odaciklari CMS'e yerlestirilmistir

CMS'de PArcacik Tanimlanmasi

Physics Goals

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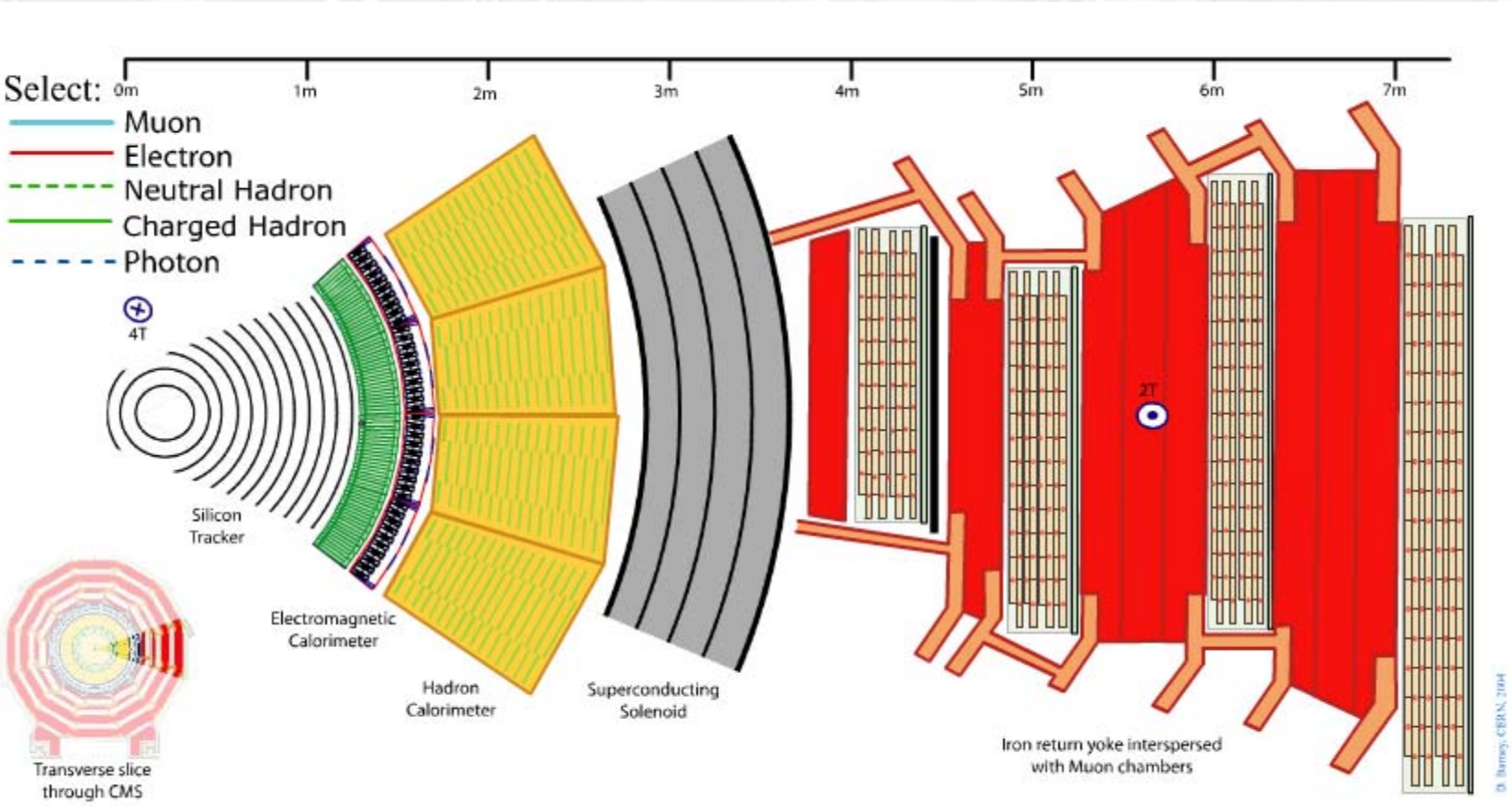
Resources

Q & A



Cogu parcacik sogrulur; birkaci kacabilir(muonlar, notrinolar…)

Run 2605 / Event 3981/ B 3.8 T/27.08.06

Physics Goals

CMS in 3 mins

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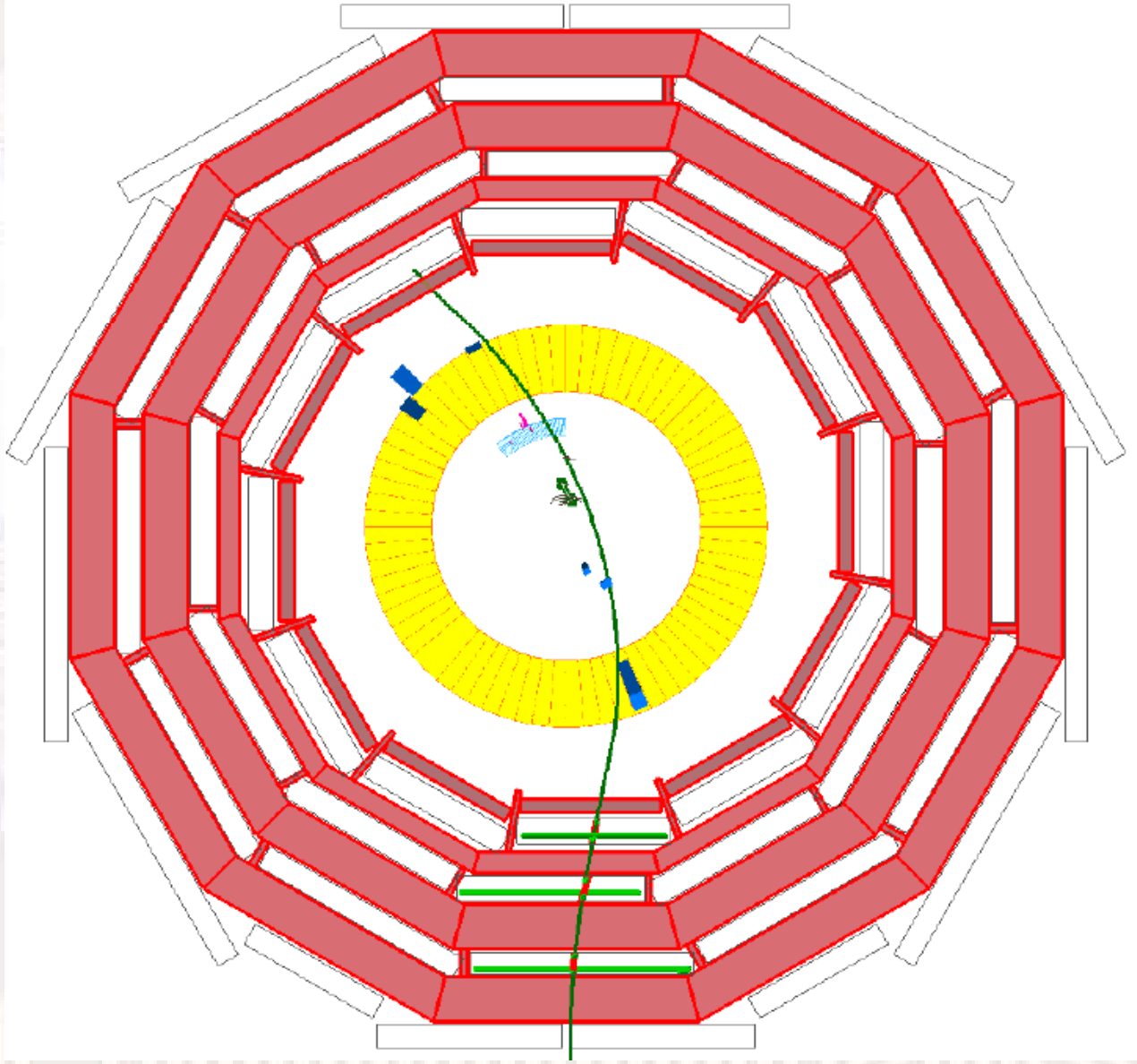
Resources

Q & A



CMS Parcalarinin Asagi Indirilmesi

Physics Goals

CMS in 3 mins

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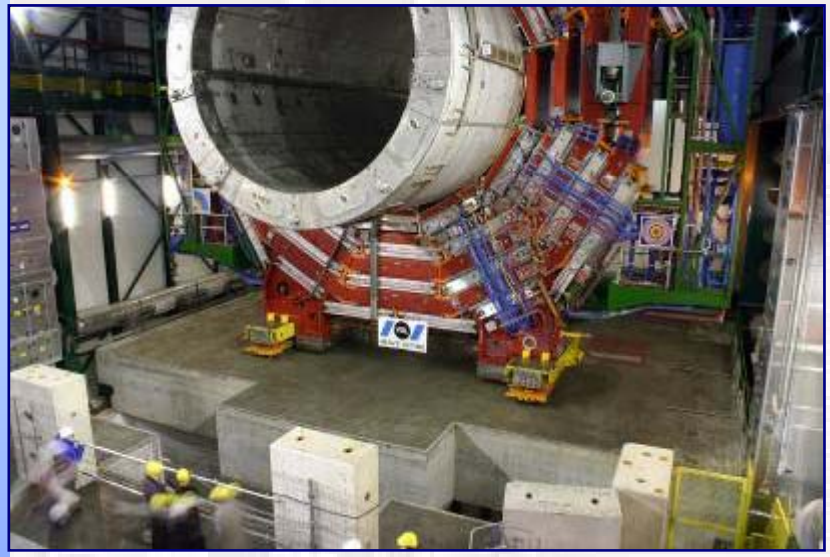
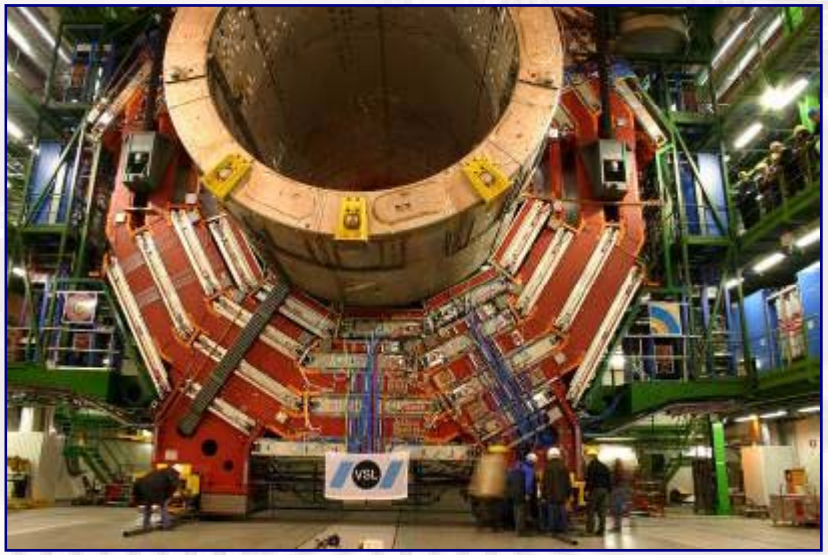
Resources

Q & A





Sogutma Tanklari

Physics Goals

CMS in 3 mins

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Resources

Q & A

- He gazi ile doludur
- Iki silindir CMS solenoid sogutma sistemi icin yaklasik 5000 litre sivi He saglar
- CMS solenoidini ~4K ‘e sogutmak 3 hafta surer
- Diger 4 silindir LHC sogutma sistemi icin gerekli sivi He saglar

YE-1

Physics Goals

CMS in 3 mins

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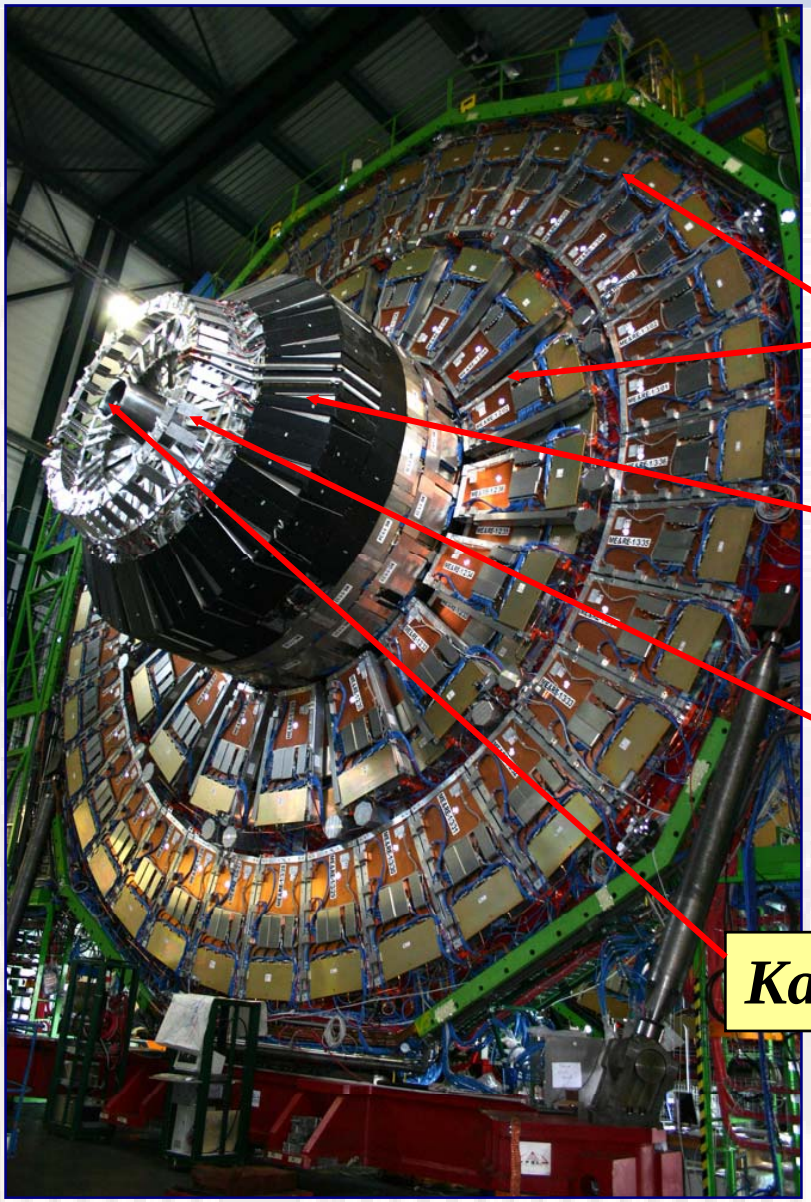
Resources

Q & A



- **YE-1 ("Yoke Endcap disc -1")**

Muon varlayicilari

Kapak Hadron Kalorimetresi

Kapak ECAL (mevcut degil)

Kapak Preshower (mevcut degil)

The UXC55 cavern yesterday

Physics Goals

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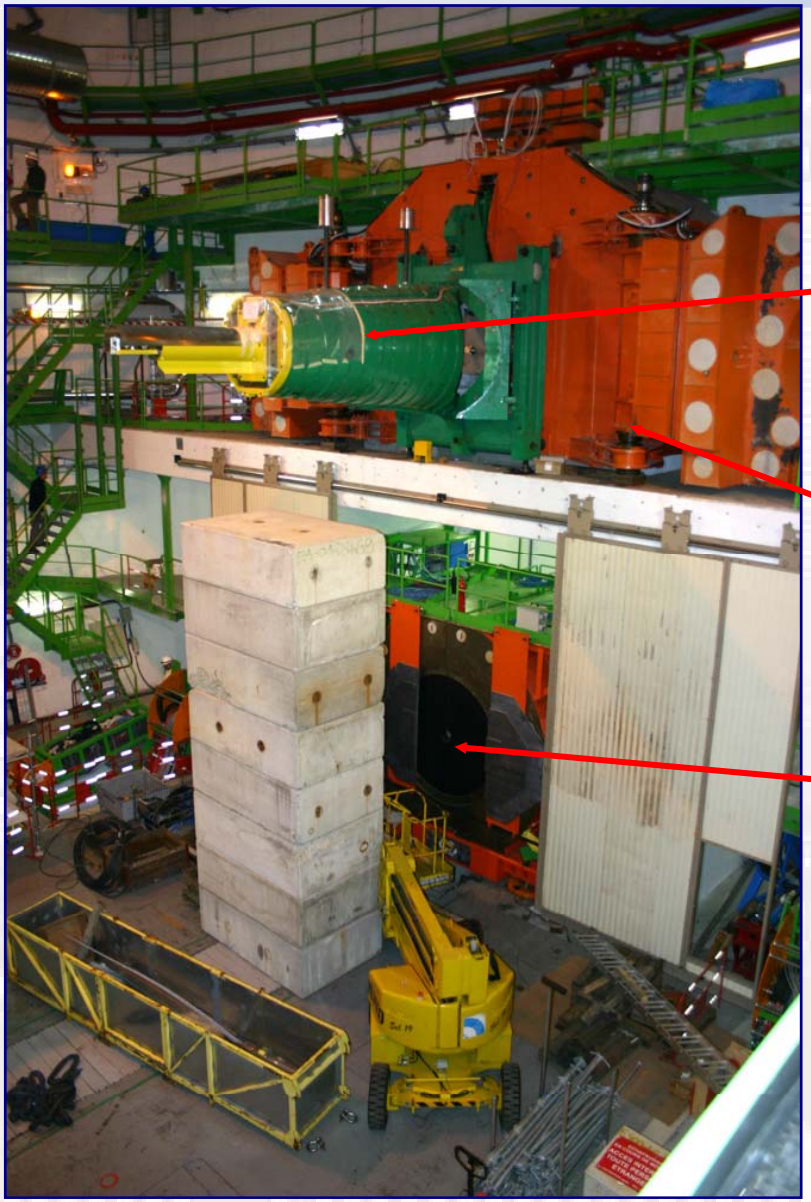
Resources

Q & A



Fixed iron nose

Rotating shielding (100 tonne doors!)

One of the forward Hadron calorimeters

Fire safety underground

Physics Goals

CMS in 3 mins

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Resources

Q & A

Can fill the experimental cavern with foam in 7 minutes!

Some Q & A

Physics Goals
CMS in 3 mins
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HCAL
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Q & A

- ***How many people are involved in building CMS ? Do they work 24 hours a day ? Do they work over Christmas ? How many man-years of effort are required to build it ?***
- **See http://cmsdoc.cern.ch/peoplestat.html**
- **At the moment there are about 2700 scientists and engineers from 184 institutes in 39 countries**
- **Also huge effort from industry**
- **Started construction about 5 years ago, but design etc. started nearly 20 years ago!**

Some Q & A

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Q & A

- ***How much power does it consume ?***
- **About 10 MegaWatts required during operation**
  - Equivalent to about 3000 average houses
- **About 1200 m^3 of water per hour for cooling**
  - The jet d'eau in Geneva pumps 1800 m^3 per hour!

Q & A

- ***Why do we have CMS and ATLAS? i.e. why 2 experiments to do the same thing?***
- **An important part of the "scientific method" is validation. We do not know the "answer" in advance. So having two detectors (built and optimized in different ways) can provide independent verification (or denial!) of discoveries**

HCAL design

- Copper - Scintillator tile calorimeter in barrel ($|\eta| < 1.5$) and endcap ($1.5 < |\eta| < 3$)
  Tail Catcher (TC) covers ($|\eta| < 0.4$) to provide adequate depth
  Coil instrumented with a scintillator layer ("massless gap")

- Separate forward calorimeters cover $|\eta| > 3$ → *see later*

- **Thickness:** HCAL ~ 5.5 λ ($\eta = 0$) + 1.1 λ in ECAL, 1.5 λ in coil, 1.1 λ in TC behind coil
  ~ 10.8 λ ($\eta = 1.3$)
  ~ 11 λ in endcap

- **Segmentation:** longitudinal — two depths (finer absorber plates in first layer)
  transverse — projective towers with $\Delta\eta \times \Delta\phi = 0.087 \times 0.087$

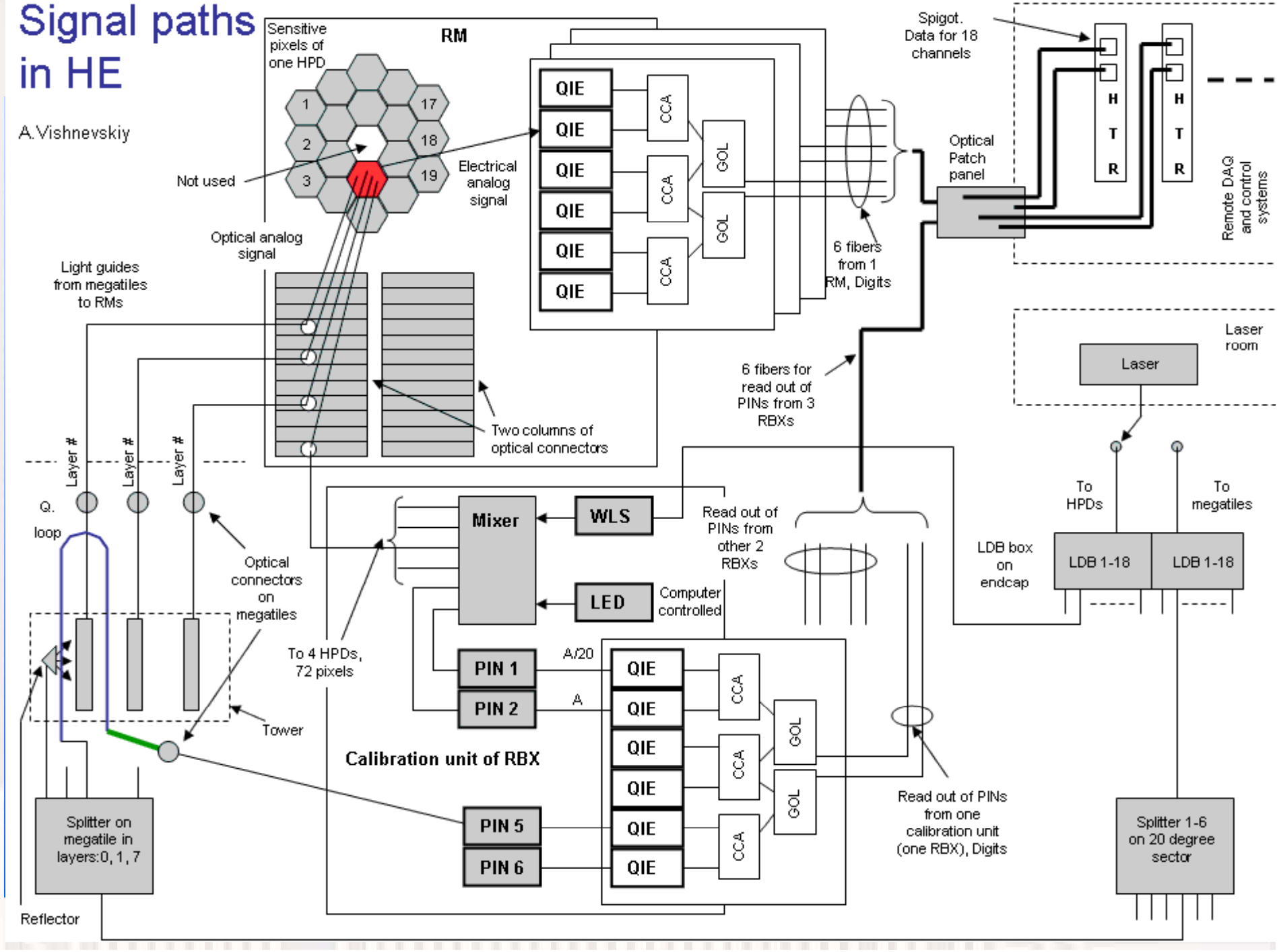
- **Readout:** Embedded wavelength-shifting fibres (as in CDF forward upgrade)

Dynamic range: 20 MeV (muon) → 2 TeV (maximum jet energy)

- **Calibration:** ^{137}Cs sources in tubes, laser light, and collider data

Signal paths in HE

A.Vishnevskiy



The Higgs mechanism. Drawing 1 : To understand the Higgs mechanism, imagine that a room full of physicists quietly chattering is like space filled only with the Higgs field ...

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Q & A

The Higgs mechanism. Drawing 2 : ... a well known scientist walks in, creating a disturbance as he moves across the room, and attracting a cluster of admirers with each step ...

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Q & A

The Higgs mechanism. Drawing 3 : ... this increase his resistance to movement, in other words, he acquires mass, just like a particle moving through the Higgs field ...

Physics Goals

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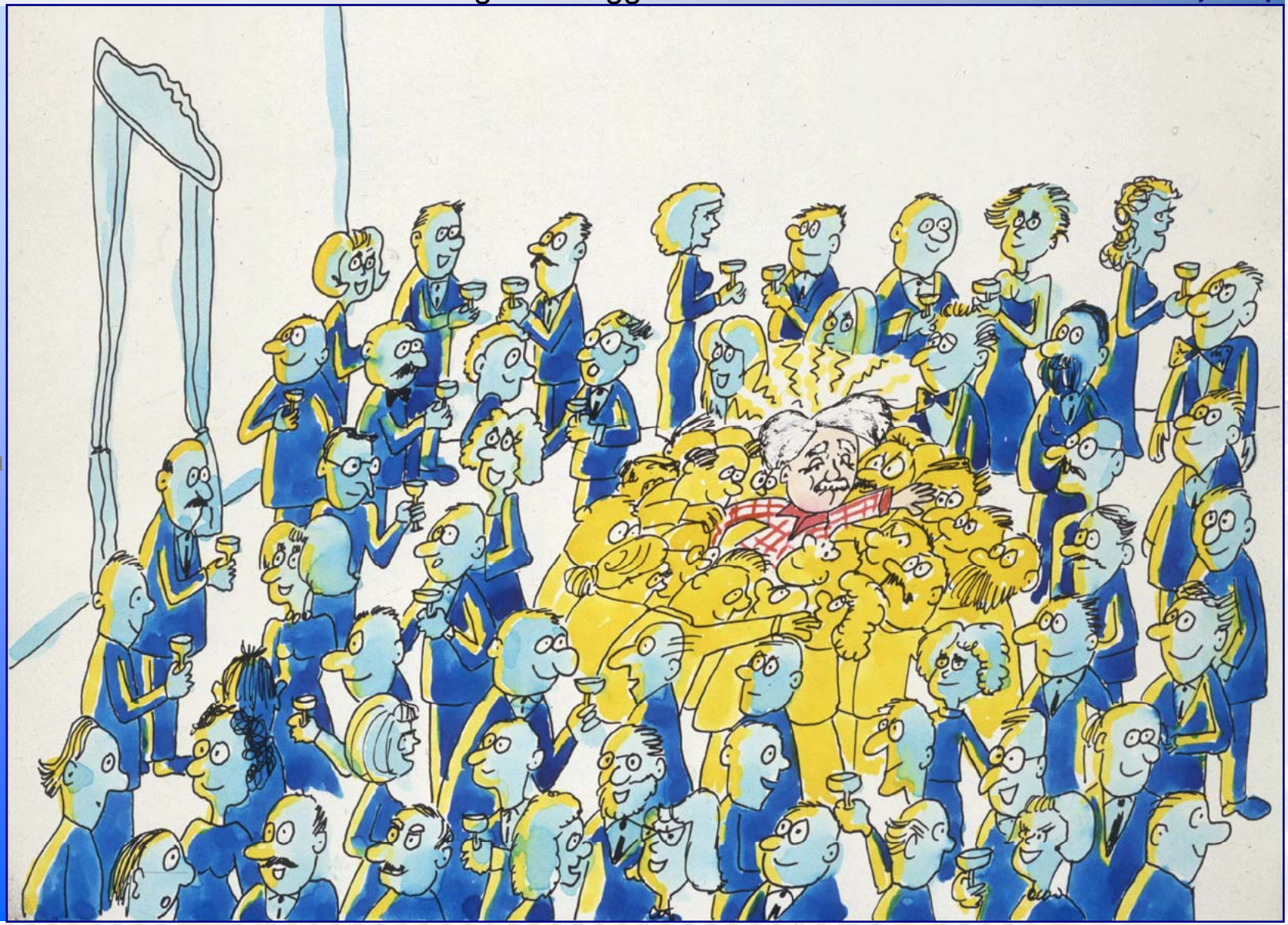
Q & A



The Higgs mechanism. Drawing 4 : ... if a rumour crosses the room ...

Physics Goals

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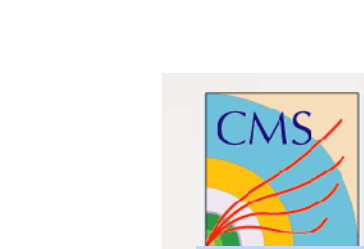
Q & A



The Higgs mechanism. Drawing 5 ... it creates the same kind of clustering, but this time among the scientists themselves. In this analogy, these clusters are the Higgs particles.

Physics Goals

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Q & A