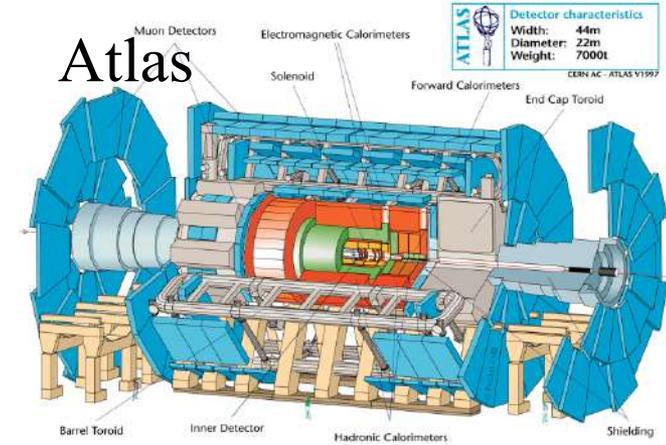


CMS

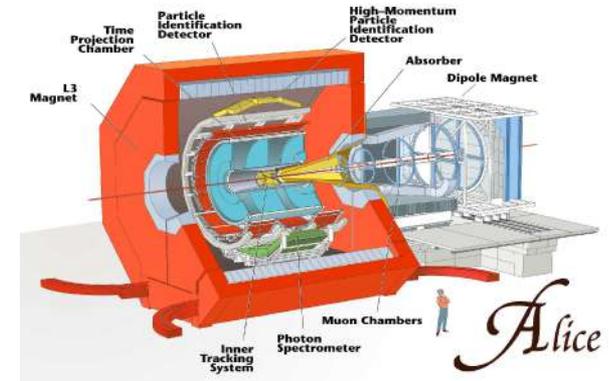
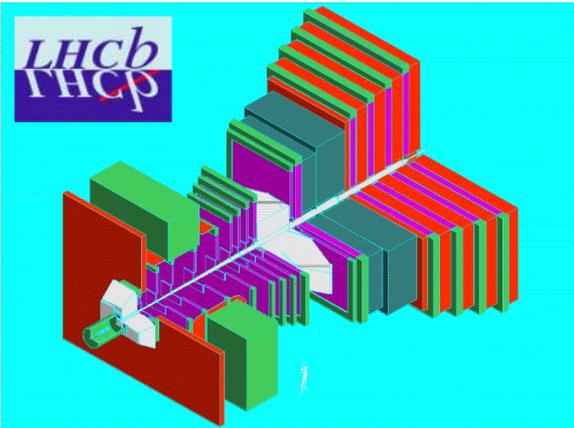
Detector characteristics
Width: 22m
Diameter: 15m
Weight: 14 500t

Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC-ATLAS V1997



CERN'de Yenileme ve Geliştirme Çalışmaları

Kerem Cankocak



CERN'de ne arıyoruz?

CERN’de ne arıyoruz?

Nerden geldik?

Nereye gidiyoruz?

“Her şey” neyden meydana gelmiştir?

Thales

Anaksagoras ...

Aristoteles:

–Toprak

–Hava

–Ateş

–Su



(c) Andy Brice 1998

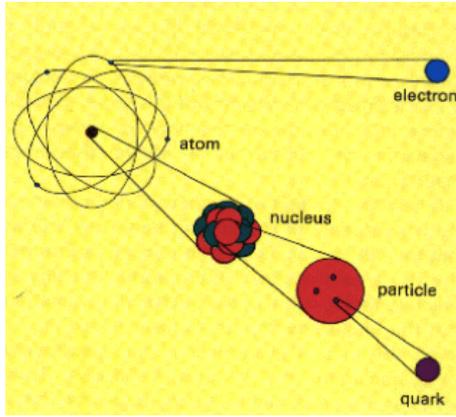
**“Uzlaşımaya göre renk vardır,
Tatlılık derler,
Acı derler,
ama gerçekte atomlar ve uzay vardır.”**

-Demokritos (585 MÖ)

Temel Parçacıkların Kısa Tarihi

- Antik Çağ : **Dört element**. MÖ 5. yüzyılda atom kuramına yönelik başarısız girişim (Demokritos).
- 18. yüzyıl : Lavoisier ve Dalton **atomik yapının** geçerliliğini deneysel olarak doğrular.
- 1868 : Mendeleev o sırada bilinen 63 atomu içeren element çizelgesini önerir. Bıraktığı "boş vakalar" kısa sürede dosyalandı. 1896'ya gelindiğinde **77 atom** keşfedilmiş ve element olarak kabul edilmişti.
- 1897 : J.J Thompson tarafından ilk atomaltı parçacığın keşfi: **elektron**. Pozitif karşılığı aranmaya başlandı, ta ki...
- 1911 : Rutherford çekirdeği keşfetti. Transmutasyon reaksiyonları hidrojen çekirdeğinin özel bir rol oynadığını gösterdi.
- (${}^4_2\text{He} + {}^{14}_7\text{N} \rightarrow {}^{18}_9\text{F} \rightarrow {}^{17}_8\text{O} + {}^1_1p$) . Rutherford buna **proton** adını verdi.

Elementler



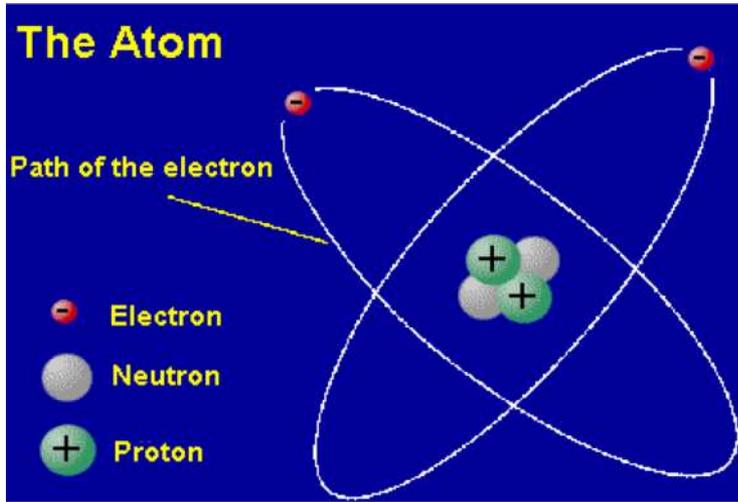
1A 1 H Hydrogen 1.008	2A 4 Be beryllium 9.012																	8A 2 He helium 4.003																
3 Li lithium 6.941		3A 5 B boron 10.81	4A 6 C carbon 12.01	5A 7 N nitrogen 14.01	6A 8 O oxygen 16.00	7A 9 F fluorine 19.00	10 Ne neon 20.18																	18 Ar argon 39.95										
11 Na sodium 22.99	12 Mg magnesium 24.31																	13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cl chlorine 35.45	36 Kr krypton 83.80											
19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.88	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.69	29 Cu copper 63.55	30 Zn zinc 65.39	31 Ga gallium 69.72	32 Ge germanium 72.58	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.90	37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium (98)	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs cesium 132.9	56 Ba barium 137.3	57 La* lanthanum 138.9	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.9	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 190.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.5	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 208.9	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)	87 Fr francium (223)	88 Ra radium (226)	89 Ac~ actinium (227)	104 Rf rutherfordium (261)	105 Db dubnium (261)	106 Sg seaborgium (263)	107 Bh bohrium (264)	108 Hs hassium (265)	109 Mt meitnerium (266)	110 Ds darmstadtium (271)	111 Uuq unnilquium (272)	112 Uub ununbium (277)	116 Uuq ununhexium (296)	118 Uuo ununoctium (298)	118 Uuo ununoctium (?)		

Lanthanide Series*	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (147)	62 Sm samarium 150.4	63 Eu europium 151.9	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.0	71 Lu lutetium 175.0
Actinide Series~	90 Th thorium 232.0	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium (237)	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (260)

Proton, elektron ve nötron evrendeki tüm elementlerin atomlarını oluşturur.

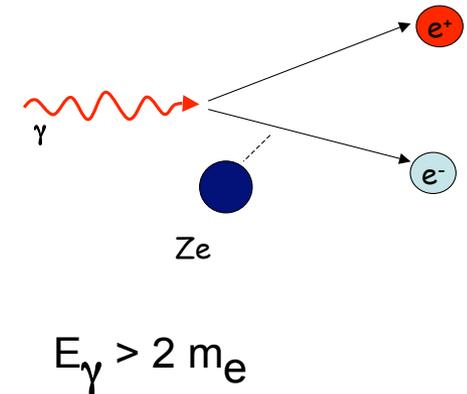
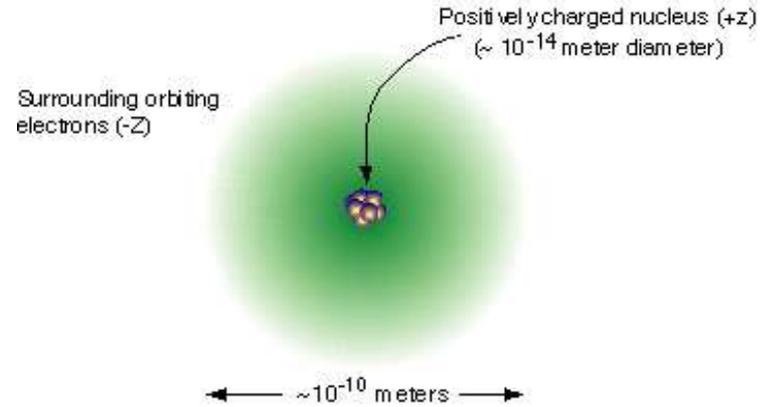
Modern çağda parçacık fiziği

- 1932 : izole edildiğinde kararlı olmayan ve şu şekilde bozulan nötronu keşfeder: $n \rightarrow p + e^- (+ \bar{\nu}_e)$. **Proton, elektron** ve **nötron** evrendeki tüm elementlerin atomlarını oluşturur.



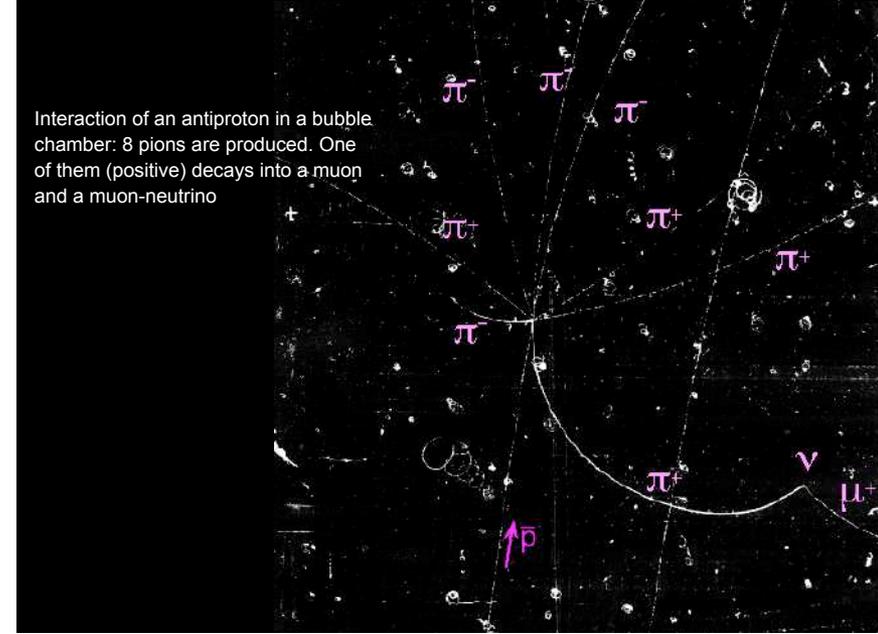
LEPTON (leptos = hafif) : e^-

BARYON (baryos = ağır) : p, n



Tüm Parçacıklar

	Fermiyonlar			Bozonlar	
	I	II	III		
Kuarklar	$\approx 2.2 \text{ MeV}/c^2$ 2/3 1/2 u yukarı	$\approx 1.28 \text{ GeV}/c^2$ 2/3 1/2 c tılsımlı	$\approx 173.1 \text{ GeV}/c^2$ 2/3 1/2 t tepe	0 0 1 g gluon	$\approx 124.97 \text{ GeV}/c^2$ 0 0 0 H Higgs bozonu
	$\approx 4.7 \text{ MeV}/c^2$ -1/3 1/2 d aşağı	$\approx 96 \text{ MeV}/c^2$ -1/3 1/2 s acayıp	$\approx 4.18 \text{ GeV}/c^2$ -1/3 1/2 b alt	0 0 1 γ foton	
	$\approx 0.511 \text{ MeV}/c^2$ -1 1/2 e elektron	$\approx 105.66 \text{ MeV}/c^2$ -1 1/2 μ müon	$\approx 1.7758 \text{ GeV}/c^2$ -1 1/2 τ tau	0 0 1 Z Z bozonu	
Leptonlar	$< 1.0 \text{ eV}/c^2$ 0 1/2 ν_e elektron nötrinosu	$\approx 0.17 \text{ MeV}/c^2$ 0 1/2 ν_μ müon nötrinosu	$\approx 18.2 \text{ MeV}/c^2$ 0 1/2 ν_τ tau nötrinosu	$\approx 80.39 \text{ GeV}/c^2$ 0 1 W W bozonu	



Interaction of an antiproton in a bubble chamber: 8 pions are produced. One of them (positive) decays into a muon and a muon-neutrino

Kuarkların 2'li ve 3'lü kombinasyonlarından yüzlerce başka "kısaömürlü" parçacık ortaya çıkar ve yok olur

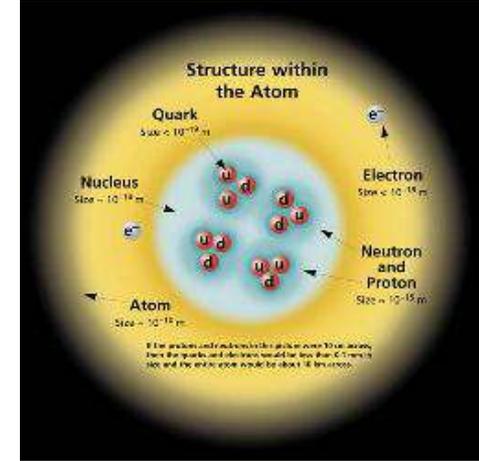
Atomu oluşturanlar

Kompozit parçacıklar

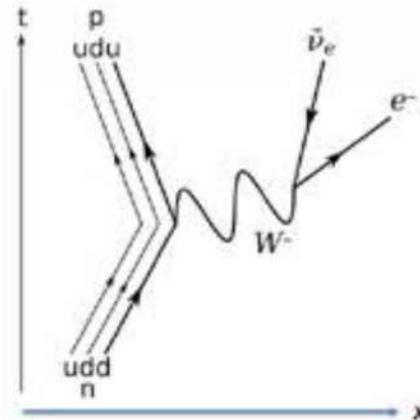
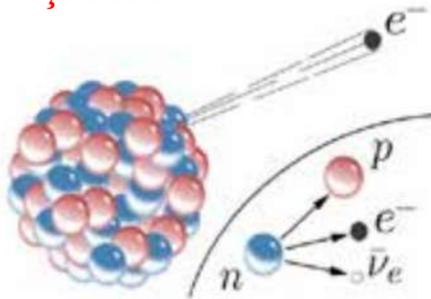
- **Mezonlar** kuark-anti-kuark durumları: $\pi^+ = u \bar{d}$.
- **Baryonlar** 3 kuark bağlı durumları $\rightarrow p: uud$.

Mesons $q\bar{q}$					
Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2.980	0

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$					
Baryons are fermionic hadrons. There are about 120 types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	uud	1	0.938	1/2
\bar{p}	anti-proton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	-1	1.672	3/2



Beta ışınımı



Ağır parçacıklar daha hafif olanlara “bozunur” ta ki en sonunda kararlı parçacıklar kalana kadar:
Proton ve elektron

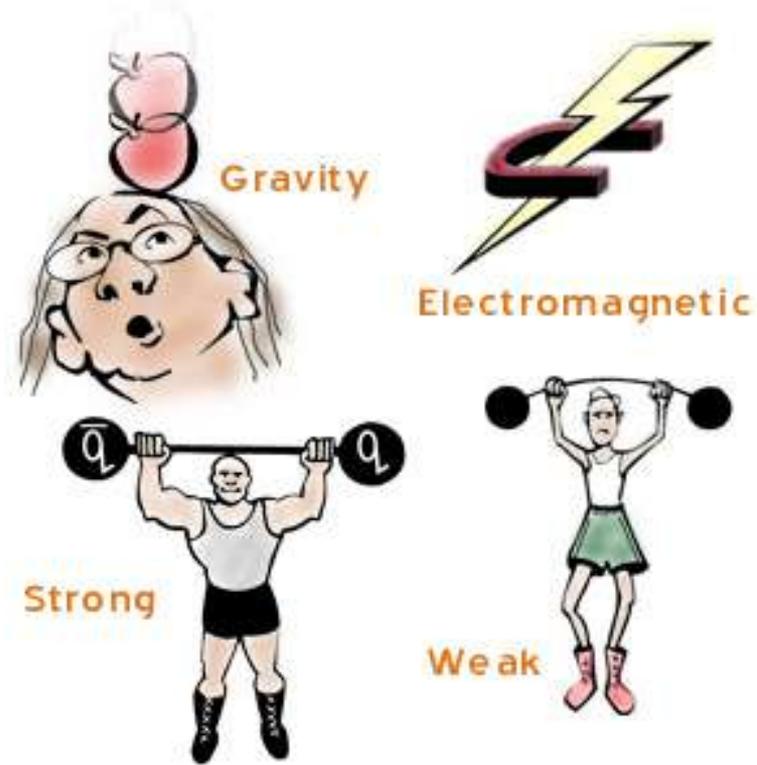
Dört Evrensel Kuvvet

Kütleçekim

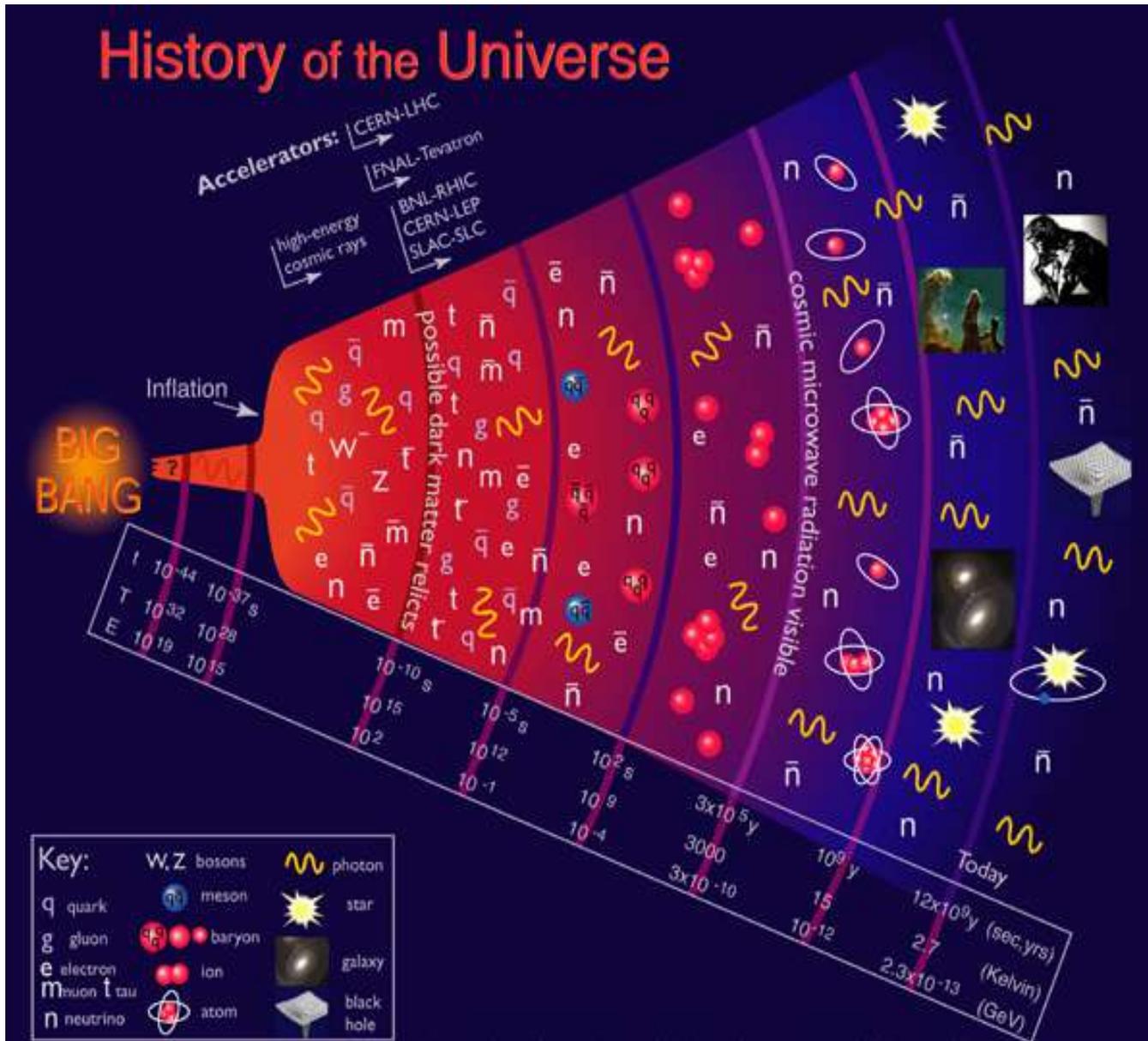
Zayıf nükleer kuvvet: Z, W^{\pm} bozon
(ex. Beta bozunumu)

Elektromanyetik kuvvet: foton
(ex. ışık, TV, radyo,...)

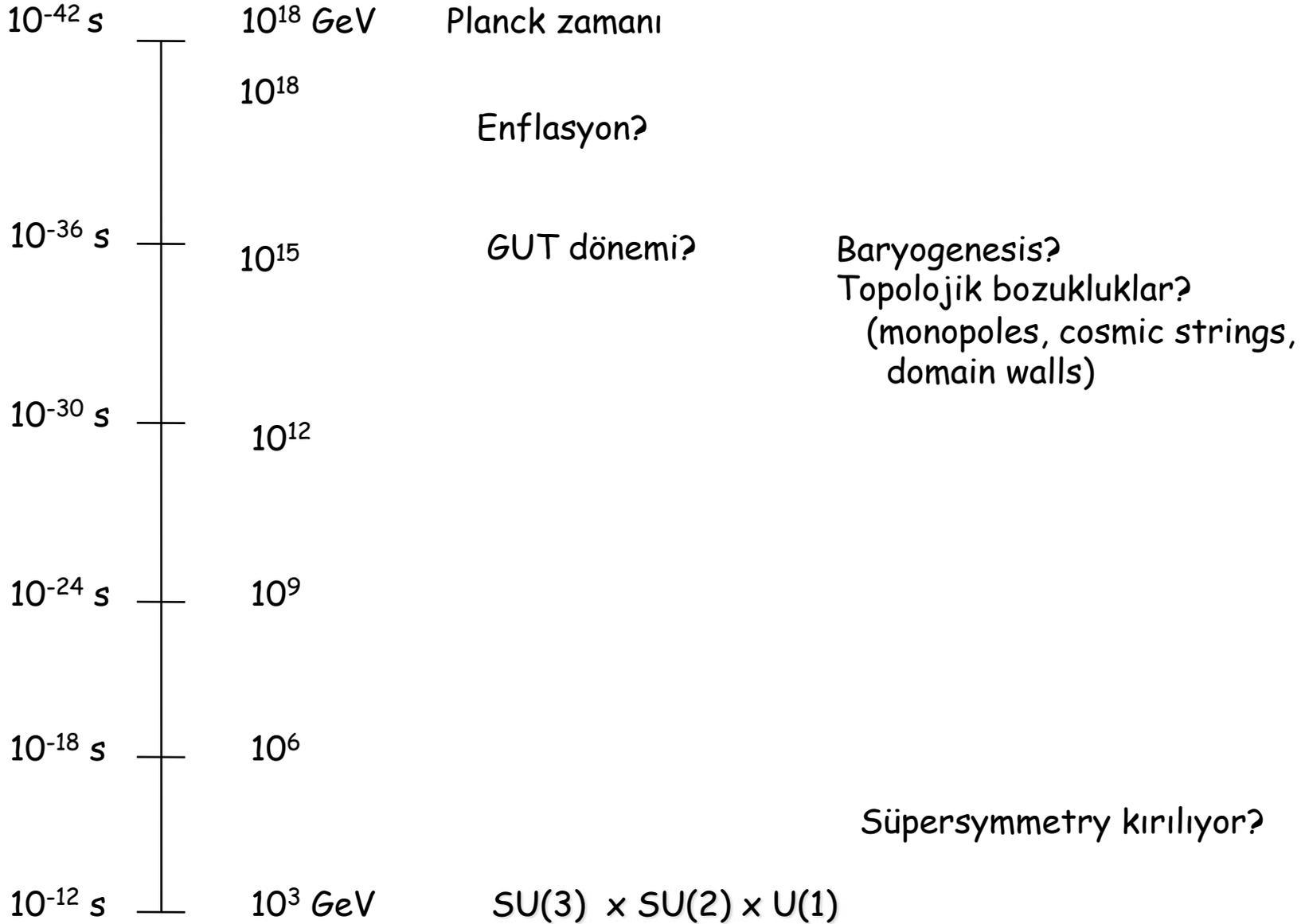
Yeğin nükleer kuvvet: g Gluon
(ex. Güneş)



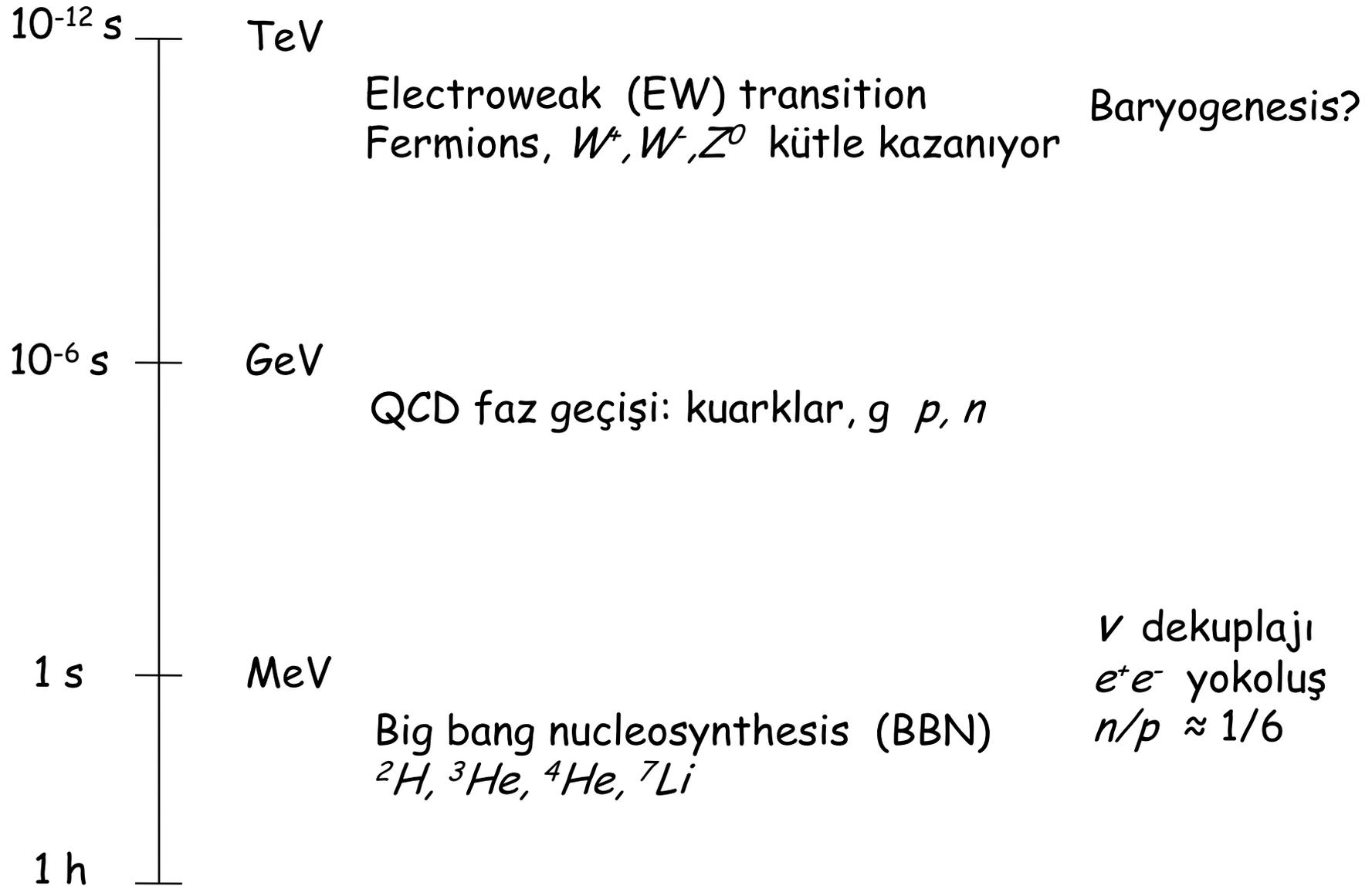
Peki.. Eksik olan ne?



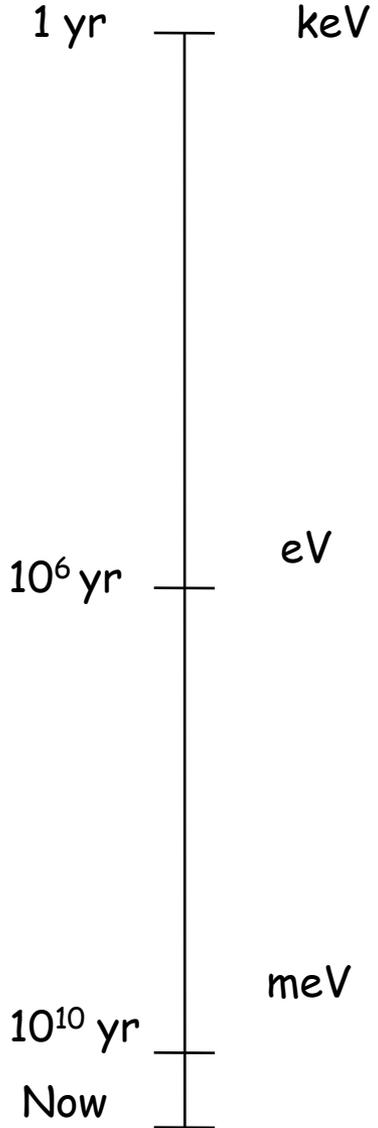
Evrenin tarihi I



Evrenin tarihi II



Evrenin tarihi III



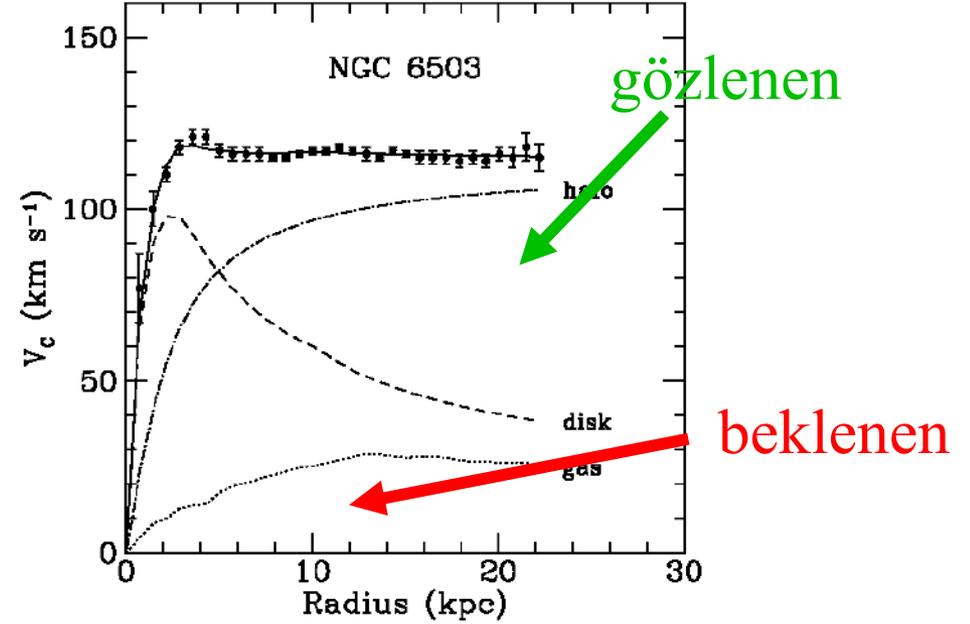
Işık ve baryonların dekuplajı => atomlar
Evren şeffaflaşıyor
Cosmic Microwave background (CMB) çıkıyor

Karanlık Çağlar

Galaksilerin oluşumu, ilk yıldızlar

Kara Madde

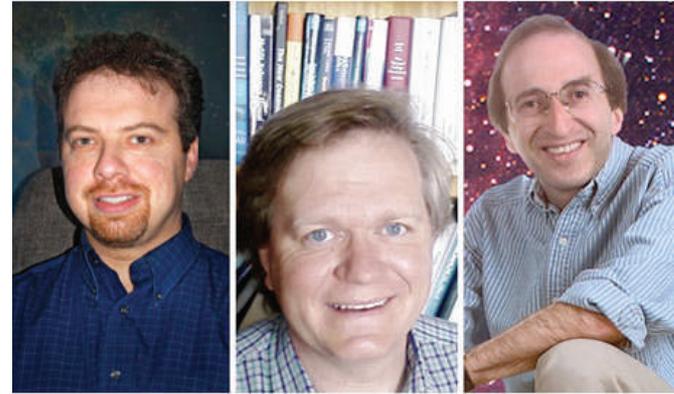
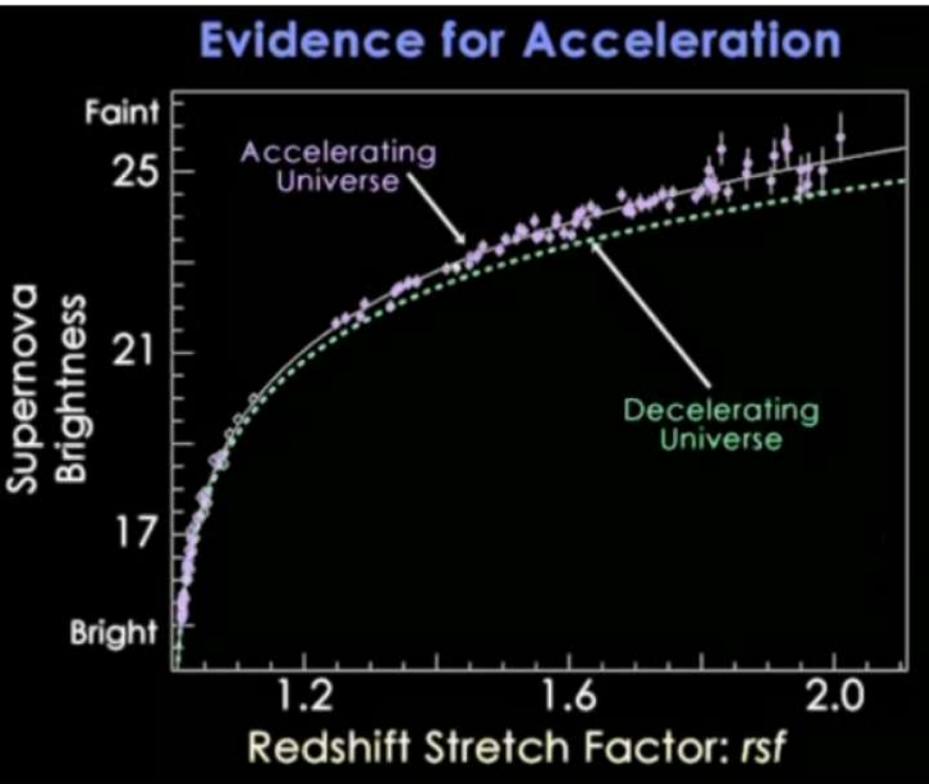
galaksileri birlikte tutmak için karanlık madde gerekli



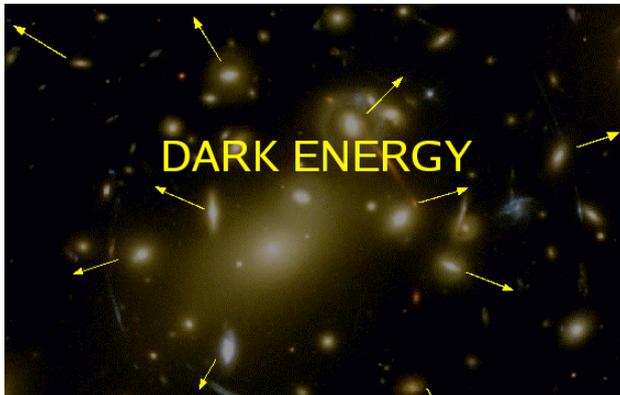
Begeman, Broeils, Sanders (1991)

$$\frac{Mv^2}{r} = \frac{GM_{\text{tot}}}{r^2} \Rightarrow v \sim r^{-1/2}$$

Hızlanan Evren (1998) → Kara Enerji



Adam G. Riess Brian P. Schmidt Saul Perlmutter



1998: Accelerating expansion

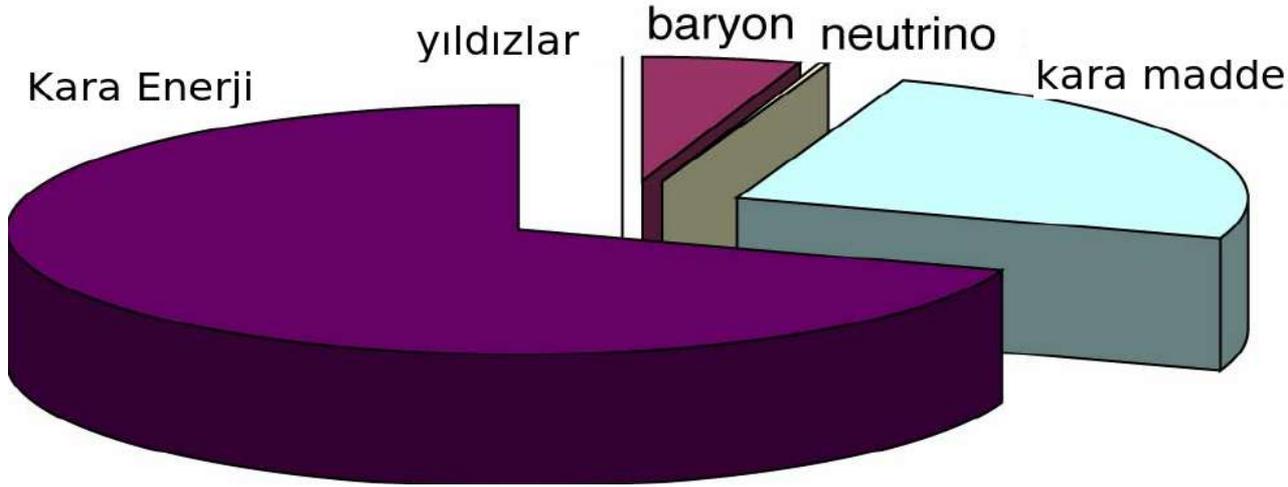
Λ

D'oh!

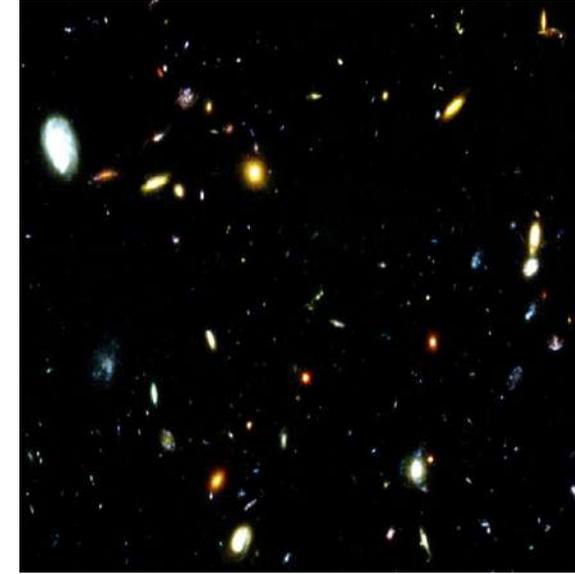
D'oh!

Güncel Kozmolojik bulgular

Evrenin tüm enerjisi



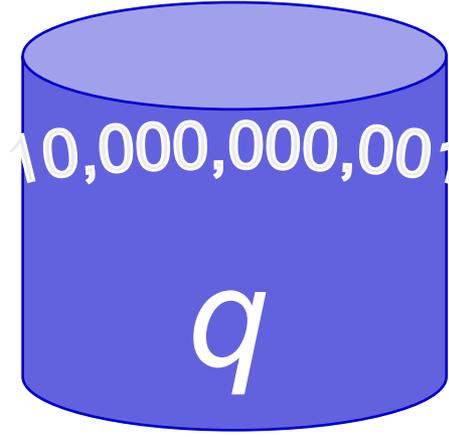
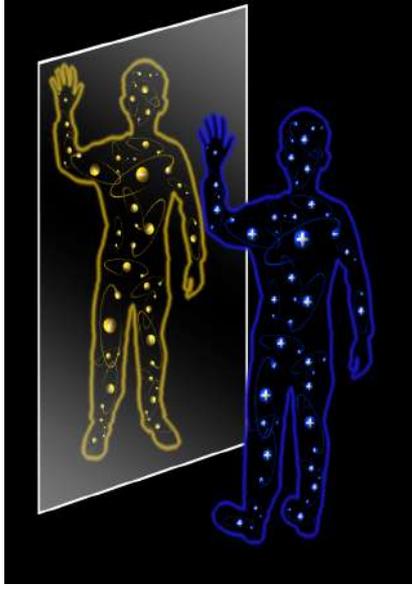
- Yıldızlar ve galaksiler $\sim 0.5\%$
- Nötrinolar $\sim 0.3-10\%$
- Geri kalan bildik madde (elektron ve protonlar) $\sim 4\%$
- **Kara Madde** $\sim 23\%$ -> adaylar hızlandırıcı fiziği ile incelenmekte
- **Kara Enerji** $\sim 73\%$
- Anti-Madde 0%
- Higgs yoğunlaşması $\sim 10^{62}\%??$



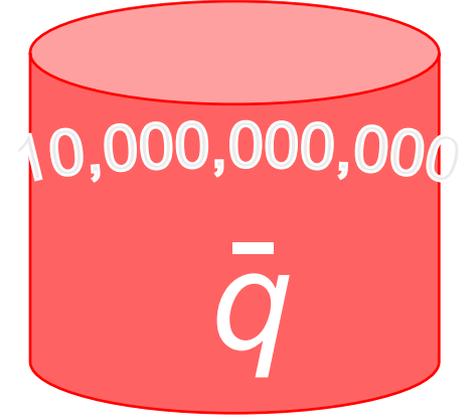
Standart
model
(bilinen fizik)

Standart
model ötesi
(yeni fizik)

Aynadan bakmak: Madde ve karşı-madde ?



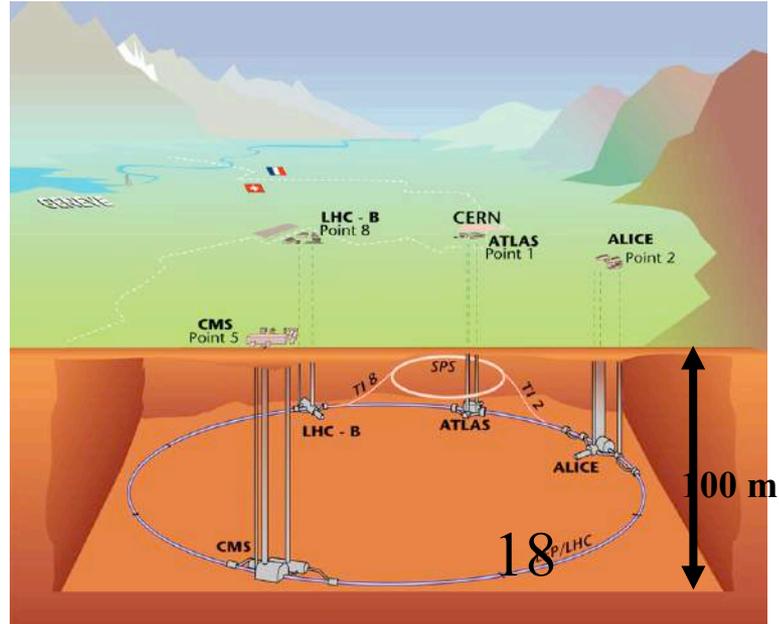
+1



Madde-antimadde simetrisinin yokluğu

Evrende niye karşı-atom yok?

İşte tüm bu soruların cevaplarından bir kısmını CERN'de bulacağımızı umuyoruz

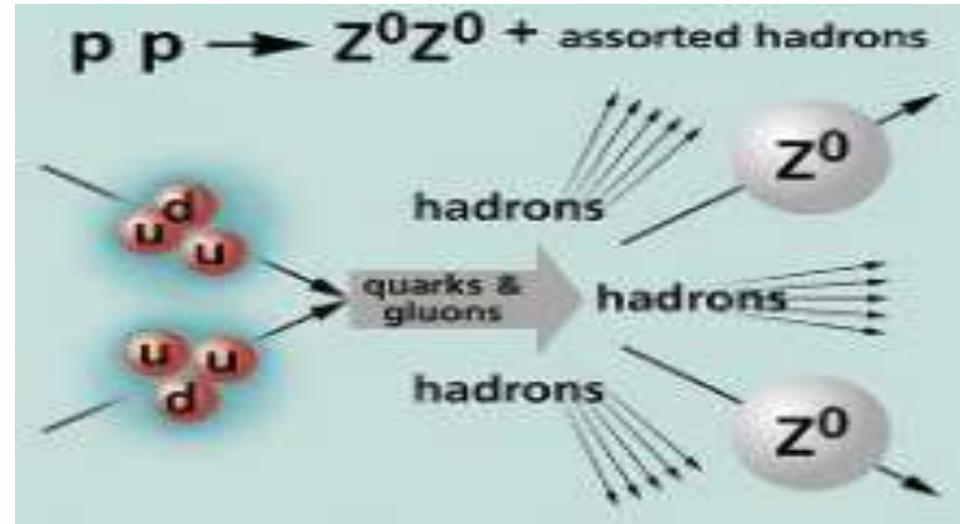
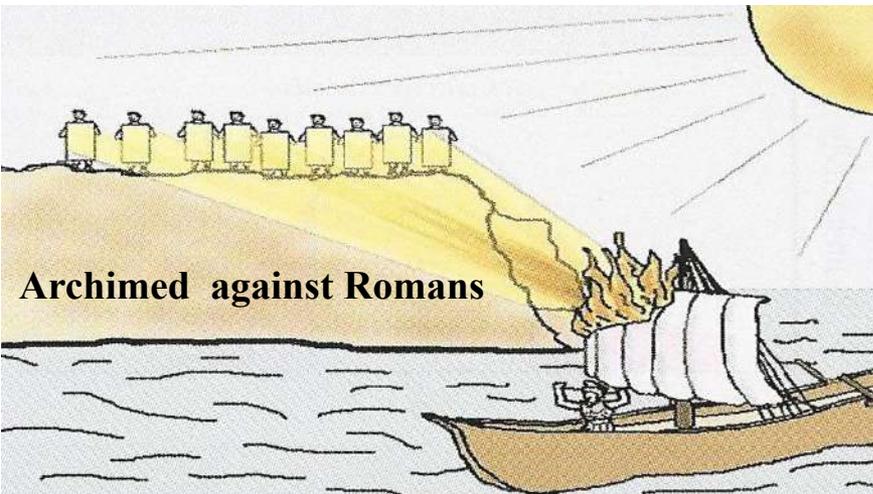


Küçük nesneleri “görmek”

Dalga boyu $\sim 1/\text{enerji}$

Kuark $\sim 1 \text{ GeV}$ enerji (yoğun enerji)

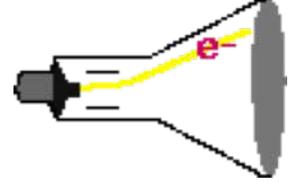
Proton kütlesi $\sim 1 \text{ GeV}/c^2 = 1.783 \times 10^{-27} \text{ kg}$
1 TeV = sivri sineğin kanat çırpışı



Atom	10^{-10} m	0.00001 GeV (electrons)
Nucleus	10^{-14} m	0.01 GeV (alphas)
Nucleon	10^{-15} m	0.1 GeV (electrons)
Quarks	?	> 1 GeV (electrons?)

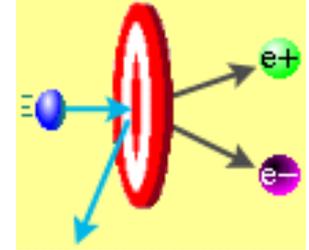
Neden parçacıkları hızlandırıyoruz?

Elektronlar: Bir metalin ısıtılması elektronların fırlatılmasına neden olur. Katot ışın tüpü gibi bir televizyon bu mekanizmayı kullanır.

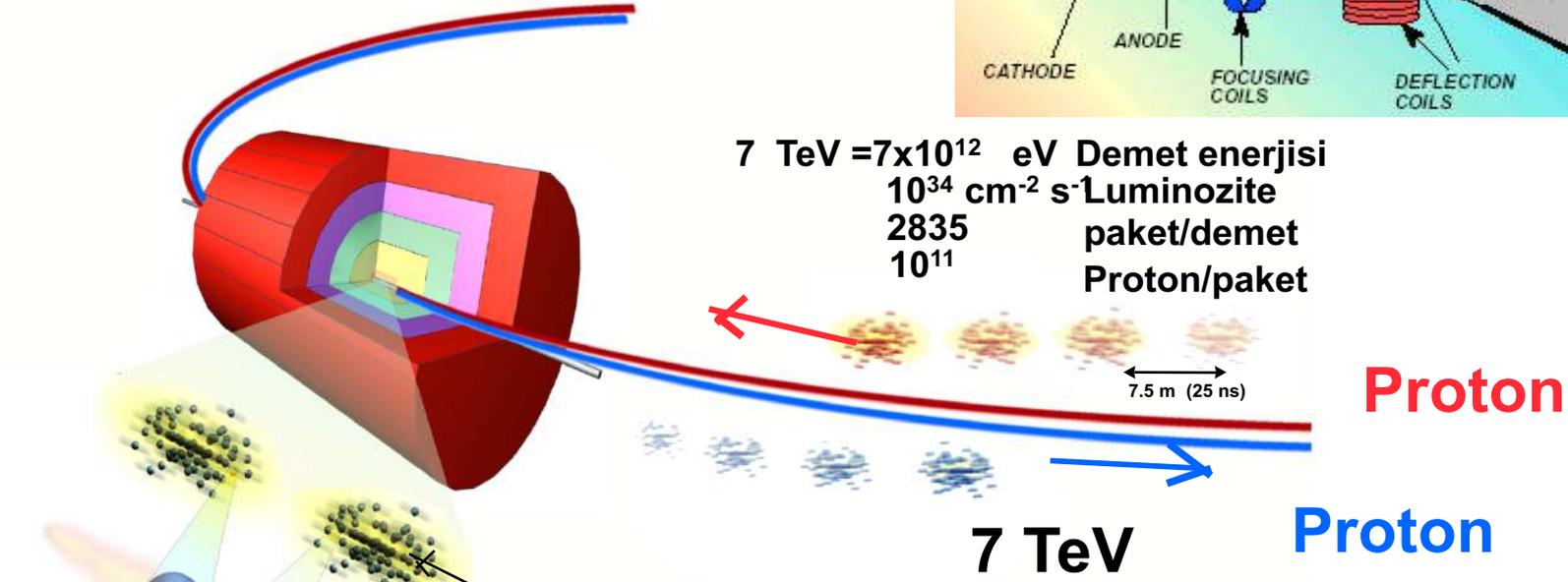
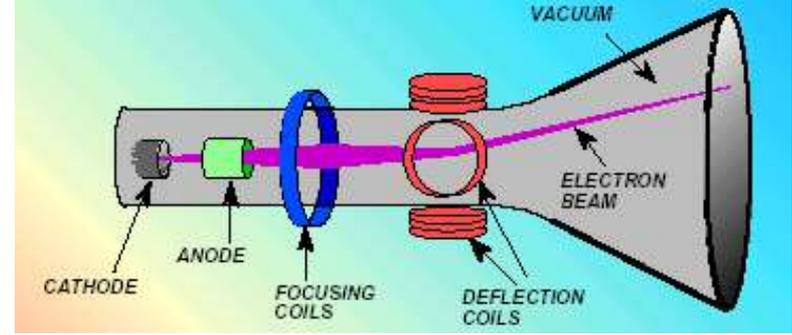


Protonlar: Hidrojeni iyonize ederek kolayca elde edilebilirler.

Karşı-parçacıklar: karşı-parçacıkları elde etmek için önce enerjik parçacıkların bir hedefe çarpmasını sağlayın. Daha sonra sanal fotonlar veya gluonlar aracılığıyla parçacık ve karşı-parçacık çiftleri yaratılacaktır. Manyetik alanlar bunları ayırmak için kullanılabilir.

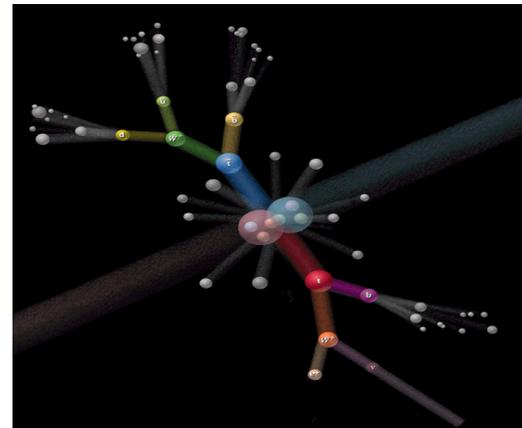


LHC büyük bir TV tüpü gibidir



7 TeV = 7×10^{12} eV Demet enerjisi
 10^{34} cm⁻² s⁻¹ Luminozite
2835 paket/demet
 10^{11} Proton/paket

Colliding bunches 4×10^7 Hz
Proton collisions 10^9 Hz
Parton collisions
New particles (Higgs, SUSY,) 10^5 Hz



Protonlar her 25 ns'de bir çarpışıyorlar..

Tesir Kesiti ve Luminozite (Parlaklık)

- “fundamental equation of high energy physics”

$$N = L\sigma\epsilon$$

number of events observed

integrated luminosity (m^{-2})

production cross section (m^2)

efficiency (acceptance)

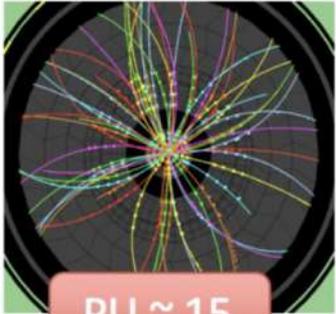
- luminosity: number per unit scattering area per unit time

Pile-up (yığılma) Sorunu

Pile-up condition at the HL-LHC

7

30 fb⁻¹



PU ~ 15

190 fb⁻¹



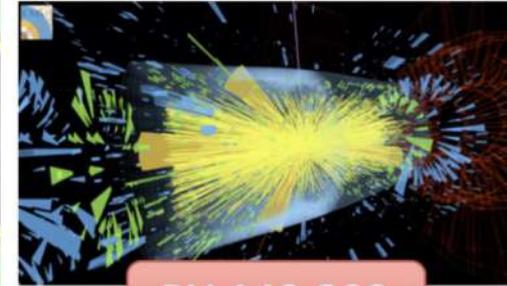
PU ~ 34

450 fb⁻¹



PU 60-80

integrated luminosity
3000 fb⁻¹
4000 fb⁻¹



PU 140-200

Run I (2010 - 2012)

Run II (2015 - 2018)

Run III (2022 - ongoing)

Expected environment at HL-LHC

Her 25 ns'de bir...! → saniyede 40 milyon (1 milyar?) çarpışma

Parçacık tespiti için temel prensipleri

Yüklü parçacıkların madde içinden geçişi

Atomik elektronlar ile etkileşim



iyonizasyon

(nötr atom \rightarrow ion^+ + serbest elektron)



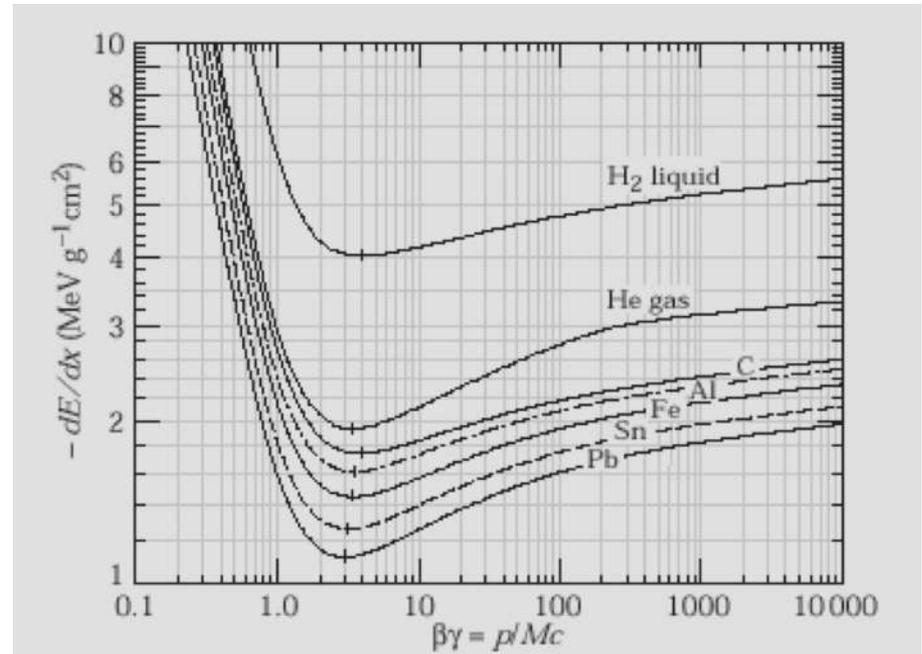
Atom seviyelerinin uyarılması

(de-excitation \rightarrow photon emission)

Ionization + excitation of atomic energy levels \rightarrow energy loss

Mean energy loss rate – dE/dx

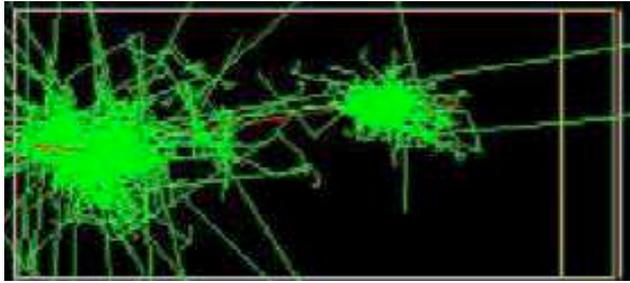
- proportional to (electric charge)² of incident particle
- for a given material, function only of incident particle velocity
- typical value at minimum:
 $-dE/dx = 1 - 2 \text{ MeV}/(\text{g cm}^{-2})$



NOTE: traversed thickness (dx) is given in g/cm^2 to be independent of material density (for variable density materials, such as gases) – multiply dE/dx by density (g/cm^3) to obtain dE/dx in MeV/cm

Hadronik dus

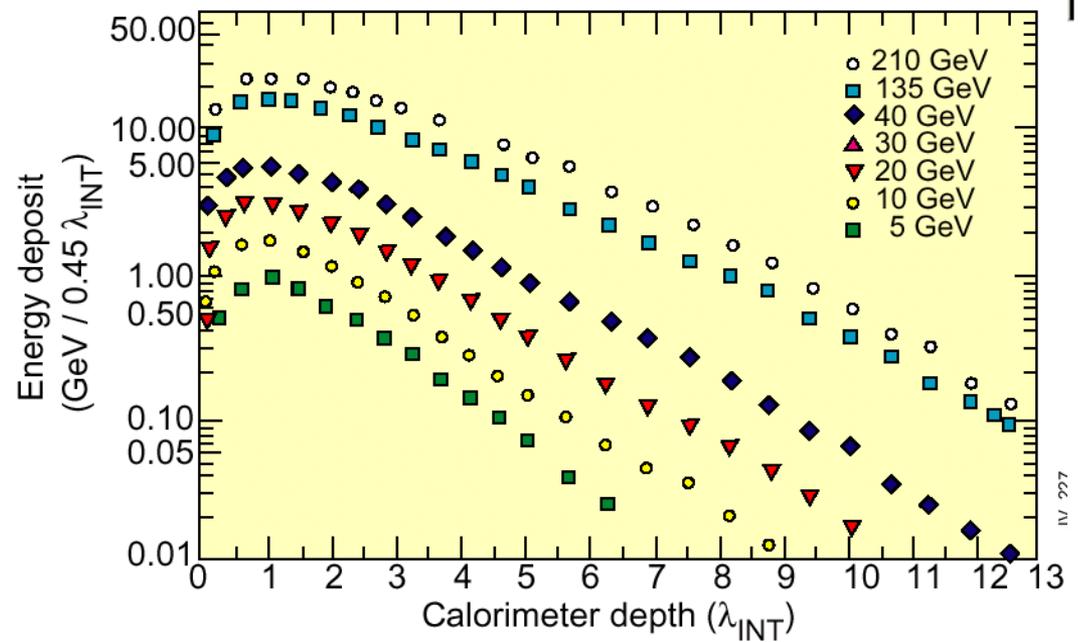
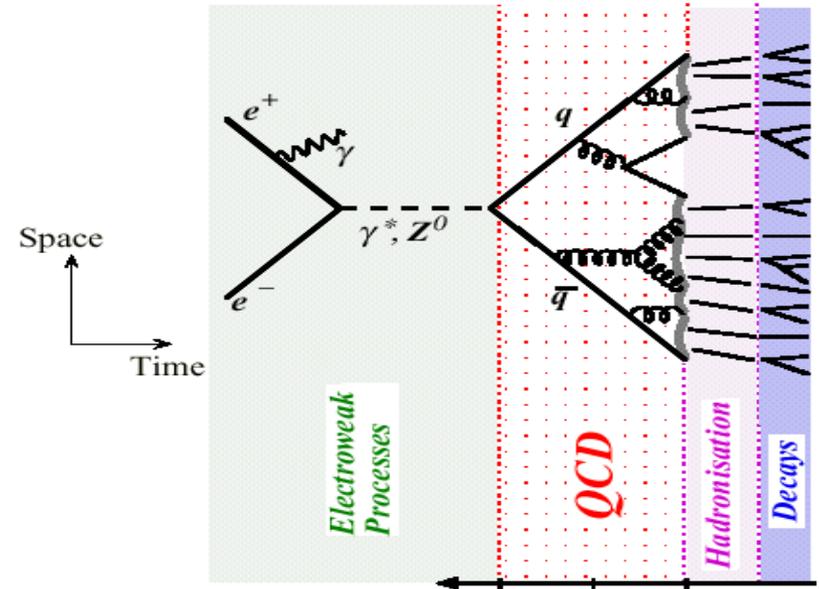
Simulation in copper



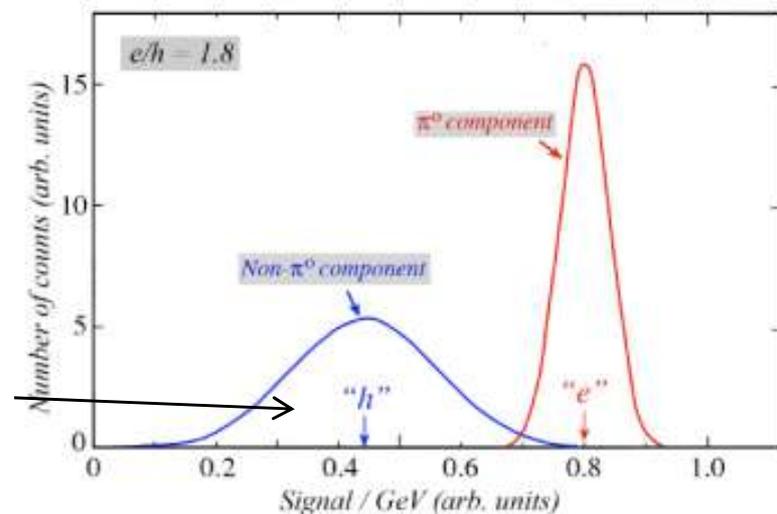
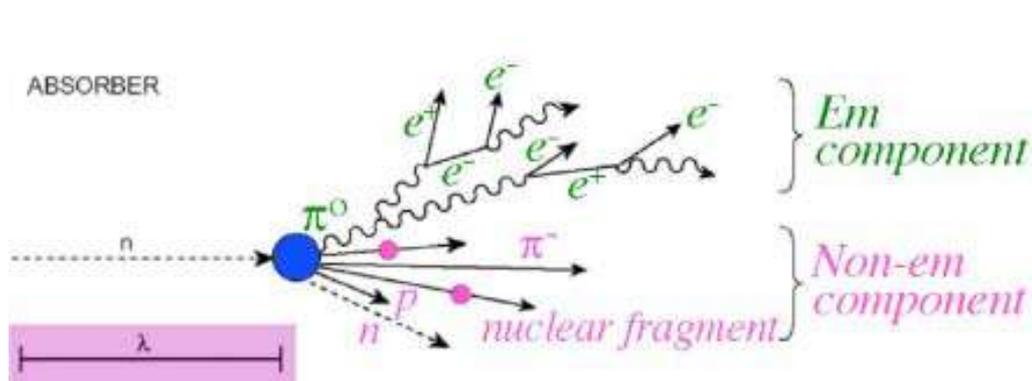
Shower development by strong interaction

An energetic hadron interacting with matter leads to multi-particle production, these in turn interact with further nuclei or decay (pion)

Multiplication continues until the pion production threshold.



EM & Hadronic Interactions



Hadrons create showers via strong interactions just like electrons and photons create them via EM.

Mean energy of pion with initial energy E_0 after traversing material depth λ (interaction length):

$$\langle E \rangle = E_0 e^{-X/\lambda}$$

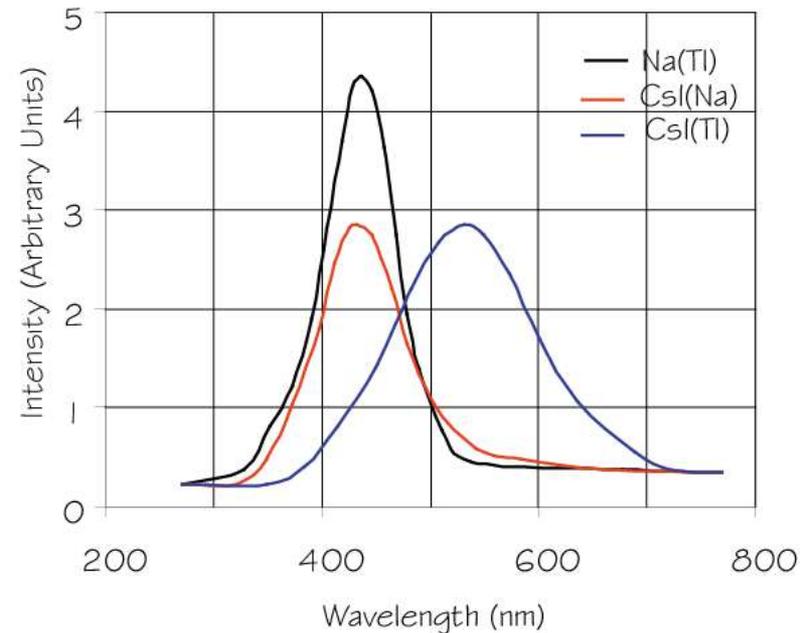
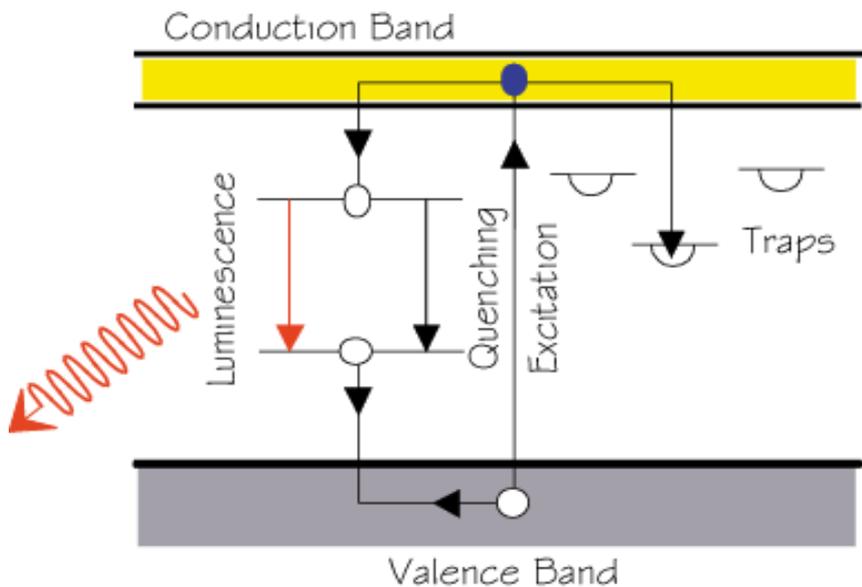
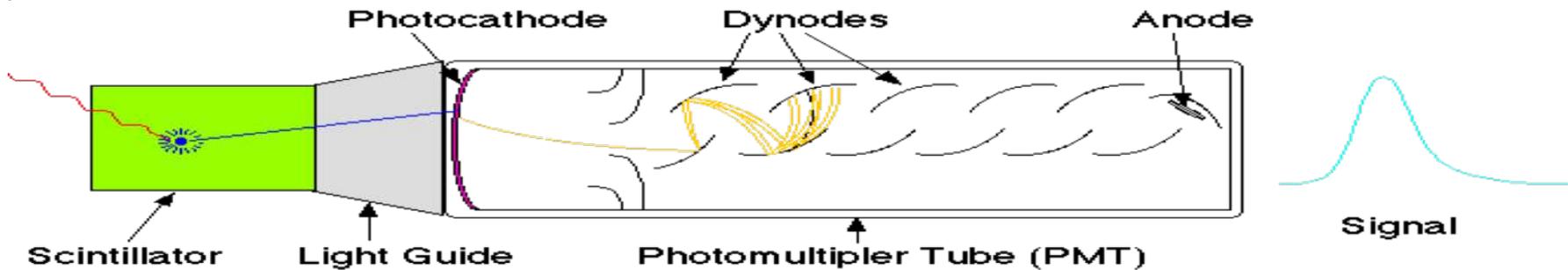
Mean energy of electron with initial energy E_0 after traversing material depth X_0 (radiation length):

$$\langle E \rangle = E_0 e^{-X/X_0}$$

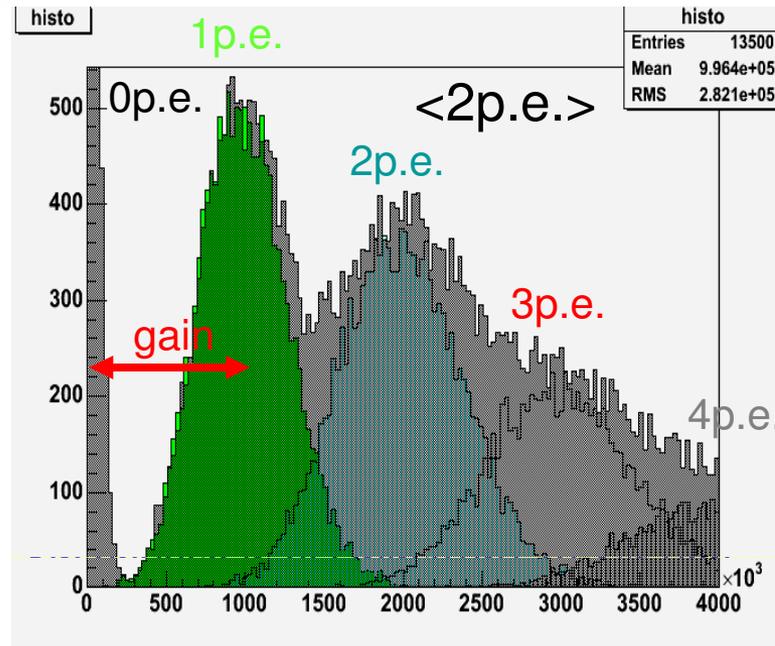
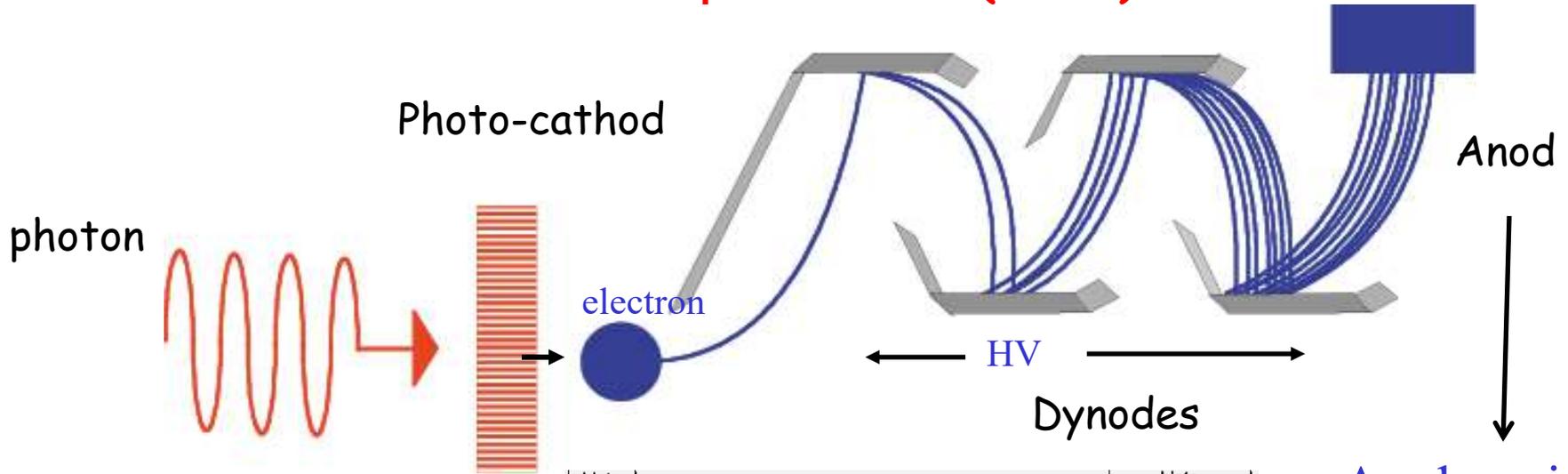
Scintillators (Scintillation)

Excitation and ionization creates scintillation light which are sent then to the Photomultipliers (PMT)

Scintillators: crystalline (thallium-sodium iodide [NaI(Tl)]) or organic (plastics)



Photomultiplier tube (PMT)



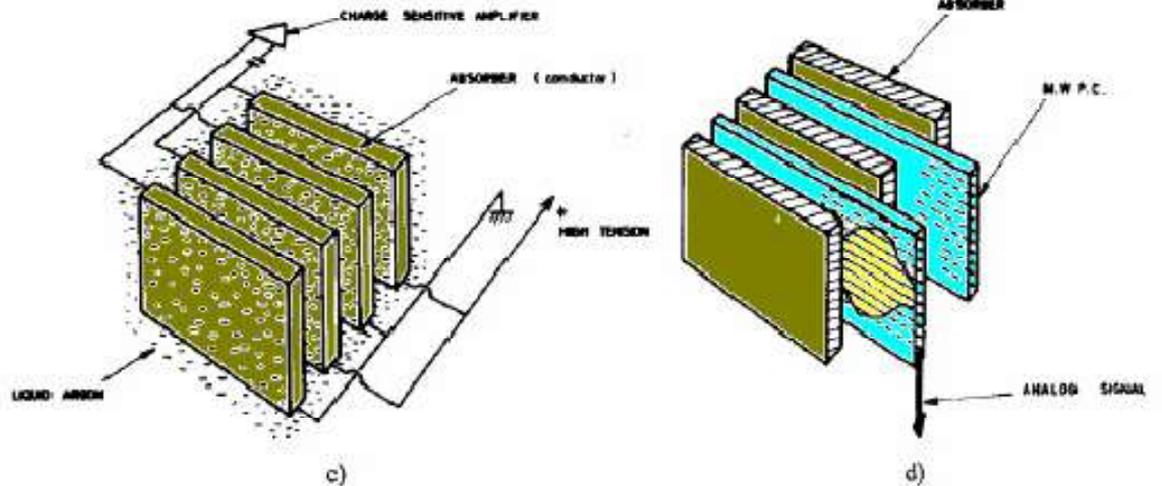
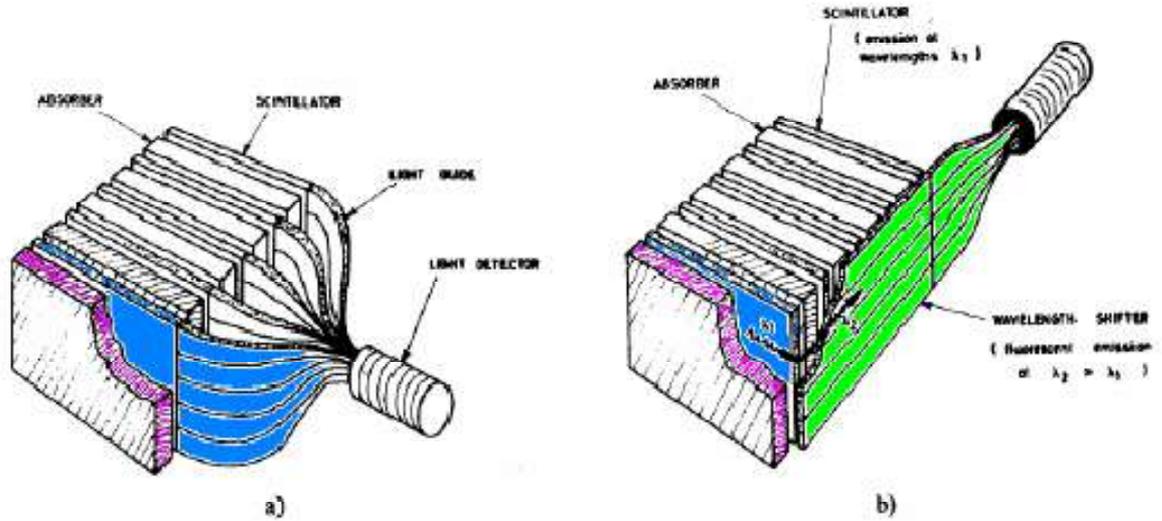
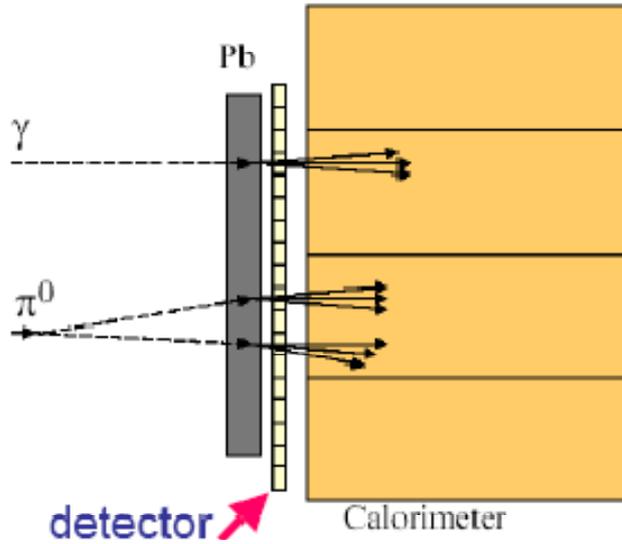
Typical gain 10^6 . In 200 ps

Analog signal

ADC

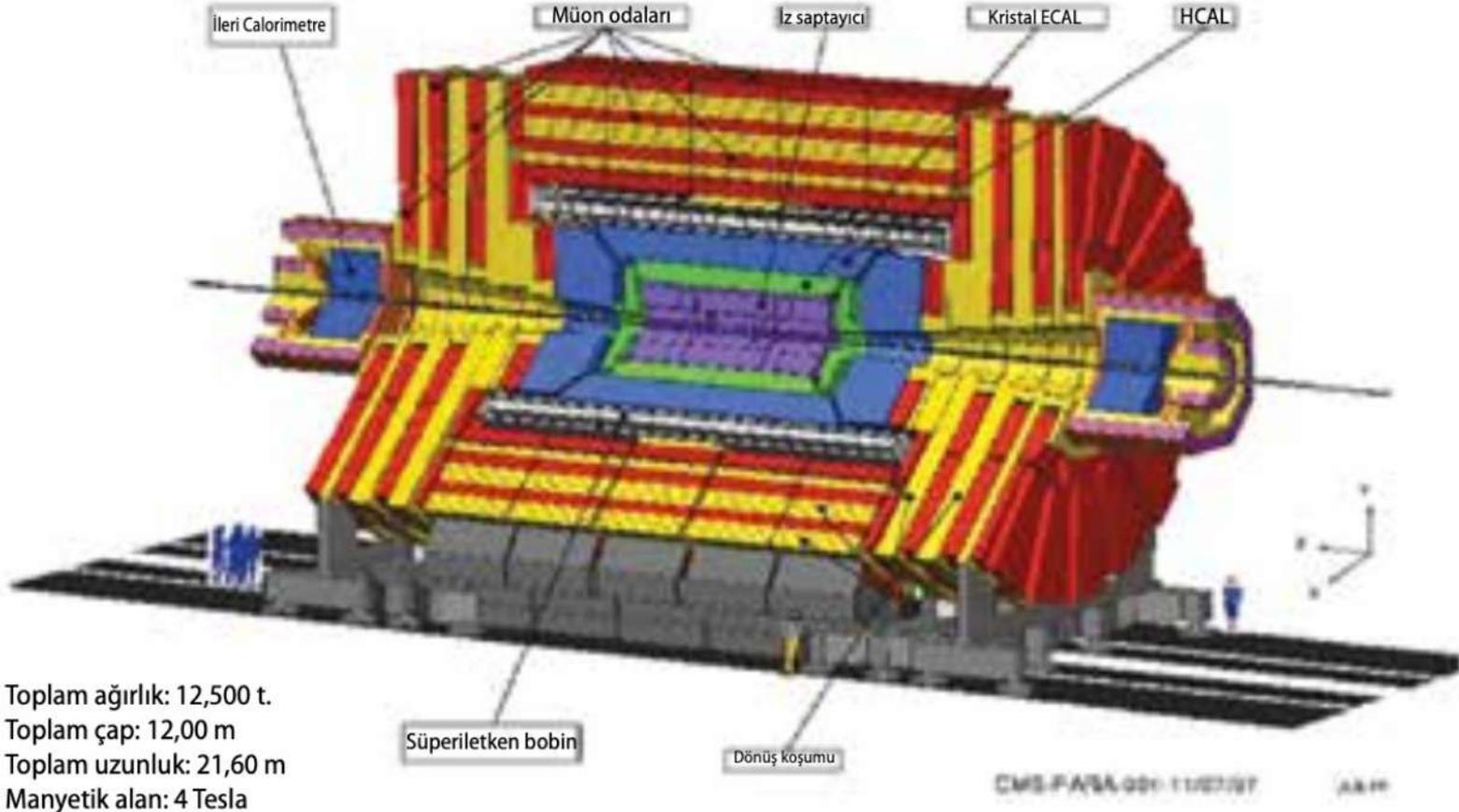
Digital signal

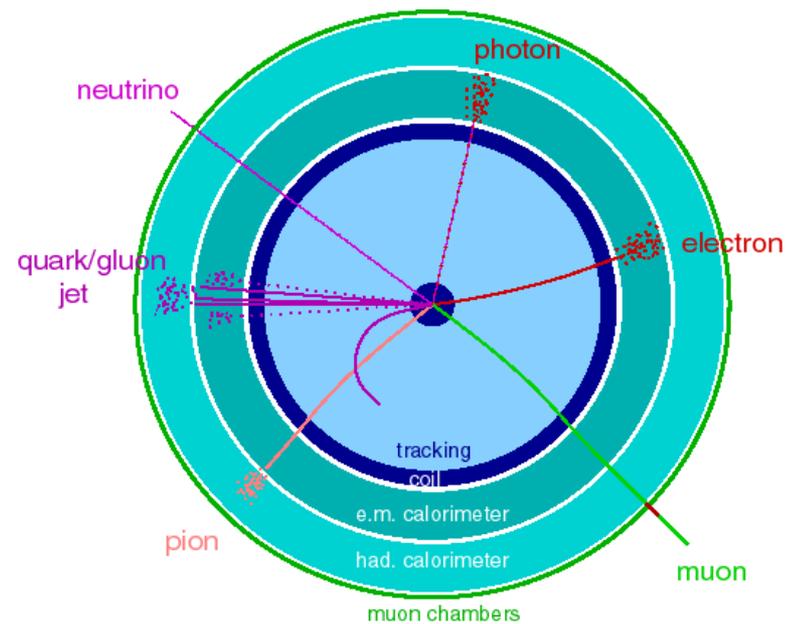
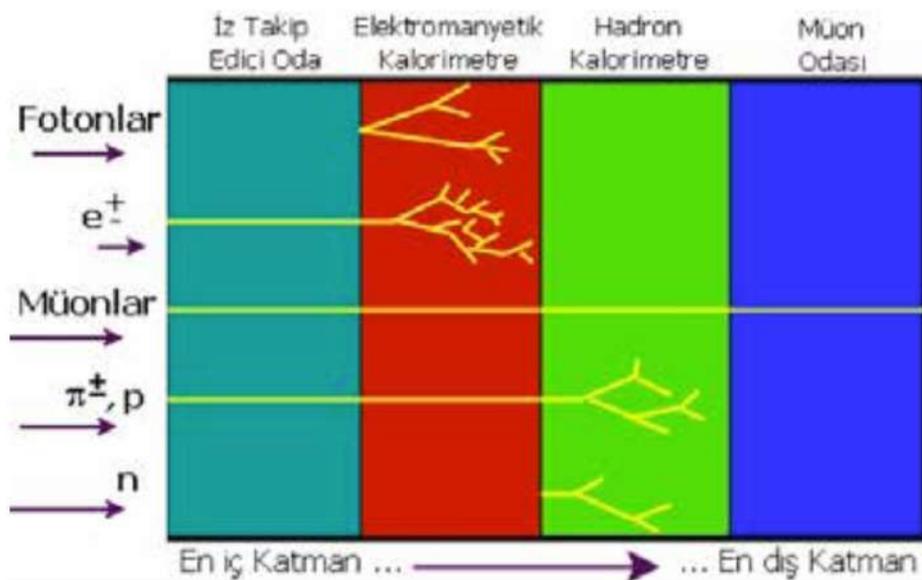
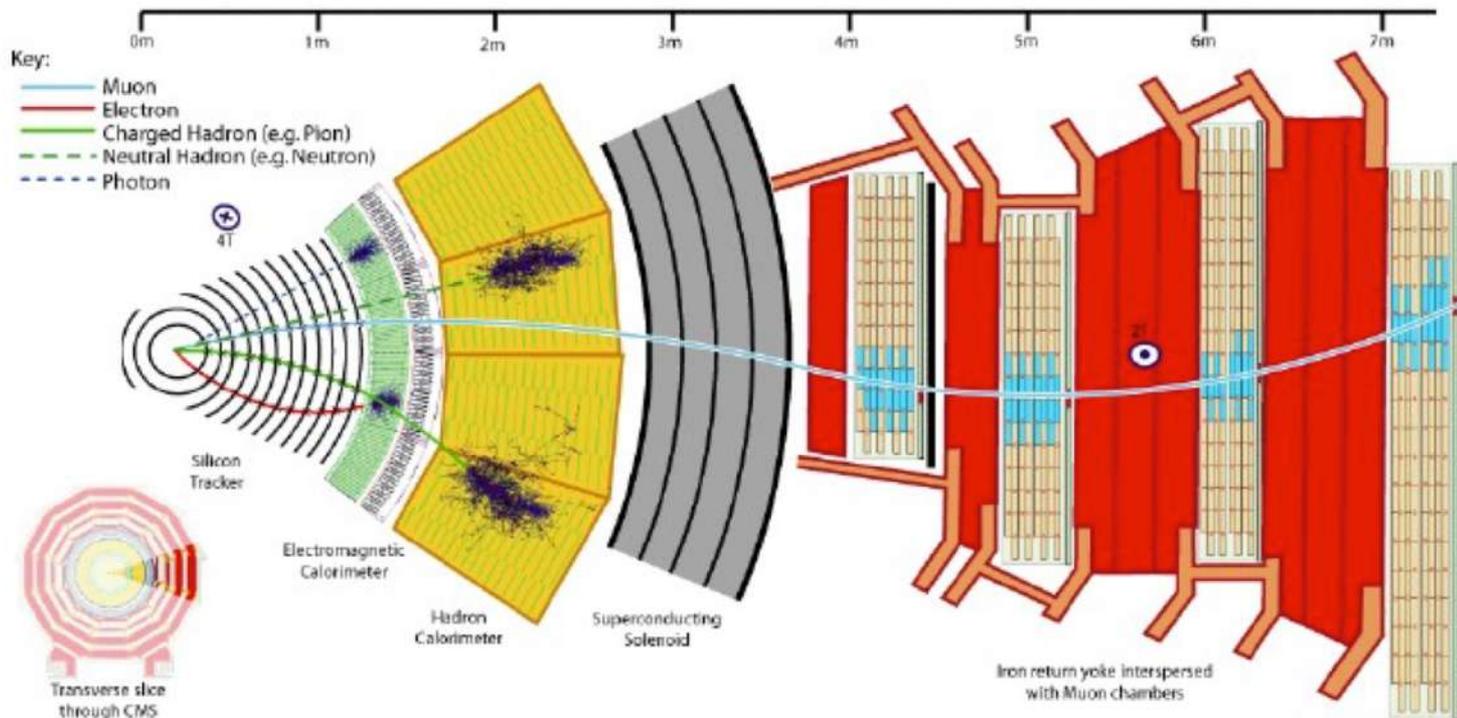
Sampling calorimeters: Absorber+sampler



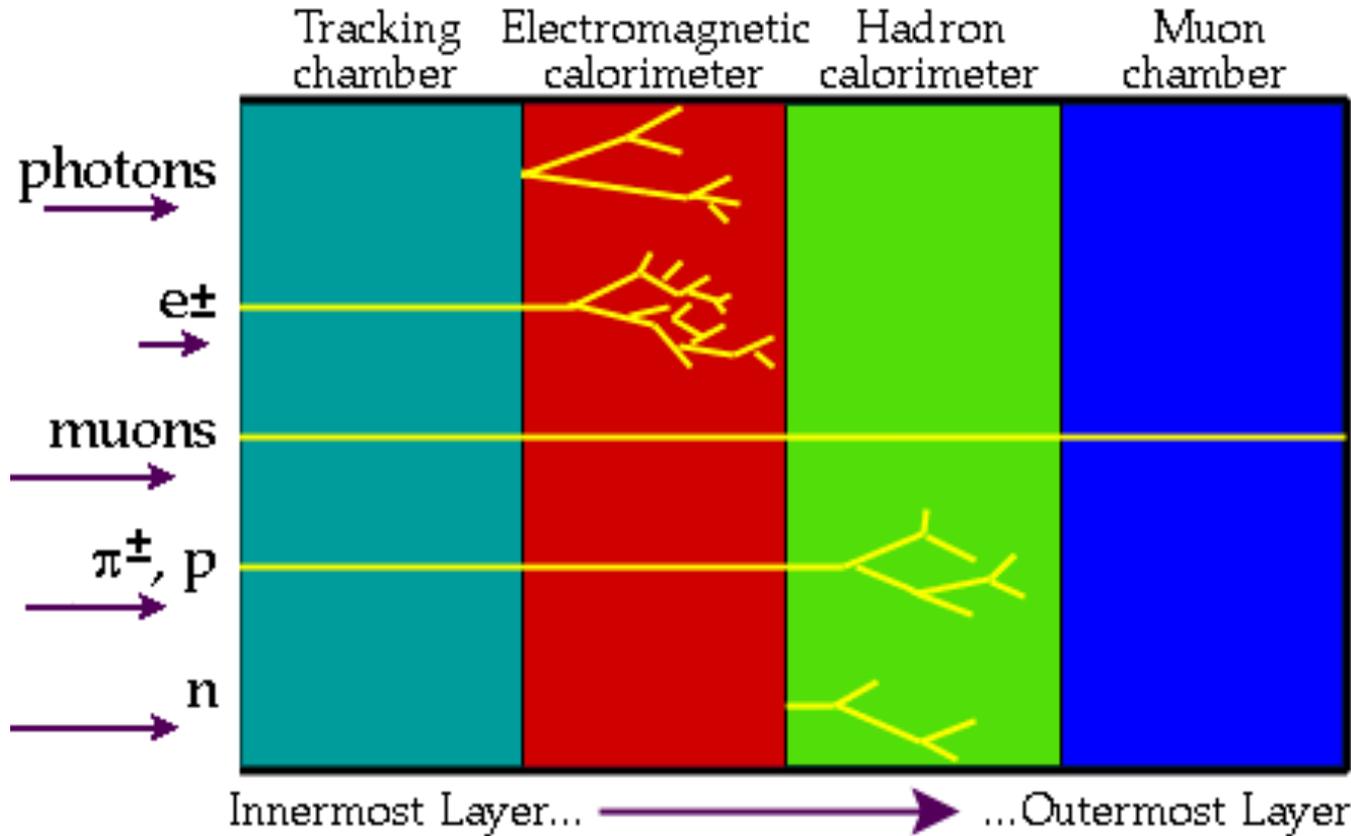
CMS Dedektörü

A Compact Solenoidal Detector for LHC [LHC için Tıkız Bir Solenid Dedektör]





Dedektörde ne gözlüyoruz?

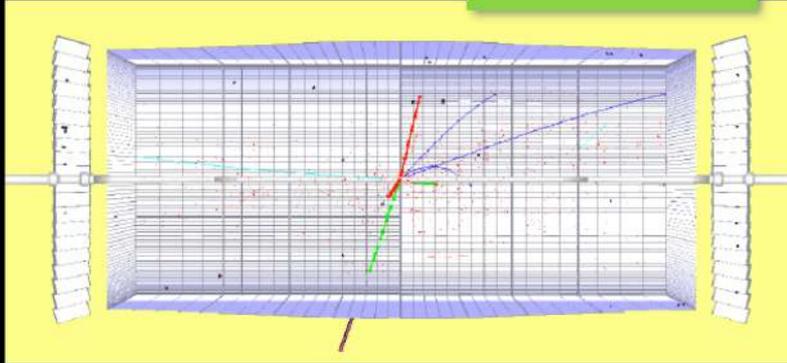


Particles are detected via their interaction with matter.

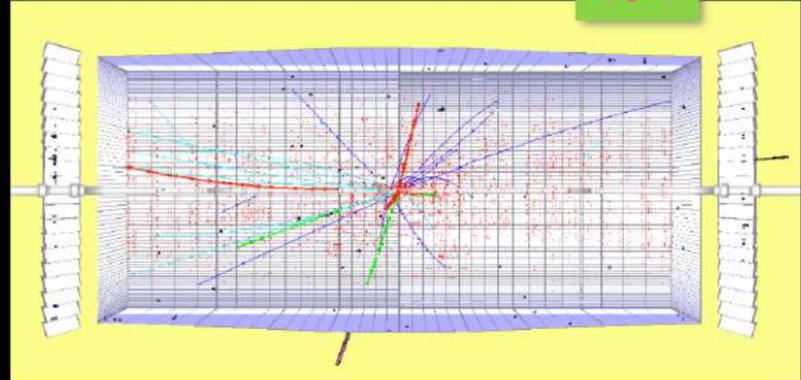
Many types of interactions are involved, mainly electromagnetic.
In the end, always rely on ionization and excitation of matter.

High Luminosity LHC

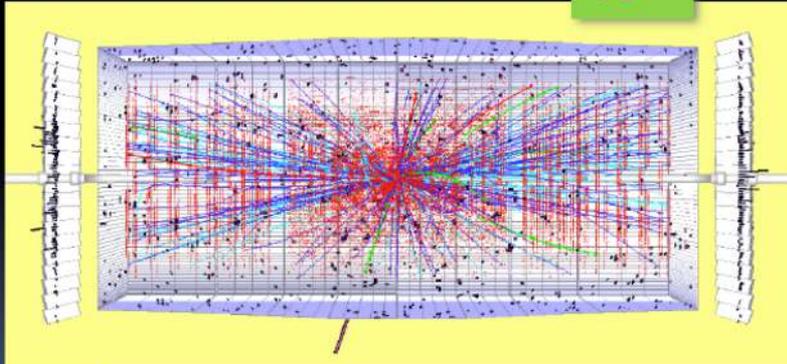
$10^{32} \text{ cm}^{-2} \text{ s}^{-1}$



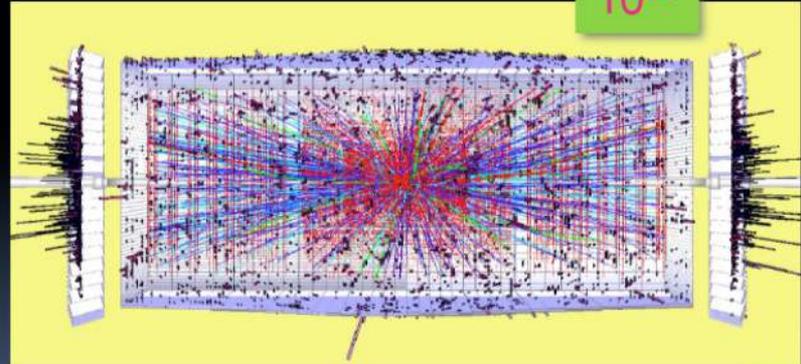
10^{33}



10^{34}



10^{35}



HL-LHC presents increased challenges for Triggering, Tracking and Calorimetry, in particular for low to medium P_T objects

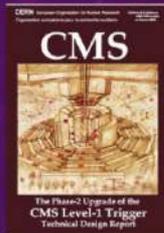
CMS Yenileme Çalışmaları

HGCAL The high-granularity calorimeter

L1-Trigger

<https://cds.cern.ch/record/2714892>

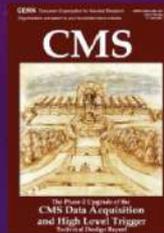
- Tracks in L1-Trigger at 40 MHz
- Particle Flow selection
- 750 MHz L1 output
- 40 MHz data scouting



DAQ & High-Level Trigger

<https://cds.cern.ch/record/2759072>

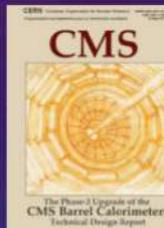
- Full optical readout
- Heterogenous architecture
- 60 TB/s event network
- 7.5 kHz HLT output



Barrel Calorimeters

<https://cds.cern.ch/record/2283187>

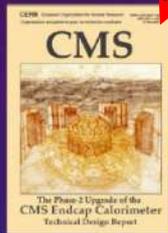
- ECAL single crystal granularity at L1 trigger with precise timing for e/ γ at 30 GeV
- ECAL and HCAL new Back-End boards



Calorimeter Endcap

<https://cds.cern.ch/record/2293646>

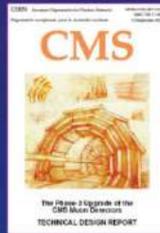
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



Muon systems

<https://cds.cern.ch/record/2283189>

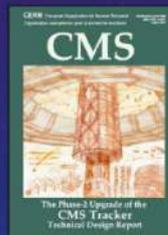
- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \approx 3$



Tracker

<https://cds.cern.ch/record/2272264>

- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \approx 3.8$

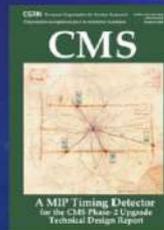


MIP Timing Detector

<https://cds.cern.ch/record/2667167>

Precision timing with:

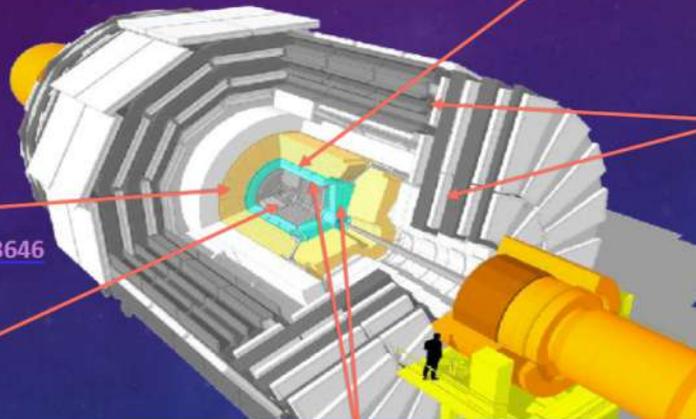
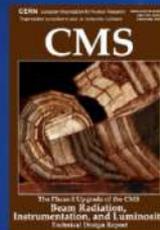
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes



Beam Radiation Instr. and Luminosity

<http://cds.cern.ch/record/2759074>

- Beam abort & timing
- Beam-induced background
- Bunch-by-bunch luminosity: 1% offline, 2% online
- Neutron and mixed-field radiation monitors



High Luminosity LHC as a Higgs factory

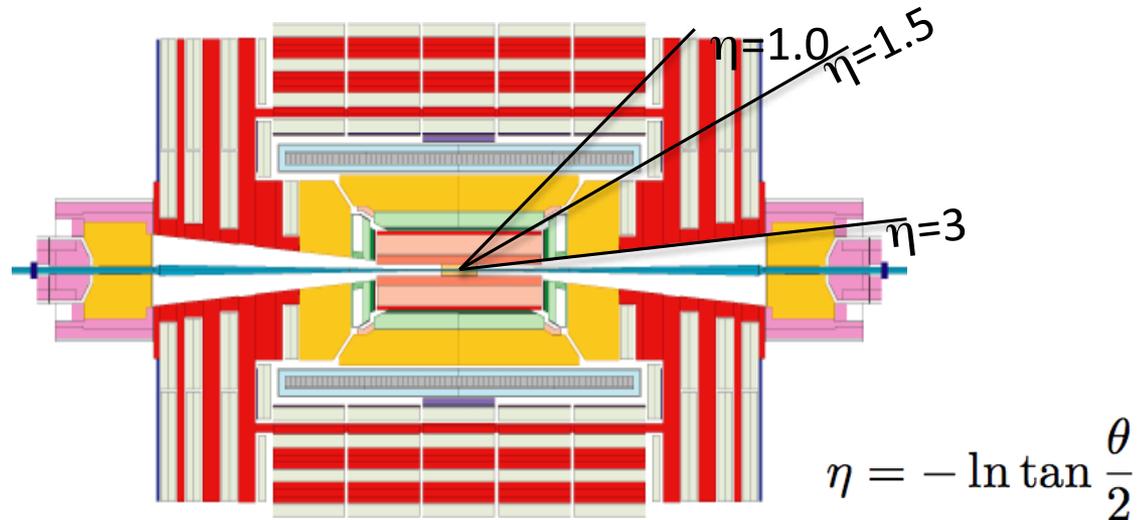
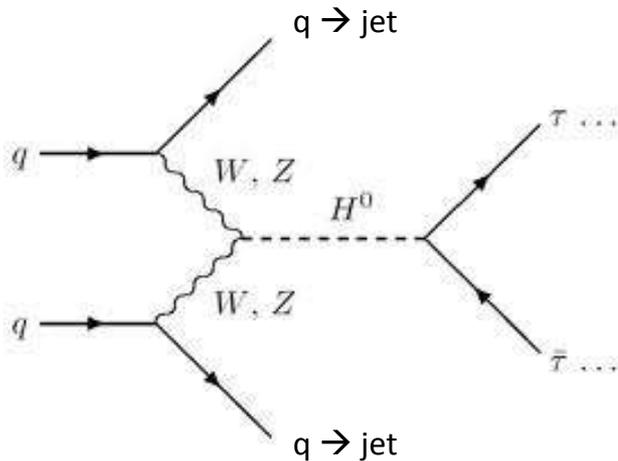
$$N = L\sigma\epsilon$$

Measure as many Higgs couplings to fermions and bosons as precisely as possible

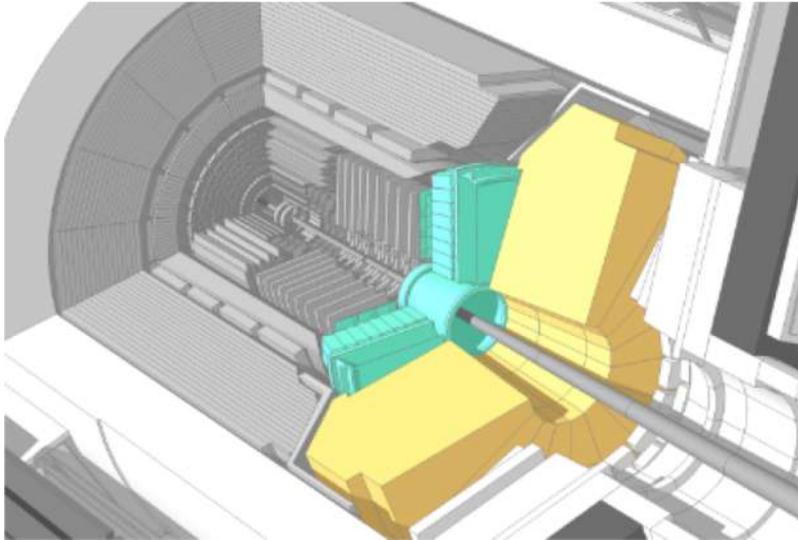
Measure Higgs self-couplings (give access to λ)

Verify that the Higgs boson fixes the SM problems with W and Z scattering at high E

Check if Higgs cancel divergences in Vector boson fusion ...etc

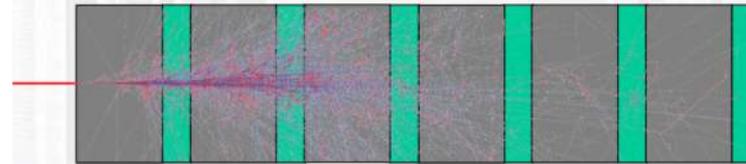


Şu anki Kapak kalorimetreleri



HCAL Endcap (HE)

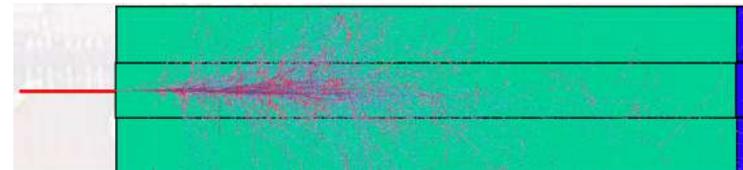
Sampling Calorimeter: Layers of passive brass absorber alternate with active scintillator layers



Scintillation
→ WLS / SiPM
readout

ECAL Endcap (EE) A Homogeneous Crystal Calorimeter:

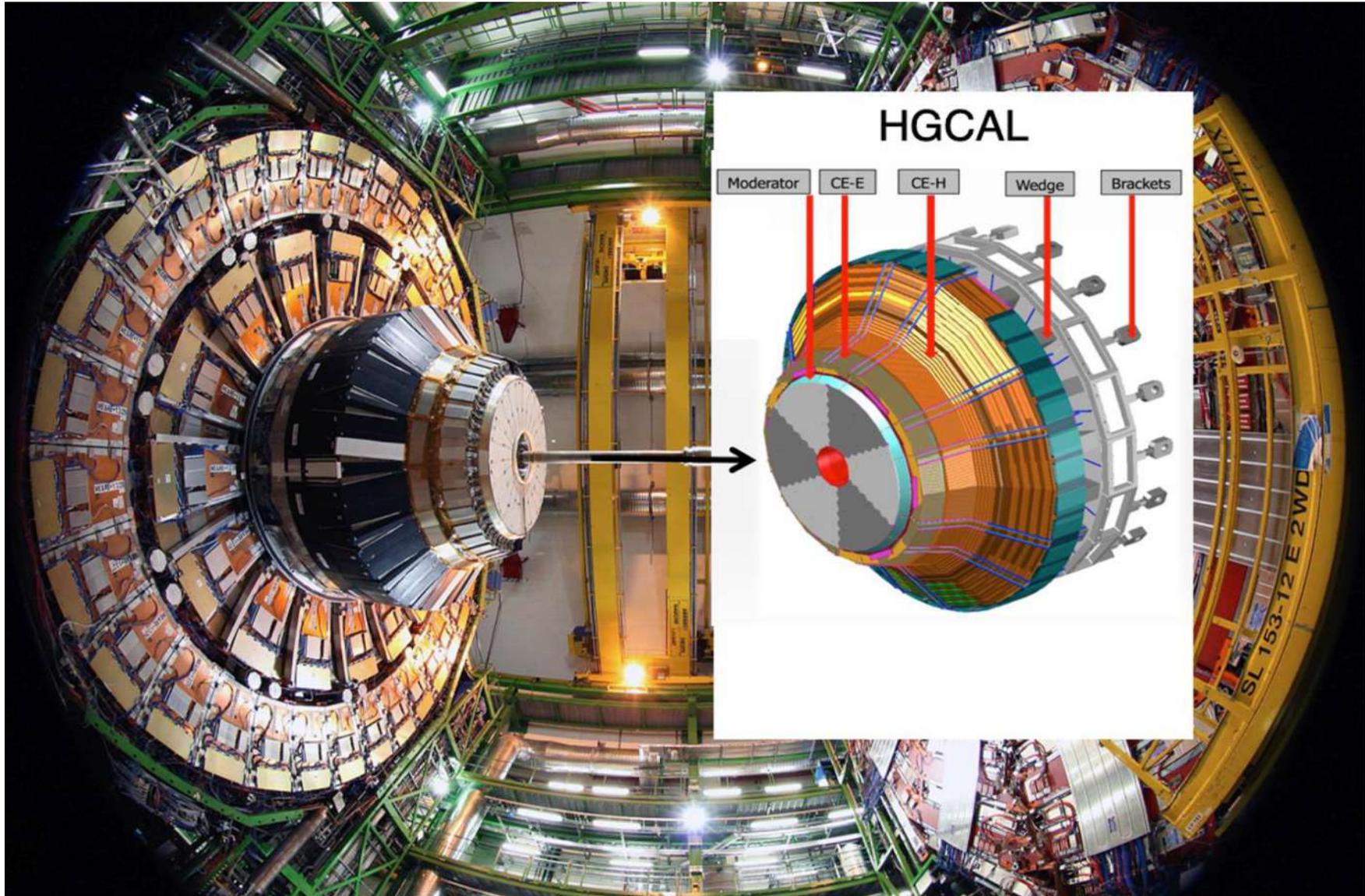
Single dense medium (PbWO₄) serves as both absorber and signal producer (scintillation)



Light detector
Vacuum
PhotoTriodes
(VPTs)

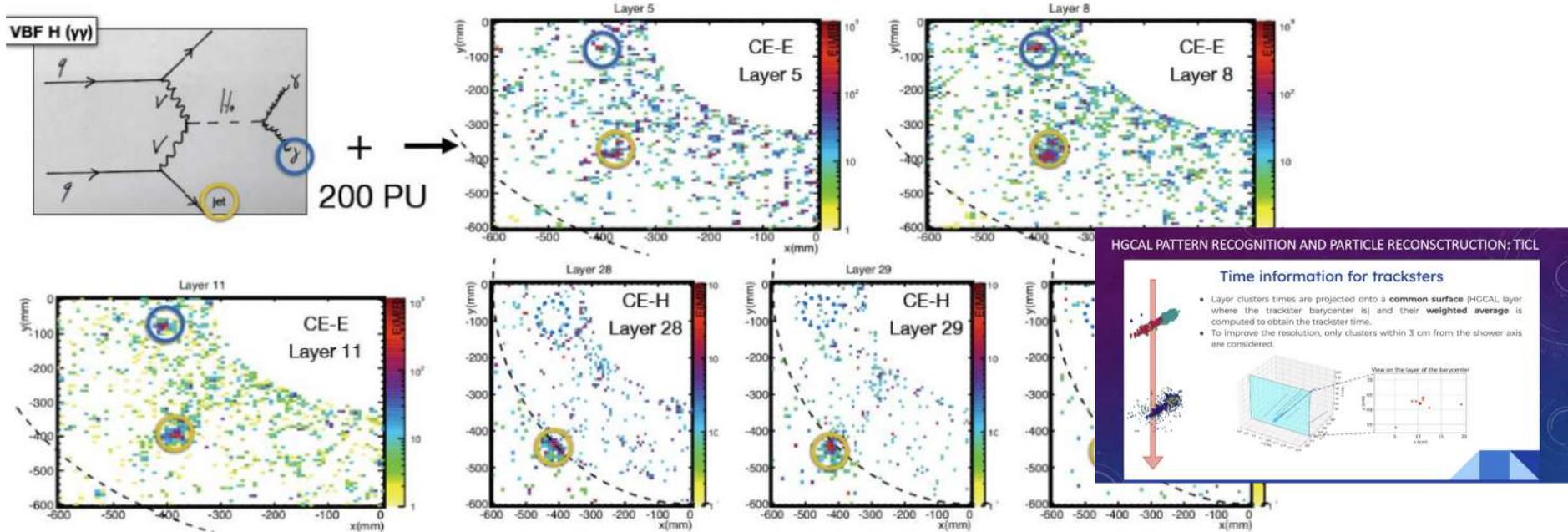


Yenilenme Projesi: HGCAL (The high-granularity calorimeter)



HGCAL için motivasyonlar

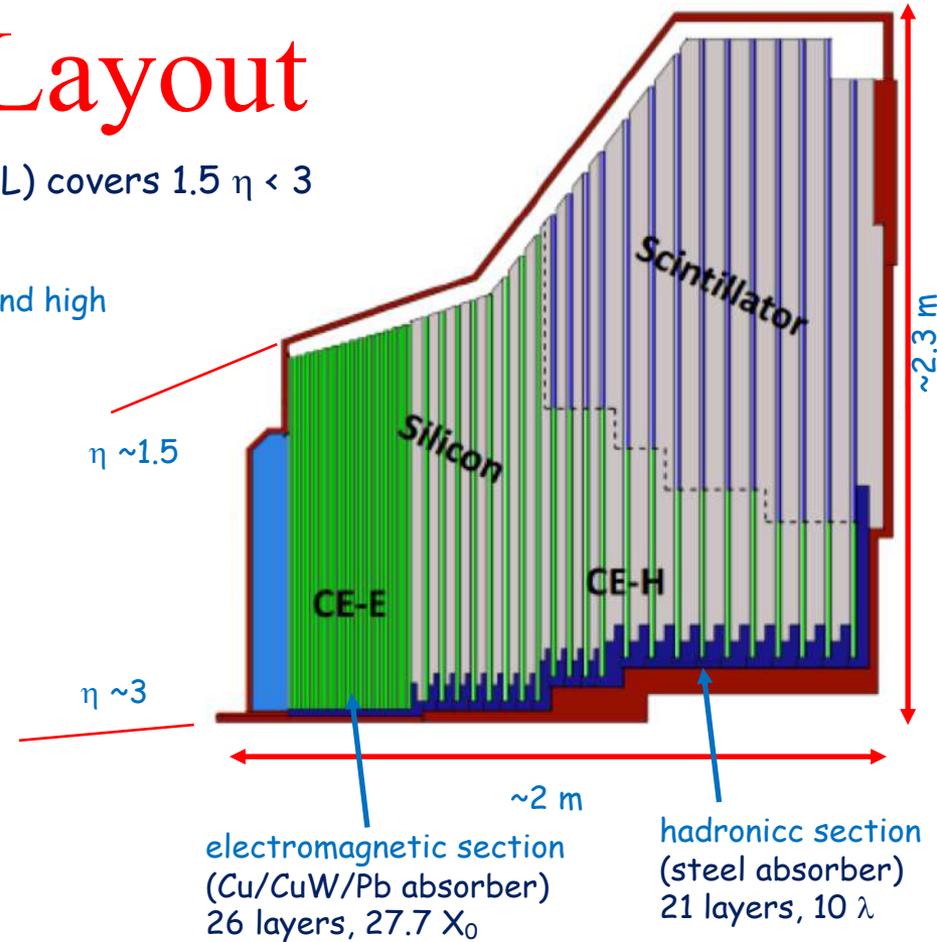
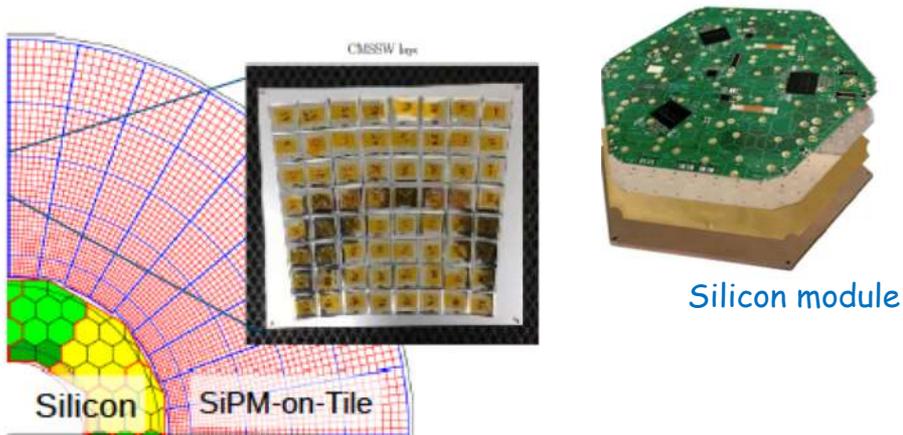
- Yüksek Radyasyon Ortamı şunları gerektirir:
Mevcut CMS Endcap Kalorimetrelerinin daha radyasyona dayanıklı bir örnekleme kalorimetresi ile değiştirilmesi:
 - Elektromanyetik Bölüm (CE-E)
 - Hadronik Bölüm (CE-H)
- Yüksek Yiğilma şunları gerektirir:
Enerji birikimlerinin izlere doğru bir şekilde atanması için yüksek granülerlik
Hassas zamanlama dedektörleri (30 ps)
- Yüksek Parlaklık şunları gerektirir:
Yüksek PU'ya rağmen daha iyi seçicilik için geliştirilmiş L1 Tetikleyici primitifleri
Tetikleyici ve DAQ sistemlerinin tamamen yenilenmesi



HGCAL Layout

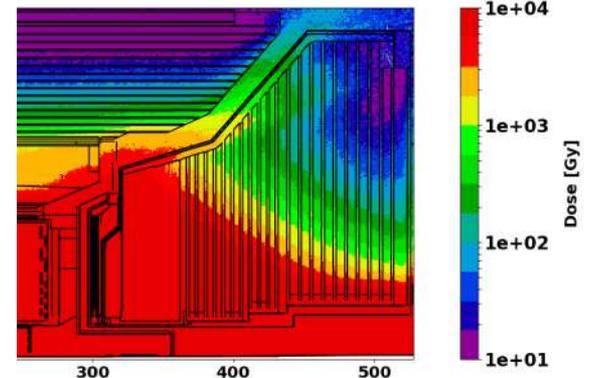
High Granularity Calorimeter (HGCAL) covers $1.5 < \eta < 3$

- Active elements: **Si sensors & SiPM on Scintillating tiles**
- Silicon sensors will be used for the electromagnetic section and high radiation regions of the hadronic section
- ~620 m² silicon sensors produced on 8" wafers
- Three different thicknesses: 120 μm , 200 μm and 300 μm
- Fluences of up to $1e^{16}$ neq/cm²
- 6 M Si channels, 0.5 or 1.2 cm² cell size
- 26.000 Si modules



electromagnetic section
(Cu/CuW/Pb absorber)
26 layers, 27.7 X_0

hadronic section
(steel absorber)
21 layers, 10 λ



- Plastic scintillator tiles with direct (on-tile) SiPM readout are used for those sections of the hadronic calorimeter that will be exposed to less than $\sim 5 \times 10^{13}$ n/cm² after $3'000 \text{ fb}^{-1}$
- ~370 m² of scintillators, 4-30 cm²
- 3700 Scintillator modules

220 tonnes per endcap, maintained at -30°C

Silicon Module of HGCAL

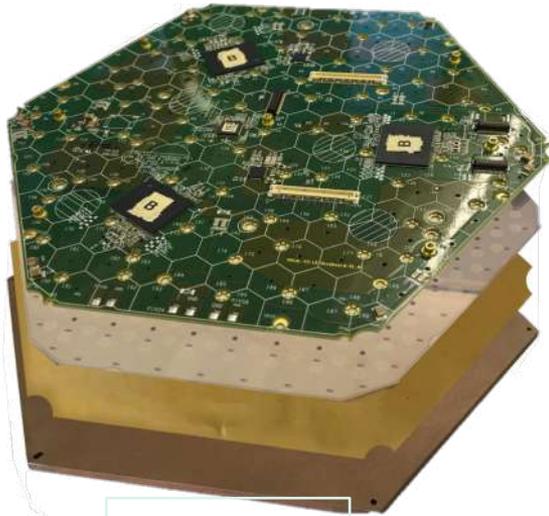
PCB ('Hexaboards'):

- PCB with electronics and connectors - Connects to motherboard for data transfer

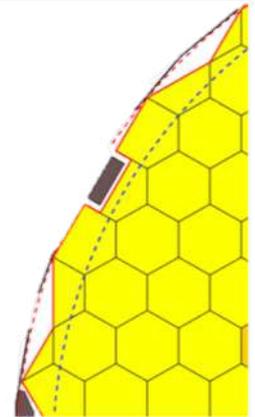
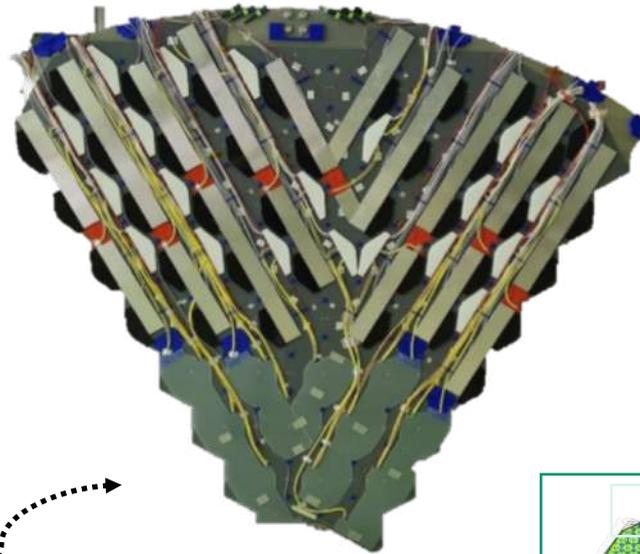
Silicon sensor

Kapton sheet: for insulation/grounding

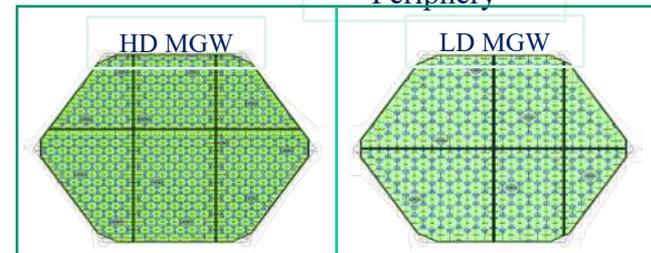
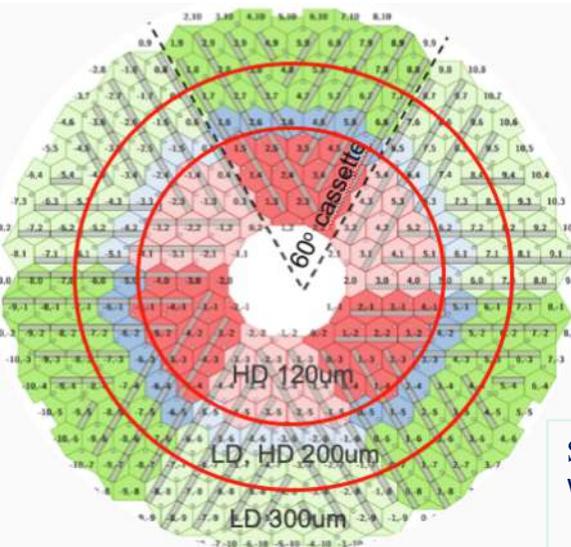
Baseplate: Rigidity, contributes to absorber material



8" LD Si Module



cassette Periphery



Silicon-only layer (in CE-E) showing "cassettes" & different sensor thicknesses
With increasing fluence thickness is reduced

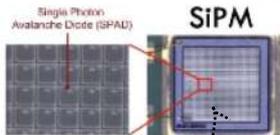
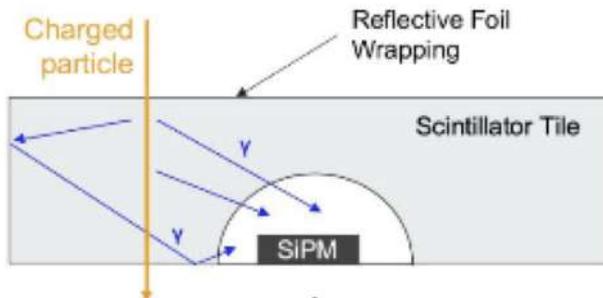
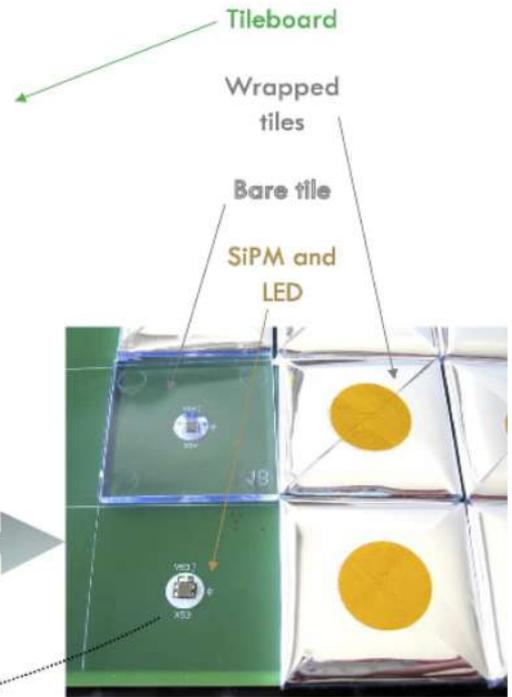
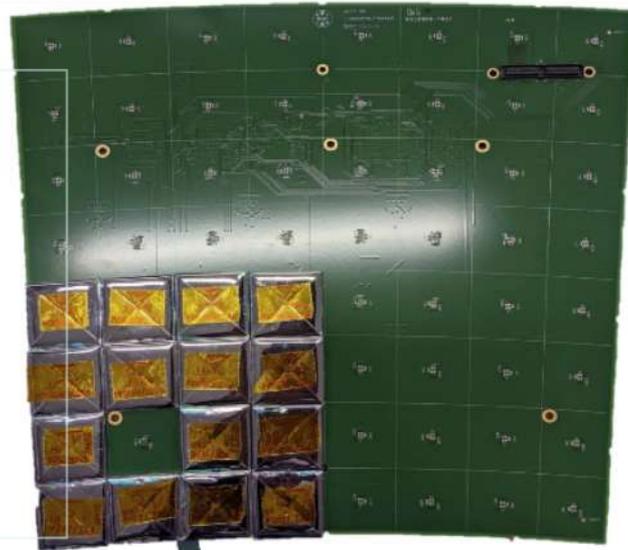
The SiPM on tile Modules of HGCAL

Tile board PCB:

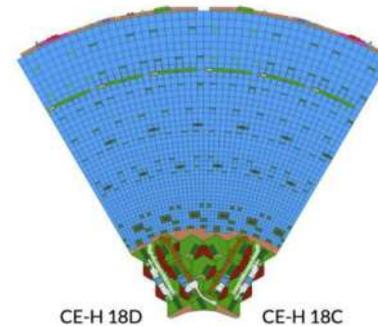
- is connecting Silicon photo to HGROC's
- and to motherboard for control and data transfer

Scintillating tiles

- Reflective foil wrapping
- Light collection by SiPM's
- LED light injection

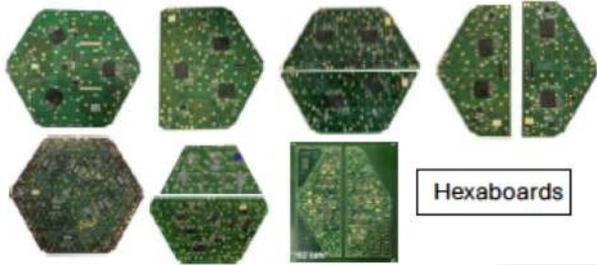


• 2 largest mixed cassettes: CE-H 18C and 18D

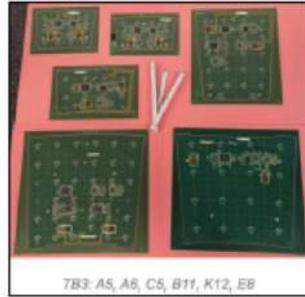


Module Type	Module Counts	
	CE-H 18C	CE-H 18D
LD Full	6	7
LD Half Top	1	2
LD Half Bottom	1	0
LD Semi Right	-	1
A5	2	2
A6	1	1
B12	3	3
D8	3	3
E8	3	3
G8	3	3
G8L	1	1
G8R	1	1

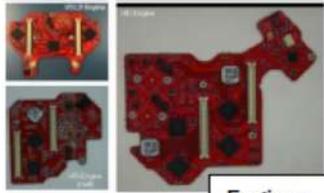
Electronics/Boards



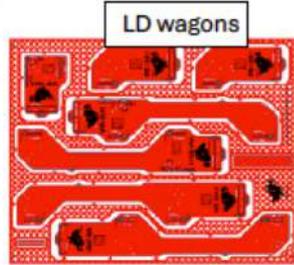
Hexaboard



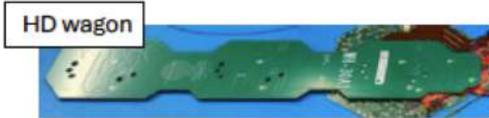
7B3, A5, A6, C5, B11, K12, E8



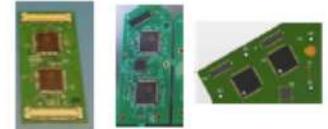
Engines



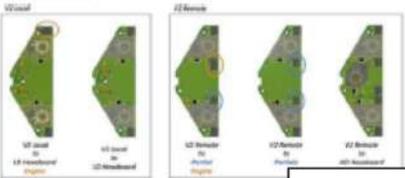
LD wagons



HD wagon



ECON mezzanines



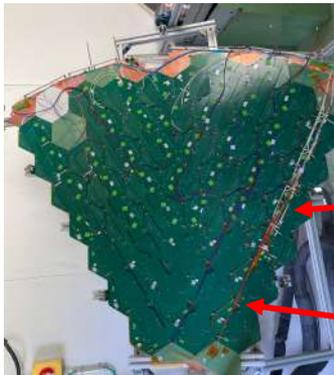
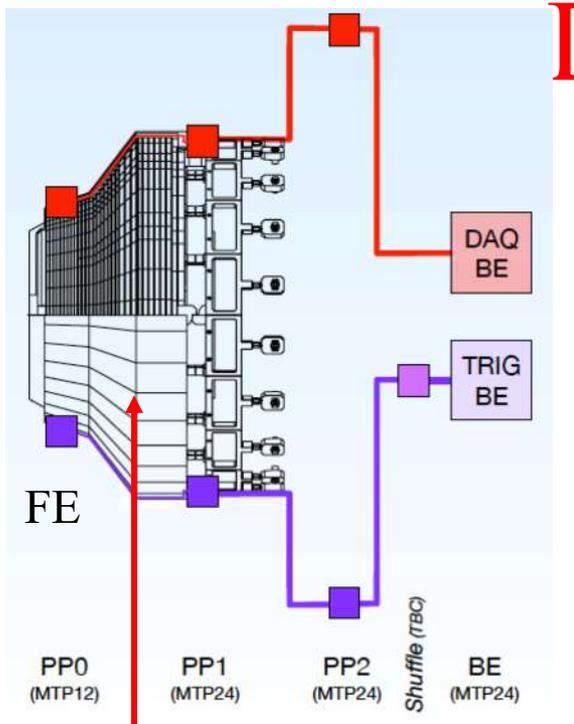
DCDC converters



busbar

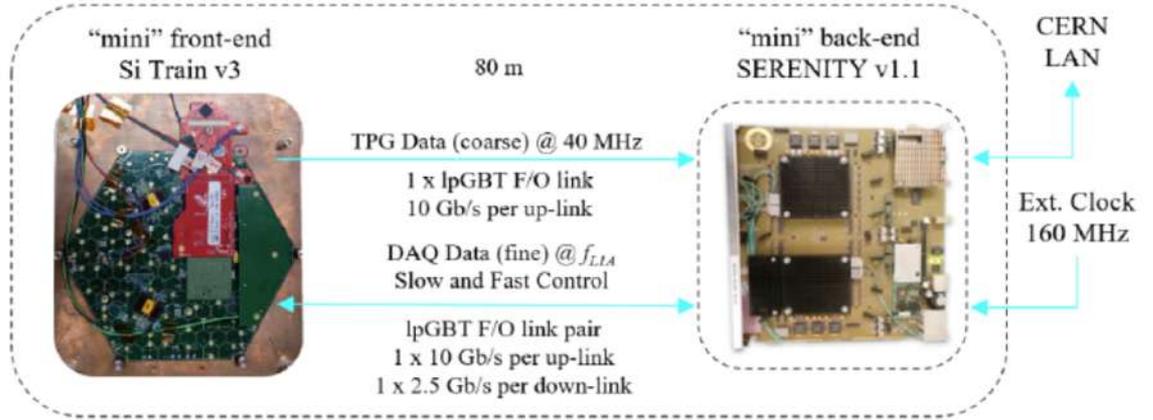


Under construction



Front-End electronics on the cassettes

Vertical Test System Electronics

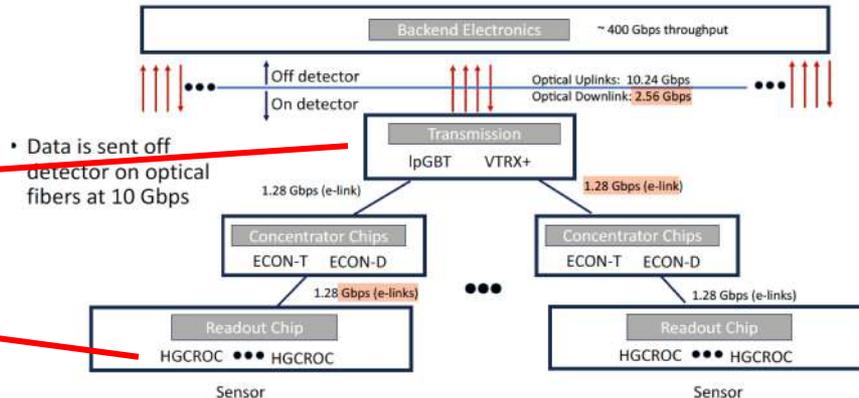


Readout chip: HGCROC

- HGCROC measures up to 72 readout channels on a module
- As well as 4 common mode channels to mi7gate noise and 2 calibra7on channels

- Trigger path
 - Sum of 4 (9) channels, linearization, 7-bit floating point output
 - 4 Trigger 1.28 Gbps output links

- DAQ path
 - 512 depth DRAM, circular buffer, storing full event info (ADC, TOT and TOA) for 12.5 μ s
 - 2 DAQ 1.28 Gbps output links





Thank you!