Parçacık fiziğinde

DENEYDEN KURAMA

nereden nereye?

İSÜ | İSTİNYE ÜNİVERSİTESİ İSTANBUL

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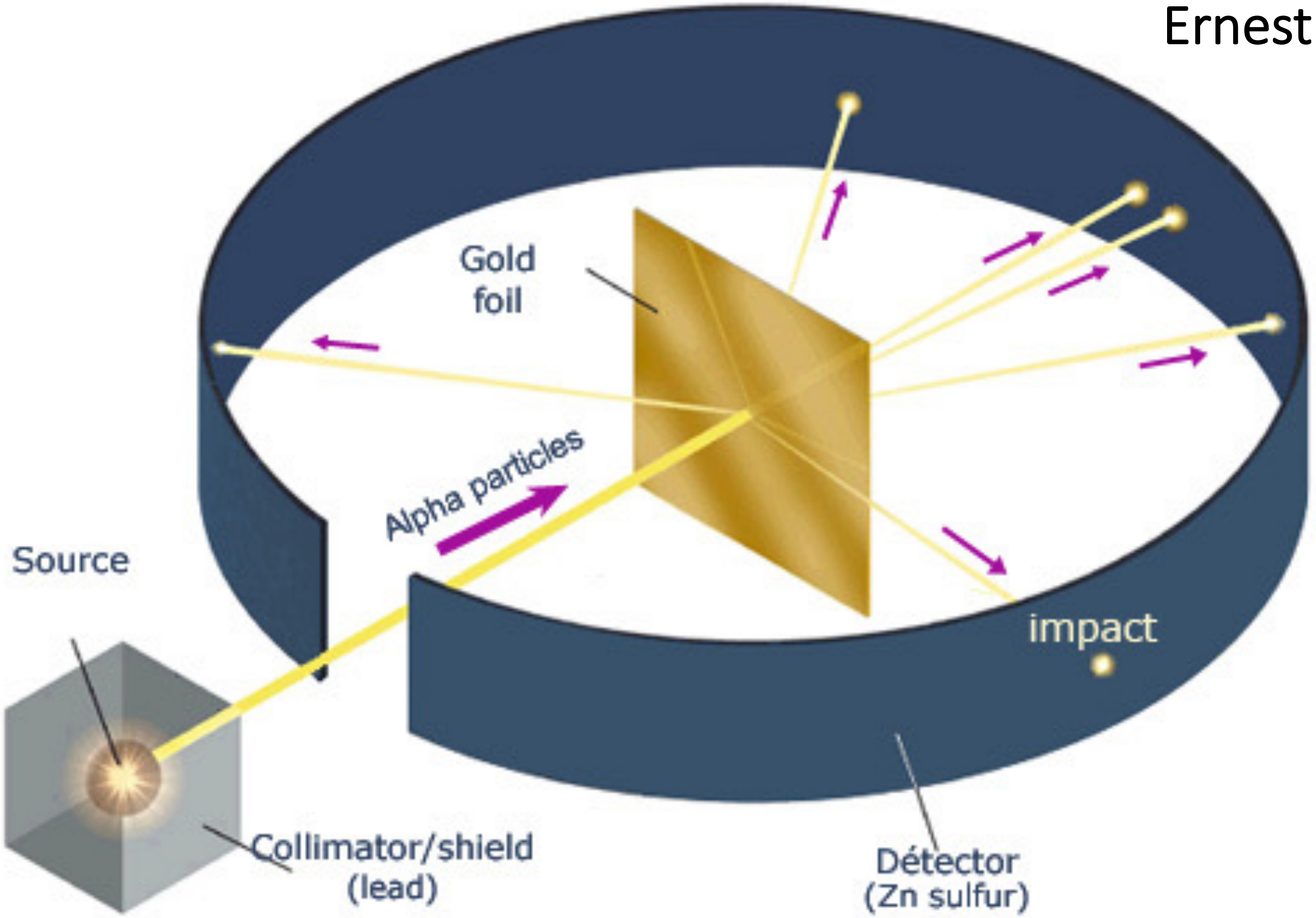
Temel Bilimler Bölümü

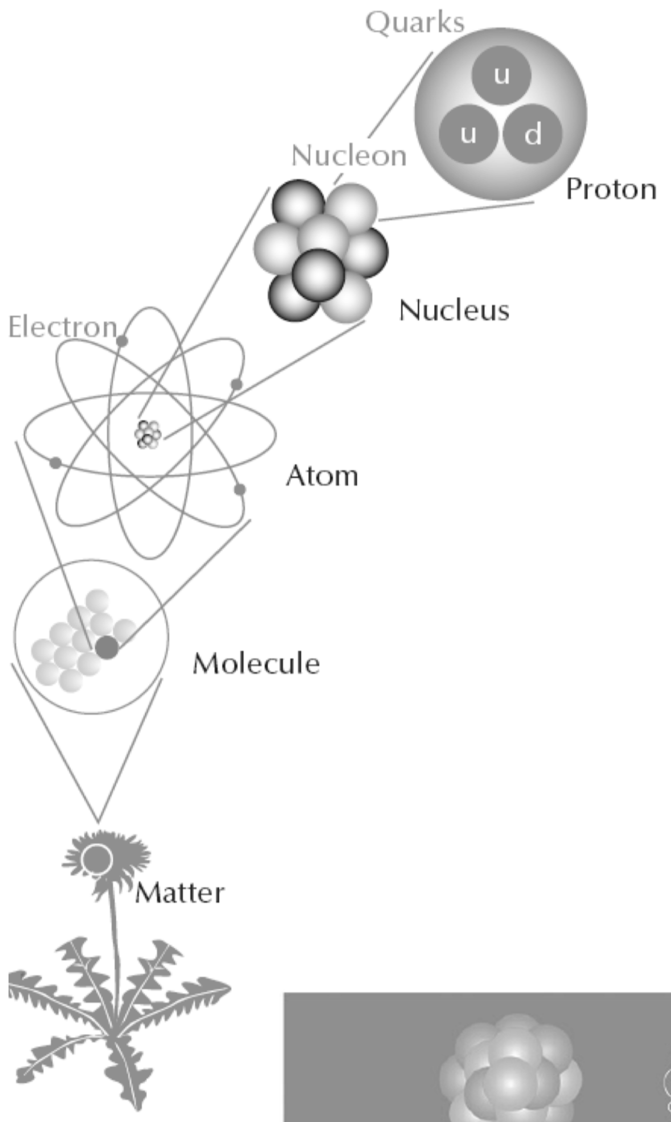
Yüksek Enerji ve Parçacık Fiziği Araştırma Grubu

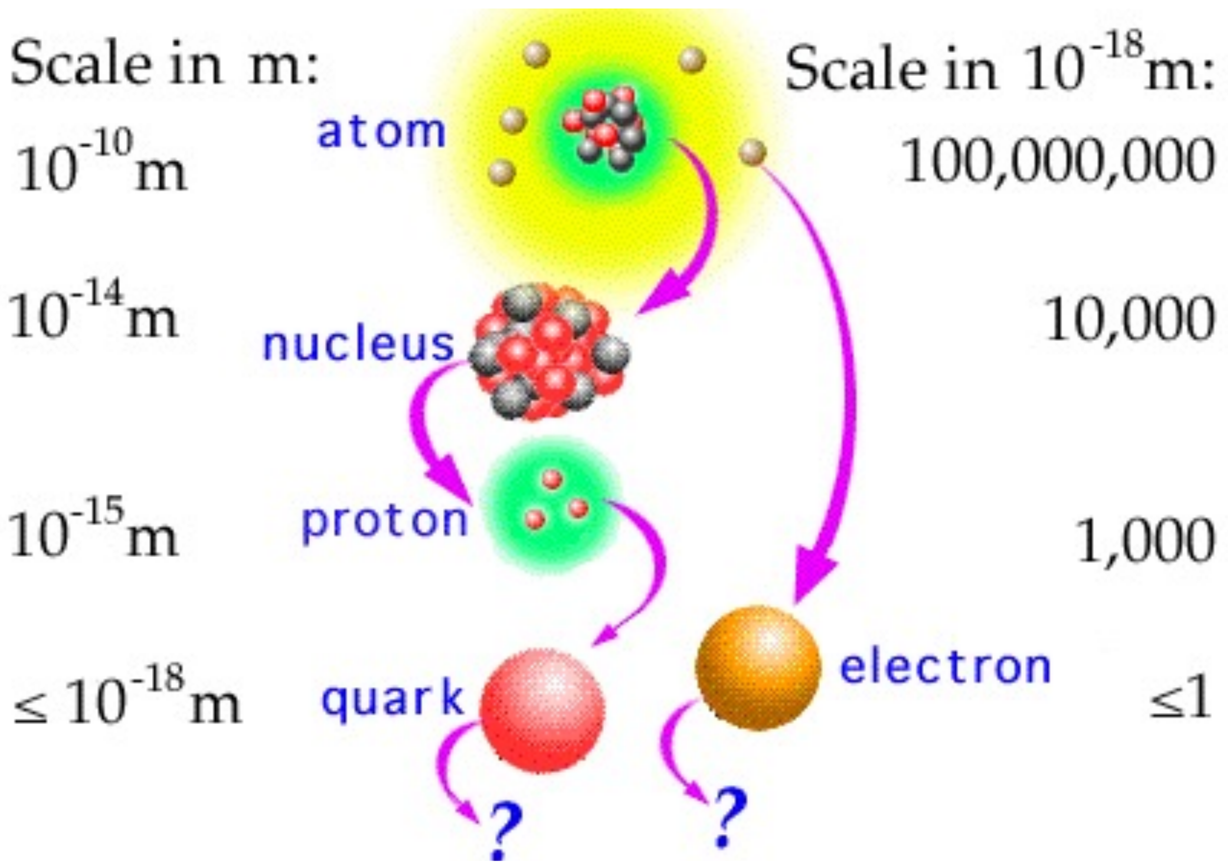
* CERN-ATLAS, CERN-CAST ve IHEP-BESIII deneyleri ulusal koordinatörü, CERN-DRD1 işbirliği takım lideri

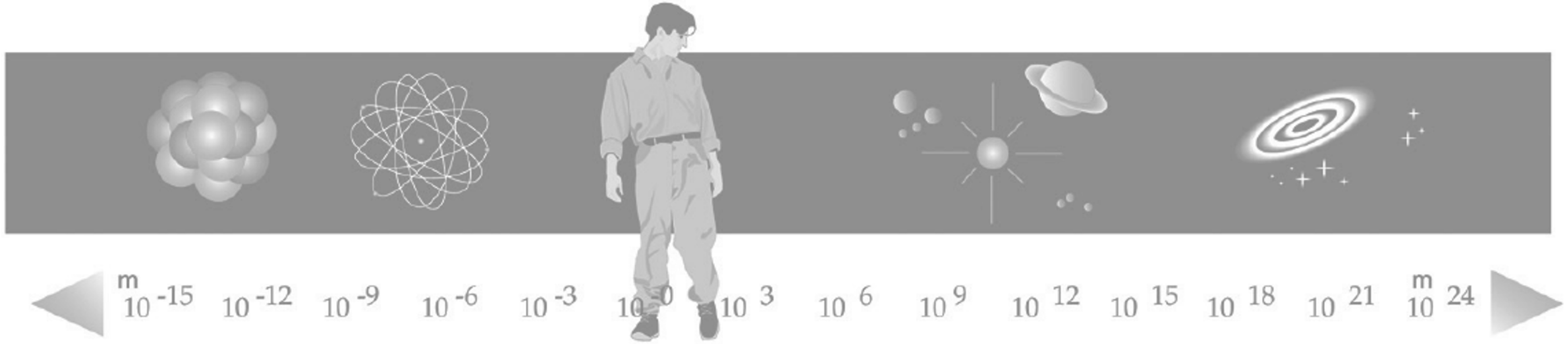
Rutherford Deneyi ve çekirdeğin keşfi

Ernest Rutherford (1911)




Quarks
u
u
d
Nucleon
Proton
Nucleus
Electron
Atom
Molecule
Matter

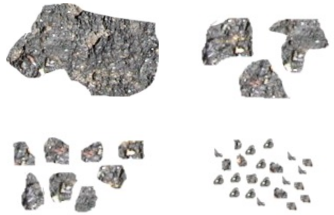

Scale in m:
Scale in 10^{-18}m:
10^{-10}m
atom
100,000,000
10^{-14}m
nucleus
10,000
10^{-15}m
proton
1,000
$\leq 10^{-18}$m
quark
electron
≤ 1
?
?


m
10^{-15}
10^{-12}
10^{-9}
10^{-6}
10^{-3}
10^{0}
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}
10^{18}
10^{21}
m
10^{24}

TEMEL PARÇACIKLAR

evrenin yapıtaşları

- Madde neden yapılmıştır?



- Parçacıkları nasıl sınıflandırırız?

- Parçacıkların özellikleri nedir?

- Parçacıklar nasıl etkileşir?

Standard Model of

FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c²	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

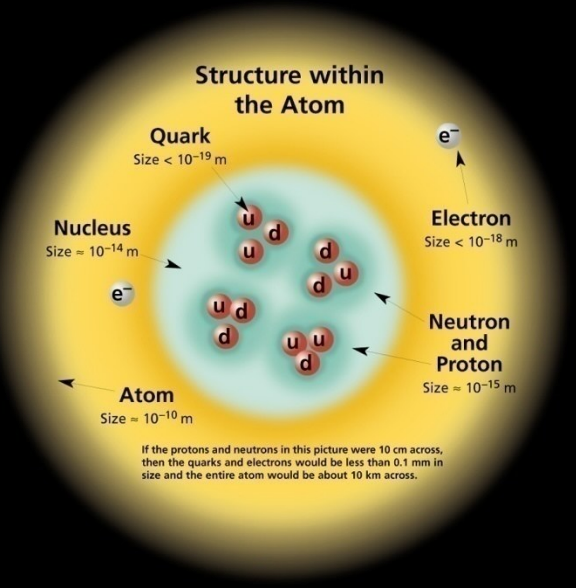
Quarks spin = 1/2

Flavor	Approx. Mass GeV/c²	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

Spin is the intrinsic angular momentum of particles. Spin is given in units of ħ, which is the quantum unit of angular momentum, where $\hbar = h/2\pi = 6.58\times10^{-25}$ GeV s = 1.05×10^{-34} J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The **energy** unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. **Masses** are given in GeV/c² (remember $E = mc^2$), where 1 GeV = 10^9 eV = 1.60×10^{-10} joule. The mass of the proton is 0.938 GeV/c² = 1.67×10^{-27} kg.



If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1

Name	Mass GeV/c²	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1

Name	Mass GeV/c²	Electric charge
g gluon	0	0

Color Charge

Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and **W** and **Z** bosons have no strong interactions and hence no color charge.

Quarks Confined in Mesons and Baryons

One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons** $q\bar{q}$ and **baryons** qqq.

Residual Strong Interaction

The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

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/c²	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

Mesons $q\bar{q}$
Mesons are bosonic hadrons.
There are about 140 types of mesons.

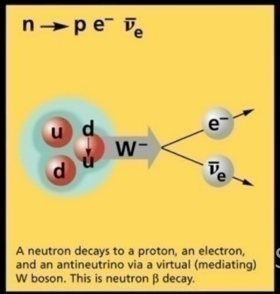
Symbol	Name	Quark content	Electric charge	Mass GeV/c²	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	–1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2 .980	0

Matter and Antimatter

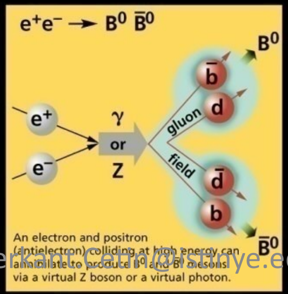
For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or – charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0, γ, and $\eta_c = c\bar{c}$, but not $K^0 = d\bar{s}$) are their own antiparticles.

Figures

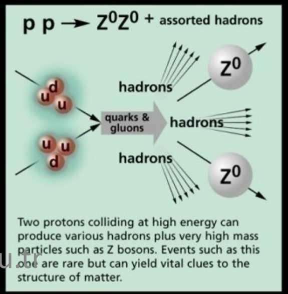
These diagrams are an artist's conception of physical processes. They are *not* exact and have *no* meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.



A neutron decays to a proton, an electron, and an antineutrino via a virtual (mediating) W boson. This is neutron β decay.



An electron and positron (antielectron) colliding at high energy can annihilate to produce B^0 and $\bar{B}^0$ mesons via a virtual Z boson or a virtual photon.



Two protons colliding at high energy can produce various hadrons plus very high mass particles such as Z bosons. Events such as this one are rare but can yield vital clues to the structure of matter.

The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at **http://ParticleAdventure.org**

This chart has been made possible by the generous support of:
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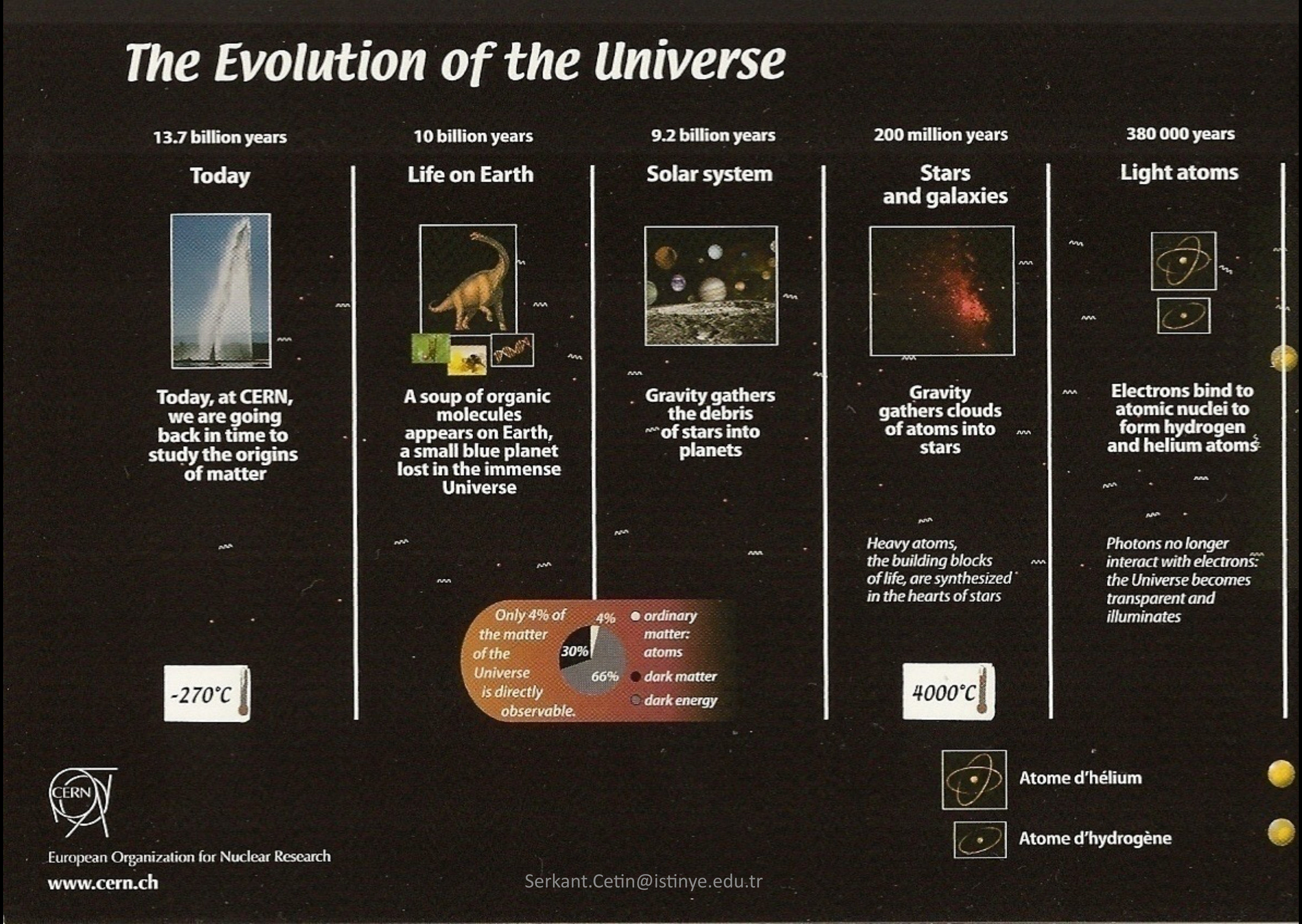
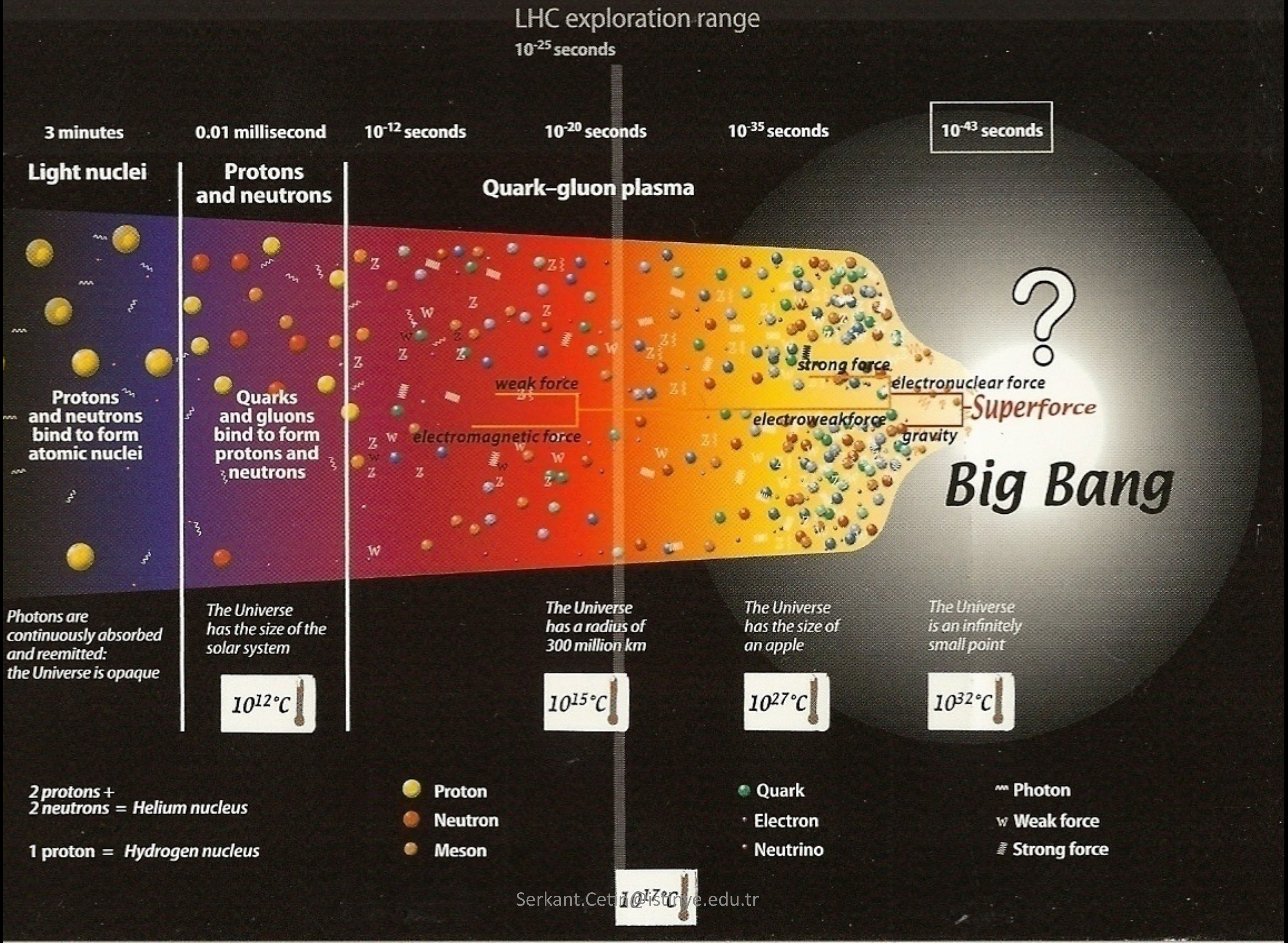
Stanford Linear Accelerator Center
American Physical Society, Division of Particles and Fields
BURLE INDUSTRIES, INC.

http://CPEPweb.org



The Evolution of the Universe
13.7 billion years
Today
Today, at CERN, we are going back in time to study the origins of matter
-270°C
10 billion years
Life on Earth
A soup of organic molecules appears on Earth, a small blue planet lost in the immense Universe
9.2 billion years
Solar system
Gravity gathers the debris of stars into planets
Only 4% of the matter of the Universe is directly observable.
4%
30%
66%
ordinary matter: atoms
dark matter
dark energy
200 million years
Stars and galaxies
Gravity gathers clouds of atoms into stars
Heavy atoms, the building blocks of life, are synthesized in the hearts of stars
4000°C
380 000 years
Light atoms
Electrons bind to atomic nuclei to form hydrogen and helium atoms
Photons no longer interact with electrons: the Universe becomes transparent and illuminates
Atome d'hélium
Atome d'hydrogène
CERN
European Organization for Nuclear Research
www.cern.ch

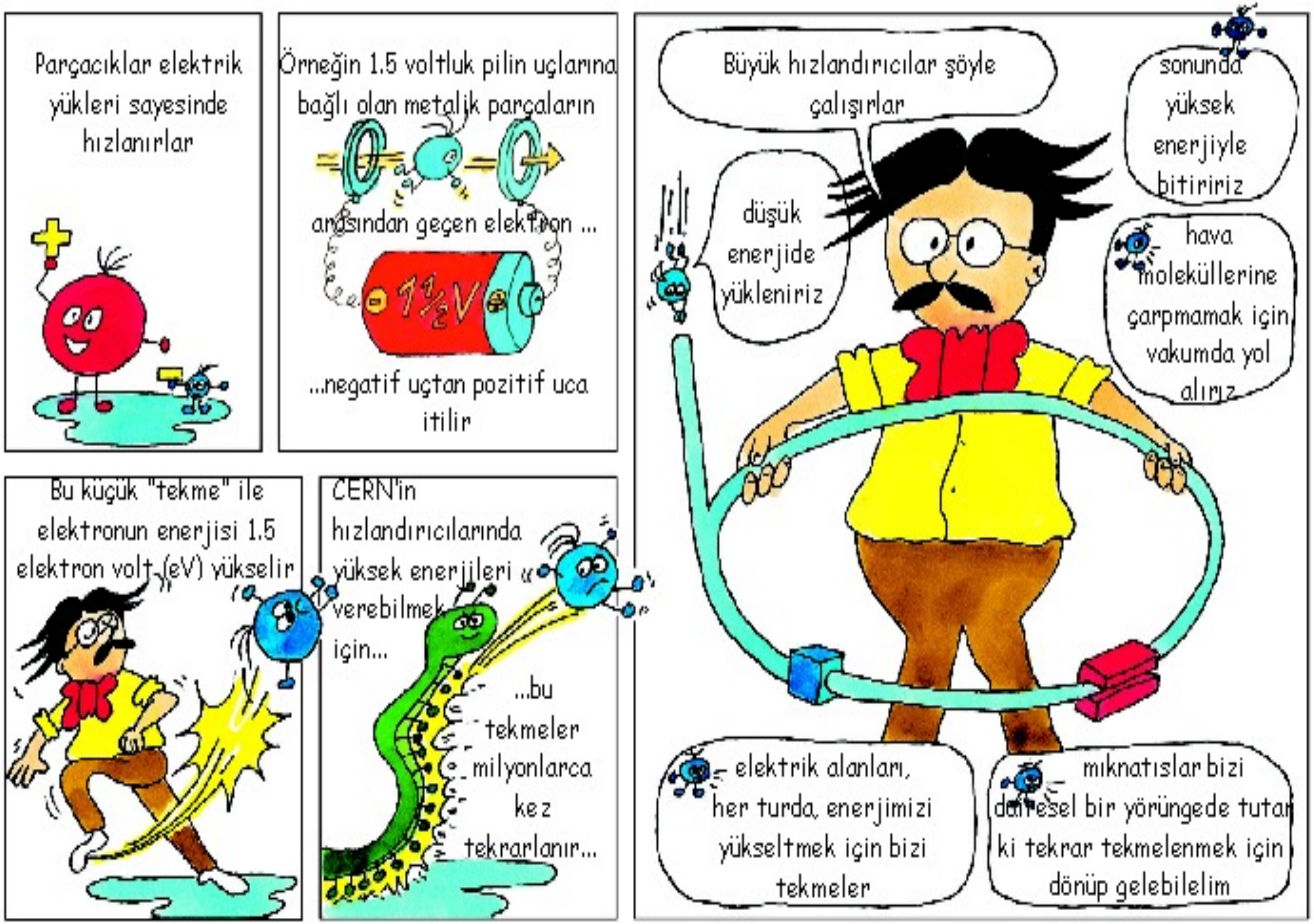


LHC exploration range
10-25 seconds
3 minutes
0.01 millisecond
10-12 seconds
10-20 seconds
10-35 seconds
10-43 seconds
Light nuclei
Protons and neutrons
Quark–gluon plasma
Protons and neutrons bind to form atomic nuclei
Quarks and gluons bind to form protons and neutrons
weak force
electromagnetic force
strong force
electroweakforce
electronuclear force
gravity
Superforce
?
Big Bang
Photons are continuously absorbed and reemitted: the Universe is opaque
The Universe has the size of the solar system
The Universe has a radius of 300 million km
The Universe has the size of an apple
The Universe is an infinitely small point
10^12 °C
10^15 °C
10^27 °C
10^32 °C
2 protons + 2 neutrons = Helium nucleus
1 proton = Hydrogen nucleus
Proton
Neutron
Meson
Quark
Electron
Neutrino
Photon
Weak force
Strong force

- Algıç
- Tetikleme ve Veri Alım Sistemi
- Elektromagnet
- Hızlandırıcı
- …

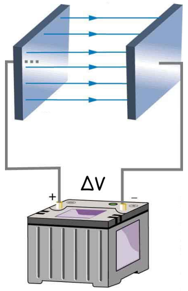
DENEYSEL PARÇACIK FİZİKÇİNİN ALET KUTUSU

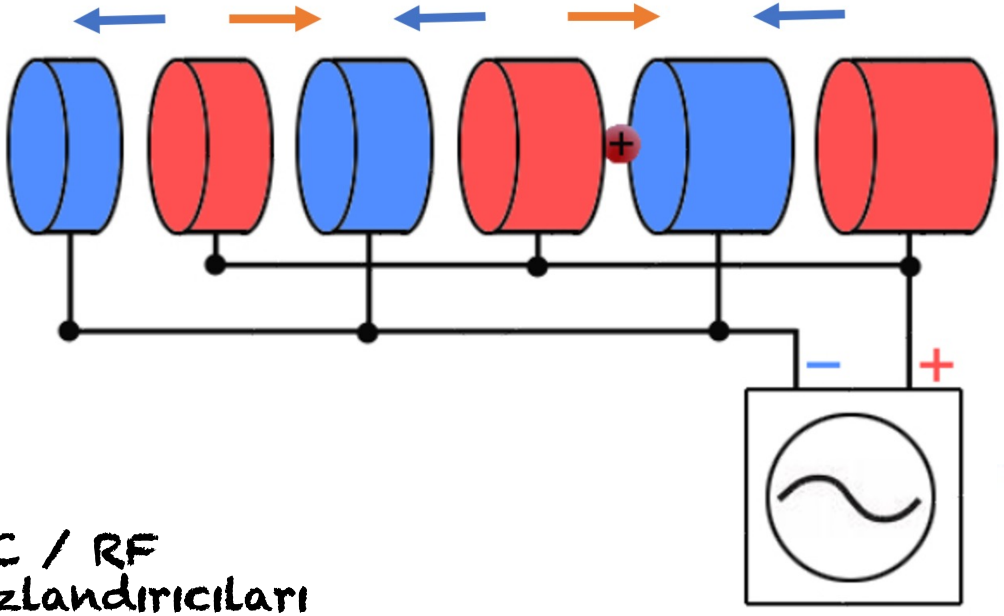
PARÇACIK HIZLANDIRICILARI



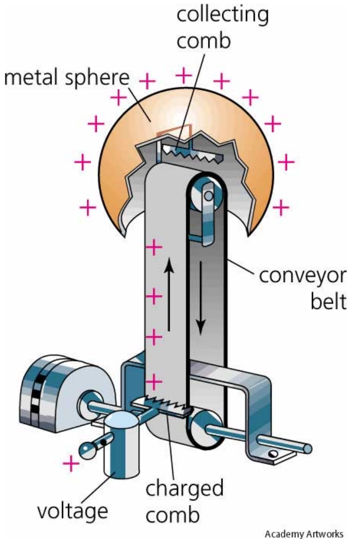
Parçacıklar elektrik yükleri sayesinde hızlanırlar
Örneğin 1.5 voltluk pilin uçlarına bağlı olan metalik parçaların
arasından geçen elektron ...
...negatif uçtan pozitif uca itilir
Bu küçük "tekme" ile elektronun enerjisi 1.5 elektron volt (eV) yükselir
CERN'in hızlandırıcılarında yüksek enerjileri verebilmek için...
...bu tekmeler milyonlarca kez tekrarlanır...
Büyük hızlandırıcılar şöyle çalışırlar
düşük enerjide yükleniriz
sonunda yüksek enerjiyle bitiririz
hava moleküllerine çarpmamak için vakumda yol alırız
elektrik alanları, her turda enerjimizi yükseltmek için bizi tekmeler
mıknatıslar bizi dairesel bir yörüngede tutar ki tekrar tekmelenmek için dönüp gelebilelim

Electrostatik Hızlandırıcılar

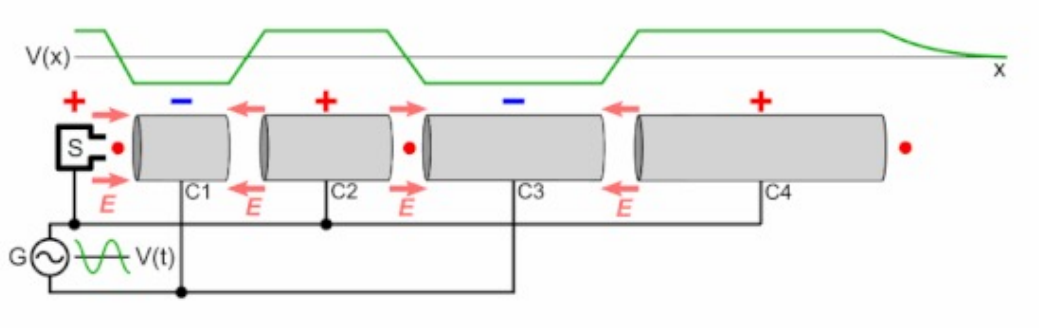




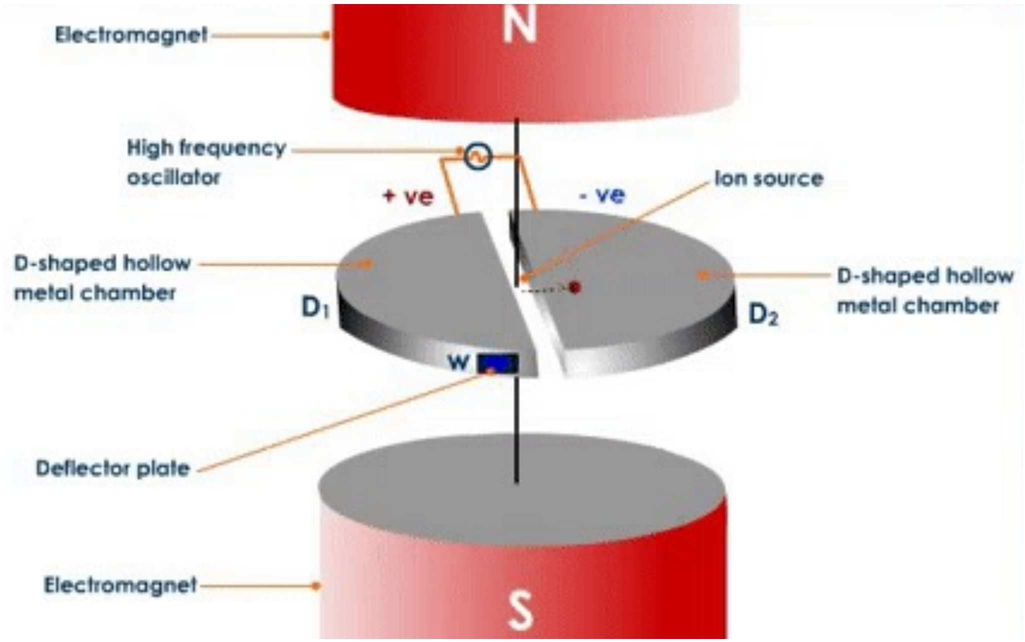
Van de Graaff Jeneratörü



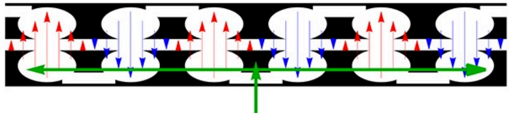
AC / RF Hızlandırıcıları

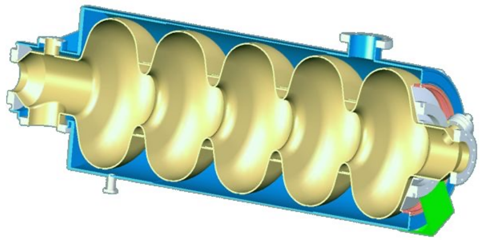


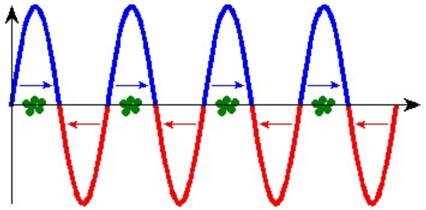
Döndürgeç (Cyclotron)



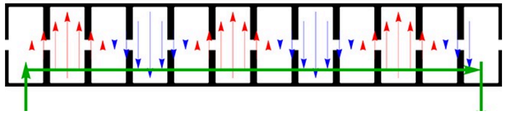
Duran dalga

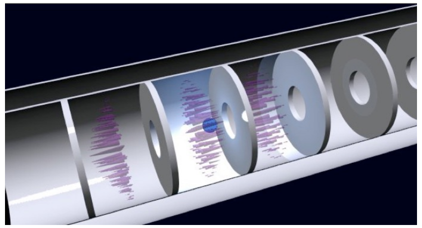


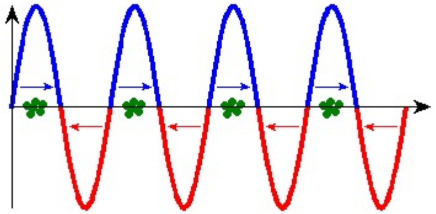




Hareketli dalga







Hızlandırıcılar da RF'in demete uyumlanması kritik önemdedir

PARÇACIK ALGIÇLARI

Parçacığın bir ortamdan geçtiğine işaret edecek ipucuna ihtiyacımız var...

Aradığımız ipucu parçacıkların maddenin içinden geçerken yaptıkları etkilşemelerde yatar...

Amacımıza yönelik iki proses şunlar:

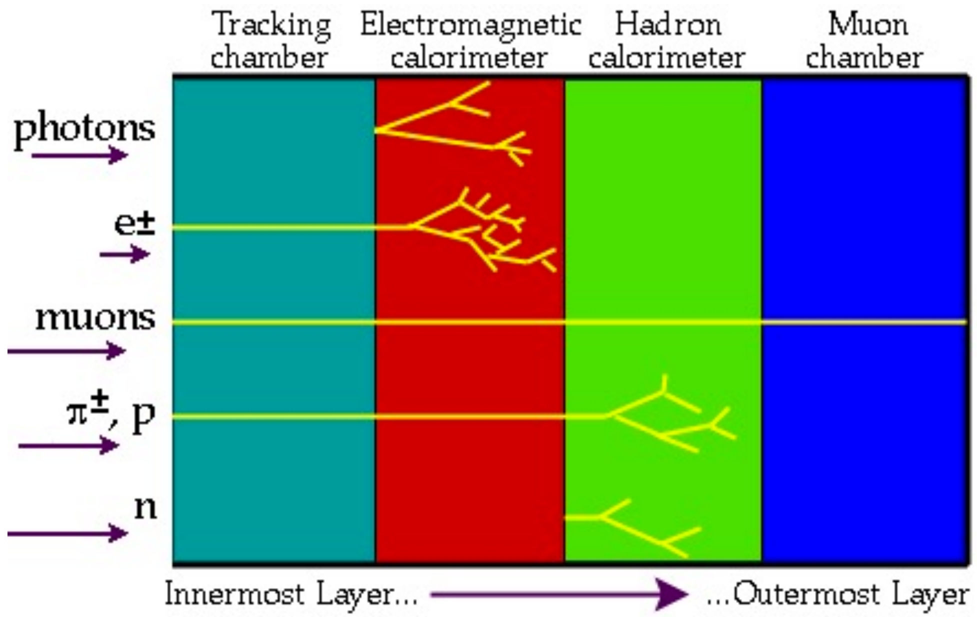
- İyonizasyon

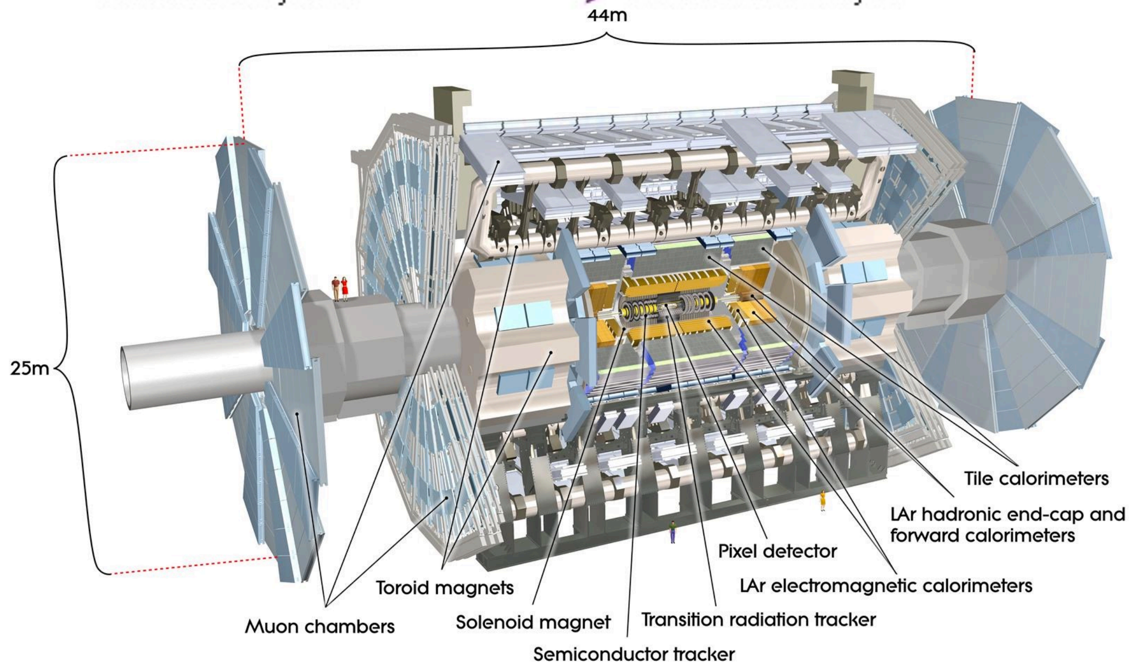
ve

- Uyarılma

Ionization (or ionisation) is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons, often in conjunction with other chemical changes. The resulting electrically charged atom or molecule is called an ion. Ionization can result from the loss of an electron after collisions with subatomic particles, collisions with other atoms, molecules and ions, or through the interaction with electromagnetic radiation.
(https://en.wikipedia.org/wiki/Ionization)

Electron **excitation** is the transfer of a bound electron to a more energetic, but still bound state. This can be done by photoexcitation (PE), where the electron absorbs a photon and gains all its energy or by electrical excitation (EE), where the electron receives energy from another, energetic electron. When an excited electron falls back to a state of lower energy, it undergoes electron relaxation. This is accompanied by the emission of a photon (radiative relaxation/spontaneous emission) or by a transfer of energy to another particle. The energy released is equal to the difference in energy levels between the electron energy states.
(https://en.wikipedia.org/wiki/Electron_excitation)





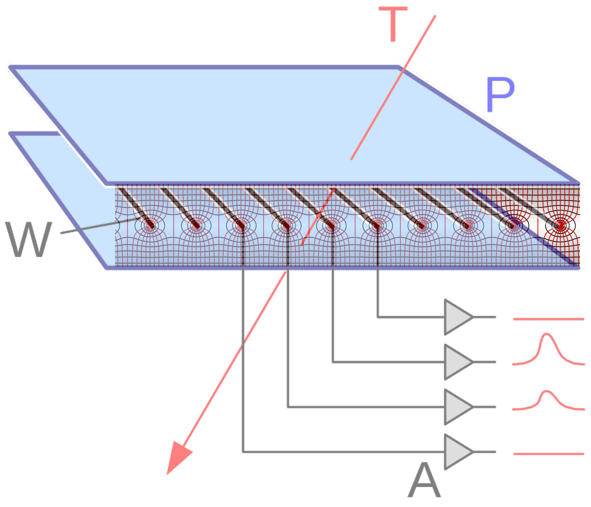
Enerjiyi ölçebilmek için soğuruculara (kalorimetre) ihtiyacımız var...

Momentumu ölçebilmek için izsürücülere ve elektromagnetlere ihtiyacımız var...

Farklı tip parçacıklar için farklı tip izsürücü ve kalorimetreler gerekli...

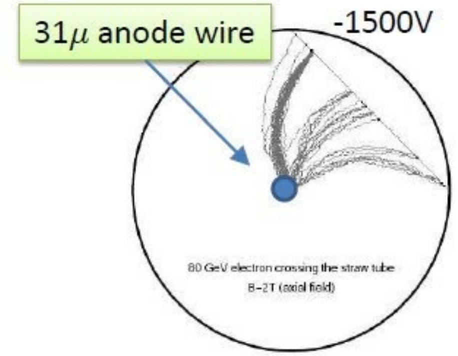
Bu yüzden parçacık fiziği deneylerinde devasa büyüklükte algıç sistemleri gerekli...

A **wire chamber** or **multi-wire proportional chamber** (**MWPC**)



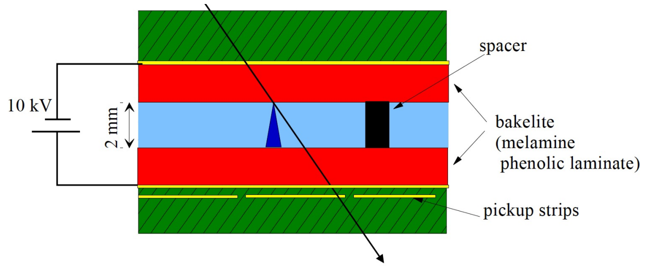
The particles flying through T will ionize gas atoms and set free a charge that an amplifier (A) collects (impulse at the output).

A straw drift tube:

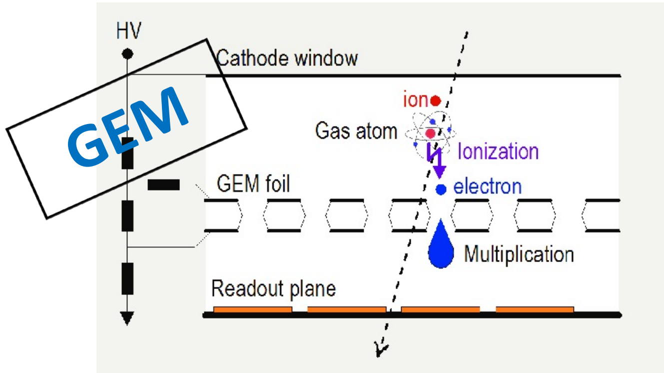


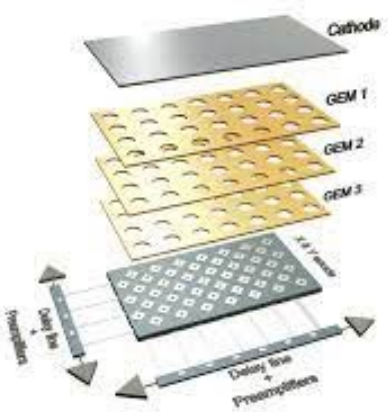
70% Xe, 27% CO_2, 3% O_2

Resistive plate chambers (RPC)

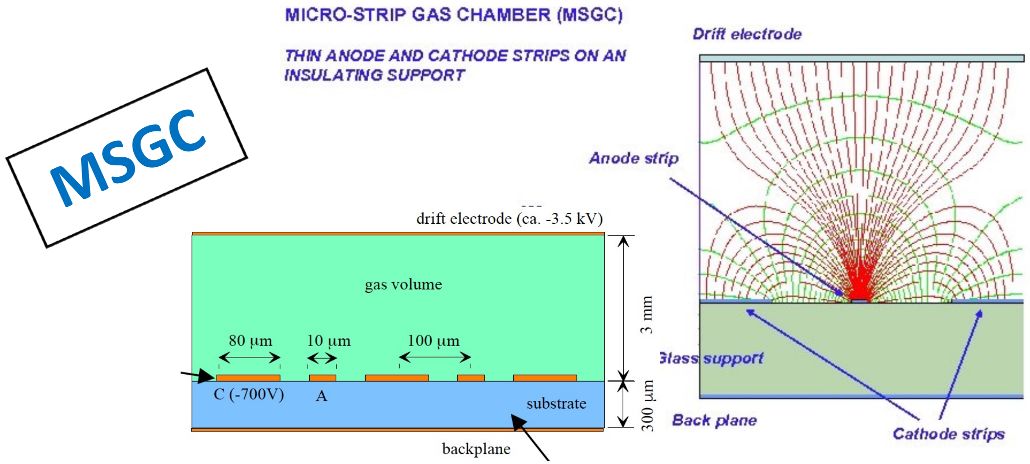


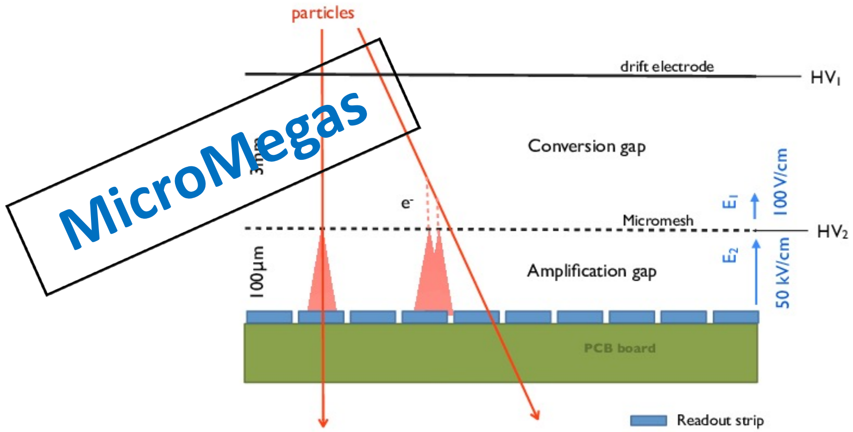
Gas: $C_2F_4H_2$, (C_2F_5H) + few % isobutane



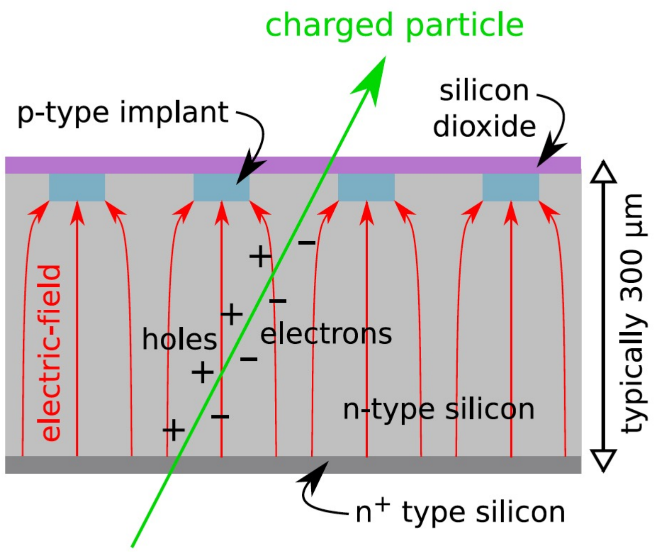


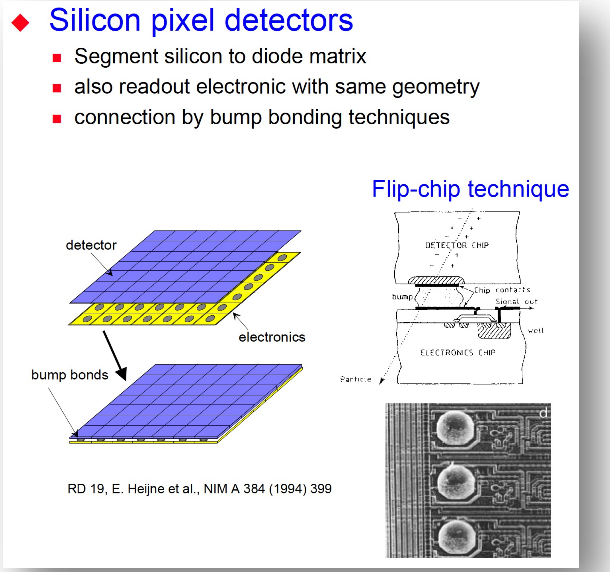
Micropattern gaseous detectors (MPGDs)





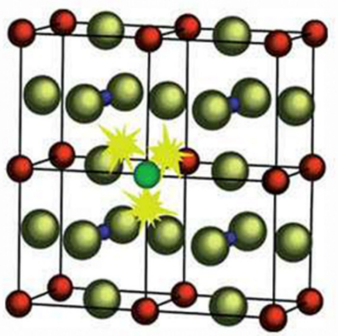
Silicon semiconductor detectors

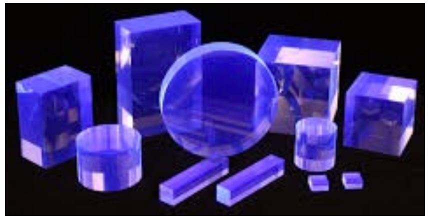




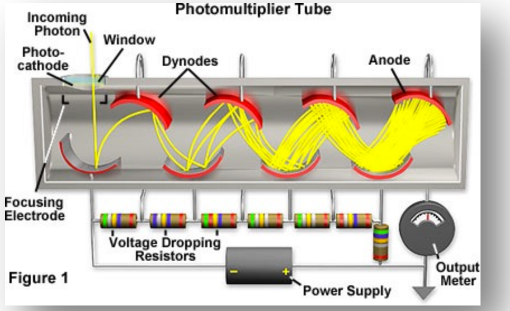
Scintillators

A scintillator is a substance that emits light when it absorbs energy from incident photons or charged particles.



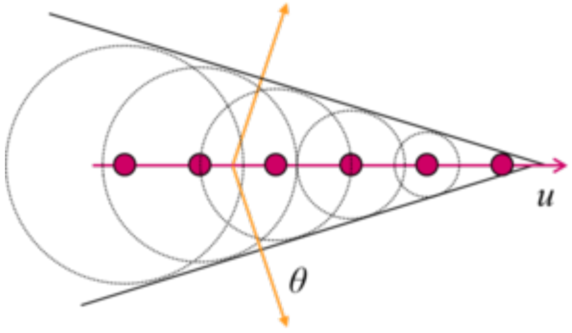


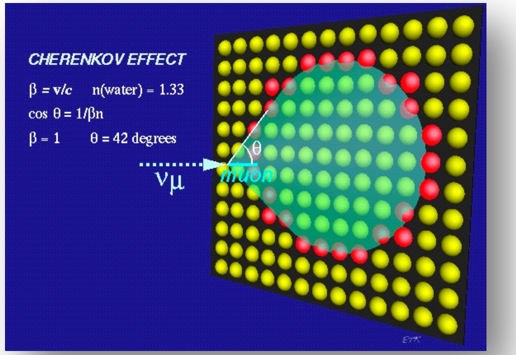
A **PMT** (PhotoMultiplier Tube) is used to convert light to an electric signal.



Cerenkov detectors

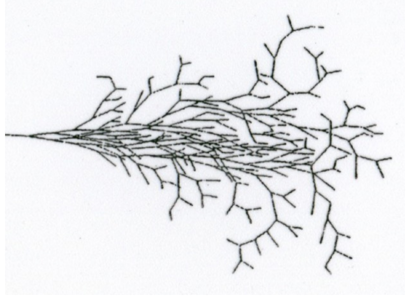
Cerenkov radiation is prompt bluishwhite **light** emitted when a charged particle passes in a dielectric medium with a velocity greater than the phase velocity of **light** in that medium. The charged particle induces polarization of the molecules in the medium, and radiation is emitted upon relaxation of these molecules.

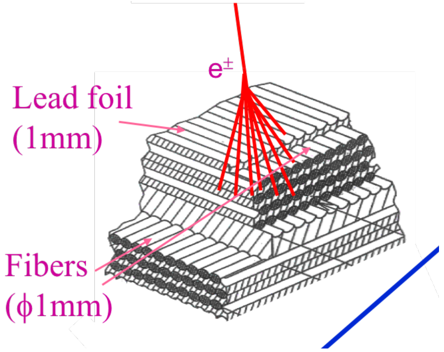




Calorimeters

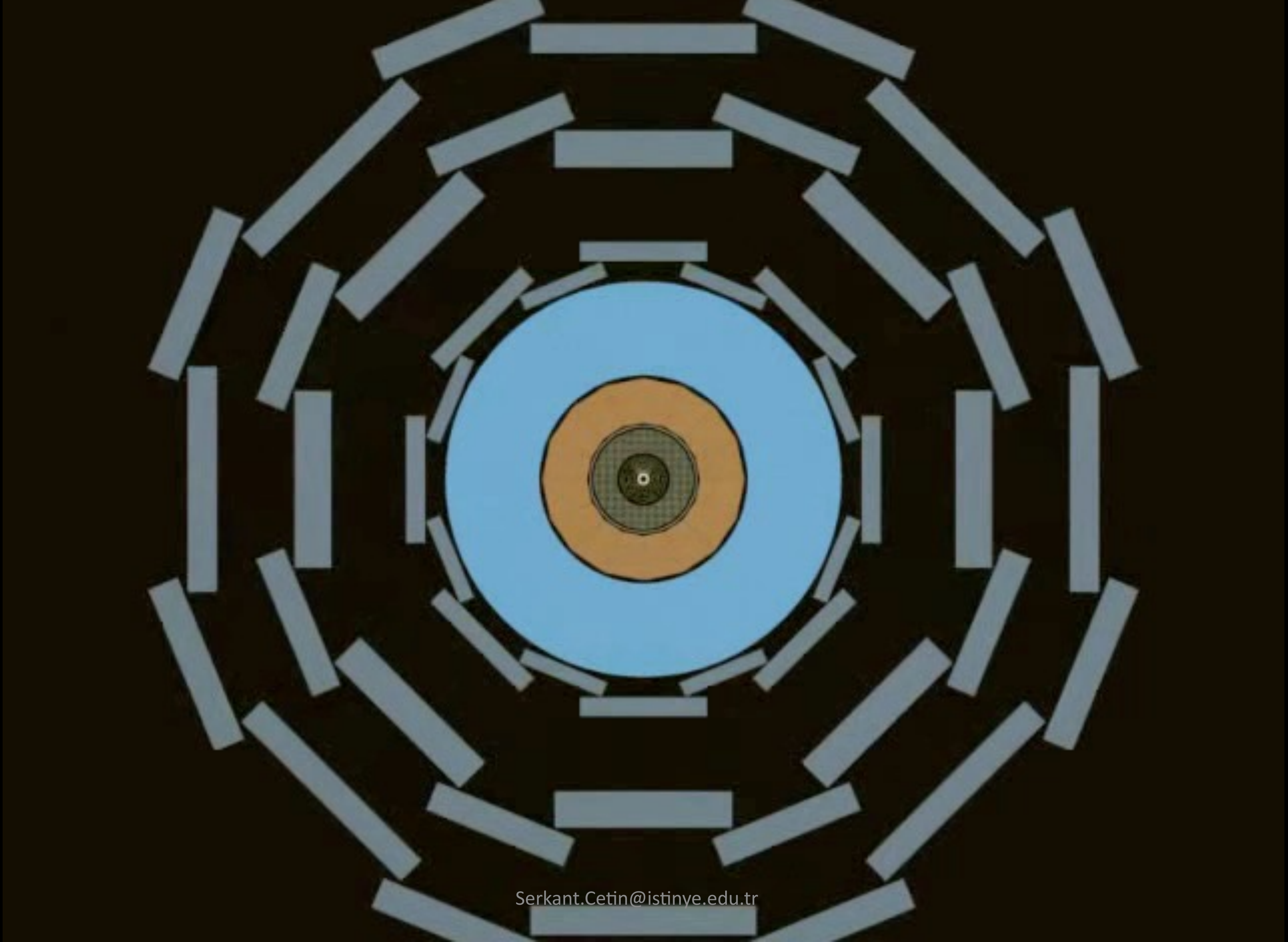
Calorimeters use partial or total absorption of particles and their showers to measure their energy.



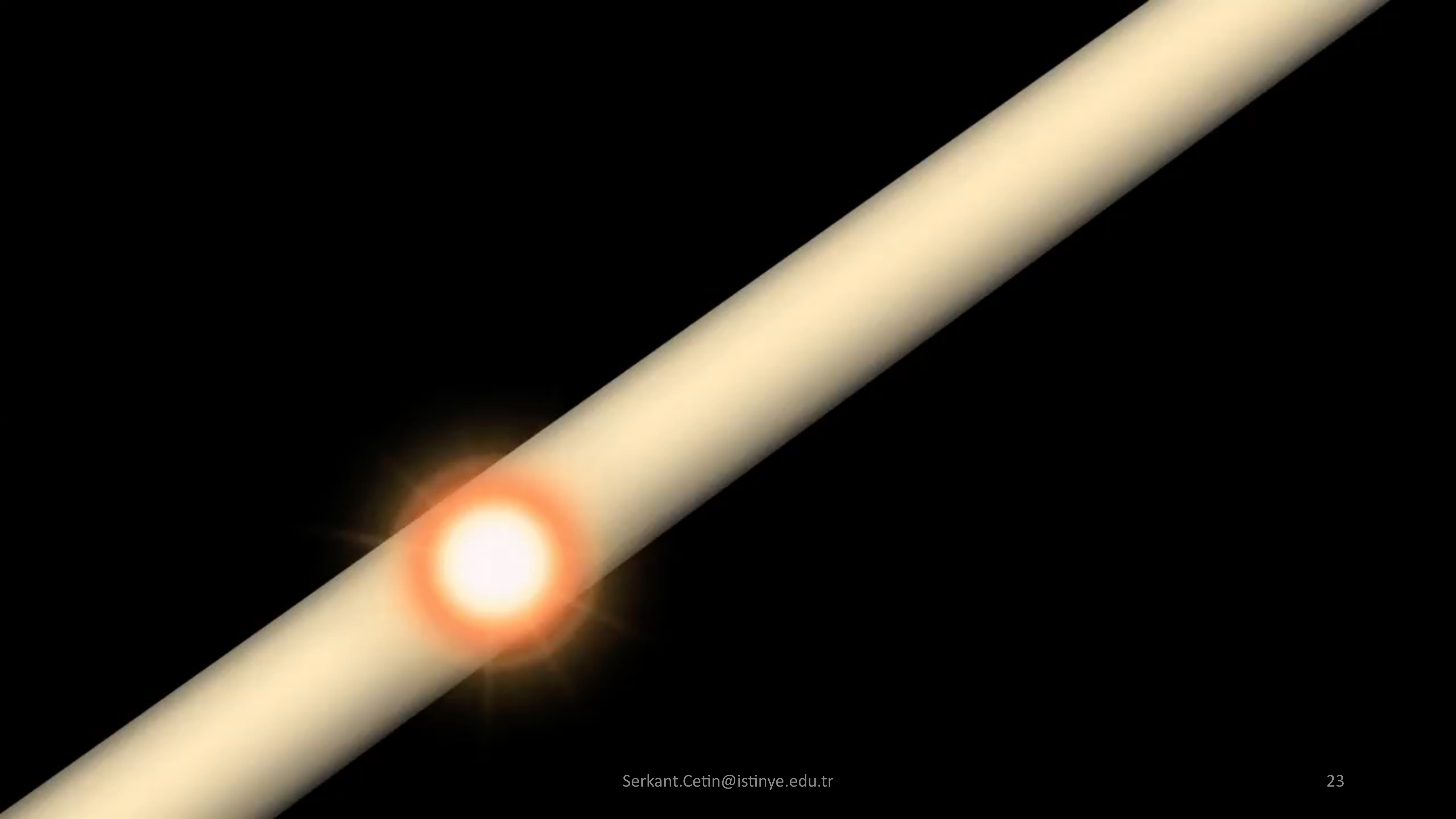


CERN Büyük Hadron Çarpıştırıcısına* ve ATLAS Deneyine bir bakalım..

*enerji öncüsü bir proton-proton çarpıştırıcısı



Şimdi deneyi yapalım…



Proton-proton Collision in the ATLAS Experiment

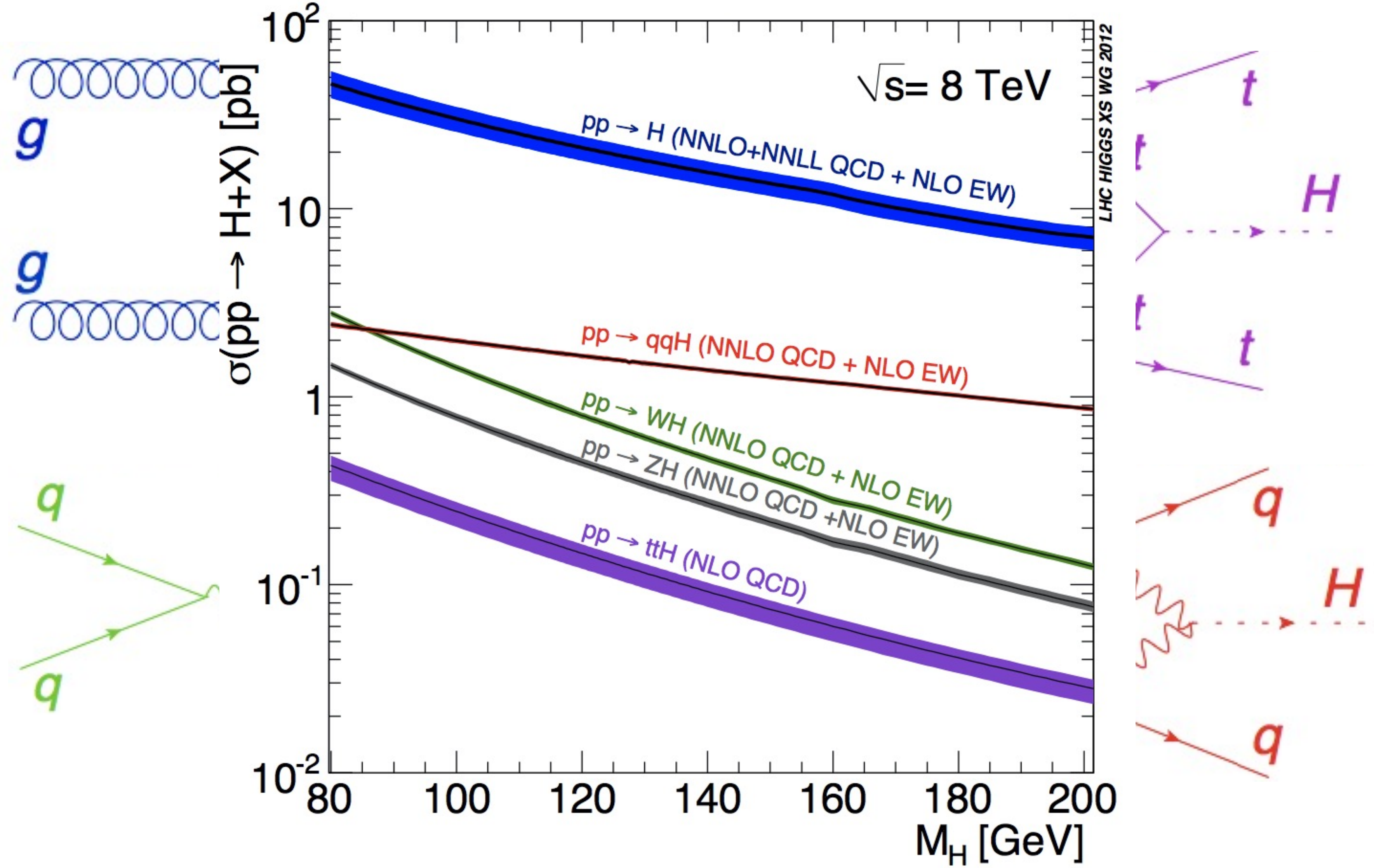
Production of the Higgs particle decaying to two Z^0 particles

ATLAS EXPERIMENT
http://atlas.ch

4 Temmuz 2012

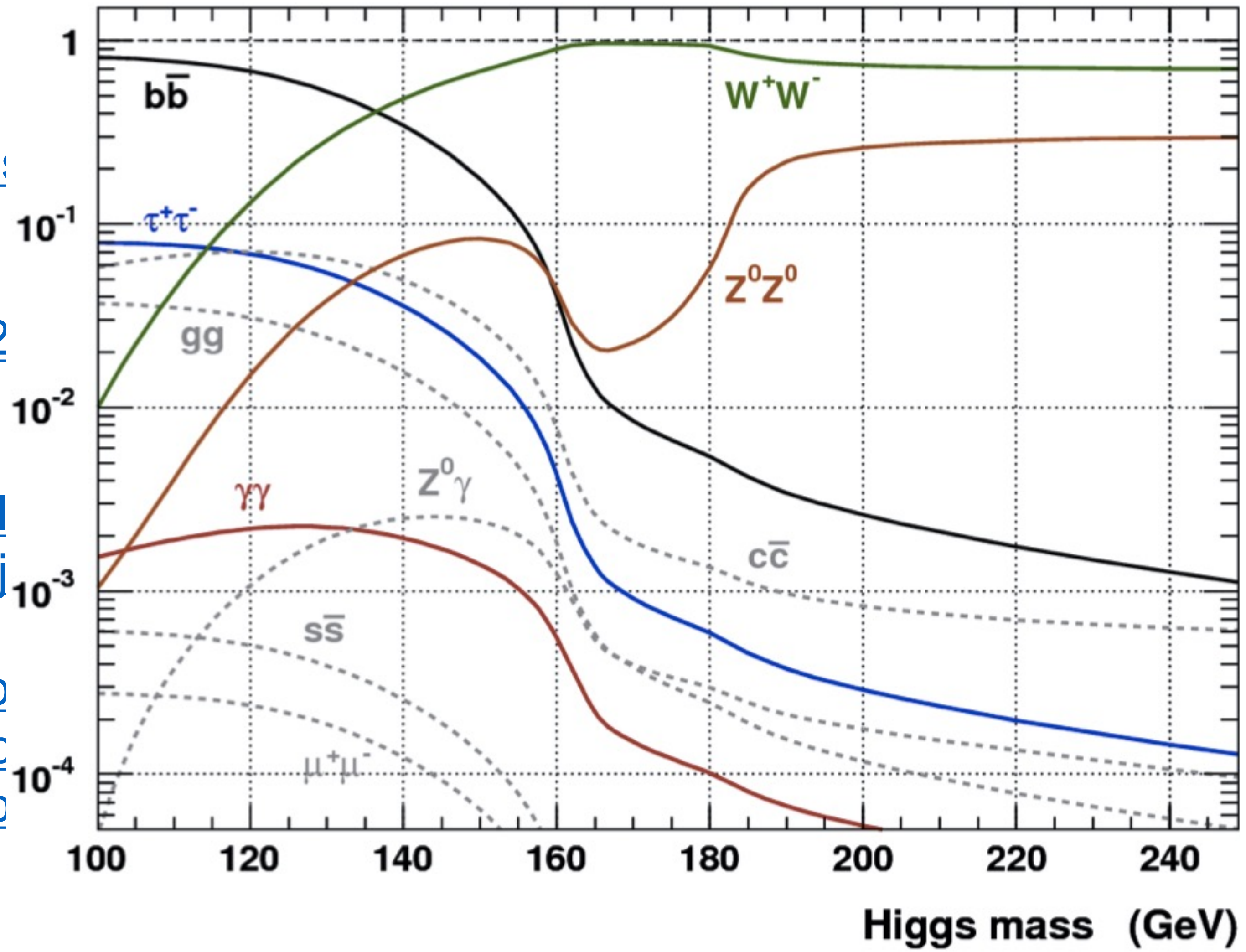
- 50 yıllık çabamızın sonunda elde ettiğimiz sonuçları gururla paylaşıyoruz: Higgs bozonunu aradığımız yerde, beklediğimiz özelliklerde yeni bir bozon bulduk!
- Bu CERN'deki fizikçilerin başarısı değil sadece.
  - Hızlandırıcı, bilgisayar ve dedektörleri geliştiren veya kilometrelerce tünel kazan fizikçi ve mühendislerin, LHC'nin her bir vidasını sıkan teknisyenlerin de değil.
  - Hatta CERN'ün çalışabilmesi için her yıl, yılda bir kahve eksik içmeyi kabul eden Avrupa ülkelerinin vatandaşlarının da değil.
  - Felsefecilerin, düşünceleri ve kavramları resmeden sanatçıların, hayallerimizi canlandıran bilimkurgu yazarlarının, tüm bilim insanlarının, bilime destek veren vizyon sahibi devlet adamlarının...
  - Kısacası doğanın güzelliği karşısından heyecanlanan tüm insanlığın başarısı!

Higgs'in LHC'de Oluşma Mekanizması

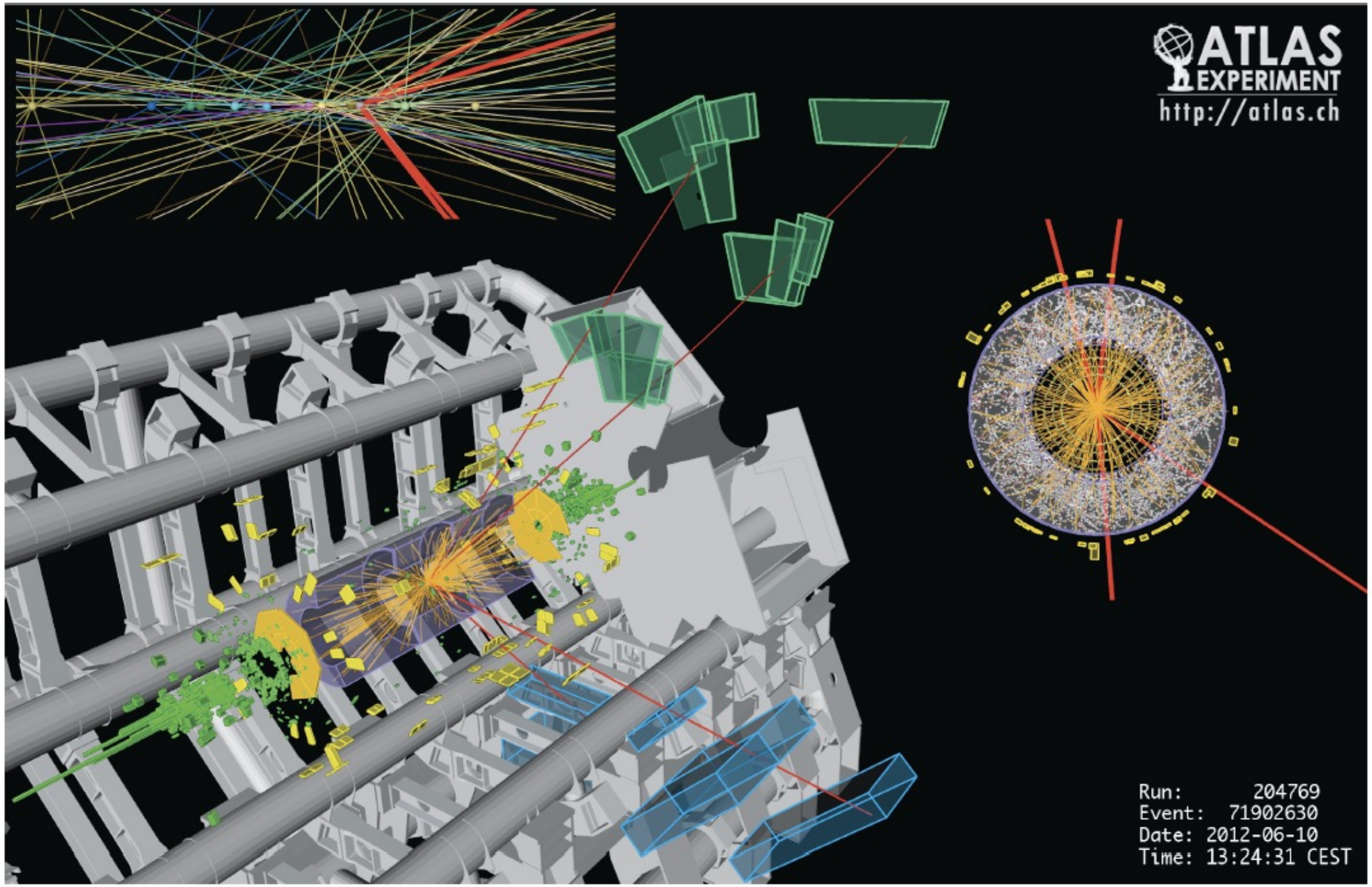


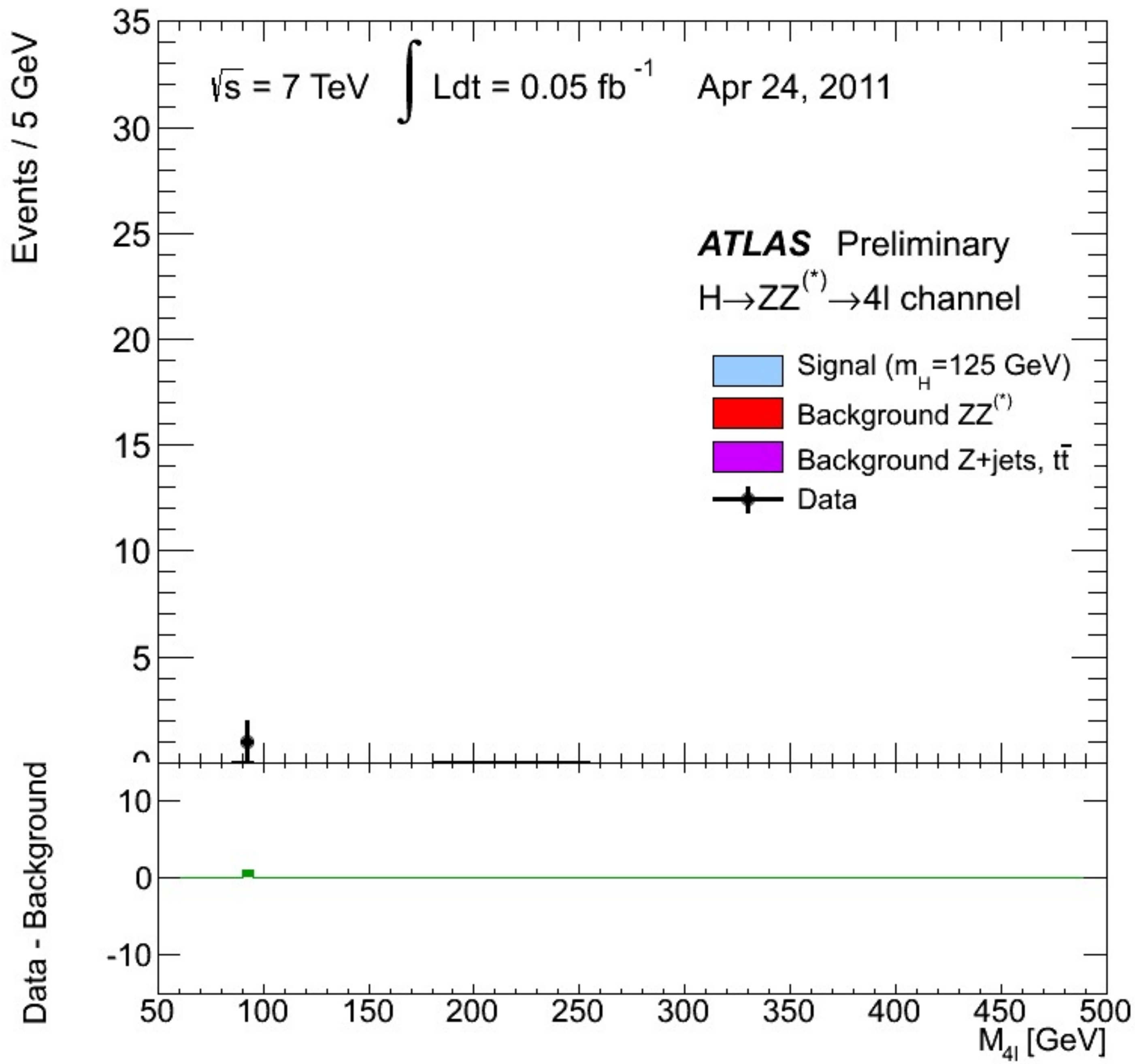
Higgs'in Bozunumları

- H → γγ
- H → ττ
- H → ZZ → 4 lepton
  - H → ZZ → 4e
  - H → ZZ → 4μ
  - H → ZZ → 2e 2
- H → ZZ → ll qq
- H → WW
  - H → WW → lν l
  - H → WW → lν j
- H → ZH/WH
  - H → ZH → ll bb
  - H → WH → lν b
  - H → ZH → νν b



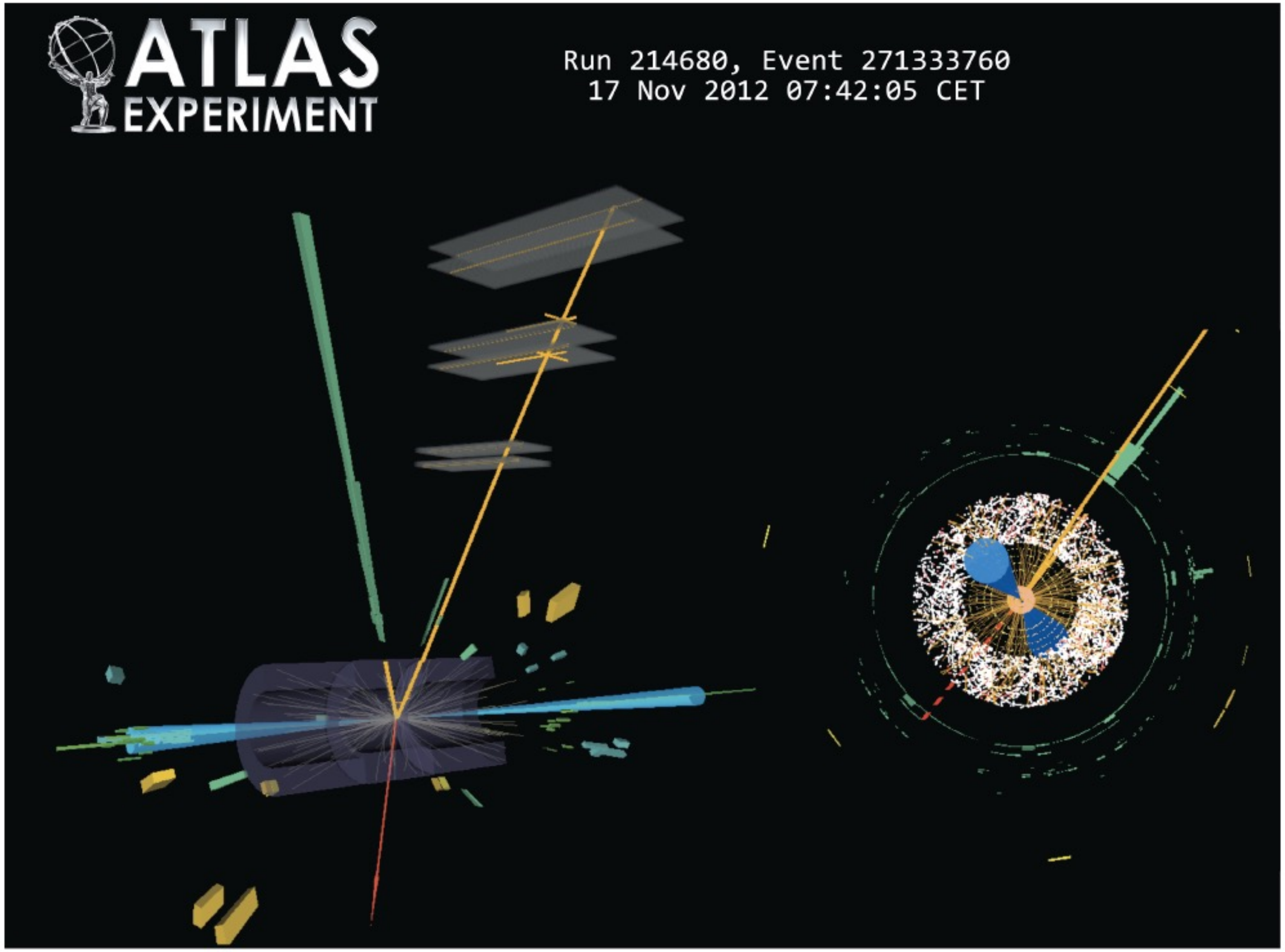
$H \rightarrow ZZ^* \rightarrow 4\ell$

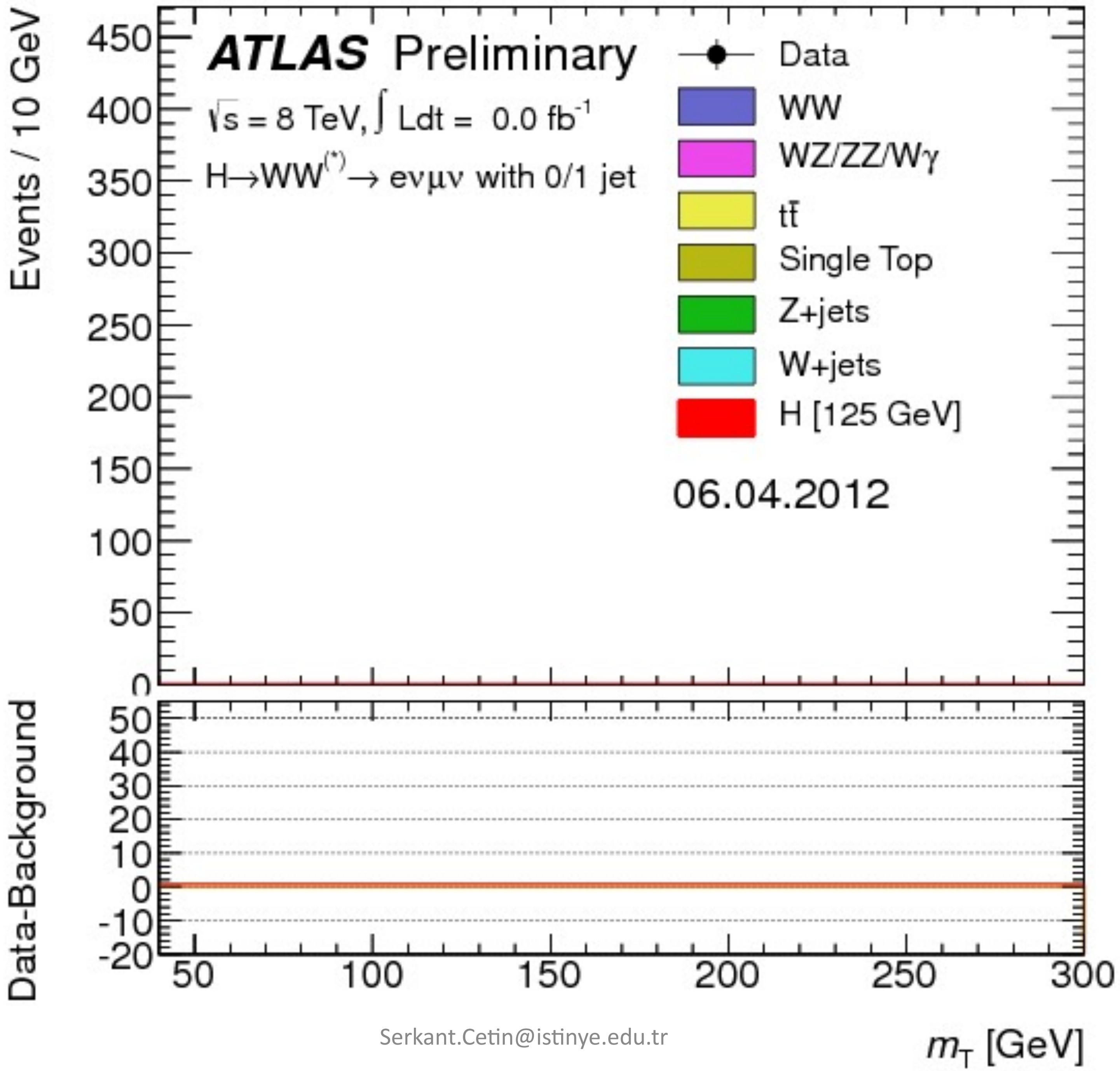




$\sqrt{s}$ = 7 TeV $\int$ Ldt = 0.05 fb^{-1} Apr 24, 2011
ATLAS Preliminary
H→ZZ$^{(*)}$→4l channel
Signal (m_H=125 GeV)
Background ZZ$^{(*)}$
Background Z+jets, $t\bar{t}$
Data
Events / 5 GeV
Data - Background
M_{4l} [GeV]
ATLAS EXPERIMENT
http://atlas.ch

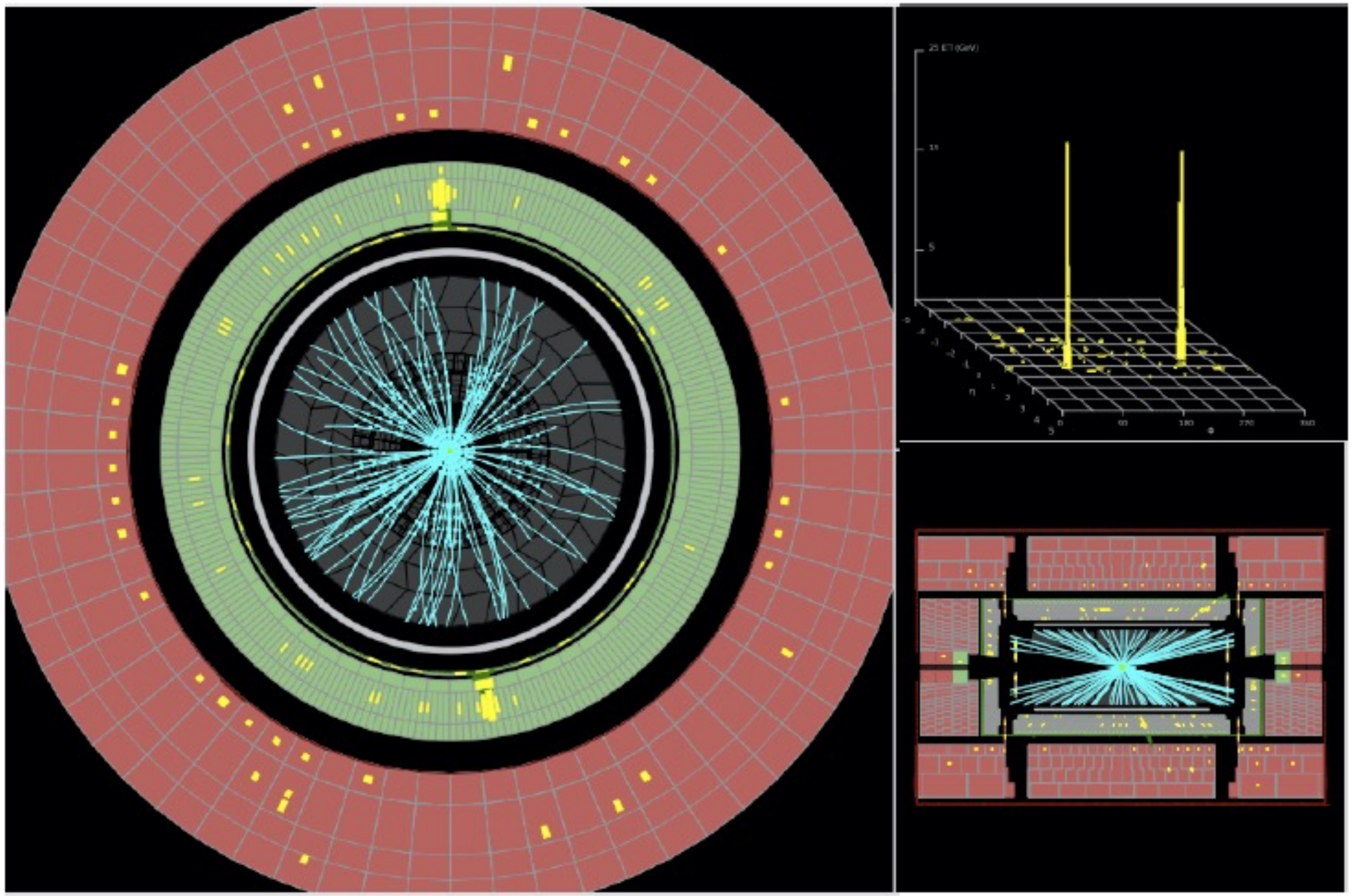
H → WW* → ℓℓ + 2ν

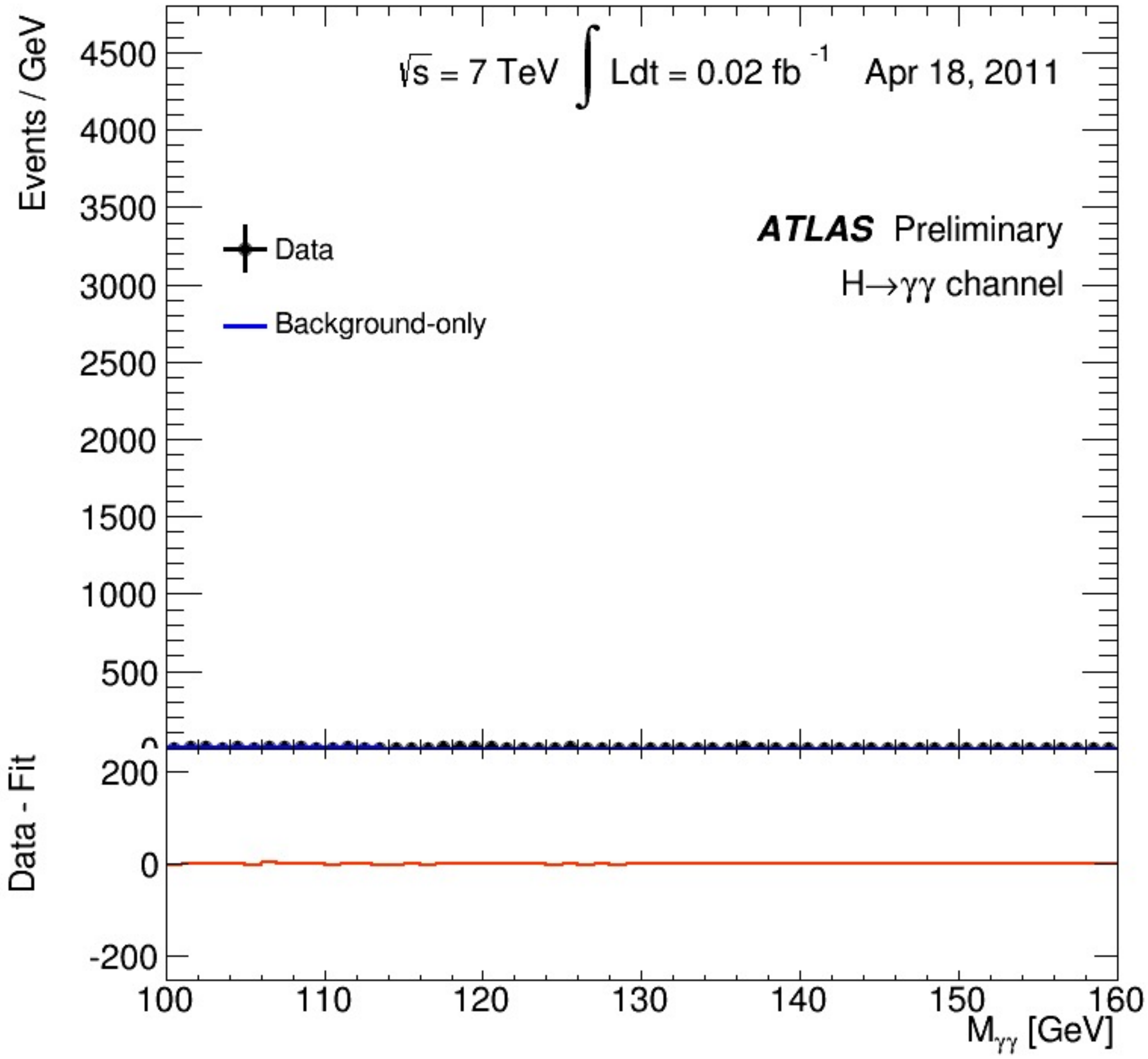

ATLAS
EXPERIMENT
Run 214680, Event 271333760
17 Nov 2012 07:42:05 CET



ATLAS Preliminary
$\sqrt{s}$ = 8 TeV, ∫ Ldt = 0.0 fb^{-1}
H→WW$^{(*)}$→ eνμν with 0/1 jet
Data
WW
WZ/ZZ/Wγ
$t\bar{t}$
Single Top
Z+jets
W+jets
H [125 GeV]
06.04.2012
Events / 10 GeV
Data-Background
m_T [GeV]

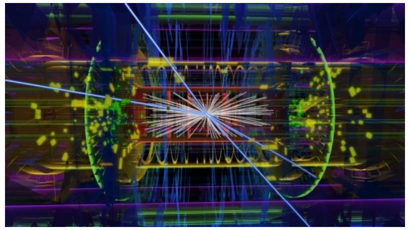
$H \rightarrow \gamma\gamma$





$\sqrt{s}$ = 7 TeV $\int$ Ldt = 0.02 fb^{-1} Apr 18, 2011
ATLAS Preliminary
H→γγ channel
Data
Background-only
Events / GeV
Data - Fit
$M_{\gamma\gamma}$ [GeV]

2013 FİZİK NOBEL ÖDÜLÜ



- 2013 yılı Fizik Nobel Ödülü açıklaması 8 Ekim 2013 tarihinde İsveç Kraliyet Bilimler Akademisi'nde şu cümle ile başladı: "*Bu yılki Fizik Nobel Ödülü tüm farkı yaratan çok küçük bir şey hakkında.*"

-Ödülü Belçika Universite Libre de Bruxelles'den **Profesör François Englert** ve Birleşik Krallık University of Edinburgh'dan **Profesör Peter Higgs** ortak olarak kazandı. Akademi açıklamasında ödüle dair yapılan alıntı ise şöyle: "*Atomaltı parçacıkların kütlelerinin kaynağını anlamamıza yardımcı olan ve öngördüğü temel parçacığın yakın geçmişte CERN Büyük Hadron Çarpıştırıcısındaki ATLAS ve CMS deneylerinde bulunmasıyla doğrulanan bir mekanizmanın kuramsal keşfi için ...*"

Büyük Hadron Çarpıştırıcısında neler oldu / oluyor / olacak ?

- 10 Eylül 2008'de başladı, 19 Eylül 2008'de arızalandı
- 23 Ekim 2009'da parçacıklar tekrar enjekte edildi ama döndürülmedi
- 20 Kasım 2009'da proton hüzmeleri döndürülmeye başlandı (düşük enerji ~0,45 TeV)
- 23 Kasım 2009'da proton hüzmeleri iki yönde aynı anda döndürülmeye başlandı ve ilk çarpışmalar gerçekleşti (düşük enerji ~0,90 TeV kütle merkezi enerjisi)
- 30 Kasım 2009'da mevcut rekor enerji olan 0,98 TeV aşılarak 1,18 TeV'lik hüzmeler her iki yönde döndürüldü ve 2,36 TeV kütle merkezi enerjisinde 16 Aralık 2009'a kadar çarpışma olayları gerçekleştirilerek veri alındı (~1 milyon çarpışma).
- 28 Şubat 2010'da hüzmeler tekrar dödürülmeye başlandı.
- 19 Mart 2010'da ilk 3,5 TeV'lik proton hüzmesi döndürüldü ve 23 Mart'ta iki yönde 3,5 TeV'lik hüzmeler rutin olarak döndürülmeye başlandı.
- 30 Mart 2010'da 3,5 TeV'lik proton hüzmelerinin çarpışmaları başladı (7 TeV kütle merkezi enerjisi). Bu enerjide 2011'in sonuna kadar veri alındı ve hüzmeler daha da sıkıştırılarak ışınlık değerleri artırıldı. Nisan 2012'de 4 TeV'lik hüzmelerle 8 TeV kütle merkezi enerjide çarpışmaları başladı ve sene boyunca sürdü. Şubat 2013'te iyileştirme çalışmaları için durduruldu, 2015 ortasında tekrar başladı ve 2019'a kadar veri alındı; sonra Faz-1 upgrade çalışmaları yapıldı... 2022'de veri alımı tekrar başladı.

Çin Bilimler Akademisi (CAS) bünyesindeki Yüksek Enerji Fiziği Enstitüsü (IHEP) BESIII Deneyine bir bakalım…

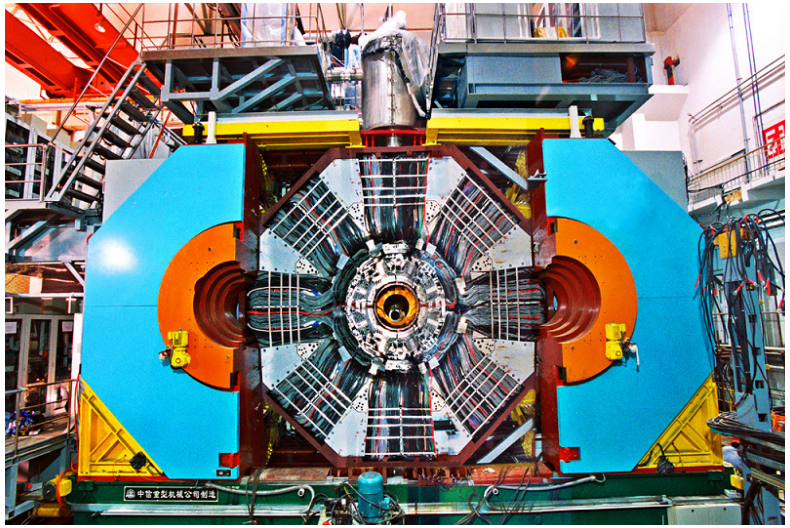
*ışınlık ~öncüsü bir elektron-pozitron çarpıştırıcısı

BEPCII çarpıştırıcısı ve BESIII deneyi

- BEPCII (Beijing Electron Positron Collider) II
- BESIII (BEijing Spectrometer) III
- BEPC and BES started in 1989.
- Upgrade of BES: 1996, BESII
- Upgrade of BEPC and BESII: 2009, BEPCII & BESIII
- Together with the upgrde of BEPC to BEPCII, BESII was upgraded to BESIII in order to achieve better spatial, energy and momentum resolutions, and to support multiple beam structure with a new DAQ system.

BEPCII ve BESIII

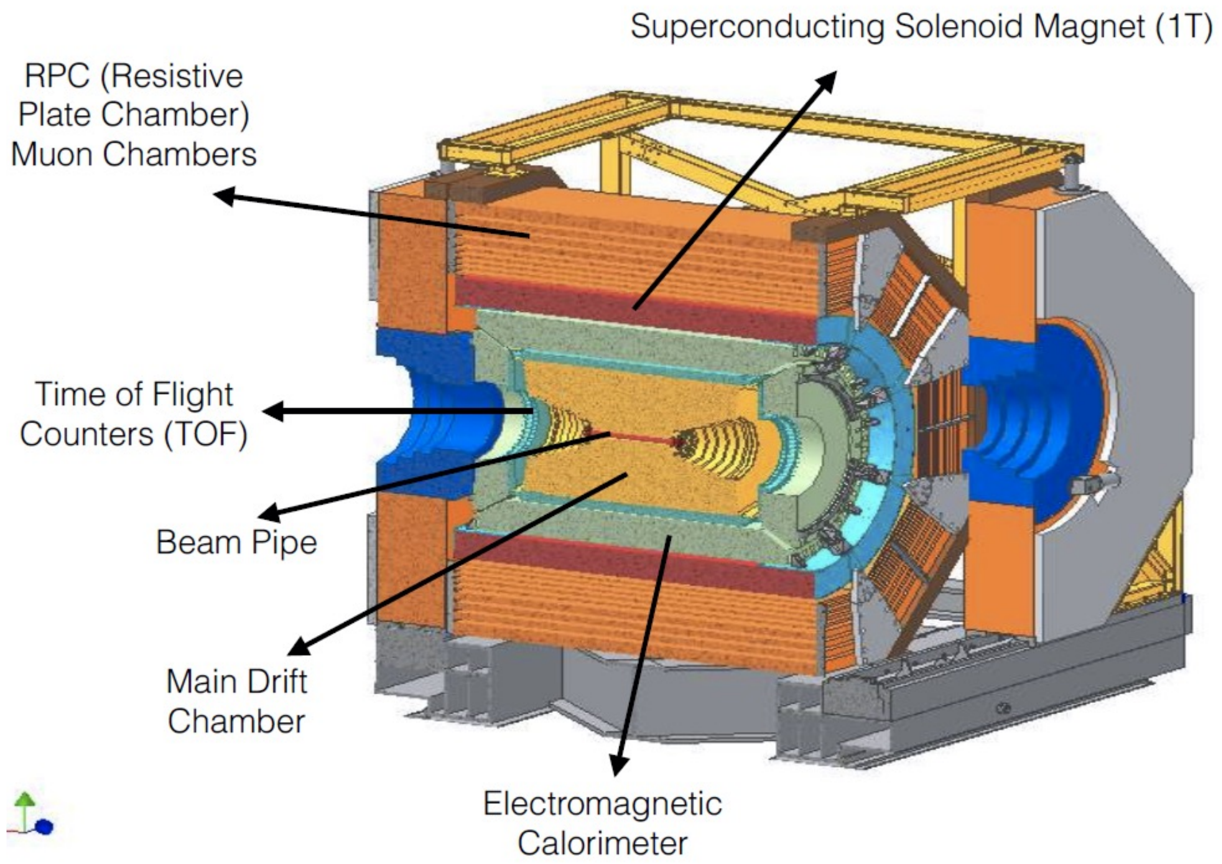
BEPCII is a symmetric collider consisting of electron and positron rings of 240 m circumference producing collisions at cm energies between 2 GeV - 4,6 GeV. The luminosity is optimized as 10^{33} $cm^{-2}s^{-1}$ at 2x1,89 GeV.



BESIII detector located on BEPCII enables to study charmonium physics, D-physics, light hadron spectroscopy and t-physics.

BESIII Algıç Sistemi

- Main Drift Chamber(MDC)
  - spatial resolution ($\sigma_{r\phi}$) 130 μm
  - momentum resolution (σ_p/p) %0,5
  - energy resolution ($\sigma_{dE/dx}$) %6
- Time of Flight Detector(ToF),
  - time resolution (σ_T) ~100 ps
- Electromagnetic Calorimeter
  - energy resolution at 1 GeV (σ_E/E) %2,5
  - spatial resolution (σ_z) 0,6 cm
- Muon Identifier
  - multilayer RPC's (resistive plate chambers)
- 1T Superconducting Solenoid Magnet
- Trigger system of 3 levels
  - Data acceptence rate ~3kHz.
- DAQ and data analysis: BOSS (BESIII Offline Software System)
  - An object oriented platform in C++
  - Operating system: SLC (Scientific Linux CERN)



Light meson physics at BESIII: htttps://arxiv.org/abs/2103.09023

Study of the standard model with weak decays of charmed hadrons at BESIII: https://arxiv.org/abs/2103.00908

Charmonium and charmoniumlike states at the BESIII experiment: https://arxiv.org/abs/2102.12044

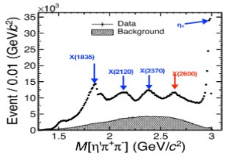
Probing the internal structure of baryons: https://arxiv.org/abs/2111.08425

New physics searches at the BESIII experiment : https://doi.org/10.48550/arXiv.2102.13290

Highlights of light meson spectroscopy at the BESIII experiment: https://doi.org/10.1093/nsr/nwab198

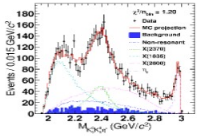
Probing CP symmetry with Entangled Double-strange baryons

BESIII Collaboration reports a new method to probe differences between matter and antimatter with an extreme sensitivity. The results are published in the journal Nature on June 2nd 2022.



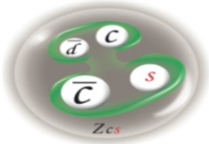
Observation of the X(2600) state

The BESIII Collaboration recently reported the observation of a new state, X(2600), using 10 billion Jpsi decay events. It was published online in the Journal of Physical Review Letter on July 19, 2022 [Phys. Rev. Lett. 129 (2022) 042001].



The BESIII Collaboration Discovered a Glueball-like Particle – X(2370)

The Beijing Electron Positron Collider II (BEPCII) has recently made a significant achievement. The BESIII experiment at BEPCII performed the first measurements of the quantum numbers of the X(2370) particle, along with its mass, production, and decay properties, and found that they are consistent with the features of a glueball, which has long been the subject of intensive experimental searches. This important result was published in the journal of Physical Review Letters on May 2nd as an Editor's Suggestion.



First evidence for the first neutral open-strange hidden-charm tetraquark state

The BESIII Collaboration recently reported the evidence of a new exotic multi-quark state, namely Zcs(3985)0. It is the neutral partner of the charged tetraquark Zcs(3985)+ observed in 2021 at BESIII. This is the first candidate of the neutral hidden-charm tetraquark with non-zero strangeness, which marks a new milestone in exploration of the genuine properties of the family of the exotic multi-quark hadrons. The paper has been published in Physical Review Letters [Phy. Rev. Lett. 129 (2022) 112003].

BESIII İŞBİRLİĞİ

15+ ülke, 80+ kurum

~600 araştırmacı

EUROPE (18)

Bochum University

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Budker Instituteof Nuclear Physics

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Ferrara University

Giulio Mezzadri , Via Paradiso, 12, 44121 Ferrara, Italy

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Universitaet Giessen

Wolfgang Kuehn, II. Physikalisches Institut, Universitaet Giessen,Heinrich-Buff-Ring 16, 35392 Giessen

University of Bristol (UK)

Jonas Rademacker,Bristol,United Kingdom

Türkiye BESIII Deneyine neden katıldı?

- Mevcut parçacık fabrikası deneylerinde tecrübe kaxanarak Türk Hızlandırıcı Merkezi parçacık fabrikası tasarımı, kurulumu ve işletimi için insan kaynağı oluşturmak…
- IHEP genel olarak bilgi paylaşımı ve hızlandırıcı/çarpıştırıcı gelştirme süreçlerinde açık ve yardımcı…
- Öğrencilerin işleyen bir deneyde yetiştirilmesi önemliydi…
- THM parçacık fabrikası için mevcut BESIII deneyi BOSS yazlım çerçevesinden faydalanmak…
- BESIII bünyesinde algıç geliştirme çalışmalarında yer almak…
- Fizik analiz araçları ve teknikleri ile ilgili bilgi transferi sağlamak…

Diğer elektron pozitron çarpıştırıcıları..

https://pdg.lbl.gov/

https://pdg.lbl.gov/

High-Energy Collider Parameters: e^+e^- Colliders (I)

Table 32.1: Updated in March 2024 with numbers received from representatives of the colliders (contact E. Pianori, LBNL). The table shows the parameter values achieved. Quantities are, where appropriate, r.m.s.; unless noted otherwise, energies refer to beam energy; H and V indicate horizontal and vertical directions; s.c. stands for superconducting. Parameters for the defunct SPEAR, DORIS, PETRA, PEP, TRISTAN, and VEPP-2M colliders may be found in our 1996 edition (Phys. Rev. **D54**, 1 July 1996, Part I).

	VEPP-2000 (Novosibirsk)	VEPP-4M (Novosibirsk)	BEPC (China)	BEPC-II (China)	DAΦNE (Frascati)
Physics start date	2010	1994	1989	2008	1999
Physics end date	—	—	2005	—	—
Maximum beam energy (GeV)	1.0	6	2.5	1.89 (2.474 max)	0.510
Delivered integrated luminosity per exp. (fb^{-1})	0.25	0.05	0.11	48	≈ 4.7 in 2001-2007 ≈ 2.7 w/crab-waist ≈ 6.8 2014-2018* ≈ 0.4 2021-2022† ≈ 1.1 2023-2024‡
Luminosity (10^{30} $cm^{-2}s^{-1}$)	50	20	12.6 at 1.843 GeV 5 at 1.55 GeV	1096	453
Time between collisions (μs)	0.04	0.6	0.8	0.006	0.0027

https://pdg.lbl.gov/

High-Energy Collider Parameters: e^+e^- Colliders (II)

Table 32.2: Updated in March 2020 with numbers received from representatives of the colliders (contact E. Pianori, LBNL). The table shows the parameter values achieved. Quantities are, where appropriate, r.m.s.; unless noted otherwise, energies refer to beam energy; H and V indicate horizontal and vertical directions; s.c. stands for superconducting. ILC and CLIC parameters are documented in the Accelerator physics of colliders review.

	CESR (Cornell)	CESR-C (Cornell)	LEP (CERN)	SLC (SLAC)
Physics start date	1979	2002	1989	1989
Physics end date	2002	2008	2000	1998
Maximum beam energy (GeV)	6	6	100 - 104.6	50
Delivered integrated luminosity per experiment (fb^{-1})	41.5	2.0	0.221 at Z peak 0.501 at 65 – 100 GeV 0.275 at >100 GeV	0.022
Luminosity (10^{30} $cm^{-2}s^{-1}$)	1280 at 5.3 GeV	76 at 2.08 GeV	24 at Z peak 100 at > 90 GeV	2.5
Time between collisions (μs)	0.014 to 0.22	0.014 to 0.22	22	8300

https://pdg.lbl.gov/

High-Energy Collider Parameters: ep, e^+e^- Colliders (III)

Table 32.3: Updated in March 2022 with numbers received from representatives of the colliders (contact E. Pianori, LBNL). The table shows the parameter values achieved. Design parameters for SuperKEKEB may be found in our 2018 edition (Phys. Rev. **D98**, 030001 (2018)) Quantities are, where appropriate, r.m.s.; unless noted otherwise, energies refer to beam energy; H and V indicate horizontal and vertical directions; s.c. stands for superconducting.

	HERA (DESY)	KEKB (KEK)	PEP-II (SLAC)	SuperKEKB (KEK)
Physics start date	1992	1999	1999	2018
Physics end date	2007	2010	2008	—
Particles collided	ep	e^+e^-	e^+e^-	e^+e^-
Maximum beam energy (TeV)	e: 0.030 p: 0.92	e^-: 8.33 (8.0 nominal) e^+: 3.64 (3.5 nominal)	e^-: 7–12 (9.0 nominal) e^+: 2.5–4 (3.1 nominal)	e^-: 7 e^+: 4
Delivered integrated luminosity per exp. (fb^{-1})	0.8	1040	557	491
Luminosity (10^{30} $cm^{-2}s^{-1}$)	75	21083	12069 (design: 3000)	4.71×10^4
Time between collisions (ns)	96	5.9 or 7.86	4.2	4.2

TAC / THM
(Türk Hızlandırıcı Merkezi / Turkish Accelerator Comlpex)
Super Charm Factory

1 GeV electrons from the energy recovery linac (ERL) collide with the **3.56 GeV positrons** from the storage ring at a cm energy of **3.77 GeV** .

ERL helps to achieve > **10^{35} cm^{-2} s^{-1}** luminosity while ~**10^{36} cm^{-2} s^{-1}** might be achievable using crab waist.

TÜBİTAK

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35 (2011) , 257 – 263.
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doi:10.3906/fiz-1101-106

A high luminosity ERL on ring e^-e^+ collider for a super charm factory

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06560, Söğütözü, Ankara-TURKEY
[3] *Institute of Physics, Academy of Science, H.Cavid Avenue 33,*
Baku-AZERBAIJAN

Parameters	Electron ERL
Electron beam energy E_{e^-} (GeV)	1
Number of electrons per bunch (10^{10})	2
Beta functions at IP β_x / β_y (mm)	80/5
Normalized emittances ε_x^N / ε_y^N (μm)	31/0.1
σ_x / σ_y (μm)	36/0.5
σ_z (mm)	5
Beam current (A)	0.48

Parameters	Positron ring
Positron beam energy E_{e^+} (GeV)	3.56
Number of positrons per bunch (10^{11})	2
Beta functions at IP β_x / β_y (mm)	80/5
Normalized emittances ε_x^N / ε_y^N (μm)	111/0.36
σ_x / σ_y (μm)	36/0.5
σ_z (mm)	5
Beam-beam tune shift (ξ_x/ξ_y)	0.012/0.13
Energy loss / turn (MeV)	0.7
Number of buches, n_b	300
Circumference, C (m)	600
Beam current (A)	4.8
Momentum Acceptance (%)	1

Collider Parameters

Crossing angle θ (mrad)	34
Collision frequency (MHz)	150
Luminosty ($cm^{-2}s^{-1}$)	$1.4 \cdot 10^{35}$

Neden Tılsım (charm) Fabrikası?

- Electron-positron colliders that produce lots of mesons with charm quarks are also referred to as D-meson factories.
- Great opportunity to study strong and weak interactions of SM and beyond.

- Discovery of J/Ψ
- Different D meson states and mixings
- Recent discovey of Z_c(3900) by BESIII; **the first tetraquark ever** seen.

Enerji Asimetrisi

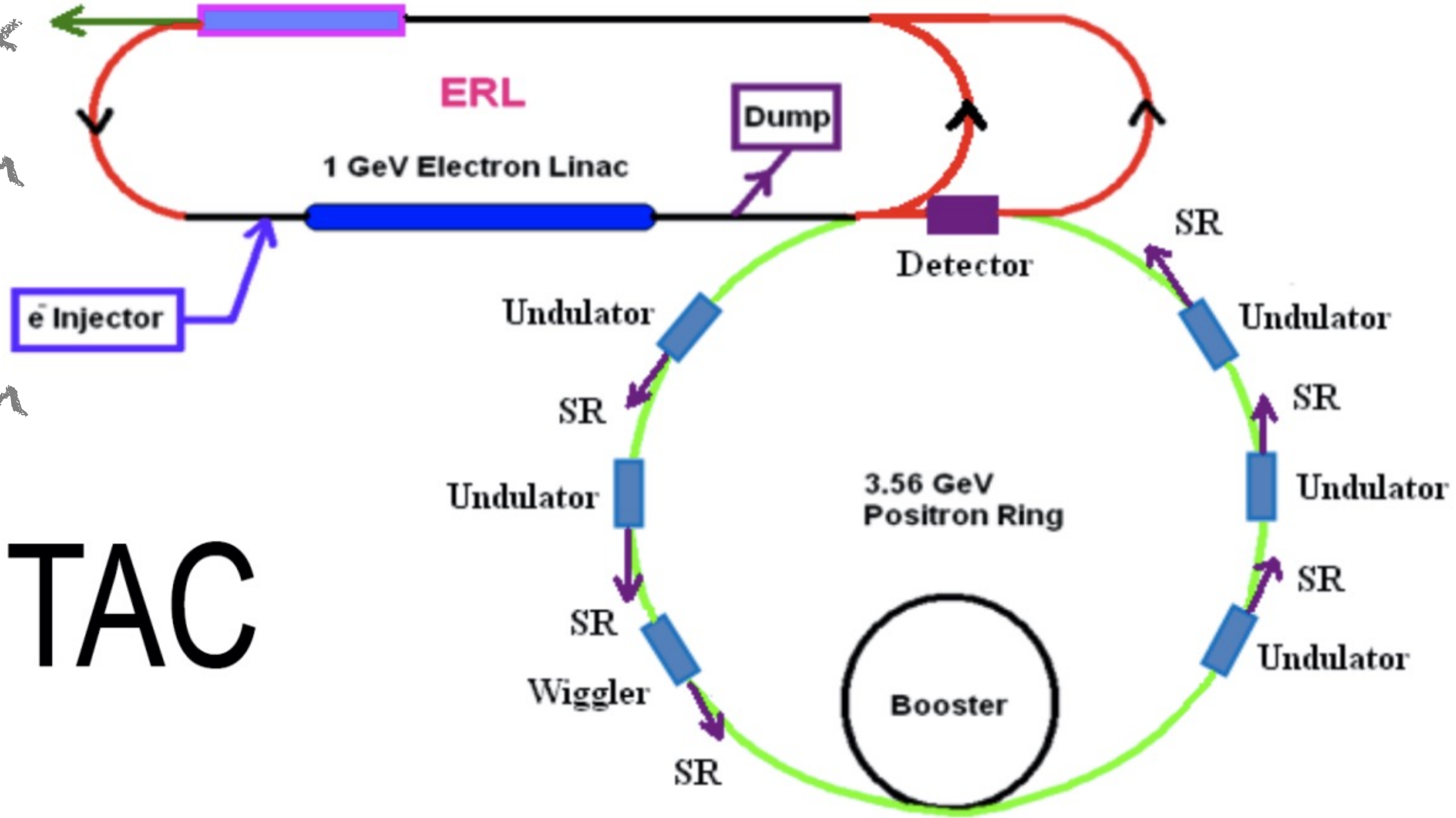
- **1 GeV electrons** from the energy recovery linac (ERL) collide with the **3.56 GeV positrons** from the storage ring at a center of mass energy of **3.77 GeV**.
- This will enable the mass production of **ψ(3770)** which decays mainly to **D-mesons**.
- The **energy asymmetric** collisions will **boost** the D-mesons in the detector making time dependent measurements possible.

Yüksek Işınlık

- In addition to the advantage of asymmetry of the collision a **very high luminosity** collider would produce more charm and enable high precission measurements for decays and mixings.
- Energy Recovery Linac helps to achieve > $\mathbf{10^{35}\ cm^{-2}\ s^{-1}}$ luminosity while ~$\mathbf{10^{36}\ cm^{-2}\ s^{-1}}$ might be achievable using crab waist.
- Hence the name “**Super**”

THM Süper Tılsım Fabrikası
mevcut durum

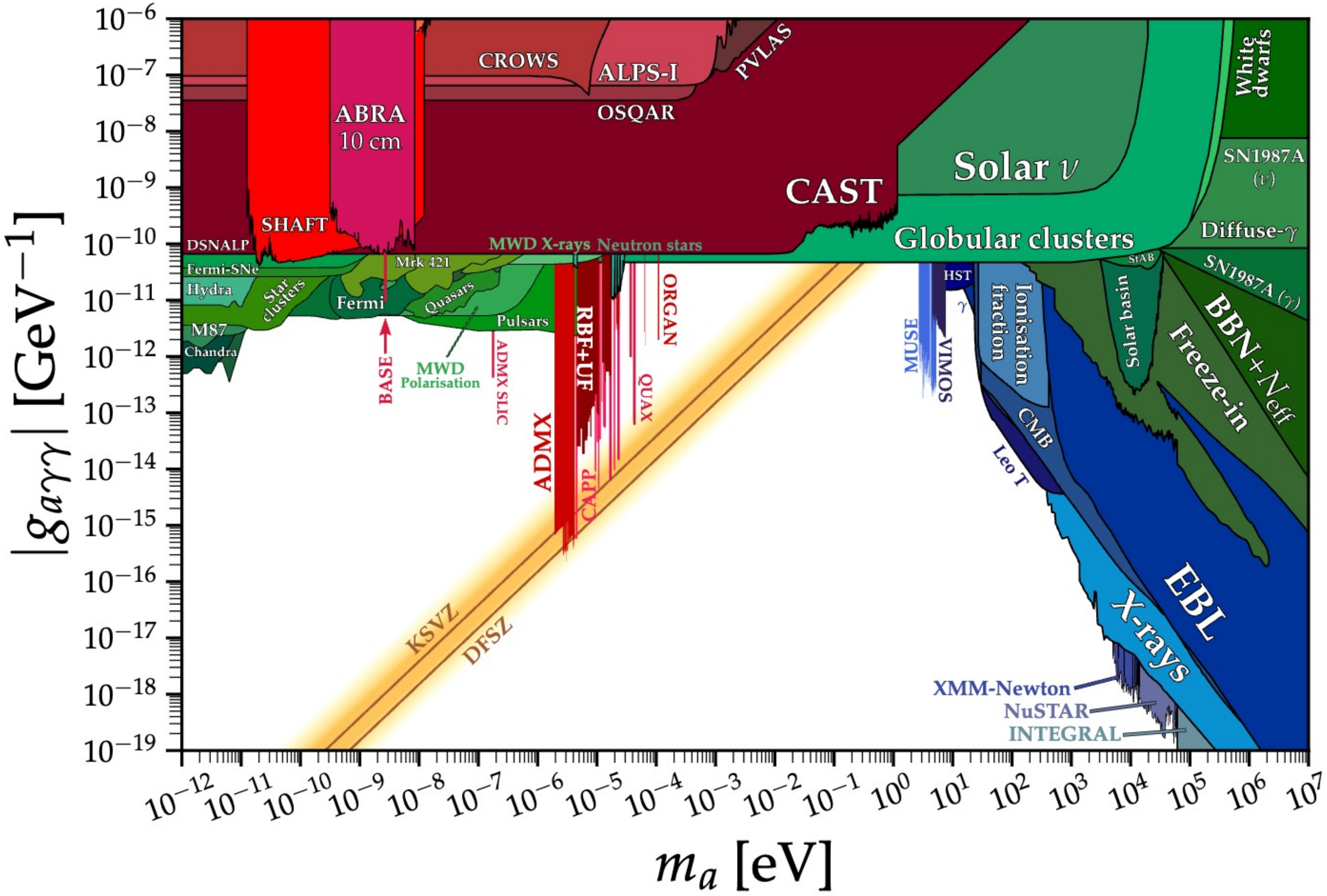
- Süpertılsım fabrikası «Türk Hızlandırıcı Merkezi» projesinin arkasında yatan ana sürücü kuvvet idi.
- THM tasarım projesi barındırdığı 4 farklı tesisin (parçacık fabrikası dahil) tasarımının yapılmasıyla tamamlandı...
- Bir sonraki adıma geçmek için şu anda karar vericilerin değerlendirme ve iradeleri beklenmekte.



Çarpıştırıcı dışı deneyler; neden? nasıl?...

Örneğin karanlık madde adayı parçacıkların araştırılması...

90. Axions and Other Similar Particles




https://pdg.lbl.gov/

20+ senelik bir Karanlık Sektör Sondası...

Neden Axion?

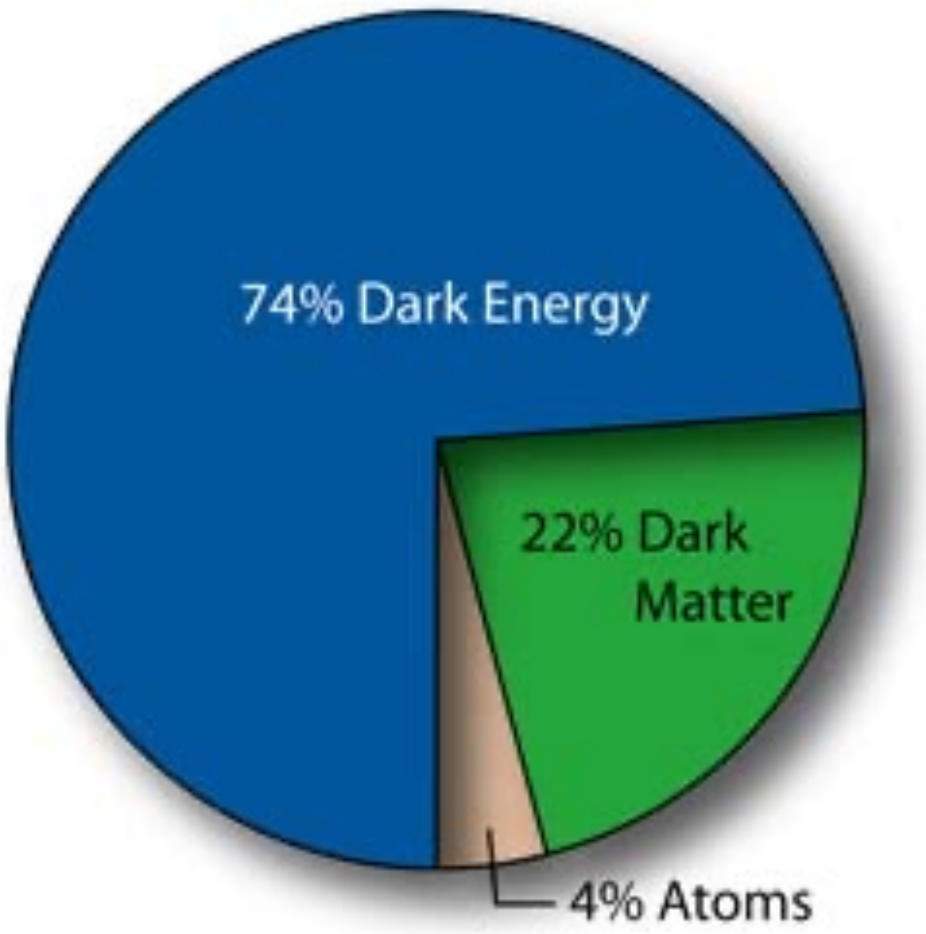
- Axions were proposed as an extension to the Standard Model of particle physics to explain one of the left intriguing problems in QCD, the so-called **strong CP problem**:

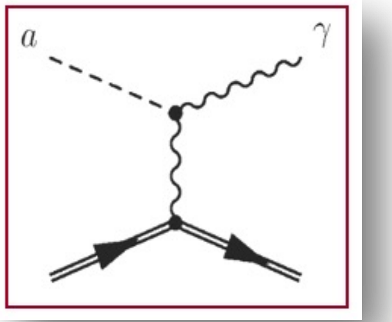
  *The **theory predicts the existence of a CP violating term** in the standard equations, yet Nature has **never exibited this in any experiment**.*

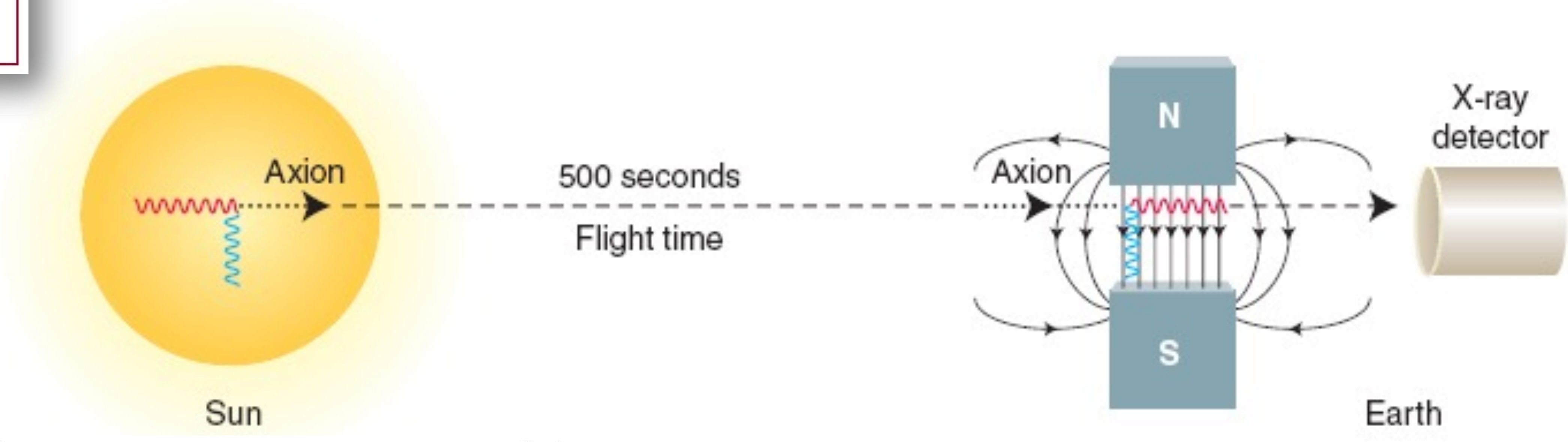
- The most elegant way to solve this problem is to introduce an **additional global symmetry** (Peccei & Quinn). As a result, the **CP violating term is eliminated** and the strong CP problem solved.
- In the real world we do not observe the Peccei-Quinn symmetry which implies that it is **spontaneously broken** at some energy scale. The **associated boson is called axion**.

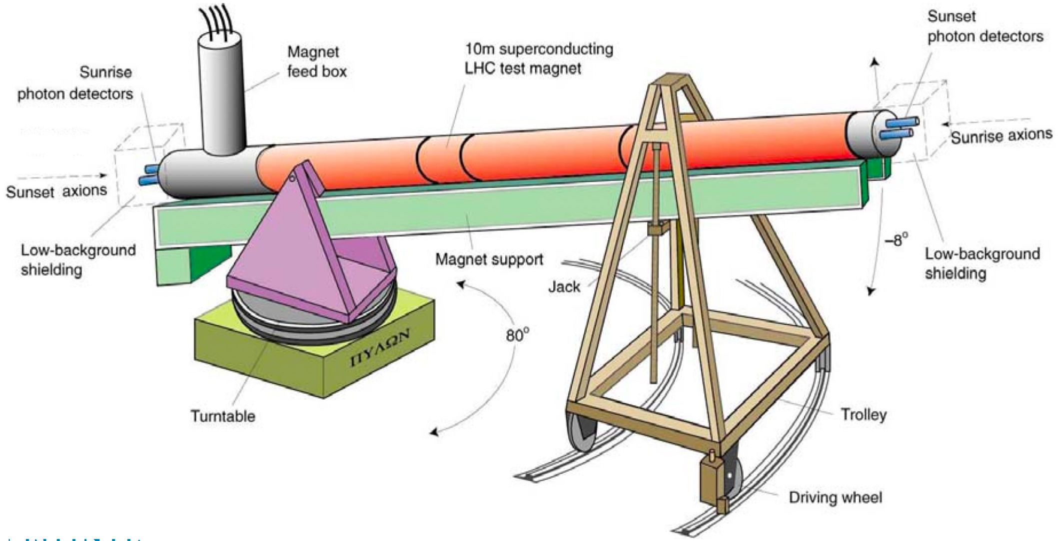
Axionların özellikleri

- Axion is a **neutral, very light particle that interacts very weakly with ordinary matter**. Owing to their potential abundance in the early Universe, axions are also leading candidates for the invisible dark matter of the Universe.




a
γ


Axion
500 seconds
Flight time
Sun
N
S
Axion
X-ray detector
Earth


Sunrise photon detectors
Magnet feed box
10m superconducting LHC test magnet
Sunset photon detectors
Sunrise axions
Sunset axions
Low-background shielding
Magnet support
Jack
80°
–8°
Low-background shielding
Turntable
Trolley
Driving wheel

ELSEVIER
Nuclear Instruments and Methods in Physics Research A 425 (1999) 480–487
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

A decommissioned LHC model magnet as an axion telescope

K. Zioutas[a], ... nski[d],
J.I. Collar[e] ... one[c],
C.K. Guérard ... Miley[d],
A. Morale ... dis[a],

CERN 99-21
SPSC/P312
August 9, 1999
Sw 199948

Proposal to the SPSC

A solar axion search using a decommissioned LHC test magnet

The Solar Axion Telescopic ANtenna

http://cds.cern.ch/record/410414/files/SC00001091.pdf

C.E. Aalseth [1], D. Abriola [2], F.T. Avignone III [1], R.L. Brodzinski [3], J.I. Collar [4*],
R. Creswick [1], D.E. Di Gregorio [2], H. Farach [1], A.O. Gattone [2], Y. Giomataris [5],
S.N. Gninenko [6], N.A. Golubev [6], C.K. Guérard [2], F. Hasenbalg [2], M. Hasinoff [7],
H. Huck [2], A.V. Kovzelev [6], A. Liolios [8], V.A. Matveev [6], H.S. Miley [3], A. Morales [9],
J. Morales [9], D. Nikas [8], S. Nussinov [10], A. Ortiz [9], G. Polymeris [8], G. Raffelt [11],
I. Savvidis [8], S. Scopel [9], I.N. Semeniouk [6], J.A. Villar [9], K. Zioutas [8,12#].

Deney aşağıdaki isimle önerilmişti:

– Solar Axion Telescopic ANtenna –

Bir sebeple :) aşağıdaki şekilde değişti:

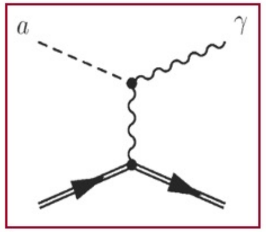
– CERN Axion Solar Telescope –

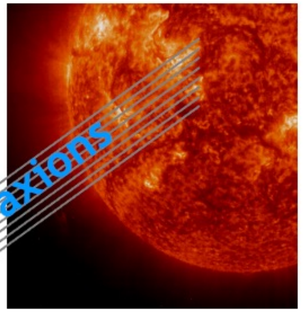
… ama logoyu koruduk :)

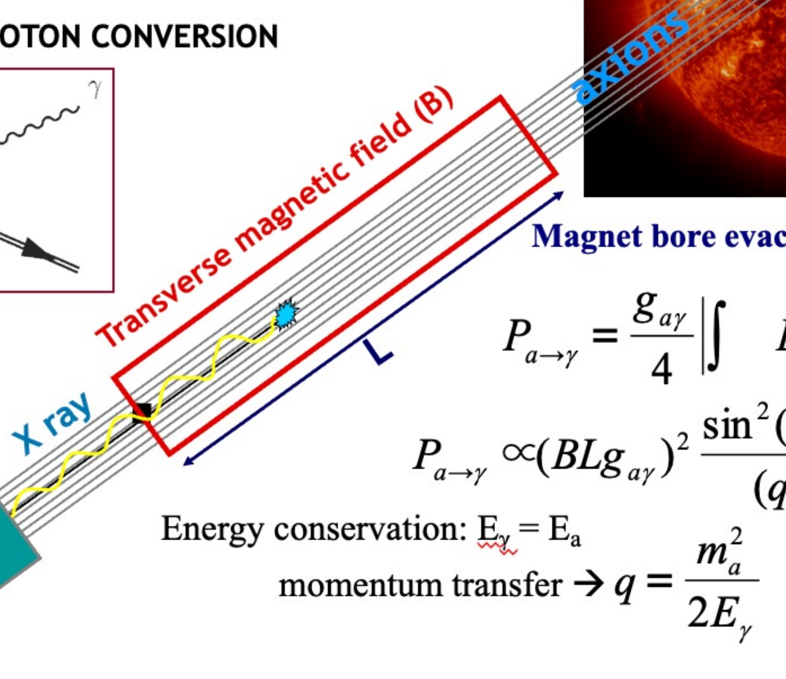
Principle of detection

[Sikivie PRL 51 (83)]

AXION PHOTON CONVERSION







Magnet bore evacuated

$$P_{a\to\gamma} = \frac{g_{a\gamma}}{4}\left|\int Be^{iqz}dz\right|^2$$

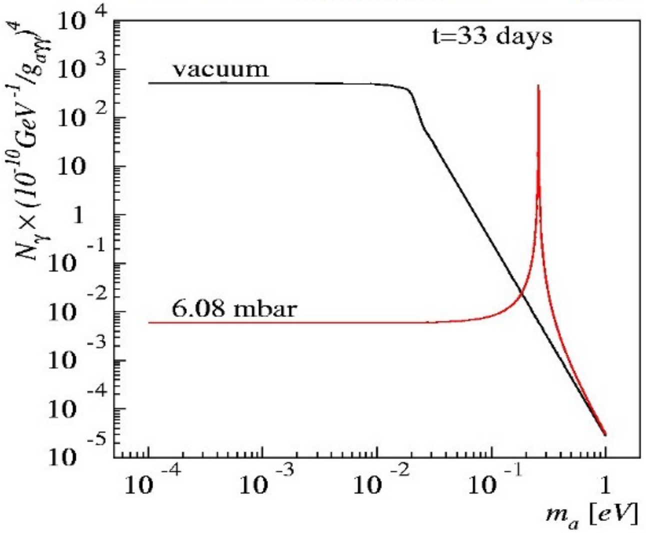
$$P_{a\to\gamma} \propto (BLg_{a\gamma})^2 \frac{\sin^2(qL/2)}{(qL)^2}$$

Energy conservation: $E_\gamma = E_a$

momentum transfer → $q = \frac{m_a^2}{2E_\gamma}$

For coherence: qL«1 (axion and photon field are in phase)

For CAST expriment $m_a < 10^{-2}$ eV



Phase II: Magnet pipes filled with buffer gas

Extending the coherence to higher axion masses …

Conversion Probability

$$P_{a\to\gamma} \propto (Bg_{a\gamma}/2)^2 \frac{1}{q^2+\Gamma^2/4}\left[1+e^{-\Gamma L} - 2e^{-\Gamma L/2}\cos(qL)\right]$$

Momentum transfer is $q = \left|\frac{m_\gamma^2 - m_a^2}{2E_a}\right|$

Γ: absorption coefficient
N_e: number of e^-/cm^3
ρ: gas density (g/cm^3)

$$m_\gamma = \sqrt{\frac{4\pi\alpha N_e}{m_e}} = \sqrt{\frac{Z}{A}\rho}$$

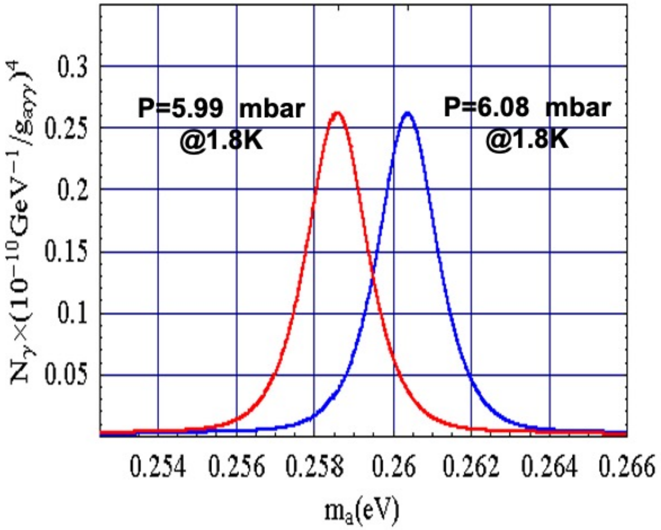
Coherence condition (qL<<1) is recovered for a narrow mass range around m_γ

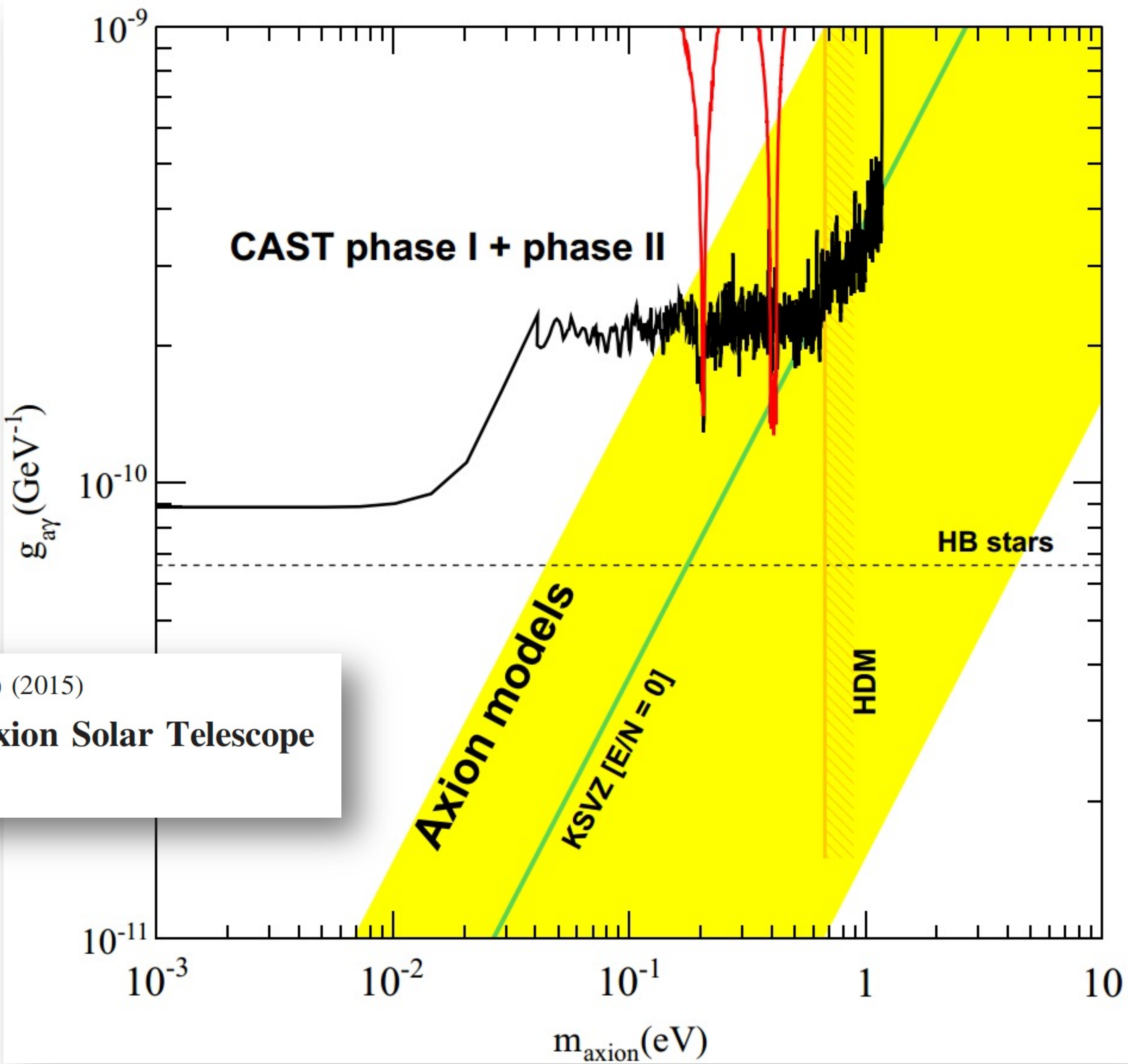
$$qL < \pi \quad \Rightarrow \quad \sqrt{m_\gamma^2 - \frac{2\pi E_a}{L}} < m_a < \sqrt{m_\gamma^2 + \frac{2\pi E_a}{L}}$$

⇒ **Every specific pressure of the gas allows the test of a specific axion mass.**

$$m_\gamma = \sqrt{0.02\frac{P(mbar)}{T(K)}}$$

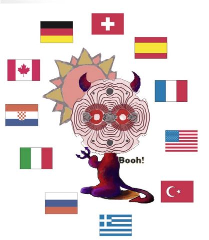
Signal: excess of X-rays over background when magnet points to the Sun

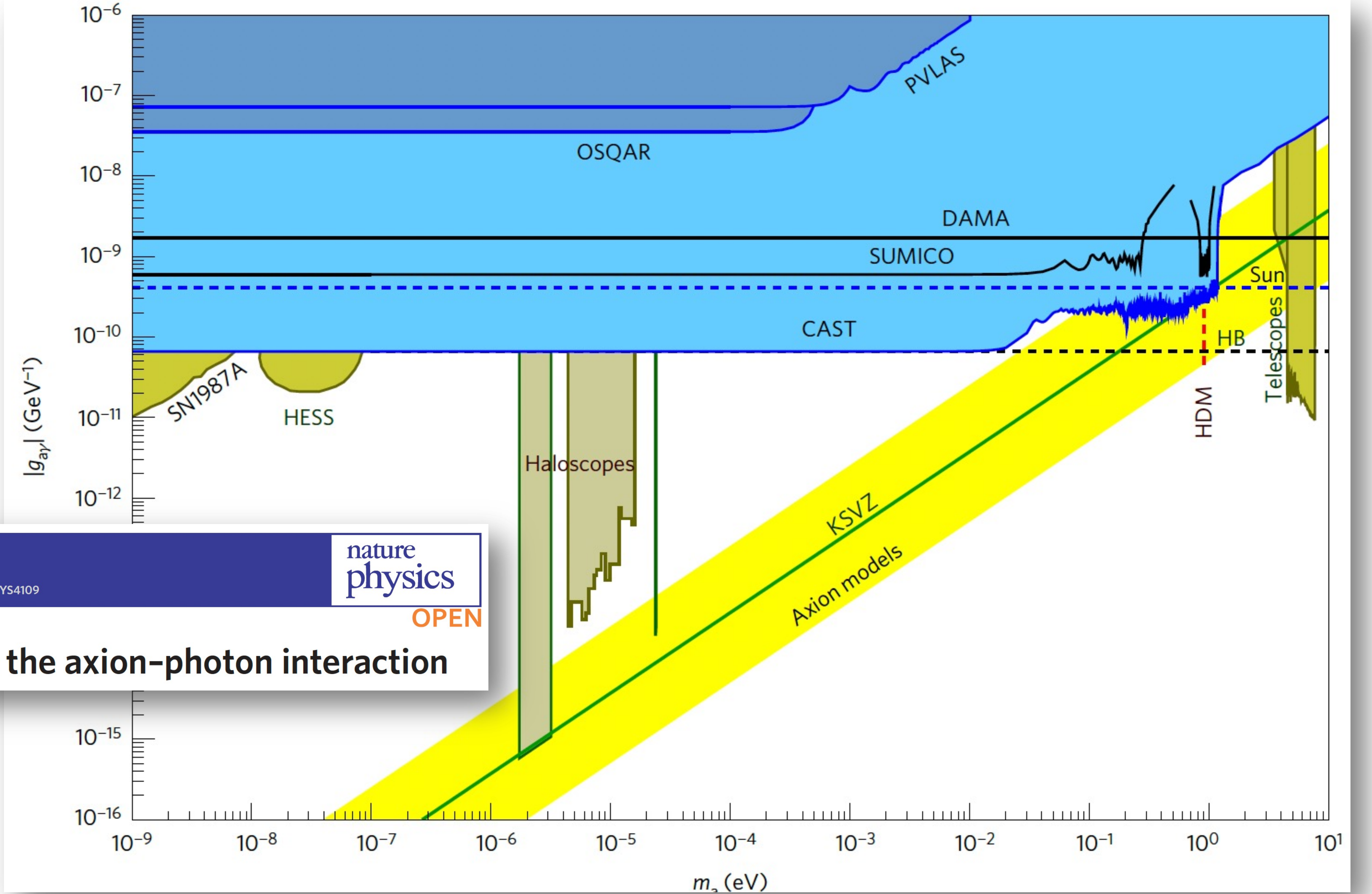




PHYSICAL REVIEW D **92**, 021101(R) (2015)

New solar axion search using the CERN Axion Solar Telescope with ^4He filling





ARTICLES
PUBLISHED ONLINE: 1 MAY 2017 | DOI: 10.1038/NPHYS4109

nature physics
OPEN

New CAST limit on the axion–photon interaction

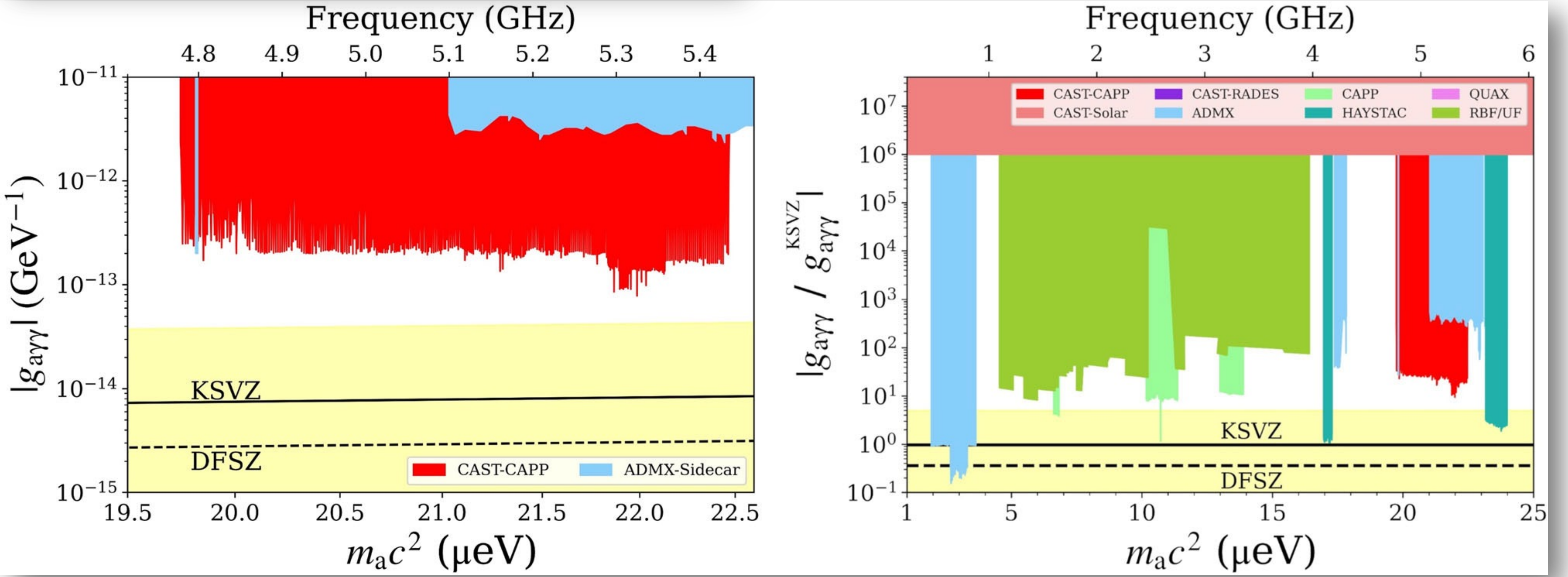
nature communications

Published online: 19 October 2022

Article

https://doi.org/10.1038/s41467-022-33913-6

Search for Dark Matter Axions with CAST-CAPP



GENEL BAKIŞ VE YORUMLAR

- LHC being the **high energy frontier** today will be operational for decades with increasing performance over the years integrating enourmous amounts of data in experiments (eg. **ATLAS**).
- There is a competition among current and future particle factories. They are modest in energy however ambitious in luminosity (**luminosity frontier**). Filling the gaps of the QCD will be possible with these machines (like **BESIII** and **TAC supercharm factory**).
- At the **low energy frontier**, experiments try to be more and more sensitive to sub keV energy particle searches for dark matter and dark energy (like in **CAST**).

İSÜ İSTİNYE ÜNİVERSİTESİ İSTANBUL

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

https://lisansustu.istinye.edu.tr

FİZİK DOKTORA PROGRAMI / 2024-2025

Eğitim dili nedir?

İngilizce

Öğrenim ücreti ne kadar?

Fizik Doktora öğrencilerine öğrenim süreleri boyunca %100 öğrenim ücreti bursu verilir.

Kimler başvurabilir?

Lisans mezunları: Fizik, Fizik Mühendisliği ya da Fizik Öğretmenliği lisans diplomasına sahip olanlar ile diğer Temel Bilim ya da Mühendislik lisans programlarından mezun olup Fizik, Fizik Mühendisliği ya da Fizik Öğretmenliği programlarında yan dal yapmış olanlar önceliklidir; dörtlük sistemde en az 3.00 mezuniyet ortalaması gereklidir.

Tezli yüksek lisans mezunları: Lisans mezuniyetleri hangi programdan olursa olsun Fizik, Fizik Mühendisliği, Fizik Öğretmenliği ya da uygulamalı fizik alanında tezli yüksek lisans derecesine sahip olanlar önceliklidir.

Programın içeriği nedir?

İSÜ Fizik Doktora Programı "Yüksek Enerji ve Parçacık Fiziği" alanında kurgulanmış tematik bir doktora programıdır. Lisans derecesiyle kabul edilenlerin 300 AKTS, Yüksek Lisans derecesiyle kabul edilenlerin 240 AKTS tamamlamaları gerekmektedir.

Araştırma Fırsatları, Uluslararası İşbirlikleri, Altyapı ve Projeler

İstinye Üniversitesi bünyesinde yer alan yetkin fizikçi akademik kadro, Yüksek Enerji Fiziği, Parçacık Fiziği, Parçacık Algıçları, Parçacık Hızlandırıcıları ve benzeri konulardaki çalışmalar için oluşturulmuş olan laboratuvar alt yapısı, hali hazırda yürütülen çeşitli dış kaynaklı (TÜBİTAK, TENMAK, TÜSEB) araştırma projeleri ve uluslararası işbirlikleri çerçevesinde gerçekleştirilen ileri fizik araştırmaları öğrencilerin kazanacakları yetkinlikler için büyük bir imkan yaratmaktadır.

İstinye Üniversitesi Avrupa Parçacık Fiziği Laboratuvarı CERN'de yürütülen dört (ATLAS, CAST, DRD1, FCC), Çin Bilimler Akademisi Yüksek Enerji Fiziği Enstitüsünde yürütülen bir (BESIII) ve ABD Brookhaven Ulusal laboratuvarında tasarlanan bir (sr-EDM) deneysel işbirliği ile CosmicWISPers adlı COST aksiyonuna dahildir. Bu imkanlar çerçevesinde, İSÜ Fizik Doktora Programı Türkiye'de özellikle yüksek enerji ve parçacık fiziği alanında az sayıda üniversitede bulunan yerel araştırma imkanını ve geniş bir uluslararası araştırma ağını doktora öğrencilerine sunmaktadır.

İşbirlikleri:

ATLAS EXPERIMENT, BESIII, pEDM, FCC hh ee he, CAST EXPERIMENT, COSMIC WISPERS CA21106

DRD1 R&D Collaboration
Development of Gaseous Detectors Technologies

Başvuru koşulları:
https://lisansustu.istinye.edu.tr/tr/basvuru-ve-kabul/programlar-ve-basvuru-kosullari

Online başvuru:
https://lisansustu.istinye.edu.tr/tr/basvuru-ve-kabul/online-basvuru

İSÜ Yüksek Enerji ve Parçacık Fiziği Araştırma Grubu:

Candan Dözen Altuntaş
Doktora Sonrası Araştırmacı

Andrew J. Beddall
Doçent

Emre Çelebi
Doktora Sonrası Araştırmacı

Serkant Ali Çetin
Profesör

Selçuk Hacıömeroğlu
Doçent

Onur Buğra Kolcu
Doktor Öğr. Üyesi

Sertaç Öztürk
Profesör

Anatoli Romaniouk
Adjunct Profesör

Sezen Sekmen
Adjunct Profesör

Sinem Şimşek
Doktora Sonrası Araştırmacı

Zekeriya Uysal
Doktora Sonrası Araştırmacı

YEDEKLER

Endüstriyel Uygulamalar,
Teknoloji Transferi ...

Applications of Particle Accelerators and Particle Detectors

with only few examples…

Particle accelerators play an important role in many functions of todays society. There are over **35 000 accelerators in operation worldwide**. A few examples are accelerators for **radiotherapy** which are the **largest application** of accelerators, altogether with more than 11000 accelerators worldwide. These accelerators range from very compact electron linear accelerators with a length of only about 1 m to large carbon ion synchrotrons with a circumference of more than 50 m and a huge rotating carbon ion gantry with a weight of 600 tons!

There are also a growing number of synchrotron light sources in the world. The light in these sources are created by electrons that are accelerated to almost the speed of light. This light can reveal the molecular structures of materials and also take x-ray pictures of the inner structure of objects. **Synchrotron light sources are very important in life sciences, material sciences and chemistry**. Another type of accelerators are used in spallation sources; here protons are accelerated to very large energies. They produce neutrons when they are smashed into a disc of tungsten. These neutrons are used for finding the inner structure of objects and atomic structures of materials. Finally there are many accelerators for basic physics, like the Large Hadron Collider at CERN.

Research & Development

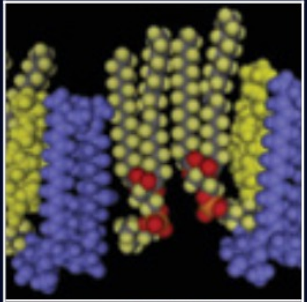
Fundamental physics
Materials science
Solid state and condensed matter physics
Biological and chemical science

Energy & Environment

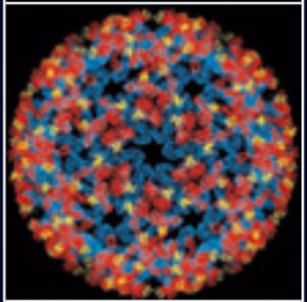
Cleaning flue gases of thermal power plants
Oil and gas exploration
Biofuel production

Health & Medicine

Treating cancer
Medical imaging



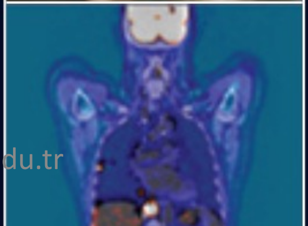
Materials research
Beams of photons, neutrons and muons are essential tools to study materials at the atomic level.



Protein modelling
Synchrotron light allows scientists to solve the 3D structure of proteins e.g. the Chikungunya virus.

Controlling power plant gas emission
In some pilot plants, electron beams are used to control emission of sulphur and nitrogen oxides.

Hadron therapy
Proton and ion beams are well suited for the treatment of deep seated tumours.



Positron Emission Tomography (PET)
Radioisotopes used in PET-CT scanning are produced with accelerators.

Industrial applications

Ion implantation for electronics
Hardening surfaces
Hardening materials
Welding and cutting
Treating waste and medical material

Material characterisation

Cultural heritage
Cargo scanning

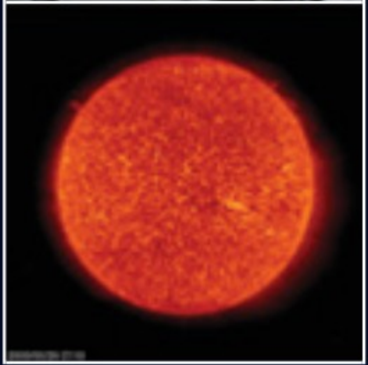
Prospects

Cleaner and safer nuclear power
Fusion energy
Replacing ageing research reactors

Ion implantation for electronics
Many digital electronics rely on ion implanters to build fast transistors and chips.

Hardening materials
Replacing steel with X-ray cured carbon composites can reduce car energy consumption by 50%.

Cultural heritage
Particle beams are used for non-destructive analysis of works of art and ancient relics.



Energy
Accelerator technologies may bring the power of the sun "down to earth", treat nuclear waste and allow for safer operation of reactors.

Irradiation of wires and cables to improve their properties

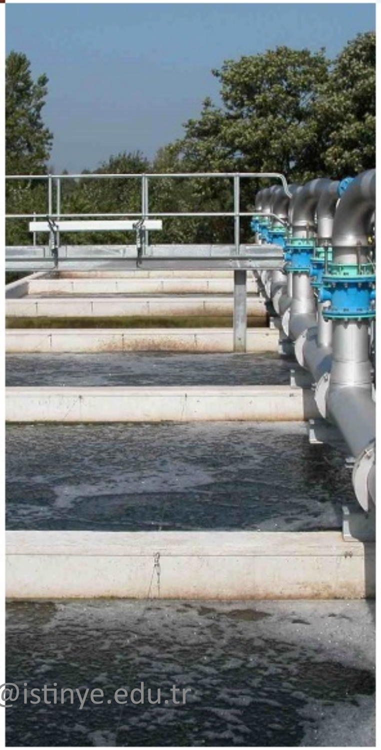
· Cables for submersible pumps
· Power wires and cables
· Cables for outside house and street wiring
· Cables for wind power generators.

Sterilization of medical devices

When exposed to ionizing radiation, some of the microorganisms perish and the others lose the ability to reproduce. The sterility assurance level after irradiation complies with modern medical standards (SAL 10-6); i.e., there is one or less nonsterile unit in one million products.

Radiation treatment of food products

This method increases the shelf life of products. It is convenient because the products are processed in packages, and the procedure itself is simple and fast. Cold pasteurization is safe and meets the highest standards, as it eliminates the use of harmful chemical preservatives. That is why the products processed by this method are clean and safe, compared to other methods.



Wastewater treatment

Another area of use of the accelerators of ELV – treatment of waste water. They were used in the liquidation of the ecological disaster in Voronezh (more than 30 years ago), when the waste of the production of "Voronezhsintezkauchuk" got into the city water intake, as well as in the wastewater treatment of textile production in the city of Daegu in South Korea. These are the only examples in the world of using accelerators as full-scale installations for environmental purposes.

Irradiation of polyethylene tape

Advantages of radiation treatment:

- Breaking strength increases by 20–40%;
- Impact breaking strength increases up to 200%.

Production of polyethylene foam

Polyethylene foam is an elastic material with properties such as:

- excellent thermal insulation
- protection against moisture and steam
- airtightness
- noise insulation
- soft and light weight
- rot resistance and durability
- ecological safety

Manufacture of hydrogel

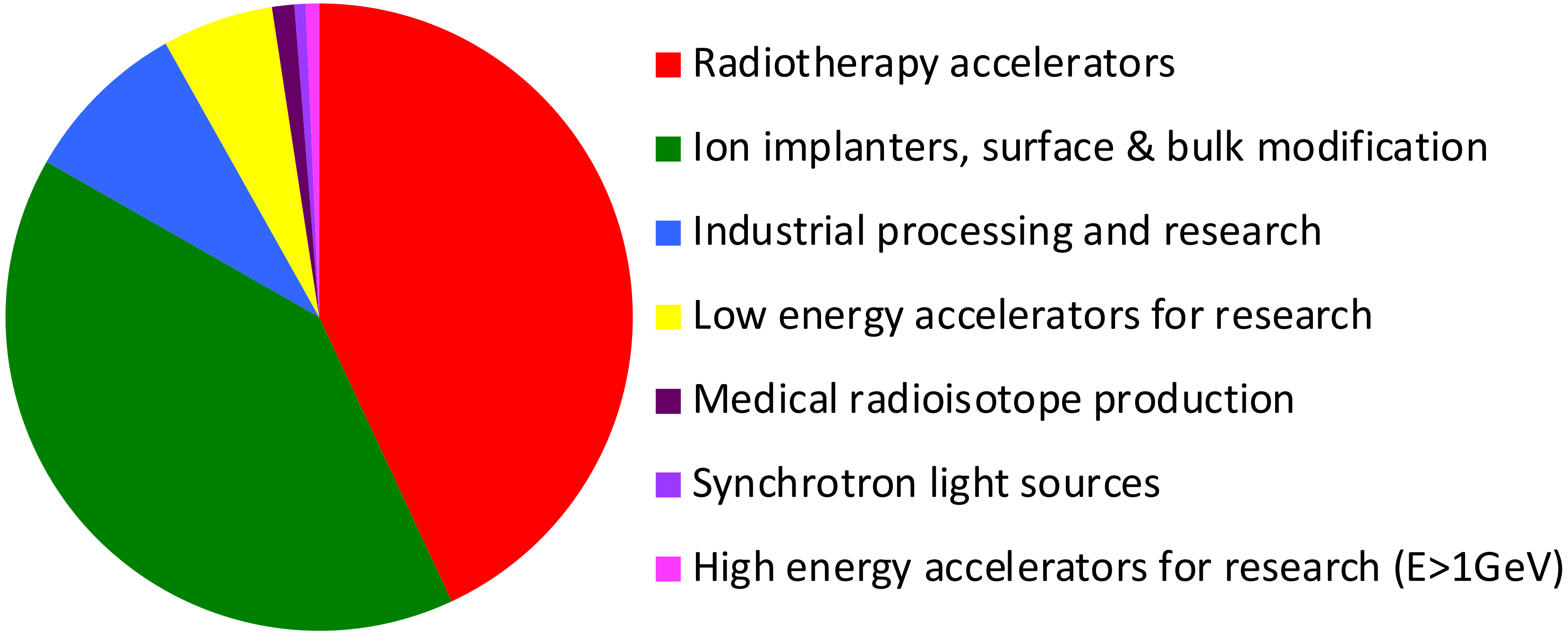
Under irradiation, a 3–5% aqueous solution of polyethylene oxide forms a hydrogel, which serves as a basis for medicinal compounds, cosmetics, and burn and wound dressings and provides an intermediate medium in ultrasound diagnostics.

Preparation of nanopowders

Nanopowders are obtained by evaporation from melts. They are used as feedstock materials in the production of ceramic and composite materials, superconductors, solar panels, filters, getters, additives for lubricants, coloring and magnetic pigments, and components of low-temperature high-strength solders.

“A beam of particles is a very useful tool…”

-Accelerators for Americas Future
Report, pp. 4, DoE, USA, 2011



There are roughly 35,000 accelerators in the world
(Above 1 MeV…)

X-ray radiotherapy

Linac

Foil to produce x-rays

Collimation system

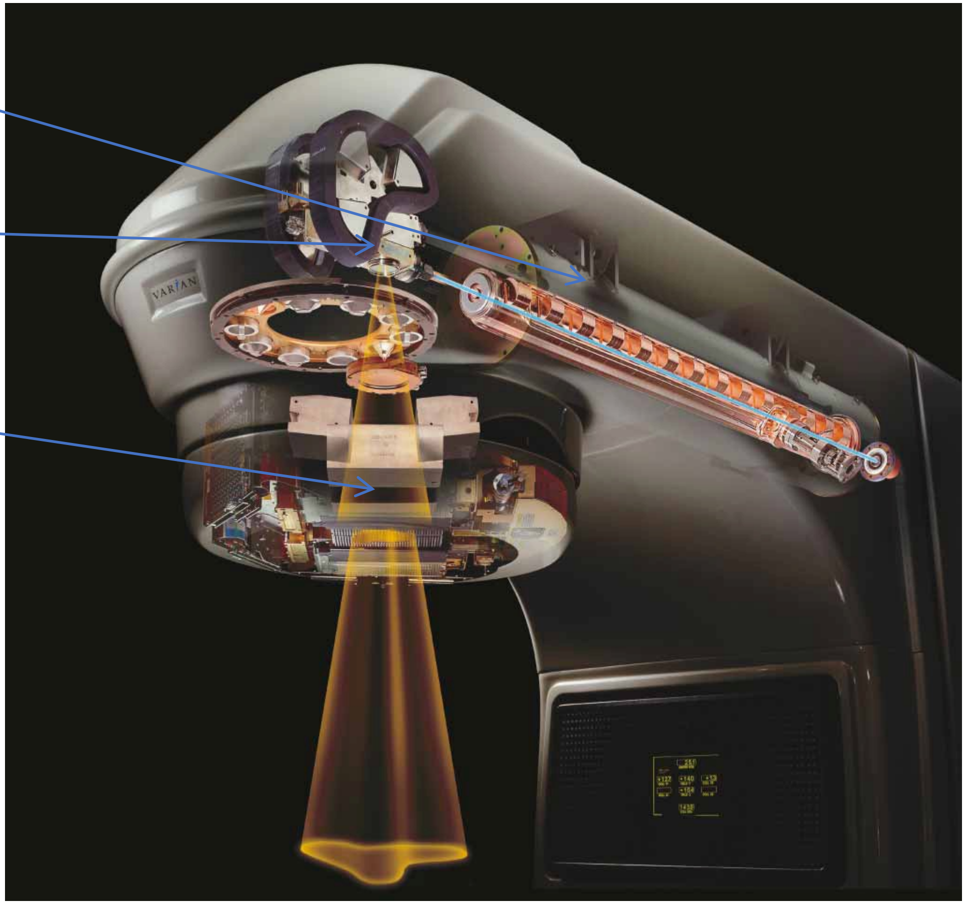
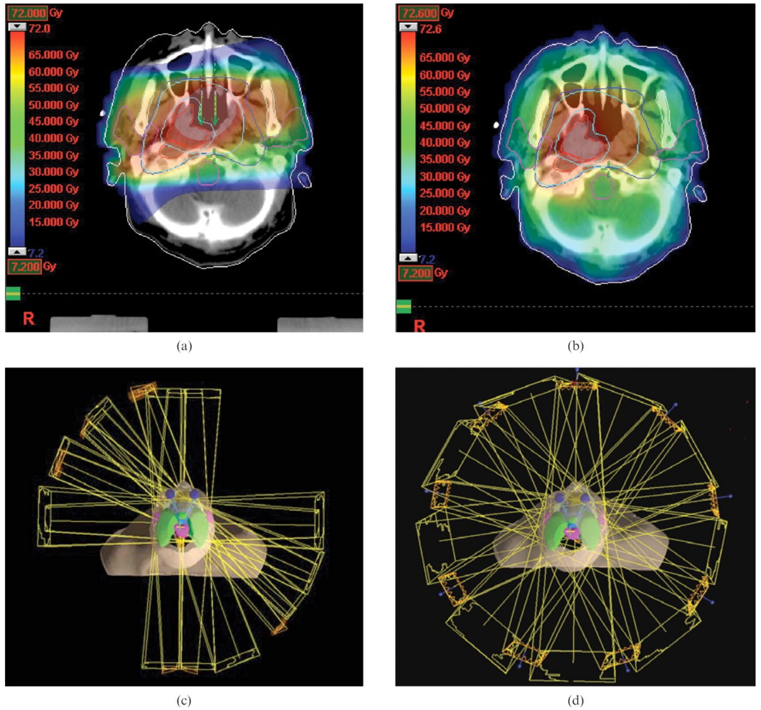


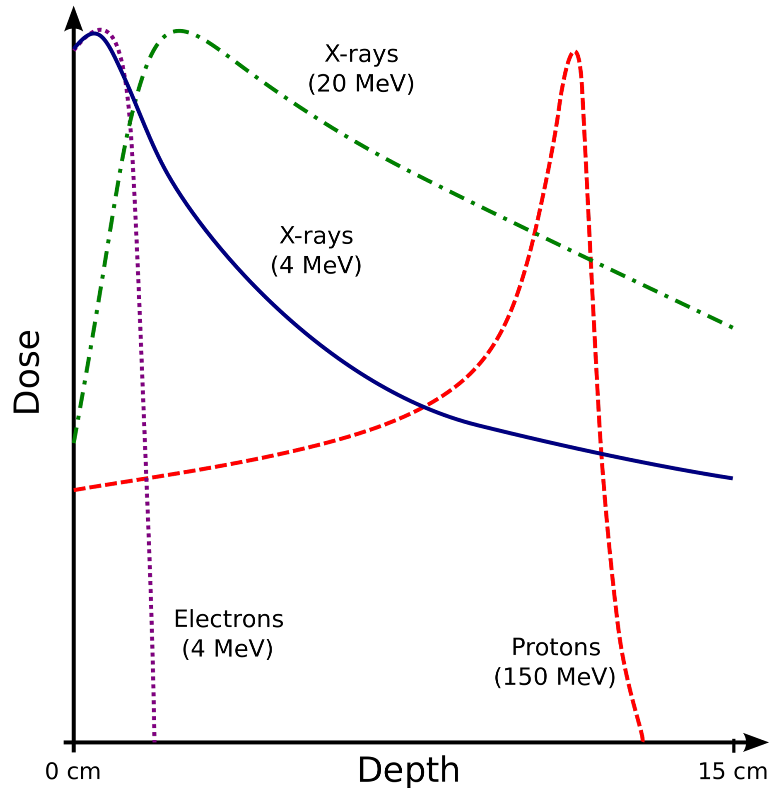
Image: copyright Varian medical systems

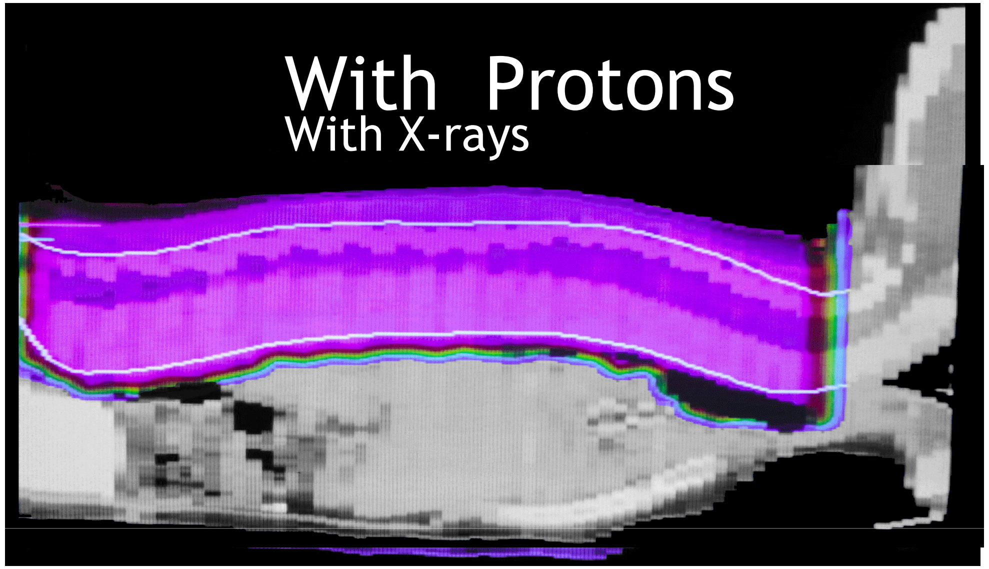


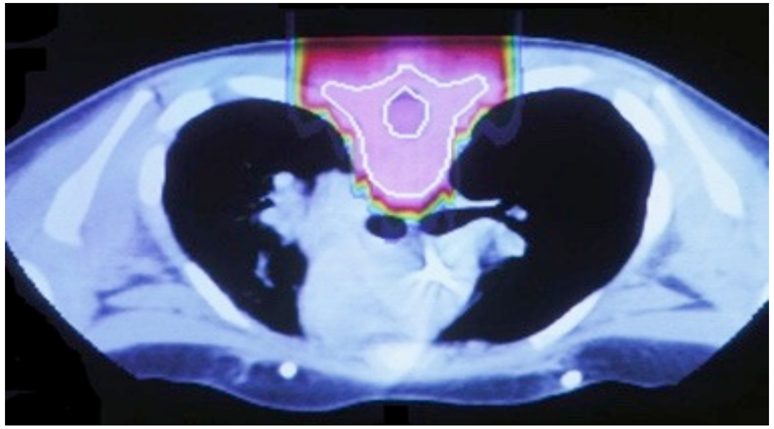
Hadron therapy

"Hadron therapy" = Protons and light ions

- Used to treat localised cancers
- Less morbidity for healthy tissue
- Less damage to vital organs
- Particularly for childhood cancers

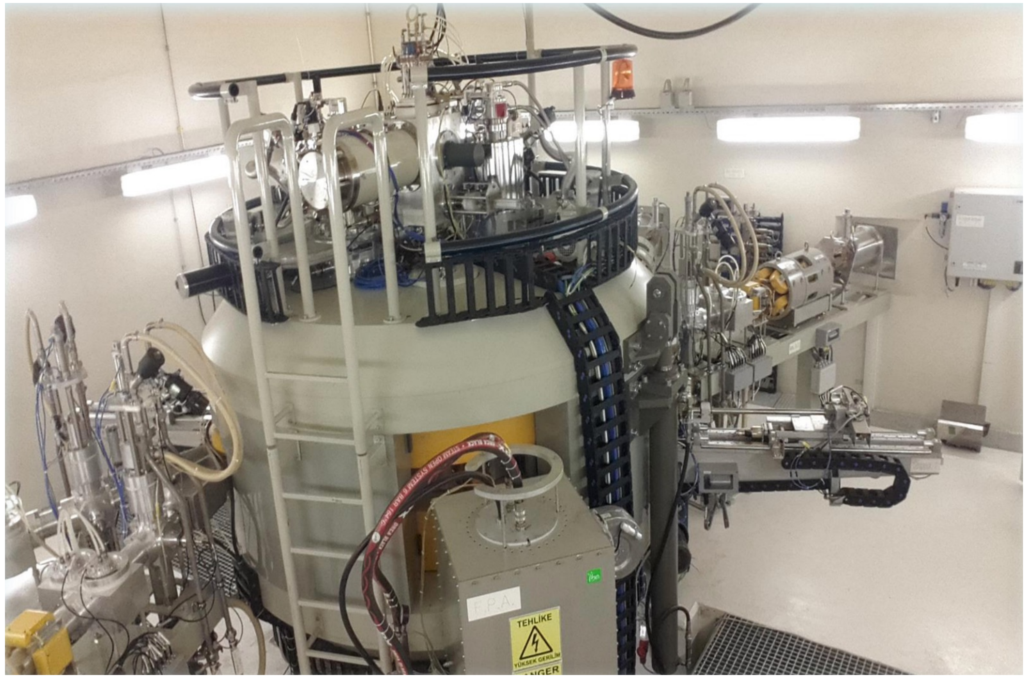






Radioisotope production

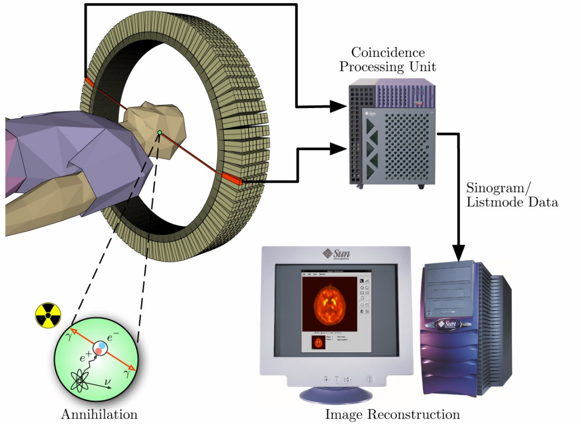
- Accelerators (compact cyclotrons or linacs) are used to produce radio-isotopes for medical imaging.
- 7-11MeV protons for short-lived isotopes for imaging
- 70-100MeV or higher for longer lived isotopes



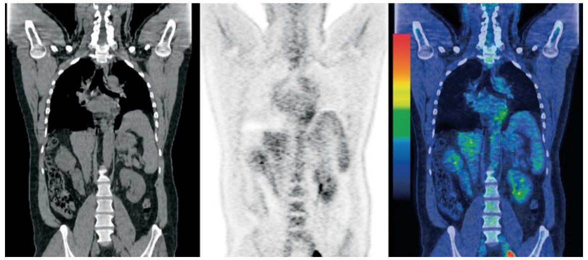
TENMAK CYCLOTRON / Ankara

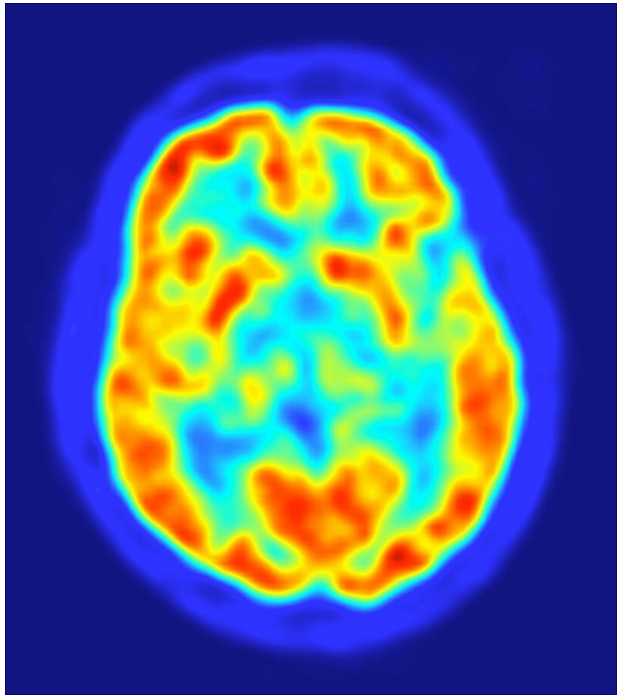
- Positron emission tomography (PET) uses Fluorine-18, half life of ~110 min

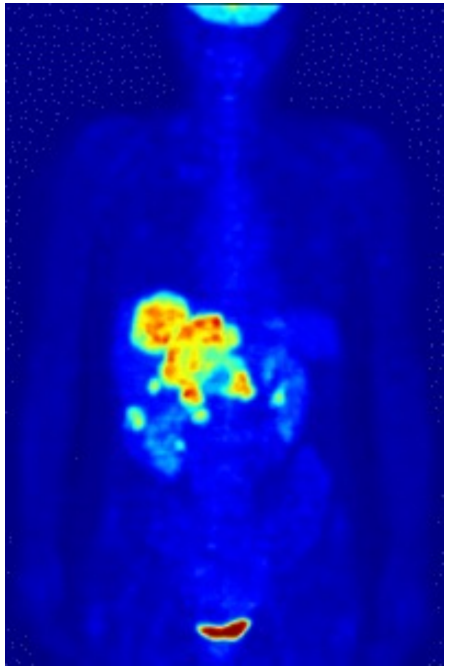
Positron Emission Tomography - Computed Tomography (PET/CT)



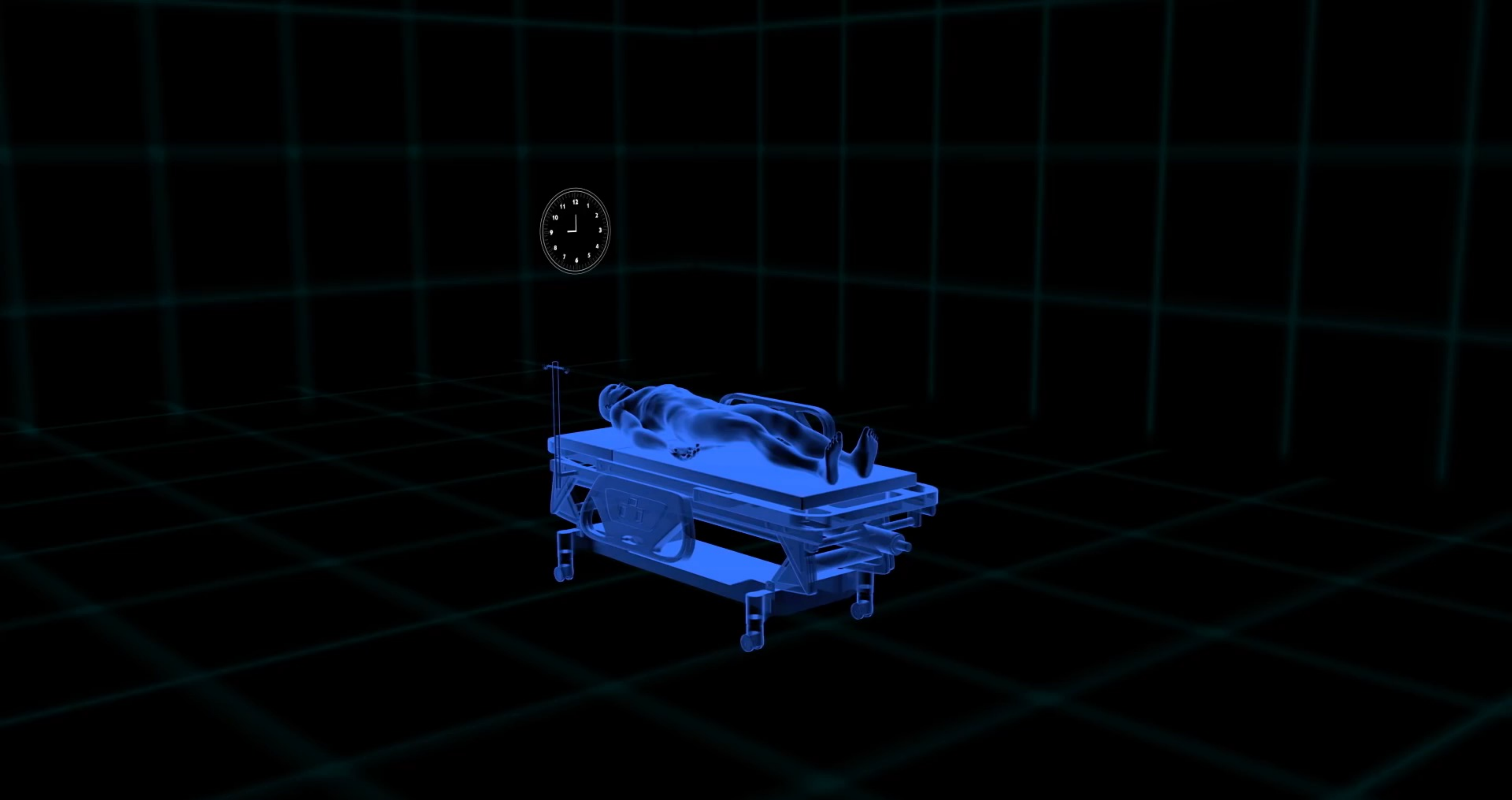
Positron emission tomography (PET) uses small amounts of radioactive materials called radiotracers or radiopharmaceuticals, a special detector system and a computer to evaluate organ and tissue functions. By identifying changes at the cellular level, PET may detect the early onset of disease before other imaging tests can.





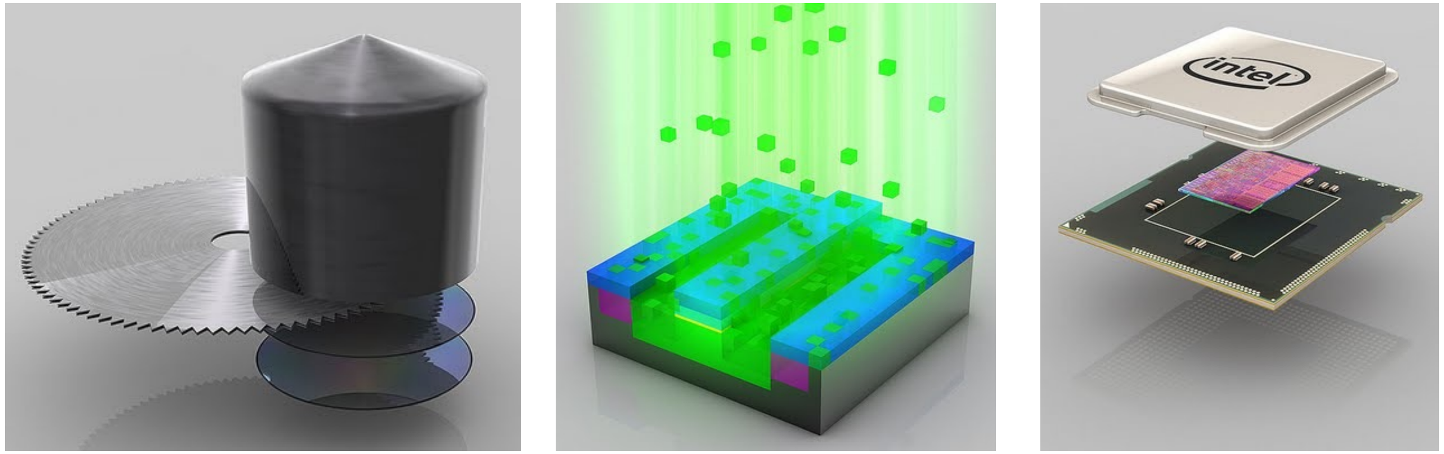


- Fluorodeoxyglucose or FDG carries the F18 to areas of high metabolic activity
- 90% of PET scans are in clinical oncology



https://youtu.be/oySvkmezdo0

Ion implantation



Images courtesy of Intel

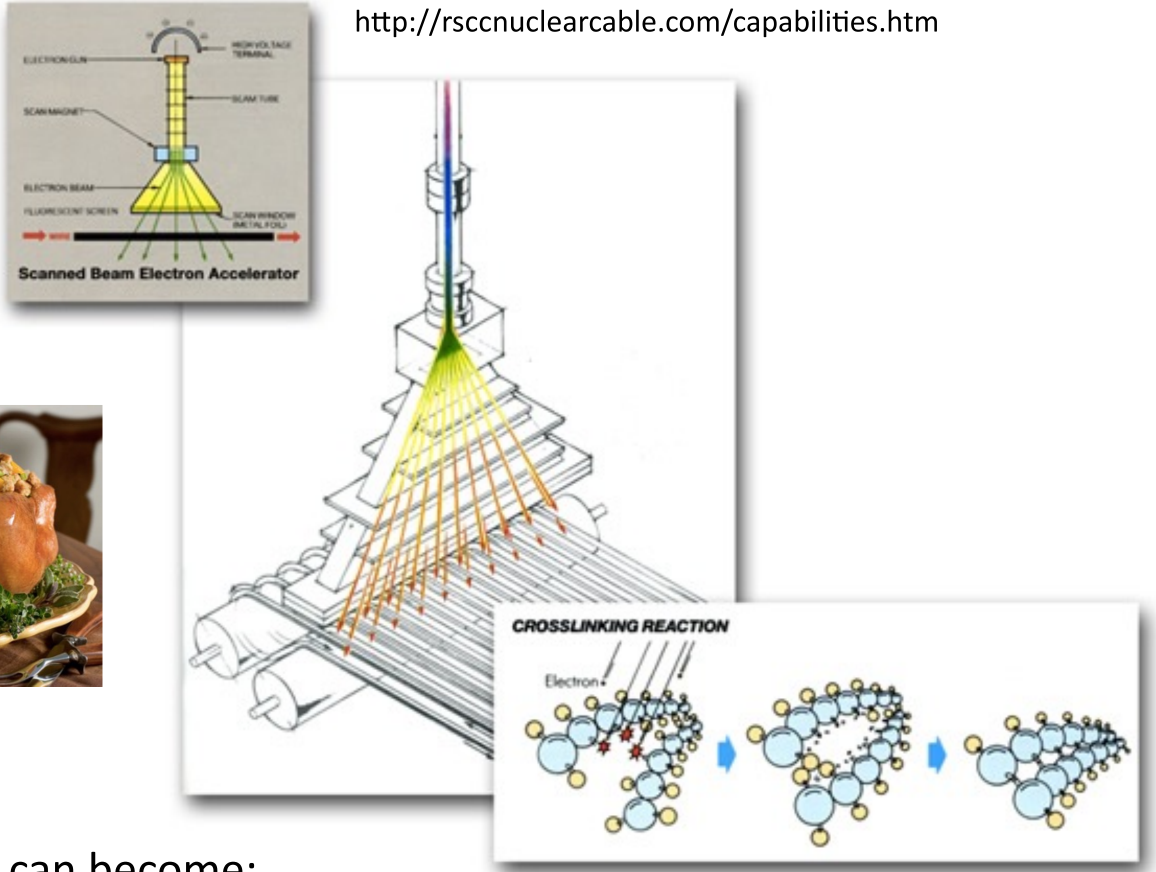
- Electrostatic accelerators are used to deposit ions in semiconductors.

Electron beam processing

In the US, potential markets for industrial electron beams total $50 billion per year.

33% Wire cable tubing
32% Ink curing
17% shrink film
7% service
5% tires
6% other

http://rsccnuclearcable.com/capabilities.htm



When polymers are cross-linked, can become:

- stable against heat,
- increased tensile strength, resistance to cracking
- heat shrinking properties etc

Equipment sterilisation

Manufacturers of medical disposables have to kill every germ on syringes, bandages, surgical tools and other gear, without altering the material itself.

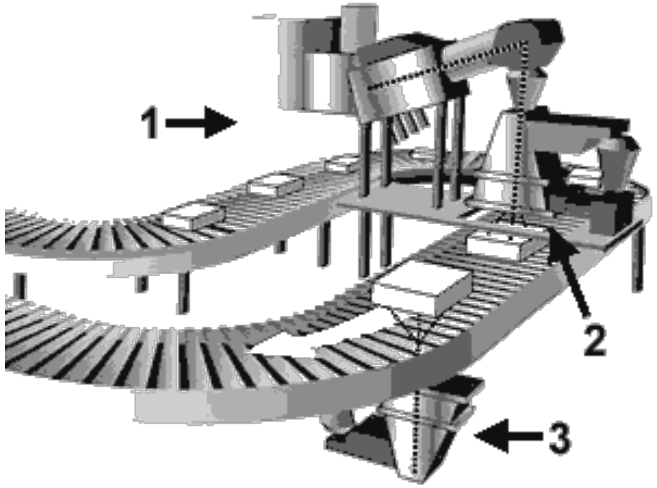
E-beam sterilisation works best on simple, low density products.

Advantages: takes only a few seconds (gamma irradiation can take hours)

Disadvantages: limited penetration depth, works best on simple, low density products (syringes)

The IBA rhodotron – a commercial accelerator used for e-beam sterilisation

Food irradiation



'Cold pasteurisation' or 'electronic pasteurisation'
Uses electrons (from an accelerator) or X-rays produced using an accelerator.

In the US all irradiated foods have this symbol

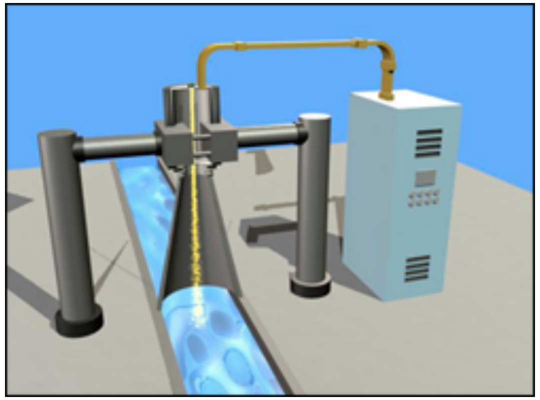
Foods authorised for irradiation in the EU:

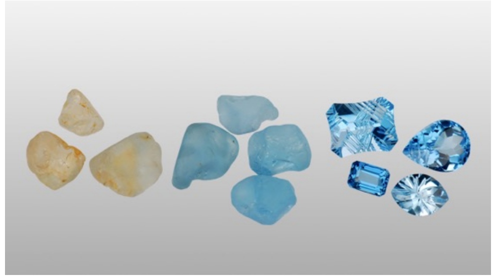
Lower dose → Higher dose

Other uses in industry…

- Non-destructive testing (weld integrity etc)
- Hardening surfaces of artificial joints
- Removal of NO_x and SO_x from flue gas emissions
- Scratch resistant furniture

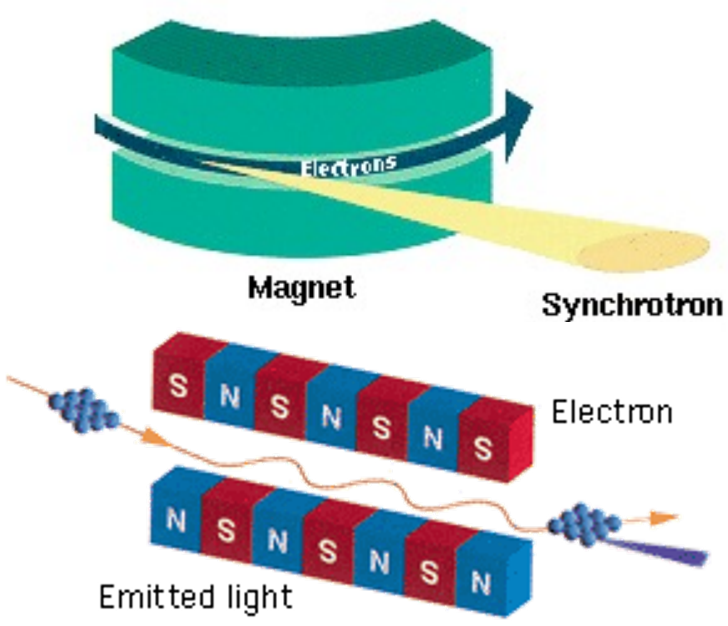
Treating waste water or sewage
Purifying drinking water
(Without additional chemicals…)

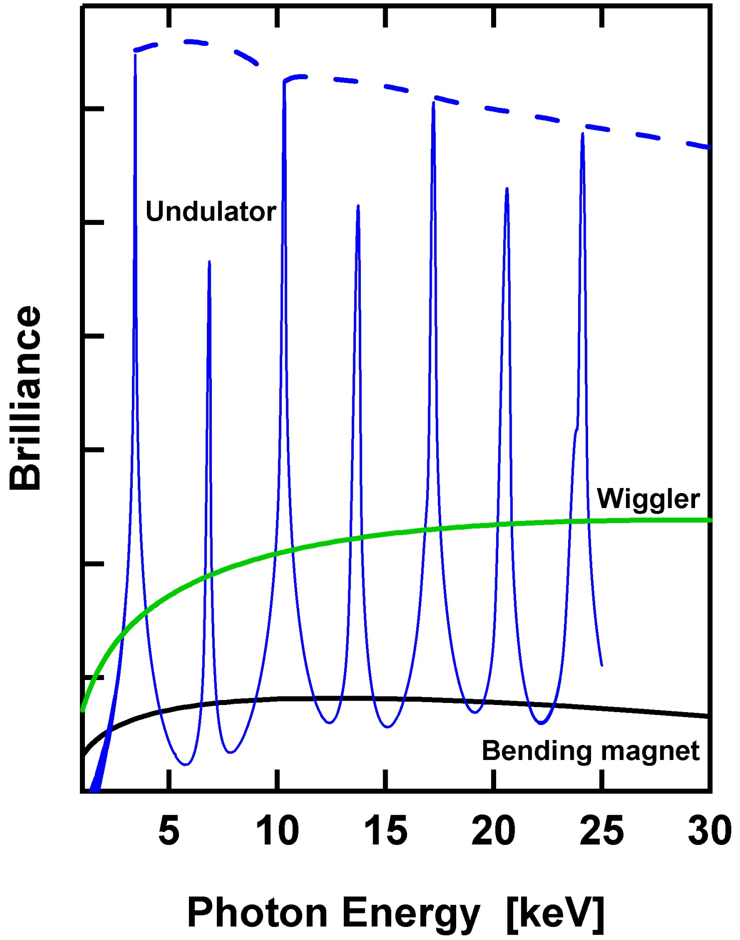




Irradiating topaz and other gems with electron beams to change the colour

Synchrotron radiation is emitted by charged particles when accelerated radially





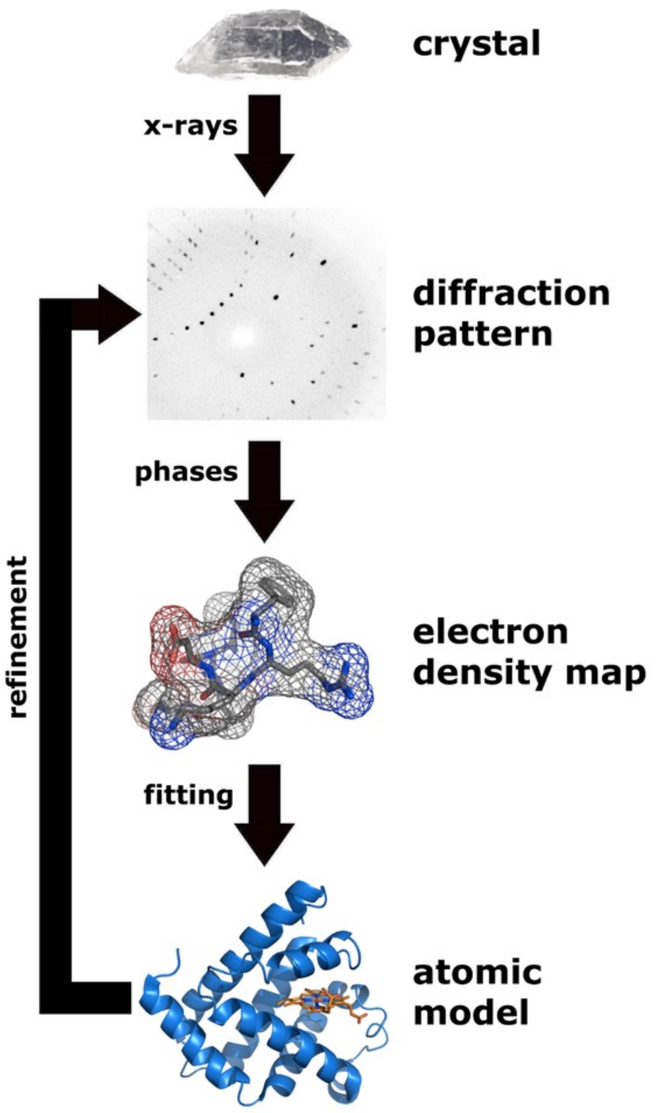
Produced in synchrotron radiation sources using bending magnets, undulators and wigglers

X-Ray crystallography

2014 was the International Year of Crystallography

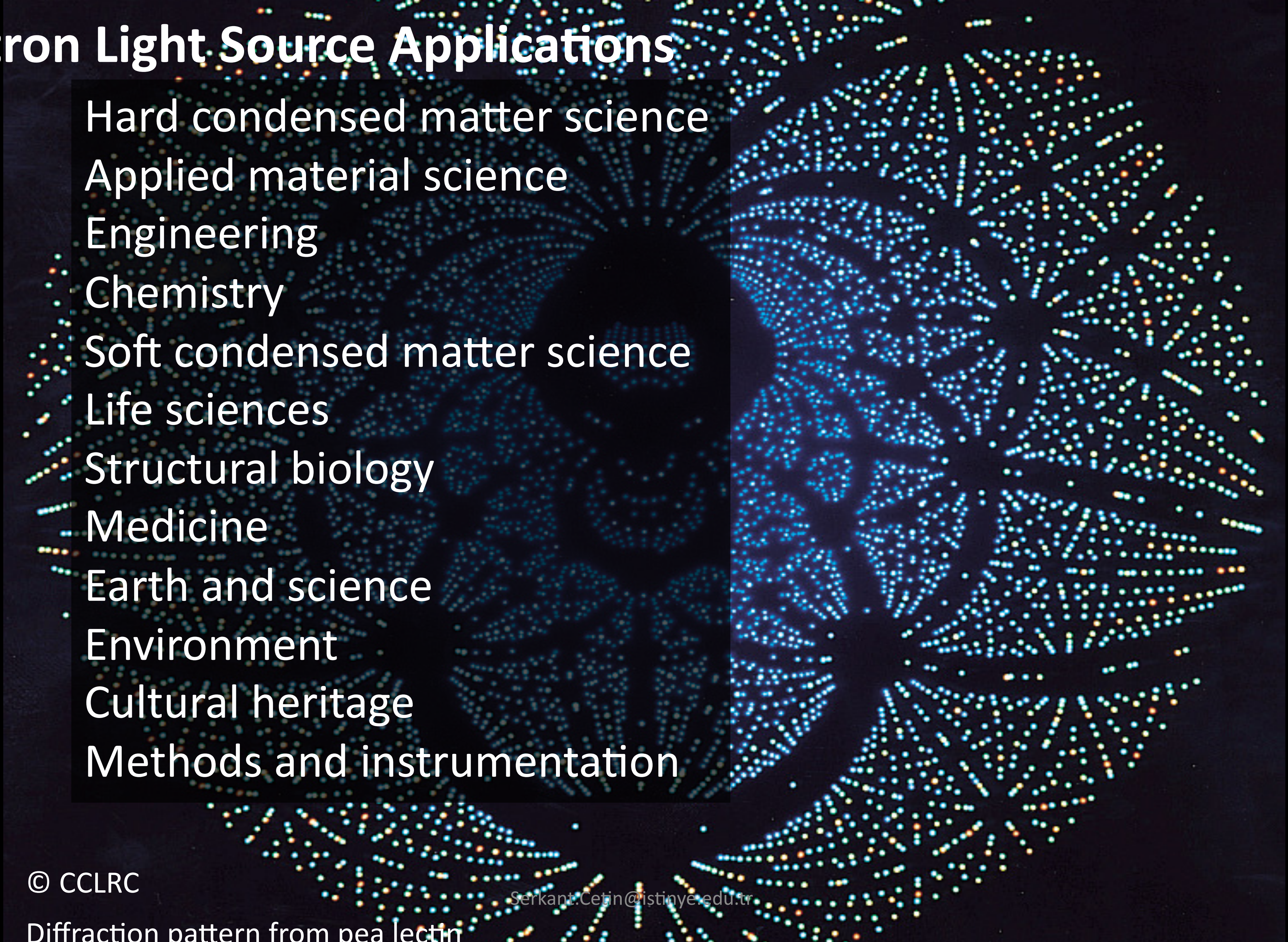
Protein crystallography is a standard technique at synchrotron light sources (Diamond light source has 5 beamlines devoted to it)

The hardest part is forming the crystal…



Synchrotron Light Source Applications

- Hard condensed matter science
- Applied material science
- Engineering
- Chemistry
- Soft condensed matter science
- Life sciences
- Structural biology
- Medicine
- Earth and science
- Environment
- Cultural heritage
- Methods and instrumentation



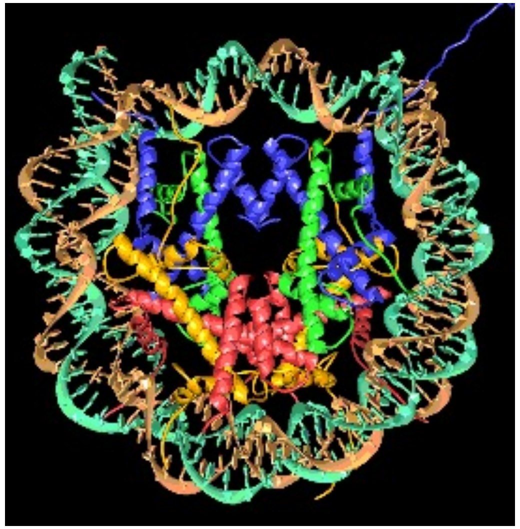
© CCLRC

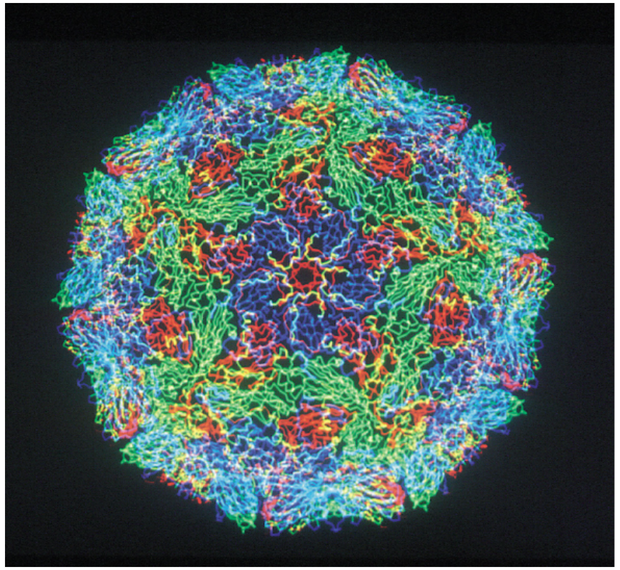
Diffraction pattern from pea lectin

Synchrotron Radiation Science

Biology

Reconstruction of the 3D structure of a nucleosome (DNA packaging) with a resolution of 0.2 nm

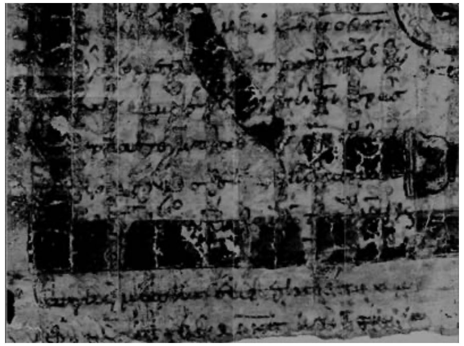




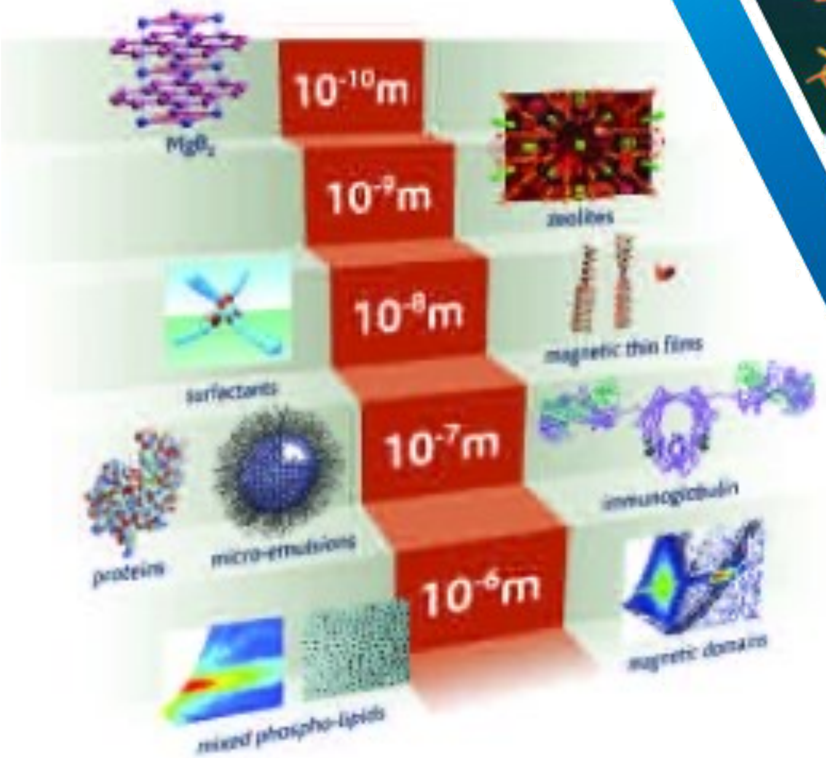
In 1990 scientists determined the structure of a strain of foot & mouth virus using Daresbury SRS.

Archeology/Heritage

A synchrotron X-ray beam at the SSRL facility illuminated an obscured work erased, written over and even painted over of the ancient mathematical genius Archimedes, born 287 B.C. in Sicily.



Using X-Ray induced fluorescence



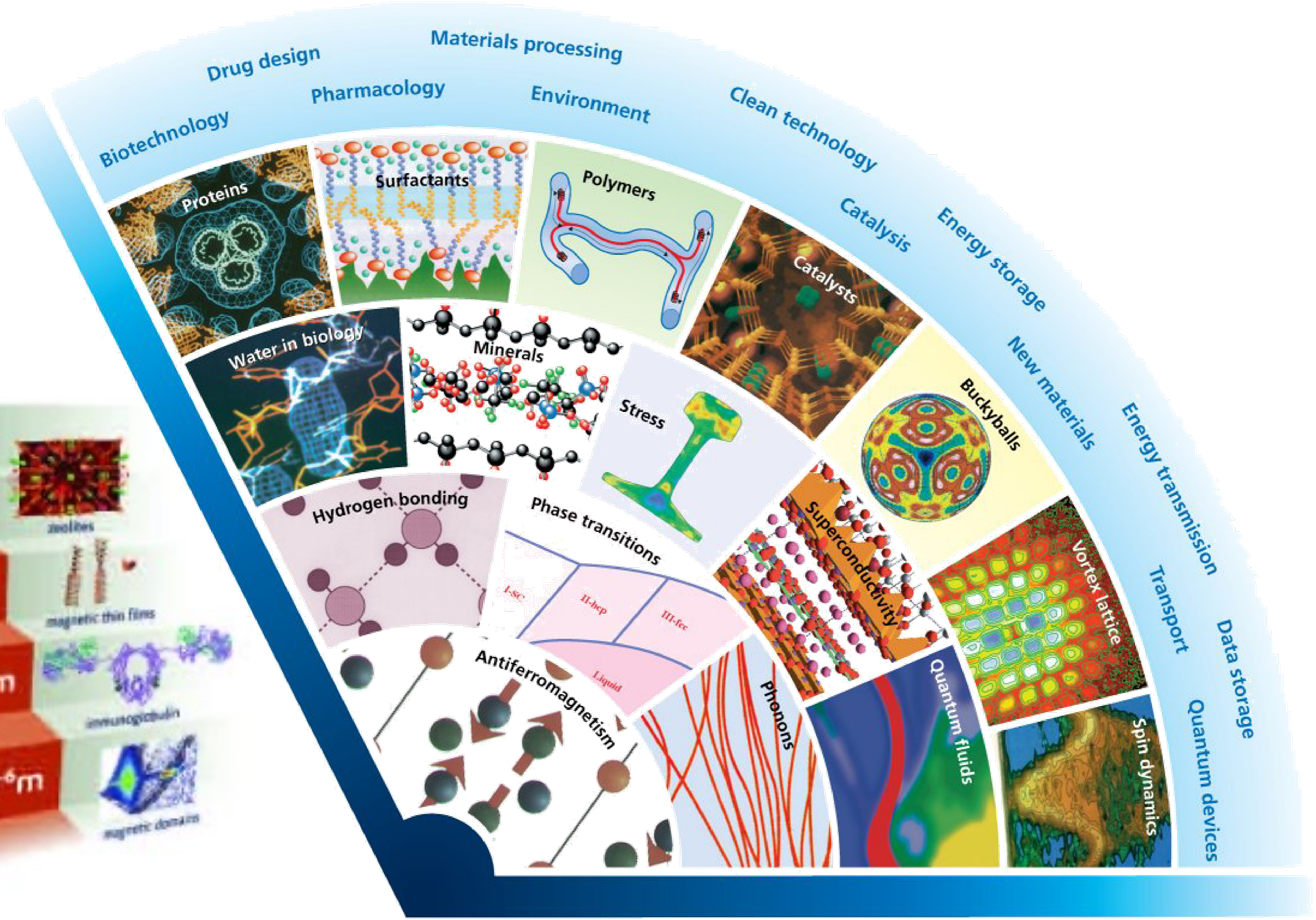
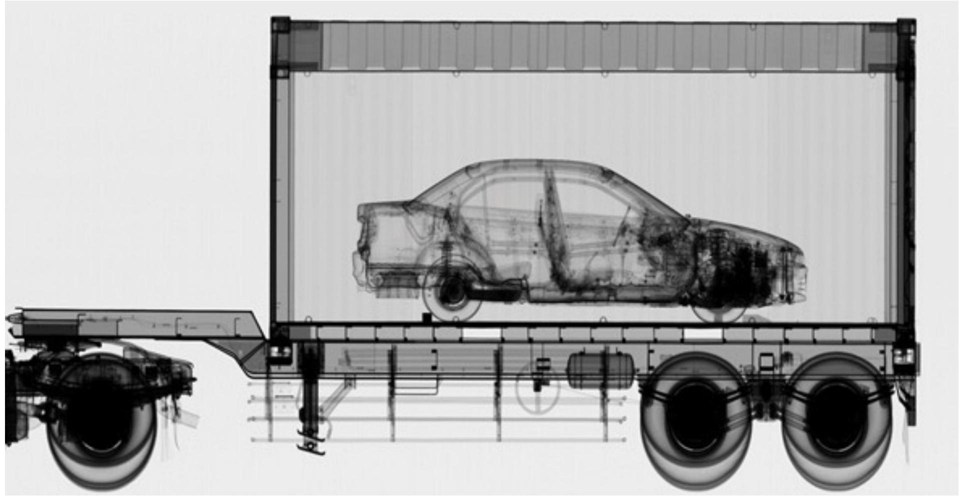


Image courtesy ISIS, STFC.

Cargo scanning



Cargo containers scanned at ports and border crossings

Accelerator-based sources of X-Rays can be far more penetrating (6MV) than Co-60 sources.

Container must be scanned in 30 seconds.

Image source: Varian medical systems

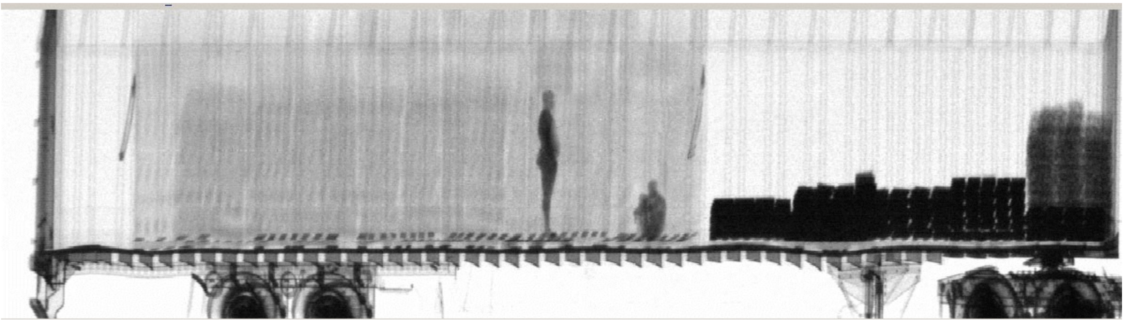
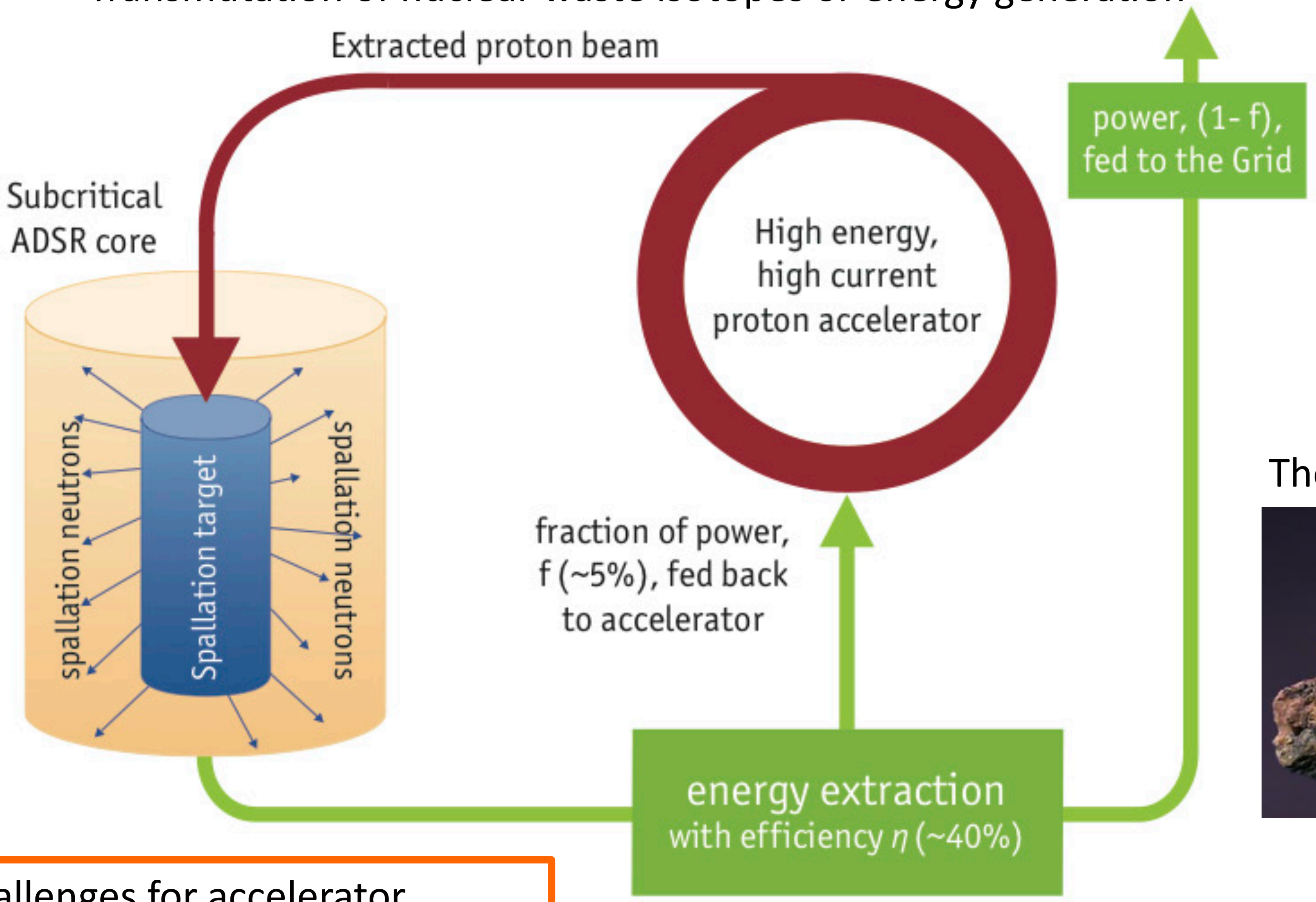


Image: dutch.euro

Accelerator Driven Systems

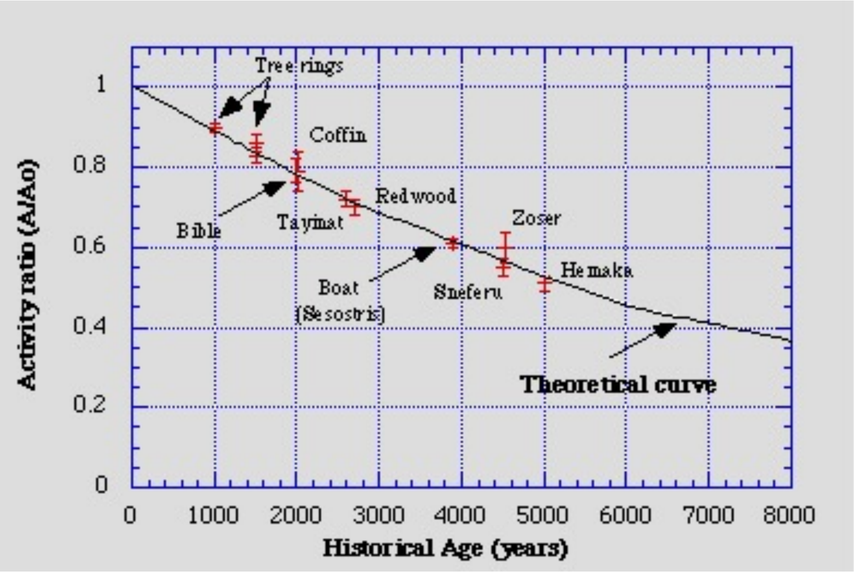
Transmutation of nuclear waste isotopes or energy generation

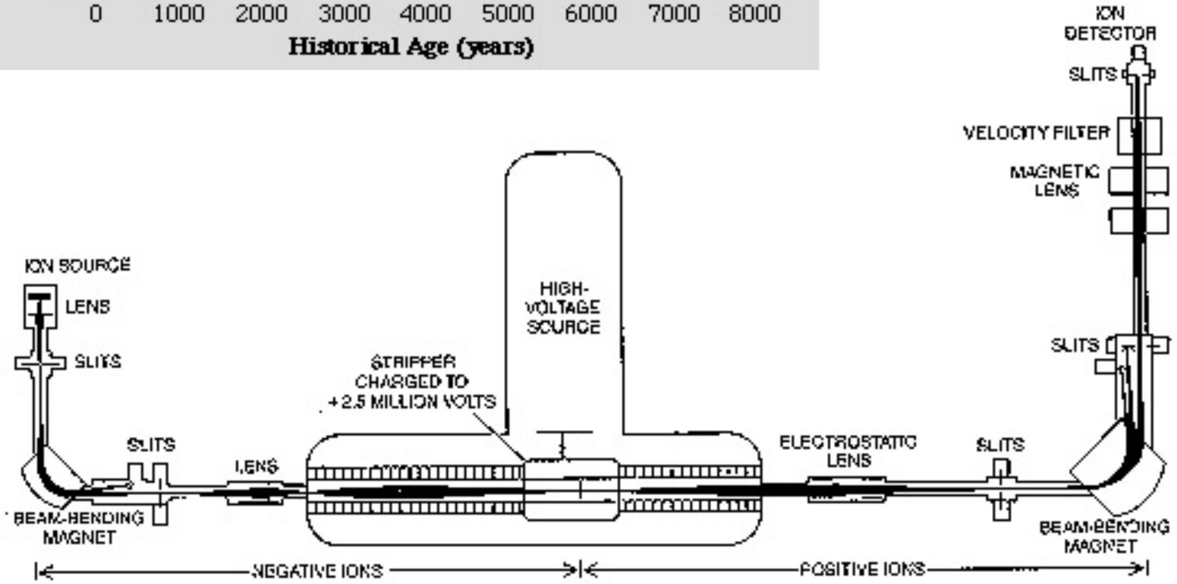


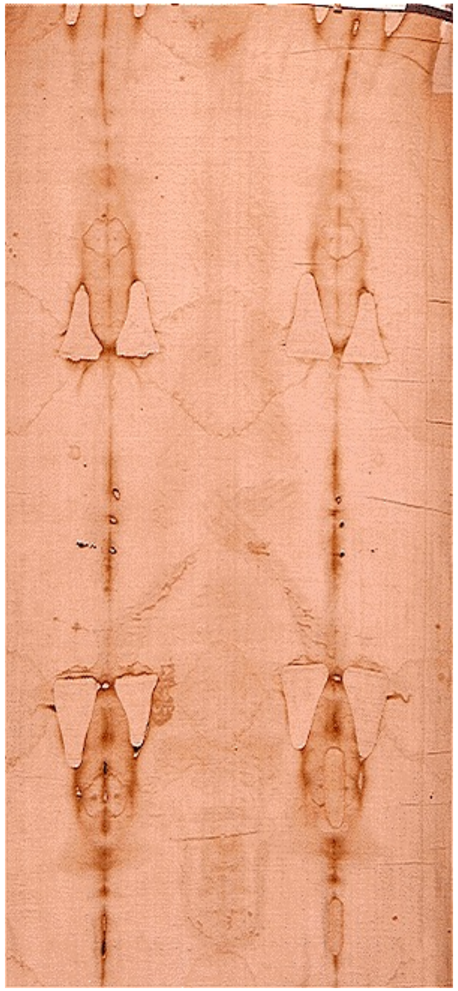
Thorium

Major challenges for accelerator technology in terms of beam power (>10MW) and reliability

Radiocarbon Dating

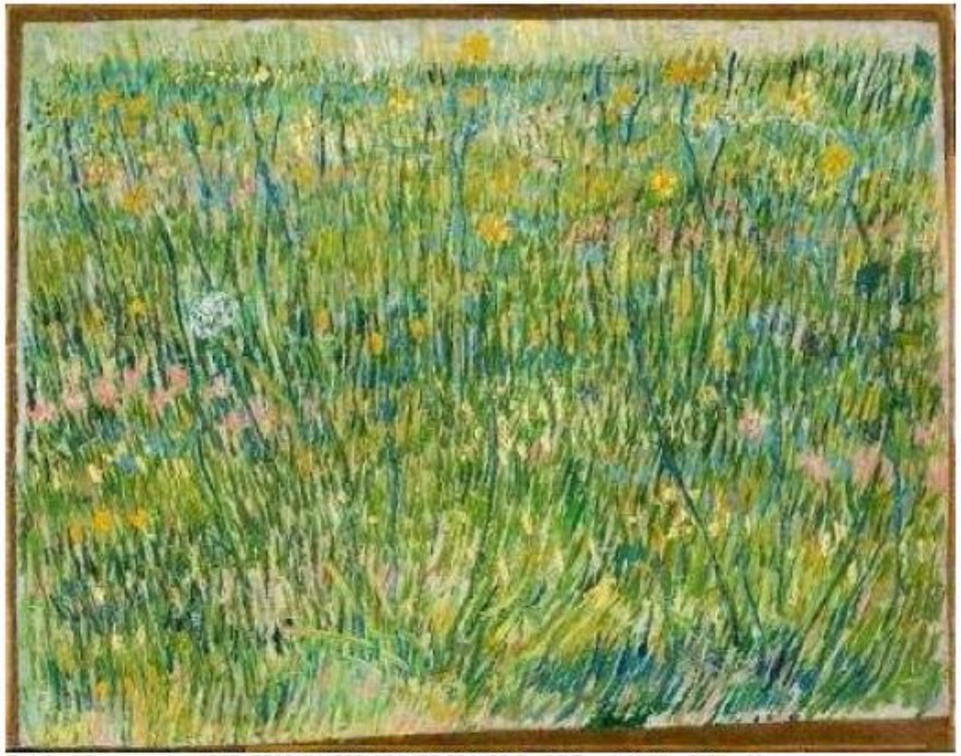






For more accuracy, isolate C-14 from other isotopes “AMS” = Accelerator Mass Spectrometry

Accelerators can study art

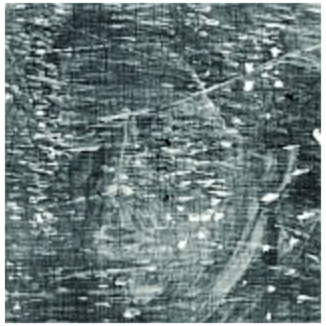


Patch of Grass, spring 1887, F583/JH1263, KM 105.264 (30,8 x 39,7 cm), Kröller-Müller Museum (Photo: Rik Klein Gotink)

This painting "Patch of grass" by Vincent van Gogh was the first one analysed by a particle accelerator

Used X-ray fluorescence technique

Distribution of Hg (red) and Sb (yellow) pigment allowed a reconstruction of underlying image

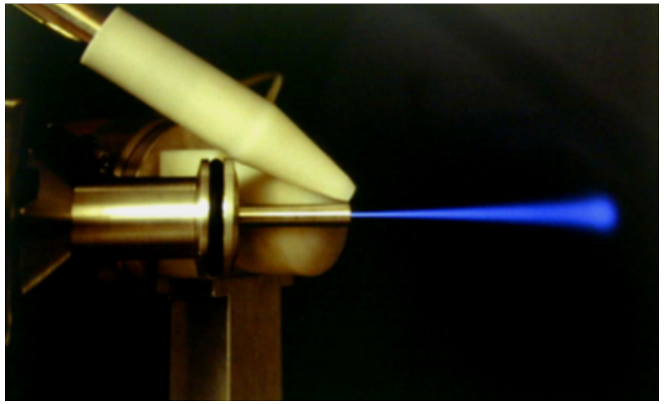


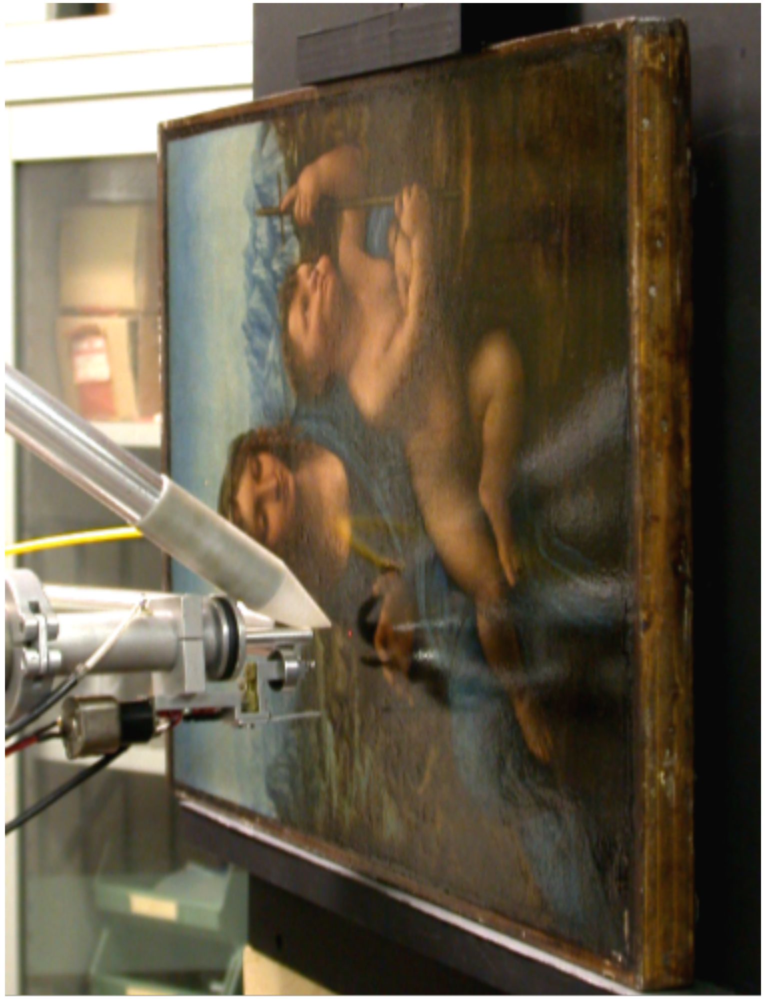
It showed a portrait of a woman underneath

http://www.javno.com/en-bestseller/van-gogh-first-victim-of-particle-bombarding_185316

Accelerators can help spot art forgeries

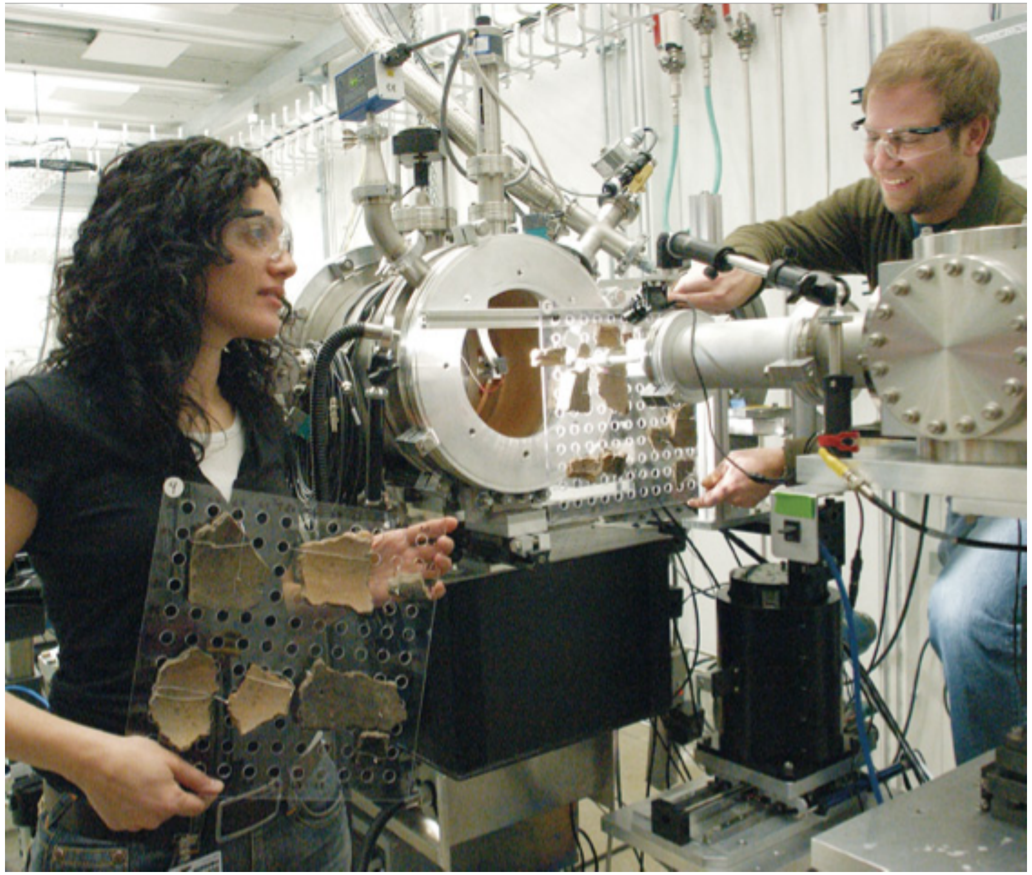
- Ion Beam Analysis (MeV) shows us the chemical composition of pigments used in paint
- Backscattered radiation can give detailed analysis of atoms present in surface.
- This allows art historians to compare them with paints available to artists like Leonardo da Vinci





Accelerators in archaeology

The interior of samples can be studied using accelerators without destroying them

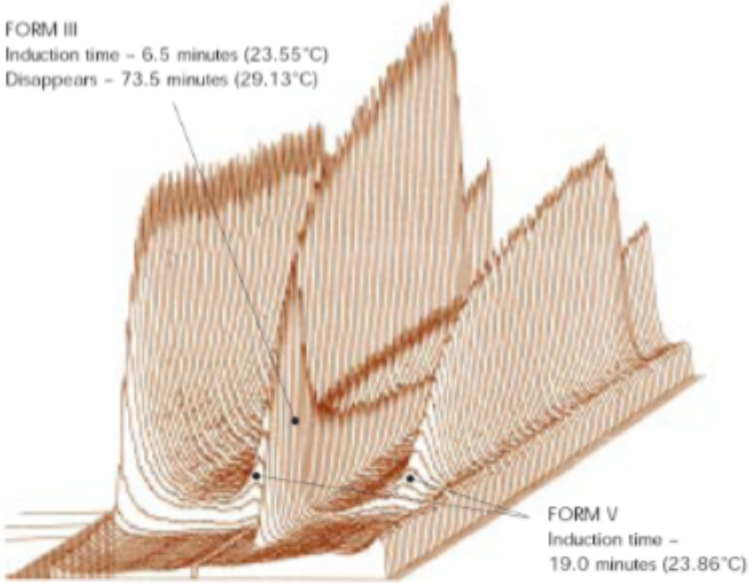


Pottery from Armenia, dating back to 1300 BC,
is set up for a synchrotron experiment

Image: Argonne National Laboratory

Crystal structure formation

Cadbury used X-rays from a particle accelerator to study how cocoa crystallises



Of the six possible crystal forms, the fifth (form V) produces the best quality chocolate

ISU ISTINYE UNIVERSITY ISTANBUL

Finally, just one more application of accelerators…

Detecting wine fraud

Use ion beam to test the bottle of "antique" wine – chemical composition of the bottle compared to a real one.

"In a recent and spectacular case, American collector William Koch sued a German wine dealer, claiming four bottles – allegedly belonging to former U.S. president Thomas Jefferson – purchased for 500,000 dollars, were fake. The case has yet to be settled."

- http://www.cosmosmagazine.com

HOME » NEWS » SCIENCE » SCIENCE NEWS

Atomic boffins spot fake wines

0 0 0 0 Emai

Bottles are zapped with beams of charged ions generated by a particle accelerator

Bottles are zapped with beams of charged ions generated by a particle accelerator

By Roger Highfield, Science Editor
7:25PM BST 03 Sep 2008

A rare wine merchant has joined forces with nuclear scientists to develop a 21st-century tool for unmasking counterfeit vintage wines.

APPLICATIONS OF ACCELERATORS
IN EVERYDAY LIFE

ACCELERATORS AND...

HEALTH

ACCELERATORS PLAY A CRUCIAL AND GROWING ROLE IN INVESTIGATING AND TREATING WIDESPREAD DISEASES SUCH AS CANCER AND DEMENTIA.

RADIOTHERAPY

X-rays generated by accelerating an electron beam have been used to destroy tumour cells for many decades. Recent developments include the computer-controlled delivery of radiation doses whose shape matches that of the tumour, thus avoiding damaging healthy tissue.

Particle beams, in particular protons and light ions, can more effectively kill cancer cells because they slow down in tissues and deposit their energy in one place. By careful treatment planning, cancers in critical areas such as the head and neck can be treated safely.

WHAT'S NEEDED: SMALLER, LESS CUMBERSOME ACCELERATOR CONFIGURATIONS ARE NEEDED THAT CAN TREAT SEVERAL PATIENTS SIMULTANEOUSLY IN AS FEWER DOSES AS POSSIBLE.

RADIO ISOTOPES

Forms of elements that are unstable (radio-isotopes) and emit radiation (particles or gamma-rays) are exploited for both imaging inside the body and therapy. Increasingly, these are created in accelerators.

Imaging relies on injecting a patient with a radio-isotope attached to a substance that localises in tissues of interest, and then detecting the radiation emitted so as to build up a computer image. Isotopes that emit single gamma-rays can be employed, but clearer images are obtained with isotopes emitting positrons (antimatter versions of electrons), which annihilate when they touch surrounding matter to release pairs of gamma-rays whose point of origin can then be mapped (positron emission tomography, PET).

Some isotopes emit radiation suitable for cancer therapy when injected attached to a carrier – for example, antibodies that 'recognise' specific cancer-tissue types and so can target cancer cells that have spread. Scientists are also studying new isotopes emitting both gamma-rays and particles that enable combined imaging and therapy.

WHAT'S NEEDED: RESEARCH IS GOING INTO MAKING NOVEL MEDICAL ISOTOPES FOR SPECIFIC APPLICATIONS, BUT THE AVAILABILITY OF ADVANCED ACCELERATOR DESIGNS IS ESSENTIAL FOR PROGRESS.

SECURITY

ACCELERATOR-GENERATED X-RAYS ARE A KEY TOOL IN THE FIGHT AGAINST SMUGGLING, PEOPLE TRAFFICKING AND TERRORISM, AND IN MAINTAINING EUROPE'S NUCLEAR DEFENCE.

BORDER SECURITY

Smuggling contraband or people has become a major concern in Europe. Accelerator-generated X-rays, gamma-rays and particles such as neutrons can penetrate containers and scan cargo, not only imaging the contents but also analysing their composition.

COUNTER-TERRORISM

Similar accelerator technology can also help security teams identify and analyse suspected terrorist threats such as explosives and chemical, biological or radiological weapons.

WHAT'S NEEDED: A NEW GENERATION OF PORTABLE, RUGGED, LOW-COST ACCELERATOR SYSTEMS IS NEEDED THAT CAN ENSURE THE RAPID DELIVERY OF 3D IMAGES.

INDUSTRY

ACCELERATED BEAMS OF ELECTRONS (E-BEAMS) AND IONS PLAY HUGE ROLES IN MANUFACTURING, AS WELL AS IN ENVIRONMENTAL HEALTH PROTECTION AND CONSERVATION.

Relatively low-energy beams have the advantage that they can be directed to cause a highly-controlled change at a selected location on, or just below, the surface of a material or object, without destroying their integrity. They also provide a significant toolbox of non-destructive techniques for analysing materials down to the atomic level.

MANUFACTURING

E-beams can modify materials by causing chemical changes or by heating up the surface. Some of the many effects achieved include crosslinking polymers used in wires, cables and tyres, curing coatings, bonding delicate materials, welding and alloying metals, drilling or cutting surfaces to create nano-structured effects, or even changing the colour of gemstones.

In the electronics industry, e-beams and proton beams can etch circuits onto microchips, while ion beams can implant atoms into silicon to make the semiconductors that are the basis for this industry.

HEALTH AND THE ENVIRONMENT

E-beams kill bacteria, so are used to sterilise medical implants and surgical implements, as well as seeds, spices and medical packaging. They also find application in cleaning up dirty water and sewage, and removing harmful sulfur and nitrogen oxides emitted from coal-fired power stations. A range of analytical methods based on ion beams can monitor air pollution such as dust.

CULTURAL HERITAGE

While museums and libraries can use e-beams to kill pests damaging artefacts made from paper textiles and wood, one of the most interesting roles of ion beams is in analysing artworks and ancient artefacts to determine their composition, origin and age.

WHAT'S NEEDED: SMALLER, MORE PORTABLE ACCELERATORS ARE REQUIRED TO EXPLOIT FULLY THE BENEFITS OF ELECTRON AND ION BEAMS, TOGETHER WITH A BETTER UNDERSTANDING OF THEM AMONG POTENTIAL USERS AND THE PUBLIC.

ENERGY

ADVANCED NUCLEAR POWER IS AN ESSENTIAL COMPONENT OF FUTURE SUSTAINABLE ENERGY GENERATION. ACCELERATOR-BASED TECHNOLOGIES CAN CONTRIBUTE TO REDUCING ITS ENVIRONMENTAL IMPACT AND TO DEVELOPING INNOVATIVE SOLUTIONS.

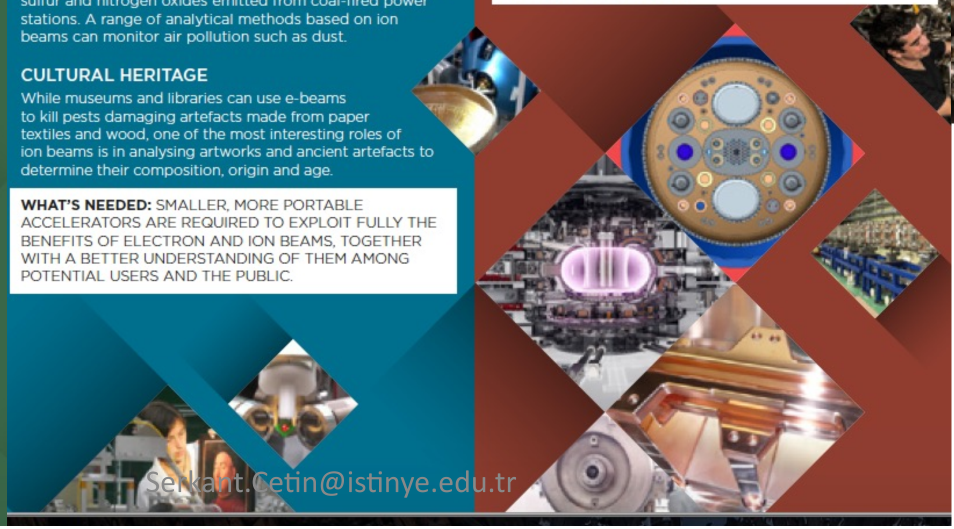
DESTROYING LONG-LIVED RADIOACTIVE WASTE

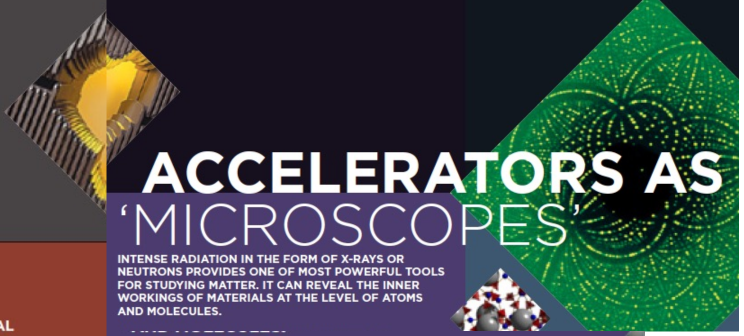
One of the main objections to nuclear energy based on uranium and plutonium fission is that it also creates very radio-toxic long-lived waste. However, a solution is now being studied, in which fast-moving neutrons created in a target by a proton accelerator cause further fission reactions in the waste, leading to shorter-lived products that are thus more manageable.

MAKING NUCLEAR FUSION A REALITY

The nuclear fusion of hydrogen isotopes, deuterium and tritium, to generate helium, neutrons and energy offers the prospect of limitless, cheap, safe power, and the development of a fusion reactor is a major, long-term, global research effort. Neutral ion beams play a crucial role in these reactors. In addition, an important aspect of this work is to probe the damage to reactor materials caused by the fusion process. This is being studied using an accelerator-based source of neutrons to mimic reactor conditions.

WHAT'S NEEDED: BOTH NUCLEAR FISSION AND FUSION RESEARCH REQUIRE CONTINUED INVESTMENT IN POWERFUL PROTON ACCELERATORS AND THEIR TECHNOLOGY.





ACCELERATORS AS 'MICROSCOPES'

INTENSE RADIATION IN THE FORM OF X-RAYS OR NEUTRONS PROVIDES ONE OF MOST POWERFUL TOOLS FOR STUDYING MATTER. IT CAN REVEAL THE INNER WORKINGS OF MATERIALS AT THE LEVEL OF ATOMS AND MOLECULES.

When a beam of X-rays or neutrons impinges on a material, they penetrate and are reflected, or scattered, off the arrays of the constituent atoms to give a scattering pattern characteristic of their arrangement. Any atomic and molecular motions, or energy changes, can be detected from changes in energy of the scattered beam.

X-ray and neutron scattering are employed to study a very wide variety of materials, from fuel-cell catalysts and photovoltaics, through advanced magnetic, electronic and engineering materials, to plastics and cleaning products. One of the most important uses is in biology and medicine to understand better the structure and behaviour of large molecules like DNA and proteins. Without these studies, many of the advances in medicine today would not have been possible.

X-rays and neutrons represent complementary tools because they interact with atoms slightly differently, so give different information.

The modern production of both X-rays and neutrons relies on large, powerful accelerators, which are installed in facilities that can be accessed by many user communities. Much research is now going into improved and novel designs to benefit scientific progress.

X-RAY GENERATION

SYNCHROTRON SOURCES

Large ring-shaped accelerators called synchrotrons, which accelerate electron beams, deliver extremely bright X-ray beams. As the electrons circulate around the ring, they emit the radiation at all wavelengths. The radiation is focused, and selected wavelengths are siphoned off to experimental areas.

FREE-ELECTRON LASERS

A more coherent X-ray source called a free electron laser is now being developed in which electrons are accelerated in a linac, and made to jiggle and bounce back and forth so that they emit bursts of very intense radiation.

NEUTRON SOURCES

Neutron beams are created in a dedicated reactor, or via an accelerator setup that provides protons to knock out neutrons from a target. The latter, so-called spallation source offers a more sustainable and environmentally friendly way of generating future neutron sources.

WHAT'S NEEDED: MORE COMPACT X-RAY SOURCES AND SPALLATION NEUTRON SOURCES – AND MORE OF THEM – ARE NEEDED TO MEET THE HIGH DEMAND.

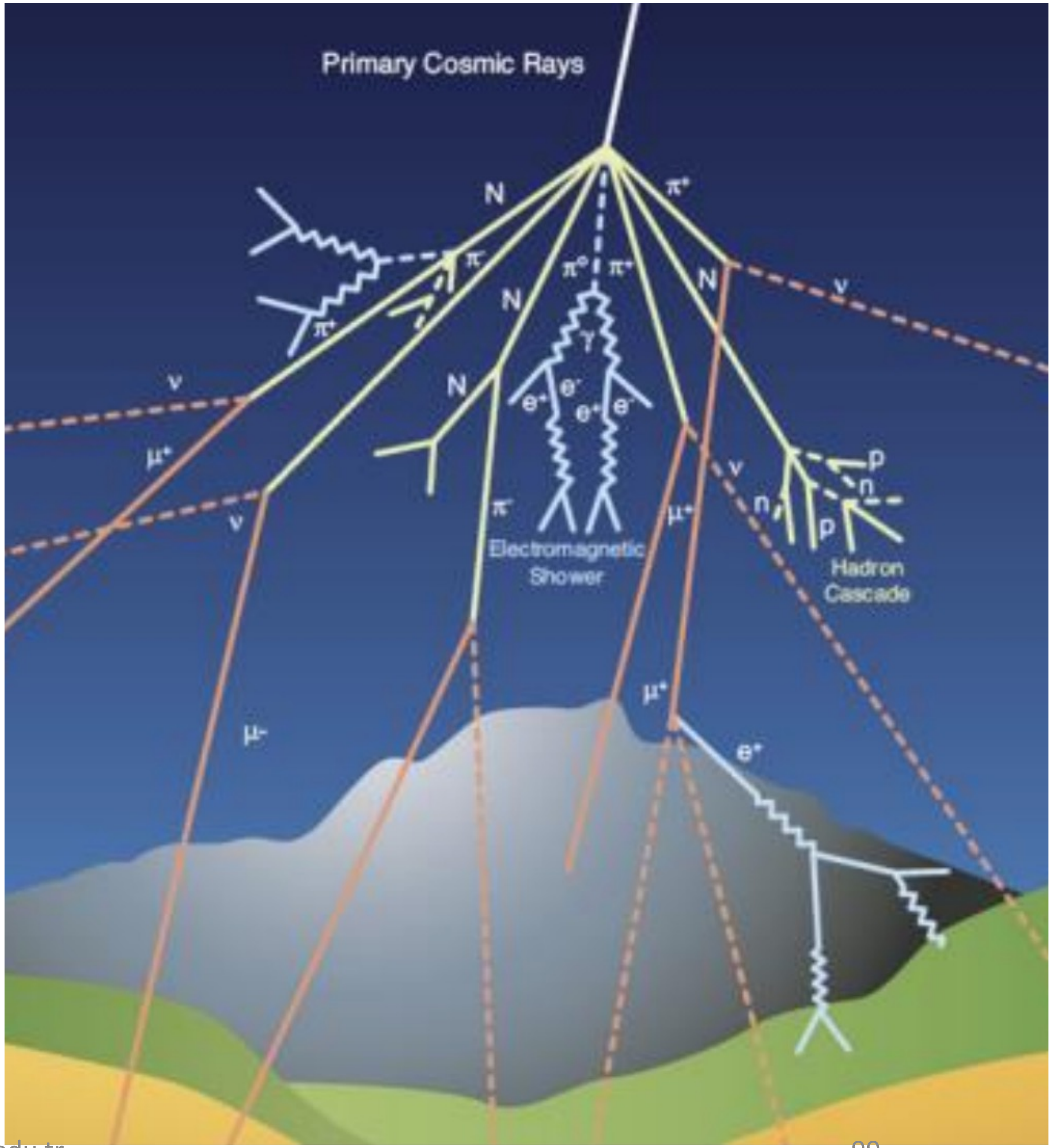
Muon Radiography and Muon Tomography

Muon radiography is a technique that uses information on the absorption of cosmic ray muons to measure the thickness of the materials crossed by the muons.

Primary cosmic rays, consisting mainly of protons and a small percentage of heavier nuclei, interact in the earth's atmosphere producing showers; muons, the decay products of pions, are higly penetrative and reach us; 10000 muons/(minute m^2) hit the ground; typically one muon per second goes through a surface the size of our hand; 600 muons cross our body every minute.

Muon radiography tracks the number of muons that pass through the target volume to determine the density on the inaccessible internal structure, and in this way find empty spaces.

It is similar to imaging with X-rays but can survey much larger objects. Since muons are less likely to interact, stop and decay in low density matter than high density matter, a larger number of muons will travel through the low density regions of target objects in comparison to higher density regions.



Muon radiography to study pyramids

Muon radiography was first used in 1971 to investigate the pyramid of Chefrten, in Giza, Egypt by Nobel laureate Luis Alvarez. Spark chambers were used. He found no evidence of void.

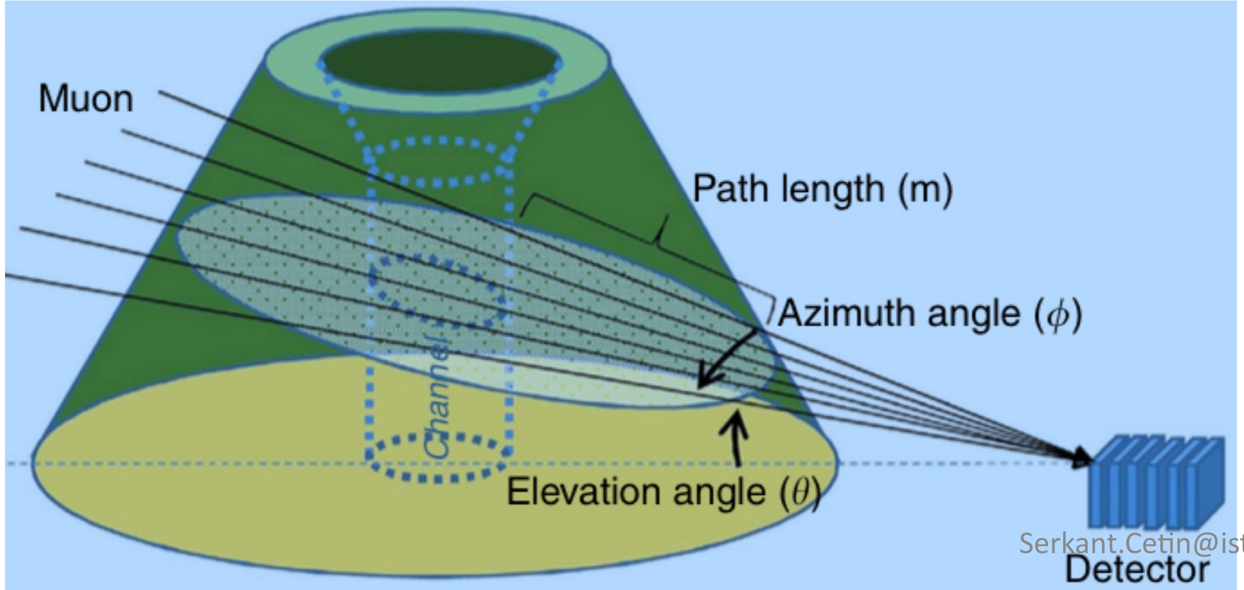
The ScanPyramids mission found a big void in the Great Pyramid (Khufu's Pyramid), above the Grand Gallery (Nature, 2017). It was observed with

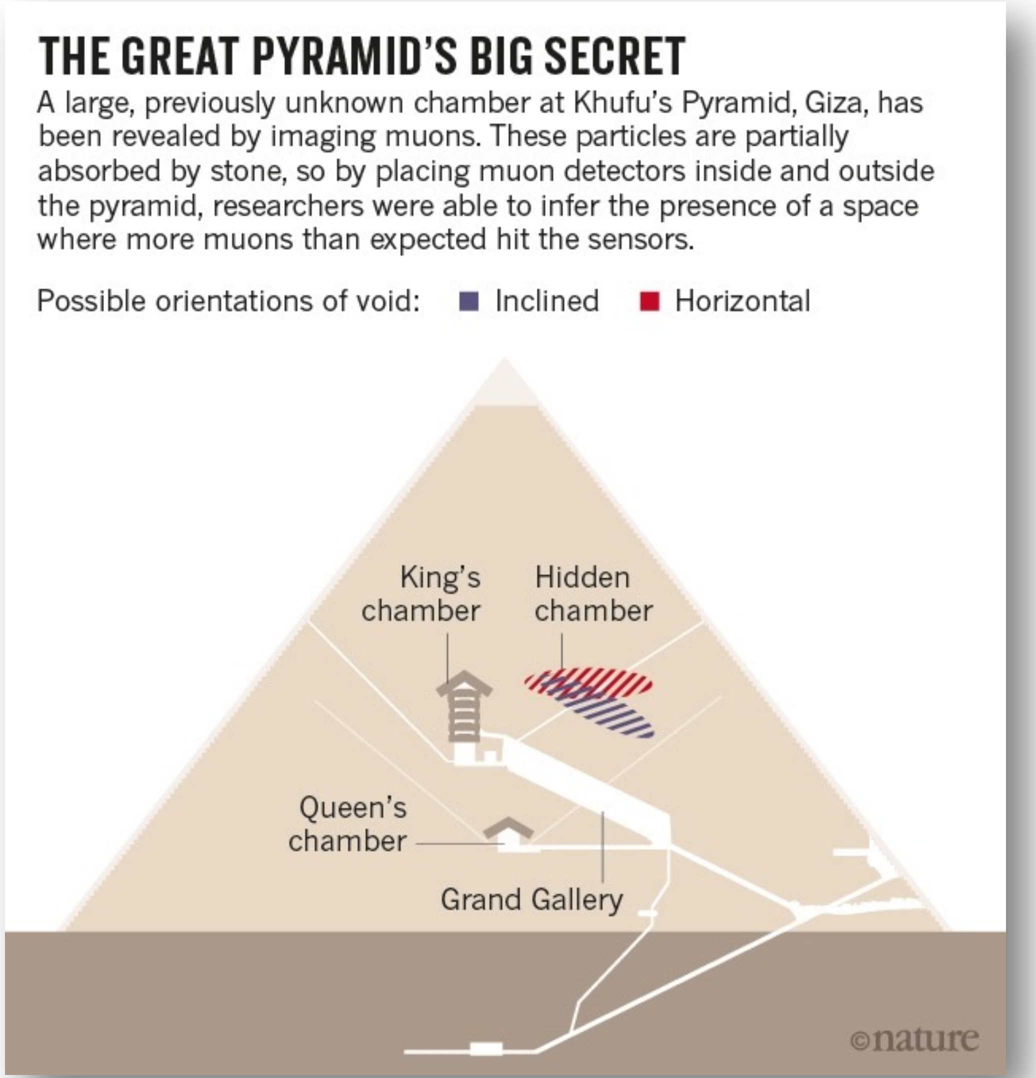
- **Nuclear Emulsion films (?)**
- Scintillator **hodoscopes (?)**

both inside the pyramid; reconfirmed with

- Gaseous chambers

outside the pyramid.

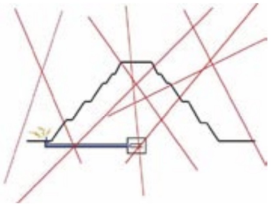




https://www.labroots.com/trending/chemistry-and-physics/7238/muon-tomography-help-finding-cavity-pyramid

https://youtu.be/ZB-MOGw0RMo

Physics in the service of Archeology

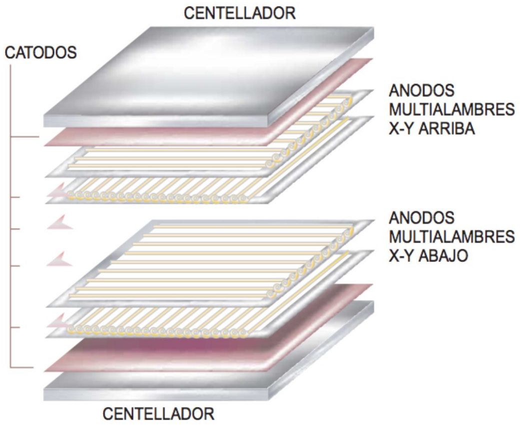


Looking for hiden chambers with muons

Ruben Alfaro-IFUNAM

IPPOG WG on Applications for Society - 4th meeting

Muon tracker

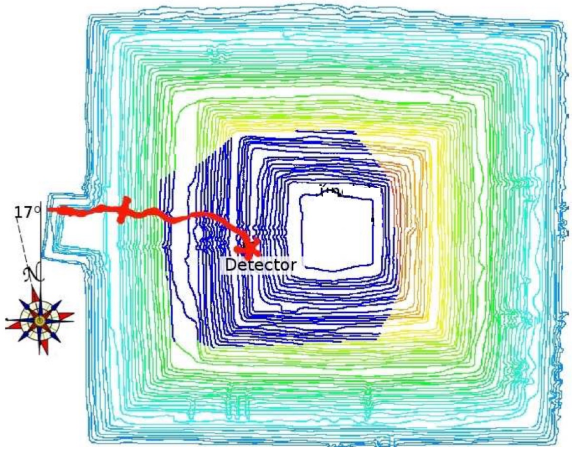


Hardware:

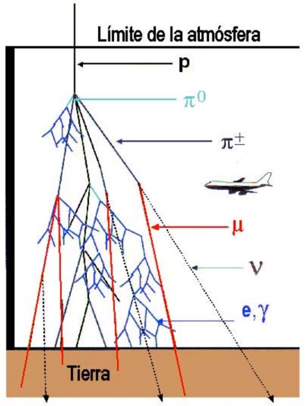
- 2 Scintillators
- 4 MWPC (2 X-Y planes)

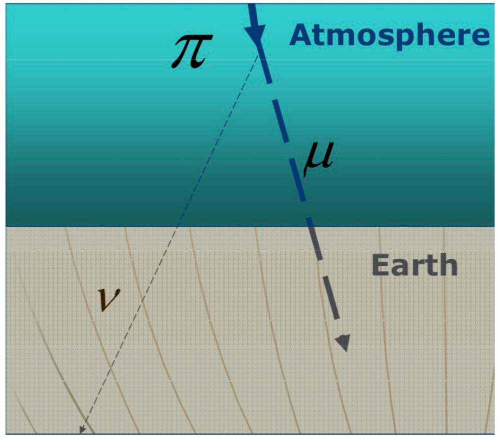
Detector Position

Blue contours Detector FOV



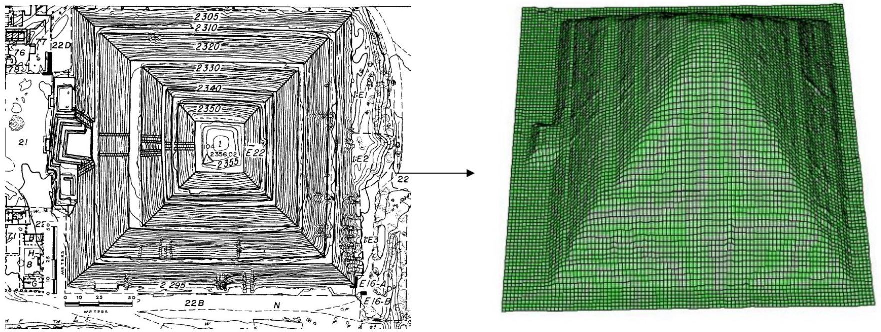
Muons as a radiation source



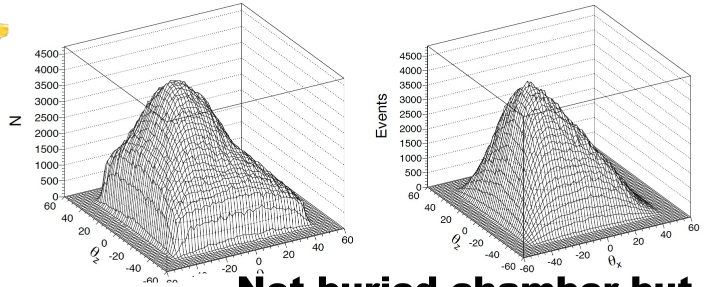


Simulation

CORSIKA
GEANT
3DField

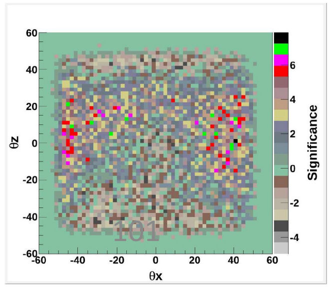


Simulation vs Data



Not buried chamber but ..

There is a density Asymmetry.
Could be because Less humidity in the soil?.



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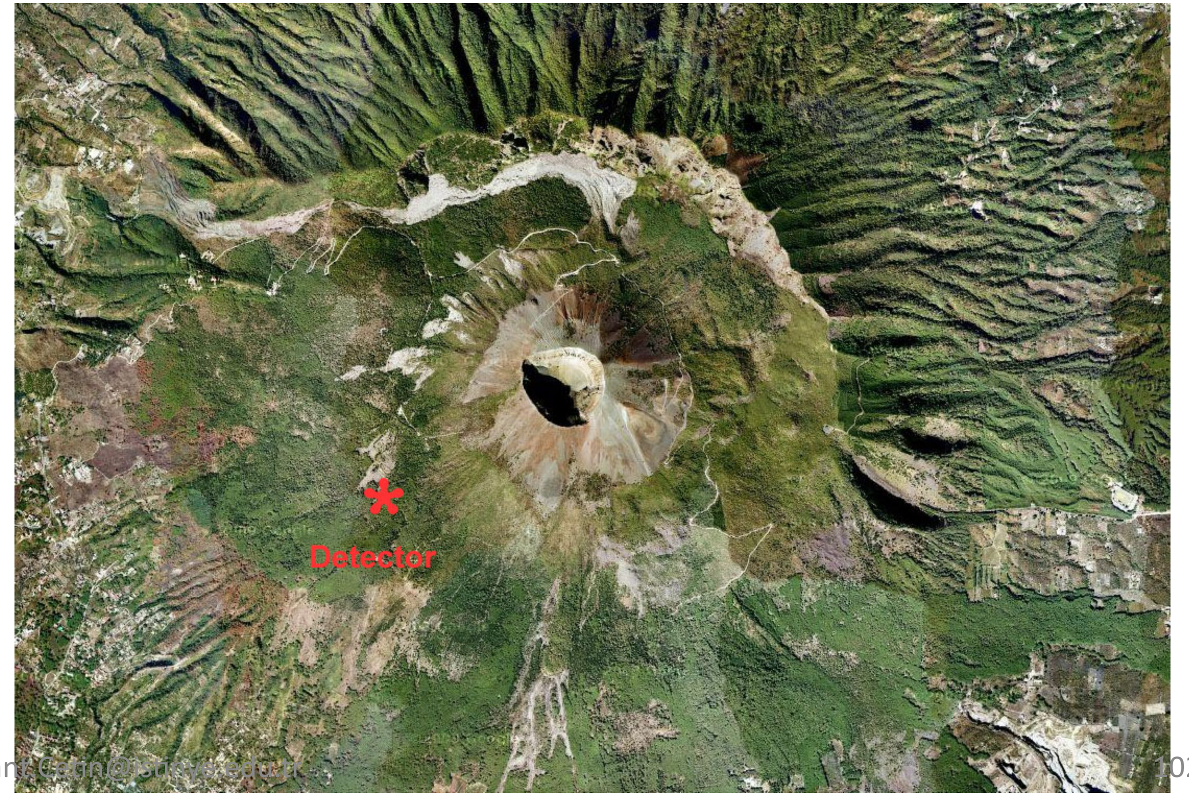
Volcanoes

Like X-ray scans of the human body, muon radiography allows to obtain an image of the internal structures of the upper levels of volcanoes. Although such an image cannot help to predict ‘when’ an eruption might occur, it can, if combined with other observations, help to foresee ‘how’ it could develop and serves as a powerful tool for the study of geological structures.

In 2007 Nagamine and Tanaka were the first to apply this technique for the study of volcanoes.



Volcanoes under study with muons:

- Vesuvius   Mu-Ray project
- Etna MeV project
- Stromboli

using nuclear emulsion films from OPERA

- Soufrière (Montserrat, Guadeloupe)
- Puy de Dôme (Massif Centrale)

TOMUVOL Collaboration

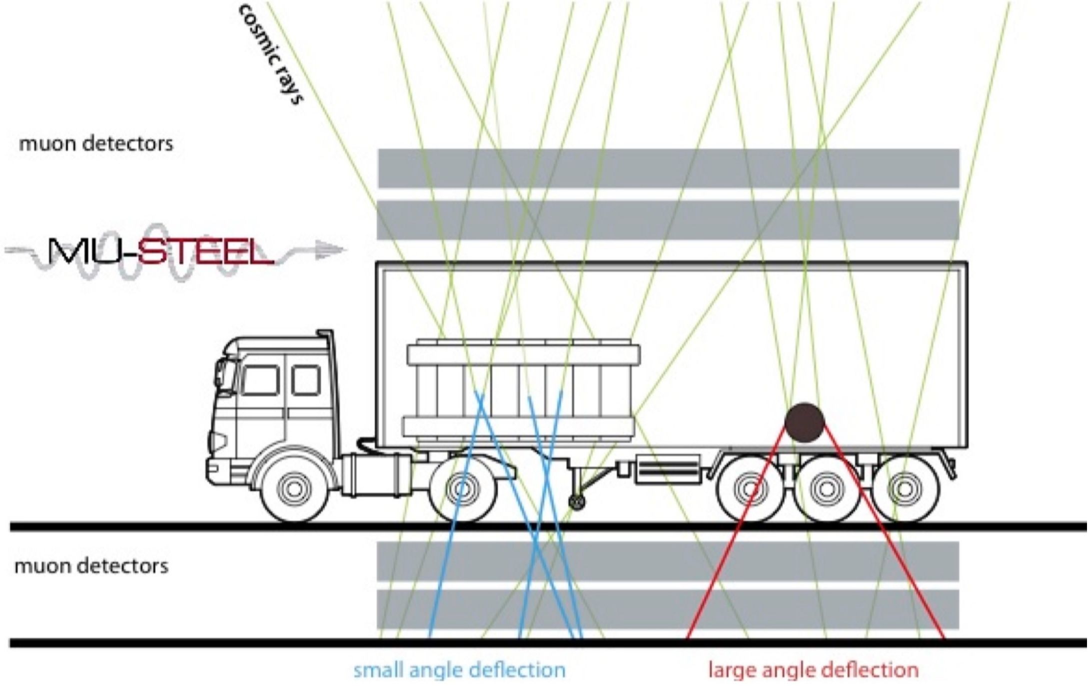
- Satsuma-Iwojima (Japan)

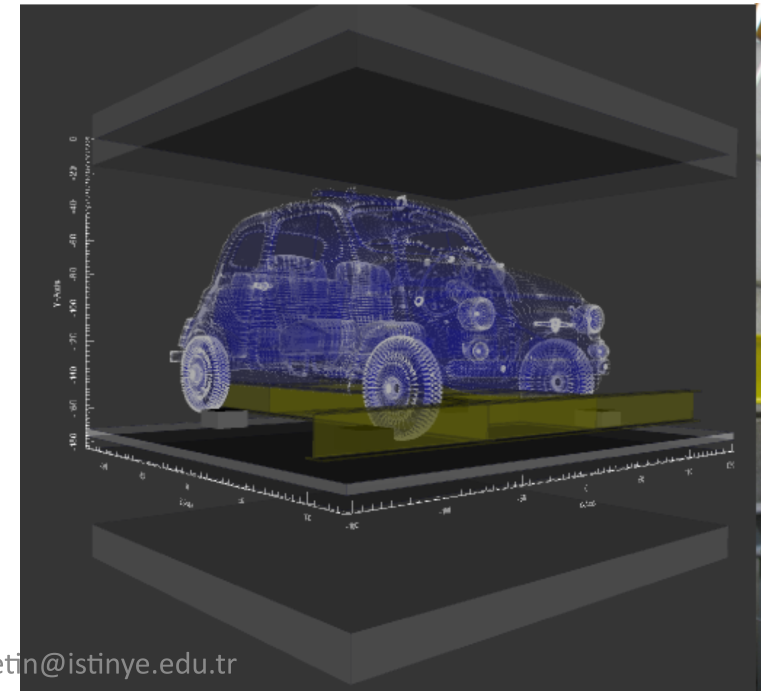
Muon scattering tomography

An extension of muon radiography based on muon absorption, muon scattering tomography, is based on the multiple Coulomb scattering of muons crossing the volume under investigation.

Muons are deflected and slow down when they interact with a material with high atomic number.

Using tracking detectors in front of and behind the volume under study the deflection is measured and thus high-z objects localized





Further Muon Tomography Applications

Muon scattering tomography is suitable for scanning large volumes, and looking for high-density objects inside them.

- Security/Safety Cargo scanners to inspect the contents of trucks and containers
- Control of spent nuclear fuel deposits (without opening, no radiation risk)
- Study of the core of the Fukushima reactor plant
- Industry : Control of trucks when entering steel foundries to detect hidden radioactive sources
- Inspection of the inner structure of a blast furnace
- Precision measurements : Measuring the alignment of structures / stability of buildings

Some Useful links

General

https://en.wikipedia.org/wiki/Muography
https://en.wikipedia.org/wiki/Muon_tomography

Muography for the study of volcanoes

Muons reveal the interiors of volcanoes
https://cds.cern.ch/journal/CERNBulletin/2010/51/News%20Articles/1312698

The secret life of volcanoes: Using Muon Radiography
https://www.scienceinschool.org/2013/issue27/muons

Attraverso la roccia – la tecnologia della radiografia muonica
https://www.asimmetrie.it/attraverso-la-roccia

https://physicstoday.scitation.org/doi/abs/10.1063/PT.3.1829?journalCode=pto

The MU-RAY project :Volcano Radiography with cosmic-ray muons
https://www.sciencedirect.com/science/article/pii/S0168900210014890?via%3Dihub

STROMBOLI: REALIZZATA LA PRIMA RADIOGRAFIA MUONICA DEL VULCANO
http://home.infn.it/it/comunicazione/comunicati-stampa/3536-stromboli-realizzata-la-prima-radiografia-muonica-del-vulcano

First muography of the Stromboli Volcano
https://www.nature.com/articles/s41598-019-43131-8

The MEV project: design and testing of a new high-resolution telescope for Muography of Etna Volcano
https://inspirehep.net/literature/1675335

http://wwwobs.univ-bpclermont.fr/tomuvol/presentation.php

Muography for the study of Pyramids

http://www.scanpyramids.org
https://www.sciencesetavenir.fr/archeo-paleo/archeologie/egypte-de-l-infrarouge-et-des-muons-pour-sonder-le-coeur-des-pyramides_103836

Cosmic-ray particles reveal secret chamber in Egypt's Great Pyramid
https://www.nature.com/news/cosmic-ray-particles-reveal-secret-chamber-in-egypt-s-great-pyramid-1.22939#/graphic

Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons
https://www.nature.com/articles/nature24647.epdf?

Muon Scattering Tomography

Progress in Muon Tomography (G. Bonomi, EPS conf.2017)
https://indico.cern.ch/event/466934/contributions/2524834/attachments/1490162/2316412/progress_in_muon_tomography_EPS-2017.pdf

https://cms.cern/content/muon-tomography

Cosmic Muon Tomography Project
http://mutomweb.pd.infn.it:5210

Medical Applications

Mars Bioimaging

First 3D colour X-ray of a human using CERN technology

Medipix is a family of **read-out chips for particle imaging and detection**. The original concept of Medipix is that it works like a camera, detecting and counting each individual particle hitting the pixels when its electronic shutter is open. This enables high-resolution, high-contrast, very reliable images, making it unique for imaging applications in particular in the medical field.

Hybrid pixel-detector technology was initially developed to address the needs of particle tracking at the Large Hadron Collider, and successive generations of Medipix chips have demonstrated over 20 years the great potential of the technology outside of high-energy physics.

MARS Bioimaging Ltd, which is commercialising the 3D scanner, is linked to the Universities of Otago and Canterbury. The latter, together with more than 20 research institutes, forms the third generation of the Medipix collaboration. The Medipix3 chip is the most advanced chip available today; *this technology sets the machine apart diagnostically because its small pixels and accurate energy resolution mean that this new imaging tool is able to get images that no other imaging tool can achieve.*

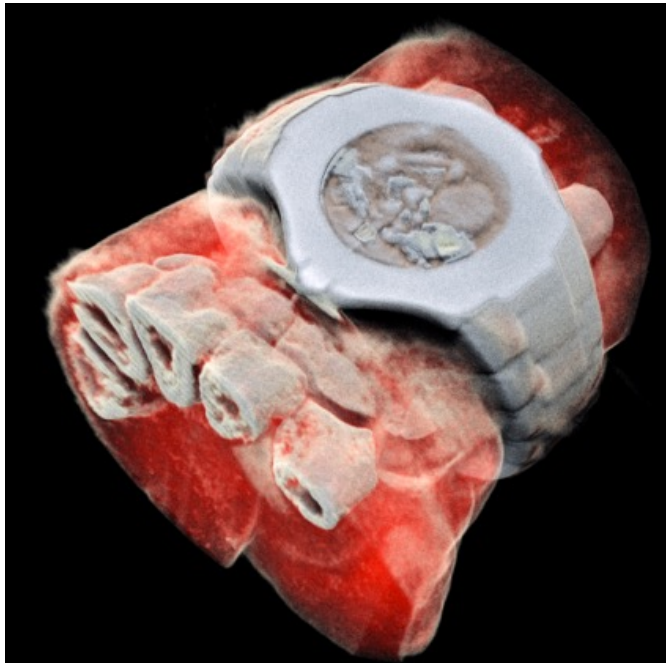


Image: Mars Bioimaging

MARS' solution couples the spectroscopic information generated by the Medipix3 enabled detector with powerful algorithms to generate 3D images. The colours represent different energy levels of the X-ray photons as recorded by the detector and hence identifying different components of body parts such as fat, water, calcium, and disease markers.