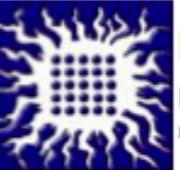




Центар за
промоцију
науке



Физички
факултет,
Београд



Институт за
нуклеарне науке
"Винча", Београд



Институт за
физику,
Београд



Друштво
физичара
Србије

ATLAS EKSPERIMENT

Marija Vranješ Milosavljević

Nikhef Amsterdam

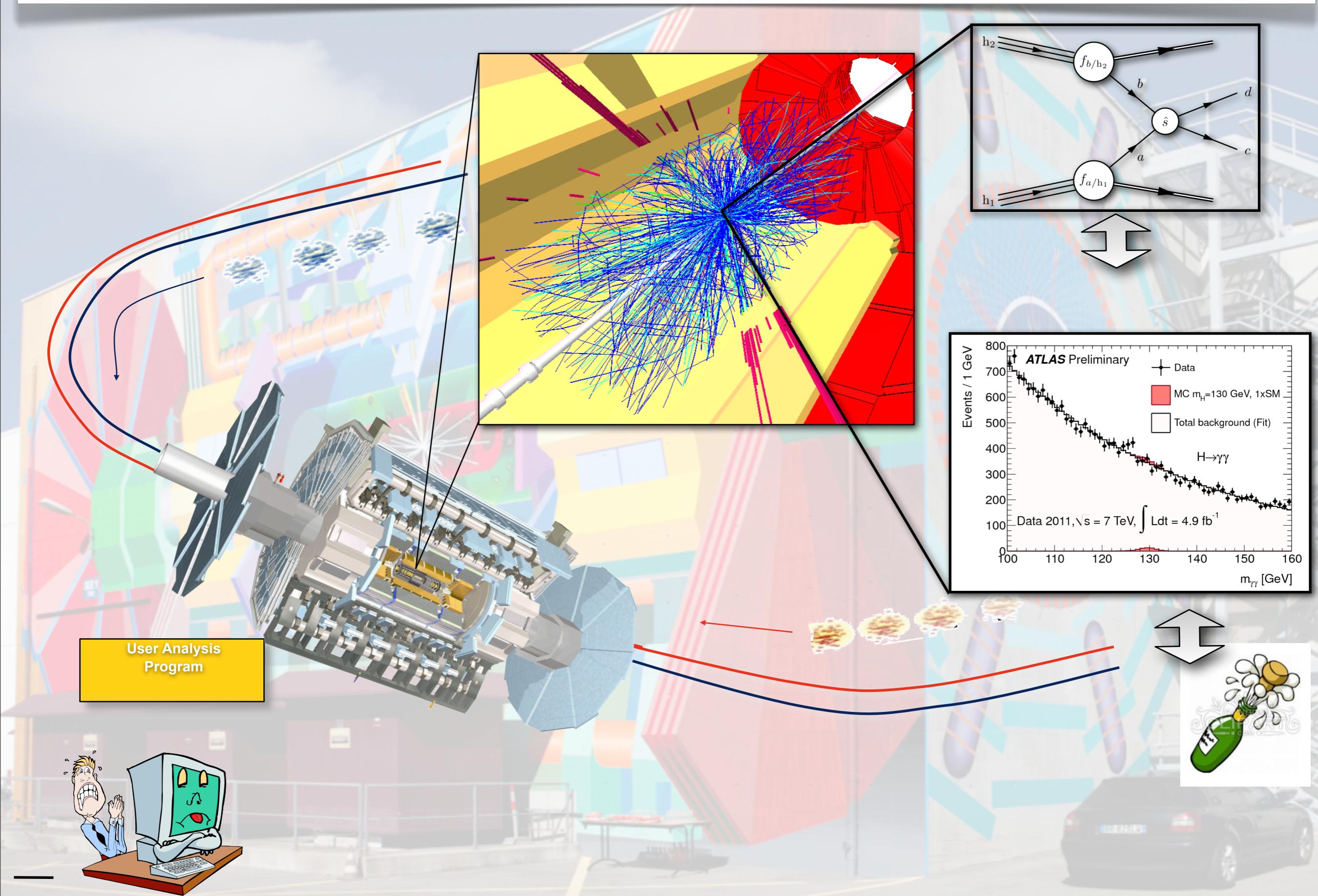
Institut za fiziku Beograd



INSTITUTE OF PHYSICS
BELGRADE



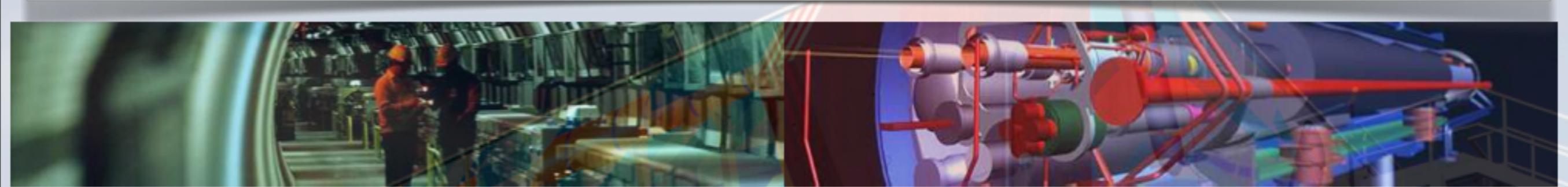
Od sudara do rezultata...



Od sudara do rezultata...

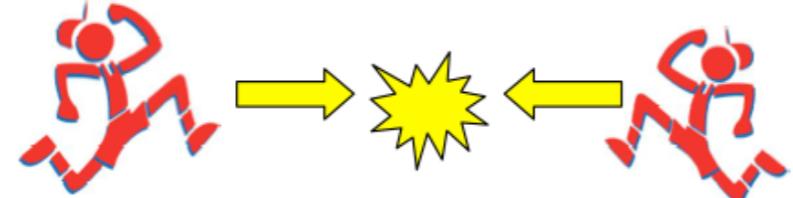


Kratko podsećanje...



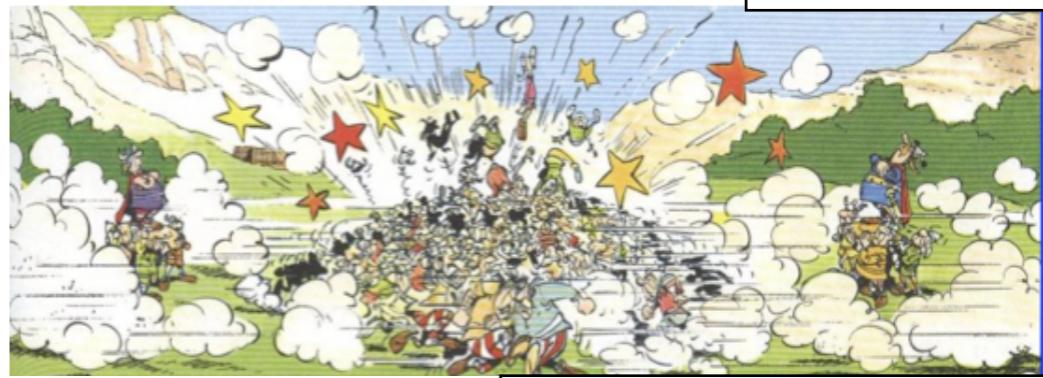
AKCELERATOR (SUDARAČ):

LEPTONSKI



precizno merenje

HADRONSKI



otkriće i precizno merenje



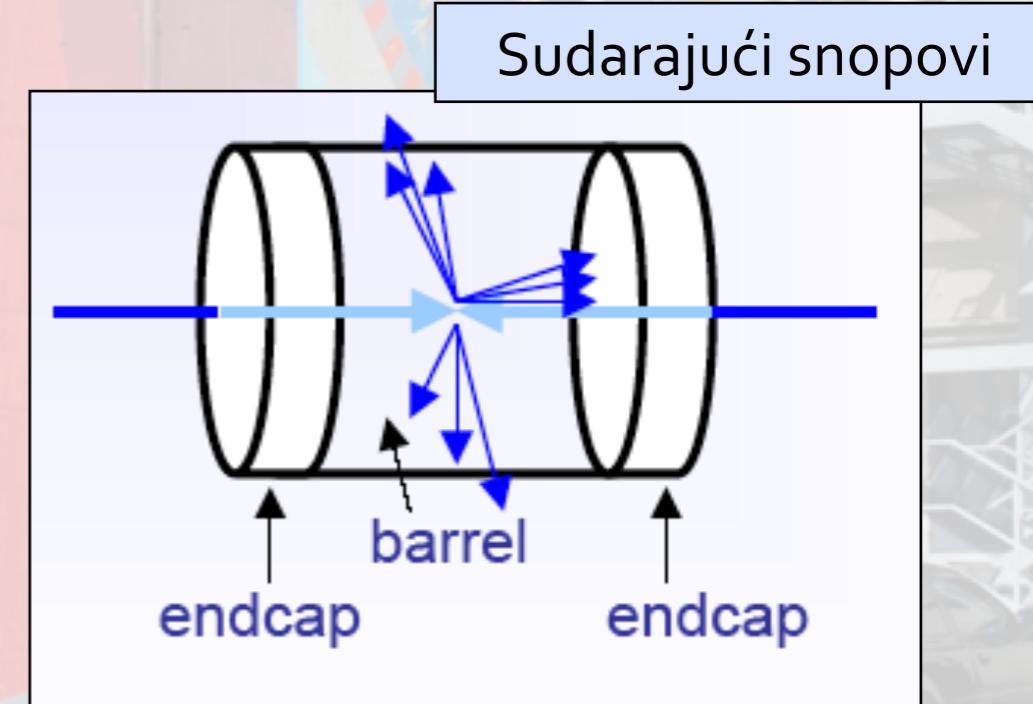
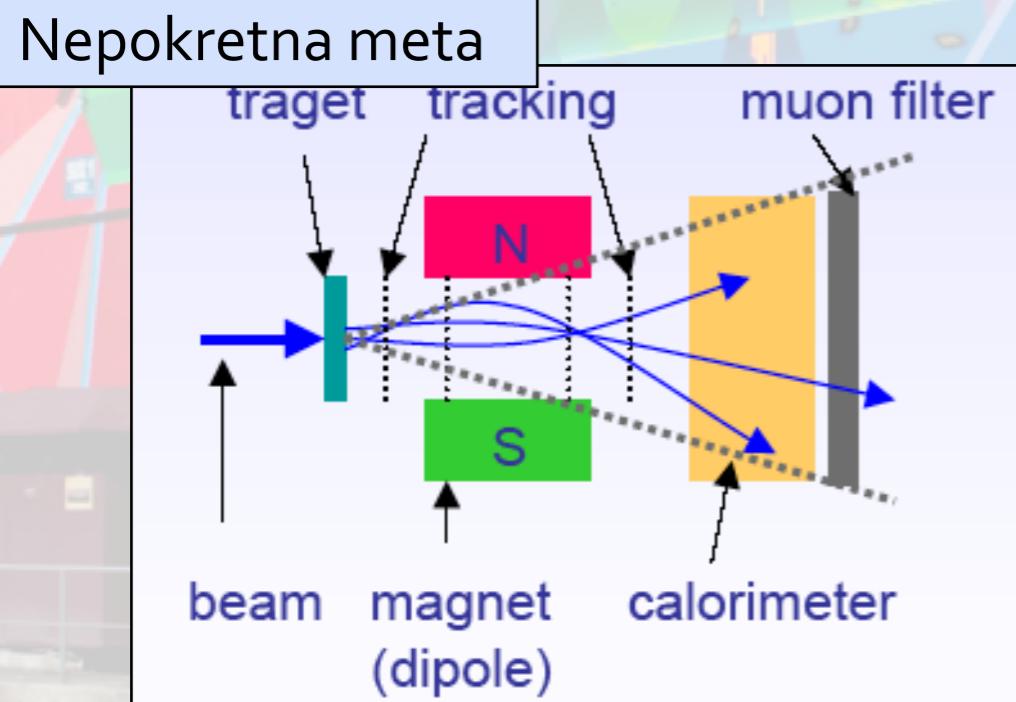
DETETKOR

Kako dizajniramo detektor?

Izgled detektora zavisi od:

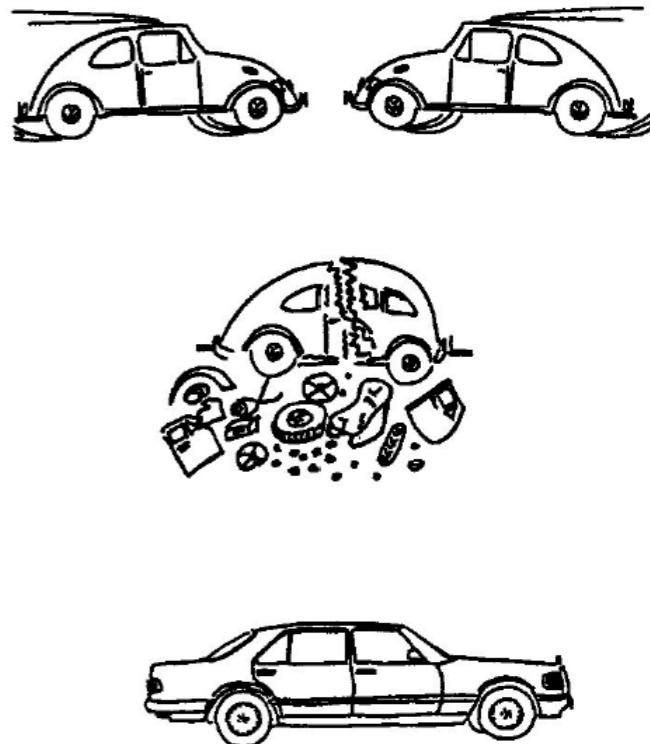
- broja čestica
- topologije događaja
- impulsa/energije
- tipova čestica
- ...

Jedan detektor? NE
Sistem detektora? DA

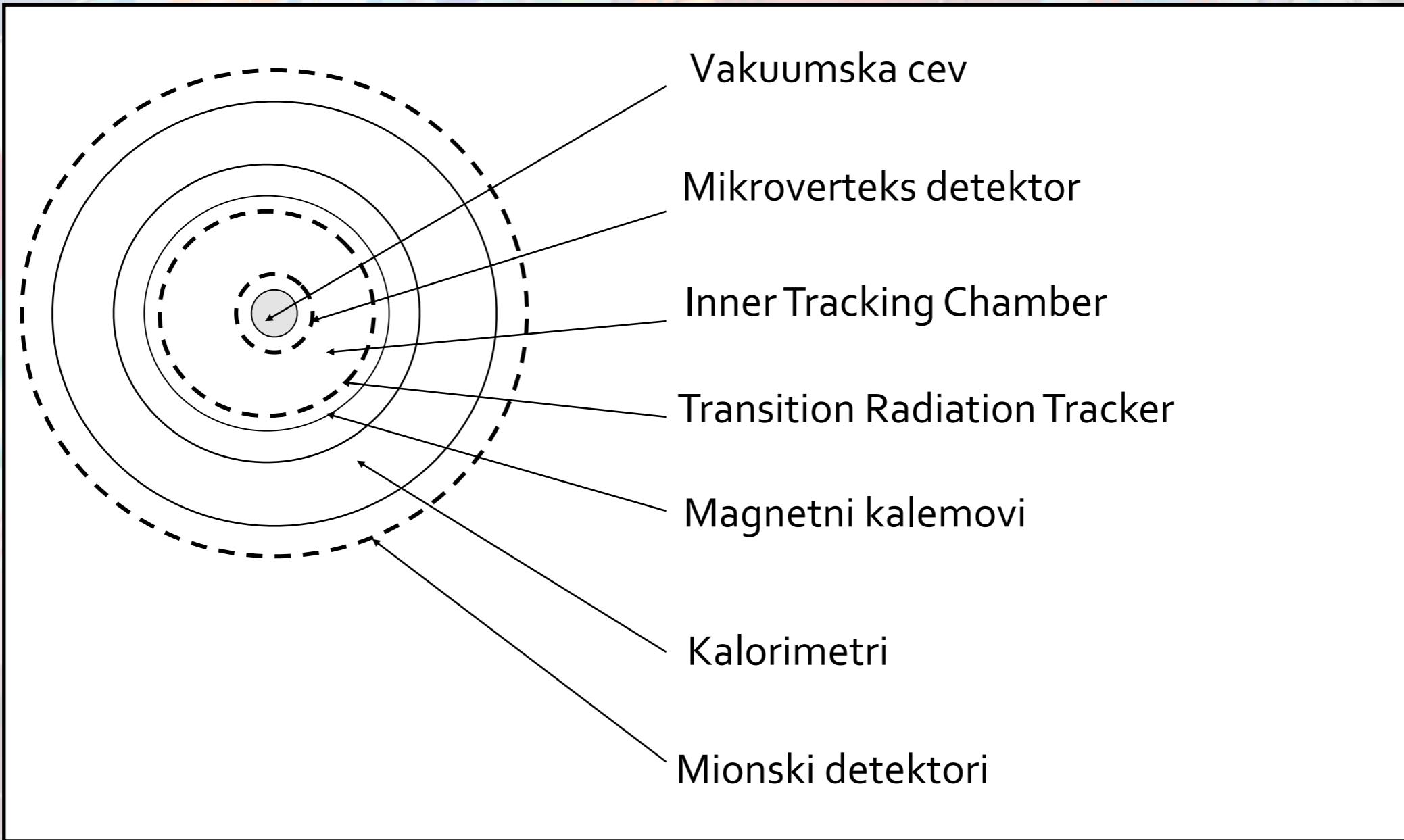


Sve počinje fizikom...

- ✓ Koja su fizička merenja (motivacija) primarna u eksperimentu
- ✓ Šta su finalna stanja (koje čestice)
- ✓ Koji nivo preciznosti želimo (preciznost → €, \$, £, Fr..)
- ✓ Kako izdvajamo (trigerujemo) relevantne događaje
- ✓ Koliko često se sudari dešavaju
 - ✓ trigger, data acquisition sistemi
 - ✓ mrtvo vreme detektora
 - ✓ kako kalibrirati detektor
 - ✓ kako meriti različite efikasnosti
- ✓ Osnovni zakoni:
 - ✓ održanje energije
 - ✓ održanje impulsa
 - ✓ $E=mc^2$
 - ✓ Naravno, postoje i druge jednačine koje koristimo, ovo su samo neki osnovni principi
- ✓ Šta naš detektor treba da meri?
 - ✓ poziciju, energiju, impuls čestica
- ✓ Poželjno je znati i:
 - ✓ tačno mesto interakcije
 - ✓ nanelektrisanja čestica
 - ✓ energiju inicijalnih čestica
 - ✓ ... i još mnogo toga ...



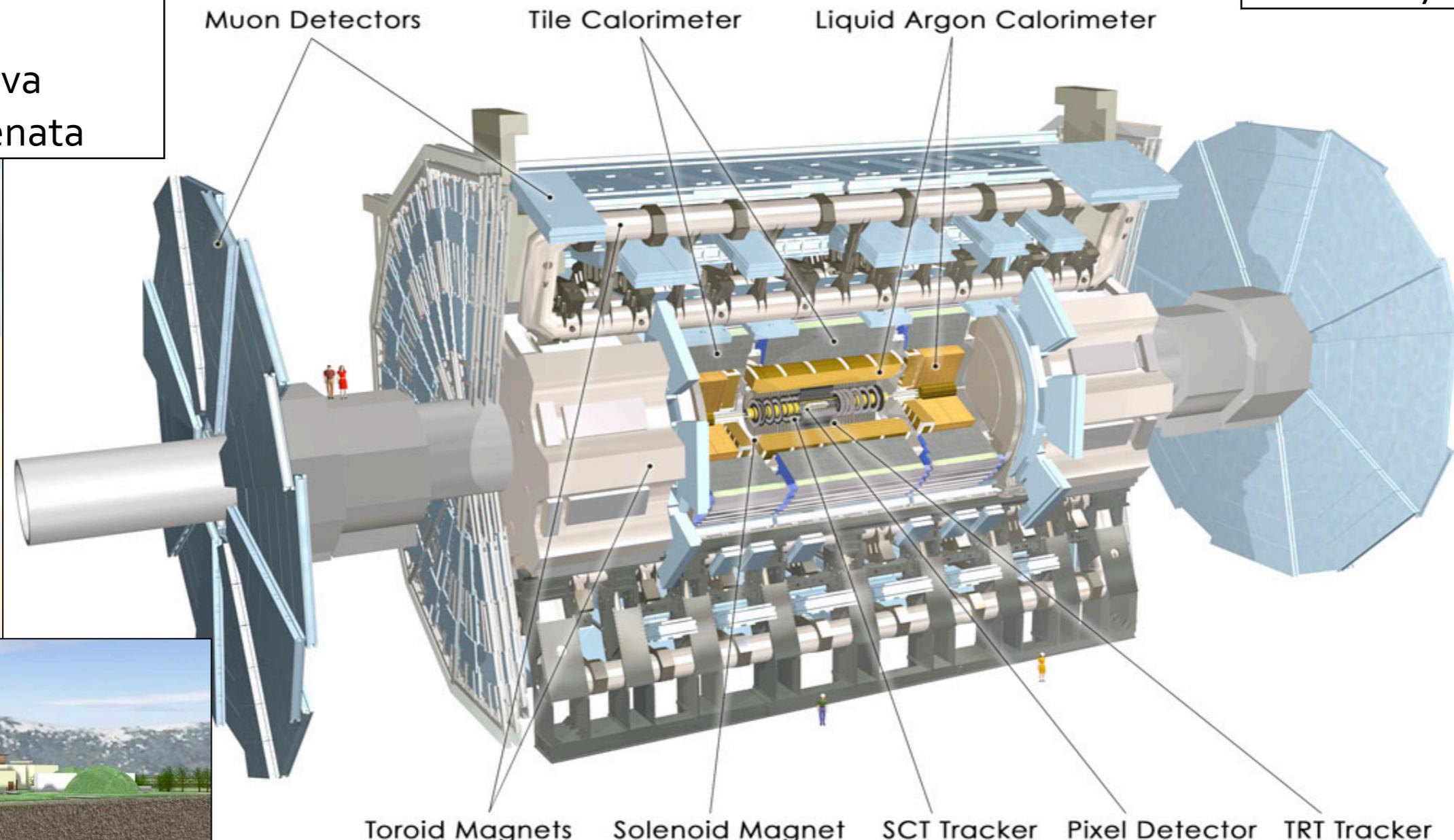
Koji su osnovni elementi detektora sa 4π geometrijom?



ATLAS - A Toroidal Lhc ApparatuS

- KOLABORACIJA:
- 38 zemalja
- 174 univerziteta i laboratorija
- ~3000 članova
- ~1000 studenata

- dužina = 45 m
- visina = 25 m
- težina = 7000 t



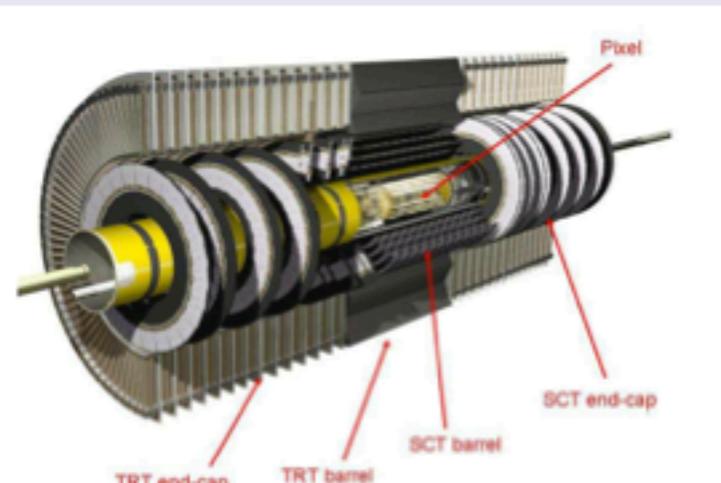
ATLAS - Point 1



ATLAS - detektorski sistemi

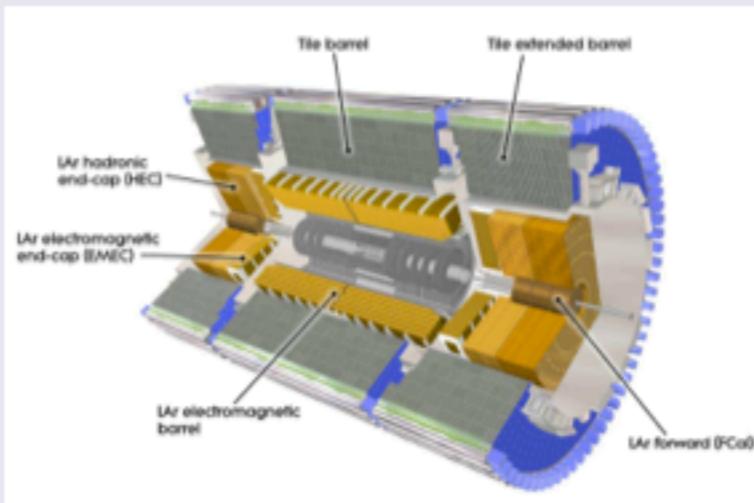
Inner detector

- pixel detector
- semiconductor Tracker
- transition radiation tracker



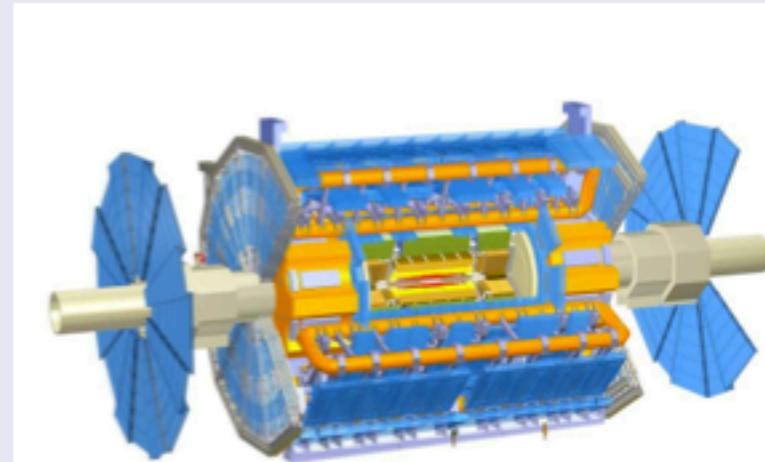
Calorimeter

- electromagnetic calorimeter
- hadronic calorimeter



Muon spectrometer

- MDT
- TGC
- CSC
- RPC

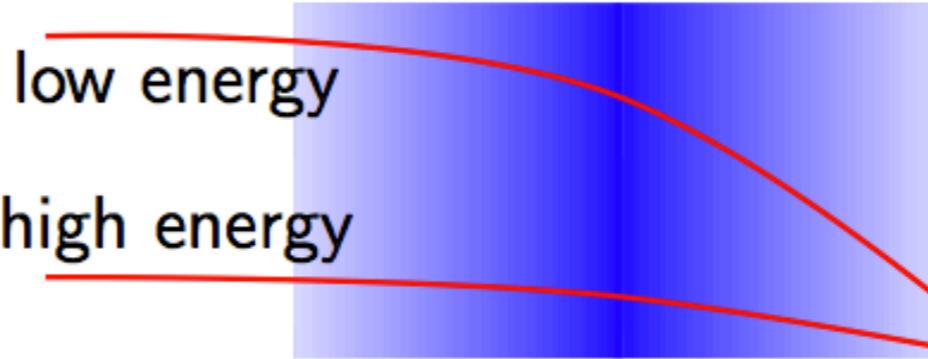
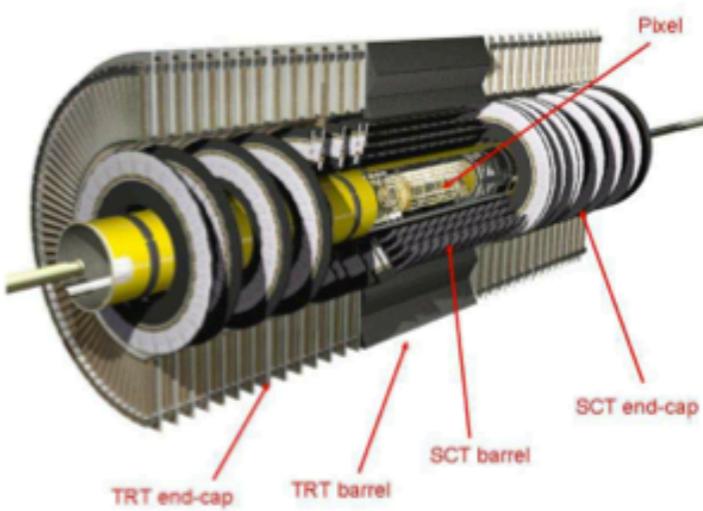


Magnetsni sistem

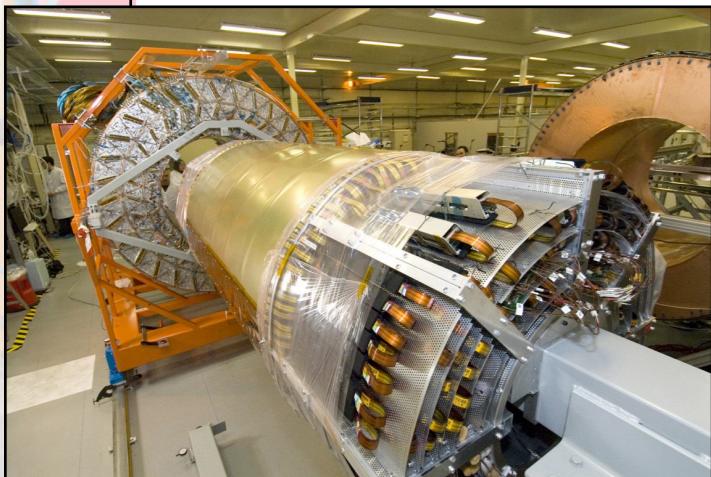
Inner detector (unutrašnji detektor)

☞ obuhvata liniju snopa, određuje trajektorije i meri impulse nanelektrisanih čestica

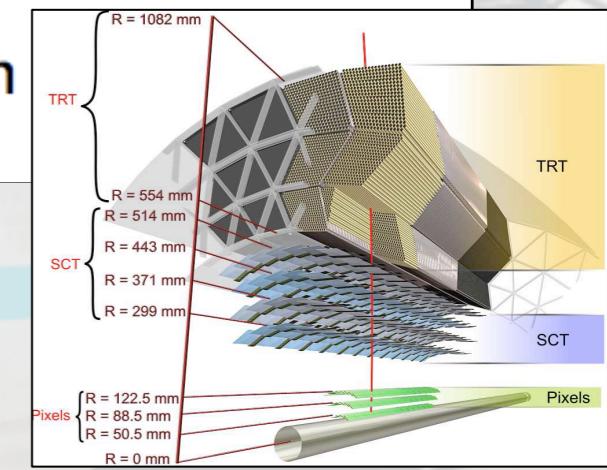
- $> 8 \cdot 10^7$ channels
- 10 cm - 1.2 m radius
- enclosed in a solenoid magnet



- pixel detector
 - tracking
- SCT - semiconductor tracker
 - tracking
- TRT - transition radiation tracker
 - tracking
 - particle identification

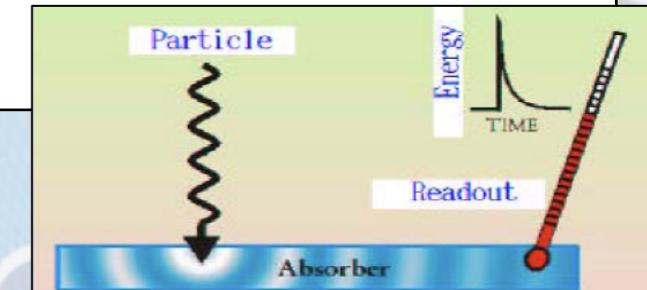


A diagram illustrating the magnetic deflection of particles. On the left, a U-shaped magnet with a North (N) pole on the left and a South (S) pole on the right is shown. A negatively charged electron (e^-) enters from the bottom left with 'lesser momentum' and exits with 'greater momentum' after being deflected upwards. On the right, a positively charged electron (e^+) enters from the bottom right with 'greater momentum' and exits with 'lesser momentum' after being deflected downwards. Below the diagrams, the Lorentz force equation is given as $\frac{dp}{dt} = \frac{q}{c} \mathbf{v} \times \mathbf{B}$ and the radius of curvature is given as $r = \frac{p_T}{0.3B}$.

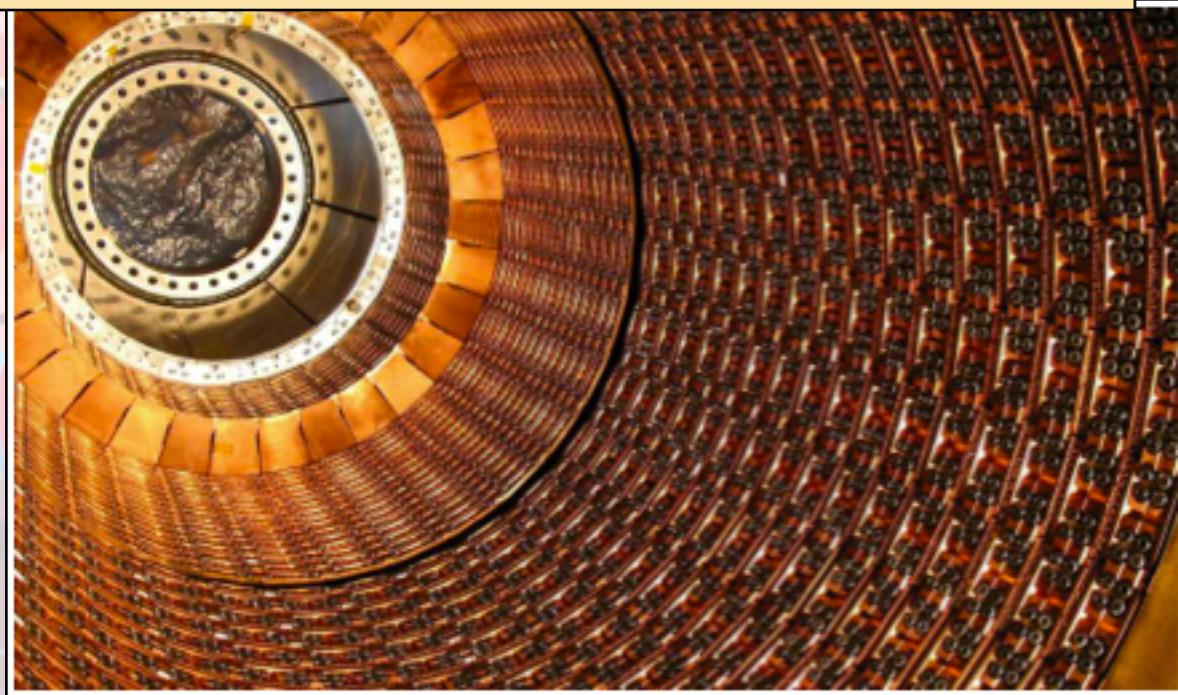


Calorimeter (kalorimetar)

- ☞ meri energiju naelektrisanih i neutralnih čestica; doprinosi određivanju nedostajuće energije.
- ☞ sastoji se iz metalnih ploča koje imaju ulogu apsorbera i iz senzorskih elemenata.
- ☞ interakcije na apsorberu izazvane upadnom česticom formiraju "pljusak čestica" koji se detektuje senzorskim elementima.



Elektromagnetski kalorimetar (liquid argon)



Hadronski kalorimetar (tile)



Muon spectrometer (mionski spektrometar)

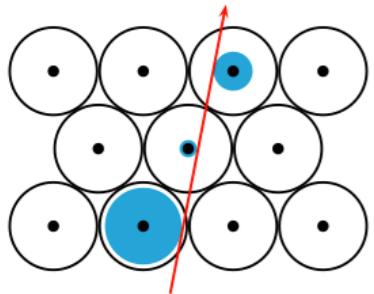
- the detector chambers
 - MDT monitored drift tubes
 - RPC resistive plate chambers
 - TGC thin gap chambers
 - CSC cathode strip chambers
- the magnet system
 - barrel toroid
 - endcap toroids
- alignment



MDT, RPC, TGT, CSC

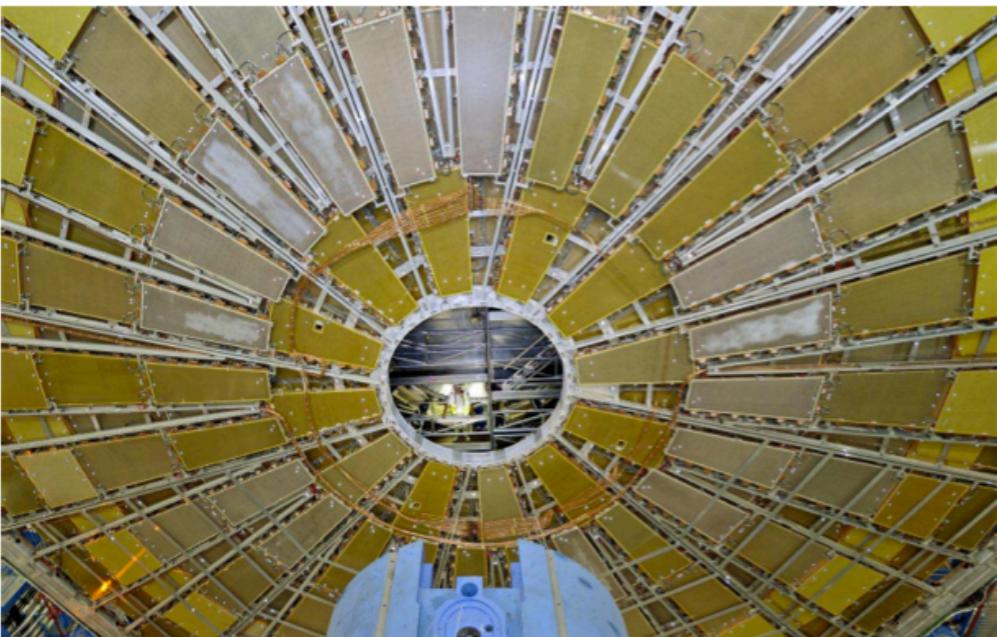
monitored drift tubes

purpose measure curvature of tracks
wire placement 15 μm
no. chambers 1171
no. tubes 354240



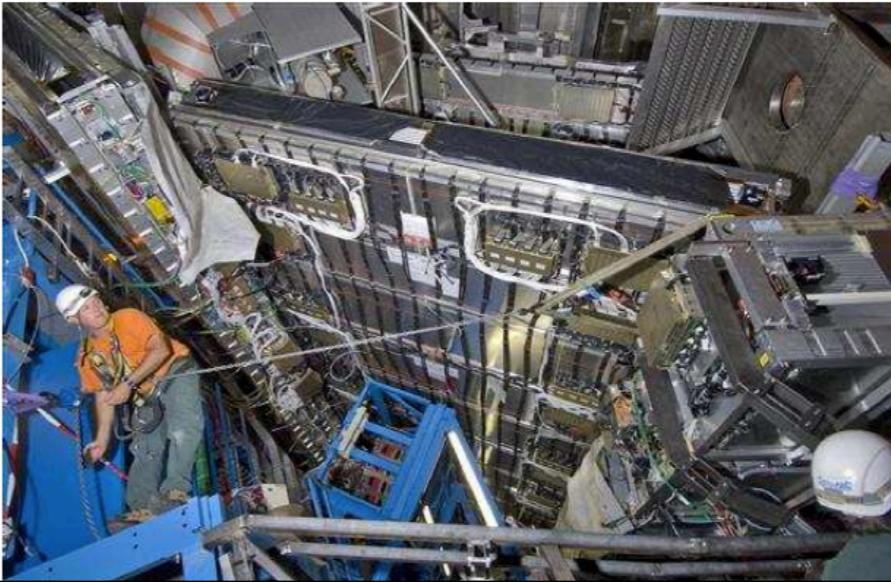
thin gap chambers

purpose triggering and 2nd coordinate measurement
no. channels 440000



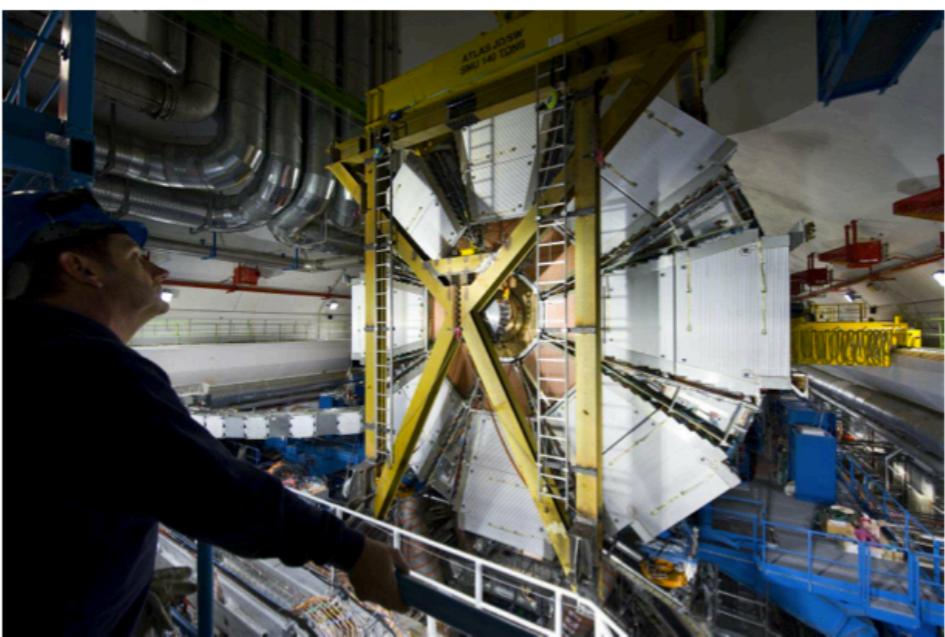
resistive plate chambers

purpose triggering and 2nd coordinate measurement
no. channels 380000



cathode strip chambers

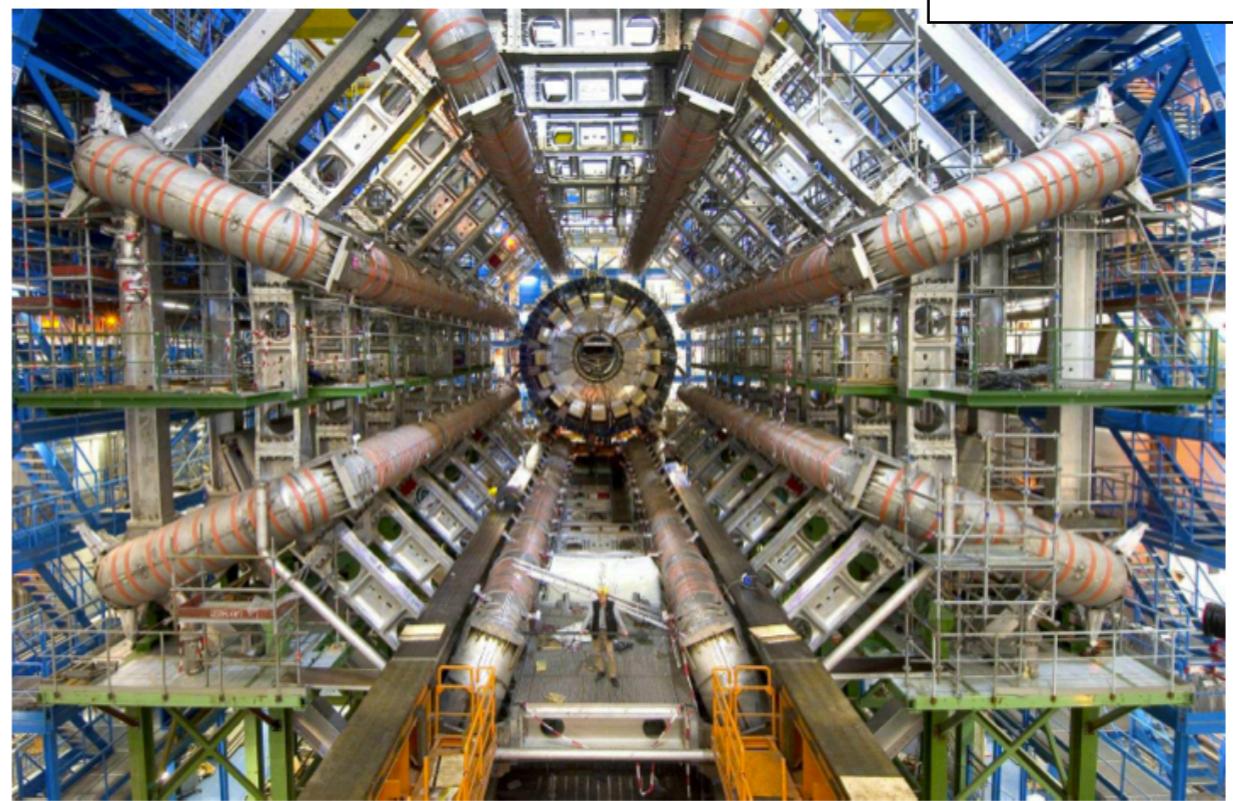
purpose precision measurement
no. channels 70000



Magnet system (sistem magneta); alignment

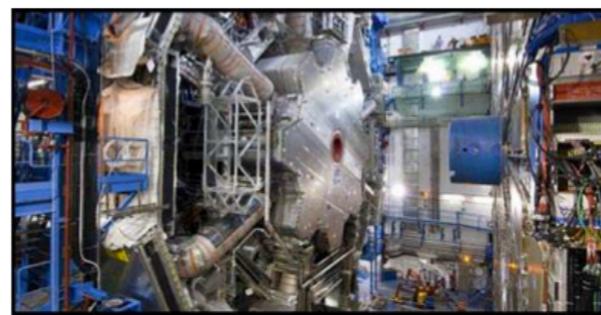
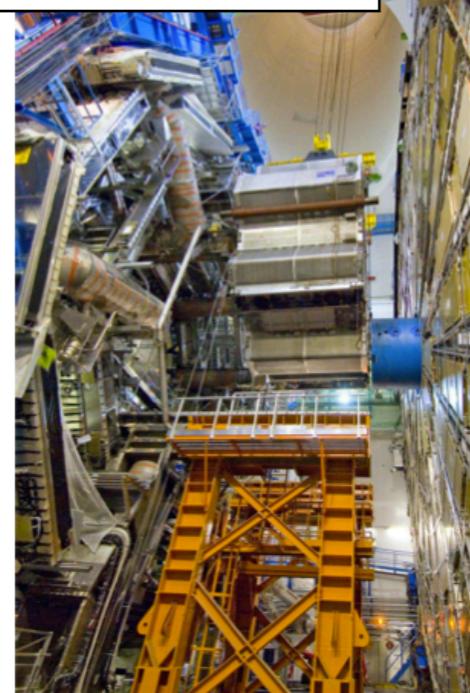


solenoid

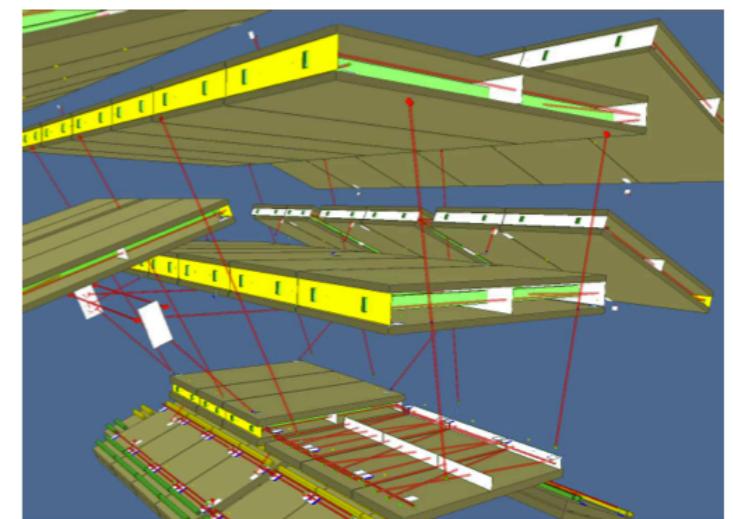


barrel toroid

end-cup toroids



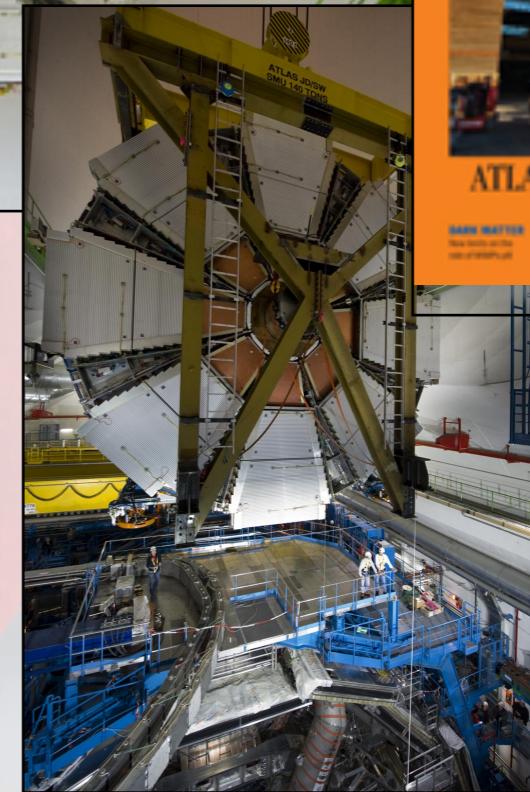
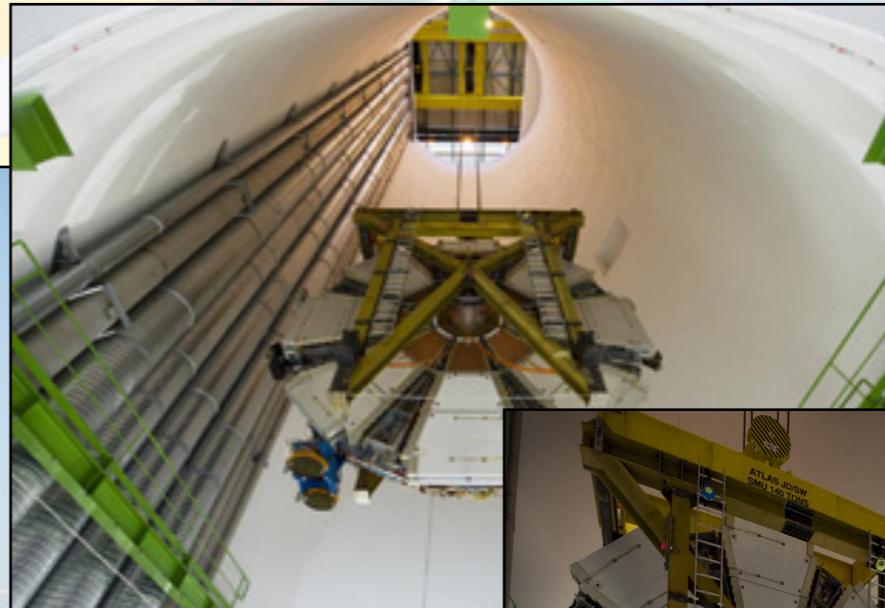
we require error on sagitta < 50 μm .



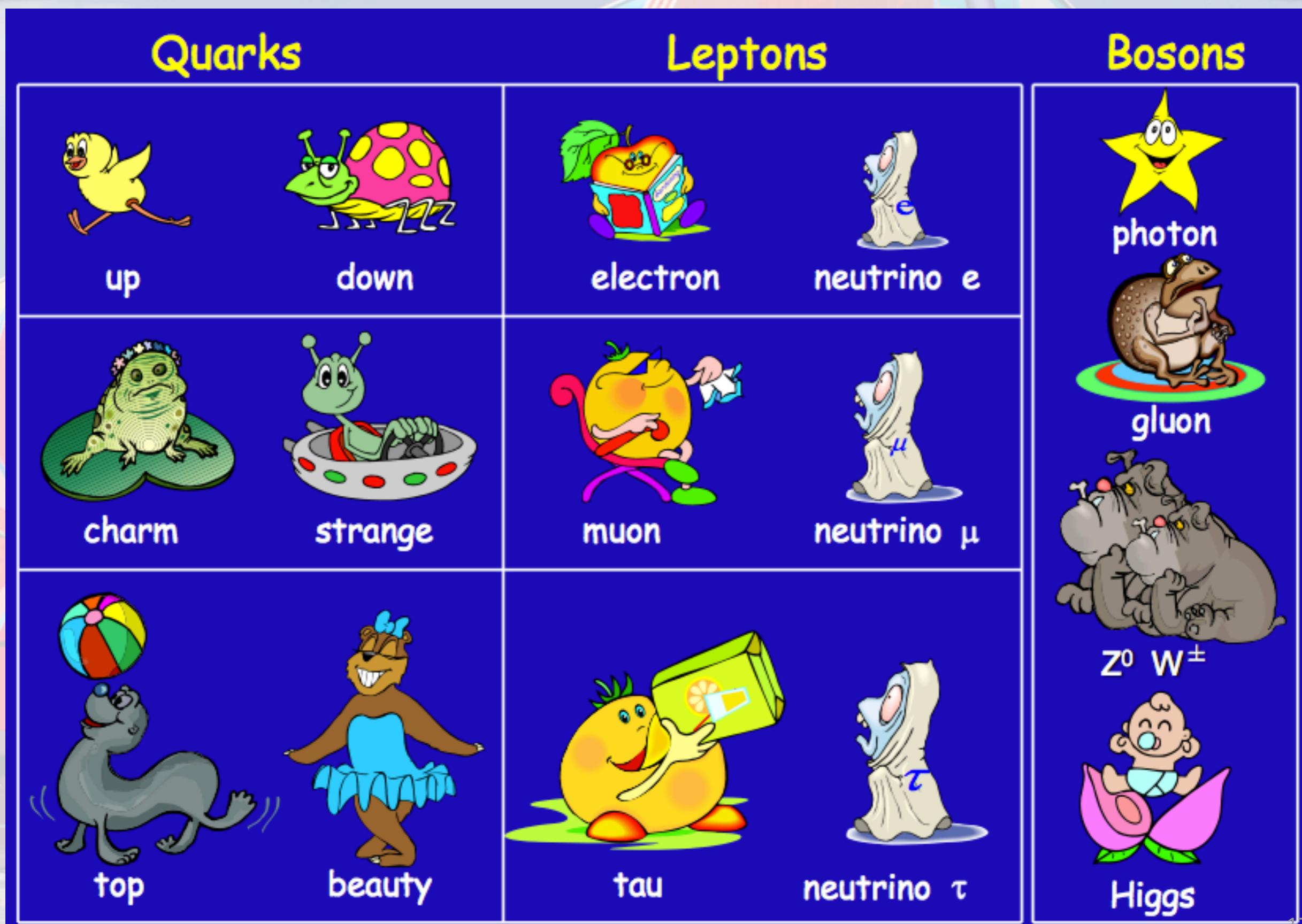
alignment

IPB - shielding system (sistem za zaštitu od zračenja)

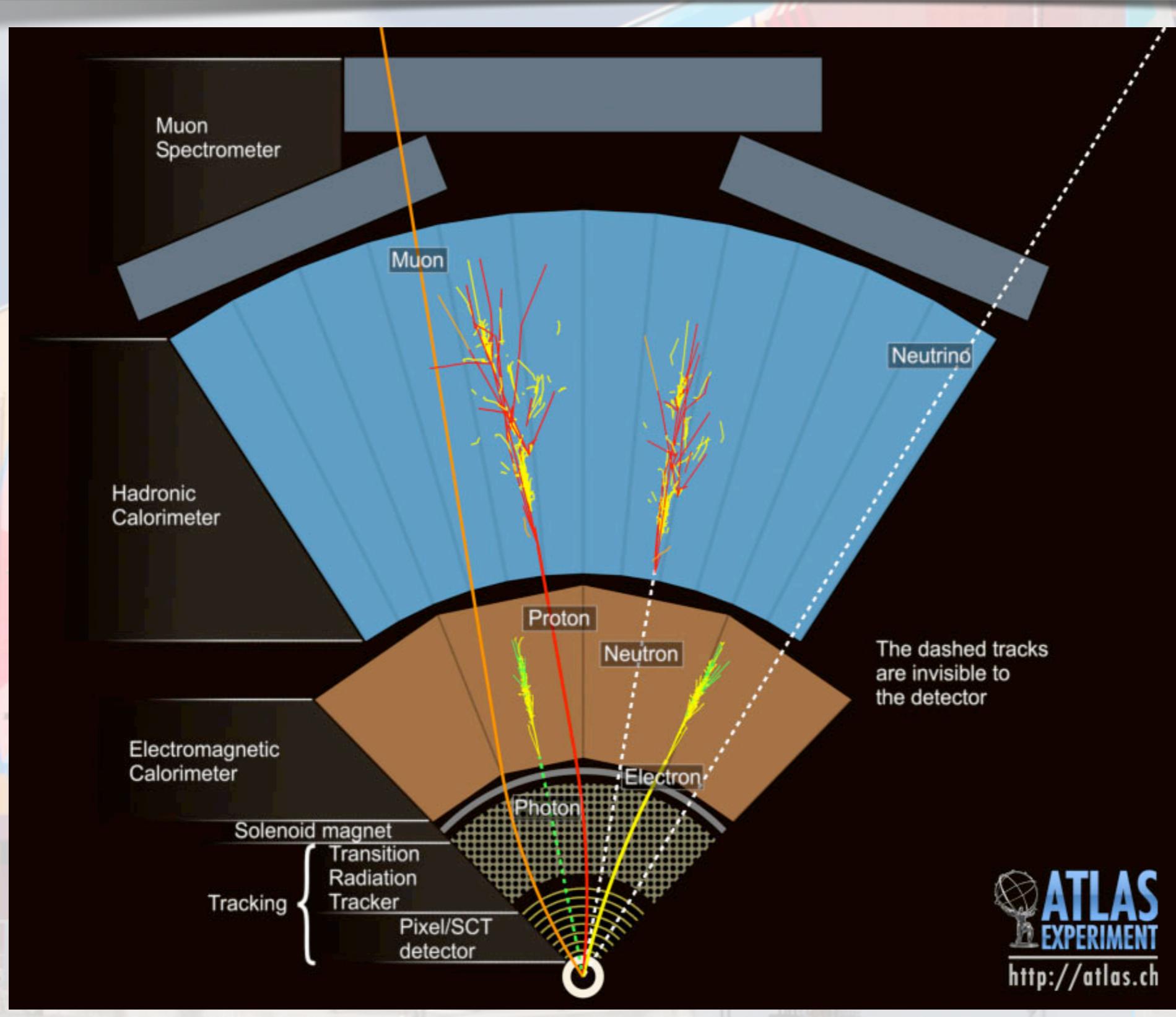
Institut za fiziku iz Beograda je pristupio ATLAS kolaboraciji sa hardverskim doprinosom u sistemu za zaštitu od zračenja, izradom zaštitnih diskova i njihovih držača. Zajedno sa mionskim komorama u prednjoj oblasti detektora, diskovi za zaštitu od zračenja sačinjavaju tzv. mali točak. Diskovi imaju trostruku ulogu: pridržavaju mionske komore malog točka, štite ove komore od zračenja i održavaju pravac magnetnog polja solenoida. Dva diska od po 87 tona su proizvedeni u Lola korporaciji u Železniku. Decembra 2004, diskovi i držači su prevezeni u CERN i posle toga uspešno instalirani. Mali točkovi su instalirani na ATLAS detektor februara 2008.



Standardni model - fundamentalne čestice



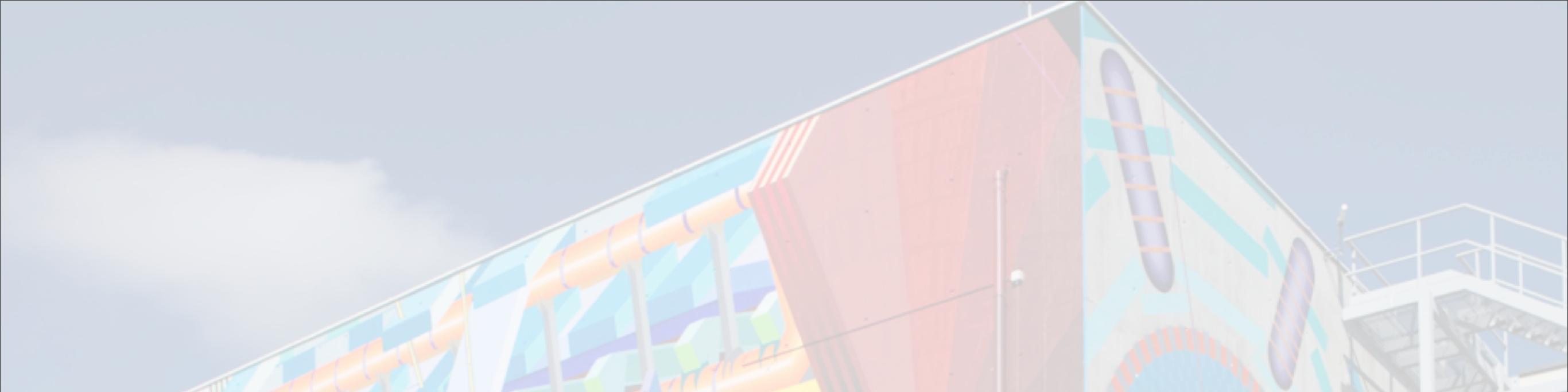
Princip detekcije - interakcija čestica sa komponentama detektora



Stabilne čestice:

- elektroni
- fotoni
- neutrina
- mion ($t=2.2$ ms)
- dugoživeće čestice
(tau, b, c..)

Sve ostale čestice se detektuju preko njihovih produkata raspada!



Ali... čemu sve to...



Standardni model

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."

FERMIOS

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

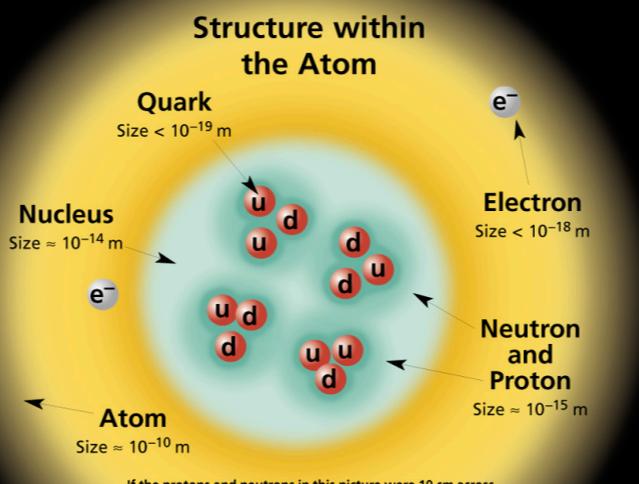
Leptons spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge
ν_e electron neutrino	<1x10 ⁻⁸	0
e electron	0.000511	-1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	-1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	-1

Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c ²	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 \hbar , which is the quantum unit of angular momentum, where $\hbar = h/2\pi = 6.58 \times 10^{-25}$ 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.



BOSONS

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

Unified Electroweak spin = 1		
Name	Mass GeV/c ²	Electric charge
γ photon	0	0
W^-	80.4	-1
W^+	80.4	+1
Z^0	91.187	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

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

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

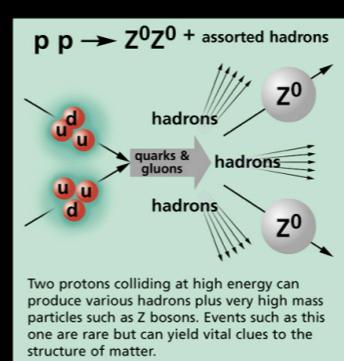
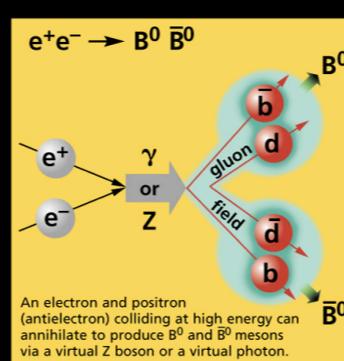
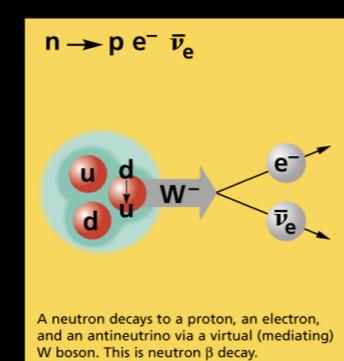
Mesons $q\bar{q}$					
Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c ²	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	db	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2.980	0

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.



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

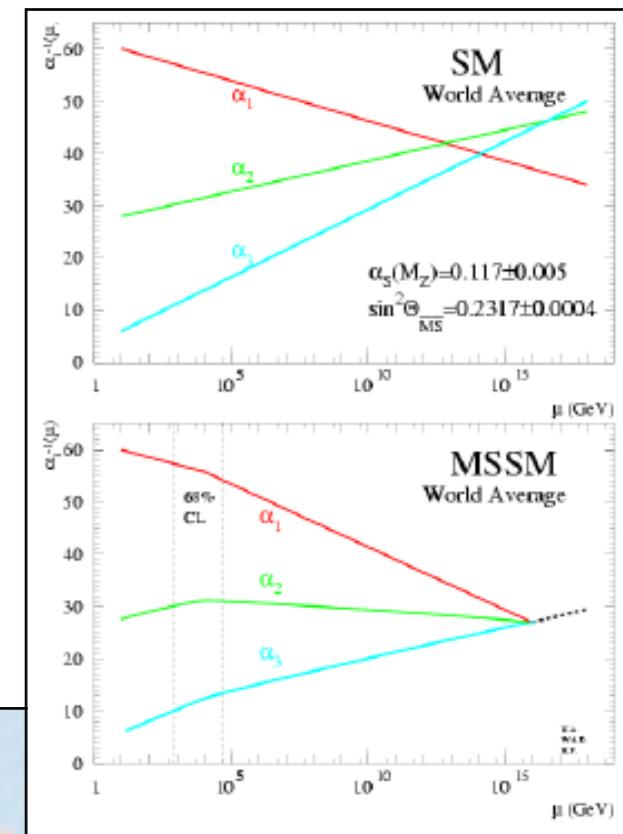
This chart has been made possible by the generous support of:
U.S. Department of Energy
U.S. National Science Foundation
Lawrence Berkeley National Laboratory
Stanford Linear Accelerator Center
American Physical Society, Division of Particles and Fields
BURLE INDUSTRIES, INC.

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<http://CPEPweb.org>

Motivacija, LHC program

MOTIVACIJA

- ✓ Poreklo masa čestica (SM potvrđen na nivou 1% na prethodnim exp.)
- ✓ Veruje se da SM nije konačna teorija (nestabilnost mase Higsa, unifikacija sila na skali 10^{15} - 10^{19} GeV)
- ✓ Supersimetrija - najbolje motivisana ekstenzija SM-a
 - ✓ omogućava unifikaciju interakcija na skali 10^{15} GeV
 - ✓ predviđa nisku masu Higsa :)
 - ✓ LSP - kandidat za česticu tamne materije
- ✓ Merenje karakteristika poznatih čestica i procesa kao što su mase, širine čestica, konstante sprezanja, preseci itd. (komplementaran pristup direktnoj potrazi za novim česticama i fenomenima: odstupanja od SM ukazuju na novu fiziku)
- ✓ ...



LHC PROGRAM

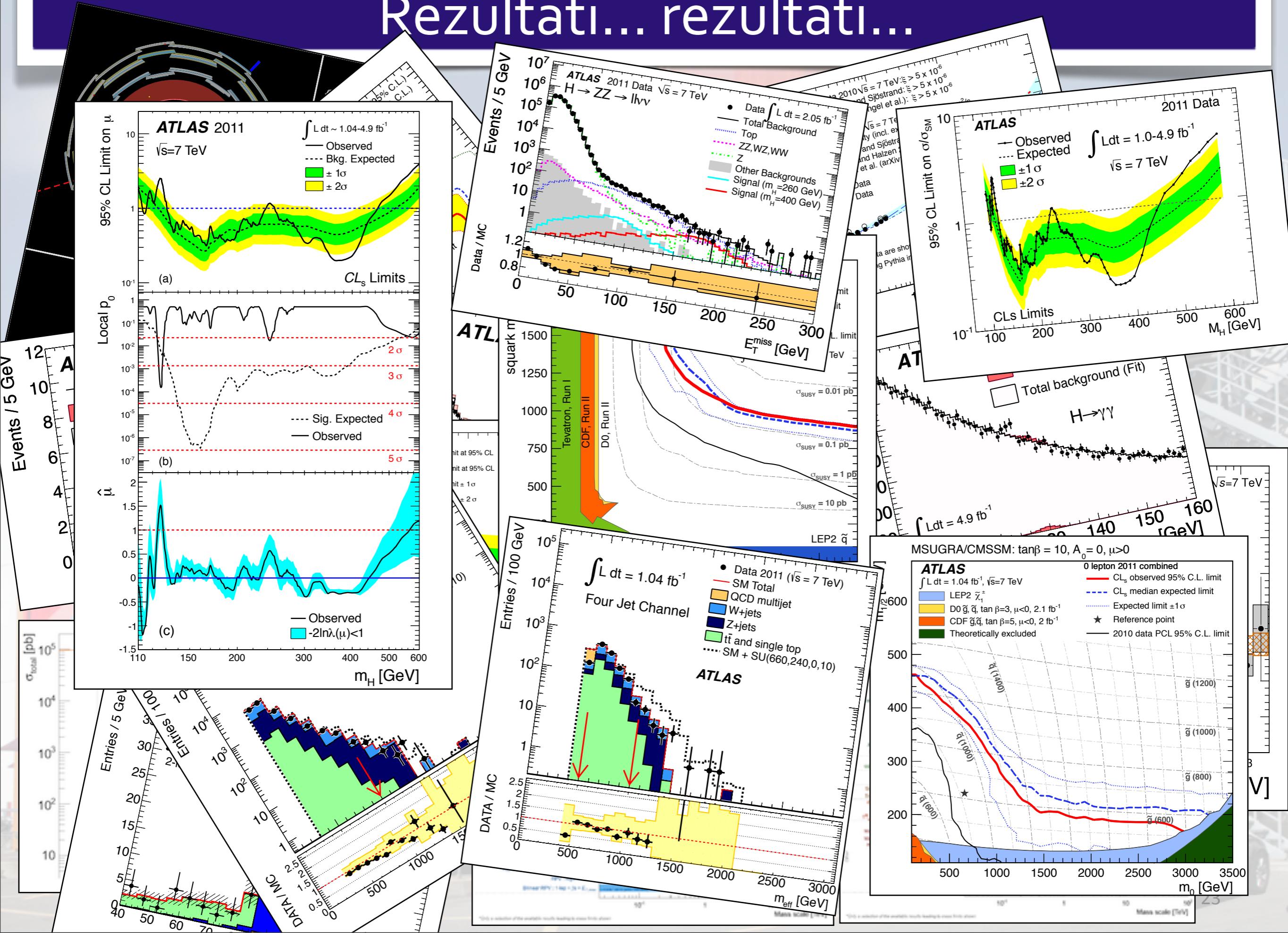
- ✓ Traženje SM Higsovog bozona u celom domenu mase ($114 \text{ GeV} < m_H < 1 \text{ TeV}$)
- ✓ Potraga za supersimetričnim česticama i drugim česticama izvan SM (leptokvarkovi, novi leptoni i kvarkovi, gradijentni bozoni do mase $\sim 5 \text{ TeV}$)
- ✓ Precizna merenja: masa W , t , konstanta jake interakcije, TGC
- ✓ Fizika B hadrona i narušenje CP simetrije
- ✓ Fazni prelaz iz hadronske materije u kvark-gluonsku plazmu
- ✓ ...

Teorija... Eksperiment...



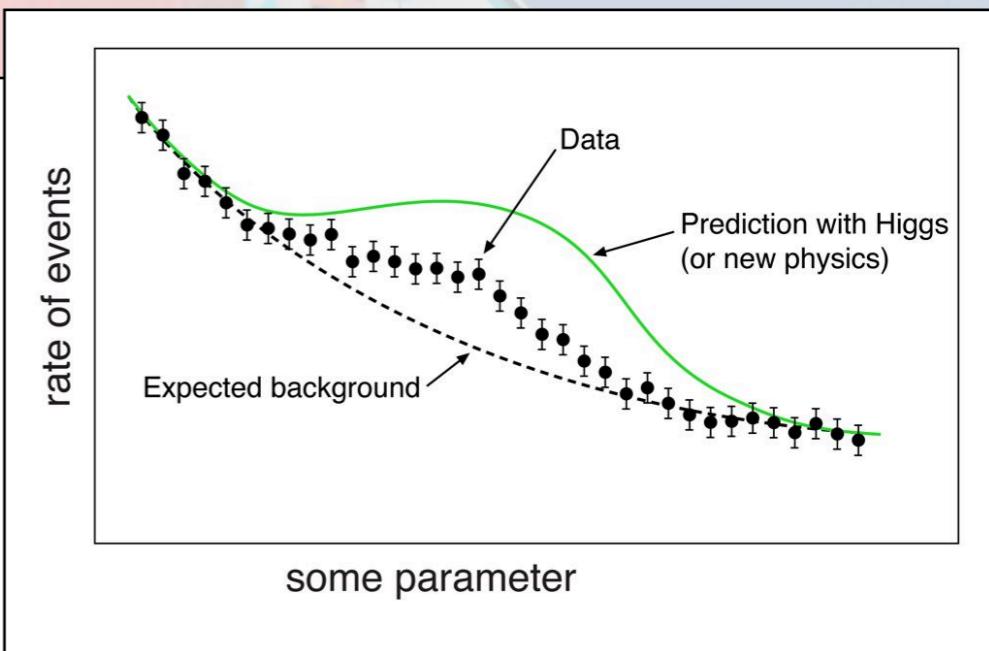
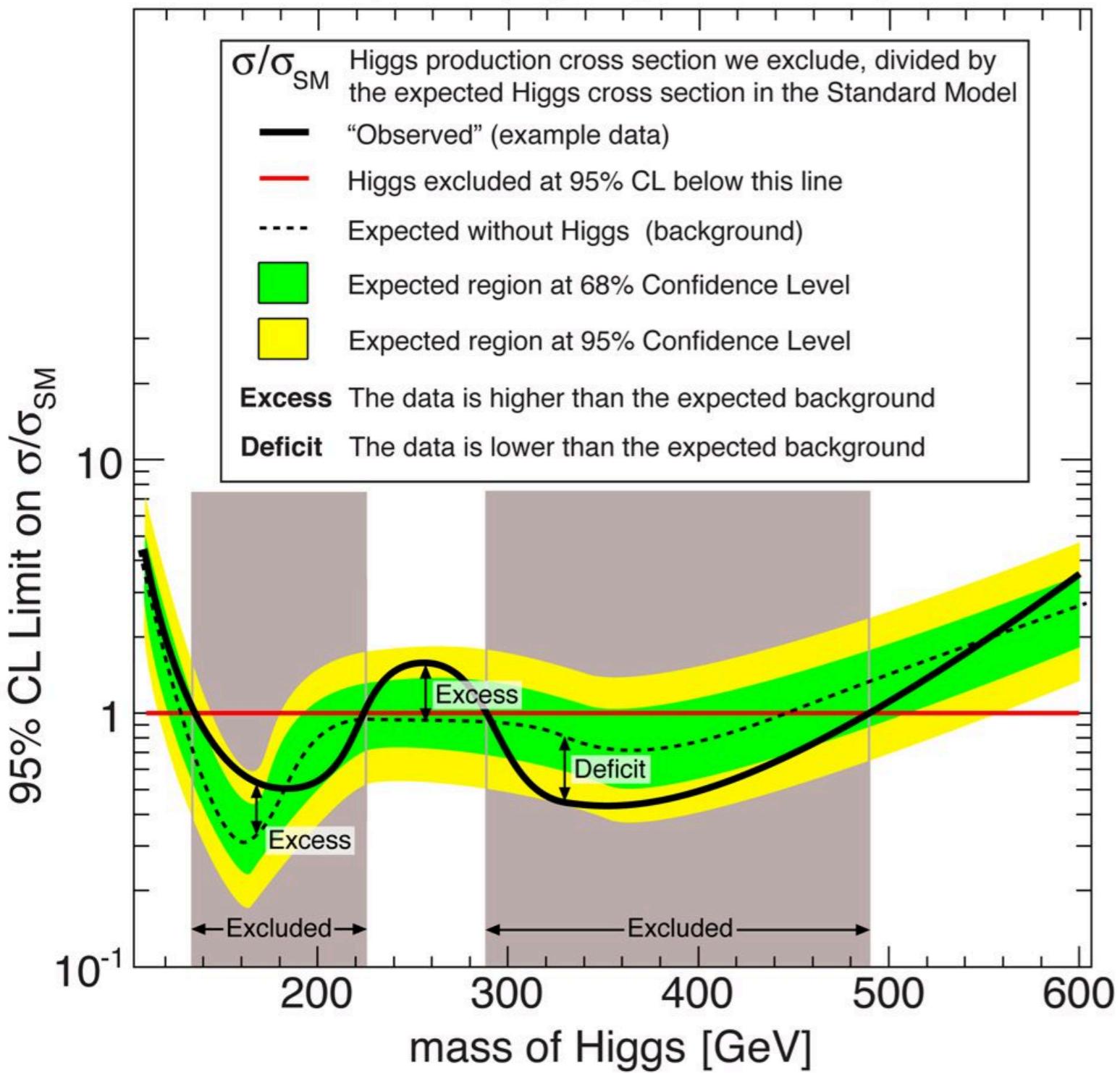
Potrebni su nam eksperimenti da bismo shvatili
šta od ovoga (?) opisuje Prirodu

Rezultati... rezultati...



Objašnjenje... kako 'čitati' rezultat

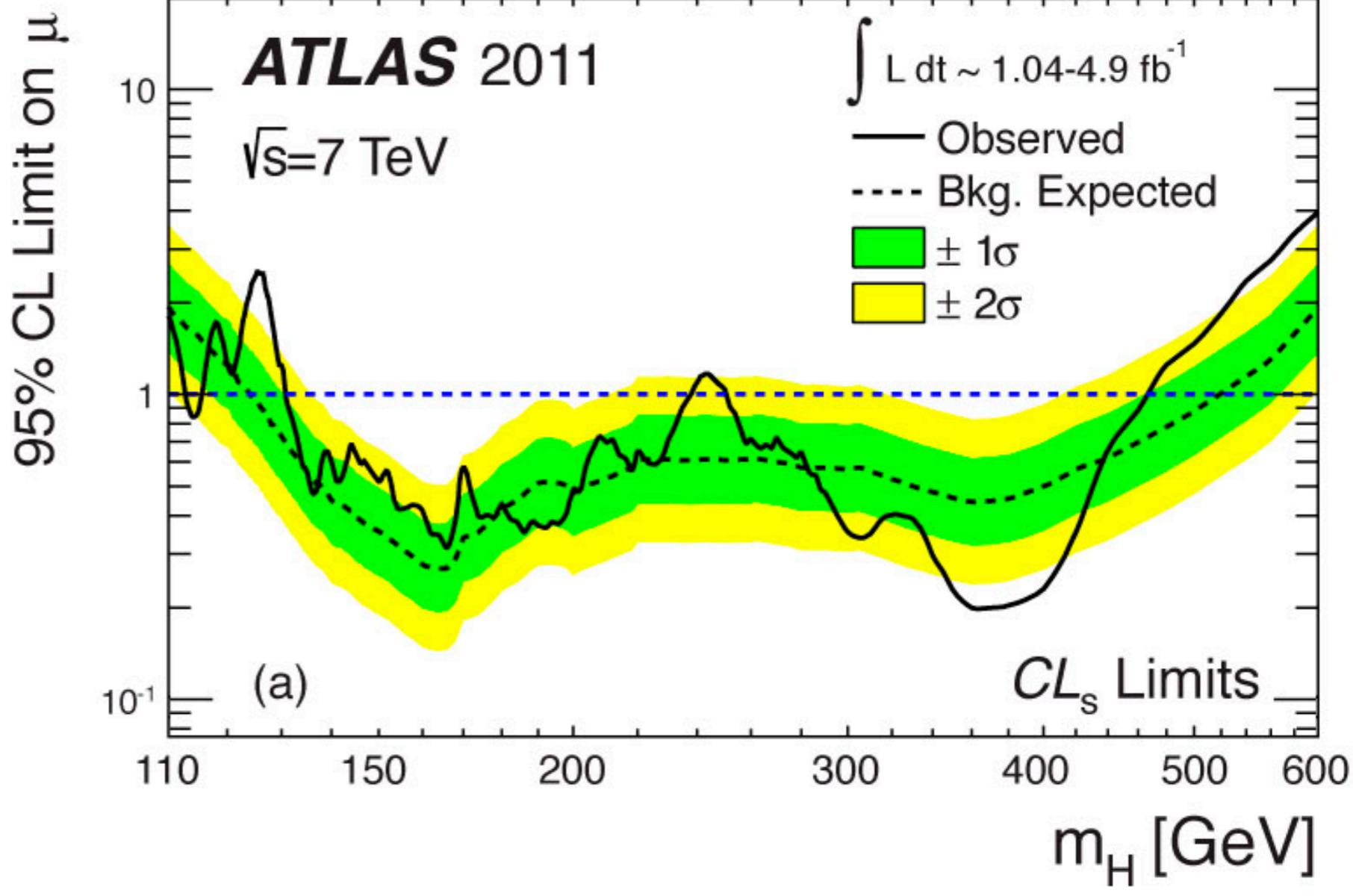
Explanatory figure (not actual data)



Higgs - poslednji 'public' rezultat



$H \rightarrow \gamma\gamma,$
 $H \rightarrow ZZ^{(*)} \rightarrow l^+l^-l'^+l'^-,$
 $H \rightarrow ZZ \rightarrow l^+l^-q\bar{q},$
 $H \rightarrow ZZ \rightarrow l^+l^-\nu\bar{\nu},$
 $H \rightarrow WW^{(*)} \rightarrow l^+\nu l'^-\bar{\nu},$
 $H \rightarrow WW \rightarrow l\nu q\bar{q}'$



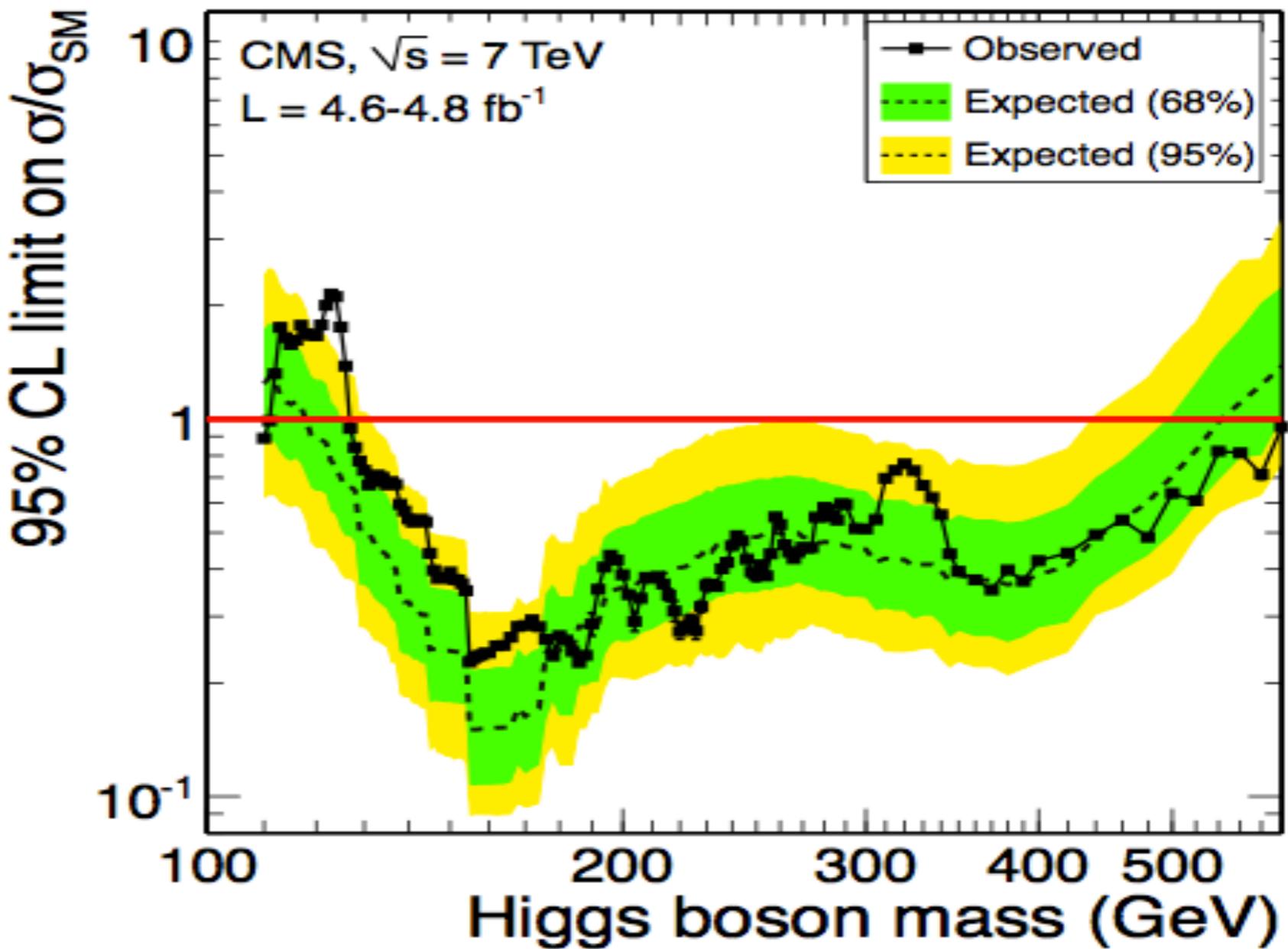
ATLAS

Ukoliko SM Higgs postoji, njegova masa je najverovatnije u oblasti 116-131 GeV.
Oblast ~ 126 GeV pokazuje najveće odstupanje, ali je potrebna još veća kolicina podataka da bi se sa sigurnošću tvrdilo da odstupanje potiče od Higgs-ovog bozona.

Higgs - poslednji 'public' rezultat



$H \rightarrow \gamma\gamma$
 $H \rightarrow \tau\tau$
 $H \rightarrow bb$
 $H \rightarrow WW^* \rightarrow 2\ell 2\nu$
 $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$
 $H \rightarrow ZZ \rightarrow 2\ell 2\nu$
 $H \rightarrow ZZ^{(*)} \rightarrow 2\ell 2q$
 $H \rightarrow ZZ \rightarrow 2\ell 2\tau$



CMS

Ukoliko SM Higgs postoji, njegova masa je najverovatnije u oblasti 110-145 GeV. Oblast ~ 124 GeV pokazuje najveće odstupanje, ali je potrebna još veća kolicina podataka da bi se sa sigurnošću tvrdilo da odstupanje potiče od Higgs-ovog bozona.

Šta nas očekuje...

Očekujemo otkriće Higgs-ovog bozona.... budite strpljivi
Očekujemo otkriće supersimetrije (SUSY)... budite strpljivi...
Očekujemo otkrića drugih čestica izvan SM-a... budite strpljivi...
Očekujemo još preciznija merenja u okviru SM-a... budite strpljivi...
Mozda pronađemo i nešto što ne očekujemo... budite strpljivi...
... budite strpljivi ...

