

CMS detektor i fizika Higgs bozona

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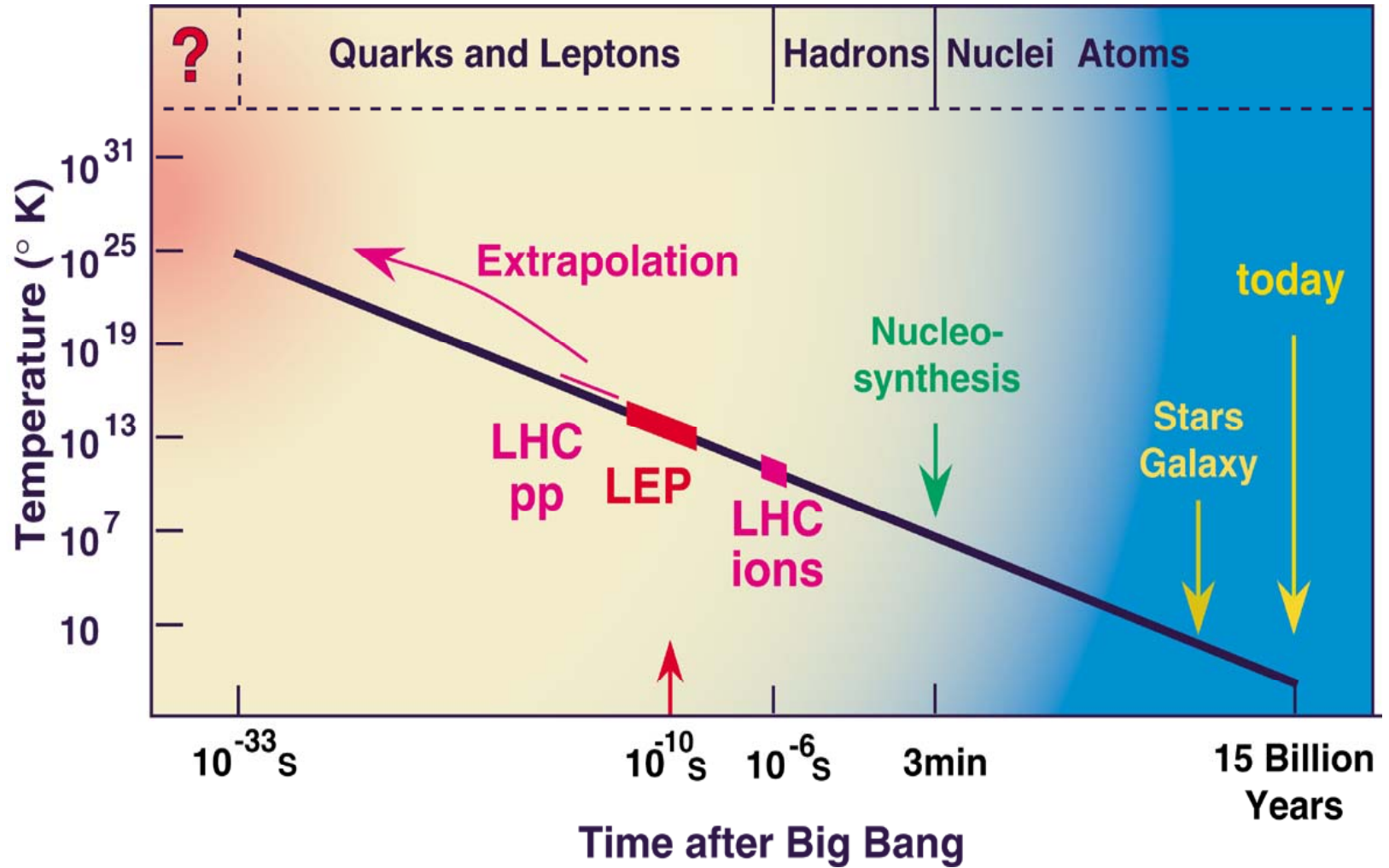


CMS kolaboracija, CERN – Ženeva

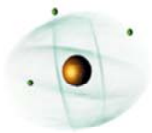
Sadržaj

- **LHC projekt**
 - Large Hadron Collider
 - Detektori na LHC-u
 - Fizika LHC-a
- **CMS detektor**
 - Subdetektori
 - Elektromagnetski kalorimetar CMS-a
 - Eksperimentalne aktivnosti u Splitu
 - Fizika CMS-a
- **Primjer potrage za Higgs bozonom: simulacija $H \rightarrow ZZ^* \rightarrow 4e$ kanala raspada**
 - Simulacija signala i pozadine
 - Rekonstrukcija elektrona u CMS detektoru
 - Analiza rezultata

Prema početku



Kratka povijest



$$\lambda = h / p$$

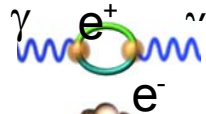
$$T \approx t^{-1/2}$$

10^{-10} m \leq 10 eV

$>$ 300000 Y

1900....

**Quantum Mechanics
Atomic Physics**



1940-50

Quantum Electro Dynamics



10^{-15} m MeV - GeV \approx 3 min

1950-65

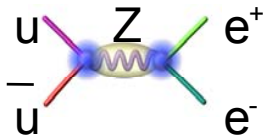
**Nuclei, Hadrons
Symmetries, Field theories**



10^{-16} m \gg GeV \approx 10^6 sec

1965-75

Quarks. Gauge theories

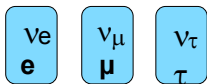


10^{-18} m \approx 100 GeV \approx 10^{10} sec

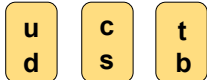
1970-83 SPS

ElectroWeak Unification, QCD

6 Leptons



6 Quarks



3 "Colors" each quark **R** **G** **B**

1990 LEP

3 families

1994 Tevatron Top quark

Origin of masses 10^{-19} m \approx 10^3 GeV \approx 10^{12} sec

The next step...

2005 LHC

Higgs ? Supersymmetry ?

Proton Decay ? 10^{-32} m \approx 10^{16} GeV \approx 10^{32} sec

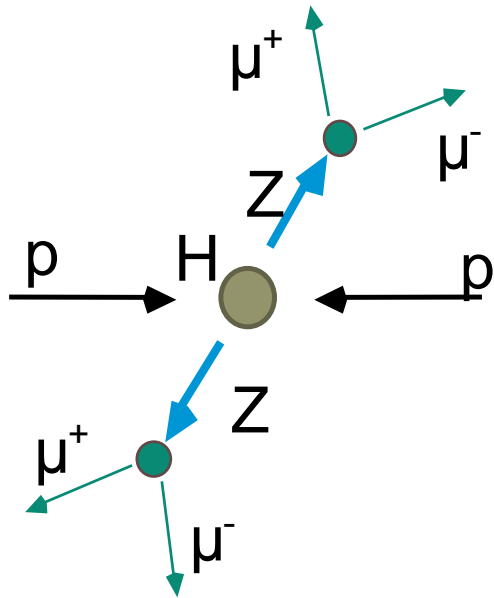
Underground Labs **GRAND** Unified Theories ?

The Origin of the Universe 10^{-35} m \approx 10^{19} GeV \approx 10^{43} sec (Planck scale)

??

**Quantum Gravity?
Superstrings ?**

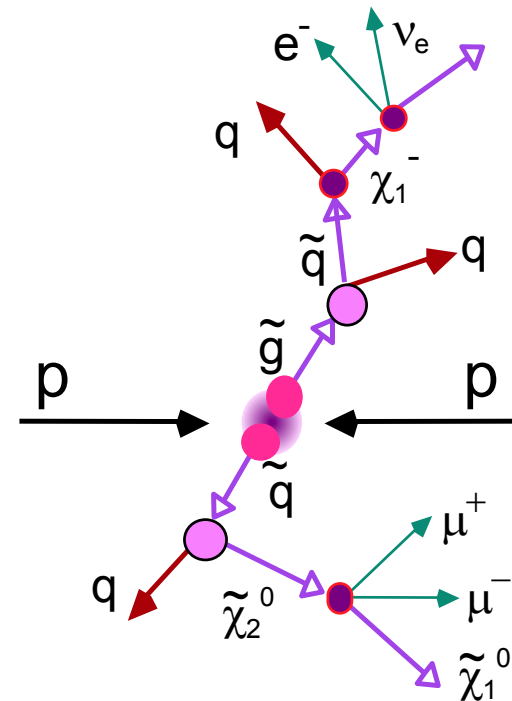
Slijedeći korak



- **Higgs bozon:** tj. pronaći mehanizam odgovoran za spontano narušenje elektroslabe simetrije Standardnog modela

- **Nove sile (simetrije)**
- Nove čestice
- Super simetrija
- Substruktura

.....

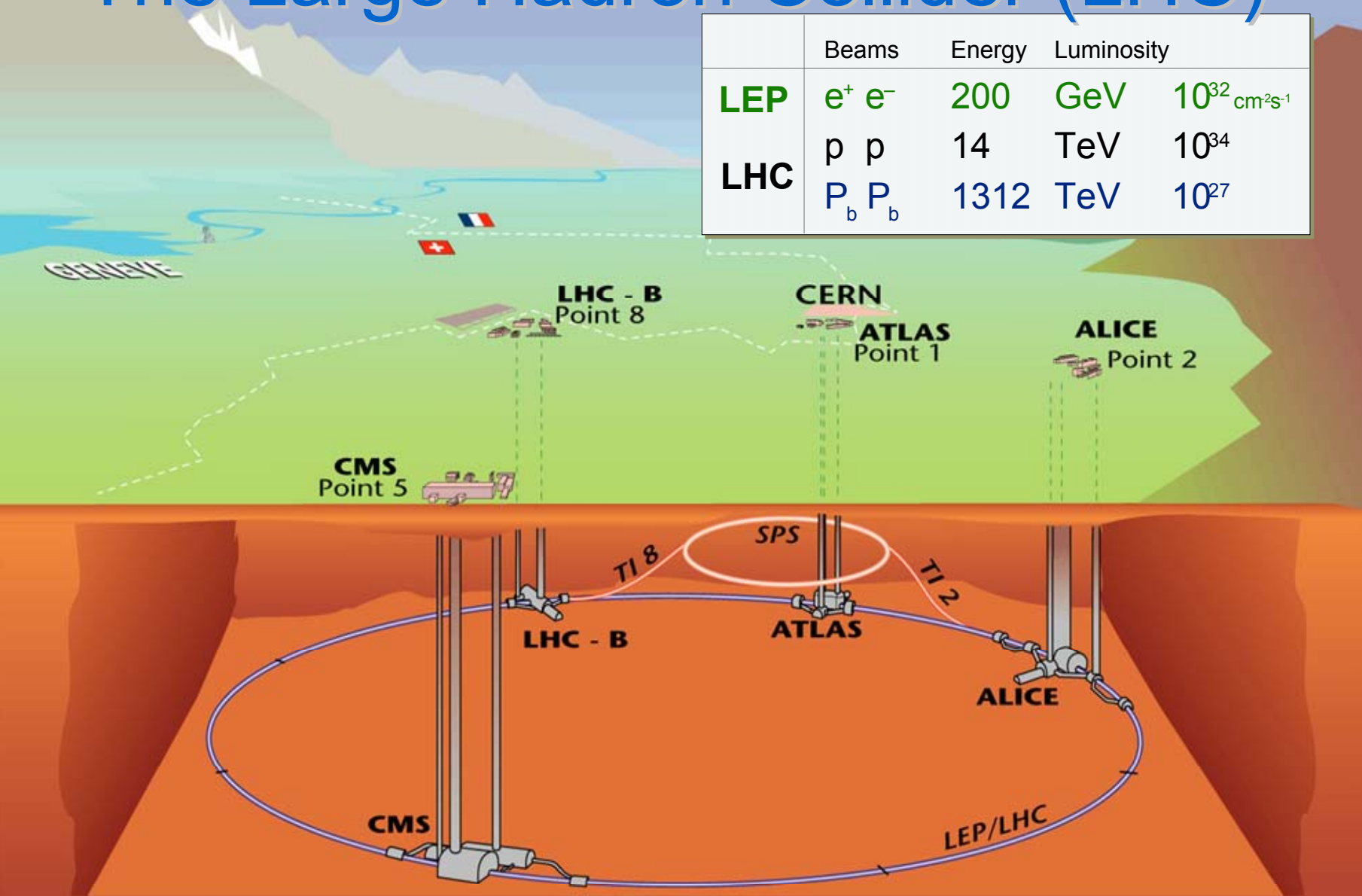


CERN site

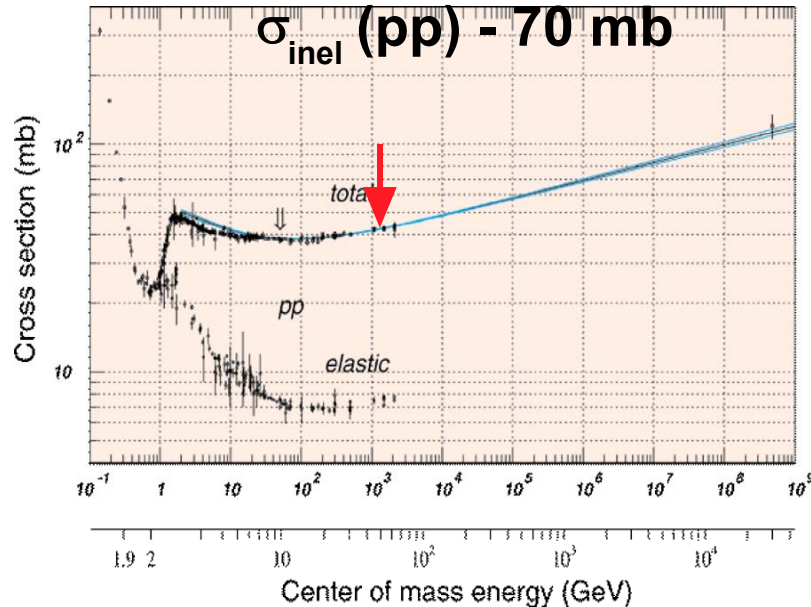


The Large Hadron Collider (LHC)

	Beams	Energy	Luminosity
LEP	$e^+ e^-$	200 GeV	$10^{32} \text{ cm}^{-2}\text{s}^{-1}$
LHC	$p p$	14 TeV	10^{34}
	$P_b P_b$	1312 TeV	10^{27}



pp udarni presjek & Min Bias

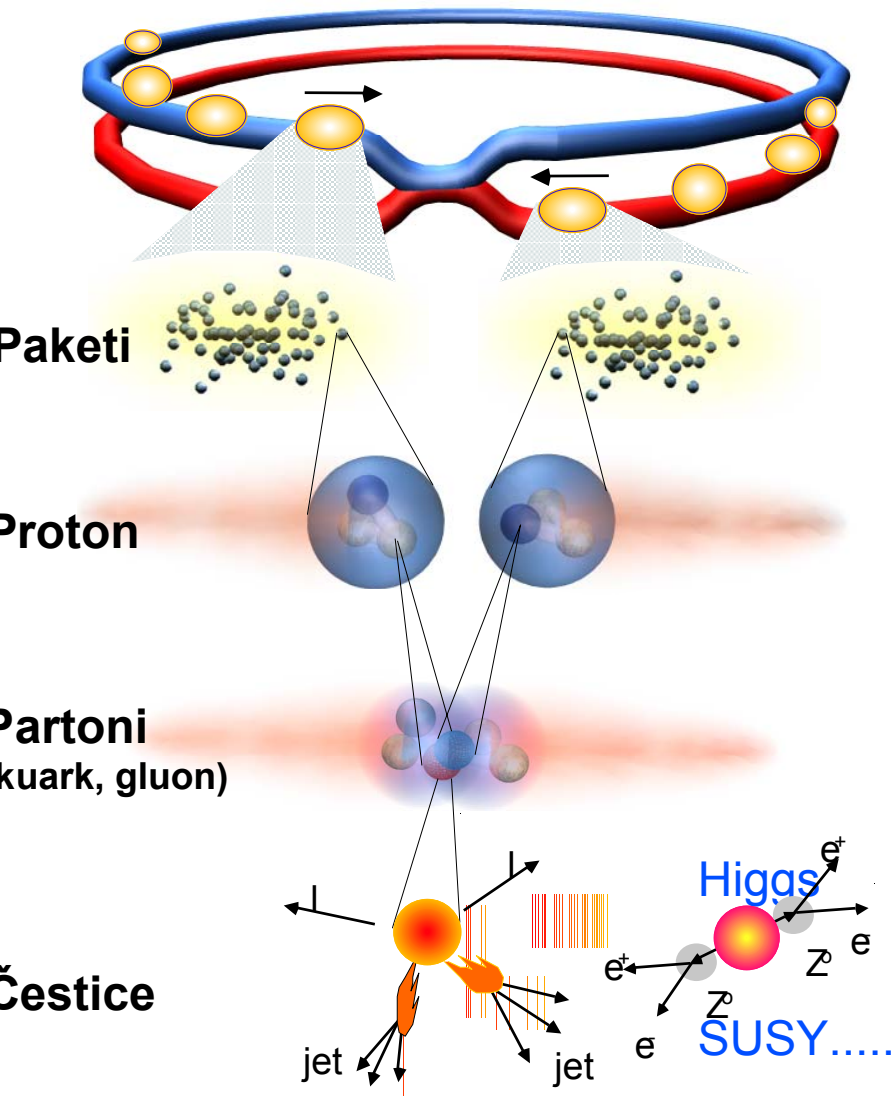


- $L = 10^{34} \text{ cm}^{-2} \text{ s}^{-1} = 10^7 \text{ mb}^{-1} \text{ Hz}$
- $\sigma_{\text{inel}} (\text{pp}) - 70 \text{ mb}$
→ **Frekv. događaja = $7 \times 10^8 \text{ Hz}$**
- $\Delta t = 25 \text{ ns} = 25 \times 10^{-9} \text{ Hz}^{-1}$
→ **Događ./25ns = $7 \times 2.5 = 17.5$**
- Svi paketi nisu puni (2835/3564)
→ **Događ./sudaru = 22**

Uvjeti rada (sažetak):

- 1) "Dobar" događaj koji sadrži raspad Higgasa +
- 2) ≈ 20 "loših" (minimum bias) interakcija

Sudari na LHC-u



Proton-Proton 2835 paketa/snop
Protona/snopu 10^{11}
Energija snopa 7 TeV (7×10^{12} eV)
Luminozitet $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

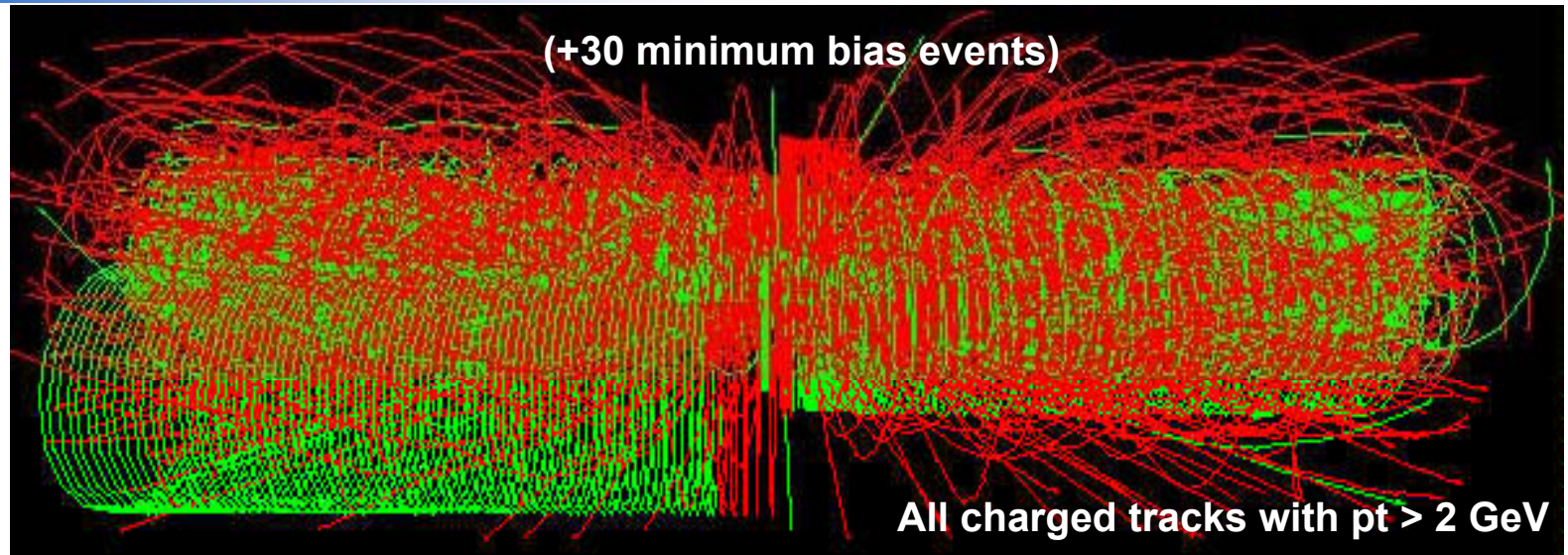
Frekvencija sudara paketa 40 MHz

Frekvencija sudara protona $10^7 - 10^9$ Hz

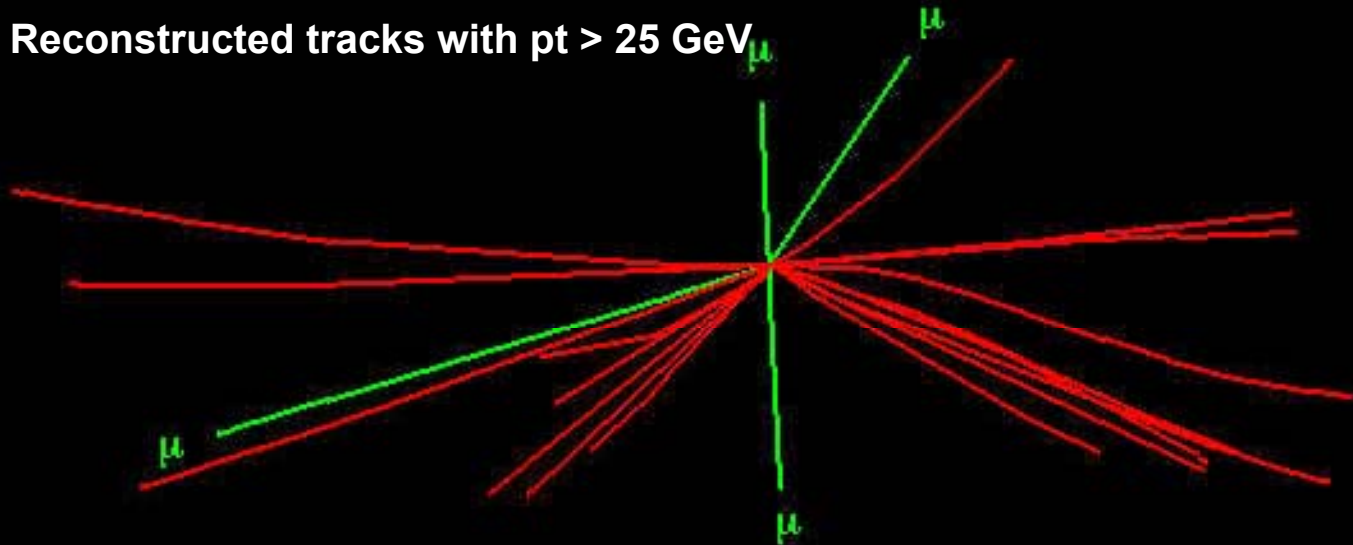
Frekvencija "nove fizike" .00001 Hz

Selekcija događaja:
1 u 10 000 000 000 000

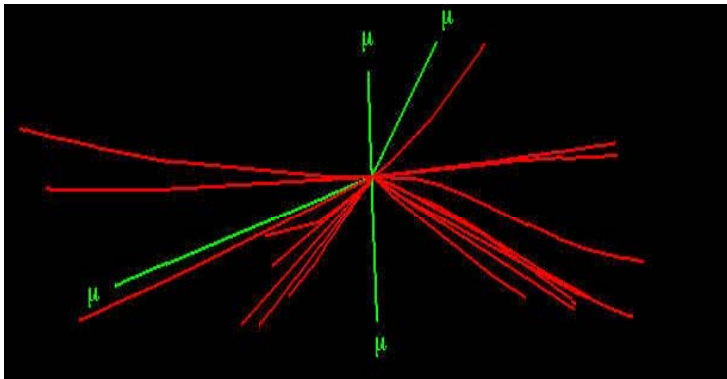
Raspad Higgs bozona u 4 miona



Reconstructed tracks with $pt > 25$ GeV

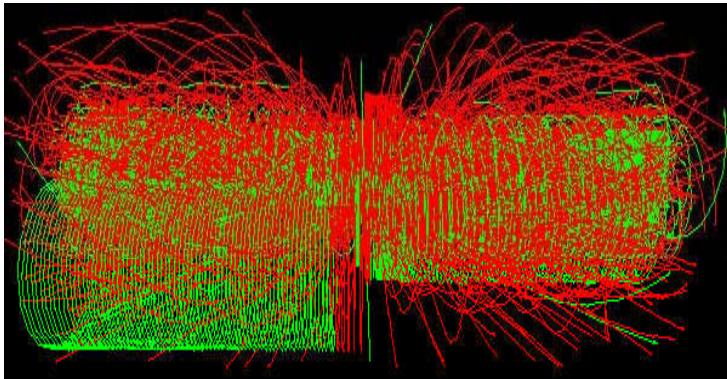


Slijedeći korak u hadronskim sudarima



U slijedećoj generaciji sudarača potrebna potraga za masivnim objektima preko širokog masenog područja.

Sudarači hadrona mogu omogućiti fiziku na visokim energijama na nivou partona i na visokom luminozitetu, ali **uz “žrtvovanje” čistih eksperimentalnih uvjeta.**



Izazovi na LHC-u:

- Detektori
- Eksperimenti
- Selekcija događaja

Detektori na LHC-u

Teški materijali
(čelik ili bakar + aktivni materijal)

Materijali s velikim brojem protona + aktivni materijal

Elektromagnetski i hadronski kalorimetri

- Identifikacija čestice (e, γ , snopovi, energija koja nedostaje)
- Mjerenje energije

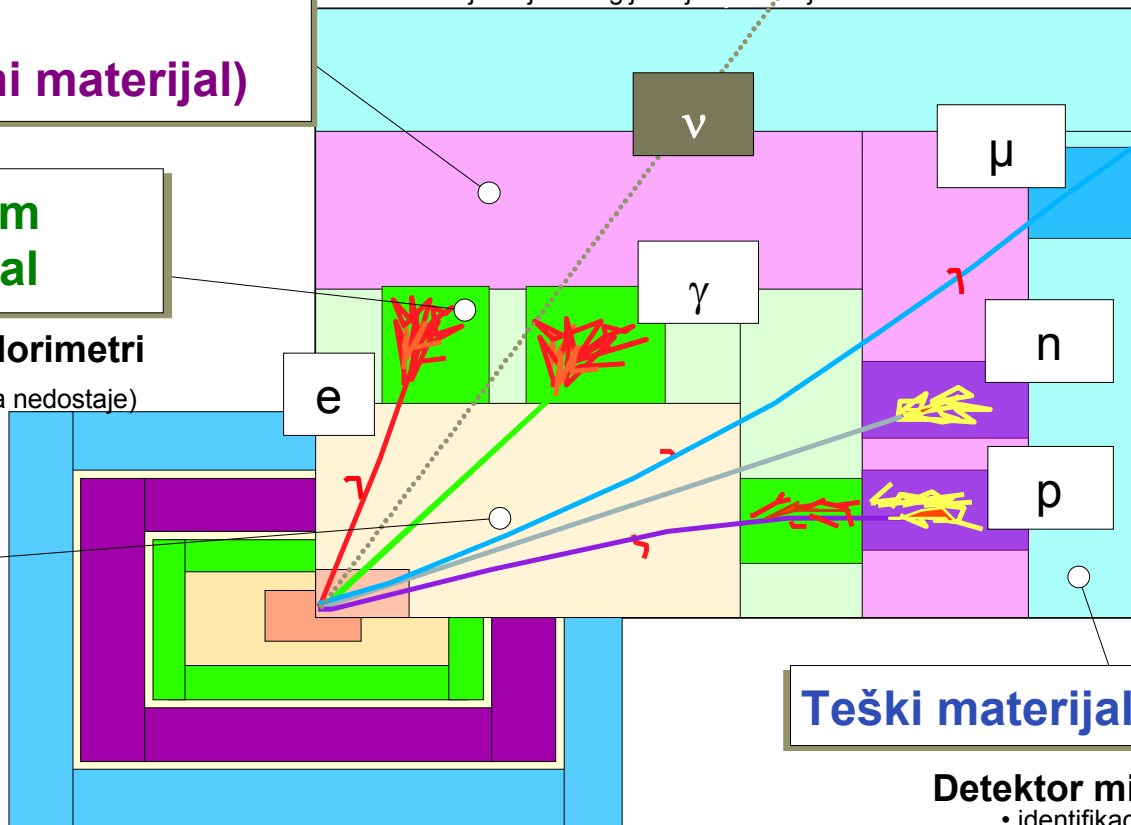
Lagani materijali

Centralni detektor

- p_T
- Pozicija em. pljuska
 - Topologija
 - Verteks

Hermetička kalorimetrija

- Mjerenje energije koja nedostaje



Teški materijali

Detektor miona

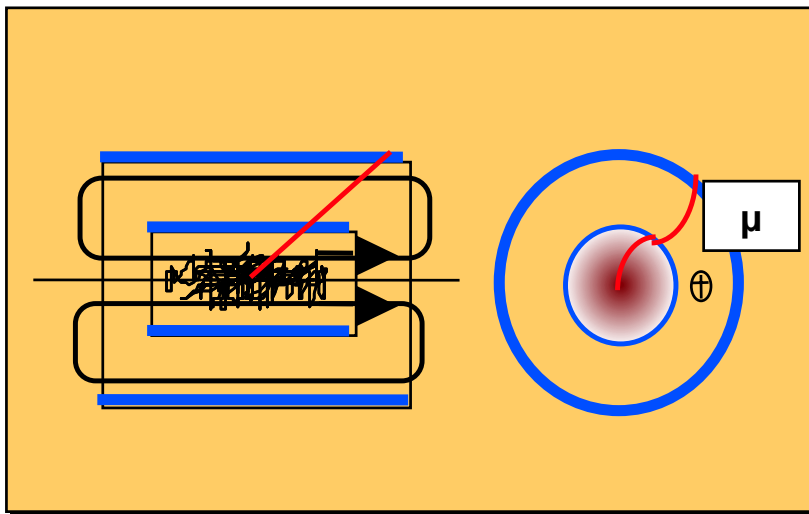
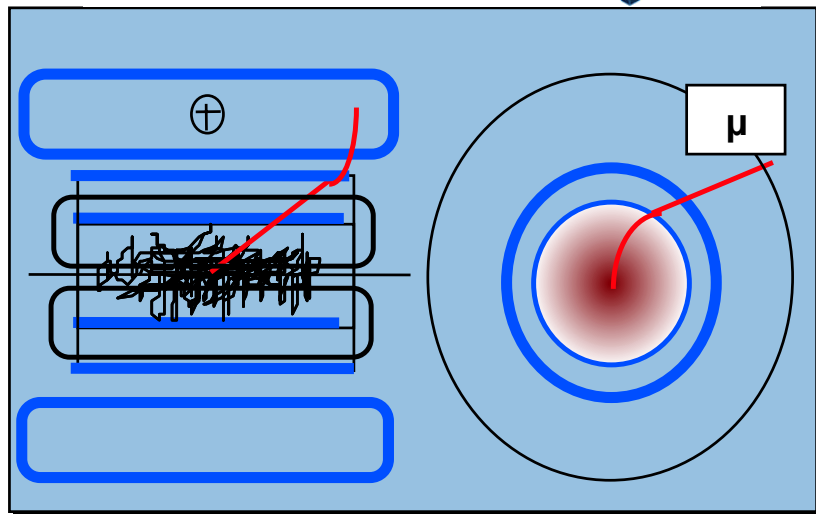
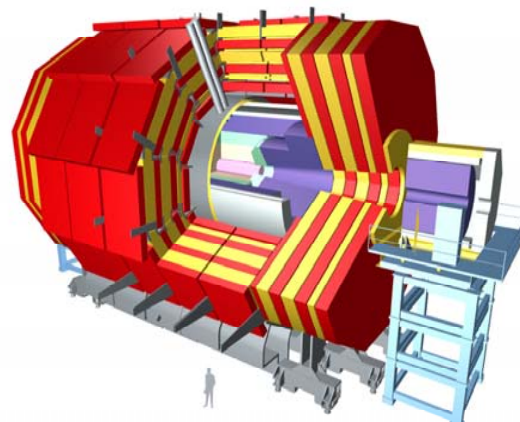
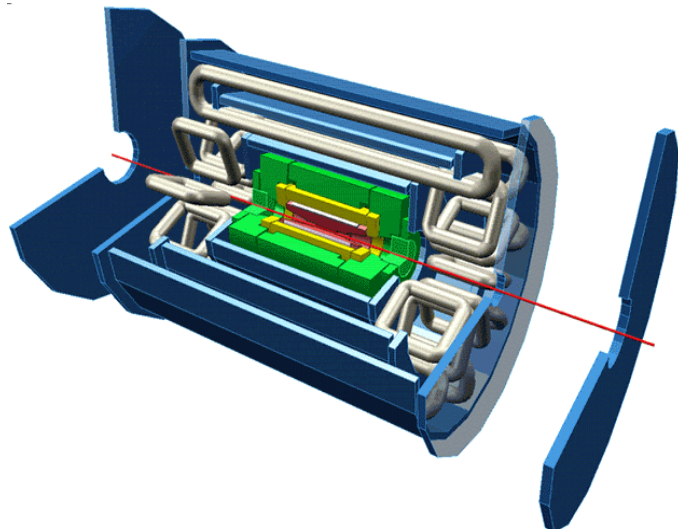
- identifikacija miona

Svaki sloj identificira čestice stvorene u sudaru i omogućuje mjerenje njihove energije ili količine gibanja

pp eksperimenti na LHC-u

ATLAS A Toroidal LHC ApparatuS

CMS Compact Muon Solenoid

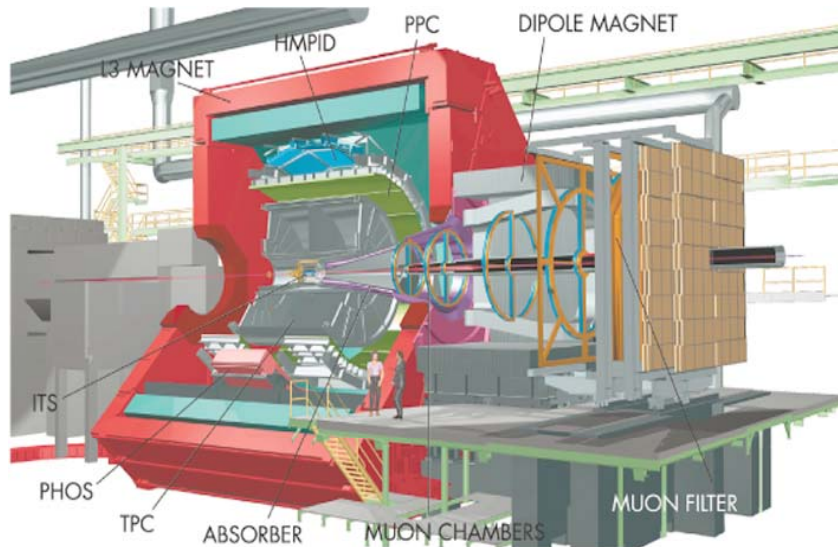


Eksperimenti za teške ione i B fiziku na LHC-u

ALICE

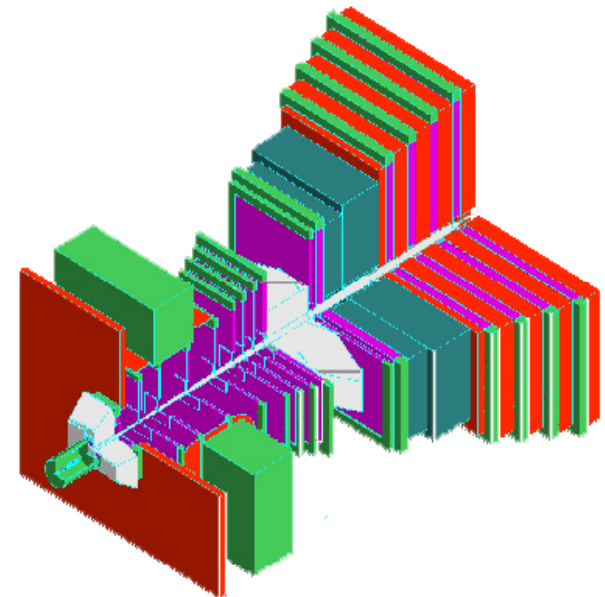
A Large Ion Collider Experiment

The ALICE Collaboration proposes to build a dedicated heavy-ion detector to study the physics of strongly interacting matter at extreme energy densities, where the formation of a new phase of matter, the quark-gluon plasma, is expected.



LHCb

(Study of CP violation in B-meson decays at the LHC collider)



Fizika na LHC-u

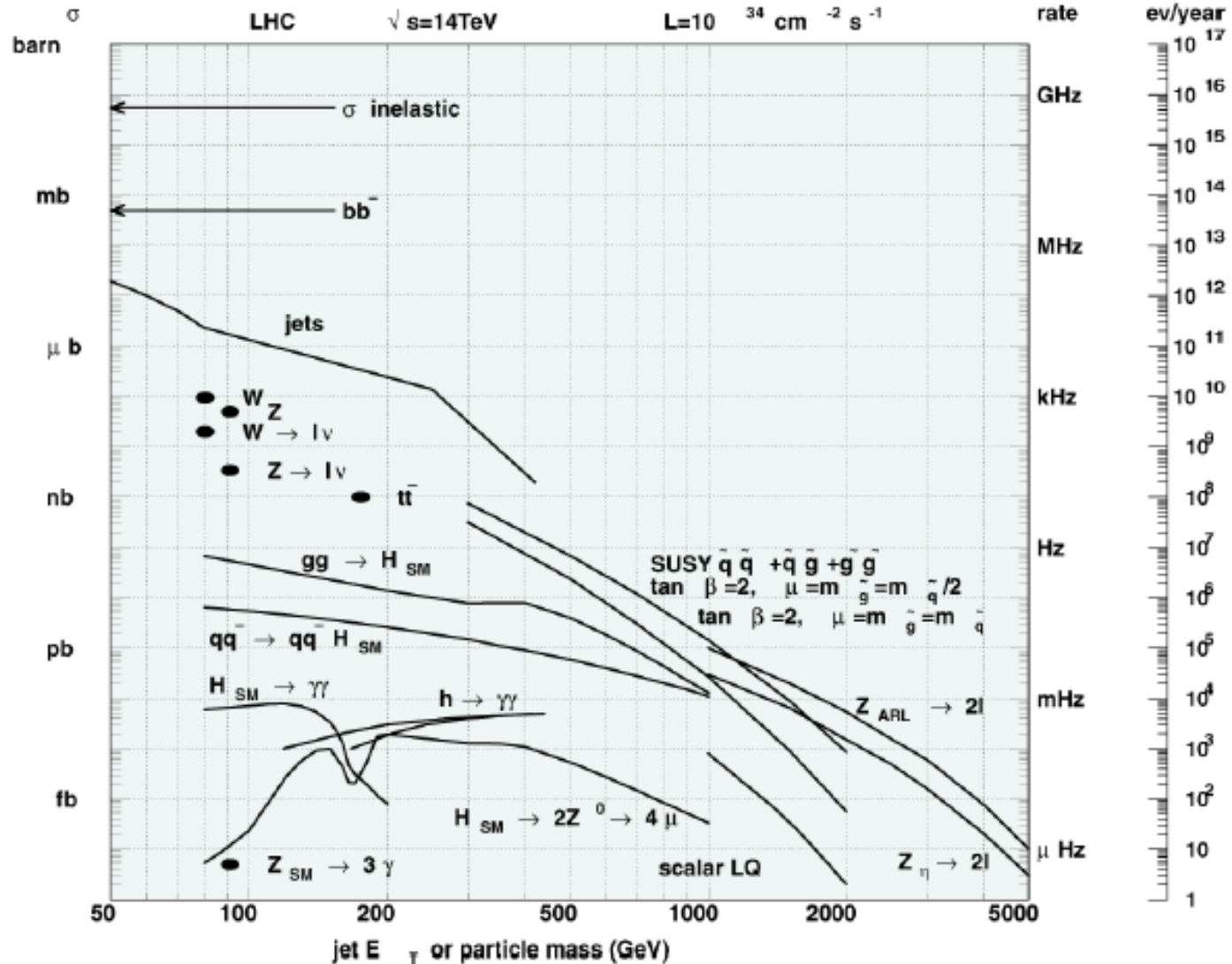
➤ **proton-proton sudari:**

- Potraga za Higgs bozonom u SM-u do oko 1 TeV,
- Potraga za Higgs bozonima u SUSY (h^0 , H^0 , A^0 , H^\pm),
- Potraga za skvarkovima i gluinima do oko 2,0 TeV,
- Potraga za sleptonima, charginima, neutralinima do oko 0,3 TeV,
- Potraga za novim bozonima: W' , Z' do oko 4,5 TeV,
- Alternativni mehanizmi lomljenja elektroslabe simetrije,
- Detaljna istraživanja top fizike,
- Testovi QCD-a,
- Testovi konstanti vezanja,
- CP narušenje u B sektoru,
- Mjerenje totalnog udarnog presjeka
- Potraga za dodatnim dimenzijama

➤ **Fizika teških iona: od O-O do Pb-Pb**

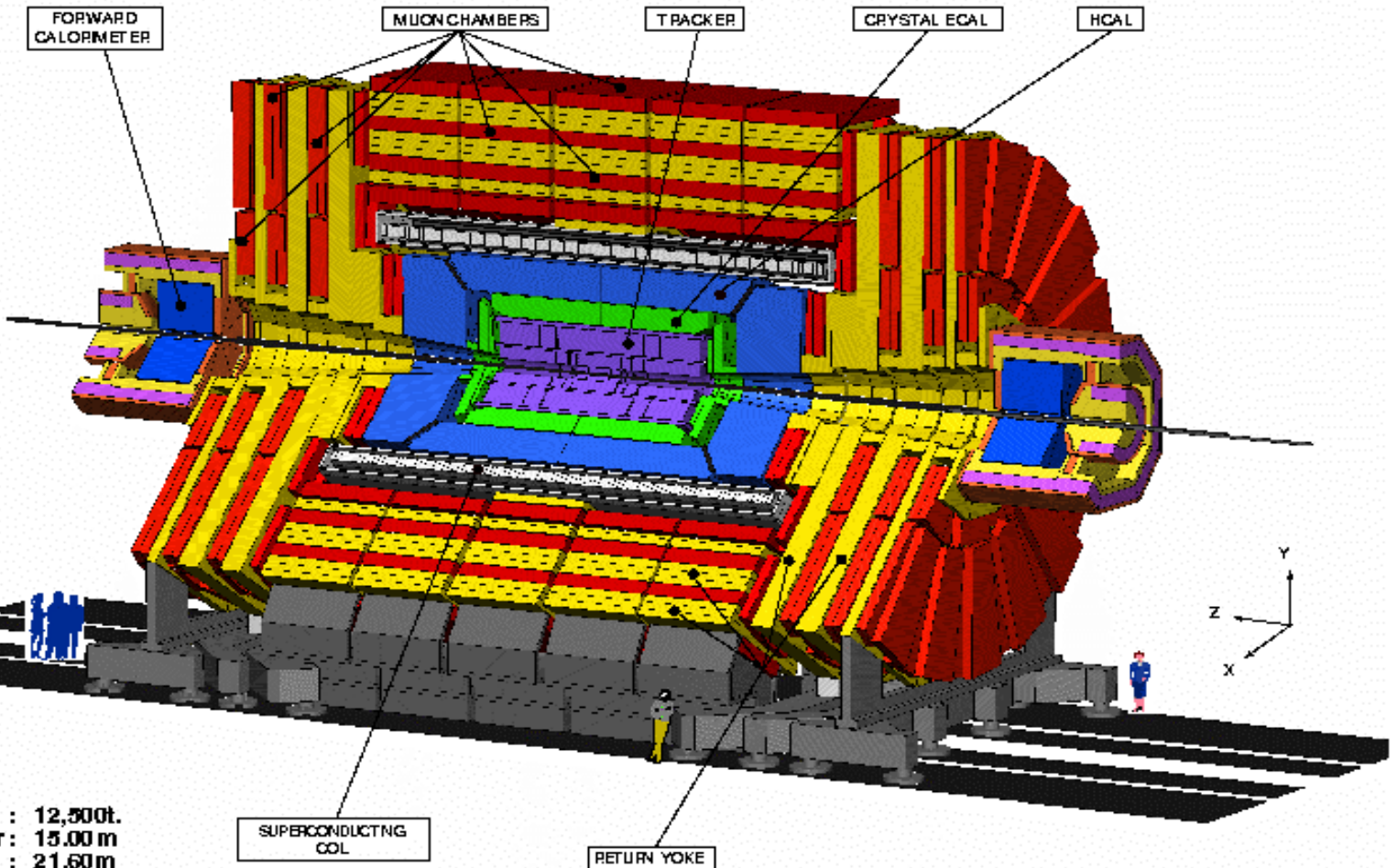
- Potraga za quark-gluon plazmom

Udarni presjeci na LHC-u



The Compact Muon Solenoid (CMS)

CMS A Compact Solenoidal Detector for LHC



Total weight : 12,500t.
Overall diameter : 15.00 m
Overall length : 21.60 m
Magnetic field : 4 Tesla

SUPERCONDUCTING SOL

RETURN YOKE

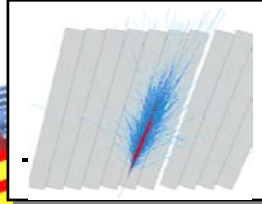
The Compact Muon Solenoid

SUPERCONDUCTING COIL

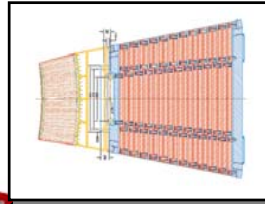
Total weight : 12,500 t
 Overall diameter : 15 m
 Overall length : 21.6 m
 Magnetic field : 4 Tesla

CALORIMETERS

ECAL Scintillating PbWO₄ Crystals



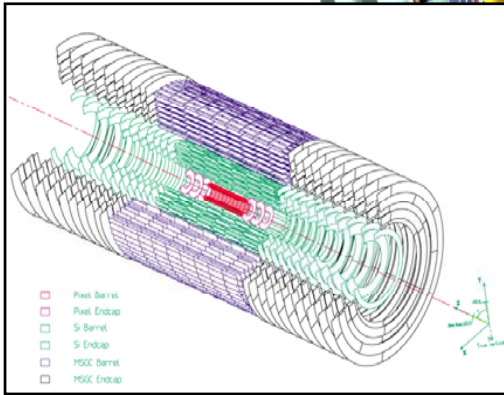
HCAL Plastic scintillator copper sandwich



copper sandwich

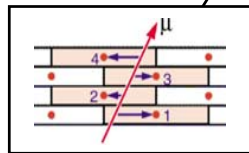
IRON YOKE

TRACKERS



Silicon Microstrips
 Pixels

MUON BARREL

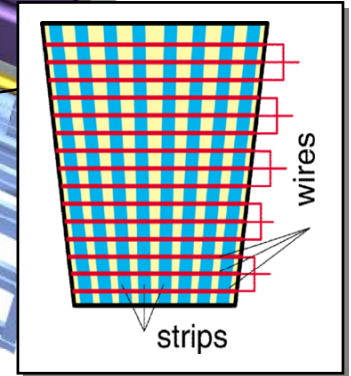


Drift Tube
 Chambers (DT)



Resistive Plate
 Chambers (RPC)

MUON ENDCAPS

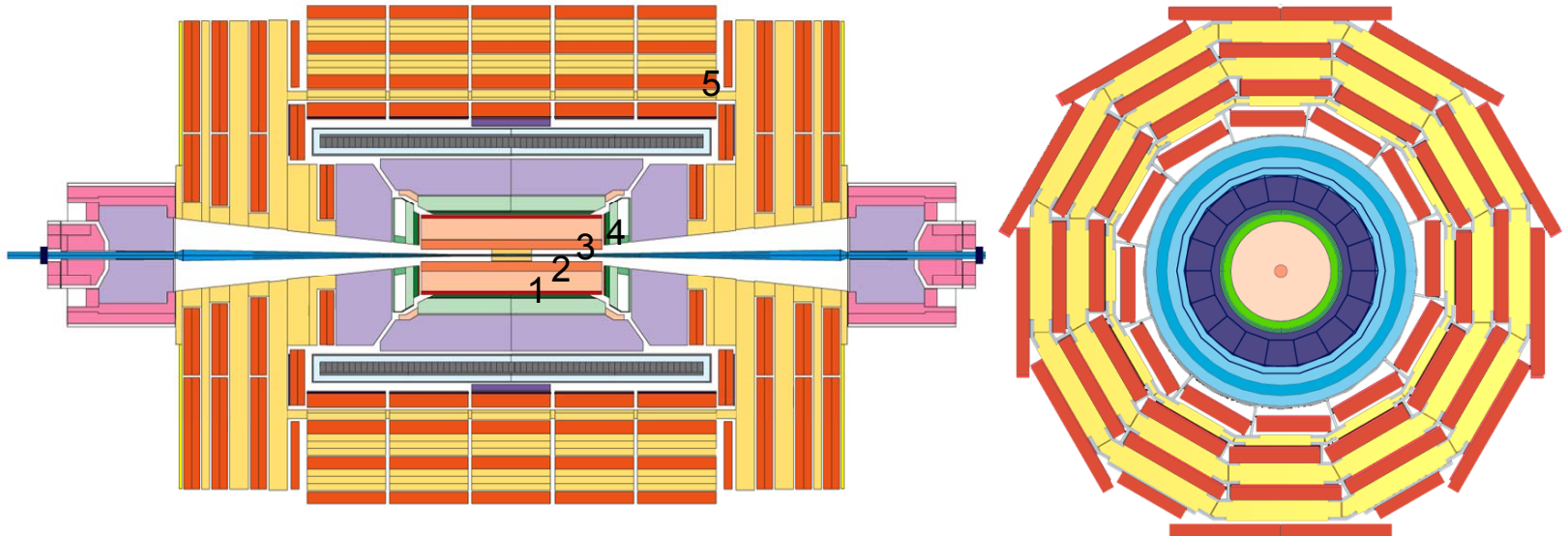


Cathode Strip Chambers (CSC)
 Resistive Plate Chambers (RPC)

Izazovi na LHC-u

- Broj elektroničkih kanala u detektoru – $O(10^7)$
 - ➔ Potreba za velikim brojem međuspojeva
- 20 sudara svakih 25 ns
 - ➔ Potreba za velikim protokom informacija
- Informacije iz subdetektora trebaju odgovarati jedne drugima
 - ➔ Potreba za sinhronizacijom elemenata detektora svakih 25 ns
- U nekim slučajevima vrijeme leta > 25 ns
 - ➔ Potreba za identifikacijom sudara paketa
- Maksimalna frekvencija spremanja podataka – 100 Hz
 - ➔ Odbacivanje većine interakcija
- Radi se “on-line”
(nemoguće “se vratiti” i ponovo razmotriti događaj)
 - ➔ Potreba za nadziranje selekcije

CMS – različiti pogledi



Detektor

- 1) Verteks
- 2) Tracker
- 3) Preshower
- 4) Kalorimetri

5) Mionski

Broj kanala

- 80000000
- 16000000
- 512000
- 125000
- 1000000

Senzori

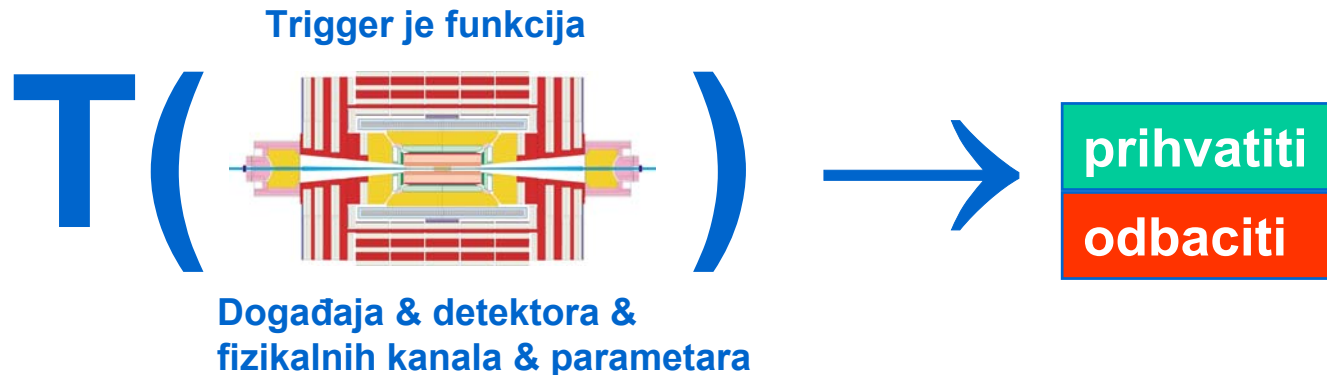
- Pikseli
- Silicijske mikropruge
- Silicij
- ECAL scintilacijski PbWO_4 kristali
- HCAL plastični scintilatori, bakreni “sandwich”
- Drift Tube Chambers (DT)
- Cathode Strip Chambers (CSC)
- Resistive Plate Chambers (RPC)

Triger/DAQ

➤ Zadatak:

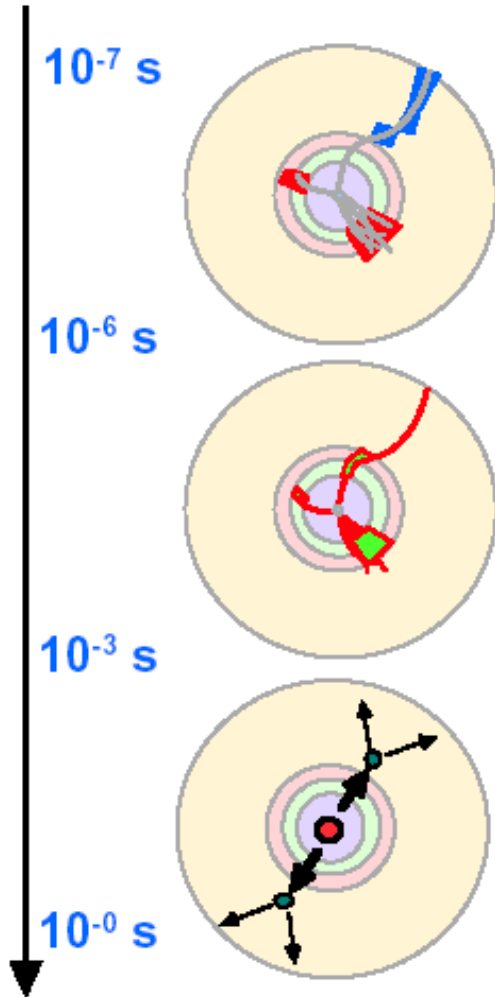
Pogledati (skoro) sve p-p sudare, te odabrati samo interesantne. Zatim sakupiti podatke iz svih detektora i spremiti ih za off-line analizu.

P.S. Za razumnu količinu CHF.



Budući da svi podaci iz svih detektora nisu odmah dostupni i funkcija je vrlo kompleksna, $T(\dots)$ se izračunava u nekoliko koraka koji se zovu TRIGGER RAZINE.

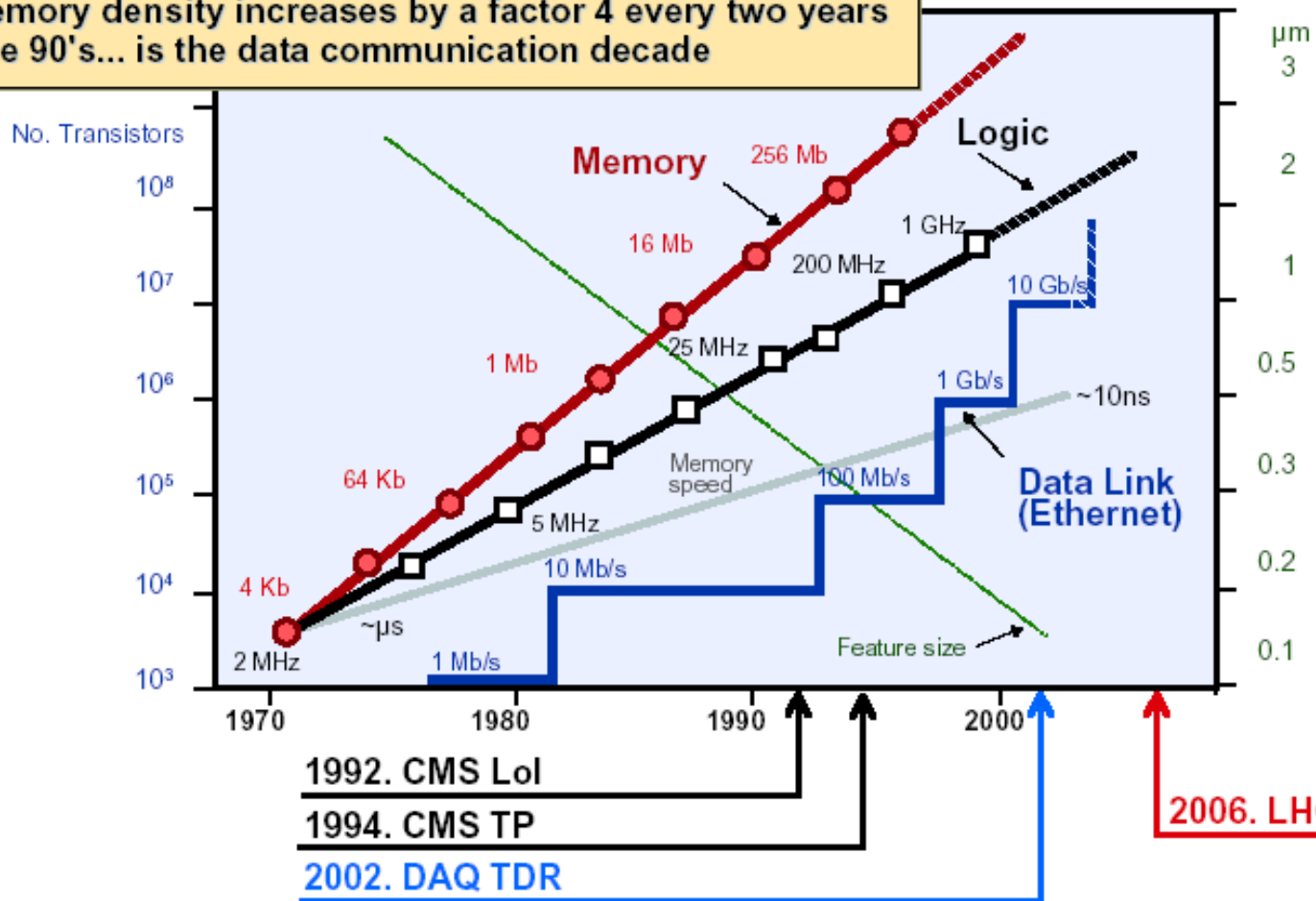
Triger razine u CMS-u



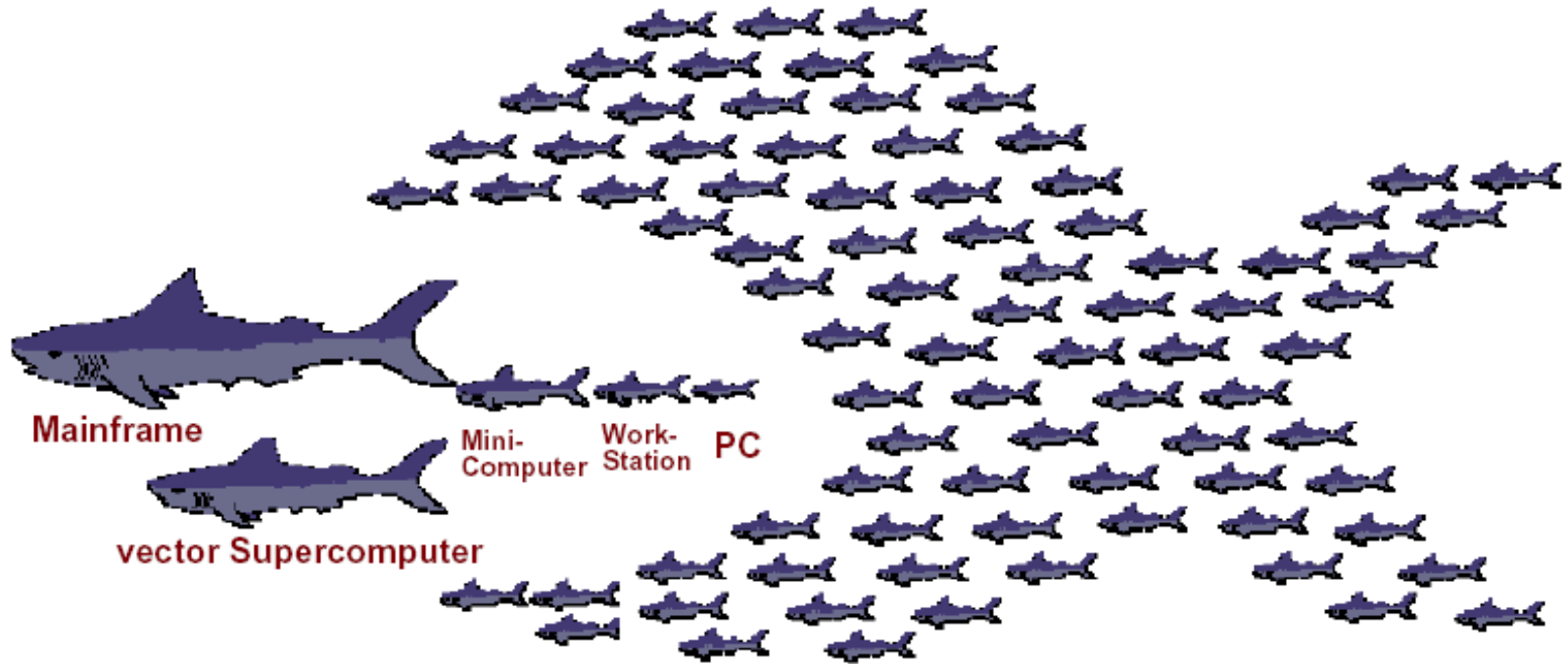
- **Frekvencija sudara 10^9 Hz**
- **Razina - 1**
selekcija događaja 10^5 Hz
 - **Identifikacija čestica** (e, μ velikog p_T , mlazovi, nedostajuća energija)
- **Razina - 2**
selekcija događaja 10^3 Hz
 - **Rekonstrukcije događaja** (raspad Z, W, ...)
- **Razina - 3**
događaji se zapisuju, 10 – 100 Hz
 - **Identifikacija fizikalnih događaja**

Tehnološki trendovi (Mooreov zakon)

- Processing power increases by a factor 10 every 5 years
- Memory density increases by a factor 4 every two years
- The 90's... is the data communication decade



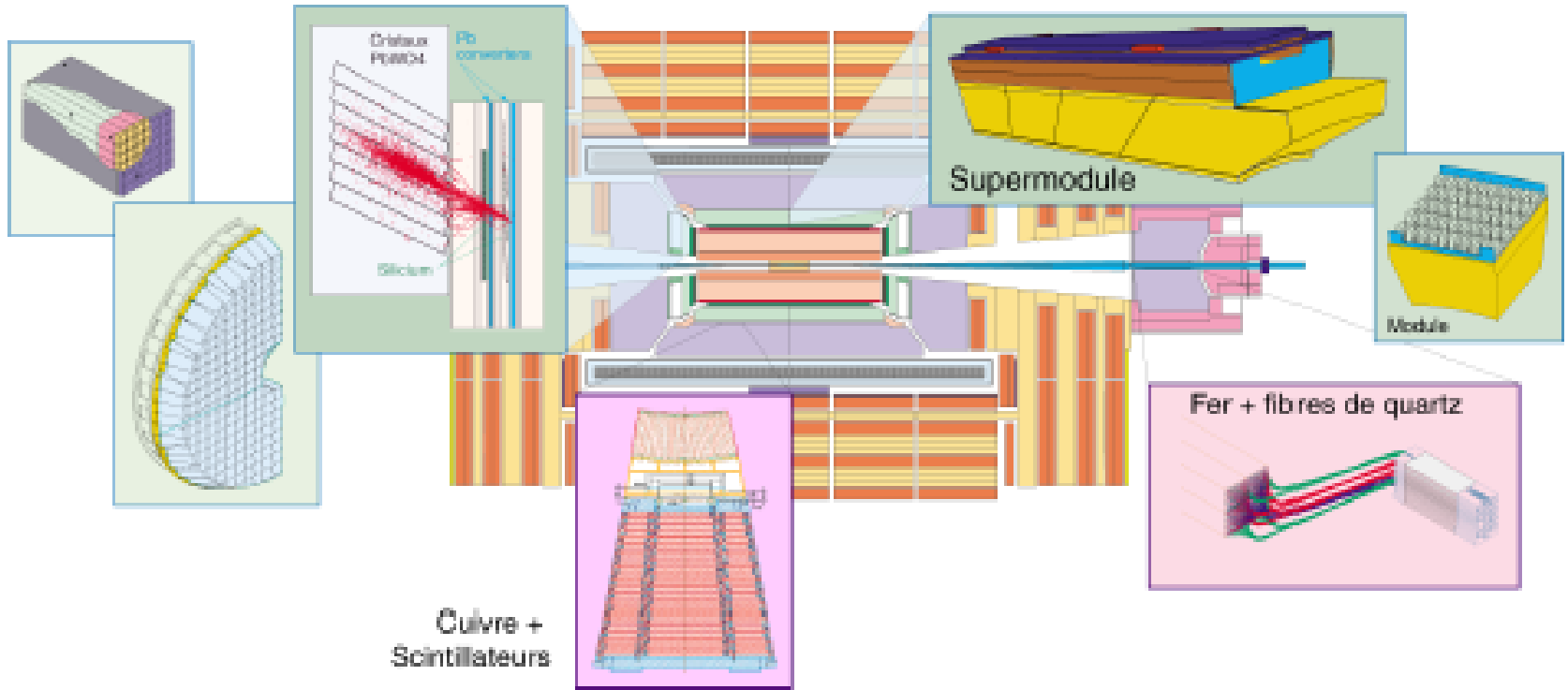
Superkompjuteri danas



Preuzeto sa: <http://now.cs.berkeley.edu>

Elektromagnetski kalorimetar CMS-a

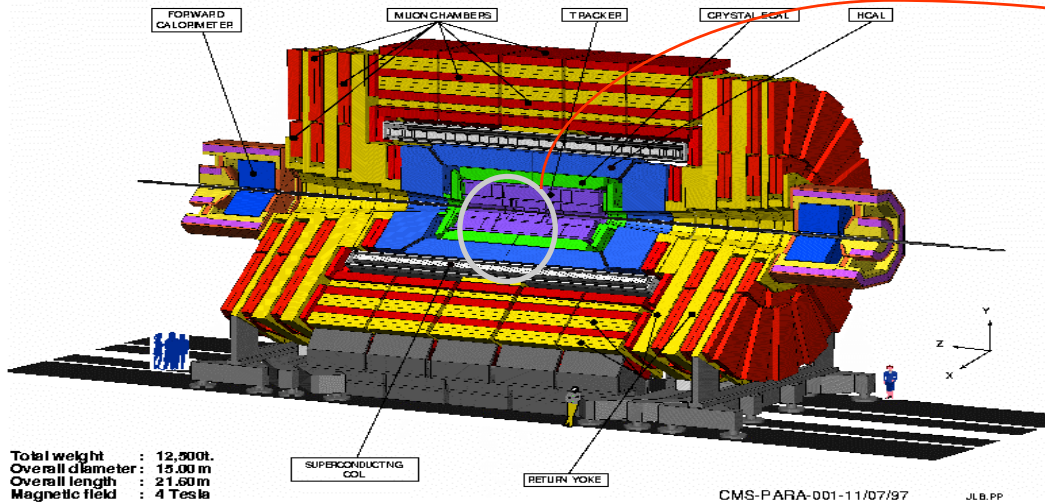
ELECTROMAGNETIC CALORIMETERS



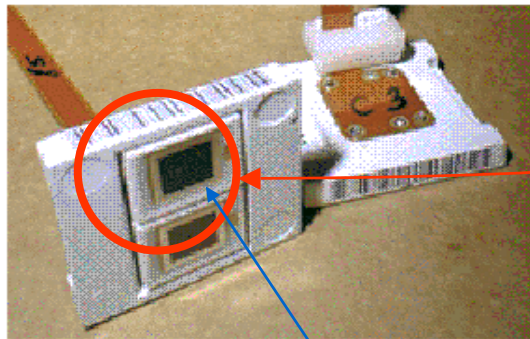
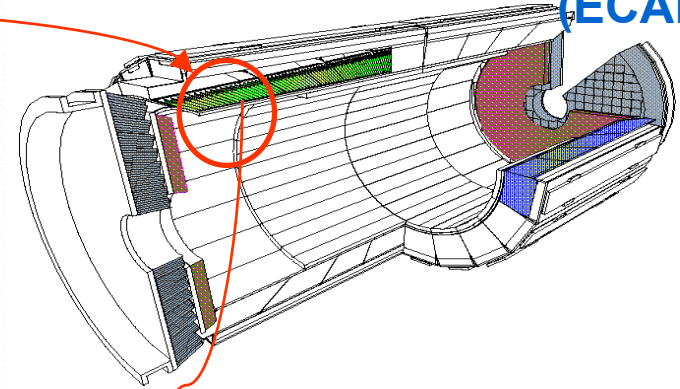
HADRON CALORIMETERS

Elektromagnetski kalorimetar CMS-a

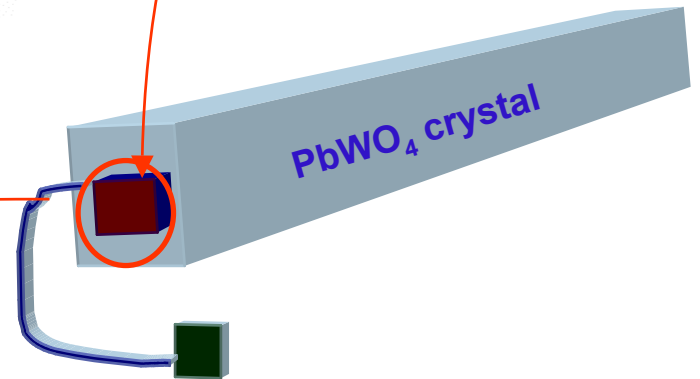
CMS
A Compact Solenoidal Detector for LHC



Elektromagnetski kalorimetar (ECAL)

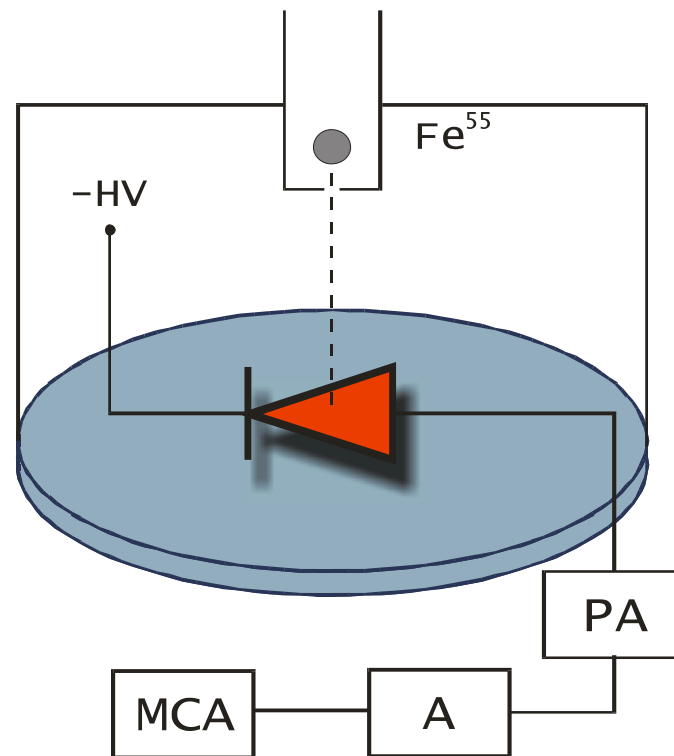
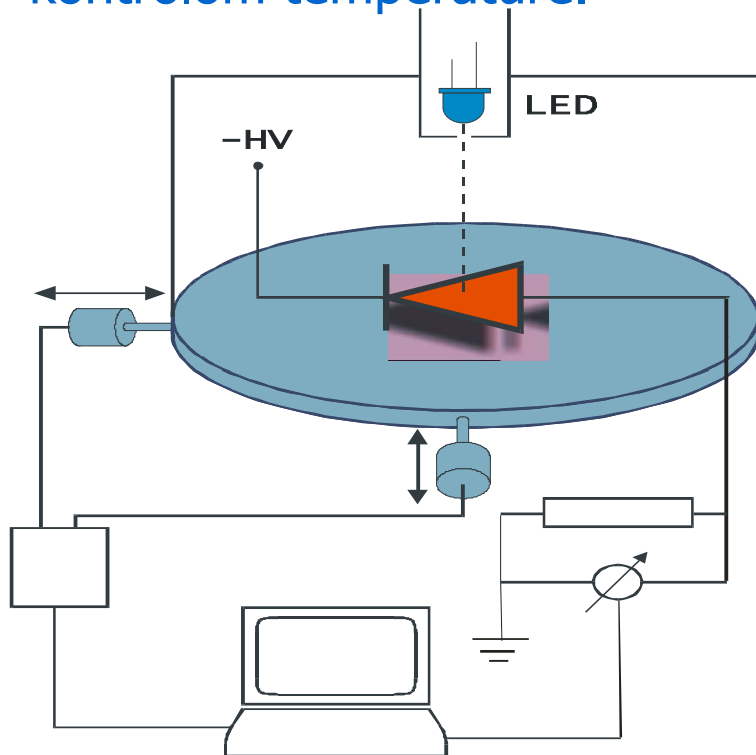


Lavinska fotodioda (APD)



Ekperimentalna mjerenja u Splitu

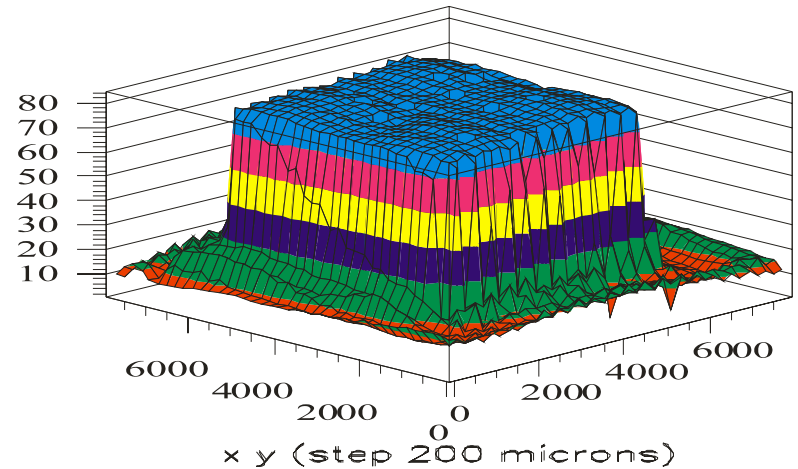
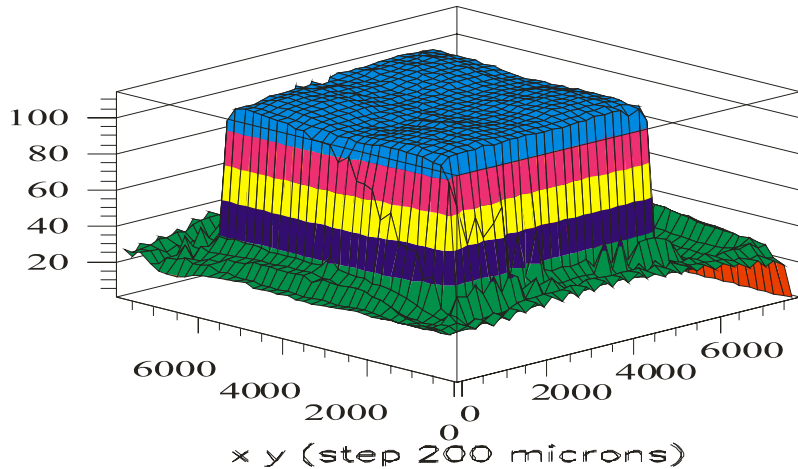
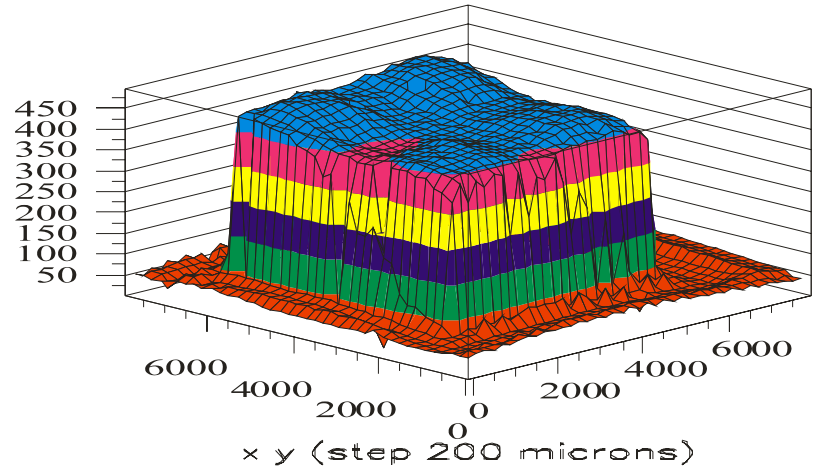
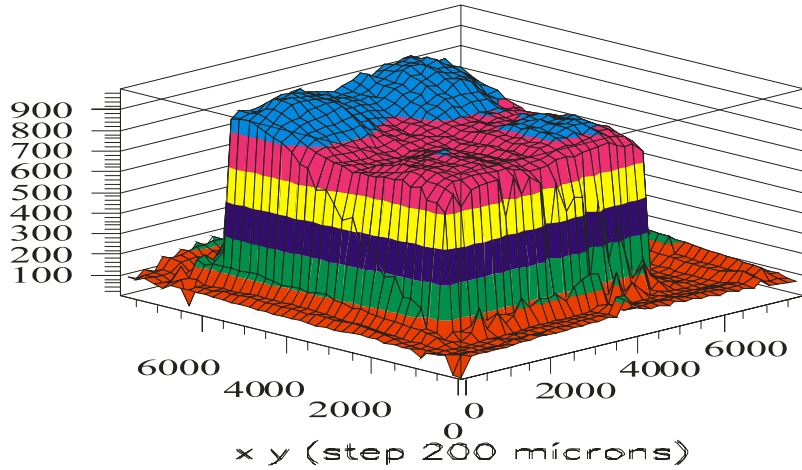
- Izgrađen je sustav za mjerenje inverzne struje 10 lavinskih fotioda (APD) istovremeno uz praćenje temperature, tijekom godine dana ili duže.
- Gradi se sustav za mjerenje odziva APD-ova na pulsno svjetlo s kontrolom temperature.



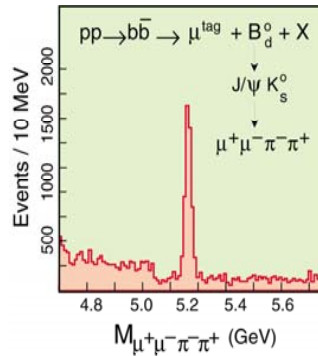
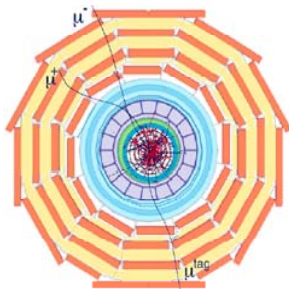
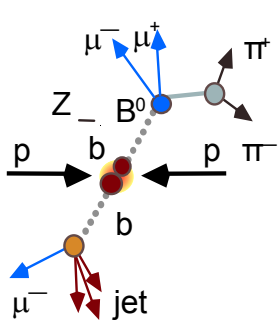
Uniformnost APD-a: rezultati

2000/09/25 07.

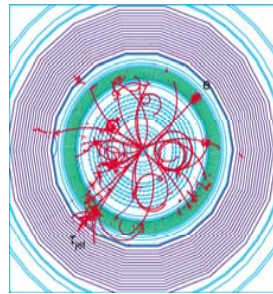
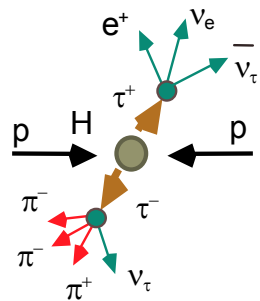
APD 3298, Uniformity response for GREEN LED (520nm)



CMS fizika: B & Supersimetrija

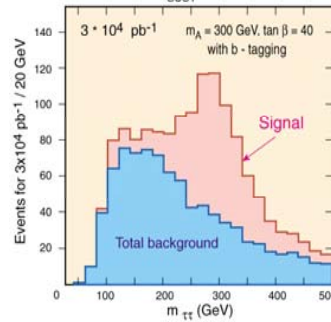


The decay B or $B^0 \rightarrow J/\psi K_S^0$ presents a very clean experimental signature. The particle content (B or B^0 meson) that gave the decay can be determined from a muon from the second b -flavored hadron in the event. An asymmetry in the two rates (B s B^0) would signal CP violation. This would be the first time that CP violation is observed outside the neutral kaon system

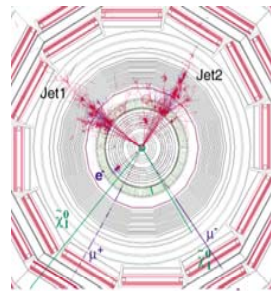
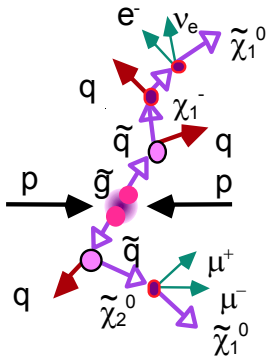


$H \rightarrow \tau \tau \rightarrow e + \tau_{jet}$ ("3-prong")

$A^0, H^0, h^0 \rightarrow \tau^+ \tau^- \rightarrow e/\mu + \tau_{jet} + E_t^{miss}$ in bbH_{SUSY} final states

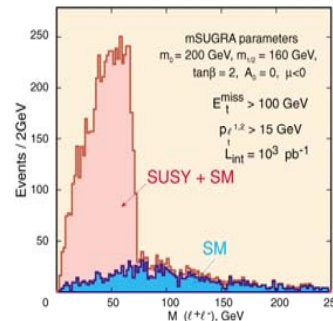


SUSY Higgs bosons in the MSSM there are 5 Higgs bosons: h, H^0, A^0 and H^\pm decaying through a variety of decay modes to $\gamma, e^\pm, \mu^\pm, \tau^\pm$ and jets in final states. Above: an example of a SUSY Higgs decay to $\tau \tau$ in CMS. On the right is the reconstructed $\tau \tau$ mass spectrum



SUSY event with 3 leptons + 2 Jets signature

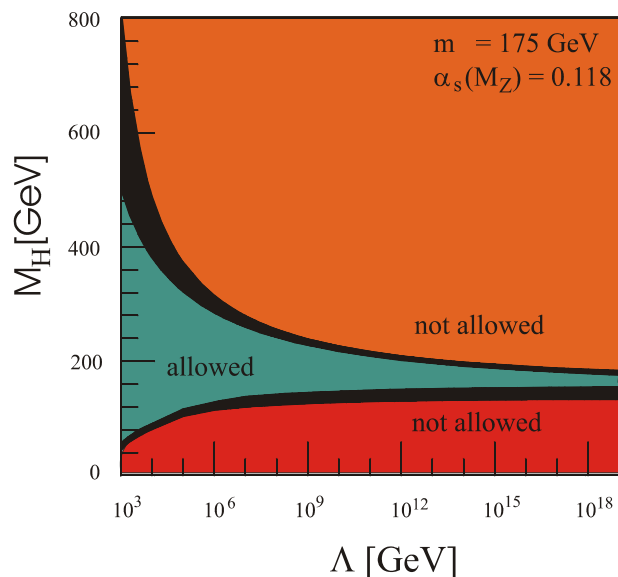
Inclusive $e^+ e^- + E_t^{miss}$ final states



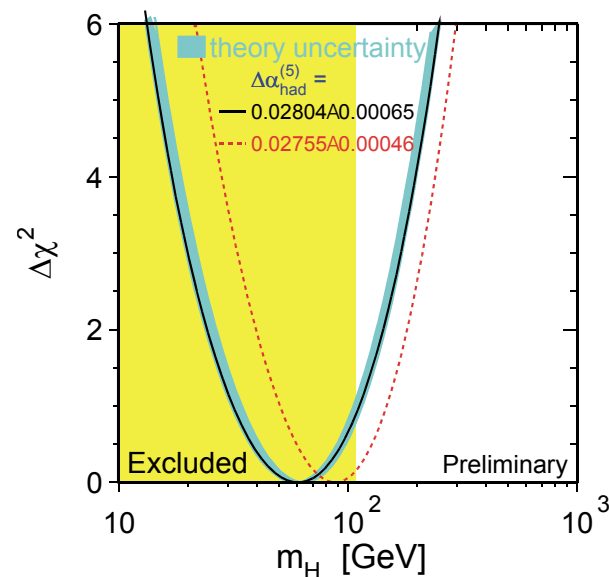
Sparticles Production of sparticles may reveal itself though some spectacular kinematical spectra, with a pronounced "edge" in the $+, -$ mass spectrum reflecting $\chi_2^0 \rightarrow +, - \chi_1^0$ production and decay. An example of such a spectrum in inclusive $+, - + E_t^{miss}$ and of a $3, \pm$ production event are shown below

Potruga za Higgs bozonom

➤ Teorijska ograničenja



➤ Indirektna potraga



- **Direktna potraga, LEP II: nagovještaj** (3 σ više događaja signala od pozadine)

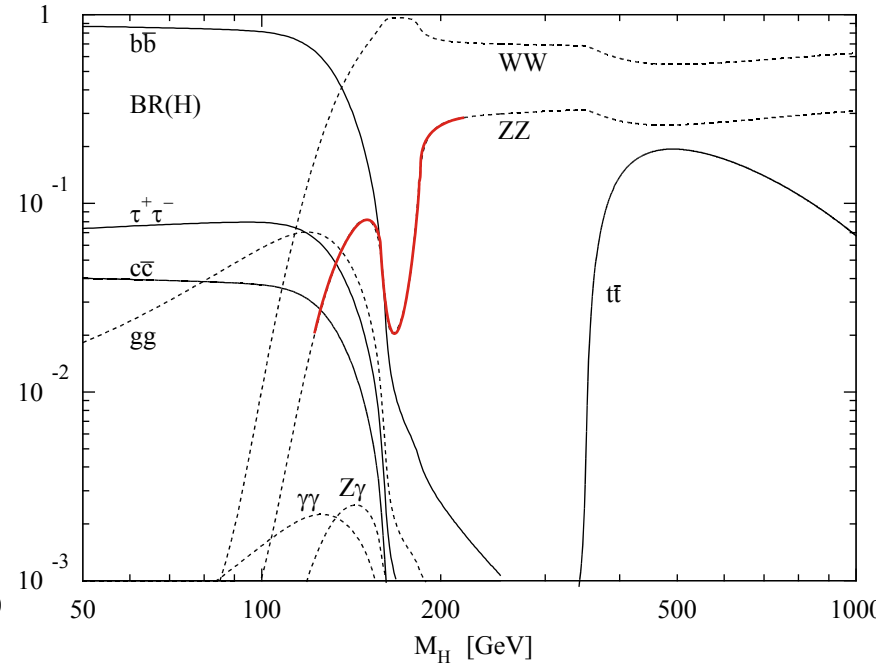
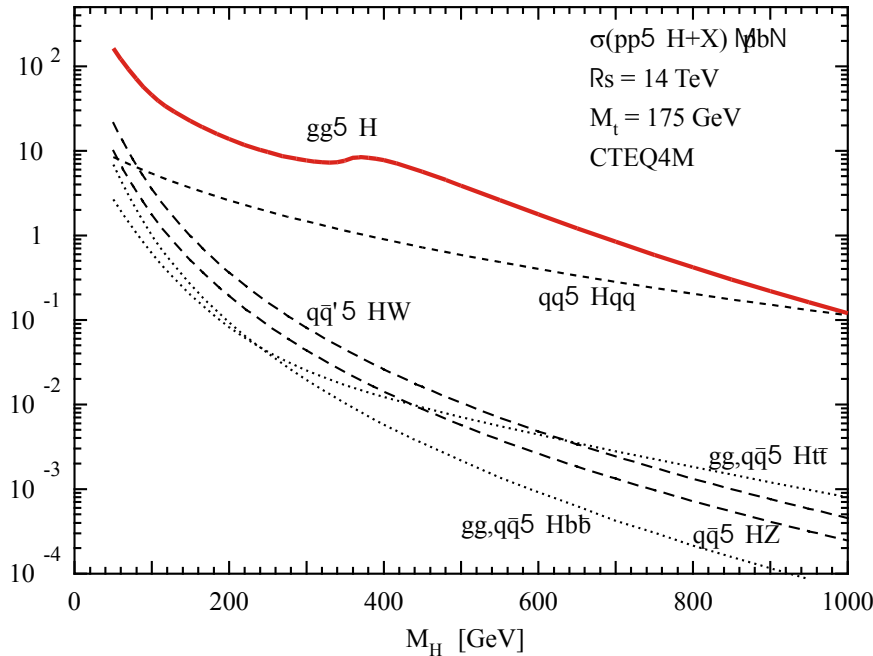
$$m_H = 115 \text{ GeV}$$

- **Higgs bozon na LHC-u**

- Potvrditi postojanje Higgs bozona od 115 GeV ili
- Pronaći Higgs bozon do mase od 1 TeV

- **Trenutno: potraga na Tevatronu**

Produkcija i raspad Higgs bozona



➤ **Oko 2 000 000 Higgs bozona s massom biti će proizvedeno na LHC-u za 10^5 pb^{-1} (1 godina rada na nominalnom luminozitetu)**

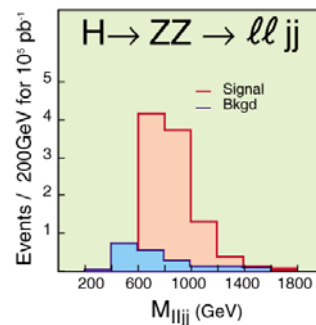
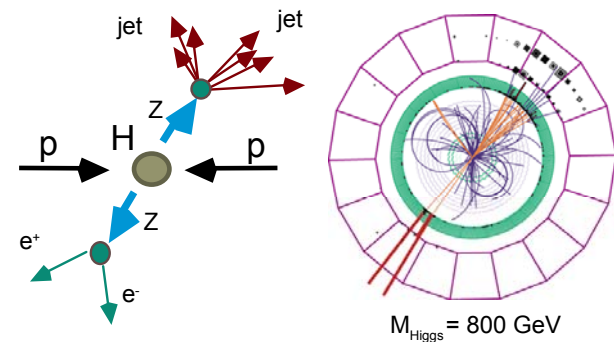
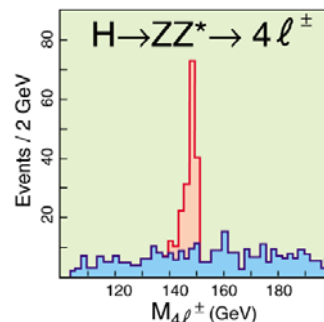
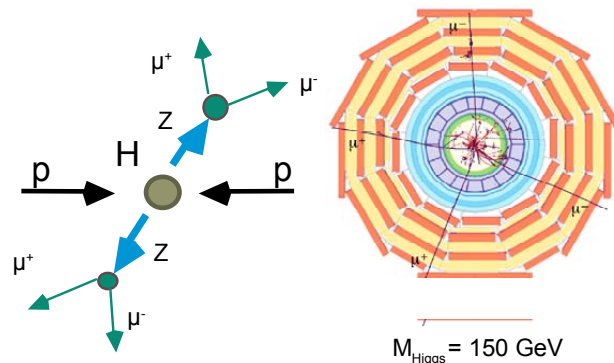
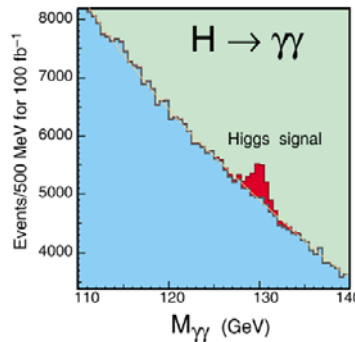
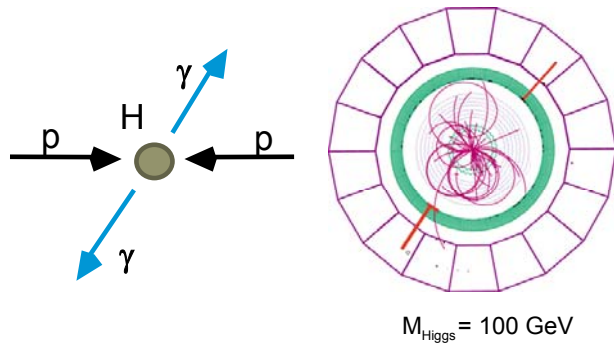
$$m_H \in (130, 180) \text{ GeV}$$

➤ **$\text{BR}(H \rightarrow ZZ^*)$ u tom području $\approx 2 - 10 \%$**

➤ **$\text{BR}(Z \rightarrow ee)^2 = 3,4\%^2 = 0,11\%$**

➤ **Očekuje se oko 40 do 200 događaja $H \rightarrow ZZ^* \rightarrow 4e$ za 10^5 pb^{-1}**

Fizika Higgs bozona na CMS-u



Higgs to 2 photons ($M_H < 140 \text{ GeV}$)

$H^0 \rightarrow \gamma\gamma$ is the most promising channel if M_H is in the range 80 – 140 GeV. The high performance PbWO_4 crystal electromagnetic calorimeter in CMS has been optimized for this search. The $\gamma\gamma$ mass resolution at $M_{\gamma\gamma} \sim 100 \text{ GeV}$ is better than 1%, resulting in a S/B of $\sim 1/20$

Higgs to 4 leptons ($140 < M_H < 700 \text{ GeV}$)

In the M_H range 130 - 700 GeV the most promising channel is $H^0 \rightarrow ZZ^* \rightarrow 2, + 2, -$ or $H^0 \rightarrow ZZ \rightarrow 2, + 2, -$. The detection relies on the excellent performance of the muon chambers, the tracker and the electromagnetic calorimeter. For $M_H \gtrsim 170 \text{ GeV}$ a mass resolution of $\sim 1 \text{ GeV}$ should be achieved with the combination of the 4 Tesla magnetic field and the high resolution of the crystal calorimeter

Higgs to 2 leptons+2 jets ($M_H > 500 \text{ GeV}$)

For the highest M_H , in the range 0.5 - 1 TeV, the promising channels for one year at high luminosity are $H^0 \rightarrow ZZ \rightarrow \nu, +, -, \nu\nu$, $H^0 \rightarrow ZZ \rightarrow \nu, +, -, jj$ and $H^0 \rightarrow W^+W^- \rightarrow \nu, +, \nu jj$. Detection relies on leptons, jets and missing transverse energy (E_{miss}), for which the hadronic calorimeter (HCAL) performance is very important

$H \rightarrow ZZ^* \rightarrow 4e$: pozadina

➤ Glavni pozadinski procesi

■ $ZZ^*/\gamma^* \rightarrow 4e$

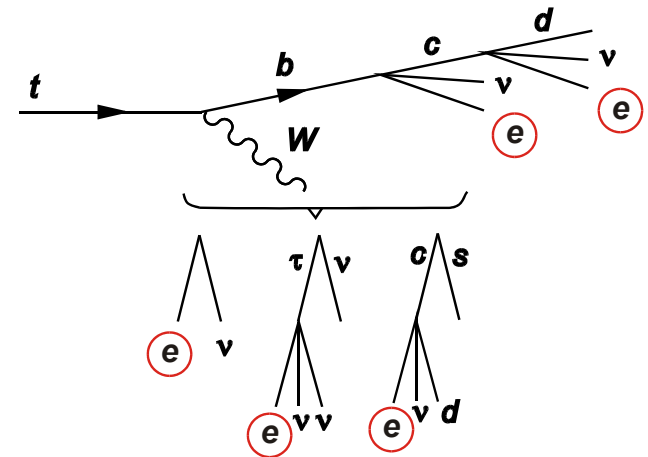
- tzv. **ireducibilna pozadina**: kinematičke karakteristike slične signalu
- jedina bitna razlika: ravna razdioba invarijante mase 4 elektrona
- Nakon preselekcije: oko **270** očekivanih događaja za 10^5 pb^{-1}

■ $t\bar{t} \rightarrow 4e$

- Nakon preselekcije: oko **2700** očekivanih događaja za 10^5 pb^{-1}
- Glavne karakteristike: “mekši” elektroni, nepostojanje Z i Z* u međustanju, neizolirani elektroni

■ $Zb\bar{b} \rightarrow 4e$

- Nakon preselekcije: oko **2000** očekivanih događaja za 10^5 pb^{-1}
- Glavne karakteristike: “mekši” elektroni, nepostojanje Z* u međustanju, barem 2 neizolirana elektrona



Monte Carlo simulacije

➤ *Monte Carlo simulacije:*

- **fizikalnih procesa**

produkcija čestica u p-p sudaru, raspad, hadronizacija, početni i konačni pljusak čestica ...

software: **PYTHIA, ISAJET, HERWIG, CompHEP, PHOTOS**

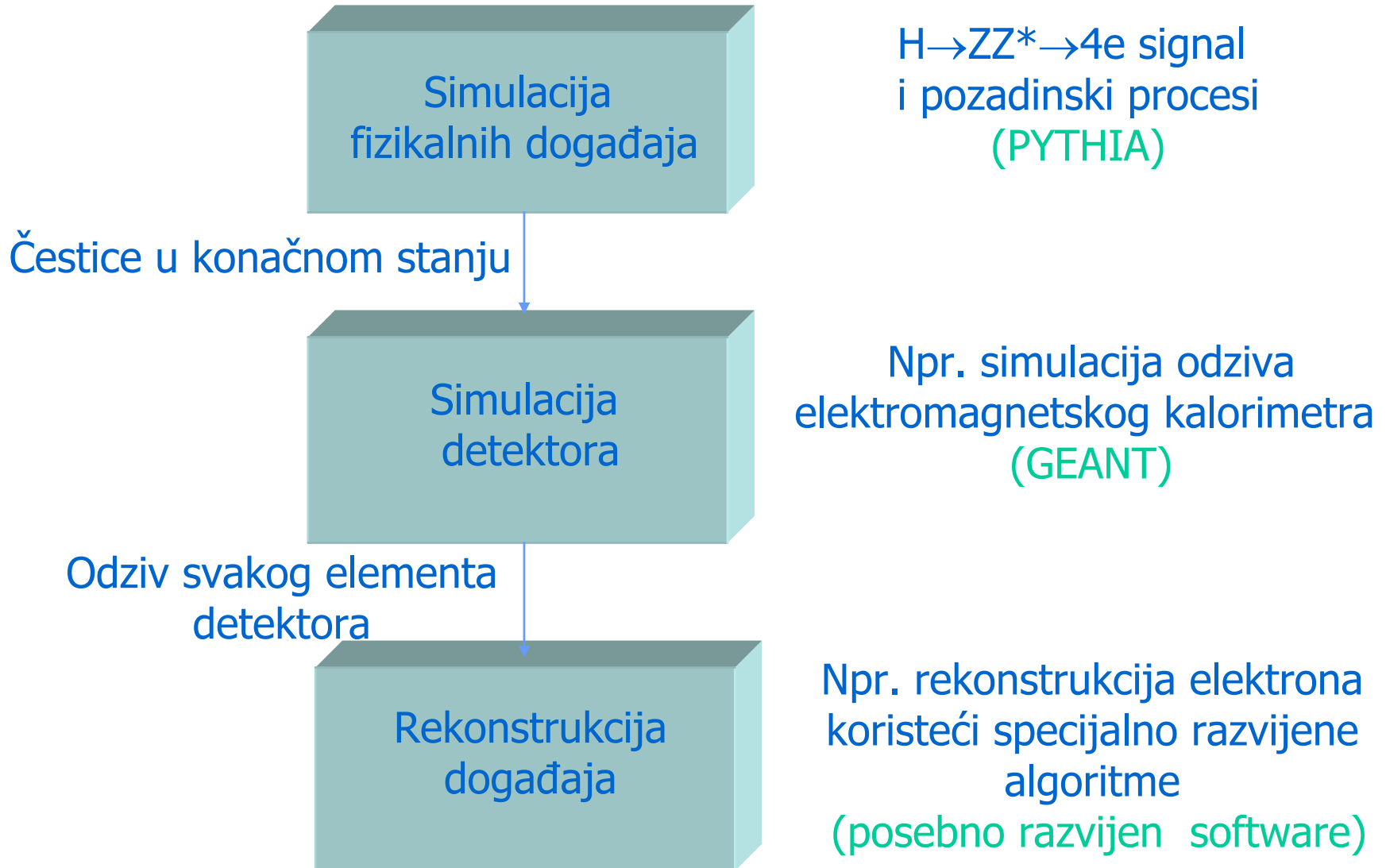
- **interakcija čestica s materijalima u detektoru**

software: **GEANT**

koriste se za:

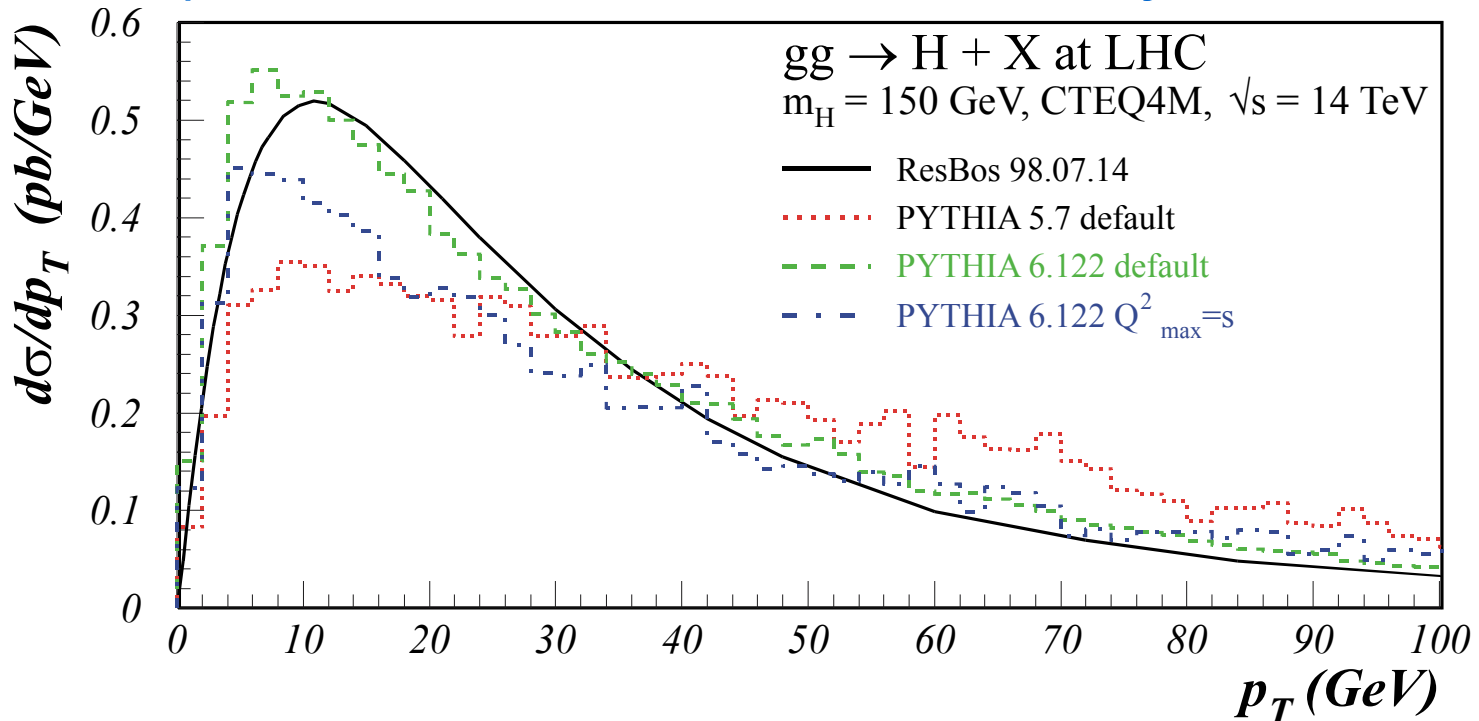
- **dizajn i optimiziranje** detektora,
- **razvoj algoritama za rekonstrukciju** fizikalnih objekata (elektron, foton, mion, snop čestica ...) u detektoru
- **provjeru experimentalnih rezultata** kada detektor započne s radom

Proces simulacije



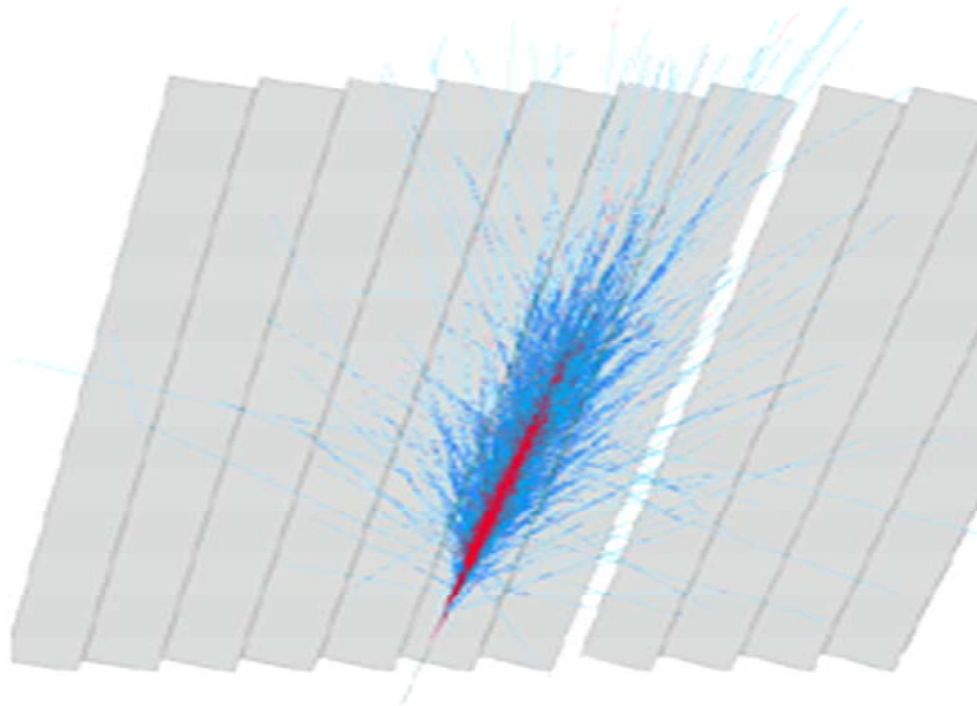
Simulacija fizikalnih događaja

- Udarni presjeci i omjeri grananja: **najnoviji teorijski proračuni** (uključuju korekcije viših redova)
- Topologija čestica u konačnom stanju: **Monte Carlo generatori**
- Usporedba rezultata s drugim teorijskim modelima:
PYTHIA: parton shower model, **ResBos**: resumacija



Simulacija odziva detektora

- “Softverska” konstrukcija detektora s **kompletnom geometrijom** i svim poznatim (relevantnim) **detektorskim efektima** (magnetsko polje, interakcije čestica s materijom, elektromagnetski pljusak čestica, ...)



pljusak čestica u elektromagnetskom kalorimetru

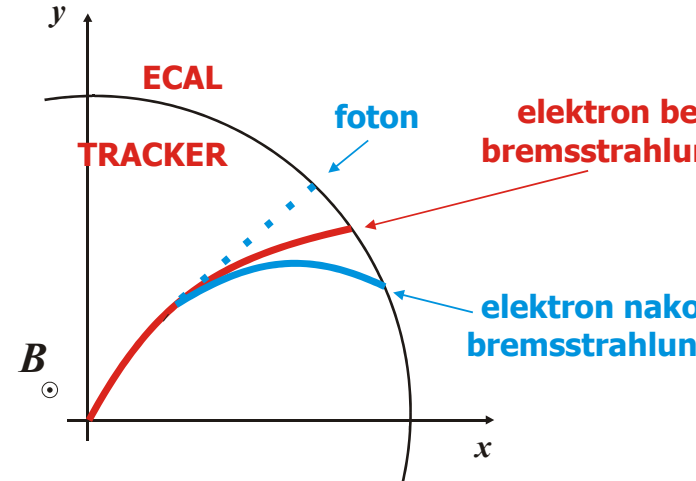
Rekonstrukcija događaja

➤ Primjer: rekonstrukcija elektrona

- Rekonstrukcija tragova u unutarnjem detektoru tragova
- Rekonstrukcija nakupina kristala u elektromagnetskom kalorimetru
- Spajanje tragova i nakupina, te procjena količine gibanja elektrona kombinirajući sva dostupna mjerenja

➤ Problem: materijal u detektoru tragova \Rightarrow bremsstrahlung!

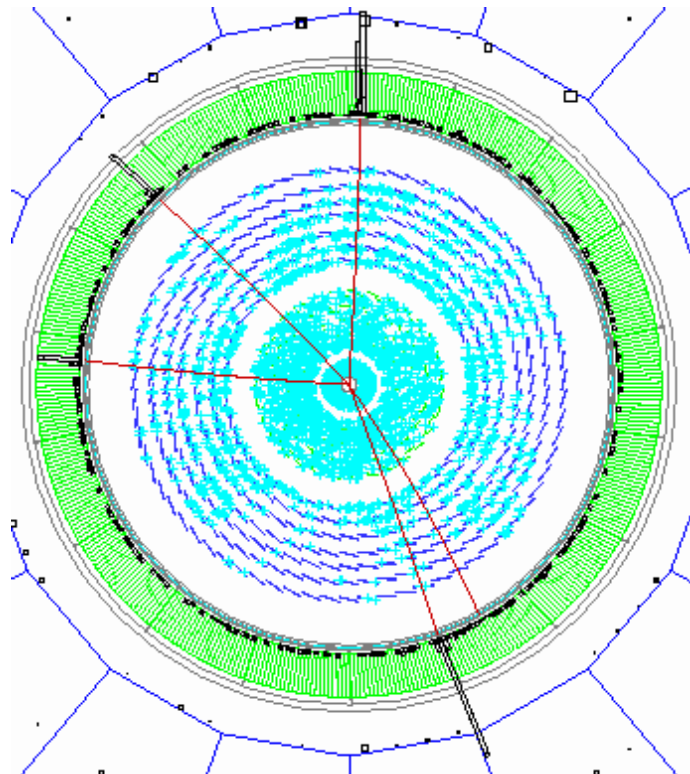
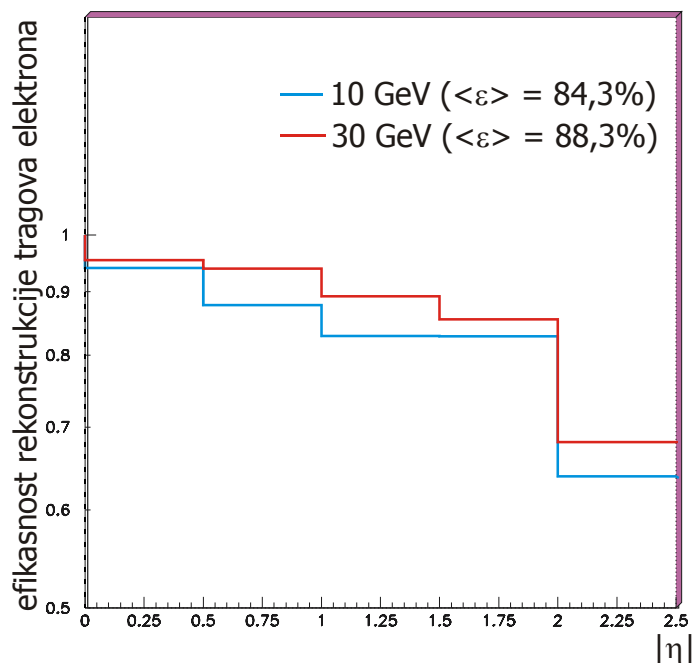
- Razvijeni algoritmi za rekonstrukciju elektrona uzimajući u obzir specifične detektorske efekte (bremsstrahlung u materijalu detektora tragova, geometrijski efekti, magnetsko polje ...)
- Potpuna migracija na nove tehnologije
Objekto programiranje i C++, objektna baza podataka, novi alati za analizu podataka - ROOT ...



Rekonstrukcija tragova

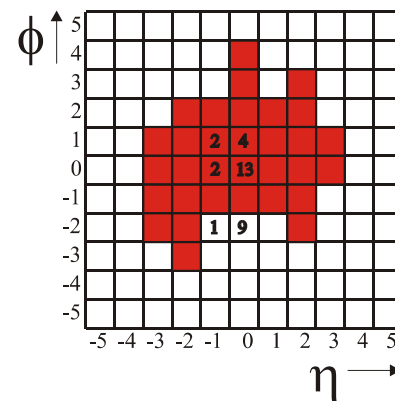
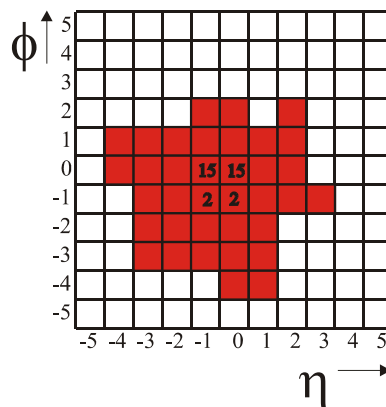
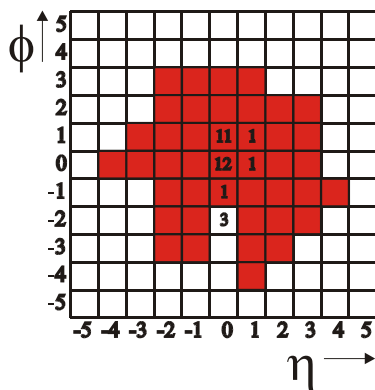
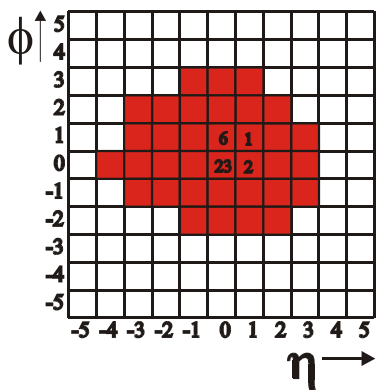
➤ Zahtjevi za rekonstrukciju tragova elektrona:

- **velika efikasnost**
- **izvrsna preciznost**



Rekonstrukcija u ECAL-u

- Identificirati **nakupinu** (*cluster*) kristala u kojima je elektron/foton ostavio svoju energiju i procijeniti tu energiju
- Zahtjevi na algoritam za traženje nakupina:
 - **Nakupina što manja da se smanji utjecaj šuma**
 - **Sposobnost razlikovanja bliskih čestica**
 - **Algoritam što fleksibilniji**
- Razvijen posebni **dinamički algoritam** koji
 - Procjenjuje energiju uzimajući u obzir predviđanje deponirane energije u kristalima.
 - Omogućuje smanjivanje efekta **bremssstrahlung**a



Razlikovanje signala od pozadine ($H \rightarrow ZZ^* \rightarrow 4e$) - 1

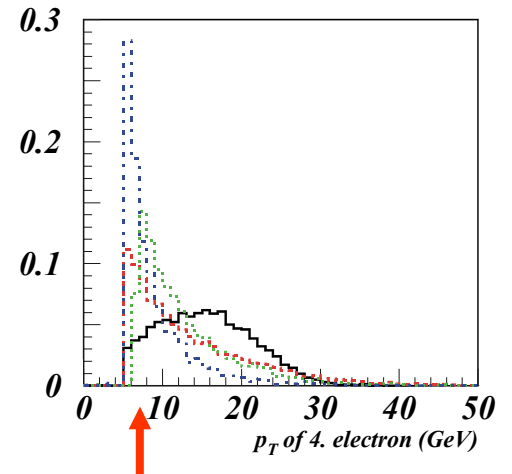
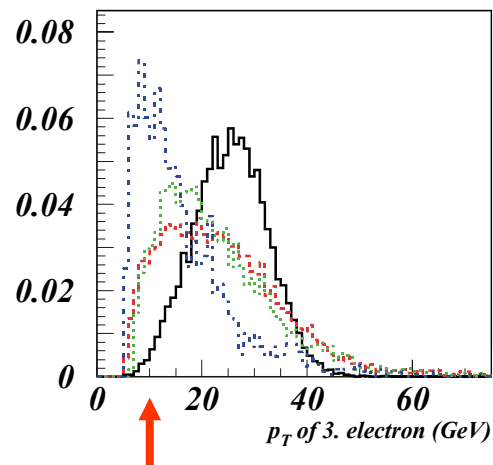
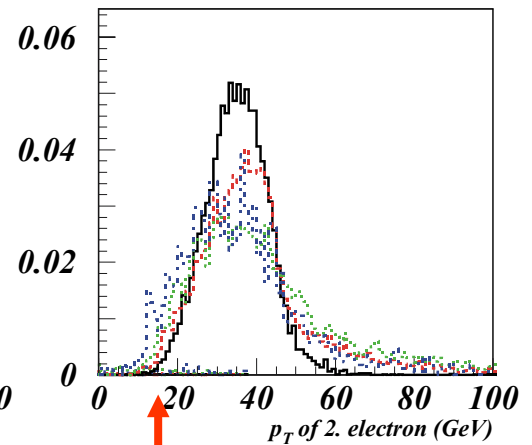
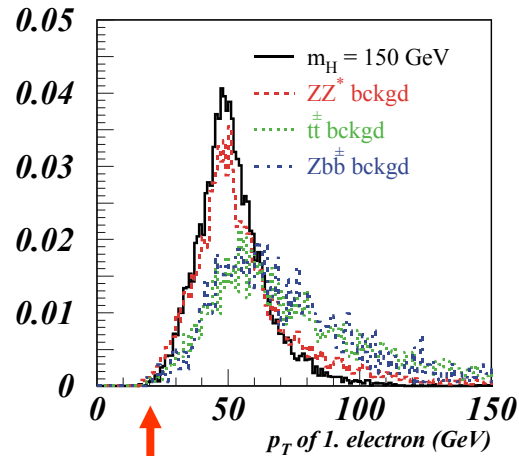
➤ Rezovi na poprečnu količinu gibanja

$$p_T^{e_1} > 20 \text{ GeV}$$

$$p_T^{e_2} > 15 \text{ GeV}$$

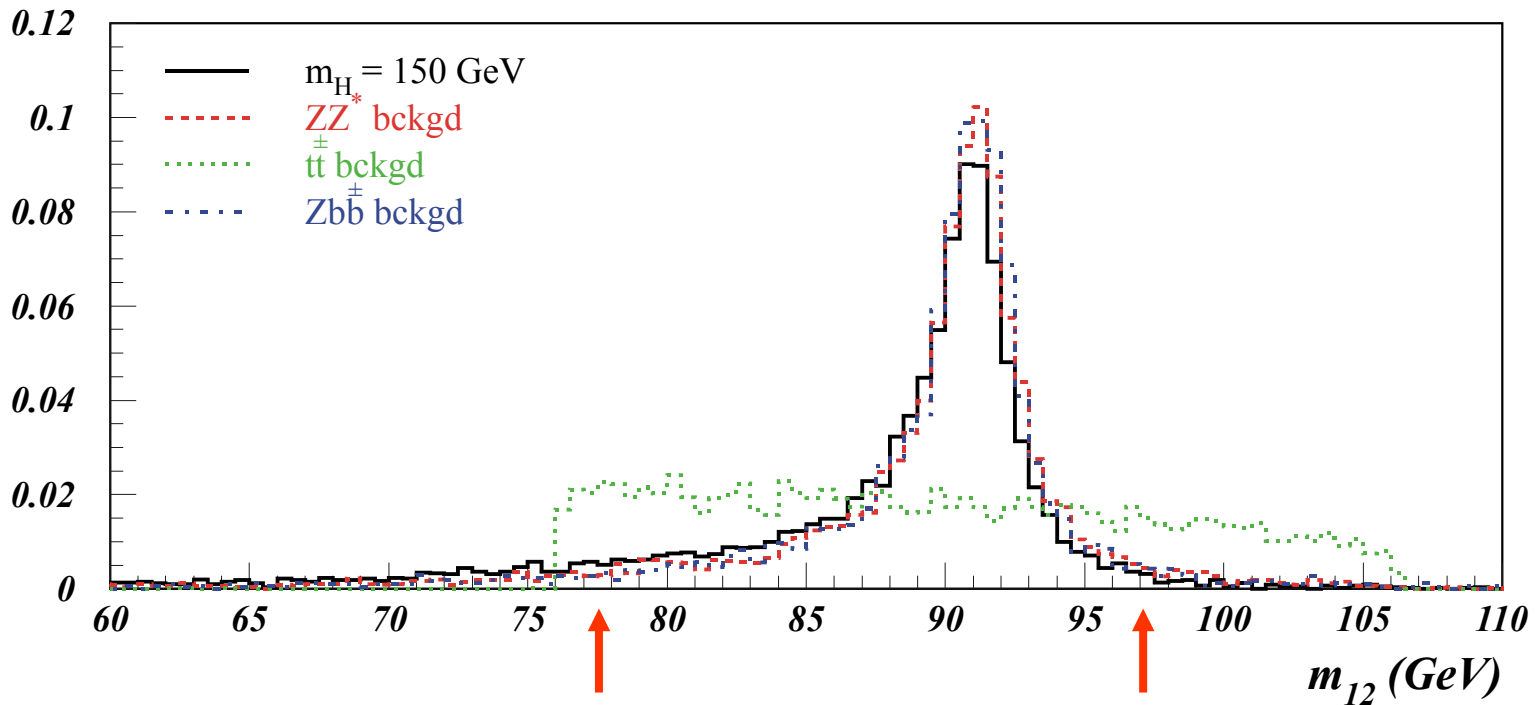
$$p_T^{e_3} > 10 \text{ GeV}$$

$$p_T^{e_4} > 7 \text{ GeV}$$



Razlikovanje signala od pozadine ($H \rightarrow ZZ^* \rightarrow 4e$) - 2

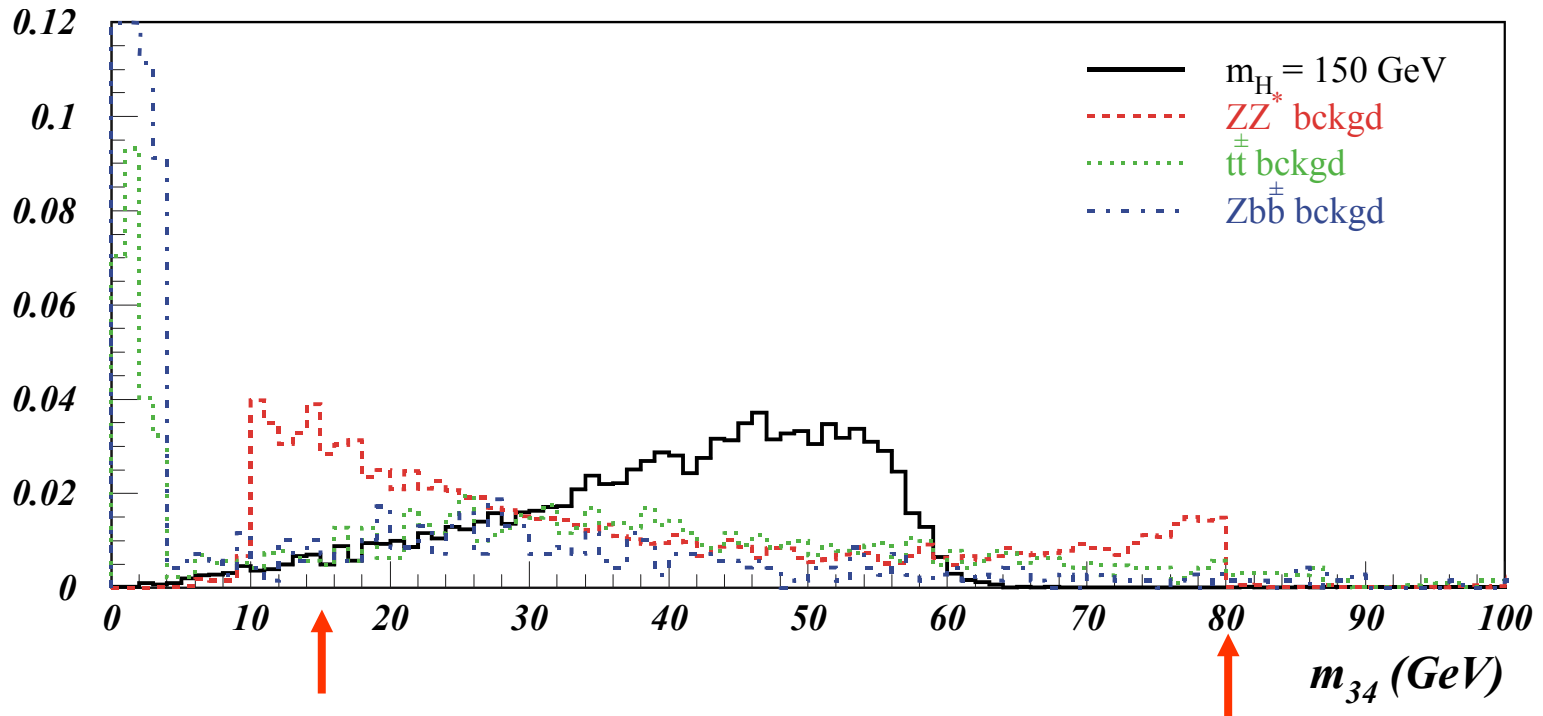
➤ Rez na masu Z bozona



$$M_Z - 13 \text{ GeV} < m_{e^+e^-} < M_Z + 6 \text{ GeV}$$

Razlikovanje signala od pozadine ($H \rightarrow ZZ^* \rightarrow 4e$) - 3

➤ Rez na masu Z^* bozona

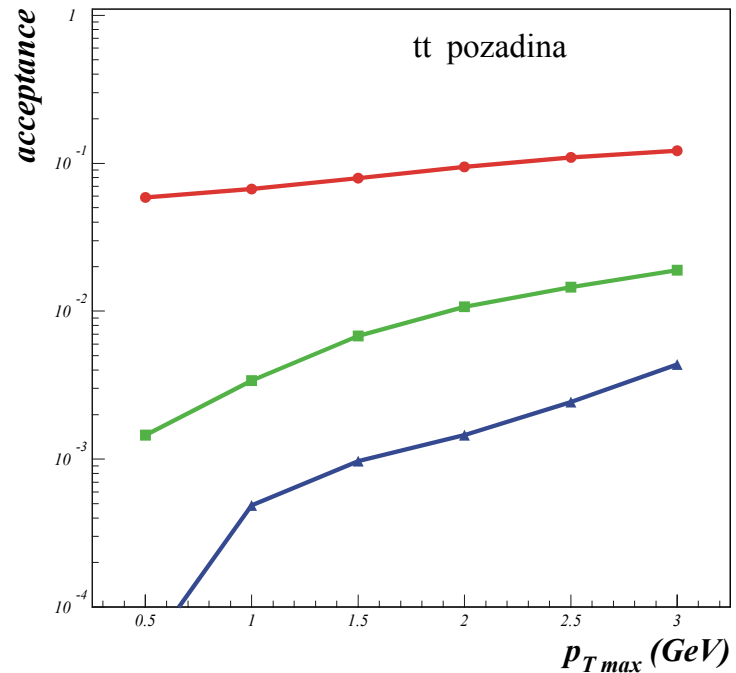
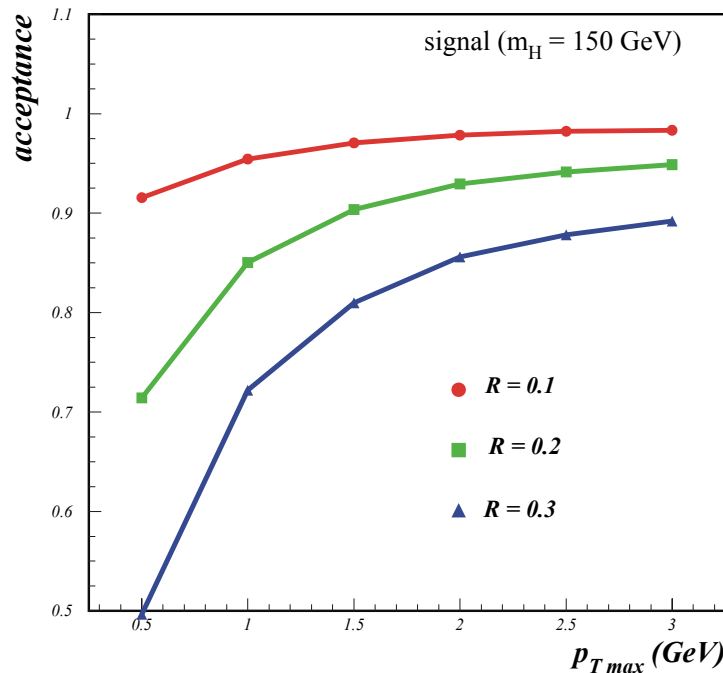


$$15 \text{ GeV} < m_{e^+e^-} < 80 \text{ GeV}$$

Razlikovanje signala od pozadine ($H \rightarrow ZZ^* \rightarrow 4e$) - 4

➤ Izolacija

promatramo nabijene čestice oko elektrona



Elektron je izoliran ako oko njega nema niti jednog nabijenog traga s $p_T > 2,5$ GeV u konusu $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0,2$

Razlikovanje signala od pozadine ($H \rightarrow ZZ^* \rightarrow 4e$) - 5

- **Rezultat rezova na nivou generatora događaja (akceptance, relativno s obzirom na preselekciju)**

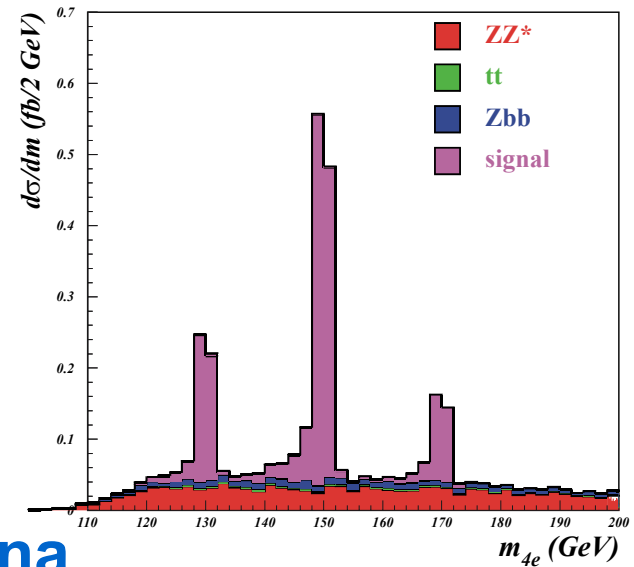
Rez	p_T elektrona	M_{Z^*}	M_Z	Izolacija	Acc. Tot.
	$p_T > 20, 15, 10, 7$ GeV	$15 < m_{ee} < 80$ GeV	$M_Z - 13 \text{ GeV} < m_{ee} < M_Z + 6 \text{ GeV}$	Bez nabijenih tragova s $p_T > 2,5$ GeV u konusu $R=0,2$	
$m_H = 130 \text{ GeV}$	0,94	0,90	0,82	0,93 (0,80)	0,64 (0,55)
$m_H = 150 \text{ GeV}$	0,98	0,95	0,91	0,94 (0,80)	0,80 (0,67)
$m_H = 170 \text{ GeV}$	0,99	0,96	0,94	0,94 (0,80)	0,84 (0,71)
ZZ^*/γ^*	0,91	0,81	0,91	0,95 (0,81)	0,63 (0,54)
tt	0,87	0,64	0,70	0,014	0,0055
Zbb	0,77	0,38	0,90	0,067	0,018

- Brojevi u zagradama odgovaraju visokom luminozitetu

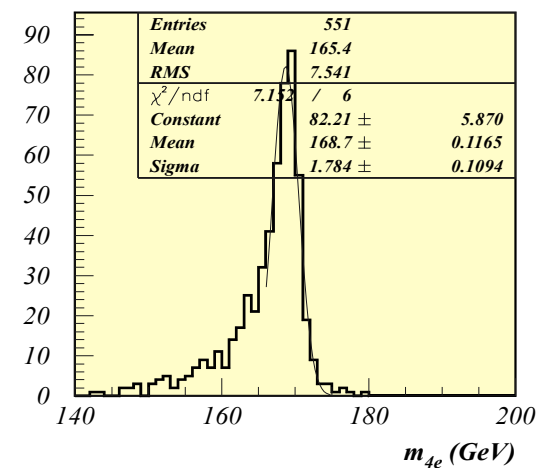
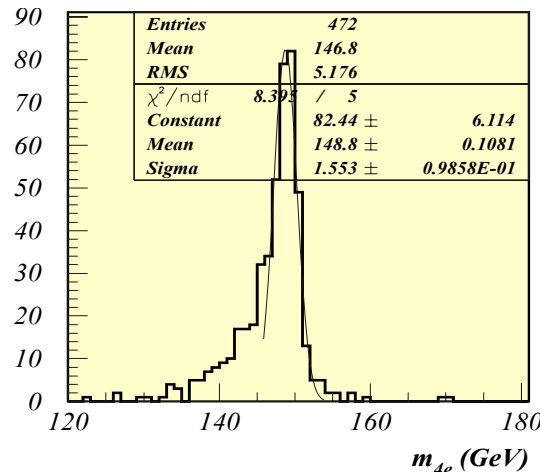
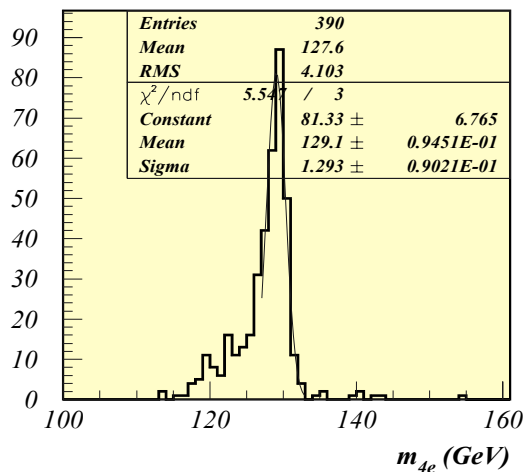
H → ZZ* → 4e: rezultati (1)

➤ Invarijantna masa 4 elektrona (na nivou MC generatora)

- **Signal:** Breit-Wigner + internal bremsstrahlung
- **Pozadina:** ravna distribucija
- **Zahtjev za što boljom rezolucijom u mjeranju količine gibanja elektrona**

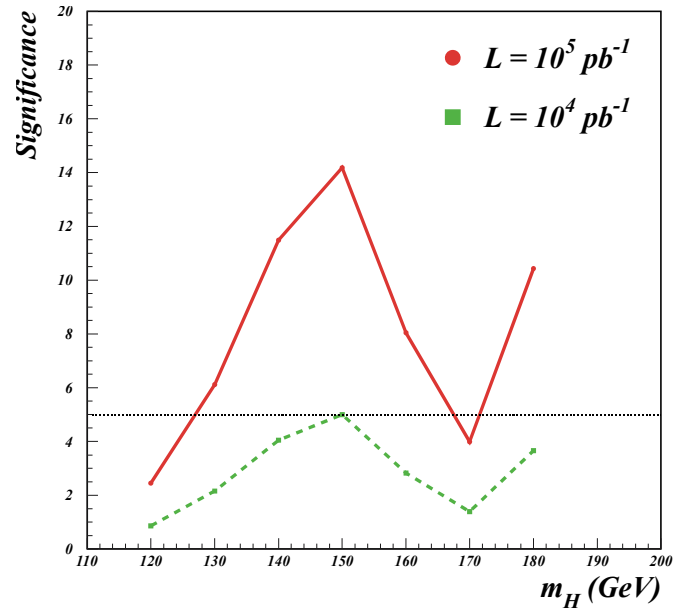
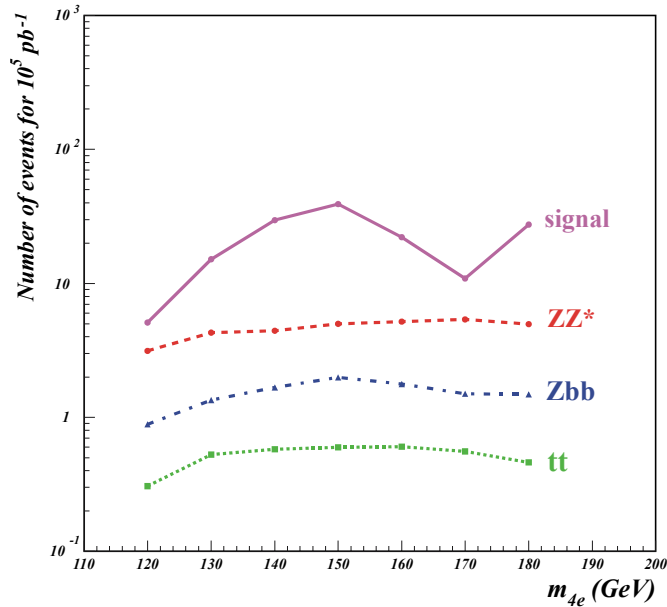


➤ Rekonstrukcija mase Higgs bozona koristeći razvijene algoritme



H → ZZ* → 4e: rezultati (2)

➤ Broj događaja i signifikantnost



➤ Moguća poboljšanja:

- Poboljšanje efikasnosti nalaženja tragova (ovdje 64% za 4 el.)
 - Potraga za fotonima izračenim internim bremstrahlungom
- Uključivanjem miona, broj događaja poraste oko 4 puta, a signifikantnost za faktor 2

Zaključak

- LHC će započeti sa radom **2006. godine** zajedno sa svojim detektorima.
- CMS detektor je trenutno **u fazi izvedbe**. Većina narudžbi prema industriji je već obavljena i dijelovi detektora već konstruirani.
- CMS će pronaći Higgs bozon do mase **od 1 TeV**, ili potvrditi indicaciju **LEP II** za Higgs bozon od **115 GeV**.
- Kroz **$H \rightarrow ZZ^* \rightarrow 4e$** kanal Higgs bozon će se naći na CMS-u, ako mu je masa između **125 GeV i 2 M_Z** .
- **Očekuje nas vrlo zanimljiva fizika na LHC-u.**