

Detekcija elementanih čestica i analiza događaja

Masterclasses program u Srbiji

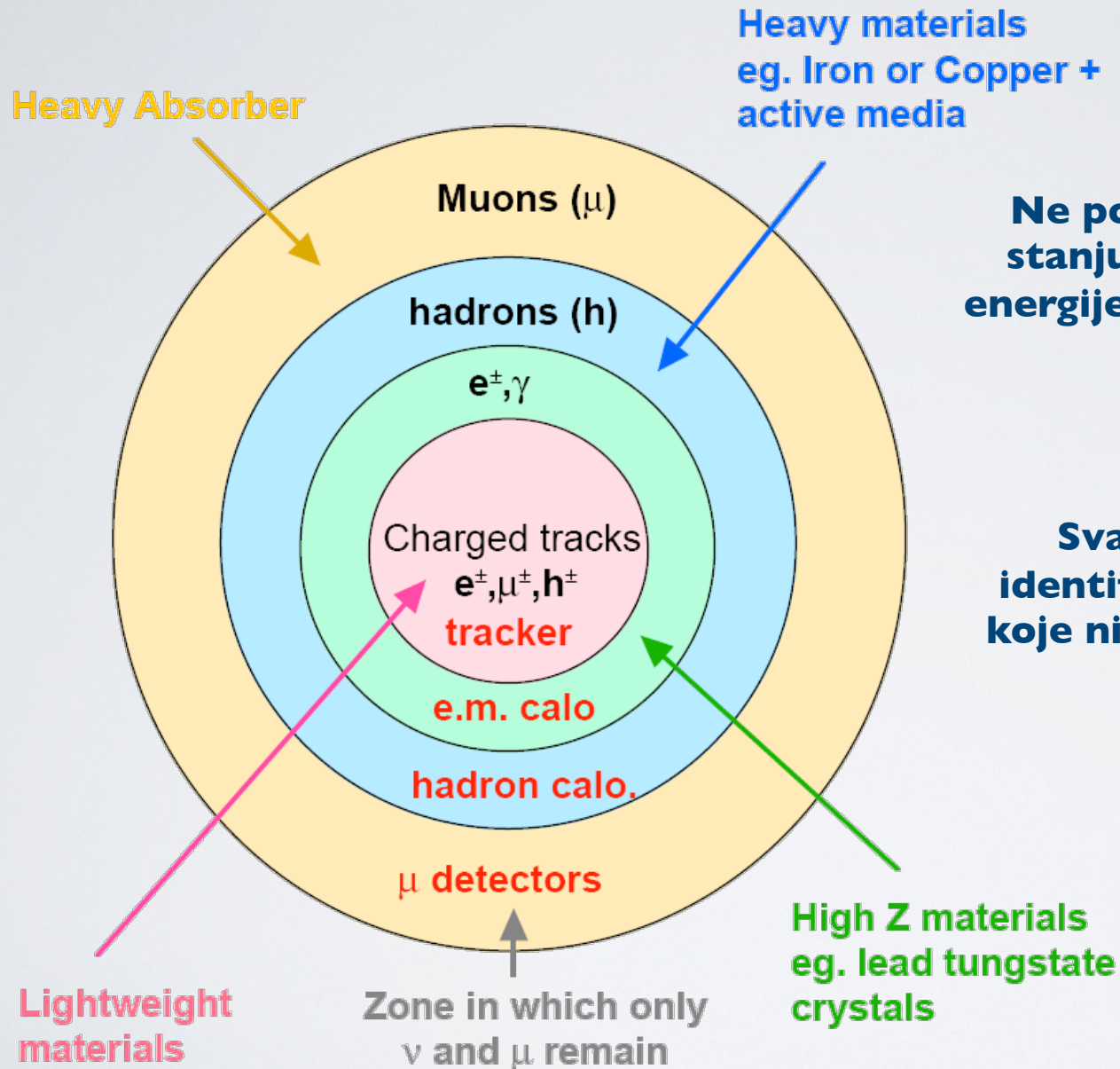
Prirodno-matematički fakultet u Novom Sadu

Predrag Milenović

Institut za fiziku viokih energija i astrofiziku, Univerzitet u Floridi
(Institut za nuklearne nauke “Vinča”, Beograd)

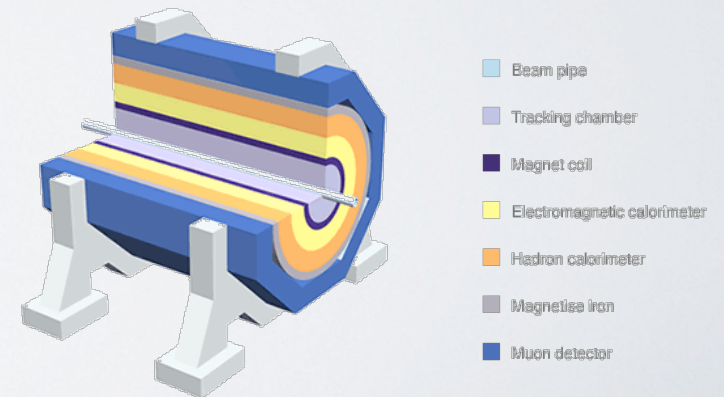


Struktura eksperimenata u HEP



Ne postoji sloj-detektor koji je u stanju da efikasno odredi i izmeri energije/impulse svih čestica nastalih u nekom događaju

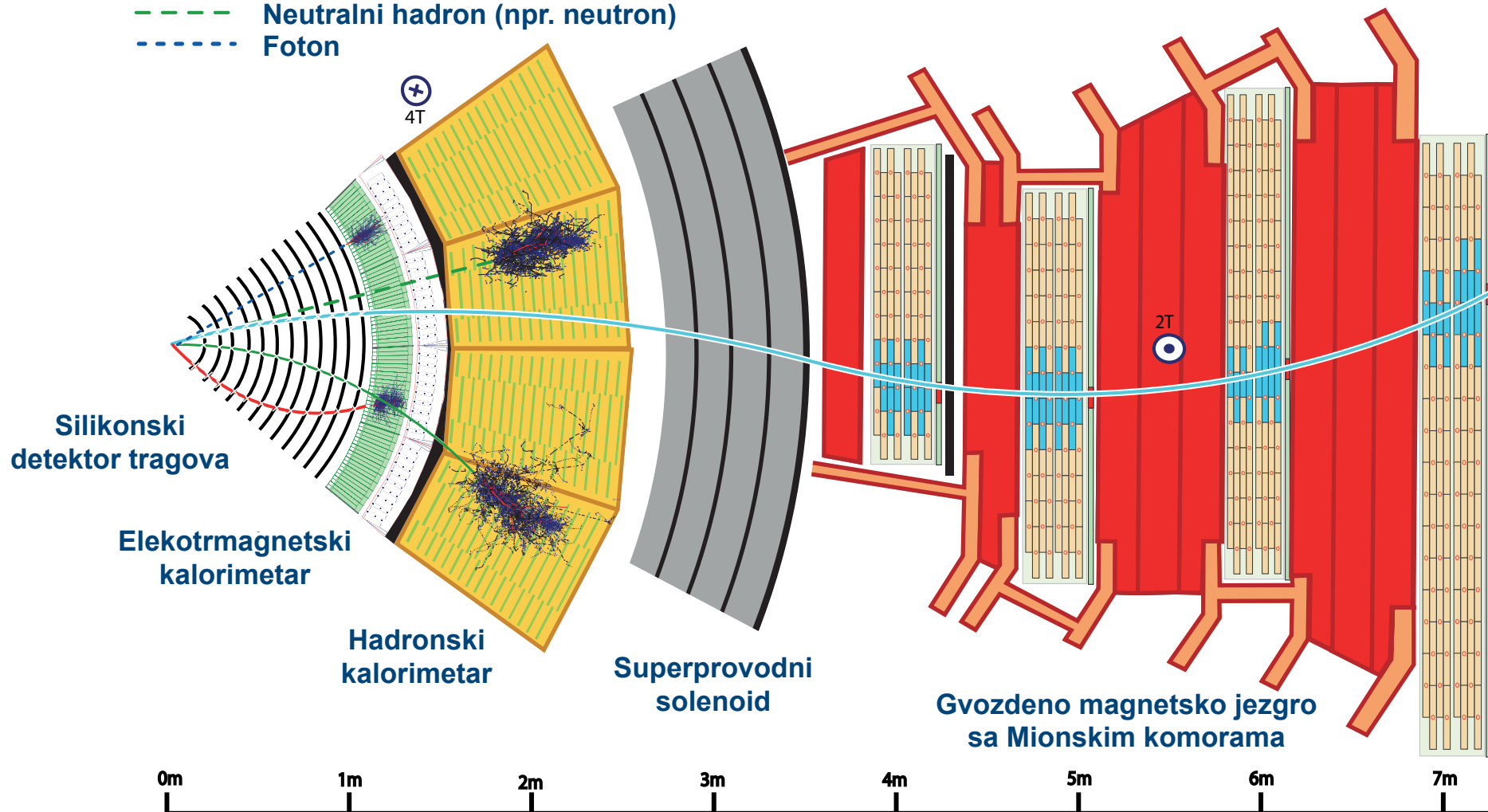
Svaki naredni sloj detektora identifikuje i meri energiju čestica koje nisu detektovane i izmerene u prethodnim slojevima



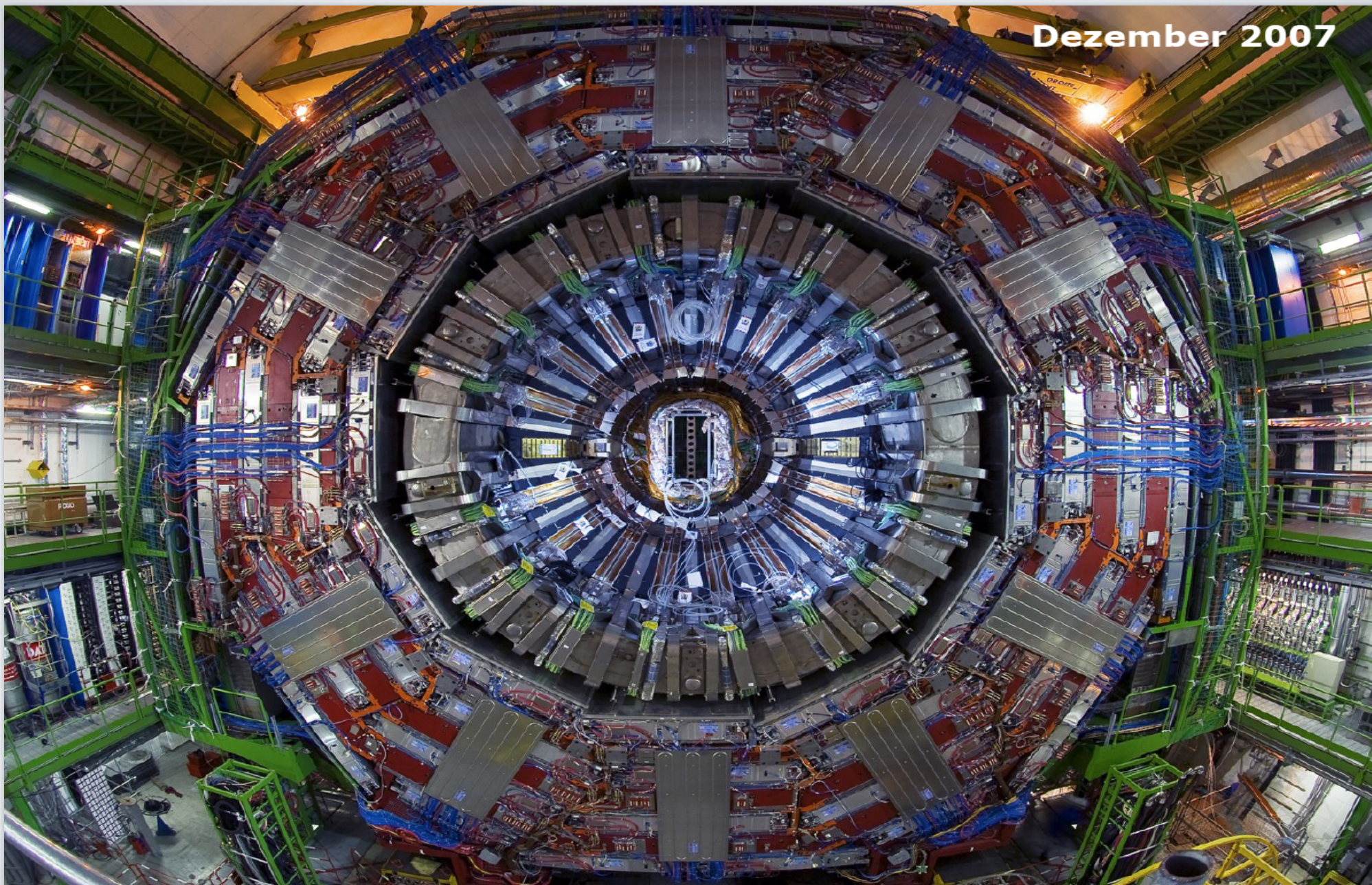
Slojevita struktura detektora CMS

Legenda:

- Mion
- Elektron
- Naelektrisani hadron (npr. pion)
- Neutralni hadron (npr. neutron)
- Foton



Kompletan detektor CMS



MC 2013 – Analiza događaja

Analiza događaja sa eksperimenta CMS:

- **Akcelerator LHC:** proton–proton sudari sa energijom **8 TeV**
- Edukativni program za vizuelizaciju događaja : **CMS iSpy**
- **Zadatak 1:** Rekonstrukcija događaja i potraga za raspadima prenosioca slabih nuklearnih interakcija:
 - pozitivan W^+ bozon: $W^+ \rightarrow \mu^+ + \text{neutrino}$ & $W^+ \rightarrow e^+ + \text{neutrino}$
 - negativan W^- bozon: $W^- \rightarrow \mu^- + \text{neutrino}$ & $W^- \rightarrow e^- + \text{neutrino}$
 - neutralan Z^0 bozon: $Z^0 \rightarrow \mu^- \mu^+$ & $Z^0 \rightarrow e^- e^+$
- **Zadatak 2:** Snimanje masenog spektra za događaje sa jednim Z^0 bozonom ili parom $Z^0 Z^0$ bozona. Upoređivanje rezultata sa vrednostima izmerenim na eksperimentima ATLAS i CMS.
- **Zadatak 3:** Upoređivanje i kombinovanje rezultata sa rezultatima studenata ostalih instituta koji učestvuju u ovom programu (V.C.)

Analiza događaja - CMS

Ekran programa iSpy

The screenshot displays the iSpy program interface. On the left is a sidebar with a tree view of detector components and event data. The main area shows a 3D wireframe model of the CMS detector with a red line representing an event track. A 3D coordinate system (x, y, z) is visible in the bottom right corner.

Detector Model

- Tracker
- ECAL Barrel
- ECAL Endcap
- ECAL Preshower
- HCAL Barrel
- HCAL Endcap
- HCAL Outer
- HCAL Forward
- Drift Tubes (muon)
- Cathode Strip Chambers (muon)
- Resistive Plate Chambers (muon)

Tracking

- Tracks (reco.)(187)
- Electron Tracks (GSF)(1)
- Clusters (Si Pixels)(963)
- Clusters (Si Strips)(7577)
- Rec. Hits (Tracking)(2684)

ECAL

- Barrel Rec. Hits(1720)
- Endcap Rec. Hits(998)
- Preshower Rec. Hits(1357)

HCAL

- Barrel Rec. Hits(870)
- Endcap Rec. Hits(337)
- Forward Rec. Hits(415)
- Outer Rec. Hits(389)

Muon

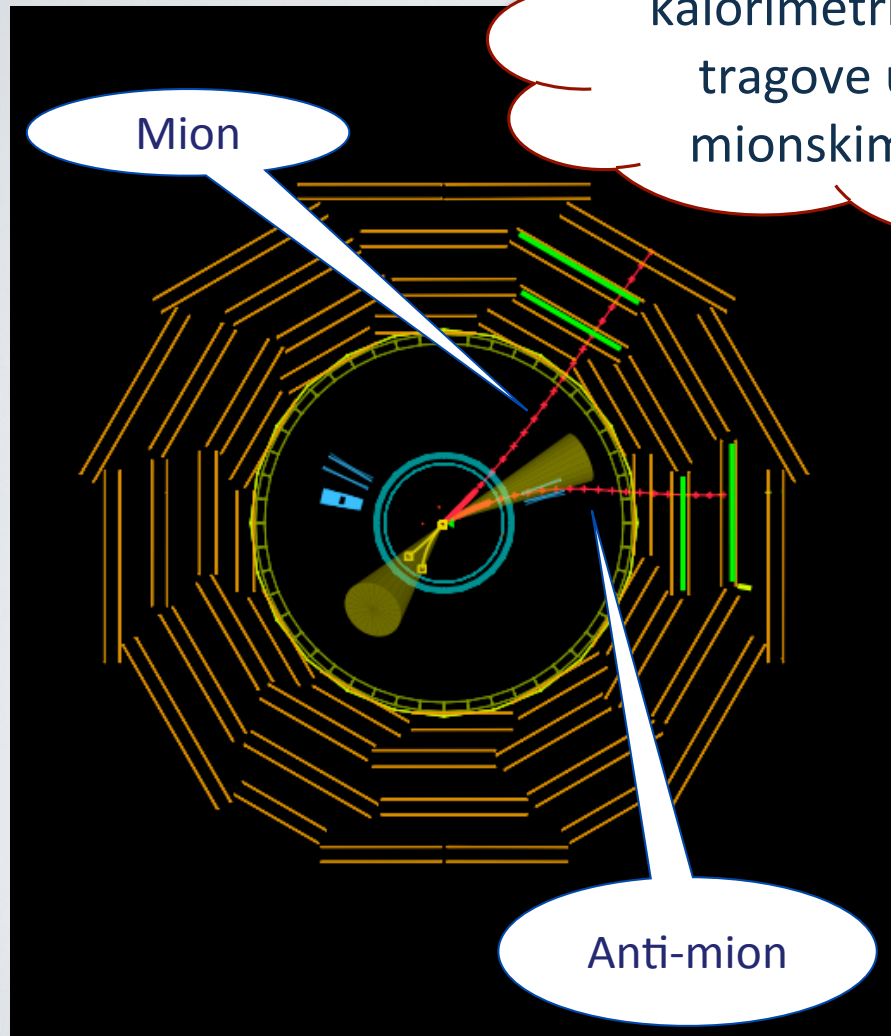
Callouts:

- Informacije o događaju (Information about the event)
- Pogled spreda ili sa strane (Front or side view)
- Selekcija događaja (Event selection)
- Selektivni prikaz poddetektora (Selective display of sub-detectors)
- 3D slika događaja (3D image of the event)

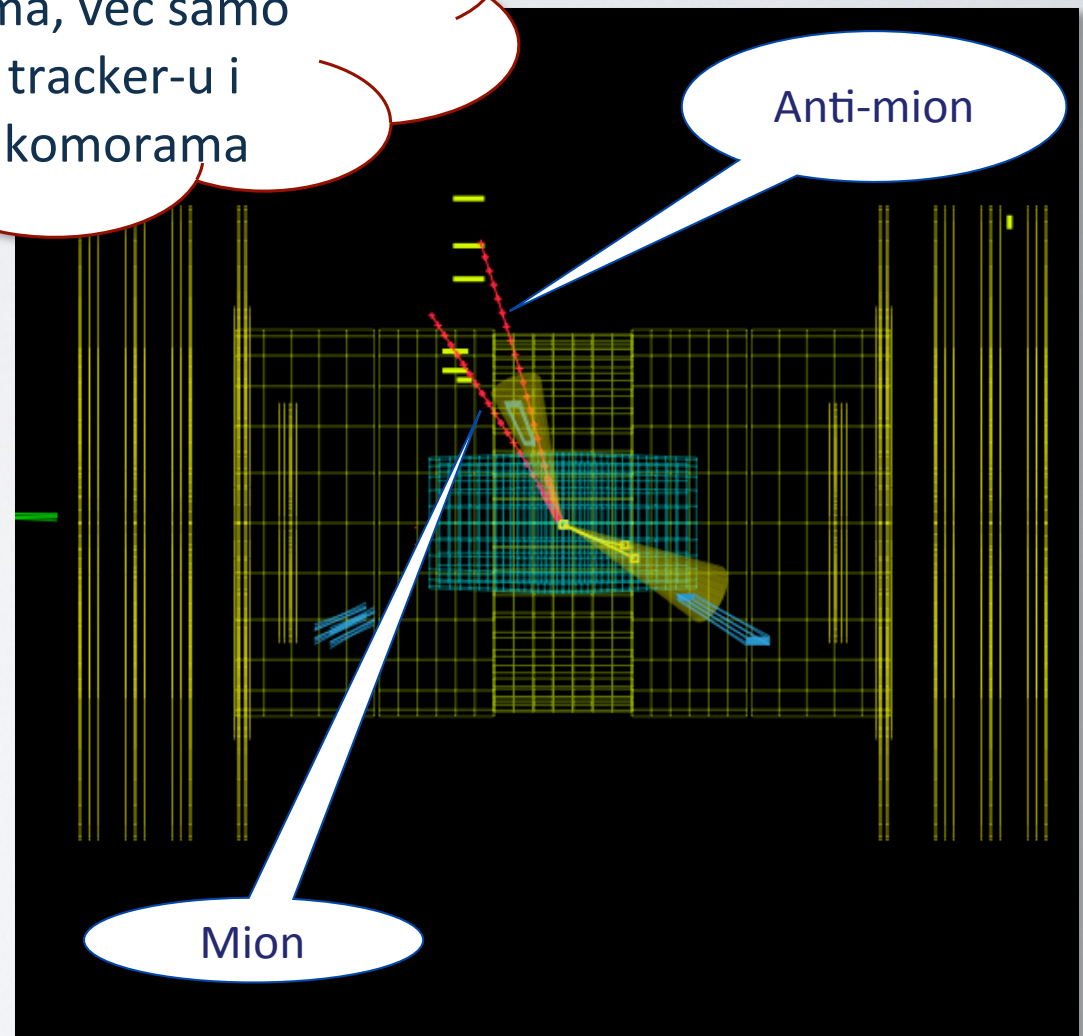
Detekcija miona

Raspad: $J/\Psi \rightarrow \mu^+ \mu^-$

(pogled spreda)



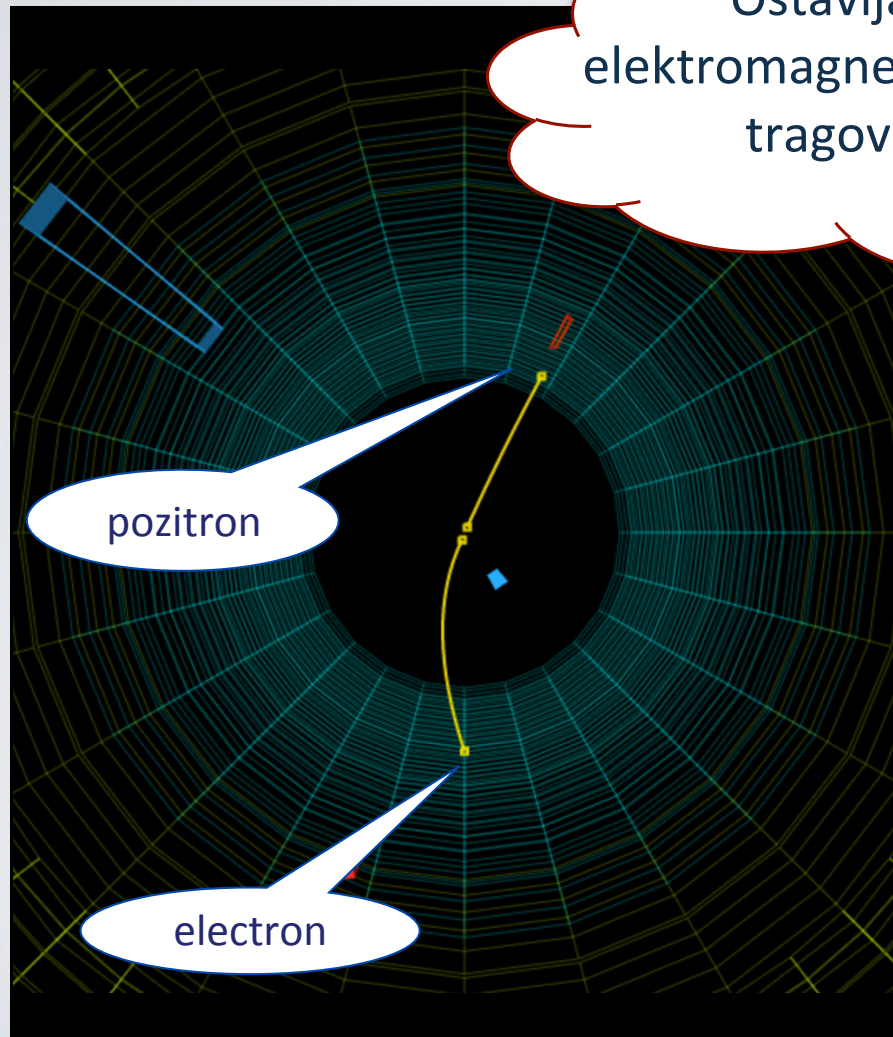
(pogled sa strane)



Detekcija elektrona

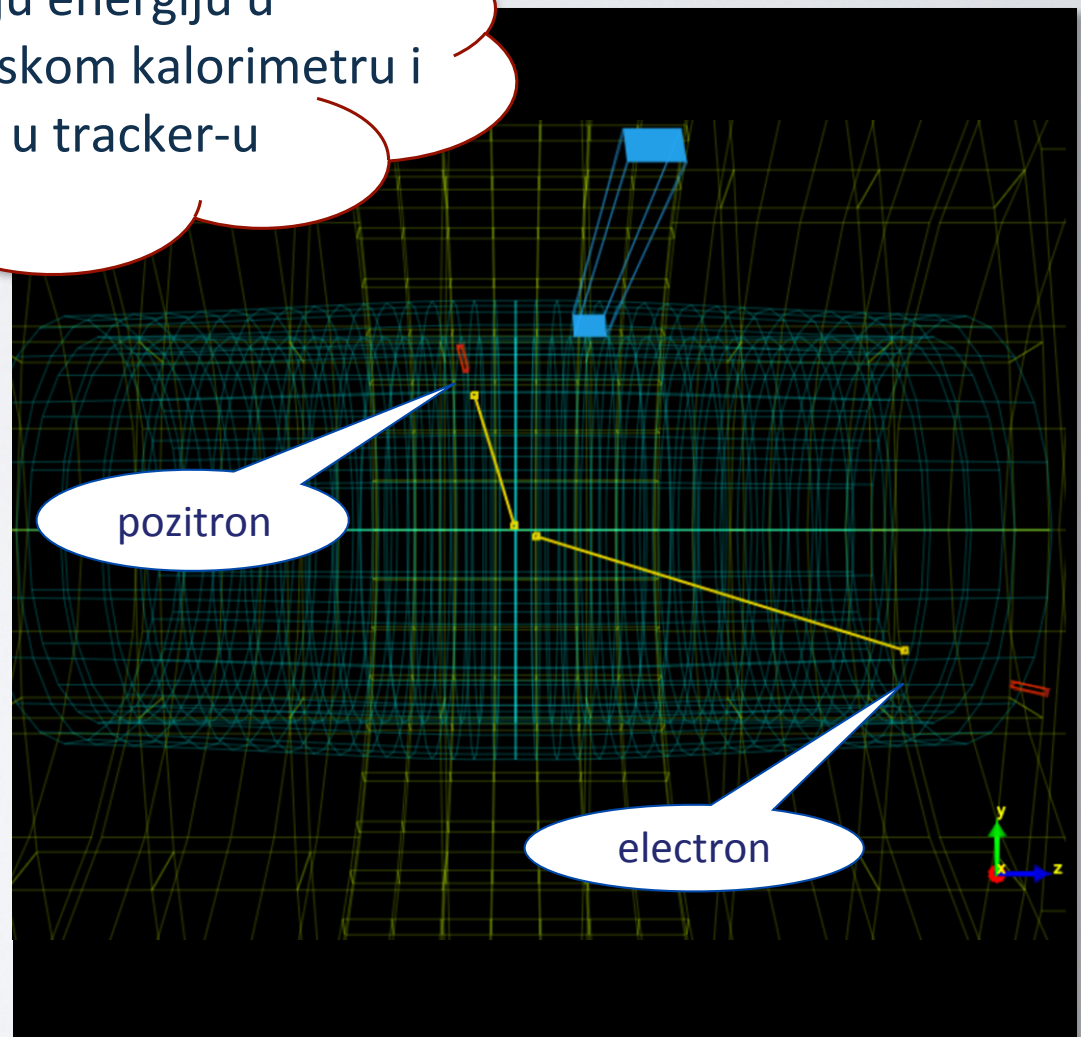
Raspad: $J/\Psi \rightarrow e^+ e^-$

(pogled spreda)



Ostavljaju energiju u
elektromagnetskom kalorimetru i
tragove u tracker-u

(pogled sa strane)

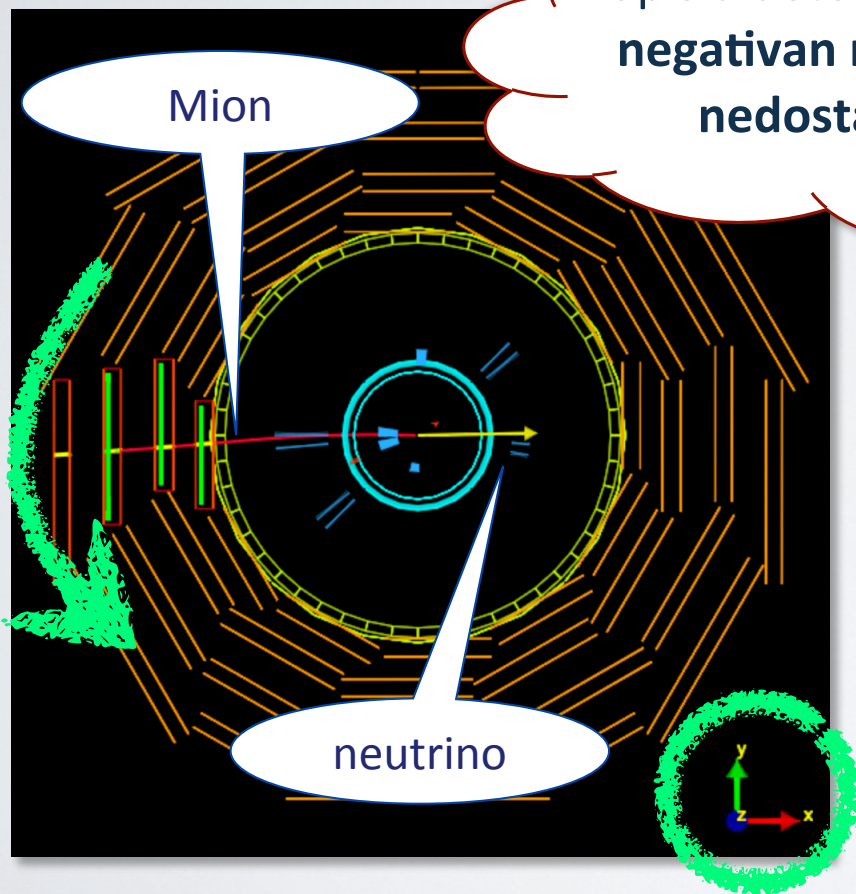


Detekcija W^- bozona

Raspadi: $W^- \rightarrow \mu^- + \text{neutrino}$

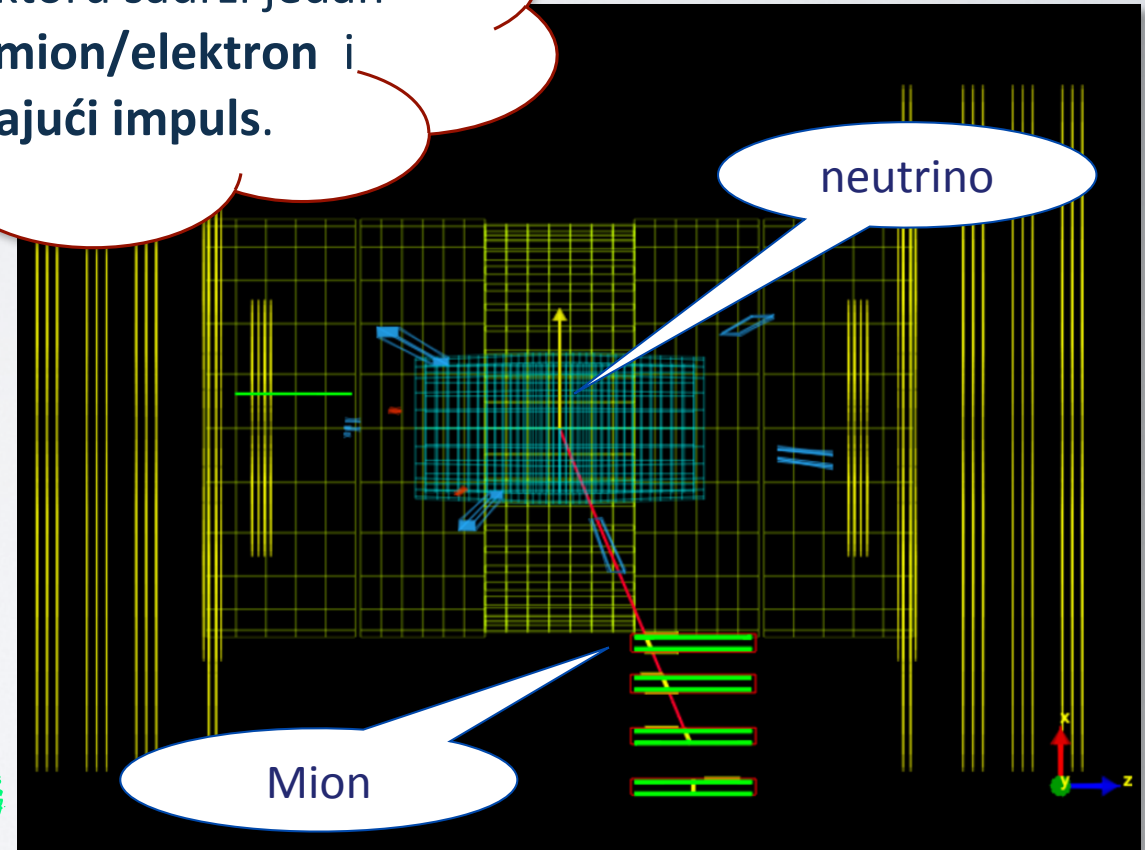
$W^- \rightarrow e^- + \text{neutrino}$

(pogled spreda)



Zapis u detektoru sadrži jedan negativan mion/elektron i nedostajući impuls.

(pogled sa strane)



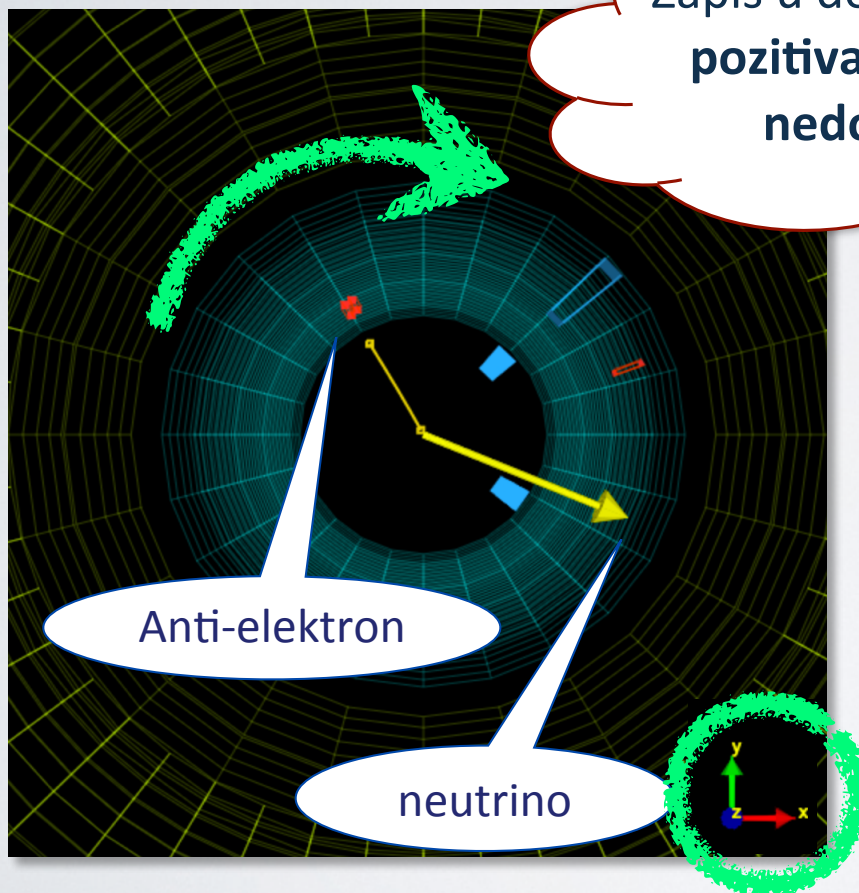
- Naelektrisanje elektrona i miona merimo na osnovu “smera zakrivljenosti” traga u magnetnom polju

Detekcija W^+ bozona

Raspadi: $W^+ \rightarrow \mu^+ + \text{neutrino}$

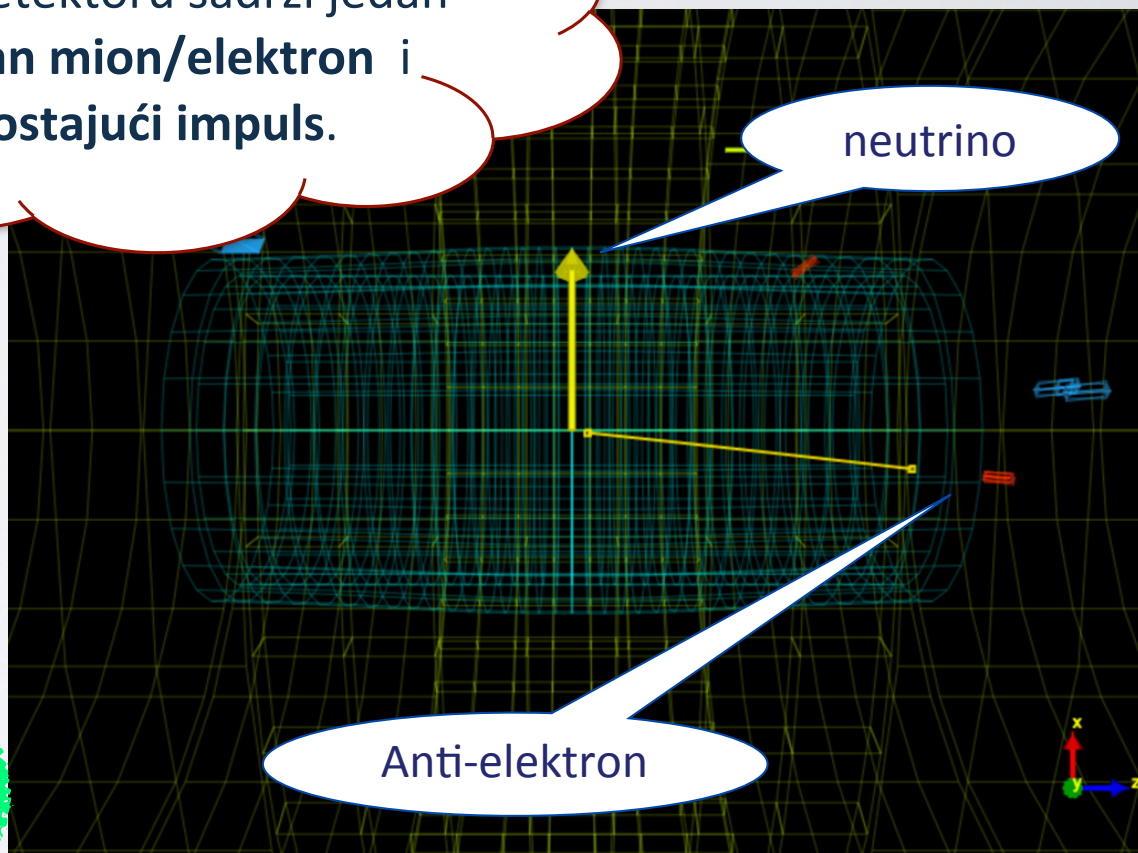
$W^+ \rightarrow e^+ + \text{neutrino}$

(pogled spreda)



Zapis u detektoru sadrži jedan pozitivan mion/elektron i nedostajući impuls.

(pogled sa strane)

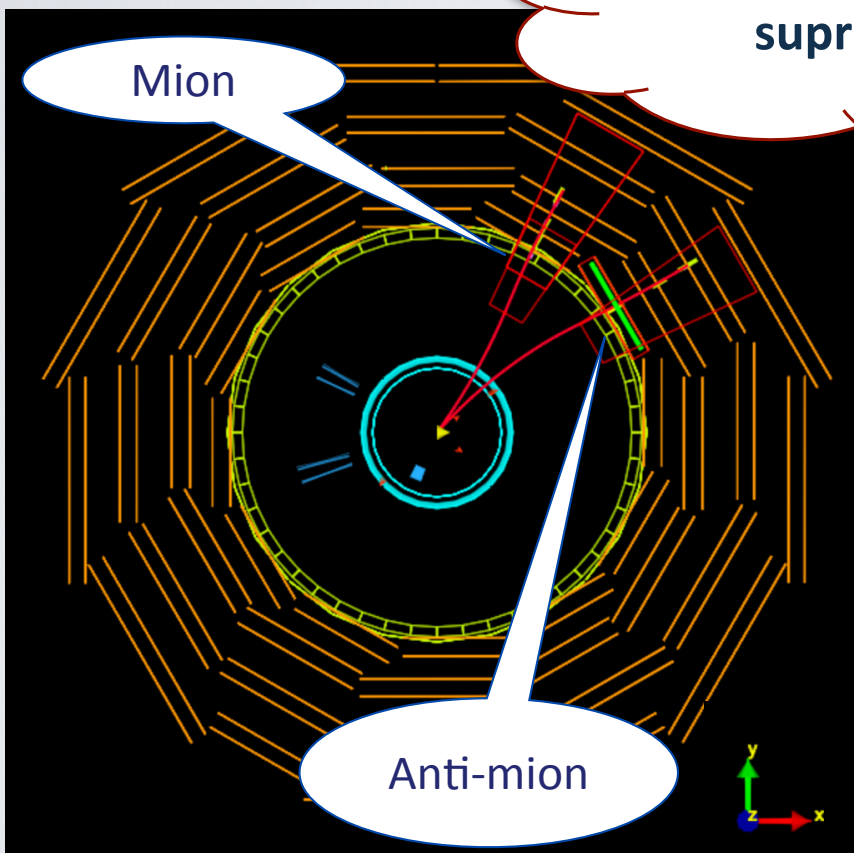


- Naelektrisanje elektrona i miona merimo na osnovu "smera zakrivljenosti" traga u magnetnom polju

Detekcija Z^0 bozona

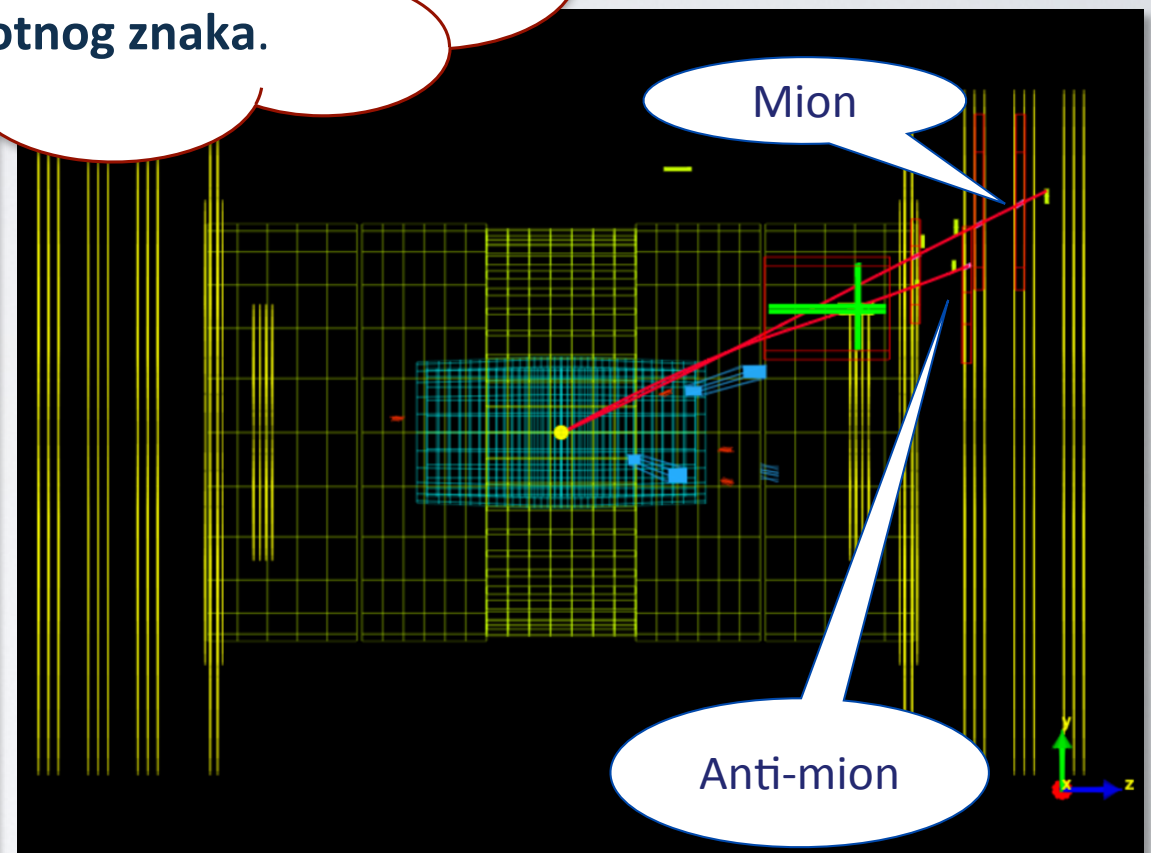
Raspadi: $Z^0 \rightarrow \mu^+ \mu^-$
 $Z^0 \rightarrow e^+ e^-$

(pogled spreda)



Zapis u detektoru sadrži jedan
par miona ili elektrona
suprotnog znaka.

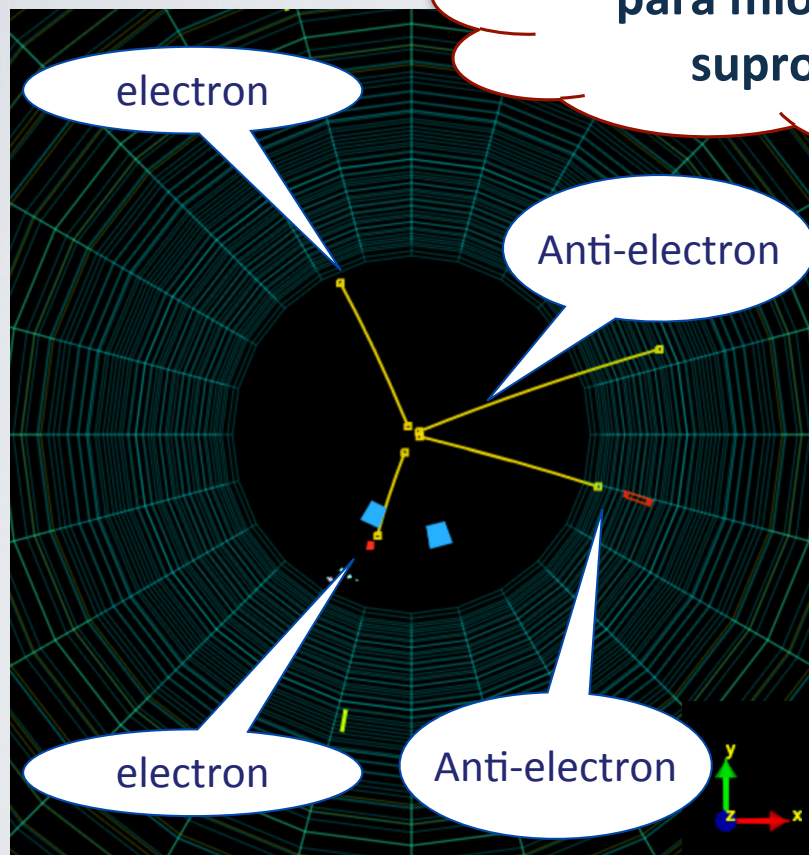
(pogled sa strane)



Detekcija para $Z^0 Z^0$ bozona

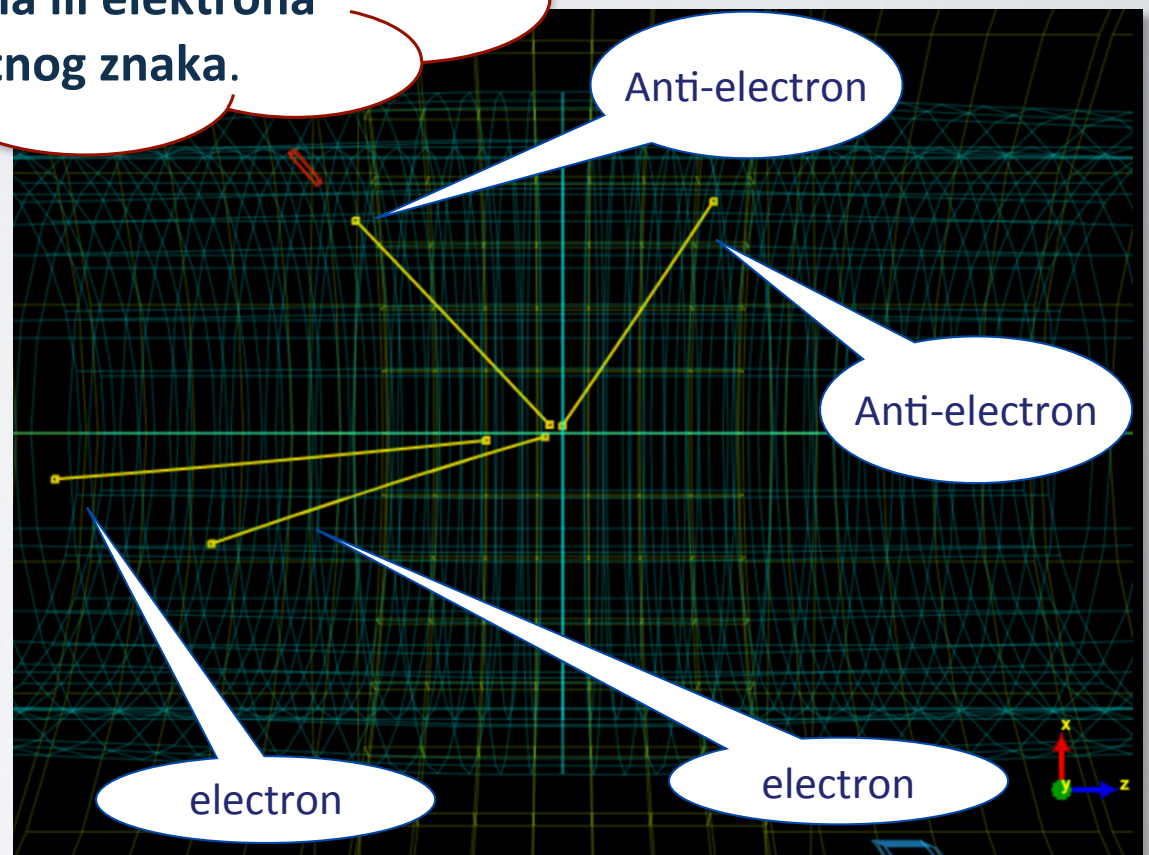
Raspadi: $Z^0 Z^0 \rightarrow \mu^+ \mu^- \mu^+ \mu^-$ & $Z^0 Z^0 \rightarrow e^+ e^- e^+ e^-$
 $Z^0 Z^0 \rightarrow \mu^+ \mu^- e^+ e^-$

(pogled spreda)



Zapis u detektoru sadrži dva para miona ili elektrona suprotnog znaka.

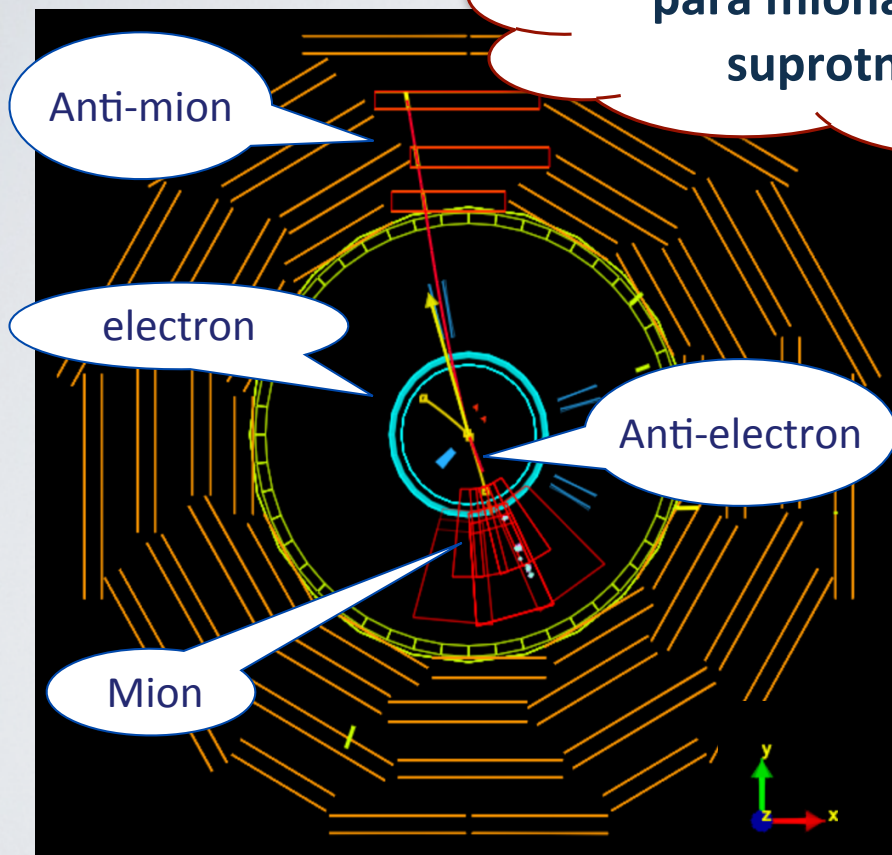
(pogled sa strane)



Detekcija para $Z^0 Z^0$ bozona

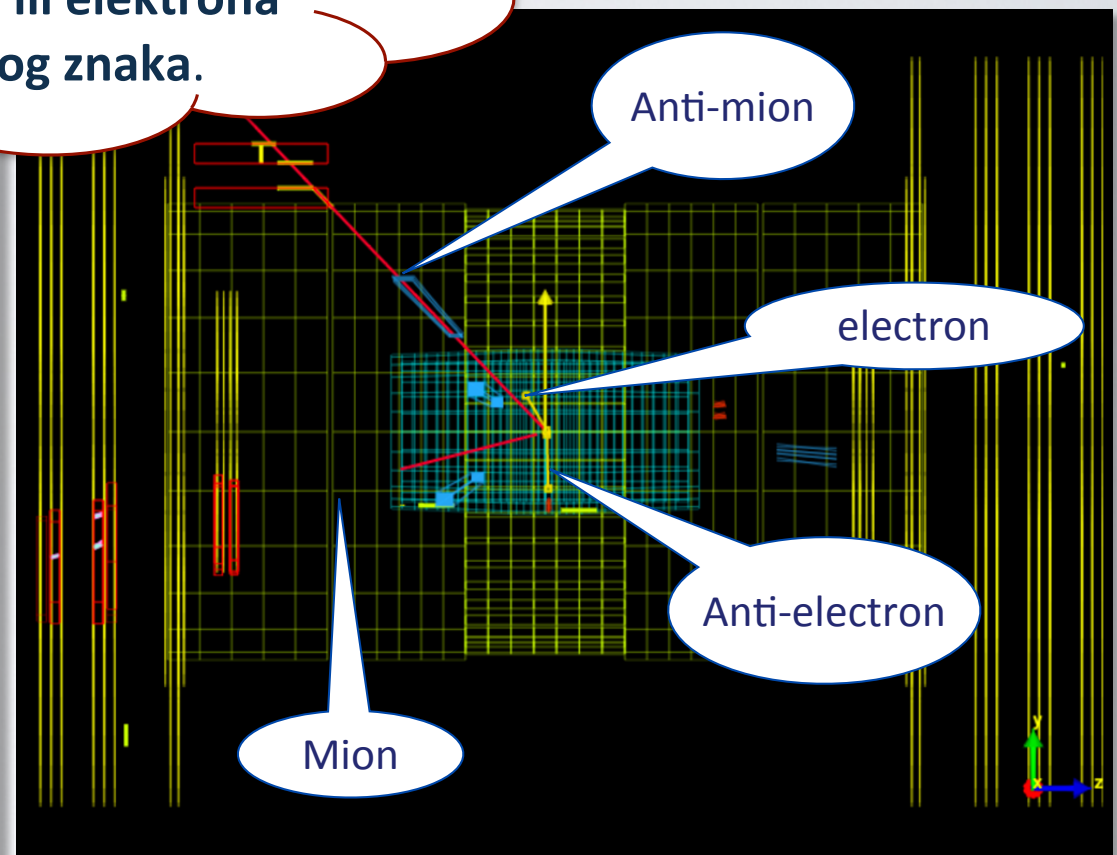
Raspadi: $Z^0 Z^0 \rightarrow \mu^+ \mu^- \mu^+ \mu^-$ & $Z^0 Z^0 \rightarrow e^+ e^- e^+ e^-$
 $Z^0 Z^0 \rightarrow \mu^+ \mu^- e^+ e^-$

(pogled spreda)



Zapis u detektoru sadrži dva para miona ili elektrona suprotnog znaka.

(pogled sa strane)



Unošenje rezultata - identifikacija događaja

EditGrid Explore Data Login Sign-up

Spreadsheet / [qnmasterclasses](#) / CMSWZ2013cern1403

File Edit View Format Insert Data Share Publish Collaborate Macro Help

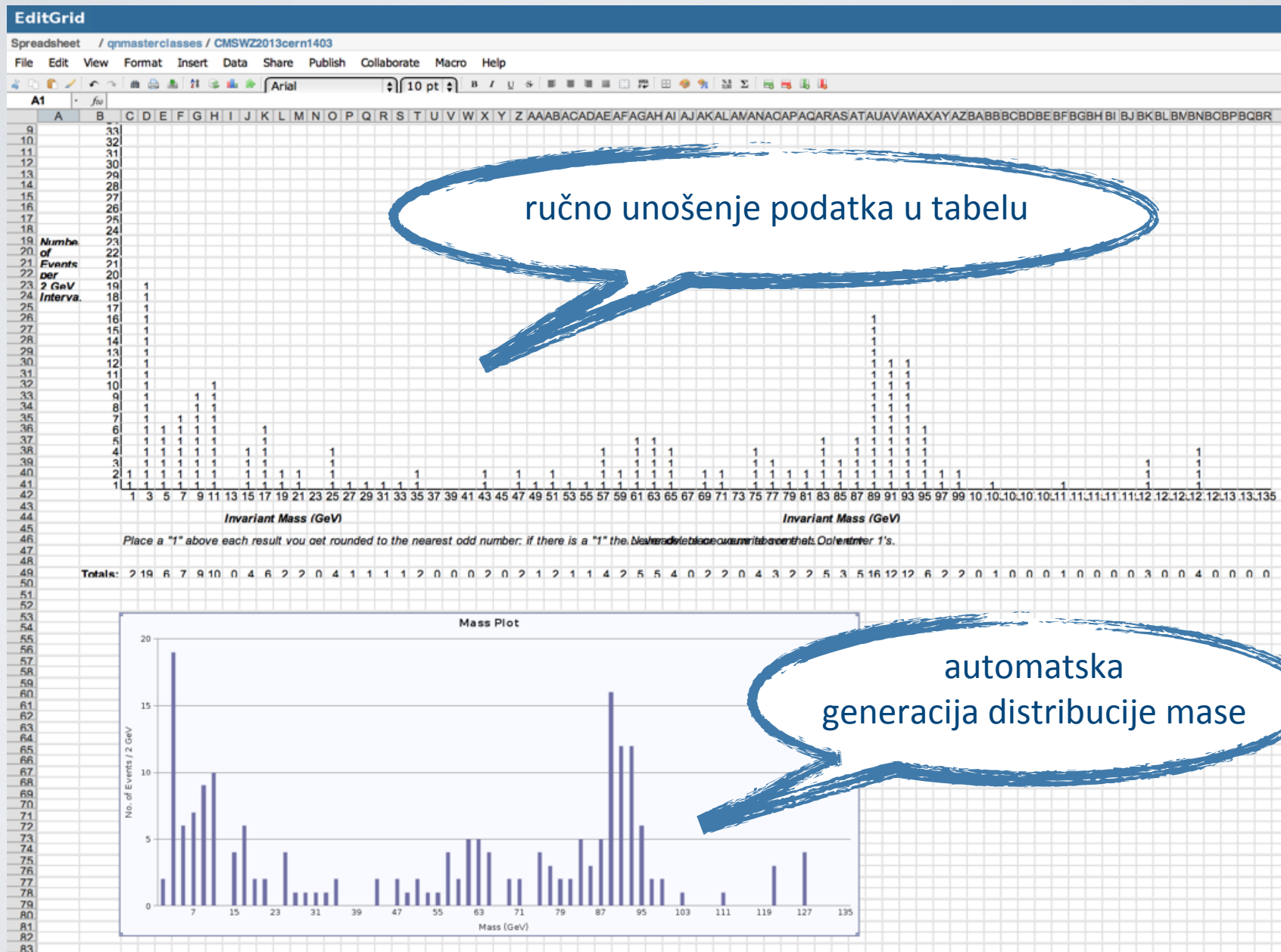
Q777 *foo*

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	Dataset	Ord No	Ev No	electron	muon	W+ cand	W- cand	W cand	Z cand	"zoo"	ZZ cand	Mass	Mass-->odd			
748	masterclass_8	712	145107936	1			1									
749	masterclass_8	713	151485214													
750	masterclass_8	714	155570482		1				1			88.70	89	<-- enter in massplot tab		
751	masterclass_8	715	167906653		1	1										
752	masterclass_8	716	173233900		1	1										
753	masterclass_8	717	176329404		1		1									
754	masterclass_8	718	177832572		1			1								
755	masterclass_8	719	177961104		1			1								
756	masterclass_8	720	182379256		1	1										
757	masterclass_8	721	187565444		1		1									
758	masterclass_8	722	187863806	1				1								
759	masterclass_8	723	198627847	1					1			99.07	99	<-- enter in massplot tab		
760	masterclass_8	724	207851362	1			1									
761	masterclass_8	725	208223322	1				1								
762	masterclass_8	726	209005266	1				1								
763	masterclass_8	727	214668394	1			1									
764	masterclass_8	728	220971693	1			1									
765	masterclass_8	729	223246523	1				1								
766	masterclass_8	730	225316422	1				1								
767	masterclass_8	731	227080019		1		1									
768	masterclass_8	732	228545532		1	1										
769	masterclass_8	733	231706892		1		1									
770	masterclass_8	734	232815808	1				1								
771	masterclass_8	735	250160544	1				1								
772	masterclass_8	736	25487594	1					1			102.10	103	<-- enter in massplot tab		
773	masterclass_8	737	255804479	1		1										
774	masterclass_8	738	25707056		1				1			3.15	3	<-- enter in massplot tab		
775	masterclass_8	739	27322212		1				1			9.11	9	<-- enter in massplot tab		
776	masterclass_8	740	274732991													
777	masterclass_8	741	292749961													
778	masterclass_8	742	295982678													

How to [Data_Lodz\(1\)](#) [Data_Lodz\(2\)](#) [Data_Lodz\(3\)](#) [Massplot_Lodz](#) [Results_Lodz](#) [Data_Jerusalem](#) [Massplot_Jerusalem](#) [Results_Jerusalem](#) [Data](#)

Done Read Write login to join chat room.

Unošenje rezultata - masa Z^0 i/ili Z^0Z^0 bozona



Konačni rezultati u Novom Sadu

EditGrid

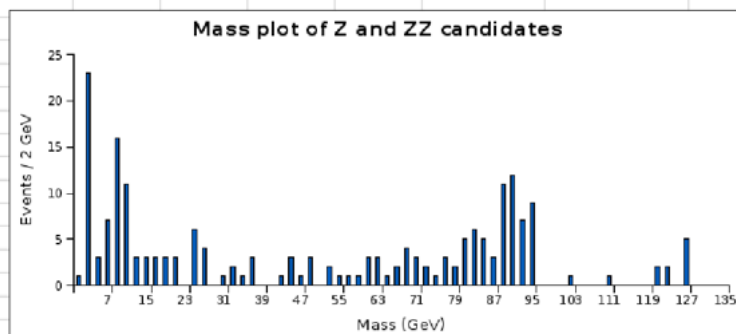
Spreadsheet / qnmasterclasses / CMSWZ2013cern1403

File Edit View Format Insert Data Share Publish Collaborate Macro Help

Arial 11 pt

A1	dataset												
	electron	muon	W+ cand	W- cand	W cand	Z cand	"zoo"	ZZ cand				sum events	
1	dataset												
2	masterclass_1	31	32	20	21	0	0	8	2			51	
3	masterclass_2	15	12	11	10	2	2	7	0			32	
4	masterclass_3	39	54	43	32	1	16	4	1			0	
5	masterclass_4	33	23	33	17	0	6	3	1			0	
6	masterclass_5	37	21	26	17	6	8	2	0			59	
7	masterclass_6	39	20	20	15	1	8	14	1			59	
8	masterclass_7	22	18	15	11	2	11	8	1			48	
9	masterclass_8	20	35	28	15	8	3	7	1			62	
10	masterclass_9	42	61	30	42	5	7	15				100	
11	masterclass_10	39	52	37	34	15	5	8	0			99	
12	masterclass_11	35	15	17	13	5	6	5	12			58	
13	masterclass_12	23	27	18	14	4	8		0			53	
14	masterclass_13	23	23	24	10	0	8	4	2			48	
15	masterclass_14	28	11	17	12	1	16	2	0			48	
16	masterclass_15	48	31	22	25	4	22	1	0			74	
17	masterclass_16	37	47	35	20	6	16	3	1			81	
18	masterclass_17	14	28	24	13	1	12	10	2			62	
19	masterclass_18	45	52	33	24	2	19	3	13			94	
20	masterclass_19	0	0	0	0	0	0	0	0			0	
21		570	562	453	345	63	173	113	38	<- Institute Totals			

e/mu = W+/W- =
1.014234875441.31304347826087



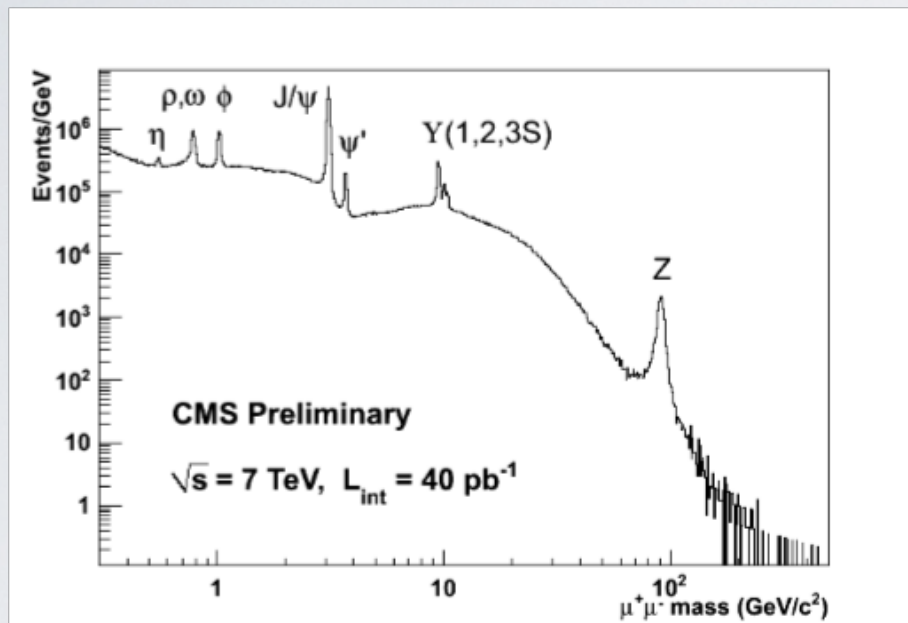
zajednički rezultati na osnovu svih analiziranih događaja u Novom Sadu

distribucije mase na osnovu svih analiziranih događaja

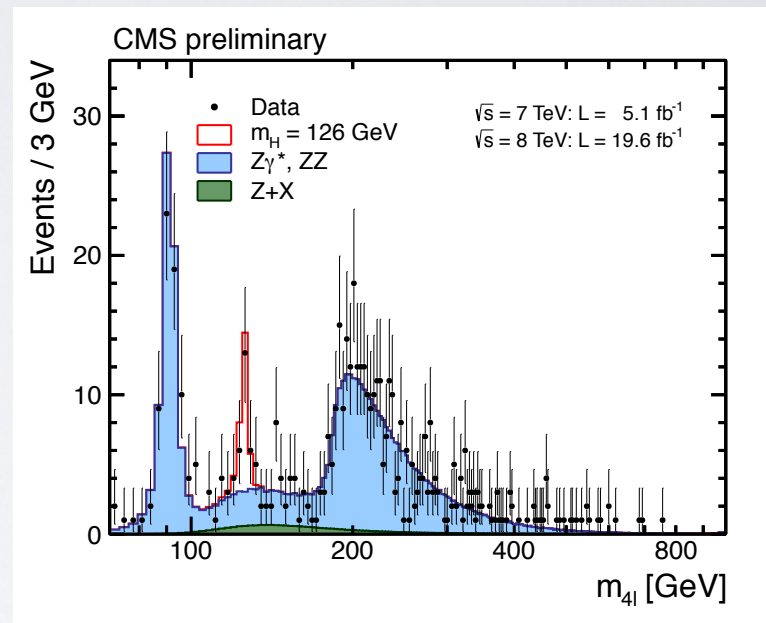
upoređivanje rezultata sa drugim institutima i diskusija sa naučnicima u CERN-u

Maseni spektar za jedan ili dva Z^0 bozona

Masesni spektar J/Psi i Y mezona, Z^0 bozona i mnogih drugih čestica



Masesni spektar za par Z^0Z^0 bozona

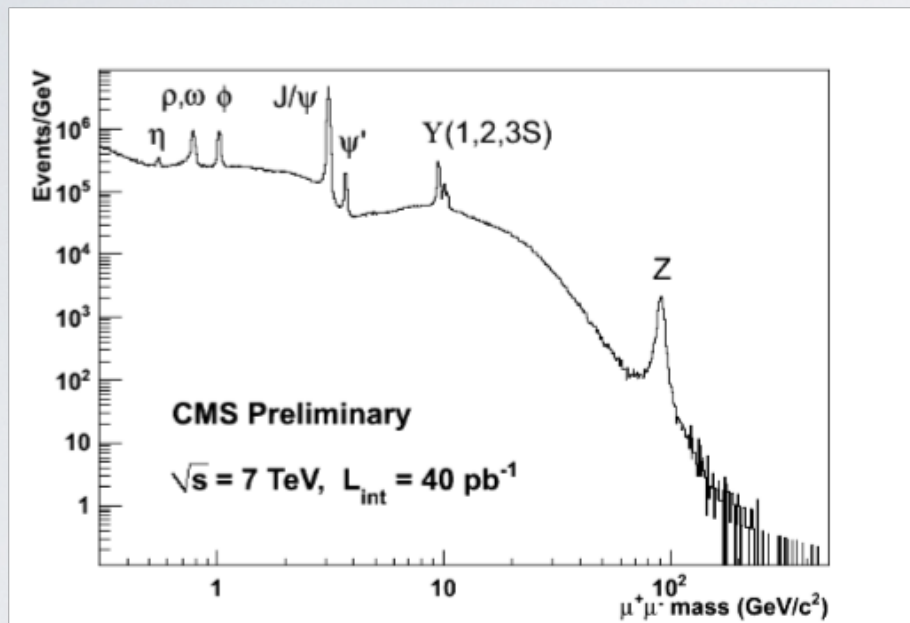


Kreirajte i vi histogram invarijantne mase za događaje sa Z^0 bozonima!

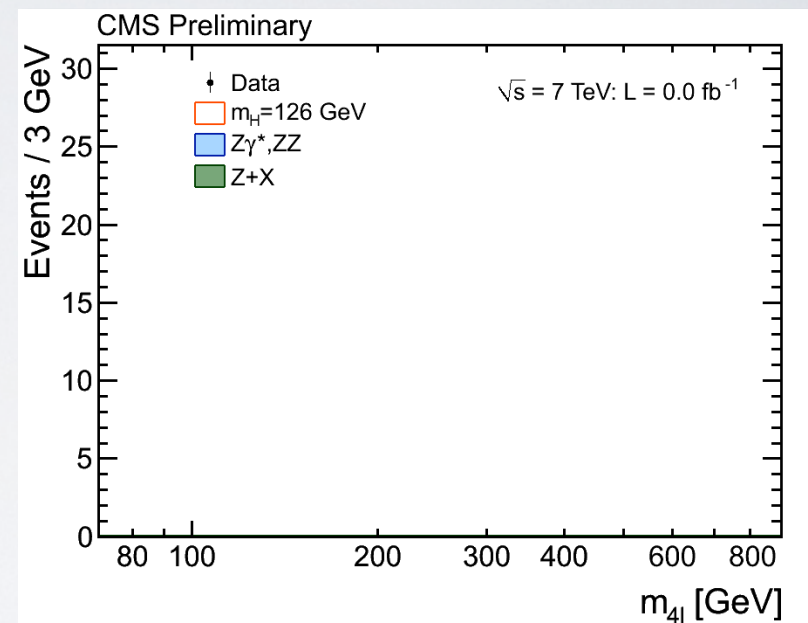
Ko zna, mozda ćete bas vi imati sreće da pronađete događaje koji su potencijalno raspadi Higgs bozona na dva $Z^0 Z^0$ bozona!!!

Maseni spektar za jedan ili dva Z^0 bozona

Masesni spektar J/Psi i Y mezona, Z^0 bozona i mnogih drugih čestica



Masesni spektar za par Z^0Z^0 bozona



Kreirajte i vi histogram invarijantne mase za događaje sa Z^0 bozonima!

Ko zna, mozda ćete bas vi imati sreće da pronađete događaje koji su potencijalni raspadi Higgs bozona na dva Z^0Z^0 bozona!!!

Vežbe MC 2013 mogu da počnu!

Nadamo se da ćete uživati i da ćete se dobro zabaviti!

