

CMS WZH Masterclass

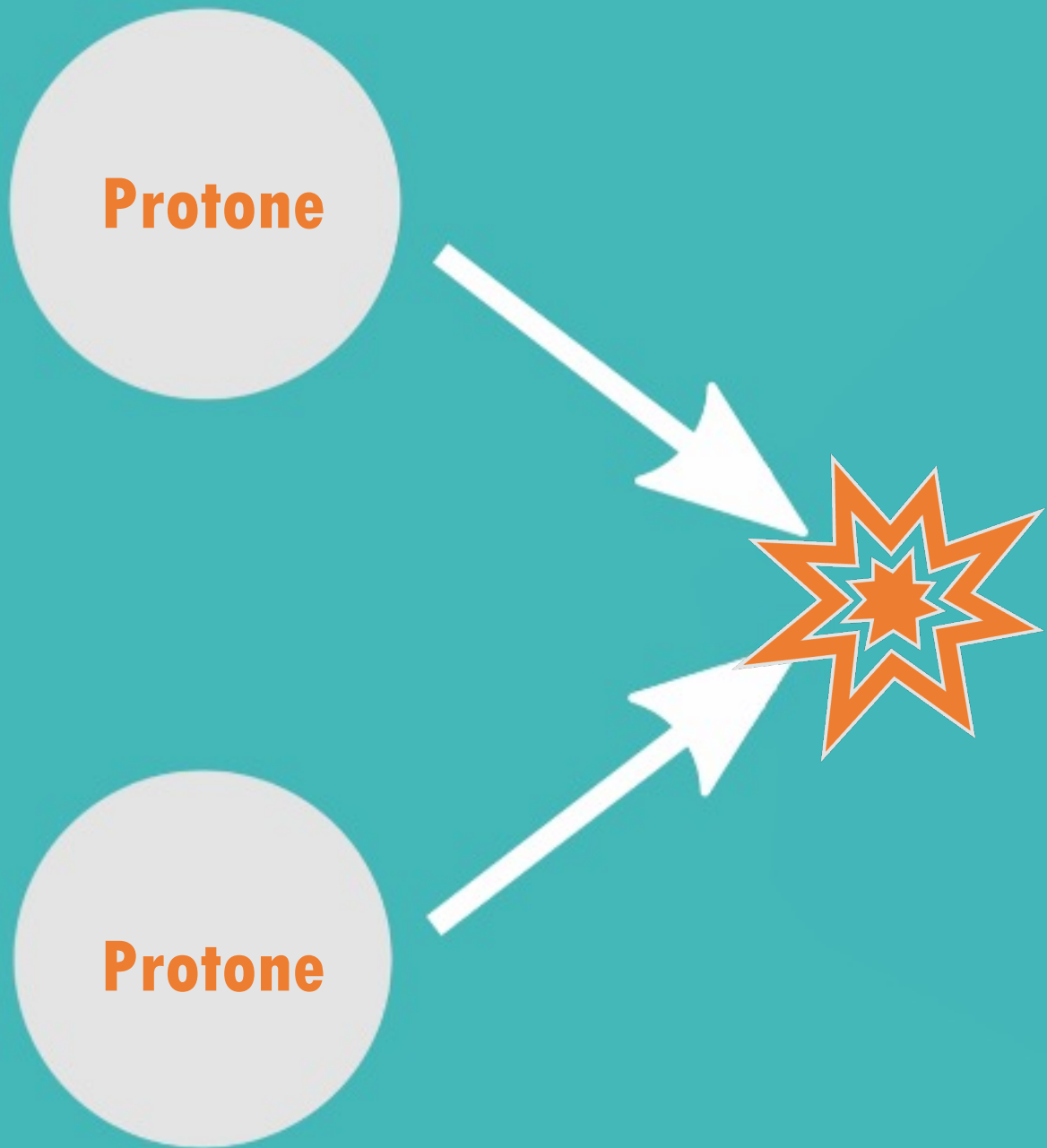
guida agli esercizi

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Valentina Mariani (vmariani@cern.ch),
Matteo Presilla (matteo.presilla@cern.ch)

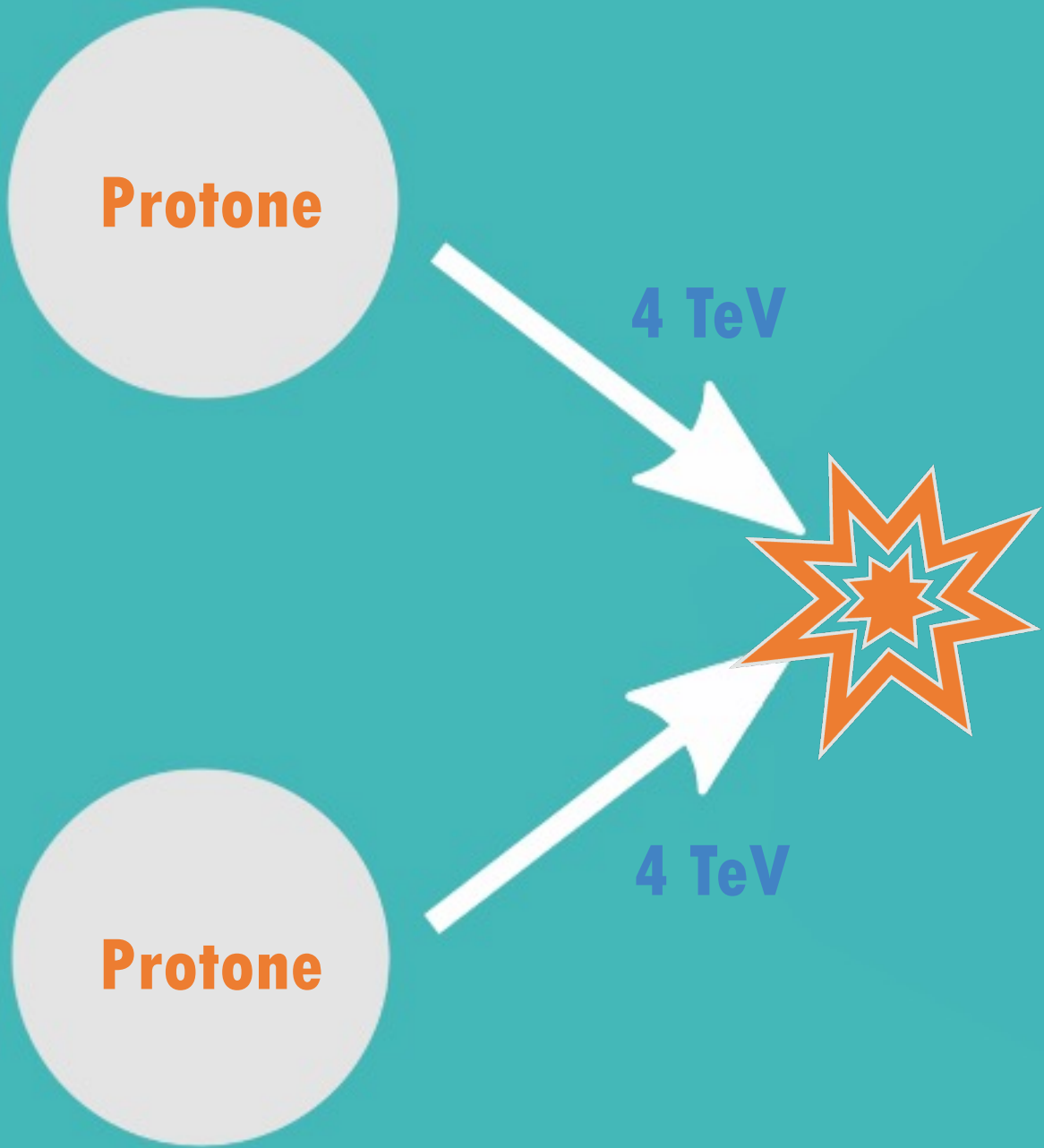
Cosa faremo?

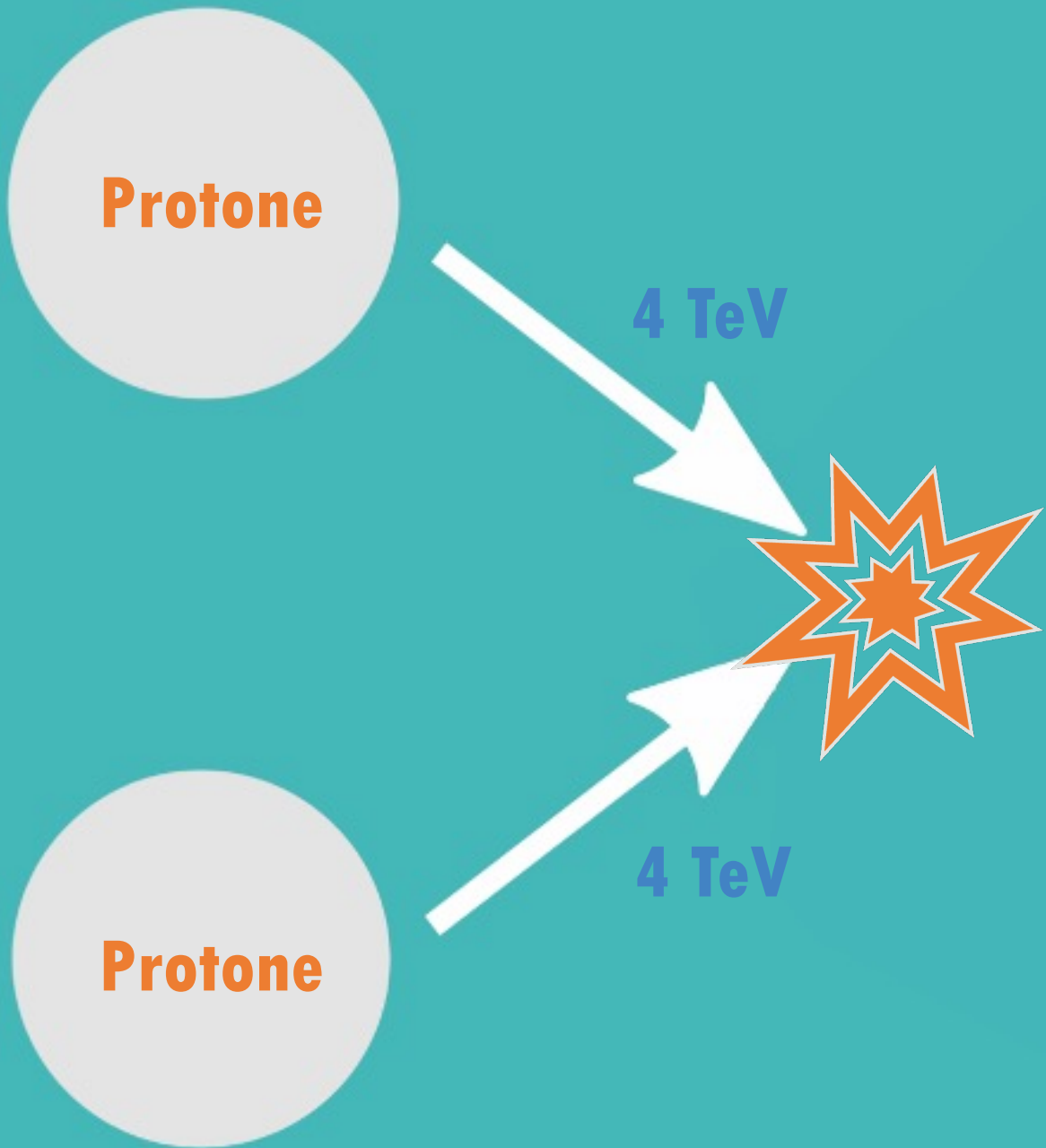
- Torniamo al 2012!
- Analizzerete **veri** dati di CMS
- Collisioni tra fasci di protoni ad un'energia nel centro di massa di 8 TeV
- Alla ricerca del **bosone di Higgs**
- Ma cosa succede nelle collisioni tra protoni?



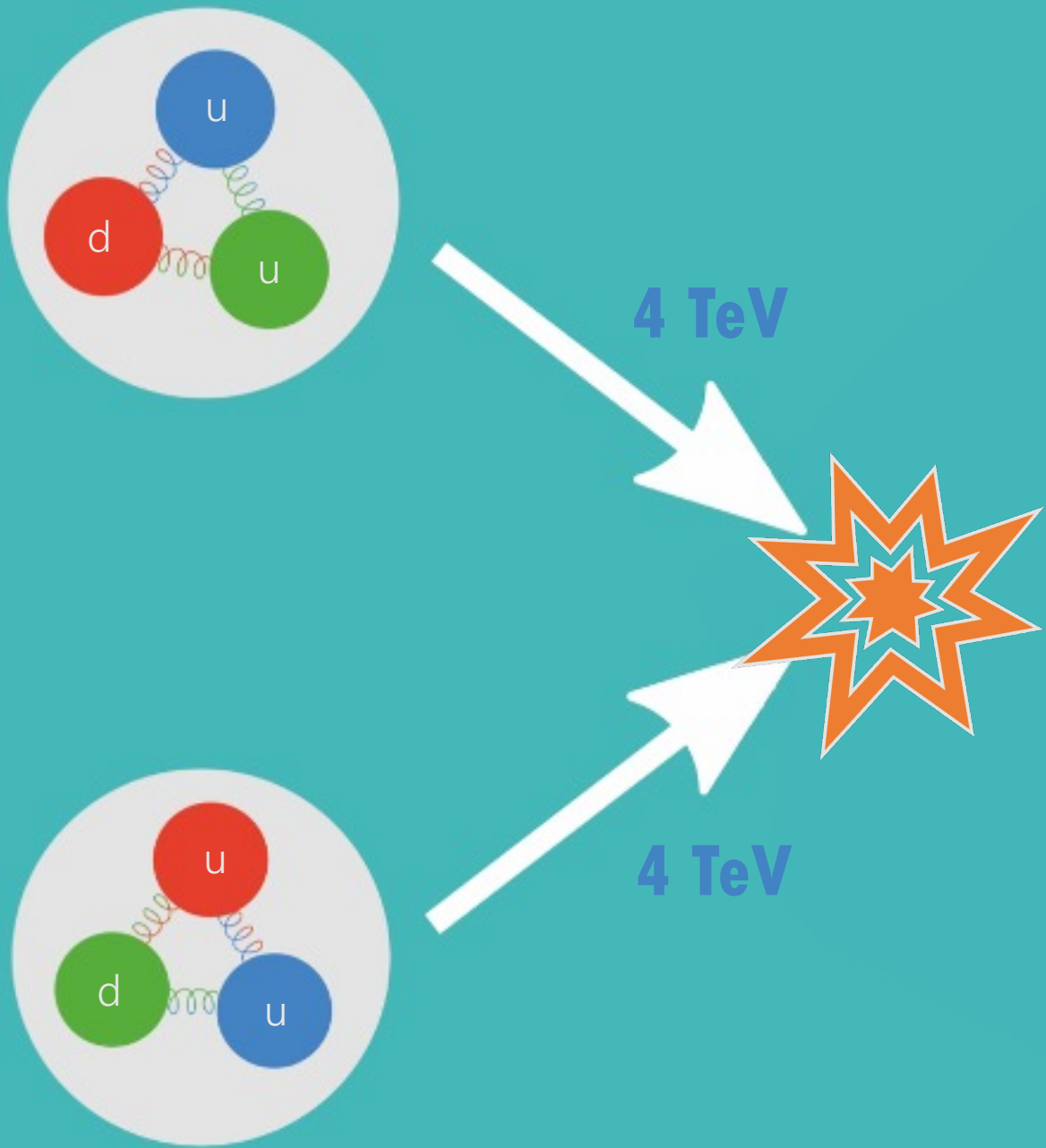


**A che energia
collidono i protoni?**

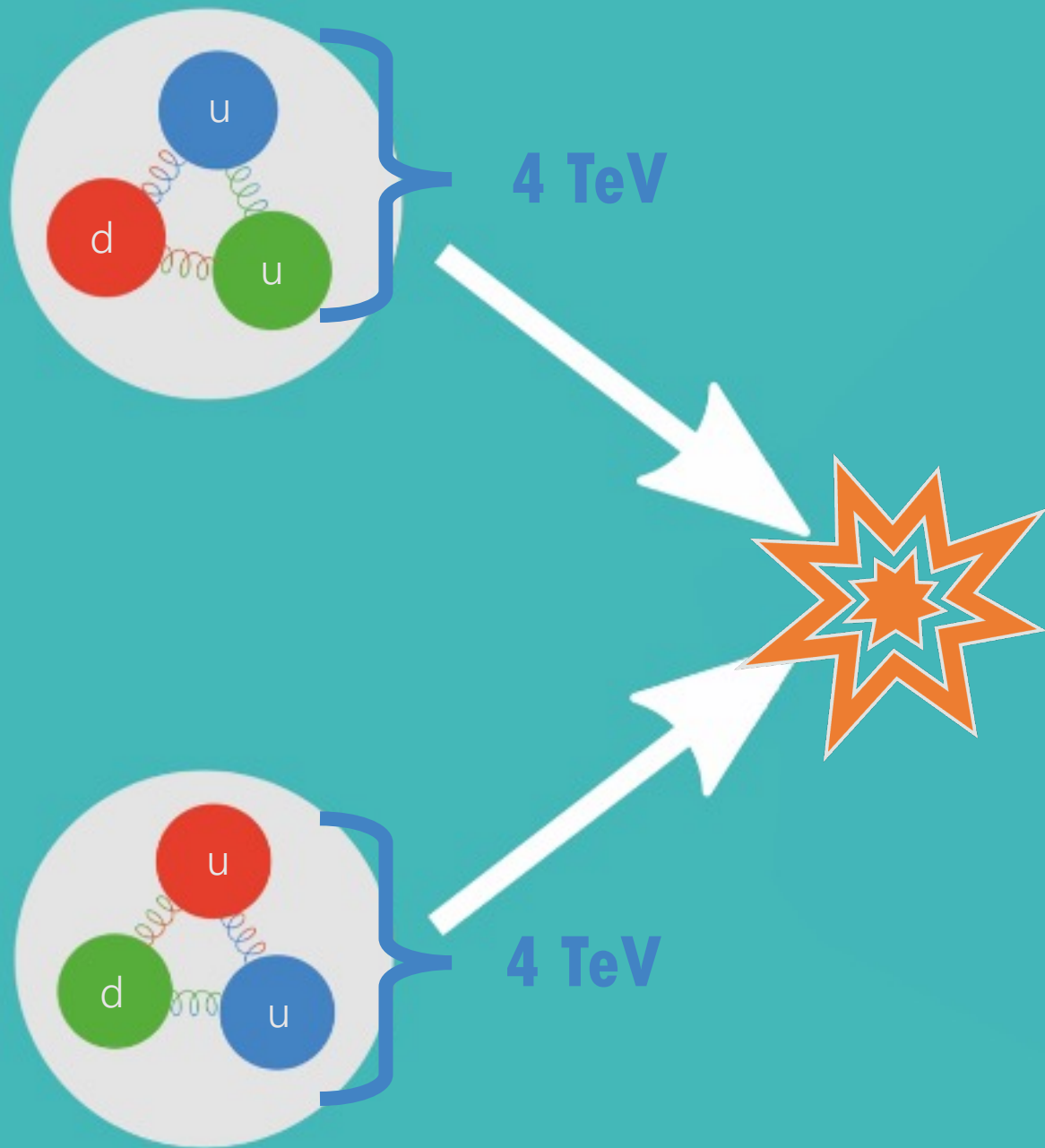




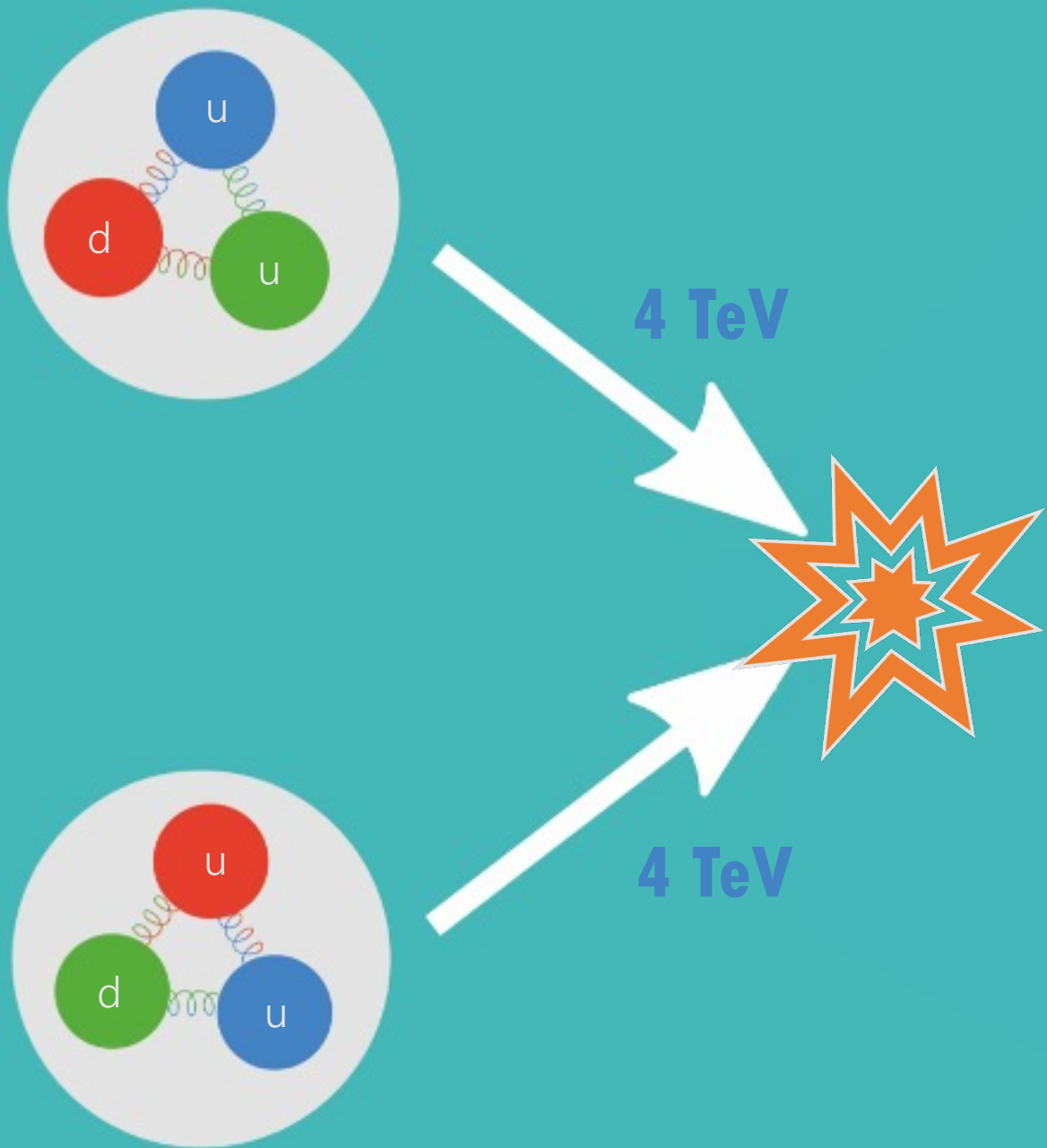
**Ma sono davvero i
protoni a collidere?**



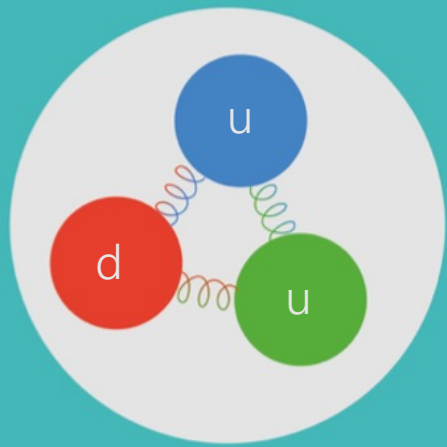
- **NO! I protoni NON sono particelle elementari: sono formati da quark**



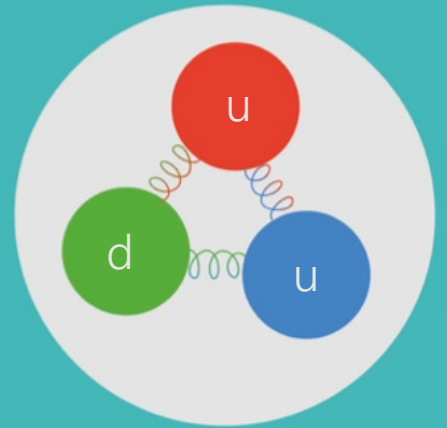
- **NO! I protoni NON sono particelle elementari: sono formati da quark**
- **L'energia del protone è distribuita tra i quark**



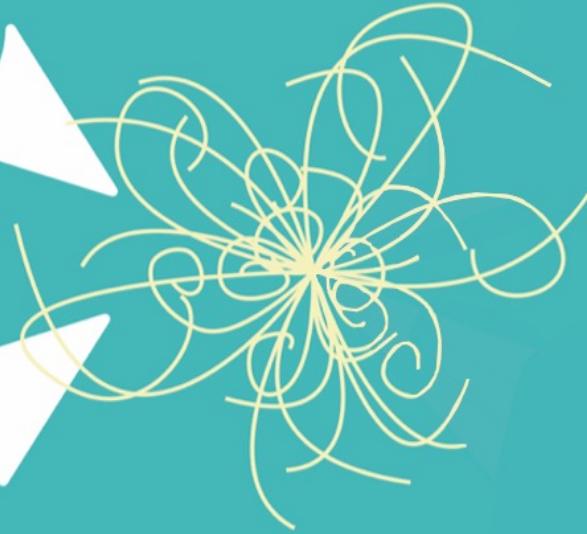
**Cosa succede dopo
la collisione?**



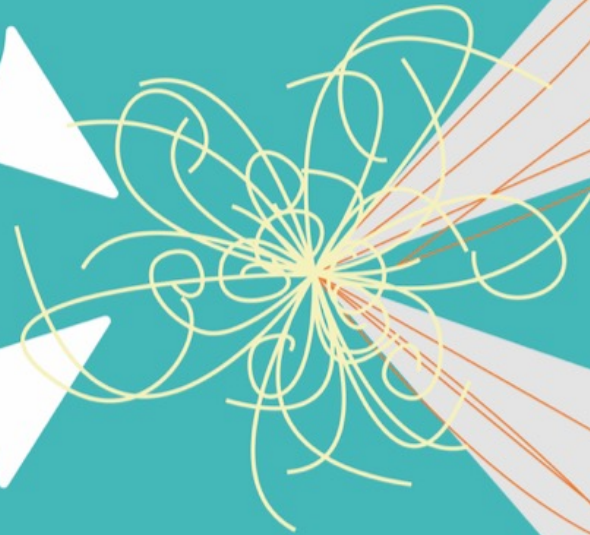
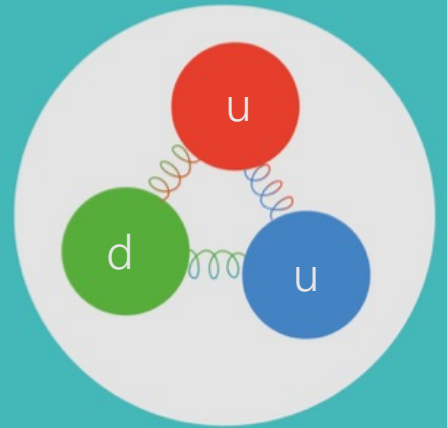
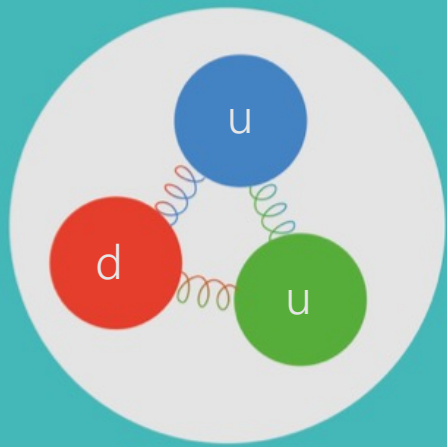
4 TeV



4 TeV

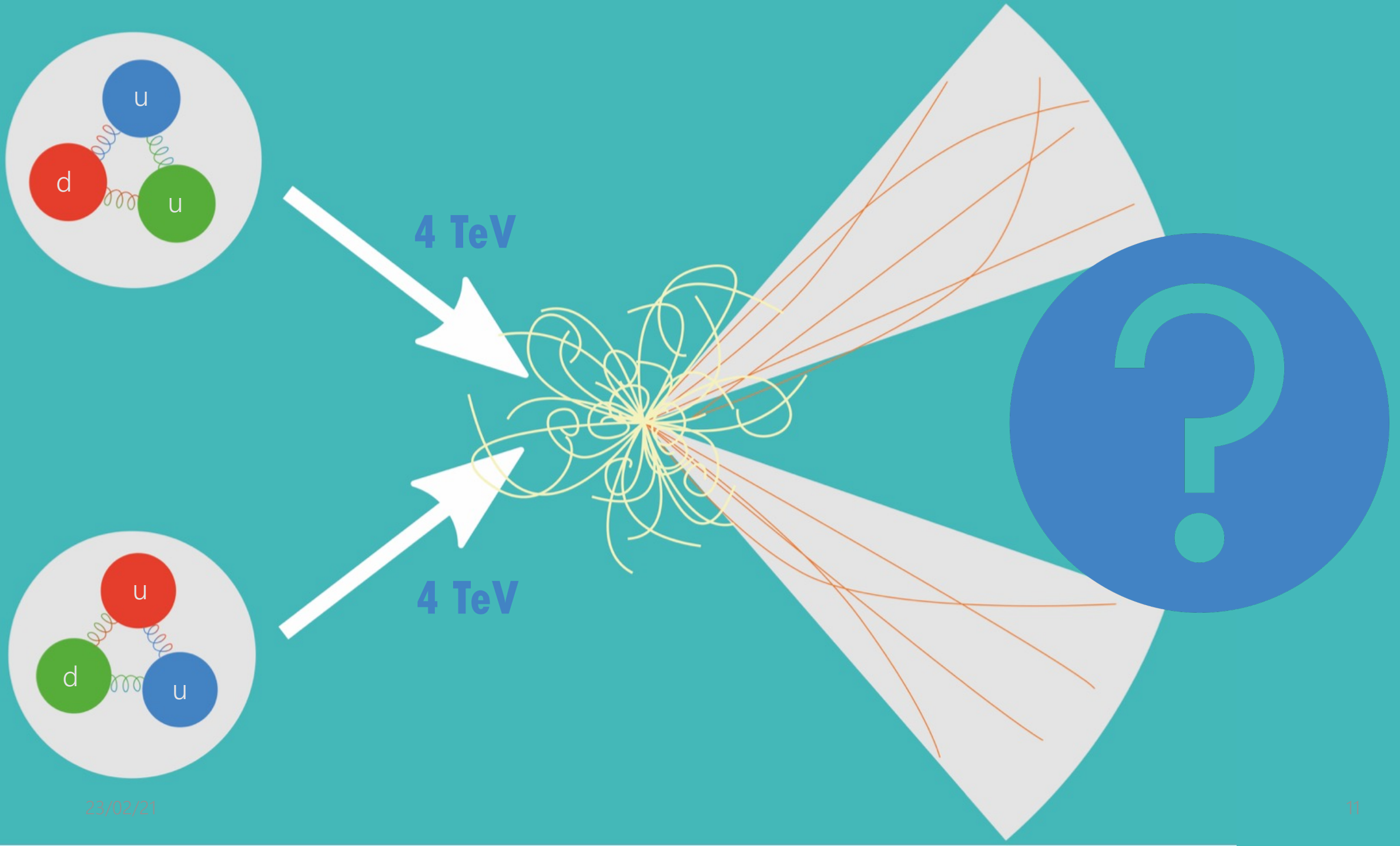


L'energia si trasforma in nuove particelle



**Che decadono in
particelle più leggere**



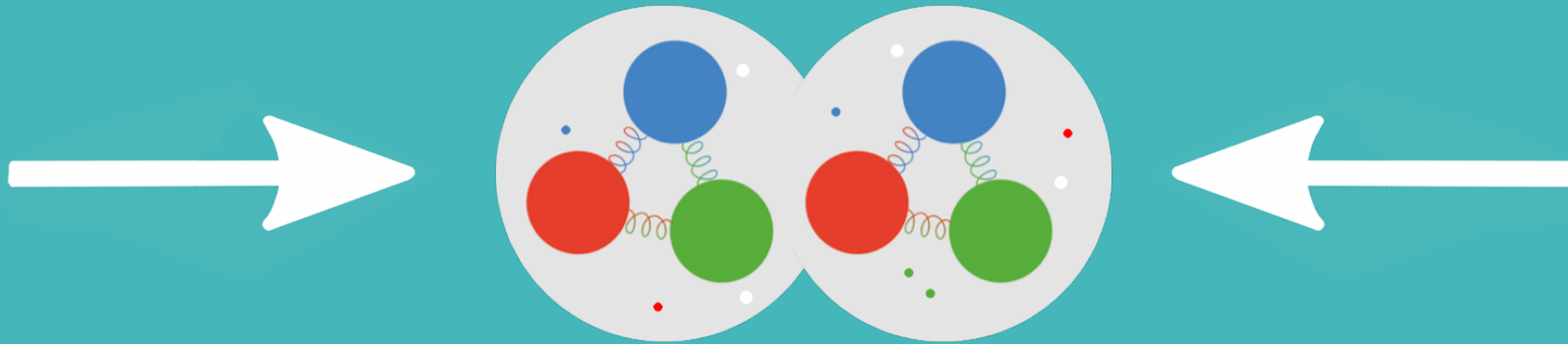


Come capiamo quali particelle vengono prodotte?

Leggi di conservazione!

Energia
Quantità di moto
Carica
Momento angolare
....

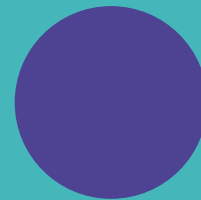
Diversi tipi di eventi



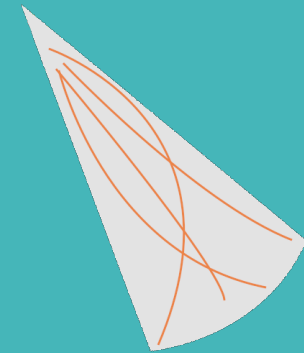
Bosone W
1 leptone



Bosone Z
2 leptoni



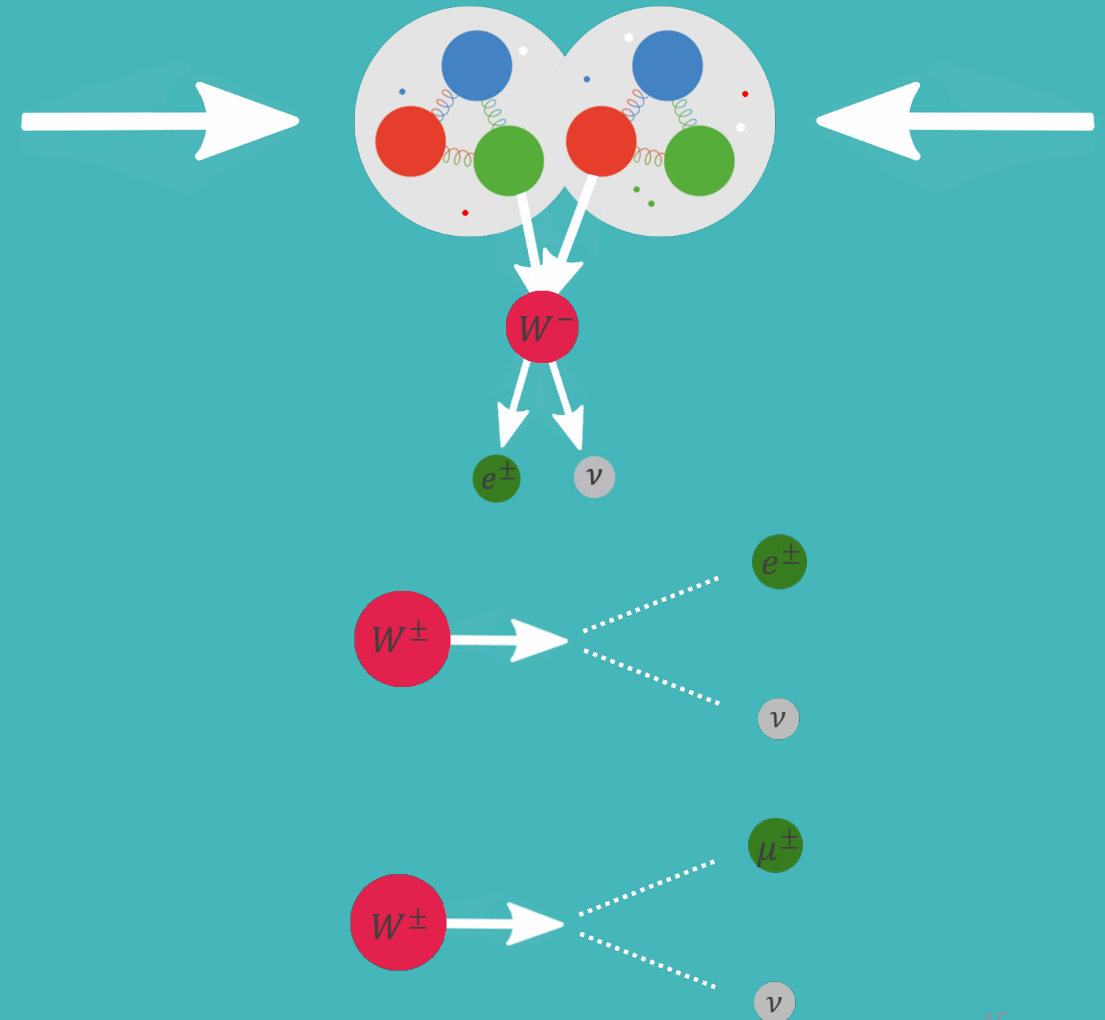
Bosone di Higgs



Zoo (background)

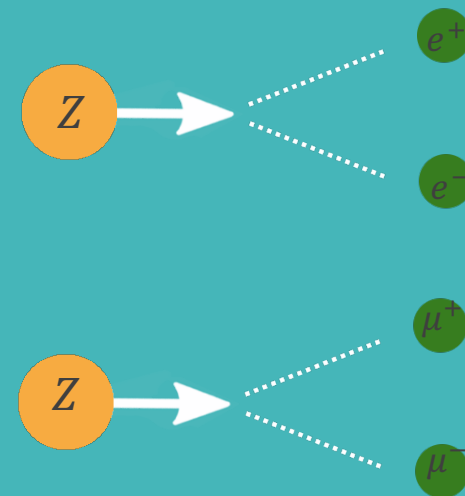
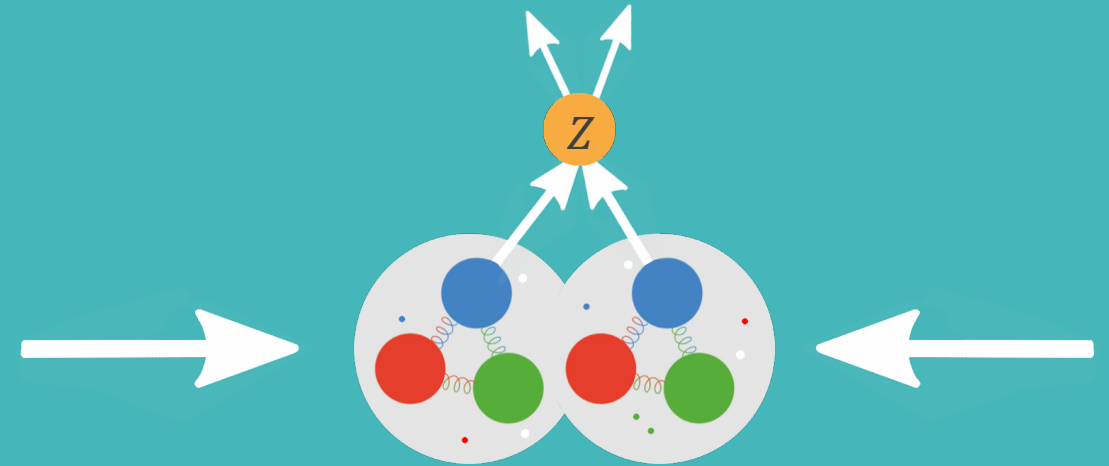
Bosone W – un leptone

- Bosoni mediatori della forza debole: W^+ e W^-
- Responsabile della radioattività
$$n \rightarrow W^{\mp} p^{\pm} \rightarrow p^{\pm} e^{\mp} \nu_e$$
- $m_W \approx 80\text{GeV} \rightarrow$ forza elettrodebole a corto raggio
- $W \rightarrow e \nu_e$ o $\mu \nu_\mu$
- In CMS: solamente un leptone (e o μ) nello stato finale $\rightarrow$ non riusciamo a ricostruire i neutrini



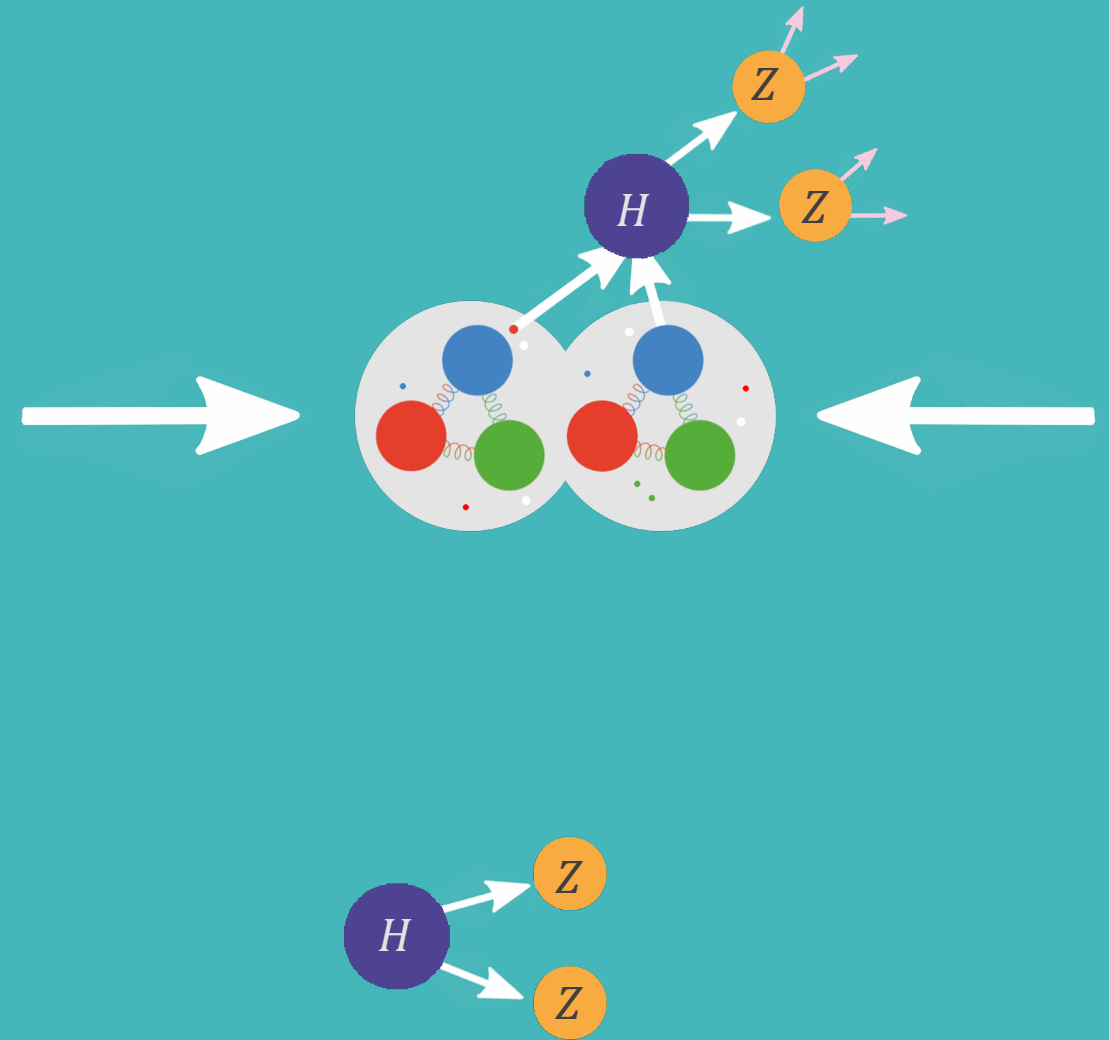
Bosone Z- due leptoni

- Bosone Z $\rightarrow$ cugino neutro del W, forza elettrodebole neutra
- $m_Z \approx 91\text{GeV} \rightarrow$ forza elettrodebole a corto raggio
- $Z \rightarrow e^+e^-$ o $\mu^+\mu^-$



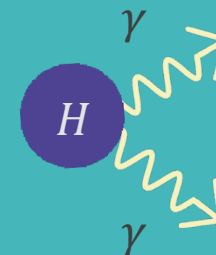
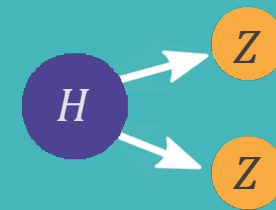
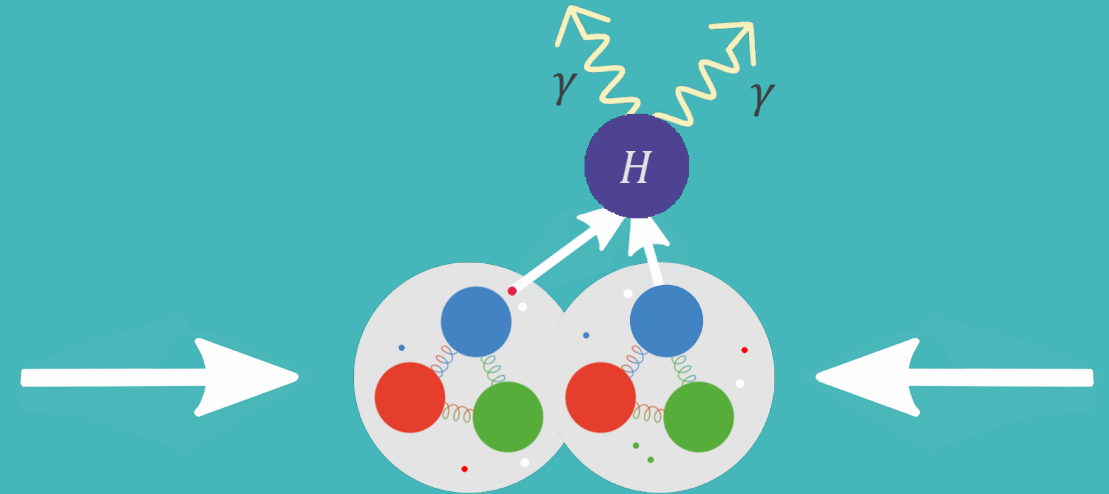
Bosone di Higgs

- Bosone di Higgs
- Scoperto nel 2012 da CMS ed Atlas
- Responsabile del meccanismo di acquisizione della massa da parte di tutte le particelle note
- Higgs ha due decadimenti in cui è abbastanza facile da ricostruire (*golden channels*)
 1. $H \rightarrow ZZ \rightarrow 4\ell$



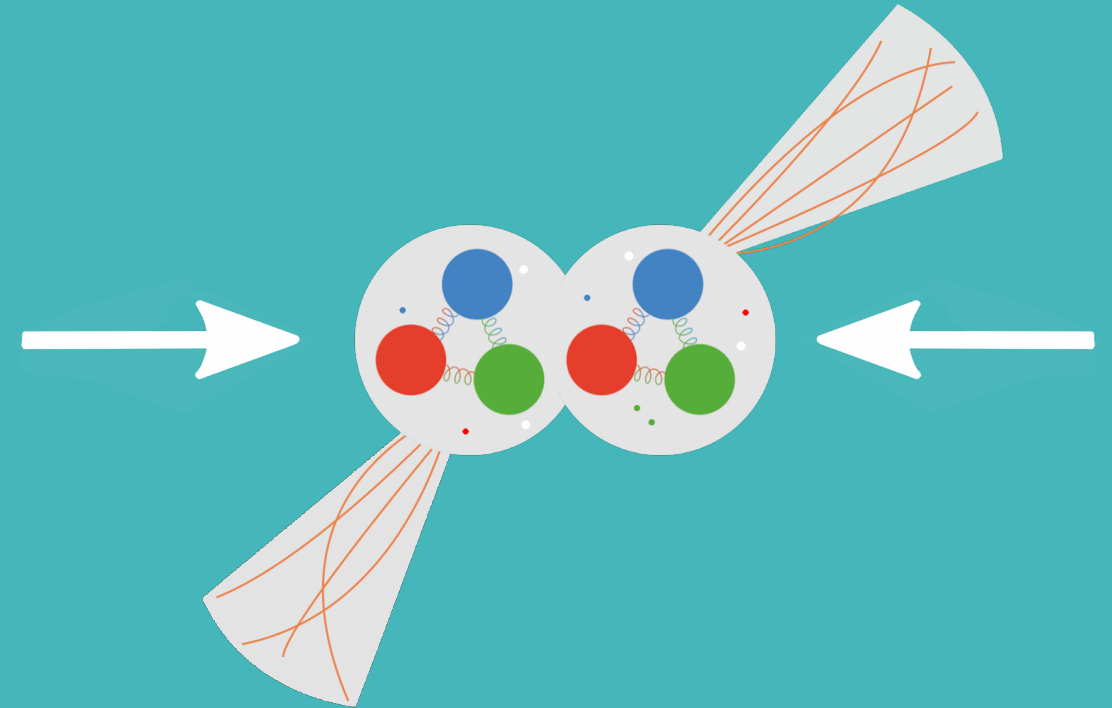
Bosone di Higgs

- Bosone di Higgs
- Scoperto nel 2012 da CMS ed Atlas
- Responsabile del meccanismo di acquisizione della massa da parte di tutte le particelle note
- Higgs ha due decadimenti in cui è abbastanza facile da ricostruire (*golden channels*)
 1. $H \rightarrow ZZ \rightarrow 4\ell$
 2. $H \rightarrow \gamma\gamma \rightarrow$ nessun leptone!



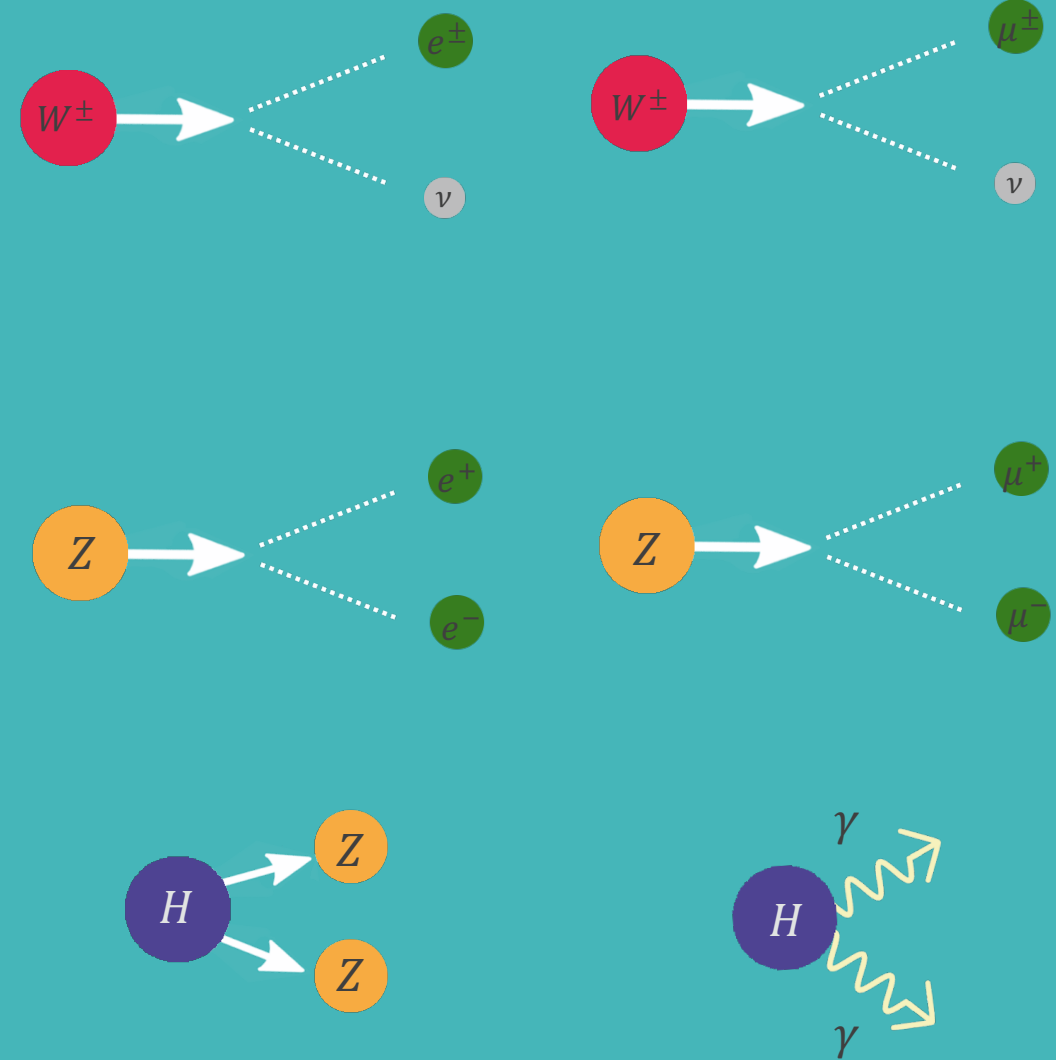
Zoo: background

- Background: prodotti della collisione che non ci interessano direttamente
- Maggiore fonte ad LHC: scattering dei quark nelle collisioni p-p
- I quark non possono esistere da soli
→ la loro energia si trasforma in getti (jet) di nuove particelle
- Zoo (per oggi): tutto ciò che non è W, Z o H



Recap

- Le particelle pesanti decadono in **particelle più leggere**, spesso troppo presto per essere ricostruite direttamente
- CMS ricostruisce con alta efficienza:
 e, μ, γ
- I **neutrini** interagiscono raramente con la materia $\rightarrow$ non riusciamo a ricostruirli direttamente $\rightarrow$ ne deduciamo la presenza **dall'energia mancante**

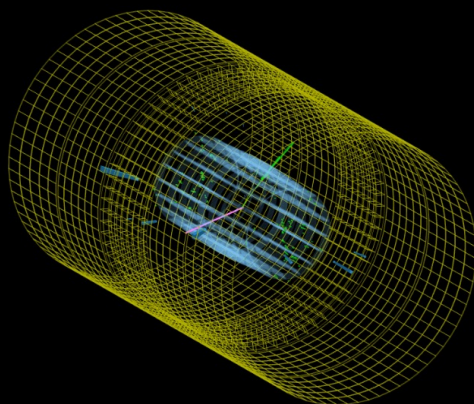


Visualizzare eventi in CMS: l'event display ed ispy

iSpy WebGL N5:Events/Run_2/Event_74 [74 of 100]

Barrel Rec. Hits [158] ☒
Endcap Rec. Hits [163] ☒
HCAL
Barrel Rec. Hits [15] ☒
Forward Rec. Hits [1] ☐
Muon ☒
Physics ☒
Vertices (Reco) [5] ☐
Electron Tracks (GSF) [1] ☒
Photons (Reco) [1] ☐
Jets (Reco) [26] ☐
Missing Et (PF) [1] ☒

CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:31:07.023581 GMT
Run / Event / LS: 167676 / 328493186 / 368

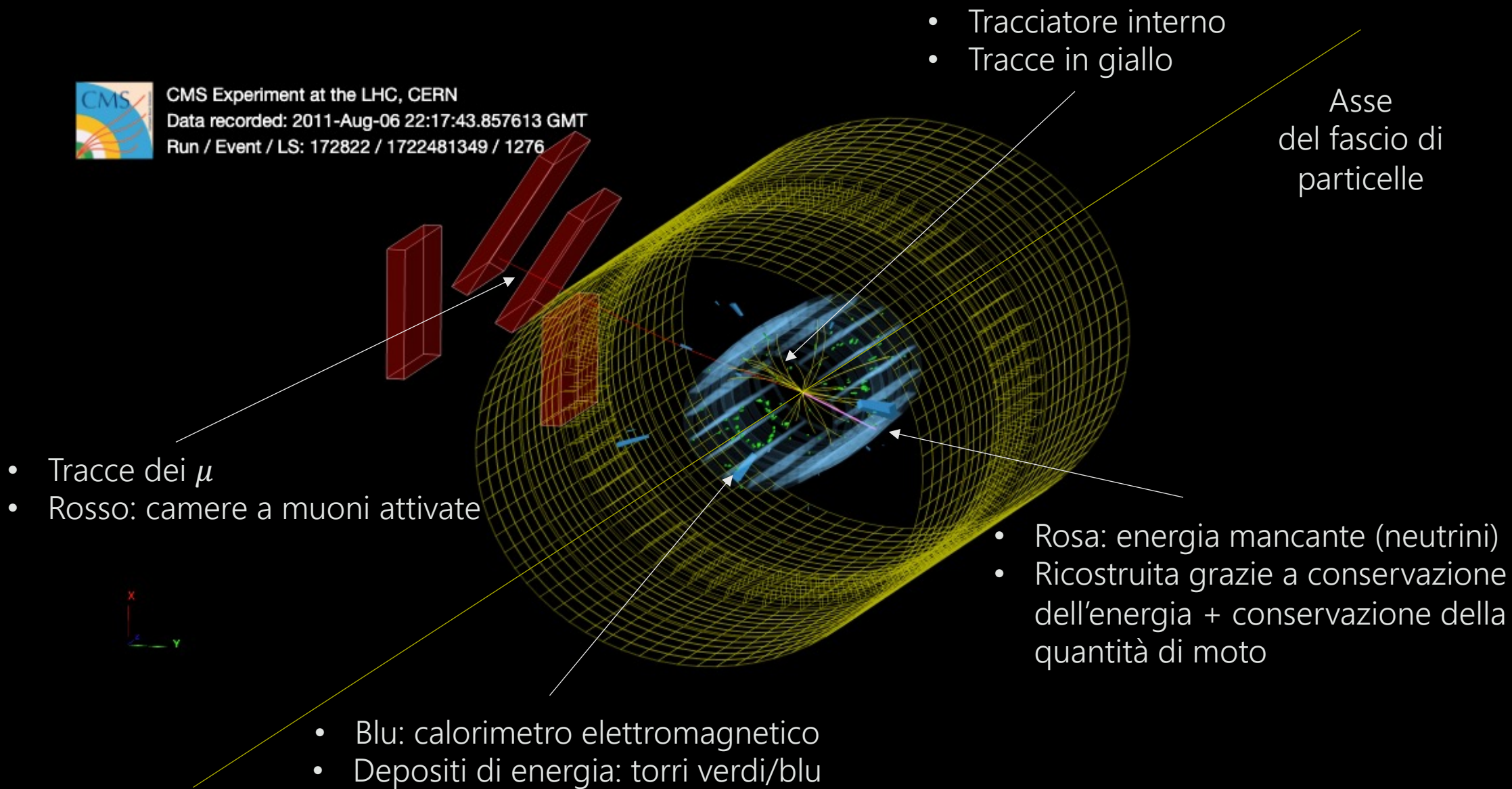


Physics: Missing Et (PF)

phi	pt	px	py	pz
-2.83213	39.6176	-37.7357	-12.0653	0

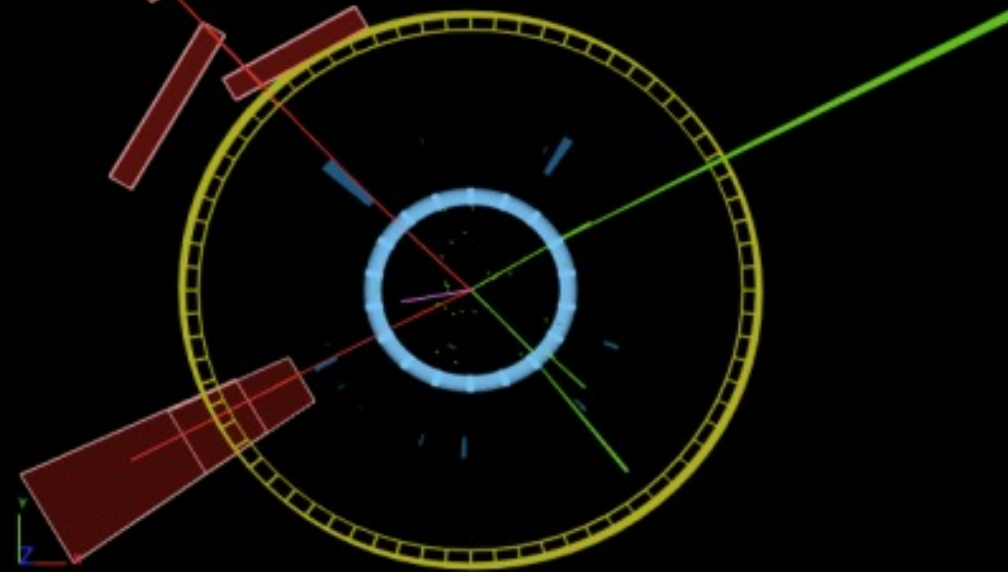


CMS Experiment at the LHC, CERN
Data recorded: 2011-Aug-06 22:17:43.857613 GMT
Run / Event / LS: 172822 / 1722481349 / 1276





CMS Experiment at the LHC, CERN
Data recorded: 2011-Aug-08 07:49:16.734479 GMT
Run / Event / LS: 172868 / 933807102 / 689



$$2e + 2\mu \rightarrow Higgs?$$



CMS Experiment at the LHC, CERN

Data recorded: 2012-Jun-12 21:20:17.109519 GMT

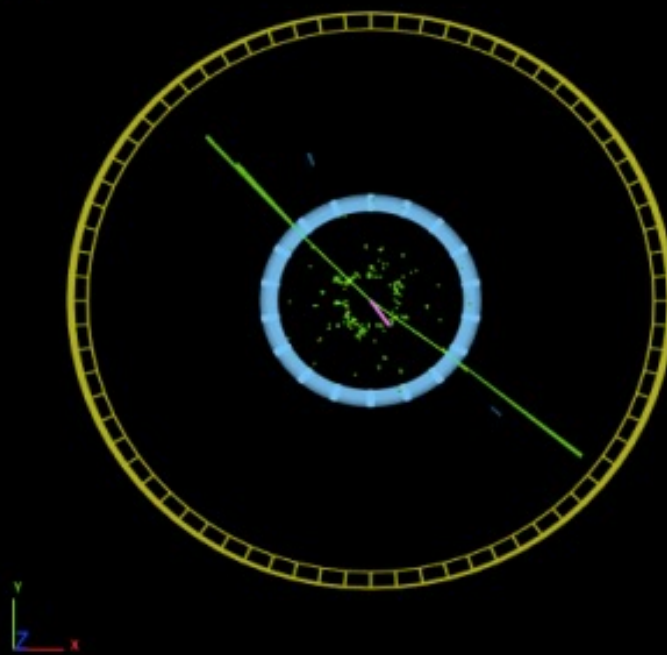
Run / Event / LS: 196197 / 352383455 / 238



$4\mu \rightarrow Higgs?$



CMS Experiment at the LHC, CERN
Data recorded: 2011-May-19 21:45:52.309850 GMT
Run / Event / LS: 165364 / 70639384 / 67



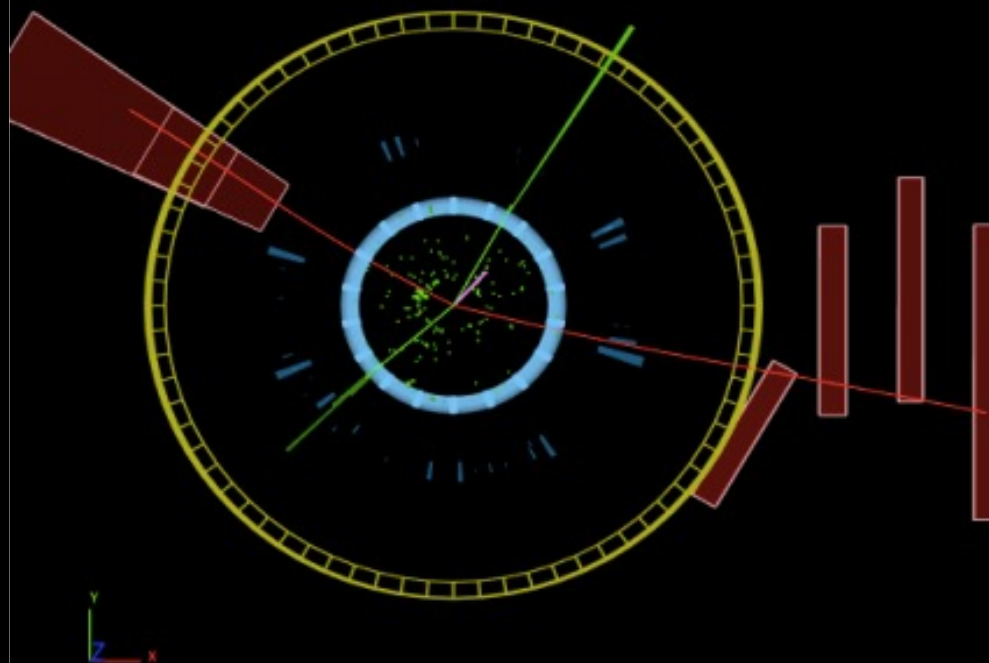
$$2e \rightarrow Z?$$



CMS Experiment at the LHC, CERN

Data recorded: 2012-Jun-07 17:03:43.595082 GMT

Run / Event / LS: 195757 / 244623214 / 148



$$2e + 2\mu \rightarrow Higgs?$$



CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:38:40.982139 GMT
Run / Event / LS: 167676 / 345503199 / 387



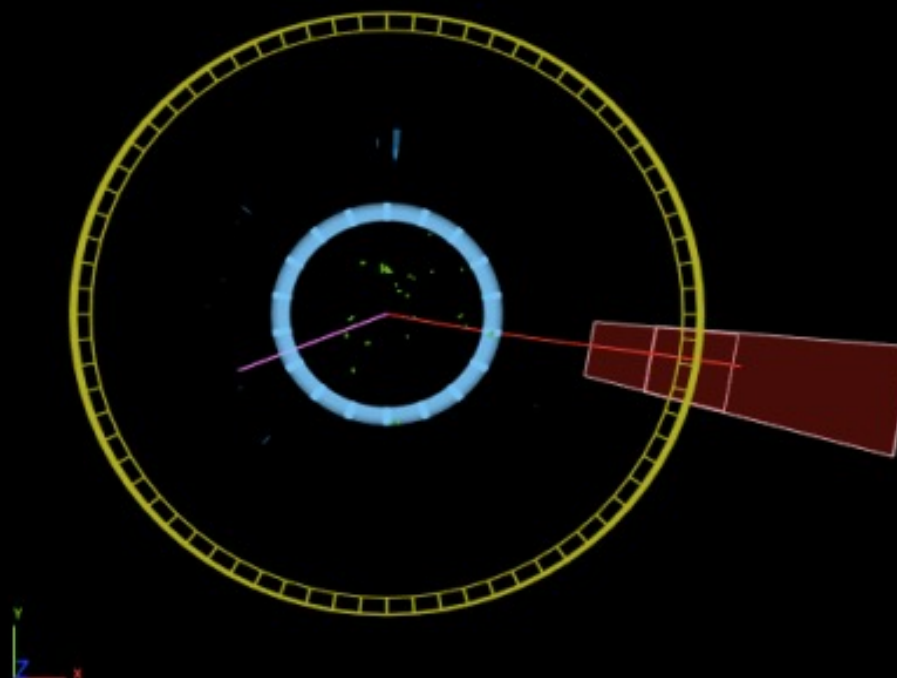
$e + \text{energia mancante} \rightarrow W?$



CMS Experiment at the LHC, CERN

Data recorded: 2011-Aug-06 22:17:40.488177 GMT

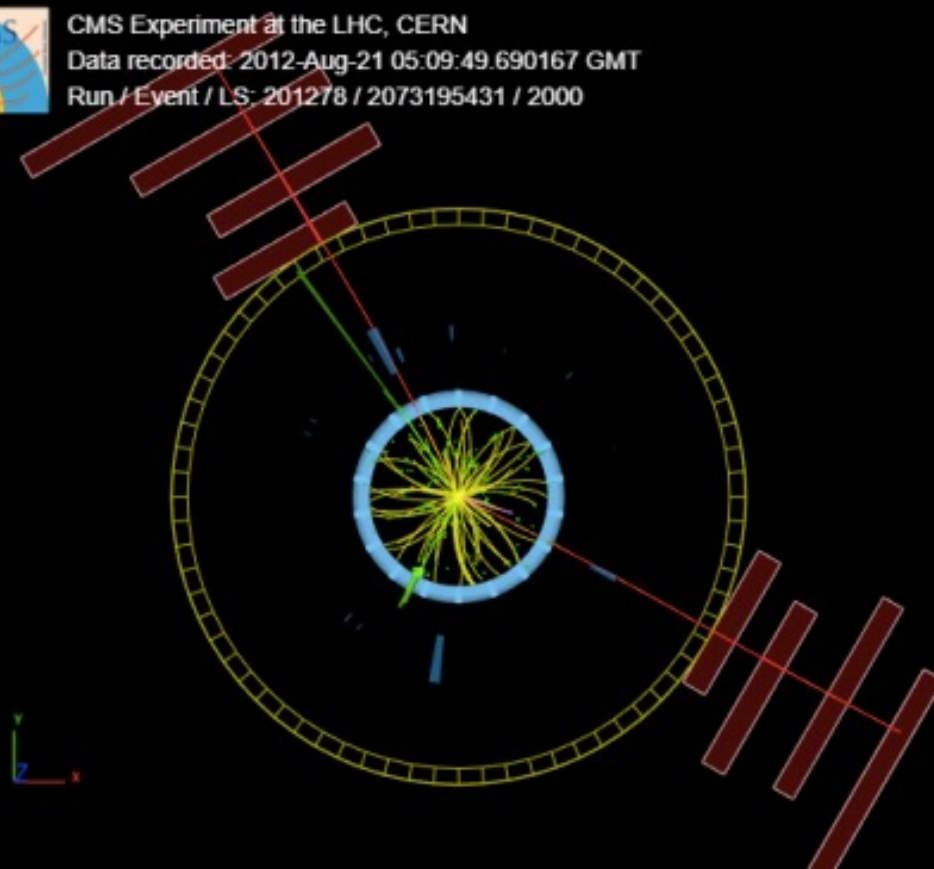
Run / Event / LS: 172822 / 1722302739 / 1276



$\mu + \text{energia mancante} \rightarrow W?$



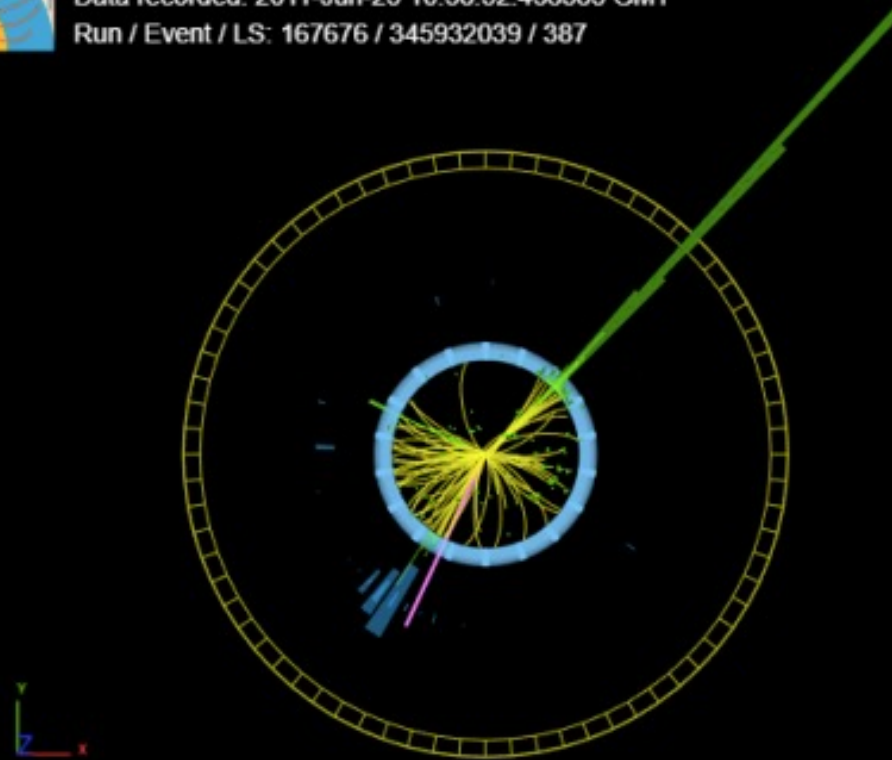
CMS Experiment at the LHC, CERN
Data recorded: 2012-Aug-21 05:09:49.690167 GMT
Run / Event / LS: 201278 / 2073195431 / 2000



$$2e + 2\mu \rightarrow Higgs?$$

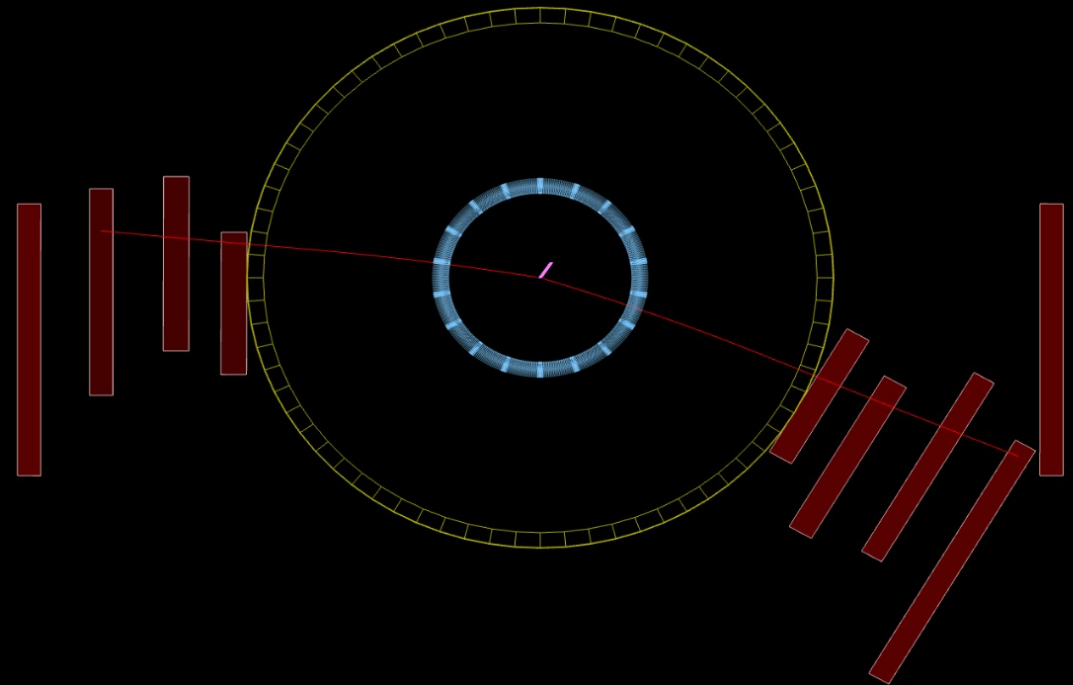
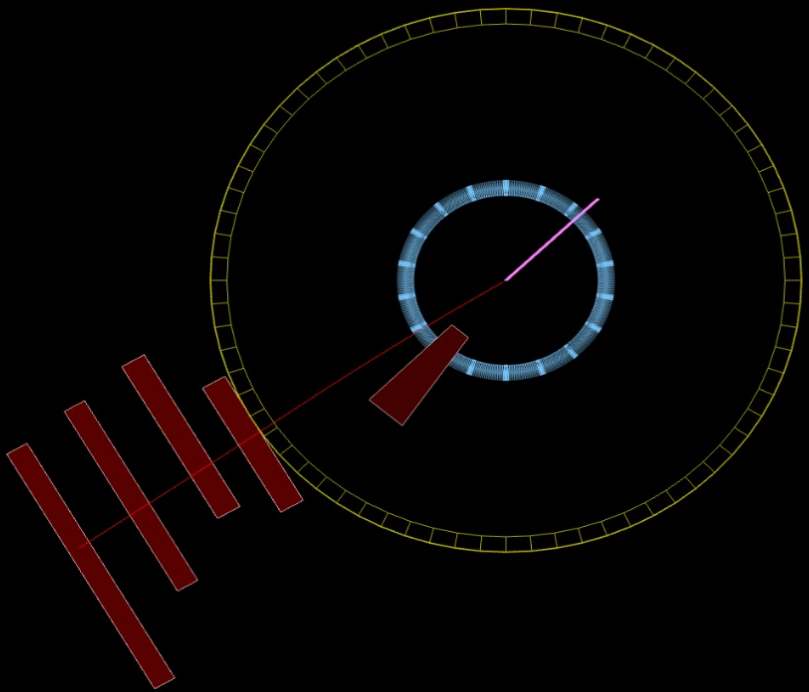


CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:38:52.436585 GMT
Run / Event / LS: 167676 / 345932039 / 387

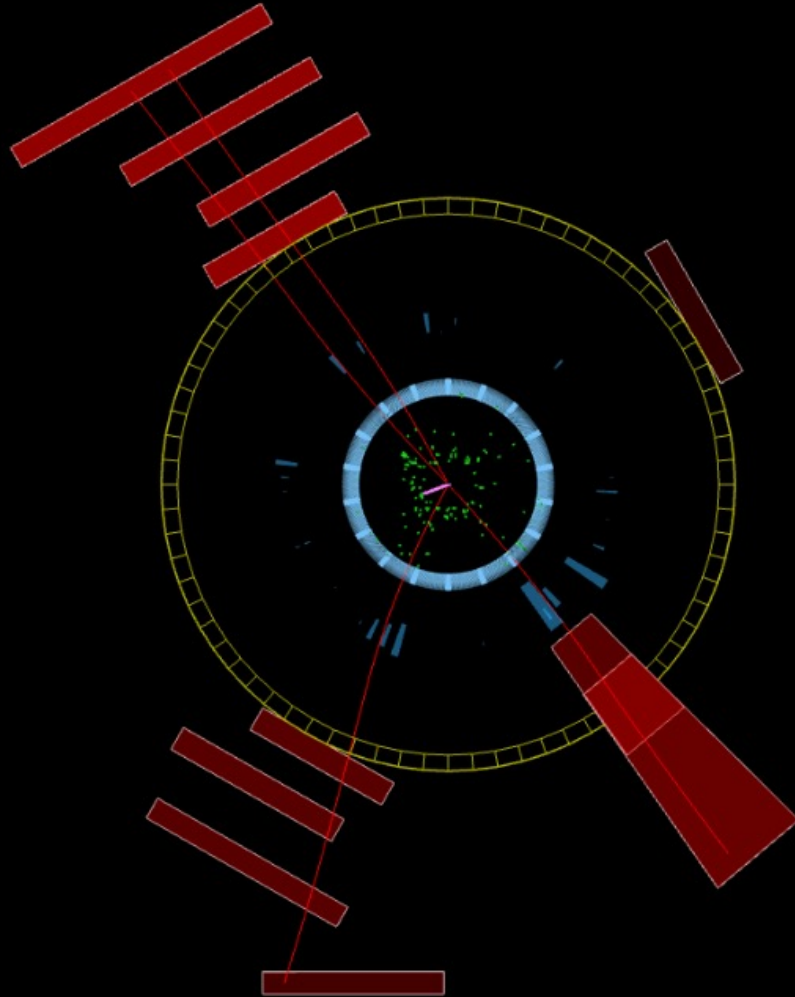


$2e + \text{energia mancante} \rightarrow Z\nu\nu? W + \text{elettroni?}$

Distinguate un W da uno Z?



Riconoscere il bosone di Higgs



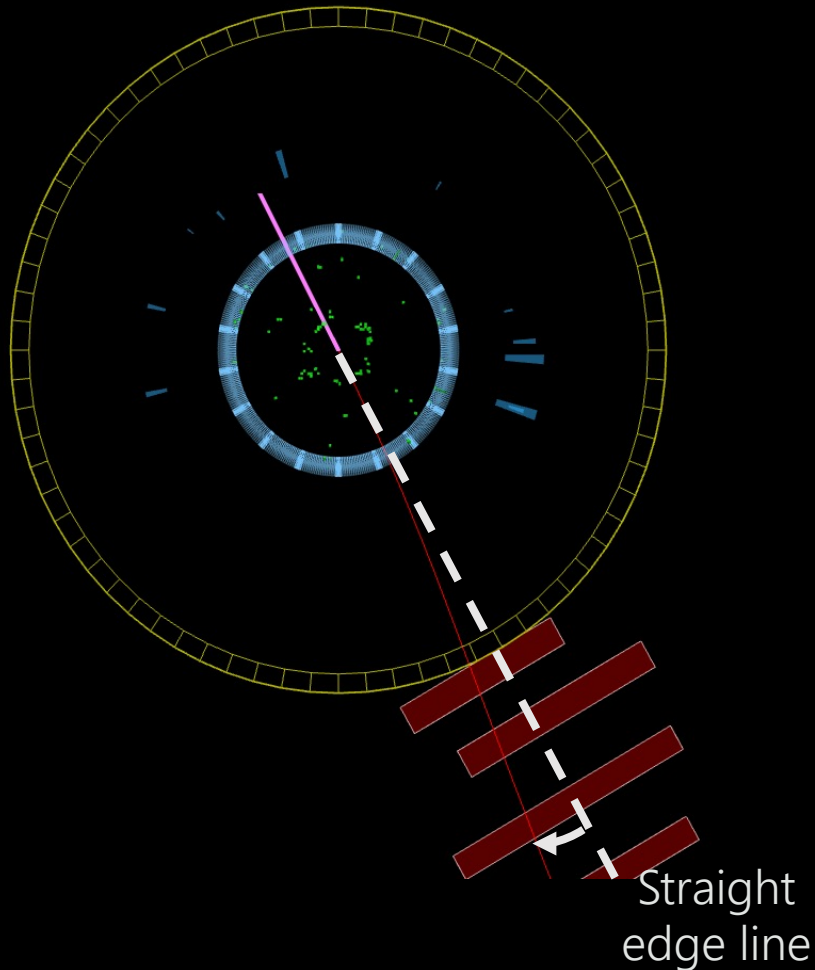
- $H \rightarrow ZZ$
 - $Z \rightarrow e^{\pm}e^{\mp}$
 - $Z \rightarrow \mu^{\pm}\mu^{\mp}$

Riconoscere il bosone di Higgs



- $H \rightarrow \gamma\gamma$
- I fotoni non lasciano segnale nel tracciatore, perché?

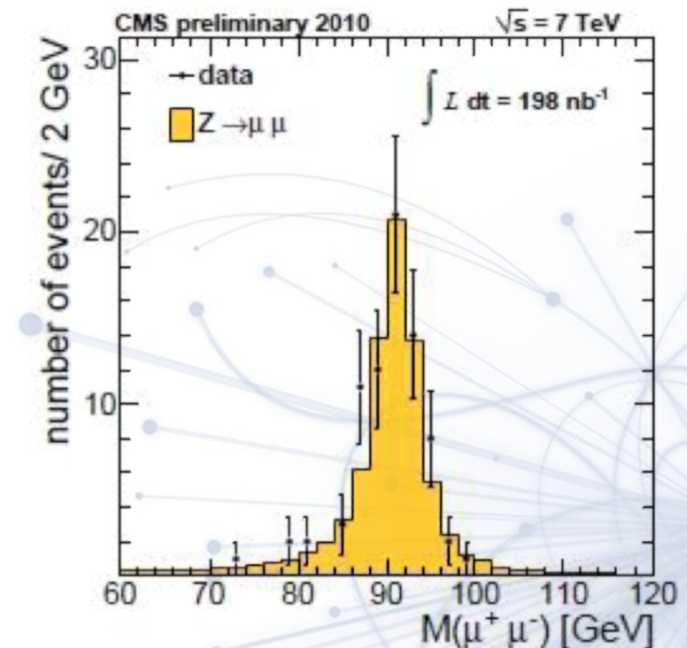
Distinguere la carica delle particelle



- Campo magnetico
- Forza di Lorentz: $\vec{F} = q\vec{v} \times \vec{B}$
- Le particelle cariche curvano
- Regola della mano destra!
- Senso orario: carica positiva

Cose interessanti da calcolare

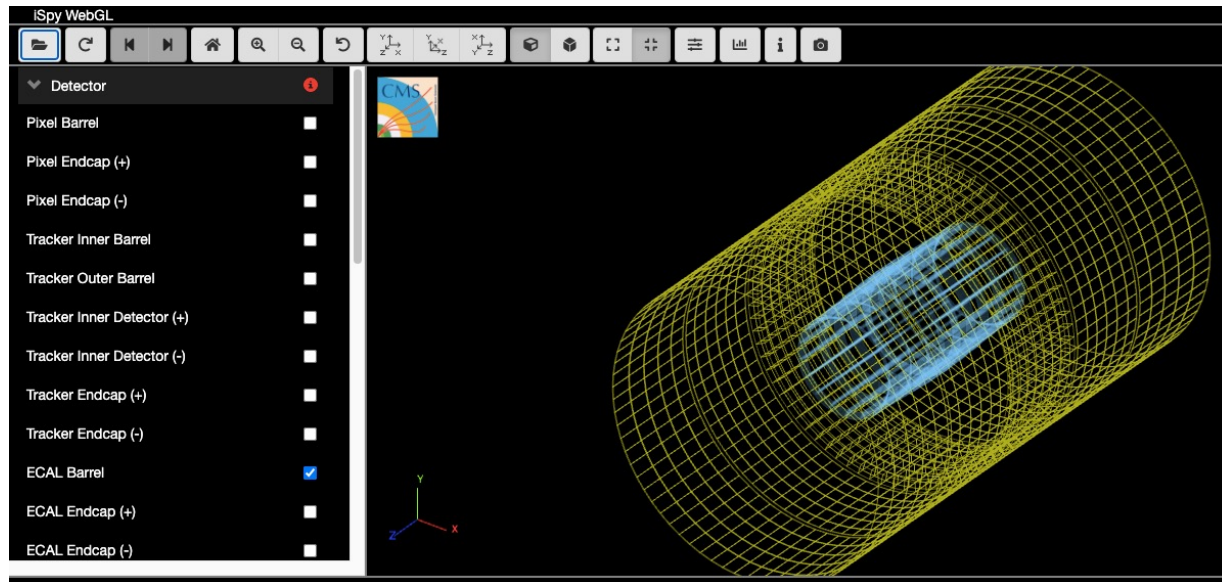
- Rapporto elettroni/muoni: idee? Uguali? Uno il doppio dell'altro? Il triplo?
- Rapporto W^+/W^- : idee? Una volta e mezzo l'altro? Cinque volte? Nessun cambiamento?
- Massa invariante dello Z e dell'Higgs



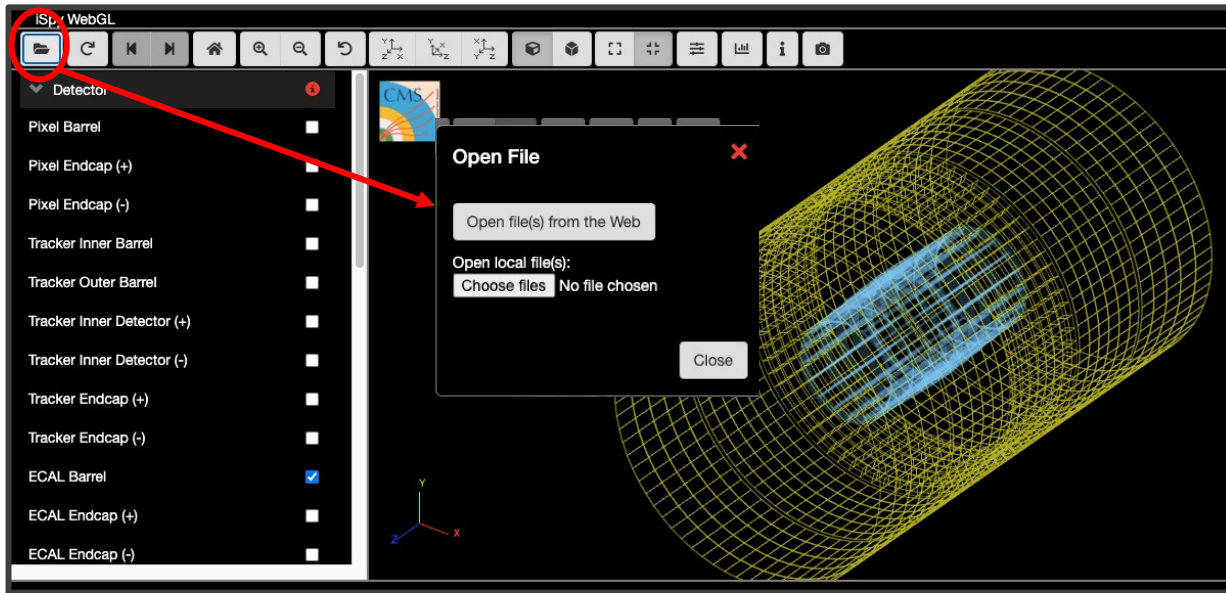
Info pratiche - Link

- CIMA : <https://www.i2u2.org/elab/cms/cima-wzh/index.php>
 - CERN-01Mar2022 → Perugia2022 → dataset
- Event display: <http://go.web.cern.ch/go/tfS9>
- CMS masterclass: <https://quarknet.org/content/cms-masterclass-documentation>

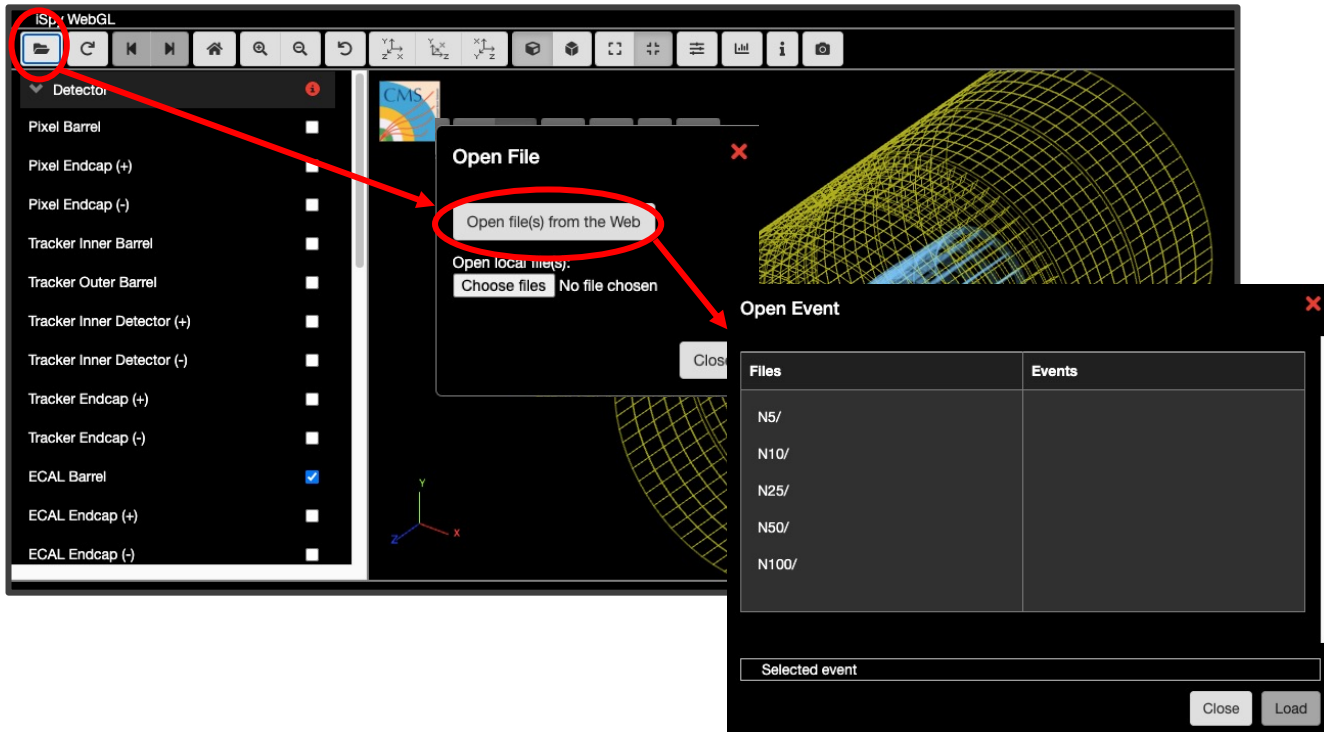
Info pratiche: event display



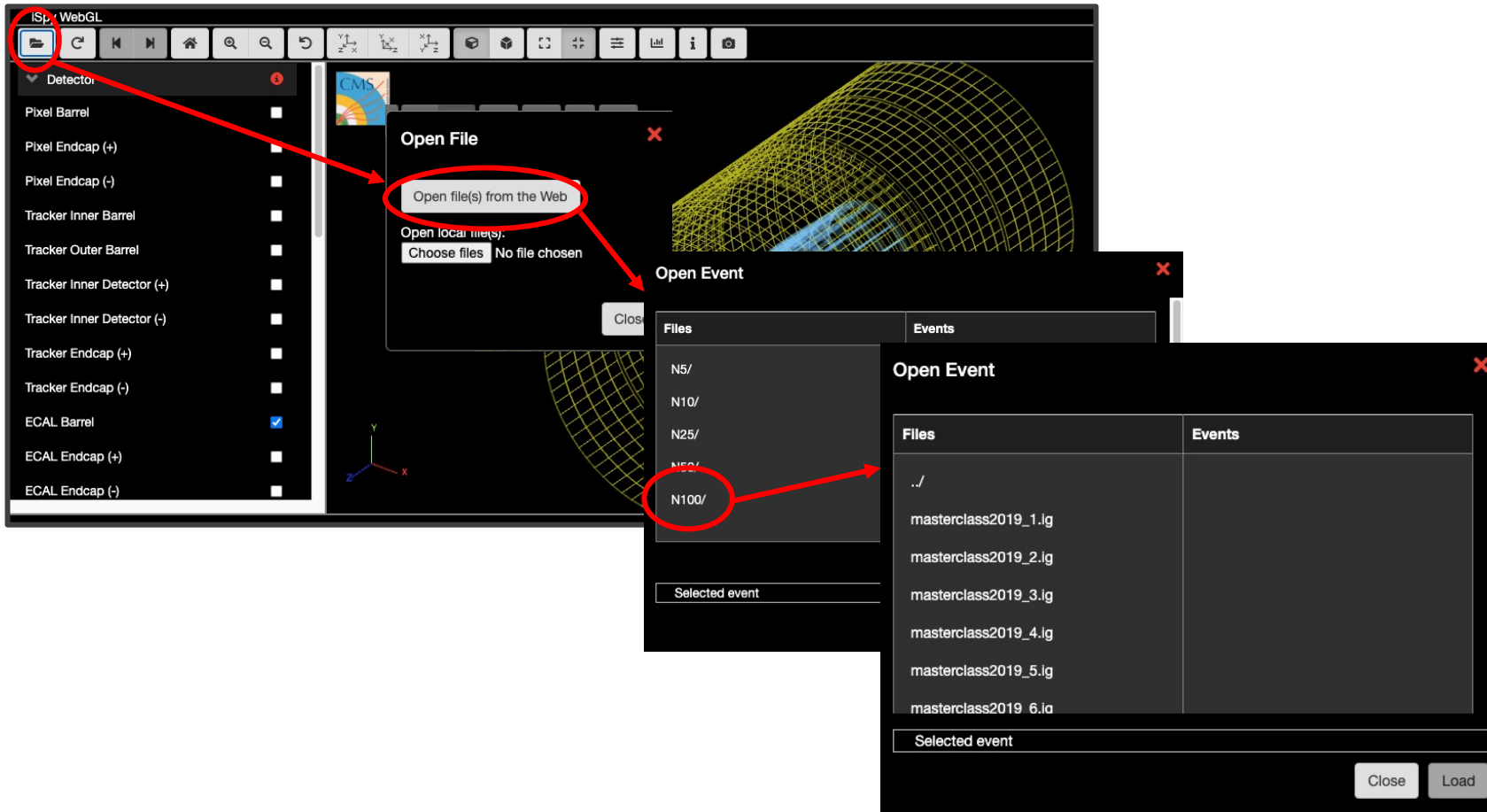
Info pratiche: event display



Info pratiche: event display



Info pratiche: event display



Info pratiche: event display

The screenshot shows the iSP WebGL interface with a sidebar on the left listing detector components. The main window displays a 3D visualization of a detector. Three overlapping 'Open Event' dialog boxes are shown, illustrating the steps to open an event display file. Red circles and arrows highlight the following steps:

- Clicking the file icon in the top toolbar.
- Selecting 'Open file(s) from the Web' in the 'Open File' dialog.
- Choosing 'N100/' in the 'Files' list of the first 'Open Event' dialog.
- Selecting 'masterclass2019_1.lg' in the 'Files' list of the second 'Open Event' dialog.

The third 'Open Event' dialog shows the mapping of files to events:

Files	Events
../	Events/Run_1/Event_1
masterclass2019_1.lg	Events/Run_1/Event_2
masterclass2019_2.lg	Events/Run_1/Event_3
masterclass2019_3.lg	Events/Run_1/Event_4
masterclass2019_4.lg	Events/Run_1/Event_5
masterclass2019_5.lg	Events/Run_1/Event_6
masterclass2019_6.lg	Events/Run_1/Event_7

The 'Selected event' field is empty, and the 'Load' button is visible at the bottom right of the dialog.

Info pratiche: event display

The image shows a sequence of four screenshots illustrating the steps to load an event display in the iSP WebGL interface. Red circles and arrows highlight the key actions:

- Screenshot 1:** The iSP WebGL interface. A red circle highlights the file icon in the top toolbar, with an arrow pointing to the next screenshot.
- Screenshot 2:** An "Open File" dialog box. A red circle highlights the "Open file(s) from the Web" button, with an arrow pointing to the next screenshot.
- Screenshot 3:** An "Open Event" dialog box. A red circle highlights the "N100/" entry in the "Files" list, with an arrow pointing to the next screenshot.
- Screenshot 4:** An "Open Event" dialog box. A red circle highlights the "Events/Run_1/Event_1" entry in the "Events" list. Another red circle highlights the "Load" button at the bottom right, with an arrow pointing to it.

The background of the interface shows a 3D visualization of a particle detector structure.

Info pratiche: event display

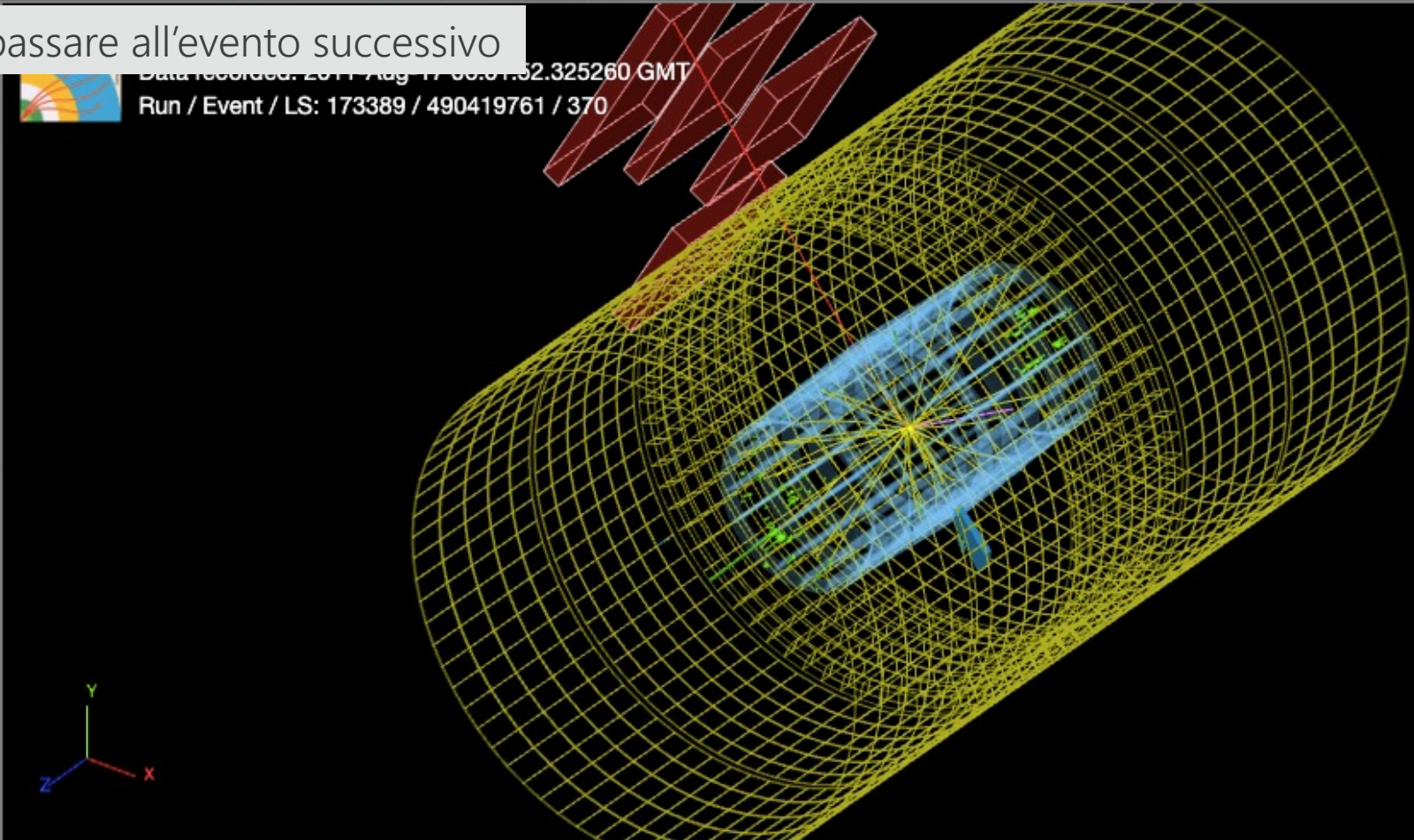
iSpy WebGL N100:Events/Run_1/Event_1 [1 of 100]

Da qui potete passare all'evento successivo

Detector

- Imported
- Provenance
- Event
- Tracking
- Tracks (reco.) [56]
- ECAL
 - Barrel Rec. Hits [130]
 - Preshower Rec. Hits [9]
 - Endcap Rec. Hits [160]
- HCAL
 - Barrel Rec. Hits [19]
 - Forward Rec. Hits [1]

Data recorded: 2011 Aug 17 00:01:52.325260 GMT
Run / Event / LS: 173389 / 490419761 / 370



Info pratiche: CIMA

CIMA

CMS Instrument for Masterclass Analysis



Choose your Masterclass

SampleTables-Jan2021
 Kharkov-CMLTP-10Jun2021
 Medford-15Jun2021
 Hammond-24Jun2021
 NotreDame-09July2021
 CERN-28Jul2021
 CERN-09Jul2021
 VCONF-Stavanger-03Aug2021
 Seattle-10Sep2021
 CERN-Fermilab-HCP-04Sep2021
 Oviedo-12Oct2021
 Test-14Sep2021
 CIEMAT-02Nov2021
 Vilnius-03Dec2021
 CERN-03Dec2021
 Sofia-03Jan2022
 Cantabria_2-5May2022
 Viterbo-16Feb2022
 IDWGS-11Feb2022
CERN-01Mar2022
 CERN-05Mar2022
 CERN-04Mar2022
 CERN-07Mar2022

Choose your location

Trieste2022A
Perugia2022
 IstanbulOzyegin2022A
 Dimitrovgrad2022
 Colmar2022

Choose your data file

50.1
 50.11
 50.12
 50.13
 50.14
 50.15
 50.16
 50.17
 50.18
 50.19
 50.2
 50.21
 50.22
 50.23
 50.24
 50.25
 50.26
 50.27
 50.28
 50.29
 50.3
 50.31
 50.32
 50.33



Info pratiche: CIMA

Inserite i dati per ogni evento

[Back](#) [Events Table \(Group 1\)](#) [Mass Histogram \(Table01\)](#) [Results \(Table01\)](#) [Event Display](#)

Masterclass: Event01

location: Table01

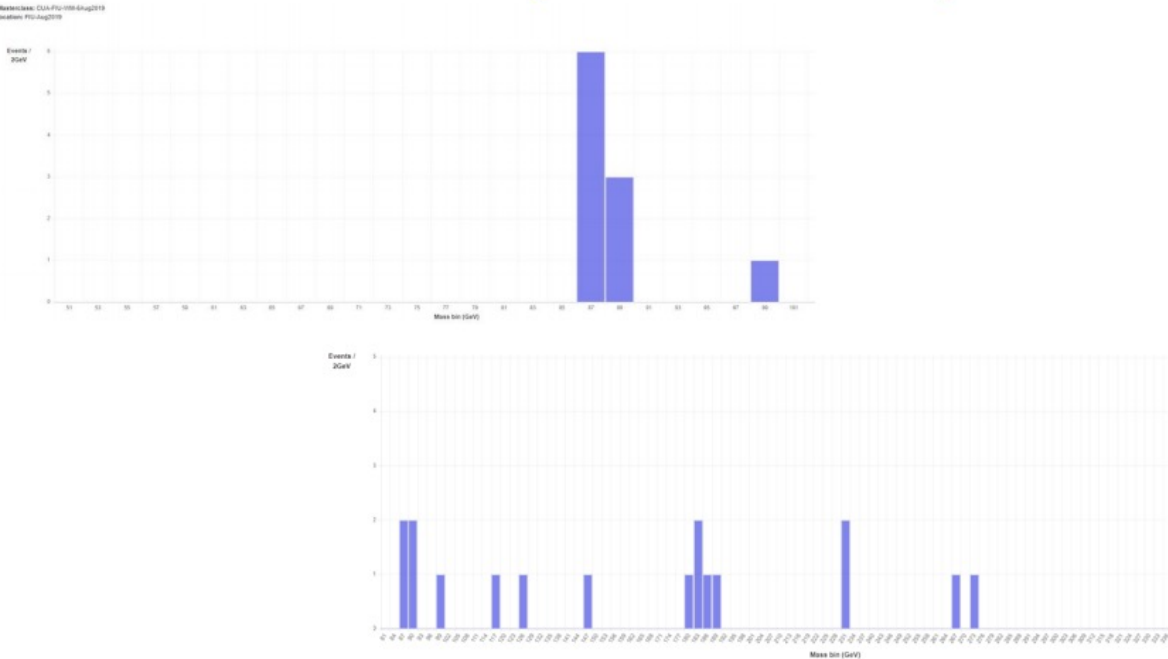
Group: 1

Select Event Event index: 14 ▾ Event number: 1-14	Final State ☐ e ν ☐ μ ν ☐ e e ☐ μ μ ☐ 4e ☐ 4μ ☐ 2e 2μ	Primary State Charged Particle: ☐ W ⁺ ☐ W ⁻ ☐ W [±] ☐ Neutral Particle (Z, H) ☐ Zoo	Enter Mass GeV/c ² Next
--	--	---	---

Event index	Event number	Final state	Primary state	Mass
13	1-13	μν	W [±]	

Info pratiche: CIMA

CIMA costruisce automaticamente l'istogramma delle masse



e la tabella con i rapporti chiave (e/μ , W^+/W^-)

Back

Events Table (Group 21)

Mass Histogram (FIU-Aug2019)

Results (FIU-Aug2019)

Masterclass: CUA-FIU-WM-6Aug2019

location: FIU-Aug2019

Group	e	μ	W+	W-	W $\pm$	Neutral	Zoo	Total
21	26	32	21	21	0	13	0	55
22	41	46	24	38	1	16	1	80
23	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
25	10	12	10	5	0	5	1	21

Total:

Group	e	μ	W+	W-	W $\pm$	Neutral	Zoo	Total
All	77	90	55	64	1	34	2	156

Ratios:

e/μ	W+/W-
0.92	0.86

Esercizi

- Siete in pochi! Un dataset ognuno! Trovate i dataset che abbiamo assegnato in questo foglio Google: <http://cern.ch/go/8btt>
- Confrontatevi, scambiarete idee e familiarizzate con l'esercizio
- Nel caso aveste domande non fatevi problemi a scriverci via email:

Matteo Magherini (matteo.magherini@cern.ch),
Valentina Mariani (vmariani@cern.ch),
Matteo Presilla (matteo.presilla@cern.ch)

- Noi ci rivediamo il 1 Marzo alle 14:30!