



INTERNATIONAL  
**MASTERCLASSES**

hands on particle physics



Pavia, 29 Febbraio 2024

# Masterclass di Fisica: 29/02/2024



Thu, Feb 29

VC 1: ATLAS Z

Ana

Arnd

Siegen



Pavia



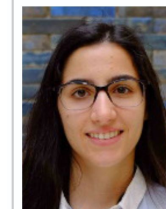
Orsay



Prague,  
Charles U.



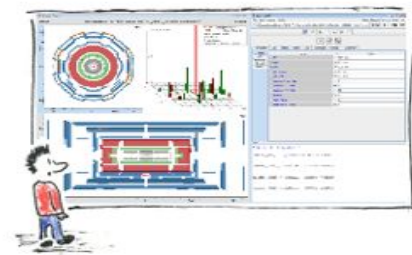
Arnd  
Behring  
(Theory)



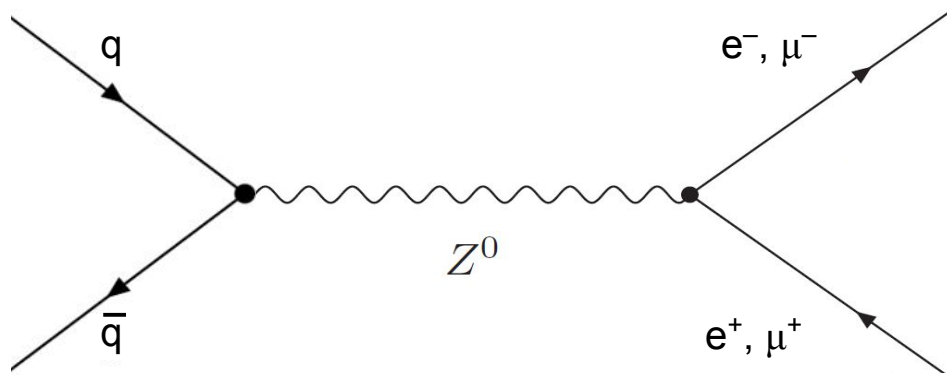
Ana Peixoto  
(ATLAS)

Oggi pomeriggio:  
13:00 inizio attività in laboratorio  
16:00 videoconferenza

- ◆ Analizzare un insieme di dati raccolti dall'esperimento ATLAS ad LHC
  - Utilizzando un event display
  - 50 eventi ogni persona
- ◆ Selezionare campione di eventi con le caratteristiche di potenziali **candidati**
  - Bosone vettore Z e altre "risonanze" di-leptoniche
  - Bosone di Higgs
- ◆ Analizzare statisticamente il campione per distinguere il segnale dal fondo
  - Cioè, costruzione di un istogramma

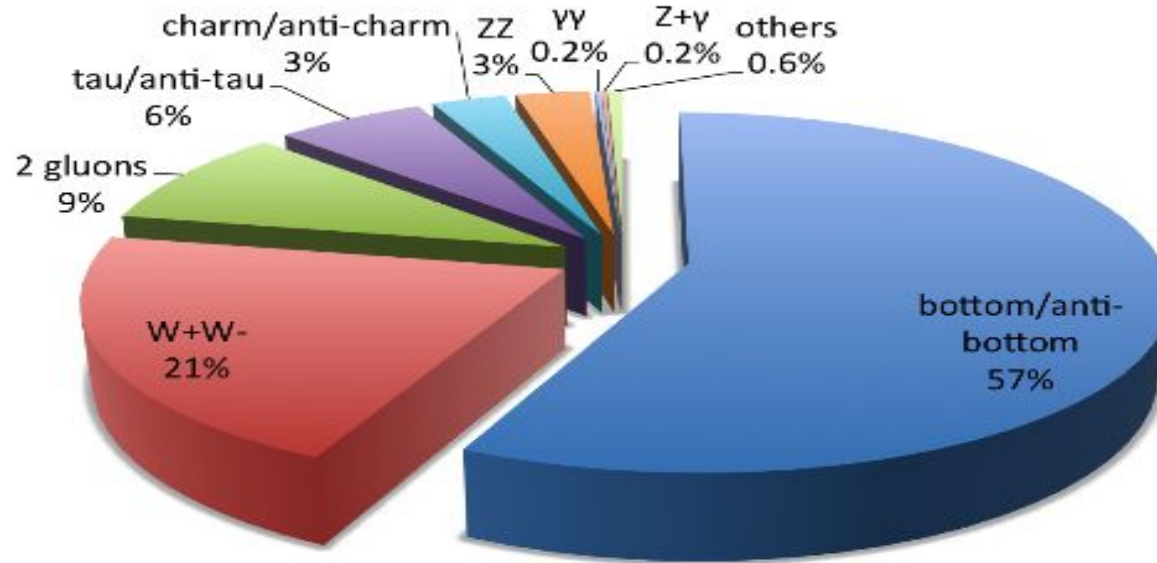


- Molti possibili canali di decadimento
  - Cercheremo il decadimento in coppie di leptoni dello stesso tipo (o elettroni o muoni) di segno opposto



# Bosone di Higgs

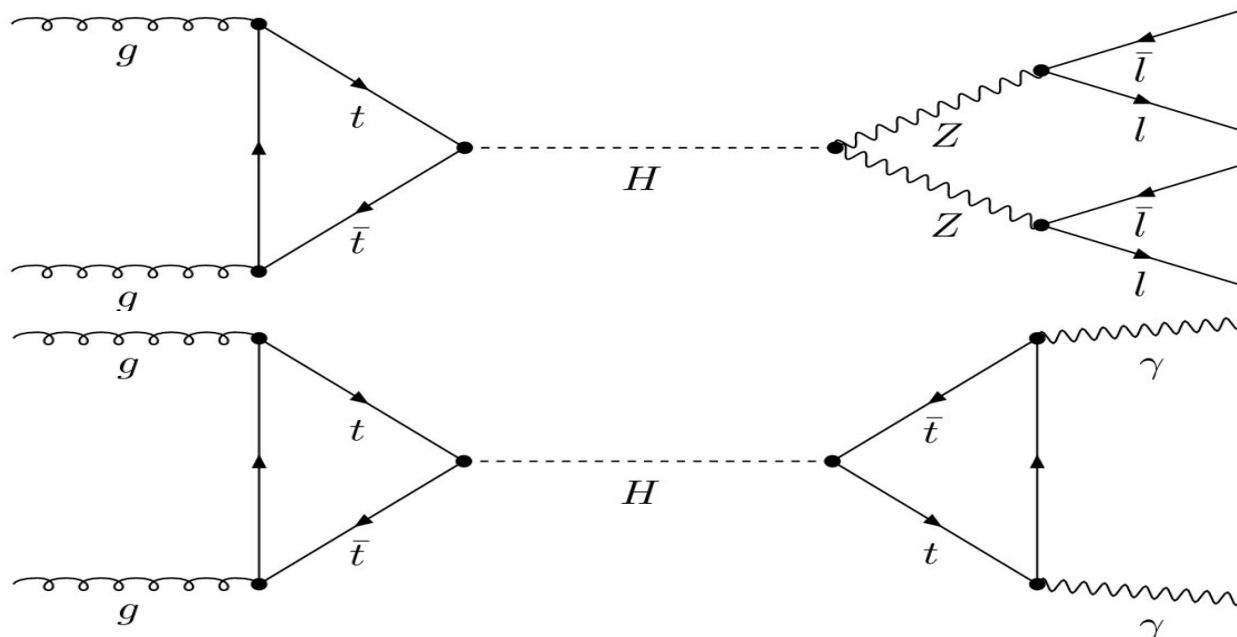
Quale canale di decadimento sceglieresti?



- A. Bottom/antibottom
- B. ZZ
- C.  $\gamma\gamma$
- D. WW

# Bosone di Higgs

- Cercheremo i canali di decadimento in
  - 4 leptoni (attraverso una coppia di Z)
  - 2 fotoni



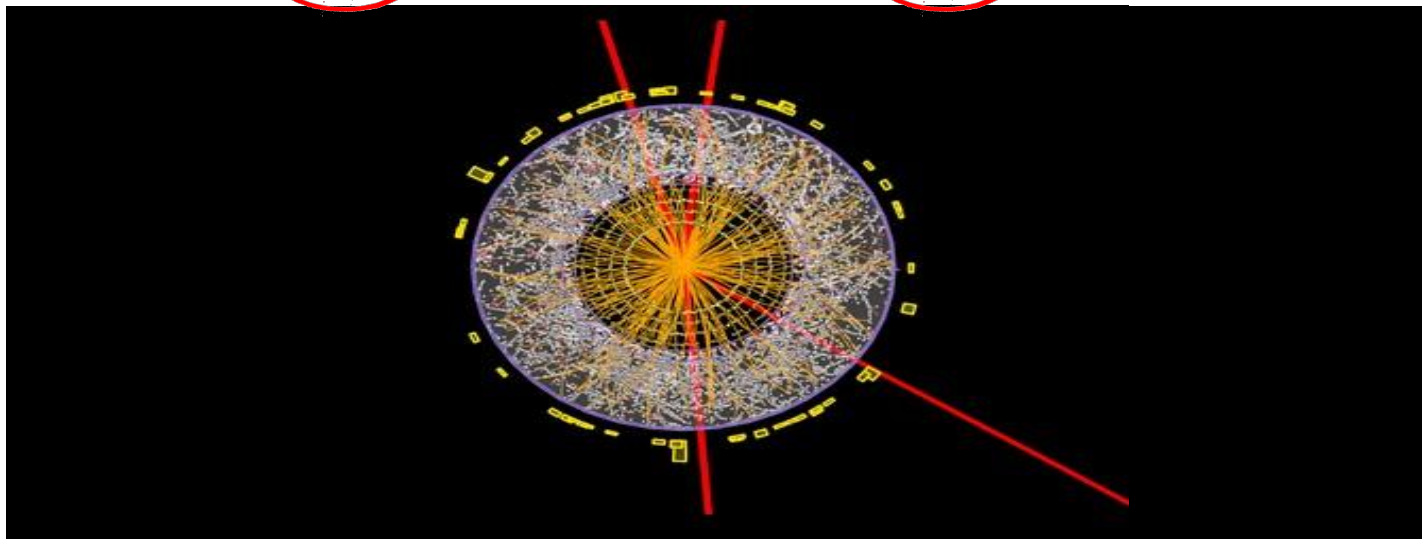
# Eventi candidati

Impossibile catalogare univocamente una data collisione (**evento**)

- Il **fondo** può avere stessa segnatura del **segnale**

$q\bar{q} \rightarrow ZZ \rightarrow \mu\mu\mu\mu$

$q\bar{q} \rightarrow H \rightarrow \mu\mu\mu\mu$



Come le distinguiamo?

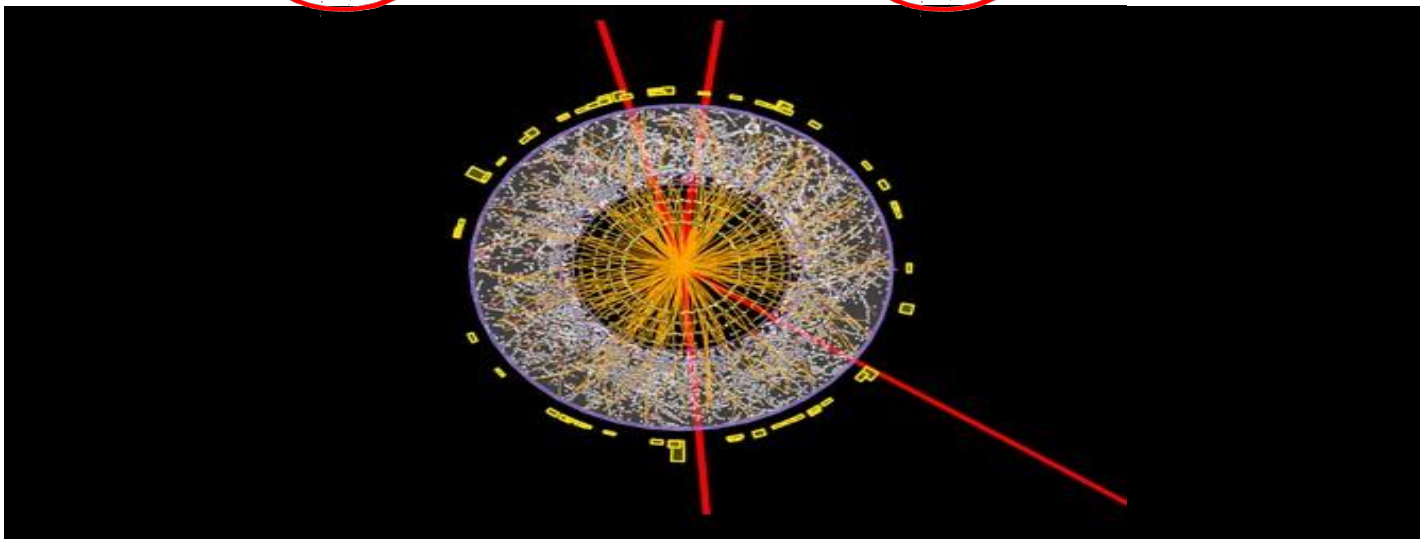
# Eventi candidati

Impossibile catalogare univocamente una data collisione (**evento**)

- Il **fondo** può avere stessa segnatura del **segnale**

$q\bar{q} \rightarrow ZZ \rightarrow \mu\mu\mu\mu$

$q\bar{q} \rightarrow H \rightarrow \mu\mu\mu\mu$



Come le distinguiamo?

- Non le distinguiamo. Necessario approccio statistico

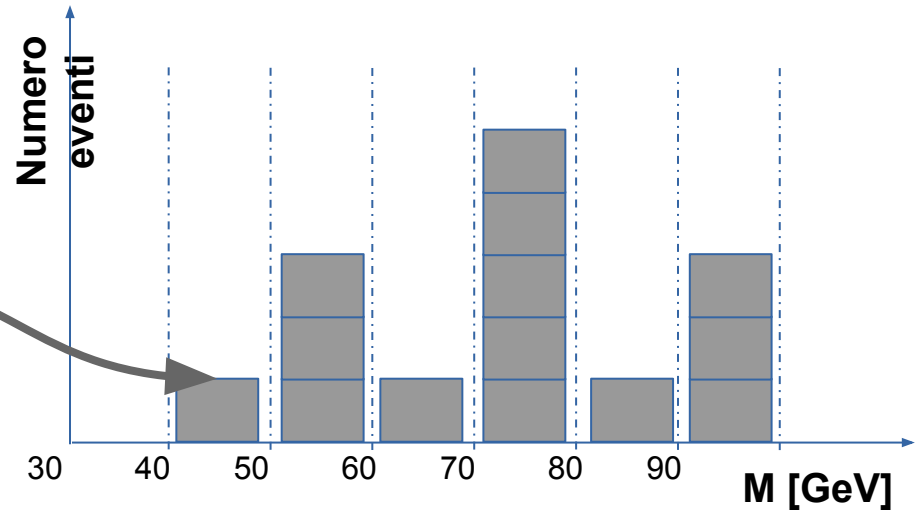
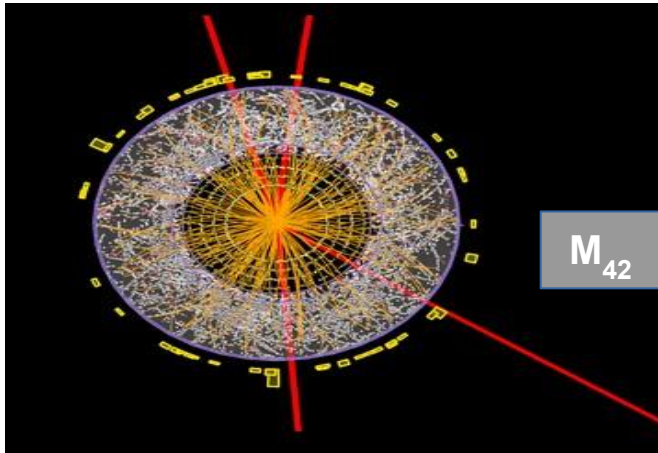


**Istogramma:** per ogni evento

- calcolo la **massa invariante** del sistema finale  $M_i$

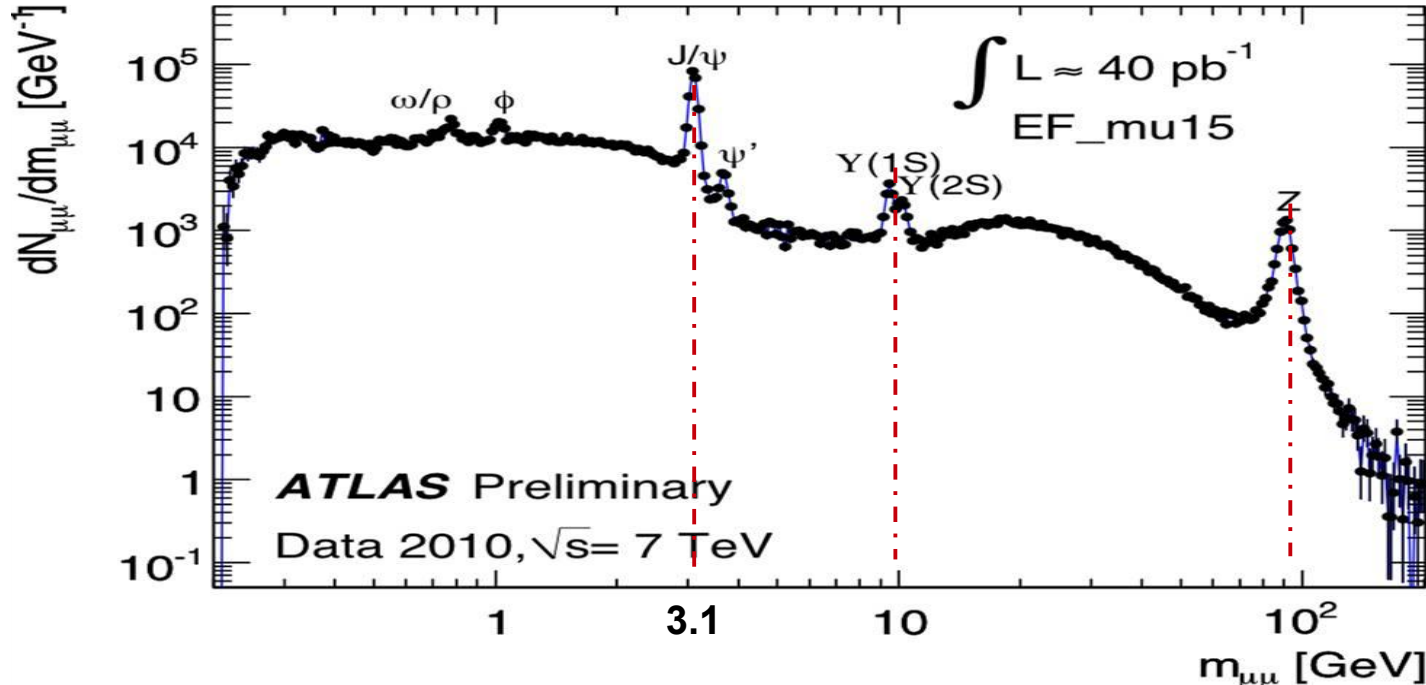
$$m_0^{(Z)} = \sqrt{\left(\frac{(E_{e^-} + E_{e^+})}{c^2}\right)^2 - \left(\frac{\vec{p}_{e^-} + \vec{p}_{e^+}}{c}\right)^2}$$

- Aggiungo un conteggio al canale dell'istogramma corrispondente ad  $M_i$

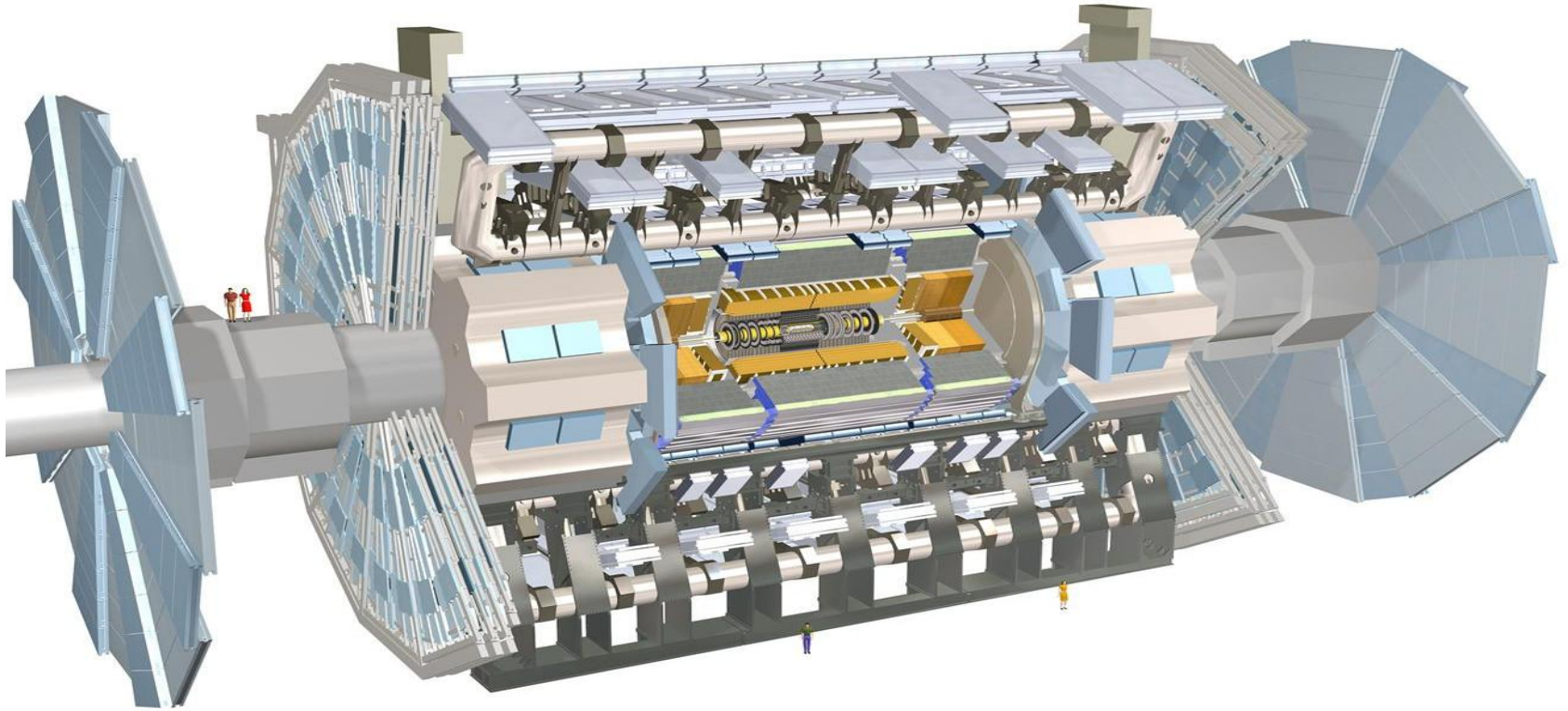


# Istogramma

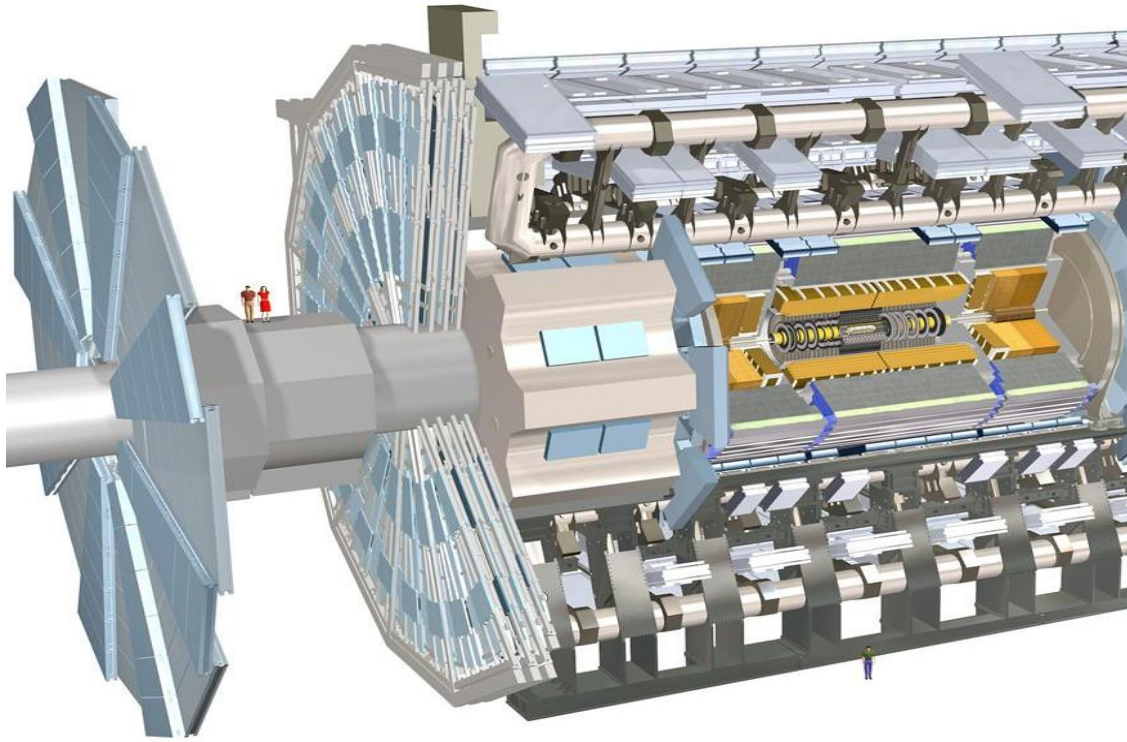
- Massa invariante del sistema dei due leptoni
  - La massa del “potenziale” progenitore



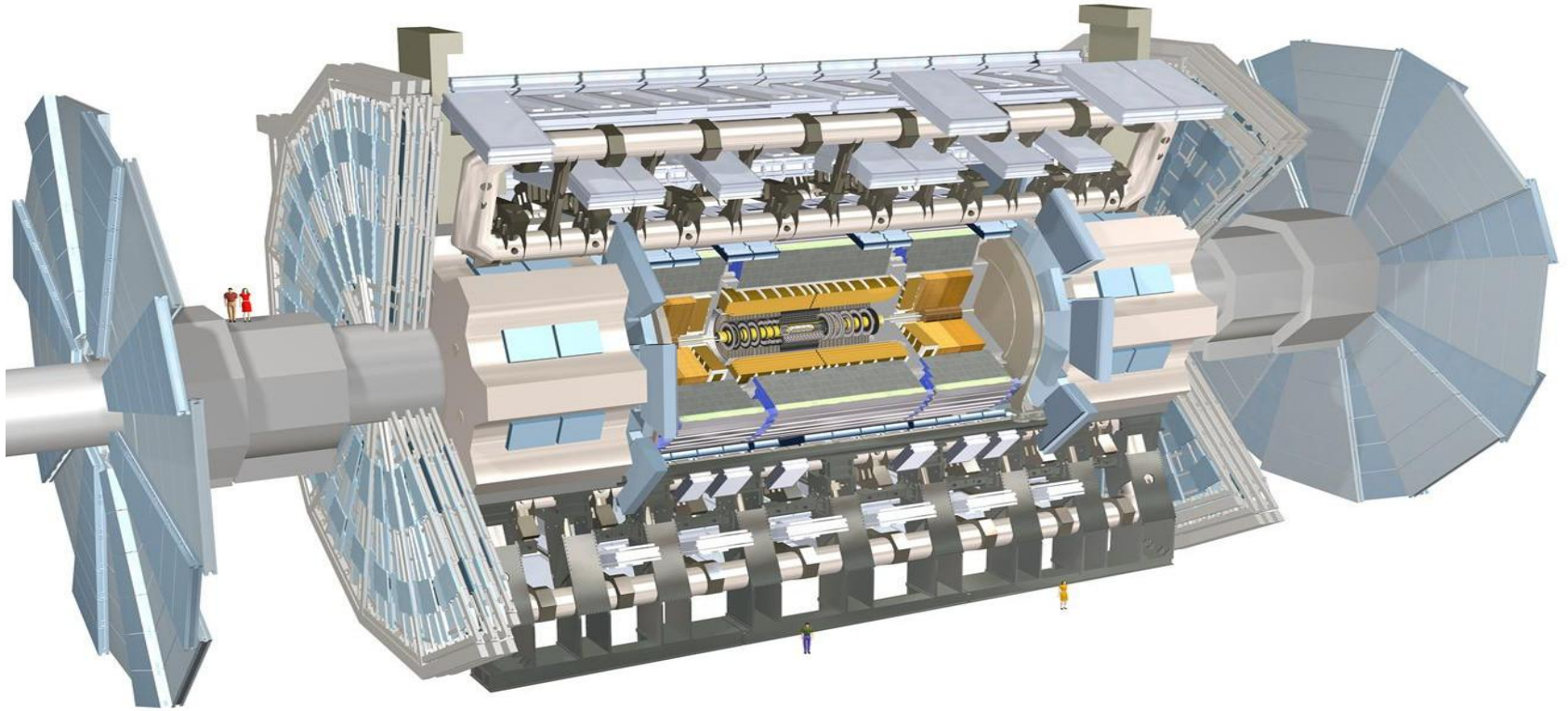
# ATLAS



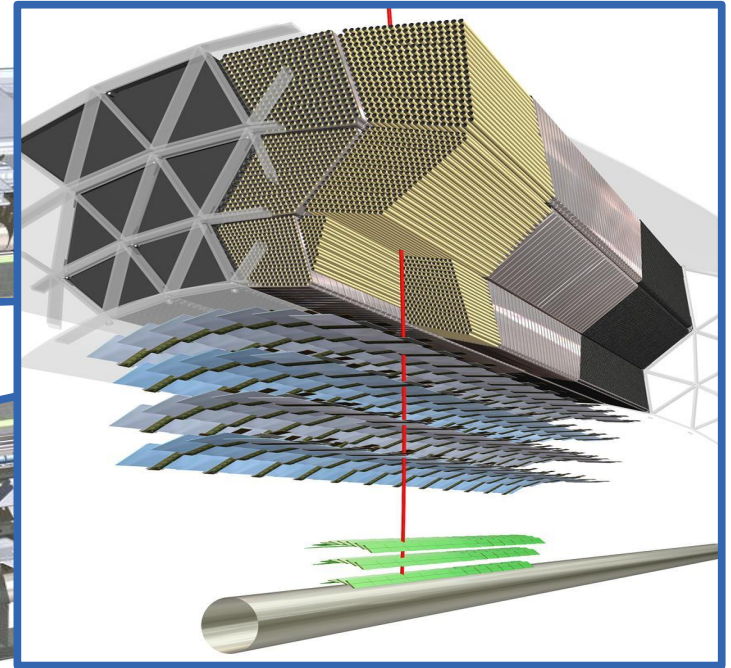
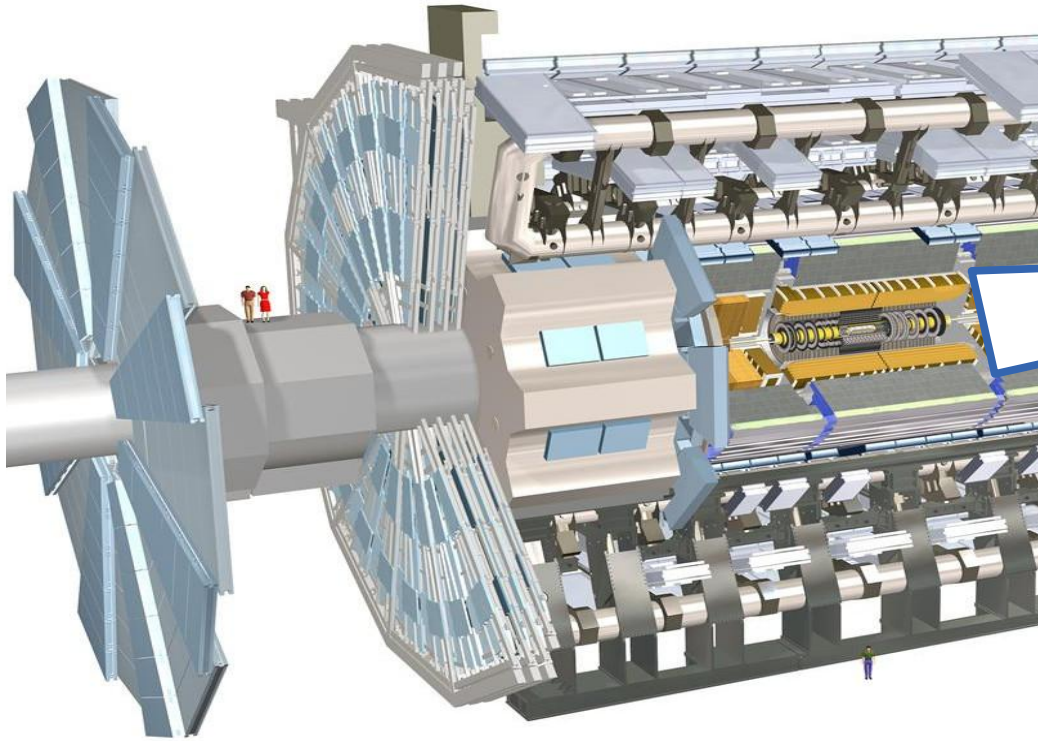
# ATLAS



# ATLAS



# Tracciatore interno



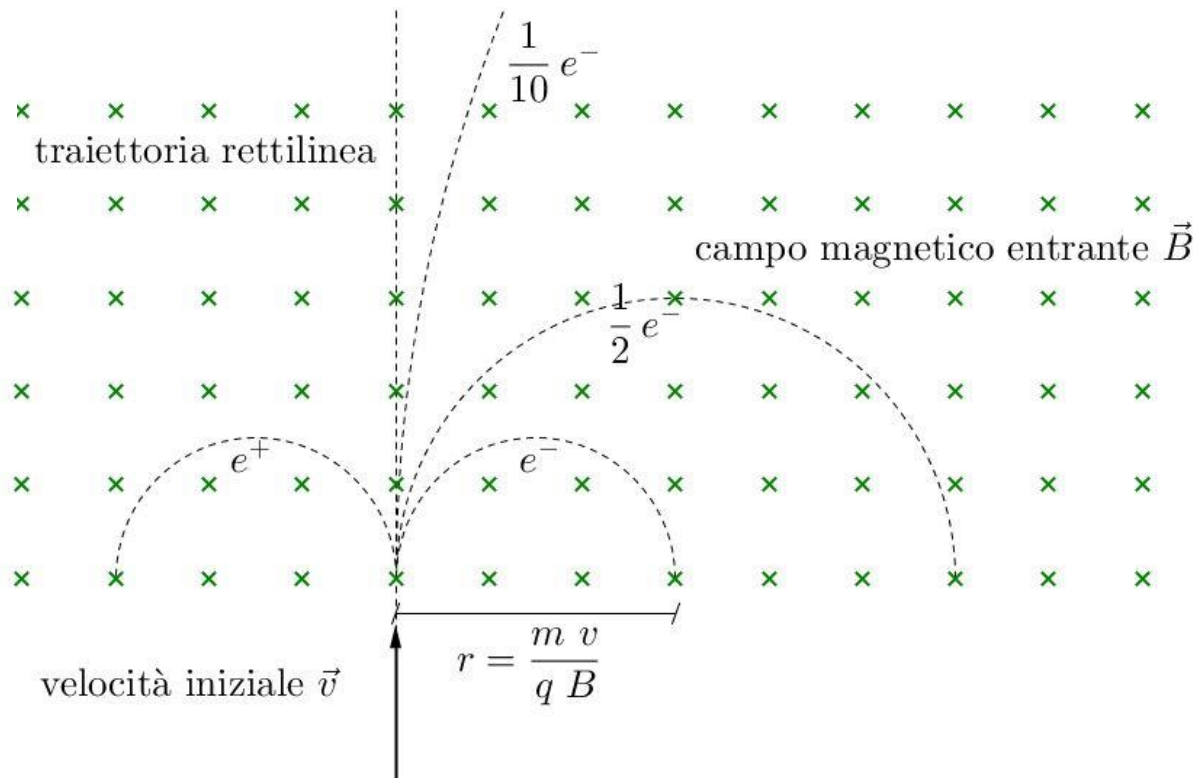
**Misura di posizione  
in campo magnetico  
( $\rightarrow$ momento)**

# Misura del momento di una particella

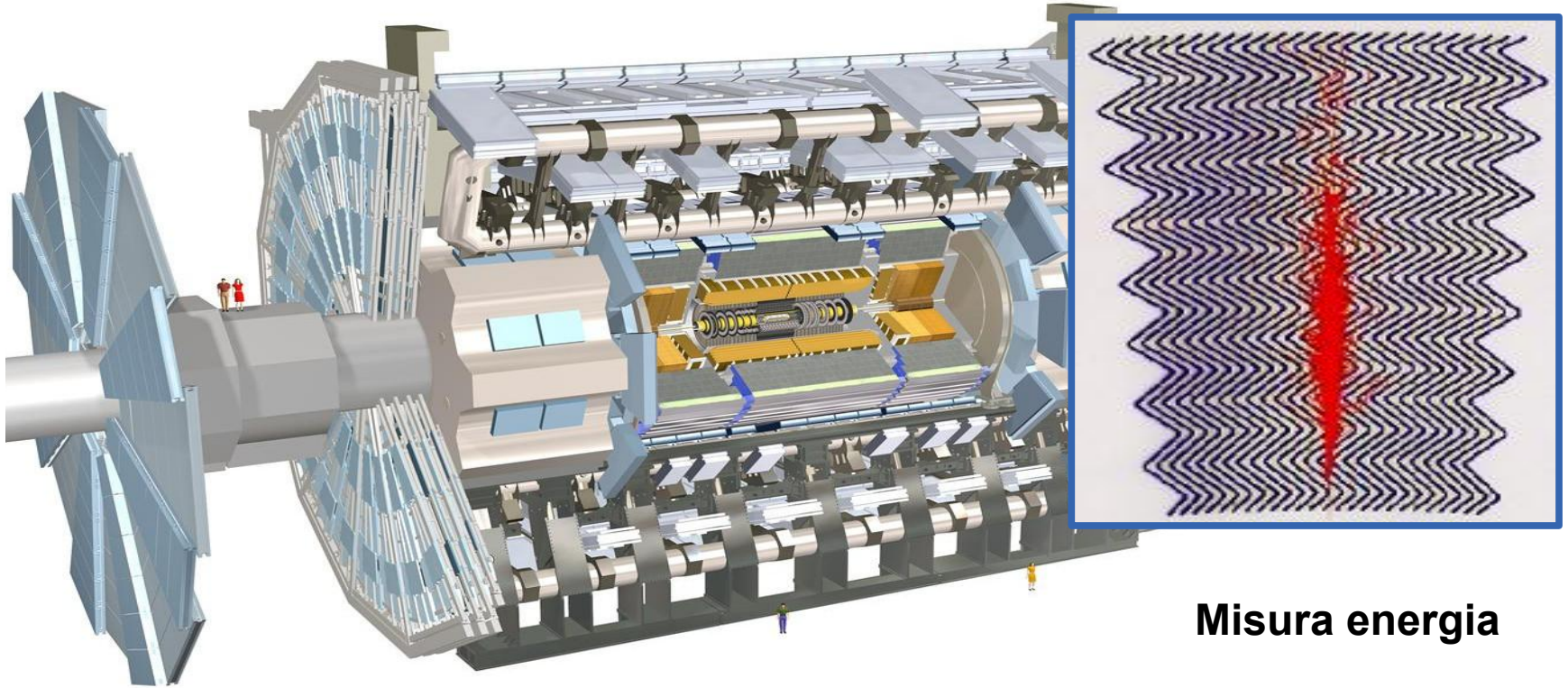
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$



Hendrik Lorentz



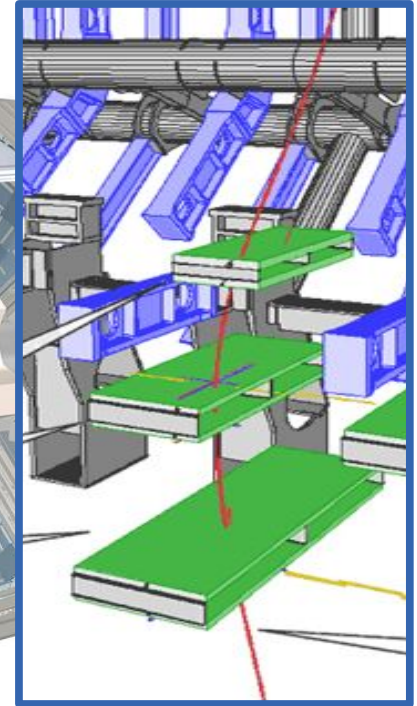
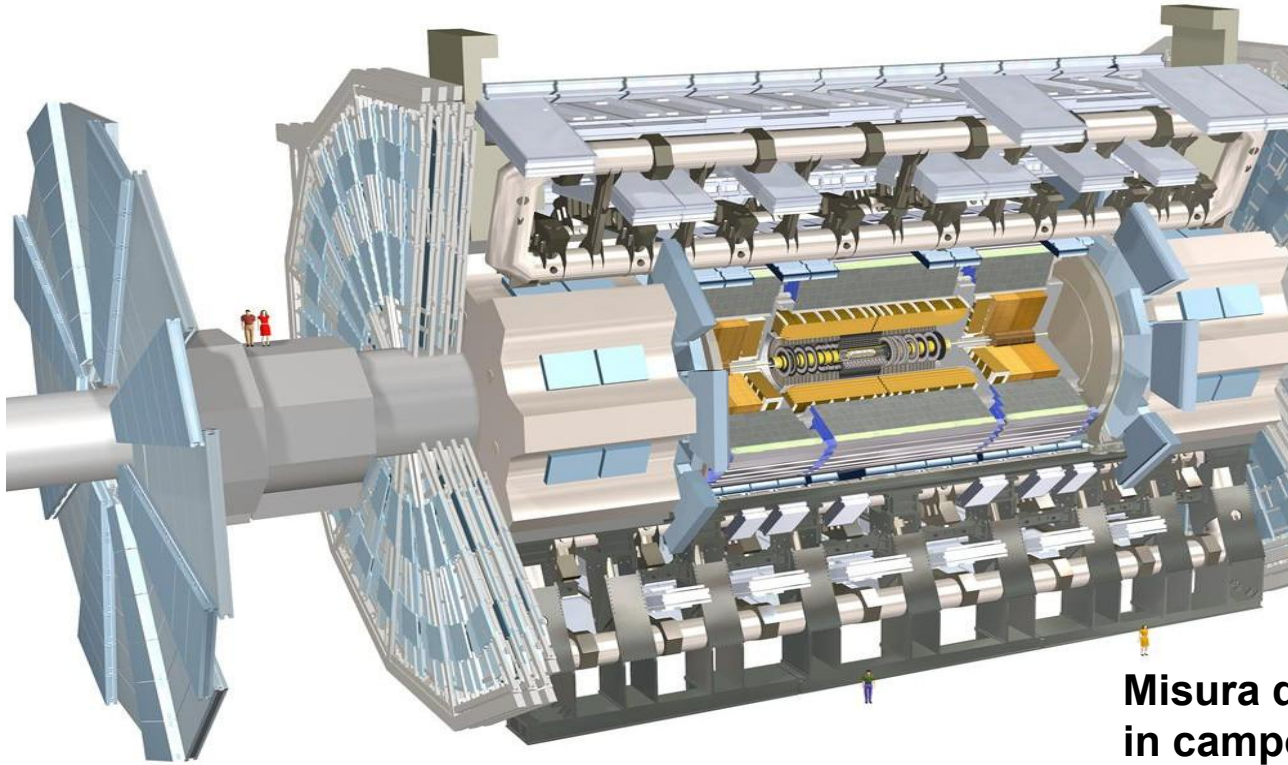
# Sistema di calorimetria



Misura energia

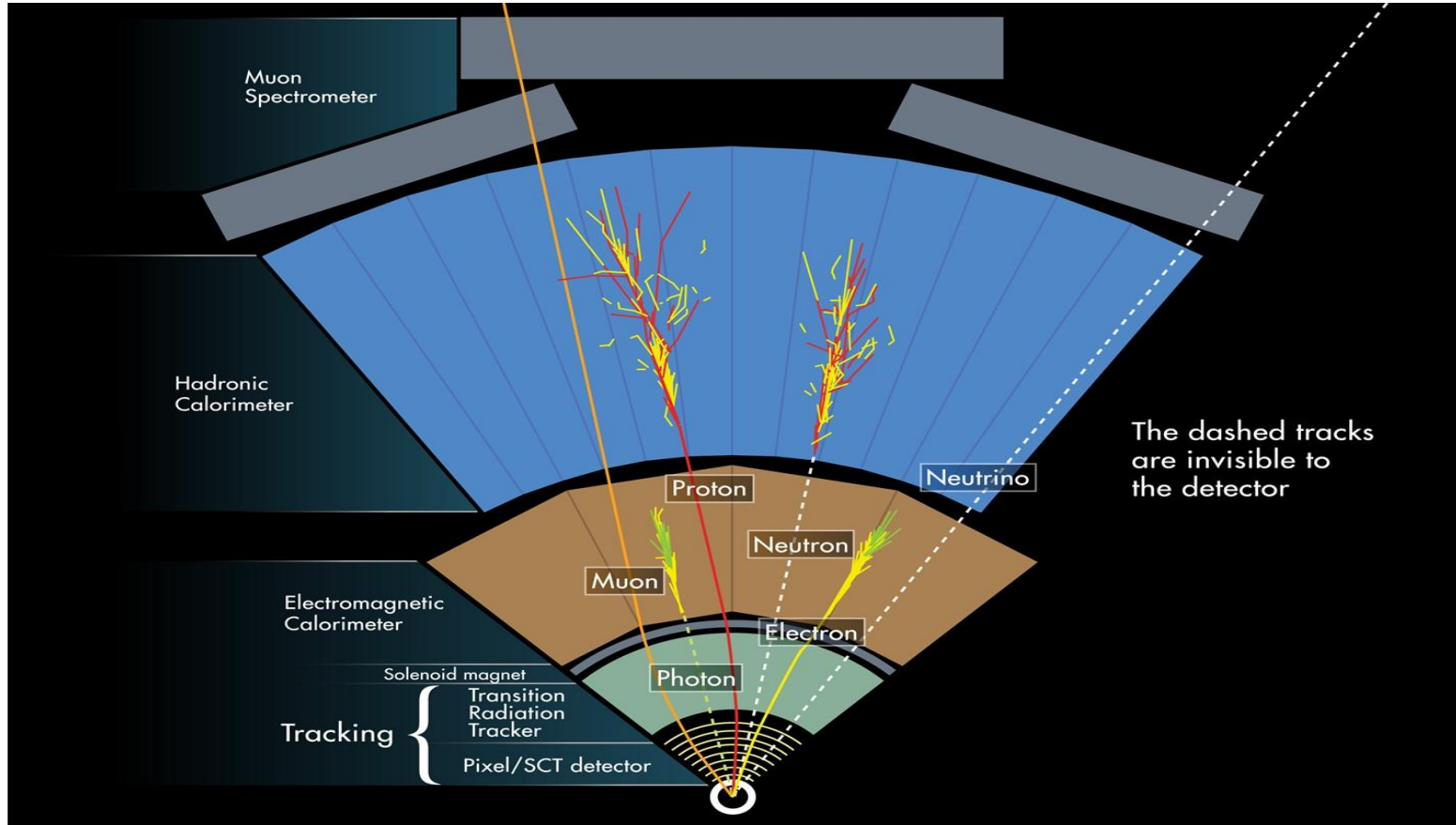


# Spettrometro muonico



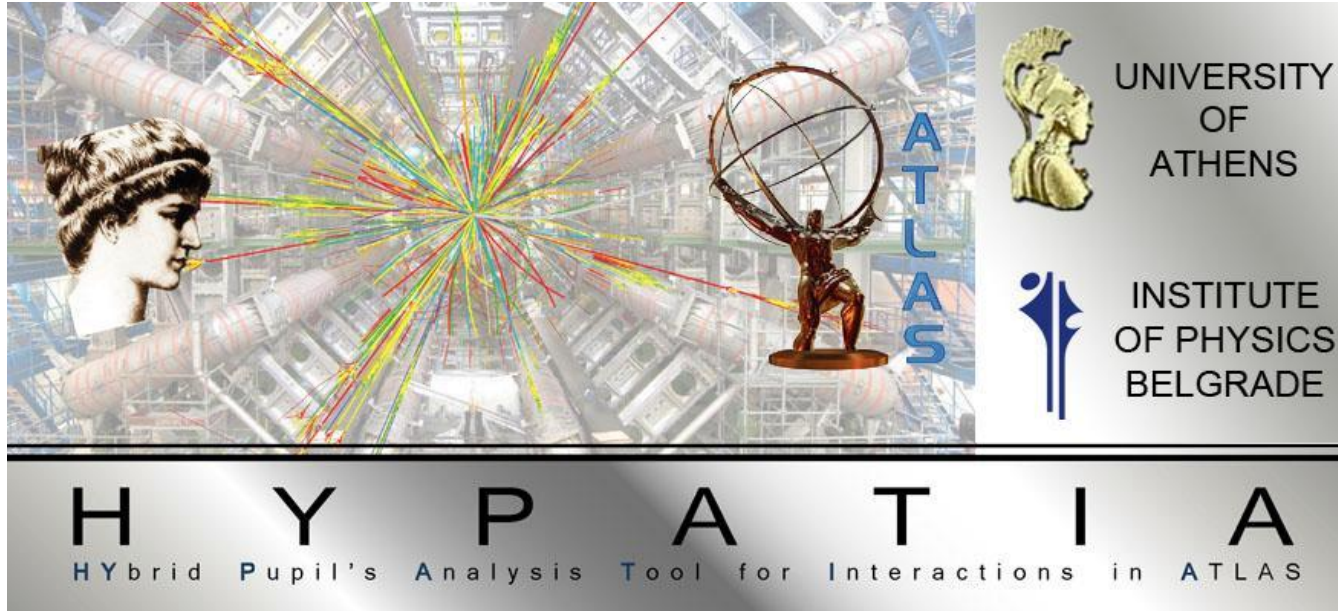
**Misura di posizione  
in campo magnetico  
(→momento)**

# Identificazione delle particelle



- ❖ Muoni, antimuoni
    - Tracce sia nel rivelatore interno che nello spettrometro
  - ❖ Elettroni, positroni
    - Tracce nel rivelatore interno che puntano a depositi di energia nel calorimetro elettromagnetico
  - ❖ Fotoni
    - Depositi di energia nel calorimetro senza tracce associate
  - ❖ Jet (decadimenti di quark e gluoni)
    - “Fascio” di tracce che puntano a depositi di energia in entrambi i tipi di calorimetri
  - ❖ Neutrini
    - Energia mancante nel piano trasverso rispetto al fascio
-

# Hypatia Event Viewer



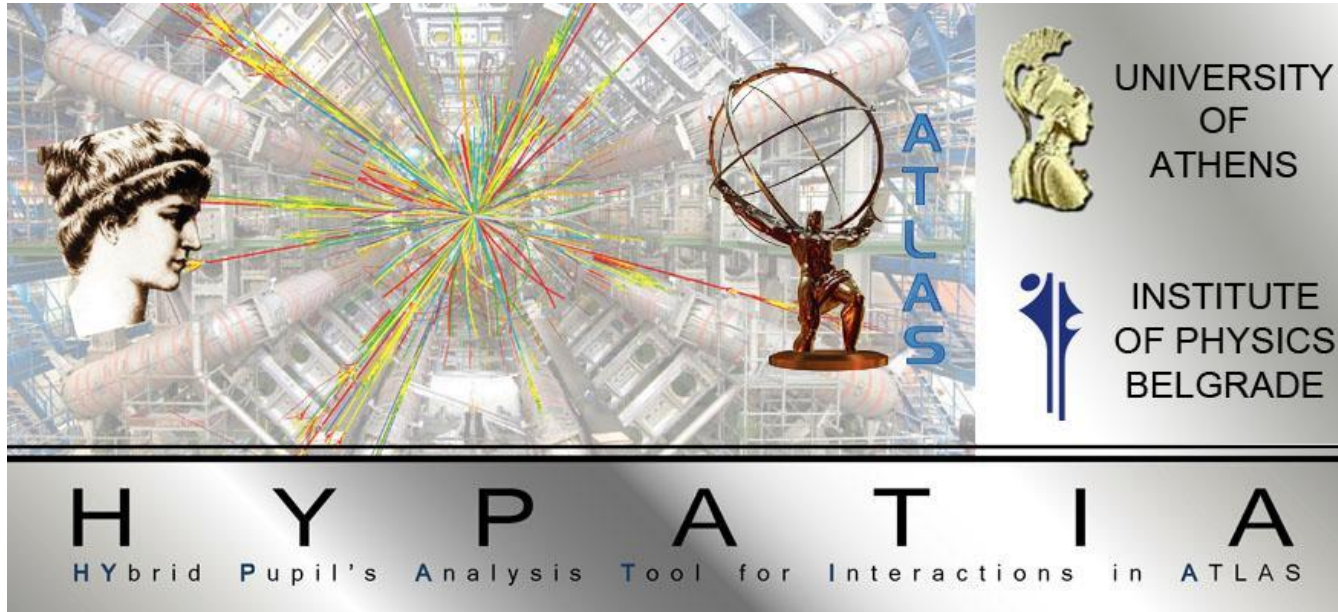
The banner features a central image of a particle detector with a complex network of colorful tracks (red, yellow, green, blue) radiating from a central point. On the left, a classical bust of Hypatia is shown in profile, with a red track extending from her eye towards the detector. On the right, a bronze statue of Atlas holding a globe is positioned next to the vertical text "ATLAS".

UNIVERSITY OF ATHENS

INSTITUTE OF PHYSICS BELGRADE

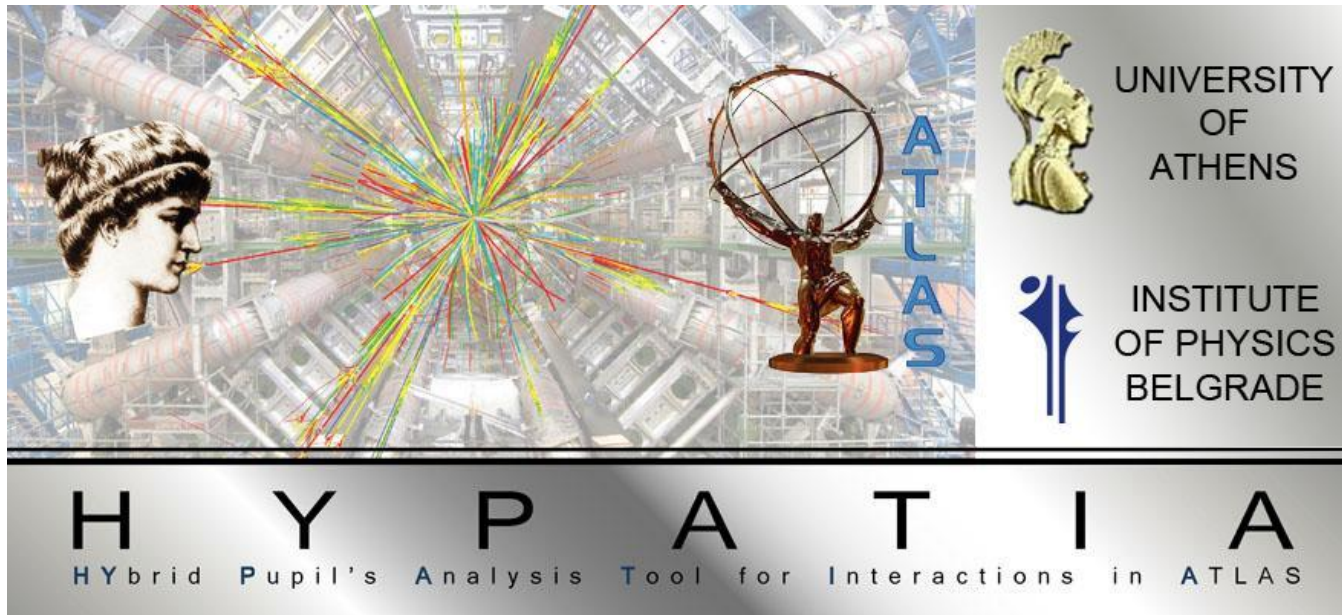
**H Y P A T I A**  
HYbrid Pupil's Analysis Tool for Interactions in ATLAS

# Hypatia Event Viewer



Doppio click sull'icona "MC.desktop" che trovate sullo schermo del laptop

# Hypatia Event Viewer

The banner features a central image of a particle detector with a complex network of colorful tracks (red, yellow, green, blue) radiating from a central point. On the left, a classical bust of Hypatia is shown in profile. On the right, a bronze statue of Atlas holding a globe is positioned. The word "ATLAS" is written vertically in blue capital letters next to the statue. To the right of the central image, the logos and names of the University of Athens and the Institute of Physics Belgrade are displayed. Below the main image, the word "HYPATIA" is written in large, black, spaced-out capital letters. Underneath "HYPATIA", the full name of the tool is written in a smaller, blue, spaced-out font: "HYbrid Pupil's Analysis Tool for Interactions in ATLAS".

UNIVERSITY OF ATHENS

INSTITUTE OF PHYSICS BELGRADE

**H Y P A T I A**  
HYbrid Pupil's Analysis Tool for Interactions in ATLAS

```
java -jar Hypatia_7.4_Masterclass.jar
```

# Hypatia Event Viewer



HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\varphi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event002.xml	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
		Tracks 76	93.3	+	42.9	-1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.764					e

Canvas Window - File: event003.xml Run: 110158020 Event: 3101

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV  $\varphi$ : -1.466 rad Collection: MET\_RefFinal

/home/negri/MasterClasses/groupA.zip/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\varphi$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.71	423.28	-1.090	1.915
Tracks 218	-	28.13	5.75	2.487	2.936
Tracks 247	-	567.48	434.30	2.080	0.872

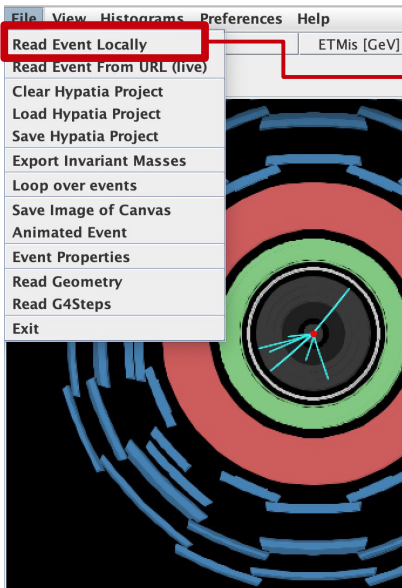
HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

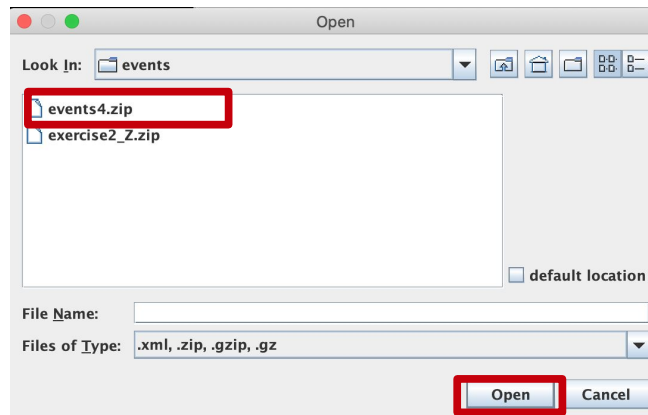
Projection Data Cuts InDet Calo MuonDet Objects Geometry

InDet	Calo	MuonDet	Objects	ATLAS	Name	Value
					<input checked="" type="checkbox"/>  Pt	> 5.0 GeV
					<input checked="" type="checkbox"/>  Pt2	< 700.0 MeV
					<input checked="" type="checkbox"/>  d0	< 2.5 mm
					<input checked="" type="checkbox"/>  z0	< 20.0 cm
					<input type="checkbox"/>  d0 Loose	< 2.0 cm
					<input type="checkbox"/>  z0-zVtx	< 2.5 mm
					<input type="checkbox"/> Layer	> 0
					<input type="checkbox"/> Number Pixel Hits	>= 2

# Data Files



Per selezionare il file di dati scaricato



[groupA.zip](#)  
[groupB.zip](#)  
[groupC.zip](#)  
[groupD.zip](#)  
[groupE.zip](#)  
[groupF.zip](#)  
[groupG.zip](#)  
[groupH.zip](#)  
[groupI.zip](#)  
[groupJ.zip](#)  
[groupK.zip](#)  
[groupL.zip](#)  
[groupM.zip](#)  
[groupN.zip](#)  
[groupO.zip](#)  
[groupP.zip](#)  
[groupQ.zip](#)  
[groupR.zip](#)  
[groupS.zip](#)  
[groupT.zip](#)



# Hypatia Event Viewer



Hybrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\varphi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event002.xml	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
		Tracks 76	93.2	+	42.9	1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.764					e

Canvas Window - File: event003.xml Run: 110158020 Event: 3101

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV  $\varphi$ : -1.466 rad Collection: MET\_RefFinal

/home/negri/MasterClasses/groupA.zip/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\varphi$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
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Tracks 247	-	567.48	434.30	2.080	0.872

HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

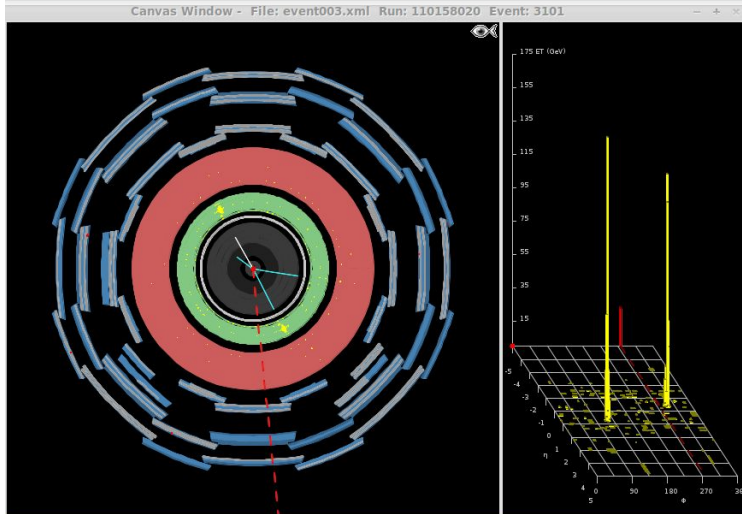
InDet	Name	Value
Calo		
MuonDet	<input checked="" type="checkbox"/>  Pt	> 5.0 GeV
Objects	<input type="checkbox"/>  Pt2	< 700.0 MeV
ATLAS	<input checked="" type="checkbox"/>  d0	< 2.5 mm
	<input checked="" type="checkbox"/>  z0	< 20.0 cm
	<input type="checkbox"/>  d0 Loose	< 2.0 cm
	<input type="checkbox"/>  z0-zVtx	< 2.5 mm
	<input type="checkbox"/> Layer	> 0
	<input type="checkbox"/> Number Pixel Hits	>= 2

# Finestra grafica

Hybrid Pupils: Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

	+/-	Pt [GeV]	$\eta$	$\phi$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	emug
-		42.6	1.479	2.310	94.165				e
+		42.9	1.779	1.413					e
+		423.3	-1.090	-0.952	994.430				e
-		434.3	2.080	0.764					e

## Vista trasversale



HYPATIA - Track Momenta Window

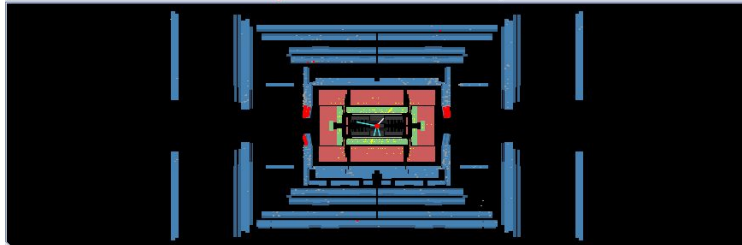
Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETRis: 22.805 GeV  $\phi$ : -1.466 rad Collection: MET\_Refinal

/home/megri/MasterClasses/groupA.op/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\eta$	$\phi$	B
Tracks 4	-	9.77	9.42	-0.195	1.302	
Tracks 184	+	449.71	423.28	-1.090	1.915	
Tracks 218	-	28.13	5.75	2.487	2.936	
Tracks 247	-	567.48	434.30	2.080	0.872	

## Sviluppo sul piano del sistema di calorimetria



HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

InDet	Name	Value
Calo		
MuonDet	<input checked="" type="checkbox"/>  PT	> 5.0 GeV
O		

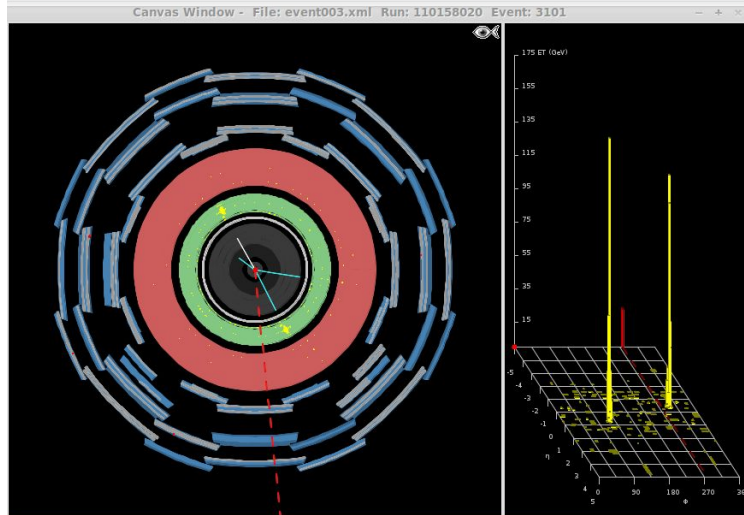
## Vista longitudinale

<input type="checkbox"/>  d0 Loose	< 2.0 cm
<input type="checkbox"/>  z0-zVtx	< 2.5 mm
<input type="checkbox"/> Layer	> 0
<input type="checkbox"/> Number Pixel Hits	>= 2

# Finestra grafica

HYBRID Pupile Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\eta$	$\phi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	emug
event002.xml	23.199	Tracks 0	217.0	-	42.6	1.479	2.310	94.165					e
		Tracks 76	93.3	+	42.9	1.779	1.413						e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.952	994.430					e
		Tracks 247	567.5	-	434.3	2.080	0.764						e



HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

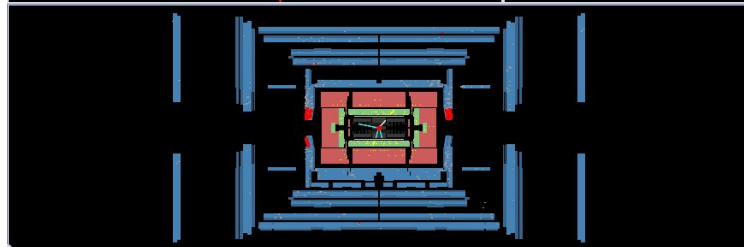
ETMis: 22.805 GeV  $\phi$ : -1.466 rad Collection: MET\_Refinal

/home/megrin/MasterClasses/groupA.zp/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\eta$	$\phi$	B
Tracks 4	-	9.77	9.42	-0.195	1.302	
Tracks 184	+	449.71	423.28	-1.090	1.915	
Tracks 218	-	28.13	5.75	2.487	2.936	
Tracks 247	-	567.48	434.30	2.080	0.872	

**Col mouse è possibile**

- selezionare una traccia
- fare lo zoom



HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

InDet	Name	Value
Calo	<input checked="" type="checkbox"/>  PT	> 5.0 GeV
MuonDet	<input type="checkbox"/>  PT2	> 700.0 MeV
Objects	<input type="checkbox"/>  d0	> 2.5 mm
ATLAS	<input checked="" type="checkbox"/>  z0	> 20.0 cm
	<input type="checkbox"/>  d0 Loose	> 2.0 cm
	<input type="checkbox"/>  z0-zVtx	> 2.5 mm
	<input type="checkbox"/> Layer	> 2.5 mm
	<input type="checkbox"/> Number Pixel Hits	> 2

← **Tasto per modalità zoom**

← **Tasto per modalità selezione**

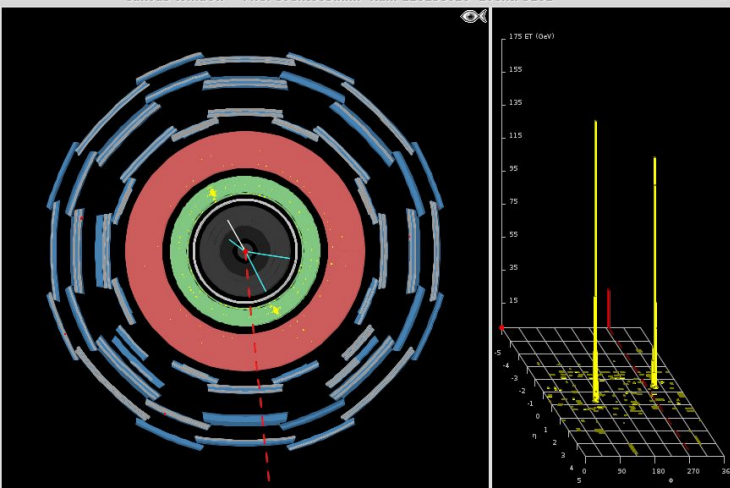
# Hypatia Event Viewer

Hybrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\varphi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
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		Tracks 76	93.2	+	42.9	1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.764					e

Canvas Window - File: event003.xml Run: 110158020 Event: 3101



HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV  $\varphi$ : -1.466 rad Collection: MET\_RefFinal

/home/negri/MasterClasses/groupA.zip/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\varphi$	$\theta$
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HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

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	<input checked="" type="checkbox"/>  z0	< 20.0 cm
	<input type="checkbox"/>  d0 Loose	< 2.0 cm
	<input type="checkbox"/>  z0-zVtx	< 2.5 mm
	<input type="checkbox"/> Layer	> 0
	<input type="checkbox"/> Number Pixel Hits	>= 2

# Finestra di controllo

HYBATIA - Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]
event002.xml	23.199	Tracks 0	217.0	-	1.478
		Tracks 76	93.3	+	42.9
event003.xml	22.805	Tracks 184	449.7	+	423.3
		Tracks 247	567.5	-	434.3

## Avanzamento eventi

Canvas Window - File: event003.xml Run: 110158020 Event: 3101

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV  $\phi$ : -1.466 rad Collection: MET\_RefFinal

/home/megri/MasterClasses/group/zip/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\phi$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.71	423.28	-1.090	1.915
Tracks 218	-	28.13	5.75	2.487	2.936
Tracks 247	-	567.48	434.30	2.080	0.872

**Analisi tracce:**  
selezionando una riga la corrispondente traccia nella finestra grafica viene colorata di bianco

HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

InDet	Name	Value
Calo	<input checked="" type="checkbox"/>  PT	> 5.0 GeV
MuonDet	<input type="checkbox"/>  PT2	> 700.0 MeV
Objects	<input type="checkbox"/>  d0	> 2.5 mm
ATLAS	<input checked="" type="checkbox"/>  z0	> 20.0 cm
	<input type="checkbox"/>  d0 Loose	> 2.0 cm
	<input type="checkbox"/>  z0-zVtx	> 2.5 mm
	Layer	> 0
	Number Pixel HITS	> 2

numero evento

# Finestra massa invariante

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\phi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event002.xml	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
		Tracks 76	93.3	+	42.9	1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.724					e

Canvas Window - File: event003.xml Run: 110158020 Event: 3101

## massa invariante

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV  $\phi$ : -1.466 rad Collection: MET\_RefFinal

/home/negri/MasterClasses/groupA.zip/event003.xml

Track	+/-	P [GeV]	Pt [GeV]	$\phi$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.71	423.28	-1.090	1.915
Tracks 218	-	28.13	5.75	2.487	2.936
Tracks 247	-	567.48	434.30	2.080	0.872

Parameter Con  
Projection D

- InDet
- Calo
- MuonDet
- Objects
- ATLAS

**Inserimento tracce**  
selezionare riga della traccia  
premere tasto opportuno

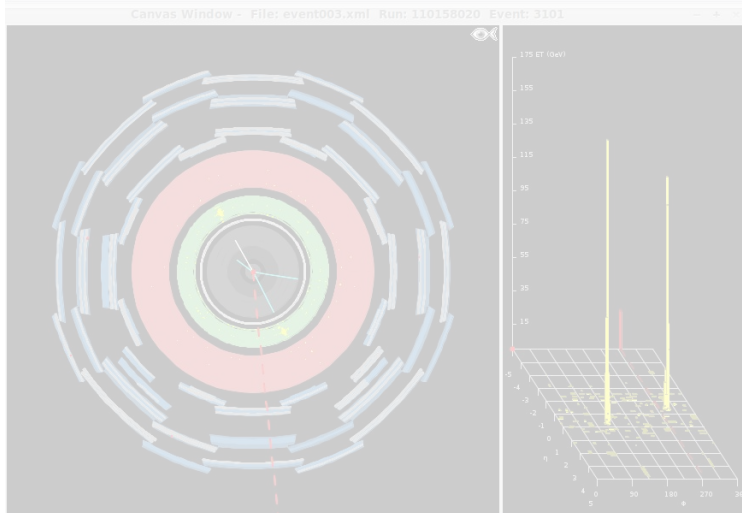
**Rimozione tracce**  
selezionare traccia  
premere "delete track"

**Calcola massa invariante**  
di ogni coppia di fotoni o  
di leptoni di carica opposta

# Finestra strumenti

HYbrid Pupile: Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	g	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	emvg
event002.xml	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
		Tracks 76	93.3	+	42.9	-1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.764					e



## Taglio sulle tracce

Visualizzazione delle sole tracce con momento superiore ad una certa soglia

Partire sempre da 5 GeV

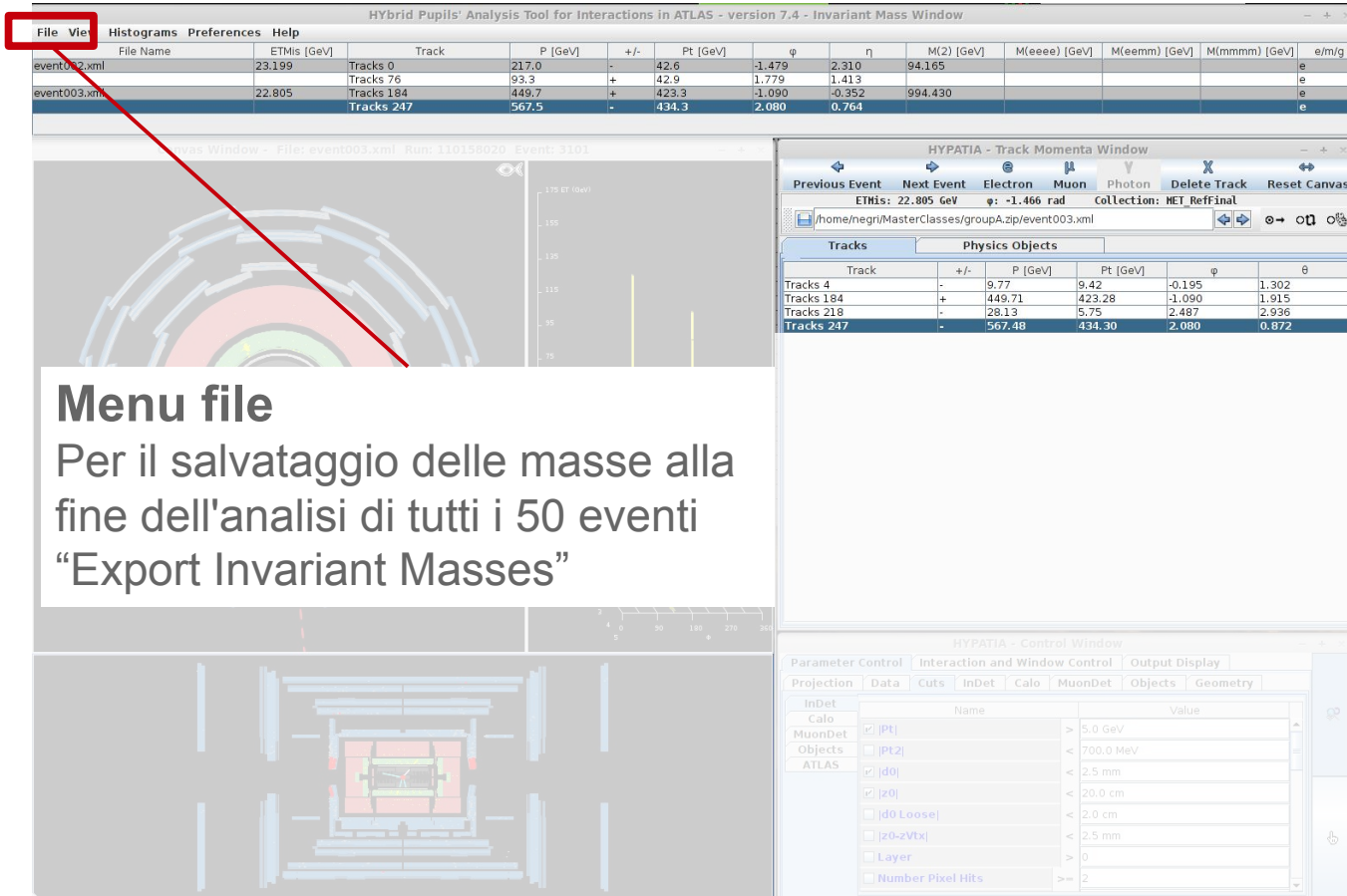
PATIA - Control Window

Parameter Control | Interaction and Window Control | Output Display

Projection | Data | **Cuts** | InDet | Calo | MuonDet | Objects | Geometry

InDet	Name	Value
<input checked="" type="checkbox"/>	PT	> 5.0 GeV
<input type="checkbox"/>	PT2	^ 700.0 MeV
<input checked="" type="checkbox"/>	d0	^ 2.5 mm
<input checked="" type="checkbox"/>	z0	^ 20.0 cm
<input type="checkbox"/>	d0 Loose	^ 2.0 cm
<input type="checkbox"/>	z0-zVtx	^ 2.5 mm
<input type="checkbox"/>	Layer	v 0
<input type="checkbox"/>	Number Pixel Hits	y 2

# Finestra massa invariante



The screenshot displays the HYPATIA software interface for ATLAS invariant mass analysis. The main window shows event data for two files: event002.xml and event003.xml. A red box highlights the 'File' menu in the top-left corner. Below the event data, a track momenta window shows detailed parameters for selected tracks. The control window at the bottom right allows for parameter adjustments.

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\phi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event002.xml	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
		Tracks 76	93.3	+	42.9	1.779	1.413					e
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
		Tracks 247	567.5	-	434.3	2.080	0.764					e

Track	+/-	P [GeV]	Pt [GeV]	$\phi$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.71	423.28	-1.090	1.915
Tracks 218	-	28.13	5.75	2.487	2.936
Tracks 247	-	567.48	434.30	2.080	0.872

Parameter	Name	Value
Calo	<input checked="" type="checkbox"/>  PT	5.0 GeV
MuonDet	<input type="checkbox"/>  PT2	700.0 MeV
Objects	<input type="checkbox"/>  d0	2.5 mm
ATLAS	<input checked="" type="checkbox"/>  z0	20.0 cm
	<input type="checkbox"/>  d0 Loose	2.0 cm
	<input type="checkbox"/>  z0-zVtx	2.5 mm
	Layer	0
	Number Pixel Hits	2

**Menu file**  
Per il salvataggio delle masse alla fine dell'analisi di tutti i 50 eventi  
“Export Invariant Masses”



# Hypatia Event Viewer



**Masse invarianti**

File Name	Tracks	Pt [GeV]	$\eta$	$M(2)$ [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event002.xml	Tracks 0	42.6	-1.479	2.310	94.165			e
event003.xml	Tracks 76	93.3	42.9	1.779	1.413			e
		423.3	-1.090	-0.352	994.430			e
		434.3	2.080	0.764				e

**Avanzamento eventi**

**Vista trasversale (dalla linea del fascio)**

**Sviluppo piano celle calorimetro**

**Vista longitudinale**

**Electron Muon Photon**

**Physics Objects**

Tracks	+/-	$\eta$ [GeV]	Pt [GeV]	$\eta$	$\theta$
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.1	423.28	-1.090	1.915
Tracks 218	-	28.1	5.75	2.487	2.936
Tracks 247	-	567.18	434.30	2.080	0.872

**Scheda oggetti: fotoni**

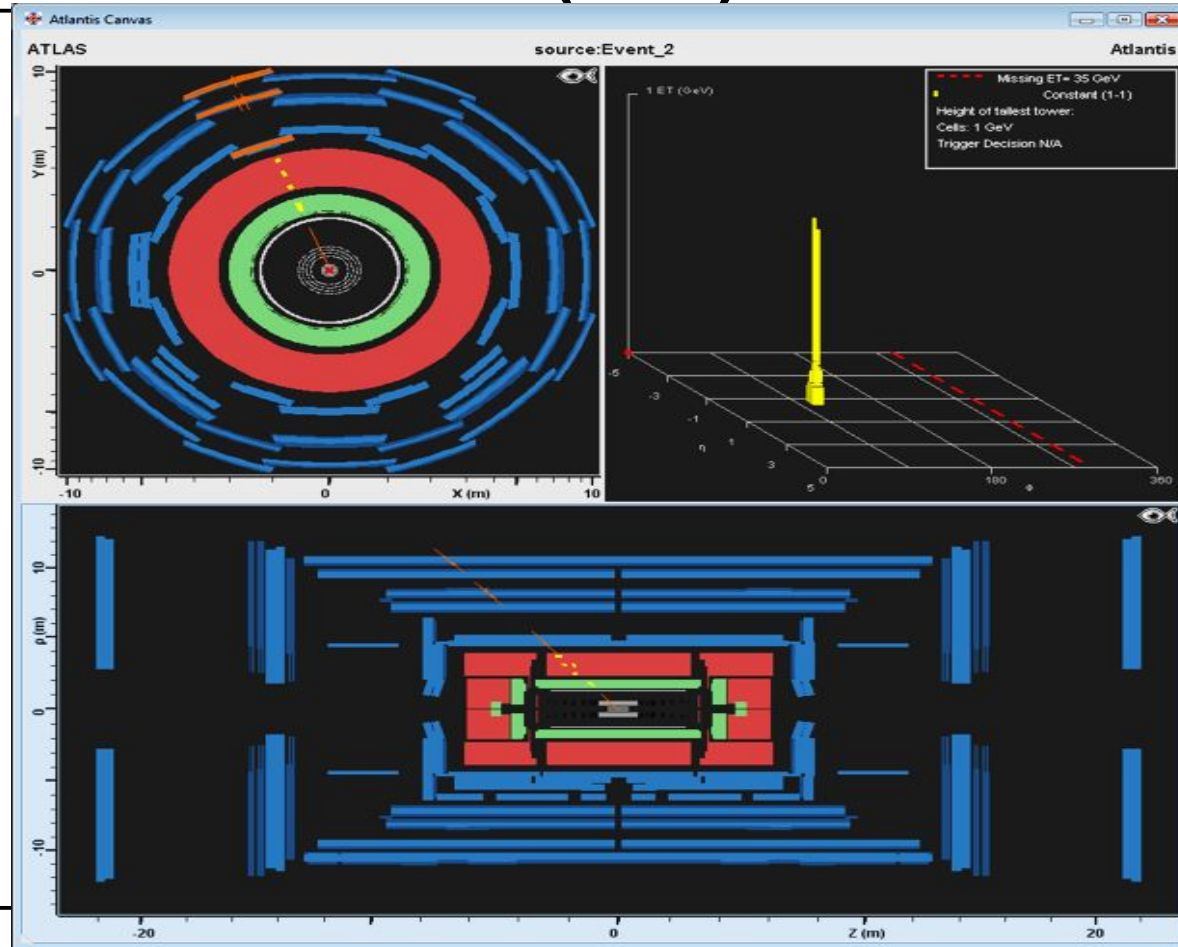
**Scheda tracce: elettroni e muoni**

**Taglio momento tracce**

Object	Name	Value
Calo	<input checked="" type="checkbox"/>  PT	> 5.0 GeV
	<input type="checkbox"/>  PT2	700.0 MeV
Objects	<input type="checkbox"/>  d0	2.5 mm
	<input checked="" type="checkbox"/>  z0	20.0 cm
ATLAS	<input type="checkbox"/>  d0 Loose	< 2.0 cm

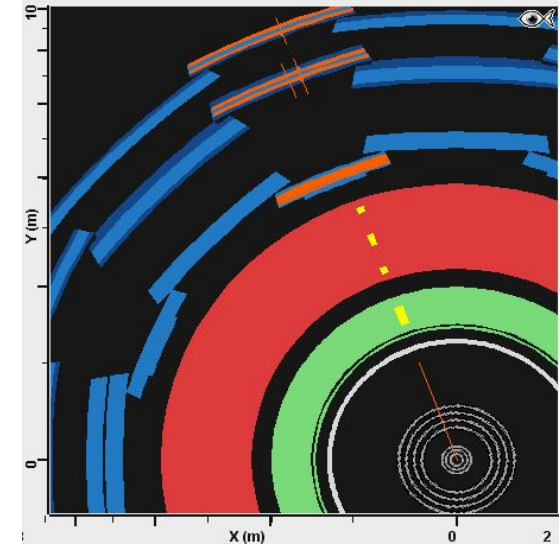
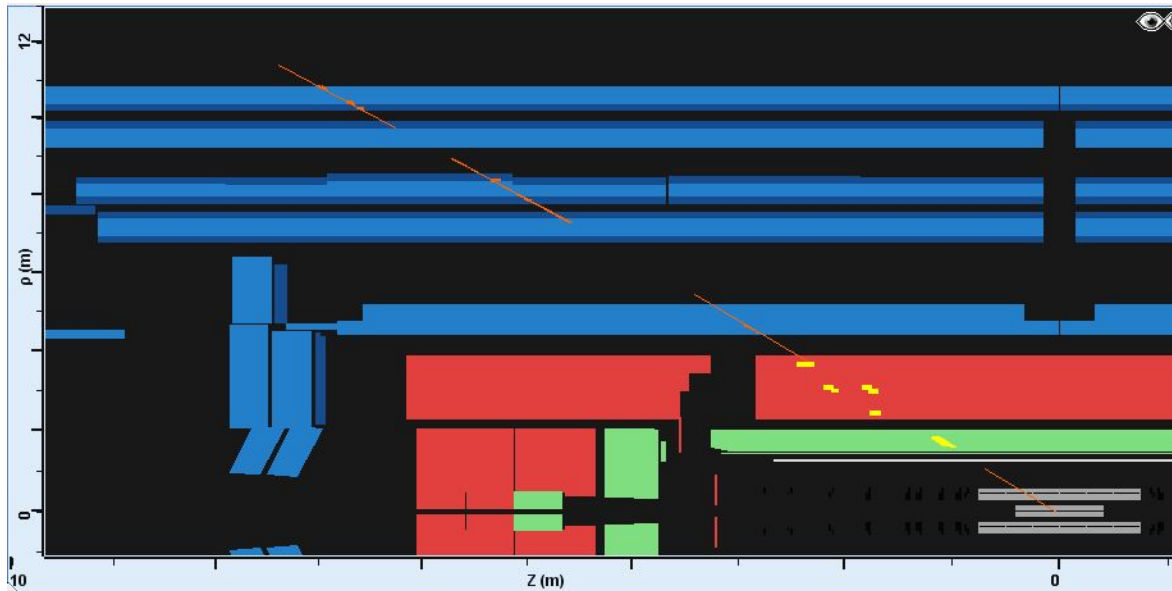
**Tasti cambio modalità: zoom / selezione**

# Identikit: (anti)muoni

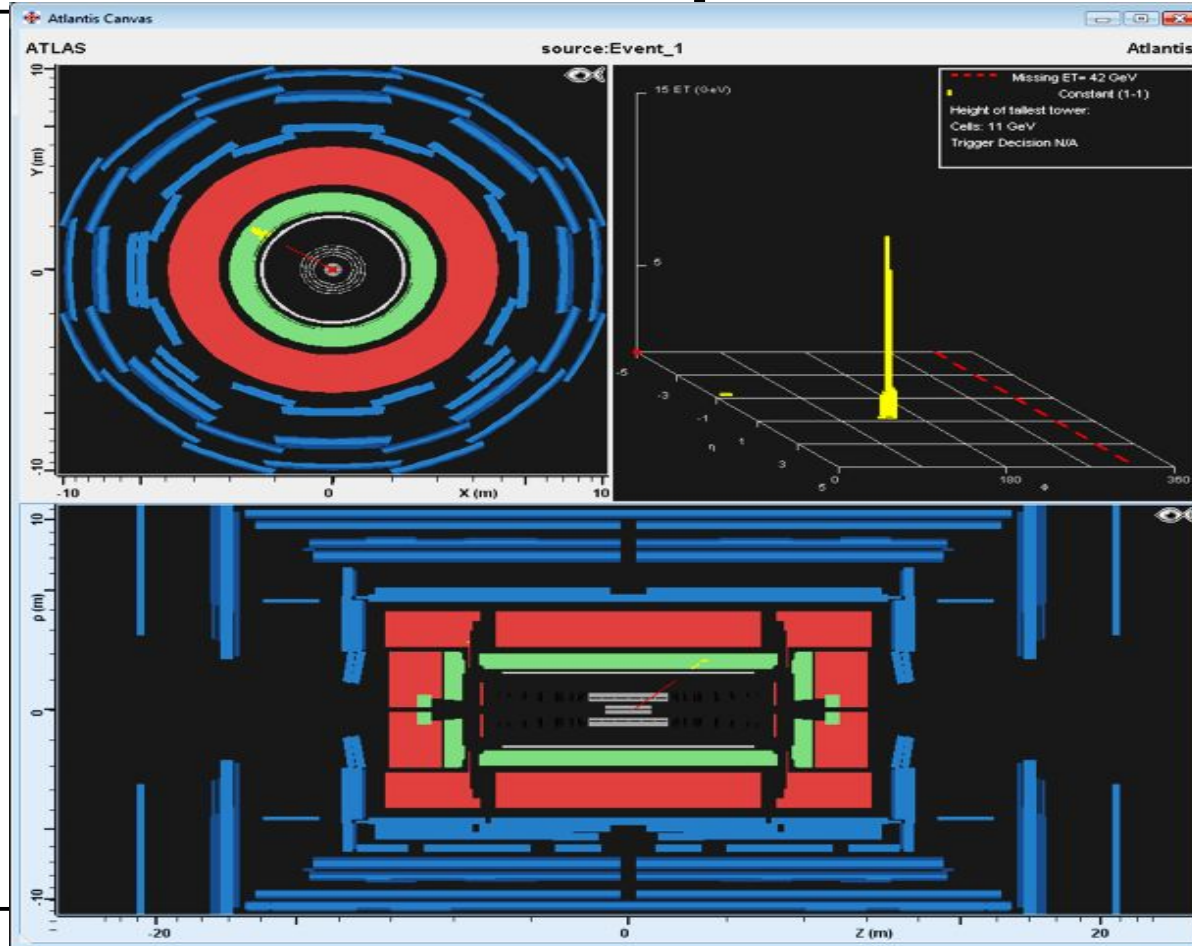


# Identikit: (anti)muoni

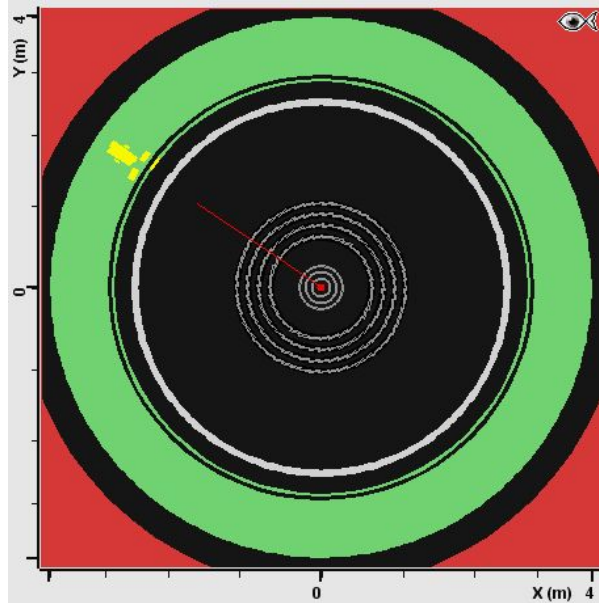
Traccia nel rivelatore interno e nello spettrometro senza significativi depositi di energia nei calorimetri



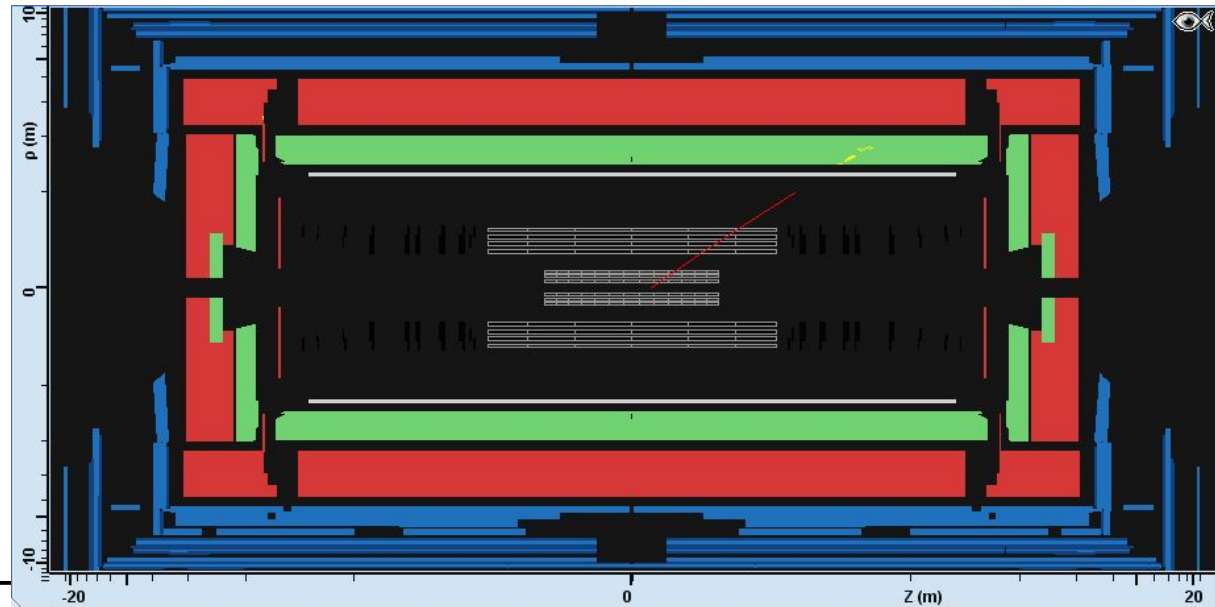
# Identikit: elettroni/positroni



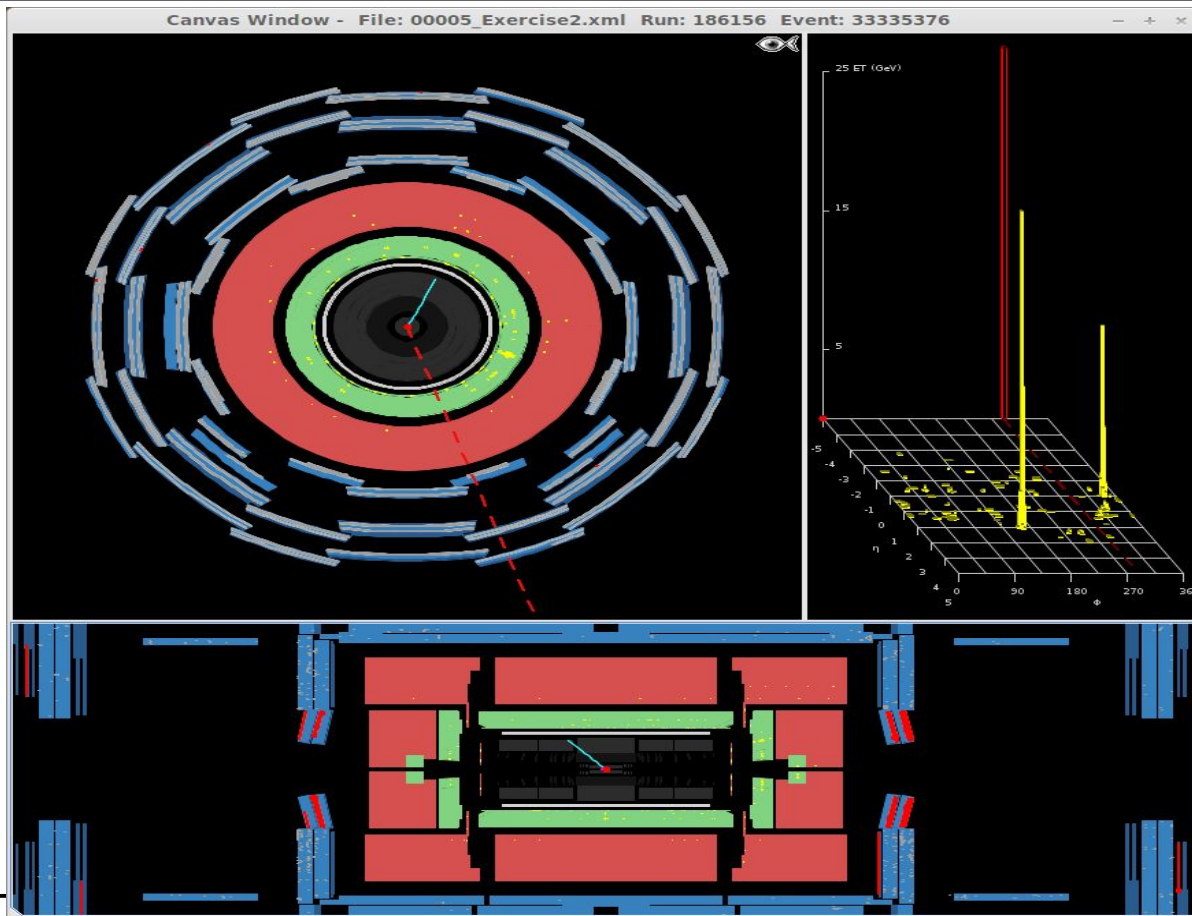
# Identikit: elettroni/positroni



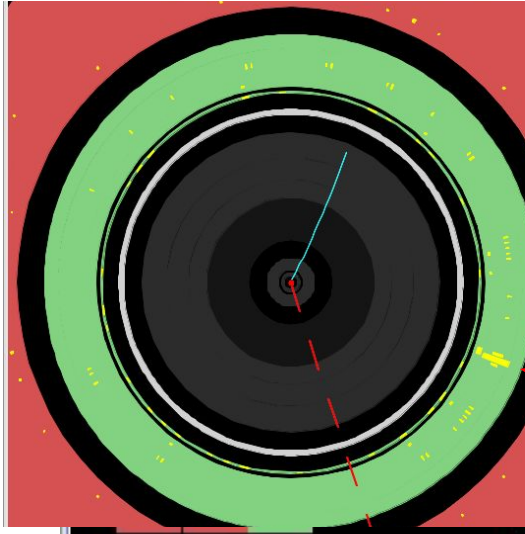
Tracce nel rivelatore interno che puntano a depositi di energia nel calorimetro elettromagnetico



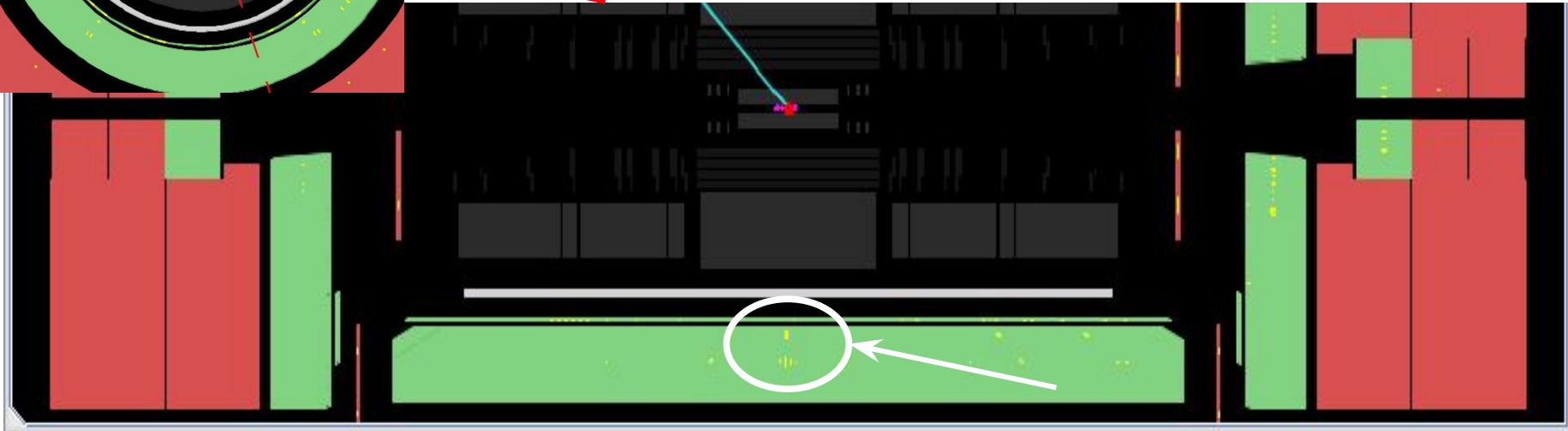
# Identikit: ftoni



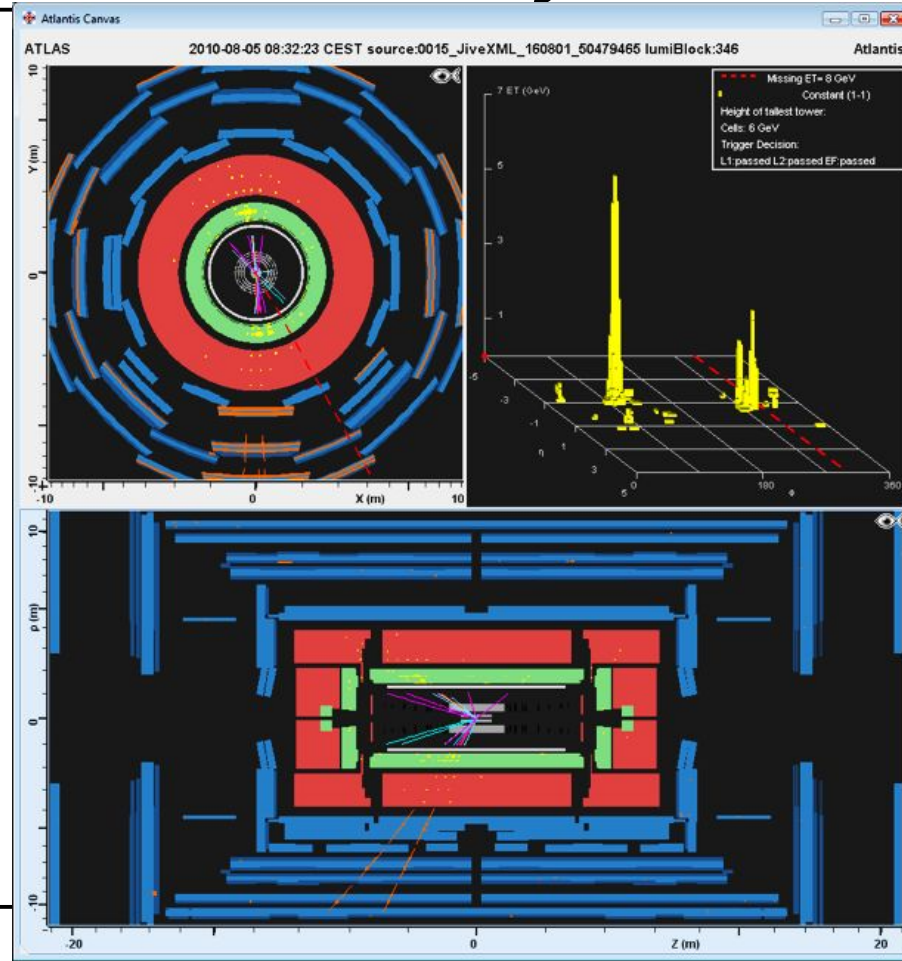
# Identikit: fotoni



Depositi di energia nel calorimetro  
elettromagnetico senza tracce associate

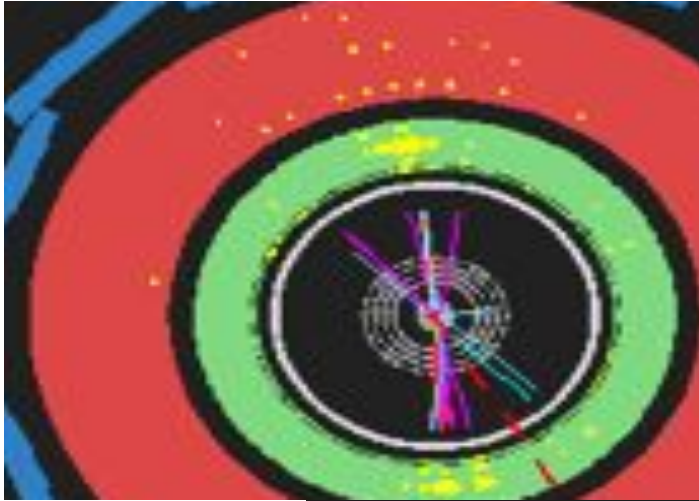


# Identikit: jets

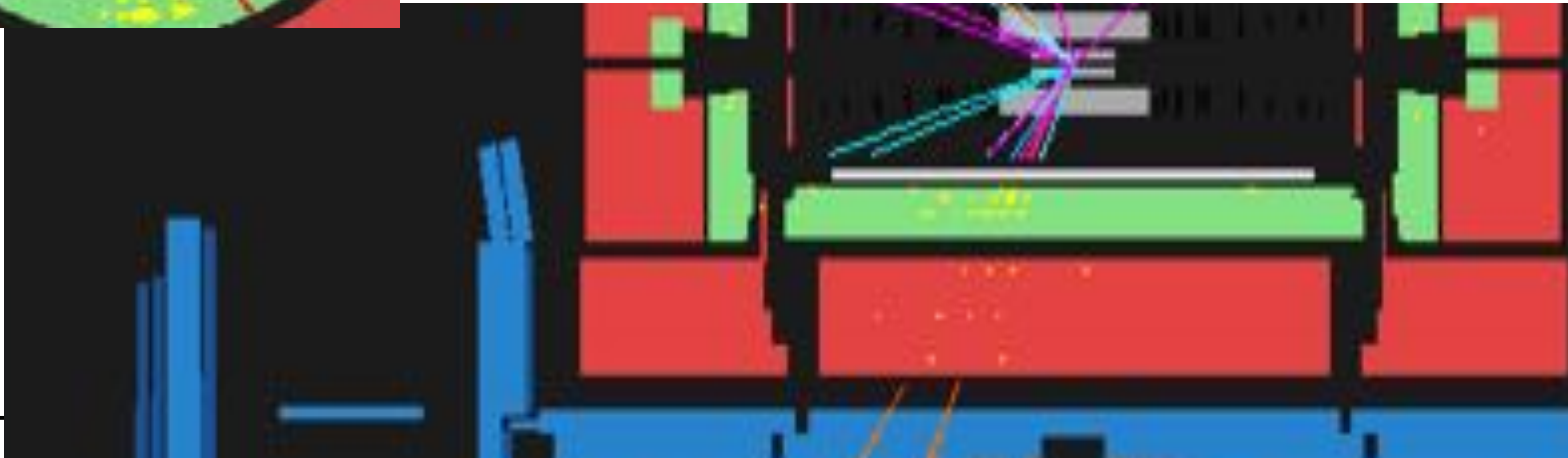




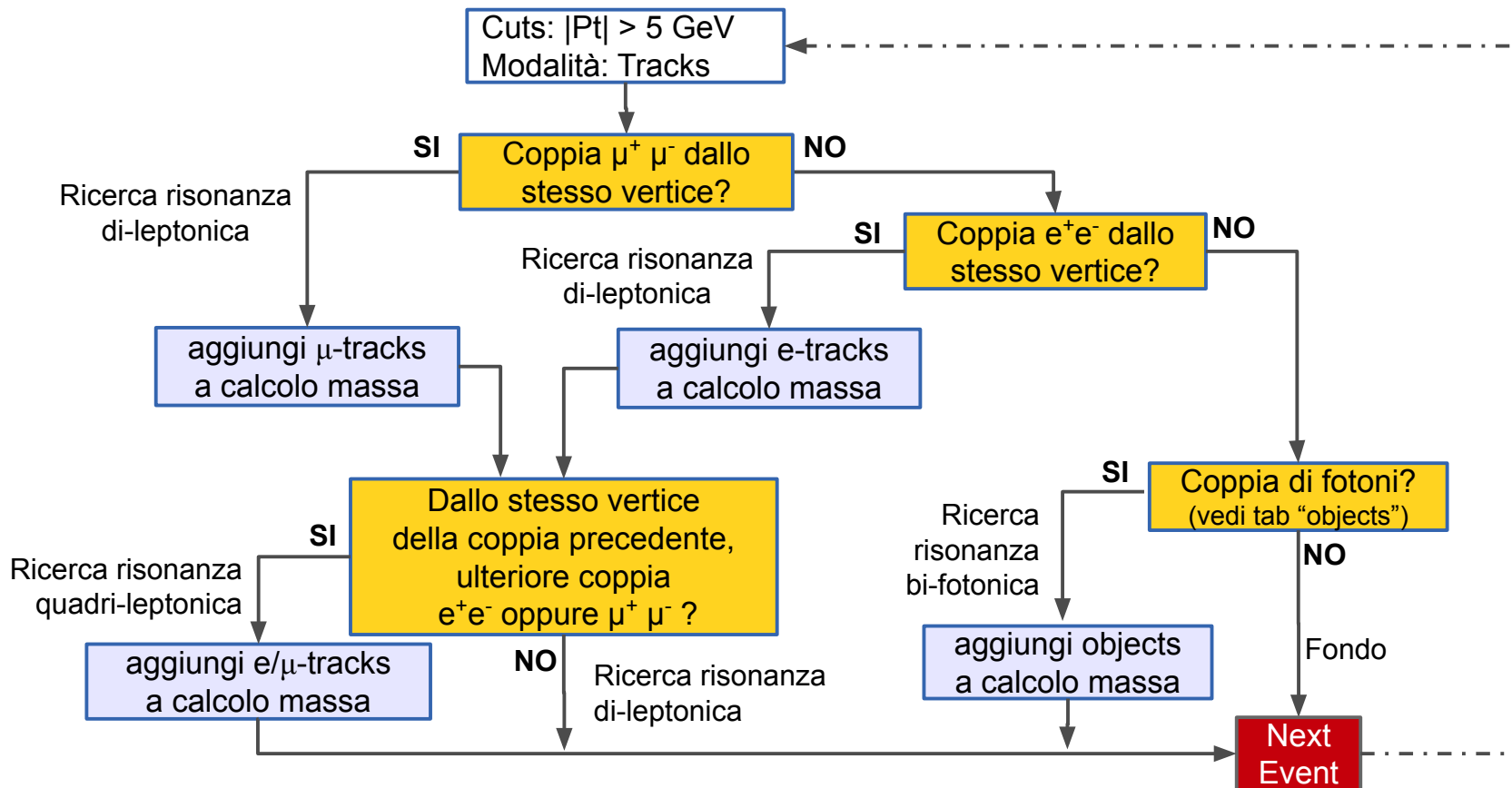
# Identikit: jets



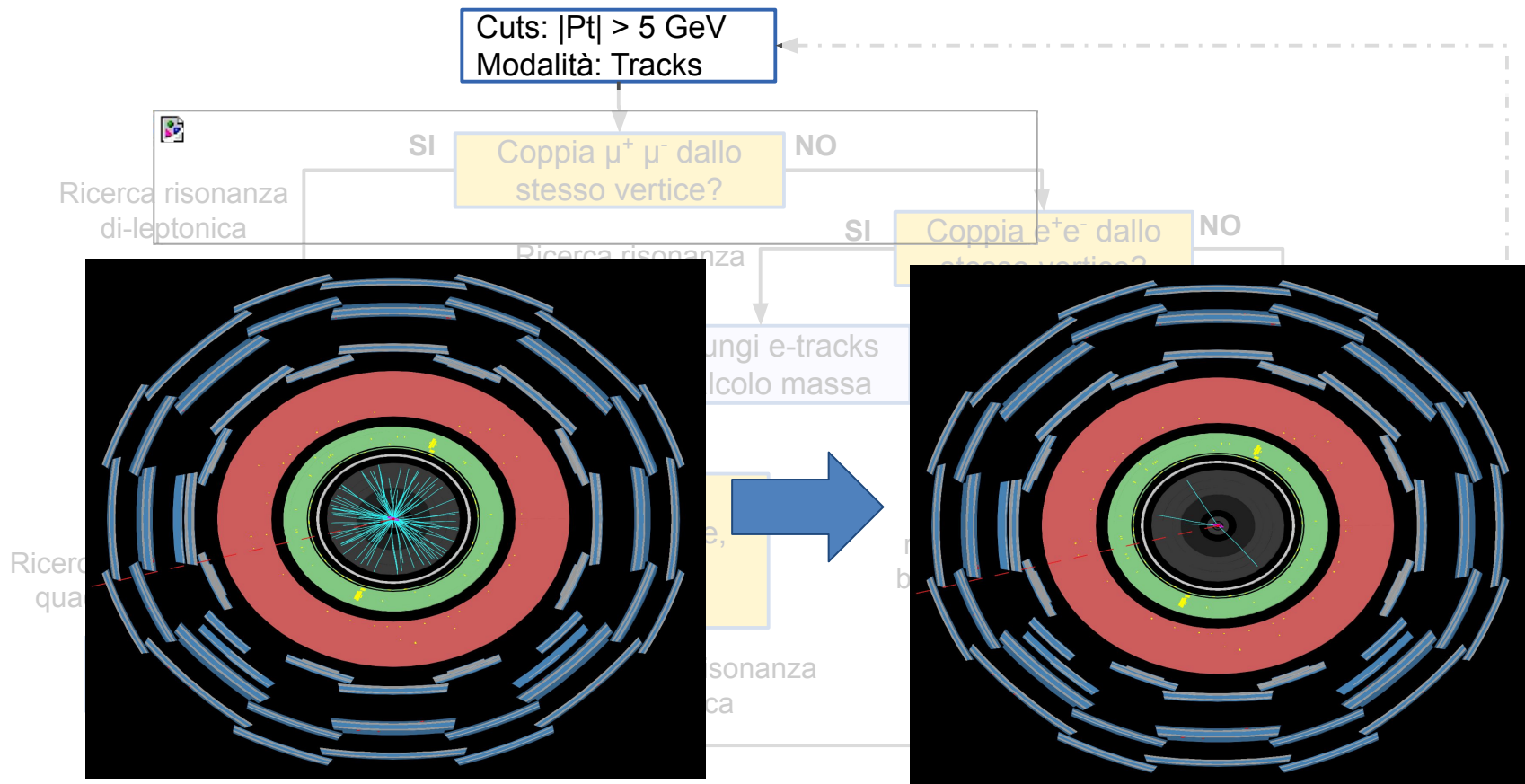
“Fascio” di tracce che puntano a depositi di energia in entrambi i tipi di calorimetri



# Piano di lavoro: flow chart



# Piano di lavoro: flow chart



# Piano di lavoro: flow chart

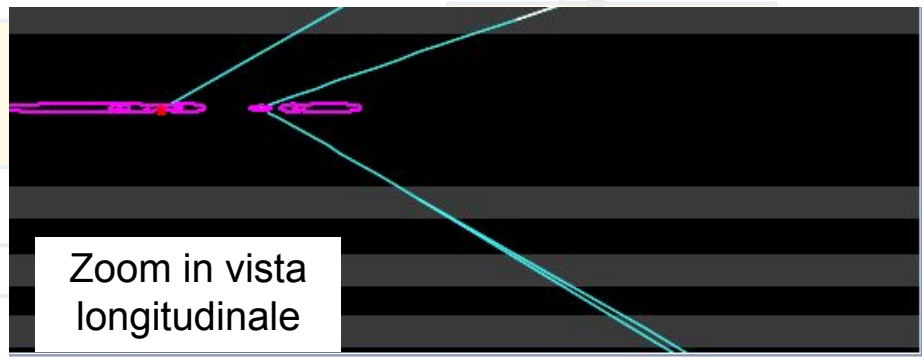
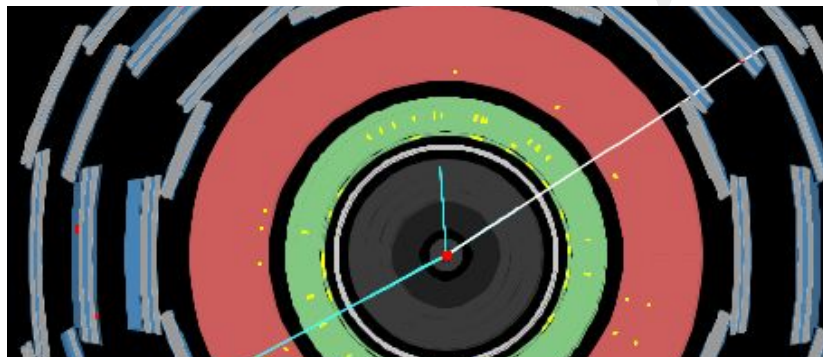
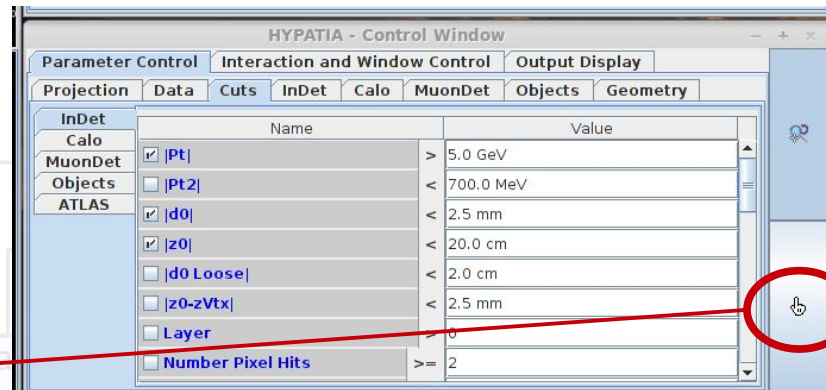
Cuts:  $|Pt| > 5$  GeV  
Modalità: Tracks

Coppia  $\mu^+ \mu^-$  dallo  
stesso vertice?

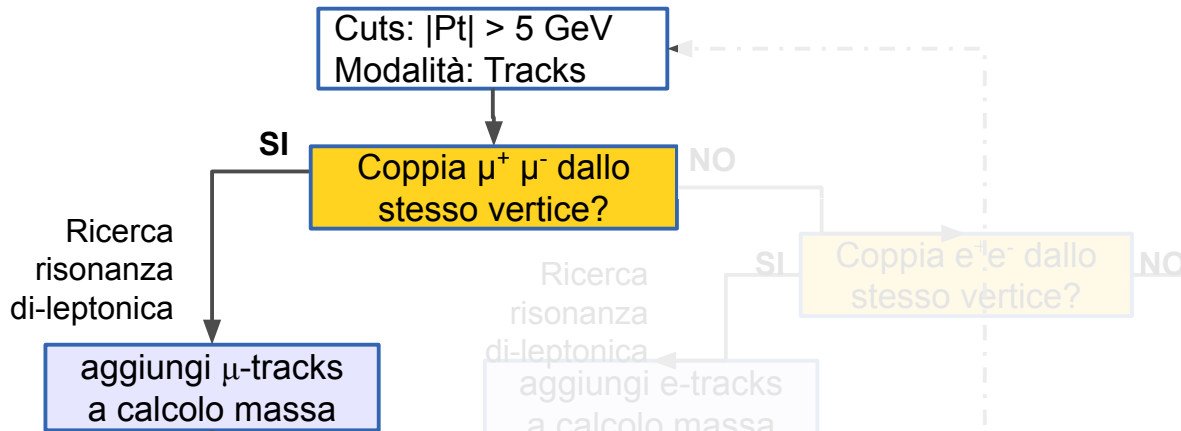
Ricerca  
risonanza  
di-leptonica

Ricerca  
risonanza

Utilizzare il mouse in modalità selezione  
per identificare le tracce nelle due viste:  
la traccia selezionata viene colorata di bianco



# Piano di lavoro: flow chart



HYBRID Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Win

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\varphi$	$\eta$	M[GeV]
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.43
		Tracks 247	567.5	-	434.3	2.080	0.764	
00007_Exercise2.xml	7.369	Tracks 22	139.5	-	47.7	0.576	1.736	86.854
		Tracks 139	73.7	+	37.7	-2.627	1.201	

Navigation: Previous Event, Next Event, Electron, **Muon**, Photon, Delete Track, Reset Canvas

ETMis: 7.369 GeV  $\varphi$ : 2.796 rad Collection: MET\_Reffinal

/home/negri/MasterClasses/exercise2\_Z.zip/00007\_Exercise2.xml

Tracks | Physics Objects

Track	+/-	P [GeV]	Pt [GeV]	$\varphi$	$\theta$
-------	-----	---------	----------	-----------	----------

# Piano di lavoro: flow chart

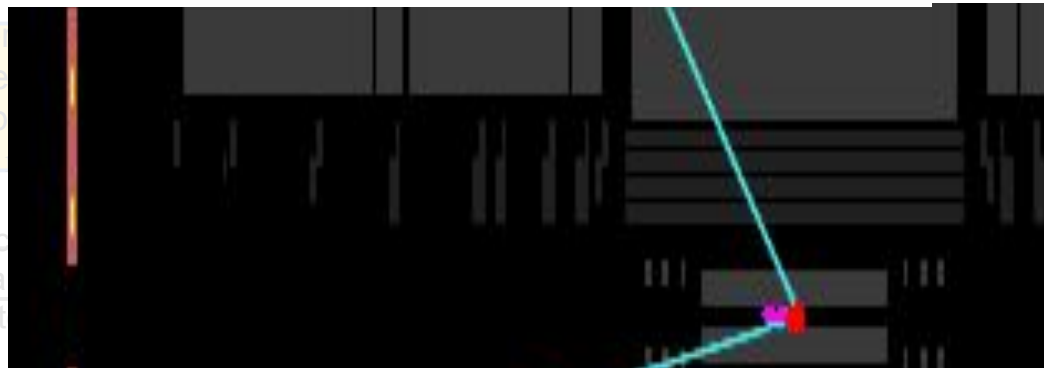
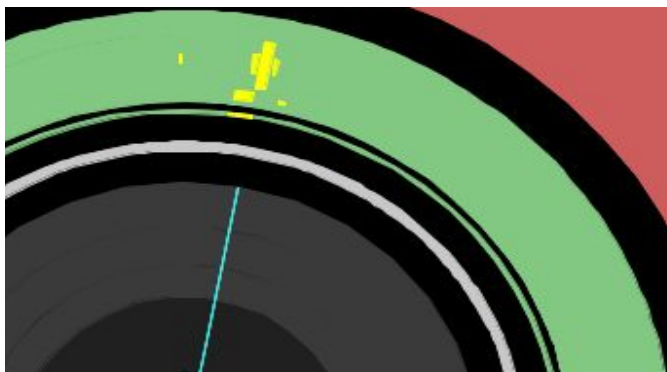
Cuts:  $|Pt| > 5$  GeV  
Modalità: Tracks

Coppia  $\mu^+ \mu^-$  dallo  
stesso vertice?

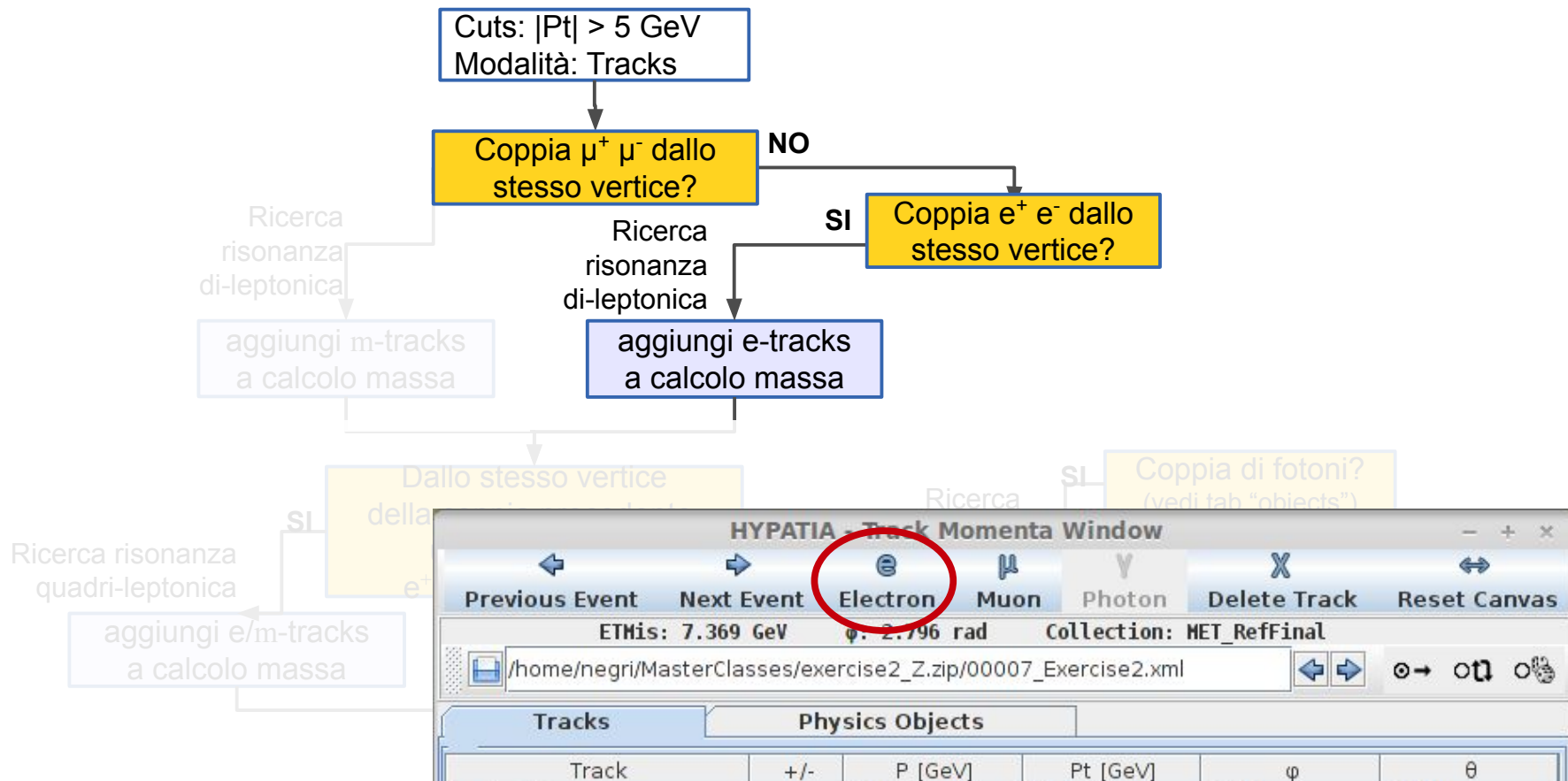
NO

Coppia  $e^+e^-$  dallo  
stesso vertice?

- Cercare depositi di energia nel calorimetro
- Verificare la presenza di tracce che puntano ai depositi
- Verificare che puntino allo stesso vertice primario



# Piano di lavoro: flow chart



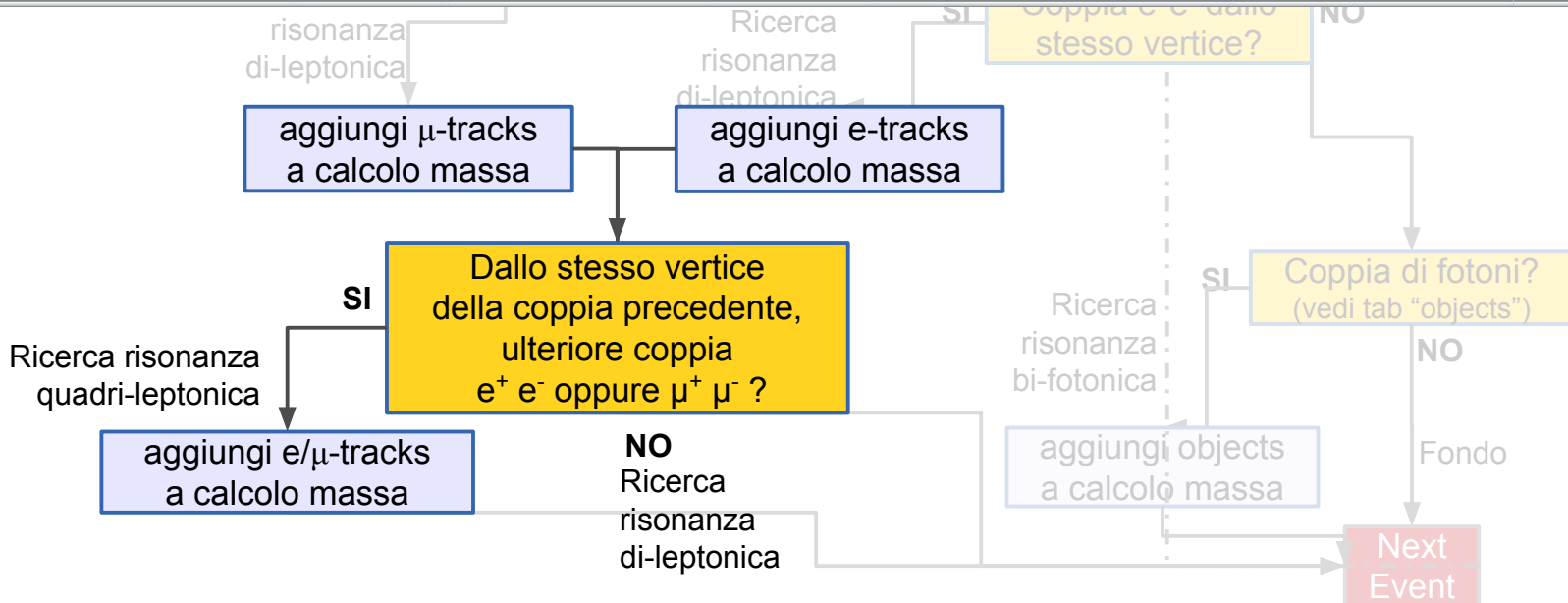
# Piano di lavoro: flow chart

Cuts:  $|Pt| > 5$  GeV  
Modalità: Tracks

HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

Hybrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\phi$	$\eta$	M(2) [GeV]	Index	CPG	Id	PS	+	PS	+	NCSD	Ident	Ident	Ident
event046.xml	37.975	Tracks 2	108.7	-	58.0	1.525	1.242	90.333											
		Tracks 21	43.4	+	41.7	2.277	-0.289												
		Tracks 4	98.8	+	61.2	-2.171	-1.058	91.492											
		Tracks 10	136.9	-	39.2	-0.248	-1.922												





# Piano di lavoro: flow chart

Cuts:  $|Pt| > 5$  GeV  
Modalità: Tracks

SI  
Coppia  $m^+ m^-$  dallo stesso vertice?

Ricerca risonanza

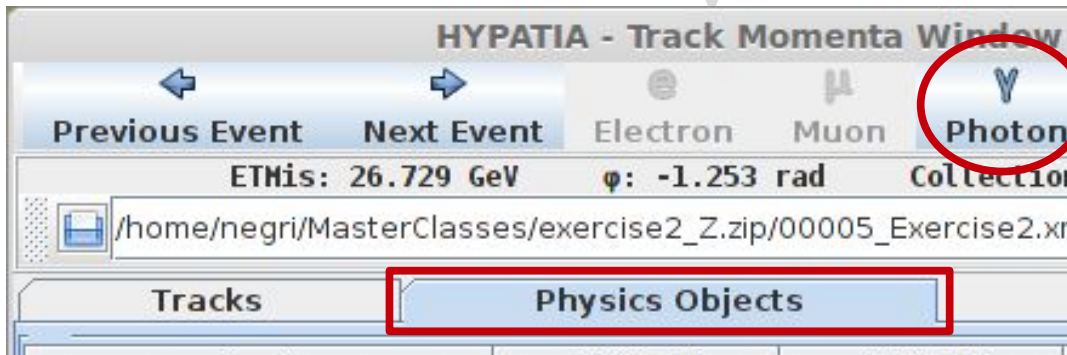
Ricerca risonanza

SI  
Coppia  $e^+e^-$  dallo stesso vertice?

NO

- Se esistono due depositi di energia senza tracce associate:

- evento per ricerca di risonanze in 2 fotoni



SI  
Coppia di fotoni?  
(vedi tab "objects")

Ricerca risonanza bi-fotonica

NO

Fondo

aggiungi objects a calcolo massa

Next Event

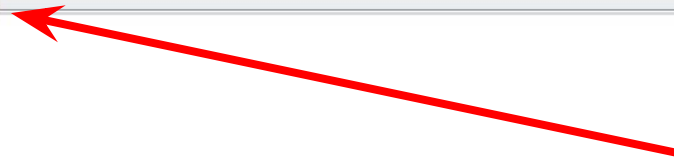
# Alla fine dei 50 eventi

Salvare sul desktop il file delle masse  
“Invariant\_masses.txt”

HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window

File View Histograms Preferences Help

	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	$\phi$	$\eta$	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
Read Event Locally	23.199	Tracks 0	217.0	-	42.6	-1.479	2.310	94.165				e
Read Event From URL (live)		Tracks 76	93.3	+	42.9	1.779	1.413					e
Clear Hypatia Project	22.805	Tracks 184	449.7	+	423.3	-1.090	-0.352	994.430				e
Load Hypatia Project		Tracks 247	567.5	-	434.3	2.080	0.764					e
Save Hypatia Project												
Export Invariant Masses												
Loop over events												
Save Image of Canvas												
Animated Event												
Event Properties												
Read Geometry												
Read G4Steps												
Exit												



# Alla fine dei 50 eventi



Aprire il link: <https://cernmasterclass.uio.no/OPIoT/index.php>  
Selezionare “Student” (Username/Password: ippog/imc)

## OPIoT – MasterClass with CERN – Student page

[Start](#) [Student](#) [Moderator](#) [Tutor](#) [Administrator](#)

### Student Tasks

Please select items from the drop-down boxes to submit your results!

2024 ▾ February ▾ 29 ▾ Pavia ▾ 3 ▾ H ▾

3 o 4

A-T

# Alla fine dei 50 eventi



Caricare il file “Invariant\_masses.txt”  
Choose file → Submit

[OPlot – MasterClass with CERN – Plot for Pavia Group 3E on 2024-02-29](#)

[Start](#) [Student](#) [Moderator](#) [Tutor](#) [Administrator](#)

Tuesday, February 27th 2024 - 21:15:20 UTC

Change date

Change institute

Change group

Upload your file:

Choose File No file chosen

Submit

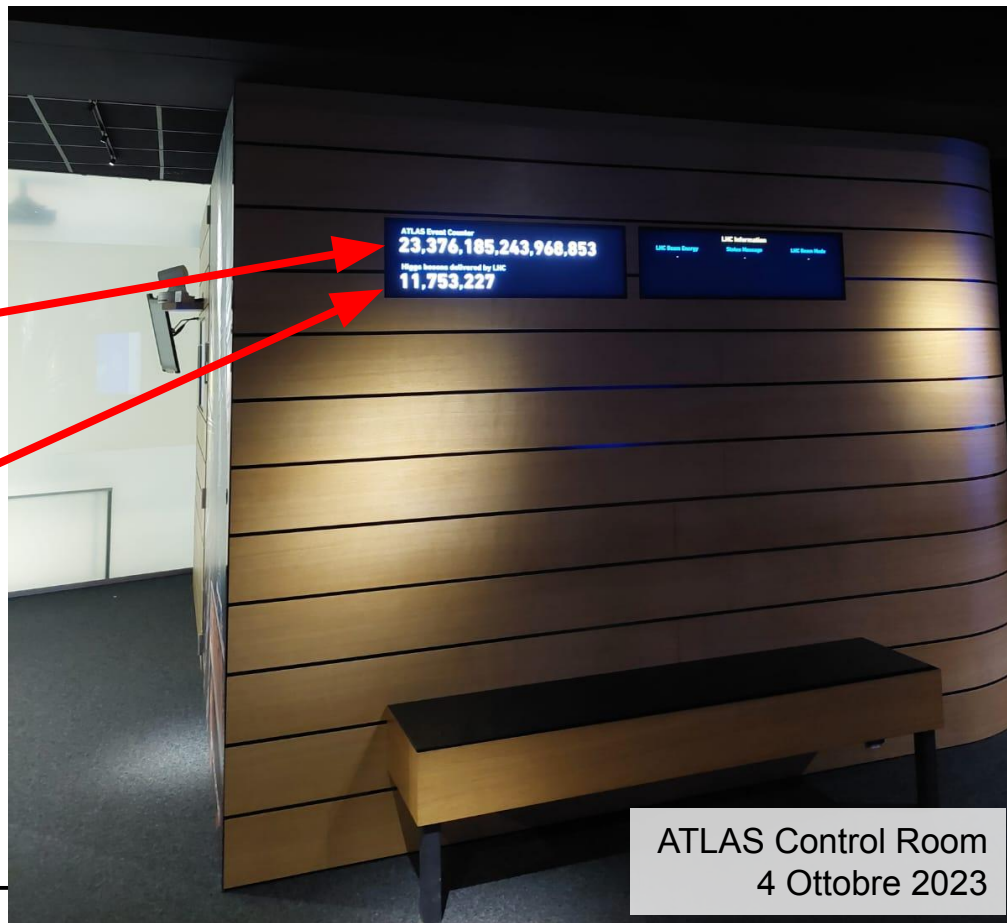
# Alla fine dei 50 eventi



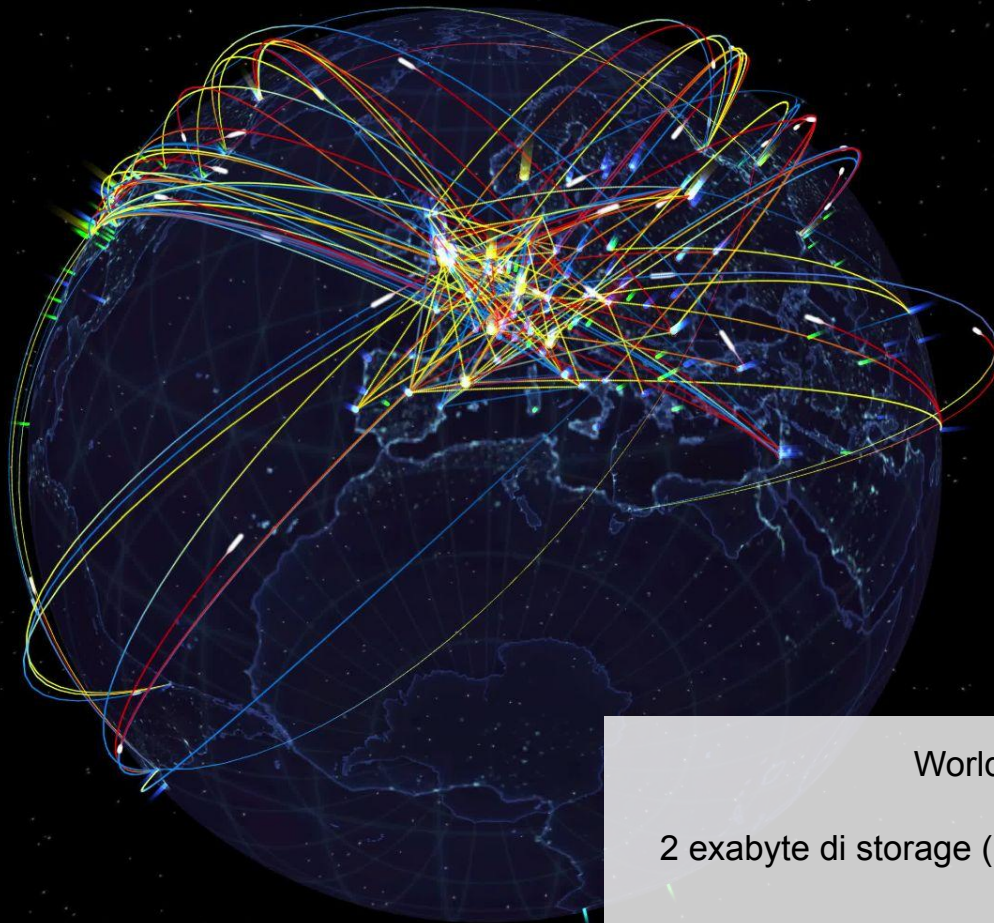
50 eventi vi sembrano tanti?

Numero di eventi osservati in ATLAS

Numero di bosoni di Higgs prodotti da LHC



ATLAS Control Room  
4 Ottobre 2023



Running jobs: 365644  
Active CPU cores: 807139  
Transfer rate: 21.54 GiB/sec

Worldwide LHC Computing Grid  
1.4 milioni di core  
2 exabyte di storage (=2000 miliardi di Gigabyte)  
42 Paesi  
170 centri di computing



Running jobs  
Active CPU c  
Transfer rate