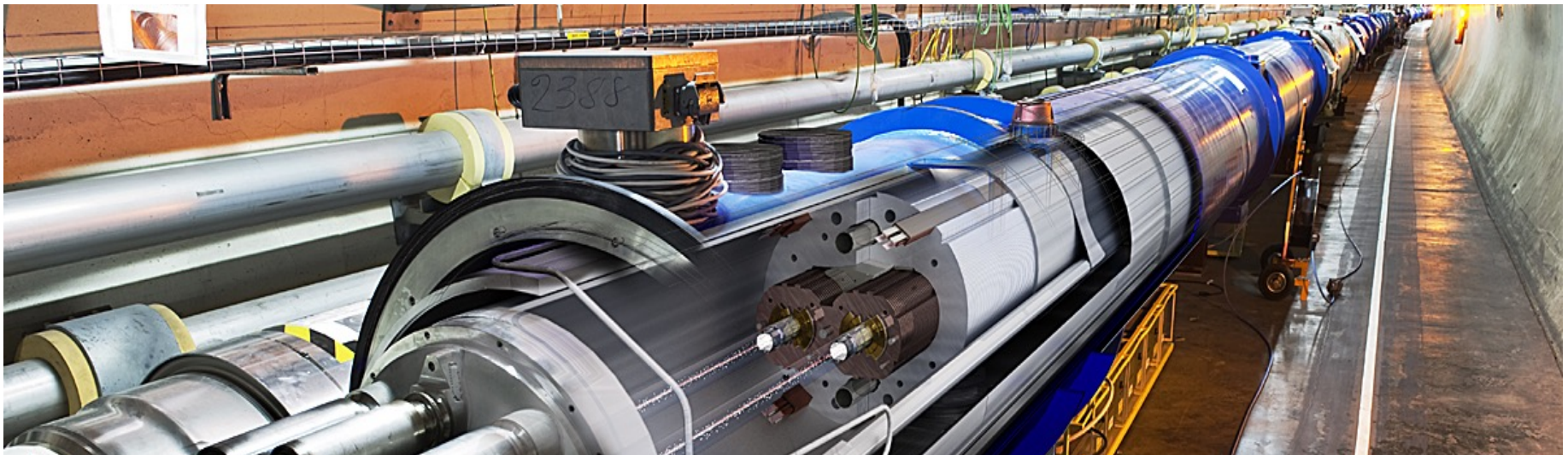




INTERNATIONAL
MASTERCLASSES

hands on particle physics



Pavia, 24 Febbraio 2022

Masterclass di Fisica:24.2.2021



Ina Carli
(ALPHA)



Jennifer Roloff
(ATLAS)



Yann Coadou
(ATLAS)

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

Thu, Feb 24

VC 1: ATLAS Z

Ina

Jennifer

Yann

Rome Sapienza



Pavia

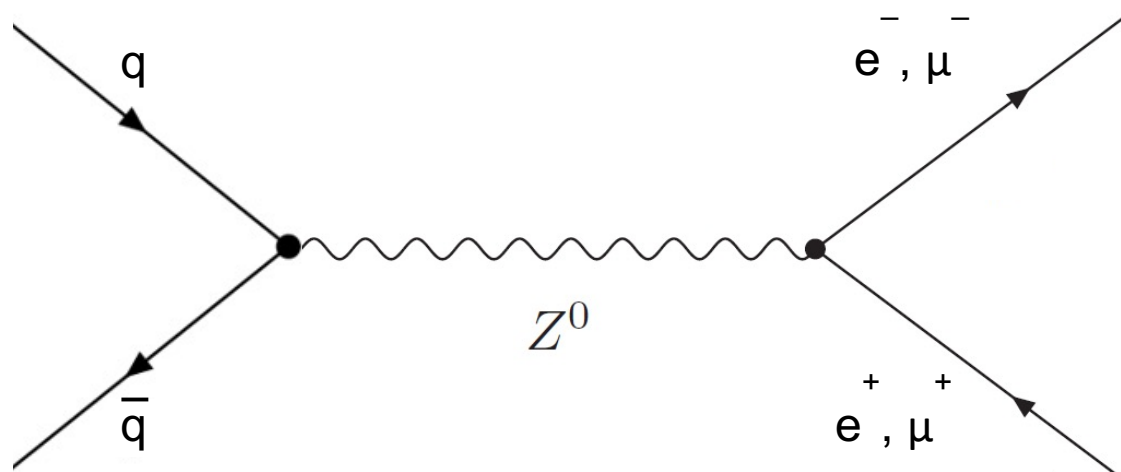


- ◆ Analizzare un insieme di dati raccolti dall'esperimento ATLAS ad LHC
 - Utilizzando un event display
 - 50 eventi ogni persona
- ◆ Selezionare campione di eventi con le caratteristiche di potenziali **candidati**
 - Bosone vettore Z e altre "risonanze" dileptoniche
 - Bosone di Higgs
- ◆ Analizzare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



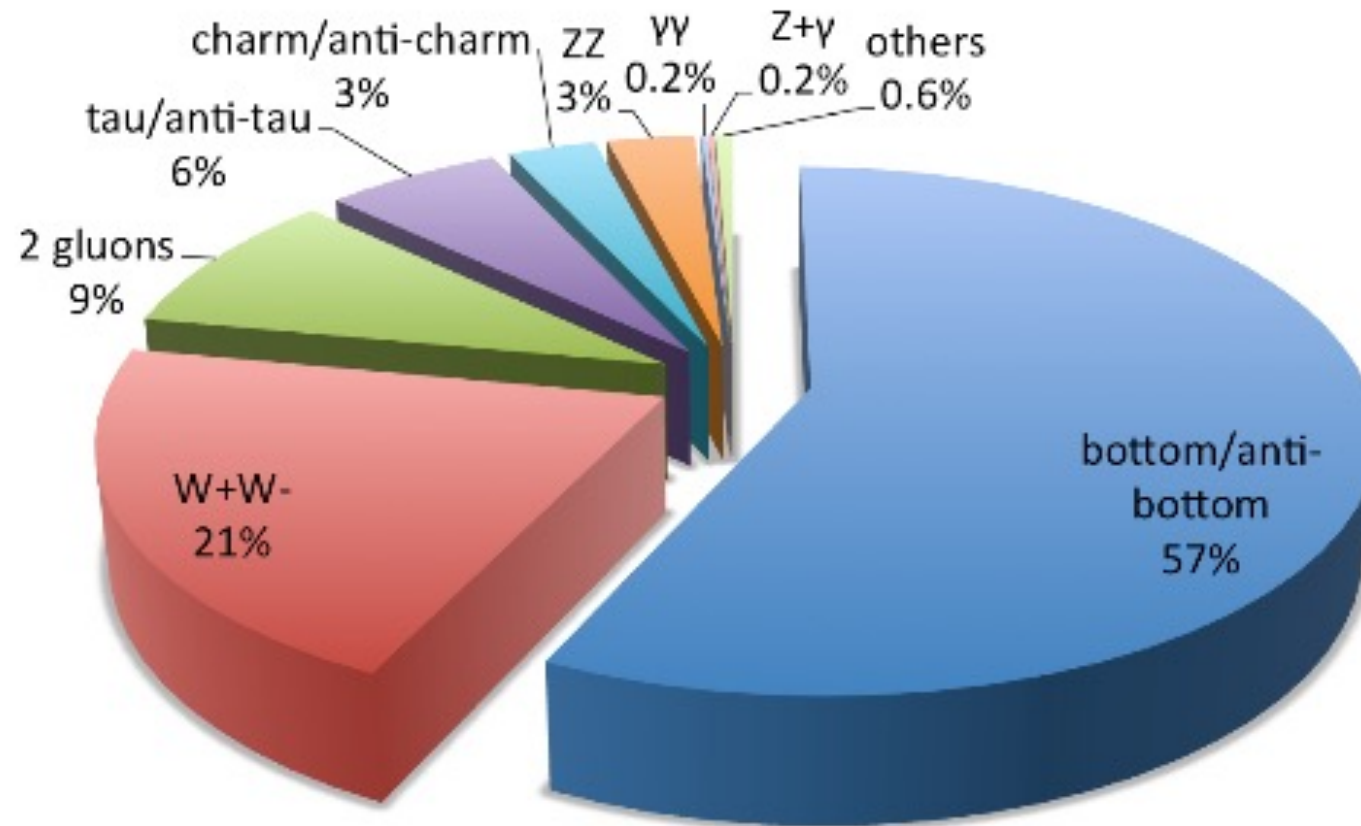
Bosone Z

- 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

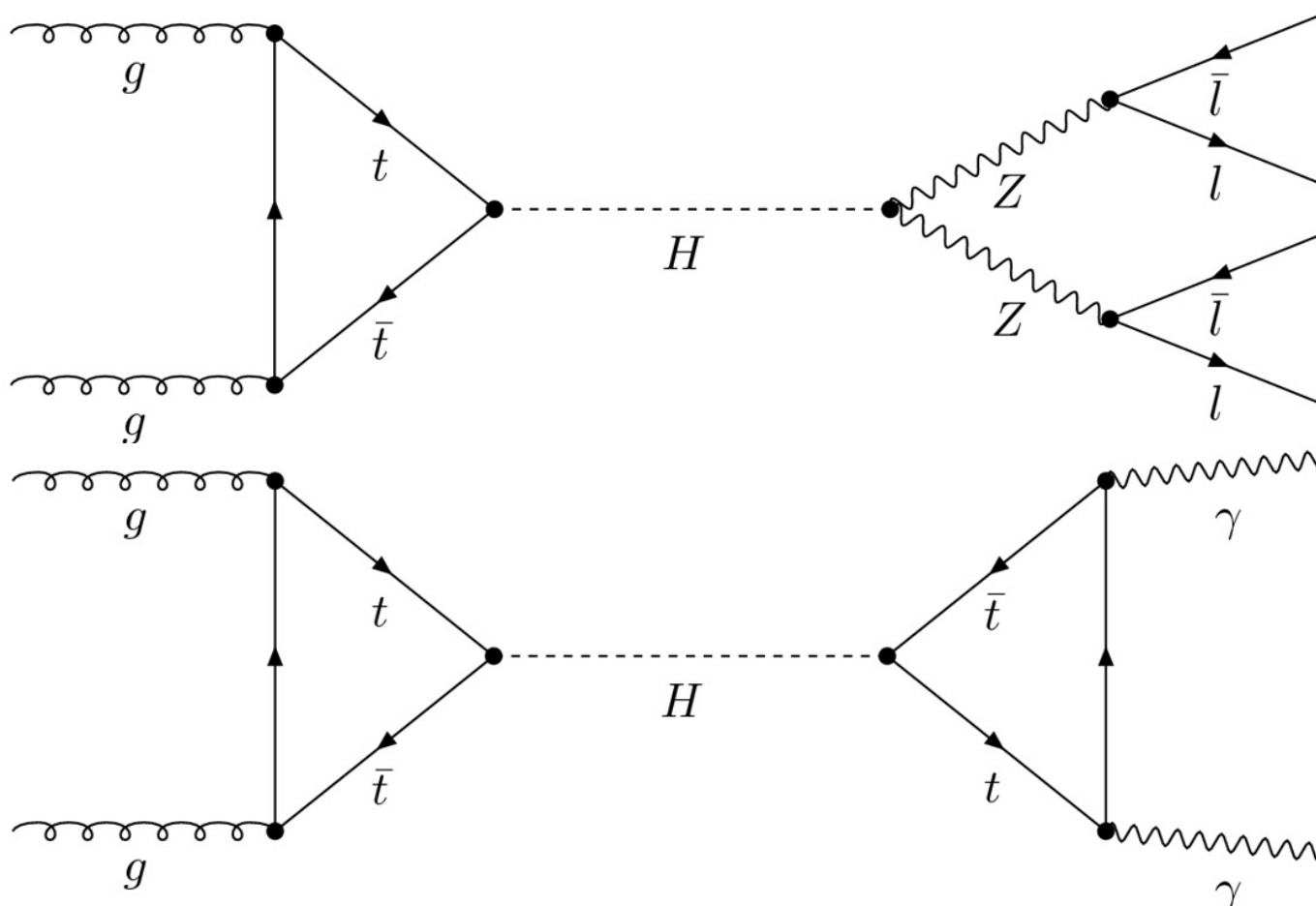
Quale canale di decadimento sceglieresti?



- 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



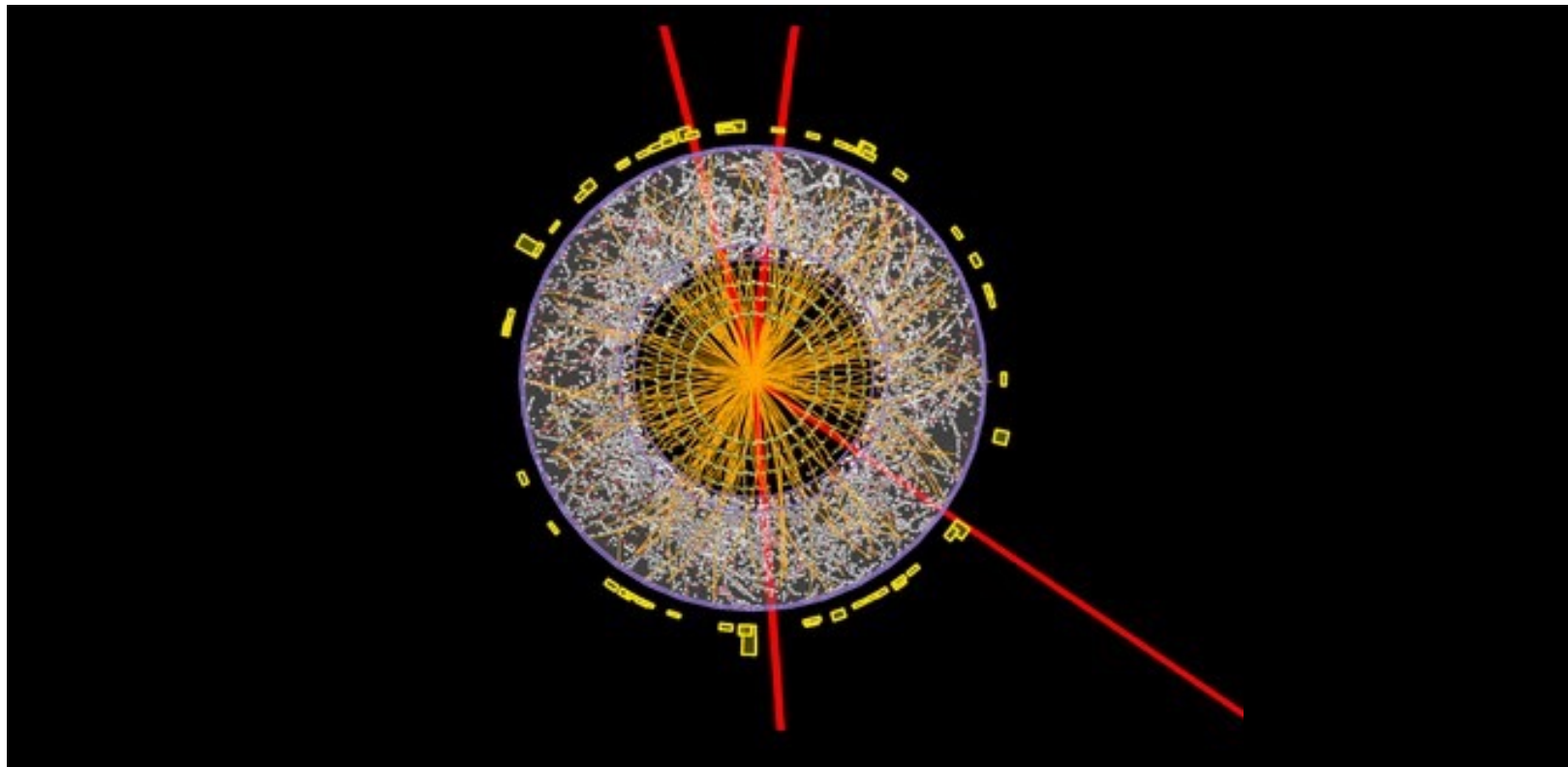
Eventi candidati

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

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

$$qq \rightarrow ZZ \rightarrow \mu\mu\mu\mu$$

$$qq \rightarrow H \rightarrow \mu\mu\mu\mu$$



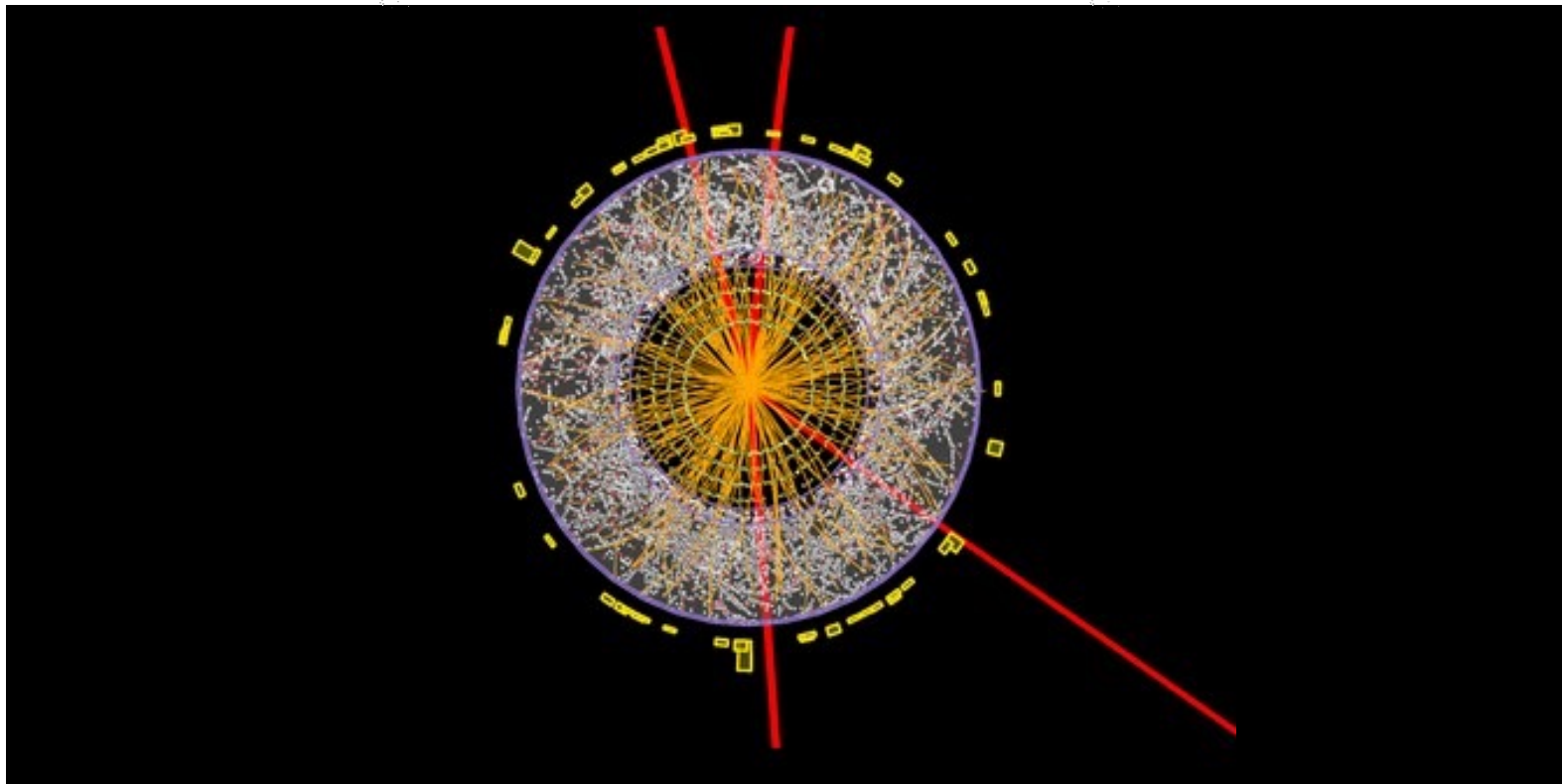
Eventi candidati

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

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

$qq \rightarrow ZZ \rightarrow \mu\mu\mu\mu$

$qq \rightarrow H \rightarrow \mu\mu\mu\mu$



Come le distinguiamo?

- Non le distinguiamo. Necessario approccio statistico

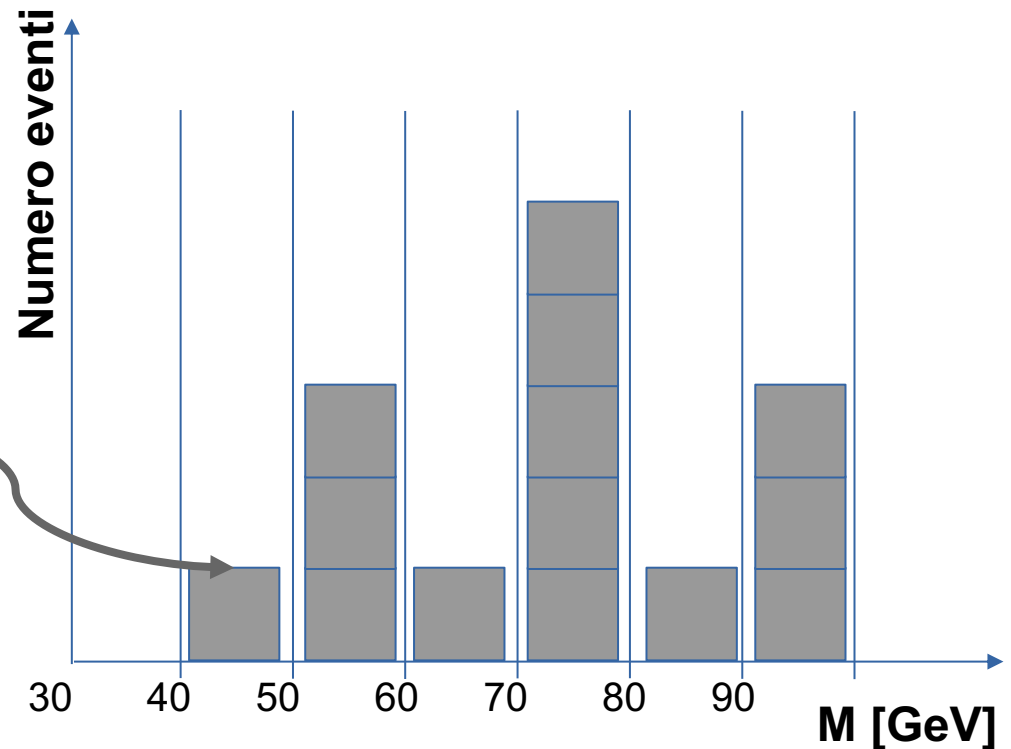
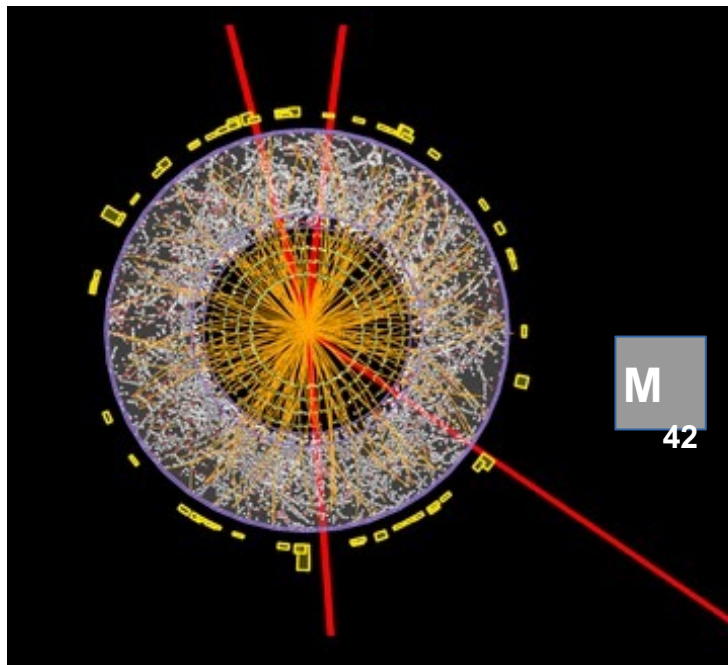
Approccio Statistico

Istogramma: per ogni evento

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

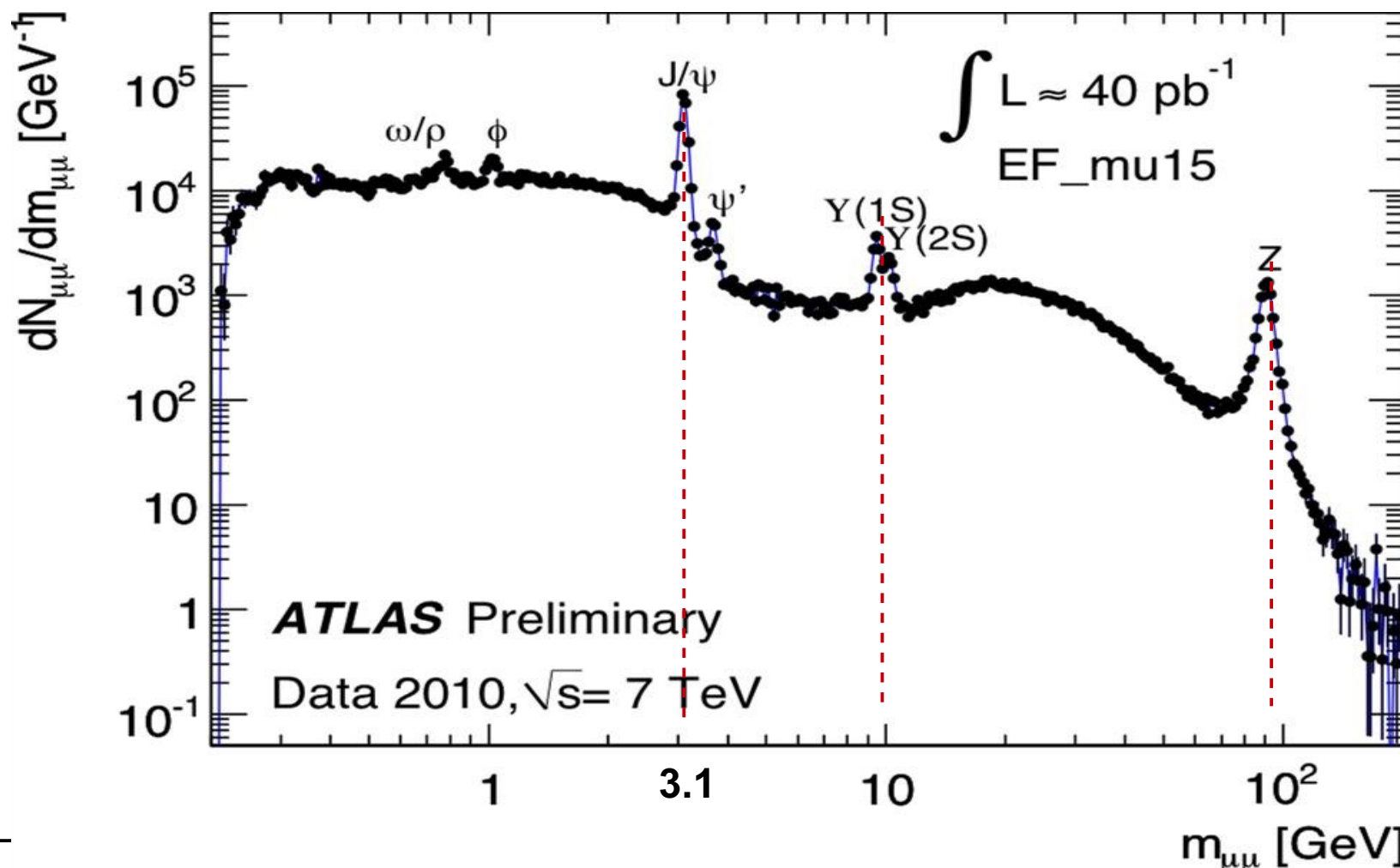
$$m_0^{(z)} = \sqrt{\left(\frac{(E_{e^-} + E_{e^+})}{c^2}\right)^2 - \left(\frac{\vec{p}_{e^-} + \vec{p}_{e^+}}{c}\right)^2}$$

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

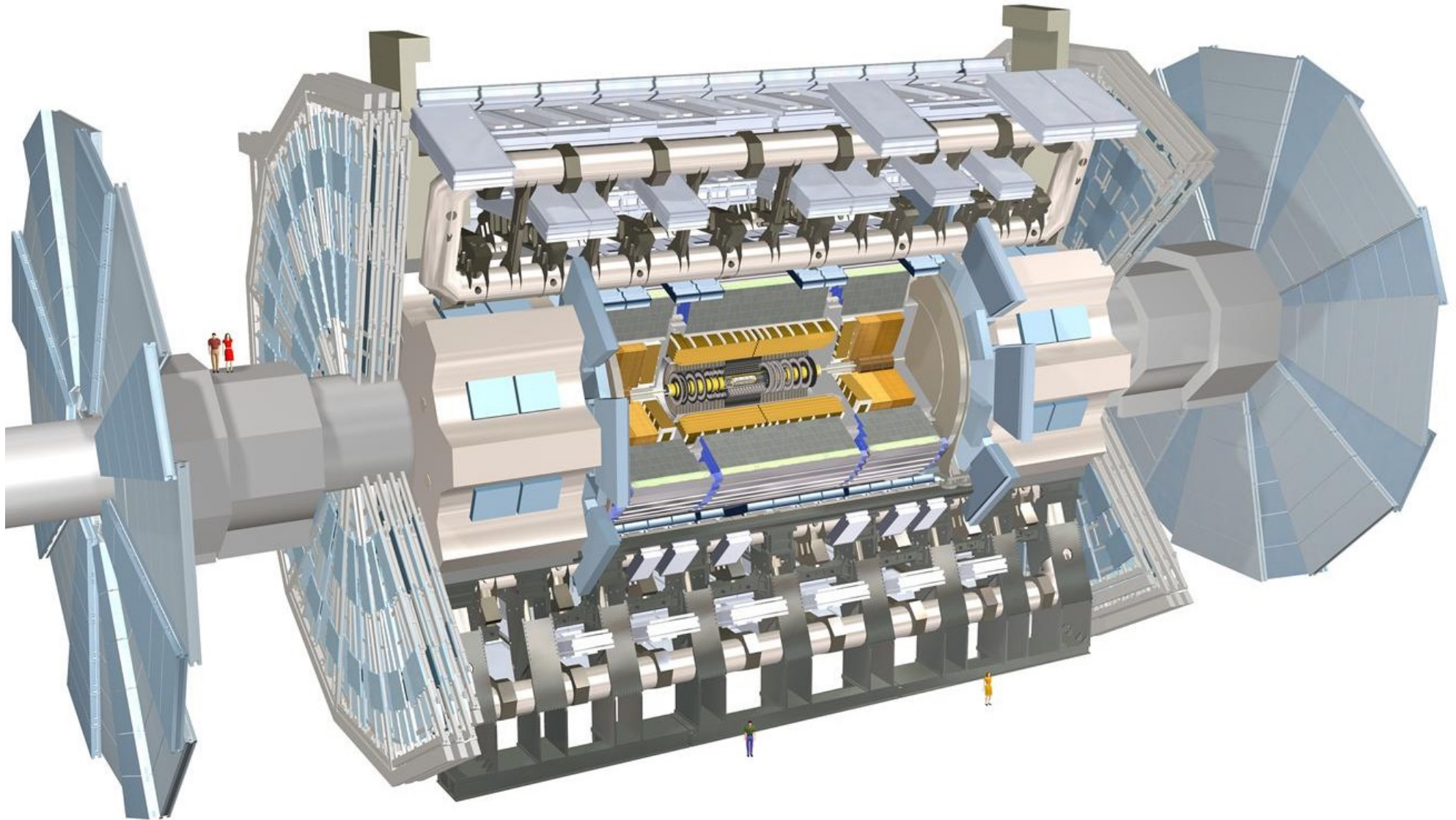


Istogramma

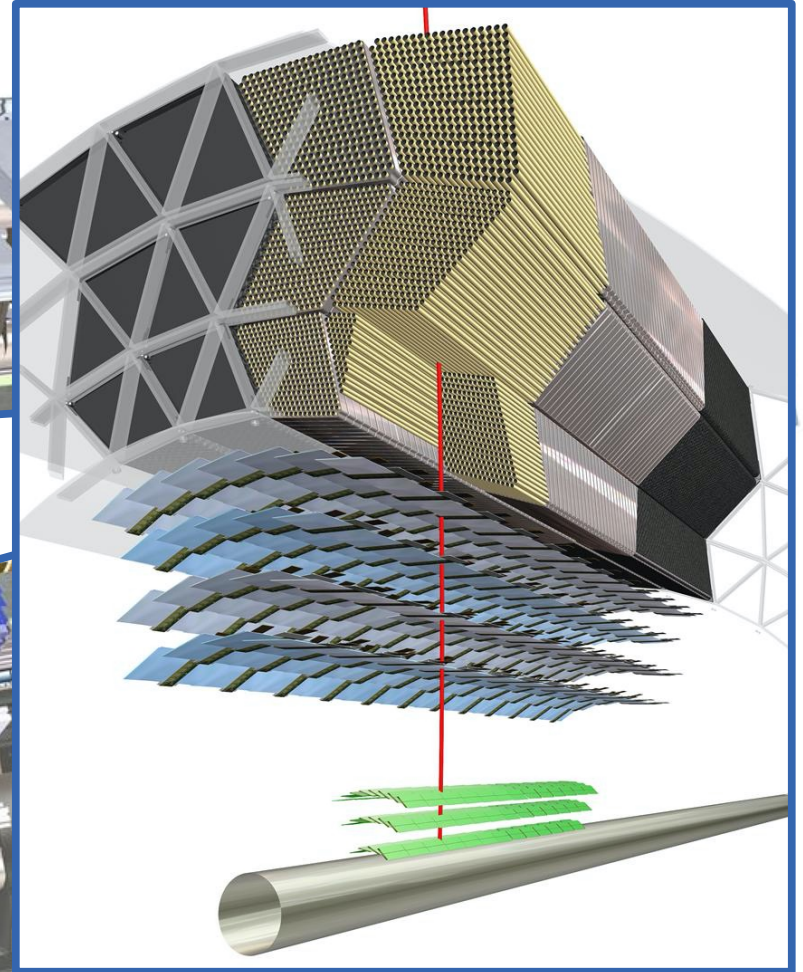
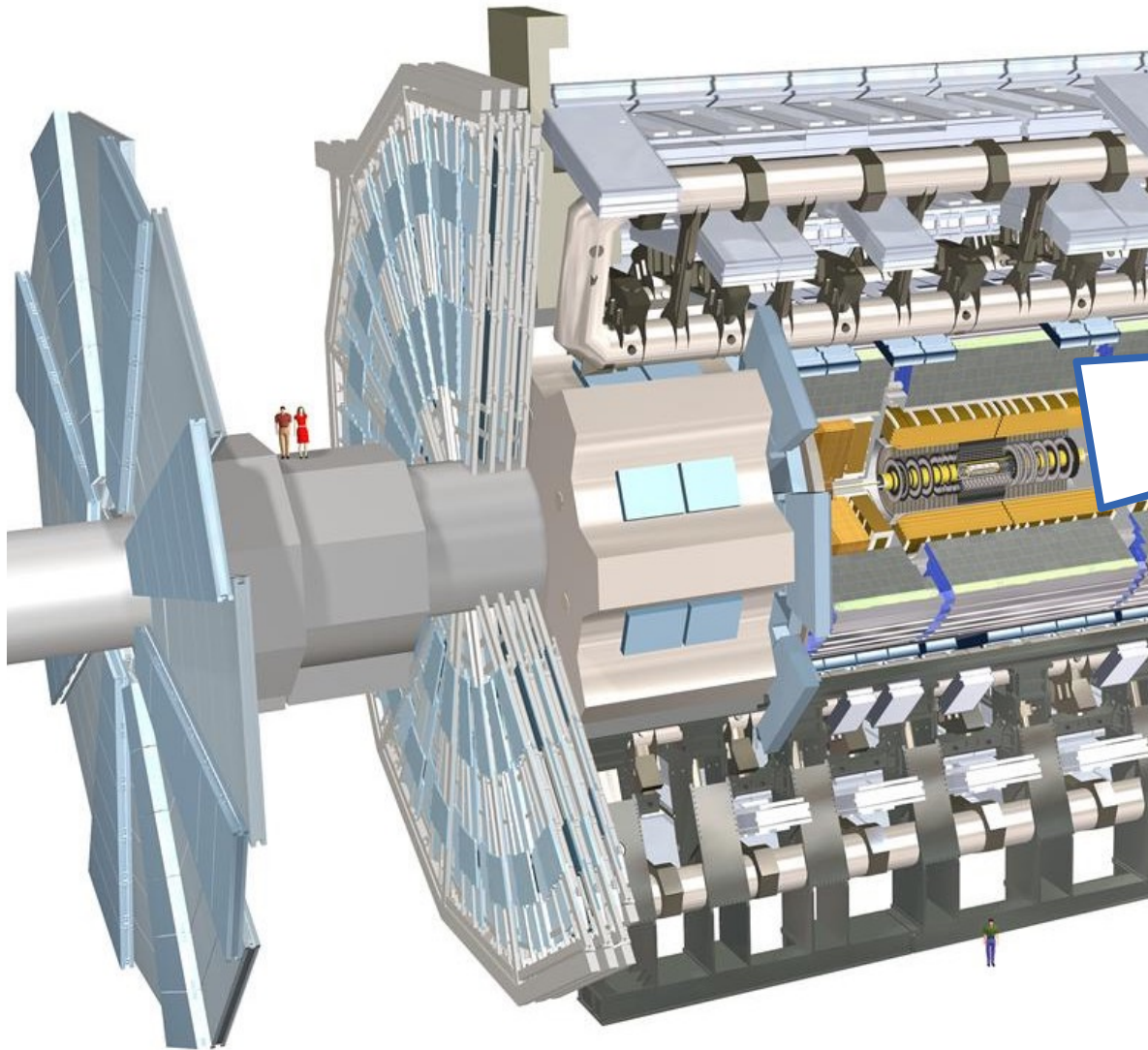
- Massa invariante del sistema dei due leptoni
 - La massa del “potenziale” progenitore



ATLAS

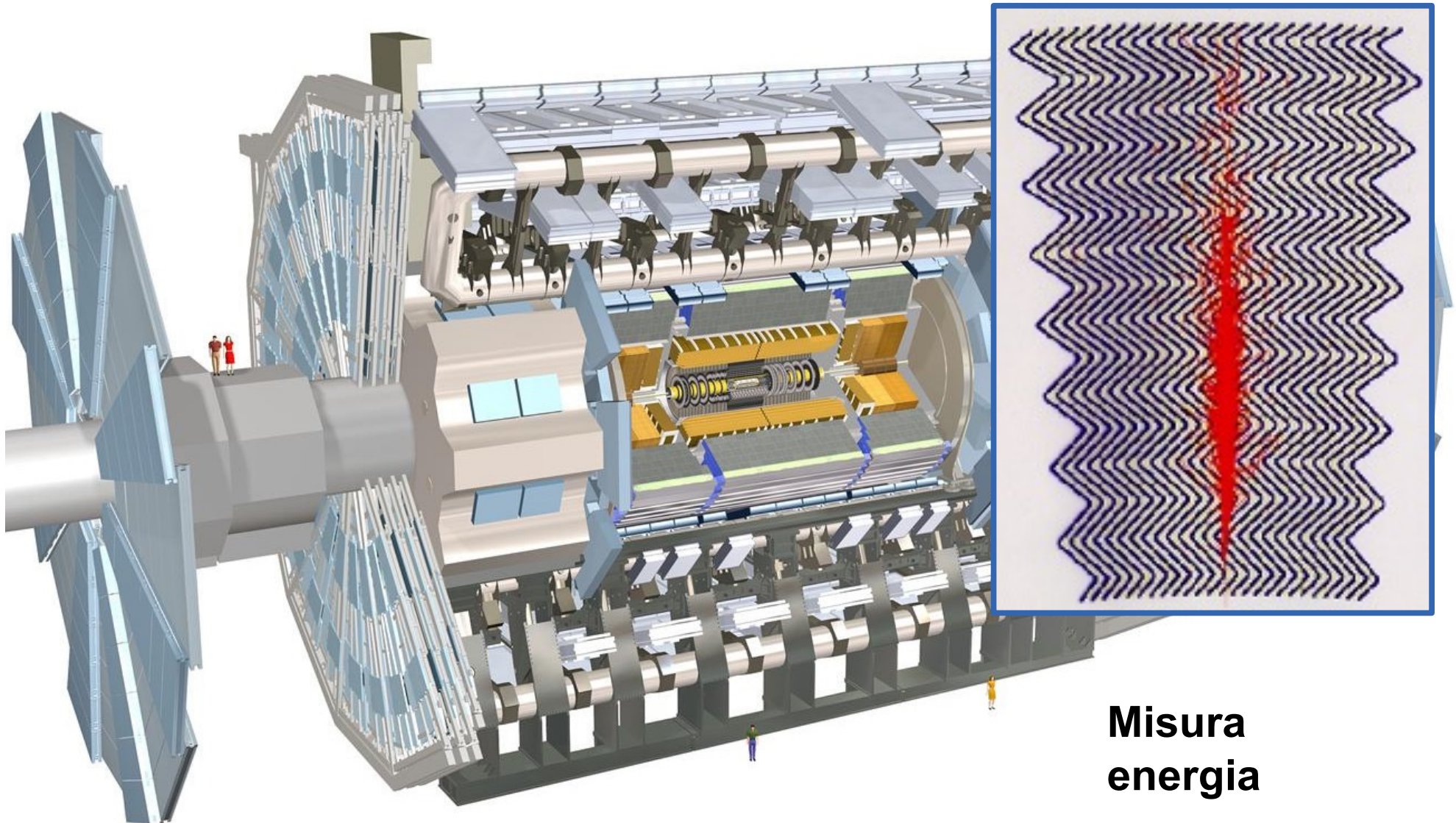


Tracciatore interno



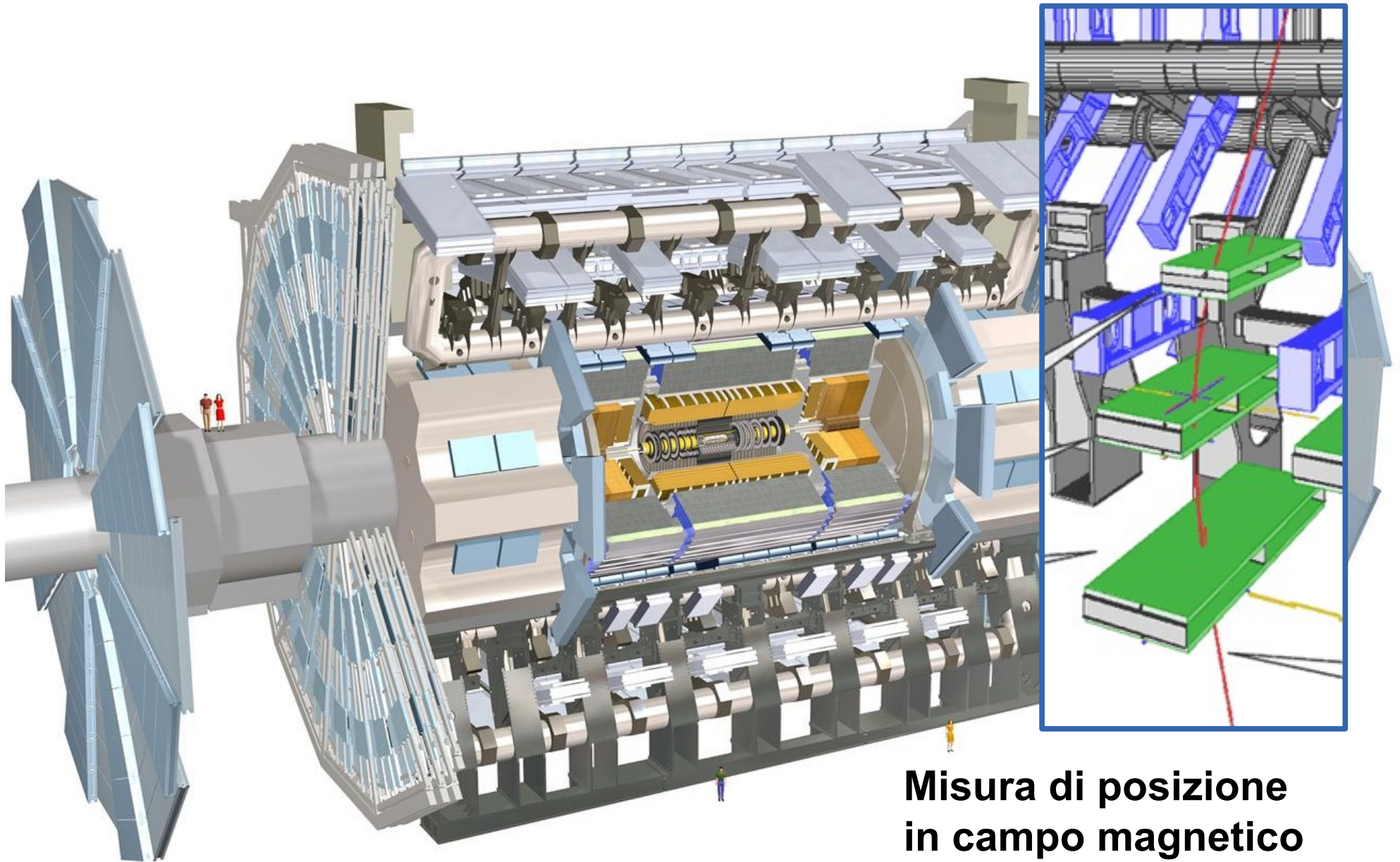
**Misura di posizione
in campo magnetico
(→momento)**

Sistema di calorimetria



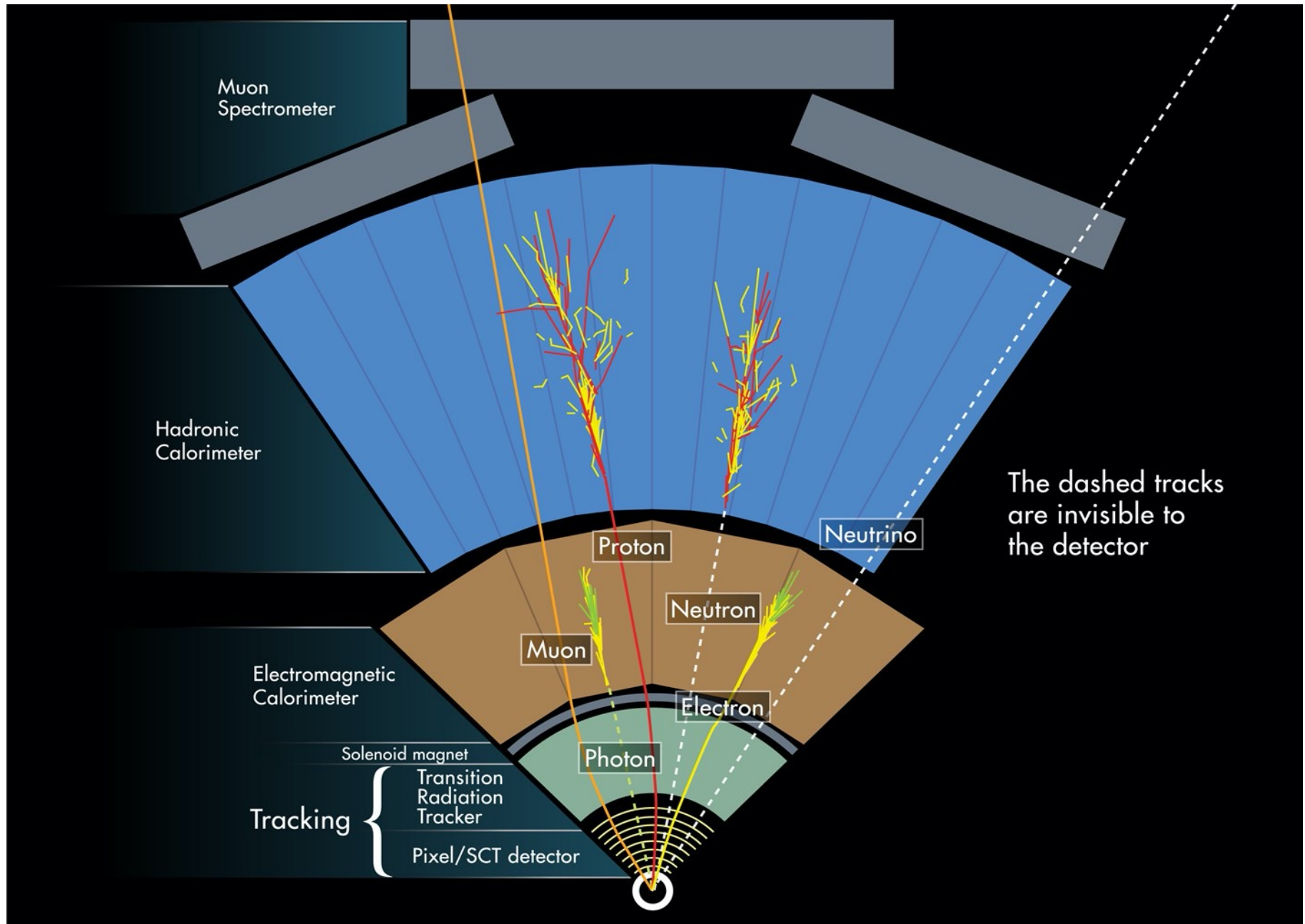
**Misura
energia**

Spettrometro muonico



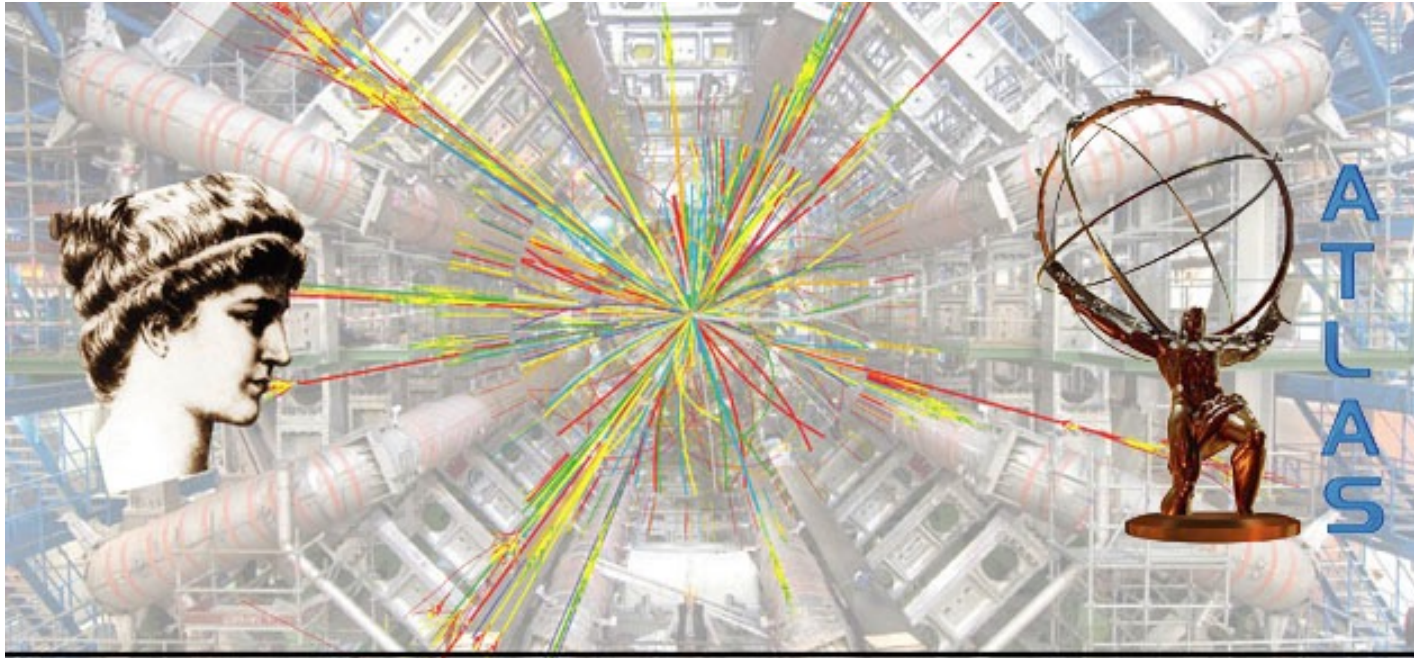
**Misura di posizione
in campo magnetico
(→momento)**

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



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



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]	ϕ	η	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

ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_RefFinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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

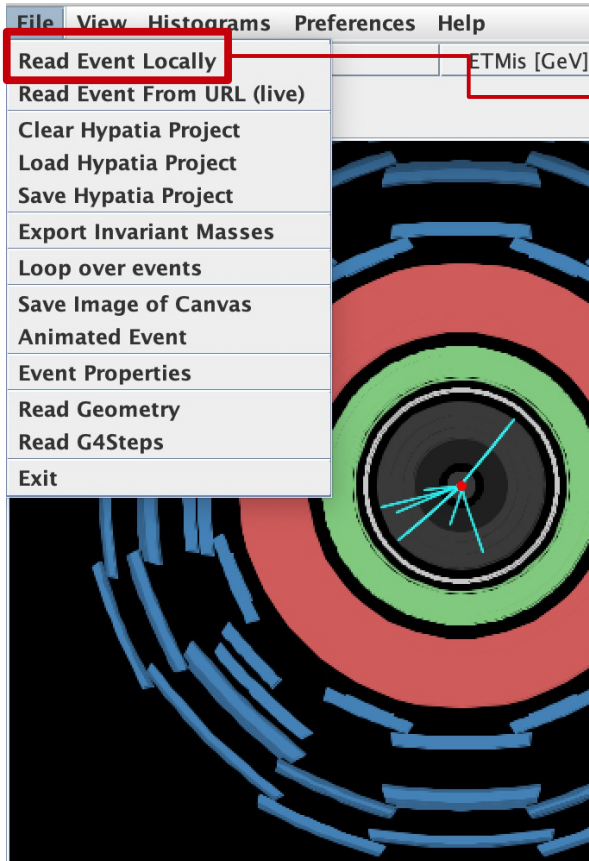
HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

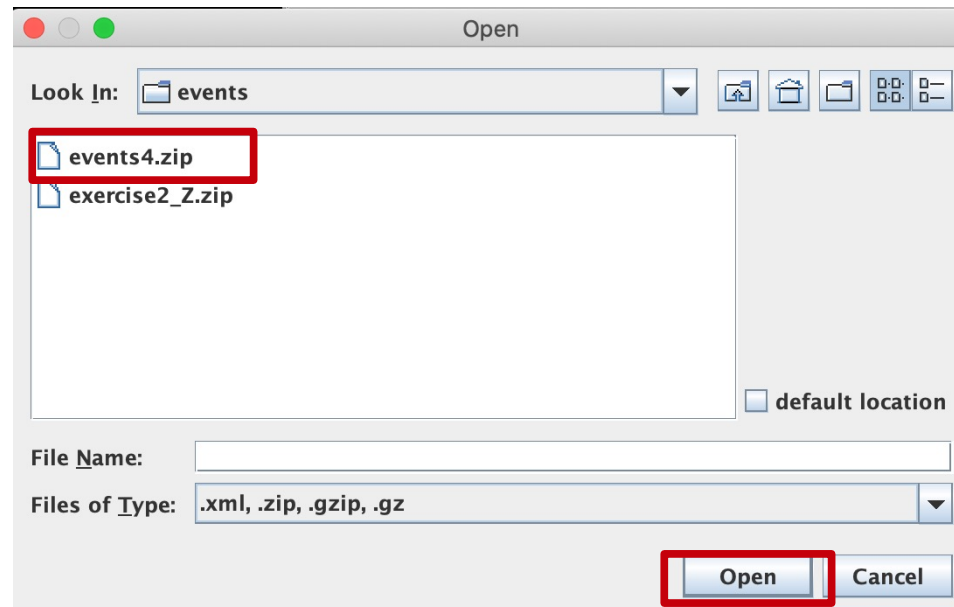
Projection Data Cuts InDet Calo MuonDet Objects Geometry

InDet	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

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](#)

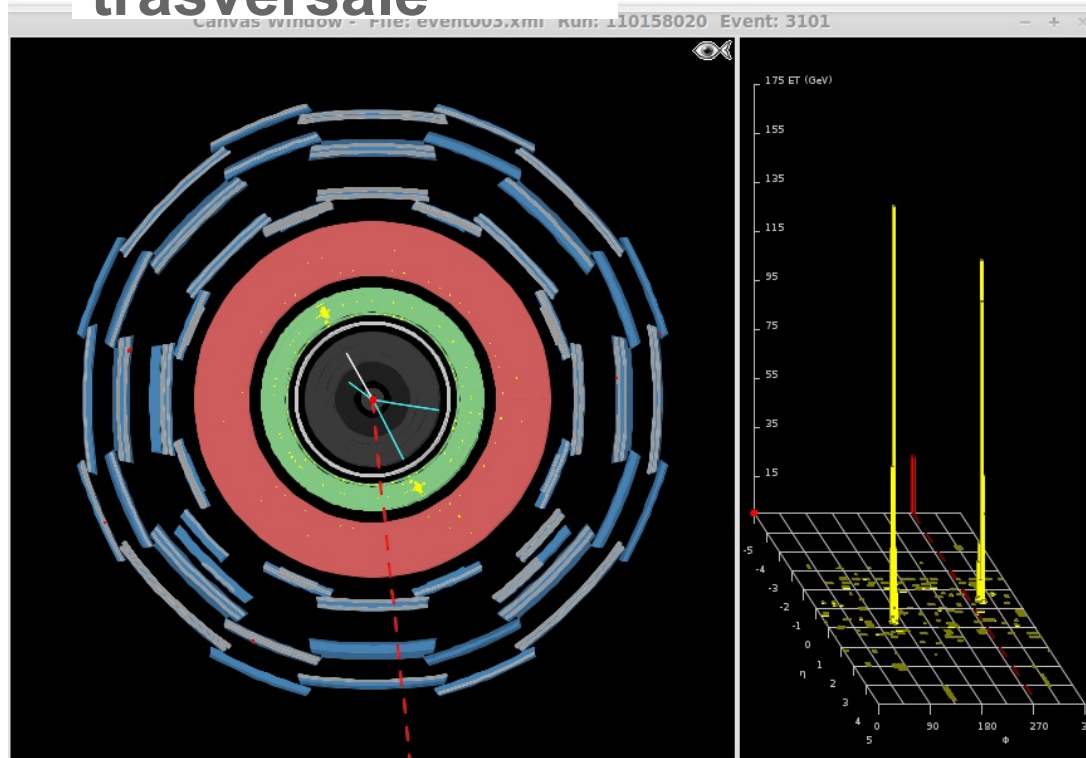
Finestra grafica

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

File View Histograms Preferences Help

	P [GeV]	+/-	Pt [GeV]	ϕ	η	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m/g
event00	217.0	-	42.6	-1.479	2.310	94.165				e
	93.3	+	42.9	1.779	1.413					e
event00	449.7	+	423.3	-1.090	-0.352	994.430				e
	567.5	-	434.3	2.080	0.764					e

Vista
trasversale



HYPATIA - Track Momenta Window

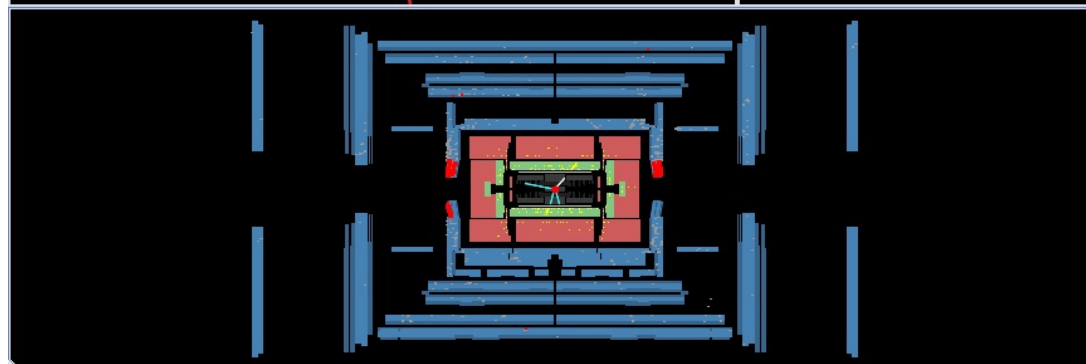
Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_Reffinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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
	<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

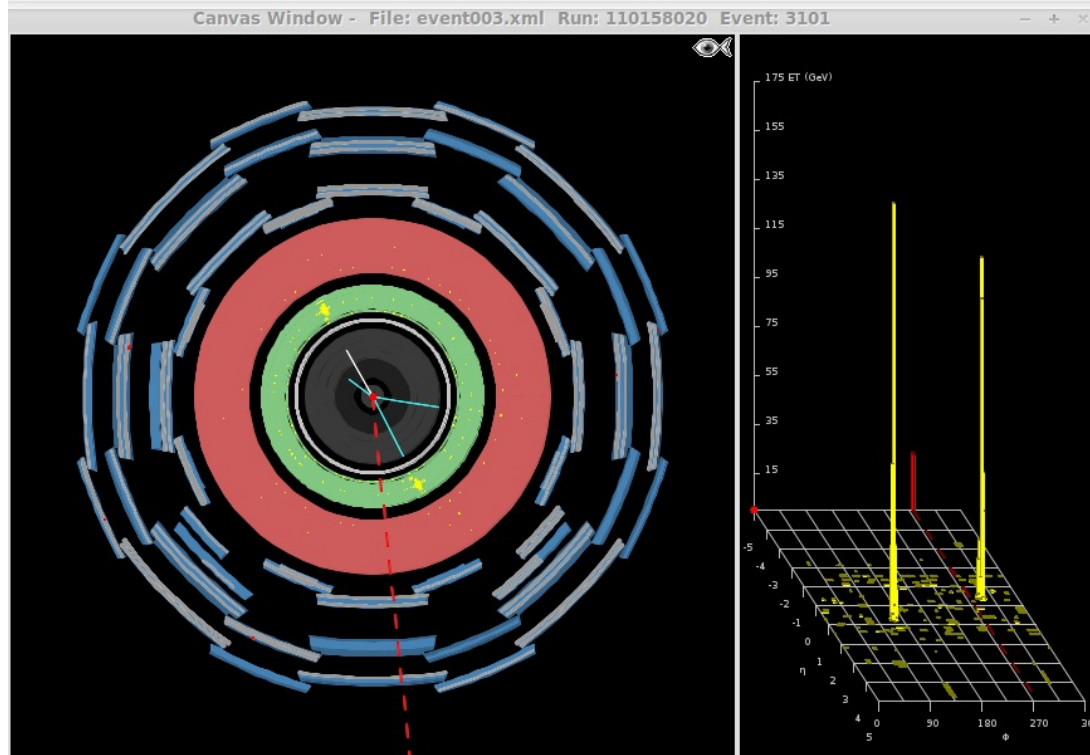
Vista longitudinale

Finestra grafica

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]	ϕ	η	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



HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

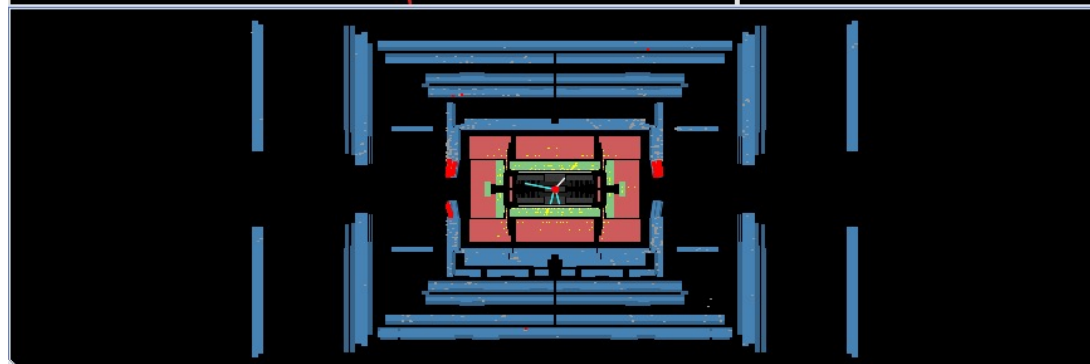
ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_Reffinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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

Projection Data Cuts InDet Calo MuonDet

InDet	Calo	MuonDet	Objects	ATLAS	Name	Value
					<input checked="" type="checkbox"/> Pt	> 5.0 GeV
					<input type="checkbox"/> Pt2	< 700.0 V
					<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

Tasto per modalità zoom

Tasto per modalità selezione

Finestra di controllo

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]	+/-						
event002.xml	23.199	Tracks 0	217.0	-	42.6					
		Tracks 76	93.3	+	42.9					
event003.xml	22.805	Tracks 184	449.7	+	423.3	-1.090	4352	994.30		
		Tracks 247	567.5	-	434.3	2.080	764			

Avanzamento eventi

numero evento

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

YPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_RefFinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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		
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 massa invariante

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

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	ϕ	η	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

massa invariante

Menu file

Per il salvataggio delle masse alla fine dell'analisi di tutti i 50 eventi
"Export Invariant Masses"

Calcola massa invariante

di ogni coppia di fotoni o
di leptoni di carica opposta

Inserimento tracce

selezionare riga della traccia
premere tasto opportuno

Rimozione tracce

selezionare traccia
premere "delete track"

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_RefFinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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

Finestra strumenti

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]	ϕ	η	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

ETHis: 22.805 GeV ϕ : -1.466 rad Collection: MET_RefFinal

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

Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
Tracks 4	-	9.77	9.42	-0.195	1.302
Tracks 184	+	449.71	423.28	-1.090	1.915
Tracks 247	-	567.5	434.3	2.080	0.764

Taglio sulle tracce

Visualizzazione delle sole tracce con momento superiore ad una certa soglia
Partire sempre da 5 GeV

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 checked="" 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	> 0
	<input type="checkbox"/> Number Pixel Hits	>= 2

Hypatia Event Viewer



Hybrid Pupils' Analysis Tool for Intermediate Energy Colliders

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	M(2) [GeV]	M(eeee) [GeV]
event002.xml	23.199	Tracks 0	217.0	94.165	
		Tracks 76	93.3		
event003.xml	22.805	Tracks 184	449.7	994.430	
		Tracks 247	567.5		

Masse invarianti

Inserimento tracce per calcolo masse

Canvas Window - File: event003.xml Run: 11

Vista trasversale (dalla linea del fascio)

Sviluppo piano celle calorimetro

Vista longitudinale

HYPATIA - Track Momenta Window

Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 22.805 GeV ϕ : -1.466 rad Collection: MET_RefFinal

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

Tracks	Track	+/-	P [GeV]	Pt [GeV]	ϕ	θ
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	

Scheda oggetti: fotoni

Scheda tracce: elettroni e muoni

Tasti cambio modalità: zoom / selezione

HYPATIA - Control Window

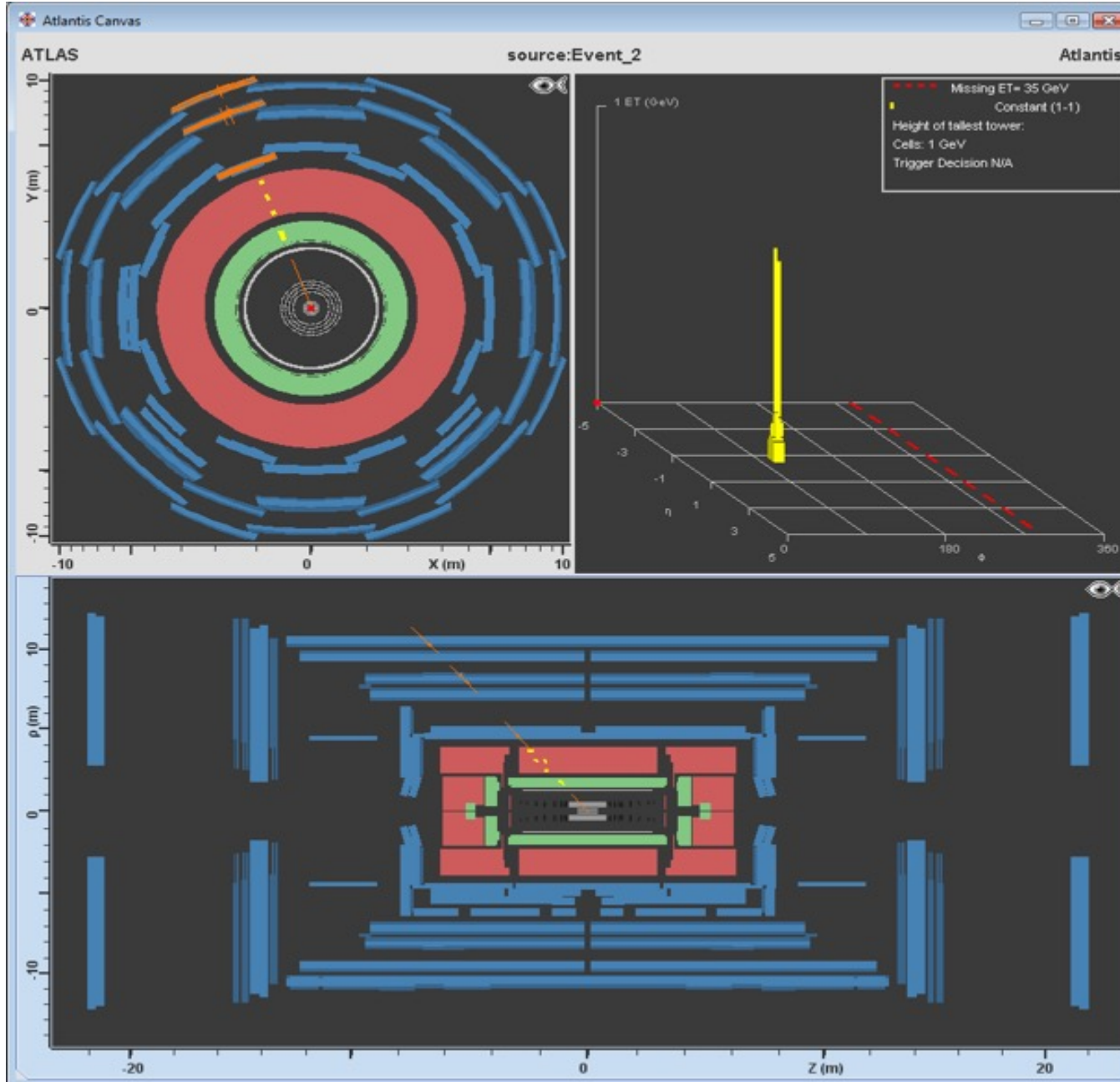
Parameter Control Interaction and Window Control Output Display

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"/> Layer	> 0
	<input type="checkbox"/> Number Pixel Hits	>= 2

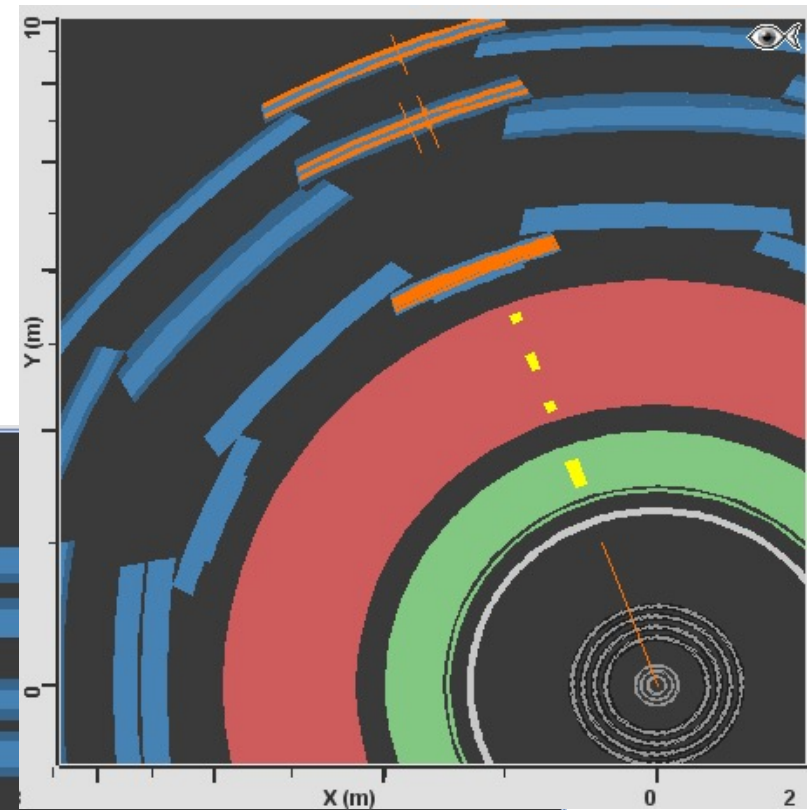
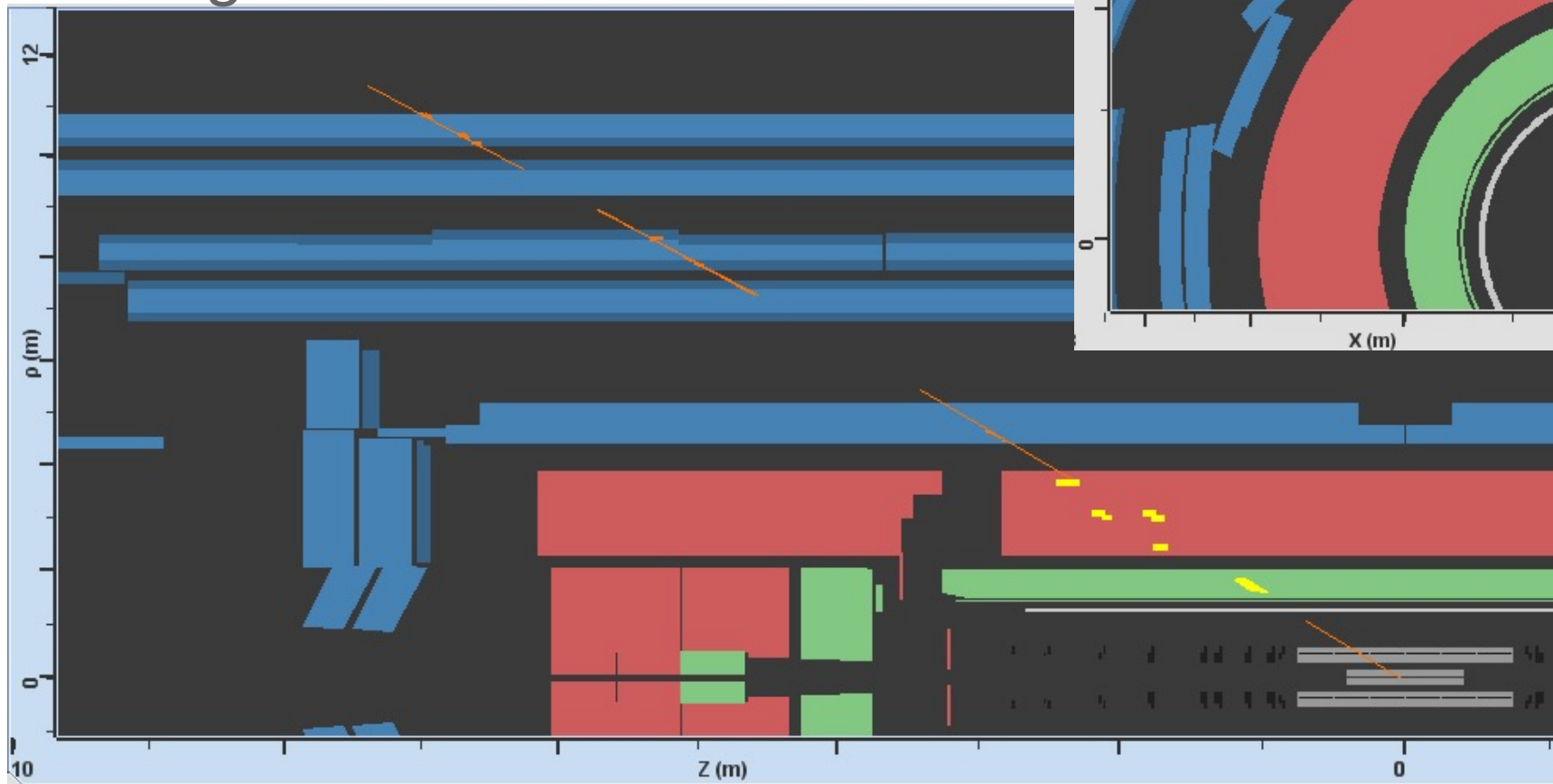
Taglio momento tracce

Identikit: (anti)muoni

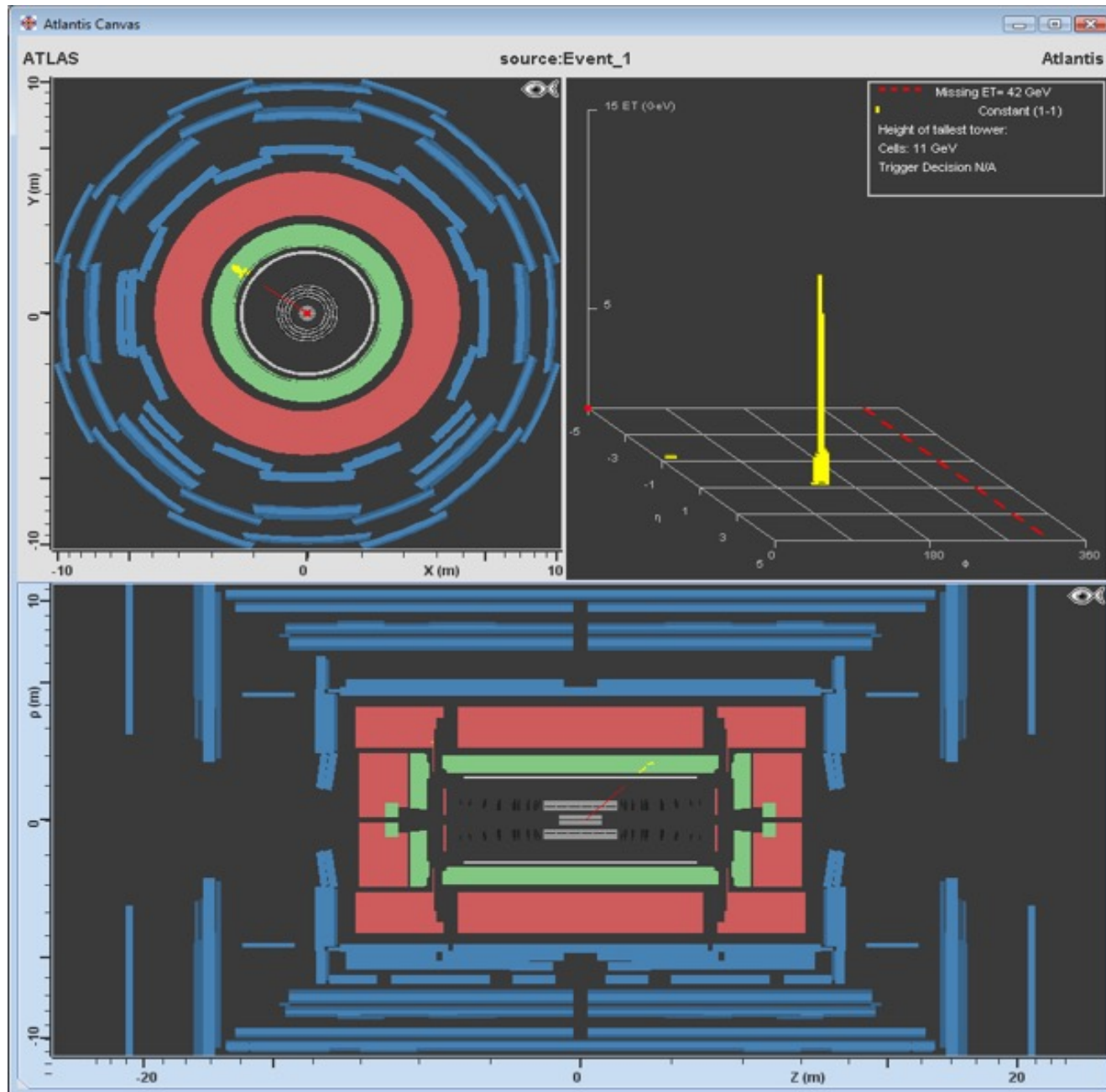


Identikit: (anti)muoni

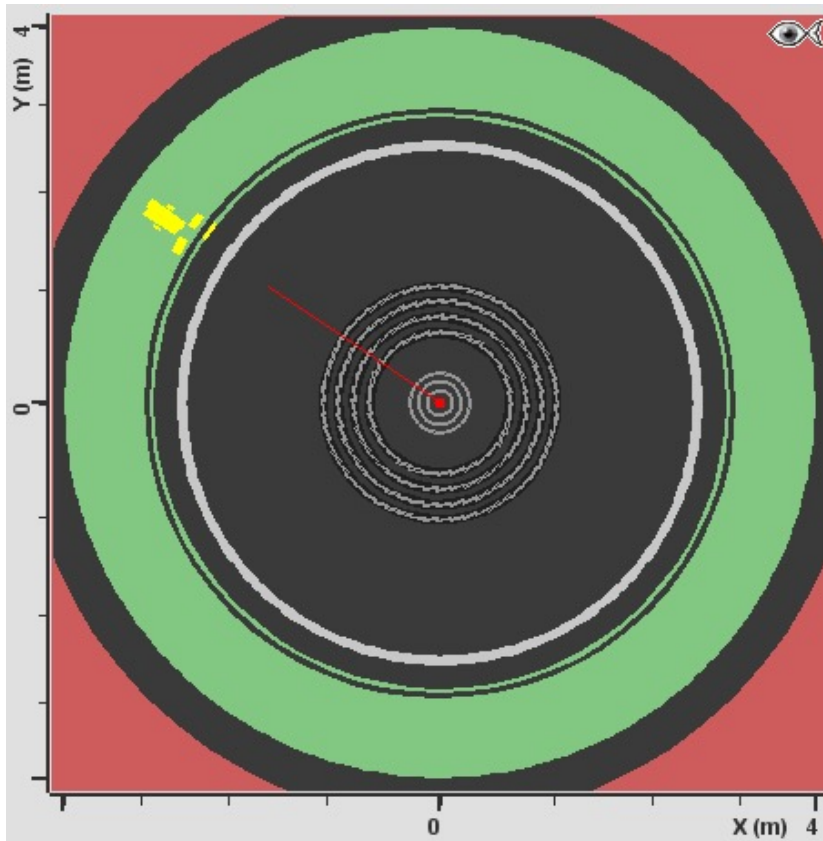
Traccia nel rivelatore interno
e nello spettrometro senza
significativi depositi di
energia nei calorimetri



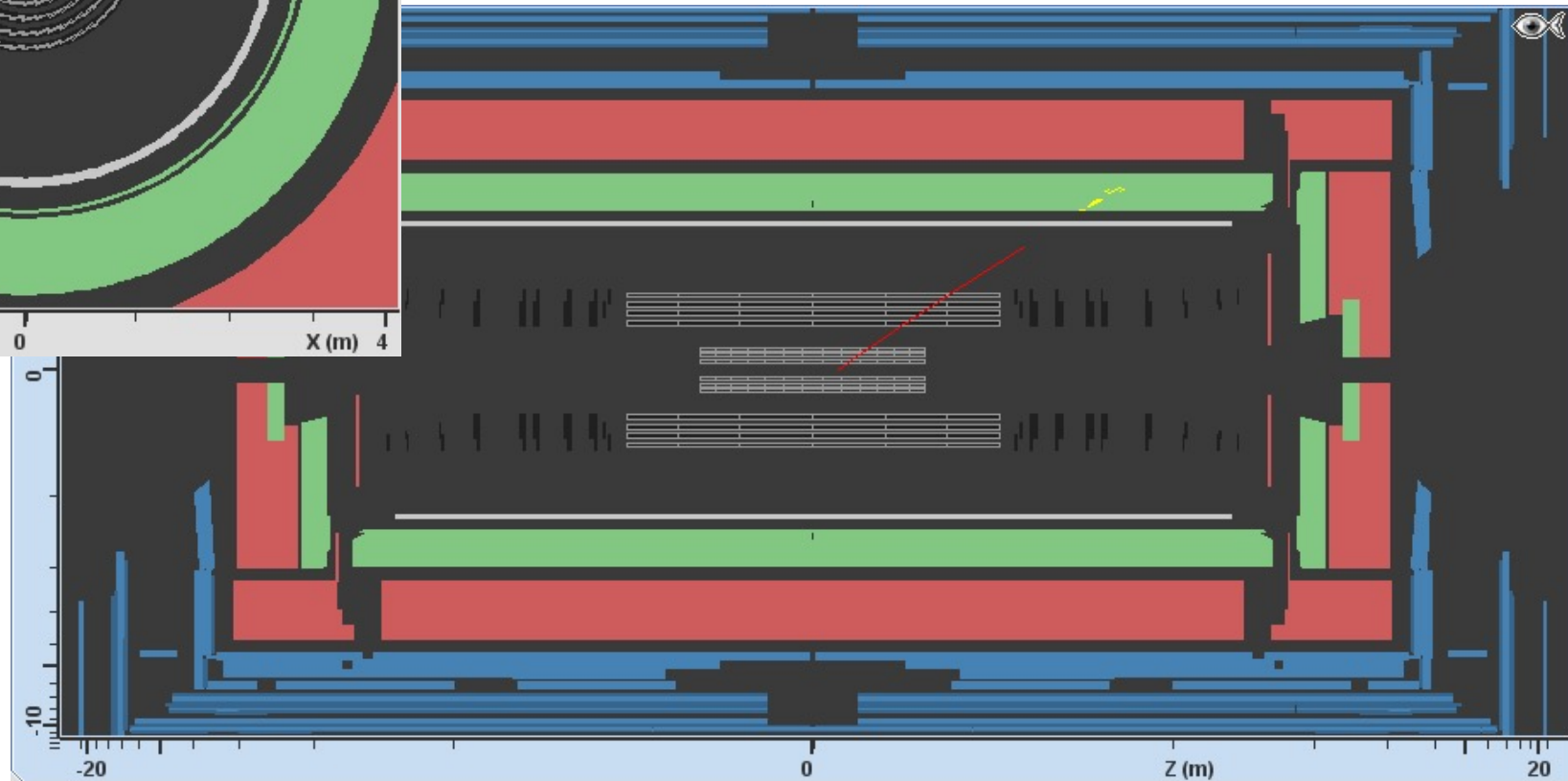
Identikit: elettroni/positroni



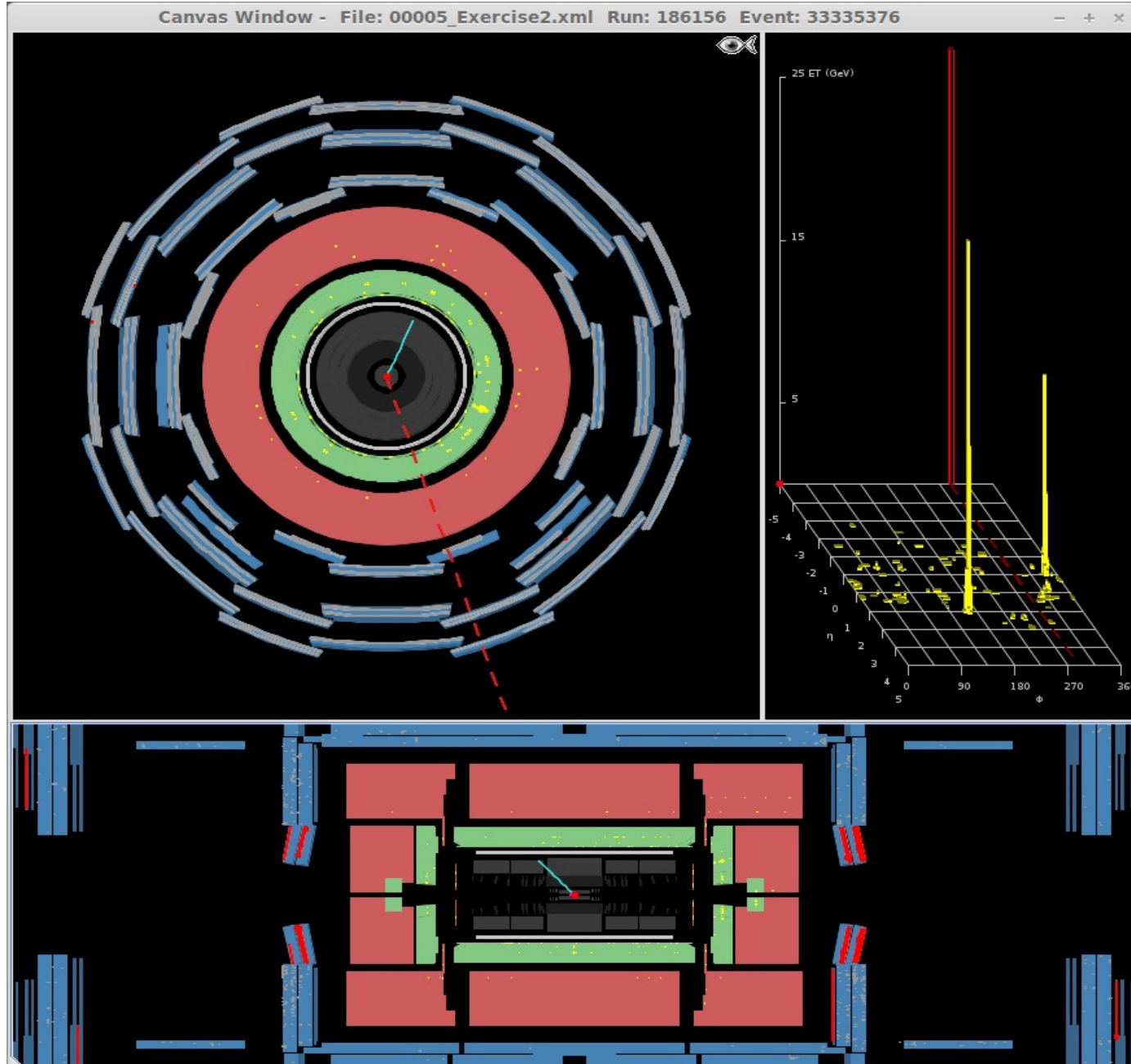
Identikit: elettroni/positroni



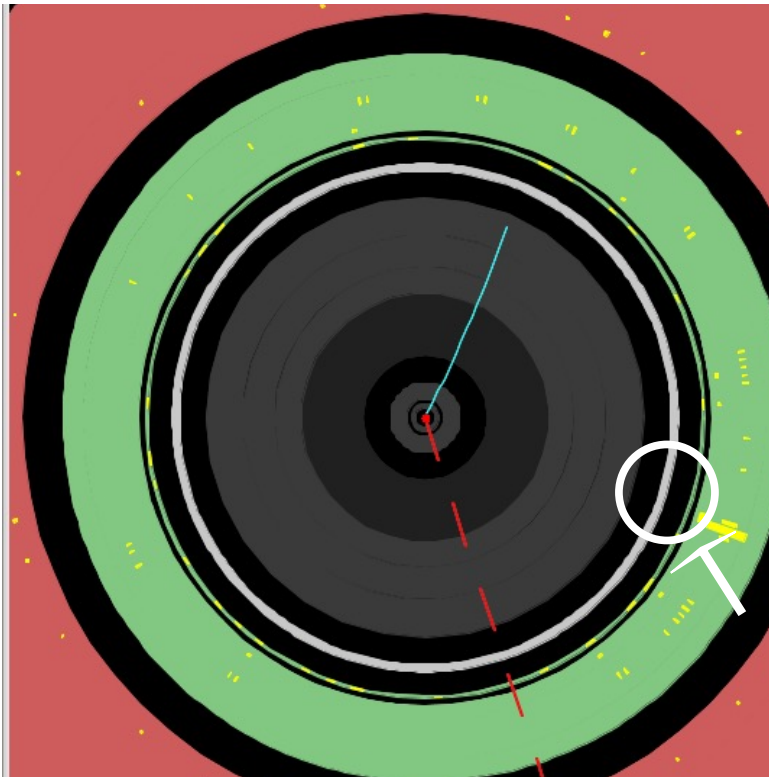
Tracce nel rivelatore interno
che puntano a depositi di
energia nel calorimetro
elettromagnetico



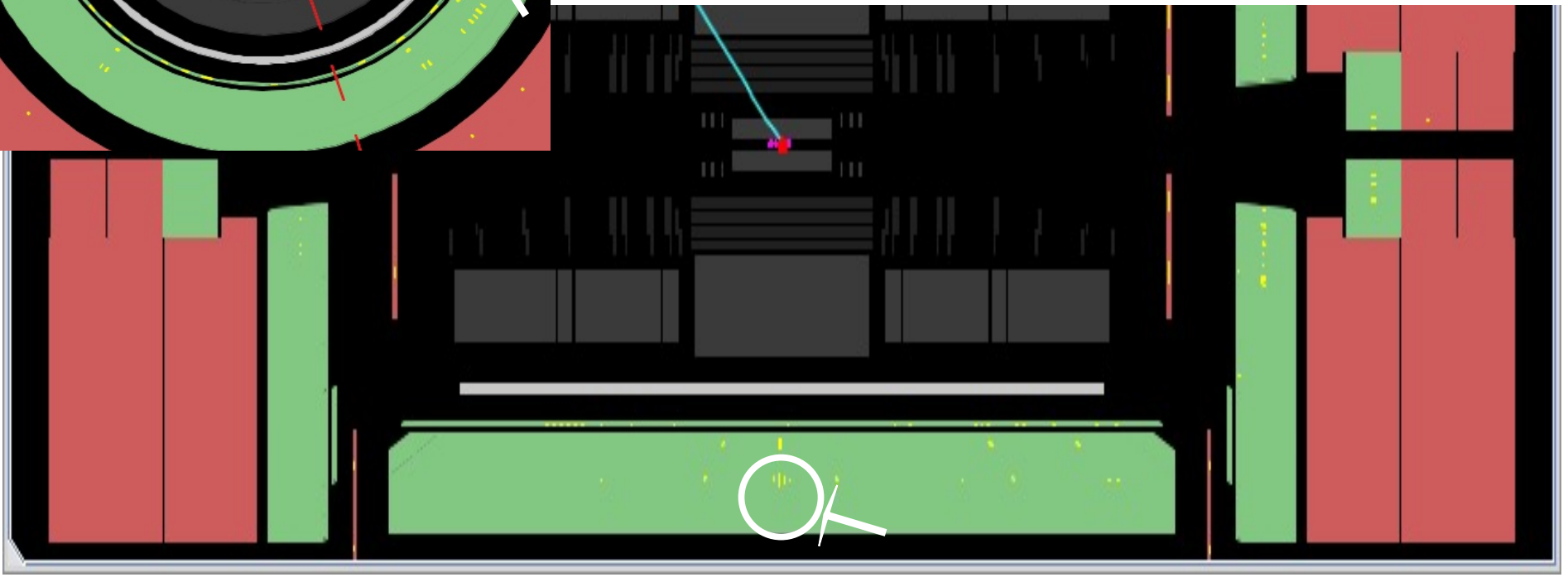
Identikit: fotoni



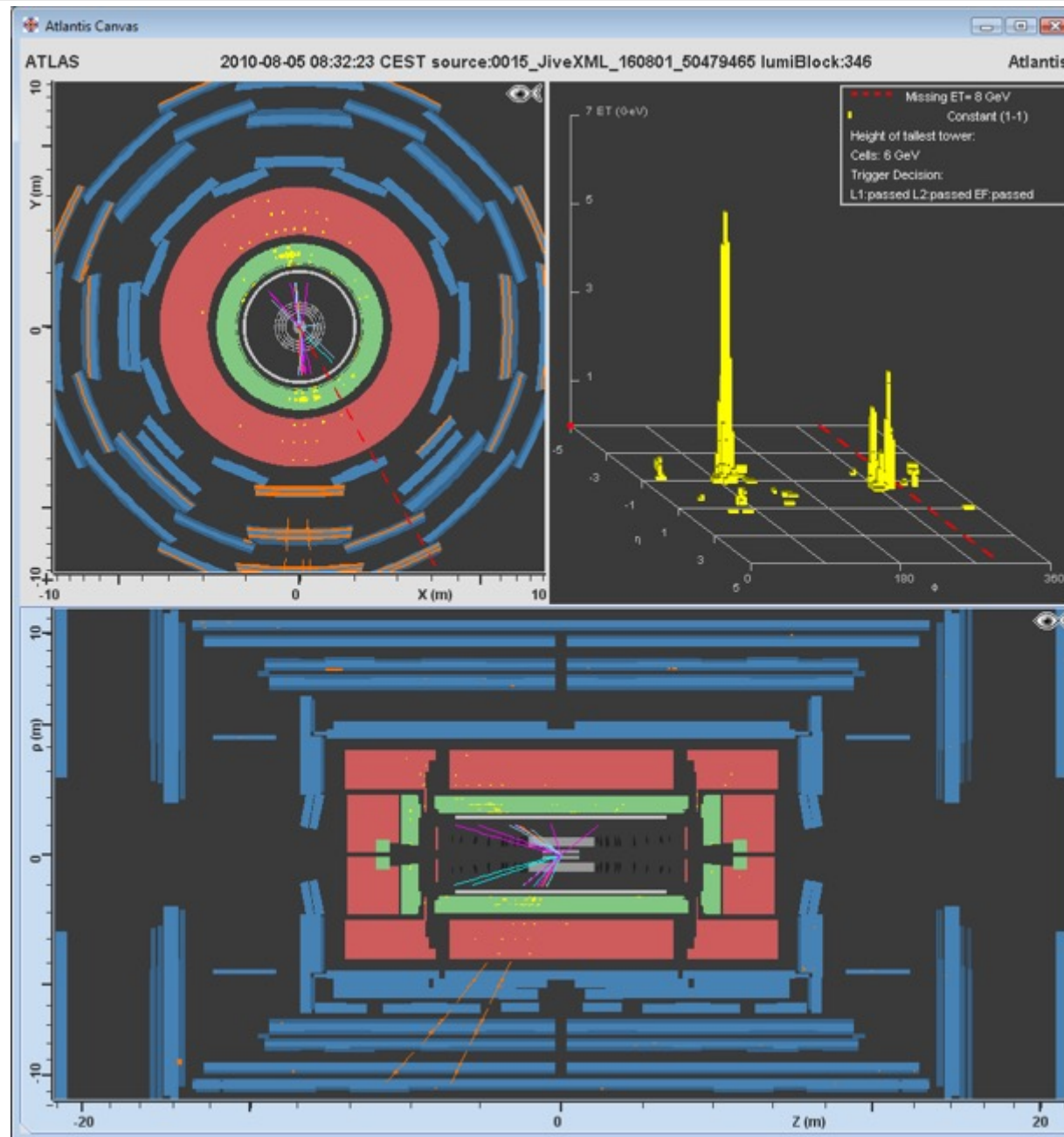
Identikit: fotoni



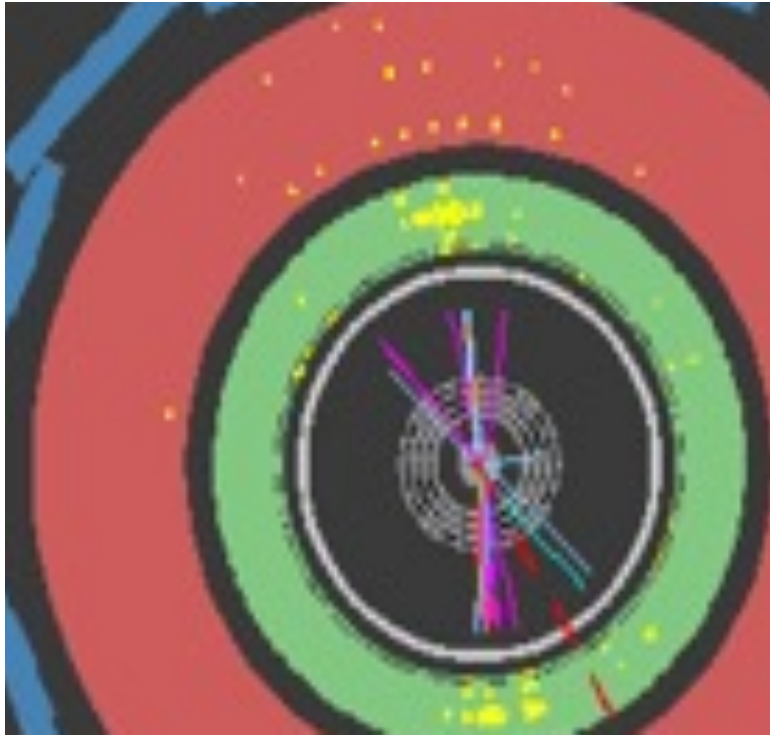
Depositi di energia nel calorimetro elettromagnetico senza tracce associate



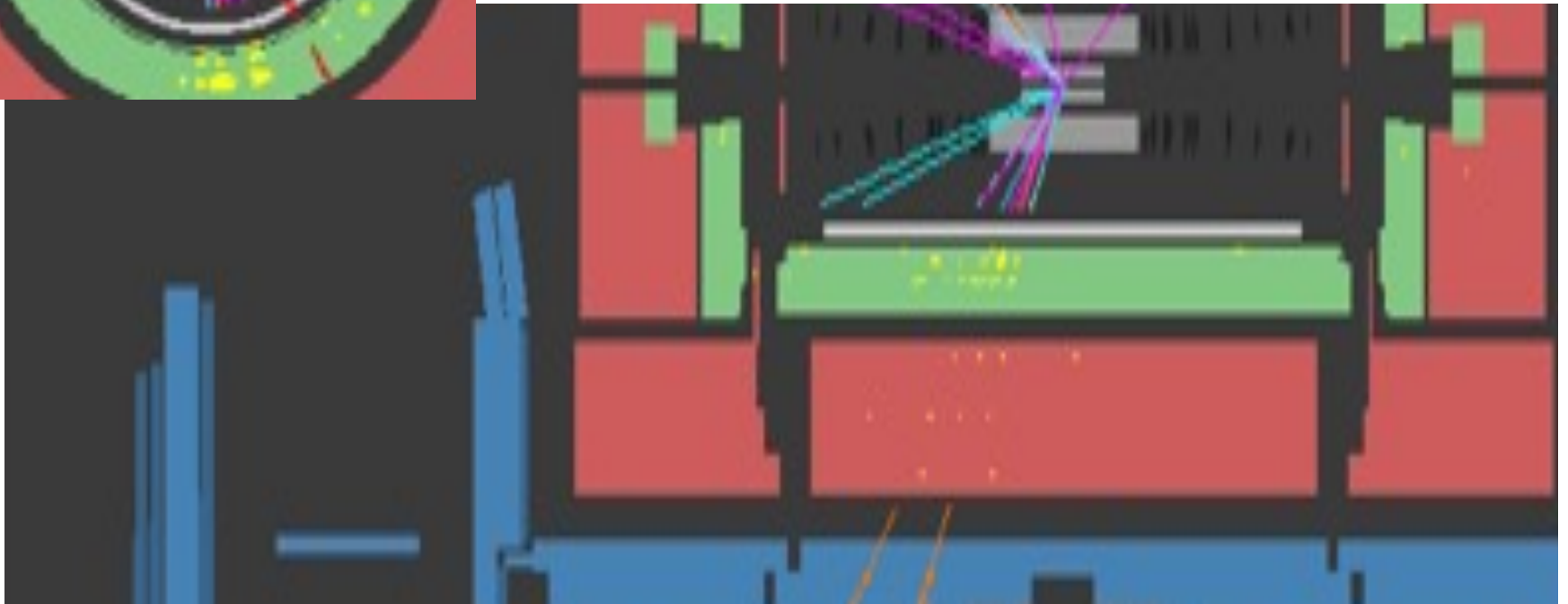
Identikit: jets



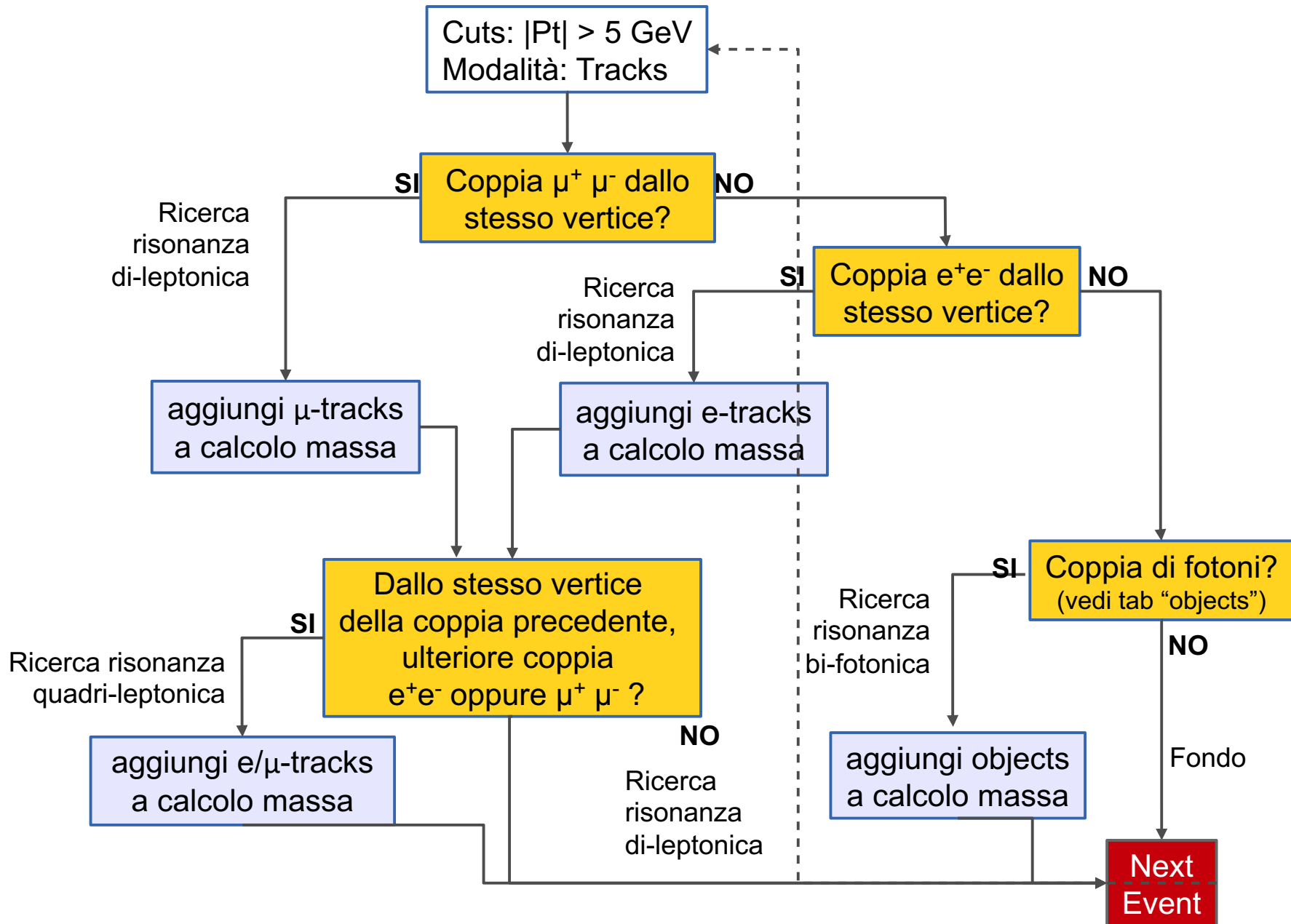
Identikit: jets



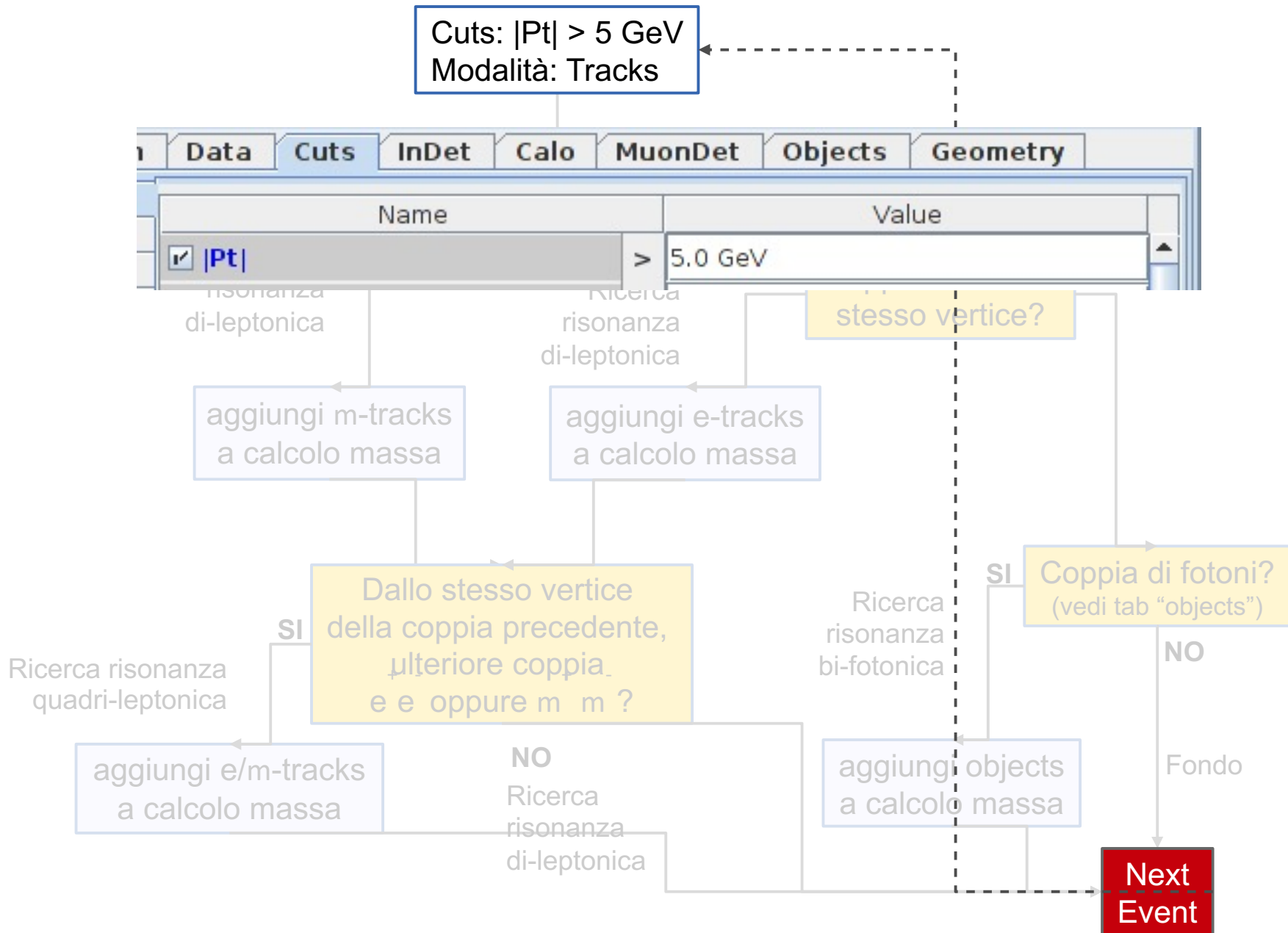
“Fascio” di tracce che puntano a depositi di energia in entrambi i tipi di calorimetri



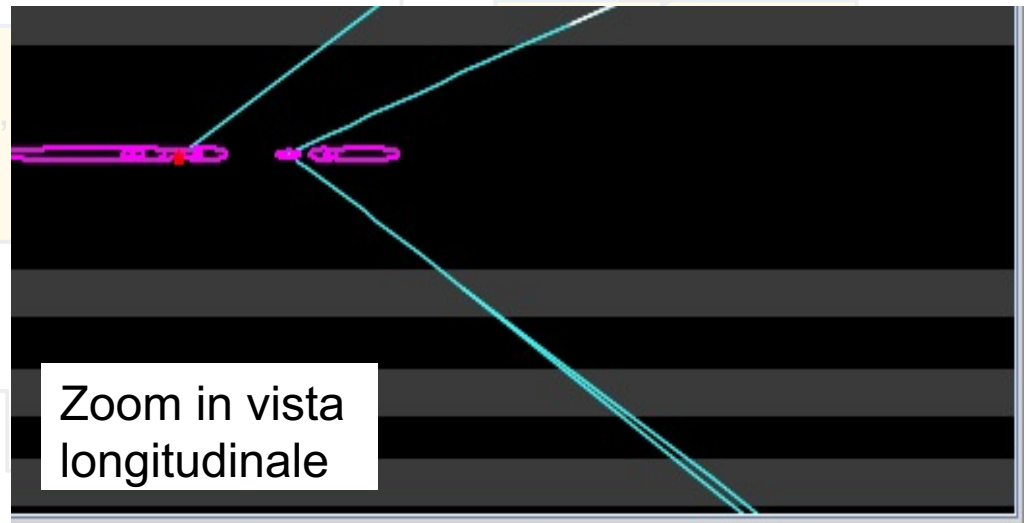
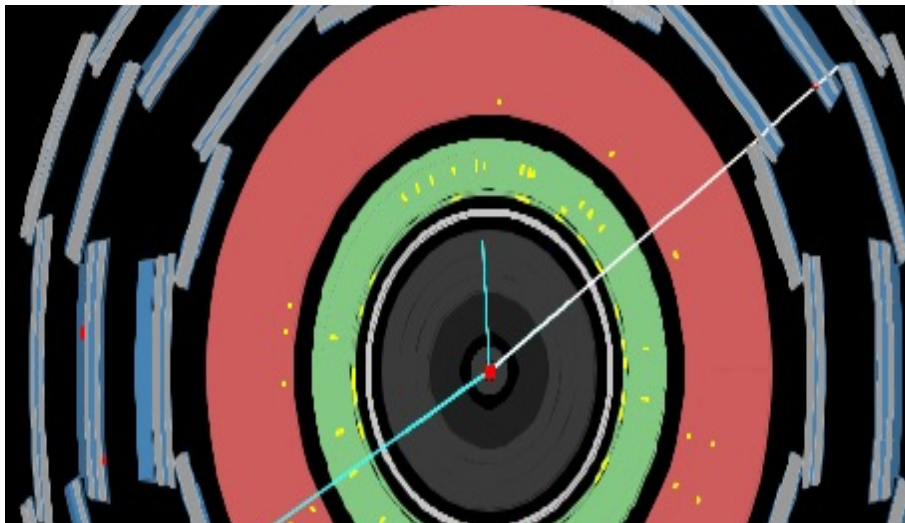
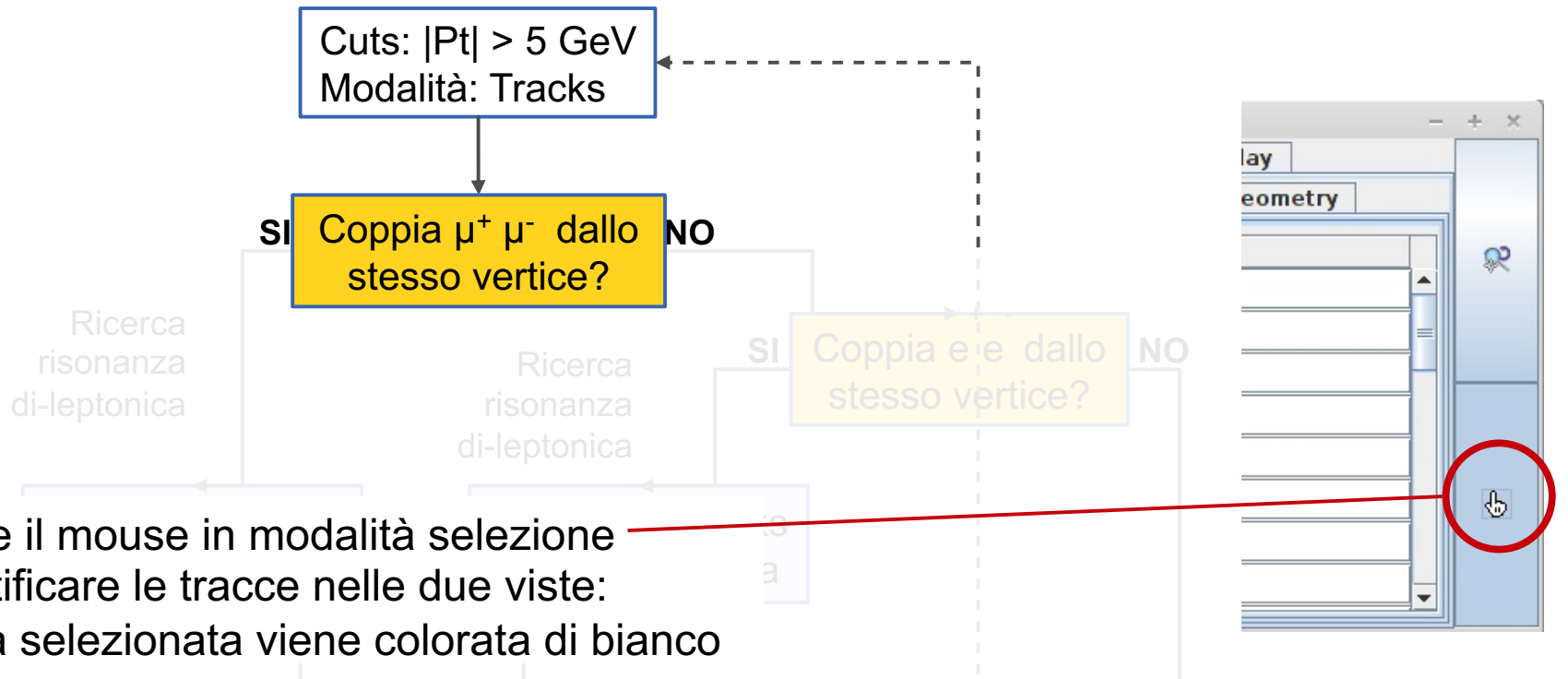
Piano di lavoro: flow chart



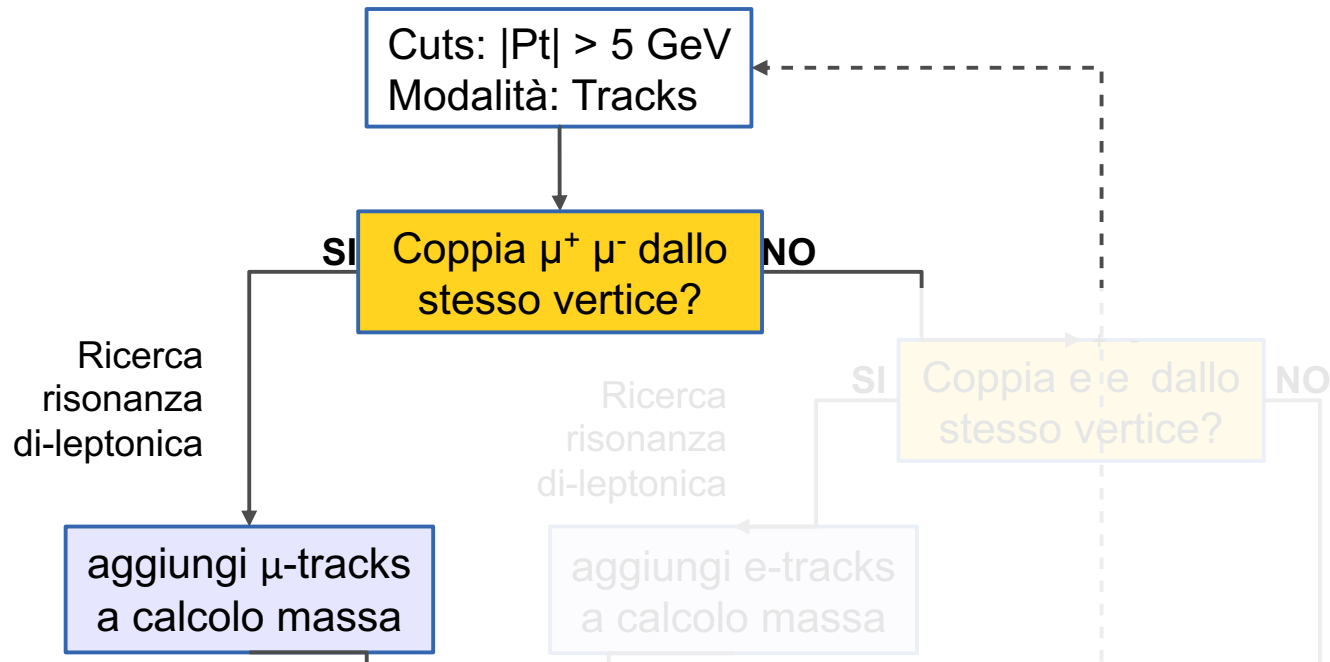
Piano di lavoro: flow chart



Piano di lavoro: flow chart



Piano di lavoro: flow chart



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

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	φ	η	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	1.291	

Previous Event Next Event Electron **Muon** Photon Delete Track Reset Canvas

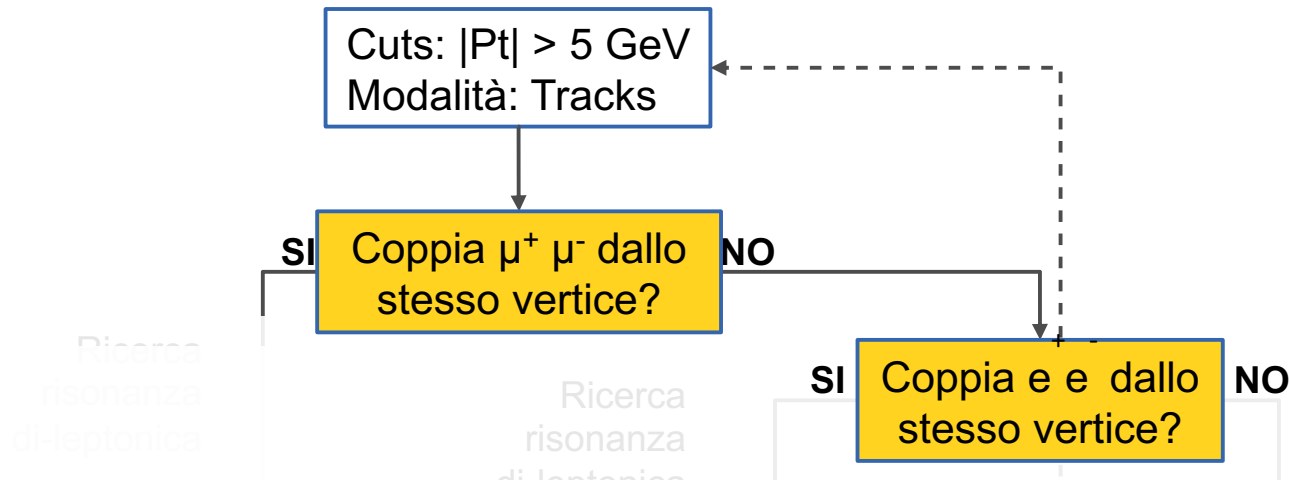
ETMis: 7.369 GeV φ: 2.796 rad Collection: MET_RefFinal

/home/negri/MasterClasses/exercise2_Z.zip/00007_Exercise2.xml

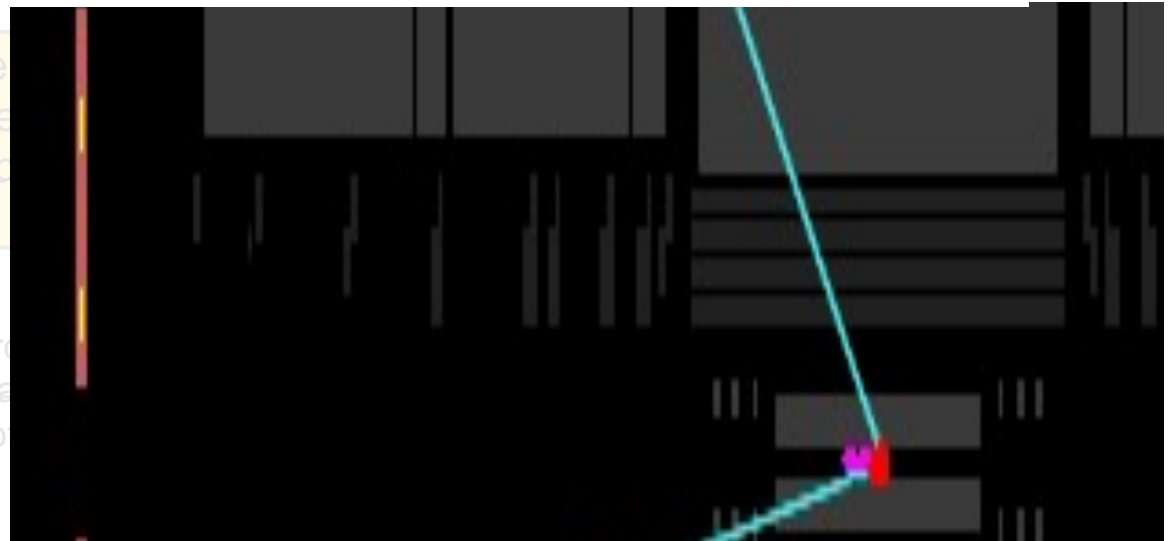
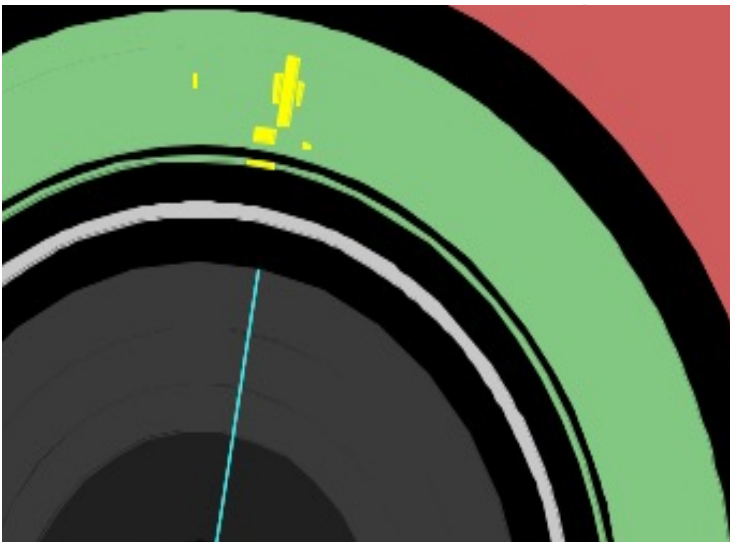
Tracks Physics Objects

Track	+/-	P [GeV]	Pt [GeV]	φ	θ
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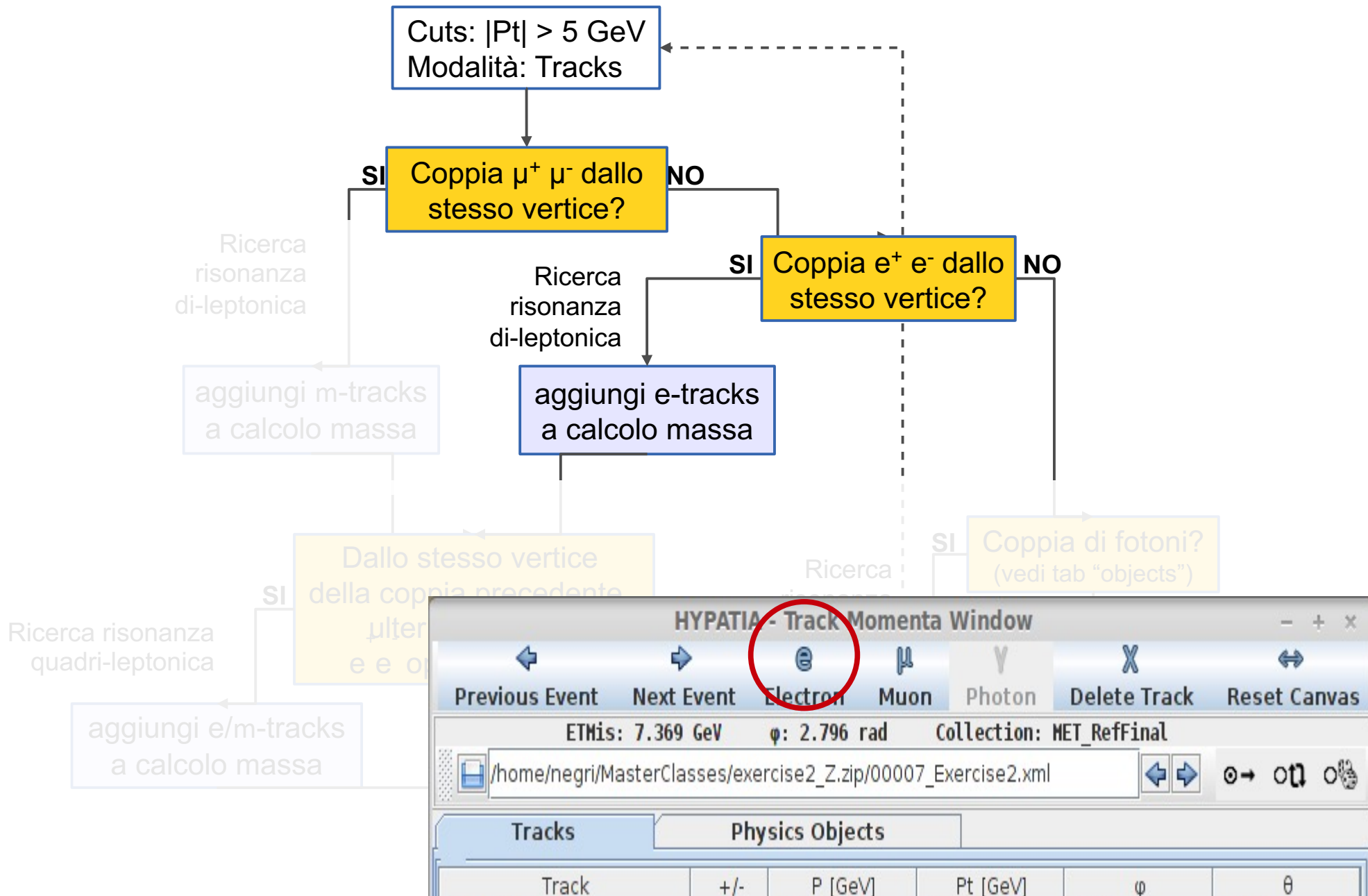
Piano di lavoro: flow chart



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



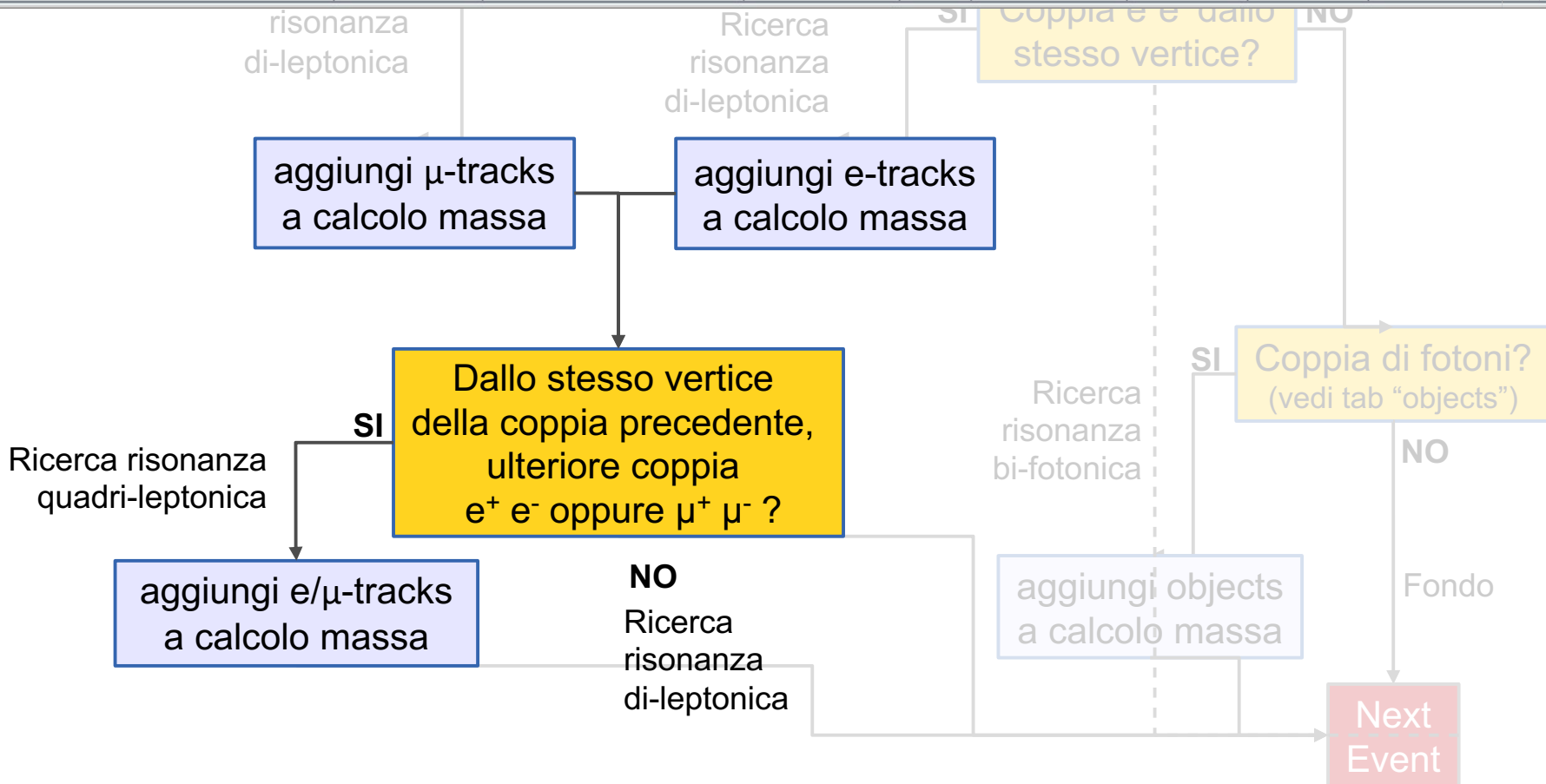
Piano di lavoro: flow chart



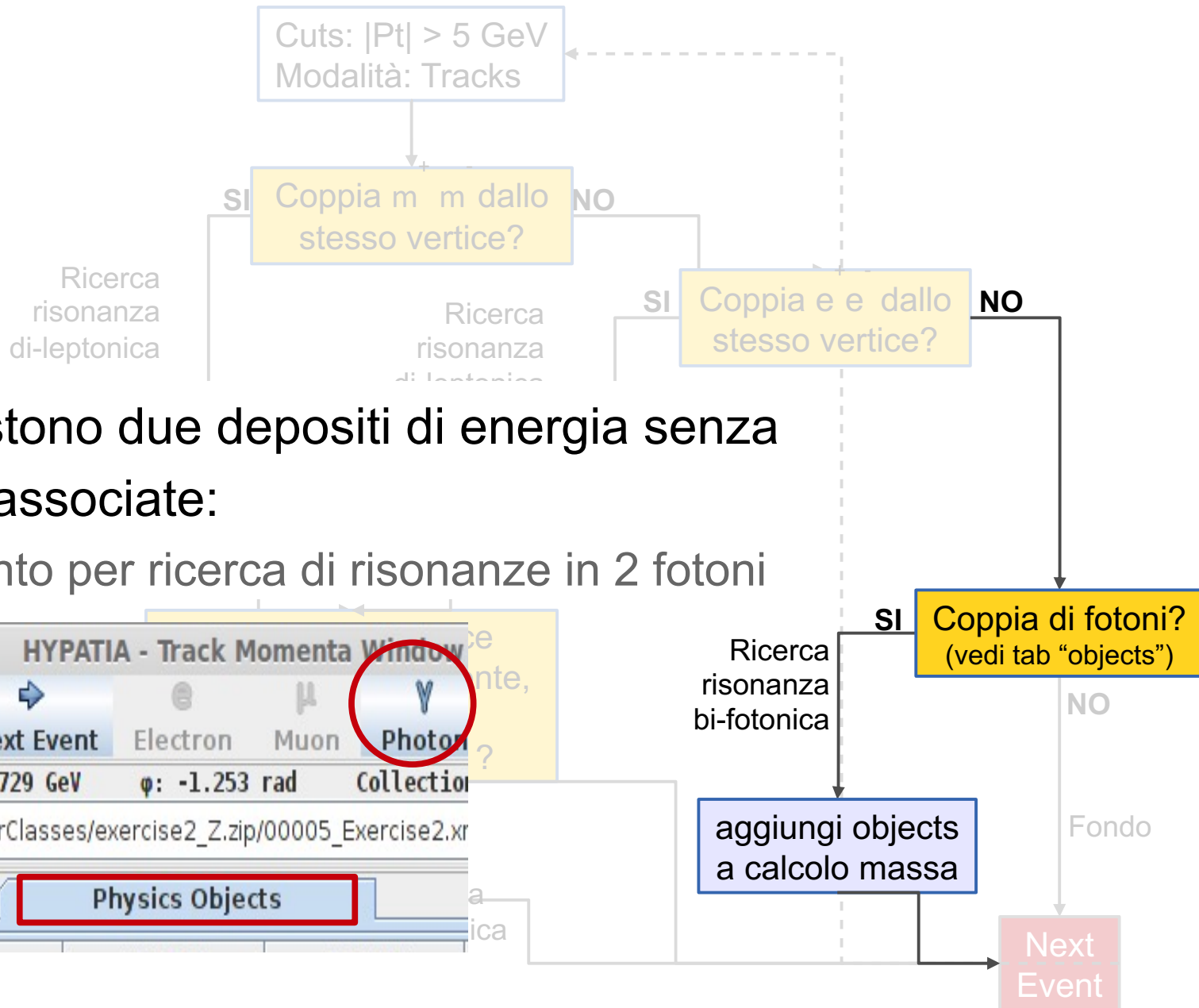
Piano di lavoro: flow chart

Cuts: $|Pt| > 5$ GeV
Modalità: Tracks

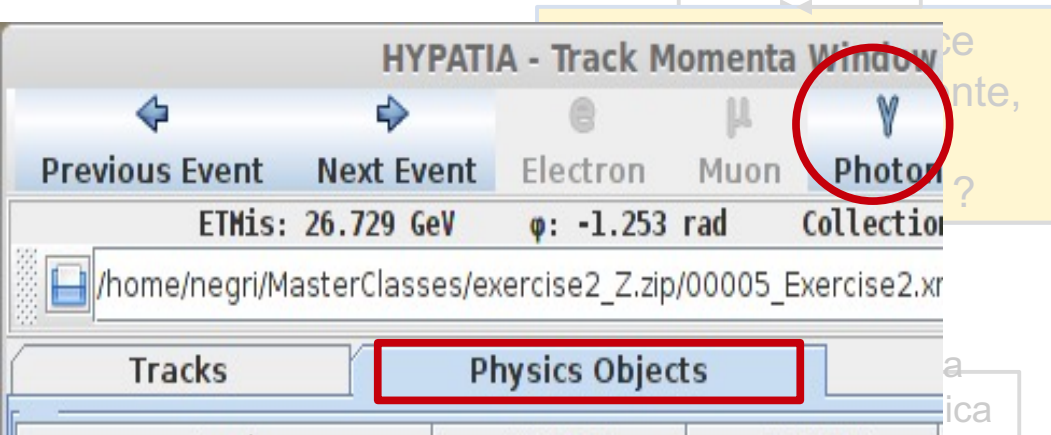
HYbrid Pupils' Analysis Tool for Interactions in ATLAS - version 7.4 - Invariant Mass Window									
File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	φ	η	M(2) [GeV]	
event046.xml	37.975	Tracks 2	108.7	-	58.0	1.525	1.242	90.333	
		Tracks 21	43.4	+	41.7	2.277	-0.289		
		Tracks 4	98.8	+	61.2	-2.171	-1.058	91.492	
		Tracks 10	136.9	-	39.2	-0.248	-1.922		



Piano di lavoro: flow chart



- Se esistono due depositi di energia senza tracce associate:
 - evento per ricerca di risonanze in 2 fotoni



Alla fine dei 50 eventi



Aprire il link:

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Alla fine dei 50 eventi



Caricare il file “Invariant_masses.txt”
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