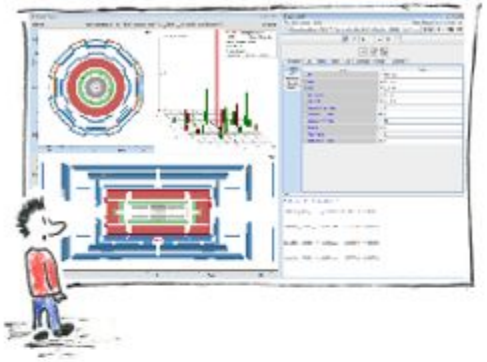
Ćwiczenie W

Krzysztof Cieśla

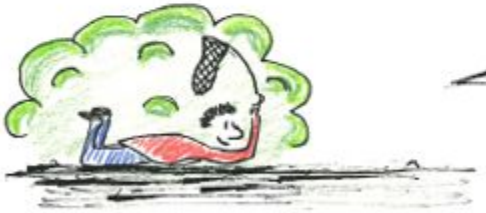
Warsztaty ATLAS Masterclasses
20 Lutego 2025

Cel ćwiczenia

Identyfikacja cząstek



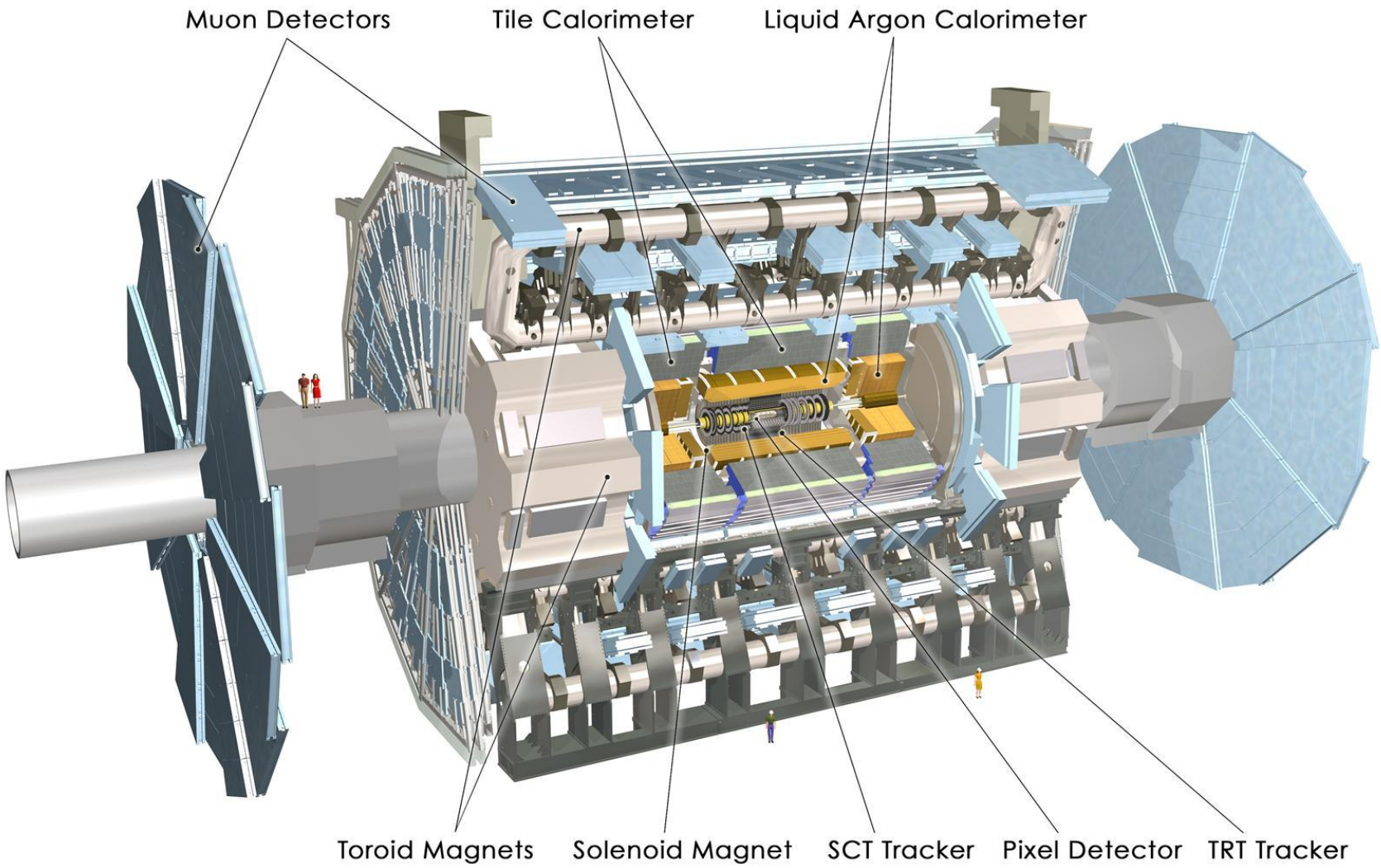
Identyfikacja przypadków



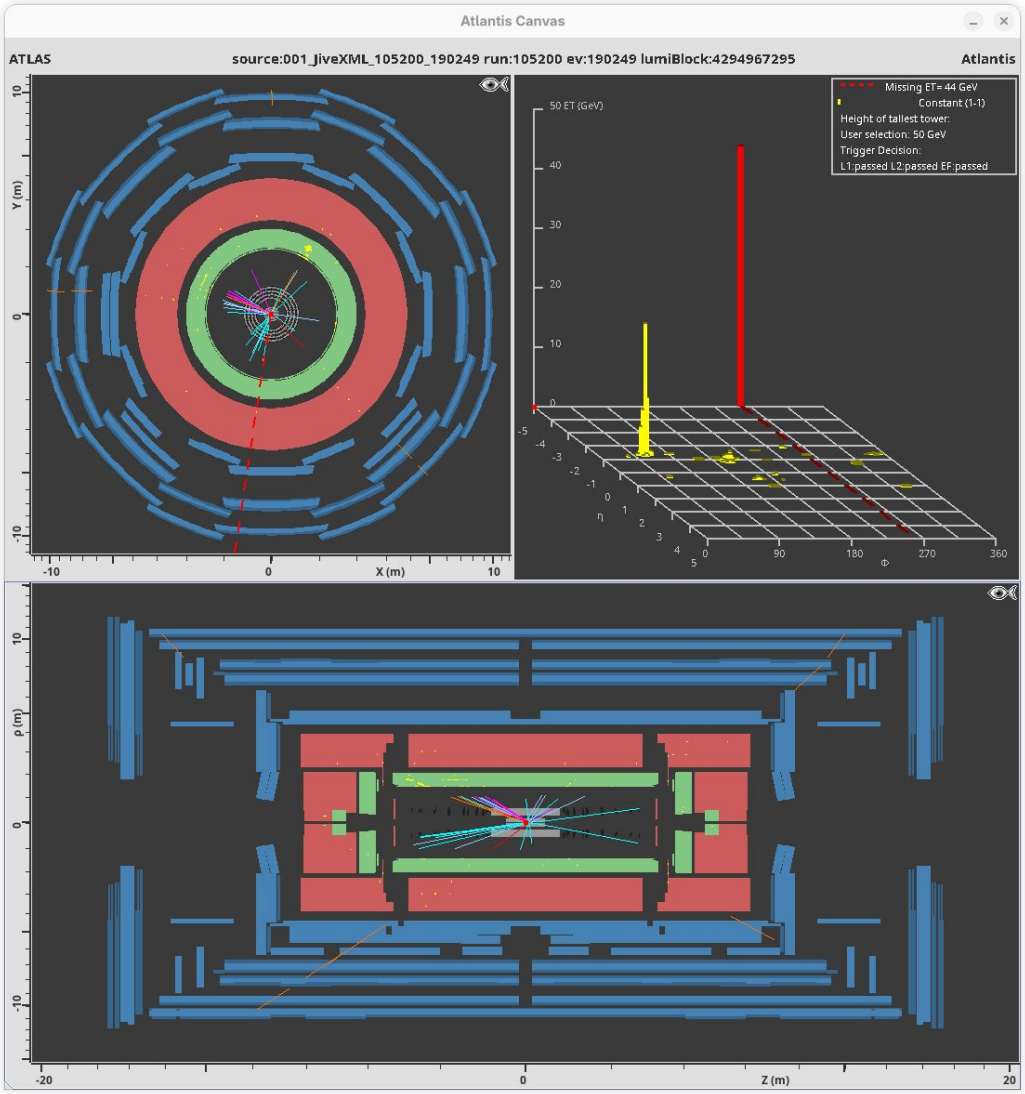
Poszukiwanie bozonu Higgsa

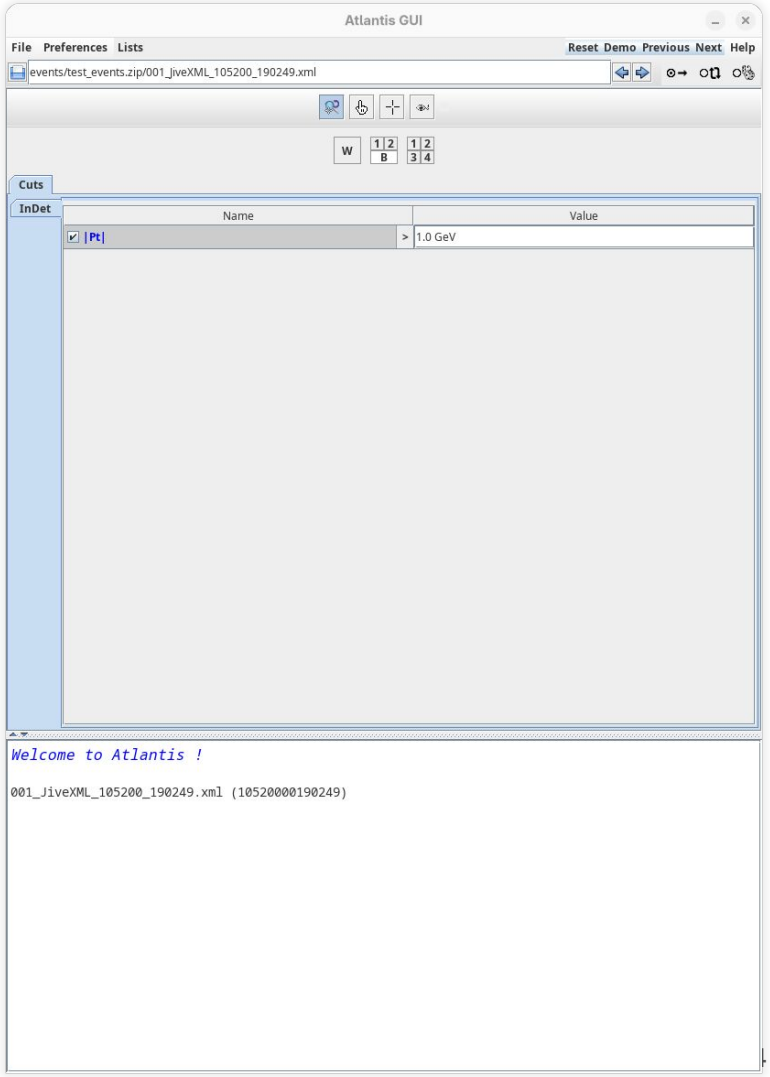
Badanie struktury protonu

Detektor ATLAS

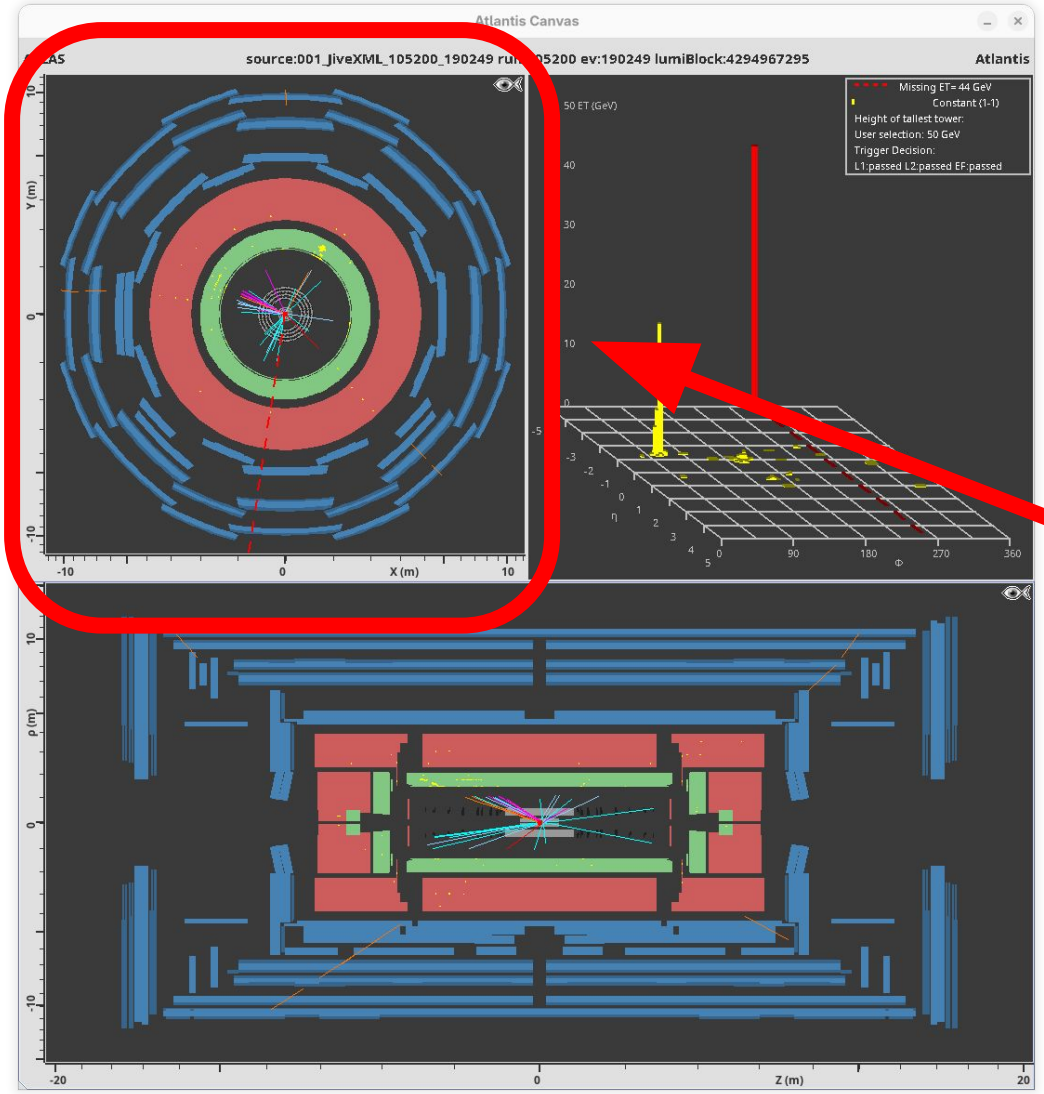


Program MINERVA



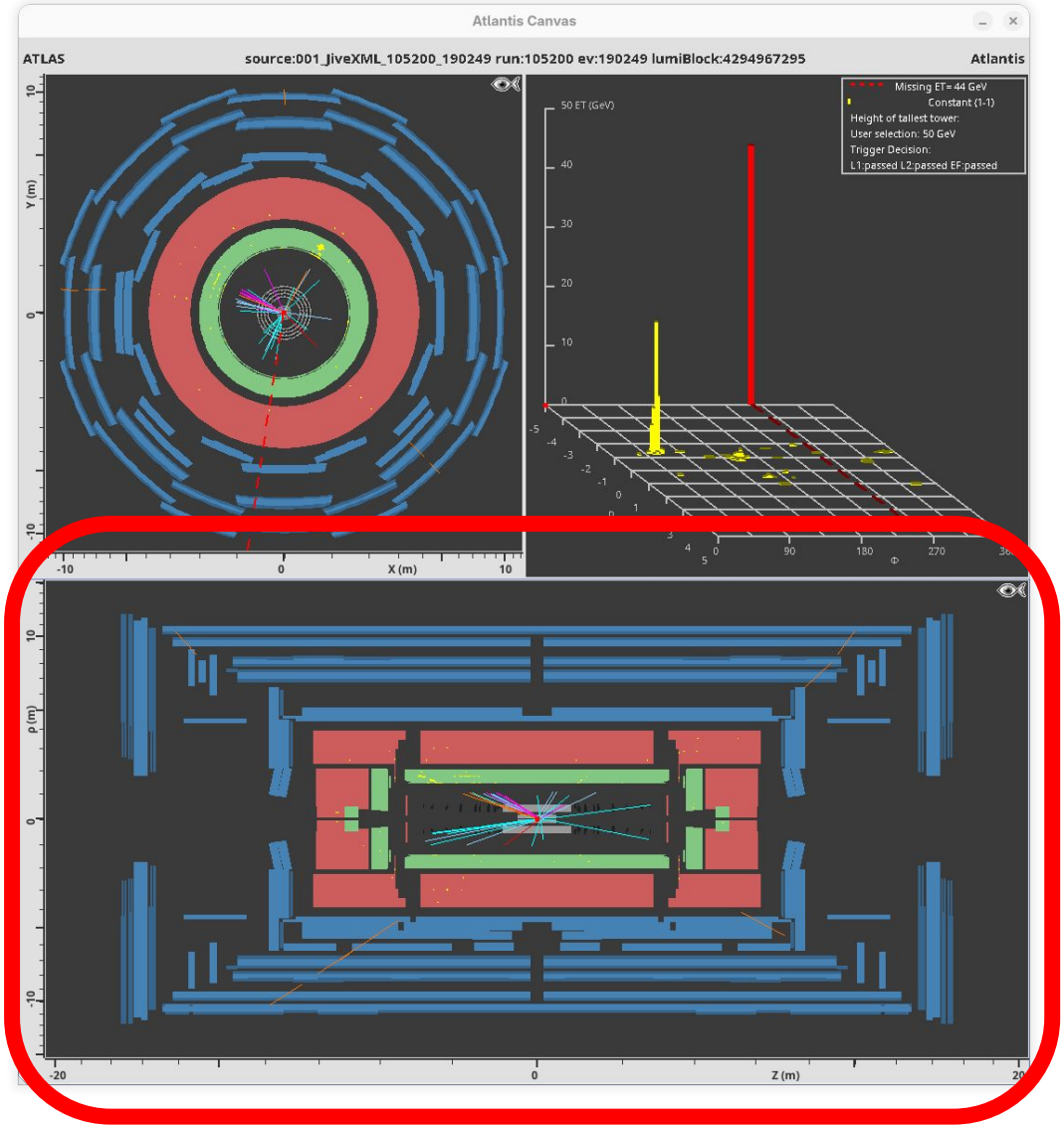


Program MINERVA



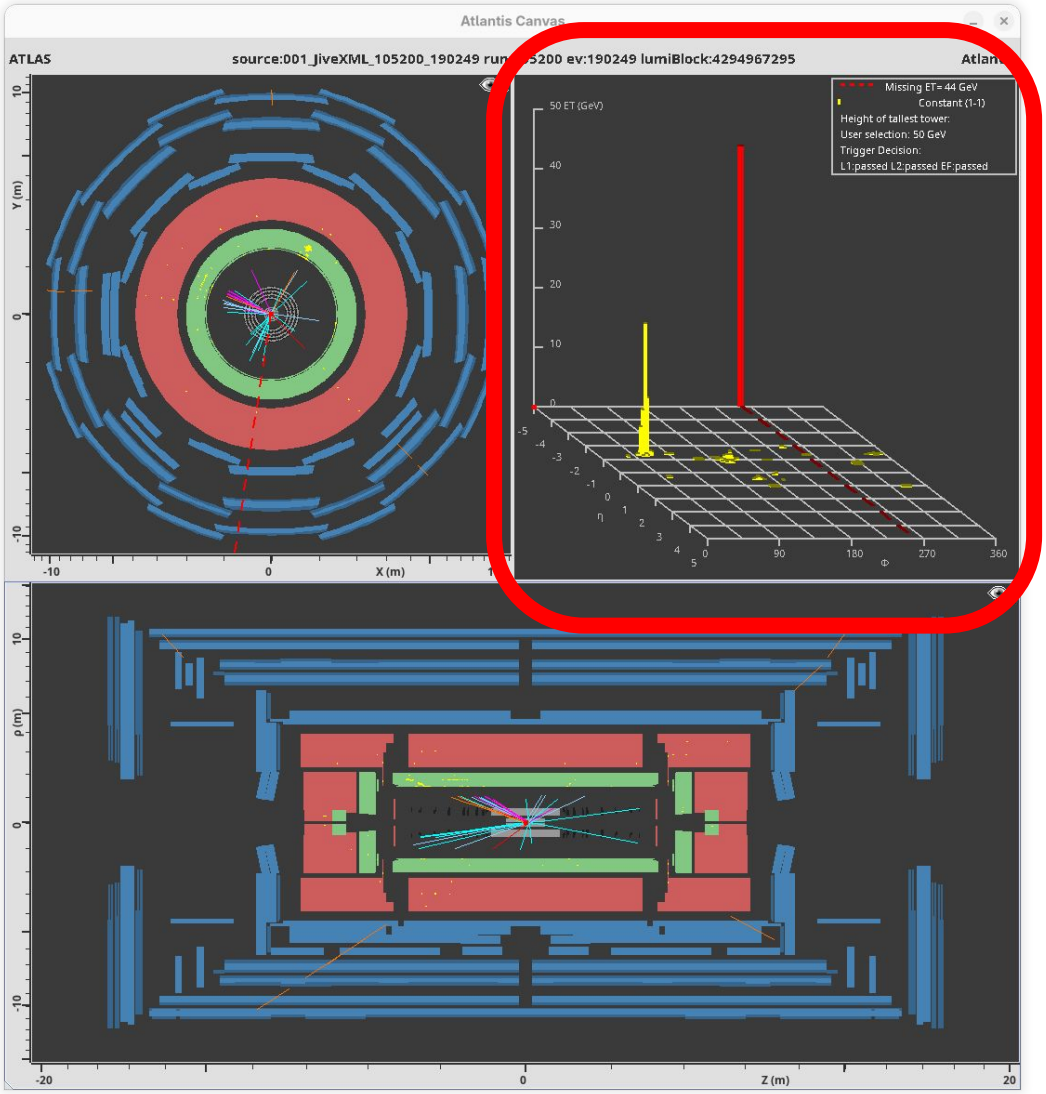
Widok detektora od strony lecącego protonu (rzut na płaszczyznę XY)

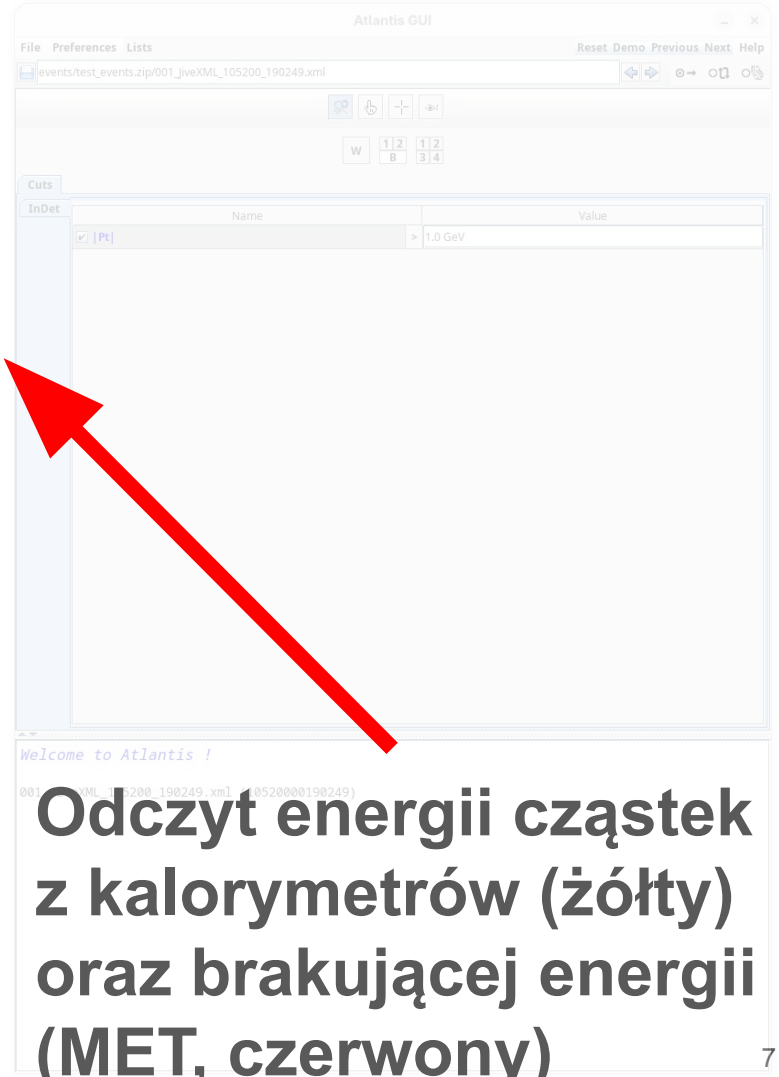
Program MINERVA



Widok na bok detektora (rzut na płaszczyznę ZR)

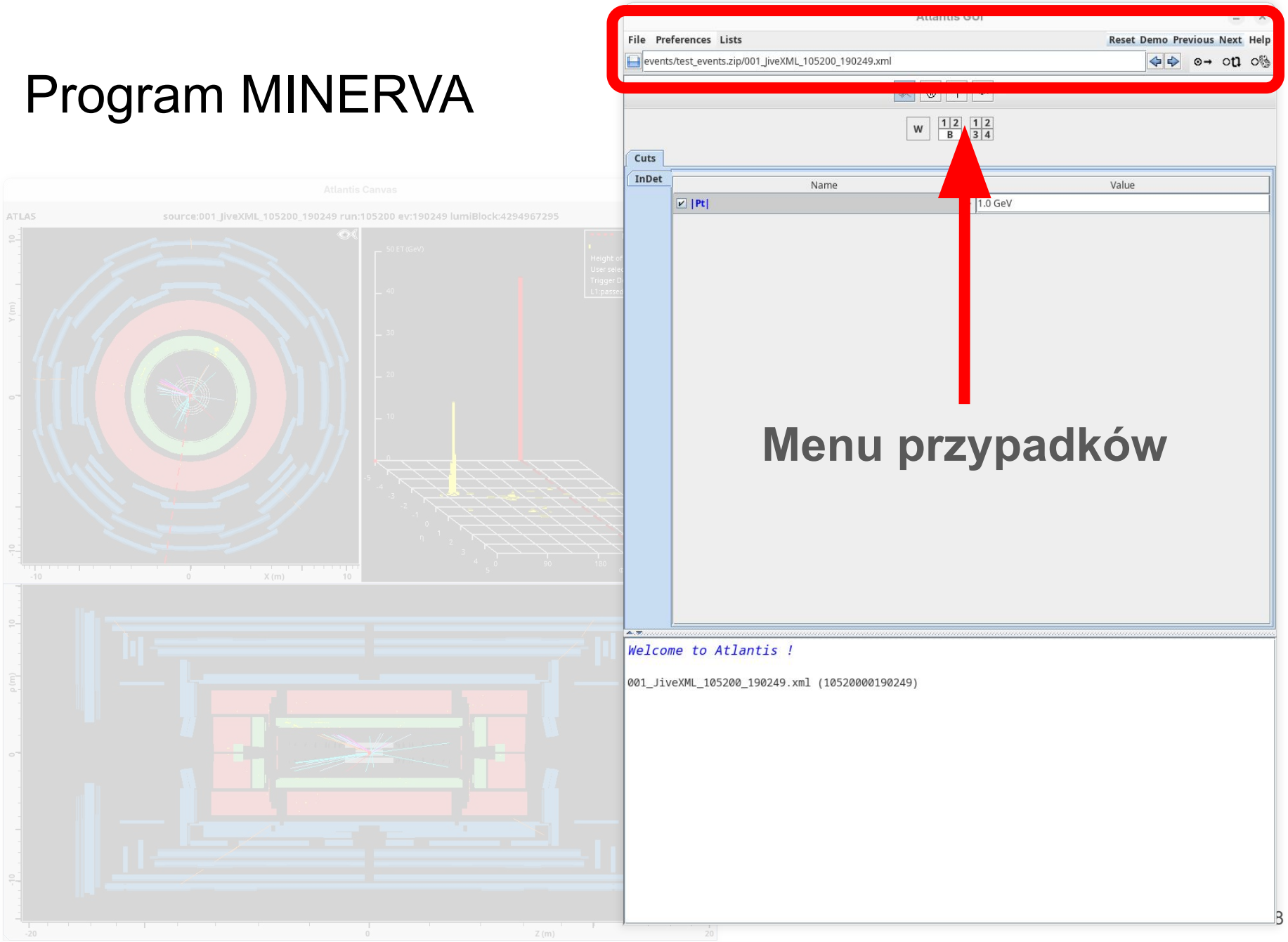
Program MINERVA





Odczyt energii cząstek z kalorymetrów (żółty) oraz brakującej energii (MET, czerwony)

Program MINERVA



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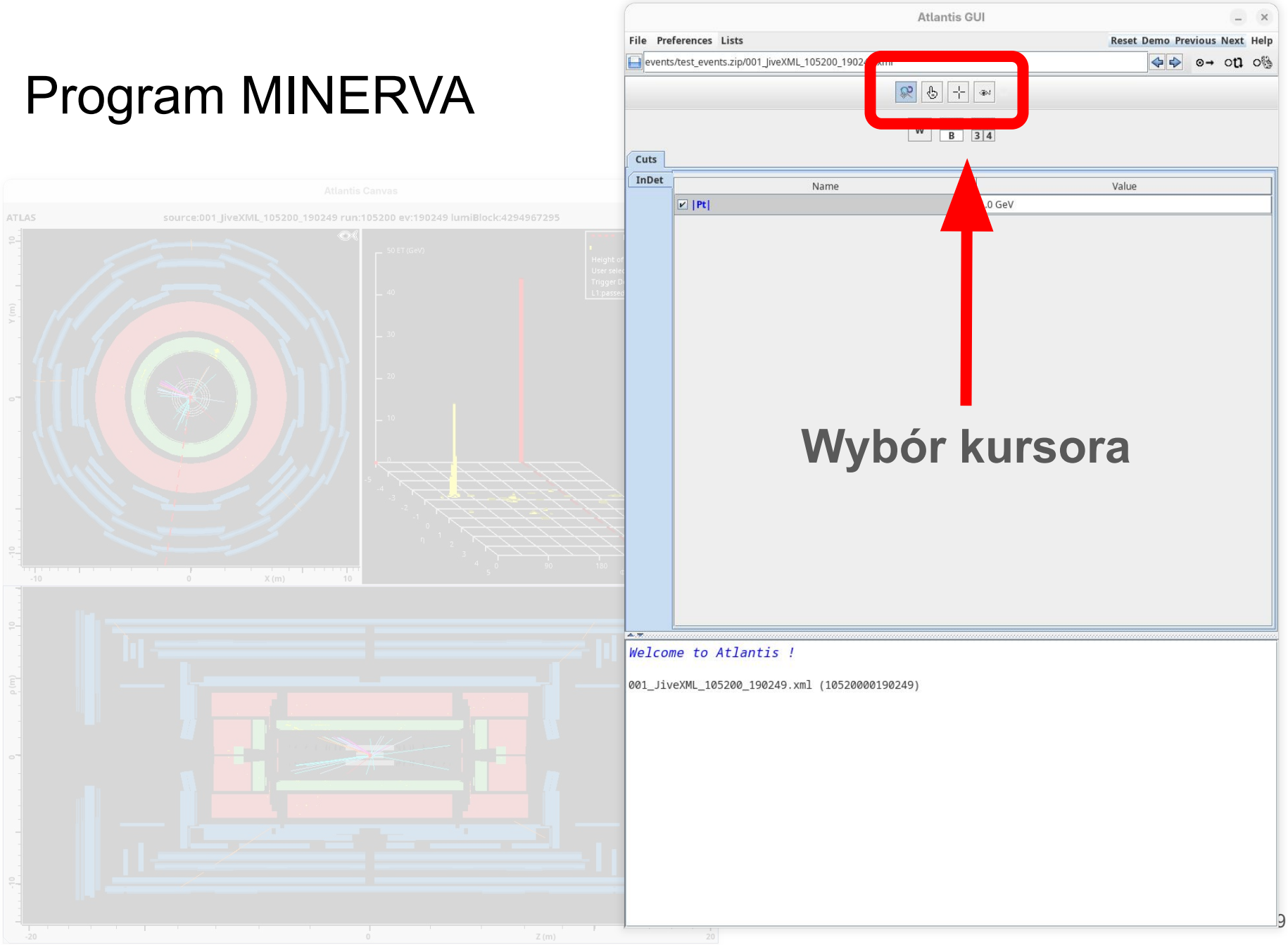
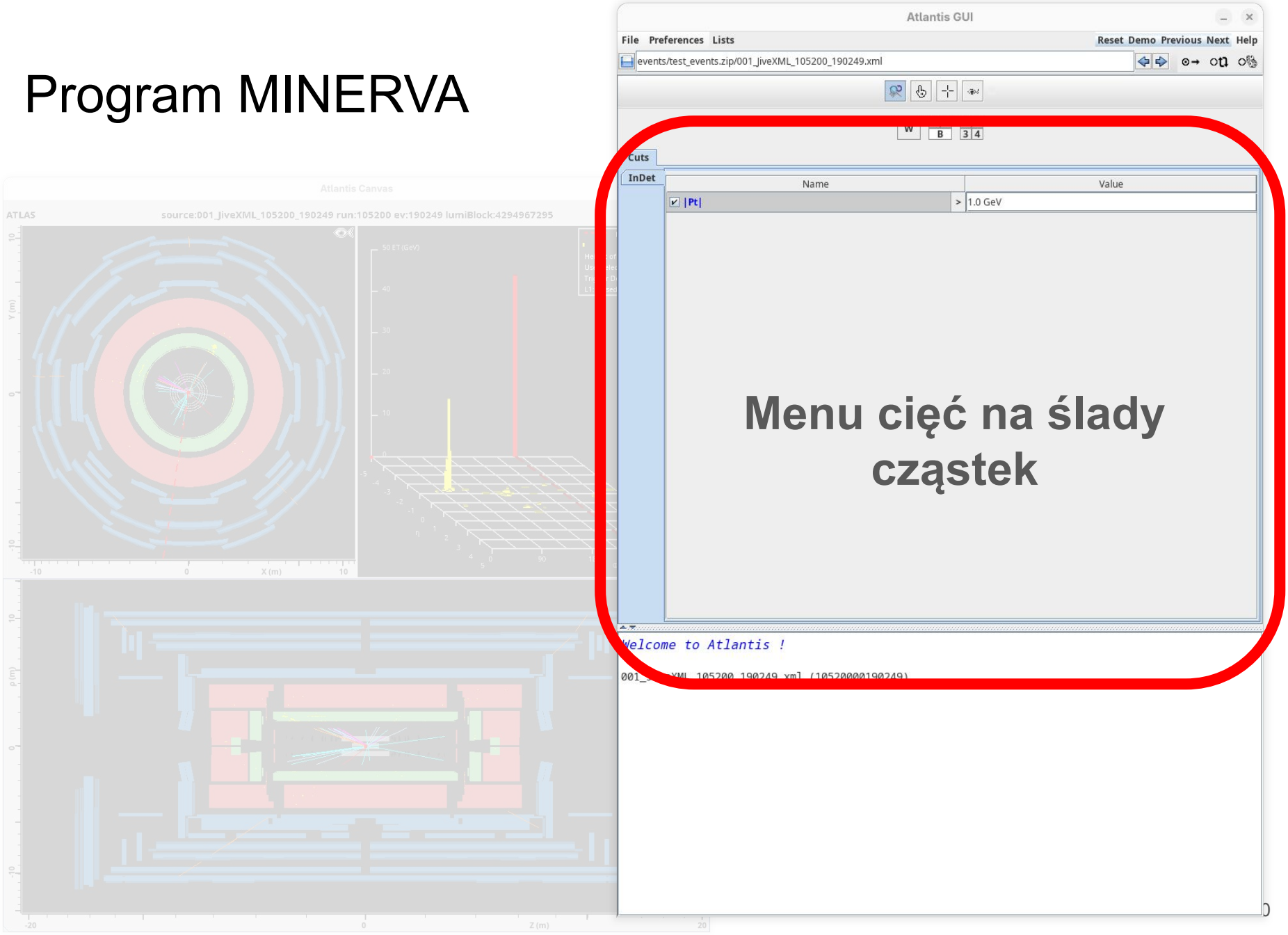
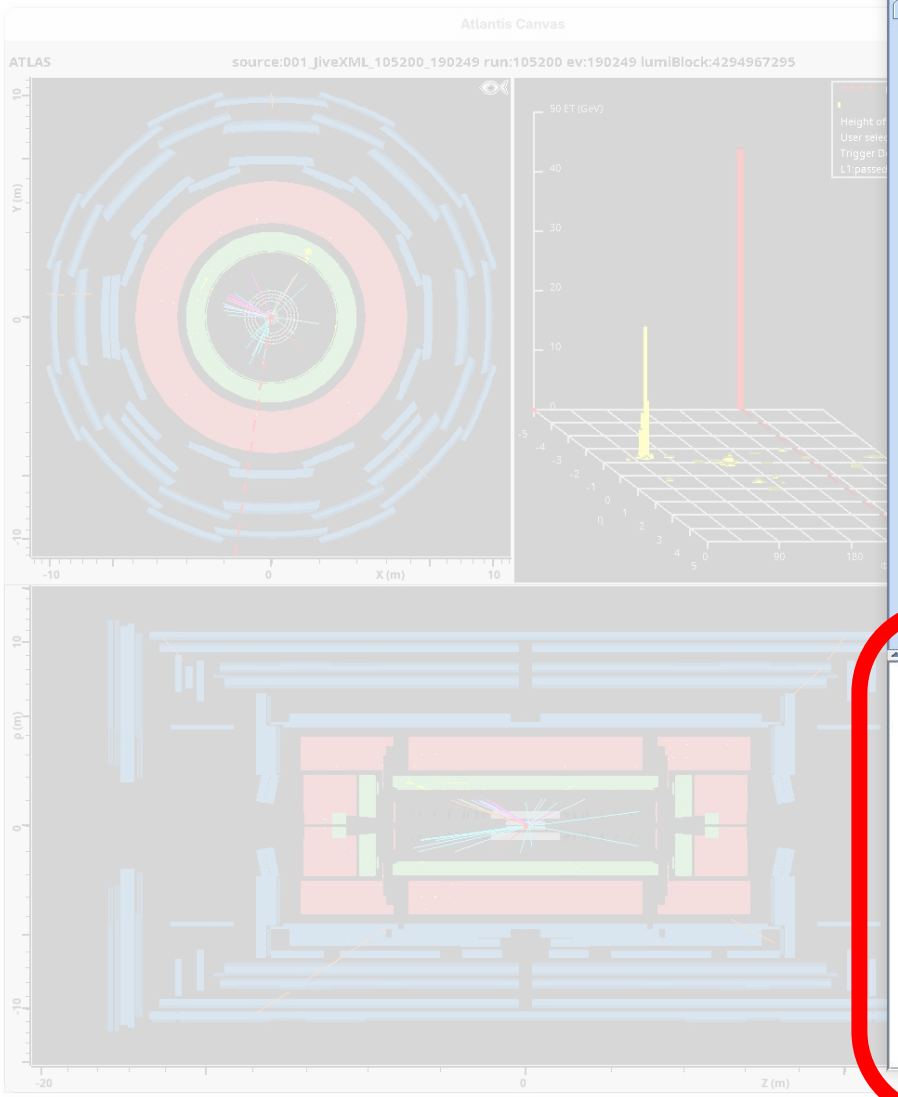
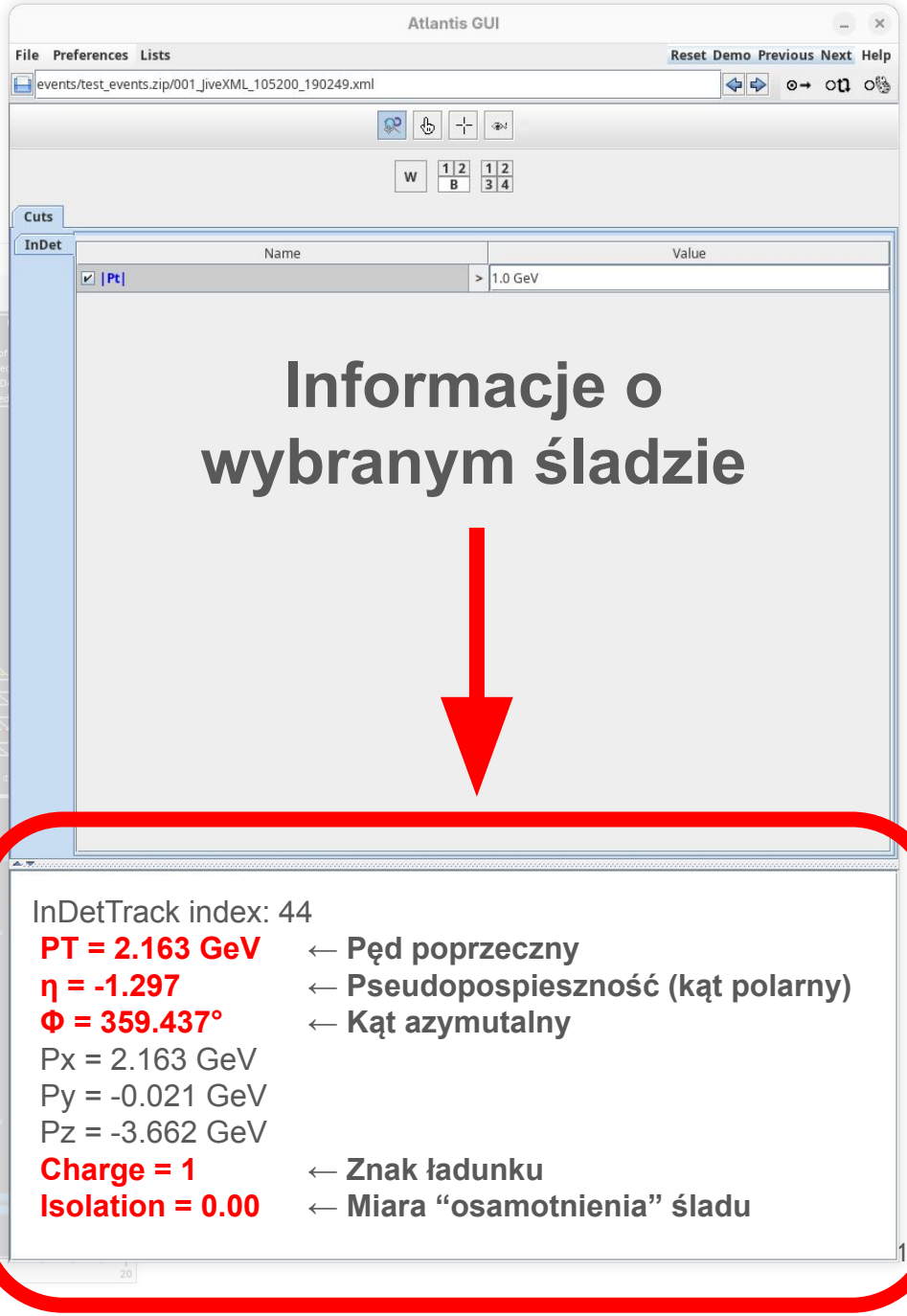


Program MINERVA

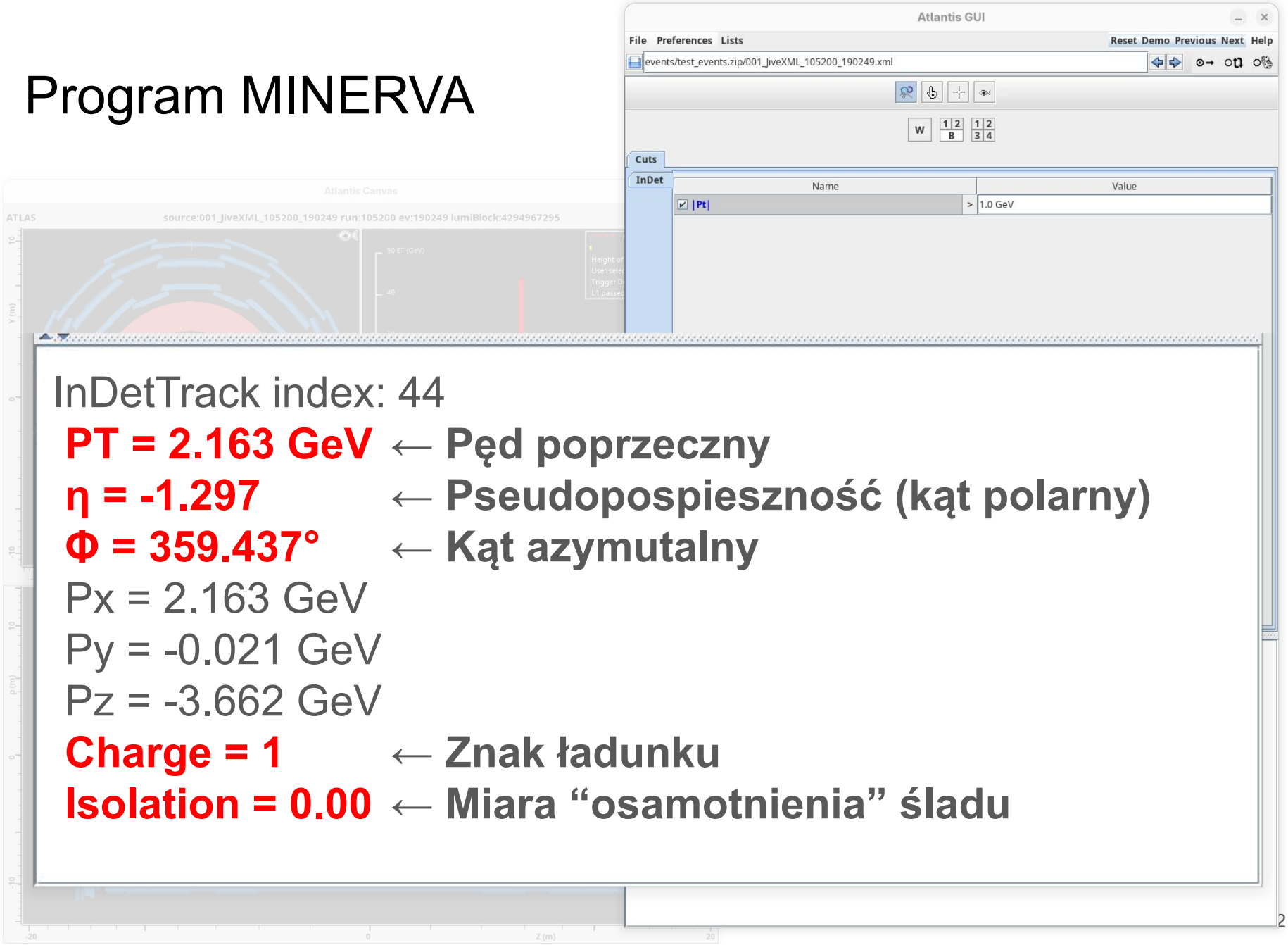


Program MINERVA





Program MINERVA



InDetTrack index: 44

PT = 2.163 GeV ← **Pęd poprzeczny**

η = -1.297 ← **Pseudopospieszność (kąt polarny)**

Φ = 359.437° ← **Kąt azymutalny**

Px = 2.163 GeV

Py = -0.021 GeV

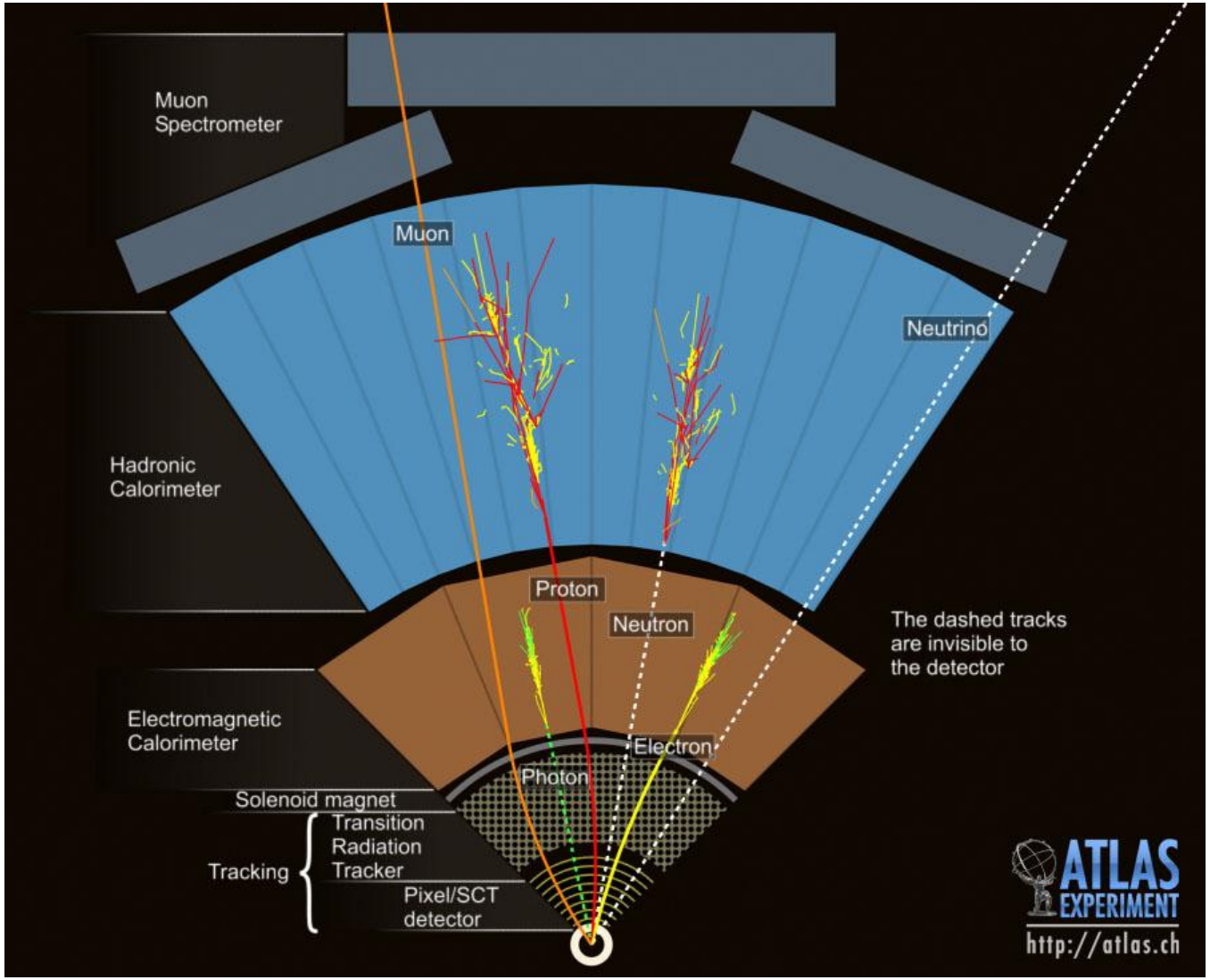
Pz = -3.662 GeV

Charge = 1 ← **Znak ładunku**

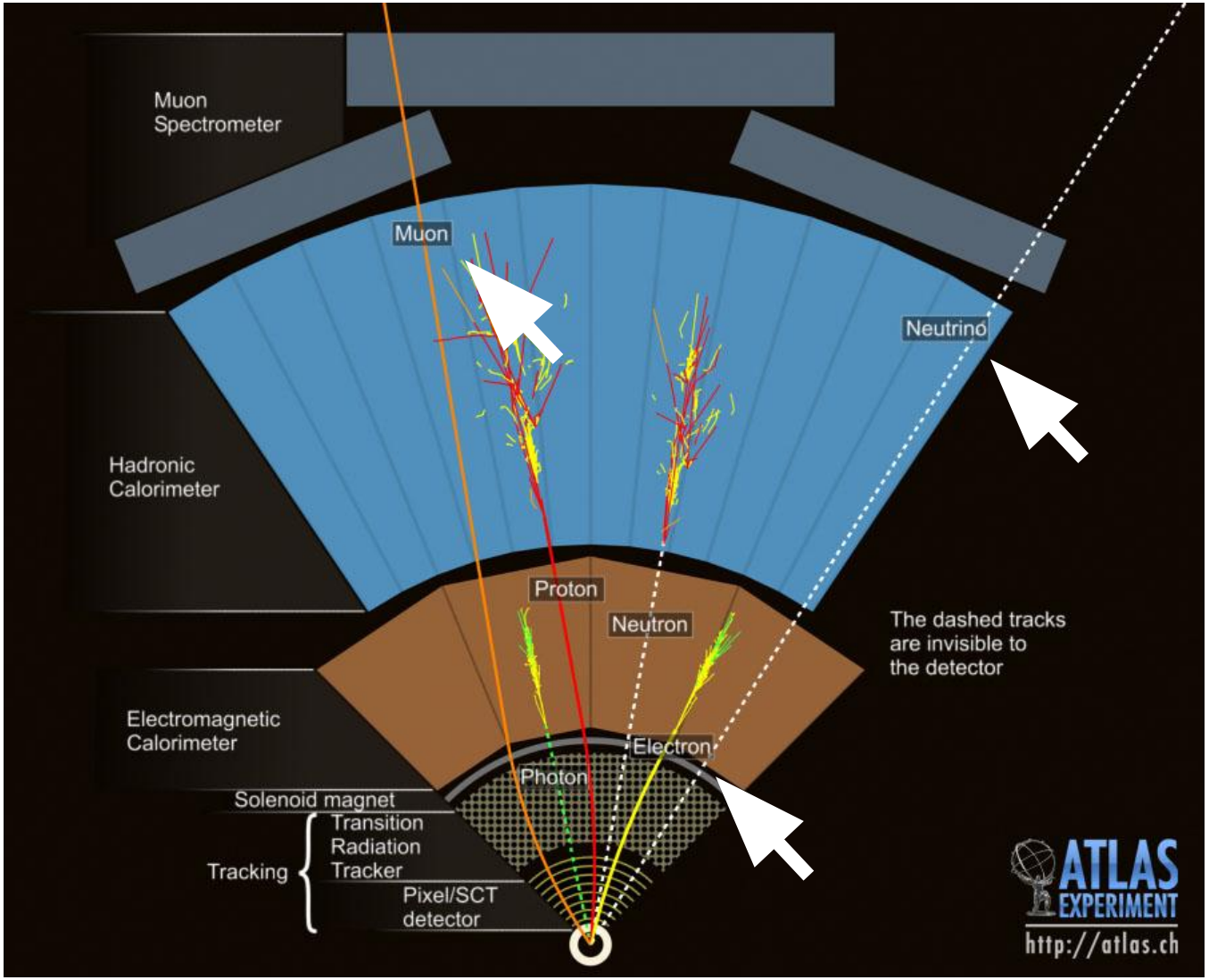
Isolation = 0.00 ← **Miara “osamotnienia” śladu**

Identyfikacja cząstek

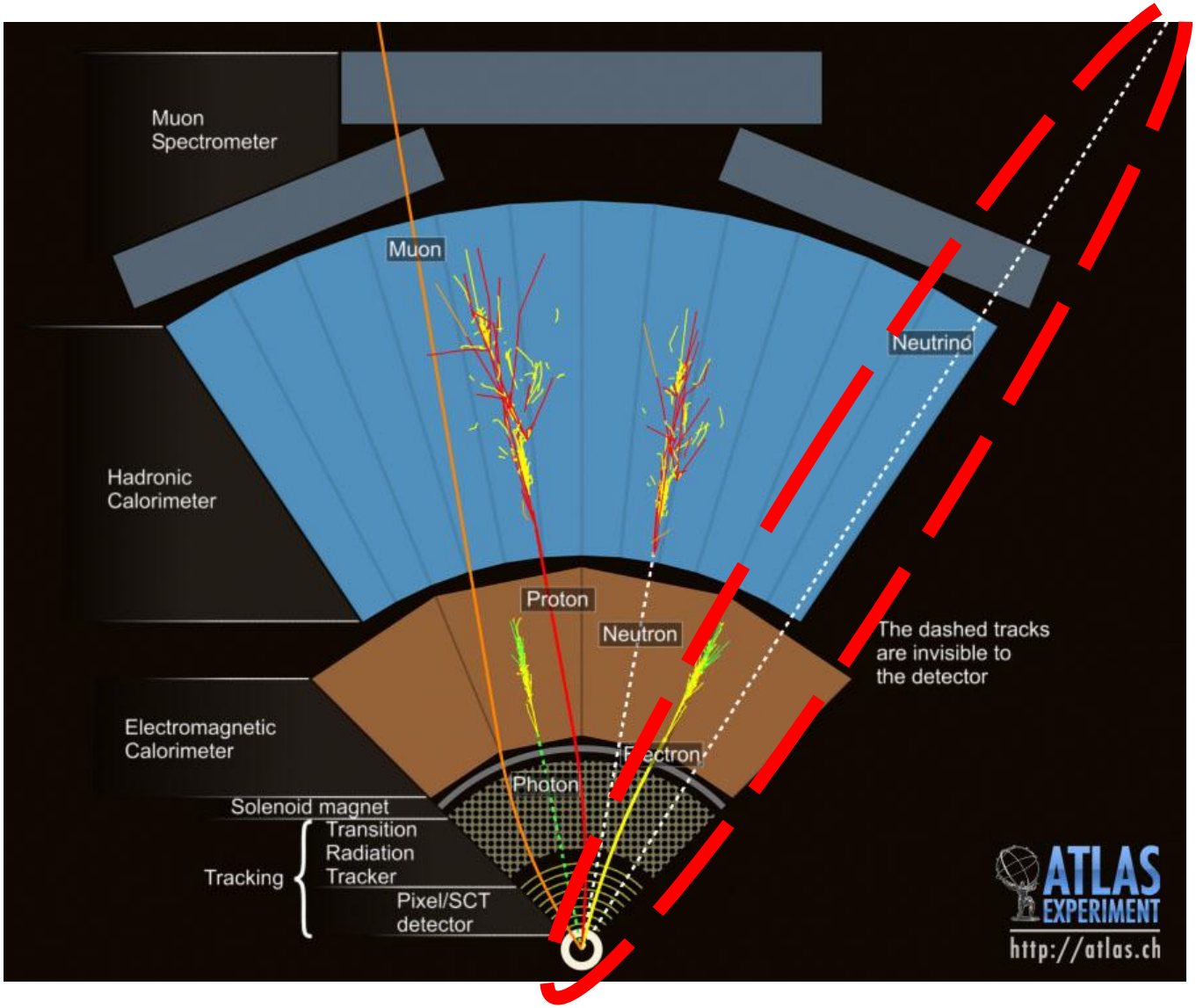
Detekcja i identyfikacja cząstek w ATLASie



Detekcja i identyfikacja cząstek w ATLASie



Detekcja i identyfikacja cząstek – neutrino



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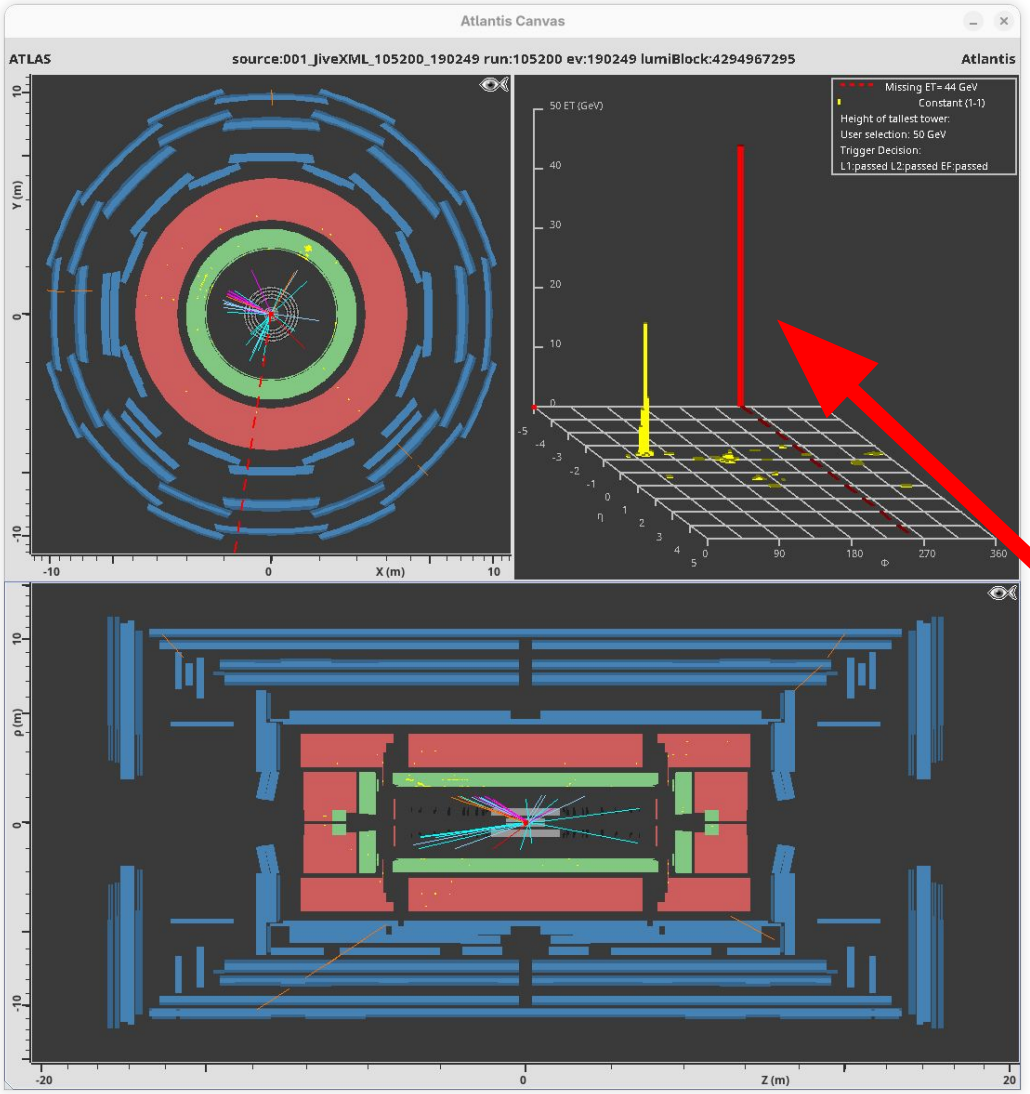
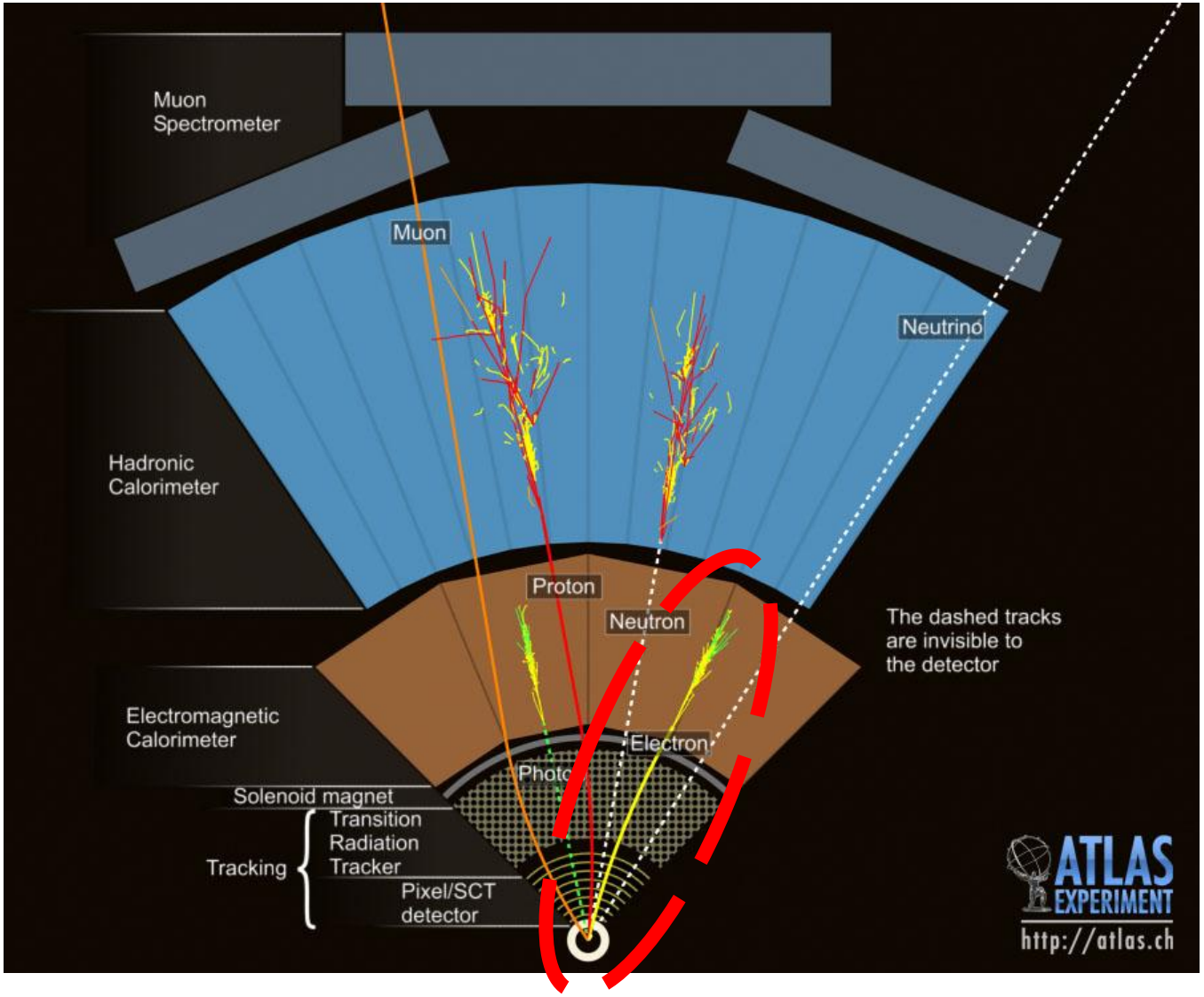


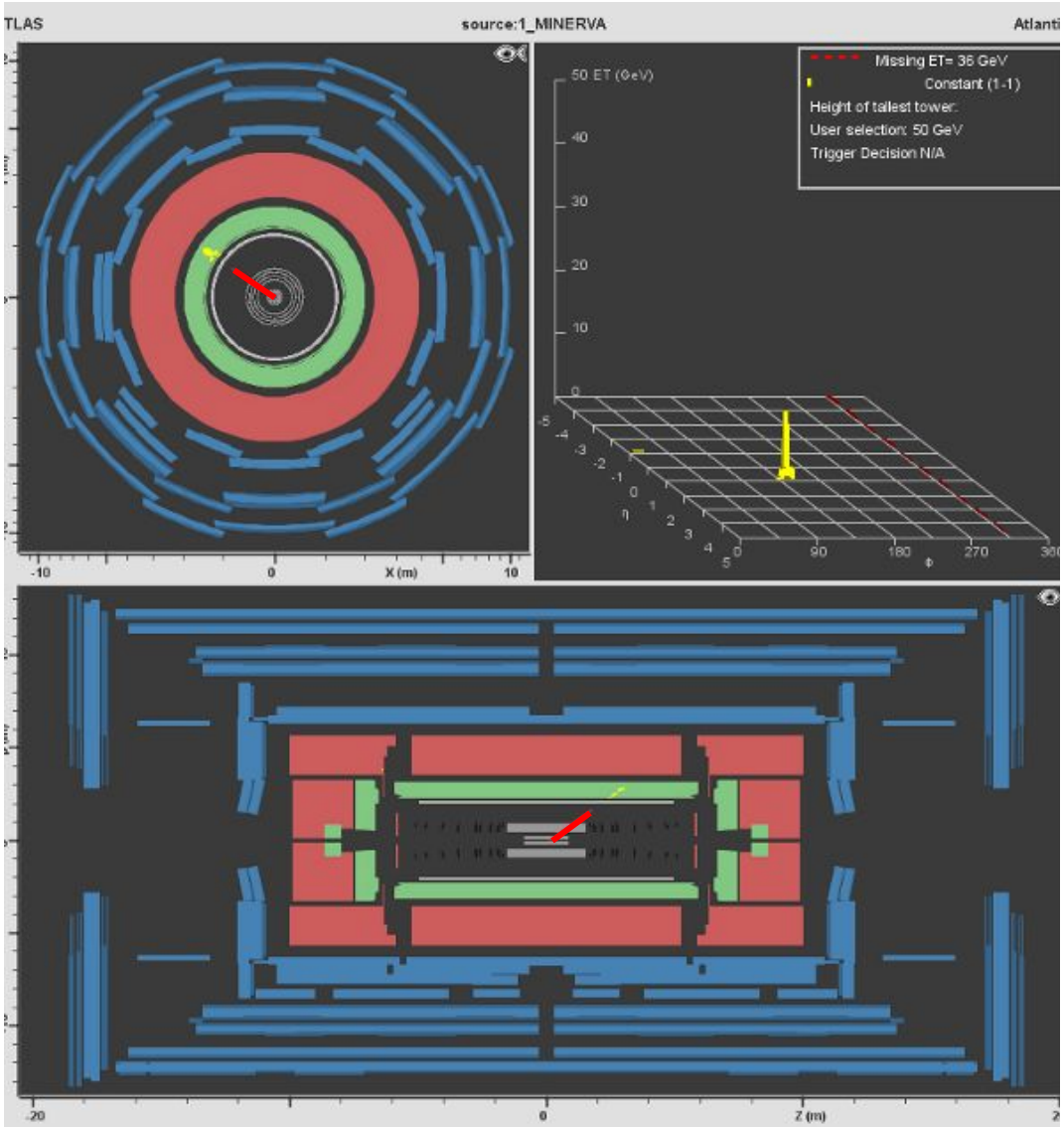
Odczyt energii cząstek z kalorymetrów (żółty) oraz brakującej energii (MET, czerwony)

Duży MET = neutrino

Detekcja i identyfikacja cząstek – elektron/pozyton



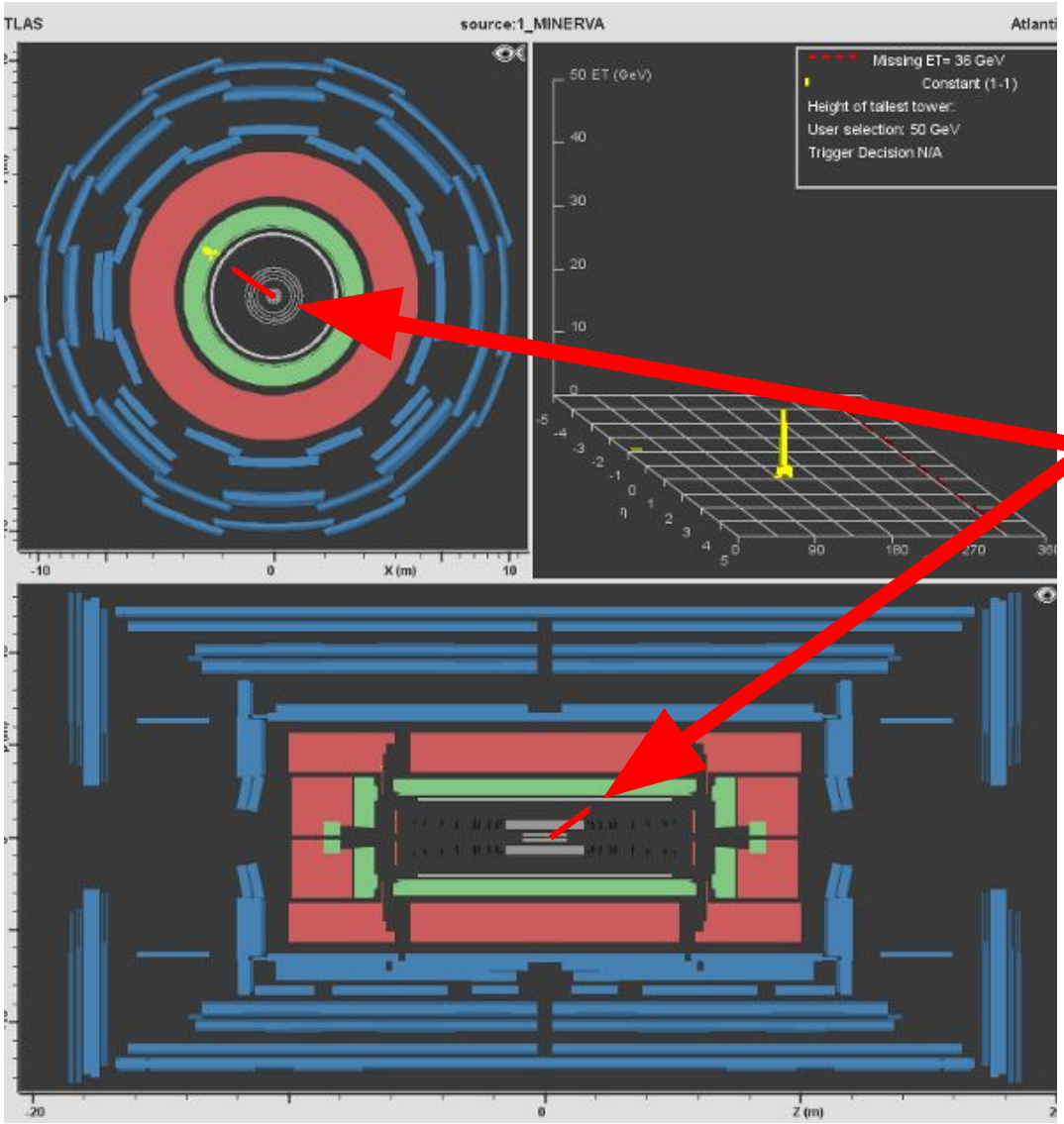
Detekcja i identyfikacja cząstek – elektron/pozyton



Elektron:

- **ślad w detektorze?**
- **depozyt energii w kalorymetrze EM na przedłużeniu śladu?**

Detekcja i identyfikacja cząstek – elektron/pozyton



Elektron:

- **ślad w detektorze!**
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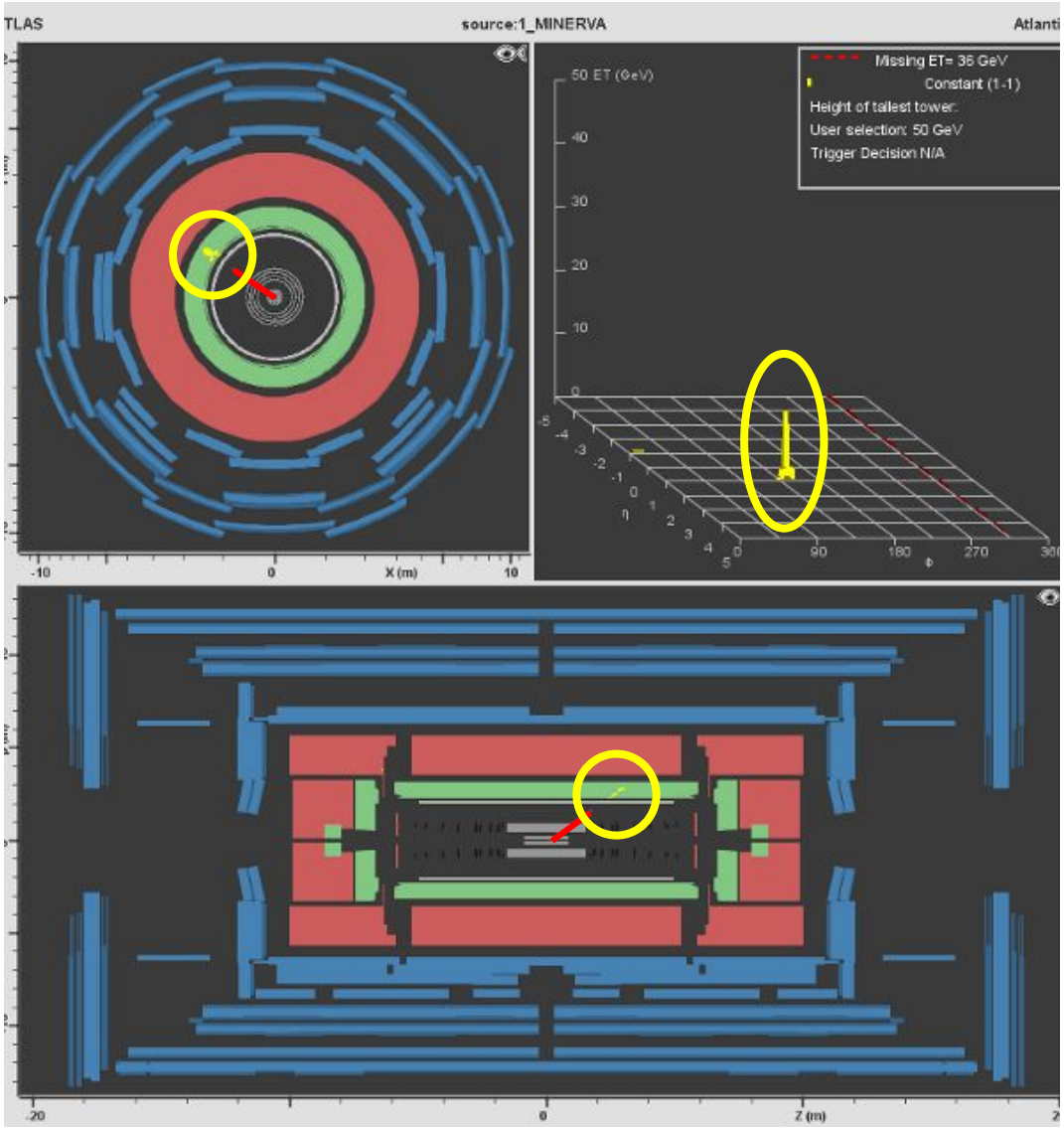
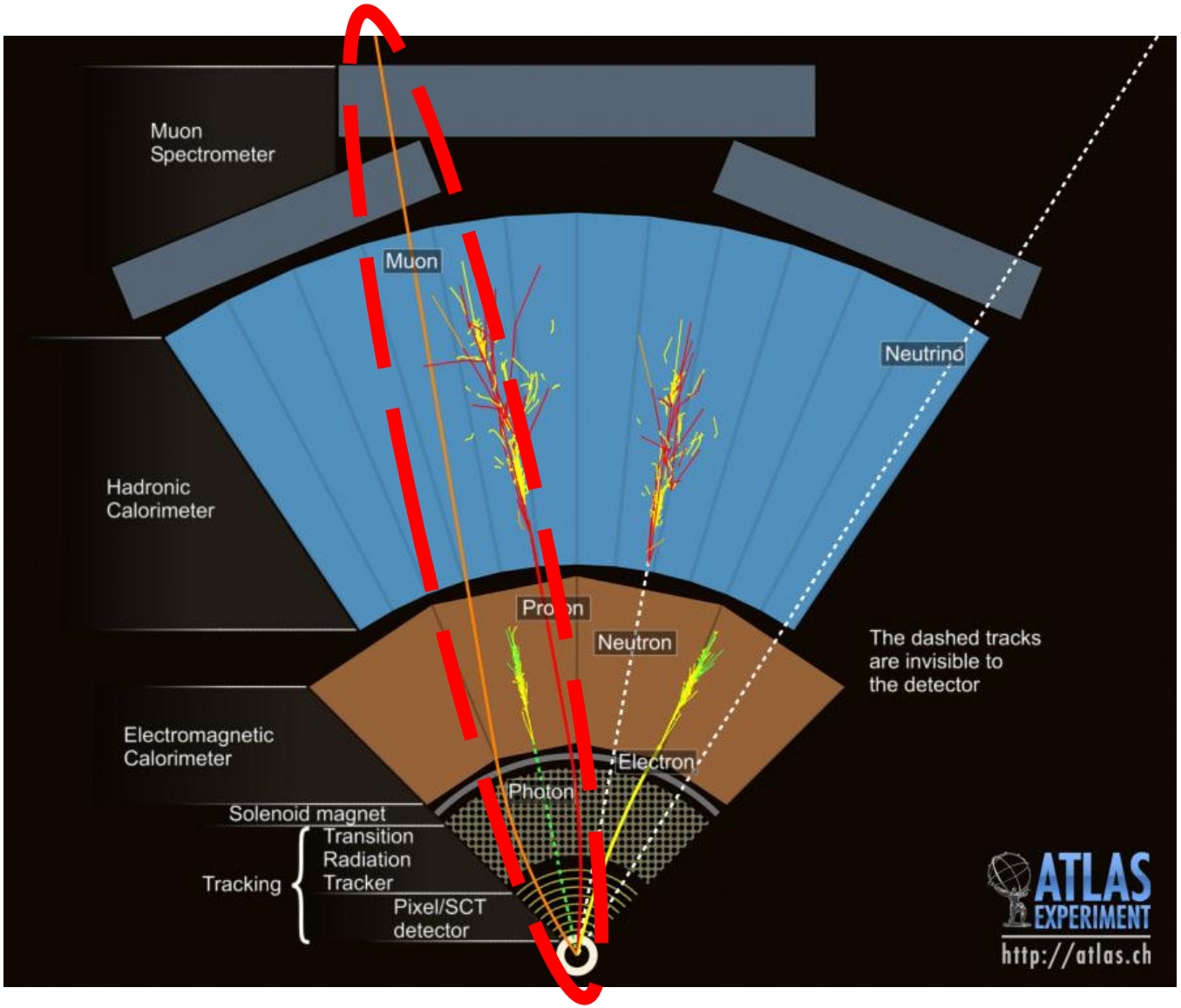
Detekcja i identyfikacja cząstek – elektron/pozyton



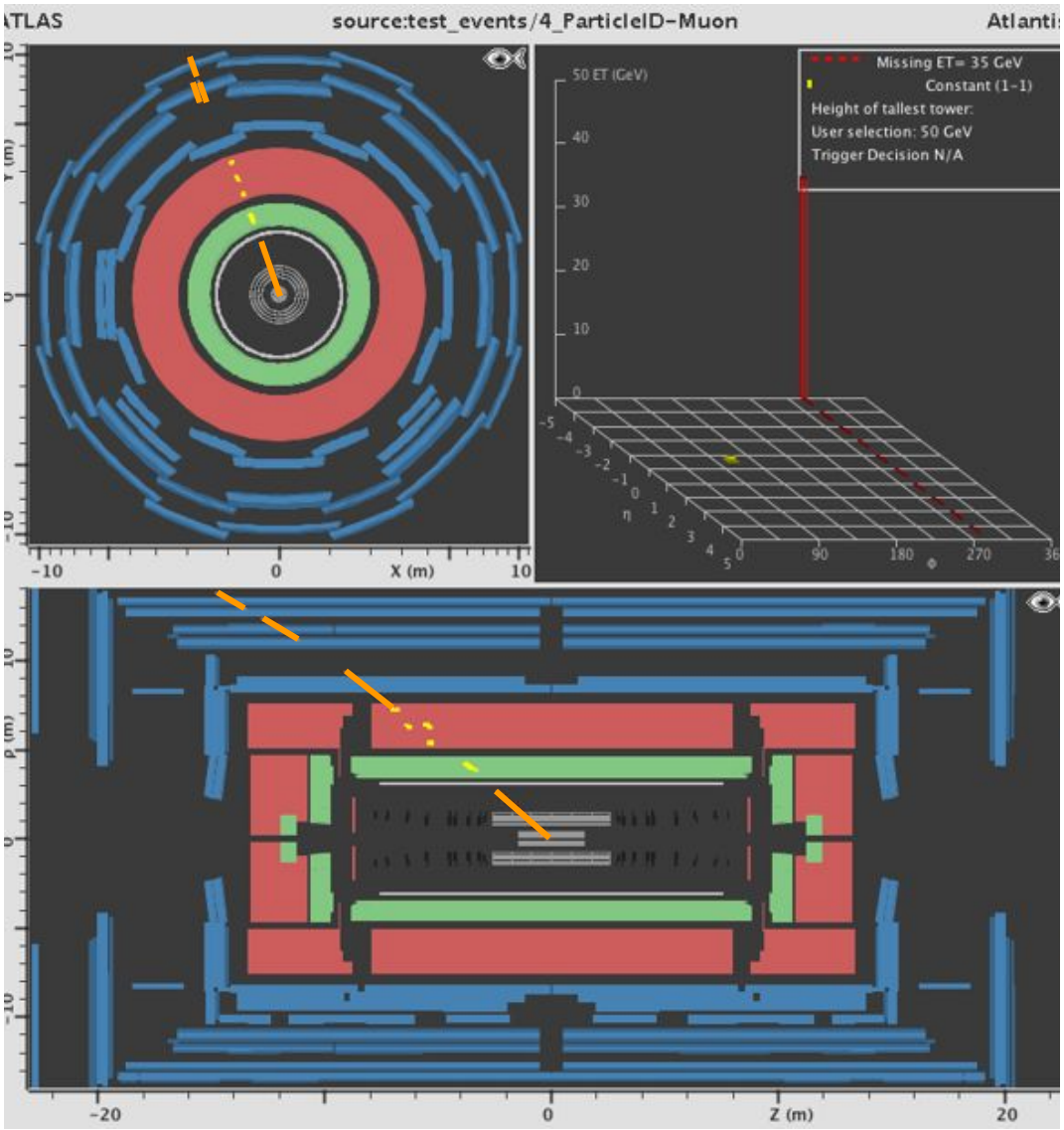
Elektron:

- **ślad w detektorze!**
- **depozyt energii w kalorymetrze EM na przedłużeniu śladu!**

Detekcja i identyfikacja cząstek – mion/anty-mion



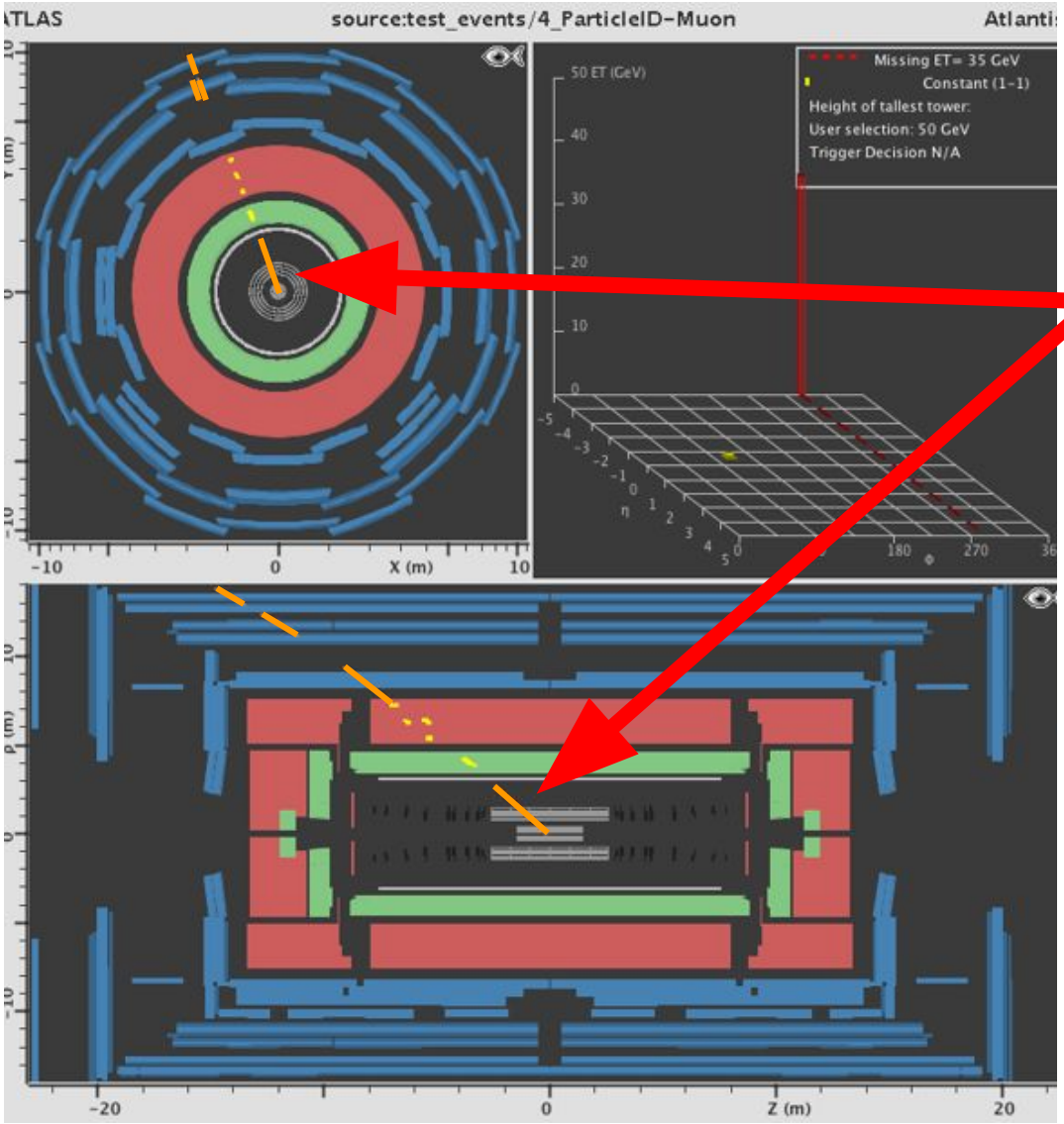
Detekcja i identyfikacja cząstek – mion/anty-mion



Mion:

- **ślad w detektorze?**
- **brak znaczącego depozytu energii w kalorymetrach na przedłużeniu śladu?**
- **ślad w detektorze mionowym na przedłużeniu?**

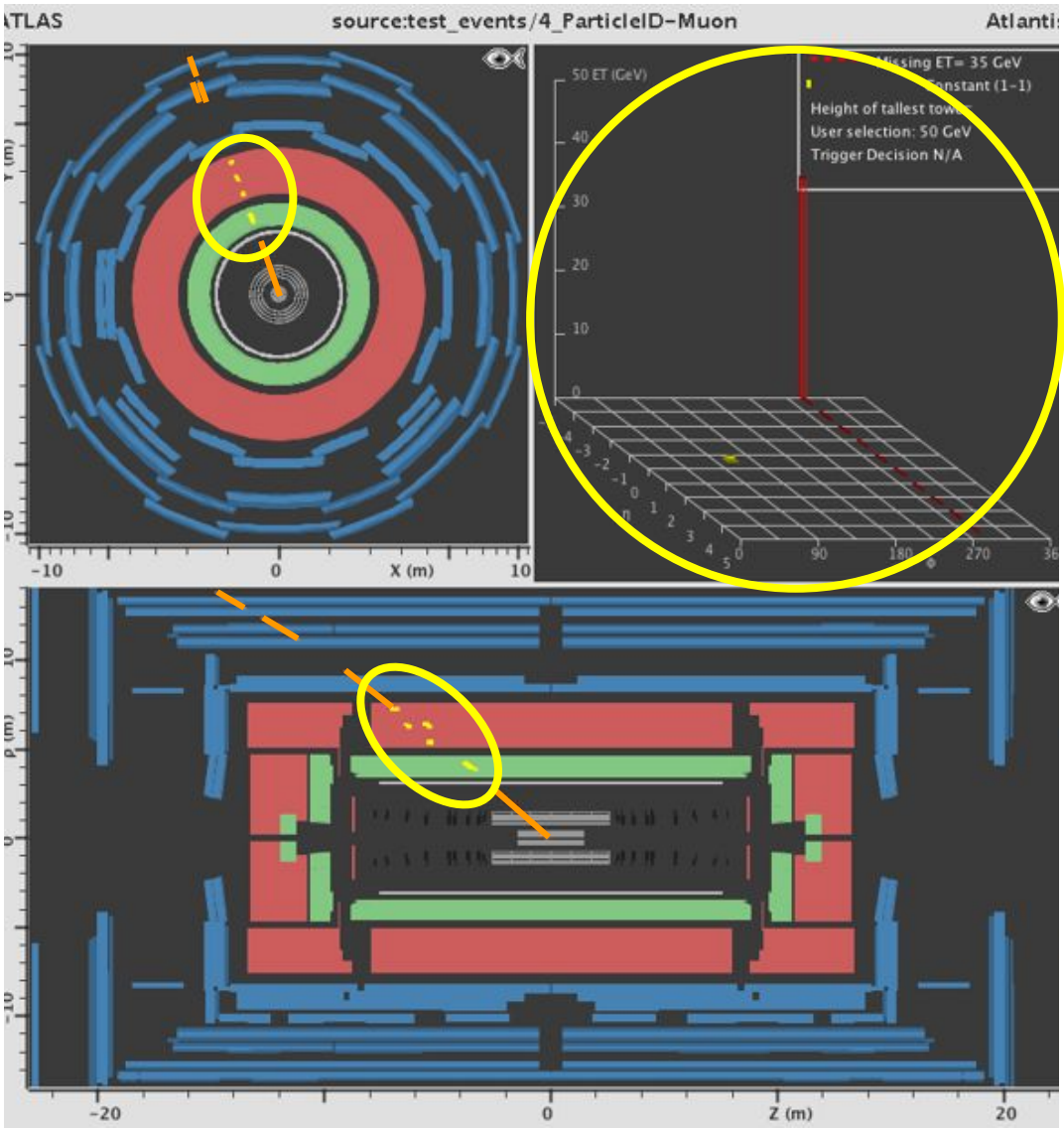
Detekcja i identyfikacja cząstek – mion/anty-mion



Mion:

- **ślad w detektorze!**
- **brak znaczącego depozytu energii w kalorymetrach na przedłużeniu śladu?**
- **ślad w detektorze mionowym na przedłużeniu?**

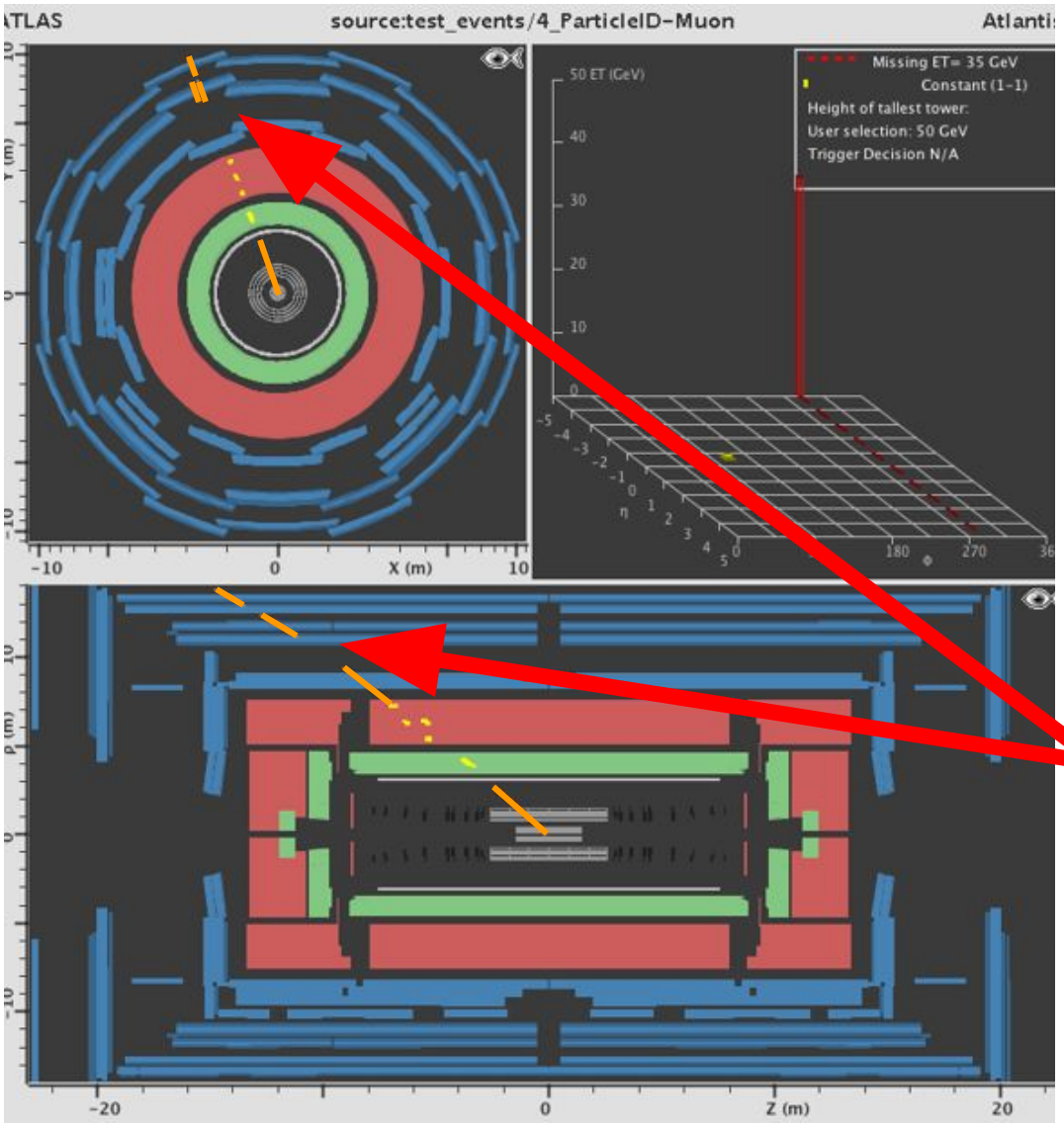
Detekcja i identyfikacja cząstek – mion/anty-mion



Mion:

- **ślad w detektorze!**
- **brak znaczącego depozytu energii w kalorymetrach na przedłużeniu śladu!**
- **ślad w detektorze mionowym na przedłużeniu?**

Detekcja i identyfikacja cząstek – mion/anty-mion

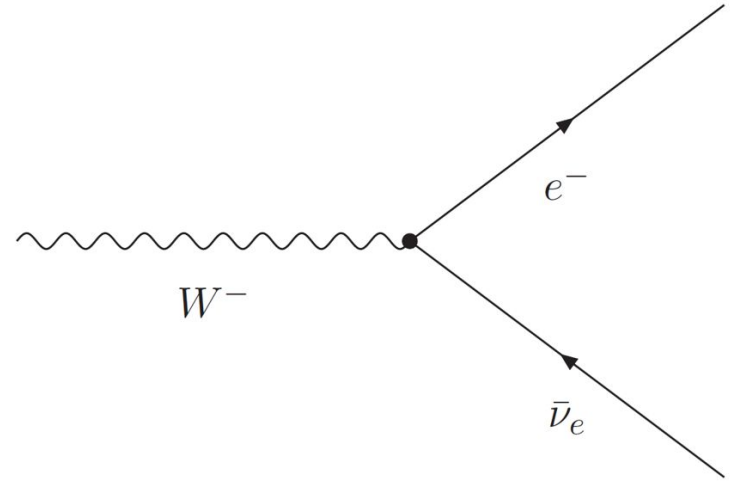


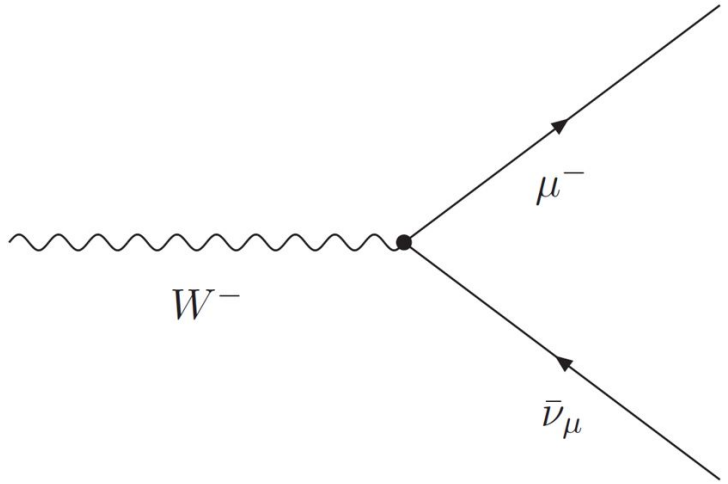
Mion:

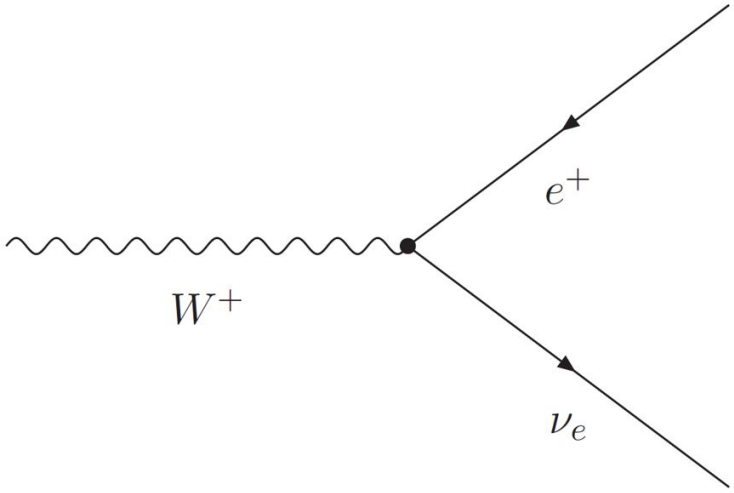
- **ślad w detektorze!**
- **brak znaczącego depozytu energii w kalorymetrach na przedłużeniu śladu!**
- **ślad w detektorze mionowym na przedłużeniu!**

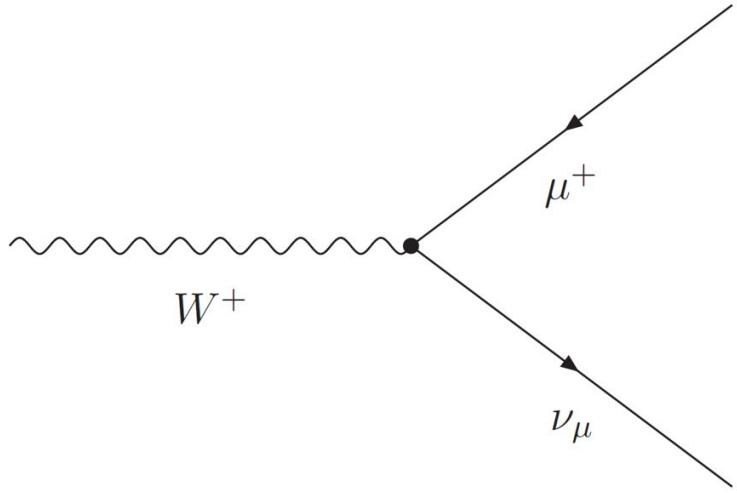
Identyfikacja przypadków

Rozpad bozonu W – sygnał

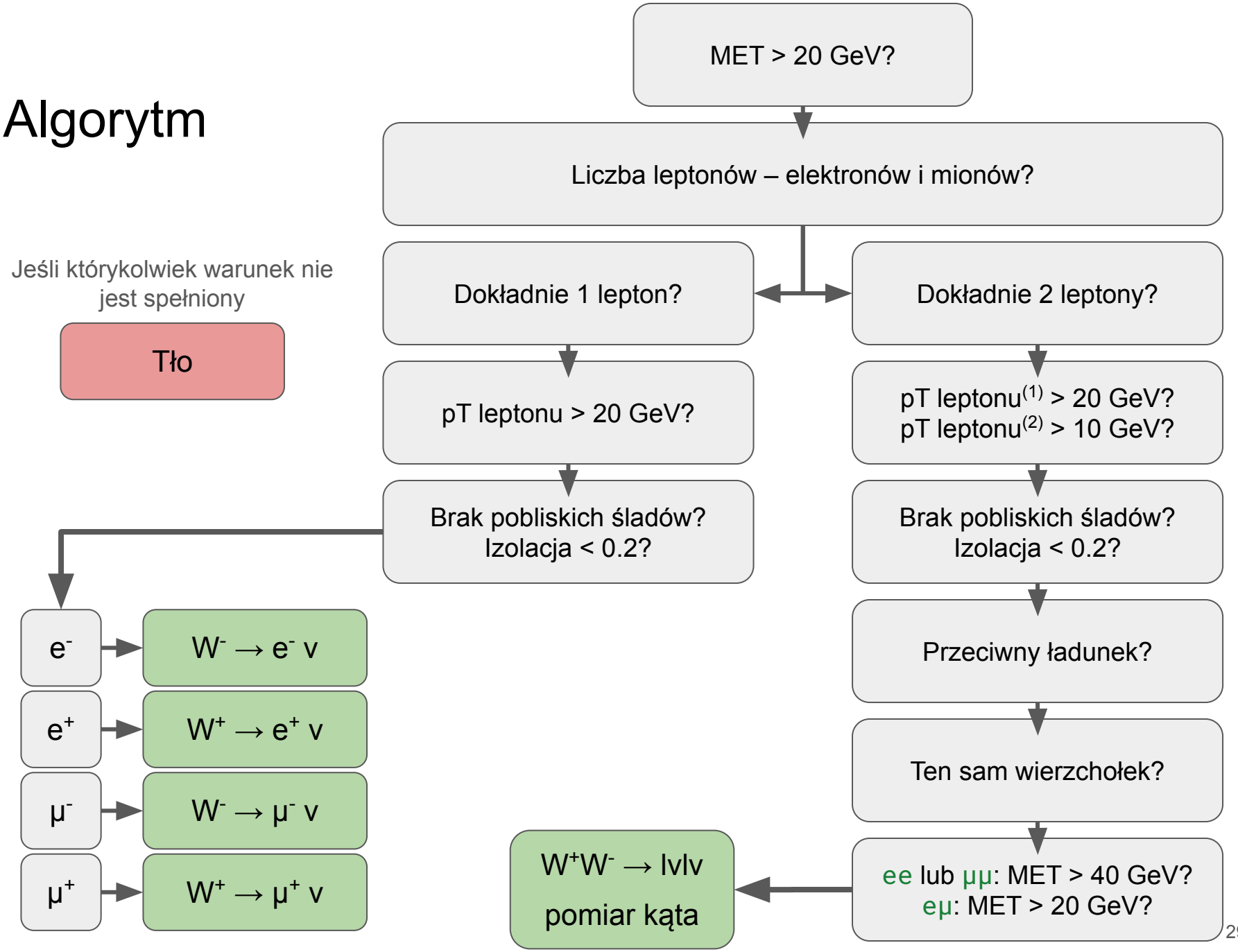








Algorytm


MET > 20 GeV?
Liczba leptonów – elektronów i mionów?
Jeśli którykolwiek warunek nie jest spełniony
Tło
Dokładnie 1 lepton?
Dokładnie 2 leptony?
pT leptonu > 20 GeV?
pT leptonu(1) > 20 GeV?
pT leptonu(2) > 10 GeV?
Brak pobliskich śladów?
Izolacja < 0.2?
Brak pobliskich śladów?
Izolacja < 0.2?
e-
W- → e- ν
e+
W+ → e+ ν
μ-
W- → μ- ν
μ+
W+ → μ+ ν
Przeciwny ładunek?
Ten sam wierzchołek?
ee lub μμ: MET > 40 GeV?
eμ: MET > 20 GeV?
W+W- → lνlν
pomiar kąta

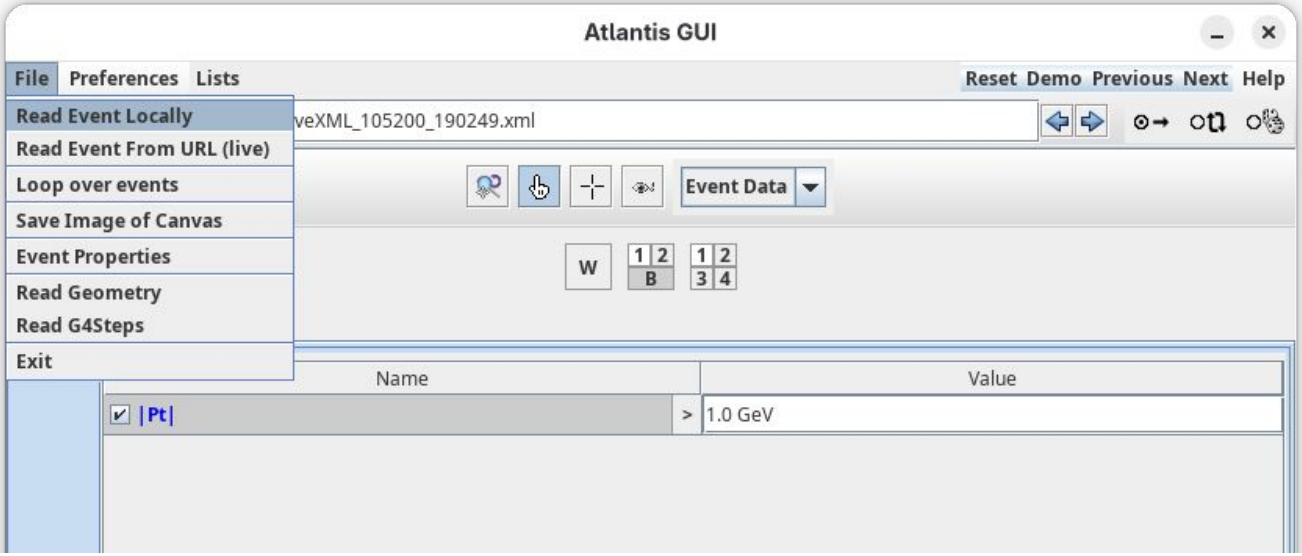
Zapis wyników

ATLAS data analysis

data sample: 5B

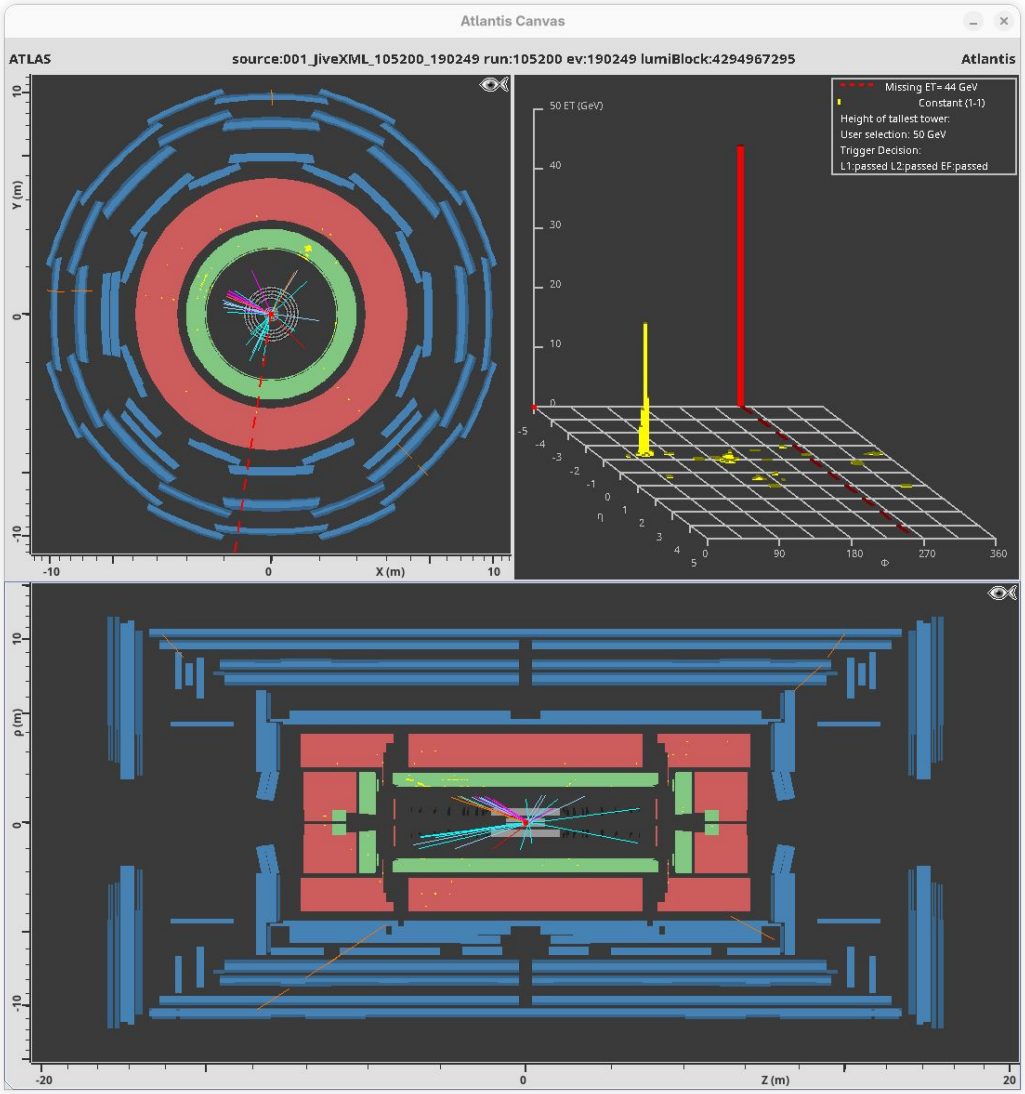
event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu + \ldots$		$W \rightarrow \nu + \ldots$		$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
	e^+	e^-	μ^+	μ^-				
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

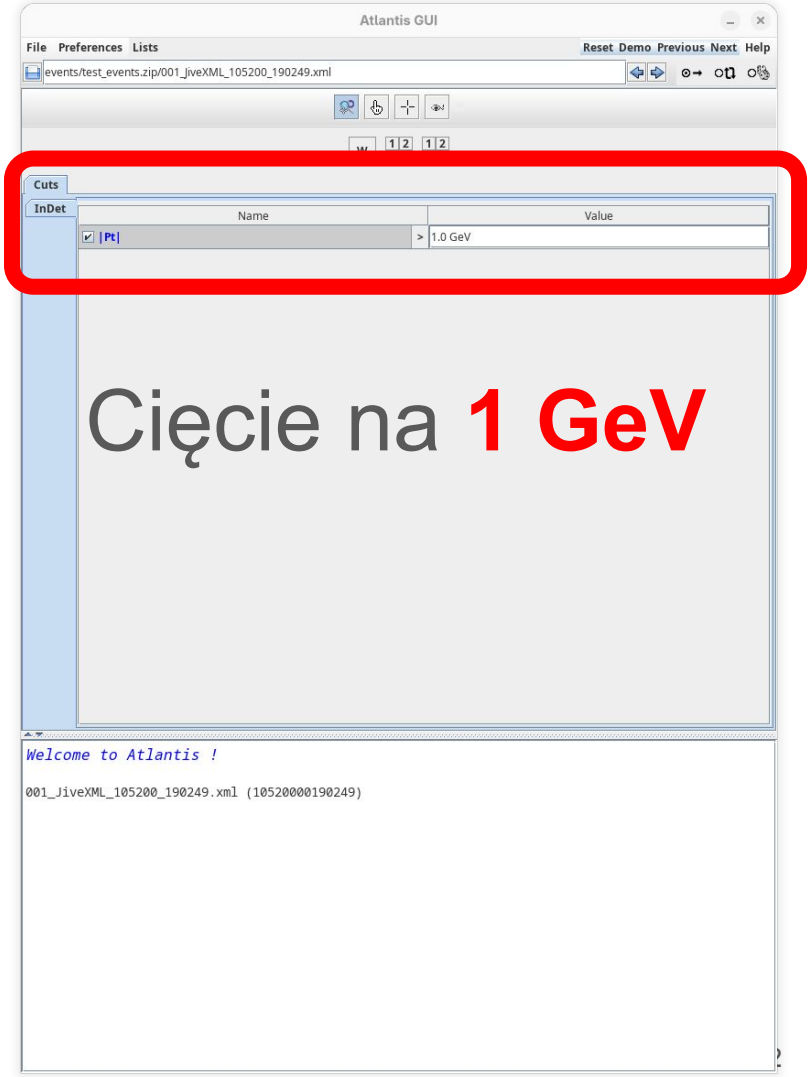
Wczytywanie przypadków



- **File > Read Event Locally**
- Nawigujemy do folderu: **Desktop > Datasets**
- Wybieramy plik: **<Twoja grupa>.zip**

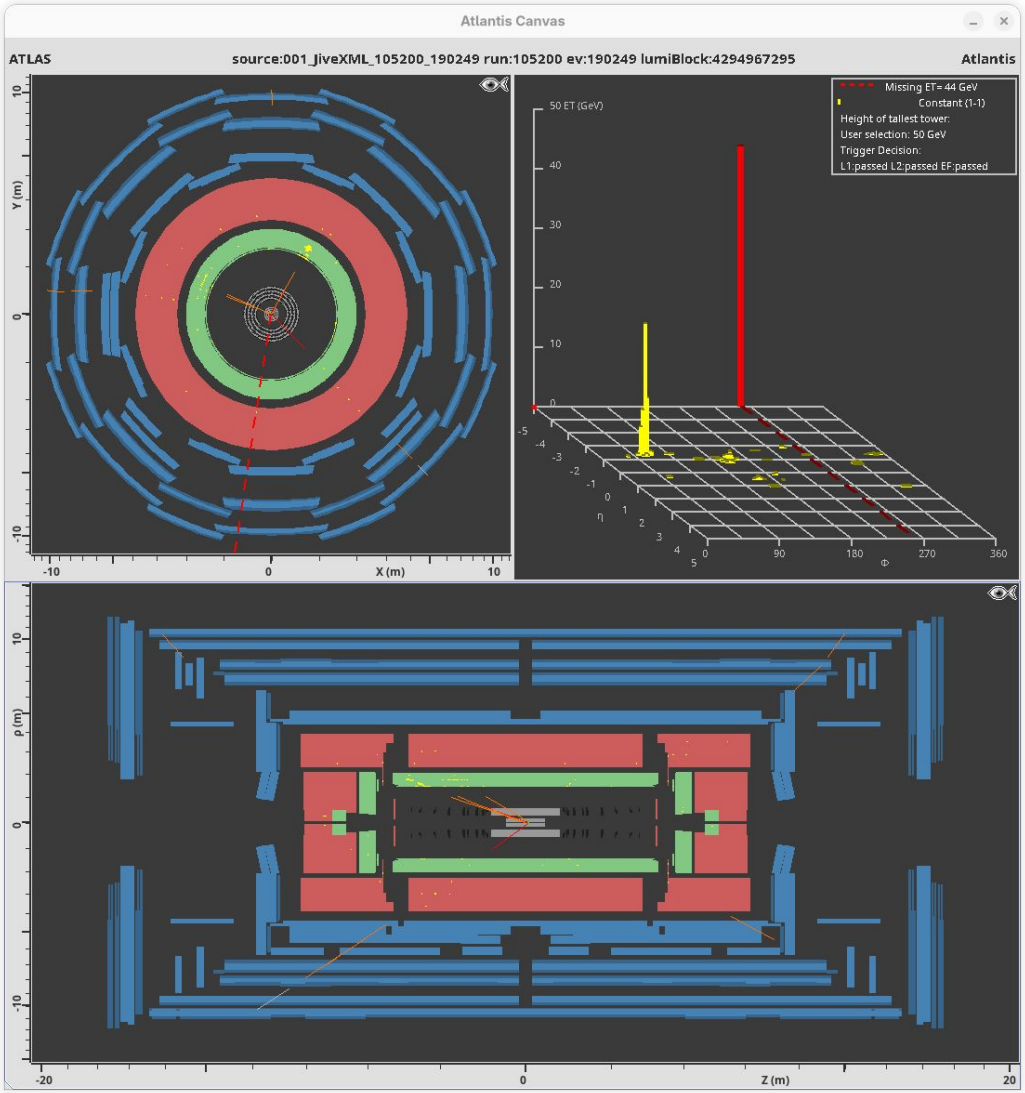
Cięcie na pęd poprzeczny śladów

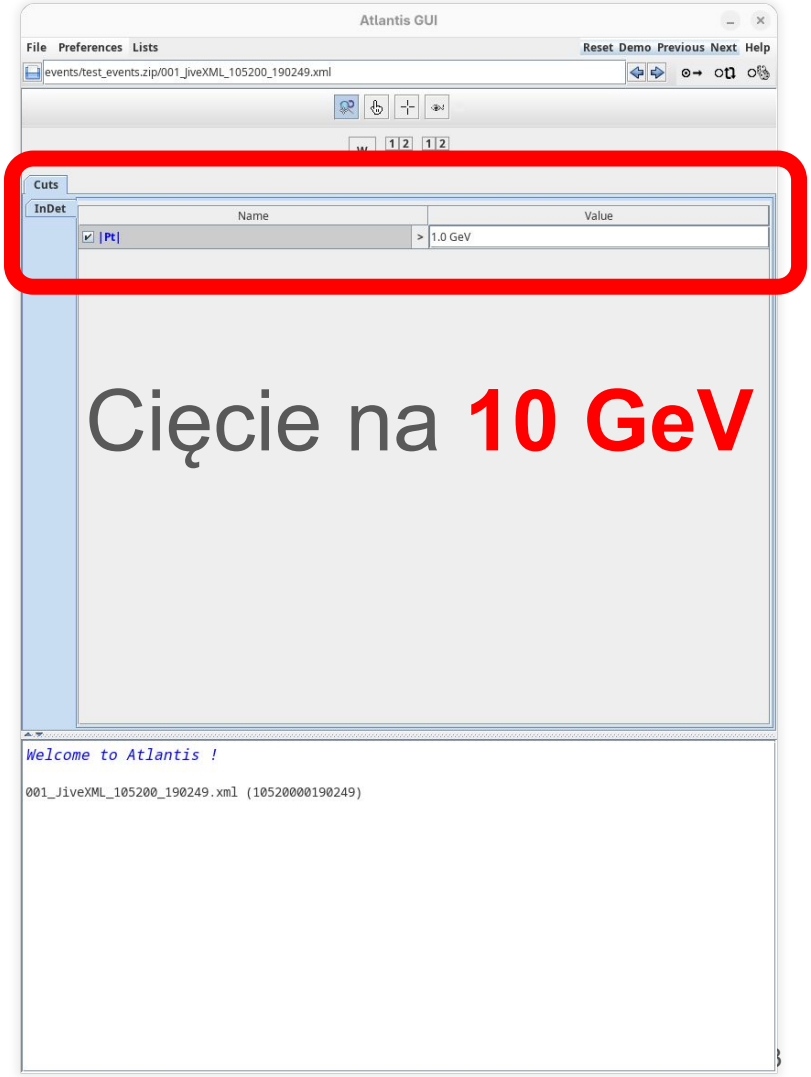




Cięcie na **1 GeV**

Cięcie na pęd poprzeczny śladów



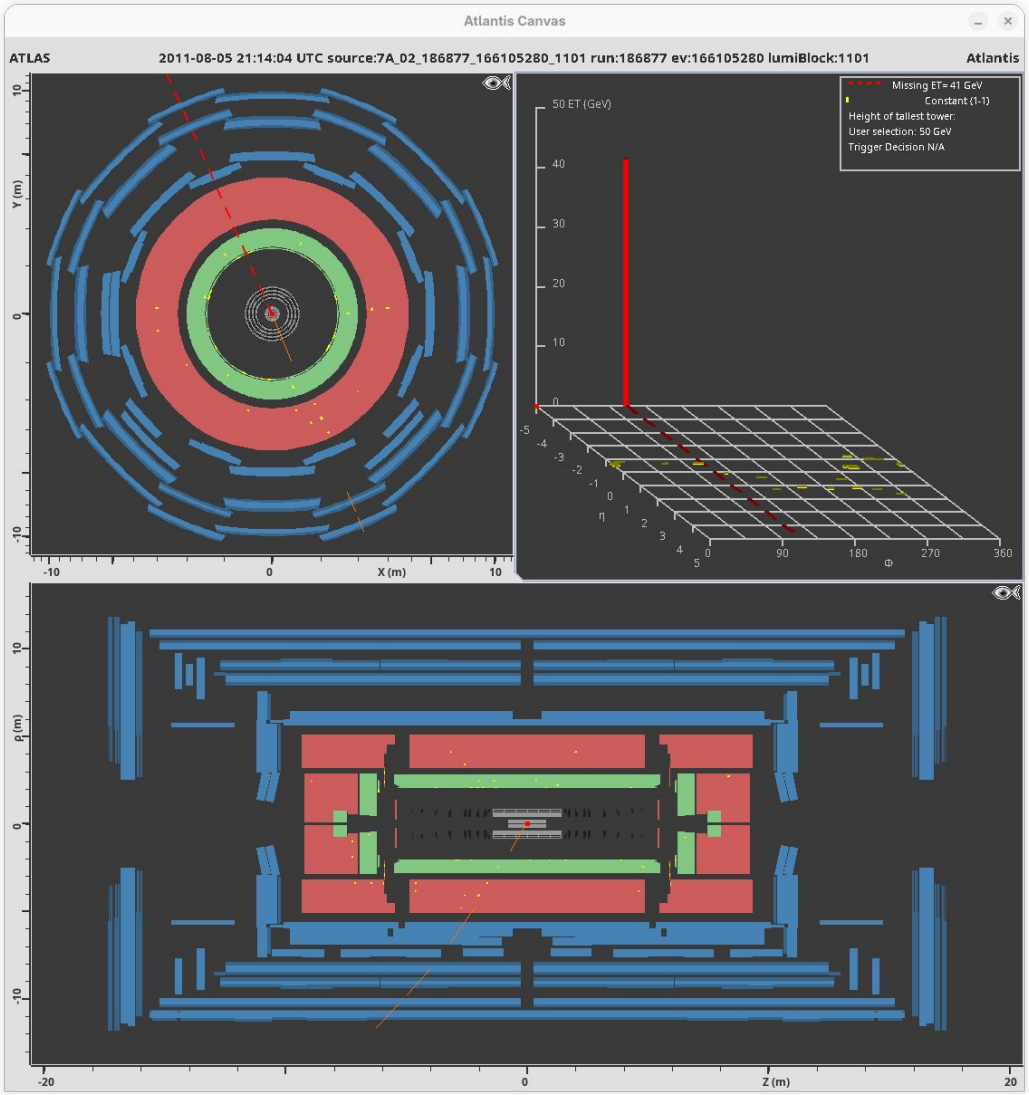


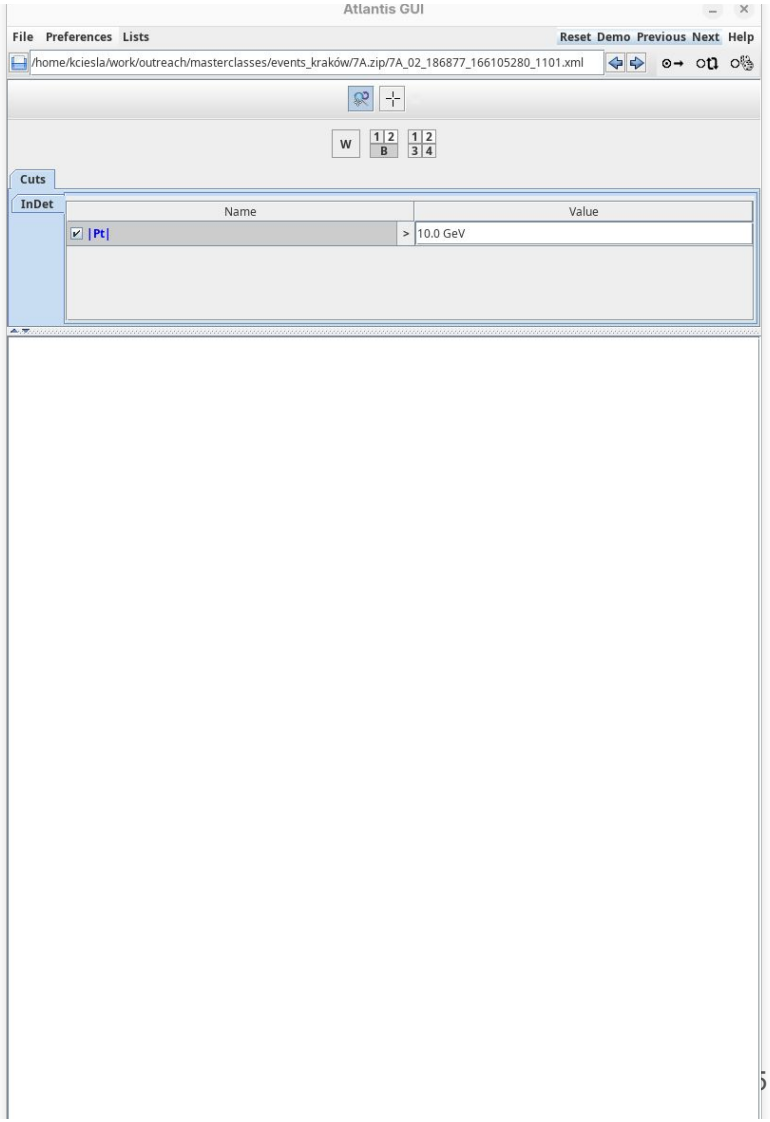
Cięcie na **10 GeV**

Przykład #1

Przypadek #1

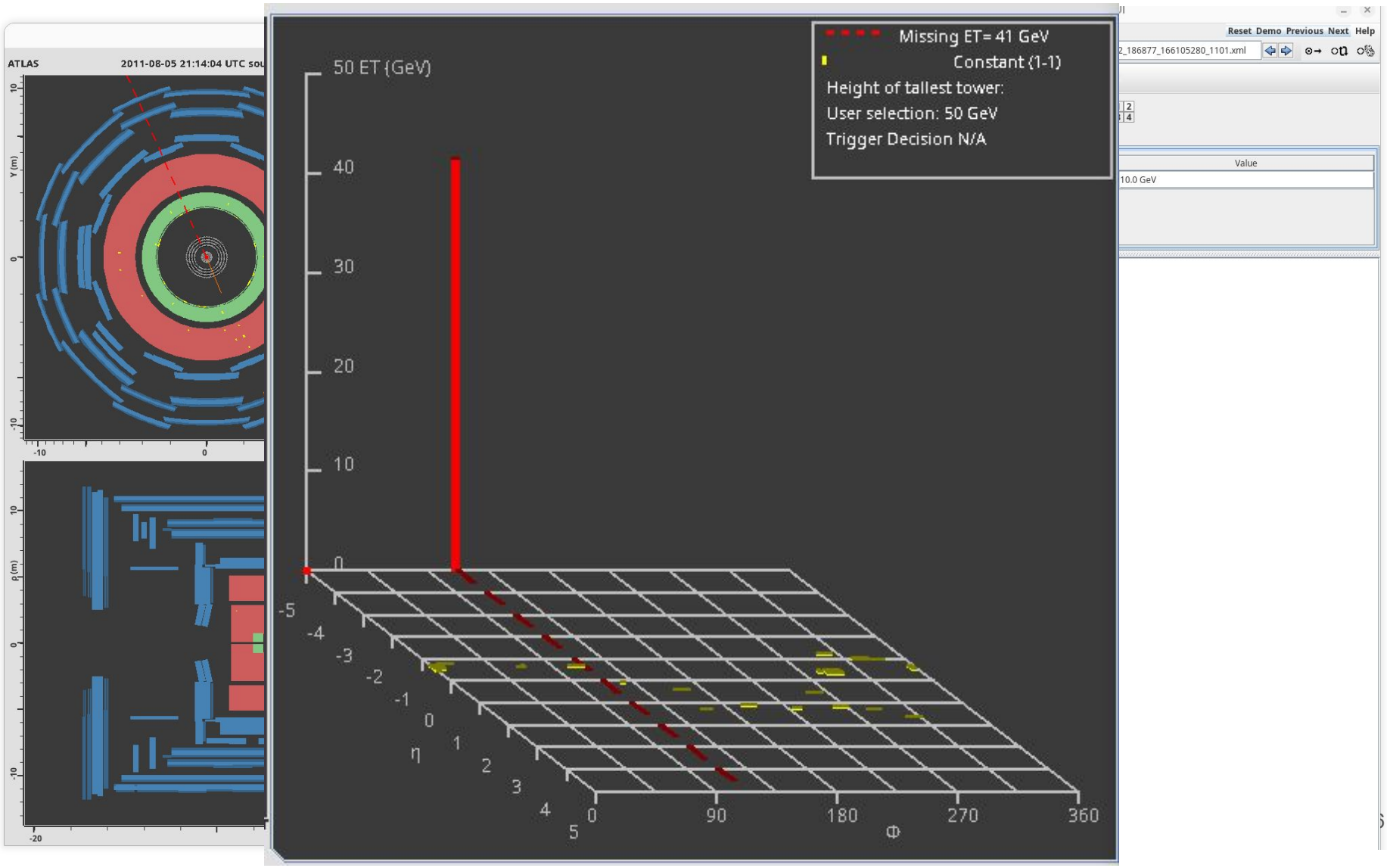
MET > 20 GeV?





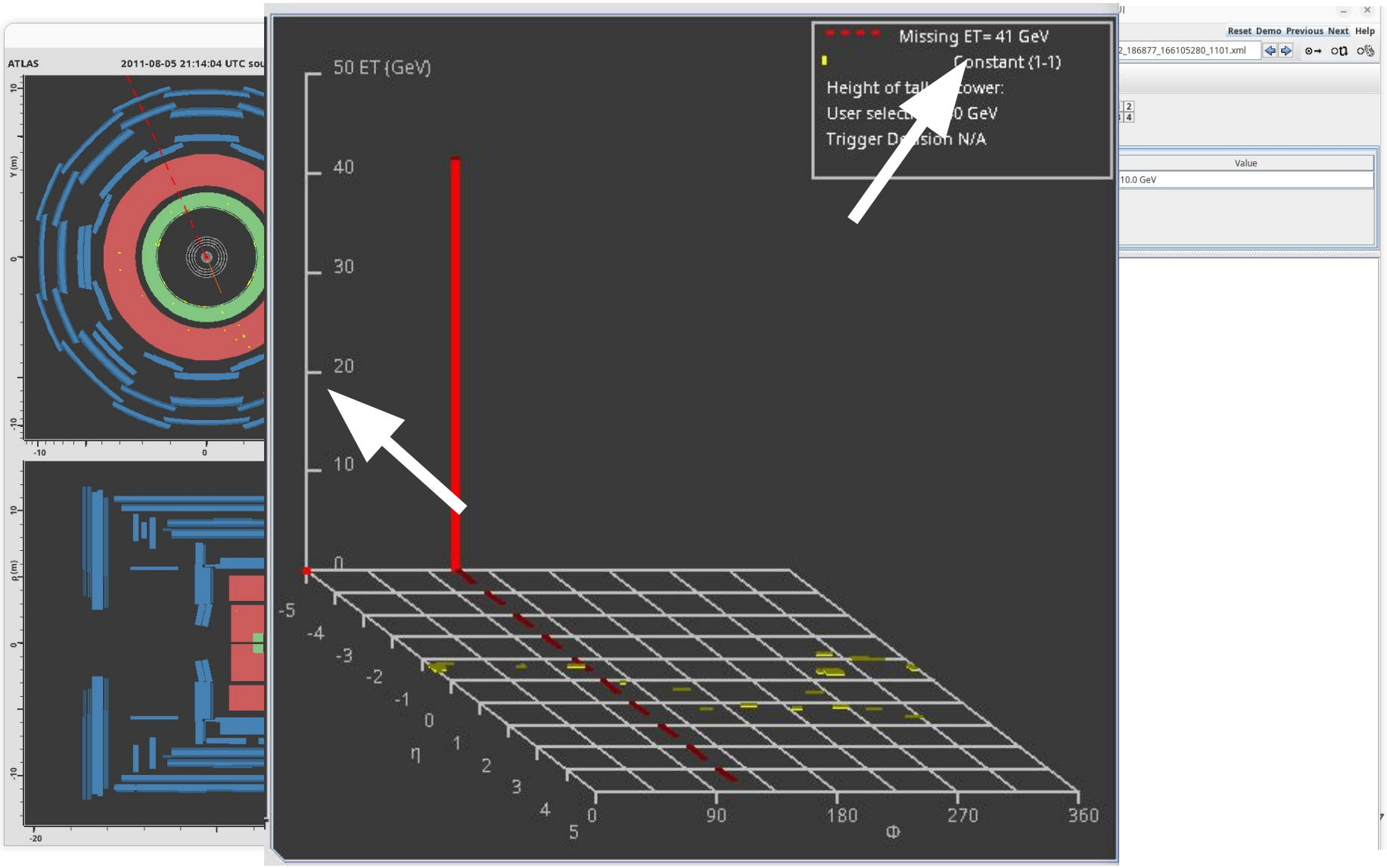
Przypadek #1

MET > 20 GeV?



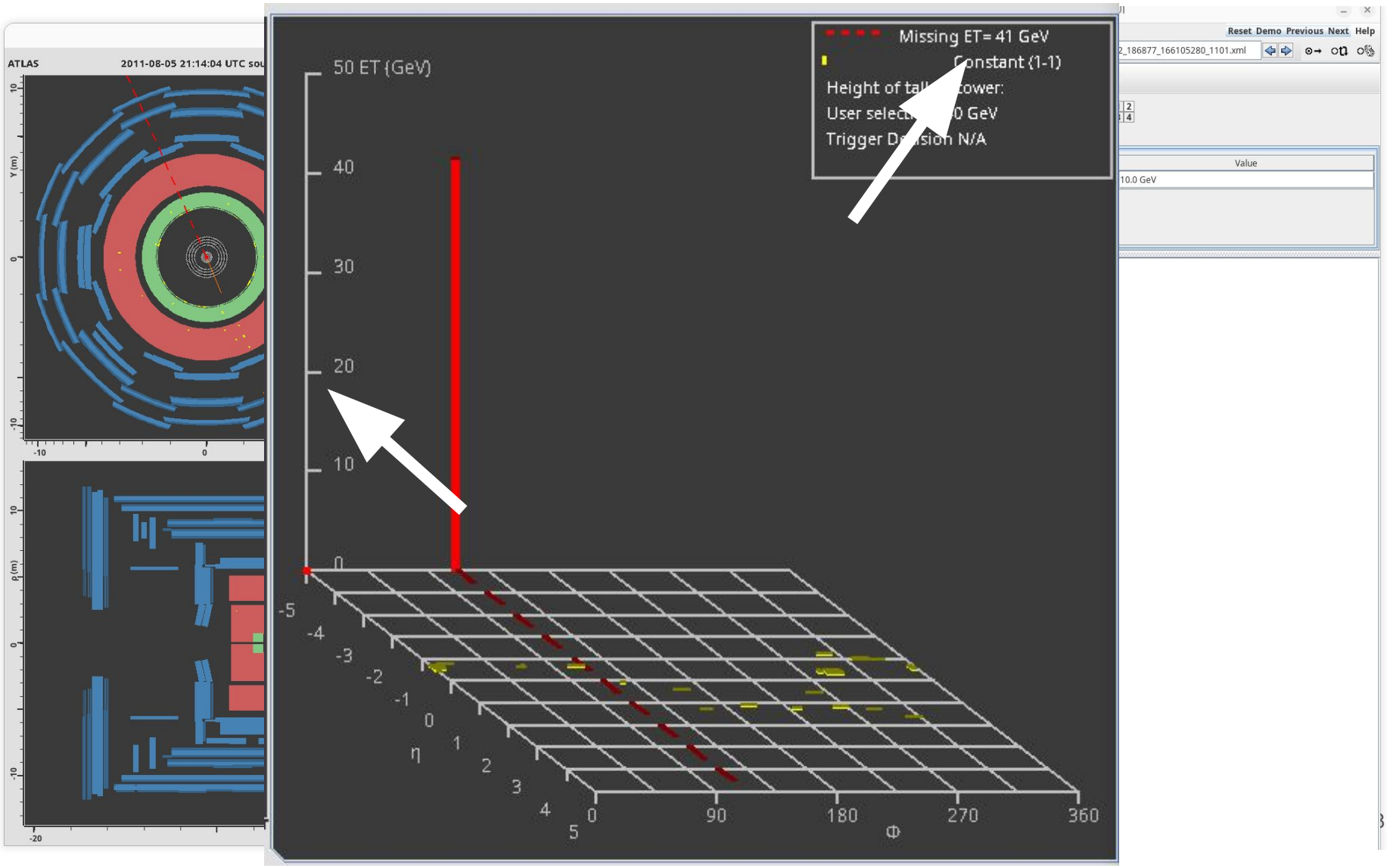
Przypadek #1

MET > 20 GeV?



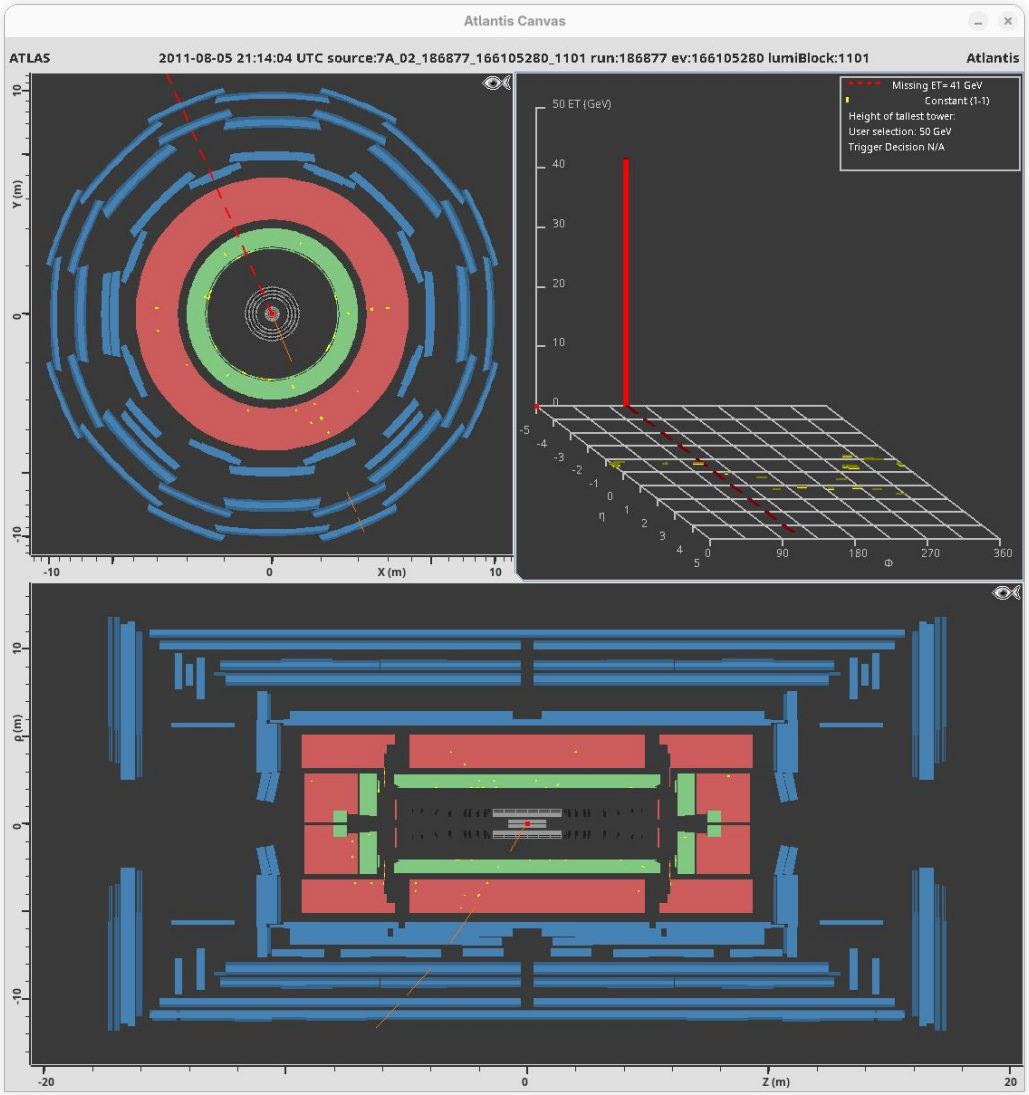
Przypadek #1

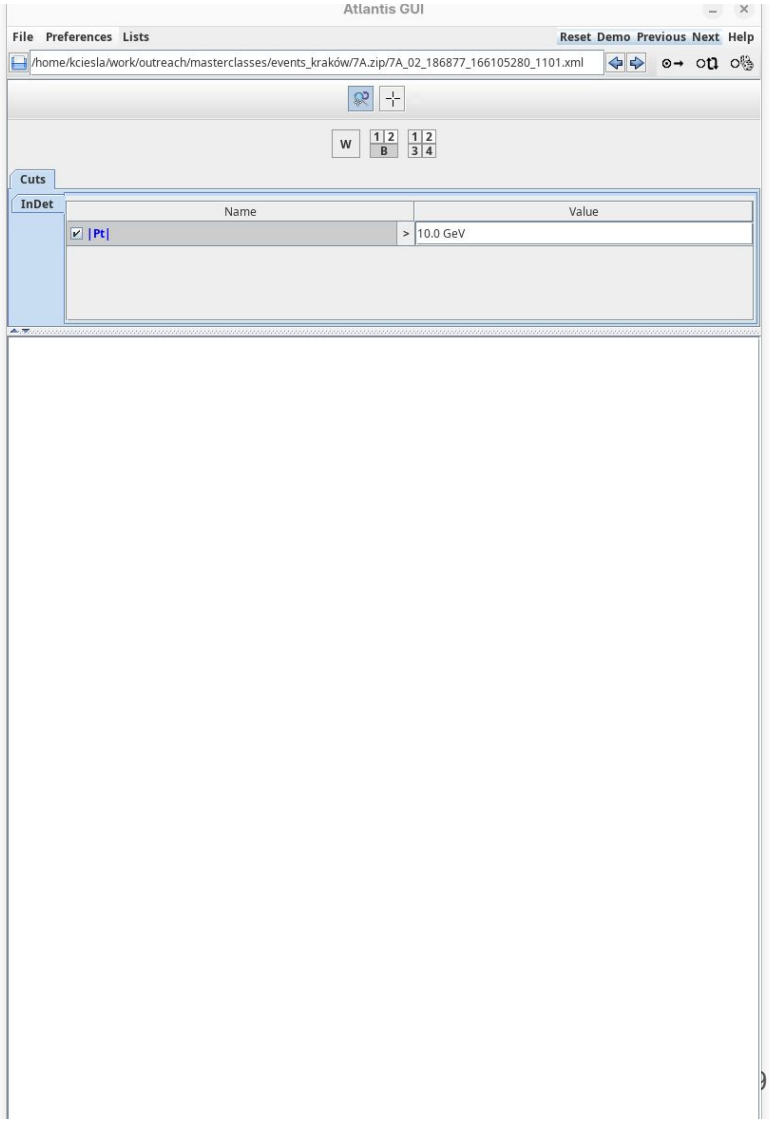
MET > 20 GeV



Przypadek #1

Liczba leptonów – elektronów i mionów?





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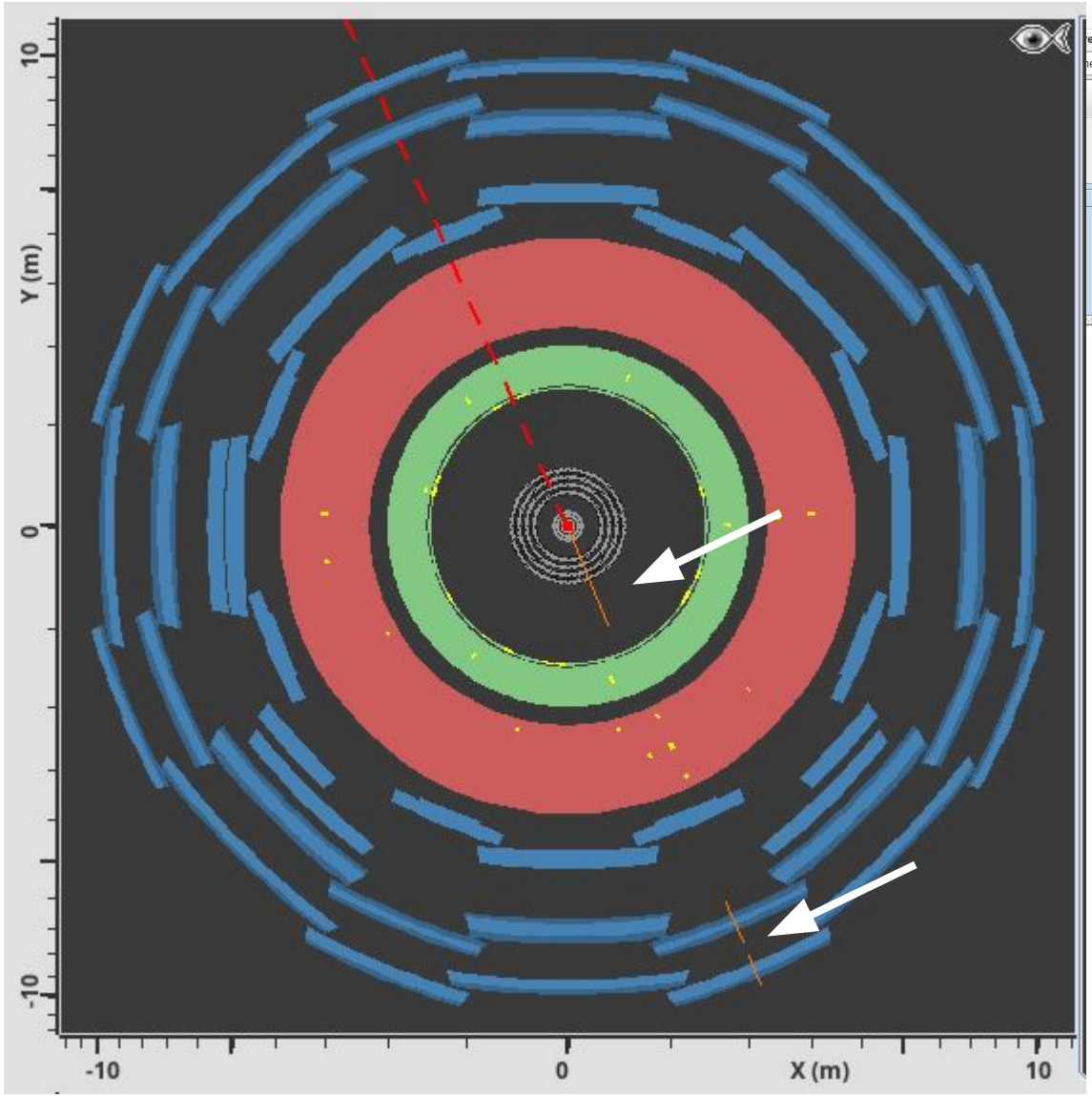

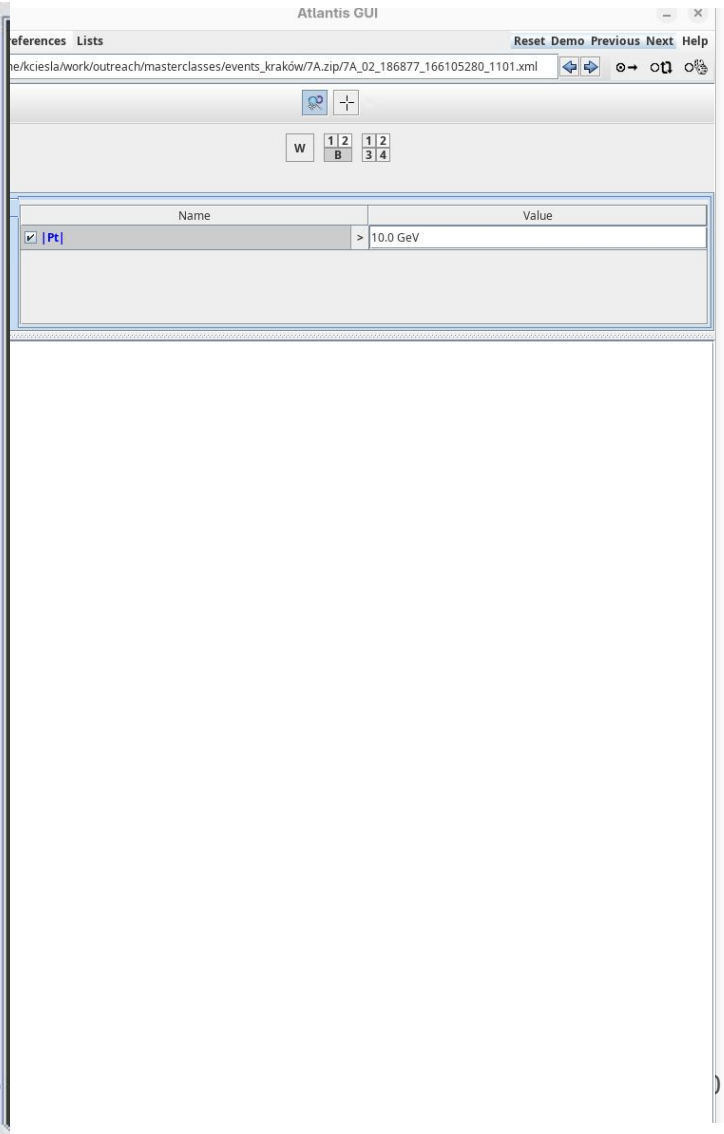

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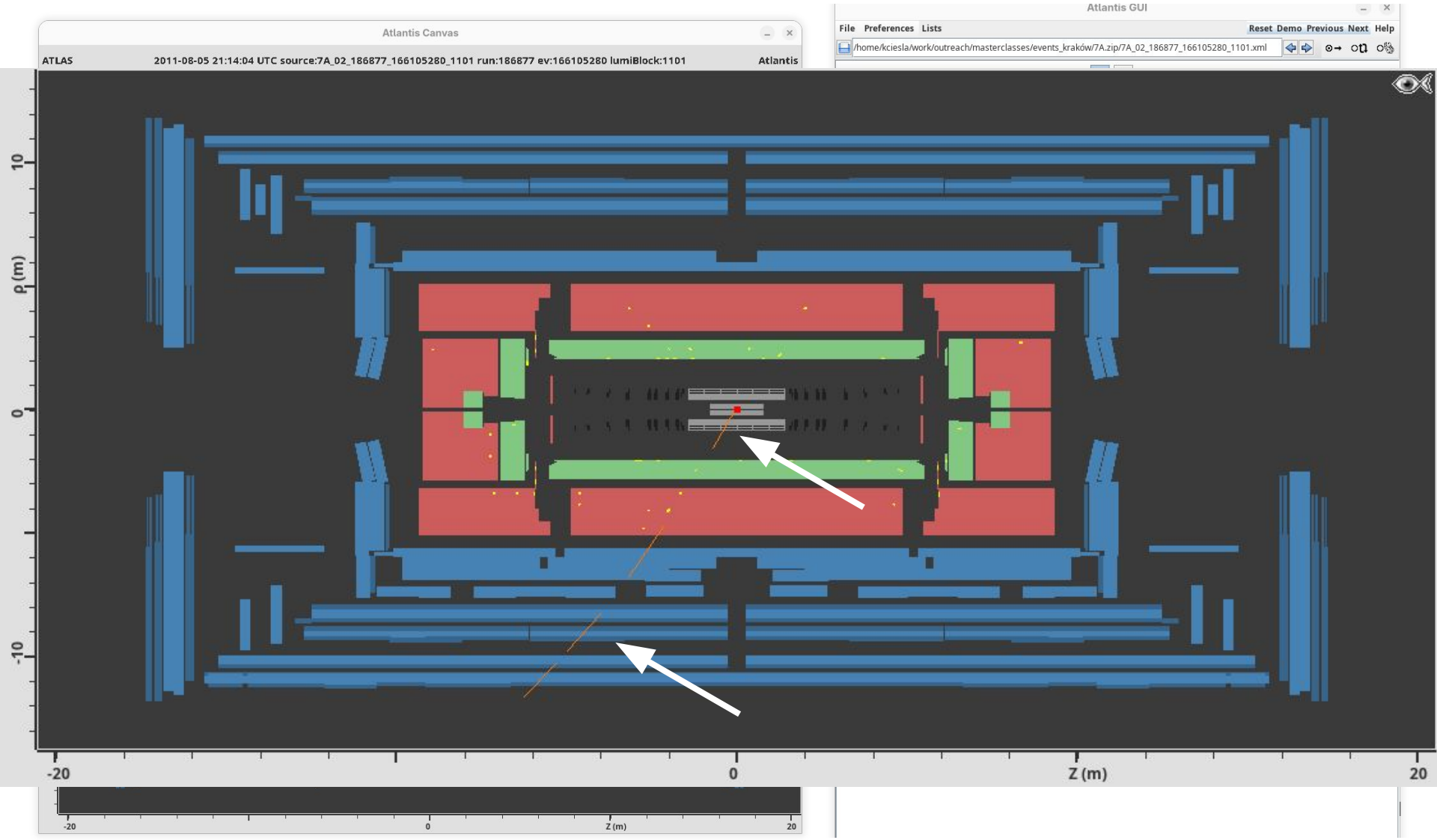
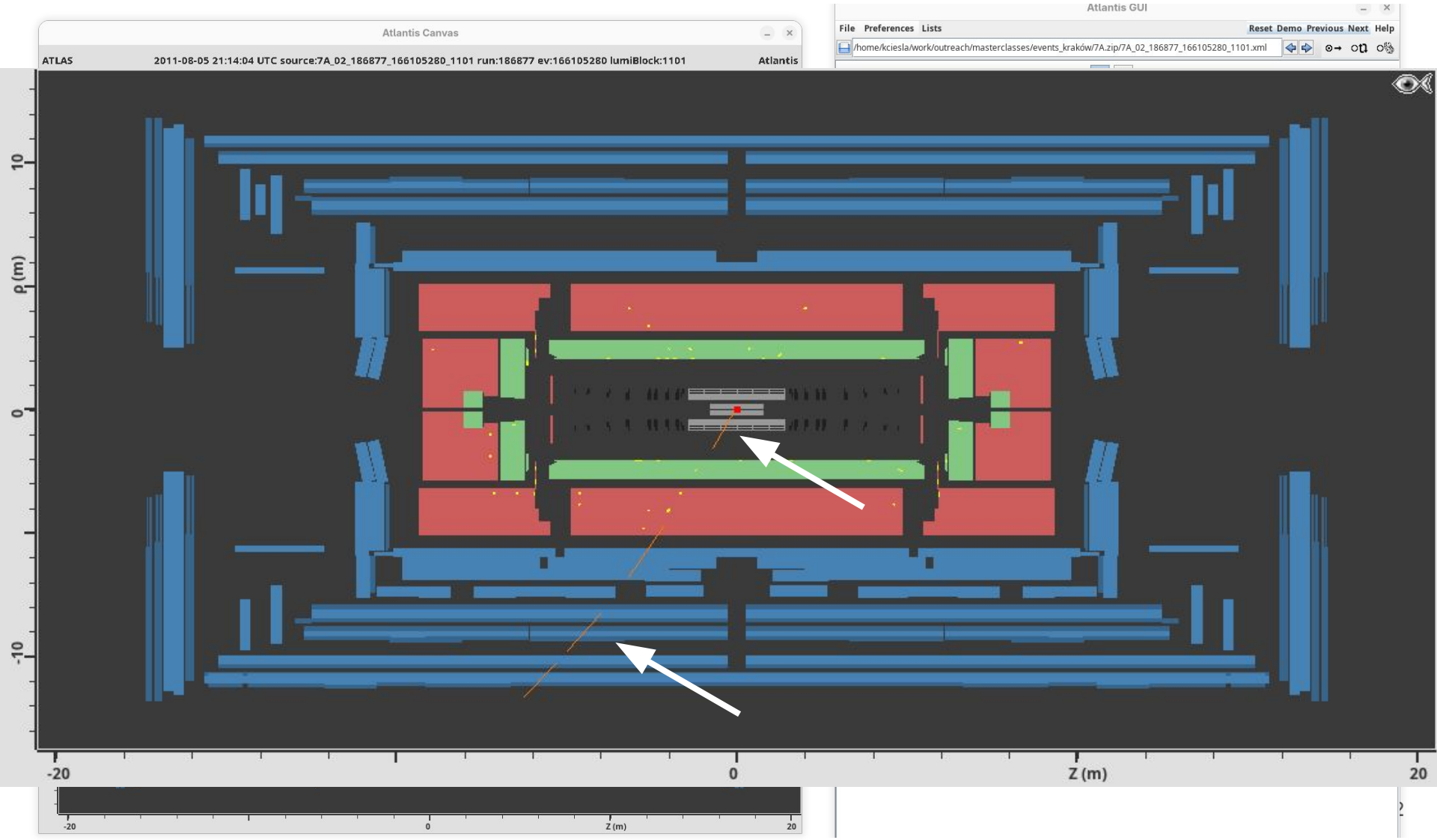


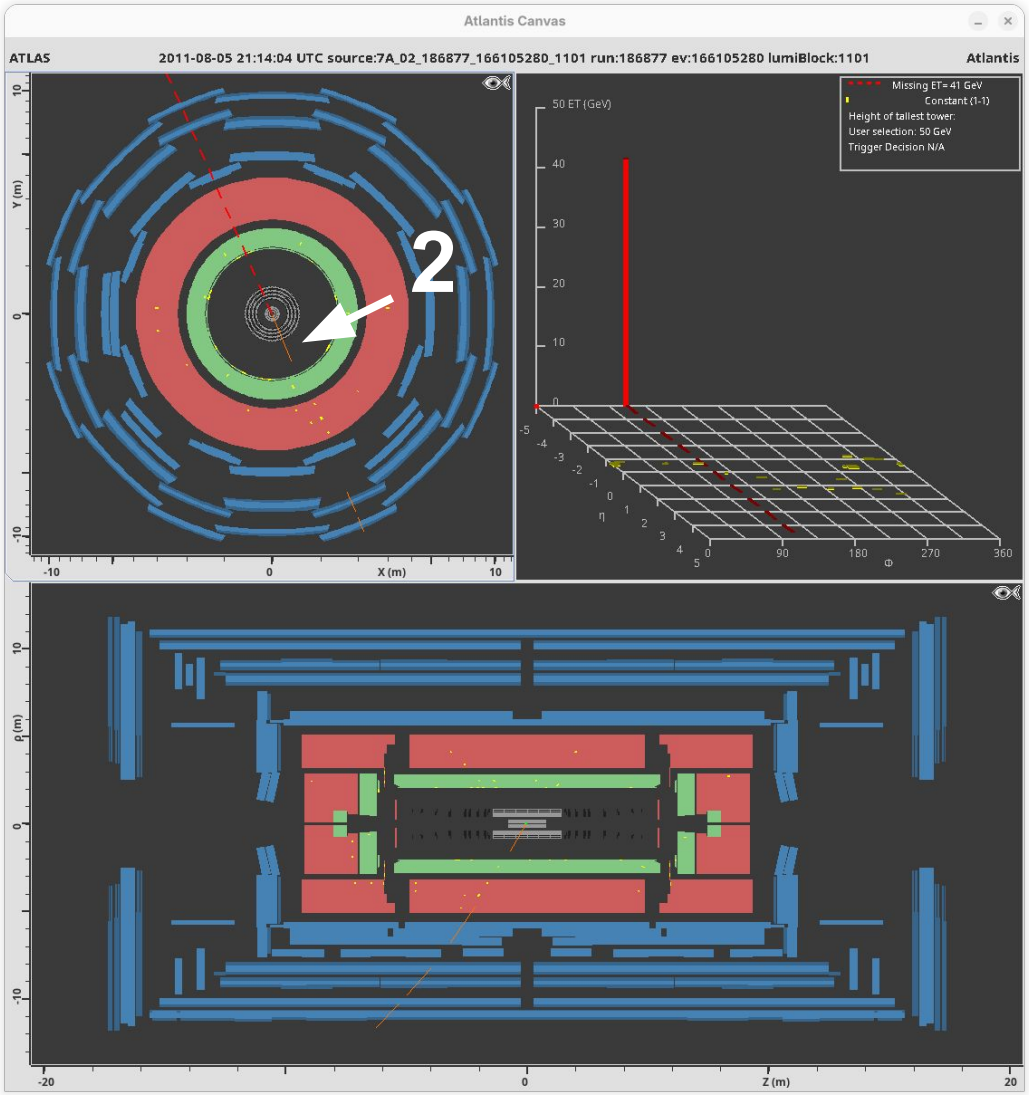
Przypadek #1

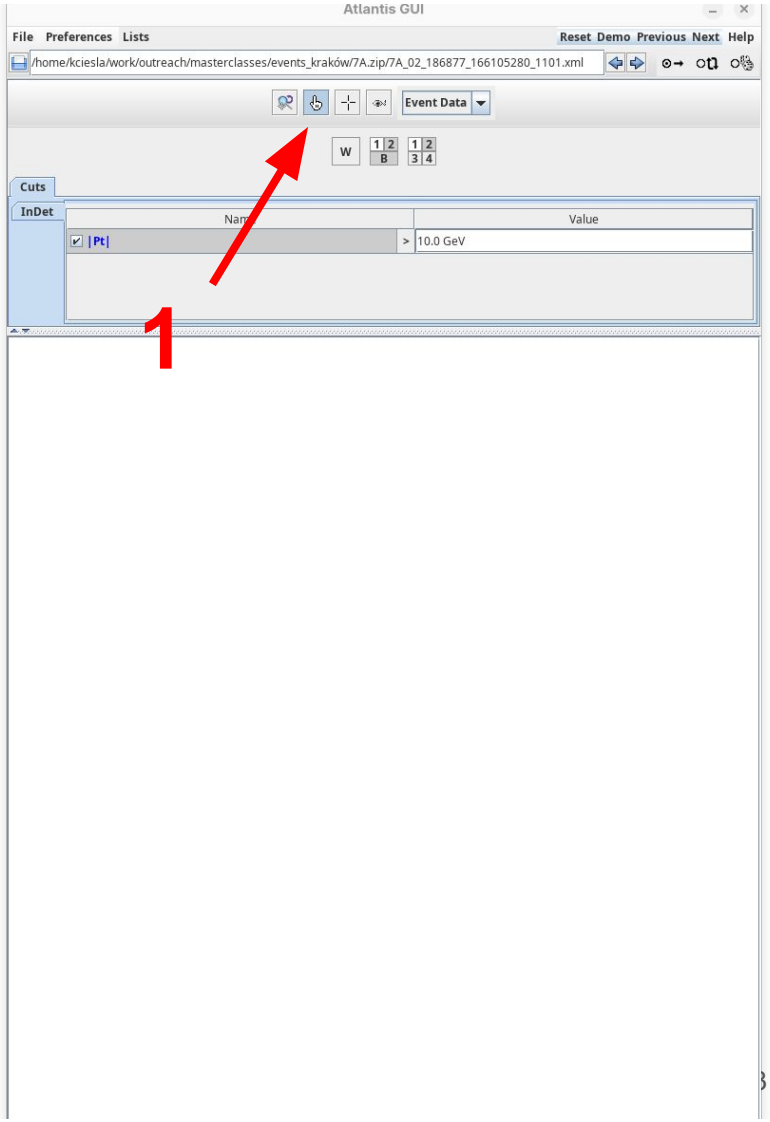
Kandydat na mion



Przypadek #1

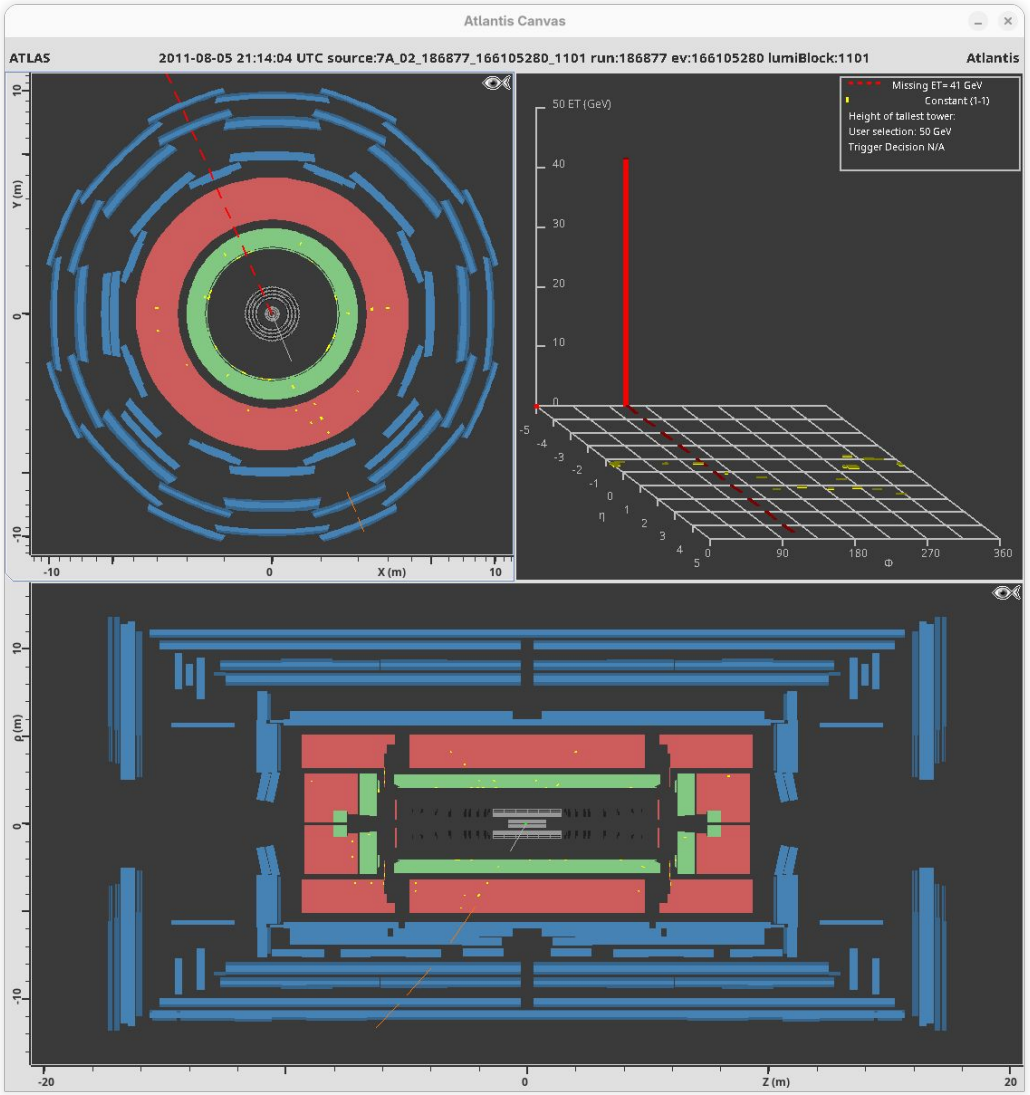
pT muonu > 20 GeV?

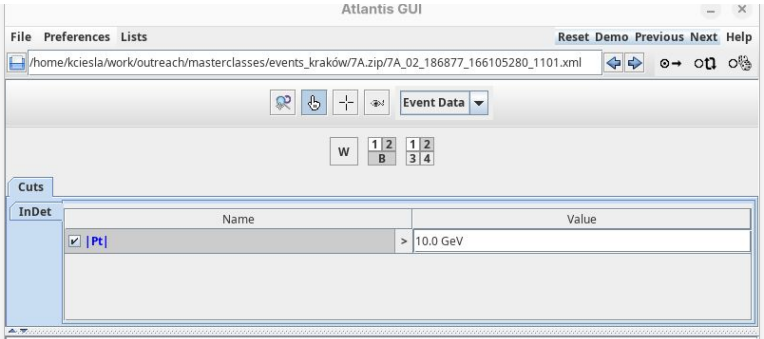




Przypadek #1

pT muonu > 20 GeV?





InDetTrack index: 2

PT = 35.838 GeV

η = -0.315

Φ = 291.733°

Px = 13.270 GeV

Py = -33.291 GeV

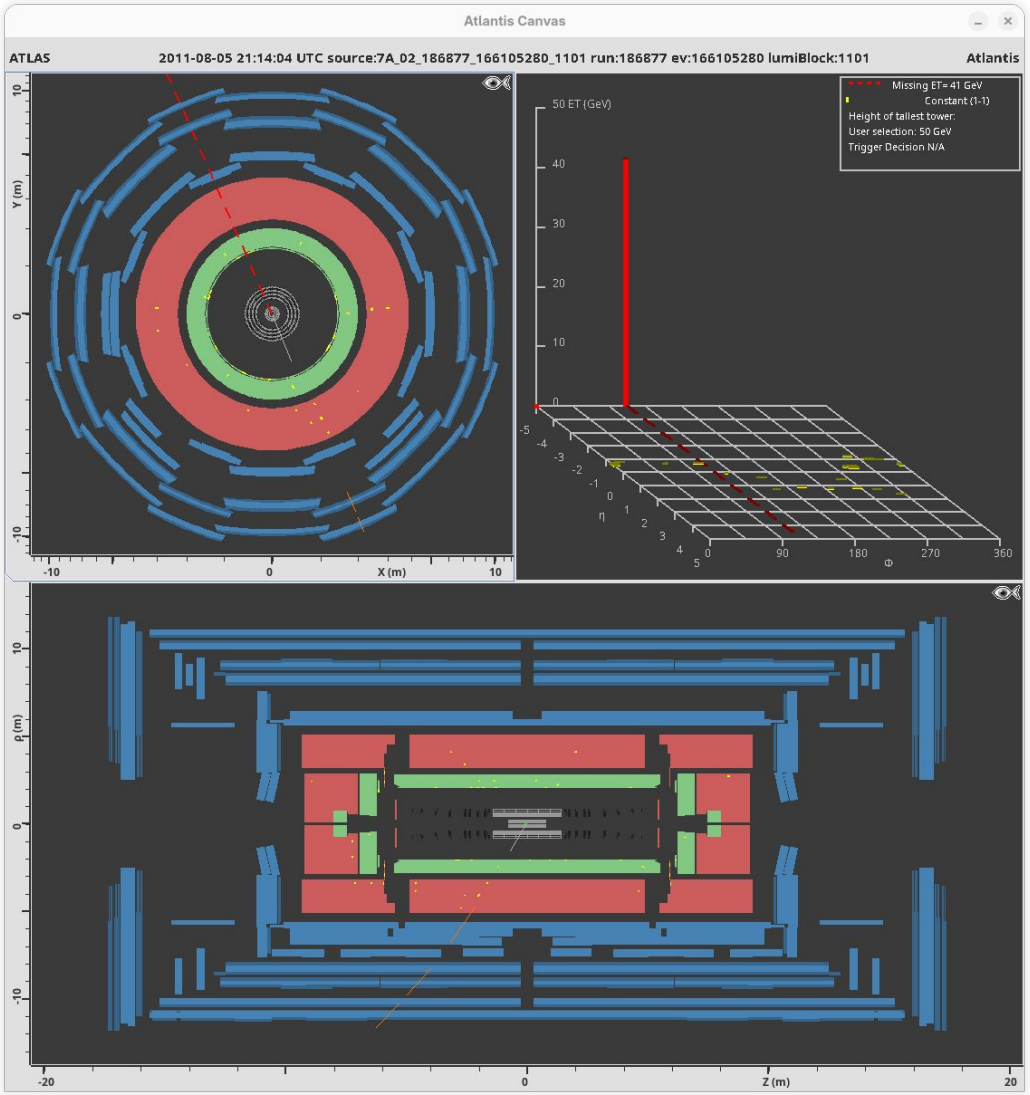
Pz = -11.470 GeV

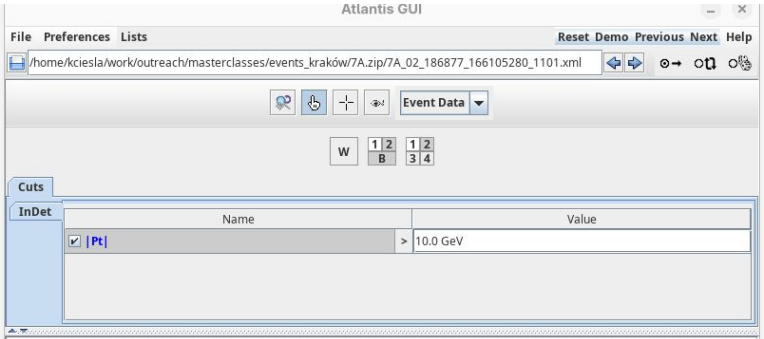
Charge = -1

Isolation = 0.00

Przypadek #1

pT muonu > 20 GeV?





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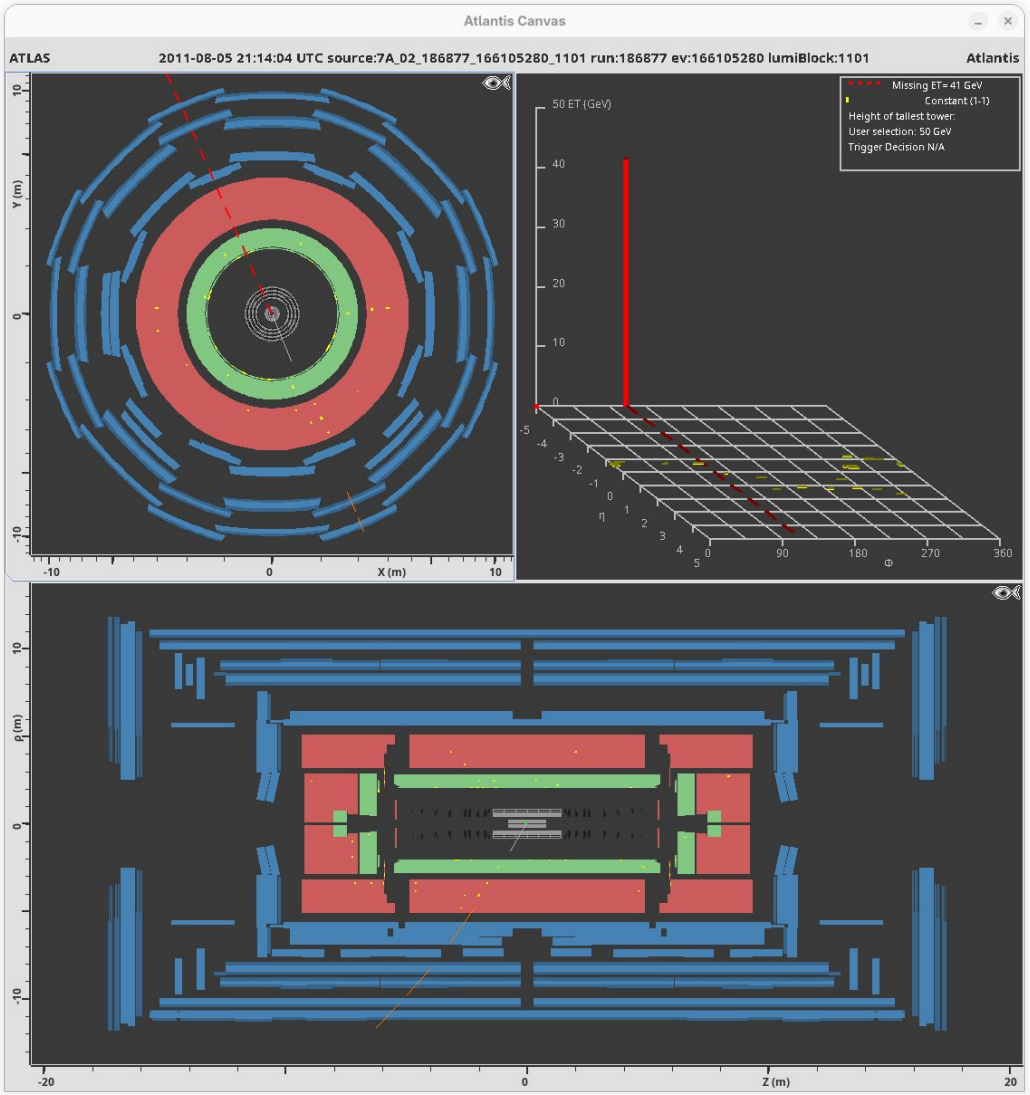
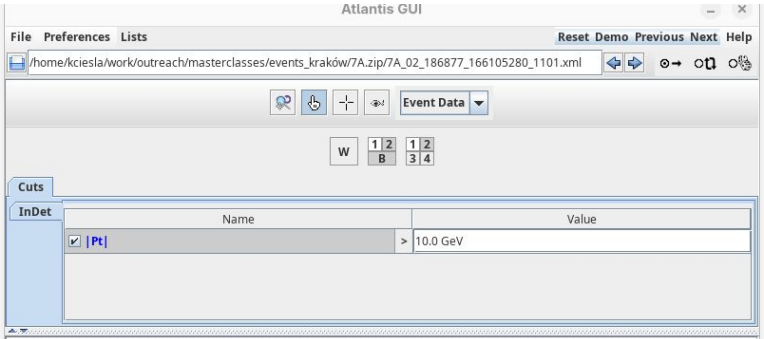
Isolation = 0.00

Przypadek #1

pT muonu > 20 GeV





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Φ = 291.733°

Px = 13.270 GeV

Py = -33.291 GeV

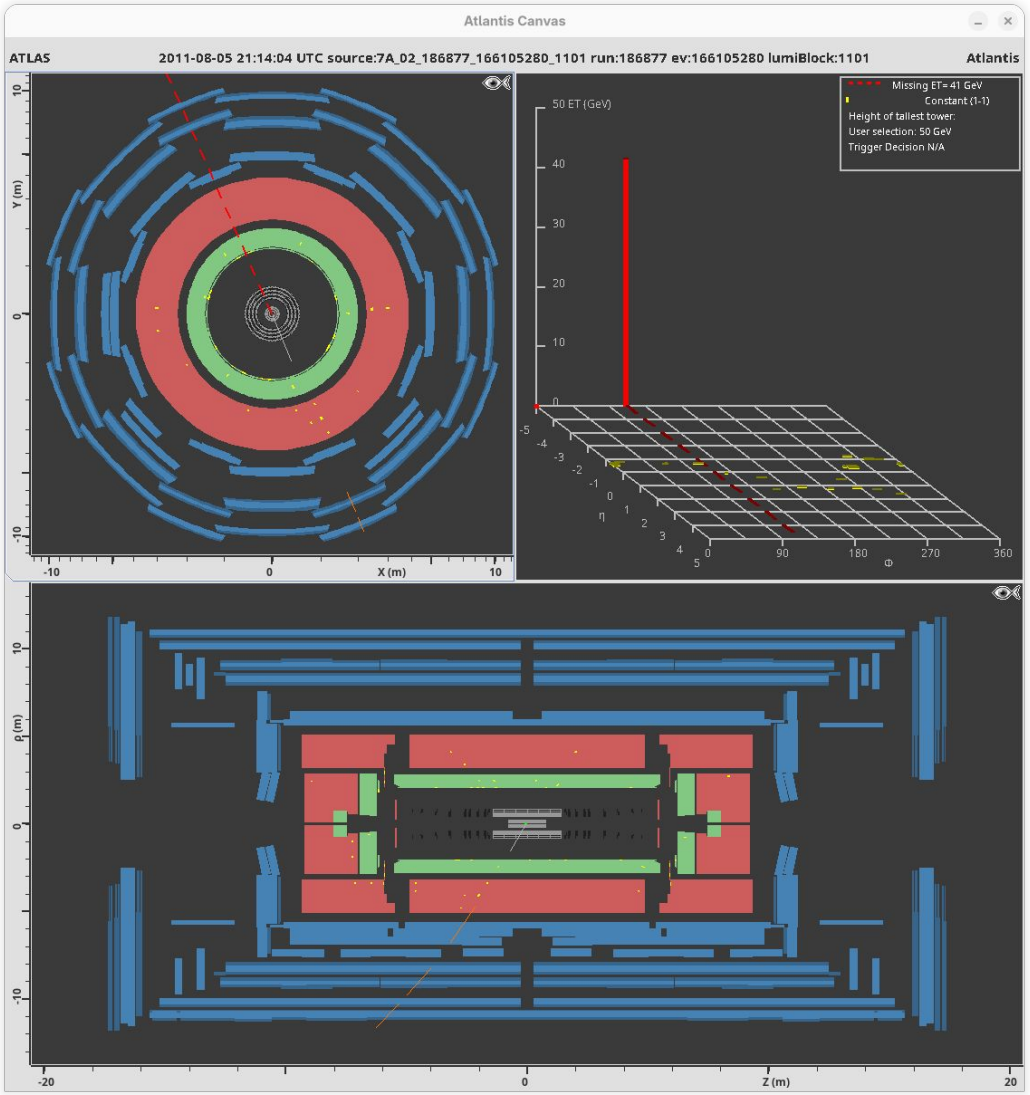
Pz = -11.470 GeV

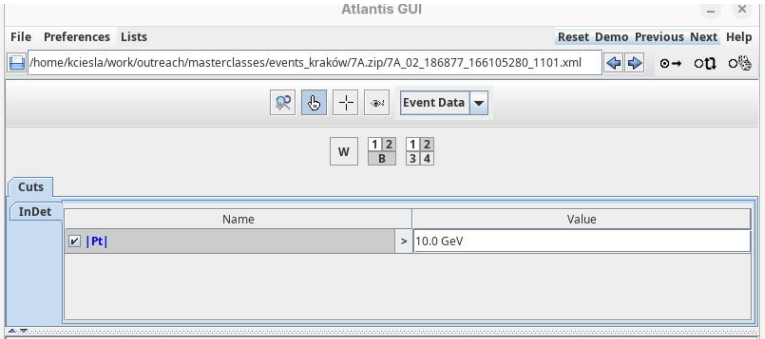
Charge = -1

Isolation = 0.00

Przypadek #1

Brak pobliskich śladów?
Izolacja < 0.2?





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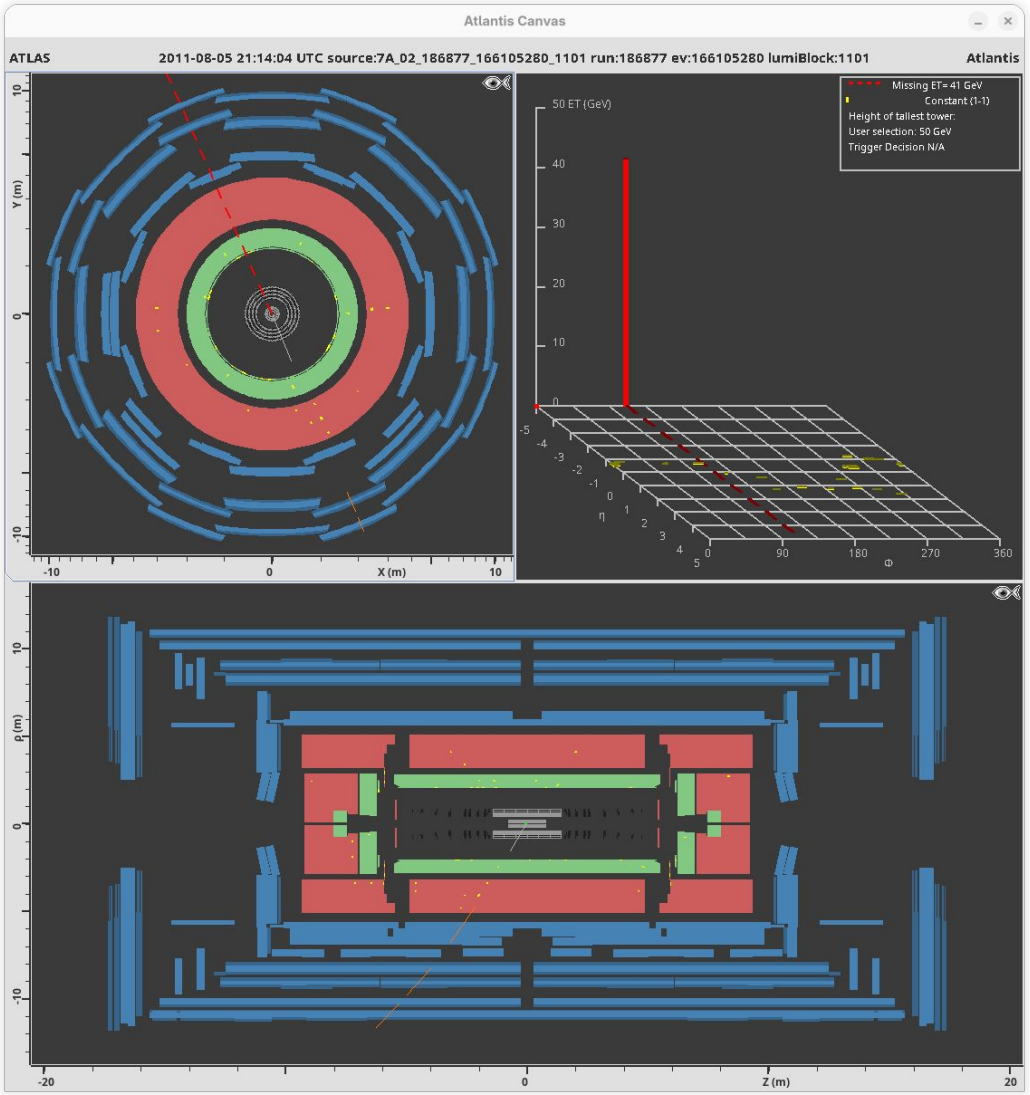
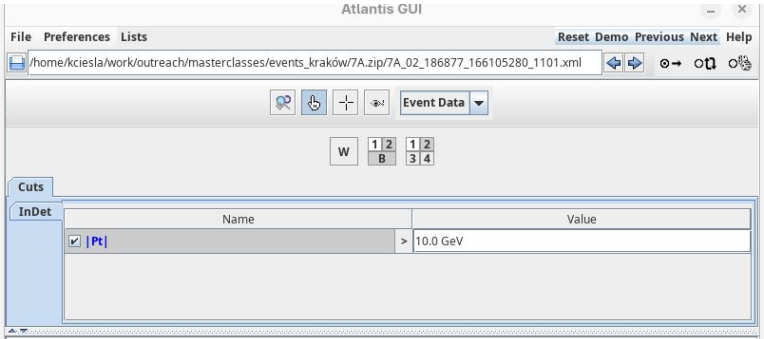
Przypadek #1

Brak pobliskich śladów
Izolacja < 0.2





InDetTrack index: 2

PT = 35.838 GeV

η = -0.315

Φ = 291.733°

Px = 13.270 GeV

Py = -33.291 GeV

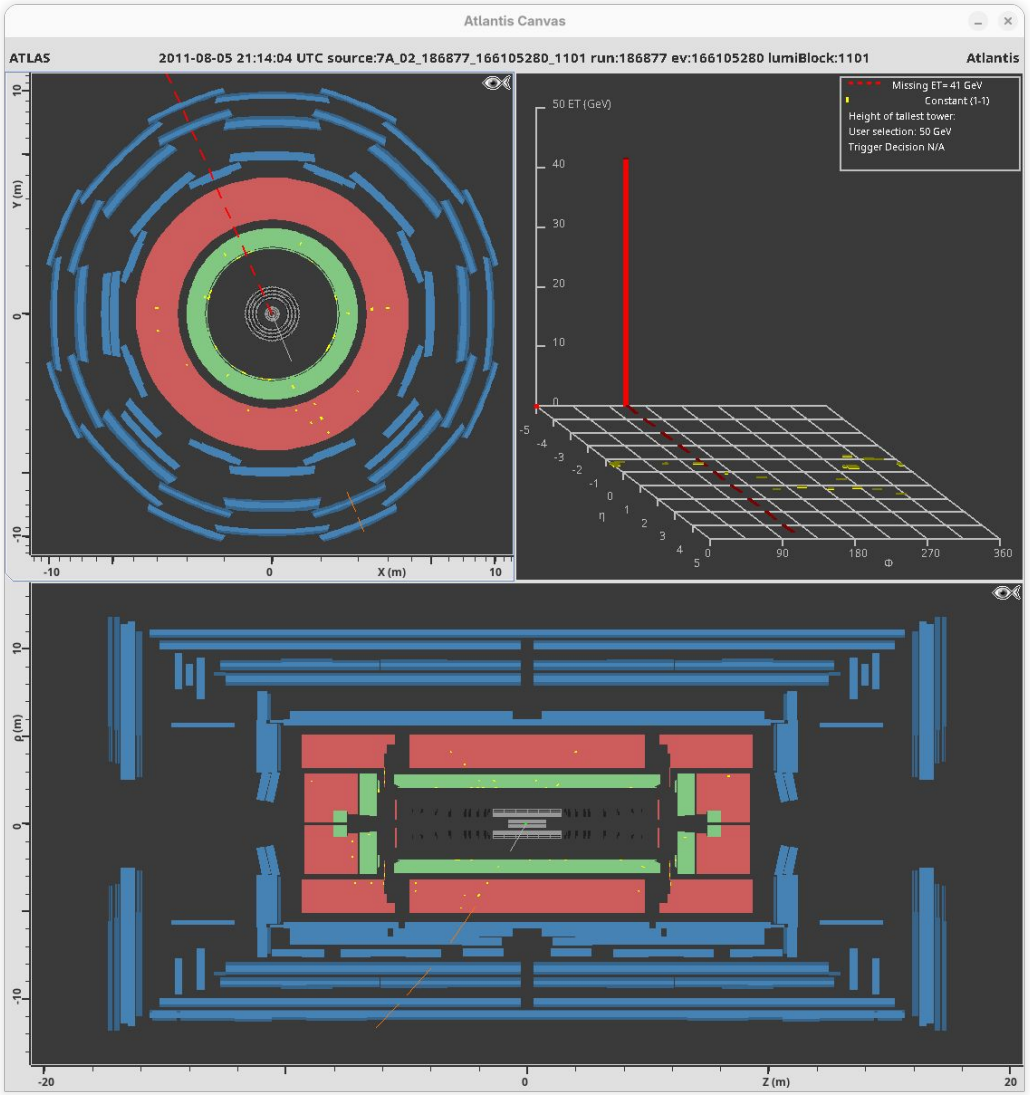
Pz = -11.470 GeV

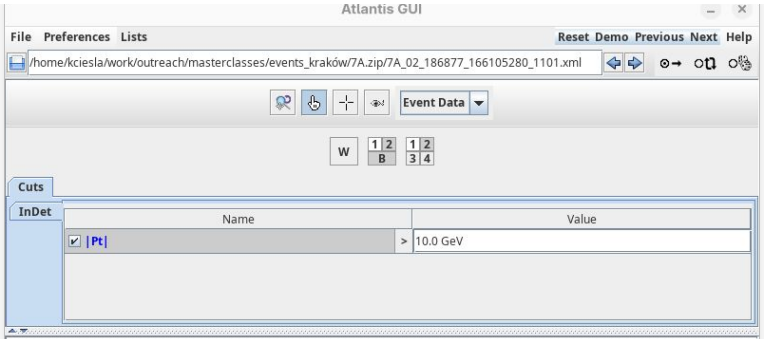
Charge = -1

Isolation = 0.00

Przypadek #1

Mion czy anty-mion?





InDetTrack index: 2

PT = 35.838 GeV

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Φ = 291.733°

Px = 13.270 GeV

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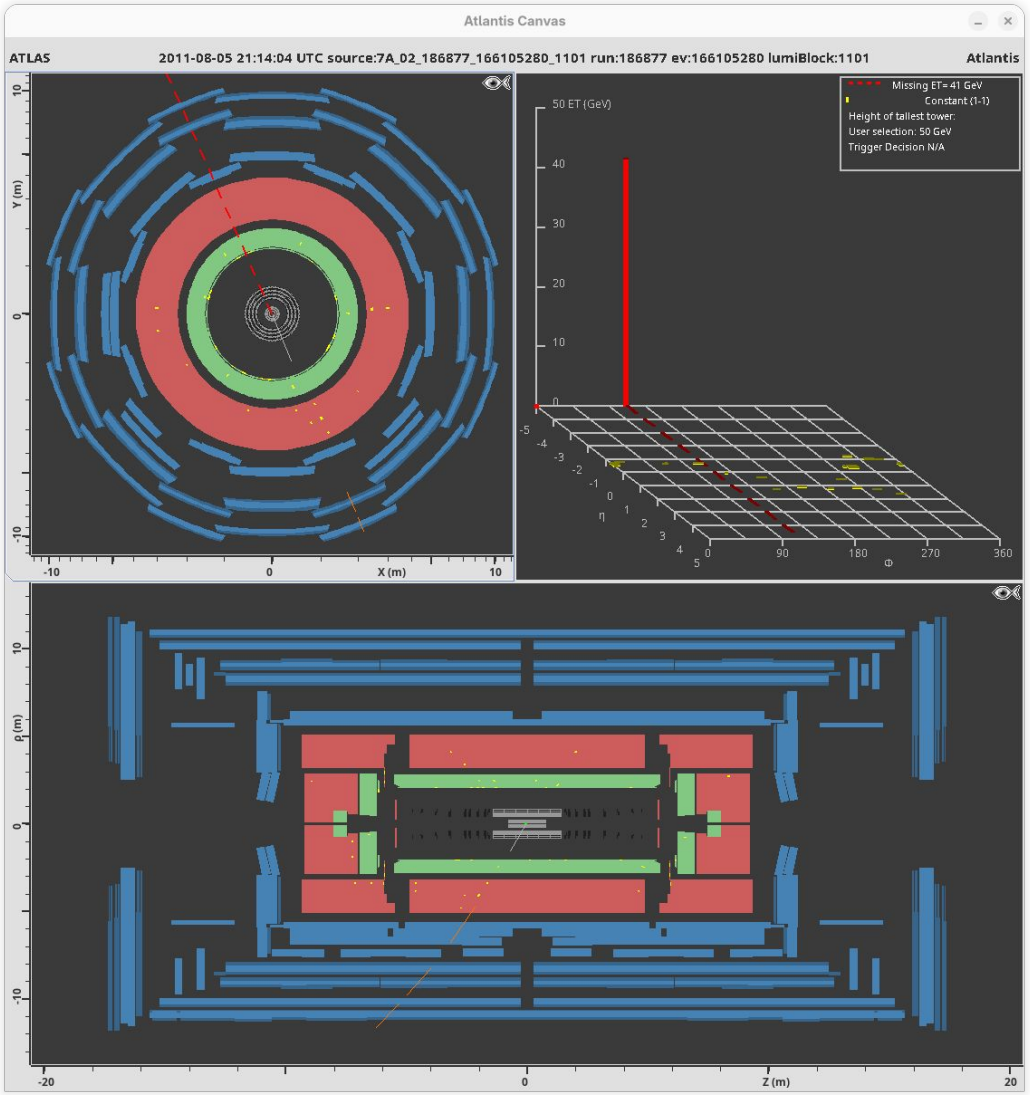
Pz = -11.470 GeV

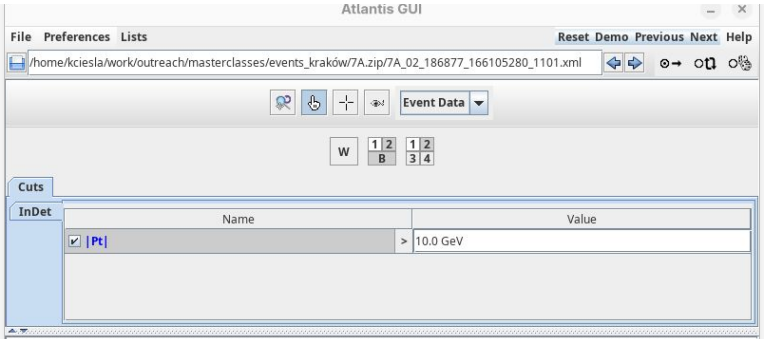
Charge = -1

Isolation = 0.00

Przypadek #1

Mion





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PT = 35.838 GeV

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Φ = 291.733°

Px = 13.270 GeV

Py = -33.291 GeV

Pz = -11.470 GeV

Charge = -1

Isolation = 0.00

Przypadek #1

$W^- \rightarrow \mu^- \nu$

ATLAS data analysis

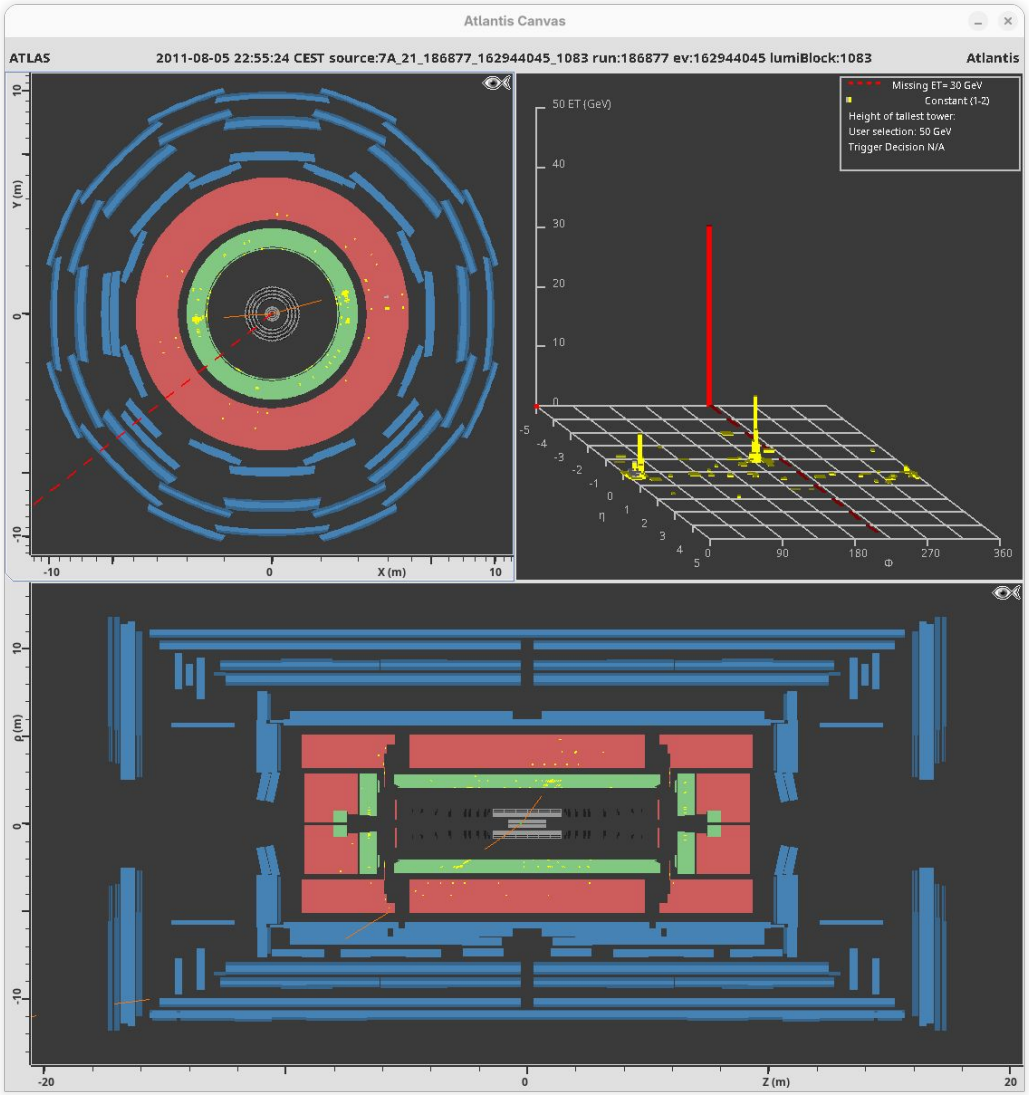
data sample: 5B

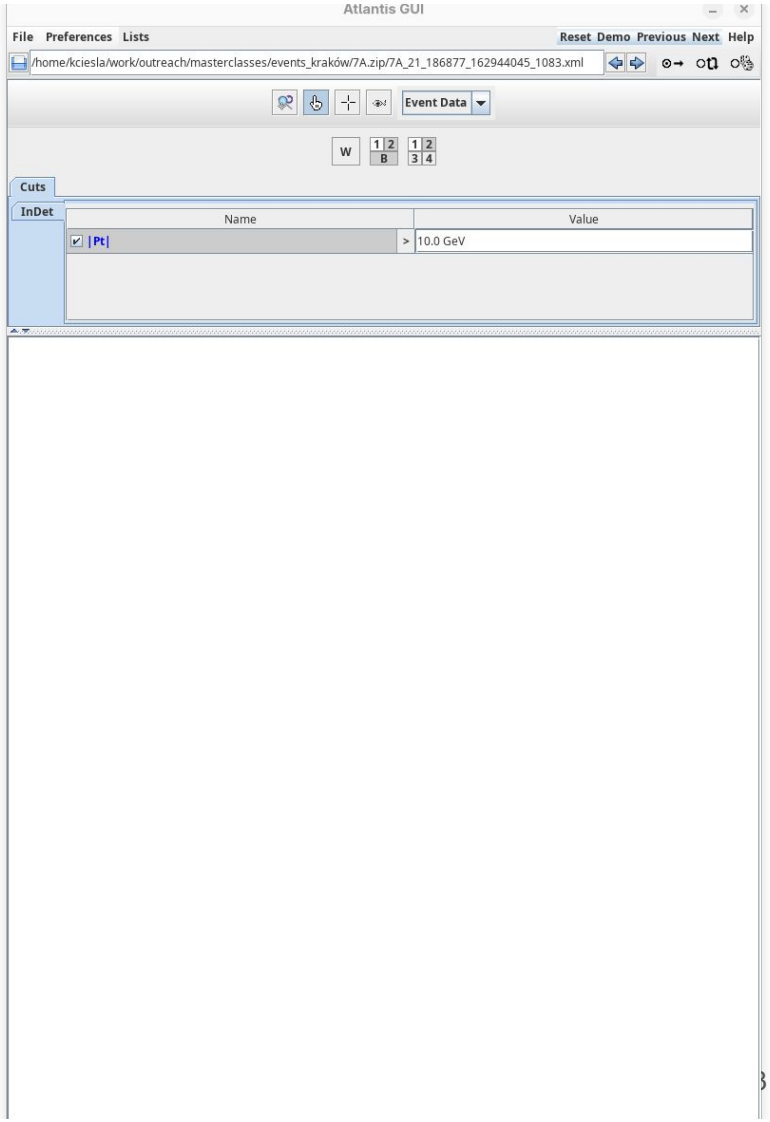
event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + ...		W → ν + ...					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2								
3								
4								
5								
6								
7								
8								
9								
10								

Przykład #2

Przypadek #2

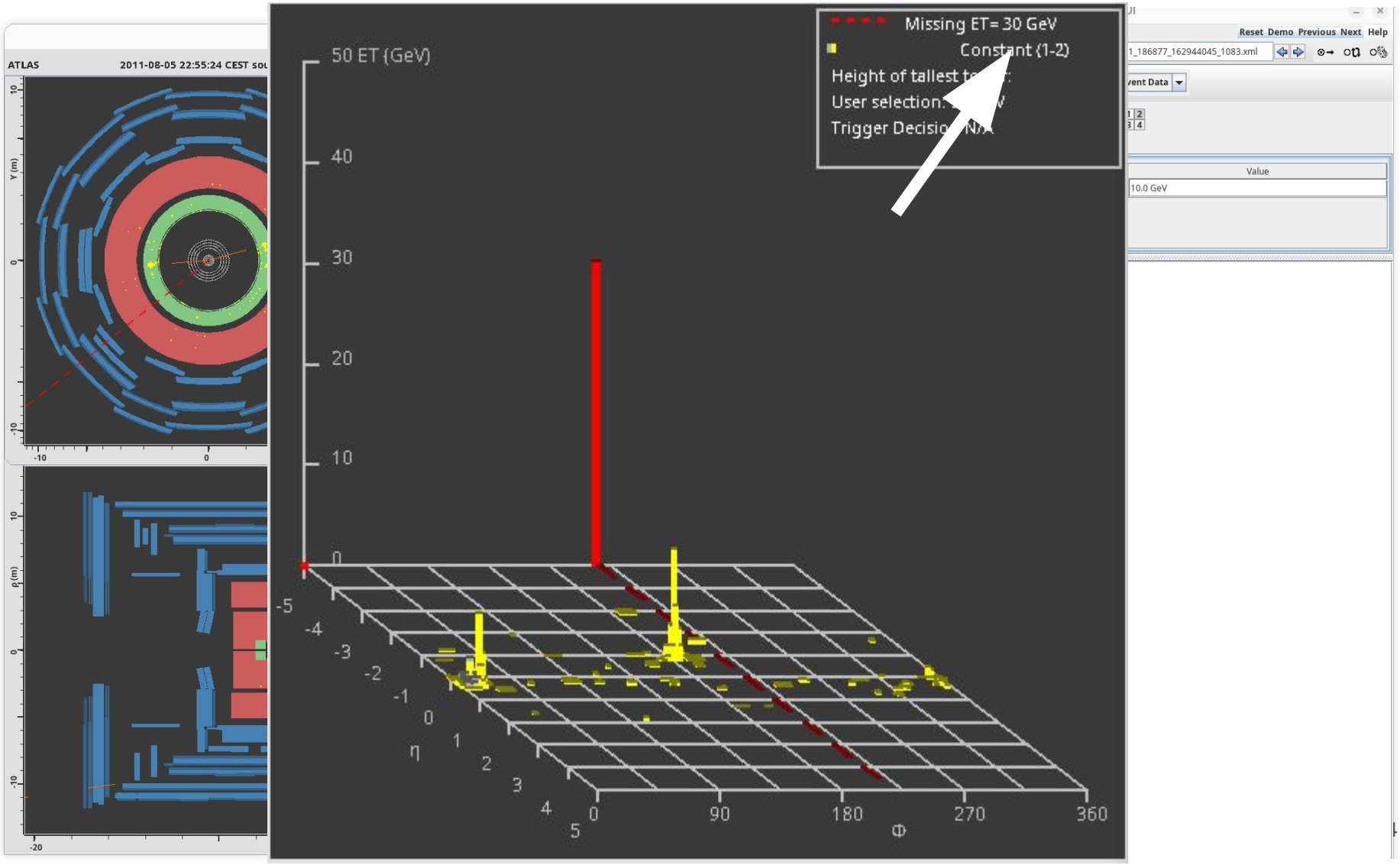
MET > 20 GeV?





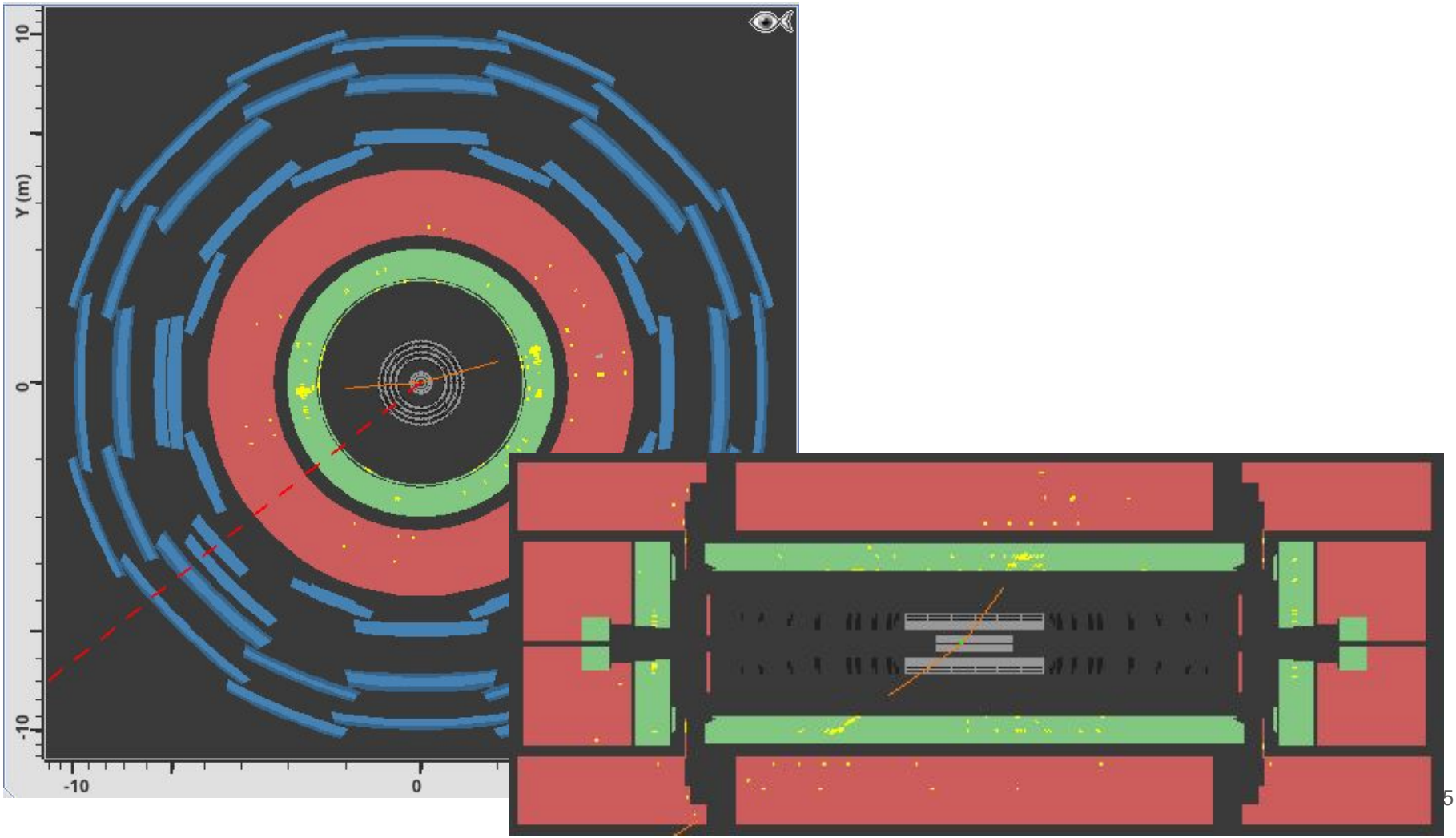
Przypadek #2

MET > 20 GeV



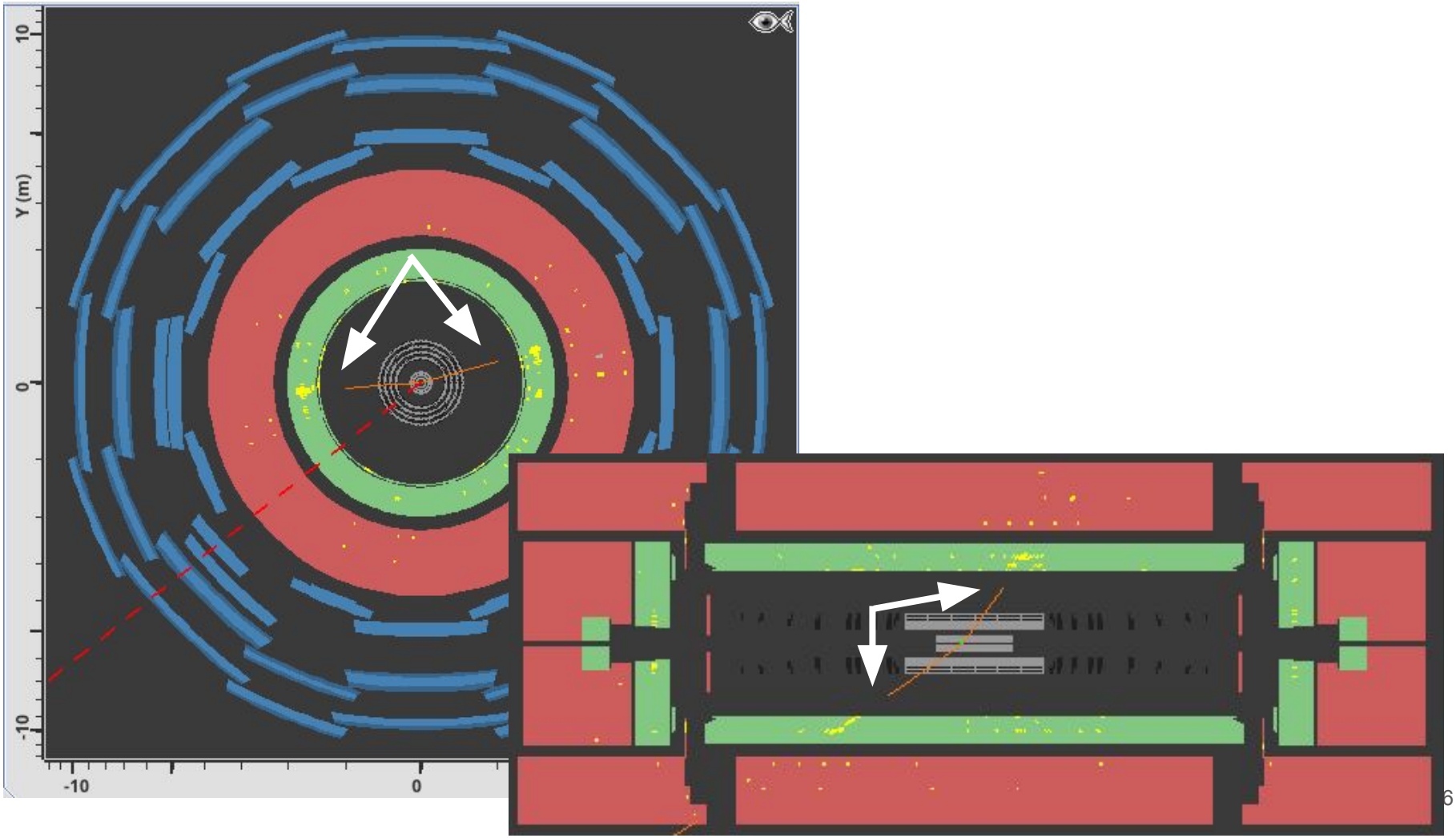
Przypadek #2

Liczba leptonów – elektronów i mionów?



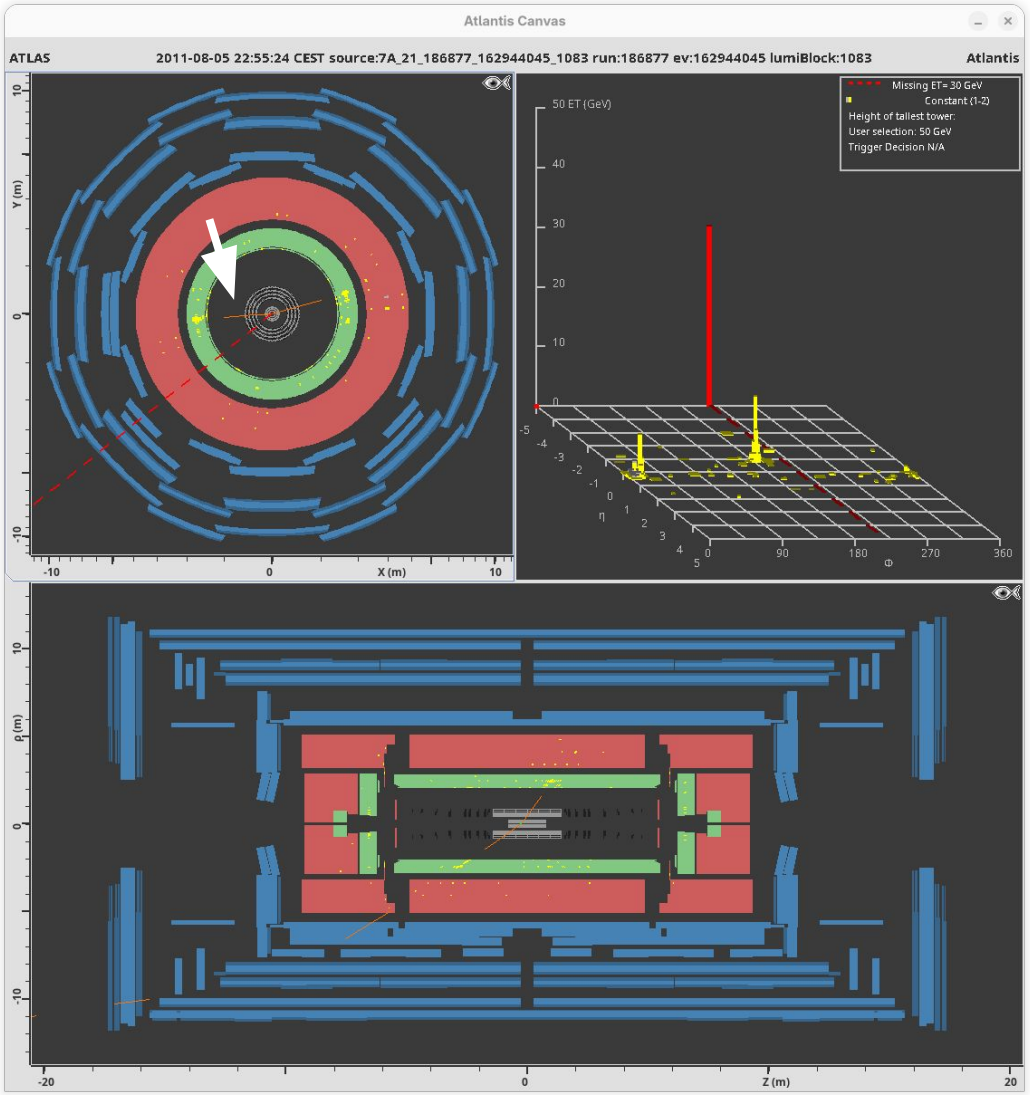
Przypadek #2

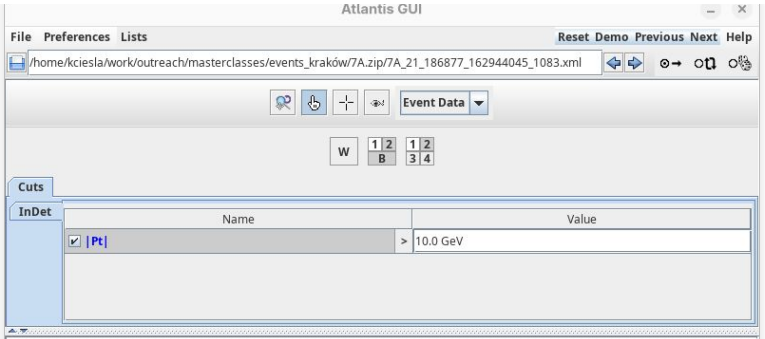
Dwóch kandydatów na elektrony



Przypadek #2

pT leptonu$^{(1)}$ > 20 GeV?
pT leptonu$^{(2)}$ > 10 GeV?





InDetTrack index: 95

PT = 16.989 GeV

η = -0.756

Φ = 183.483°

Px = -16.957 GeV

Py = -1.032 GeV

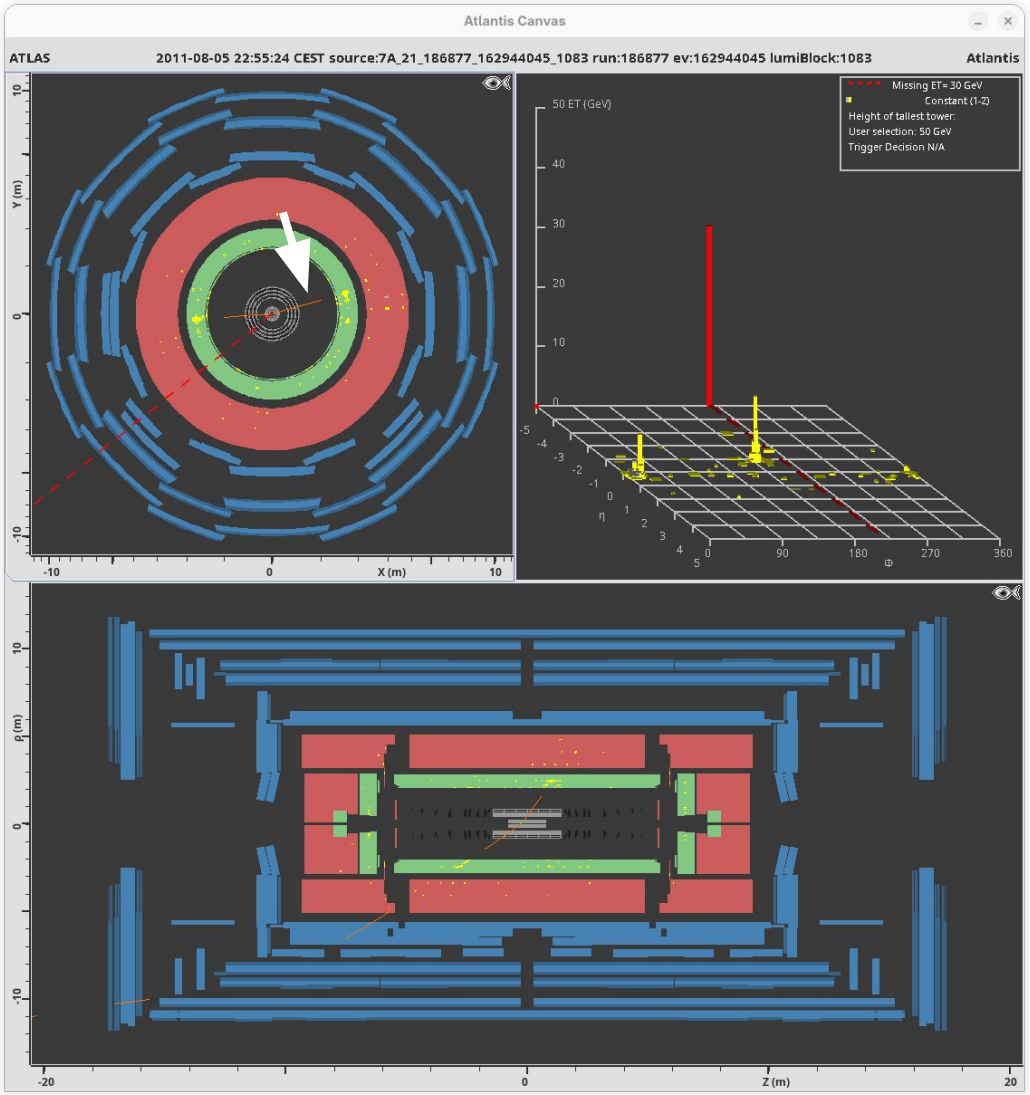
Pz = -14.102 GeV

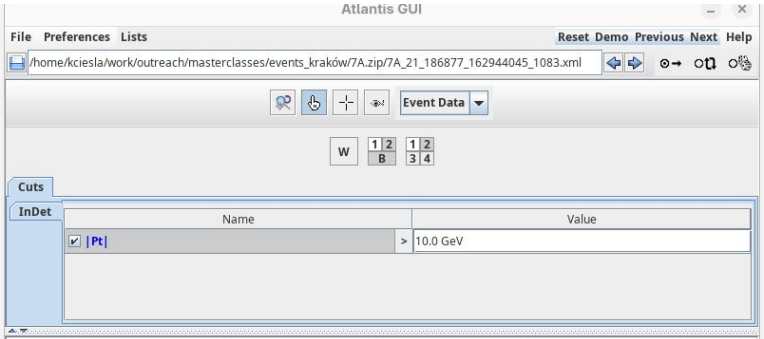
Charge = -1

Isolation = 0.94

Przypadek #2

pT leptonu$^{(1)}$ > 20 GeV?
pT leptonu$^{(2)}$ > 10 GeV?





InDetTrack index: 3

PT = 19.427 GeV

η = 0.383

Φ = 14.703°

Px = 18.791 GeV

Py = 4.931 GeV

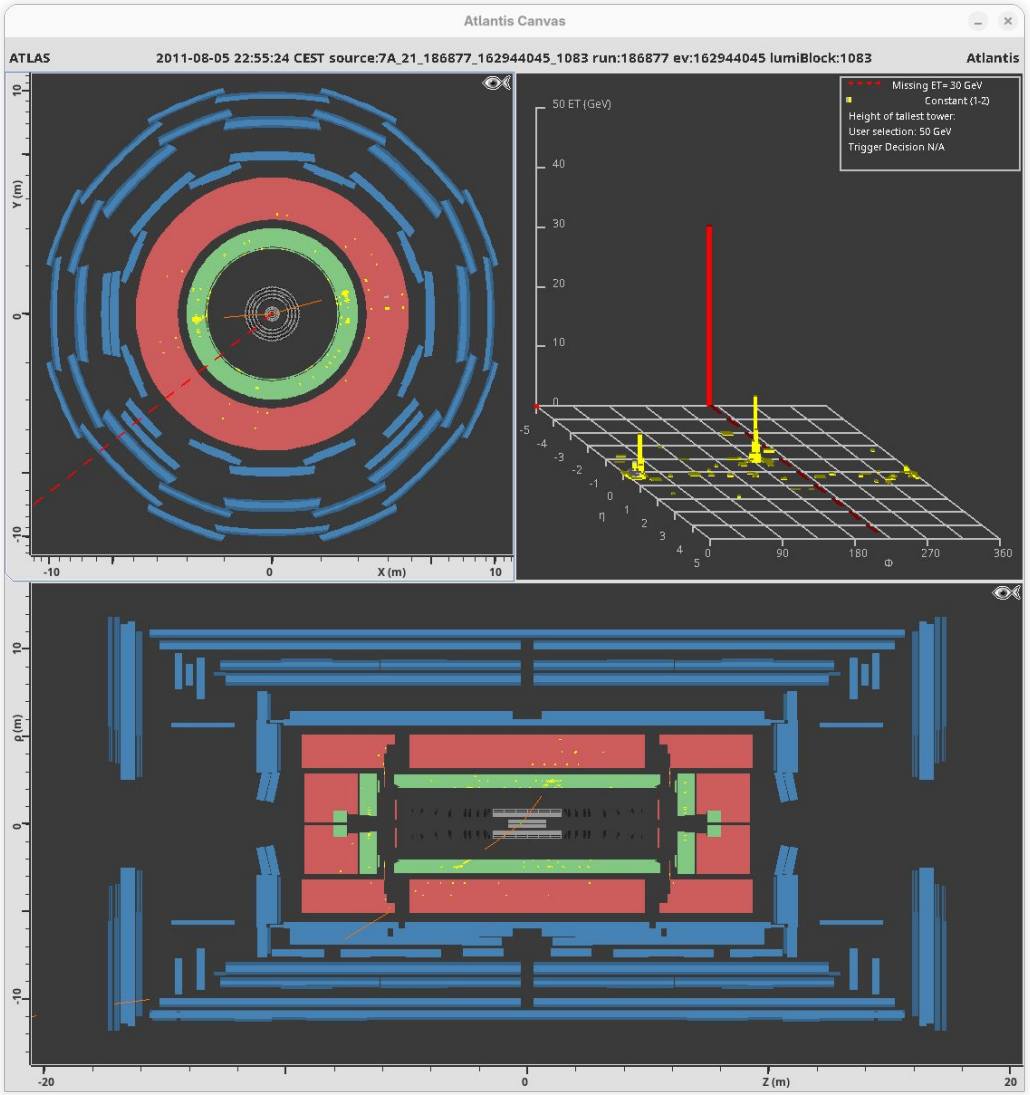
Pz = 7.633 GeV

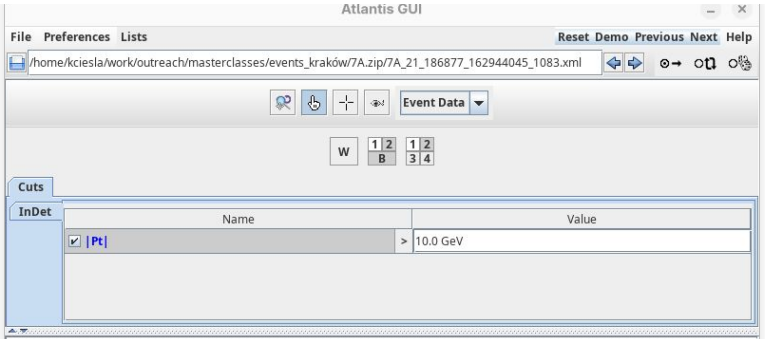
Charge = -1

Isolation = 1.35

Przypadek #2

pT leptonu$^{(1)}$ > 20 GeV
pT leptonu$^{(2)}$ > 10 GeV





InDetTrack index: 3

PT = 19.427 GeV

η = 0.383

Φ = 14.703°

Px = 18.791 GeV

Py = 4.931 GeV

Pz = 7.633 GeV

Charge = -1

Isolation = 1.35

Przypadek #2

Tło

ATLAS data analysis

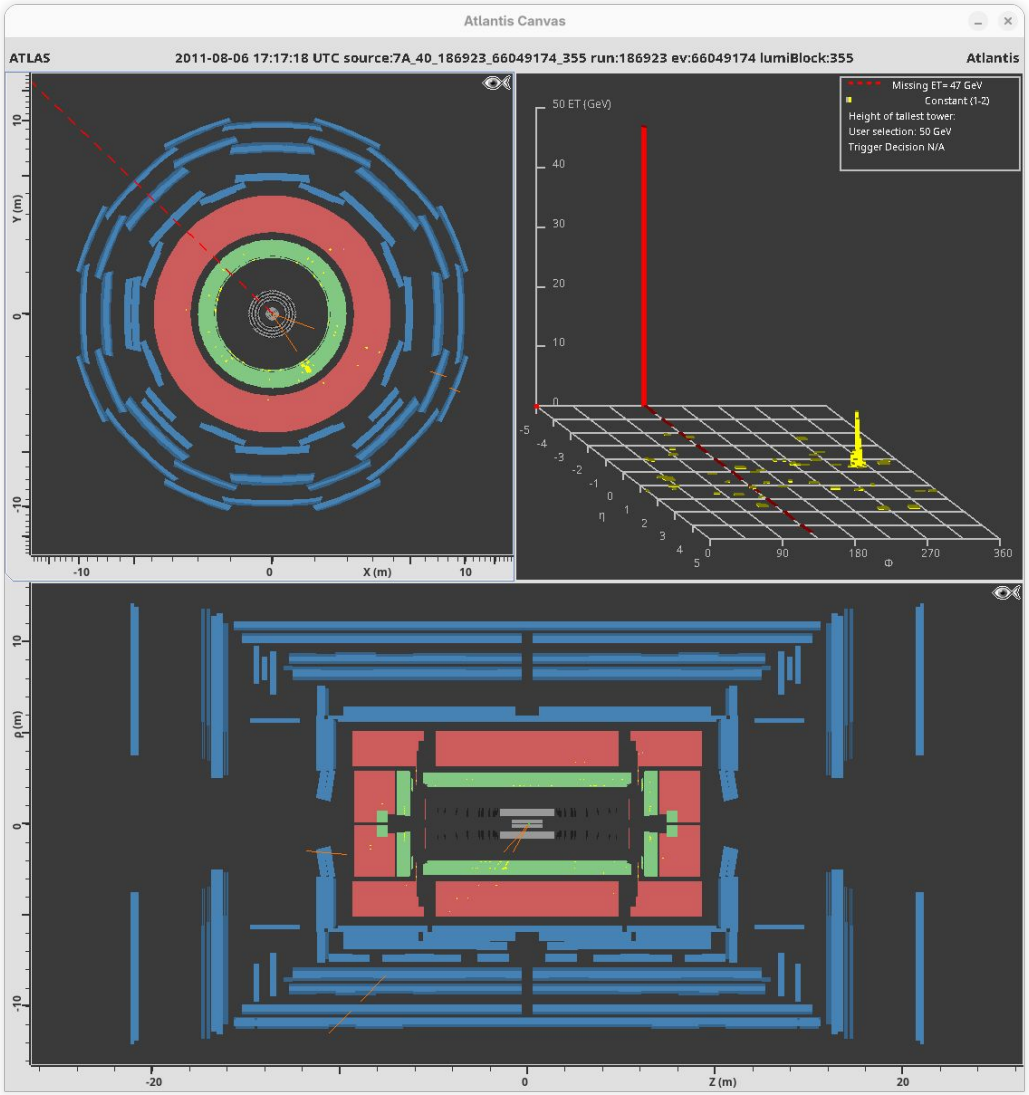
data sample: 5B

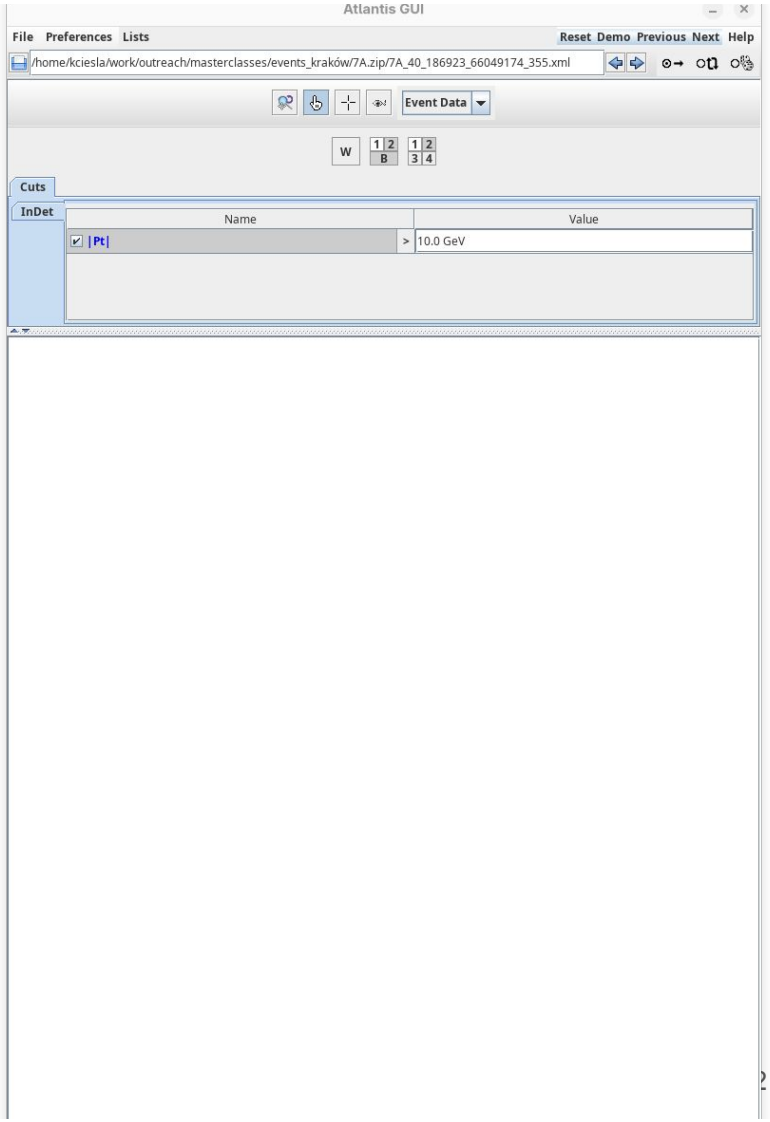
event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu + \ldots$		$W \rightarrow \nu + \ldots$		$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
	e^+	e^-	μ^+	μ^-				
1				X				
2							X	
3								
4								
5								
6								
7								
8								
9								
10								

Przykład #3

Przypadek #3

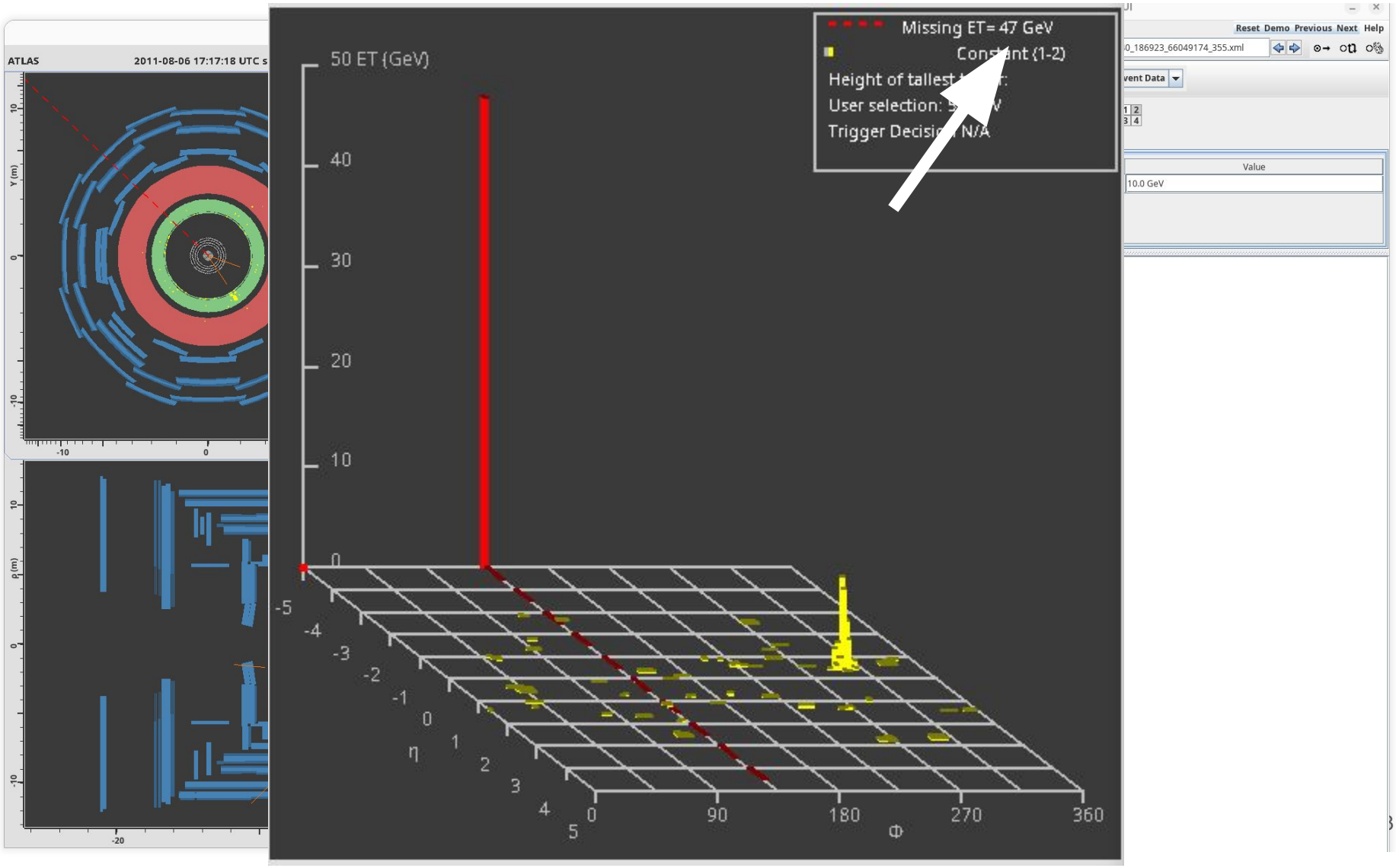
MET > 20 GeV?





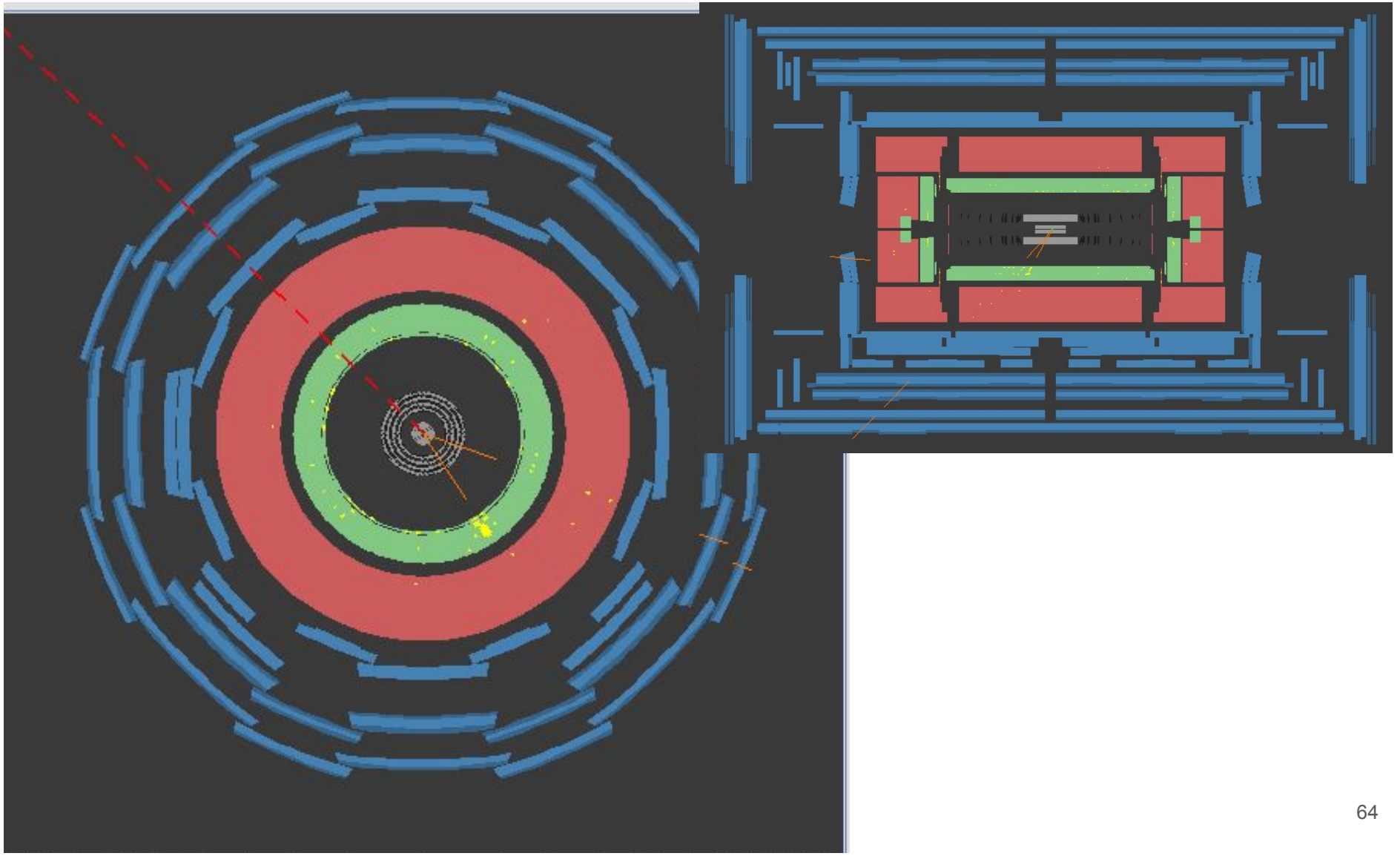
Przypadek #3

MET > 20 GeV



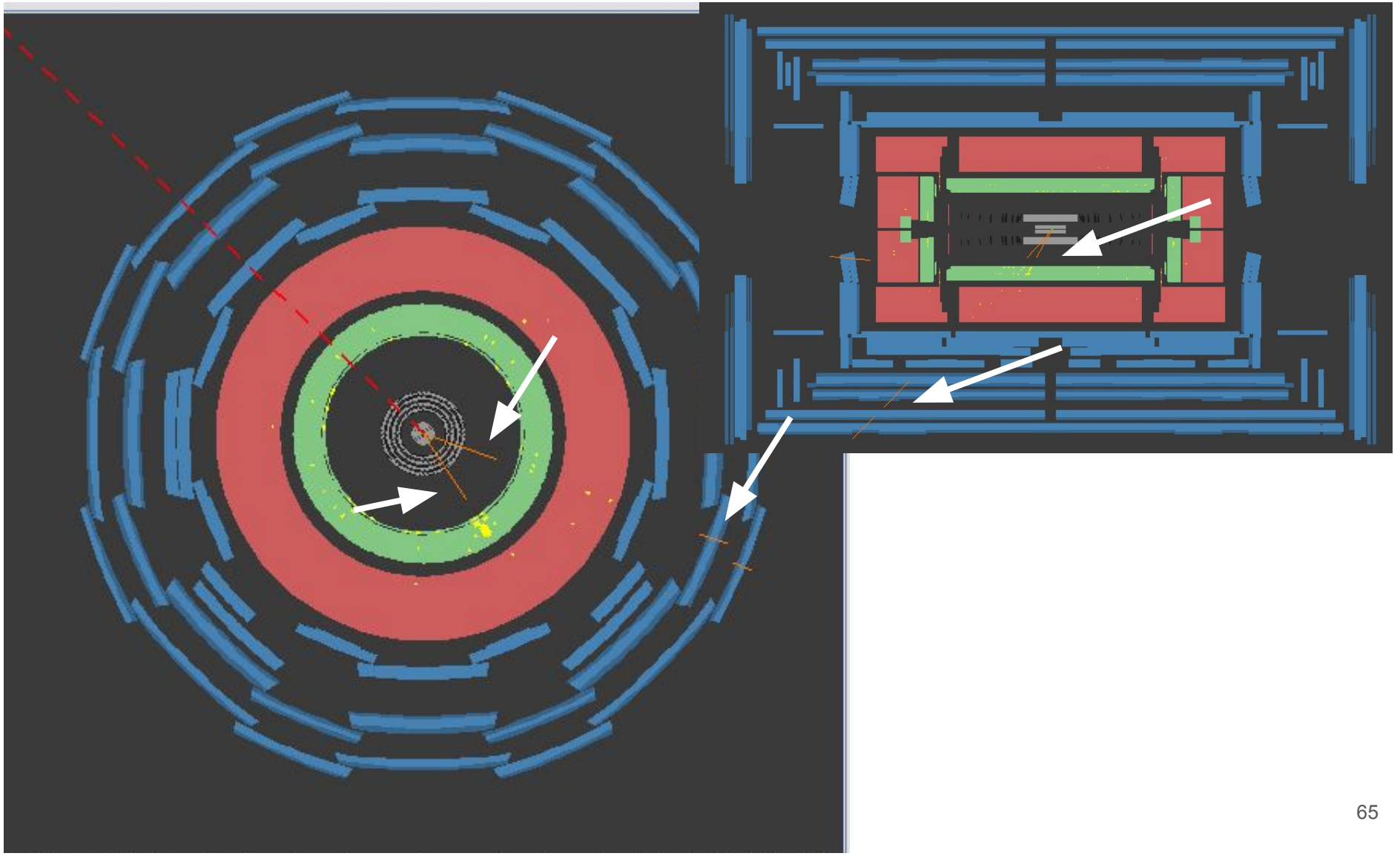
Przypadek #3

Liczba leptonów – elektronów i mionów?



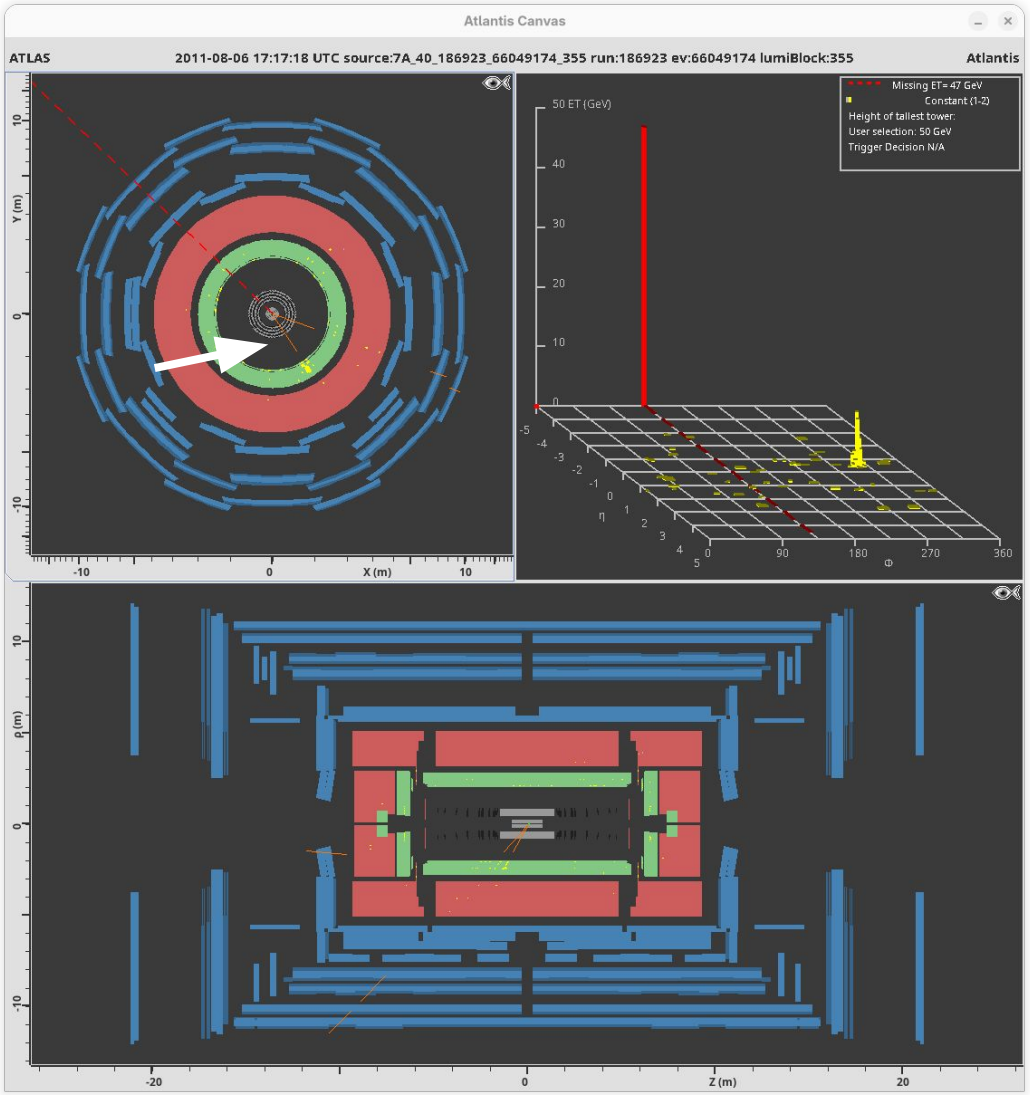
Przypadek #3

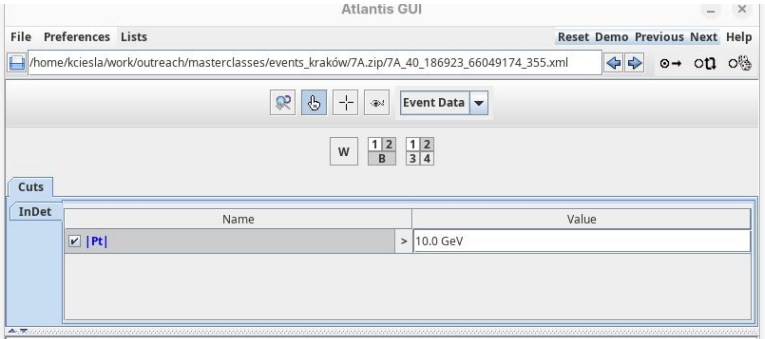
Kandydat na mion
Kandydat na elektron



Przypadek #3

pT leptonu$^{(1)}$ > 20 GeV?
pT leptonu$^{(2)}$ > 10 GeV?





InDetTrack index: 72

PT = 24.949 GeV

η = -0.402

Φ = 302.431°

Px = 13.380 GeV

Py = -21.058 GeV

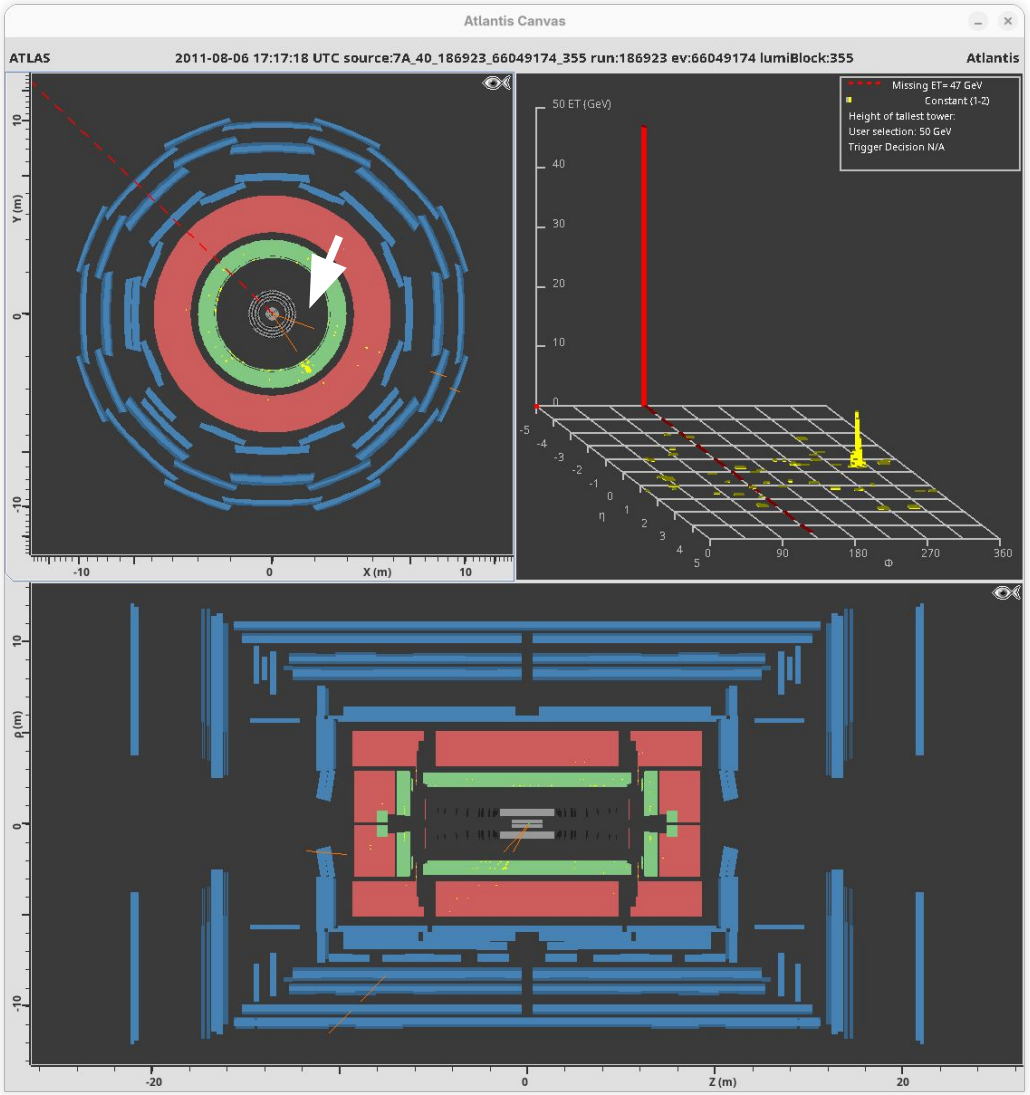
Pz = -10.305 GeV

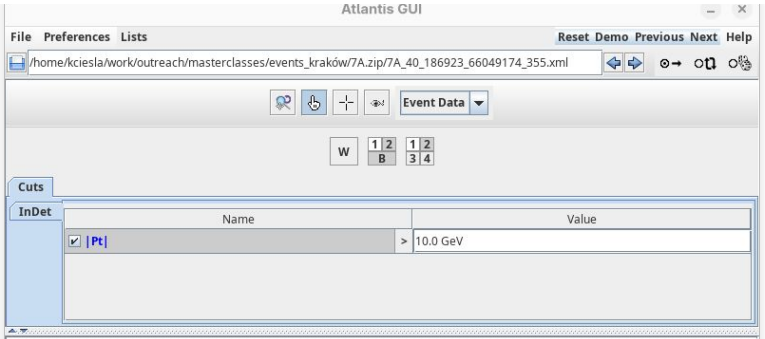
Charge = -1

Isolation = 0.00

Przypadek #3

pT leptonu$^{(1)}$ > 20 GeV
pT leptonu$^{(2)}$ > 10 GeV





InDetTrack index: 5

PT = 20.045 GeV

η = -0.622

Φ = 342.036°

Px = 19.068 GeV

Py = -6.182 GeV

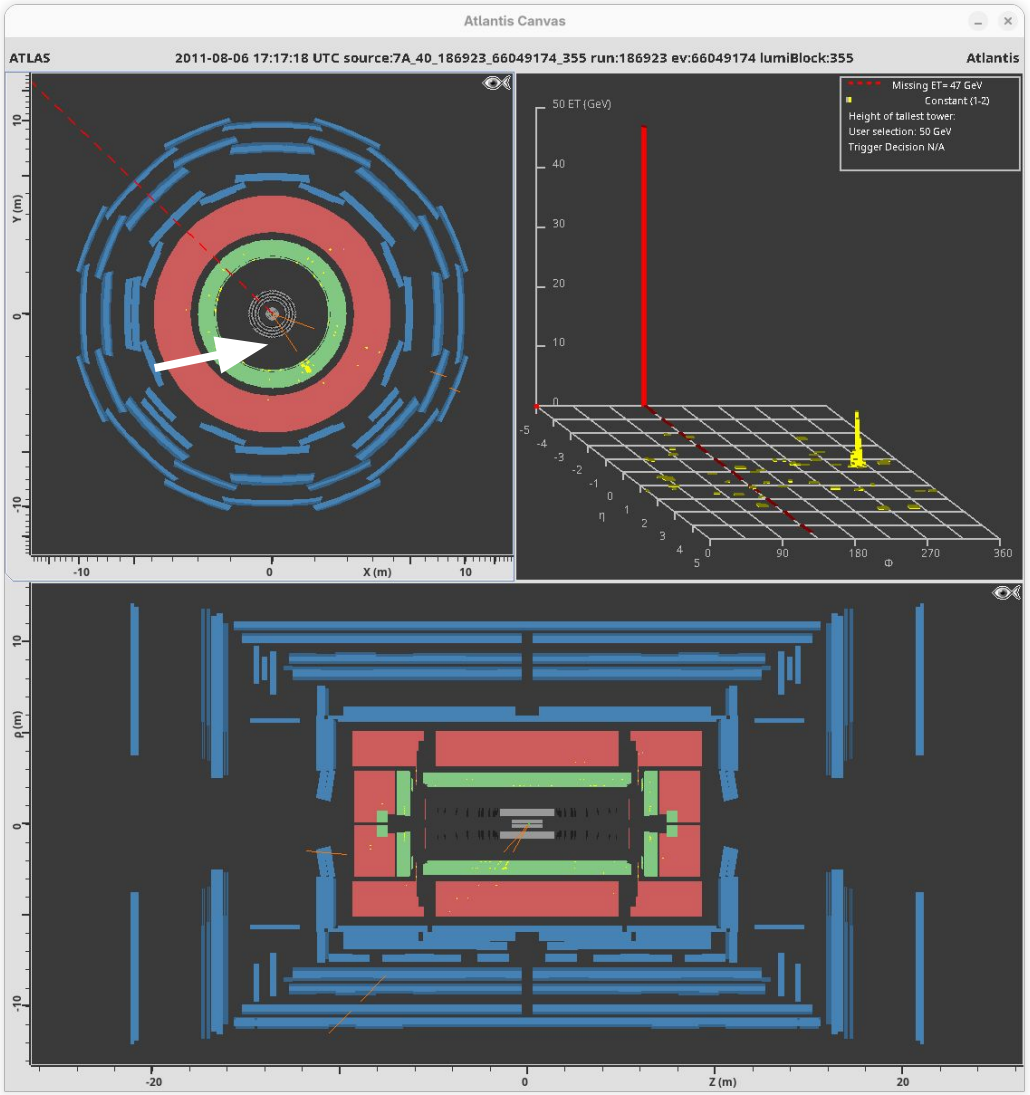
Pz = -13.278 GeV

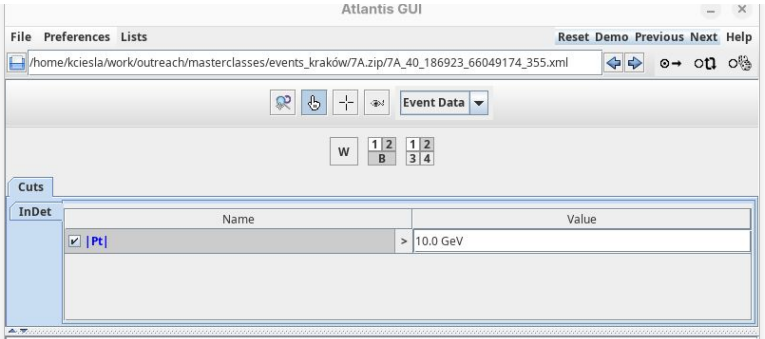
Charge = 1

Isolation = 0.00

Przypadek #3

Brak pobliskich śladów?
Izolacja < 0.2?





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Pz = -10.305 GeV

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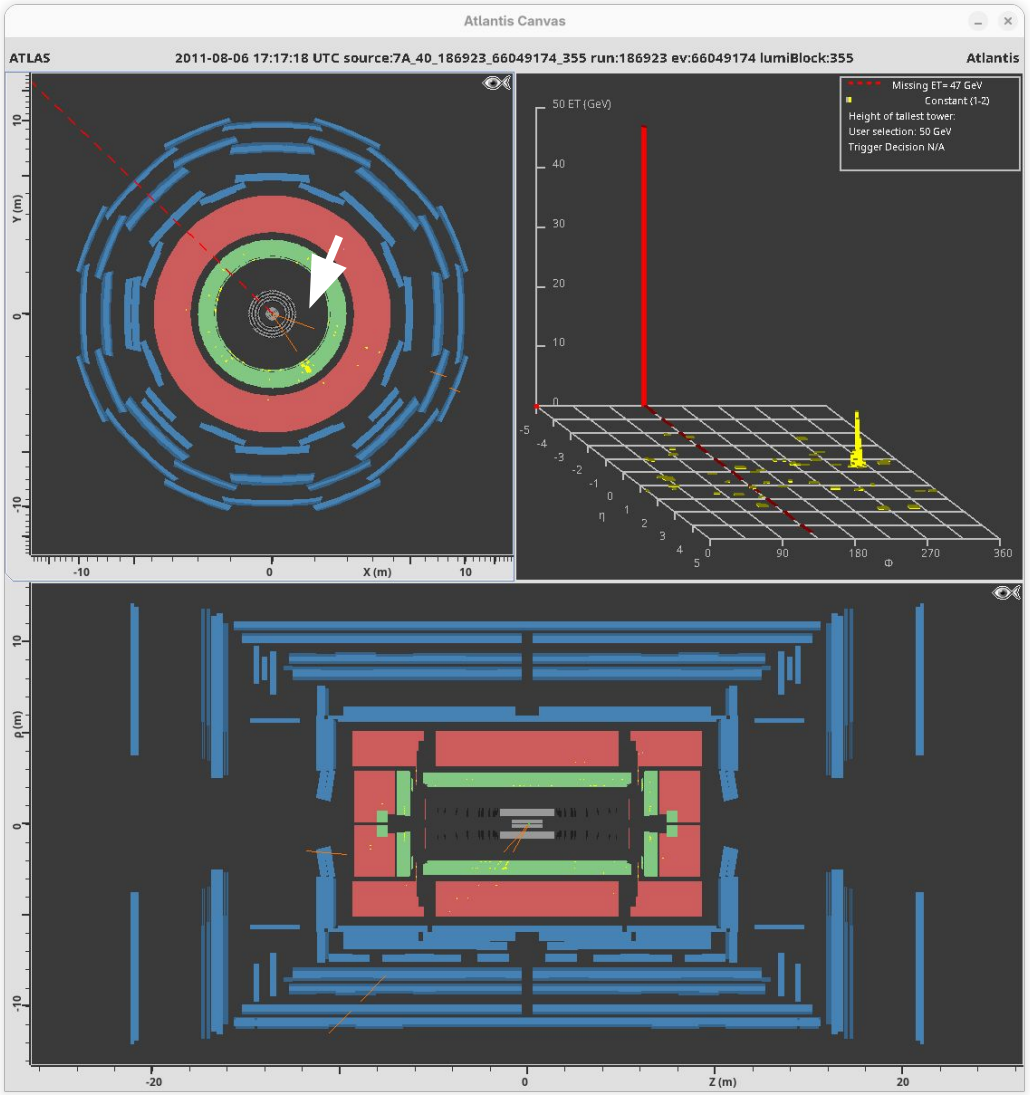
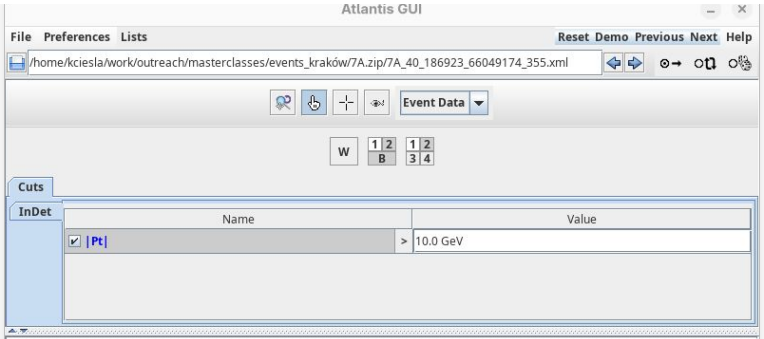
Isolation = 0.00

Przypadek #3

Brak pobliskich śladów
Izolacja < 0.2





InDetTrack index: 5

PT = 20.045 GeV

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Φ = 342.036°

Px = 19.068 GeV

Py = -6.182 GeV

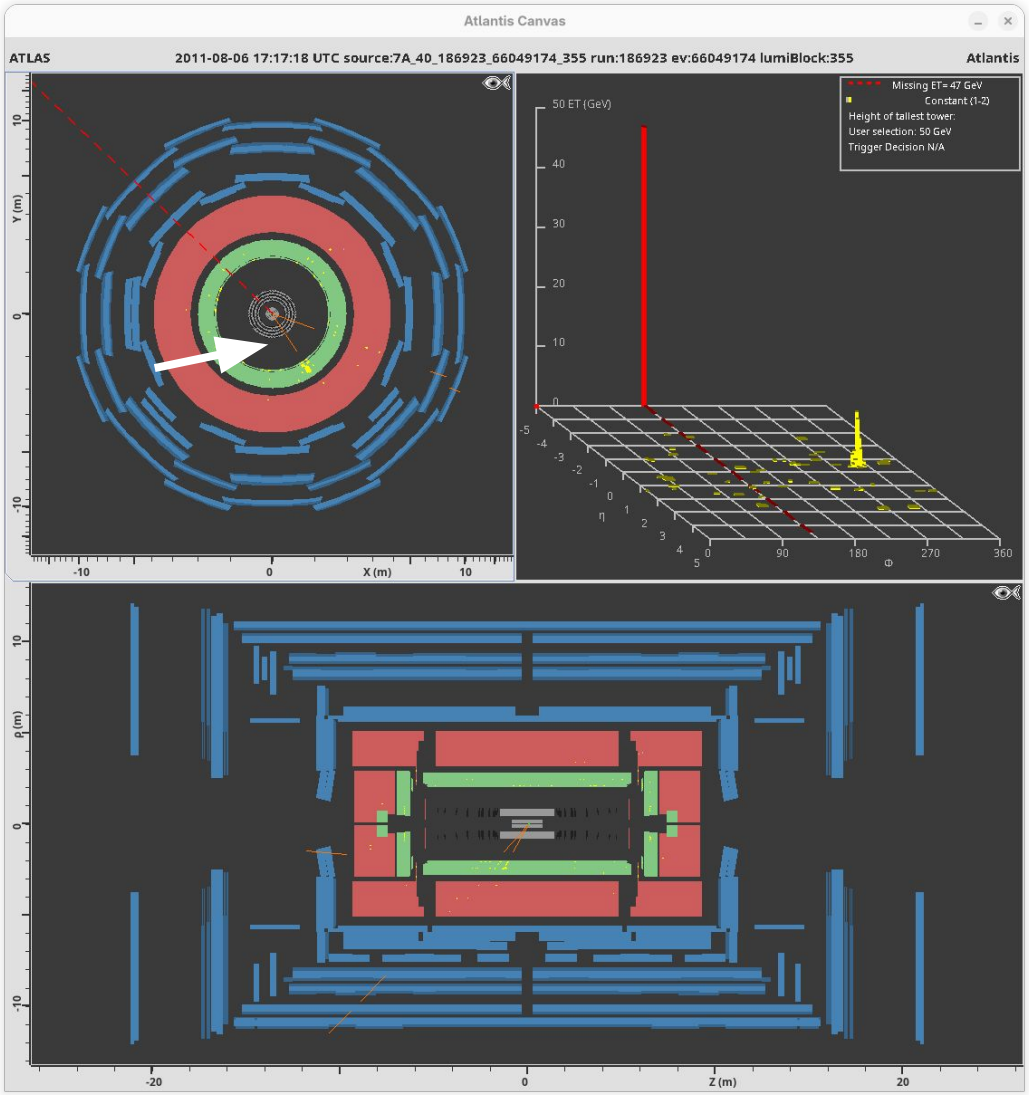
Pz = -13.278 GeV

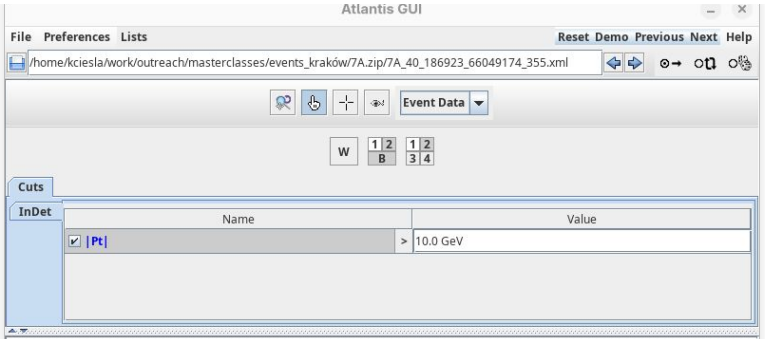
Charge = 1

Isolation = 0.00

Przypadek #3

Przeciwny ładunek?





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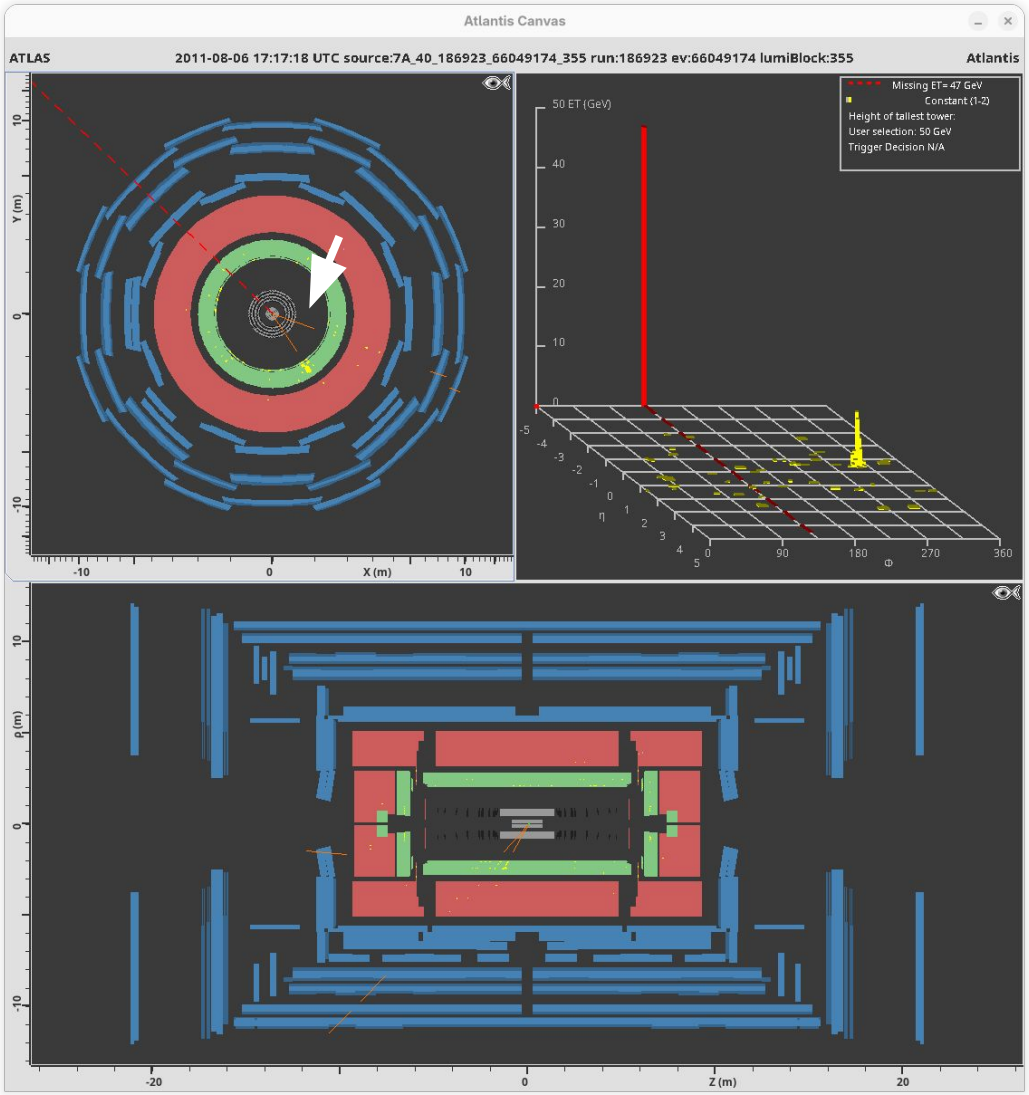
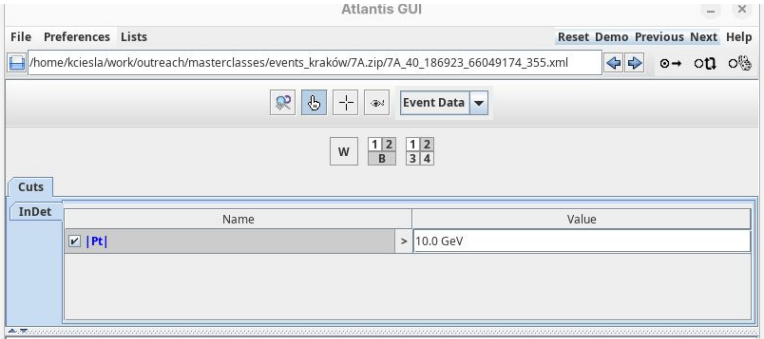
Przypadek #3

Przeciwny ładunek





InDetTrack index: 5

PT = 20.045 GeV

η = -0.622

Φ = 342.036°

Px = 19.068 GeV

Py = -6.182 GeV

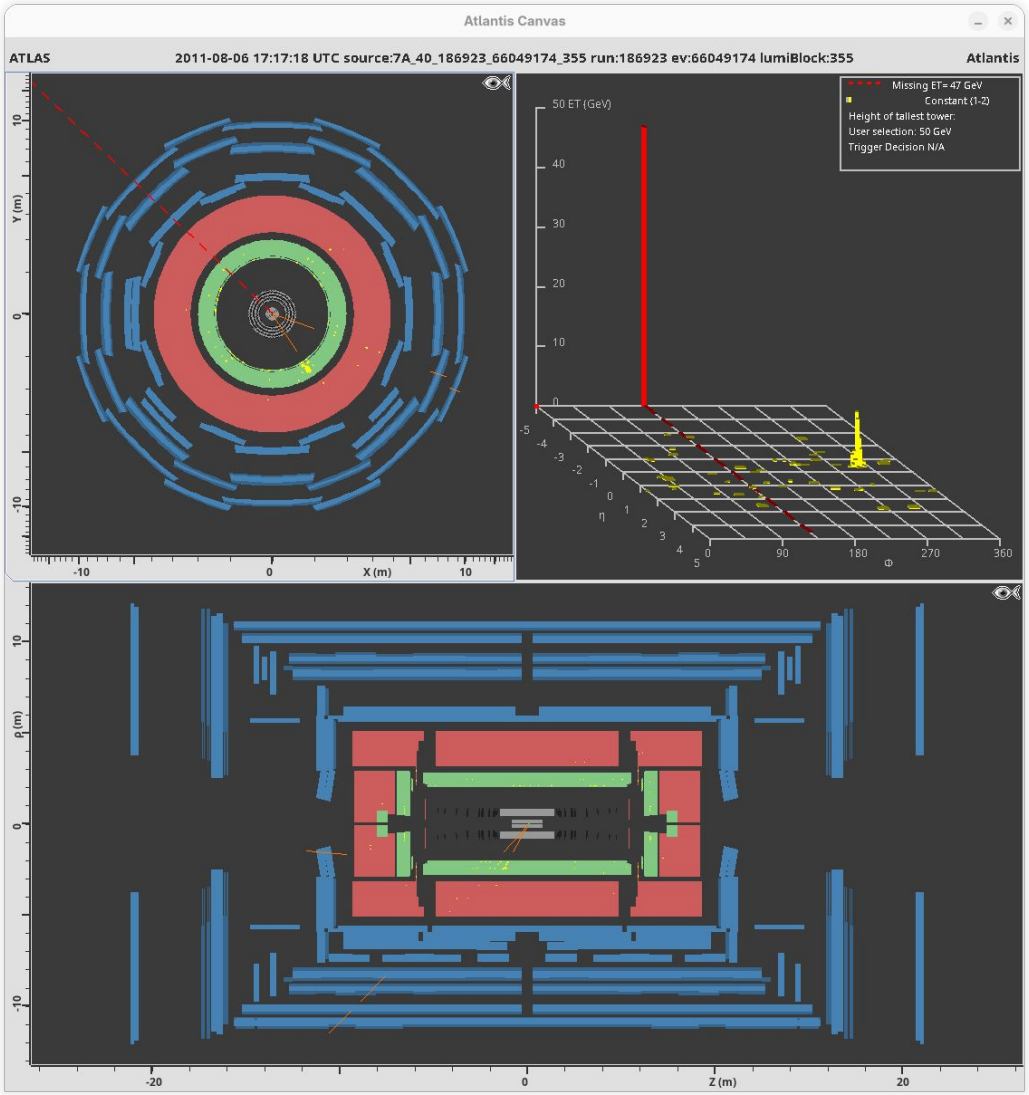
Pz = -13.278 GeV

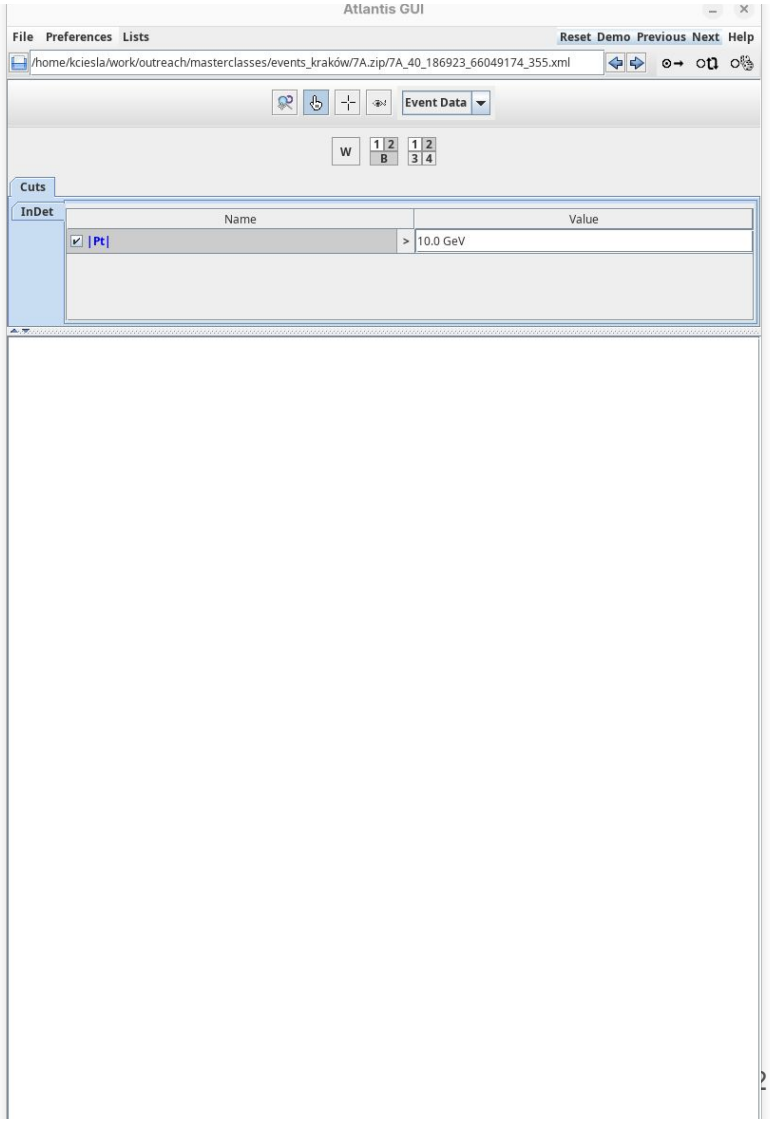
Charge = 1

Isolation = 0.00

Przypadek #3

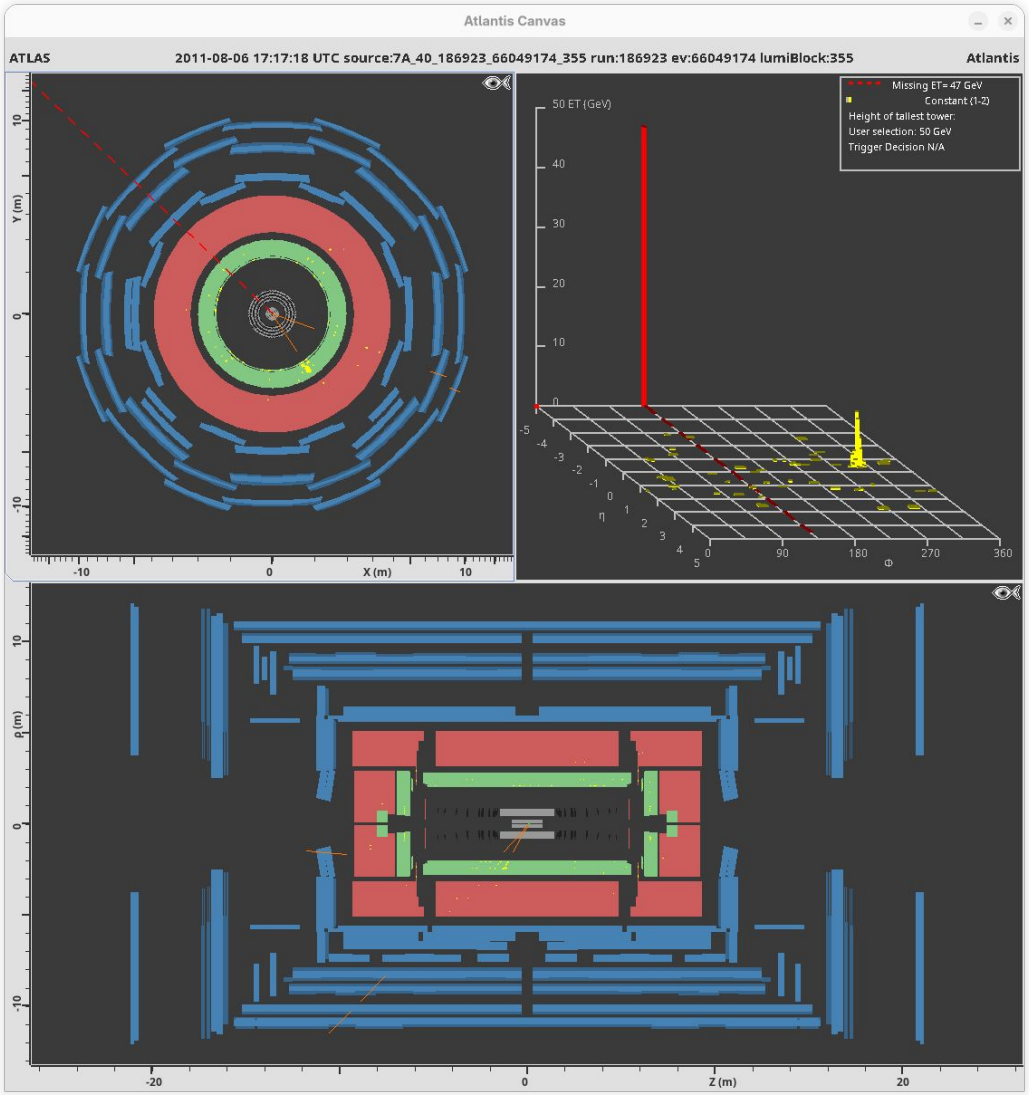
Ten sam wierzchołek?

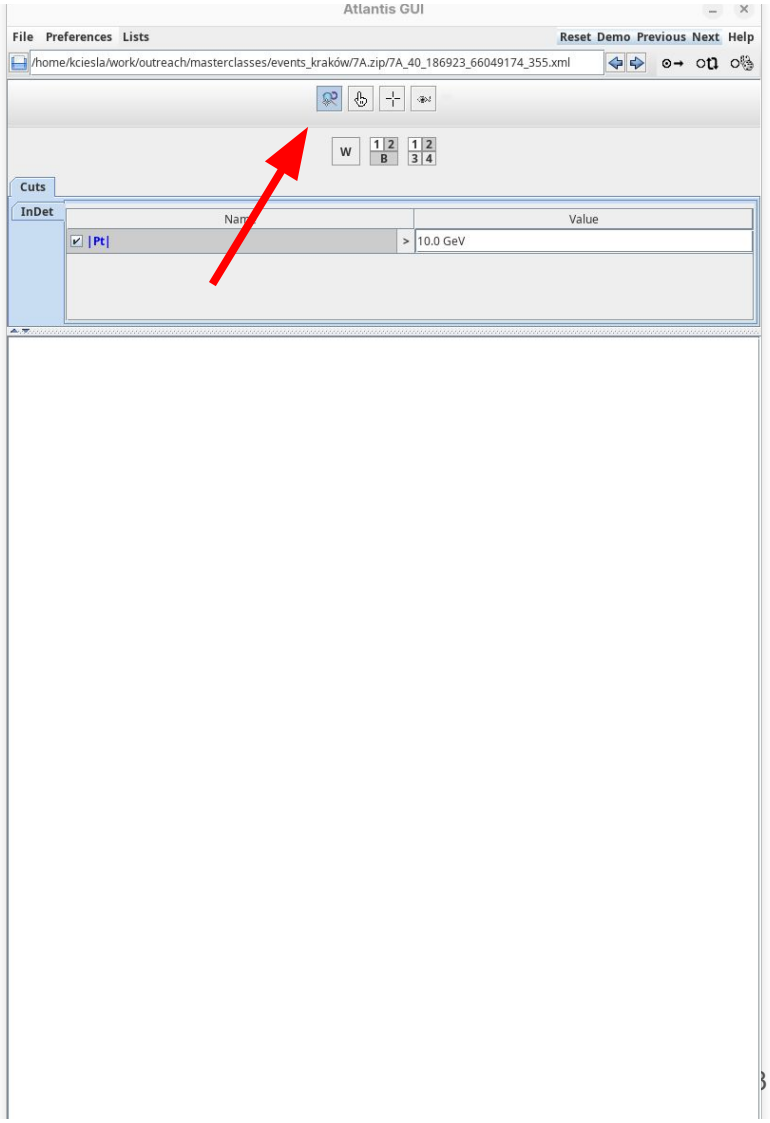




Przypadek #3

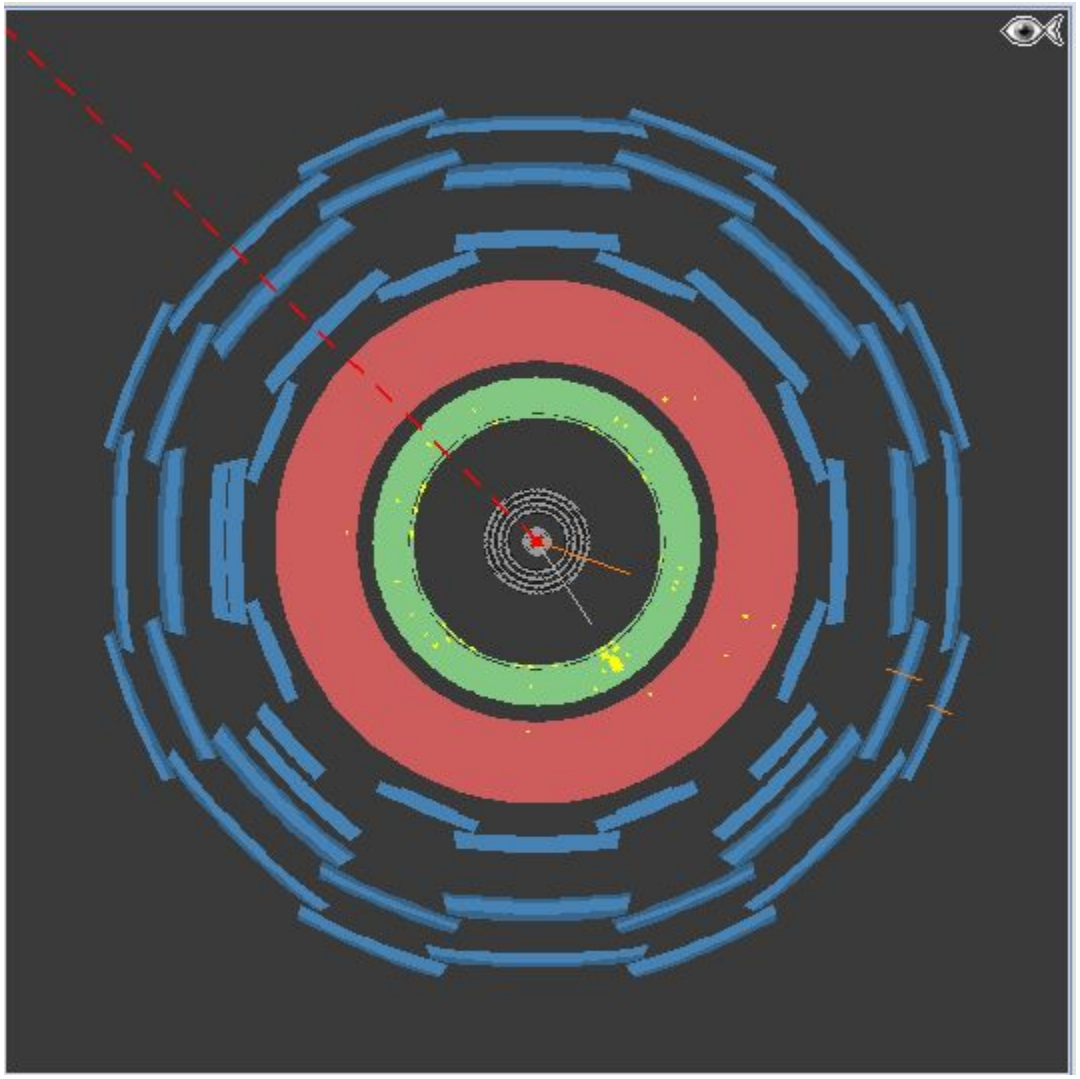
Ten sam wierzchołek?





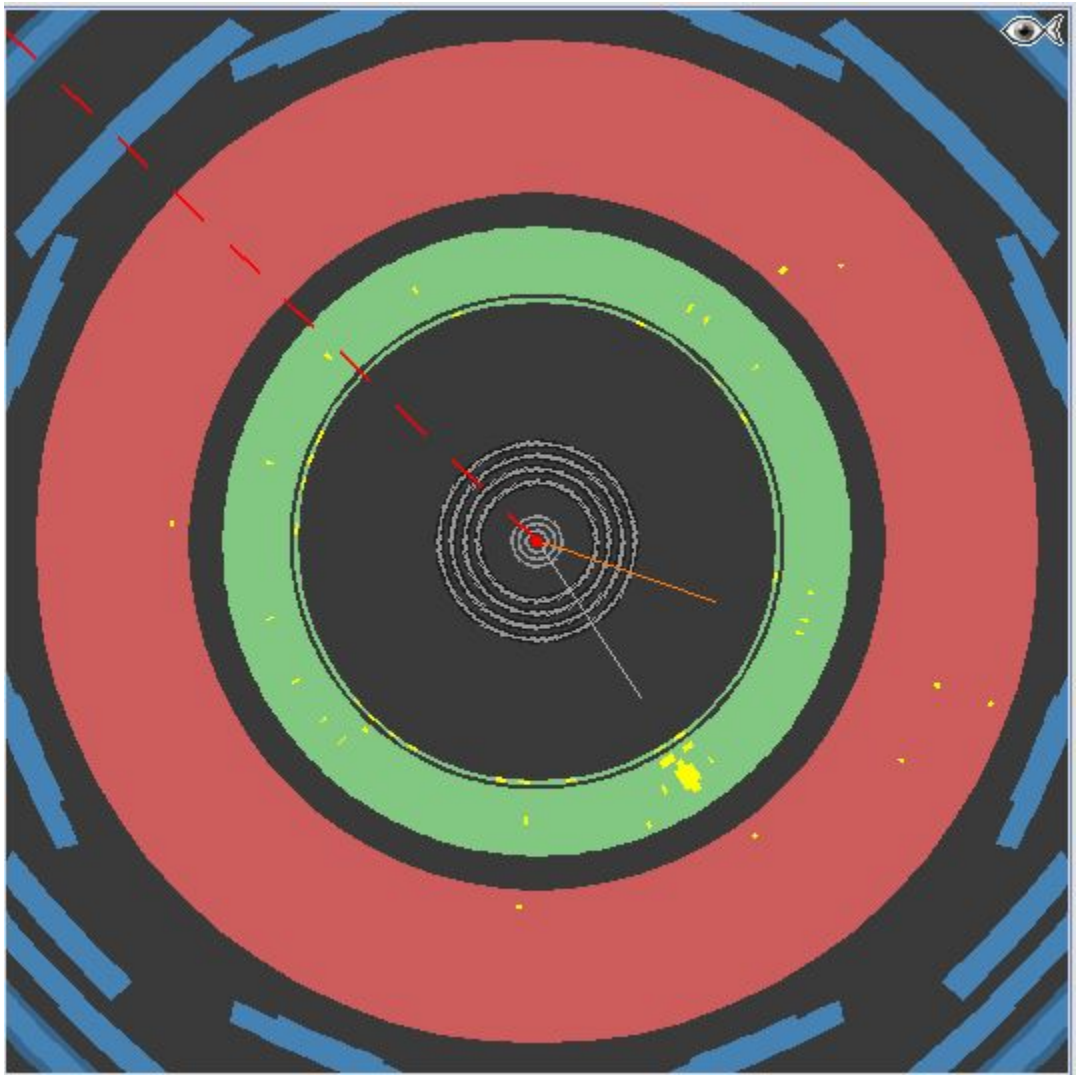
Przypadek #3

Ten sam wierzchołek?



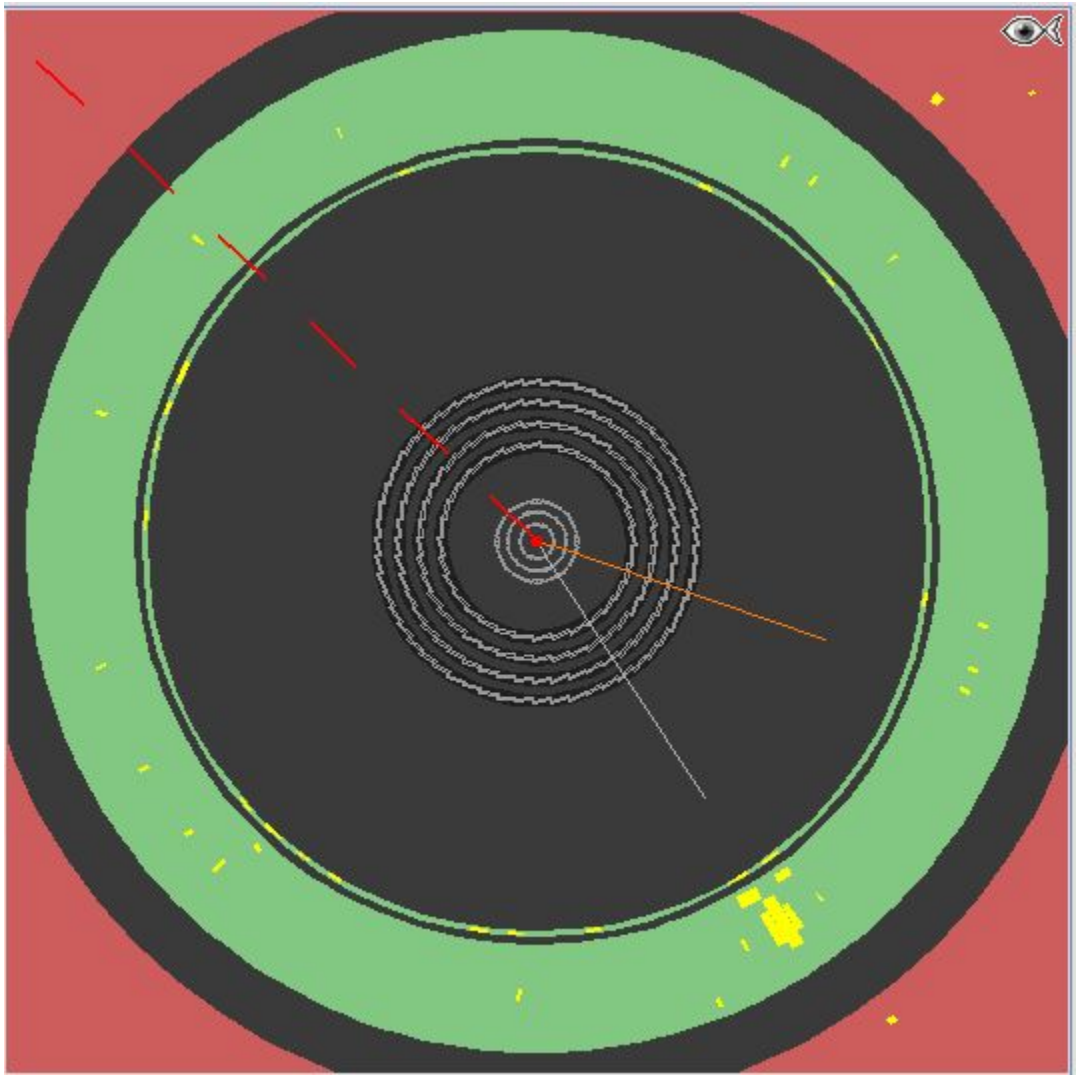
Przypadek #3

Ten sam wierzchołek?



Przypadek #3

Ten sam wierzchołek?



Przypadek #3

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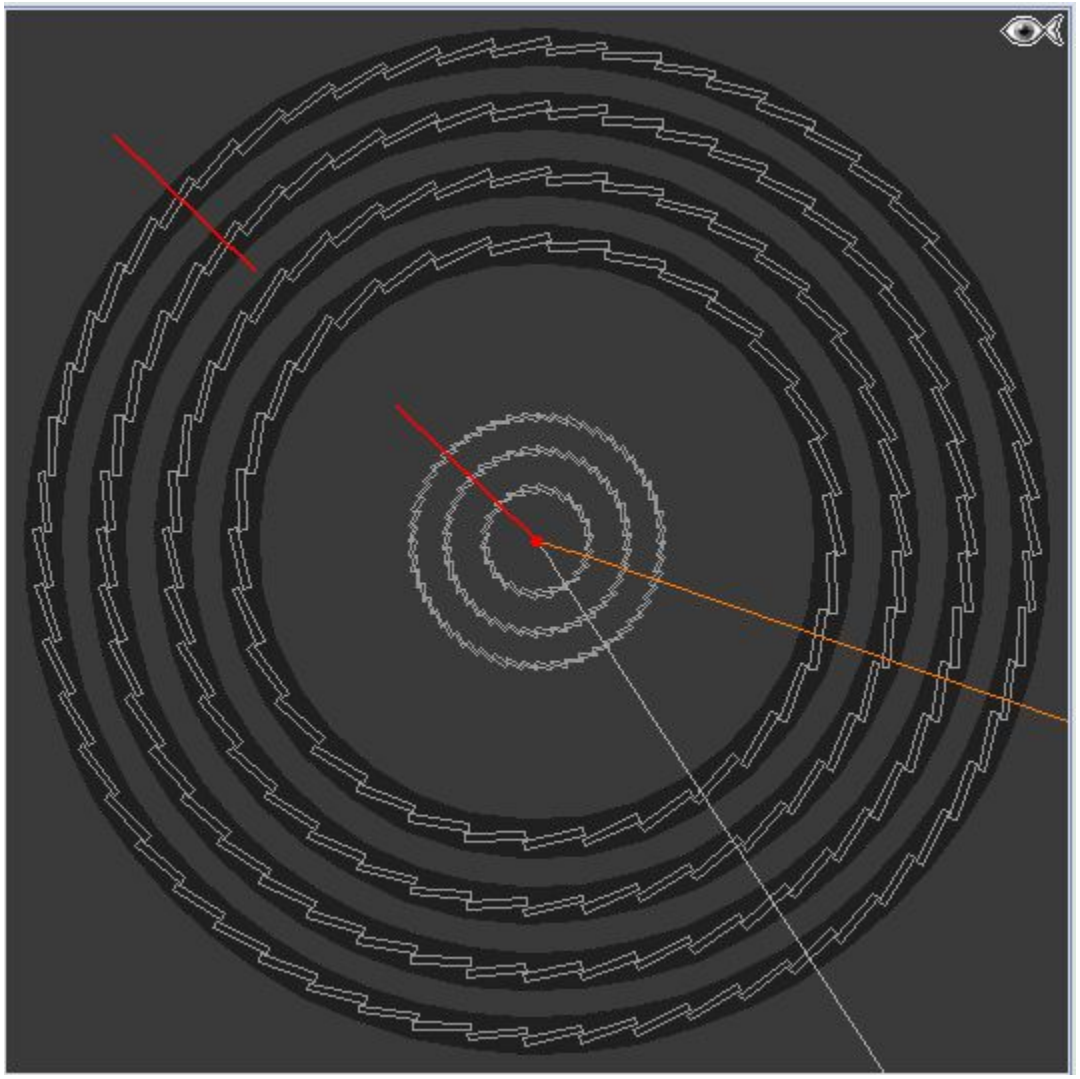

Przypadek #3

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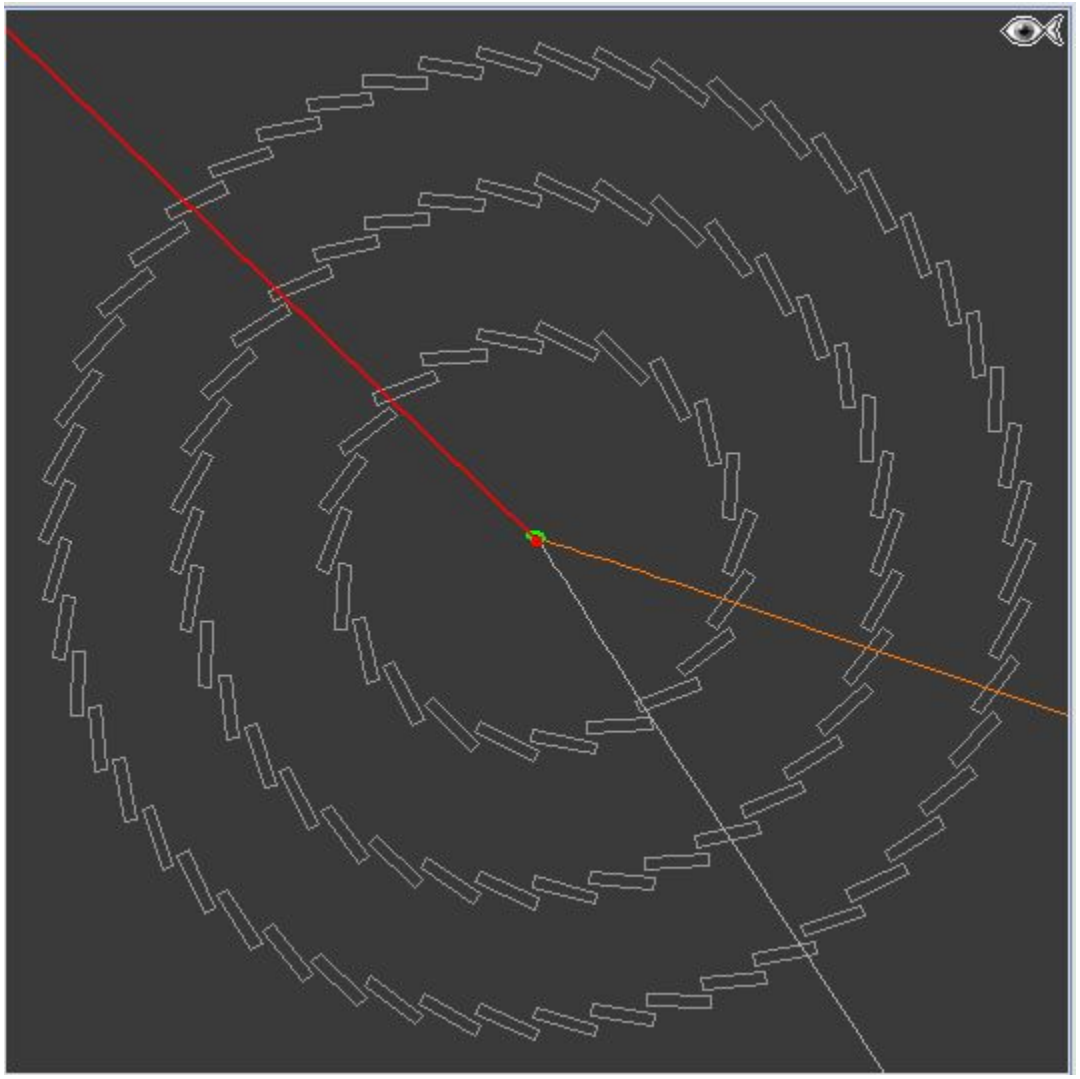

Przypadek #3

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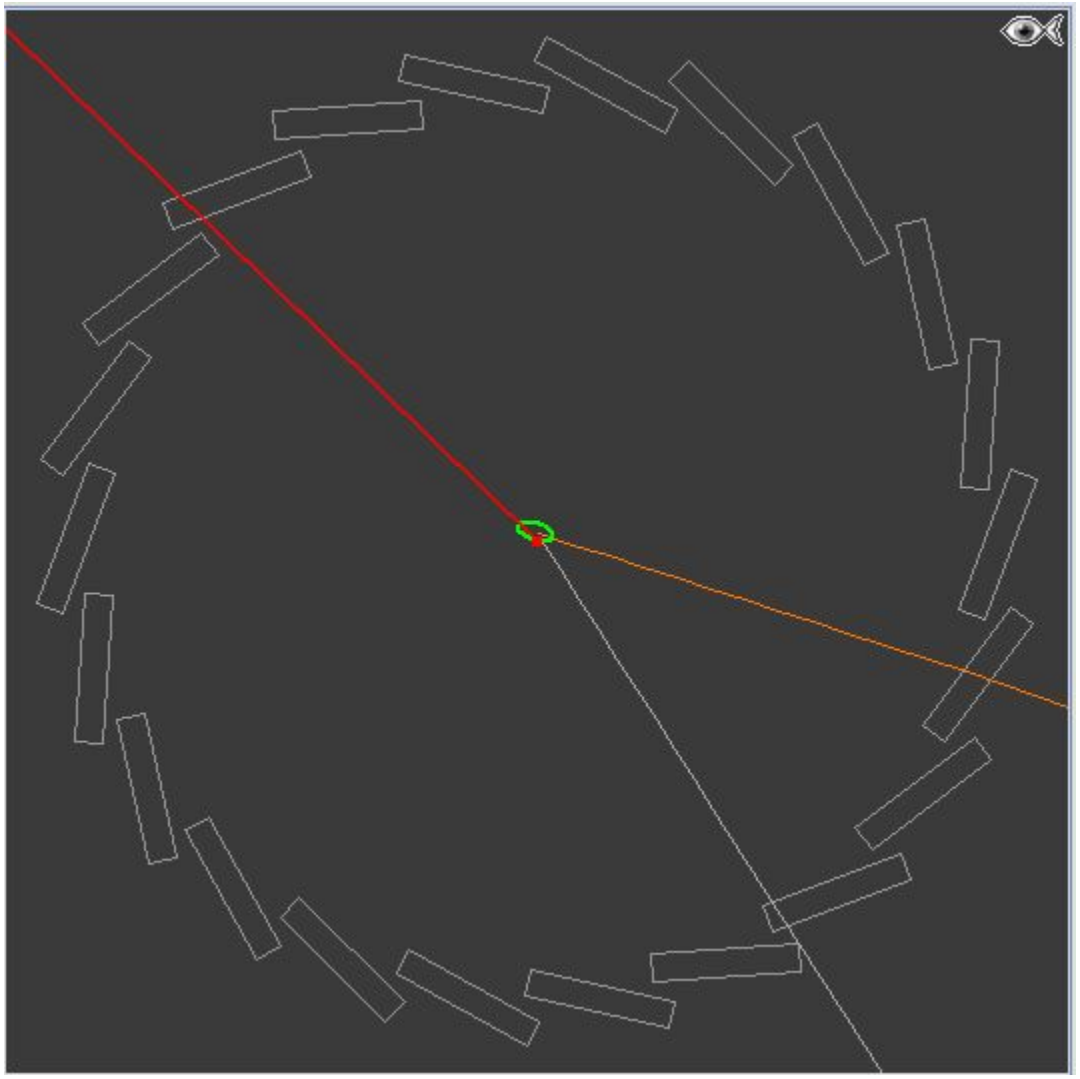
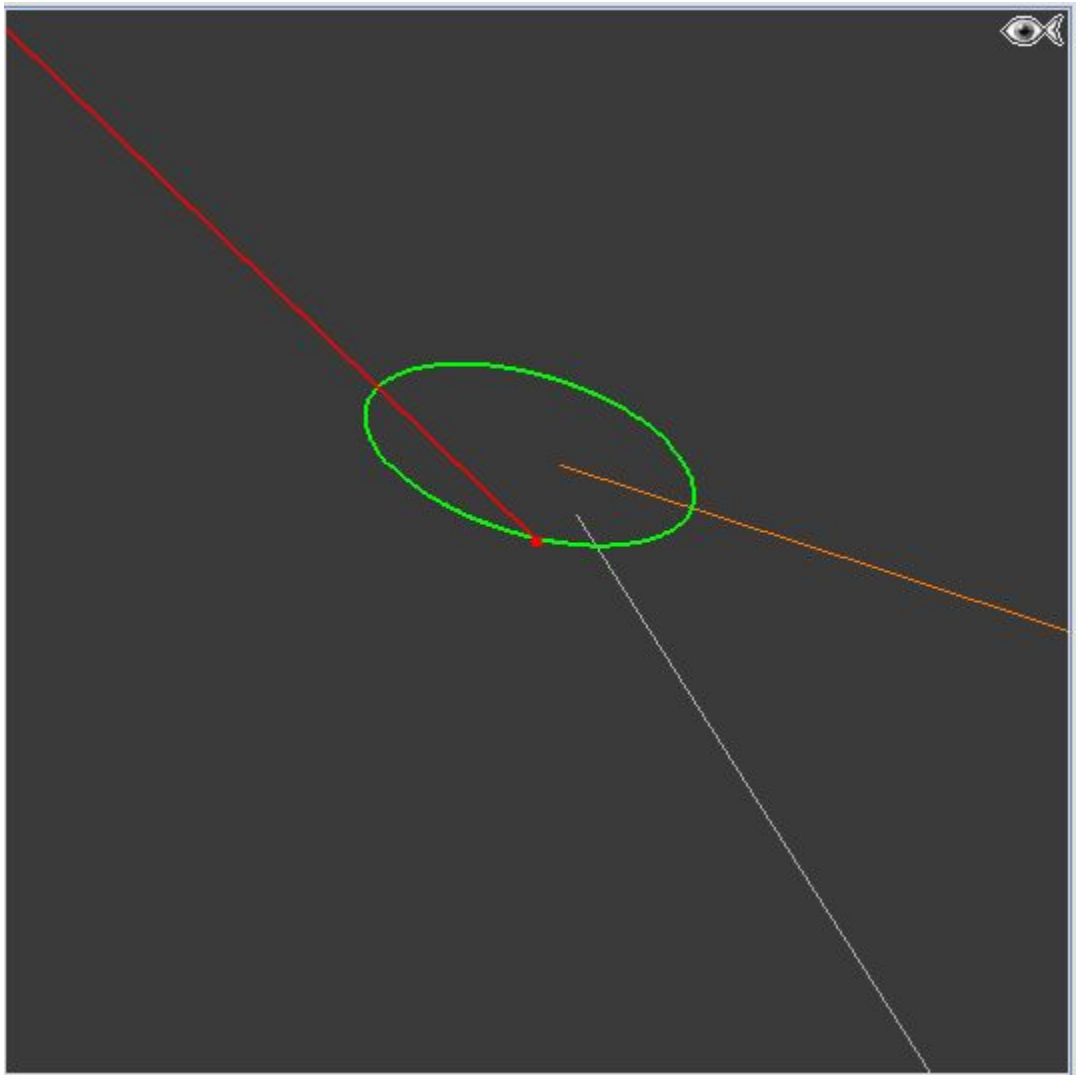


Przypadek #3

Ten sam wierzchołek?



Przypadek #3

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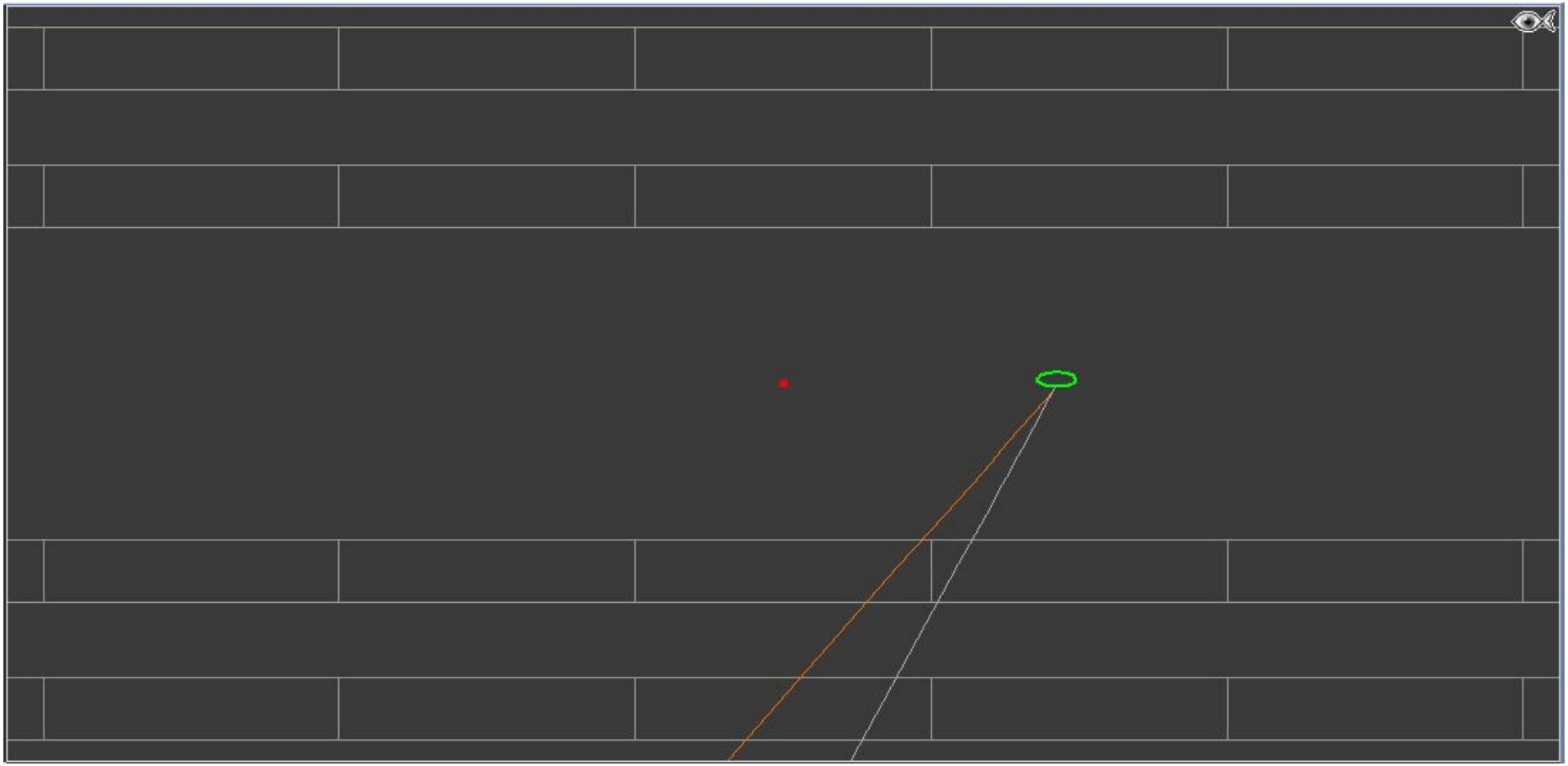
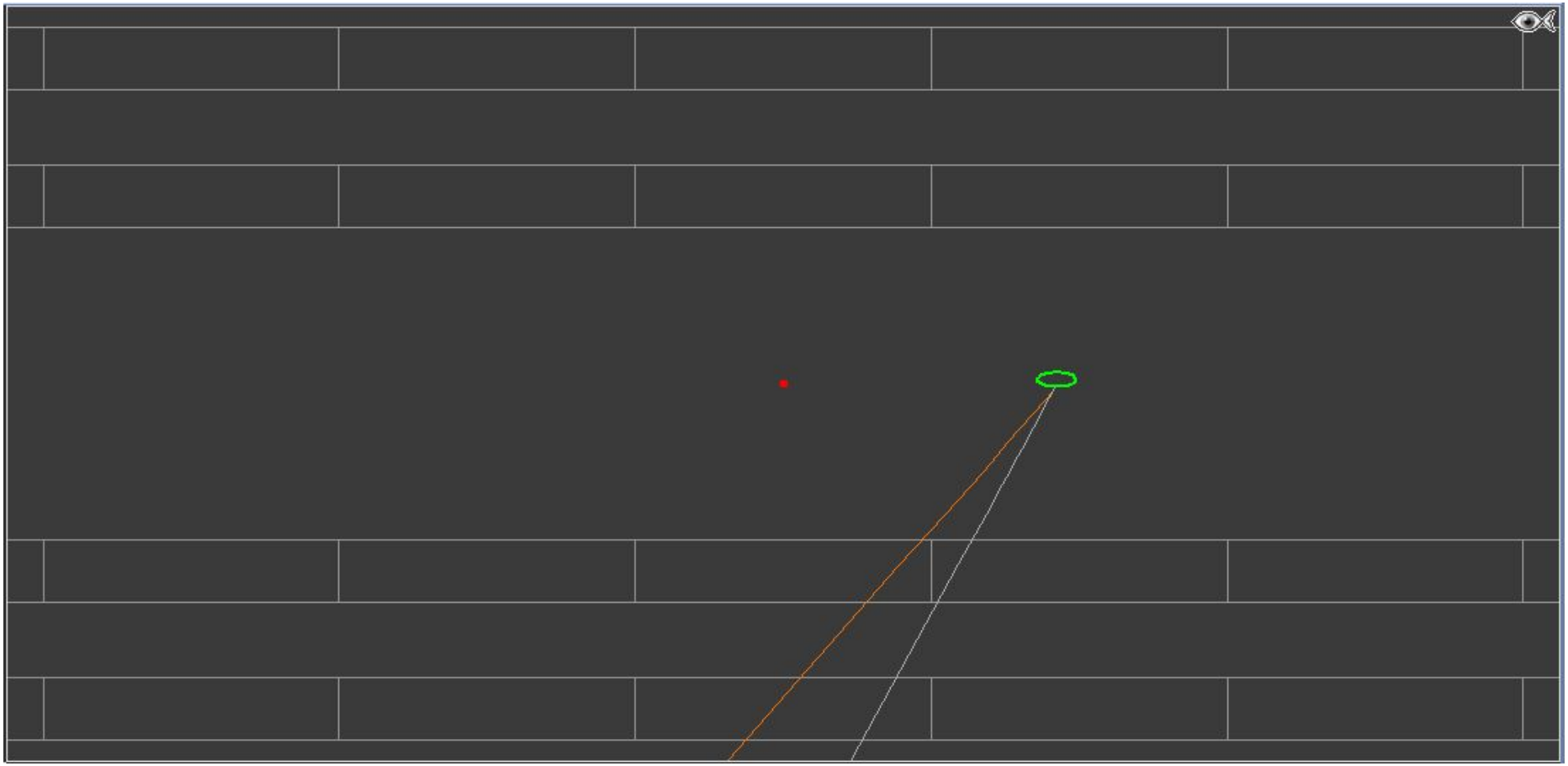


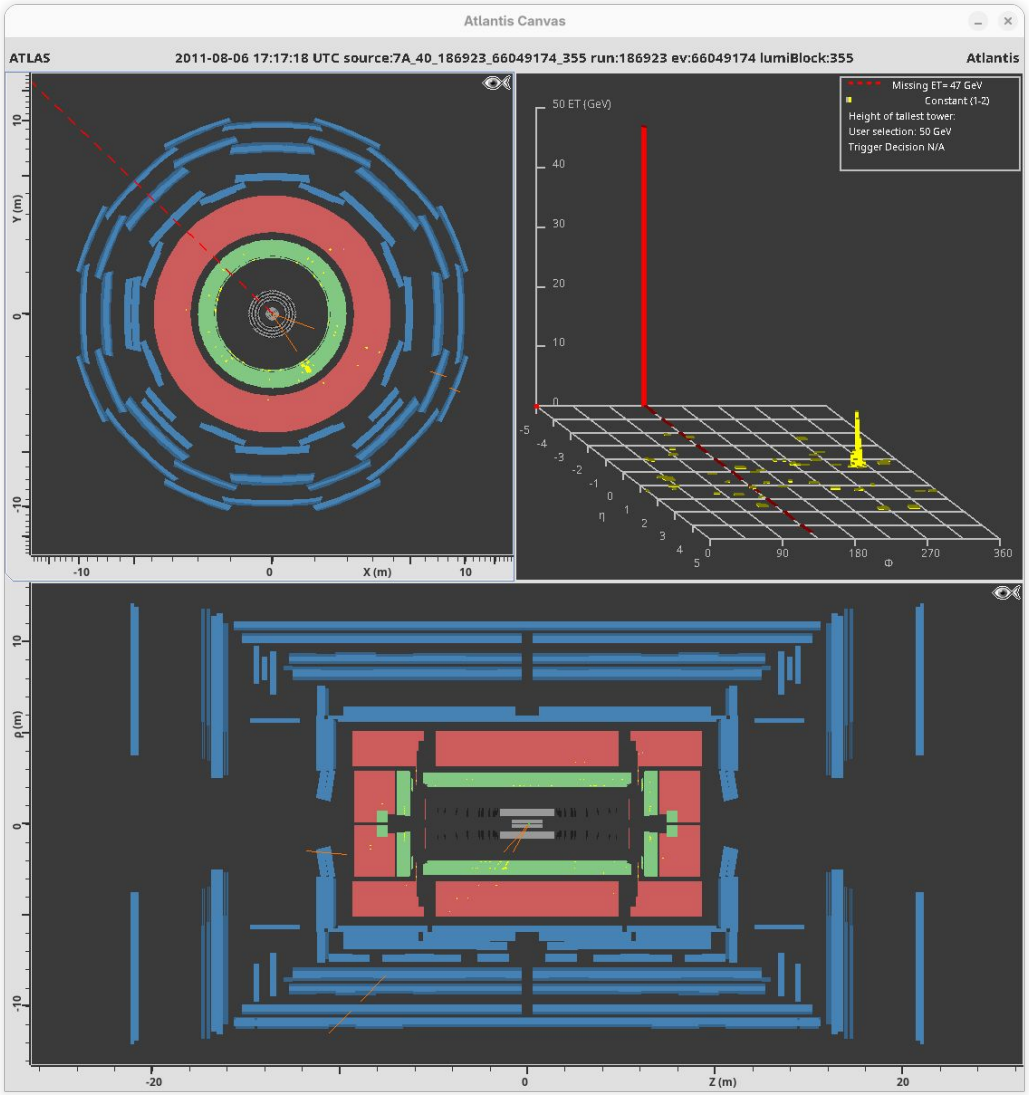
Przypadek #3

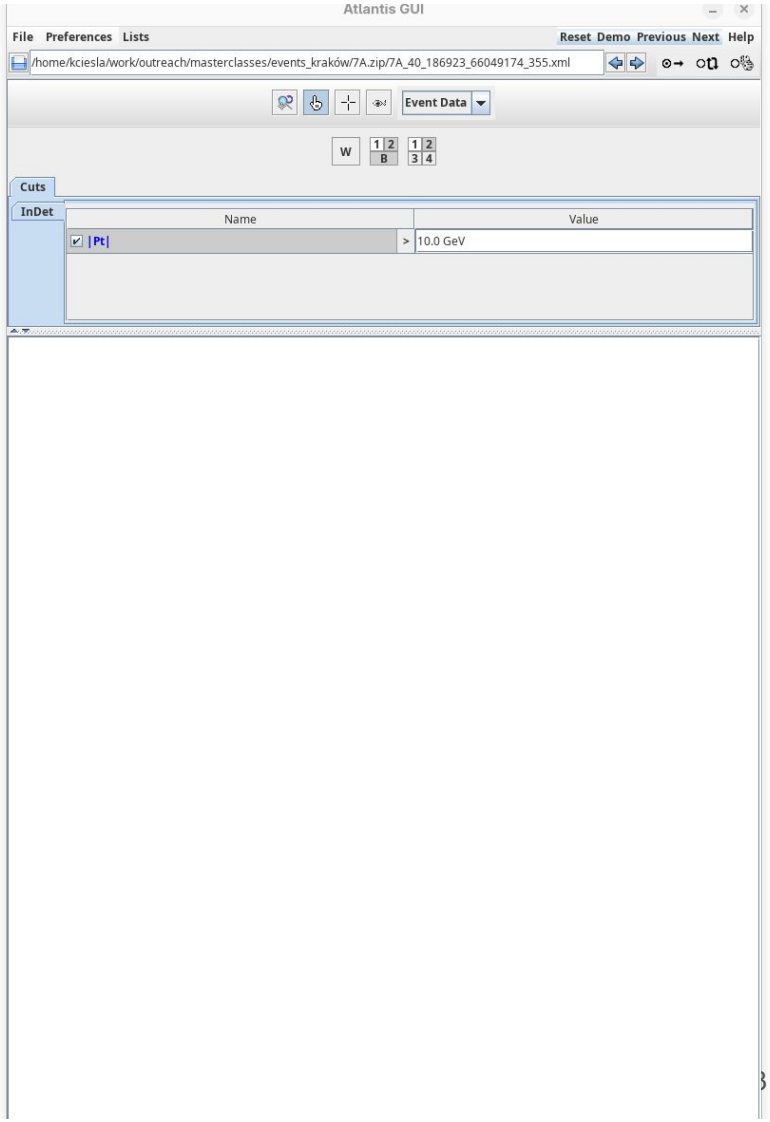
Ten sam wierzchołek



Przypadek #3

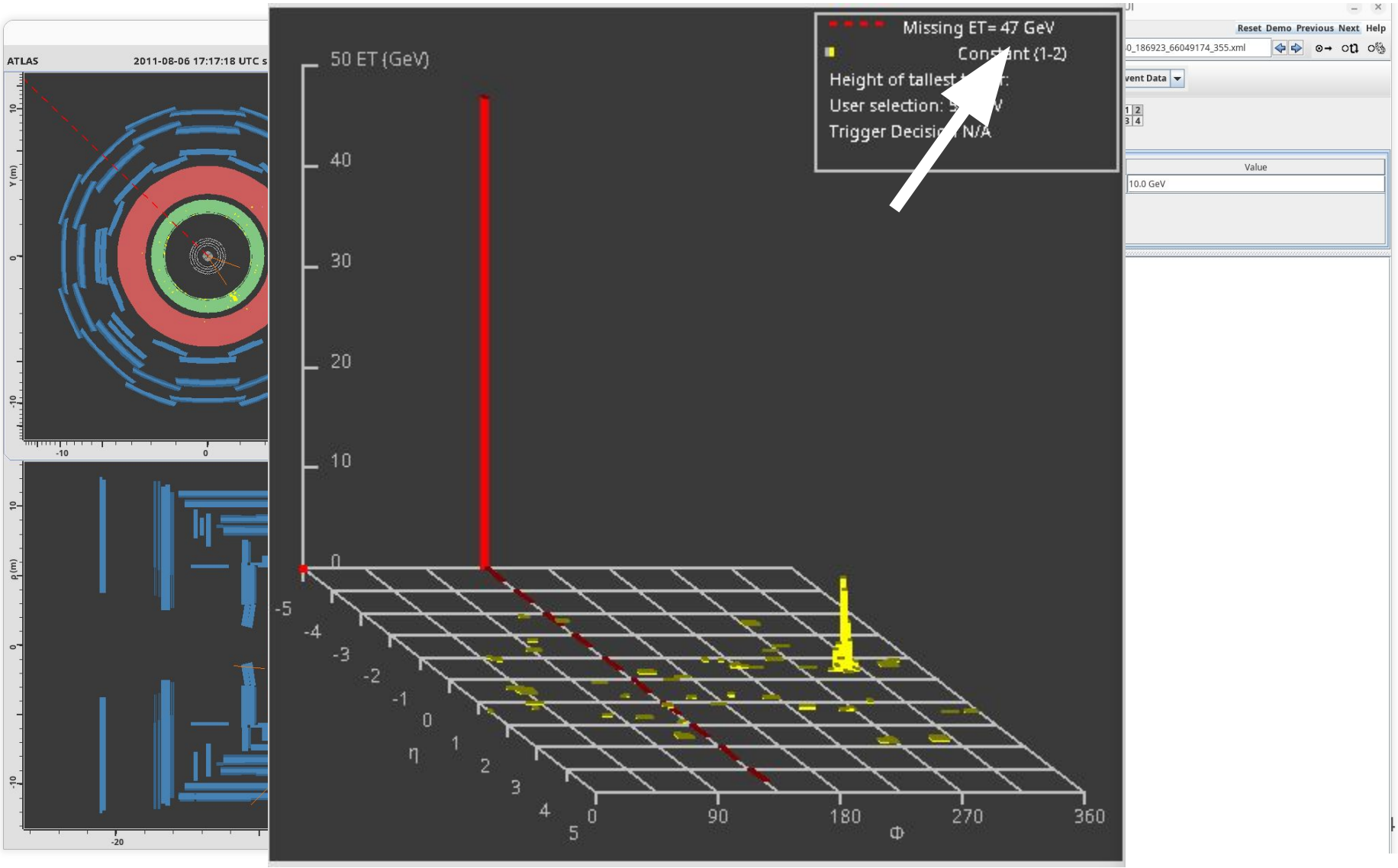
ee lub μμ: MET > 40 GeV?
eμ: MET > 20 GeV?





Przypadek #3

eμ: MET > 20 GeV



Przypadek #3

$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta

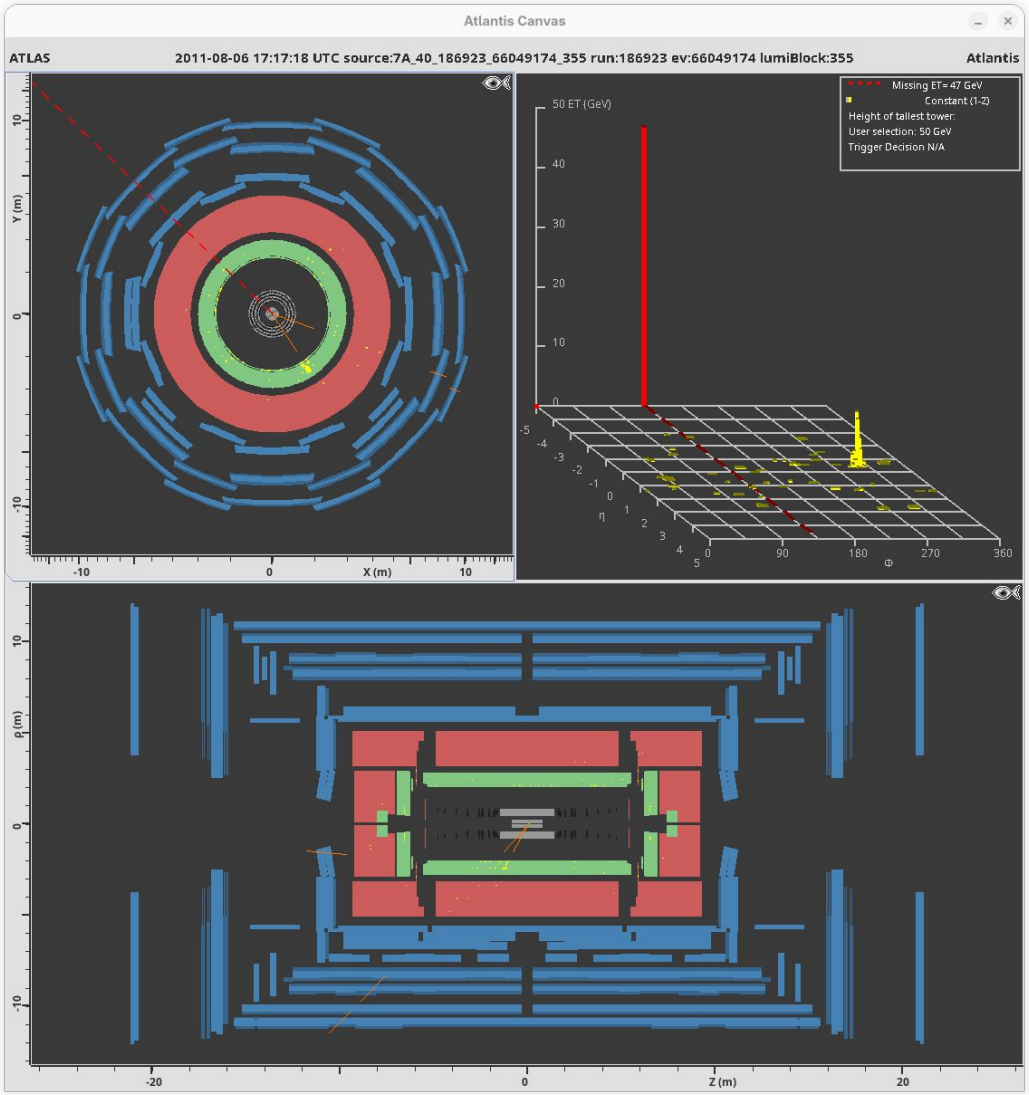
ATLAS data analysis

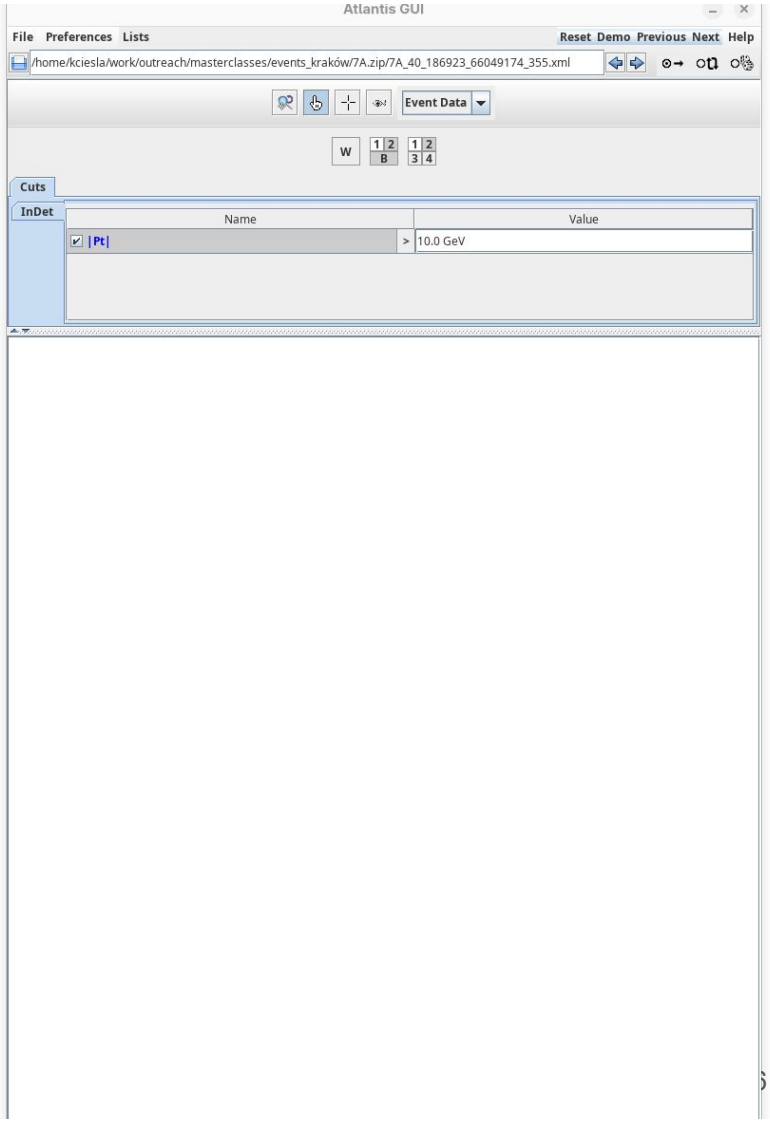
data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu$ + ...		$W \rightarrow \nu$ + ...					
	e^+	e^-	μ^+	μ^-	$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2							X	
3					X			
4								
5								
6								
7								
8								
9								
10								

Przypadek #3

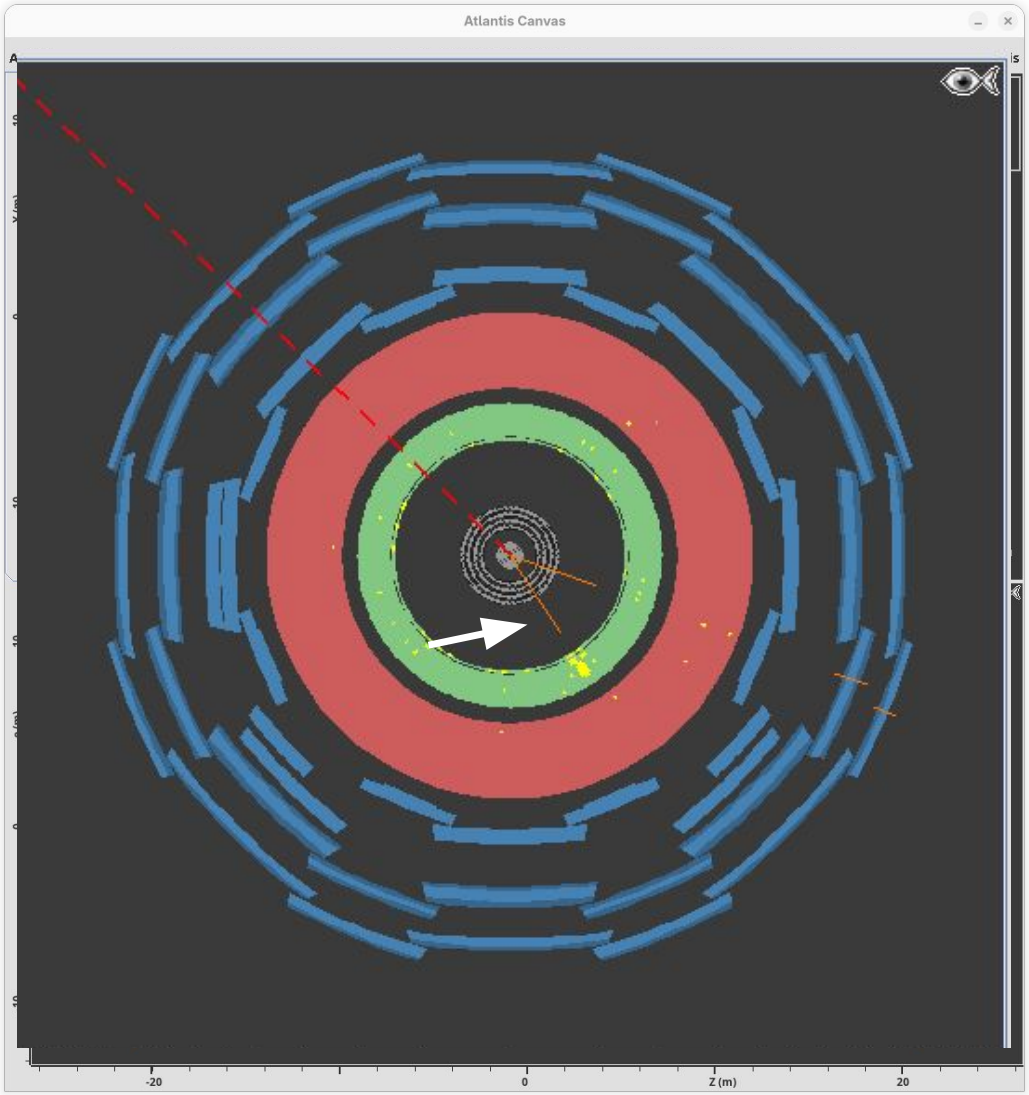
$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta





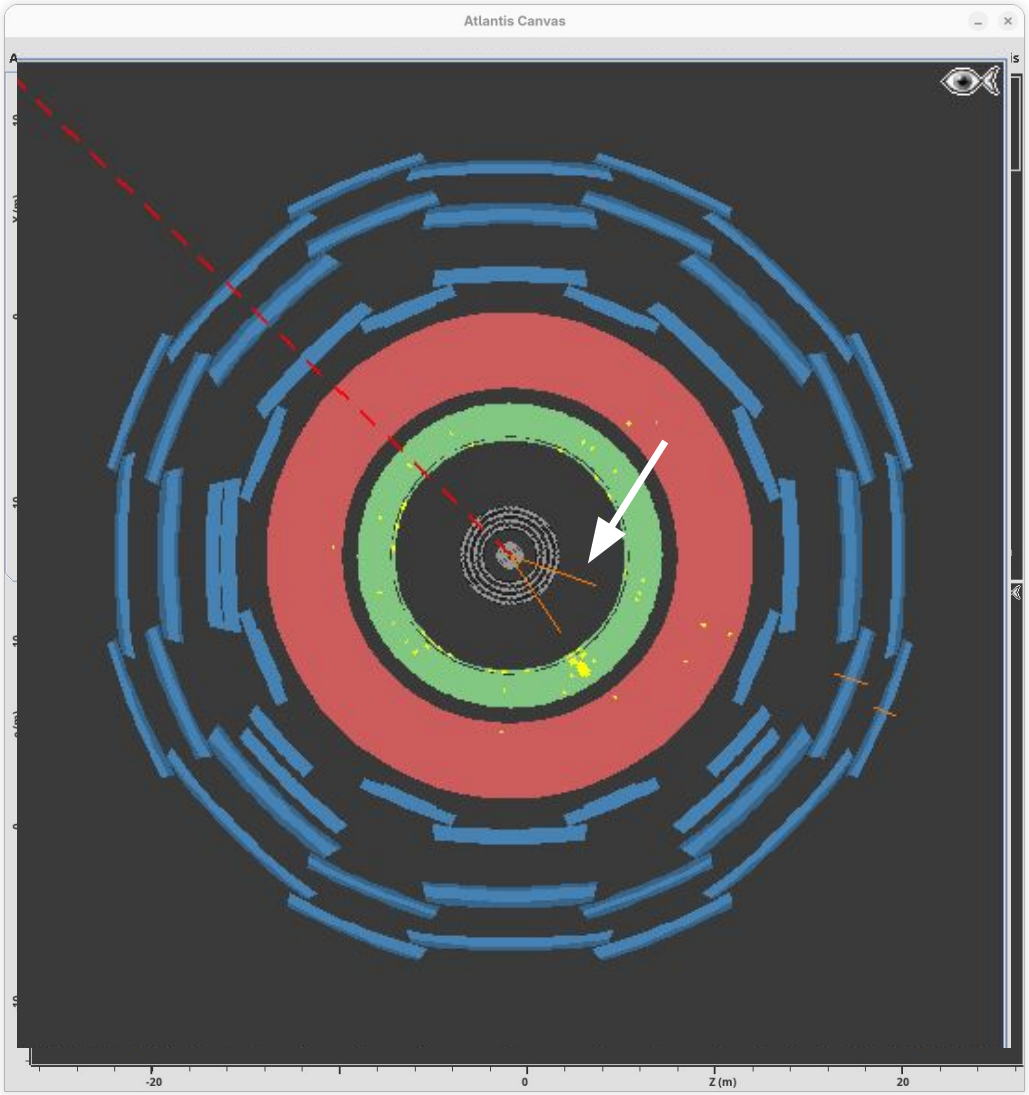
Przypadek #3

$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta



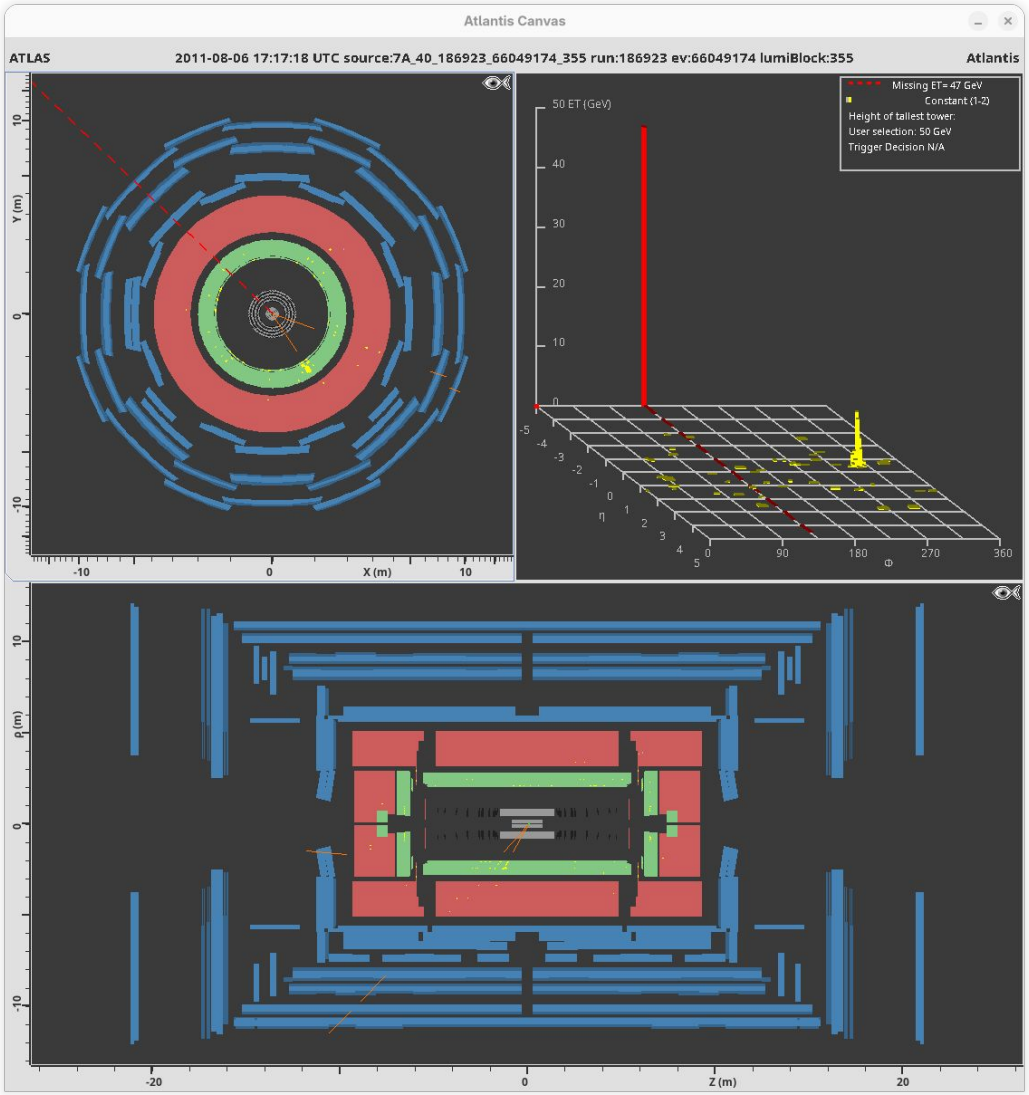
Przypadek #3

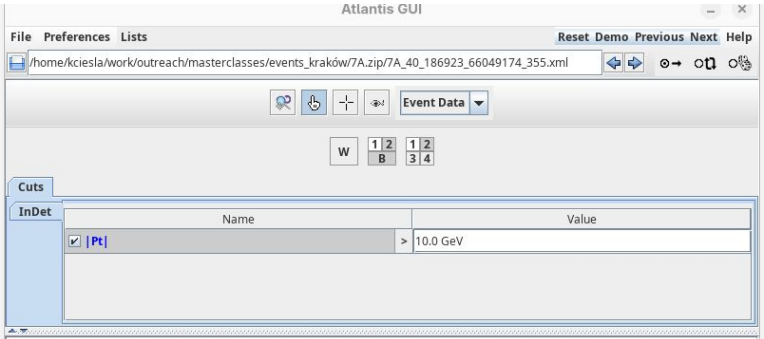
$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta



Przypadek #3

$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta





ΔΦ = 39.6° (0.691)

ΔR = 0.725

Przypadek #3

$W^+W^- \rightarrow l\nu l\nu$
pomiar kąta

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + ...		W → ν + ...					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				x				
2							x	
3					x	40		
4								
5								
6								
7								
8								
9								
10								

Przypadek #4

Tło

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu + \ldots$		$W \rightarrow \nu + \ldots$		$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
	e^+	e^-	μ^+	μ^-				
1				x				
2							x	
3					x	40		
4							x	
5								
6								
7								
8								
9								
10								

Przypadek #5

Tło

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu + \ldots$		$W \rightarrow \nu + \ldots$		$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
	e^+	e^-	μ^+	μ^-				
1				x				
2							x	
3					x	40		
4							x	
5							x	
6								
7								
8								
9								
10								

Przypadek #6

$W^+ \rightarrow e^+ \nu$

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + ...		W → ν + ...					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2							X	
3					X	40		
4							X	
5							X	
6	X							
7								
8								
9								
10								

Przypadek #7

$W^+ \rightarrow \mu^+ \nu$

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + ...		W → ν + ...					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2							X	
3					X	40		
4							X	
5							X	
6	X							
7			X					
8								
9								
10								

Przypadek #8

$W^+ \rightarrow \mu^+ \nu$

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + ...		W → ν + ...					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2							X	
3					X	40		
4							X	
5							X	
6	X							
7			X					
8			X					
9								
10								

Przypadek #9

Tło

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	$W \rightarrow \nu + \ldots$		$W \rightarrow \nu + \ldots$		$WW \rightarrow l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
	e^+	e^-	μ^+	μ^-				
1				X				
2							X	
3					X	40		
4							X	
5							X	
6	X							
7			X					
8			X					
9							X	
10								

Przypadek #10… i tak aż do #50

$W^- \rightarrow e^- \nu$

ATLAS data analysis

data sample: 5B

event number	signal with 1 lepton (l)				signal with 2 leptons (ll)		Back-ground	Comment
	W → ν + …		W → ν + …					
	e^+	e^-	μ^+	μ^-	WW → $l^+ \nu l^- \nu$	$\Delta\phi_{ll}$ round off to whole number		
1				X				
2							X	
3					X	40		
4							X	
5							X	
6	X							
7			X					
8			X					
9							X	
10		X						

Dziękuję za uwagę!