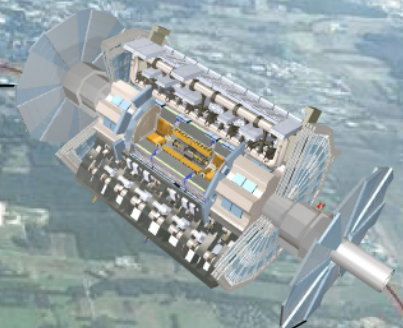
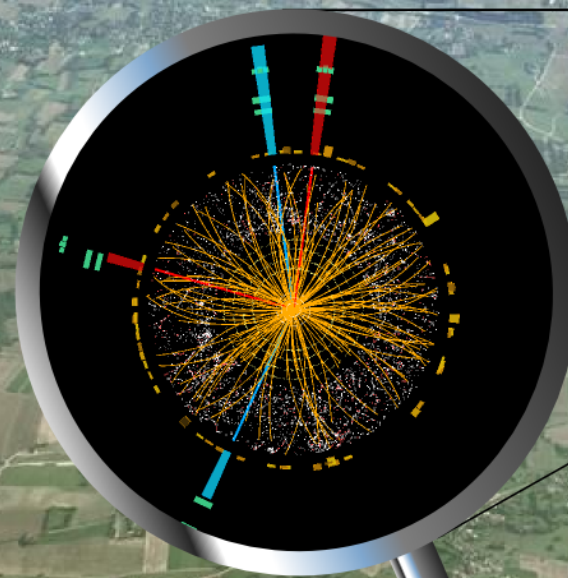


# Détecter des particules « pour de vrai » avec ATLAS

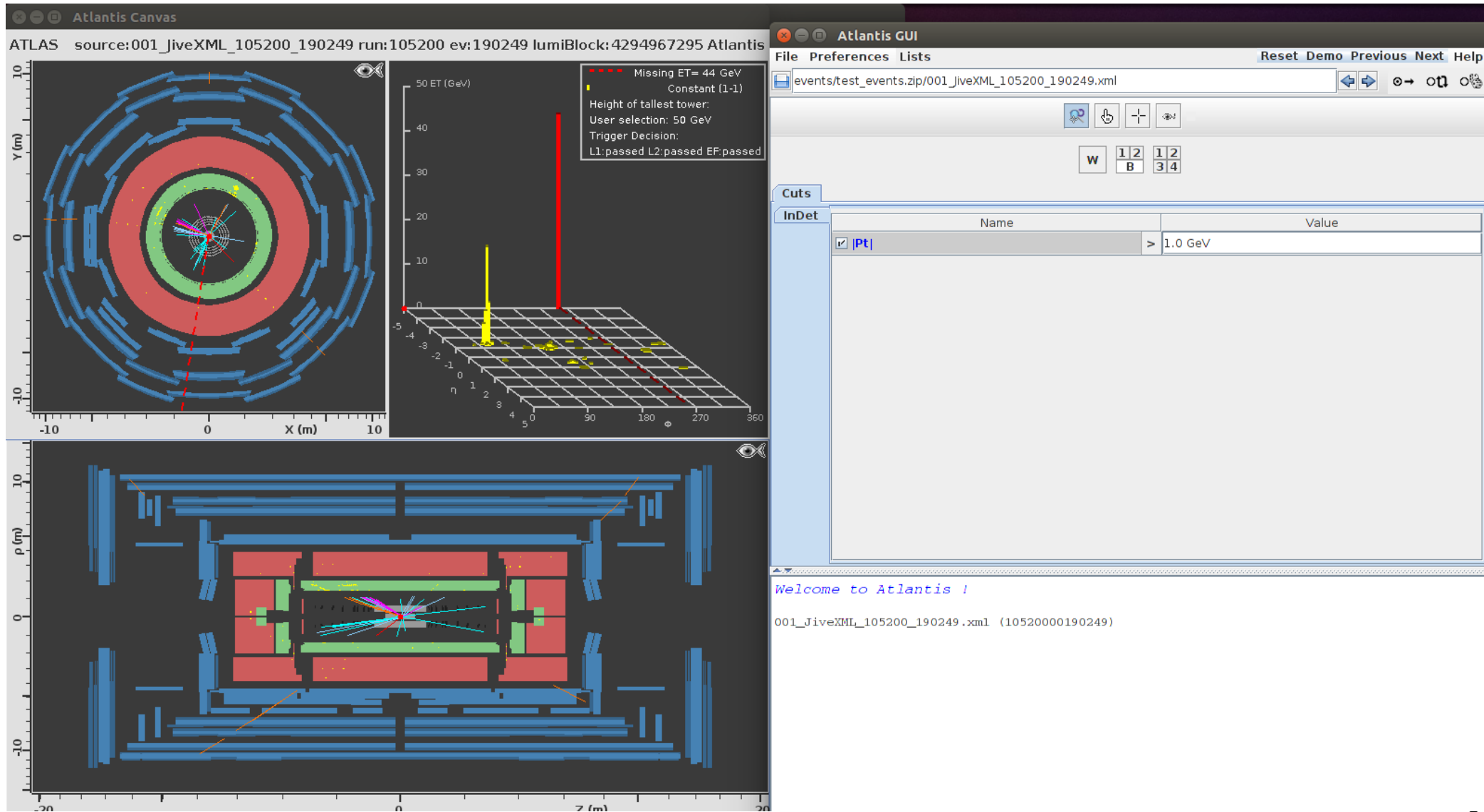
INTERNATIONAL  
**MASTERCLASSES**

hands on particle physics

Centre de physique des  
particules de Marseille



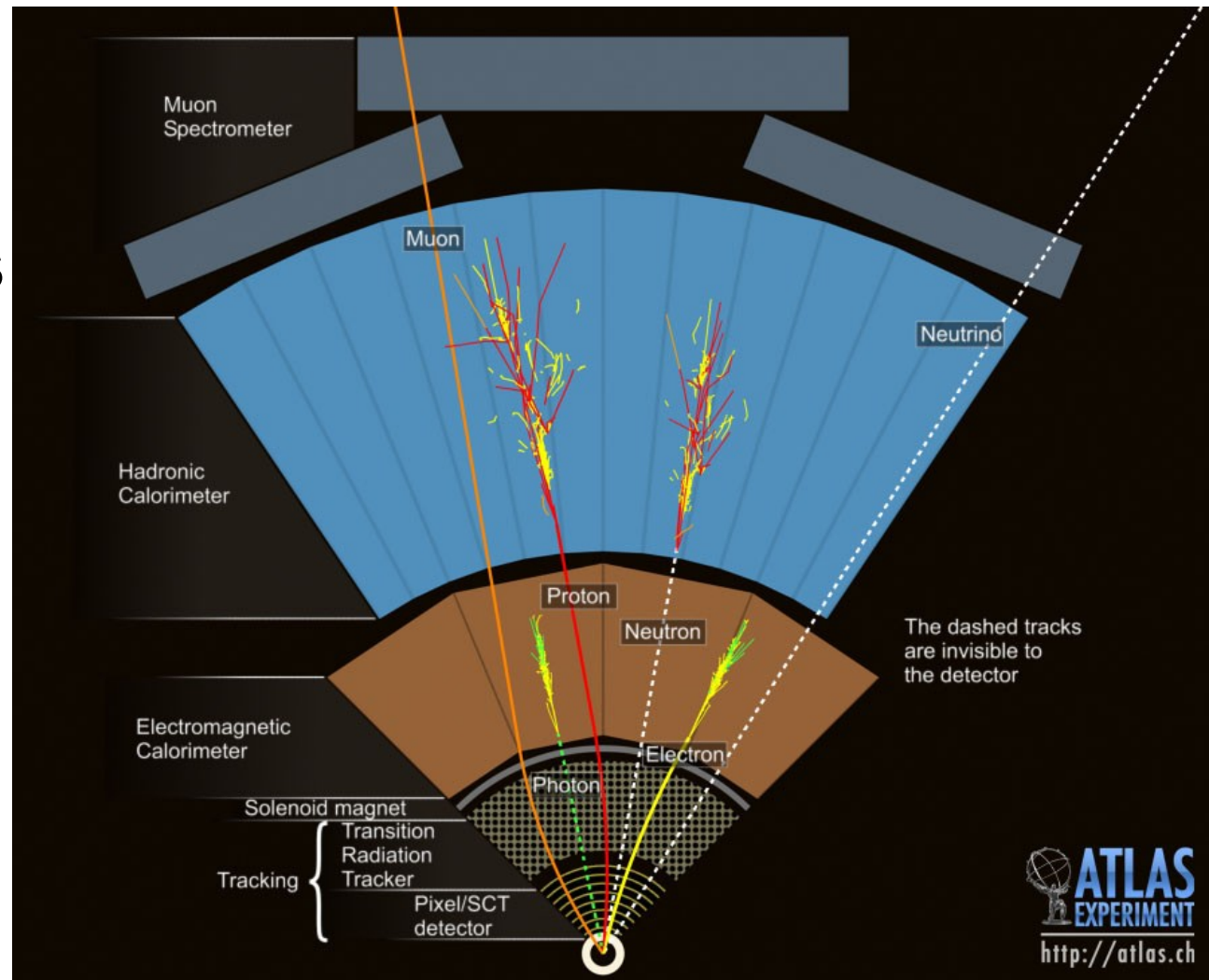
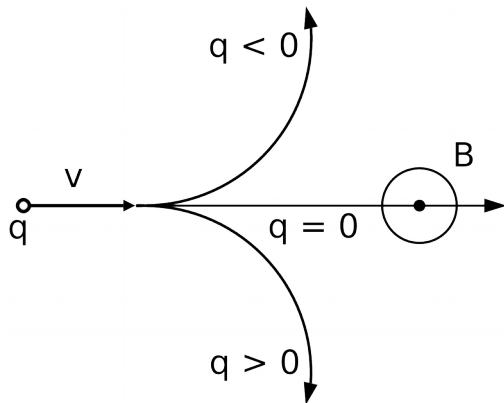
# Identifier des événements avec Minerva



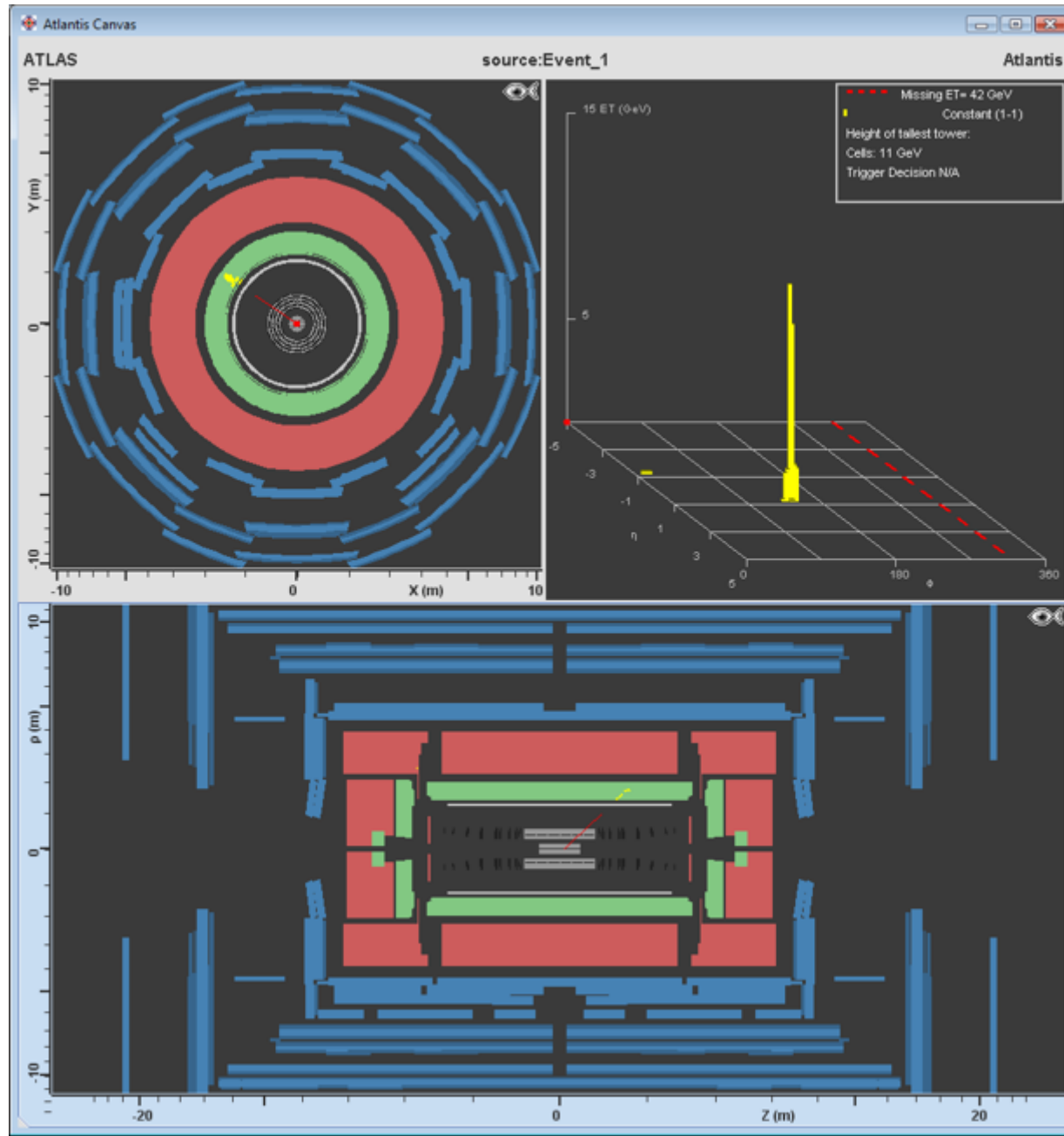


# Identifier les électrons/positrons et photons

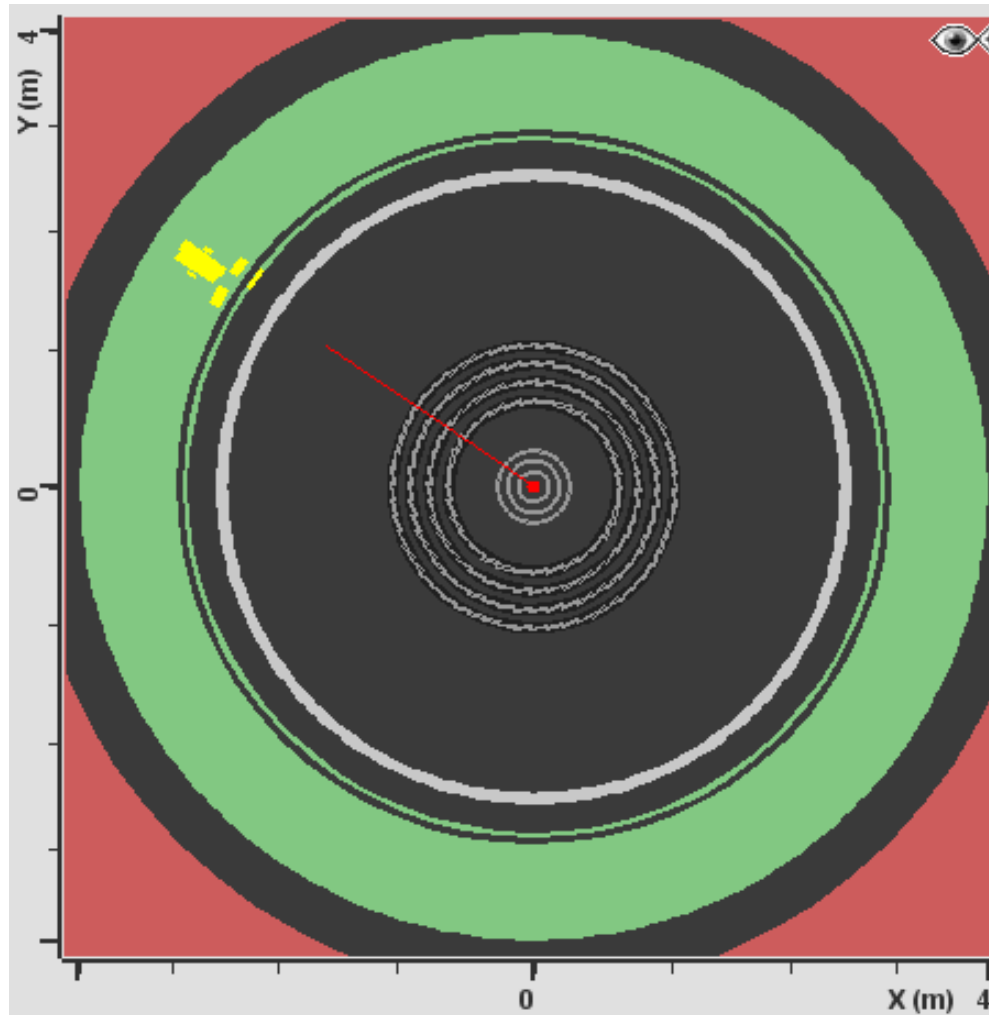
- Gerbe dans le calorimètre EM
- $e^+/e^-$  : particule chargée, trace dans le trajectographe
- Courbure de la trace  $\rightarrow$  signe de la charge électrique



# Identifier les électrons/positrons avec Minerva

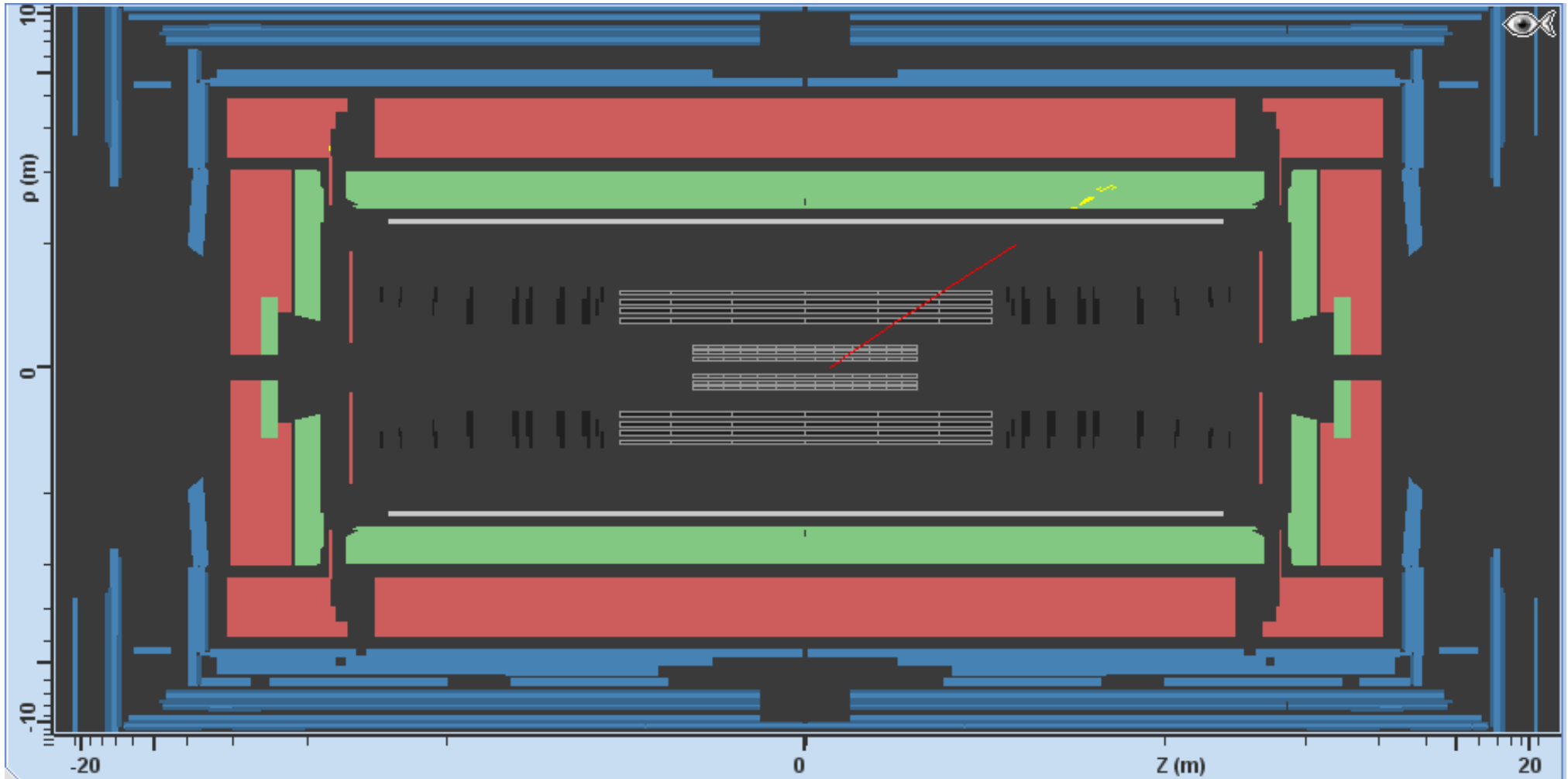


# Identifier les électrons/positrons avec Minerva



- Trace dans le trajectographe
- Énergie dans le calorimètre

# Identifier les électrons/positrons avec Minerva



- Trace dans le trajectographe
- Énergie dans le calorimètre

# Identifier les électrons/positrons avec Minerva

The image displays the Atlantis GUI interface. On the left, there are three main views: a top-down view of the ATLAS detector, a 3D plot of the event showing a yellow track, and a longitudinal cross-section of the detector. The top-right panel shows event details: 'source:Minerva1', 'Atlantis', 'Missing ET= 42 GeV', 'Constant (1-1)', 'Height of tallest tower: Cells: 11 GeV', and 'Trigger Decision N/A'. The bottom-right panel shows a data table with columns 'Name' and 'Value'. A red box highlights a hand cursor icon in the toolbar, with a red arrow pointing to it. Below the toolbar, the text 'Welcome to Atlantis !' and 'Minerva.xml (10602000326459)' is visible.

Name	Value
Status	
<input checked="" type="checkbox"/> InDet	
<input checked="" type="checkbox"/> Calo	
<input checked="" type="checkbox"/> MuonDet	
<input checked="" type="checkbox"/> Objects	

- Choisir la main et cliquer sur la trace
- Des infos apparaissent dans la fenêtre en bas à droite

# Identifier les électrons/positrons avec Minerva

The screenshot displays the Atlantis GUI interface. On the left, there are two plots: a top view of the ATLAS detector and a cross-sectional view. The top view shows a yellow track in the inner detector. The cross-sectional view shows the track passing through the detector layers. On the right, the Atlantis GUI window shows a toolbar with a hand icon highlighted by a red box. Below the toolbar, there is a table with columns for Name and Value. The table contains the following data:

Name	Value
Status	<input checked="" type="checkbox"/>
InDet	<input checked="" type="checkbox"/>
Calo	<input checked="" type="checkbox"/>
MuonDet	<input checked="" type="checkbox"/>
Objects	<input checked="" type="checkbox"/>

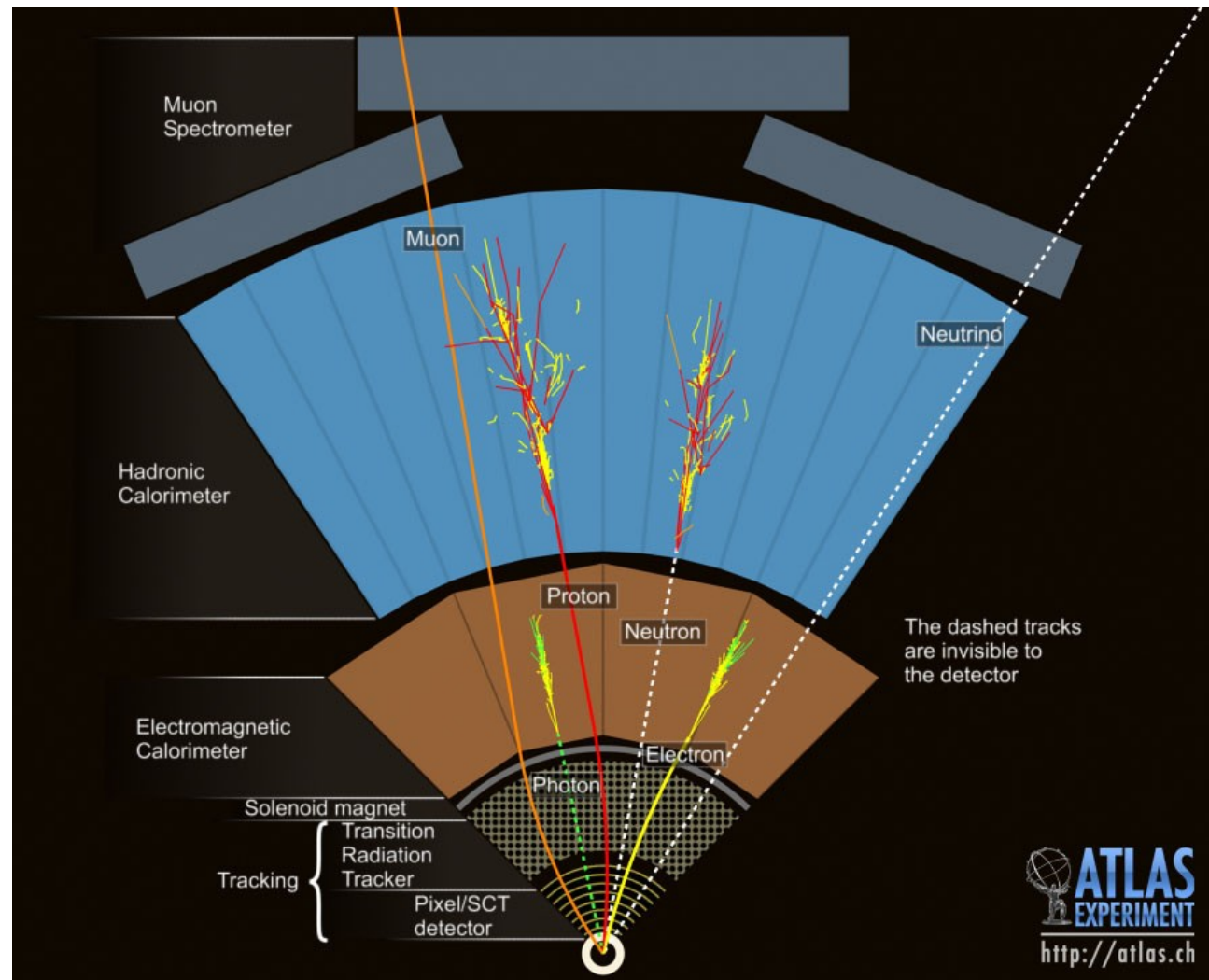
Below the table, there is a list of event files. The first file is 'Exercise2-Event04.xml (161562003969900)'. The second file is 'Exercise2-Event05.xml (160472004700963)'. The third file is 'InDetTrackIndex\_0'. The fourth file is 'PT=44.730 GeV'. The fifth file is 'η = -1.139'. The sixth file is 'Φ = 190.952°'. The seventh file is 'Px = -43.915 GeV'. The eighth file is 'Py = -8.498 GeV'. The ninth file is 'Pz = 62.730 GeV'. The tenth file is 'Charge = -1'. The eleventh file is 'Charge = -1'. The twelfth file is 'PT=44.730 GeV'. The thirteenth file is 'Charge = -1'. The fourteenth file is 'Charge = -1'. The fifteenth file is 'Charge = -1'. The sixteenth file is 'Charge = -1'. The seventeenth file is 'Charge = -1'. The eighteenth file is 'Charge = -1'. The nineteenth file is 'Charge = -1'. The twentieth file is 'Charge = -1'. The twenty-first file is 'Charge = -1'. The twenty-second file is 'Charge = -1'. The twenty-third file is 'Charge = -1'. The twenty-fourth file is 'Charge = -1'. The twenty-fifth file is 'Charge = -1'. The twenty-sixth file is 'Charge = -1'. The twenty-seventh file is 'Charge = -1'. The twenty-eighth file is 'Charge = -1'. The twenty-ninth file is 'Charge = -1'. The thirtieth file is 'Charge = -1'. The thirty-first file is 'Charge = -1'. The thirty-second file is 'Charge = -1'. The thirty-third file is 'Charge = -1'. The thirty-fourth file is 'Charge = -1'. The thirty-fifth file is 'Charge = -1'. The thirty-sixth file is 'Charge = -1'. The thirty-seventh file is 'Charge = -1'. The thirty-eighth file is 'Charge = -1'. The thirty-ninth file is 'Charge = -1'. The fortieth file is 'Charge = -1'. The forty-first file is 'Charge = -1'. The forty-second file is 'Charge = -1'. The forty-third file is 'Charge = -1'. The forty-fourth file is 'Charge = -1'. The forty-fifth file is 'Charge = -1'. The forty-sixth file is 'Charge = -1'. The forty-seventh file is 'Charge = -1'. The forty-eighth file is 'Charge = -1'. The forty-ninth file is 'Charge = -1'. 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The hundred and eighty-fourth file is 'Charge = -1'. The hundred and eighty-fifth file is 'Charge = -1'. The hundred and eighty-sixth file is 'Charge = -1'. The hundred and eighty-seventh file is 'Charge = -1'. The hundred and eighty-eighth file is 'Charge = -1'. The hundred and eighty-ninth file is 'Charge = -1'. The hundred and ninetieth file is 'Charge = -1'. The hundred and ninety-first file is 'Charge = -1'. The hundred and ninety-second file is 'Charge = -1'. The hundred and ninety-third file is 'Charge = -1'. The hundred and ninety-fourth file is 'Charge = -1'. The hundred and ninety-fifth file is 'Charge = -1'. The hundred and ninety-sixth file is 'Charge = -1'. The hundred and ninety-seventh file is 'Charge = -1'. The hundred and ninety-eighth file is 'Charge = -1'. The hundred and ninety-ninth file is 'Charge = -1'. The hundredth file is 'Charge = -1'.

- PT = impulsion transverse
- Ici charge négative → électron

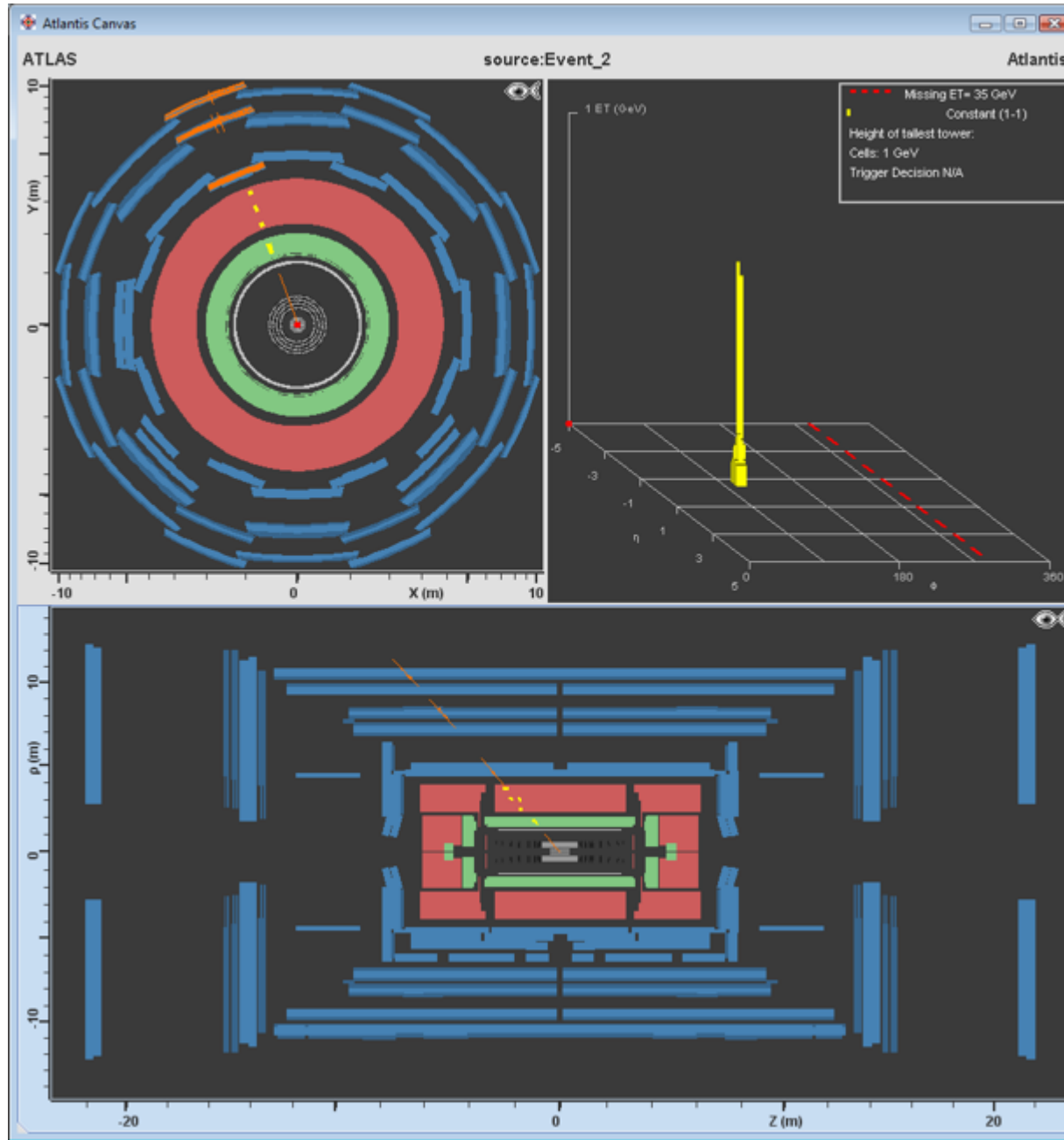


# Identifier les muons et antimuons

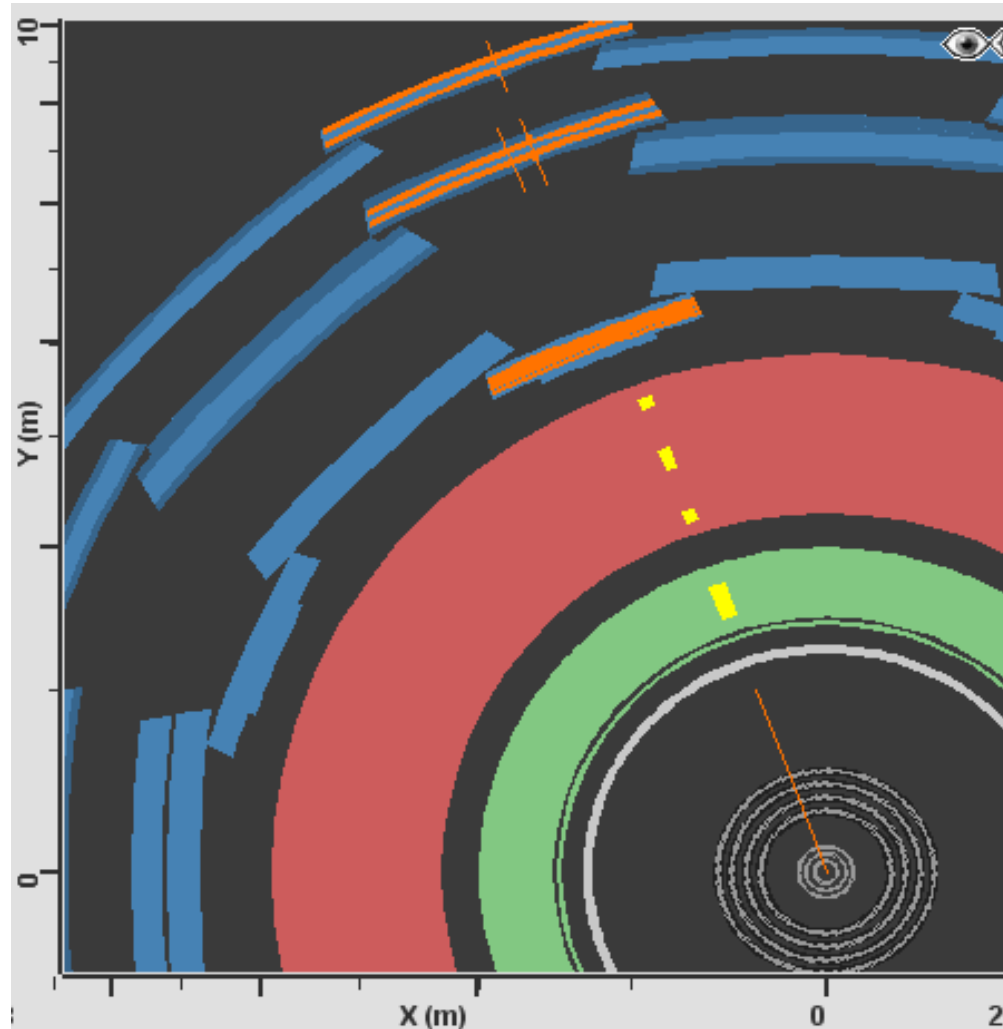
- Particule chargée, trace dans le trajectographe
- Un peu d'énergie dans le calorimètre
- Trace dans le détecteur à muons
- Courbure de la trace → signe de la charge électrique
- Continue sa course à l'extérieur d'ATLAS



# Identifier les muons/antimuons avec Minerva

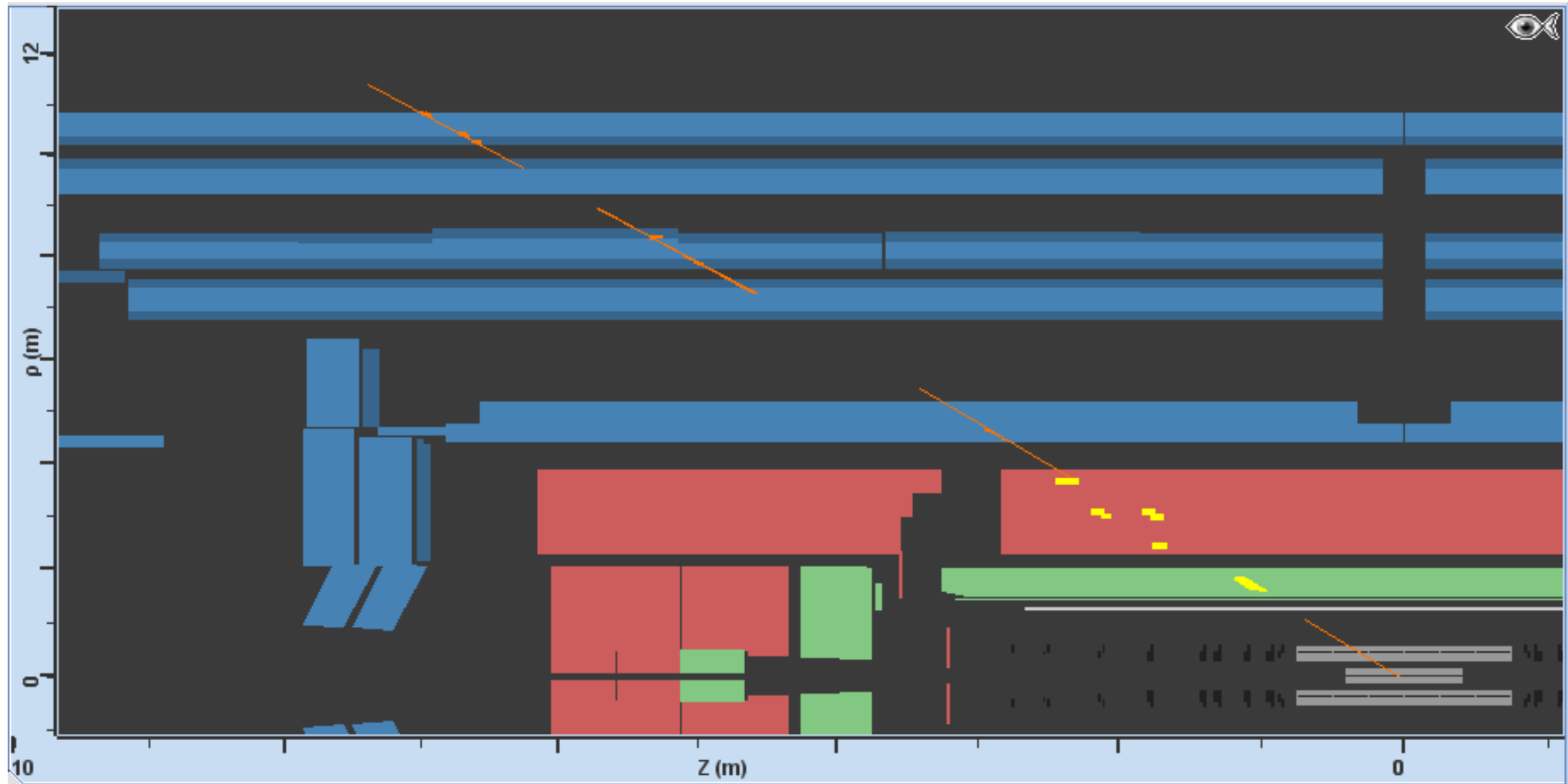


# Identifier les muons/antimuons avec Minerva



- Trace dans le trajectographe et le système des muons
- Un peu d'énergie dans les calorimètres

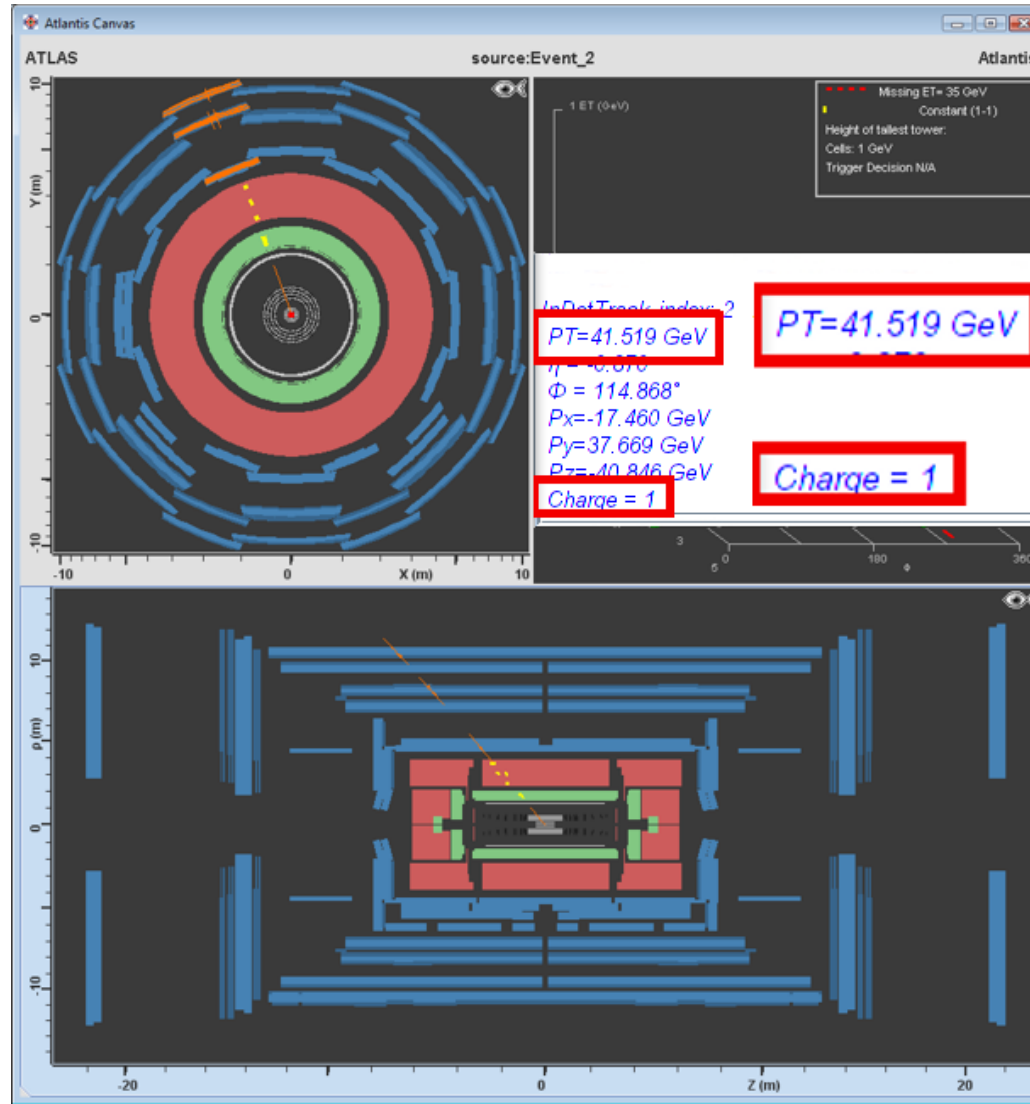
# Identifier les muons/antimuons avec Minerva



- Trace dans le trajectographe et le système des muons
- Un peu d'énergie dans les calorimètres



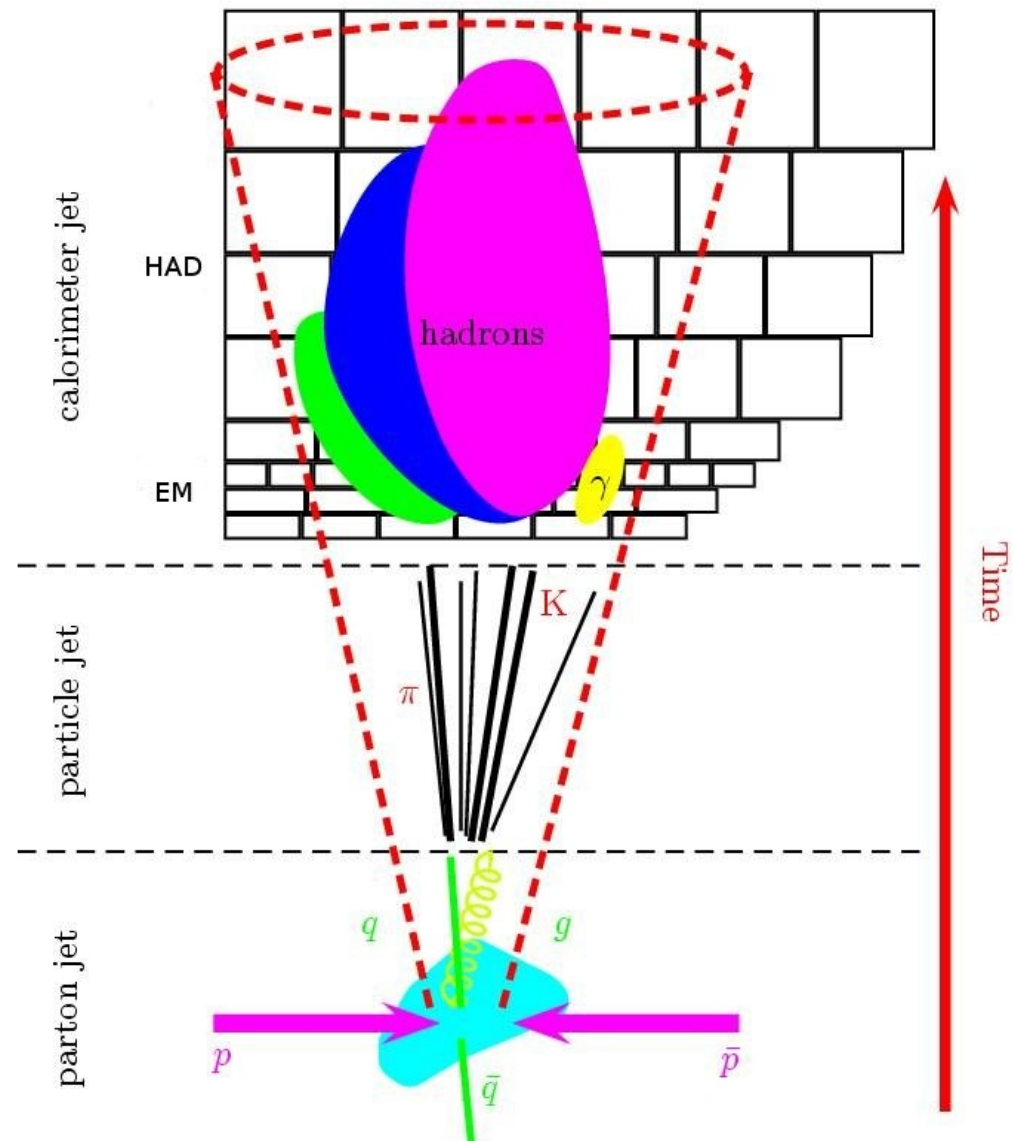
# Identifier les muons/antimuons avec Minerva



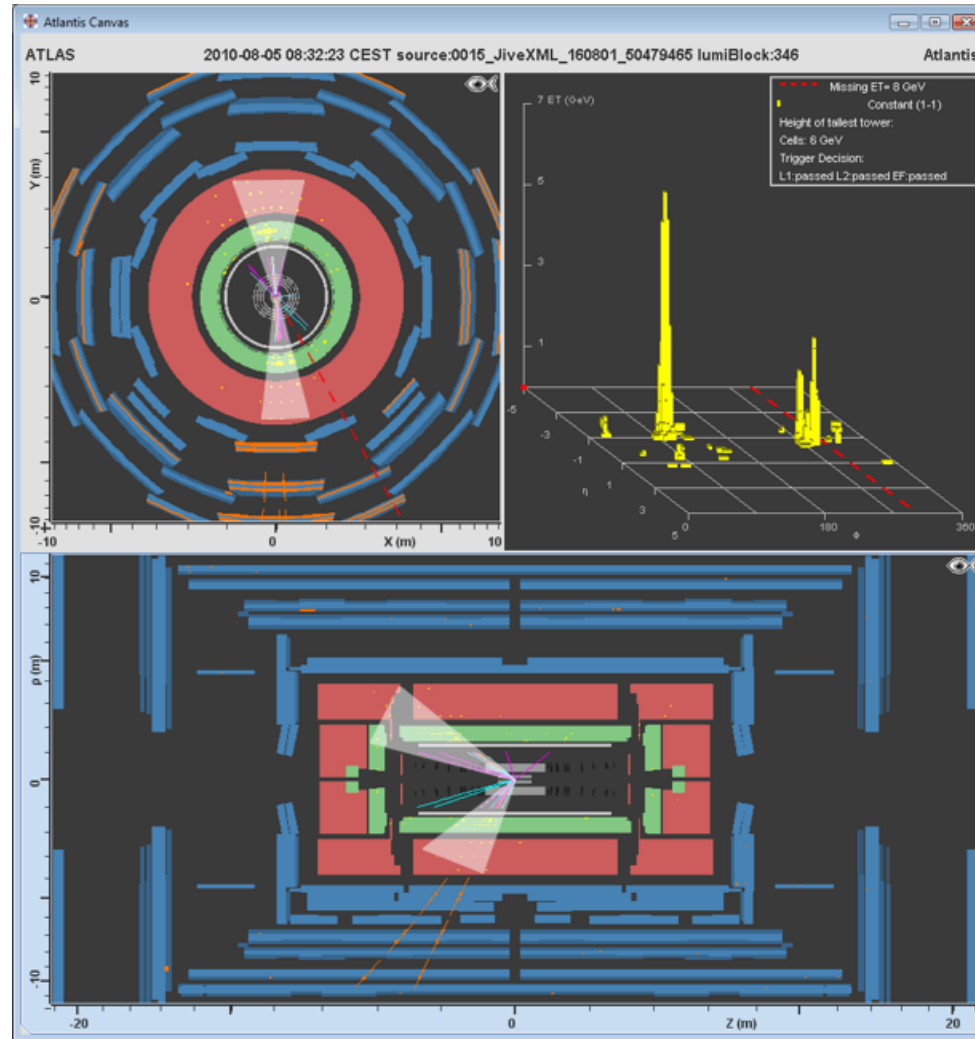
- Positif : antimuon

# Identifier les quarks/antiquarks et gluons

- Jamais seuls, forment des hadrons
- Gerbes dans le calorimètre EM et surtout hadronique
- Particules chargées, traces dans le trajectographe

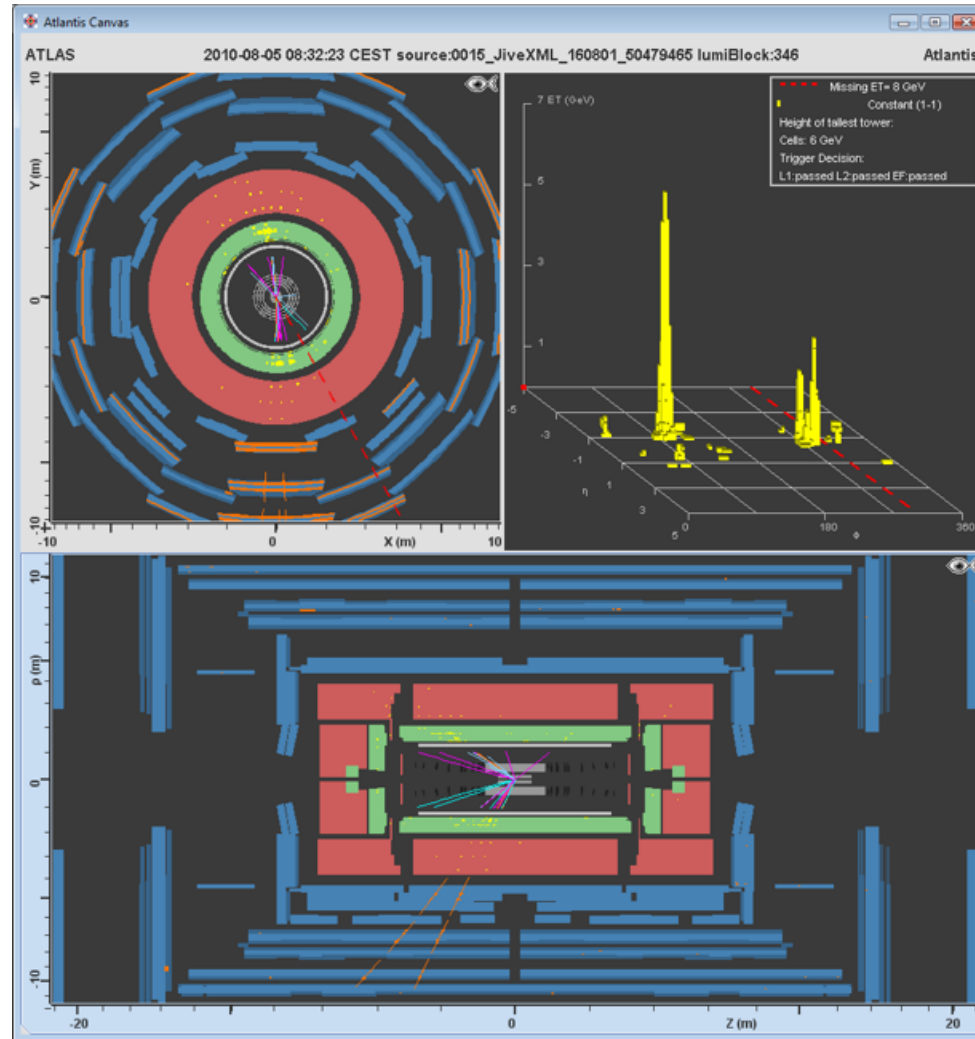


# Identifier les jets avec Minerva



- Nombreuses particules → nombreuses traces
- Dépôts d'énergie dans les calorimètres (surtout hadronique)

# Identifier les jets avec Minerva

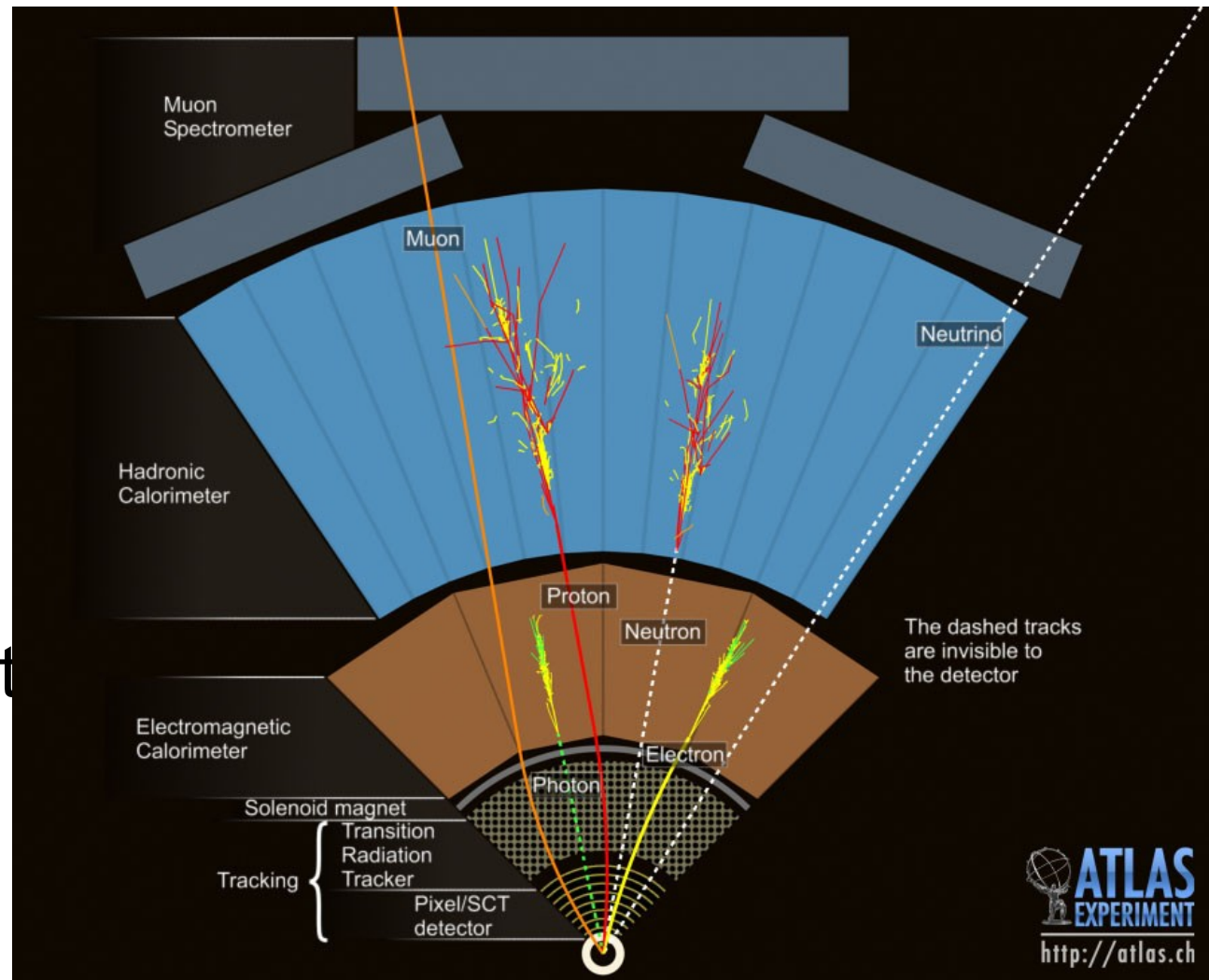


- Nombreuses particules → nombreuses traces
- Dépôts d'énergie dans les calorimètres (surtout hadronique)



# Identifier les neutrinos

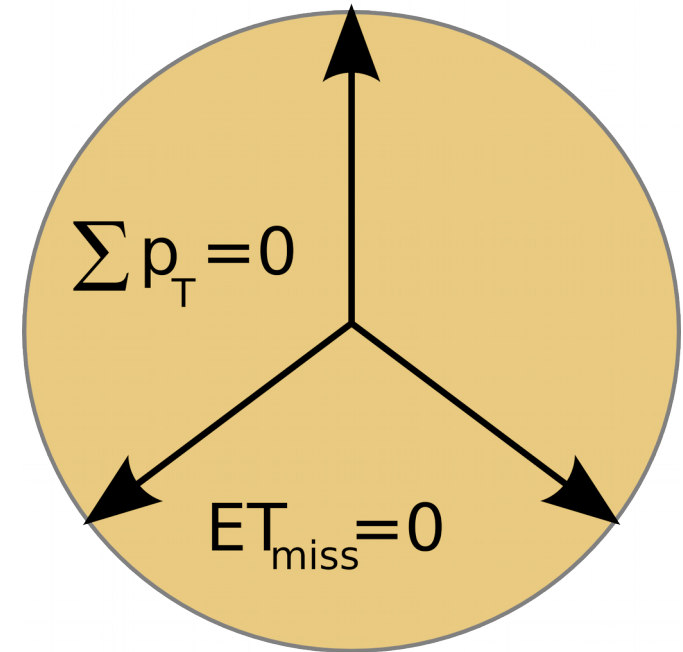
- Particule neutre qui n'interagit presque pas avec la matière
- Aucune trace dans le détecteur
- Identifié par induction, en utilisant la conservation de l'impulsion



# Energie transverse manquante

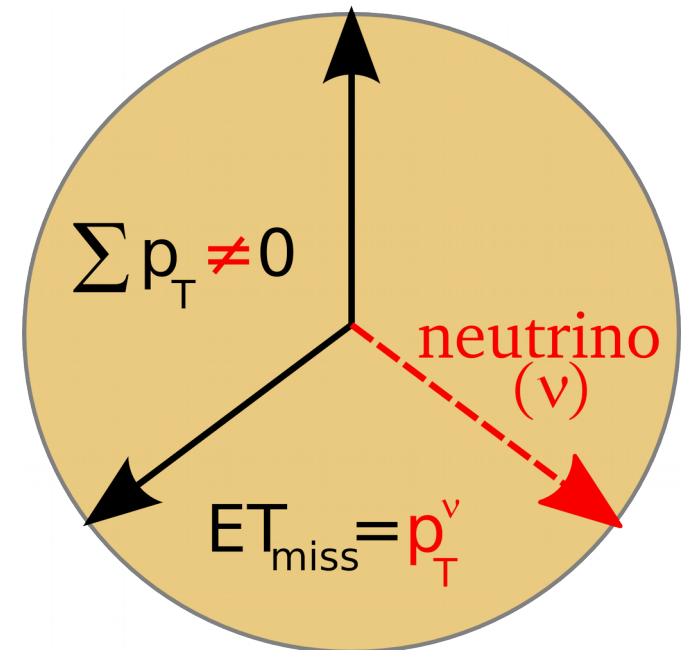
- Sans neutrino

- ▶ 3 particules reconstruites
- ▶ Somme des impulsions dans le plan transverse : 0
- ▶ Donc  $E_{T\text{miss}} = 0$

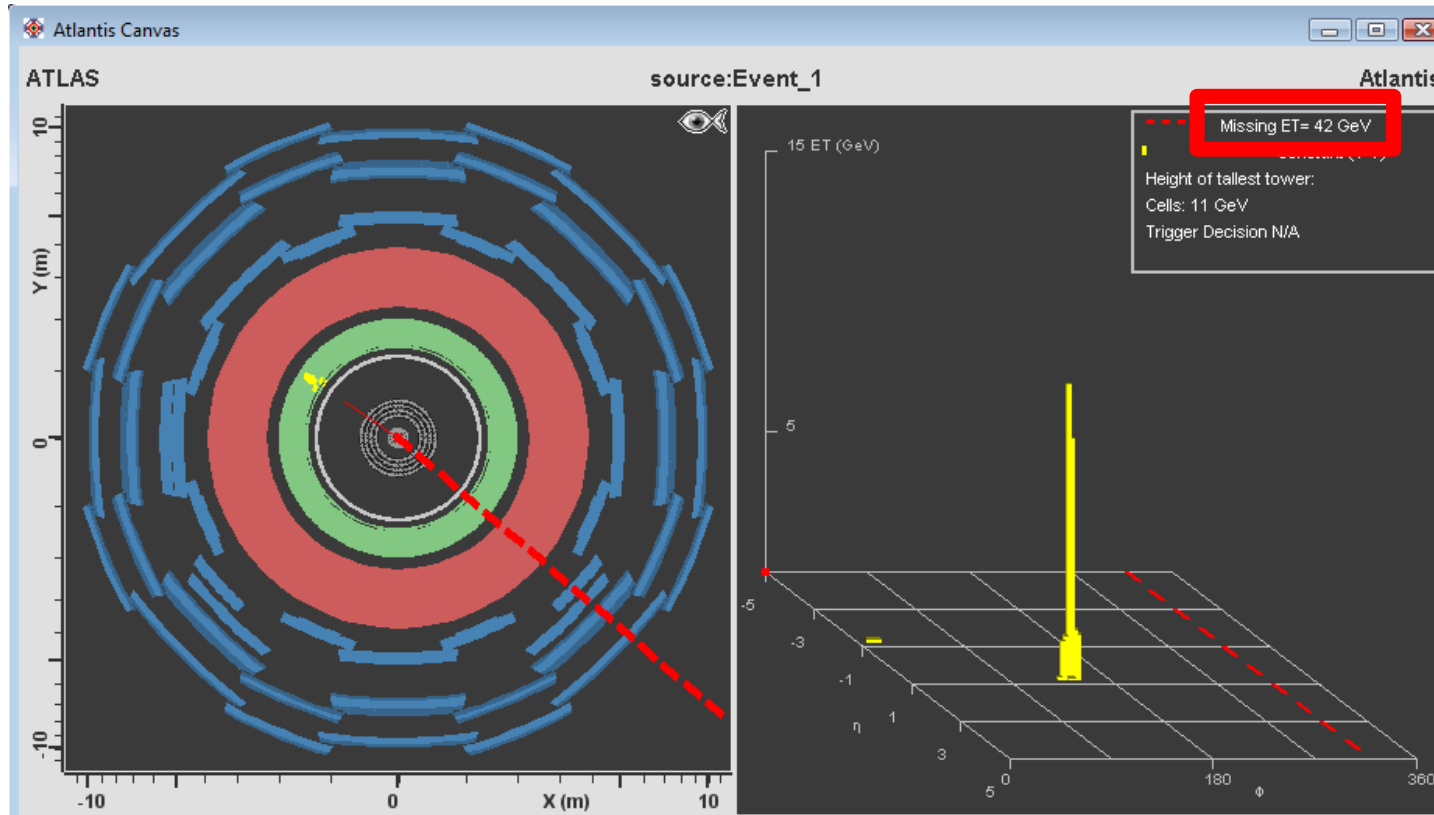


- Avec un neutrino

- ▶ On « voit » seulement une partie de l'événement
- ▶ La somme des impulsions n'est pas nulle
- ▶ La différence est  $E_{T\text{miss}}$ , associée au neutrino



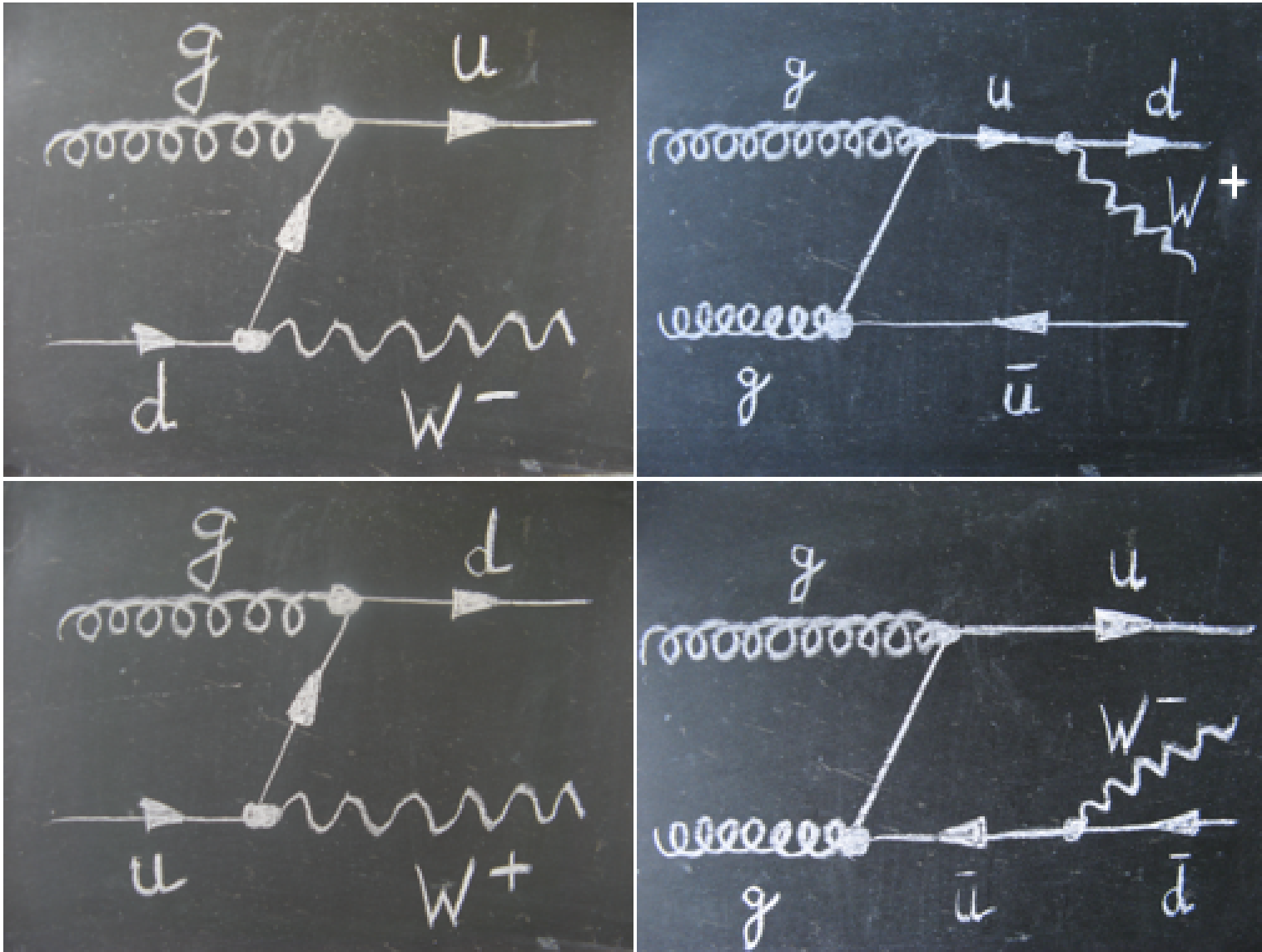
# Identifier un neutrino avec Minerva



- Par conservation, la somme des impulsions dans le plan transversal vaut 0
- Sinon, « énergie transverse manquante (Missing ET) » : particules indétectables (comme les neutrinos), non détectées ou mal mesurées

# Analyse : observer des bosons $W$

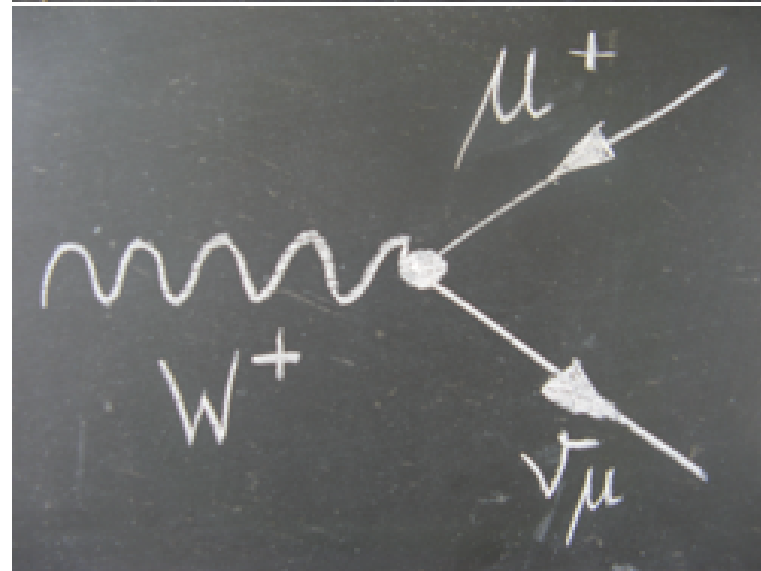
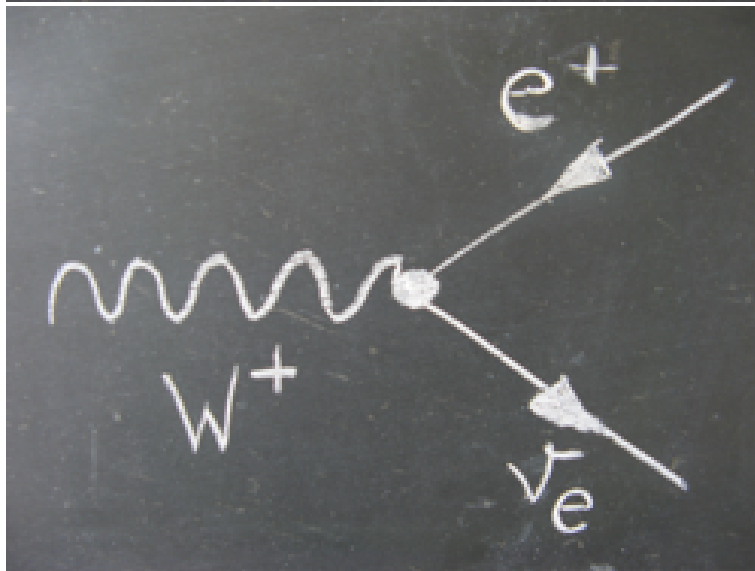
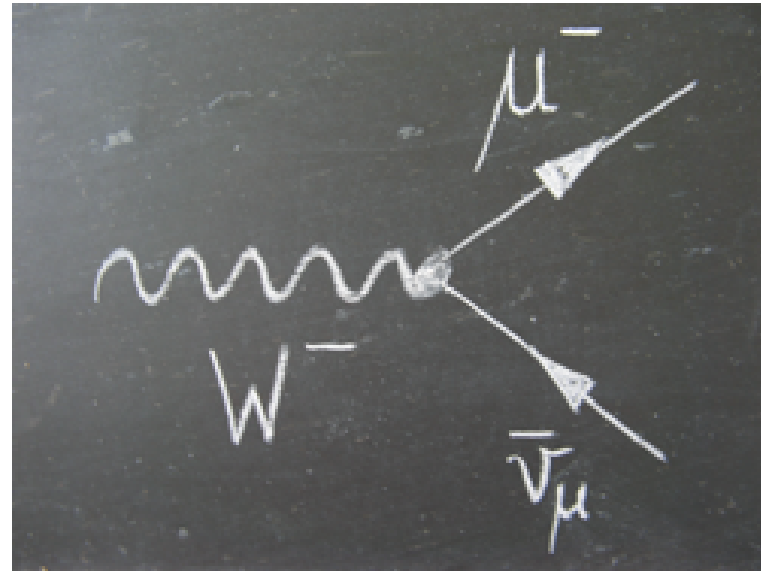
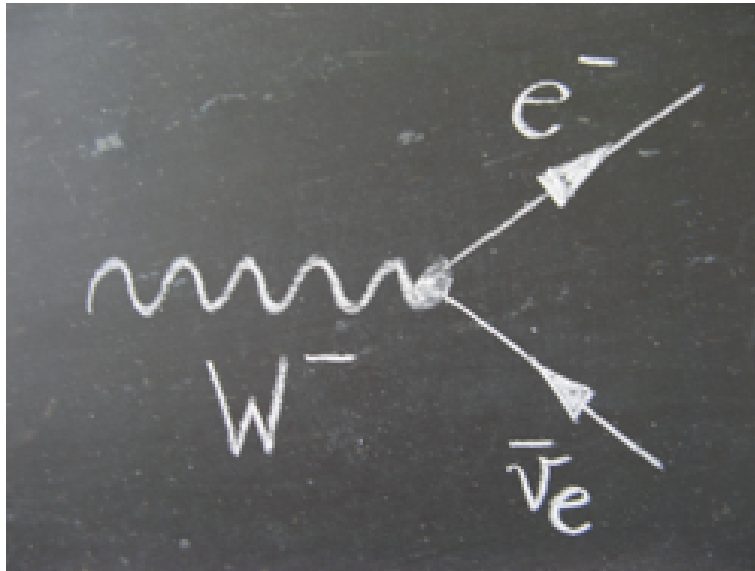
## *Production*





# Analyse : observer des bosons $W$

## *Désintégration*

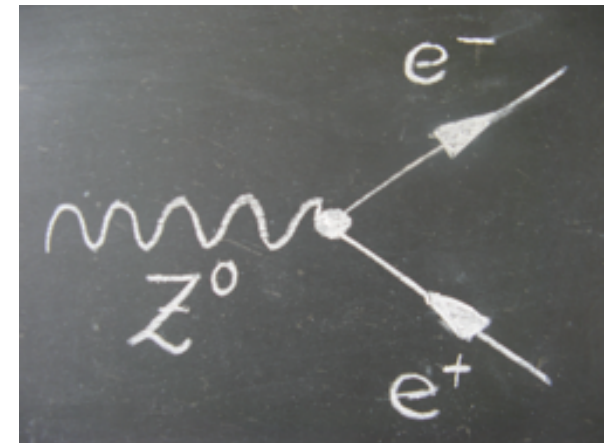
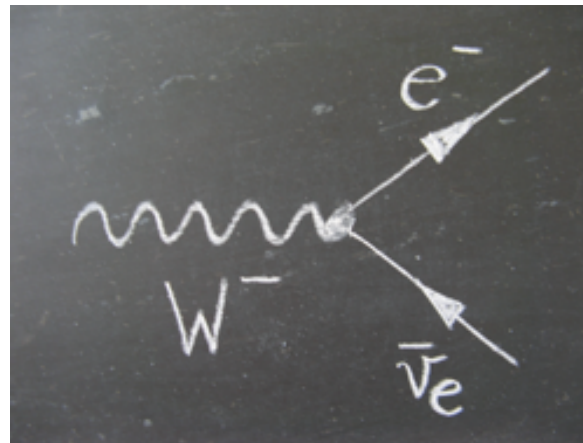
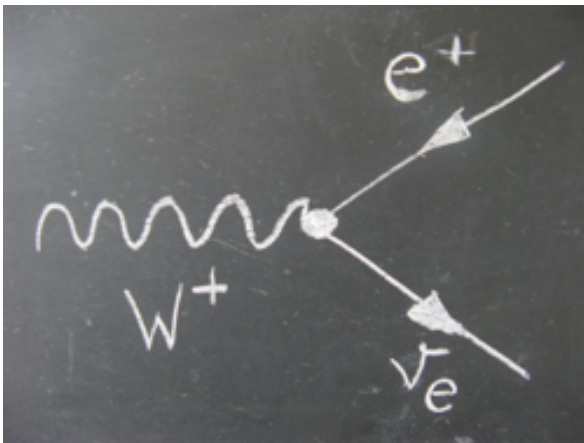


# Difficulté : le bruit de fond

- Signature similaire à ce que l'on cherche, mais venant d'une source différente
- Peut être un vrai processus qui fournit le même état final
- Ou bien dû au fait qu'une particule n'est pas vue dans le détecteur
  - par exemple s'échappe le long du faisceau
- Ou bien à une mauvaise reconstruction dans le détecteur
  - il y a un jet et je crois que c'est un électron
- Ou encore à la présence d'autres particules dans l'événement
  - chaque événement contient plusieurs collisions

# Exemple de signal et bruit de fond

- Signal : désintégration de bosons  $W \rightarrow e\nu$
- Bruit de fond :  $Z \rightarrow ee$
- Un des  $e$  n'est pas reconstruit



- Si on cherche des événements  $Z$ , alors les  $W$  peuvent être un bruit de fond !

# Et vous ?

- Recherche de bosons  $W$ 
  - ▶ et mesure de la structure du proton
- Recherche du boson de Higgs
  - ▶  $H \rightarrow W^+ W^- \rightarrow$ 
    - $e^+ \nu \quad e^- \nu$
    - $e^+ \nu \quad \mu^- \nu$
    - $e^- \nu \quad \mu^+ \nu$
    - $\mu^+ \nu \quad \mu^- \nu$