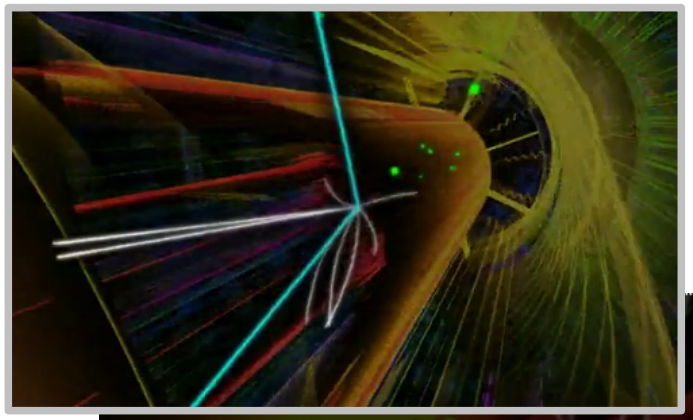
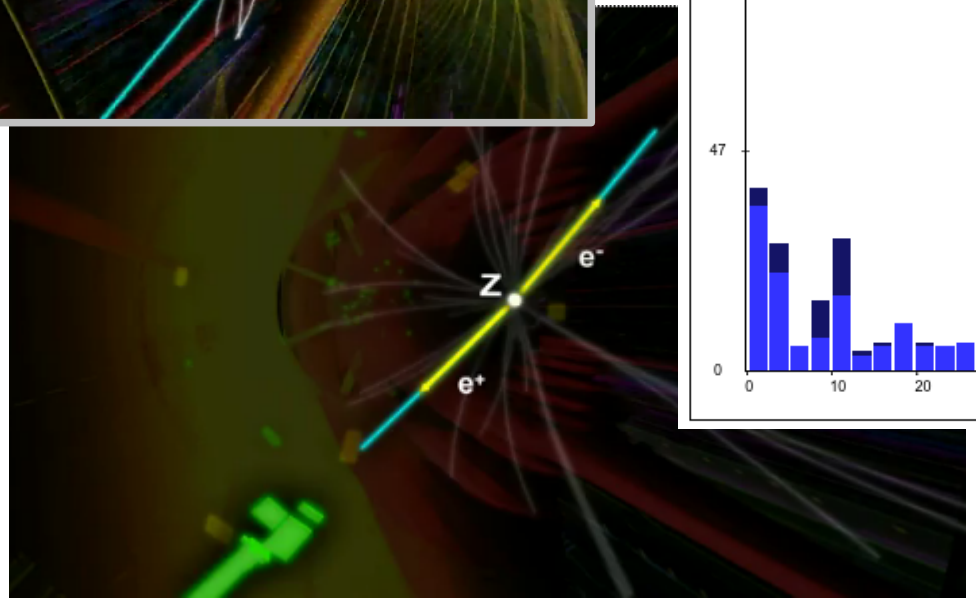
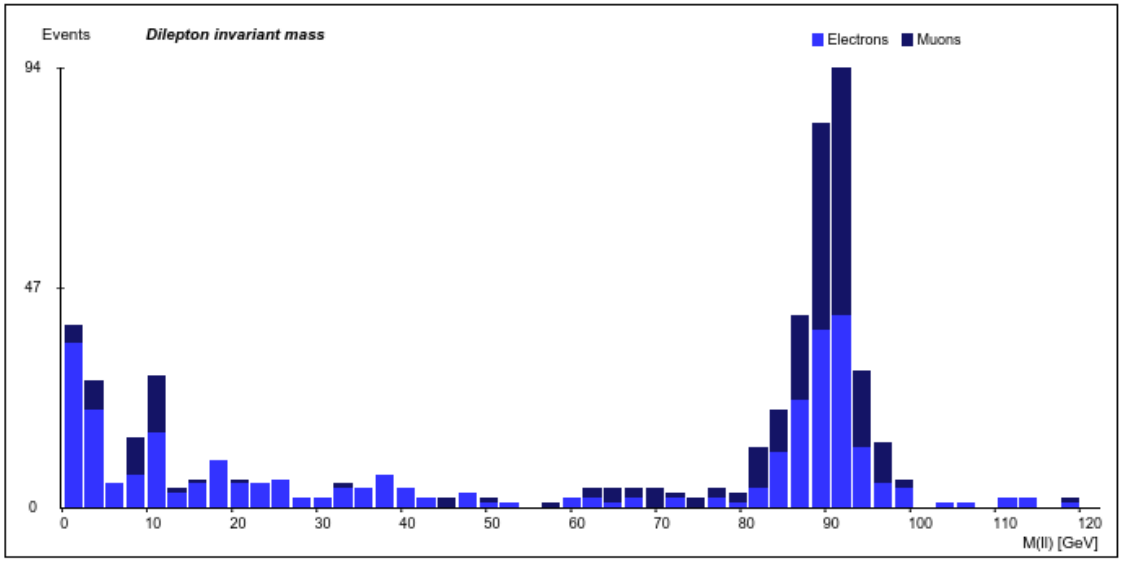
Masterclass – parcours Z :

discussion de distributions en masse invariante relativiste







Plan

I . Résultats : Strasbourg – jeu 17 mars 2016

II. Signal Higgs $\longrightarrow \gamma\gamma$ // bruit de fond,
pour ATLAS run I

III. Notes synthétiques

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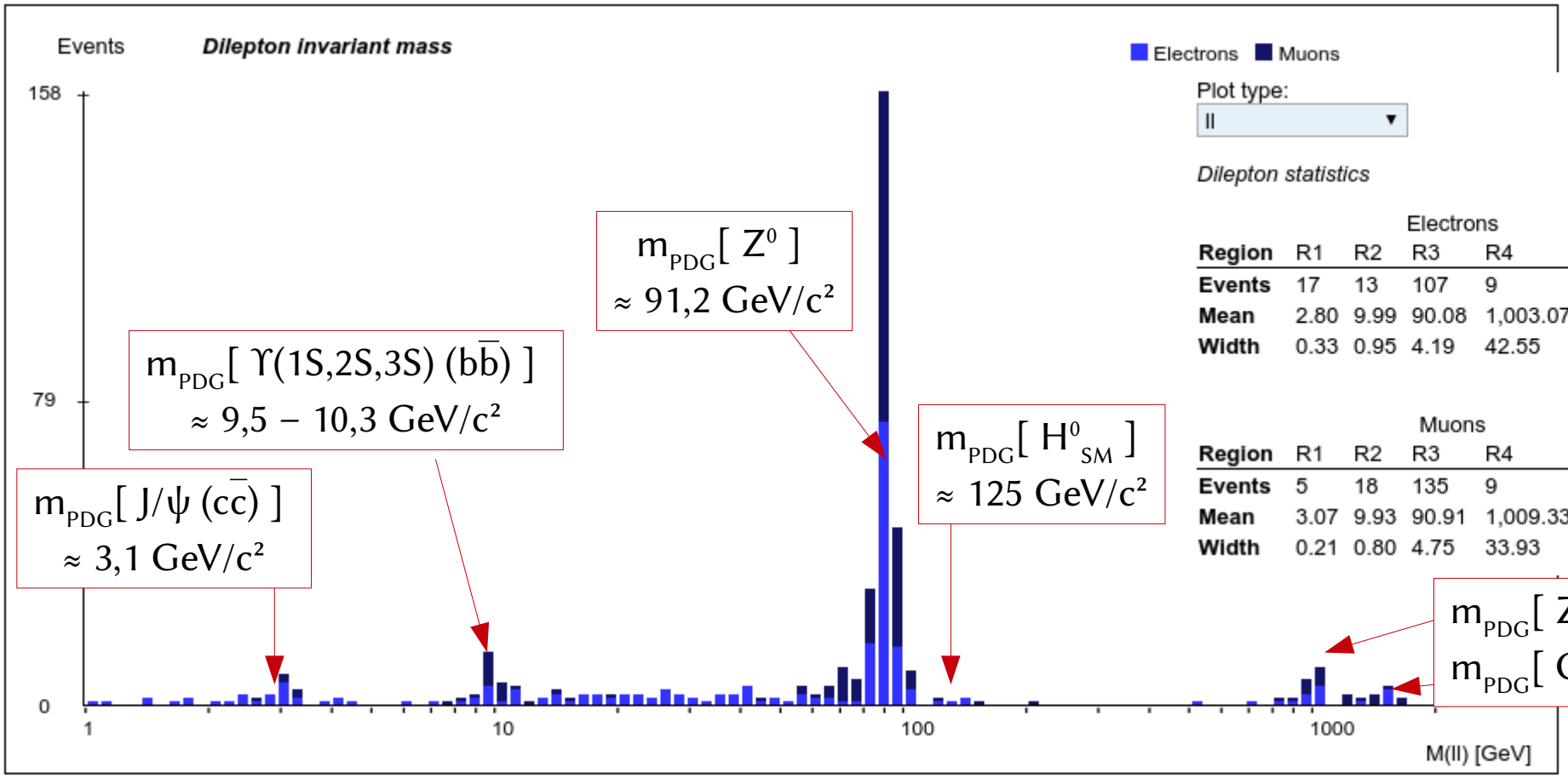
I.1 – $m_{inv}(l^+l^-)$: distribution



Bins: 100 **X-Axis:** Logarithmic **Upper:** 2000

Update plot Reset

R1 Min:	2.0	**R2 Min:**	8.0	**R3 Min:**	80.0	**R4 Min:**	900.0	**R5 Min:**	1400.0
R1 Max:	3.5	**R2 Max:**	13.0	**R3 Max:**	110.0	**R4 Max:**	1100.0	**R5 Max:**	1600.0

PDGlive

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Collection Oplot : 17 mars 2016

I.2 – $m_{inv}(l^+l^-l^+l^-)$: .

Dilepton statistics

Electrons

Region	R1	R2	R3	R4	R5
Events	64	86	433	37	6
Mean	2.91	9.65	89.21	993.63	1,488.83
Width	0.44	1.38	3.58	33.72	24.64

Muons

Region	R1	R2	R3	R4	R5
Events	49	57	532	34	4
Mean	3.09	9.98	90.56	1,009.94	1,448.42
Width	0.25	0.77	3.43	44.82	25.30

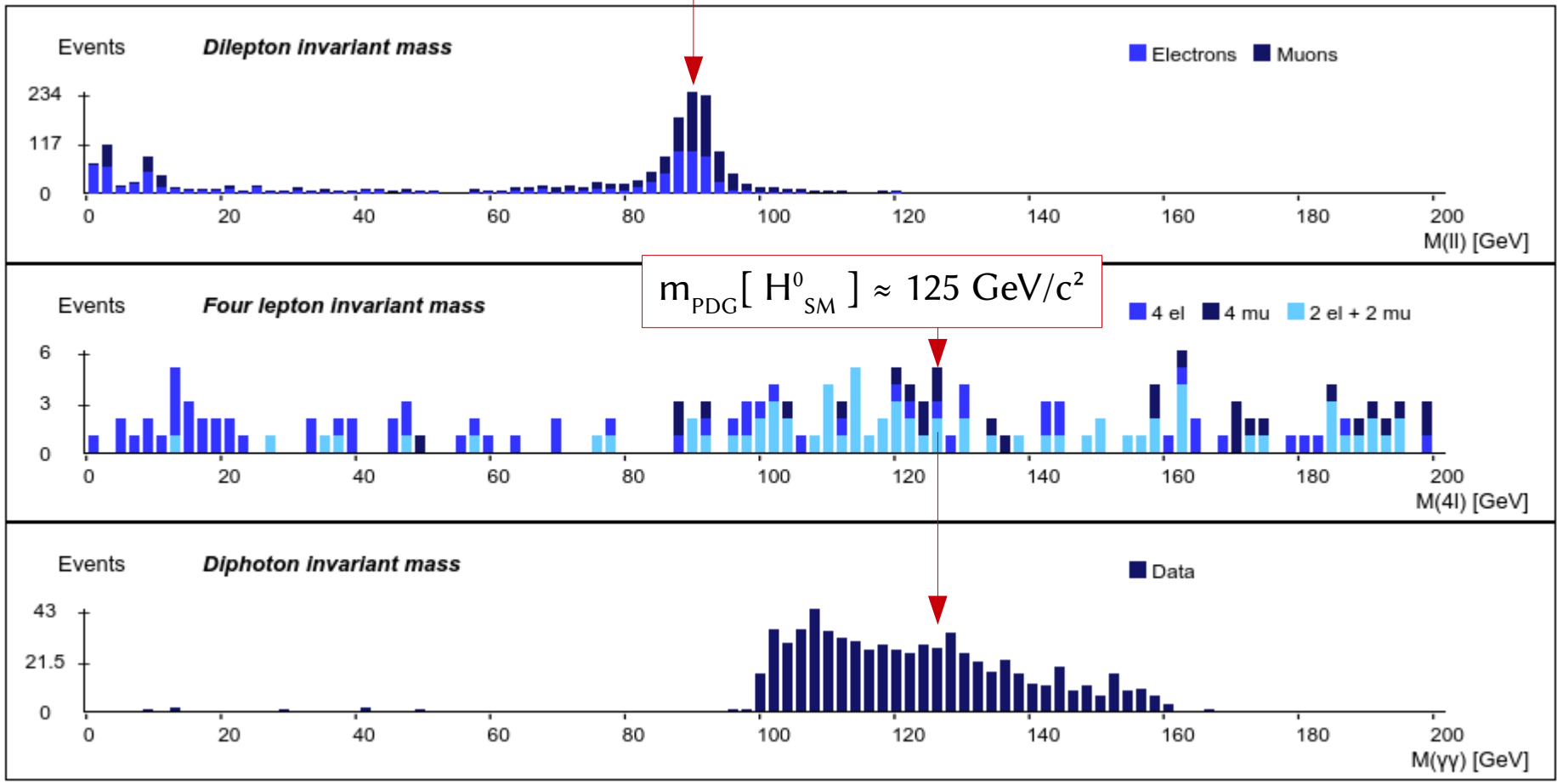
Number of events

	Student distribution	Expected
ll	1894	2438
4l	264	40
γγ	679	1125
Sum	2784	3603

Plot type: ll+4l+γγ

Dilepton statistics

$m_{PDG}[\ Z^0\ ] \approx 91{,}2\ GeV/c^2$



$m_{PDG}[\ H^0_{SM}\ ] \approx 125\ GeV/c^2$

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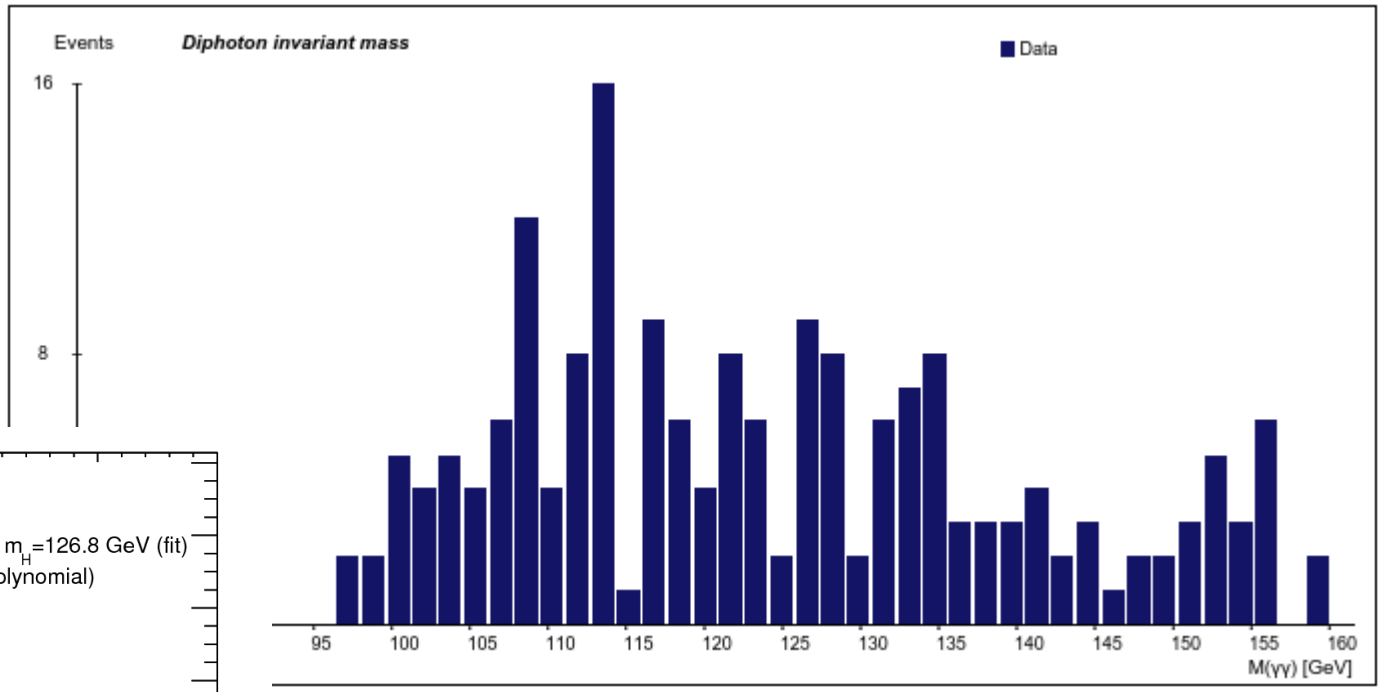
II.1 – Lycée vs ATLAS (LHC run I) : Higgs → γγ

Résultats ATLAS
25.5 fb^{-1} → signal "net"
suffisamment "net" = ?!



$m_{inv}(\gamma\gamma)$

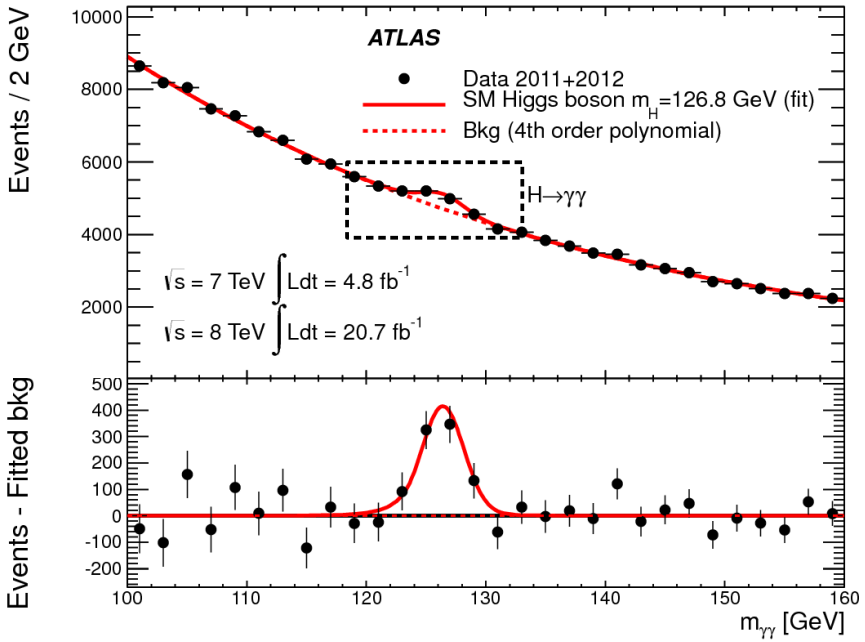


Fig.13, Higgs → γγ Run I = arXiv:1408.7084

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III.1 – Notes : résumé

1. Z^0 : Masse PDG (⟶ PDG = ?)
Masse mesurée en TP (μ + err) ⟶ notion de Gaussienne + écart type (pr Term, ok)

Transition : Z^0, signal très net // Higgs, cas plus ambigu… ⟶ notion de rapport S/B

2. Higgs : Après 2012, existence du Higgs = prouvée, m_{PDG}
Différence avec Z^0 : rapport Signal ou Bruit ?
Ex. : Soit 1 bin, Bin content = 3 ⟶ 1,2,3 coup(s) de signal ? sûr à 100 % ?
⟶ pas de distinction 100 % fiable au cas par cas !
But : distinguer *statistiquement* un signal (surpopulation) qui émerge au-dessus d'un bruit de fond

Illustration : « significance » avec graphe H ⟶ γγ
Higgs signal (Sbg) vs qté équiv ATLAS (0.08 fb-1 ~ 8.10^{12} évts pp) (*NB* : stratégie de déclenchement pour l'enregistrement …)
Stat++ : ⟶ 2 fb^{-1} (~ 2.10^{14} évts pp)
⟶ 10 fb^{-1} (~ 10^{15} évts pp) *NB :* 5 fb^{-1} 7 TeV = 5σ 2012 ! 7 TeV, arXiv:1202.1408
⟶ 25 fb^{-1} (~ 2.10^{15} évts pp = Run I, *Fig.13, Higgs ⟶ γγ Run I = arXiv:1408.7084*)

3. Autres résonances : J/ψ, ϒ

4. Les hypothétiques exotiques
NB : Injection de signal simulé,
« Si m(Z') = …, alors ATLAS verrait … »

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Annexes

Annexe 1 : ven 18 mars 2016

Annexe 2 : Lycée vs ATLAS

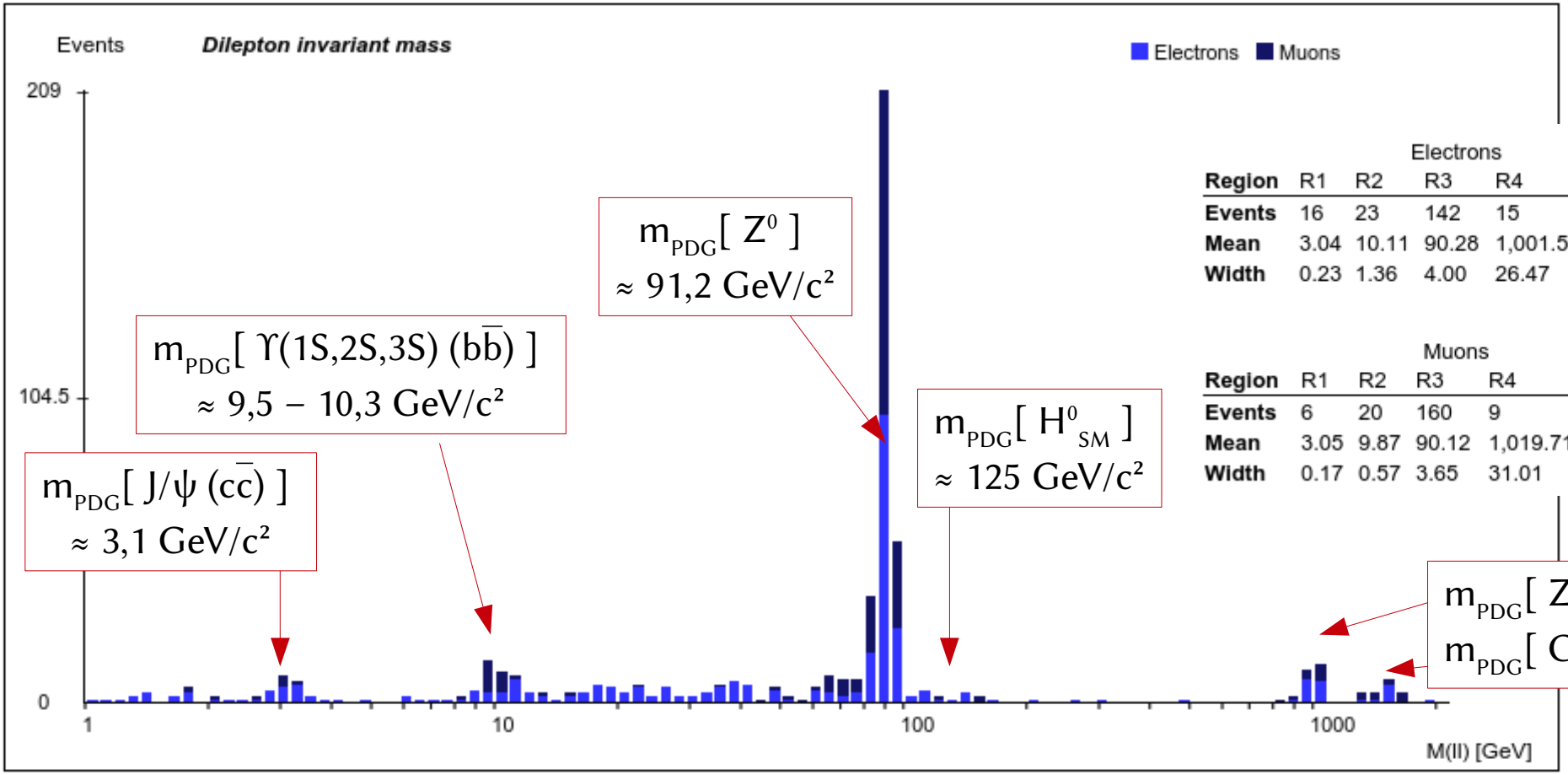
Annexe 3 : caractéristiques de particules

Annexe 4 : détails IPPOG

A.1 – $m_{inv}(l^+l^-)$: distribution

Plot type: ll

Dilepton statistics



Electrons

Region	R1	R2	R3	R4	R5
Events	16	23	142	15	7
Mean	3.04	10.11	90.28	1,001.53	1,482.52
Width	0.23	1.36	4.00	26.47	26.07

Muons

Region	R1	R2	R3	R4	R5
Events	6	20	160	9	3
Mean	3.05	9.87	90.12	1,019.71	1,515.00
Width	0.17	0.57	3.65	31.01	49.10

Bins: 100 X-Axis: Logarithmic Upper: 2000

Update plot Reset

R1 Min:	2.5	R2 Min:	8.5	R3 Min:	82.0	R4 Min:	900.0	R5 Min:	1400.0
R1 Max:	3.5	R2 Max:	12.0	R3 Max:	110.0	R4 Max:	1100.0	R5 Max:	1600.0

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Collection Oplot 18 mars 2016

$A.2 - m_{inv}(l^+l^-l^+l^-)$: .

Electrons

Region	R1	R2	R3	R4	R5
Events	22	24	140	15	7
Mean	3.03	10.20	90.07	1,001.53	1,482.52
Width	0.42	1.40	3.63	26.47	26.07

Muons

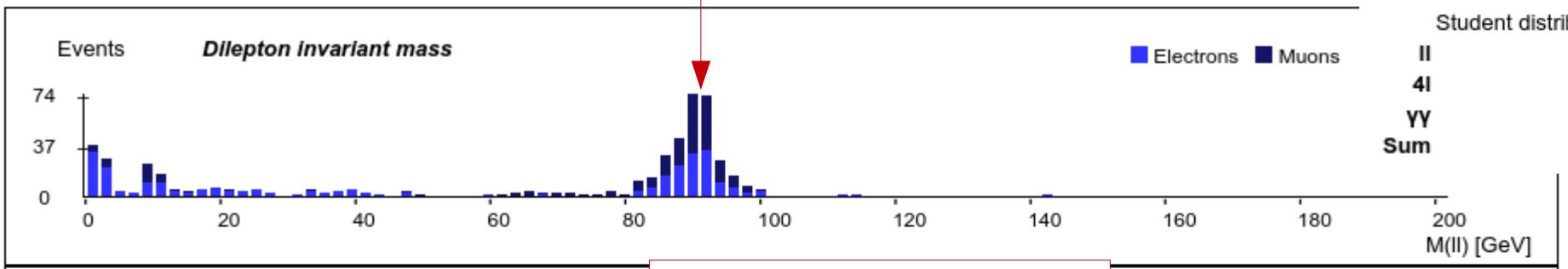
Region	R1	R2	R3	R4	R5
Events	7	21	159	9	3
Mean	2.90	10.00	90.06	1,019.71	1,515.00
Width	0.39	0.83	3.58	31.01	49.10

Number of events

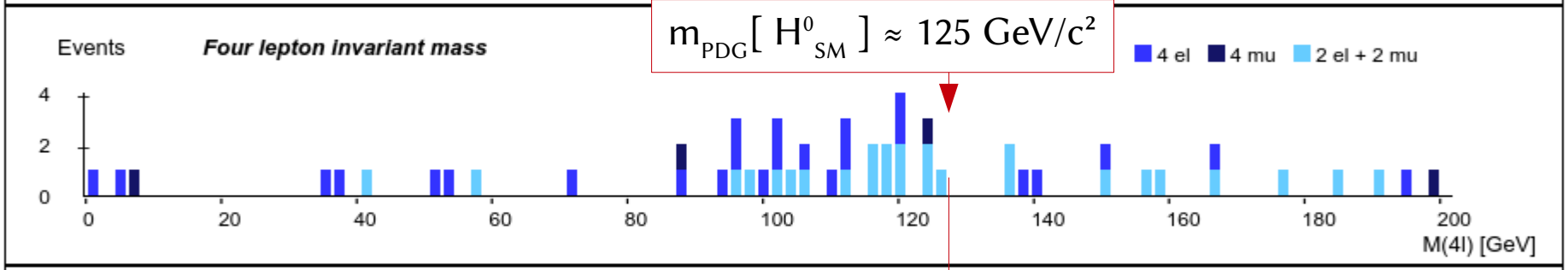
$m_{PDG}[\ Z^0\ ] \approx 91{,}2\ GeV/c^2$

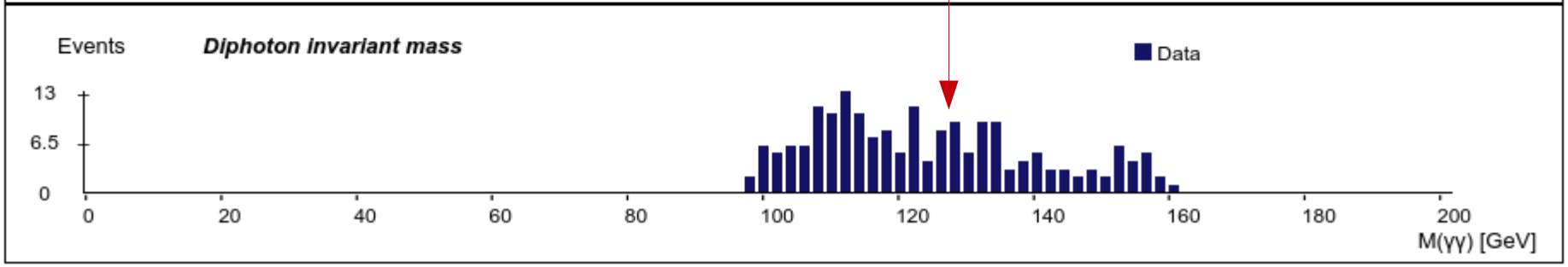
Student distribution Expected

ll	580	1008
4l	79	40
γγ	191	465
Sum	850	1513



$m_{PDG}[\ H^0_{SM}\ ] \approx 125\ GeV/c^2$





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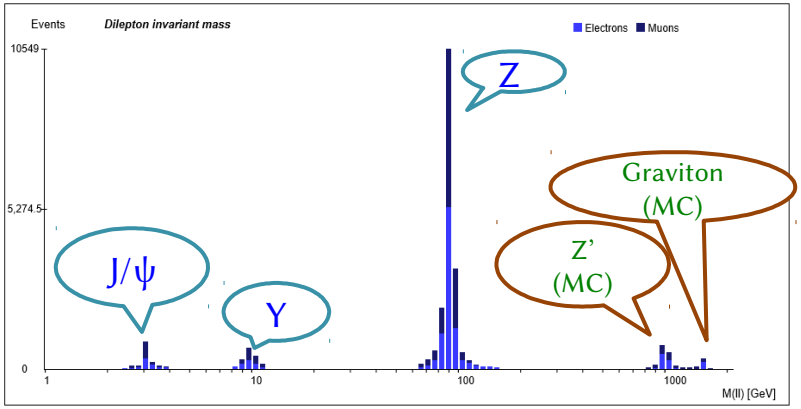
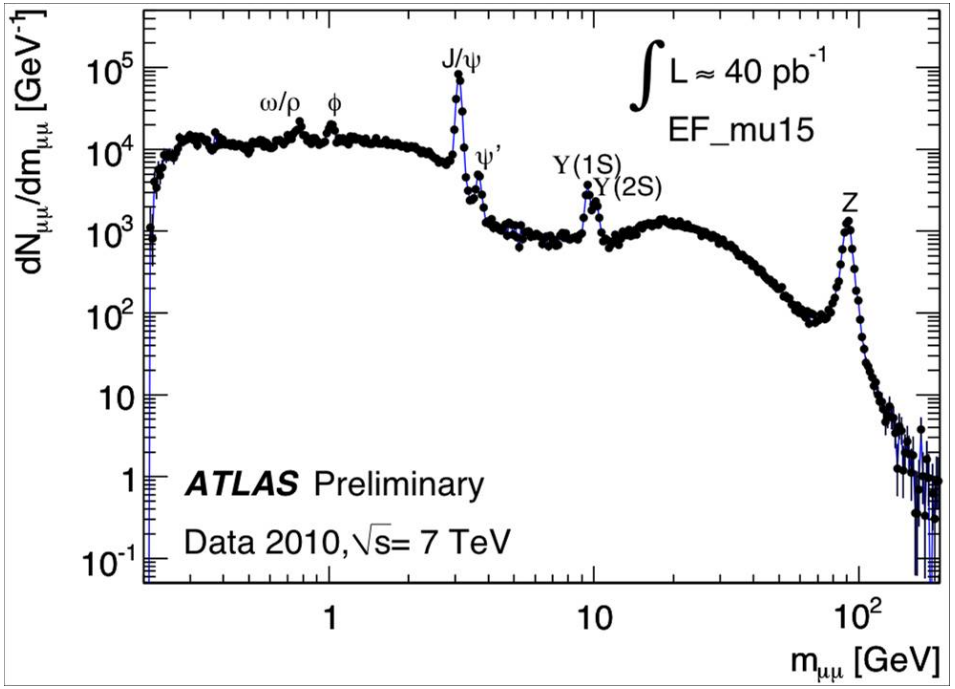
B.1 – Lycée vs ATLAS : $M_{inv}(l^+l^-)$, de 1 à 2000 GeV/c^2



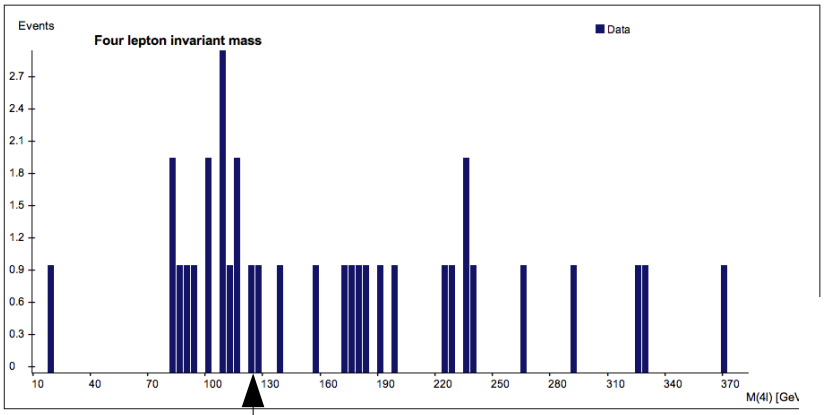


Continuum

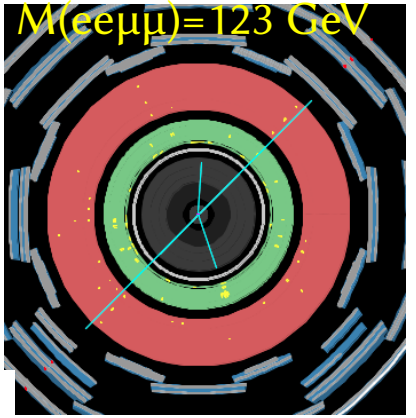
$\mu^+\mu^-$

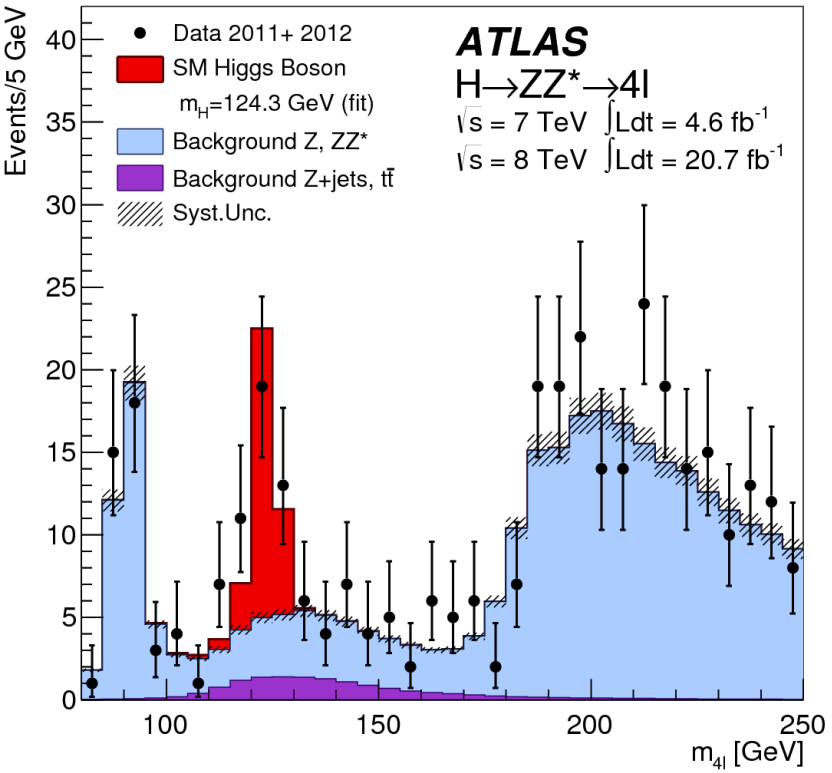
(similaire, pour e+e-)

B.2 – Lycée vs ATLAS : Higgs → ZZ* → 4l±



- ATLAS results
  - H → ZZ* → l⁺l⁻l⁺l⁻
  - 25.3 fb⁻¹



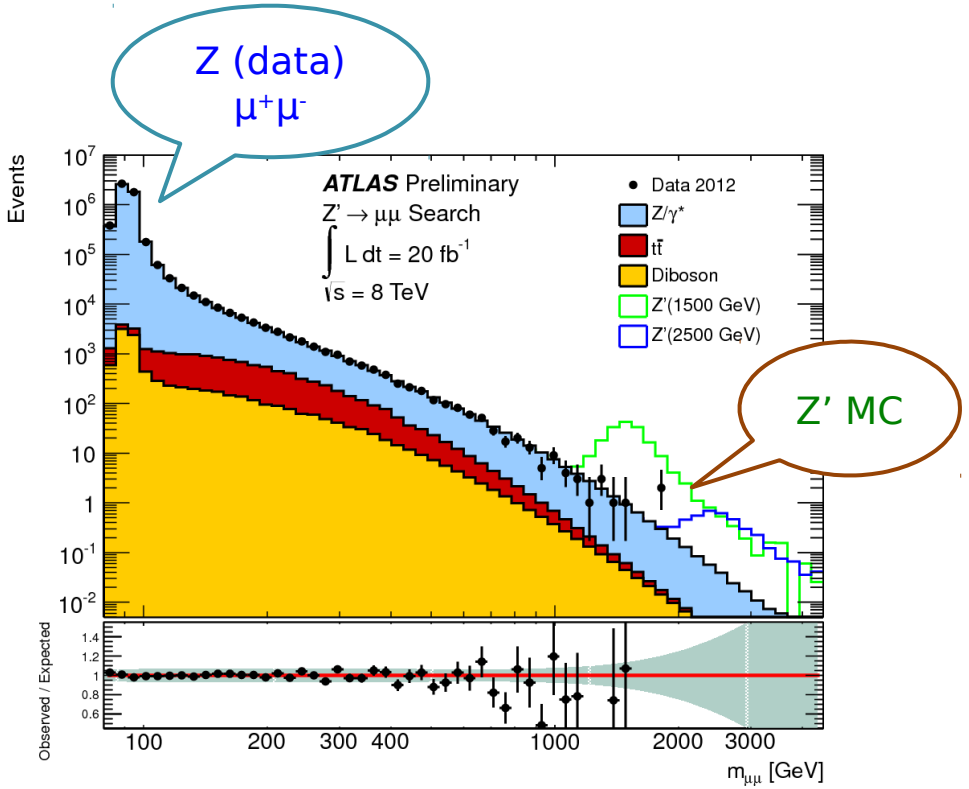


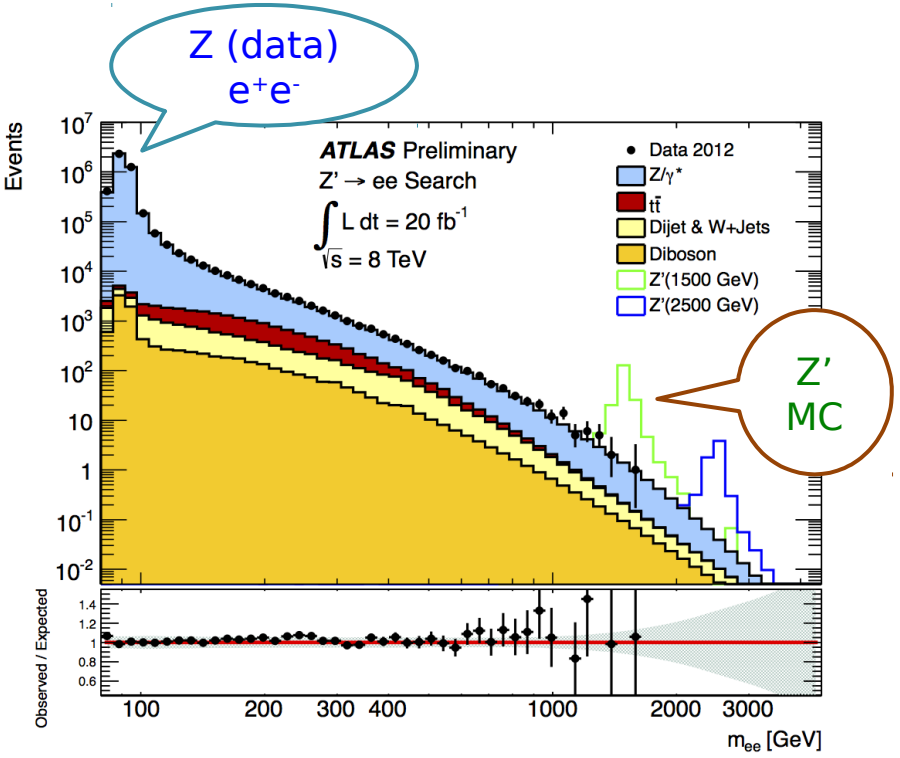
$e^+e^-\ e^+e^-$
ou
$e^+e^-\ \mu^+\mu^-$
ou
$\mu^+\mu^-\ \mu^+\mu^-$

B.3 – Lycée vs ATLAS : Z'

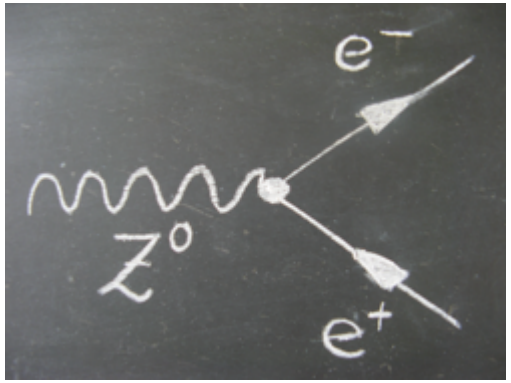
Y-a-t-il de la nouvelle physique ?
Par exemple un nouveau boson Z' ?

- ATLAS status:
  - Z ?: oui
  - Z' ? non (pas encore ?)
    - masse(Z') attendue > 2-2.5 GeV





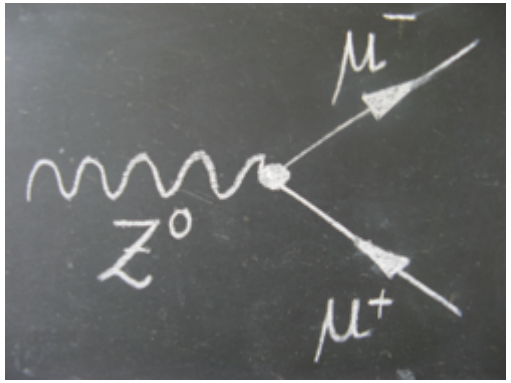
C.1 – Caractéristiques : Z^0



Z^0, temps de vie caractéristique : 3. 10^{-25} s …

Proba désintégration Z ⟶ e+e- = (3.363±0.004)%

$m(Z^0) \approx 91$ GeV



Proba désintégration Z ⟶ μ+μ- = (3.366±0.007)%

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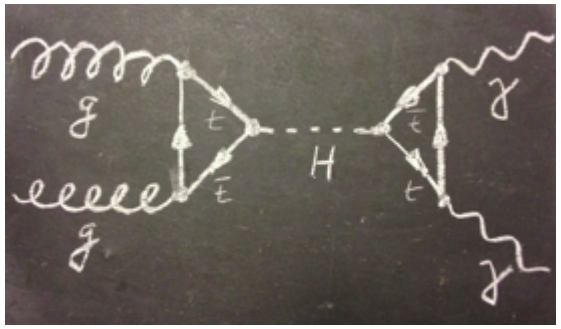
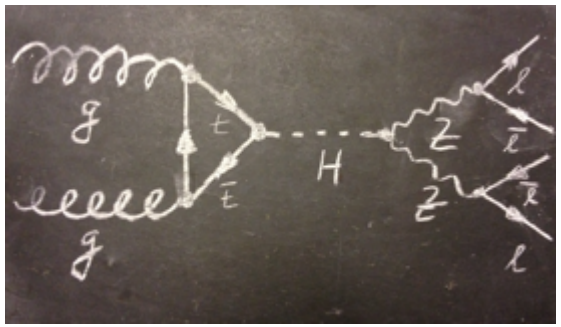
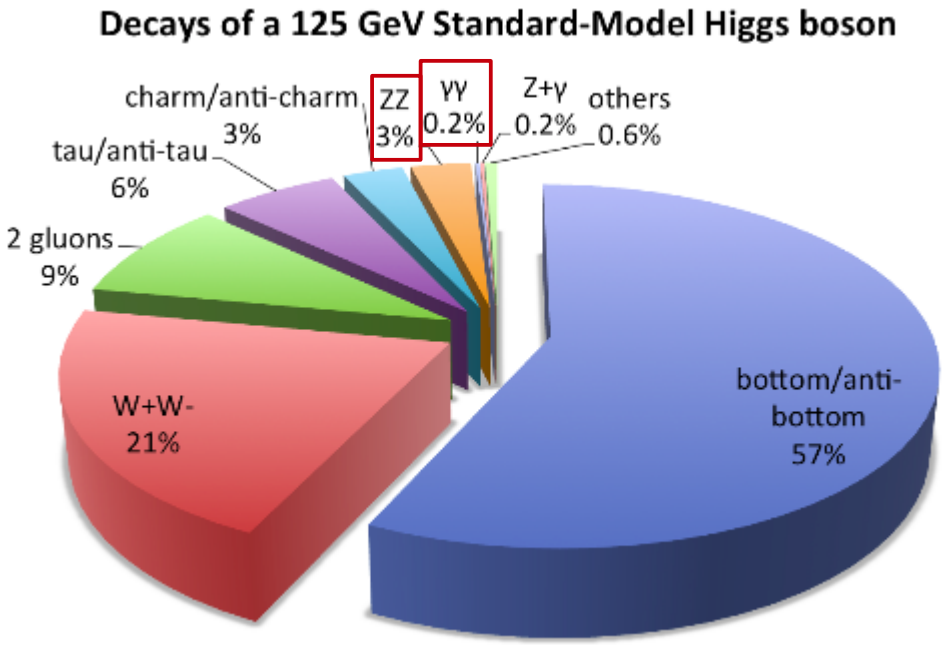
C.2 – Caractéristiques : Higgs *(Std Model)*



$m(H_{SM}) \approx 125$ GeV



Higgs Boson, temps de vie caractéristique : < 3. 10^{-25} s ...



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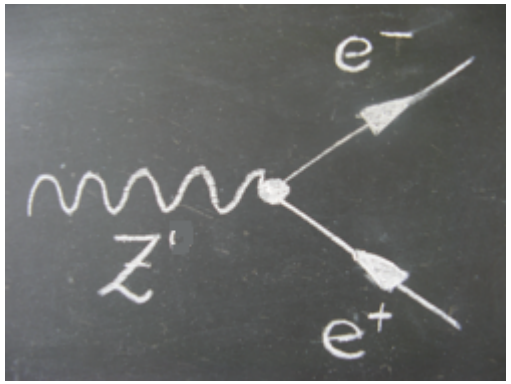
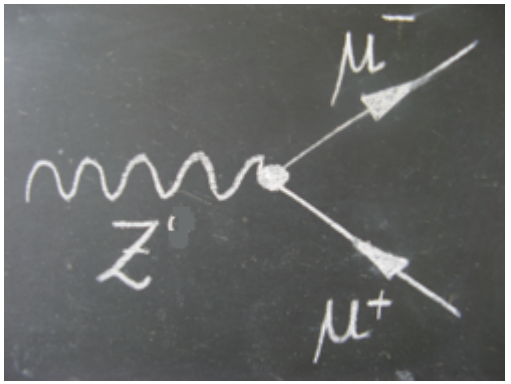
C.3 – Caractéristiques : Z'



m(Z') > 1-2,5 TeV



Le boson Z' n'a encore jamais été observé dans les expériences.
C'est un partenaire lourd du boson Z
dont l'existence est prévue par certaines théories
qui vont au-delà du Modèle Standard
⟶ introduction nouvelle force faible.

Pour plupart des modèles, ⟶ modes de production + désintégration du boson Z' = très similaires à ceux du boson Z ordinaire

Les mêmes techniques pour le Z =
peuvent être utilisées pour rechercher le boson Z' !

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D.1 – Questions potentielles : briefing ippog

- **di-lepton measurement**
  - Compare the histograms of the electron-positron and muon-antimuon pairs.
    - Can you point out differences/similarities?
    - How often does the Z boson decay into electron-positron pairs? How often does the decay result in muon-antimuon pairs?
    - What did you expect? Why?
    - Do you notice any other particles? At which invariant masses?
  - What is the most probable mass of the Z boson?
    - Why is there not one exact value for the Z boson mass?
    - What could be the possible explanations of why the distribution is so wide?
- Have you discovered the Z' boson?
  - If you think so, what is the Z' boson's mass?
- Have you discovered the Graviton?
  - If you think so, what is the Graviton mass?
- Why is it useful to combine your results with those obtai groups?

- **di-photon measurement**
  - Do you see any sign of Higgs decaying to 2 photons, H→γγ?
    - If not, what could be the reasons?
    - In fact the full sample does contain real Higgs candidates, even if you have not found them!
  - Any sign of the Z' boson or Graviton?
    - Why/why not?

- **4-lepton measurement**
  - Do you see any sign of Higgs decaying to 4 leptons, H→ZZ→llll?
    - If not, what could be the reasons?
  - In fact the whole sample contains Higgs candidates. At which mass?
  - Any sign of the Z' boson or Graviton?
    - Why/why not?

D.2 – Données TP : contenu

Datasets: ATLAS real pp-data from 2012 at 8 TeV + MC simulations

Di-leptons: ~20000 events from data
- Di-electrons and di-muons from Z (mainly), J/ψ and ϒ
- 2000 fully simulated Z' events (mass 1 TeV),
  equally shared among the e^+e^- and $\mu^+\mu^-$ decay channels
- 600 fully simulated Graviton events (mass 1.5 TeV),
  equally shared among the e^+e^- and $\mu^+\mu^-$ decay channels

Di-photons: Higgs candidates (data) and simulated Gravitons
- Higgs candidates: real data events corresponding to 2 fb^{-1}
  ~10000 events
  γγ cuts as in ATLAS publication – including converted photons,
- ~400 fully simulated Graviton events (mass 1.5 TeV) decaying into di-photons

4 leptons: Higgs candidates (data) and simulated Gravitons
- Higgs candidates: 40 events
  cuts as in ATLAS publication
- ~400 fully simulated Graviton events (mass 1.5 TeV) decaying into two Z-bosons
  (which subsequently decay into $e^{\pm}$ and $\mu^{\pm}$)

Srce : IPPOG, ATLAS / Guide for tutors