LHC Run I Bounds on Minimal Lepton Flavour Violation in Type–III See–saw: A Case Study

based on arXiv:1708.08456

Nuno Rosa
in collaboration with O.Eboli and M.C. Gonzalez-Garcia

October 23, 2017

University of Barcelona

UNIVERSITAT DE BARCELONA

elusives
neutrinos, dark matter & dark energy physics

Introduction

What we know so far about neutrinos?

Introduction

What we know so far about neutrinos?

- Without any doubt the most solid evidence of Physics Beyond the Standard Model!!!

Introduction

What we know so far about neutrinos?

- Without any doubt the most solid evidence of Physics Beyond the Standard Model!!!
- Old fashioned receipt:

Introduction

What we know so far about neutrinos?

- Without any doubt the most solid evidence of Physics Beyond the Standard Model!!!
- Old fashioned receipt:
  - Extend the model and find a mechanism capable of generating neutrinos with tiny masses.

Introduction

What we know so far about neutrinos?

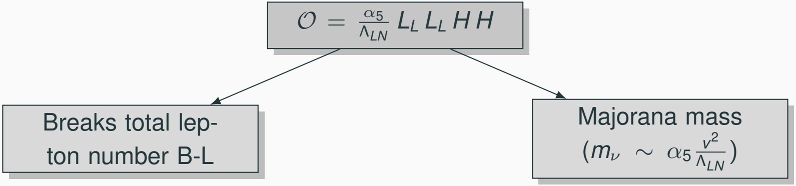
- Without any doubt the most solid evidence of Physics Beyond the Standard Model!!!
- Old fashioned receipt:
    - Extend the model and find a mechanism capable of generating neutrinos with tiny masses.
    - Strongest candidate: See-saw mechanism :)

Introduction

What we know so far about neutrinos?

- Without any doubt the most solid evidence of Physics Beyond the Standard Model!!!
- Old fashioned receipt:
  - Extend the model and find a mechanism capable of generating neutrinos with tiny masses.
  - Strongest candidate: See-saw mechanism :)

Dynamics: dimension-five operator



$$\mathcal{O} = \frac{\alpha_5}{\Lambda_{LN}} L_L L_L H H$$

Breaks total lepton number B-L

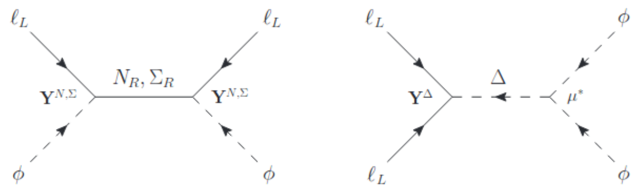
Majorana mass $(m_\nu \sim \alpha_5 \frac{v^2}{\Lambda_{LN}})$

Introduction

- Three types of new states can generate $\mathcal{O}_5$ at tree level.

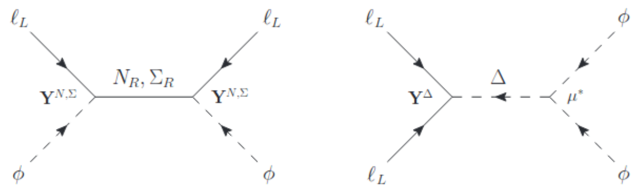
Introduction

- Three types of new states can generate $\mathcal{O}_5$ at tree level.



Introduction

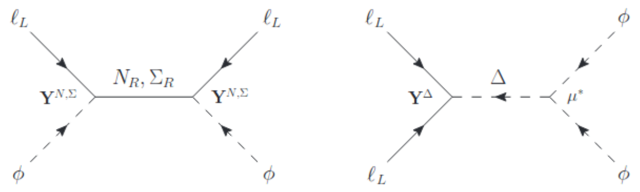
- Three types of new states can generate $\mathcal{O}_5$ at tree level.



- Type-I see-saw: new singlet scalares N_R, and $m_\nu \sim v^2 \frac{Y^{N\,T} Y^N}{M_N}$

Introduction

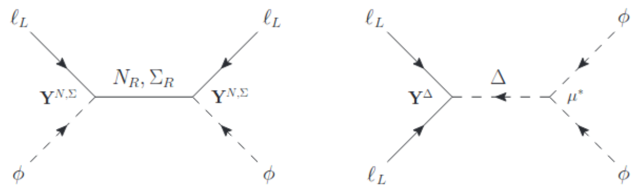
- Three types of new states can generate $\mathcal{O}_5$ at tree level.



- Type-I see-saw: new singlet scalares N_R, and $m_\nu \sim v^2 \frac{Y^{N\,T}\,Y^N}{M_N}$
- Type-II see-saw: new triplet scalares Δ, and $m_\nu \sim v^2 \frac{Y^{\Delta}\,\mu^*}{M_\Delta^2}$

Introduction

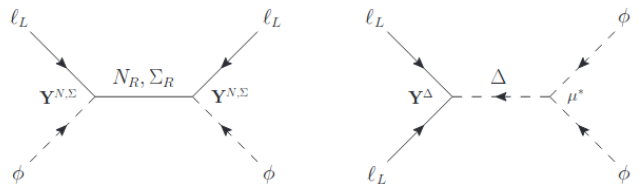
- Three types of new states can generate $\mathcal{O}_5$ at tree level.



- Type-I see-saw: new singlet scalares N_R, and $m_\nu \sim v^2 \frac{Y^{N\,T}\, Y^N}{M_N}$
- Type-II see-saw: new triplet scalares Δ, and $m_\nu \sim v^2 \frac{Y^{\Delta}\, \mu^*}{M_\Delta^2}$
- Type-III see-saw: new triplet fermions Σ_R, and $m_\nu \sim v^2 \frac{Y^{\Sigma\,T}\, Y^{\Sigma}}{M_\Sigma}$

Introduction

- Three types of new states can generate $\mathcal{O}_5$ at tree level.



- Type-I see-saw: new singlet scalares N_R, and $m_\nu \sim v^2 \frac{Y^{N\,T}\,Y^N}{M_N}$
- Type-II see-saw: new triplet scalares Δ, and $m_\nu \sim v^2 \frac{Y^{\Delta}\,\mu^*}{M_\Delta^2}$
- Type-III see-saw: new triplet fermions Σ_R, and $m_\nu \sim v^2 \frac{Y^{\Sigma\,T}\,Y^{\Sigma}}{M_\Sigma}$

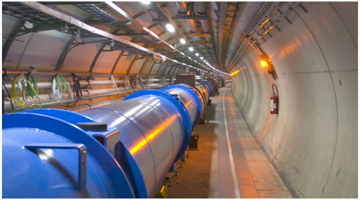
$M \sim \Lambda_{LN} \sim 10^{14-15}$ **GeV** $\Longrightarrow$ $\mathcal{O}(1)$ **Yukawa couplings.**

Introduction

- If NP scale beyond $\sim$ GeV the neutrino oscillations experiments cannot clarify its origin...

Introduction

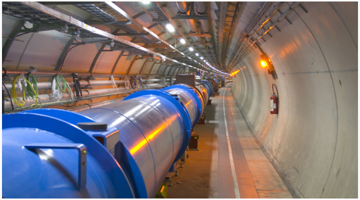
- If NP scale beyond $\sim$ GeV the neutrino oscillations experiments cannot clarify its origin...



- We have LHC with a reach at the TeV scale.

Introduction

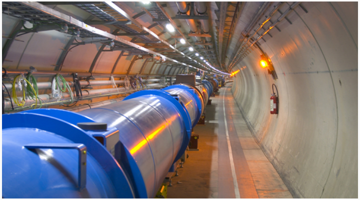
- If NP scale beyond $\sim$ GeV the neutrino oscilations experiments cannot clarify its origin...



- We have LHC with a reach at the TeV scale.
- This pushes the Minimal Lepton Flavour Violation (MLFV) to the frontline. From the effective theory point of view:

Introduction

- If NP scale beyond $\sim$ GeV the neutrino oscilations experiments cannot clarify its origin...



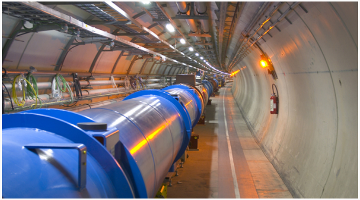
- We have LHC with a reach at the TeV scale.

- This pushes the Minimal Lepton Flavour Violation (MLFV) to the frontline. From the effective theory point of view:

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{\alpha_5}{\Lambda_{LN}}\mathcal{O}_5 + \sum_i \frac{\alpha_{6,i}}{\Lambda^2_{FL}}\mathcal{O}_{6,i} + \ldots$$

Introduction

- If NP scale beyond $\sim$ GeV the neutrino oscilations experiments cannot clarify its origin...



- We have LHC with a reach at the TeV scale.
- This pushes the Minimal Lepton Flavour Violation (MLFV) to the frontline. From the effective theory point of view:

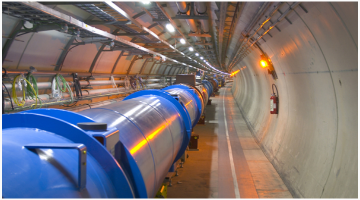
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{\alpha_5}{\Lambda_{LN}}\mathcal{O}_5 + \sum_i \frac{\alpha_{6,i}}{\Lambda_{FL}^2}\mathcal{O}_{6,i} + \ldots$$

- We can relate $M \sim \Lambda_{FL} \sim \mathcal{O}(TeV)$ and keep $\Lambda_{FL} << \Lambda_{LN}$.

M.B. Gavela, T. Hambye, D. Hernandez, P. Hernandez, JHEP 0909:038,2009

Introduction

- If NP scale beyond $\sim$ GeV the neutrino oscilations experiments cannot clarify its origin...



- We have LHC with a reach at the TeV scale.
- This pushes the Minimal Lepton Flavour Violation (MLFV) to the frontline. From the effective theory point of view:

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{\alpha_5}{\Lambda_{LN}}\mathcal{O}_5 + \sum_i \frac{\alpha_{6,i}}{\Lambda_{FL}^2}\mathcal{O}_{6,i} + \ldots$$

- We can relate $M \sim \Lambda_{FL} \sim \mathcal{O}(TeV)$ and keep $\Lambda_{FL} << \Lambda_{LN}$.

M.B. Gavela, T. Hambye, D. Hernandez, P. Hernandez, JHEP 0909:038,2009

New states can be light enough to be produced in LHC:)

Introduction

- Within MLFV, the observable signatures are fully determined by the neutrino parameters.

Introduction

- Within MLFV, the observable signatures are fully determined by the neutrino parameters.
- Type-I see-saw new states they can only be produced via their mixing with the SM neutrinos $\Rightarrow$ small production rates.

Introduction

- Within MLFV, the observable signatures are fully determined by the neutrino parameters.
- Type-I see-saw new states they can only be produced via their mixing with the SM neutrinos ⇒ small production rates.
- Type-III seesaw fermions, are SM triplets with weak-interaction pair-production cross section ⇒ LHC potential.

Introduction

- Within MLFV, the observable signatures are fully determined by the neutrino parameters.
- Type-I see-saw new states they can only be produced via their mixing with the SM neutrinos ⇒ small production rates.
- Type-III seesaw fermions, are SM triplets with weak-interaction pair-production cross section ⇒ LHC potential.

Our main goal will be obtaining bounds for the triplet masses using this particular model and data from the LHC Run.

Introduction

- In the MLFV Type-III see-saw mechanism, the heavy leptons are produced by:

$$\boxed{q\,\bar{q} \to W^* \to E_i^{\pm}\,N}$$

$$\boxed{q\,\bar{q} \to Z^*/\gamma \to E_i^{+}\,E_i^{-}}$$

- The decay mode of the quasi-Dirac state:

$$N \to l_\beta^- W^+$$
$$N \to \nu_i Z$$
$$N \to \nu_i h^0$$

- The decay mode of the heavy charged leptons:

$$E_2^+ \to \nu_i W^+$$
$$E_1^- \to l_\beta^- Z$$
$$E_1^- \to l_\beta^- h^0$$

Introduction

- In the MLFV Type-III see-saw mechanism, the heavy leptons are produced by:

$$\boxed{q\,\bar{q} \to W^* \to E_i^\pm\,N}$$

$$\boxed{q\,\bar{q} \to Z^*/\gamma \to E_i^+\,E_i^-}$$

- The decay mode of the quasi-Dirac state:

$$N \to l_\beta^-\,W^+$$
$$N \to \nu_i Z$$
$$N \to \nu_i h^0$$

- The decay mode of the heavy charged leptons:

$$E_2^+ \to \nu_i W^+$$
$$E_1^- \to l_\beta^-\,Z$$
$$E_1^- \to l_\beta^-\,h^0$$

- The decay widths will depend on the triplets mass and on the Yukawa couplings between the SM leptons and new states.

Introduction

- In the MLFV Type-III see-saw mechanism, the heavy leptons are produced by:

$$\boxed{q\,\bar{q} \to W^* \to E_i^{\pm}\,N}$$

- The decay mode of the quasi-Dirac state:

$$N \to l_\beta^- W^+$$
$$N \to \nu_i Z$$
$$N \to \nu_i h^0$$

$$\boxed{q\,\bar{q} \to Z^*/\gamma \to E_i^+\,E_i^-}$$

- The decay mode of the heavy charged leptons:

$$E_2^+ \to \nu_i W^+$$
$$E_1^- \to l_\beta^- Z$$
$$E_1^- \to l_\beta^- h^0$$

- The decay widths will depend on the triplets mass and on the Yukawa couplings between the SM leptons and new states.
- These couplings are fully determined by the oscilation data up to Majorana phase.

O.J.P. Eboli, J. Gonzalez-Fraile, M.C. Gonzalez-Garcia JHEP12(2011)009

Introduction

- In the MLFV Type-III see-saw mechanism, the heavy leptons are produced by:

$$\boxed{q\,\bar{q} \to W^* \to E_i^{\pm}\,N}$$

$$\boxed{q\,\bar{q} \to Z^*/\gamma \to E_i^{+}\,E_i^{-}}$$

  - The decay mode of the quasi-Dirac state:

$$\begin{aligned} &N \to l_\beta^-\,W^+ \\ &N \to \nu_i Z \\ &N \to \nu_i h^0 \end{aligned}$$

  - The decay mode of the heavy charged leptons:

$$\begin{aligned} &E_2^+ \to \nu_i W^+ \\ &E_1^- \to l_\beta^- Z \\ &E_1^- \to l_\beta^- h^0 \end{aligned}$$

- The decay widths will depend on the triplets mass and on the Yukawa couplings between the SM leptons and new states.
- These couplings are fully determined by the oscilation data up to Majorana phase.

O.J.P. Eboli, J. Gonzalez-Fraile, M.C. Gonzalez-Garcia JHEP12(2011)009

Consequence: the free parameters are the Majorana phase and the mass of the new states. The model is more unuambigously testable.

Case study: $pp \to l\, l'\, j\, j\, \nu\, \nu$

- ATLAS studies from LHC Run I to Type-III see-saw signatures, with $\sqrt{s} = 8$ TeV and an integrated luminosity of $20.3\,\text{fb}^{-1}$.

ATLAS Collaboration,PhysRevD.92.032001

Case study: $pp \to l\,l'\,j\,j\,\nu\,\nu$

- ATLAS studies from LHC Run I to Type-III see-saw signatures, with $\sqrt{s} = 8$ TeV and an integrated luminosity of $20.3\,\text{fb}^{-1}$.

  ATLAS Collaboration,PhysRevD.92.032001

- Final state topology with two charged leptons, two jets (hadronically decay from W) and missing energy:

$$p\,p \to N\,E^{\pm} \to W^{\pm}\,l^{\mp}\;\; W^{\pm}\,\nu$$

Case study: $pp \to l\, l'\, j\, j\, \nu\, \nu$

- ATLAS studies from LHC Run I to Type-III see-saw signatures, with $\sqrt{s} = 8$ TeV and an integrated luminosity of 20.3 fb^{-1}.

  ATLAS Collaboration,PhysRevD.92.032001

- Final state topology with two charged leptons, two jets (hadronically decay from W) and missing energy:

$$p\, p \to N\, E^{\pm} \to W^{\pm}\, l^{\mp} \;\; W^{\pm}\, \nu$$

- They presented their results as number of events for the six different flavour and charge lepton pair combinations: same sign (SS) and opposite sign (OS) ee, $e\mu$ and $\mu\mu$.

Case study: $pp \to l\, l'\, j\, j\, \nu\, \nu$

- ATLAS studies from LHC Run I to Type-III see-saw signatures, with $\sqrt{s} = 8$ TeV and an integrated luminosity of 20.3 fb^{-1}.

  ATLAS Collaboration,PhysRevD.92.032001

- Final state topology with two charged leptons, two jets (hadronically decay from W) and missing energy:

$$p\,p \to N\,E^{\pm} \to W^{\pm}\,l^{\mp} \;\; W^{\pm}\,\nu$$

- They presented their results as number of events for the six different flavour and charge lepton pair combinations: same sign (SS) and opposite sign (OS) ee, $e\mu$ and $\mu\mu$.

PERFECT TO TEST MLFV SCENARIO :)

Different subprocesses

- Process 1:

$$pp \to E_1^- \tilde{N} \,(E_1^- \to l_\beta^- Z, Z \to \nu_i \nu_i)(\tilde{N} \to l_\gamma^+ W^-, W^- \to jj) \Rightarrow \sigma^{(1)}_{\beta\gamma} |\tilde{Y}_\beta|^2 |\tilde{Y}_\gamma|^2$$

- Process 2a:

$$pp \to E_2^+ \tilde{N}, (E_2^+ \to \nu_i W^+,\ W^+ \to jj)(\tilde{N} \to l_\beta^+ W^-, W^- \to l_\gamma^- \nu_\gamma) \Rightarrow \sigma^{(2a)}_{\beta\gamma} |\tilde{Y}_\beta|^2$$

- Process 2b:

$$pp \to E_2^+ \tilde{N}, (E_2^+ \to \nu_i W^+, W^+ \to l_\gamma^+ \nu_\gamma)(\tilde{N} \to l_\beta^+ W^-, W^- \to jj) \Rightarrow \sigma^{(2b)}_{\beta\gamma} |\tilde{Y}_\beta|^2$$

- Process 2c:

$$pp \to E_2^+ \tilde{N}, (E_2^+ \to \nu_i W^+, W^+ \to jj)(\tilde{N} \to \nu_j Z, Z \to l_\beta^- l_\beta^+) \Rightarrow \sigma^{(2c)}_{\beta\beta}$$

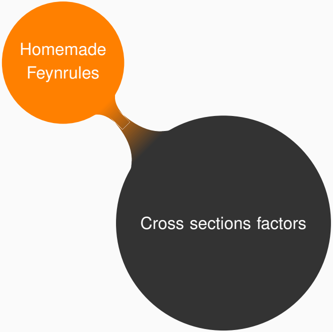
- Process 3:

$$\left.\begin{array}{l} pp \to E_1^+ E_1^-, (E_1^+ \to l_\beta^+ Z, Z \to jj)(E_1^- \to l_\gamma^- Z, Z \to \nu_i \nu_i) \\ pp \to E_1^+ E_1^-, (E_1^+ \to l_\beta^+ Z, Z \to \nu_i \nu_i)(E_1^- \to l_\gamma^- Z, Z \to jj) \end{array}\right\} \Rightarrow \sigma^{(3)}_{\beta\gamma} |\tilde{Y}_\beta|^2 |\tilde{Y}_\gamma|^2$$

Analysis ingredients

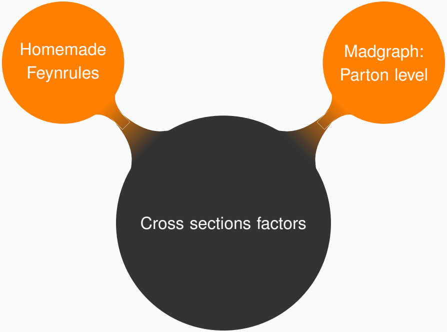
Cross sections factors

Analysis ingredients


Homemade Feynrules

Cross sections factors

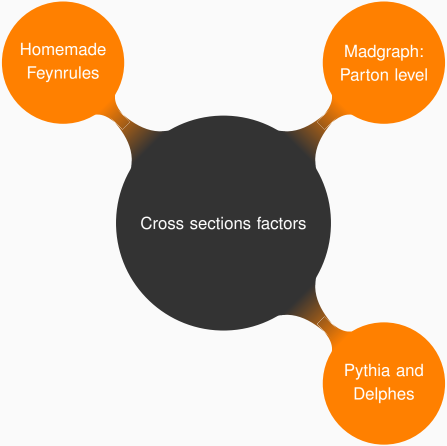
Analysis ingredients


Homemade Feynrules

Madgraph: Parton level

Cross sections factors

Analysis ingredients



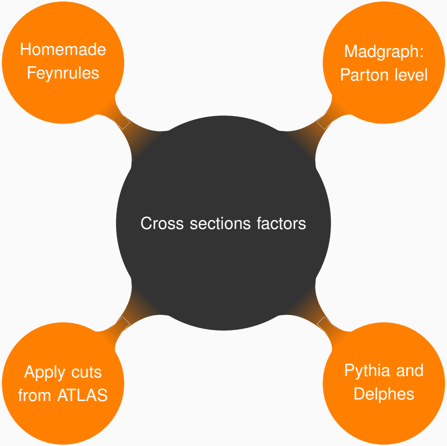
Homemade Feynrules

Madgraph: Parton level

Cross sections factors

Pythia and Delphes

Analysis ingredients



Homemade Feynrules

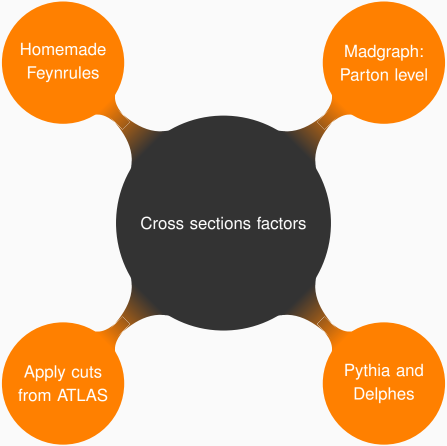
Madgraph: Parton level

Cross sections factors

Apply cuts from ATLAS

Pythia and Delphes

Analysis ingredients



Homemade Feynrules

Madgraph: Parton level

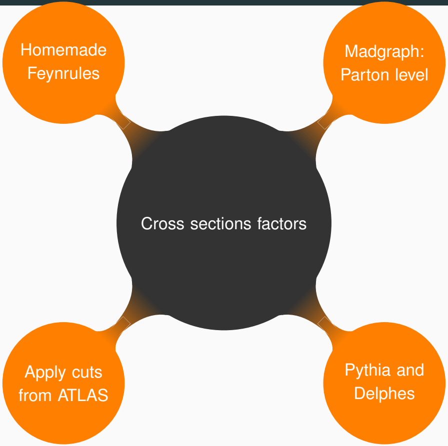
Cross sections factors

Apply cuts from ATLAS

Pythia and Delphes

The cross section factors depend on the mass. Also on flavour, indirectly because of ATLAS cuts.

Analysis ingredients



Cross sections factors

Homemade Feynrules

Madgraph: Parton level

Apply cuts from ATLAS

Pythia and Delphes

The cross section factors depend on the mass. Also on flavour, indirectly because of ATLAS cuts.

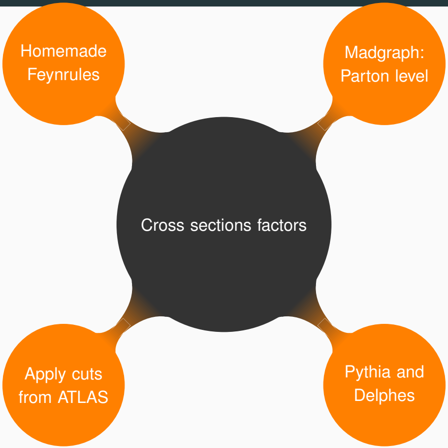
- For a final state composed by two opposite charge leptons:

$$\sigma^{OS}_{ee} \equiv \left[\sigma^{(1)}_{ee} + \sigma^{(3)}_{ee}\right] |\tilde{Y}_e|^4 + \sigma^{(2a)}_{ee}|\tilde{Y}_e|^2 + \sigma^{(2c)}_{ee}$$

$$\sigma^{OS}_{e\mu} \equiv \left[\sigma^{(1)}_{e\mu} + \sigma^{(1)}_{\mu e} + \sigma^{(3)}_{e\mu} + \sigma^{(3)}_{\mu e}\right] |\tilde{Y}_e|^2 |\tilde{Y}_\mu|^2 + \sigma^{(2a)}_{e\mu}|\tilde{Y}_e|^2 + \sigma^{(2a)}_{\mu e}|\tilde{Y}_\mu|^2$$

$$\sigma^{OS}_{\mu\mu} \equiv \left[\sigma^{(1)}_{\mu\mu} + \sigma^{(3)}_{\mu\mu}\right] |\tilde{Y}_\mu|^4 + \sigma^{(2a)}_{\mu\mu}|\tilde{Y}_\mu|^2 + \sigma^{(2c)}_{\mu\mu}$$

Analysis ingredients



Cross sections factors

Homemade Feynrules

Madgraph: Parton level

Apply cuts from ATLAS

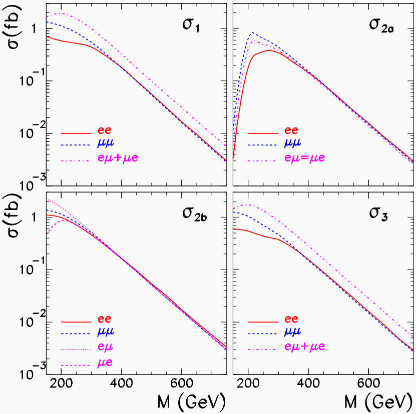
Pythia and Delphes

The cross section factors depend on the mass. Also on flavour, indirectly because of ATLAS cuts.

- For a final state composed by same charged leptons:

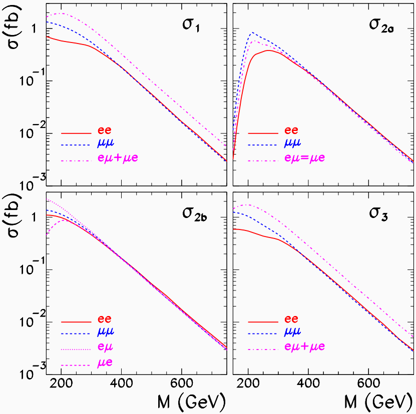
$$\sigma_{ee}^{SS} \equiv \sigma_{ee}^{(2b)} |\tilde{Y}_e|^2$$
$$\sigma_{e\mu}^{SS} \equiv \sigma_{e\mu}^{(2b)} |\tilde{Y}_e|^2 + \sigma_{\mu e}^{(2b)} |\tilde{Y}_\mu|^2$$
$$\sigma_{\mu\mu}^{SS} \equiv \sigma_{\mu\mu}^{(2b)} |\tilde{Y}_\mu|^2$$

Cross section factors from the different subprocesses



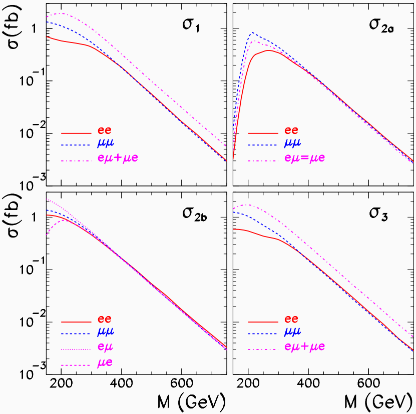
- *ee*, $e\mu$, μe, $\mu\mu$ have similar cross section factors for $M > 300$ GeV.

Cross section factors from the different subprocesses



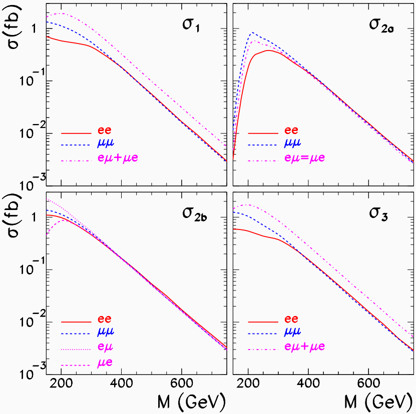
- *ee*, *e*μ, μ*e*, $\mu\mu$ have similar cross section factors for $M > 300$ GeV.
- Closer to threshold the detection and acceptance eficiencies induce differences on the final states.

Cross section factors from the different subprocesses



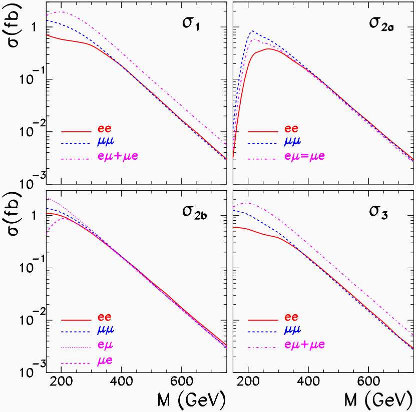
- *ee*, $e\mu$, μe, $\mu\mu$ have similar cross section factors for $M > 300$ GeV.
- Closer to threshold the detection and acceptance eficiencies induce differences on the final states.
- In σ_{2a} both leptons originate from a single triplet fermion ⇒ reduced acceptance at small masses due to the OS lepton pair invaraint mass cut.

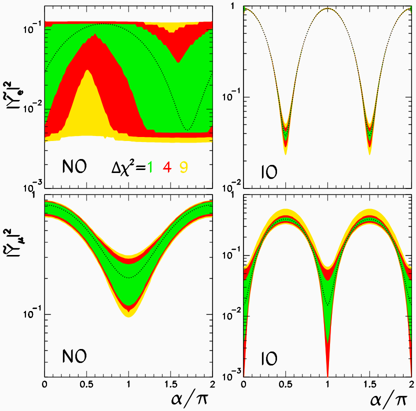
Cross section factors from the different subprocesses



- *ee*, $e\mu$, μe, $\mu\mu$ have similar cross section factors for $M > 300$ GeV.
- Closer to threshold the detection and acceptance eficiencies induce differences on the final states.
- In σ_{2a} both leptons originate from a single triplet fermion $\Rightarrow$ reduced acceptance at small masses due to the OS lepton pair invaraint mass cut.

Cross section factors from the different subprocesses



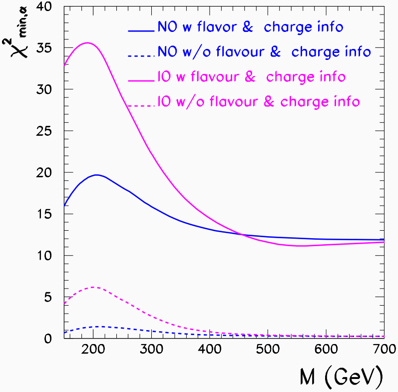


- Use the neutrino oscillation analysis.

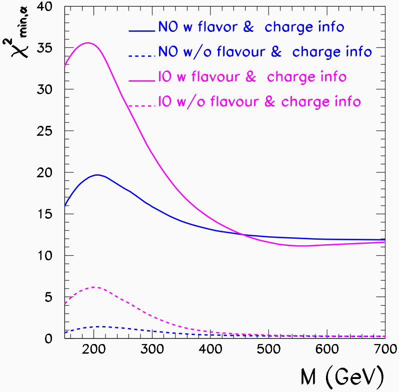
Ivan Esteban et al. JHEP 01(2017)087

- Combining it with the cross section factors it is possible to calculate the expected signal number events.

Case Study: Analysis of the likelihood function

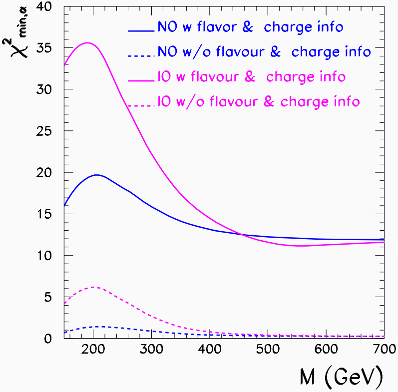


Case Study: Analysis of the likelihood function



About data dependent on the charge and flavour:

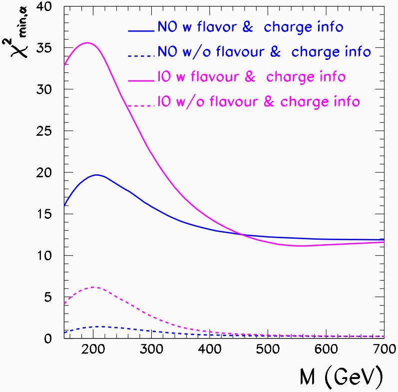
Case Study: Analysis of the likelihood function



About data dependent on the charge and flavour:

- Large M limit(in the SM) $\chi^2_{6d,SM} = 11.8$.

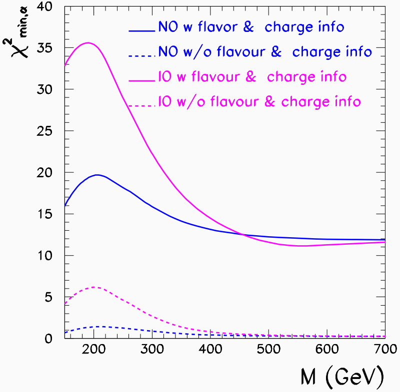
Case Study: Analysis of the likelihood function



About data dependent on the charge and flavour:

- Large M limit(in the SM) $\chi^2_{6d,SM} = 11.8$.
- OS $\mu\mu$ channel 3 events observed, 10 expected.

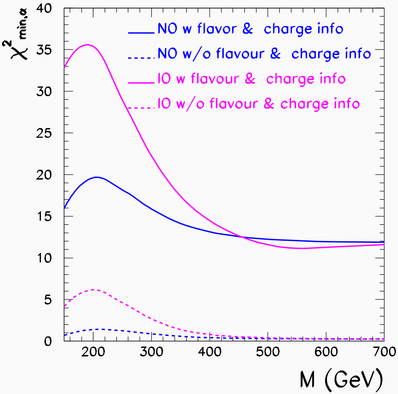
Case Study: Analysis of the likelihood function



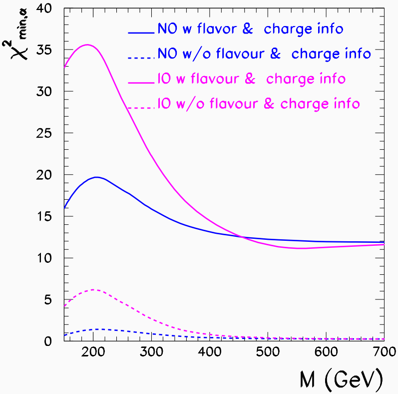
About data dependent on the charge and flavour:

- Large M limit(in the SM) $\chi^2_{6d,SM} = 11.8$.
- OS $\mu\mu$ channel 3 events observed, 10 expected.
- $\chi^2_{6d} - \chi^2_{6d,SM} < 4 \Rightarrow$ absolute bound on the triplet mass of 300 (375) GeV for NO(IO) light neutrino masses .

Case Study: Analysis of the likelihood function

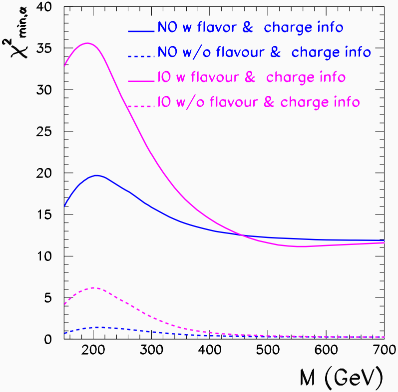


Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

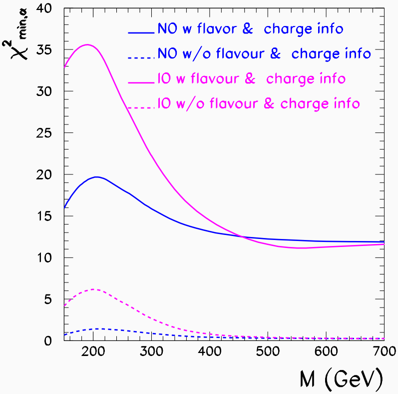
Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

- Large M limit(SM) $\chi^2_{tot,SM} = 0.25$.

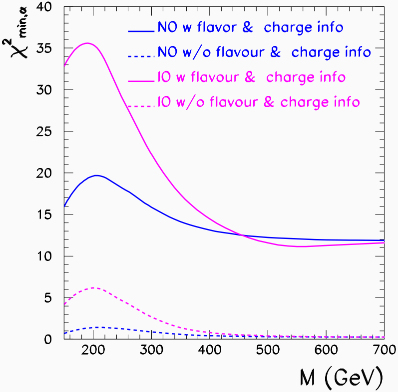
Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

- Large M limit(SM) $\chi^2_{tot,SM} = 0.25$.
- The deficit of OS $\mu\mu$ channel is compensated by the slight excess in other channels.

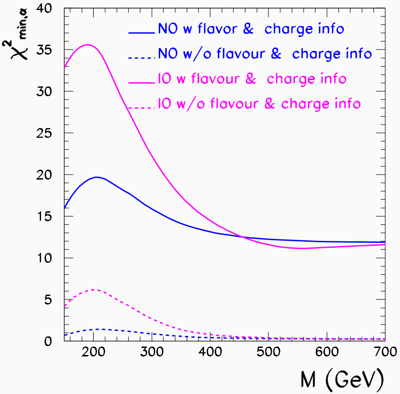
Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

- Large M limit(SM) $\chi^2_{tot,SM} = 0.25$.
- The deficit of OS $\mu\mu$ channel is compensated by the slight excess in other channels.
- $\chi^2_{tot} - \chi^2_{tot,SM} < 4 \Rightarrow$no absolute bound on the triplet mass for NO.

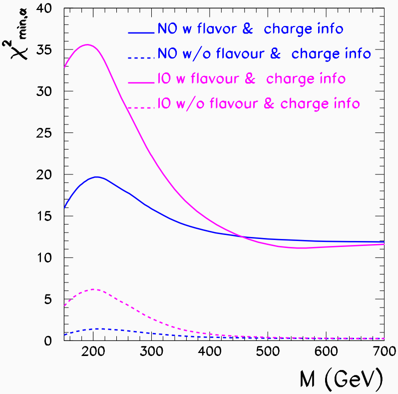
Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

- Large M limit(SM) $\chi^2_{tot,SM} = 0.25$.
- The deficit of OS $\mu\mu$ channel is compensated by the slight excess in other channels.
- $\chi^2_{tot} - \chi^2_{tot,SM} < 4 \Rightarrow$no absolute bound on the triplet mass for NO.
- $\chi^2_{tot} - \chi^2_{tot,SM} < 4 \Rightarrow$an absolute bound on the triplet mass of 260 GeV for IO.

Case Study: Analysis of the likelihood function



Same analysis but summing all information from all channels :

- Large M limit(SM) $\chi^2_{tot,SM} = 0.25$.
- The deficit of OS $\mu\mu$ channel is compensated by the slight excess in other channels.
- $\chi^2_{tot} - \chi^2_{tot,SM} < 4 \Rightarrow$no absolute bound on the triplet mass for NO.
- $\chi^2_{tot} - \chi^2_{tot,SM} < 4 \Rightarrow$an absolute bound on the triplet mass of 260 GeV for IO.

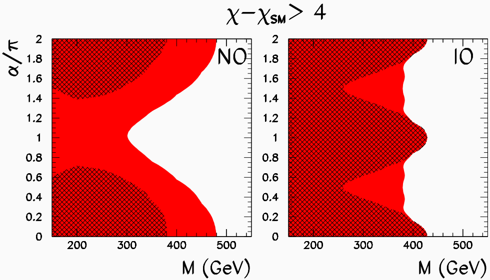
THE FLAVOUR AND CHARGE INFO REALLY IMPORTANT ON IMPOSING A BOUND!!!!

Case Study: bounds dependence on the unknown phase α

We considered the flavour and charge info (full regions) or the total data summed (hatched region).

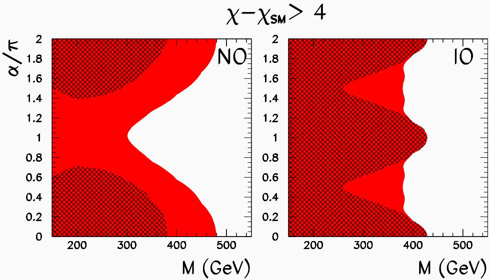
Case Study: bounds dependence on the unknown phase α

We considered the flavour and charge info (full regions) or the total data summed (hatched region).



Case Study: bounds dependence on the unknown phase α

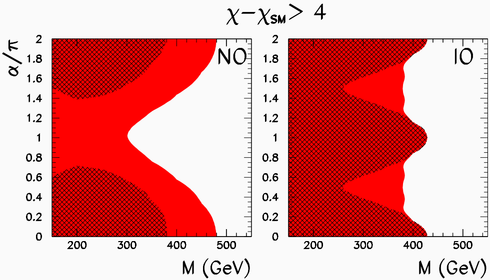
We considered the flavour and charge info (full regions) or the total data summed (hatched region).



- The bound of 300 GeV corresponds to $\alpha = \pi$ for NO.

Case Study: bounds dependence on the unknown phase α

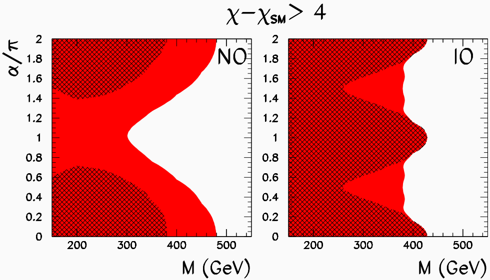
We considered the flavour and charge info (full regions) or the total data summed (hatched region).



- The bound of 300 GeV corresponds to $\alpha = \pi$ for NO.
- We can get a stronger bound if $\alpha = 0,\ 2\pi \Rightarrow M > 480$ GeV, for NO.

Case Study: bounds dependence on the unknown phase α

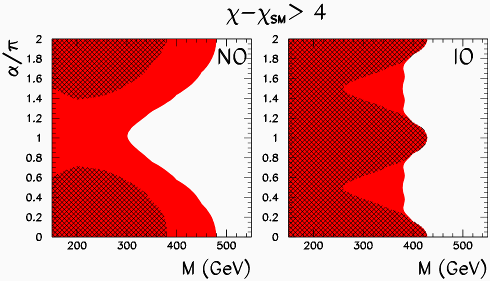
We considered the flavour and charge info (full regions) or the total data summed (hatched region).



- The bound of 300 GeV corresponds to $\alpha = \pi$ for NO.
- We can get a stronger bound if $\alpha = 0,\ 2\pi \Rightarrow M > 480$ GeV, for NO.
- For IO, the dependence on α is weaker: it is possible to obtain a bound of $M > 380$ GeV $\Rightarrow \alpha \sim 3\pi/4, 3\pi/2$. It is close for almost all values of α.

Case Study: bounds dependence on the unknown phase α

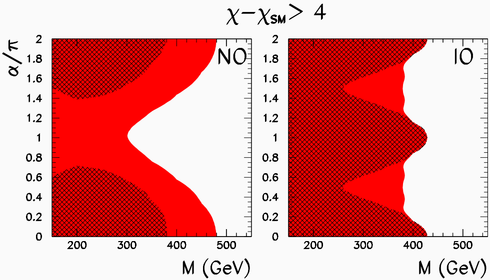
We considered the flavour and charge info (full regions) or the total data summed (hatched region).



- The bound of 300 GeV corresponds to $\alpha = \pi$ for NO.
- We can get a stronger bound if $\alpha = 0,\ 2\pi \Rightarrow M > 480$ GeV, for NO.
- For IO, the dependence on α is weaker: it is possible to obtain a bound of $M > 380$ GeV $\Rightarrow \alpha \sim 3\pi/4, 3\pi/2$. It is close for almost all values of α.
- The strongest bound in IO is $M > 430$ GeV if we take $\alpha = 0,\ 2\pi$.

Case Study: bounds dependence on the unknown phase α

We considered the flavour and charge info (full regions) or the total data summed (hatched region).



- The bound of 300 GeV corresponds to $\alpha = \pi$ for NO.
- We can get a stronger bound if $\alpha = 0,\ 2\pi \Rightarrow M > 480$ GeV, for NO.
- For IO, the dependence on α is weaker: it is possible to obtain a bound of $M > 380$ GeV $\Rightarrow \alpha \sim 3\pi/4, 3\pi/2$. It is close for almost all values of α.
- The strongest bound in IO is $M > 430$ GeV if we take $\alpha = 0,\ 2\pi$.
- No bound for $70^o < \alpha < 250^o$ (NO) is possible to obtain if only the total number of events is considered.

Conclusions

- We have obtained bounds for the triplet masses within MLFV Type-III see-saw and using the data from Run I with ATLAS detector: two leptons, two jets and missing energy.

Conclusions

- We have obtained bounds for the triplet masses within MLFV Type-III see-saw and using the data from Run I with ATLAS detector: two leptons, two jets and missing energy.
- But the most important message is:

Conclusions

- We have obtained bounds for the triplet masses within MLFV Type-III see-saw and using the data from Run I with ATLAS detector: two leptons, two jets and missing energy.
- But the most important message is:

Without flavour and charge info, it is not possible to obtain unambigous limits on the mass of the new triplet fermions.

Conclusions

- We have obtained bounds for the triplet masses within MLFV Type-III see-saw and using the data from Run I with ATLAS detector: two leptons, two jets and missing energy.
- But the most important message is:

Without flavour and charge info, it is not possible to obtain unambigous limits on the mass of the new triplet fermions.

As a WISH for Christmas, RUN II data categorized by flavour channels and charge.

Conclusions

- We have obtained bounds for the triplet masses within MLFV Type-III see-saw and using the data from Run I with ATLAS detector: two leptons, two jets and missing energy.
- But the most important message is:

Without flavour and charge info, it is not possible to obtain unambigous limits on the mass of the new triplet fermions.

As a WISH for Christmas, RUN II data categorized by flavour channels and charge.

Muchas Gracias, Merci, Eskerrik asko