# Optimization of search variables for the pair production of first generation leptoquarks at CMS

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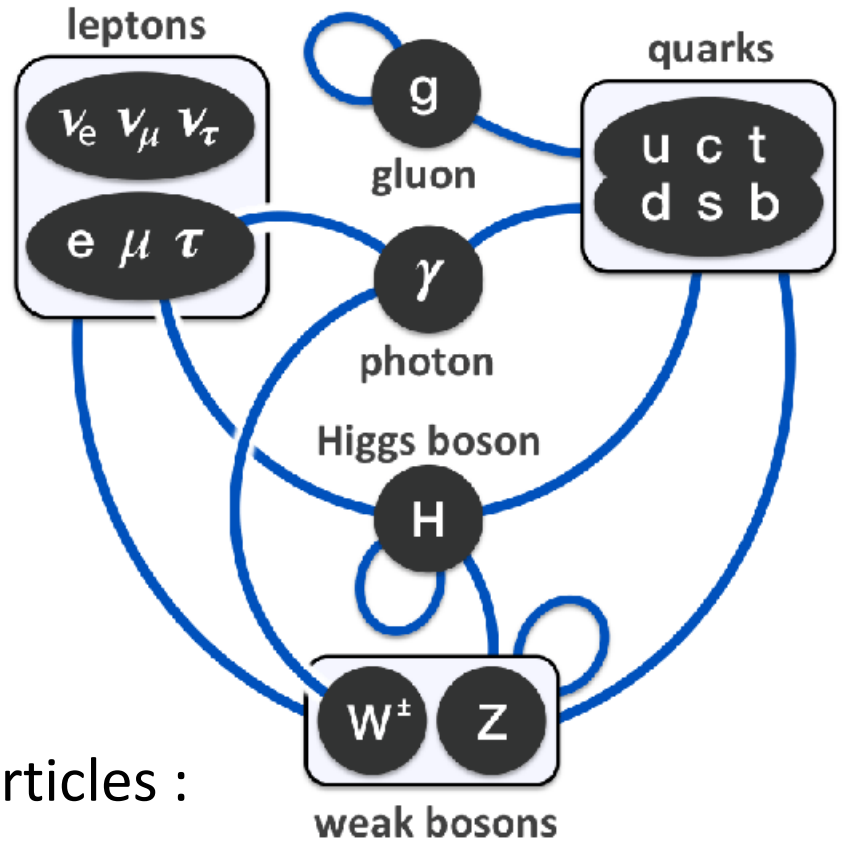
VSRP 2017, TIFR-Mumbai

# Motivation : Standard Model and Beyond…

- The SM is a successful theory which describes the three fundamental forces in nature: Electromagnetic, Weak and Strong.
- Limitations: Despite it's success, the SM does not account for gravity. It fails to explain phenomenon like "dark matter", "dark energy" , neutrino oscillations and **existence of new particles**

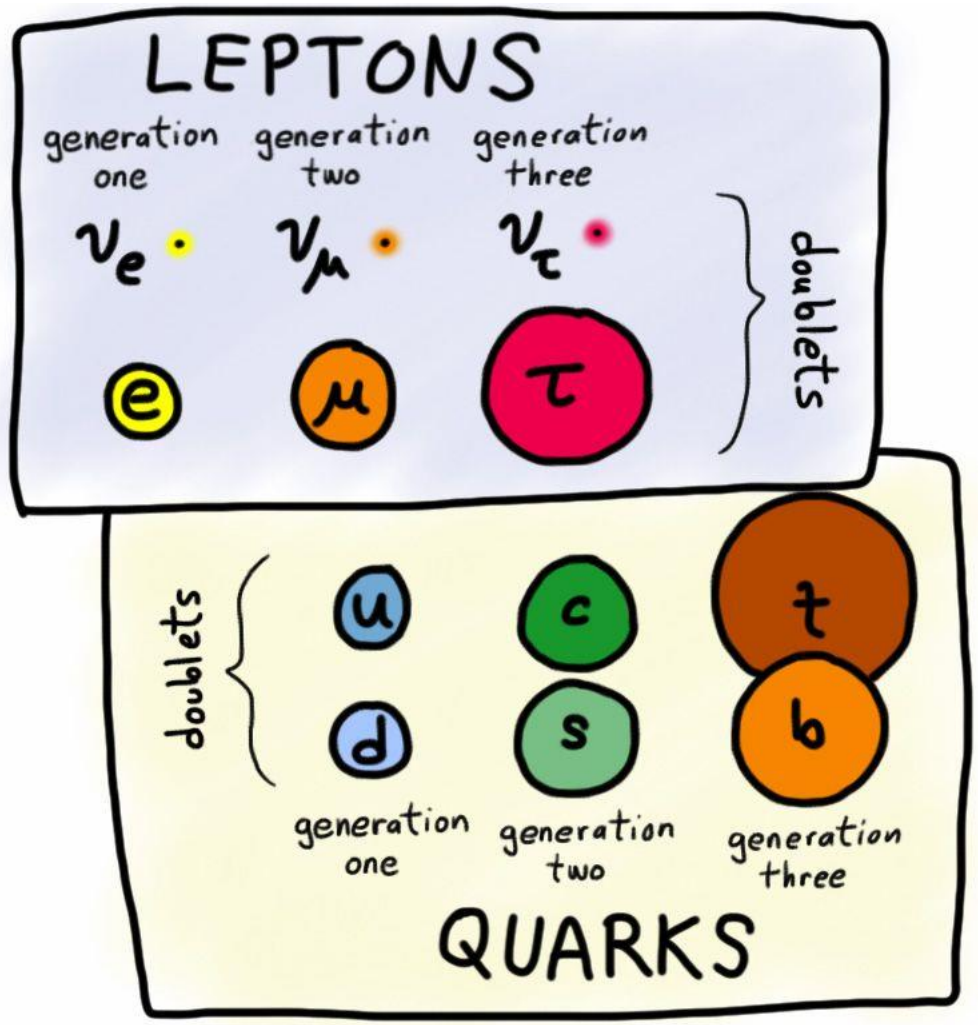



## Leptons and Quarks:

- Fundamentally we are made up of only two types of particles : Leptons and Quarks.
- The **Leptoquark model** searches for the existence of hypothetical particles called " Leptoquarks" which have dual properties of both leptons and quarks.

# Three generations of Leptons and Quarks:

Leptons and quarks naturally fit into three generations of doublets based on the way they interact with the weak force. Physicists do not know why both types of particles conform to the same pattern.



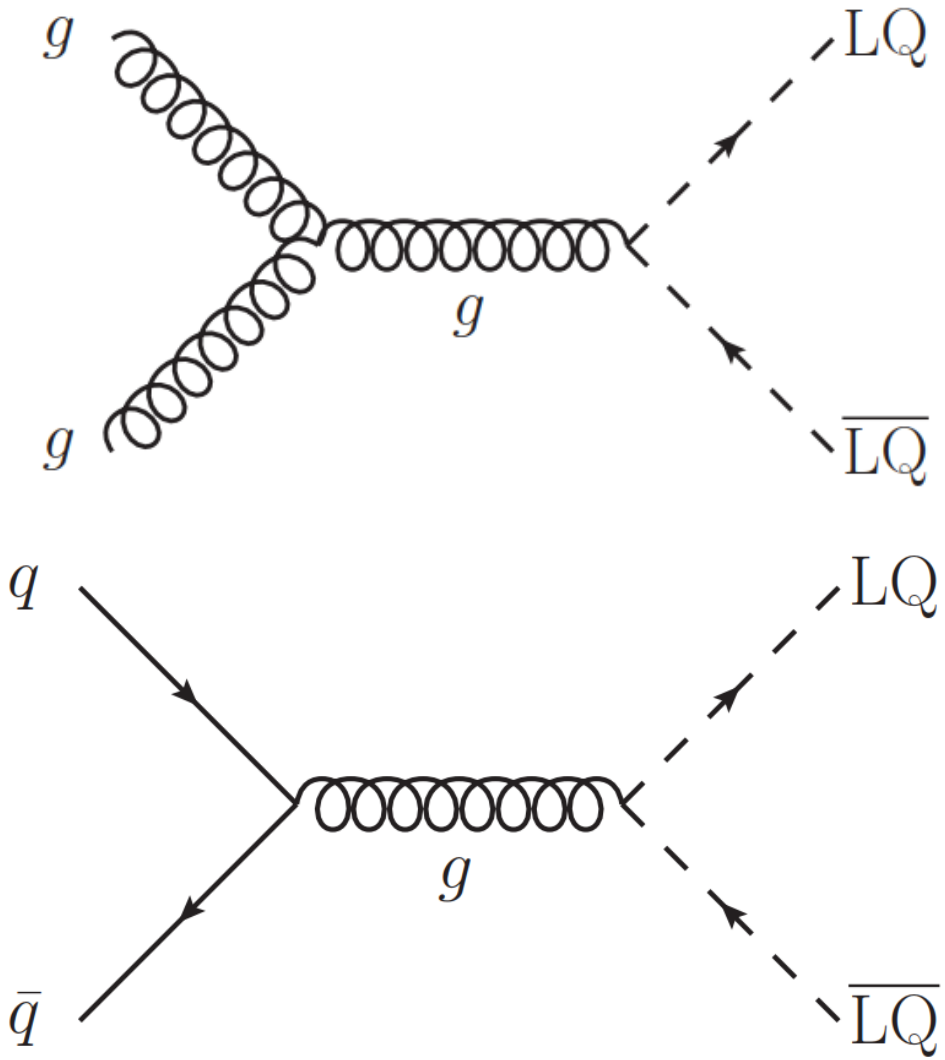

http://cms.web.cern.ch/news/hunt-platypus-particle

# The Platypus Particle

- "A leptoquark would be a strange amalgam of familiar leptons and quarks, the way that a platypus has features of both mammals and birds."
  *–Fermilab ,Oct 5,2012*

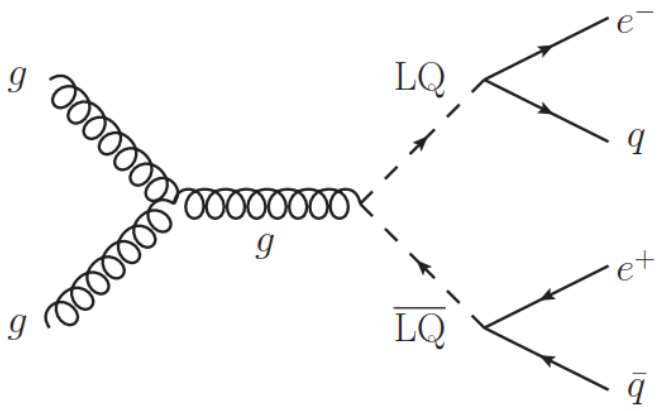
http://img08.deviantart.net/ed01/i/2015/163/3/b/particle_platypus_by_sideshowbobfanatic-d8x1tbz.jpg

# Leptoquark production



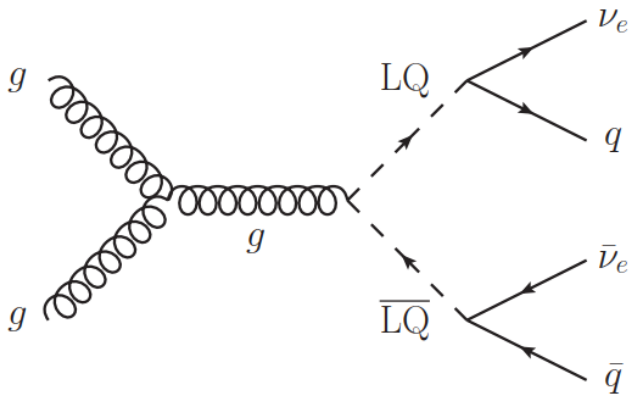

- Leptoquark pair production in pp collisions occurs primarily through quark-antiquark annihilation and gluon-gluon fusion

# Leptoquark decay mode




$\text{BR}(\text{LQ}\overline{\text{LQ}} \to e^- q e^+ \bar{q}) = \beta^2$

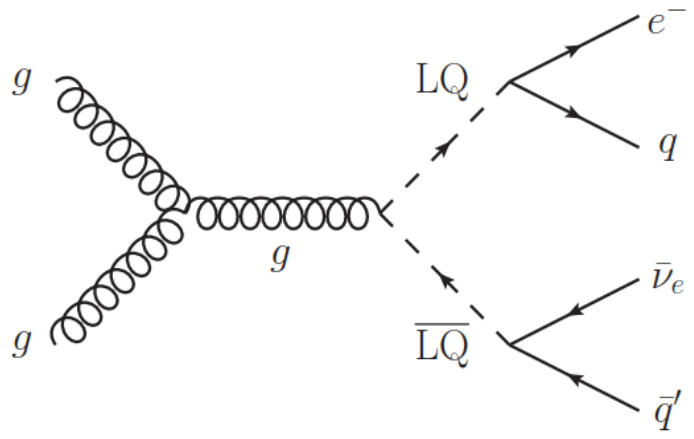
(a) $eejj$ channel




$\text{BR}(\text{LQ}\overline{\text{LQ}} \to \nu_e q \bar{\nu}_e \bar{q}) = (1-\beta)^2$

(c) $\nu\nu jj$ channel

- Where β is the branching fraction, β=1 in our case.



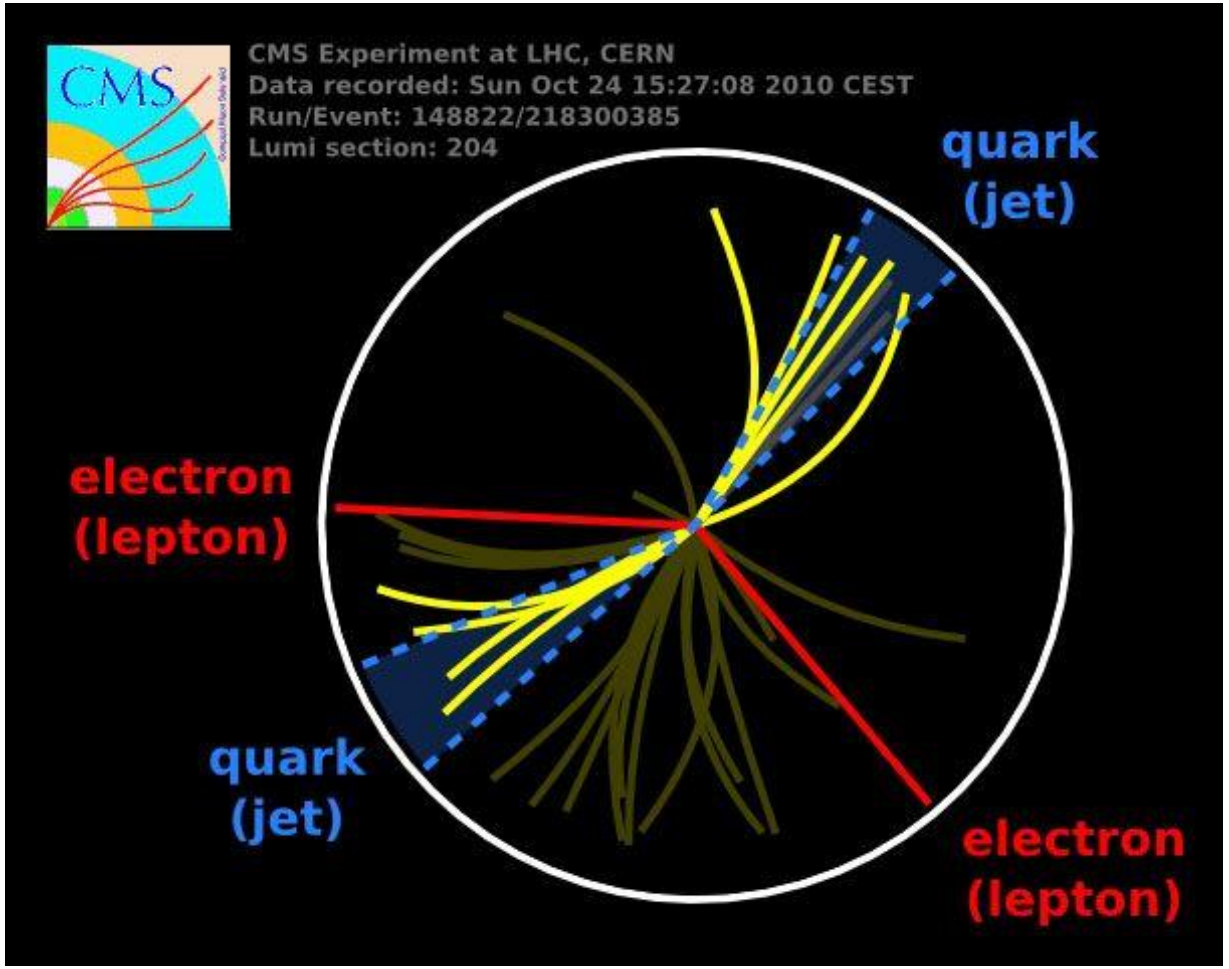

$\text{BR}(\text{LQ}\overline{\text{LQ}} \to e^- q \bar{\nu}_e \bar{q}', \nu_e q' e^+ \bar{q}) = 2\beta(1-\beta)$

(b) $e\nu jj$ channel

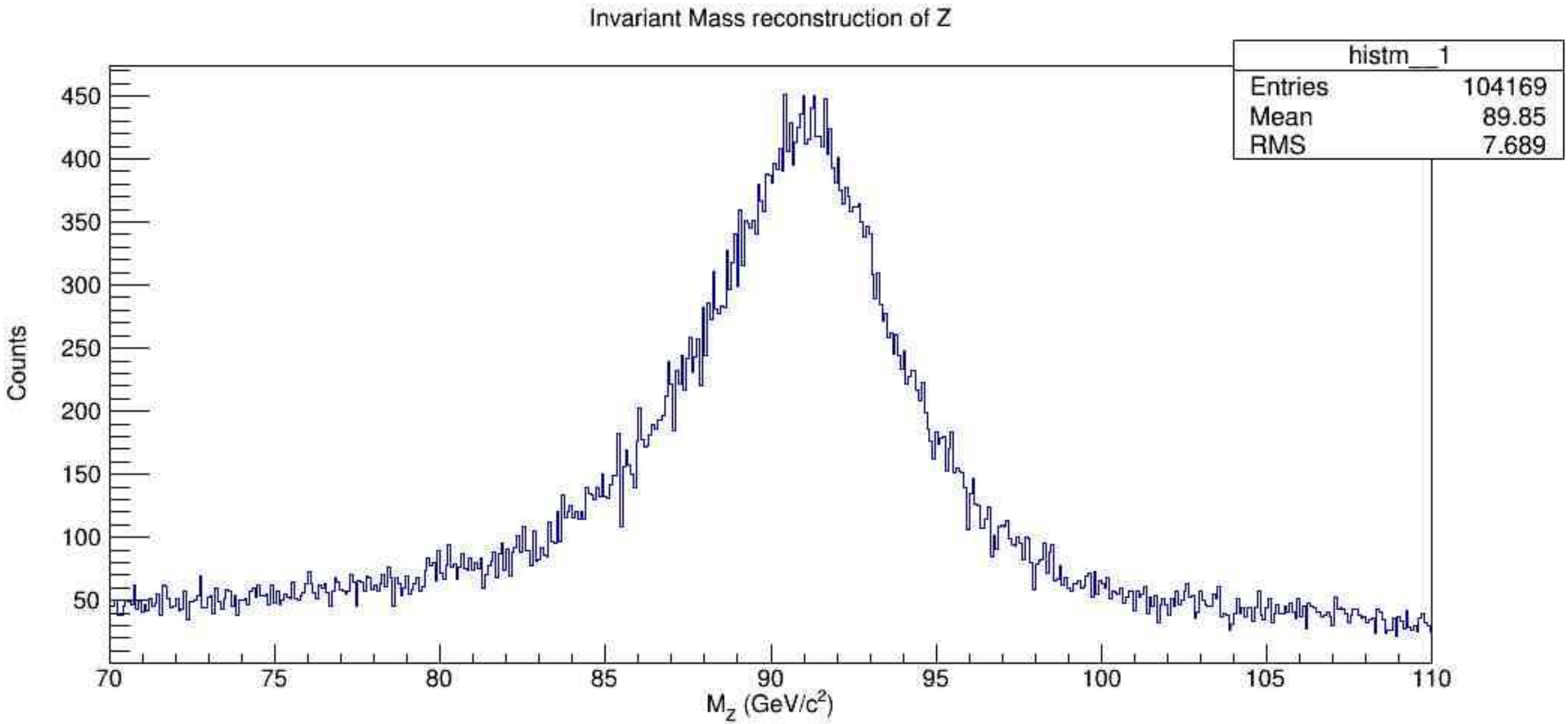
# The Search for *eejj* events

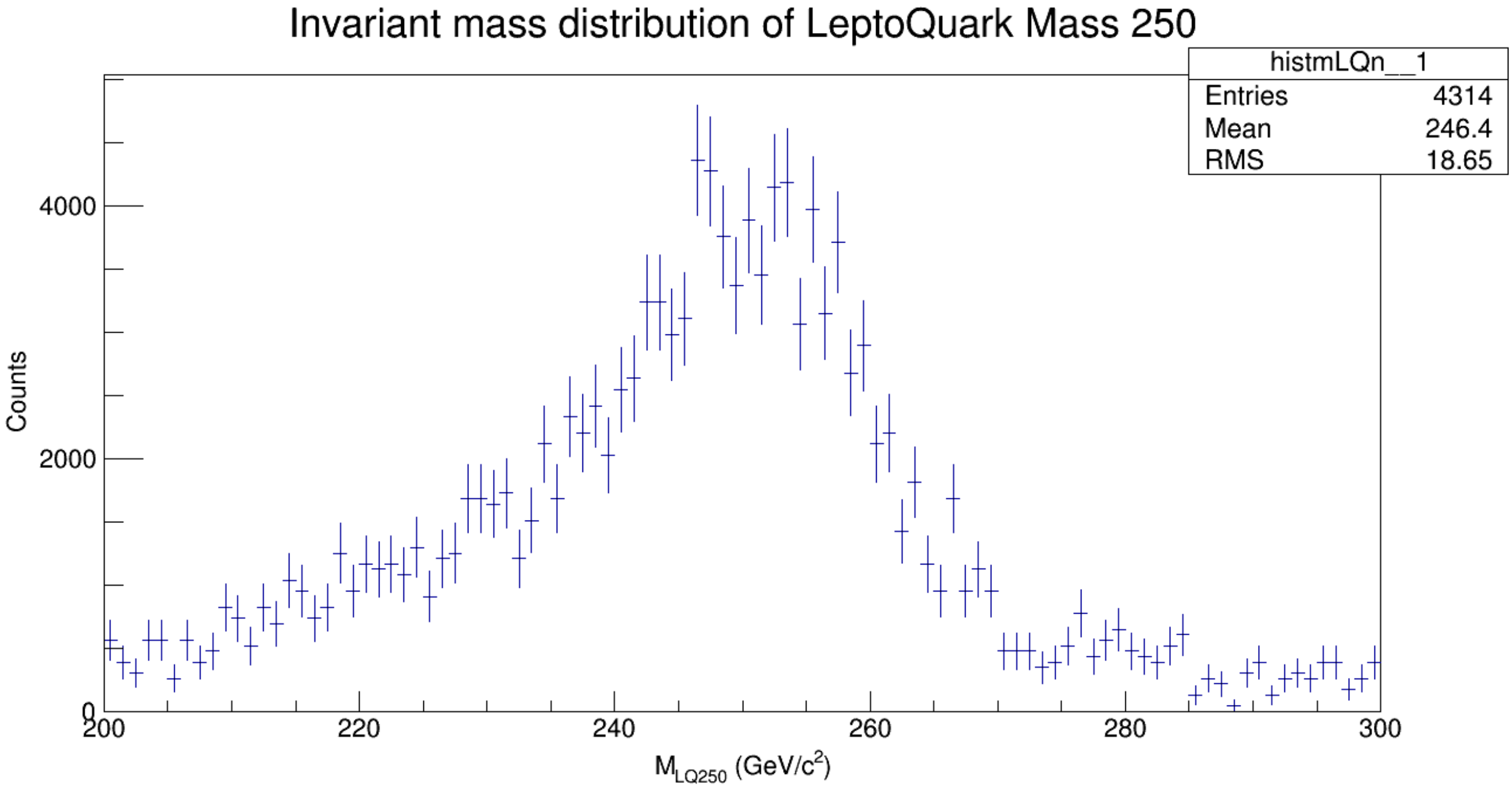
We want to filter out the events with the following criteria:

- The events contains exactly two electrons
- The events has at least two jets. We select the leading and the next leading jet with the highest $P_T$ for our analysis.




http://cms.web.cern.ch/sites/cms.web.cern.ch/files/styles/large/public/field/image/CMSResult121012_Figure01.jpg?itok=5IstnKTI


Invariant Mass reconstruction of Z
histm__1
Entries 104169
Mean 89.85
RMS 7.689
Counts
450
400
350
300
250
200
150
100
50
70
75
80
85
90
95
100
105
110
M_Z (GeV/c^2)


Invariant mass distribution of LeptoQuark Mass 250
histmLQn__1
Entries 4314
Mean 246.4
RMS 18.65
Counts
0
2000
4000
200
220
240
260
280
300
M_LQ250 (GeV/c^2)

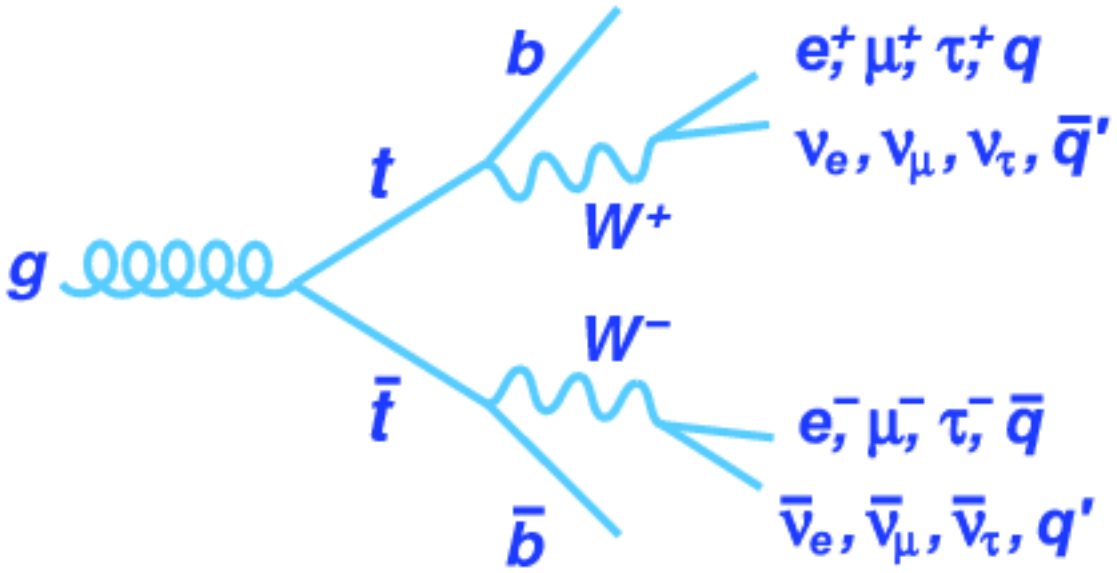
# Optimization variables

- $S_T$ : Sum of $P_T$ of two electrons and two leading jets.
- $M_{ee}$ : Invariant Mass of the two electrons.
- $M_{\mathrm{ej}}$ : Average of LQ pairs with minimum difference.

# Filtering out the “good” events

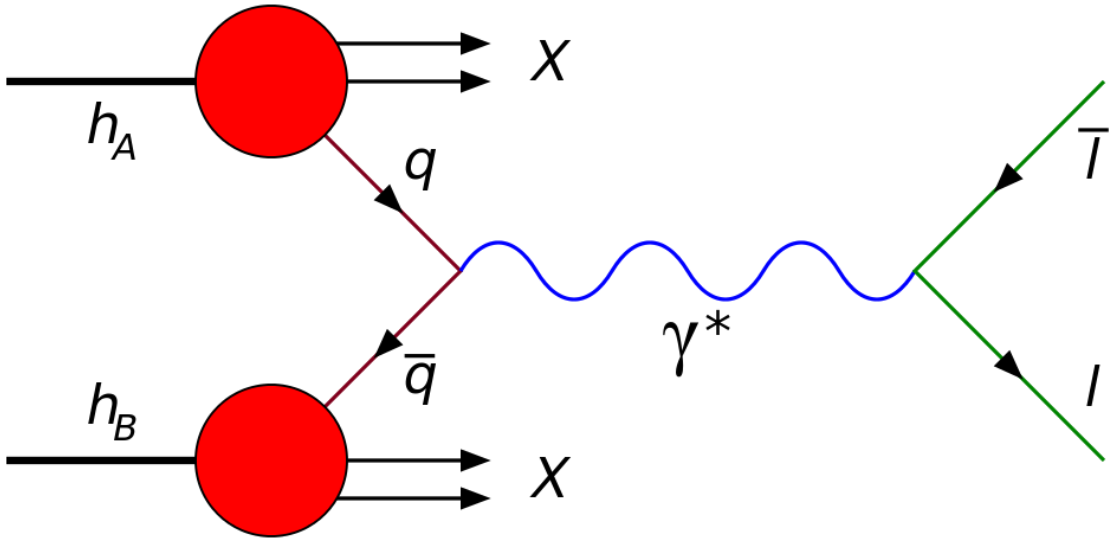
We apply a few preselection cuts to the electron and jet parameters to eliminate low energy processes and reduce the background:

- Electron is detected in the barrel or endcap region of the ECAL and $E_T$ (Transverse Energy)>50 GeV
- At least two jets with $P_T$ >50 GeV/c
- $M_{ee}$ > 50 GeV/$c^2$
- $S_T$> 300 GeV/c



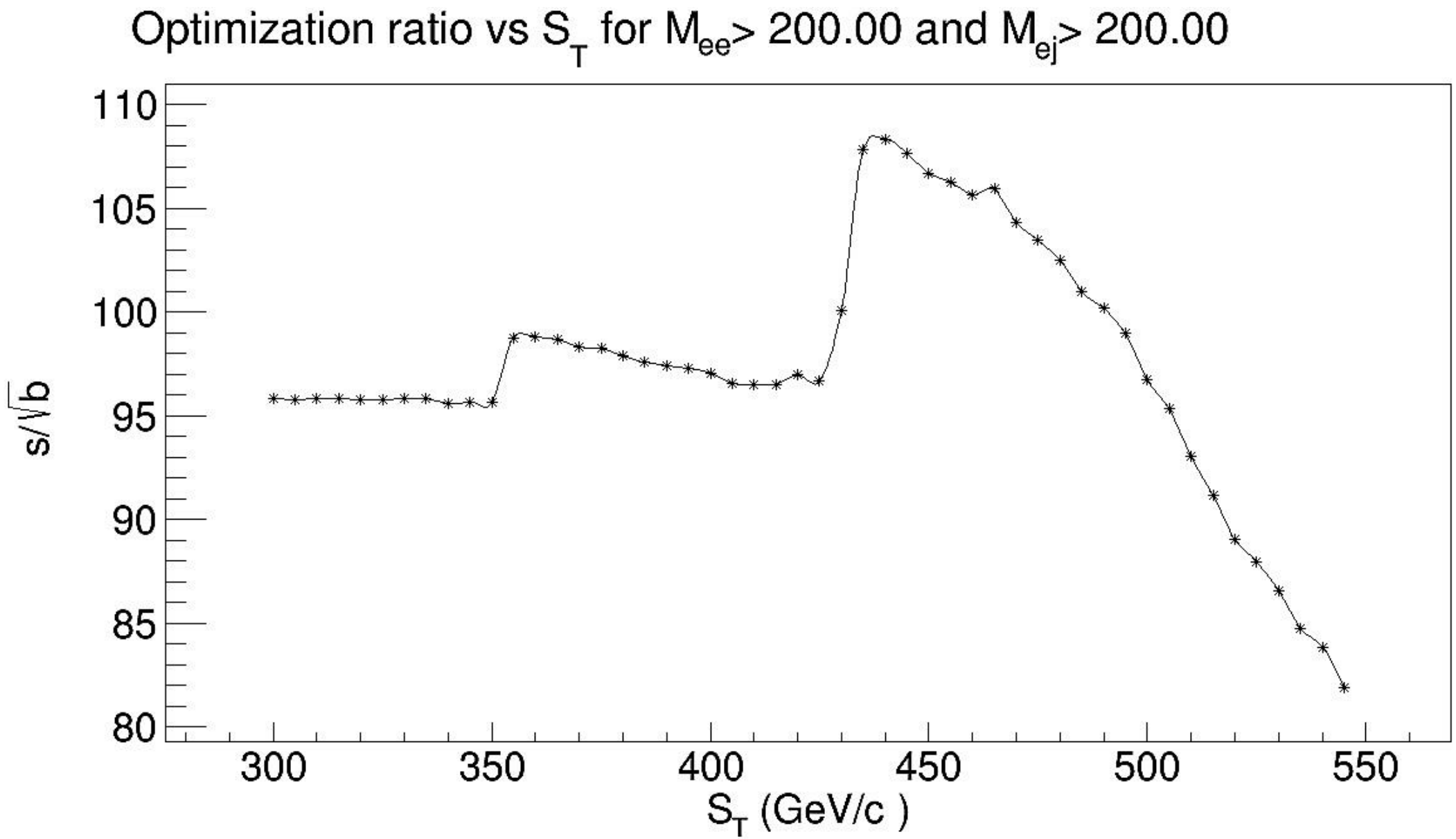

# Some of the background processes

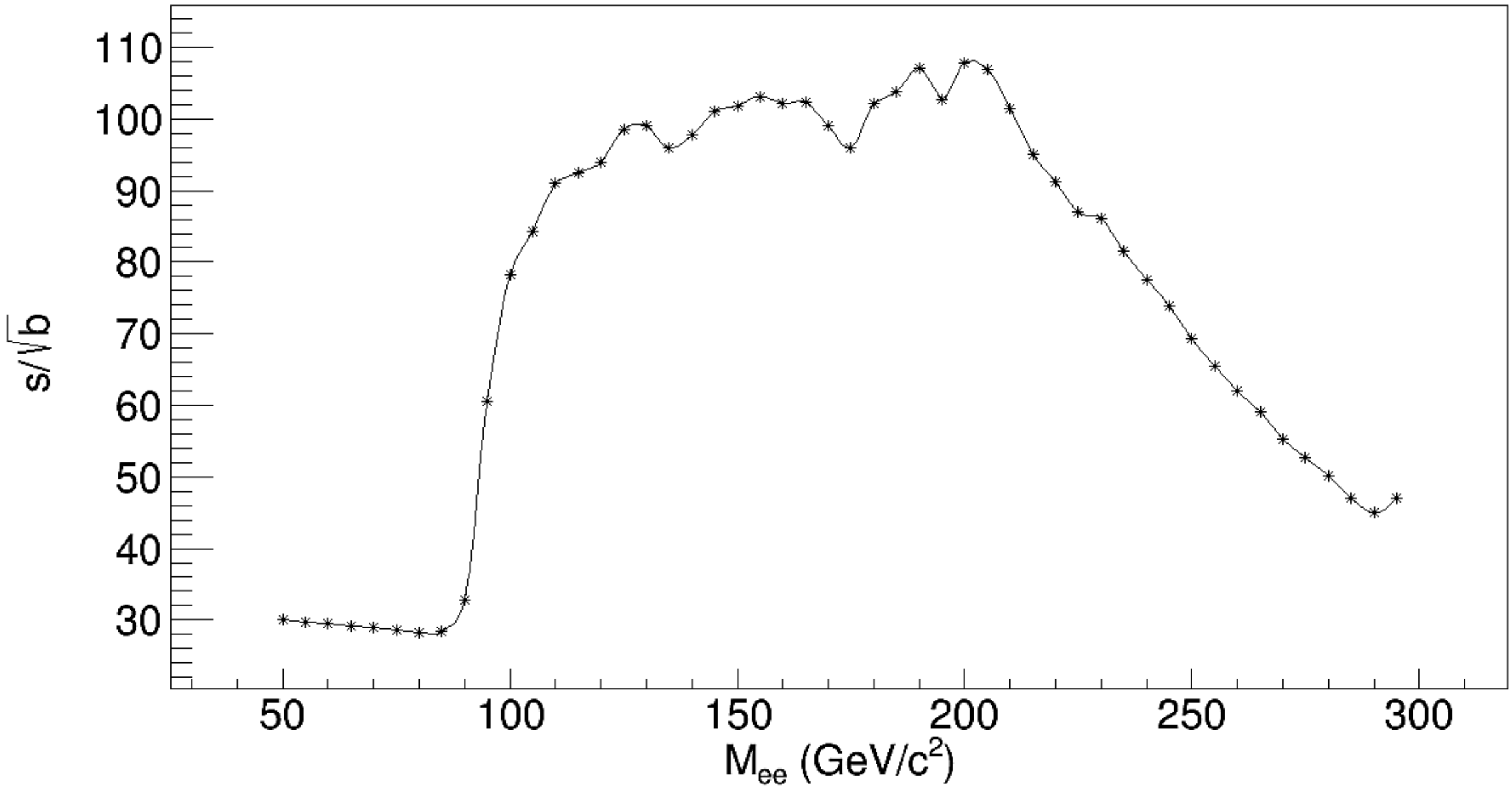
- TTbar decay

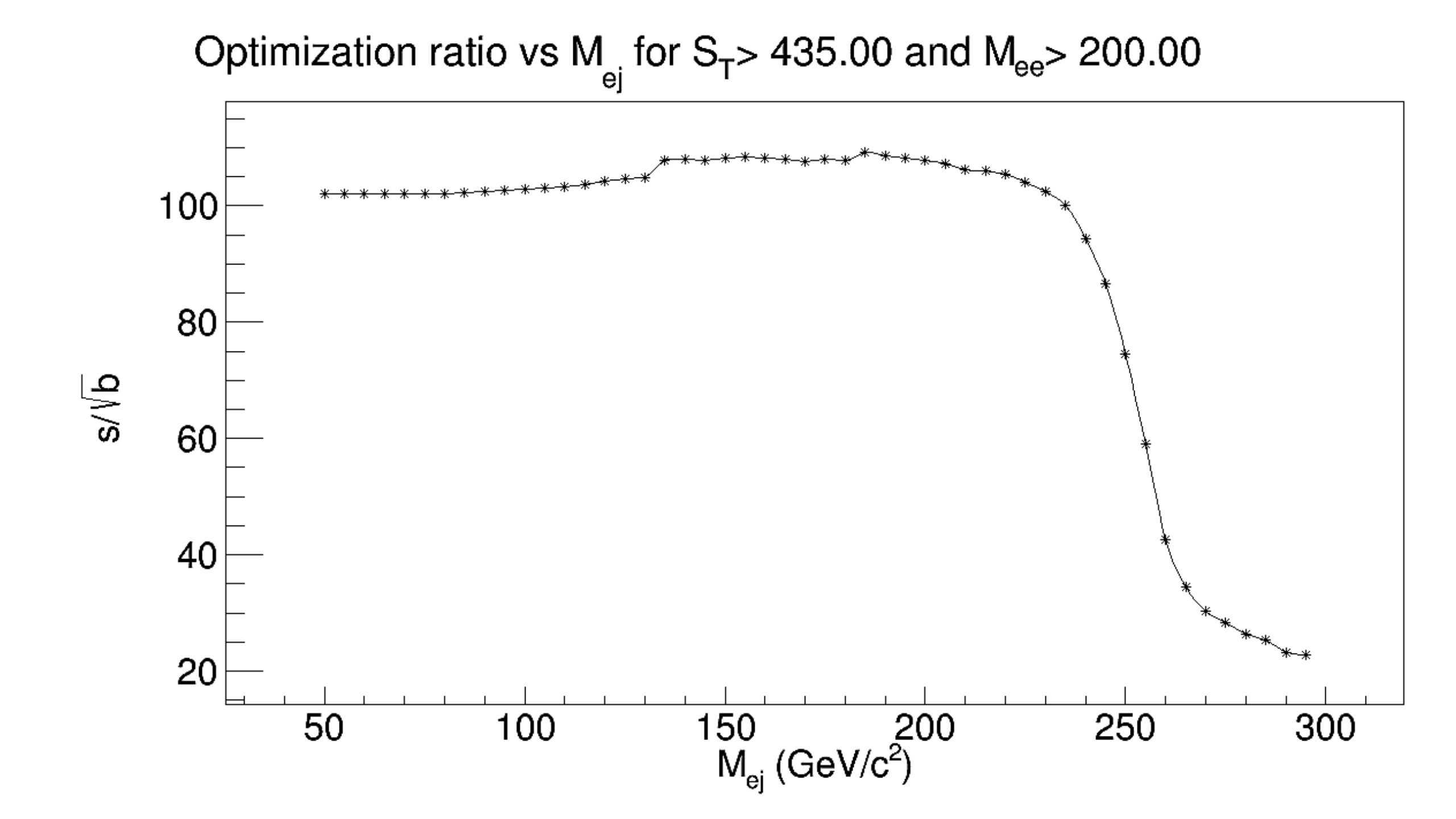



- Drell-Yan

# Optimization of variables to maximize the significance

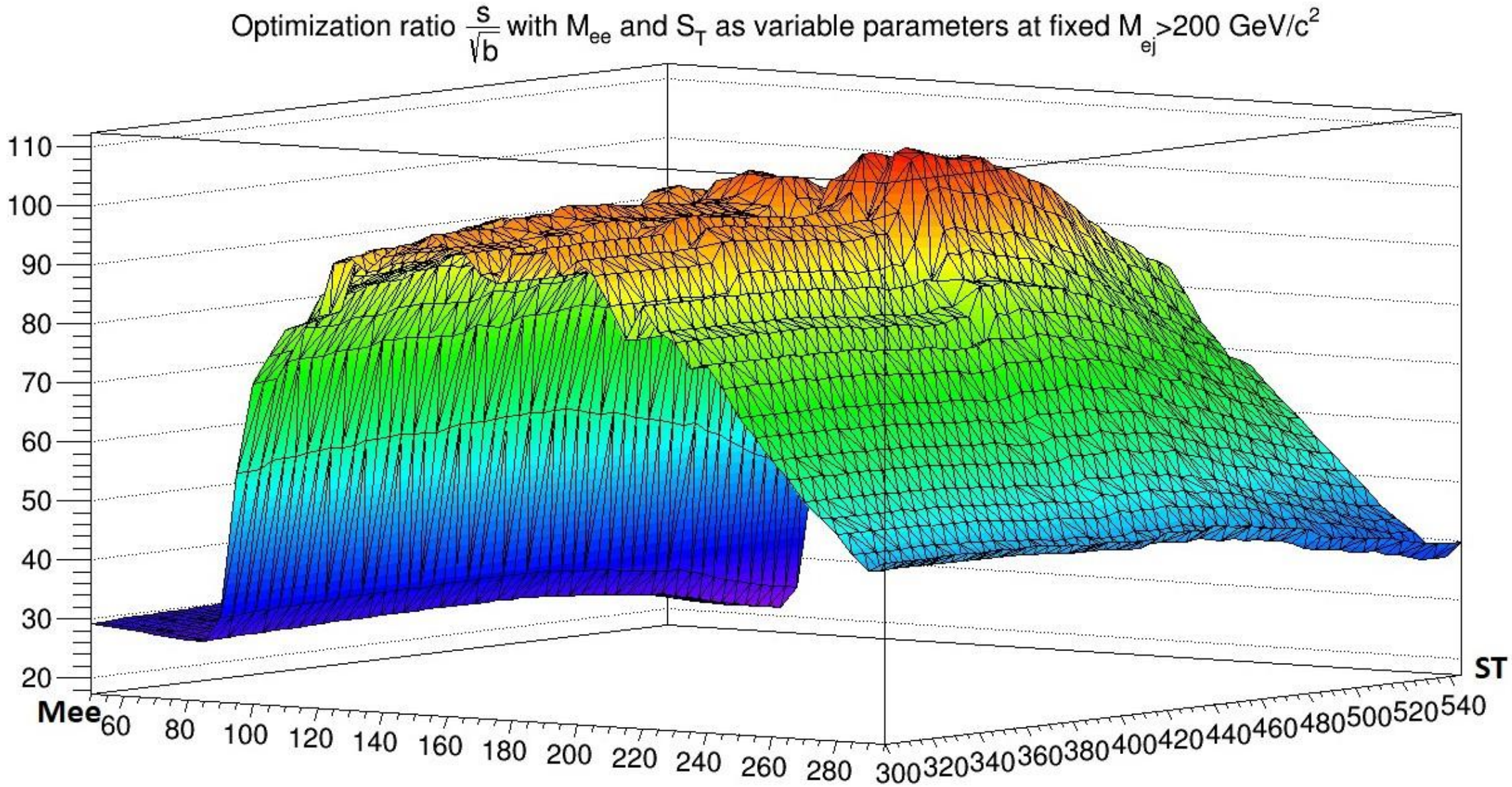



Optimization ratio vs $M_{ee}$ for $S_T$> 435.00 and $M_{ej}$> 200.00
$s/\sqrt{b}$
110
100
90
80
70
60
50
40
30
50
100
150
200
250
300
$M_{ee}$ (GeV/$c^2$)


Optimization ratio vs M_ej for S_T> 435.00 and M_ee> 200.00
s/√b
100
80
60
40
20
50
100
150
200
250
300
M_ej (GeV/c^2)

*"Why scour a mountain of data to search for a particle that might not exist?"*

*……"Because it could be there."* - George Mallory (Mt Everest mountaineer)



# Conclusion

- Have we found the Leptoquark yet ?

No. But the peak of the mountain like hypersurface is definitely a good place to start looking for it !

- Maximum value of significance (peak of the mountain) is obtained around the point

$S_T$**>435 GeV/c ,**$M_{ee}$**>200 GeV/**$c^2$ **,**$M_{ej}$**>200 GeV/**$c^2$

# Future Prospects

- Introduce b-tagging of jets and find out the optimization values.
- Repeating the same procedure for higher Leptoquark masses.

# Thanks


❖Prof Gagan Mohanty

❖Muzamil Ahmad Bhat