Effects of the muon g-2 discrepancy on the Higgs boson searches at LHC

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Ideas and goals of the work

The muon g-2 discrepancy is an open problem in particle physics

The idea is to solve it, at least partially, remaining within the standard model

This would surely have consequences on other predicted, but undiscovered particles, like the Higgs boson

This could be a powerful tool to restrict the mass interval where the Higgs boson can lie

Check the possible effects on the early searches for the Higgs boson at LHC

The magnetic moment of a particle with spin

Is defined as

$$\boldsymbol{\mu} = g \frac{e}{2m} \mathbf{S}$$

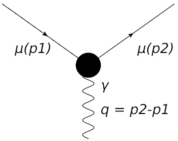
Dirac Theory gives us $g = 2$
However, the experimental value is higher

$$g > 2$$

We define the anomalous magnetic moment as

$$a_l = \frac{g-2}{2}$$

The anomalous magnetic moment can be computed using QFT



There are various different contributions

- QED contributions
- EW contributions
- HLO contributions
- HHO contributions

The various contribution values are

- $a_\mu^{QED} = 116584718.08\,(15) \times 10^{-11}$
- $a_\mu^{EW} = 154\,(2) \times 10^{-11}$
- $a_\mu^{HLO} = 6894\,(46) \times 10^{-11}$
- $a_\mu^{HHO} = 116\,(39) \times 10^{-11} - 98\,(1) \times 10^{-11}$ $+$

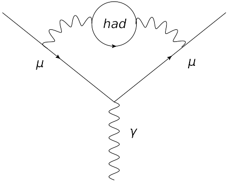
- $a_\mu^{SM} = 116591784(60) \times 10^{-11}$
- $a_\mu^{EXP} = 116592089\,(63) \times 10^{-11}$

$$\boldsymbol{\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM} = (305 \pm 87) \times 10^{-11}}$$

3.5 σ discrepancy!!!

Hadronic Leading Order contribution

The related Feynman diagram



it cannot be computed in standard ways, because of our ignorance of light quarks' masses $\rightarrow$ it should be computed using a dispersion relation

$$a_\mu^{HLO} = \frac{1}{4\pi^3} \int_{4m_\pi^2}^{+\infty} ds K(s) \sigma_{had}(s)$$

where $K(s)$ is the weight function defined by

$$K(s) = \int_0^1 dx \frac{x^2(1-x)}{x^2 - (1-x)\frac{s}{m_\mu^2}}$$

and $\sigma_{had}(s)$ is the inclusive cross section for the process

$$e^+e^- \rightarrow \quad hadrons$$

The value obtained in this work is

$$a_\mu^{HLO} = 6883(25) \times 10^{-11}$$

which is compatible with those of other authors

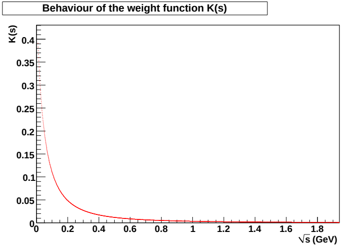
$a_\mu^{HLO} = 6894(46) \times 10^{-11}$	M. Davier (2007)
$a_\mu^{HLO} = 6909(44) \times 10^{-11}$	K. Hagiwara et. al. (2007)

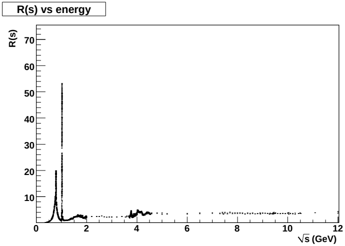
with this new value, the discrepancy is slightly higher (4σ)

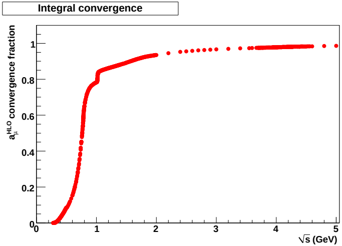
$$\boldsymbol{\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM} = (316 \pm 78) \times 10^{-11}}$$

we want to solve the discrepancy within the standard model, without introducing new physics (like *SUSY*)

Comparing the behaviour of the weight function and the cross section







we notice that most of the contribution comes from the low energy region
$(2m_\pi < \sqrt{s} < 1.8 \quad GeV)$

- The idea is to increase the low energy data in a way of solving the discrepancy
- This should be done carefully
- The main requirement is to keep the new values within the experimental errors
- The most acceptable solution is to increase the data in the region $2m_\pi < \sqrt{s} < 1.8 \quad GeV$ by 60 % of the error
- In this way the discrepancy is lowed under 2σ

Which consequencies could this have?

- The hadronic correction to the electromagnetic coupling constant, $\Delta\alpha^{(had)}\left(M_Z^2\right)$, is also computed with a dispersion relation

$$\Delta\alpha^{(had)}\left(M_Z^2\right) = \frac{M_Z^2}{4\pi^2\alpha} p.v. \int_{4m_\pi^2}^{+\infty} \frac{dq'^2}{M_Z^2 - q'^2} \sigma_{had}\left(q'^2\right)$$

- $\Delta\alpha^{(had)}\left(M_Z^2\right) = 0.02758 \pm 0.00027$
- The increases should be apply also in this case
- The new value stands

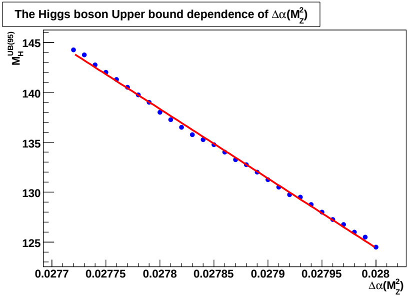
$$\Delta\alpha^{(had)}\left(M_Z^2\right) = 0.02758 \Rightarrow \Delta\alpha^{(had)}\left(M_Z^2\right) = 0.02771$$

$\Delta\alpha^{(had)}\left(M_Z^2\right)$ is one of the parameters that enters the "*Global fit* of the *LEP Electroweak Working Group*"

The other parameters are:

1. $M_W = 80.398 \pm 0.025 \quad GeV$
2. $M_{top} = 172.6 \pm 1.4 \quad GeV$
3. $sin^2\theta_w^{eff} = 0.23153 \pm 0.00016$
4. $\alpha_s\left(M_Z^2\right) = 0.118 \pm 0.002$
5. $M_{Higgs} = ?$

We can set an upper bound for the Higgs boson mass

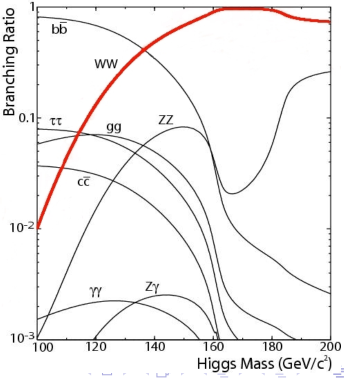


With $\Delta\alpha^{(had)}\left(M_Z^2\right) = 0.02771$, we got $M_H^{UB(95)} \approx 144 \quad GeV$

How can this new upper bound affect the Higgs boson searches at LHC?

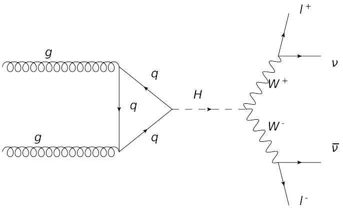
- The LHC currently runs at $\sqrt{s} = 7 \ \ TeV$. The integrated luminosity is estimated to be $\mathcal{L}_{int} = 1 \ \ fb^{-1}$ by the end 2011

- The gluon-gluon fusion channel dominates the production at LHC: around 90%
- The $H \rightarrow WW^{(*)}$ decay channel has the highest BR for larger M_H
- However, the new upper bound would suggest a light mass Higgs



- To check the effects, a simulation of the signal and the backgrounds processes have been performed with *PYTHIA*
- The *ATLAS* detector have been simulated with *PGS* (**P***retty* **G***ood* **S***imulation*)

The signal ($M_H = 140 \quad GeV$
$\sigma = 188 \quad fb$ at $\sqrt{s} = 7 \quad TeV$)



Backgrounds (with estimated cross section at $\sqrt{s} = 7 \quad TeV$):

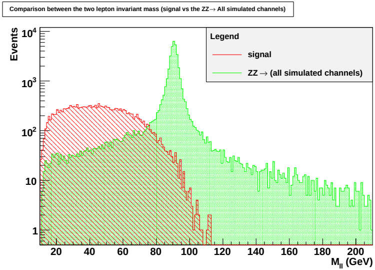
- $WW^{(*)}$ continuum production (3 pb)
- $t\bar{t}$ production (148 pb)
- WZ/ZZ production (1.1 pb/0.7 pb)
- $W + jets$ (26.7 pb)
- $Z + jets$ (2.5 pb)
- $QCD \quad multijet \quad production$ ($\mathcal{O}$ (nb))

Data analysis

- The first requirement is to have two opposite charge leptons $(e^+e^-, \mu^+\mu^-, e^{+(-)}\mu^{-(+)})$ with $p_T > 20 \quad GeV$ in order to be compatible with the trigger requirements
- The lepton pair invariant mass, can be used to remove most of the backgrounds from the Z bosons
- $M_{ll} = \sqrt{(E_{l_1} + E_{l_2})^2 - (\mathbf{p}_{l_1} + \mathbf{p}_{l_2})^2}$
- We require

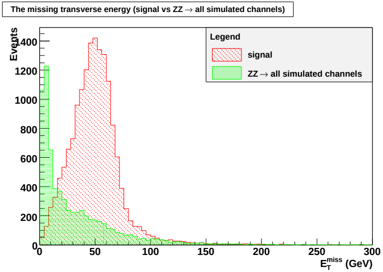
$$15 \quad GeV < M_{ll} < 80 \quad GeV$$

$$102 \quad GeV < M_{ll} < 144 \quad GeV$$



To further remove the Z background and the QCD backgrounds we set requirements on the transverse missing energy

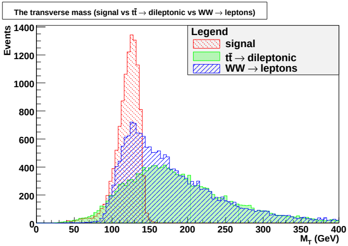
$$E_T^{Miss} > 40 \quad GeV$$



Channel	Triggered events	After cuts	(%)
Signal	168	41.4	24.6
$WW^{(*)}$	2371	282.2	11.9
$t\bar{t}$	30816	2402.6	7.8
Z and other W backgrounds	6485	23.5	0.3

After these requirements, all the QCD multijet background disappears

- The largest remaining backgrounds are the $WW^{(*)}$ and $t\bar{t}$
- To suppress them we set the transverse mass to be smaller than M_H: $M_T < 144 \quad GeV$



$$M_T = \sqrt{\left(E_T^{ll} + E_T^{miss}\right)^2 - \left(p_x^{ll} + p_x^{miss}\right)^2 - \left(p_y^{ll} + p_y^{miss}\right)^2}$$

Channel	Before M_T cut	After M_T cut	(%)
Signal	41.4	40.9	99
$WW^{(*)}$	282.2	100.9	35.7
$t\bar{t}$	2402.6	670.3	27.9
Other	23.5	12.2	51.9

0 jet analysis

1. We require the complete absence of jets with $p_T > 20 \quad GeV$
2. Strongly suppress $t\bar{t}$ background

1 jet analysis

1. We require the presence of only one jet with $p_T > 20 \quad GeV$
2. We require that the jet has not been identified as a b-jet
3. $\mathbf{P}_T^{tot} = \mathbf{P}_T^{l_1} + \mathbf{P}_T^{l_2} + \mathbf{P}_T^{jet} + E_T^{miss} < 20 \quad GeV$

In both cases we can make a more refined selection on the M_{ll}

$$M_{ll} < 60 \quad GeV$$

- **19.3 signal events**
- *53.8 background events*

- **5.9 signal events**
- *16.9 background events*

Systematic errors

Possible systematic errors sources:

- JES (**J**et **E**nergy **S**cale): $\pm 5\%$
- LES (**L**epton **E**nergy **S**cale): $\pm 1\%$
- ISR (**I**nitial **S**tate **R**adiation)
- FSR (**F**inal **S**tate **R**adiation)
- "b-tagging" uncertainty: $\pm 10\%$
- Cross section and integrated luminosity uncertainty

Source	0 jet analysis (%)	1 jet analysis(%)
JES ($\pm 5\%$)	0.3	3
LES ($\pm 1\%$)	0.9	2.7
ISR turned off	9.6	4.5
FSR turned off	11.5	5.4
BTAG	0	10
Luminosity and cross section	14.9	14.9
Total	**21.1**	**19.7**

Results

- Statistical significance

$$\mathcal{S} = \frac{signal + background}{\sqrt{background}}$$

- To take into account the systematic errors, a more refined calculation of $\mathcal{S}$ has been done:
- Poisson distributions with $n = n_B$ convolved with a gaussian distribution for the systematic uncertainties, giving the significance of the signal events excess with respect to the null hypothesis (i.e. only SM background is present)
- For the 0 jet analysis:

$$\mathcal{S}_{0jet} = 1.3$$

- For the 1 jet analysis:

$$\mathcal{S}_{1jet} = 0.9$$

Conclusions

1. The muon g-2 discrepancy has been partially solved, bringing it down to 2σ, setting a new upper bound for the Higgs boson mass
2. There is a negative effect for the Higgs boson searches $\rightarrow$ no evidence of the Higgs boson by the end of the "7 TeV" run (2011)
3. However, as $\mathcal{S} \propto \sqrt{\mathcal{L}_{int}}$, with a larger data sample, the discovery of the Higgs boson within the $H \rightarrow WW^* \rightarrow leptons$ could be possible (a 5x larger sample is required)
4. Standing to this analysis, the Higgs constrained by the new upperbounds, could be discovered within this channel, but not at an early stage


Danke