



für Bildung und Forschung



Search for a light CP-odd Higgs boson decaying into $\tau\tau$

ATLAS ATLAS

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Introduction

- Standard Model (SM) very successful in describing most experimental results
- but the SM can not explain everything
- \rightarrow for example the anomalous magnetic moment of the muon



Introduction

• the anomalous magnetic moment of the muon is precisely measured (Brookhaven National Laboratory):

$$a_{\mu}^{\text{exp}} = 116\ 592\ 091\ (63)\cdot 10^{-11}$$

- with QCD corrections still a deviation (arxiv:1705.00263): $a_{\mu}^{SM} = 116591776(44) \cdot 10^{-11}$ $\rightarrow a_{\mu}^{exp} - a_{\mu}^{SM} = 313(77) \cdot 10^{-11}$
- \rightarrow Model beyond the standard model: 2 Higgs doublet model (2HDM)
- \rightarrow different types of 2HDM
- →here: flavour-aligned 2HDM (arxiv:1711.11567)

Theory – 2HDM

 $M_{\rm H} = M_{\rm H^{\pm}} = 150 \text{ GeV}$

 $M_H = M_{H^{\pm}} = 200 \text{ GeV}$



Maximum a_{μ} as a function of M_A for different fixed values of ζ_I and M_H (arxiv:1711.11567)

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Theory – 2HDM

- another Higgs doublet \rightarrow four additional Higgs bosons:
- 1. two CP-even, neutral, one heavy, one light (standard model)
- 2. two CP-even, charged (one positive, one negative)
- 3. one CP-odd, neutral, light
- further defined by the couplings for the new doublet:
- 1. high coupling to leptons: $\zeta_l \approx 50 \cdot \zeta_l^{SM}$
- 2. coupling to up-type quarks: $\zeta_u \approx 0.5 \cdot \zeta_u^{SM}$
- 3. coupling to down-type quarks: $\zeta_d \approx 0$

Analysis

- search for the light CP-odd Higgs boson ungere-
- $BR(A \rightarrow \tau \tau) \approx 100\%$

$$\Rightarrow gg \rightarrow A \rightarrow \tau\tau \rightarrow e\mu \ (+\nu_e \nu_\mu \nu_\tau \nu_\tau)$$



- analysing for different masses of A (currently 60GeV and 70GeV)
- \rightarrow cuts for the analysis are defined by maximizing the significance:

$$\sigma = \sqrt{2 \cdot \left[(s+b) \cdot \log\left(1 + \frac{s}{b}\right) - s \right]}$$

Analysis

- Signal simulated as SM Higgs boson with smaller mass
- \rightarrow using a scale factor of 0.5

	$\frac{\sigma_{tot} (gg \to A)}{\sigma_{tot} (gg \to h)}$						
ζ _u \M _A ,GeV	40	50	60	70	80	90	
-0.5	0.72	0.73	0.71	0.69	0.68	0.66	
-0.4	0.48	0.48	0.47	0.45	0.44	0.43	
-0.3	0.29	0.28	0.27	0.26	0.25	0.25	
0.3	0.20	0.21	0.21	0.21	0.21	0.21	
0.4	0.36	0.38	0.38	0.38	0.38	0.38	
0.5	0.58	0.61	0.61	0.61	0.61	0.60	

ratio of the cross section calculated with the flavour-aligned 2HDM

(arxiv: 1711.11567) by Dominik Stöckinger and Vladimir Khasianevich

Analysis for m = 60 GeV

- using an e- μ -trigger (p_T^{μ} > 24GeV and p_T^{e} > 7GeV)
- baseline cuts: $p_T^e > 8$ GeV, $p_T^{\mu} > 25$ GeV, no further leptons (e/ μ), opposite charge, $p_T^{jet} > 20$ GeV, MET > 20GeV, no b-jet
- additional cuts for the mass of 60GeV:

ATLAS Work in Progress	Signal		Background		
cut	Events	eff. in %	Events	eff. in %	significance
baseline	783.75	100.00	144115.18	100.00	2.06
mass of lepton system < 40GeV	702.78	89.67	33329.67	23.13	3.84
total transverse mass < 50GeV	469.99	59.97	5875.68	4.08	6.05
ΔR of the leptons < 1.7	435.42	55.56	4242.03	2.94	6.58
Δ η of the leptons < 0.9	361.52	46.13	2131.58	1.48	7.62
p _T ^{second lepton} < 55GeV	349.40	44.58	1948.02	1.35	7.70
$p_T^{\text{first jet}}/p_T^{\text{higgs}} < 1.6$	349.40	44.58	1884.94	1.31	7.82

Results for m = 60 GeV



 p_{T} of the lepton system



 p_T of the second lepton

Results for m = 60 GeV



mass of the lepton system



total transverse mass

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Analysis for m = 70 GeV

- baseline cuts are the same as for m = 60GeV
- additional cuts for the mass of 70GeV:

ATLAS Work in Progress	Signal		Background		
cut	Events	eff. in %	Events	eff. in %	significance
baseline	989.42	100.00	144115.18	100.00	2.60
mass of the lepton system < 45GeV	918.16	92.80	45500.77	31.57	4.29
total transverse mass < 60GeV	653.06	66.00	10357.45	7.19	6.35
$\Delta \eta$ of the leptons < 1.3	624.03	63.07	7175.45	4.98	7.26
p _T ^{first jet} /p _T ^{higgs} < 2.1	624.03	63.07	7070.19	4.91	7.32
$p_T^{\text{first lepton}}/p_T^{\text{second lepton}} < 6.3$	618.25	62.49	6902.57	4.79	7.33
ΔR of the leptons < 3.2	618.25	62.49	6889.65	4.78	7.34

Results for m = 70 GeV



 \boldsymbol{p}_{T} of the lepton system



 p_T of the second lepton

Results for m = 70 GeV







total transverse mass

Summary and Outlook

- standard model not explaining the anomalous magnetic moment of the muon
- \rightarrow new model to describe difference
- \rightarrow search through process $A \rightarrow \tau \tau \rightarrow ll + 4\nu$ for small masses of A
- in the future:
- 1. implementing the analysis with a CP-odd Higgs boson as signal
- 2. implementing a control region (leptons have charge with same sign)
- unblinding signal region and interpret results in context of the 2HDM

Thank you for listening

Sources

- Standard Model picture (slide 2): https://atlas.cern/discover/physics
- Muon g-2 (slide 3): <u>https://arxiv.org/abs/1705.00263</u>
- flavour-aligned 2HDM (slide 3): https://arxiv.org/abs/1711.11567
- a_{μ} graphs (slide 5): <u>https://arxiv.org/abs/1711.11567</u>