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Search for Hidden Higgs decays in the ATLAS detector

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Summary. — In this paper, a brief overview of the search for the Higgs boson in Hidden Valley models is given. Hidden Valley models predict Higgs decays to neutral particles, which can be also long lived with decay paths comparable to the LHC detectors dimensions. Decay final states consist of collimated leptons (Lepton Jets). Results are presented of a search for Higgs decays to long lived particles in the ATLAS detector at the LHC, based on 1.92 fb^{-1} data collected during 2011 at a 7 TeV center-of-mass energy.

PACS 13.75.Cs – Nucleon-nucleon interactions (including antinucleons, deuterons, etc.).
PACS 12.60.Fr – Extensions of electroweak Higgs sector.
PACS 14.80.Da – Supersymmetric Higgs bosons.

1. – Hidden Valley scenario

Many extensions of the Standard Model (SM) predict a light Higgs, in the mass range 100–140 GeV c^{-2}, with decays branching fractions significantly different than the SM ones (fig. 1). An interesting possibility arises if additional light hidden sectors, weakly coupled to the SM, exist. These sectors include neutral particles that can be long-lived, with decay lengths comparable or larger than the detector dimensions [1,2], and to which the Higgs may decay([1]). Possible topological signatures of such extensions of the SM are clusters of highly collimated charged particles. Neutral particles with long decay paths and collimated final states represent, from an experimental point of view, a challenge both for the trigger and for the reconstruction capabilities of the detectors, due to their finite granularity. The ATLAS air core toroid Muon Spectrometer [3] (MS) allows to

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([1]) These long-lived particles occur in many models, including gauge-mediated extensions of the Minimal Supersymmetric Standard Model (MSSM), MSSM with R-parity violation and the Hidden Valley (HV) scenario.

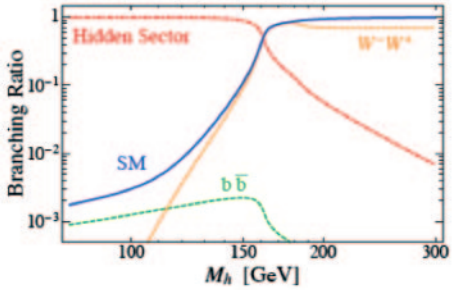

Fig. 1. – Higgs boson branching ratios in Hidden Sector compared with SM. The former is dominating at low Higgs masses.

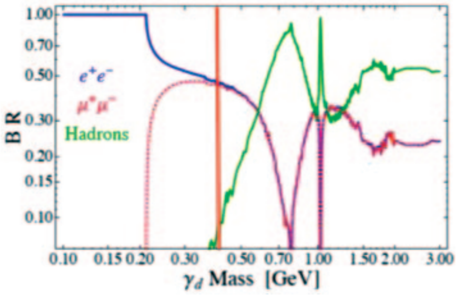

Fig. 2. – Branching ratio of γ_d as a function of its mass. A mass of $400\,\mathrm{MeV}\,c^{-2}$ is chosen to maximize its decay branching fraction to muons (45%).

reconstruct charged tracks in a standalone configuration, a crucial feature for detecting tracks not coming from the primary interaction vertex.

2. – Higgs to Lepton Jets

Possible characteristic topological signatures of light Higgs in such extensions of the SM [2] are due to Lepton Jets (LJs), *i.e.* clusters of highly collimated electrons, muons and possibily charged pions. A LJ is a cluster of highly collimated charged particles: electrons, muons and possibly pions. These arise if light unstable vector bosons with masses in the MeV to GeV range (dark or hidden photons, γ_d) reside in the hidden sector and decay predominantly to SM particles. The search presented in this note is focused on long-lived LJ containing only muons (Muon Jet). The benchmark channel used for this analysis is the simplest Higgs decay scenario with two dark photons resulting in only two MJs in the final state ($BR(\gamma_d \to \mu^+\mu^-) = 45\%$, fig. 2). MJs from γ_d displaced decays are characterized by a pair of muons, not linked to the primary vertex of the event, in a very narrow cone ($\Delta R \leq 0.1$). These objects are reconstructed with a simple clustering algorithm, associating all the muons in cones of opening $\Delta R = 0.2$. Only events with 2 MJs are kept for the subsequent analysis. A certain number of discriminating variables have been studied in order to separate the signal from the background. The main background source, QCD di-jet production, can be strongly reduced using isolation criteria in the calorimeter around the MJ direction, $\Delta\phi$ the difference in azimuthal angle between the two MJs and the Σp_T for the MJs(2). Finally, to reduce the background

(2) Defined as the sum of the p_T's of the inner detector tracks inside a cone $\Delta R < 0.4$ around the direction of the MJ.

coming from cosmic muons a cut on the impact parameters of the muon tracks with respect to the primary interaction vertex is used. The results of this analysis in the simplest case of Lepton-jet decays in two-muons, are expected to be presented by ATLAS at the 2012 summer conferences. At the same time the development of novel strategies to search for more complex signal topologies is in progress.

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