



Search for a Higgs portal to the dark sector in ATLAS

O. K. Baker * (Yale)

on behalf of the ATLAS collaboration

10th Patras Workshop, CERN

***analysis mainly by T. Lagouri, Yale University**



The Higgs boson discovery and properties



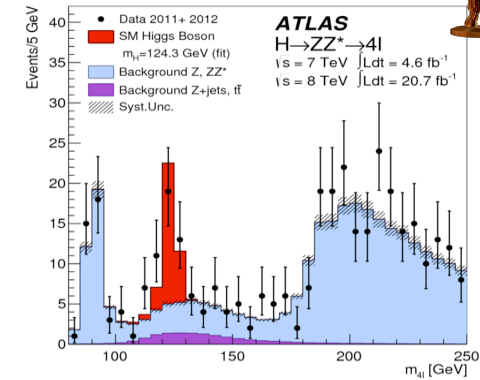
Higgs discovery channels

see PLB 726, 88 (2013)



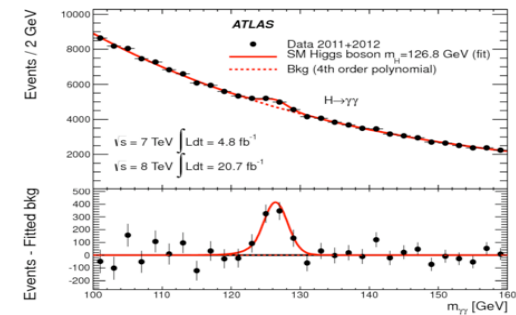
$$H \rightarrow ZZ^* \rightarrow 4l$$

$$\mu = 1.44 + 0.40 - 0.35$$



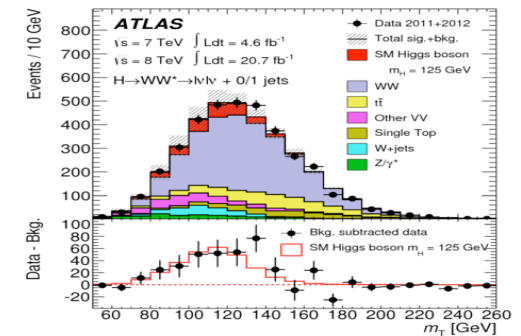
$$H \rightarrow \gamma\gamma$$

$$\mu = 1.55 + 0.33 - 0.28$$



$$H \rightarrow WW^* \rightarrow 4l$$

$$\mu = 0.99 + 0.32 - 0.29$$





Higgs discovery channels



see PLB 726, 88 (2013)

focus on $H \rightarrow ZZ^* \rightarrow 4l$ channel

$$H \rightarrow ZZ^* \rightarrow 4l$$

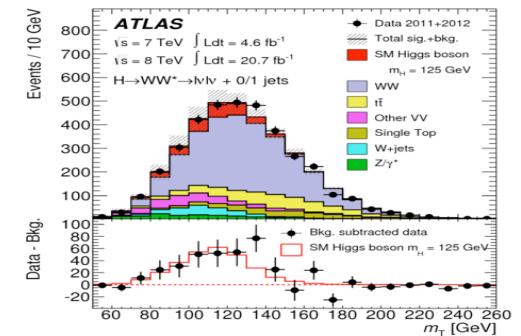
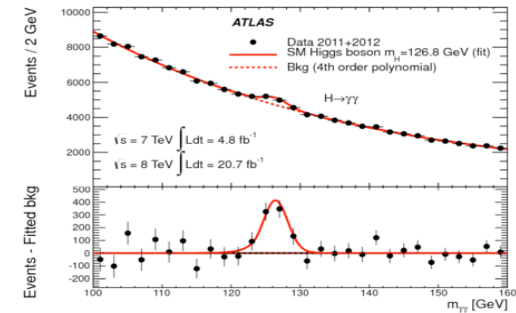
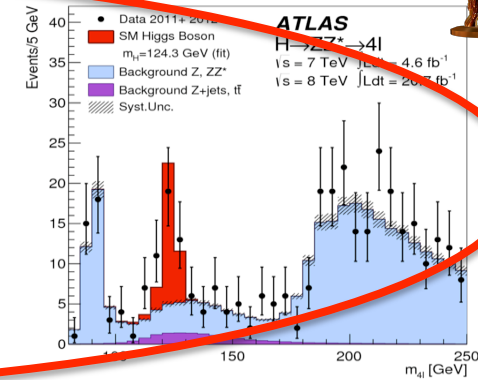
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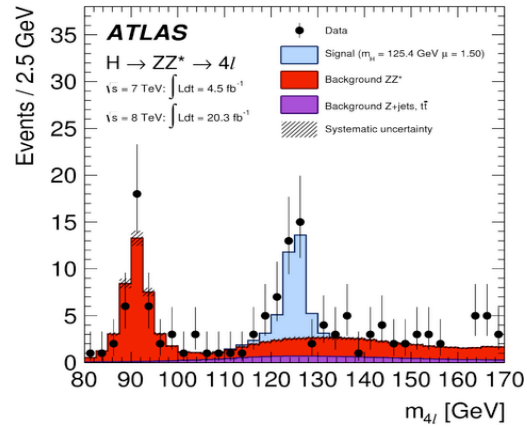
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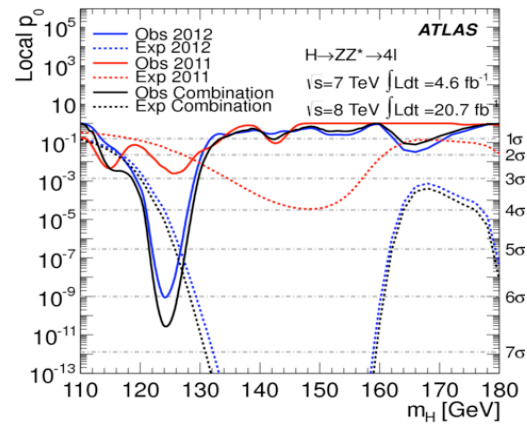
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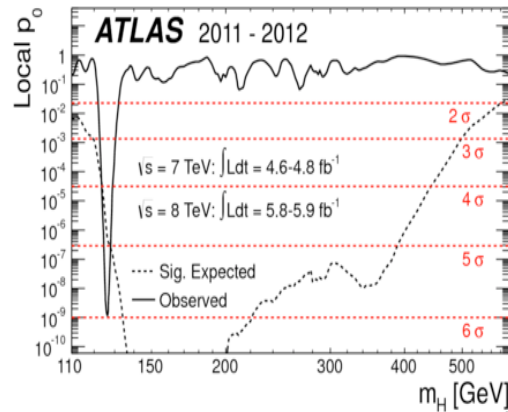


see PLB 726, 88 (2013)

**Higgs boson discovery
in 4l channel**



**significance well in excess
of 5σ
4l channel alone**



**and so far,
nothing else!**



spin properties of the discovered particle from 4l

see PLB 726, 88 (2013)

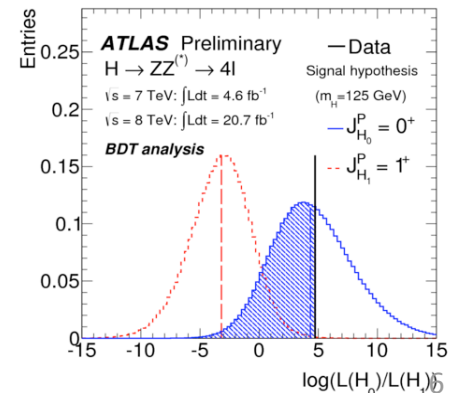
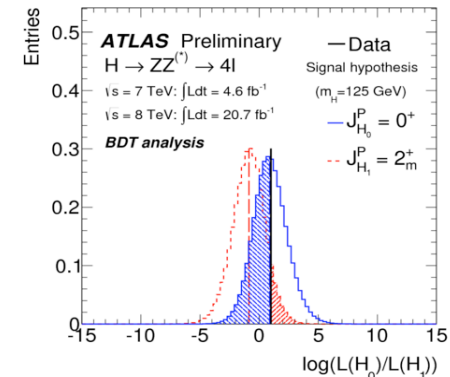
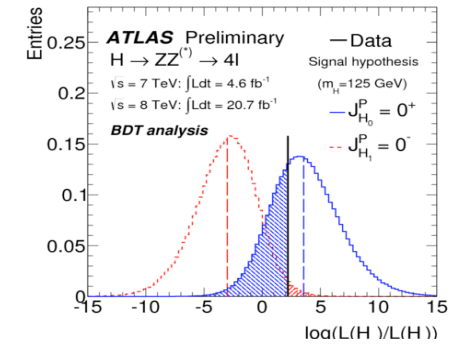


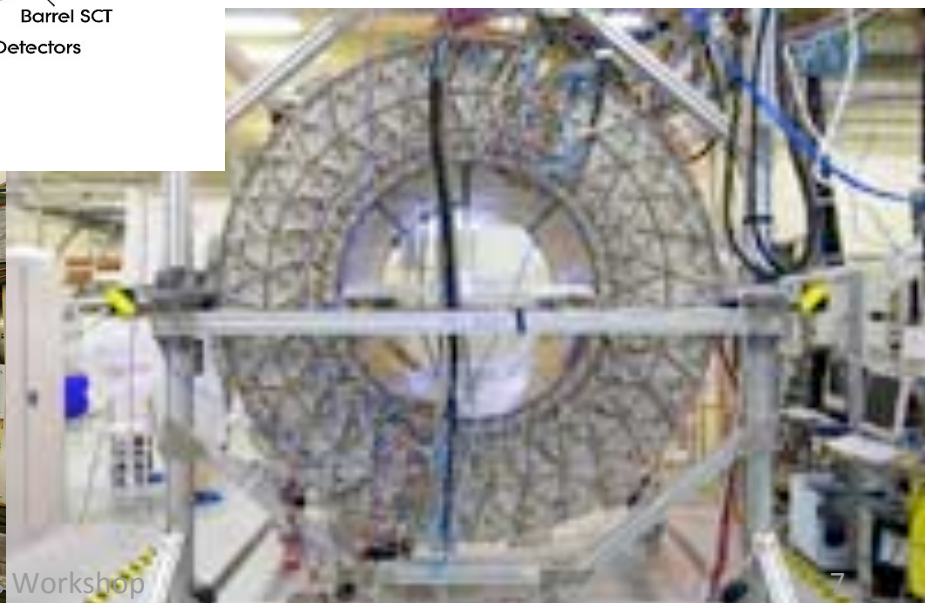
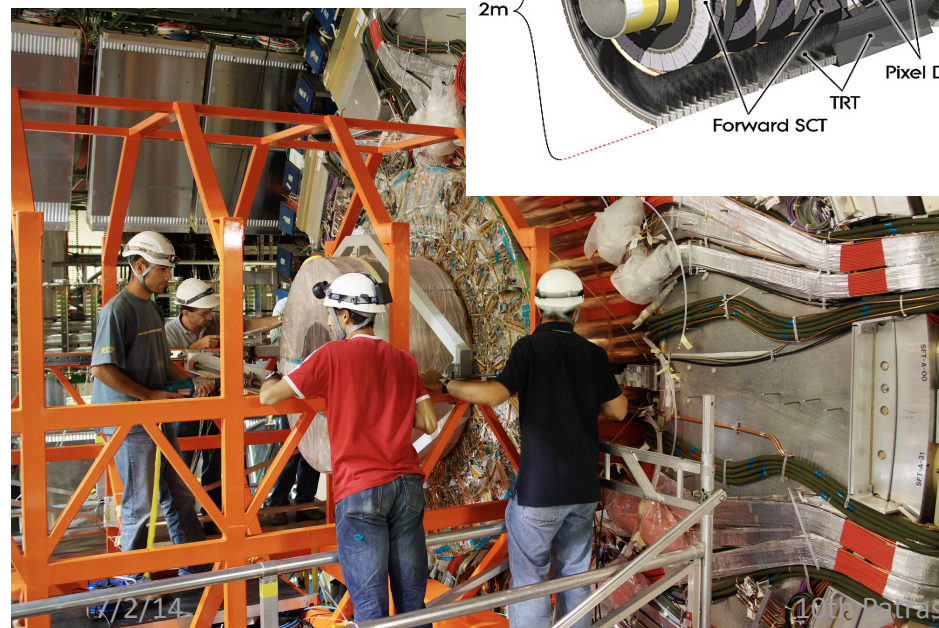
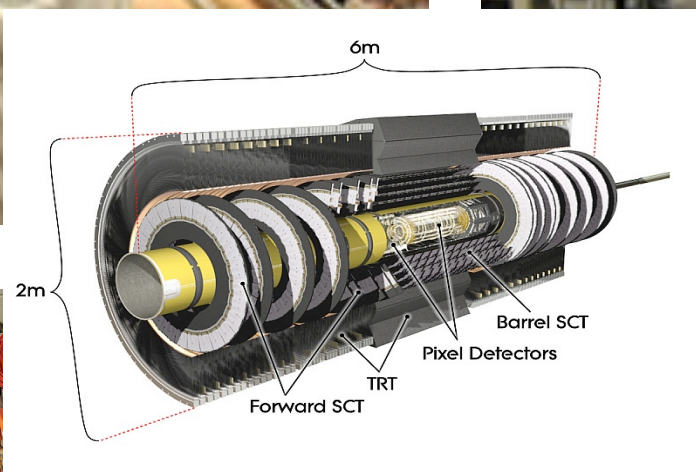
excluded at >97.8% confidence levels
 When all channels considered

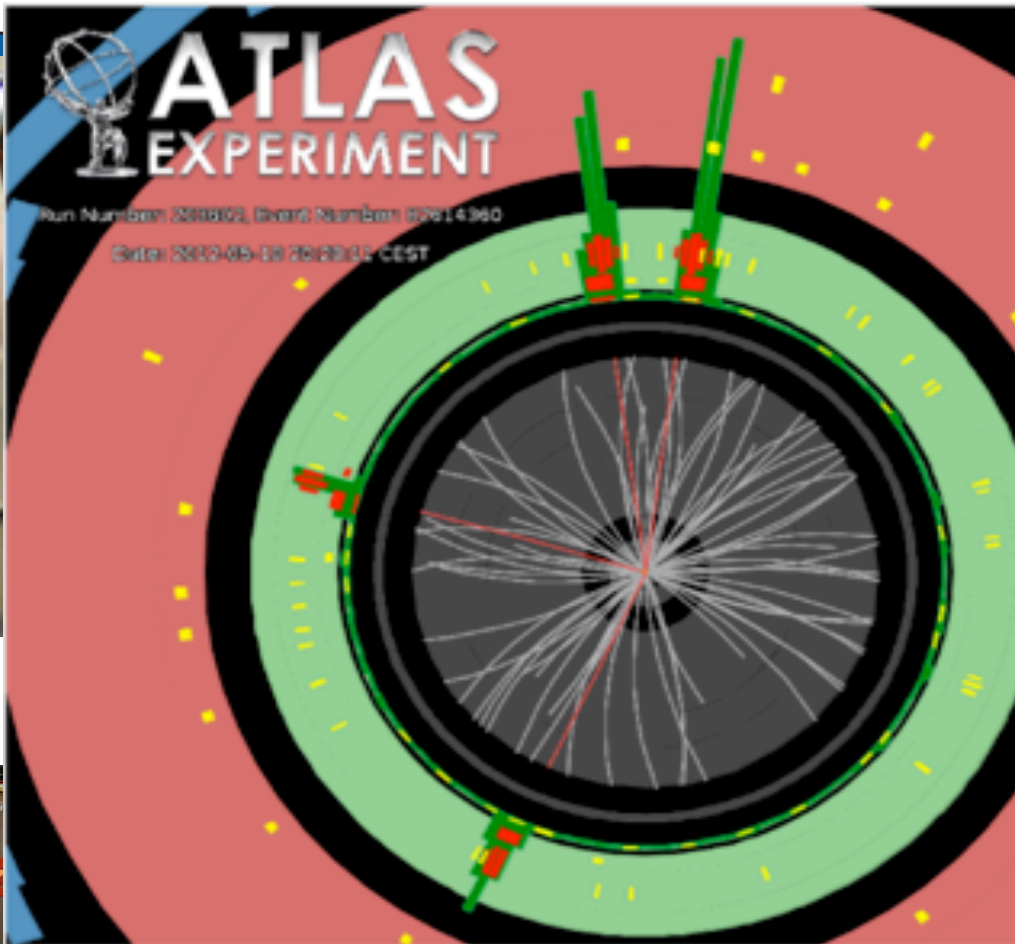
spin hypothesis 0^+
 favored over 0^-

spin hypothesis 0^+
 favored over 2^+
 (done in context of graviton;
 not universally ruled out)

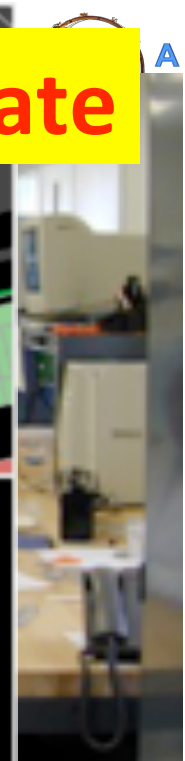
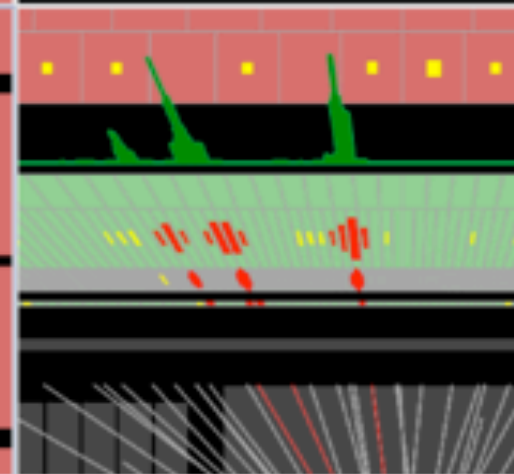
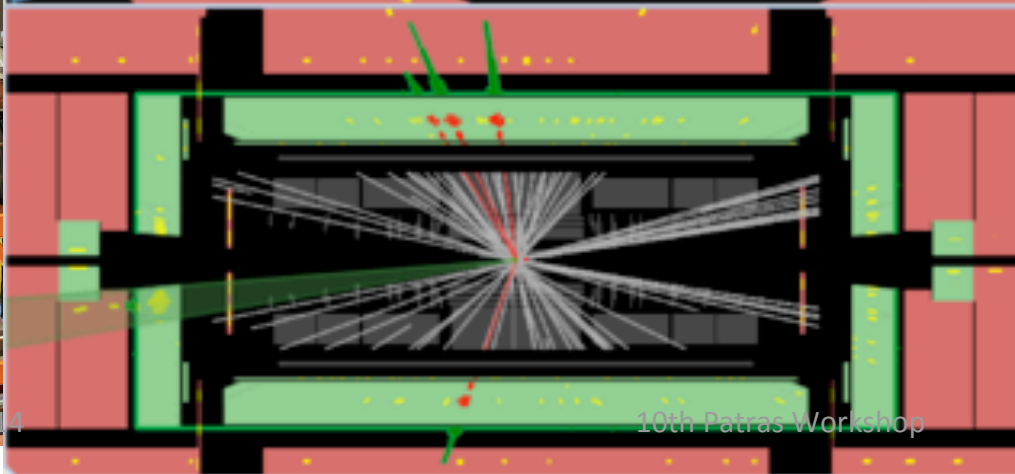
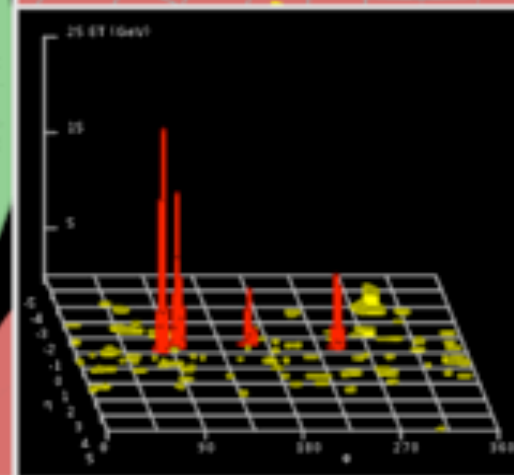
spin hypothesis 0^+
 favored over 1^+
 (Landau-Yang thm; however
 consider $H \rightarrow a^0 a^0 \rightarrow \gamma\gamma\gamma\gamma$
 that looks like $H \rightarrow \gamma\gamma$)







4e candidate





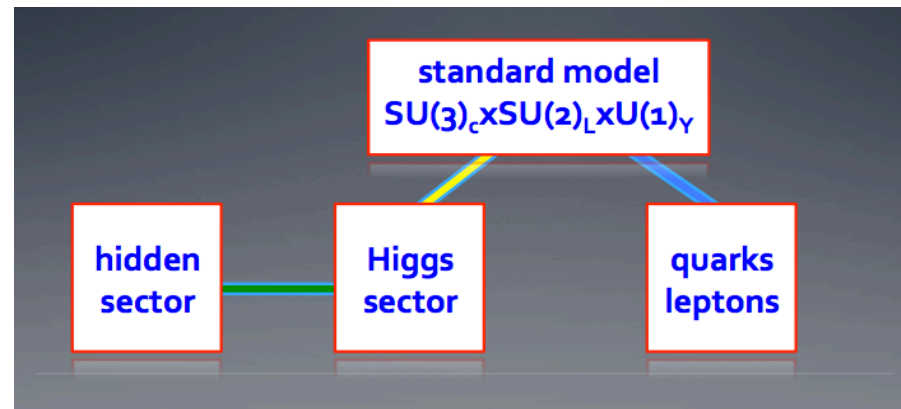
The Higgs boson as a portal to a hidden or dark sector



Higgs portal to dark sector



Higgs as a portal to the hidden or “dark” sector



- motivation from astrophysics (dark force mediator; DM): PAMELA, ATIC, Fermi/GLAST, AMS data all showing electron-positron excess in cosmic rays
- the muon $g-2$ data/prediction discrepancy of 3.6σ (light Z_d : 10 – 500 MeV)
- also particle physics motivation (dark or hidden sectors): theoretical arguments (extra $U(1)$'s, hidden sector, etc)
- motivation from cosmology: modification to GR?



Higgs as a portal . . .

$H \rightarrow 4l$ examples

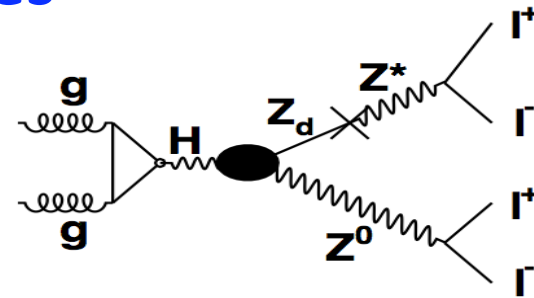


hidden sector, or heavy, or dark photon (γ_D, γ')

hidden sector, or dark Z-boson ($Z', Z_D, \text{ or } Z_{\text{dark}}$)

(H Davoudiasl et.al., PRD 88, 015022 (2013)

tl and okb, ATL-COM-PHYS-2013-1308)





Higgs as a portal . . .

$H \rightarrow 4l$ examples

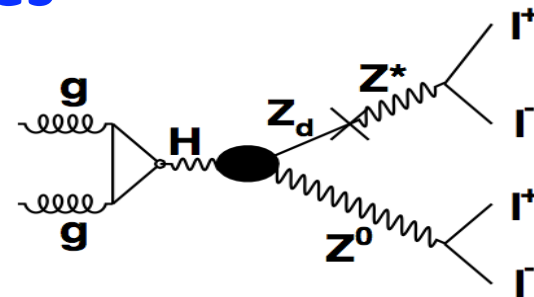


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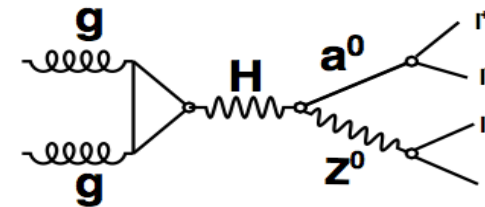
(H Davoudiasl et.al., PRD 88, 015022 (2013))

tl and okb, ATL-COM-PHYS-2013-1308)



pseudoscalar boson couples to Higgs; decays to leptons

(ND Christensen et.al., JHEP 1308, 019 (2013))



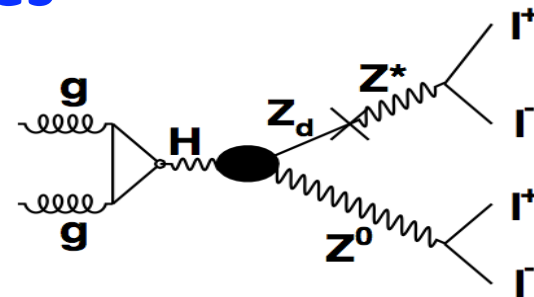


Higgs as a portal . . .

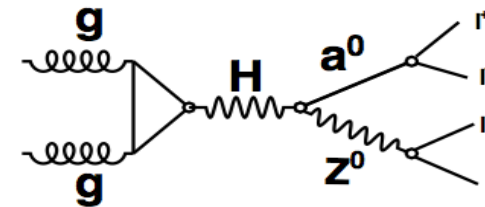
$H \rightarrow 4l$ examples



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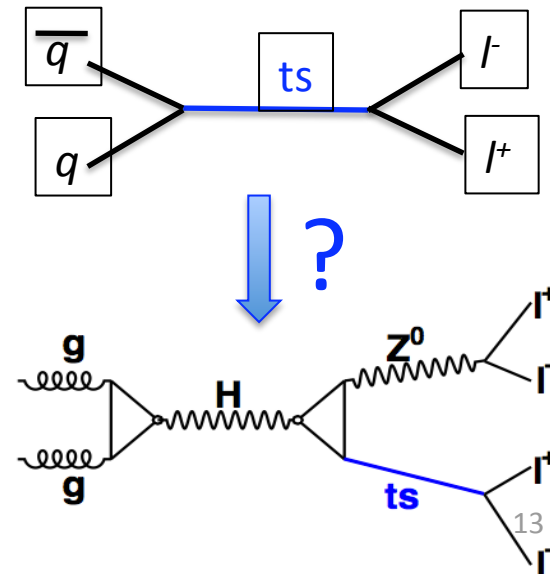


pseudoscalar boson couples to Higgs; decays to leptons
 (ND Christensen et.al., JHEP 1308, 019 (2013))



torsion field (ts) couples to fermions
 (axial vector) modifications to GR
 (A.S. Belyaev, I.L. Shapiro PLB 425, 426 (98)
 ATLAS collab JHEP 1211, 138 (2012))

torsion field (ts) couples to Higgs via heavy particle (ttbar for eg) loop?





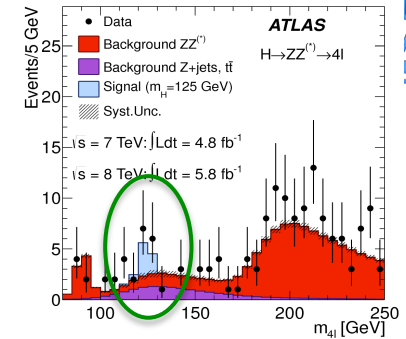
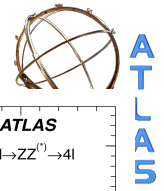
analysis strategy

- 1. use Higgs decays: $H \rightarrow ZZ^* \rightarrow 4l$ events from HSG2 cut-based 'Moriond' analysis (Phys. Lett. B 726 (2013) 88)
 - 36 Higgs decays to $4e, 4\mu, 2\mu 2e,$ and $2e 2\mu$
 - $115 \text{ GeV} < M_{4l} < 130 \text{ GeV}$
- 2. use Z^0 ($Z1$) and Z^* ($Z2$) mass distributions
 - leading dileptons: invariant mass (m_{12}) closest to Z^0 PDG value
 - subleading dileptons: highest invariant mass (m_{34})
- 3. search for narrow peak or excess above background in m_{34} mass distribution; signals V_D
 - use Roostats and BumpHunter statistical tools
- 4. in the absence of a signal, set upper limits on the relative branching ratio

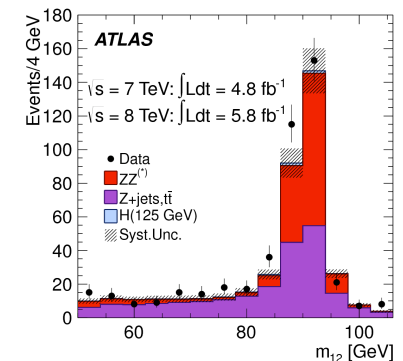
$$\frac{bf(H \rightarrow ZV_D \rightarrow 4l)}{bf(H \rightarrow 4l)}$$

7/2/14

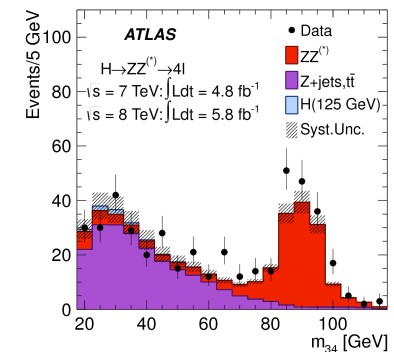
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m_{4l} spectrum



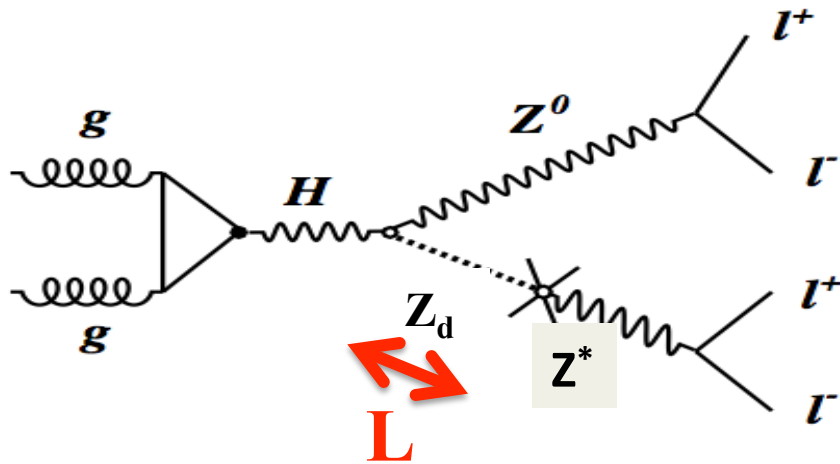
m_{12} spectrum



m_{34} spectrum



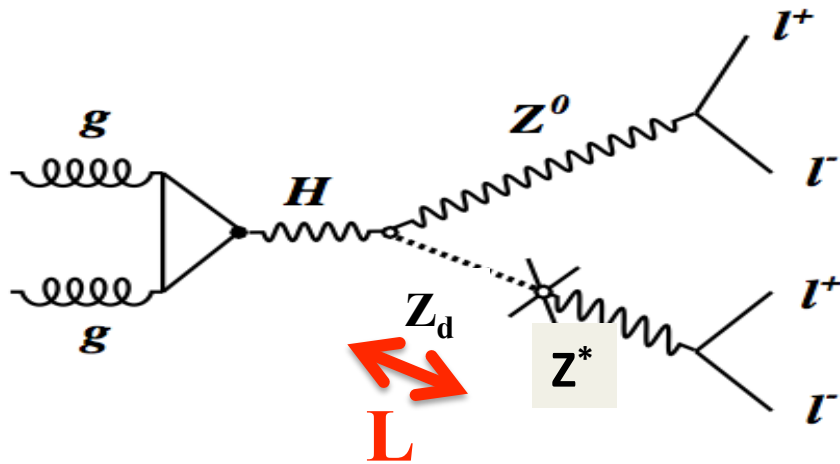
$H \rightarrow ZZ_d \rightarrow 4l$ kinetic mixing



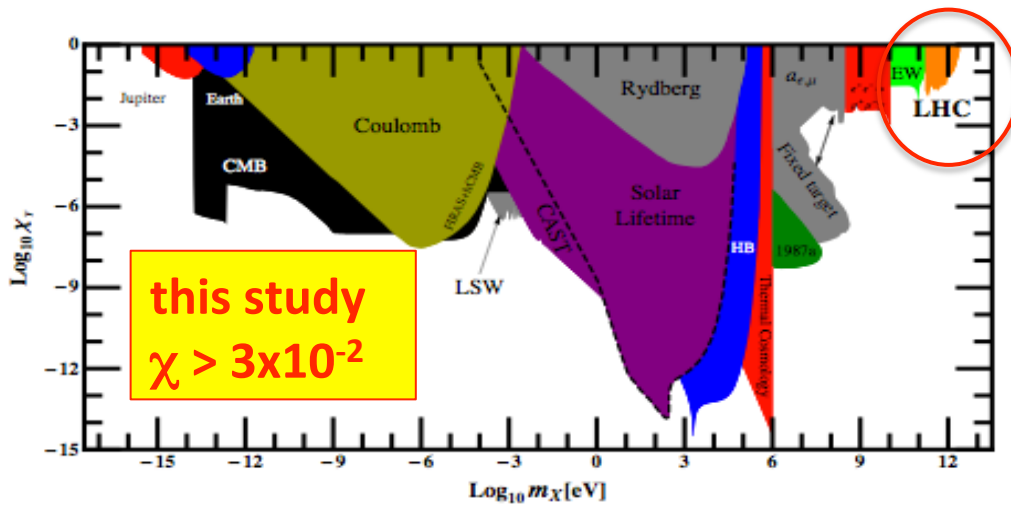
$$P_{osc} \sim \chi^2 \sin^2\left(\frac{|\Delta m|^2 L}{4E}\right) ; \text{ particle energy } E$$



H \rightarrow ZZ_d \rightarrow 4l kinetic mixing



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J. Jaeckel, et.al.,

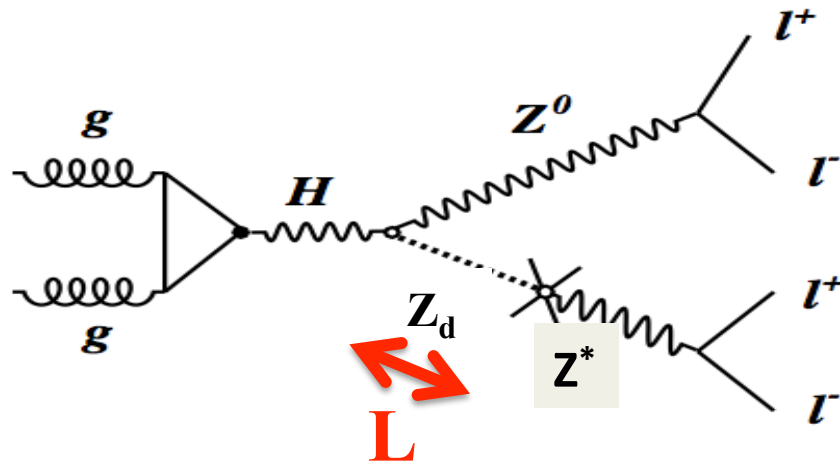
Phys. Dark Univ. 2 (2013) 111; arXiv: hep-ph.1212.3620



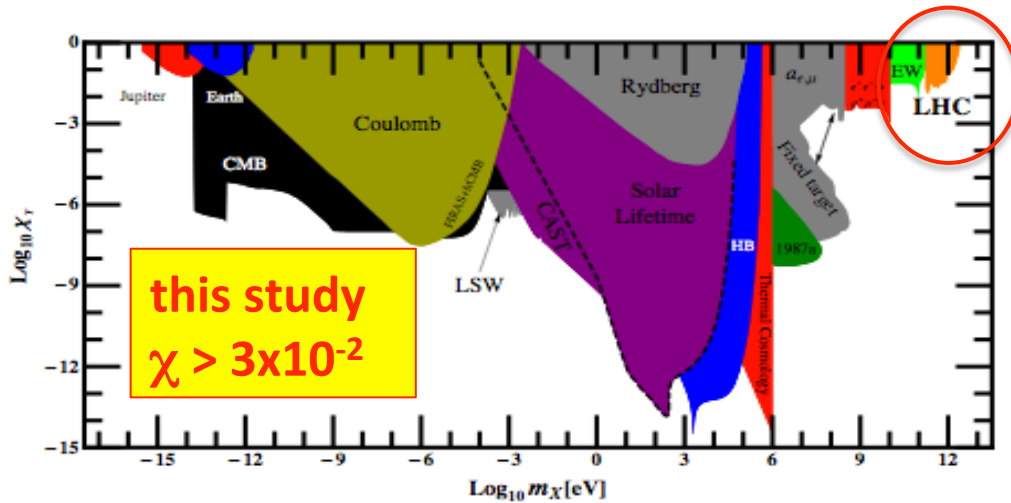
H \rightarrow ZZ_d \rightarrow 4l kinetic mixing



compatible with LEP limits and ATLAS cuts

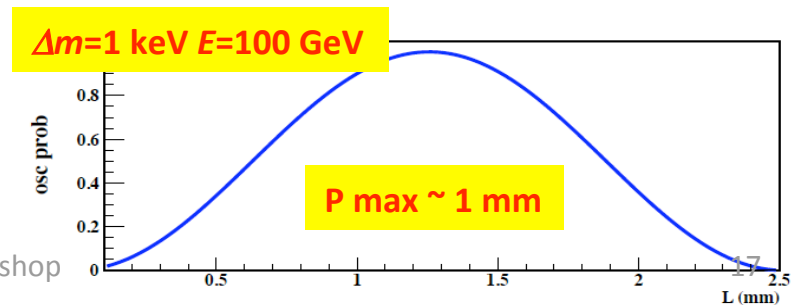
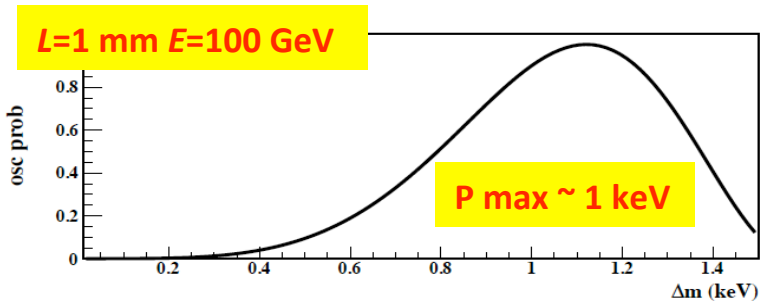


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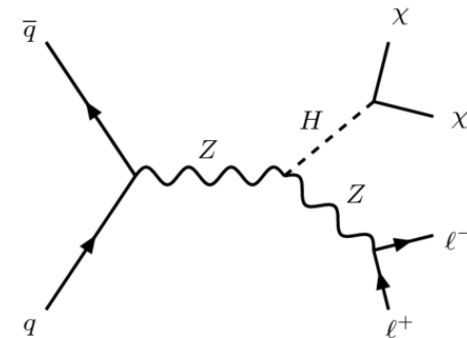




example related studies/processes and possibilities



- $H \rightarrow Z_d + Z_d$
 - no Z constraint
- invisible Higgs searches
 - mono- X
 - $q\bar{q} \rightarrow \gamma H \rightarrow \gamma + \text{invisible}$
 - $gg \rightarrow gH \rightarrow g + \text{invisible}$
 - $q\bar{q}$ or $gg \rightarrow ZH$; $q\bar{q} \rightarrow W^\pm H$
 - jets and missing E_T in final states
- hidden valley models
 - lepton jets
 - highly collimated lepton pairs (an Exotics subgroup)
 - optimal for low mass dark vector boson searches





summary



- four lepton final state one of the Higgs 'discovery channels'
- may provide a portal to a 'dark' or 'hidden sector'
- one example (being investigated presently)