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# Response to questions from reviewers on Fermilab Theoretical Physics

# Question 1

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We would like to better understand the connection to Fermilab theory group.  
How many physics initiatives from LPC were inspired by discussions with the theory group?

- The group makes many contributions across the LHC program, CMS/ATLAS/LHCb.
  - for this review have focussed particularly on LPC cross-cut.
- Authorship: original work by **Lykken, Vega-Morales** and LPC collaborators inspired CMS study **CMS-HIG-14-018** with Vega-Morales as co-author.
- Beyond “inspiration” actively engaged in experimental analyses in several ways:
  - proposed analysis strategy, e.g. idea for a new type of search.
  - helped in its implementation, e.g. supplied Madgraph files for event simulation.
  - aided in interpretation of results, e.g. comparison with theoretical predictions.
- **Fermilab theorists initiated and participated in >10 LPC analyses in last 3 years**
  - broad range of topics: Higgs studies, dark matter searches, SUSY, exotica.

# Example: light stop searches

- Light stop searches fruition of initial work in 2008.

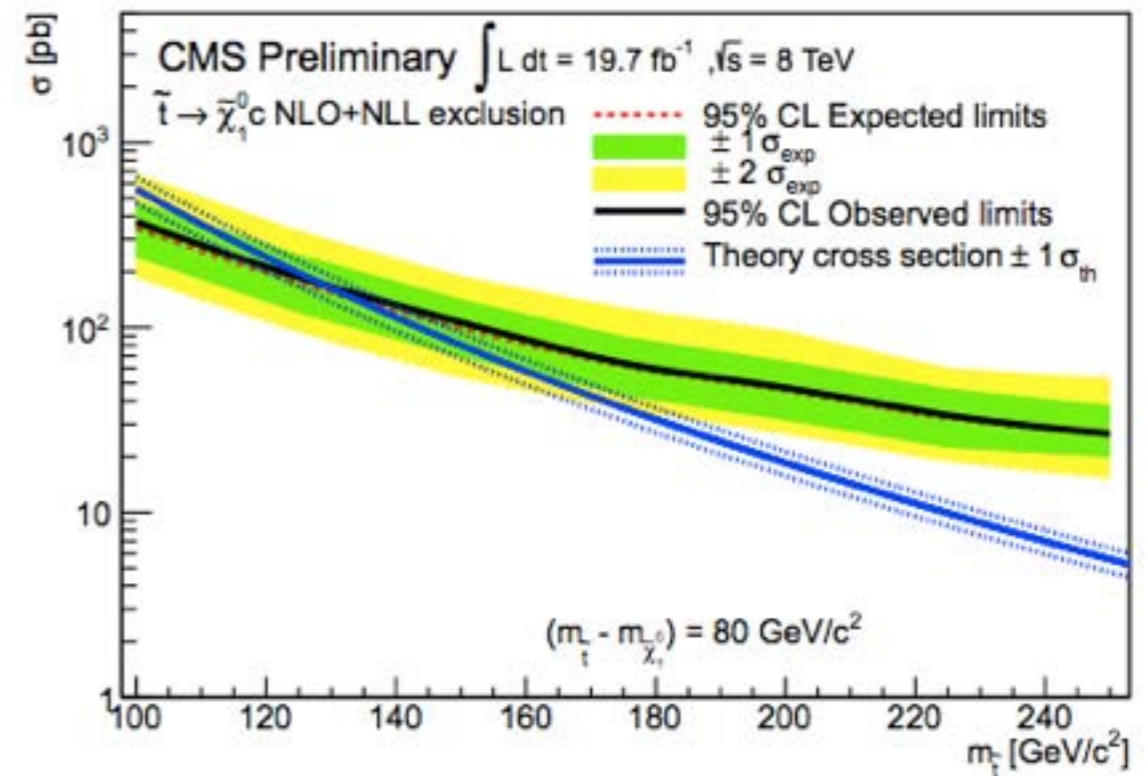
ANL-HEP-PR-08-46  
EFI-08-22  
FERMILAB-PUB-08-269-T

Light Stop Searches at the LHC in Events with One  
Hard Photon or Jet and Missing Energy

M. Carena<sup>1</sup>, A. Freitas<sup>2,3,4</sup> and C.E.M. Wagner<sup>3,4</sup>



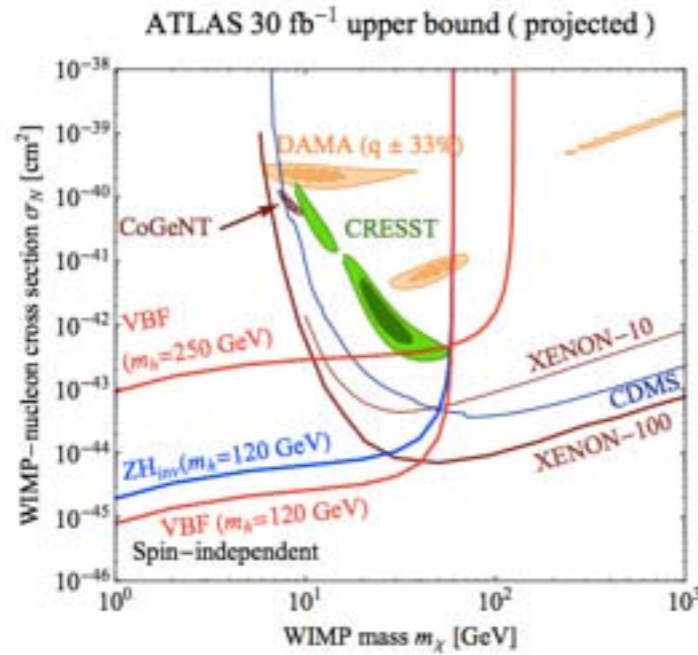
**CMS-SUS-13-009**: Search for top squarks decaying to a charm quark and a neutralino in events with a jet and missing transverse momentum



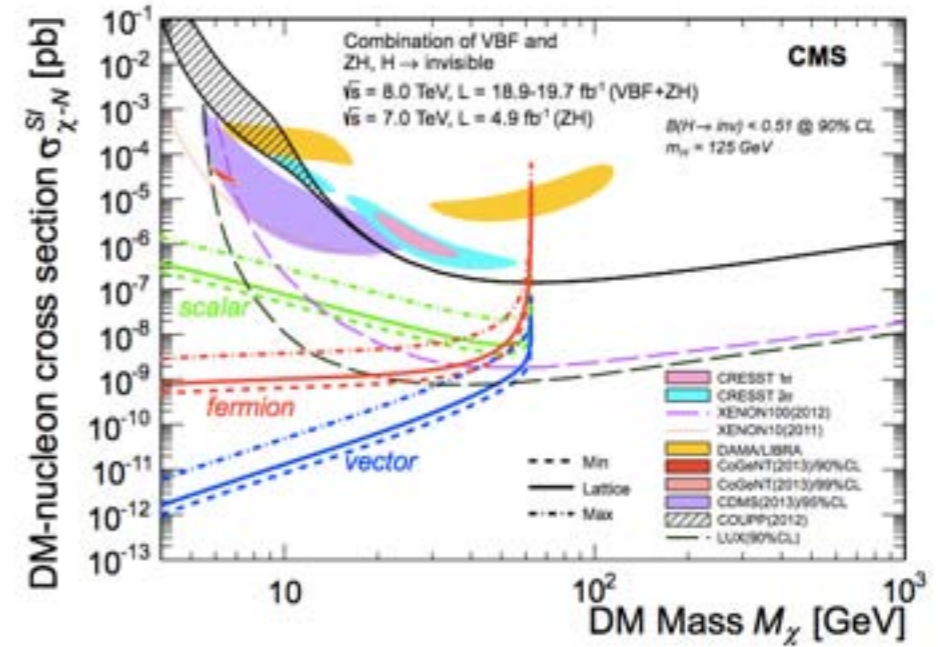
# Examples: dark matter and flavor-violating Higgs decays

DM limits

Fox, Harnik, Kopp, Tsai, 1109.4398

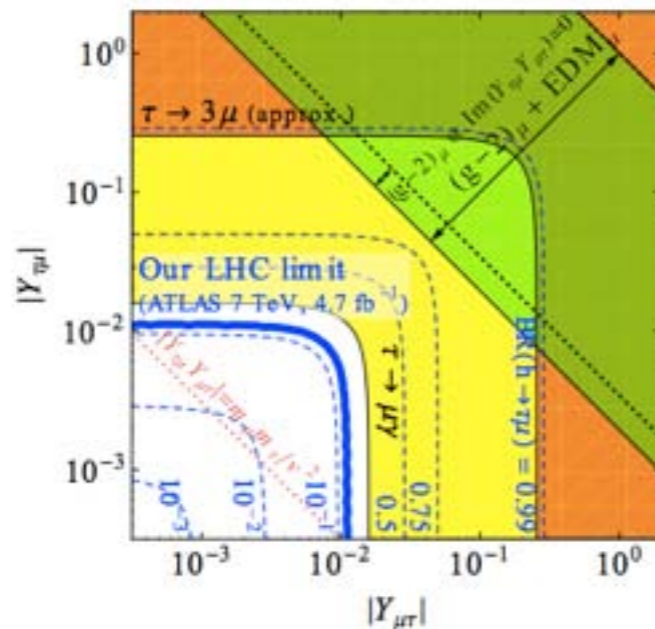


CMS-HIG-13-030

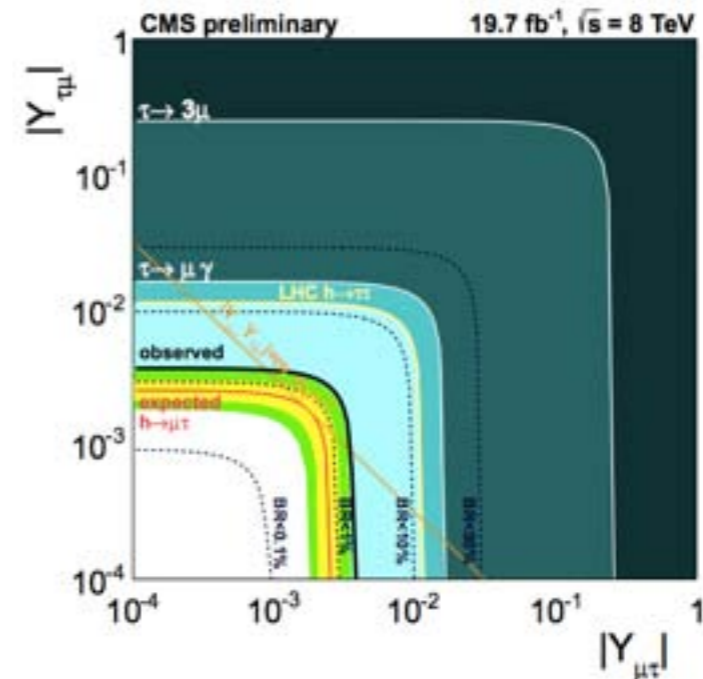


Harnik, Kopp, Zupan, 1209.1397

H → μτ



CMS-HIG-14-005



# Theory-LPC collaborative works

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- **CMS-EXO-12-048**: Dark matter mono-jet. **Patrick Fox and Roni Harnik** were among the theorists who proposed the search. They worked with the local LPC group working on the analysis (headed by **Sarah Al-Malik**) and also provided Madgraph files.
- **CMS-EXO-12-047**: Dark matter mono-photon. **Patrick Fox and Roni Harnik** were among the theorists who proposed the search. They worked with the group working on the analysis (**Mani Tripathi** and exotics convener **JP Chou**) and provided MC events.
- **CMS-EXO-12-052**: Search for pair-produced resonances decaying to jet pairs. **Dobrescu** interacted extensively with **Kai Yi, Rob Harris and Eva Haldakiakis** for over 2 years. Wrote the MadGraph files used by CMS for the signal simulations
- **CMS PAS EXO-12-007**: Search for neutral color-octet weak-triplet scalar particles. **Dobrescu** interacted extensively with **Kaori Maeshima, Aron Soha and Sho Maruyama** for over 2 years. Wrote the MadGraph files for the models targeted in this search, which were key to the CMS signal simulations.
- **CMS-EXO-12-023**: Search for Heavy Resonances Decaying into  $b\bar{b}$  and  $b\bar{g}$  Final States. **Dobrescu** wrote the MadGraph files for simulating the  $b\text{-}b\bar{b}$  resonance signal that were used by **John-Paul Chou**.



# More theory-LPC collaborative works

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- **CMS-HIG-14-002**: Higgs width constraint. **Campbell and Ellis** worked with **Yanyan Gao and Andrei Gritsan** to provide analytic expressions for matrix elements that were incorporated into matrix element method algorithms. Provided capability for generating events in MCFM for use in analysis.
- **CMS-HIG-14-005**: Higgs to tau mu. The search was suggested by **Harnik** in a paper with **Kopp** and Zupan. **Colin Jessop** of ND was a main CMS person on the search.
- **PAS-SUS-12-004**: **Carena** et al (Light stau phenomenology) triggered interest in the search for light staus within the LPC, specifically **Eva Halkiadakis**.
- **CMS-HIG-12-033** and **CMS-HIG-13-021**: inspired by **Carena** et al (Benchmark scenarios for Additional Higgs searches): and discussions with CMS/LPC members , specifically with **Landsberg**.
- **PAS-SUS-13-009** and others: recent results from ATLAS and CMS collaborations on stop searches in mono-photon and mono-jets based on original proposal by **Carena** and Freitas (Light Stop Searches at the LHC in Events with One Hard Photon or Jet and Missing Energy). Discussion with LPC members on the topic in the past years (**Sarah Malik**).

# Ongoing theory-LPC collaborative works

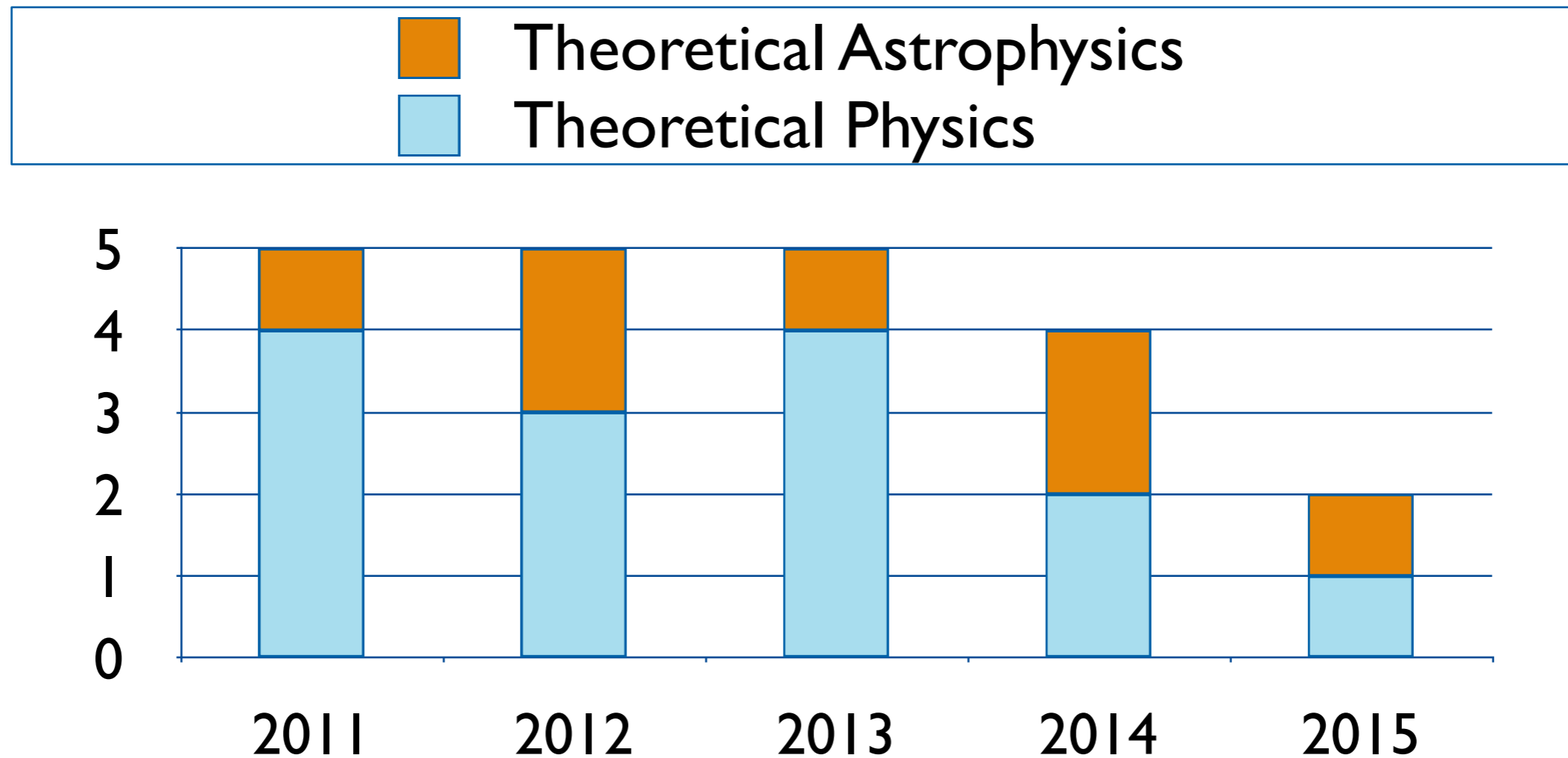
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- Not yet come to fruition but in the pipeline.
- Razor search for DM. CMS is finalizing this search which was proposed by [Harnik and Fox](#). They also provided MG files. [Perini](#) is the CMS contact person.
- CP violation in Higgs to tau tau. A CMS team is currently investigating the feasibility of this search which was suggested by members of the theory group. [Andrew Askew](#) of CMS is involved in the study (c.f. arXiv: 1501.03156).
- Four top final state (pairs of t tbar resonances). [Dobrescu](#) has given [Francesco Yumicheva](#) MadGraph files, and had extensive discussions with him and his student.
- DM pair production in association with a boosted hadronic W or Z. [Dobrescu](#) has suggested this search to [Caroline Milstene and Sudhir Malik](#) in May 2012. Provided them with MG files and had many communications on this subject until Sep. 2013.
- Searches in the W+jets final state. [Dobrescu](#) has suggested various new particle searches to [Ilya Osipenkov and Kalanand Mishra](#), and have written MG5 files for them.

## Question 2

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What is FNAL policy regarding postdoc/student mentoring onsite?  
(Just describe how you mentor the Graduate Fellows.)





# Graduate Student Research Program in Theoretical Physics

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- Students arrive with well-defined projects and committed mentors.
  - Application requires summary of agreed-upon research project .
  - Selection based on project merit & feasibility, letters of support, balance of between research areas, etc...
  - University advisors updated and often involved.
- Students leave enriched and prepared for postdoctoral positions.
- All student fellows have obtained very good postdocs:
  - Gordan Krnjaic returning to Fermilab as **Schramm Fellow**;
  - Roberto Vega-Morales received **Sakurai dissertation award**.
- Positive feedback from past fellows and advisors.

# Typical student projects

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- Lattice QCD students tend to be in the middle of a multi-year project involving the Fermilab mentor.
- Perturbative QCD students tend to work on a  $\sim 1$  year project, as specified in the plan.
- Model building and pheno students often work on several short projects with mentors, other staff, other students and/or postdocs.
- Astro students adhere to each of these models, depending on the research.

## Question 3

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The Fermilab theory group proposed several new initiatives. These include an expanded visitor program, at least one new staff hire in the area of neutrino phenomenology, a restoration of their visiting graduate student program, as well as a restoration of a 1:1 faculty:postdoc ratio. Can the group prioritize these ideas?

- As resources become available, priority order is as follows:
  1. Hire junior neutrino theorist(s) once we can find the right person(s)!
  2. Enhance visitors program / increase number of RAs
    - RA's quantized and 3-year commitment
    - Visitors more continuous
  3. Graduate student fellows program

# Bonus question: current positions of past theory RAs

<http://theory.fnal.gov/people/ellis/alumni.html>

