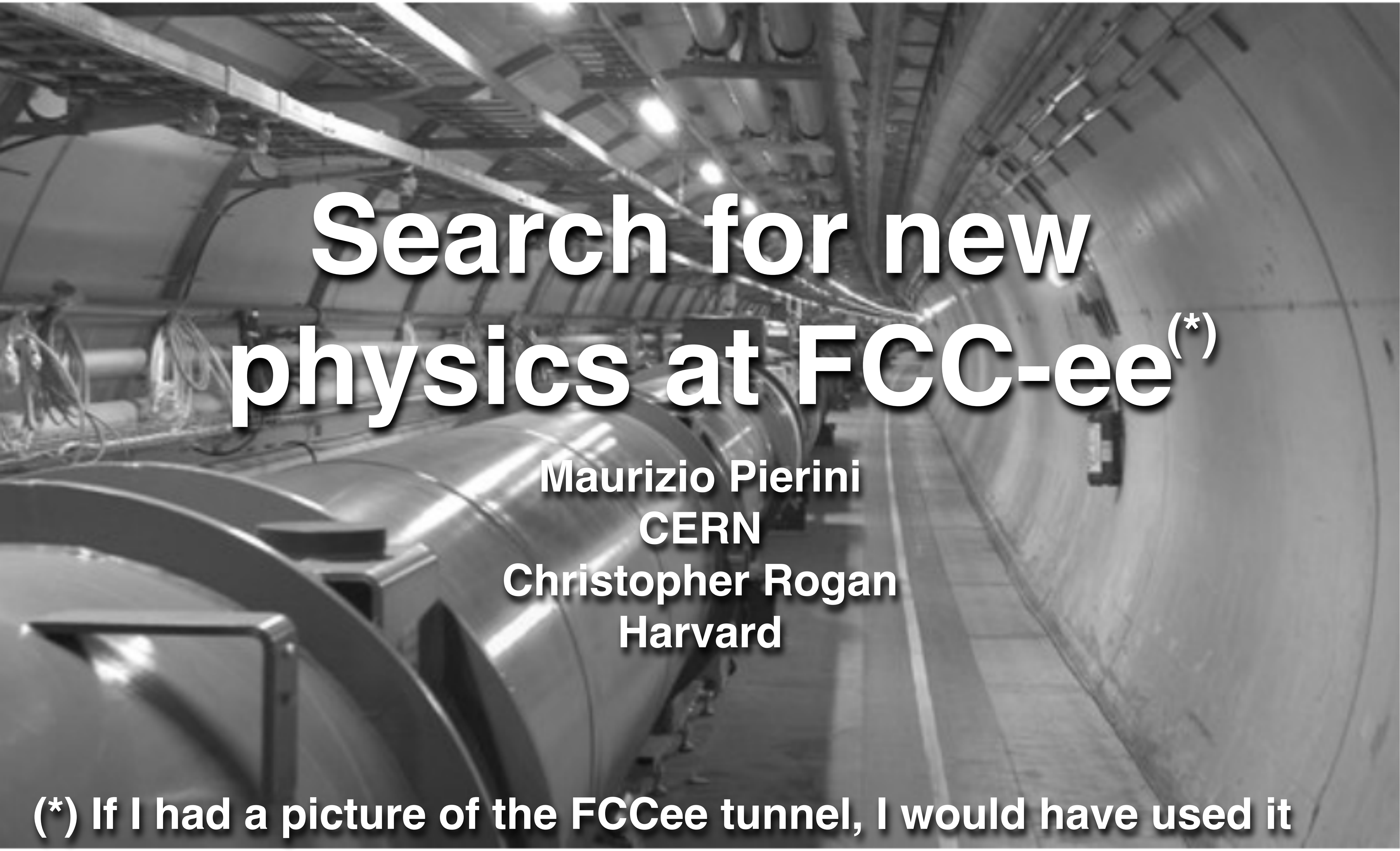


Search for new physics at FCC-ee(*)

Maurizio Pierini
CERN
Christopher Rogan
Harvard

(*) If I had a picture of the FCCee tunnel, I would have used it

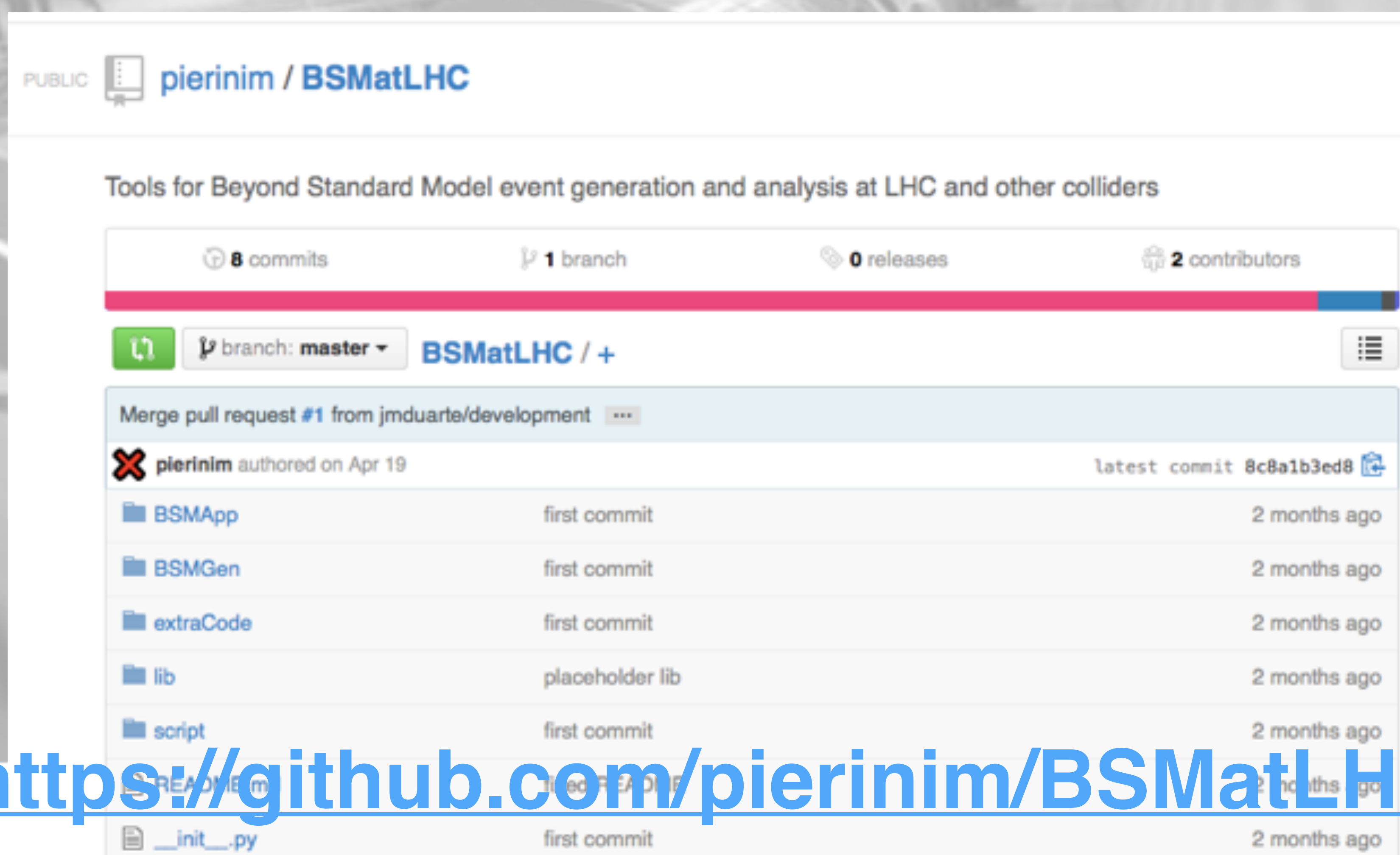
Outine

- Event Generation
  - home made tools we played with so far
- SUSY models (searches with Missing Energy)
- Monophoton/monoZ signatures
- Displaced signatures
  - implications for detector design (e.g., trigger)?
- Conclusions

Event Generation

What we have so far

- Tool developed to run Pythia8 for event generator (LHC, adapted for FCCee & FCChh)
- Scripts to handle scans (Simplified Models, resonance scans, Standard Model processes)
- Several Options to read and process the events



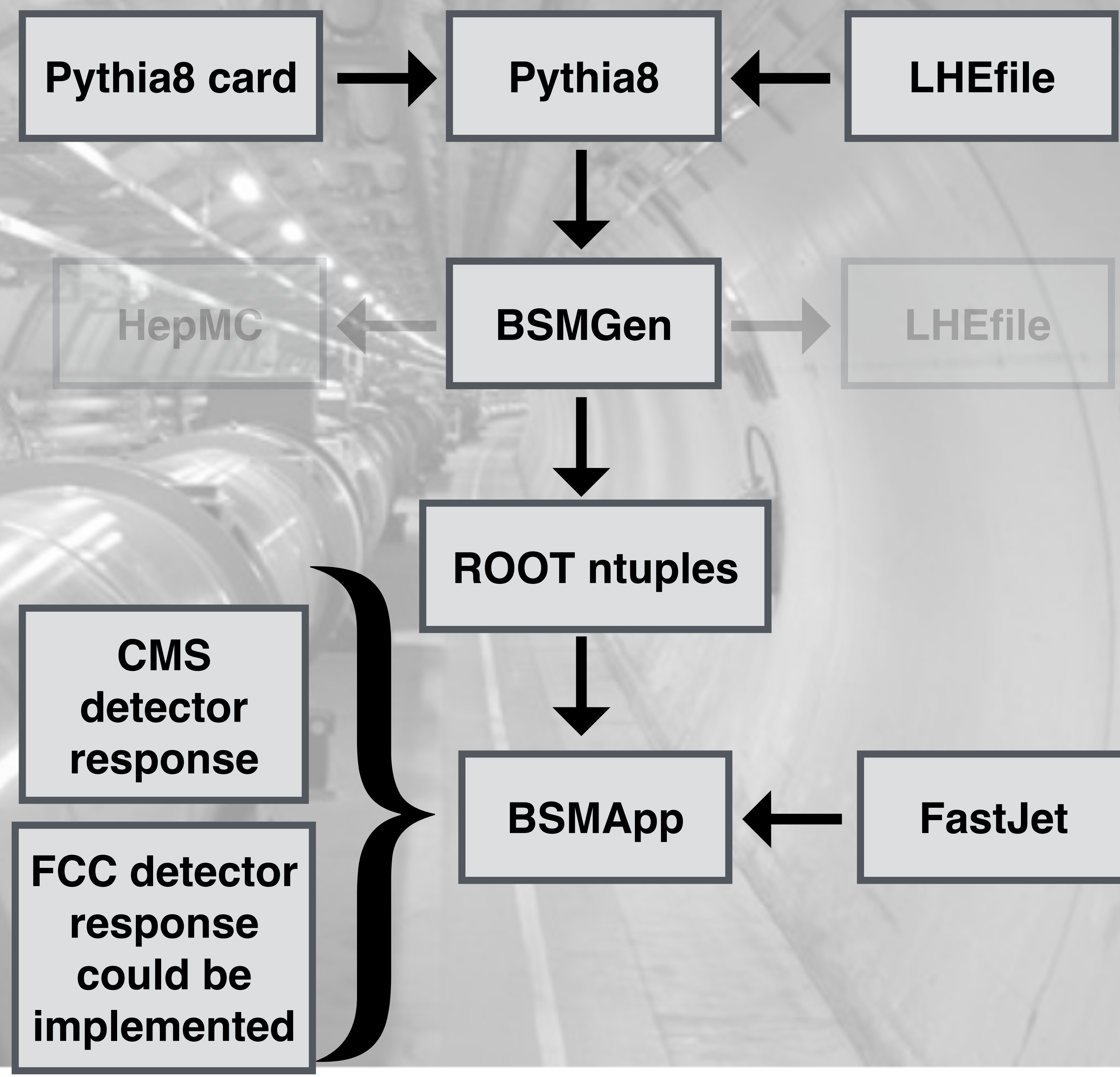
https://github.com/pierinim/BSMatLHC

Event Generation

- We start from SUSY LH files, where the spectra of SUSY particles is generated
- ee collisions are generated with PYTHIA8
- Several options to further process the events
  - **OPTION1**: shower the events & ntuplize them (for GEN-LEVEL study)
  - **OPTION2**: save the events in StdHEP or HepMC format and process with DELPHES (once we have a blessed FCCee card. Did someone check the existing one?)
  - **OPTION3**: Save the events as LHE files, which can be loaded in the framework (when ready), showered in pythia, and reconstructed with G4 detector simulation

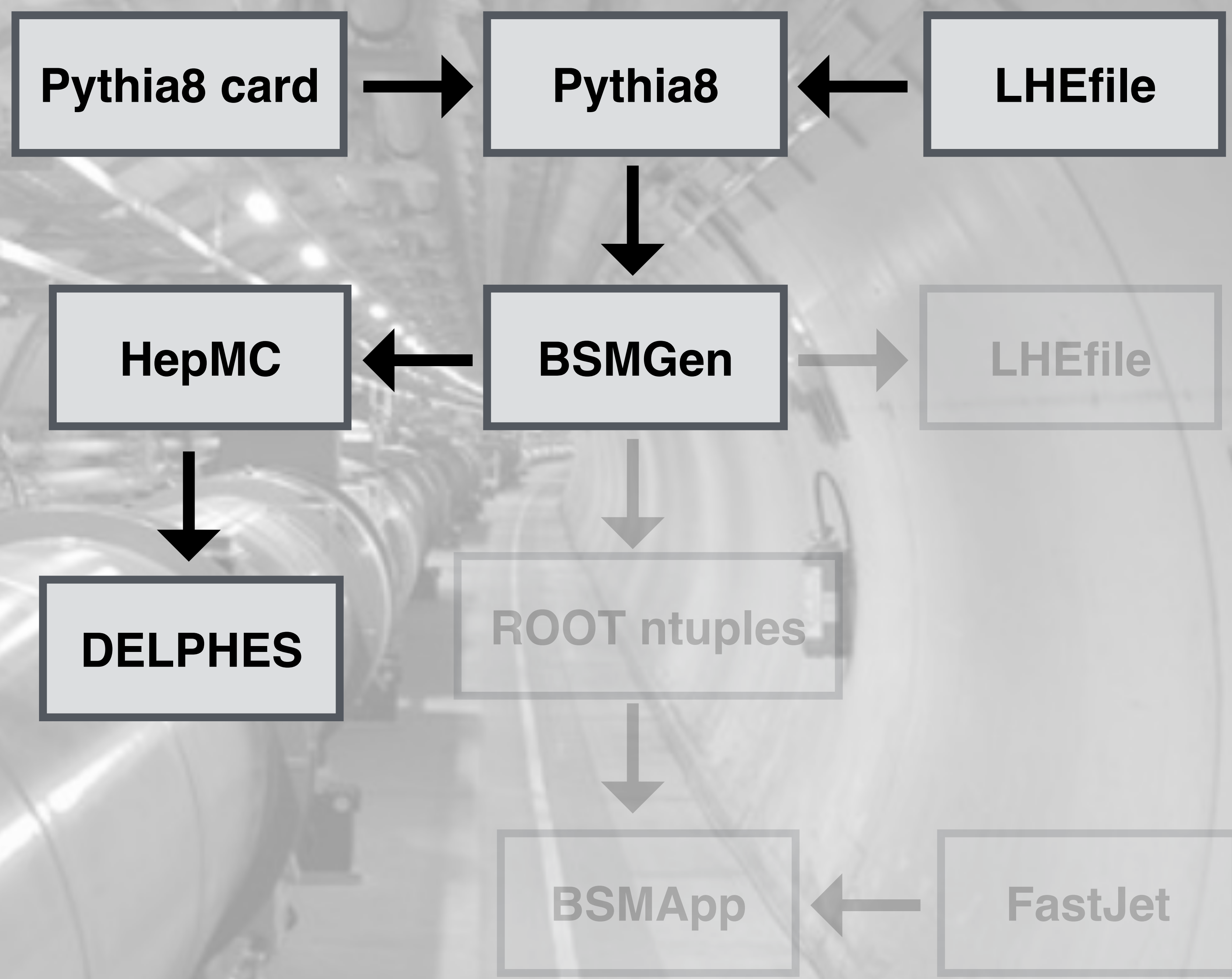
Option 1

- Homemade package (**BSM@LHC**), already developed for some LHC pheno study
- Parametric simulation of the detector response
- Interfaced to Pythia or to LHEfiles
- Need some work, but it could be shared to interested people



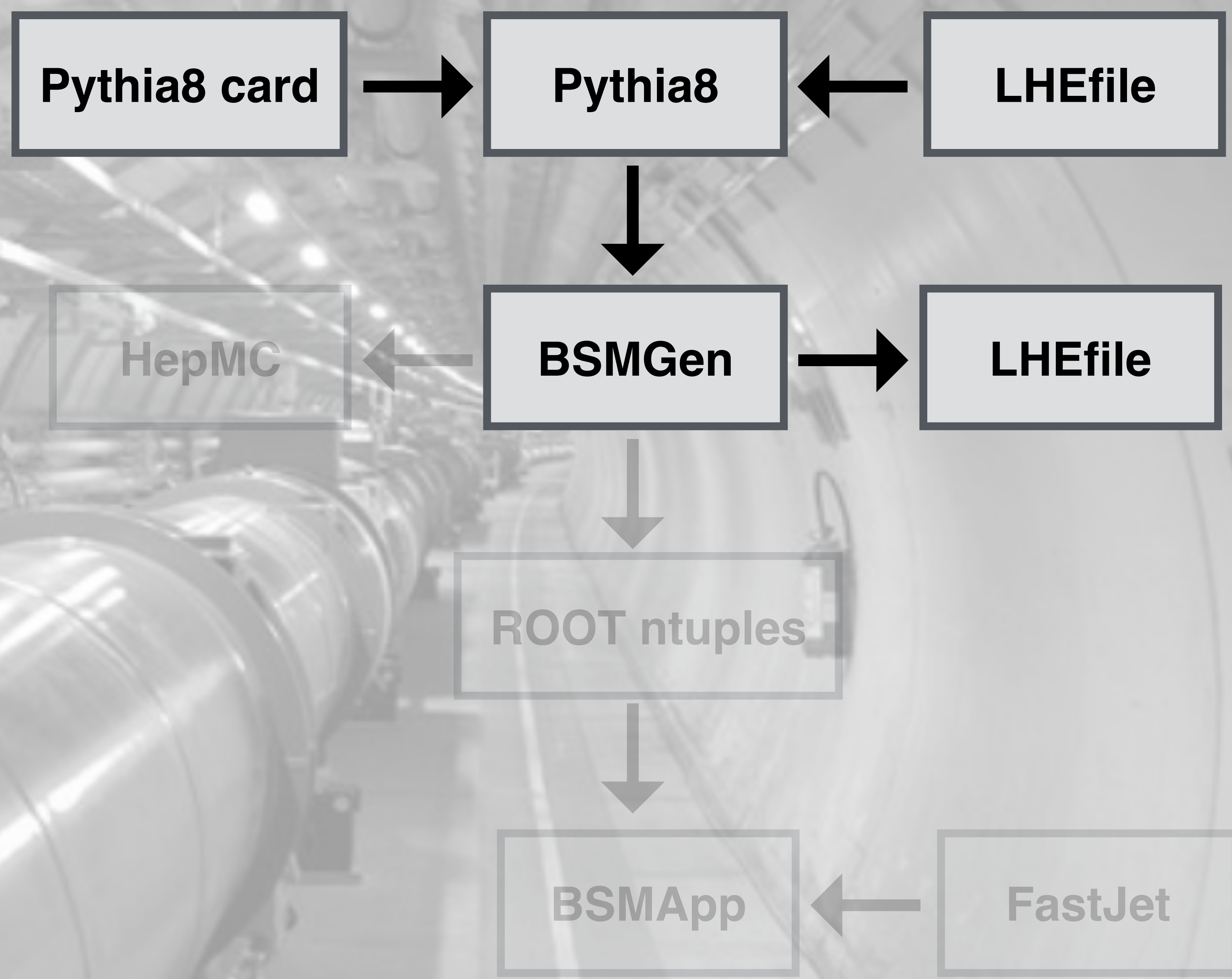
Option 2

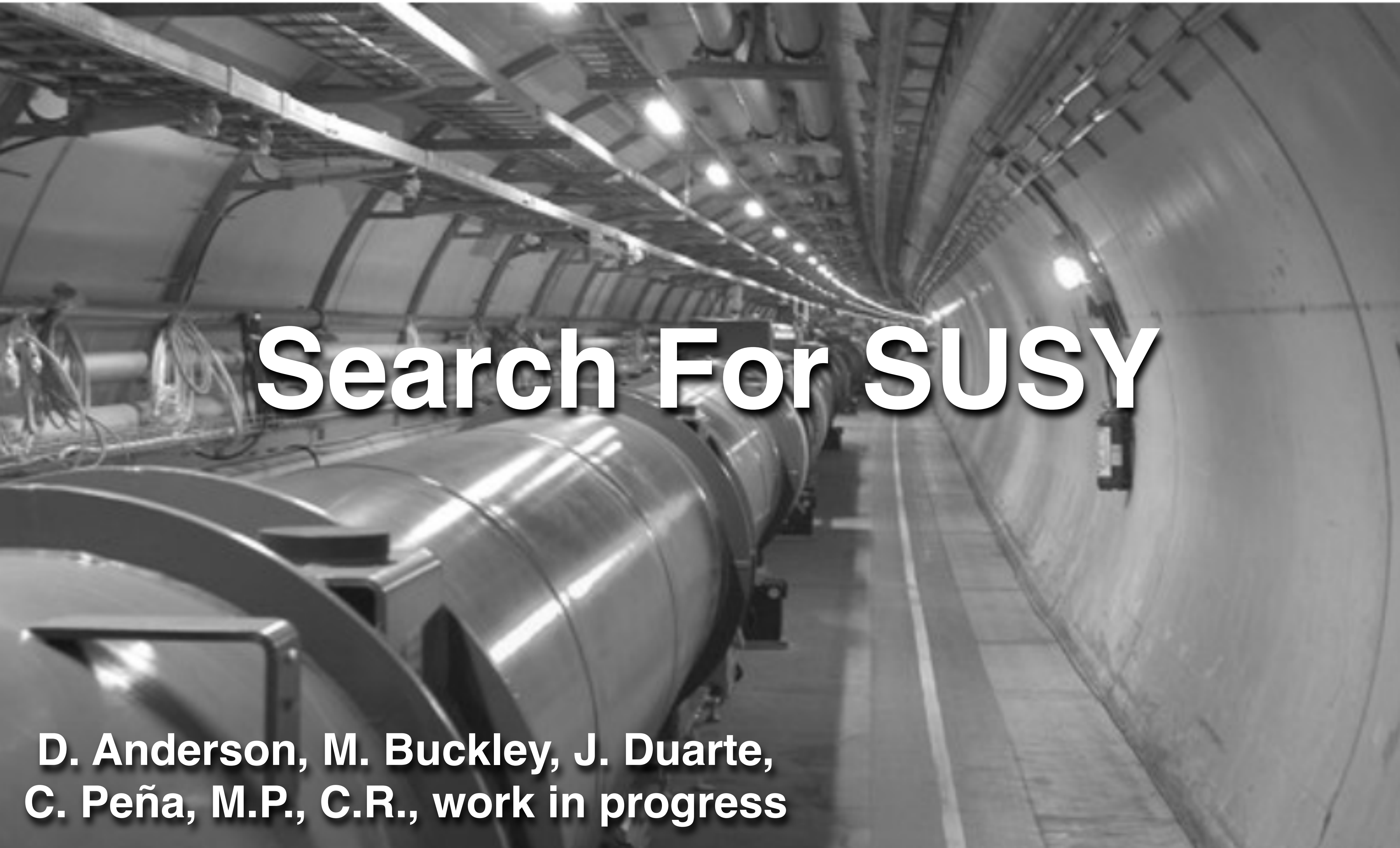
- We can provide the HepMC files (store them where?)
- Do we need first to validate the DELPHES card?
- (to my knowledge) the DELPHES card is a combination of ATLAS&CMS performances
- Is a centralized validation option planned?



Option 3

- Legacy option (waiting for the framework to be developed)
- Can we use some central (EOS?) space @ CERN
- Are people interested to access these files
- (I can keep them on some disk, while waiting for the central framework option)

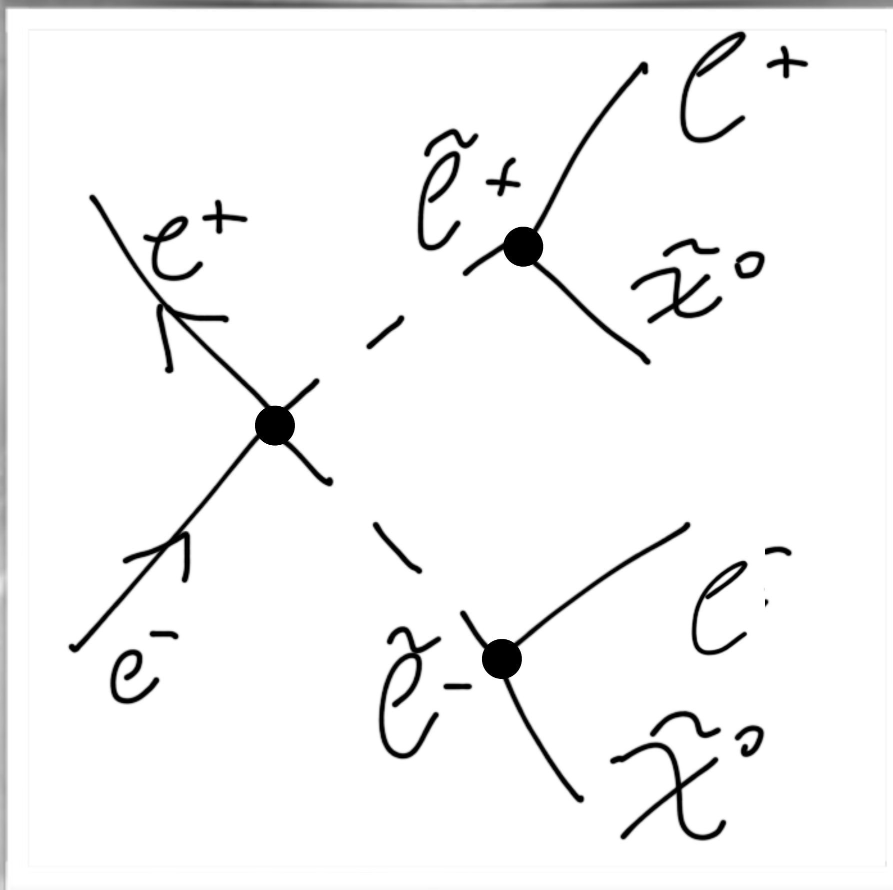




Search For SUSY

D. Anderson, M. Buckley, J. Duarte,
C. Peña, M.P., C.R., work in progress

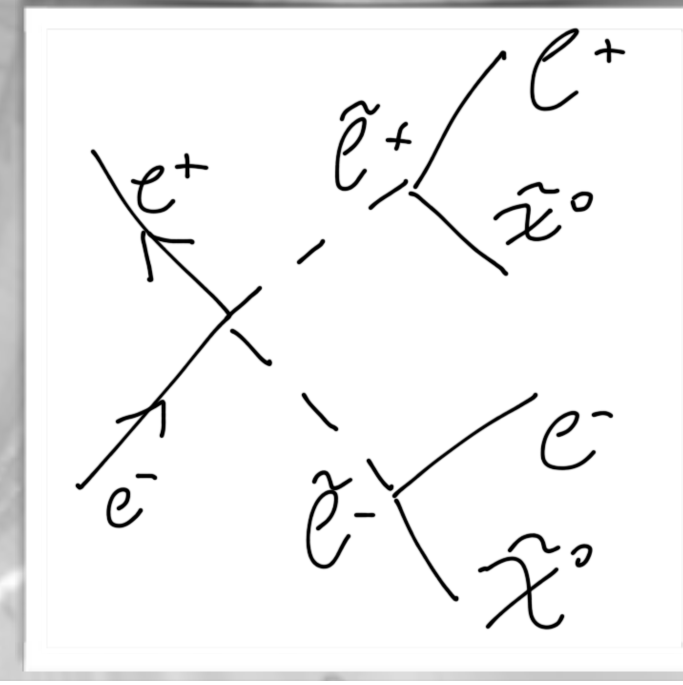
Slepton Production

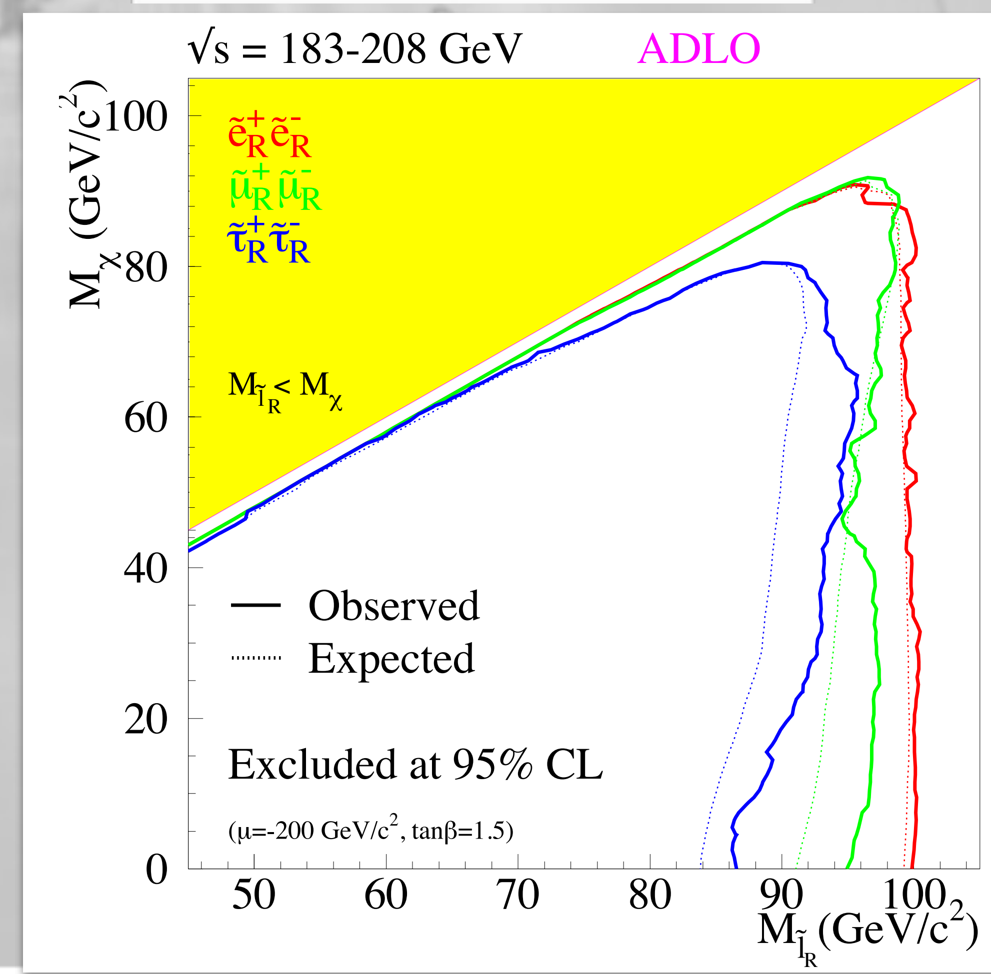


- Dilepton + Missing energy signature
- Can probe Flavor Violation in SUSY
- Established experimental handles
  - Missing energy
  - Visible Mass

Slepton Production

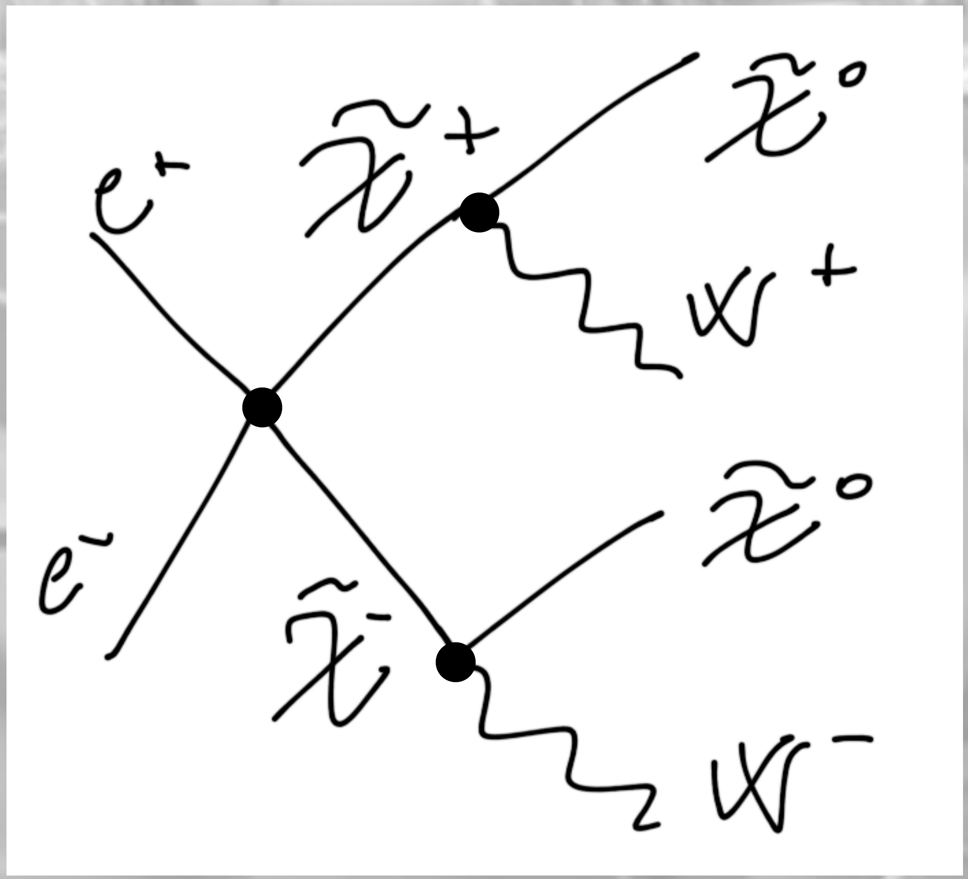
- Dilepton + Missing energy signature
- Can probe Flavor Violation in SUSY
- Established experimental handles
  - Missing energy
  - Visible Mass
- New opportunities (in light of what learned with MET searches at the LHC)?
  - e.g., adapted SuperRazor http://arxiv.org/abs/1310.4827

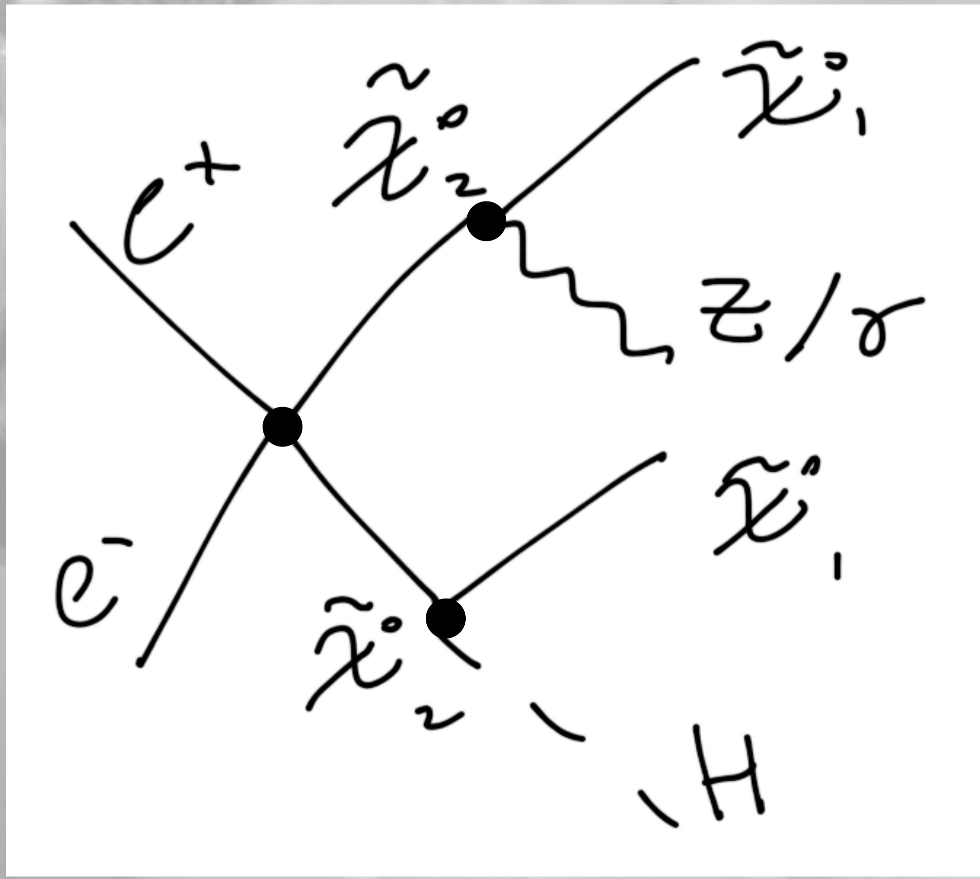




EWkino Production

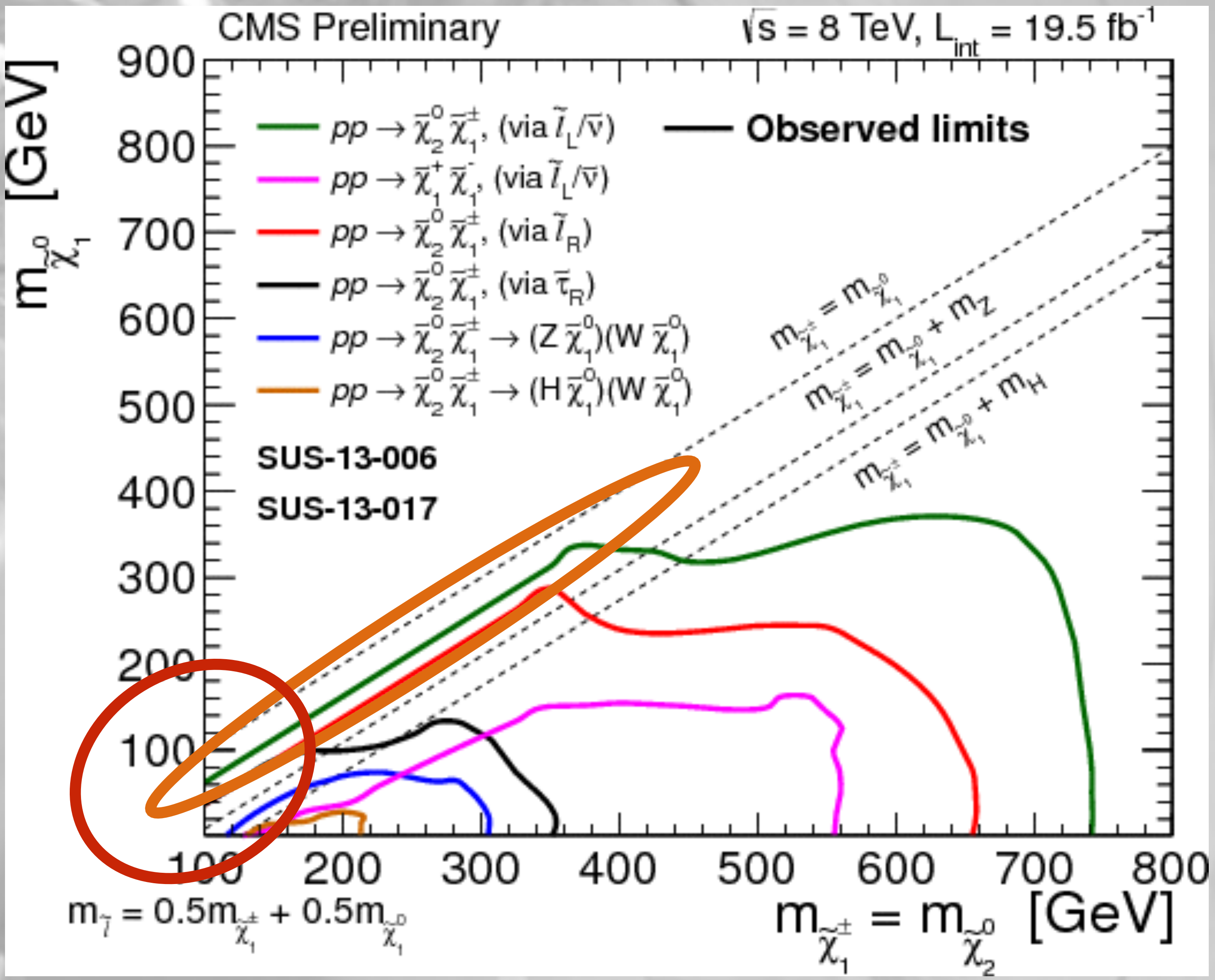
- Several final states (WW, HH, HZ, ZZ, Hɣ, Zɣ, ɣɣ)
- Z pole almost entirely explored. Higher energies still interesting. Final states with Higgs offer a new opportunity
- Unlike the LHC, probed masses are ~ 100 GeV (small kinematic separation from background)



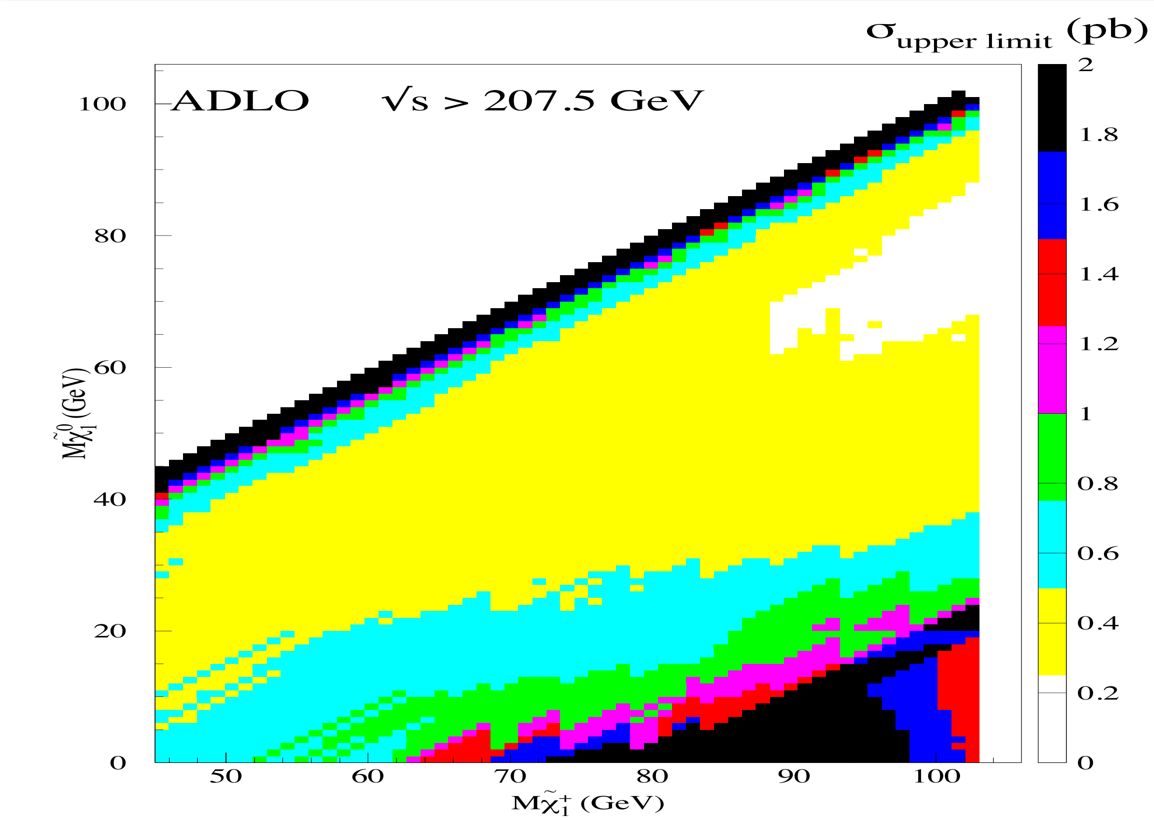


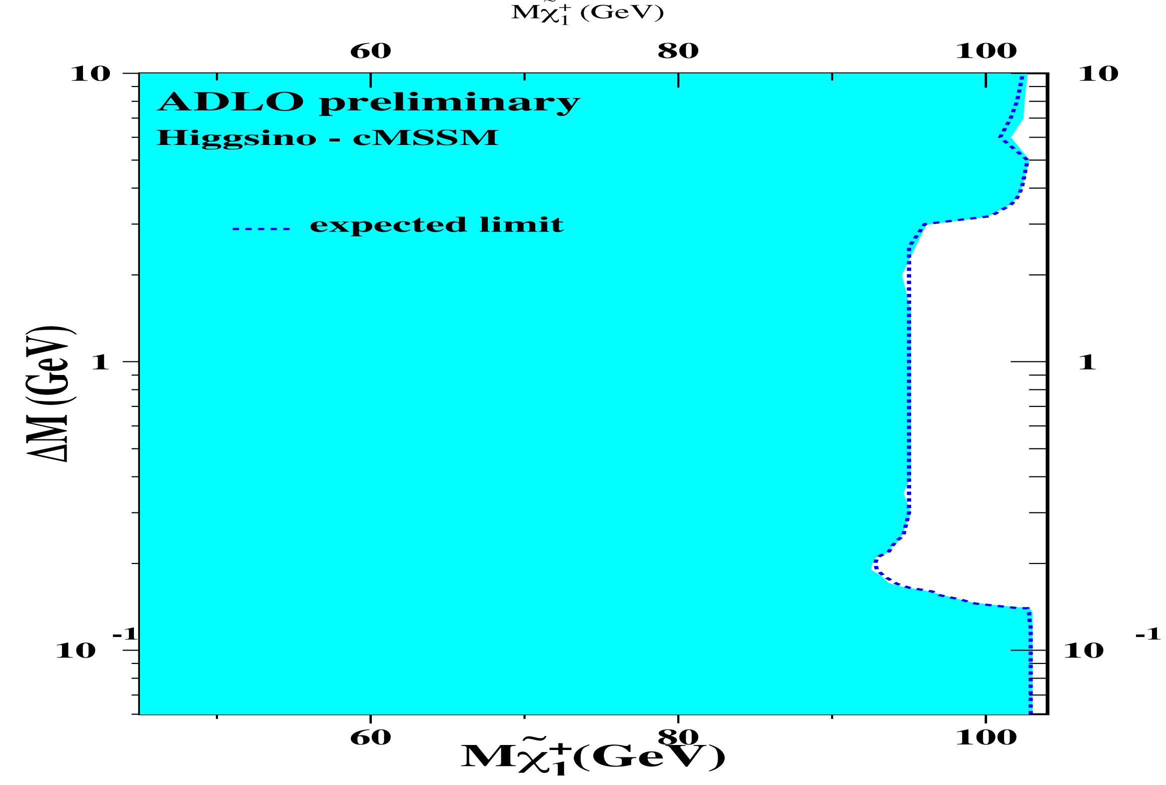
EWkino Production

- The LHC has a remarkable sensitivity to ewkinos
- On the other hand, limits are weaker if no slept on in the cascade
- Two “blind spots”
  - **Compressed spectra** (soft leptons)
  - **low masses** (too much W/Z bkg)

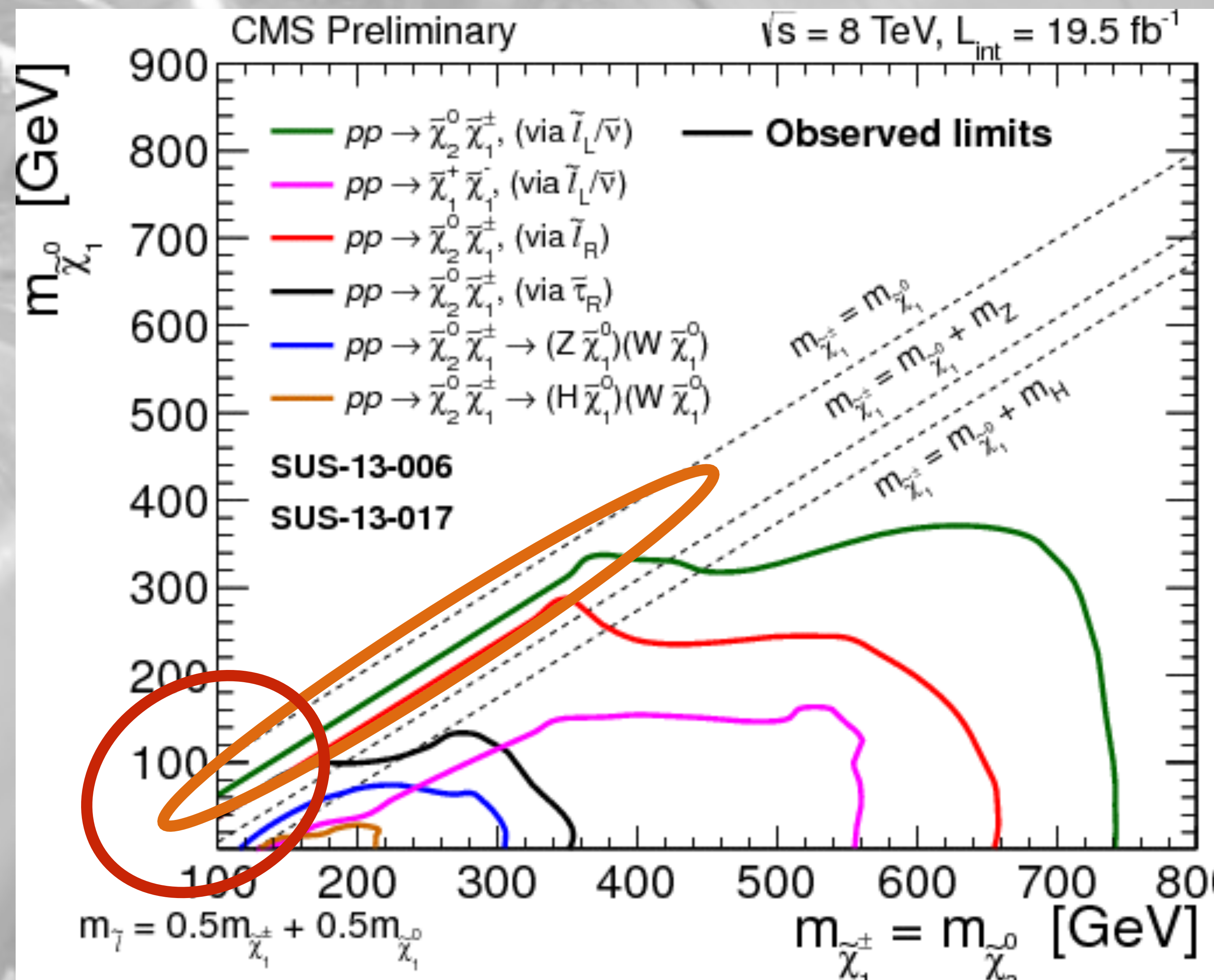


EWkino Production



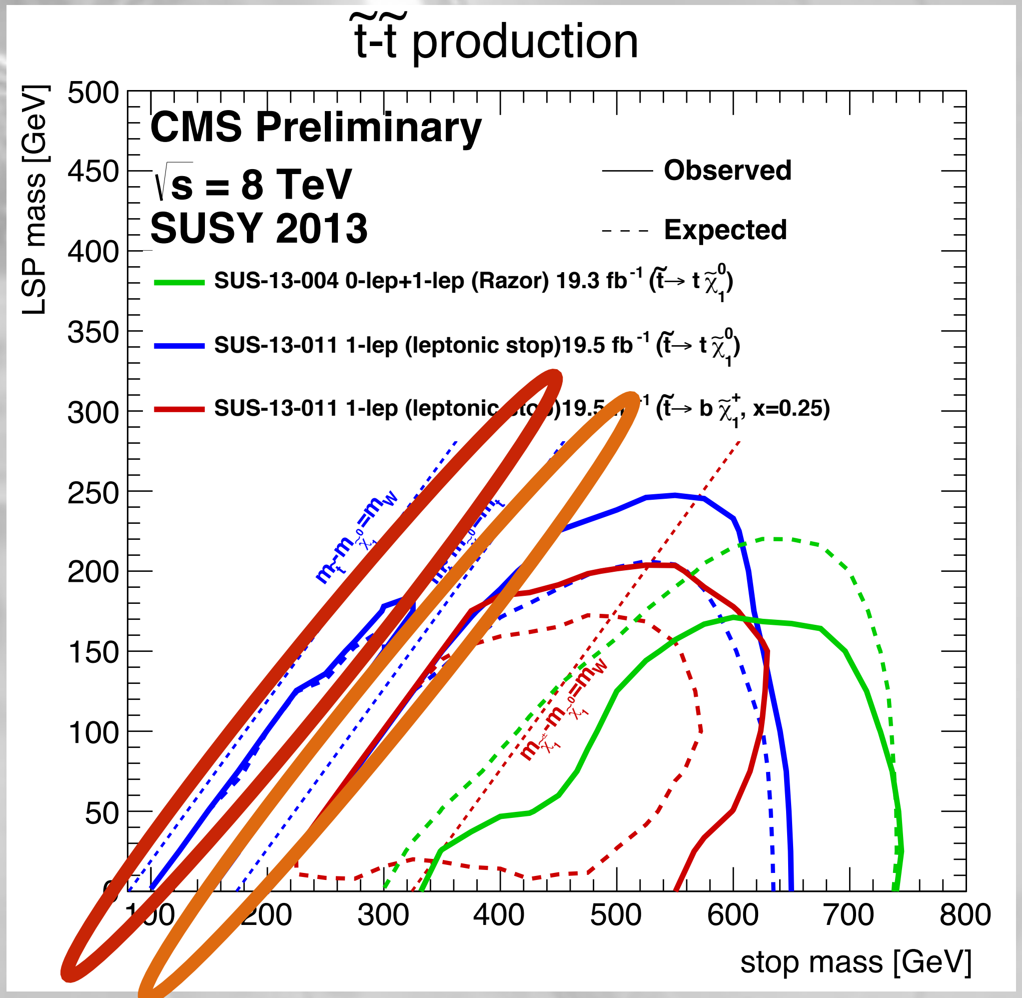


Both regimes were probed at LEP and can be probed with FCCee at any sqrt(s)



Stop ~ degenerate to Top

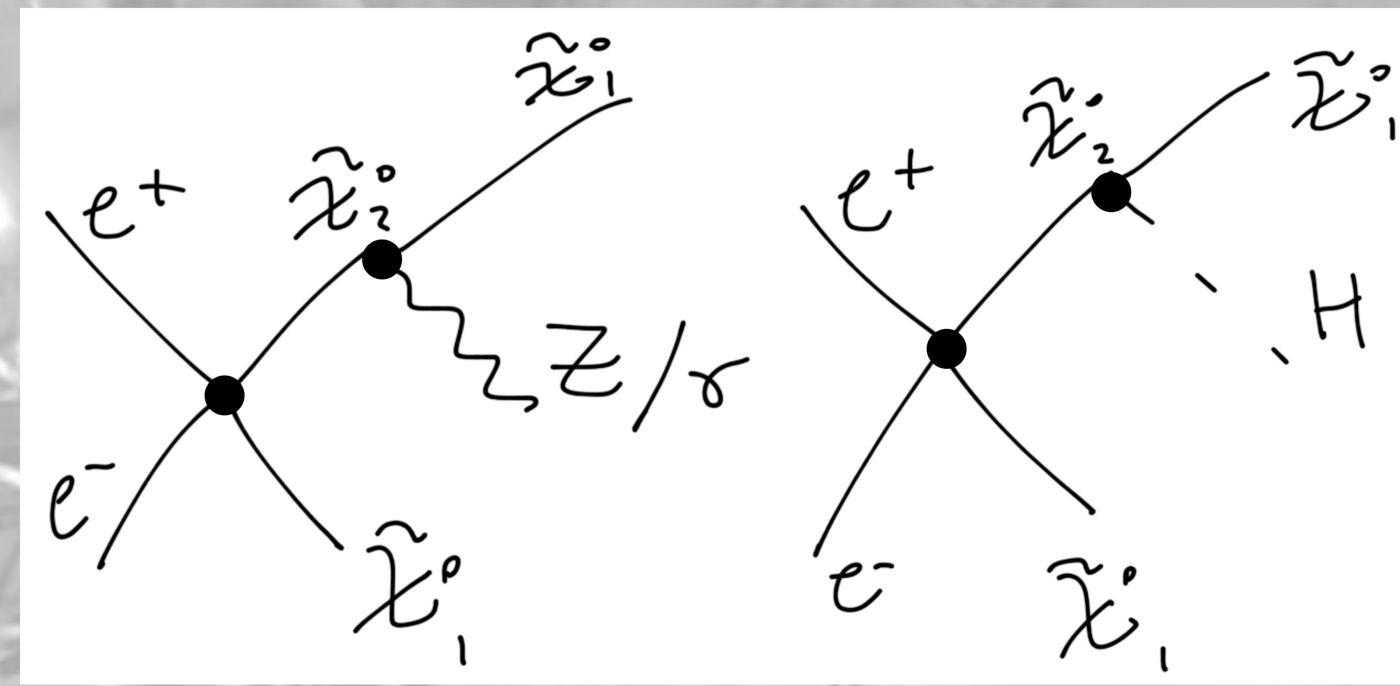
- LHC searches excluded large part of the natural SUSY preferred m_{stop} range (150-250 GeV)
- For m_{stop}-m_{LSP} ~ m_{top} the analyses have a blind spot (signal ~ tt bkg)
- For small mass differences, the LHC search loose sensitivity
- Experimental advantages
  - no other background (e.g., W+jets)
  - Closed kinematic
- In a more clear environment, squarks (scalars) could be better separated from quarks (fermions)
  - visible mass/missing energy
  - angular distribution of top quarks
  - total cross section

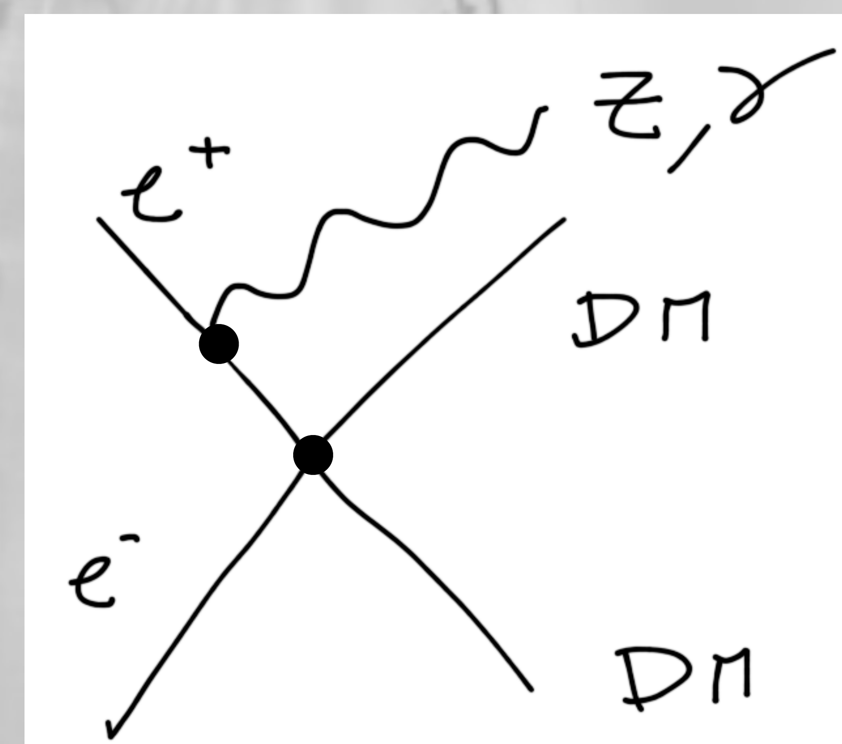



MonoX searches

MonoX

- Signature can originate from decay
    - neutralino cascade decay
- It can be originated from ISR
    - DM production + emission of some particle (e.g., ɣ/Z), depending on DM nature
- MonoZ can originate from Higgs boson decaying to invisible





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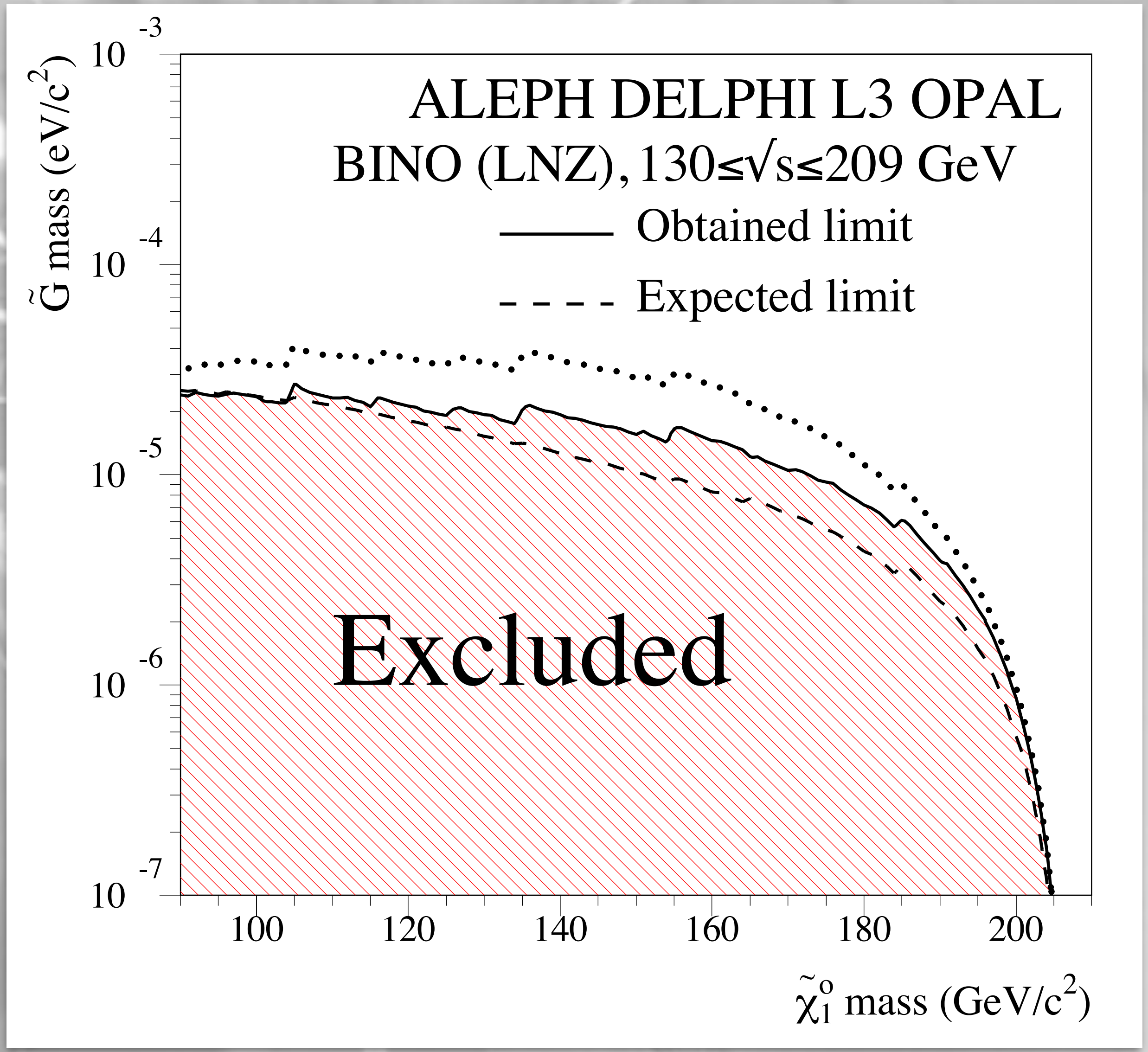
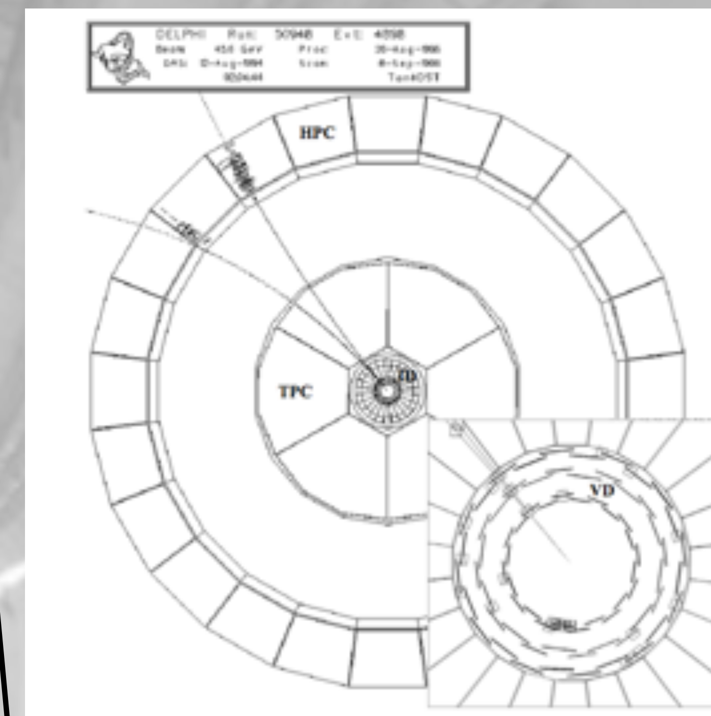
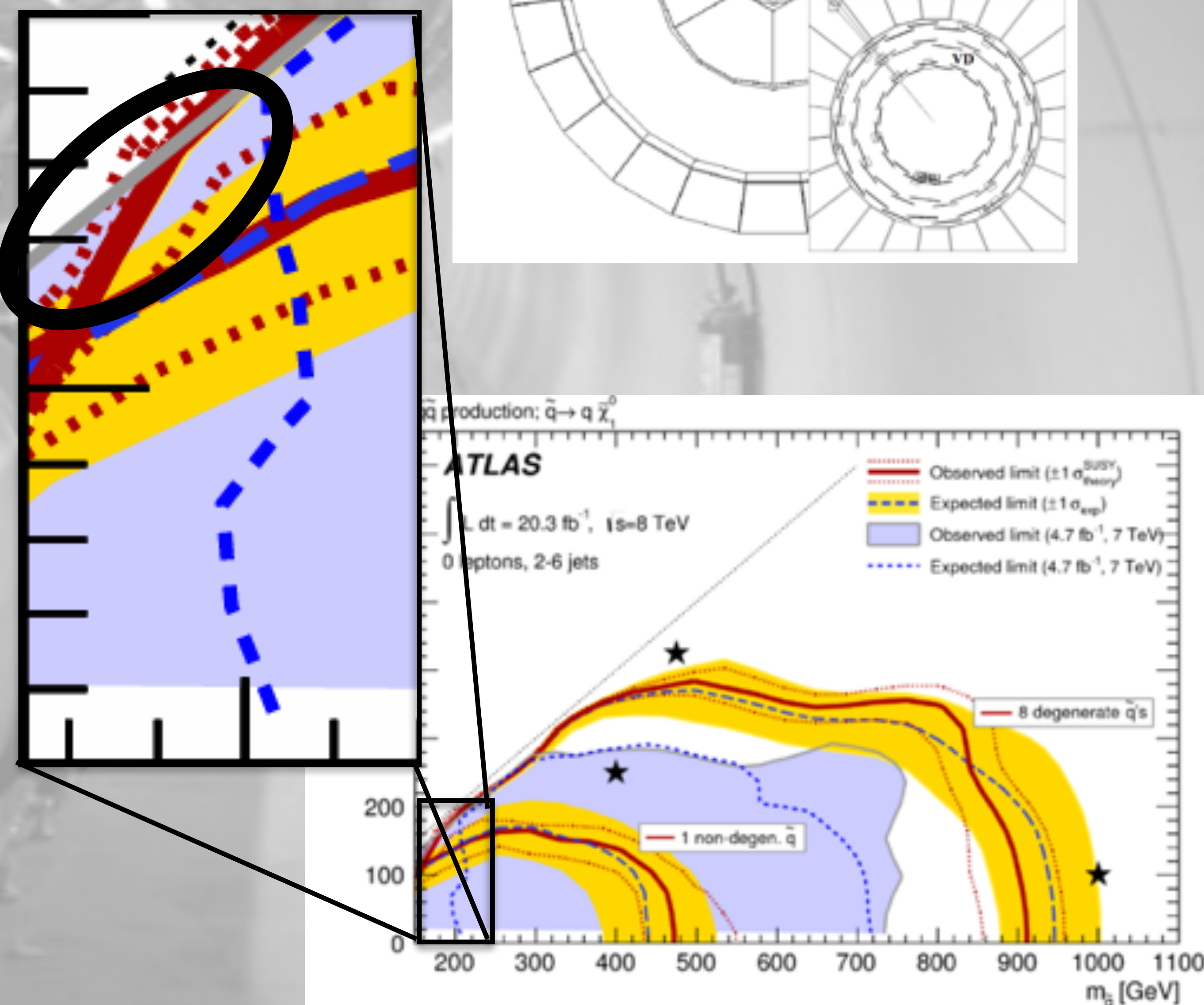


Monojets

- In a leptonic environment, a monojet signature can be extremely interesting
- Several models
  - sterile neutrinos
  - very-compressed light squarks (is the cross section large enough?)
- Exploited with or without additional handles (as in compressed SUSY spectra)
  - disappearing tracks
  - displaced vertices
  - soft particles

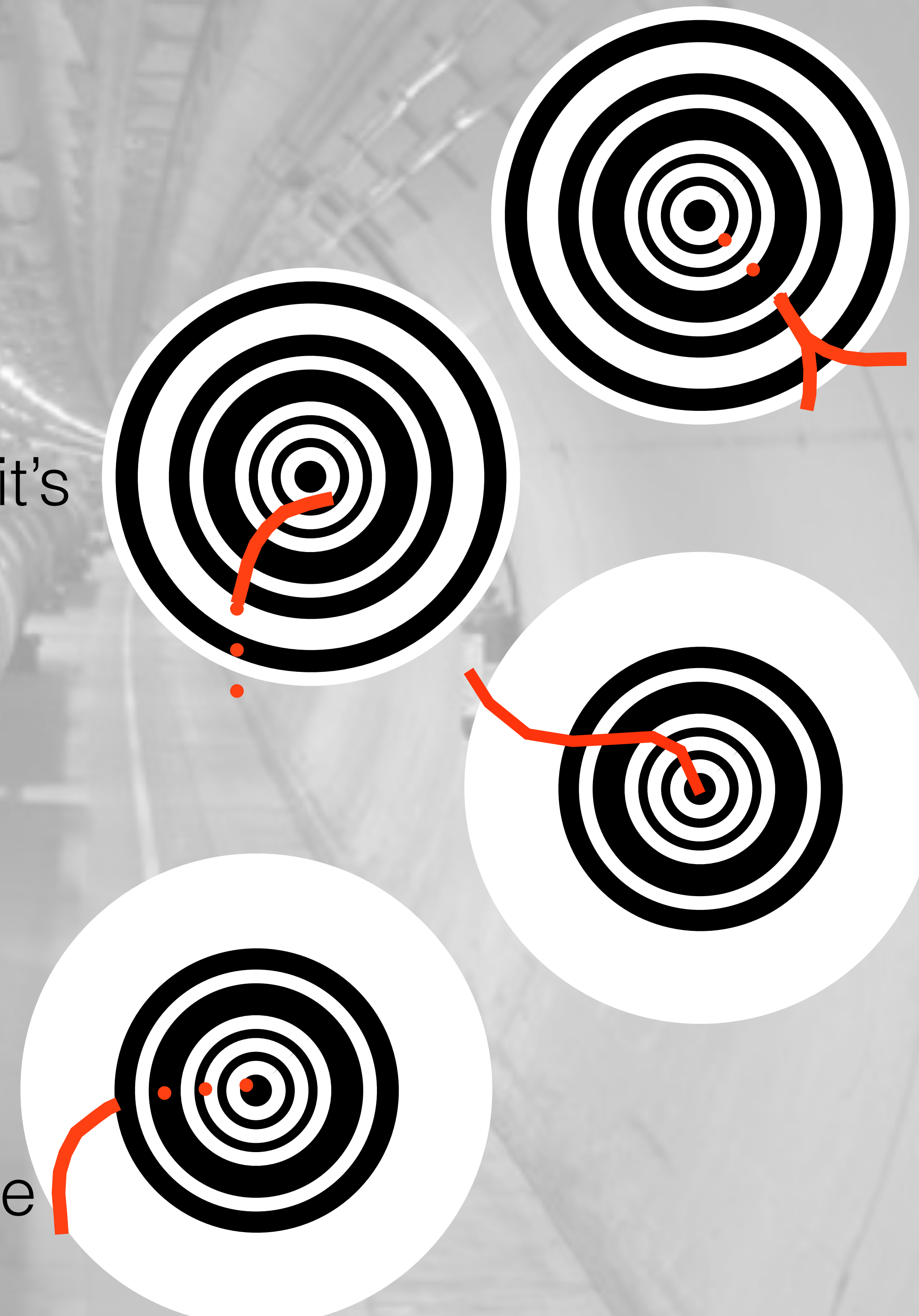





Displaced Signatures

Possible signatures

- Displaced vertices (sterile neutrinos, etc)
- Stopping Tracks
  - at FCCee one could see soft pions(so it's more a track kink)
- Heavy stable charged particles
- Non-pointing (slow) muons
  - background from cosmics (dE/dX in the muon system?)



Problems and Opportunities

- Several NP models predict particles to be produced displaced from the production vex
  - Sterile neutrinos
  - Hidden valley
  - compressed SUSY spectra (with and without R-parity violation
- In the worst case scenario one can ignore this topology (e.g. sterile neutrinos were studied with monojet/acoplanar jets). But this could be limiting
- Assessing the reach on these models requires an established detector geometry
  - a larger (than LEP detectors) tracker volume helps to probe large lifetimes
  - a dedicated trigger might have to be put in place (e.g., when track in the inner volume)
  - constraints on detector design?
- A G4 simulation of the backgrounds

Final Remarks

Background Samples

- Backgrounds are quite common to ewkinos and monoX searches
  - WW/ZZ/ZH, Z+ISRɣ,…
  - can be generated as for signal
  - parametric detector response might be good enough
- Similar considerations for stop search
  - tt production
- For displaced signatures, the background is mainly instrumental
  - detailed detector simulation needed

(Many) Other topics to cover

- This is just the obvious, many more BSM signatures could be tested
  - FCNC Z decays
  - (Rare) Higgs decays to lighter Higgses
  - Rare top decays
- Need to put together a global effort, with more people contributing
  - join the mailing list
  - subscribe to tasks
- Need to act now
  - Evaluate potential impacts on detector design (e.g., trigger & displaced decays)

Synergies with other groups

Need People to Join

https://twiki.cern.ch/twiki/bin/viewauth/FCC/FCCeeNewPhysics

Model	Signature	Beam Energy	References	Contributors
Light top squark Simplified Model	2 x (b W* χ^0_1)	tt-threshold		
$\chi^+ \chi^- / \chi^0_2 \chi^0_2$ Simplified Model	2 x (W*/Z*/H*/gamma χ^0_1)	Z-pole, WW-threshold, 250 GeV, tt-threshold		
$\chi^0_2 \chi^0_1$ Simplified Model	2 x (Z*/gamma χ^0_1)	Z-pole, WW-threshold, 250 GeV, tt-threshold		
$\chi^0_1 \chi^0_1$ Simplified Model	Z*/gamma + 2 x (χ^0_1)	Z-pole, WW-threshold, 250 GeV, tt-threshold		
Heavy Neutrinos	W* lepton + v	Z-pole		

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https://e-groups.cern.ch/e-groups/Egroup.do?egroupId=10122602&tab=3