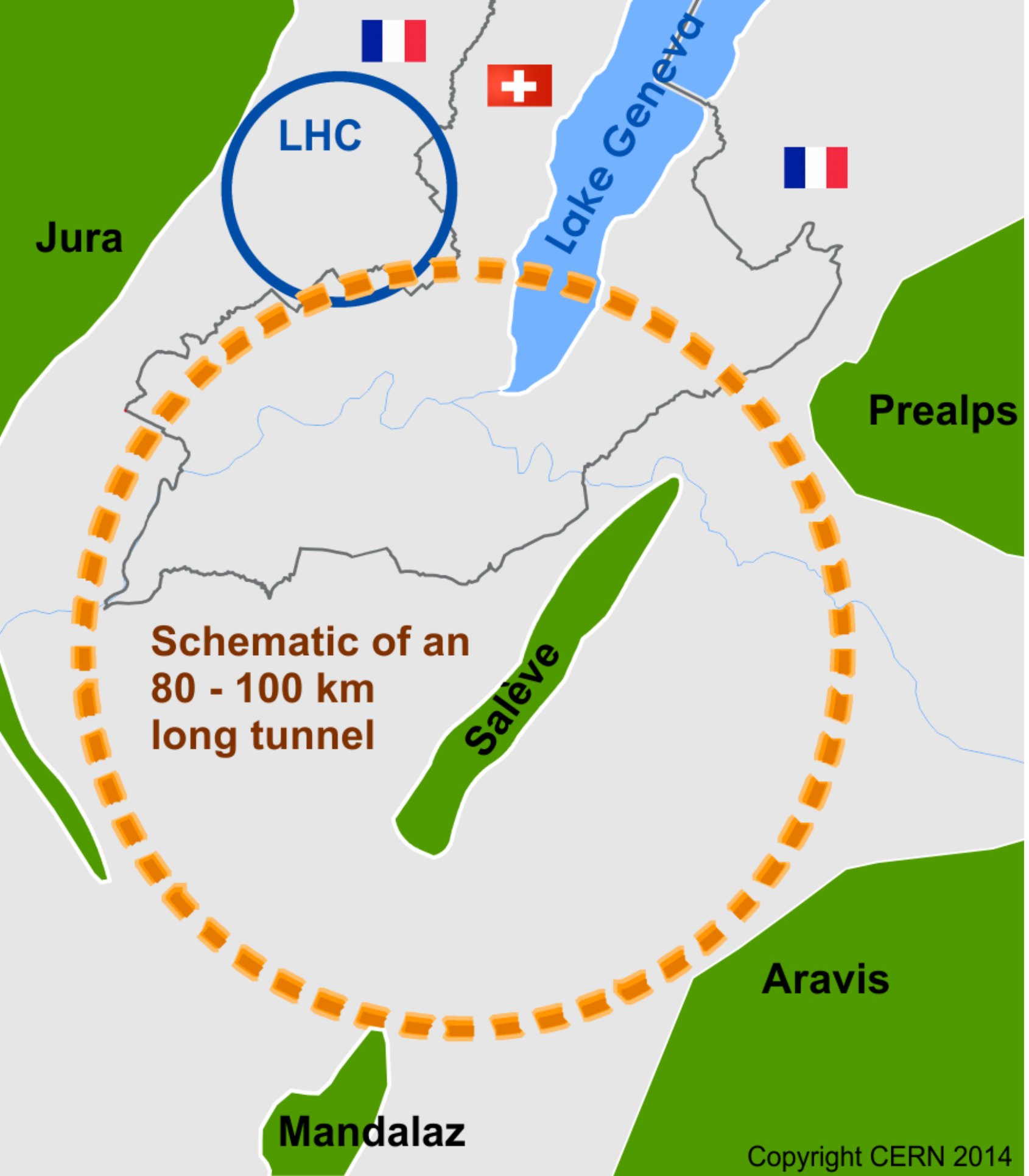


FCC
hh ee he

Dark Matter
FCC-ee

Markus Klute (MIT)
September 23rd, 2020
Snowmass EF10 Meeting

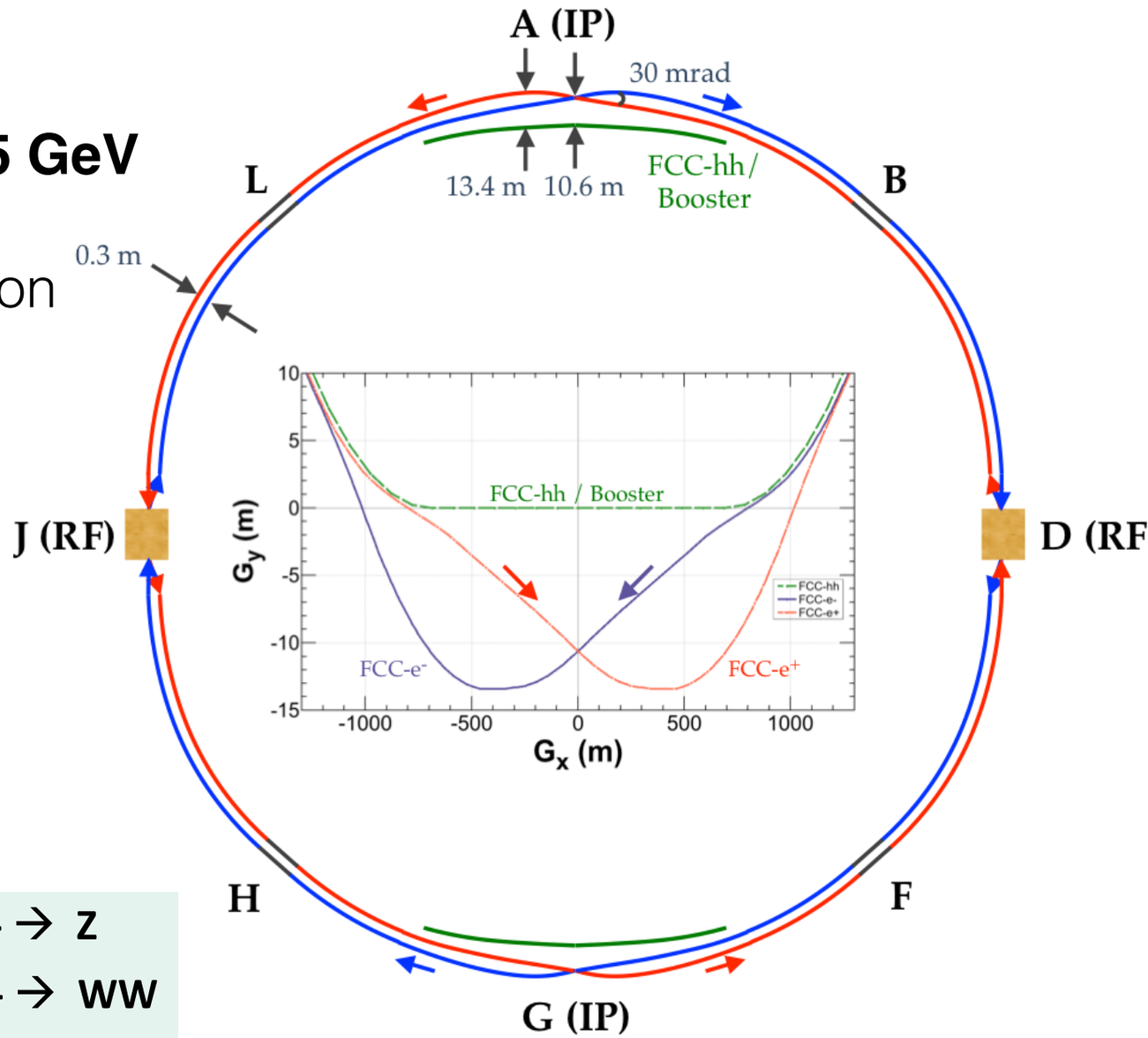
FCC-ee

- **FCC-ee** is an electron-positron collider sharing infrastructure with a subsequent hadron collider (FCC-hh)

- Beam energies range from **45.6 to 182.5 GeV** covering the Z-pole, W-pair threshold, ZH production and the top-pair production

- Double-ring collider with 2 (or 4) interaction regions and a booster synchrotron in a ~100km tunnel

- Injector complex with linac, pre-booster, and e+ source with damping ring



(4y) Z peak	**E_{cm} = 91 GeV**	**$5\ 10^{12}$**	**e+e- → Z**
(2y) WW threshold	**E_{cm} = 161 GeV**	**10^8**	**e+e- → WW**
(3y) ZH threshold	**E_{cm} = 240 GeV**	**10^6**	**e+e- → ZH**
(4y) $\bar{t}t$ threshold	**E_{cm} = 350 GeV**	**10^6**	**e+e- → $\bar{t}t$**
(ny) H(optional)	**E_{cm} = 125 GeV**	**10^4**	**e+e- → $\bar{H}$**

Letters of Interest

Link to PDF

Snowmass2021 - Letter of Interest

Searches for Long-Lived Particles at the FCC-ee

Thematic Areas:

■ (EF08) BSM: Model specific explorations
■ (EF09) BSM: More general explorations
■ (EF10) BSM: Dark Matter at colliders
■ (RF6) Dark Sector Studies at High Intensities

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Abstract:
The FCC-ee is a frontier Higgs, Top, Electroweak, and Flavour factory. It will be operated in a 100 km circular tunnel built in the CERN area, and will serve as the first step of the FCC integrated programme towards $\geq$ 100 TeV proton-proton collisions in the same infrastructure [1]. In addition to an essential and unique Higgs program, it offers powerful opportunities for discovery of direct or indirect evidence for BSM physics, via a combination of high precision measurements and searches for forbidden or rare processes, and feebly coupled particles.

The direct search for Long Lived particles (LLPs) in the high luminosity Z run, with $5 \cdot 10^{12}$ Z produced, is particularly fertile; high statistics of Higgs, W and top decays in very clean experimental conditions will also be recorded. This motivates an out-of-the-box optimization of the experimental conditions, which is the object of this letter of intent.

Link to PDF

The invisible Higgs branching fraction at FCC-ee

Letter of Interest submitted to Snowmass 2021

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[3]Massachusetts Institute of Technology, USA

Thematic Areas:

■ (EF01) EW Physics: Higgs Boson properties and couplings
■ (EF02) EW Physics: Higgs Boson as a portal to new physics
□ (EF03) EW Physics: Heavy flavor and top quark physics
□ (EF04) EW Physics: EW Precision Physics and constraining new physics
□ (EF05) QCD and strong interactions: Precision QCD
□ (EF06) QCD and strong interactions:Hadronic structure and forward QCD
□ (EF07) QCD and strong interactions: Heavy Ions
■ (EF08) BSM: Model specific explorations
■ (EF09) BSM: More general explorations
■ (EF10) BSM: Dark Matter at colliders

Contact Information:
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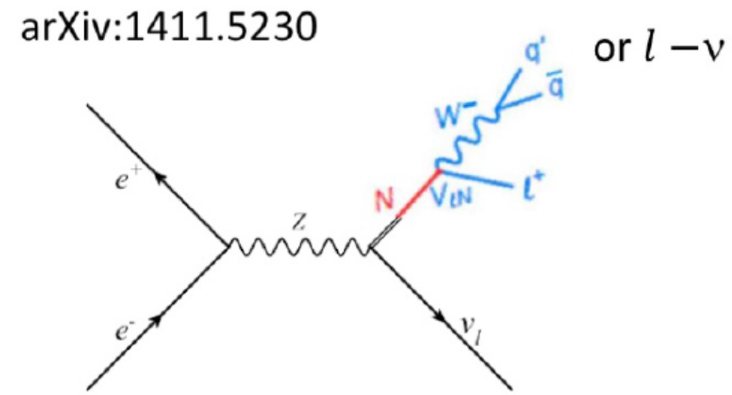
The FCC-ee is a frontier Higgs, Top, Electroweak, and Flavour factory. It will be operated in a 100 km circular tunnel built in the CERN area, and will serve as the first step of the FCC integrated programme towards 100 TeV proton-proton collisions in the same infrastructure [1]. With its large luminosity at the HZ cross section maximum ($\sqrt{s} \simeq 240$ GeV) and at and above the top-pair threshold ($\sqrt{s}$ from 340 to 365 GeV), and its several interaction points, the FCC-ee physics programme includes the measurement of the Higgs parameters with unrivalled accuracy. The high statistics of FCC-ee lead to demanding requirements on detector design or on theoretical calculations, the ultimate goal is that experimental or theory systematic errors match the statistical limit.

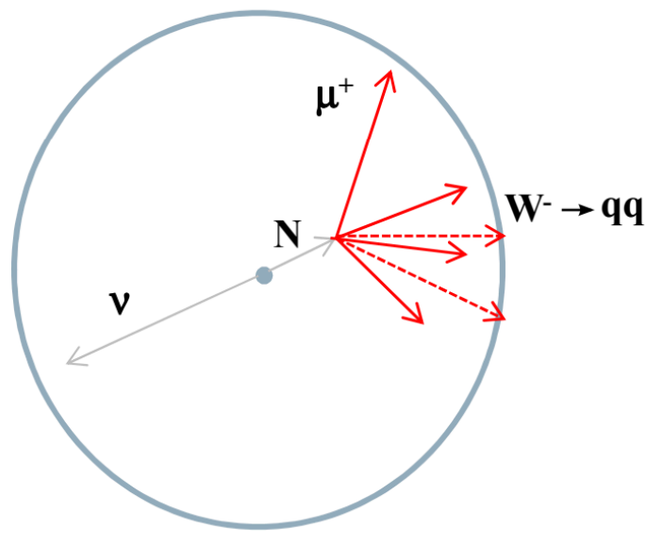
The Higgs factory, with over one million Higgs bosons produced at $\sqrt{s} \sim 240$ and 365 GeV, can give access to Higgs decays with branching ratios of a fraction of a per mil. For example, in the Standard Model, the Higgs boson decays invisibly only through the $H \to ZZ \to \nu\bar{\nu}\nu\bar{\nu}$ process, with a branching fraction of about 10^{-3}. The rate for invisible decays of the Higgs boson may be significantly enhanced in the context of several BSM scenarios [2, 3, 4],including those in which the Higgs boson acts as a portal to dark matter (DM) [5, 6, 7, 8]. Preliminary studies of the invisible decay channel at FCC-ee have already been performed [9, 10] in the HZ channel with $Z \to \ell^+\ell^-$, and will need to be ascertained with realistic detector simulation. The study is more challenging with hadronic Z decays, for which the performance needs to be quantified. The requirements on the detector design (hadronic mass resolution, hadronic recoil-mass resolutions, maybe b-tagging performance) to approach the ultimate statistical sensitivity on the invisible branching fraction will be studied, in the context of the constraints from the full interaction region layout (in particular, with realistic beam energy spread).

Long-Lived Particles

Contact: Rebeca Gonzalez Suarez

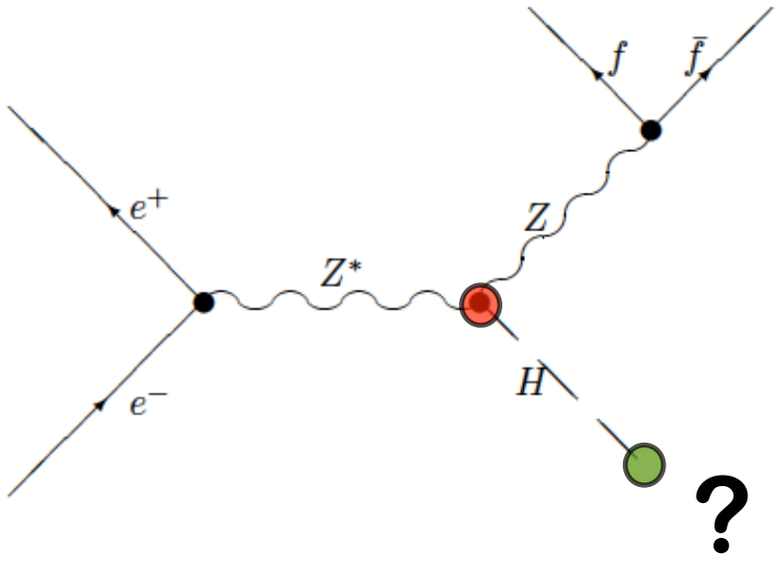
- The large statistics and clean environment of a Tera-Z machine (10^{12} Z) will help extend the sensitivity to models and particles that would escape direct detection at a hadron collider.
- Opportunity to design detectors for LLP searches
- Few examples to show the various advantages of a e^+e^- collider
  - Direct search: ALPS, Axions, Dark photons
  - Direct search: Sterile Neutrinos
  - Indirect search: Z' composite

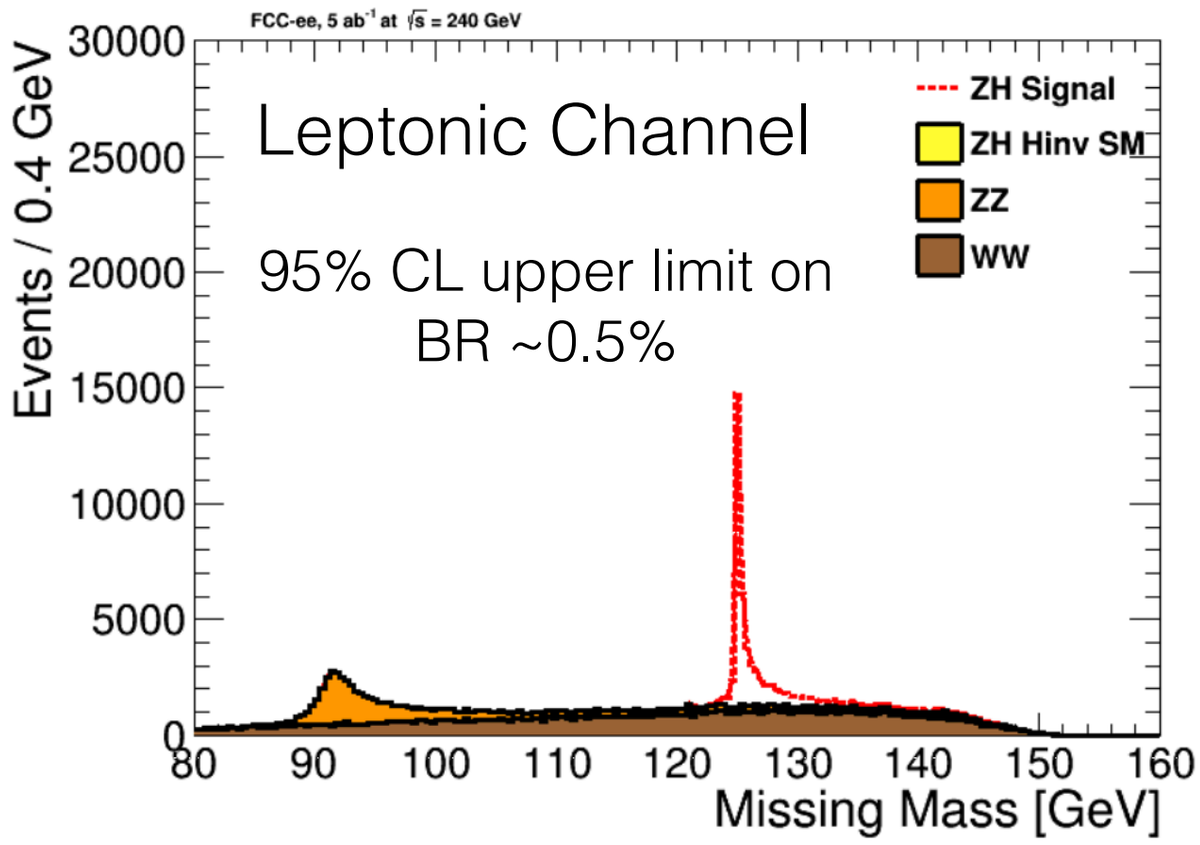




Higgs to Dark Matter Decays

Contact: Markus Klute





- Leptonic channels have been studied in the past
- Goal: study “ultimate” statistical sensitivity including hadronic channels