ETH zürich

PhD Seminar (PSI WHGA/001) *August 27th, 2015*

Same-Sign Dileptons at CMS

Constantin Heidegger
Institute for Particle Physics, ETH Zürich

on behalf of the CMS Collaboration

Supersymmetry

- Standard Model (SM) has several open questions
  - hierarchy problem, flavor mixing, dark matter, dark energy, …
- need theory beyond the SM
- Supersymmetry (SUSY) one of them, able to deliver answers to many questions
  - hierarchy problem, dark matter candidate, unification?, …
- Minimal-Supersymmetric SM doubles the particle spectrum of SM
- SUSY searches
  - direct: search for new particles
  - indirect: deviations from SM (e.g. cross sections different to SM prediction)
- SUSY not yet experimentally observed

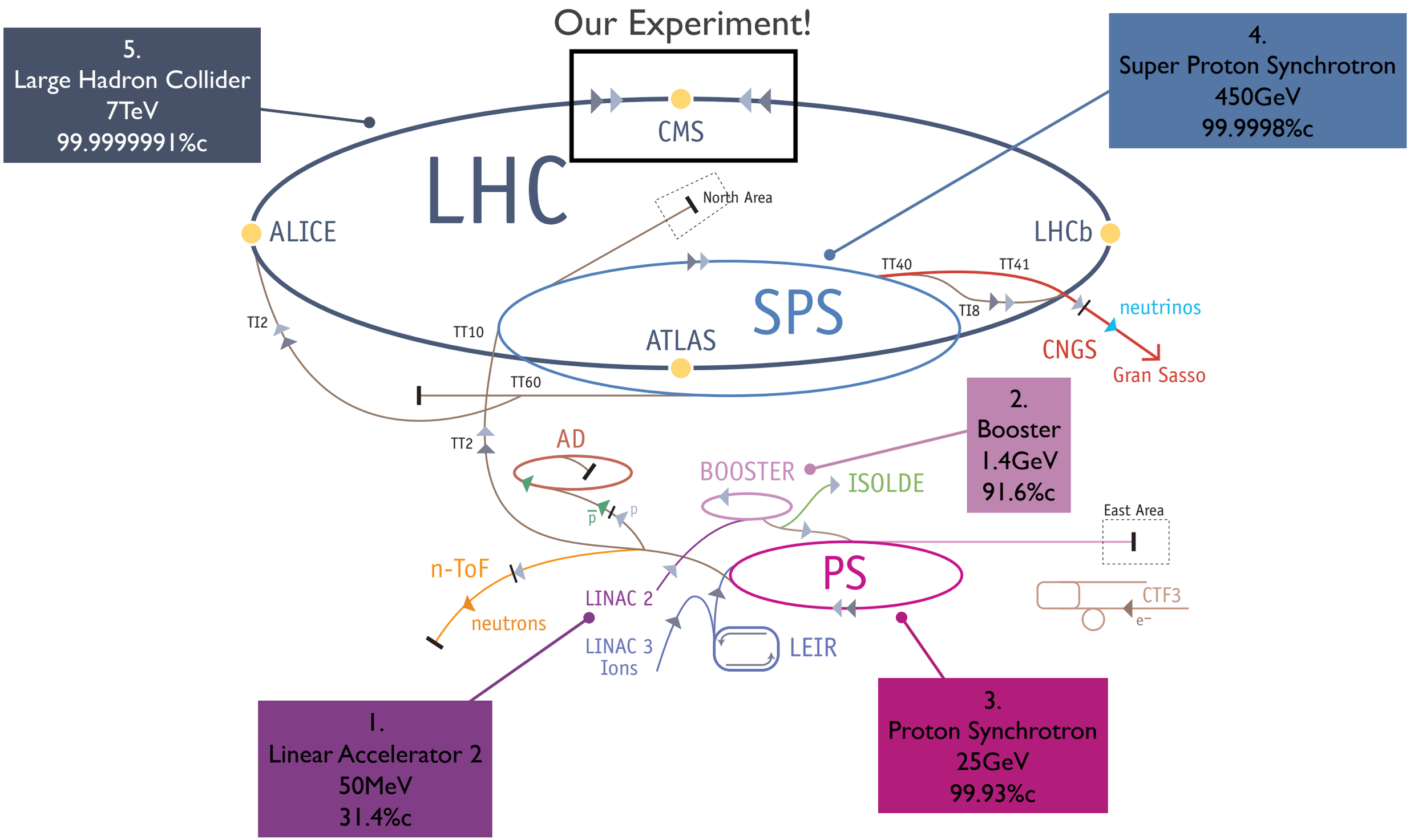
Why Same-Sign Dileptons?

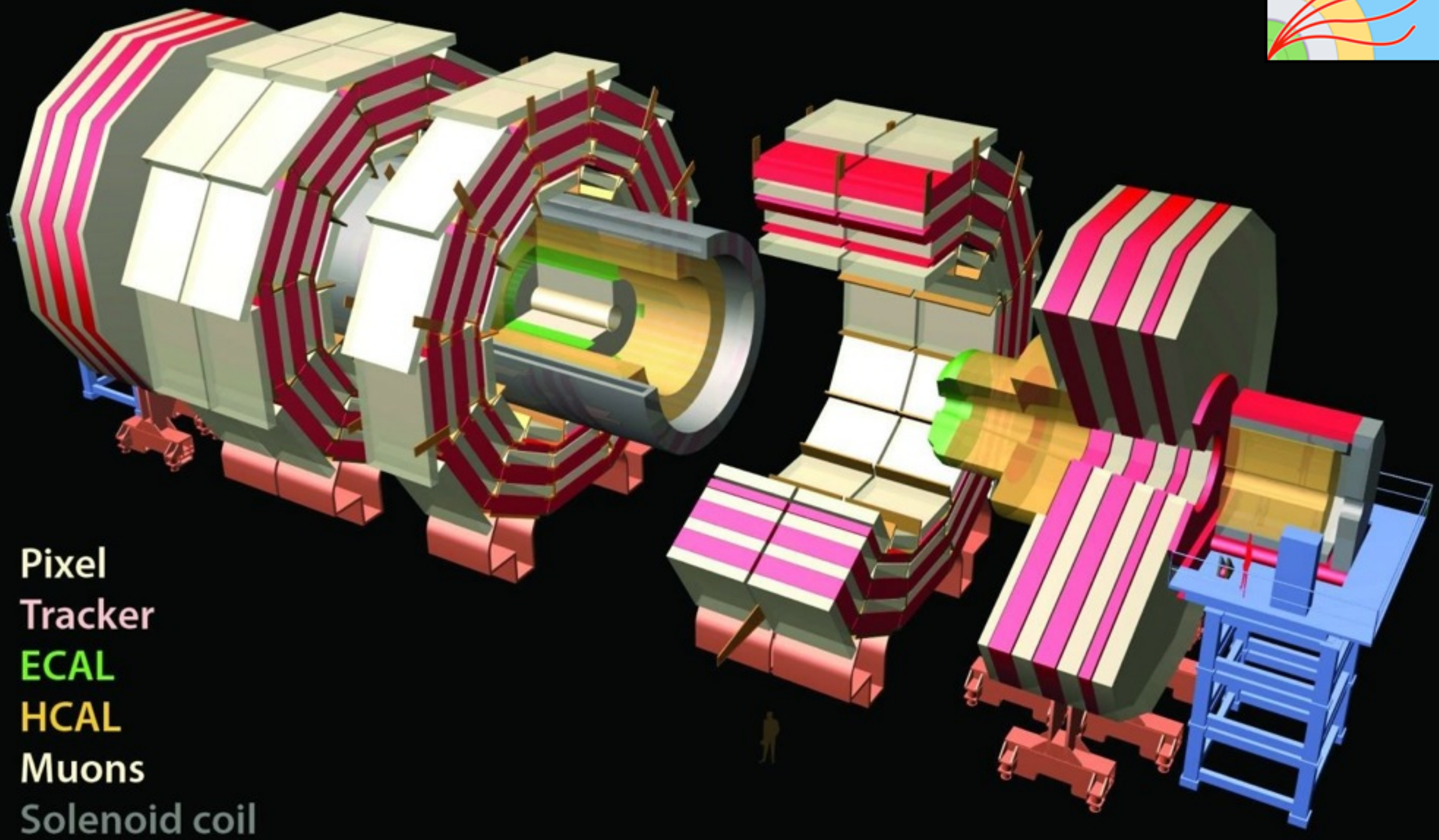
- look for decays of new particles (direct SUSY search)
- final states with **two leptons of the same charge**
- advantages
  - small cross sections for SM backgrounds
  - different SUSY production and decay modes accessible in one analysis
  - larger signal-selection efficiency than in SUSY searches with 3 or more leptons in the final state
- disadvantages
  - estimation of backgrounds and signal selection not easy (see later)
  - only sensitive to SUSY production and decay modes with two leptons

Outline

- The CMS Experiment at the CERN LHC
- Signatures of „Leptonic SUSY“
- Search Strategy and Background Estimation
- Expectations for LHC Run 2

LHC Accelerator Chain

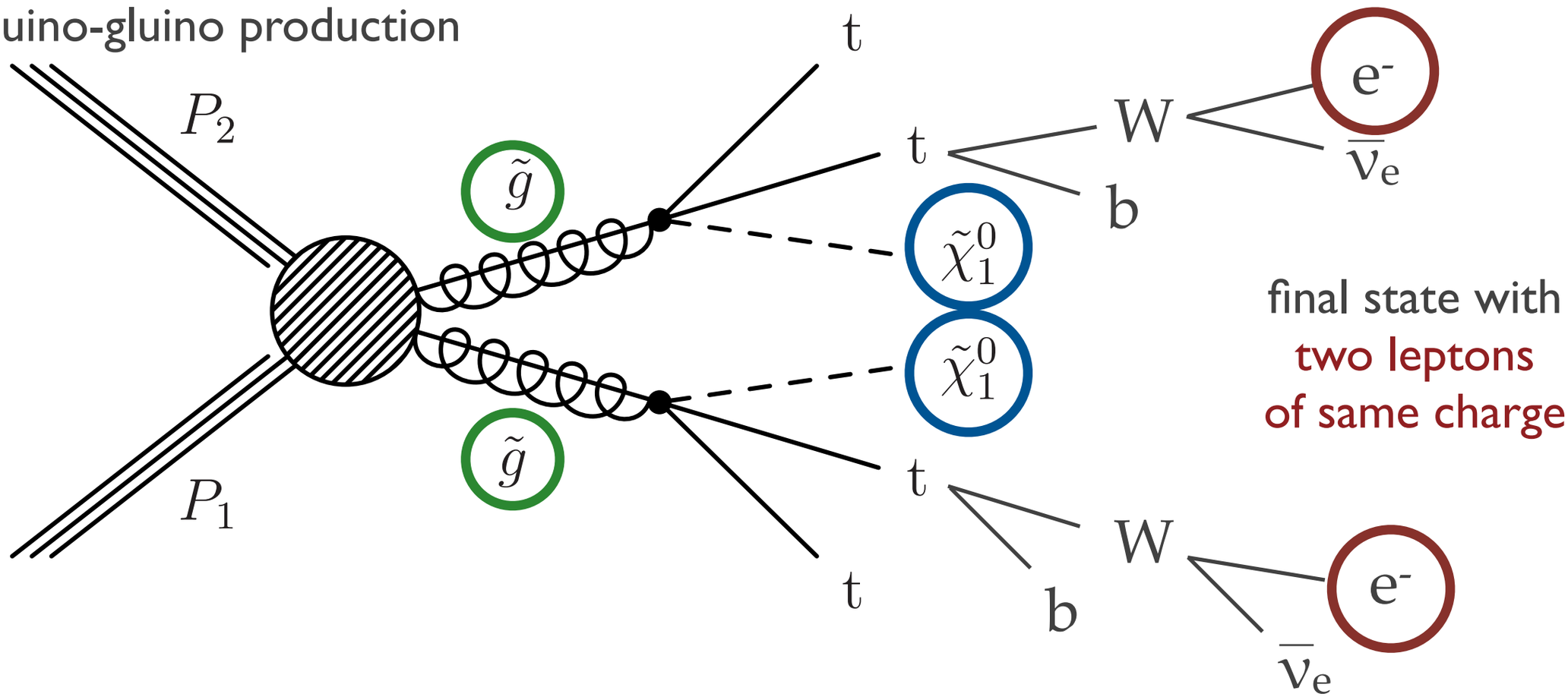




Total weight 12500 t, Overall diameter 15 m, Overall length 21.6 m, Magnetic field 4 Tesla

Signatures of „Leptonic SUSY“

e.g. gluino-gluino production



final state with
two leptons
of same charge

Typical signature of a leptonic SUSY process:

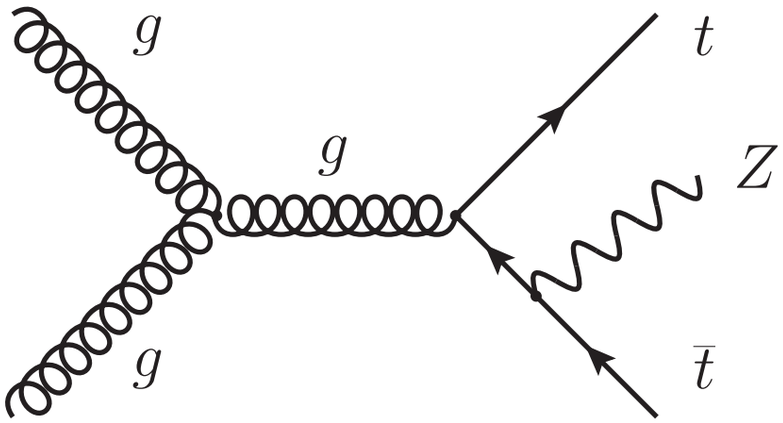
- **two hard, isolated leptons** of same charge in the central part of the detector
- a number of **hard, central jets** (e.g. several b-tagged jets from top decays)
- large **missing energy** in the plane transverse to the beam (MET)

Search Strategy

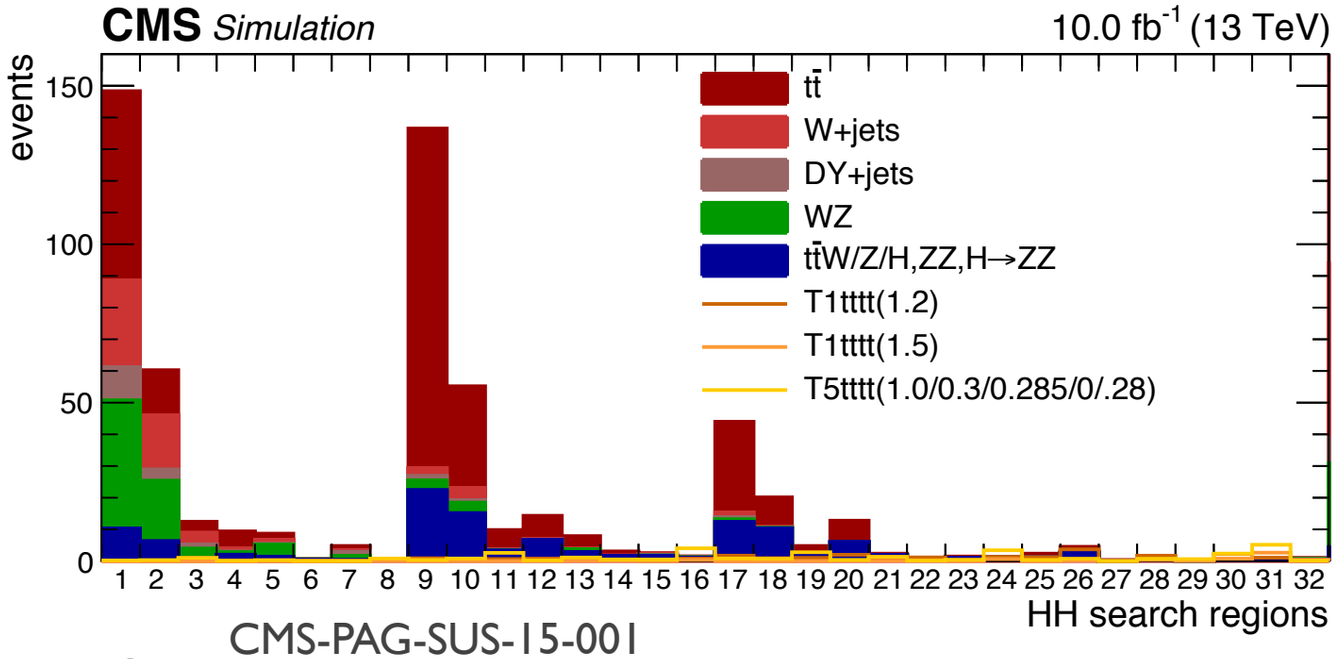
- cut-and-count analysis
- define important kinematic objects:
  - electrons, muons, jets, MET
- define regions of phase space (64 „signal regions“, SR) according to 4 key observables:
  - MET, HT (sum of jet energies), number of jets, number of b-jets
- count the number of events in each SR
- compare to the expected number of background events per SR
- hypothesis test: could background alone produce the observed number of events?
- result either significance (observation) or upper limit (exclusion) at 95% confidence level

Physics Related Backgrounds

- rare SM processes
  - TTbar+H
  - TTbar+V (V=W,Z)
  - WZ, …
- also produce hard, isolated leptons and a number of jets
- number of events estimated from Monte Carlo simulations
- present in many signal regions:



TTbar+Z



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CMS-PAG-SUS-15-001

Experimental Backgrounds

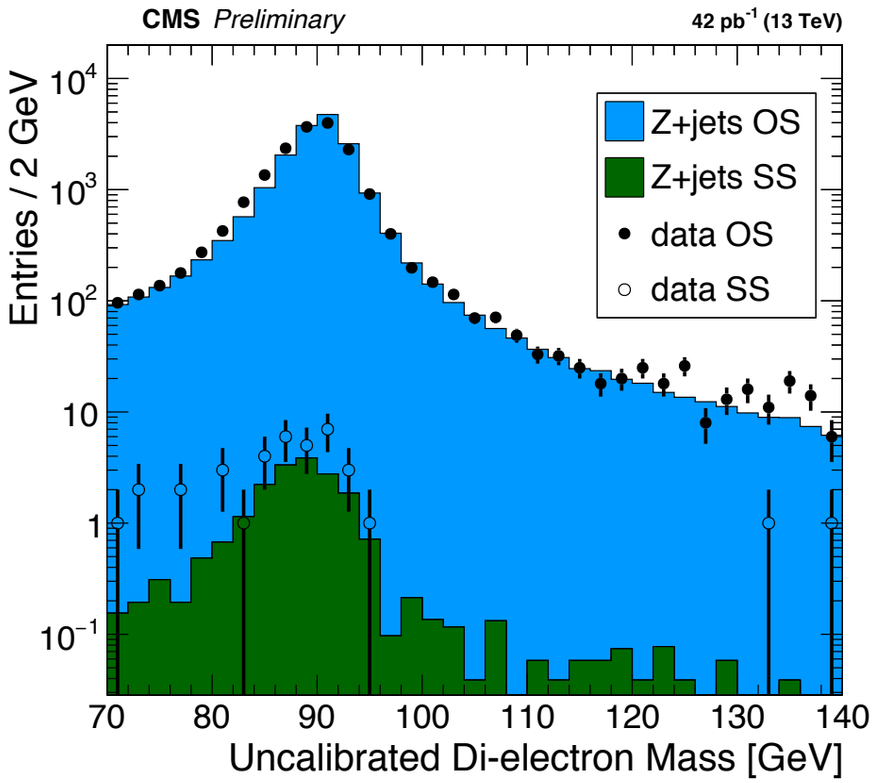
- charge mis-identification of an opposite-sign (OS) lepton pair
  - Drell-Yan
  - TTbar

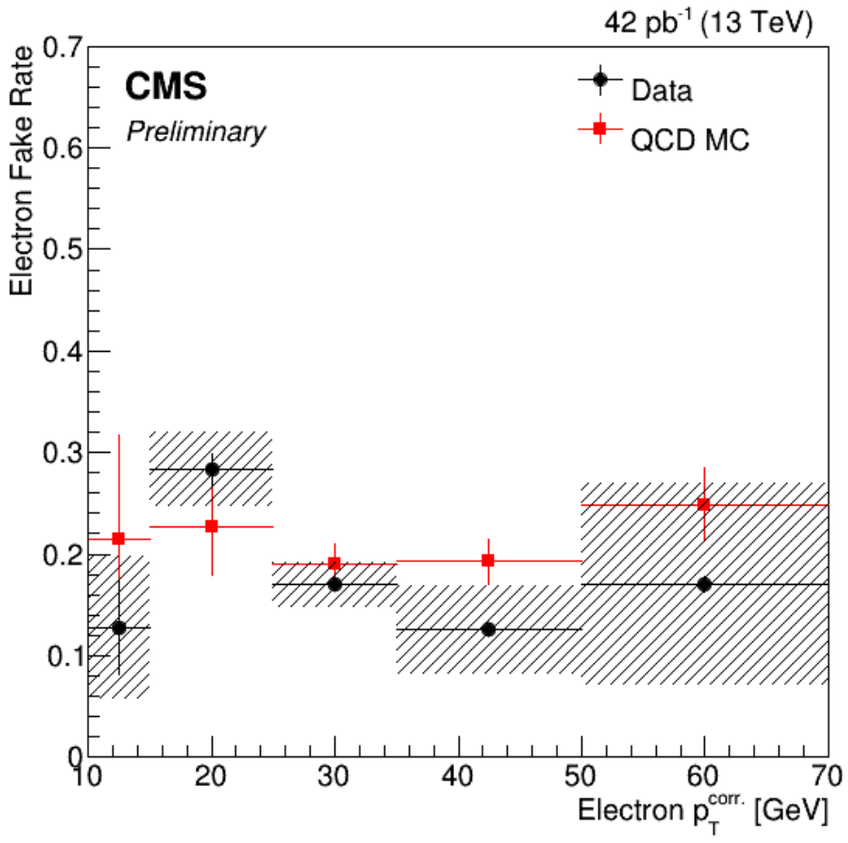
small

- mis-identification of jets as leptons („fake leptons“)
  - W+Jets
  - TTbar

dominant in most signal regions

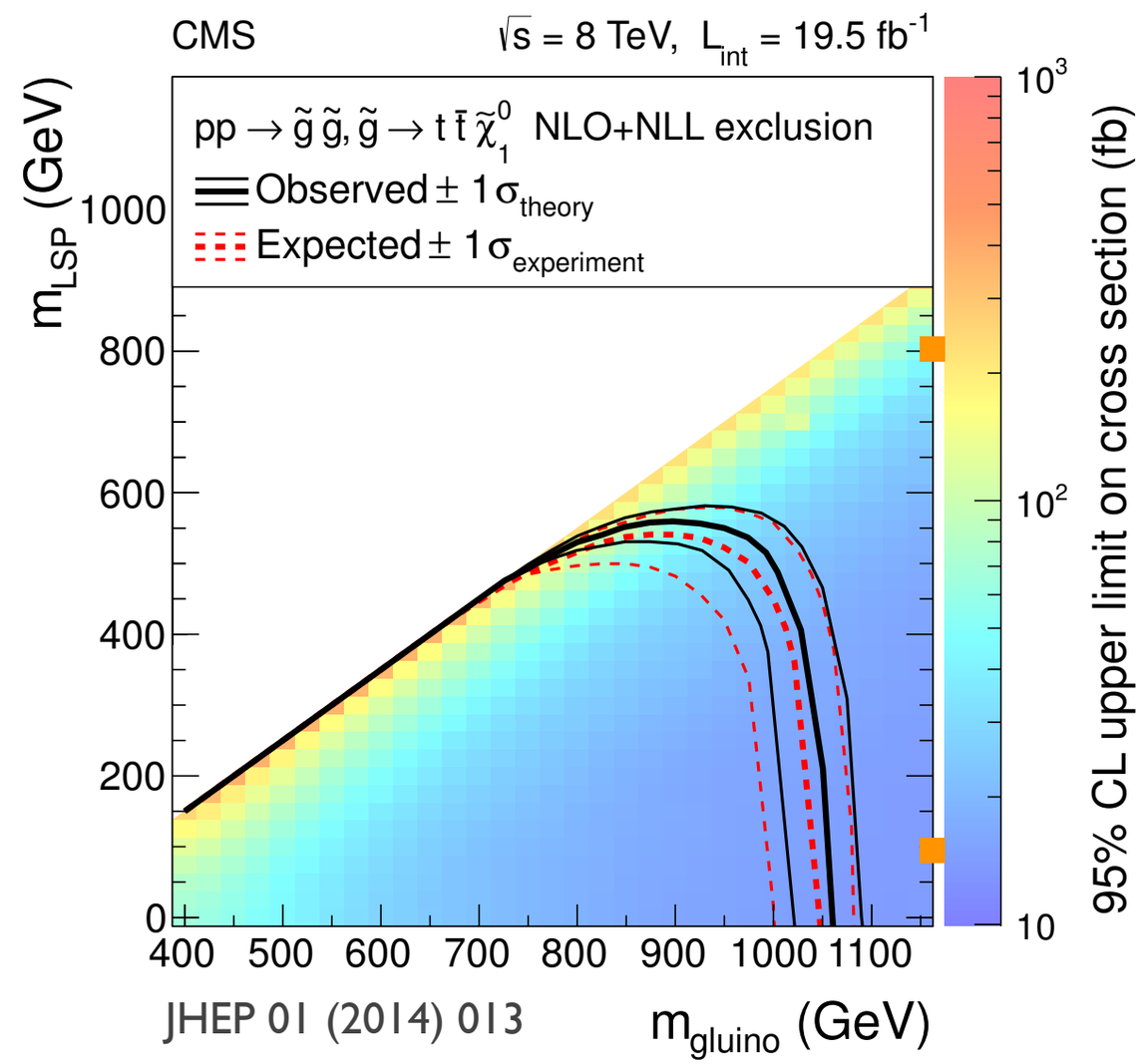
- data-driven estimation methods:
  - measure probability of mis-identification in control region
  - from this, compute expected number of events in SR





Expectations for LHC Run 2

- after 2 years of maintenance and upgrades, started data taking with design conditions (13TeV, 25ns) this year (= begin of LHC Run 2)
- not enough data yet to do SSDL analysis
- expectations from Monte Carlo simulated events with different mass points at 10/fb
- compare to 8TeV upper limits on signal strength
  - expected upper limits pushed well above 8TeV results
  - two orders of magnitude gain in sensitivity
- soon enough data is taken for driving conclusions towards discovery or exclusion



JHEP 01 (2014) 013

Conclusion

- SUSY a promising candidate to answer open questions of SM
- direct search for SUSY in the same-sign dilepton analysis
- several different SUSY production and decay modes accessible
- established search strategy and methods of background estimation
- use of both Monte Carlo simulations and data driven methods
- significant gain in sensitivity for search for leptonic SUSY
- soon enough data taken to conclude either towards discovery or exclusion

Hopefully LHC Run 2 data will let us find Supersymmetry eventually!

End

The ECO Same-Sign Dileptons Team

Cristina Botta, Marco Peruzzi, Giovanni Petrucciani
CERN

Constantin Heidegger, Jan Hoss, Boris Mangano, Matthieu Marionneau
ETH Zürich

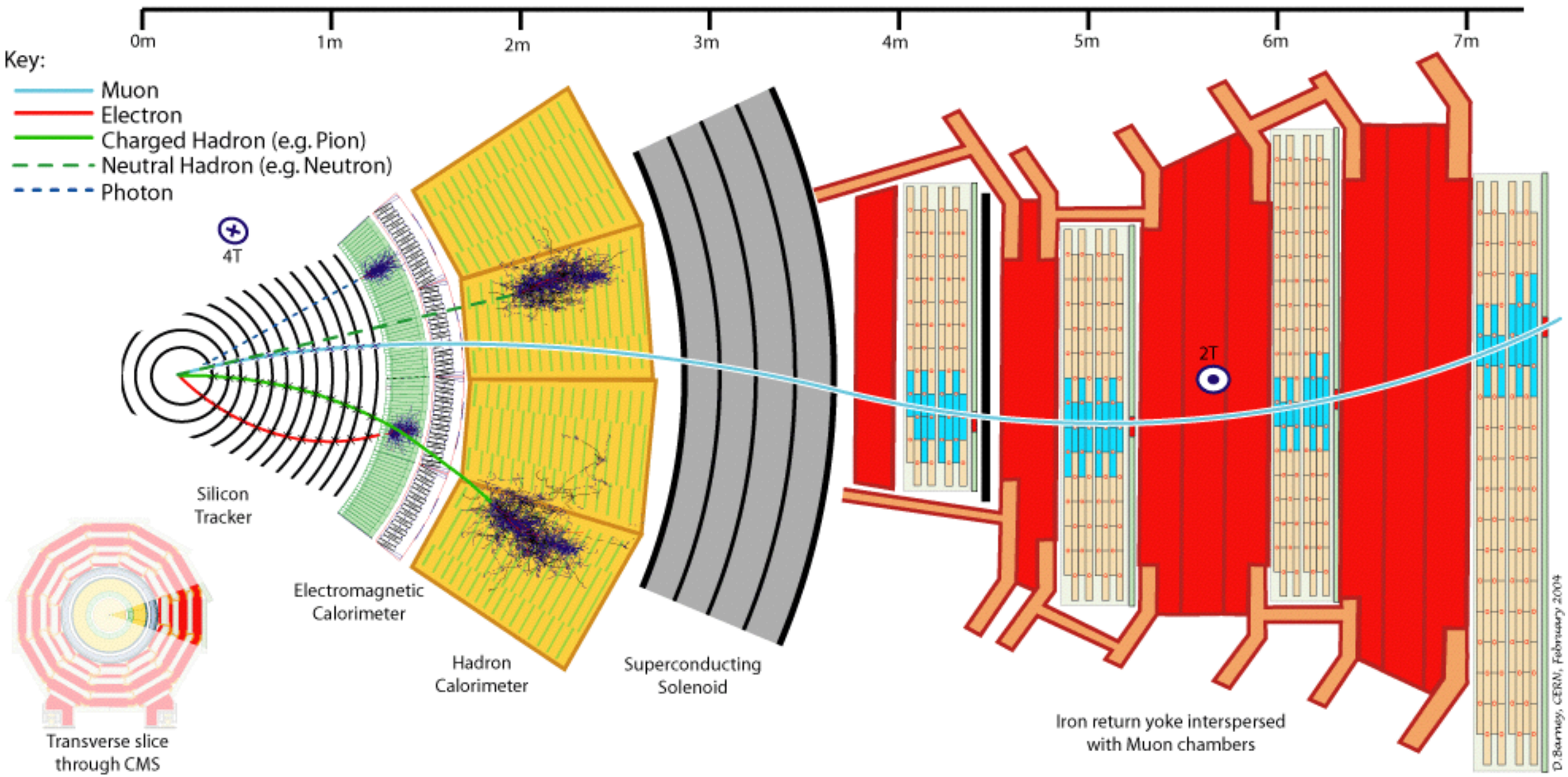
Sergio Sánchez Cruz, Santiago Folgueras, Jesús Vizán
Universidad de Oviedo

Universidad de Oviedo

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

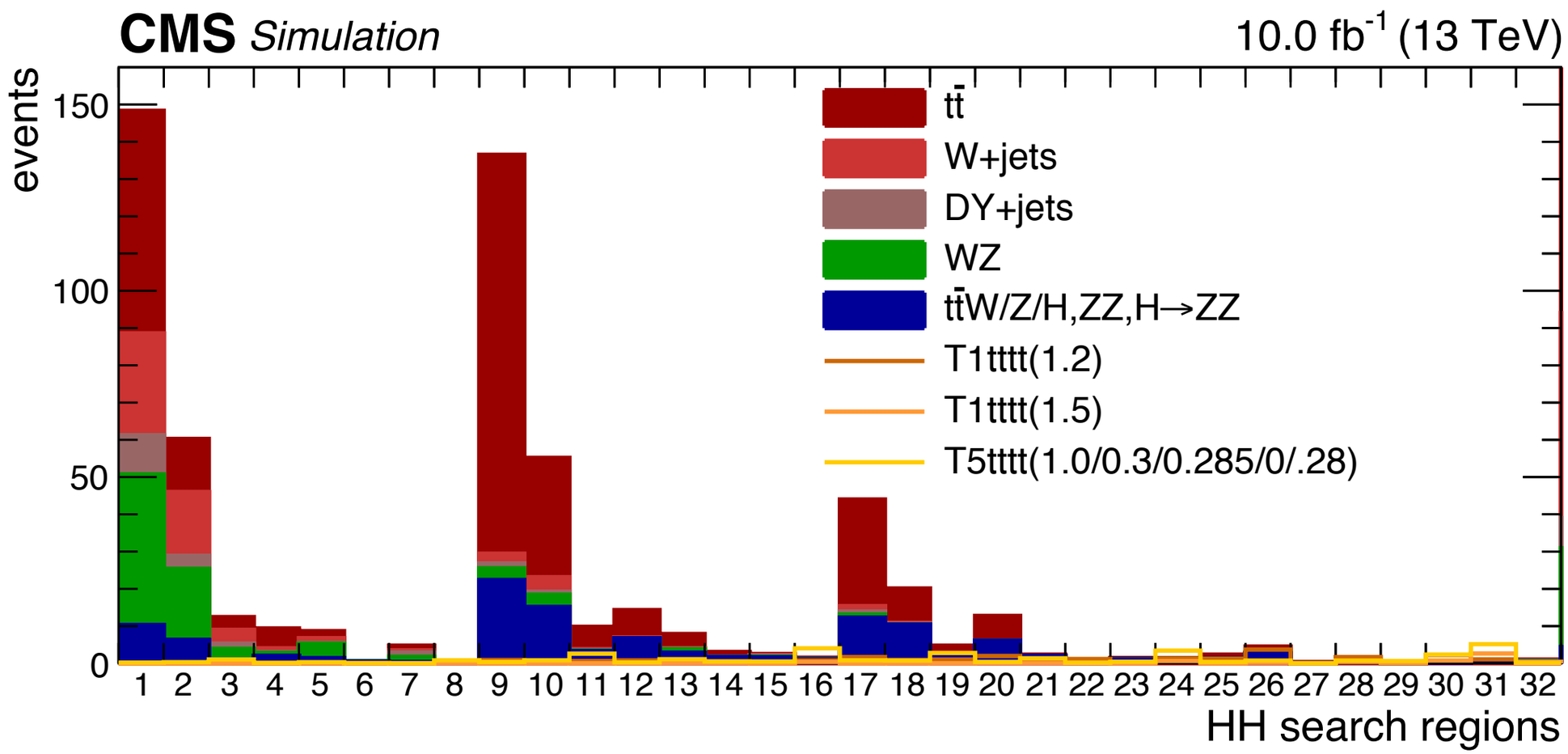
Backup

CMS Detection Principle



Background Composition

- expected background composition for high-energy lepton search:



- fake background (TTbar, W+Jets) is dominant!

Challenges in SSDL Analysis

- lepton identification
  - How do we know, if what we measure is a lepton?
  - How do we know, it is a „good“ lepton from SUSY?
- experimental resolution
  - detector noise
  - reconstruction of kinematic objects (leptons, jets, MET)
  - jet-energy scale and resolution
- background estimation
  - definition of control regions and extrapolations in data-driven methods
  - Can the Monte Carlo simulations be trusted?
- and many more …