ZH-Events and My Experience at KIT

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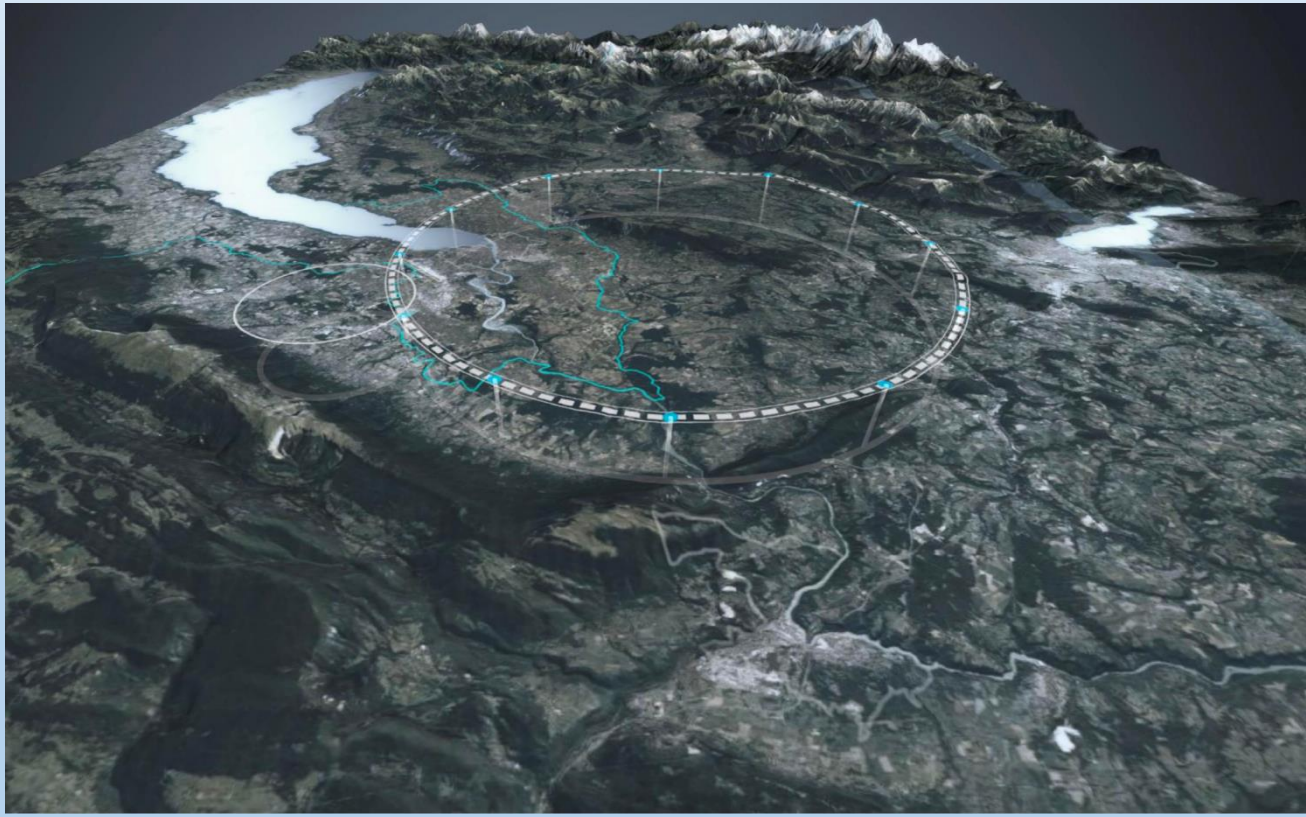
Future Circular Collider (FCC)

- Particle accelerator near Geneva, Switzerland
- Circular Collider



- Work in 2025: Simulation of the processes
  - -physics
  - -programming
  - -statistics

- My object of study this week:
  - e^- e^+ collisions
  - Z and H
  - H decay in τ^- and τ^+
  - many possibilities for the decay of Z and τ^- /τ^+ :

  We choose to look at Z > e^- e^+ and hadronic decay of τ^- /τ^+ .

❖Center of mass energy $\sqrt{s} = 240\ GeV$

❖$e^-\ e^+$-> Z H (e^- and e^+ exchange a virtual Z* boson), H -> τ^- / τ^+

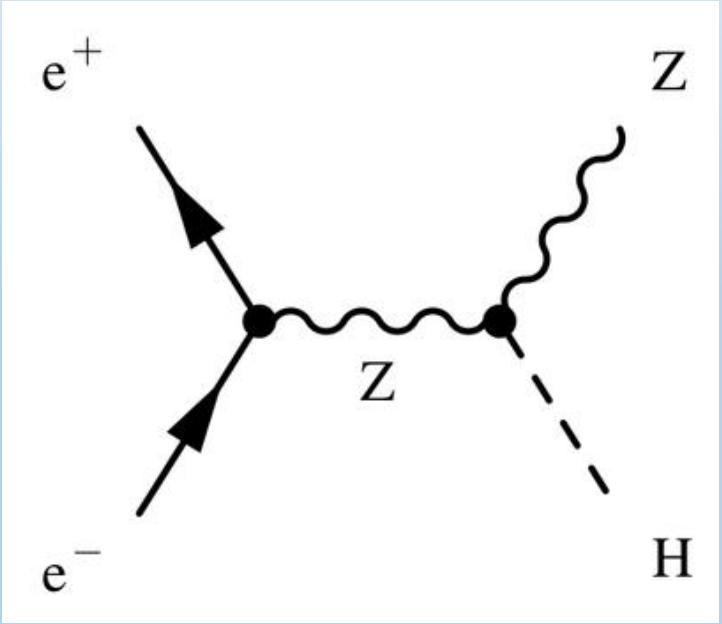
❖Decay of τ^- /τ^+ :

-hadronic decay: (anti-)pion(-s) and (anti-)neutrino

-leptonic decay: neutrino, anti-neutrino, (anti-)lepton

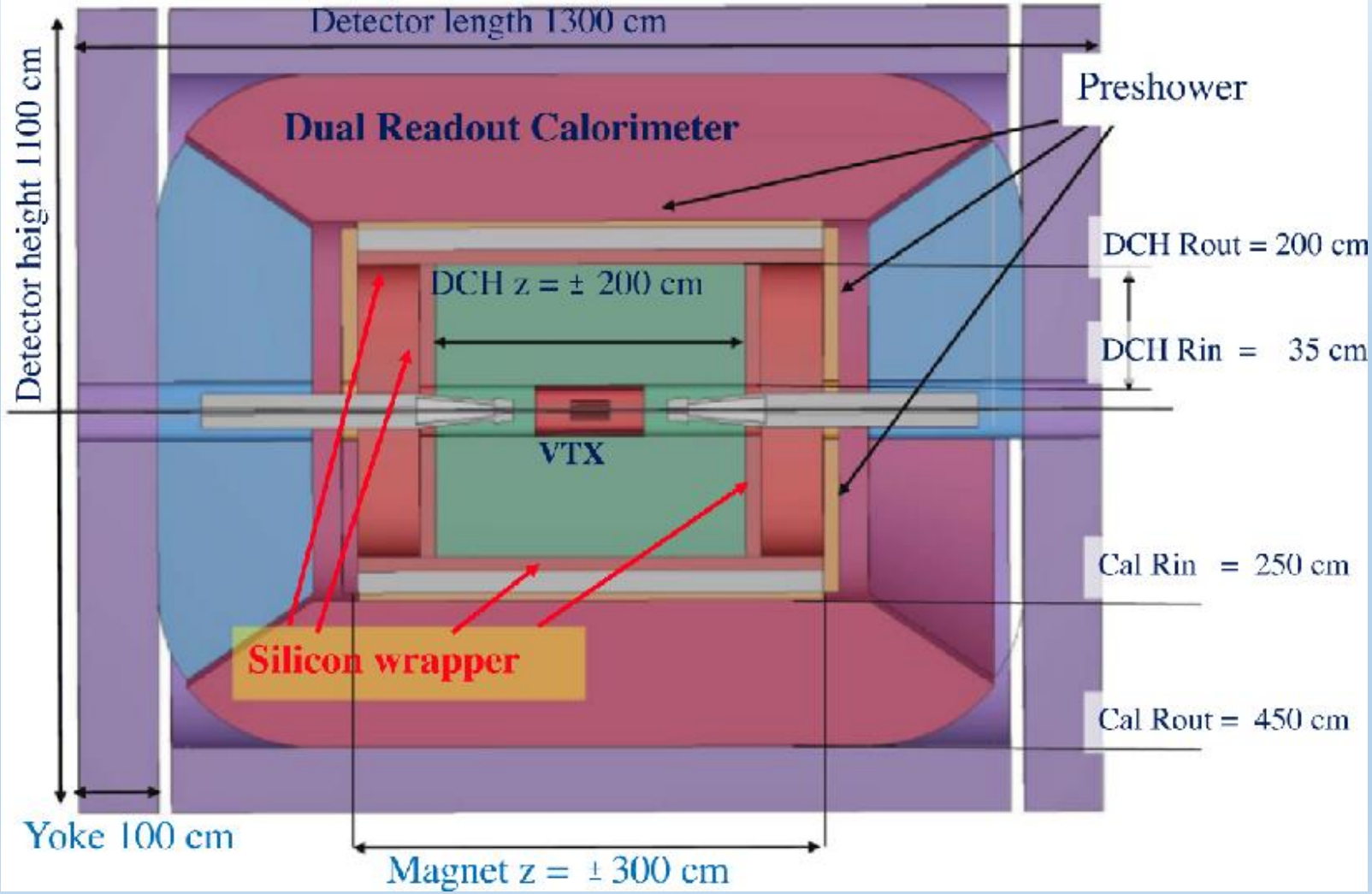
❖Branching Ratio: Probability of a particular decay

Decays	Branching Ratio in %
$\tau^\pm \rightarrow \mu^\pm \nu_\mu \nu_\tau$	17.39 ± 0.04
$\tau^\pm \rightarrow e^\pm \nu_e \nu_\tau$	17.82 ± 0.04
$\tau^\pm \rightarrow \pi^\pm \nu_\tau$	10.82 ± 0.05
$\tau^\pm \rightarrow \rho^\pm \nu_\tau \rightarrow \pi^\pm \pi^0 \nu_\tau$	25.49 ± 0.09
$\tau^\pm \rightarrow a_1^\pm \nu_\tau \rightarrow \pi^\pm 2\pi^0 \nu_\tau$	9.26 ± 0.10
$\tau^\pm \rightarrow a_1^\pm \nu_\tau \rightarrow \pi^\pm \pi^\mp \pi^\pm \nu_\tau$	9.02 ± 0.05
$\tau^\pm \rightarrow a_1^\pm \nu_\tau \rightarrow \pi^\pm \pi^\mp \pi^\pm \pi^0 \nu_\tau$	4.49 ± 0.05
total	94.29 ± 0.17



Source: https://www.researchgate.net/figure/Leading-order-Feynman-diagrams-of-the-highest-cross-section-Higgs-production-processes-at_fig5_343743281

IDEA Detector (FCC)



Source: https://www.semanticscholar.org/paper/The-%C2%B5-RWELL-technology-for-the-pre-shower-and-muon-Farinelli-Amoroso/fb1a8c33286183afeb471b318b732011f48a3274/figure/0

Simulation

1. Event generation
    - MadGraph5 Software

2. Showering / Hadronizing
    - Pythia 8 Software
    - decays of unstable particles (taus after the decay of the Higgs-Boson)

3. Detector Simulation
    - Delphes Software
    - detector structure

4. Analysis:

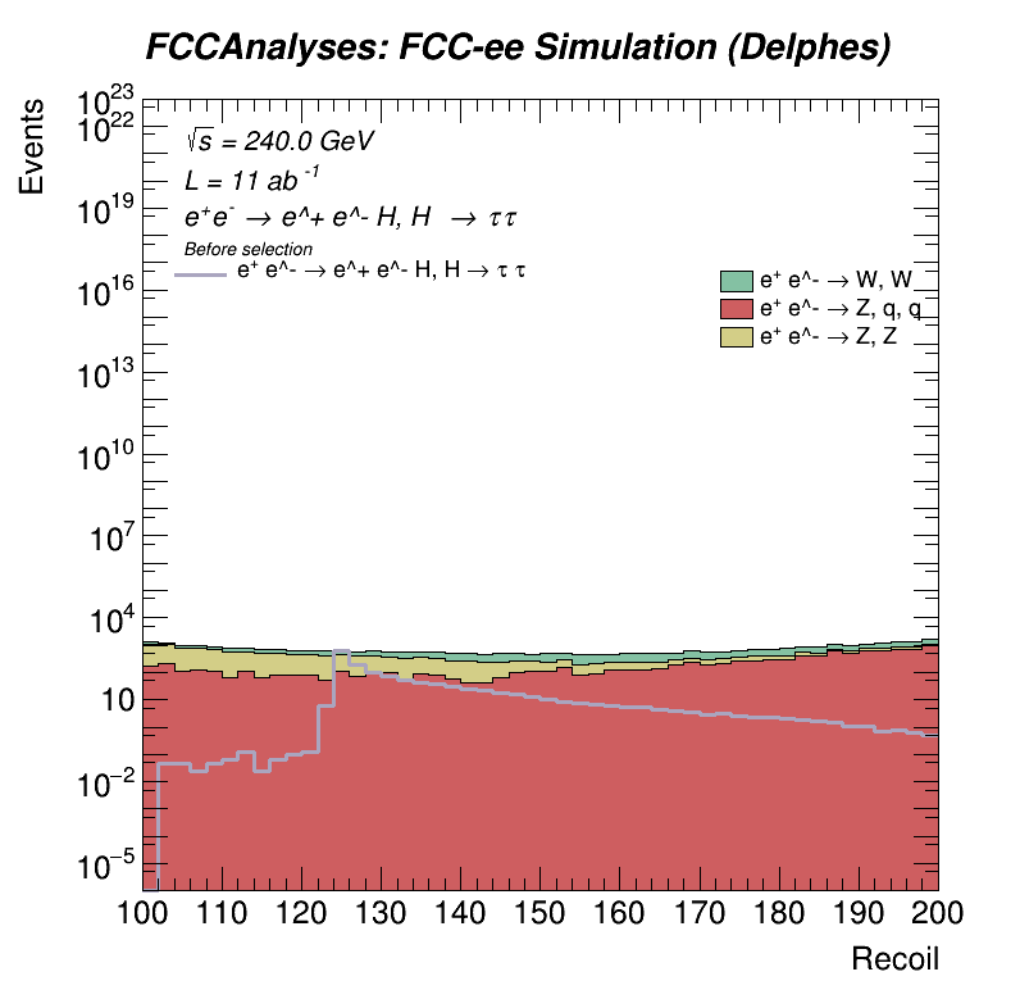
- First part: Specific data formats (EDM)-> Flat Data Structure (n-Tuples)
- Second Part: Object selections on both signal and background

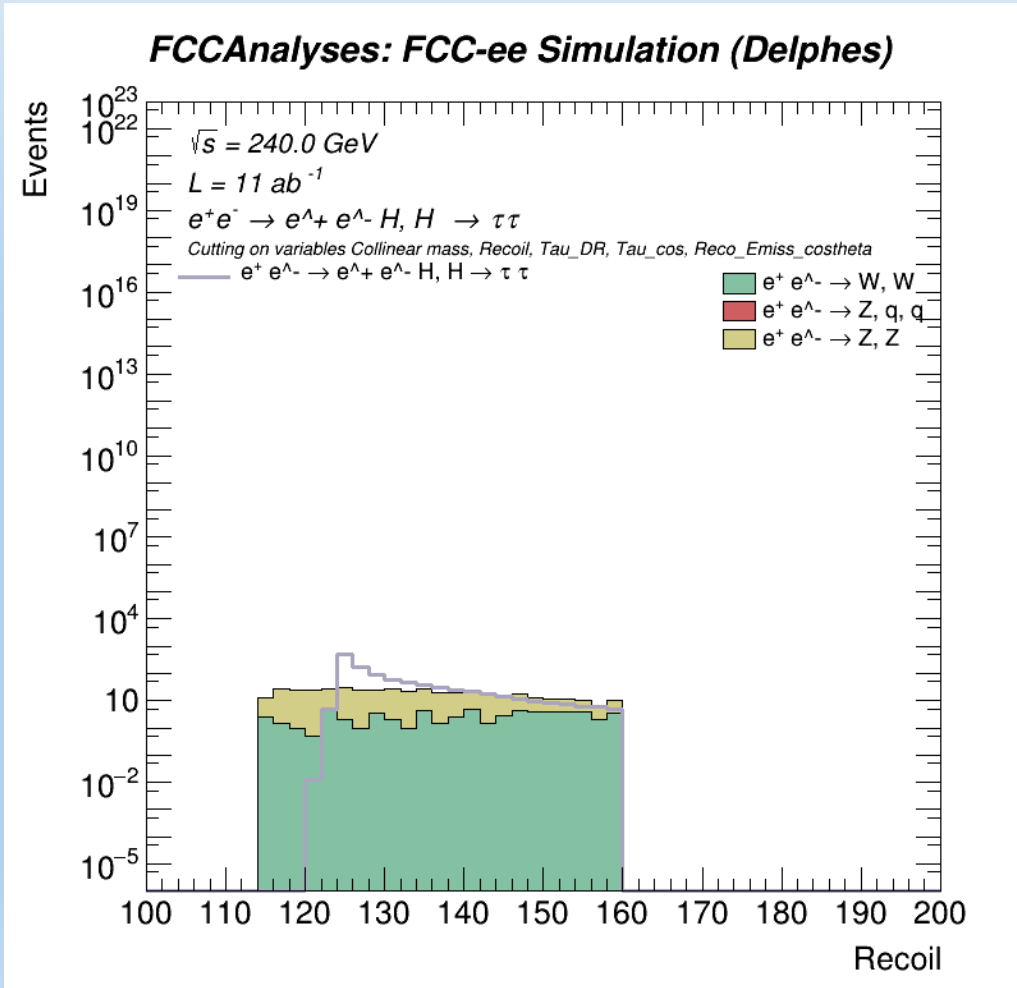
- Final part: n-Tuples -> Histograms
- Plotting -> stacked Histograms (signal + background)

- Combine Software:

- Statistics
- Takes uncertainty into account

Before cuts VS After cuts





Cuts on the Background	
None	- 5,58 % / +5,63 %
100 < Collinear mass < 150 GeV	- 3,61 % / +3,72 %
115 < Recoil < 160 GeV	- 5,68 % / +5,77 %
Tau_DR > 2	-4,51 % / +4,63 %
Tau_cos < -0,6	-3,79 % / +3,86 %
Reco_Emiss_costheta < 0,96	-5,29 % / +5,36 %
General Condition (includes all selections)	-3,38 % / +3,48 %

Relative uncertainty of

σ_{ZH} . BR(H -> $\tau^- \tau^+$) : -3,38 % / +3,48 %

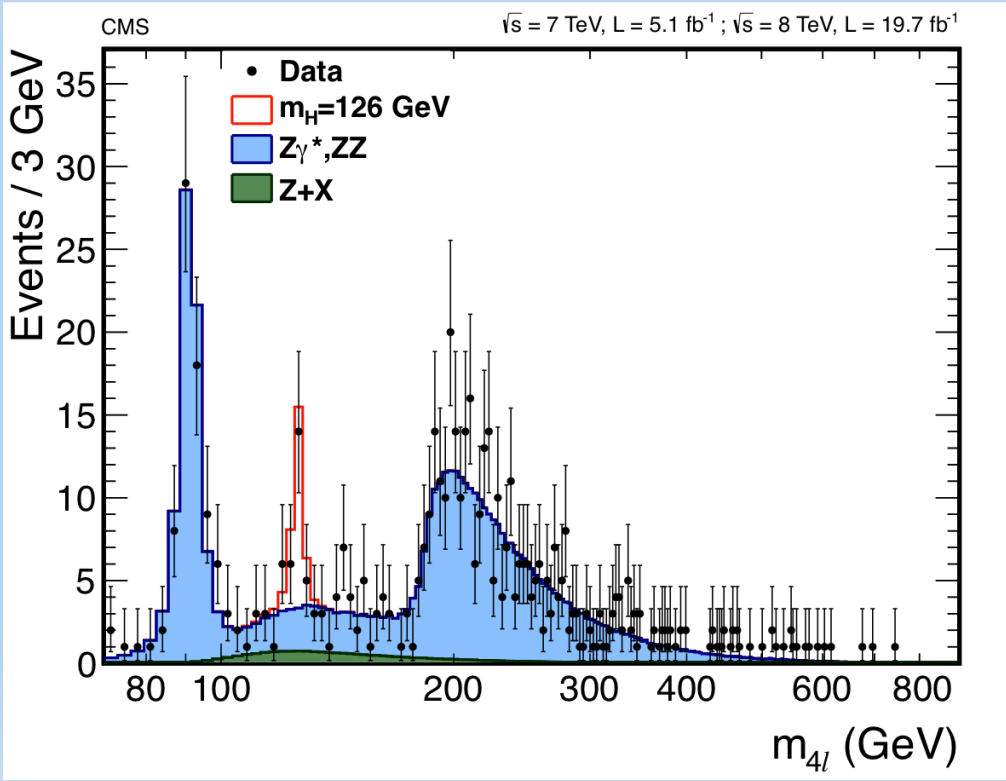
σ and Discovery of the Higgs Boson

- Comparison between the simulations and experimental data

- Discrepancy > 3σ: strong indication for new physics
- Discrepancy > 5: discovery of new physics

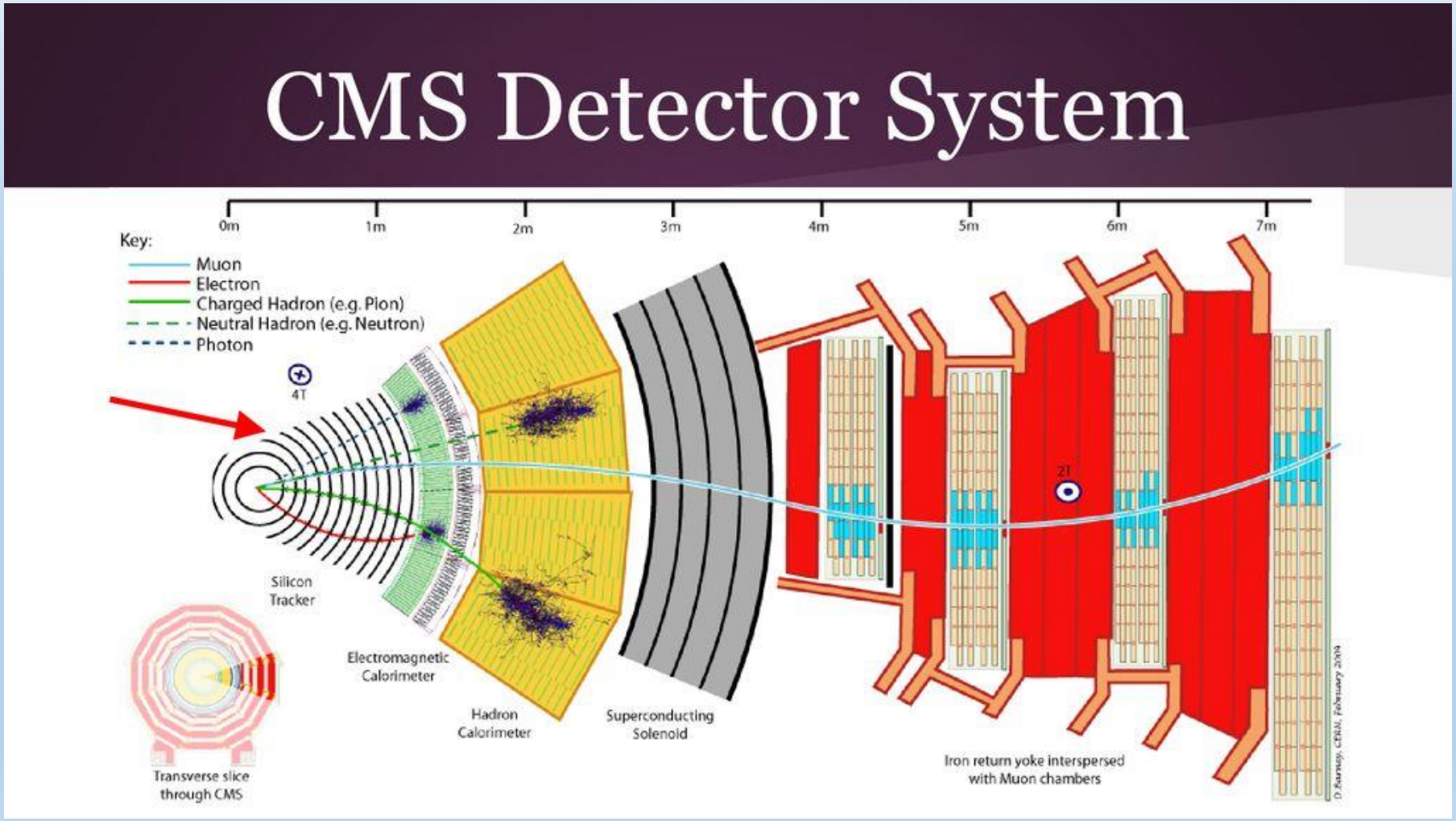
- The discovery of the H – Boson:

Discrepancy of around 6σ



Source: https://cms.cern/sites/default/files/field/image/image1.png

CMS Detector (LHC)



Source: https://slideplayer.com/slide/17026024/98/images/5/CMS+Detector+System.jpg

My Expirience at KIT

❖I learned about:

- CMS
- New particle accelerator FCC
- Simulation of events and its analysis
- Experimental Particle Physics
- Programming and problem-solving skills
- Statistics
- Math
- On-going research
- Scientific projects for the future

Sources:

- https://www.etp.kit.edu/
- https://cms.cern/
- https://de.wikipedia.org/wiki/Large_Hadron_Collider
- https://en.wikipedia.org/wiki/Future_Circular_Collider
- https://de.wikipedia.org/wiki/Compact_Muon_Solenoid
- https://en.wikipedia.org/wiki/Tau_(particle)#Tau_decay
- https://de.wikipedia.org/wiki/Pion
- https://de.wikipedia.org/wiki/Higgs-Boson
- https://de.wikipedia.org/wiki/Z-Boson
- https://en.wikipedia.org/wiki/Virtual_particle
- https://de.wikipedia.org/wiki/Feynman-Diagramm
- https://en.wikipedia.org/wiki/Neutrino
- https://en.wikipedia.org/wiki/Rho_meson

Thank you for your attention and this amazing week at KIT! ☺