W mass and calorimetry for future experiments

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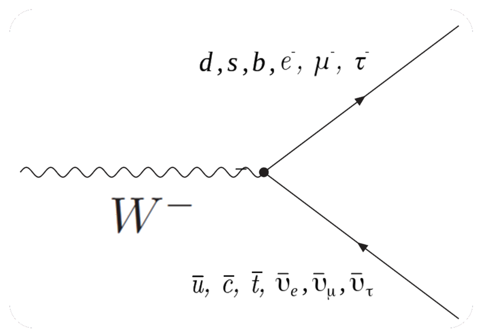
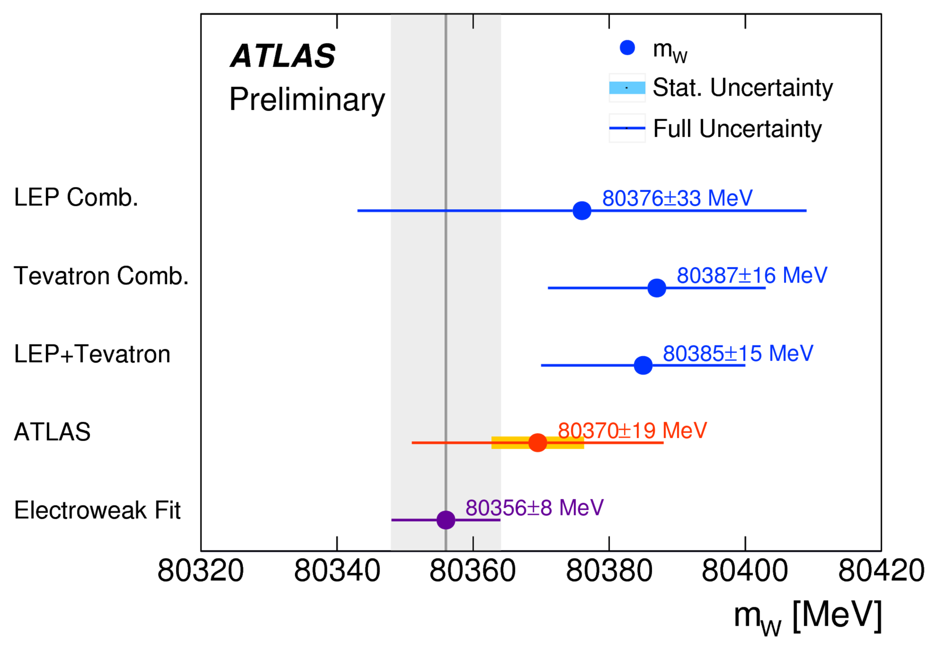
W boson

W^+ W^-

- Weak interaction boson
- Discovery : in $p\bar{p}$ collisions, UA1 and UA2 collaborations, CERN, 1983





W^+ decays to $(u,\bar{d})$ $(c,\bar{s})$ (e^+,ν_e) (μ^+,ν_μ) (τ^+,ν_τ)

W mass measurement

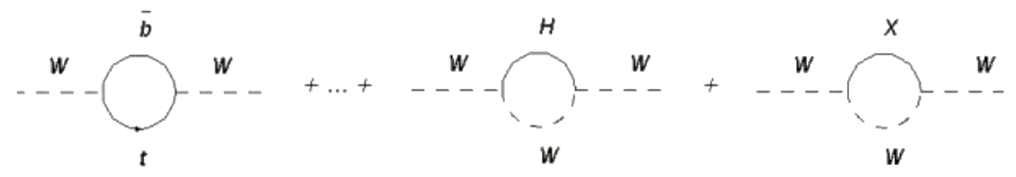
- e^+e^- collisions :
  - Measurement at pair production threshold : determination from the cross section σ_{WW}
  - Direct measurement : reconstruction from the decay products
- pp collisions : comparison of variables sensitive to M_W with simulated event samples. The templates are tuned with W-like Z events analysis.

W mass : Why to precisely measure it ?

If all masses (M_W, M_Z, M_{top}, M_H) and all electroweak parameters ($\sin^2\theta_w, \alpha_{QED}$) are measured with precision, the standard model has nowhere to go. For example:

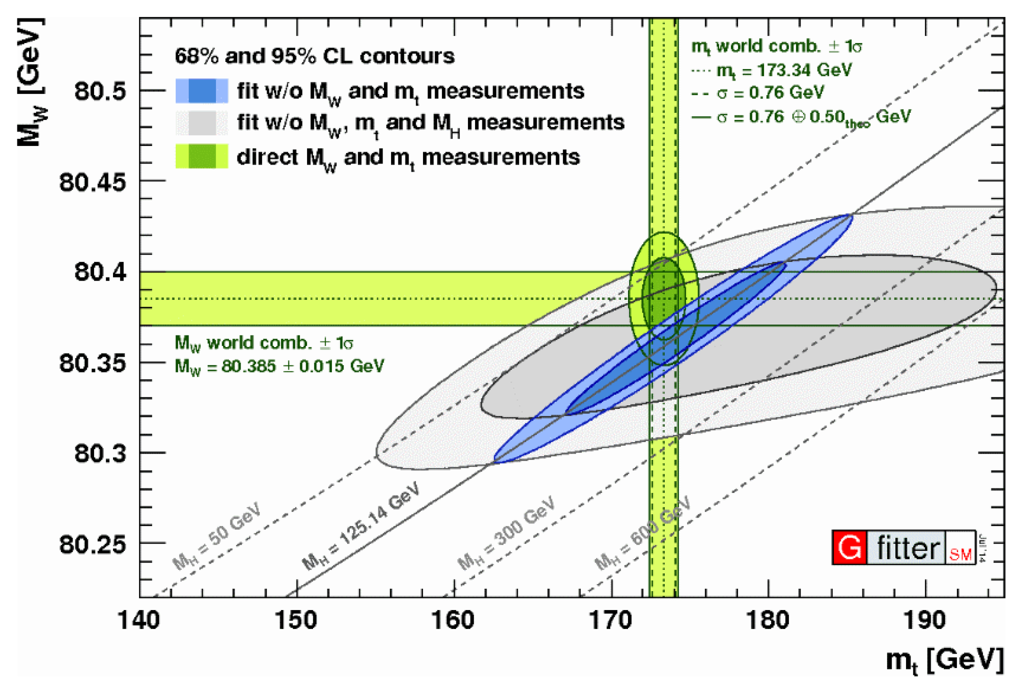
$$M_W^2 = \frac{\pi\alpha_{QED}(M_Z^2)}{\sqrt{2}G_F}\frac{1}{\sin^2\theta_w(1-\Delta r)}$$

$$\Delta r = -\frac{\cos^2\theta_W}{\sin^2\theta_W}\Delta\rho + \frac{\alpha}{3\pi}\left[\frac{1}{2} - \frac{1}{3}\frac{\sin^2\theta_W}{1-\tan^2\theta_W}\right]\log\frac{m_H^2}{m_Z^2} + ... \sim 1\% \text{ with } \Delta\rho = \frac{\alpha m_t^2}{\pi m_Z^2} - \frac{\alpha}{4\pi}\log\frac{m_H^2}{m_Z^2} + ... \sim 1\%$$



New physics with quantum effects through loops

- Any deviation of the measurements with respect to predictions and among themselves would reveal the existence of **new, weakly interacting particles** through global fits to the electroweak sector.

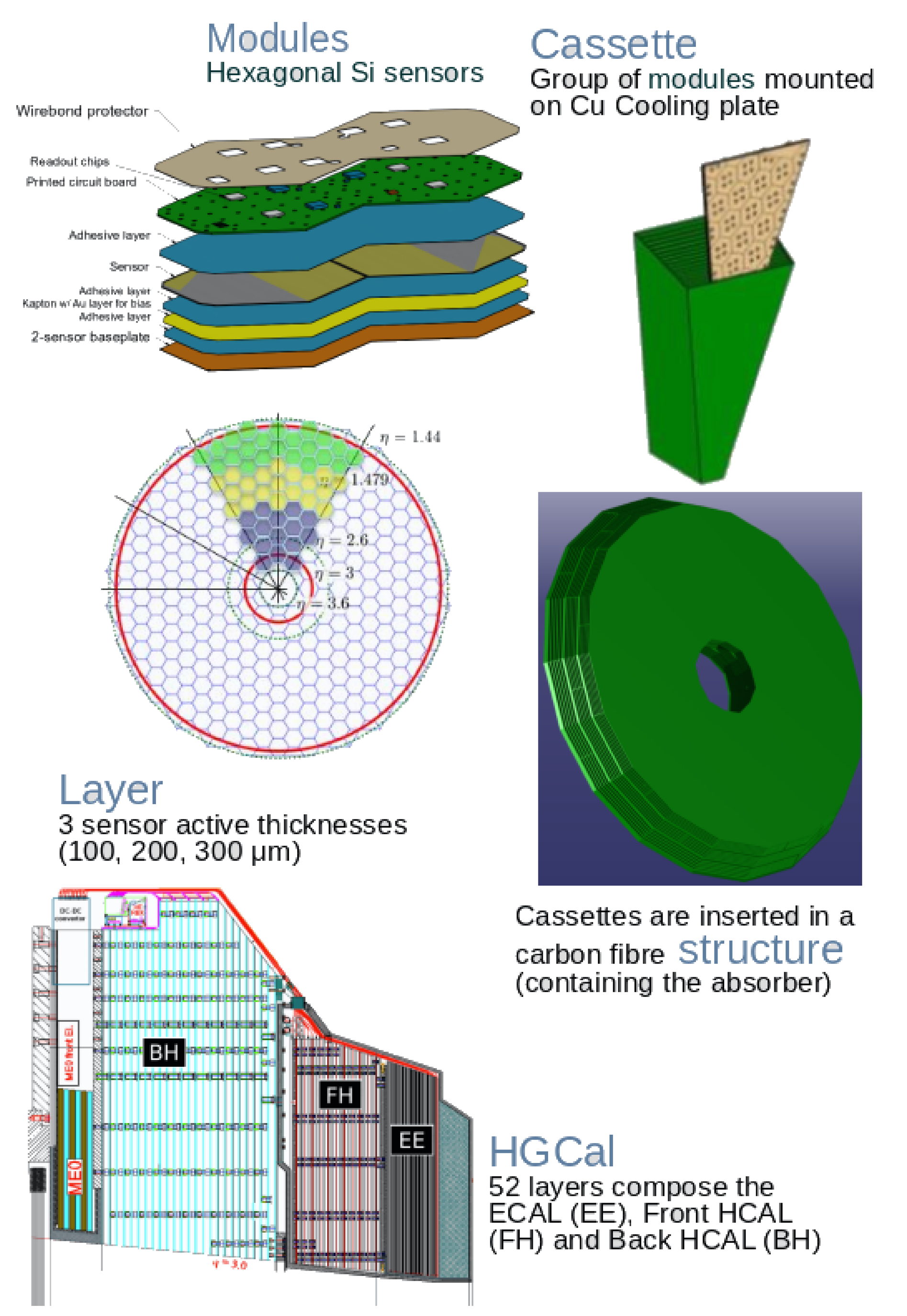


- Test of the **internal consistency of the Standard Model**
- Precision electroweak measurement are a key tool for constraining theories describing **physics beyond the Standard Model**.

CMS endcap for HL-LHC : HGCal

- LHC phase-II : With the Higgs boson as central program, HL-LHC is a **pp collider** starting in **2025**. This High-Luminosity LHC would begin with an instantaneous luminosity of $5\times10^{34} cm^{-2}s^{-1}$ to reach $3000 fb^{-1}$ after 10 years.
- **High Granularity Calorimeter** : CMS forward calorimeter

10 times more than LHC



Challenges : Radiation tolerance and event pileup

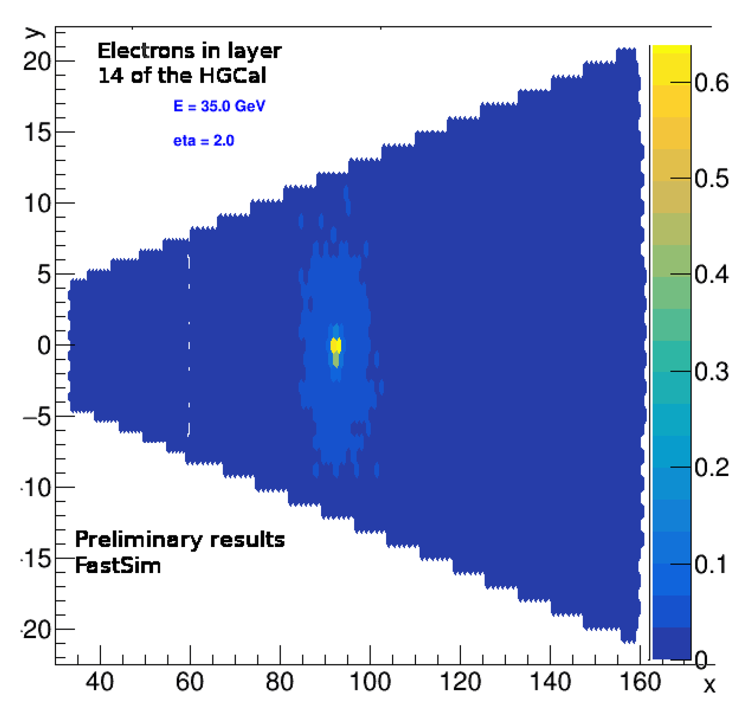
First **Si-based calorimeter** technology in hadronic cells.

Unprecedented transverse and longitudinal segmentation **facilitate particle-flow** calorimetry and ensure a **good energy resolution**

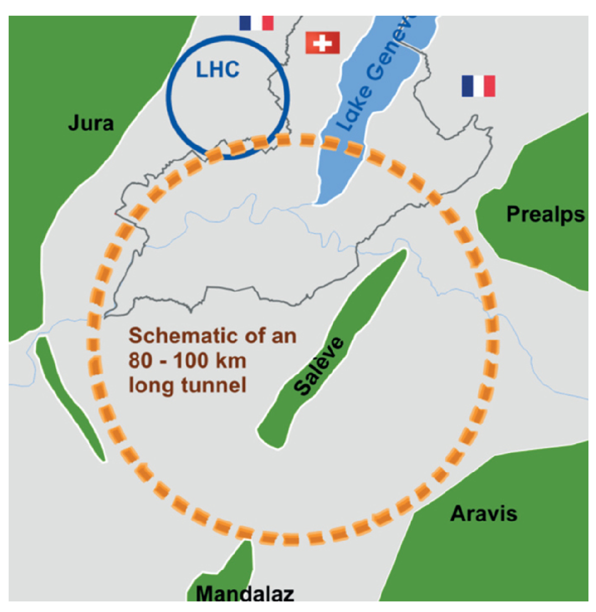
Intrinsic high-precision timing capabilities of Si add extra dimension in the event reconstruction allowing the **pileup rejection**.

- A **Fast Simulation** for the HGCal : Simple, fast and flexible tool able to reproduce the electromagnetic and the hadronic shower development in the HGCal. Complementary to the CMSSW full simulation.

10^6 events in 360 secs
→ **2.6kHz generation rate**



Future Circular Collider - FCC



- FCC : one of the **post-LHC** projects proposed in the context of the European Strategy (2013). Multi-purpose collider with **about 100 km** of circumference.

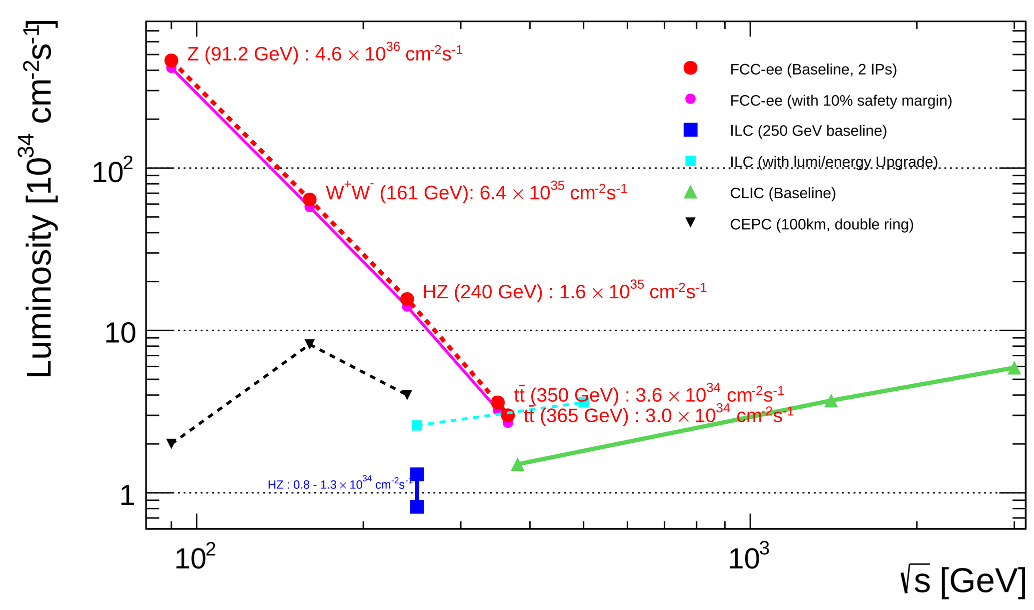
  The first phase, **FCC-ee** is the e^+e^- collider project that plans to deliver the highest luminosity (up to $2.3\times10^{36} cm^{-2}s^{-1}$) to several detectors, at **centre of mass energies between 90 and 400 GeV**. It will study the four heavy particles of the standard model (Z, W, H, t) with unrivalled **accuracy** (10^{-5} to 10^{-6}). These measurements will allow to discover the new weakly coupled physics in range 10 to 100 TeV.

The ultimate goal of the FCC is a proton-proton collider with $\sqrt{s} = 100$ TeV. The physics cases of the two machines present many complementarities and are scientifically synergetic. A FCC-he option is also conceptually studied.

- FCC-ee detector :

  Challenges : experimental and theoritical uncertainties control and high statistics required (up to 100 kHz event rate)

  Detector design :
  → A detector concept (IDEA) based on the **state-of-the-art** technologies which should be **optimised** for precision measurements.
  → Another detector concept based on the **CLIC collider** is also under study.



- The constraints given by physics needs, will determine by simulation the whole detector design. For the W mass the requirement is a measurement with a **total uncertainty of 0.5 MeV** (reduction by a factor 30).

Calorimetry requirements for the W mass measurement

For the W mass measurement the constraints are set on the calorimetry. The required parameters to optimise in these two projects are :

- e^+e^- collisions : Lepton momentum and angular resolution, jet energy and angular resolution, granularity, and particle-flow capabilities
- pp collisions : recoil measurement.