FACULTY
OF SCIENCES

DEPARTMENT < ... >
RESEARCH GROUP < ... >

STUDY OF TOP QUARK PRODUCTION AT FUTURE ELECTRON-POSITRON COLLIDERS

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WHY STUDY TOP QUARKS?

Unique properties:

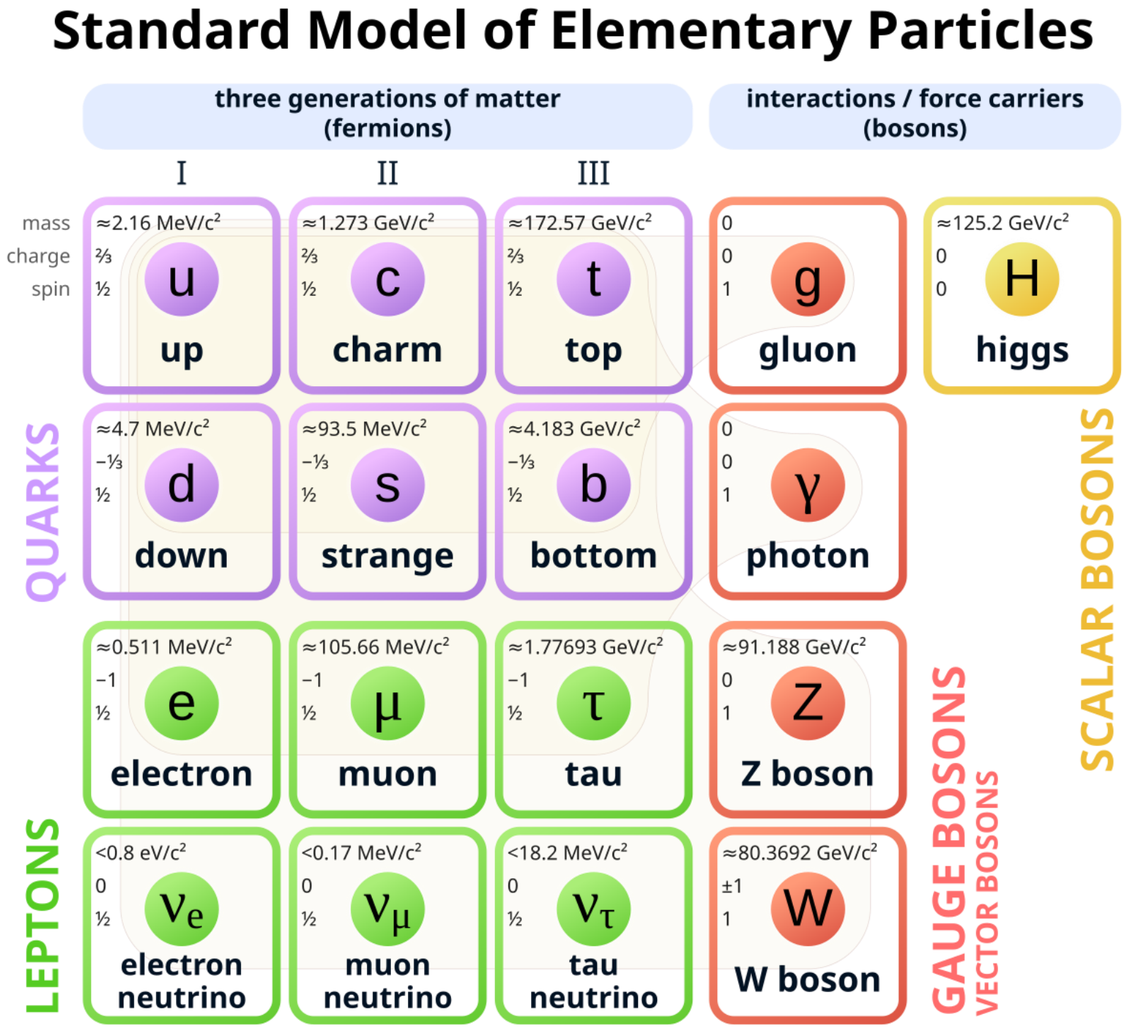
- Heaviest SM particle
- Yukawa coupling ≈ 1

Clean decay signature:

- Decays before hadronizing

BSM physics:

- More precise measurements yield a deeper insight



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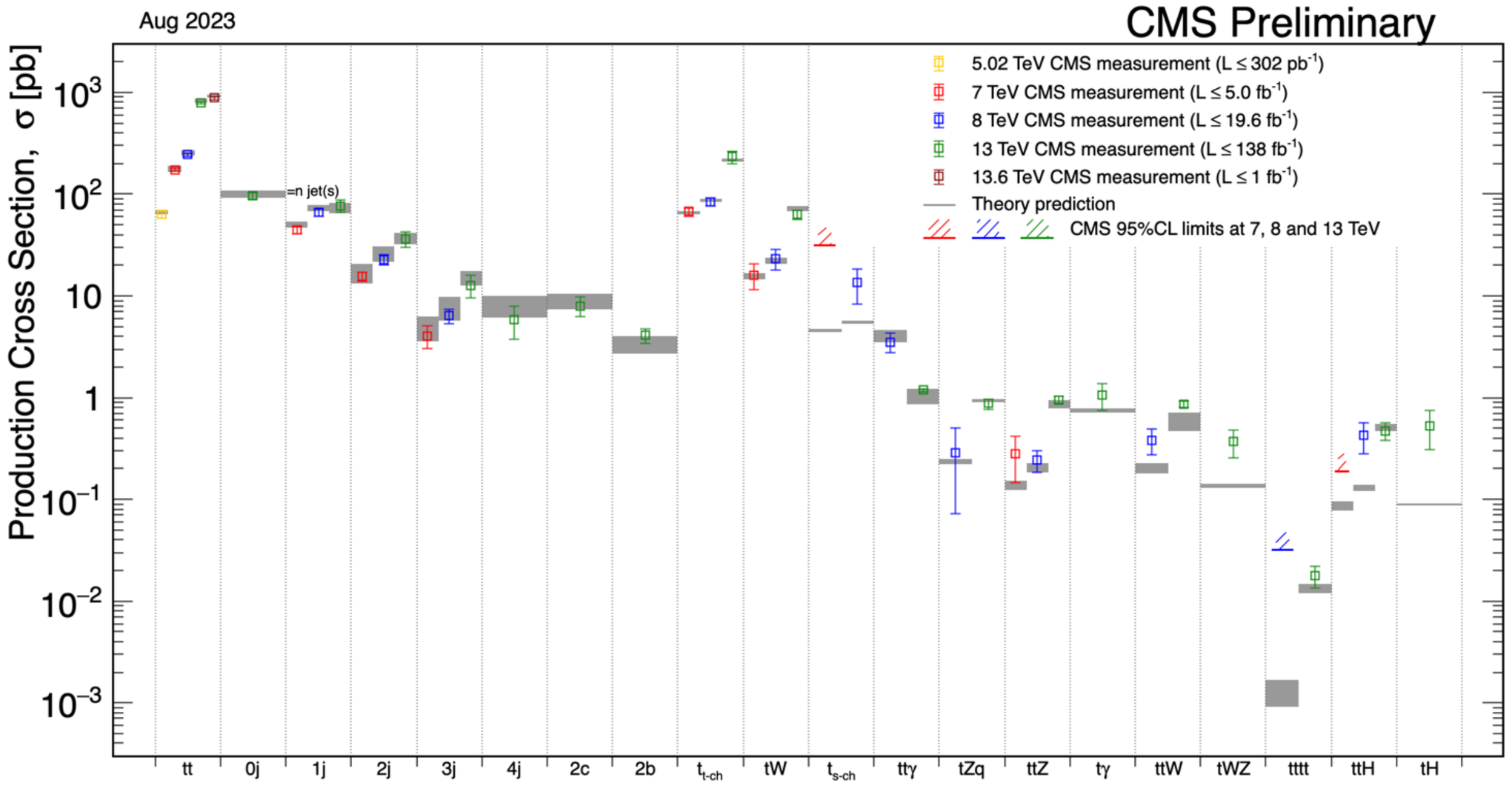
EXTENSIVE TOP QUARK RESEARCH AT LHC



All results at: http://cern.ch/go/pNj7

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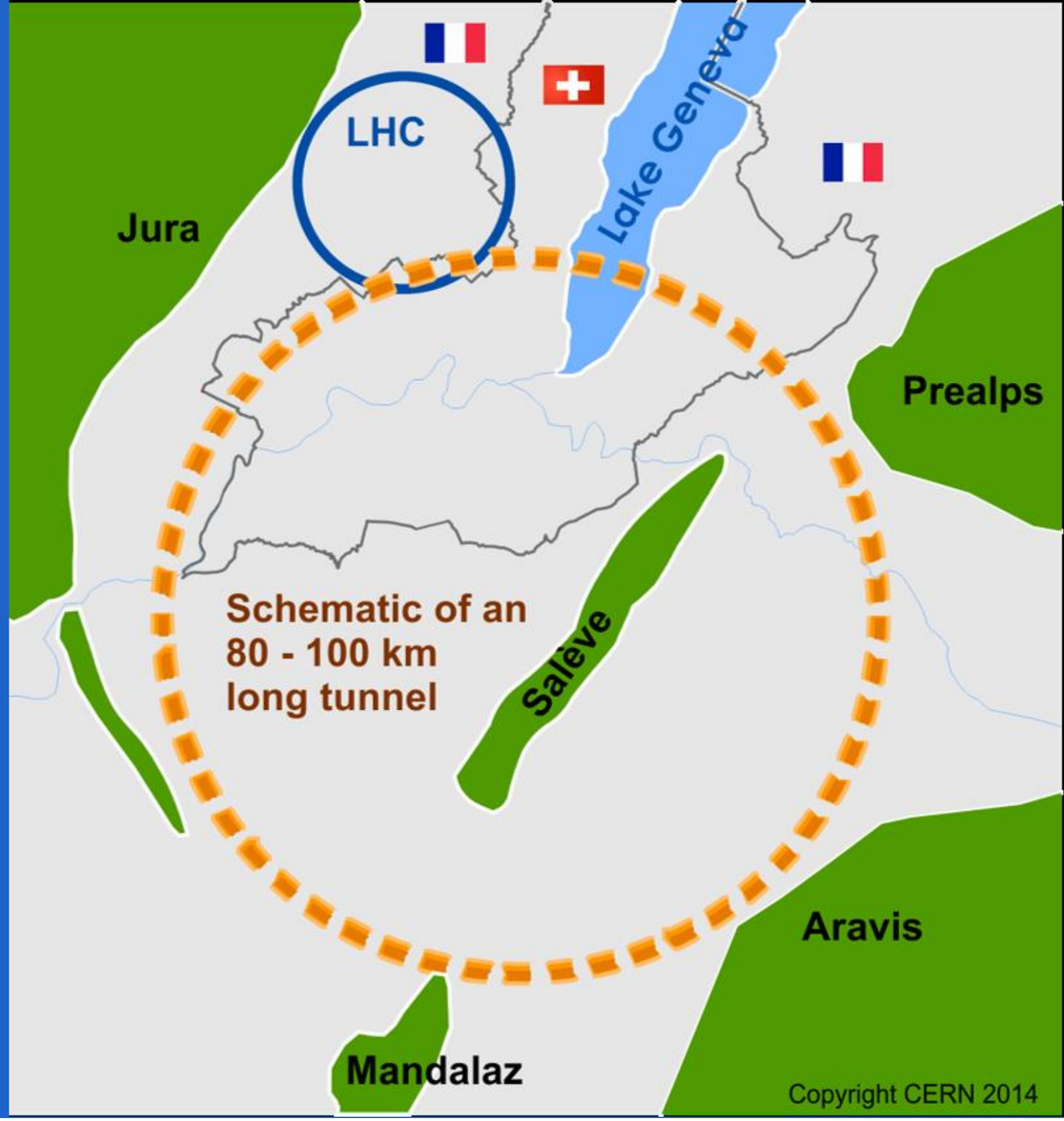
THE NEED FOR A NEW COLLIDER



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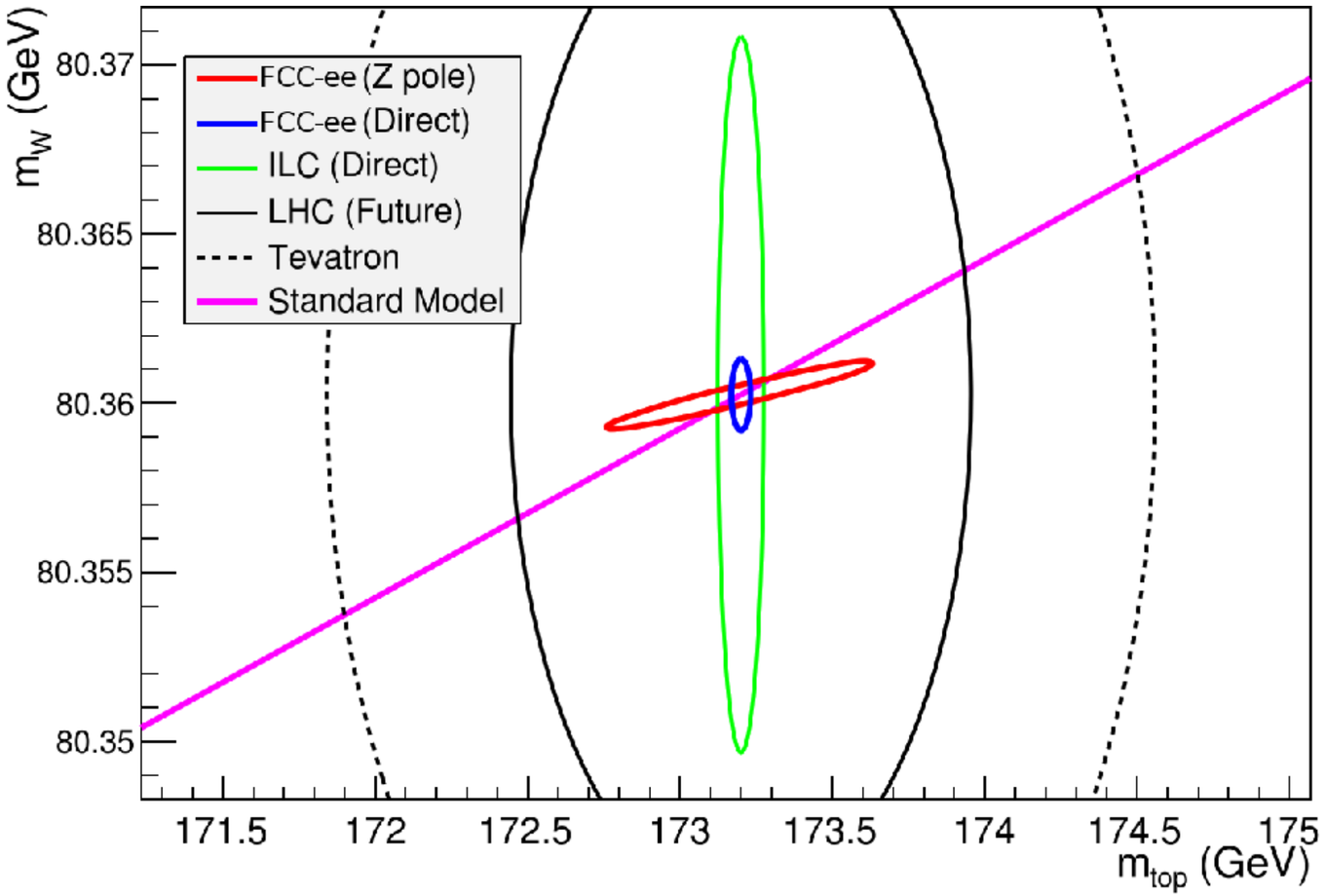
THE NEED FOR A NEW COLLIDER

- Improve precision in: electroweak observables

- Look for new physics effects through this high precision

d'Enterria, David (CERN)



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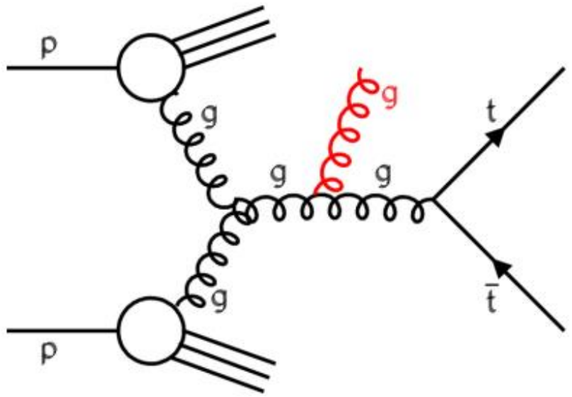
HADRON AND LEPTON COLLIDERS

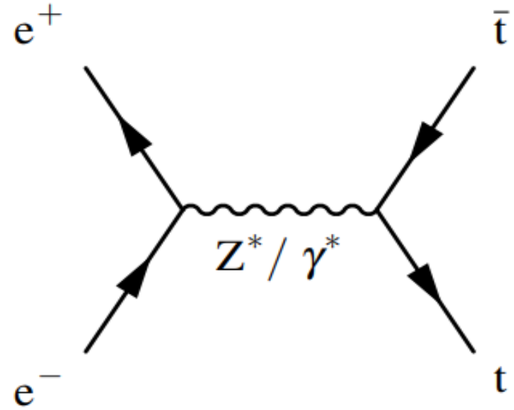


Proton is a compound object:

- Initial state unknown
- Limits in achievable precision

High Energy Circular colliders possible

High rates of QCD backgrounds



e^+e^- are pointlike

- Initial state well-defined
- Beam polarization distinguishes Z/γ
- High-precision measurements

High energies (> 380 GeV) require linear colliders

Clean experimental environment

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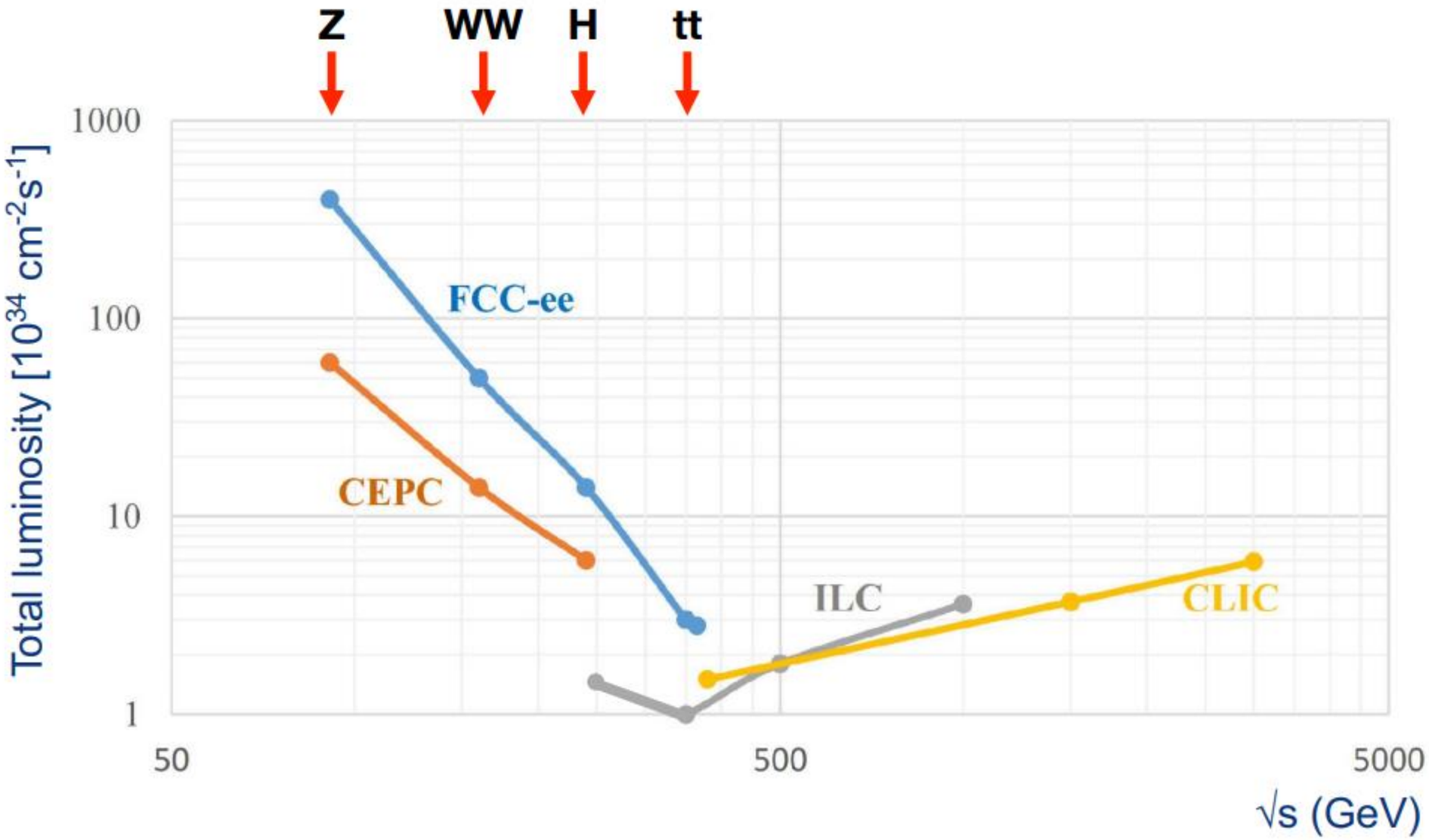
FUTURE LEPTON COLLIDERS LUMINOSITIES



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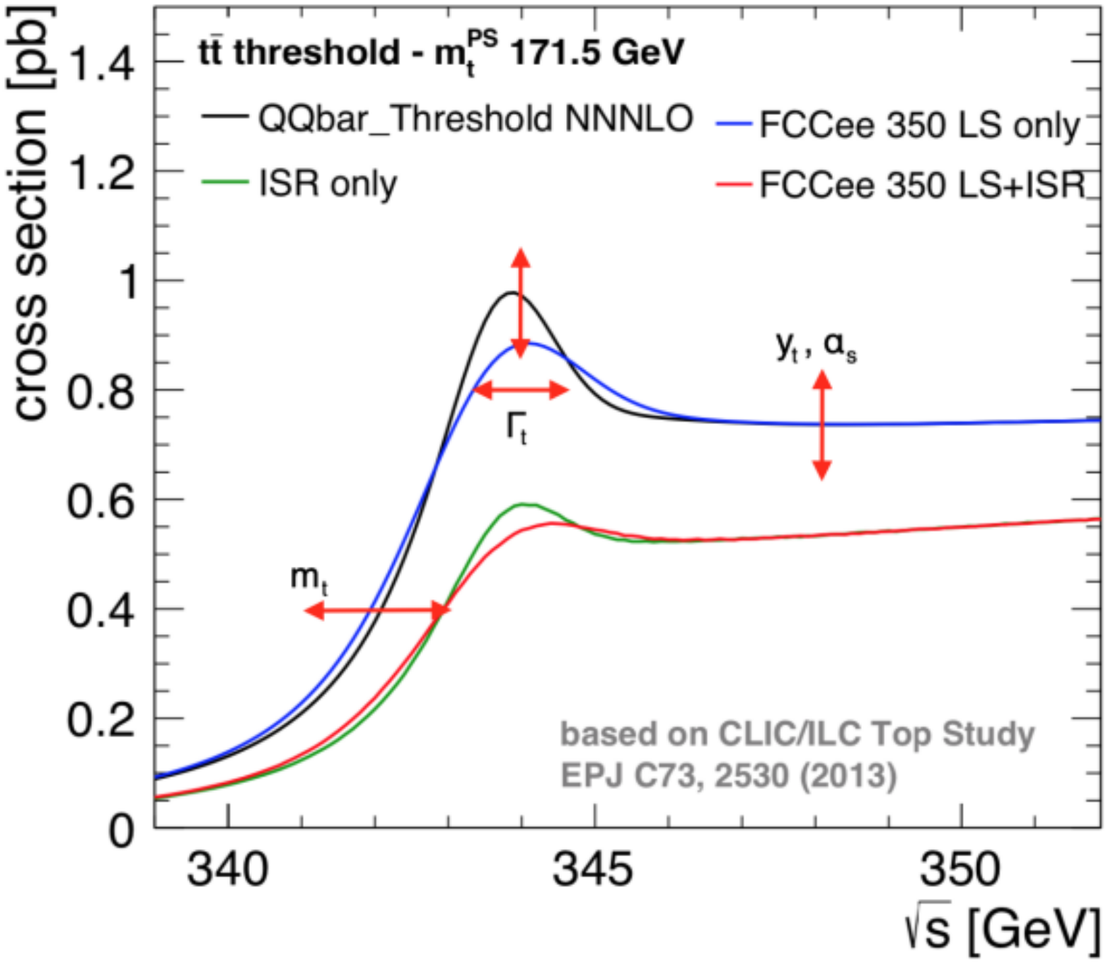
CROSS SECTION THRESHOLD SCAN

FCC improves precision on measurements of the top quark:

- Mass and Width
- Couplings: y_t, g_{tWb}, g_{Ztt}, $g_{\gamma tt}$
- FCNC and rare decays
- Asymmetries and other properties



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ANALYSIS OF THE TOP QUARK

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STRATEGY

- Decay Channels:

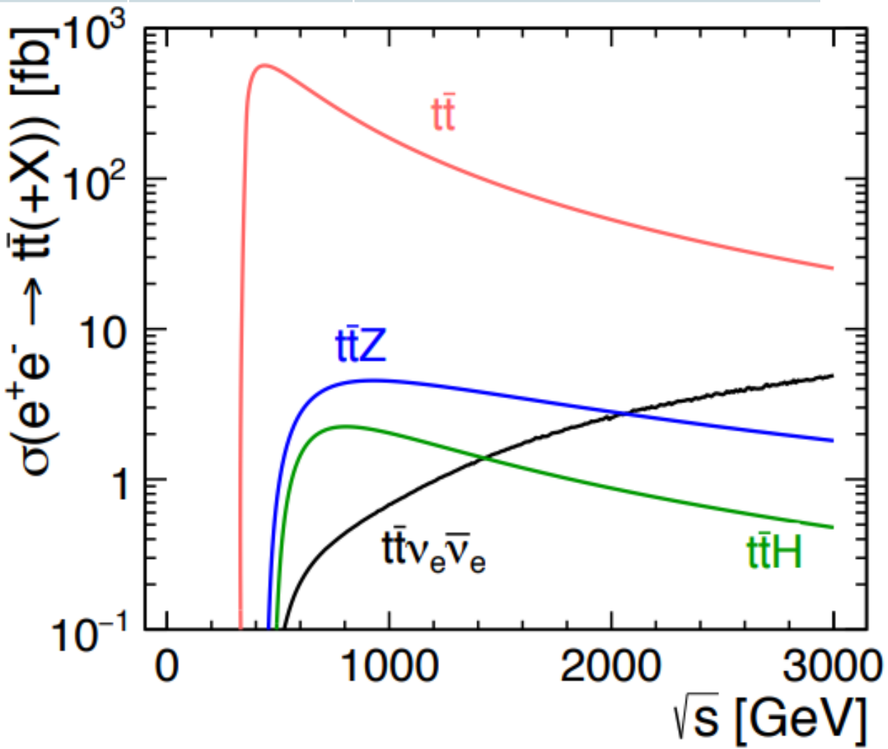
$$t\bar{t} \rightarrow b\bar{b}W^+W^- \rightarrow b\bar{b}qq\bar{q}\bar{q}$$

$$t\bar{t} \rightarrow b\bar{b}W^+W^- \rightarrow b\bar{b}q\bar{q}l^-\bar{\nu}(l^+\nu)$$

$$t\bar{t} \rightarrow b\bar{b}W^+W^- \rightarrow b\bar{b}l^+\nu l^-\bar{\nu}$$

Final state	BR [%]	Signature
Fully Hadronic	46.2	6 jets
Semi Leptonic	43.5	4 jets, 1 $l^{\pm}$, 1 ν
'Fully' Leptonic	10.3	2 jets, 2 $l^{\pm}$, 2 ν

- Threshold energy range
  - Gives less background



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SIMULATION FRAMEWORK: **KEY4HEP**

Event Generation:	• Madgraph + Pythia8
Detector Simulation:	• Delphes
Data Format: EDM4HEP	• Contains full information about simulation and reconstruction
FCCAnalysis:	• preform associations
Machine Learning	• Event Selection and Reconstruction

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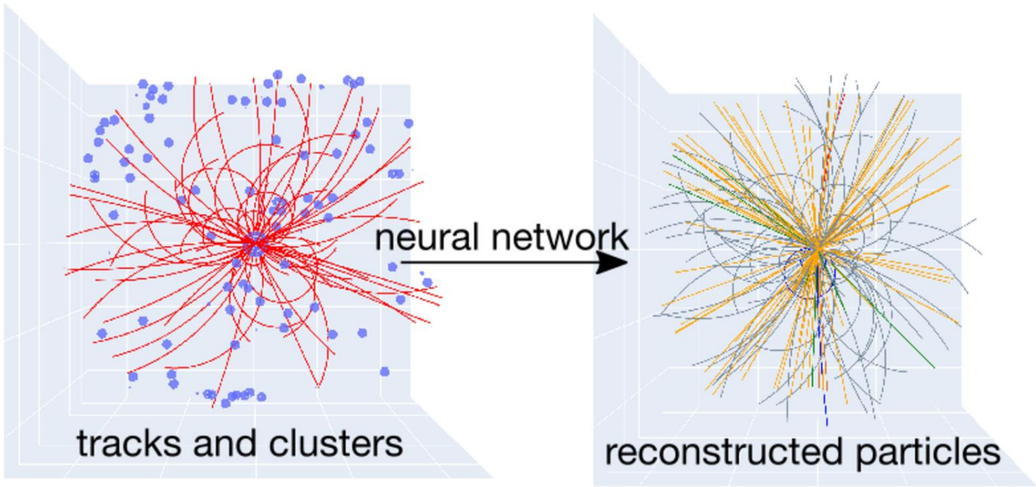
METHODS OF RECONSTRUCTION

- Kinematic fitting: χ^2 , Likelihood Methods

- BDT's for selecting the proper combination of final-state objects

- Deep Neural Networks for top-tagging:
  - DeepAK8, ATLAS t-tagger



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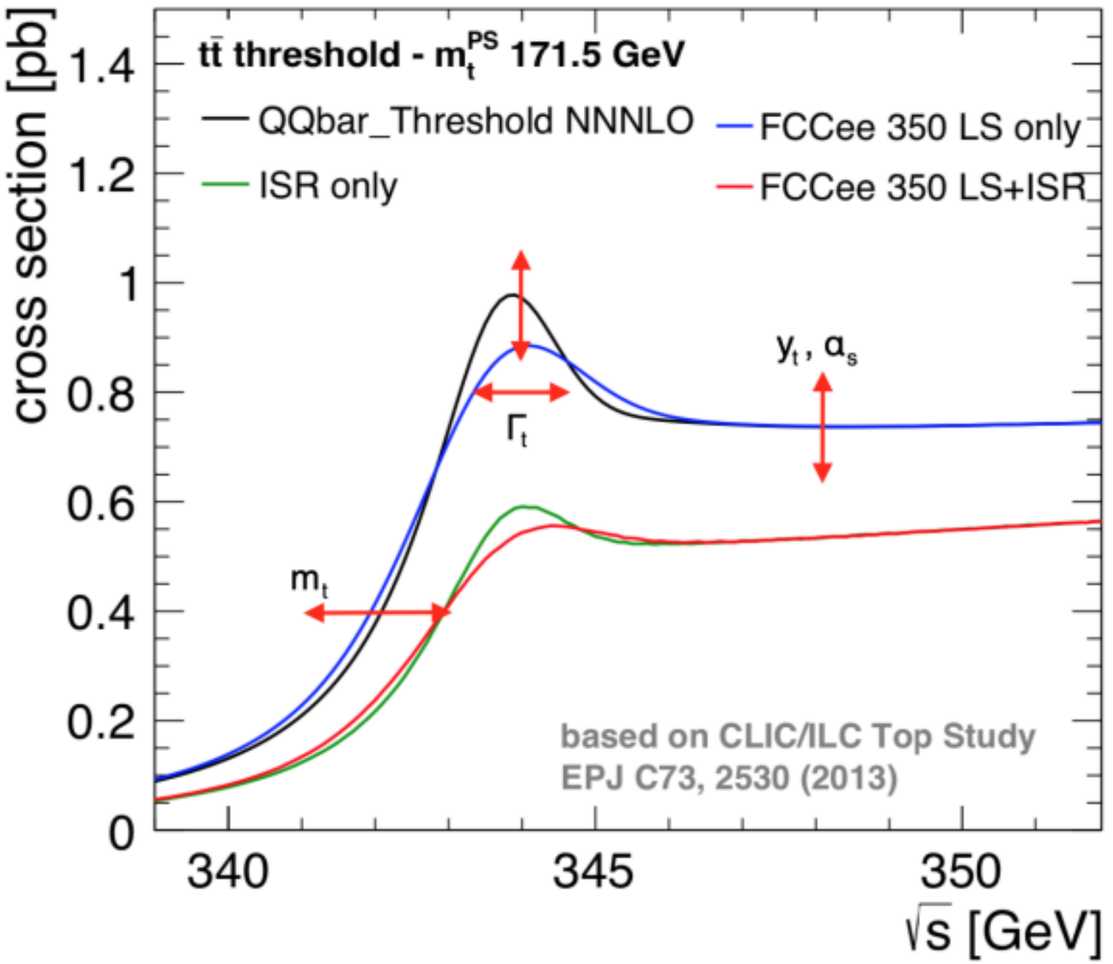
NEXT STEPS

- Develop advanced algorithms to:
  - Reconstruct the top quark with high precision
  - Separate signal vs background

- Investigate how to measure top quark parameters from the threshold cross section scan

- A look into Toponium?
  - Spin correlations



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QUESTIONS?

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BACKUP

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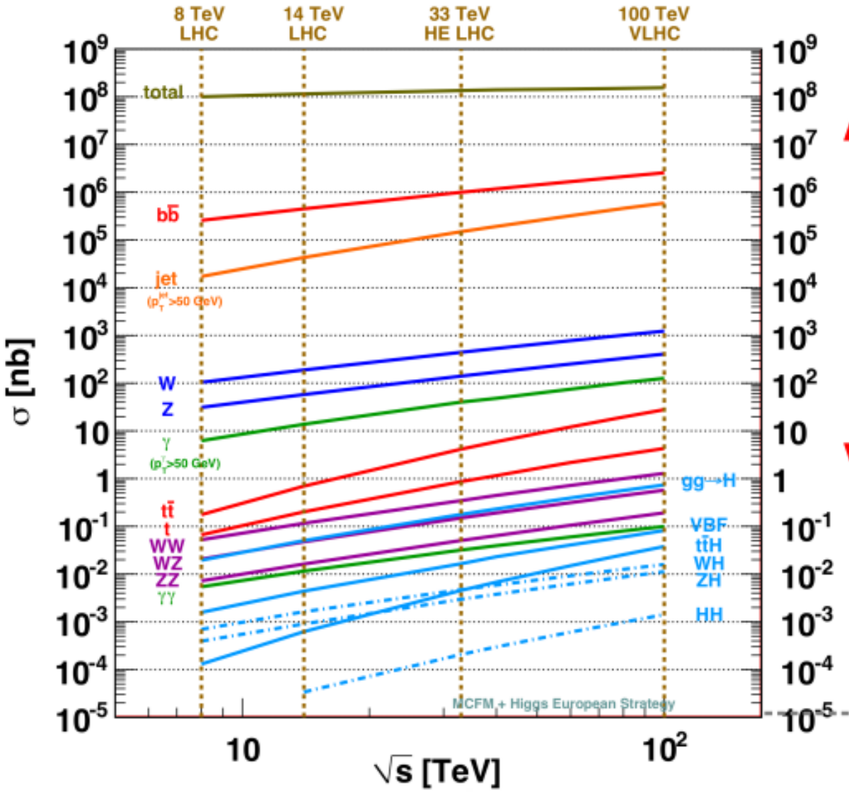
FCC TIMELINE

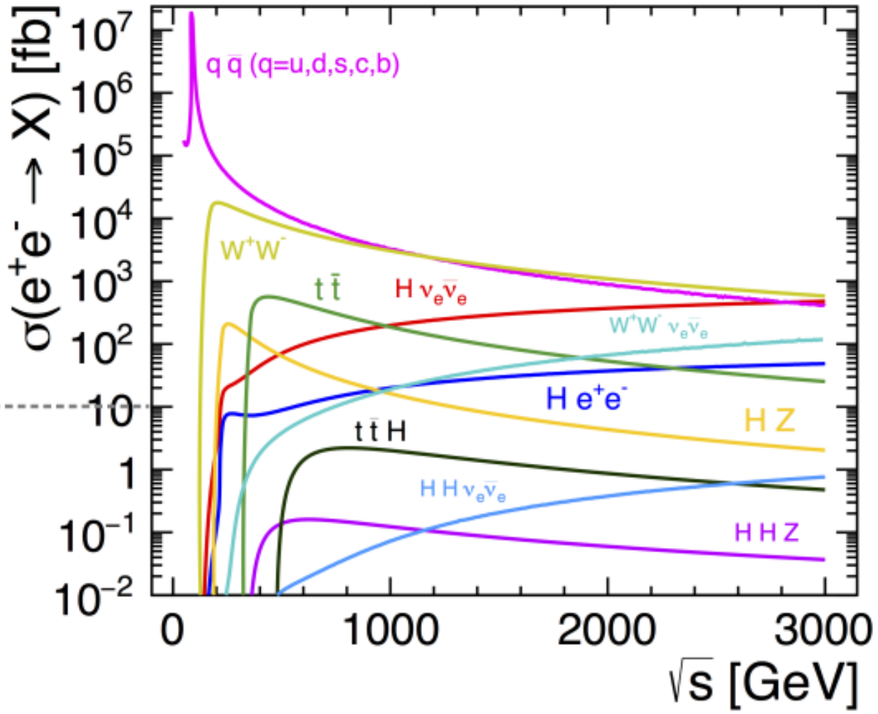
The tentative timeline is:

- **2025:** Completion of the FCC Feasibility Study
- **2027–2028:** Decision by the CERN Member States and international partners
- **2030s:** Start of construction
- **Mid-2040s:** FCC-ee begins operation and runs for approximately 15 years
- **2070s:** FCC-hh begins operation and runs for approximately 25 years

DISCUSSION ON BACKGROUNDS



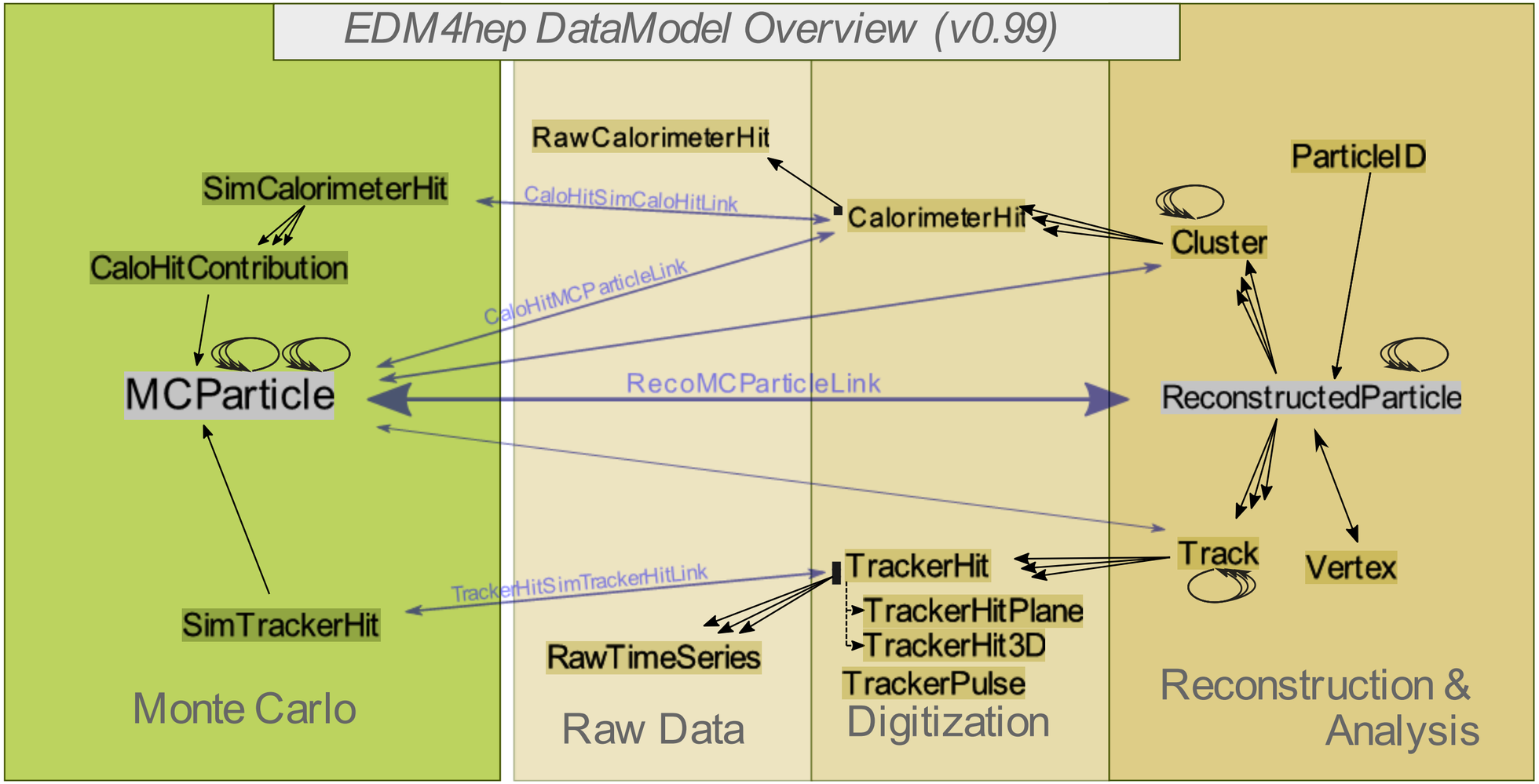
8 orders of magnitude!



pp collisions:
Interesting events need to be found in huge number of collisions

e⁺e⁻ collisions:
More “clean”, all events usable

TOP QUARK RECONSTRUCTION



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KEY4HEP DETAILED

- Madgraph + Pythia8
  - generate simulated event samples and compute cross sections for hard scattering and decay processes of particles
  - Specify additional parameters such as ISR/FSR
  - generates Monte Carlo data and hold information about all of the event particles at all stages before detection.

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KEY4HEP DETAILED

- Delphes
  - Takes the input from Madgraph/Pythia
  - Simulates the detector (IDEA) response
  - Reconstructs our particles and saves them
  - Represents the detector’s “view”

KEY4HEP DETAILED

- FCCAnalysis
  - Works on top of EDM4hep
  - Allows one to preform various associations like:
    - Reconstructed with MC generated particles
    - Vertex reconstruction
    - ...

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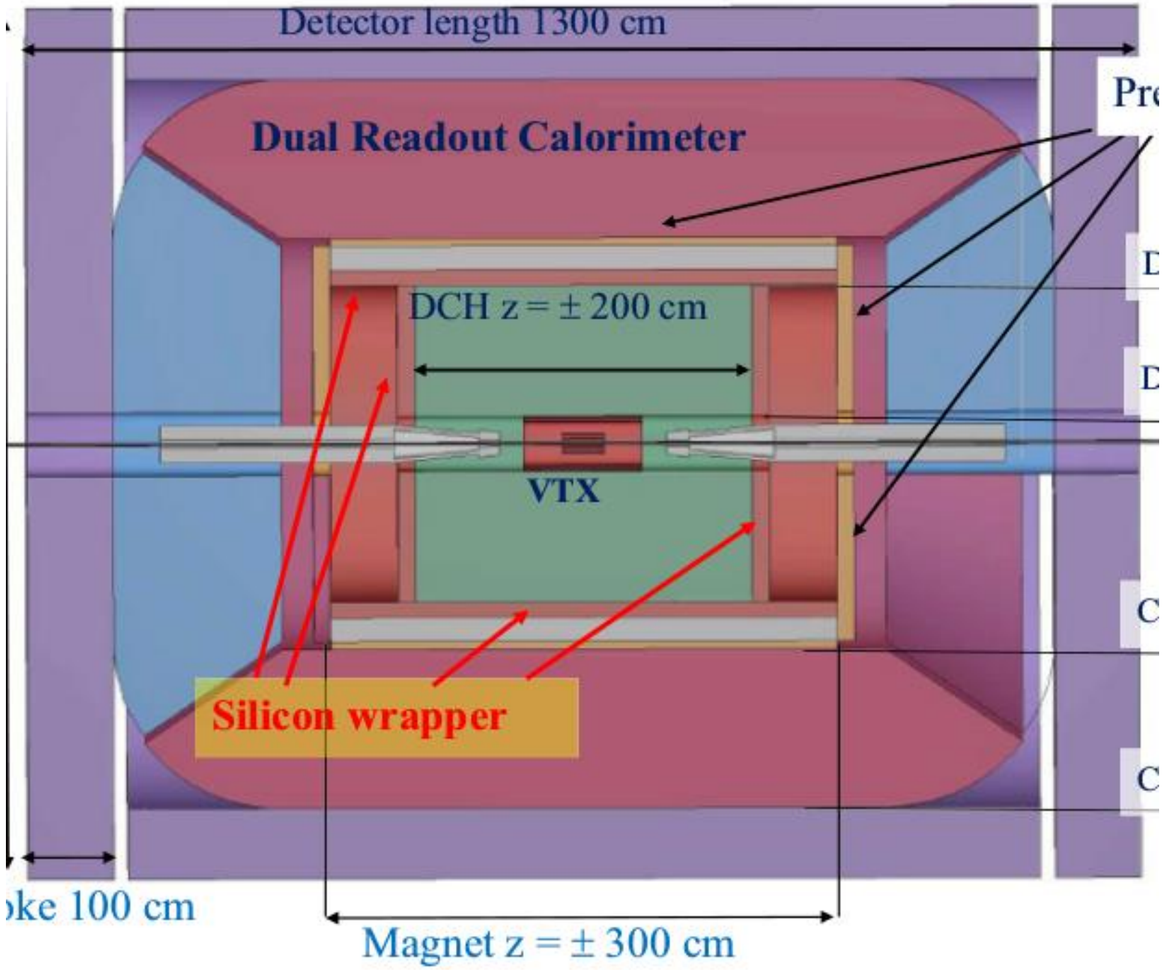
DETECTORS

- IDEA (International Detector for Electron-positron Accelerators)

- CLD (CLIC-like Detector)



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