

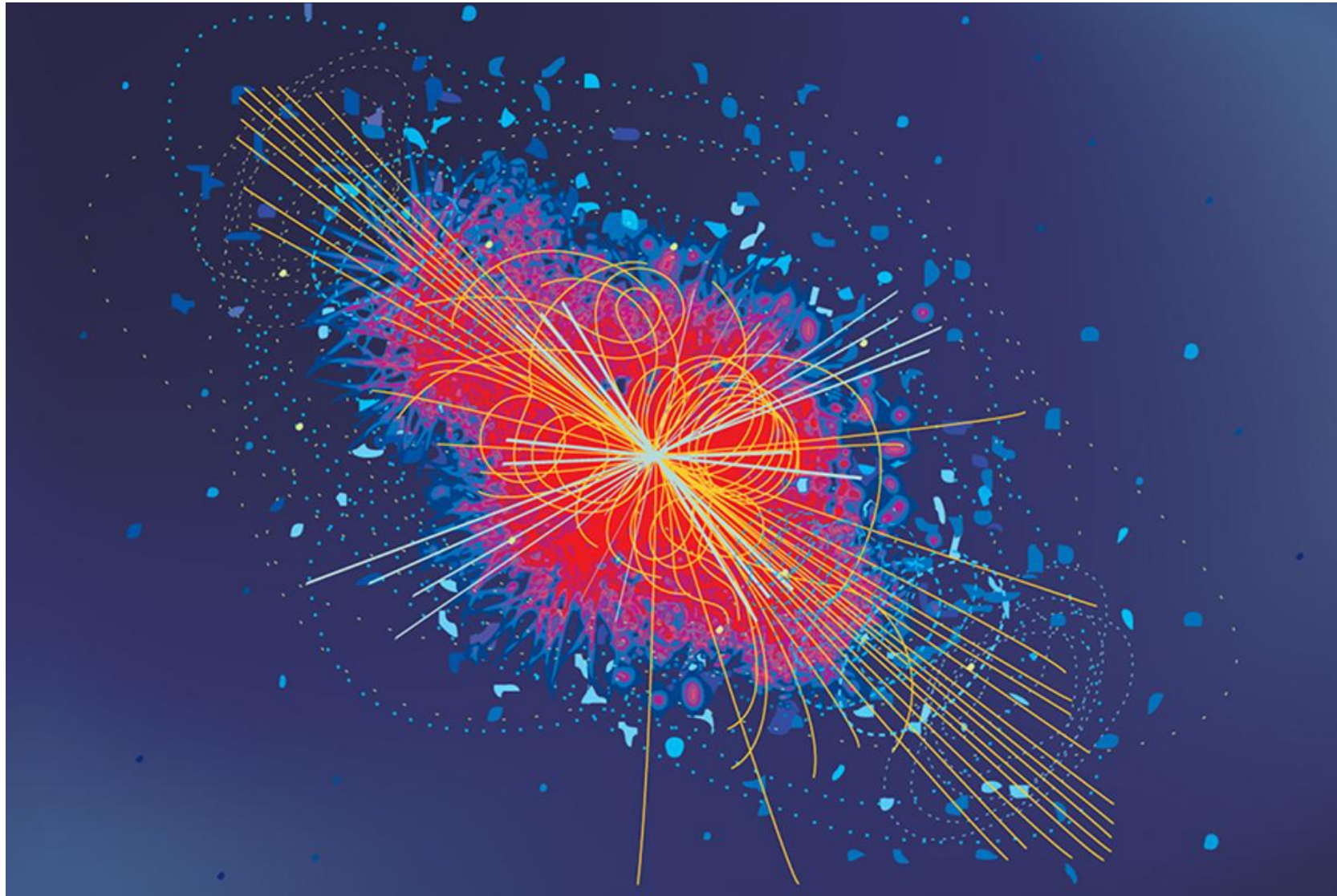
# Towards a future collider

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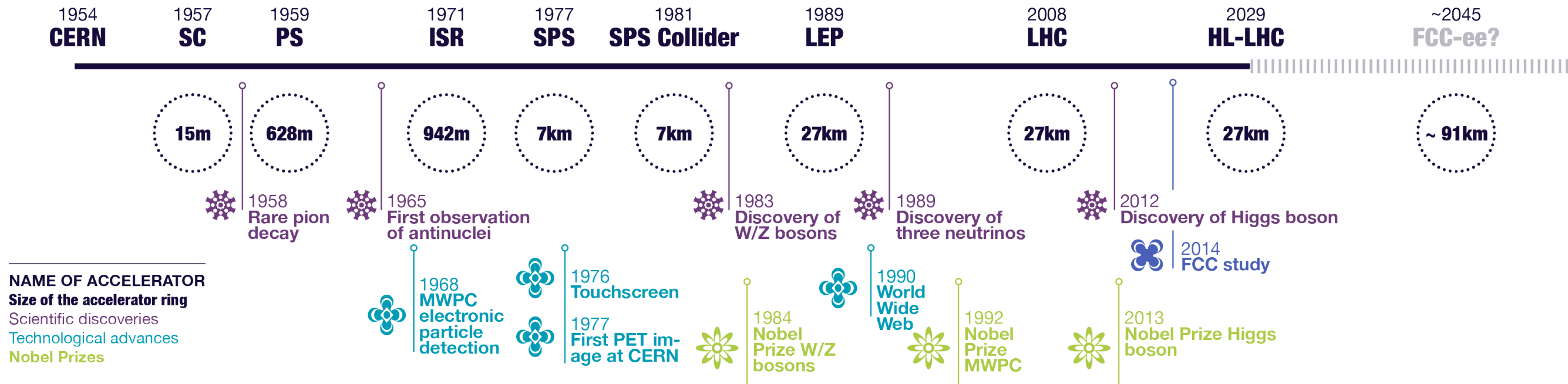
Heimbach, Germany  
September 7-18, 2026

# Why collide?

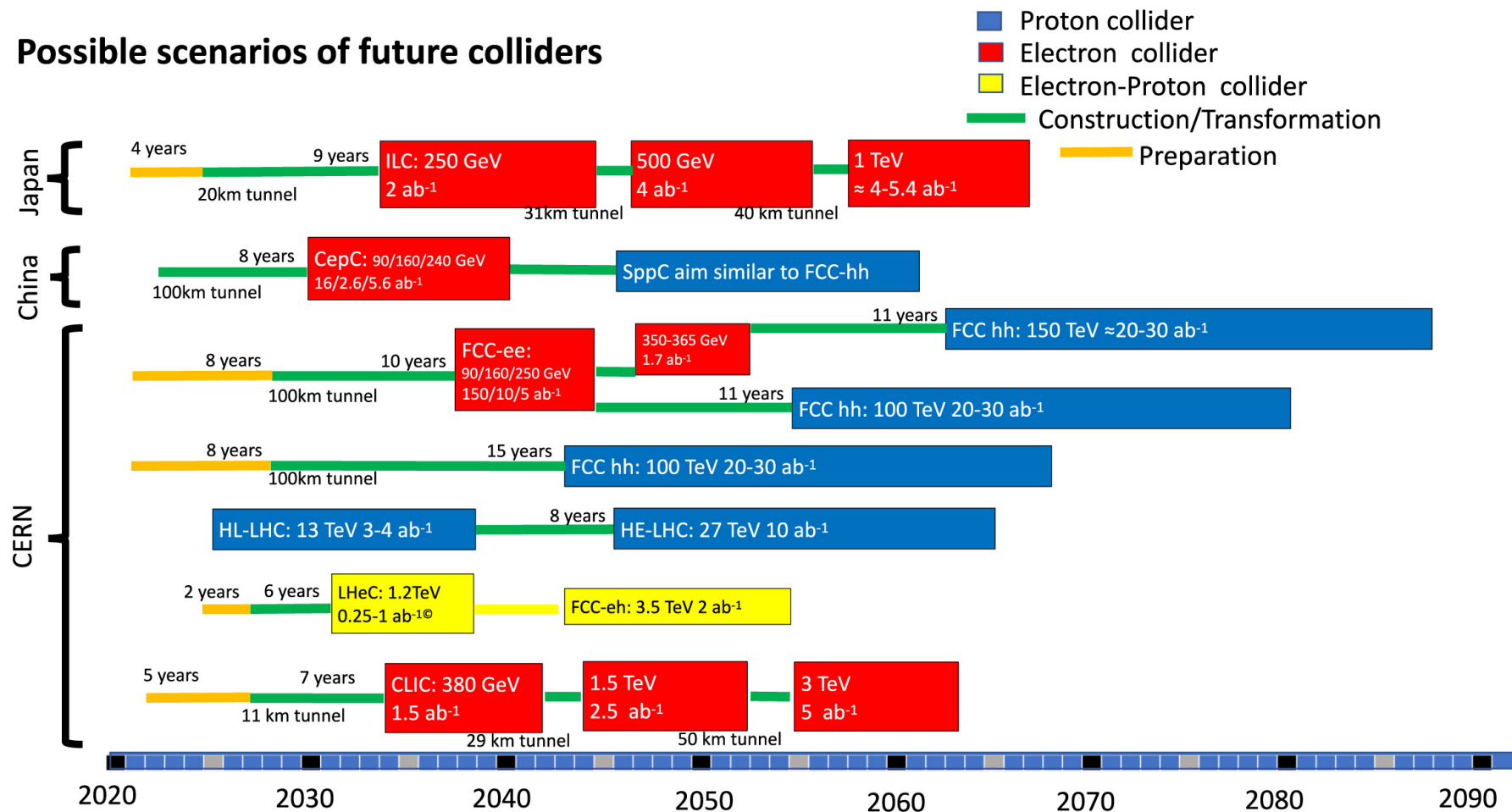


- The standard model of particle physics is **incomplete**
- Must probe new physics by **high-precision** and **high-energy** means
- **Collider experiments** are a sure pathway to **controlled production** of high-energy phenomena in laboratory conditions

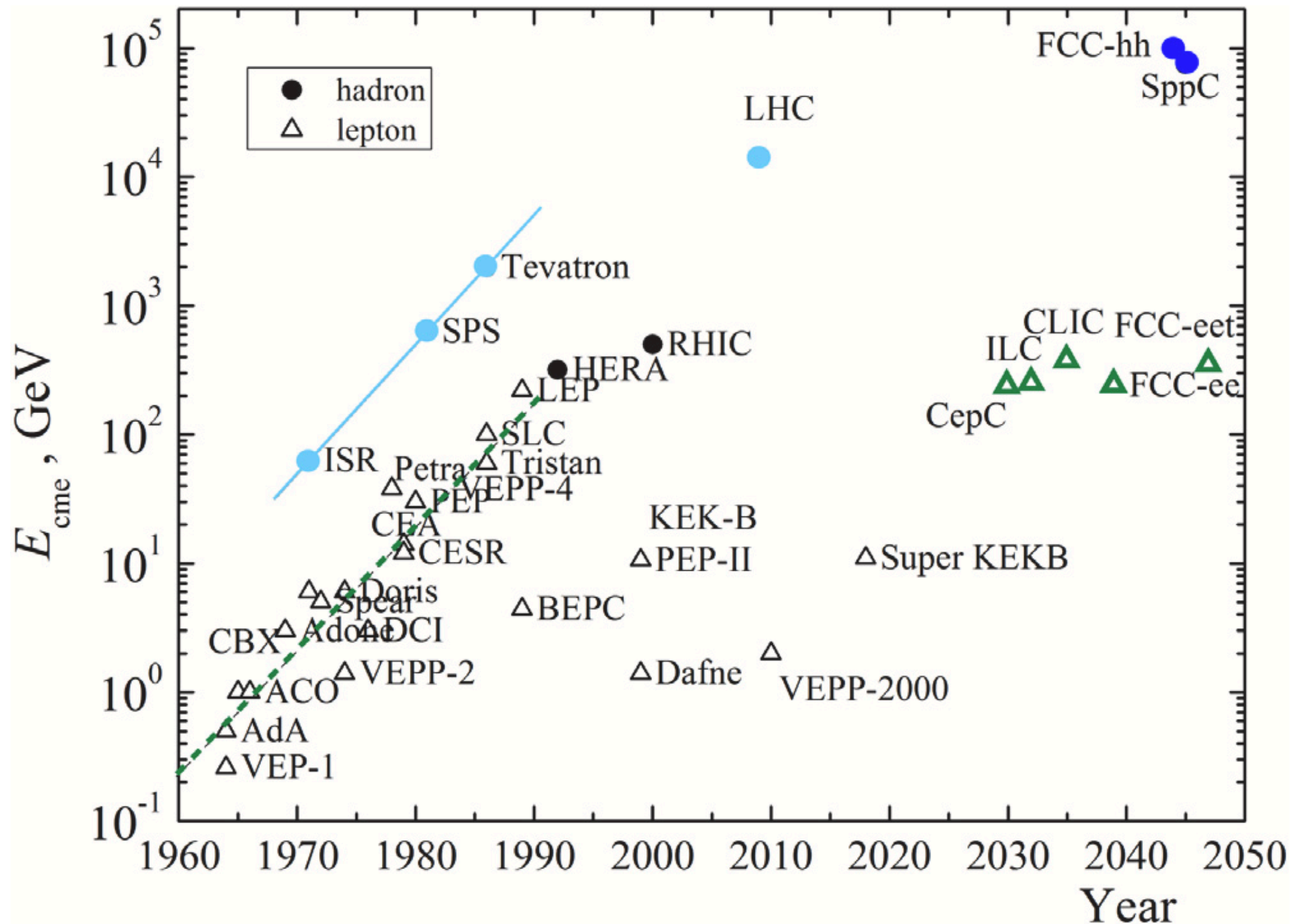
# Roadmap for future collider



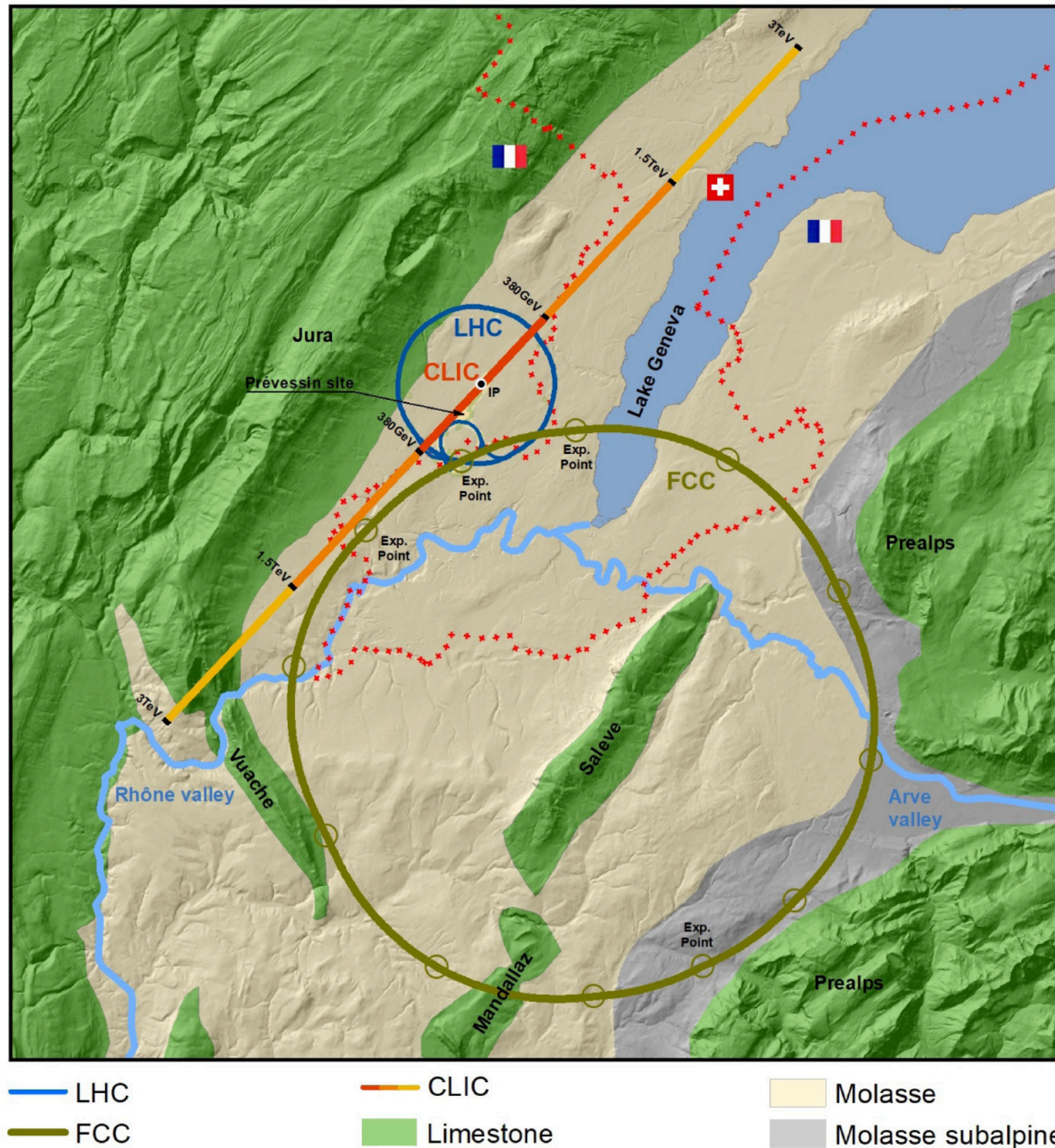
## Possible scenarios of future colliders



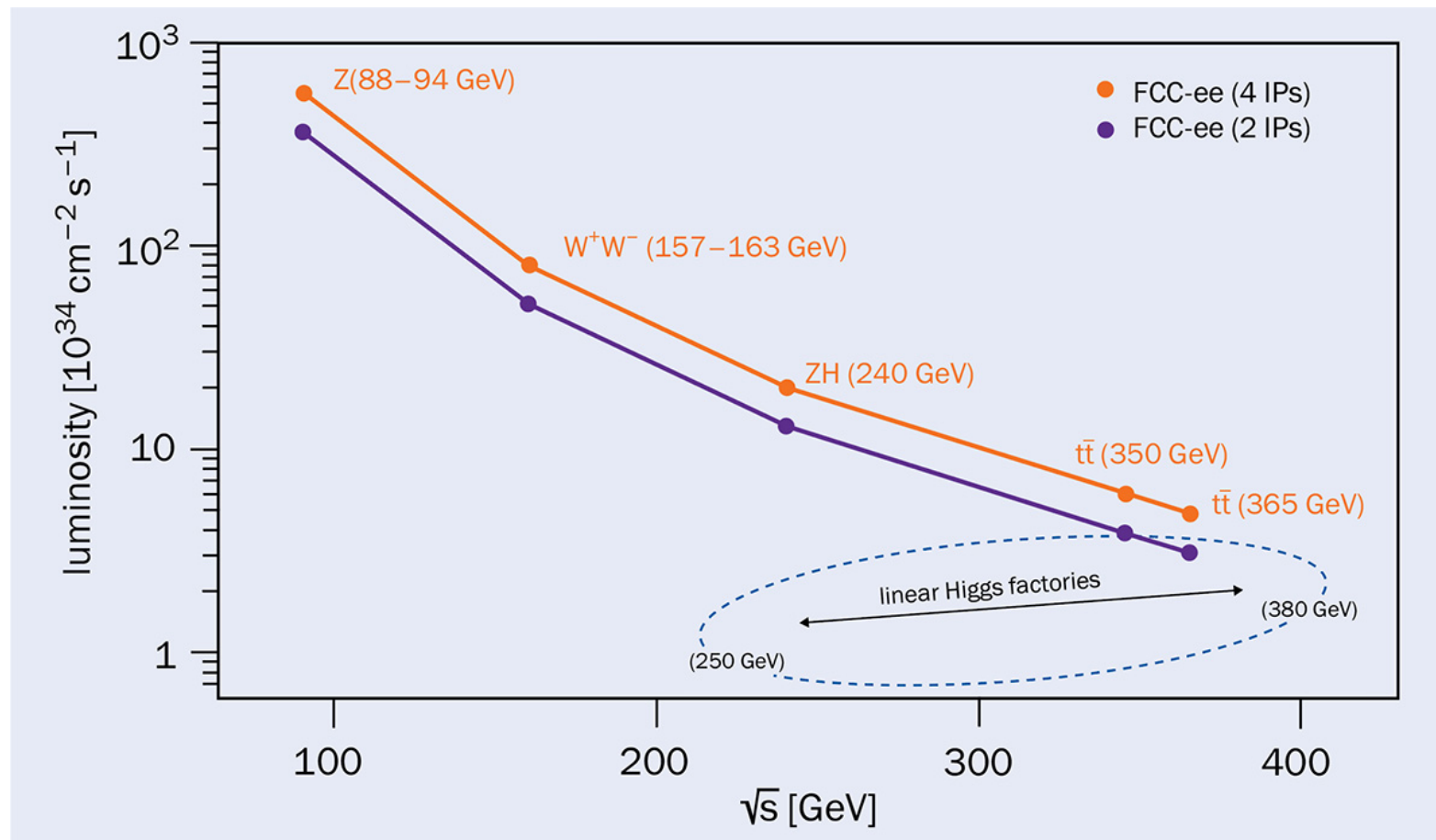
# Past, present, future



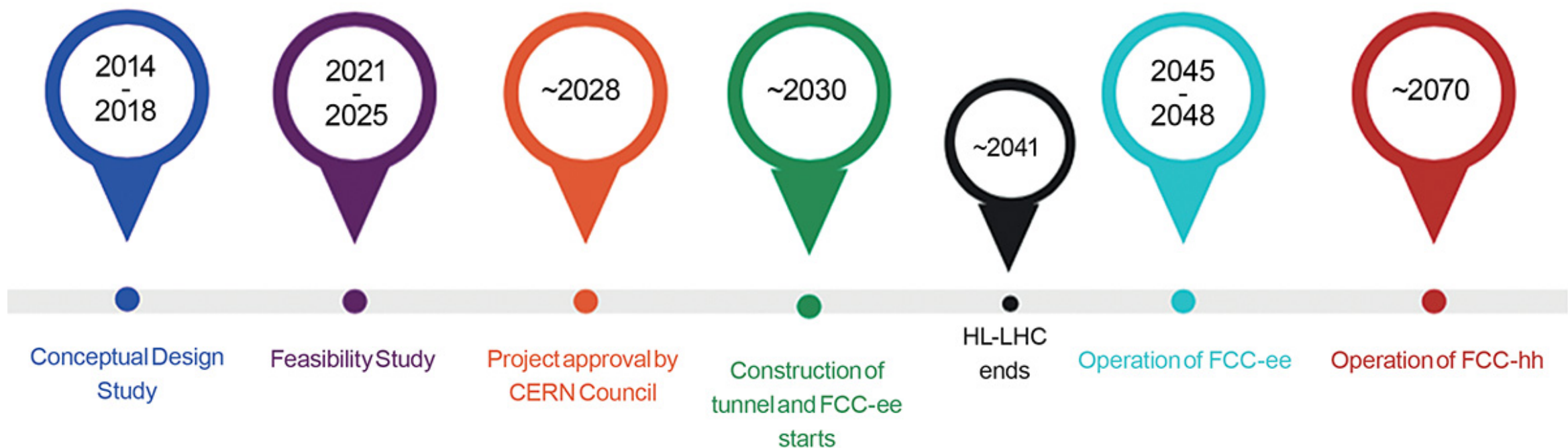
# Future Circular Collider



# FCC-ee timeline

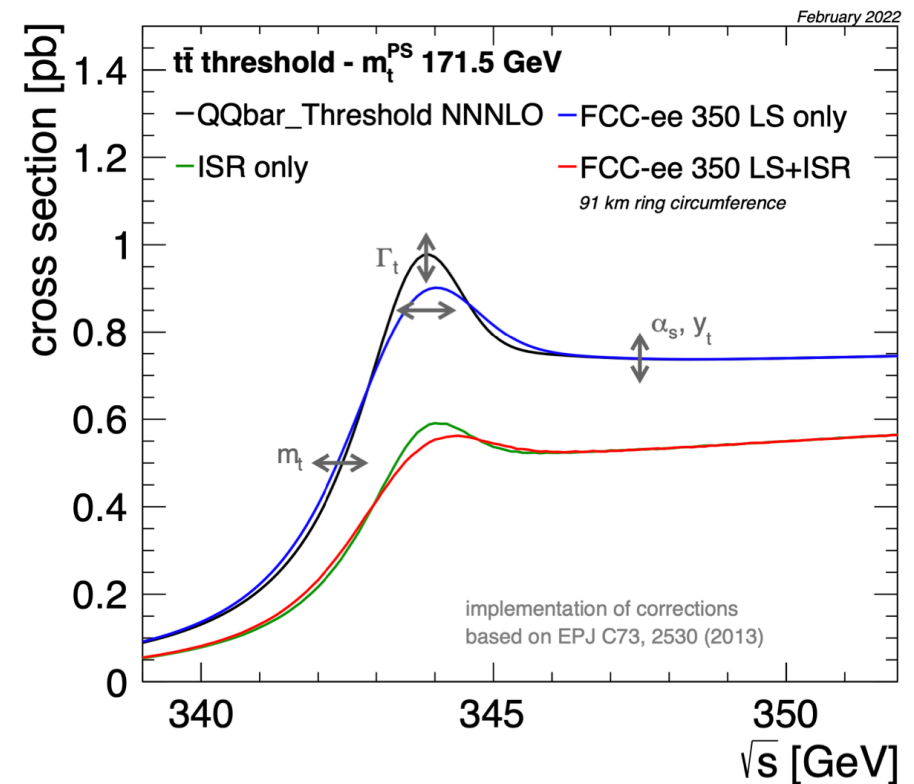
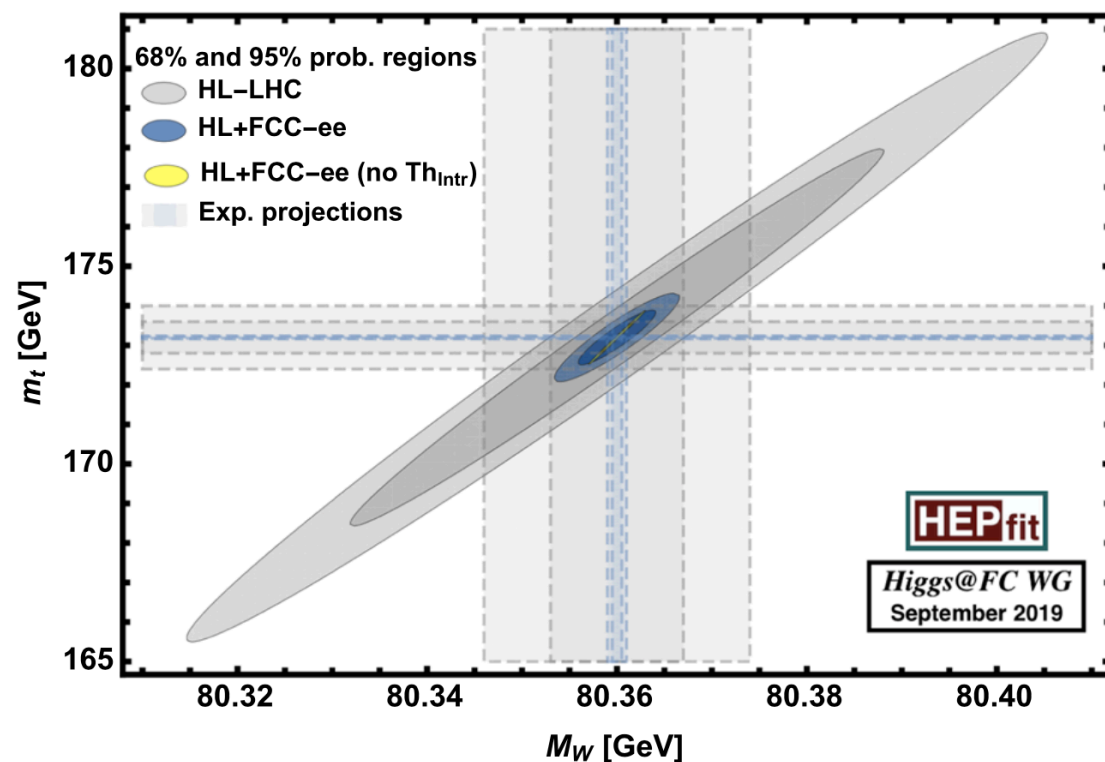
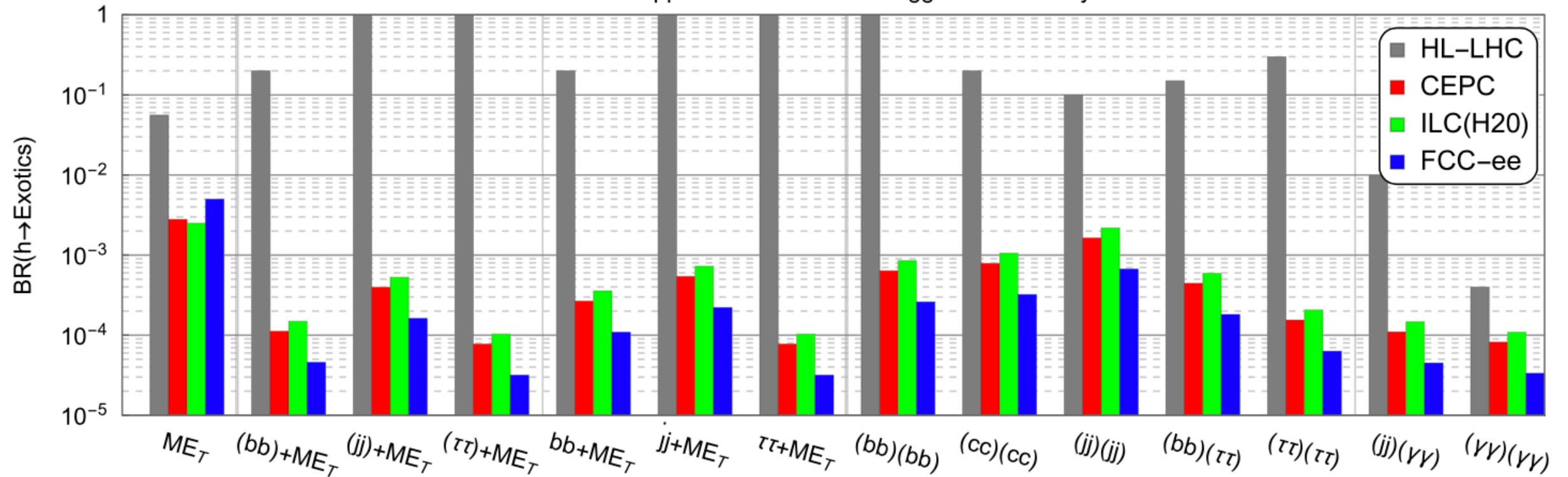


- Collision energies to go from **Z pole** to **top quark pair production threshold**
- **Energy scan** at the main operating energy points
- **High precision era** for electroweak, Higgs, and top physics
- **No pileup**

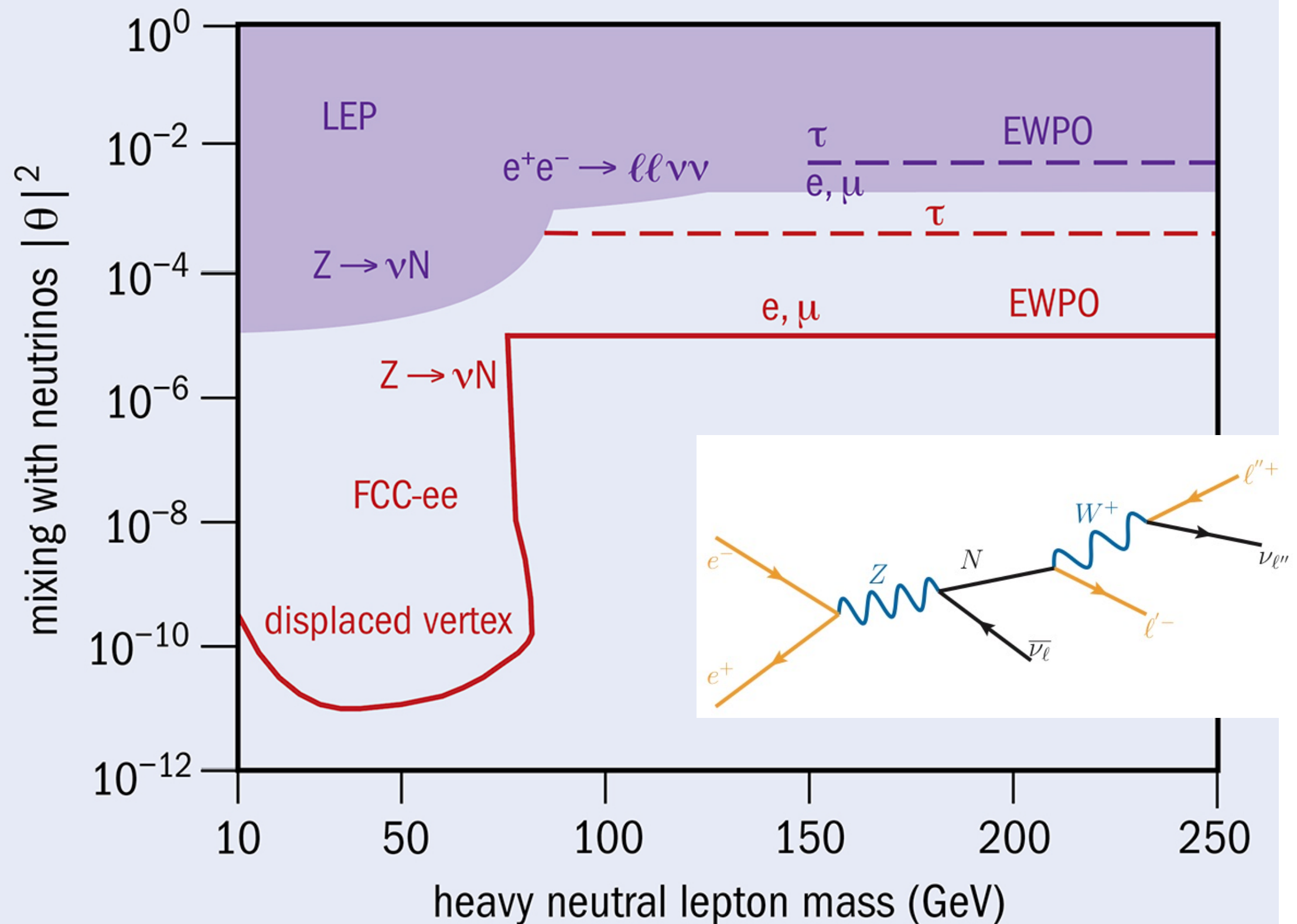


# FCC-ee highlights

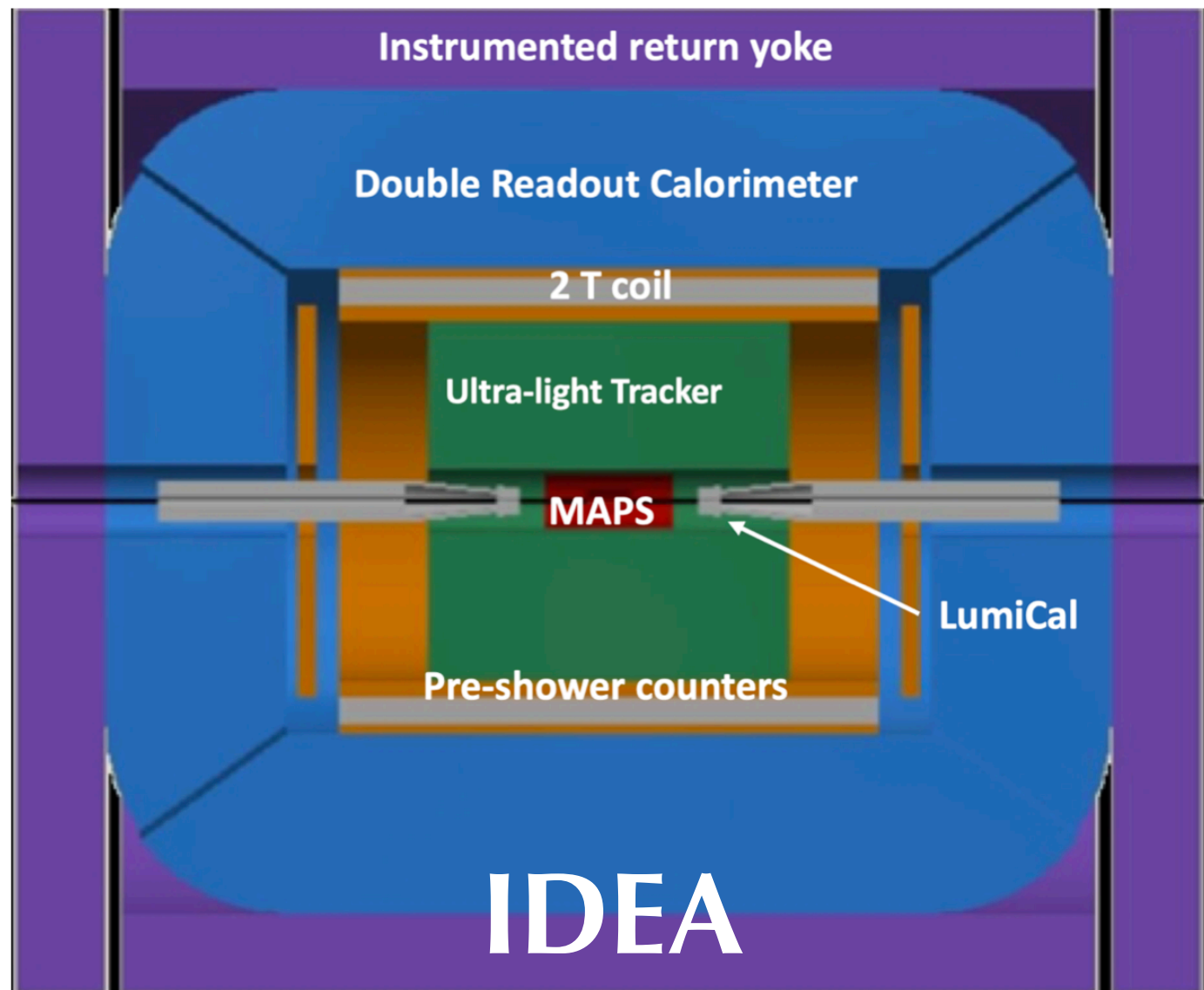
95% C.L. upper limit on selected Higgs Exotic Decay BR



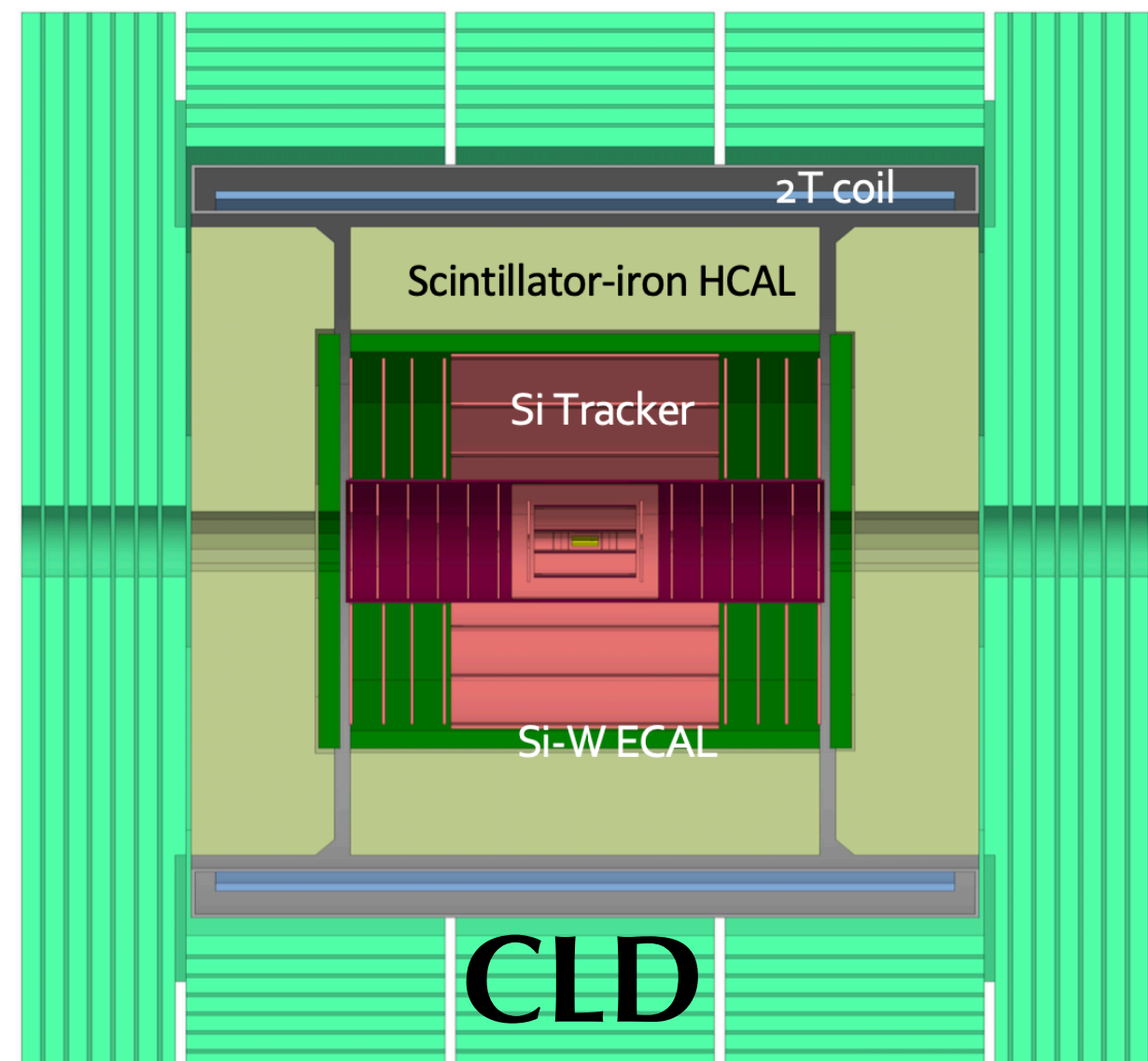
# FCC-ee highlights



# FCC-ee detectors



- Silicon vertex detector
- Drift chambers for tracking
- Solenoid coil inside calorimeter
- Micro-RWELL for muon detection



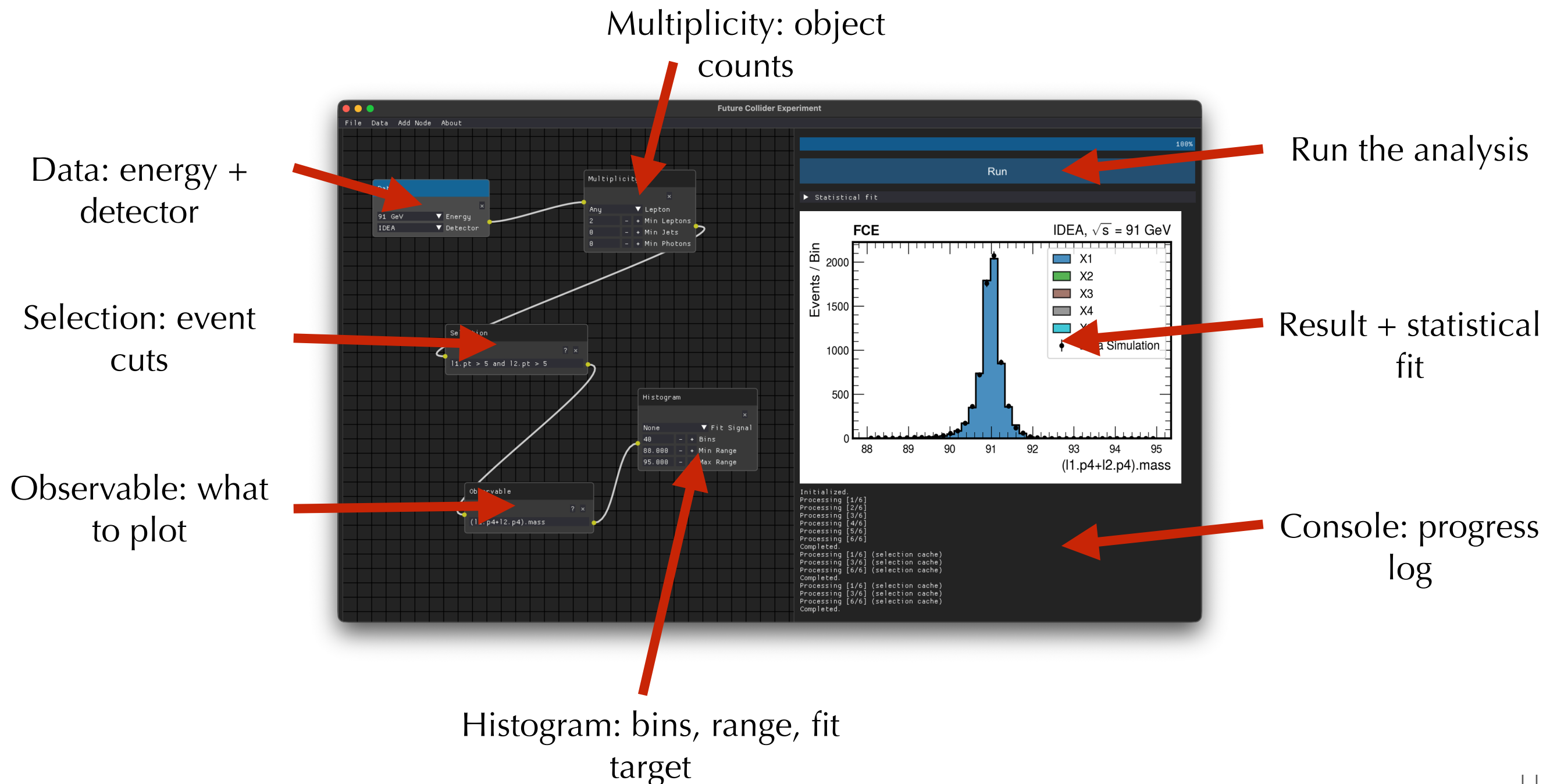
- All silicon vertex detector and tracking
- High-granularity calorimeter
- Solenoid coil outside calorimeter
- RPC-based muon system

# The project: Future Collider Experiment

- **Time travel** a few decades into the future
- **Discover** how the physics analysis works with the data taken by the next-generation collider experiments
- **Measure** the already known processes
- **Hunt** for new particles and interactions

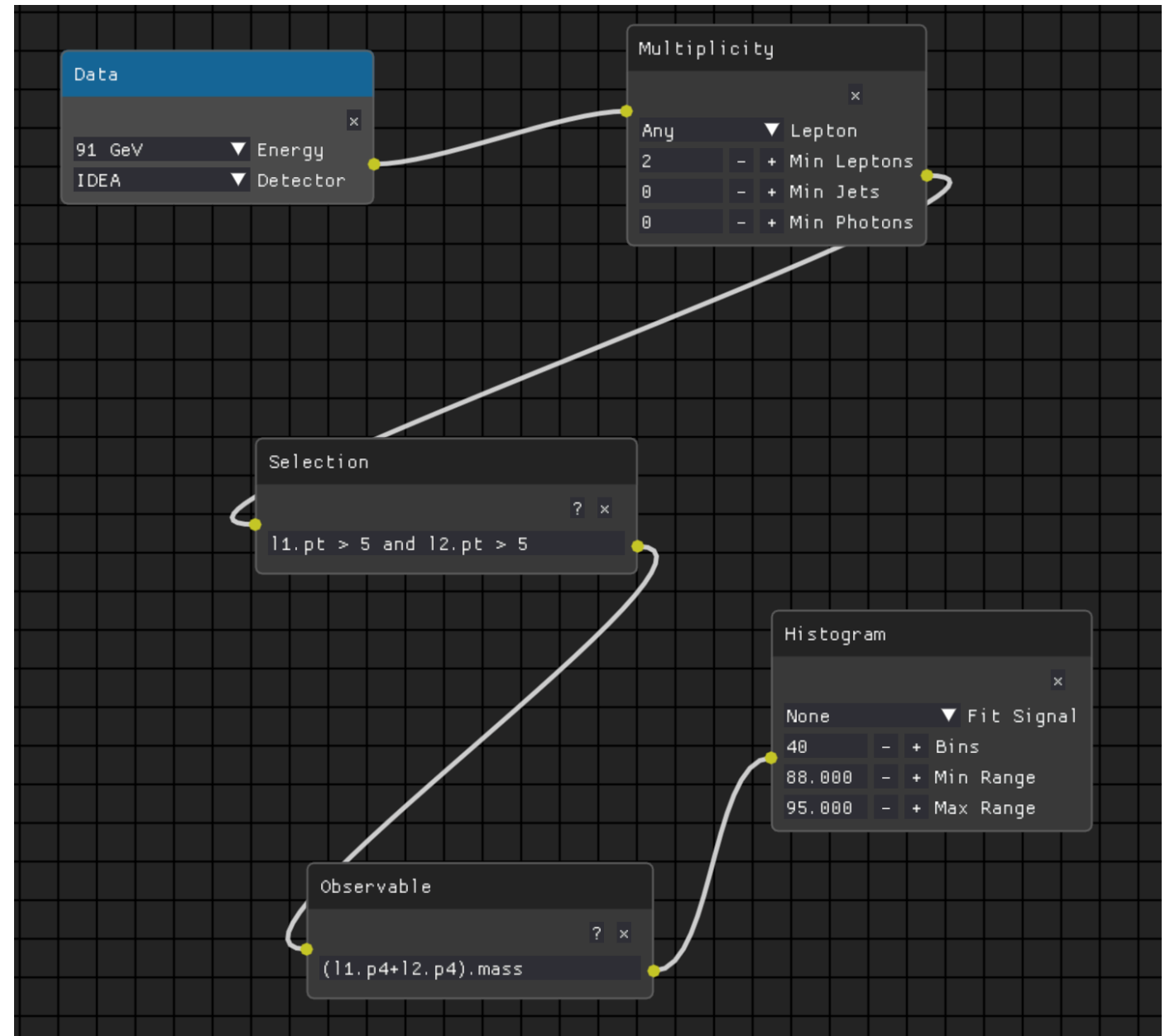
# FCE

- Build the analysis by connecting nodes - no code to write
- `pip install fce` | runs natively on macOS, Windows and Linux



# The analysis pipeline

- Data - collision energy (91 / 160 / 240 / 365 GeV) and detector (IDEA or CLD); exactly one per pipeline
- Multiplicity - minimum number of leptons / jets / photons; chain several, combined with AND
- Selection - a boolean cut expression; chain them, or branch for independent regions
- Observable - the quantity plotted on the x-axis
- Histogram - number of bins, range, and the optional Fit Signal



# Writing a selection

## VARIABLES (objects are pT-sorted)

|          |     |     |       |       |              |       |                    |         |          |     |
|----------|-----|-----|-------|-------|--------------|-------|--------------------|---------|----------|-----|
| nlep     | nel | nmu | njets | nphot | event counts |       |                    |         |          |     |
| l1, l2   |     | .pt | .eta  | .phi  | .e           | .d0   | .z0                | .charge | .flavour | .p4 |
| j1, j2   |     | .pt | .eta  | .phi  | .e           | .btag | btag > 0.7 = b-jet |         |          |     |
| ph1, ph2 |     | .pt | .eta  | .phi  | .e           |       |                    |         |          |     |
| met      |     | .pt | .phi  |       |              |       |                    |         |          |     |

## 4-VECTOR ARITHMETIC

|                      |                                  |
|----------------------|----------------------------------|
| (l1.p4 + l2.p4).mass | invariant mass of the pair [GeV] |
| l1.p4.deltaR(l2.p4)  | angular separation               |
| mT(l1, met)          | transverse mass [GeV]            |

## WORKED EXAMPLES

**l1.pt > 20 and l2.pt > 10**

both leptons hard – suppresses fake leptons

**(l1.p4+l2.p4).mass > 80 and (l1.p4+l2.p4).mass < 100**

mass window around the Z peak at 91 GeV

**njets >= 2 and j1.btag > 0.7**

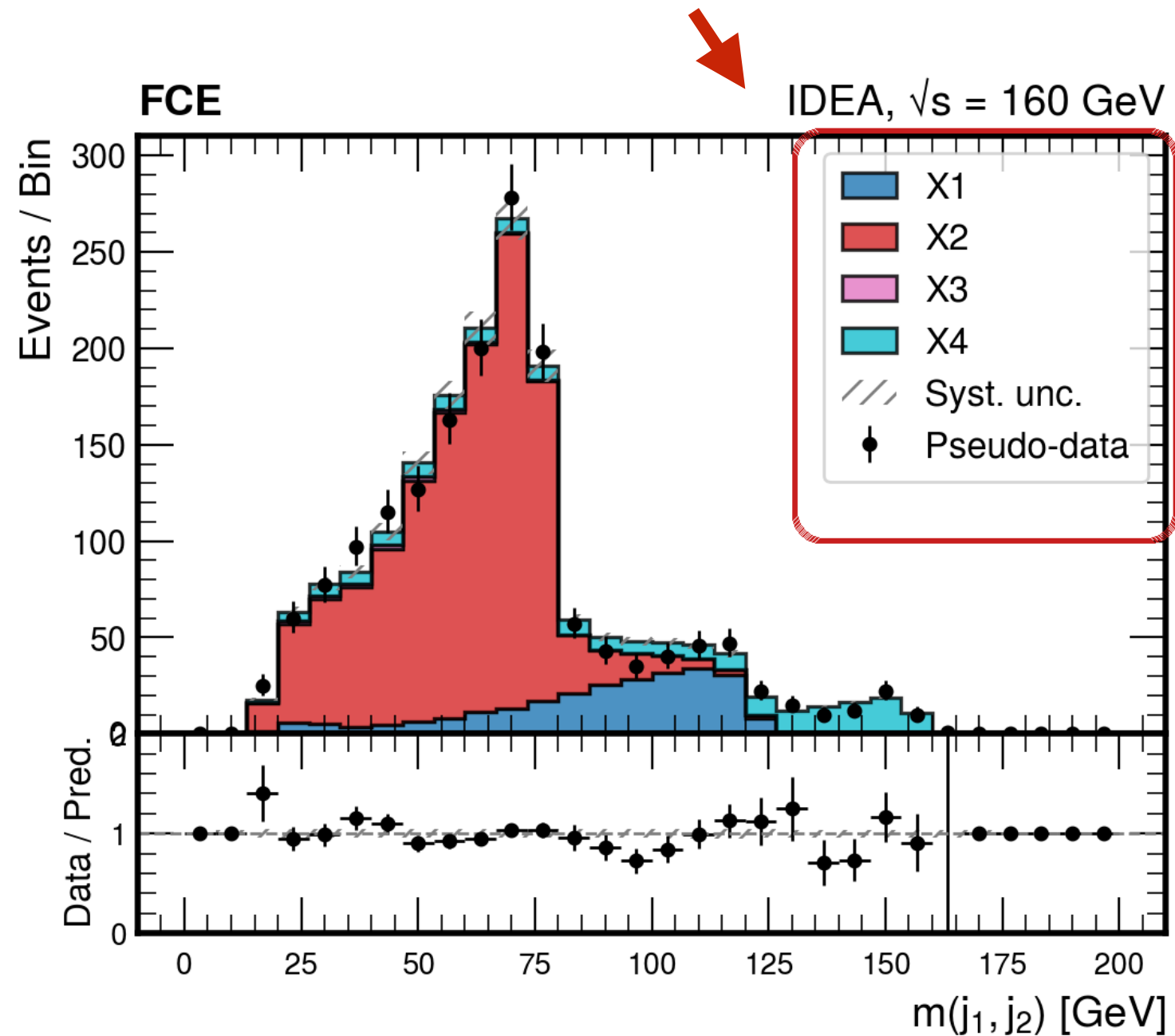
two jets, the leading one b-tagged – top searches

Operators > < >= <= == !=    Logic and or not ( )    Missing objects return -999

The ? button inside the Selection node opens this whole reference in the app

# Task

What are these processes? Give the detailed definition and measure their production cross sections



# Installation

## Install

```
$ pip install fce
```

**fce 0.0.11**

`pip install fce`

## Run

```
$ fce
```

## Data sets

The simulated collision events for the four centre-of-mass energies (91, 160, 240 and 365 GeV) are downloaded from inside the app:

```
Data > Download > All
```

```
Data > Download > IDEA | CLD > 91 | 160 | 240 | 365 GeV
```

Files land in `~/.fce/datasets` and are re-used across sessions

# Learning support

- Tutorial (Help menu, also shown on startup): 11 pages that highlight each node as they explain it
- Exercises (Help menu): 5 graded exercises - count leptons, Z peak, pT cut, statistical fit, Higgs at 240 GeV
- Save / Load Pipeline (File menu): users can stop and resume where they left off
- Data > Download: fetch the samples per detector and energy from inside the app
- Node states are colour-coded - Done, Cached, Active, Stopped, Error - and results are cached, so re-running is fast

# The work plan

- Split into **two research groups** = two collaborations (**IDEA** and **CLD**)
- **Organize** your experiment:
  - Define physics processes to target
  - Work out strategies to look for new physics
  - Optimize task forces
  - Select the spokesperson ...
- ➔ Study **FCC-ee** collisions at the four main energy points (**91, 160, 240, and 365 GeV**)
- ➔ Prepare your results in the **presentation** format discussing observations and underlying physics
- ➔ The **assessment** of the results will be based on the quality of your discoveries as well as the level of understanding of the obtained results
- ➔ **Good luck!**

