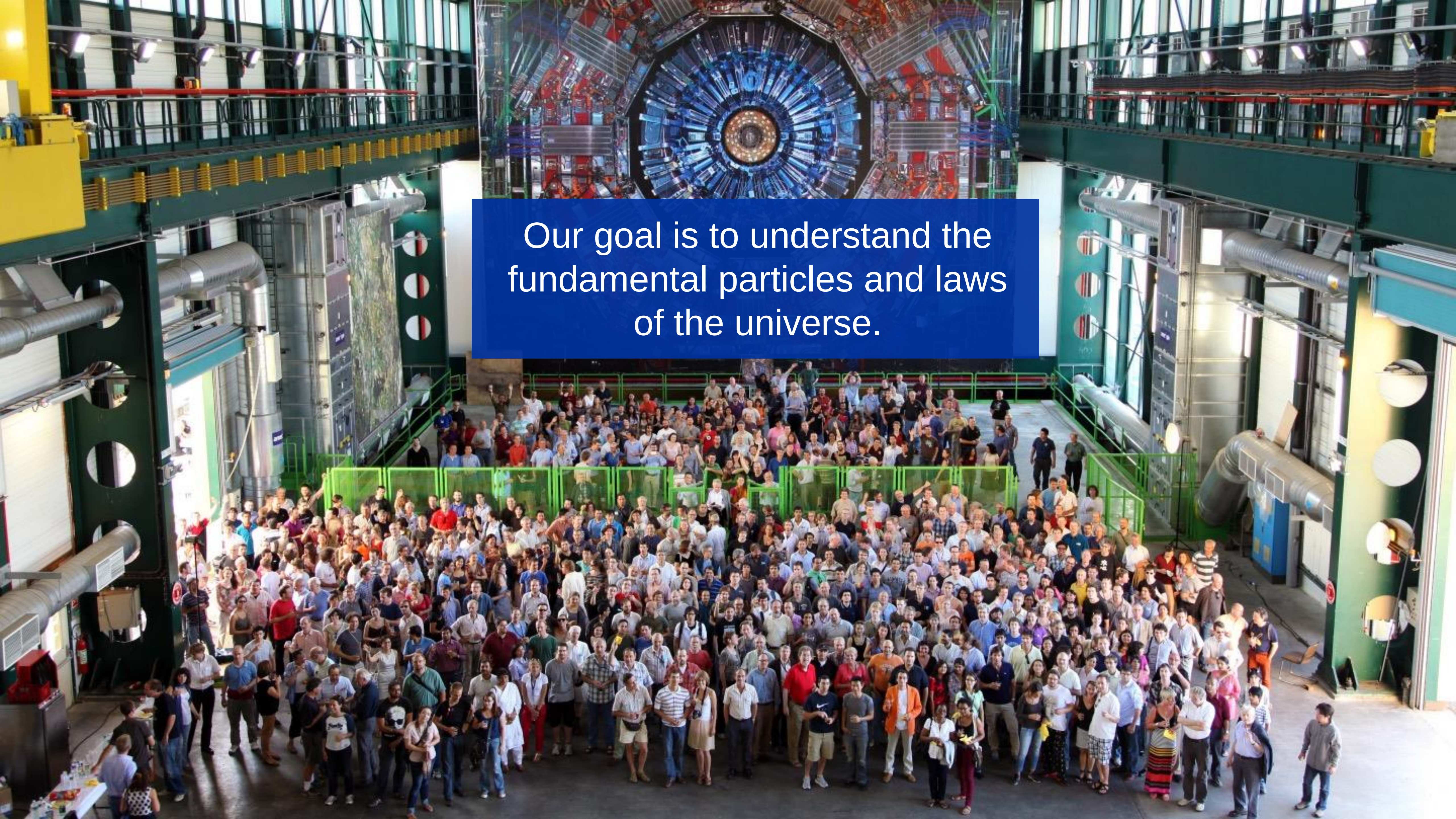
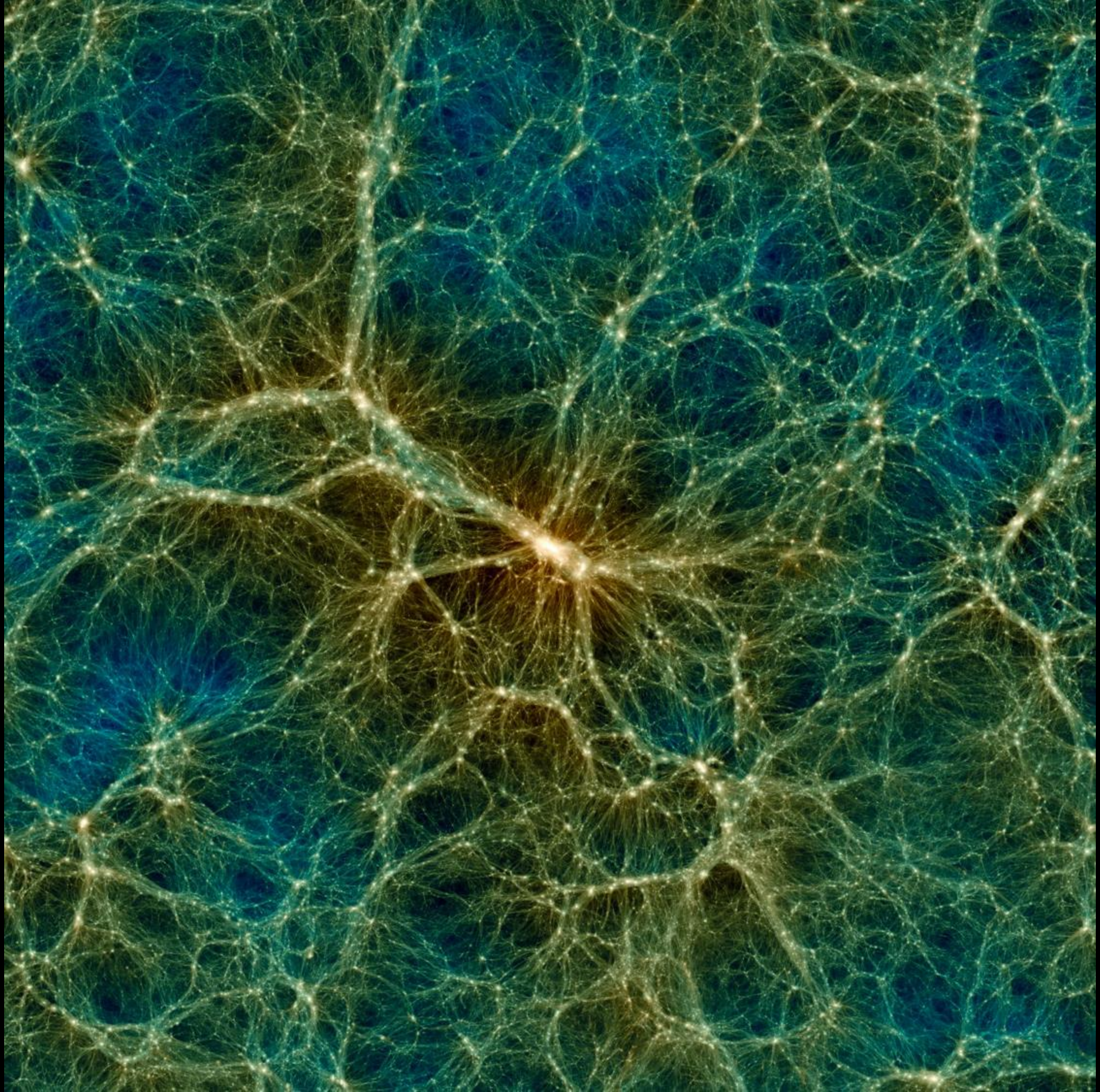
UHF Solenoid Workshop
Welcome to CERN!

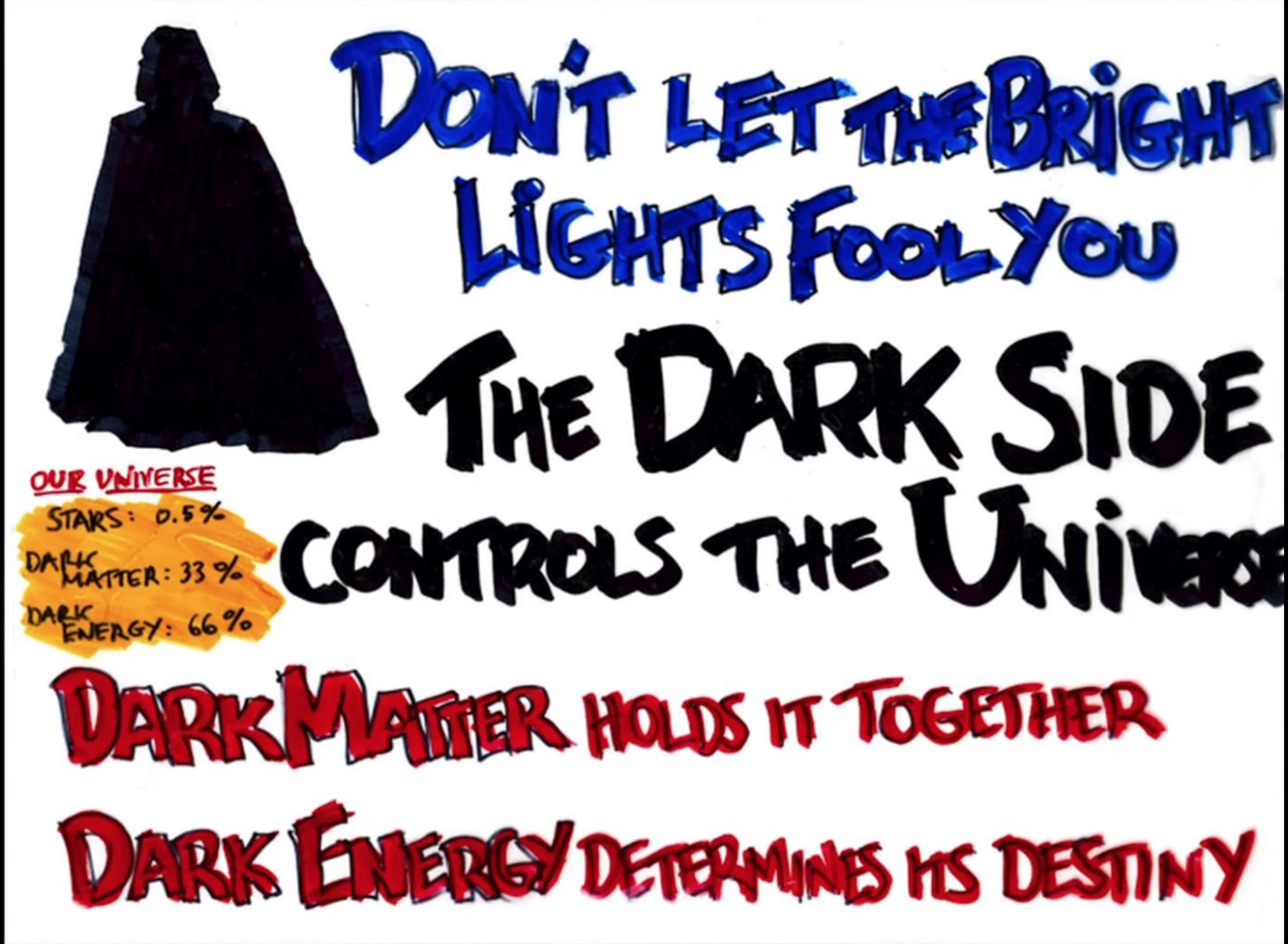

Our goal is to understand the fundamental particles and laws of the universe.


Who is Higgs?
Why did he freeze in the Universe?
Why do we exist?
Who is dark matter?
Who saved us from a complete annihilation?
Hitoshi Murayama
©Warner Bro.

Cosmic web of Dark Matter Decorated by Stars



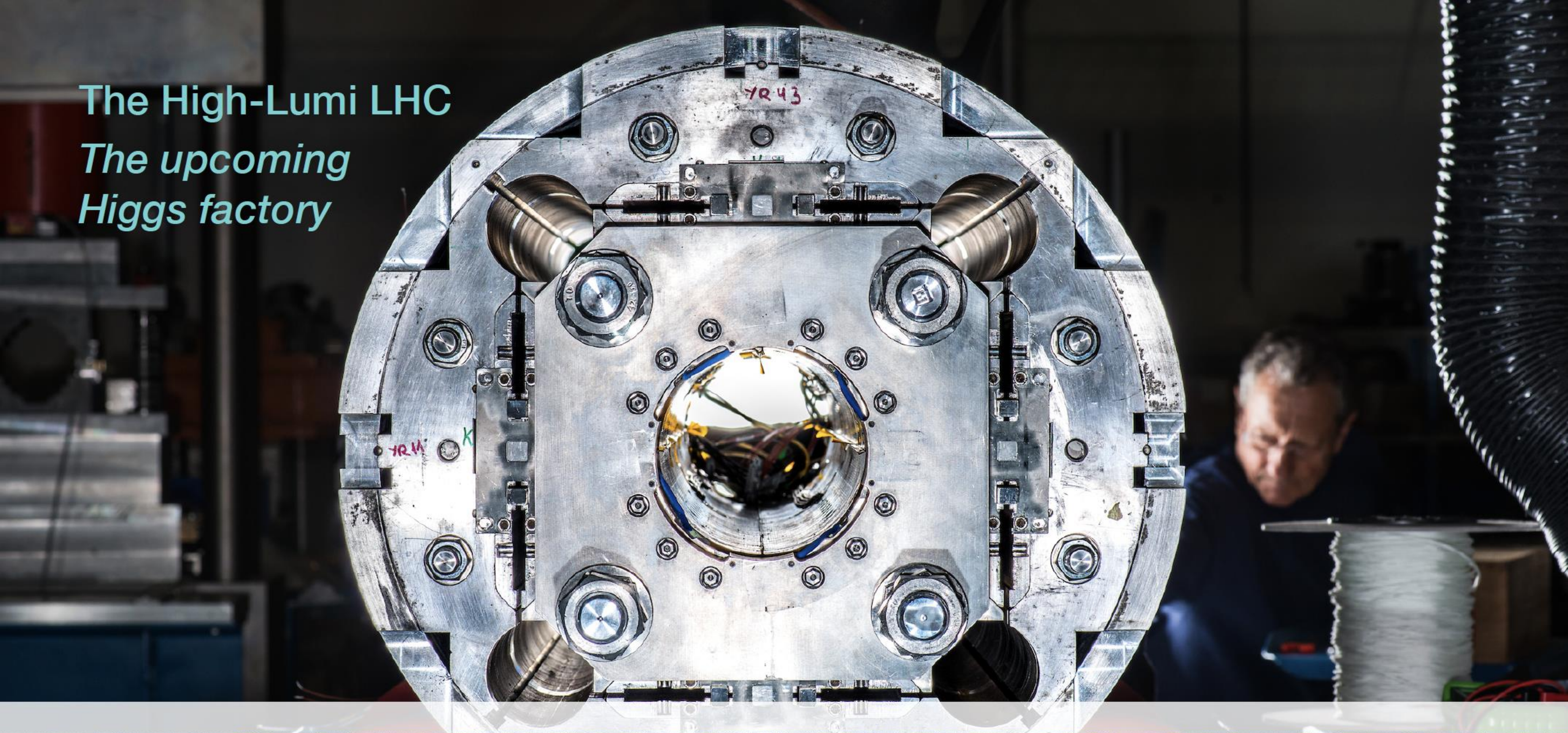
Simulation of the large-scale structure of the universe, showing dense clusters of galaxies, filaments, galactic walls and voids.
Credit: Uchuu project.



Michael Turner

The High-Lumi LHC

The upcoming Higgs factory



Run 1

Run 2

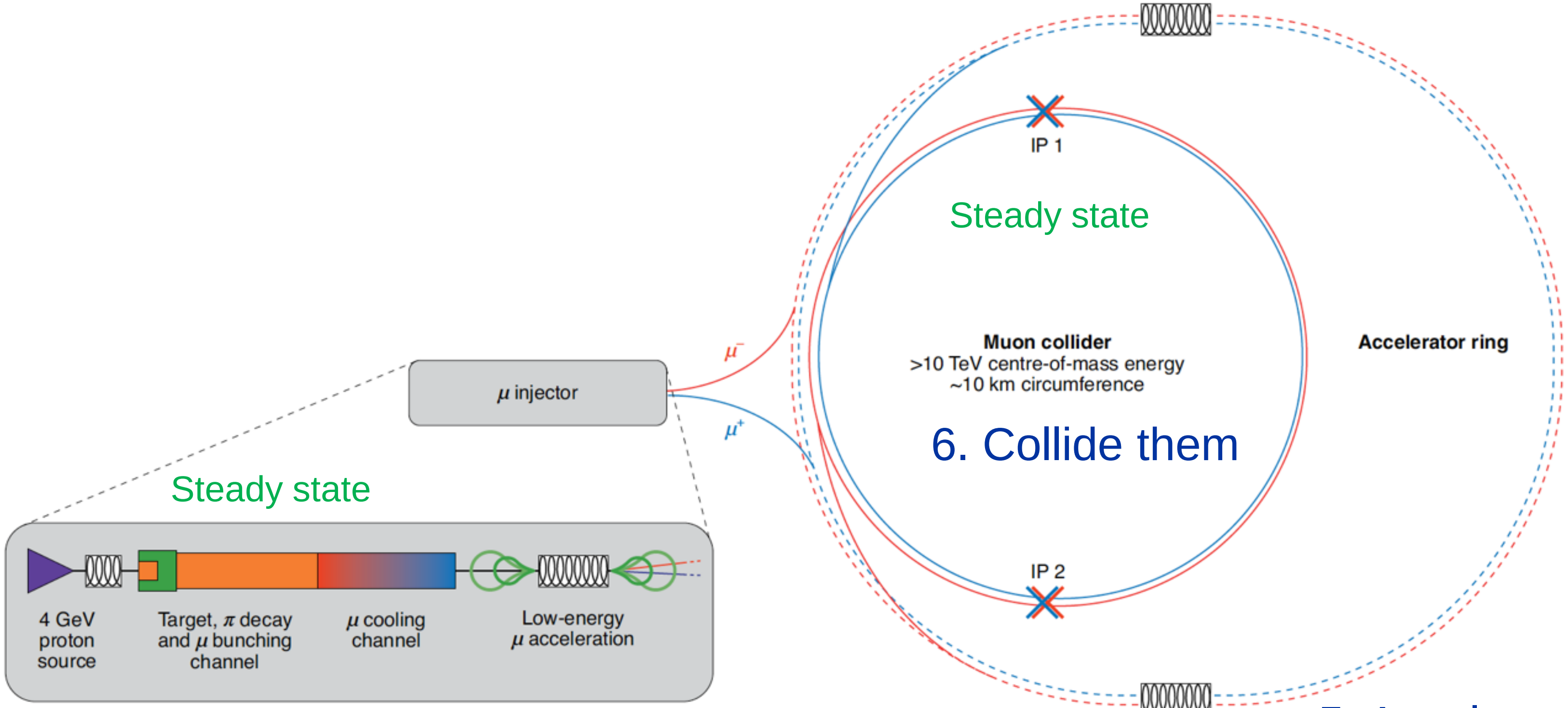
Run 3: We are here

HL-LHC: 14 TeV
6000 fb-1 (ATLAS+CMS)

Muon Collider

Large mass (207 m_e) suppresses synchrotron radiation => circular collider
Fundamental particle yields clean collisions & requires less energy than protons
But lifetime at rest is only 2.2 μs (fortunately increases with energy)!

$\sqrt{s}$	$\int \mathcal{L}dt$
3 TeV	1 ab^{-1}
10 TeV	10 ab^{-1}
14 TeV	20 ab^{-1}



1. Produce muons

2. Capture them

3. Cool them

4. Accelerate them

5. Accelerate them

Pion (π) production:
Proton + carbon target$\rightarrow$ $\pi^{+/-}$ + X

Pion decay:

$\pi^{+}\rightarrow \mu^{+} + \nu_{\mu}$

$\pi^{-}\rightarrow \mu^{-} + \overline{\nu}_{\mu}$

(Lifetime: 26 nsec.)

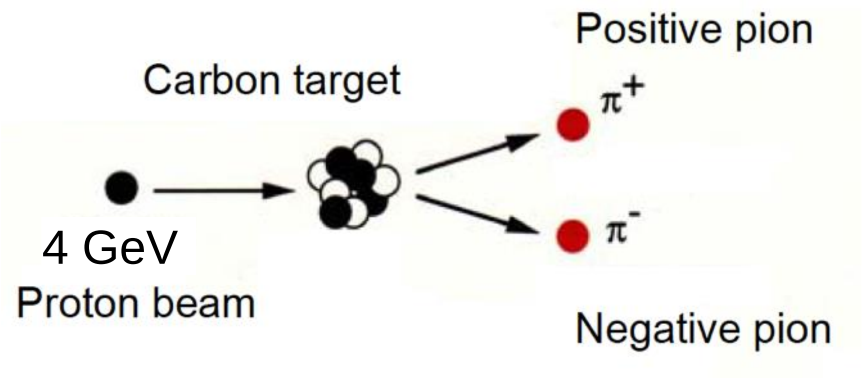
Muon decay

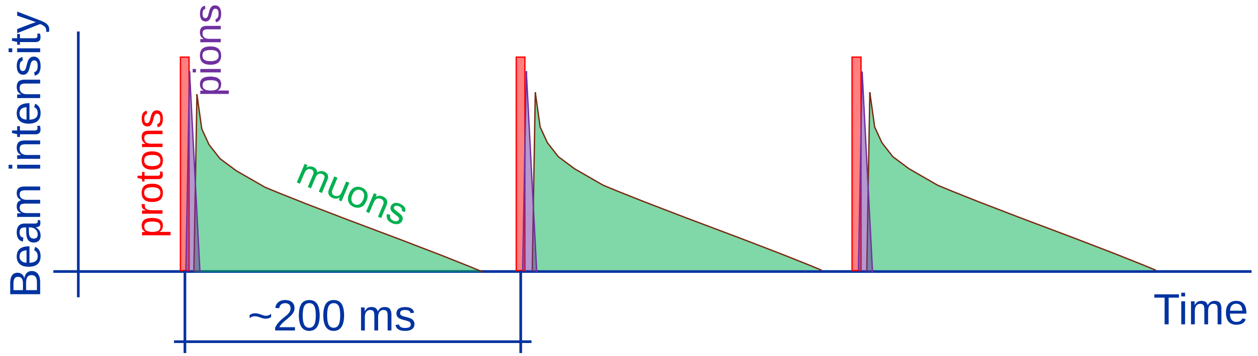
$\mu^{+}\rightarrow e^{+} + \nu_{e} + \overline{\nu}_{\mu}$

$\mu^{-}\rightarrow e^{-} + \overline{\nu}_{e} + \nu_{\mu}$

(Lifetime: 2.2 μsec.)

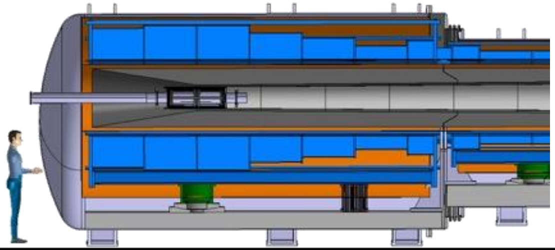
At 3 TeV – lifetime is 63 ms
At 10 TeV - lifetime is 210 ms





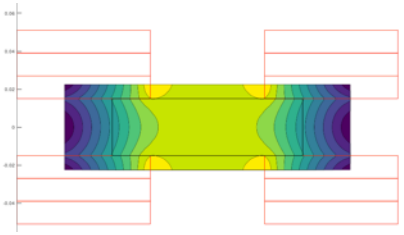
Muon Collider magnets

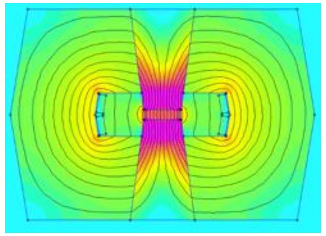
20 T, 200 mm
Radiation heat load ≈ 5…10 kW
Radiation dose: 80 MGy

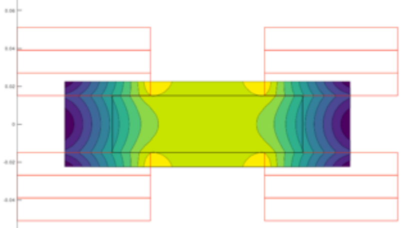


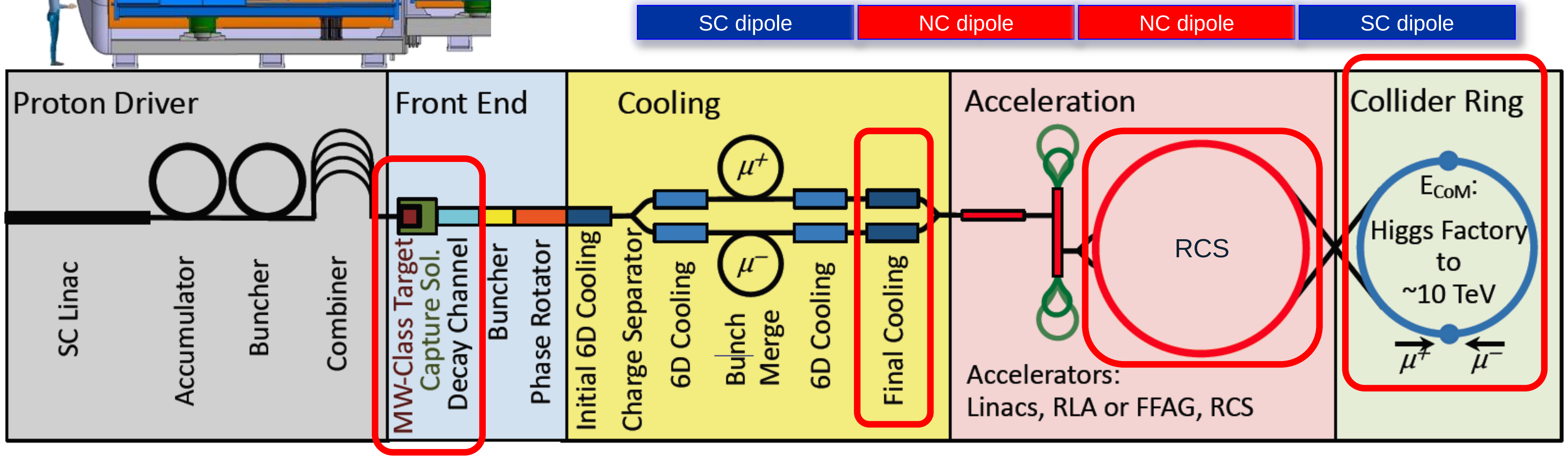
NC ±1.8 T, 400 Hz
100 mm x 30 mm

SC < 10T
100 mm x 30 mm

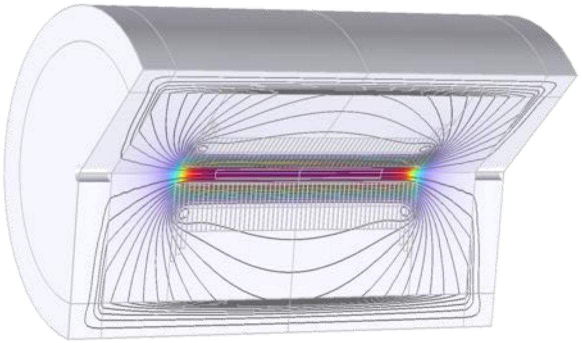




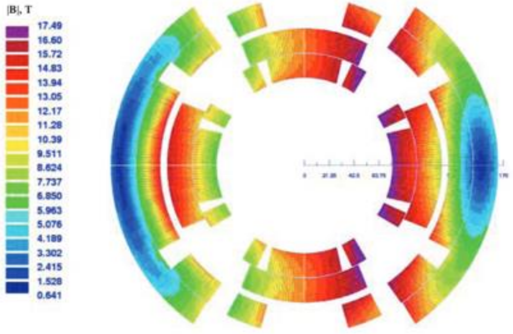




> 40 T, 60 mm



16 T peak, 160 mm
Radiation heat load ≈ 5 W/m
Radiation dose ≈ 20…40 MGy

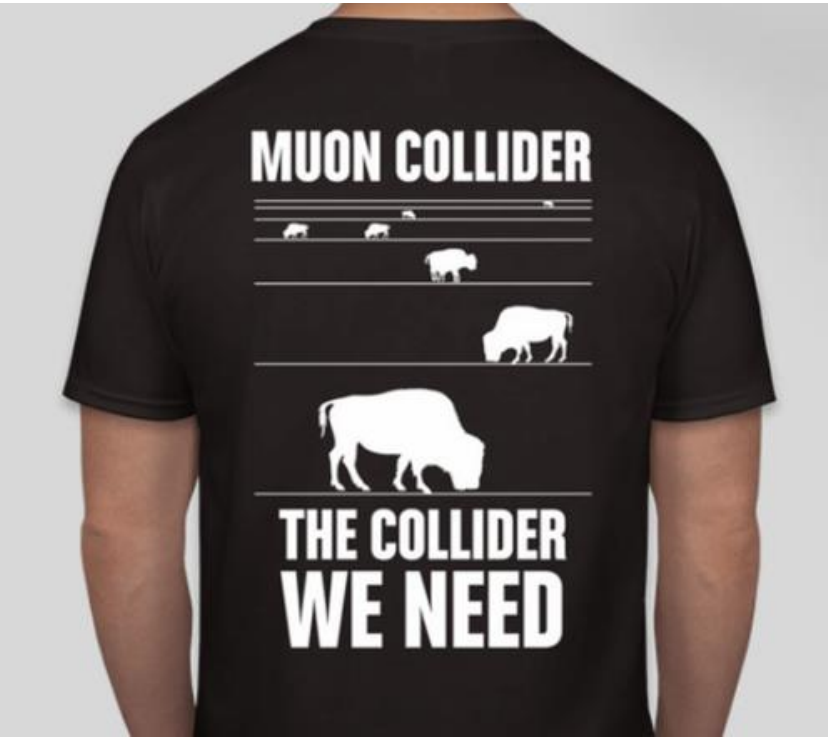


Muon Collider

Very challenging - but significant, long-term, worldwide interest

Part of the European Accelerator R&D roadmap

- *“an international design study for a muon collider, as it represents a unique opportunity to achieve a multi-TeV energy domain beyond the reach of e+e– colliders, and potentially within a more compact circular tunnel than for a hadron collider”*



International MUON Collider Collaboration

MuCol

Why UHF solenoids at CERN?

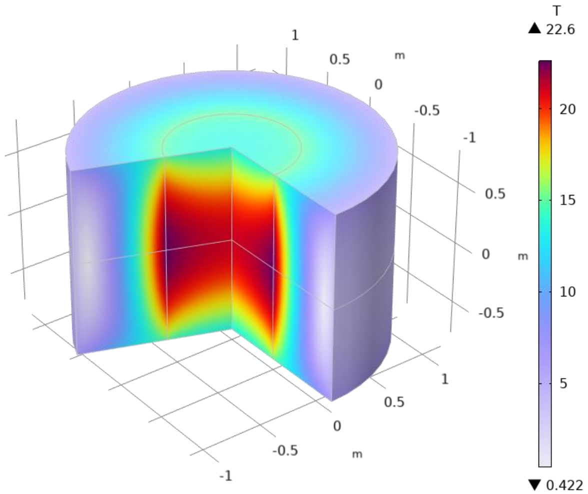
- The performance of the muon collider depends critically on achieving **high- and ultra-high-field levels**:
  - 20 T at the beam target, 1.4 m bore;
  - 40 T for final cooling, 6 cm bore.

- Solenoids are an **ideal R&D vehicle** for novel technology, e.g. HTS, also for accelerator magnets:
  - Field reach, force and stored energy for a given material cost is advantageous when compared to dipoles, turnover can be fast.
- There are **clear and strong synergies** between work for HEP and needs of other fields of scientific and societal applications.

This Workshop on UHF Solenoids is an important milestone

CERN

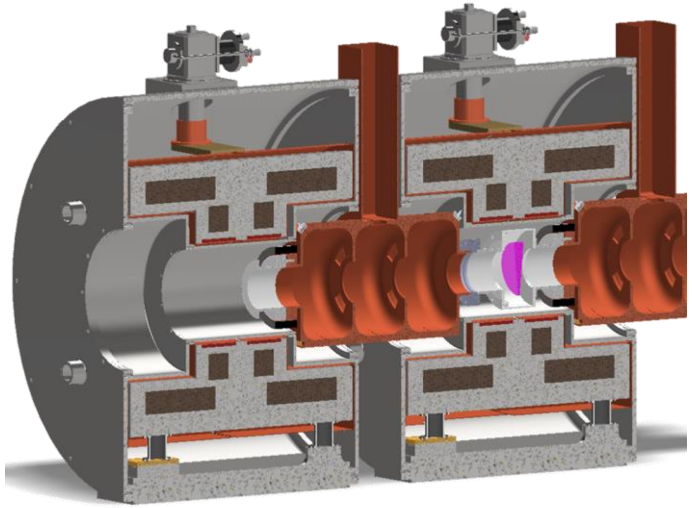
20T at 20K in a 1 m bore

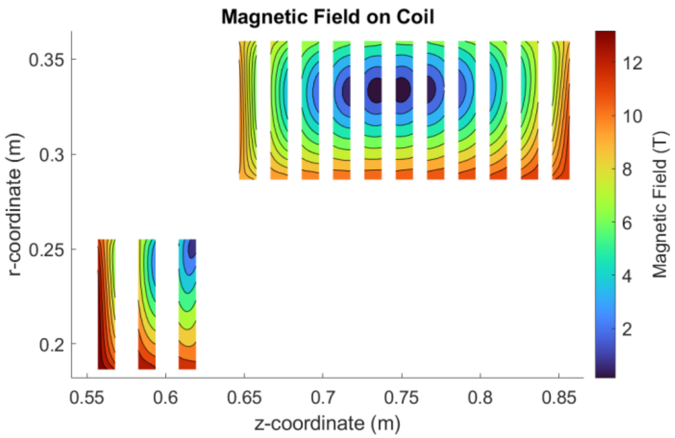


- 20@20 is a demonstrator of mature HTS magnet technology for the **target solenoid of the Muon Collider**
  - HTS conductor development
  - Construction of large bore magnets
  - Management of forces and stress at material limits
  - Protection strategy for magnets with large stored magnetic energy
- 20@20 will **profile CERN as a major worldwide player** in HTS conductor and magnet technology
- **Engage and prepare EU industry** for a possible construction **(e.g. THEVA and BNG)**
- 20@20 will be **a world-wide unique test facility**

- **Shared technology development with fusion** (same objective, same technology)
  - Declared interest and on-going collaboration with partners from the public sector (F4E, EUROFusion) as well as **private sector (Eni, GFG)**
- Potential application for **high field science**

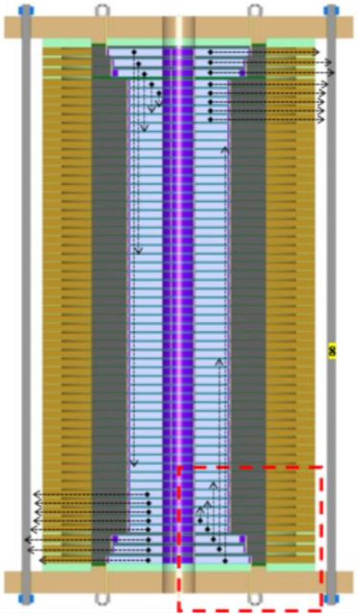
Split 7T in 350 mm bore

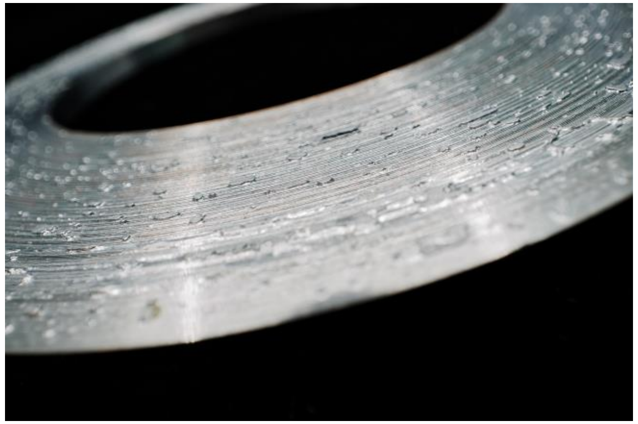




- The 7T split solenoid demonstration magnet is the **steppingstone towards the magnets that power the 6D cooling cells of the Muon Collider**
  - Dry-cooled, partial-insulation, novel HTS magnet technology operating at 20 K
  - Protection of HTS magnets with high stored energy and high current density
  - Complex system integration, management of large forces and thermal gradients
- **Technology relevant to next generation MRI machines**
  - Helium-free, lower consumption, simpler engineering, easier maintenance
  - Suitable to improve healthcare in remote world regions
  - Opportunity for increasing market penetration, seeking interest from the big three (Siemens, GE, Philips)

40 T in a 60 mm bore





- The UHF 40 T demonstration magnet is a crucial milestone towards achieving the **luminosity of the Muon Collider**
  - Field level is at the frontier of magnet science
  - Ultra-compact, partial-insulation novel HTS magnet technology
  - Management of forces and stress at material limits
  - Requires characterization of material properties at unprecedented levels of field and detail
  - Development of novel design and analysis tools

- **Shared technology development with high magnetic field science/NMR**
  - Structural biology and proteomics
  - Drug discovery
  - Solid-state physics for scientific and societal applications
  - Collaboration with high magnetic field laboratories **(EMFL and NHMFL)**

UHF Solenoid Workshop

This Workshop on UHF Solenoids is organized under the auspices of the International Muon Collider Collaboration (IMCC), supported by the EU Design Study MuCol, in conjunction with the High Field Magnet R&D Programme

International MUON Collider Collaboration

MuCol

HFM
High Field Magnets Programme

Bigs thanks to the Program Committee and Organizers

- L. Bottura, B. Bordini (CERN, Switzerland)
- M. Statera (INFN-LASA. Italy)
- S. Awaji (Tohoku University, Japan)
- S. Hahn (Seoul National University, South Korea)
- M. Bird (NHMFL, Florida)

Have great workshop!