# Open hardware and big science

## A CERN perspective

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# Outline

1. Introduction to CERN
2. Introduction to Open Source Hardware
3. Open Source Hardware in practice
4. How to get organised

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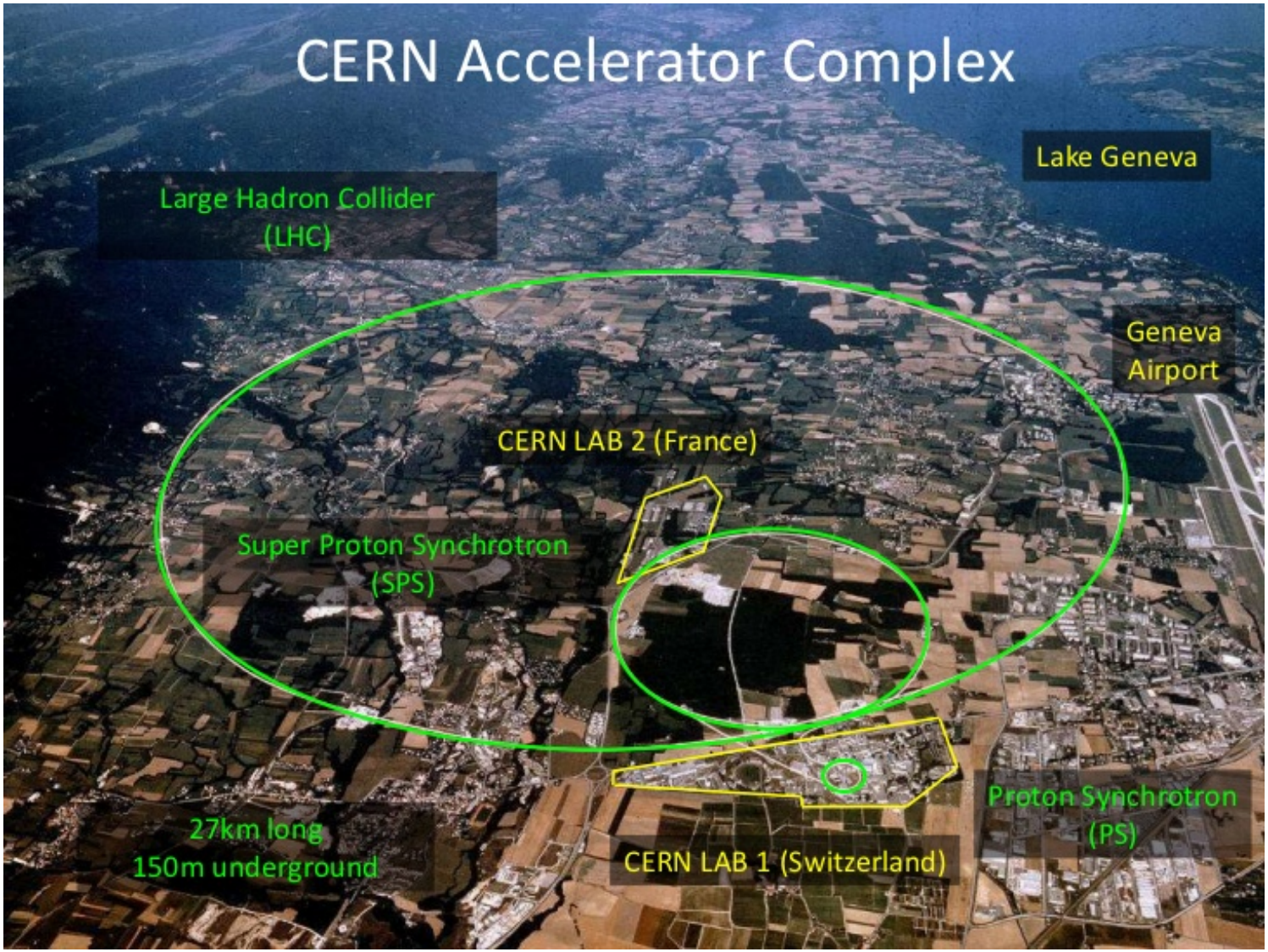
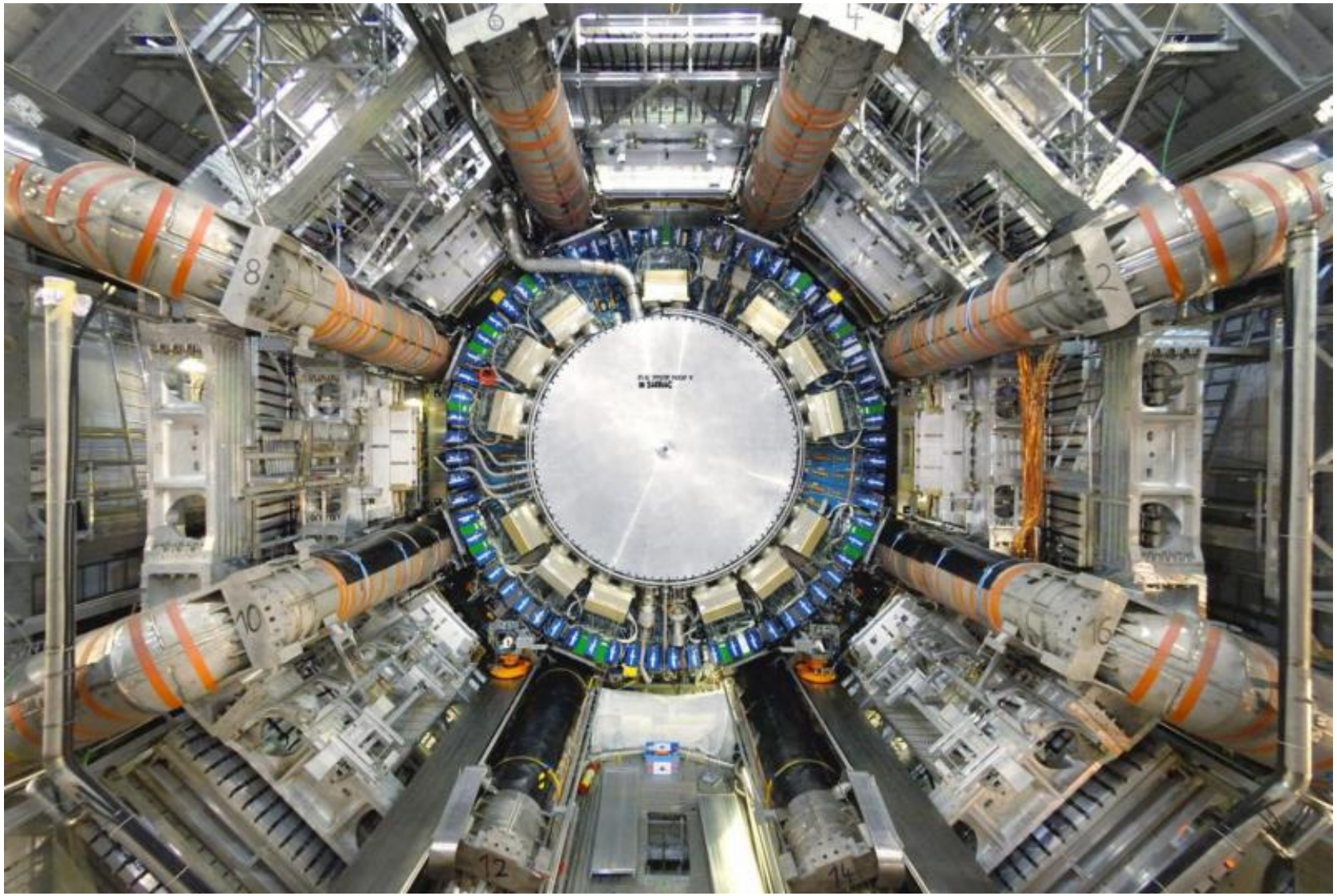
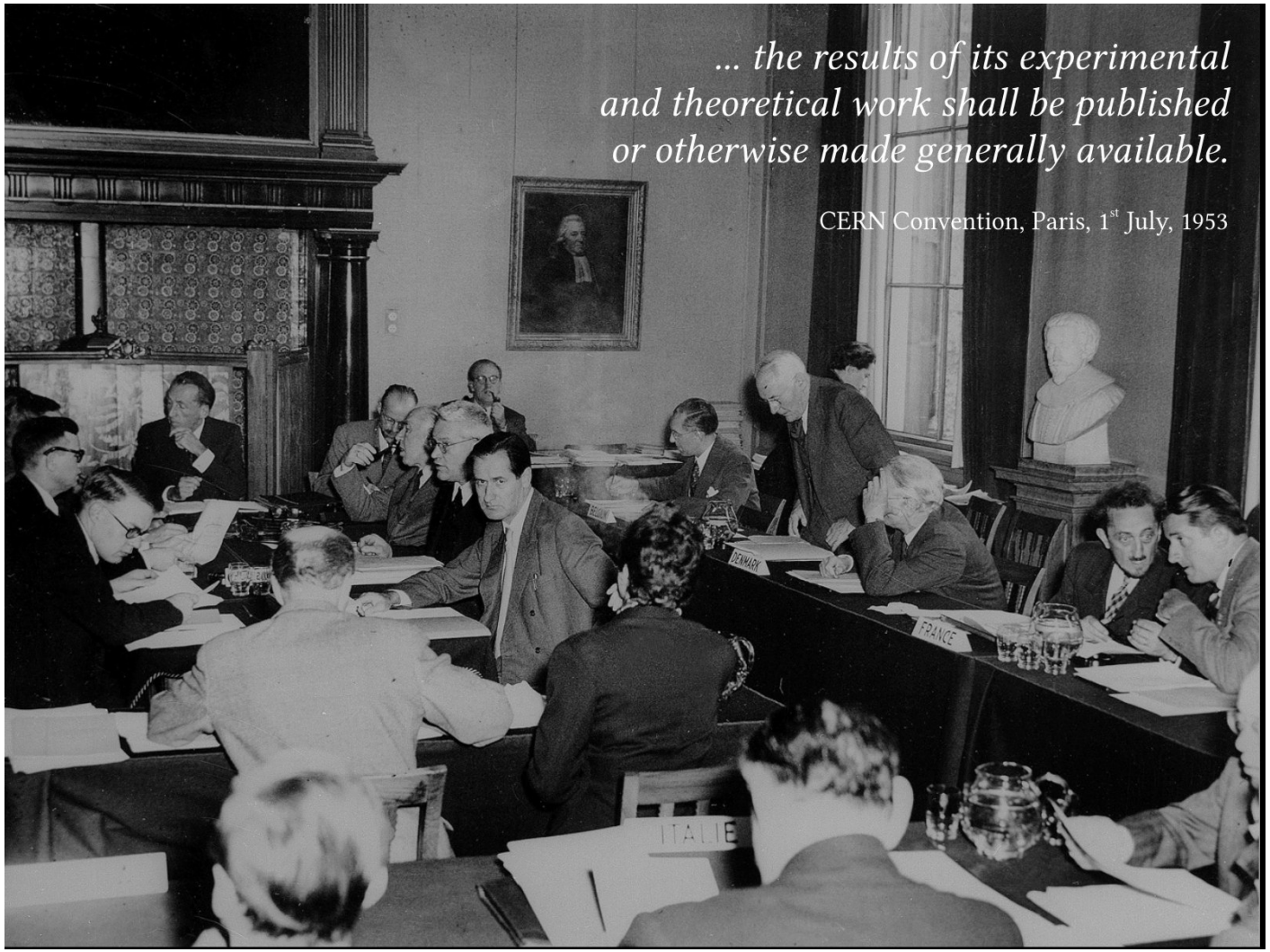
# Accelerators



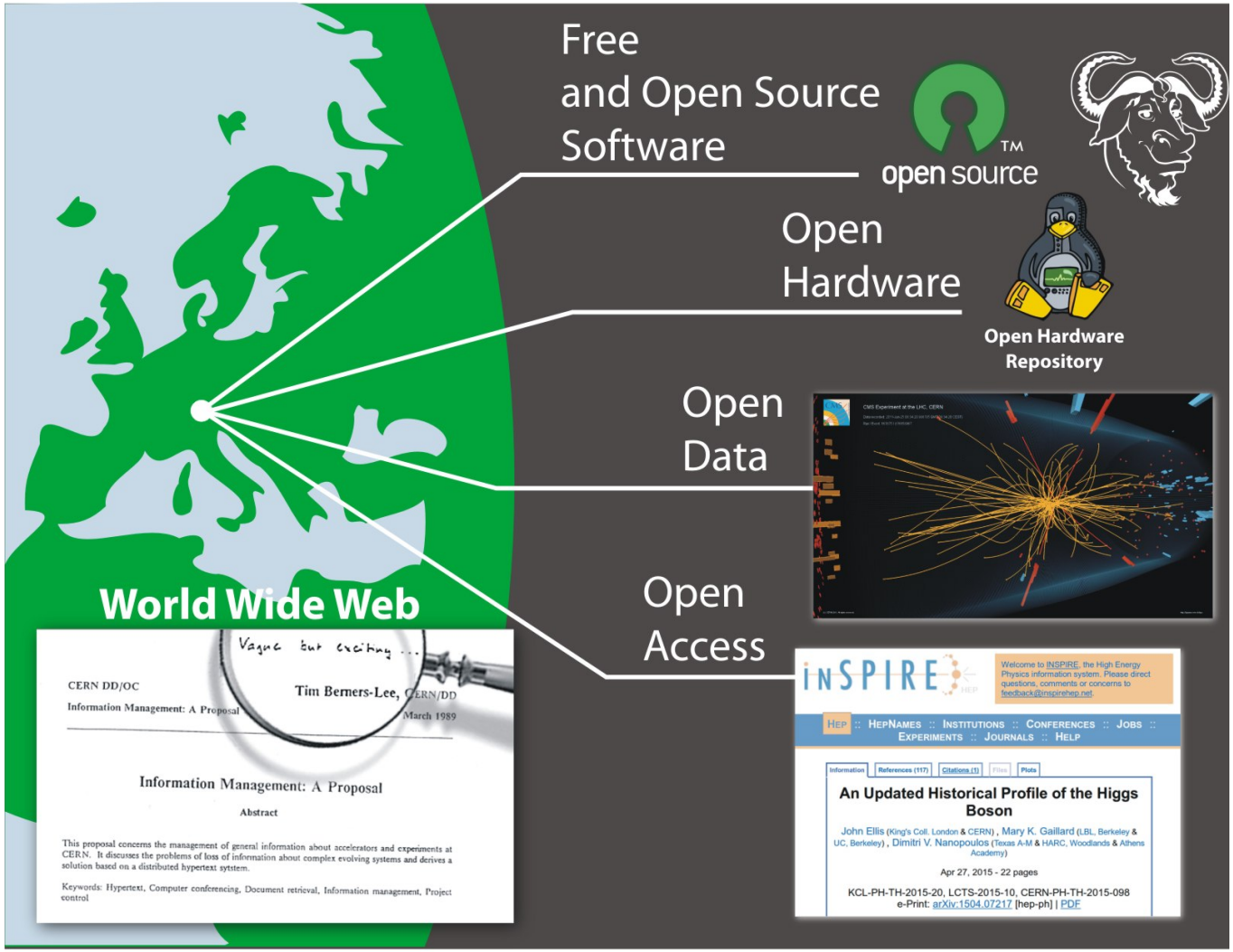
# Detectors



# Dissemination



# How to interpret one's dissemination mandate in the 21st century



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# Why we use Open Hardware

## Design re-use

- When it's Open, people are more likely to re-use it.
- When it's Open, people are much more likely to contribute.

## Peer review

- Get your design reviewed by experts all around the world.
- Therefore the designs will become better.

## Dissemination of knowledge

- One of CERN's key missions!

# Why we use Open Hardware

## Get a design just the way we want it

- We specify fully the design.

## Healthier relationship with companies

- No vendor-locked situations. Companies selected solely on the basis of technical excellence, good support and price.

## Spend money where you or your funding agencies want

- Makes life easier for public institutions.
- Opens the door to smaller companies with good local support.

# There is an Open Source Hardware definition!

## Check out http://www.oshwa.org/definition/

- Inspired by the Open Source definition for software.
- Focuses on ensuring freedom to *study, modify, distribute, make and sell* designs or hardware based on those designs.
- Now we know exactly what we mean when we say OSHW!

# CERN Open Hardware License – ohwr.org/cernohl

## Provides a solid legal basis

- Developed by Knowledge and Technology Transfer Group at CERN.
- Open Software licences not usable (GNU, GPL, . . . ).

## Practical: makes it easier to work with others

- Upfront clear: anything you give is available to everyone.
- Everyone can use it for free.
- No strings attached. *Really!*

# CERN Open Hardware License – ohwr.org/cernohl

## Same principles as Open Software

- Anyone can see the source (design documentation).
- Anyone is free to study, modify and share.
- Any modification and distribution under same licence.
- Persistence makes everyone profit from improvements.

## Hardware production

- When produce: licensee is invited to inform the licensor.

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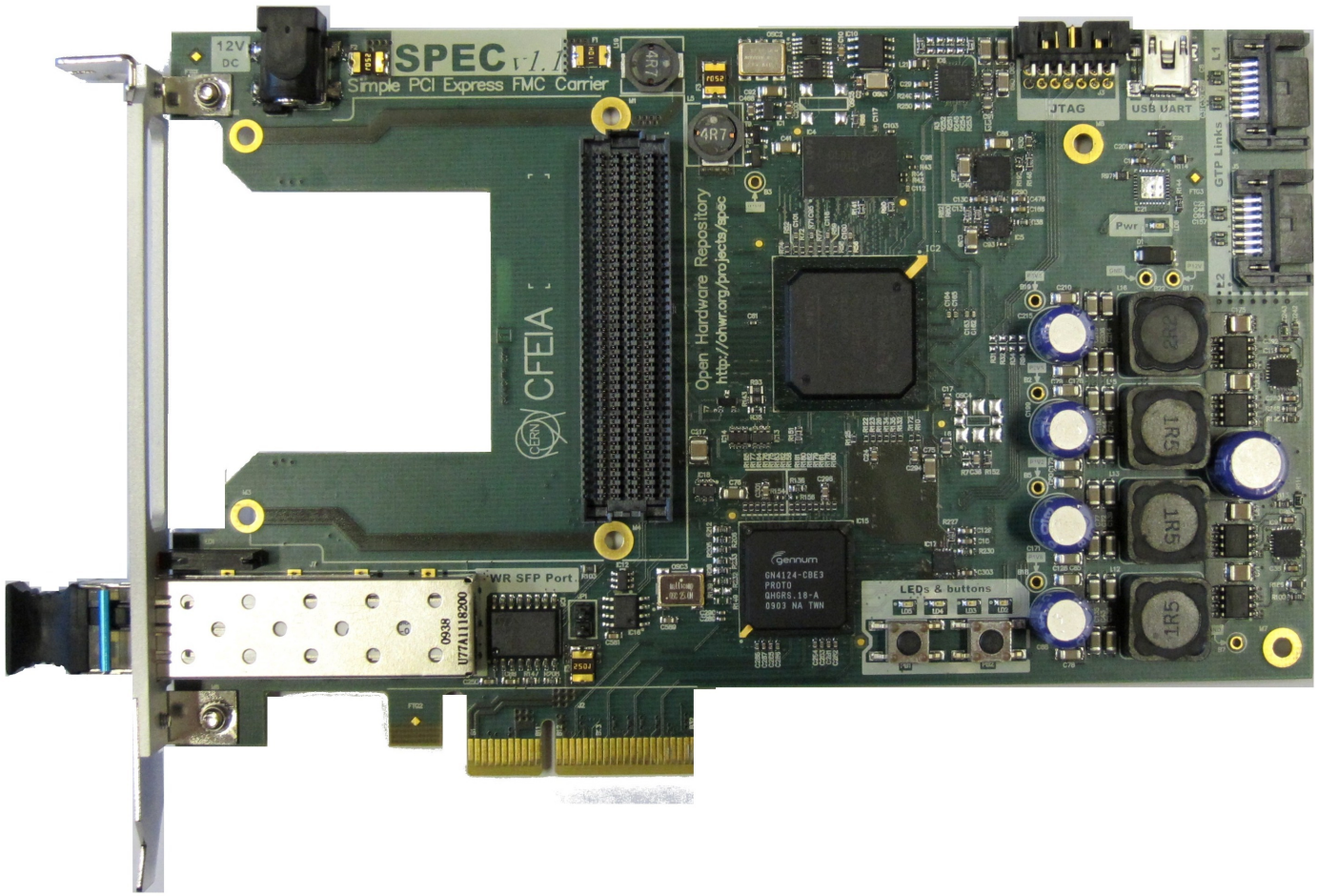
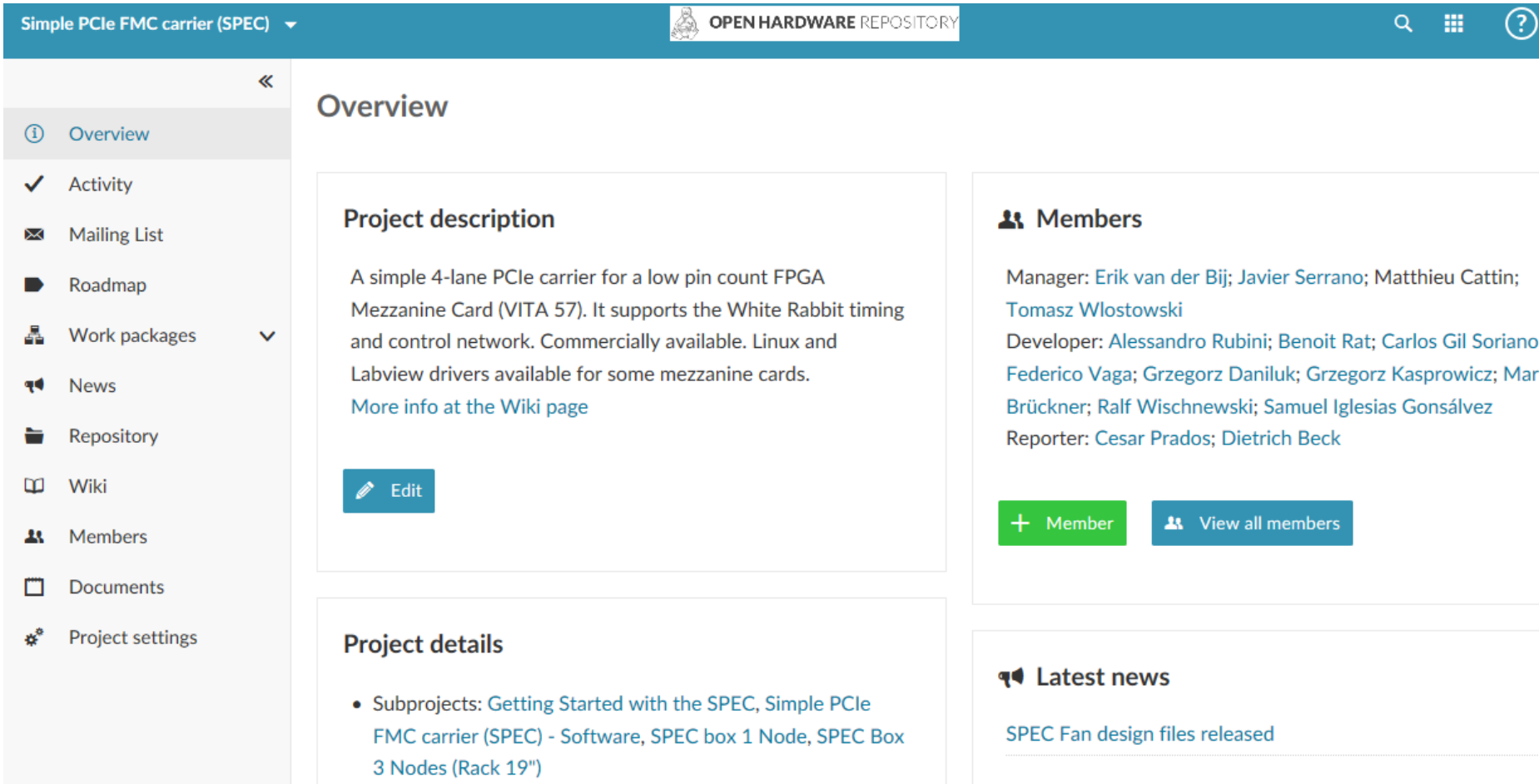
# Example: SPEC - Simple PCI Express FMC carrier

## Made in Spain, The Netherlands, Greece & Poland



# Example of a project in the Open Hardware Repository – ohwr.org



# Be Open

## Use OHR to the fullest

- Document everything on OHR:
  - schematics, mechanics, status.
- Discuss over mailing list. Already from start of project.
- Document design review results.
- Track Issues and detected bugs.

## Don’t be afraid to show mistakes!

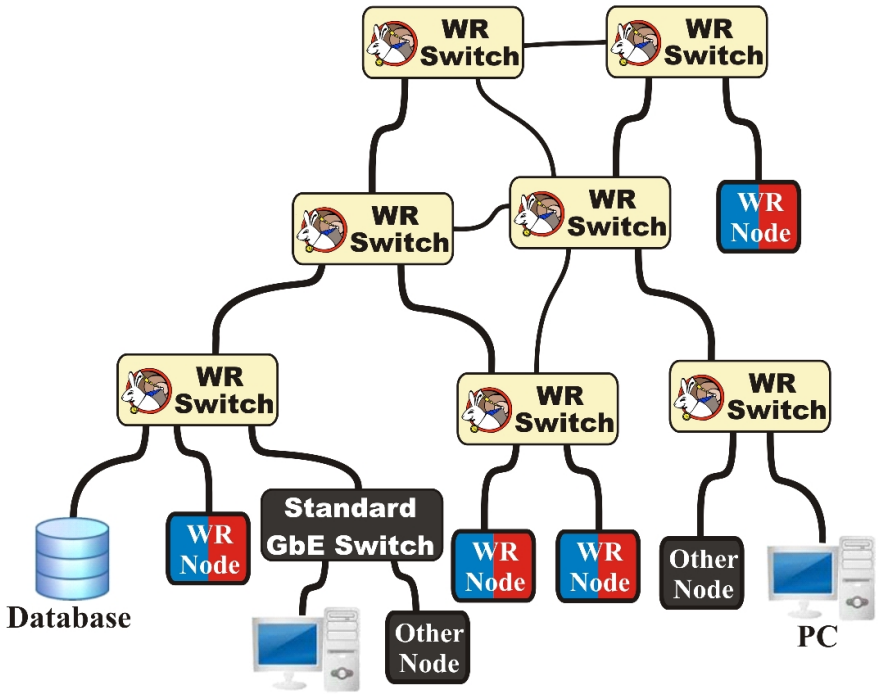
- E.g. SPEC: 86 Issues documented, 40 still ’Open’.
- Issues may help others when adapting a design.
- OHR becomes a teaching tool.

# White Rabbit – Innovation with Open approach

- Hardcore innovation.
- An enabling technology.
- Started at CERN and GSI high-energy physics labs.
- Everything Open: hardware, gateware, software.
- Made extensive use of small companies to develop.
- Companies develop and sell products based on it.

# White Rabbit – is Ethernet

- Bandwidth: 1 Gbps
- Single fiber medium
- Up to 10 km links
- WR Switch: 18 ports
- Ethernet features (VLAN) & protocols (SNMP)
- Synchronization:
  - accuracy better than 1 ns
  - precision (tens of ps sdev skew max)



# WR time transfer performance: lab tests

## 3 cascaded switches

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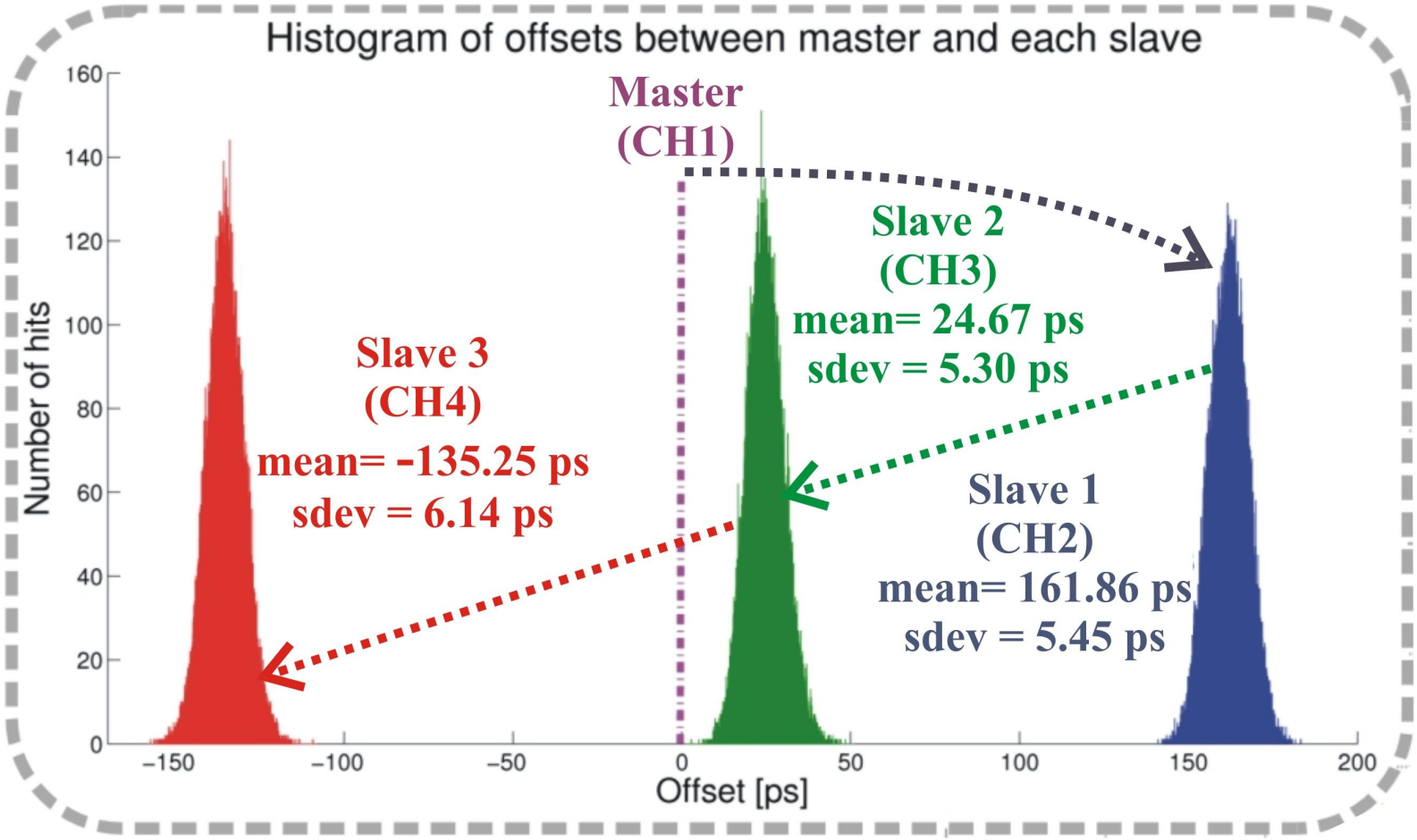
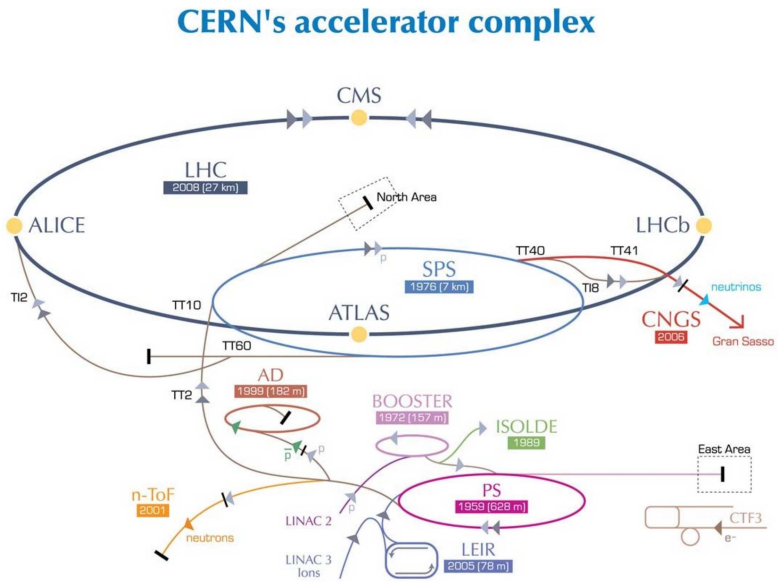


# White Rabbit applications

- Particle accelerators
  - **CERN (Switzerland/France)**
  - **GSI (Germany)**



# White Rabbit applications

- Particle accelerators
  - CERN (Switzerland/France)
  - GSI (Germany)
- Cosmic ray & neutrinos detectors
  - **LHAASO (China)**
  - **HiSCORE (Siberia)**
  - **KM3NET (Mediterranean)**
- Metrology laboratories
  - **MIKES (Finland)**
  - **VSL (Netherlands)**

Dutch Metrology Institute

**All users:** `www.ohwr.org/projects/white-rabbit/wiki/WRUsers`

# How can this map to Quantum Engineering?

What could be your “killer app”?

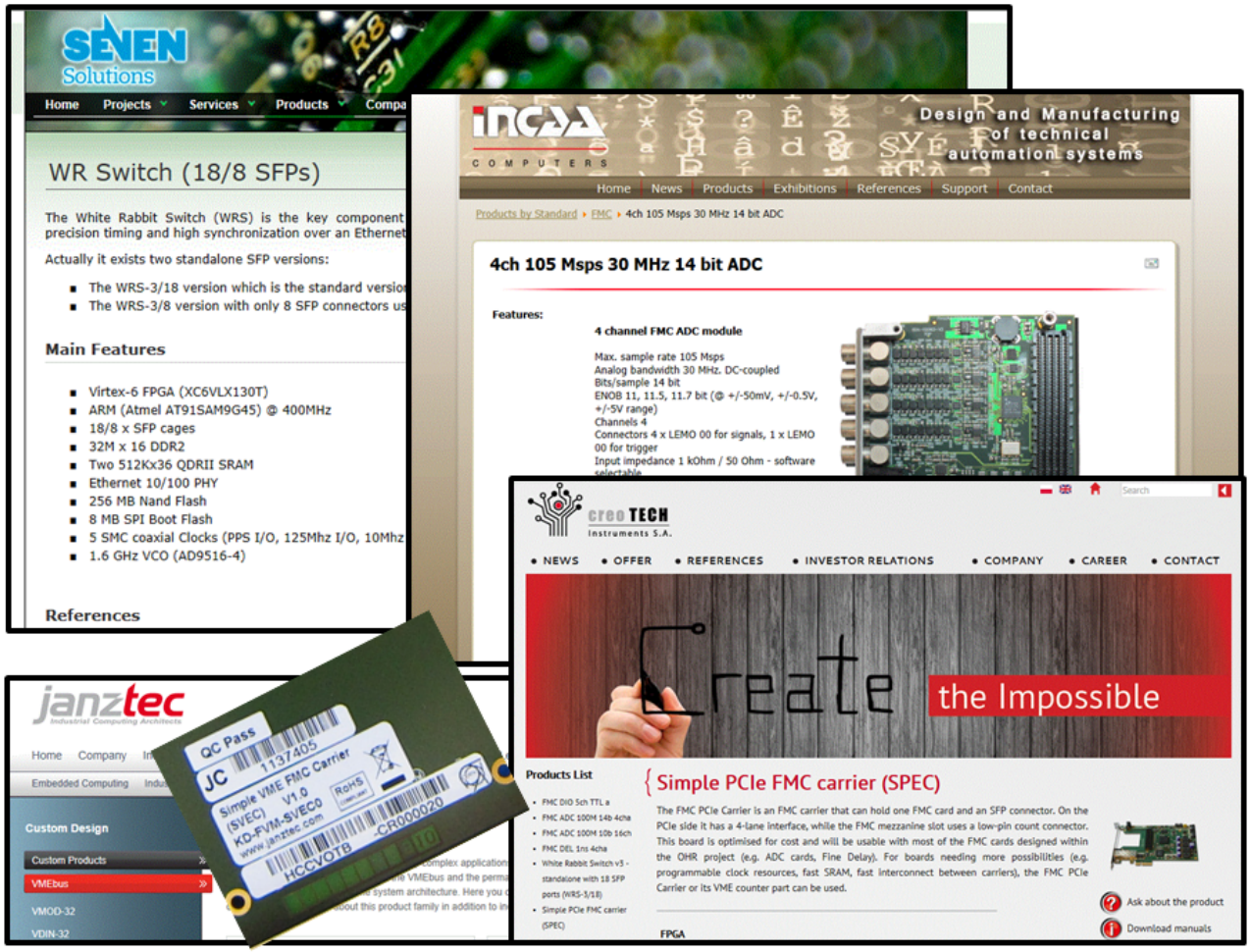
# Business models

## Dispelling the commercial vs open myth

| | Commercial | Non-commercial |
|---|---|---|
| Open | **Winning combination. Best of both worlds.** | Whole support burden falls on developers. Not scalable. |
| Proprietary | Vendor lock-in. | Dedicated non-reusable projects. |

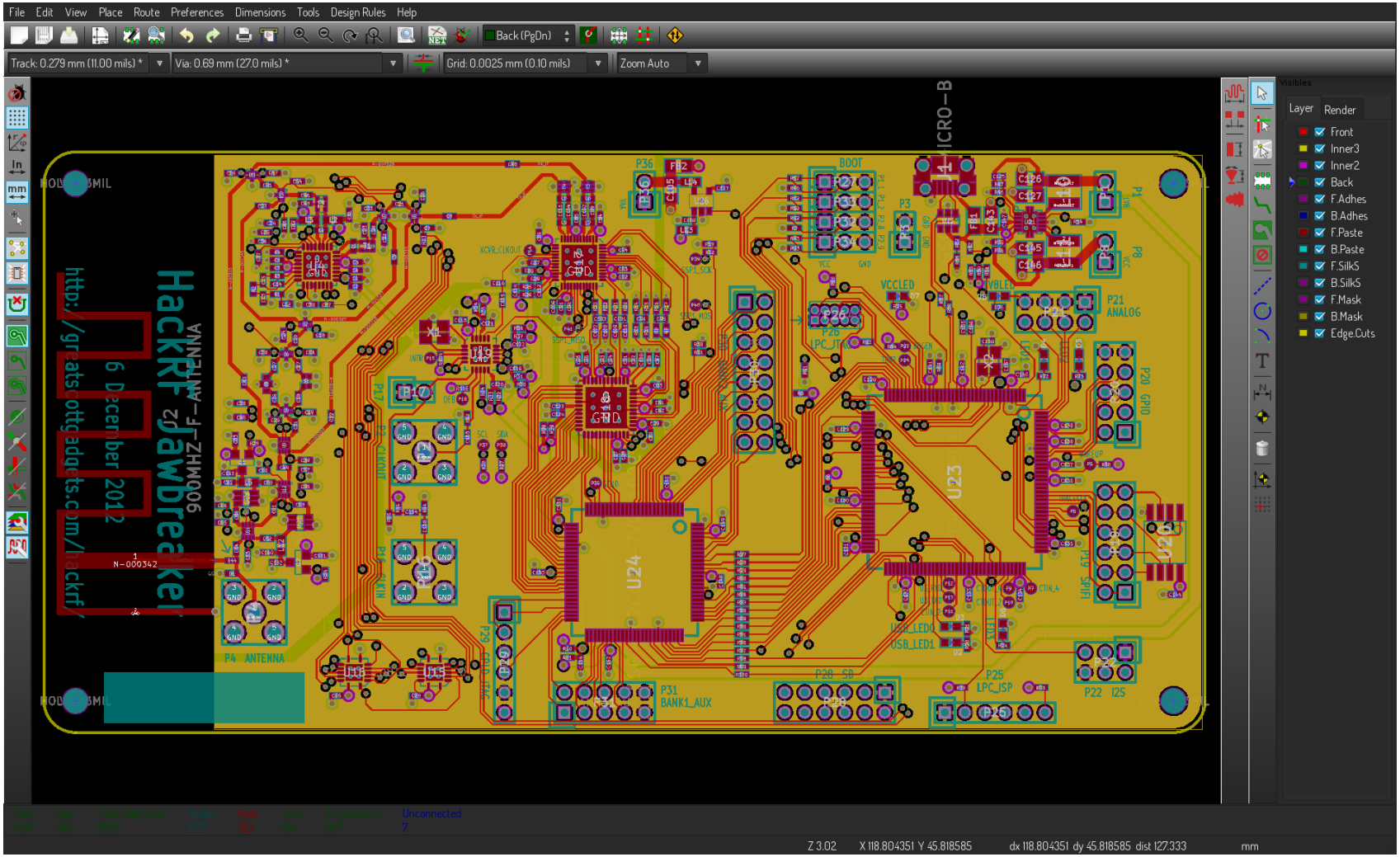
# Where the rubber meets the road

## Seven years of experience at CERN



# Free-as-in-freedom design tools

## The last hurdle to efficient sharing - kicad-pcb.org



# Free-as-in-freedom design tools

## Similar case in the Quantum Engineering community?

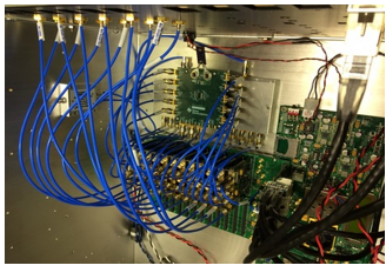
**Tools should be free and open to be able to share**

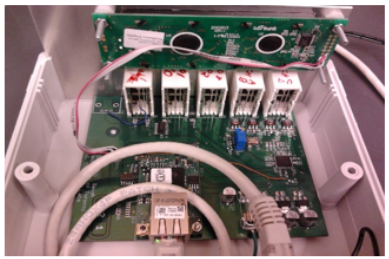
- Simulation tools
- Control software
- Data processing tools
- Quantum Information Software

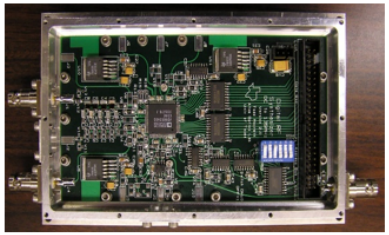
# Hardware for quantum engineering projects

## Duplication of effort: different labs build similar equipment

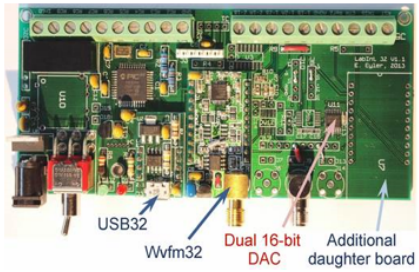
DDS



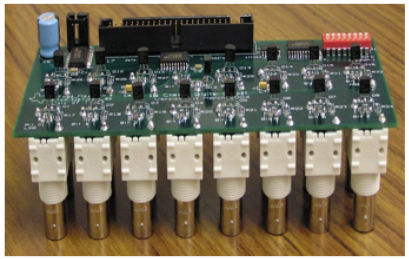




DAC



Digital IO



AOM driver

slide courtesy of G.Kasprowicz

# Quantum engineering project: Sinara

## Open source hardware for quantum applications

### Sinara - github.com/m-labs/sinara/wiki

- Open-source hardware ecosystem designed for use in quantum physics experiments running ARTIQ control software.
- All design files, sources, mechanics, documentation published.
- Project shared under OHL, managed using github.

### International collaboration

- Institutes: NIST Boulder, UMD, ARL, Warsaw WUT, Oxford University, Uni Hannover, PTB
- Industry: Mlabs, Quartiq, Creotech, Technosystem

# Sinara hardware

## Licenced under CERN OHL

- DDS (MTCA octal 2.4GS/s, Eurocard quad 1GS/s ). Flexible analog front-ends
- ADC (MTCA octal 125MS/s, Eurocard octal 1MS/s)
- DAC (MTCA, Eurocard 32channel )
- Digital IO (BNC, SMA, LVDS)
- Deterministic real time controller (sub ns)
- Slow control VHDCI breakout
- Camera Link,
- Clock distribution
- 8 channel RF amplifier for AOM

- Many other modules in development (Piezo drivers, HV supplies, temperature controllers, magnetic field stabilisers)
- Control software (ARTIQ:https://m-labs.hk/artiq/) written mostly in Python including FPGA HDL, GPL

# Quantum engineering project: Easy Φ

## Open source hardware for quantum applications

### Easy Φ - easy-ph.ch

- Easy Φ is a platform aiming at physicists.
- Developed for the needs of quantum optics, usable for applications in physics or biology.
- Open standard platform.

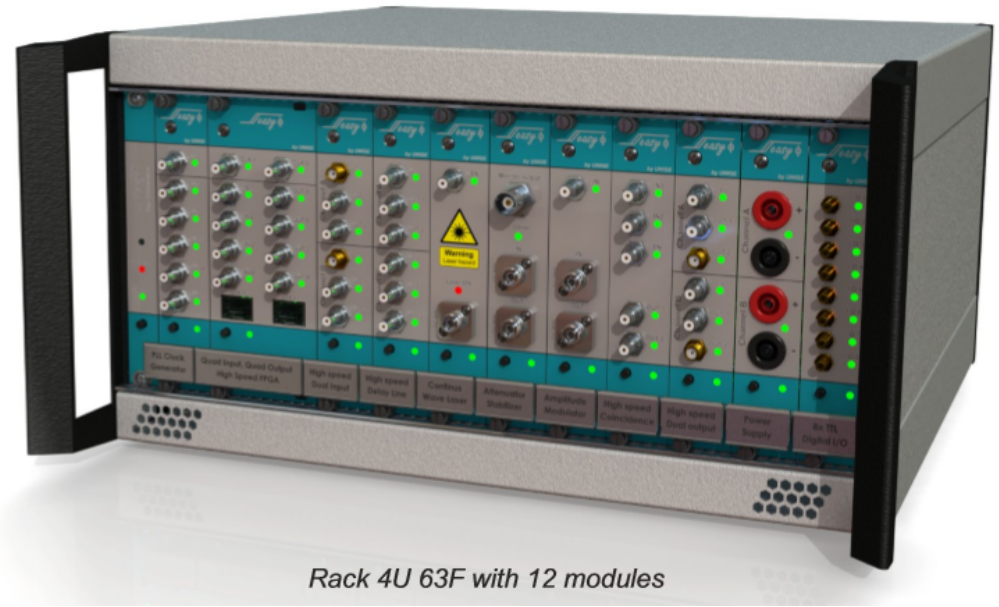
### Single institute, but Open

- University of Geneva
  - Group of Applied Physics in Optics

# Easy Φ hardware

## Licenced under CERN OHL

- Dual High-Speed Universal Input
- Dual High-Speed Universal Output
- Dual High-Speed Delay Line
- High speed coincidence
- Thermocouple temperature measurement
- Optical amplitude modulator
- ...



*Rack 4U 63F with 12 modules*

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# Public institutions

## They serve the interests of a whole society

- Try to maximise positive impact of decisions.
- Not always easy.

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## Can be “tractor” institutions

- To help take projects to a mature state where they can be sustained commercially.
- Liaising with other public institutions to reach critical mass.
- Also with their procurement hat.

# The funding agencies conundrum

# Issues with “coopetition”

Research groups sometimes end up behaving as private companies (but with public money!) because of wrong incentives by funding agencies.

# The power of getting organised

Look at Open Hardware, Open Access. . . even CERN itself!
These things looked highly improbable before people got organised to make them happen.

# Check out zenodo.org!

## Why?

- Science cannot be open without open data ...
  - ... and software and hardware
- Avoid triple pay for tax payers
- Makes sharing research very easy!

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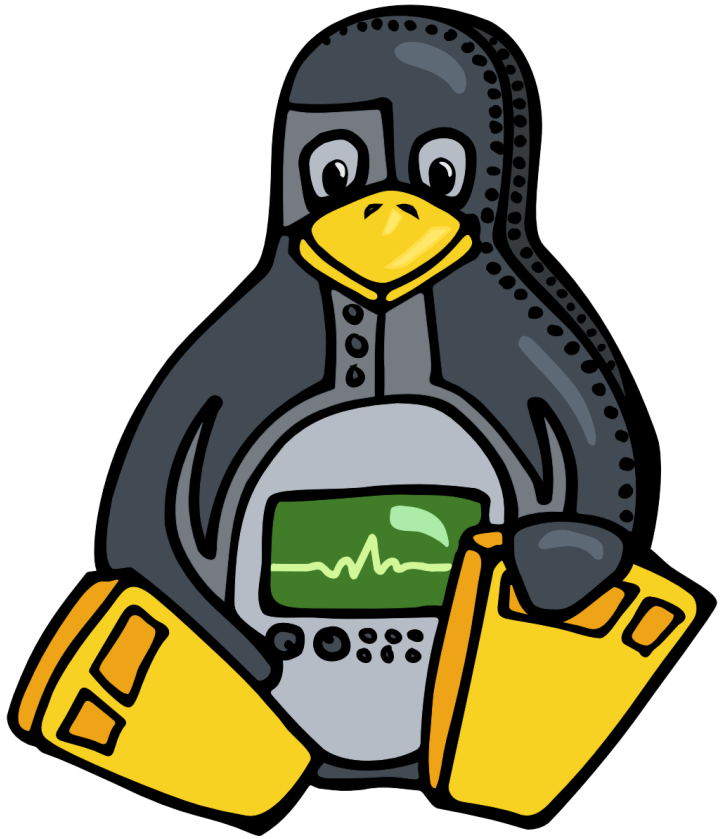
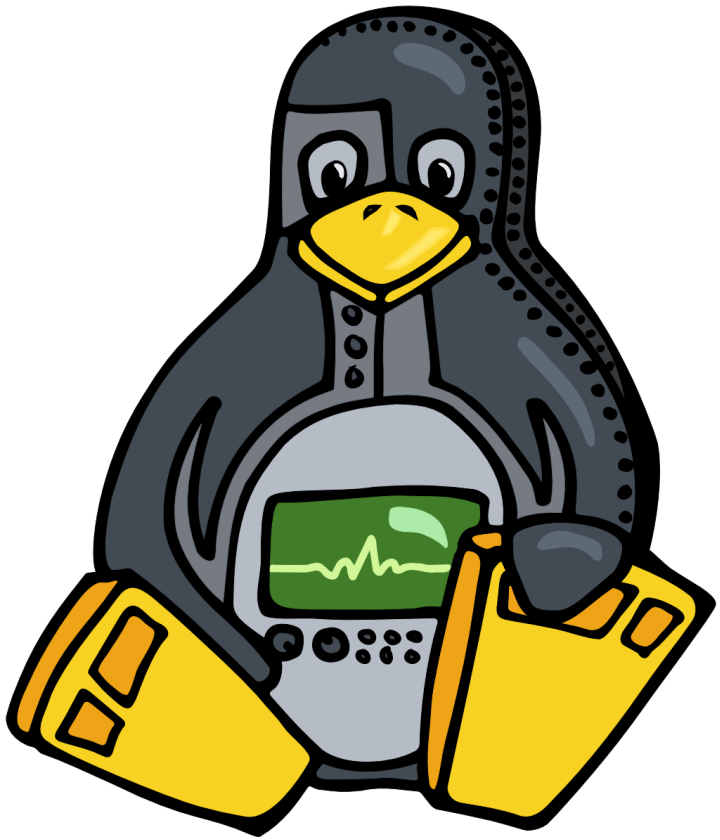
## How?

- Open attitude from day 1
- Communities of interest in Zenodo
- Involving key commercial and non-commercial actors from the start

# Quantum Engineering

## How to get organised

- Open Hardware
- Open Software
- Site to collaborate
- Coordination
- Need for a "Tractor" institution?



# So, how can the Quantum Engineering Community get organised?