

CNRS Helmholtz Dark Matter Lab (DMLab)



Thomas Schörner (DESY) and Dirk Zerwas (DMLab)

14 September 2026



Research Particle Physics

CNRS Helmholtz

France:

- **CNRS:** IN2P3=CNRS Nucléaire et Particules)
- CEA Saclay (IRFU)
- Universities

Germany

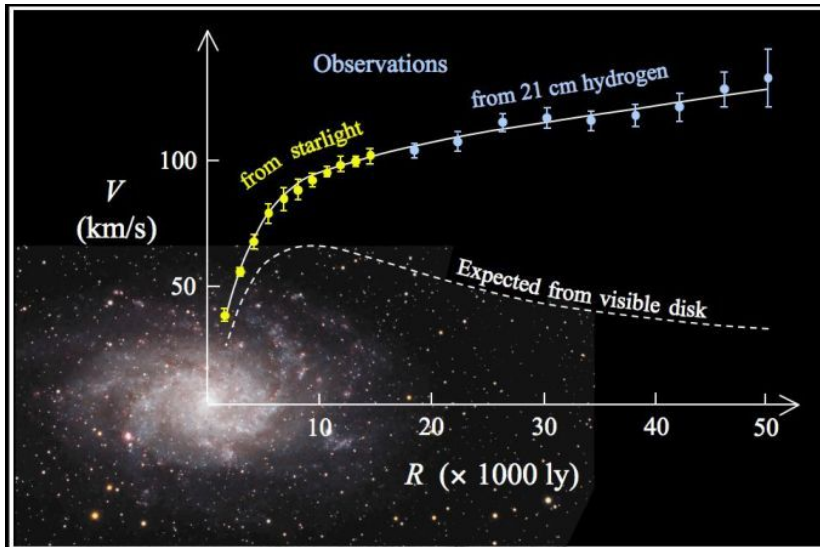
- Universities (1808 Wilhelm von Humboldt “**Einheit von Forschung und Lehre**”)
- Max Planck Institutes (Munich, Heidelberg,...) “**Individual excellence**”
- **Research centers:** DESY, GSI, Karlsruher Institut für Technologie (KIT)
- **2001 “Helmholtz Gemeinschaft e.V.”** (Association Helmholtz Loi 1901 with Research centers as members)

France+Germany:

- Historically many direct and indirect adhoc collaborations starting with CELLO at DESY, LEP, LHC at CERN)
- CNRS Helmholtz Dark Matter Lab
- CNRS Nucleaire et Particules + DESY + GSI + KIT

Dark Matter - “DM”

Abundantly present in the universe - What is its nature?

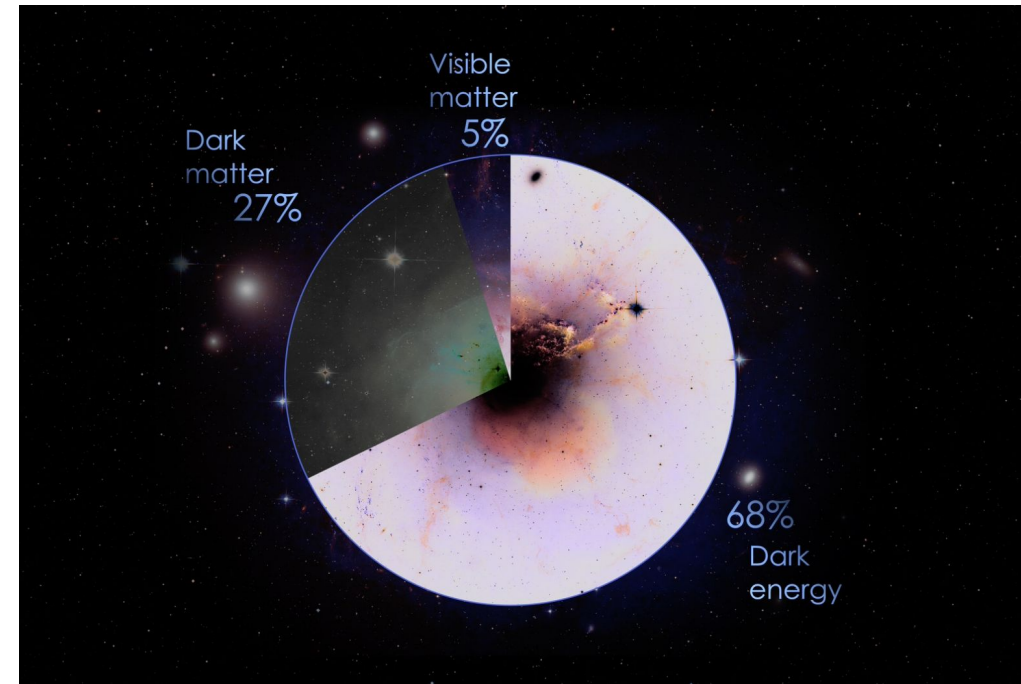


Dark Matter (Zwicky and a bit of Kepler)

- Gravitational force: GMm/r^2
- Centrifugal force: mv^2/r
- result: $v^2 \sim 1/r$, i.e. velocity should decrease with distance, it does **not**
- Need additional invisible, weakly interacting matter

Cosmological Model (Λ CDM)

- Measure the Cosmic microwave Background (CMB) fluctuations (Hubble, Planck satellite)
- Quantifies contributions from:
 - Standard Model of Particle Physics (5%)
 - Dark Matter (27%)
 - Dark Energy (68%)

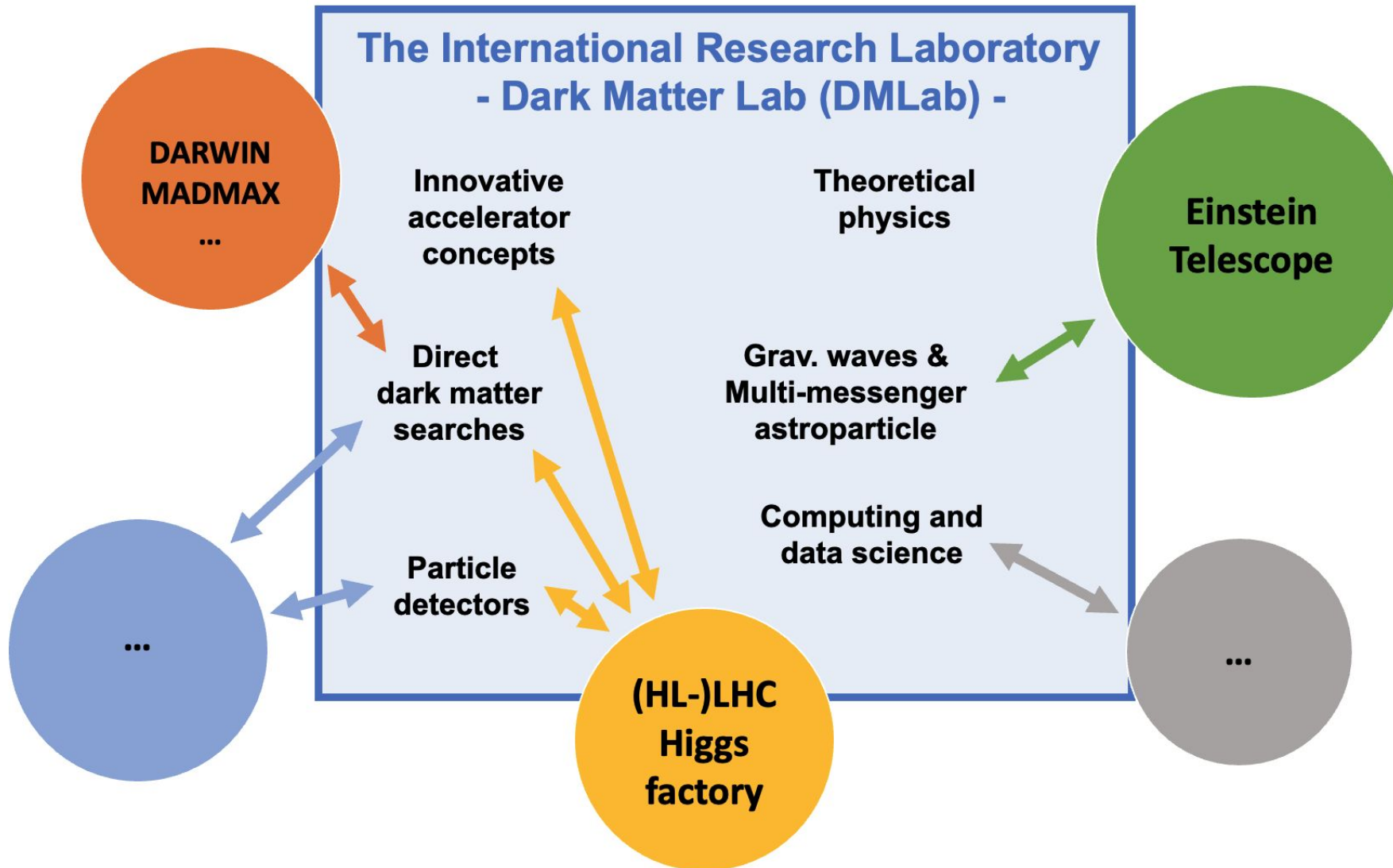


Task

- Look at signals and models of dark matter
- Including detection and production techniques

Scientific Topics of DMLab

Central theme dark matter



IRL tasks:

- develop new ideas
- across topic boundaries
- glued by dark matter

Formally

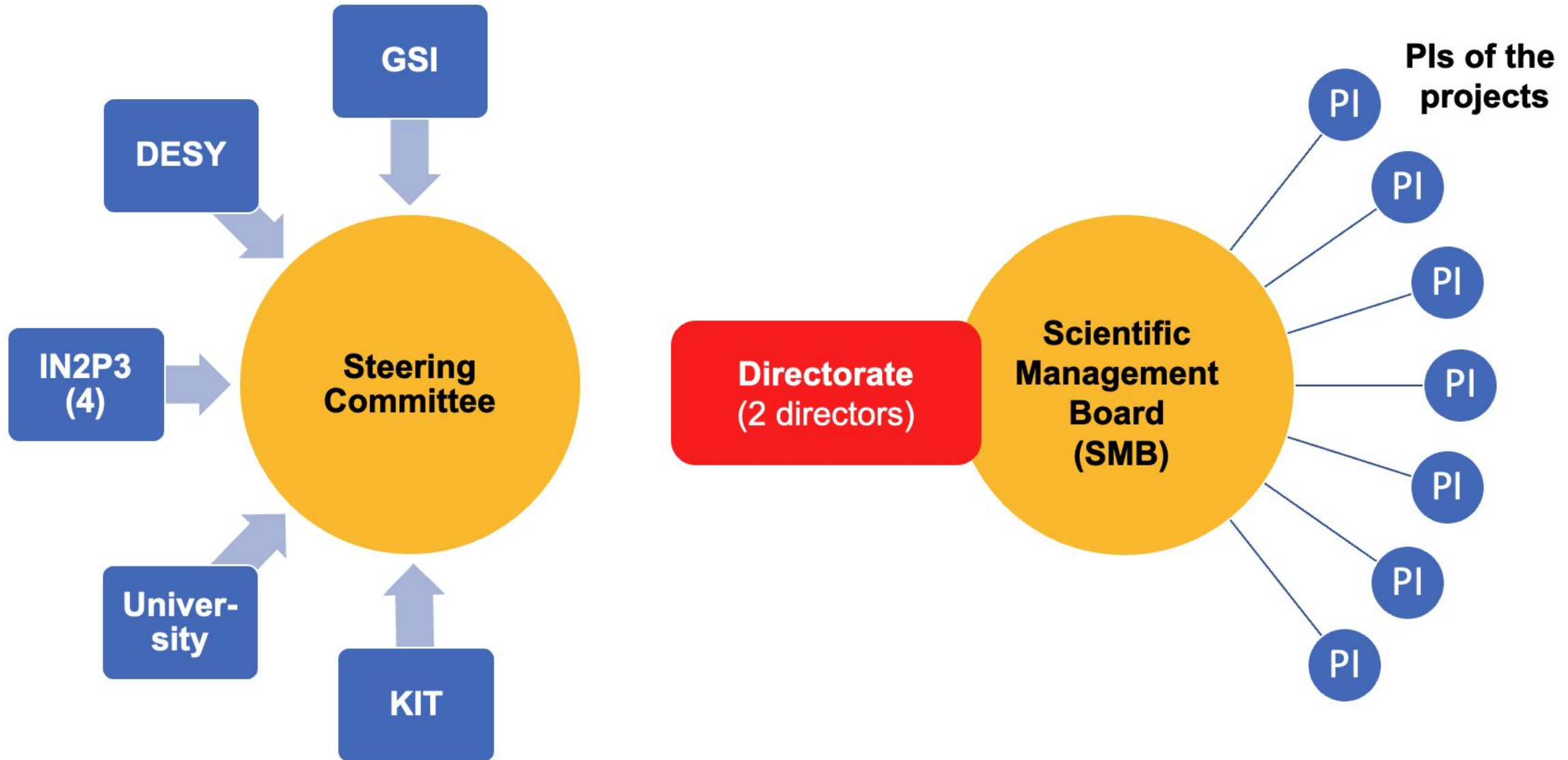
- **long term visits to DESY, KIT and GSI**
(sabbaticals/expatriation=change of lab, 1y minimum)
- **working visits** (typically 1-2 weeks)
- workshops broad and narrow
- common work
- try for common funds

Active since 2024:

- 2 DFG-ANR
- 1 annual workshop
- 2 special PhDs
- regular visits (mostly PhD)

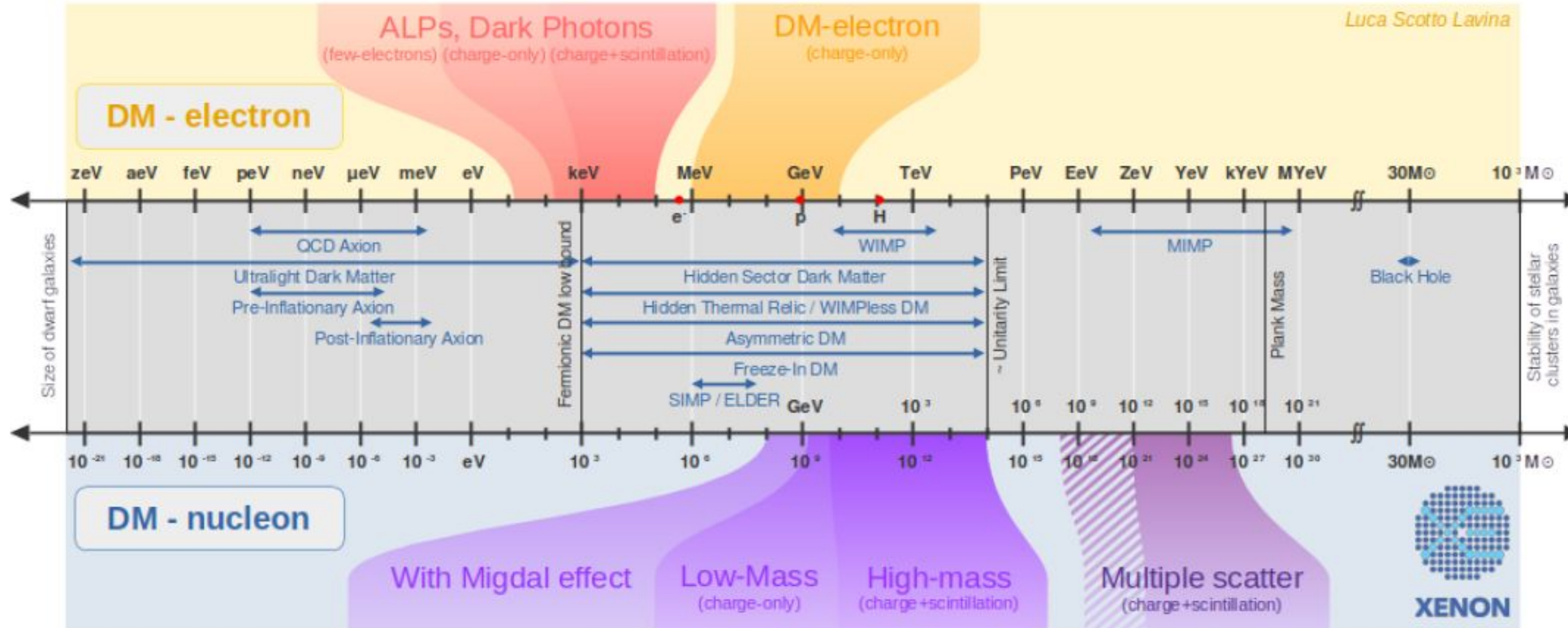
The IRL DMLab - A CNRS International Research Lab

Bringing all scientific and R&D threads in DM research together



Dark Matter: Direct Search

MADMAX



- Nature, mass and coupling of dark matter unknown
- WIMP: XLZD (KIT)
- WISP: MADMAX

Measure a WISP

- Mass 10^{-6} eV (WIMP 1 GeV) Wave property of particle (meter-like)
- Interact with B-field
- Enhance signal with di-electric disks
- Position precisely in cold to obtain ~ 10 μ m precision (CPPM)
- special PhD position with DESY and ANR-DFG

Dark Matter: Innovative Acceleration Methods

Plasma

Acceleration in a nutshell

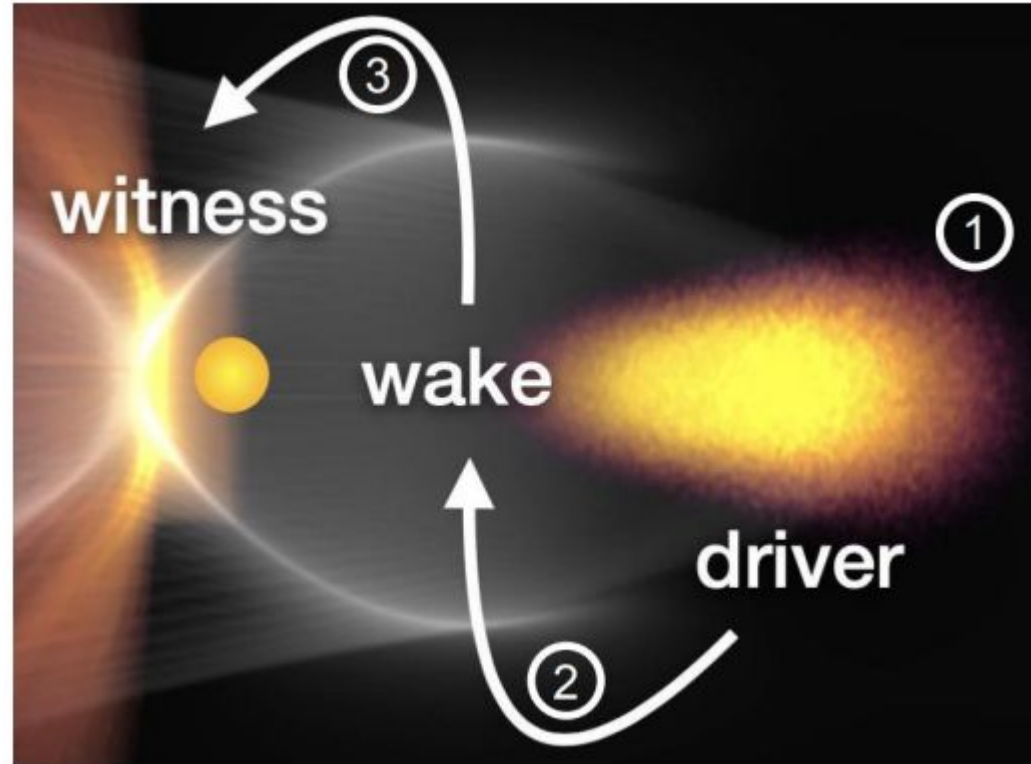
- electric fields accelerate
- Particle energy: $e \times V$
- RF: $e \times MV$
- Plasma: $e \times GV$

Energy Frontier

- Higgs Factory: 0.25TeV
- Multi-TeV
- High field: compact machine

Plasma acceleration in a nutshell

- Gas = Atoms
- Atoms= electrons + nucleus
- separate electrons and nucleus
- insert beam of particles (neutral or charged)
- shapes electrical fields
- next beam/bunch is accelerated



Installations at DESY

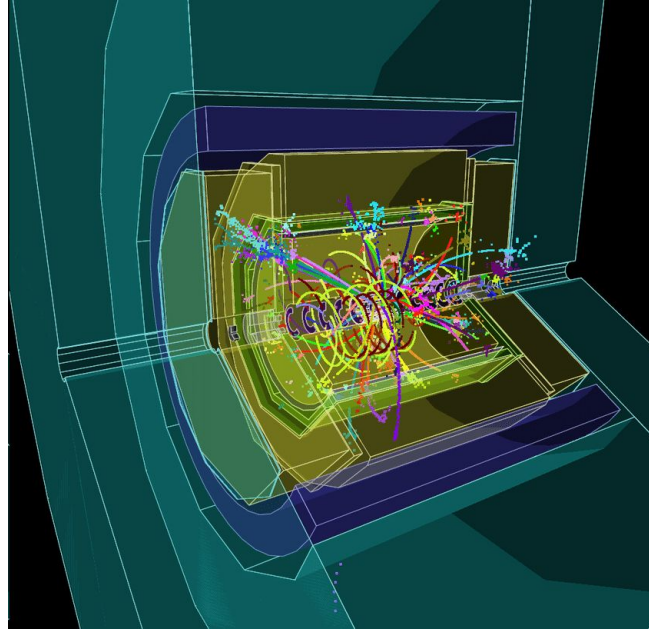
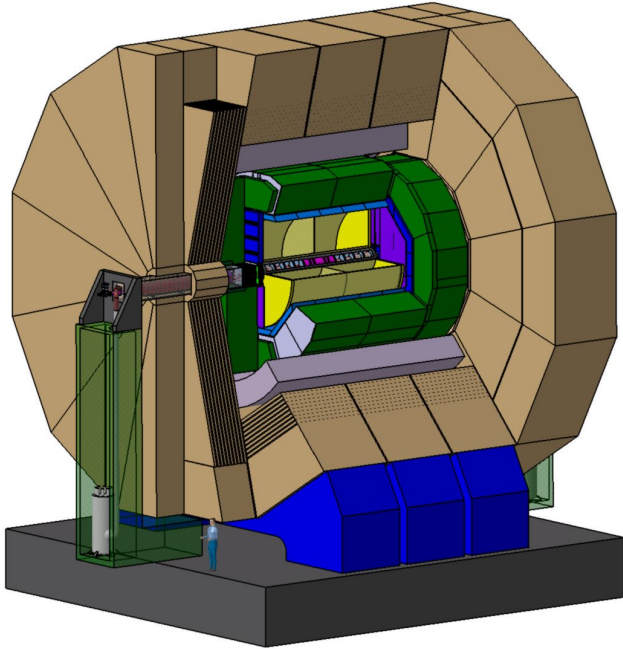
- KALDERA (Laser)
- Flashforward (Beam)
- Preparation of injector for Petra IV

Collaboration

- special PhD with KIT
- KIT : PhD visit via DMLab
- DESY : multiple PhD visits via DMLab (work on gas injection simulations and validation)

Dark Matter: Detector Development and Tests

HGCAL and Testbeam



ILD: Higgs Factory Detector

- Total size: 16m x 16m x 14m

Particle Physics Experiments in a nutshell

- high energy collisions produce particles
- Measure tracks in B field: momentum and position
- Measure energy in calorimeter: energy and position
- Combine all in ParticleFlow (particles, jets, missing Energy)
- Deduce particles produced and decayed

Energy Frontier Experiments

- Measure particle Energies: Calorimeters
- SiW electromagnetic calorimeter
- AHCAL hadronic calorimeter
- SiW+AHCAL: part of the ILD detector concept

Testbeam

- Electrons up to 6GeV
- Single particles
- Test of prototypes before production

Visit

- HGCAL hadronic calorimeter for the HL-LHC being produced
- Testbeam

Collaborations

- Combined testbeam at DESY and CERN
- DFG-ANR project on precise timing for calorimeters (machine learning) with several PostDocs and a thesis student

Today

3 Plasma

5 PETRA 3

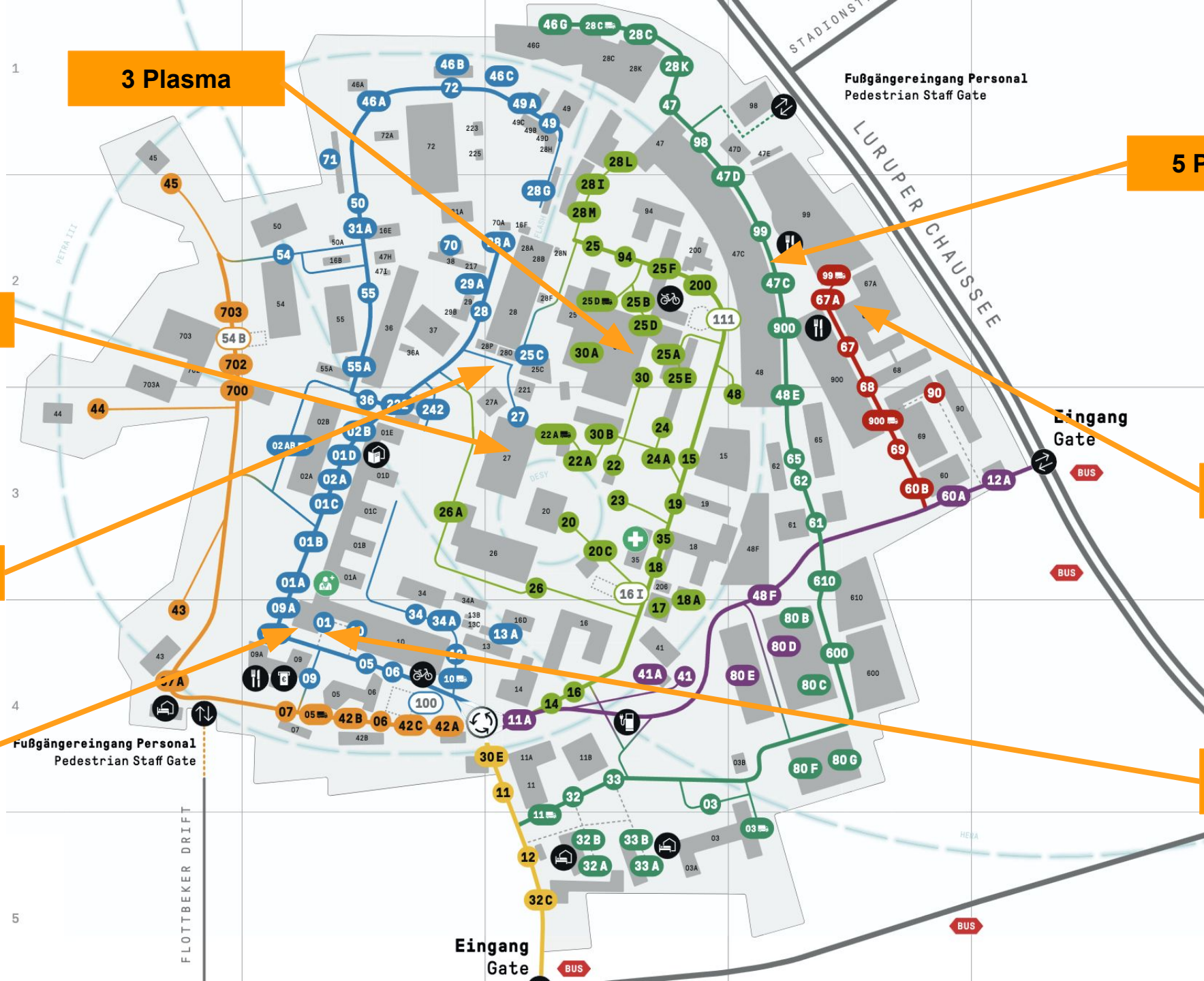
2 Testbeam

4 MADMAX

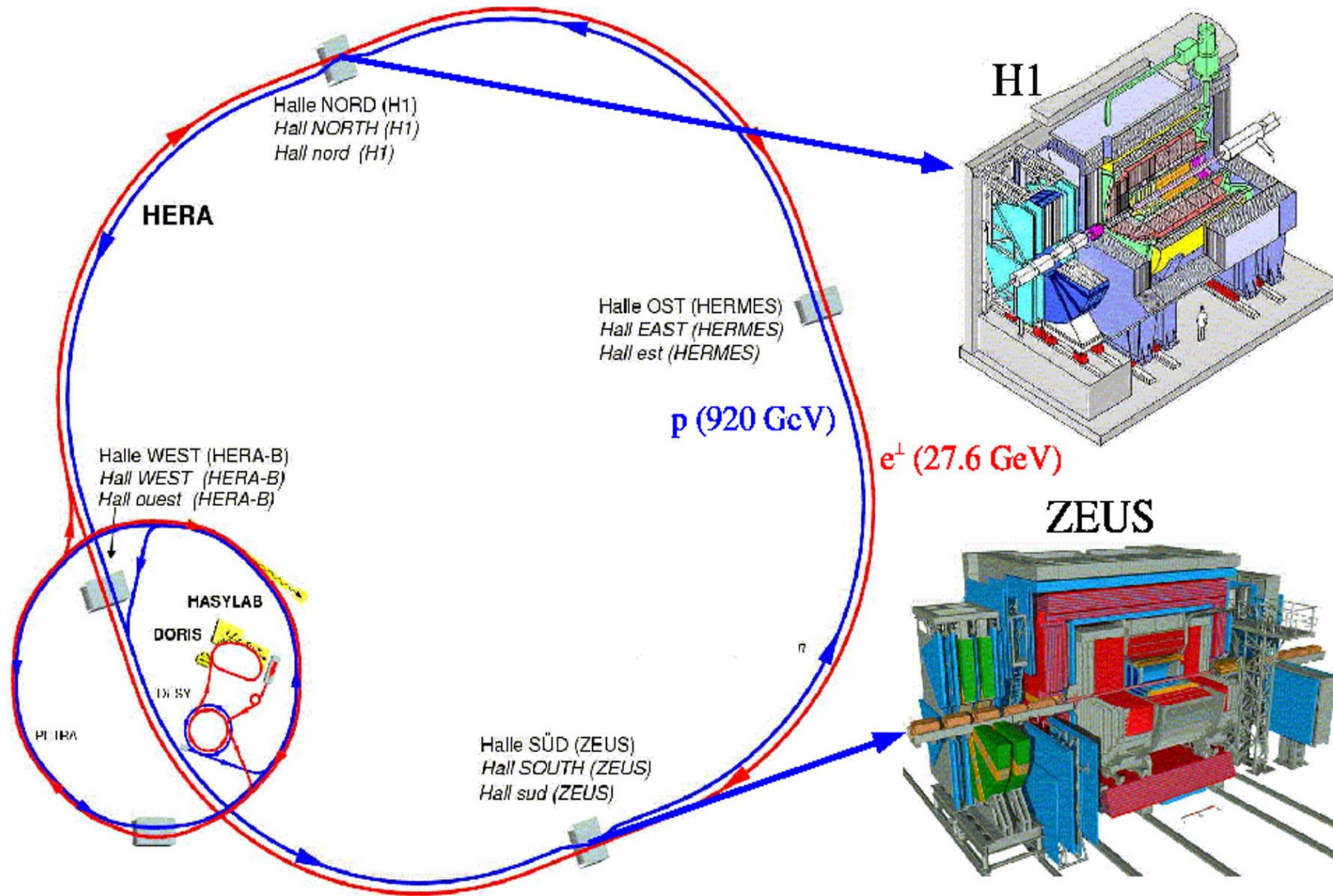
1 Calorimeters

Now

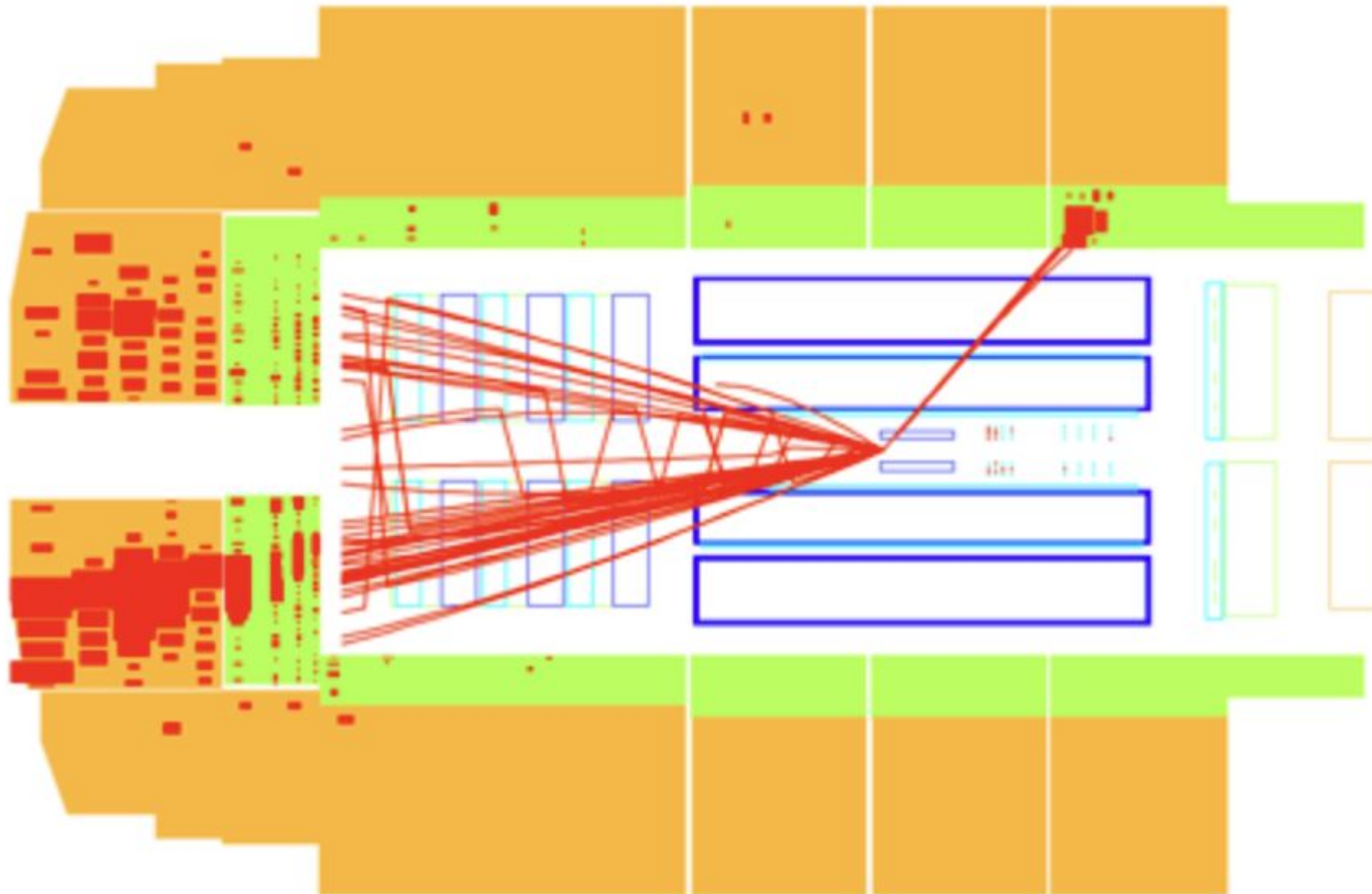
6 DESY and FH Directors



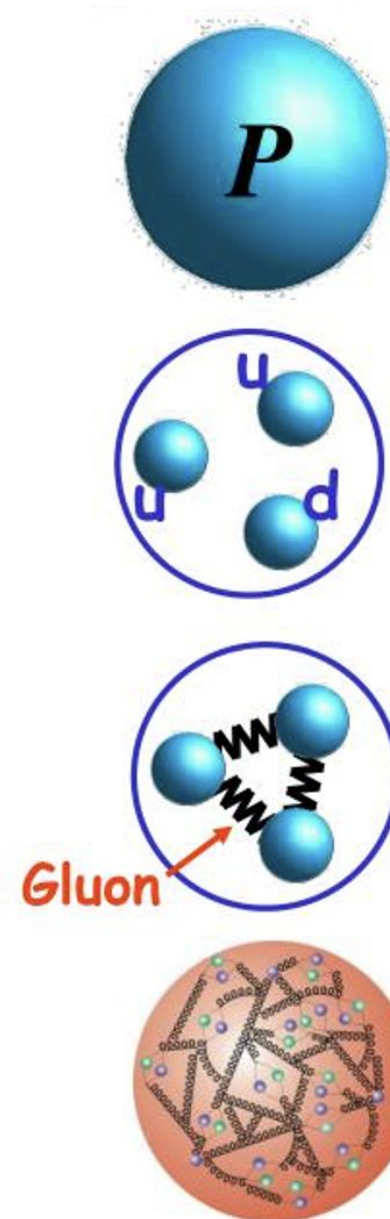
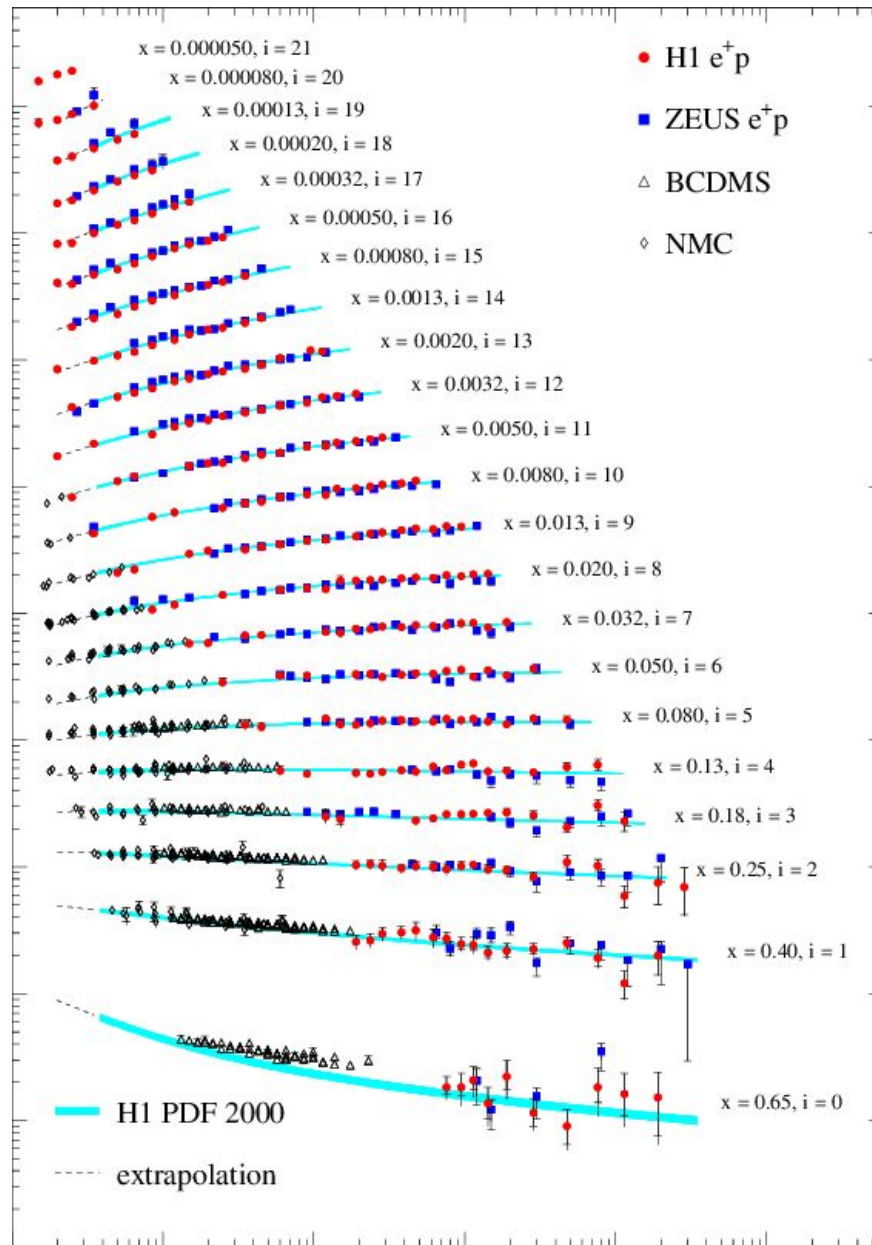
HERA - Electron-Proton Collisions 1992-2007



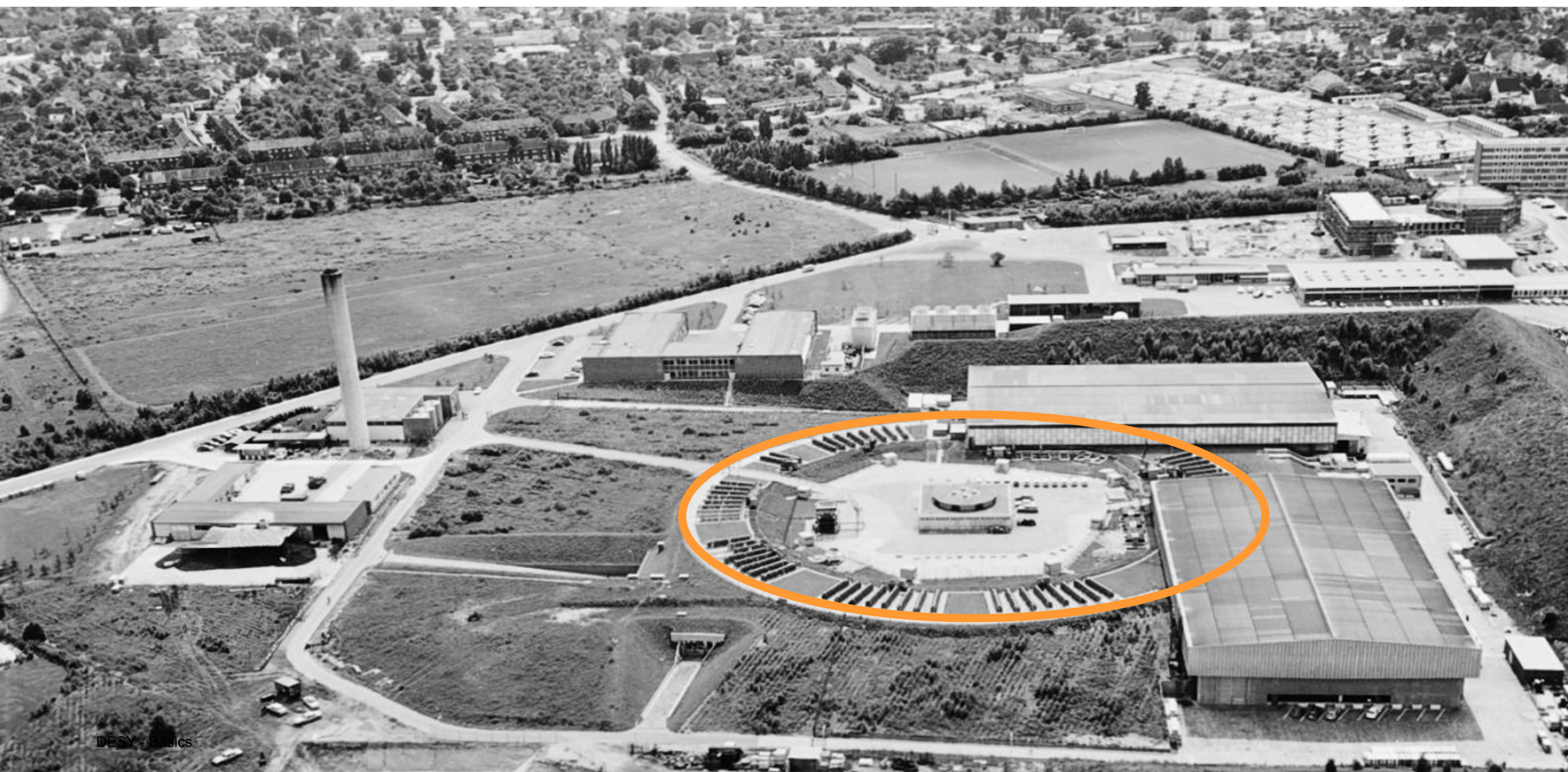
HERA - Electron-Proton Collisions 1992-2007



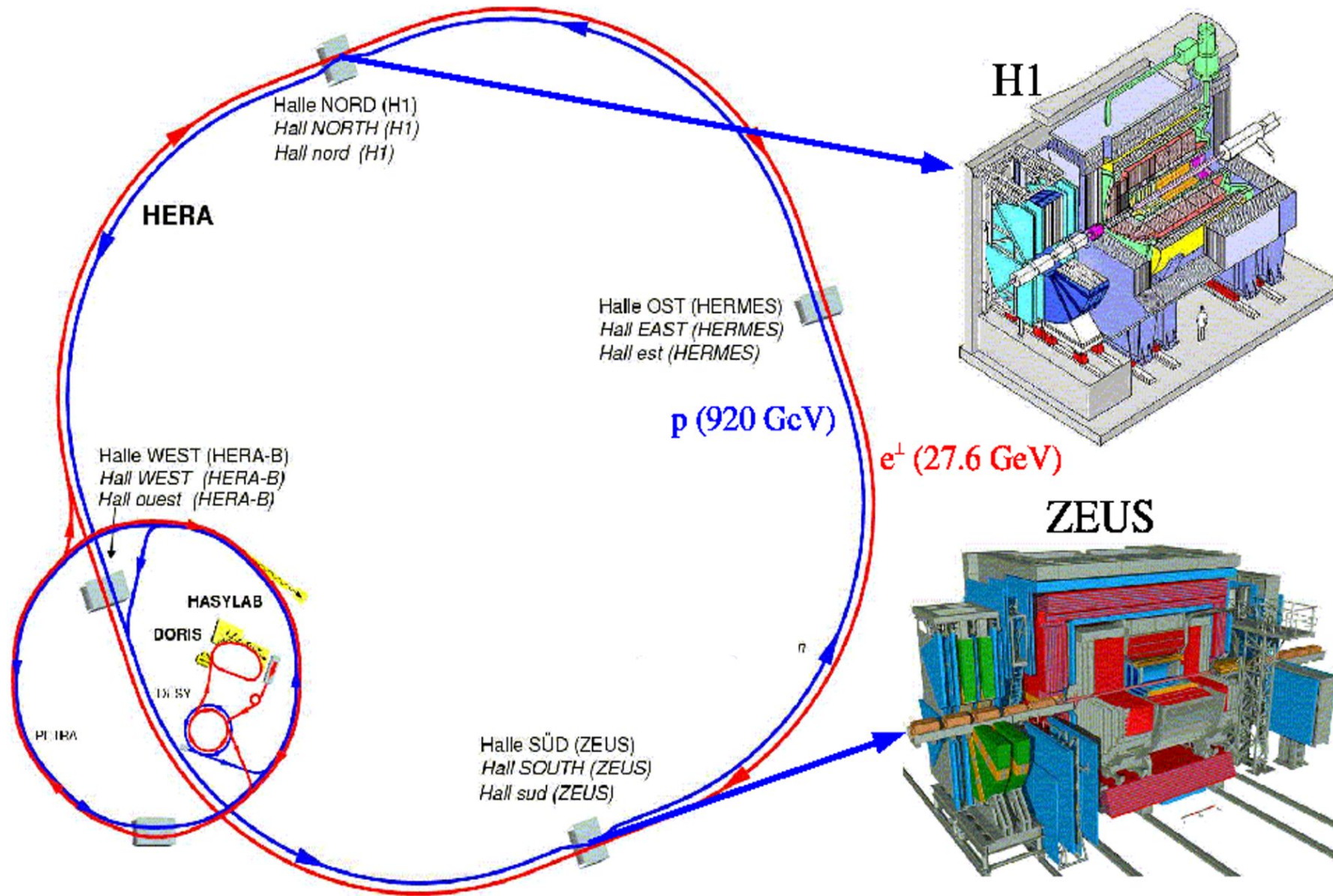
HERA - Electron-Proton Collisions 1992-2007



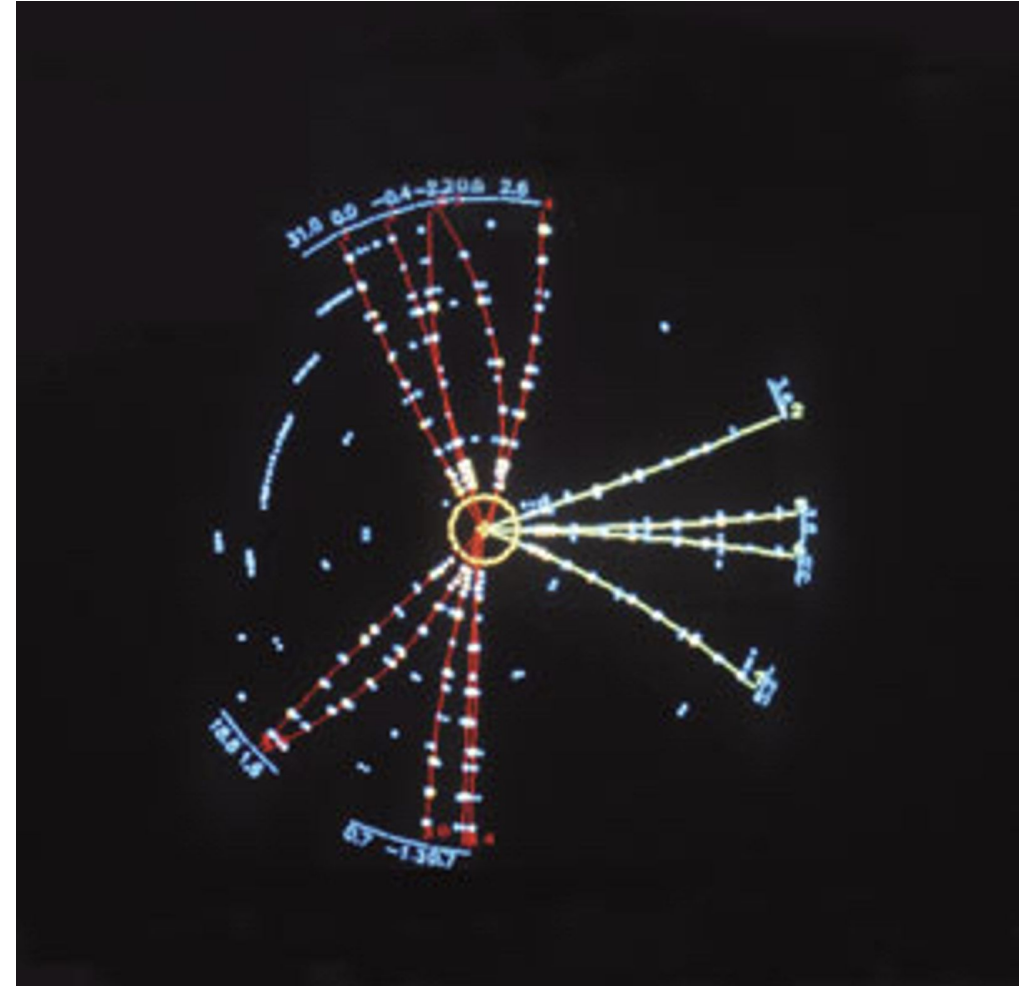
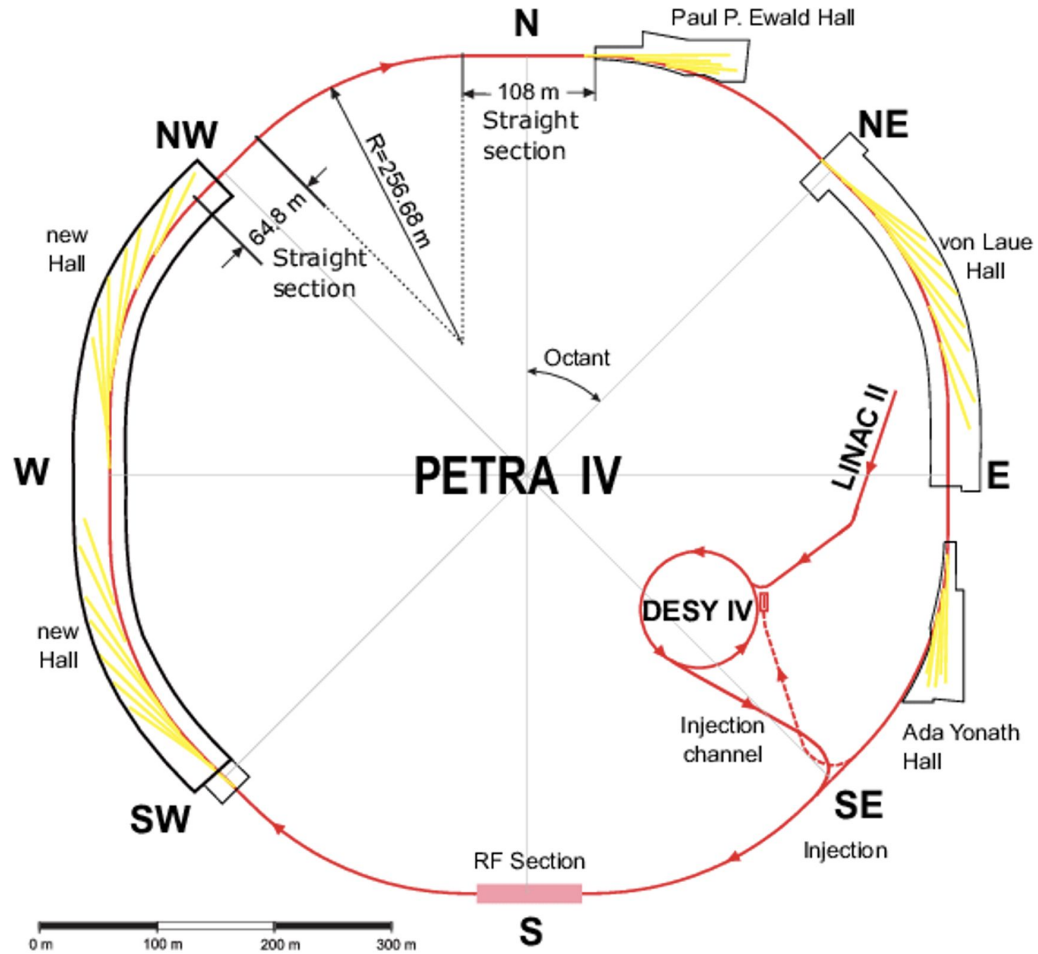
1959: How It All Started: The DESY Machine

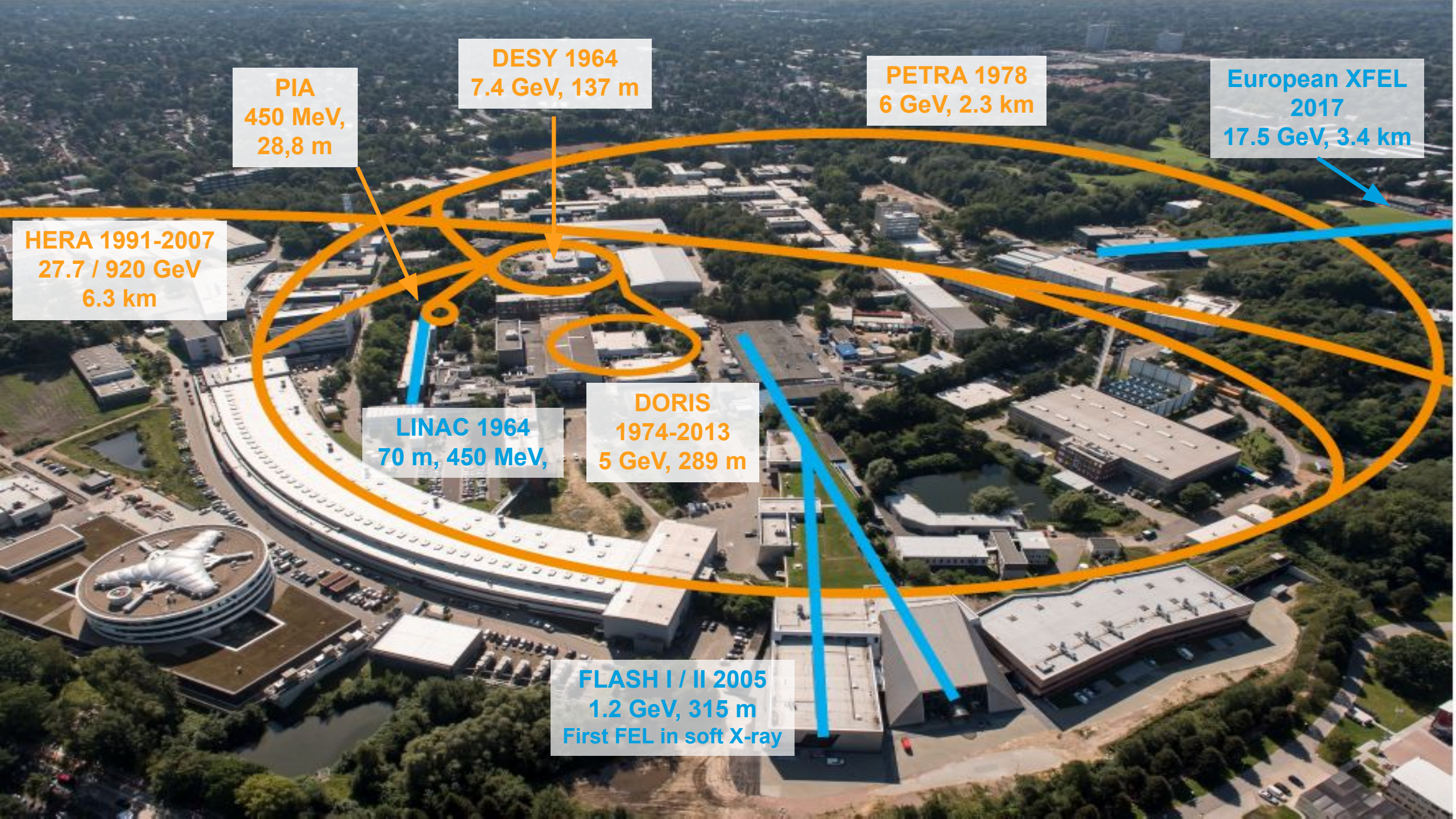


DESY, DORIS, PETRA and HERA



PETRA (and the Gluon)





PIA
450 MeV,
28,8 m

DESY 1964
7.4 GeV, 137 m

PETRA 1978
6 GeV, 2.3 km

European XFEL
2017
17.5 GeV, 3.4 km

HERA 1991-2007
27.7 / 920 GeV
6.3 km

LINAC 1964
70 m, 450 MeV,

DORIS
1974-2013
5 GeV, 289 m

FLASH I / II 2005
1.2 GeV, 315 m
First FEL in soft X-ray