Available test beam facilities and specific infrastructure

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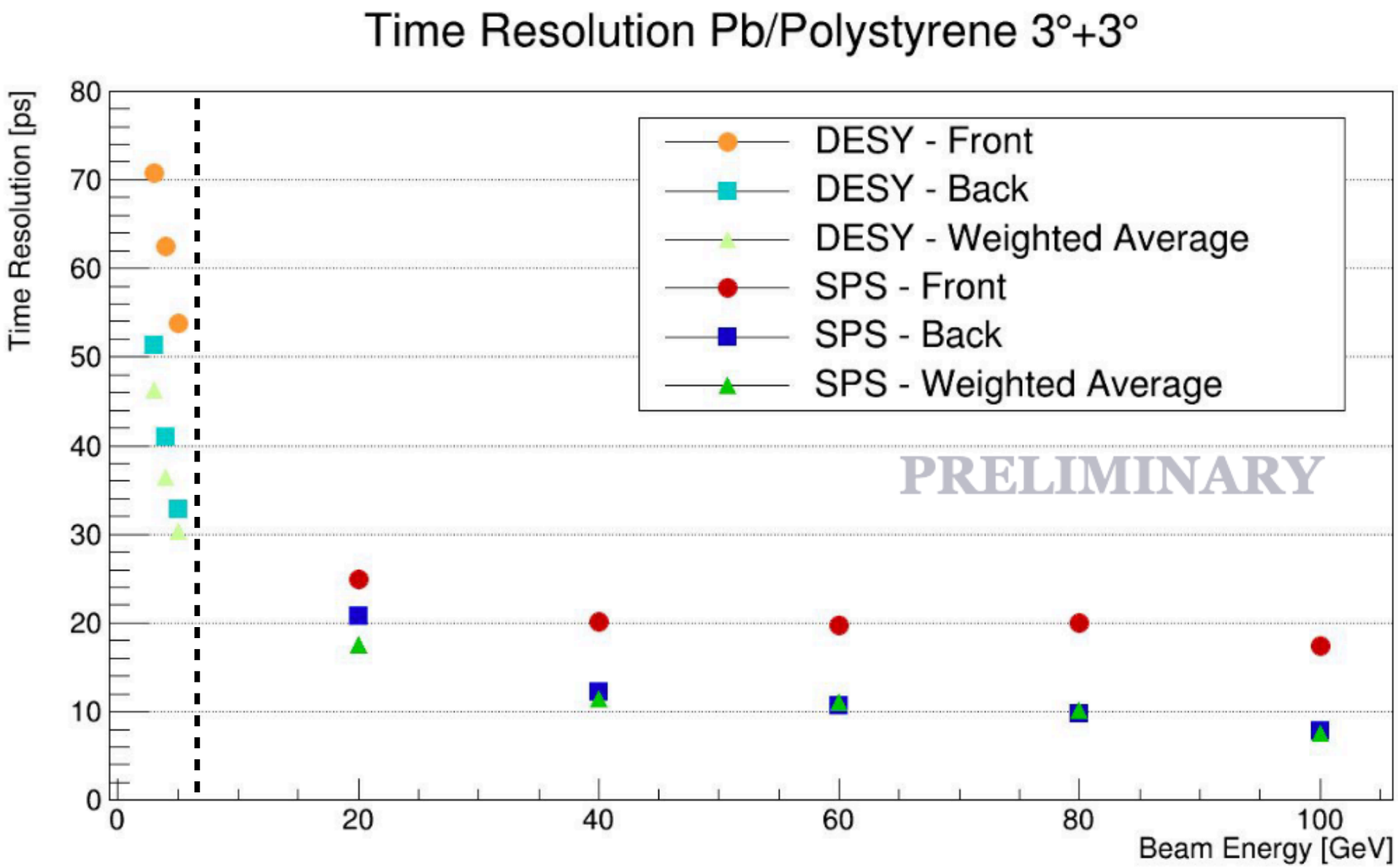
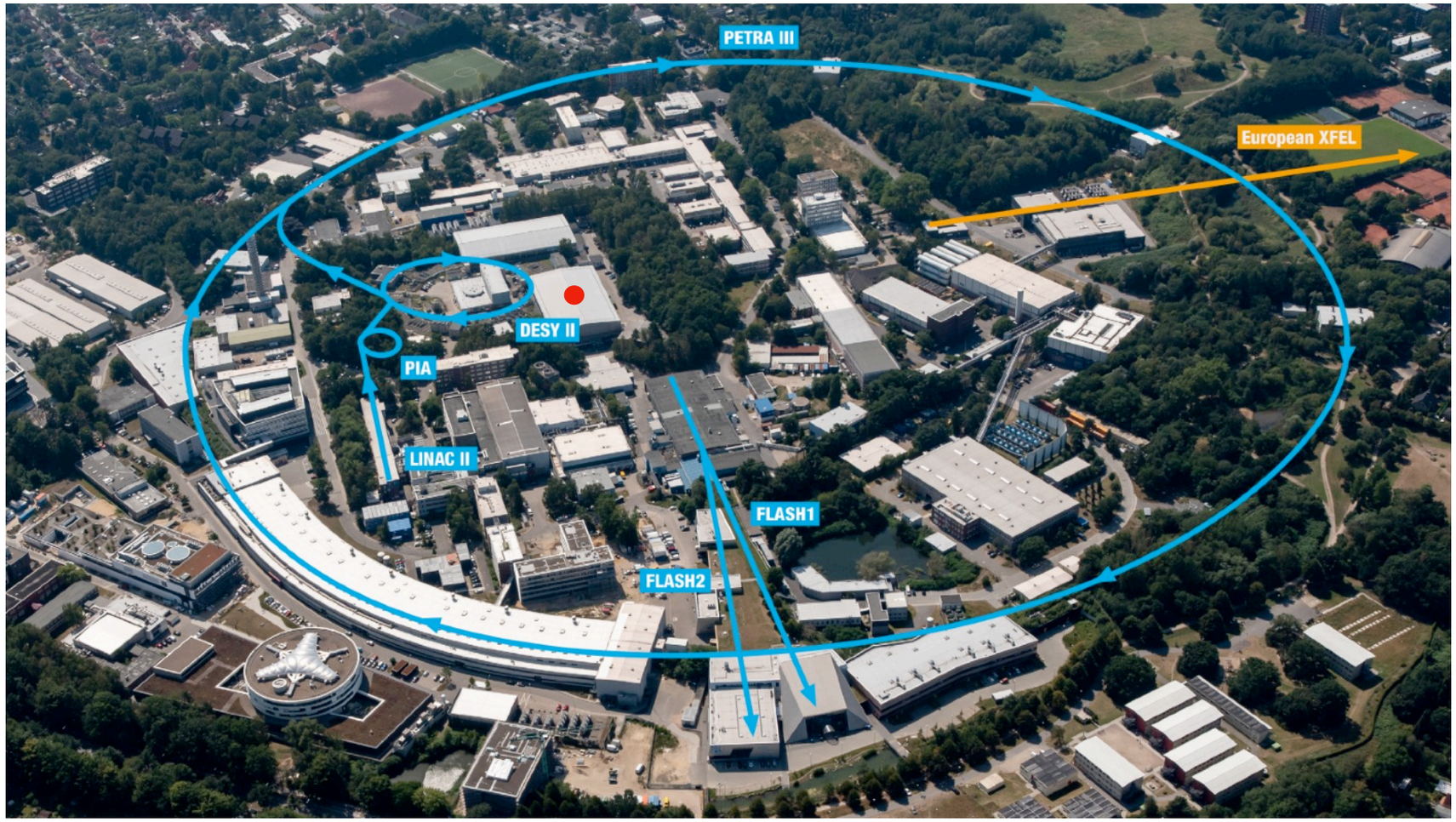
ECAL prototypes in test beam



Low energy
(below 6 GeV)

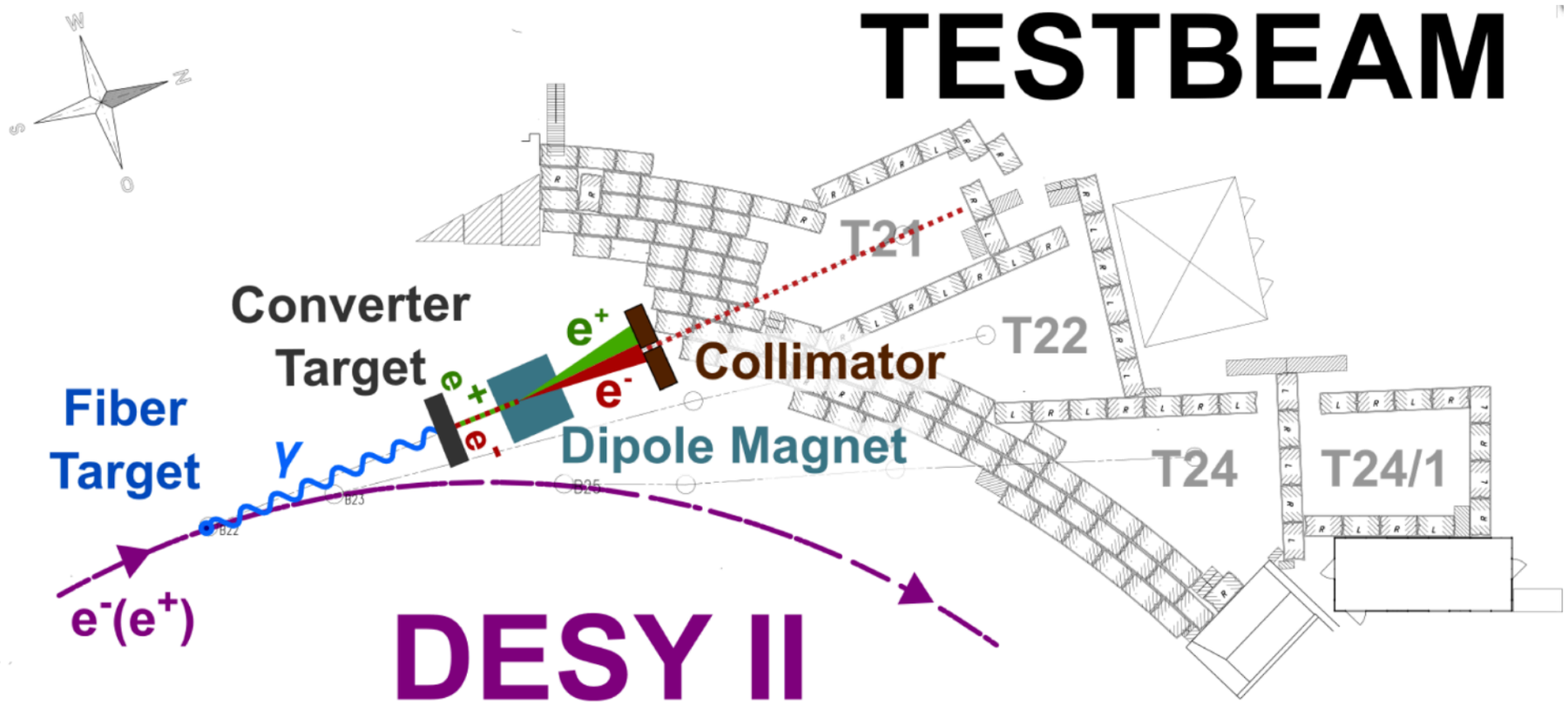
High energy
(up to 100 GeV)

DESY test beam facilities



- Location: Hamburg (Germany)
- DESY II electron/positron synchrotron:
  - Circumference: 292.8 m
  - Injector for 2.3 km-long PETRA III storage ring (High-brillance X-ray source)
- Test beam hall (bld. 27):
  - 2 test beam campaigns with LHCb ECAL prototypes in 2022 (2 weeks in May + 1 week in November/ December)

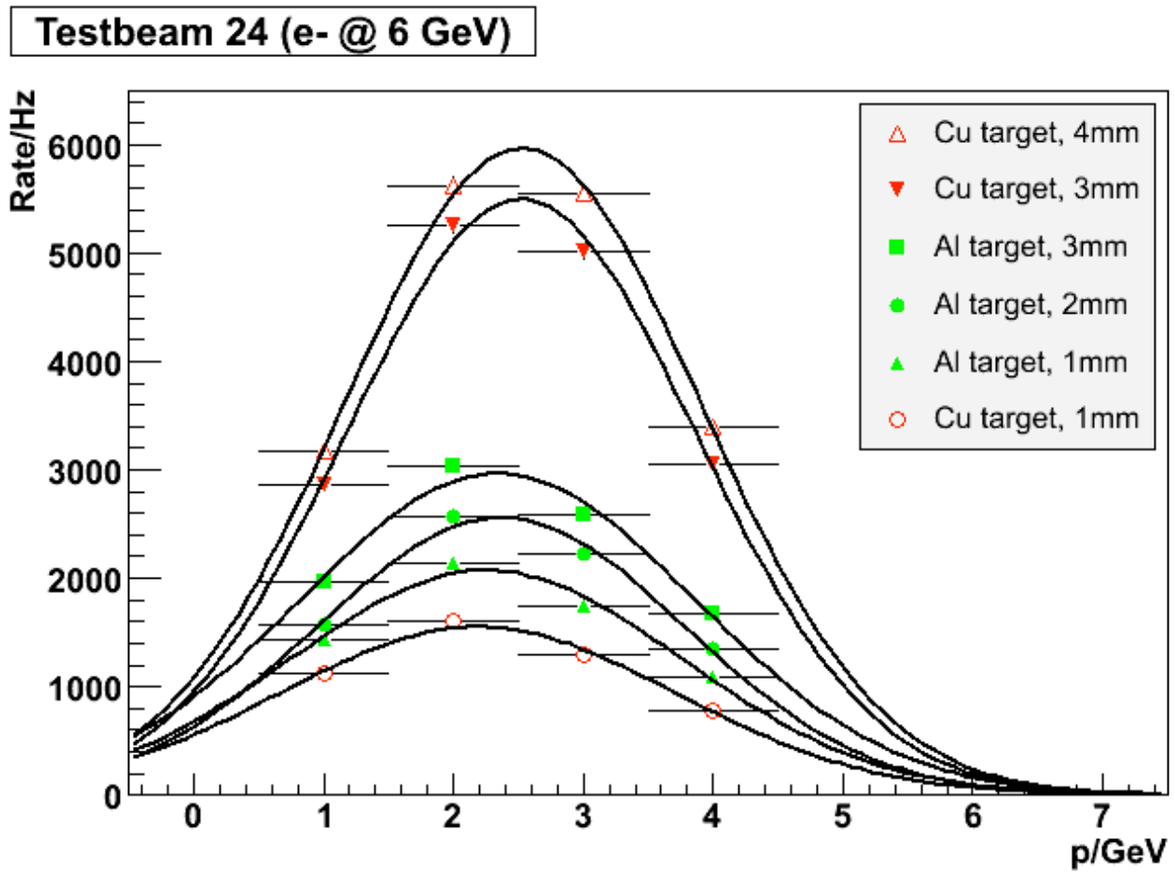
Beam generation



- Electron/positron accelerated by DESY II up to 7 GeV
- Bremsstrahlung photon beam generated by a carbon fiber target
- Photons converted to e^+/e^- pairs via a metal plate target (Cu or Al)
- Resulting beam momentum selected by setting the dipole magnet current before the collimator

Beam characteristics

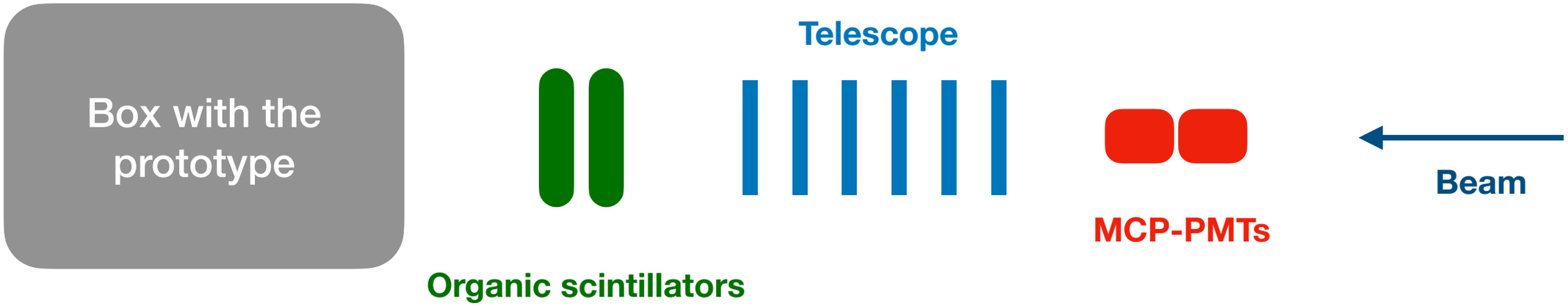
- Electron/positron beam:
  rate up to ~1k part./cm^2
- Selectable energy from 1 to 6 GeV
- Momentum spread: 1.5 to 12.7%
- Divergence ~ 1 mrad
- Good availability of the beam (very rare interruptions)
- Good stability of the beam (very few variations of the rate)



B (T)	$\bar{p}$ (GeV/c)	σ (GeV/c)	$\frac{\sigma}{\bar{p}}$ (%)
0.12	0.907	0.116	12.7
0.30	2.162	0.197	9.1
0.44	3.001	0.111	3.7
0.59	3.989	0.128	3.2
0.75	5.078	0.163	3.2
0.90	6.003	0.093	1.5

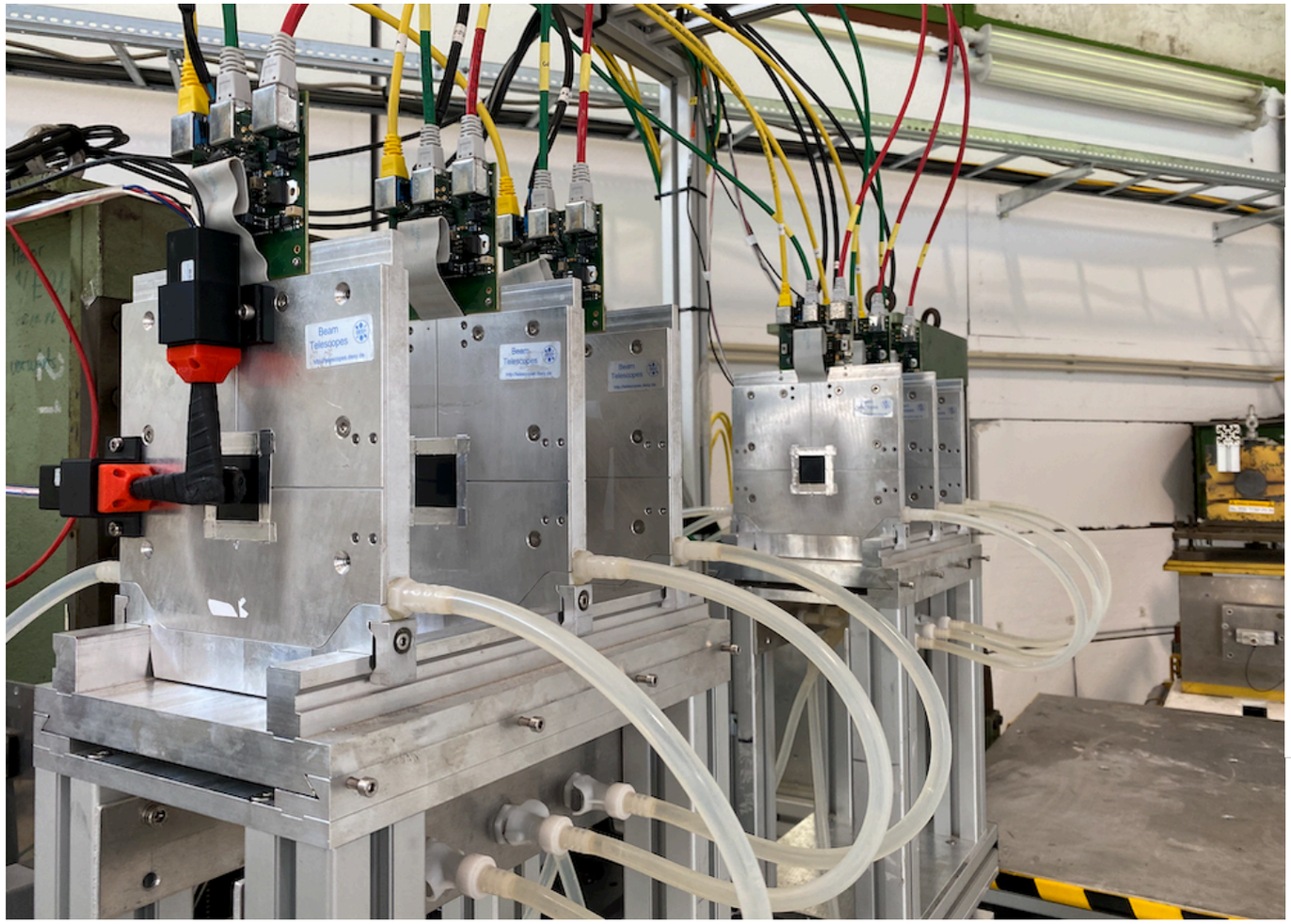
Link: The DESY II test beam facility

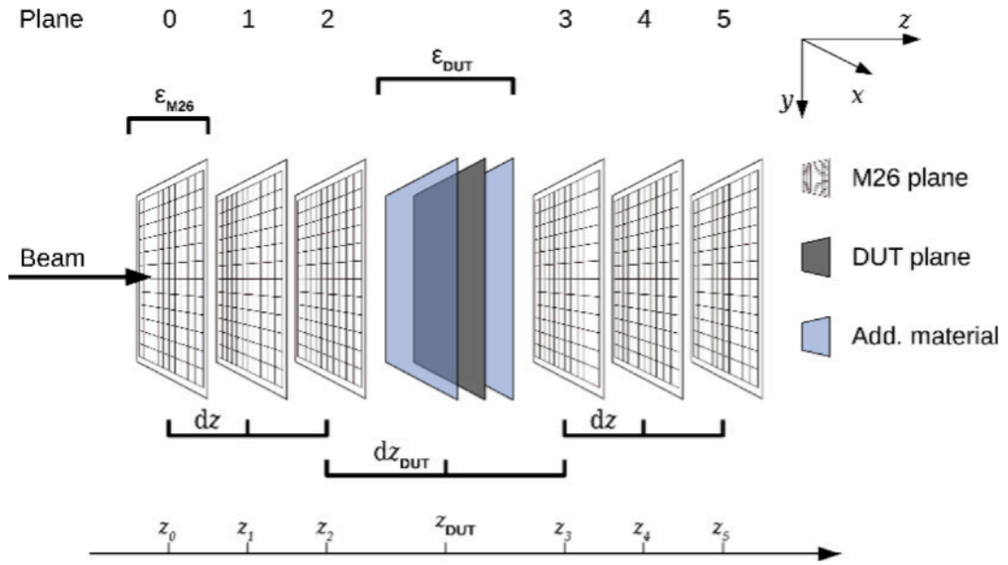
Overview of the test beam setup for ECAL prototypes



- Setup installed at TB line 24 (May 2022):
  - 2 MCP-PMTs: time reference
  - Telescope: tracking
  - 1 pair of organic scintillators: trigger signal
  - Dark box with ECAL prototype, connections, rotating axes to incline the module

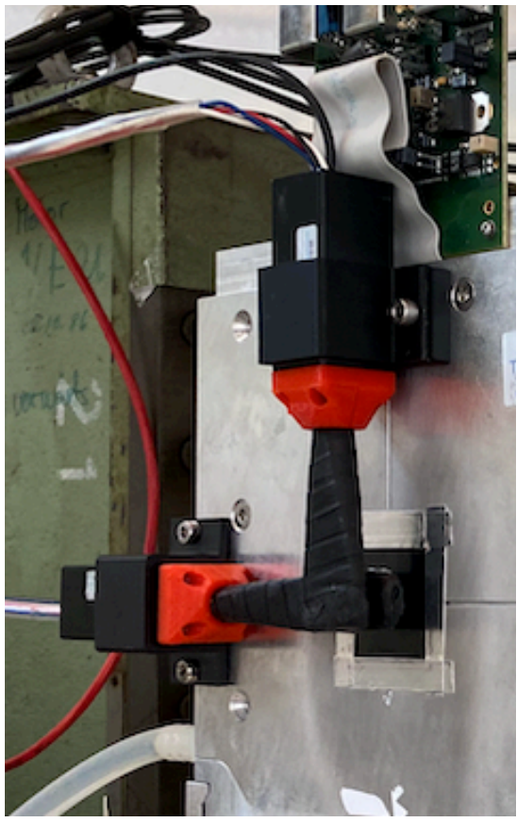
Tracking detector: Mimosa telescope





- 6 planes of Mimosa26 silicon pixel sensors
- Operated by EUDAQ framework and analyzed by Corryvreckan offline reconstruction software
- Spatial resolution on reconstructed tracks ~2μm

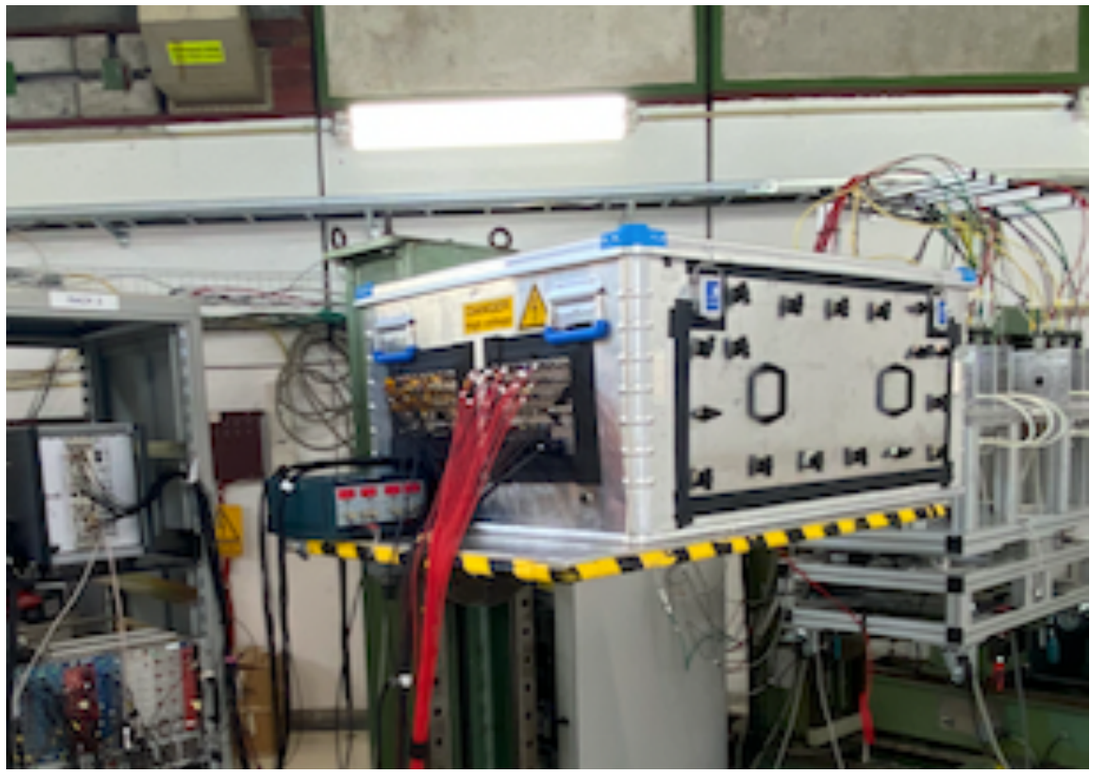
Trigger and time reference



- 1 pair of organic scintillators downstream of the telescope providing a trigger signal in coincidence

- 2 MCP-PMTs providing a reference for time measurements: intrinsic time resolution ~15ps

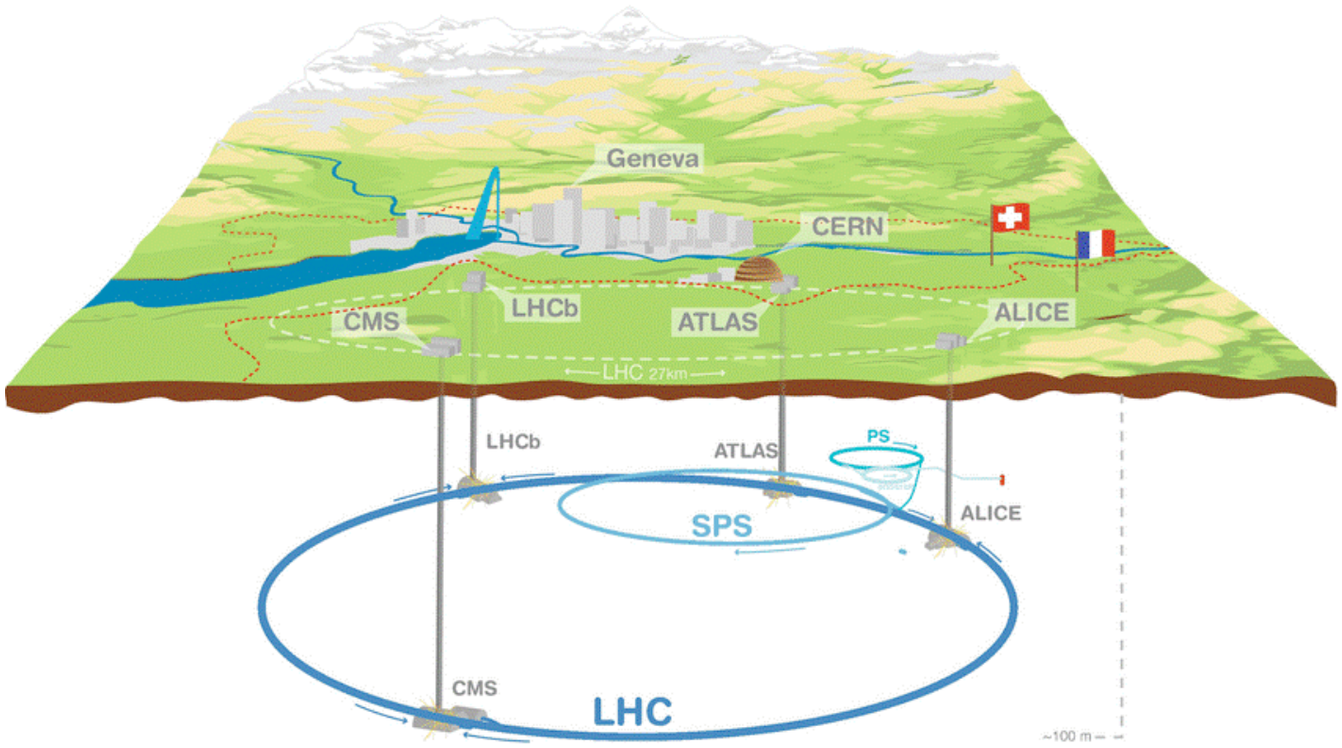
Prototype box on moveable support



- ECAL Prototypes placed in a dark box designed to fix them, set their angular inclination with remotely-controlled rotating axes and manage connections with HV power supply and DAQ system (more details in Matteo's talk)

- Box fixed on a 2-axes moveable support, remotely controlled from the control room (maximum load: 1t, sub-millimeter (x,y) precision)

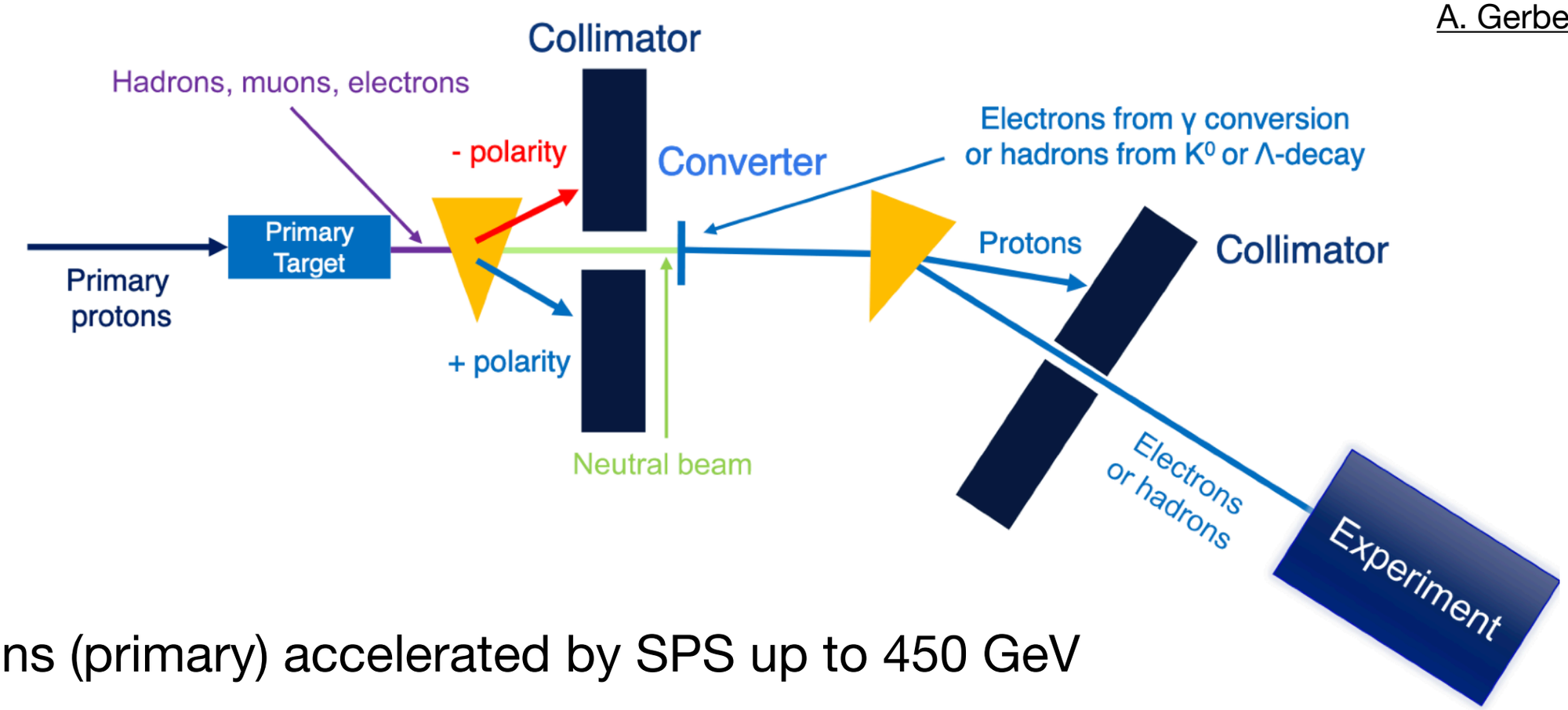
SPS test beam facilities



- Location: CERN (Switzerland)
- Super Proton-Synchrotron
  - Circumference: 7 km
  - Injector for LHC
- Test beam hall (North Area) located in Prévessin (France)
  - 2 test beam campaigns with LHCb ECAL prototypes in 2022 (2 weeks in May + 2 weeks in October)

Beam generation

A. Gerbershagen



- Protons (primary) accelerated by SPS up to 450 GeV
- Interaction with primary target (Be) initiating hadronic cascades followed by electromagnetic cascades (hadrons, muons, electrons produced)
- Neutral beam selected with magnets and collimator and converted into e^+/e^- pairs or hadrons
- Type and momentum of the particles in the experiment area selected using a series of adjustable magnets and collimator

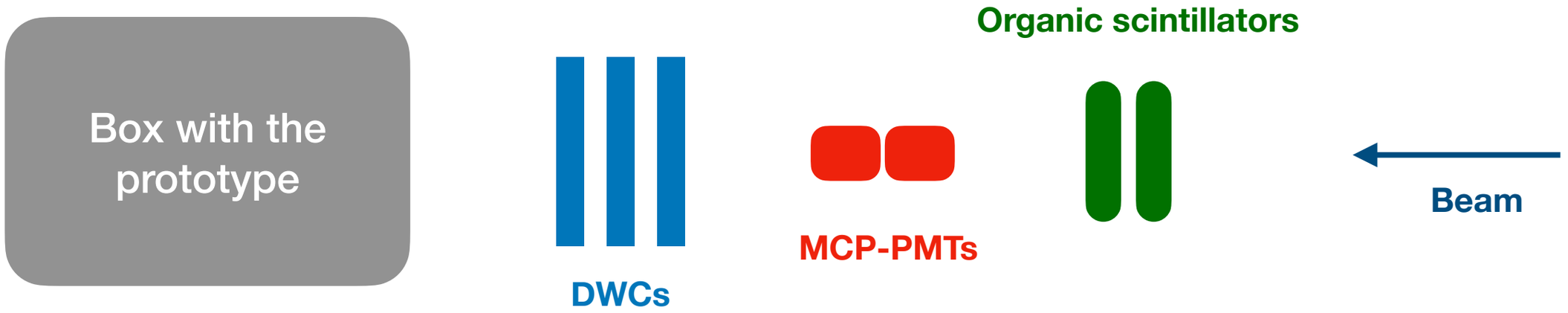
Beam characteristics

A. Gerbershagen

Parameters	T2		T4	
Beam Line	H2	H4	H6	H8
Maximum Momentum [GeV/c]	400 / 360	400 /330	- / 205	400 / 360
Maximum Acceptance [uSr]	1.5	1.5	2	2.5
Maximum Δp/p [%]	± 2.0%	± 1.4 %	±1.5%	±1.5%
Maximum Intensity / spill * (Hadrons / Electrons)	$10^7/10^5$	$10^7/10^6$	$10^{7\,**}/10^5$	$10^{7\,**}/10^5$
Available Particle Types	Primary protons*** OR electrons OR muons OR mixed hadrons (pions, protons, kaons)			

- Available particles: electrons, muons, primary protons, mixed hadrons
- Selectable energy from ~20 and up to ~300 GeV (electrons measured during last test beam campaign in October)
- Momentum spread below ~2%
- Divergence ~ 2 μrad
- Variable availability and stability of the beam (relies on main users activities e.g. LHC)

Overview of the test beam setup for ECAL prototypes

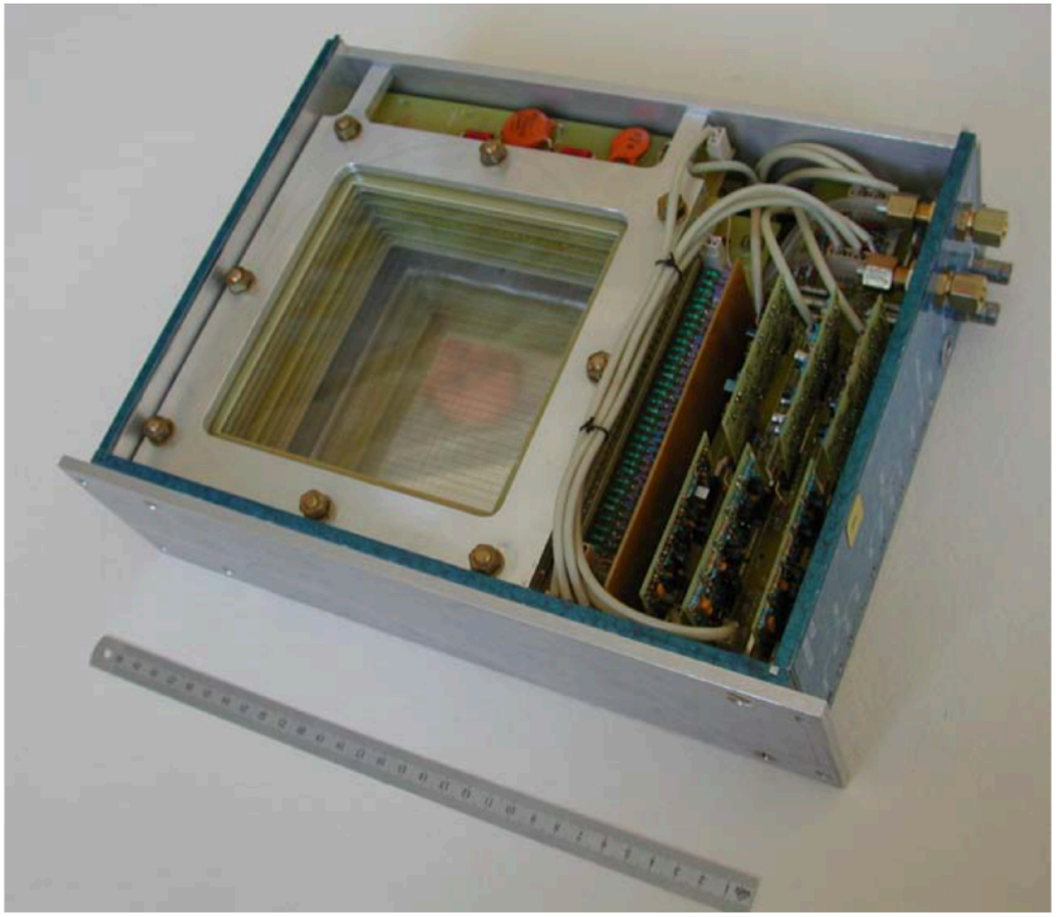


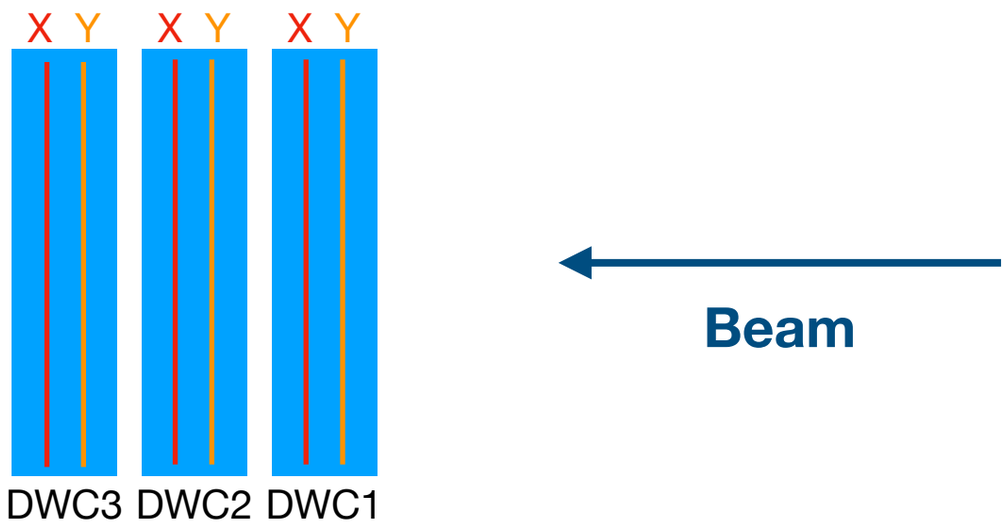
- Setup installed at TB line H2 (October 2022):
  - 2 MCP-PMTs: time reference
  - 1 pair of organic scintillators: trigger signal
  - 3 Delay Wire Chambers: tracking
  - Dark box with ECAL prototype, connections, remotely controlled rotating axes to incline the module (more details in Matteo's talk)

Tracking detector: Delay Wire Chambers

P. Gorbunov

- DWC: X-Y Multi Wire Proportional Chambers with cathode delay line readout
- Working area: 120 x 120 mm^2
- Gas: Ar (80%) and CO_2 (20%)
- HV: 2.25 kV
- Readout: CAEN TDC V1290N
- Resolution (one chamber): ~100 μm





Summary and outlooks

- Beam facilities at DESY II and CERN SPS accelerators allow to perform measurements with ECAL prototypes on a wide range of energy (~ 1-300 GeV)
  - ➡ Important measurements to characterize the prototypes, the PMTs, the cables and for the readout electronics R&D

- 4 test beam campaigns (2 at DESY + 2 at SPS ~ 7 weeks) already achieved in 2022 in addition to 2020 and 2021 campaigns (many results presented yesterday) → more to come next year
  - ➡ Beam time requests at DESY and SPS already discussed

- Follow Matteo's talk for more details about the inside of the prototype box and on the DAQ operations!

Thank you!