
CERN

# Test Beams at CERN

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http://test-beam-facilities.web.cern.ch/publicDB.php
https://ps-sps-coordination.web.cern.ch/ps-sps-coordination/

# Why do we do test beams?

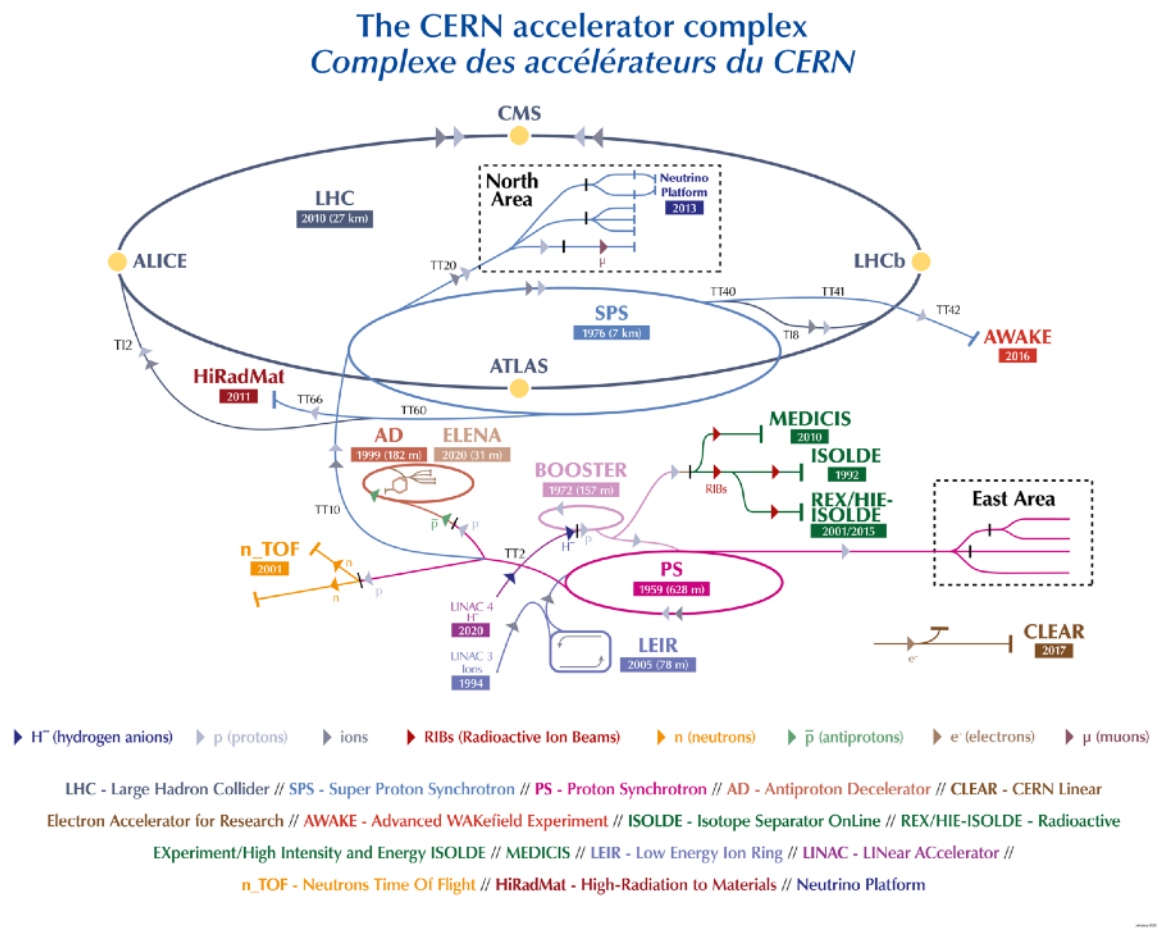
- For R&D: qualifying new devices and technologies.
- For detector construction or upgrades: Validating designs prior to production. Initial calibrations. DAQ integrations, full slice tests,…
- During operations: Verifying calibrations and performances on the prototype detector. Investigate features in the data…

Side benefits: Building collaborations, defining milestones and deadlines in the project, publications, acquiring hands on experience….

- Outreach: f.i. Beamline for schools (CERN & Desy), FNAL summer students.

Please, do your DAQ developments commissioning in the Lab, prior to the test beam. The operation of the beam lines is expensive, even if provided for free to the user, make the best out of the delivered particles.

# The CERN Accelerator Complex




Two testbeam facilities:

East Area:

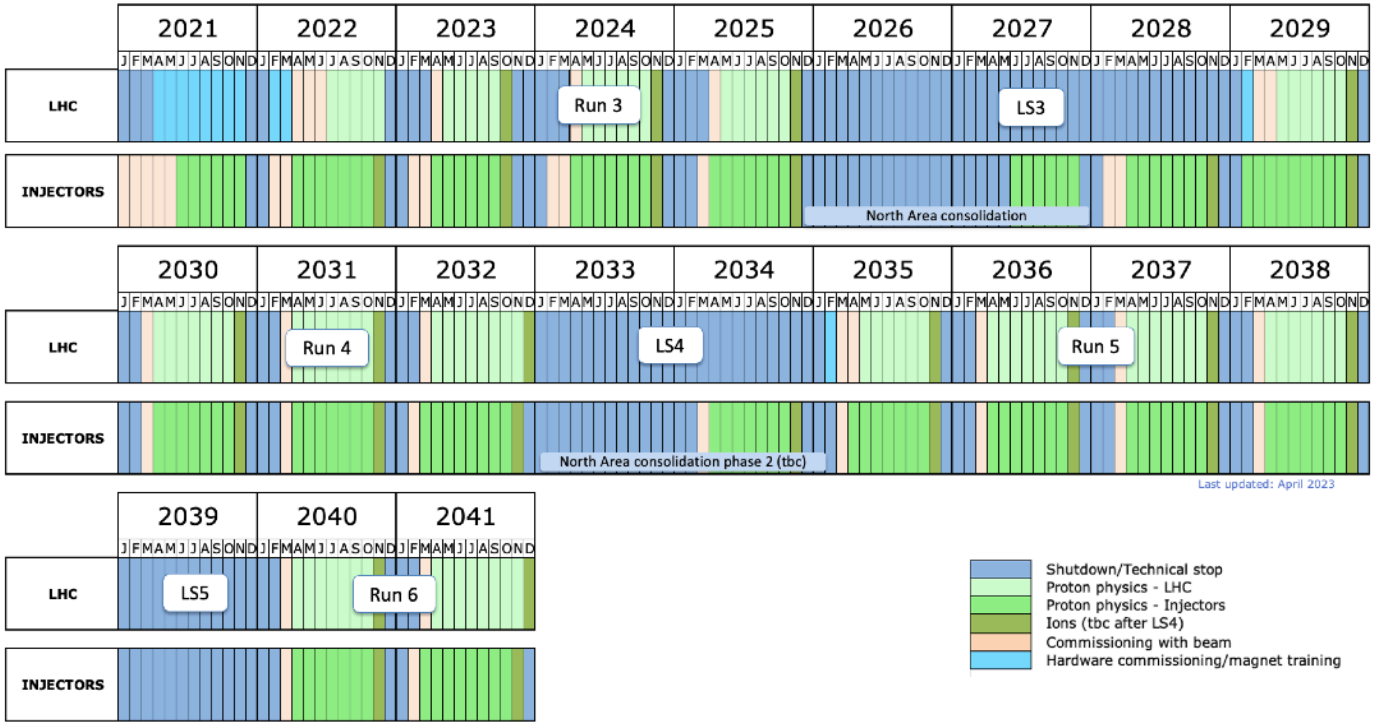
≤16 GeV/c secondary beams.

North Area:

≤ 400 GeV/(Zc) primary beams

≤ 360 GeV(Zc) secondary beam

# Long term injector schedule




- No beams to PS East Area in 2026 and 2033
- No beams to SPS North Area in 2026-mid 2028 and 2033-2034

# PS East Area Renovation

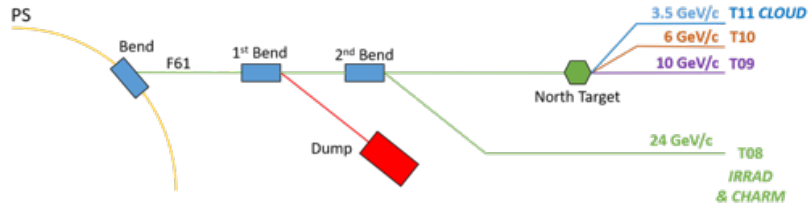
EAST AREA RENOVATION

Renovation project 2016-2021 (27MCHF)

- Scope: civil engineering (facades and roof), magnets, power converters, cooling and ventilation, new beam lines and experimental area layout, beam instrumentation, user zones, gas distribution, safety, …
- Energy saving: pulsed magnets (11GWh -> 0.6GWh), building isolation (energy saving subsidies for local&federal authorities)

| beam line | Max mometum old facility | Max momentum now |
|---|---|---|
| T9 | 10 GeV/c | 15 GeV/c |
| T10 | 6 GeV/c | 12 GeV/c |

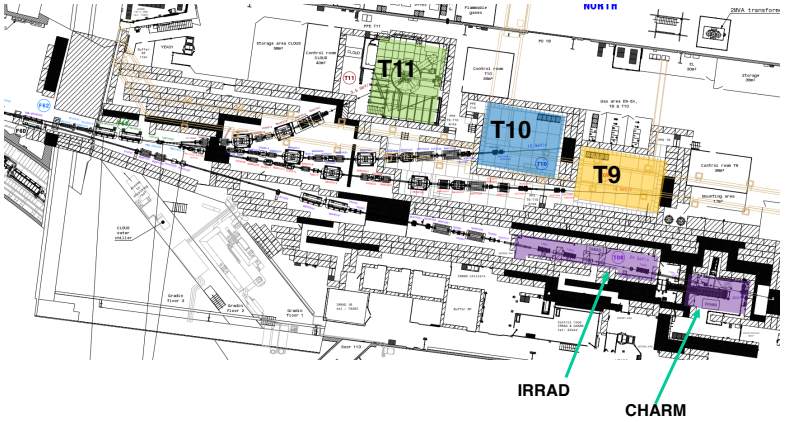
2014-2018:




The East Area is ready for the next 50 years!

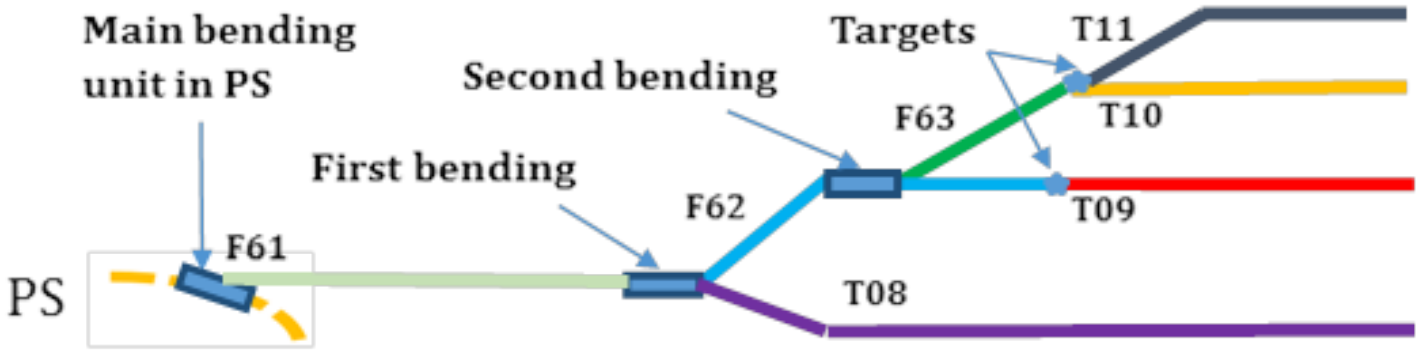
East Hall under construction - 1962

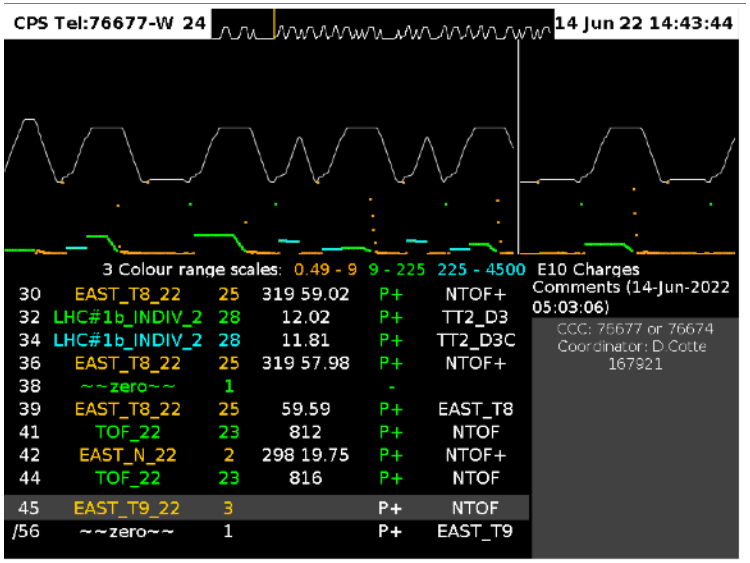

East Hall now




2 years in 2 mn time lapse video

# East Area Secondary Beamlines




- Spill duration: 0.4 second flat top
- Usually : 1-2 cycles per minute per East Destination
- Max 6 East cycles / 40 seconds due to RP Limit
- Super-cycle structure dependent on all users (SPS, nTOF …)

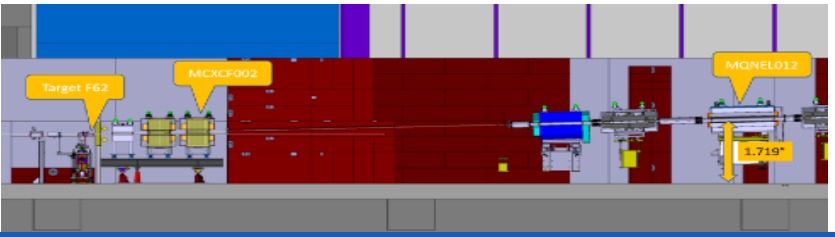
# Characteristics of the Secondary Beams

| Parameter | T09 Target | T10/T11 Target | |
|---|---|---|---|
| Beam Line | T09 | T10 | T11 |
| Secondary beam Max Momentum (GeV/c) | 16 | 12 | 3.5 |
| Δp/p (%) | 0.7 to 15.0 | 0.7 to15.0 | 0.7 to15.0 |
| Maximum intensity/spill (hadrons/ electrons) | $10^6$ | $10^6$ | $10^6$ |
| Available particle types | Pure electrons (T09) or mixed/pure hadrons or pure muons | | |

T11 is the Area for the CLOUD experiment.

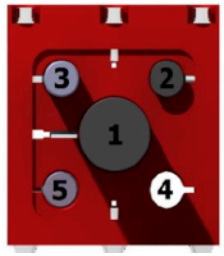
T09 is used, in 2024, for about 13 weeks for the Water Cherenkov Test Experiment.

**30-35 mrad vertical production angle**




**Multi-target configuration**

| Head | Material | Length (mm) | Diameter (mm) | Comments |
|---|---|---|---|---|
| 1 | Be | 200 | 10 + Al case | Electron enriched |
| | W | 3 | | |
| 2 | Al | 100 | 10 | Electron enriched |
| | W | 3 | | |
| 3 | Al | 200 | 10 | Hadron |
| 4 | Air | - | - | Empty |
| 5 | Al | 20 | 10 | Hadron |



# SPS North Area Consolidation

2 phase project (2019-2026, 2027-2030)

Phase1 “Urgent Items”:

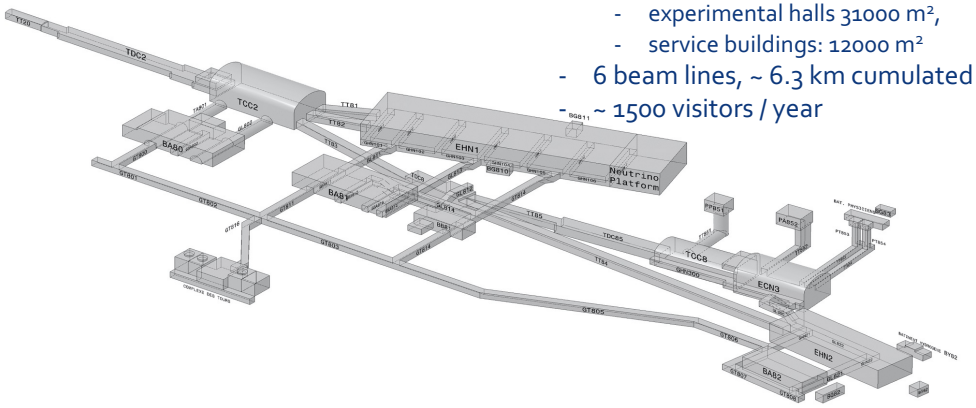
- power converters of NA61 and Morpurgo magnets,
- 50% of the upstream area power converters, magnets
- civil engineering of upstream area
- 60% of beam instrumentation,
- technical services,
- safety infrastructure.

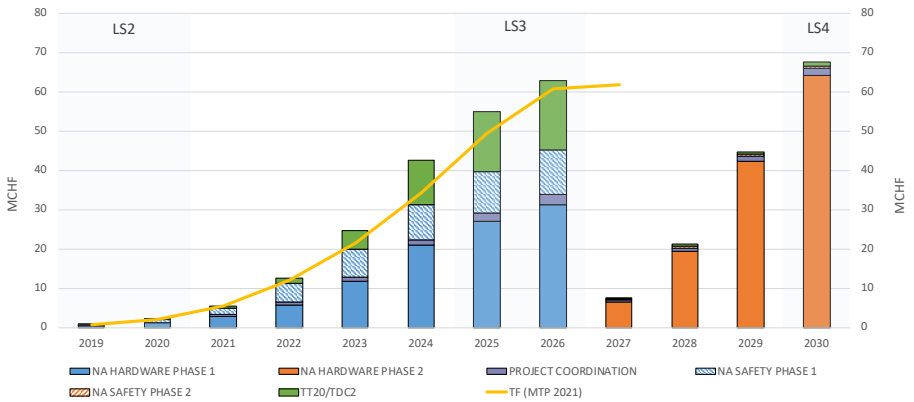
Phase2 “Performance Increase” linked to **Physics Beyond Colliders:**

- 50% of power converters serving experimental halls,
- upgrades for higher intensity,
- civil engineering experimental halls and service buildings.
- remaining safety items.

**A few numbers:**

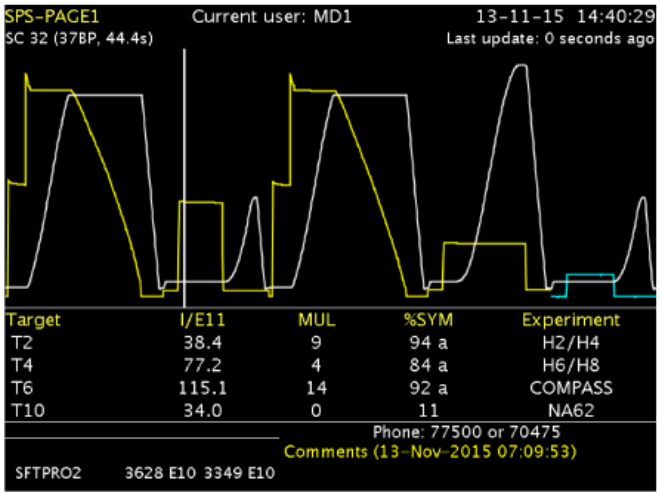
- Overall surface **60000 m²**:
  - underground 16600m²,
  - experimental halls 31000 m²,
  - service buildings: 12000 m²
- 6 beam lines, ~ 6.3 km cumulated
- ~ 1500 visitors / year

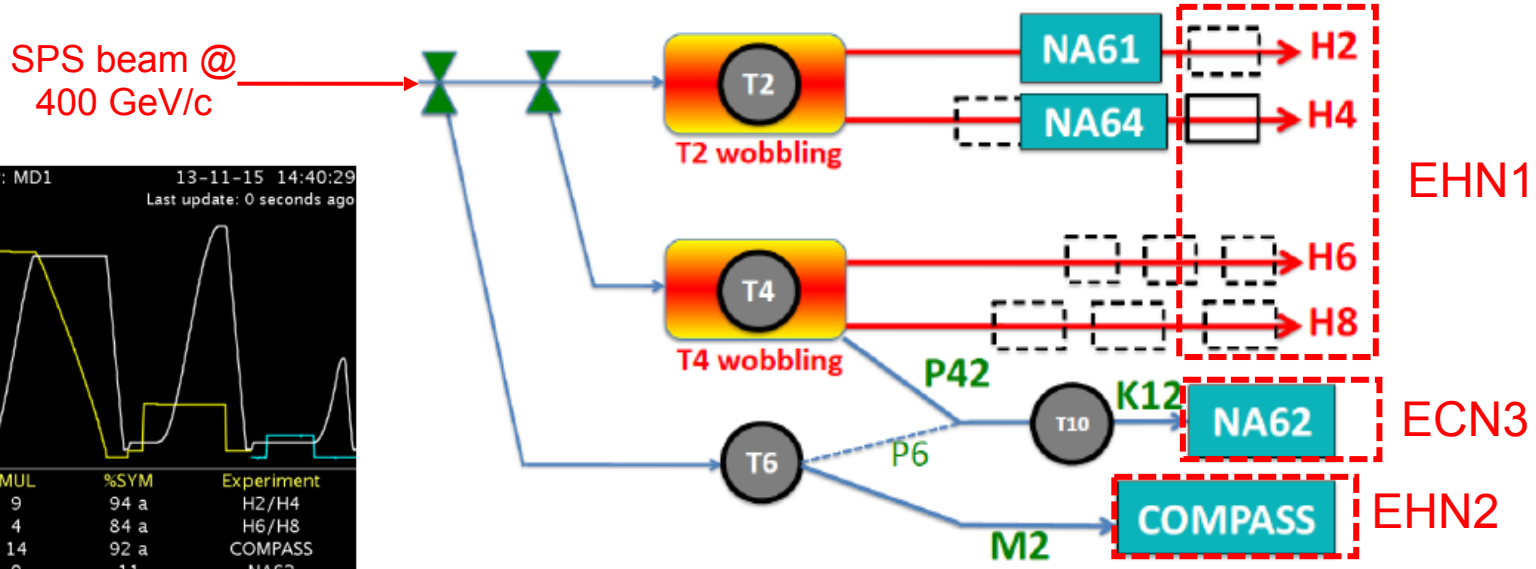



Phase-I budget recently updated to 87MCHF

# North Area Secondary Beamlines




The 400GeV/c primary beam is slow-extracted to 3 primary targets: T2, T4 and T6.

Typically: 2 cylces (4.8s flat top) per SPS supercycle (rule of thumb ~3000 spills/day)

The supercylce composition depends on the needs of the physics program, along the day and the other SPS users (LHC, AWAKE, HiRadMat, and Machine development program)

# The EHN1(887) testbeam hall

# Characteristics of the Beams

| Parameter | T2 Target | | T4 Target | |
|---|---|---|---|---|
| Beam Line | H2 | H4 | H6 | H8 |
| Attenuated primary proton / Secondary beam | 400/360 | 400/360 | -/205 | 400/360 |
| Maximum Δp/p (%) | 2.0 | 1.4 | 1.5 | 1.5 |
| Maximum intensity/spill (hadrons/electrons) | $10^7/10^6$ | $10^7/10^7$ | $10^7/10^5$ | $10^7/10^5$ |
| Available particle types | Primary protons (not in H6) or pure electrons or pure/mixed hadrons or pure muons | | | |
| Ion Beam Availability | Yes | Yes | No | Yes |

Beam energies in H2 and H4 are coupled, as are the energies in H6 and H8.

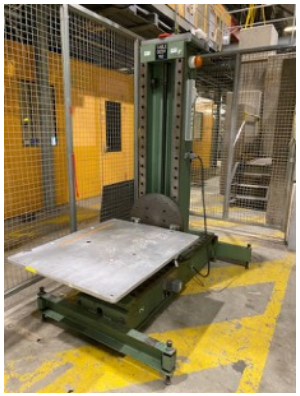
Electrons from γ conversions in H2 and H4 (highest purity)

γ can be made available as tertiary beam (needs ad-hoc installation)

Beam lines are instrumented with profile monitors, intensity counters, Cherenkov detectors (XCET, and CEDAR) and Secondary Emission Monitors at the target.

Multiple Experimental Areas per beam line.

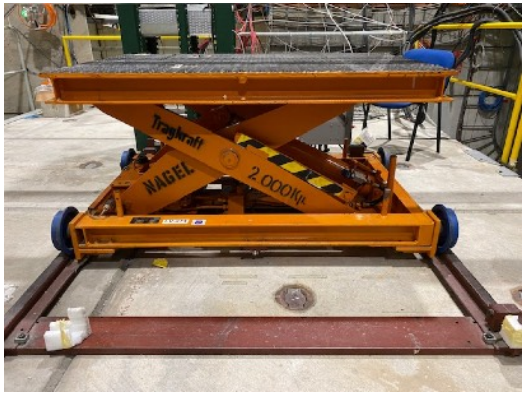
# XY positioning tables



Desy 1.0T, 6 tables

LAPP ?T

Goliath 5T H4




Trackgraft 2T H8

Nikhef 10T H2

Saphir 15T H8

https://asm.cern.ch/experimental-area/tables-description

There are more tables but owned by collaboration (ATLAS, CMS)

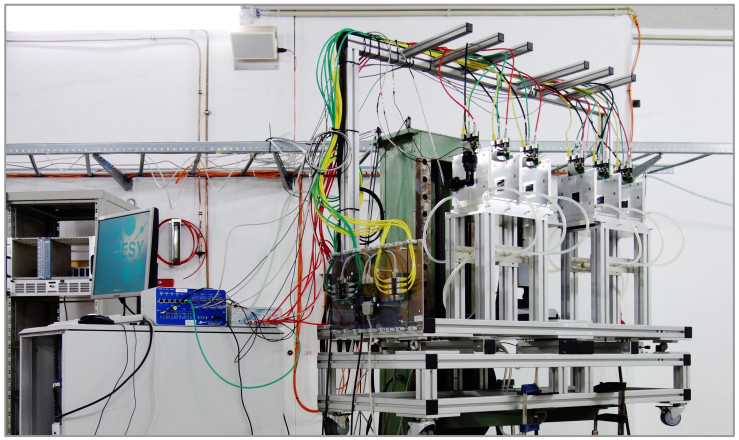
# Final remarks and conclusions

- CERN is committed for the long term availability of the test beam facilities (EA-cons, NA-cons)
- In the immediate future, availability of the CERN testbeams will be reduced due to LS3 and NA-cons.
- Subscribe to ps-sps-users e-group to stay informed on the CERN testbeds (call for beam time requests etc).
- Scheduling: 2 weeks in East Area, 1 week at North Area by SPS coordinator, longer requests require approval by CERN scientific committee. Can DRDC help here?

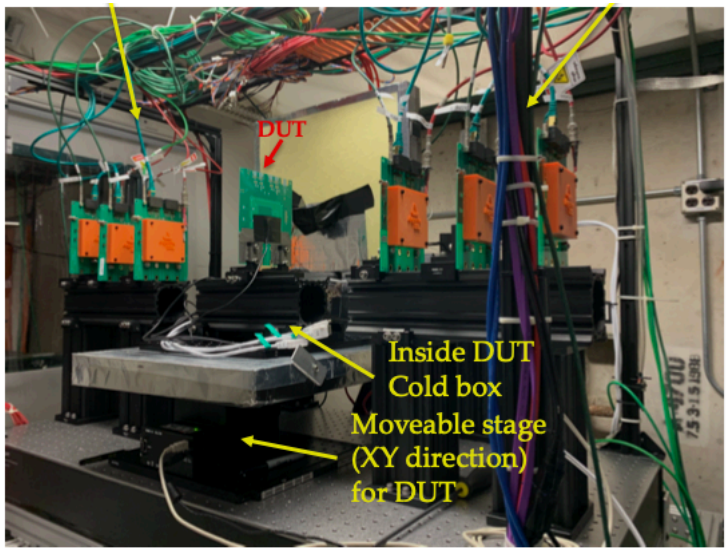
# Additional information

# Beam telescopes

- Most beam lines provide instrumentation, for the beam line physicist, but also for the users: Trigger counters, profile monitors, TOF, Cerenkovs,…
- The Si sensors need high resolution tracking for the validation of the devices under test.
- Users+Facilities developed a number of telescopes, some are made available to other users.
- There is an effort towards the development of common tools (AIDA-TLU, Caribou DAQ, EUDAQ2, Coryvreckan & EUTelescope) in parts through EU FP (EUDET, AIDA, AIDA2020, AIDAInnova) and a big push from our DESY colleagues.



Telescope of the EUDET family (Mimosa 26) at DESY




Argonne Apollo FEI4 based telescope, at FNAL TB-6.2

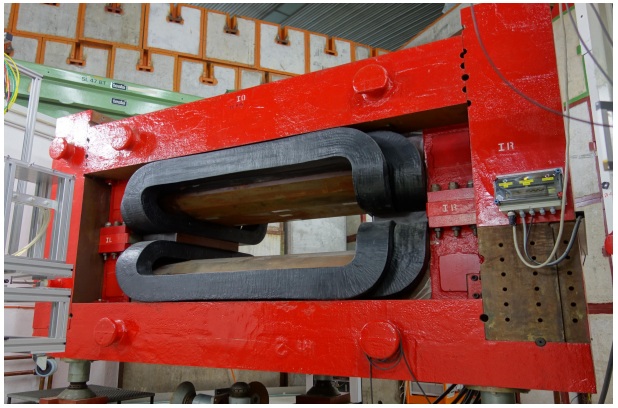
# Experimental spectrometer magnets at Test Beams:

In some applications large experimental magnets are a must.

CERN, DESY, RCNP and Spring-8 facilities provide access to experimental magnets.

Some become facilites on their own, c.f MADMAX experiment prototype test in the Morpurgo magnet during SPS shutdowns, test of CMS equipment in M1 prior to installation in the experimental cavern.

A new 4T magnet is being prepared in the FCC context, possibly available to other user teams (contact B. Cure, CERN for inputs to the user specification) [Slides]



Big Red Magnet at DESY TB21

DESY: superconducting Solenoid (1T)

Morpurgo SC dipole at CERN H8 (1.5T)

M1 SC Helmhotz coils at CERN H2 (3T)

# Beam Telescopes and Test Beams

The Beam Telescopes and Test Beams workshop series started at DESY around the EUDET telescopes in 2013.


It is now a fully mature work-shop, with still a very young mind, covering TB related topics: Facilities, DAQ, Beam instrumentation, Results. Hands on sessions & Tutorials

link to 10th BTTB indico

## Test beams* in the world, status November 2021

| Laboratory | Number of beam lines | Particles | Energy range | Diagnostics etc. | Availability | Information, Contacts & comments |
|---|---|---|---|---|---|---|
| **CERN / PS (CH)** | 2 | e, h, μ (sec.) | 0.5 - 10 GeV/c | Threshold Cherencov, scintillators, MWPCs, delay wire chambers, scintillators, magnet, movable platform | 9 months per year, continous except winter shutdown<br>Duty cycle depends on PS / SPS / LHC operation mode and is typical<br>* PS ~1-3%<br>* SPS: 20-40% | Contact beam time request and scheduling:<br>Barbara Holzer<sps.coordinator@cern.ch><br>https://cern.ch/ps-sps-coordination<br><br>Contact beam lines:<br>J. Bernhard et. al. <sba-physicists@cern.ch><br>http://sba.web.cern.ch/sba/ |
| **CERN / SPS (CH)** | 4 | p (prim.)<br>e, h, μ (sec.)<br>e, h (tert.)<br>Pb ions (prim)<br>other ion species (out of fragmented primary Pb ions) | 400 GeV/c<br>10 - <400 GeV/c<br>10 - 200 GeV/c<br>20 - 400 GeV/c<br>proton equivalent (z=1) | Delay wire chambers, filament scanners, XEMC calorimeters, Threshold & CEDAR, hodoscopes, magnet, movable platform | | |
| **CERN / CLEAR (CH)** | 1 | e- | 50-250 MeV/c<br>25-750 MeV/c | plasma lens sttand,<br>12GHz RF stand,<br>THz RF stand | 8-9 months per year | Contact: <CLEAR-Info@cern.ch><br>https://clear.web.cern.ch |
| **DAFNE BTF Frascati, (IT)** | 2 | e+/e- both primaries and secondaries | Rep Rate 1-50Hz,<br>1-300 ns<br>1 to $10^{10}$p/pulse<br>parameters depending on DAFNE inj | Calorimeter, silicon pixel, movable platform, gas system,<br>HV, trigger, networking, live data | depending on DAFNE schedule,<br>from 25 to 35 weeks/year<br>Hall2 under final commissioning | Contact: <btf@lists.lnf.infn.it><br>Luca Foggetta <luca.foggetta@lnf.infn.it><br>http://www.lnf.infn.it/acceleratori/btf |
| **DESY (D)** | 3 | e+, e- (sec.)<br>e- (prim.)<br>photons (tagged) | 1 - 6 GeV/c<br>6.3 GeV/c<br>0.7-1.2 GeV/c | Trigger systems and beam telescopes, magnet (~1T) | 11 months per year,<br>Duty cycle ~ 80% | Contact: <Testbeam-Coor@desy.de><br>http://testbeam.desy.de |
| **ELPH (Sendai) (JP)** | 2 | e+, e- (conv.) | 0.1-1.0 GeV/c<br>beam rate < 500kHz<br>(typical rate: 2kHz) | | 2 months/year | Contact:<br>Toshimi Suda <suda@lns.tohoku.ac.jp><br>https://www.lns.tohoku.ac.jp/en/users/ |
| **FERMILAB/ FTBF (US)** | 2 | p (prim.)<br>e, h, μ (sec.)<br>h (tert.) | 120 GeV/c<br>1-66 GeV/c<br>200-500 MeV/c | Cherencov, TOF, pb-glass calorimeters, MWPC, Si Tracker, see website for more | 24 hrs/day<br>6% duty cycle | Contact: <FTBF_Co@fnal.gov><br>http://ftbf.fnal.gov<br>more contacts:<br>Mandy Kiburg <rominsky@fnal.gov><br>Evan D. Niner <edniner@fnal.gov> |

*Beam lines with beams of energies higher than 100 MeV/c

## Test beams* in the world, status November 2021

| Laboratory | Number of beam lines | Particles | Energy range | Diagnostics etc. | Availability | Information, Contacts & comments |
|---|---|---|---|---|---|---|
| **IHEP Bejing (CN)** | 2 | e (prim.)<br>e (sec.)<br>p, π (sec.) | 1.1 - 2.5 GeV/c<br>100 - 300 MeV/c<br>0.4 - 1.2 GeV/c | MWPC, TOF<br>Cherencov,<br>CAMAC system, platform | Availability: 3 mouths per year,<br>duty cycle depends on BEPCII<br>operation mode | Contact: Xiaoyu Yang <yangxy@ihep.ac.cn> |
| **IHEP Protvino (RU)** | 5 | p (prim),<br>p, K, π, μ, e (sec.)<br>C-12 (prim) | 70 GeV/c<br>1-45 GeV/c<br>6-300 GeV/c | Cherenkov,<br>TOF, MWPC | two months per year<br>duty cycle (U-70 machine): 15-30% | Contact: Alexandre Zaitsev <alexandre.zaitsev@cern.ch> |
| **PSI / piE1, piM1, etc. (CH)** | 2-4 | π+-, μ+-, e+-, p | 50-450 MeV/c, rate <$10^9$ $sec^{-1}$<br>20nsec structure<br>continuous beam<br>at very high rate | | 6-8 months per year | Beam time allocated by programme committee (twice per year)<br>Contact: Davide Reggiani <davide.reggiani@psi.ch> |
| **PSI / PIF (CH)** | 1 | p | 5 - 230 MeV/c<br>max. current 2 - 5 nA, rate <$10^9$ $sec^{-1}$,<br>typ. flux $10^8$ $cm^{-2}$ $sec^{-1}$for wide beam,<br>energy, beam spot<br>and flux selectable by user | | 11 months per year,<br>mostly during weekends | Contact: Wojtek Hajdas <wojtek.hajdas@psi.ch> |
| **SLAC End Station A (US)** | 0 | e (prim.)<br>e (sec.) | 2.5 - 15 GeV/c<br>1 - 14 GeV/c | | Currently no beam,<br>9 months per year,<br>50% duty cycle | No beam for the coming years<br>Contact: Carsten Hast <hast@slac.stanford.edu><br>https://slacportal.slac.stanford.edu/sites/ard_public/tfd |
| **RCNP Osaka Univ. (JP)** | 7 | p<br>Heavy ions<br>n<br>μ+ | ~400MeV<br>~100AMeV<br>White n, max 400MeV<br>quasi mono-energetic: ~400MeV<br>24-110MeV/c | Magnet<br>Si / PPAC / TOF<br>TOF<br>profile monitor / TOF / μSR | 7-8 month per year<br>No beam in 2019-2020 | Contact: director@rcnp.osaka-u.ac.jp<br>http://www.rcnp.osaka-u.ac.jp/index_en.html |
| **SPRING-8, Compton Facility (JP)** | 2 | photons (tagged)<br>e+, e- (conv.) | 1.3 - 2.9 GeV/c<br>0.4 - 2.9 GeV/c | Magnet, MWDC, TOF,<br>Calorimeter | >60 days per year | Contact: Masaru Yosoi <yosoi@rcnp.osaka-u.ac.jp><br>http://www.spring8.or.jp/en/<br>http://www.rcnp.osaka-u.ac.jp/Divisions/np1-b/ |
| **University of Bonn ELSA (D)** | 1 | e- | Energy range: 1.2 - 3.2 GeV/c<br>rate: ~500Hz - 625 MHz | Trigger, beam telescope | upon request, ~30 days/ year | Contact: Daniel Elsner <elsner@physik.uni-bonn.de><br>http://www-elsa.physik.uni-bonn.de/elsa-facility_en.html |
| **University of Mainz MAMI (D)** | 3 | e-<br>gamma | Energy range for e- and gamma beam:<br>< 1.6 GeV/c<br>e- intensity < 100μA | Energy tagged photon beam | upon request, ~30 days/ year | Contact: Susanne Fischer <fischer@kph.uni-mainz.de><br>http://www.kph.uni-mainz.de/eng/index.php |