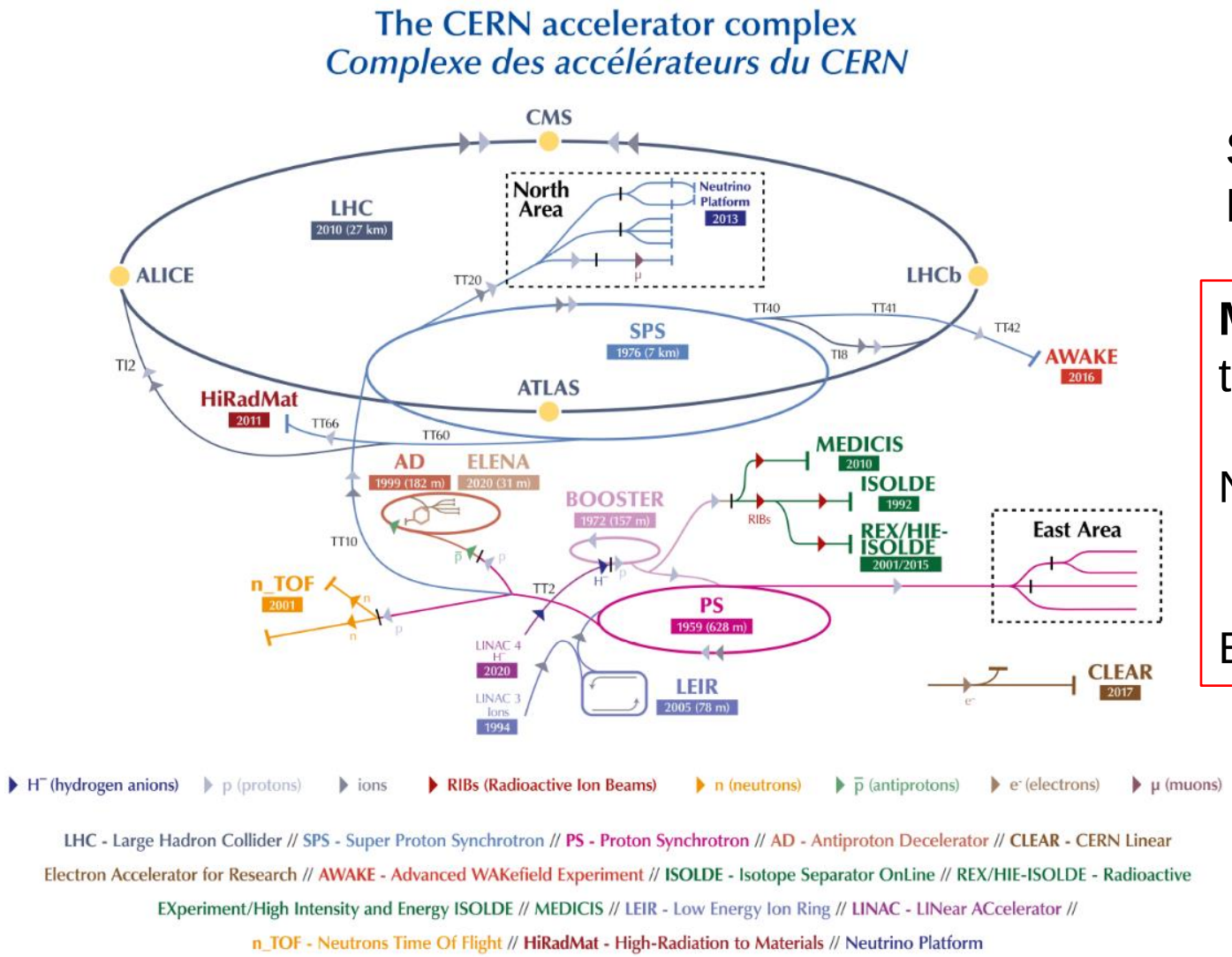
CERN Beamlines and facilities

P. Alexaki, D. Banerjee, E. Barber, J. Bernhard, M. Brugger, N. Charitonidis, G. Dal Maso, M. van Dijk, S. Fiore, A. Goillot, M. Jaekel, P. Martinengo, F. Metzger, L. Nevay, G. Pezzullo, B. Rae, F. Ravotti, S. Schuh, F. Stummer

19.05.2025

CERN Accelerator Complex



SPS: protons @ $400\mathrm{GeV}/c$ ions @ $380\mathrm{GeV}/Z$
PS: protons / ions @ $24\mathrm{GeV}/Z$

Maximum momenta available to the users in the PS/SPS Test Beam Facilities:

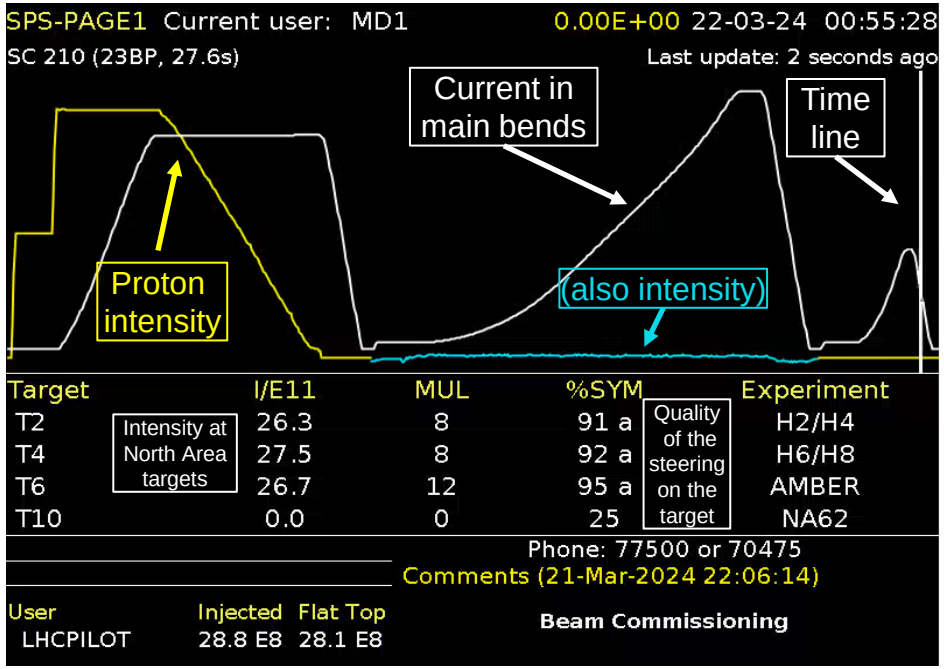
North Area → $\leq 360\mathrm{GeV}/c$ (secondary beam) or primary beams

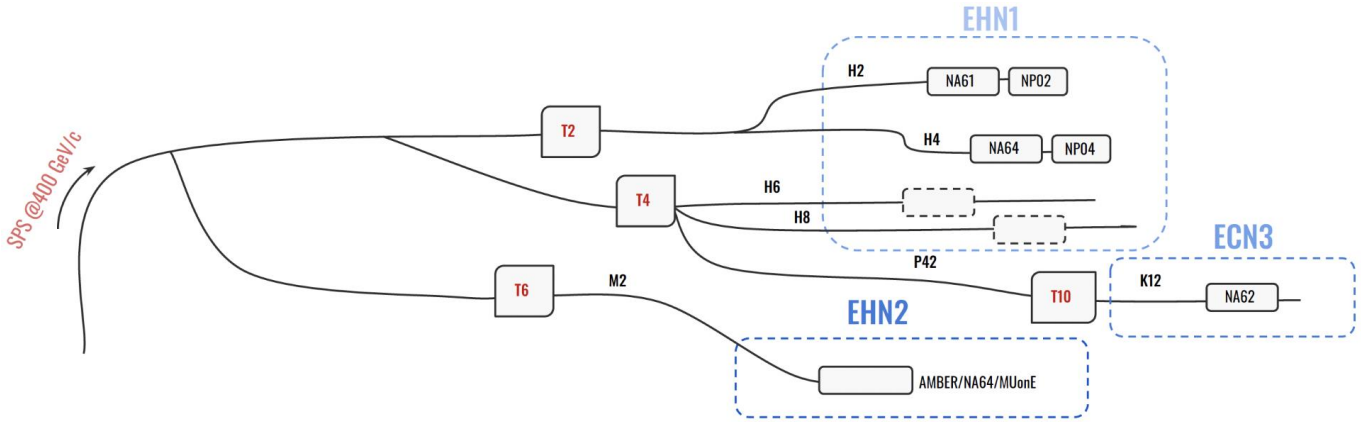
East Area → $\leq 16\mathrm{GeV}/c$ (secondary beam only)

North Area Secondary Beamlines

North Area Secondary Beamlines

- **Spill of 4.8s flat top (14.4s for full North cycle)**
  - The 400 GeV/c primary beam is slowly extracted to three primary targets → T2, T4, T6
  - Typically 3 cycles / SPS supercycle for North Area for a total of ~3000 spills / day
  - Supercycle structure depends on SPS physics program (LHC, AWAKE, HiRadMat, Machine Development)
- **North Area will be renovated in upcoming long shutdowns**
  - Dedicated talk by L. Nevay next!

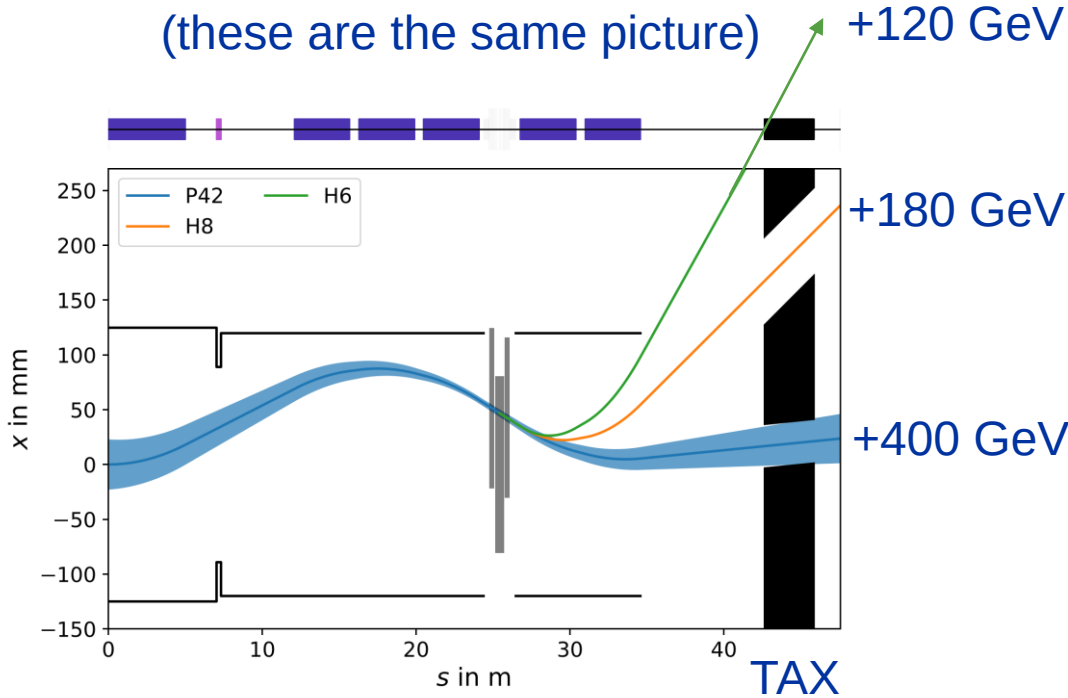




North Area target wobbling

- **Beam on target produces all momenta below primary momentum (400 GeV/c)**
  - Magnet behind target bends secondaries to angle depending on momentum
  - Three beamlines can be served simultaneously
  - Changing position and angle target (B1+B2) and final magnet (B3) allows to send a variety of beams
  - Momenta sent to three beamlines (H6/H8/P42) selected simultaneously (and with limited choices)
- **Wobbling of the T4 target shown**
  - T2 wobbling similar (goes to H2/H4)
  - T6 has no wobbling (only for muon/hadron beamline M2)

(these are the same picture)



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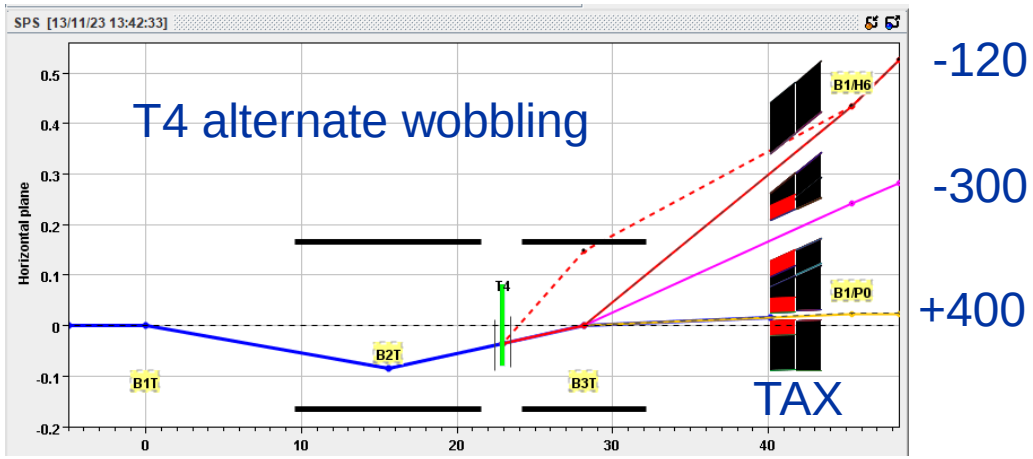

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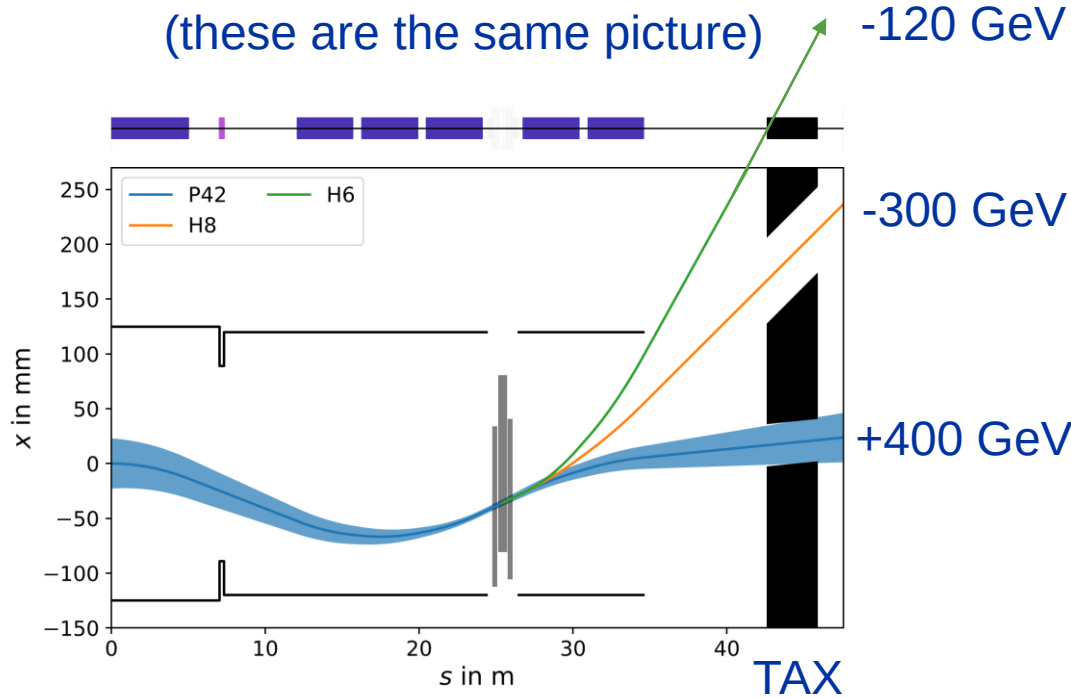


Characteristics of the beams

Parameter	T2 Target		T4 Target	
Beamline	H2	H4	H6	H8
p attenuated primary / secondary beam in GeV/c	$400/360$	$400/360$	$-/205$	$400/360$
Maximum $\Delta p/p$ in %	± 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 or pure electrons or pure/mixed hadrons or pure muons			
Ion beam availability	Yes	Yes	No	Yes

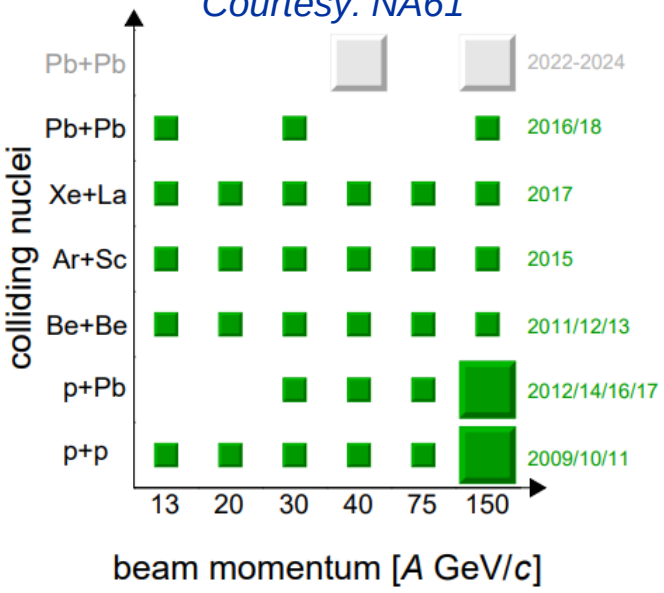
- **T6 target** → Serves the **M2** beam that is mostly used for the AMBER experiment
  - $< 4.8 \times 10^8$ hadrons/spill with < 280 GeV/c (requires additional shielding around target); increase to 10^9 with improved shielding in future
  - $< 2 \times 10^8$ muons/spill with < 280 GeV/c
  - NA64μ and MUonE also performing physics and test runs

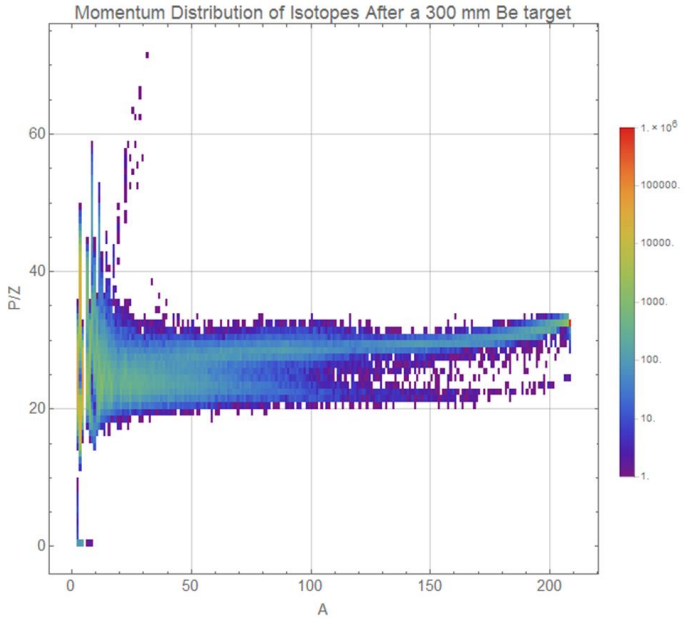
- **P42** beam also originates from the T4 target and transports the proton beam that has not interacted onto the T10 target to produce typically 75 GeV/c kaon beams guided via **K12** to NA62

Ion beams

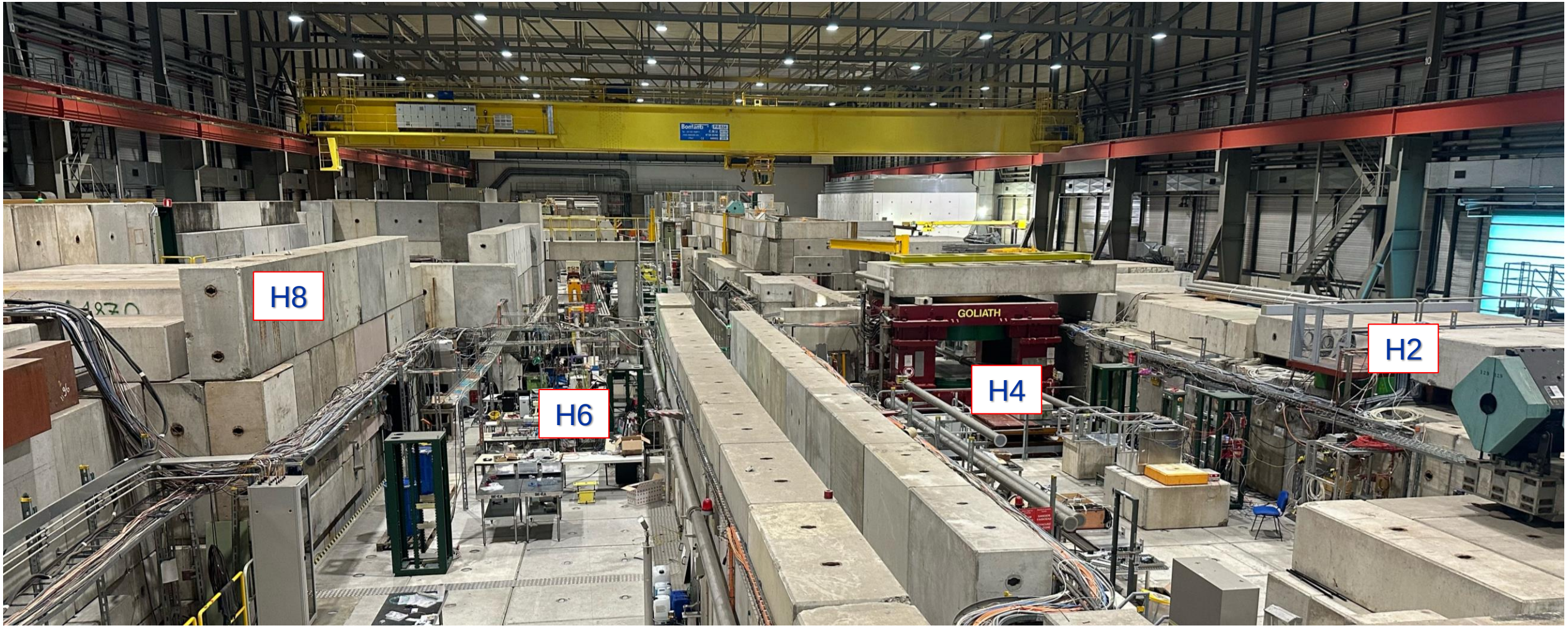
- **Ion beams are available in the North Area**
  - Typically 2-4 weeks at the end of the year (typically with lead ions)
  - Argon and xenon beams have also been used in the last decade
  - 2025 also has an oxygen run in July (1 week)
- **Primary and fragmented ion beams are available**
  - Primary beam set by general program, usually driven by NA61 in H2
  - 2024: 3 weeks @ 150 AGeV/c Pb ions and 1 week @ 13.5 AGeV/c
  - Fluence highly adjustable, between 10^3 – 10^5 primary or fragments / spill
  - Fluence is limited by RP considerations, with special measures 10^7 primary
- Test beam users like **Medipix, Nucleon**, **HERD, PAN** request ions
- **HEARTS/CHIMERA** requested low energy ions in T08

Courtesy: NA61

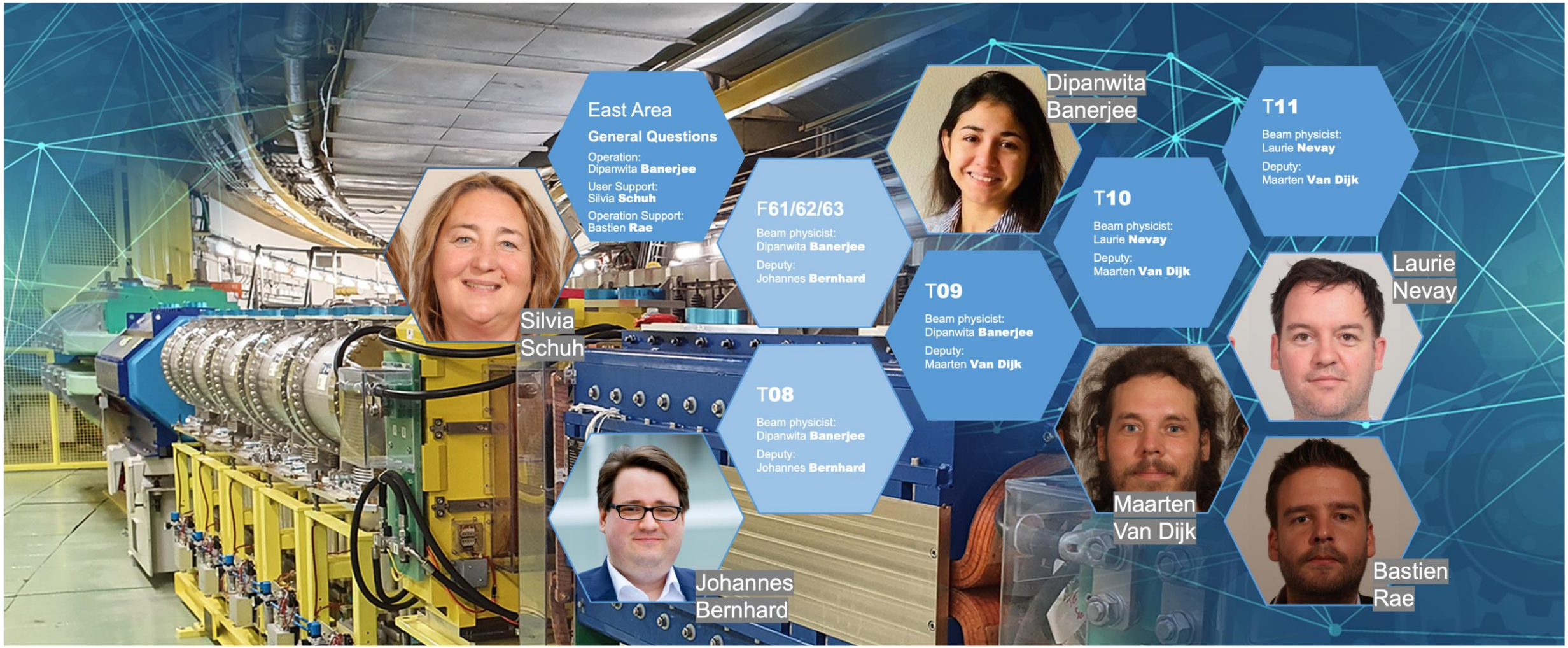




EHN1 (B-887, Prevessin Site)



East Area – Secondary Beamlines



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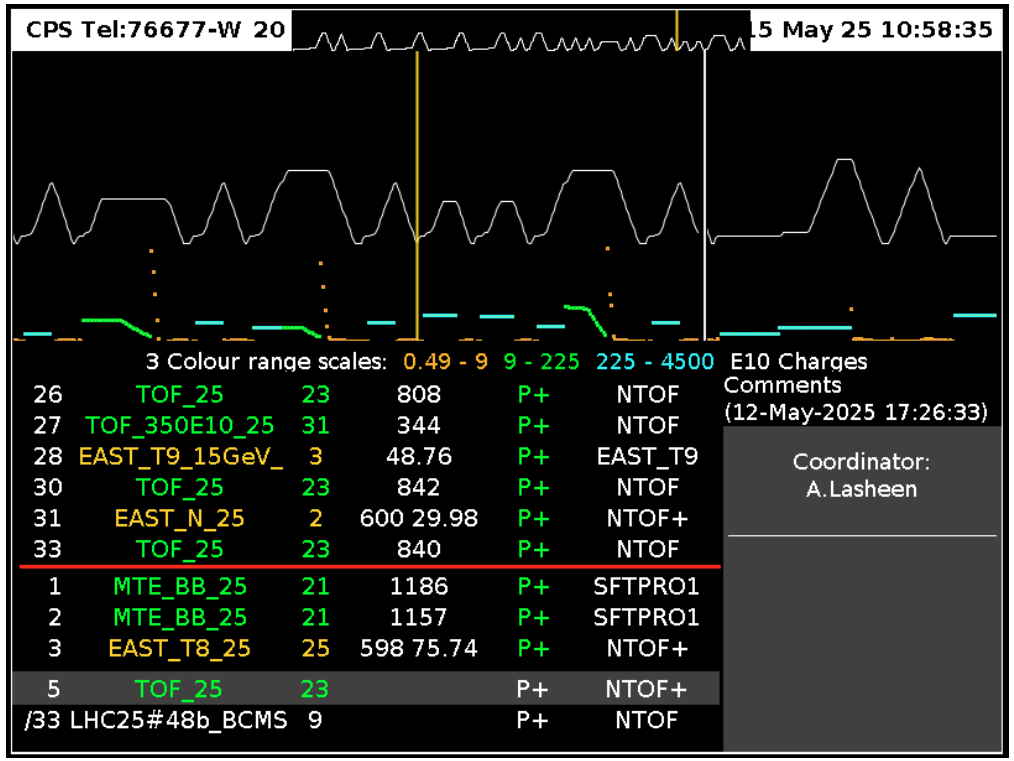
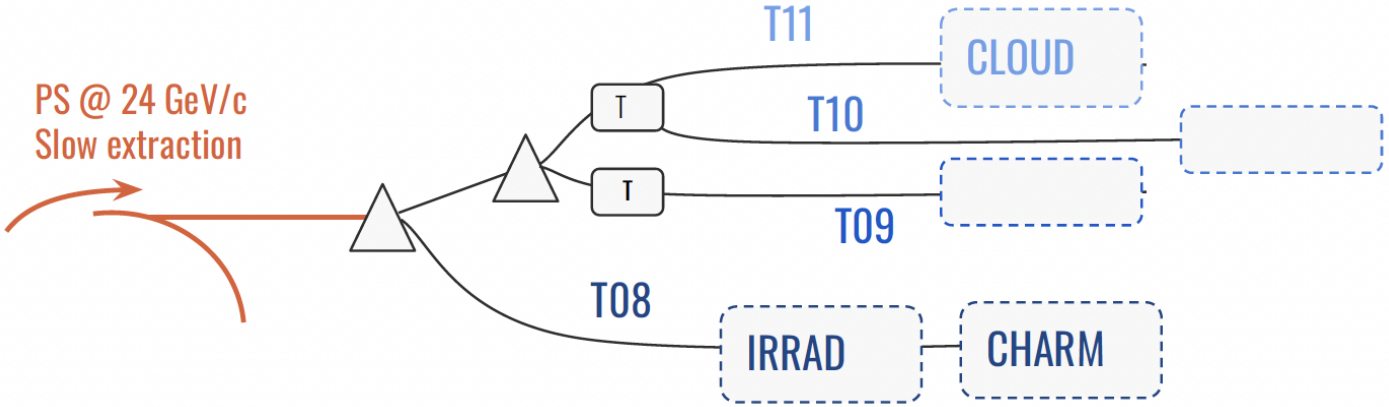




Spill duration: $0.4s$ flat top
Usually : $\mathbf{1-2}$ **cycles per minute per East Destination**
Max $\mathbf{3.3\times10^{10}}$ **protons/second per destination**
(limited by RP for secondary lines)
Max $\mathbf{6.6\times10^{10}}$ **protons/second** for T08

Supercycle structure dependent on all users (SPS, nTOF, …)

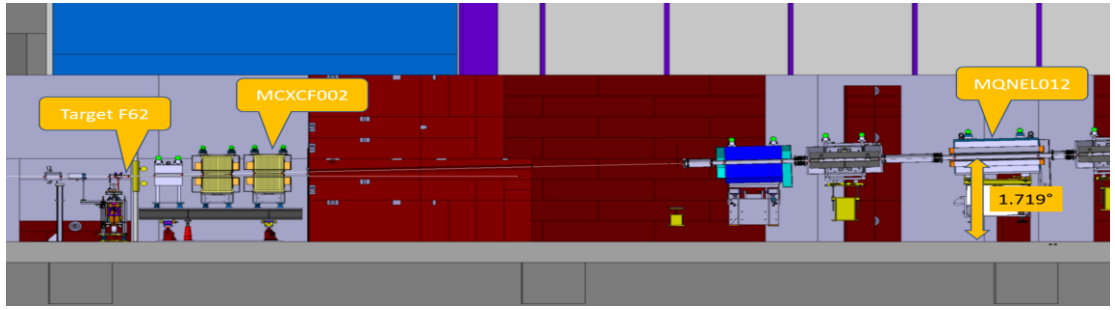
The East Area was extensively renovated in LS2

Characteristics of the beams

Parameter	T09	T10	T11
$p_{\max}$ of secondary beam in $^{\mathrm{GeV}}/_{c}$	16	11.5	3.5
$\Delta p/p$ in %		± 0.7 to ± 15	
Maximum intensity/spill (hadrons/electrons)		10^6	
Available particle types		Pure electrons (T09 only) or mixed electrons (T10) or mixed/pure hadrons or muons	

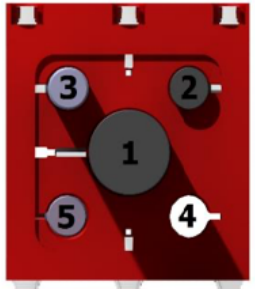
- **T11 serves the CLOUD experiment which is a permanent installation**

$30 - 35\mathrm{mrad}$ vertical production angle

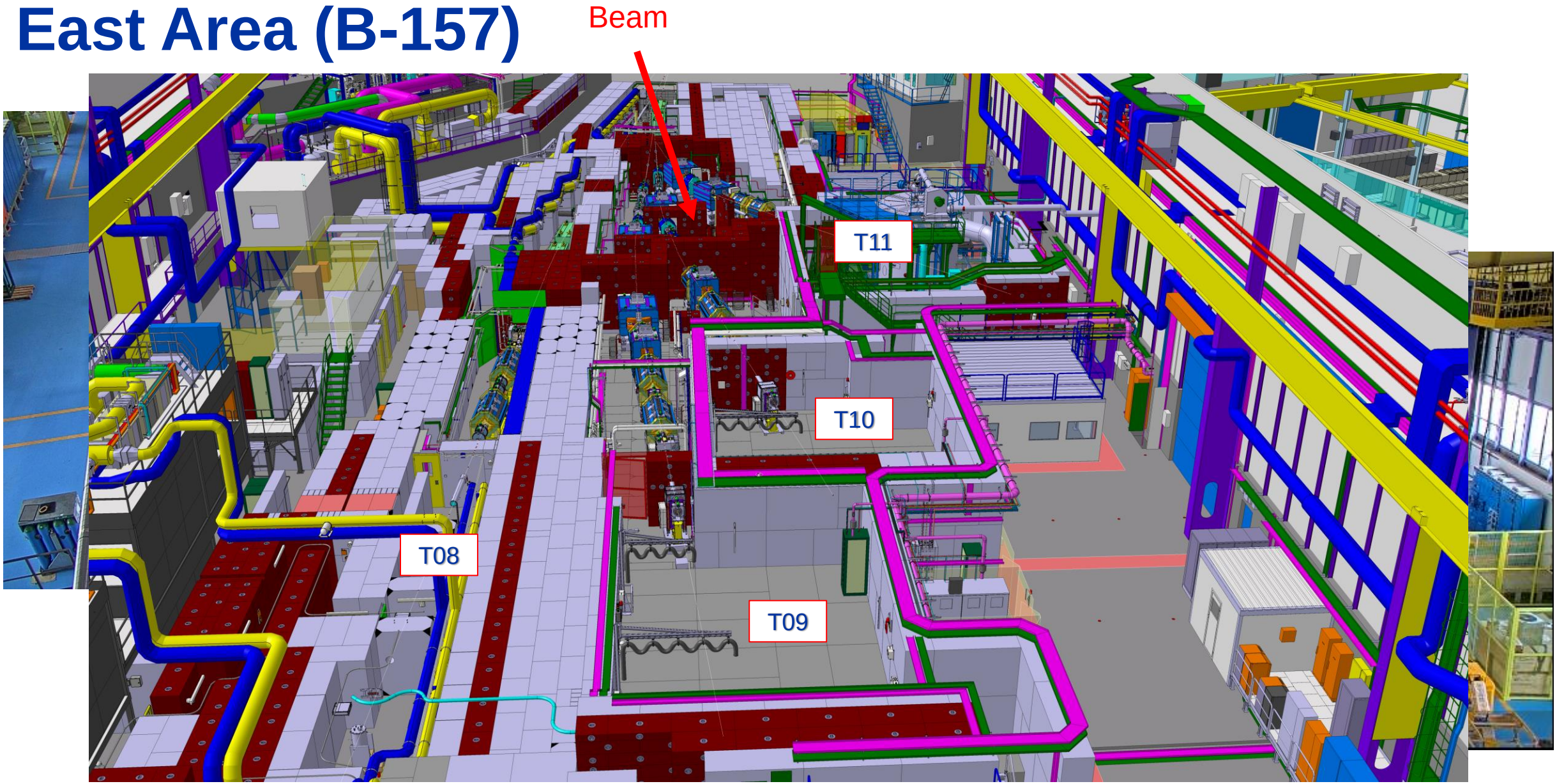


Multi-target configuration

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



East Area (B-157)

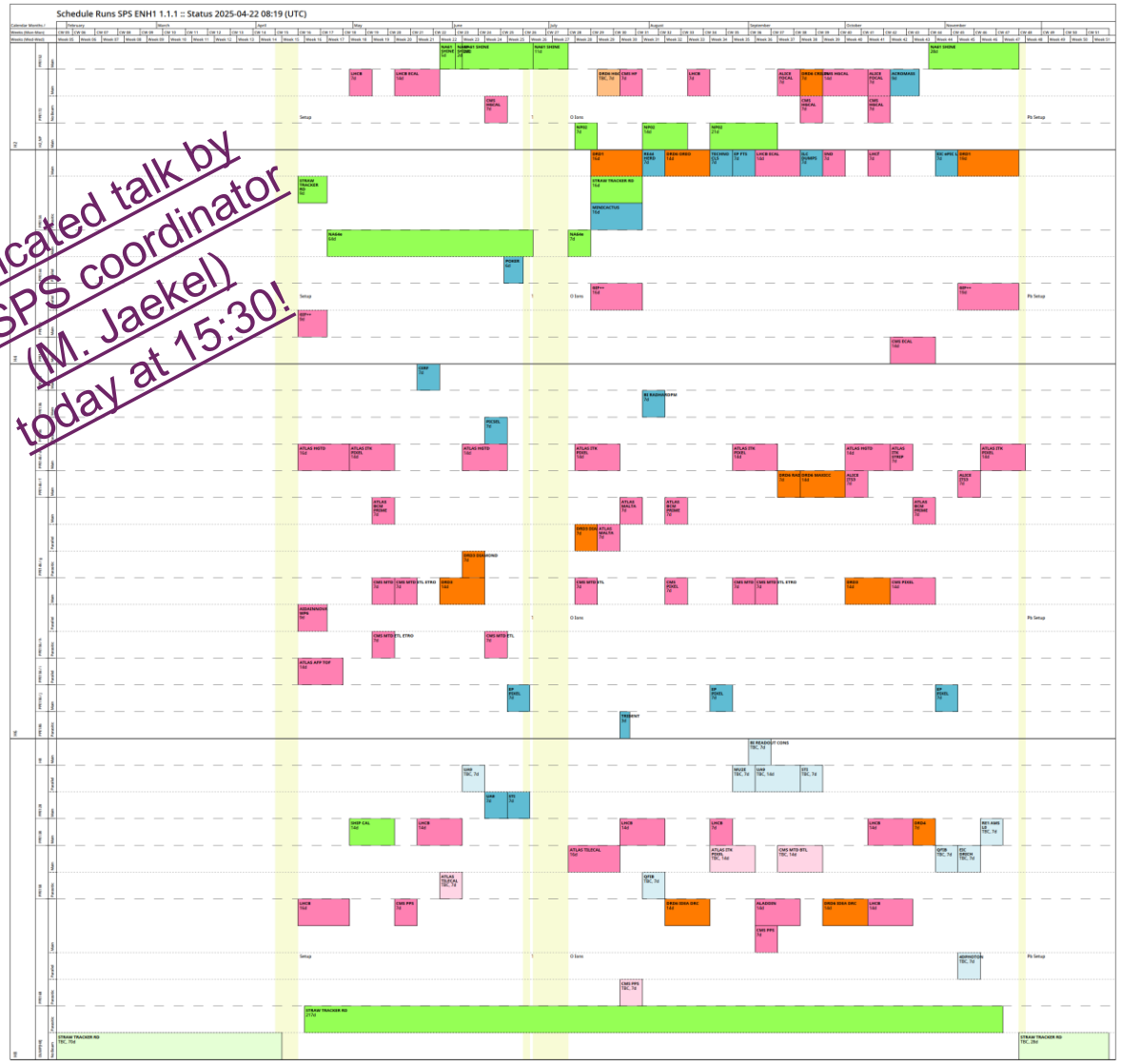


Schedule and planning (North and East Area)

Scheduling is based on priorities of different experiments and is defined by the SPS coordinator & scientific committees and approved by the CERN research board

- **The beam time request goes via PS/SPS physics coordinator (~ Sept/Oct for next year)**
  - Latest schedule on PS-SPS users website
  - Short (< 1 week @ SPS or < 2 weeks @ PS) requests handled by the PS/SPS physics coordinator directly
  - Longer requests require recommendation by CERN physics committees (SPSC, LHCC, DRDC, INTC, RB)
  - Long-term schedule for CERN available on EDMS
  - CERN Long Shutdown 3 (LS3) starts 31 Aug 2026 and ends some time Q2/3 2029 – no beam in between

Current North Area schedule (v1.1.1)



Dedicated talk by PS/SPS coordinator (M. Jaekel) today at 15:30!

IRRAD Proton Facility

Coordinator: F. Ravotti

CHARM

Coordinator: S. Fiore

GIF++

Coordinator: P. Martinengo

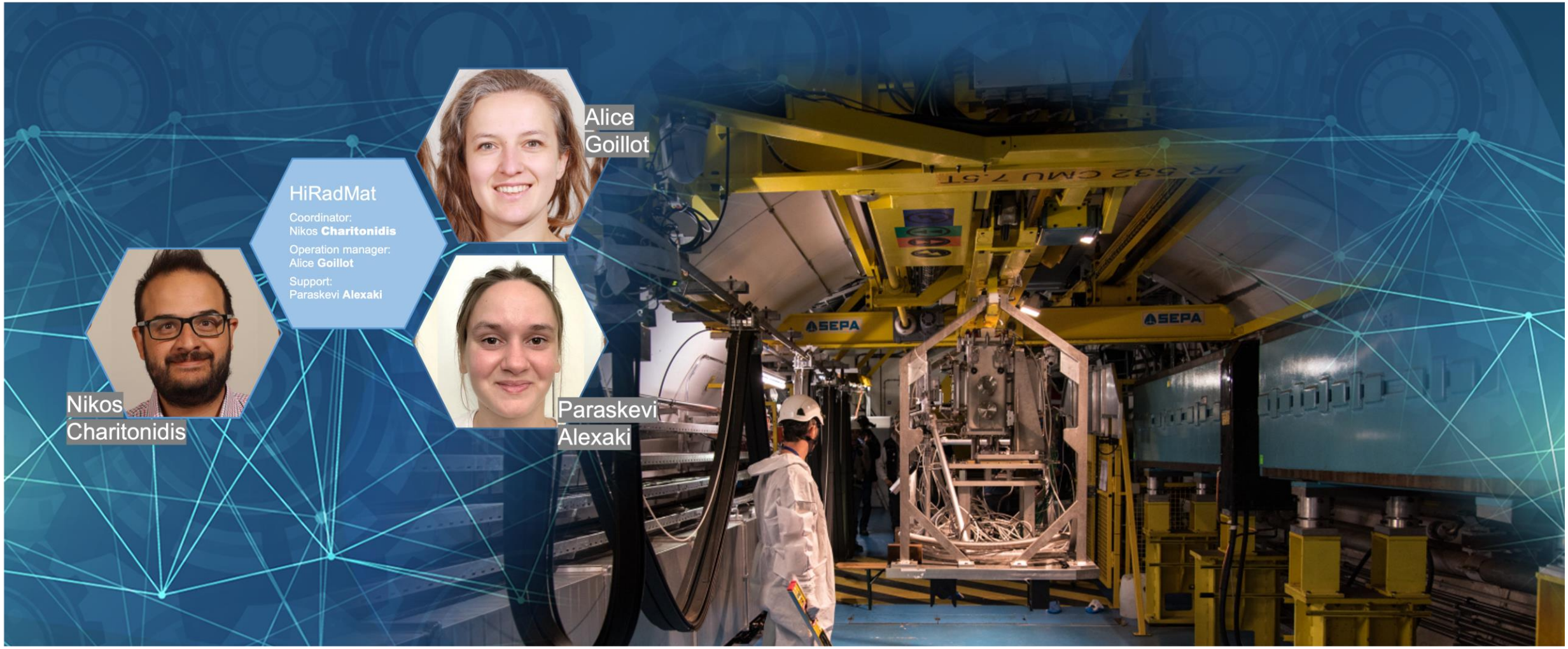
Irradiation facilities

HEARTS

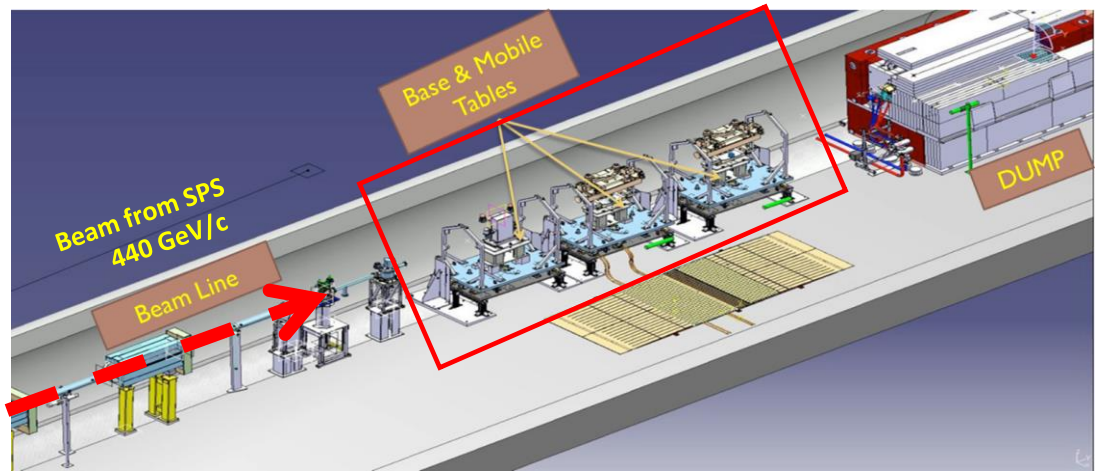
High-Energy Accelerators for Radiation Testing and Shielding

Coordinator: R. Garcia Alia

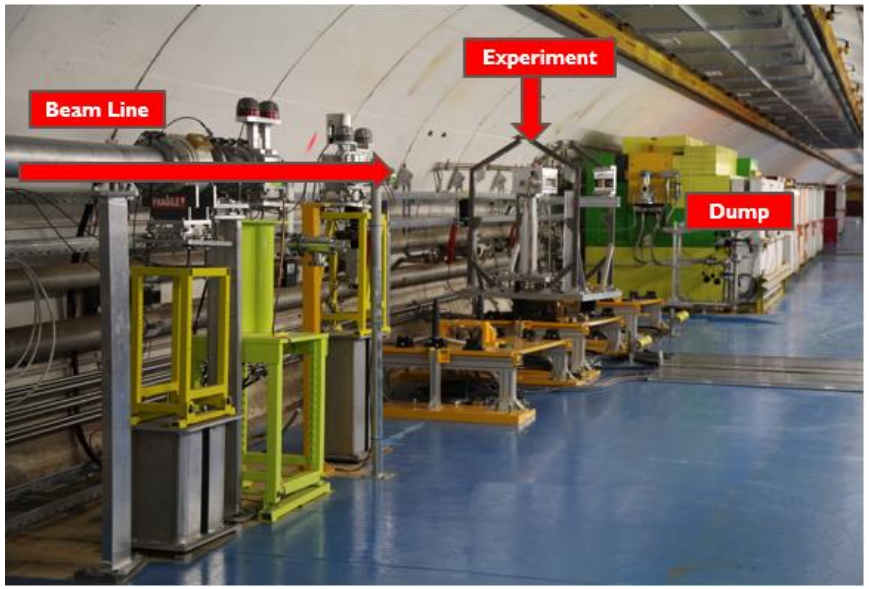
HiRadMat


HiRadMat
Coordinator:
Nikos **Charitonidis**
Operation manager:
Alice **Goillot**
Support:
Paraskevi **Alexaki**
Alice Goillot
Nikos Charitonidis
Paraskevi Alexaki
SEPA
SEPA

HiRadMat: High Radiation to Materials



- **3 stands for experiments underground**
  - Supporting remote installation and transport to a dedicated cool—down zone
  - Automatic connections for signals, electricity (low and high voltage) and water
- **Preparation lab at surface**
  - Safe commissioning / installation and pre-flight check of the experiment
- **Availability of various experimental instruments:**
  - High Speed Camera, Laser-Doppler Vibrometer, Microphones, Beam Loss Monitors...



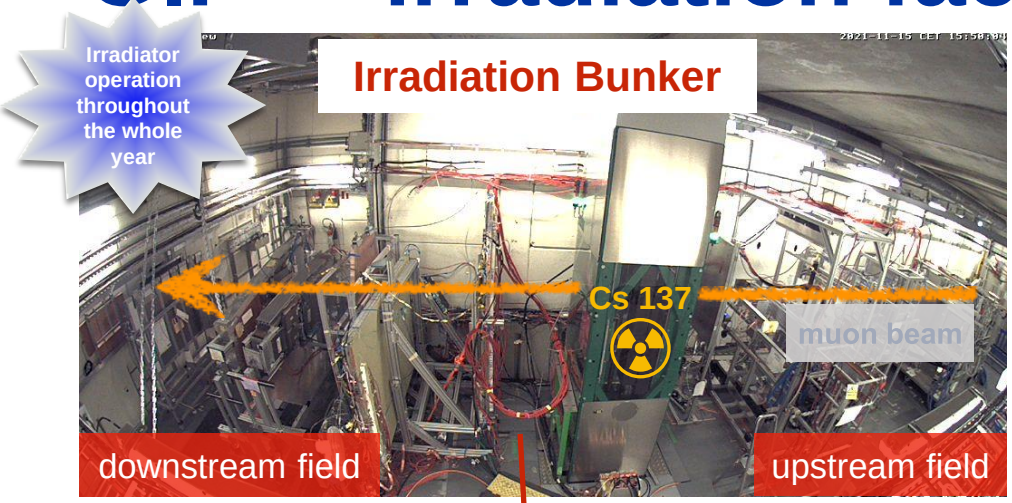
Experiment @ HiRadMat

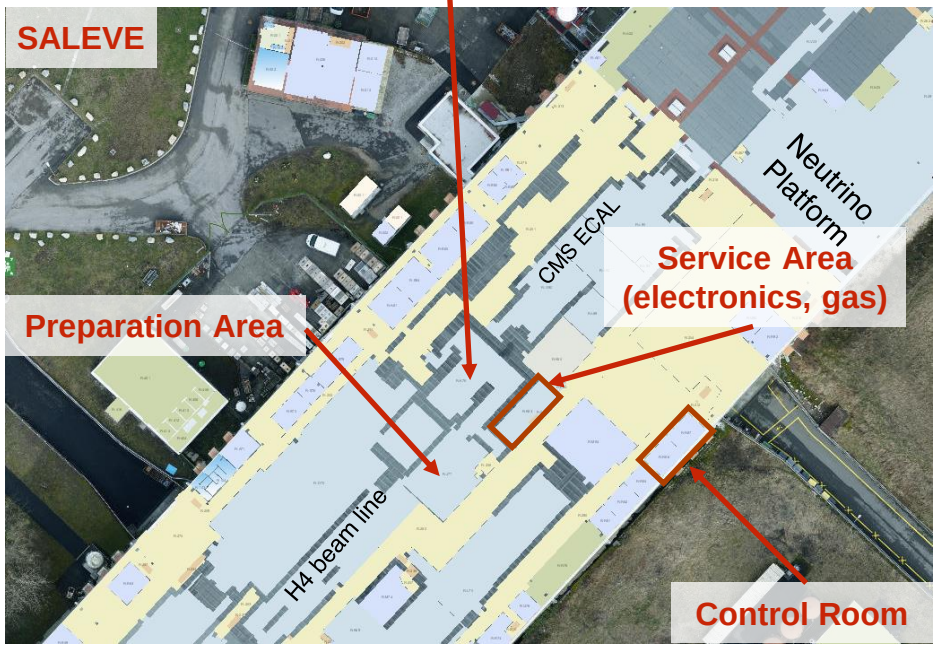
1. Application for beam time
2. Initial discussion with facility's management
3. Review by Scientific Board
4. Review by Technical Board

For more information :
http://www.cern.ch/hiradmat
hiradmat.sps@cern.ch

	Protons	^{208}Pb Ions
Beam Momentum	440 GeV/c	173.5 GeV/n (36.1 TeV per ion)
Pulse Energy	up to 4.3 MJ	up to 21 kJ
Minimum Bunch Intensity	$5 \cdot 10^9$ protons	$3 \cdot 10^7$ ions
Maximum Bunch Intensity	$2.1 \cdot 10^{11}$ protons	$7 \cdot 10^7$ ions
Number of Bunches	1 to 288	52
Maximum Pulse Intensity	$6 \cdot 10^{13}$ protons	$3.64 \cdot 10^9$ ions
Bunch Length	1.5 ns (4 sigma)	1.5 ns (4 sigma)
Bunch Spacing	25 ns	100 ns
Max. Pulse length	7.95 us	5.2 us
Cycle length	22.9 or 40.8 s	13.2 s
Beam Size at Target	variable around 1 mm^2	variable around 1 mm^2

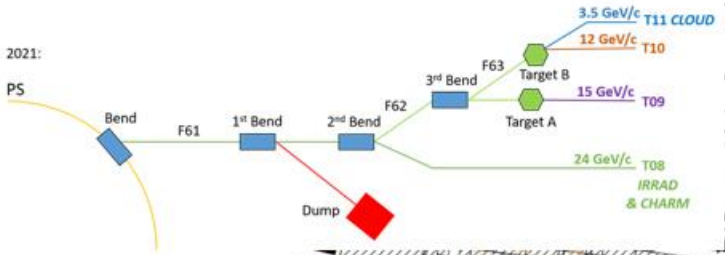
GIF++ irradiation facility @ North Area (H4)

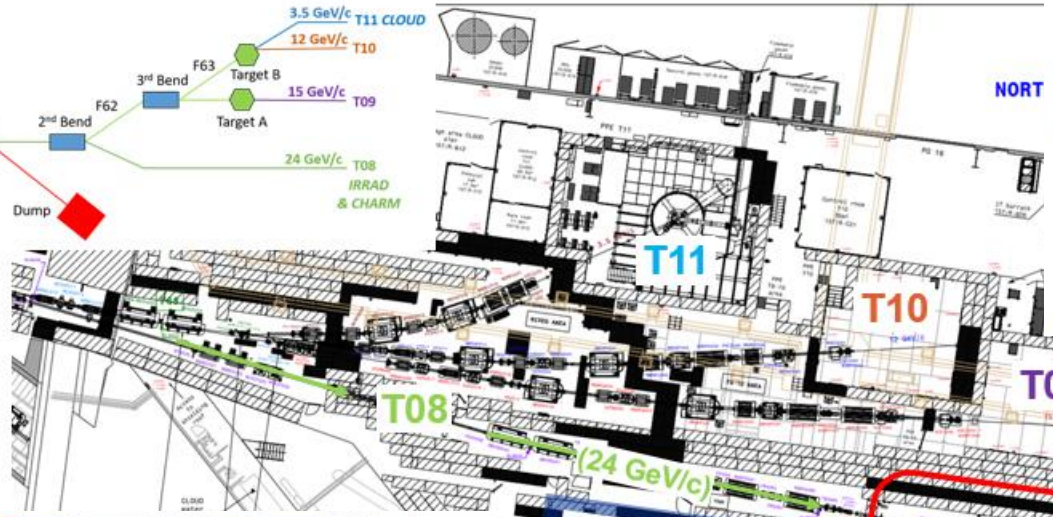


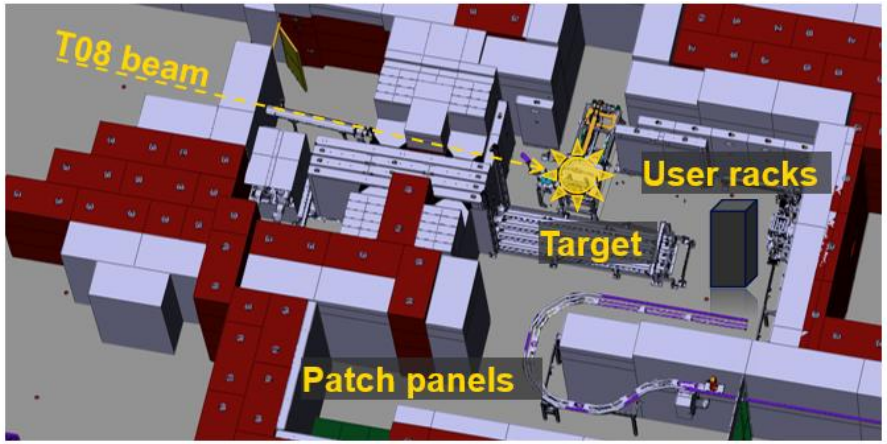


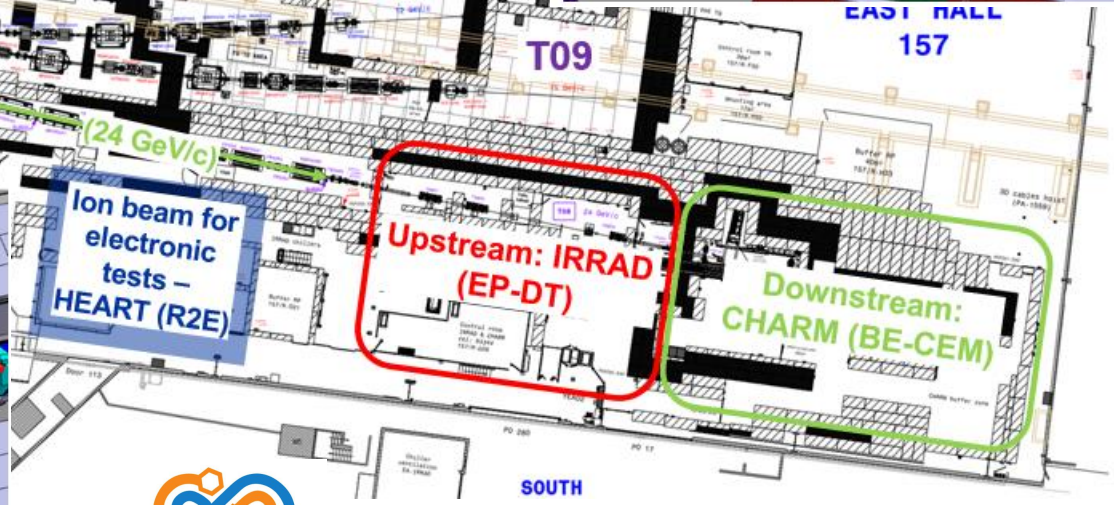
- **GIF++ combines high energy muon beam with 12 TBq* ^{137}Cs gamma source** *) 14TBq as of 2014
  - Joint EP & BE facility, operated by EP-DT
  - Designed for testing real size detectors
  - ≈100 m^2 irradiation fields, 2 irradiation zones with independent attenuation systems
  - Central Control System, wide range of available gases (+ custom gases), common DCS…
- **Detector validation tests under realistic conditions: high radiation background & muon beam**
  - Ageing studies under HL-LHC radiation conditions
  - Search for eco-friendly gas mixtures
  - Mass-production test of muon chambers
  - Radiation tests of electronics and optical components

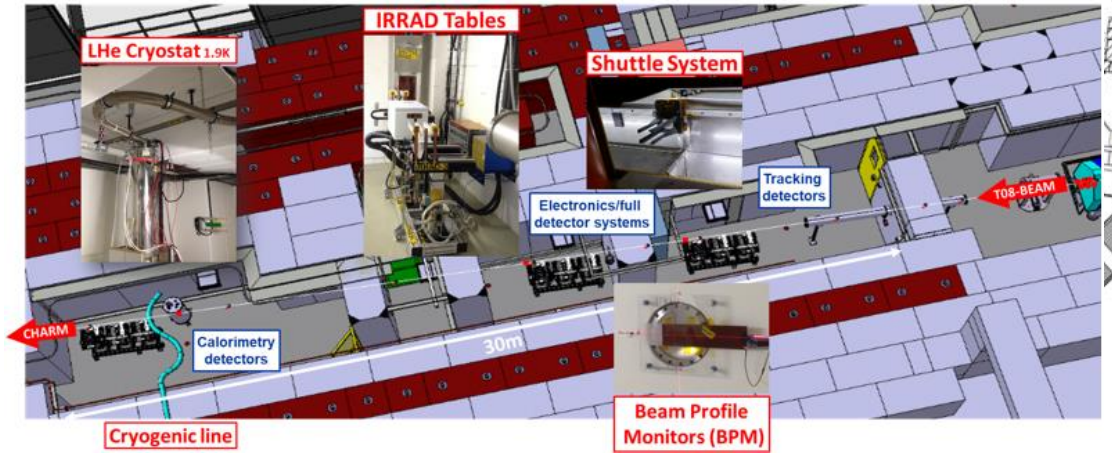
IRRAD / CHARM Irradiation Facilities (T08)





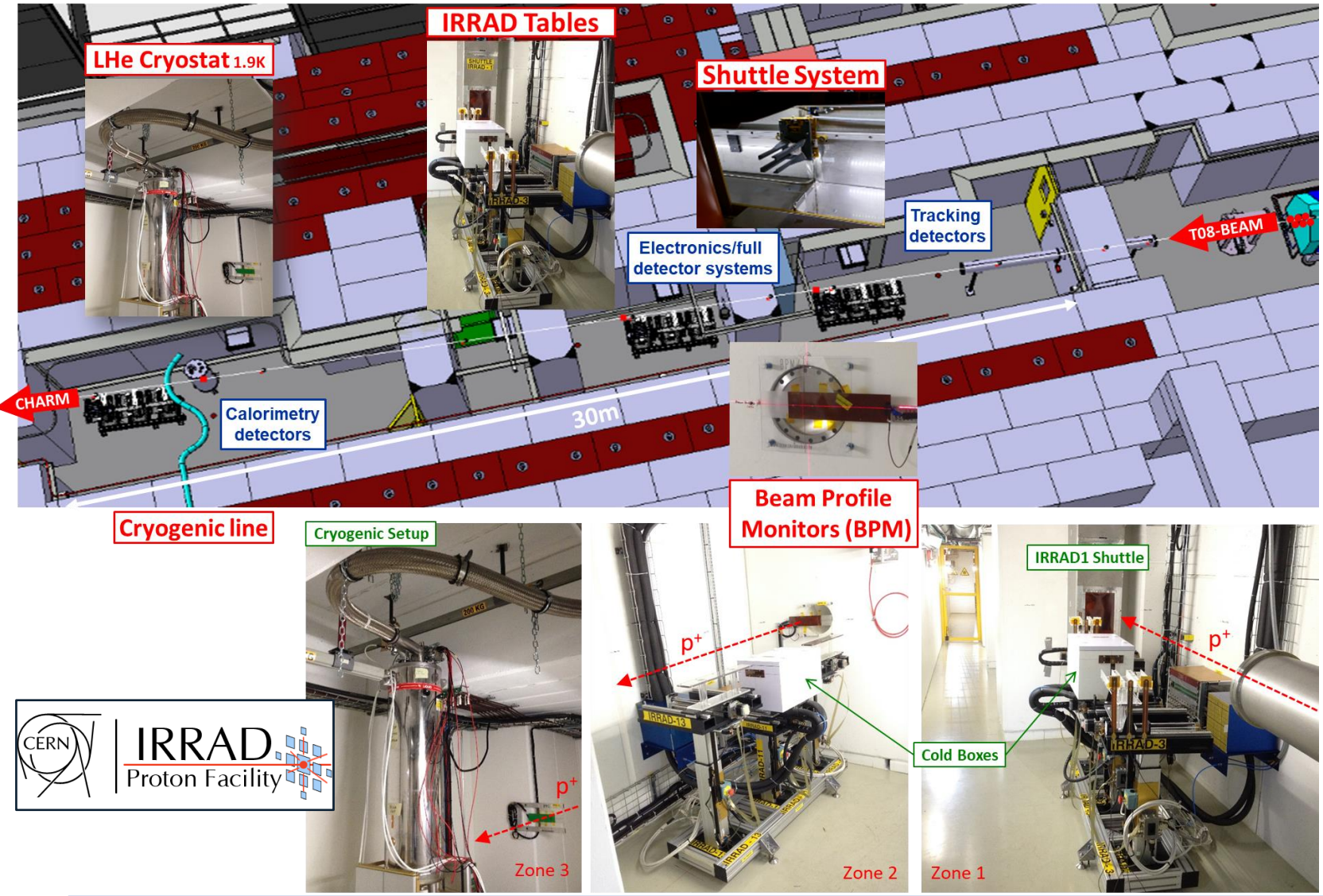






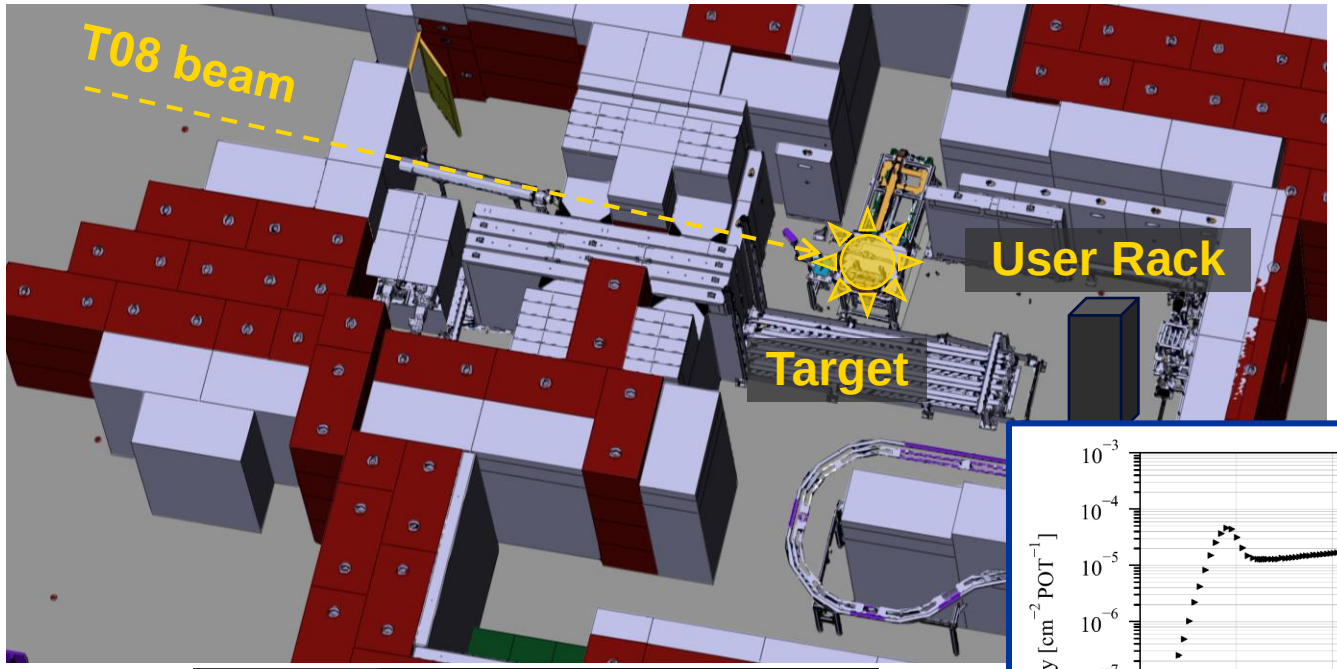
Testing of electronics components with heavy ion (Pb) beams (typically ~2w per year) on the T8 beam line.

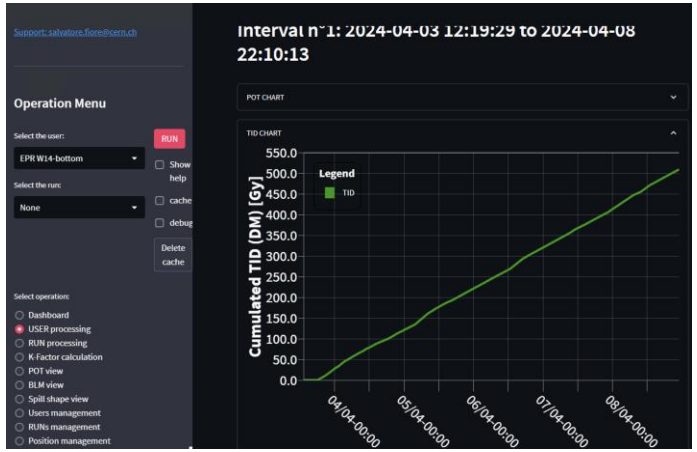
Proton Facility IRRAD (CERN EP)



- **24 GeV/c protons**
  - 400ms spills
  - ~8×10^{11} protons per spill
- **~1×10^{16} n$_{(1\ MeV\ Si\ eq,)}$ / cm^2 / w**
  - beam spot 12x12mm2 FWHM
- **1 shuttle system** (small samples)
- **9 irradiation tables**
  - 6x room temperature
  - 2x cold boxes (-25°C)
  - 1x cryogenic setup (1.9K)
- **local user infrastructure**

Mixed-Field Facility CHARM (CERN BE)





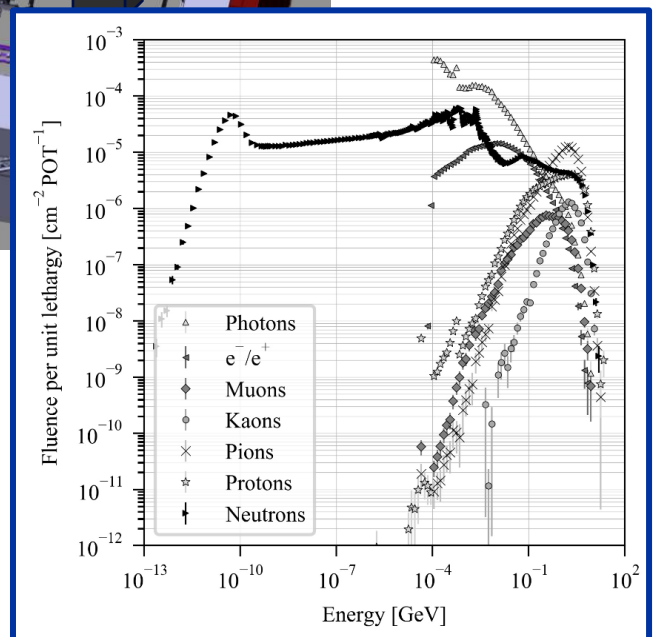


Fig. 4: Particle spectra for the configuration cpOOOO - test location R13.

- **Mixed-field radiation field**
  - 24 GeV/c p+ on target
  - various testing positions and radiation mixes available
- **TID ~500 Gy / w** (typical)
  - individual dosimetry provided to each user
- **User equipment**
  - setups hosted in standard 21” rack, moved in irradiation position by robotic conveyor
  - additional lower radiation intensity positions
  - mock-up for dry run available in the preparation room

Summary

- **CERN offers a great variety of test beam options and irradiation facilities**
  - Primary + secondary beams available in North area (≤ 400 GeV/c) and secondary in East Area (≤ 16 GeV/c)
  - Variety of irradiation facilities: SPS primary beam @ HiRadMat (440 GeV/c), mixed field μ/γ @ GIF++, PS primary beam @ IRRAD (28 GeV/c), mixed field @ CHARM (24 GeV/c beam on thick target)

- **For North and East Area beams: Please contact in advance Sps.Coordinator@cern.ch and sba-operation@cern.ch to optimally use your beam time and the facilities**
  - Visit https://ps-sps-coordination.web.cern.ch/ps-sps-coordination/ for the updated version of the schedule and other useful information
  - Subscribe to *ps-sps-users* e-group
  - Visit https://be-dep-ea.web.cern.ch/experimental-areas/beamline-responsibles for further information
  - In case of questions – don‘t hesitate to reach out!!

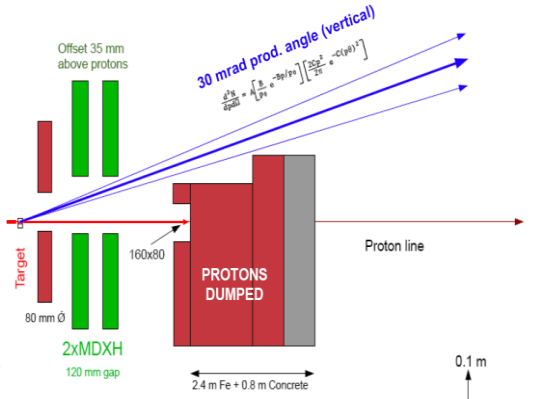
Looking forward to seeing you at CERN!

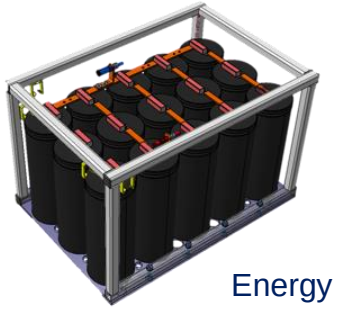
home.cern

Backup slides

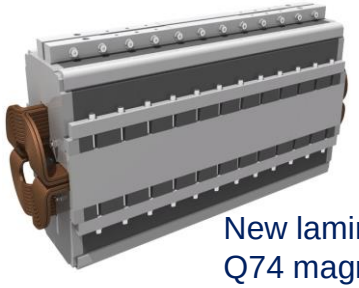
East Area Renovation

- **The renovation was complected during LS2 and included:**
  - Full refurbishment of East Hall with its beamlines and infrastructures
    - Upgrade of heating/ventilation, improved thermal insulation, wall and roof cladding, separated cooling for primary and secondary beamlines
  - Improved radiation protection
    - Improved equipment accessibility and faster repair times, primary beam dump just downstream of the primary target
  - Change in the beamline layout
    - Higher maximal p and improved selectivity of particle types
  - Completely new magnet powering scheme
    - Cycled powering leading to reduction of annual power consumption from 11 to $0.6\mathrm{GWh}$
    - Less magnet types for better maintenance





Energy storage unit



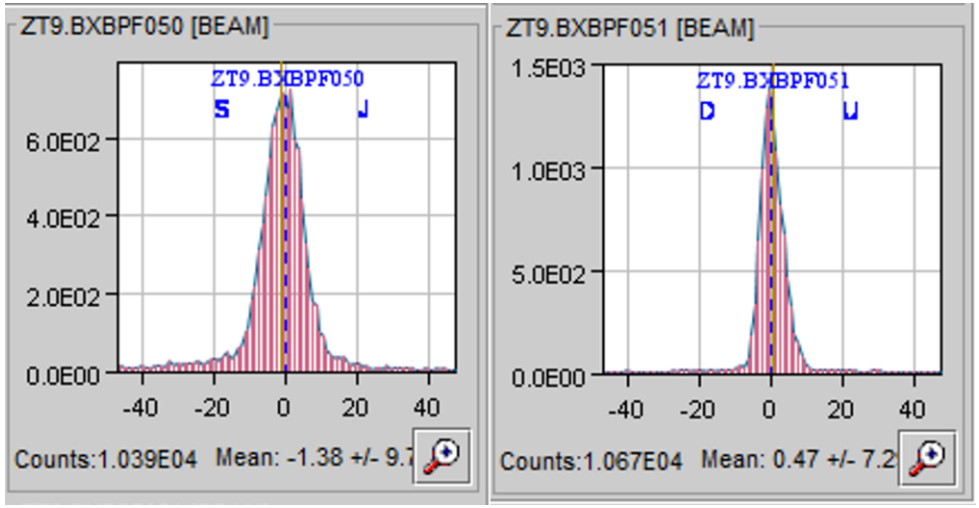
New laminated Q74 magnet

Beam Instrumentation in the North and East Area

- **Threshold Cherenkov gas counters (XCET) and CEDARs → used for particle tagging**
  - In the East Area new high pressure XCETs are available that go up to 15bar
  - Refrigerant gases like R218 and R134a can be used for low momenta particle tagging

- **Beam profile & intensity monitors:**
  - Scintillators & Analog / Delay Multi Wire Chambers are installed in several positions along the beamlines
  - In the East Area Scintillating Fibre Hodoscopes (XBPF) are used as profile monitors
  - As part of the consolidation efforts under NACONS all Analog / Delay Wire Chambers will be replaced by XBPFs

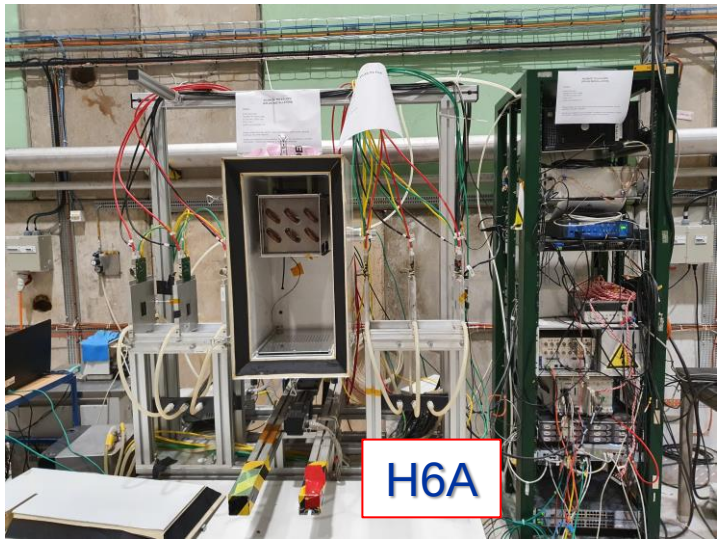
- **FISC scanners (only North Area):**
  - Precise slower profile monitors
  - Can also be used for measurements of beam divergence

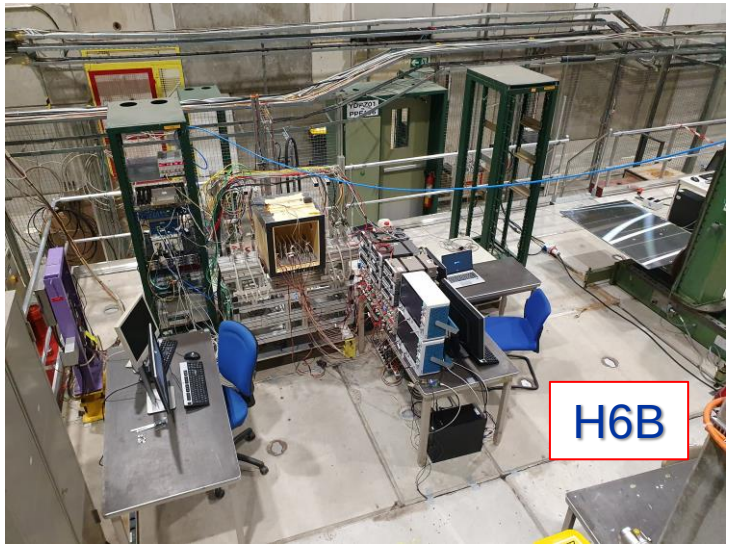


Telescopes in CERN North Area (SPS)

- **Two telescopes installed permanently (not managed by BE-EA):**
  - ACONITE in H6A
  - AIDA telescope in H6B
  - A mobile telescope AZALEA is also available
  - **Contact: Andre Rummler or PS/SPS physics coordinator**

- **Properties:**
  - 6 Mimosa-26 planes
  - TLU/EUDAQ based
  - Dedicated remote control PCs in control huts
  - High degree of usage and increasingly simultaneously
  - Separate $x - y$ table can be booked and installed behind telescopes serving larger DUTs
  - Remote controlled high voltage (ISEG modules with 8 channels up to $-500\mathrm{V}$ and 8 channels up to $-2000\mathrm{V}$)





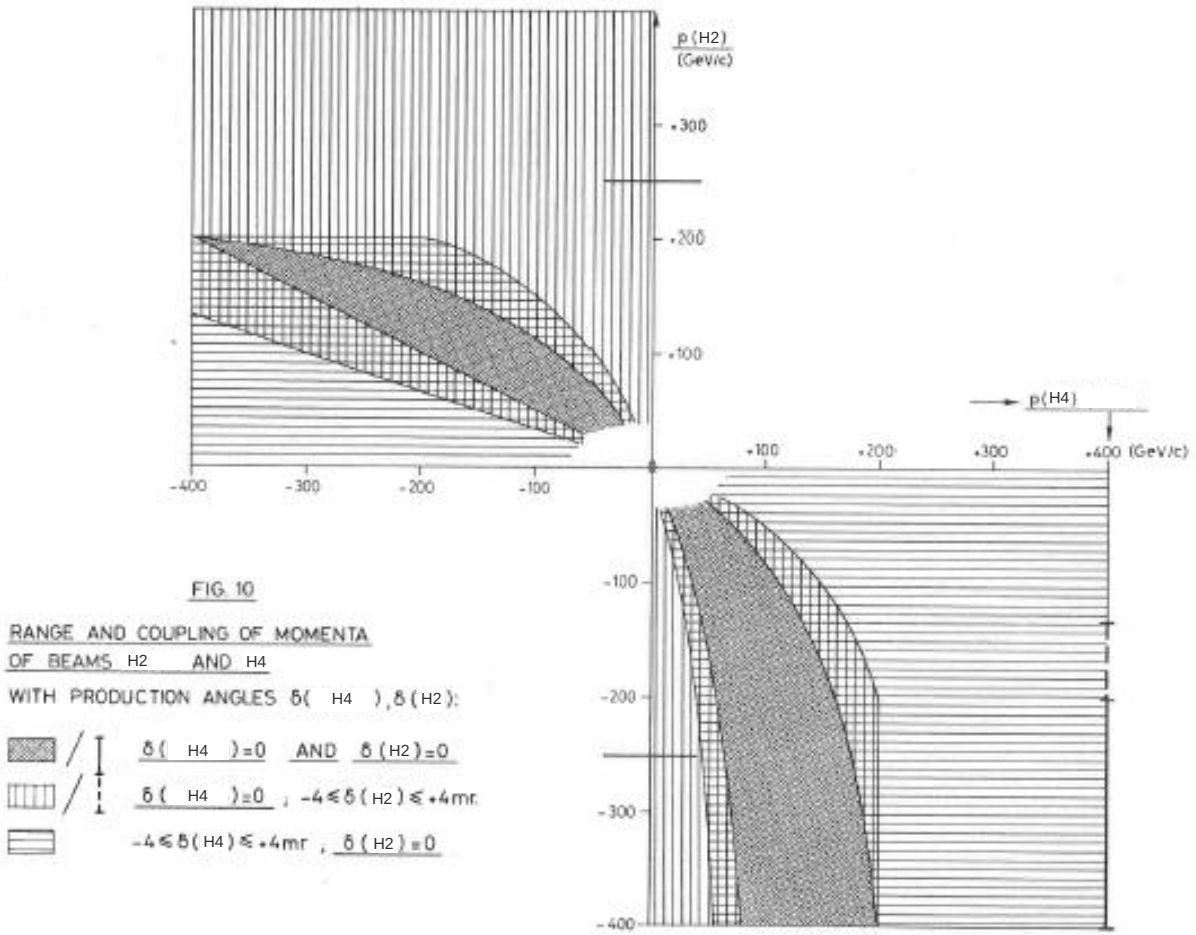
Large aperture magnets for tests with beam

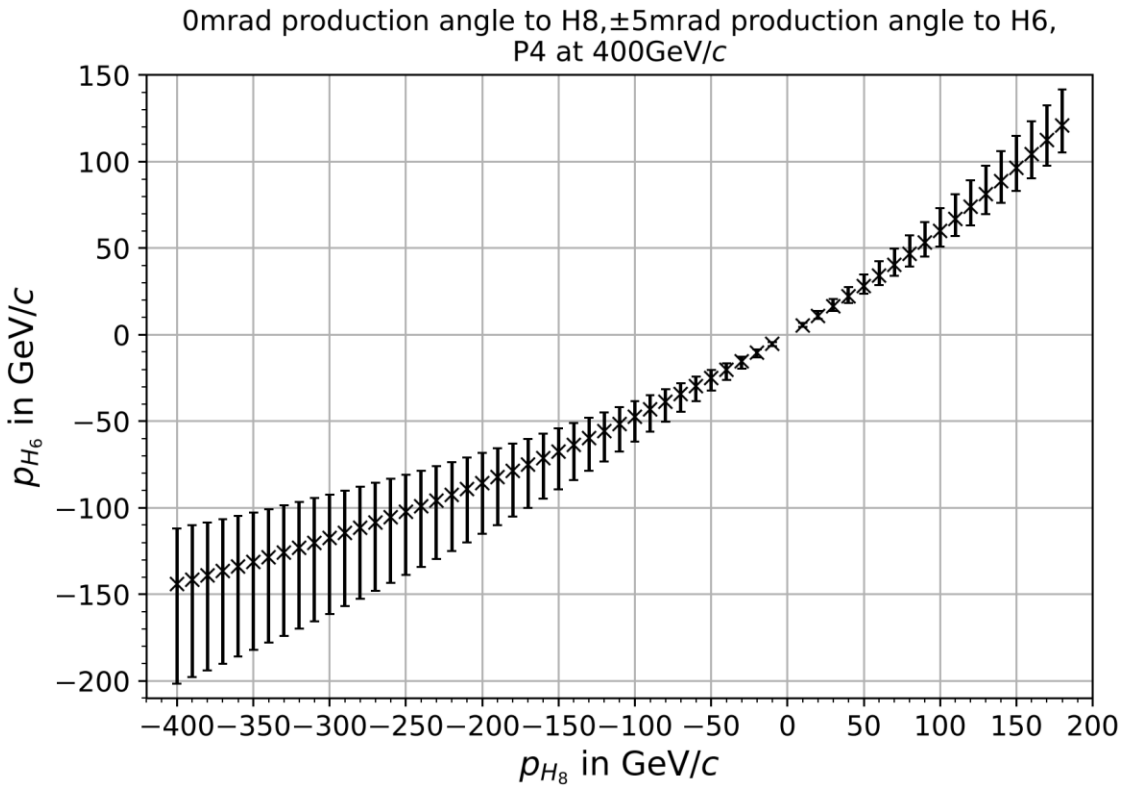
GOLIATH
- EHN1, H4 beamline
- Large classical dipole
- $160 \times 240 \times 360\mathrm{cm}^3$
- 1.5T field

Morpurgo
- EHN1, H8 beamline
- Superconducting dipole
- $1.6\mathrm{m}$ diameter, $4\mathrm{m}$ length
- $1.5\mathrm{T}$ field

CMS M1 magnet
- EHN1, H2 beamline
- Superconducting dipole
- $82\mathrm{cm}$ gap, $1.4\mathrm{m}$ diameter
- $3.0\mathrm{T}$ field

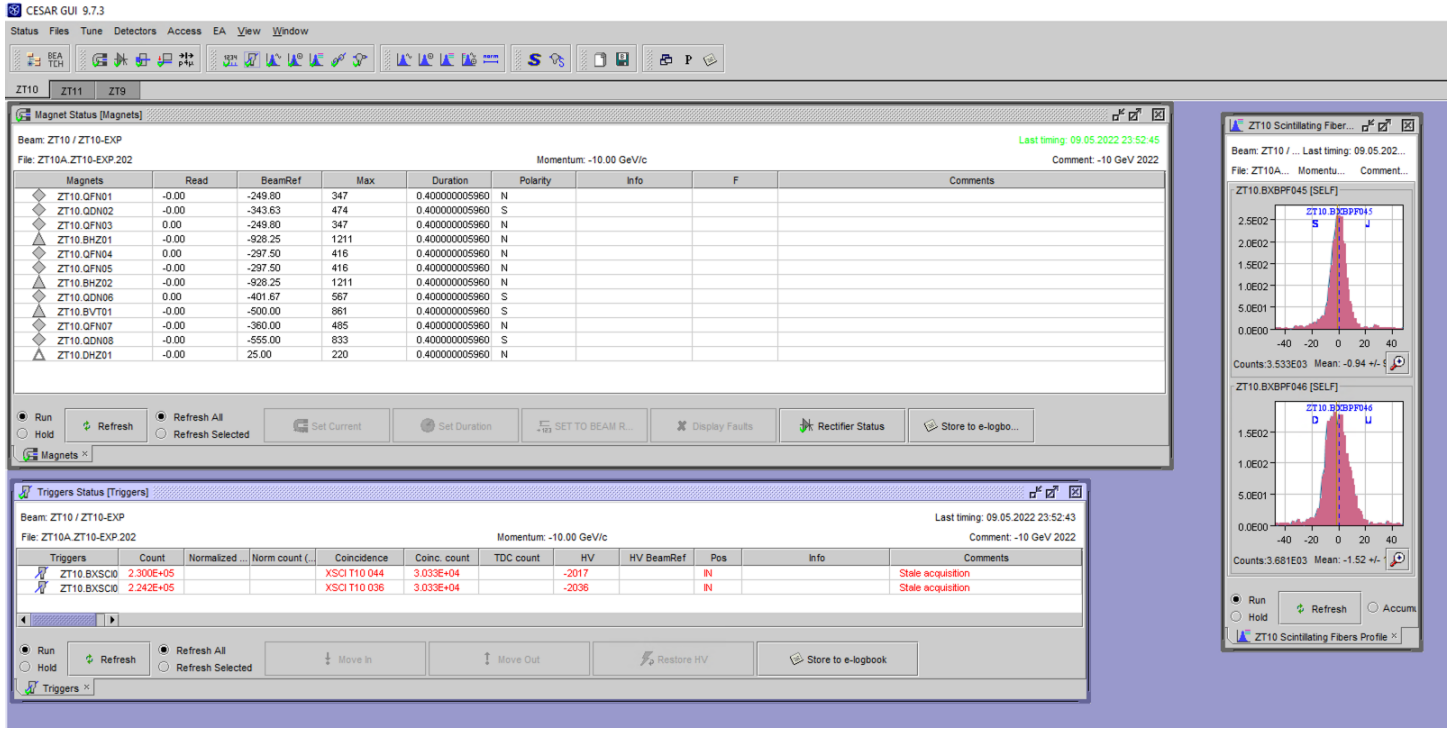
T2 (left) and T4 (right) wobbling solutions





Access and Beam Control Software

- **The beam can be controlled using the CESAR interface (will be replaced after LS3)**
  - Magnet currents can be changed, collimators can be controlled, Threshold Cherenkov pressure can be set, beam files can be loaded, beam profiles and trigger information can be accessed etc.,

- **The zone can be accessed with a dosimeter and safety equipment**
  - Helmet, safety shoes
  - No special access request is needed

- **2-3 members from each user group are given the patrol rights**
  - Required only to turn on the beam
  - Needs on-site training