

# Electron & Positron beams in the CERN secondary areas

**N. Charitonidis** [CERN, BE-EA] on behalf of BE-EA-LE colleagues

**04 September 2025**

# Outline

- **Introduction – Scope of the presentation**
- **Overview of the CERN secondary areas**
- **Possibilities of today's available electron / positron beams at CERN**
- **Outlook for the future !**

# Introduction

- The secondary beam areas of CERN are unique, versatile facilities that can offer particle beams of a very broad range of momenta and intensities.
- Electron & positron beams of high purity have been and are available, while they are recently requested more and more for physics & R&D purposes

PHYSICAL REVIEW LETTERS 130, 071601 (2023)

**Precision Measurement of Trident Production in Strong Electromagnetic Fields**

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(CERN NA63)

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We demonstrate experimentally that the trident process  $e^- \rightarrow e^- e^+ e^-$  in a strong external field, with a spatial extension comparable to the effective radiation length, is well understood theoretically. The experiment, conducted at CERN, probes values for the strong field parameter  $\chi$  up to 2.4. Experimental data and theoretical expectations using the local constant field approximation show remarkable agreement over almost 3 orders of magnitude in yield.

DOI: 10.1103/PhysRevLett.130.071601

NA63

PHYSICAL REVIEW LETTERS 123, 121801 (2019)

Editors' Suggestion

**Dark Matter Search in Missing Energy Events with NA64**

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(NA64 Collaboration)

NA64

**CMS ECAL intercalibration with cosmic rays and 2006 test beam electrons**

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The CMS Electromagnetic Calorimeter (ECAL) calibration foresees dedicated protocols both before and during the data taking. Up to now test beam electrons and cosmic muons have been used to precalibrate ECAL. During the summer 2006, nine ECAL supermodules have been exposed to a high energy electron beam at the CERN SPS north area facility and the intercalibration coefficients of the 1700 channels have been measured for each supermodule. The reproducibility of the intercalibration has been tested by measuring a supermodule twice. Different calibration methods based either on single crystals or on matrices of crystals energy reconstruction have been used. The intercalibration coefficients obtained have also been compared with those calculated by means of the cosmic ray muons.

Keywords: calorimetry, LHC, CMS, electromagnetic, calibration, high energy

CMS

Nuclear Instruments and Methods in Physics  
Research Section A: Accelerators, Spectrometers,  
Detectors and Associated Equipment  
Volume 1024, 1 February 2022, 166129

**Muon detection in electron-positron annihilation for muon collider studies**

N. Amagane<sup>a,b</sup>, M. Antonelli<sup>c</sup>, F. Anulli<sup>d</sup>, G. Ballerini<sup>e,f</sup>, L. Bandiera<sup>g</sup>, N. Bartosik<sup>h</sup>, M. Bouce<sup>g</sup>, A. Bertolin<sup>h</sup>, C. Bino<sup>b</sup>, O.R. Blanco-García<sup>c</sup>, M. Boscolo<sup>c</sup>, C. Brizzolari<sup>e,f</sup>, A. Cappati<sup>e,b</sup>, F. Casabura<sup>1,d</sup>, M. Casarise<sup>1</sup>, G. Cavoto<sup>1,d</sup>, G. Cesarini<sup>1,d</sup>, F. Collamati<sup>d</sup>, G. Cotta<sup>a,b</sup>, C. Curatolo<sup>h,m</sup>, M. Zanetti<sup>1,h</sup>

LEMMA

Eur. Phys. J. C (2021) 81:238  
https://doi.org/10.1140/epjc/s10052-021-09021-y

Regular Article - Experimental Physics

**Investigation on steering of ultrarelativistic  $e^\pm$  beam through an axially oriented bent crystal**

L. Bandiera<sup>1</sup>, I. V. Kyrillidis<sup>2,3,a</sup>, C. Brizzolari<sup>4,5</sup>, R. Camattari<sup>1,6</sup>, N. Charitonidis<sup>7</sup>, D. De Salvador<sup>8,9</sup>, V. Guidi<sup>1,6</sup>, V. Mascagna<sup>4,5</sup>, A. Mazzolari<sup>1</sup>, M. Presti<sup>4,5</sup>, M. Romagnoni<sup>1,10</sup>, N. F. Shul'ga<sup>2,3</sup>, M. Soldani<sup>1,6</sup>, A. Sytov<sup>1</sup>, E. Vallazza<sup>5</sup>

**Experimental Study of Single Vertex ( $e^- - e^+$ ) Pair Creation in a Crystal**

Albany SUNY, Anecy L.A.P.P., Frascati Nat.Lab./INFN, Lyon Univ.

Albany SUNY  
Cue N. Kimball J. Marsh B. Sun C.R.  
Anecy L.A.P.P.  
Dufournaud J. Peigneux J.P. Sillou D. Spighel M.  
Frascati Nat.Lab./INFN  
Bologna G.  
Lyon Univ.  
Belkacem A. Chevallier M. Clouvas A. Gaillard M.J. Genre R. Kirsch R. Poizat J.C. Remillieux J.  
Spokesman: Remillieux, J. Contactman: Sillou, D.

NA33

**Study of Unexplained Hard Photon Production by Electrons Channelled in a Crystal**

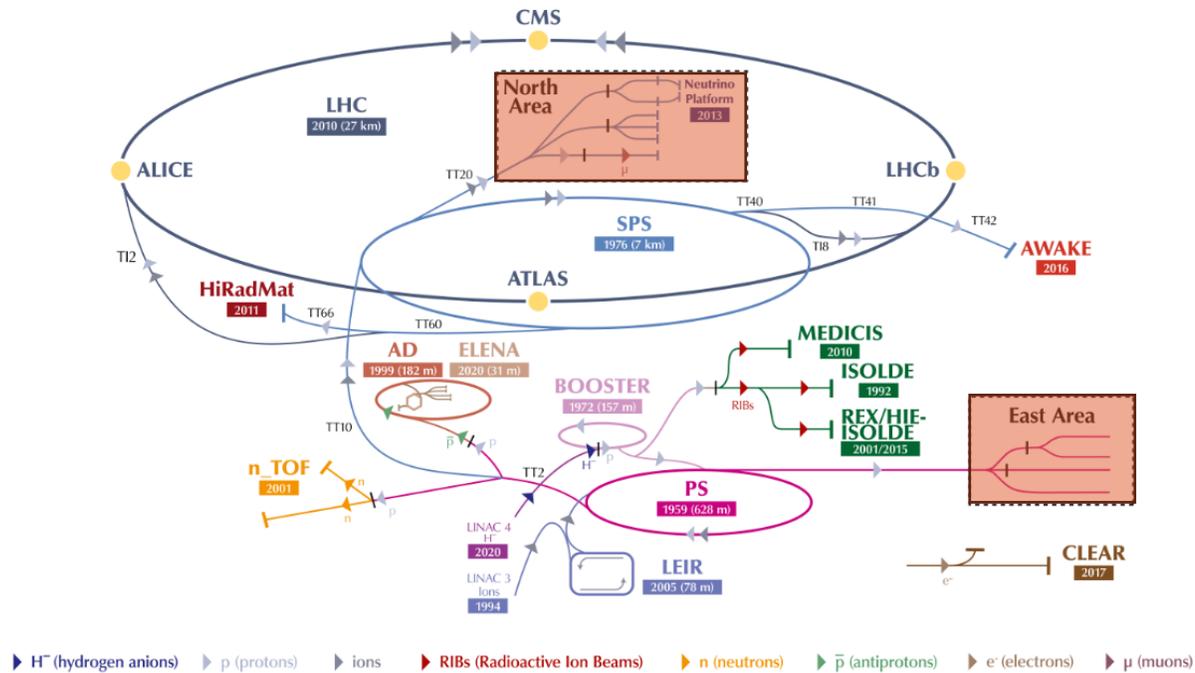
Albany SUNY, Anecy L.A.P.P., Lyon Univ.

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Bologna G. Gouanere M. Peigneux J.P. Sillou D. Spighel M.  
Lyon Univ.  
Artru X. Belkacem A. Chevallier M. Gaillard M.J. Genre R. Kirsch R. Poizat J.C. Remillieux J.  
Spokesman: Remillieux, J. Contactman: Spighel, M.

NA42

# The secondary beam areas at CERN

The CERN accelerator complex  
Complexe des accélérateurs du CERN

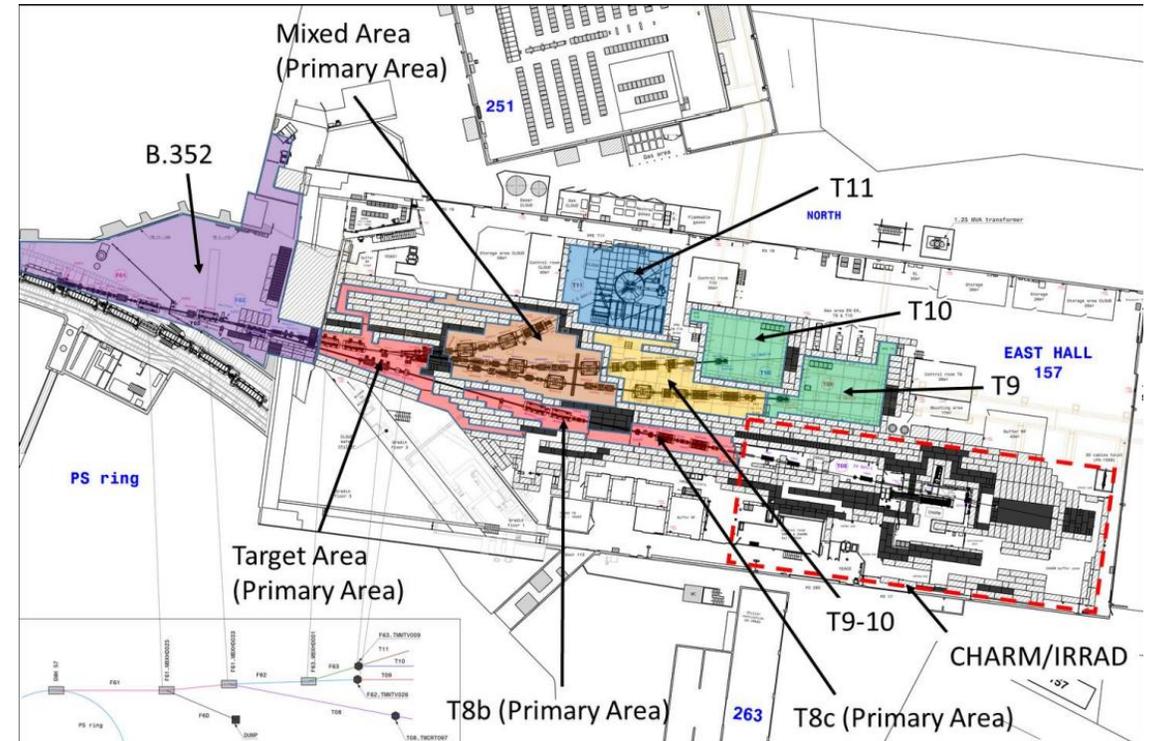
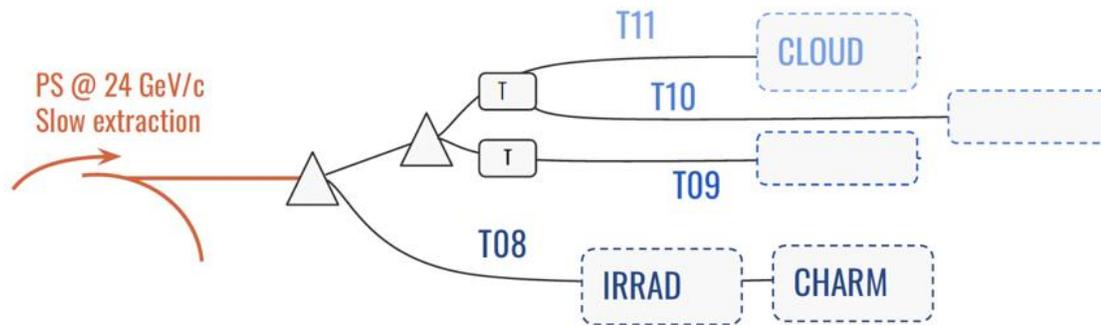


- SPS : protons/ions @ 400 GeV/c/Z
- PS: protons /ions @ 24 GeV/c/Z
- North Area →  $\leq 400$  GeV/c/Z (primary beam) or  $\leq 360$  GeV/c/Z (secondary beams)
- East Area →  $\leq 10$  GeV/c secondary beams
- Electrons / positrons available both in North & East areas !

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE-ISOLDE - Radioactive Experiment/High Intensity and Energy ISOLDE // MEDICIS // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n\_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // Neutrino Platform

# East Area of CERN/PS

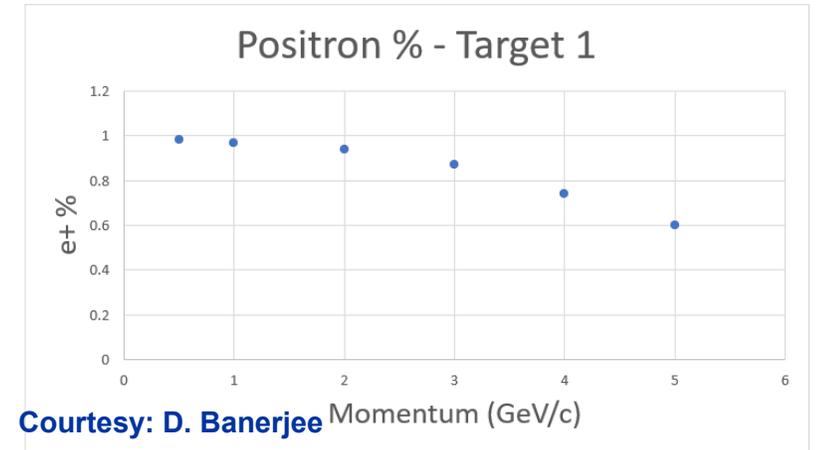
- Two beamlines available for tests : T9 and T10
- Flexible areas, with infrastructure support available from the different CERN groups
- Quick access, short routes from control to experimental areas !



# Electron beam properties in the East Area

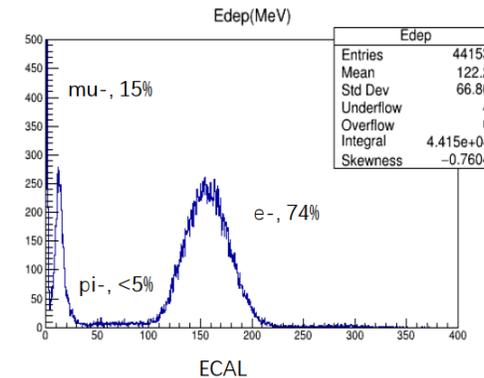
- Electron beams of various purities and intensities are available, **between 0.1 & 5 GeV/c**
- Electrons & positrons produced equally, choice to transfer one of the two signs in the various experiments.
- **> 90% electron purity** for momenta **<5 GeV/c** reaching **~99%** at 1 GeV/c
- Rates, in all momenta **up to  $\sim 10^5$  particles / spill in T09**
- **Spill structure from PS accelerator:**
  - 400 ms spill length
  - $\sim 1$  spill every 18s, more on demand

XCET Data – Plot 2

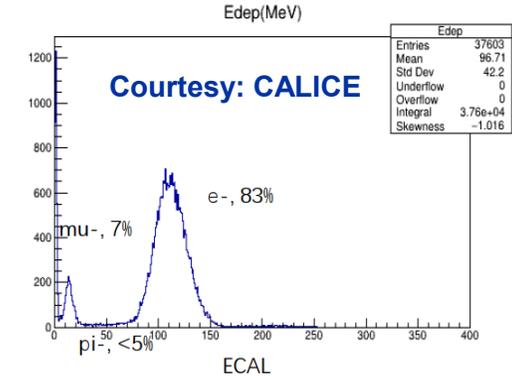


## ECAL Energy Response to e-

4 GeV/c e- energy deposition in ECAL



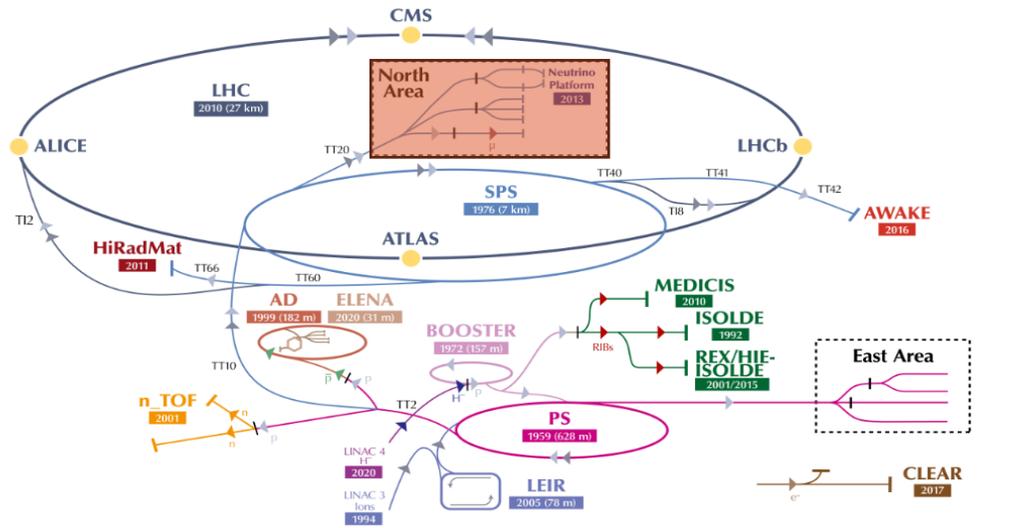
3 GeV/c e- energy deposition in ECAL



# North Area of CERN SPS

Beam from SPS

The CERN accelerator complex  
Complexe des accélérateurs du CERN



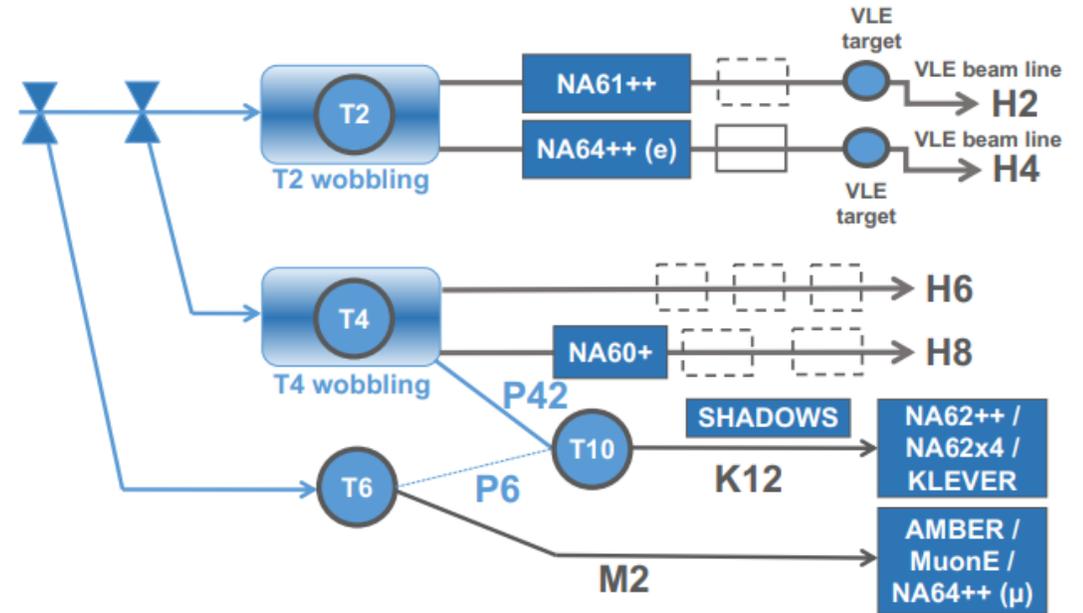
▶ H<sup>-</sup> (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons) ▶  $\bar{p}$  (antiprotons) ▶ e<sup>-</sup> (electrons) ▶  $\mu$  (muons)

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear

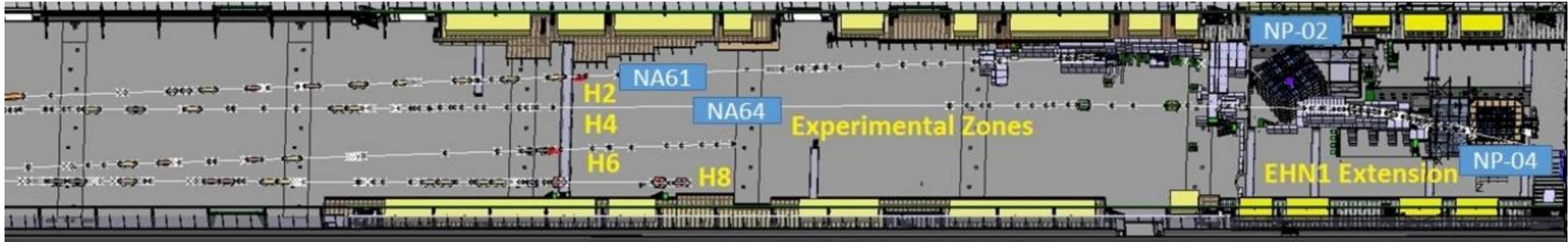
Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE-ISOLDE - Radioactive

EXperiment/High Intensity and Energy ISOLDE // MEDICIS // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator //

n\_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // Neutrino Platform



# North Area of CERN SPS

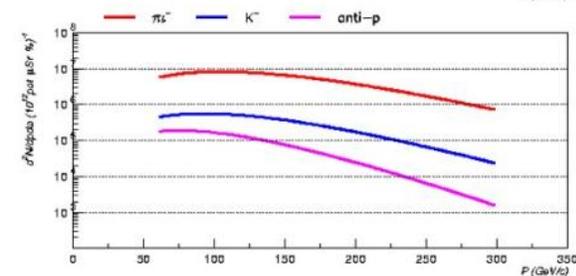
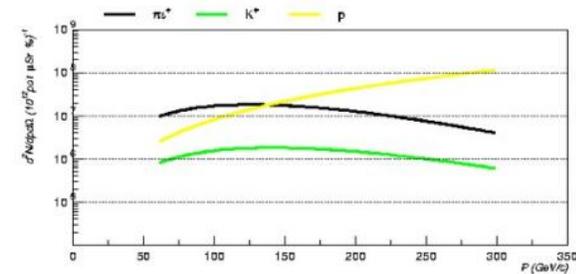


## The EHN1 experimental hall

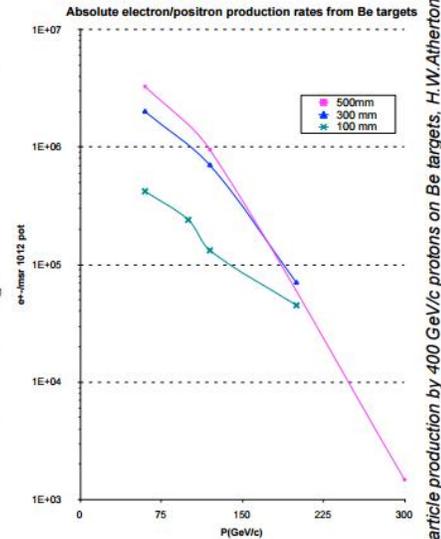
400 GeV/c beam from the SPS impinges on 3 Be targets, producing essentially all the secondaries that can be chosen with the magnetic spectrometers of the secondary lines.

- N.B: Slow extraction, 4.8s spill duration, 1 spill ~20 seconds
- Electron beams available for test-beams only in EHN1 (H2/H4/H6/H8 lines)

### Hadron beams



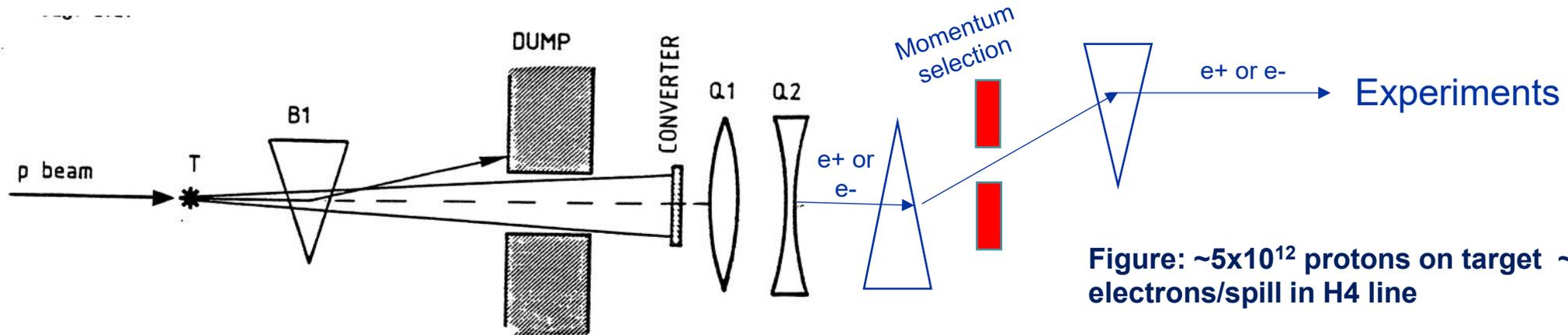
### Electron beams



Particle production by 400 GeV/c protons on Be targets. H.W.Atherton et. al.

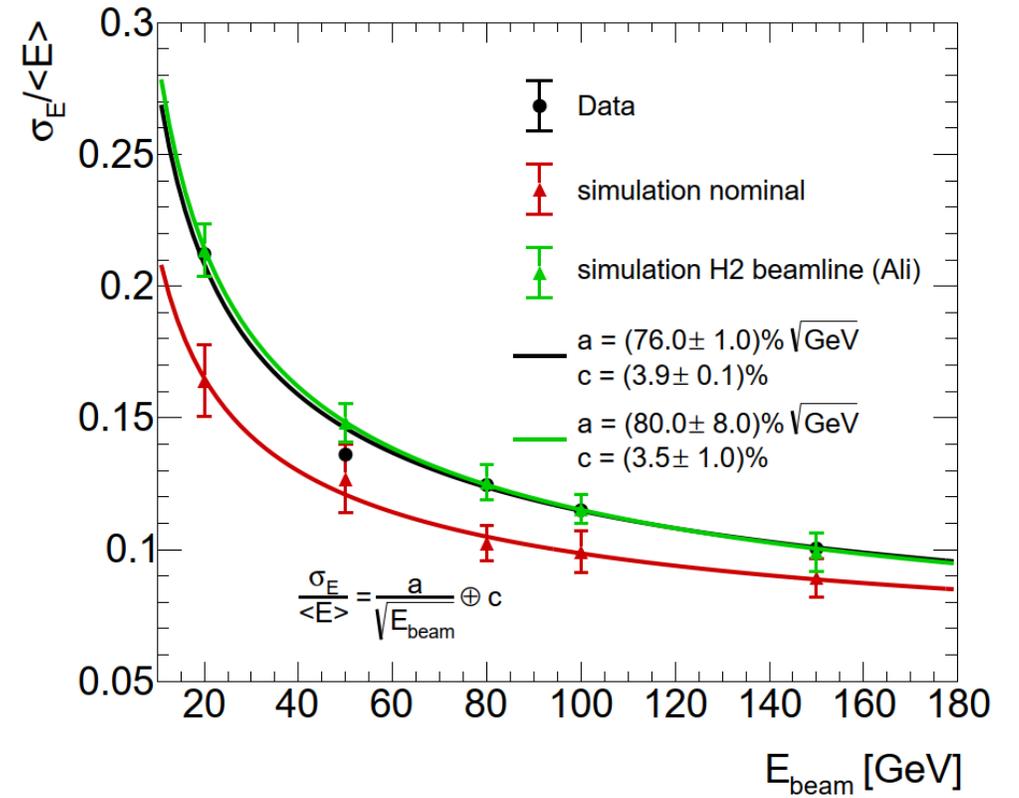
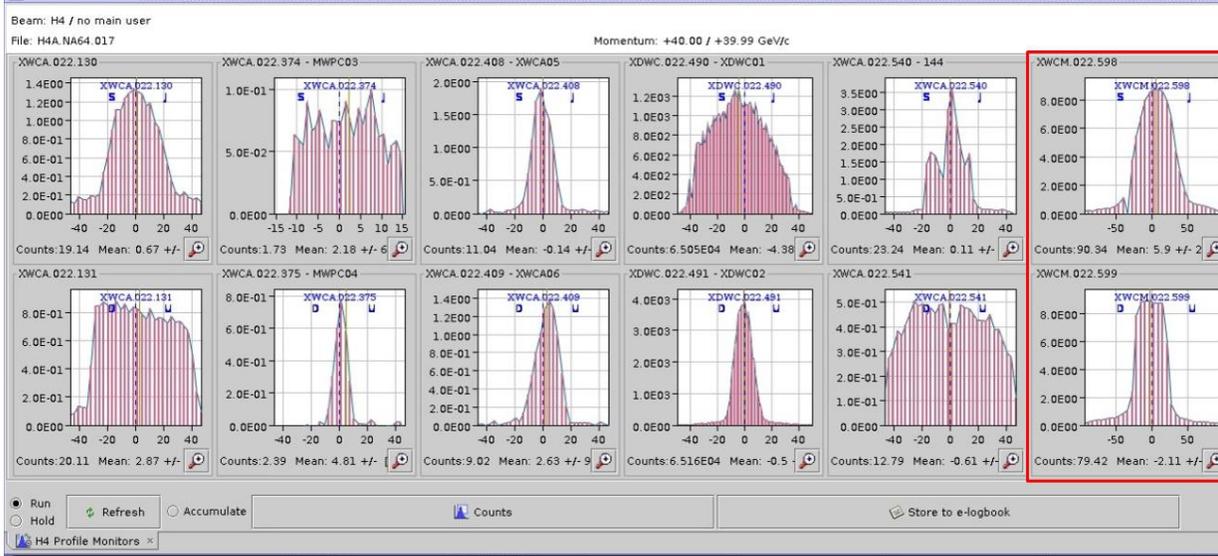
# Electron beam properties in the North Area (1)

- **Mechanism 1** : Production of electrons / positron from the neutral channel ( $\pi^0 \rightarrow \gamma\gamma$  and then, in a Pb converter  $\gamma \rightarrow e^+e^-$ )



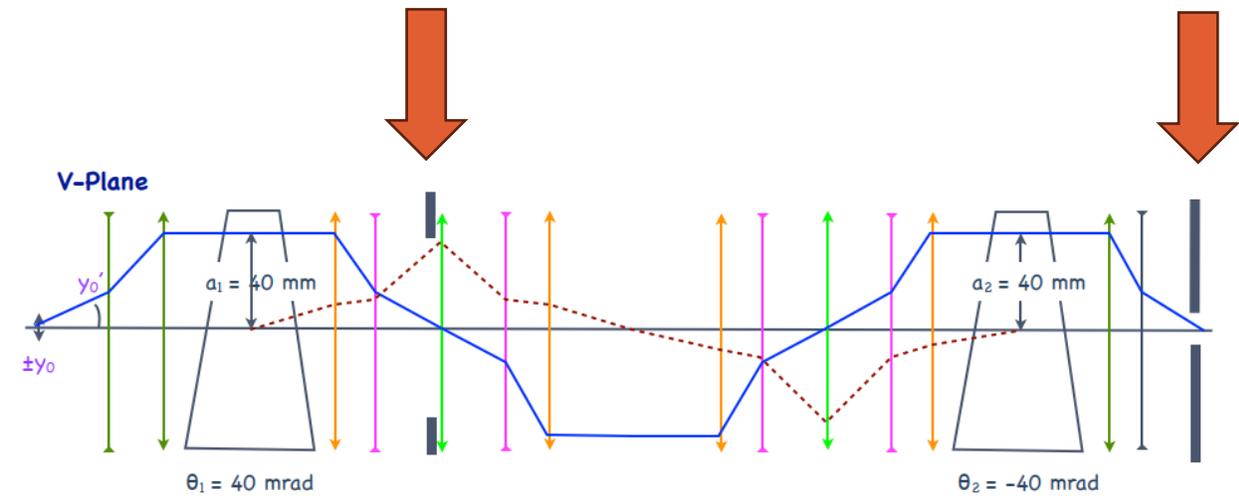
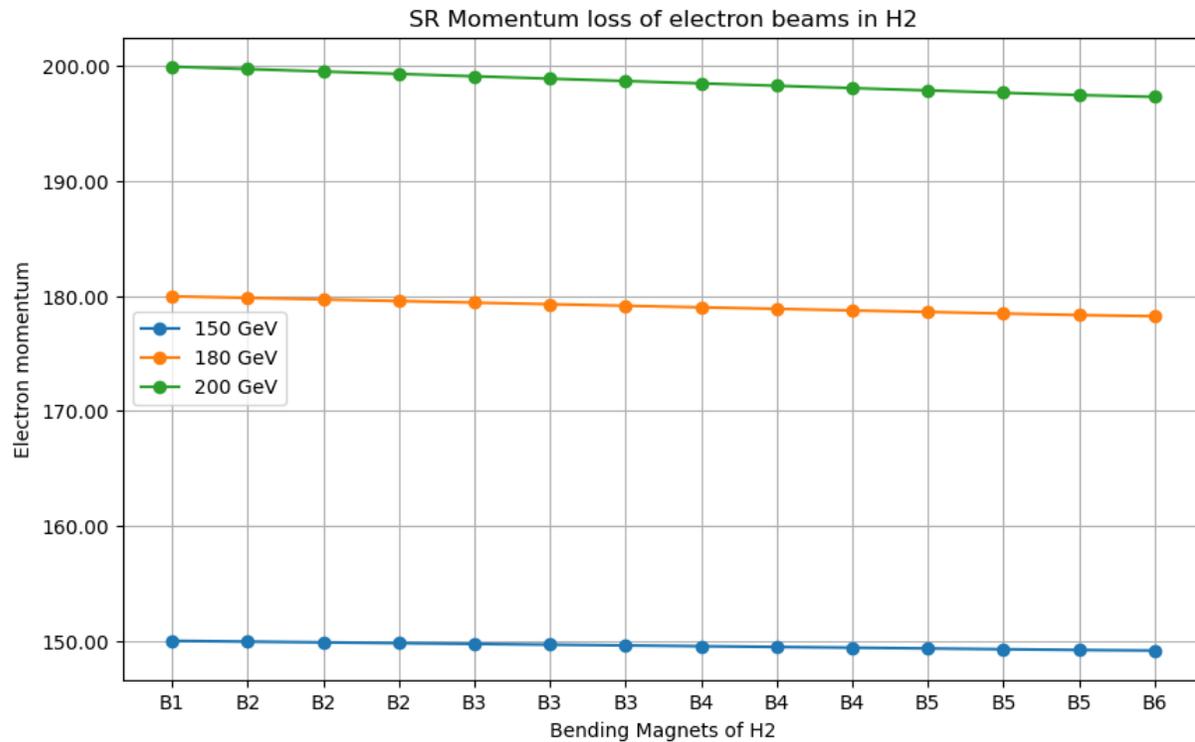
- Intensities between  $10^3 - 10^7$  particles per spill, depending on the collimation & momentum selection precision
- Purity between **50 – 100%** depending on the beamline, momentum & exact target station configuration
- Converter: Pb, 4mm thickness
- **Only available in H2 / H4 lines – H6 & H8 don't have this option**

# Examples of Electron Beams



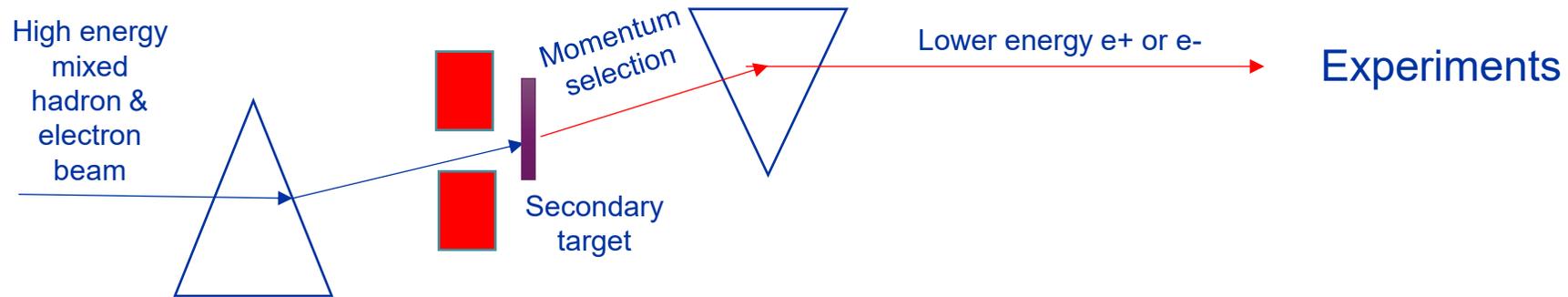
# In the high energies: synchrotron radiation helps !

- In the electron / positron moment  $> 120 \text{ GeV}/c$ , we can 'clean' the beam by adjusting the magnets for the lower electron momentum and collimating away the hadrons.



# Electron beam properties in the North Area (2)

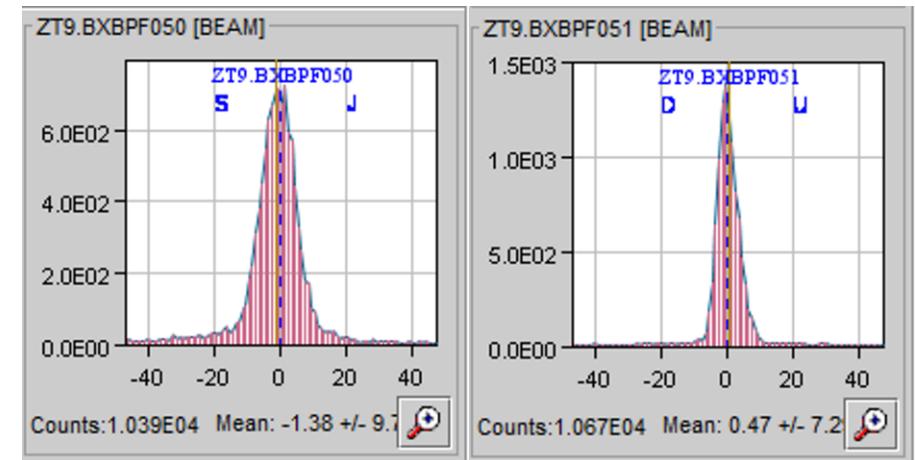
- **Mechanism 2** : Bremsstrahlung of electrons/positrons produced at the upstream targets, using a secondary target



- Intensities between  $10^2$ –  $10^4$  particles per spill, depending on the collimation & momentum selection precision
- Purity between 10 – 90% depending on the beamline, momentum & exact target station configuration
- Secondary target: Cu, Pb, 3 – 300mm
- Available in H6 & H8 beamlines

# 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, operating under vacuum
  - Can also be used for measurements of beam divergence
- **Pb glass calorimeter available on request**



# 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

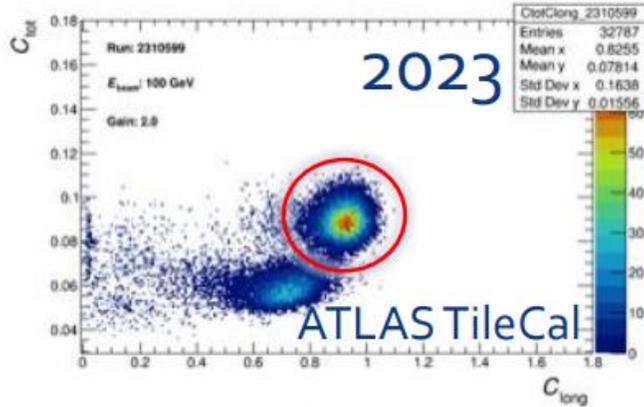
The screenshot displays the CESAR GUI 9.7.3 interface. The main window is titled 'Magnet Status [Magnets]' and shows a table of magnet parameters for beam ZT10 / ZT10-EXP. The table includes columns for Magnets, Read, BeamRef, Max, Duration, Polarity, Info, F, and Comments. Below the table are control buttons for Run, Hold, Refresh, Refresh All, Refresh Selected, Set Current, Set Duration, SET TO BEAM R..., Display Faults, Rectifier Status, and Store to e-logbook.

The 'Triggers Status [Triggers]' panel is also visible, showing a table of trigger parameters for beam ZT10 / ZT10-EXP. The table includes columns for Triggers, Count, Normalized, Norm count, Coincidence, Coinc. count, TDC count, HV, HV BeamRef, Pos, Info, and Comments. Below the table are control buttons for Run, Hold, Refresh, Refresh All, Refresh Selected, Move In, Move Out, Restore HV, and Store to e-logbook.

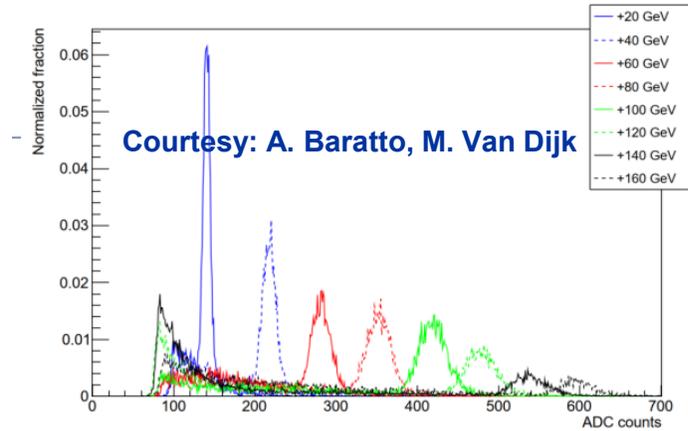
On the right side of the interface, there are two plots showing beam profiles. The top plot is titled 'ZT10 Scintillating Fiber...' and shows a peak at approximately 0. The bottom plot is titled 'ZT10 BXBP046 [SELF]' and shows a peak at approximately 0. Both plots have a y-axis labeled 'Counts' and an x-axis labeled 'Mean'.

# Examples of electron beams in EHN1

...as measured by the various experiments

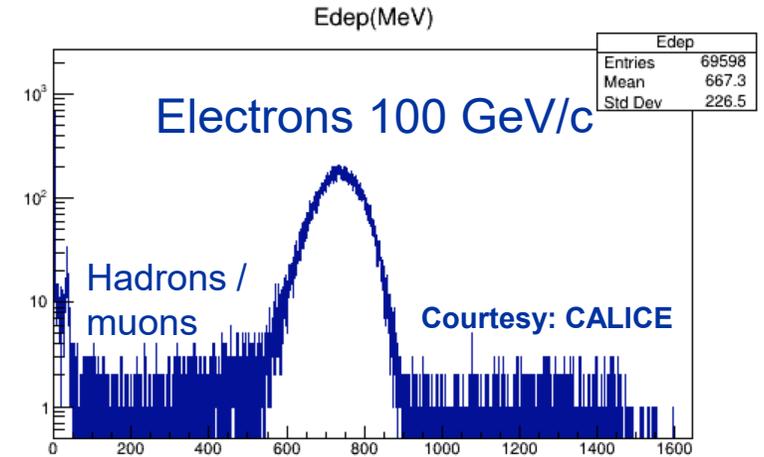


H8



Courtesy: A. Baratto, M. Van Dijk

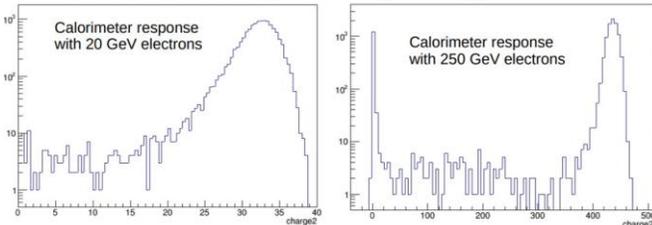
H8



H2

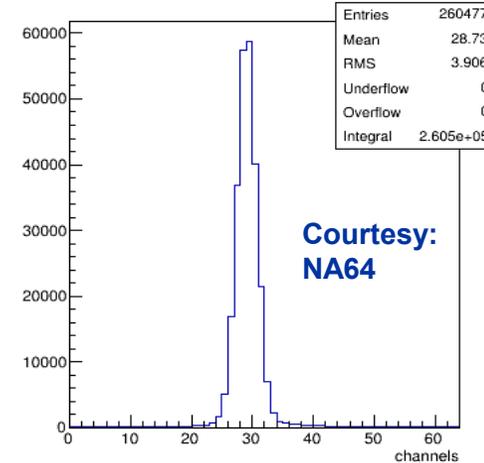
## Beam Quality

- Had excellent beam quality for electrons, muons, pions
- Very high purity achieved after wobbling change of Friday
- Adjusted momentum collimators for some runs to reduce momentum spread at high energy



H4

## ST01X channels distribution

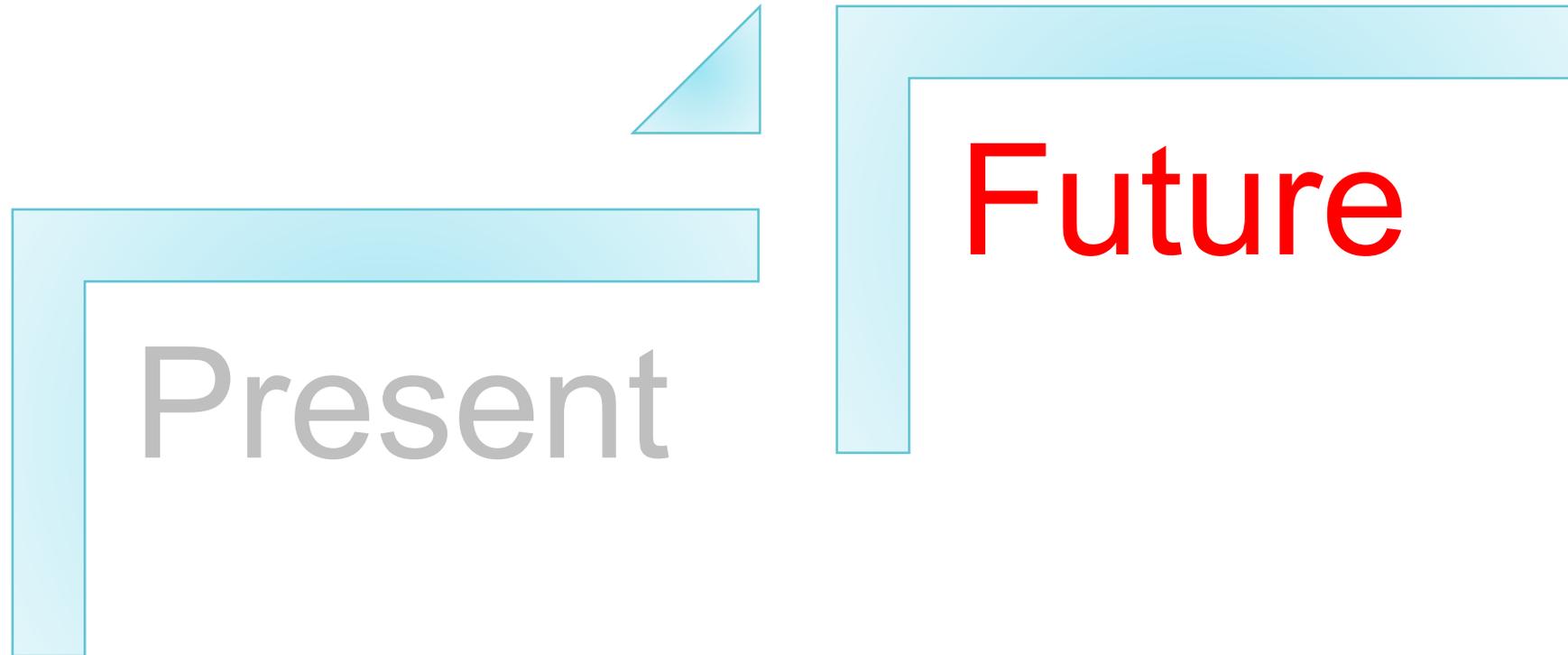


Courtesy: NA64

H4

Many thanks to Bastien and Nikos for their prompt and efficient work in setting up beams experiments for initial requirements. Managed to cover almost the full momentum range for electrons. Courtesy: FASER

# Future Proton-driven Facilities



# Future Proton Facilities – CERN ECN3

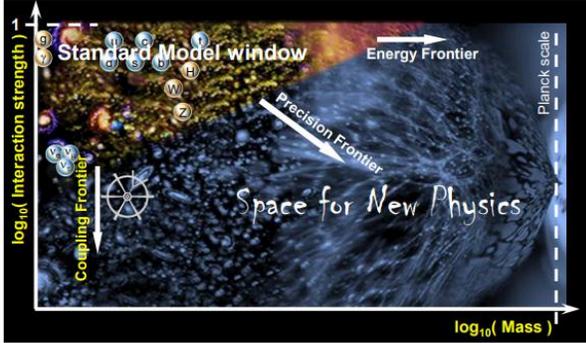
- New proposals are coming up for the North Area
- **BDF/SHiP** : An experiment that would allow a full investigation of hidden sectors in the GeV mass range.
- **SHiP** would require unprecedented intensity extracted towards the CERN North Area ( $4 \times 10^{13}$  protons / slowly extracted spill –  $O(4 \times 10^{19})$  protons per year)
- **More requests for electron beams are to come up ?**
  - higher intensities...?
  - Crystal studies ...? More collimated and bright beams ?



## Challenge accepted



- Outstanding *observed features* that SM does not resolve, and with no experimental hints / guidance so far!
  - Precision cosmology: Evidence for dark matter is overwhelming
    - Neutrino oscillation: Mass hints to new potentially weak fields
    - Baryon flavour precision: Absence of explanation for matter-antimatter asymmetry
- **New Physics** should either be very heavy OR interact very feebly to have escaped detection!



“Coupling Frontier” : Any Particles engaging in Feeble Interactions (FIPs) with the SM particles

→ Sharing the Universe already with feebly coupled, not-understood neighbours...!

Standard Model mass scale is particularly interesting to explore... – we know for sure it exists!...

Chamonix Workshop 2025, Chamonix, France – 29 January 2024 R. Jacobsson 2

# Summary

- The CERN's secondary beam areas are excellent facilities for providing high quality electron beams, in a variety of intensities and purities
  - Many fixed target experiments & R&D efforts have made use up-to date and more are to come
- The future “landscape” will include higher proton intensities extracted towards the NA targets
- If there are requests for exciting experiments, don't hesitate to contact us !

*Looking forward to seeing you (also) at CERN!*

East Area – Secondary Beamlines



Don't hesitate to contact us :

[sba-operation@cern.ch](mailto:sba-operation@cern.ch)

<https://be-dep-ea.web.cern.ch/>

[For test-beam applications:](#)

[sps.coordinator@cern.ch](mailto:sps.coordinator@cern.ch)

<https://ps-sps-coordination.web.cern.ch/ps-sps-coordination/>

North Area Secondary Beamlines



