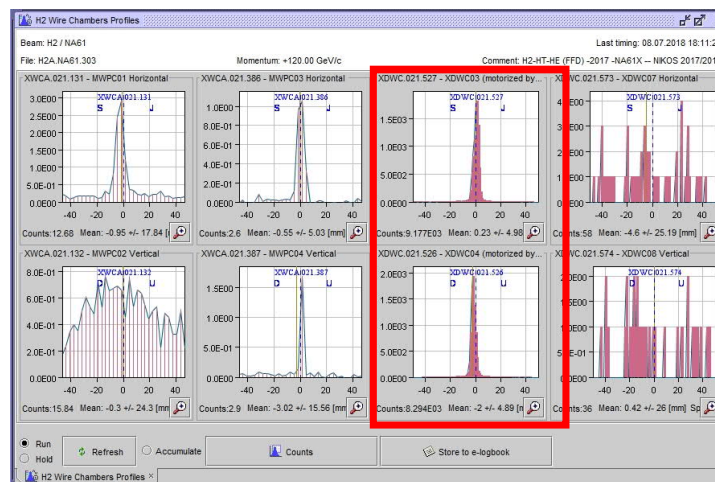
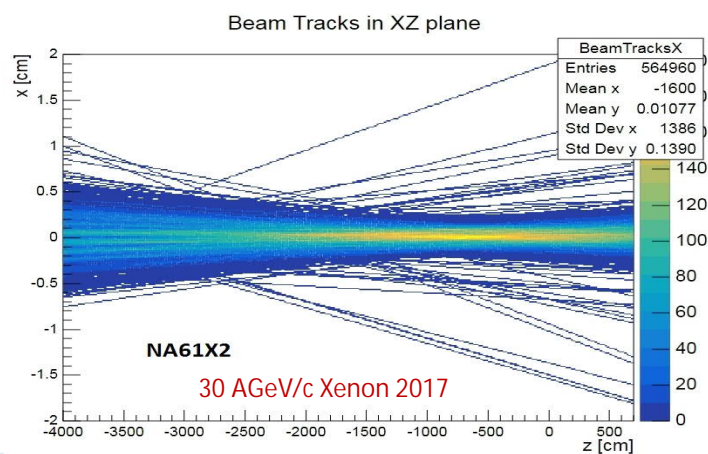




CERN SPS/H2 beam line : Providing particles for NA61/SHINE



120 GeV/c protons 2018

N. Charitonidis (CERN, EN-EA)

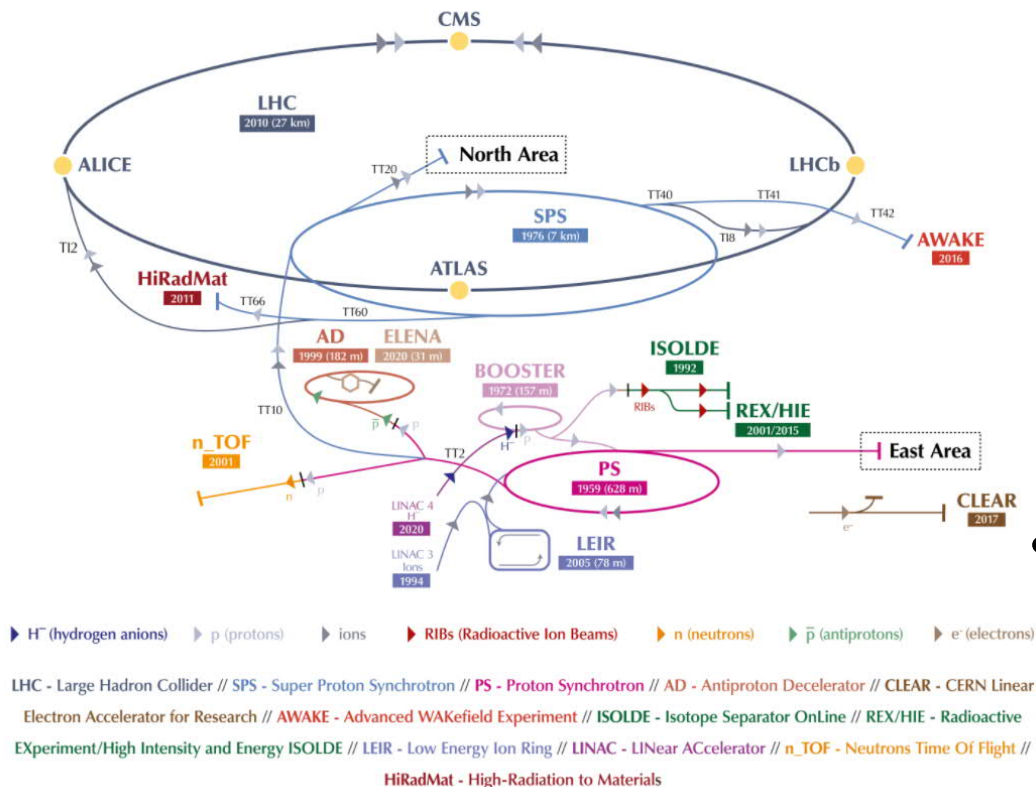
October 2020

Presentation outline

- Introduction– CERN accelerator complex
 - LHC & Injectors
 - SPS and North Area
- H2 beam line for NA61
 - Beam line Operational Principles
- Summary & Future

CERN accelerator complex

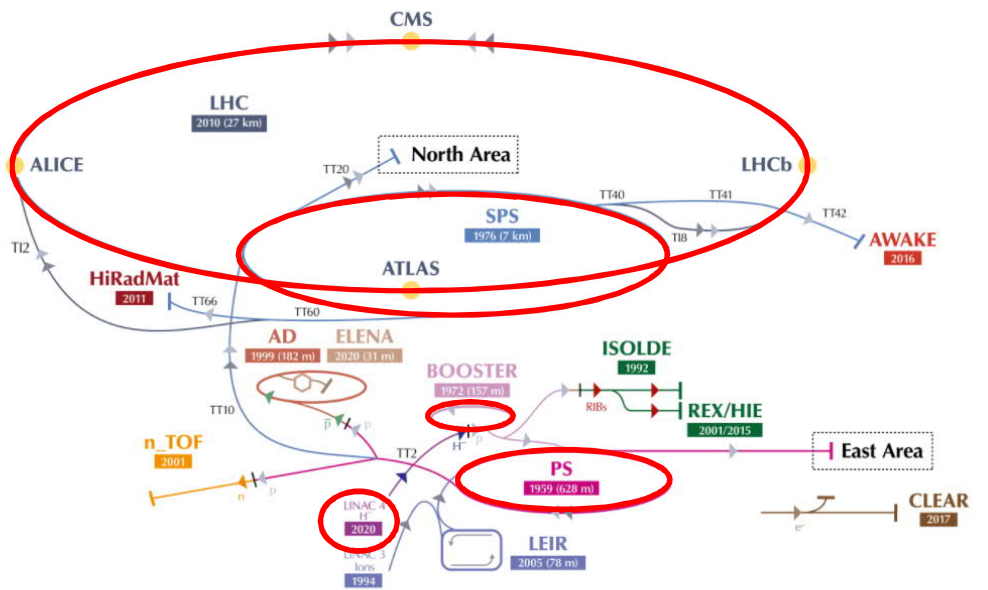
The CERN accelerator complex
Complexe des accélérateurs du CERN



- A “complex” complex of *machines* that produce, accelerate, transport or collide particles with fixed targets or with other beams.
 - Machines that collide beams are referred to as “colliders”
 - LHC the largest collider constructed up-to-date!
- Since the largest machine is the LHC, the accelerators that “inject” LHC with particles may be referred to as “injectors”

CERN accelerator complex

The CERN accelerator complex
Complexe des accélérateurs du CERN



▶ H⁻ (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons) ▶ \bar{p} (antiprotons) ▶ e⁻ (electrons)

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 - Radioactive Experiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials

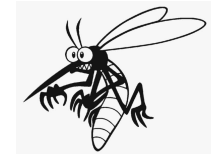
• Protons

• Linac4 → Booster → PS → SPS → LHC

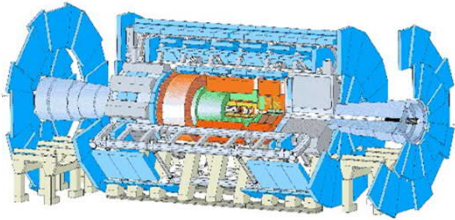
• Increasing momentum from eV/c → TeV/c

• LHC collides beams at 13 TeV/c center of mass → Plans for the future to collide at 14 TeV* and higher in the future.

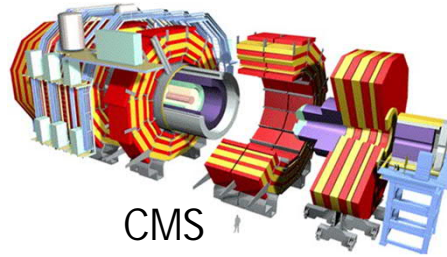
* 1.5 TeV/c : The kinetic energy of a mosquito moving....



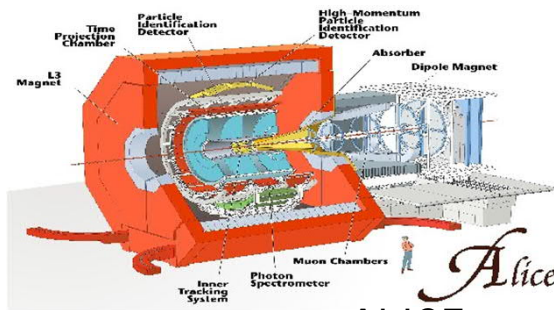
Large LHC Experiments



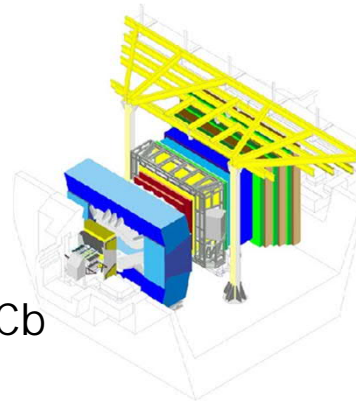
ATLAS



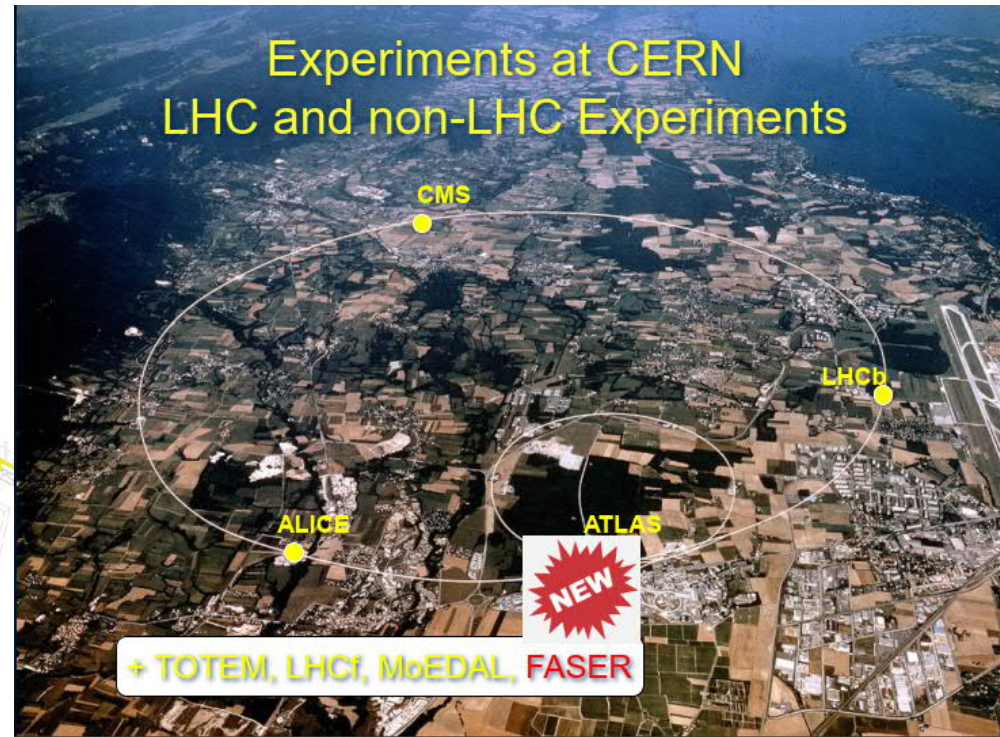
CMS



ALICE



LHCb



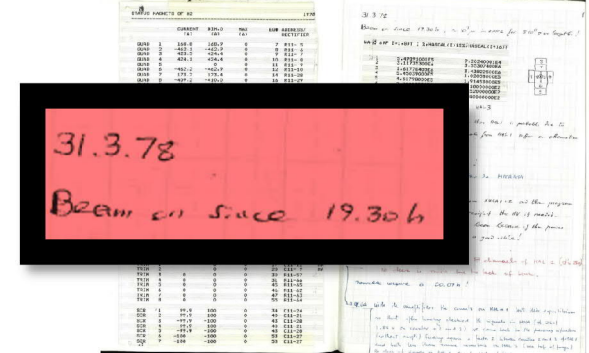
The CERN's Secondary Beam Areas

- All the injectors the particles circulating are *protons* (for most part of the year) or *various species of ions* for a few weeks / year.
 - SPS a fixed momentum of 450 GeV/c protons
 - PS a fixed momentum of 24 GeV/c protons
 - Fixed Target Experiments (like NA61/SHINE) are studying interactions of different particles, with variable energies!
 - Also: All the complex LHC experiments need different particles and different energies to calibrate properly their detectors.
- CERN Secondary Beam Lines – Facilities where all kinds of particles can be available, on a wide-range of momenta and conditions.

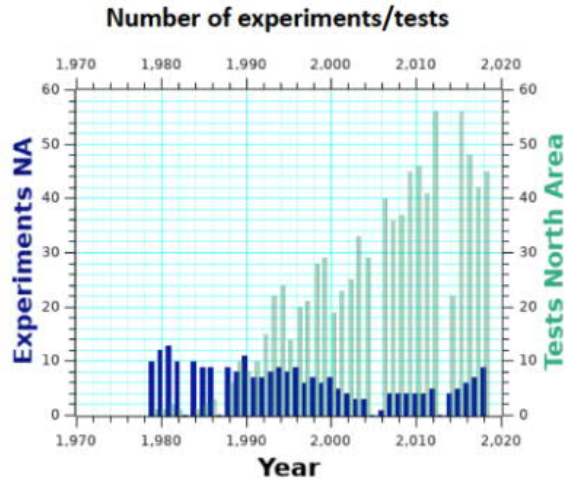
North Area Secondary Beam Lines



M2 was the first beam to be switched on in 1978

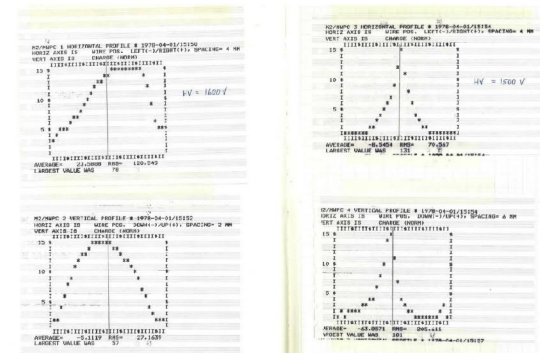


Since then, very exciting physics program with very important physics results:



Experiment	Publications (INSPIRE – 2020)
NA58 (COMPASS)	1016
NA61 (SHINE)	415
NA62	229
NA63	9
NA64	8
NA65 (DsTAU)	8
DUNE	68
...	...

First Beam Profiles



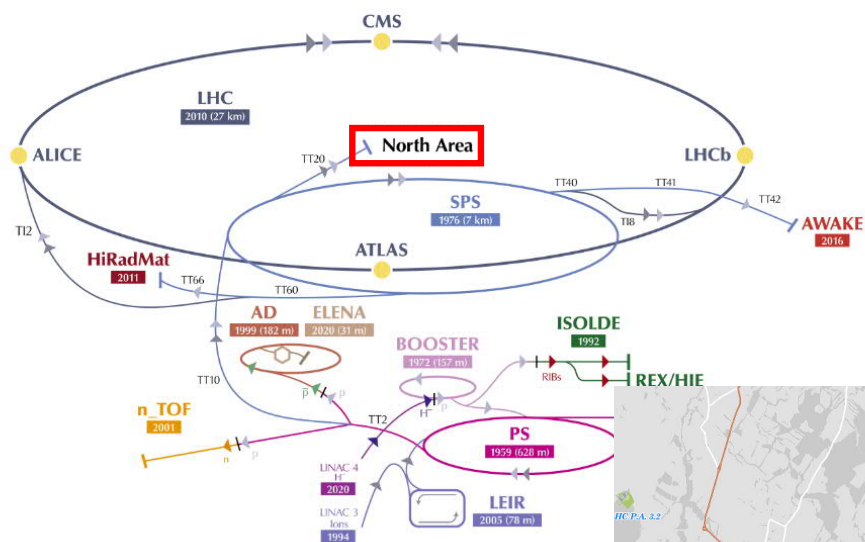
29/10/2020

N. Charitonidis - Overview of NA line operation after LS2

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North Area Secondary Beam Lines

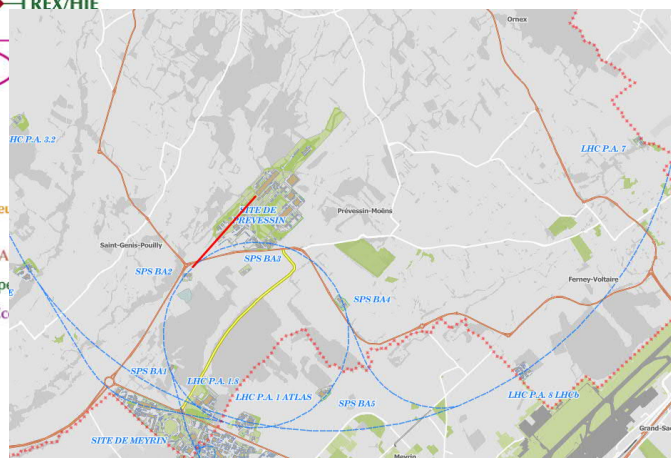
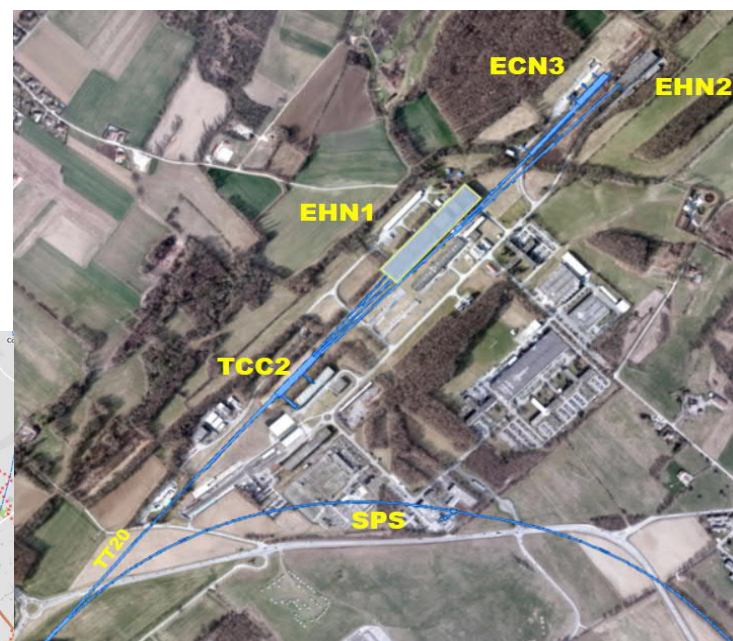
The CERN accelerator complex
Complexe des accélérateurs du CERN



▶ H^- (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons)

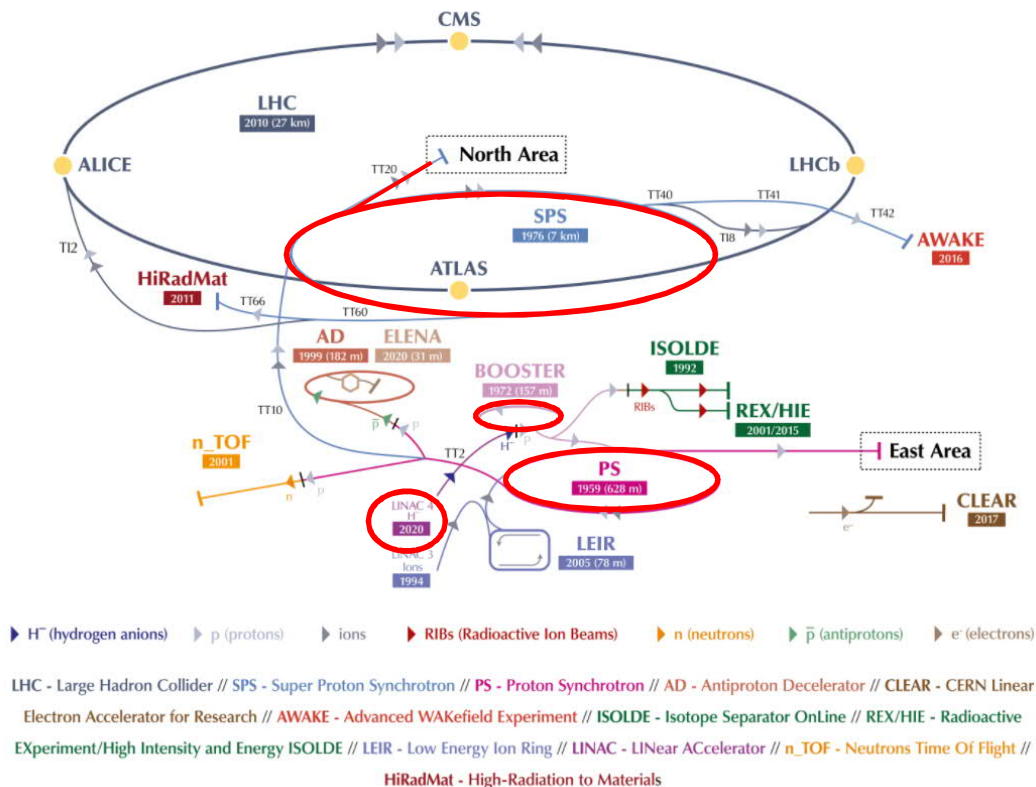
LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - A Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Experiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACCELERATOR
 HiRadMat - High-Radiation to Materials

Unique facilities hosting many permanent fixed-target experiments and temporary "test-beams"



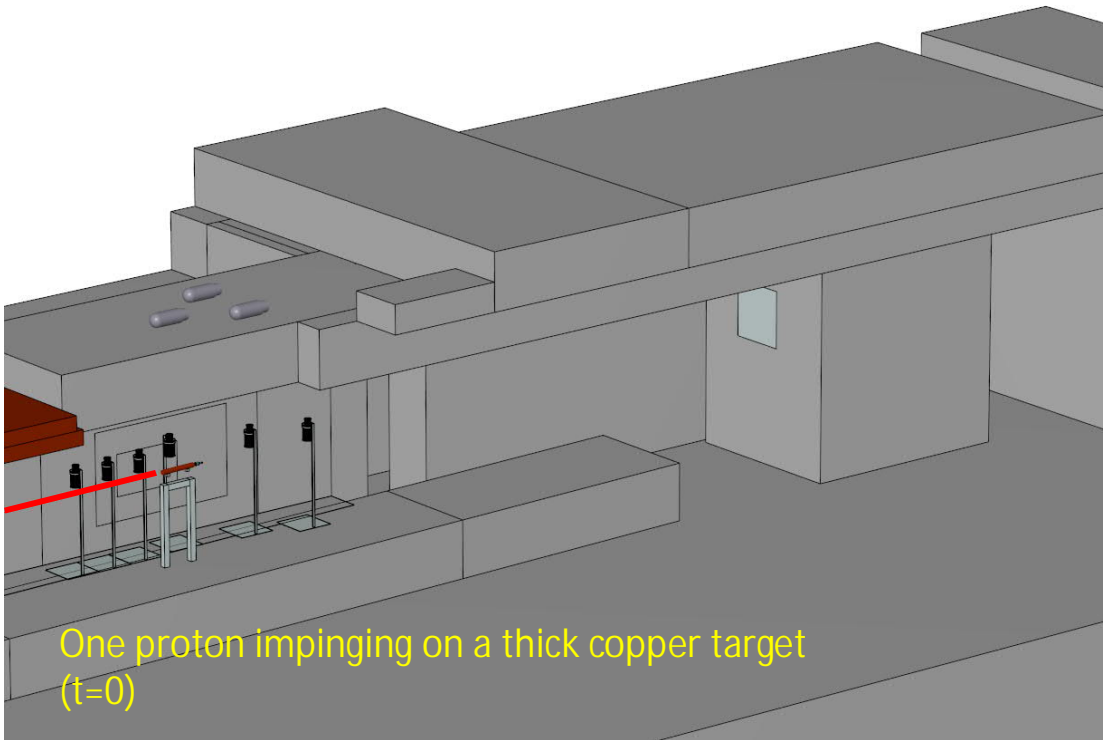
CERN accelerator complex

The CERN accelerator complex
Complexe des accélérateurs du CERN

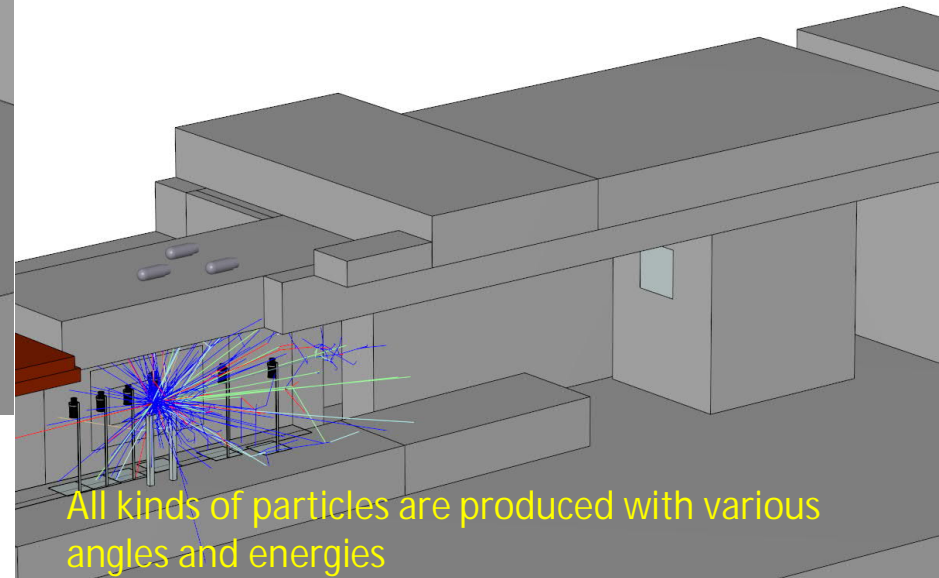


- Protons from SPS are extracted towards the North Area Targets via the transfer line TT20.
- The 400 GeV/c beam is impinging to 3 different targets in order to produce the secondary particles that the various experiments need.
- The H2 line that serves NA61 starts from the "T2" target.

Secondary Particle Production

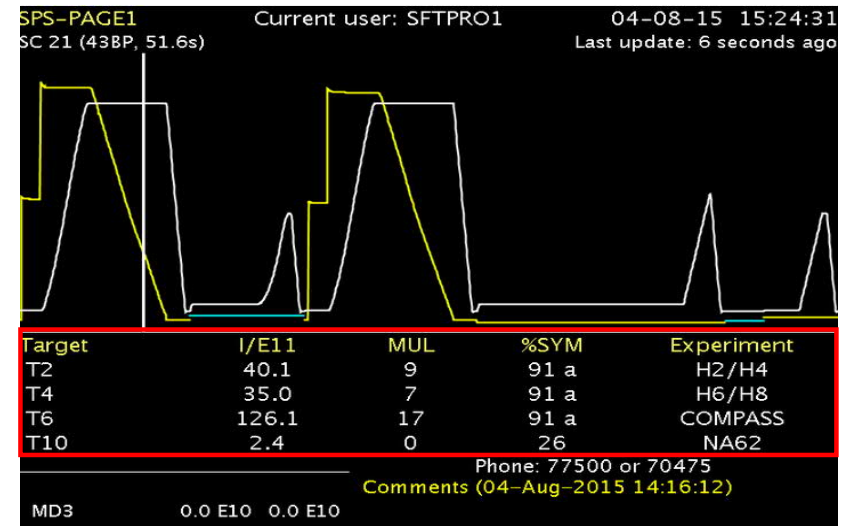
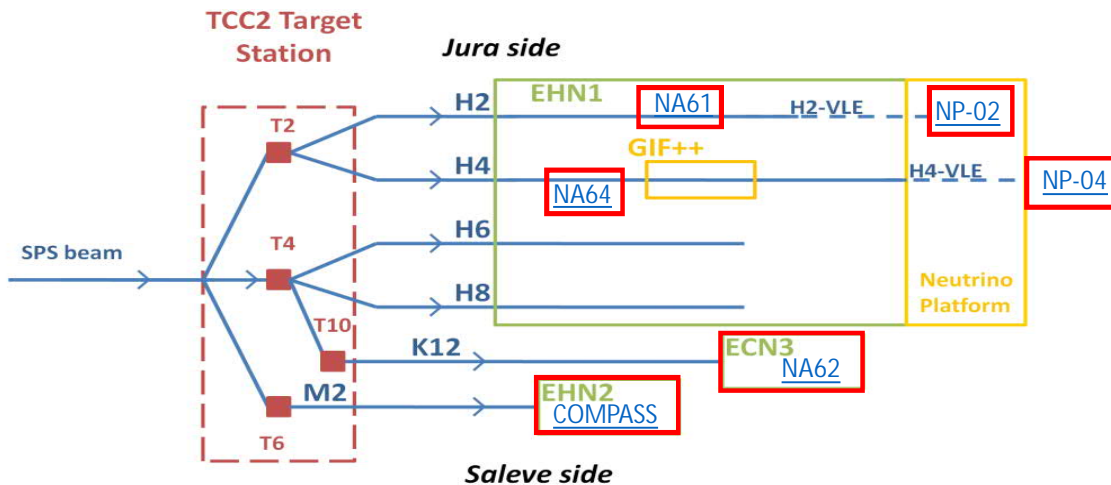


Using that very simple principle, and extracting the 400 GeV/c proton beam from SPS we produce secondary particles that subsequently are selected and transported to the various experiments (including NA61/SHINE)

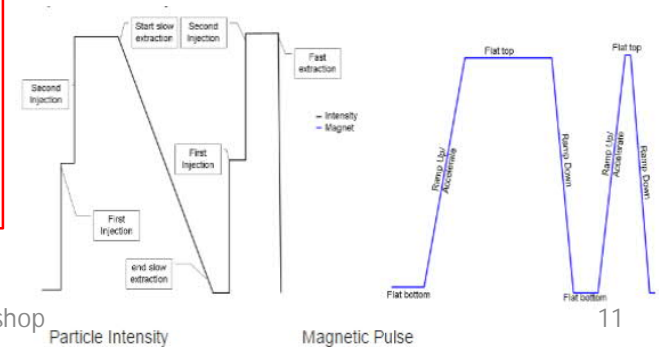


North Area Secondary Beam Lines

The 400 GeV/c primary beam from SPS is *slowly* extracted onto 3 'primary' targets



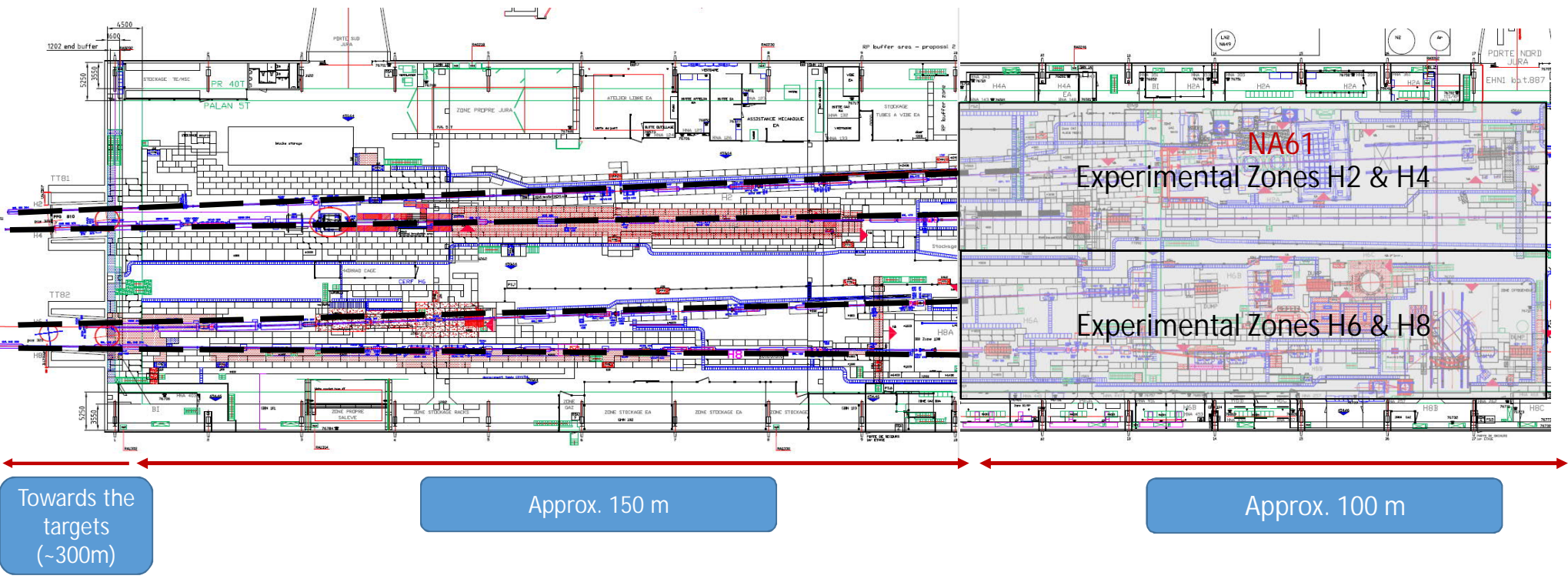
- Spill duration approx. 5 seconds
- Usually : 2 cycles / SPS supercycle for NA
- Cycle length / repetition frequency dependent on the physics program of all the facilities served by SPS plus the filling of LHC



Beams in the TCC2 target station

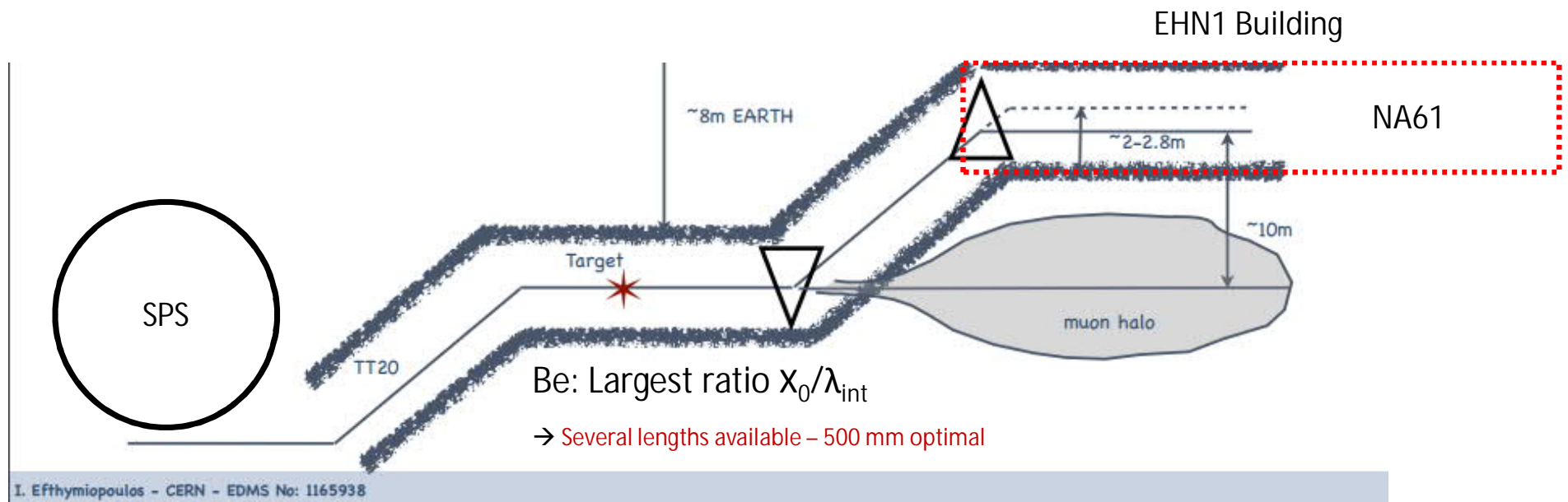


Schematic of the beam lines & experimental areas in EHN 1 Top view of b. 887 @ CERN, Preveessin

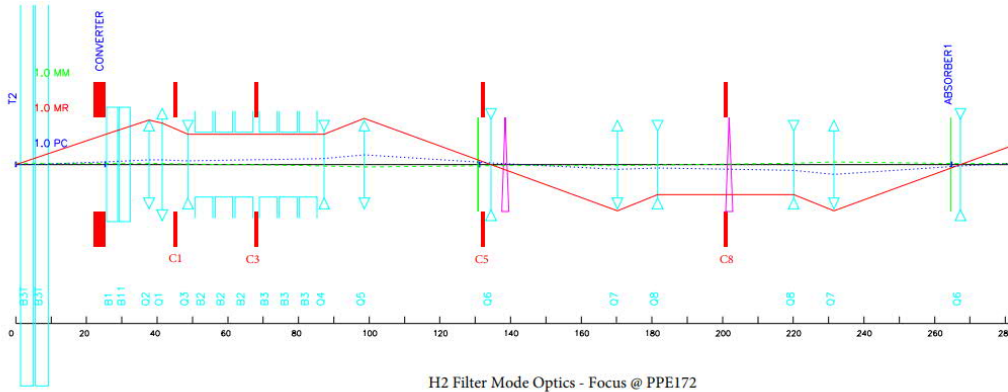


The H2 beam line of CERN – North Area

H2 : A precise (2% dp/p acceptance), robust, flexible magnetic spectrometer

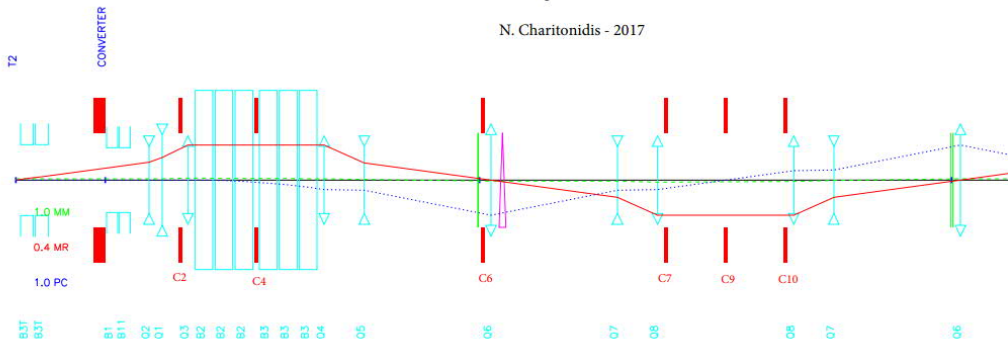


H2 optics



H2 Filter Mode Optics - Focus @ PPE172

N. Charitonidis - 2017

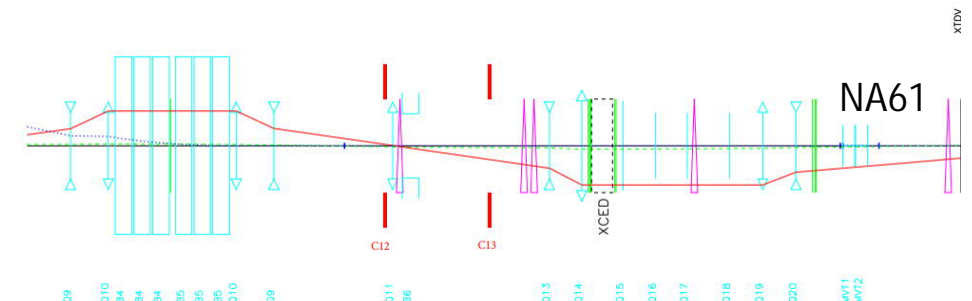
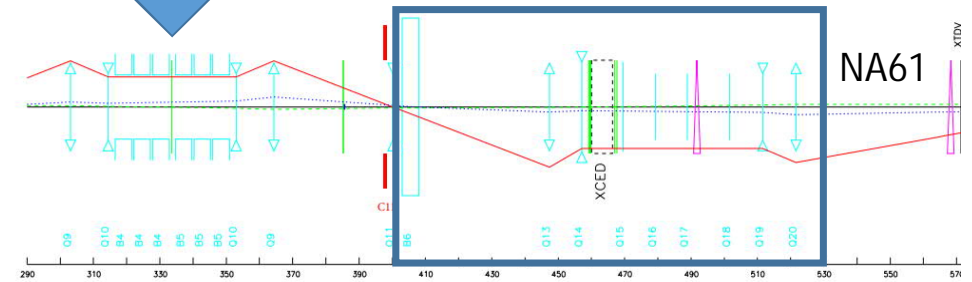


Momentum definition V-bends



Definition of beam size / divergence in NA61

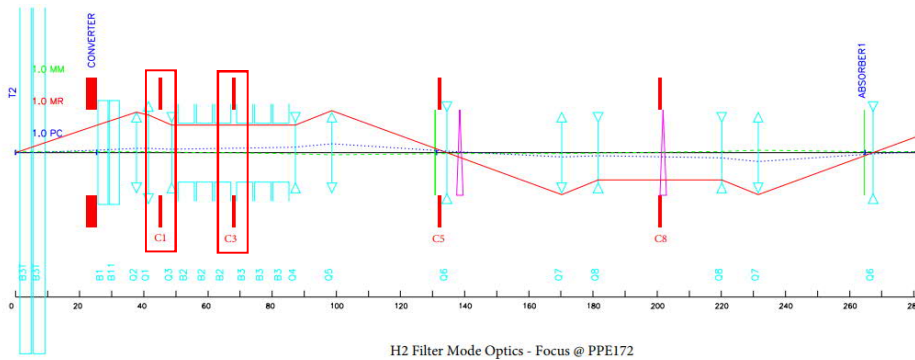
Based on factors as material, momentum, NA61 target shape...



For each NA61 application, different tuning may be necessary !

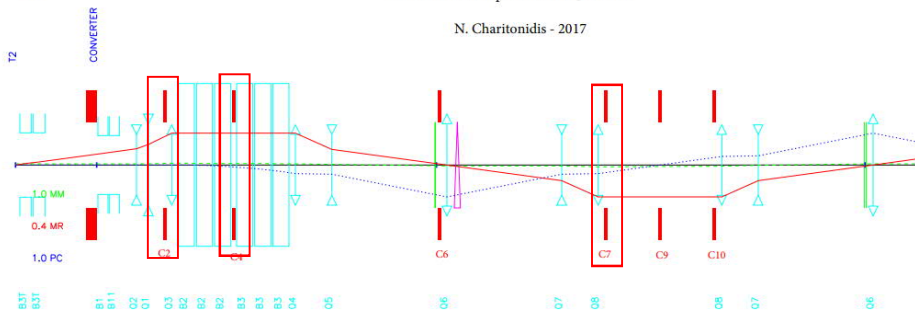
Collimators

- Acceptance collimators – Define the shape and the intensity of the beam
 - Located at the points that the beam envelope is large, allowing to define the angular aperture of the beam (“acceptance”)



H2 Filter Mode Optics - Focus @ PPE172

N. Charitonidis - 2017



29-Oct-20

N. Charitonidis – Summer Students Lecture

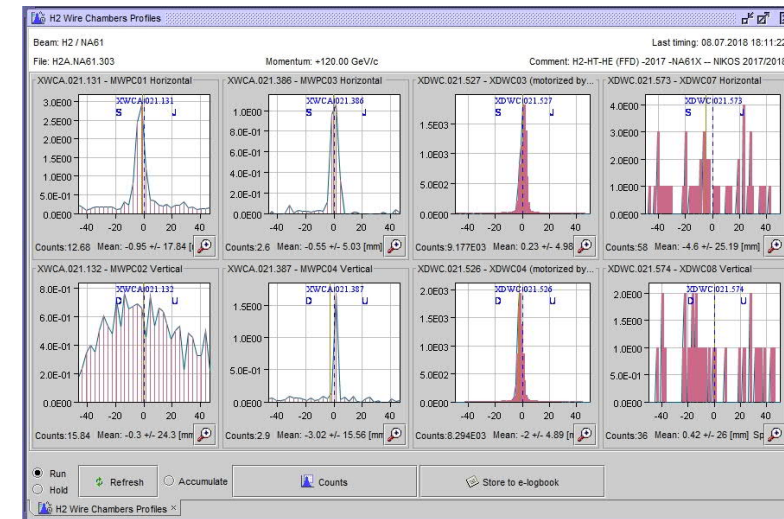
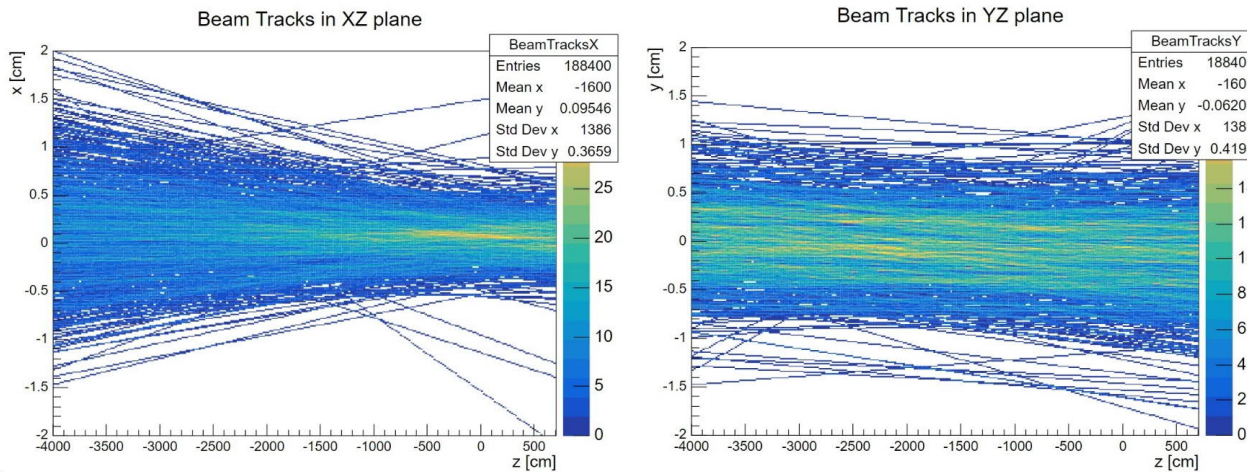
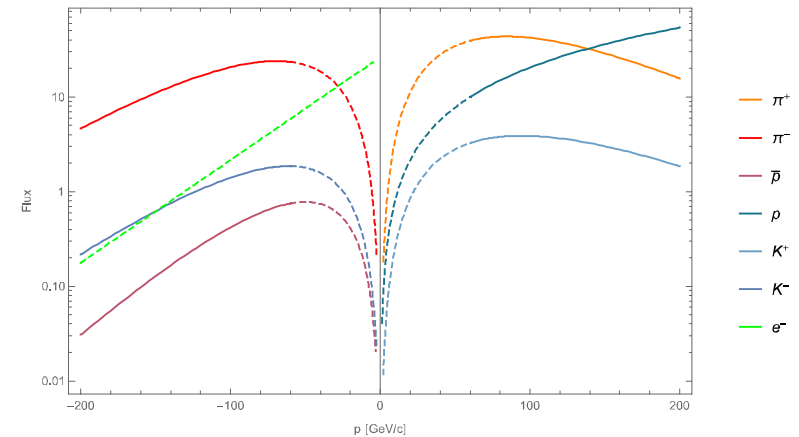
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Cleaning collimators

- A repetition of an earlier acceptance collimator in order to *clean* the secondaries created at the edges of the earlier collimators

Possibilities of H2 beam line

- Any energy of hadrons or electrons possible between $\sim 10 - 400$ GeV/c
- Positive or negative charge
- High (10^7) or low (100) particles/spill
- Variable spot size and variable "waist"



Limitations and future of H2 beam line

- Designed in the 1970s – “The 300 GeV/c working group”
 - Lower energies not favored
 - < 10 GeV impossible (also length-wise)
 - Production usually maximum @ $p_T = 0.3$ GeV/c
 - Large angles → Large spot-sizes & lower rate

CERN LIBRARIES, GENEVA



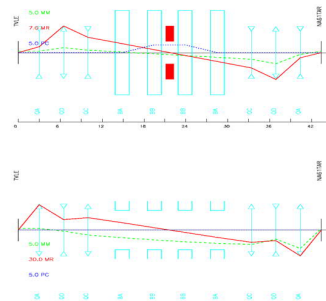
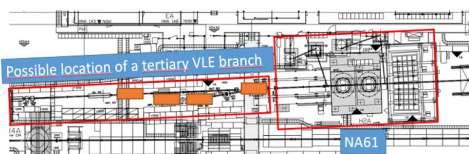
CM-P00095176

CERN/SPC/299
11 December, 1970

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

NA61++ Low energy beam ?

- A possibility of implementing a (very) low energy beam before NA61 has been preliminary studied in the PBC context.



* The possibility for a < 30 GeV/c beam, and, if possible and needed, proton enhanced (from the neutral channel) beam will be studied more in detail in synergy with NA61 starting from 2020.

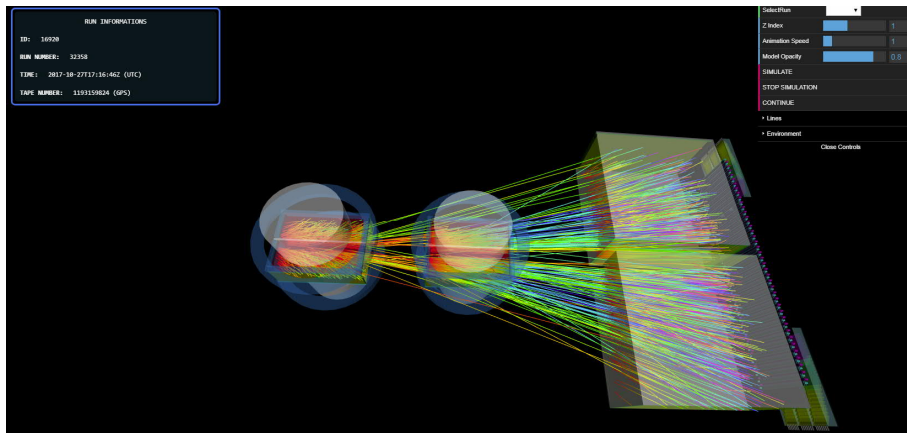
A DESIGN OF THE EUROPEAN 300 GeV RESEARCH FACILITIES

Chapter 1

A NA61-CERN working group is studying this possibility for beams < 10 GeV/c

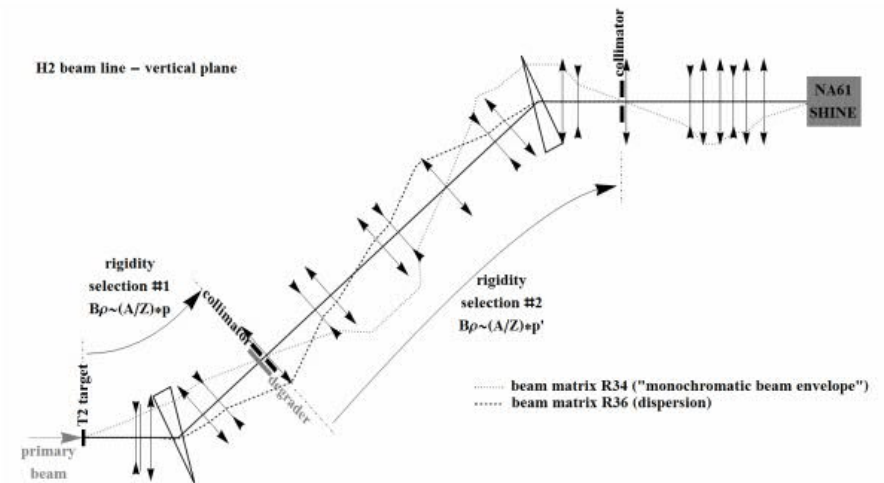
Conclusions

- An excellent collaboration between CERN and NA61 in the last years, and the optimization of H2 beam line towards serving NA61 physics goals will continue.
- Many ideas for exciting physics- Looking forward for the restart in 2021!
- In case if questions on the beam line or the accelerator chain please don't hesitate to contact me !



29/10/2020

N. Charitonidis - NA61 Outreach Seminar



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