Two New Low Energy Beam Lines at the CERN North Area: from Design to Commissioning

M. Rosenthal, N. Charitonidis, Y. Karyotakis, A.C. Booth, P. Chatzidaki, E. Nowak, I. Ortega-Ruiz, P. Sala,
P. Carriere, L. Gatignon, S. Girod, V. De Jesus, E. Harrouch, A. Rahmoun

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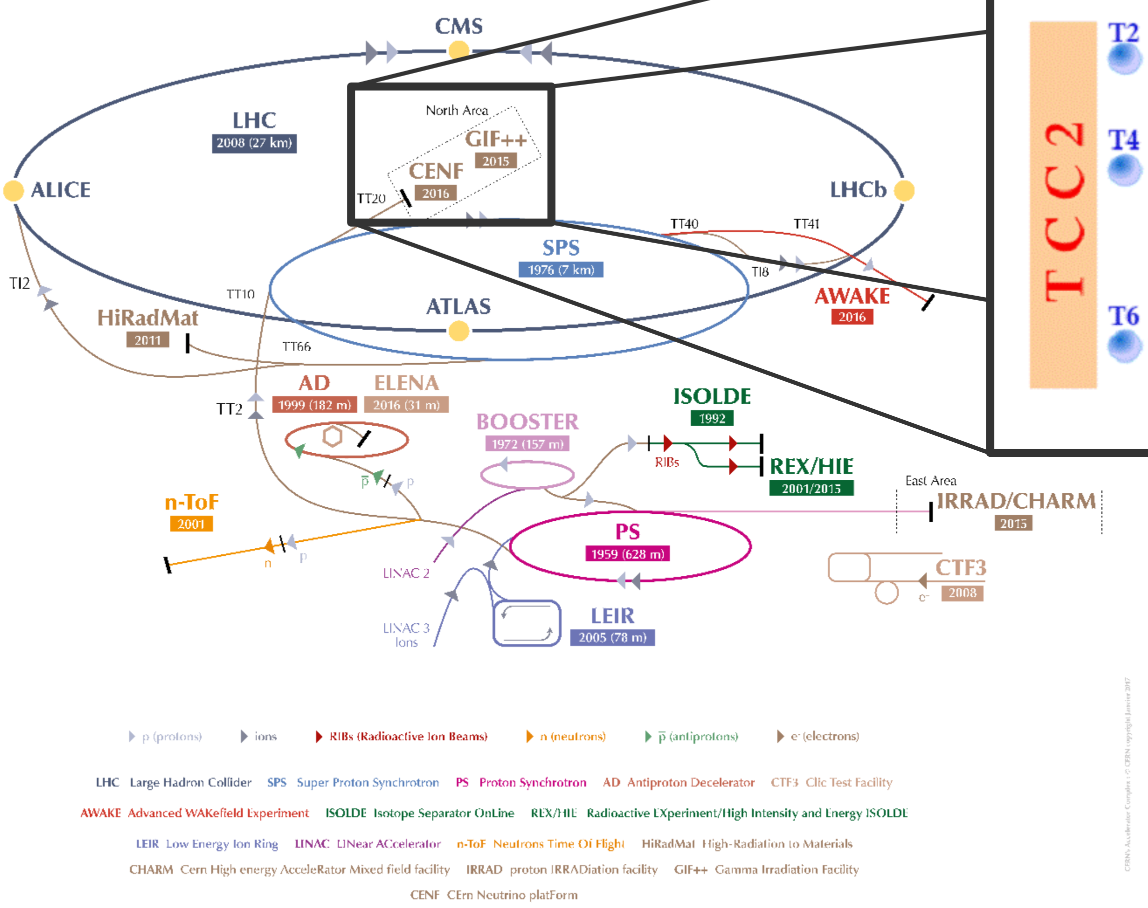
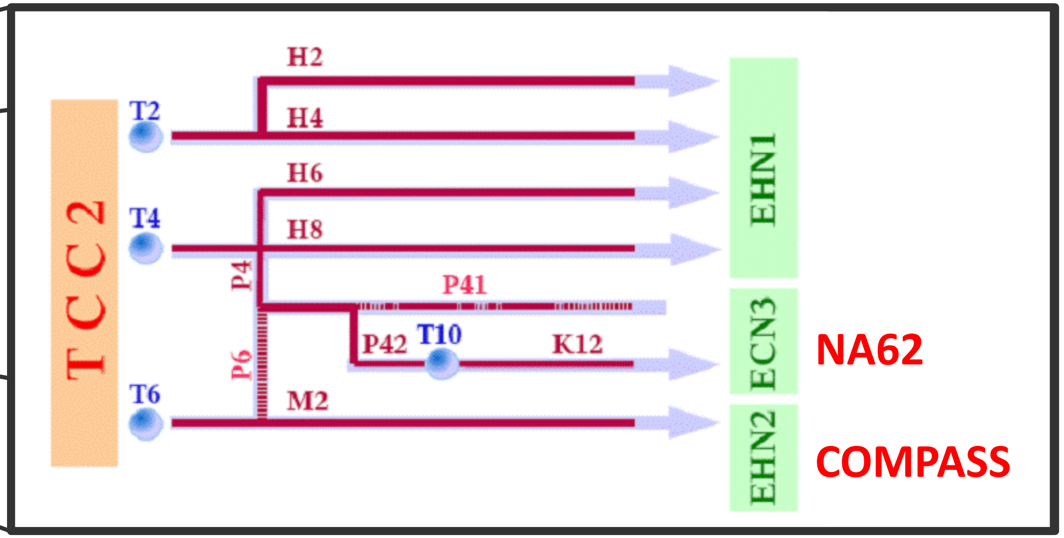
Outline

- Brief overview of the CERN North Area
- New VLE tertiary branches of the H2 and H4 beam lines
  - Beam line design, instrumentation and optics optimization
  - Development of full Monte-Carlo models and expected performance
  - Commissioning and first analysis of measured beam line data
- Summary

The CERN North Area

(see also introduction talk by A. Gerbershagen)

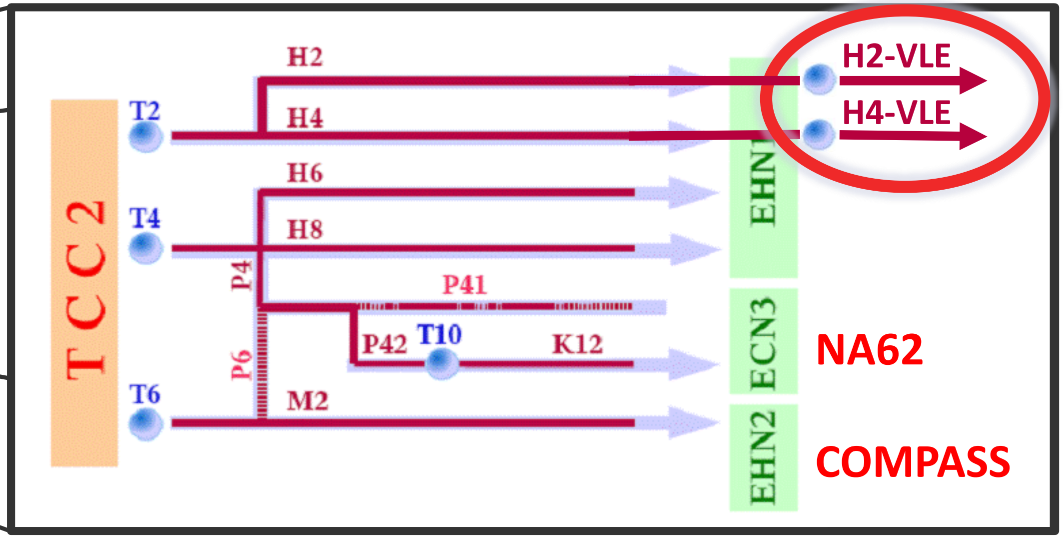


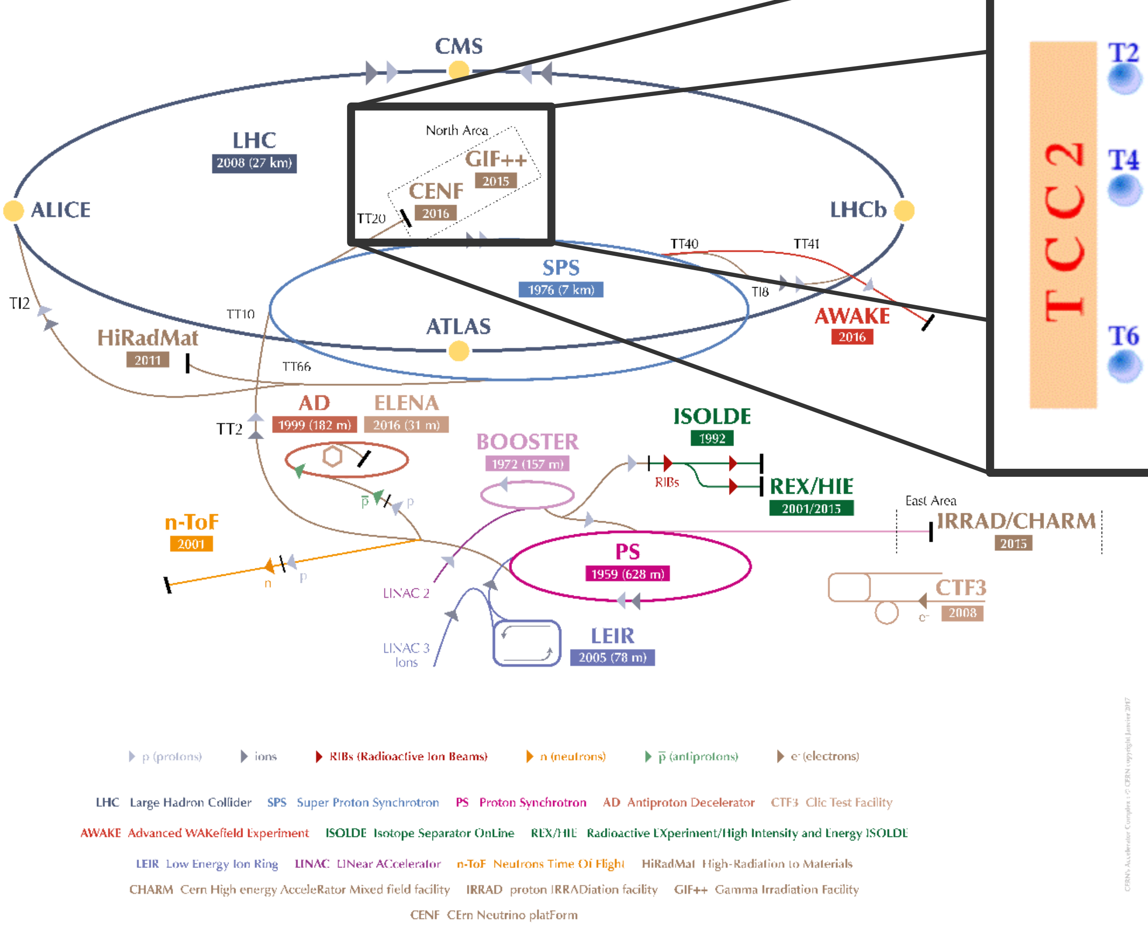


- SPS proton beam (400 GeV/c) slowly extracted and directed to North Area Targets (T2, T4, T6, T10)
- Production of secondary and tertiary beams
  - electrons, muons, hadrons
  - momentum range: ~10 GeV/c – 400 GeV/c
- Low momentum limit mainly defined by:
  - Particle production flux
  - Hardware limitations of magnets

The CERN North Area

Extended by new “very low energy” branches in 2018





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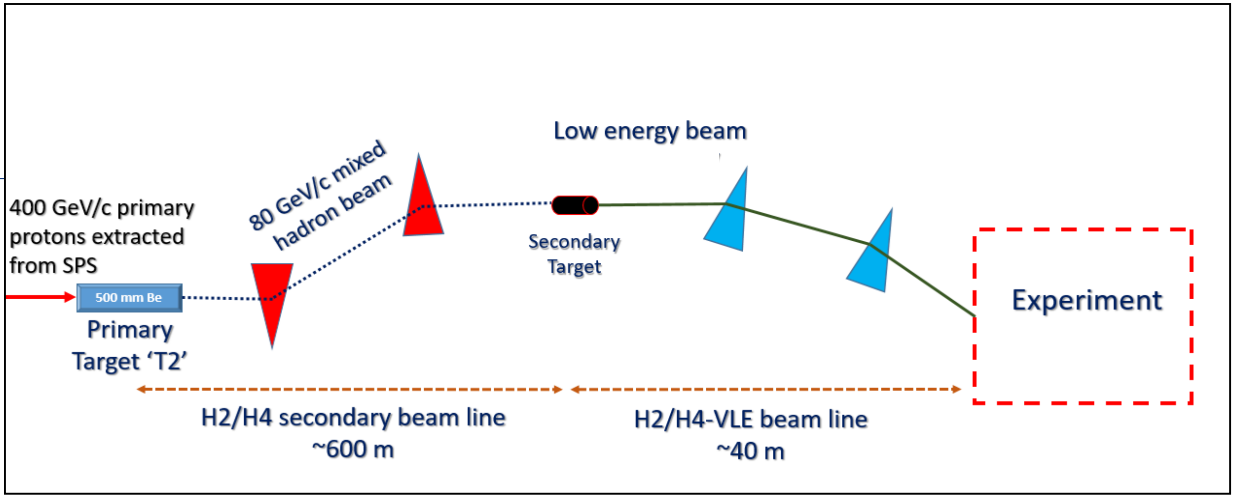
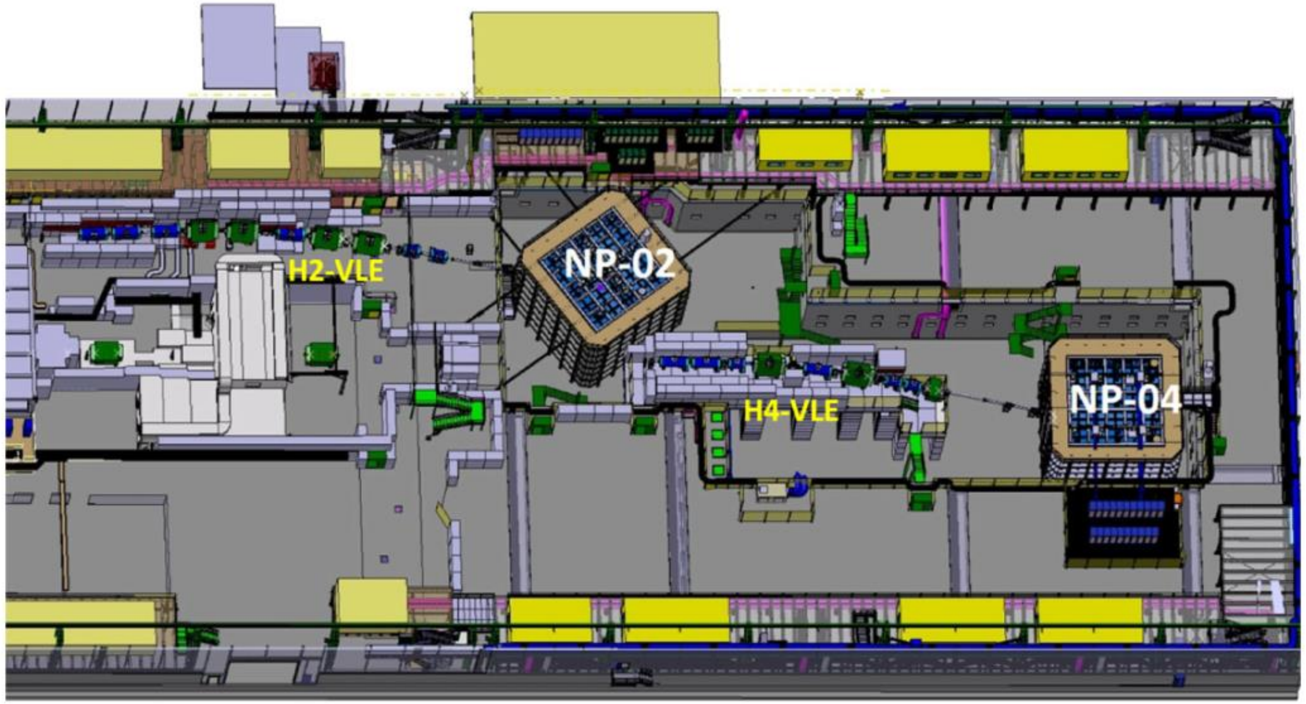
H2-VLE and H4-VLE

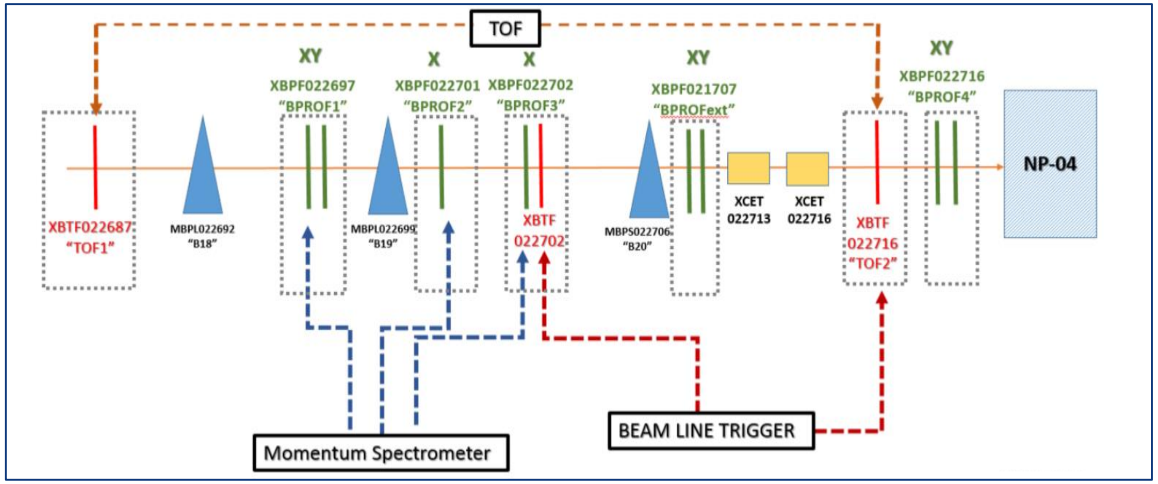
- Secondary hadron beam ~80 GeV/c on secondary target to produce locally a tertiary VLE beam (0.3 – 7 or 12 GeV/c)
- VLE beams composed of pions, protons, kaons, electrons, muons.
- Different target materials to optimize total particle rate vs. pion-positron-ratio:
  - Copper for $p > 3$ GeV/c
  - Tungsten for $p \leq 3$ GeV/c
  - (Lead for pure electron beams)
- First experiments are the two large-size detector prototypes (LAr-TPC) in the framework of the Neutrino Platform Project

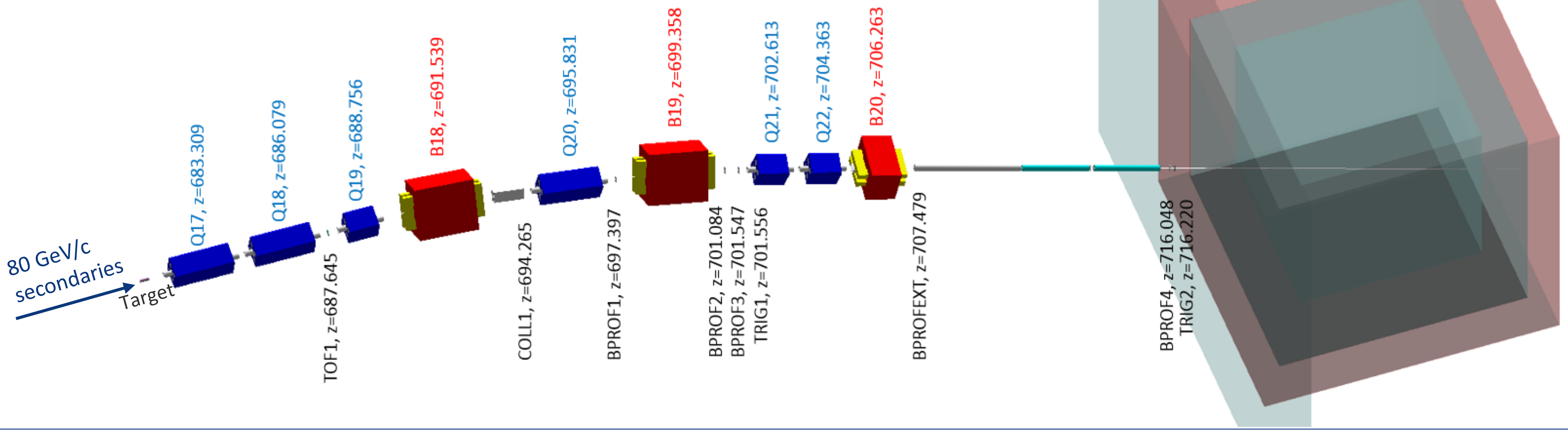




Beam Line Design (H4-VLE)

Instrumentation:

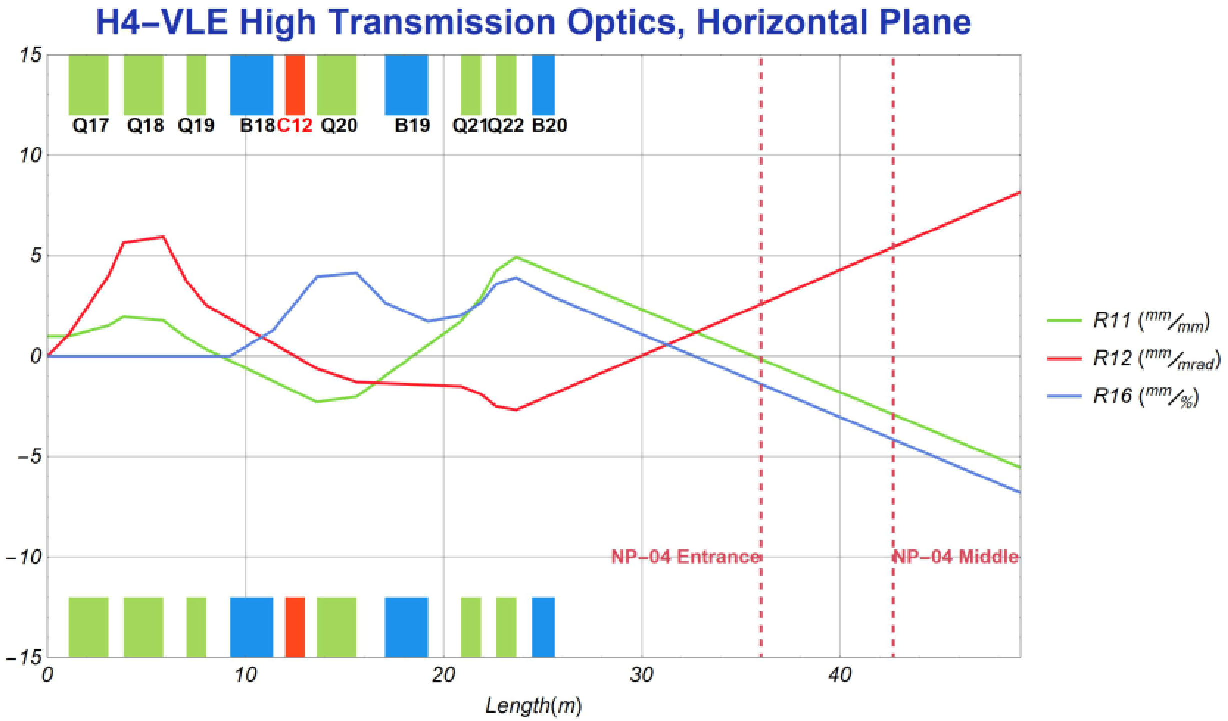


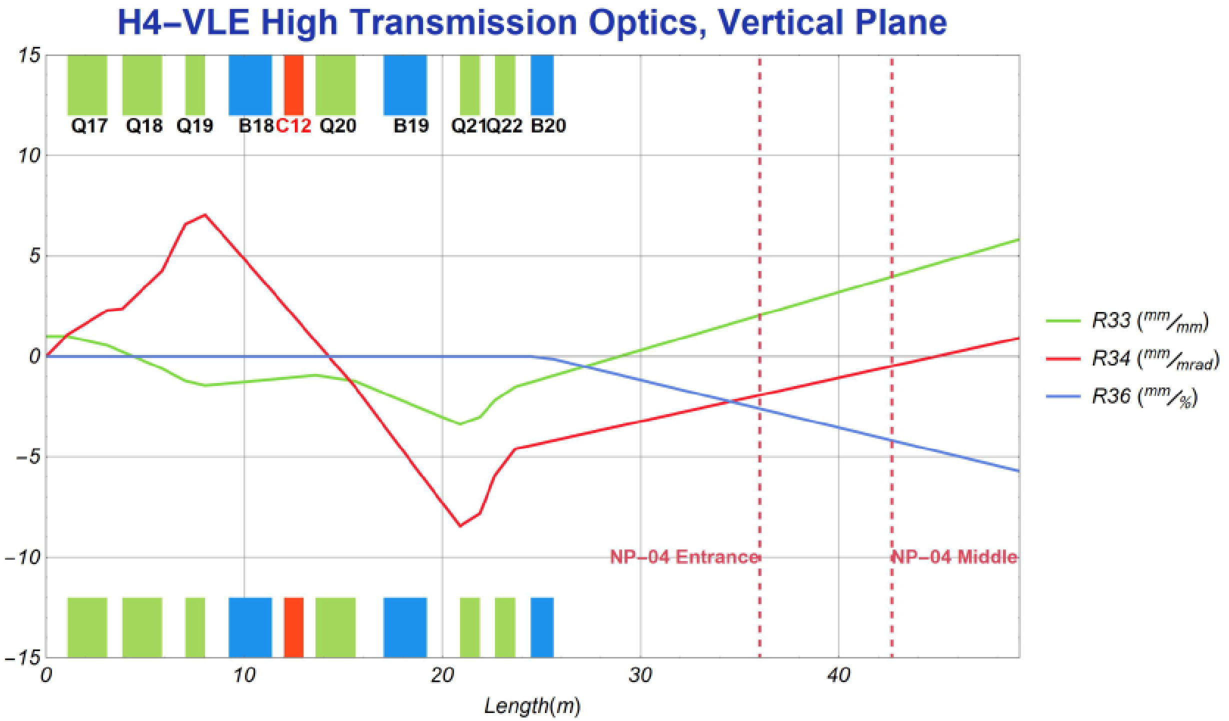


marcel.rosenthal@cern.ch

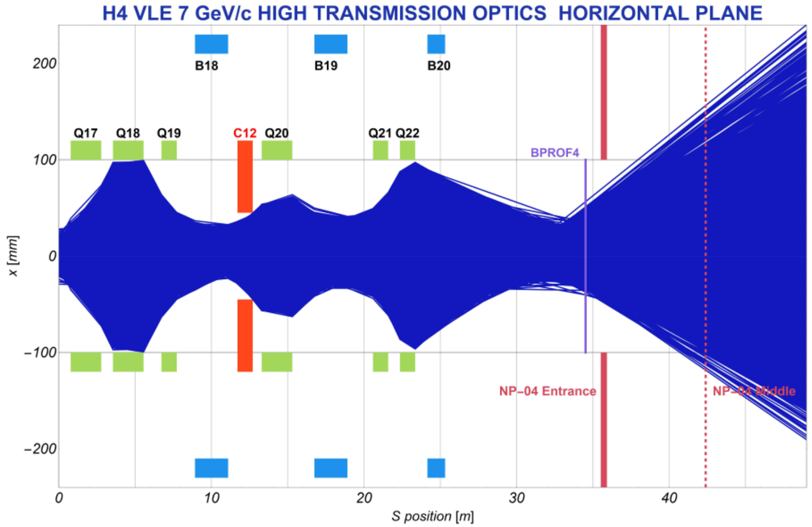
Beam Optics Optimization

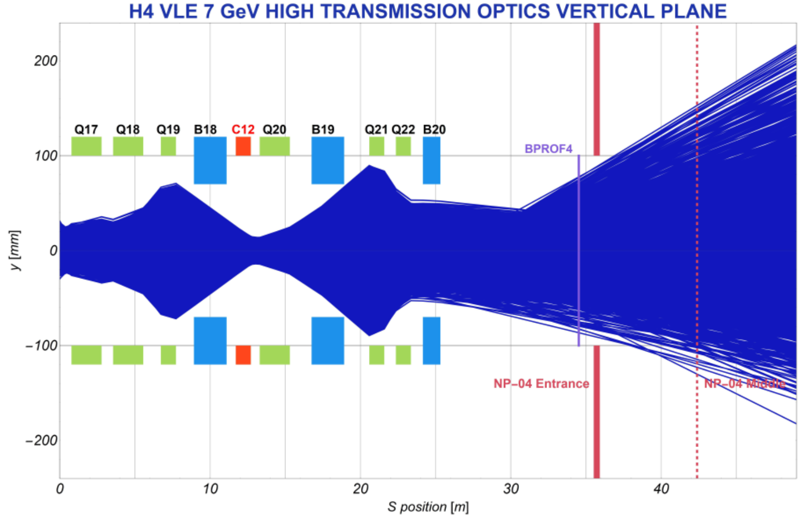
- Beam Optics Calculation and Tracking of the beam optics using MADX / MADX-PTC *(Methodical Accelerator Design – Polymorphic Tracking Code)*
- Evaluation and optimization using the linear R-Matrix parameters



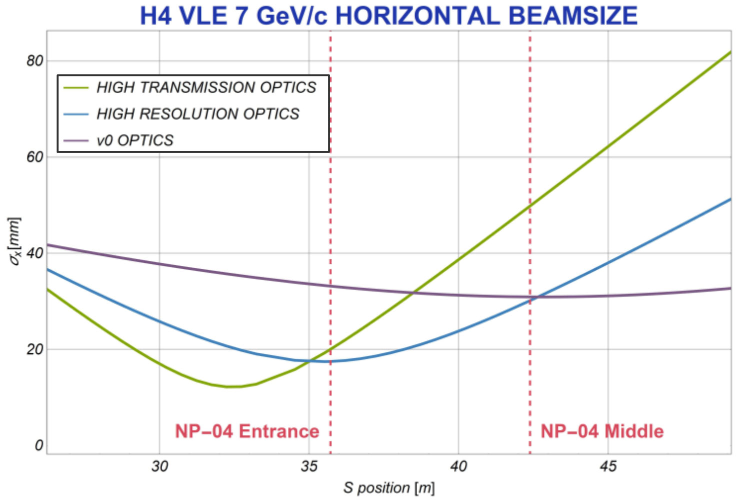


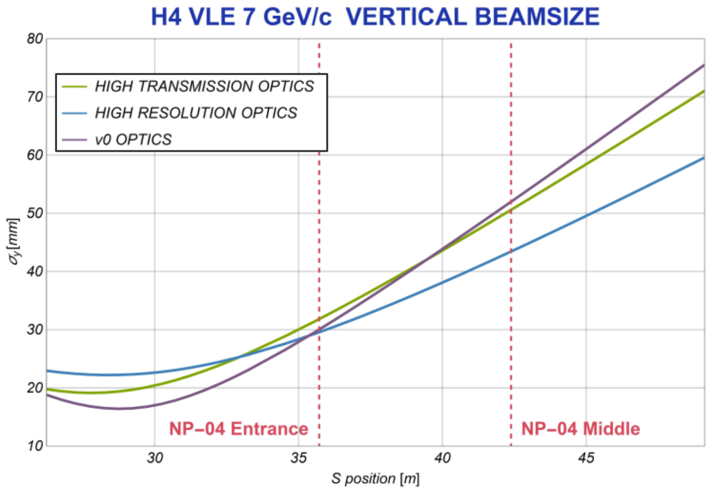
Beam Optics Optimization





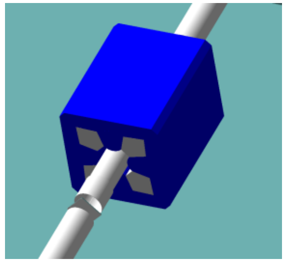
- Tracking to obtain the entire beam behaviour
- Two different optimization goals achieved:
  - Maximizing particle transmission
  - Minimizing beam spot size at detector entrance

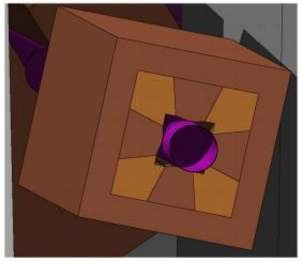




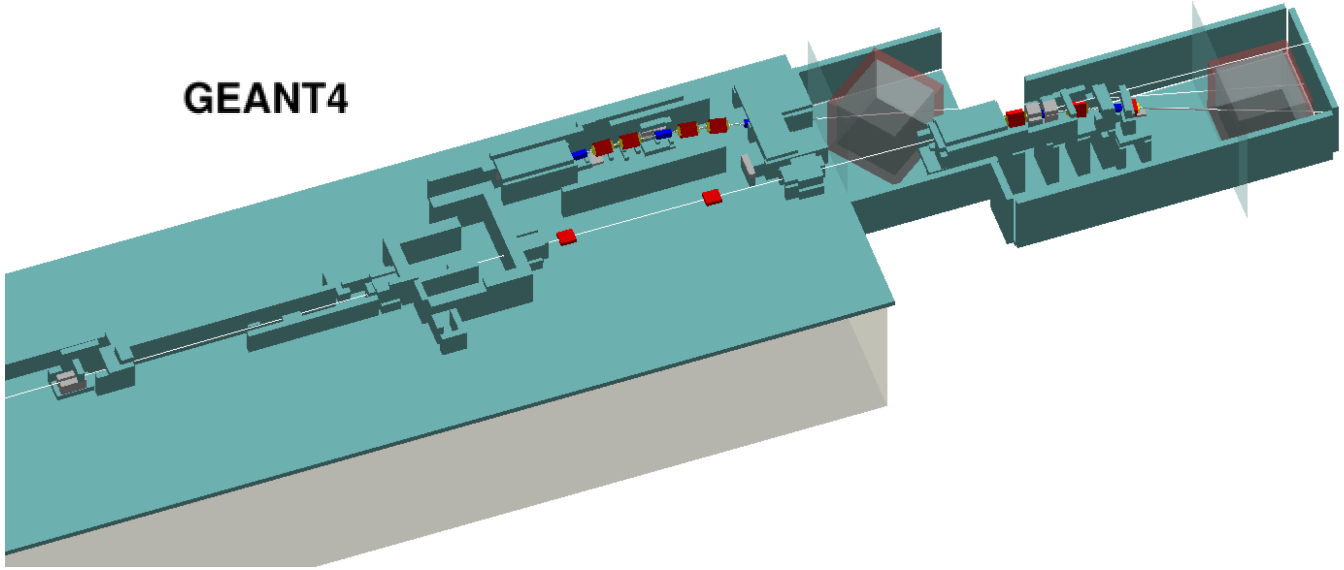
Monte-Carlo Simulations

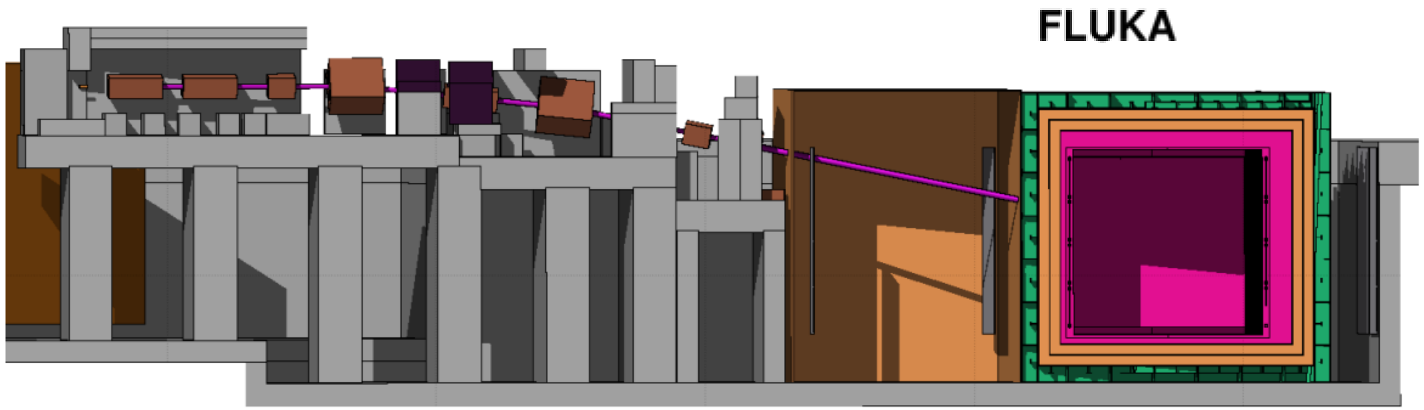
- Full Monte-Carlo models implemented in Geant4 (via G4Beamline) and FLUKA
  - More realistic magnet geometry:





  - Detailed modelling of concrete and iron blocks for shielding studies
  - Implementation of magnetic field settings (beam optics)
- Full simulations of particle-matter interactions, e.g. particle production, transmission and decay



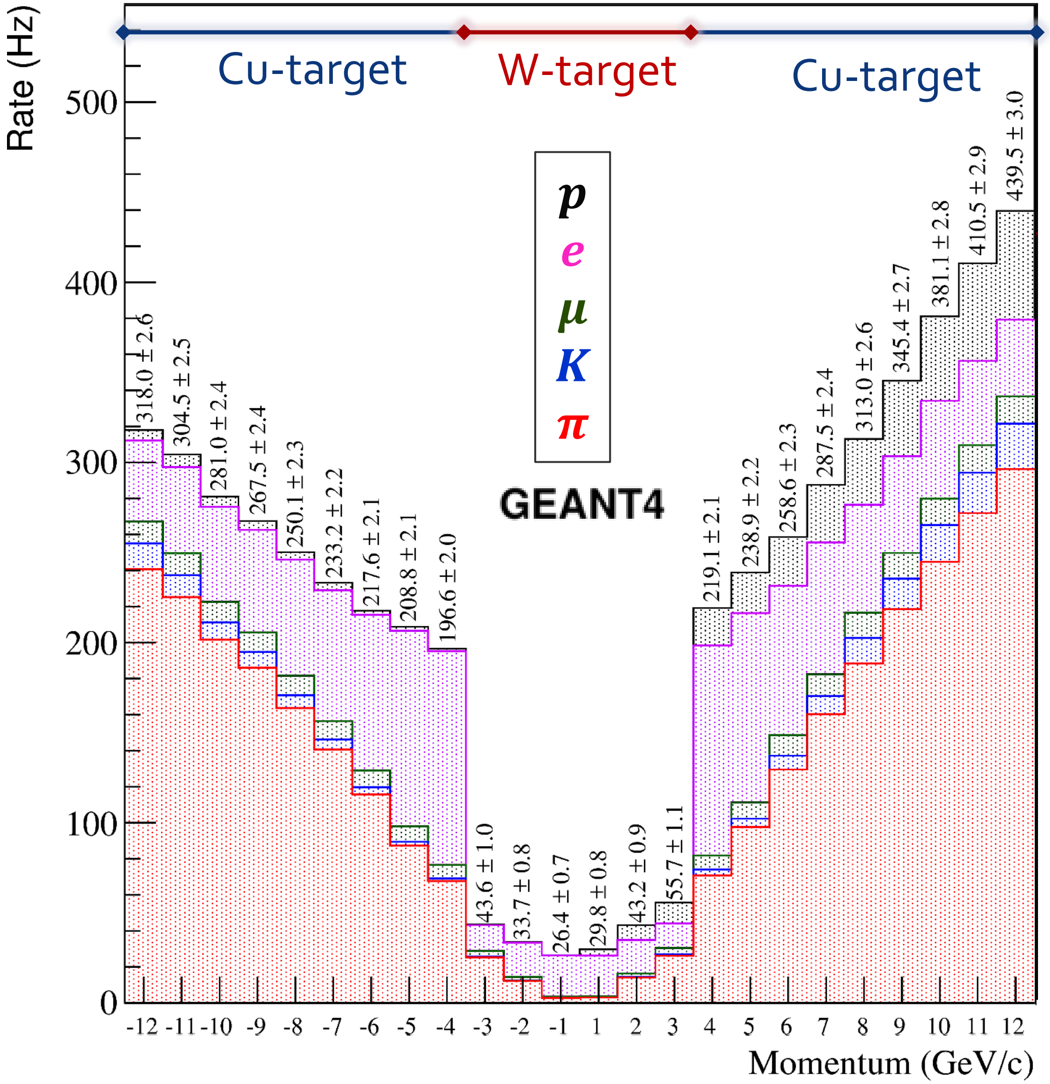


Expected Beam Line Performance (H2-VLE)

- Example: Expected beam line performance with GEANT4 (Physics List: FTFP_BERT)

- Secondary hadron beam @ 80 GeV/c
  - Assumed composition: 70% π^+, 24% p, 6% K
  - Trigger rate normalized to 10^6 secondaries at beginning of H2/H4 line per 4.8 seconds (spill length)

- Trigger rate reduces towards lower momenta
  - Rate jump between 3 and 4 GeV/c due to target material change
  - Simultaneous change of pion-to-positron ratio with material change



Expected Beam Line Performance (H4-VLE)

- Example: Expected beam line performance with GEANT4 (Physics List: FTFP_BERT)

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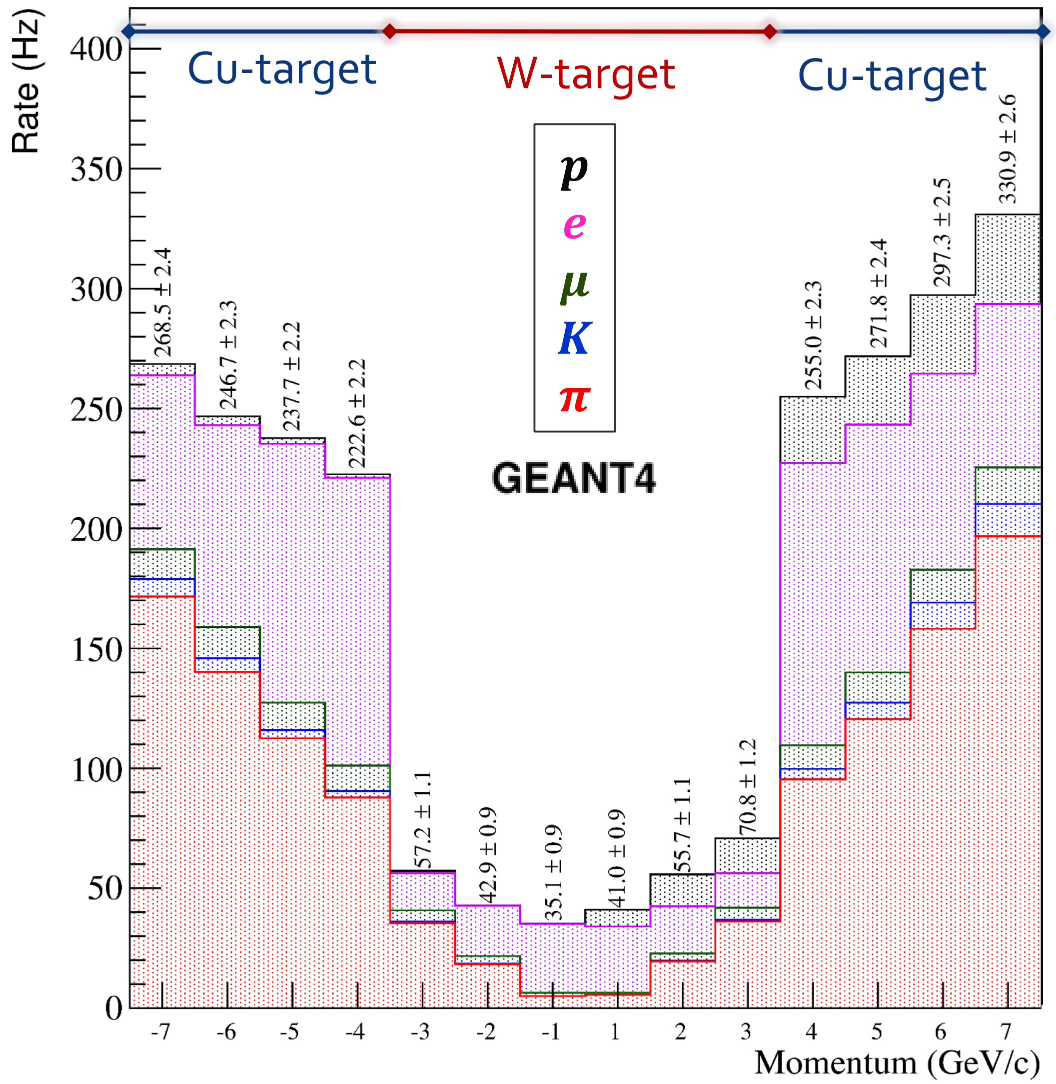
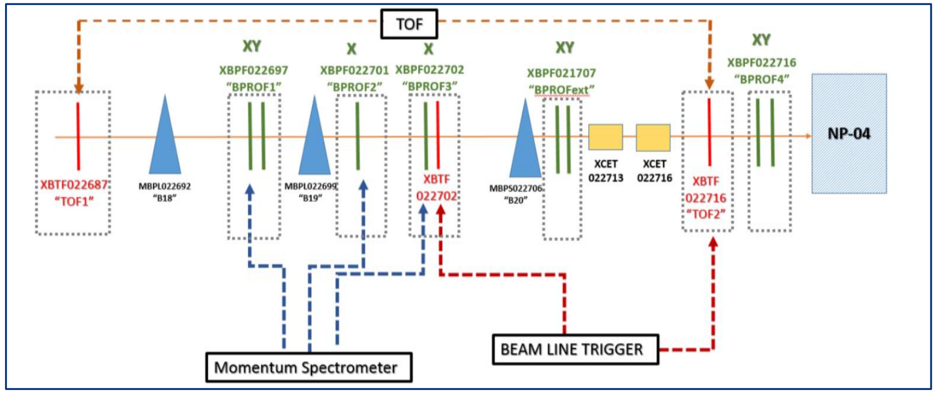
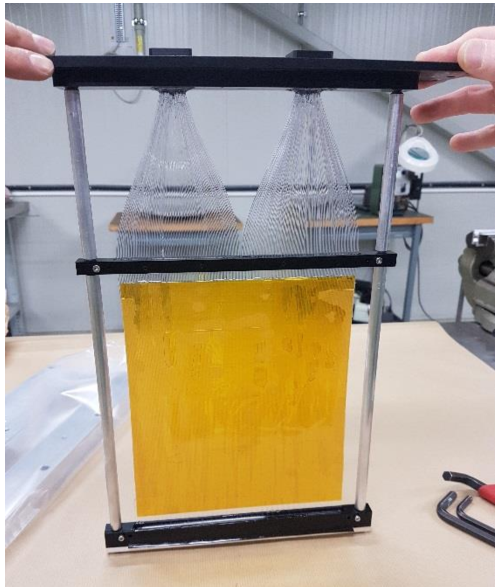


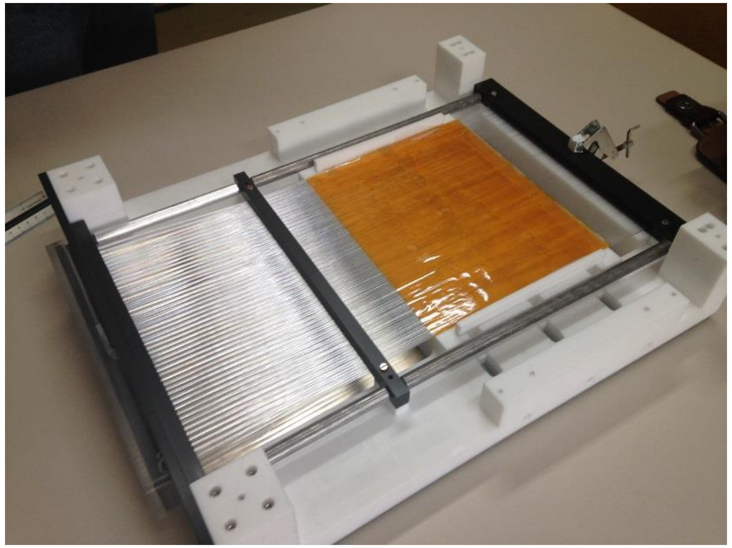
Beam Line Instrumentation

- Goals of the beam line instrumentation:
  - Transverse profiles for beam tuning
  - Trigger of experiment
  - Particle identification on event-by-event basis:
    - Momentum measurement
    - Time-of-Flight measurement
    - Tagging by Cherenkov light
- Installed detectors in H4-VLE:
  - Newly developed scintillating fiber detectors:
    - 8 beam profile monitors (XBPF)
    - 3 triggering monitors (XBTF)
  - 2 threshold Cherenkov counters using different pressures and/or gases





XBTF (Trigger)



XBPF (Profile)

marcel.rosenthal@cern.ch

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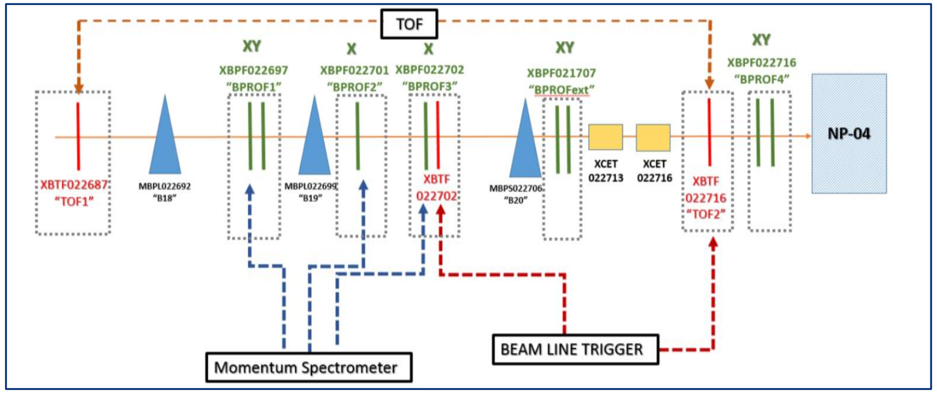
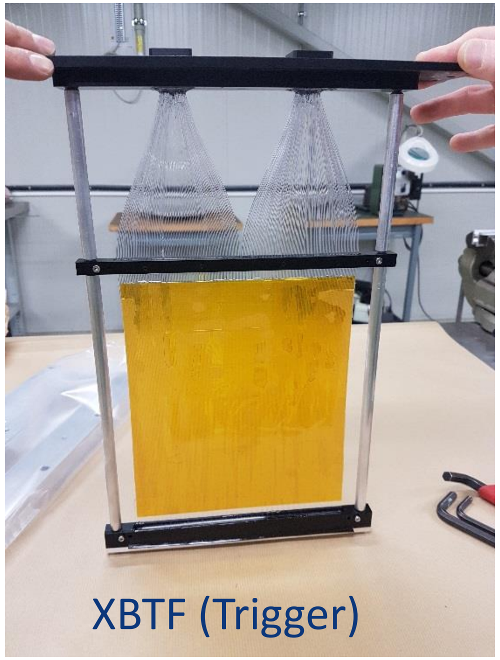


p (GeV/c)	e	µ	π	K	p
1	CH1	TOF	TOF	/	TOF
2	CH1	TOF	TOF	/	TOF
3	CH1	CH2	CH2	TOF	TOF
4	CH1	CH2	CH2	TOF	TOF
5	CH1	CH1	CH1	CH2	!CH
6	CH1	CH1	CH1	CH2	!CH
7	CH1	CH1	CH1	CH2	!CH



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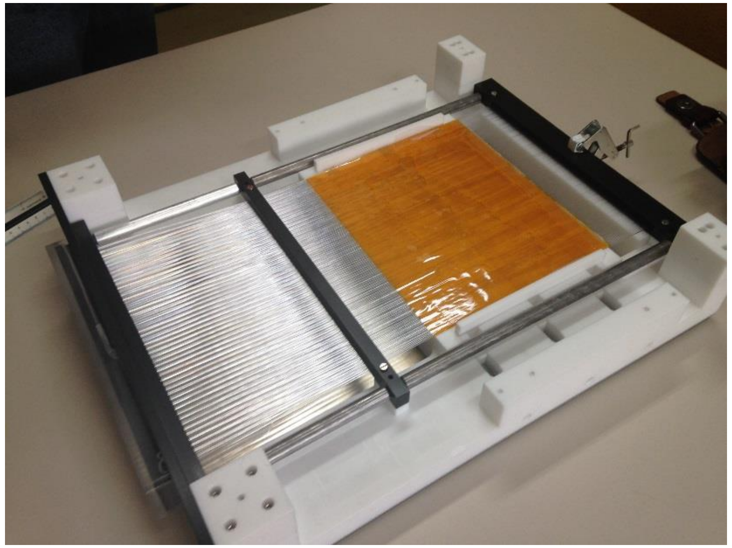
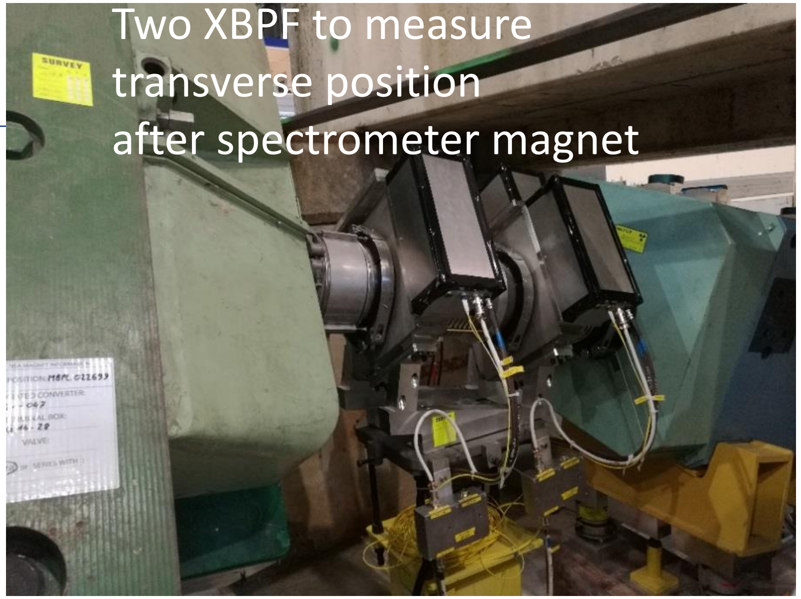
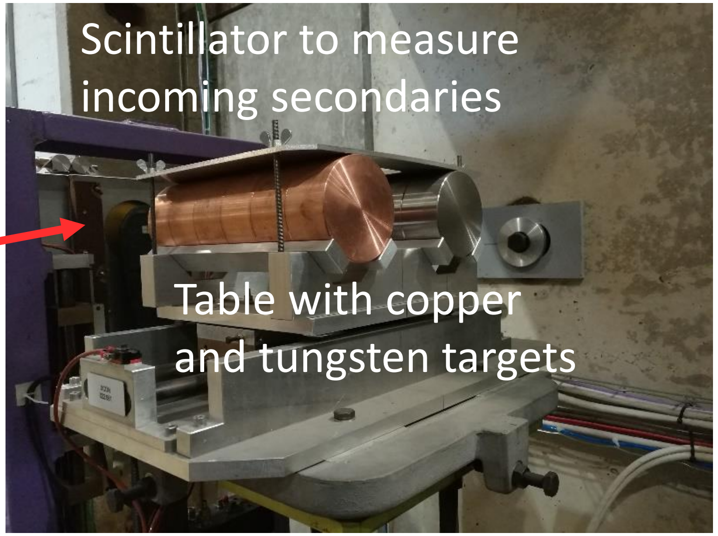


XBPF (Profile)

Commissioning of the 2 lines

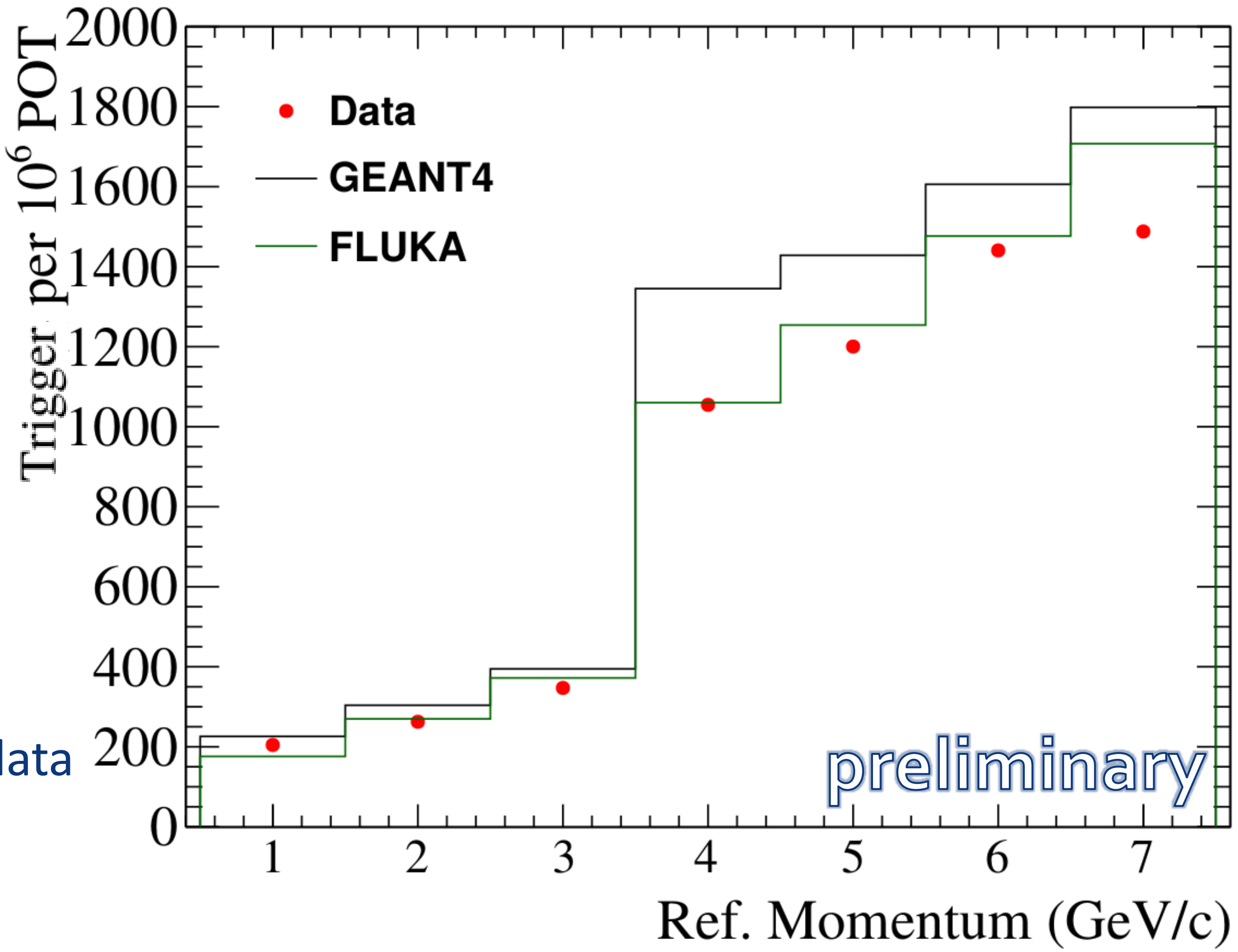
- Commissioning of H2-VLE and H4-VLE in 2018
- First beam taken in H4-VLE end of September 2018 and H2-VLE in November 2018





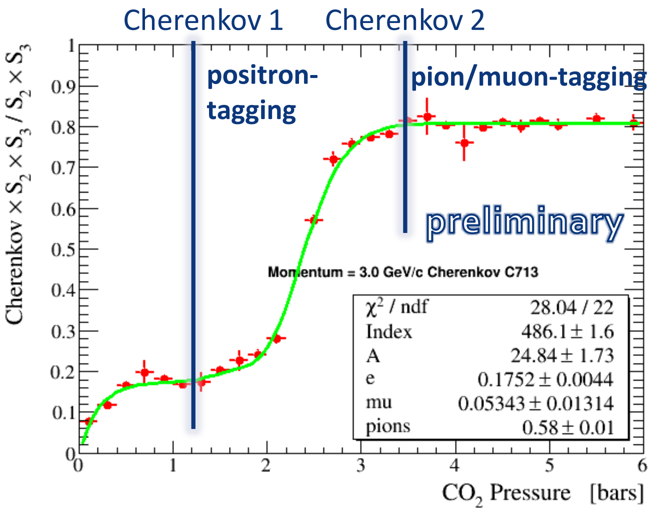
First Commissioning Results of H4-VLE

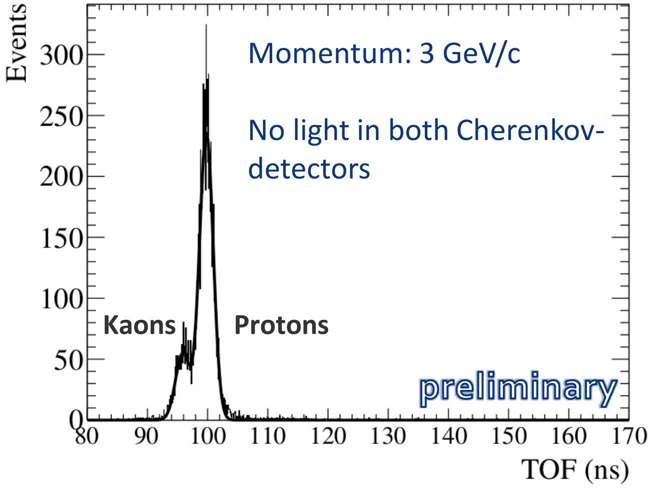
- Measured trigger rates have been compared to Geant4 and FLUKA simulations
- A 95% percent efficiency for each trigger plane has been assumed.
- The data has been normalized to 1 Mio. events on the secondary target (VLE-target)
  - 1-3 GeV/c tungsten
  - 4-7 GeV/c copper
- Very good agreement of simulations with data could be achieved

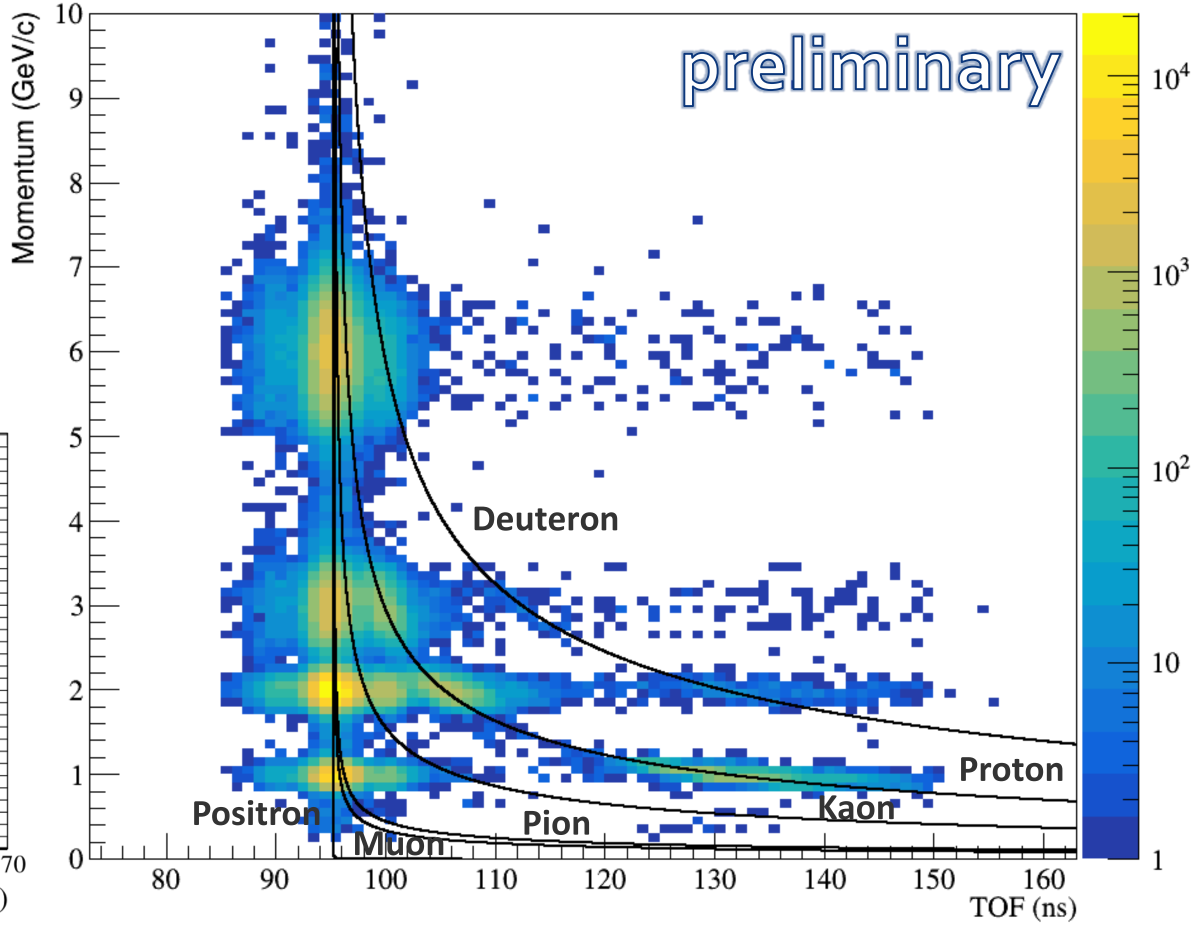


First Commissioning Results of H4-VLE

- Particle ID on event-by-event basis requires combination of time-of-flight, reconstructed momentum and Cherenkov tagging
- Expected ToF vs. momentum diagram could be measured
- Available PID capacities depend on momentum:
  - Example for 3 GeV/c







Summary

- The CERN North Area has been extended within the framework of the CERN Neutrino Platform Project.

- Two new very low energy branches extending the existing H2 and H4 beam lines have been successfully designed and commissioned.

- First experimental data for the DUNE collaboration could be taken end of 2018.
  - The observed beam line performance in H4-VLE agrees well with the expectations obtained by two different Monte-Carlo-Codes GEANT4 and FLUKA.
  - Similar measurements performed in H2-VLE, analysis on-going.

- First analysis also indicate a good prediction of the beam composition at various momenta.
  - More detailed analysis on-going.

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