

M2 Experimental Beamline Optics Studies for next generation Muon Beam Experiments at CERN

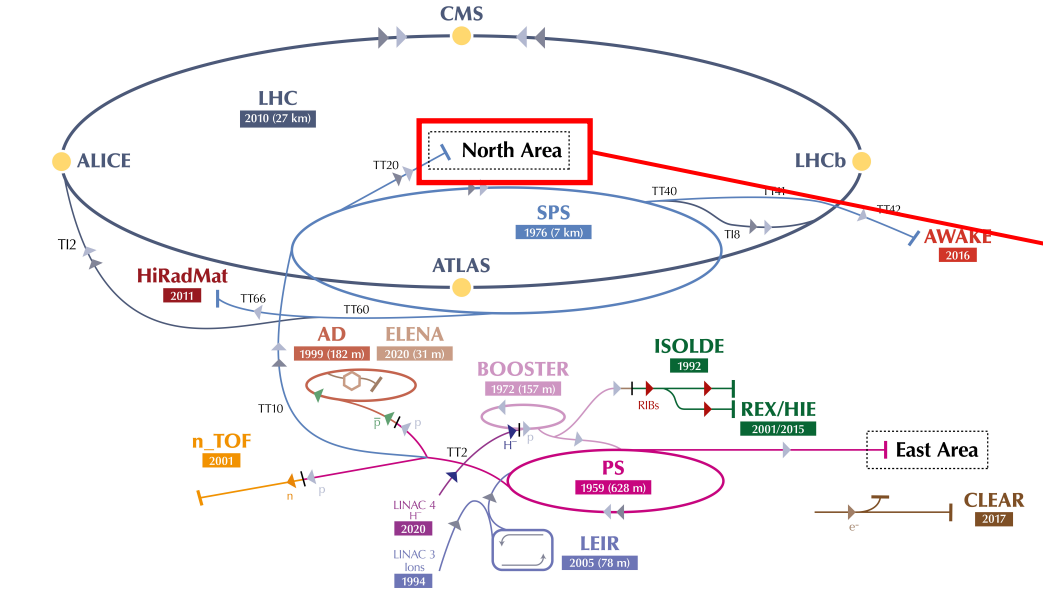
D. Banerjee,
CERN BE-EA-LE



Physics Beyond Colliders Proposals for the M2 Beamline

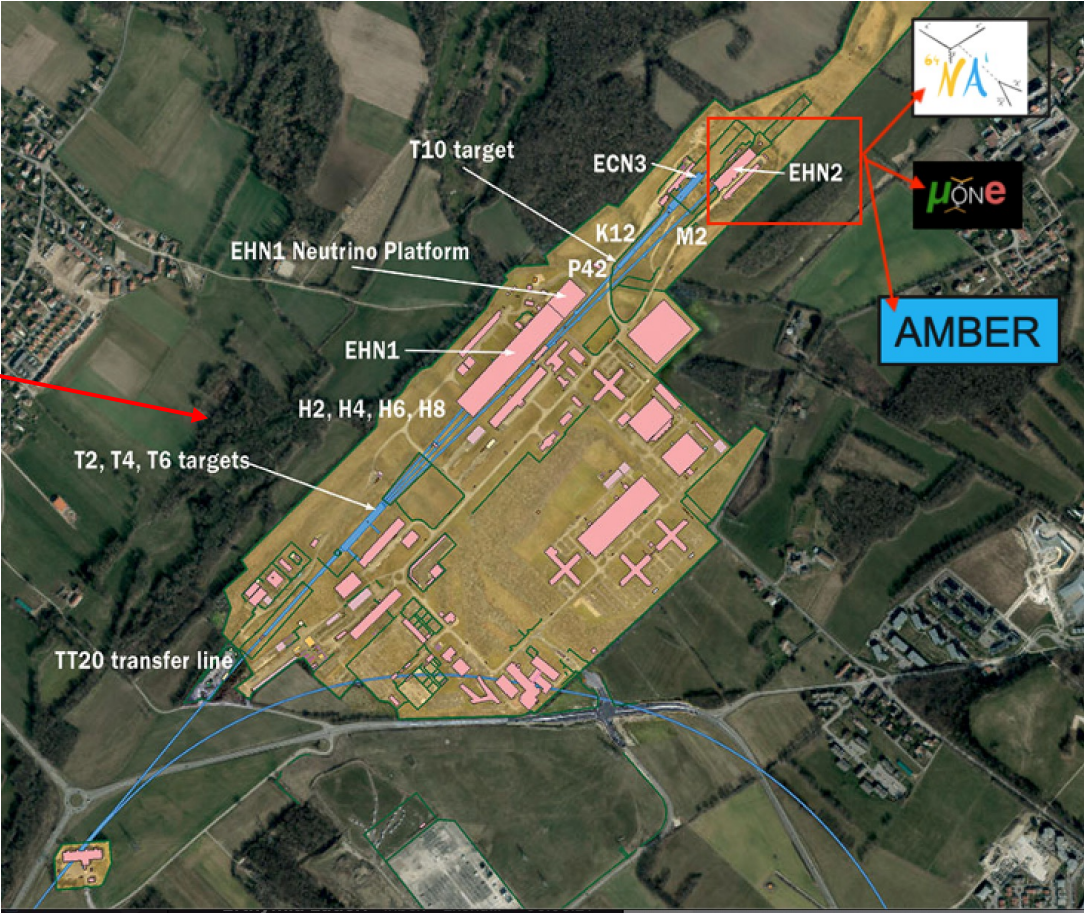
- Several projects for the ENH2 beamline in the CERN North Area have been proposed in context of PBC:

The CERN accelerator complex
Complexe des accélérateurs du CERN



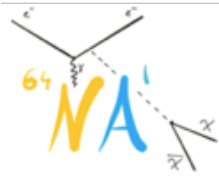
▶ H^- (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons) ▶ \bar{p} (antiprotons) ▶ e^- (electrons)

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



Physics Beyond Colliders Proposals for the M2 Beamline

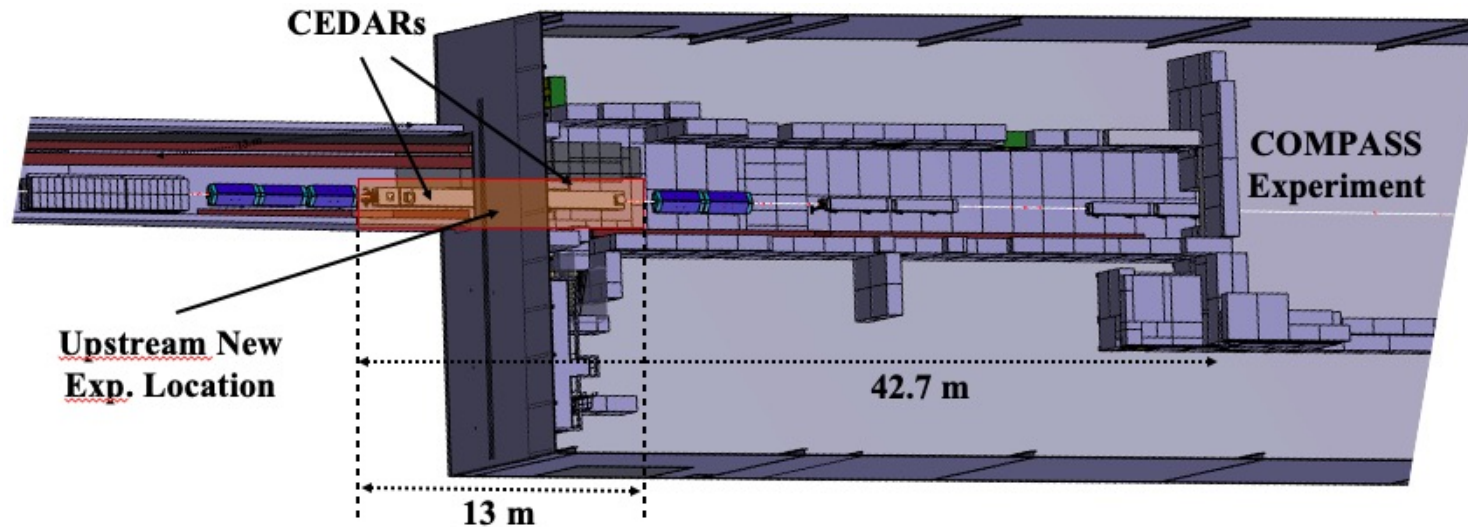
- Several projects for the ENH2 beamline in the CERN North Area have been proposed in context of PBC:
 - **NA64 μ** is the muon program of NA64e looking for a dark photon and a new massive gauge boson, Z_μ , that couples predominantly to the 2nd and 3rd lepton generations.
 - Requires medium to high intensity focussed 160 GeV/c muon beam with divergence < 1.5 mrad.
 - Setup around 15 - 25 m long and about 120 cm x 60 cm transversely.
 - In 2021 they aim to do a test run with a minimal setup of 13 m.
 - **MUonE** - aims to investigate the hadronic contribution to the vacuum polarisation in context of $(g-2)_\mu$
 - Requires high intensity 160 GeV/c, low divergence muon beam.
 - Full setup around 40 m long.
 - In 2021 they aim to do a pilot run with up to three stations and the ECAL requiring a space of 7 m.
 - Successor to the COMPASS experiment - **A QCD Facility (AMBER)**
 - The ENH2 hall currently hosts COMPASS with a 55 m long setup.
 - In 2021 they aim to do a test run for their proton radius measurement with the TPC and 160 GeV/c μ beam requiring a space of about 9 m.



All 2021 test runs have been approved.

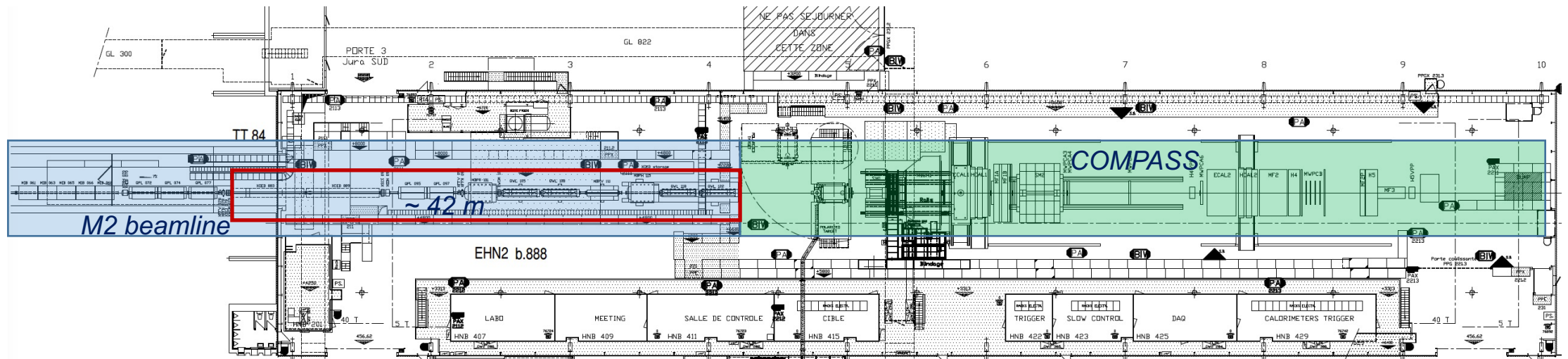
Space required for the installation

- Currently the EHN2 hall houses the 55 m long COMPASS spectrometer to be used for the approved AMBER Drell Yan runs in 2022 and beyond.
- Upstream of the COMPASS setup 2 CEDAR detectors are located which will not be used during the 2021 COMPASS transversity run.
- This 13 m available space was deemed feasible for all three 2021 test runs without any major modifications to the beamline.



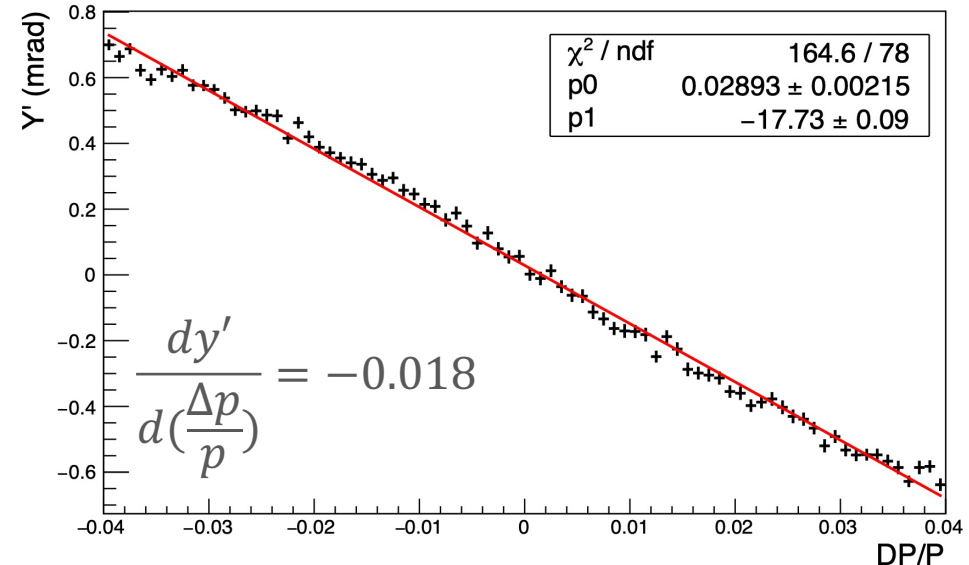
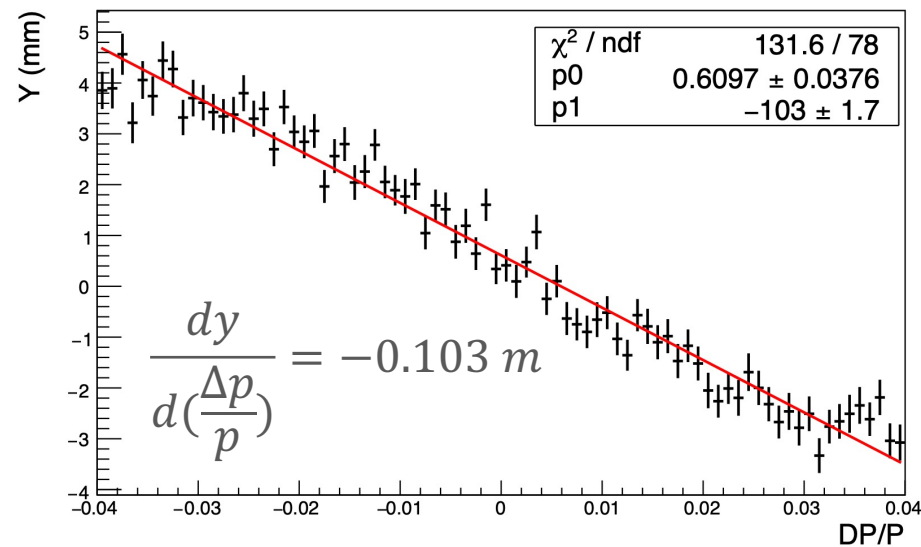
Space required for the installation

- After the 2021 runs NA64 μ would require a space of 25 m, MUonE would require a space of 40 m for their full setup and AMBER will require their 55 m long COMPASS spectrometer.
- In order to accommodate NA64 μ and MUonE the beamline elements downstream of the current CEDARs will be removed.
- A rail system will be installed and the magnets and detector components will be installed on it to reduce the change-over time.
- All integration studies for the 2021 runs as well as the rail design have been completed.

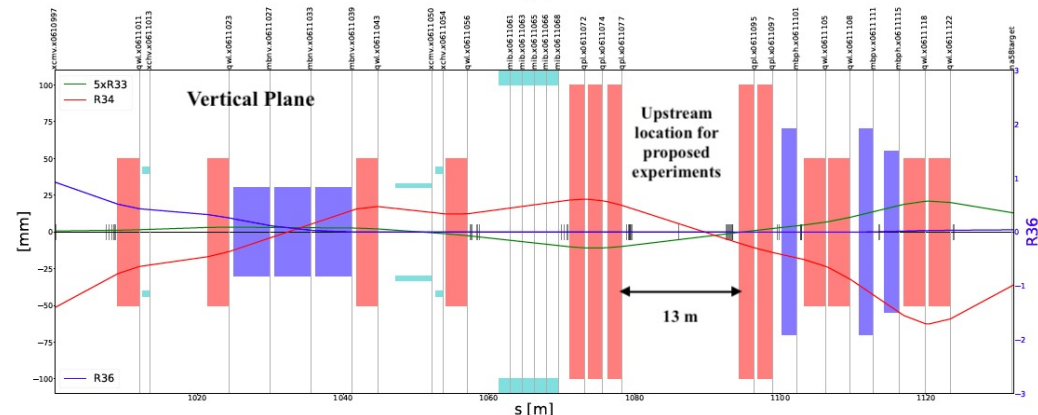
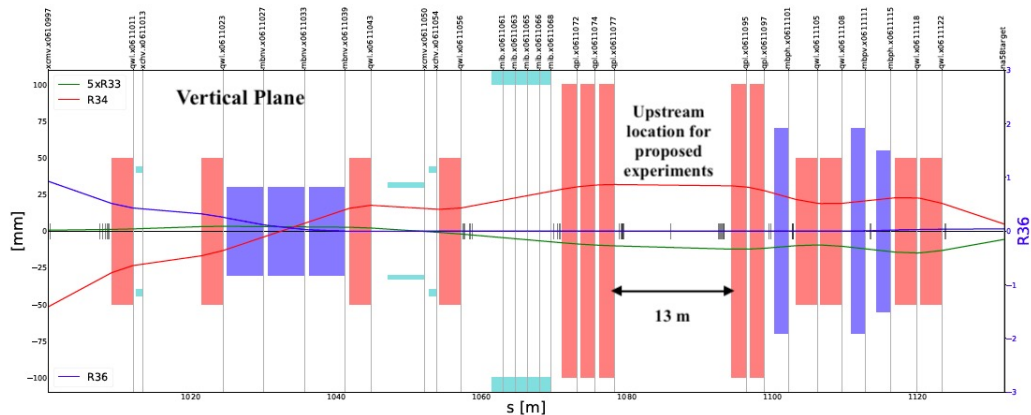
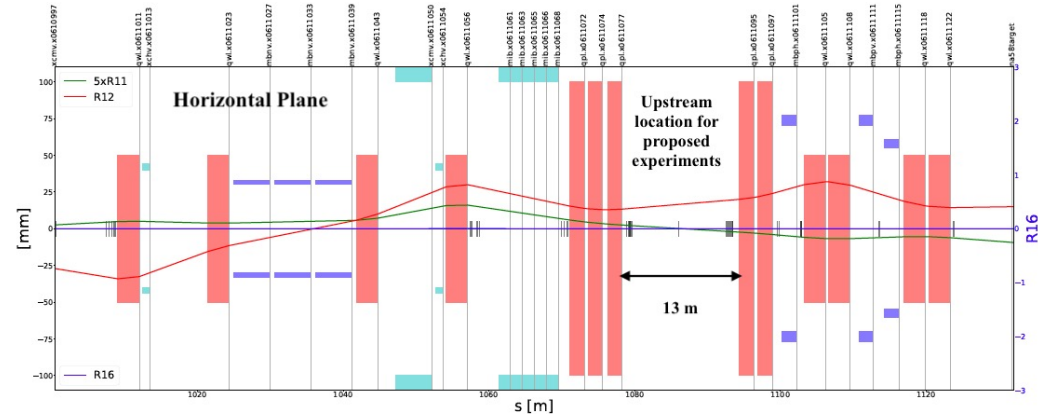
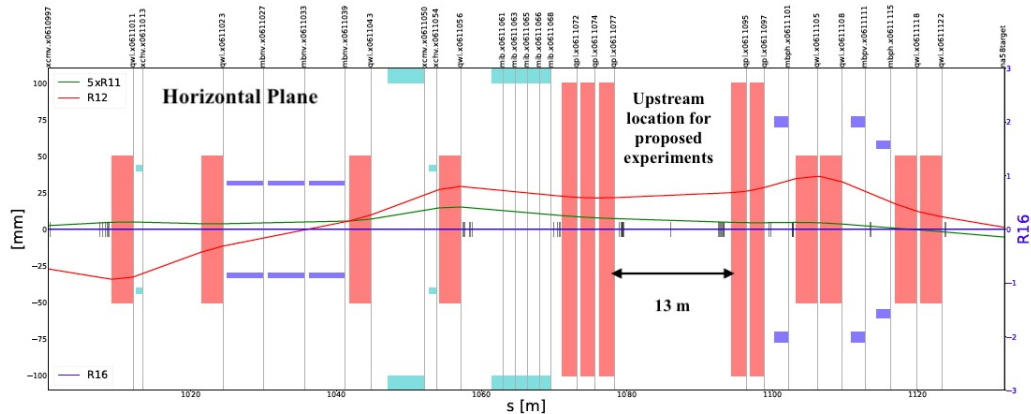


Optics Studies

- The M2 beamline is ~ 1.1 km long transporting secondary particles from the target to the EHN2 hall.
- It has a 700 m long hadron section to allow hadron decays to muons followed by 9.9 m Be in a bend to absorb the hadrons with the muons passing through. A 400 m long muon section selects the final muon momentum and cleans the muon beam halo.
- The scattering in the absorbers located inside the vertical bends results in a correlation between y , y' and $\frac{\Delta p}{p}$.
- These correlations were added as transport matrix elements, R36 and R46, by means of an arbitrary matrix in MADX to study the optics options at the upstream location.



Optics Studies



Parallel beam optics for MUonE

Small beam size optics for NA64 μ / AMBER

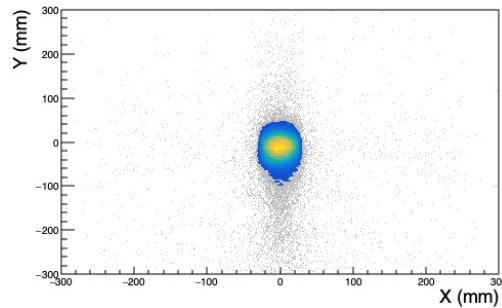


Upstream Location- Two Optics options

Parallel beam

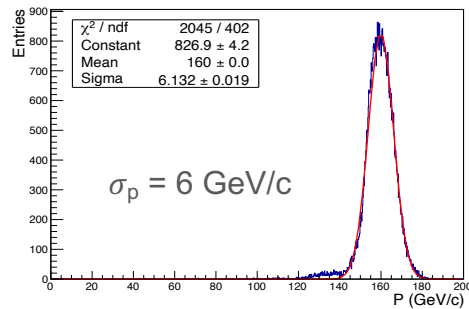
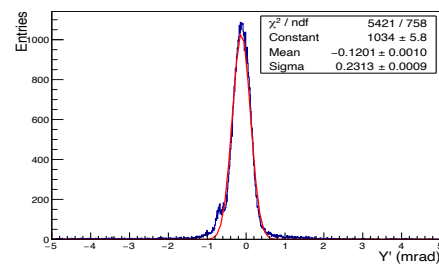
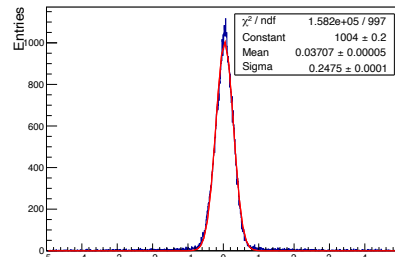
$$\sigma_x = 13 \text{ mm}$$

$$\sigma_y = 22 \text{ mm}$$



$$\sigma_{x'} = 0.23 \text{ mrad}$$

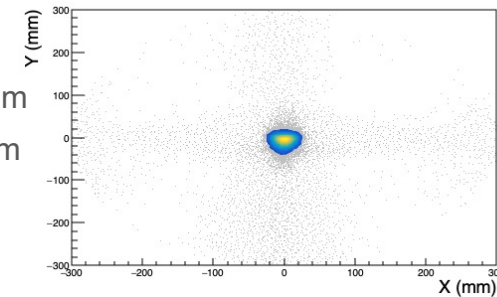
$$\sigma_{y'} = 0.24 \text{ mrad}$$



Focussed beam

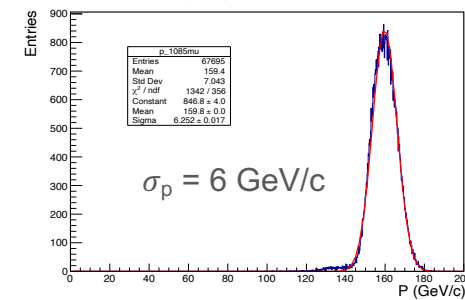
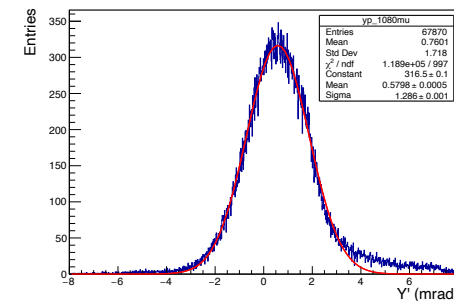
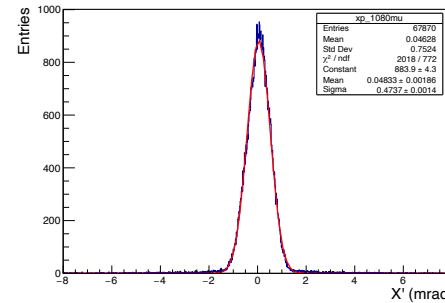
$$\sigma_x = 9.99 \text{ mm}$$

$$\sigma_y = 11.8 \text{ mm}$$



$$\sigma_{x'} = 0.47 \text{ mrad}$$

$$\sigma_{y'} = 1.3 \text{ mrad}$$



Conclusion

- Three new projects have been proposed for the EHN2 beamline in context of the PBC studies – AMBER, MUonE and NA64 μ .
- Test runs for all three experiments have been approved.
- Feasibility studies in terms of space, beam parameters and parallel running performed by the Conventional Beams Working Group.
- Space for all three test runs as well as optics options have been finalised.
- Preparation for the 2021 test runs are ongoing – no showstoppers.
- Future studies include higher intensities for Drell Yan, an RF separated option for AMBER, integration of the final MUonE and NA64 μ setup.

THANK YOU FOR YOUR ATTENTION !!

