Background: MiXE is a non-destructive technique using a muon beam (few 10s of MeV, few 10s of kHz) in air to measure elemental composition of samples with excellent depth resolution. The project at PSI is entering its third year and numerous samples have been successfully measured. Varying the incident muon energy allows for fine depth resolution, but the other axes rely on employing masks, which severely reduce statistics and introduce significant background, depending on the material composition. The addition of a tracker would not only eliminate the need for such masks, but also allow to conduct element-sensitive tomography on the sample. Adding such a detector is therefore very high priority for us. The next beamtimes are expected to be around end of May or beginning of June 2023 (9-10 days) and September 2023 (9-10 days).

Detector: The twin GEM-TPC consists of two time-projection chamber detectors in a mirror configuration. Each detector features a drift region in a very uniform field cage, GEM stacks for amplification and a 1D strip readout. The X coordinate is calculated from the charge cluster on the strip plane and the Y coordinate from the charge drift time. The interplay of the two mirrored detectors allows both for high multiplicities, among other advantages. The detector prototype is currently in it's 4^{th} iteration and has been shown to deliver great results. The spatial resolution in both axes is on the order of a few 100 microns. It is located in Helsinki, but will be moved to CERN in the coming weeks for further (in-beam) testing. Currently, the readout system is being migrated to VMM3, which still requires some to be conducted. The prototype would be available to be used for the May/June beamtime of MiXE at PSI. However, some modifications are necessary in this case (see below).

General plan: Since the next beam time is approaching fast, we plan to use most of the existing hardware to evaluate the feasibility and performance of the detector on the MiXE setup this year. Depending on how the project evolves in the next few weeks we have two general options:

- Use the twin GEM-TPC prototype as is and use ~1 day of beamtime for pure evaluation.
- Build a new gas volume / mounting structure to use with a single GEM-TPC module. Assuming we do not see adverse effects during ~1 day of evaluation, this would allow us to keep the detector for the whole beamtime (~9-10 days) with the potential of already significant improvements of sample measurements.

Since the latter option would allow for much more promising results, we strive to implement this. The next main steps to achieve this goal are:

- Geant4 simulations to confirm feasibility (see below)
- Moving the current detector prototype to CERN
- Testing the prototype in-beam at CERN
- Finalizing the readout software and analysis
- Designing a new gas volume / mounting structure to be used at MiXE (see below)
- Move the detector to PSI and change to the new mounting structure
- Integrate the detector into the MiXE DAQ and test setup

Later this year, developments towards a specialized detector prototype can then be started, after the results have been evaluated. Several ideas have already been mentioned (e.g. using Timepix readout, etc.).

Boundary conditions / MC simulation: To achieve reasonable statistics at MiXE it is imperative that the high purity germanium detectors are located close to the sample. Furthermore, since we are at relatively low energies (for HEP standards at least), multiple scattering in the foils and gas is also of concern. Geant4 simulations will be done to confirm that the GEM-TPC detector can be adapted to

these requirements. (Very) preliminary results look promising, but they also indicate that great care will need to be taken in minimizing the material budget and to consider using a low-density gas mixture, e.g. HeCO2.

Required Hardware Modification: We plan to use only a single GEM-TPC module, which will be kept in unmodified condition. The gas volume / mounting structure should be miniaturized as much as possible. Furthermore, it should be mounted directly on the beam pipe to avoid one additional foil. Design and production will be conducted at PSI.