LEMMA-TB

N.A.

(99% recycled from a presentation by Marco Zanetti)

LEMMA-TB

- The idea is to assess the physics features of the LEMMA production process
- A 45 GeV positron beam on target → mu pair production at threshold
- Exploit the CERN North Area
  - Only facility in the world providing high energy positron “beam”
  - Large emittance and very low intensity (w.r.t what needed by LEMMA)

Recap

Goals

- Cross section (differential in energy) measurement
- Measure intrinsic mu beam emittance
- (possibly) Assess spent positron beam properties

Past experience

- 2 “opportunistic” beam tests in 2017/8
- Limited by tracking resolution and DAQ dead time
- Still a paper published

The LEMMA-TB proposal

- A dedicated setup to address the above goals
- Fast pixel modules for tracking nearby the target
- High performance trigger and DAQ system

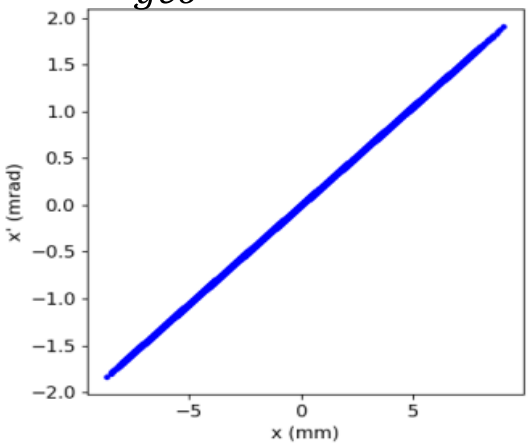
The challenge (I)

- The issue with the emittance:
  - Emittance of e+ beam in the NA is very large (several order of magnitudes larger than in the LEMMA scheme)
  - Intrinsic emittance due to muon kinematics and interaction with the target is tiny!
- Aim at measuring the "intrinsic" muon emittance by correcting event-by-event for the incoming e+ kinematics:

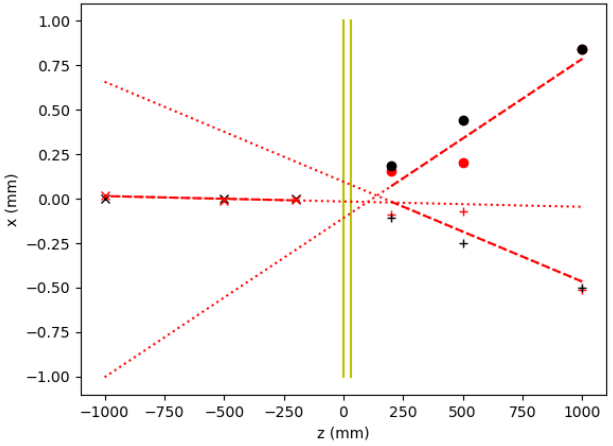
$$x = x(\mu) - x(e^+)$$
$$x' = x'(\mu) - x'(e^+)$$

- Requires extremely good tracking resolution before and after the target

$\varepsilon_{geo} = 3.8$ nm rad



intrinsic true μ^- emittance



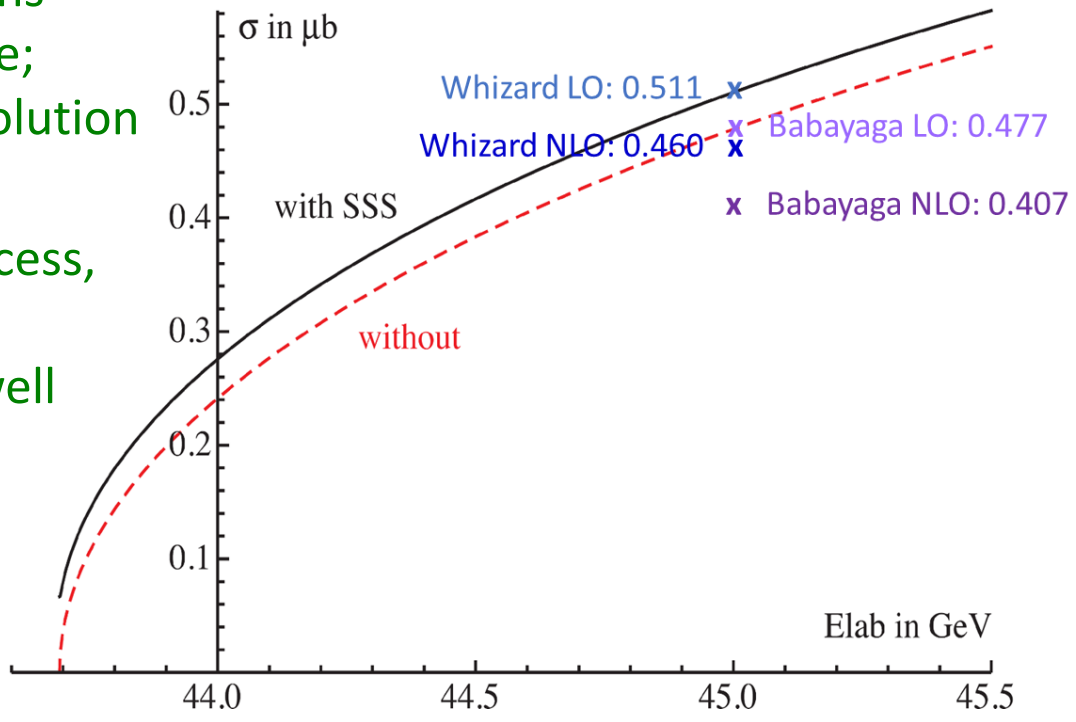
The challenge (II)

- Each muon –and corresponding e^+ – needs to be tracked individually ⟶ need to resolve in time the structure of the NA spill (~1 MHz)
- ⟶ Fast and dead-time-less trigger and DAQ systems

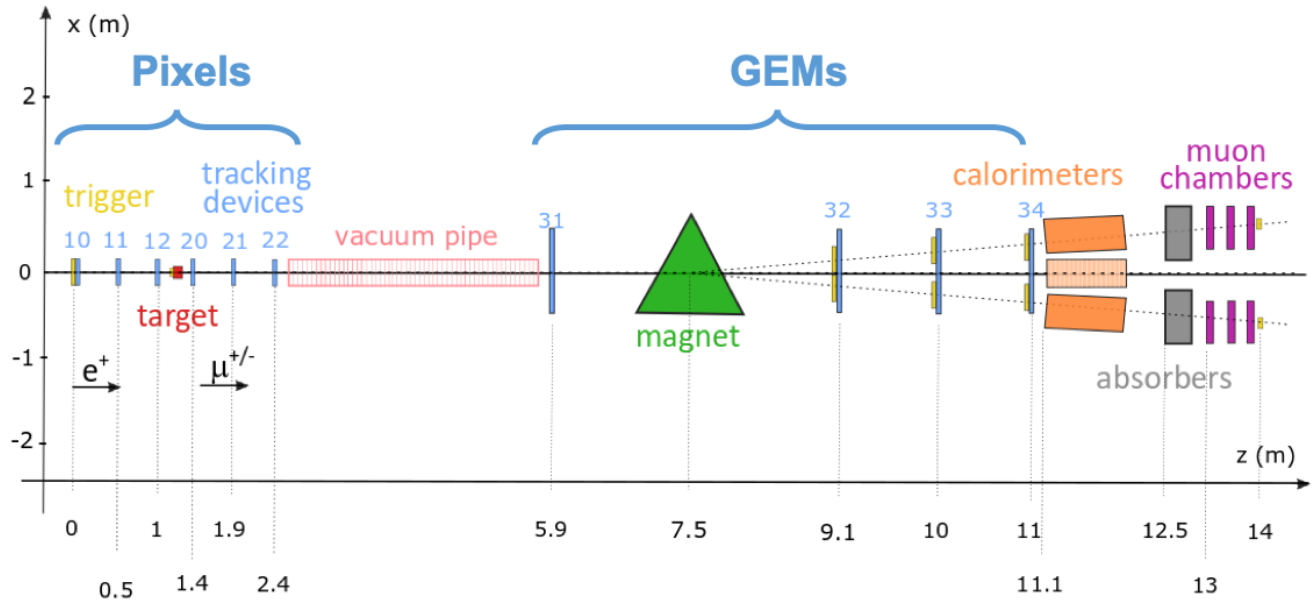
- Very large background to fight to isolate (eventually steer) the signal muons
  - Emerging positrons have a continuous energy spectrum, swept in a large direction range by the magnet

The challenge (III)

- Cross section measurement requires full control of efficiencies and acceptances
- Differential measurement is challenging because the **incoming energy spread and the positron energy loss in the target** are not negligible
  - Direct normalization to positrons at a given energy is not possible; accurate simulations + deconvolution are necessary
  - Reference to other physics process, e.g. Bahbha or $\gamma\gamma$ production is an option, but challenging as well



Experiment from 2022 on



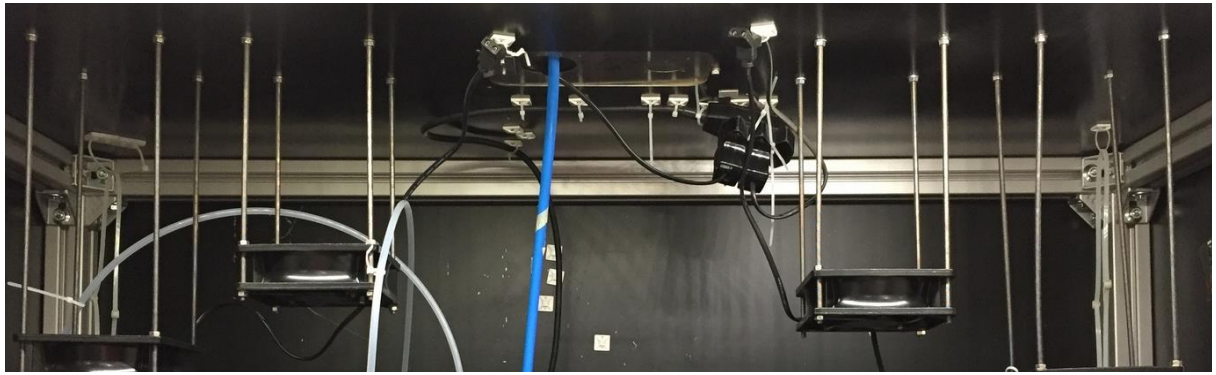
- Fast and high-resolution pixel-based telescopes in the target region
- Fast GEM detectors beyond the magnet
- Combination of several Calorimeters
- 4+2 Muon chambers
- Improved (integrated, low dead time) DAQ system
- Improved trigger system

Status

- Proposal submitted to the SPSC in 2020, very well received and supported
- Essentially in idle state during the pandemic → unavoidable delay w.r.t to schedule
- Now back to work:
  - Pixels electronics
  - Detectors integrations (common readout, synchronization, etc.)
  - Trigger
  - Simulation and reconstruction
- Major news: Wisconsin group (S. Dasu, T. Bose, etc.) has joined the experiment
  - GEM readout
  - Simulation and reconstruction

Pixels

- We bought 12 “CMS Layer1” modules (state of the art)
  - 0.5 MHz, about 100 um pitch
  - 4x7 cm^2 active area, to be arranged in pairs, 3x2 stations around the target
  - Tilted along both axis aiming at <20 um resolution
- They arrived “naked” need to be equipped (clock, trigger, readout boards, control, LV, HV, etc.)
- Collaboration with CHROMIE

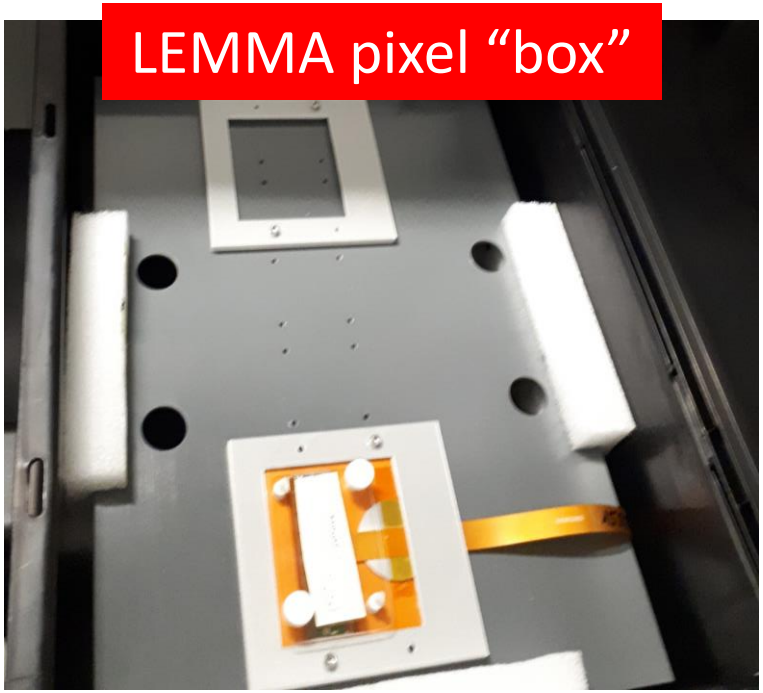


Pixels

- CHROMIE has not started its operations (expected by summer), main issue is procurement and deployment of (obsolete) electronics
- Usage of borrowed legacy electronics is our backup option, we aim at developing our own front-end/control board
  - Experience based on what developed for CMS DT phase 2 board
- Modules now in Padua together with their test board

Pixels

LEMMA pixel “box”

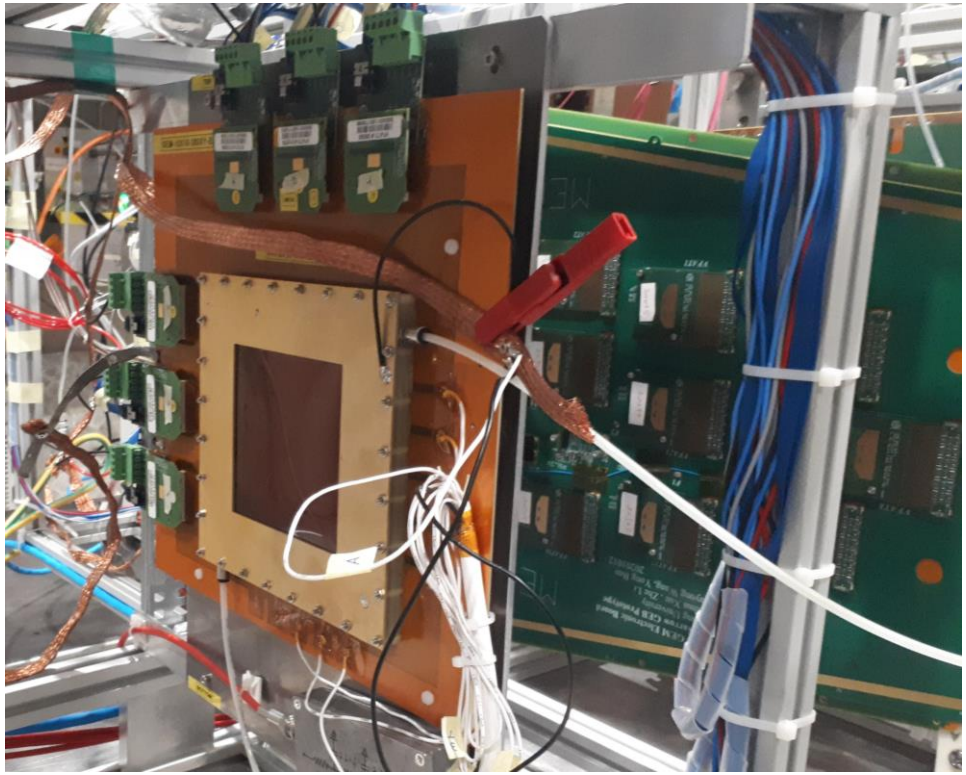


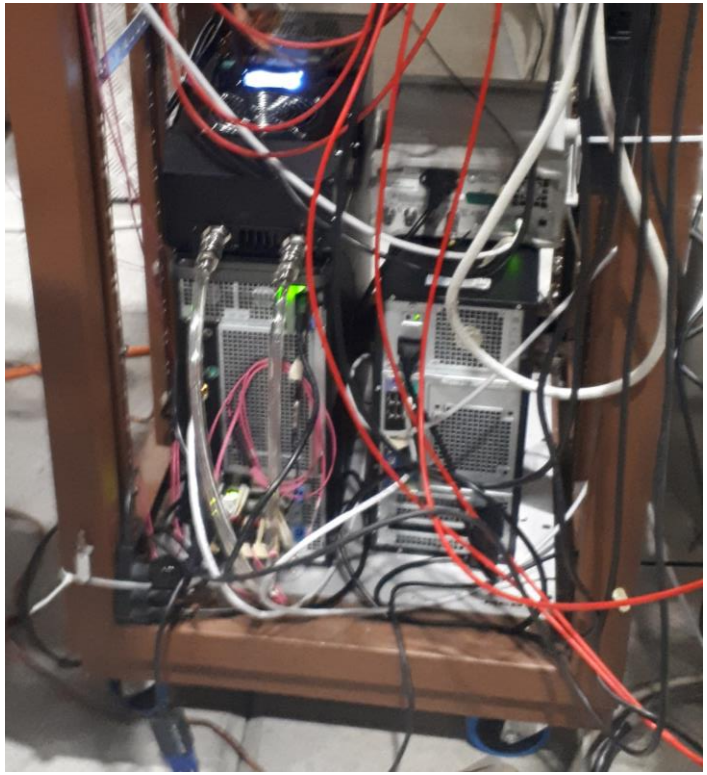
Cabling extension

Test board

GEM

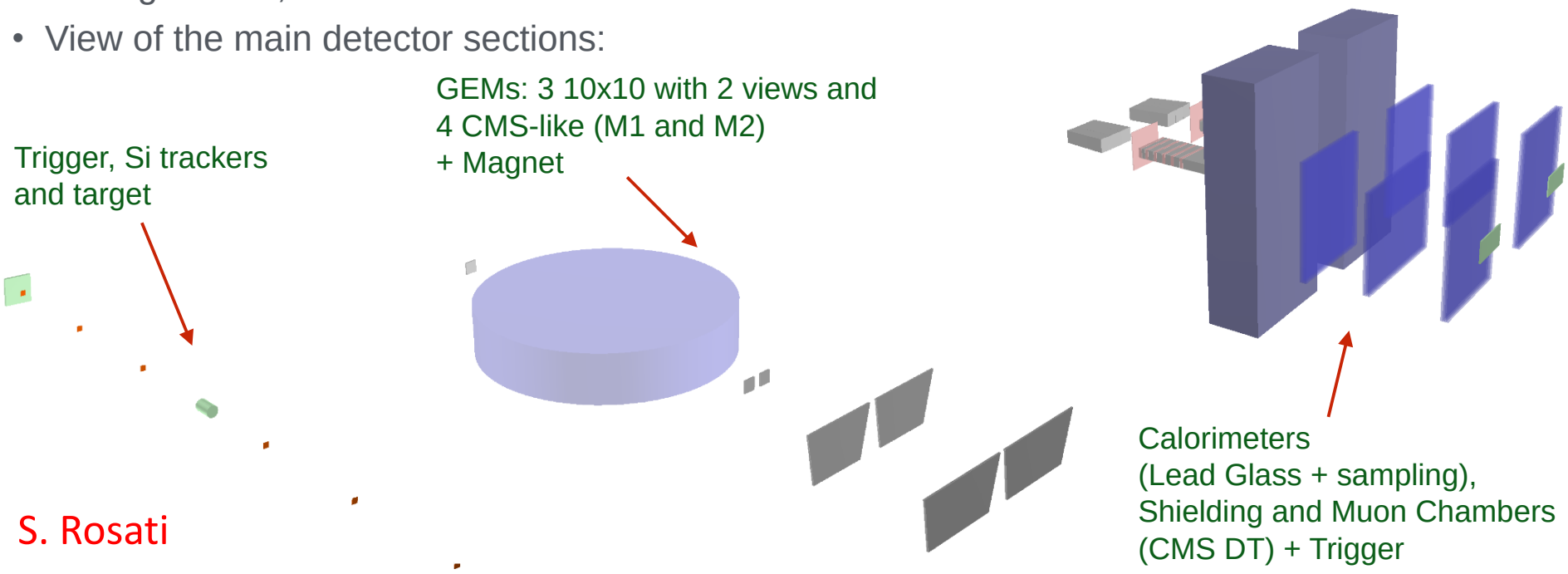
- CMS-like and 10x10 stations currently at a beam test in H4
  - Carried out by Bari and Wisconsin
- Very similar read-out scheme as DT (PICe board)





Simulation

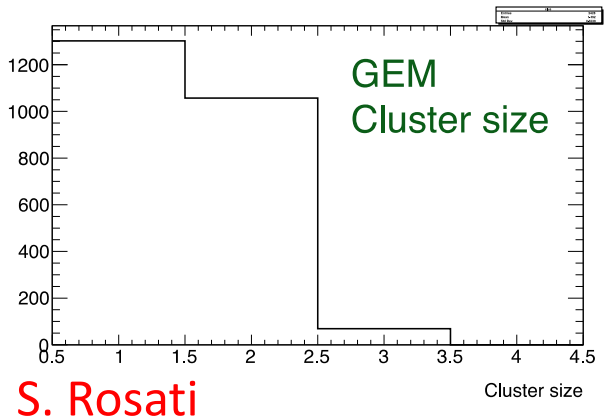
- Develop a simulation to support the TB measurements (starting from an existing TB2018 sim)
- Included the new detectors foreseen, make the detector description more flexible (GDML) to add / move parts very easily
- Added digitization with more realistic detector response (resolutions, efficiencies etc..)
- Study acceptances before the installation and define an optimal layout
- Develop reconstruction well before the TB, including e.g. studies and corrections for misalignments, efficiencies and other realistic detector effects
- View of the main detector sections:



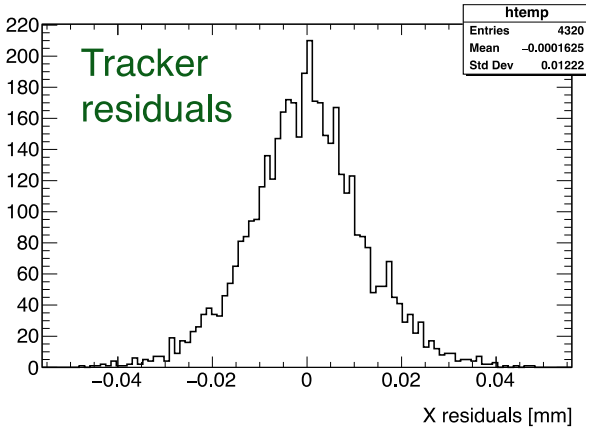
S. Rosati

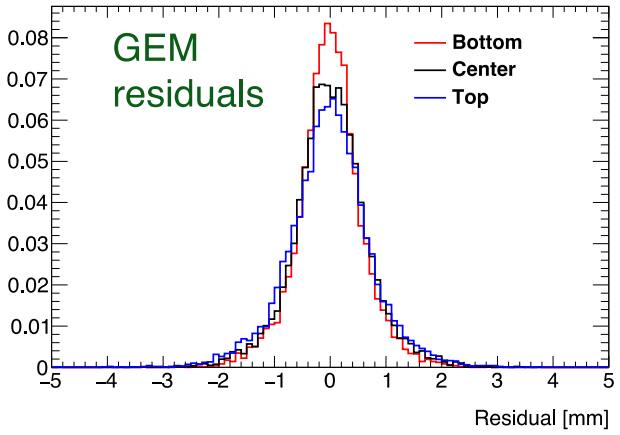
Simulation, Reconstruction

- Simulation output in a standard root tree
  - Contains MC event (particle gun or external generator), hits, digits
- Possibility to inspect the beam profile and composition at any position along the detector
  - Dummy surfaces to pick up the MC event composition and the (dummy) hits
  - Useful for acceptance and background studies
- Starting to develop the reconstruction on top of this tree
  - At the moment using the digits positions stored in the tree, but we could move to use digits identifiers (i.e. channel numbers) and get the position via the GDML det. Descr. (simple XML file describing the geometry)
    - In this way it would be straightforward to use the same code also for the data reconstruction, just adding a simple interface



S. Rosati





Sim/Reco to-do list

S. Rosati

- Filter for signal generation
  - Select muon pair production events at generator level (e+ particle gun)
  - Ensures to correctly take into account the cross section reduction along the target length
    - E.g. drop by a factor ~2 of the cross section for a 45 GeV e+ beam and a 6 cm target
- Finalize the digitization
  - Develop the missing DT digitization, plus some possible improvements in Si trackers, GEM and calo
- Develop a simple combined reconstruction
  - Standalone tracking in the various subdetectors and combination of the track segments in the full reco
- Alignment procedure
- Analysis to perform a full benchmark emittance measurement, including all relevant systematics
  - Other possible measurements include γγ production (would need an additional small forward calorimeter)

- After some stop in the last couple of months now the activities on the sim are re-starting, depending on the TB plans and schedule

Summary

- Resuming activities, main tasks:
  - Pixel electronics
  - Detector integration
  - Trigger
  - Simulation/Reconstruction
- Reassessing human and budgetary resources
  - Wisconsin group giving a boost
- A lot of work, beamtime request likely for spring 2023