LEMMA TB

Istituto Nazionale di Fisica Nucleare

Context

- Following the recent **European Strategy update**, a Muon Collider Collaboration has been established
  - Collaboration meeting on July 3: https://indico.cern.ch/event/930508/
- Among the two proposed production schemes for a Muon Collider, the **MAP** scheme is considered more advanced (baseline)
- However, the **LEMMA** scheme is considered an interesting alternative, to be developed in parallel
- Need to develop the concept of both schemes towards a **demonstrator** has been stressed
  - See D. Schulte's accelerator talk @ said meeting: https://indico.cern.ch/event/930508/contributions/3920338/attachments/2068494/3472140/MC_Facility_final.pdf

LEMMA TB: Motivation

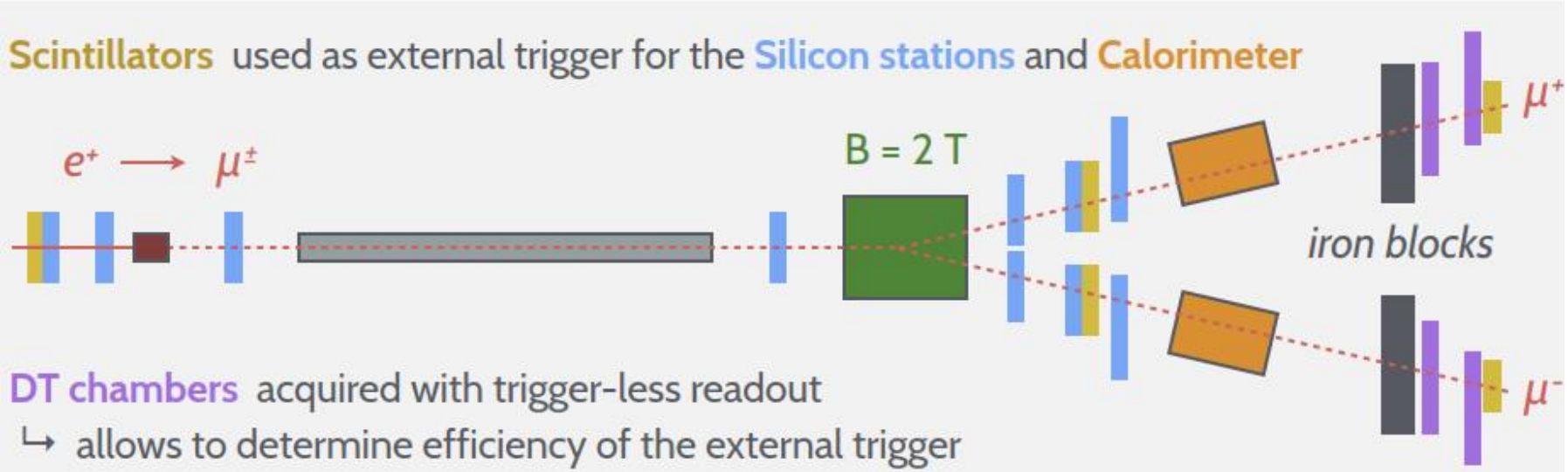
- Experimentally measure the key parameters of the LEMMA approach
  - **Emittance** of emerging μ beam
  - $\mu^+\mu^-$ production **cross-section at threshold**
  - properties of **spent e^+ beam** (transverse emittance and energy spectrum)
  - Effect of the **target material/thickness**

- Although these are theoretically known and can be obtained from simulations**, precise measurements do not exist at the $\mu^+\mu^-$ production threshold**
  - GEANT does not include e.g. near-threshold Coulomb enhancements, and has not been experimentally tested in this regime

Past TBs

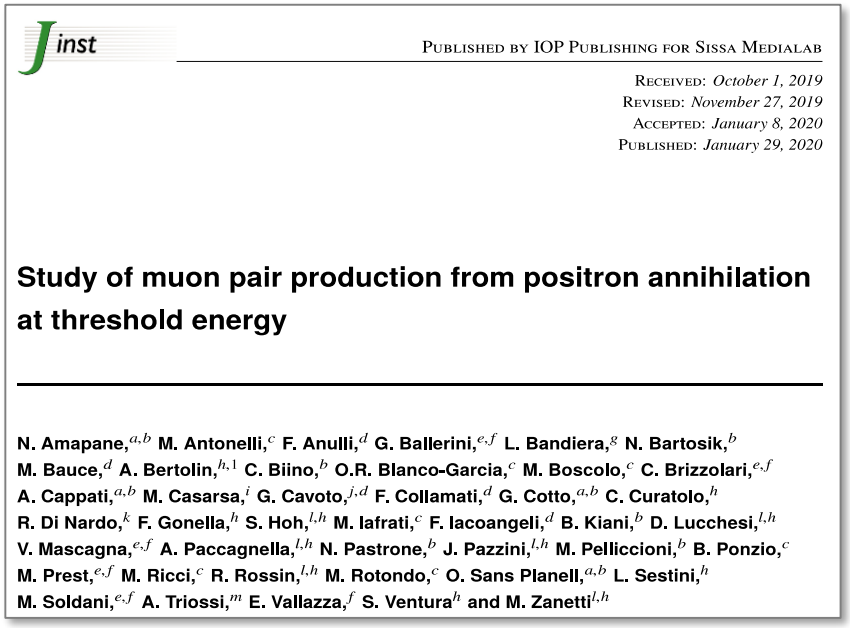
- 1 week in 2017 at H4, **1+1 weeks in 2018 at H2** (North Area)

Layout of the experimental setup: August 2018



Experience and Results

- **Low-budget**: mostly re-use available detectors and DAQ
- **Lot of experience gained**, decent result published (**JINST 15 P01036**)
- However, **severe limitations in the setup did not allow pursuing high precision measurements**
  - Resolution of the available tracking system too modest
  - Too large trigger/DAQ dead time
  - A single week of data taking barely sufficient to set up detectors and trigger properly



Jinst

Published by IOP Publishing for Sissa Medialab

Received: *October 1, 2019*
Revised: *November 27, 2019*
Accepted: *January 8, 2020*
Published: *January 29, 2020*

Study of muon pair production from positron annihilation at threshold energy

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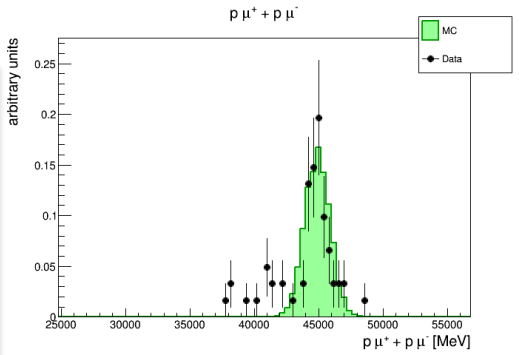
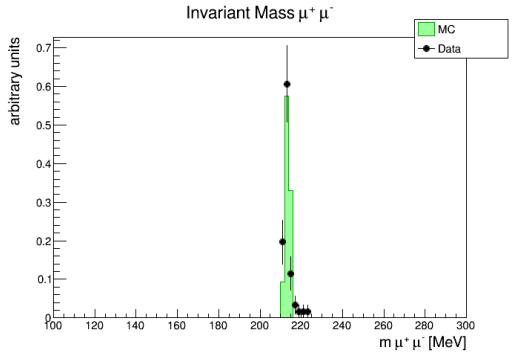
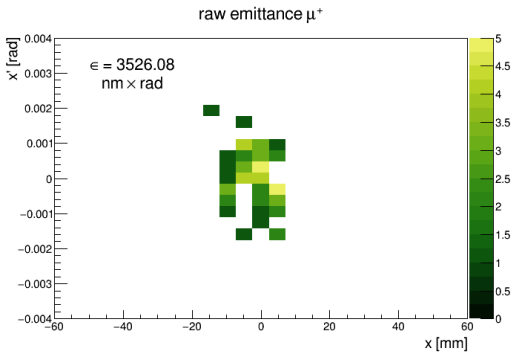
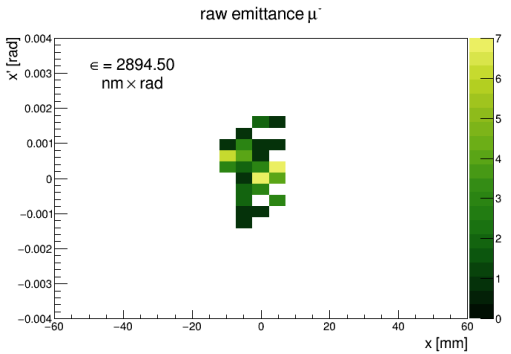








The challenge

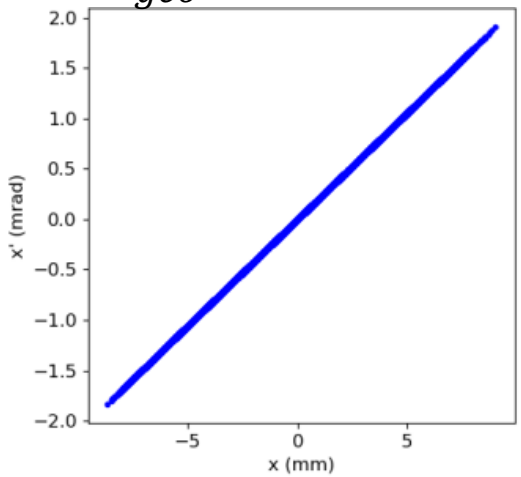
- **"intrinsic" emittance of emerging μ's is tiny**, and buried deep into the emittance of the incoming e^+beam
  - In order to get a meaningful result, **the measured muon kinematics must be corrected by that of the the incoming positron**:

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

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

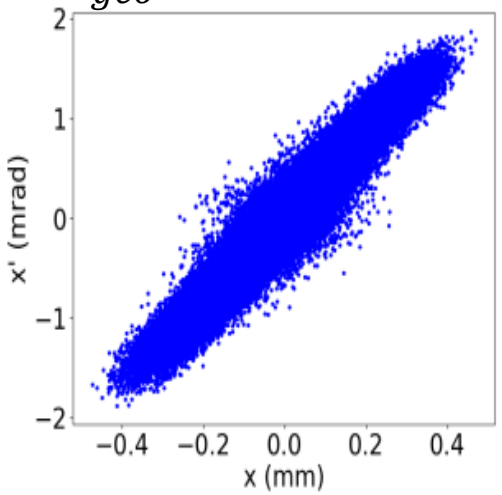
  - Requires **extremely good tracking resolution both before and after the target**

$\varepsilon_{geo} = 3.8$ nm rad



intrinsic true μ^- emittance

$\varepsilon_{geo} = 30.1$ nm rad



Positron-corrected measured μ^- emittance with reasonably achievable tracking system

(C. Curatolo)

The challenge (cont.)

- Cross section measurement requires:
  - an **efficient trigger and DAQ system** with **small dead-time**
  - ability to **assess the trigger efficiency**
  - **well controlled acceptance**
  - **Normalization to either incoming e+ rate on target, or other physical processes** (Bhabha, $\gamma\gamma$)

- >1 week is essential to set up, calibrate and align detectors, set up and validate the trigger, and take data

More like a small experiment than a typical test beam

Future TBs

- Experiment being redesigned accordingly
- Request for 3-weeks beam time in H4 submitted to SPSC
  - http://cds.cern.ch/record/2712394

CERN-SPSC-2020-004

LEMMA-TB: an experiment to measure the production of a low emittance muon beam

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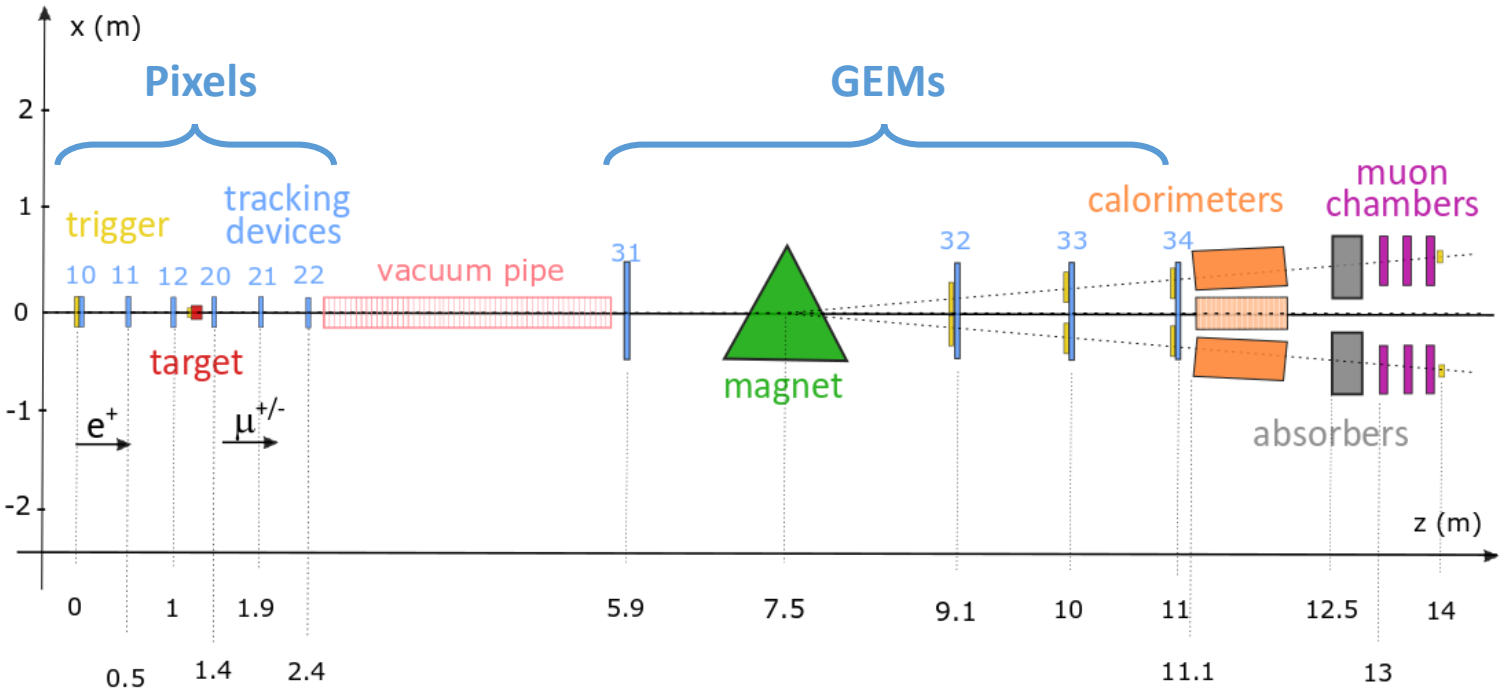
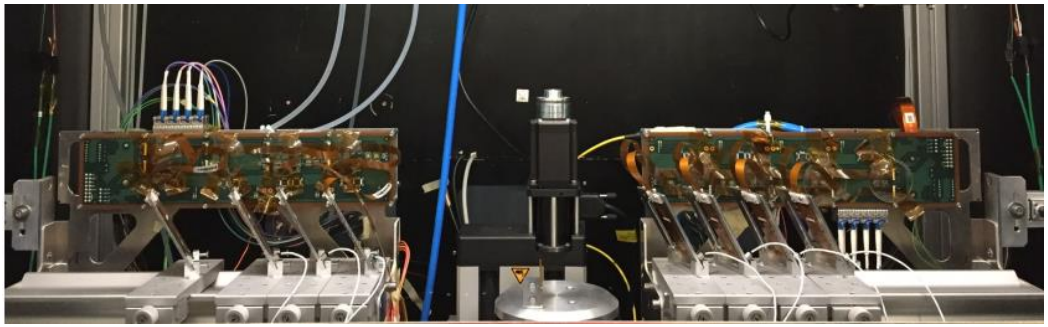
Proposed layout

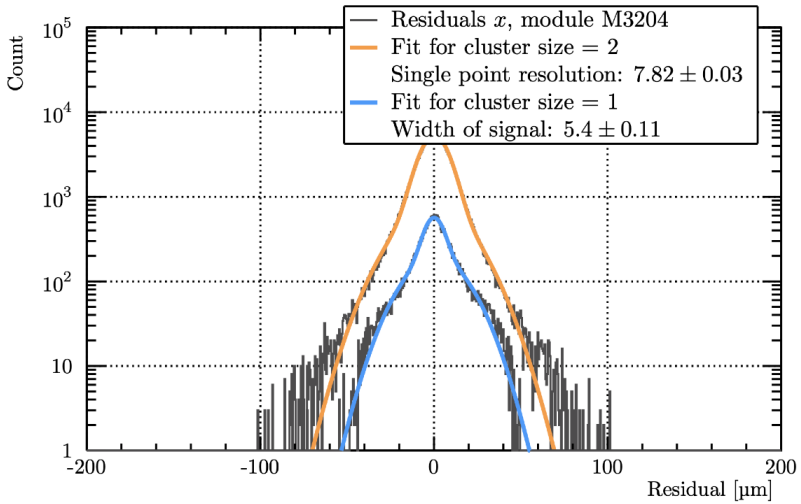


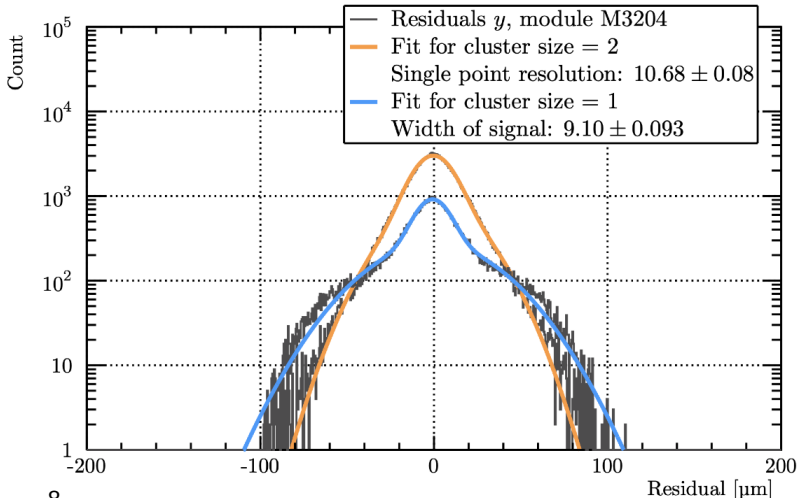
- Fast, high-resolution pixel telescopes (CMS modules) before and after the target
- Fast GEM detectors from CMS before and after the magnet
- Combination of several calorimeters
- 4+2 Muon chambers (triggerless readout); ready
- Improved (integrated, low dead time) DAQ system
- Improved trigger system

Pixels



- 12 new modules (from CMS upgrades) being produced:
  - 20 kE total, need to grant planned SJ to PD (10 kE)
- PD will take care of mechanical supports
- Expertise and technical support from the CHROMIE community
  - We'll borrow all read-out and powering/control electronics
- Need to develop an appropriate trigger system (TTC based)

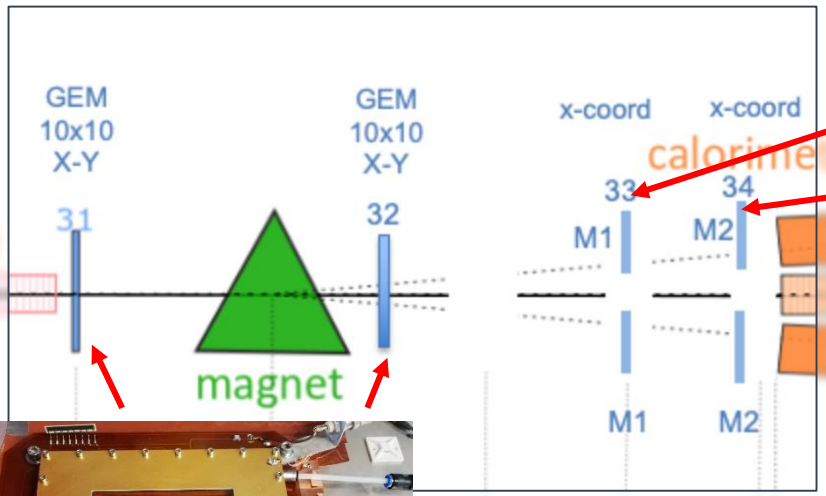


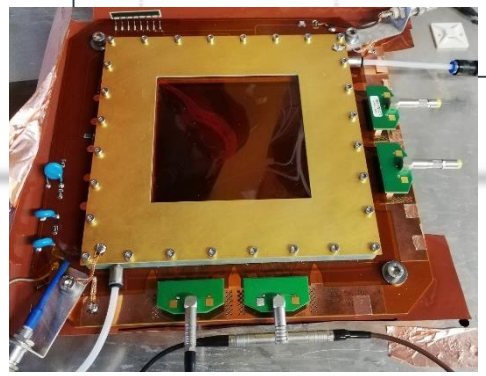


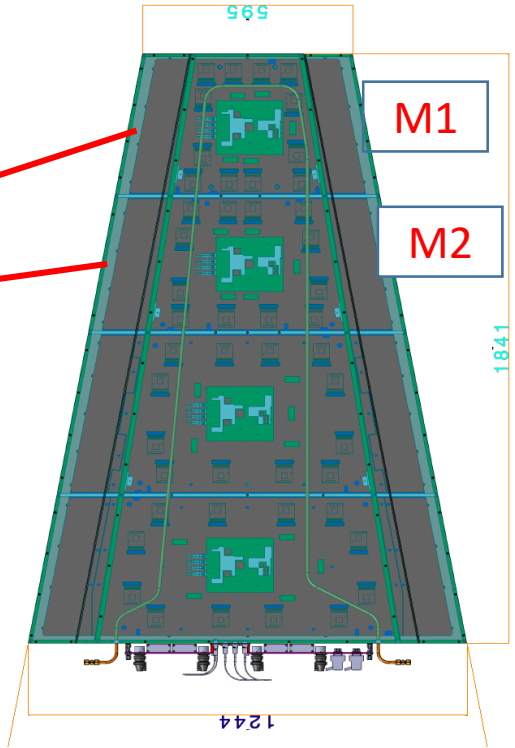
N. Deelen, N. Bacchetta

GEMs

- 2 Dedicated Hi-res 10x10 triple-GEM
  - X-Y, 260 μm pitch (75 μm resol.)
- Standard CMS GE2/1 "M1" and "M2" modules in muon arms
  - Trapezoidal, 364-593 μm resol.
- All read out by CMS Phase 2 DAQ







A. Colaleo et al.

Calorimeters

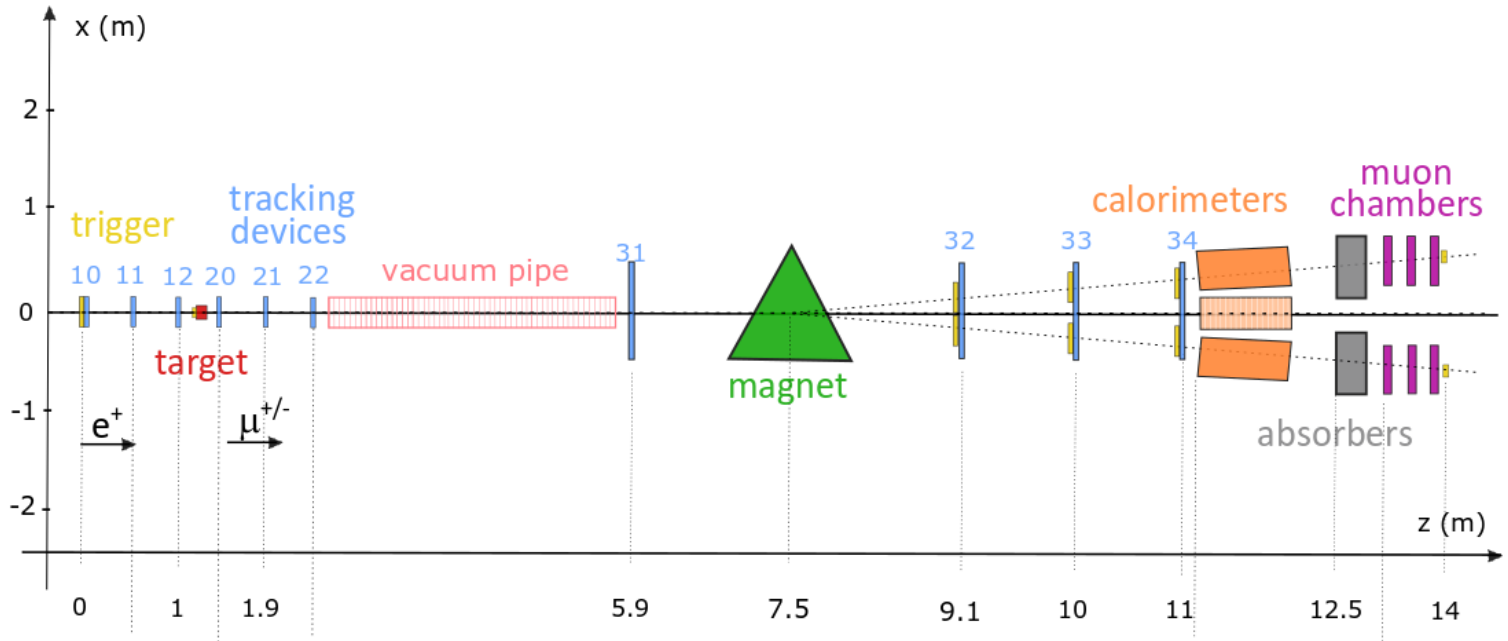
- Calorimeters offer a window on **Bhabha** and **γγ** processes, with several potentially interesting applications

- In 2018, we had lead glass (OPAL) + Cherenkov (crysBeam Smart Absorbers) on muon arms
  - Used for studies of μ/e ratios on muon arms

- **More performing calorimeters would allow much more**
  - Tag Bhabha events (with calorimeters on muon arms)
  - Detect $e^+e^- \rightarrow \gamma\gamma$ **(**with additional central calorimeter)
    - Signature: 45 GeV collinear photon
  - These well known processes can be used to **provide normalization for x-section measurement**…
    - Challenges: properly define acceptance + background from radiative bhabha
    - Still at the level of general ideas; need to be developed from scratch

Trigger

- In principle based on a "simple" set of scintillators
  - **In front of target** to tag incoming positrons
    - Should precisely **define acceptance of target**
    - Rate: expecting 10^7 e^+ per 4.8 s spill
  - (if needed) **on muon arms** (and possibly after iron absorbers)
    - Tag bhabha and $\mu^+\mu^-$
    - Control of acceptance and efficiency is critical
- Actual design depends on what will be feasible with DAQ



What needs to be done

- A lot of work ahead!
  - Define the proper configuration and positioning of the tracking detectors
  - Complete detectors, mechanic, readout
  - DAQ and trigger
  - Integration of detector systems; possibly including integration tests
  - Reconstruction software
  - Simulation studies
  - Develop analysis strategy – e.g. techniques and feasibility for relative normalization of xsection measurements, etc.

- Where we (TO) can contribute:
  - **miniDT** integration, operation, reconstruction
  - **Trigger system** concept (and construction?)
  - **Simulation, experiment design, definition of analysis strategy**
  - …