Istituto Nazionale di Fisica Nucleare

Test beam analysis: results

Preshower and muon chambers

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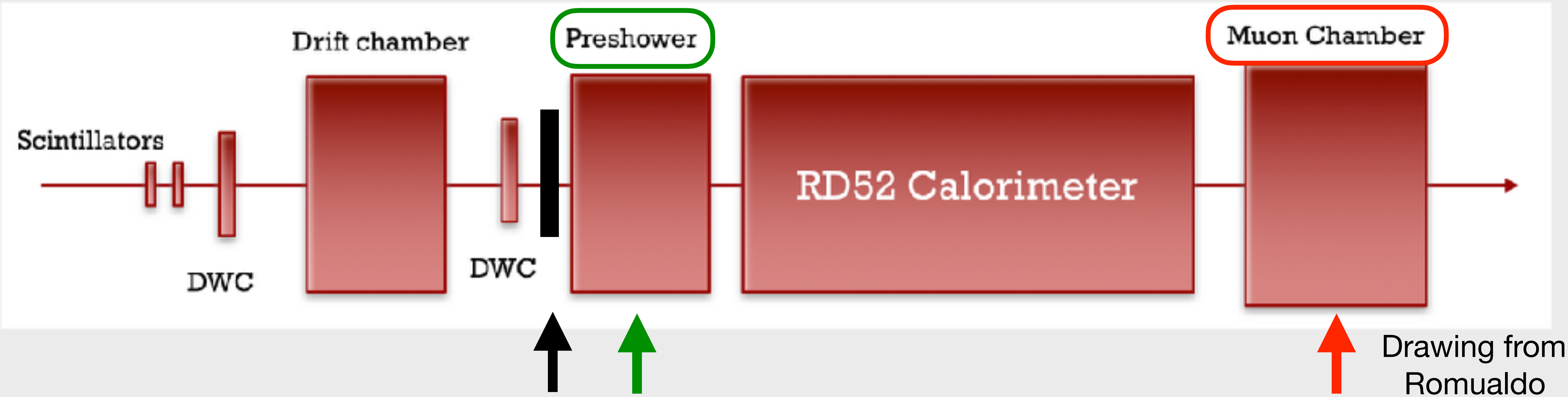
Outline

- Introduction to the **preshower** and **muon chambers** setup
- Reconstruction of events
- Alignment of the system wrt the rest of the test beam setup
- Efficiency estimation
- Analysis: μ/e runs + lead thickness scan
- Counting particles in clusters
- Comparison with "simple" GEANT4 simulation
- "Clustering" simulation data to obtain test beam results
- Extrapolation of preshower information to calorimeter

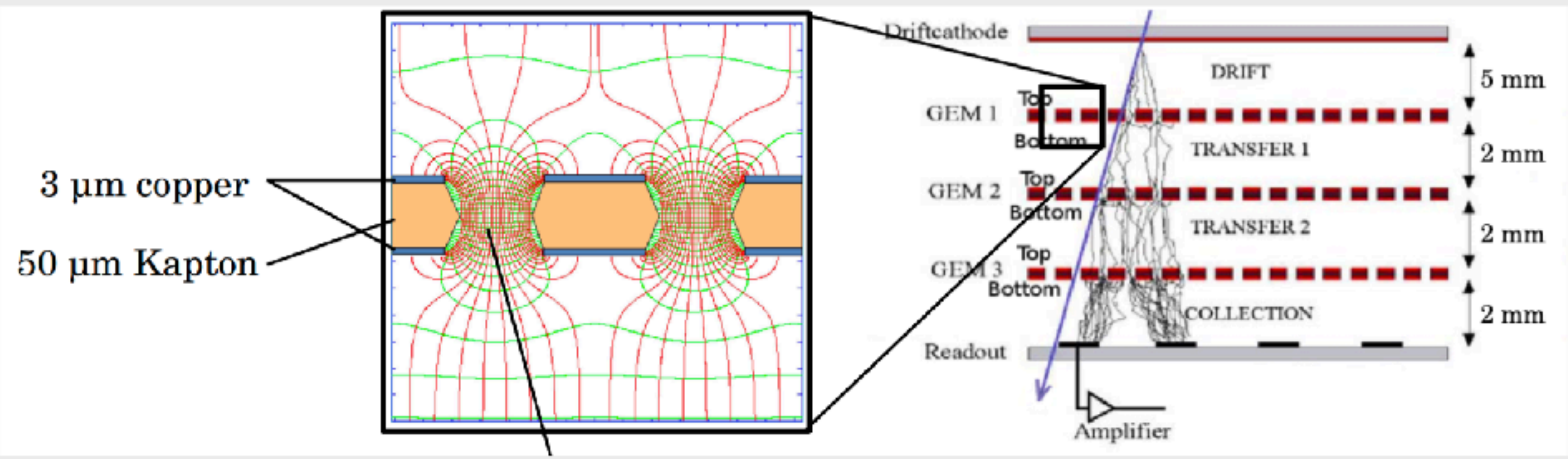
Pre-Shower and Muon system



- **Pre-shower**: GEM technology
- **Muon system**: GEM + μ-RWELL technology
- Different **lead** thickness in front of the pre-shower: X_0 in [1 - 2.5]

GEM technology

- GEM foil: 50 μm kapton foil copper coated on both side
  - voltage applied produces high intensity electric field ⇒ amplification stage
- Triple-GEM technology:
  - Drift volume: ionization
  - 3 GEM foils with transfer region in between: amplification
  - Read-out PCB: signal extraction

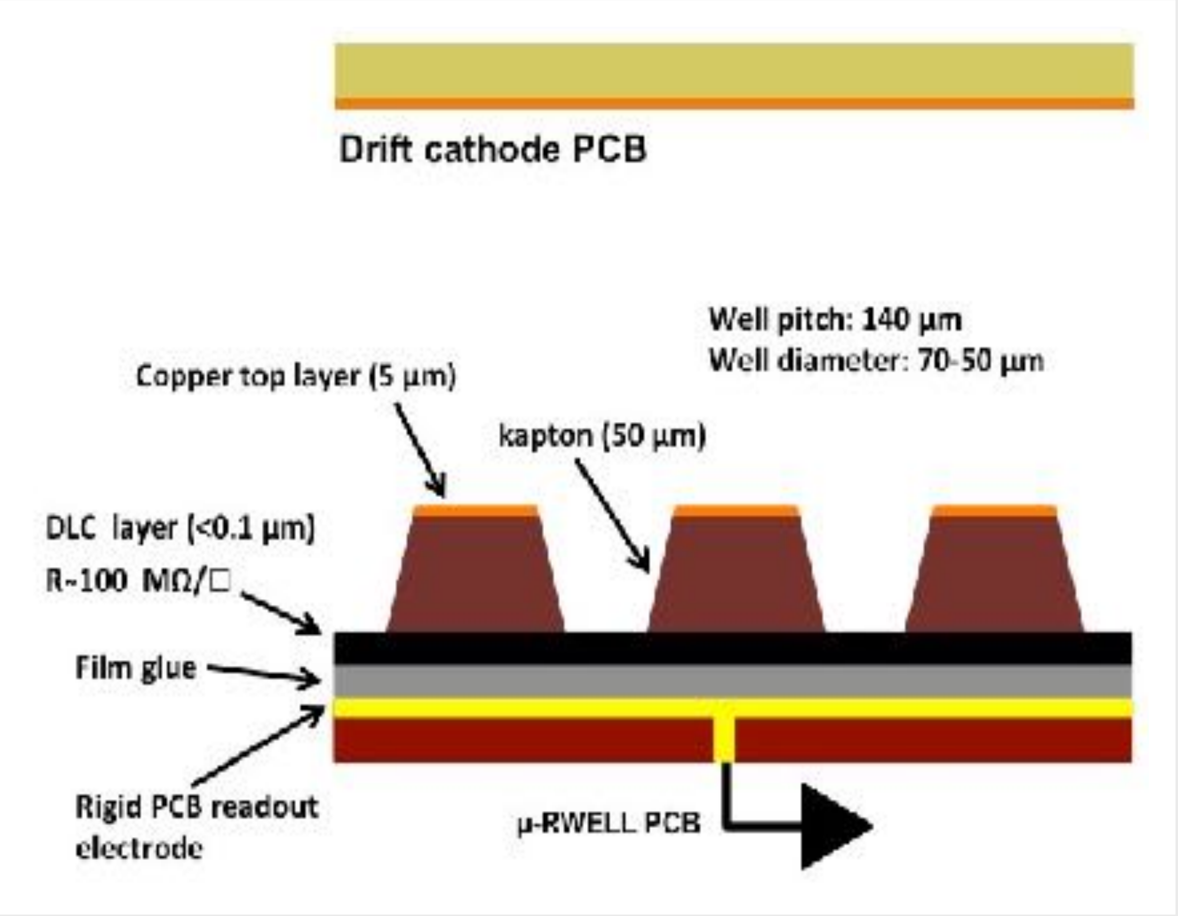


µ-RWELL technology

- The µ-RWELL technology is composed of only 2 elements:
  - <u>**µ-RWELL PCB**</u> and **cathode**

↓

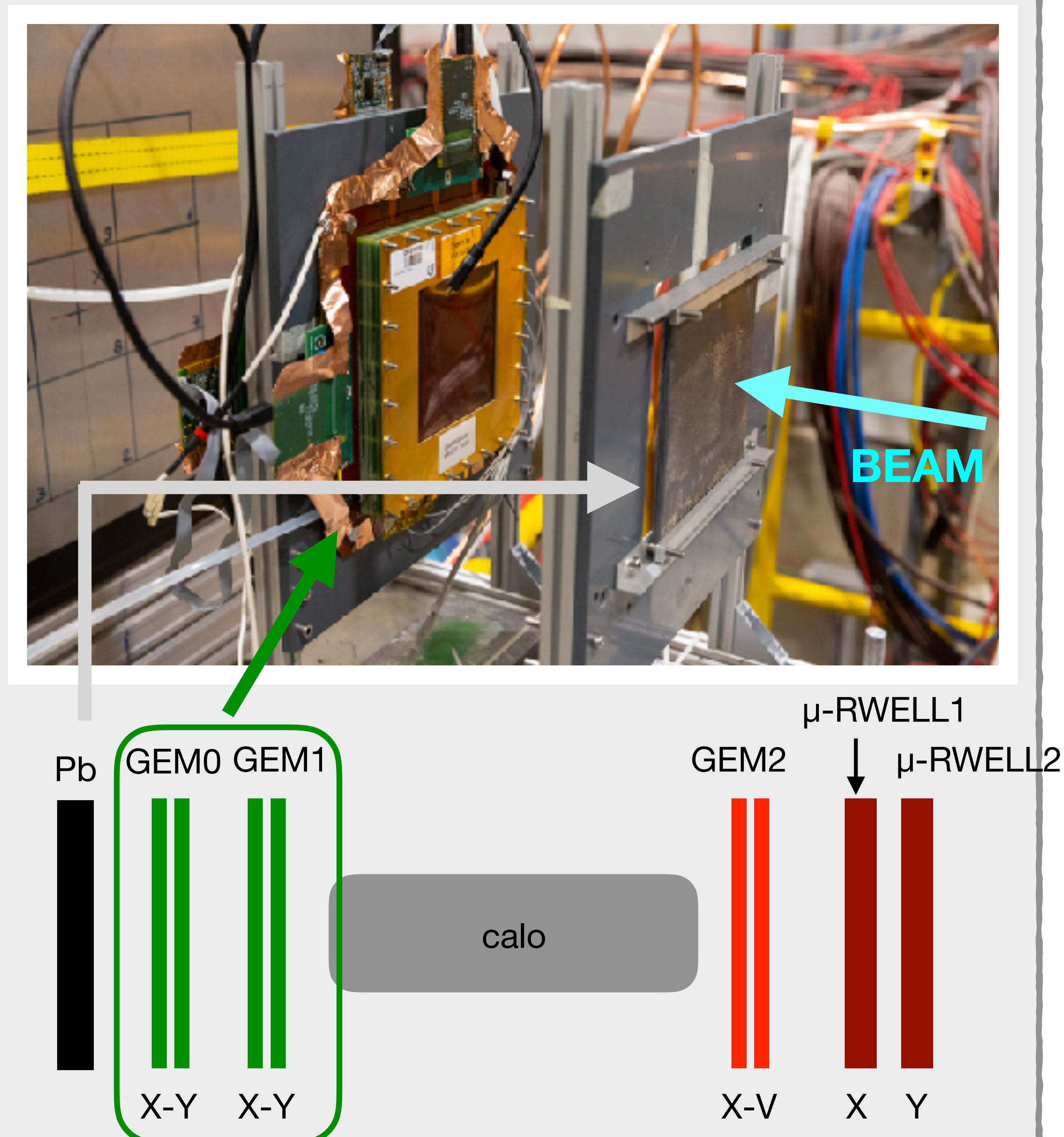
- a **WELL patterned kapton foil** as amplification stage
- a **resistive layer** for discharge suppression and current evacuation
  - Low rate particle scheme: 100 kHz/cm^2
  - High rate particle scheme: > 1 MHz/cm^2
- a standard readout PCB



Pre-Shower setup

- **2 Triple-GEM** detectors
  - “10x10” cm^2
  - both X-Y read-out
  - 128 channels (strips) per view
  - 650 μm pitch
  - spatial resolution: ~ 150 μm
  - Gas mixture: Ar/CO_2/CF_4 45/15/40
  - Gain ~ 10 k, **coupled HV for GEM0 and GEM1**

HV (V)	Pre-shower
Drift	1000
GEM1	425
Transfer1	600
GEM2	420
Transfer2	600
GEM3	415
Transfer3	1000

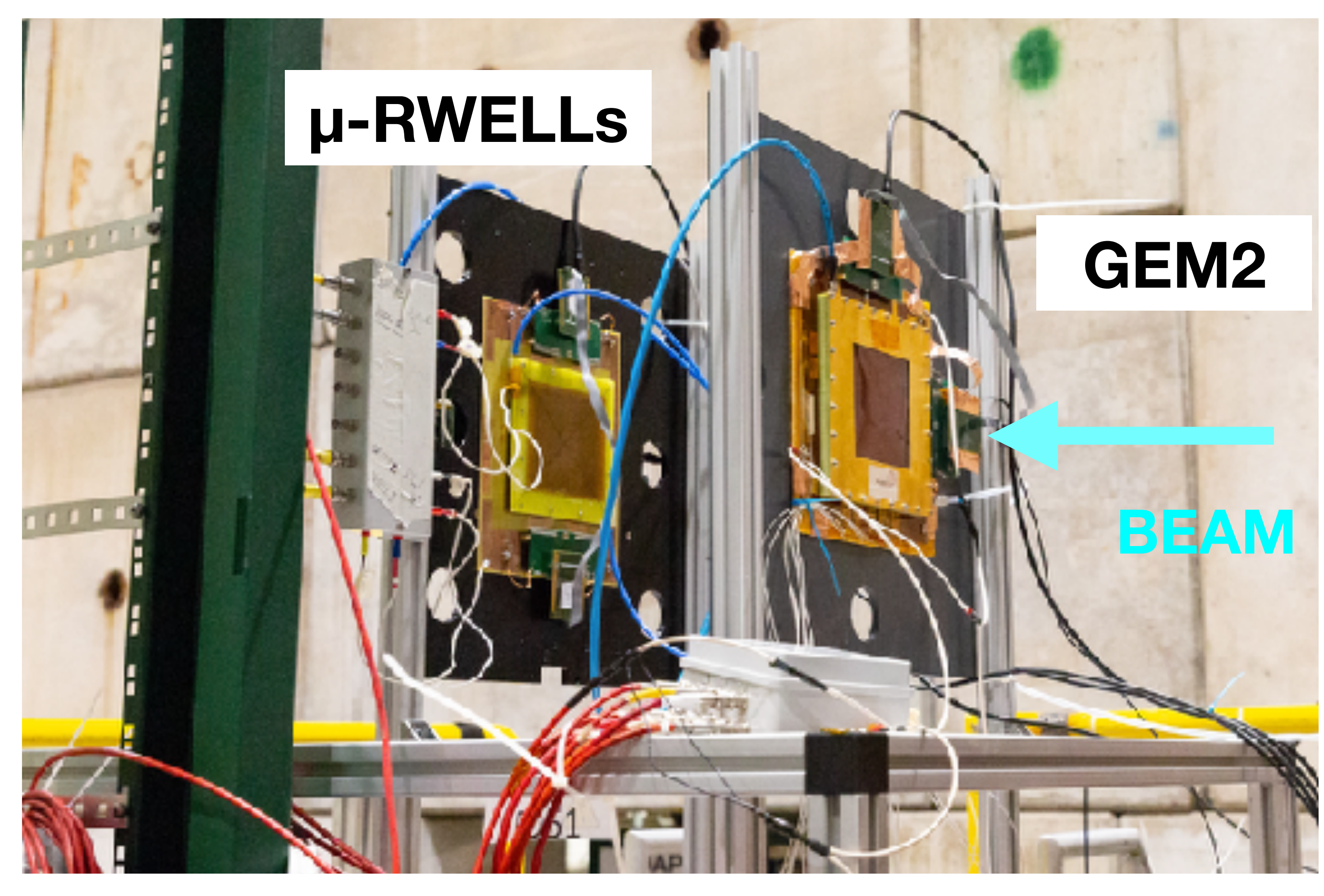


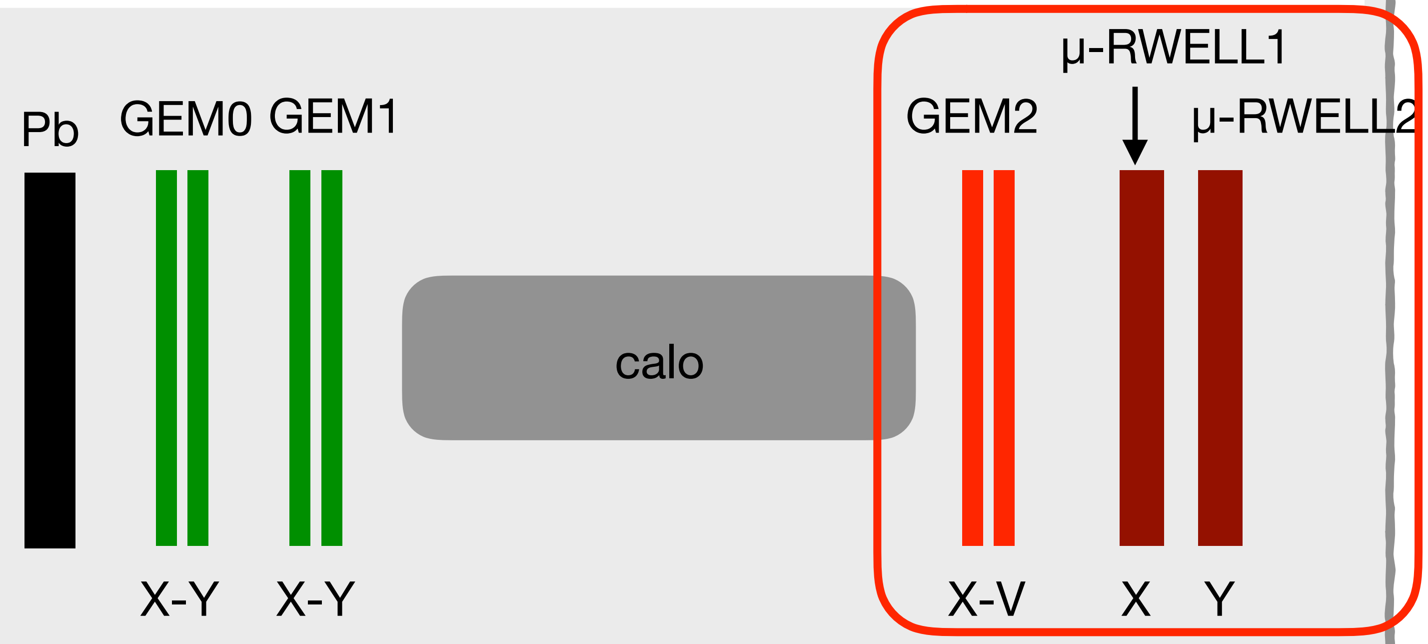
Muon system setup (1)

- **1 Triple-GEM** detector
  - same as before

    except:
  - read-out: X-V
  - Gain ~ 10 k, HV:

HV (V)	Muon
Drift	1000
GEM1	420
Transfer1	600
GEM2	415
Transfer2	600
GEM3	410
Transfer3	600

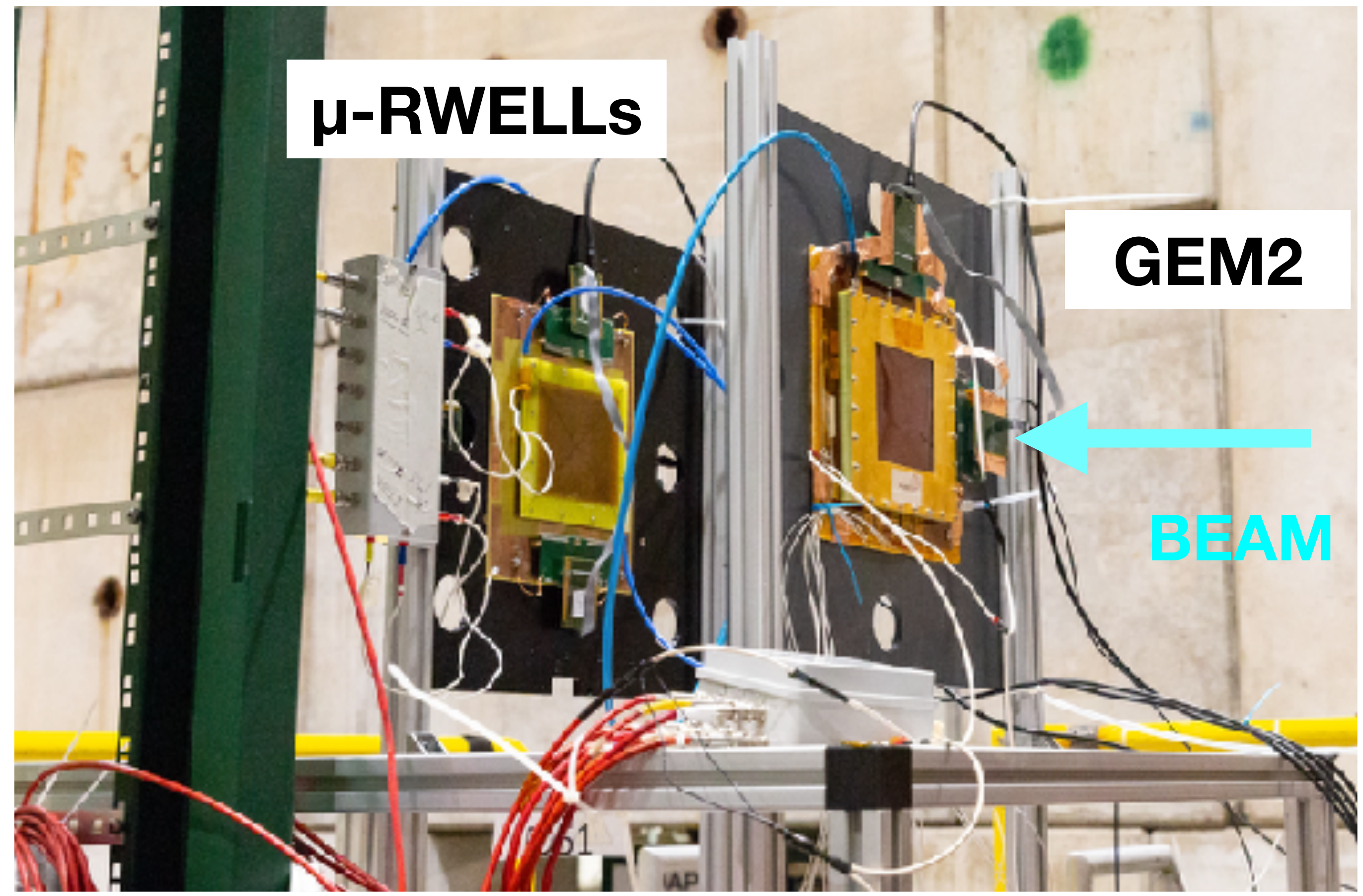


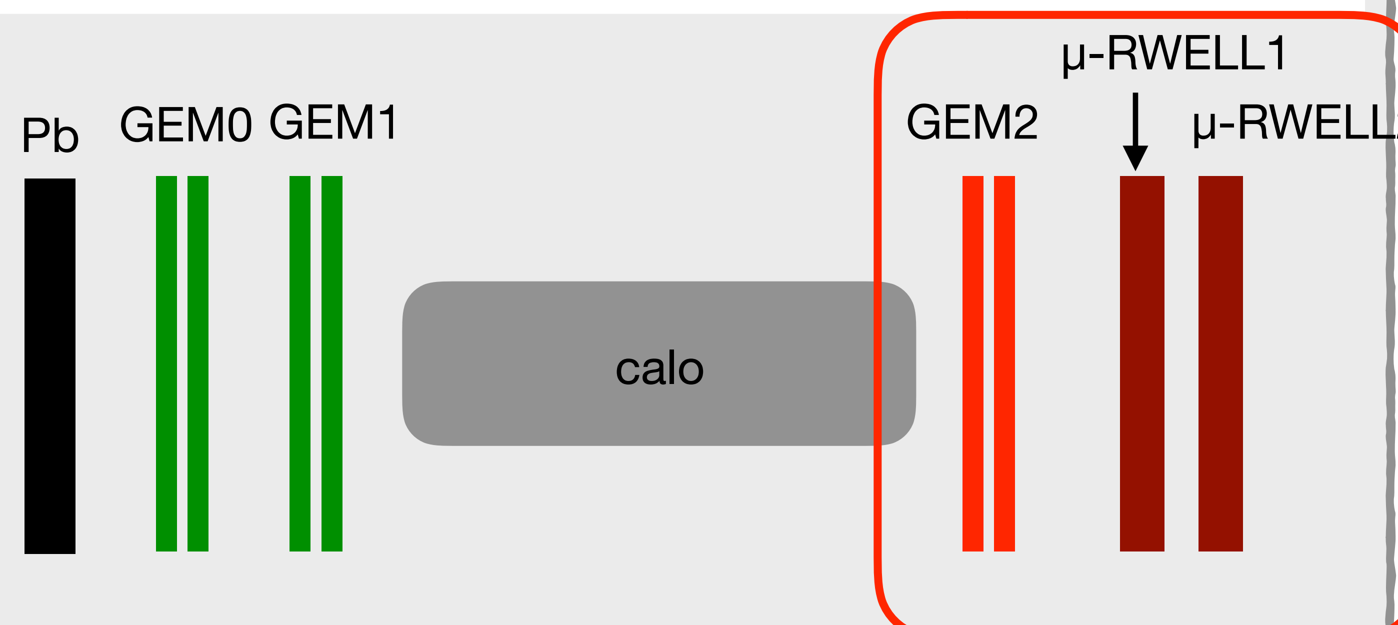


Muon system setup (2)

- **2 μ-RWELL detectors**
  - 10 x 10 cm^2
  - first: X read-out, second: Y read-out
  - 256 channels (strips) per detector per view
  - 400 μm pitch
  - spatial resolution: ~150 μm
  - Gas mixture: $Ar/CO_2/CF_4$ 45/15/40
  - Gain ~ 10 k

HV (V)	u-RWELL1	u-RWELL2
Drift	2400	2400
WELL	570	585





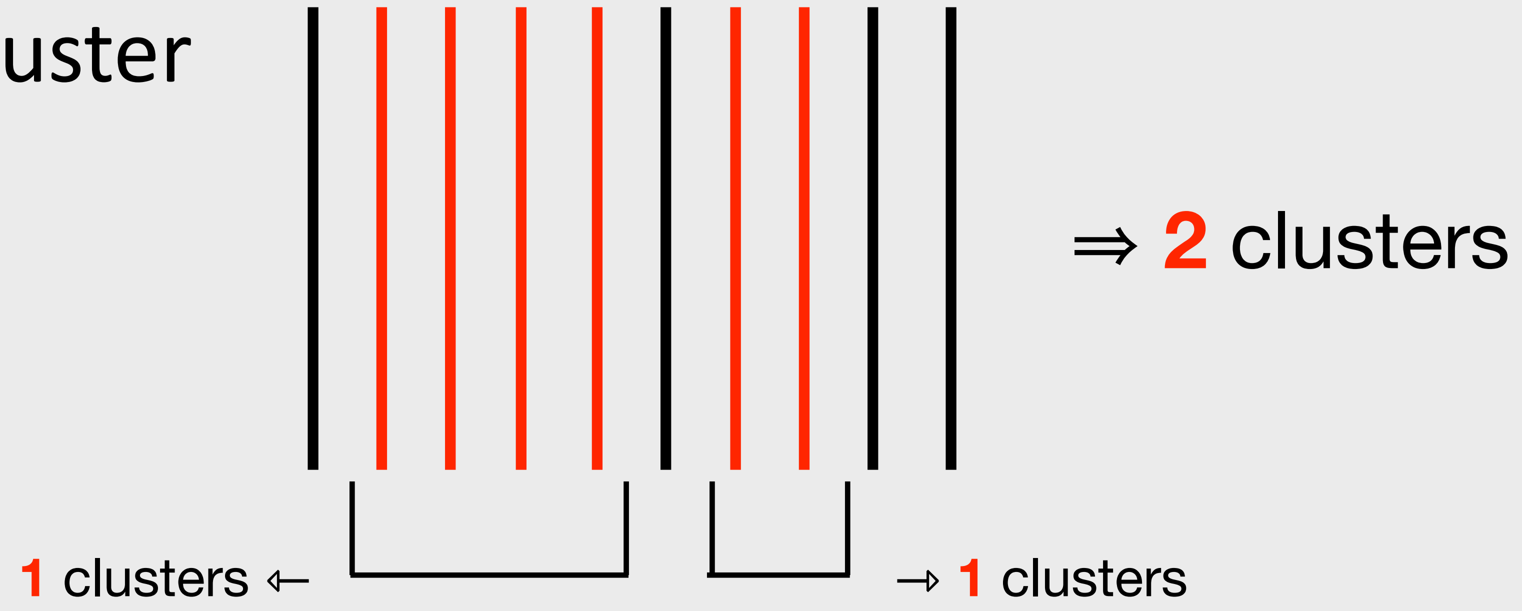
General info on measurements

- Lead thickness scan with electron beam
- Muon / Electron beam with no additional lead
  - 5 mm lead always in front of all pre-shower and muon system detectors
- Runs used:
  - 51 (calo #12688): MUON 40 GeV - Pb: 0 mm (+ 5 mm) = ~ 1.0 X_0
  - 71 (calo #12709): ELECTRON 20 GeV - Pb: 0 mm (+ 5 mm) = ~ 1.0 X_0
  - 66 (calo #12705): ELECTRON 20 GeV - Pb: 3 mm (+ 5 mm) = ~ 1.5 X_0
  - 65 (calo #12704): ELECTRON 20 GeV - Pb: 6 mm (+ 5 mm) = ~ 2.0 X_0
  - 64 (calo #12703): ELECTRON 20 GeV - Pb: 10 mm (+ 5 mm) = ~ 2.5 X_0

Event reconstruction

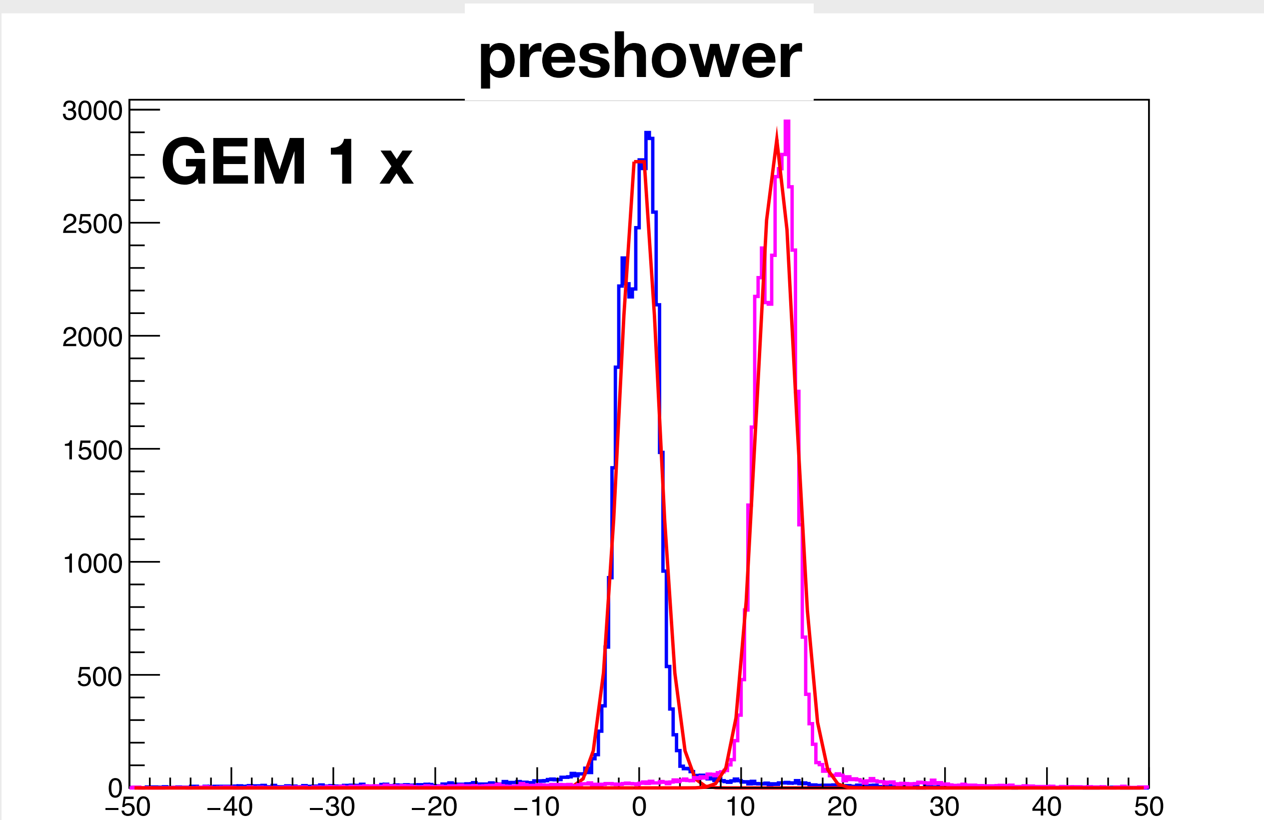
GRAAL : GEM Reconstruction And Analysis Library

- Developed in last 3 years, successfully used to reconstruct and analyze raw data acquired by GEMs for several test beams
- **Goal**: transform the data acquired with the APV25 into collections of Hit (strips) and Clusters (group of strips) which are used in the analysis
- Contiguous strips on the same detector and view are collected together to create a cluster



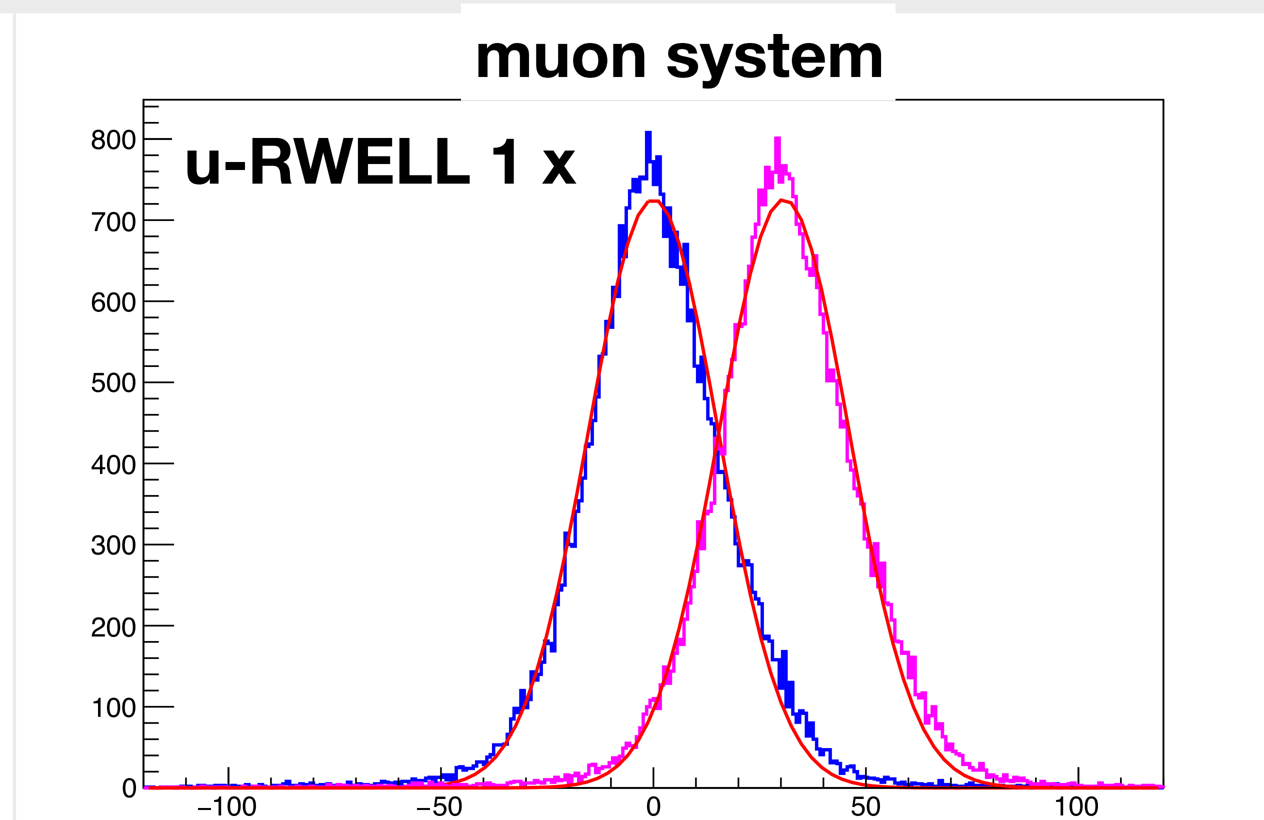
Alignment

- Used ancillaries to align preshower and muon system detectors
- Muon run used (to have muon system information too)
- Residuals distribution used to align (simple shift) → applied "shift" corrections to all ntuple



Before Alignment
Mean 13.5 mm
Sigma 1.9 mm

After Alignment
Mean 0.0 mm
Sigma 1.9 mm



Before Alignment
Mean 30.8 mm
Sigma 15.3 mm

After Alignment
Mean 0.0 mm
Sigma 15.3 mm

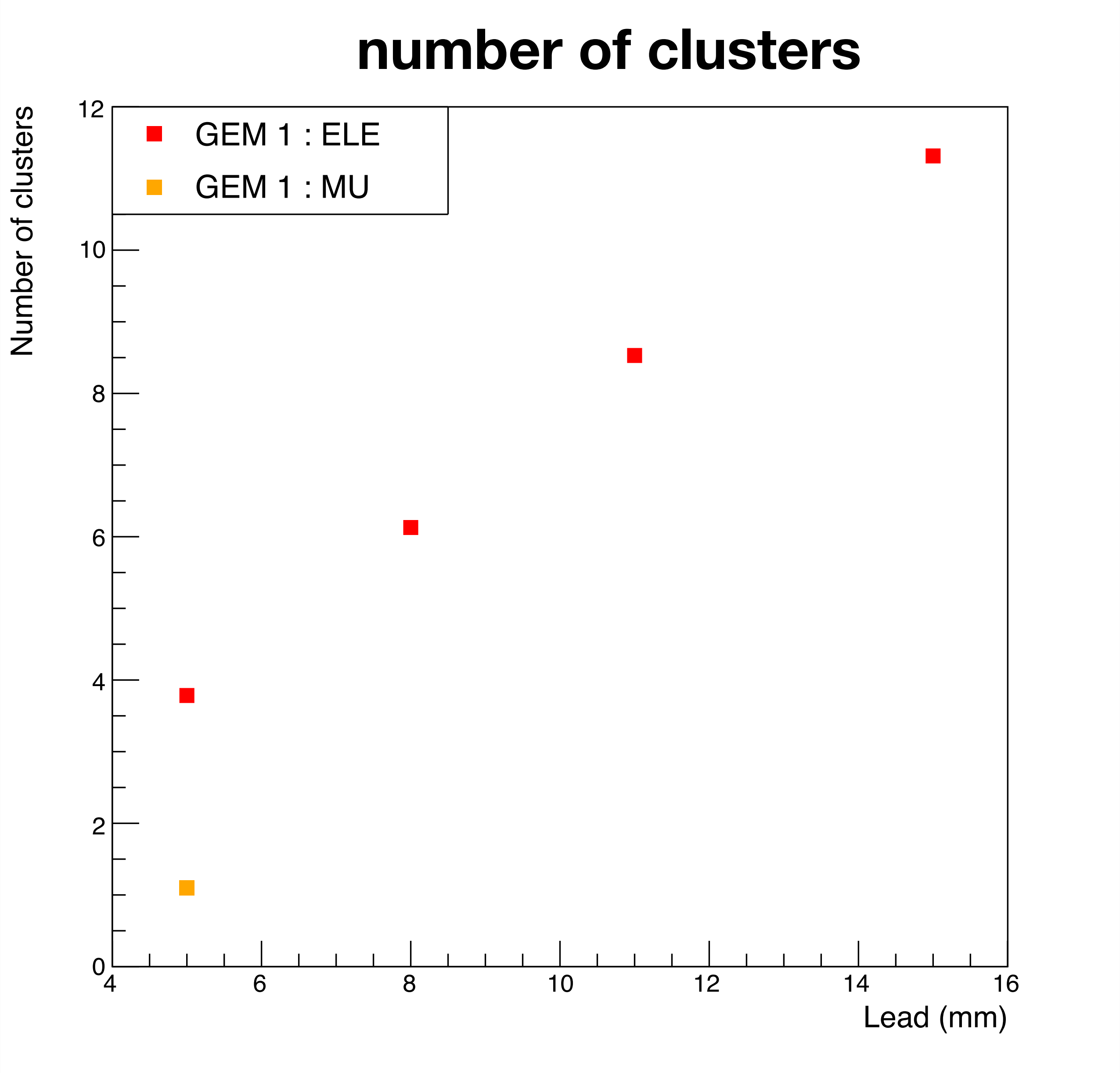
Efficiency

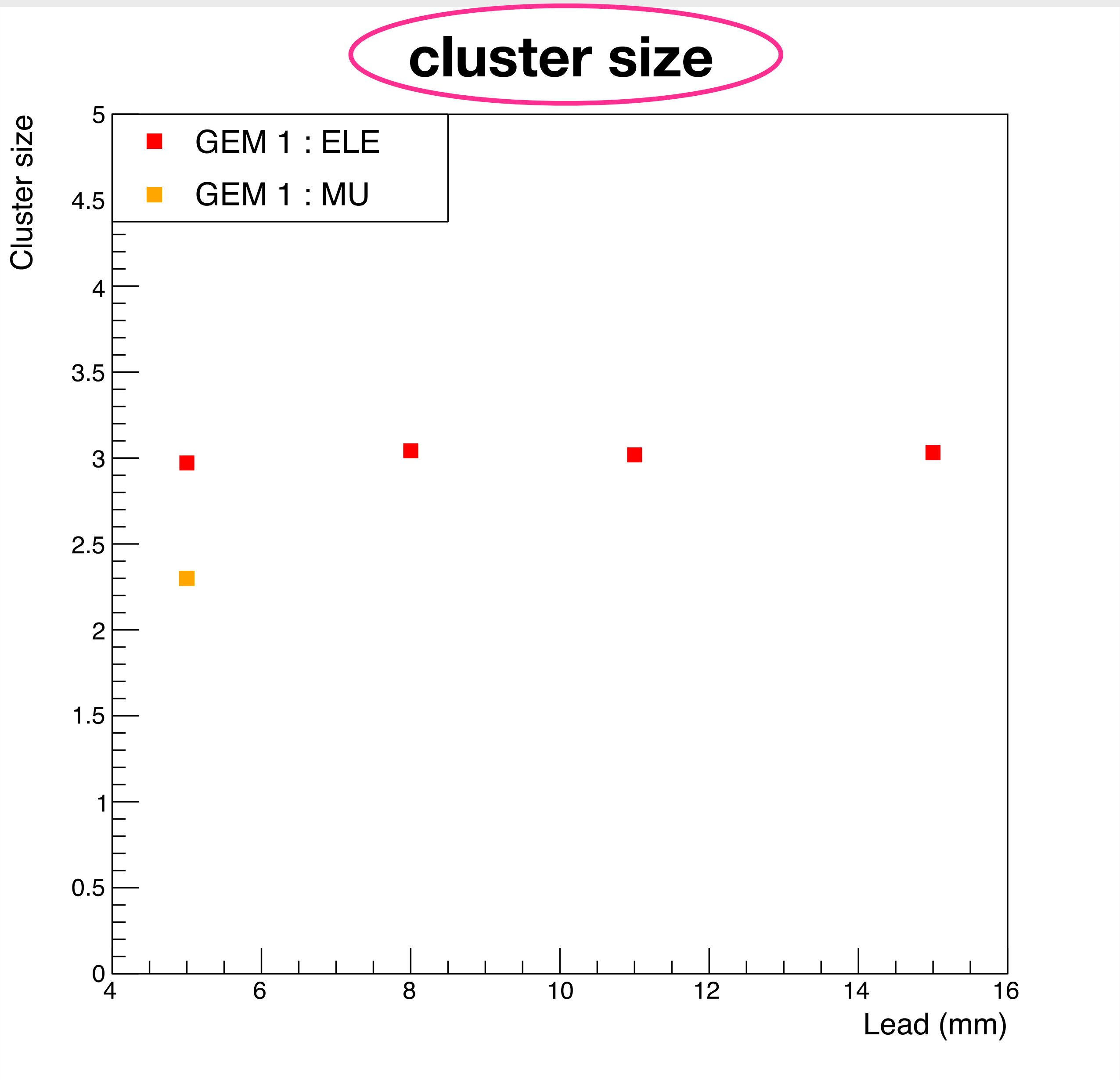
- MUON RUN to have correct information
- Denominator: all events that are MU tagged and have a track from the DWC
- Numerator: filled if cluster is found inside 3 sigma from the extrapolated expected position from DWC → per each chamber

GEM **0**x	GEM **0**y	GEM **1**x	GEM **1**y	GEM **2**x	u-RWELL **1**x	u-RWELL **2**y
32%	28%	98%	97%	96%	96%	94%
★	★					

Number and size of clusters

GEM 1x

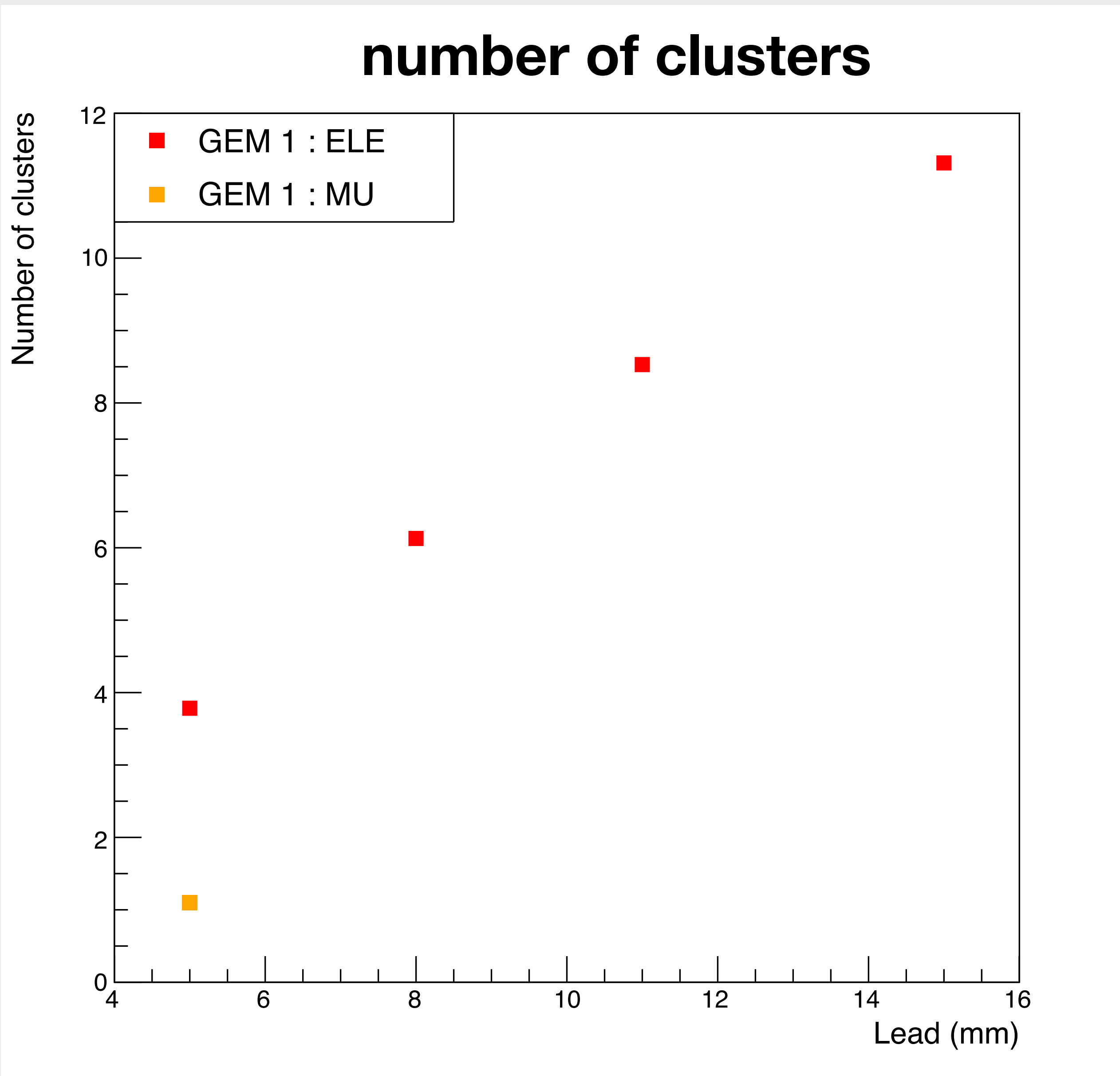


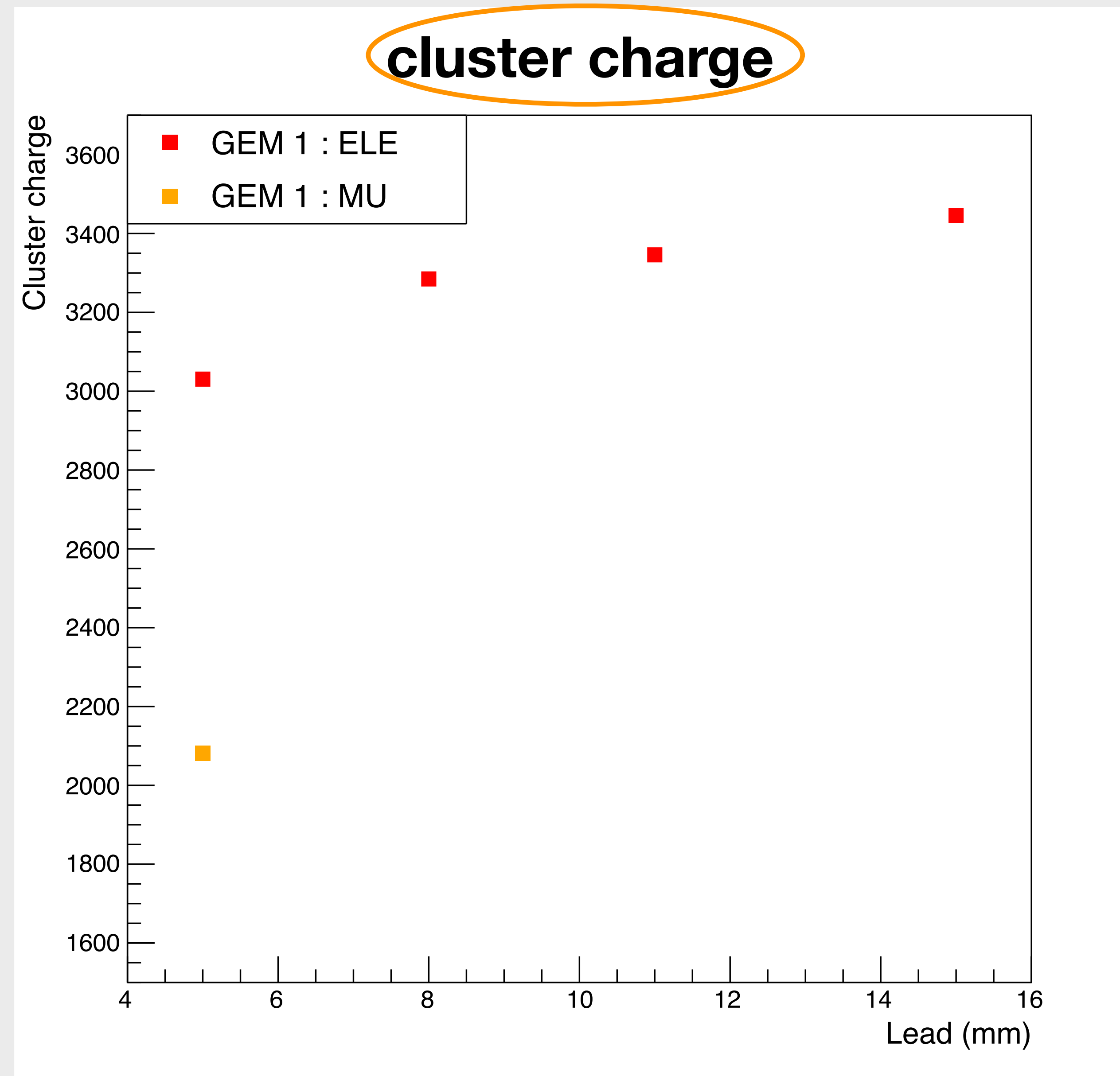


Number of clusters increases with Pb, while cluster size is constant

Number and charge of clusters

GEM 1x

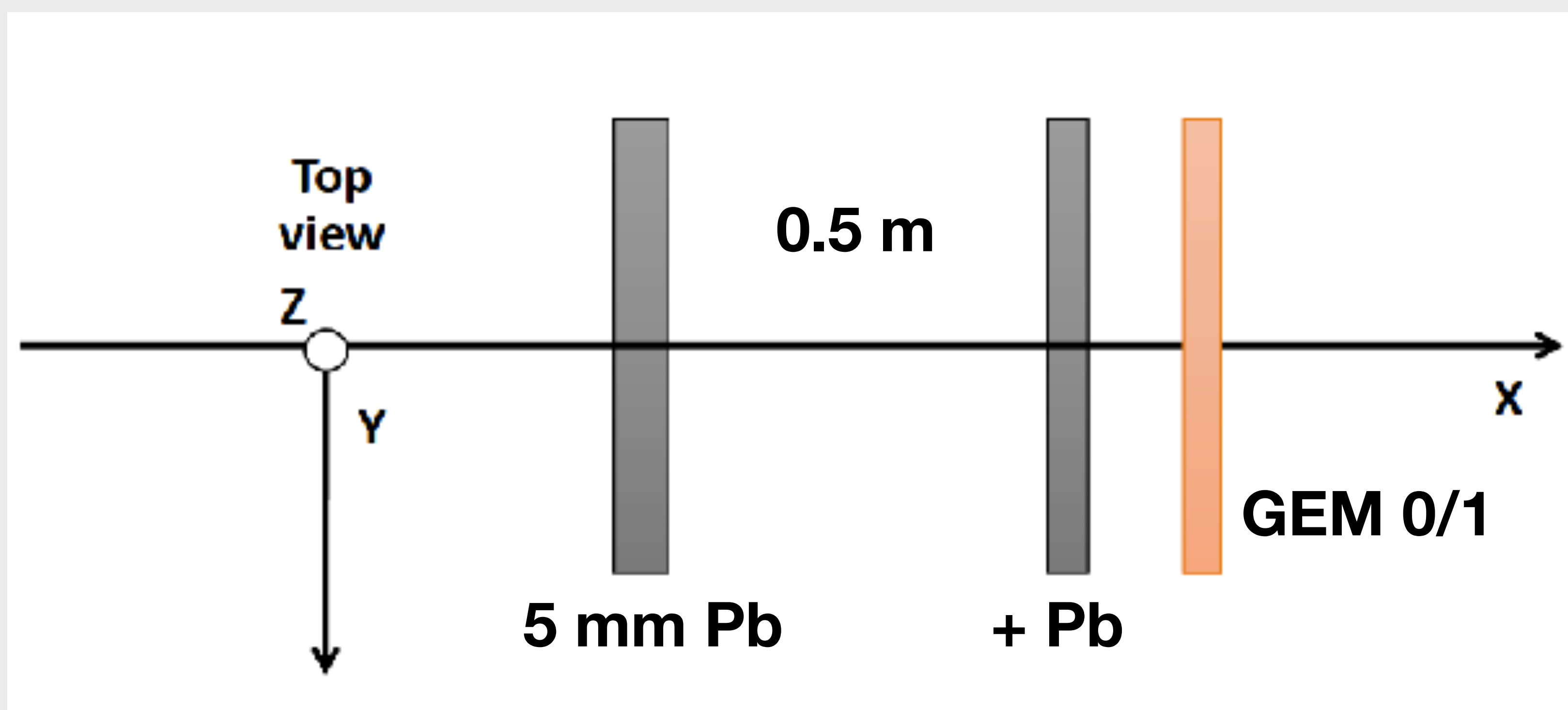




Cluster charge increases with Pb even if less than number of clusters

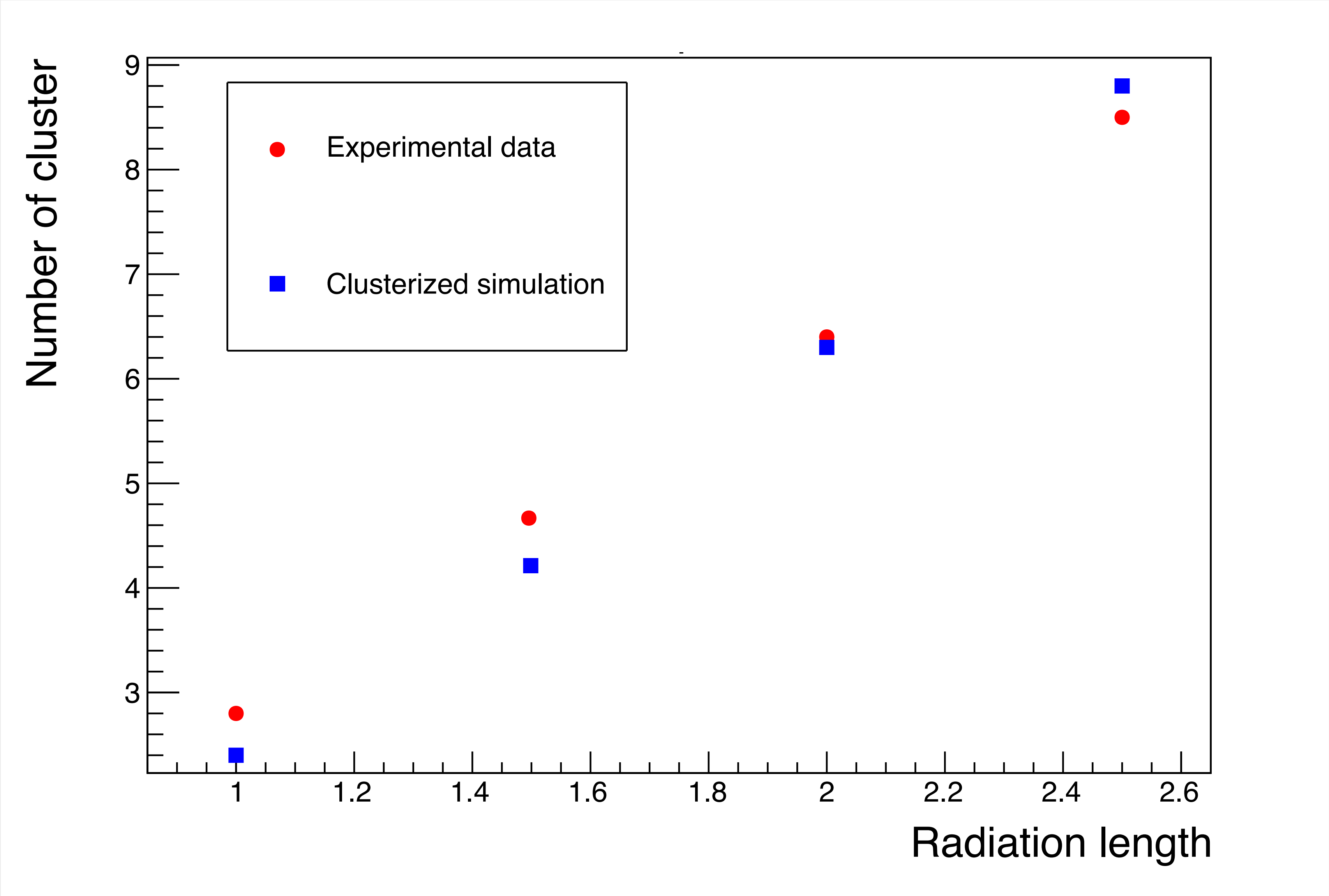
Simple simulation with GEANT

- Want to see the effect of different lead thicknesses on electrons
- Used GEANT to simulate the two lead volumes and the GEM surface
- Counted particles on the GEM 1x surface
- Simulated 1000 **electrons (20 GeV)**



Clustering from simulation data

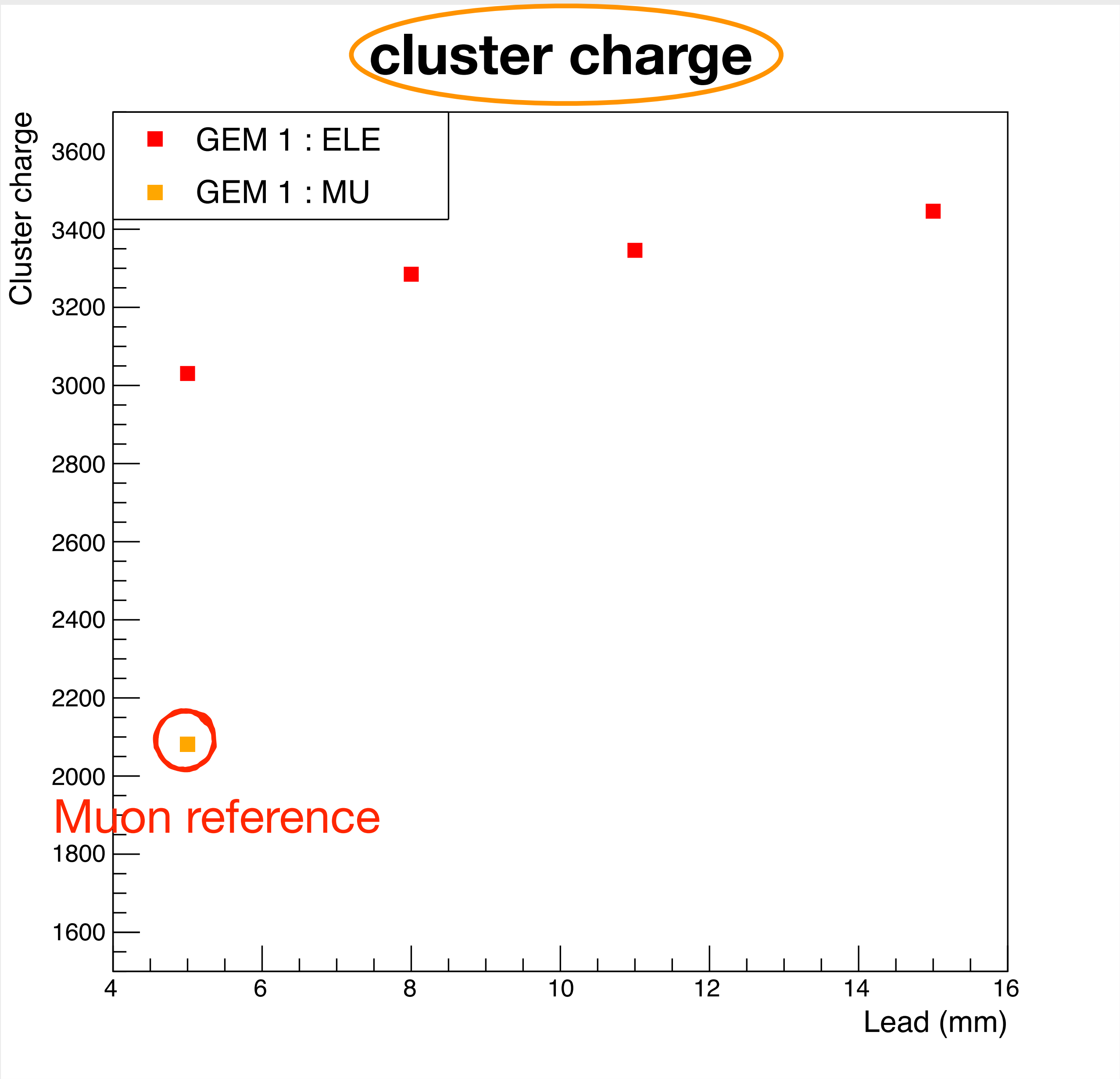
- Comparison between number of clusters distributions obtained with clustering on simulation data and on experimental data
  - Energy cut: > 5 MeV



Simulation validated

Counting particles in clusters (1)

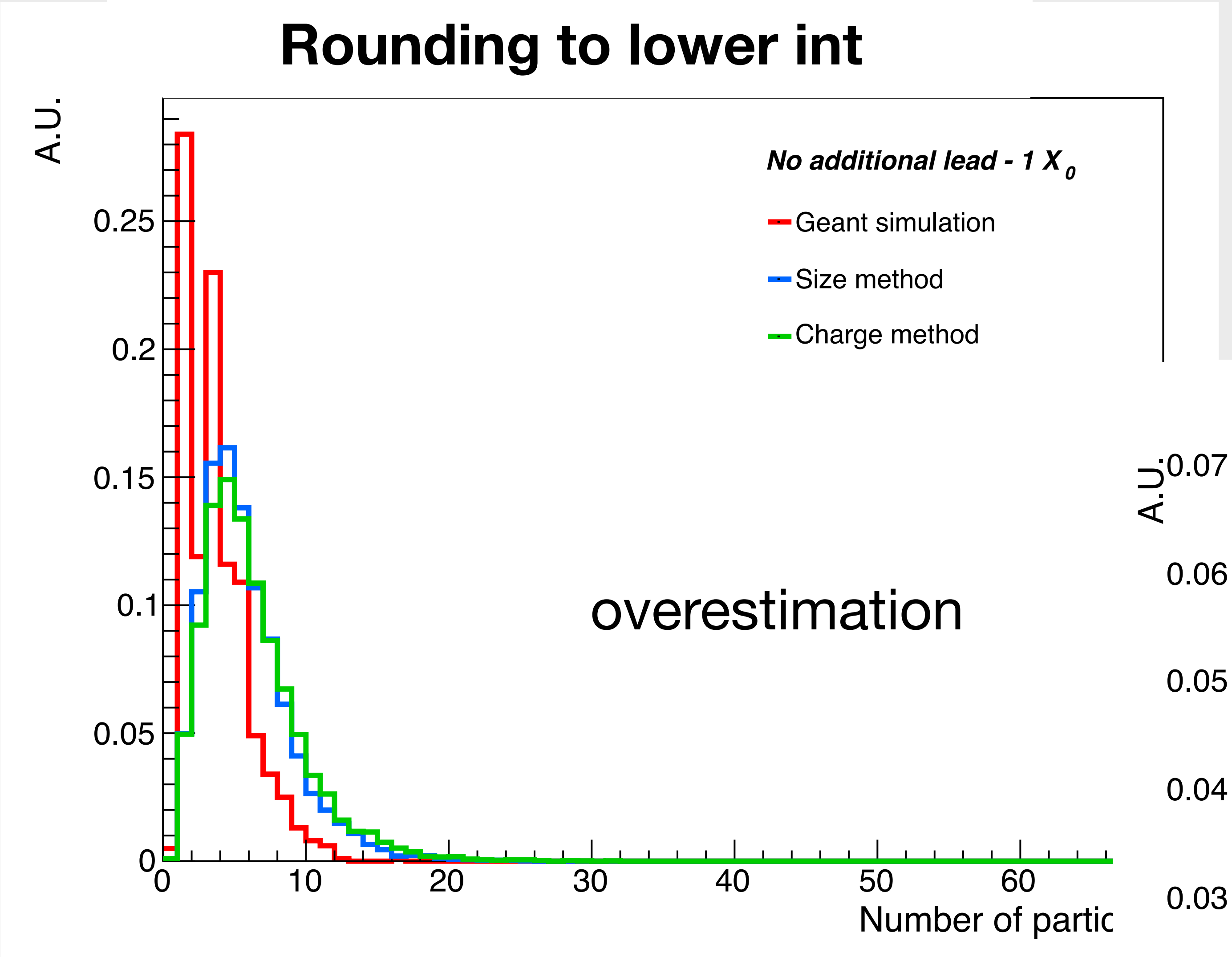
- Took muon average cluster charge as reference = 1 particle
- Divided cluster charge of electron clusters by muon reference cluster charge and got a guess on how many particles are present in each electron cluster
- Corrected for the number of saturated strips
- Same procedure using cluster size



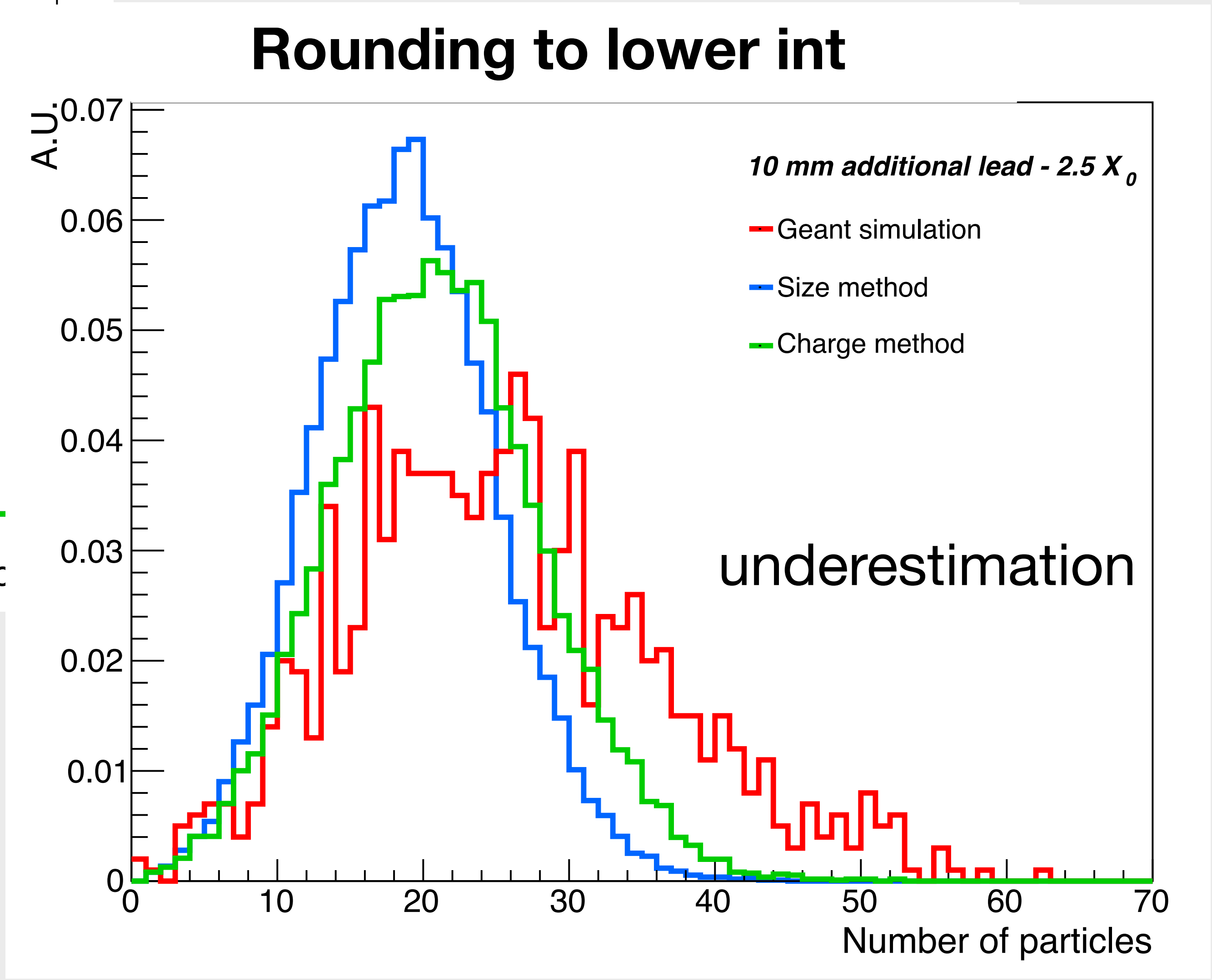
- Comparison between **GEANT simulation**, **Charge** method, **Size** method

Counting particles in clusters (2)

No additional Pb

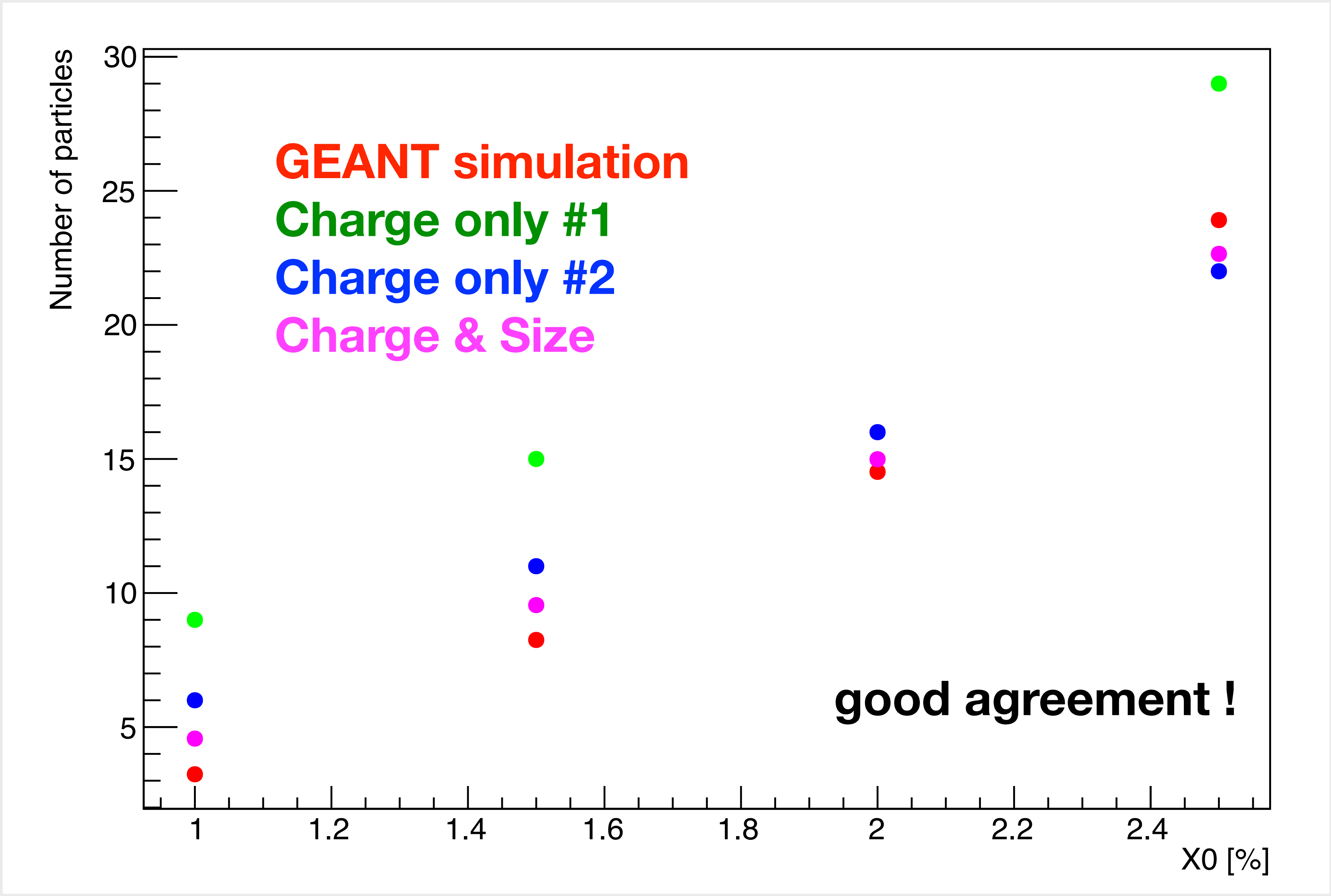


+10 mm Pb



Counting particles in clusters (3)

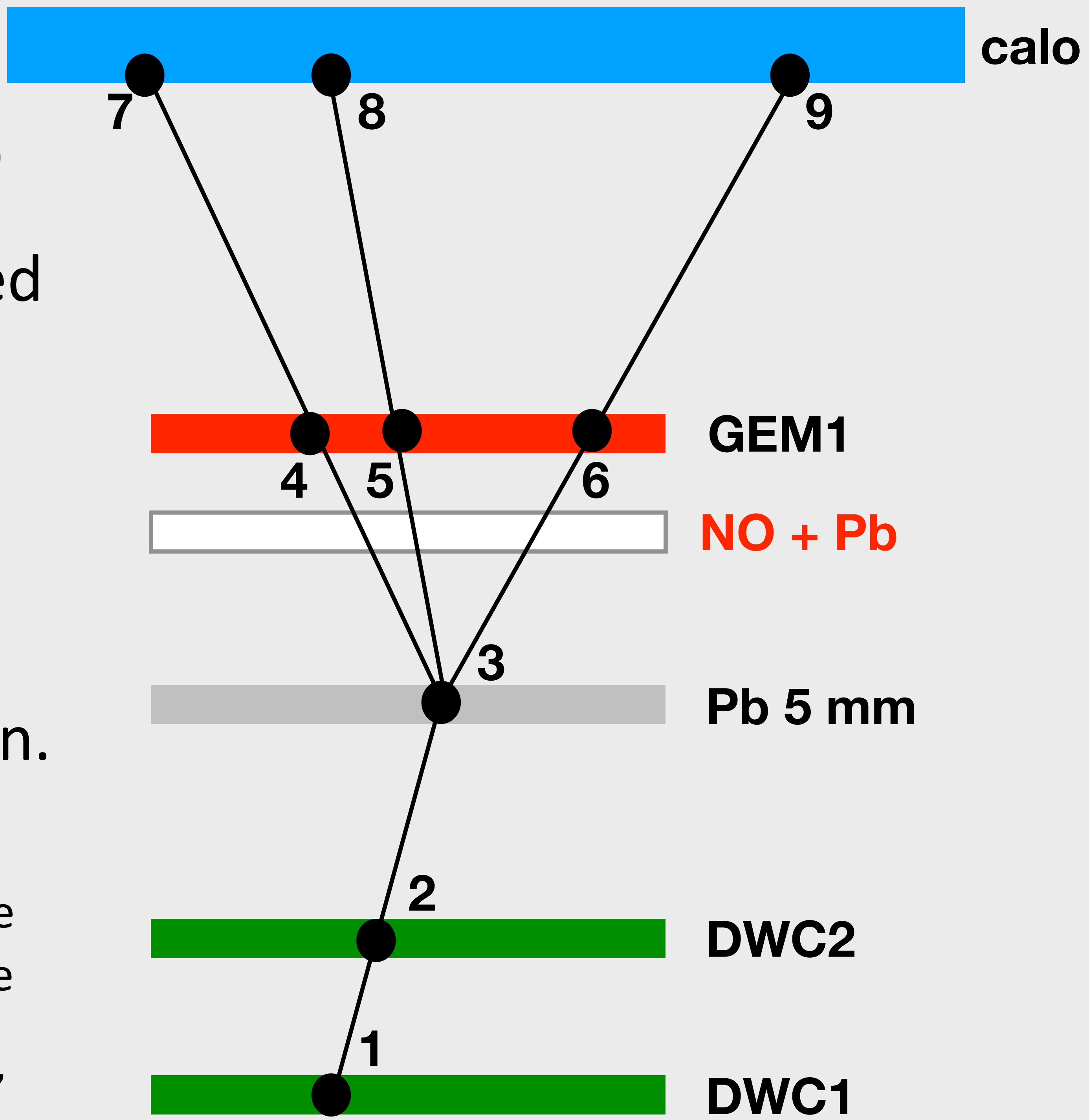
Best result: combining cluster size and charge in a parametric function to count particles from TB data to reproduce simulation results



particles = ceil (Cluster_charge * Cluster_size / 18000) - 1

Extrapolation to calorimeter (1)

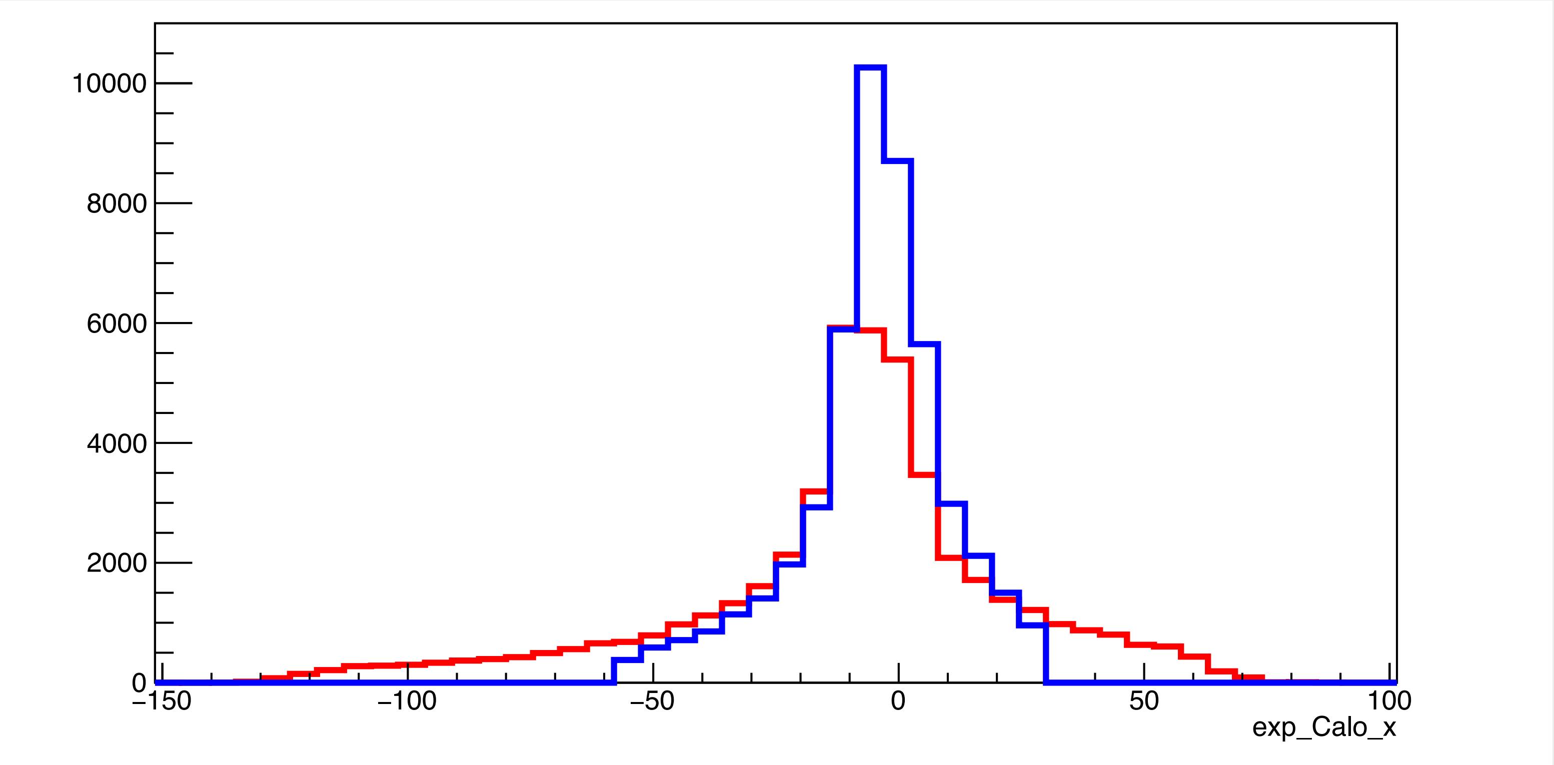
- Extrapolate preshower information on particle position to the calorimeter surface
- Feasible with no additional Pb
- Added the extrapolated expected position + estimation of the uncertainty* to the ntuples



* Scaled the size of each cluster in the range [0,1] where 0(1) is the smallest (biggest) cluster in the Run. This gives an idea on how big the **uncertainty on the position** is. If the cluster is big, it probably contains more than one particle, but we give only one position i.e. the center of the cluster, with a big "scaled size info"

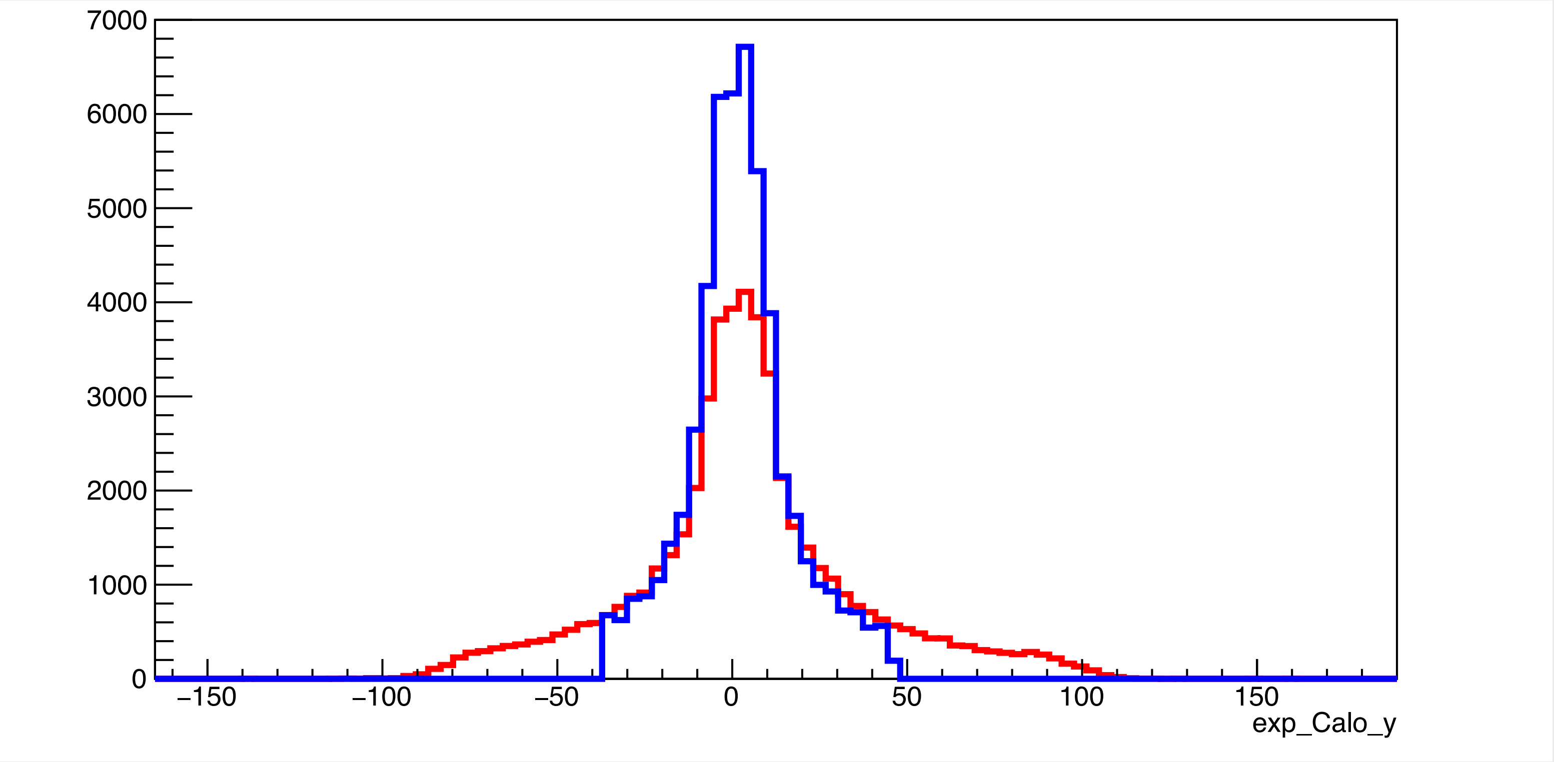
Extrapolation to calorimeter (2)

x position



Beam profile:
GEM 1x
expected calo surface

y position



Beam profile:
GEM 1y
expected calo surface

Conclusions

- Preshower (2 GEMs, x-y) + muon system (1 GEM + 2 u-RWELLs, x-y)
- Reconstruction of events + alignment of the system wrt the rest of the test beam setup
- Efficiency estimation: ≥ 95 % (except for GEM0)
- Effect of Pb: increasing lead thickness → increase in number and charge of clusters but not in size (more than one particle in the same space)
- Counting particles in clusters: good agreement comparing counting particles results to “simple” GEANT4 simulation
- Similar results when comparing “clustering” simulation data with TB data
- Extrapolation of preshower information (position of particles) to calorimeter can provide additional information to calorimeter measurements

Backup

Simulation of 5 mm gaps with Garfield

- Used Garfield to simulate energy release of electrons and muons in the 5 mm gas volume of GEM/μ-RWELL detectors ($Ar/CO_2/CF_4$)
- Electron and muons produce the same amount of primary electrons
- It is reasonable to assume that the greater cluster size is due to electrons produced in the lead