Detecting muons with SC16 detectors

Particle Physics Day 2019

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in collaboration with
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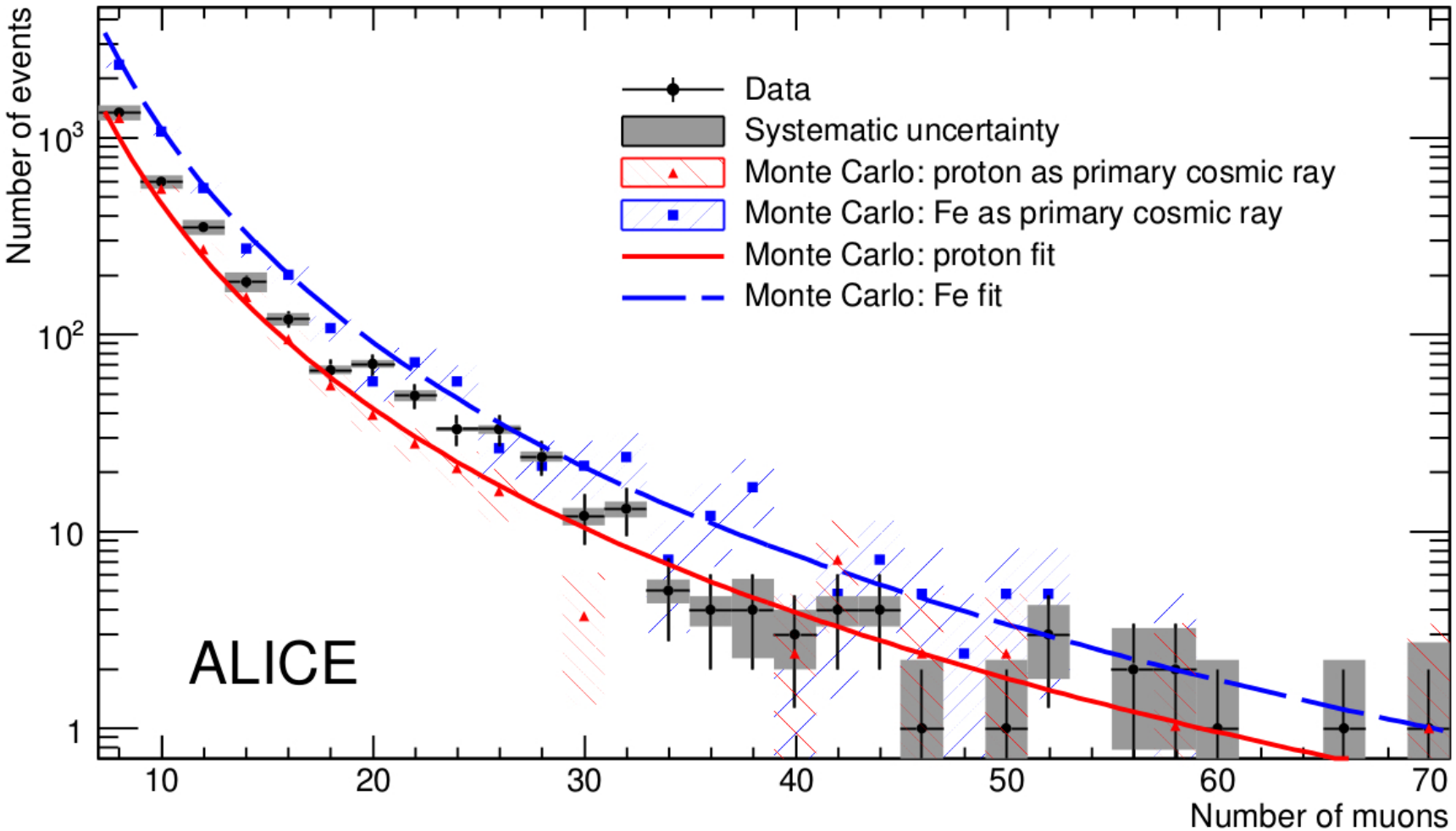
Detecting muons with SC16 detectors

- High-multiplicity muon events ($>10\ \mu/\mathrm{m}^2$) observed in several experiments
  - LEP – DELPHI, ALEPH, and L3+C
  - LHC – ALICE
  - EMMA – SC16 scintillation detectors
- CERN experiments
  - excellent tracking and identification but short measurement times (ALICE only few tens of days in 9 years) and small fiducial area
- EMMA
  - long measurement times, large fiducial area, moderate tracking and no identification
- Origin of the high-multiplicity muon events not fully understood
- Updated LHC cross section results have increased the yield of energetic muons
  - ALICE high-multiplicity data overlaps better with model predictions
  - p- and Fe-induced showers cannot yet be distinguished

Detecting muons with SC16 detectors

Introduction – ALICE results (31 days of data taking)

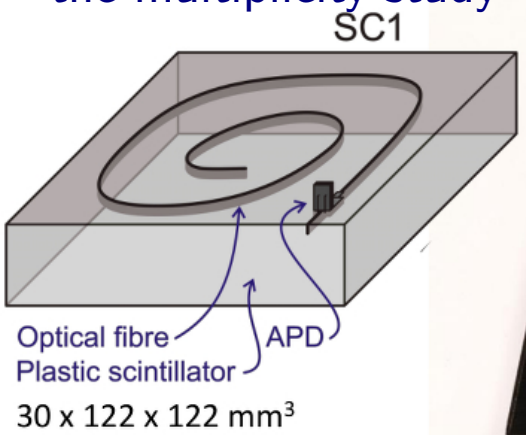


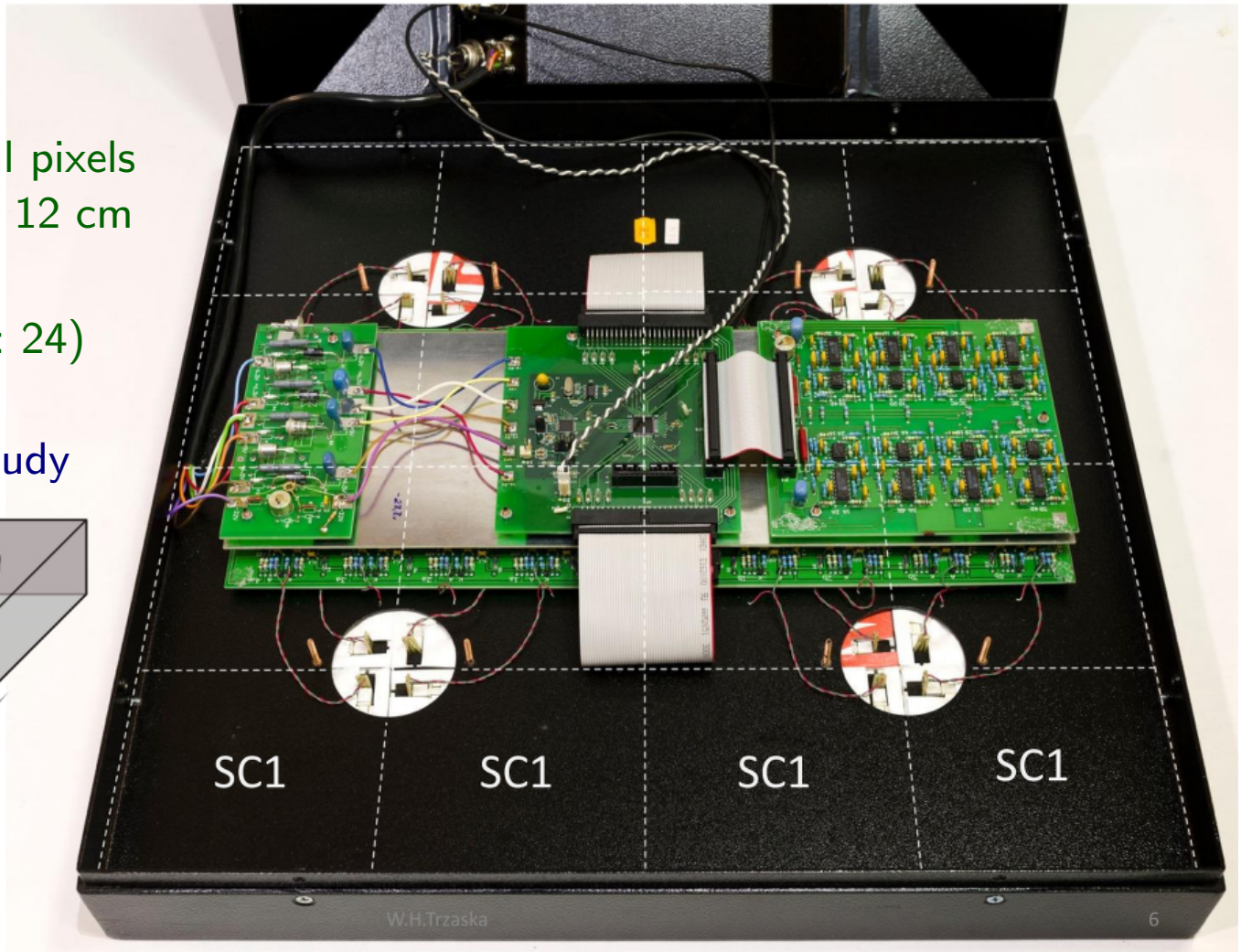
- The ALICE Collaboration,
  Study of cosmic ray events with high muon multiplicity using the ALICE detector at the CERN Large Hadron Collider, JCAP01(2016)032

Detecting muons with SC16 detectors

SC16 detector

- 1 SC16 = 4×4 SC1
  = 16 individual pixels
  of 12 cm × 12 cm
- We have 97 SC16s
  (EMMA: 73, Canfranc: 24)
  - 50 SC16s used in
    the multiplicity study





- P. Kuusiniemi *et al.*,
  Performance of tracking stations of the underground cosmic-ray detector array EMMA. Astroparticle Physics 102 (2018) 67 – 76.

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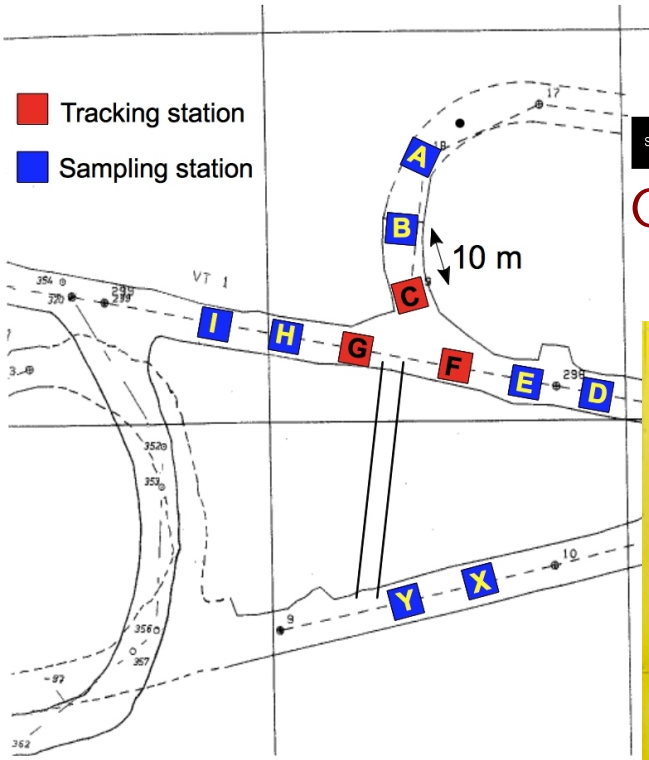
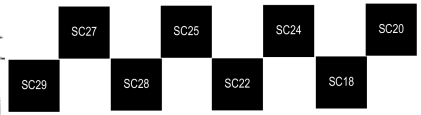
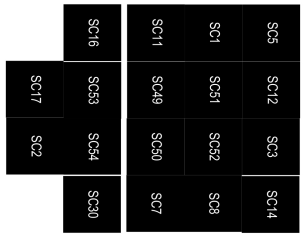
EMMA – Experiment with MultiMuon Array



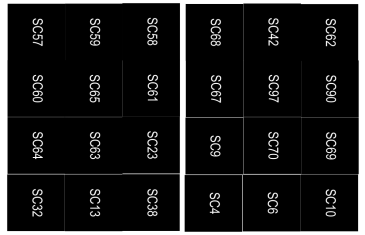


C – 128 pixels

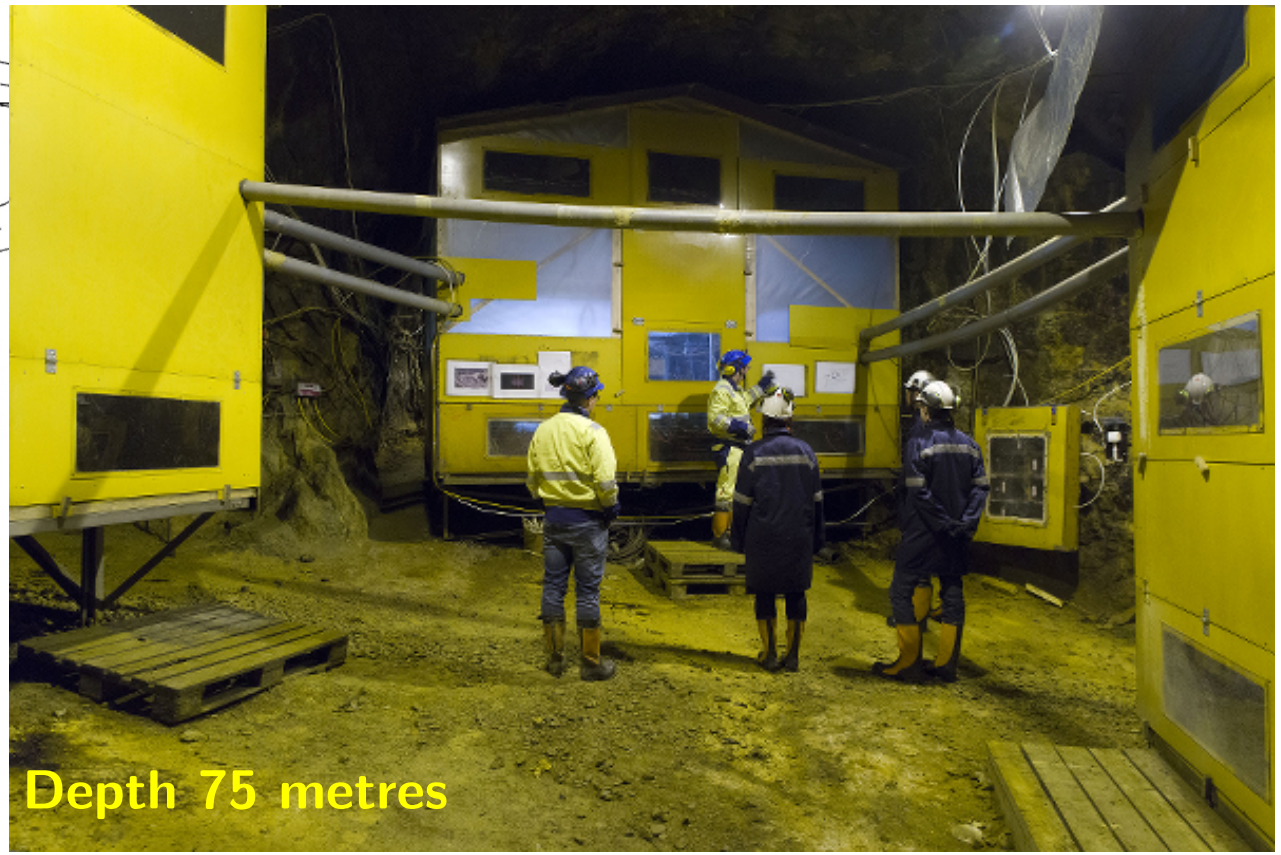
F – 288 pixels



G – 384 pixels



- In total, 50 SC16s
  - 800 pixels of $12\ \text{cm}^2 \times 12\ \text{cm}^2$
  - total area $11.5\ \text{m}^2$



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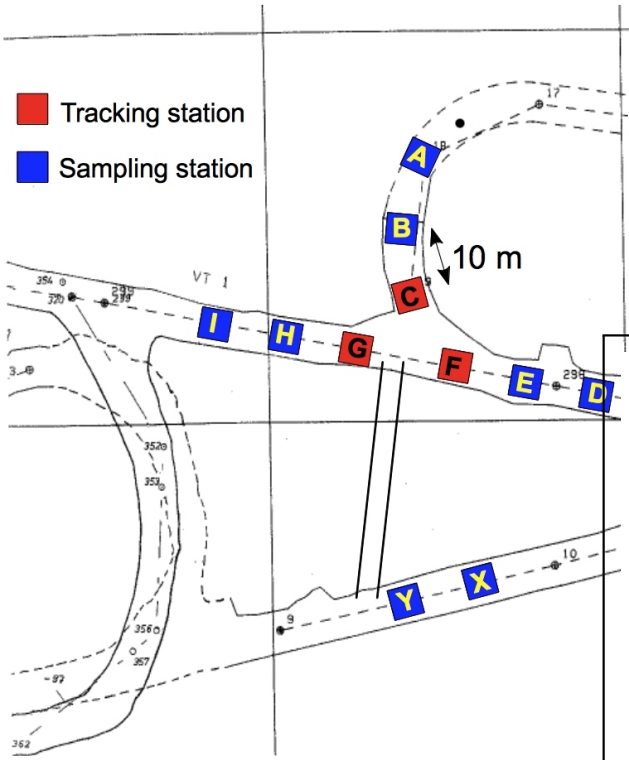
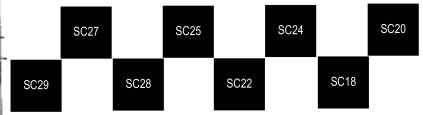
EMMA – Experiment with MultiMuon Array





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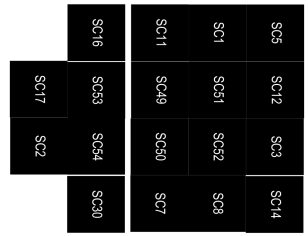

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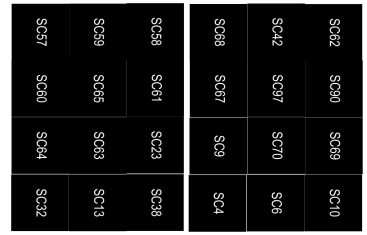

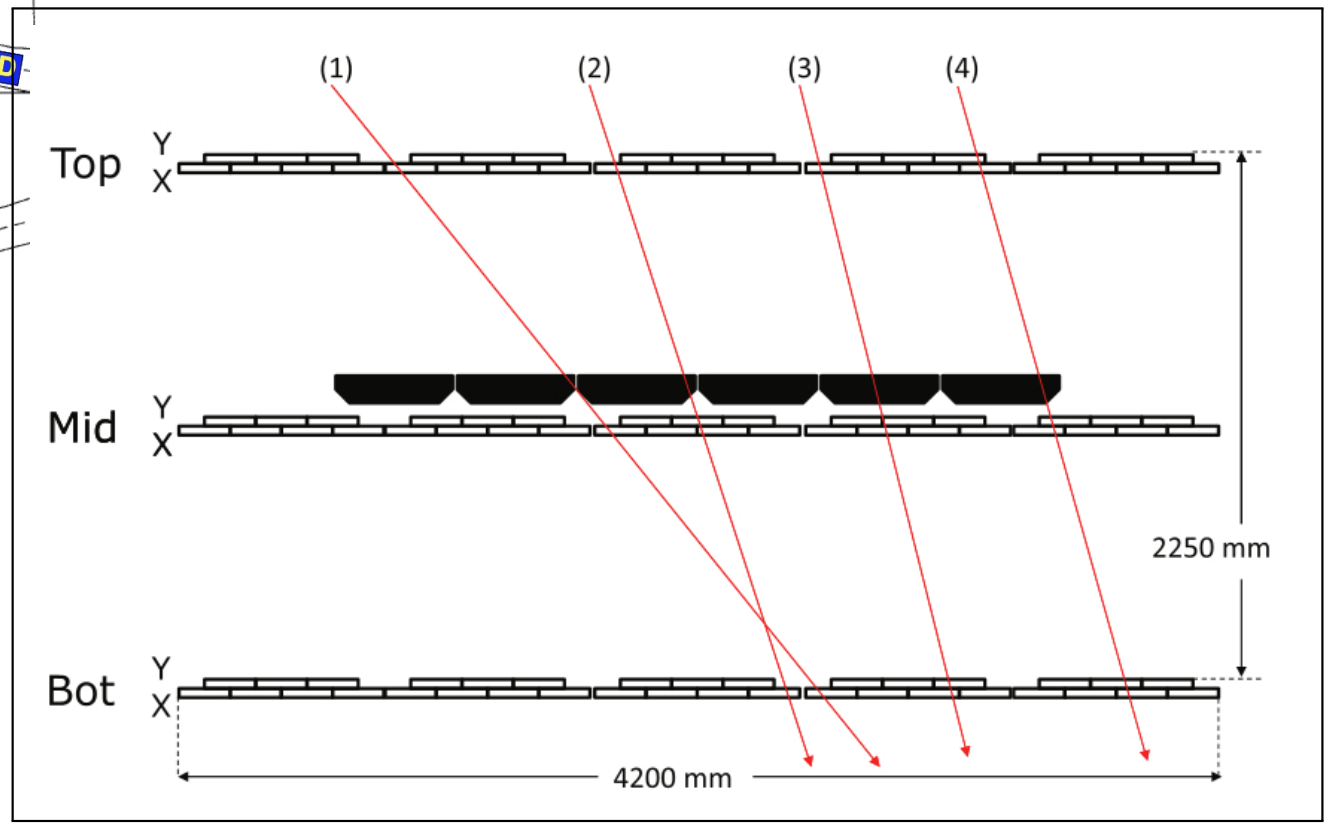

- At the depth of 75 m, the single-μ flux $\sim$1 m^{-2}s^{-1}
- Number of *knee* region showers is couple/day

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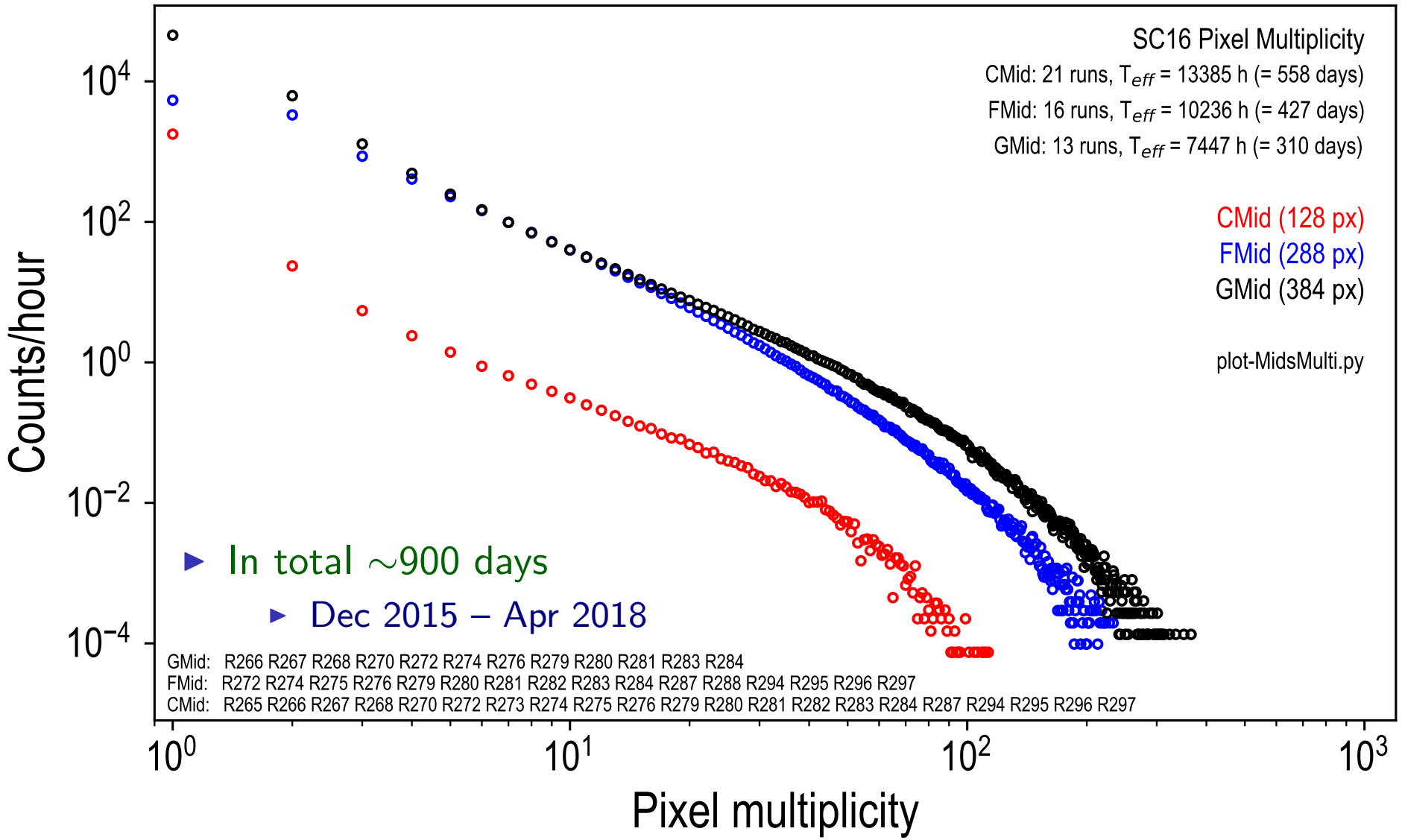
EMMA – Multiplicities per station



- In total ∼900 days
  - Dec 2015 – Apr 2018

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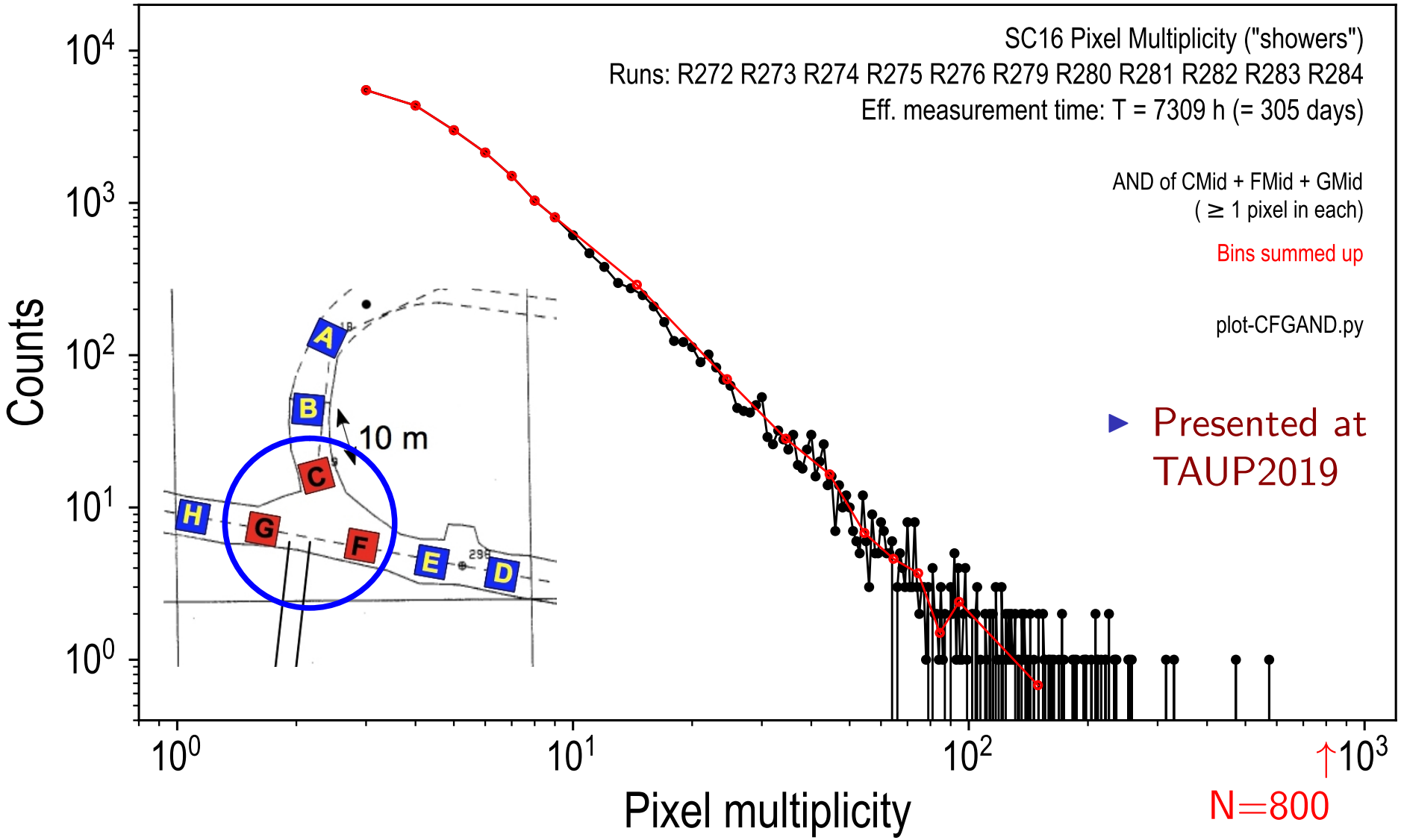
EMMA – Multiplicities in showers



- Presented at TAUP2019

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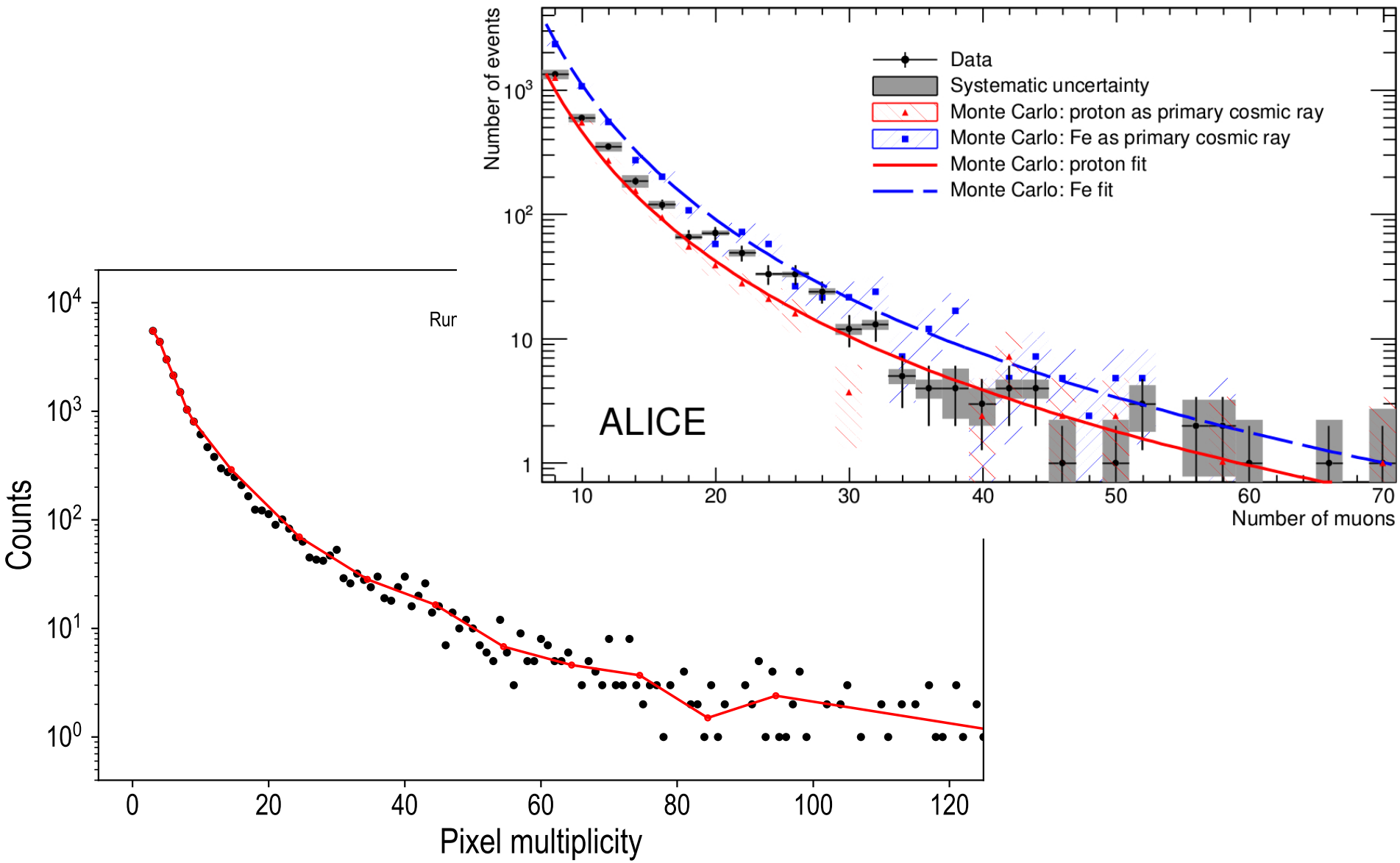
EMMA – Multiplicities in showers – Comparison with ALICE



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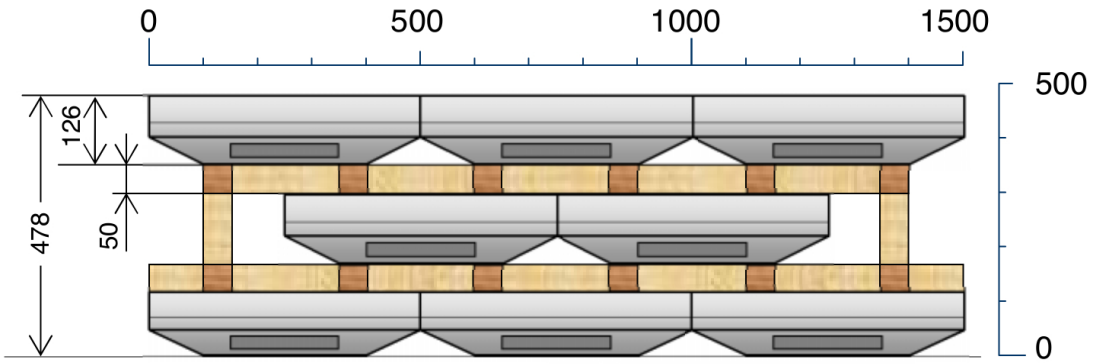
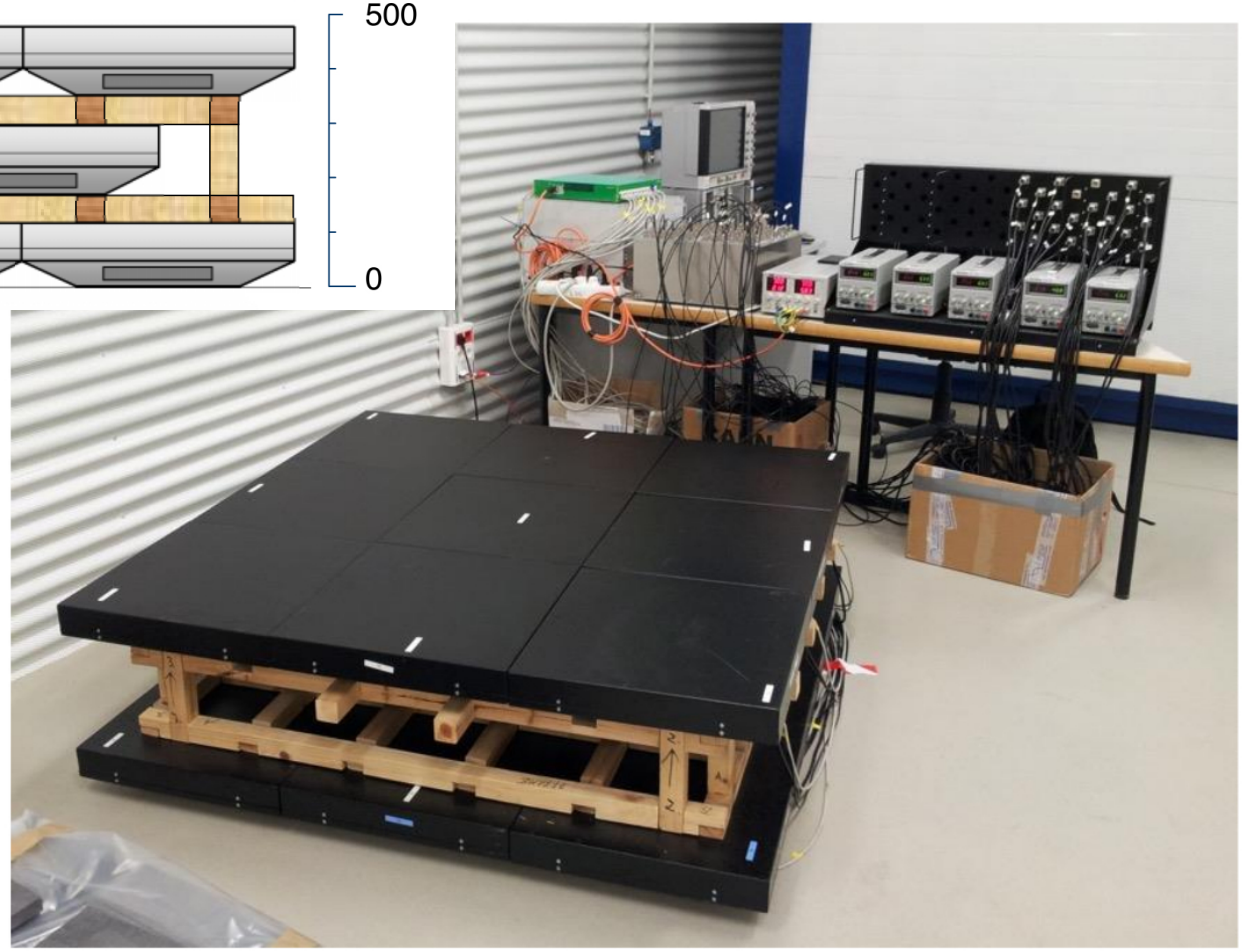
Canfranc





- LSC – Laboratorio Subterráneo de Canfranc, Spain
- Muon flux determination
  - with the angular information
- Integrated fluxes
  - Lab 2400: $(5.26 \pm 0.21) \times 10^{-3}$ m^{-2}s^{-1} [Hall A]
  - Lab 2500: $(4.29 \pm 0.17) \times 10^{-3}$ m^{-2}s^{-1}

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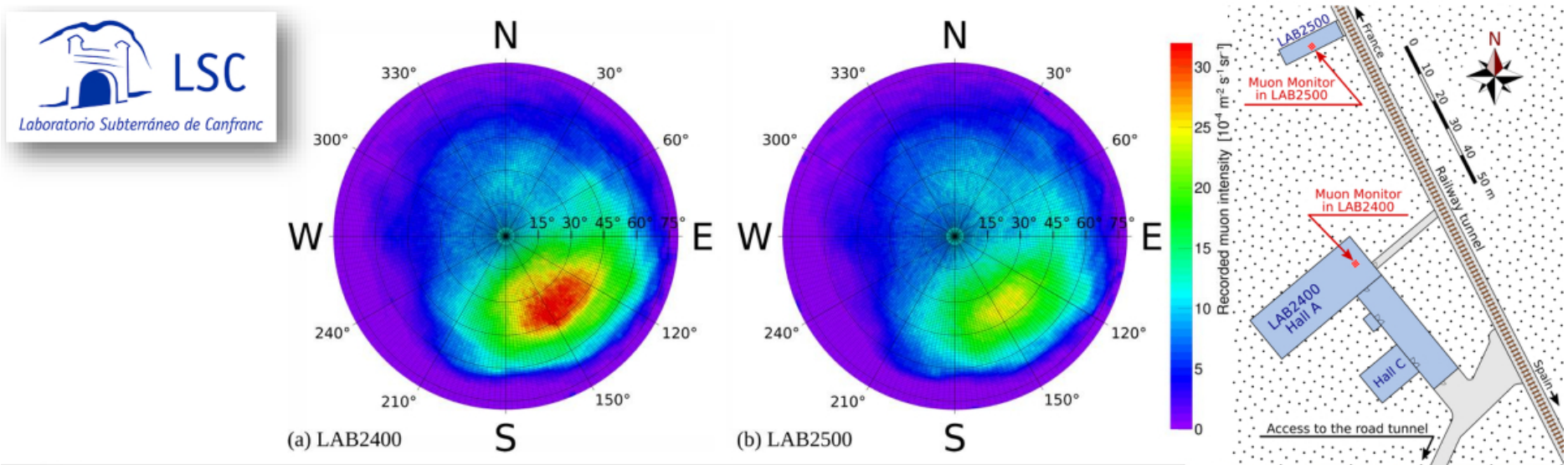
Canfranc



- W.H. Trzaska *et al.*,
  Cosmic-ray muon flux at Canfranc Underground Laboratory.
  European Physical Journal C 79 (2019) 721,
  arXiv:1902.00868v1 [physics.ins-det] 3 Feb 2019, 4 pages.

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Summary

- High-multiplicity muon events observed in several experiments at CERN and also by EMMA
  - muon density $> 10\ \mu/\mathrm{m}^2$
- Experiments at CERN can study these only in short periods
- EMMA can study long time
- LHC has provided updated cross section values
  - increase of high-energy muons
- The agreement of ALICE data with the predictions has improved, but the origin of the high-multiplicity data is not yet fully understood
  - p- and Fe-induced showers cannot yet be distinguished
- EMMA has now the first set of high-multiplicity data for 900 days for single stations, and 305 days for showers
  - experimental data has mostly been sorted
  - simulations with Corsika and Geant4 are in progress
- We expect we can contribute in the physics of high-energy interaction with the EMMA data