MID activities in Hungary: gaseous detector option

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All colors of Physics

Summary

- Physics environment of the MuonID
- Key properties of gaseous trackers for MuonID
- Muography: innovation and tech.transfer
- Wigner RCP / Vesztergombi Lab
- Upcoming plans: beam test, technical design

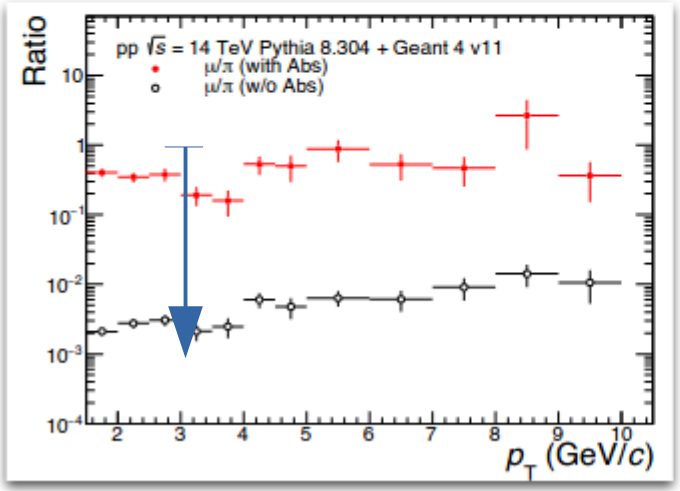
Recall absorber (finite) efficiency

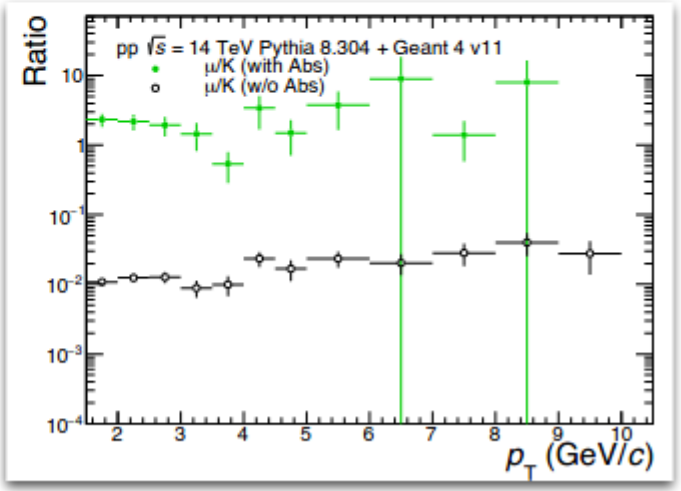
Less than 3 orders of Magnitude!

Note: low energy mu scatters more

Rejection factors (just due to absorber)

Only primary particles which reach the muonID region are considered, rejection factors between 50-100% are seen





Recall (modest) hit rate outside the absorber

Relatively low rate!

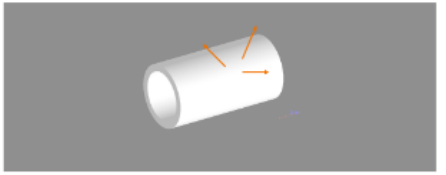
Note: most particles are secondaries

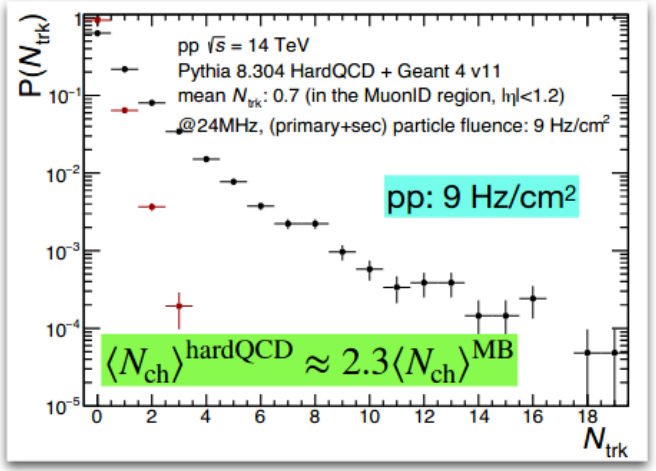
Note: high multiplicity in PbPb

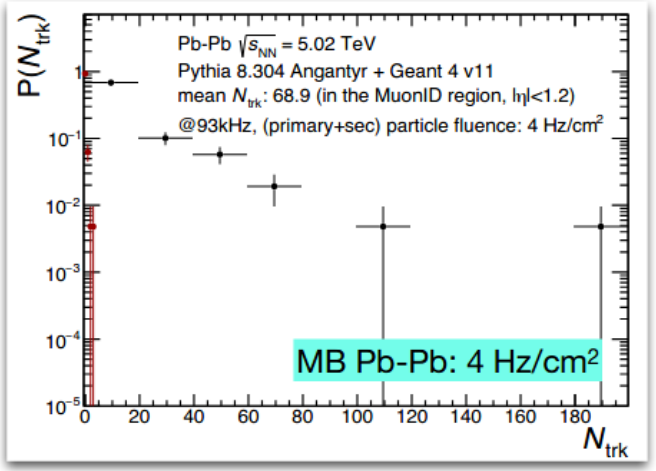
Particle fluence in the muonID region

Primary particles which were not filtered by the absorber

Secondary particles can be produced in the absorber







Quick calculation on a toy-model detector

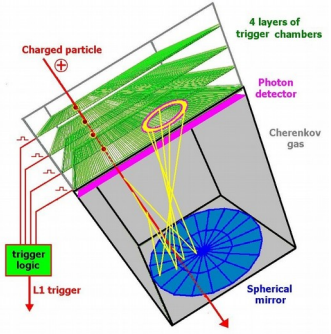
- Hit rate (A. Ortiz, UG week): **9 (4) Hz/cm² pp (PbPb)**
- Single channel rate (100 cm^2 segmentation): **1 kHz**
- Time resolution **1 μs** (lets make it pessimistic)
- Occupancy: **0.1 % per event**
- Note steel absorber rejection is in this order of magnitude
- This is with NO optimization – better time resolution easily managable, finer segmentation achievable

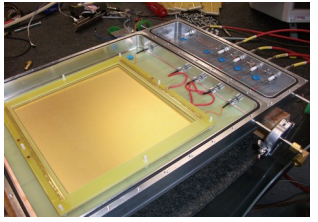
Why not an optimized MWPC, then?

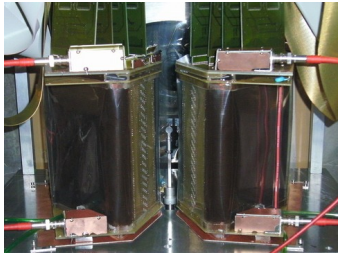
- MWPC-s well understood for over five decades
- **High efficiency, low cost** – reasonable time and position resolution
- **Gas**: non-flammable Argon+CO_2 mixture (typical flow 1 litre/hour for 1 m^2).
  No aging, no safety issues, no greenhouse issues …
- **Rate capability**: Expected 0.1kHz/cm^2, MWPC-s 100kHz/cm^2
- High voltage conveniently below 1.7kV, should tolerate modest B-field
- Available earlier experience (see next slide)

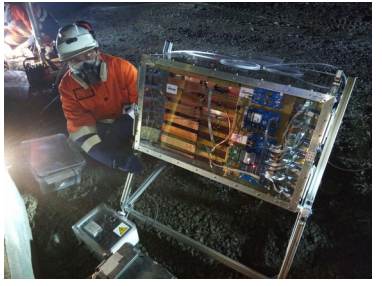
Experitise, earlier activities at Wigner RCP

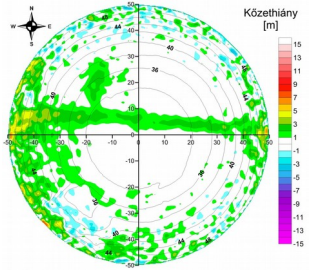
- **ALICE VHMPID** + HPTD :
  Tracking d. + Cherenkov d.
- **ALICE GEM TPC** UG:
  GEM QA, Uniformity scan
- **NA61 LMPD** :
  TPC for backscattering
- **Muography** : imaging hill-sized objects via measuring the absorption of cosmic muons
- **VLAB**: Gaseous det. lab.,
  Clean room, Construction hall

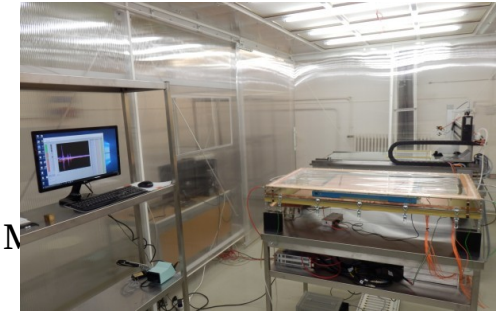


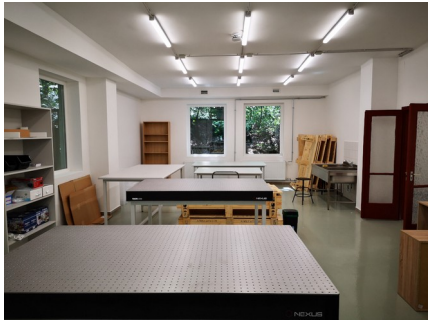






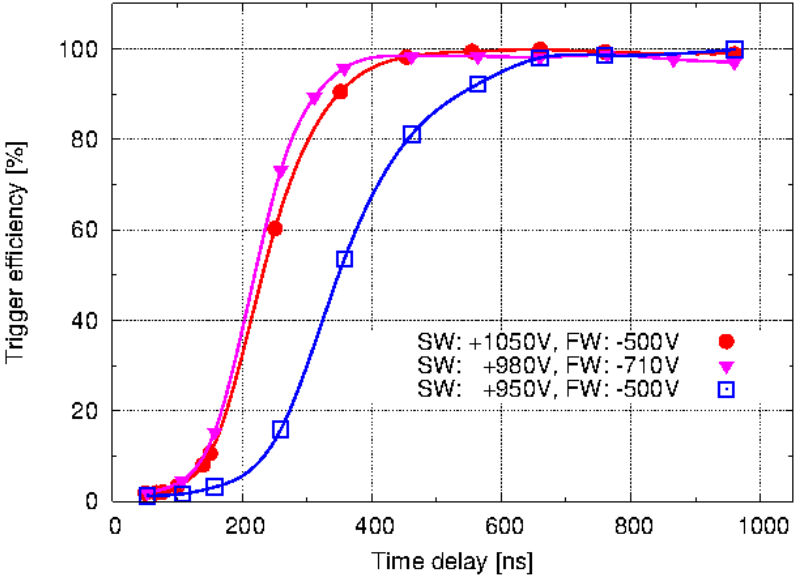






Possible option: “Close Cathode Chamber” – available beam test data, results

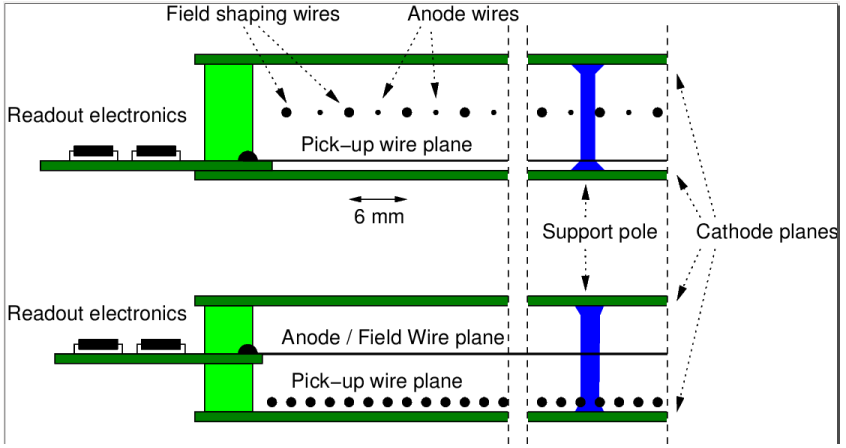
- Easy construction, **high (>99%) single layer** efficiency. Time resolution <200ns
- Position resolution better than 5mm (if needed), 12kg / m^2

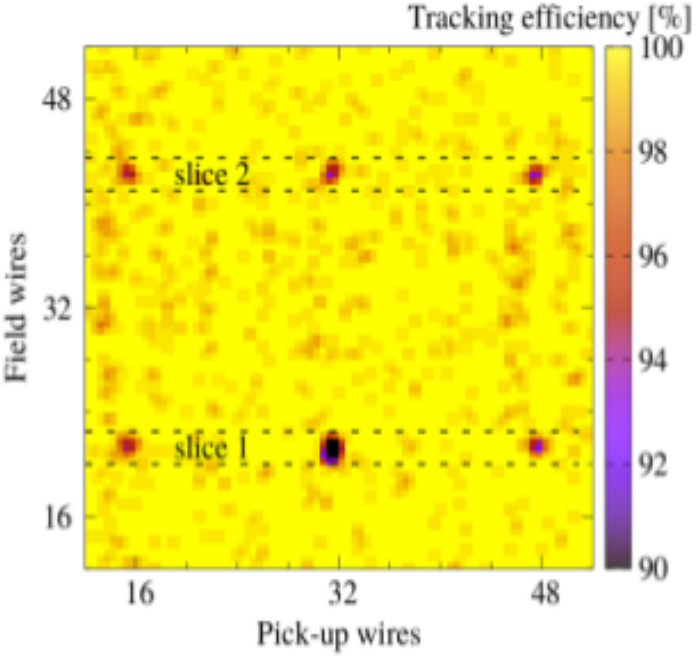


NIMA 698 (2013) 11.
NIMA 639 (2011) 274.
NIMA 648 (2011) 163
Nucl.Phys. Proc. Supp. 197 (2009) 296

Possible robust option: muon-detecting MWPC-s

- More conventional MWPC-s, technology from cosmic muon imaging
- More than 120 m^2 produced by now. **2D detector!** Weight 15kg /m^2



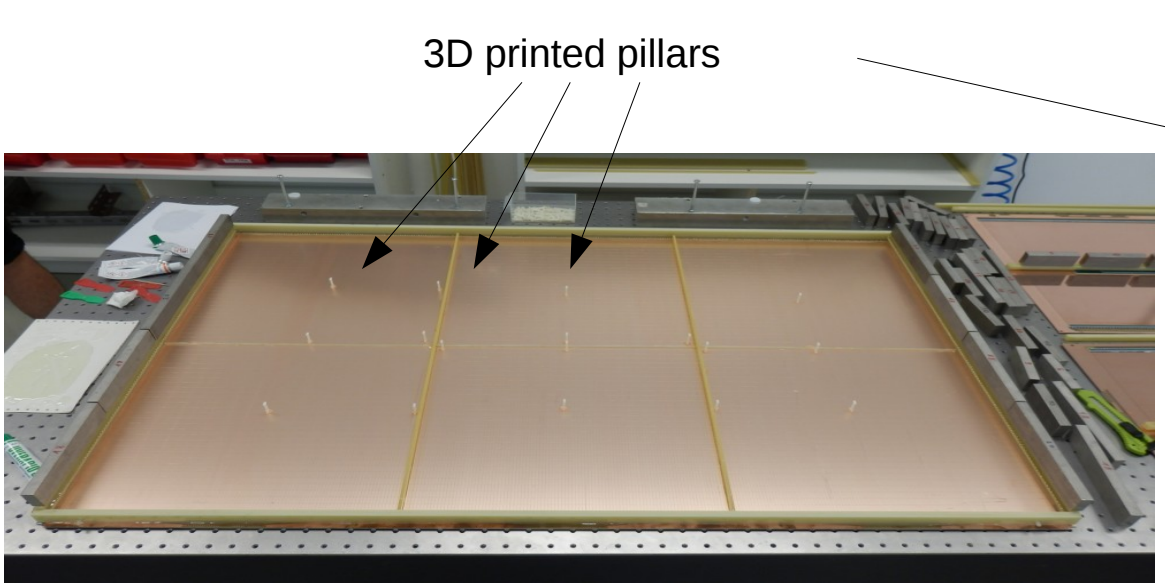


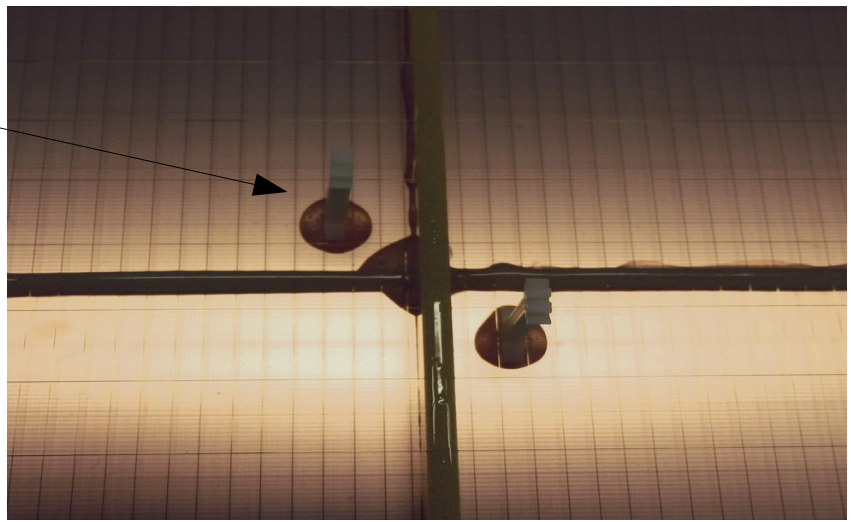
Eur. J. Phys. **36** 065006 (2015)
arXiv:1607.08494, AHEP
Scientific Reports, Volume 8, Article number: 3207 (2018)

NOTE: above 99% efficiency!!

Detector production at Wigner RCP VLAB

- Standardized structure, by now more than 150 detector layers (total area above 100 m2) produced

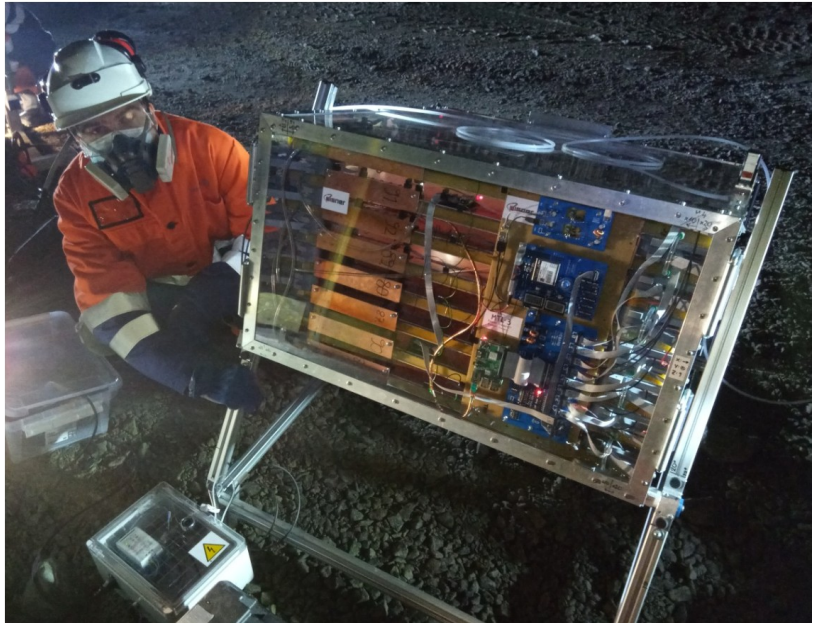




Extensive projects for cosmic muon imaging – **Muography**

From lab…

… to an operational mine



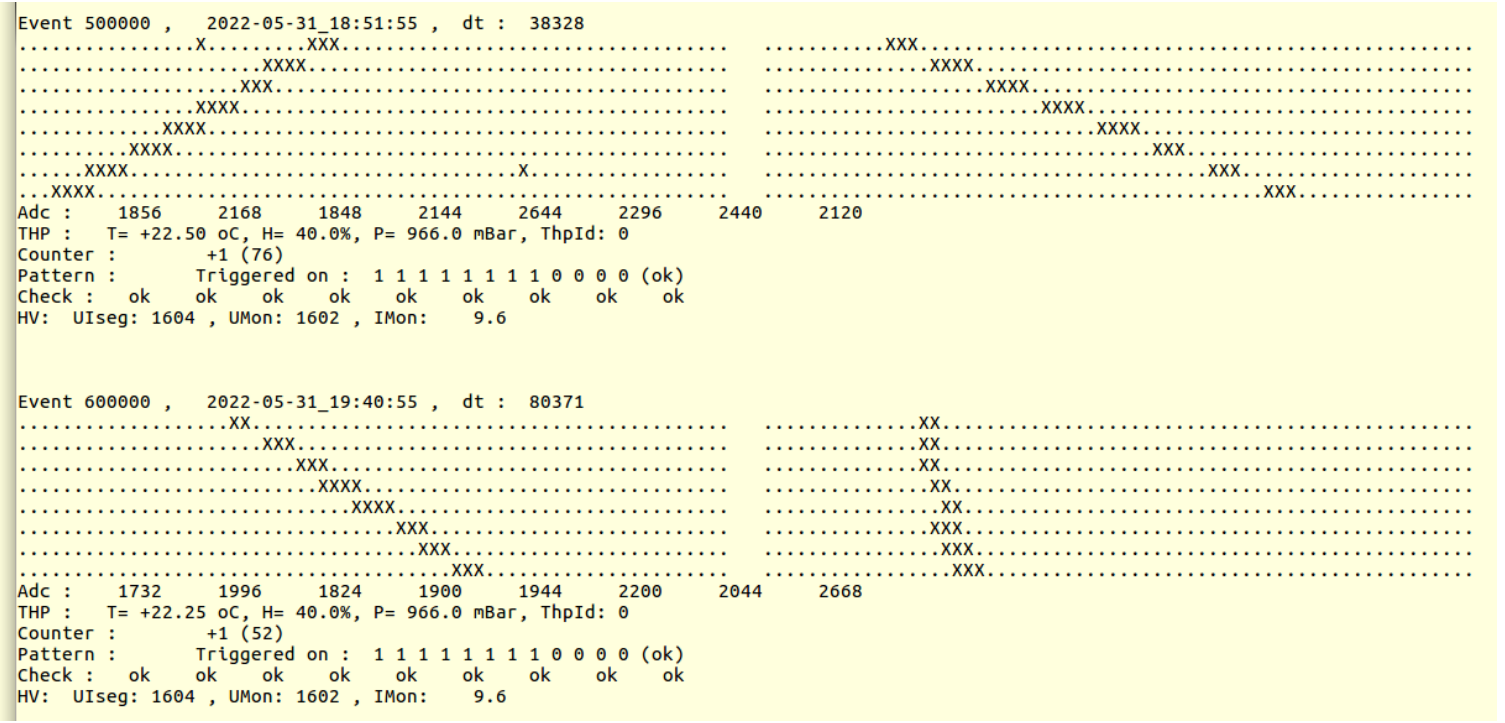
Development of Muographic Instruments: Outstanding Project financed by NRDI Fund

Cosmic muon tracks (8 chambers)

- Note the low noise and high efficiency operation, 1+1D from layers

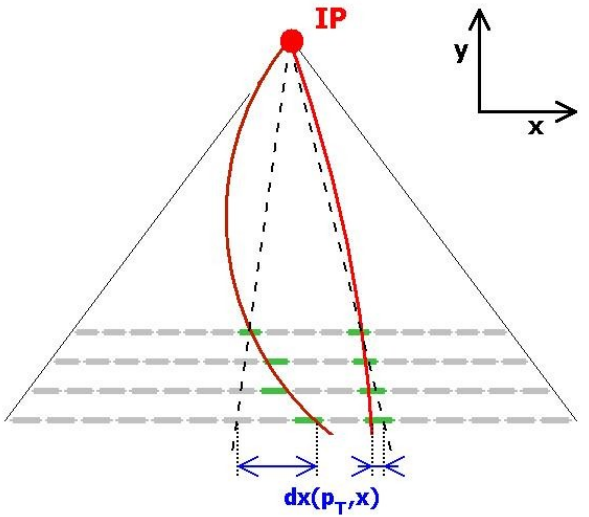
Front view

Side view



Practical realization of MuonID w. “tracking”

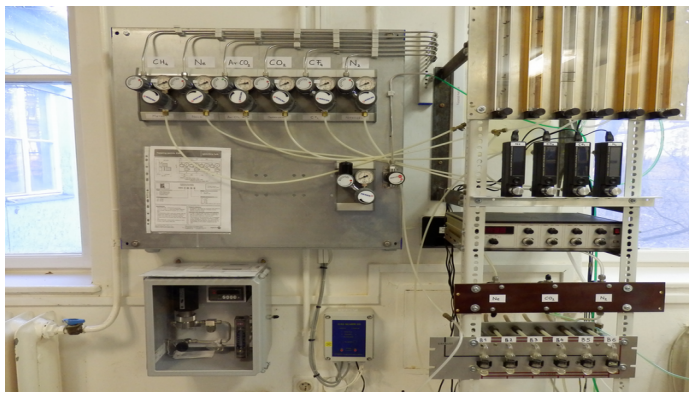
- Total net area 180 m^2: may be 3 layers with MWPC (540m^2 total detector area)
- Multiple layers and 1cm position resolution enables **“tracklet” pattern recognition** – suppression of leaking hadron showers
- **Simple and low cost electronics** allows high number of channels (144k ?)

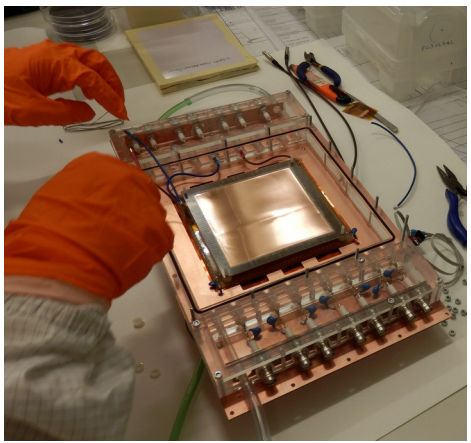


Low vs. high pT

Vesztergombi Laboratory for High Energy Physics

- National recognized Research Infrastructure
- Both internal and external “users”
- Lab spaces, gas systems, expertise
- Underground laboratory (10-20-30m)
- Electronics, readout, HV supplies, ...



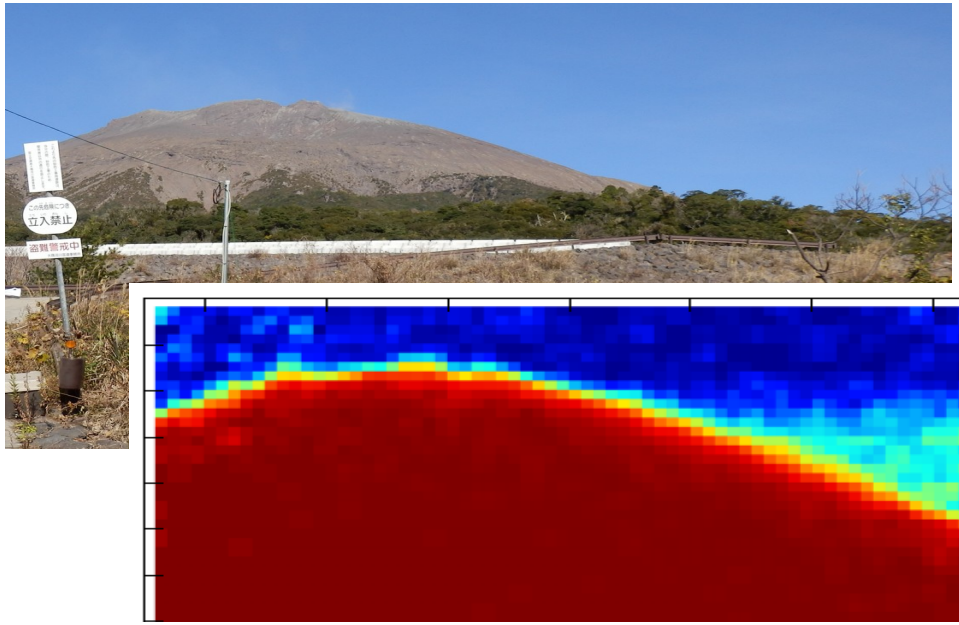


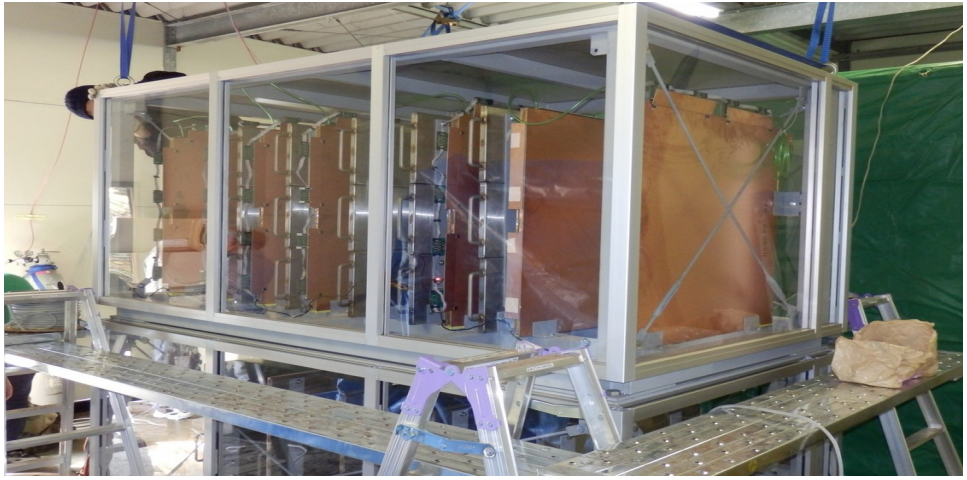
Laboratory environment available

- Expansion completed by early 2022
- High production rate (2-4 m^2 / week) as of now

Application and tech-transfer highlight: Sakurajima Muography Observatory

- Currently running at Sakurajima (Kyushu), funded and managed by University of Tokyo. Joint patent (2016) licensed by NEC Corporaion. **Now total 8 square meter**, the world's largest

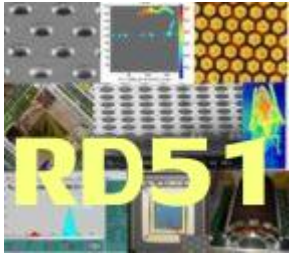




Patent: H. Tanaka, K. Tarou, D. Varga, G. Hamar, L. Oláh: Muographic Observation Instrument, Japanese Ref. No.: 2016-087436, date 25/04/2016, PCT WO2017187308A1

Fundamental science:
High energy physics instrumentation,
best of detector physics

Applications in industry, geo-sciences, engineering: technology transfer and innovation, efficient production and quality control



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Muographers

Intense
H2020 MSCA RISE 2018
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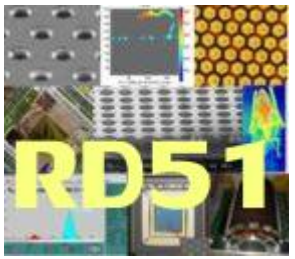
Fundamental science:
High energy physics
instrumentation,
best of detector physics

Applications in industry,
geo-sciences, engineering:
technology transfer
and innovation,
efficient production and
quality control

ess EUROPEAN SPALLATION SOURCE



Mine.io

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AGEMERA

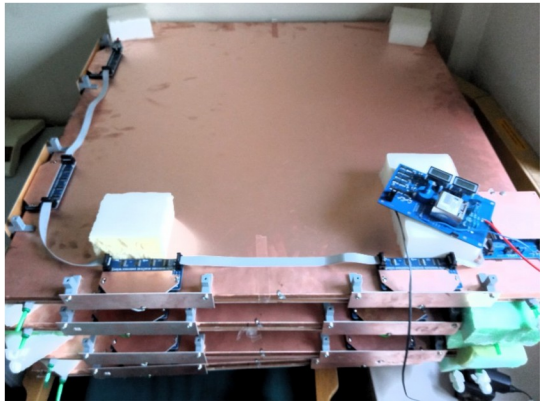
Combined detector?
Scintillator + mini-tracker

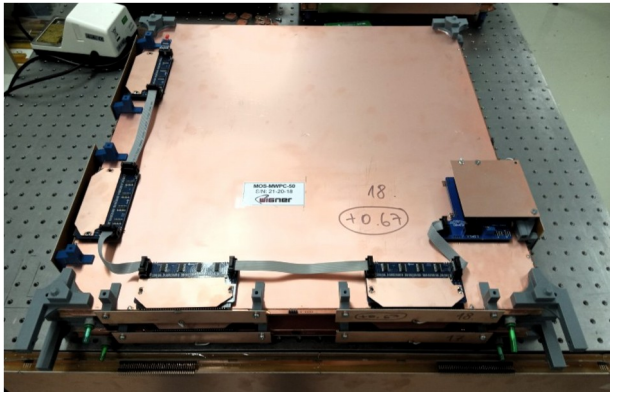
- **Timing from Scintillator** (less layers needed, e.g. one layer with 1D data + timing, or larger segmentation...)
- **Tracklet from MWPC** (larger segmentation if higher occupancy is allowed)

- Low energy muons scatter more, one must open up the matching radius. Directionality information can help reducing fake matches
- Need to be justified if simulations suggest shower leakage, correlated particle production...

Outlook: beam tests

- Beam test participation with MWPC-s (see talk by Solangel Rojas Torres)
- 4 pieces of 80cm modules (already at CERN) and 4 pieces of 50cm modules
- Joint beam test option with Mexican scintillator prototypes (common trigger, off-line event matching)
- Effect of absorbers? Beam capability verification?





Conclusions

- Gaseous detector seems to be a reasonable option for MuonID: high efficiency, robust, cost efficient, MWPC with friendly gas
- Detector design, production capability and expert manpower fully available at Wigner RCP
- Weak timing resolution (multi-100ns) well compensated by low occupancy due to high segmentation
- Good position resolution allows “tracklets” directional info
- Possibly in combination with better timing detectors

Selected references

- MWPC/CCC

Construction and readout system for gaseous muography detectors, D.Varga, Sz.J.Balogh, Á.Gera, G.Hamar, G.Nyitrai, G.Surányi, J.Adv.Instr.Sci. 307, https://doi.org/10.31526/jais.2022.307 2022

Gaseous detectors for field applications: Quality control, thermal and mechanical stability, Á. Gera, G. Hamar, G. Nyitrai, D Varga et al, Instruments 6 74, https://www.mdpi.com/2410-390X/6/4/74 2022

Towards low gas consumption of muographic tracking detectors in field applications, G. Nyitrai, G. Hamar, D. Varga, Journal of Applied Physics 129, 244901 (2021); https://doi.org/10.1063/5.0053984 https://arxiv.org/abs/2105.09577

Eur. J. Phys. **36** 065006 (2015) arXiv:1607.08494, AHEP 2016 (2016) 1962317

- Muography

Muography of the active Sakurajima volcano: recent results and future perspectives of hazard assessment. L. Oláh, H.K.M. Tanaka, D Varga et al. J.Adv.Instr.Sci, 285. https://doi.org/10.31526/jais.2022.285 (2022)

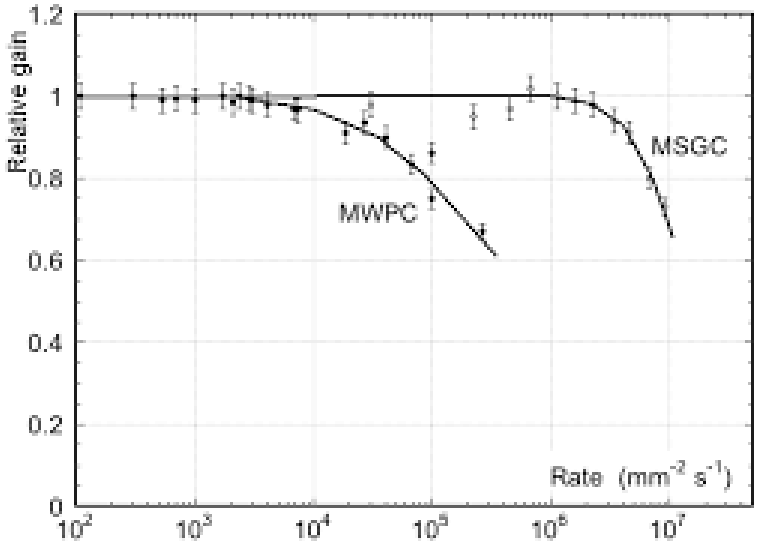
Muography: Exploring Earth's Subsurface with Elementary Particles. Editors: László Oláh, Hiroyuki K. M. Tanaka, Dezsö Varga. Geophysical Monograph Series*. Wiley 2022, ISBN 1119723027, 9781119723028, 352*

Scientific Reports, Volume 8, Article number: 3207 (2018)

L. Oláh et al, Phyl.Trans.Roy.Soc. A 377, 20180135.

Backup

- Rate capability
- No observed ageing for non-CH-based quencher



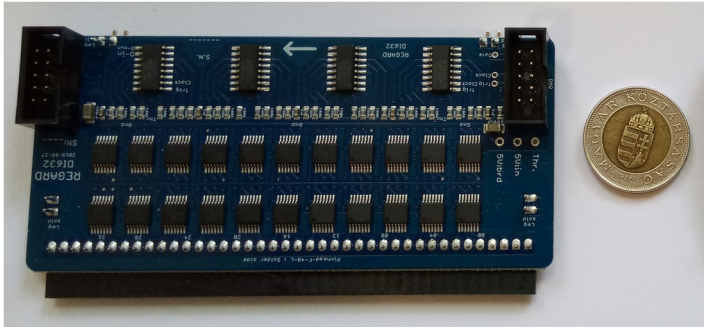
Readout system: custom designed front-ends

- Key features:

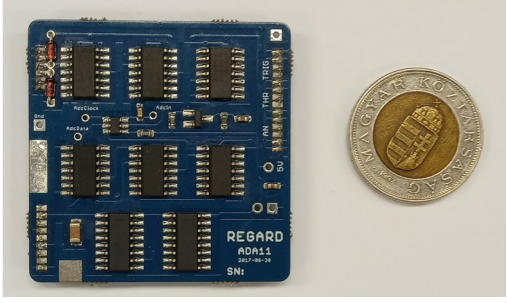
  reliability, cost efficiency and power economy

- Power below 2 mW/channel, cost below 2 Eur/channel
- No ADC: common discrimination threshold

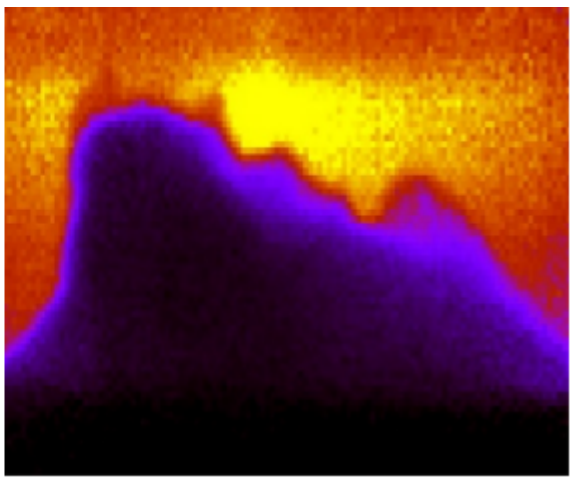
32 channel, serial readout



16 channels, serial readout



Manfredonic castle (Mussomeli, Sicily) imaging, preliminary.



Modularity of detector system

- Independent modules, on same target, total **8.7 square meter** sensitive area installed as of Aug. 2019