

Imaging with Cosmic Muon Induced Secondaries

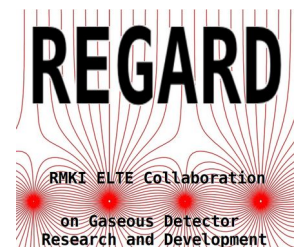
Gergő Hamar

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REGARD Det.Phys.Group**

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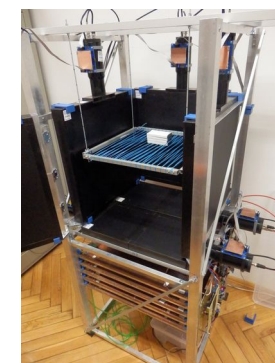
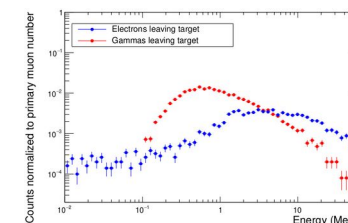
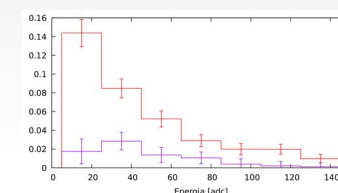
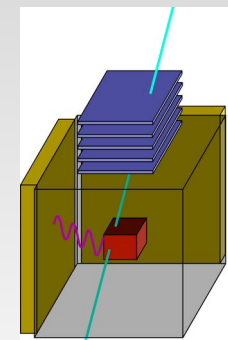
for the WignerRCP + Novi Sad Uni. Collaboration

G.Hamar, D.Hajnal, K.Bikit, D.Mrdja, D.Varga, et al.



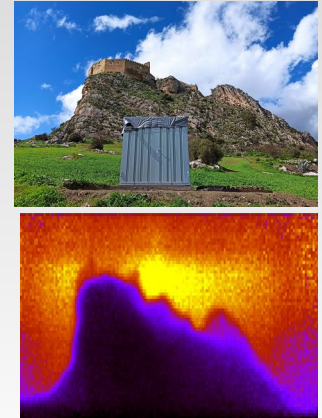
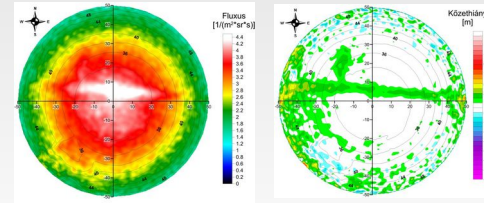
Outline

- **Alternative Muography**
Scattering, Secondaries
- **Detectors and Requirements**
Muon Tracking: CCC, Secondaries: Spectra
- **MUCA Experiment**
First imaging with secondaries
- **Early results**
Imaging, Identification,
- **Simulations**
Geant4, e/γ ratio, forward/sideward
- **Upgrade: COMIS**
Large cover, Combined DAQ, e/γ separation p.
- **Summary**

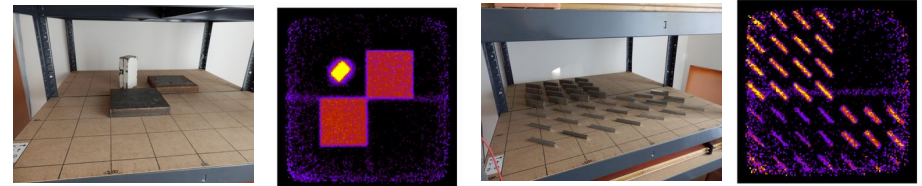


Alternative Muography

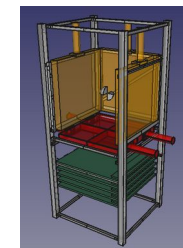
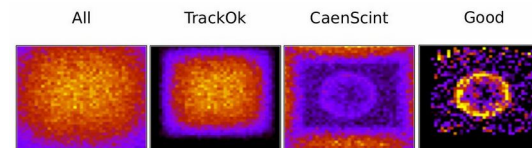
- **Muography (Classic/Attenuation M.):**
Cosmic muon flux attenuated by material (density-length)
Directional measurement : muogram → densitymap of large objects
GeoPhysics, Araeology, Industrial appl., Meteorology, ...
(volcano,cave,tunnel,pyramid,furnace..)



- **Muon Scattering Tomography**
Multiple scattering on high-Z material
Two tracklet matching : scatter map → high-Z materials
Disclose hidden objects, Homeland security, AirCargo, ...



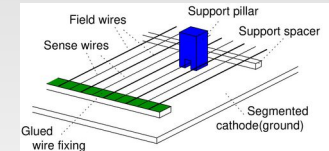
- **Muon induced sceondaries**
Secodary particles generated in material
Differential secondary spectra → material identification
Araeology, GeoPhysics,



Detectors and Requirements for Imaging w Secondaries

■ Muon Tracking Detectors

- Good spatial resolution (~mm at target level)
- Robustness (day/night var., transportation, ..)
- Scalability (medium/large surface)
- Cost efficient (large area det., multiple layers)
- Remote access/control/analysis



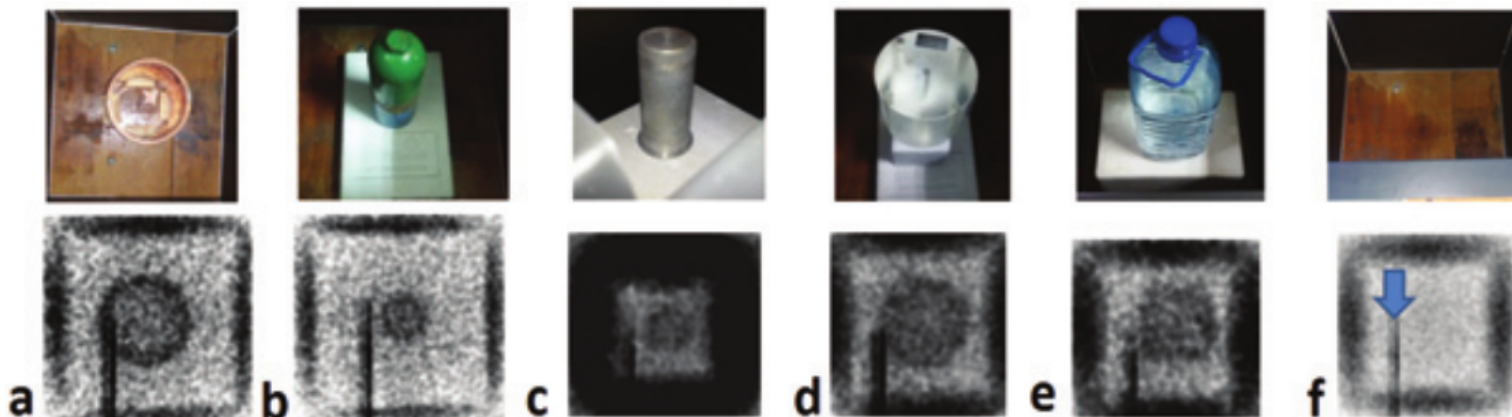
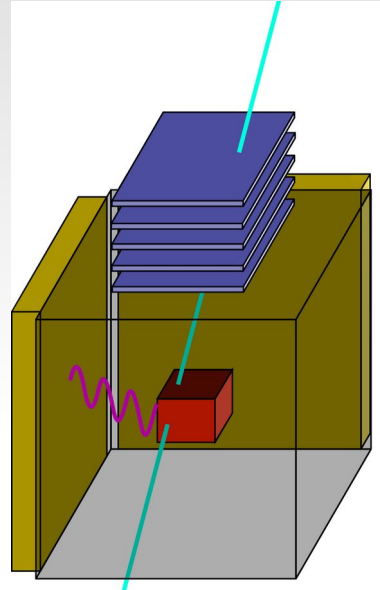
■ Detecting Secodaries

- Energy measurement : spectra
- High efficiency for secondaries (e, γ)
- Thin input window (low E-cut)
- Identification?
- Dividable (separate signal from muon signal)



MUCA Experiment

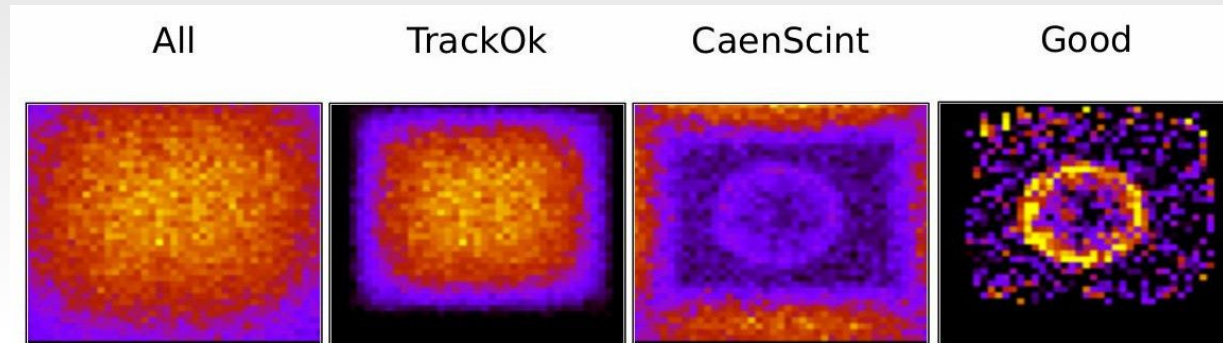
- **Novi Sad Uni + Wigner RCP**
- Muon Tracking :
CCC : good resolution
25x25cm² area x 4 layers
- Secondaries:
 - **HPGe** : good E resolution
 - **Plastic Scint.** : large coverage
- DAQ: separate ones :(
Tracker: Wigner MT DAQ
Scint: Caen MCA one channel
→ offline event combination
- **MUCA** (MuonCamera) located at Novi Sad University



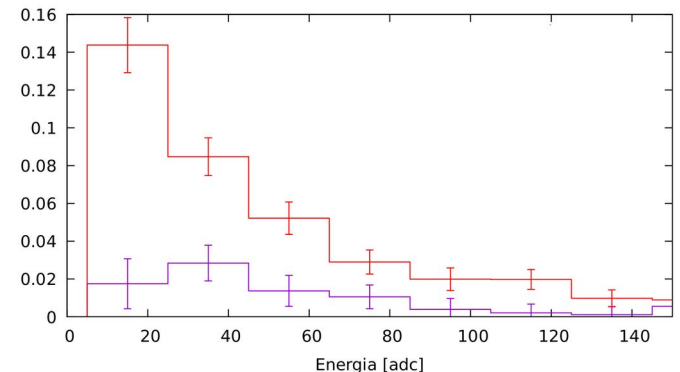
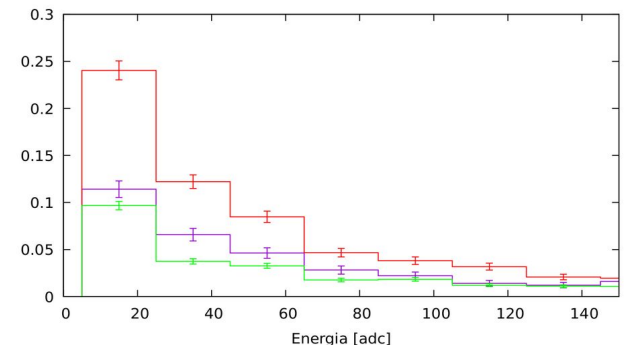
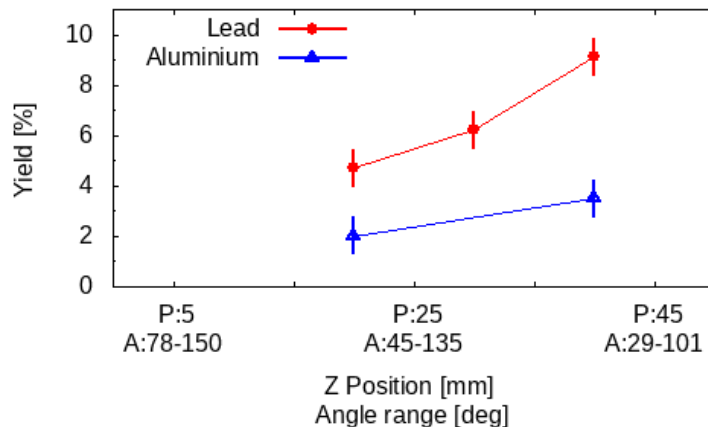
MUCA Results

- Example of analysis chain:
 - Tracker: Hits \rightarrow Clusters \rightarrow Tracks (with timetag)
 - CaenMca: Threshold \rightarrow TimeTag selection
 - Maps on TargetPlane
 - Geometric filter for non-target secondaries

- Various targets
 - Lead, Iron, Alum.,
 - Plastics, Body-phantoms,

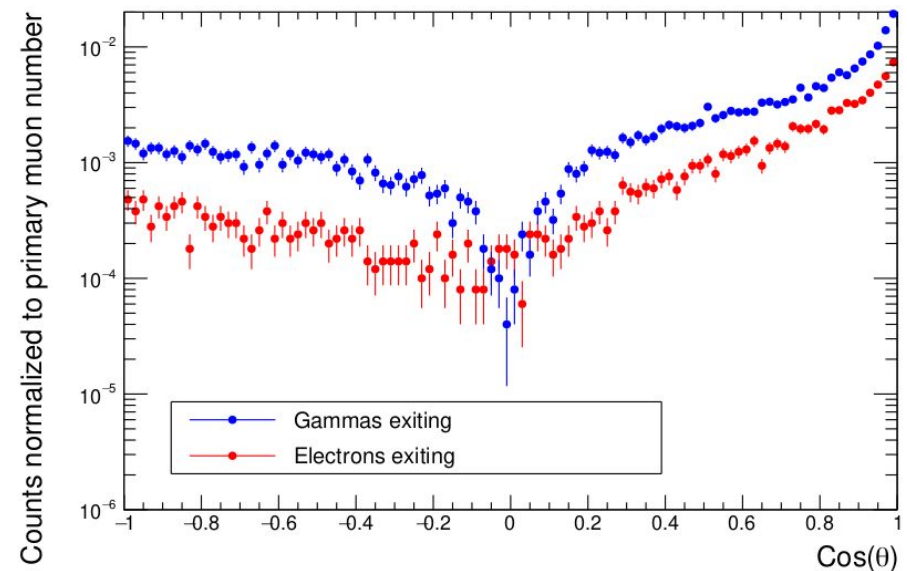
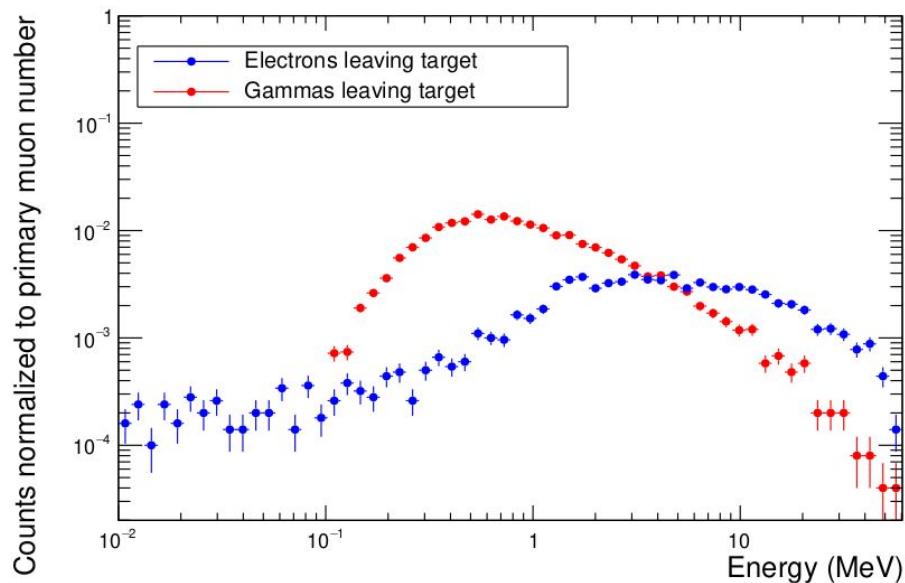


- Background (nontriggered MCA, natural radioactivity)
- 2D/3D reconstruction
- Material identification capability proven



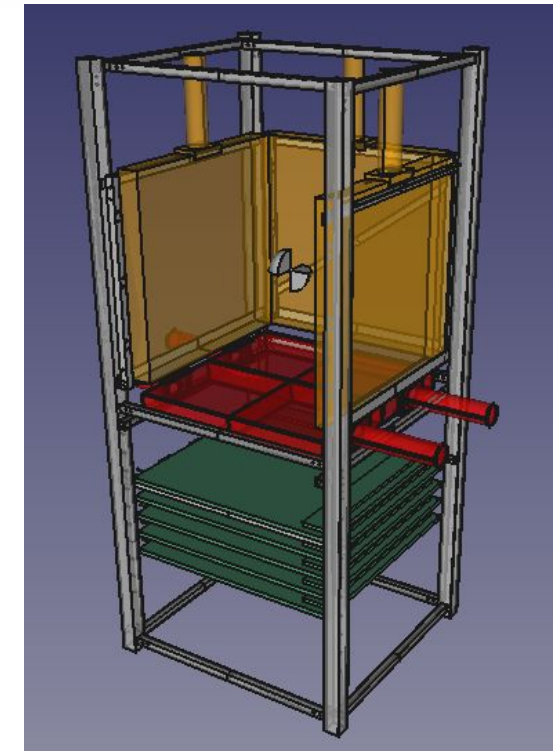
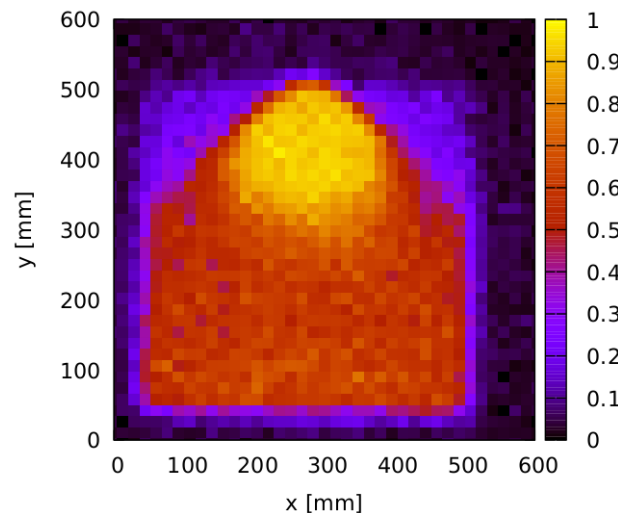
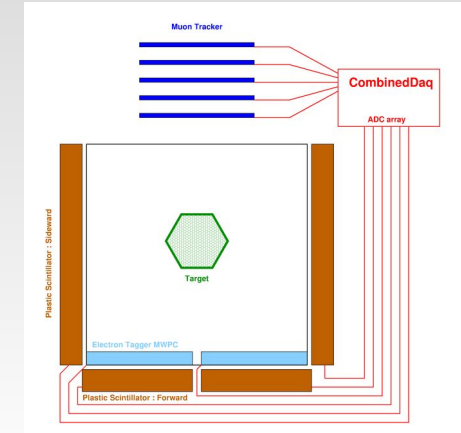
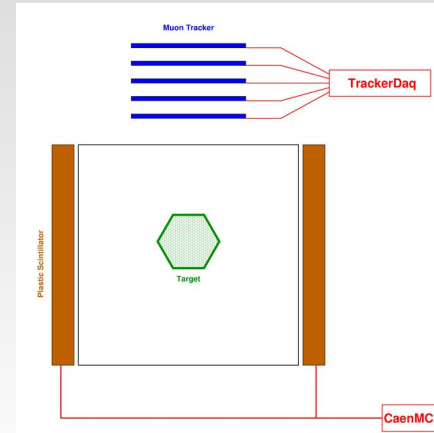
Simulations

- **Geant4** simulations
- ParticleGun studies : var. energy and angle of incidence wrt experiment
- Angular dep. : forward region is more populated
Sideward scattering (MUCA) → **Forward** + Sideward
- Separate **Electron and Gamma spectra**
very different, depends on the material,
simple **e/ γ ratios** change over magnitudes (Lead: 00.3, Polyst.: 33.5)
- Real Cosmic Spectrum
- General geometry



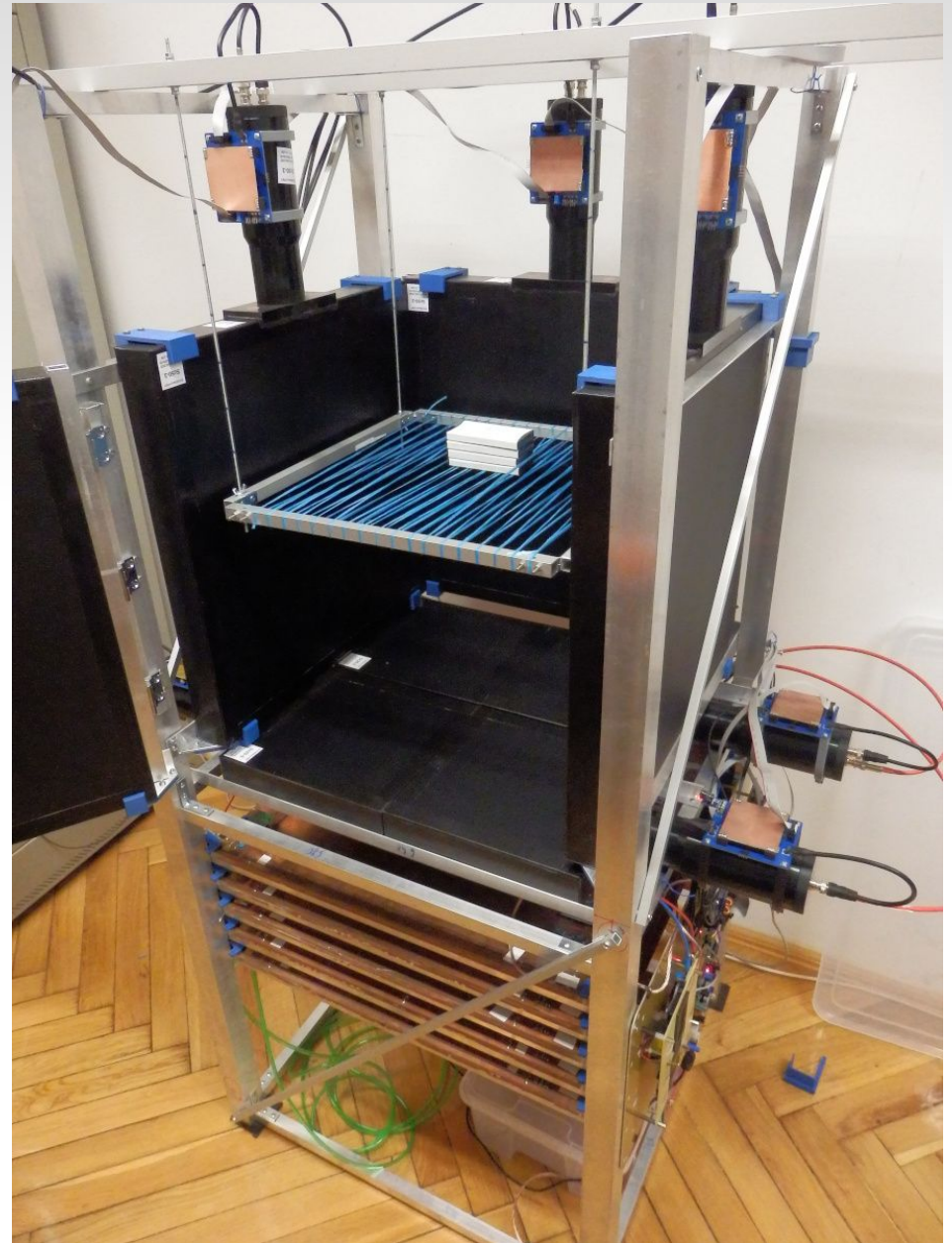
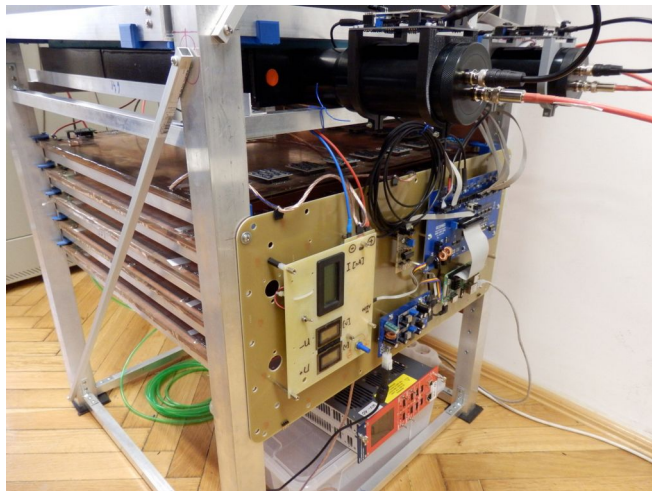
Upgrade Plans

- Cosmic Muon Induced Secondaries
- Include **forward** region
avoid muon → shall be segmented
- **Tagging of electrons/gammas**
event-by-event
- Design a **combined**
data acquisition system
- **Compact design** (portable if needed, eg. to Museums)
- Photon collection efficiency of large plastic scintillators



COMIS experiment

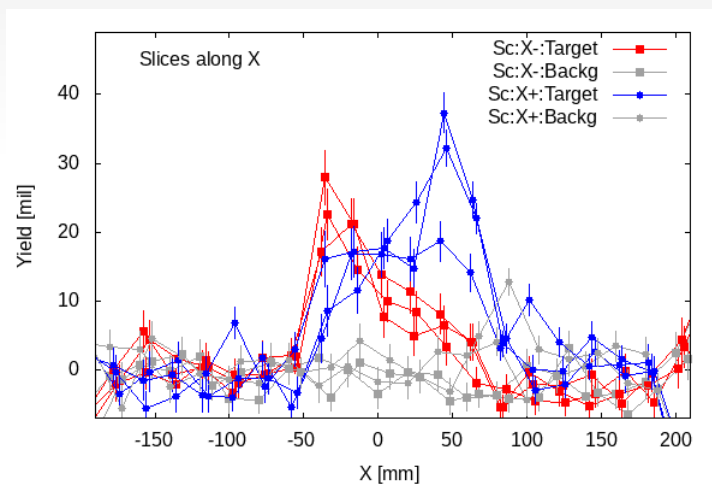
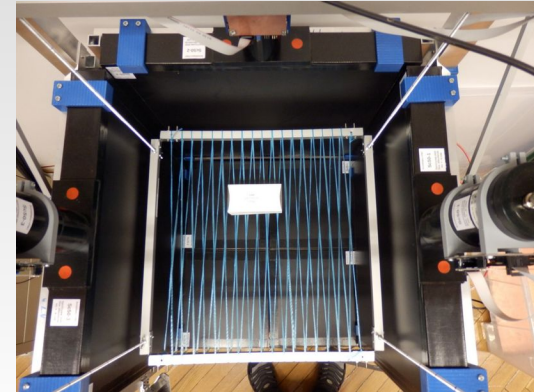
- Cosmic Muon Induced Secondaries
- Tracker: 5 x CCC : 50x50 cm²
- Scintillators:
 - Sideward : 50x50x5 cm³ x 4
 - Forwad : 25x25x5 cm³ x 4
- FEE : Wigner-Muograph-FEE
Scint.: ADC+Trigger
- Global trigger on :
ForwardScints fast TriggerOut
- DAQ: Muograph-like:
RPI+MtDaq+AdcArray
(double timing: Scint, GasD)



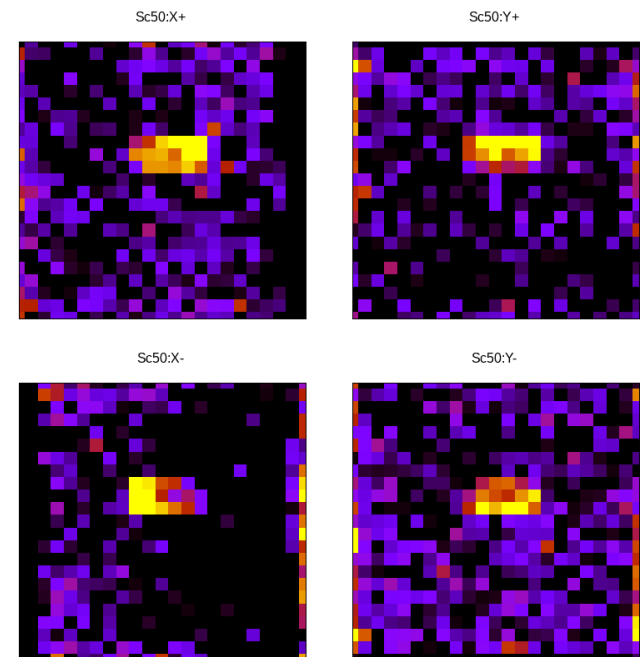
COMIS experiment

First Images

- Lead Target on hollow TargetHolder
- Image of the four surrounding scintillators all of them can „see” it
internal absorption is clearly visible
→ attenuation as extra info for material id.

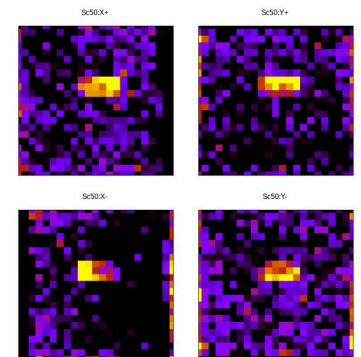
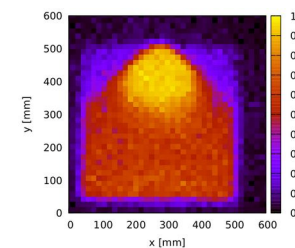
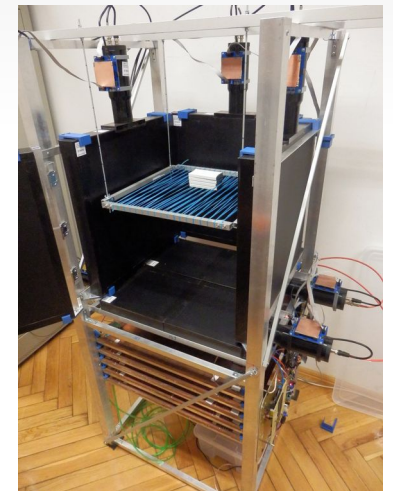
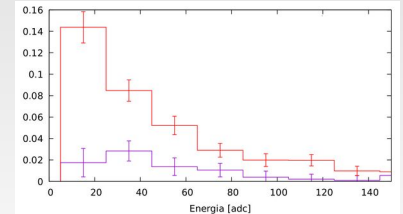


- Tuning of the gains and thresholds
- Systematic scan on materials
- Test on „interesting” targets
- Construction of Thin-Cathode MWPC for electron tagging (e/ γ sep.)
DAQ part is already prepared



Summary

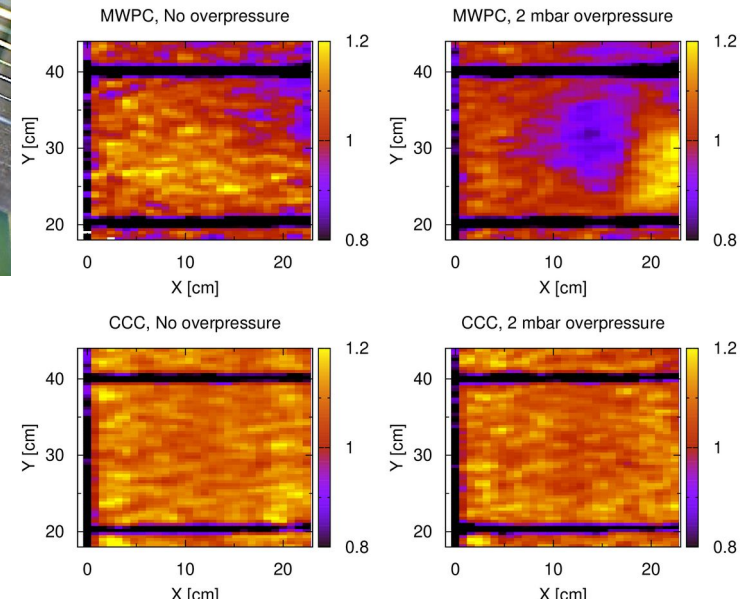
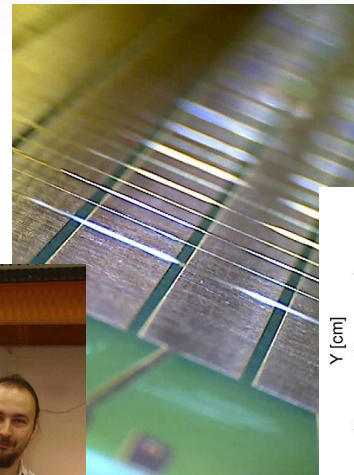
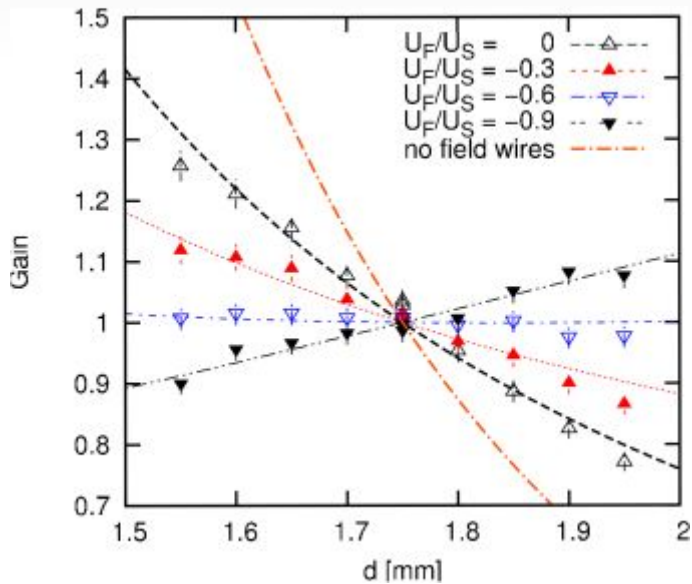
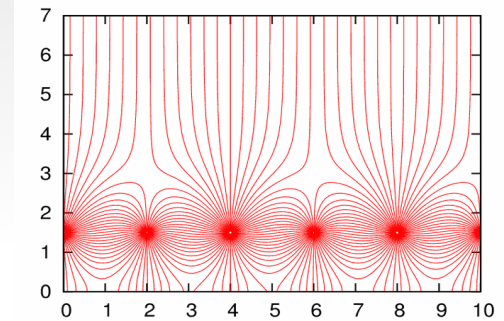
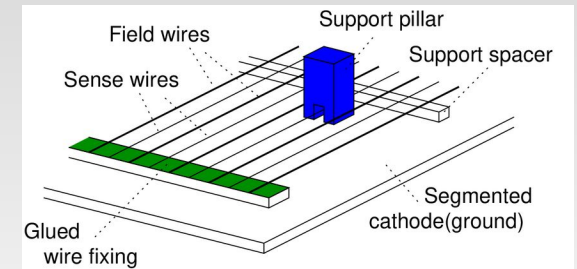
- Imaging with **Cosmic Muon Induced Secondaries**
- Archaeology, Material id.
- **MUCA**: first experiment,
- Systematics measurements started
- **Material identification** : experimentally proven
- **Simulations**:
 - understanding physics
 - upgrade: +forward, e/ γ separation
- **COMIS**
 - Compact design** and DAQ
 - Forward+Sidew. region
- **Outlook**
 - e/ γ separation chamber
 - material type – spectra
 - compare w simulations
 - interesting targets



Backup Slides

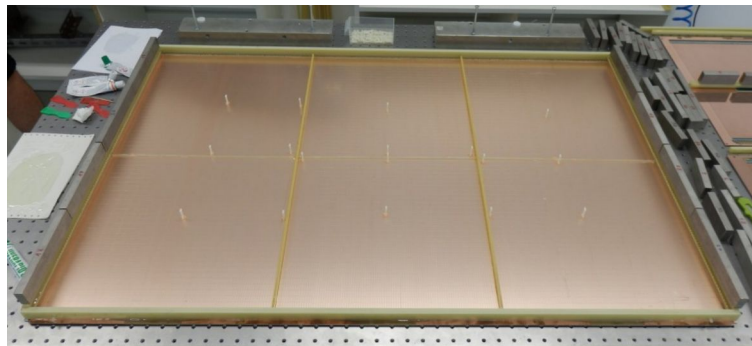
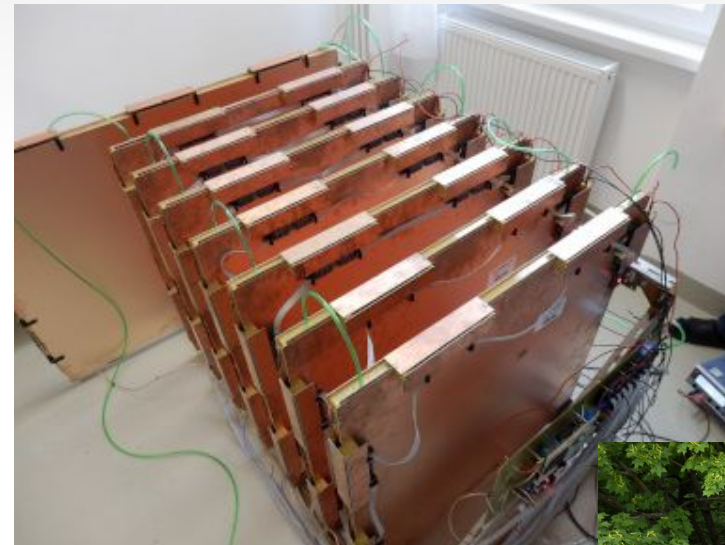
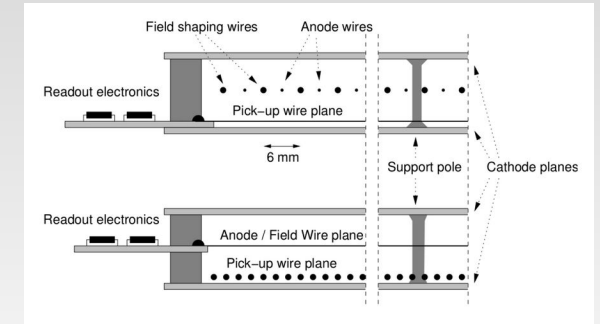
REGARD - Close Cathode Ch

- **Close Cathode Chamber (CCC)**
- Sense+Field wires, FW on negative potential
Insensitive to WirePlane distance,
- No robust frame is needed, Lightweight
- Simple construction due to relaxed conditions
- Good position resolution, Low occupancy



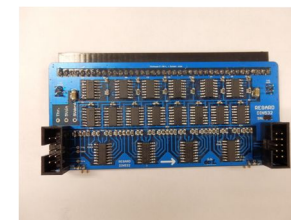
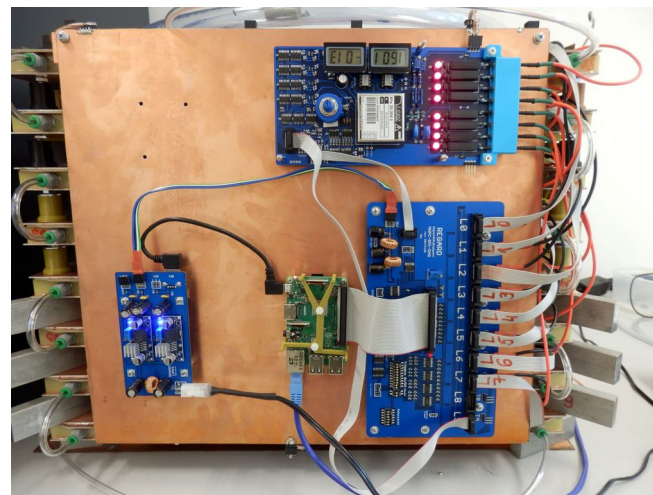
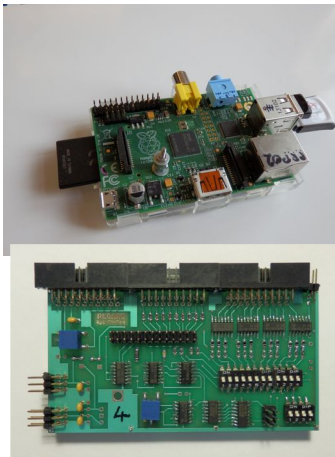
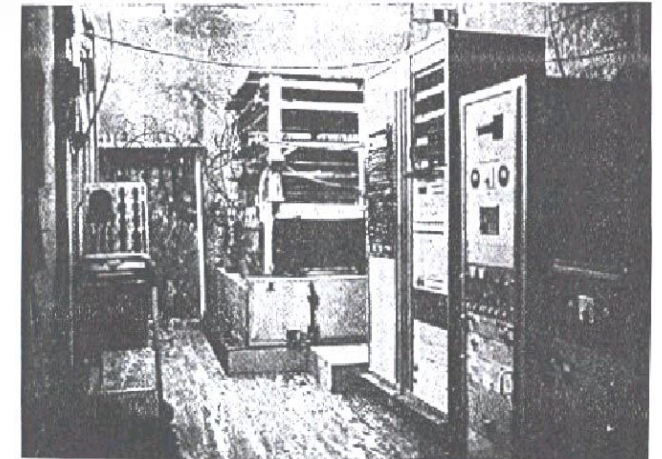
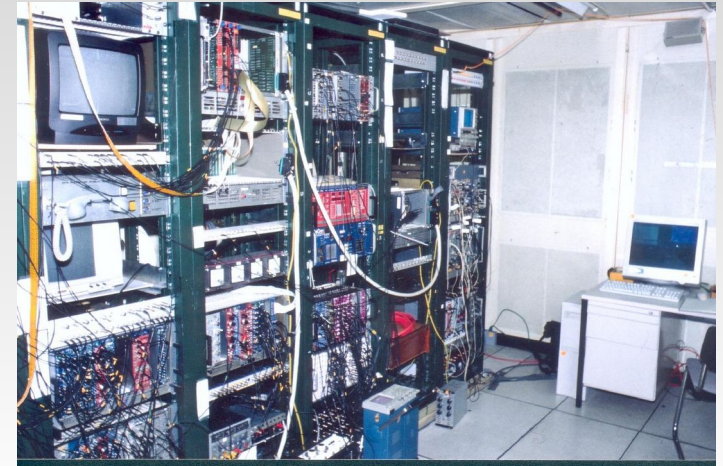
REGARD : Modified MWPC

- Modified MultiWire Proportional Chamber
- Larger size detectors $\sim 1\text{m}^2$
- Sense+Field+PadWires : Projective geometry
- Moderate resolution $\sim 1\text{cm}$, low n.ch \rightarrow Few FECs,
- Simple and cost-efficient construction



Data Acquisition

- **RaspberryPi** microcomputer (low cost)
ARM CPU + Broadcom
Peripherals: USB, HDMI, **GPIO**, ...
- DataStorage + Access + Control
OS eg. Raspbian linux
- GPIO pins (10MHz) adaptable
for any custom protocol
- **FEE**: Digital: Preamp+Discrimination
→ ShiftReg : chainable, simple
power < 5mW/ch
- Trigger : N-fold coincidence for layers



Muograph Portfolio

- Application based design, considering size, consumption, durability, target and focus, portability, and user access.
- **MTL-X** : MWPC: 768mm, p:12mm : Mining, Large tunnels
Large tracker ideal for deep underground measurements
- **MTS50** : MWPC: 512mm, p:8mm : Standard tunnels, Mines
Scale-down version of the MTL type, fits through 60cm doors
- **MTS40** : CCC: 400mm, p:3mm : Tunnels, Caves
High resolution and largish surface CCC design
- **MTS25** : CCC: 256mm, p:4mm : Natural caves
Good resolution one-man-carry design for tough-access caves
- **BHD-X** : CCC: 64x256mm², p:4mm : BoreHole application
Four-layered tracker, fits into 10cm diameter holes
- **MMOS** : MWPC:1152x768mm², p:12mm : SakurajimaMO
Box-enclosed, runs in system of 12 MMOS.
- **MtEtna** : MWPC:1152x768mm², p:12mm : Mussomeli,Etna
Step-elevated geometry to enhance acceptance in target region

	Lead	Copper	Water	Polystyrene
$\gamma, E \geq 0.1 \text{ MeV}$	20.7%	10.6%	0.14%	0.14%
$e^-, E \geq 1 \text{ MeV}$	6.68%	13.1%	6.08%	4.7%