T2DM2 STATUS UPDATE. INTRODUCTION OF **MUST²** DETECTOR.

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Région PACA
Département de Vaucluse
Communauté de communes du Pays d'Apt
Liberté • Égalité • Fraternité République Française
LSBB Laboratoire Souterrain à Bas Bruit
Low Noise Inter Disciplinary Underground Science & Technology

OUTLINE

1. T2DM2
   - LSBB
2. MUST^2 camera
   - Features
   - Electric field design
   - Assembly
   - Gas selection
   - Mesh pickup
   - First results
   - Protocol for auto trigger validation
3. Data acquisition
4. Next step

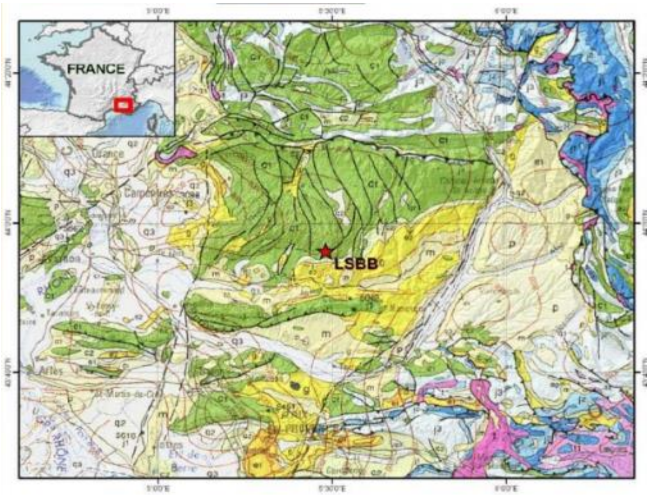
1. T2DM2

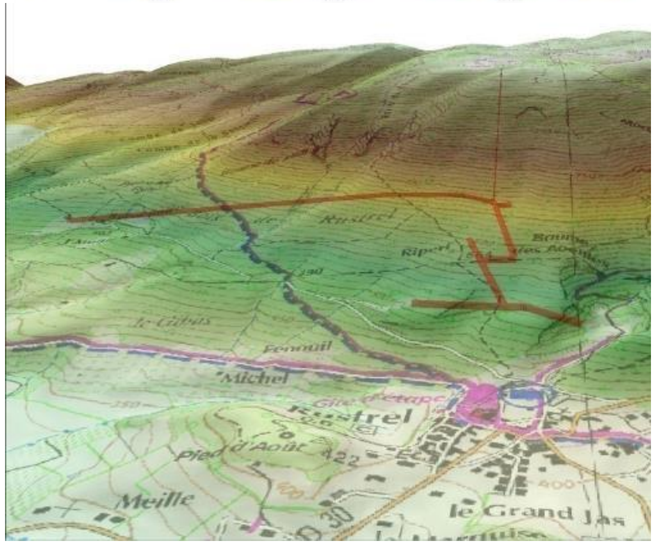
Temporal Tomography of rock mass Density by the Measure of Muons

OBJECTIVES: <u>Develop a new non-destructive technique to image in situ unreachable volumes.</u>

- Monitor temporal density variations (landslide, fracturing, underground survey).
- Develop and construct a new type of detector by merging different technologies in a new configuration
- Assembly of the detectors and its peripherals and tune up
- Adapt the CERN software and develop our own to:
  - Command the electronics
  - Analyse the data

1. T2DM2





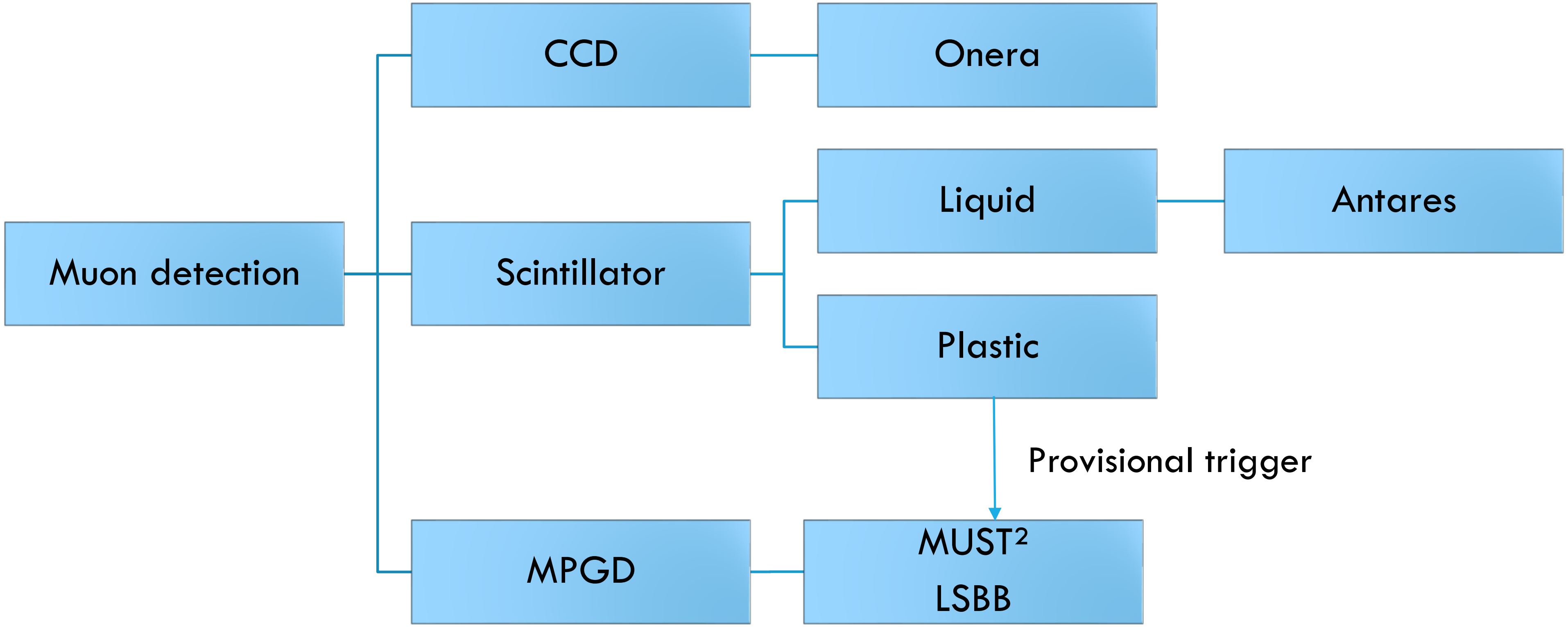
Laboratoire Souterrain à Bas Bruit (LSBB)

Low Background Noise inter-Disciplinary URL

- The layout of the galleries allows to deploy the camera network easily between 0 and 550m deep
- Clean room to assemble detectors
- Low background noise environment
- At the heart of one of the major seismogenic regions of South-Eastern France.
- Unsaturated zone of karst aquifer within *Fontaine-de-Vaucluse* carbonate reservoir

1. T2DM2

Muon detection at LSBB


Muon detection

CCD

Onera

Scintillator

Liquid

Antares

Plastic

Provisional trigger

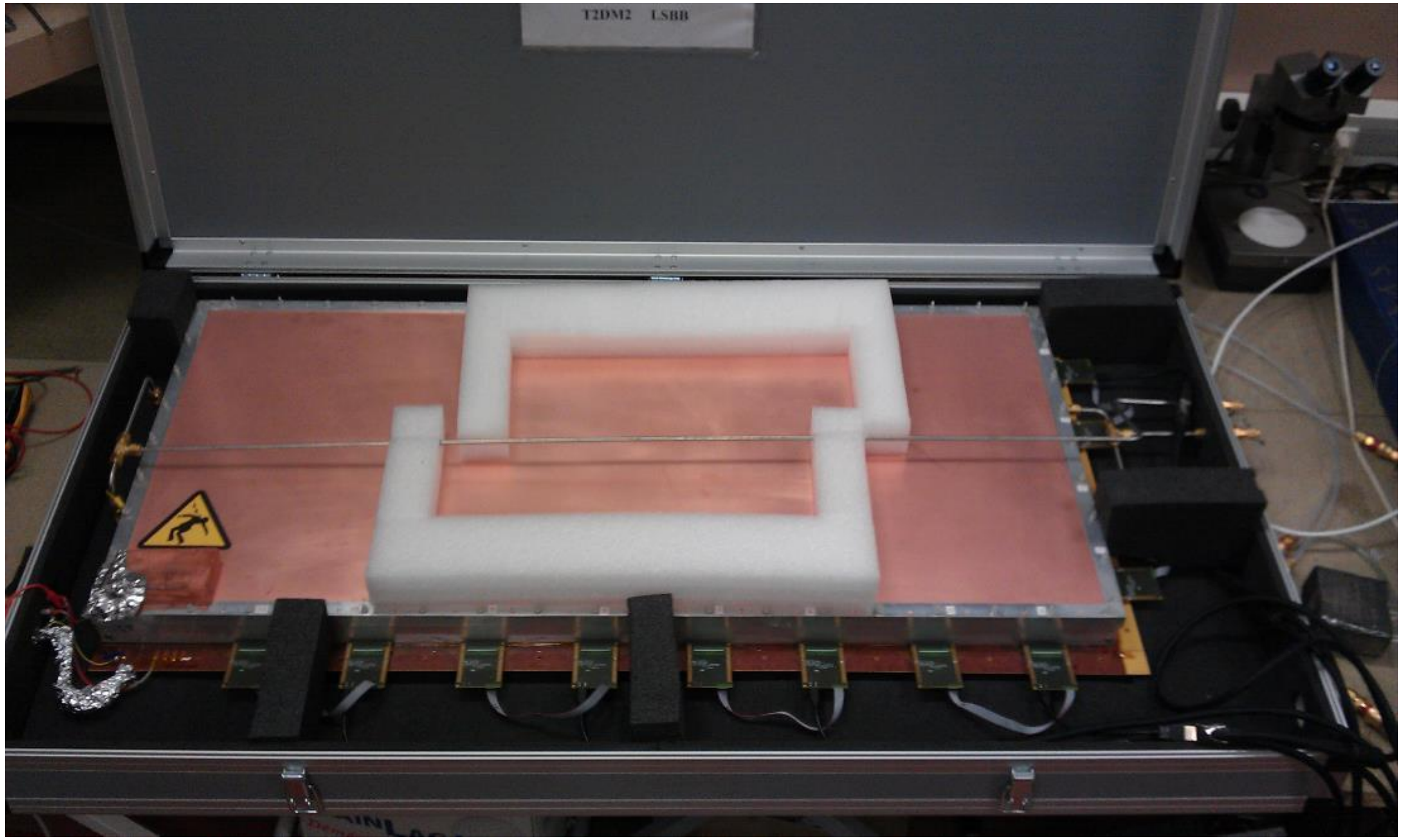
MPGD

MUST²
LSBB

2. MUST^2 CAMERA

Features

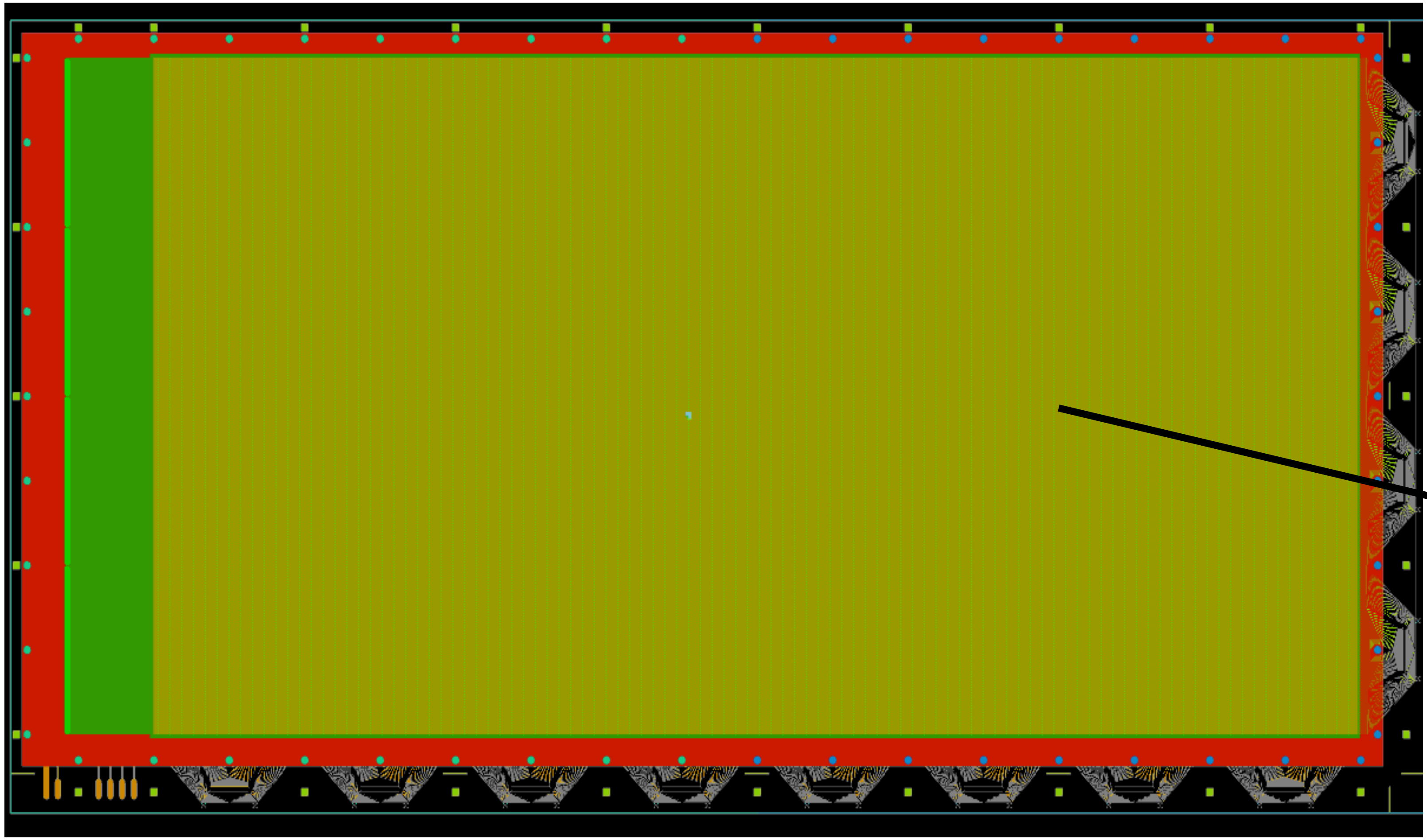
MUon **S**urvey **T**omography based on
Micromegas detectors for **U**nreachable **S**ites **T**echnology



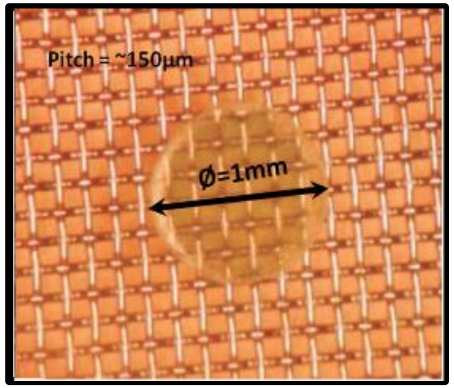
- Enclosed in a sturdy case for transport and field operation.
- Can be piled up directly w/o problems
- Case is dust proof and protects the electronics from humidity.
- Outer dimensions: 150 x 80 cm
- Weight: 28kg filled and wired
- All gas and electric connectors include feedthroughs so the detector can be connected/detached when necessary easily and to keep the gas-tightness.

2. MUST^2 CAMERA

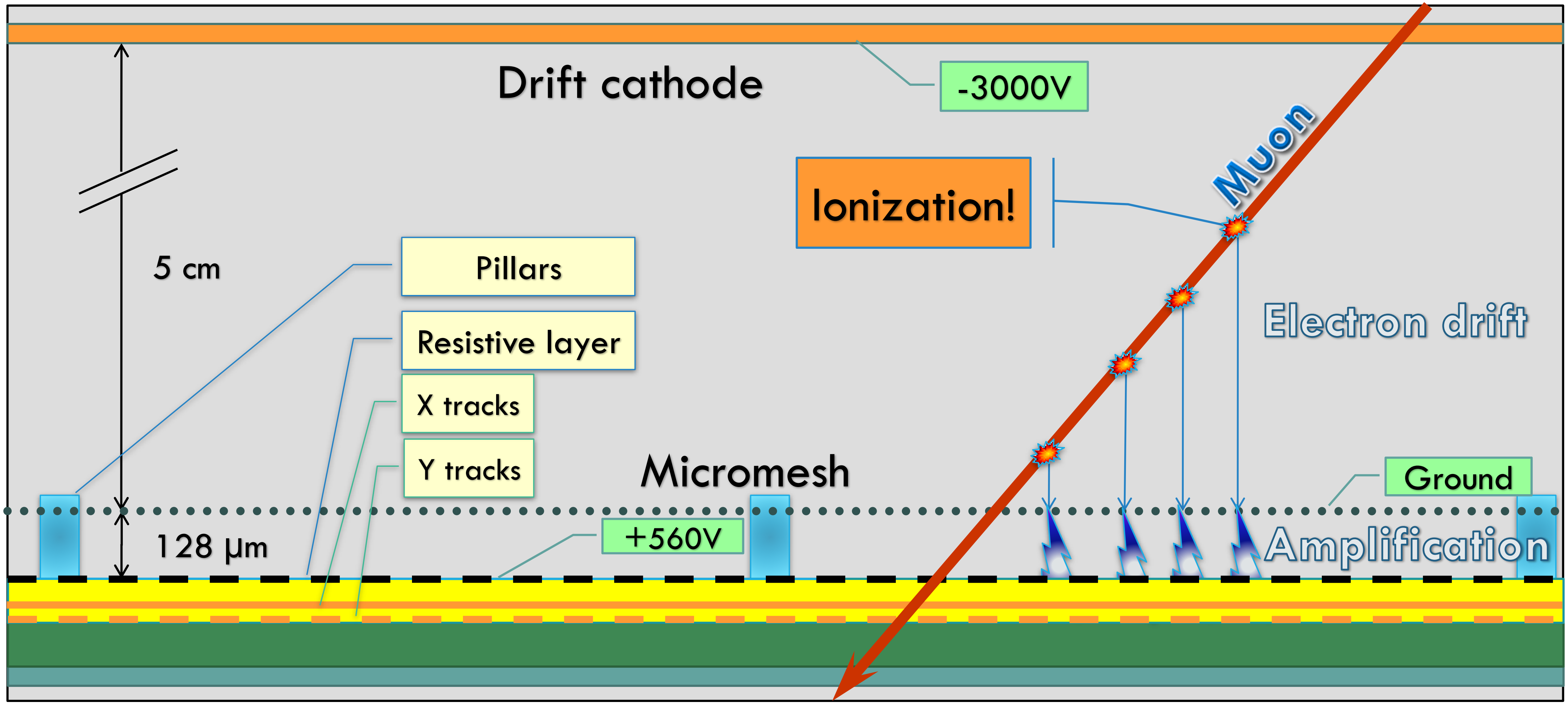
Features



- Bulk Micromegas
- 1024 channels in horizontal
- 512 in vertical
- Active surface ~0.45m^2
- Dead area ~0.4%

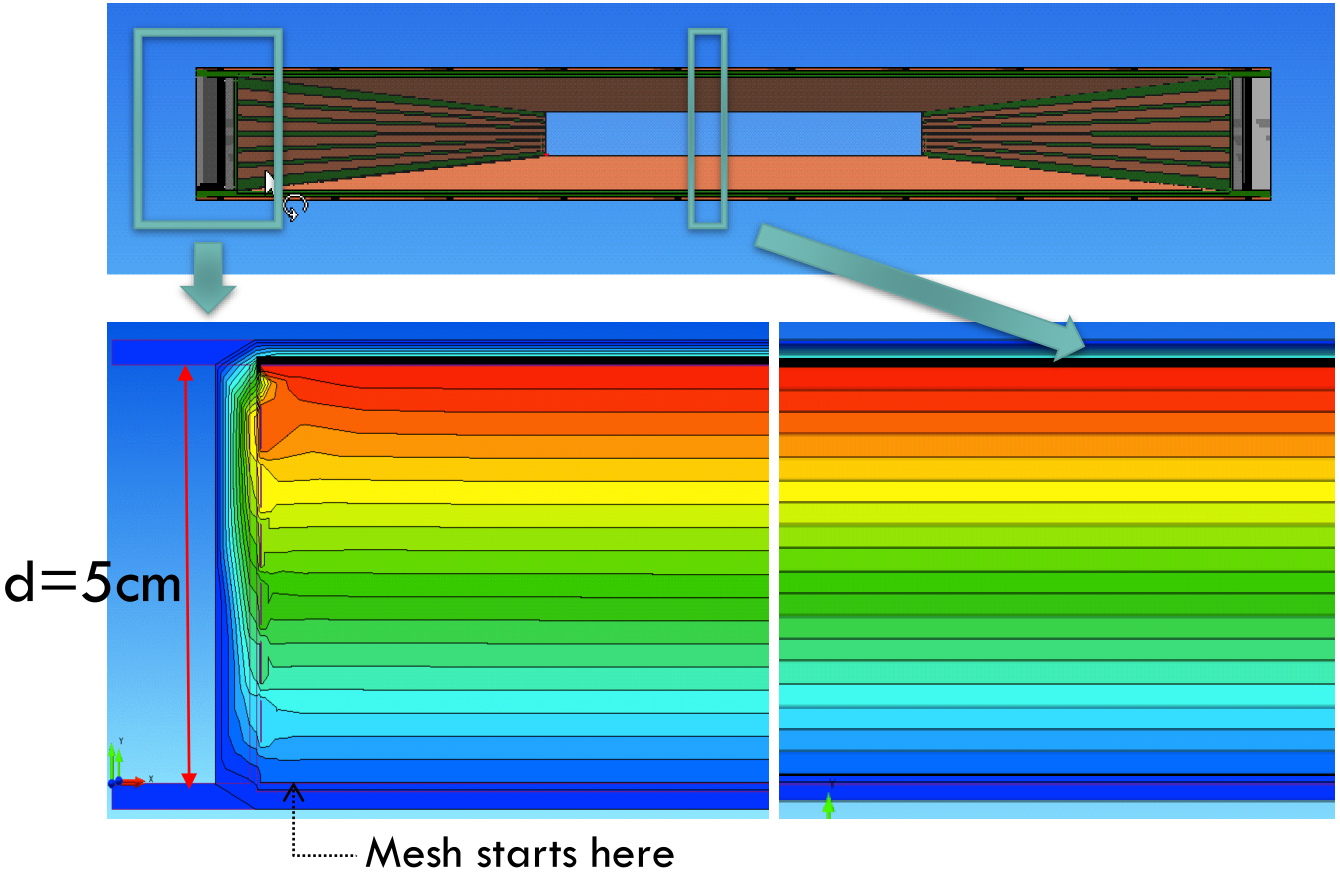


2. MUST² CAMERA



2. MUST² CAMERA

Electric field design



The TPC is 5cm height from the drift cathode to the micromesh.

↓

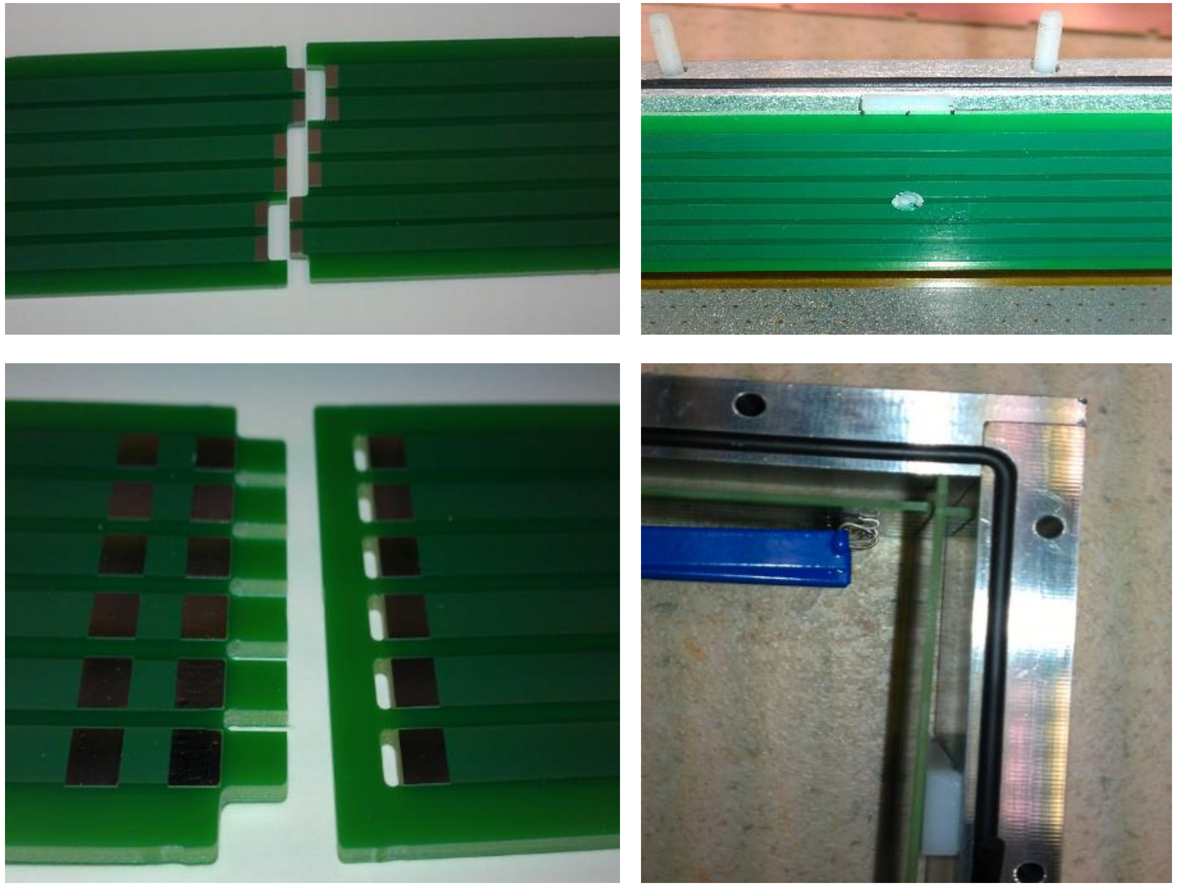
Distortion of $\vec{E}$ in the edges

↓

Simulations performed to design a field homogenizer to keep the electric field as regular as possible

2. MUST^2 CAMERA

Electric field design

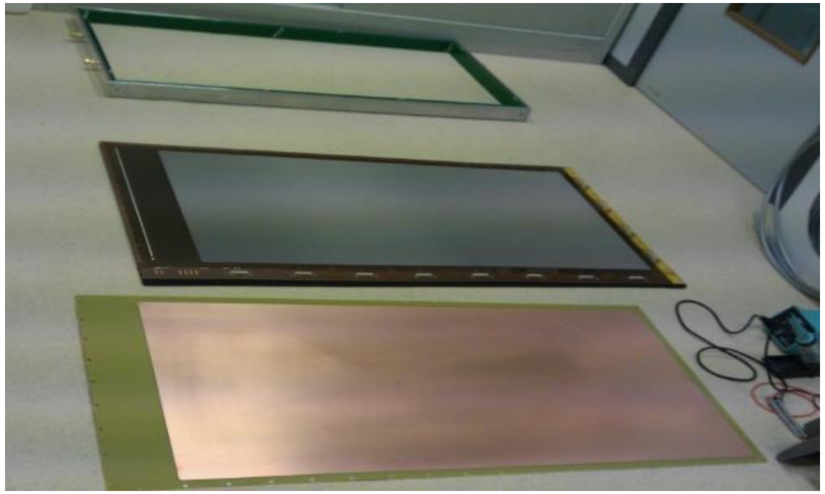


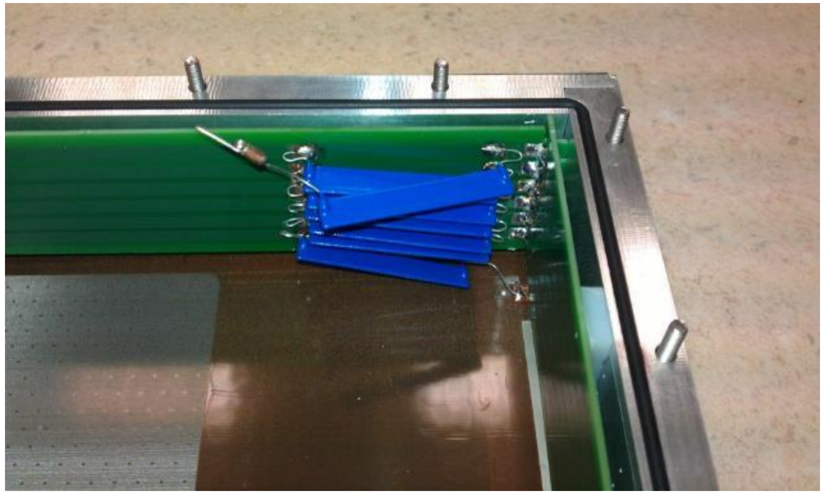
PCB frame:

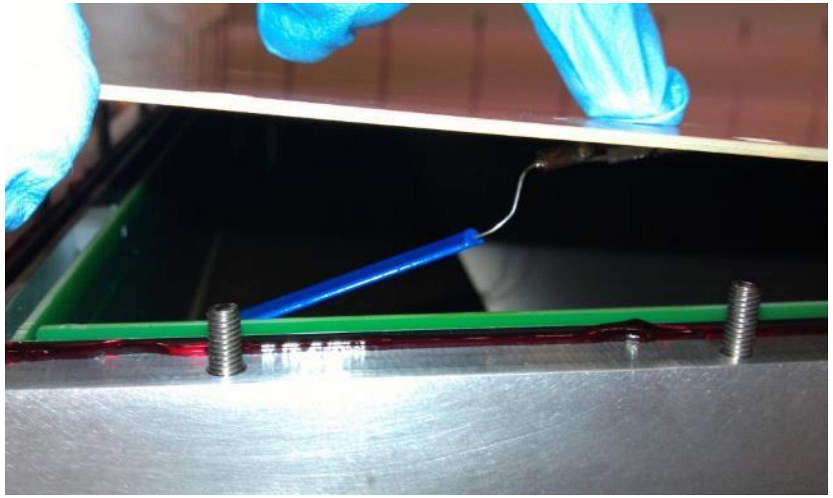
- ✓Self-supporting
- ✓Steady tracks
- ✓Ease to solder
- ✓Modular
- ✓Cheap and easy to get
- ✓Gas distributor

2. MUST² CAMERA

Assembly

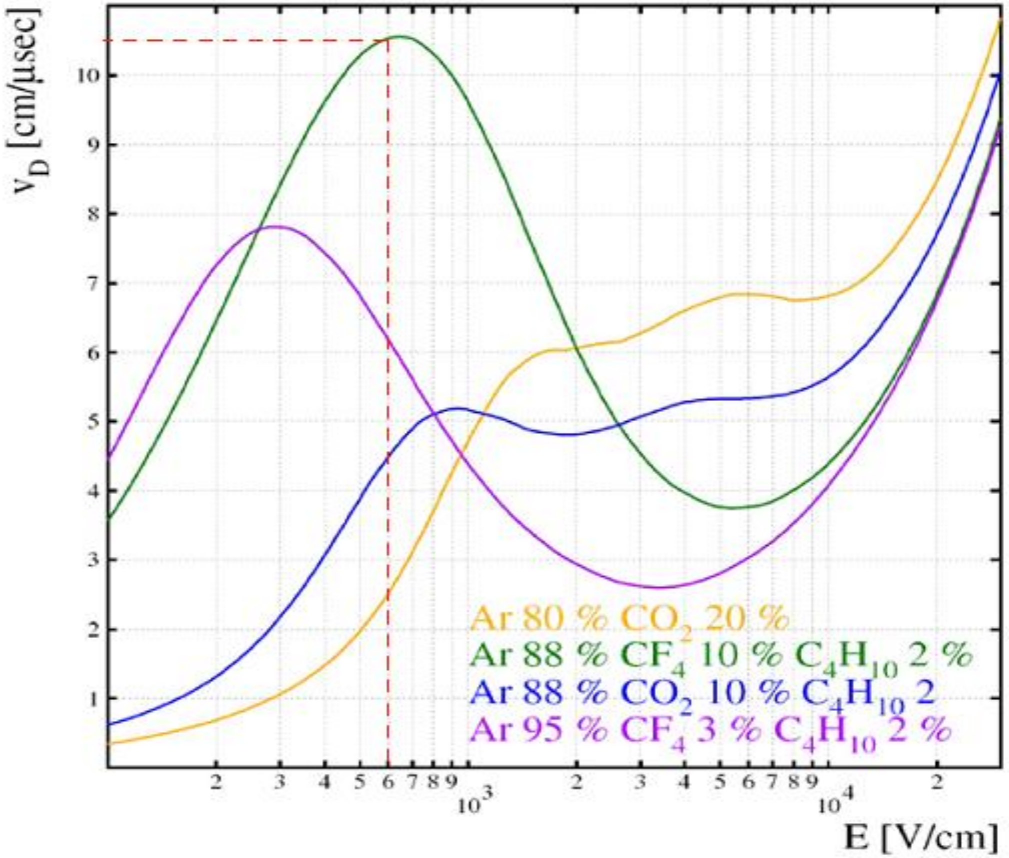






2. MUST² CAMERA

Gas selection



- Different mixtures considered.
- Simulations performed with Garfield to estimate drift speed.
- The cathode voltage is chosen in order to maximize the drift speed.
- The best theoretical candidates are:
  - Ar, R14(10%), Isobutane(2%)
  - Ar, R14(3%), Isobutane(2%)
- Our current blend is Ar, R14(4.8%) Isobut(1.4%)

2. MUST² CAMERA

Mesh pickup

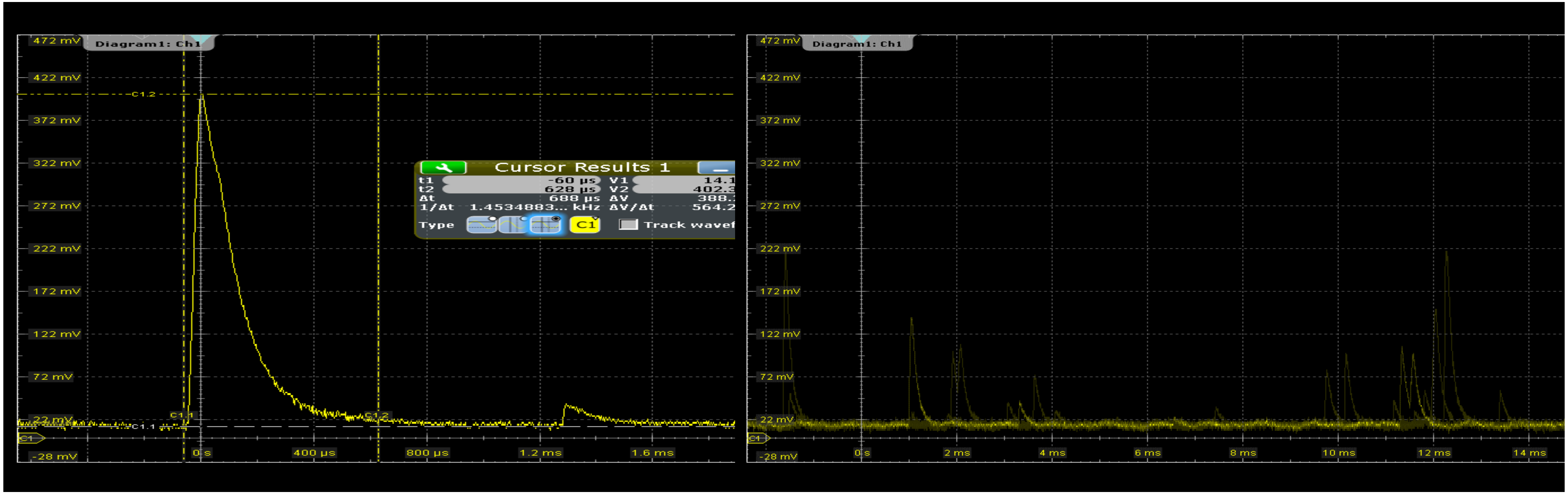
Portable NIM:

- 2 lines HV power supply Iseg NHQ 214M
- Amplifier Ortec 474
  - Used to invert the polarity
- Discriminator Ortec 584
  - Creates a NIM pulse for the FEC card
  - Adjusts the trigger threshold

2. MUST² CAMERA

Mesh pickup

- V_{drift_cat} = -3kV
- $V_{resistive\_an}$ = 580V
- RMS_{noise} = 5mV (2σ)



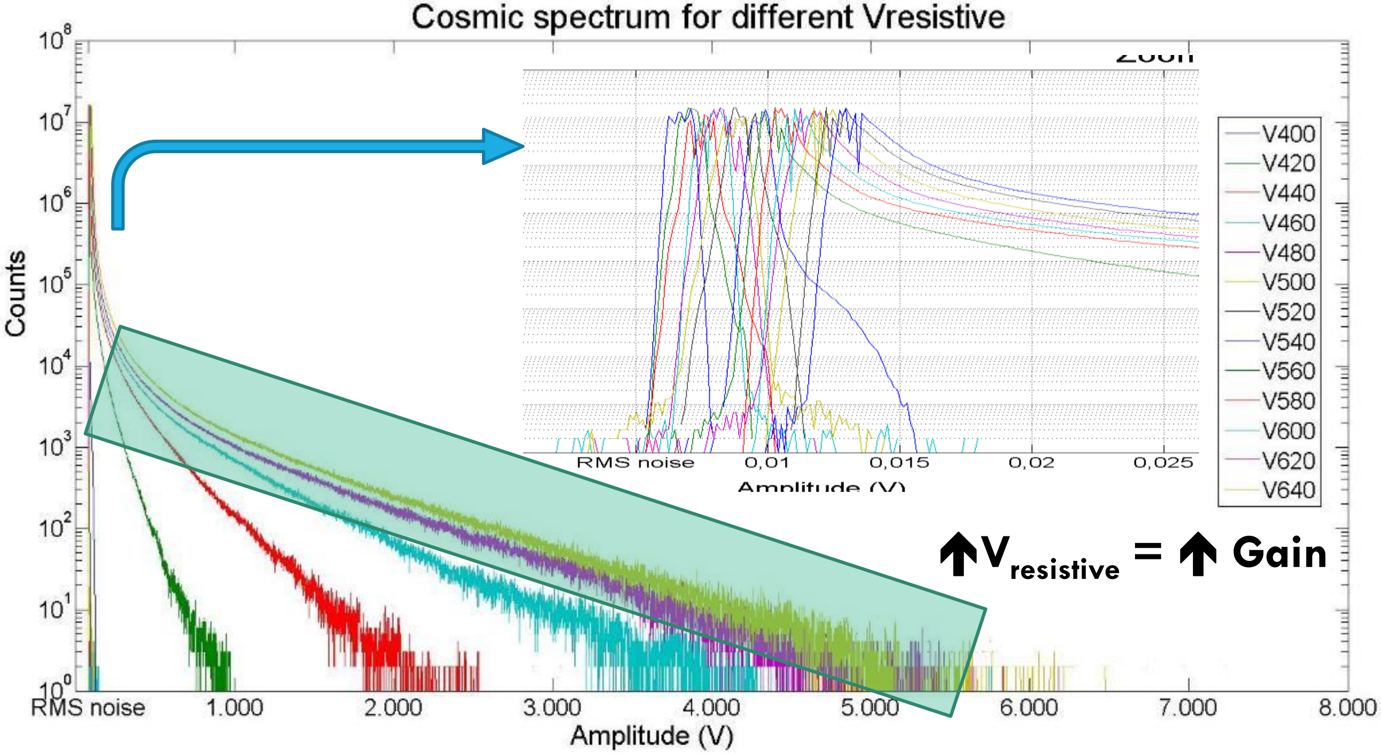
```
Cursor Results 1
t1          -60 µs   V1        14.1
t2          628 µs   V2        402.3
Δt          688 µs   ΔV        388.
1/Δt  1.4534883... kHz  ΔV/Δt  564.2
Type                C1   ☐ Track wavef
```

No need of preamplifier, amplitude goes up to 800mV

2. MUST² CAMERA

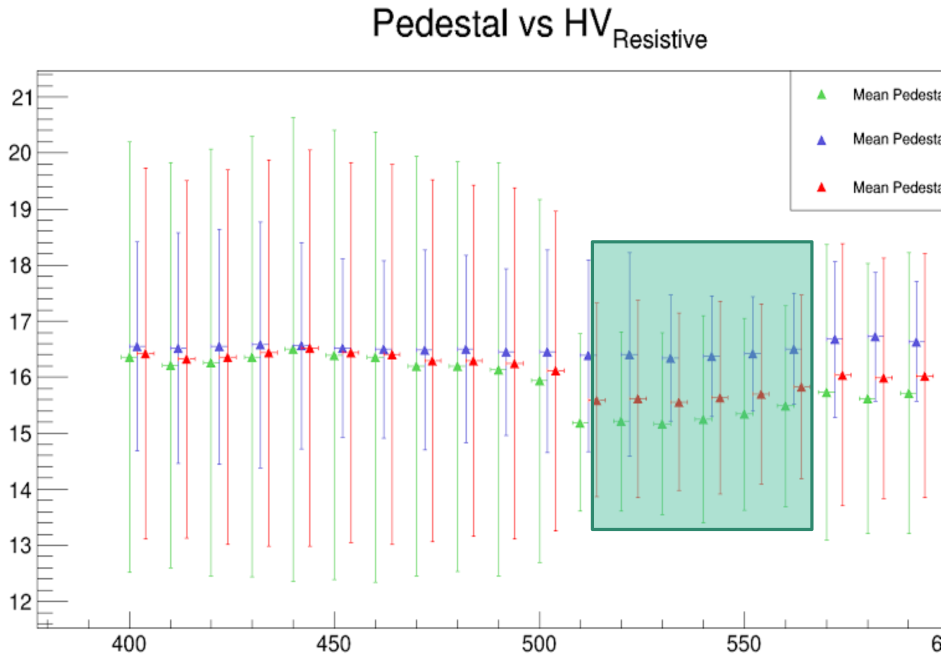
First results

Cosmic calibration: Effect of the **resistive tracks** voltage
Operation range: 400-700V ≡ 30-55kV/cm



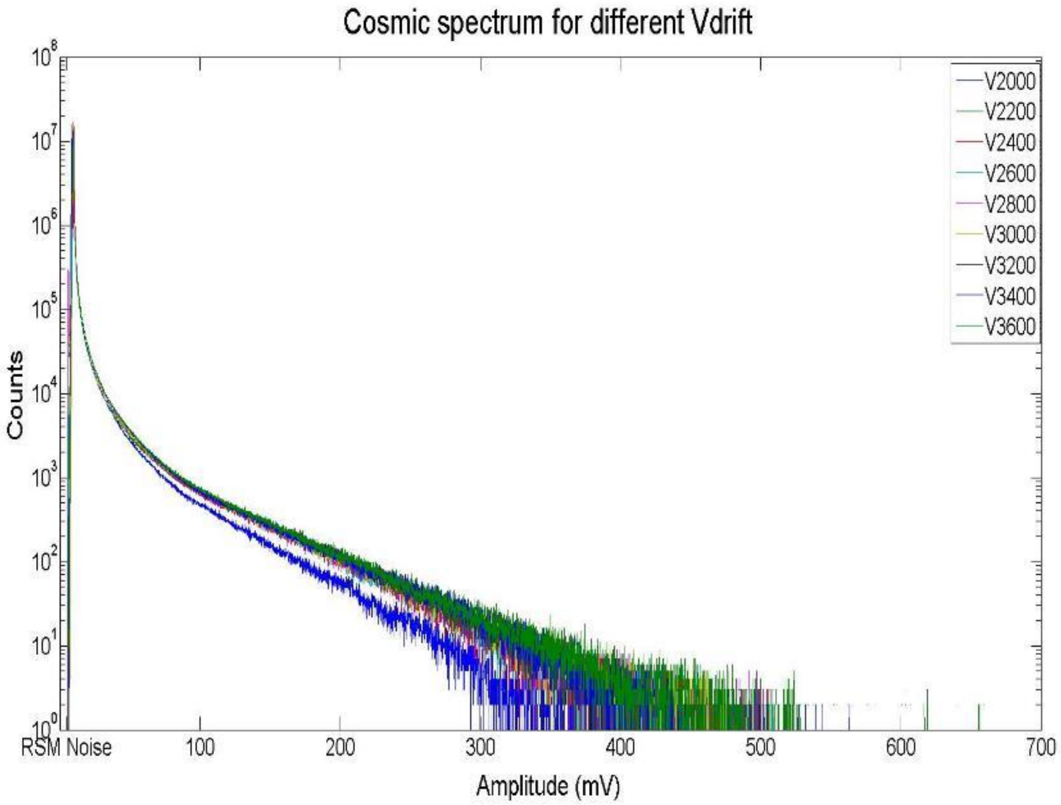
↑$V_{resistive}$ = ↑ Gain

Noise pedestals in APV25



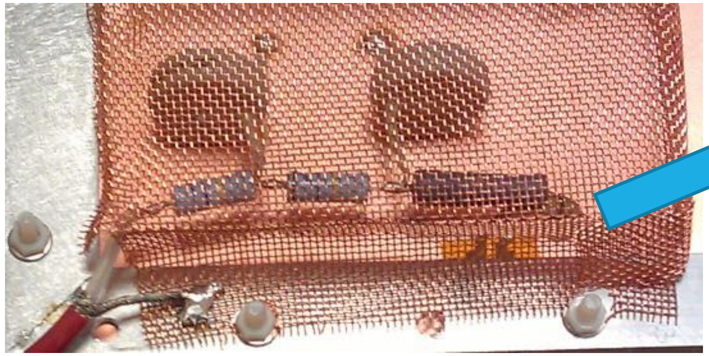
2. MUST^2 CAMERA

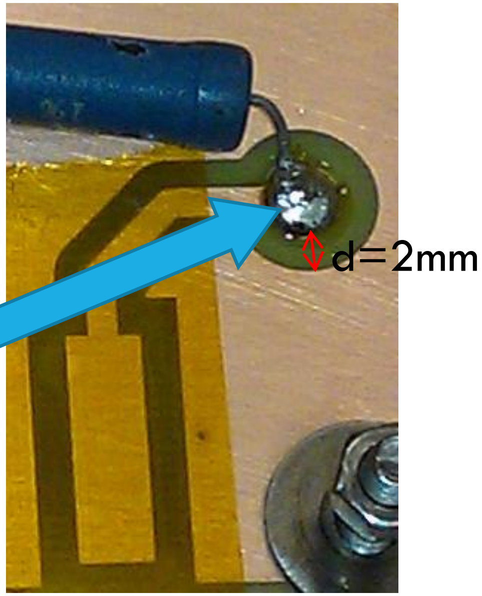
First results



Effect of the **drift cathode** voltage Operation range: -2000 -3600V ≡ 400-720V/cm

Sparks appear at 3800V





2. MUST² CAMERA

Operation protocol for auto trigger validation

- Random coincidence rates
  - 3 plastic scintillators and Micromegas non-aligned
- Scintillators event rate
  - 3 plastic scintillators vertically aligned

$$\text{Event rate \#1} = \text{Number of muons } (\Omega, A) \cdot \eta_{\text{scintillators}}$$

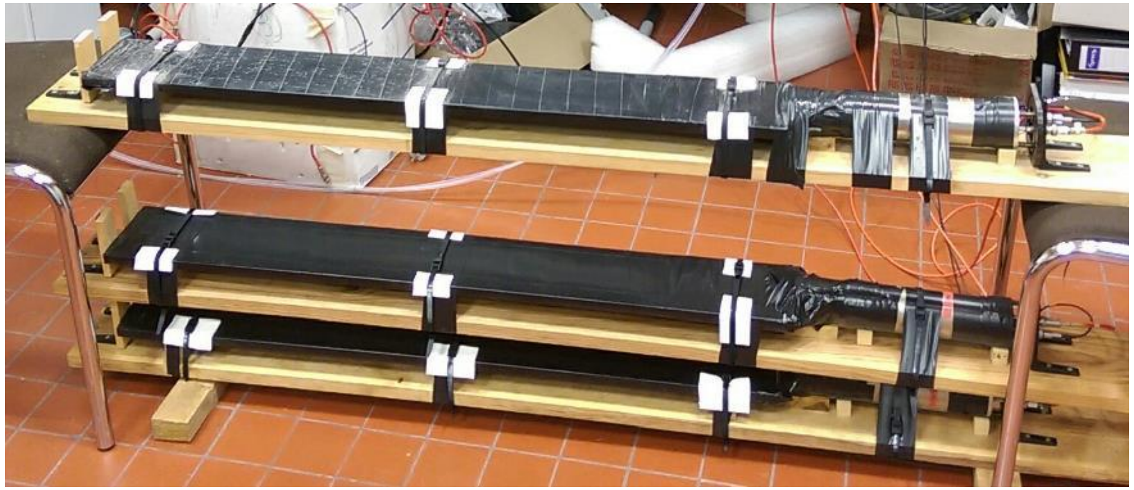
- MUST² mesh trigger efficiency
  - 3 plastic scintillators vertically aligned and the MUST² camera between them

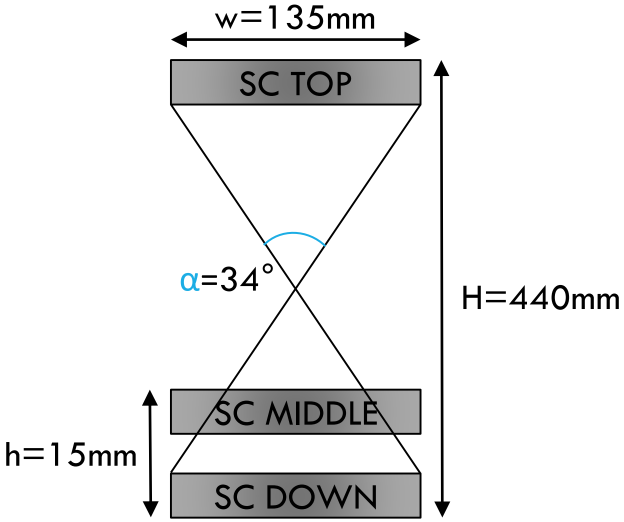
$$\text{Event rate \#2} = \text{Number of muons } (\Omega, A) \cdot \eta_{\text{scintillators}} \cdot \eta_{\text{MUST}^2}$$

$$\boxed{\eta_{MUST^2} = \frac{Event\ rate\ _{\#}2\ \_\ \ Random\ 4det}{Event\ rate\ _{\#}1\ \_\ \ Random\ 3scint}}$$

2. MUST² CAMERA

Scintillator setup for event rate

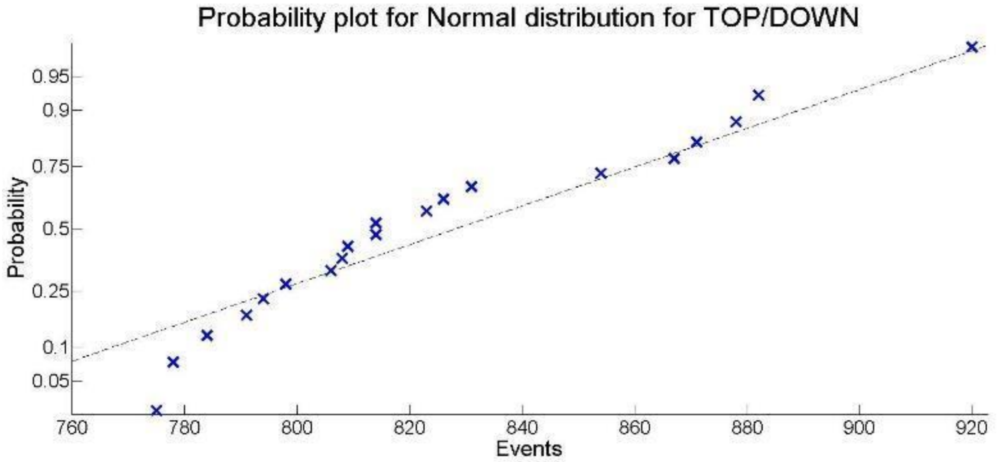


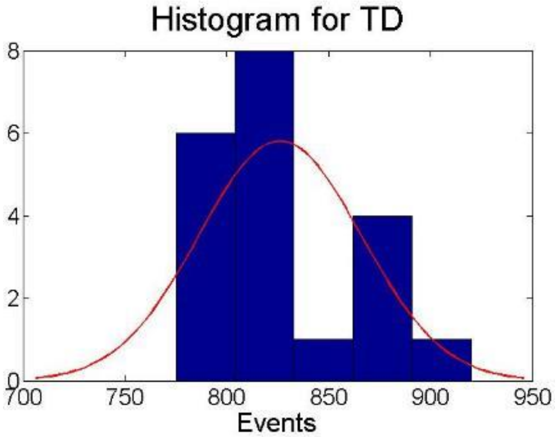


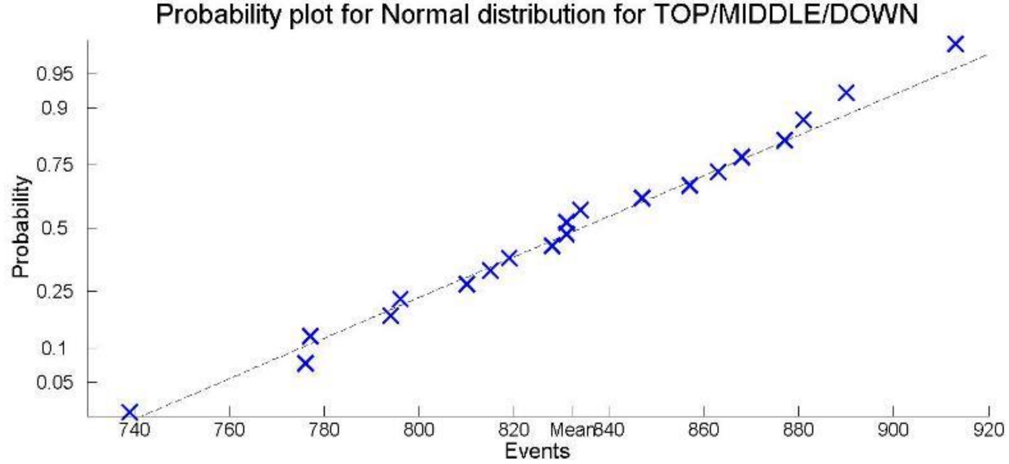
- Angle 34°
- Coincidence TOP/DOWN and TOP/MIDDLE/DOWN
- 20 acquisitions of 5 min for each
- Coincidence card: LeCroy 465
- NIM pulse adjusted to 100ns

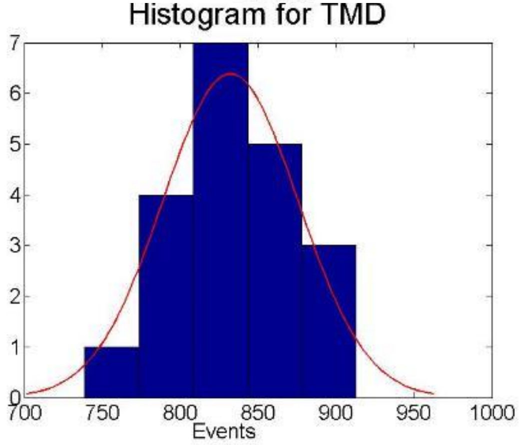
2. MUST² CAMERA

Scintillator event rate


Probability plot for Normal distribution for TOP/DOWN


Histogram for TD


Probability plot for Normal distribution for TOP/MIDDLE/DOWN


Histogram for TMD

Summary Statistics

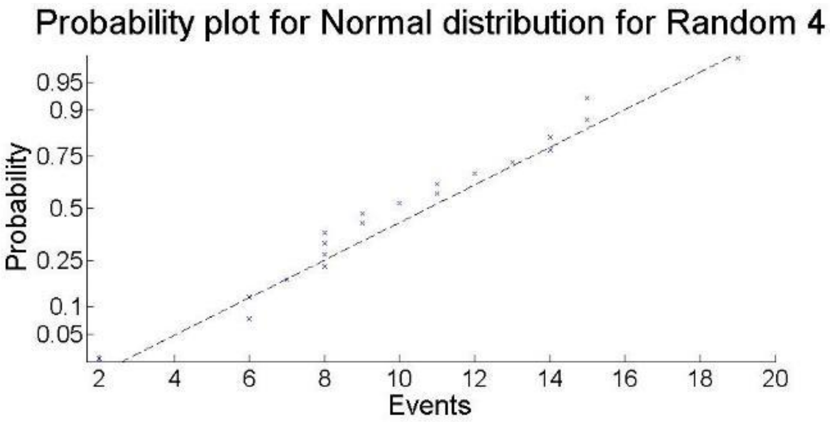
	TMD	*TD*
Count	20	20
Average	832,3	826,15
Geometric mean	831,21	825,255
Variance	1893,17	1589,61
Standard deviation	43,51	39,86
Coeff. of variation	5,22 %	4,82 %
Minimum	739,0	775,0
Maximum	913,0	920,0
Range	174,0	145,0
Stnd. skewness	-0,346453	1,47943
Stnd. kurtosis	-0,186177	-0,0737746
Sum of squares	1,38904E7	1,36807E7

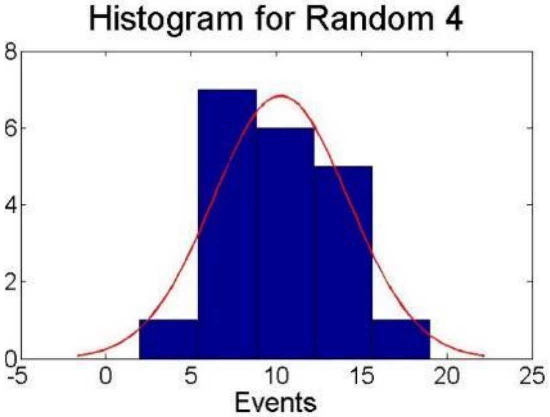
t test to compare means
Null hypothesis: mean1 = mean2
assuming equal variances: t = 0,466044
P-value = 0,643844
Hypothesis accepted

2. MUST² CAMERA

Scintillator setup for random coincidences

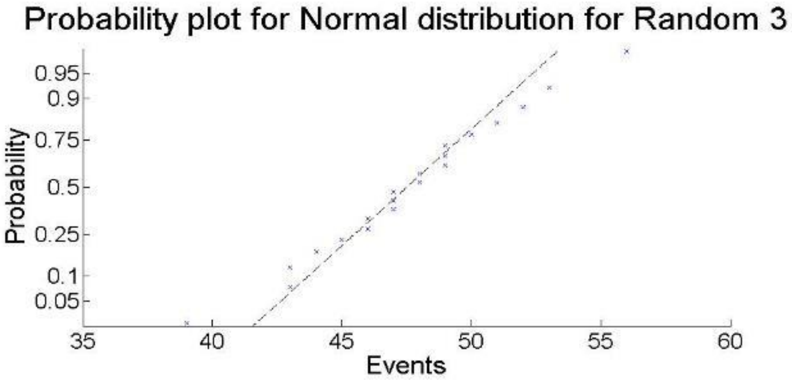
- Random coincidences quantified for:
  - 3 scintillators and MUST²
  - 3 scintillators

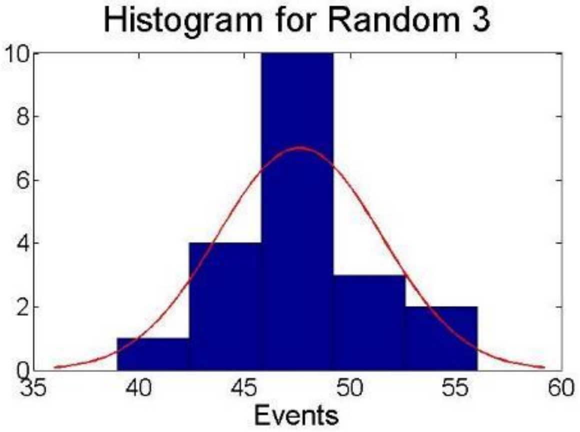

Probability plot for Normal distribution for Random 4


Histogram for Random 4

Summary Statistics for Rn4

Count	20
Average	10,25
Standard deviation	3,97
Coeff. of variation	38,75%
Stnd. Skewness:	0,371229
Stnd. Kurtosis:	0,172937


Probability plot for Normal distribution for Random 3

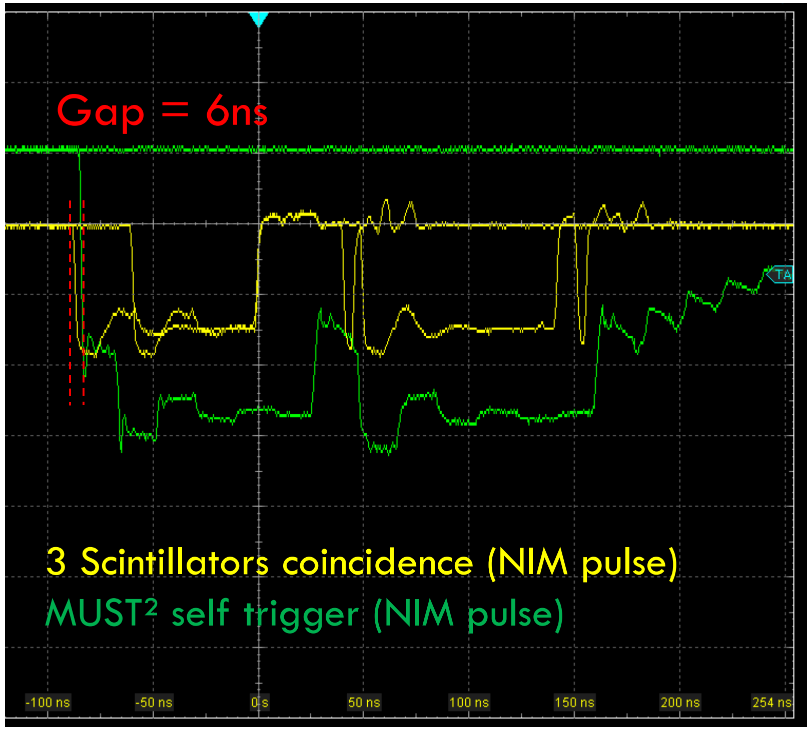

Histogram for Random 3

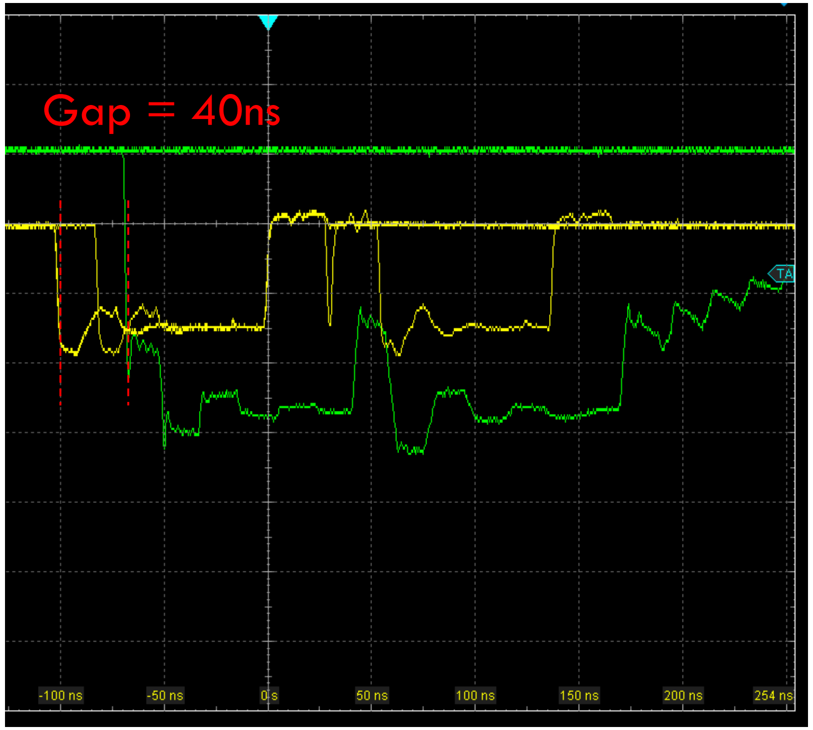
Summary Statistics for Rn3

Count	20
Average	47,6
Standard deviation	3,87162
Coeff. of variation	8,133%
Stnd. skewness	-0,0128048
Stnd. kurtosis	0,577323

2. MUST² CAMERA

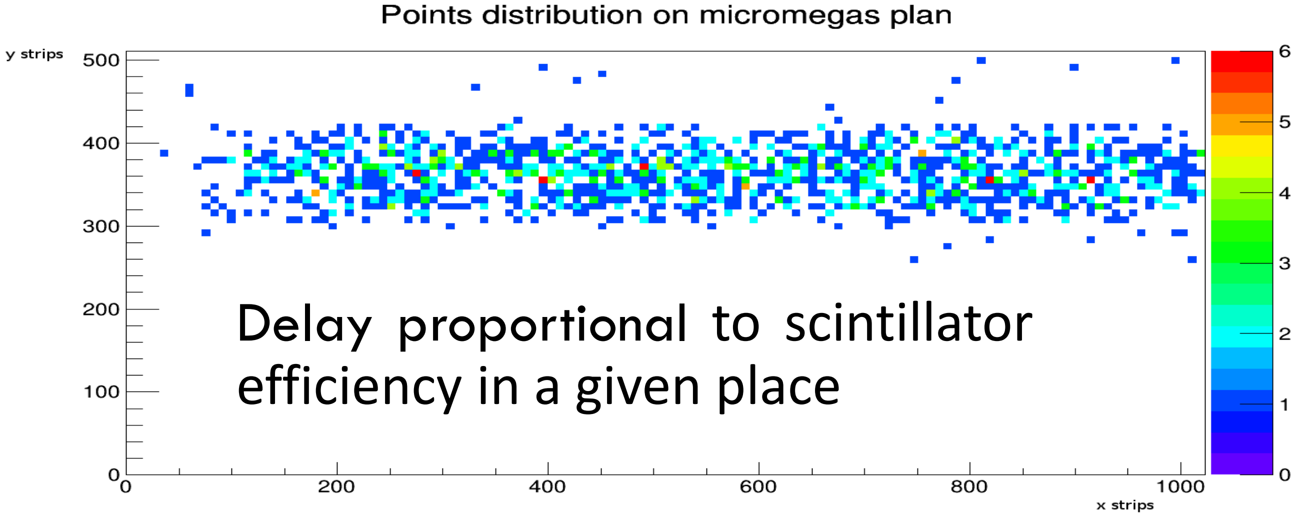
4 detectors coincidence



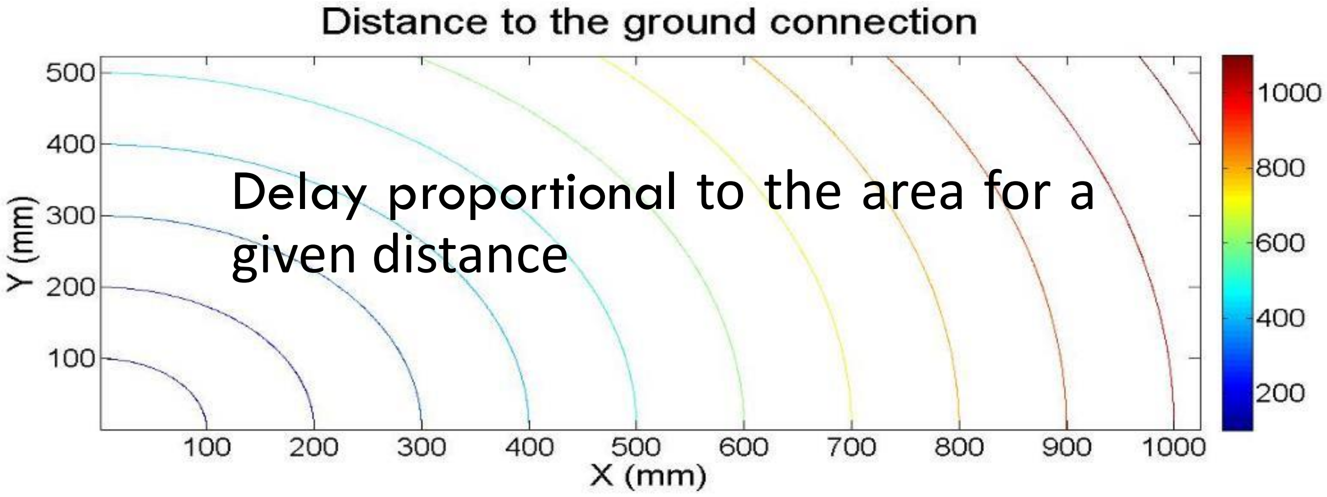


The gap between pulses is variable and depends on the position where the even is originated in the detector.

2. MUST^2 CAMERA

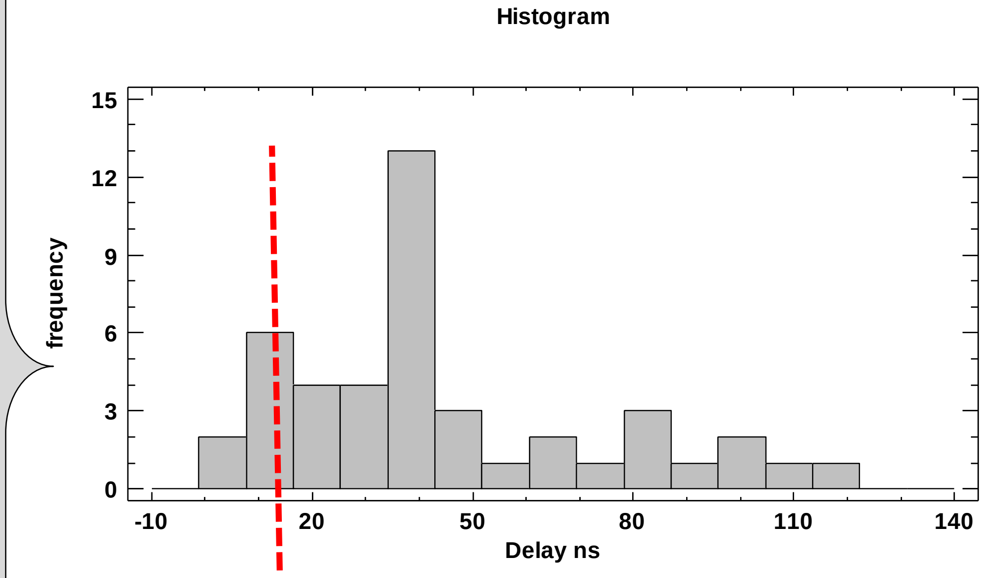

Points distribution on micromegas plan

Delay proportional to scintillator efficiency in a given place


Distance to the ground connection

Delay proportional to the area for a given distance

- Measured delay behaves as expected.
- APV25 take snapshots of 675 ns, delay within acceptable values.


Histogram

Worst Ar$^+$ drift time in Amp gap

3. DATA ACQUISITION

Hardware involved

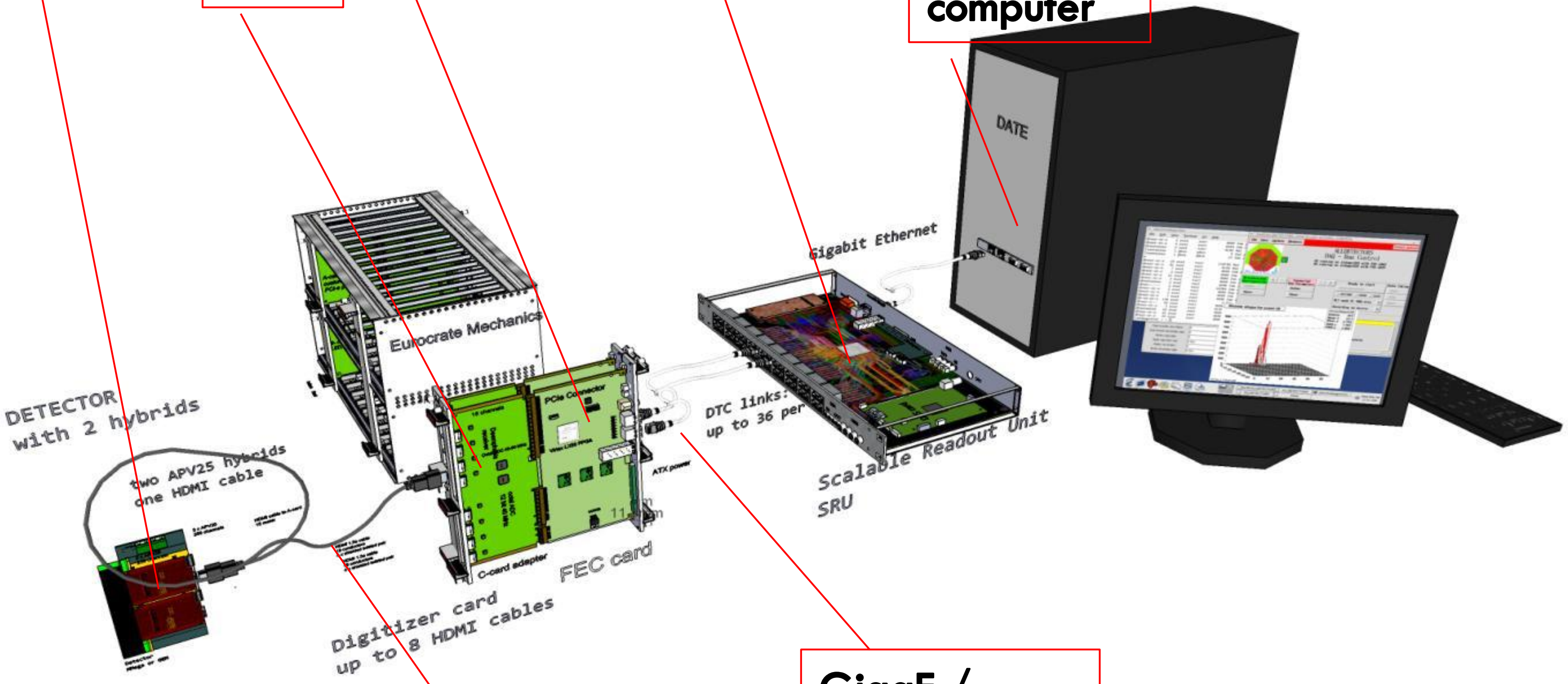
APV 25

ADC

FEC

SRU

DAQ computer



HDMI

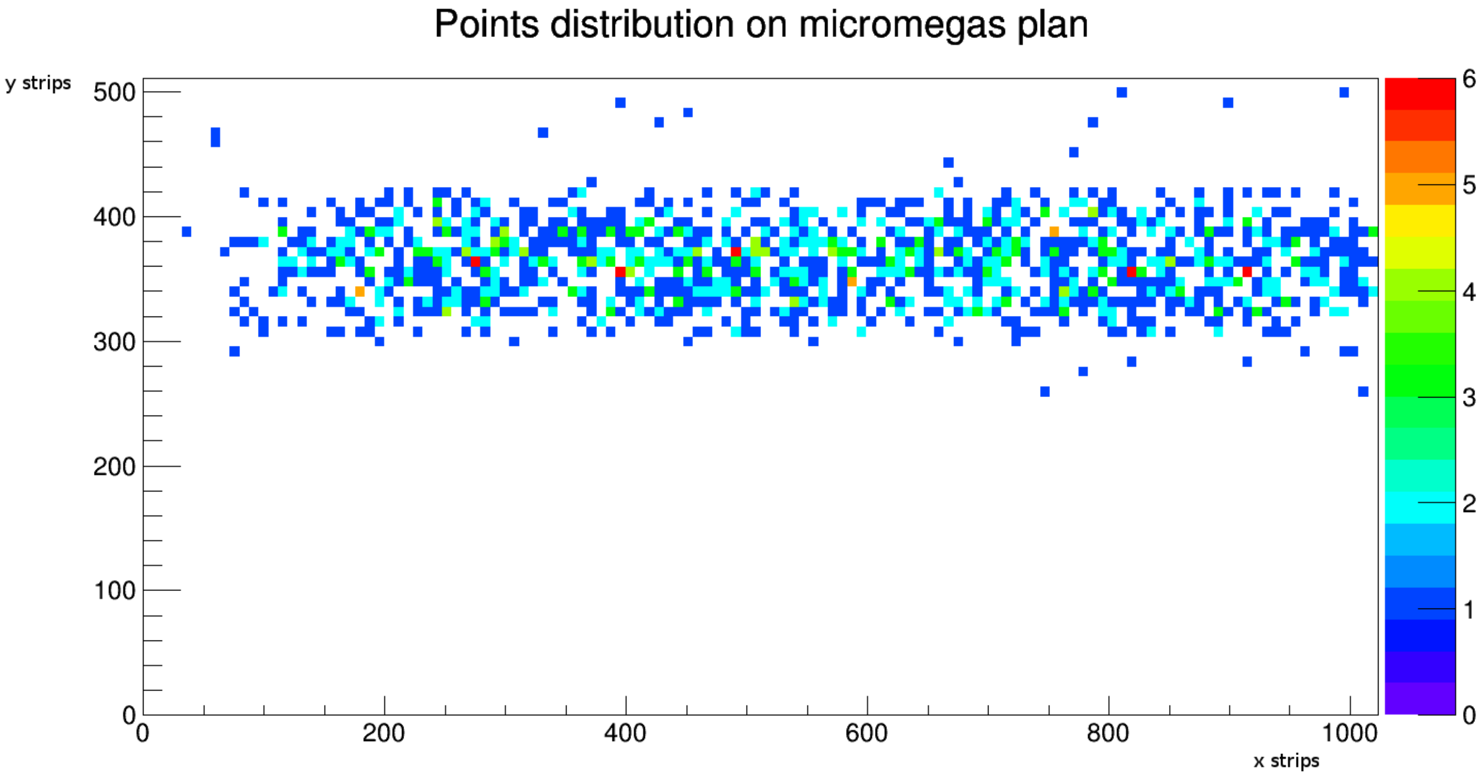
GigaE / Optical fibre

SRS system by RD51

- PROS:
- Highly scalable
- Modular
- Software already created
- Inexpensive
- CONS:
- Hard to purchase
- Length limitations
- Specific software > Needs customization

3. DATA ACQUISITION

First results



We are able to reconstruct images with a pixel density of >115 cm²

Summarized in another presentation by Dr. Serre **next Friday afternoon**

WG2 - Physics Issues

4. NEXT STEP

Production

- First stage: Installation of a network with six muon cameras at the LSBB facilities as a technique demonstrator to obtain a measure of rock densitometry.
  - 4 supplied by CERN (delivered)
    - 2 already assembled and fully operational
    - 2 assembled but not tested.
  - 2 supplied by ELVIA (pending)

4. NEXT STEP

Short term goals:

- Energy resolution
- Characterize all the detectors individually
- Finish the MUST^2 network
- Obtain the first images with recognisable shapes (i.e., cliff, mountain, etc.)

Long term challenges:

- Introduce the improvements we have made in next version:
  - Detector design, components selection & software
- Scale up the network.
- Conduct the industrialization process of the MUST^2 detector and peripherals.
- Try to reduce the CERN dependence as supplier:
  - Diversify the suppliers and assure the continuity of the components.

QUESTION TIME

Thanks for you attention

REFERENCES

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