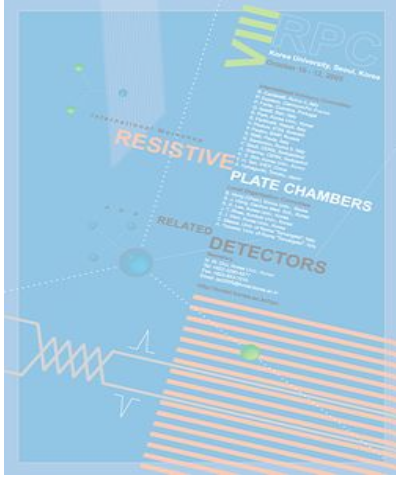
VII Workshop on Resistive Plate Chambers and Related Detectors



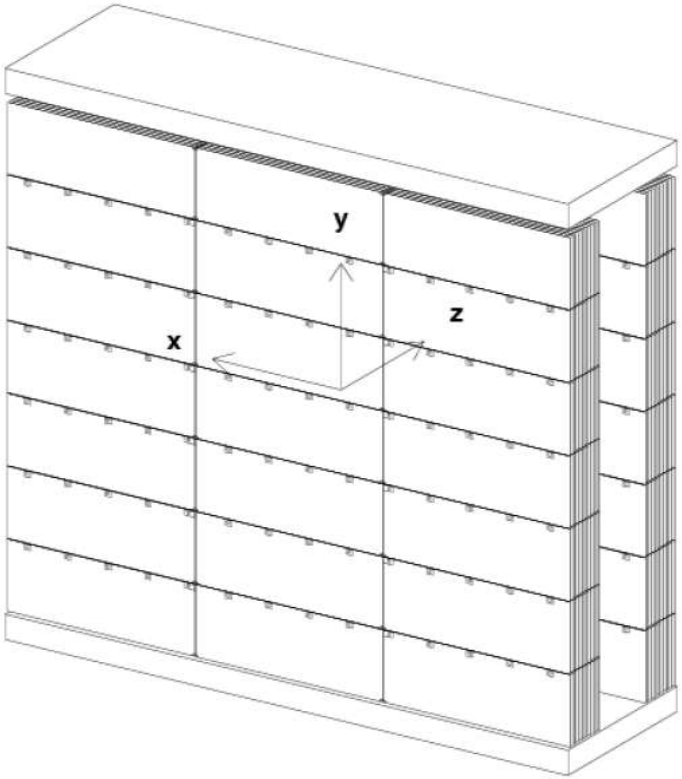
Korea University, Seoul
October 10-12, 2005

The OPERA RPC system: installation and underground test results

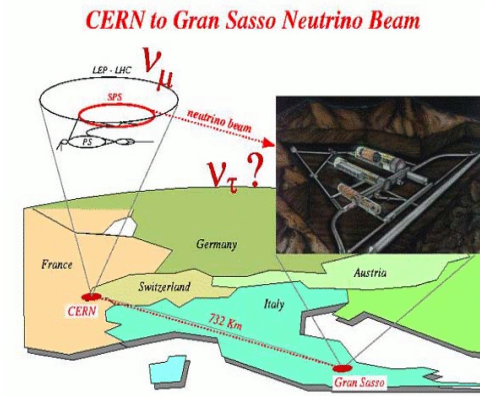
A. Longhin (INFN & Padova University)
on behalf of the OPERA RPC group
(Bologna, LNF, LNGS-L'Aquila, Napoli, Padova, Zagreb)

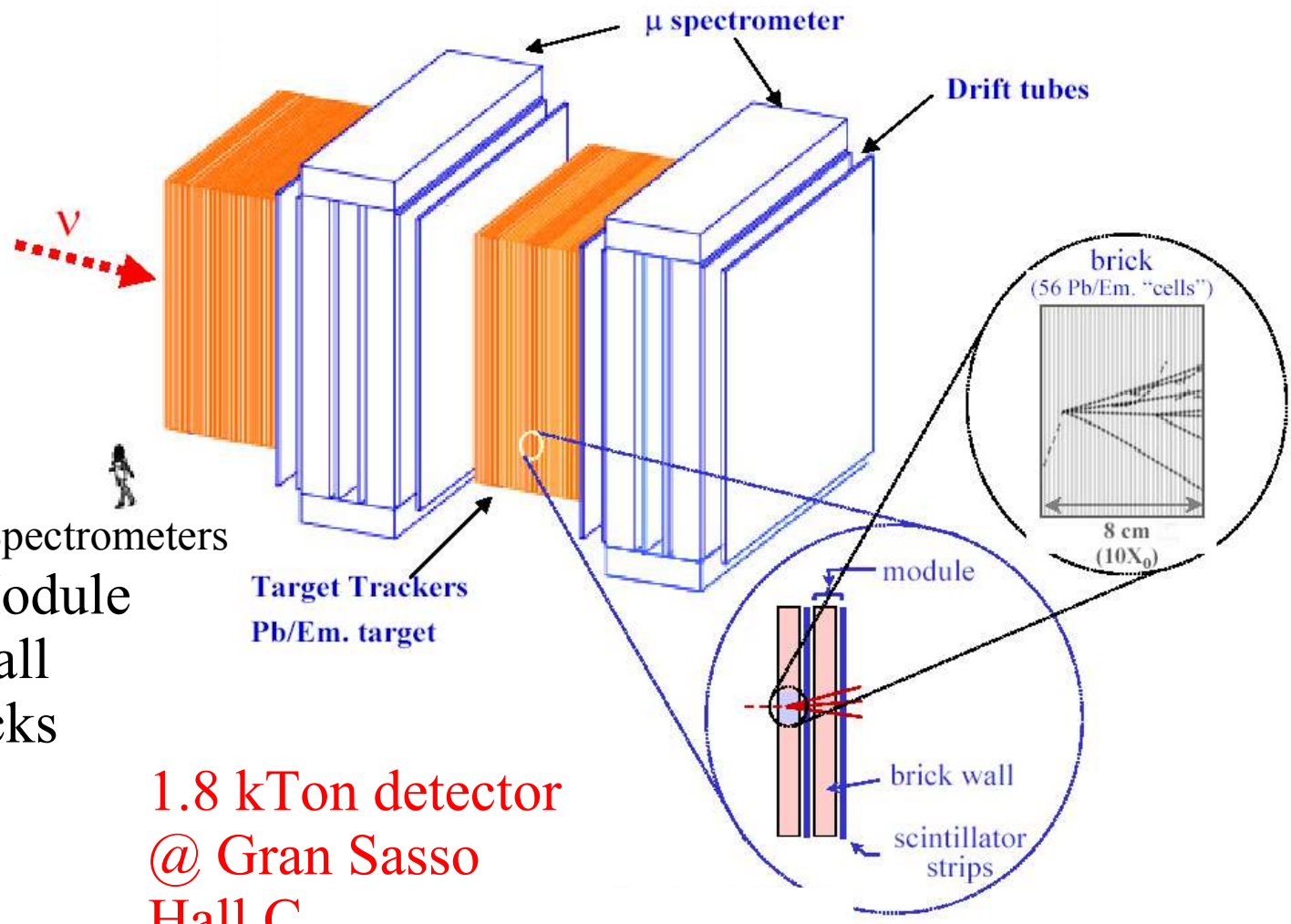
Outline

- Introduction to the OPERA RPC system
- Installation of RPCs
- Underground RPC test results
  - ✗ efficiency
  - ✗ currents
  - ✗ noise maps
  - ✗ cluster size
- Conclusions and Outlook



The OPERA detector

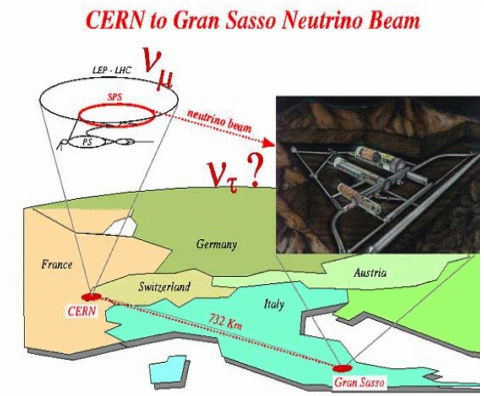




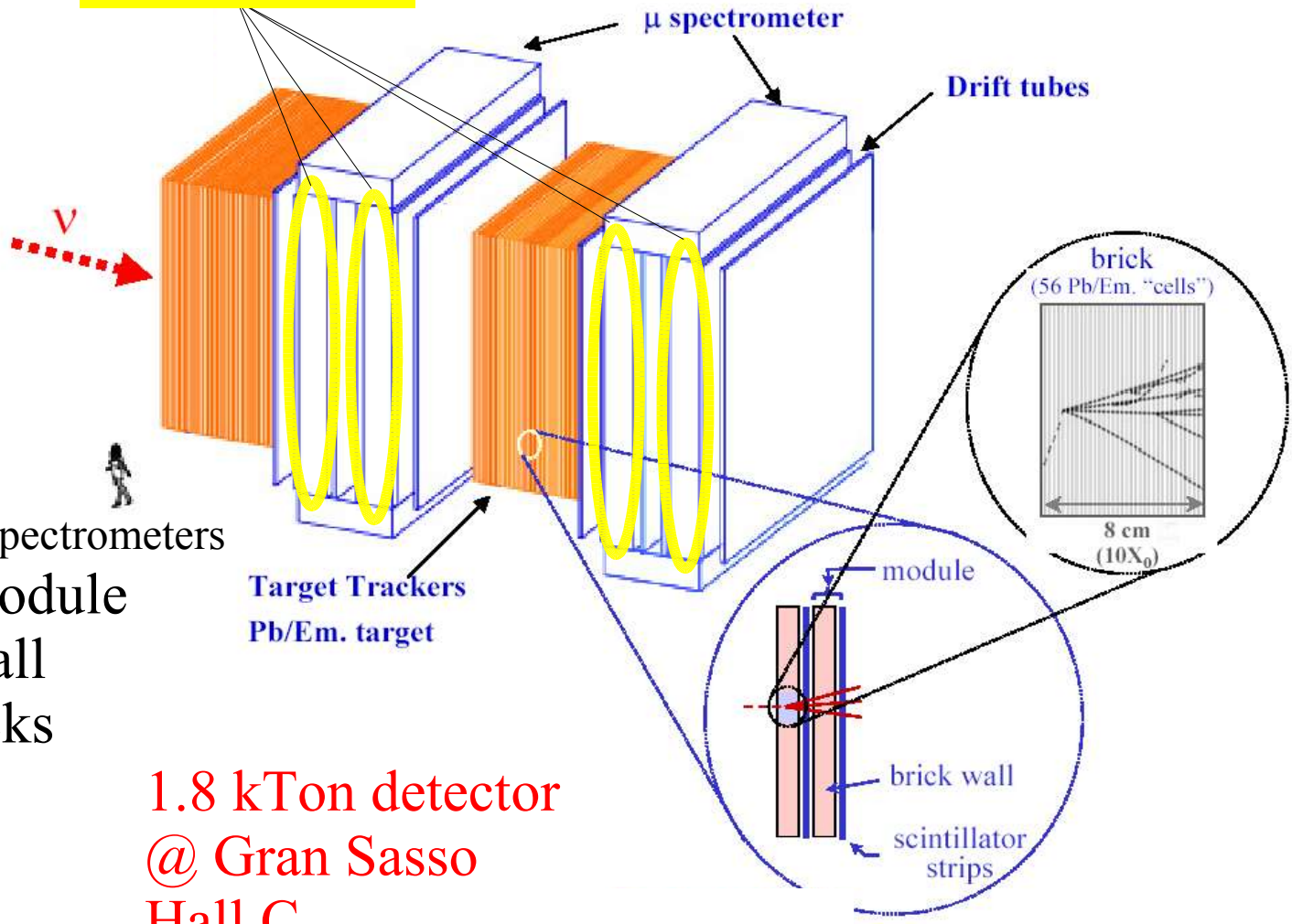
- 2 SuperModules & 2 Spectrometers
- 31 walls/SuperModule
- 52 x 54 bricks/wall
- Tot. 206.336 bricks

1.8 kTon detector
@ Gran Sasso
Hall C

The OPERA detector



RPCs!!!



- 2 SuperModules & 2 Spectrometers
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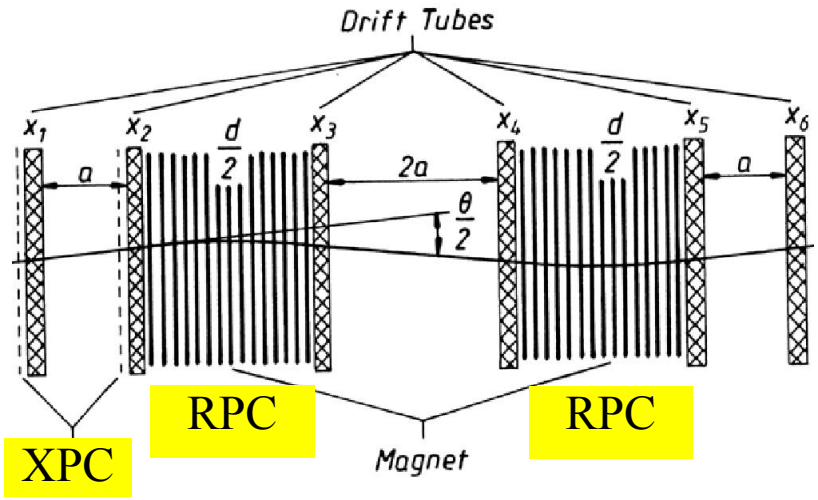
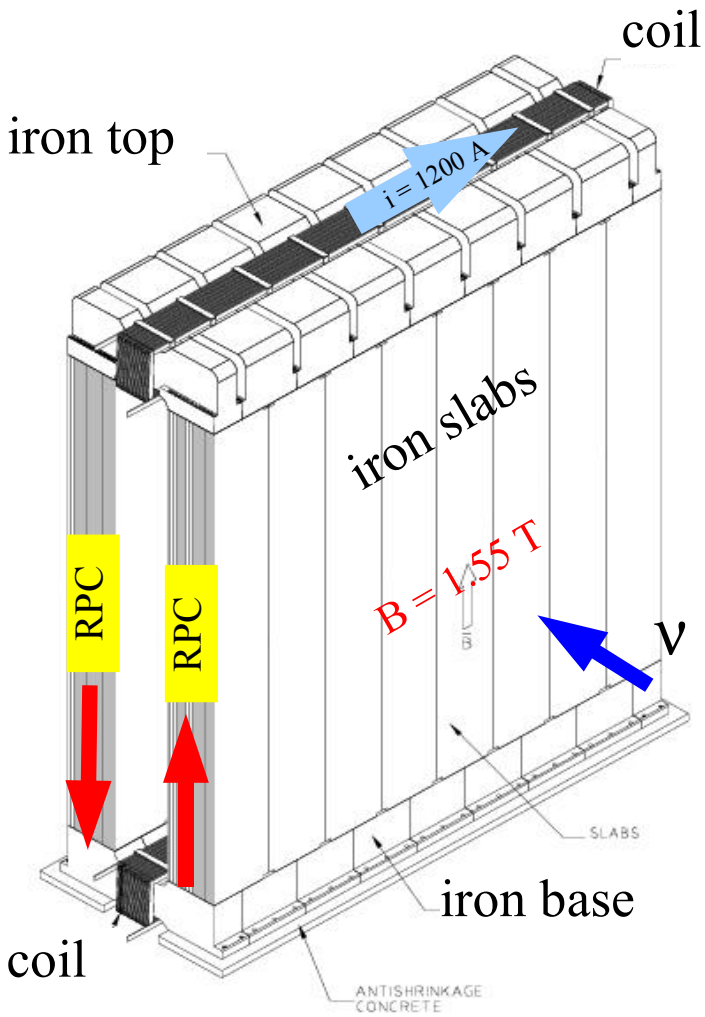
RPCs & the OPERA spectrometer

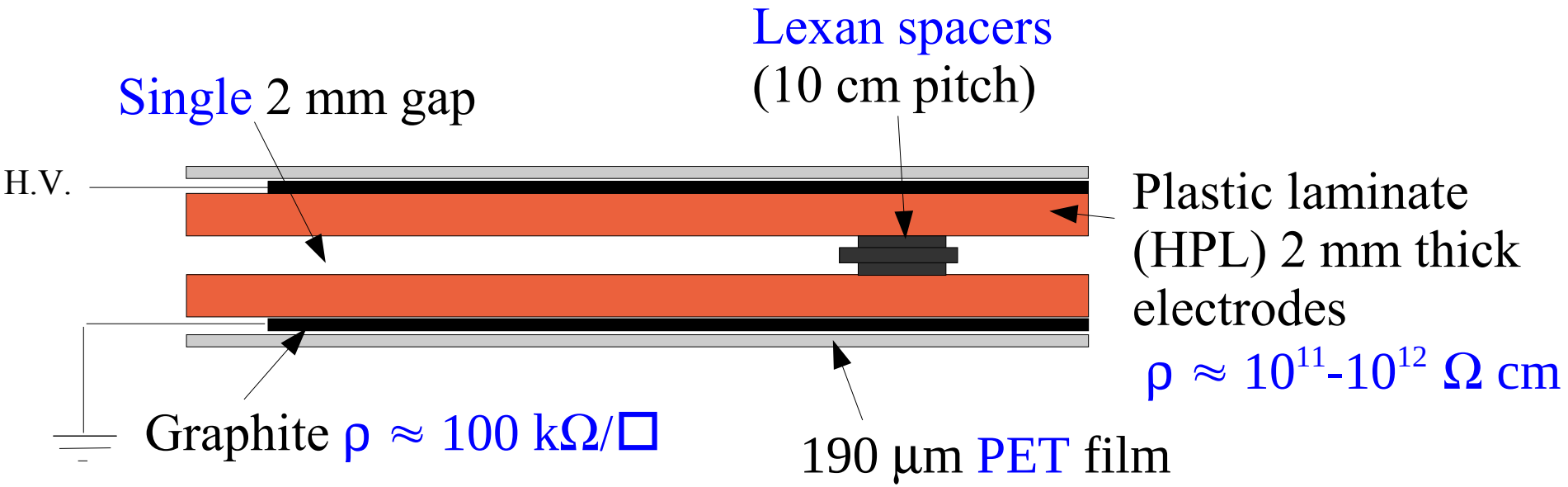




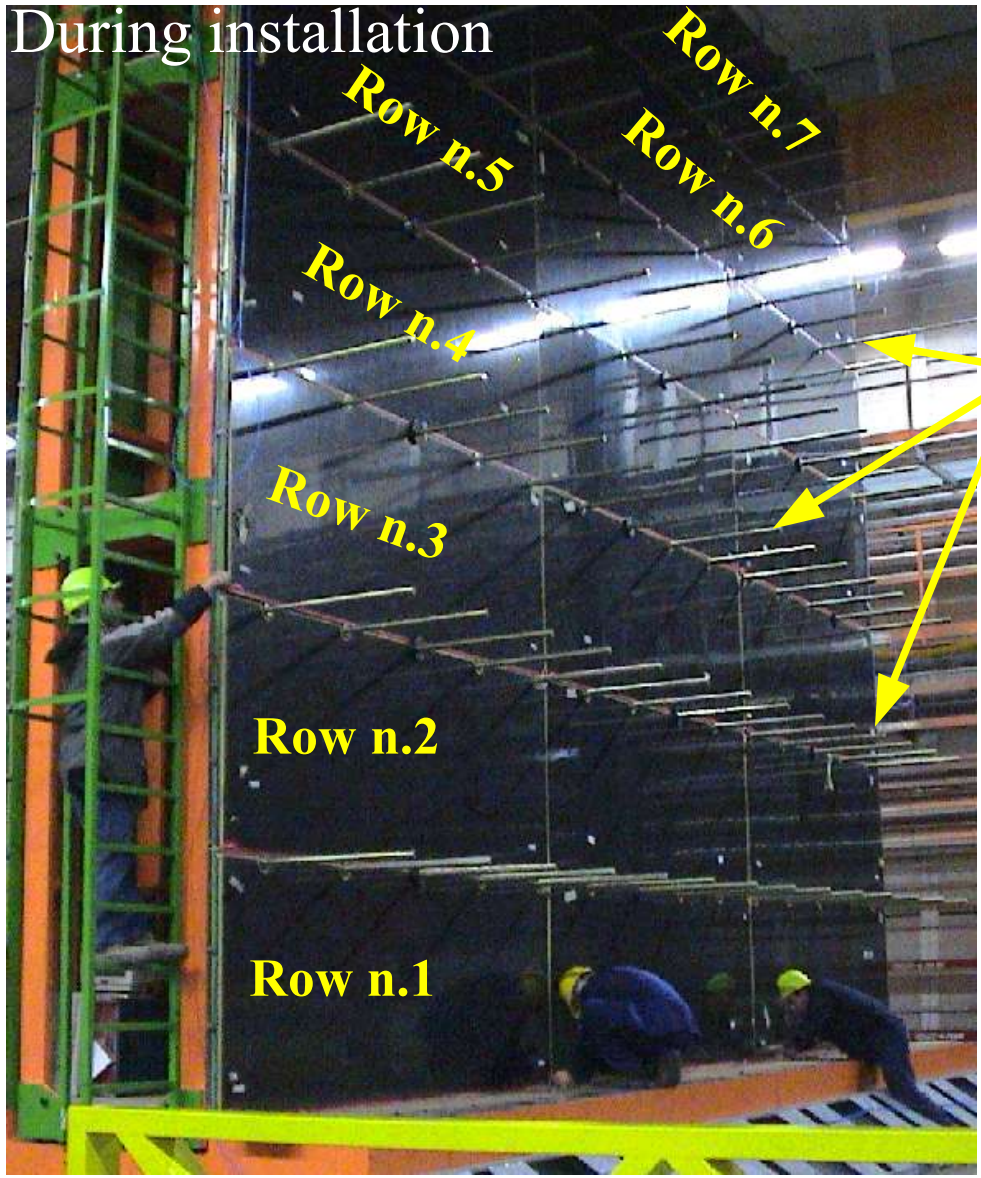
- Dipolar magnet (B=1.55 T)
- 22+2 layers equipped with horizontal and vertical digital strip readout
- 5 cm iron + 1 cm gap
  - 0.6 mm RPC + PET film + H/V strips planes + plastic foam

OPERA RPCs

- "Standard" bakelite RPC (General Tecnica)
- Streamer mode operation
- Rectangular shape: area ~ 3.2 m^2
  + "grooves" to house the structure of bolts of the spectrometer



The OPERA RPC system: layer



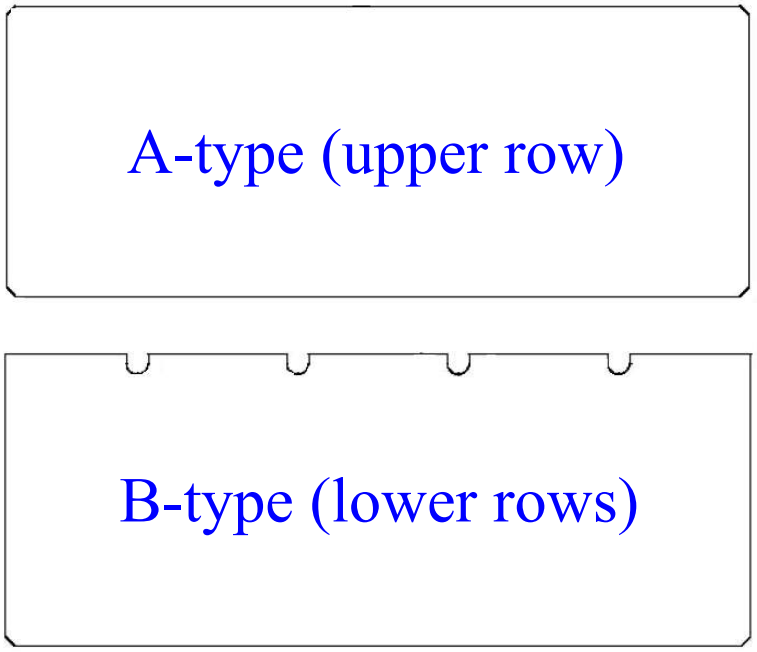
Bolts

1 Layer

=

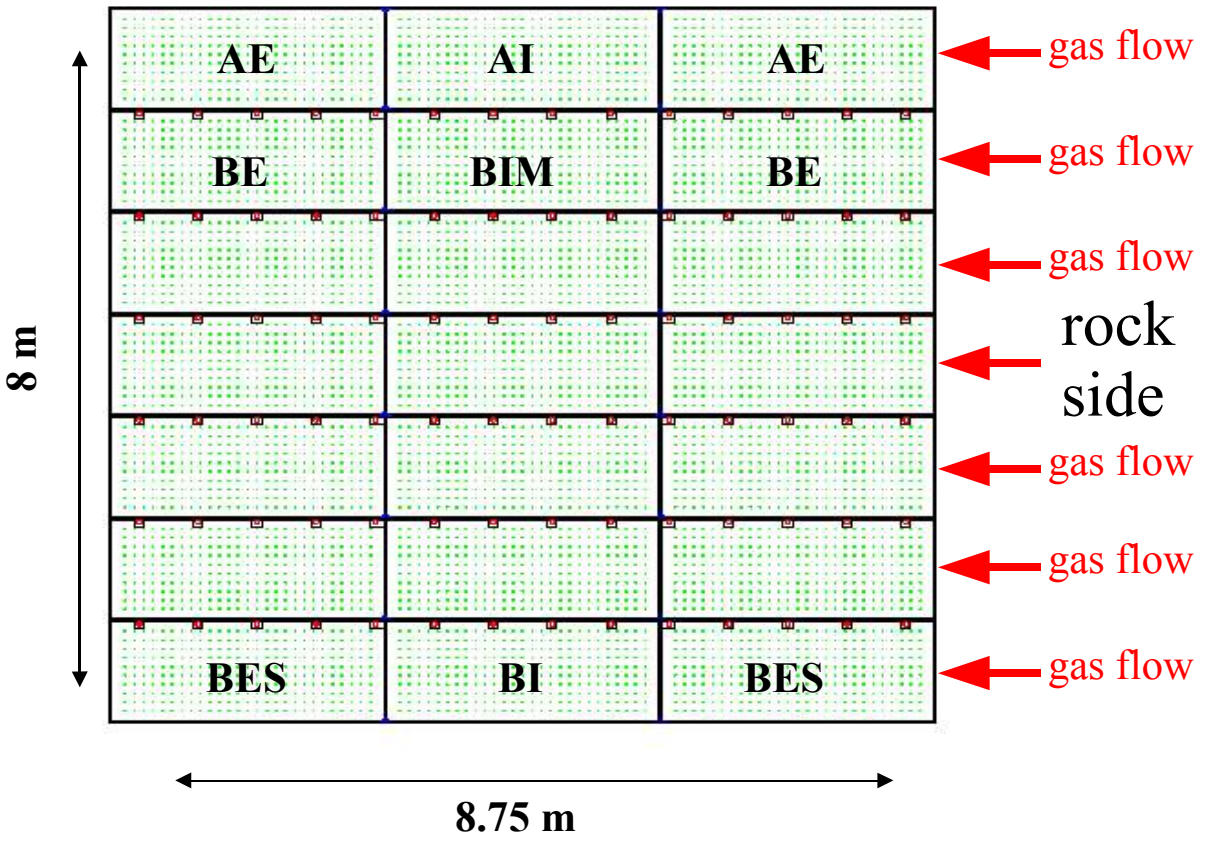
7×3 RPCs

(~70 m²)



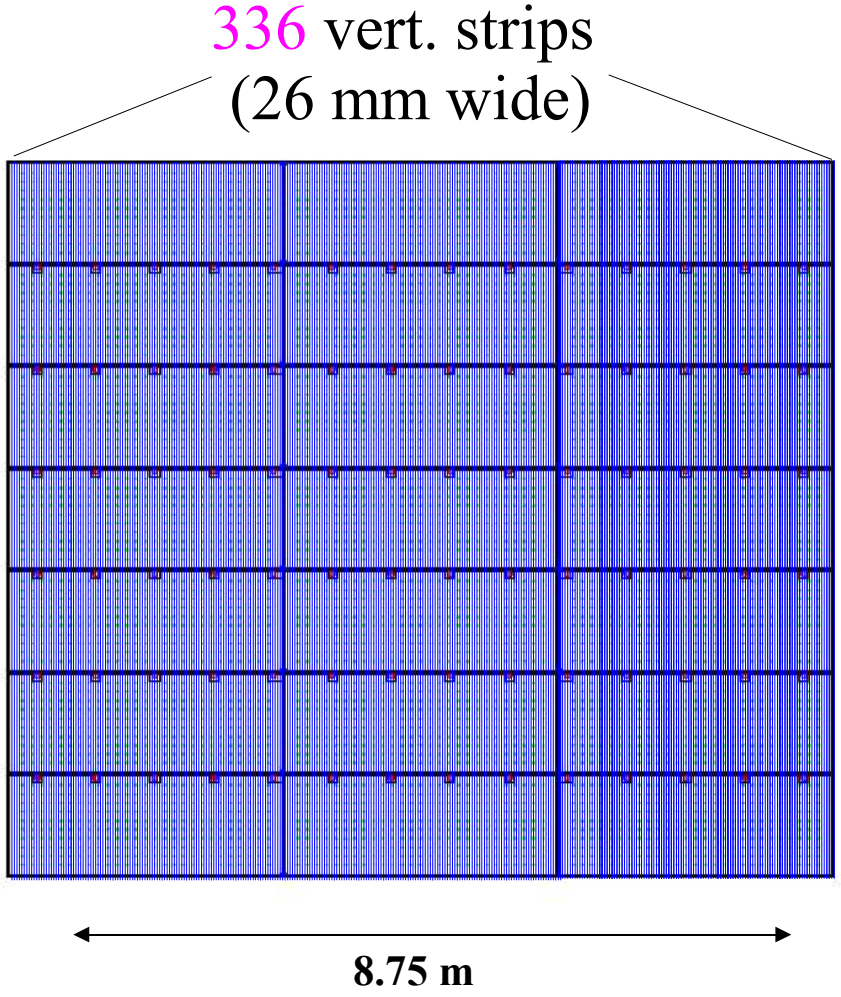
The OPERA RPC system: layer

- Each row is flushed separately from rock side to corridor side
- Independent HV connections



The OPERA RPC system: layer

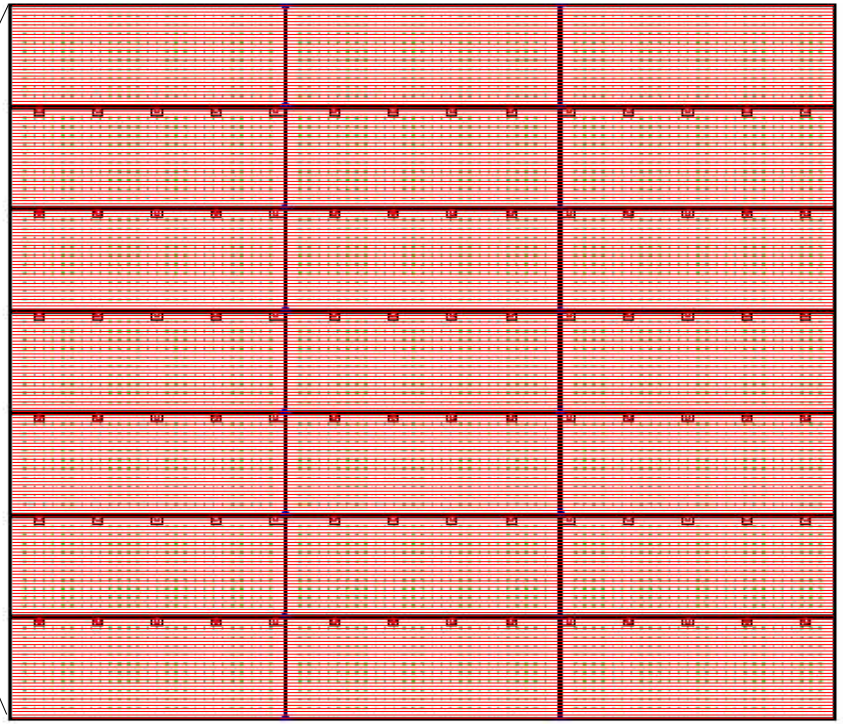
Digital readout



The OPERA RPC system: layer

Digital readout

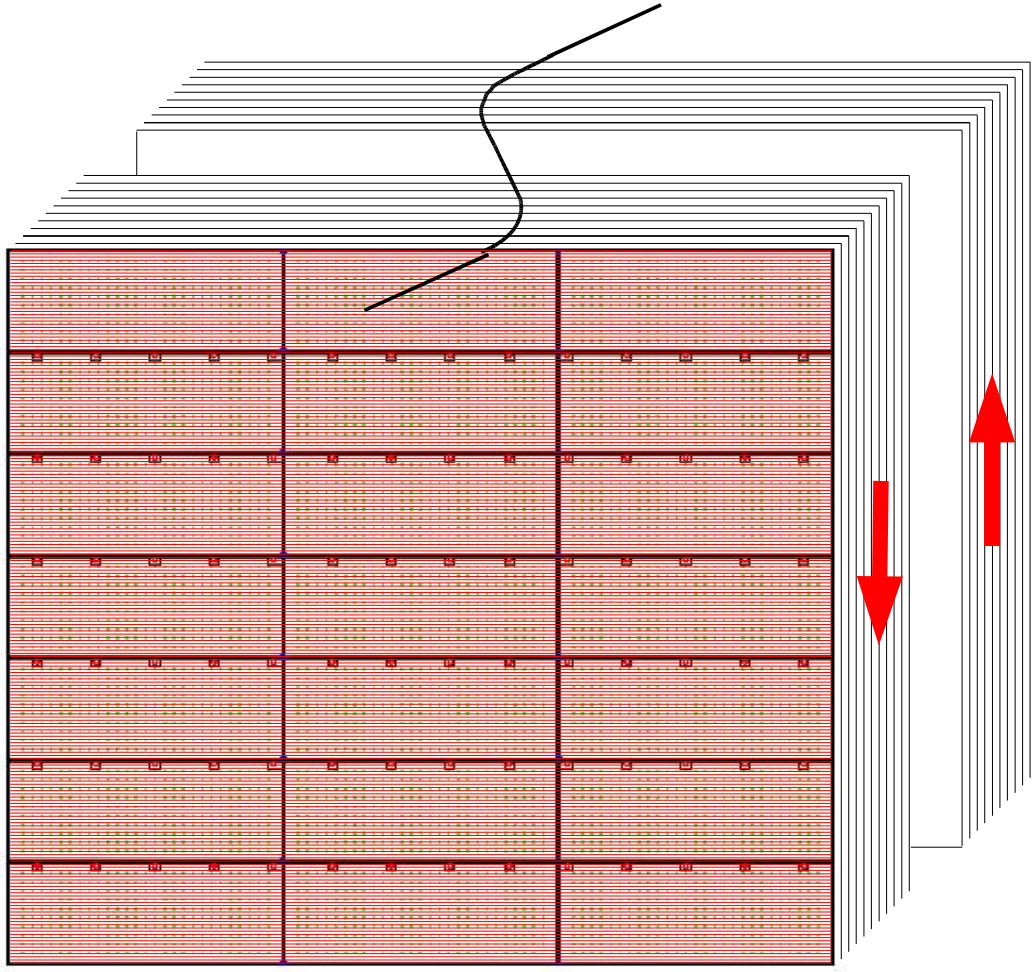
224 hor. strips
(35 mm wide)



rock
side

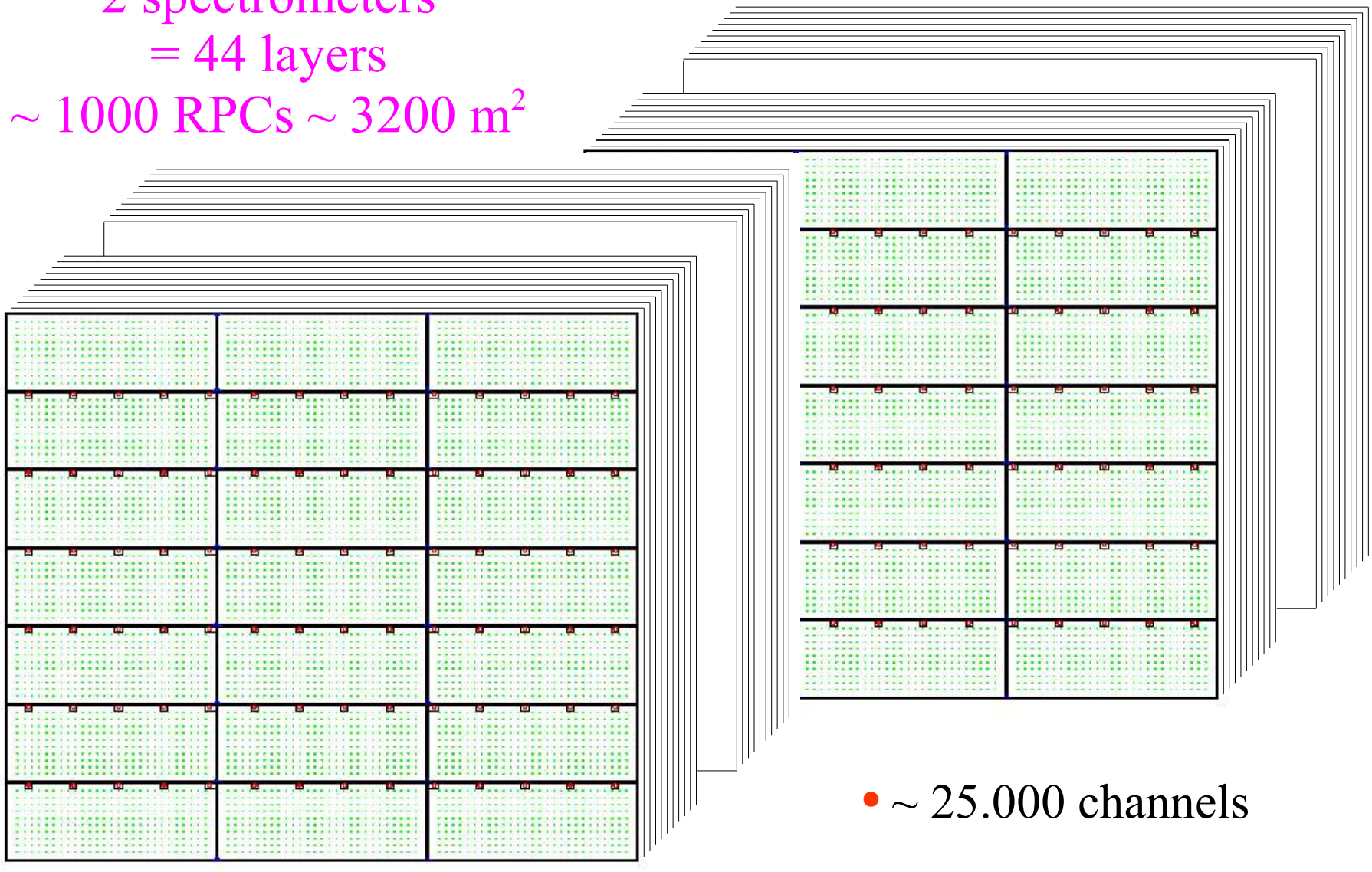
The OPERA RPC system: S.M.

1 spectrometer
= 22 layers
~ 500 RPCs ~ 1600 m^2



The OPERA RPC system

2 spectrometers
= 44 layers
~ 1000 RPCs ~ 3200 m^2



- ~ 25.000 channels

Installation

Due to the nature of the detector the installation of RPCs and of the mechanical structure had to be synchronous. RPCs are safely locked inside the iron slabs and hence not fully accessible thereafter !

$\Rightarrow$

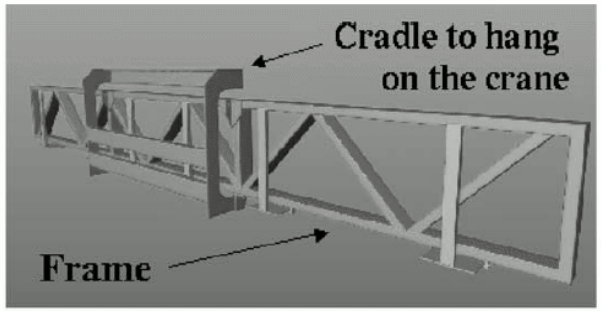
beside detailed surface quality tests ...
(*"The quality control tests for the RPCs of the OPERA experiment"*, Nucl. Instrum. Meth. A **533** (2004) 203)

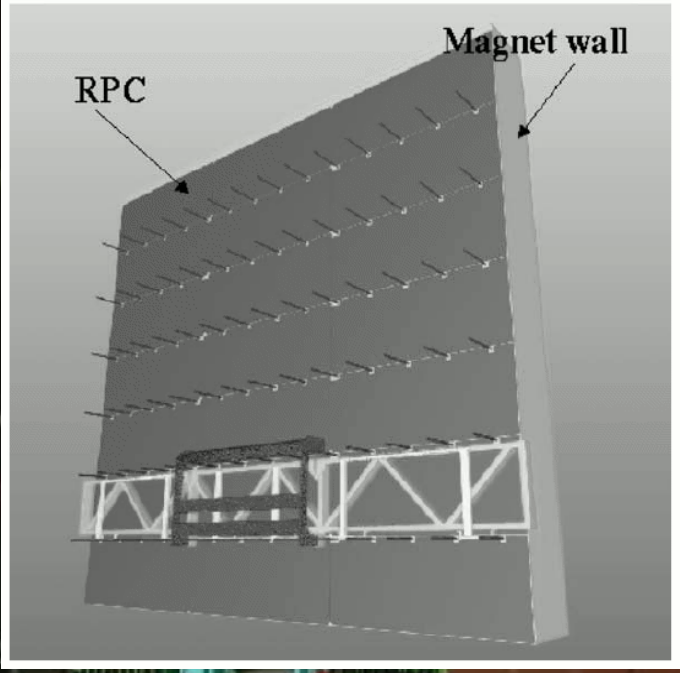
... several "online" checks on RPCs also performed during installation :

- Flux RPC rows with N_2 for ~ 0.5 days, @ 6.5 kV
- measure currents vs time during irons slabs installation
  - to check possible increase due to anomalous pressure/strains
  - to check HV connections
- Check continuity of signal strips
- Check tightness of gas connections (over several hours)

Installation phases (I)

Installation phases (II)





3 RPCs in one shot

Gas + HV
connections at
gound level

RPCs mounted
by mean of a cradle

Installation phases (III)

Installation phases (IV)

Installation milestones

- 30th November 2003

  First RPC wall completed

- 19th May 2004

  First Spectrometer completed

- 16th March 2005

  Second and Final Spectrometer completed

Underground test set-up

- A general test of installed RPCs became possible in spring 2005
- 4 full layers were instrumented to reconstruct real (cosmic) tracks and measure efficiency, strip multiplicity, tracking performances besides currents, and noise.

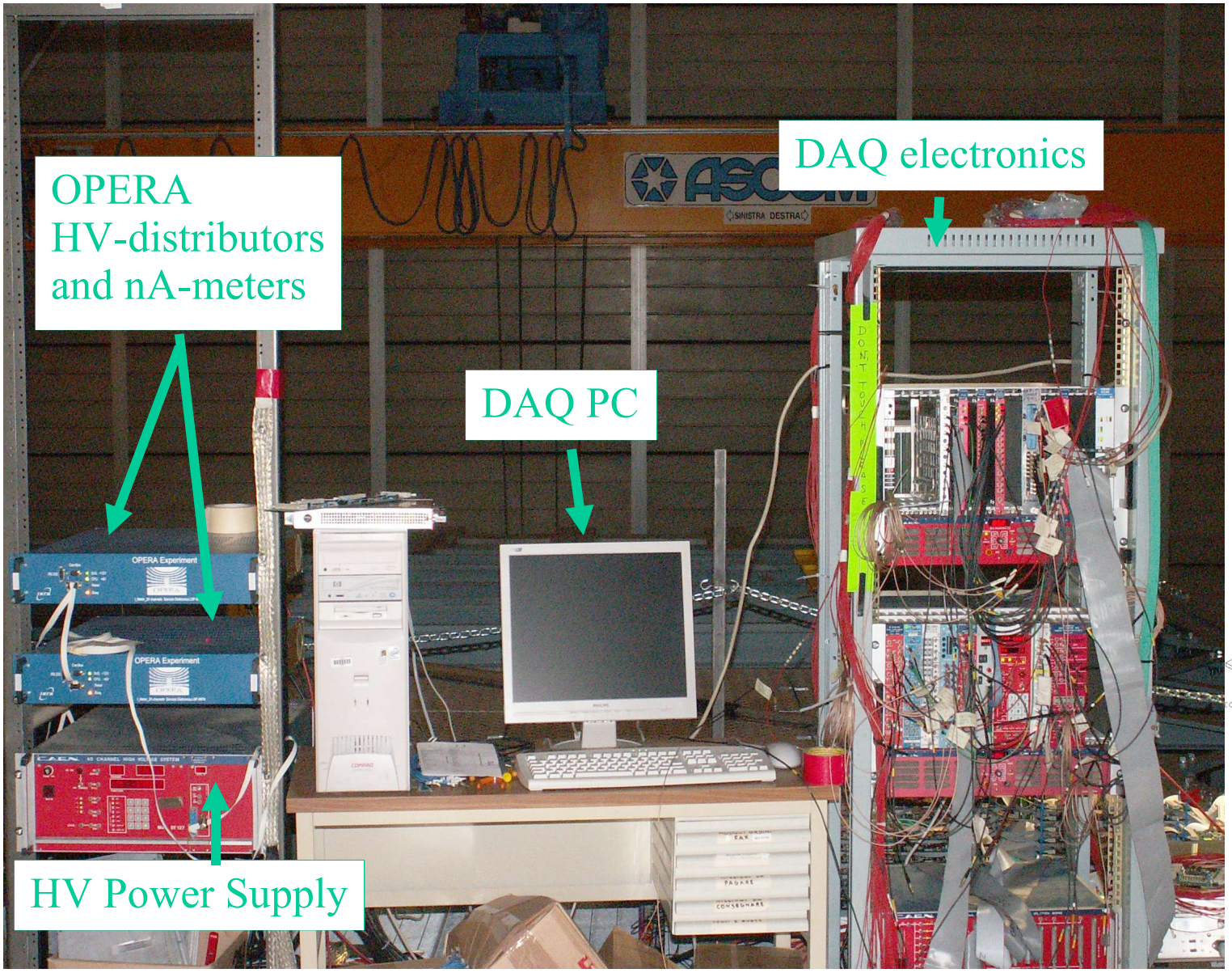
Underground test set-up (I)

- 4 RPC layers tested (~1/10 of the whole detector):
  - n. 19 → 22 of spectrometer A
  - 84 RPCs in total (4 layers × 7 rows × 3 RPCs) ~ 280 m^2

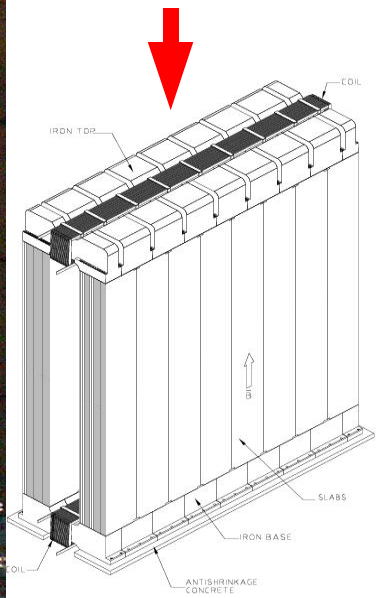
Underground test set-up (II)

- Final HV system and signal cabling
- Gas system:
  - Ar / $C_2H_2F_4$ / I-C_4H_{10} / SF_6 = 75.4 / 20 / 4 / 0.6
  - Premixed bottles (< 4 days autonomy at 5 refills/day)
  - No exhaust, as gas flow (~ 0.1 m^3/h) << air flow inside Hall C (~10000 m^3/h)
- Dedicated Electronics:
  - 896+1344 channels read out by MACRO FE boards
- Dedicated DAQ:
  - CAMAC acquisition of a STAS system
- B = 0

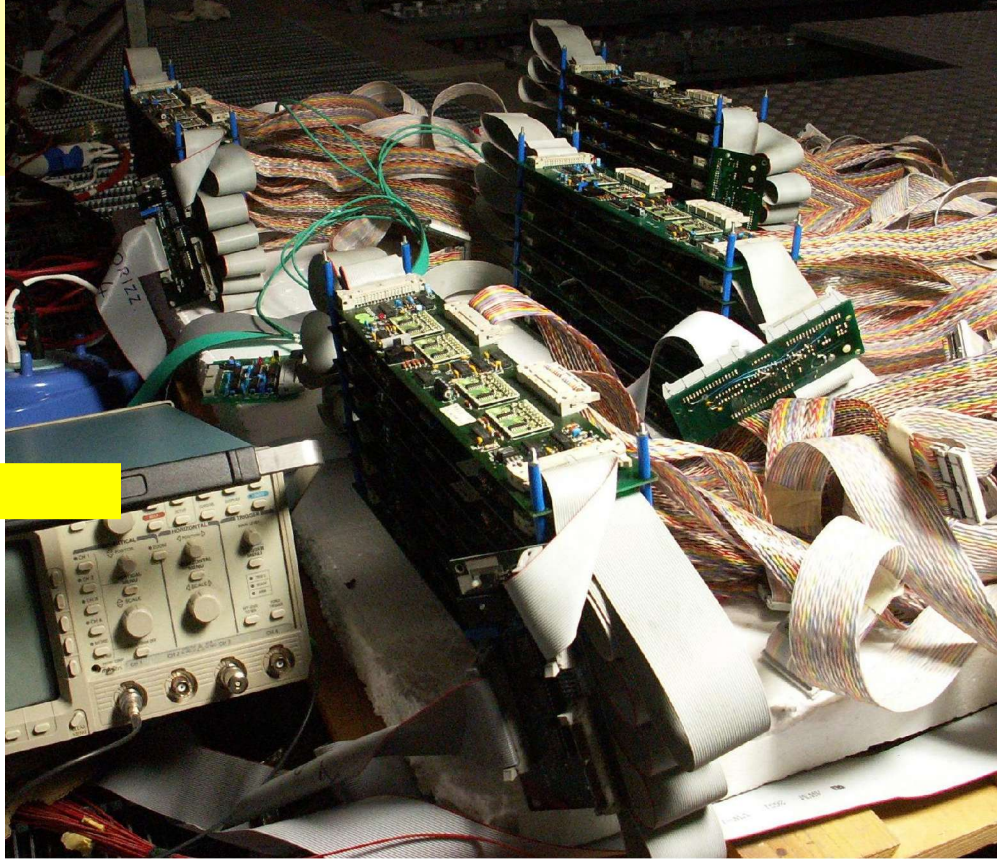
Underground test set-up (III)



HV control + FE boards and DAQ system on top of the spectrometer

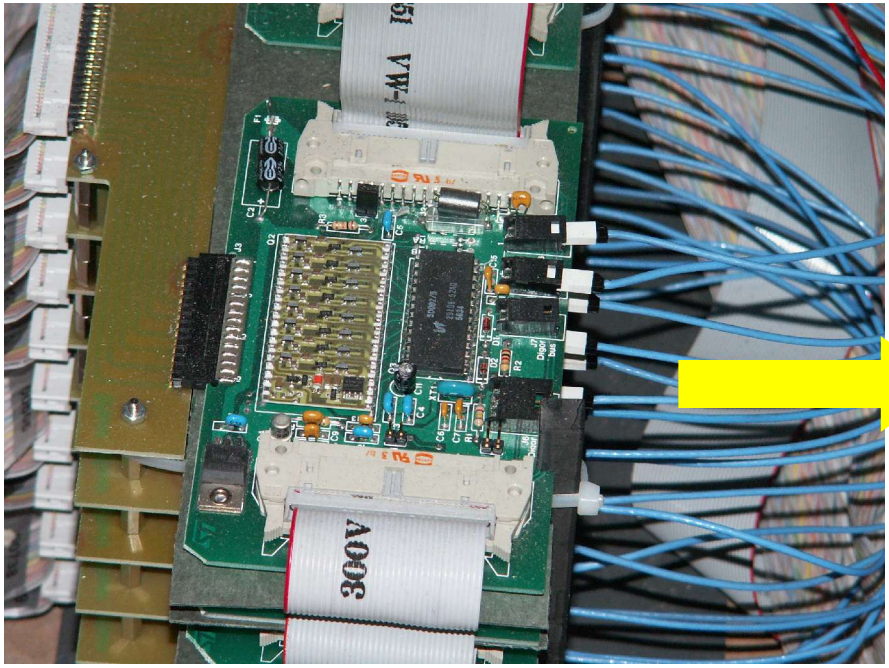


FE electronics



Horizontal strips FE board:

- 32 ch (7/layer → 896 ch in total)
- Positive signal input
- 1.2 μs TTL output

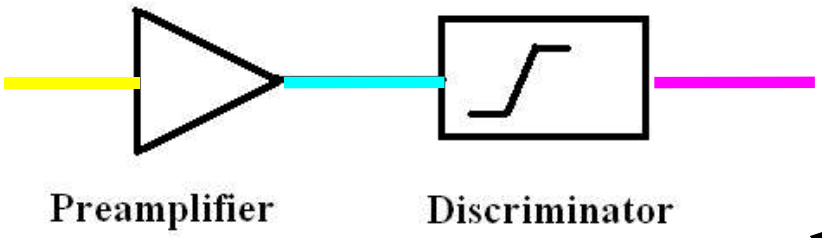


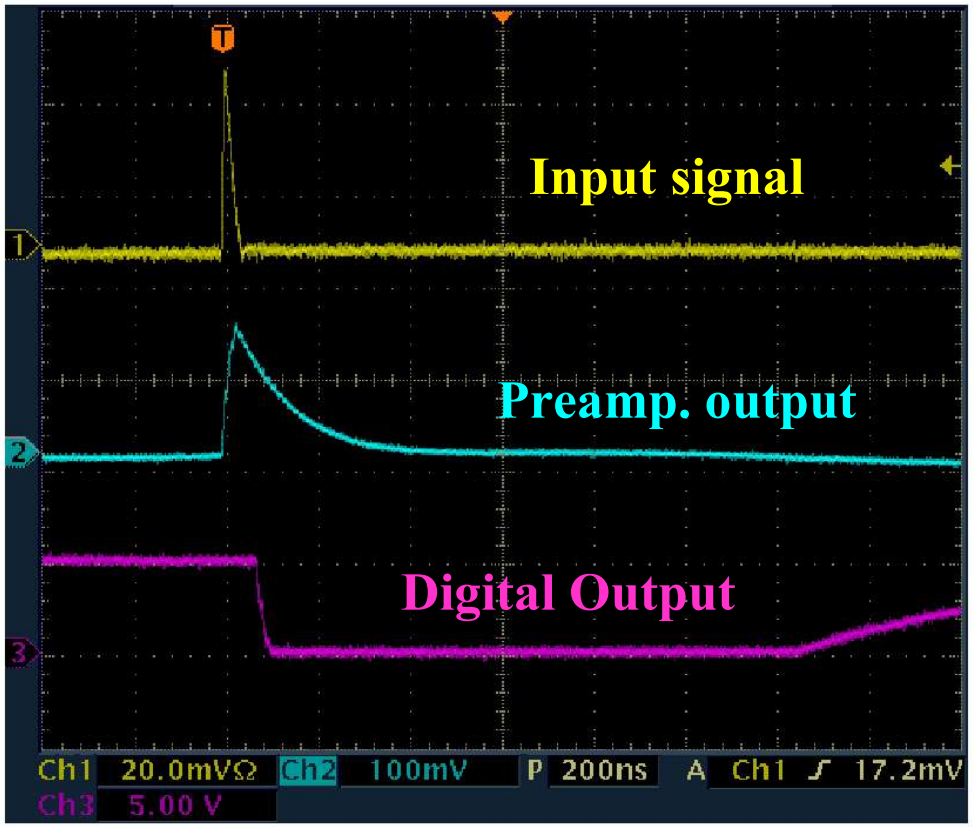
Vertical strips FE board:

- 8 ch (42/layer → 1344 ch in total)
- Negative signal input
- 10 μs TTL output

FE electronics: horizontal strips

MACRO FE boards originally designed for streamer tube strips
(preamplifier + discriminator)





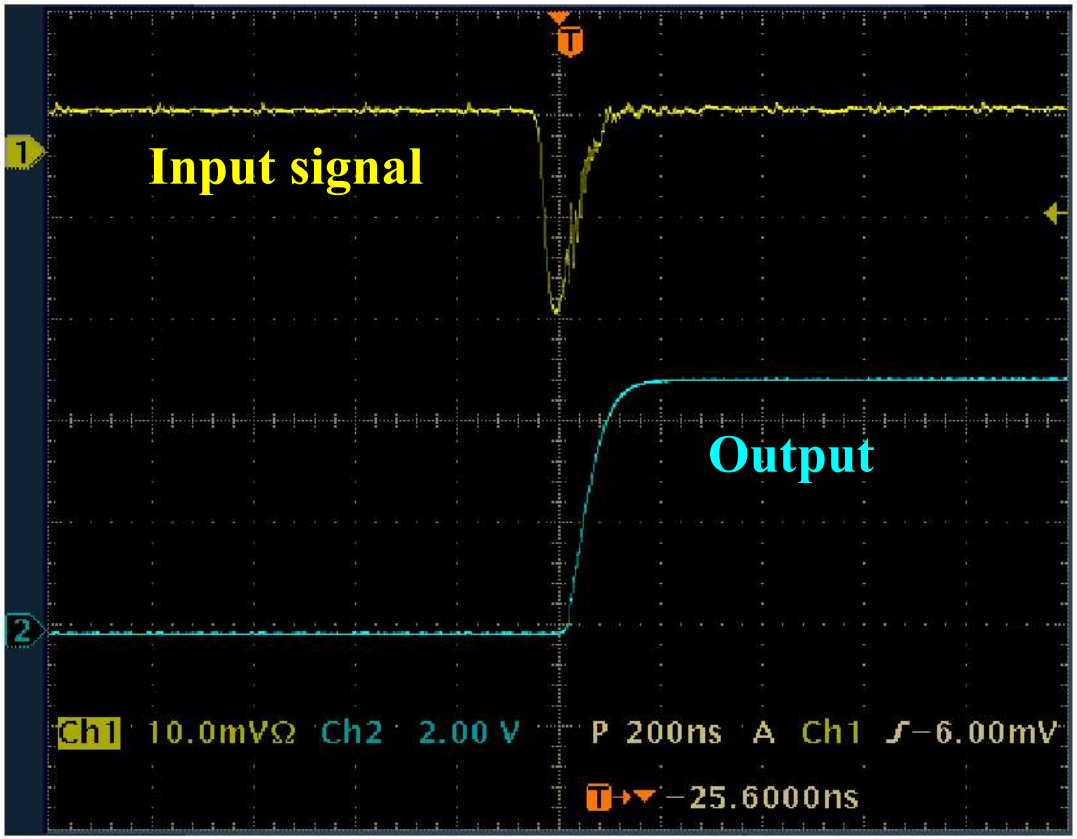
Typical RPC signal:

- rise-time 10 ns
- trail-time 30 ns

100 mV on preamp. output = 40 mV effective threshold on signals

FE electronics: vertical strips

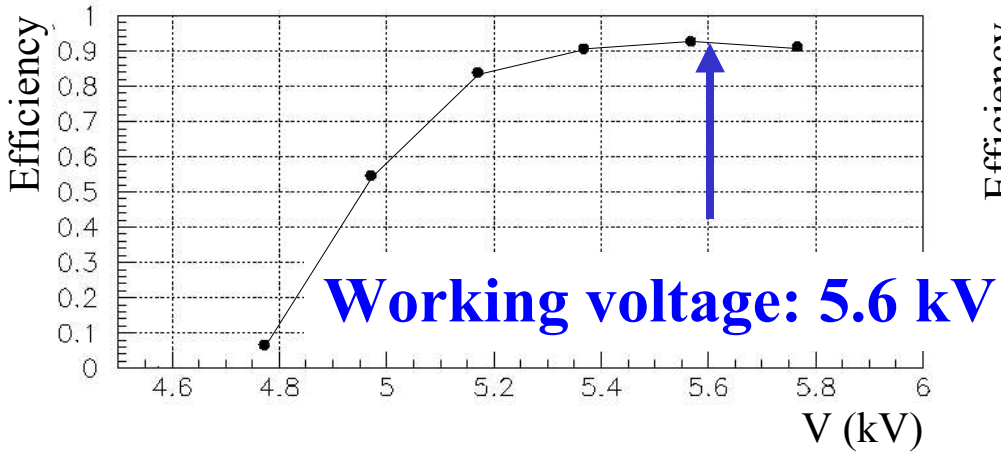
MACRO FE boards originally designed for streamer tube wires
(no preamplifier, fixed threshold discriminator)



Fixed threshold = 15 mV

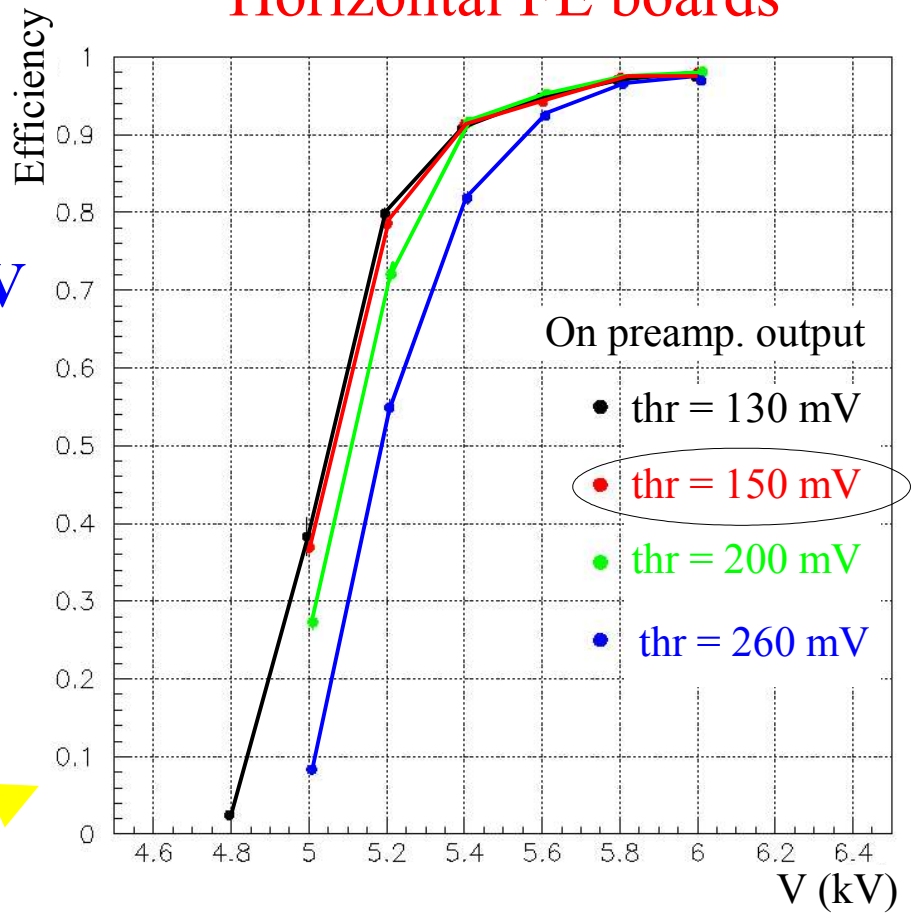
Preliminary tests (I)

The working voltage and thresholds were fixed according to the results of the cosmic rays surface tests at the external Gran Sasso laboratory



Working voltage: 5.6 kV

Horizontal FE boards



Threshold:

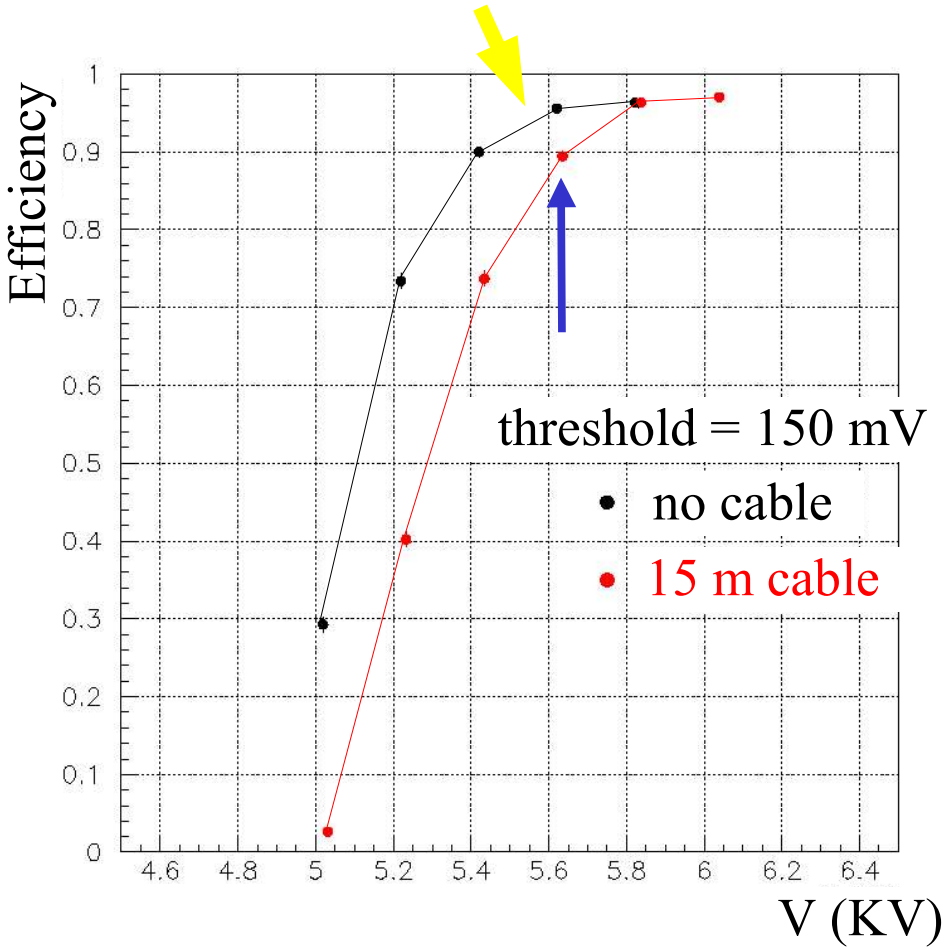
- Not too low → noise
- Not too high → low efficiency

150 mV looks appropriate for horizontal FE boards, but …

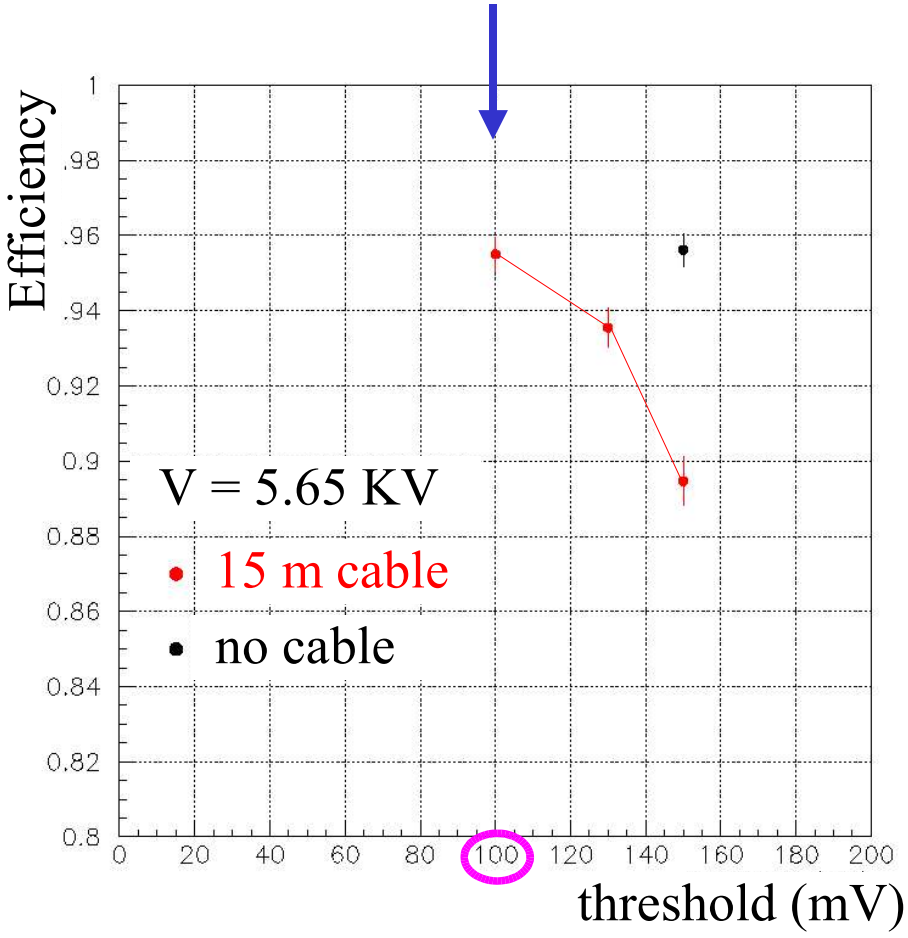
Preliminary tests (II)

Signal cables: 7-13.5 m long

15 m long twisted flat cables lower signal amplitude significantly



A good threshold for horizontal FE boards is 100 mV



Underground measurements

~ 60 h of data-taking

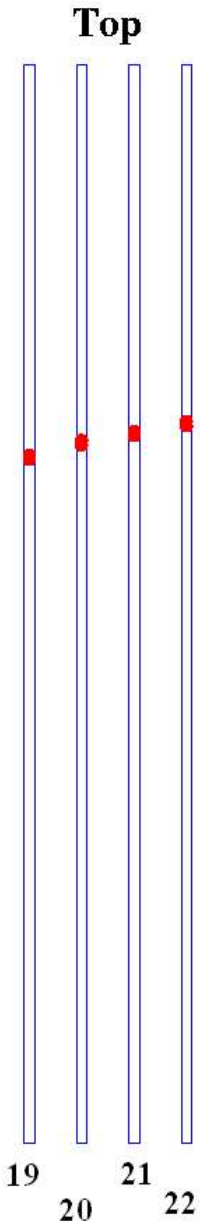
~ 1300 reconstructed μ (24 di-μ, 3 tetra-μ,1 hexa-μ)

Efficiency and cluster size measurement (layer 20)

Rate, operating current vs HV for all tested layers

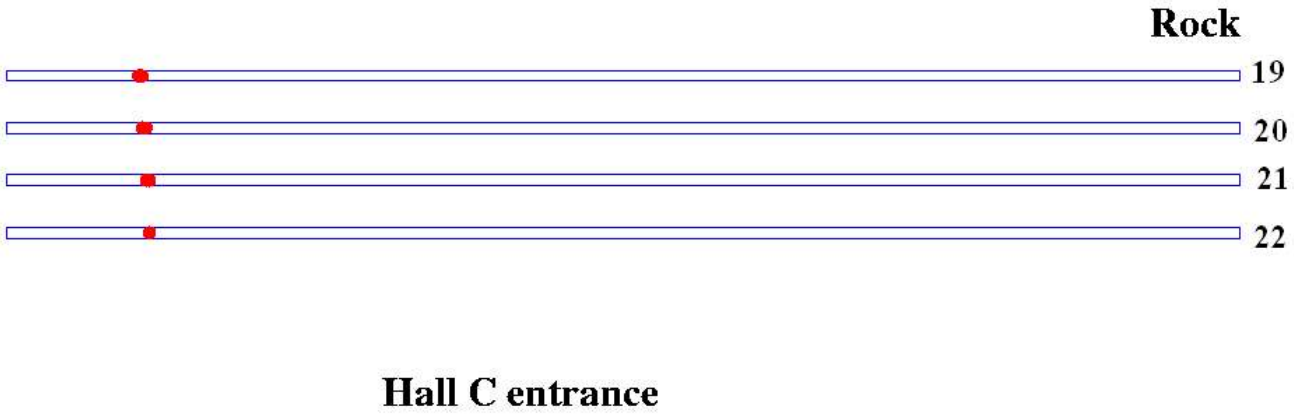
Noise maps for all tested layers

Event display: single μ

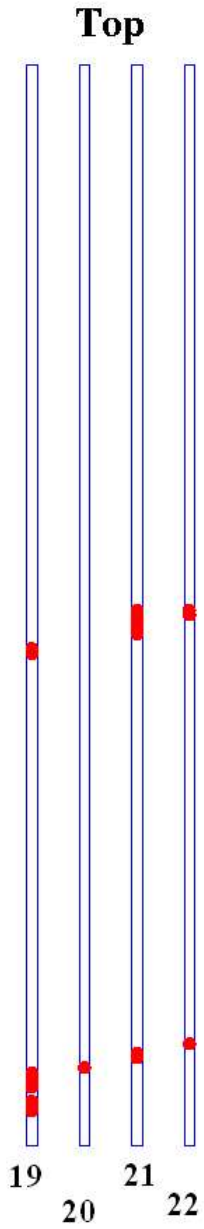


Horizontal view

Vertical view

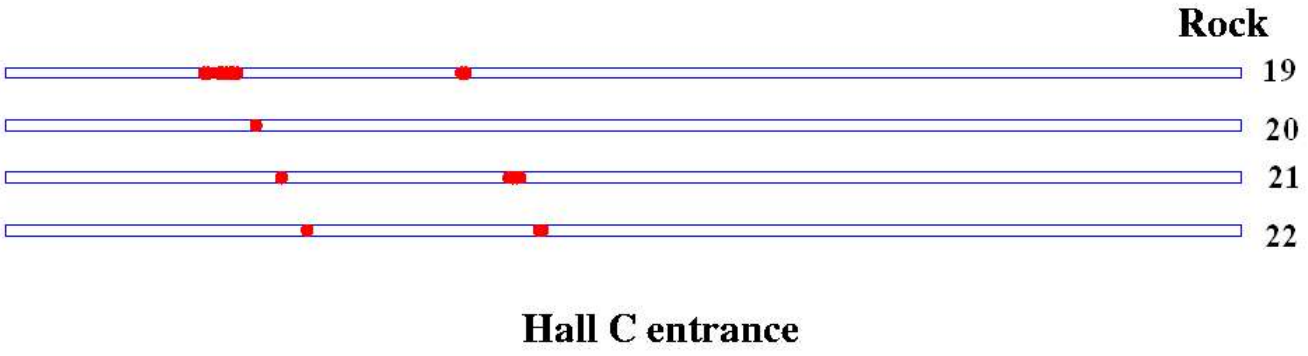


Event display: di-μ

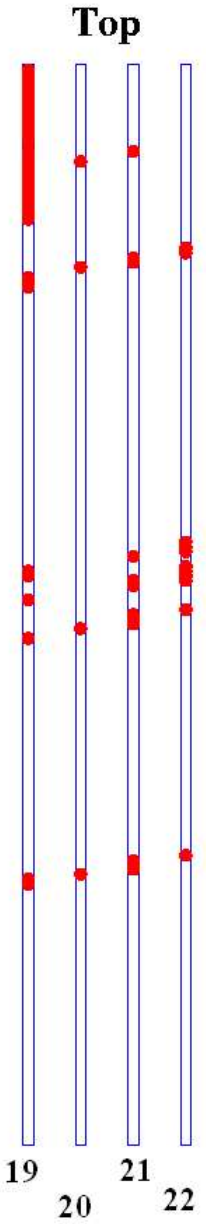


Horizontal view

Vertical view

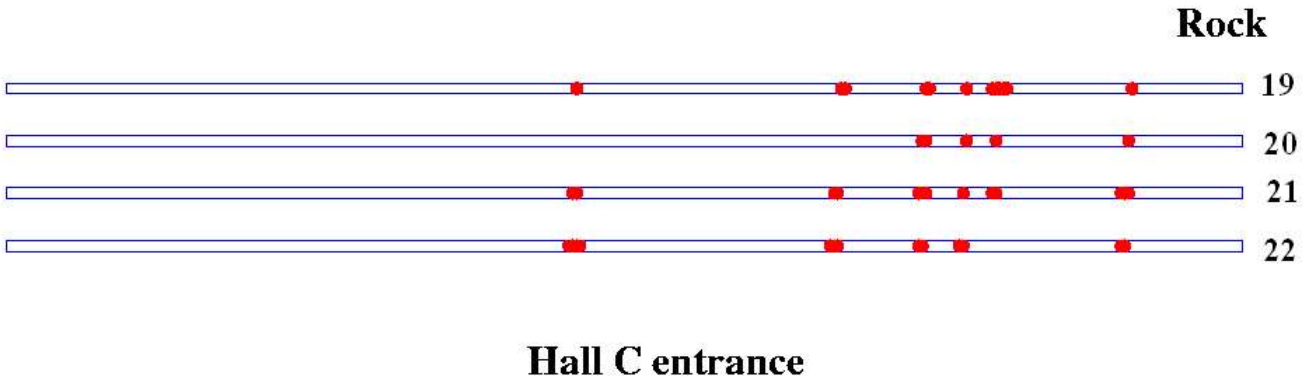


Event display: μ bundle

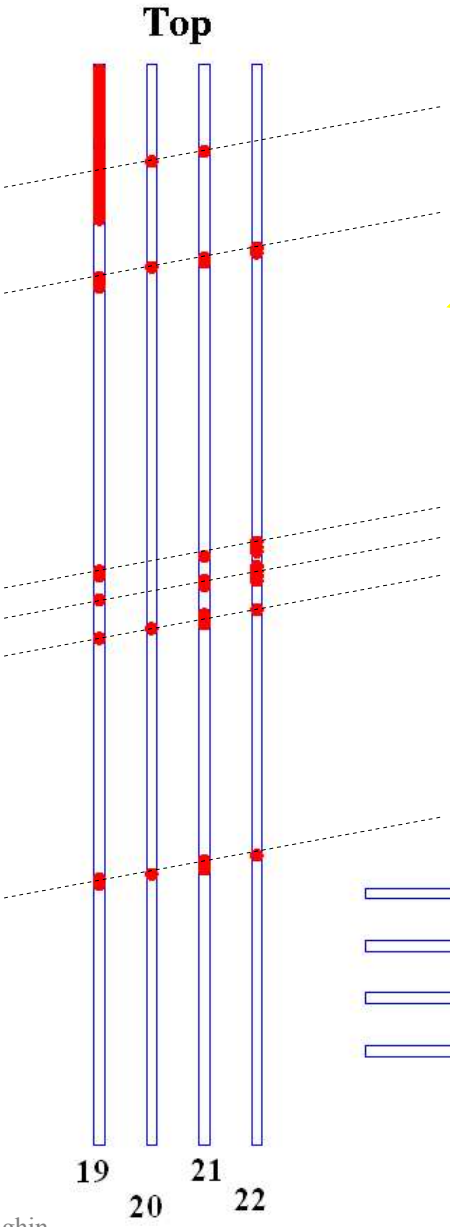


Horizontal view
(very low angle!)

Vertical view

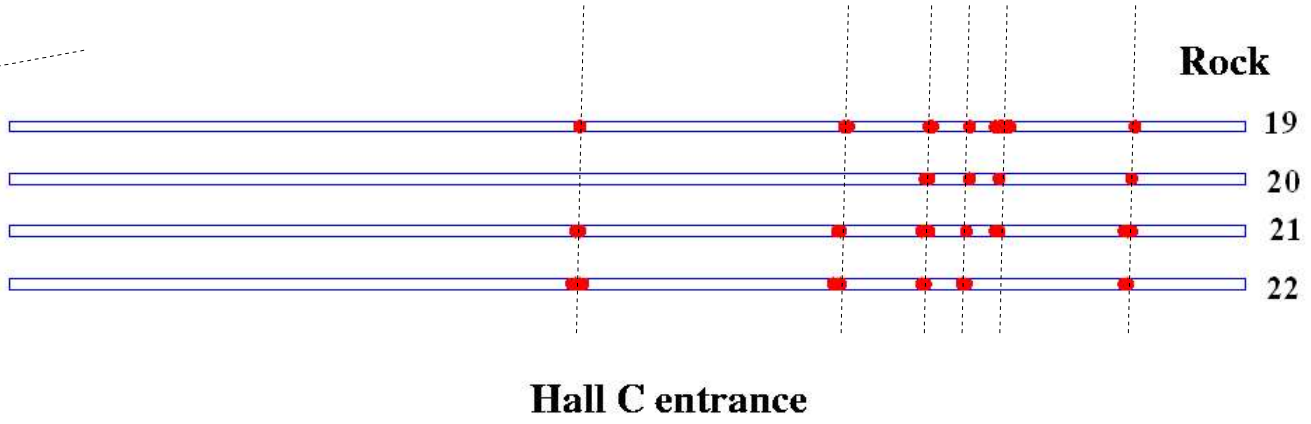


Event display: μ bundle

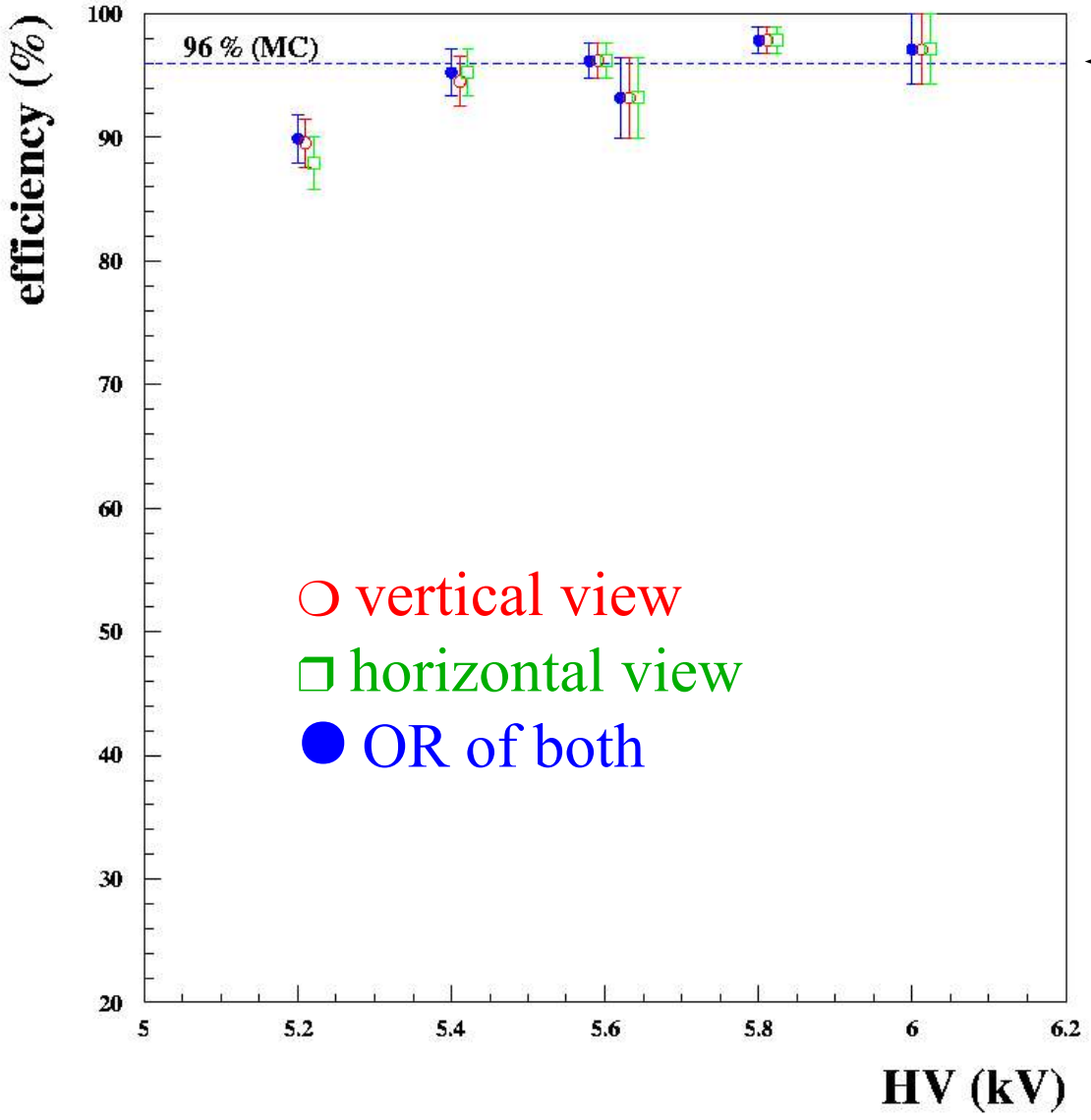


Horizontal view
(very low angle!)

Vertical view

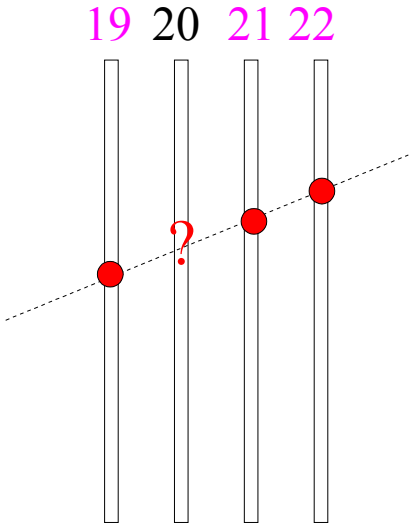


Efficiency (II)



← geometrical limit (96%)

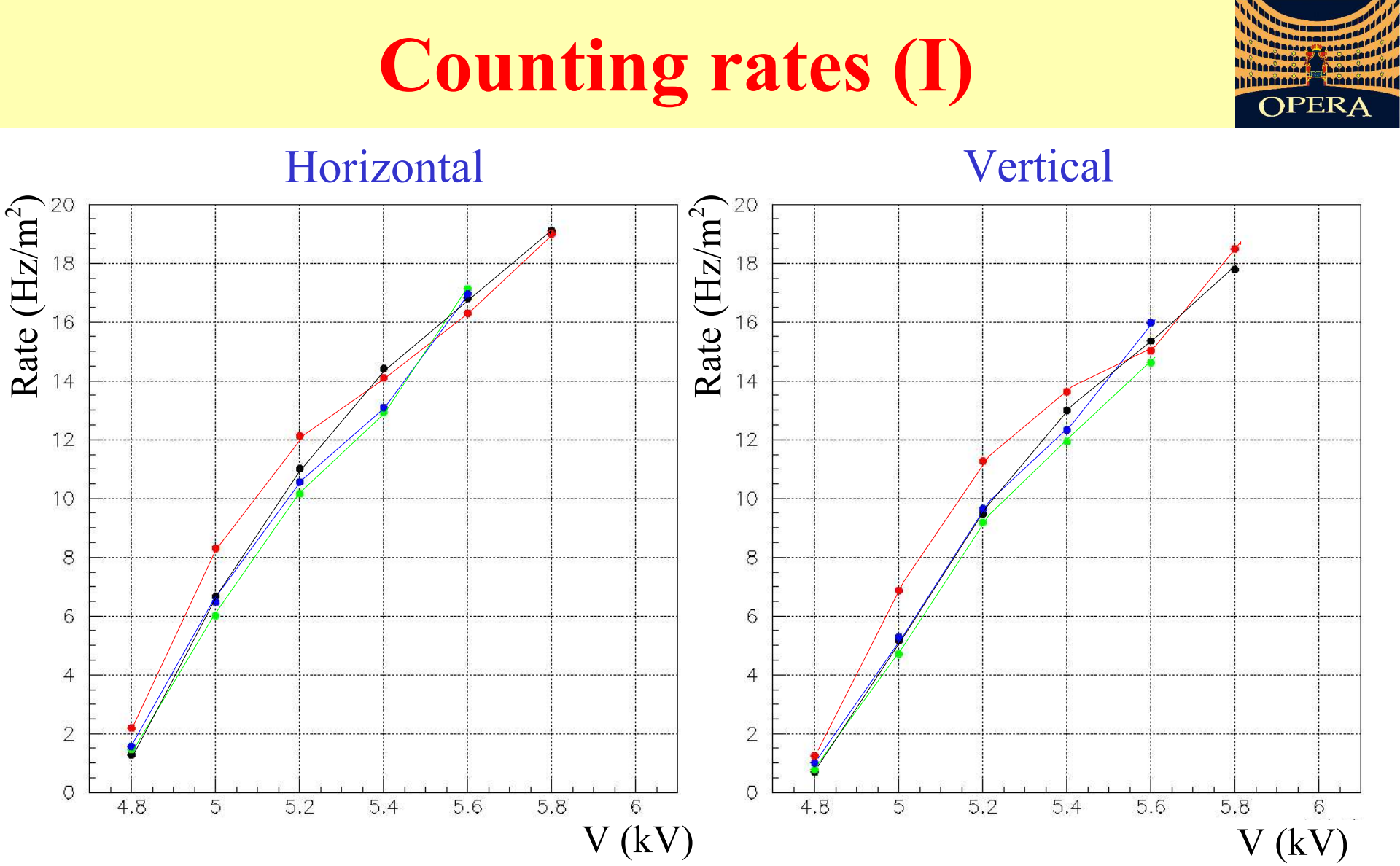
- Trigger : AND of layers 19, 21, 22 (horizontal strips)



- Off-line tracking

- Good efficiency !
- No difference among the two views → no efficiency loss due to electronics

Counting rates (I)

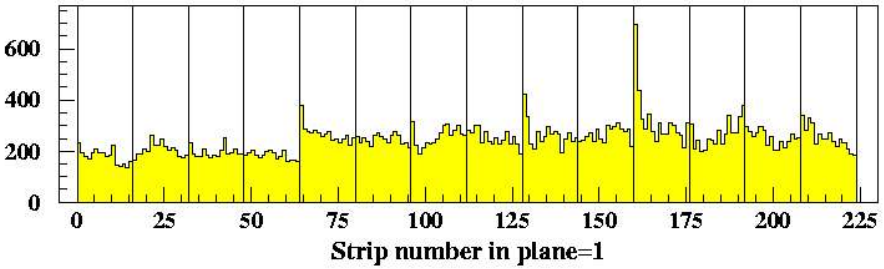


- @ 5.6 kV (working point) ~ 17 Hz/m^2 (1.2 kHz/layer - cosmics 6 mHz/layer !)
- Slightly lower for vertical strip planes
- Good uniformity among different layers (different colours in the plot)

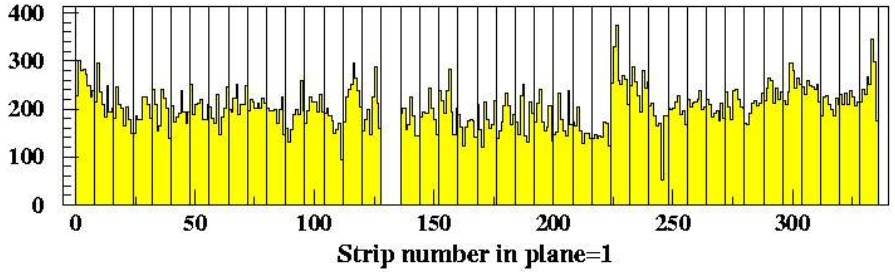
Counting rates (II)

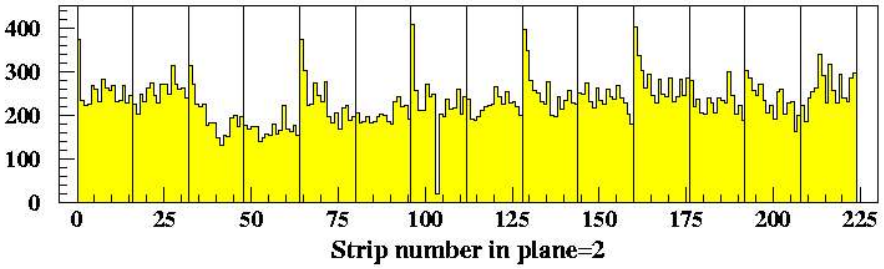
Down Horizontal Up

Corridor Vertical Rock



22





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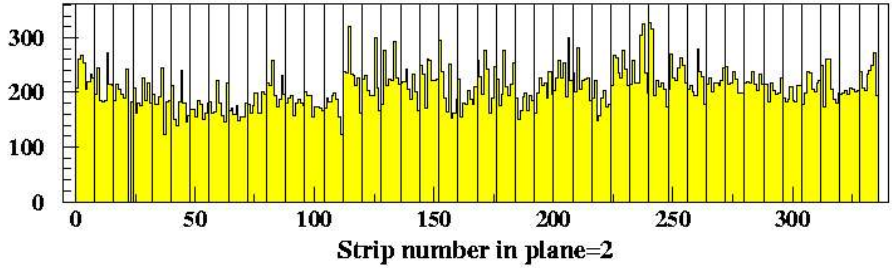
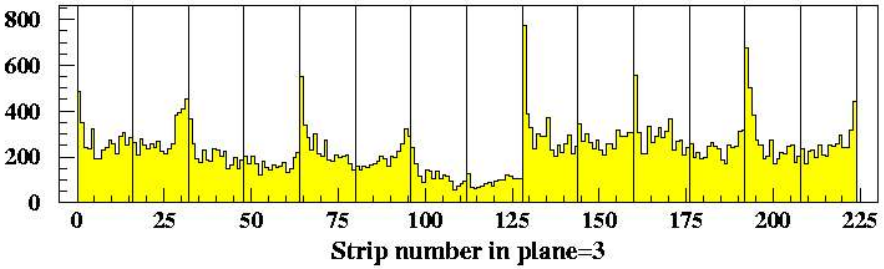
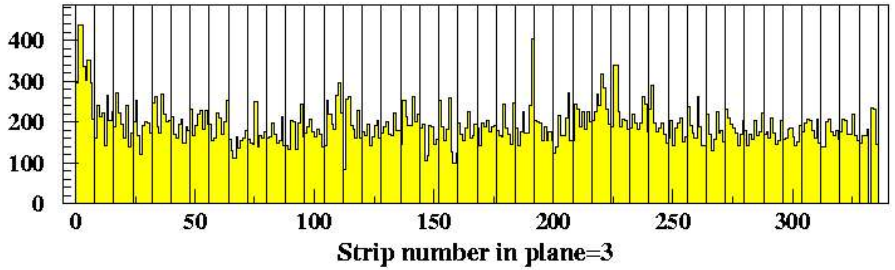
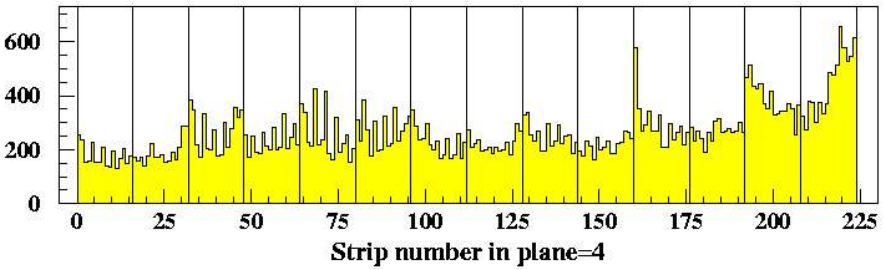


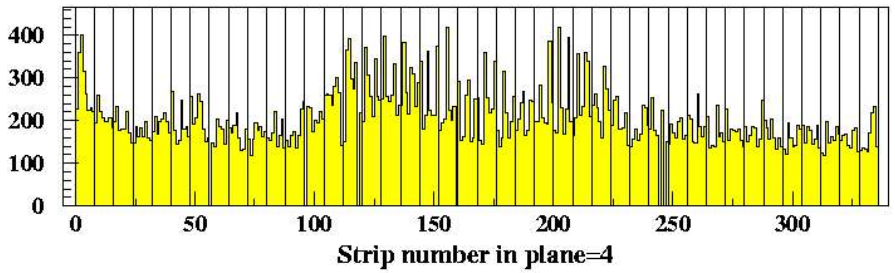


20





19



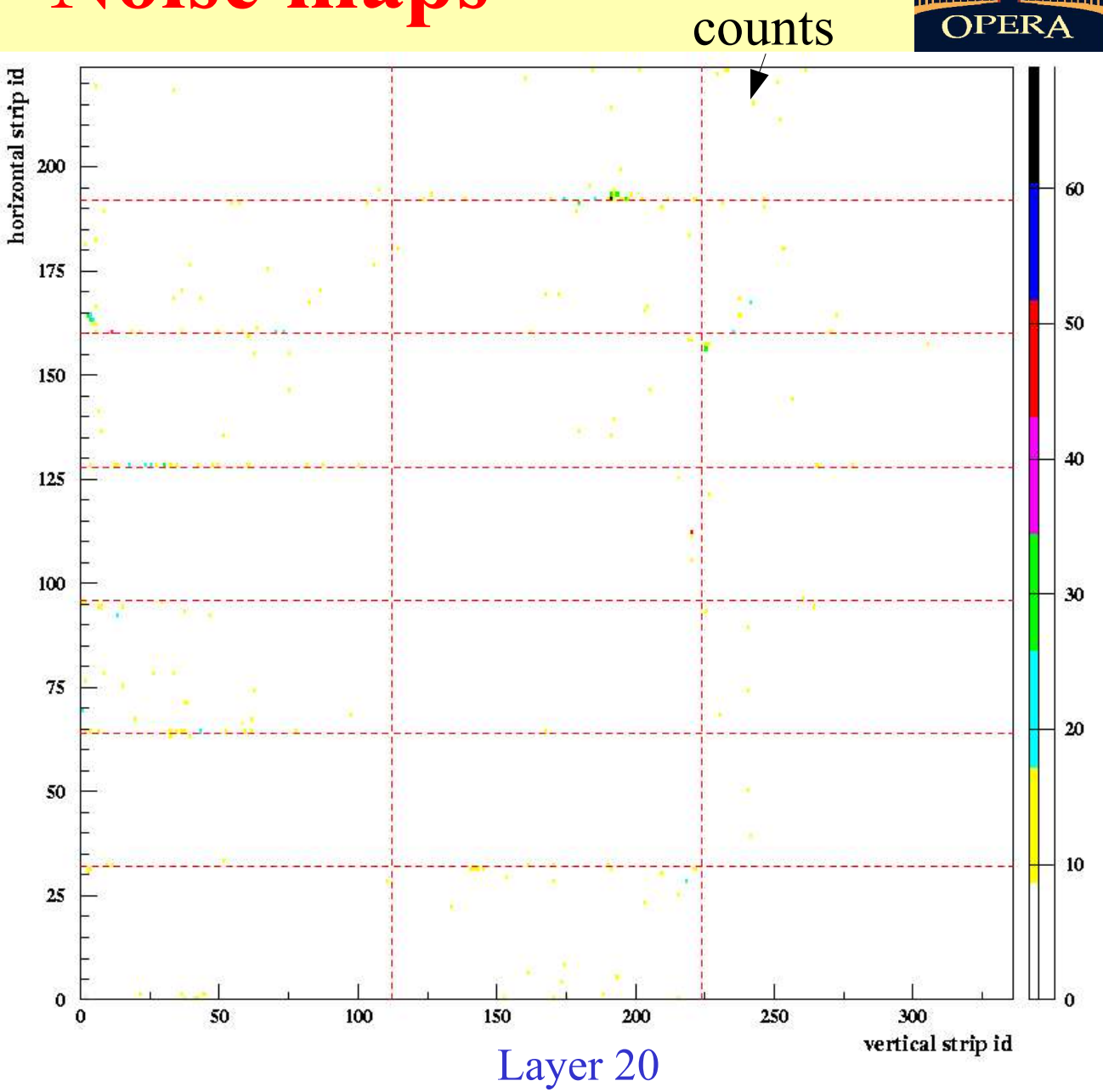
Noise maps

Self-triggered layer
AND of hor. and vert. strips

Intrinsic noise location
bins ~ 3×3 cm²

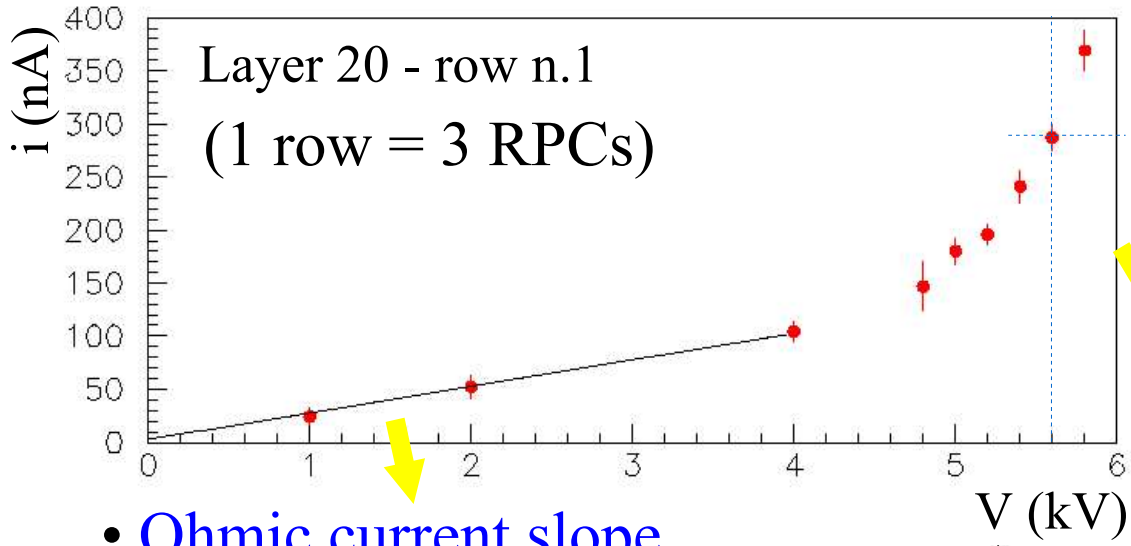
- The most noisy rate:
  ~ 2 Hz / bin
- The Average:
  0.015 Hz/bin
- The Quality test cut:
  5 Hz/bin

Some patterns seen at quality test at surface are confirmed



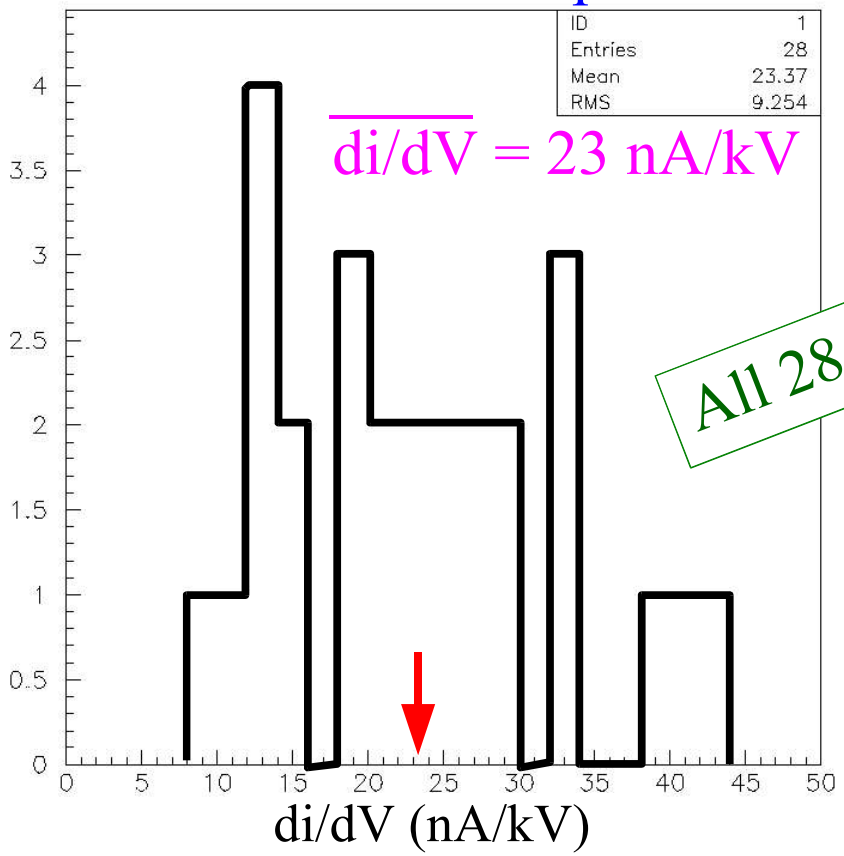
Layer 20

Currents

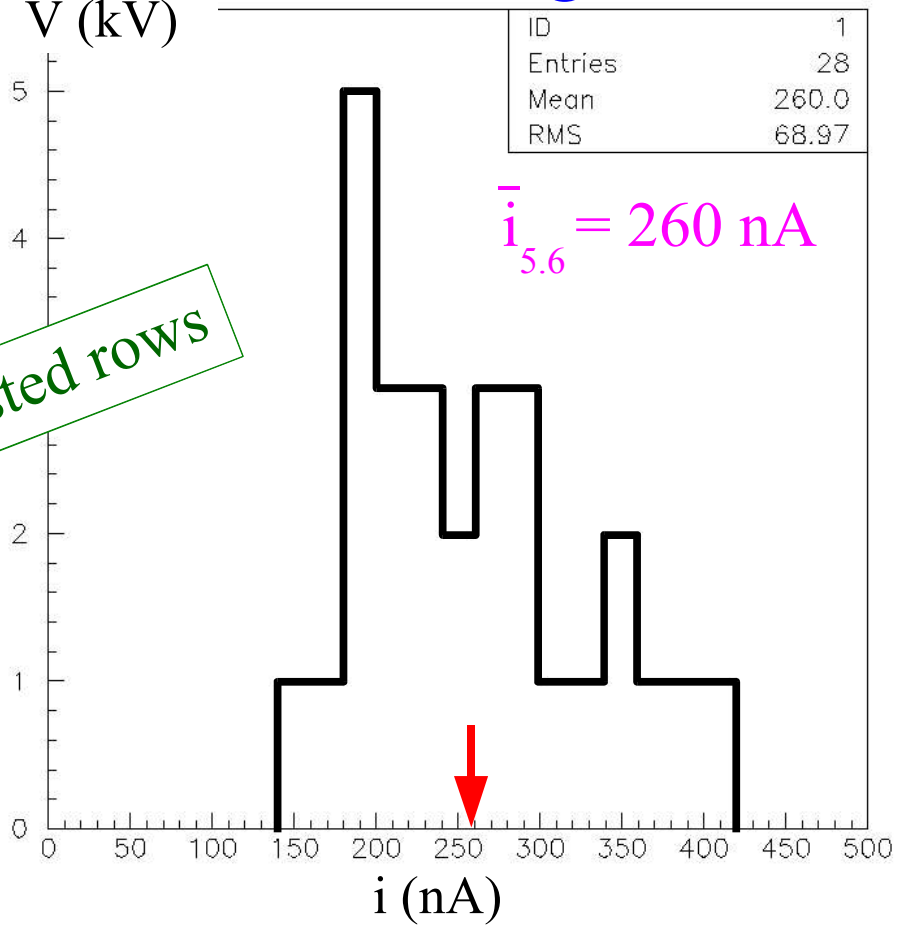


Very low currents, also at low voltage

- Ohmic current slope

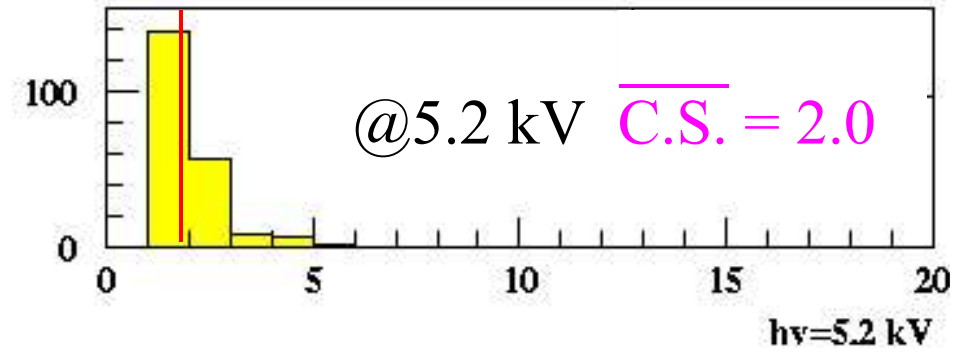


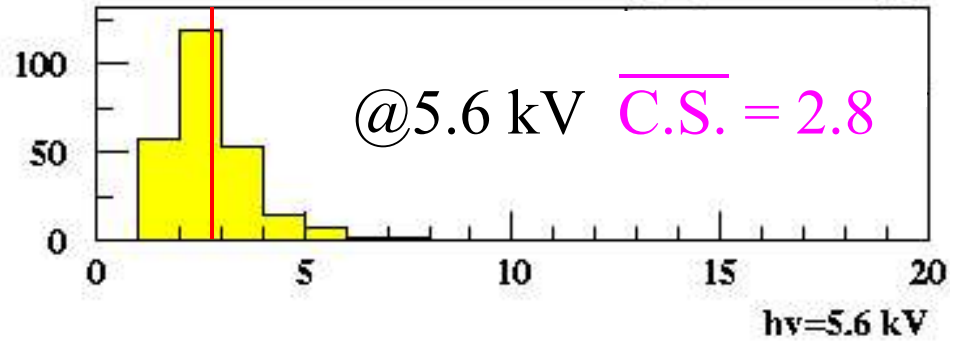
- Current @ V= 5.6 kV

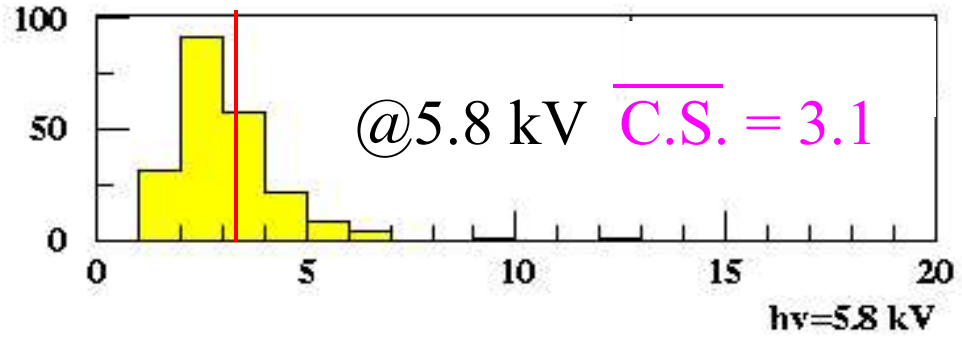


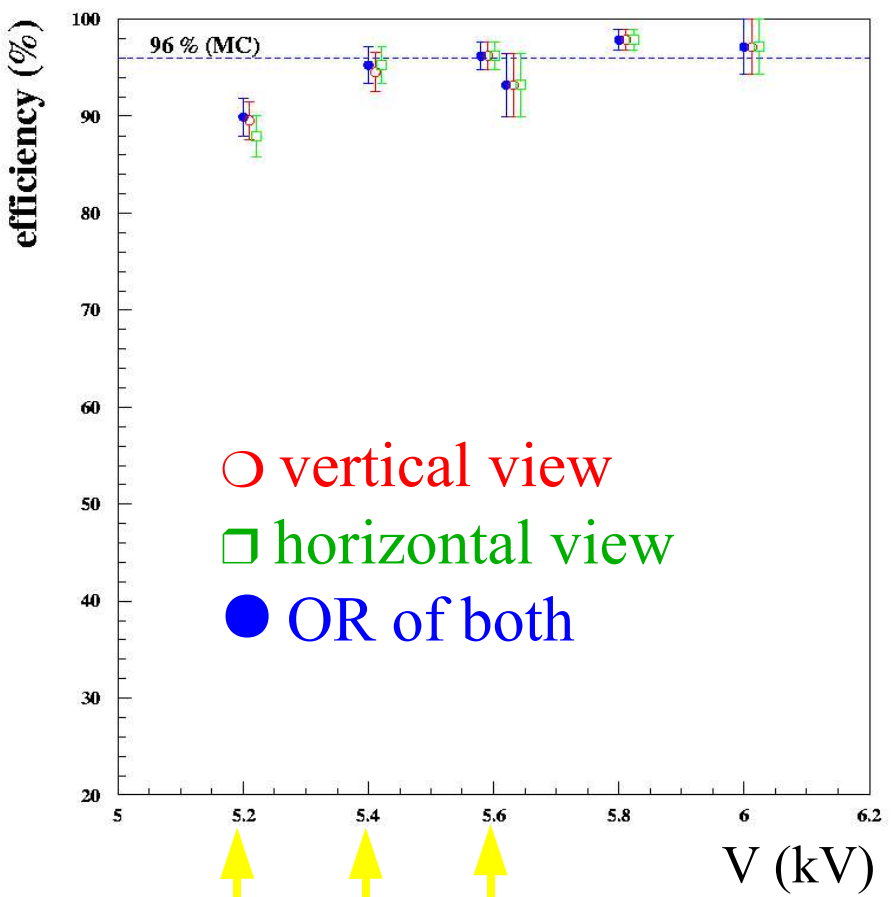
All 28 tested rows

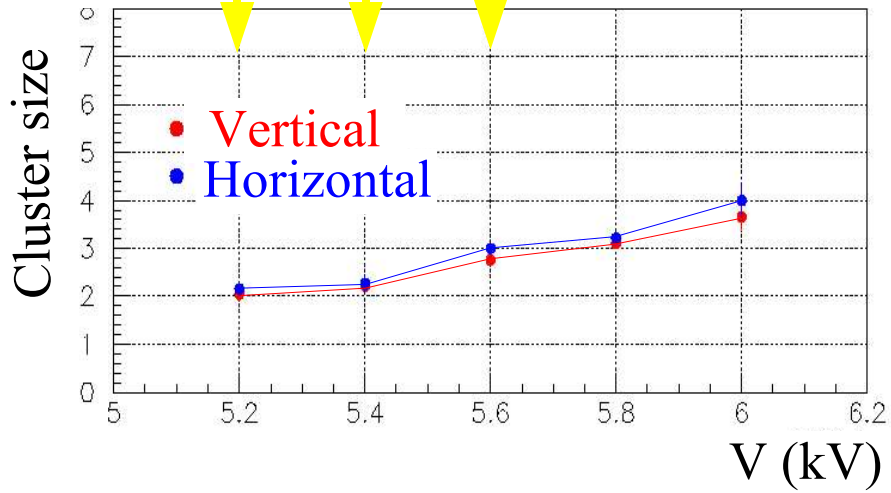
Cluster size



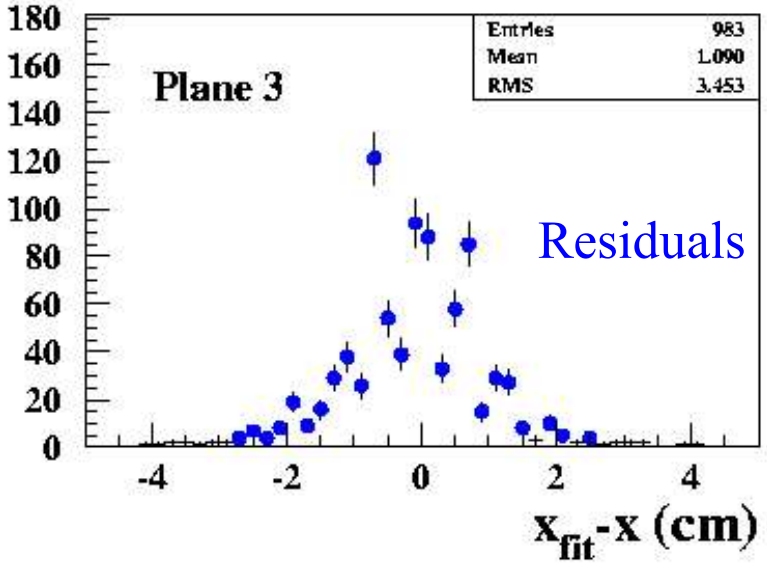








Fit residuals

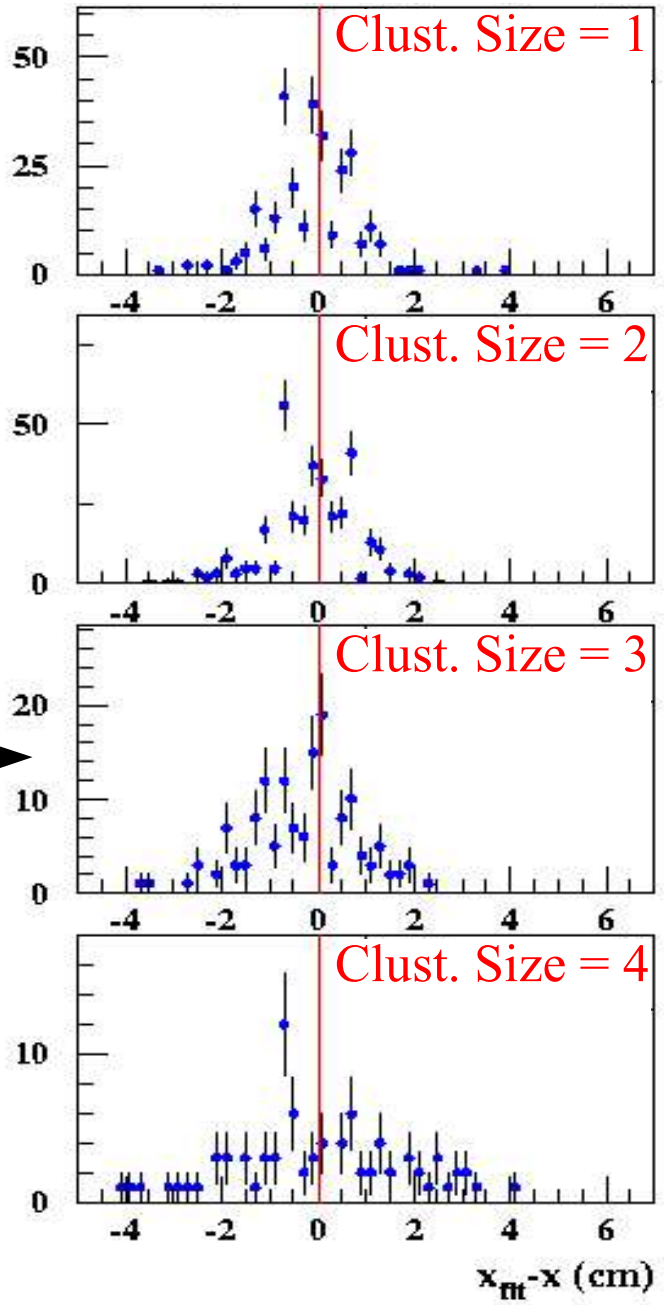


Cluster size is function of:

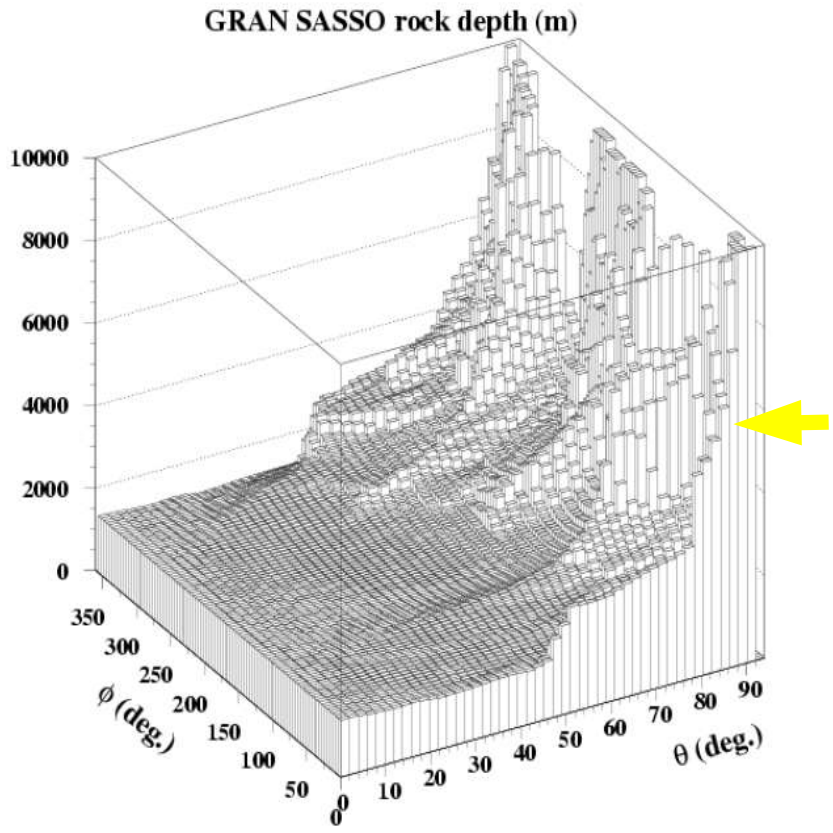
- Electronics (threshold)
  - extrapolation to OPERA not straightforward
- Particle impact point
- Cross-talk (high cluster size values)

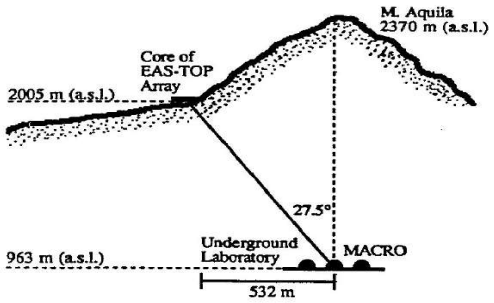
well contained within 1 strip (~3 cm)

Fit residuals in cluster-size bins

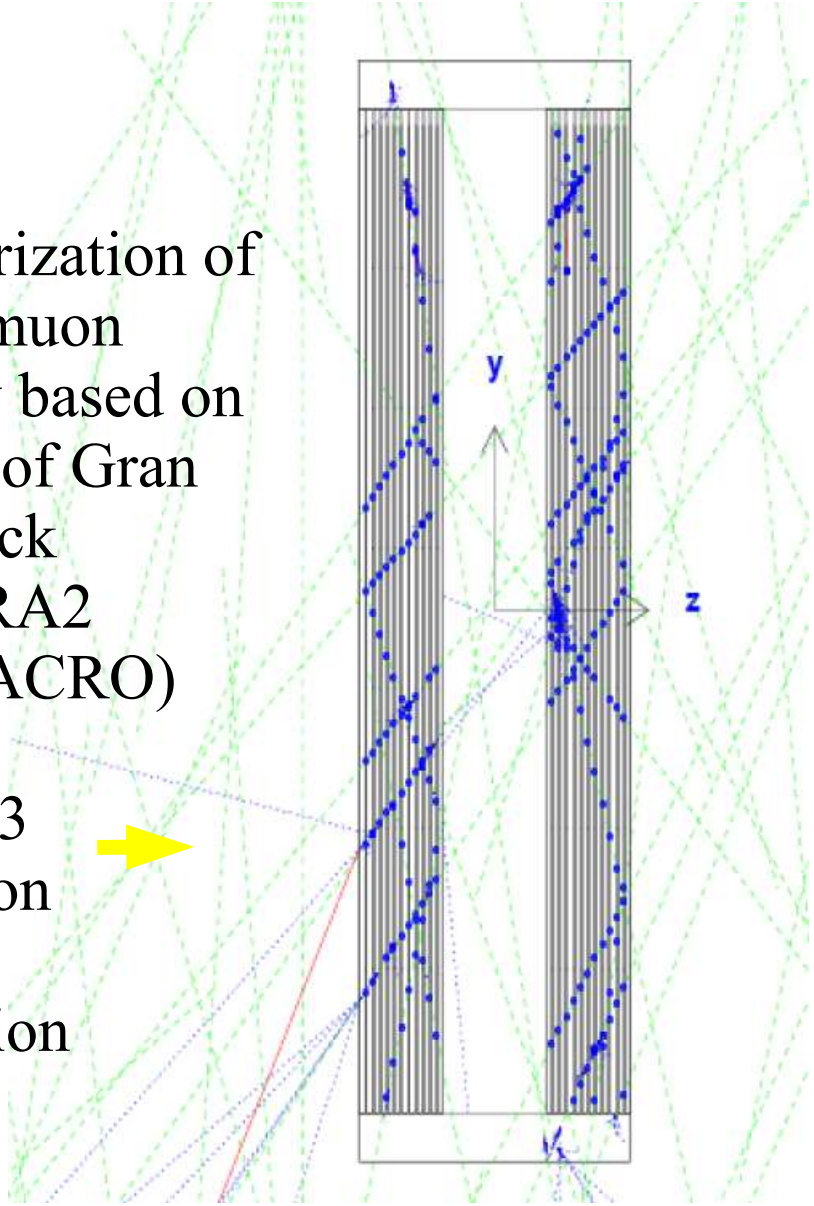


Cosmic muon simulation





Parametrization of cosmic muon intensity based on the map of Gran Sasso rock (GENERA2 from MACRO)
+
GEANT3 simulation
+
digitisation



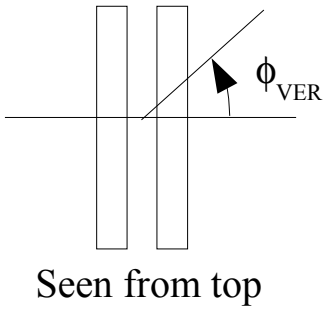
μ angular distributions & absolute rate

• All events:
(visual scan to skip casual coincidences, noise)

MC : (18.5 ± 0.4) μ/h
Data: (21.0 ± 0.6) μ/h

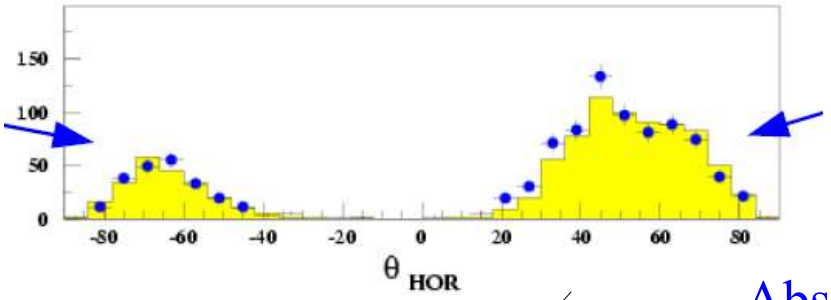
• Clean events:
(1 cluster/plane/view, $\chi^2 < 2$):

MC : (15.2 ± 0.3) μ/h
Data: (15.6 ± 0.5) μ/h



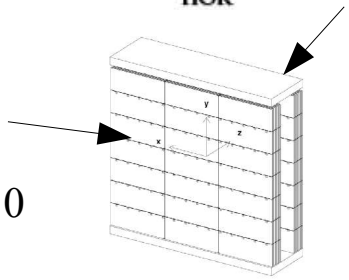
Seen from top

north



south

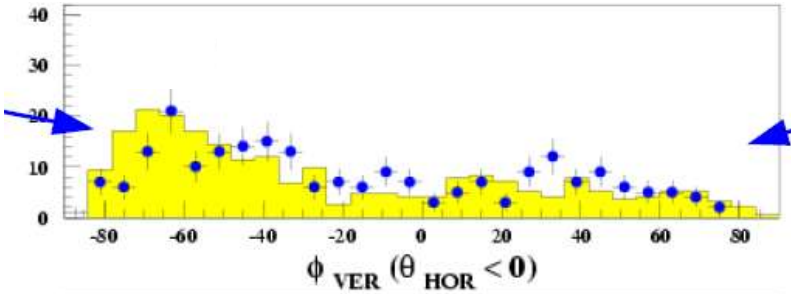
Absolute MC normalisation



$\Theta_{hor} < 0$

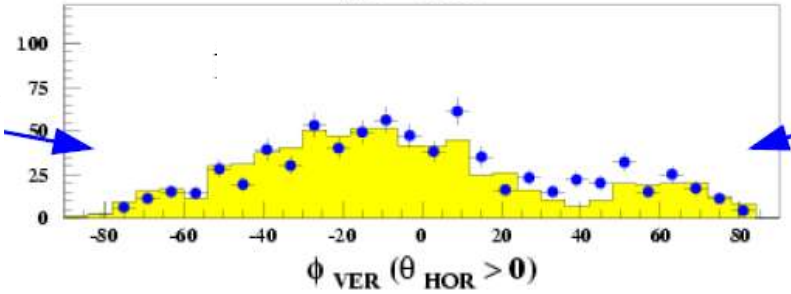
$\Theta_{hor} > 0$

Rock side (Teramo)



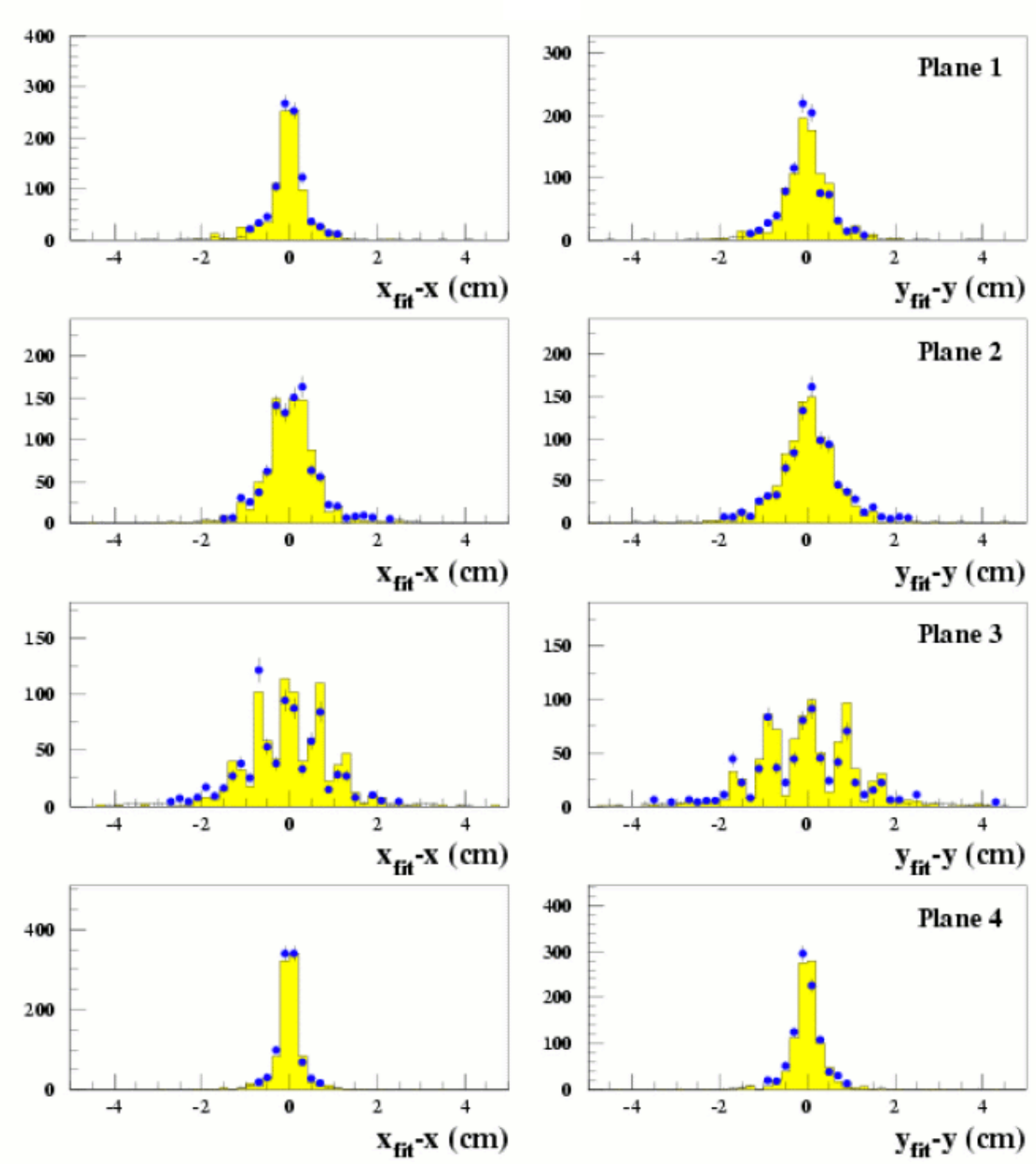
Corridor side (L'Aquila)

Corridor side (L'Aquila)



Rock side (Teramo)

Residuals



Straight line fit

Trigger planes
(used in the fit)

Layer 20
(not used in the fit)

- No alignment
- Absolute MC normalisation

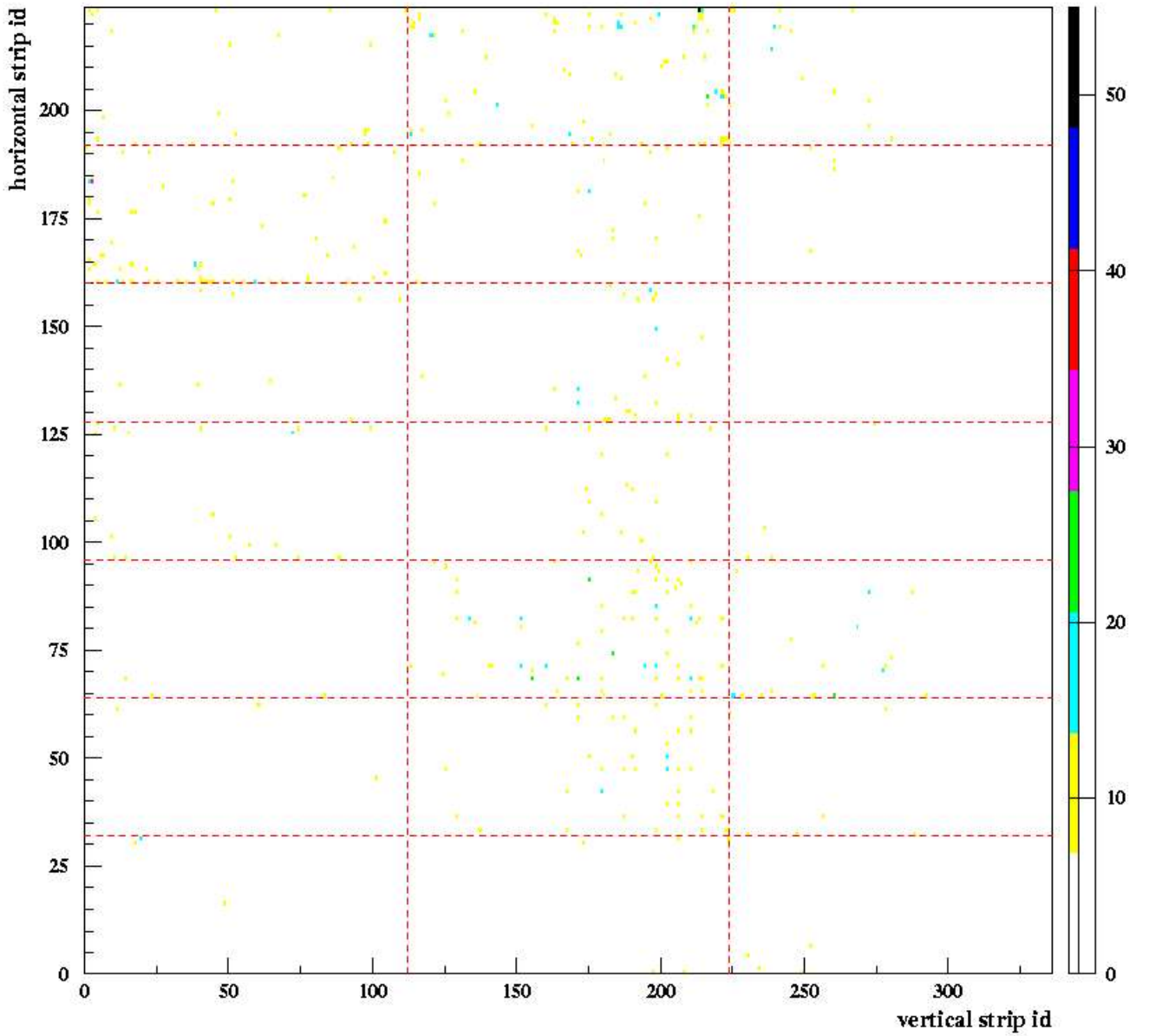
→ Residuals well described by MC !

Conclusions and Outlook

- Complete OPERA RPC system installed since March 2005
- RPC commissioning started on 4 layers (over 44 of the two spectrometers) with no major problems (efficiency, currents, noise, grounding)
- Good efficiencies measured (96%, due to geometry)
- Low and stable currents observed ($i_{5.6} = 260$ nA)
- Counting rates < 20 Hz/m^2 (1.2 kHz/layer @ 5.6 kV)
- Intrinsic detector noise not increased wrt to QC tests (noise-maps)
- Cosmic angular distributions: good MC description in shape and normalisation without hard tuning
- Satisfactory results, even with low statistics
- After this first validation, future tests (starting these days) tests will be with final electronics

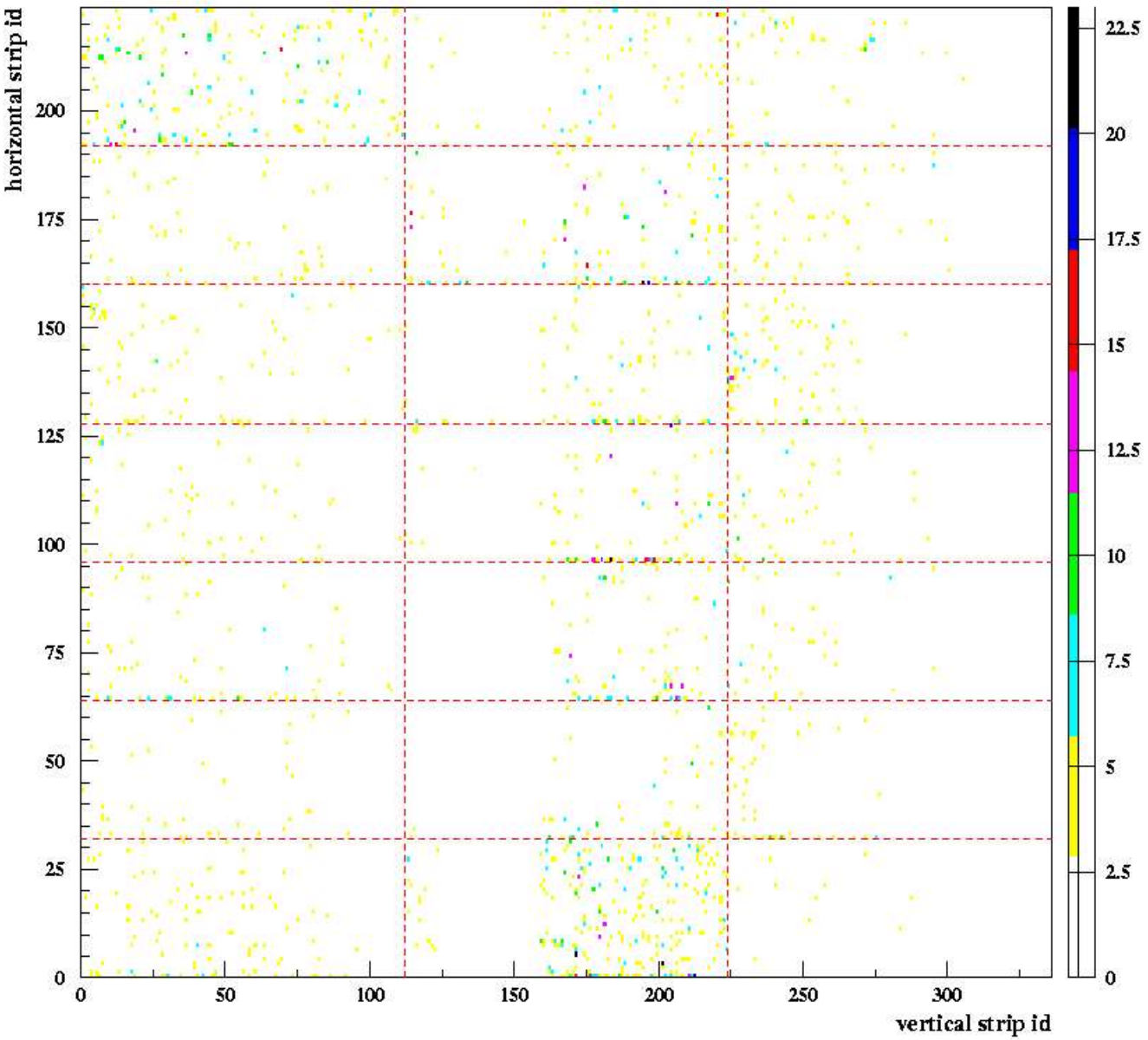
Backup slides

Noise maps



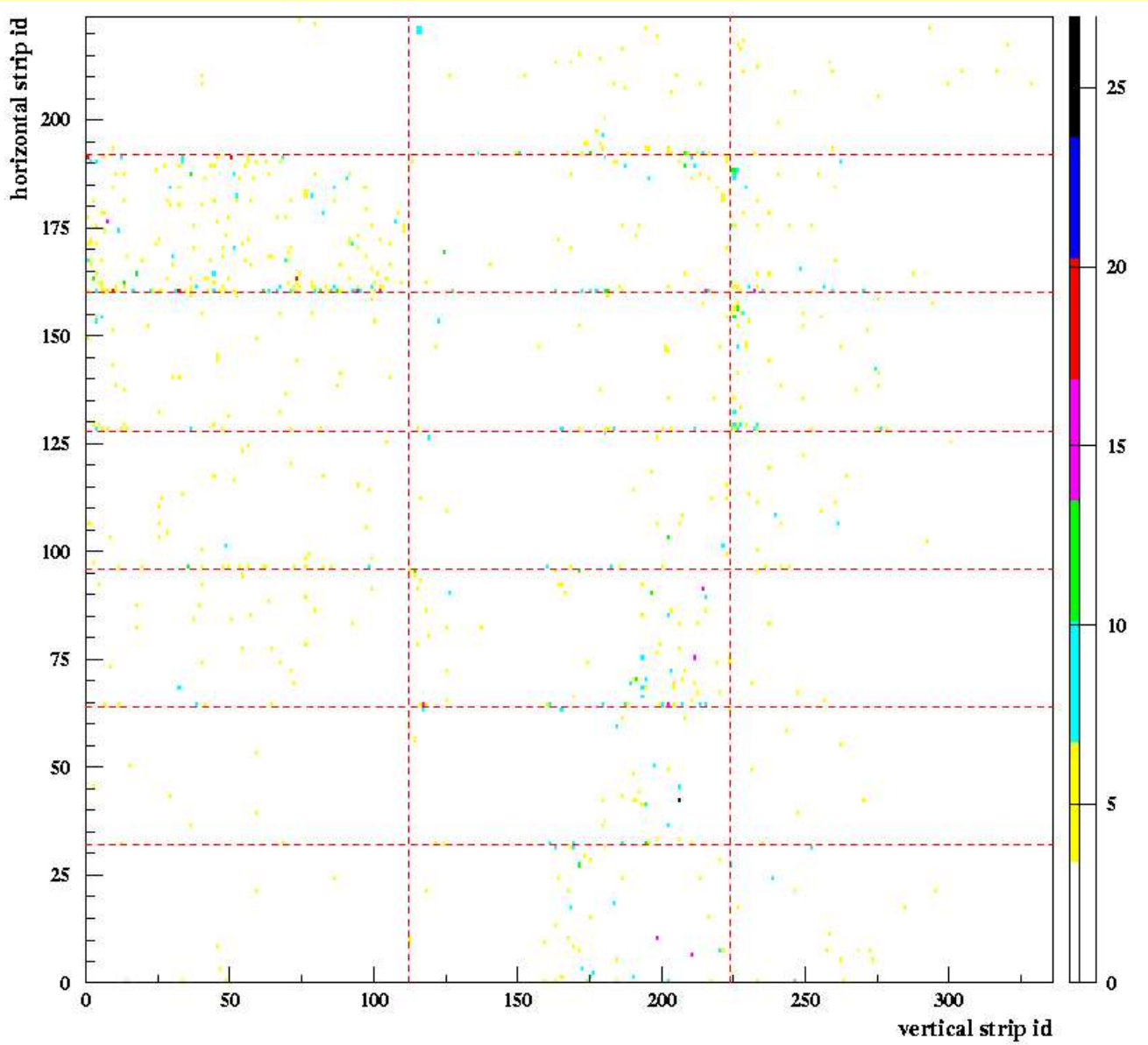
Layer 19

Noise maps



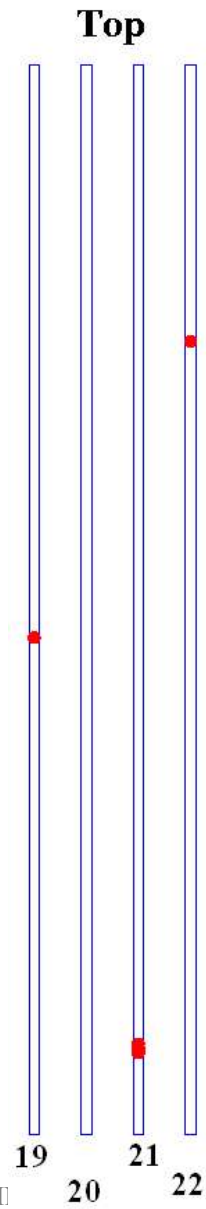
Layer 21

Noise maps



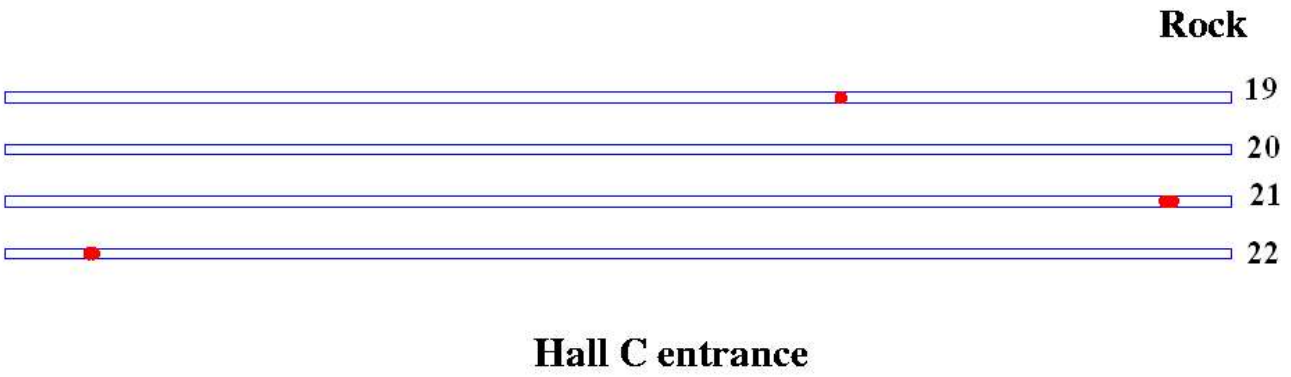
Layer 22

Event display: casual coincidence

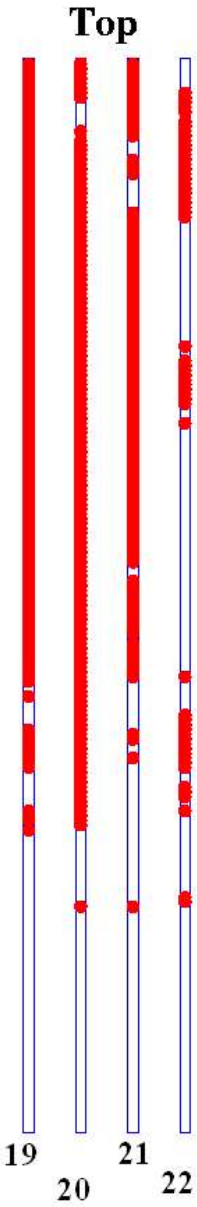


Horizontal view

Vertical view

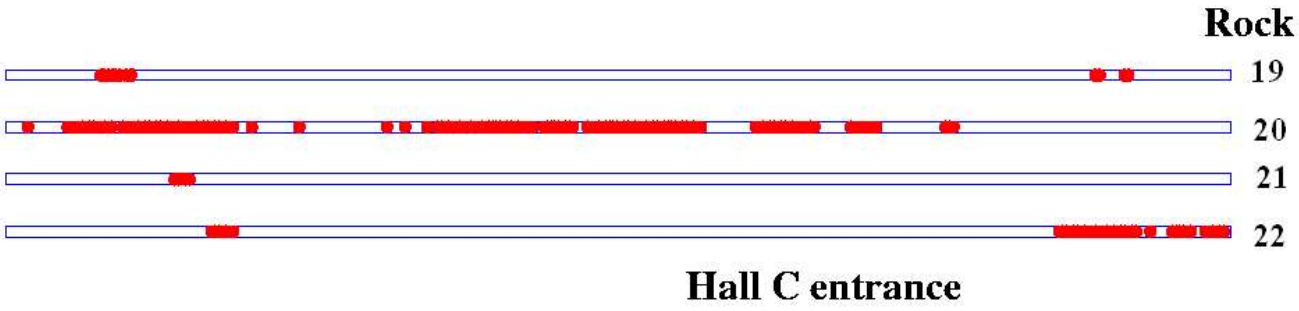


Event display: noise

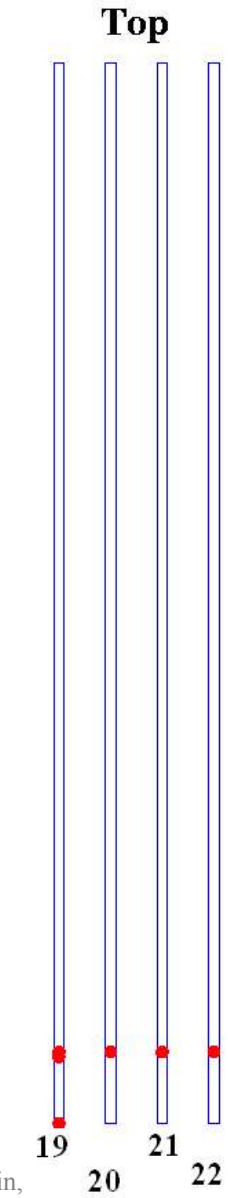


Horizontal view

Vertical view



Event display: elevator induced noise



Horizontal view

Vertical view