Test results from a prototype RPC setup for the OPERA Target Tracker

VI Workshop on RPC, Coimbra, 26-27 November 2001

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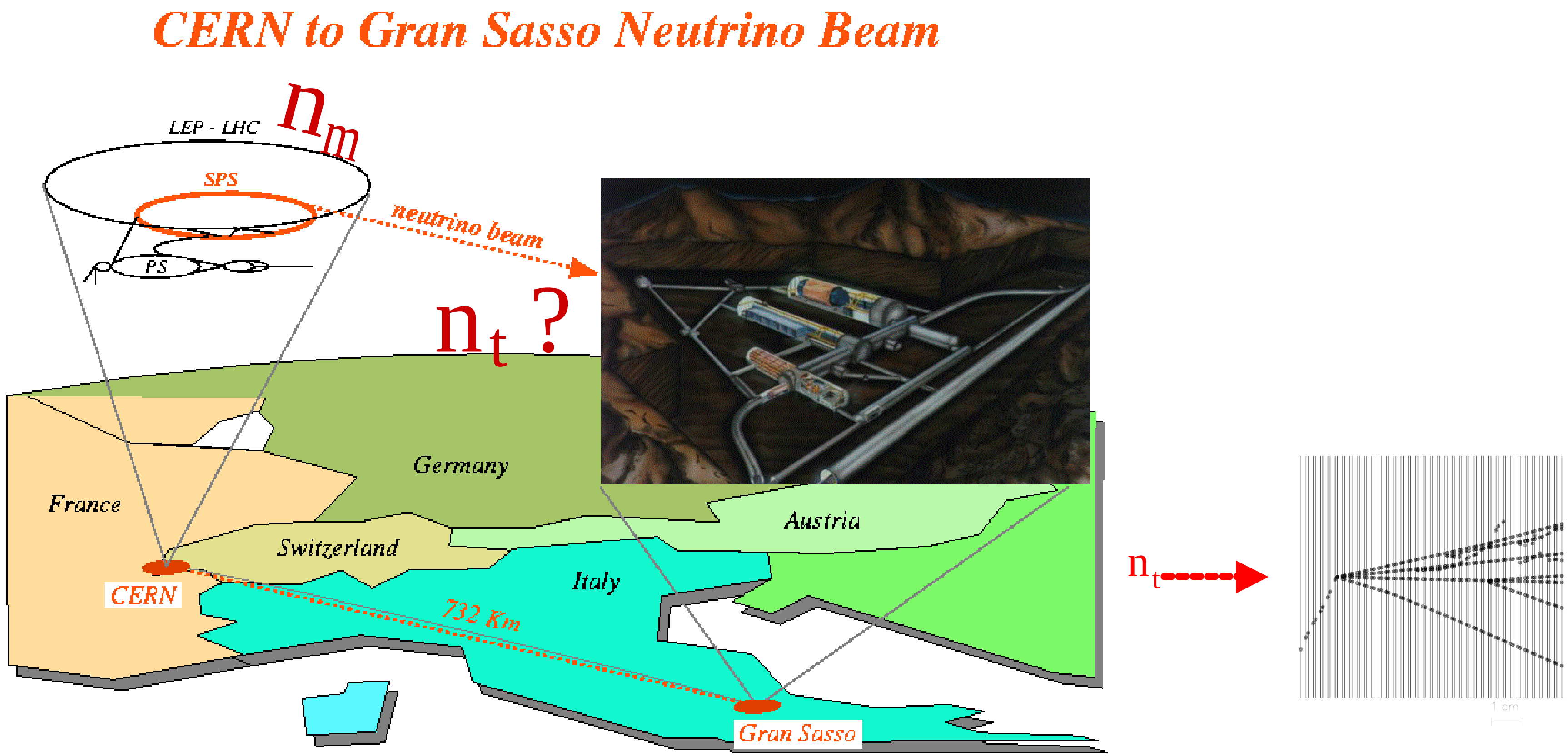
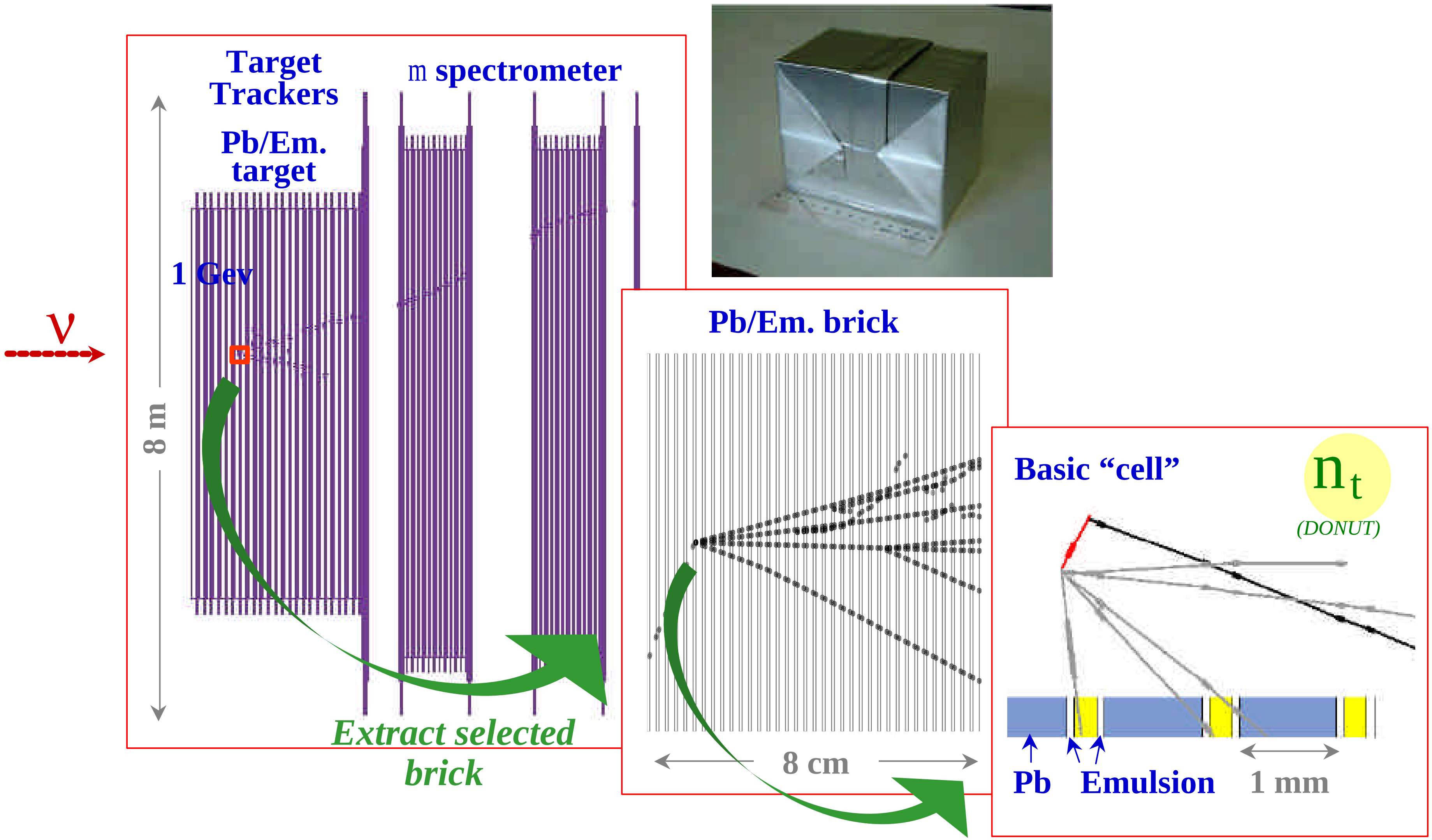




Electronic detectors

→ select n interaction brick

→ m ID, charge and p

Emulsion analysis

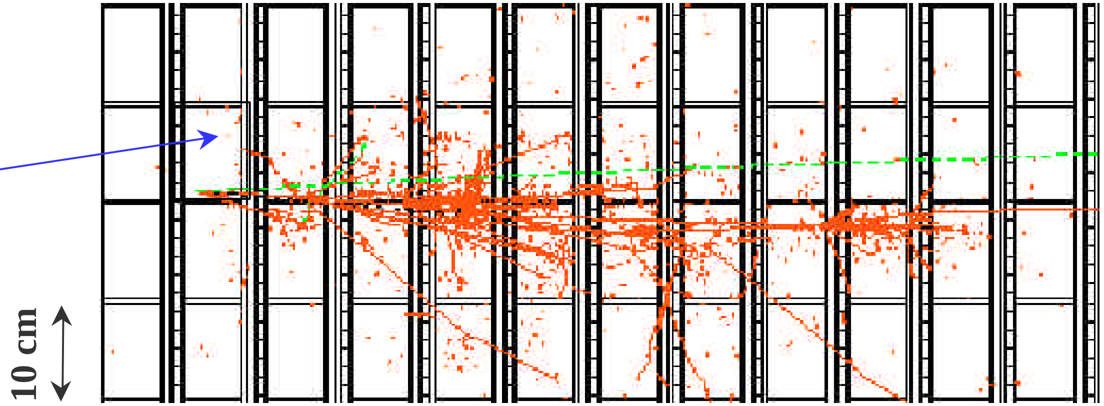
® vertex search

→ decay search

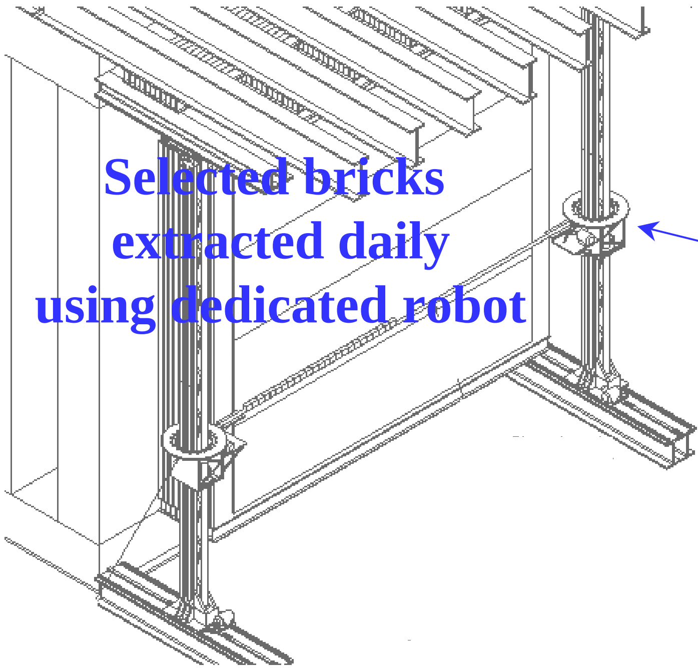
→ e/g ID, kinematics

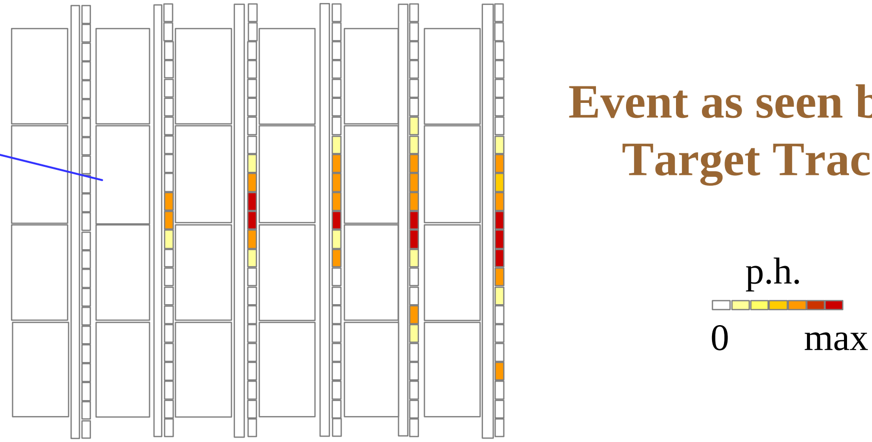
The Target Tracker

- **Target Tracker tasks:**
  - **a) trigger on neutrino interactions**
  - **b) select bricks efficiently**
  - **c) initiate muon tagging**



Sampling by Target Tracker planes (X,Y) with coarse resolution (1 cm)





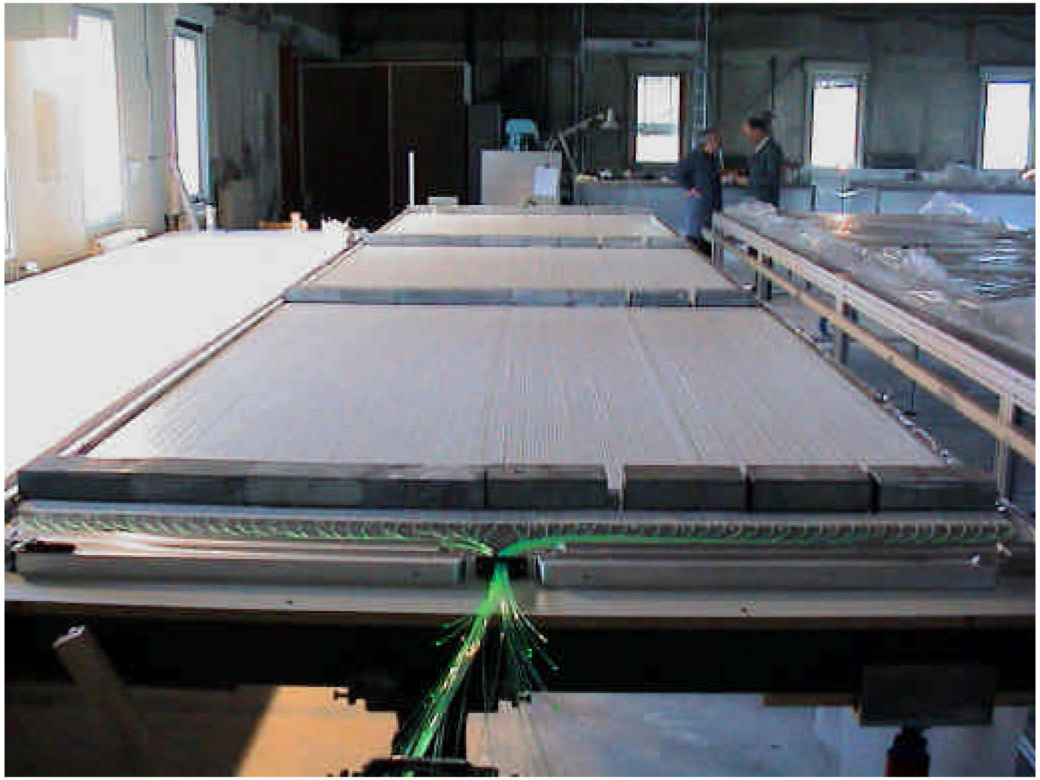
Event as seen by the Target Tracker

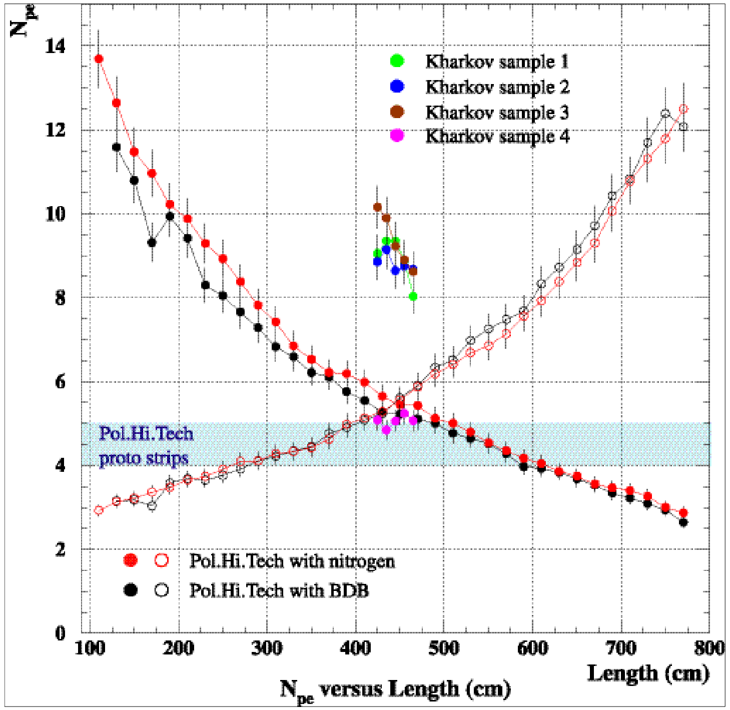
The target is made of 235,000 bricks !

Target Tracker: plastic scintillators

Full scale prototype module

- 64 strips of 6.7 m long, 2.6 cm wide, 1 cm thick extruded plastic scintillator
- readout by wavelength shifting optical fibres





> 5 p.e. / readout end

(in the middle, worst case for two-end readout)

The goals for the RPC option

- Better spatial and angular resolution than with scintillators

→ better brick finding efficiency and more precise muon tracking

- Less distance and material in between walls

→ better track following between bricks, less sensitive to backscattering

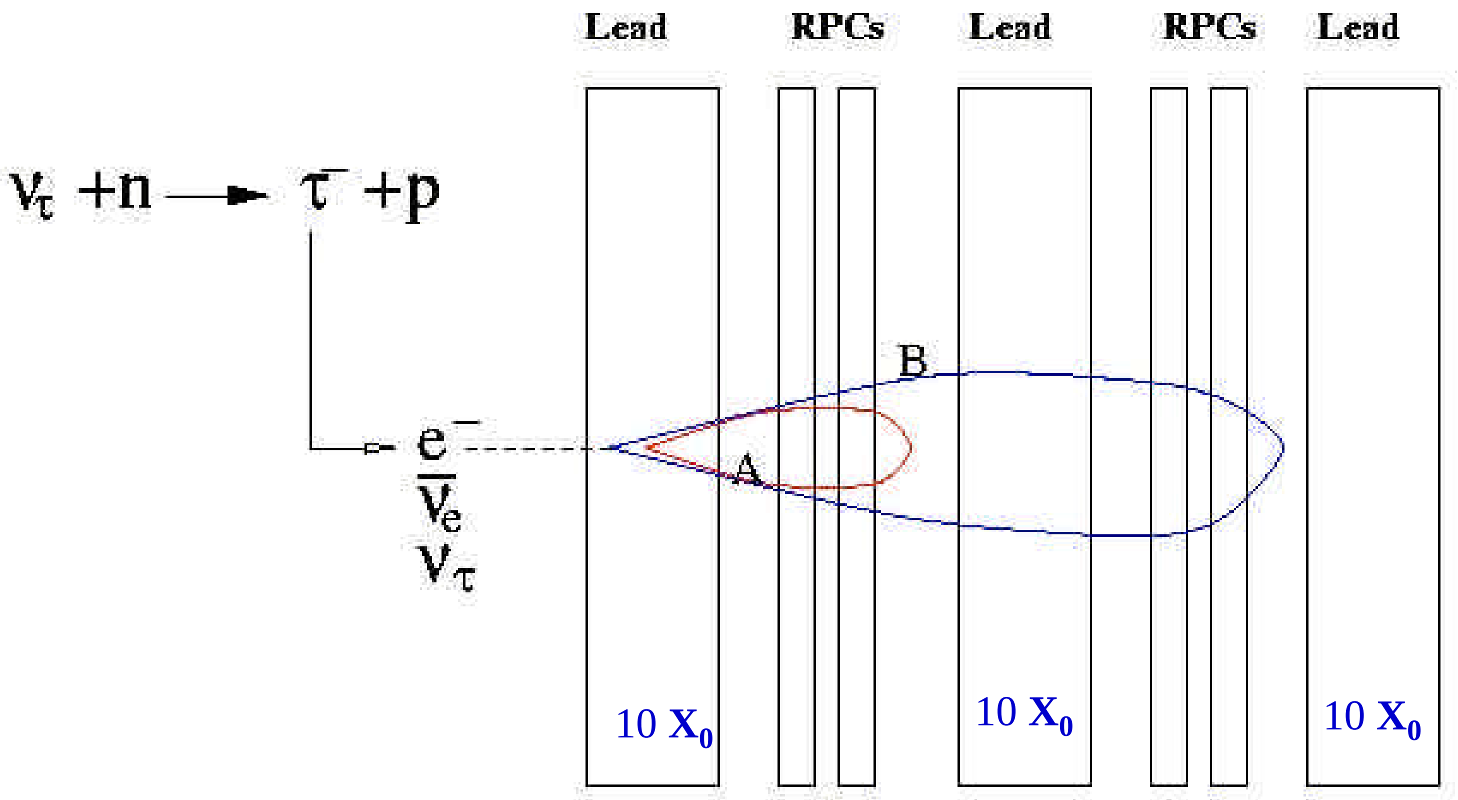
- Simpler construction and installation, cheaper readout

Problem:

The noise can interfere with the capability of triggering on single electrons with very low background

→ Two planes of RPC (each with X and Y views) will be needed in between every two walls in order to suppress the background by requiring local coincidences

The quasi-elastic events



In A the electromagnetic shower is limited to only one plane of the target tracker (depending on the energy of the electron and on where the neutrino interacted in the brick)

The RPC

- “Standard” Bakelite (2mm) RPC with a 2mm gap, constructed at General Tecnica
- The bakelite is treated with linseed oil (a few microns) in order to reduce the noise, the RPC operate in streamer mode
- The gas mixture is 48% Ar, 48% R134A, 4% C4H10, the chambers operate at about 8 KV
- Planes (6.7x6.7 m^2) are built out of 18 chambers of 225x112 cm^2 for a total of 6500 m^2
- There are two planes per gap (doublet), each plane is readout with X and Y strips with 1 cm pitch
- The signals are read out with ADC providing a better space resolution by computing the center of gravity of the strips with an induced signal
- The total thickness of a doublet is 26 mm and corresponds to 3% of X_0
- The two planes are staggered in X and Y by 5 cm in order to avoid the superposition of dead regions (3.5% of the surface of a doublet cannot be used for coincidences for a m.i.p.)

The experimental setup

A prototype resembling the OPERA wall structure was built by using 6 RPC (each 60x70 cm^2)
Each RPC was readout with X and Y strips (of 1 cm pitch) in the central region16x16 cm^2 covered by the lead bricks

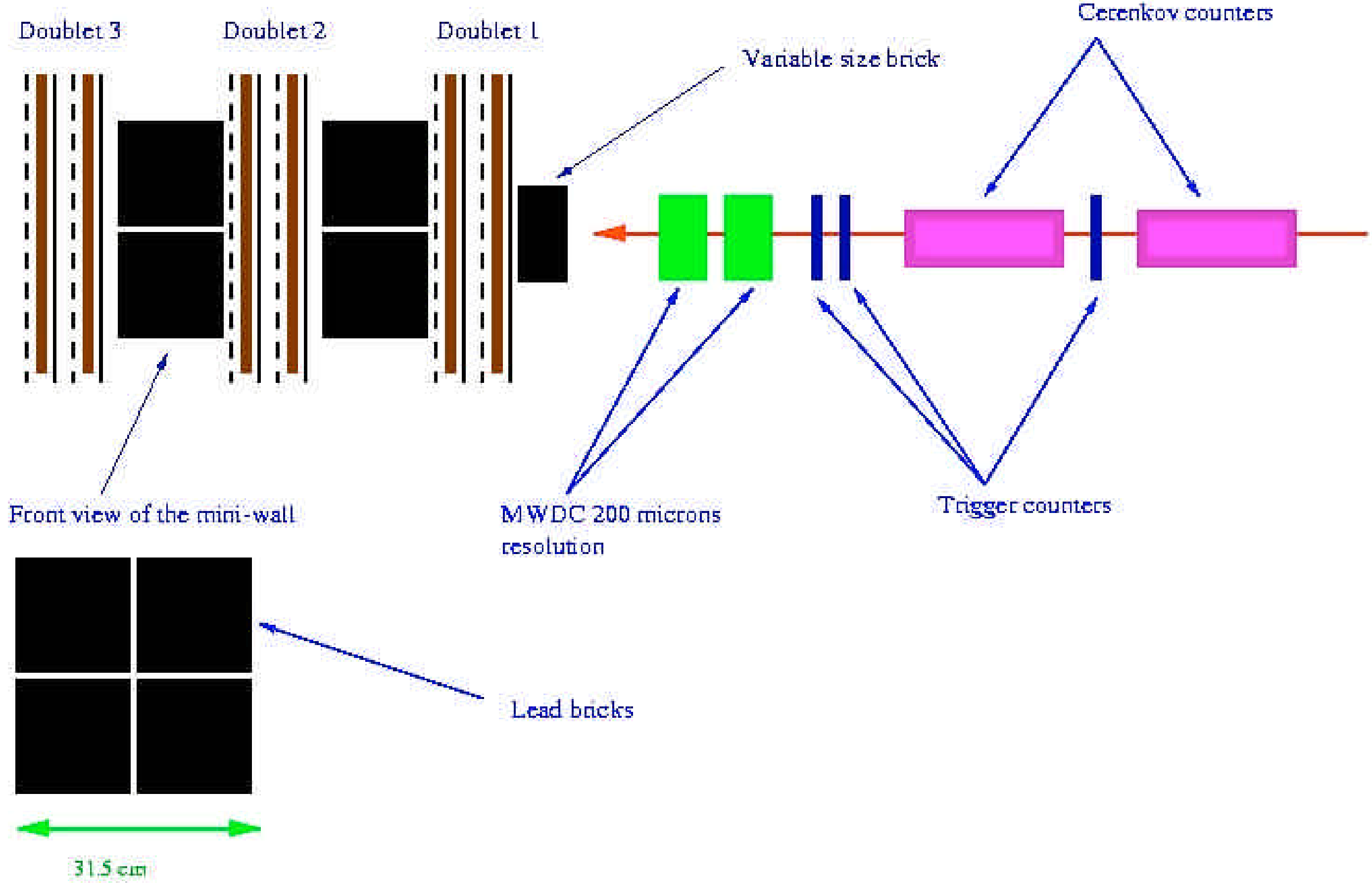
Setup at the T9 and T7 beams

Exposures:

Pions muons and electrons for 2 weeks at T9 and one week at T7

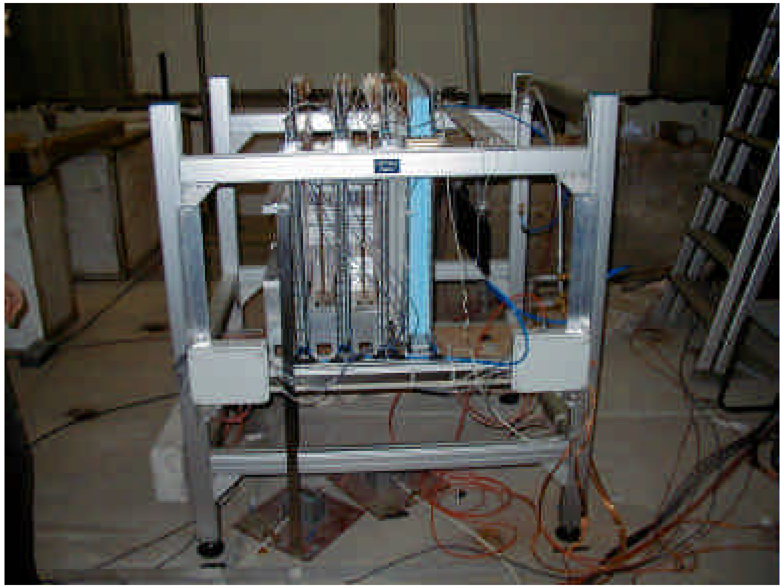
Measurement of the background:

1 month in HALL B in Gran Sasso

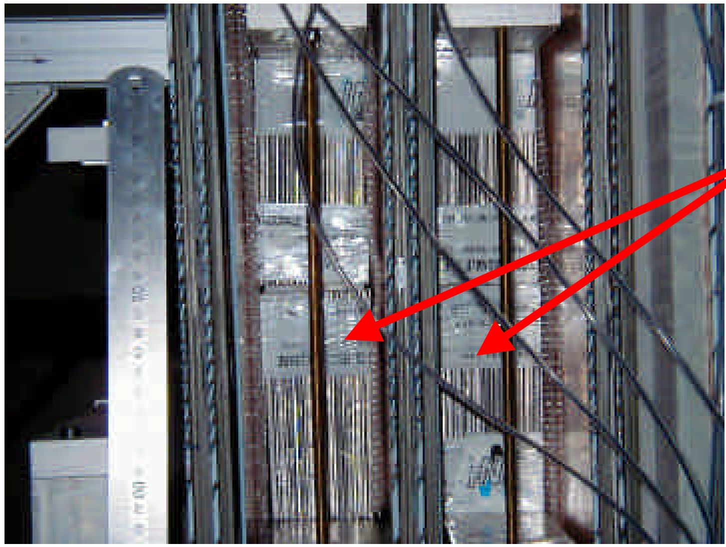


The prototype

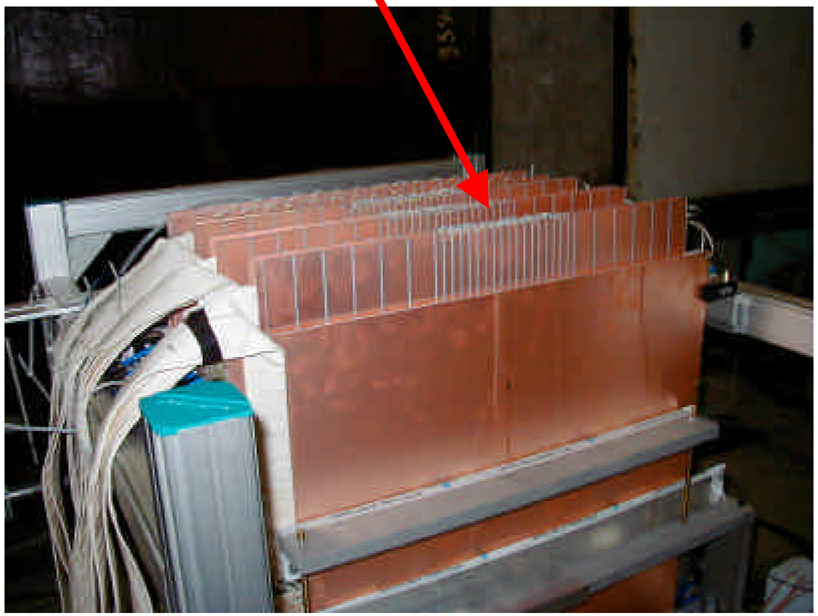
Side view



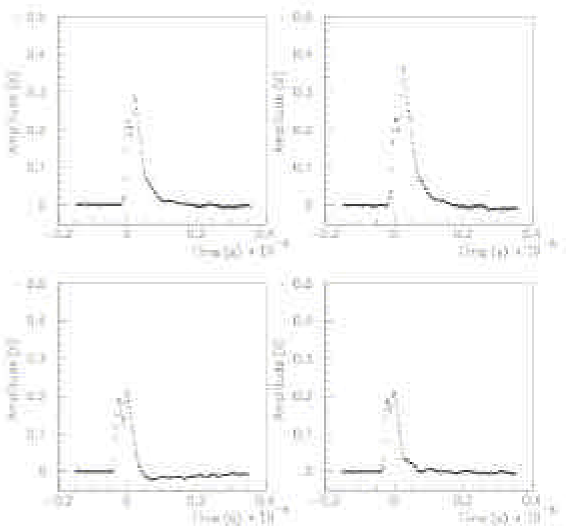
Central region equipped with 1 cm strips.
Readout with ADC CAEN V792
Charge sensitive, 12 bits for a total of 192 channels (16 x 6 planes x 2 views)



Lead bricks

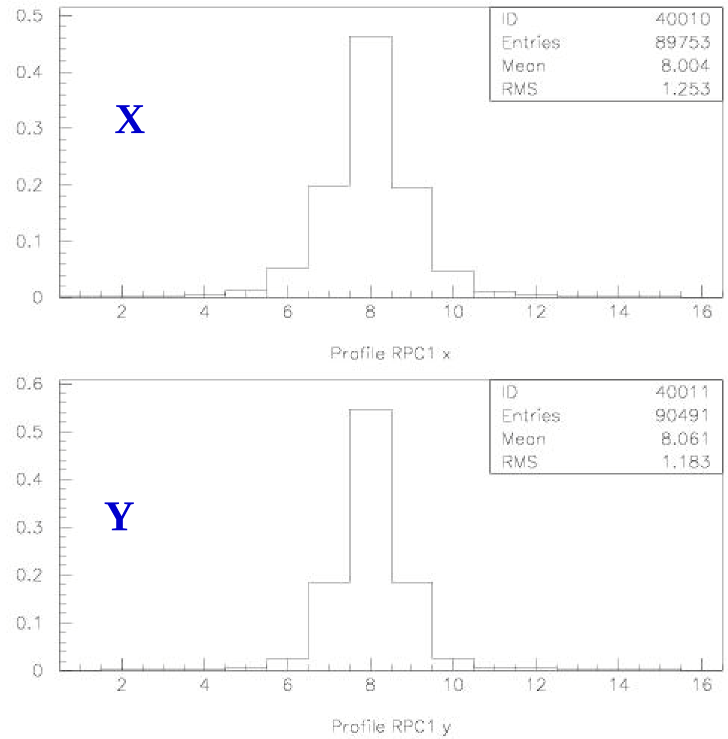


The induced signal

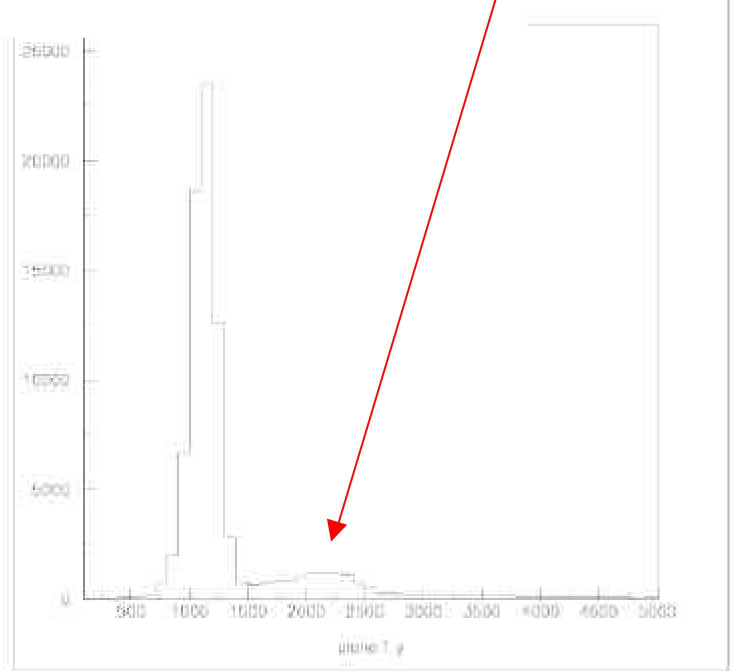


Double streamers
about 15%

Charge sharing among strips



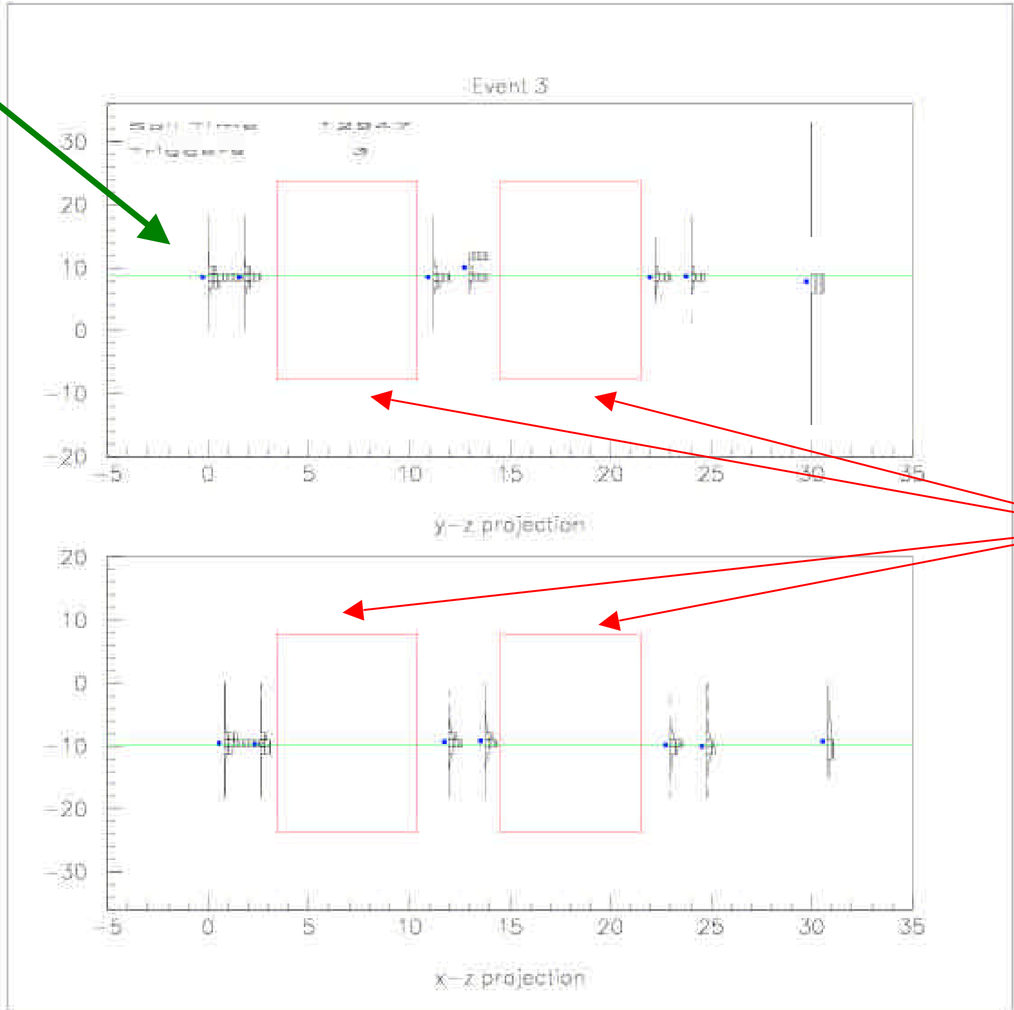
Charge spectrum (summing all strips)



3 strips contain 85% of the total charge in X (cathode) and 91% of the total charge in Y (anode)

Muon event

Signals on the first doublet

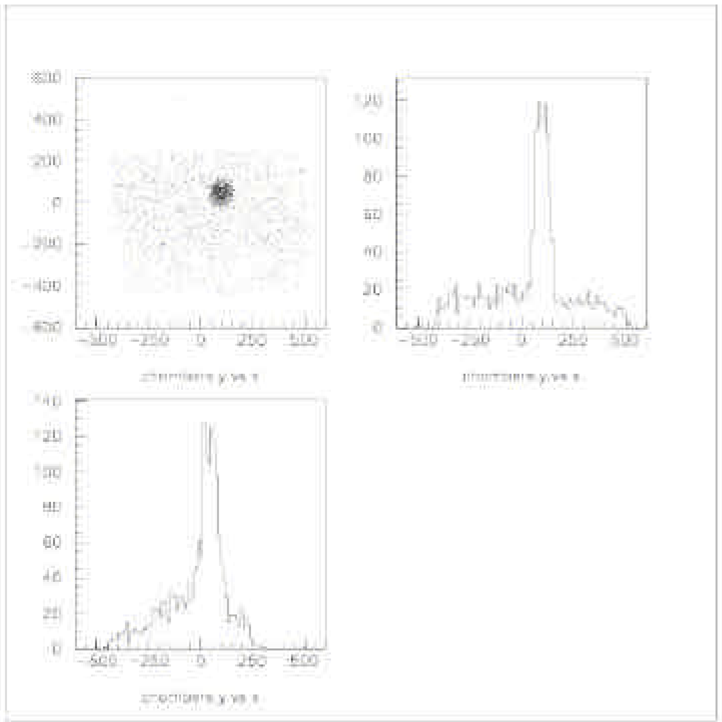


Lead walls

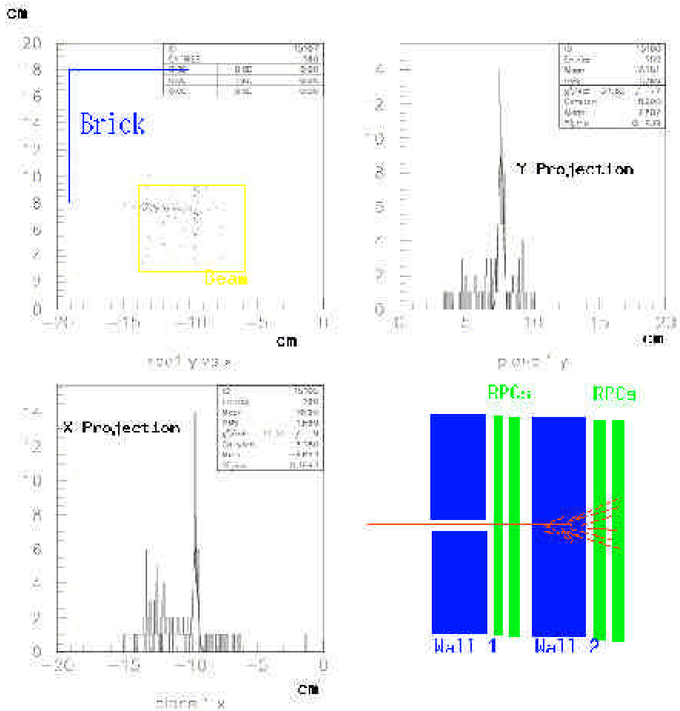
Space resolution

By comparing for m.i.p. the extrapolation of the MWDC with the position of the center of gravity on the first doublet (without lead in front) we measured a space resolution of about 1 mm.
Tracks fitted from hits in the 3 doublets (interleaved with the lead walls) have residuals of about 1 mm and a pointing accuracy of 5 mrad

Spacer tomography (MWDC)



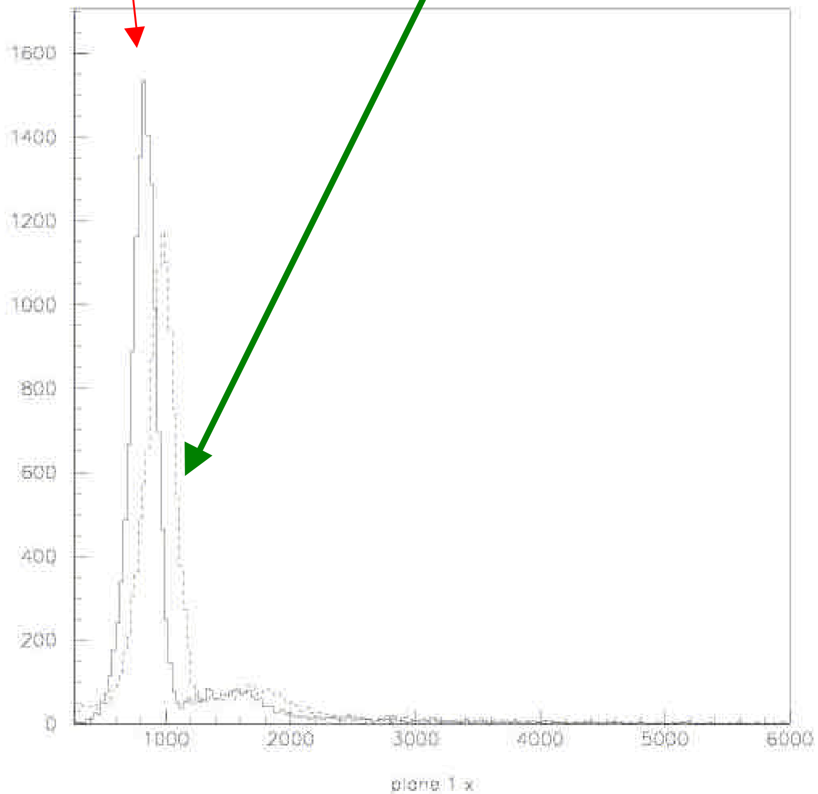
Electrons: empty cross in between lead bricks (RPC)



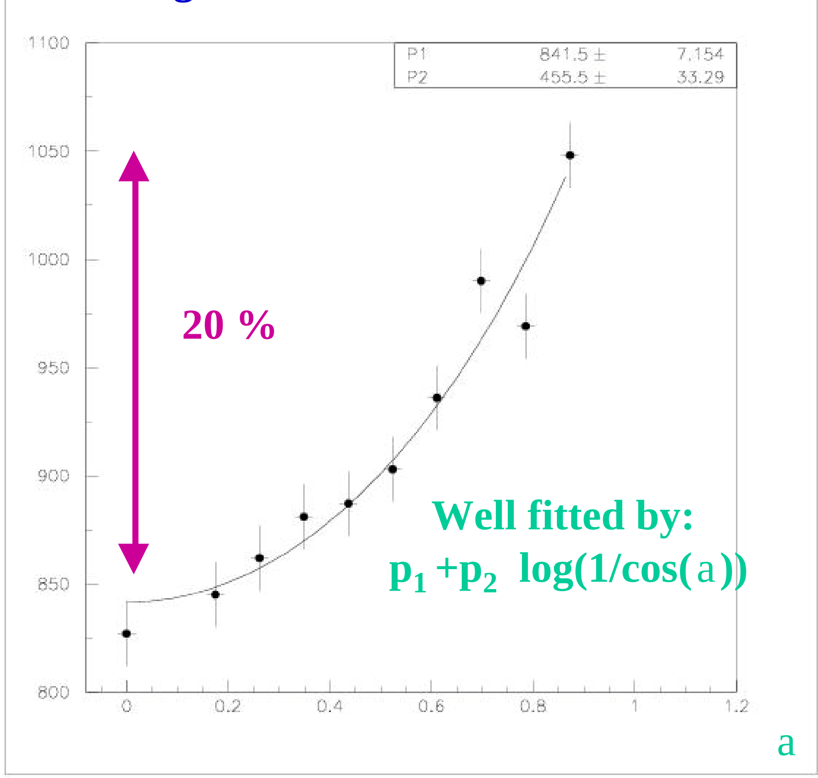
Angular response

Spectrum at perpendicular incidence

Spectrum at 45 degrees, looks multiplied by a constant factor !
No increase of double streamers

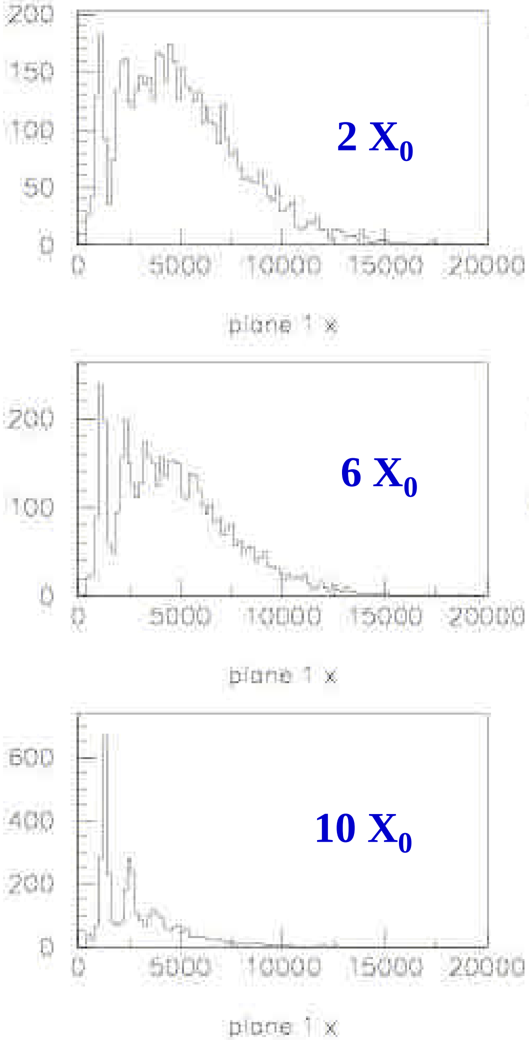


Average pulse height as a function of the incidence angle w.r.t the normal



The response is not saturated but there is still a logarithmic dependence on the ionization, like observed in streamer tubes

Response to electrons



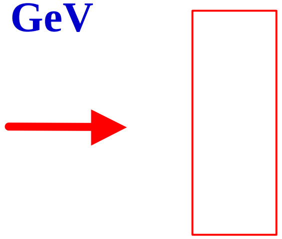
Total pulse heigth on the first RPC of the first doublet for 2 GeV electrons as a function of the thickness of the variable brick

Shower maximum

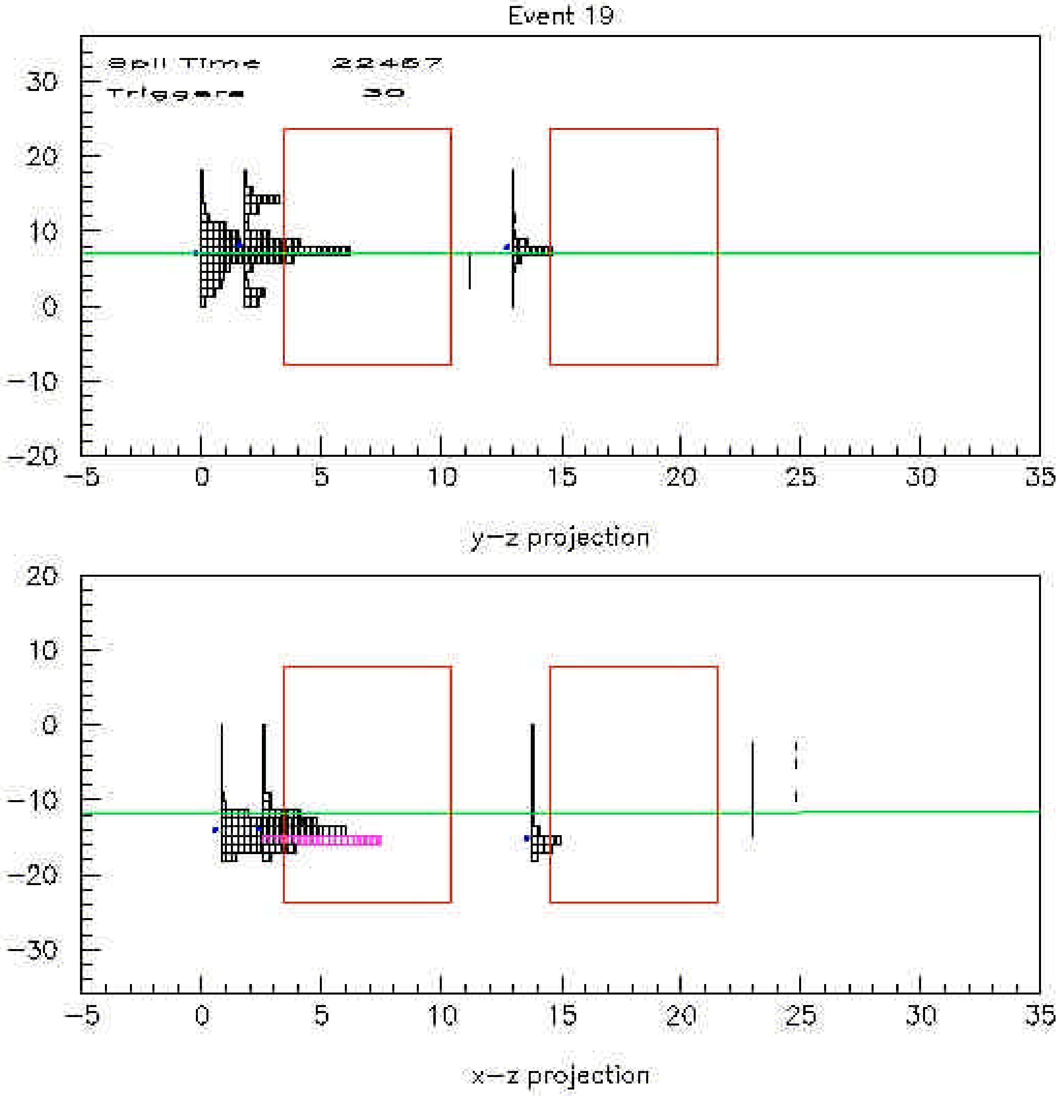
Contributions of the single particles clearly visible when the density is low

Electron passing through two walls

2 GeV

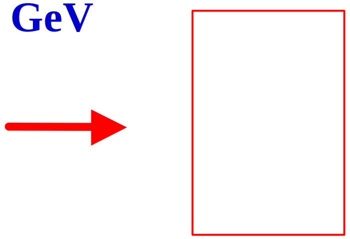


4 X_0 (variable thickness brick)

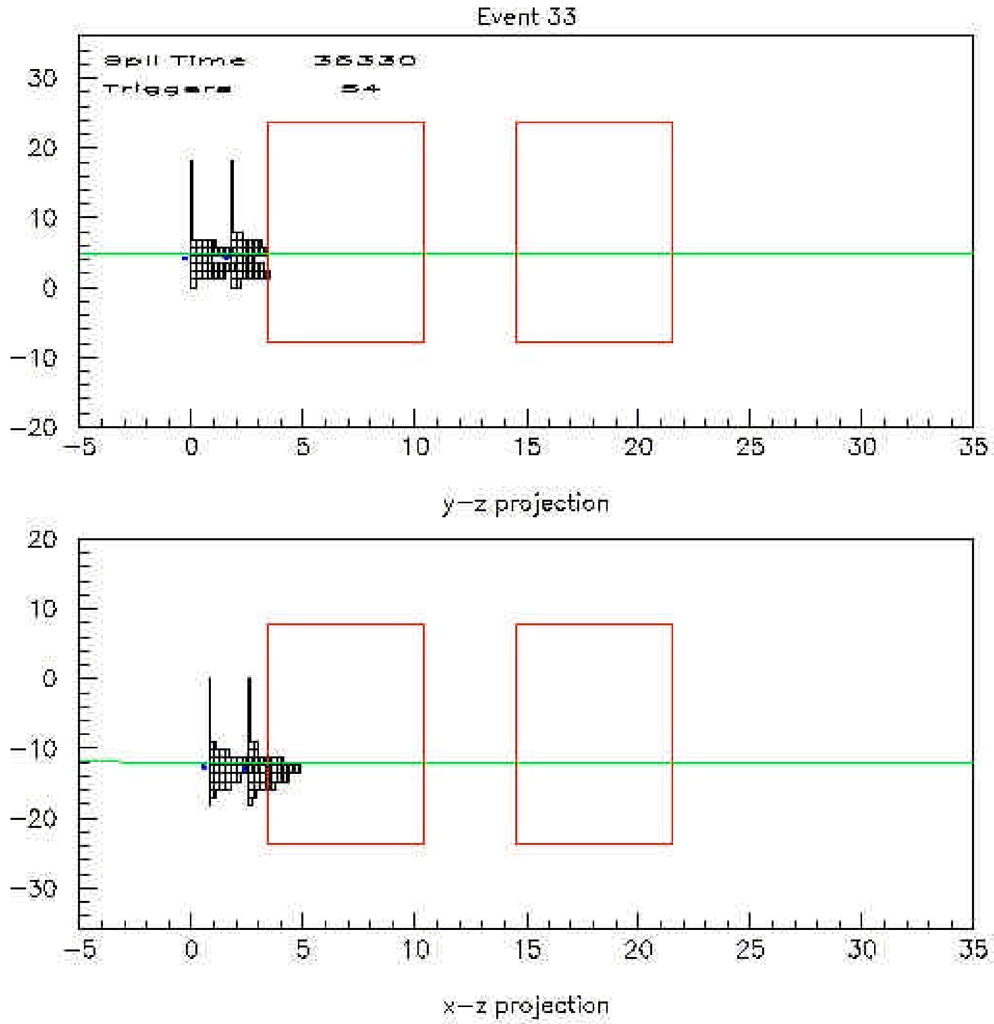


Electron stopping in the second wall

2 GeV

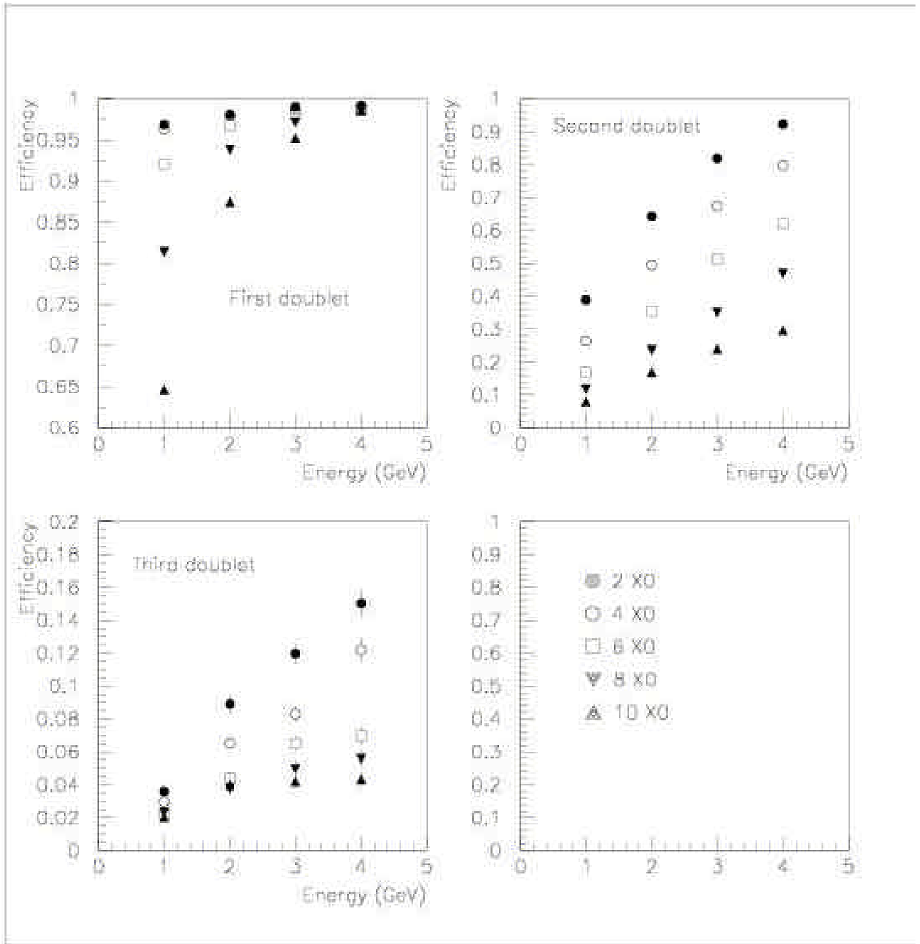


$8\ X_0$ (variable thickness brick)

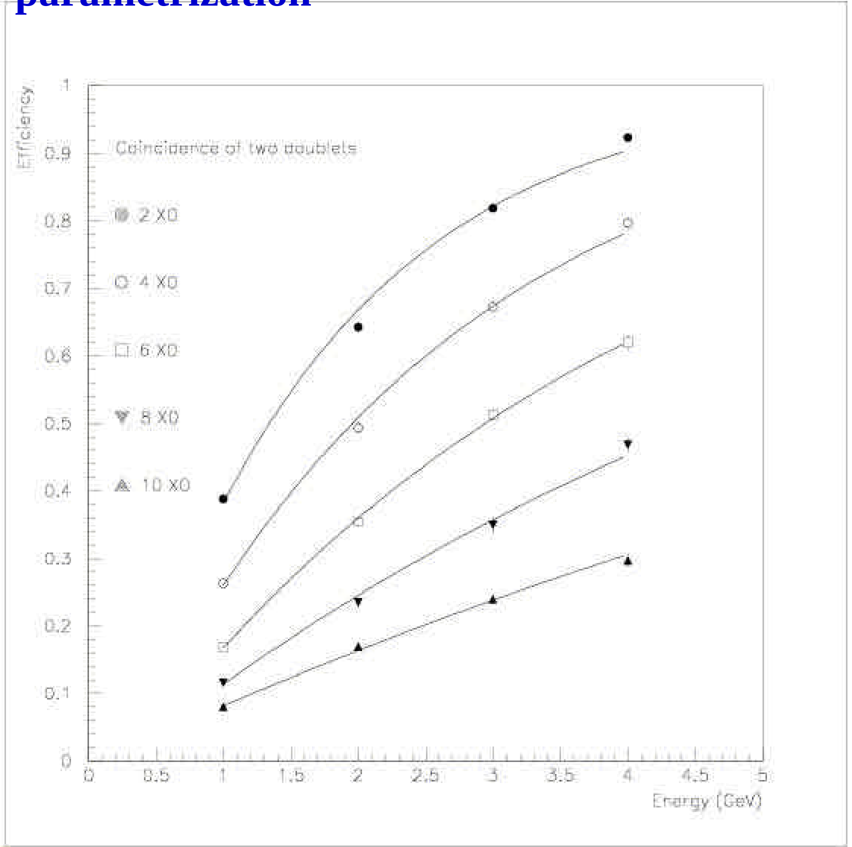


Response to electrons II

Probability of passing 1,2,3 walls as a function of the energy of the electron and its starting position in the first wall



Probability of crossing 2 walls as a function of the energy of the electron and its starting position in the first wall with superimposed curves from a global parametrization



Low energy electron trigger

By convoluting the parametrizations from test-beam data with the spectrum of electrons from tau quasi-elastic events:

- **62% of these events will leave a signal in two doublets of RPCs (background free with respect to the RPC noise)**
- **38% will leave a signal only in one doublet, these compete with the background**

The background can be rejected by requiring local coincidences in the doublet and by applying cuts on the pulse height and on the charge sharing on the strips

The goal is to keep the background below one trigger per day (taking into account the duty cycle of the neutrino spill)

A dedicated measurement was performed with the same setup used at the test-beam in the HALL B in Gran Sasso for a running time of 1 month.

Background measurement in Gran Sasso

- For each RPC setup an X-Y coincidence in order to select only signals coming from the central region completely covered by the lead bricks
- Setup two trigger schemes:

T1 OR of the 6 RPCs
T2 OR of the coincidences on the each of the 3 doublets

T1 is useful for the study of the singles and provides unbiased data sets including also the T2 events
T2 allows to concentrate on the events which look like the signal.

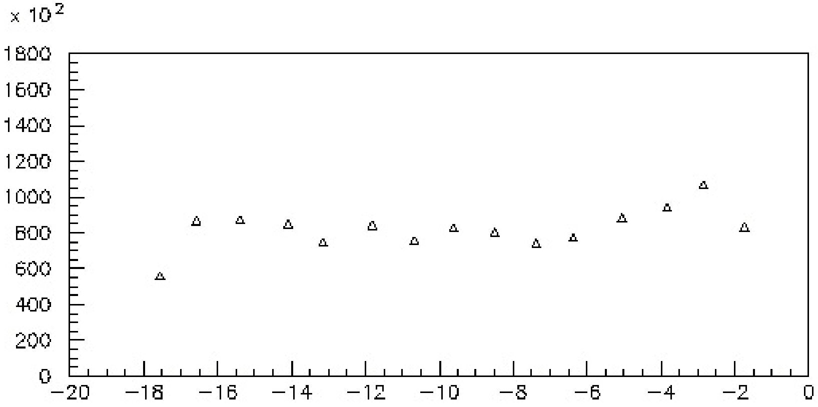
Typical trigger rates in the HALL B (at 97% efficiency for a m.i.p.) at a temperature of 15 degrees:

T1: 30 Hz/m2 (at CERN 800 Hz/m2)
T2: <0.1 Hz/m2

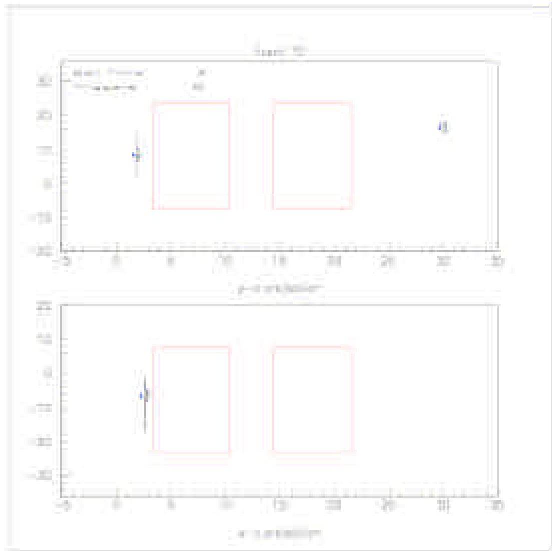
Given the T2 rate, the neutrino spill duty cycle (4×10^{-6}) and the differences in pulse height and shape between the T2 events and the signals from electromagnetic showers, the T2 events are not a problem: they imply the extraction of < 1 brick/day

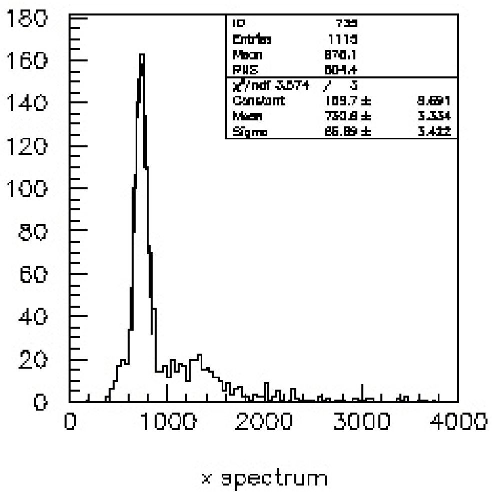
T1 events

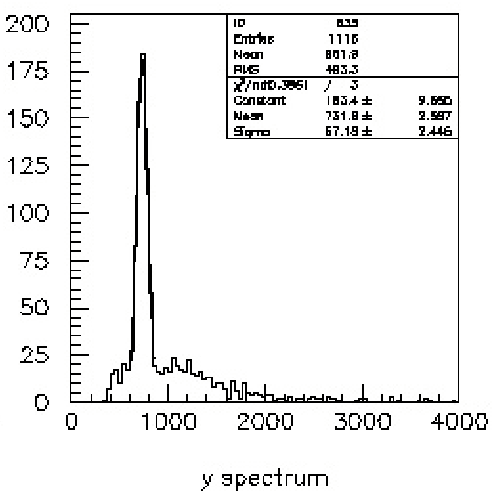
The trigger rate (pulse height weighted) is reasonably uniform on all the strips



Typical event





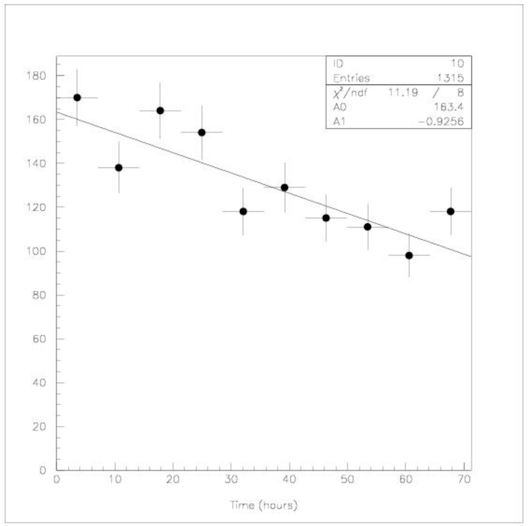


The spectra are very similar to those of m.i.p. measured at the test-beams.
It is a good handle for calibration under Gran Sasso!

T2 events

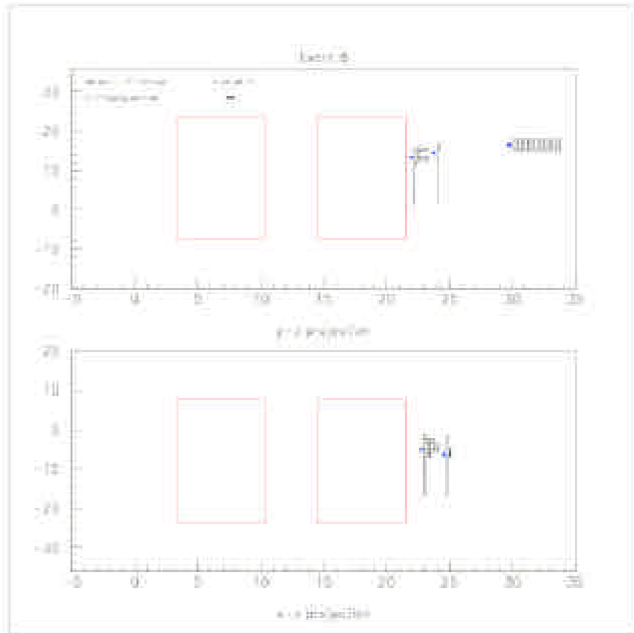
Studying the T1 events one can look for events with signals one more than one RPC:

given the low T1 rate accidental coincidences are very rare and indeed one ends up only the T2 events which are locally correlated within a doublet

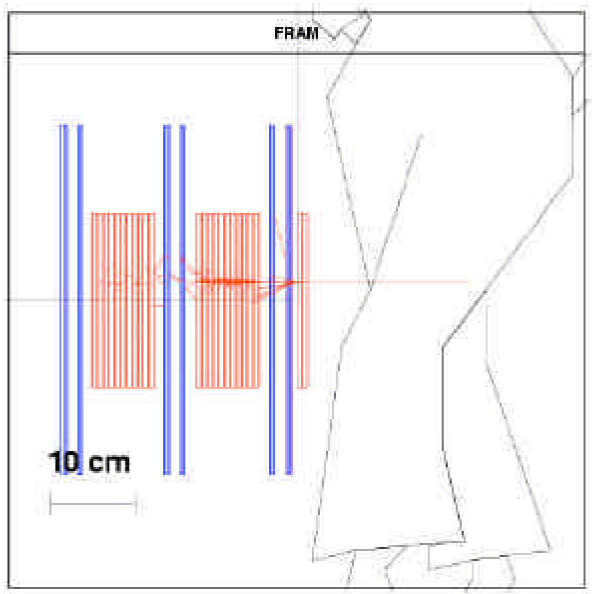


The T2 rate was not constant with time, in particular decreasing during the weekend.
Some correlation found with the parallel Radon measurements (Bi^{214} one of the Radon daughters decays one hour after the Rn decay emitting a 3.3 MeV electron)

Typical T2 event



The simulation



In order to develop a reliable simulation we setup a full Geant 3 simulation of the test-beam setup

The simulation of the RPC was performed by assigning to each Geant charged particle signals taken from the parametrizations of the test-beam results obtained with m.i.p. (spectra, charge sharing, angular effects, etc..)

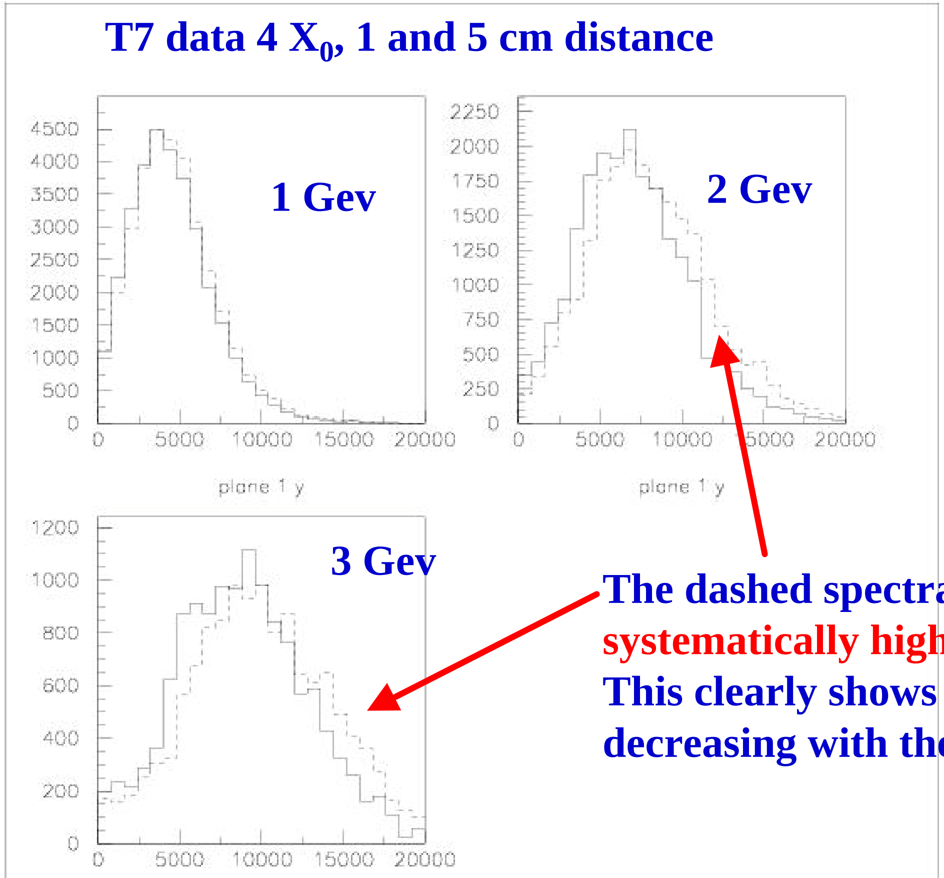
The test-beam data taken with electromagnetic showers are then a good benchmark to check the simulation

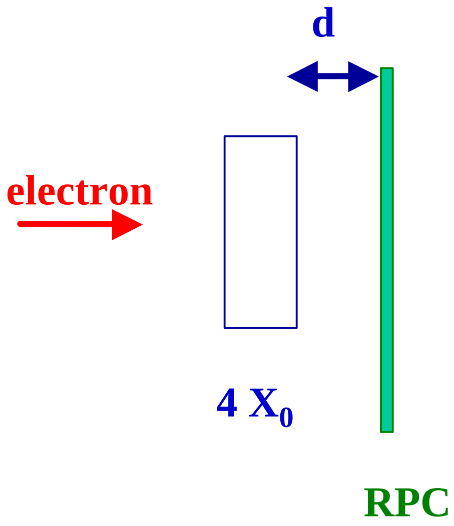
The only free parameter of the simulation is the size of the interdiction region.

Simple idea already reported in the literature for the simulation of the calorimeters readout with streamer tubes:
If two particles are closer than the size of the interdiction region they will produce only one streamer

The method can be tested experimentally by changing the density of particles in a shower while keeping the electron energy and the thickness of the absorber constants but increasing the distance between the RPC and the absorber.

The simulation II





Change d from 1 to 5 cm

The dashed spectra obtained with a distance of 5 cm are systematically higher than the solid ones (1 cm)
This clearly shows the effect of the interdiction region decreasing with the lower density

Given the parametrization of the m.i.p. response from the data and a radius of the interdiction region tuned at 2.5 mm the simulation is able to reproduce all the data of electromagnetic showers at better than 10%: spectra, shapes, density effects for any configuration of electron energy and thickness of the absorber in front of the RPC.
The size of the interdiction region is also in agreement with the angular measurements which do not show an increase of the double showers up to 50 degrees.
This simulation method was hence implemented in a full simulation of the OPERA RPC target tracker

Conclusions

- **The test -beam results show the validity of the RPC option or the target tracker**

- **The good space resolution and angular resolution, when incorporated in a full OPERA simulation result in a better brick finding efficiency and muon tracking than in case of the scintillator option**

- **By using two RPC planes per wall the capability of triggering on single low energy electrons is not worsened by the noise**

But:

Despite the fact that compared to scintillators RPC have better performance, and have some advantages in the construction and installation ….
Given that OPERA Spectrometers + Target Tracker would have implied the construction of 11000 m^2 of RPC and given the uncertain situation of congestion at G.T….

The collaboration decided to build the Target Tracker with the scintillator strips which are considered a safer and more traditional technique

We enjoyed a lot anyway the R&D we did on this unusual application of the RPC in a tracking calorimeter. It allowed us to gain experience also for the application of the RPC in the inner tracker of the OPERA spectrometers.