A large area TOF-tracker

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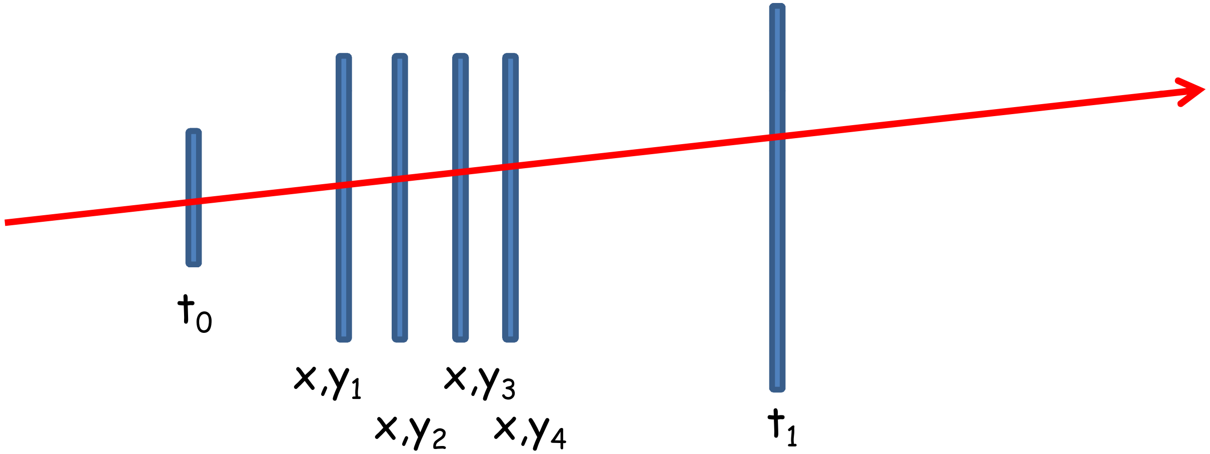
Outlook.

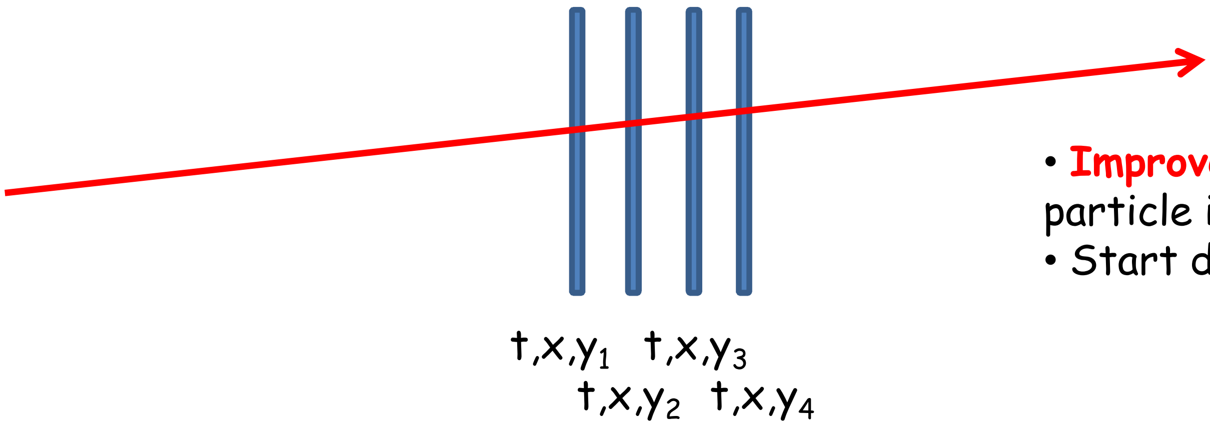
- Motivation.
- Setup description.
- Performance evaluation.
  - Efficiency
  - Time precision
  - Position precision

Motivation.

Identification of particles by **time-of-flight** relies on the accurate measurement of the flight path by **tracking detectors** and on the measurement of the **flight time** by dedicated start and stop detectors. These tasks are normally performed by detectors specialized for each task.



but there may be **advantages in performing the measurements by detectors capable of performing both tasks simultaneously**



- **Improved time precision** (each particle is measured several times)
- Start detector **t_0 not needed**.

Motivation.

But also can be used for:

- Precise measurement of single cosmic rays: **muon tomography**
- **Station for detector testing**

Expected performance

- Time precision ~ 100 ps.
- High efficiency > 99%.
- 2D sub-millimeter spatial precision.
- Readout by few channels ~ 50 channels/layer.
- Limited multi-hit capability

Previous work. RPC2012

TOFtracker: gaseous detector with bidimensional tracking and time-of-flight capabilities

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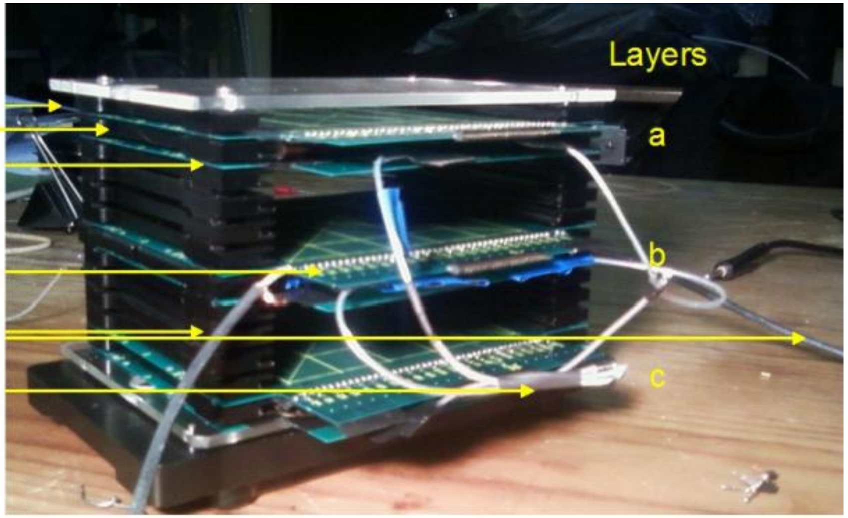
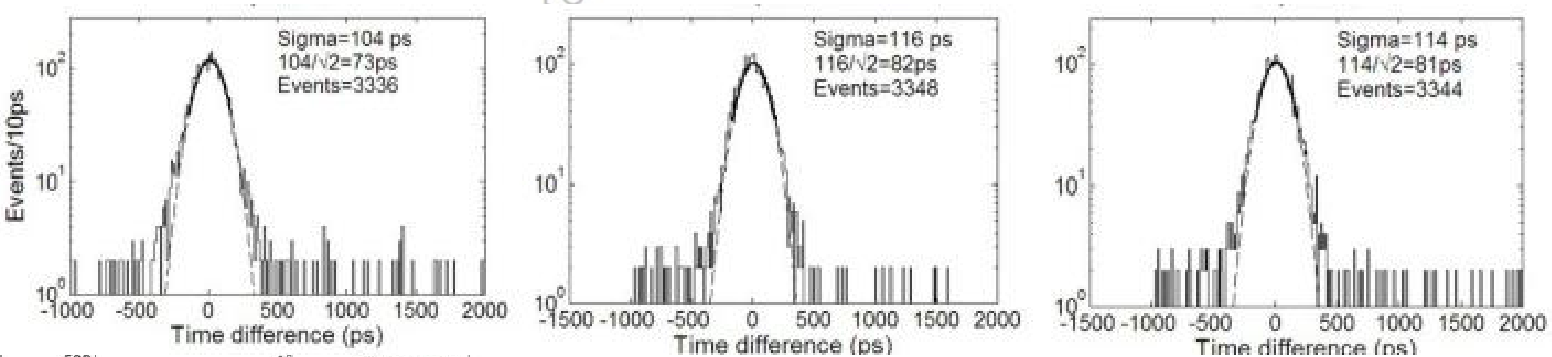
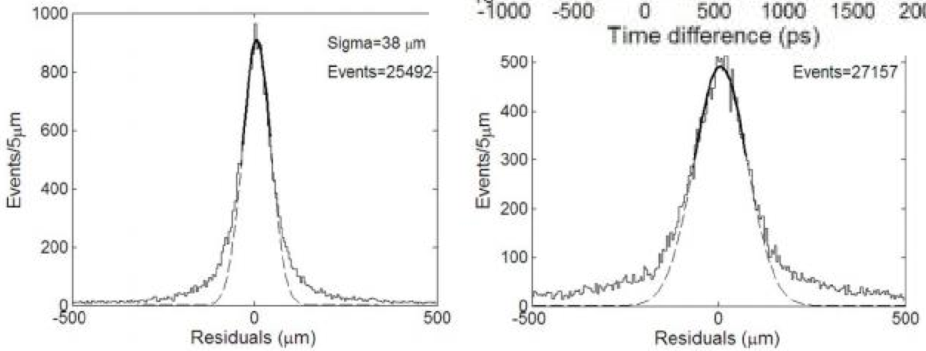
$80 \times 80\ mm^2$

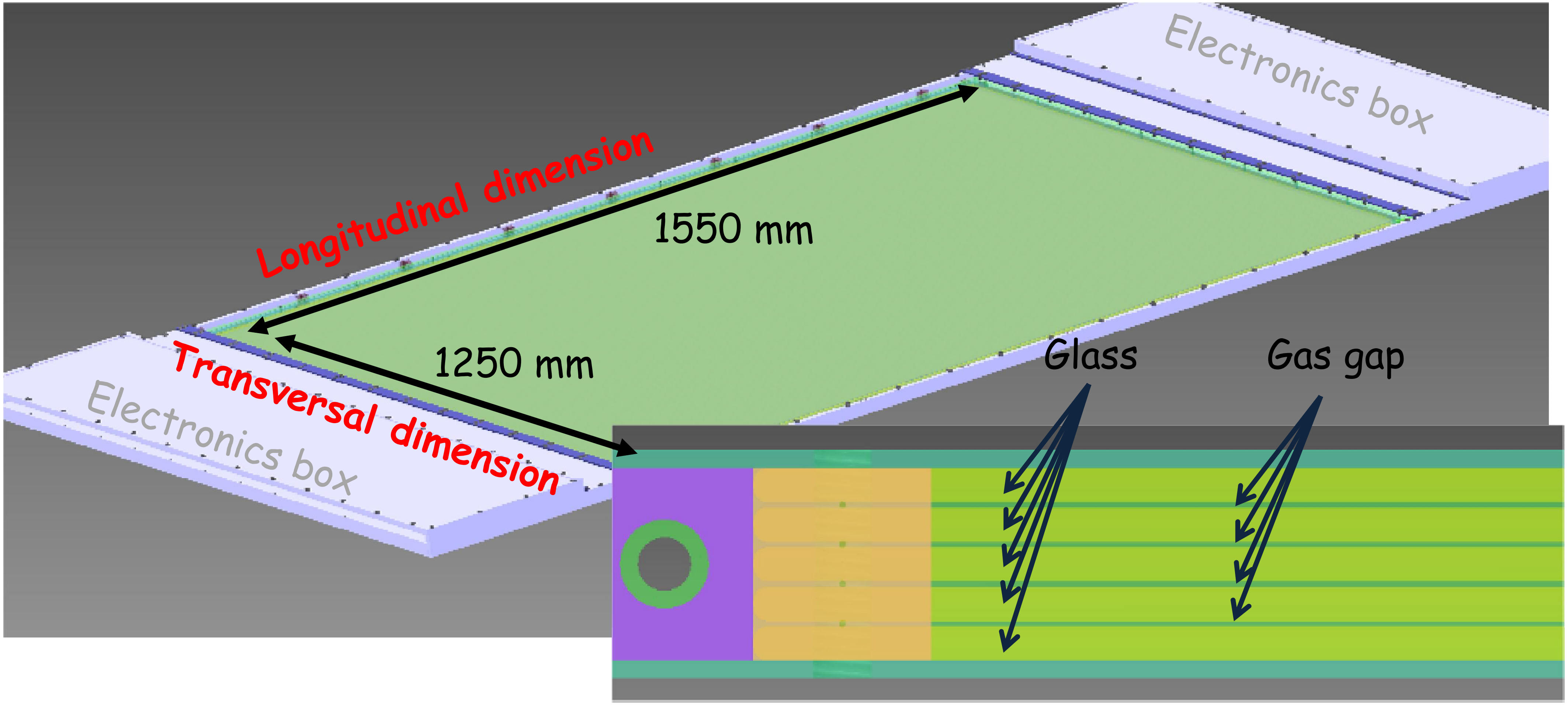






Single layer precision = 77 ps σ 38 μm σ

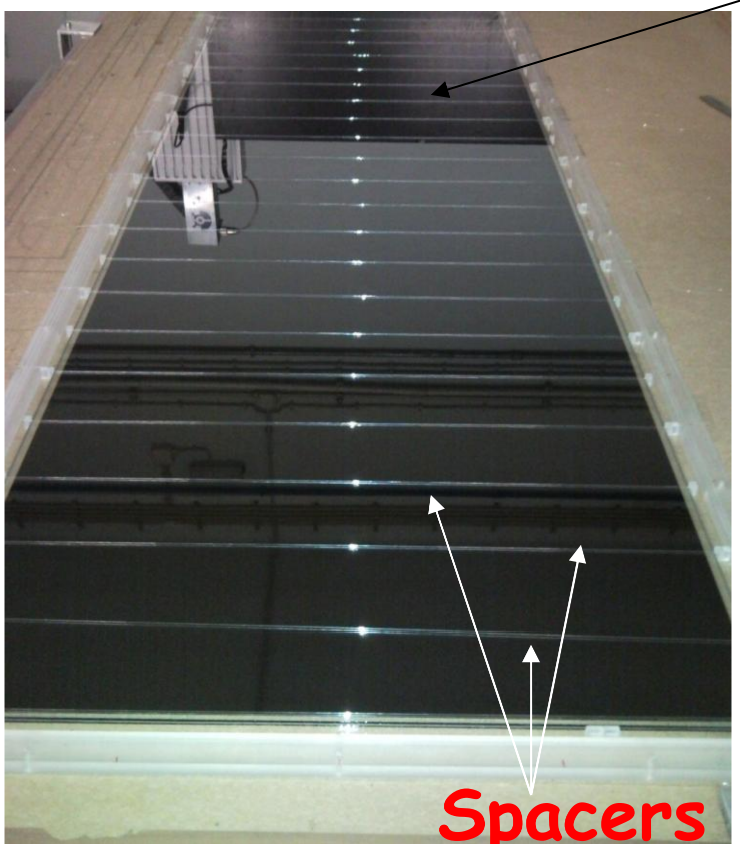
Setup: Description. RPC Sensitive Volume.

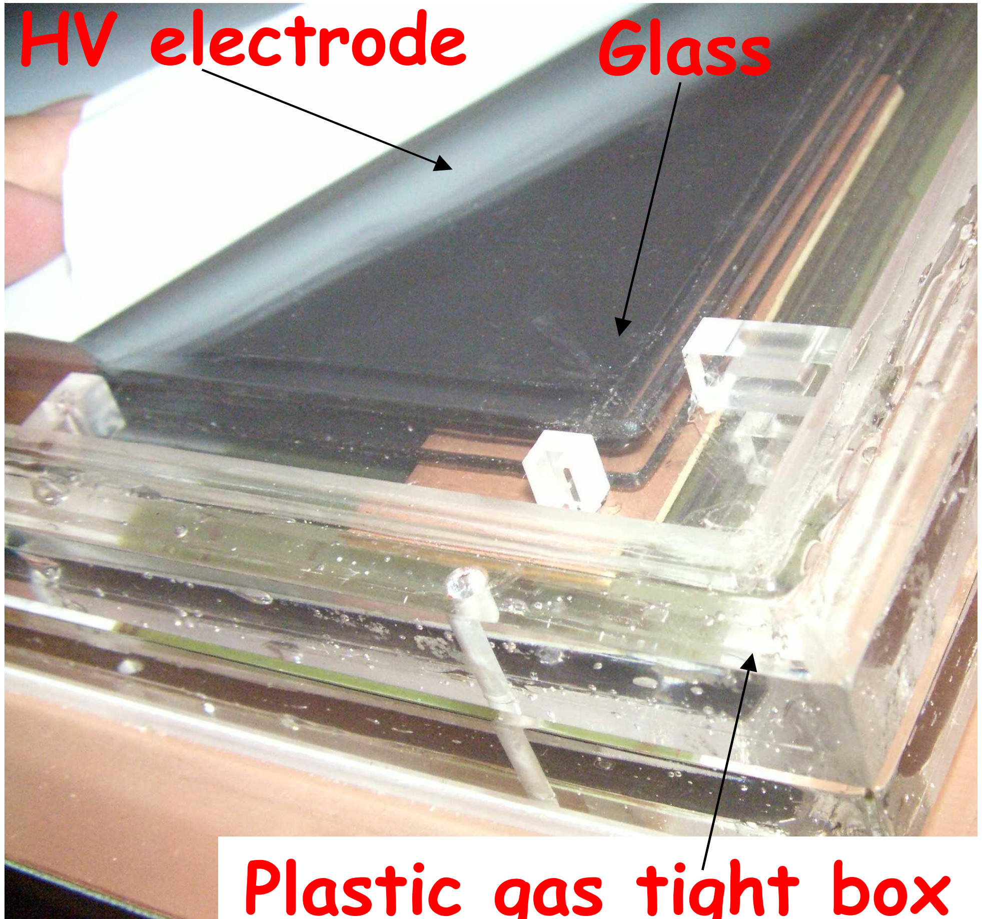


Size **(~1550 x 1250 mm²), 4 x 0.3 mm gas gaps** assembled in **multi-gap** configuration

Setup: Description. RPC Sensitive Volume.

The RPC sensitive volume was built based on modules. A module contains the glass and HV electrodes enclosed in a plastic gas tight box with feed-throughs for gas and High Voltage.



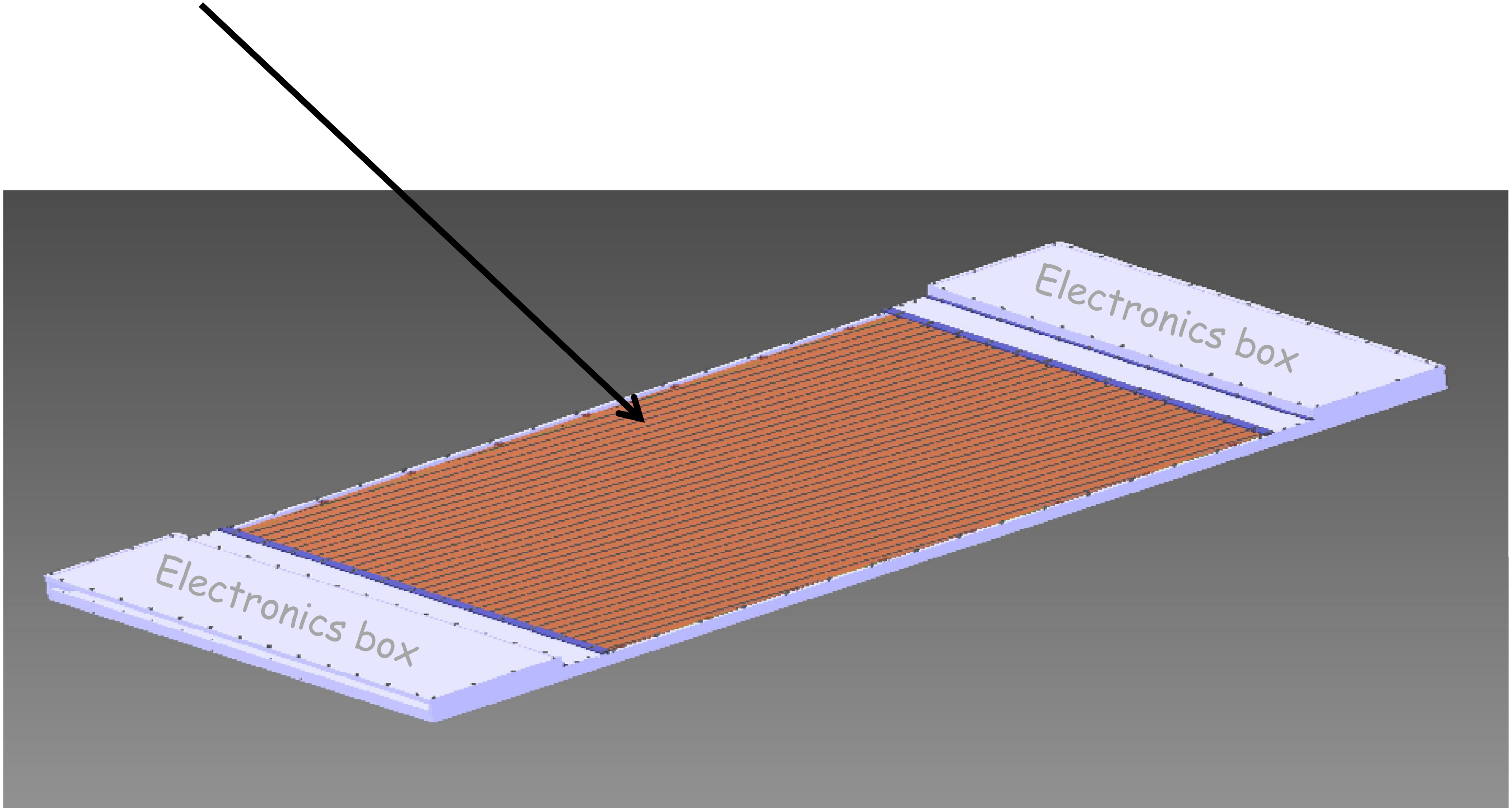


Gaps are defined in between **2 mm soda-lime glass electrodes (~10^{12} Ωcm)**

Operated in open gas loop **in pure Freon** $C_2H_2F_4$.

Setup: Description. RPC signal readout. Anode.

Signals are readout in both anode and cathode.
ANODE. 2.3 mm (2.5 mm pitch) longitudinal strips.



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Signals are readout in both anode and cathode.

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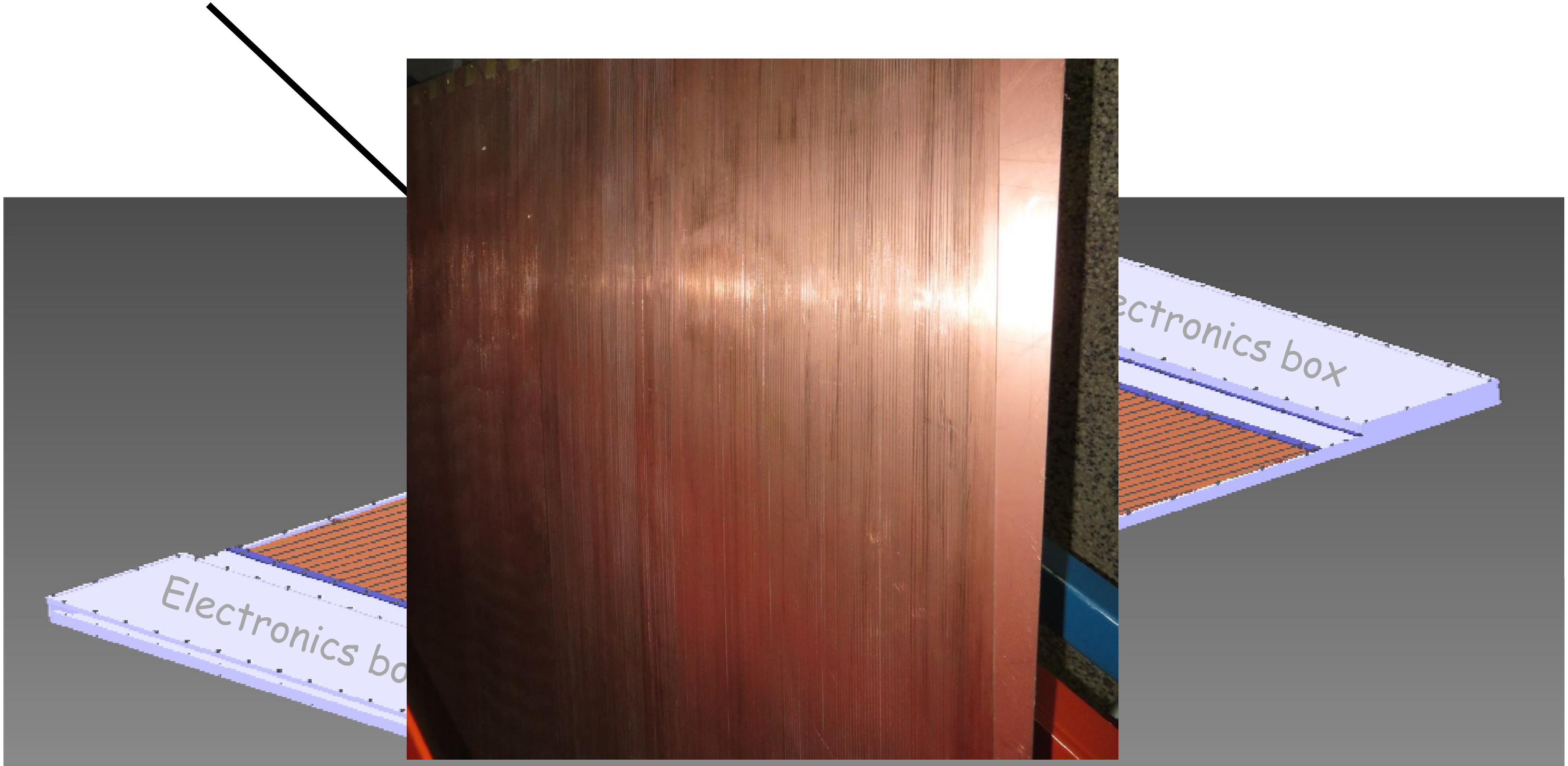


Printed Circuit Board detail

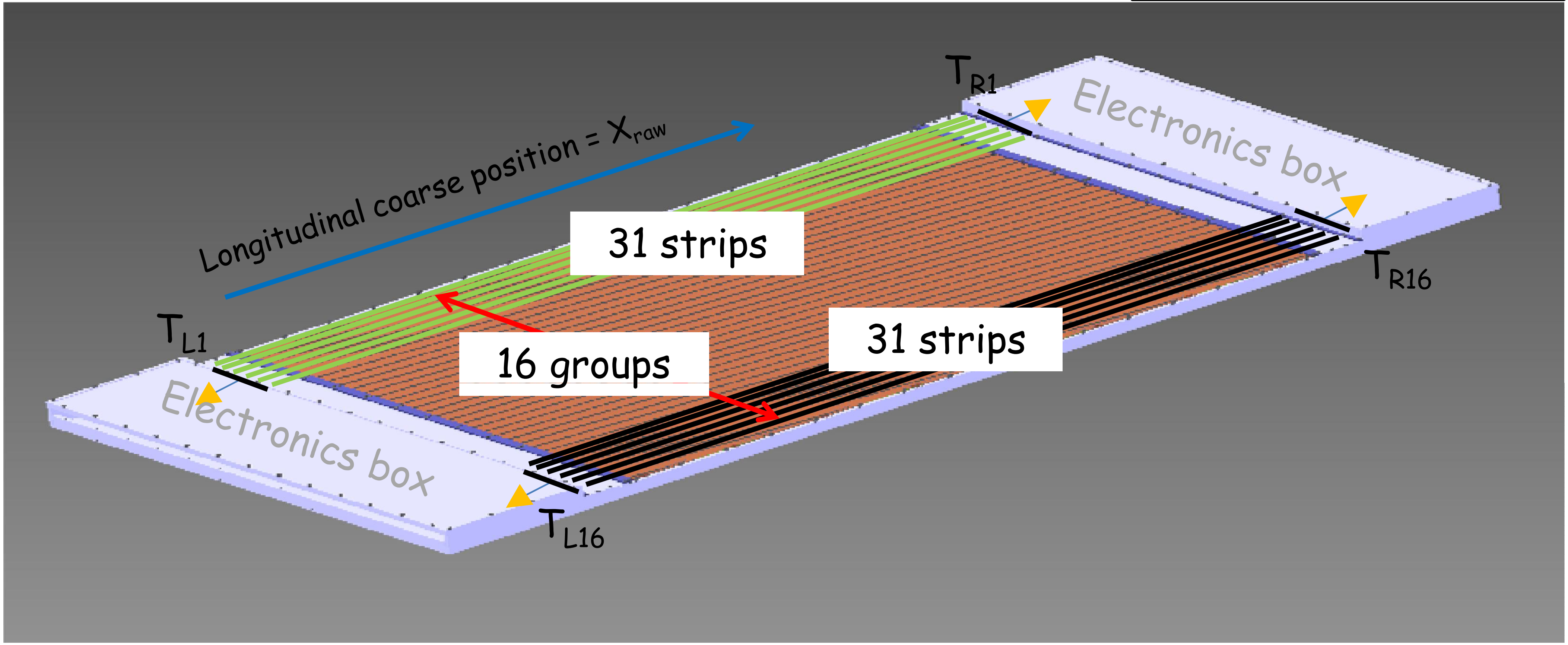
Setup: Description. RPC signal readout. Anode.

Signals are readout in both anode and cathode.

ANODE. 2.3 mm (2.5 mm pitch) longitudinal strips.

- **Time is readout** at both ends in 16 groups of 31 strips
  - => **Longitudinal coarse position, X_{raw}**
  - => **Time, T**

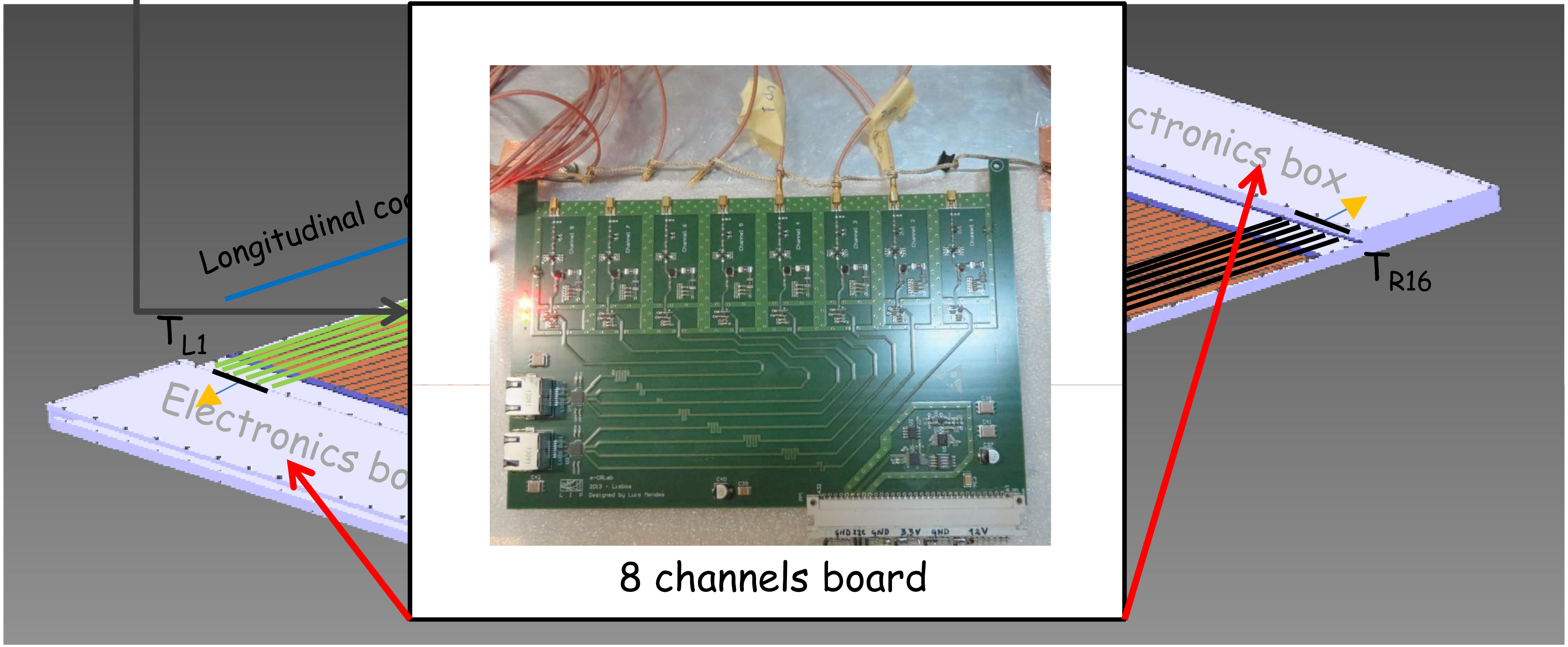
$$X_{raw} = T_L - T_R$$
$$T = (T_L + T_R)/2$$



Setup: Description. RPC signal readout. Anode. Timing FEE.

Timing signals are readout by **fast amplifiers + comparator** 32 ch/layer

The outputs of one on every four channels are added together and sent to the DAQ → Only 4 ch/layer are sent to the DAQ



8 channels board

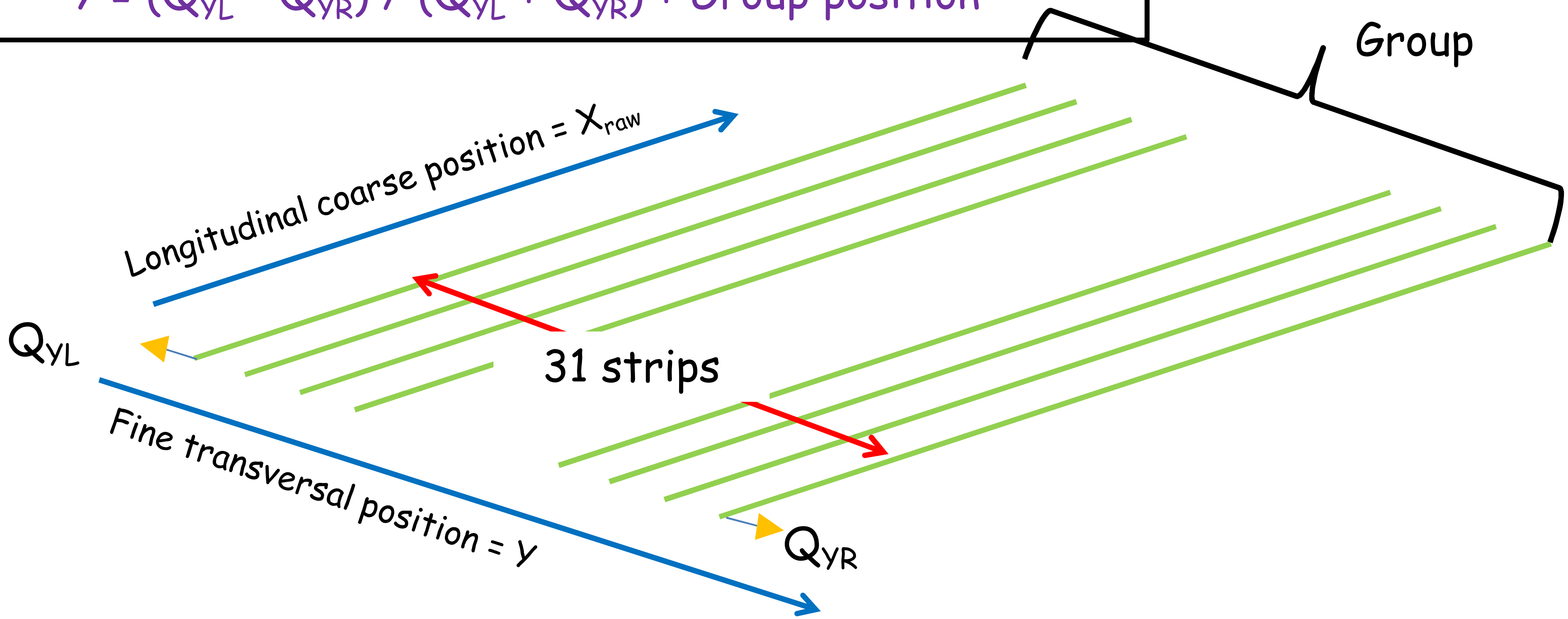
Setup: Description. RPC signal readout. Anode.

Signals are readout in both anode and cathode.

ANODE. 2.3 mm (2.5 mm pitch) longitudinal strips.

- **Time is readout** at both ends of groups of 31 strips
  - => **Longitudinal coarse position.**
  - => **Time**
- **Charge is readout** in each group of 31 strips (charge division).
  - => **Fine transversal position.**

$$Y = (Q_{YL} - Q_{YR}) / (Q_{YL} + Q_{YR}) + \text{Group position}$$

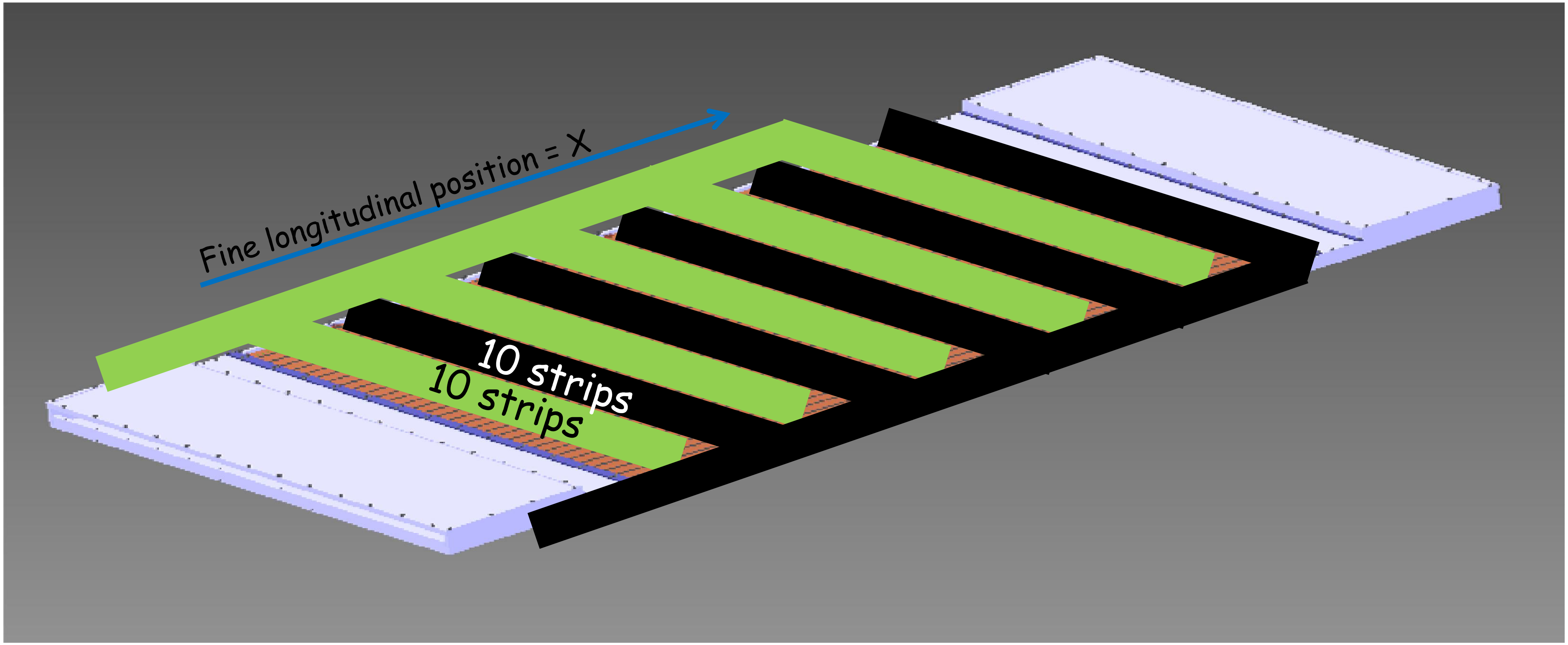


Setup: Description. RPC signal readout. Cathode.

Signals are readout in both anode and cathode.
CATHODE. 2.3 mm (2.5 mm pitch) transversal strips

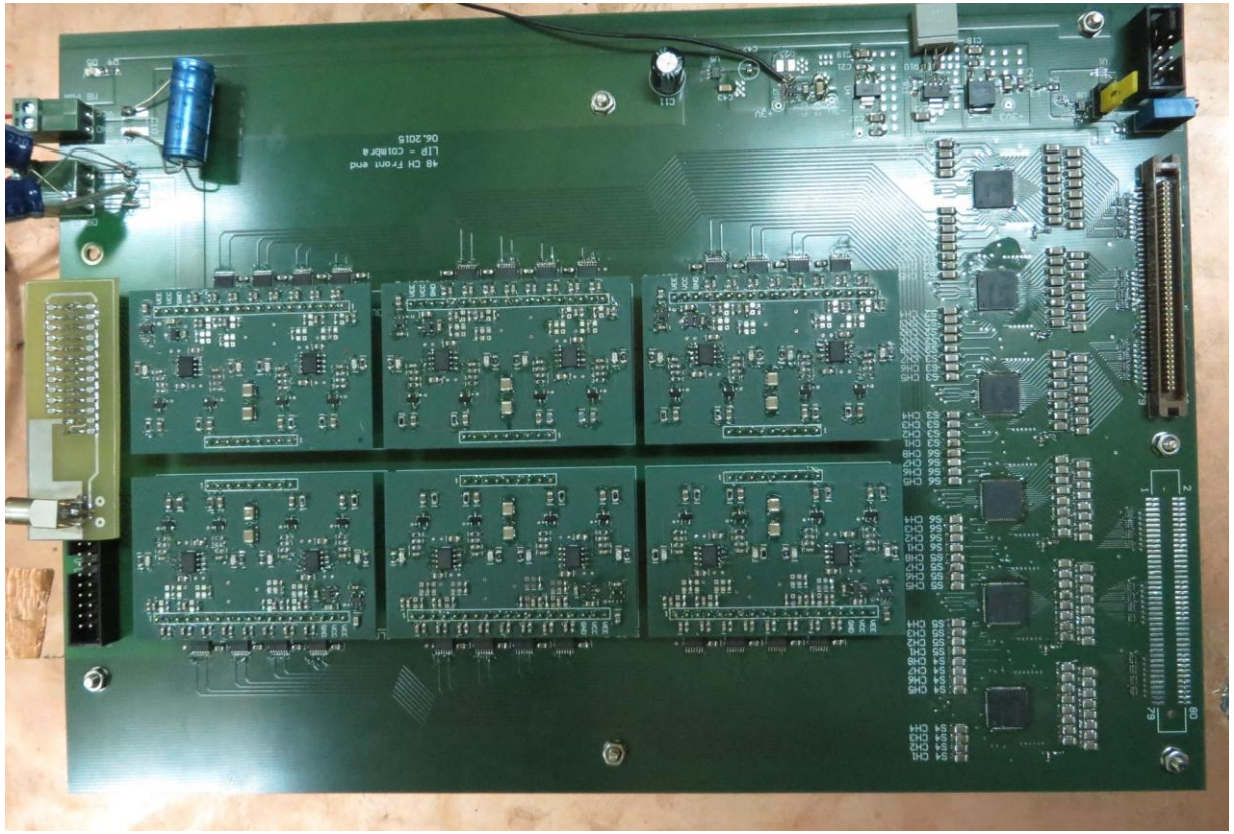
- Charge is readout in each group of 10 strips (charge division) .
  Readout in parallel in two groups
  => Fine longitudinal position.

$$X = (Q_{XL} - Q_{XR}) / (Q_{XL} + Q_{XR}) + X_{raw}$$



Setup: Description. RPC signal readout. Anode & cathode. Charge FEE.

Charge signals are readout by **charge sensitive amplifiers**. 17 + 4 ch/layer

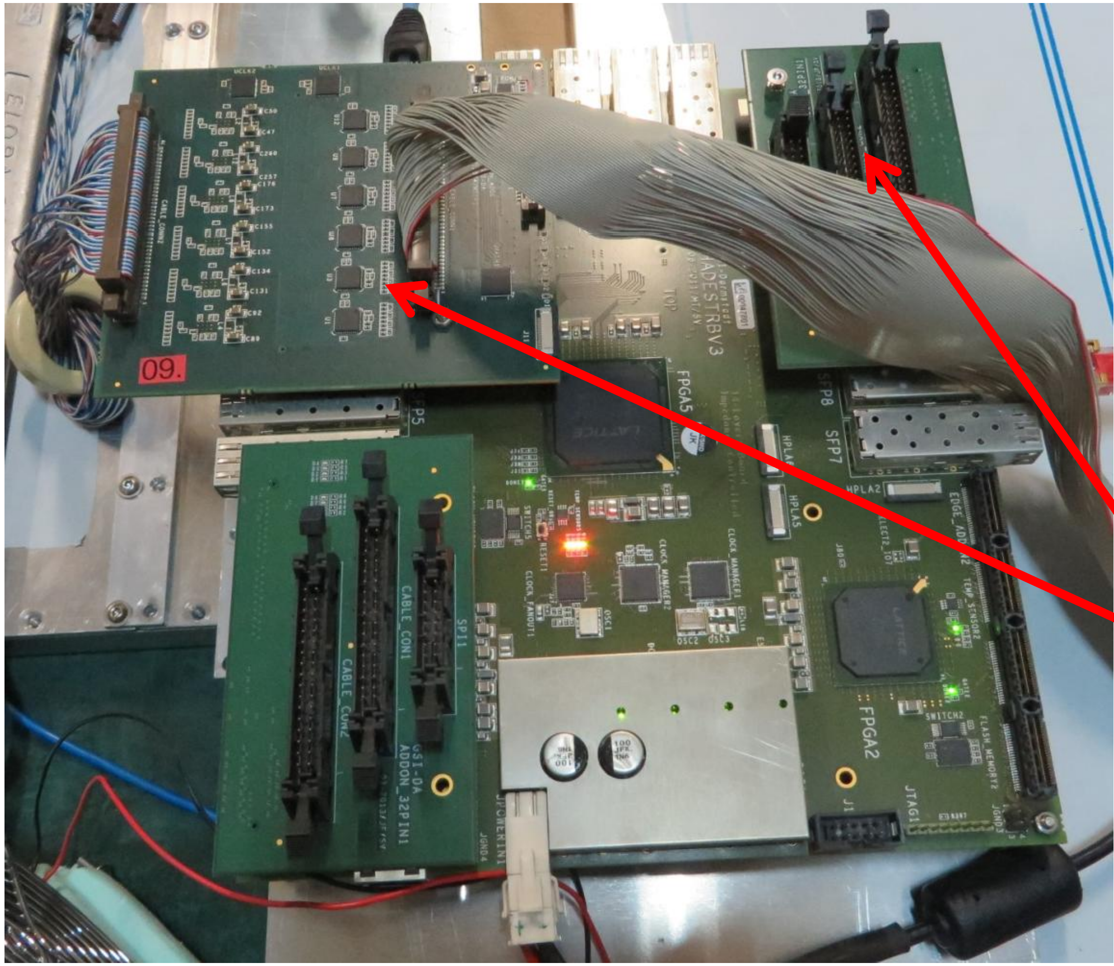


MB with 6 x 8 channels DB => 48 Channels.
Differential output

Each layer is equipped with a MB and 24 channels.

Setup: Description. DAQ.

DAQ is based in the new **TRB3** platform developed by the TRB collaboration (http://trb.gsi.de/)



One central FPGA with trigger management capabilities plus 4 sockets with capability to operate.

- 64 Multi-hit TDC
- 48 ADCs channels @ 40 MHz

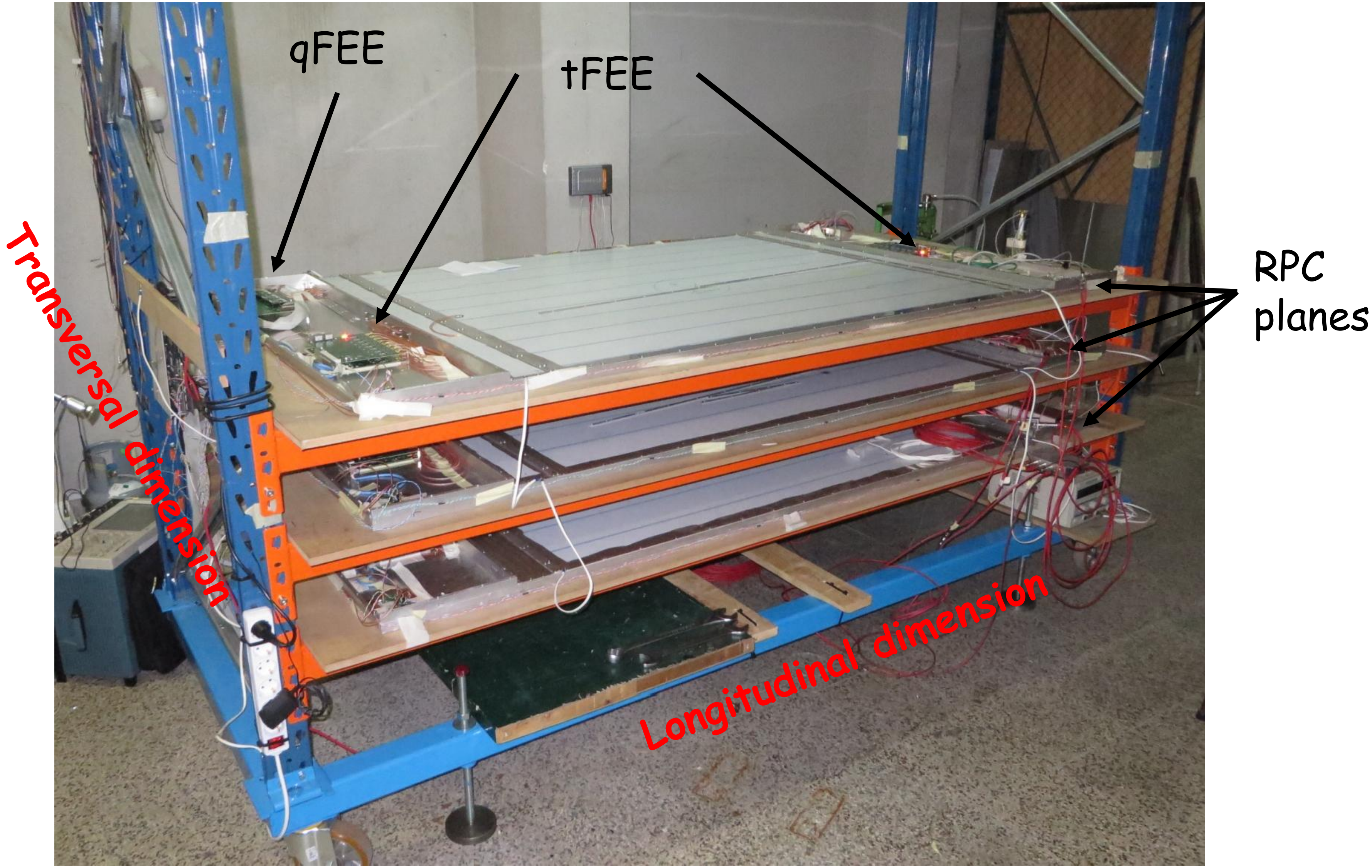
And much more

A Neiser *et al* 2013 JINST **8** C12043
doi: 10.1088/1748-0221/8/12/C12043

Whole system readout
- 21*3 charge sensing channels
- 4*3 timing channels.

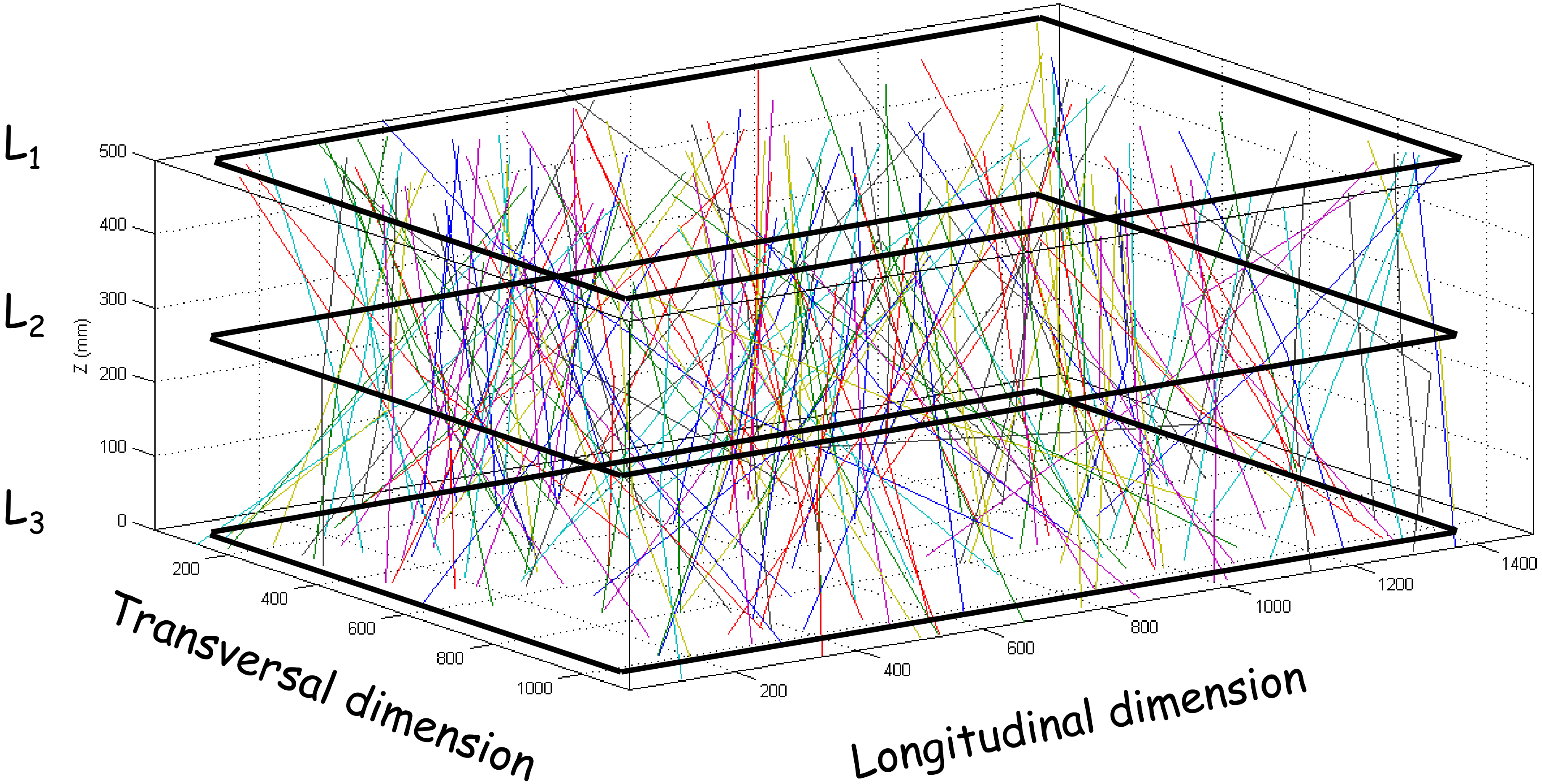
→ 75 ch

Setup. Current status.



Three layers completely equipped

Analysis. Event selection.



Sample of muon tracks. Events selection

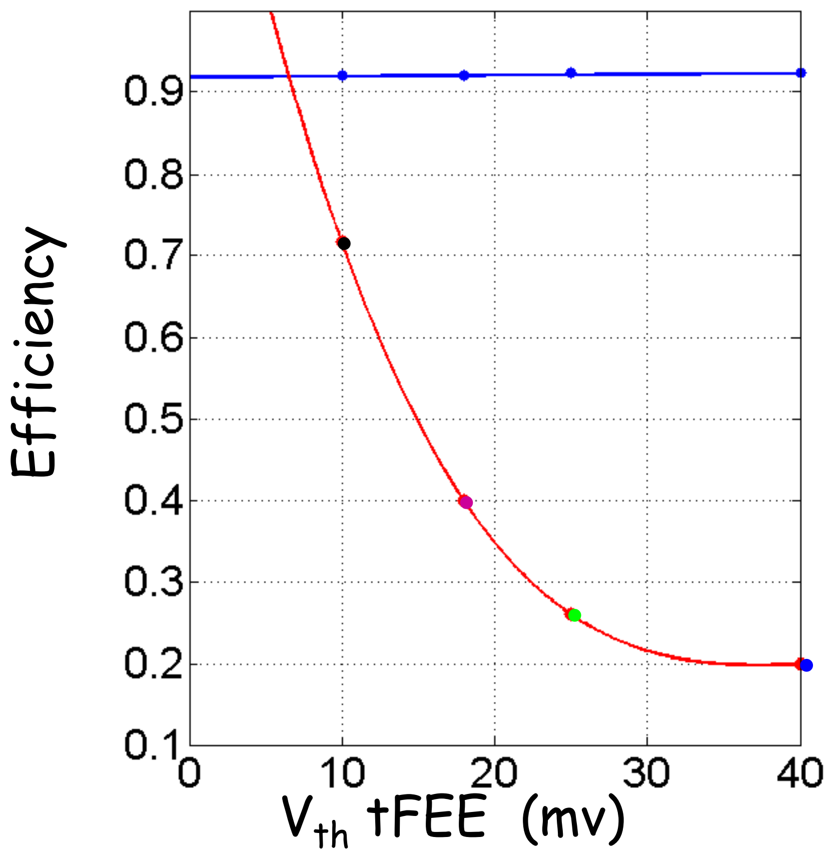
Events with **time information** (left & right) and **only one muon** in the effective area => multiplicity 1.

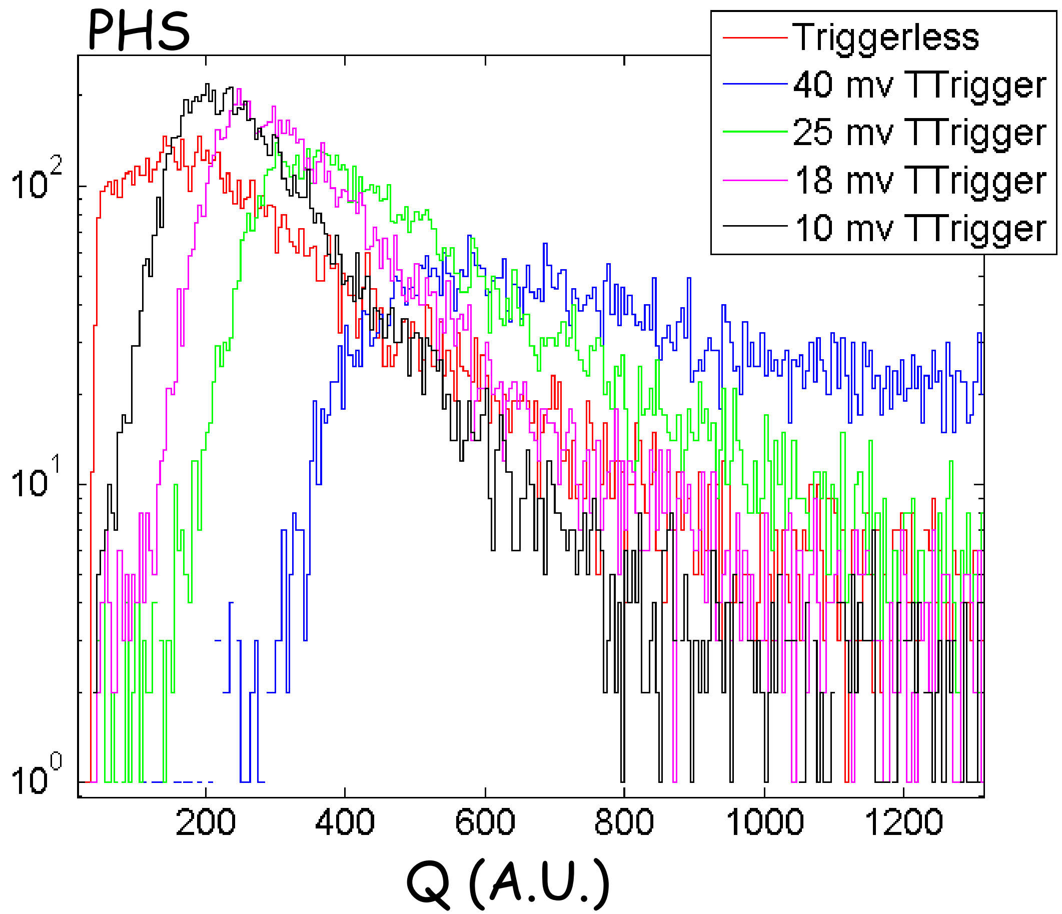
Full effective area is used in the analysis.

Basic alignment performed by hand.

Efficiency.

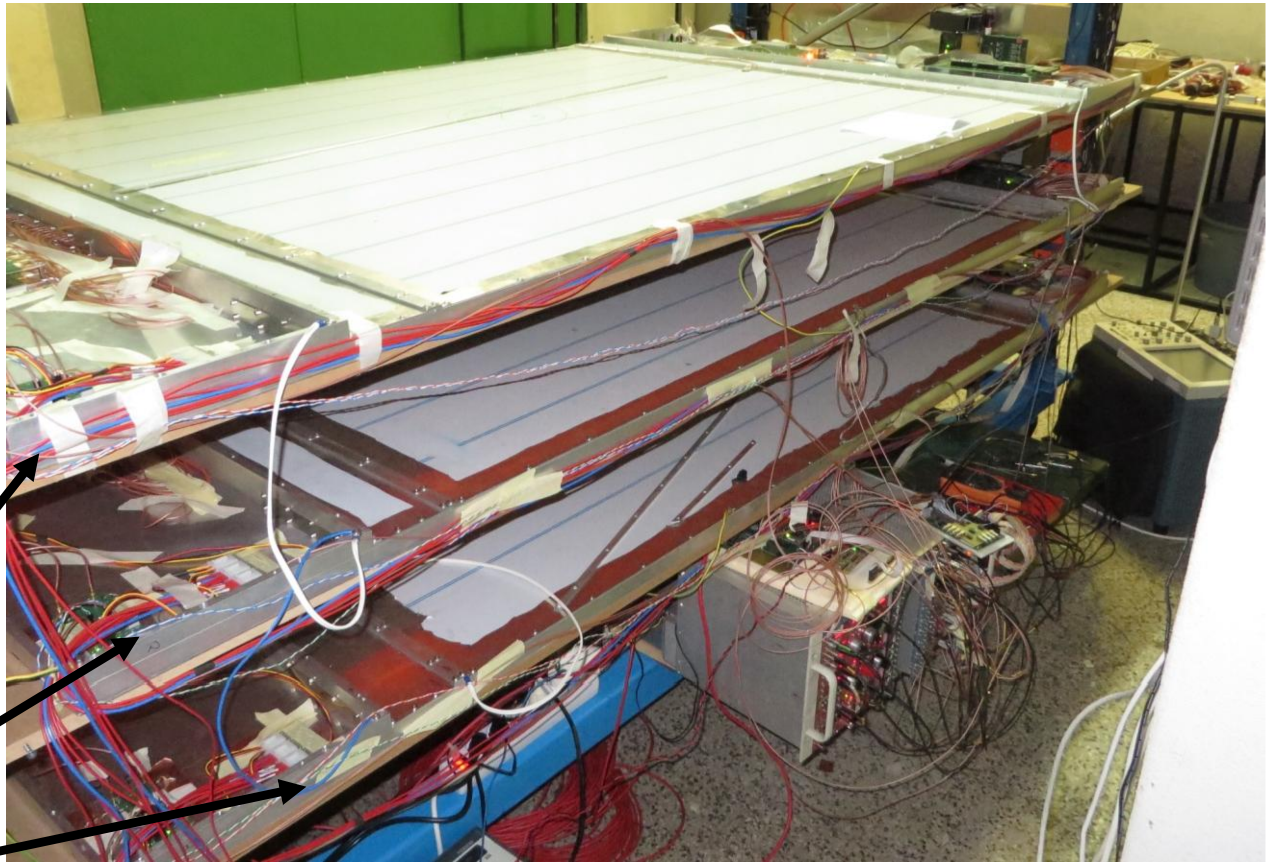
- Q_{eff}, calculated from the charge signal.
- T_{eff}, calculated from the timing signal.





Timing channels (tFEE) are less sensible that charge channels (qFEE).
We need to decrease V_{th} tFEE . 5 mV is possible but system is instable
=> improving system stability

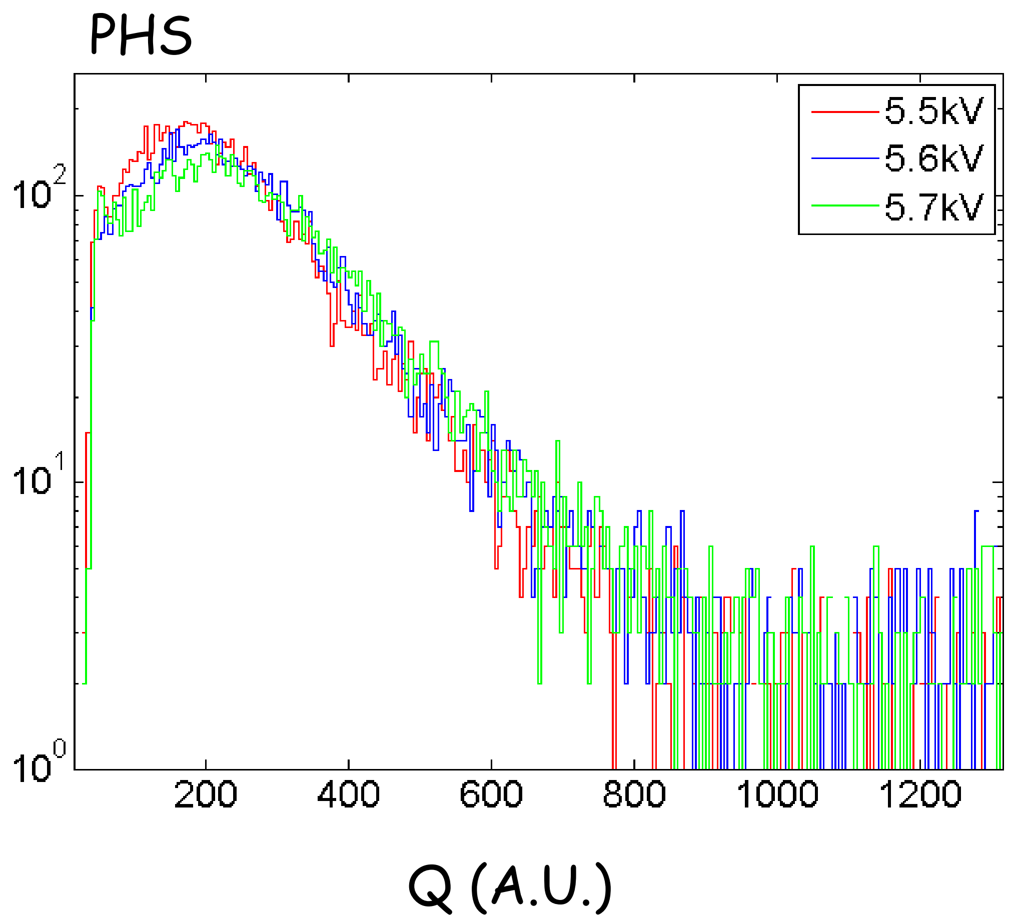
Efficiency.

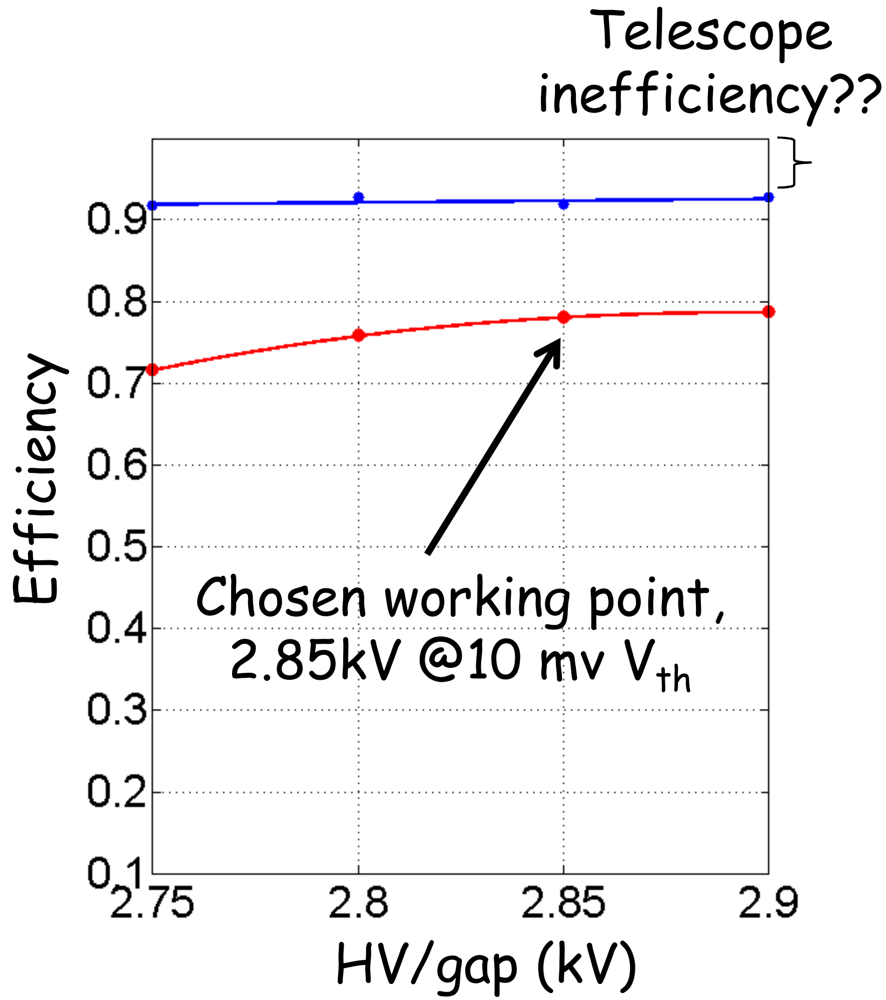


•Cable optimization, mainly LV distribution
• Grounding
• FEE cover installation

Efficiency.

- Q_{eff}, calculated from the charge signal.
- T_{eff}, calculated from the timing signal.





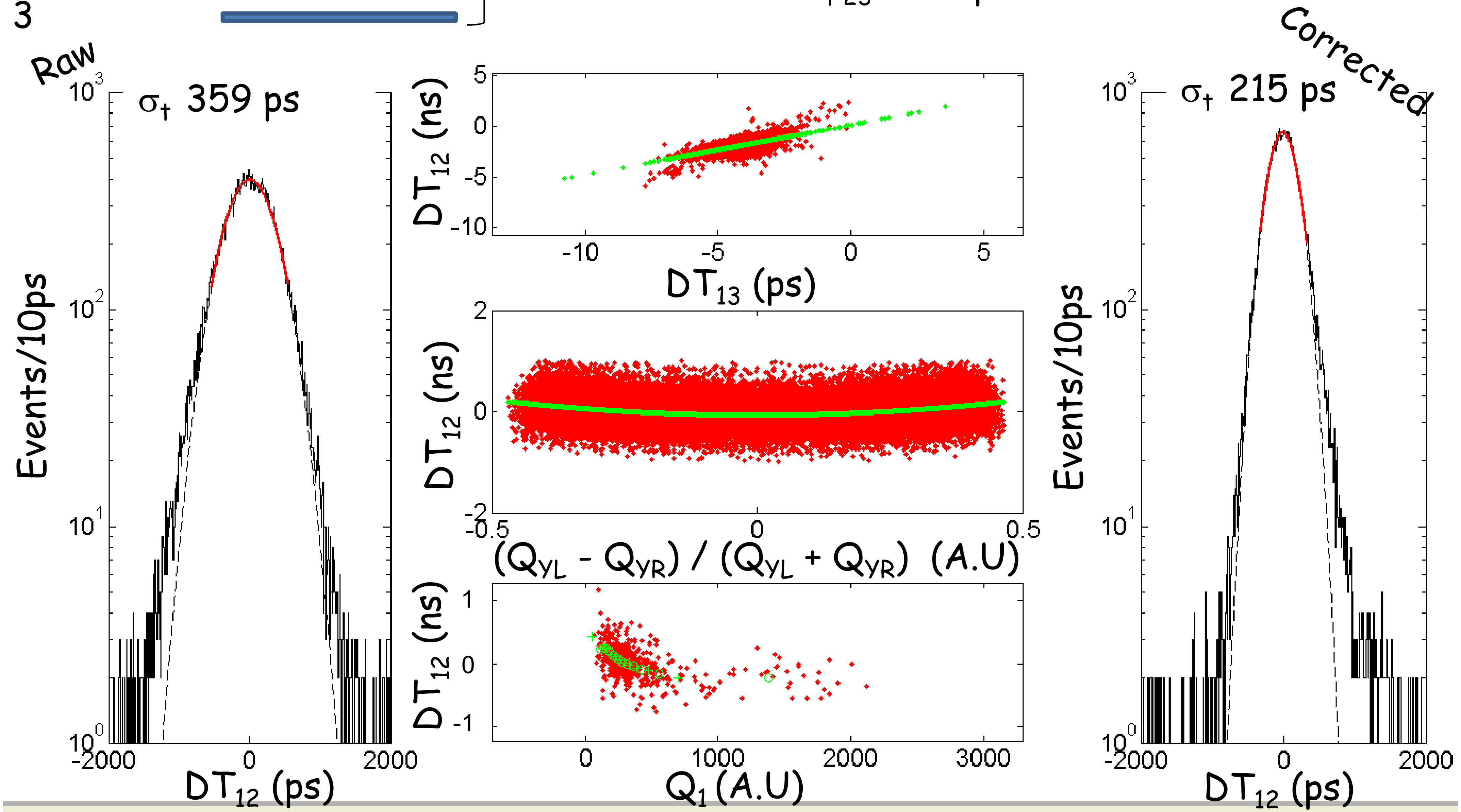
92 % efficiency on the qFEE does not depend on HV

Time precision.

Preliminary results

$\sigma_{t\,12}$ ~215 ps
$\sigma_{t\,23}$ ~213 ps

~214/√2=152ps



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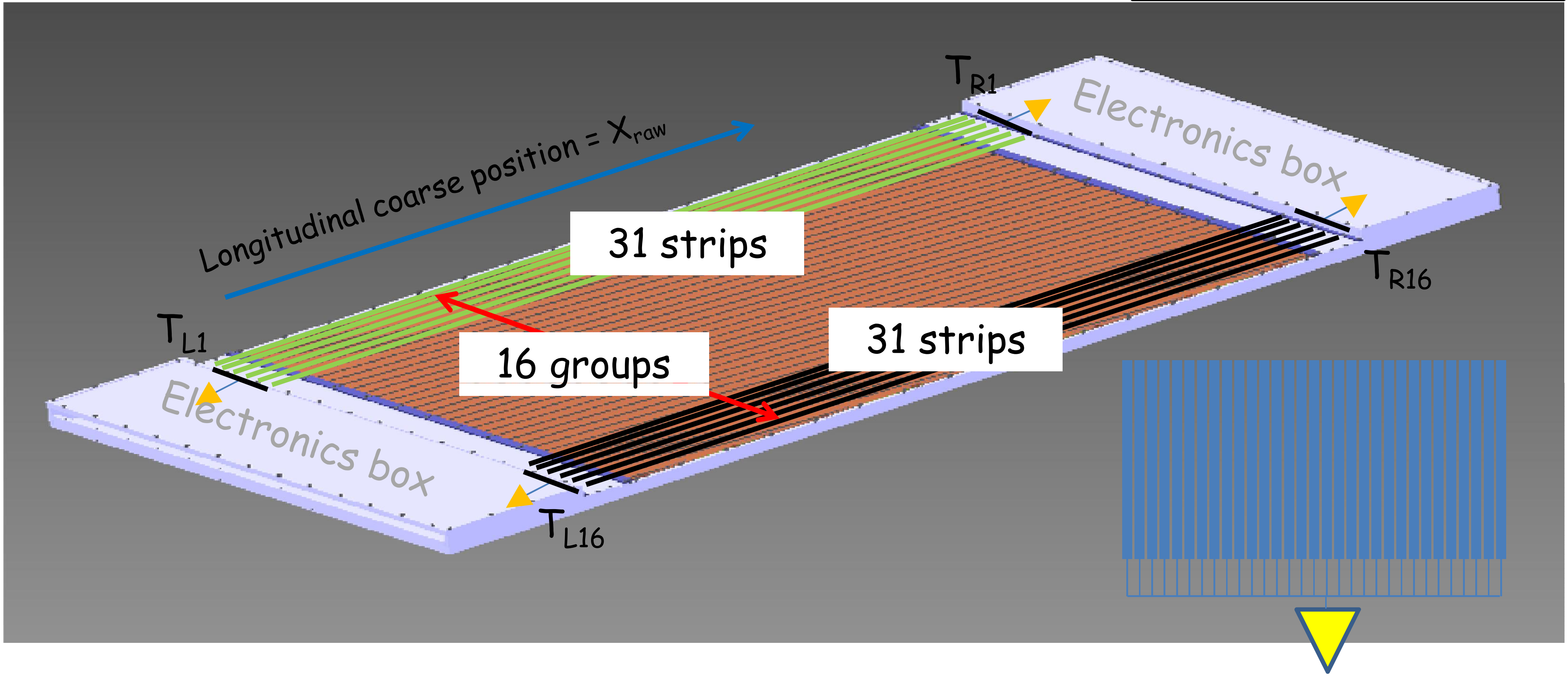
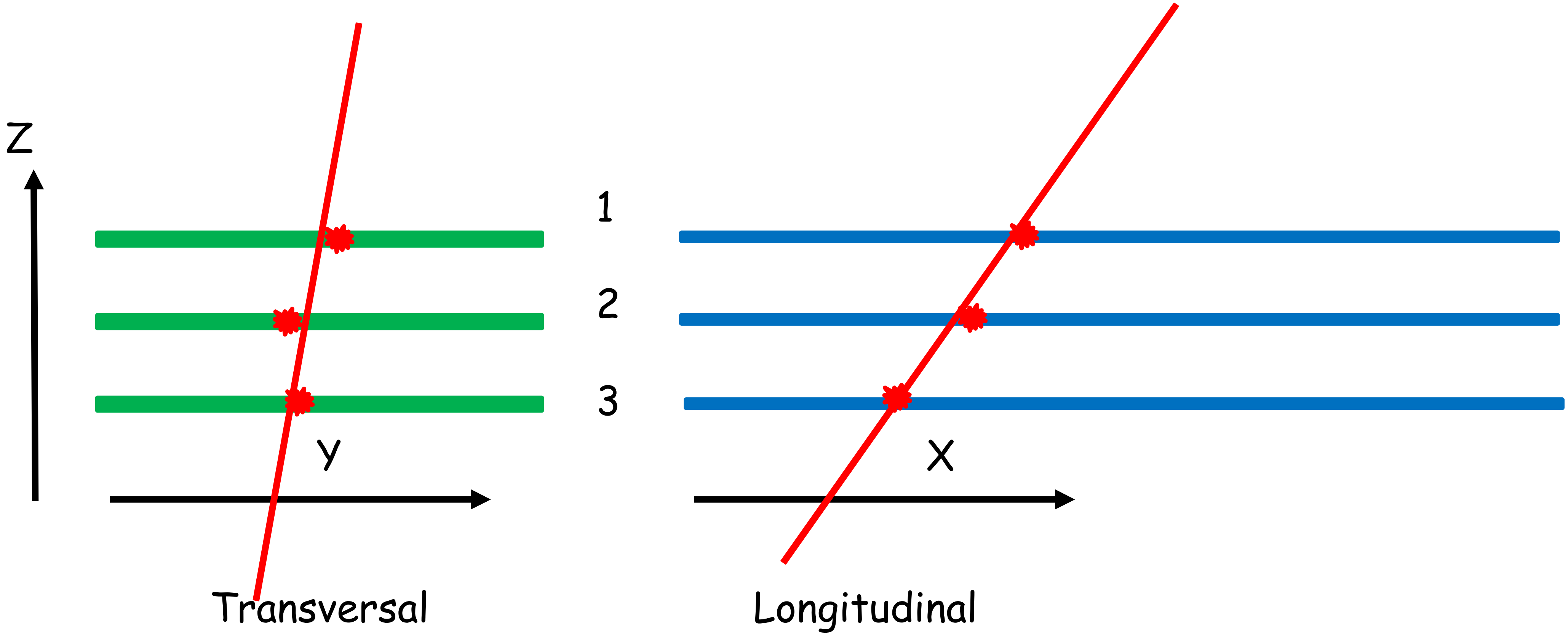


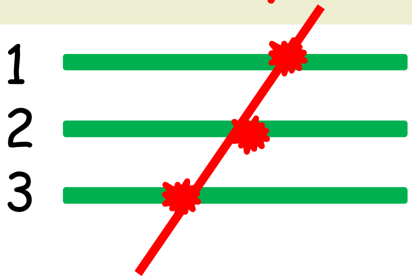
Position precision.

Residuals = difference between the measured value and the predicted value from a linear fit

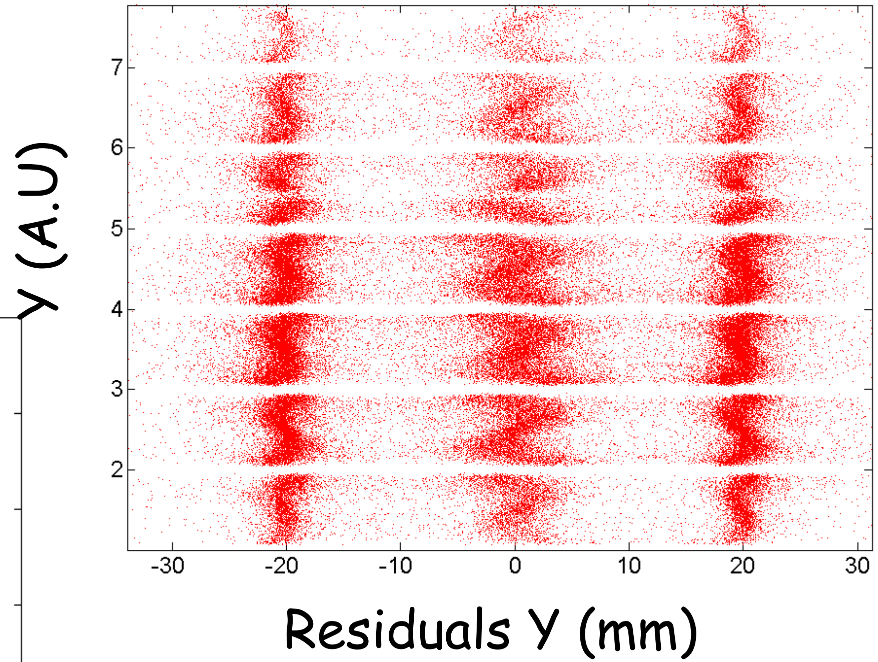


Position precision (transversal, short dimension).

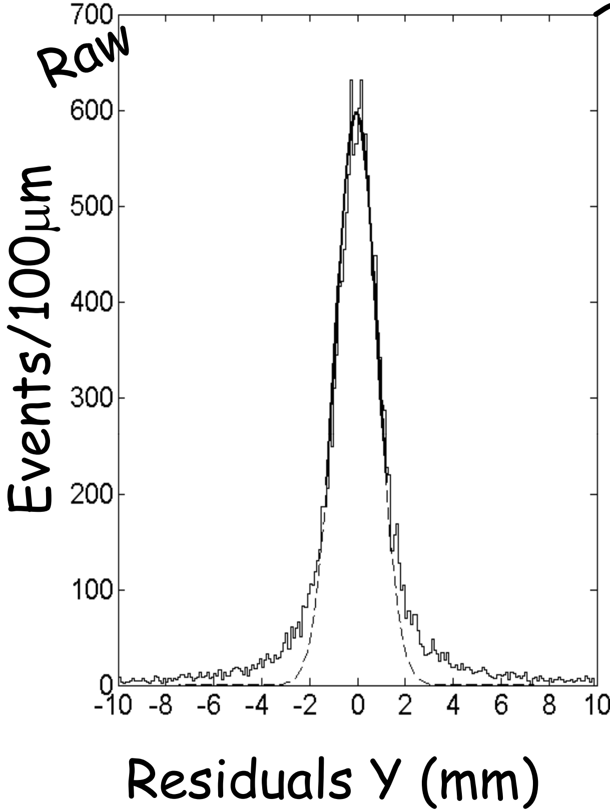
Preliminary results



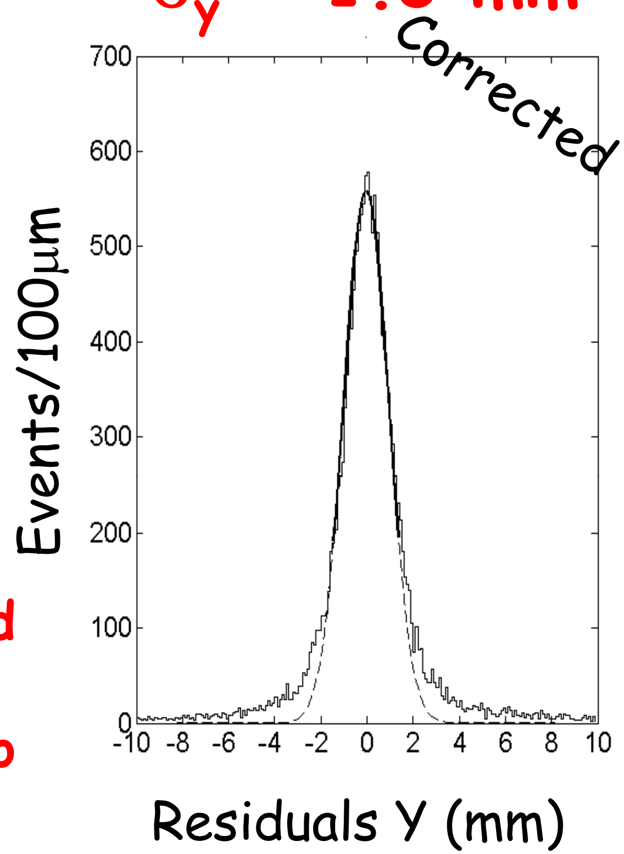
$Y_i = (Q_{YL} - Q_{YR}) / (Q_{YL} + Q_{YR})$ + Group position



σ_y ~ 1.5 mm



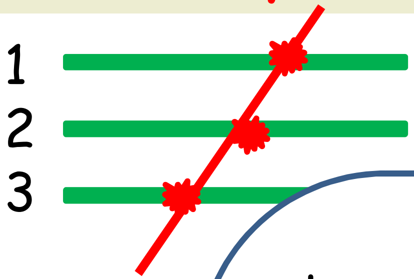
σ_y ~ 1.3 mm



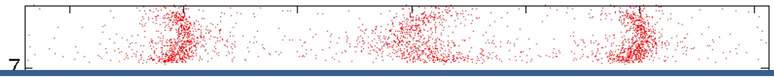
- Basic alignment performed by hand.
- Systematic errors need to be studied.

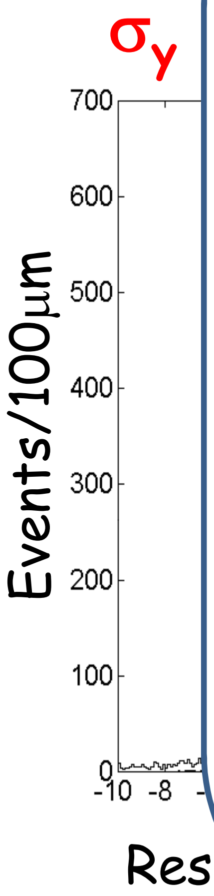
Position precision (transversal, short dimension).

Preliminary results



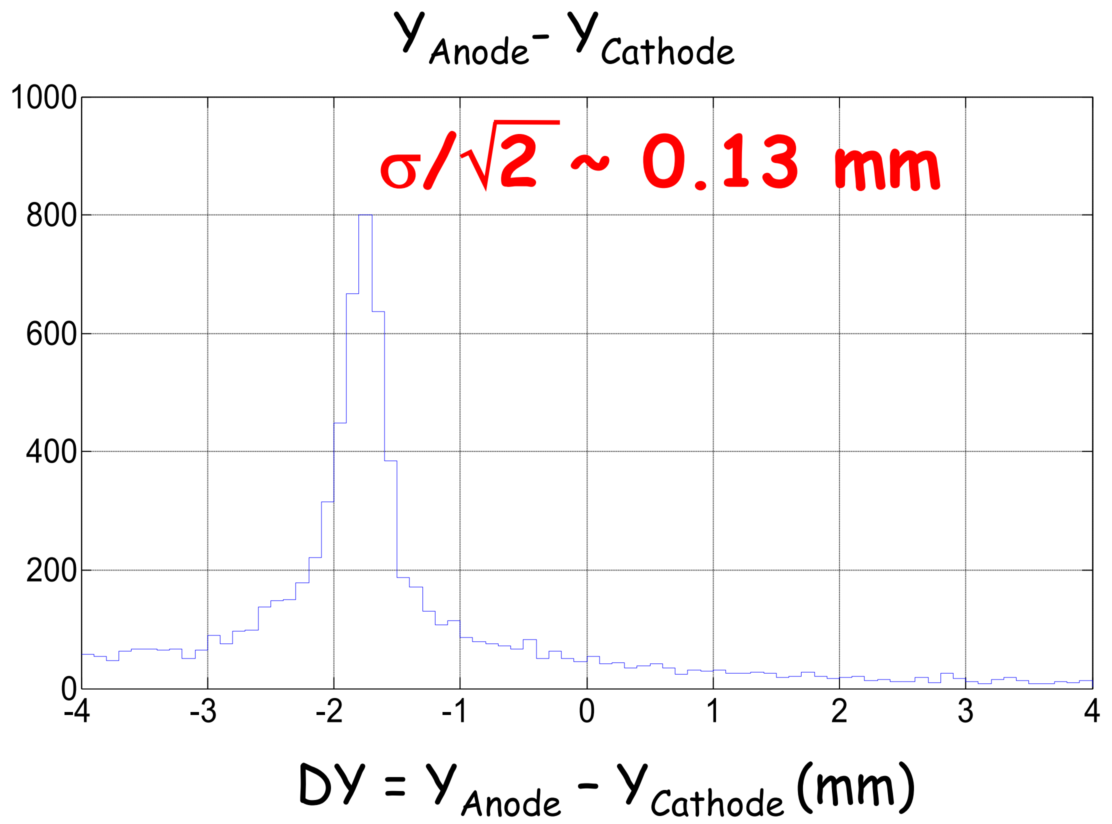
$Y_i = (Q_{YL} - Q_{YR}) / (Q_{YL} + Q_{YR})$ + Group position

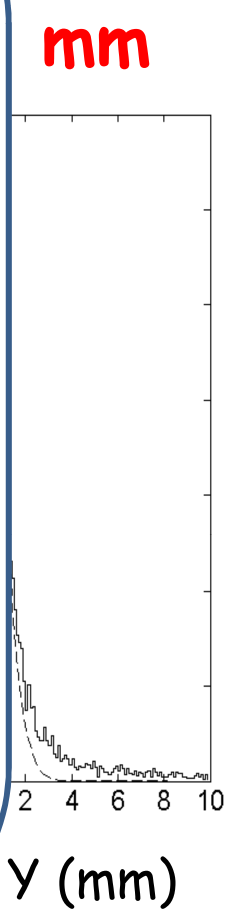




Electronic precision

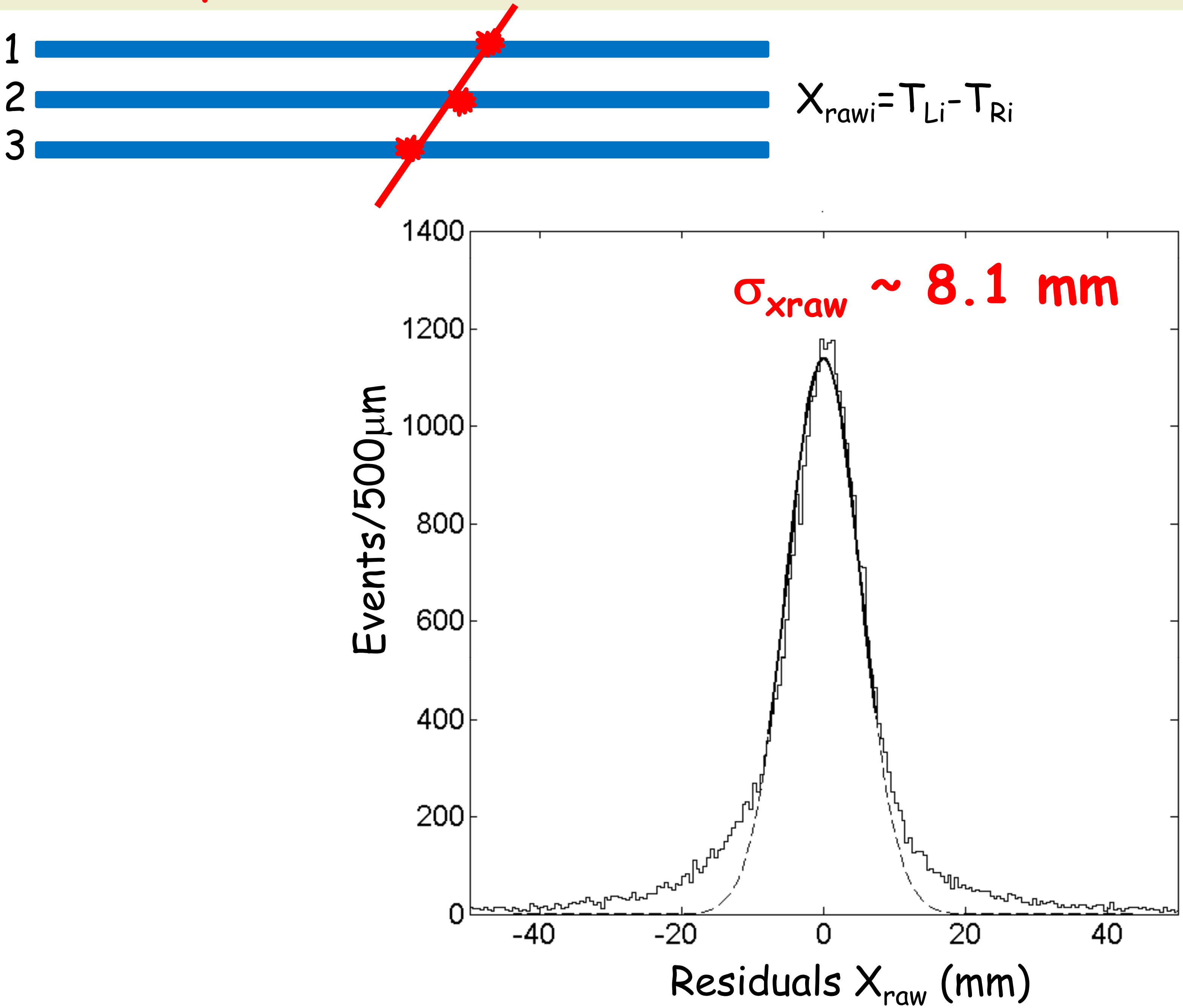
Layer equipped with the same strips in anode and cathode





Position precision (longitudinal, long dimension). Using time.

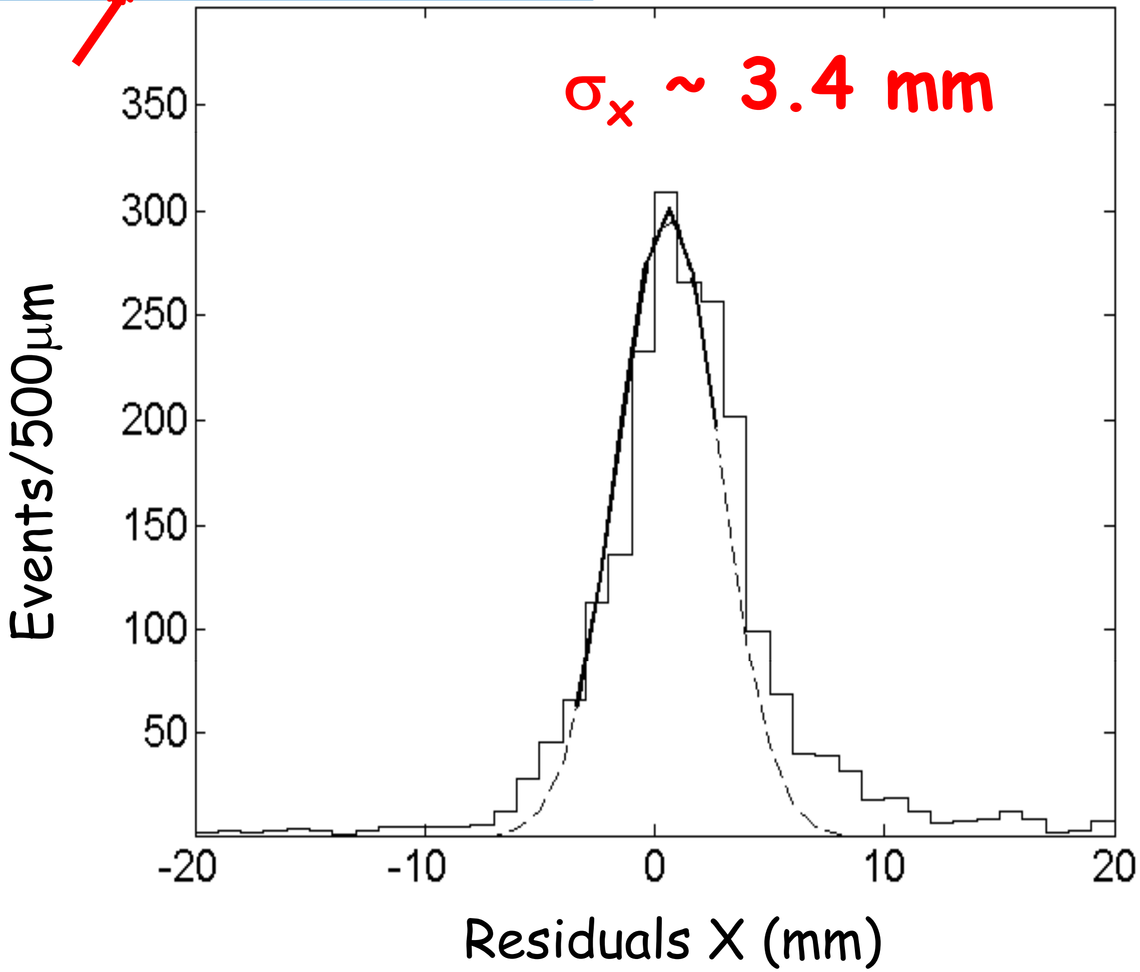
Preliminary results



Position precision (longitudinal, long dimension). Using time + charge.

Preliminary results

$X_i = (Q_{XL} - Q_{XR}) / (Q_{XL} + Q_{XR}) + X_{raw}$



To be studied

- Lack of sensitivity compared with signal readout in Y
- Wrong X_{raw} in some cases

Conclusions

Three layers of large area (~2 m^2) RPC detectors capable of measuring time and 2D position at the same time has been assembled and tested with cosmic ray muons.

The system is only readout by 53 channels/layer (time+charge)

Preliminary results suggest a time precision of **~150 ps σ** and position precision (residuals) of **~ 1.3 mm** and **~ 3.4 mm σ (Y,X) over the entire area of the detector, without cuts,** a fine alignment procedure or systematic error corrections (so **systematics ->jitters**).
Electronics resolution 0.13 mm σ.

The system could be used as a **TOF-tracker for particle identification** in HEP experiments or other applications.