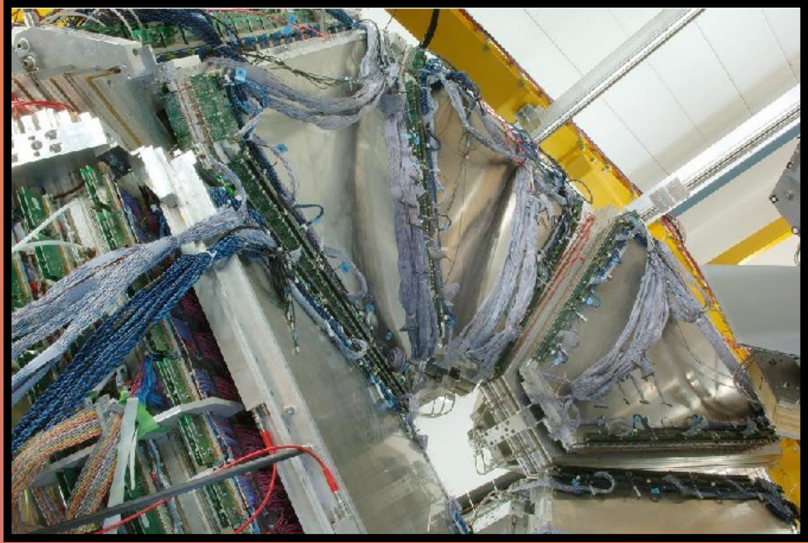


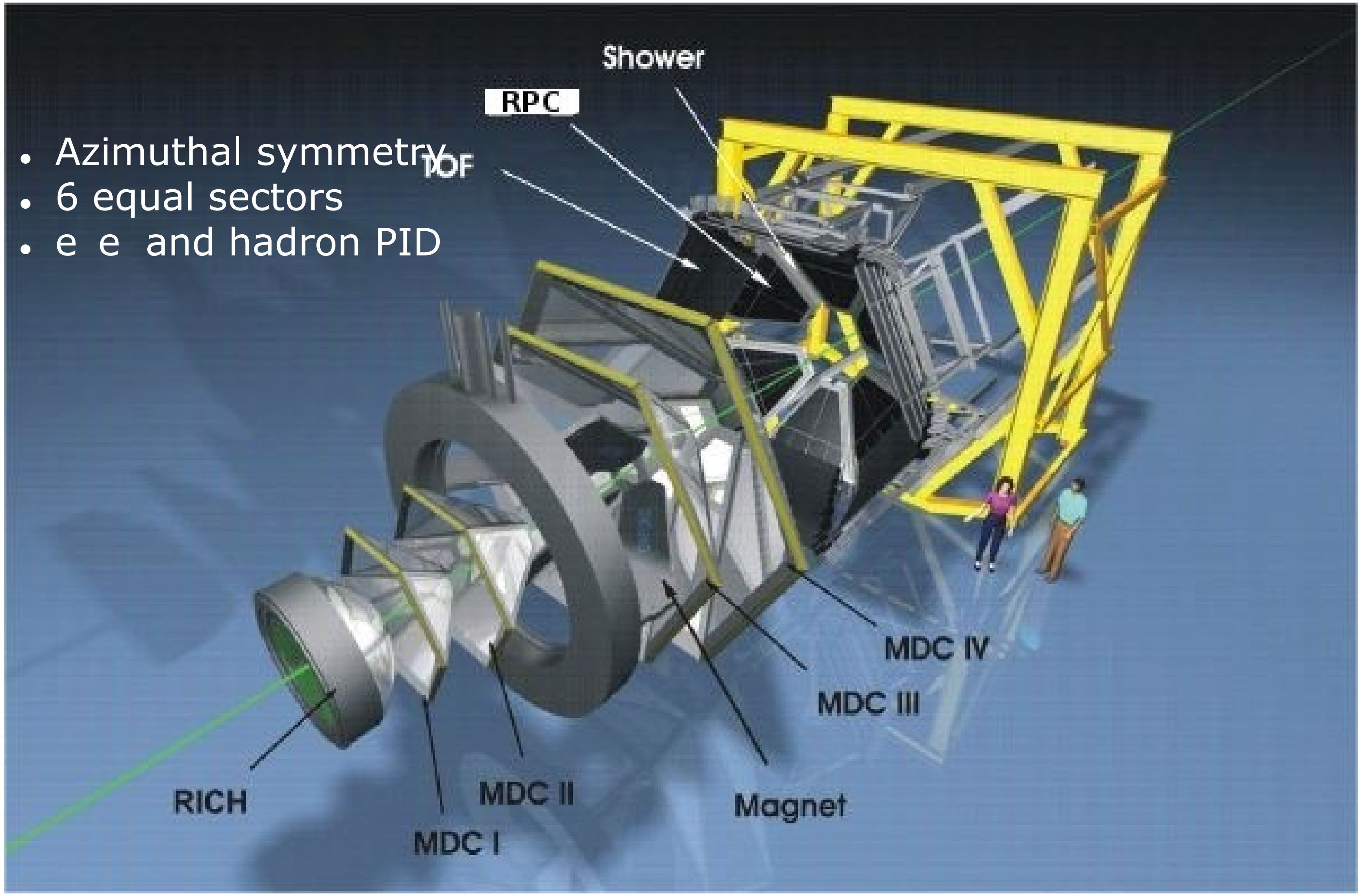
Cosmic Ray Physics with the HADES RPC ToF Wall

Georgy Kornakov

Results from 2012 data analysis

The HADES experiment at GSI

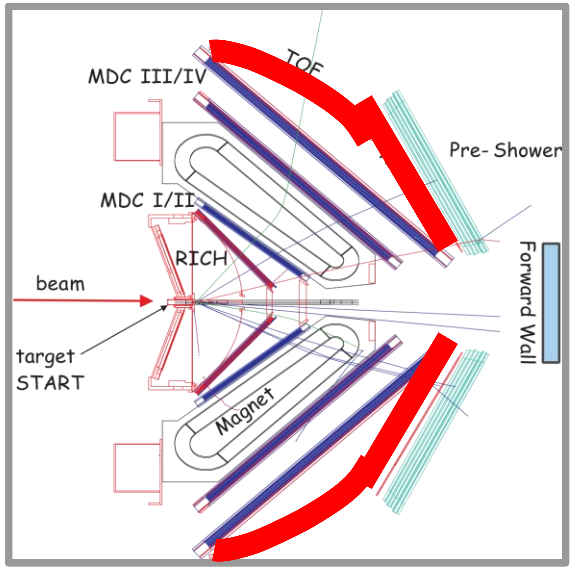
- Azimuthal symmetry
- 6 equal sectors
- e e and hadron PID

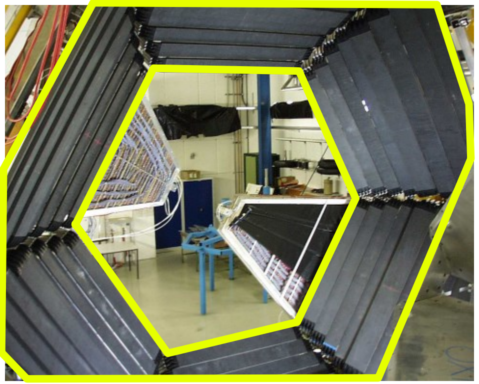


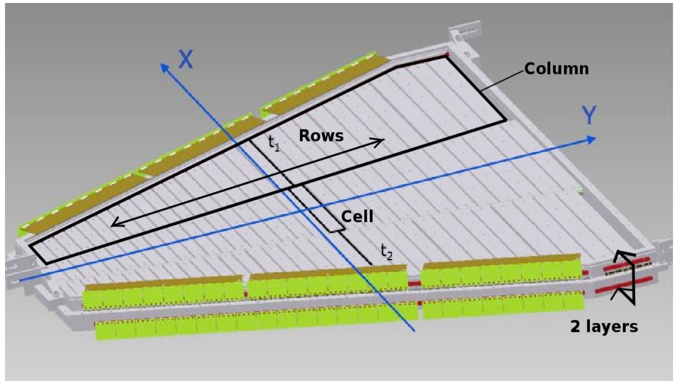
The HADES experiment at GSI

HADES

Beam detectors RICH MDC+Magnet **TOF + RPC** Shower F. Wall





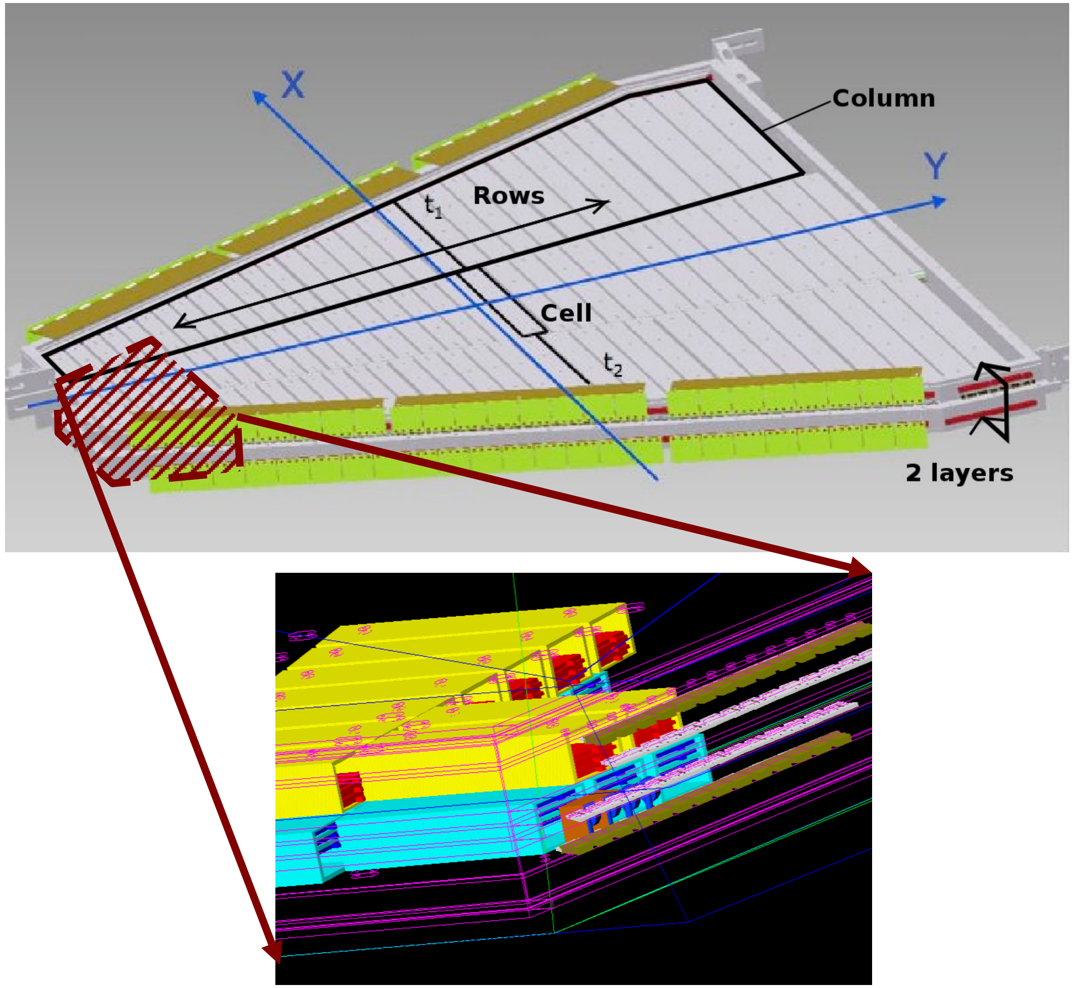


	TOF	RPC
Technology	Scintillator	Resistive plate chambers
Forward angle	44º<θ<88º	12º<θ<45º
Time resolution	150 ps	<100ps

The HADES RPC TOF Wall

The HADES RPC TOF Wall

Lip (Coimbra), **GSI** (Darmstad), **IFIC** (Valencia) and **LabCAF** (Santiago)

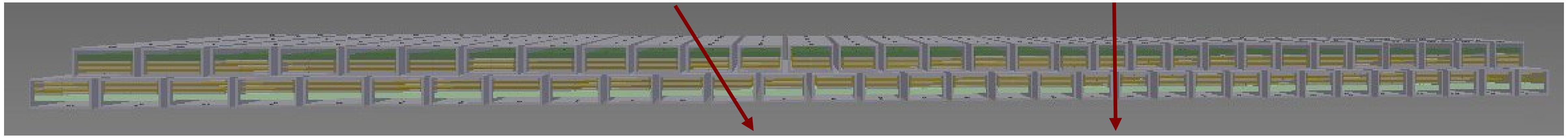


Design requirements:

- time resolution below 100 ps
- efficiency close to 100%
- occupancy below 20%

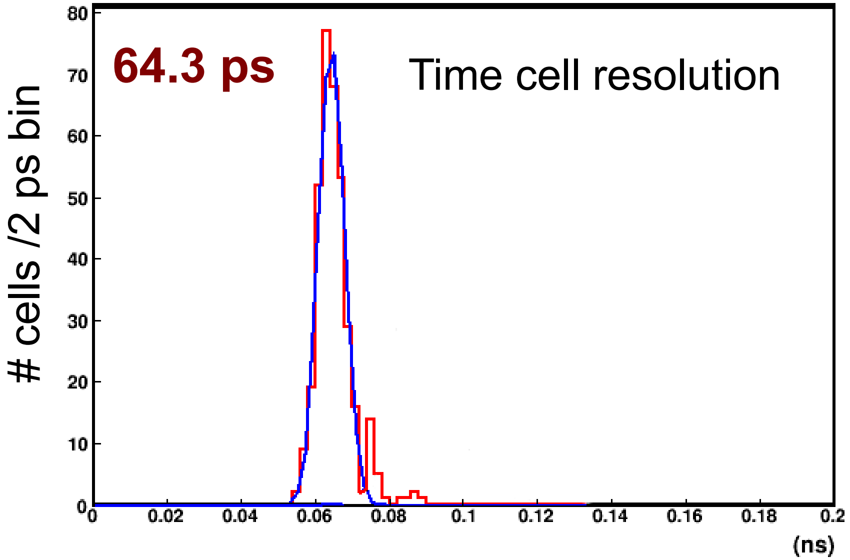
- 2 layers
- 3 columns/layer
- 31 cells/column
- 2 channels/cell

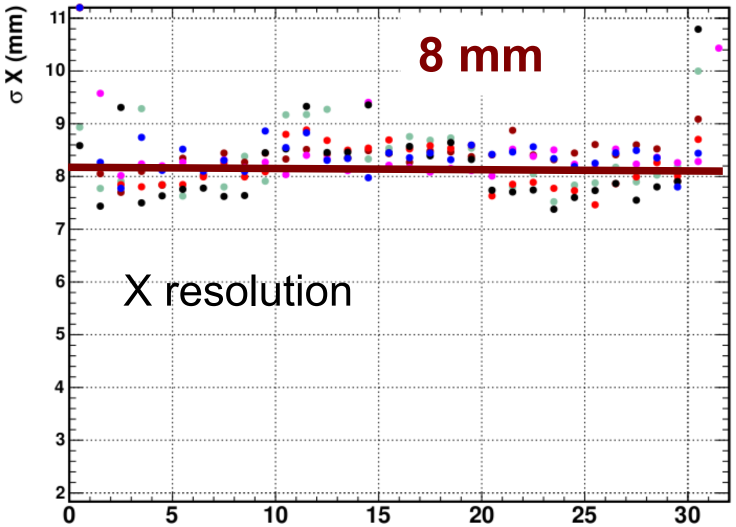
The HADES RPC TOF Wall



- 2 layer design allows to measure precisely the efficiency and the resolution.
- The time resolution and the position resolution can be estimated using overlapped cells.

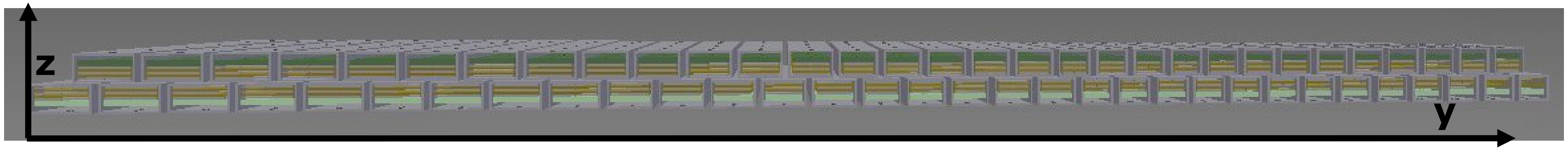
One sector time and X-position resolution (all cells)



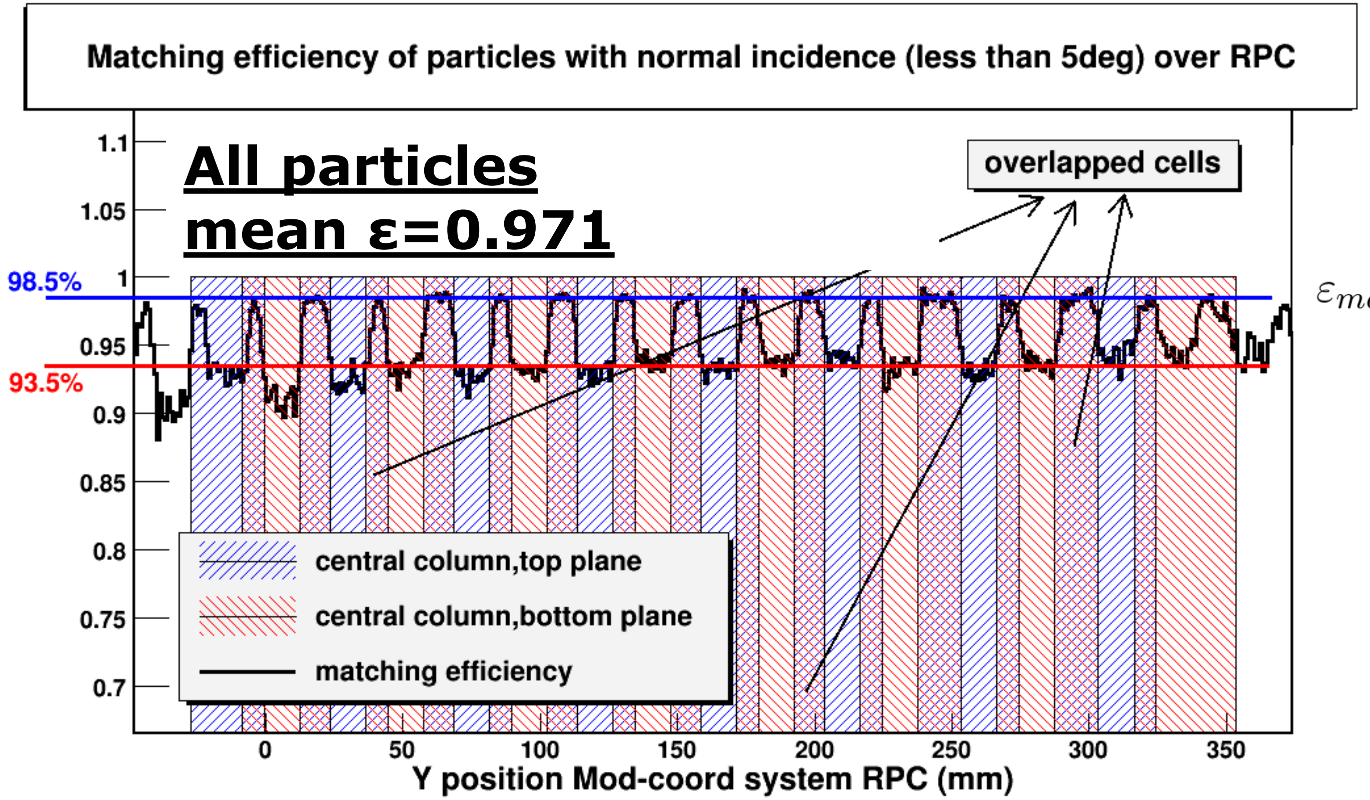


Cell number

The HADES RPC TOF Wall



- Efficiency requires external detectors and tracking.
- The intrinsic cell efficiency is estimated using the modulation effect due to areas covered by two or only one cell.



$$\varepsilon_{min} = \varepsilon_{int} \cdot \varepsilon_{ext}$$

$$\varepsilon_{max} = \left(1 - (1 - \varepsilon_{int})^2\right) \cdot \varepsilon_{ext}$$

$$\varepsilon_{int} = 2 - \frac{\varepsilon_{max}}{\varepsilon_{min}}$$

Cosmic Ray analysis

The tRPC Tof wall commissioning:

- $600 \cdot 10^6$ of events were taken with 2-sector coincidence trigger (~100 Hz)
- 34 millions of events (~5 days of continuous stable run):

- Surface:	**~1.2 m^2**
- Mean position resolution:	**~ 5 cm^2**
- Granularity:	**up to ~100 particles / event**
- Time resolution	**~ 80ps (hit) / ~ 170ps (track)**

Cosmic Ray analysis

Extended air shower structure and parametrisation

[J.Linsley, *19th ICRC* 1985]

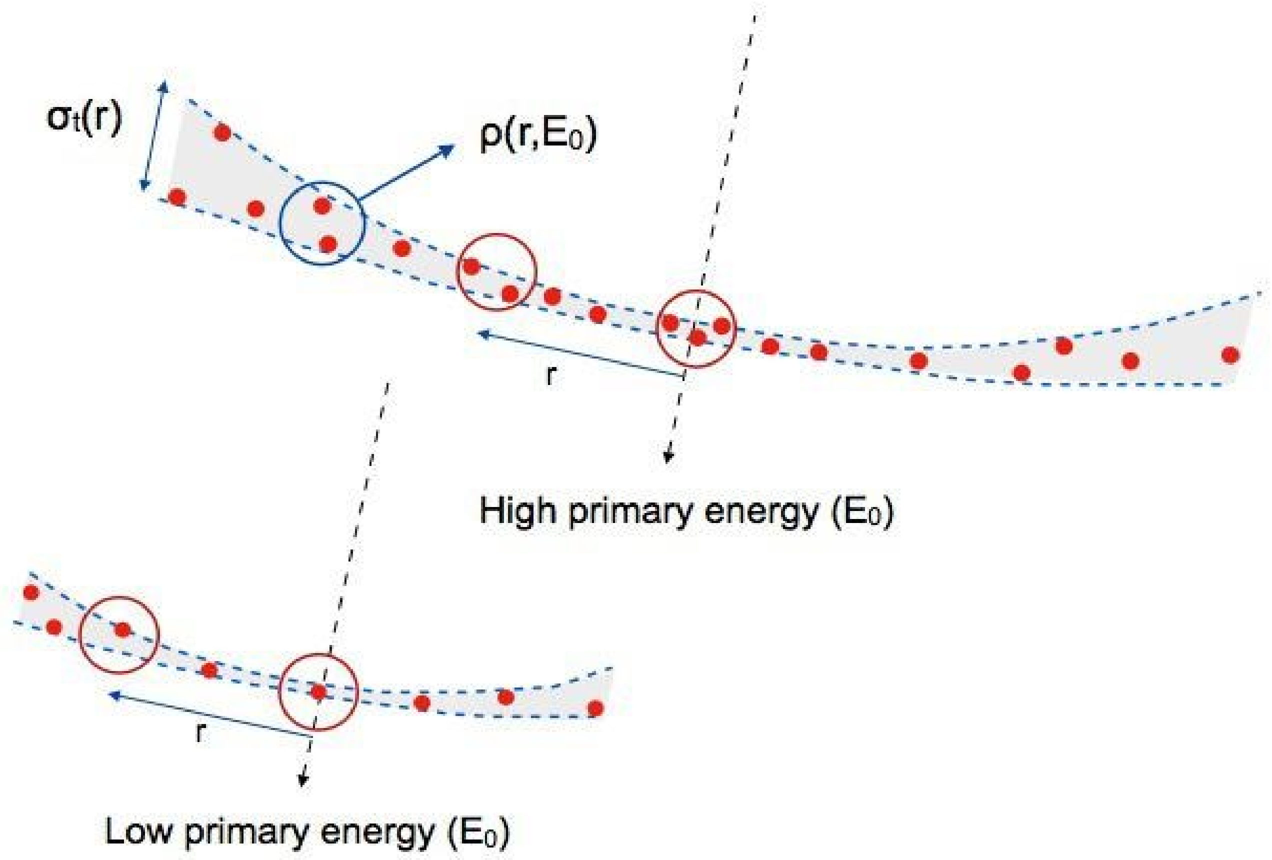
$$\sigma_t(r) = \sigma_{t_0} \left(1 + \frac{r}{r_t}\right)^{\beta}$$

[T. Bezbouruah, *Astropart.Phys*. 11, 1999]

$$\rho(r, N_0) = \epsilon \cdot N_0 \cdot r^{-n}$$

[A.M. Hillas *Phys.Rep.C* 20,1975]

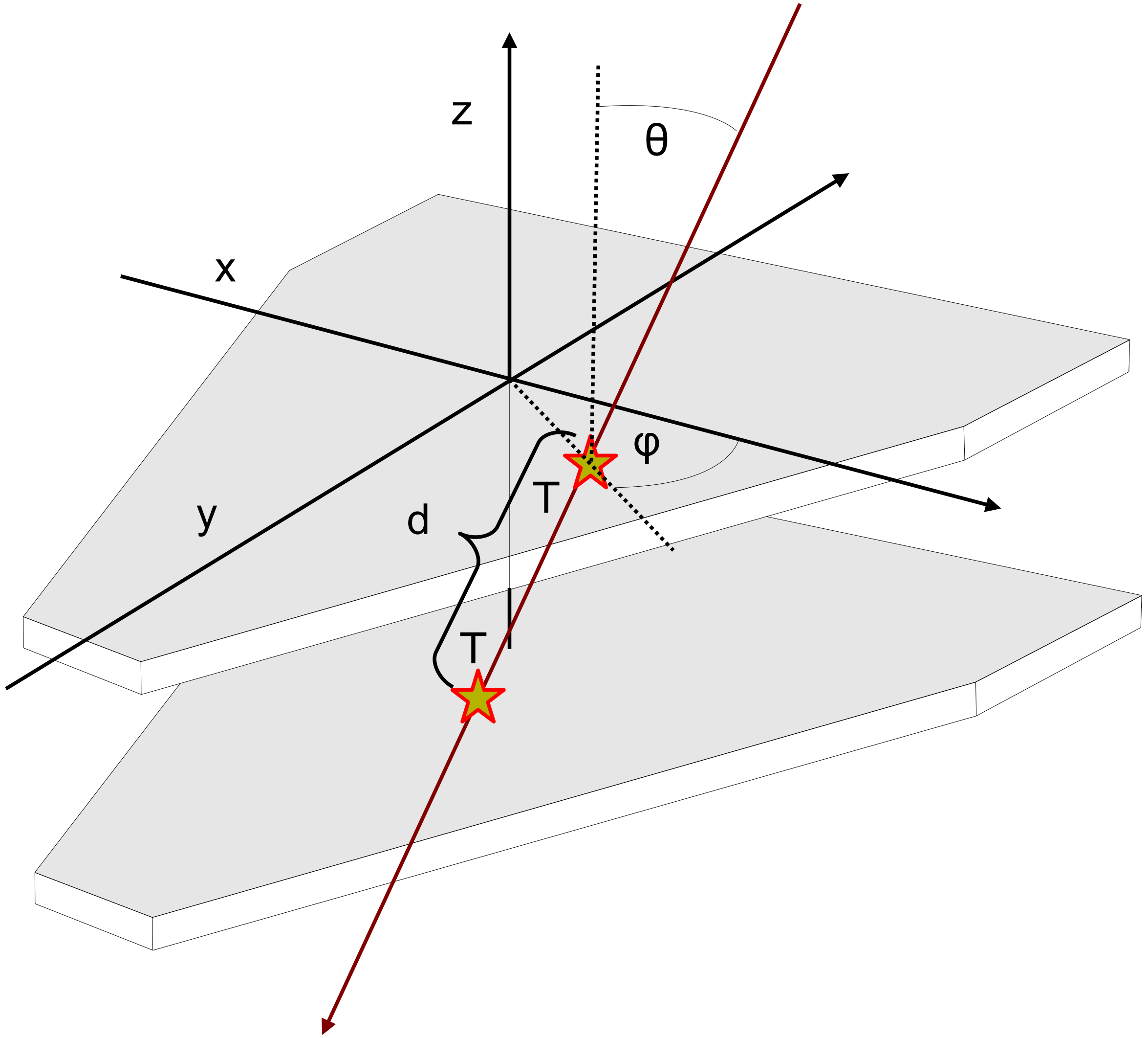
$$E_0(N_0) = \alpha \cdot N_0^b$$



$$\boxed{E_0 = \alpha \left[\frac{\rho}{\epsilon}\left(r_t\left[\left(\frac{\sigma_t}{b}\right)^{1/\beta} - 1\right]\right)^{n}\right]^{b}}$$

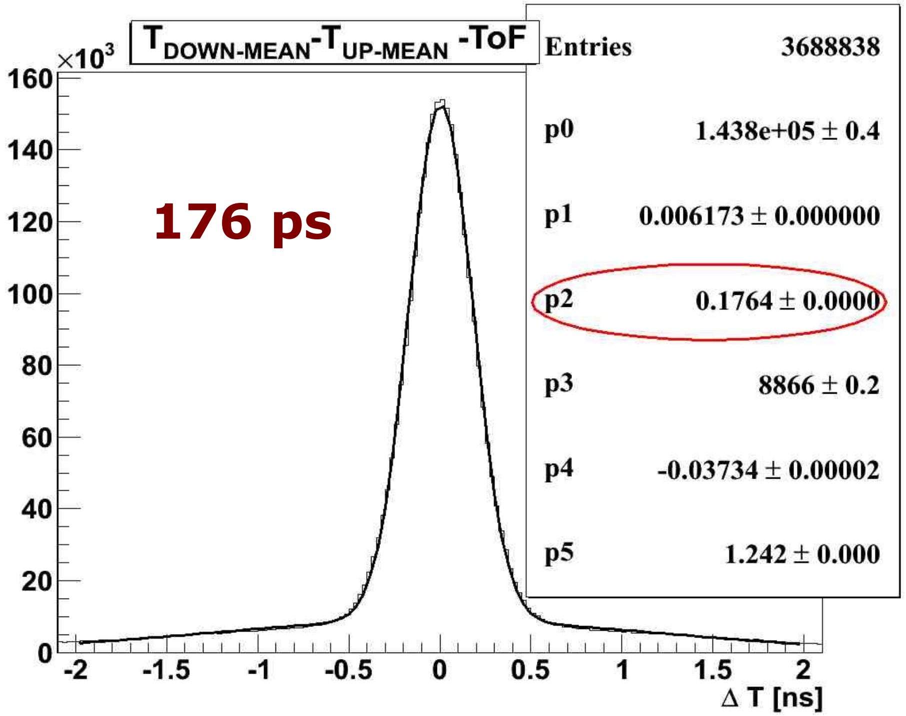
Cosmic Ray analysis

Calibration, synchronization and event reconstruction



$$\Delta T = (T_{up} - \tau_{up}) - (T_{down} - \tau_{down}) + d/c = 0$$

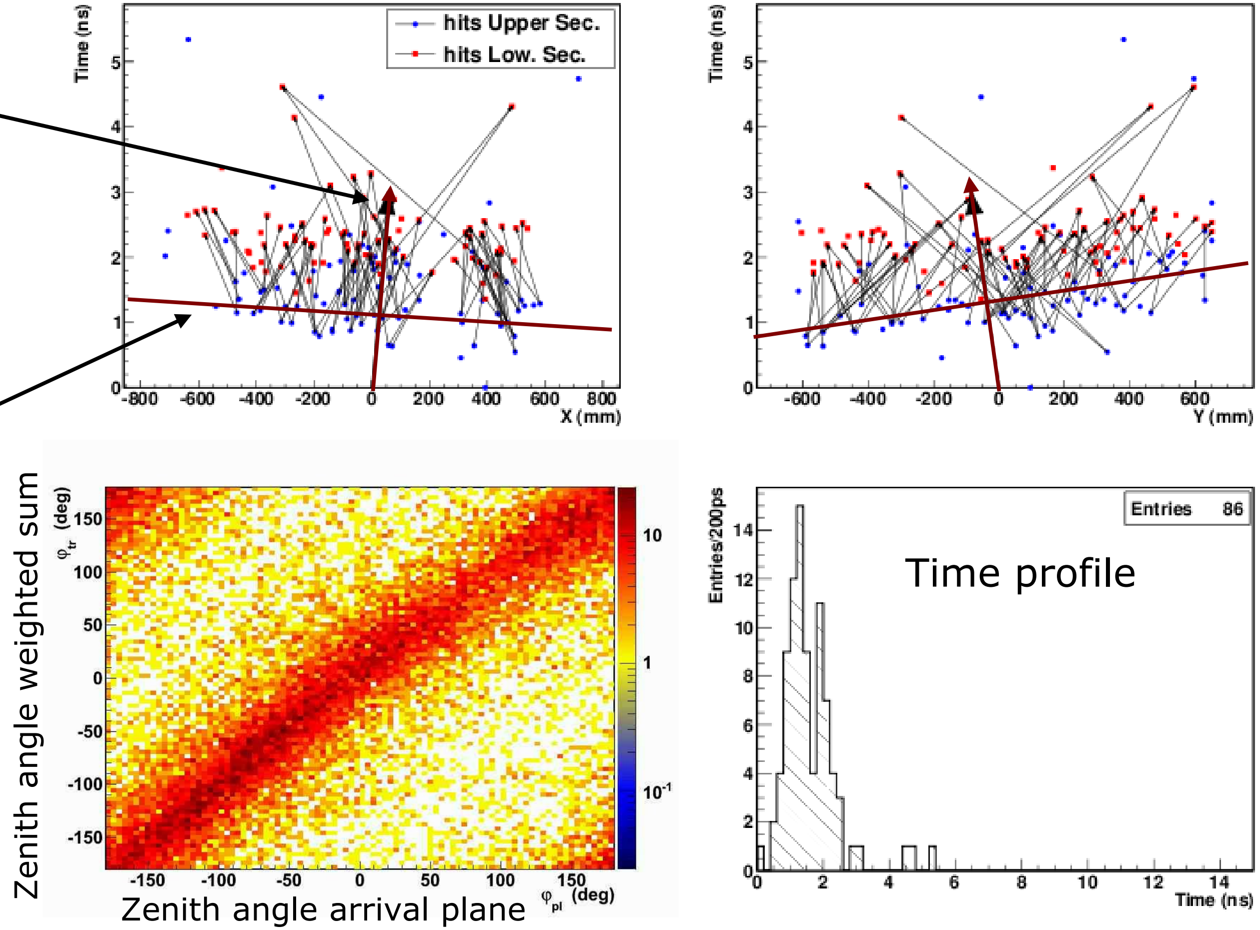
After minimisation



Shower arrival direction

Weighted sum method

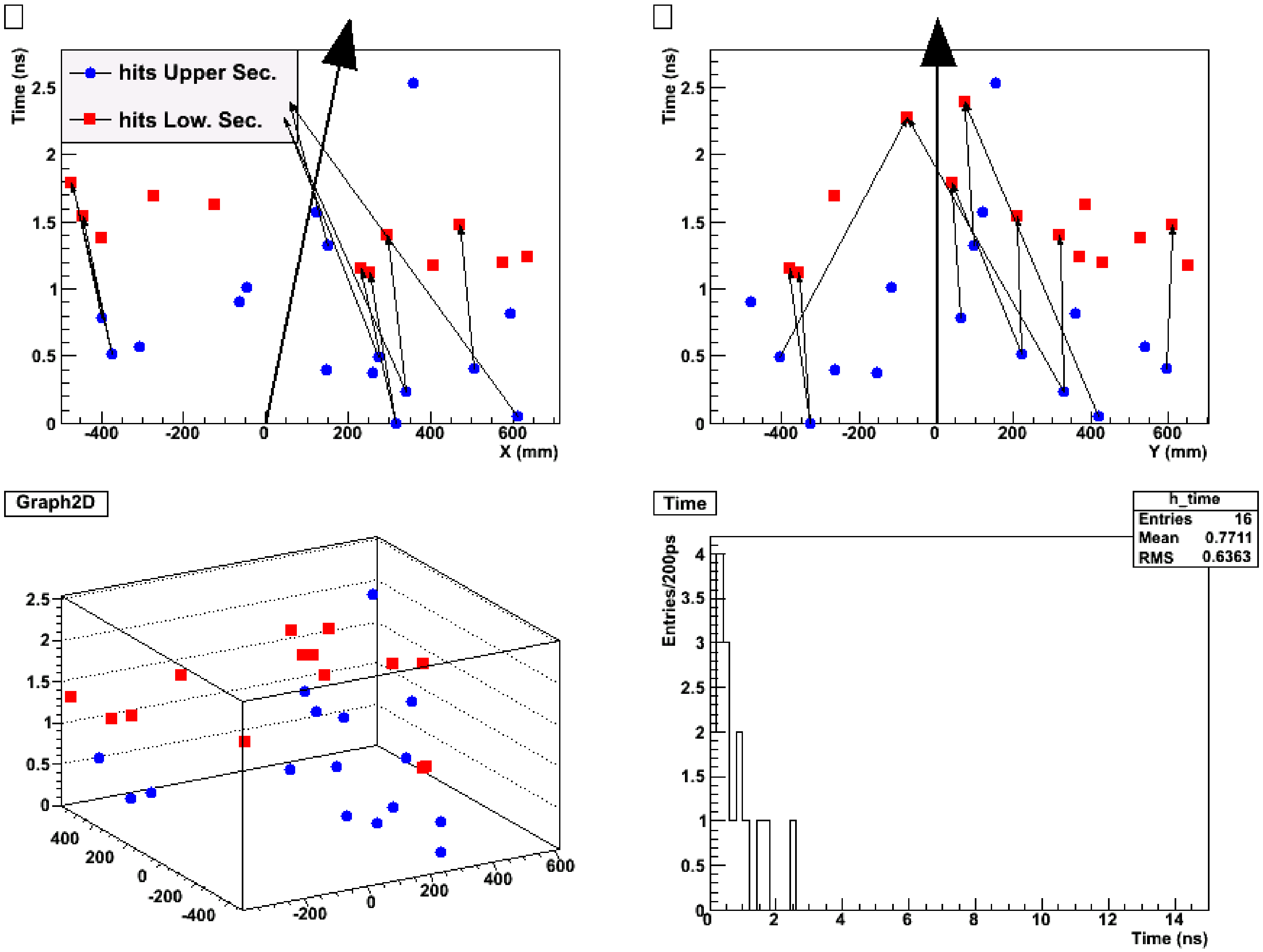
Plane fitting method



A weighted sum of track candidates provides a good estimation of the shower arrival direction.

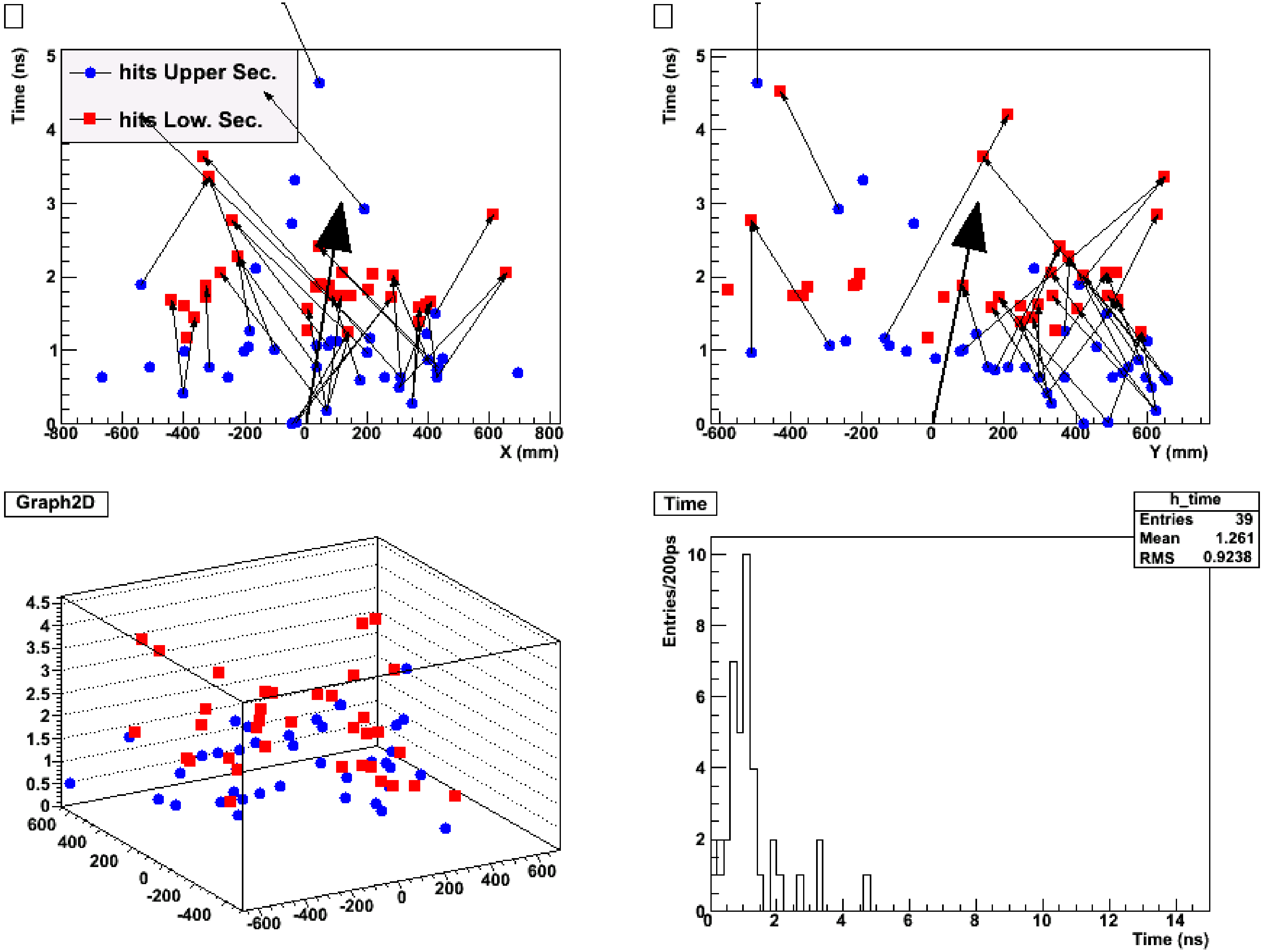
Cosmic Ray analysis

Shower arrival direction



Cosmic Ray analysis

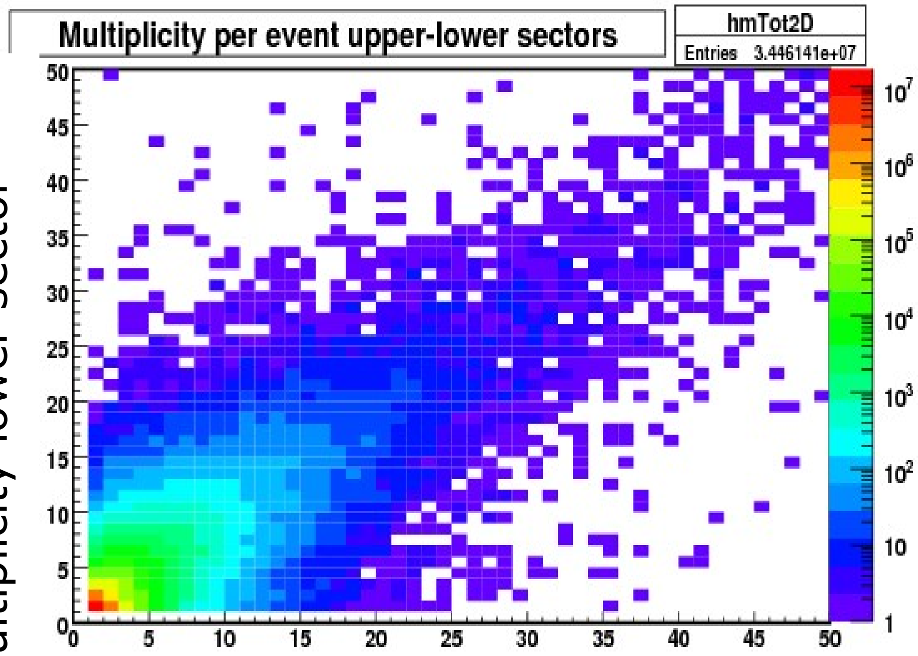
Shower arrival direction



Cosmic Ray analysis

Results: multiplicity distribution trend

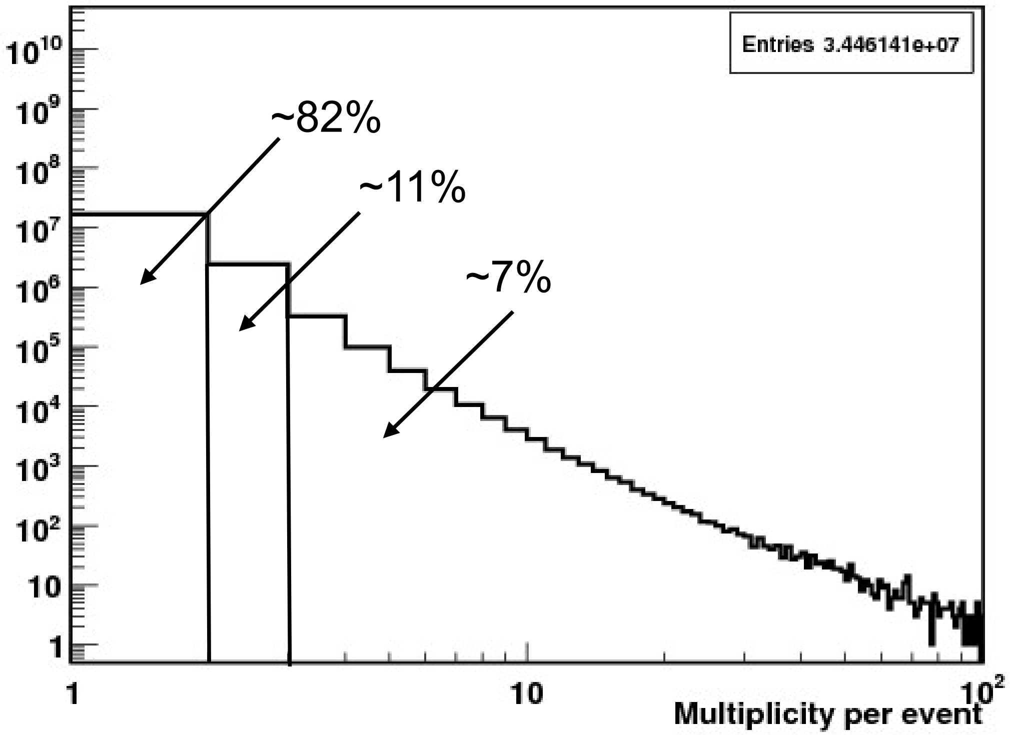
Multiplicity distribution
Upper sector vs lower



Multiplicity lower sector

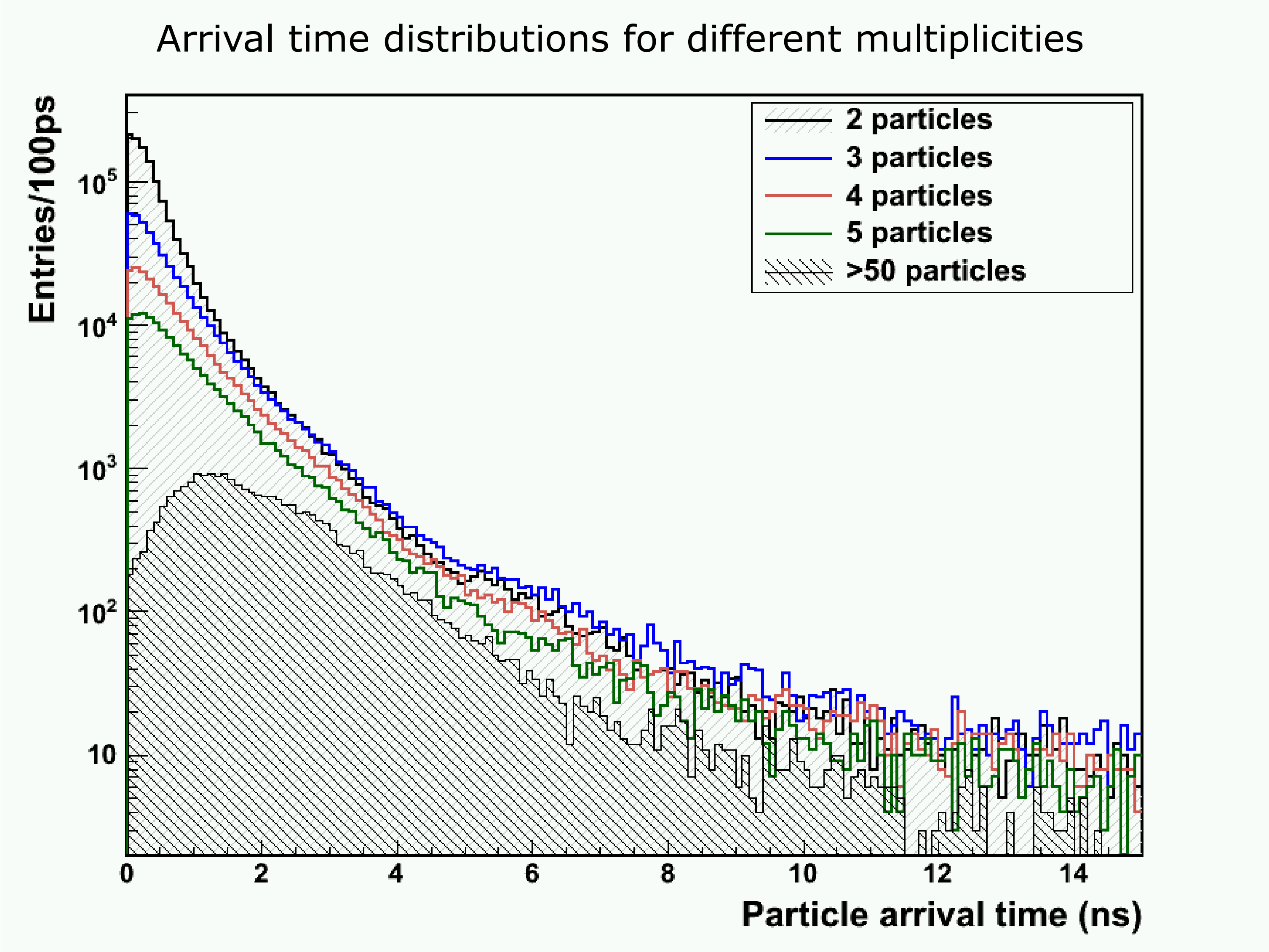
Multiplicity lower sector

Multiplicity distribution



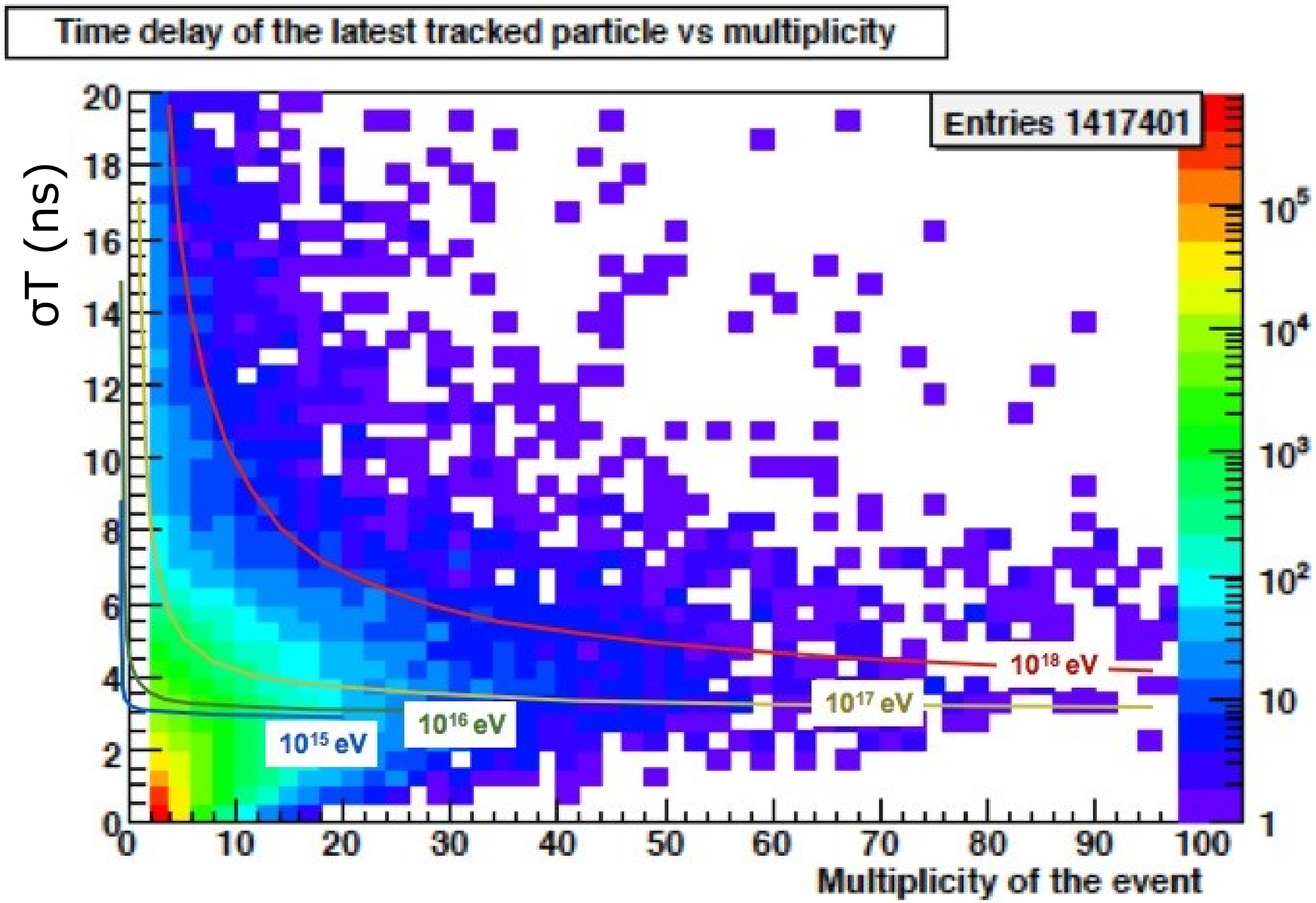
Multiplicity of the event

Results: arrival time differences



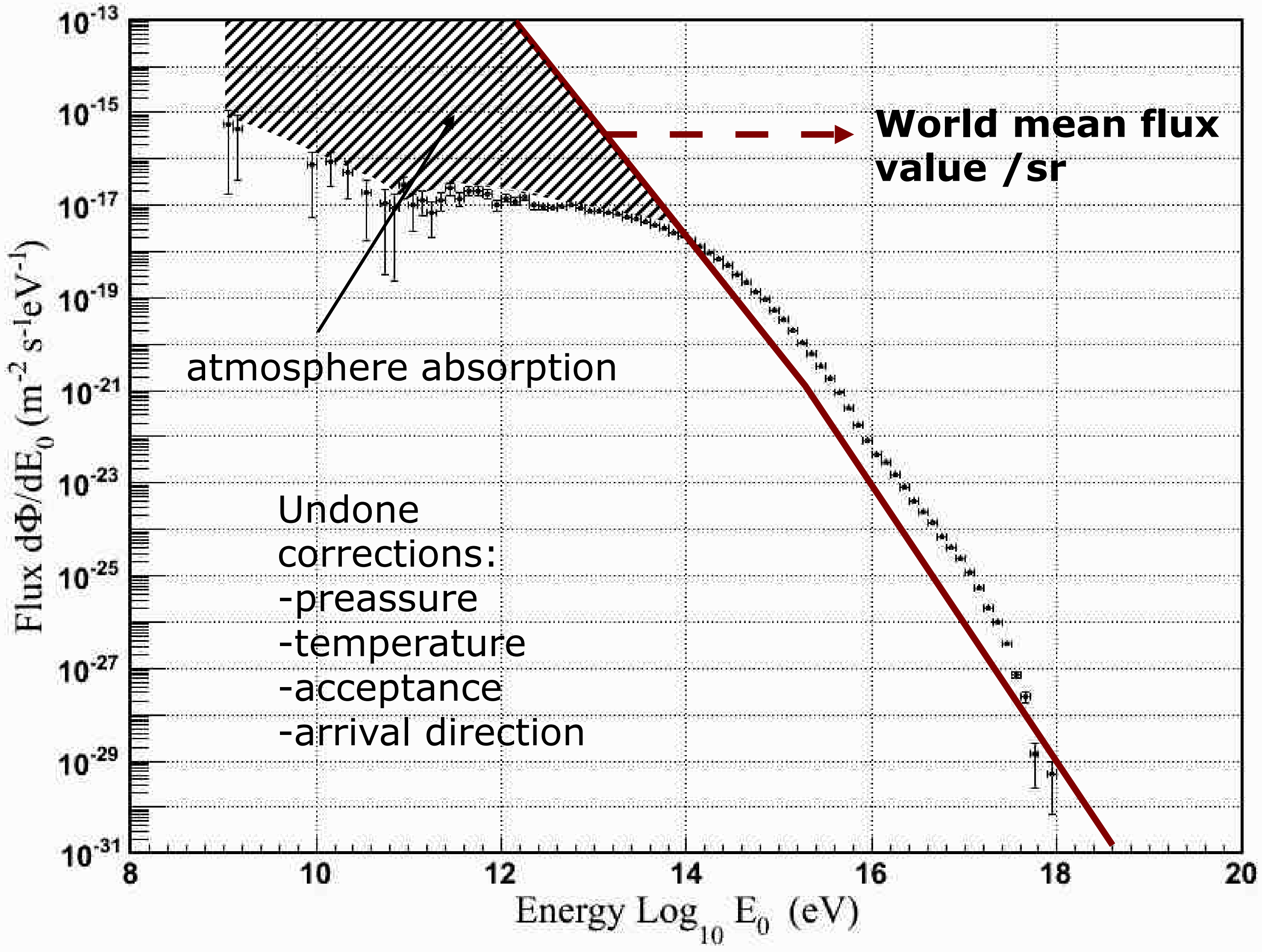
Cosmic Ray analysis

Results: multiplicity – time width chart



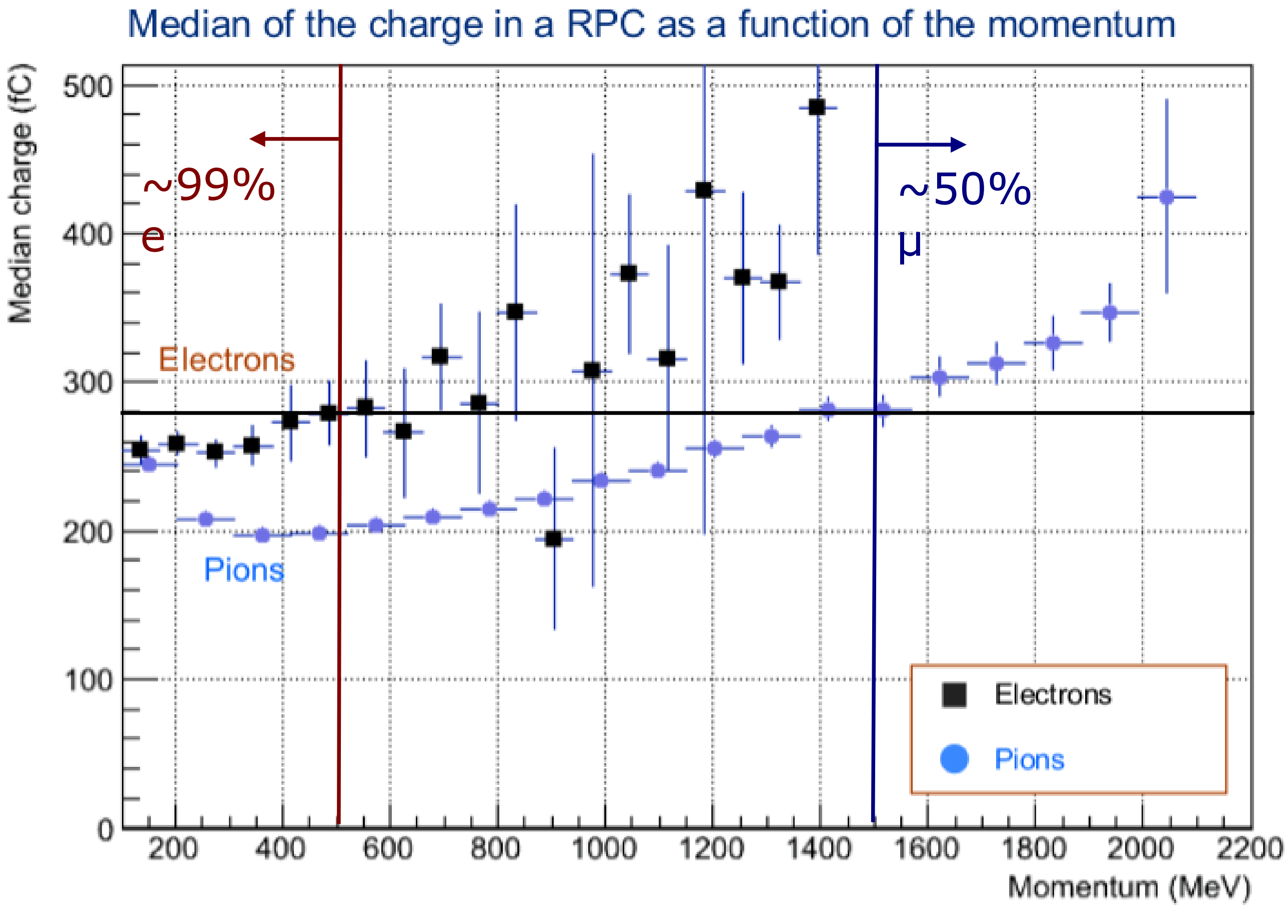
$$E_0 = \alpha \left[\frac{\rho}{\epsilon} \left(r_t \left[\left(\frac{\sigma_t}{b} \right)^{1/\beta} - 1 \right] \right)^n \right]^b$$

Results: flux distribution of primary cosmic rays



Cosmic Ray analysis

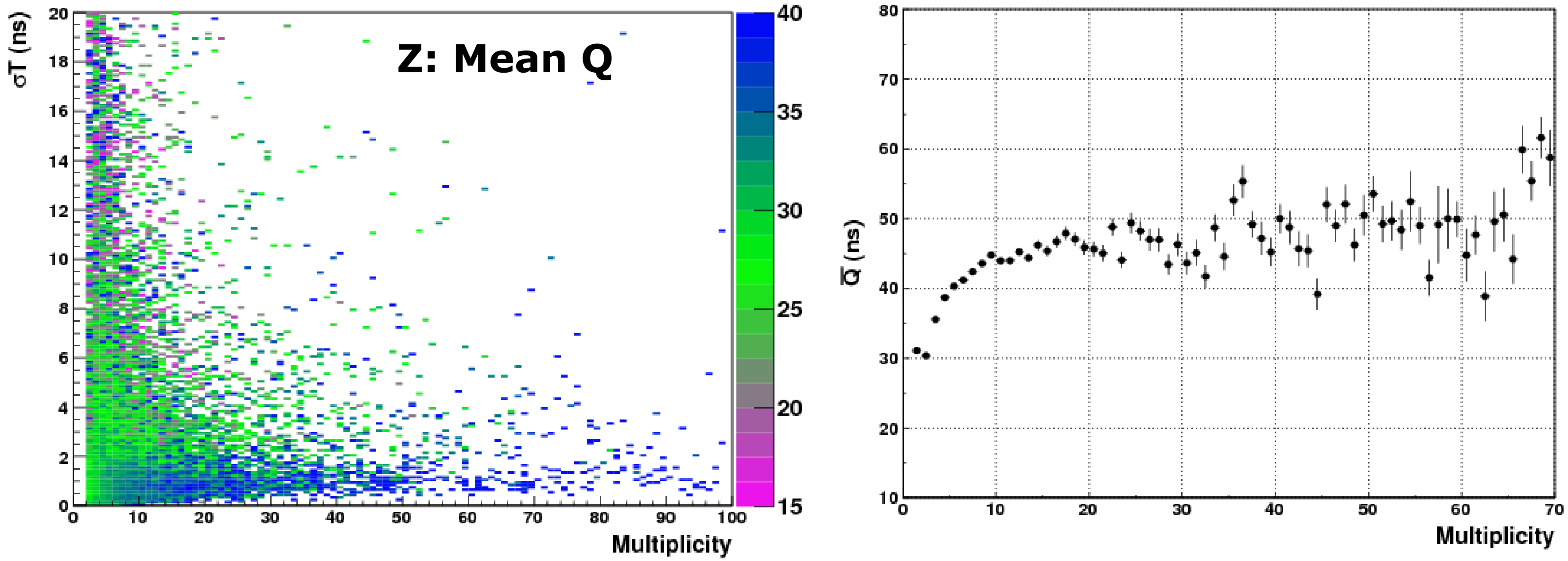
Results (beam)



Cosmic Ray analysis

Results: electron/muon estimation

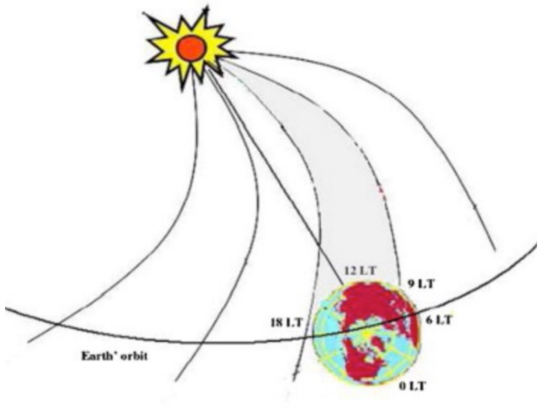
Mean charge distributions



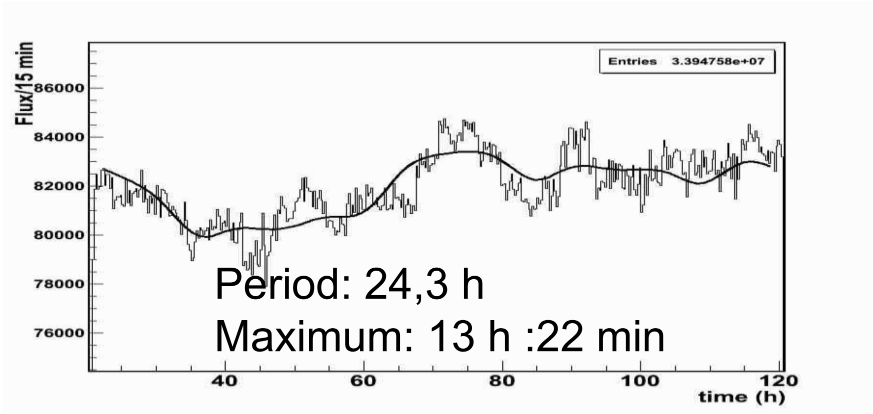
RPC detector may access to the charge of arriving particles.

Comparison with beam data may allow to perform electron/muon estimation.

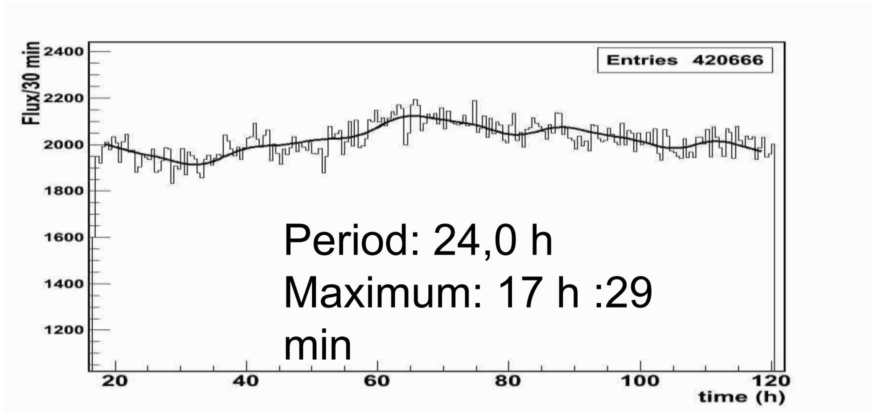
Results: diurnal effect



Flux of events with 1 particle (15 min bin)



Flux of events with 2&3 particles (30 min)

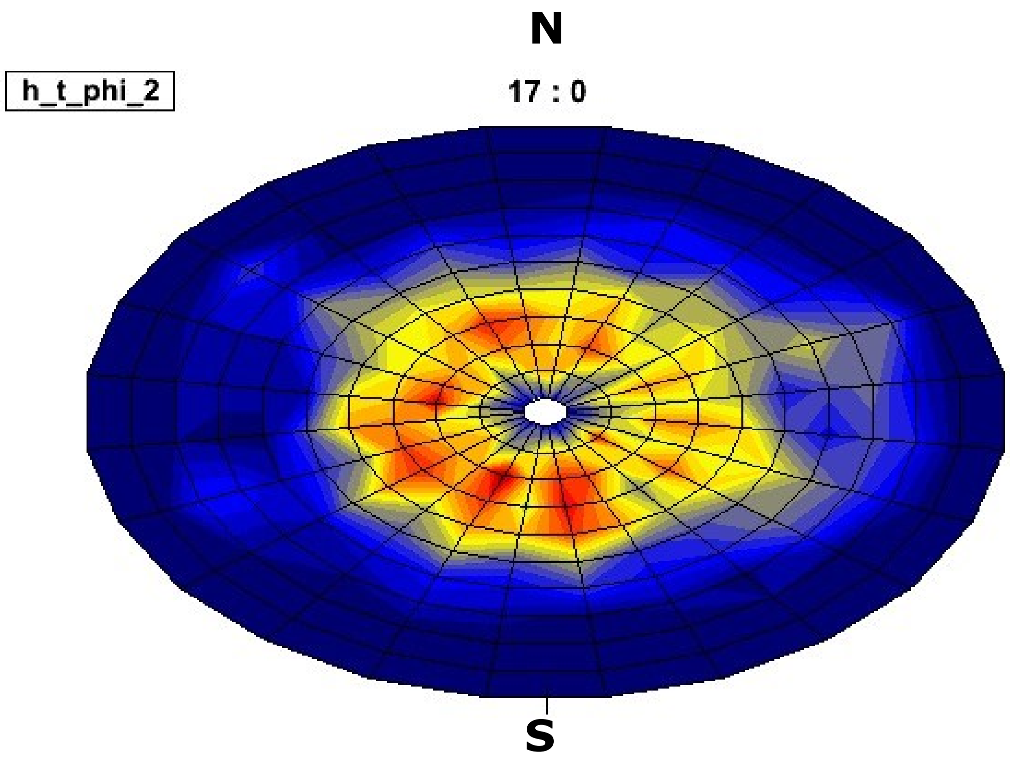


Data allow to analyse the Solar magnetic field.

$$\sum_n c_1 + c_2 \cdot sin\big((Time/T) \cdot 2 \cdot \pi \cdot n + c_3\big)$$

Cosmic Ray analysis

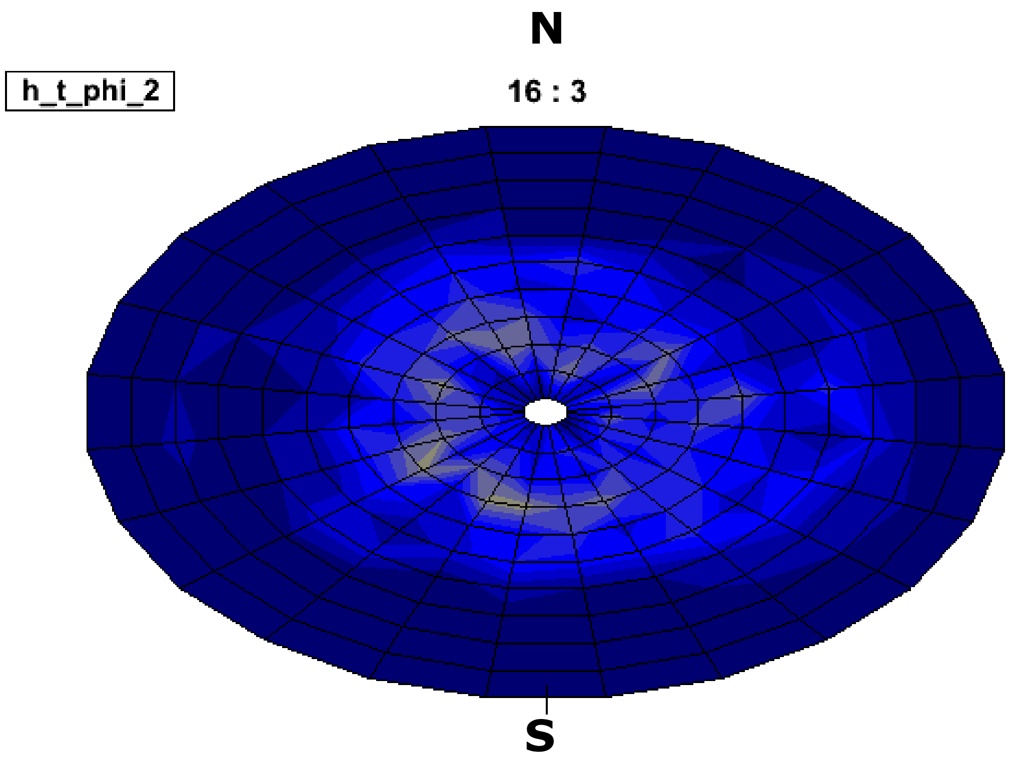
Results



- Events with 2 tracked particles.
- Time difference between both particles <2 ns (primaries 10 -10 eV close to the core). These events keep memory of the primary.
- No acceptance, efficiency or pressure corrections made.

Cosmic Ray analysis

Results



- Events with 2 tracked particles.
- Time difference between both particles <2 ns (primaries 10^{14}-10^{15} eV close to the core). These events keep memory of the primary.
- No acceptance, efficiency or pressure corrections made.

Cosmic Ray analysis

Results: summary (AS OF 2012)

A high granularity timing RPC two plane detector may provide:

- Energy of the primary.
- Arrival direction (direct estimation from the tracked particles).
- Very precise arrival time distribution.
- Very precise multiplicity measurement.
- electron-muon ratio estimation through charge measurement.
- muon energy estimation from charge-time.
- muon pt estimation (as probes of nuclear collisions).

Extra information provided by timing RPCs can improve the measurement of the nuclear collisions happened in the high atmosphere.

Cosmic ray experiments may access nuclear collisions at and above the available energies in accelerator experiments. (ARGO, URAGAN, IceCube).

Timing RPC detectors are very good alternative to provide extra information.

Thanks