# First results about atmospheric muons from the L3+C experiment at CERN

**The L3 collaboration**
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**EuroConference on Frontiers in Particle Astrophysics and Cosmology**
San Feliu de Guixols, Spain,30 September-5 October 2000

# Outline

- Purpose of L3+C
- The '99 L3+C setup.
- Detector performance.
- Analysis.
- Results.
  The vertical muon spectrum.
  The charge ratio.
- The 2000 setup
- Conclusions

# Purpose of L3+C

- Precise measurement of the atmospheric muon momentum spectrum.

  2.5% systematic uncertainty (goal)

  constraints parameters included in air shower calculations and reduces uncertainty in atmospheric NEUTRINO spectrum.

- Precise measurement of the muon charge ratio.

  1% uncertainty (goal)

  sensitive to primary composition.

- Study of multi muon events.

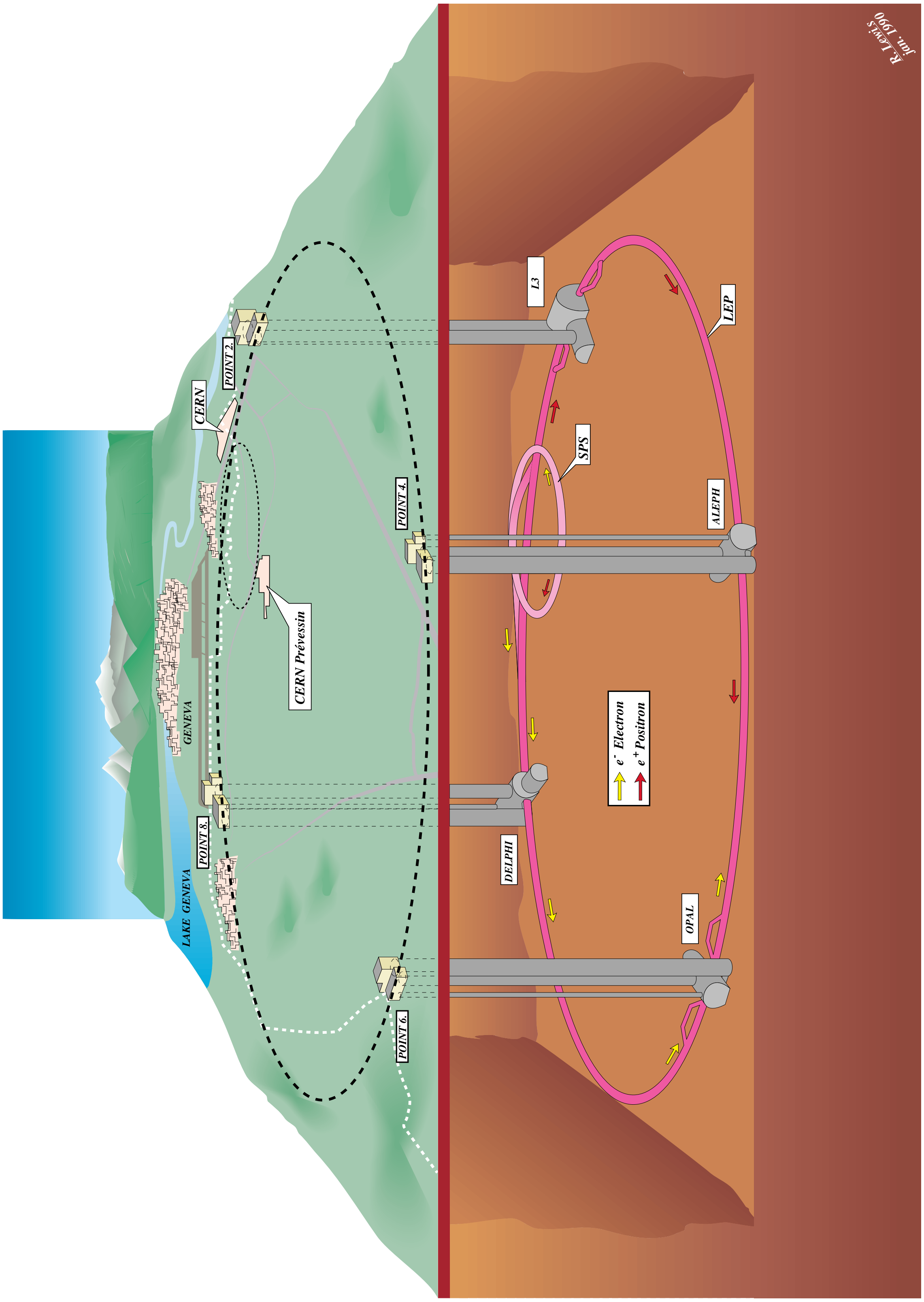
  shower energy from surface array. (only in 2000 setup)

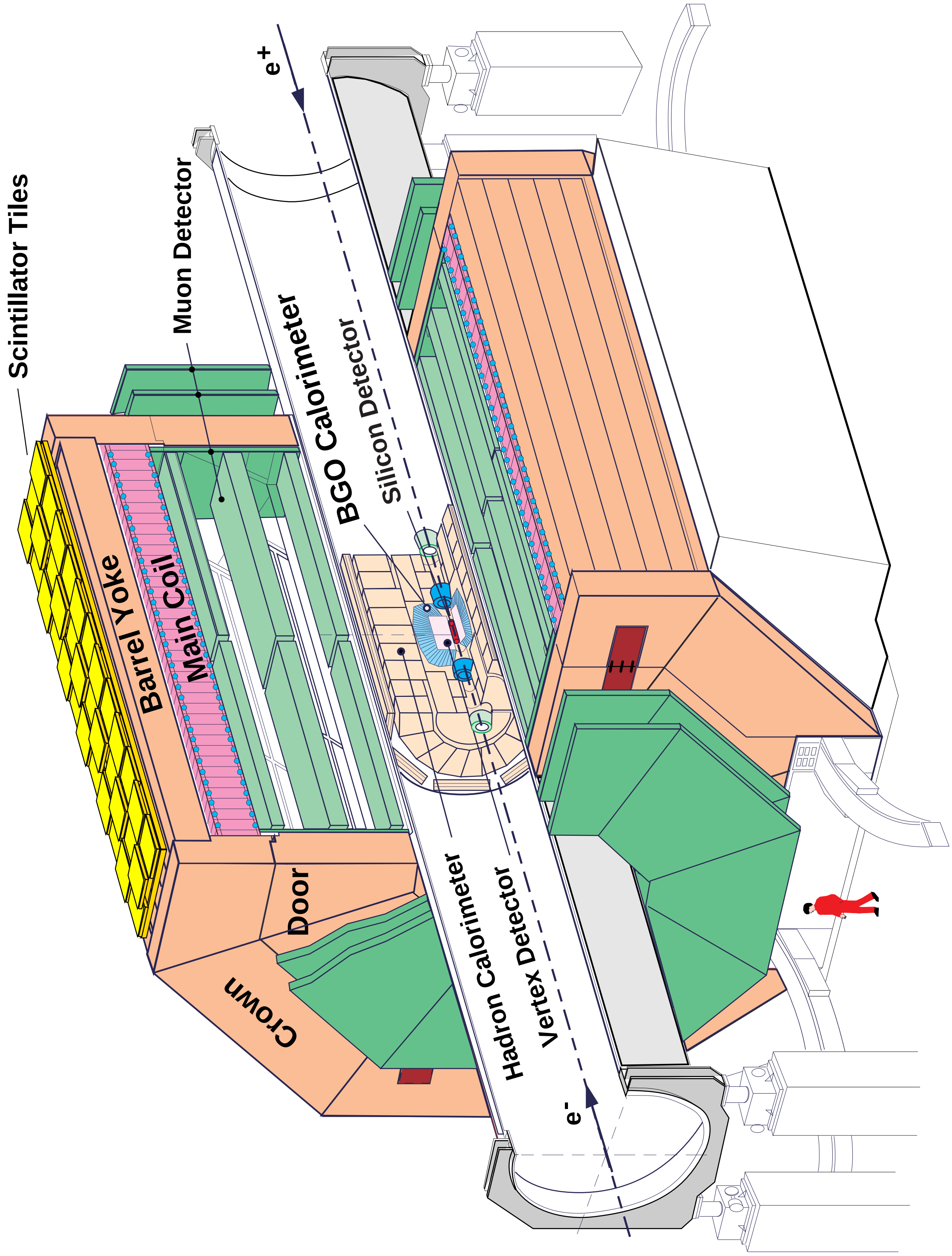
  muons measured in L3.

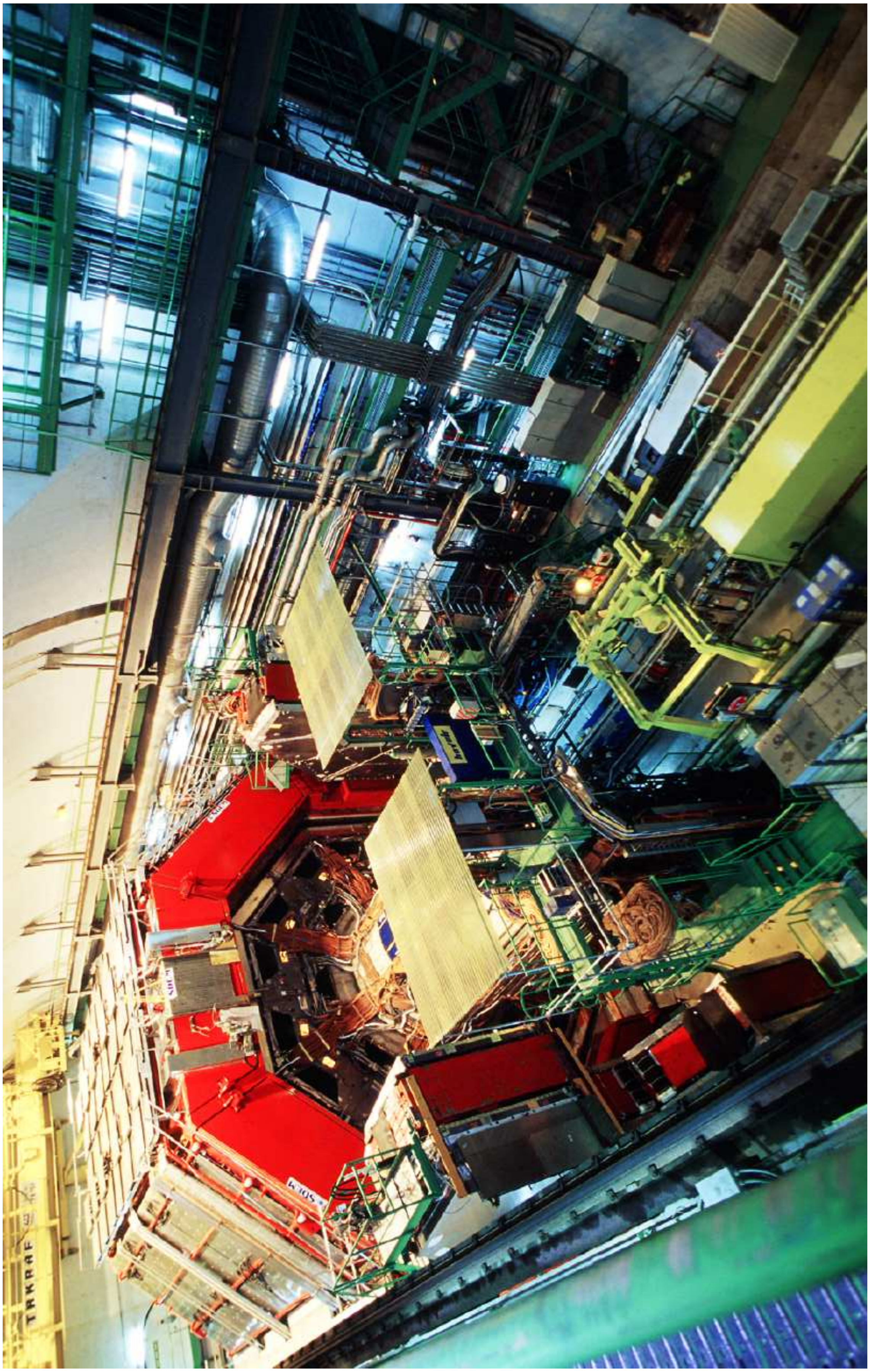
  very forward particle production, primary chemical composition.

- other topics: GRB, bursts from point sources, assymetries...

LEP at CERN (Geneva)     Longitude: $6^0$ E;   Latitude $46^0$ N;   Altitude 450 m;   L3 -45 m

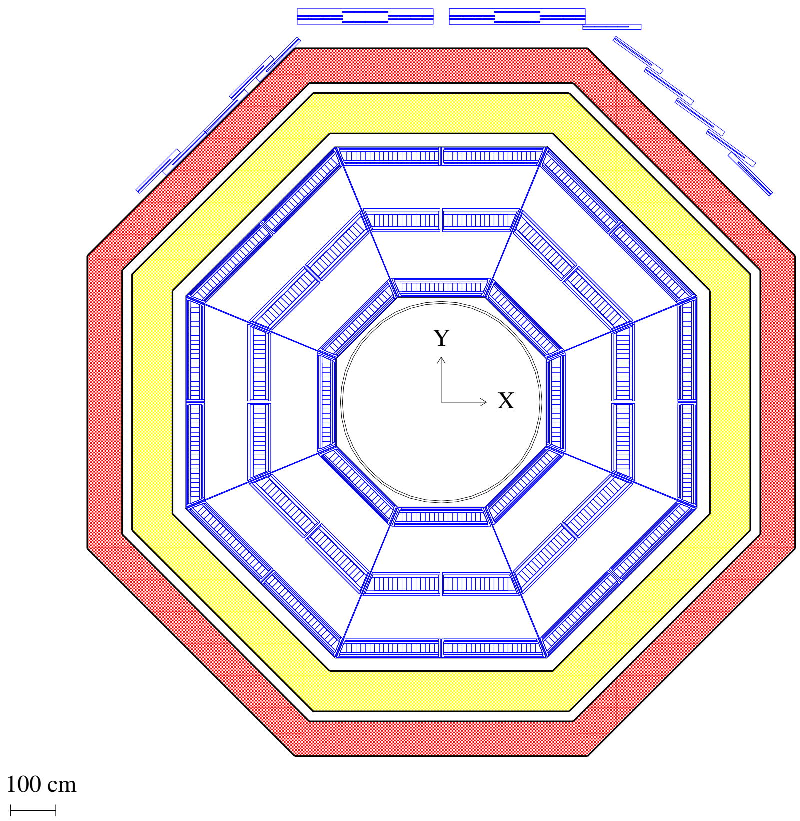



Scintillator Tiles
Muon Detector
e+
BGO Calorimeter
Silicon Detector
Barrel Yoke
Main Coil
Door
Crown
Hadron Calorimeter
Vertex Detector
e-



# The muon spectrometer:

- Detector volume: 1000 $m^3$ of B-field.
- Underneath 30 m of molasse.
  (15 GeV/c cutoff)
- Magnetic Field: 0.5 T.
- 80 drift P chambers arranged in octants. (Measure positions in the bending plane.)
- 96 octant arranged drift chambers to get Z. (Z: along beam axis)
- Cosmic read-out independent of L3 main experiment.
- Scintillators to measure arrival time. ( $200m^2$)



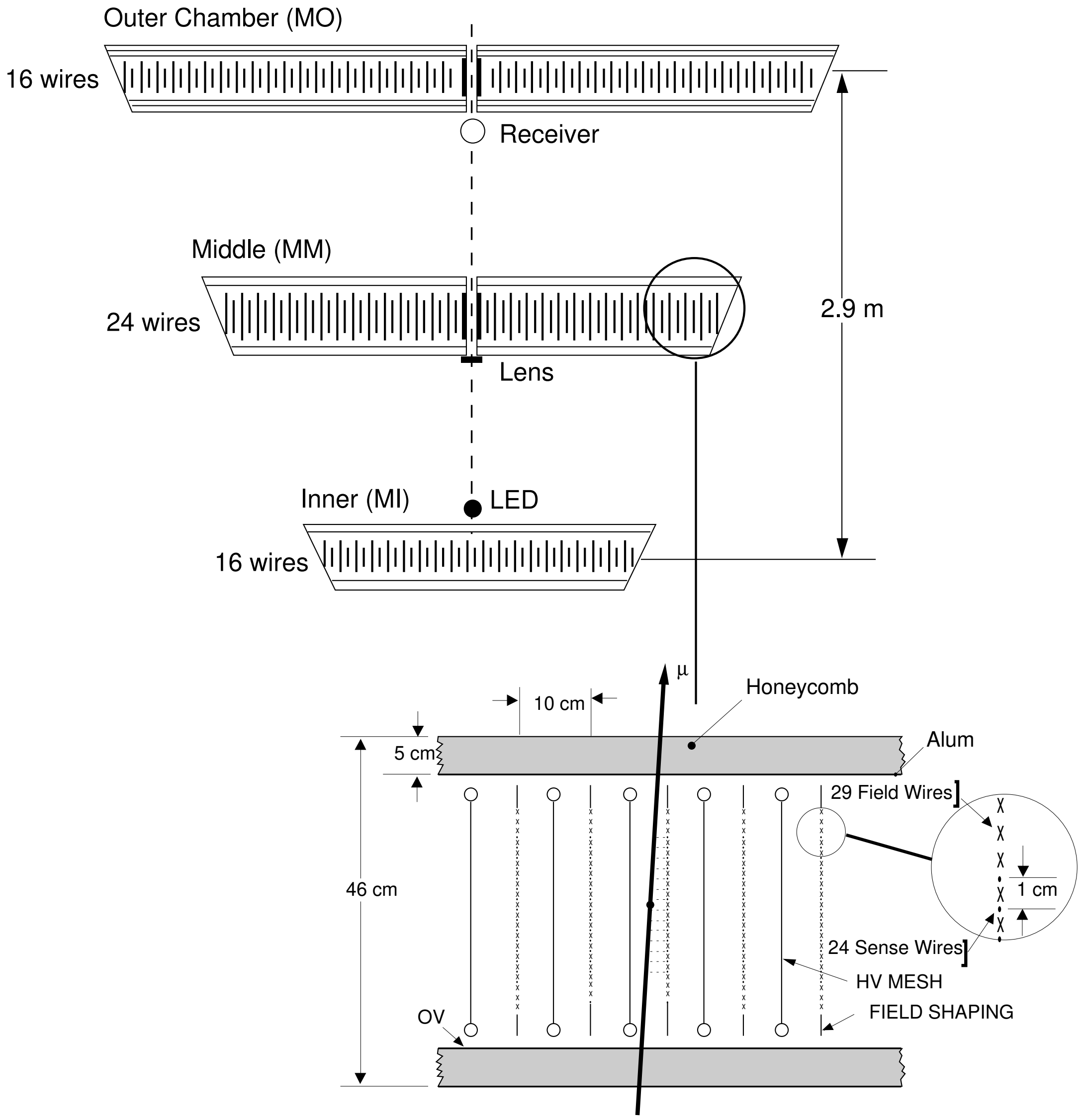
# The muon P chambers:

- Alignments known to 20 $\mu$m.

  monitored continuosly

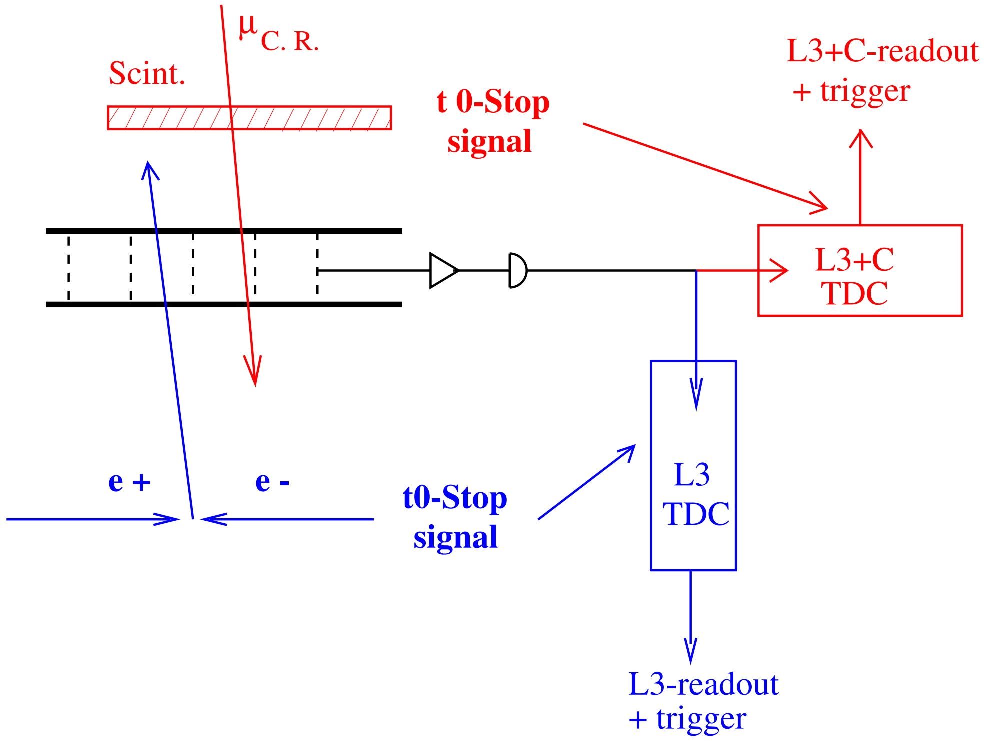
- Single wire resolution: 200 $\mu$m.
- Outer chambers : 16 wires

  middle chamber : 24 wires



# The T0 detector:

- Signals from 96 tiles (25 X 25 $cm^2$ each) sent through WLS fibers to 2 PMTs → (6 $m^2$. modularity)
- 34 modules → 200 $m^2$
- 34 X 2 PMT informations to the DAQ.



# Monitoring:

- Status of the spectrometer and LEP,continously monitored.
- Calibration data taken in parallel with L3.
- Survey online sent to the DataBase:

  - Run conditions. (Start-end,Live time,physics or calibration...)
  - HV and Discrim. in muon chambers,scintillators.
  - Magnet status.
  - Temperature at surface, atmospheric pressure.
  - DAQ conditions (Trigger class, DAQ occupancy...)
  - LEP induced scintillator noise.

  ...

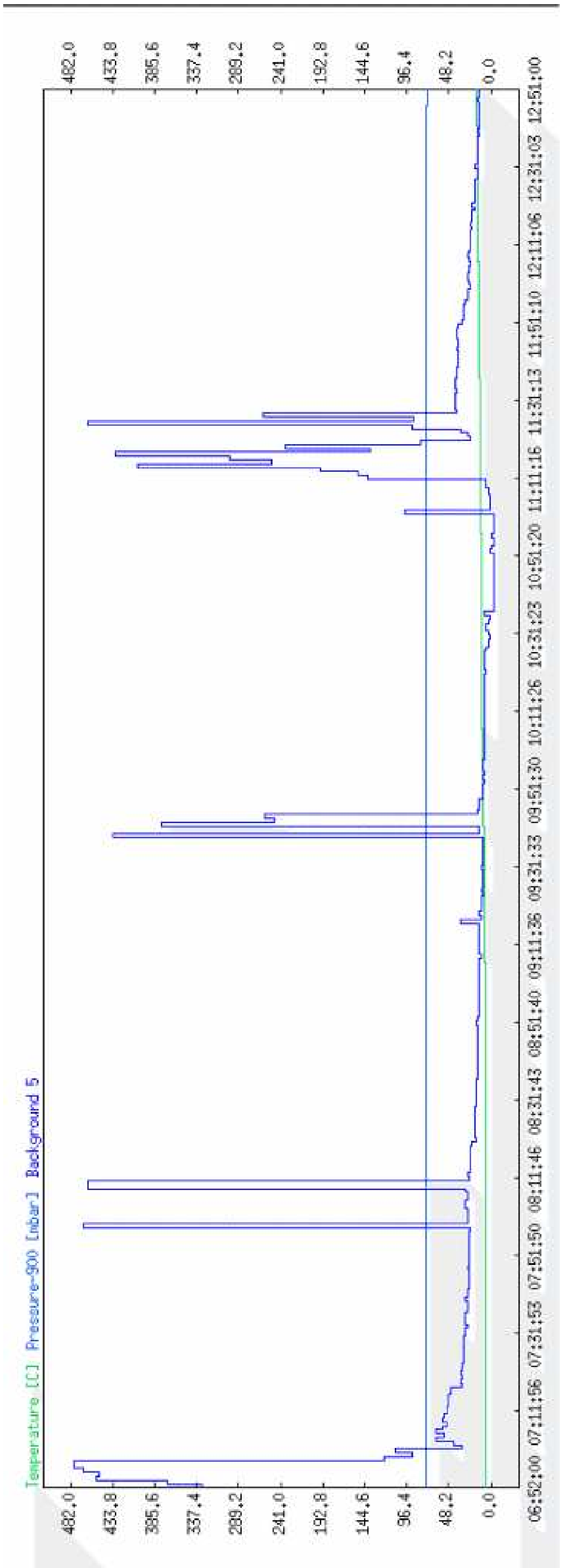
# DAQ:

- 10 X $10^{10}$ events on tape (99+2000)
- DAQ efficiency : 67% (99), 85% (2000)
- Main source of dead time:

  Start-Stop runs

  Human interventions.

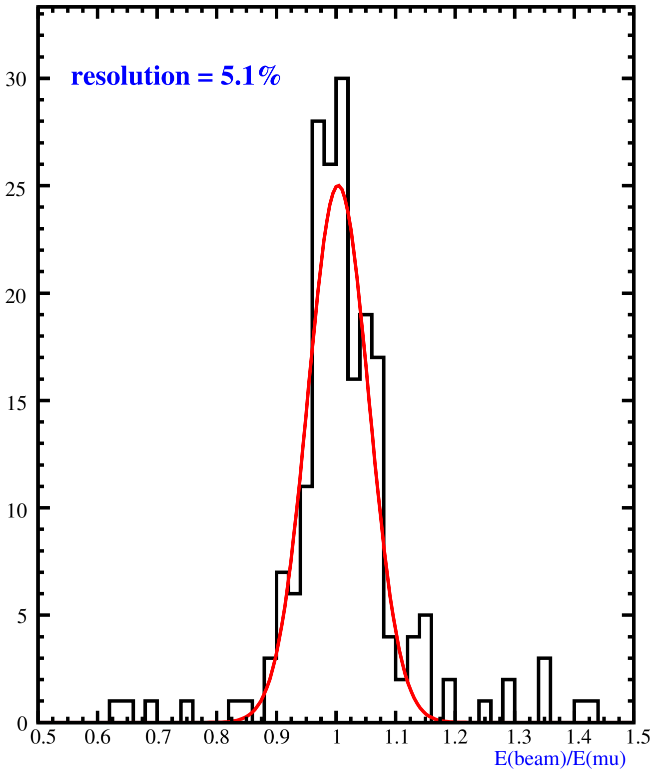
  Computer problems.


Temperature [C]
Pressure-900 [mbar]
Background 5
482,0
433,8
385,6
337,4
289,2
241,0
192,8
144,6
96,4
48,2
0,0
06:52:00
07:11:56
07:31:53
07:51:50
08:11:46
08:31:43
08:51:40
09:11:36
09:31:33
09:51:30
10:11:26
10:31:23
10:51:20
11:11:16
11:31:13
11:51:10
12:11:06
12:31:03
12:51:00

# Detector performance:

- Calibration using $e^+e^- \rightarrow Z^0 \rightarrow \mu^+\mu^-$ at the $Z^0$ resonance.
- Track selection:
  Both muons have hits in all 3 chambers.
  One of the muons crosses a scintillator.
- Resolution: 5.1 % at 45.6 GeV/c.
- Efficiency checked up to a few %

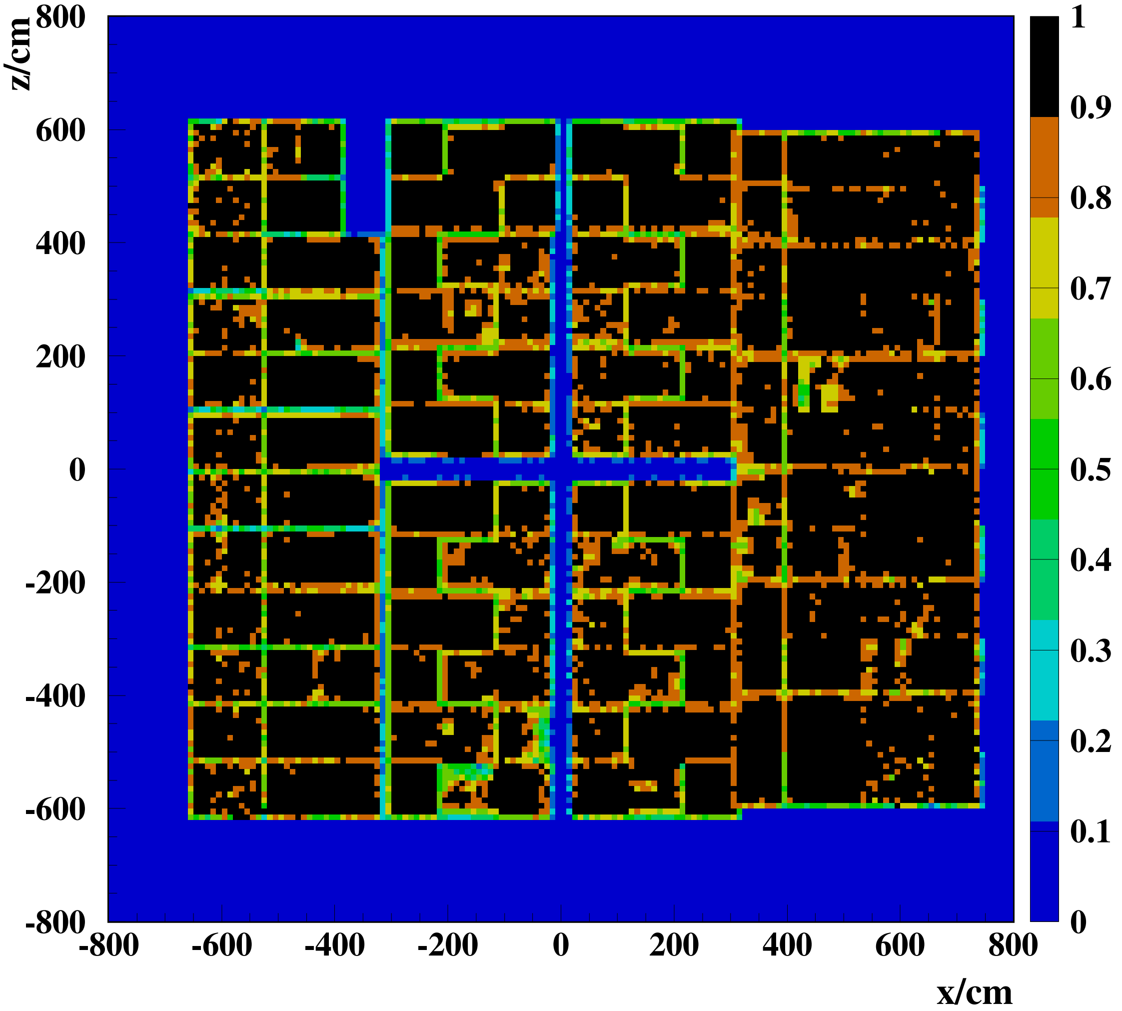
L3+C resolution at 45 GeV




L3+C resolution

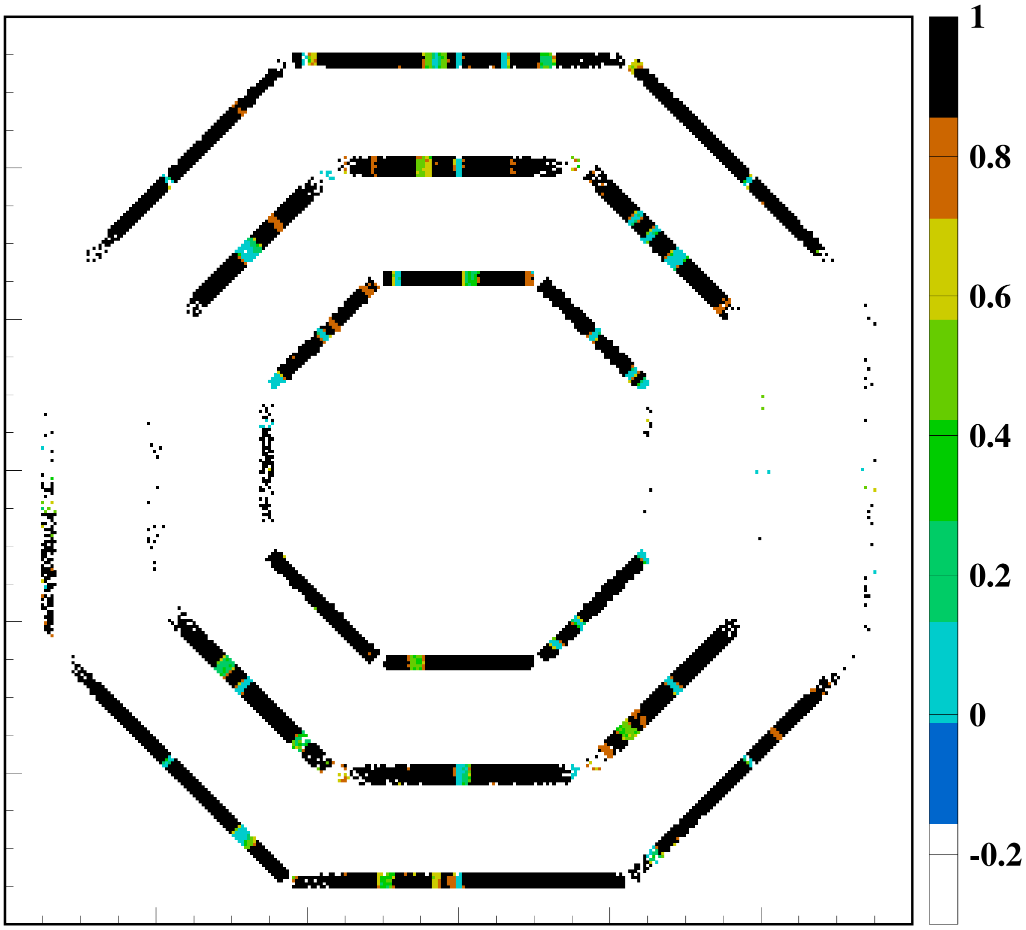
# Time-0 scintillator efficiency:

- A special trigger class with a no-scintillator requirement.
- Reconstruction of the events with $T^0$ from the chambers.
- Average efficiency 96%



# Muon chamber efficiency:

- We use the upper octants to X-ray the lower octants. (And vice versa).
- Tracks crossing inefficient regions are not used in the analysis.



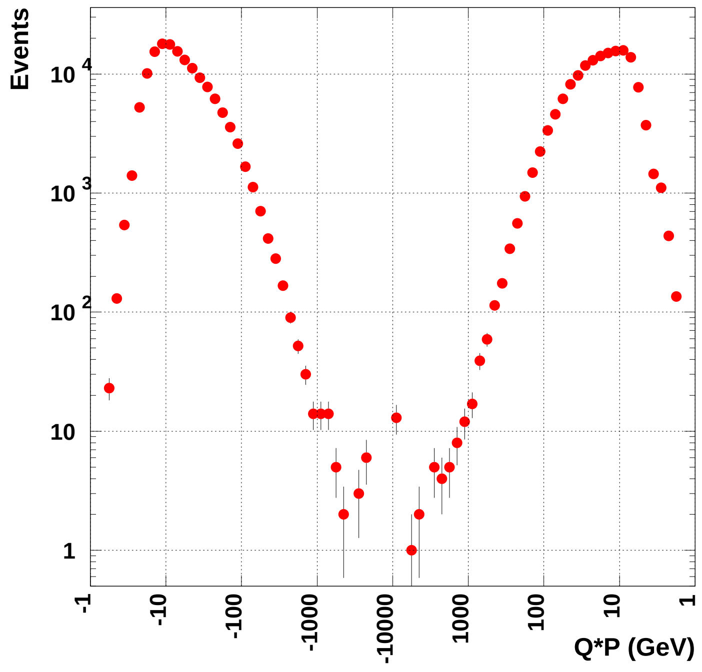
## Event selection:

- Two matched sub-tracks.
- Each with 3 P layers.
- Each with > 2 Z layers.
- Angle with respect to wire-plane $< 25^0$.
- P hits per layer $> 70\%$.
- Circle-fit $\chi^2/dof < 10$.
- Zenith angle $< 10^0$.

## Used data set :

- Datataking period: 15/9/99 - 9/11/99.
- Livetime: 30 days 8:44:55:25.
- Selected events: 299050.

# Vertical Spectrum Raw event sample.



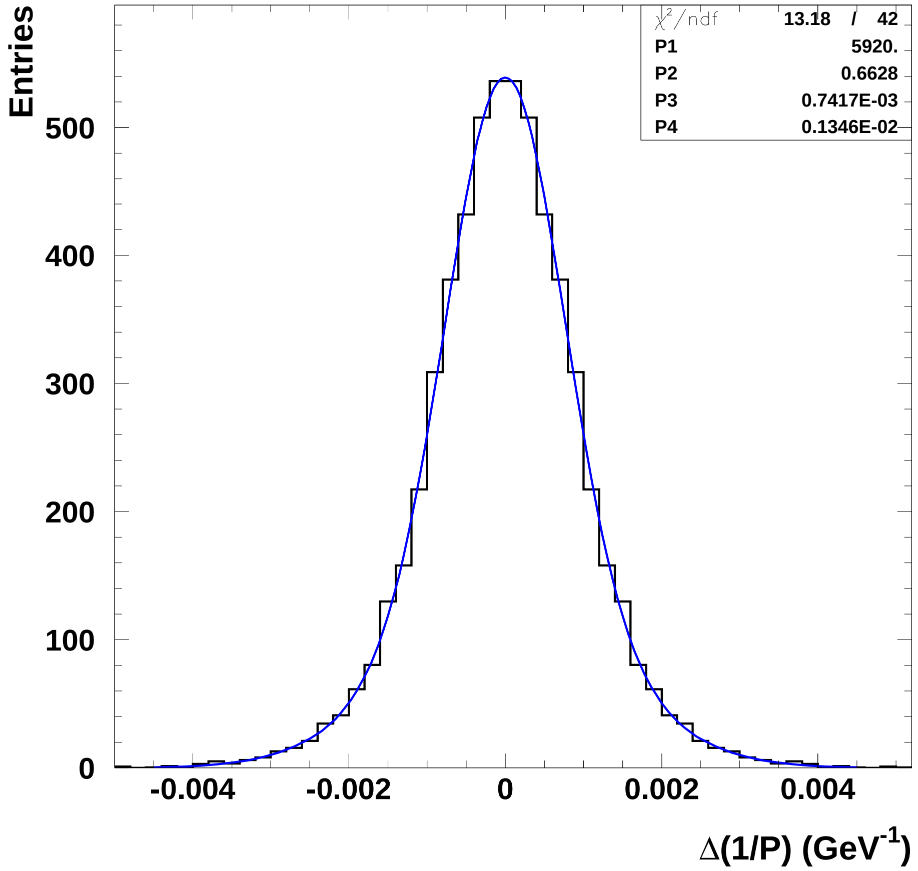

Efficiency corrections are applied.

- Muon chamber efficiency.
- Scintillator efficiency.
- Reconstruction efficiency.
- Matching efficiency.
- Trigger efficiency.
- ...

# The momentum resolution.

Determine the resolution on weighted average using the upper and lower half of a track.

Resolution at 100 GeV/c




The mom. res. allows to deconvolute the spectrum.

# The flux:

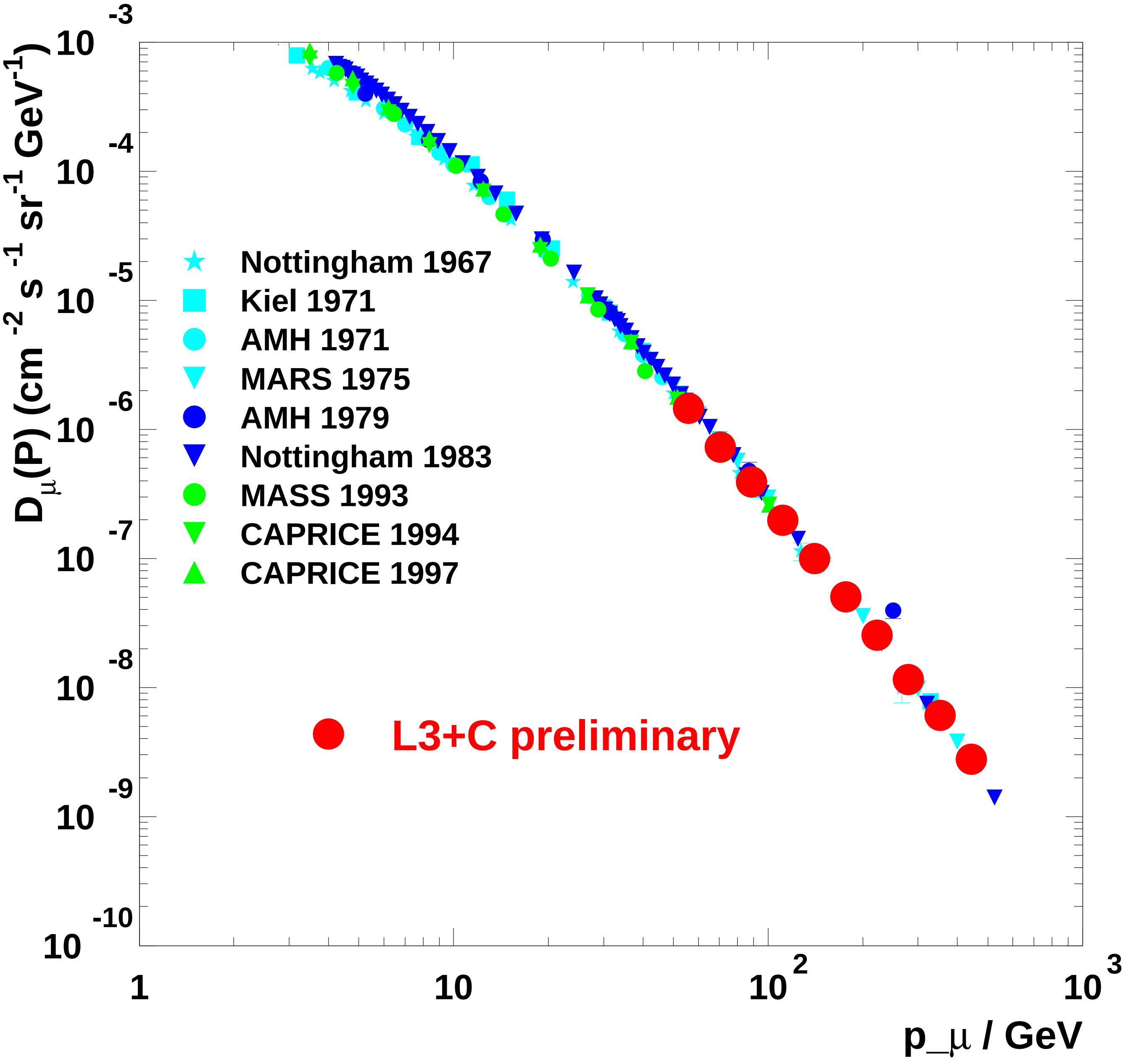
- Determine Data efficiency and MC efficiency.
- MC:$\rightarrow$ surface : CORSIKA
- (molasse+detector):GEANT
- Determine MC acceptance:

$$A_{mc} = \frac{N_{acc}}{N_{gen}} \cdot \Omega \cdot S$$

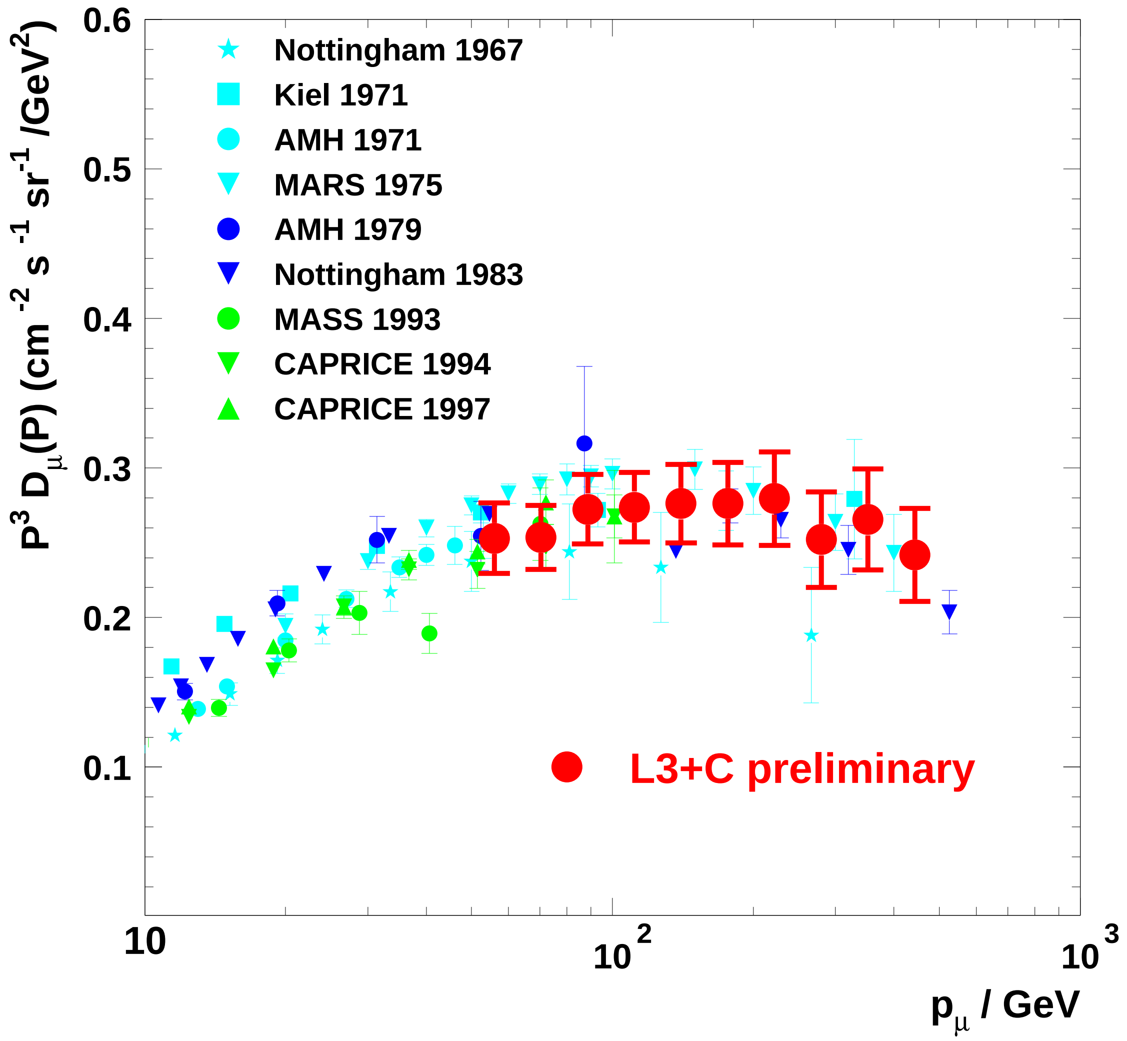
- Determine flux:

$$\phi = N_{data} \cdot \frac{\epsilon_{mc}}{\epsilon_{data}} \cdot \frac{1}{A_{mc} \cdot T}$$

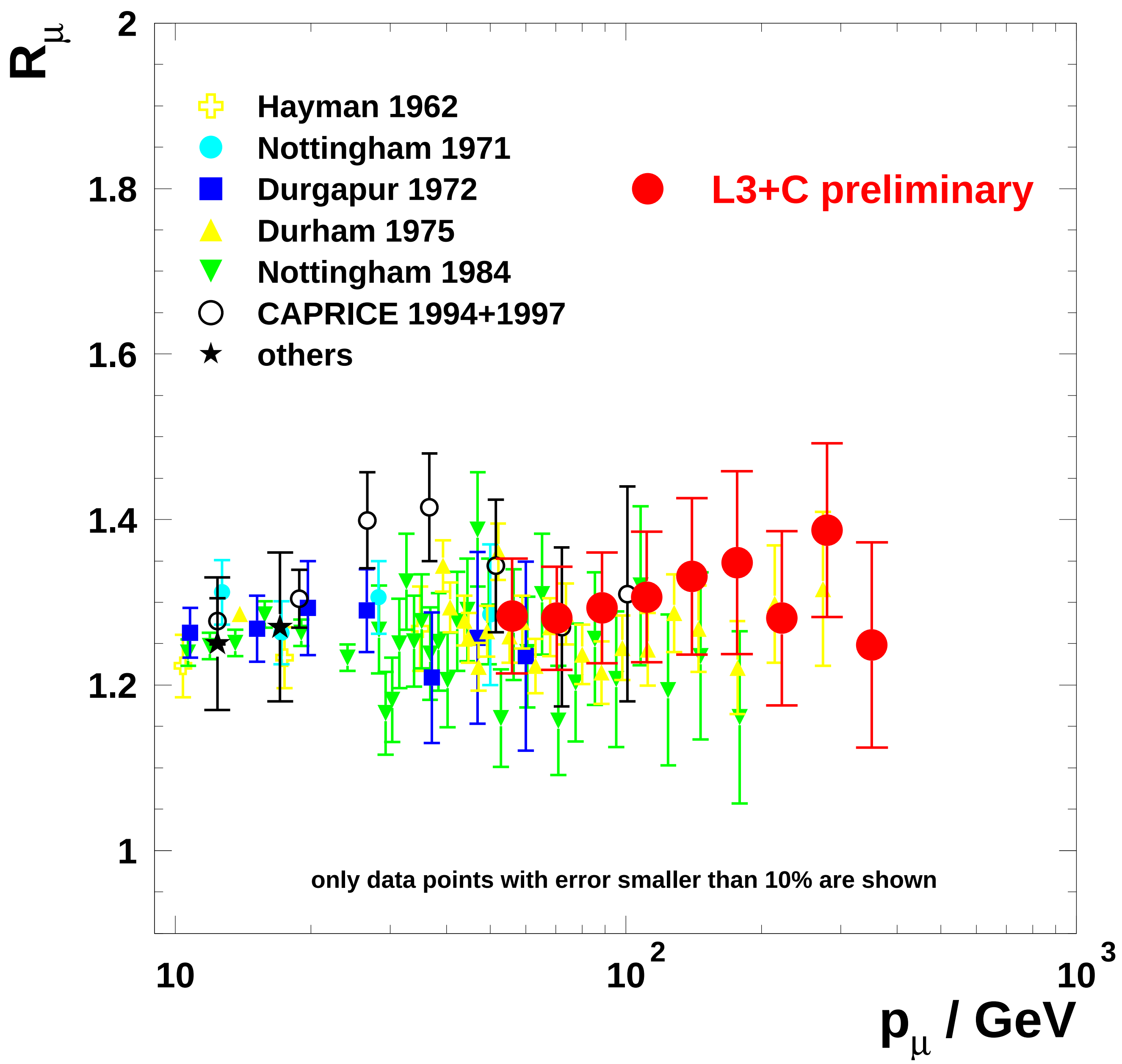
# Spectrum ( 0 - $10^0$ ):



# Spectrum $\times p^{-3}$ (0 - $10^0$):

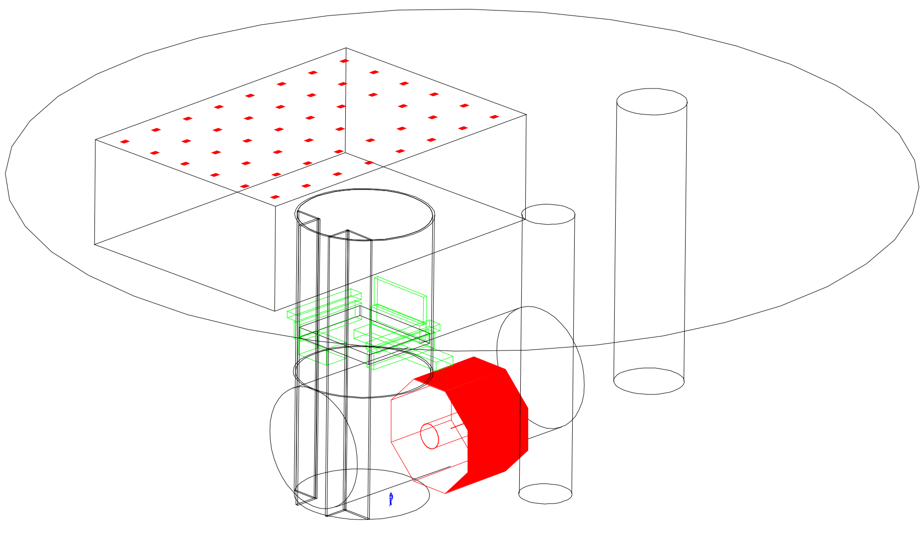


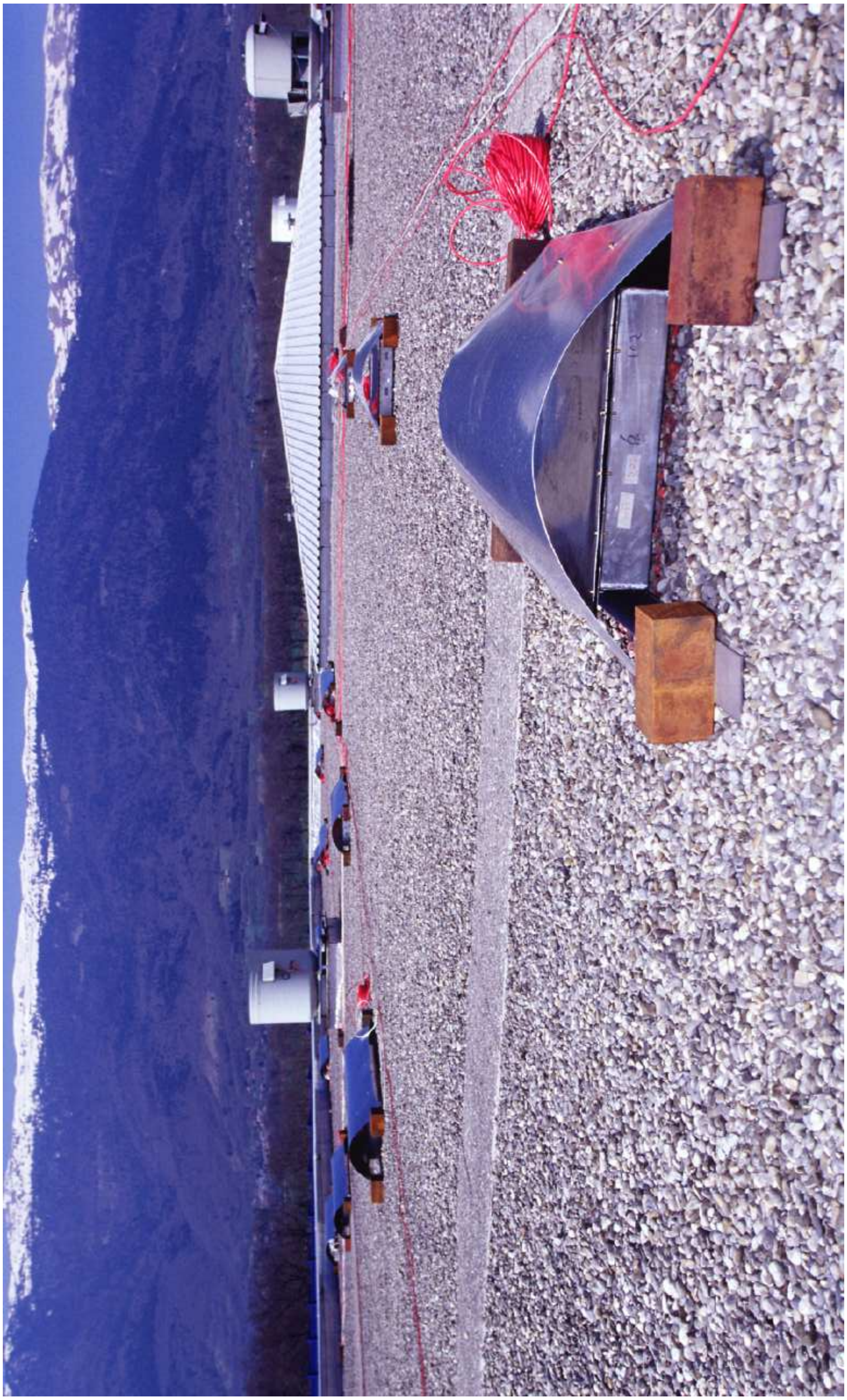
# Charge ratio ( 0 - $10^0$ ):



## 2000 setup.The air shower array :

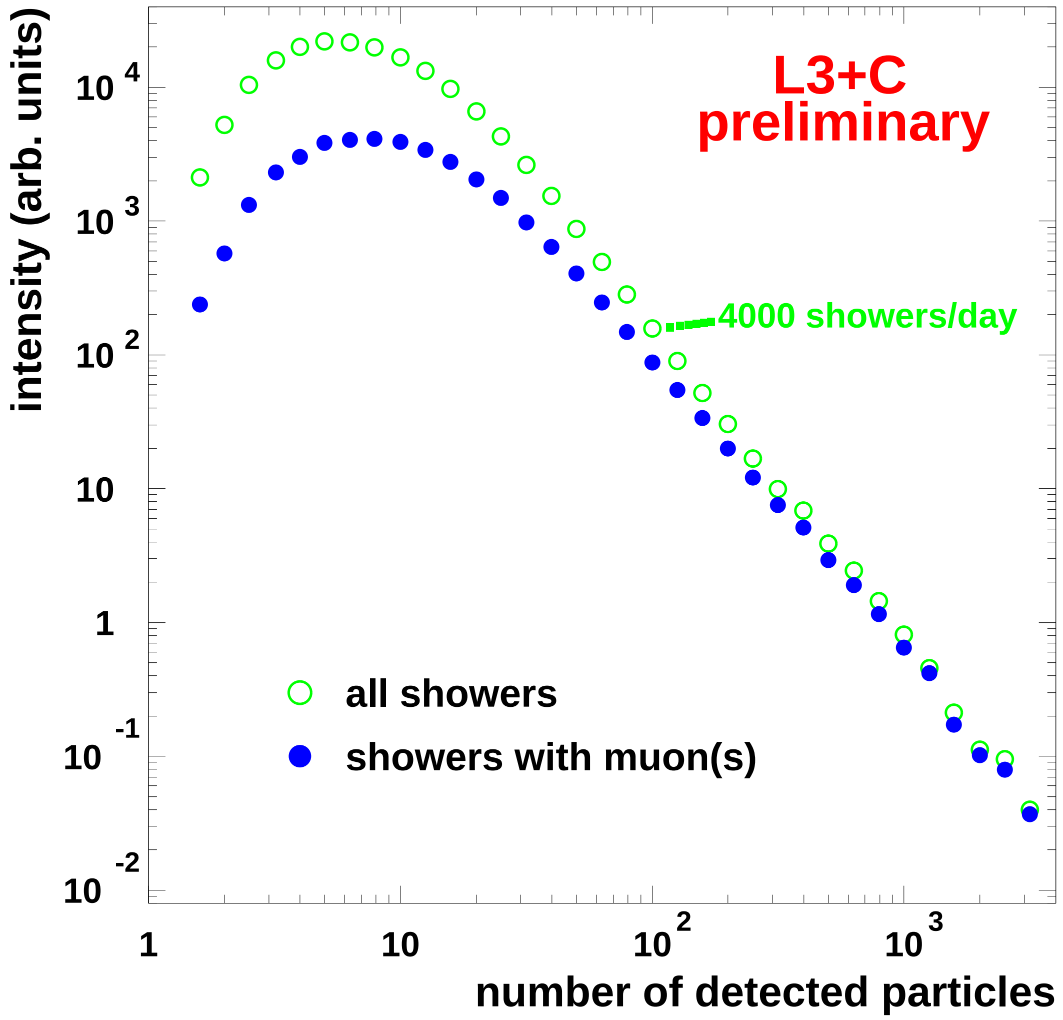
- The setup:
  Surface: 30X54 $m^2$.
  50 scintillator modules (0.5 $m^2$.)
- Data taking started April 6th 2000.
- Trigger:
  Hits in 3 adjacent rows.
- Timing from L3+C GPS.
- Energy threshold $\approx$ 10 TeV.
- Energy resolution $\approx$ 30% TeV.
  (when shower core inside array)
- Angular resolution $\approx 1^0$.





# Air shower array

data from one week (uncorrected)




Roughly:

N particles in the array $\rightarrow$ shower energy $\rightarrow$ N TeV

# Air shower array. Statistics.

- $10^5$ showers per day.
  (rate:1.7 Hz)
- 30% of showers have associated muons in L3.
  (coincidence rate: 0.6 Hz)
- The 'knee' region:

  $E > 10^{14}$ ev : 2000 events/day (200 with core in the array)

  $E > 10^{15}$ ev : 25 events/day (2.5 with core in the array)

## Summary and outlook

- A new type of cosmic ray detector, L3+C combines surface air shower data with precise muon measurements, 30 m. underground.
- First preliminary results on vertical muon spectrum and charge ratio up to momenta of 500 GeV.
- Substancial reduction in statistical and systematic errors expected in the future.
- The measurement will be extended to larger zenit angles. ($\approx\ 50^0$) and wider momentum range. (goal: 20 GeV $\rightarrow\approx$ 1 TeV)
- Multi-muon events and shower energy measurements will be used to constrain the chemical composition of the primaries in the knee region and to study very forward particle production.
- Several other topics are under investigation.
- Experiment is running till November 2000.