The L3 + Cosmics experiment.

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(On behalf of the L3 collaboration.)

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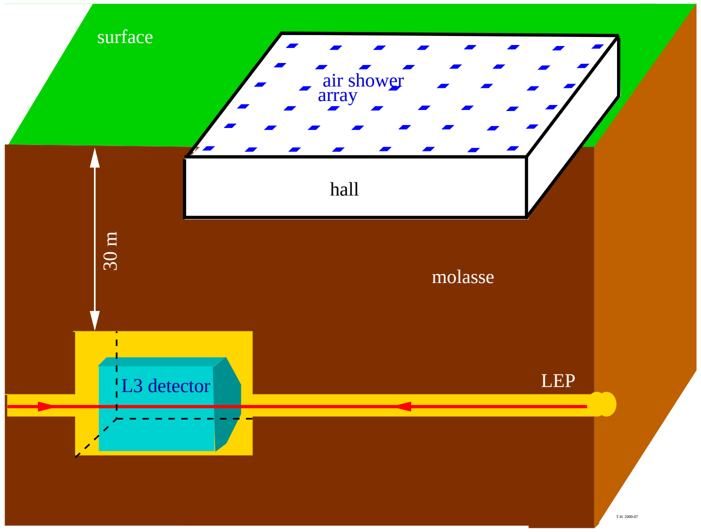
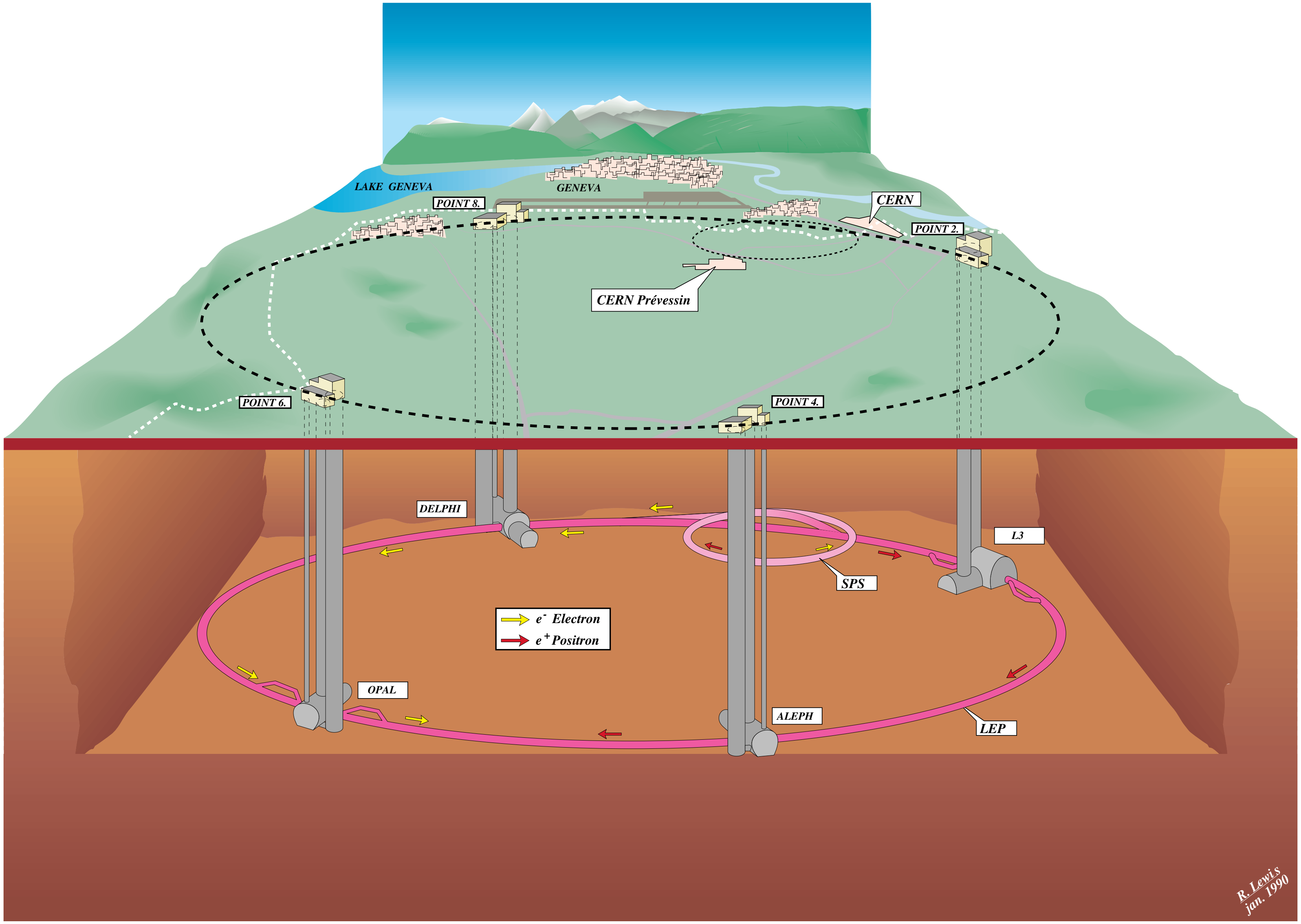


Contents

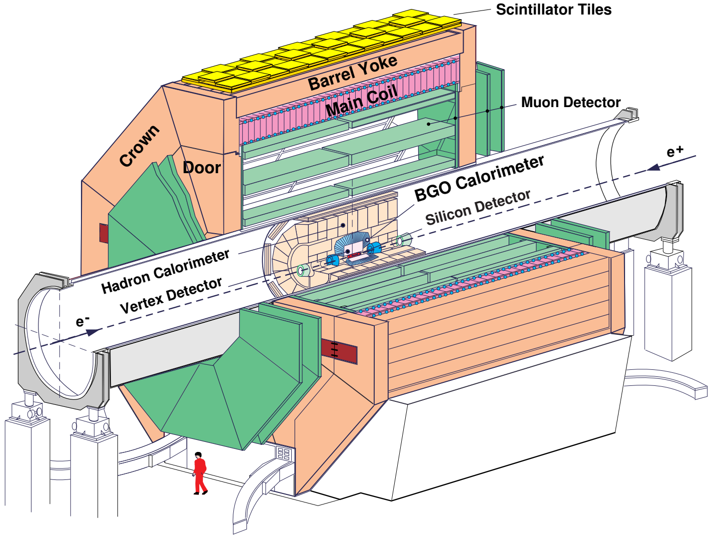
- The L3+C tool-set.
- Physics topics addressed by L3+C
- Brief description of one of the topics:
  - The moon shadow.
- Conclusions.

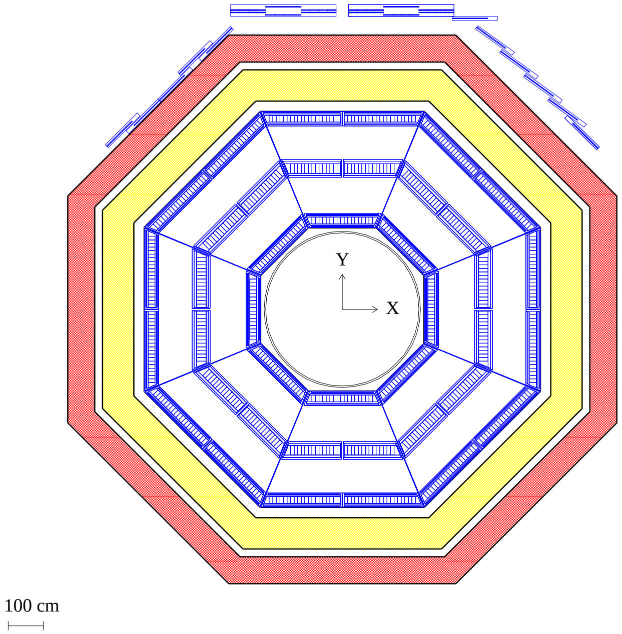
LEP at CERN (Geneva) Longitude: 6^o E; Latitude: 46^o N; Altitude: 450 m; L3: -45 m



The L3+C setup

The μ detector





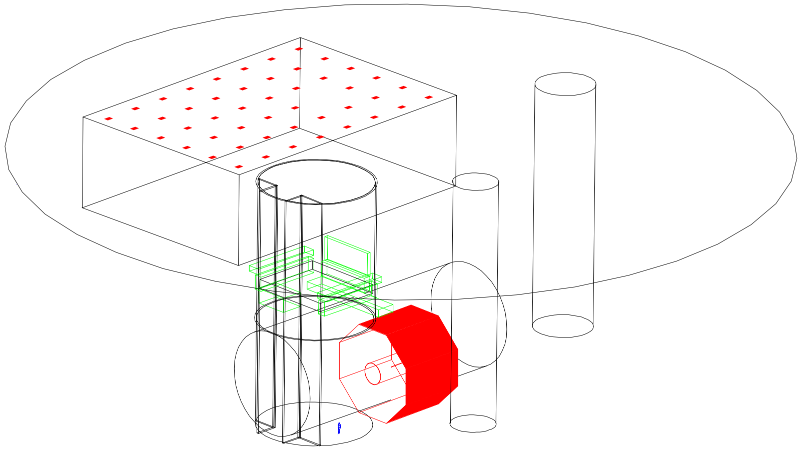
- **Magnet (0.5 T, 1000 m^3)**
- **High precision P and Z drift chambers ($>$ 22000 channels)**
- **t_o-detector (202 m^2 of scintillator)**
- **Trigger and DAQ independent of L3**

The L3+C setup

The μ detector. Properties.

- **Hadronic and EM components filtered by 30 m. of molasse**
- **μ threshold:** $E_\mu > 18GeV(> 7Gev)$
- **Geometrical acceptance :**$\Sigma \cdot \Omega \simeq$ **200** m^2sr
- **Momentum resolution:** $\Delta p/p =$ **2.6** $\%$ **at 100 GeV/c**
- **Angular resolution:** $\delta\ \Theta <$ **5 mrad above 100 GeV/c**
- **GPS timing :event time to 1** μ**sec**
- **Trigger and DAQ independent of L3**
- **Online Monitoring and DataBase independent of L3**

The L3+C setup,Air Shower Scintillator Array



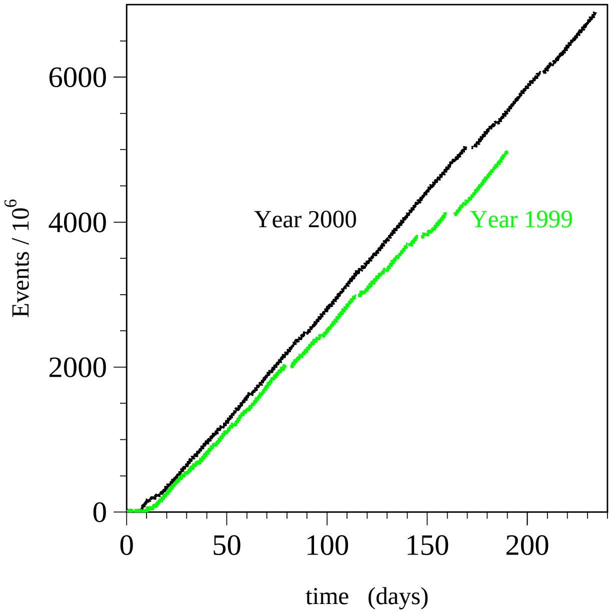
The L3+C setup

The air shower scintillator array.

- 47 modules of scintillation counters, 0.5 m^2 each.
- Layout: six rows on a 30 x 50 m^2 surface.
- GPS synchronised clock.
- Arrival times + Integrated signal intensity recorded for each module.
- Trigger: ≥ 1 detector “hit” per row of 8 detectors for 3 adjacent rows
- Shower rate =1.7 Hz (47$\%$ associated with a muon in L3)
- E-trigger threshold =10 TeV
- $\Delta\ \Theta$ of shower axis= 4^o above 30 TeV
- 25 events/ day with E 10^{15} eV
- Events flagged when L3+C gets a trigger and vice versa

Number of collected events during the two years

11.85 $\cdot\ 10^9$ **μ-triggers, 312.1 d live-time**



+ 28 $\cdot\ 10^6$ **shower-triggers, 212 d live-time**

Physics topics addressed by L3+C

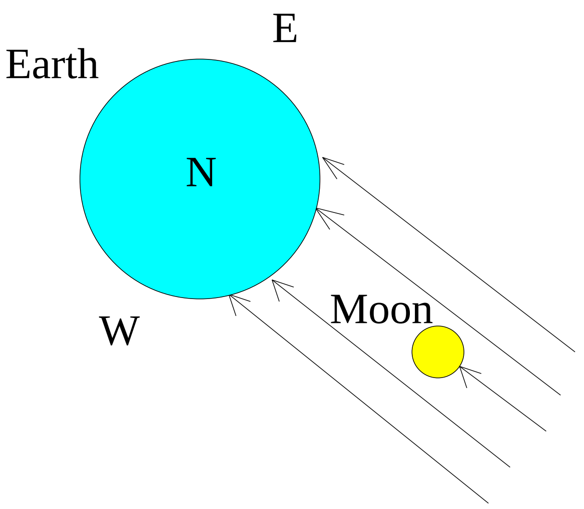
- The μ-momentum spectrum and charge ratio.
- The primary cosmic ray composition.
- The primary antiprotons around 1 TeV and the Moon shadow.
- Search for burst signals from point sources.
- Search for VHE Gamma Ray Bursts.
- Seach for HE protons from Sun (solar flares).
- Correlations over large distances.
- Search for exotic events.

We will concentrate next in the 3rd topic: the Moon shadow analysis.

The moon shadow

Cosmic rays are blocked by the Moon. (Clark 1957)

$\rightarrow$ deficit of CR when looking the Moon.



- Size of the deficit $\rightarrow$ angular resolution of the experiment
- Position of the deficit $\rightarrow$ pointing error.

Moon shadow has been observed. (SOUDAN. MACRO, CASA...)

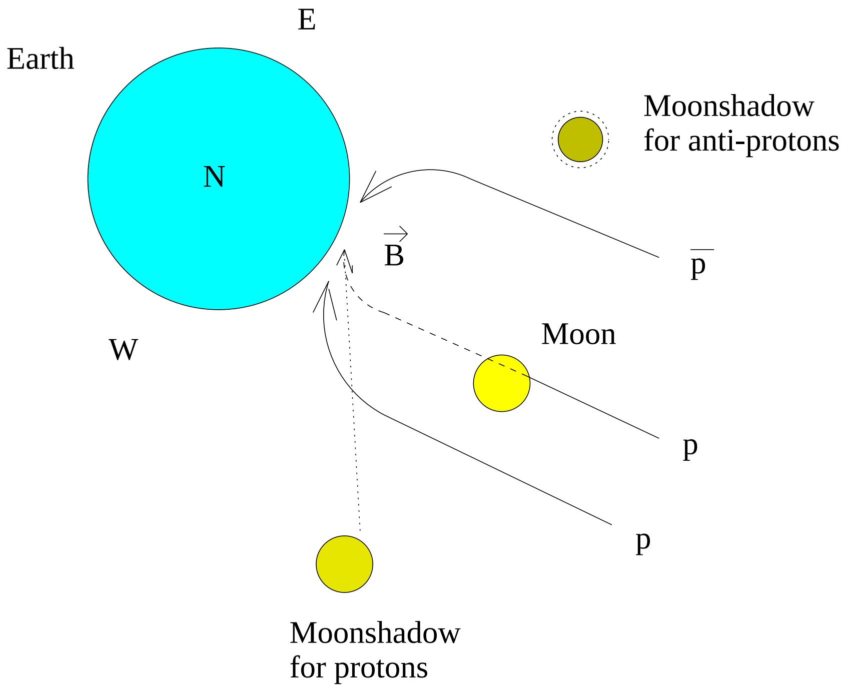
Effects of the geomagnetic field

positive charged particles deflected to the East

$\rightarrow$ Deficit appears shifted to the West.

$\rightarrow$If present,antimatter in CR will induce a deficit in the opposite side.

Deflection $\simeq 1^O$/ E(TeV/c)



Earth-Moon $=$ ion spectrometer (Urban et al., ARTEMIS experiment)

Trajectory of the Moon as seen from L3+C

GENEVA:(6.02^0N, 46.25^0E)

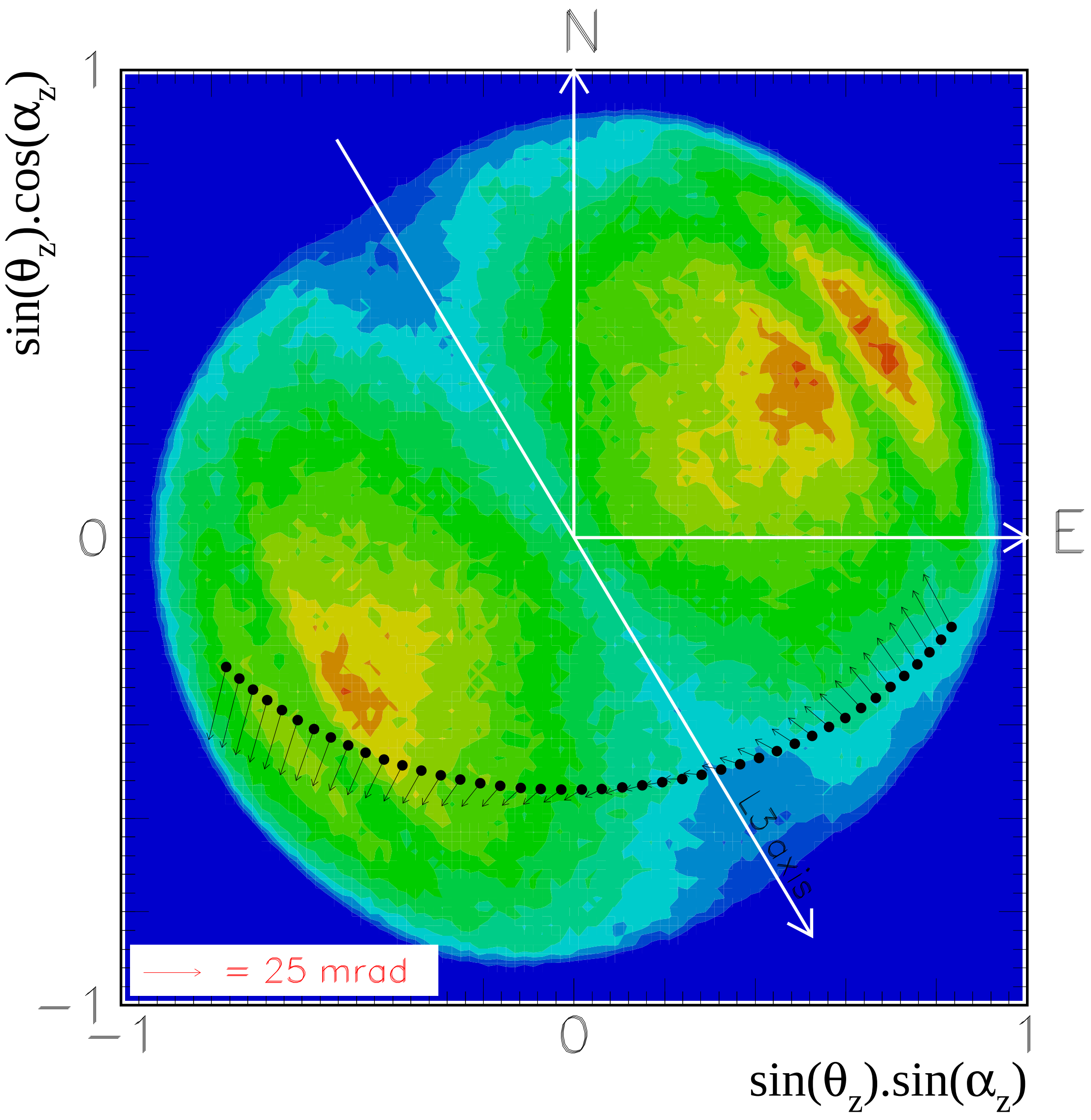
Sky seen by L3+C:

1 pixel = 1 direction

Moon trajectory:

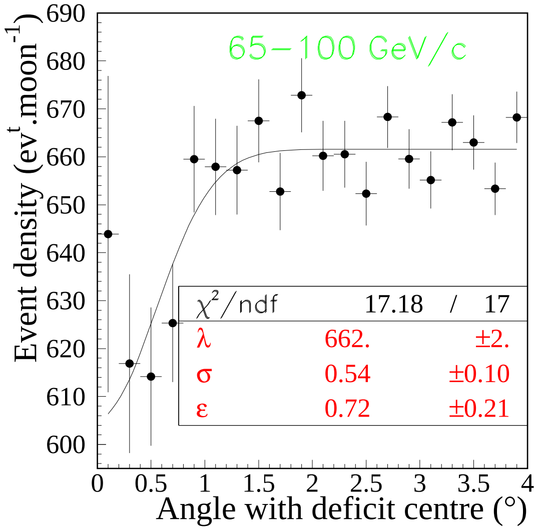
Deflection = f(Moon location)

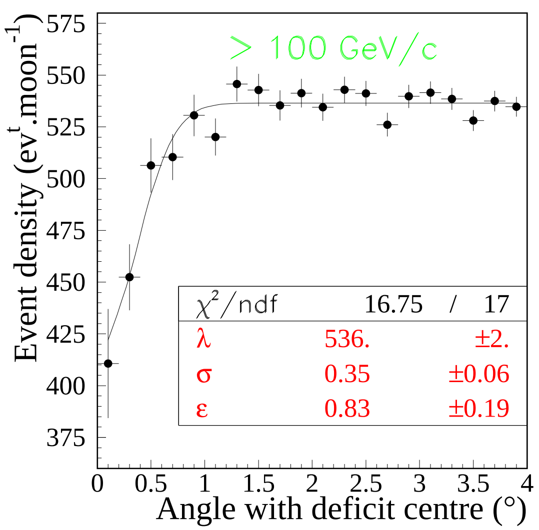
1 TeV protons



Observation of the Moon shadow in L3+C

$$f(\theta) = \lambda \cdot (1 - \epsilon \frac{R_{Moon}^2}{2\sigma^2} \cdot e^{-\frac{\theta^2}{2\sigma^2}}) \tag{1}$$





σ is the experimental angular resolution.Here includes:

- The angle between μ and primary particle
- the multiple scattering (mainly in the molasse)
- the detector angular resolution

+ the Moon shadow elongation by geomagnetic field.

The last contribution can be strongly reduced by a good choice of reference system.

Determination of the pointing error

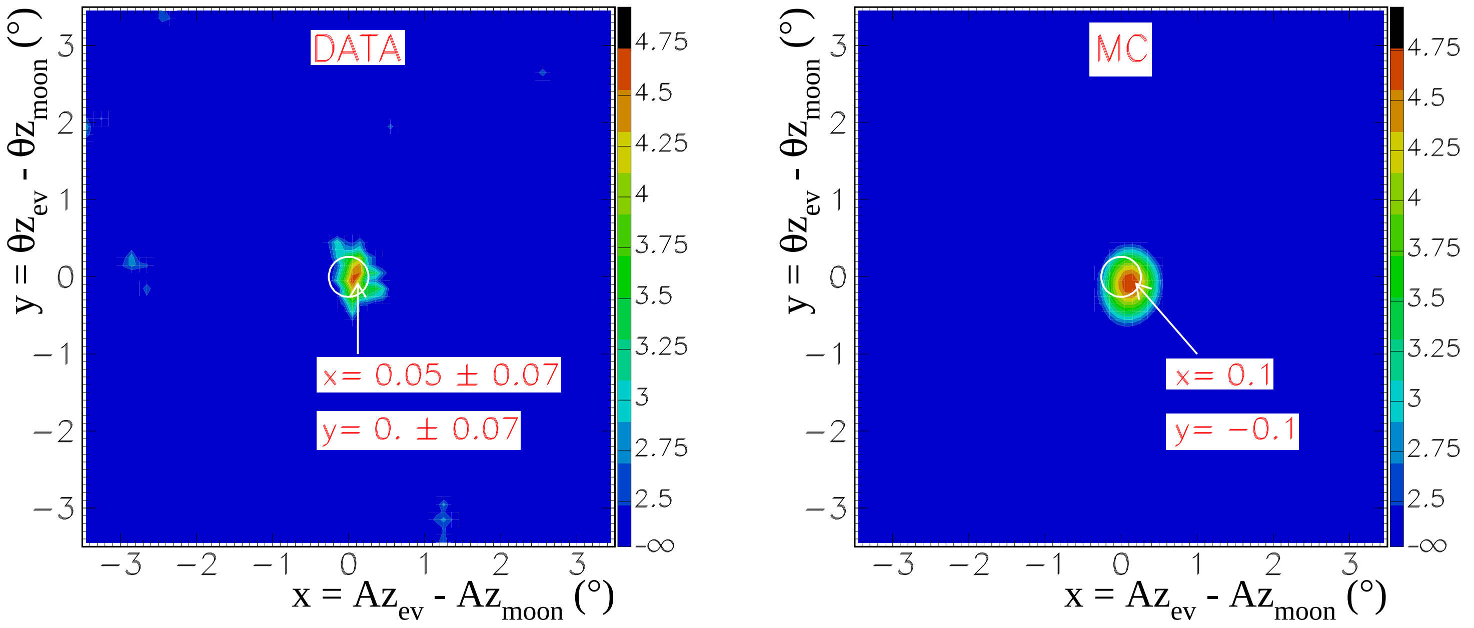
$|\ p_\mu\ | > 100$ GeV/c, use local coordinates system Zenith vs Azimuth

Background: Moon's path on sky delayed in time.

Substracted from source map $\longrightarrow$ Moon effect.

Smoothing: uniform distribution.

Result in standard deviations from normal distribution.

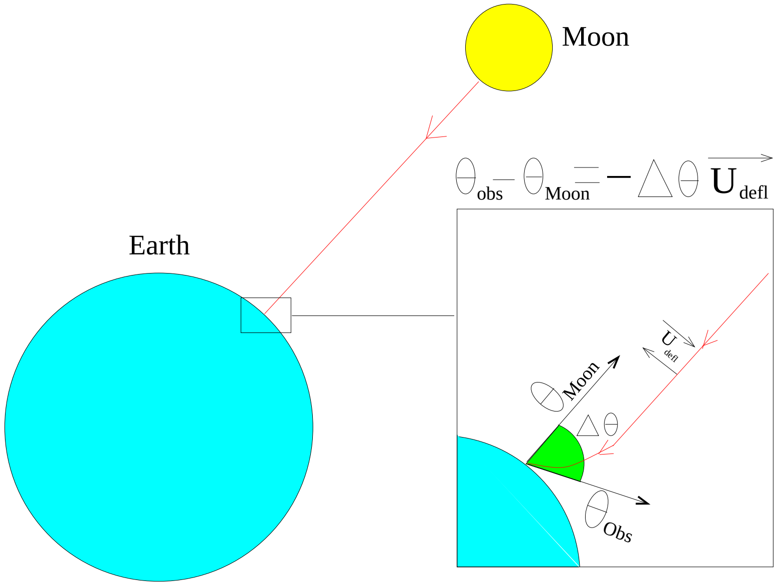


From comparison Data-Mc :pointing error $\simeq 0.1^o$

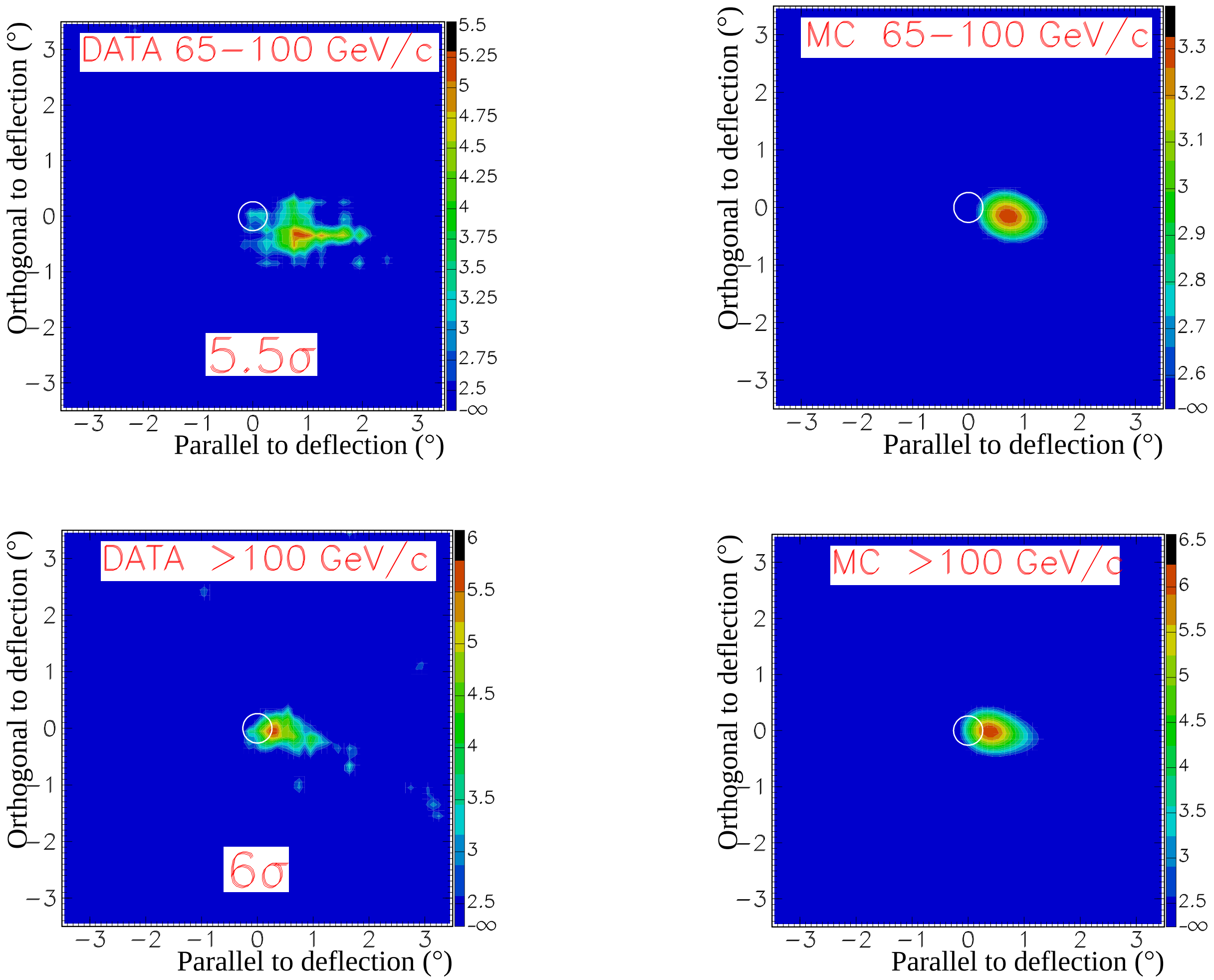
Deflection coordinate system

Choose a reference system with axes parallel to the deflection (Horizontal) and normal to the deflection Vertical)

- **Coordinates given by θ_H and θ_V**
- **Along V, dispersion due to angular resolution**
- **Along H, dispersion due to angular resolution + geomagnetic effect**
  $\longrightarrow$Signal density optimized along H



Observation of the geomagnetic field effect in the system H-V



65 - 100 GeV/c:Δx=0.80^o

>100 GeV/c:Δx=0.25^o

Determination of the effective angular resolution.

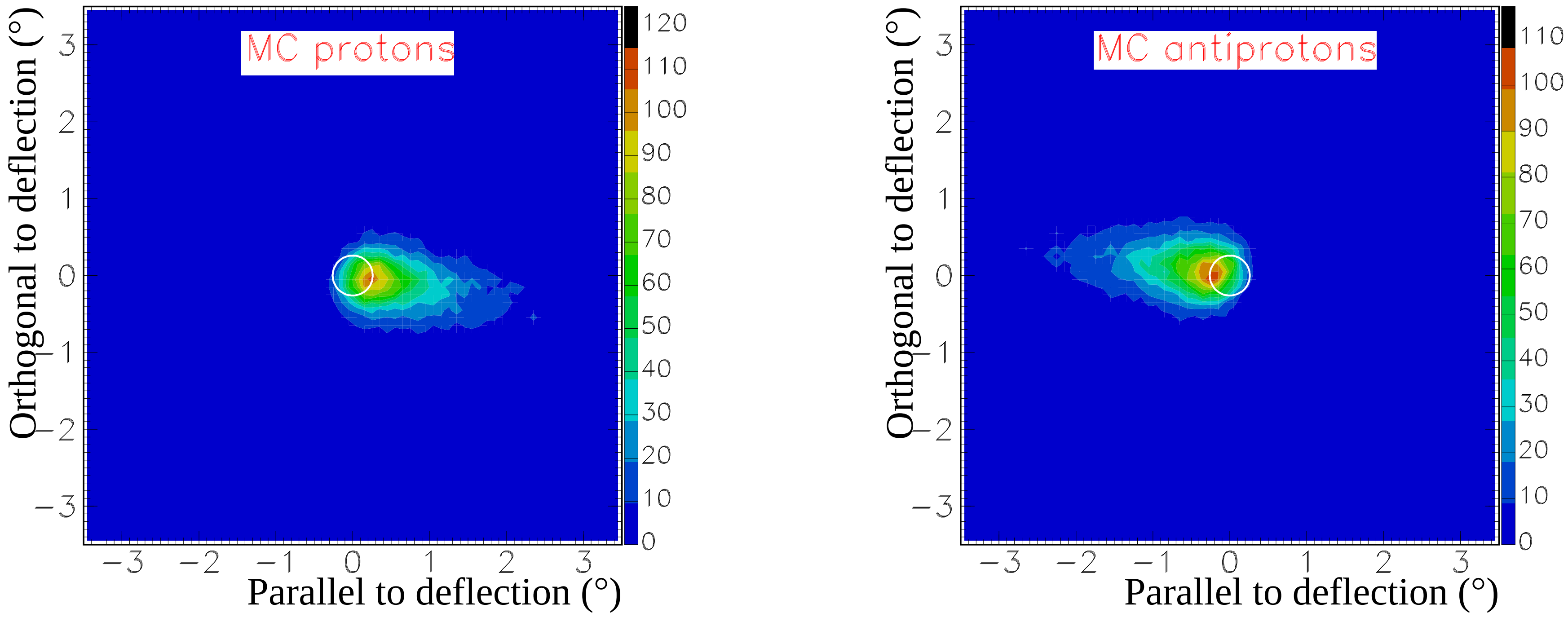
- Geomagnetic field $\longrightarrow$ horizontal axis.
- Projection on vertical axis: angular resolution only.

- Project Moon window contents on vertical axis.
- Fit to a gaussian.
- σ **values obtained:**
  - LE (Low Energy sample,65 - 100 GeV/c): $0.30^o \pm 0.07^o$
  (recall : 0.54 ± 0.10^o in local zenith-azimuth system)
  - HE (High Energy sample,$>$100 GeV/c:): $0.22^o \pm 0.05^o$
  (recall : $0.35^o \pm 0.06^o$ in local zenith-azimuth system)

Search for antimatter

Simulation: “anti-shadow” symmetric to Moon shadow.

$| \, p \, | > 100$ GeV/c



Measurement of the $\bar{p}/\bar{p}$ ratio.

Select $\mid p_\mu \mid >$ 65 GeV/c.$\rightarrow$ (0.5-2. TeV for primary protons)
Work on the deflection coordinates system.

Hypothesis: $\bar{p}$, p spectrums with same index.

Assumption: data can be described by
- A planar background
- 2 symmetric Gaussian deficits for p and $\bar{p}$

Maximum likelihood fit:

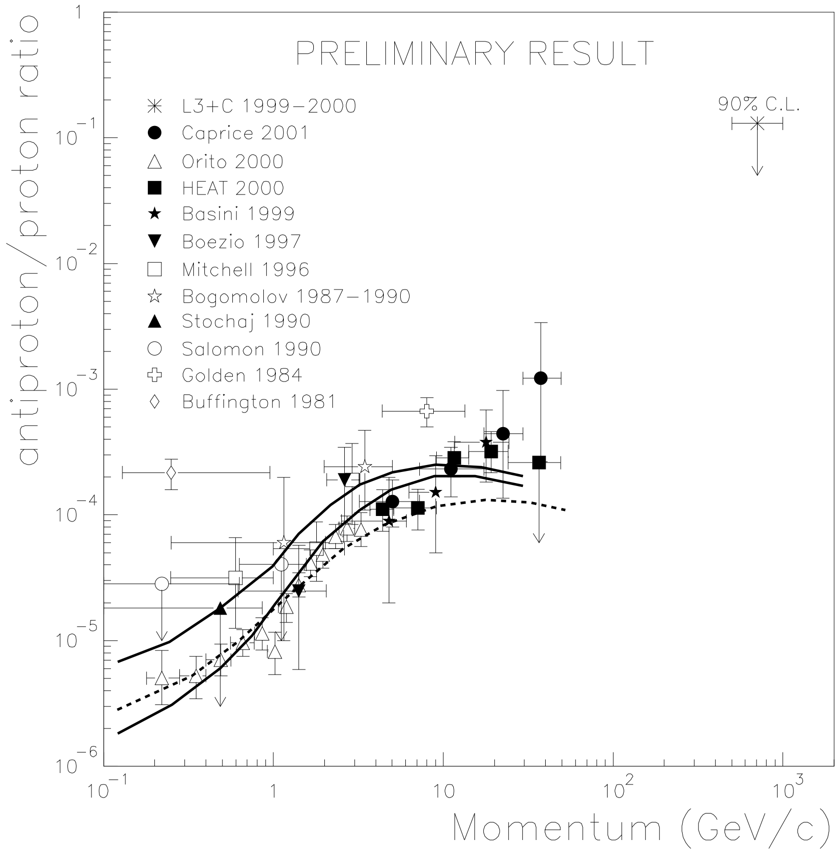
$$f(x,y) = ax + by + c - N[\, G(x_o, y_o, \sigma) + r\, G(-x_o, -y_o, \sigma)\,]$$

x_o,y_o :offset due to the geomagnetic field.
r :$\bar{p}/p$ ratio.

$\longrightarrow$ Moon shadow observation with 8σ significance

Preliminary measurement: r= -0.14 $\pm$ 0.15 $\longrightarrow$ r< 0.13 with 90 % C.L.

Existing data in $\bar{p}/p$ ratio. L3+C provisional limit.



L3+C: $\bar{p}/p \leq$ 0.13 (90 % CL)
Expected with full statistics: $<$ 0.1

Summary

- The L3+C experiment at CERN that combines a small air shower scintillator array in surface with the high resolution underground muon spectrometer from L3 has been described.

- The analysis of the data to study topics related to neutrino physics, solar physics, primary composition, point sources, GRB's..., using the measurement of atmospheric muons in the range 18 GeV to 2 TeV , is underway.

- A significant moon shadow effect has been observed. The good angular resolution of the experiment has allowed to observe clearly the offset and the elongation of the Moon "muon shadow" expected for the geomagnetic field for 2 different energy ranges. A preliminary measurement of the $\bar{p}/p$ ratio yields un upper limit of 0.13 at 90% C.L. for the muon sample with $E_\mu \geq 65$ GeV/c. A more sophisticated method to determine the angular resolution using the dimuon events sample, along with the introduction of the He in the game is expected to give improved results before summer.