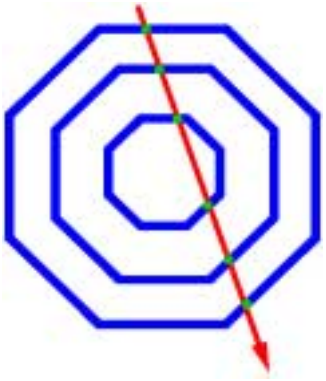

Preliminary results from the L3+C experiment at CERN

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October 2000

Outline:

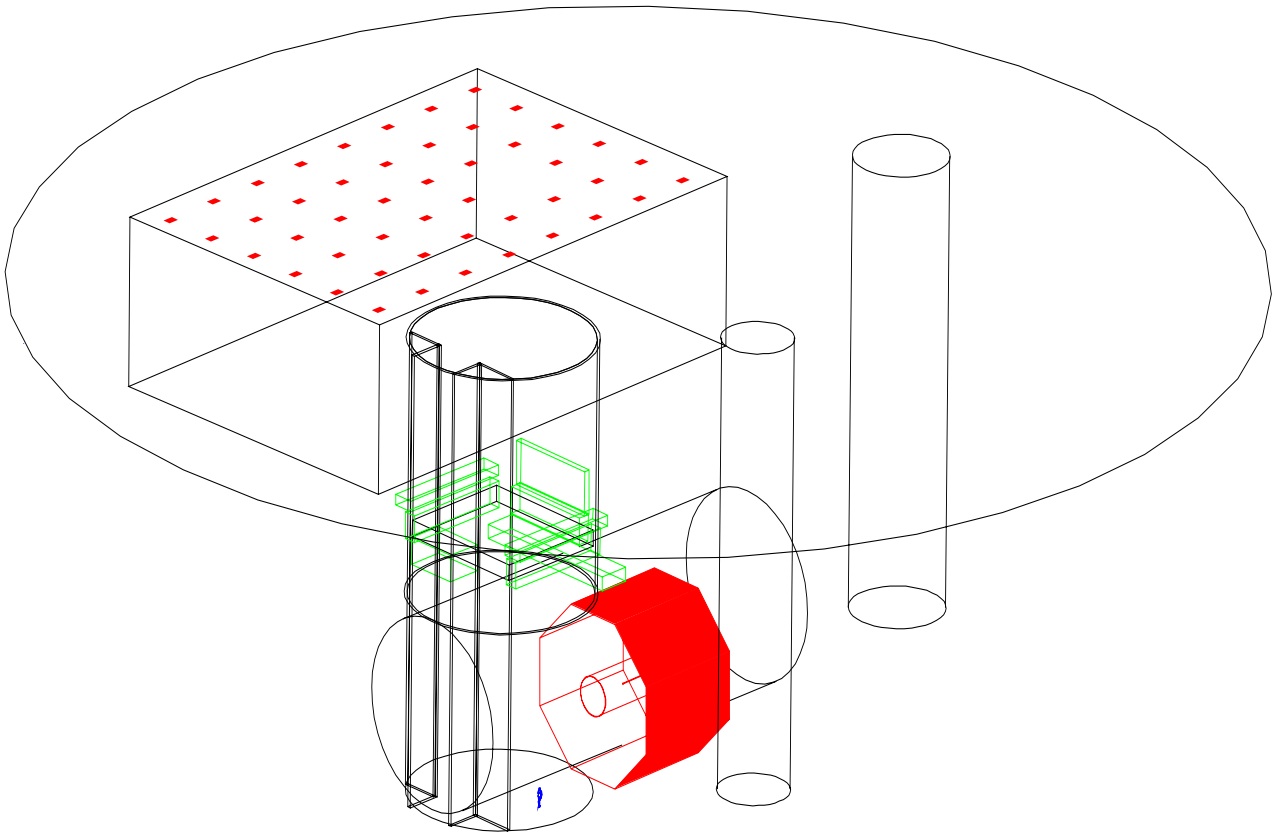
- The L3+C Experiment
- The muon spectrometer
- The air shower array
- Preliminary results:
  - Vertical muon momentum spectrum
  - Charge ratio
  - Sideral anisotropy
- Conclusion

L3+C Experiment

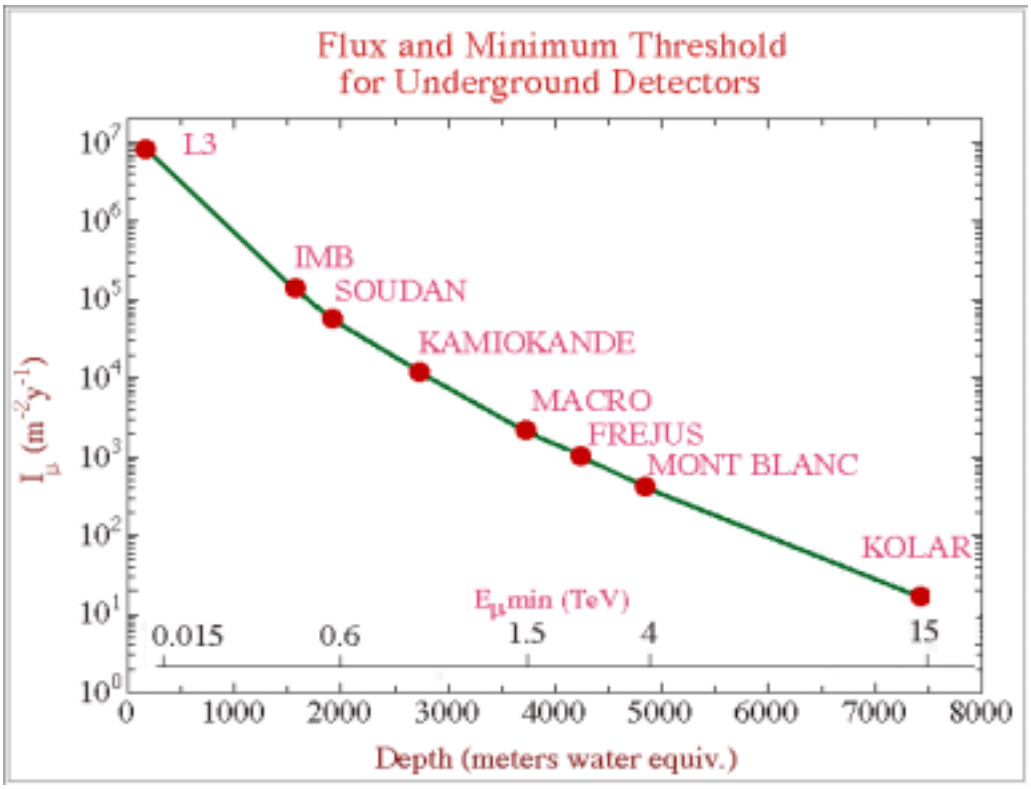
At LEP accelerator, CERN
6.02°E, 46.25°N. altitude:450m

air shower array

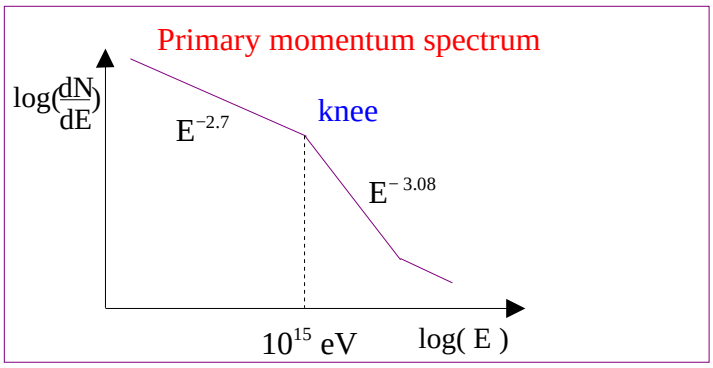
muon spectrometer (L3 detector)
(under 30 m of molasse)

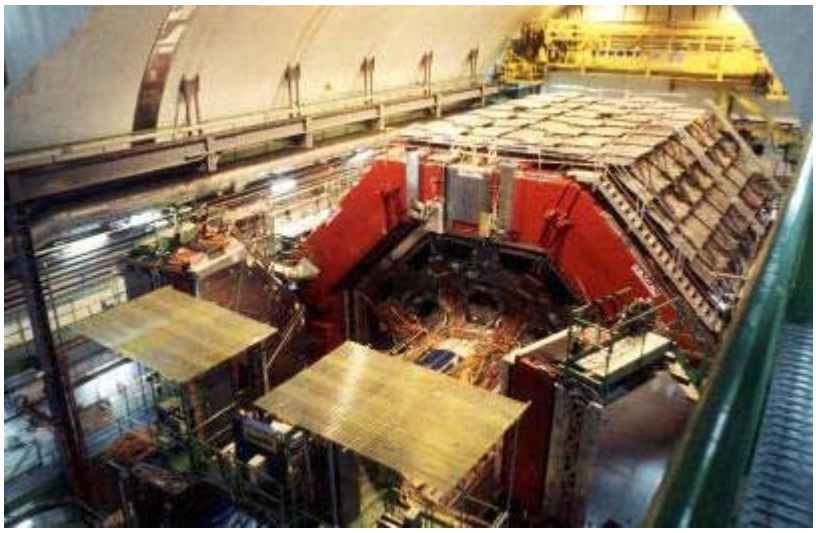


GOALS



- Measurement of the momentum spectrum including angular distribution and charge ratio (Normalization of the atm. muonic neutrino flux above 20 GeV).
- Primary composition at the knee region via μ− momentum distributions in multi−muon events combined with the estimated measured primary energy of the cosmic air shower array.
- Time variations (pressure, temperature).
- Anisotropy and point sources (GRB's)
- Exotic Events
- Moon shadow
- Solar flares





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The μ−spectrometer (L3)

- Acceptance : up to **200 m²sr**
- Threshold : E_μ > **15 GeV**
- Mom.resol. (at L3 level):
  $\Delta p / p$ = **4.4 %** at 50 GeV/c
- Ang. Resol.: δ < **3.5 mrad** above 100 GeV
  (from multiple scattering in the rock)
- Systematic errors (absolute flux): ~ **2.5 % (Goal)**
- GPS timing
- Trigger and DAQ indep. of L3

Summary of Data−Taking

- Period: **May−November 1999** and
  April − November 2000
- Trigger rate: ~ **450 Hz**
- # Events: **$11 \cdot 10^9$** (by November)
- Total eff. runtime: **306 days**
- # processed Event (up to now): **$8 \cdot 10^9$** (5'000 CPU days)
- # reconstructed Events: **$2.5 \cdot 10^9$**

Monte Carlo:

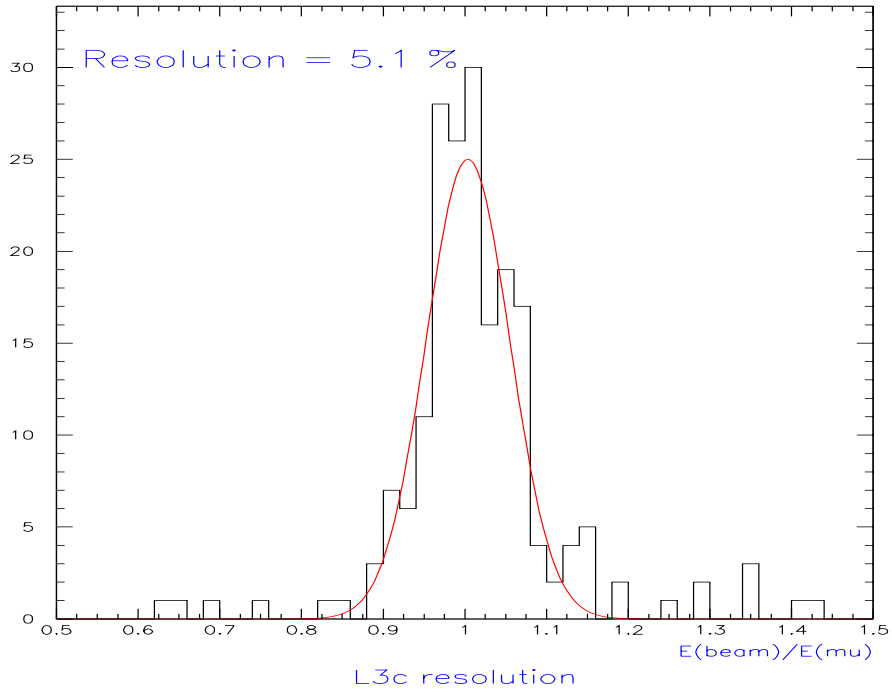
(Mainly on Asgard cluster at ETH)

- # generated events: **$2.5 \cdot 10^9$** (with last program version)
- # reconstructed events: **$0.3 \cdot 10^9$** (5'000 CPU days)

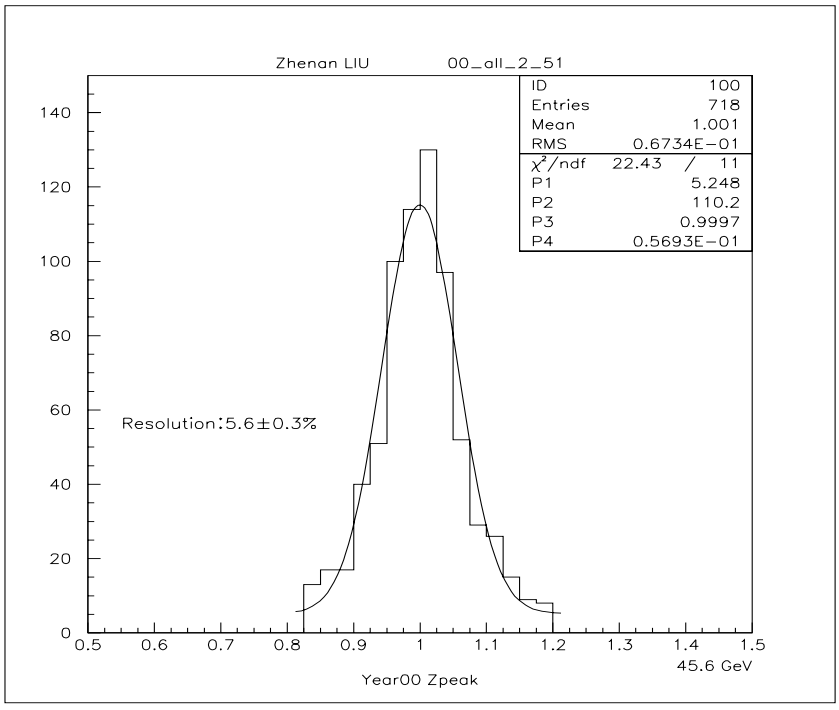
Momentum resolution at 45.6 GeV

$$e^+e^- \rightarrow Z^0 \rightarrow \mu^+\mu^-$$

1999



2000



Efficency also checked via Z^0 analysis!

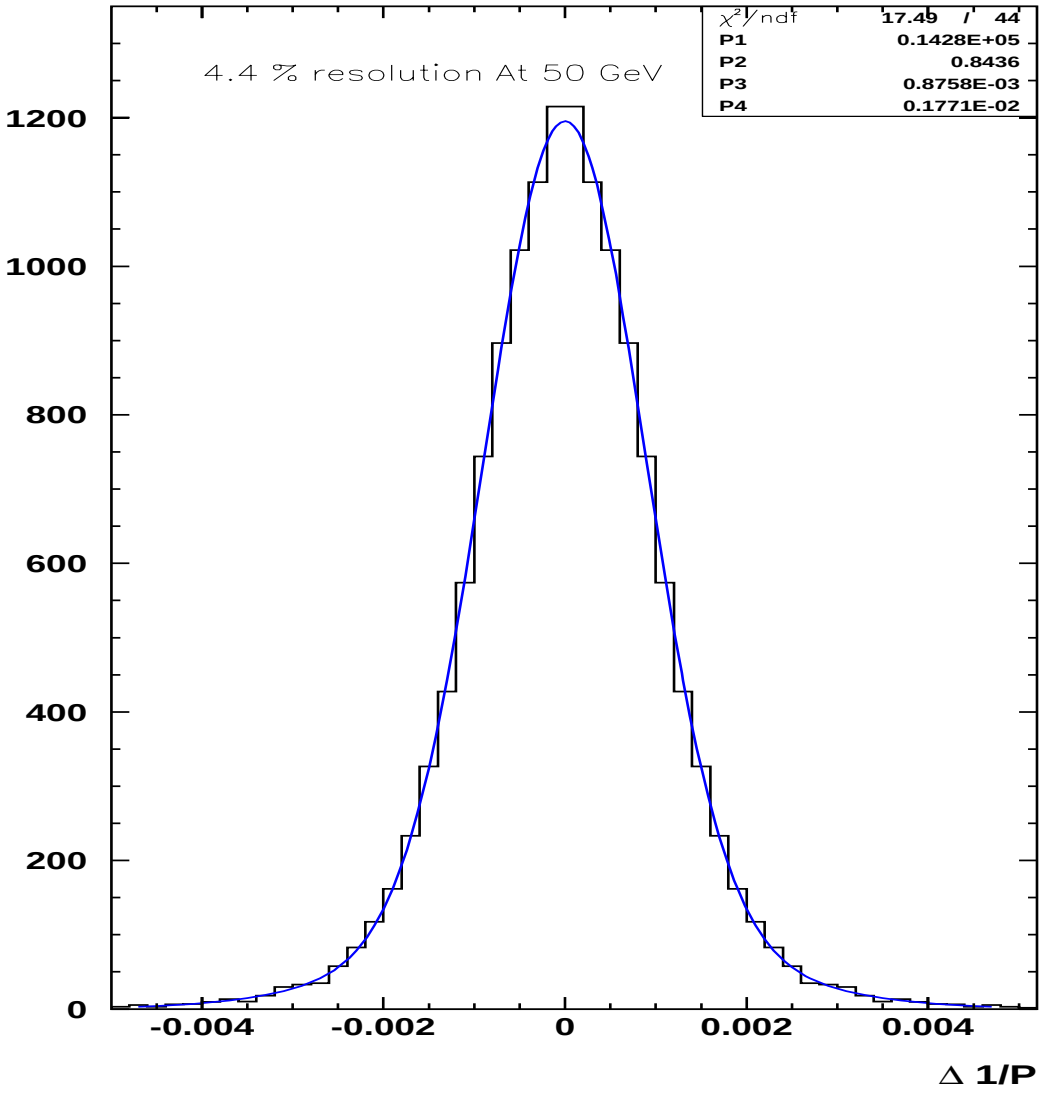
Momentum resolution

2nd Method:

- Determined with weighted average using the upper and a lower half of a track

$$\Delta\left(\frac{1}{p}\right) = \left(\frac{1}{p}\right) \cdot \left(\frac{\Delta p}{p}\right)$$

2 octant resolution at 50 GeV



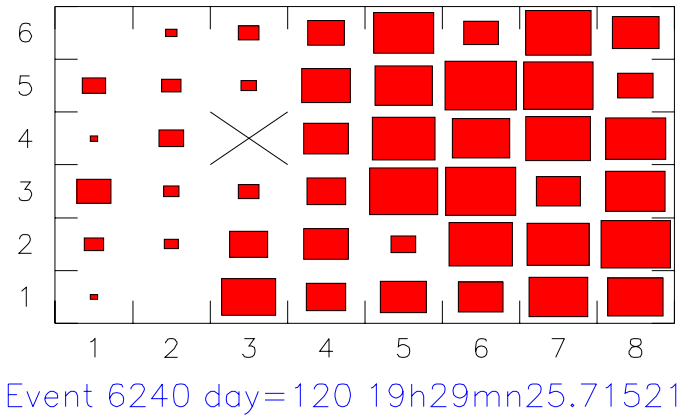
The two methods are in **agreement**!

(On the original transparent this photo fills the full page)

Air shower array

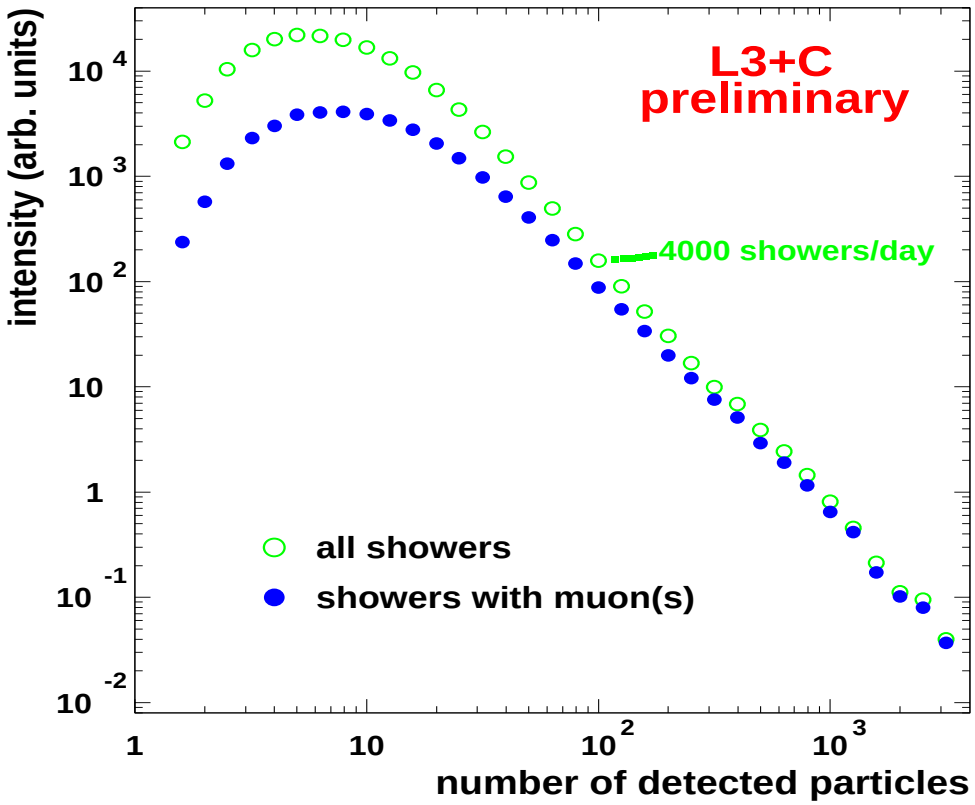
- Operational since April 2000
- 50 scintillators of 0.5 m^2 each
- Covered area: 30 m x 54 m
- E−threshold: 10 TeV
- Shower rate: 1.7 Hz
- # Events: > 30 million
- 30% of showers associated with muon in L3.
- $> 10^{15}$eV $\rightarrow$ 25 events/day
  (2.5 with core above array)
- $\Delta E / E \rightarrow$ 30 % (when core above array)
- $\Delta\theta$ of shower axis: above 30 TeV 1°
  at E−threshold 2°
- GPS timing

Event example



Multiplicity distribution in shower array

- data from one week

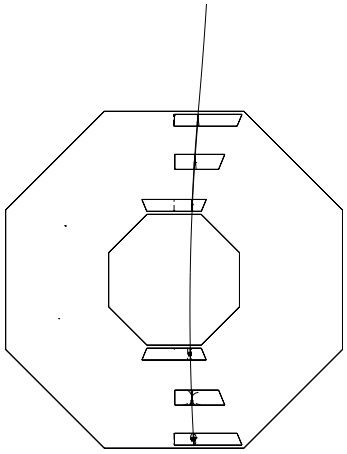


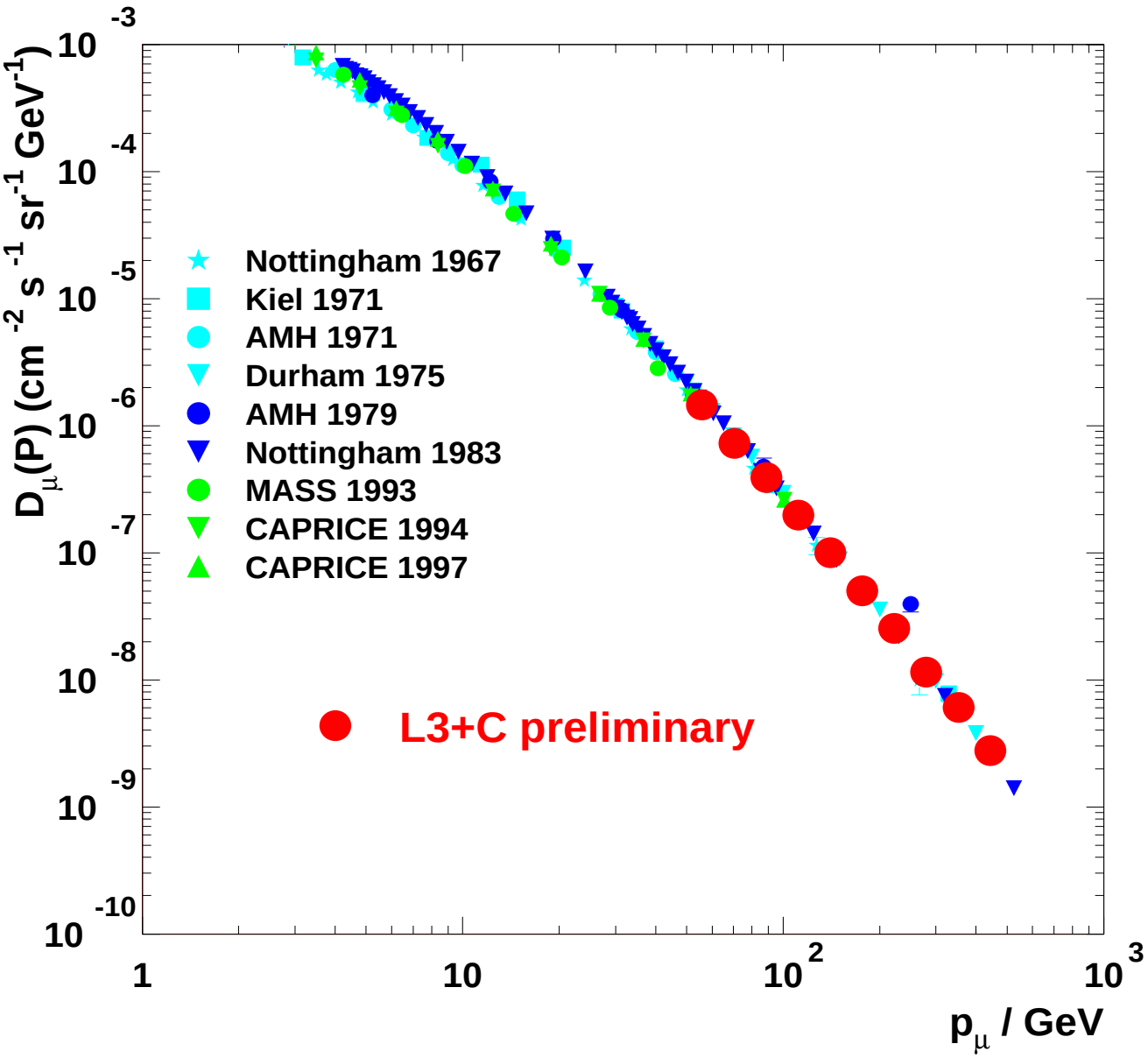
Roughly:

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

Vertical momentum spectrum

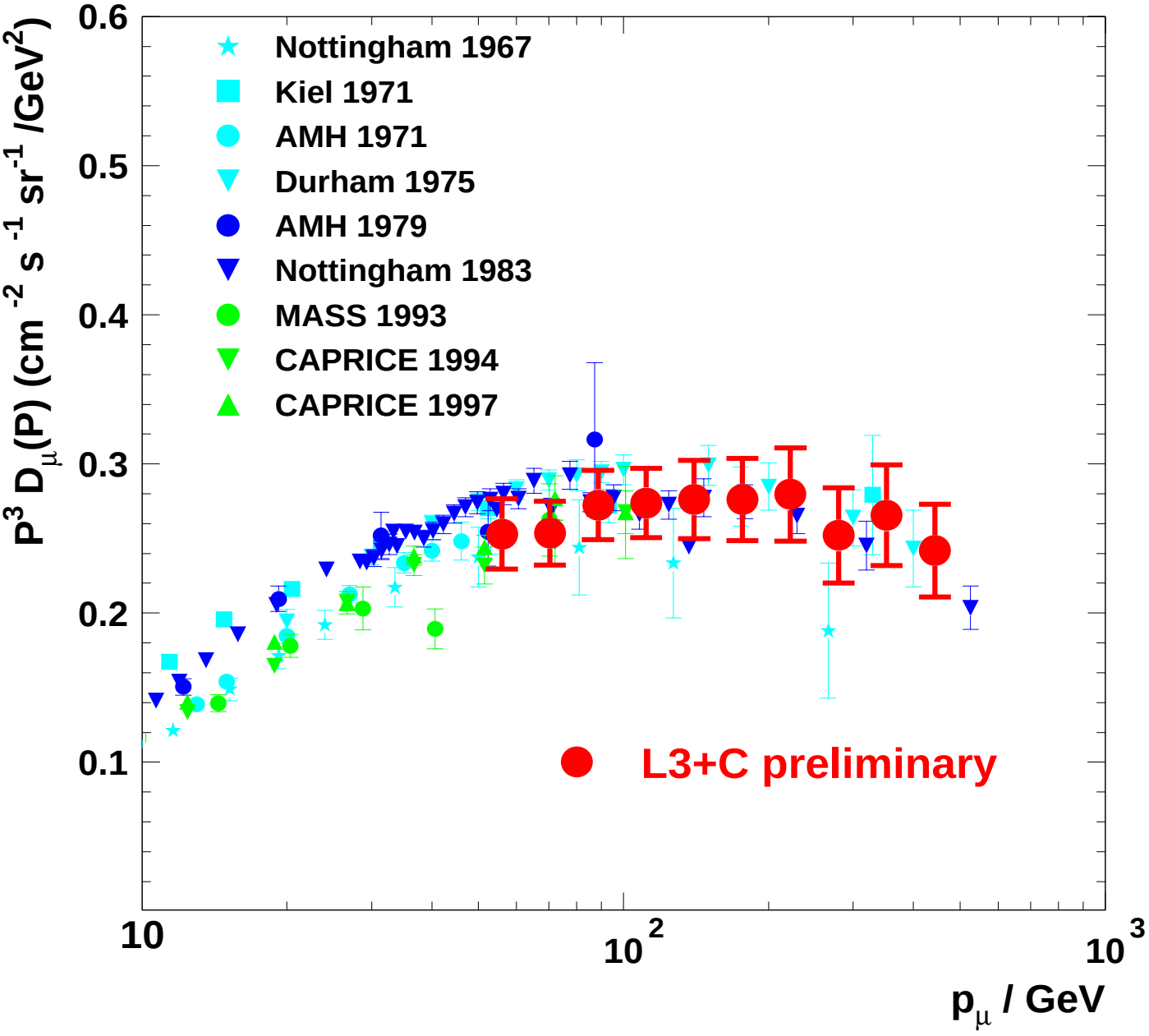
- used livetime: 30 days (1999)
- 'golden' muons only: passing upper and lower octant
- zenith angle < 10°
- momenta 50 GeV−500 GeV
  → ~50000 events





Vertical momentum spectrum

Flux $\times$ p^3



Systematic error dominant. Now: 9%. Goal:2.5%

Systematic Uncertainties Normalization

Status and Goals

Vertical spectrum, near 100 GeV, relative Errors:

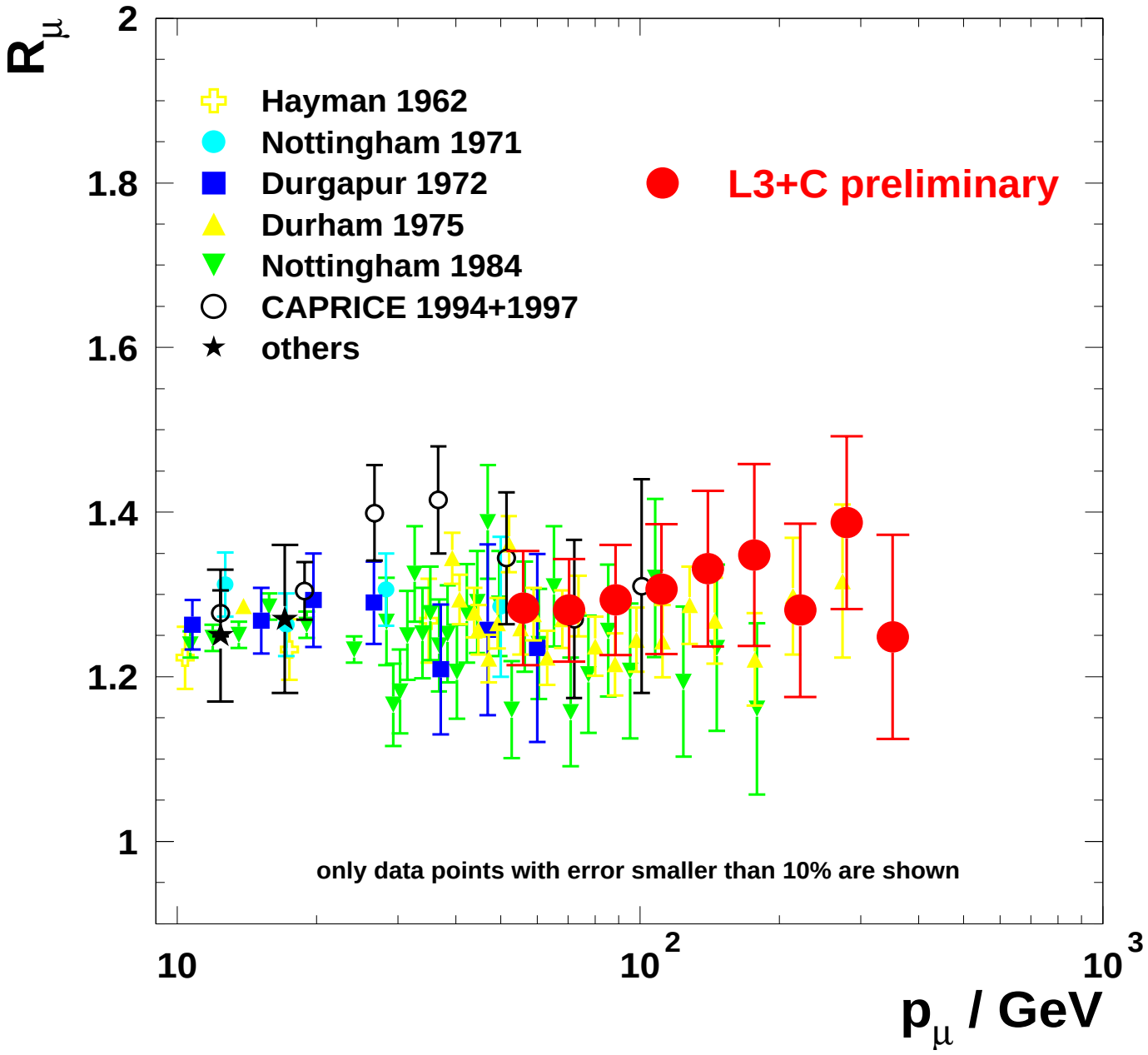
(Period: Sep. 1999− Nov. 1999)

Source	error now	final error
trigger eff.	0.5%	0.5 %
scintill. eff.	1 %	0.3 %
P chamber eff.	6 %	1 %
Z chamber eff.	1 %	0.5 %
reconstr.eff. and backtrack.correct.	6 %	2 %
momentum resolution	3 %	0.5 %
pressure / temperature correct.	1 %	0.3 %
Noise (LEP, electronics ...)	3 %	0.3 %
TOTAL	9%	2.5 %

(Status in May 2000: Error was still 19 %)

Charge ratio for vertical muons

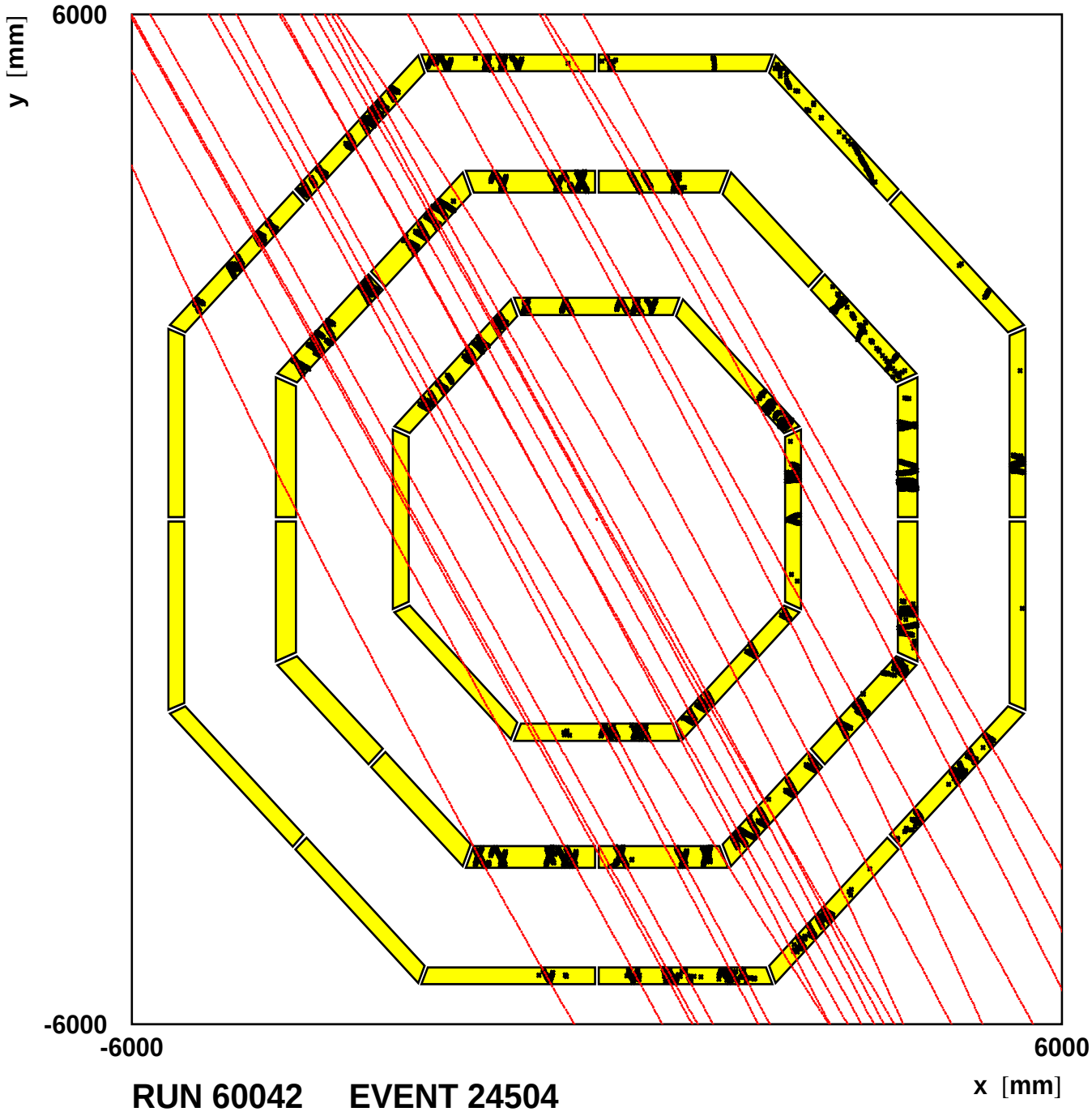
Zenith angle < 10°



Error: systematic + statistics

(only 30 days)

Multimuon Event



~ 200 events per day with multiplicity >10

Look at Sideral anisotropy

1. Point sources: search of neutral particles (γ−rays,?) in given direction.

2. Large scale anisotropies:

studied with full sky harmonic analysis.

Propagation of charged particles is governed by magnetic fields

- Galactic magnetic field: ~ 2 μG

(Larmor radius for 1TeV: particle $4 \cdot 10^{-4}$ pc)

- Solar magnetosphere: influence on anisotropy measurements is important for E < ~ 1TeV

→ **Structure of magnetic field influence anisotropy**

Other factors which influence large scale anisotropy:

- Distribution of sources concentreted in the galactic disk.
  → anisotropy gives informations about origin of CRs.
- Motion of observer with respect to the CRs sources (Compton−Getting Effect):

$$E' = \frac{E}{1-\beta\cos(\vartheta)} \qquad f' = \frac{f}{(\ 1-\beta\cos(\vartheta)\ )^{2.7}}$$

Example: Earth's orbital vel.: 30 km/s → Δ (f'/f) = 0.03 %(seasonal effect)

The anisotropy of the primary CRs can be measured with cosmic ray muons.

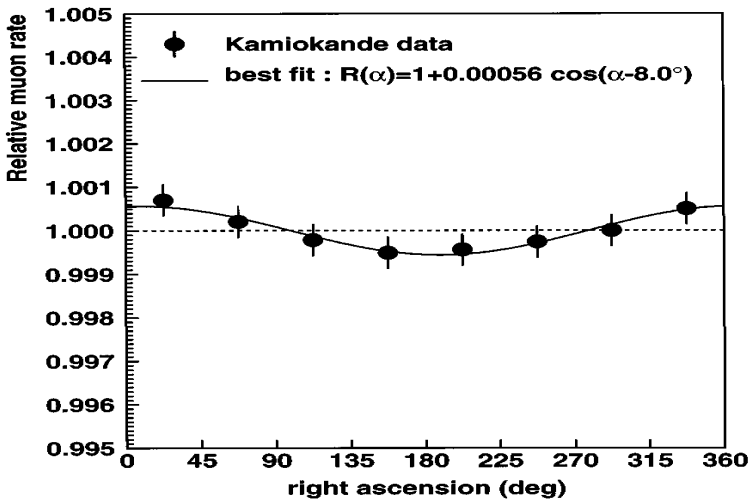
Many μ−underground experiments reported about anisotropy (**Primary E−range: 10^{11} eV − 10^{14} eV**)
Order of magnitude: 0.05%

E.g. Kamiokande Experiment reported about an anisotropy of this order in the RA distribution with a 2.8 standard deviation

Phys. Rev. D ***56****, 23 (1997).*

Kamiokande II+III measurement

Used data:
Kamiok. II: Jan ’87− Dec ’89
+
Kamiok III: Jan ’91− Dec ’94



First harmonic: Amplitude: $(5.6\pm1.9)\cdot10^{-4}$
Phase: $8.0° \pm 19.1°$

Measured magnitude of anisotropy is somewhat larger for **higher Energies** (see EAS array measurement).

Compare Kamiokande II+III with L3+C

	Kamiokande	L3+C
Livetime	$179 \cdot 10^6$ s	$26 \cdot 10^6$s
Average rate of selected muons	0.33 Hz	~ 50 Hz
# muon events	$58 \cdot 10^6$	~ 1'000 $\cdot 10^6$

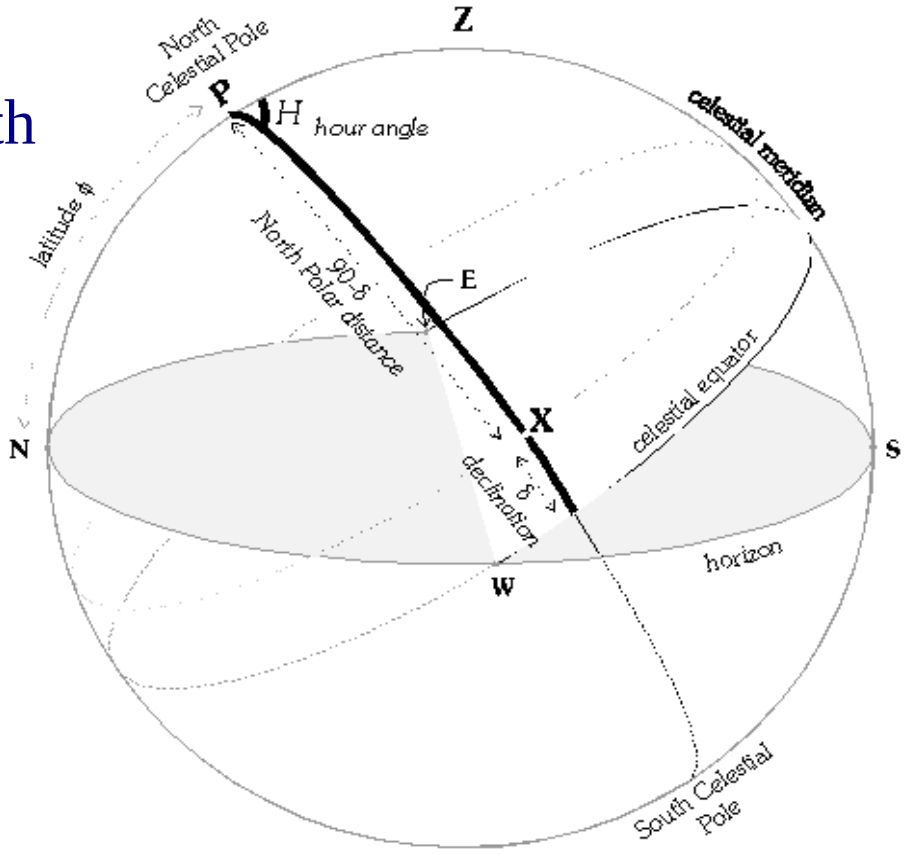
L3+C has a very high statistics and in principle should be able to get a good measurement of the sideral anisotropy of CR's.

METHOD

Local Equatorial coordinates

fixed respect to Earth

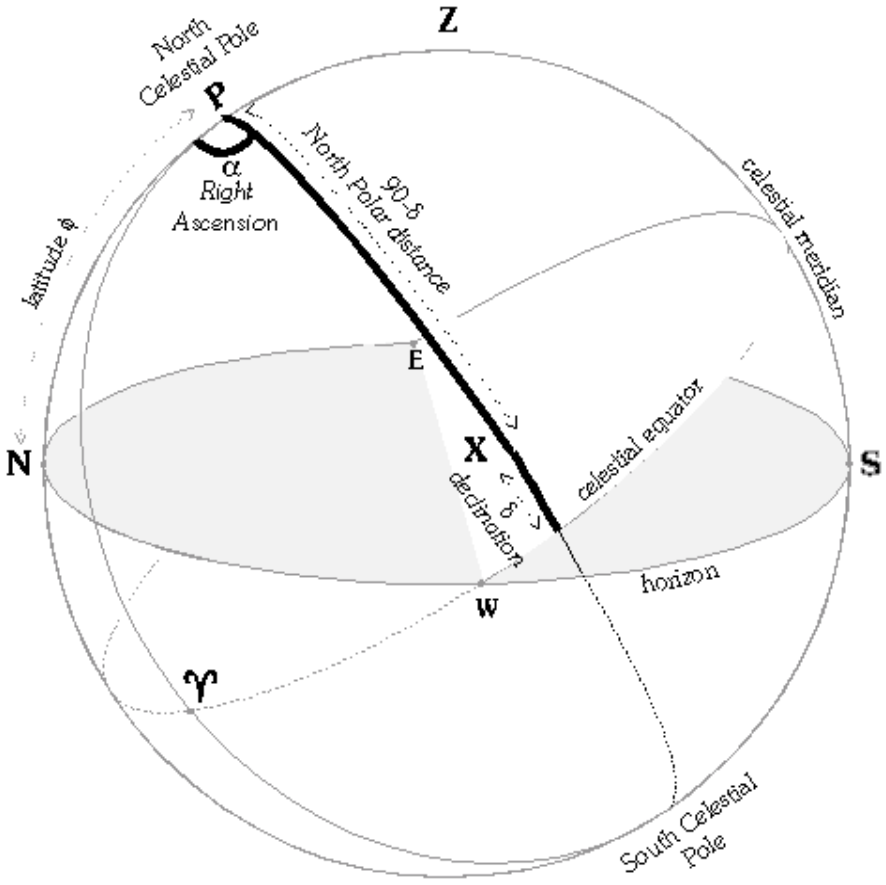
Coordinates:
Hour Angle: H
Declination: δ



Equatorial coordinates

fixed respect to Sky

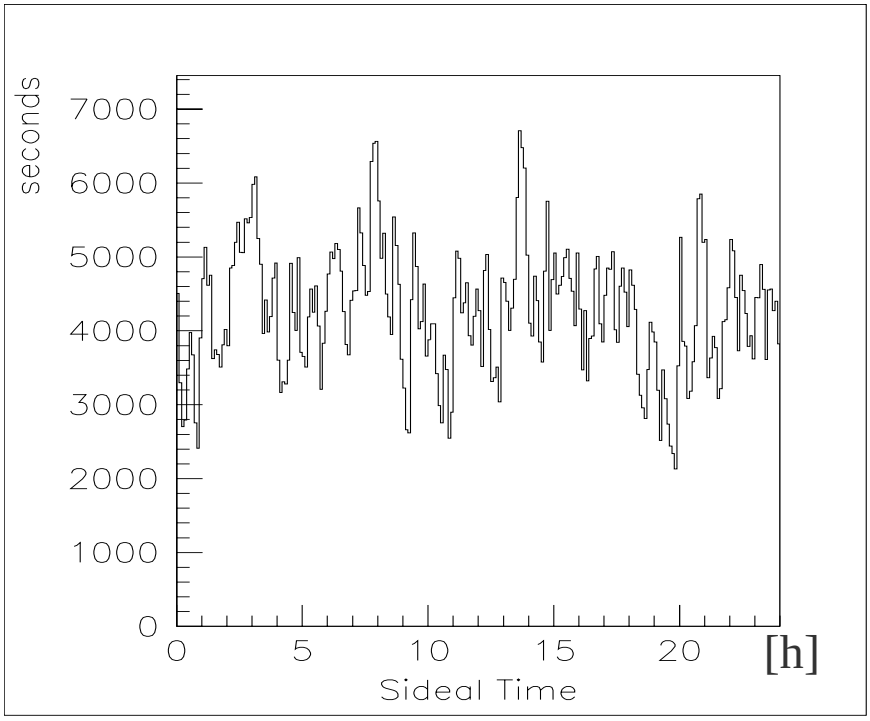
Coordinates:
Right Ascension: α
Declination: δ



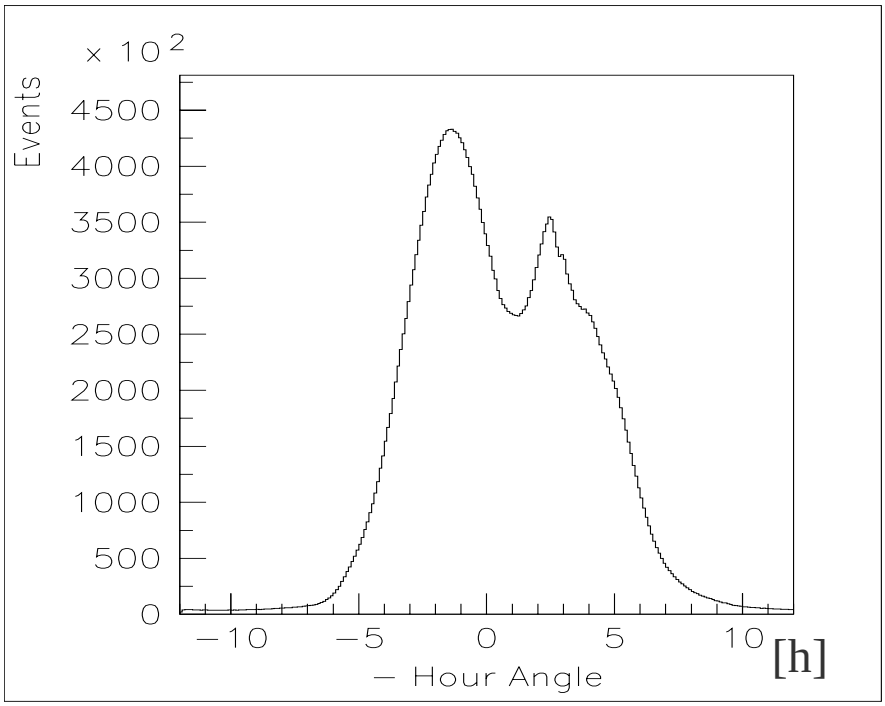
Example: (1st trial)

- 2’205 "good" runs from 14 Sep −9 Nov ’99.
- 32.7 Million Events with Energy > 30 GeV.

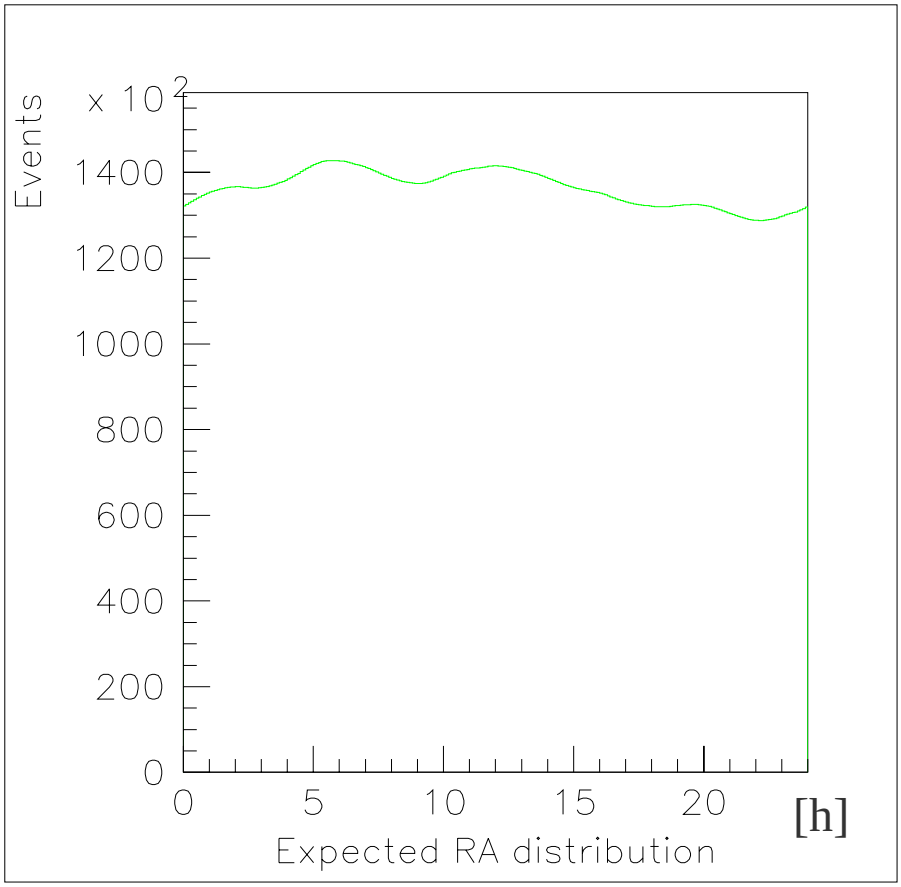
Sideral Time Distribution (corrected for livetime)



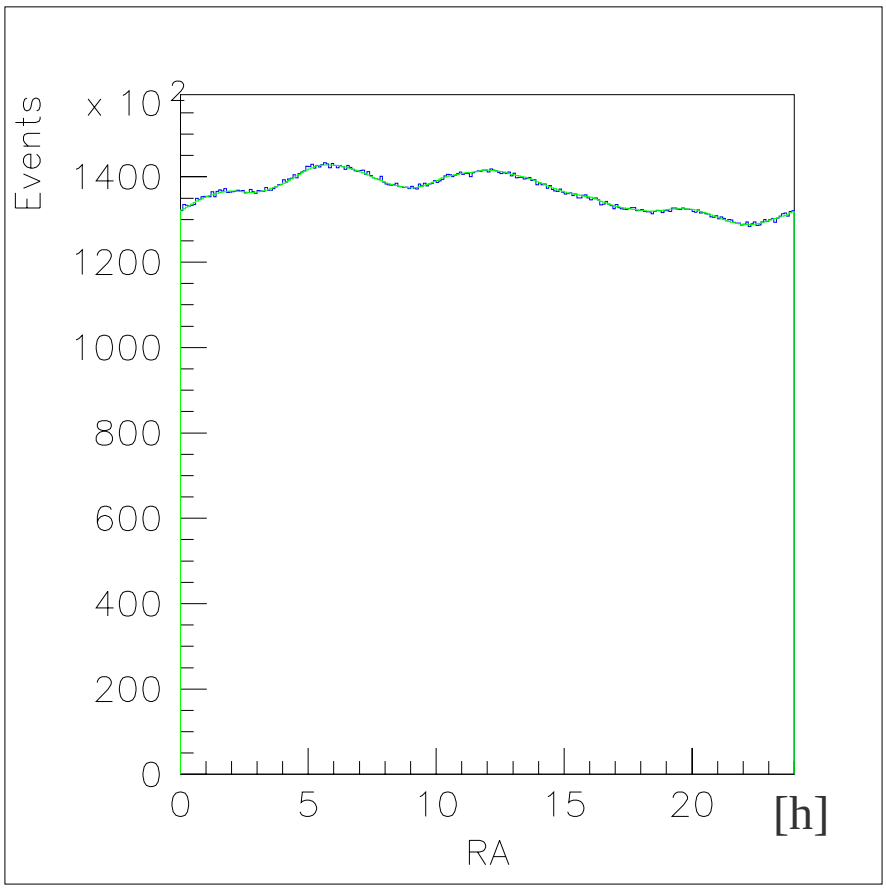
Hour Angle Distribution (= R.A. − Sideral Time)



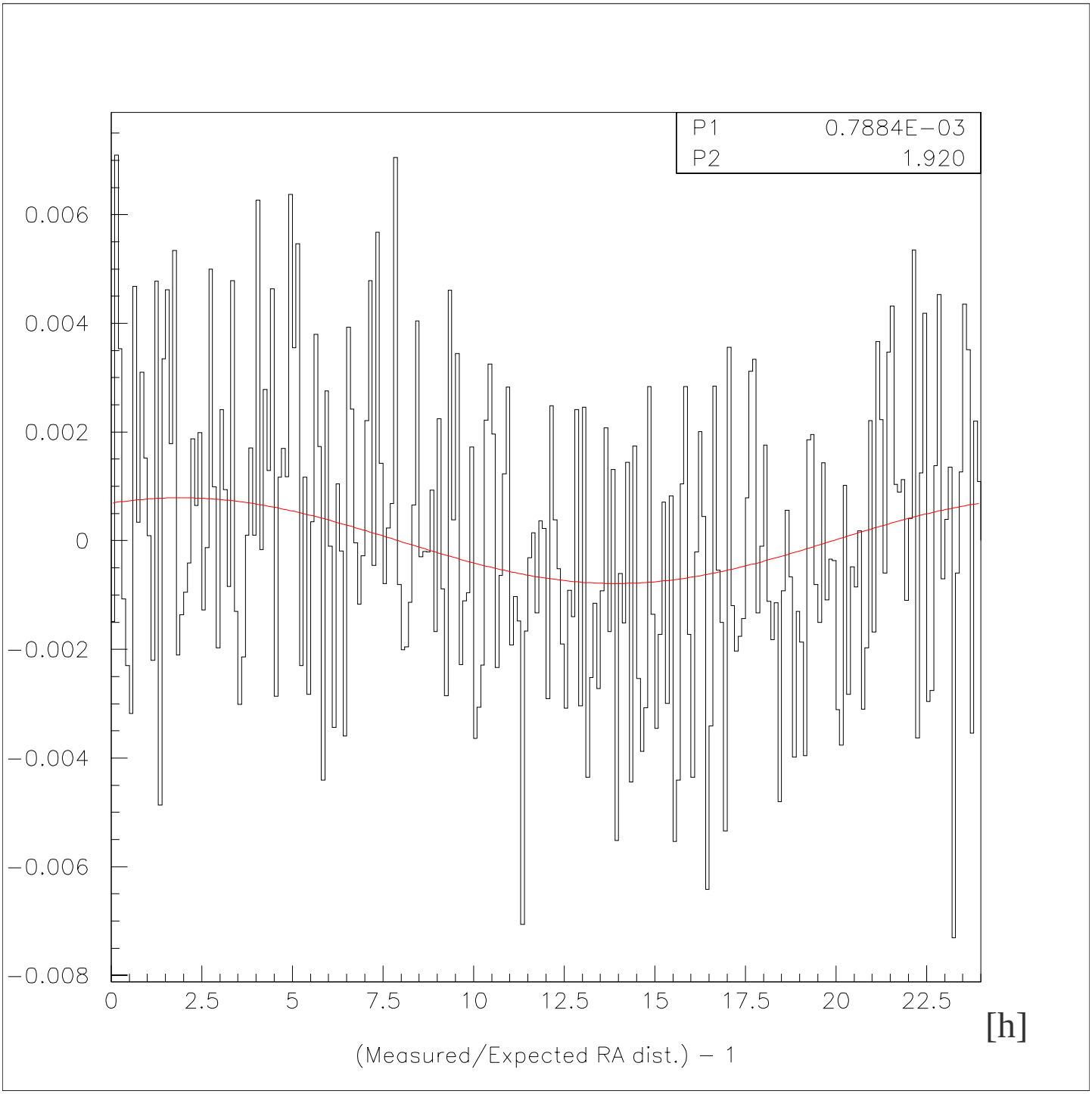
Convolution of the 2 previous distributions give
Expected Right Ascension Distribution



Compare with Measured Right Ascension Distribution



$$\frac{\text{Measured RA distrib.}}{\text{Expected RA distrib.}} - 1$$

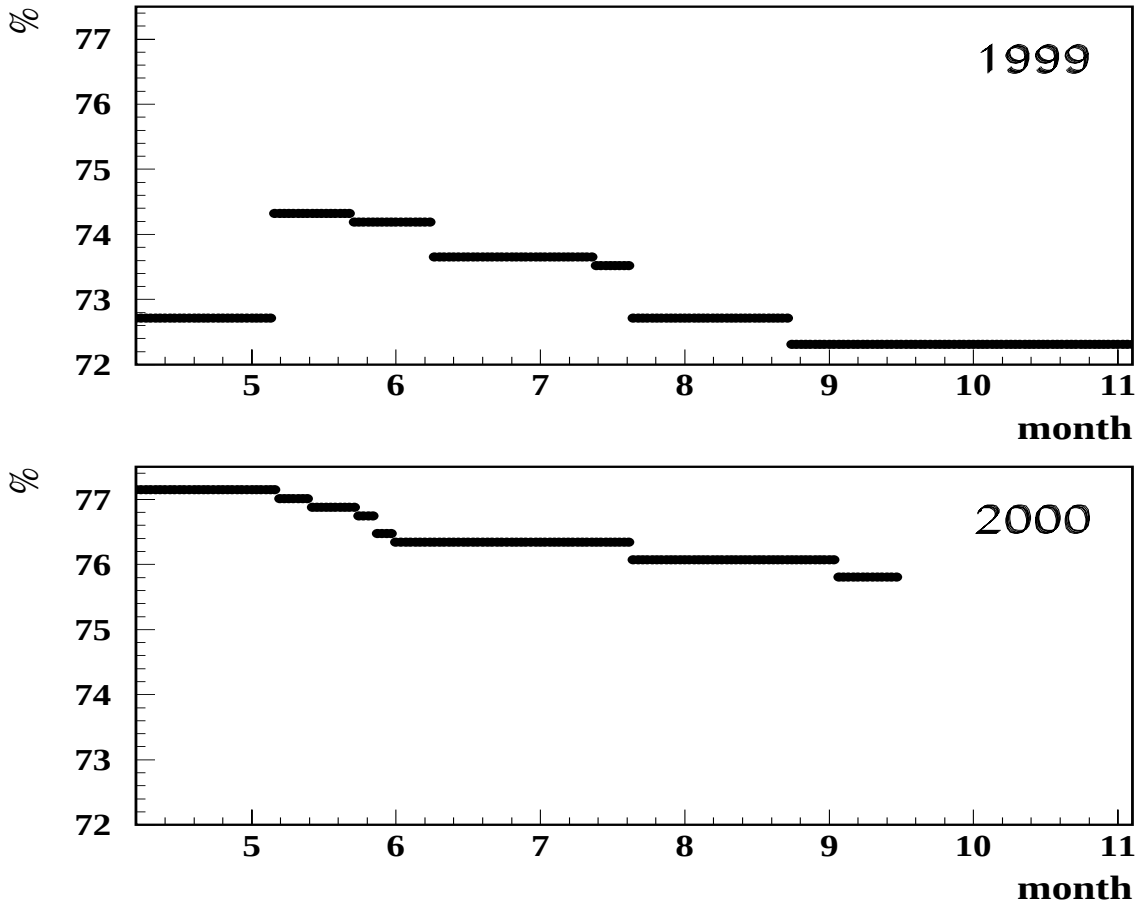


Fit with the first harmonic

Need to be done:

- Different period of analysis to take into account hardware interventions and changes
- Correct for the influence of the pressure and temperature on the flux of CR's
- Separate daily and seasonal variation of the CR's flux from sideral anisotropy $\rightarrow$ Unfortunately no data in the winter period (15 Nov − 30 Mar)
- Influence of different event selection.
- Error calculation

Percentage of good μ−chamber cells according to database



Conclusion

- The vertical muon spectrum and charge ratio have been measured up to now with a precision of about 10%.
- A final precision of less than 3 % is expected.
- The measurement will be extended to larger zenith angles and momentum range (20−2000 GeV)
- Combining the primary and muon energy provides a unique opportunity to study cosmic rays.
- Sideral anisotropy analysis started.