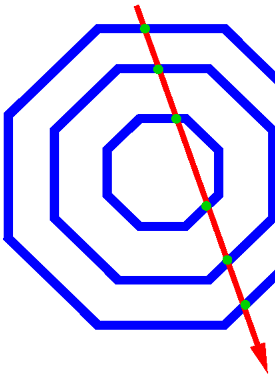

Selected results obtained with the L3+C experiment

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October 2001

Outline:

- The L3+C Experiment
- Performances of L3 as a muon telescope
- Anisotropy and Point sources search :
  - Overview
  - Method of analysis
  - Results
- Conclusion

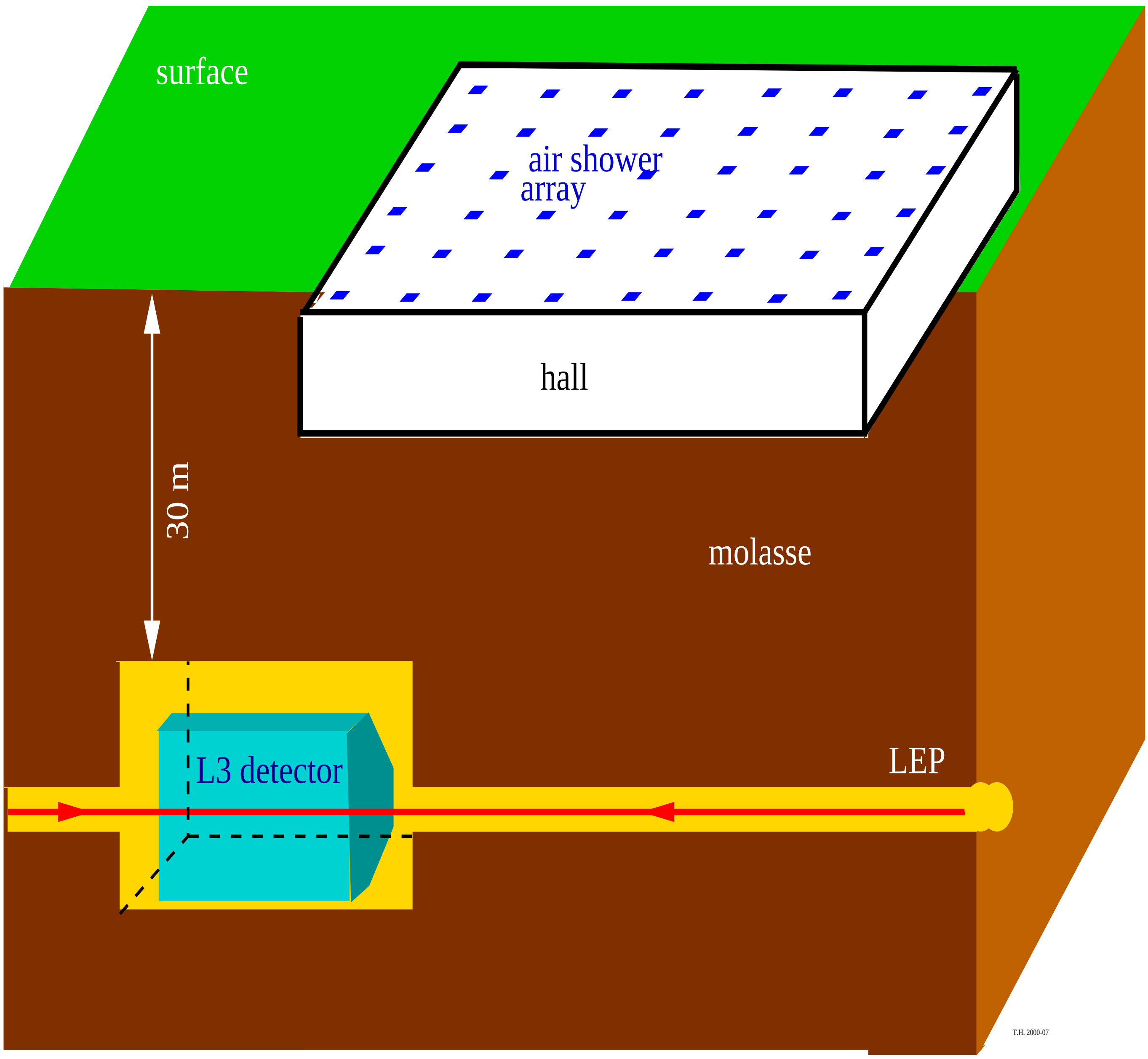
ETH IPP

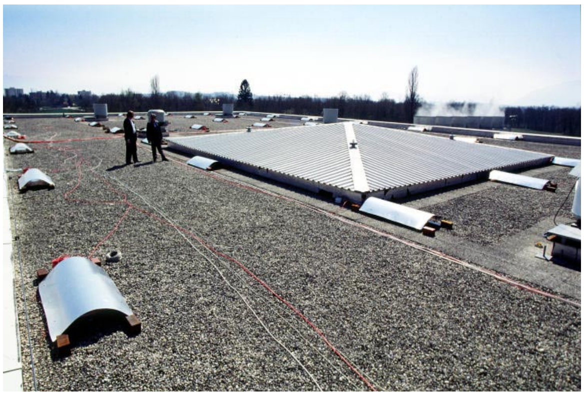
L3+C Experiment

The experiment consists of:

- air shower array (to measure primary energy)
  (Data taking period:2000−2001)

- muon spectrometer (L3 detector)
  (Data taking period:1999−2000)





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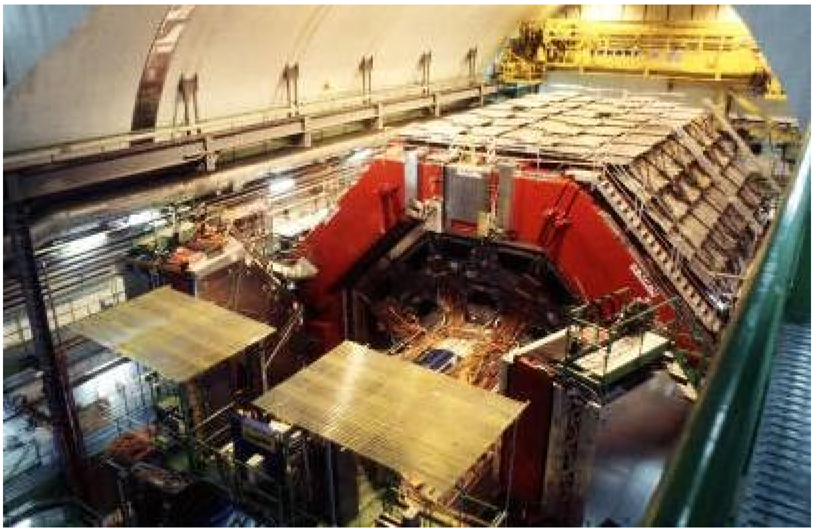
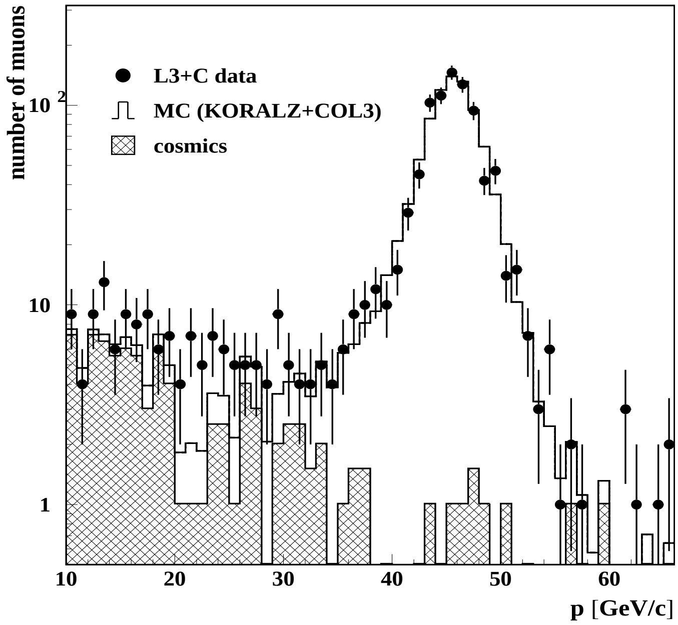


(On the original transparent this photo fills the full page)

Performance of the muon detector

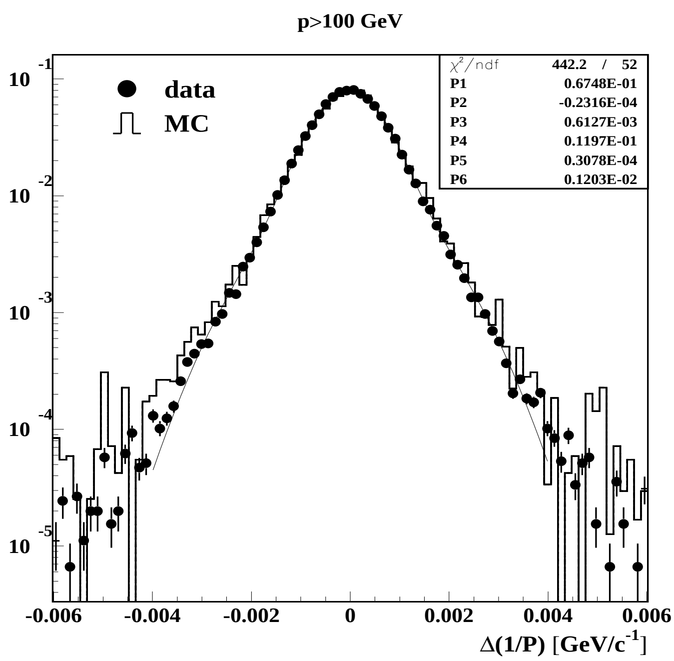
Momentum resolution

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



45 GeV: 4.6 %
(one octant resolution)

Compare upper and lower subtracks



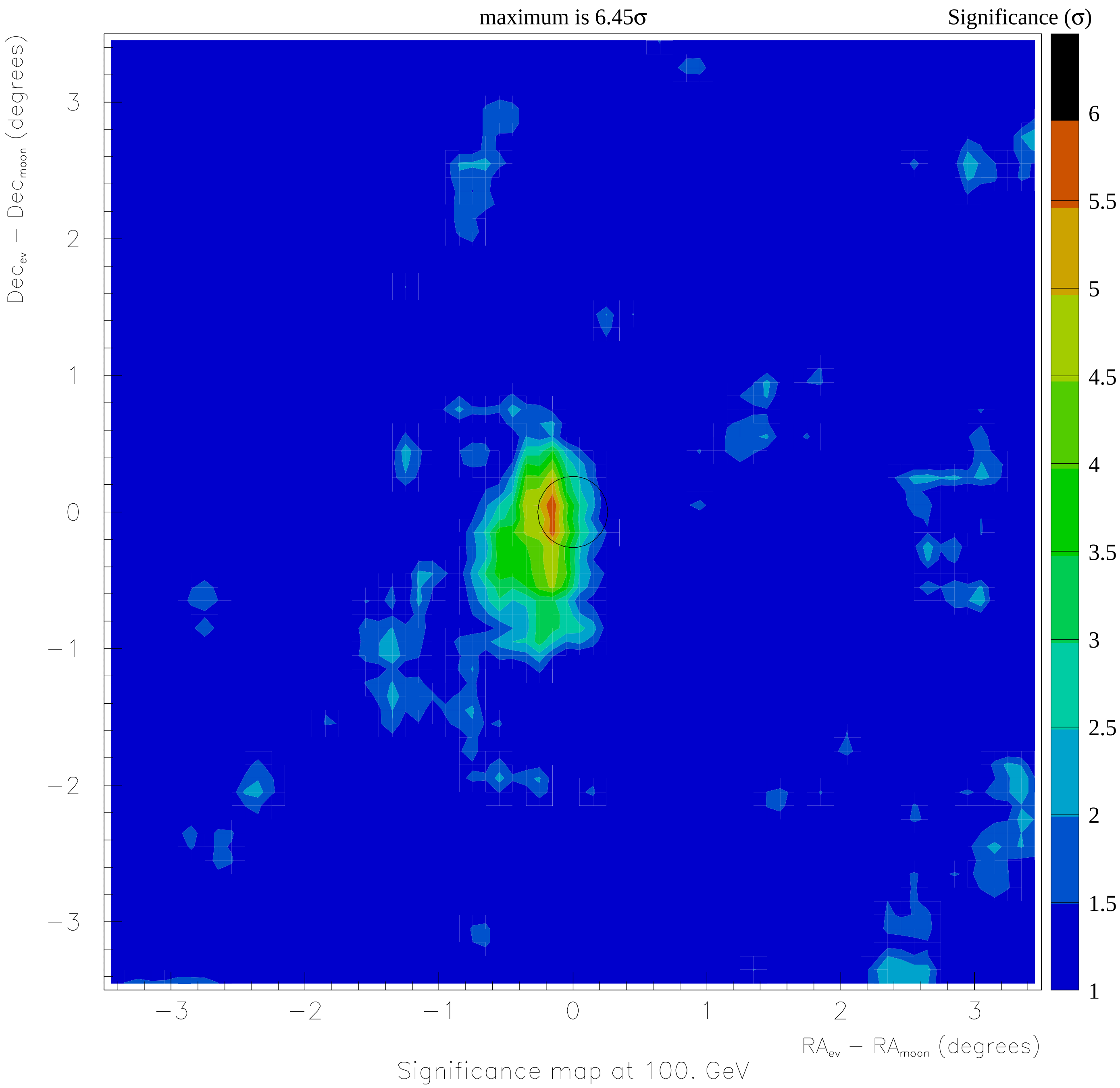
50 GeV : 3.8 %

100 GeV : 7.7 %

Set different momentum cuts ≡ "Detector at different depths"

Moon shadow

Pointing precision can be checked with moon shadow!



(Possibility to set limit to anti−proton flux)

Anisotropy and Point sources search

Overview

GeV−TeV cosmic rays are known to be very isotropic.
→ Large scale fluctuations ~ 0.05%.

Reason:

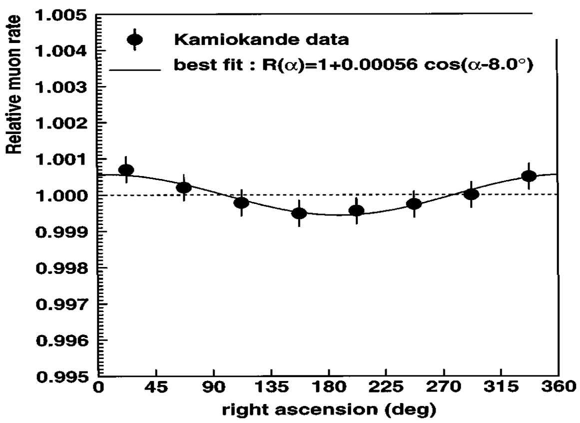
- The galactic magnetic field (~ 2 μG) spread out the charged cosmic rays in all directions.

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

- Solar magnetosphere plays also a role for primary E < ~ 1TeV

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

Kamiokande II+III measurement



Relative muon rate as function of Right Ascension of arrival direction

First harmonic:
Amplitude: $(5.6 \pm 1.9) \cdot 10^{-4}$
Phase: 8.0° ± 19.1°

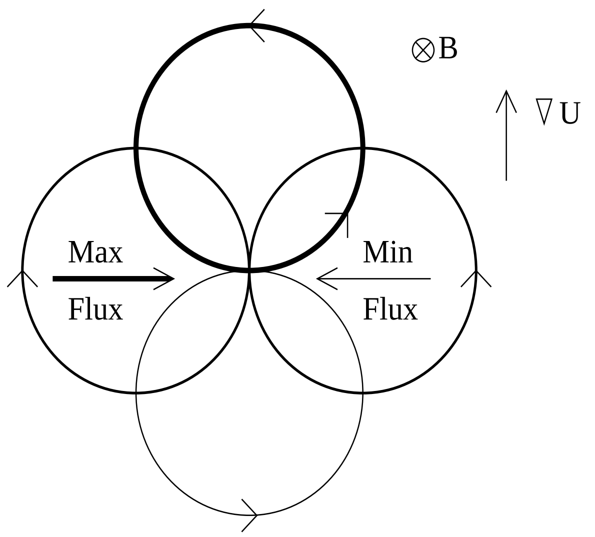
Deviation from isotropy may come from:

- Motion of observer with respect to frame where CR are isotropic (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 $\rightarrow$ Δ (f'/f) = 0.03 %(seasonal effect)

- Streaming in the direction of $\mathbf{B} \times \nabla \mathbf{U}$,where **U** is the cosmic−ray density

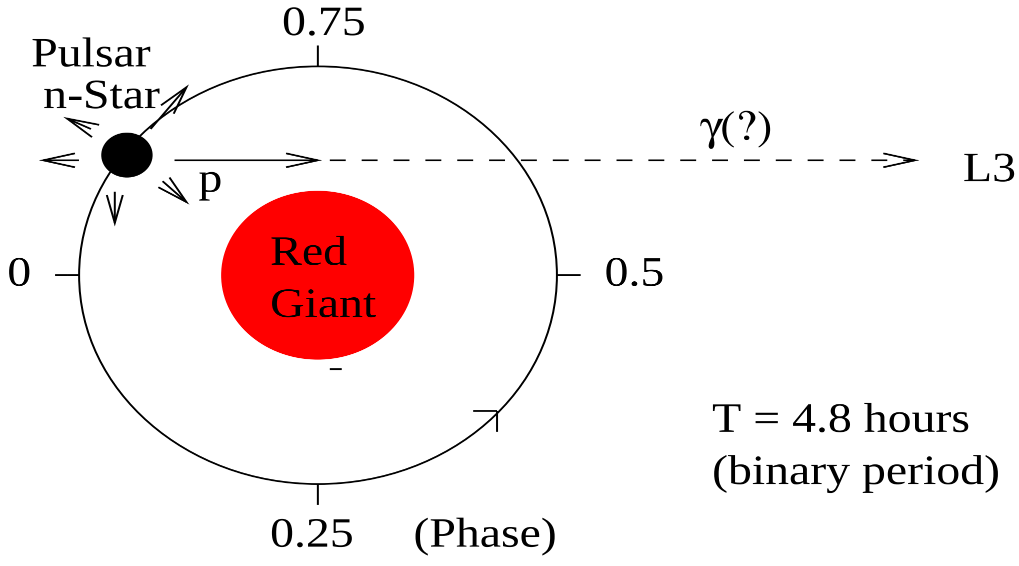


- Point sources of neutral particles:
  - γ's (produce μ via π−photoprduction)
  - Neutrons (decay $\rightarrow$ only for galactic sources and very high energy > 10^{17}eV)
  - ν's (detection of up−going has lower background)
  - Exotic particles (SUSY, ...)

Experimental status

- Satellite experiments explored several γ ray sources (continous and GRB) up to ~30 GeV.
- Cerenkov telescopes observe E−range 0.5−100 TeV
  - (example HEGRA detected GRB and continous sources like BL Lac object Mkn 421 (strong activity in Jan 2001 reported!))
  - sensitivity limited by very small field of view, operation during clear and moonless nights only
- EAS scintillator arrays explore E > 10−100 TeV
  - Tibet−III air−shower array reported 4.8 σ multi−TeV signal from Crab Nebula (ICRC 2001)
  - Akeno EAS array PeV γ's from Cyg X−3 (1985) (→ from same source Fly's Eye detector up to 10^{18}eV (1988)) (?)

Modell for Cyg X−3



- **Muons detections from point sources:**
  - γ induced EAS are muon poor (protons generate ~ 50 × more μ)
  - Muons telescopes have normally better angular resolution and operate continously with a large field of view.
  - Soudan−1 reported observations of muons > 650 GeV from Cyg X−3 with flux up to 10^{-9} cm^{-2} s^{-1} (Marshak et al. 1985) (seen also by other experiments in same decade)
  - Soudan−2 observed 5σ excess from AGN 3−C 273 (never published, today is gone!)

L3+C

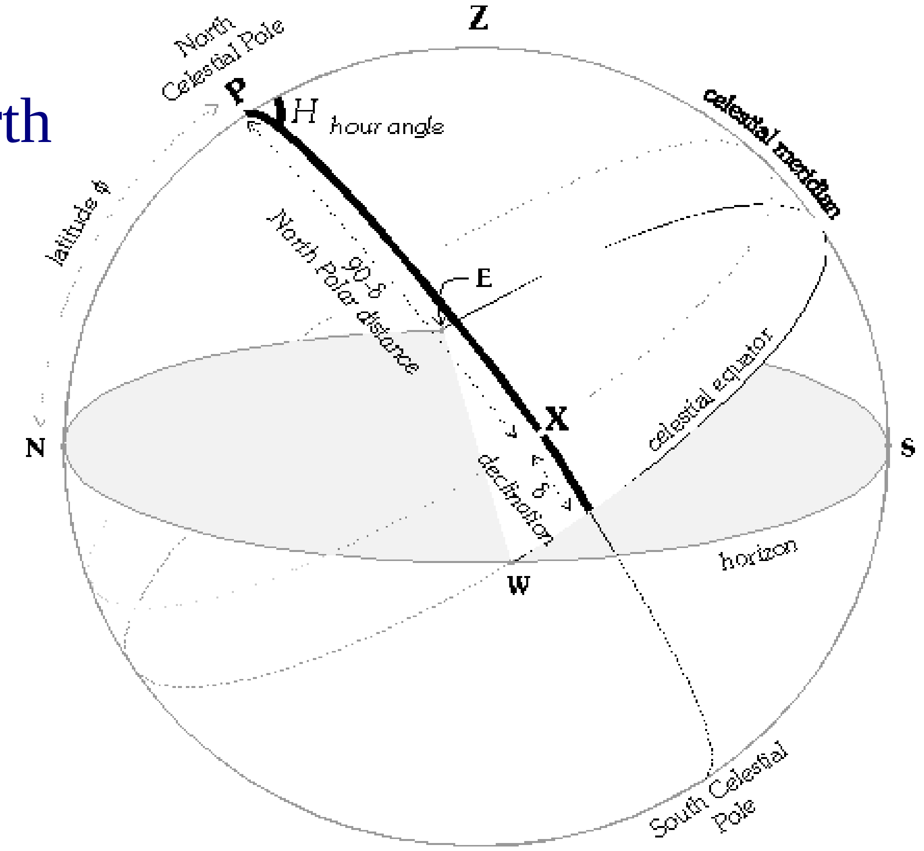
- Very good angular resolution
- Acceptance up to 200 m^2sr
- Lower energy threshold compared with other underground experiment (15 GeV)
- Possibility to fix energy threshold
- Don't expect to see excesses from known sources (but may be from bursts).

METHOD

Local Equatorial coordinates

fixed respect to Earth

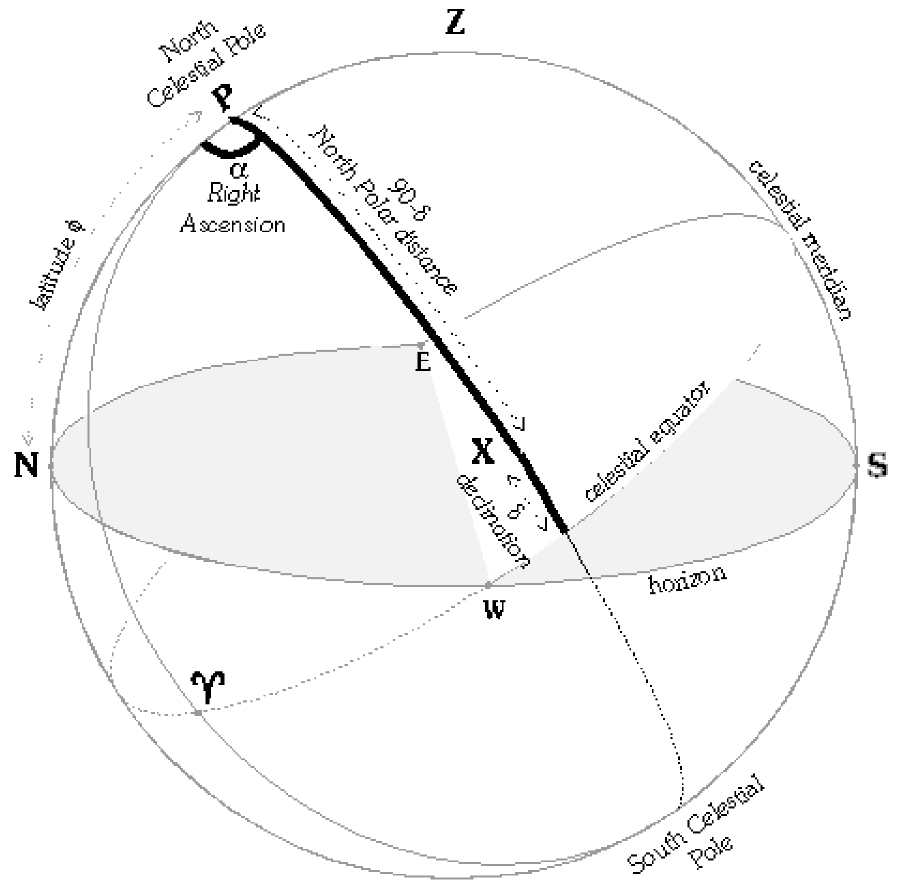
Coordinates:
Hour Angle: H
Declination: δ



Equatorial coordinates

fixed respect to Sky

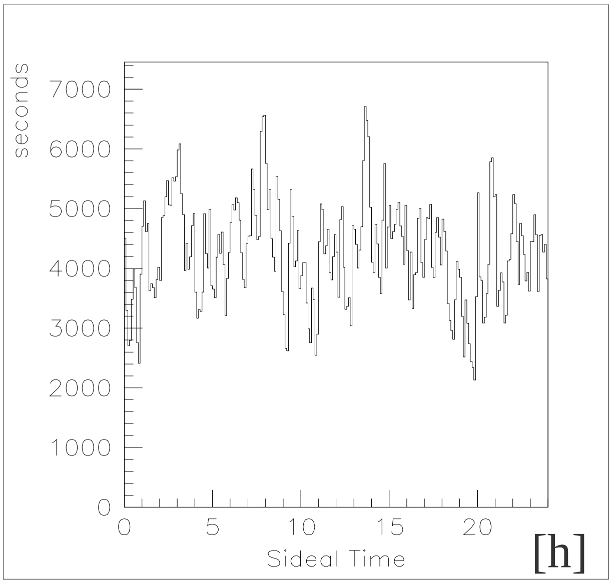
Coordinates:
Right Ascension: α
Declination: δ



[Right Ascension] = [sideral time] − [hour angle]

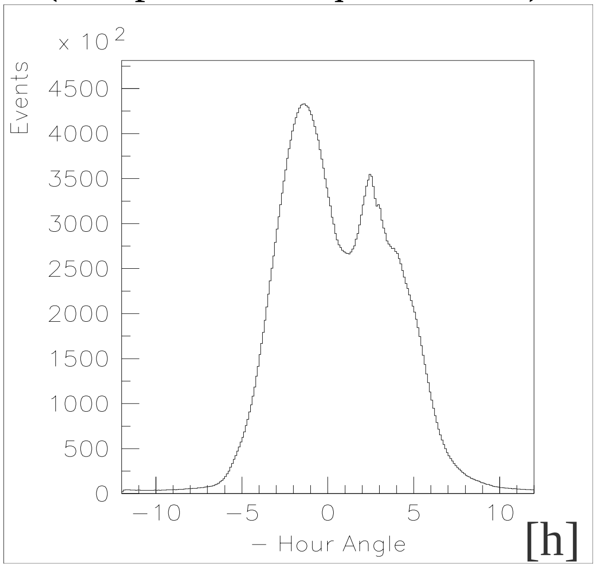
Idea: Scan the sky in a band of fixed declination

Livetime distiribution



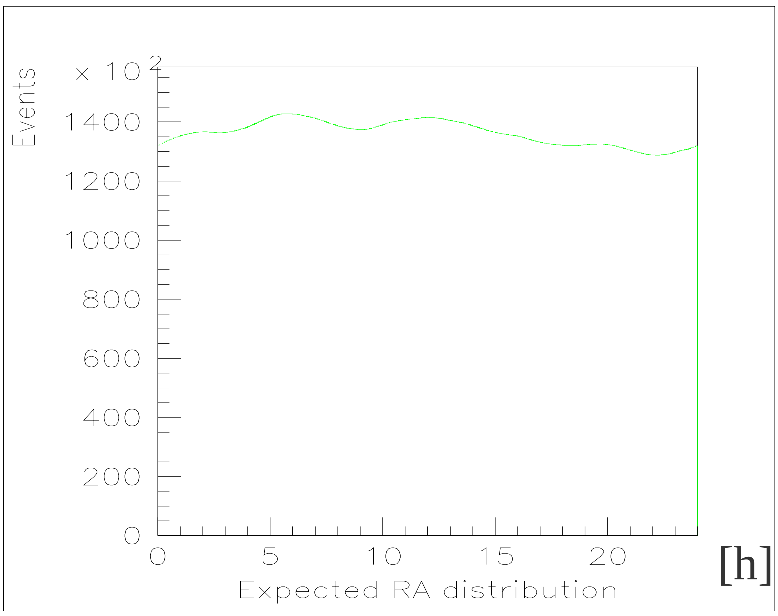
×

−Hour Angle distribution
(acceptance in equat. coord.)



= (convloution)

Expected Right Ascension Distribution

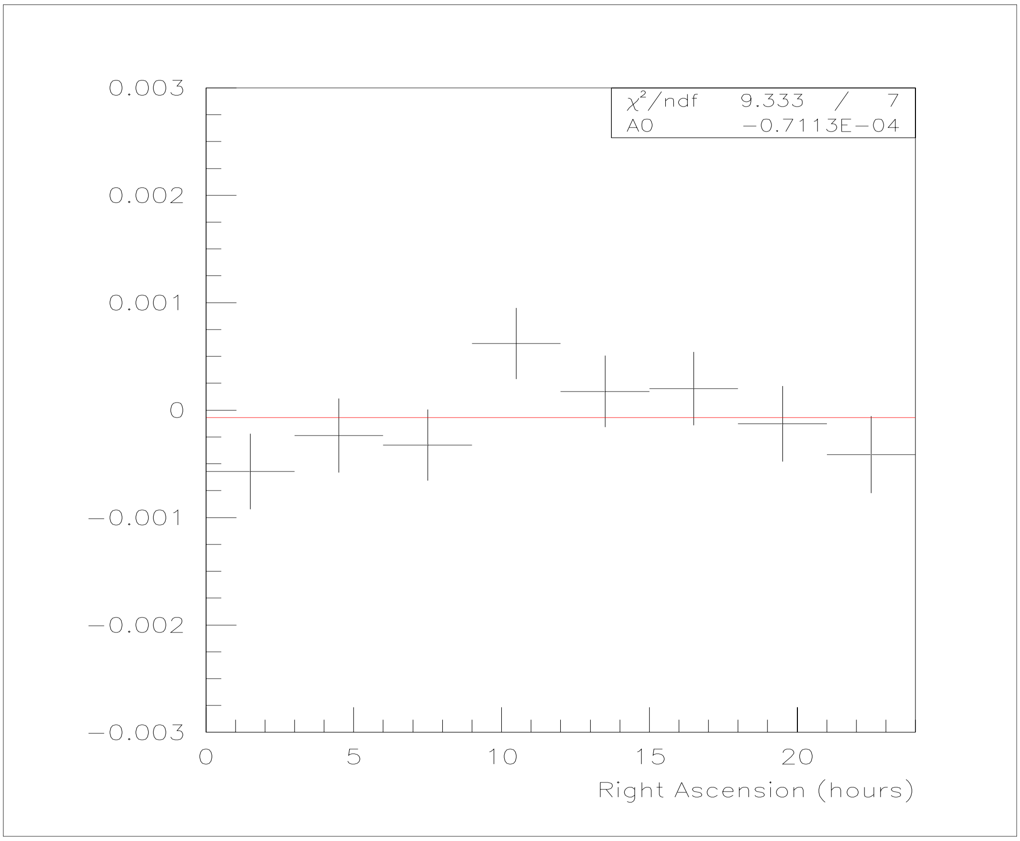


Large scale anisotropy

Look at the fluctuations on the Right ascension distribution.(All declinations)

Example: Energy cut: 30 GeV
$200 \cdot 10^6$ selected events of '99 and 2000

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



- No significant large scale fluctuation
- Fluctuations < 0.05%

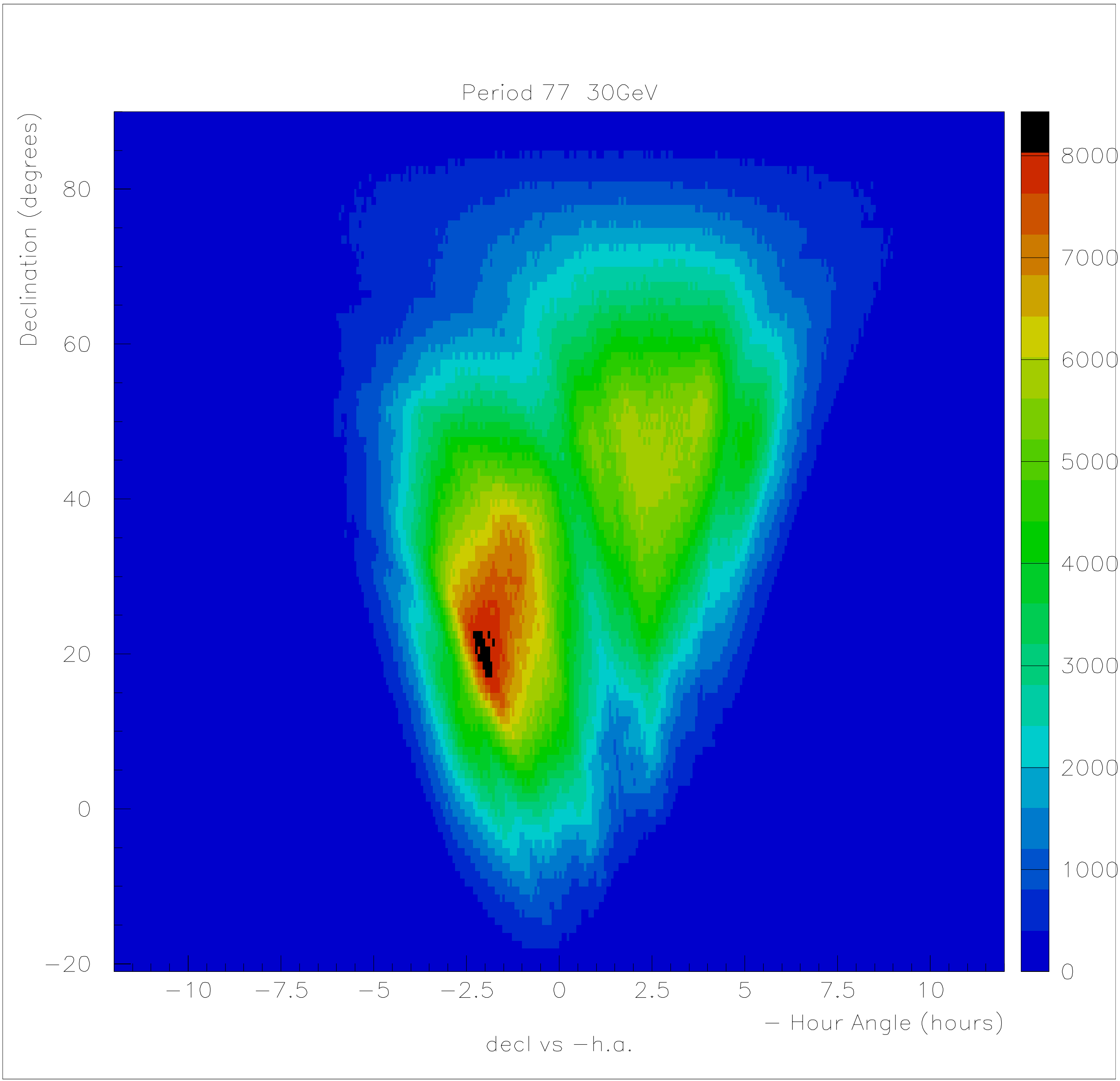
Point sources search

2D Analysis.

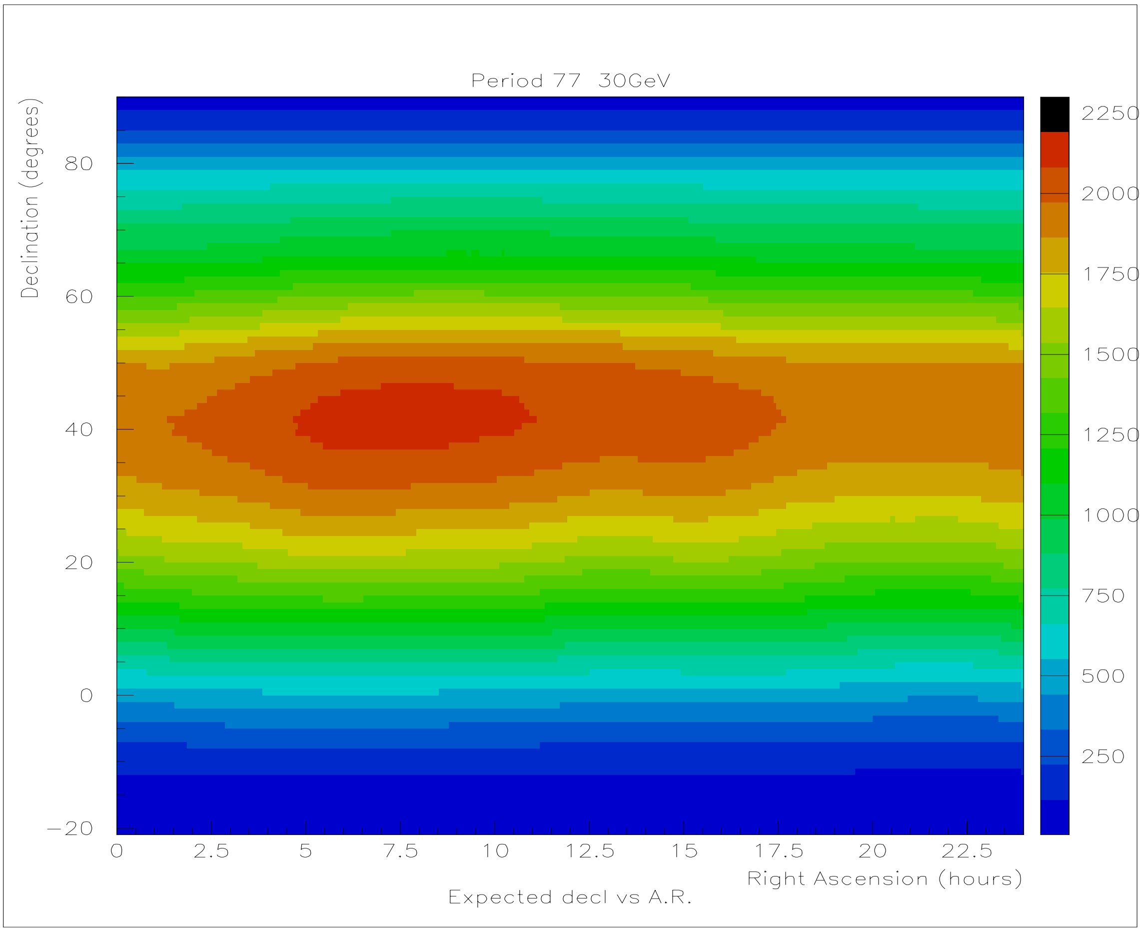
Apply the convolution procedure to all single declination bands.

Acceptance in local equatorial coordinates

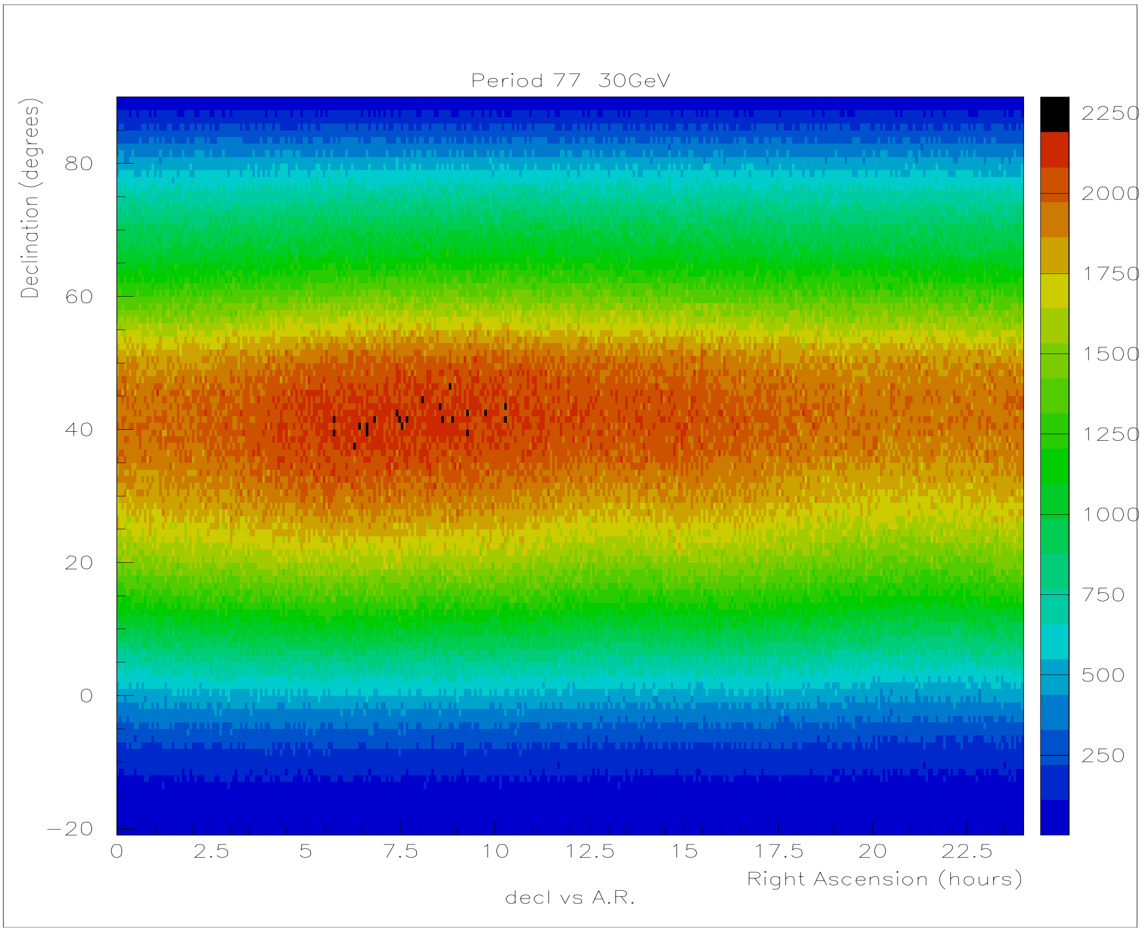
(2 Nov – 13 Nov 2001)



Expected events distribution (background)



Measured events distribution



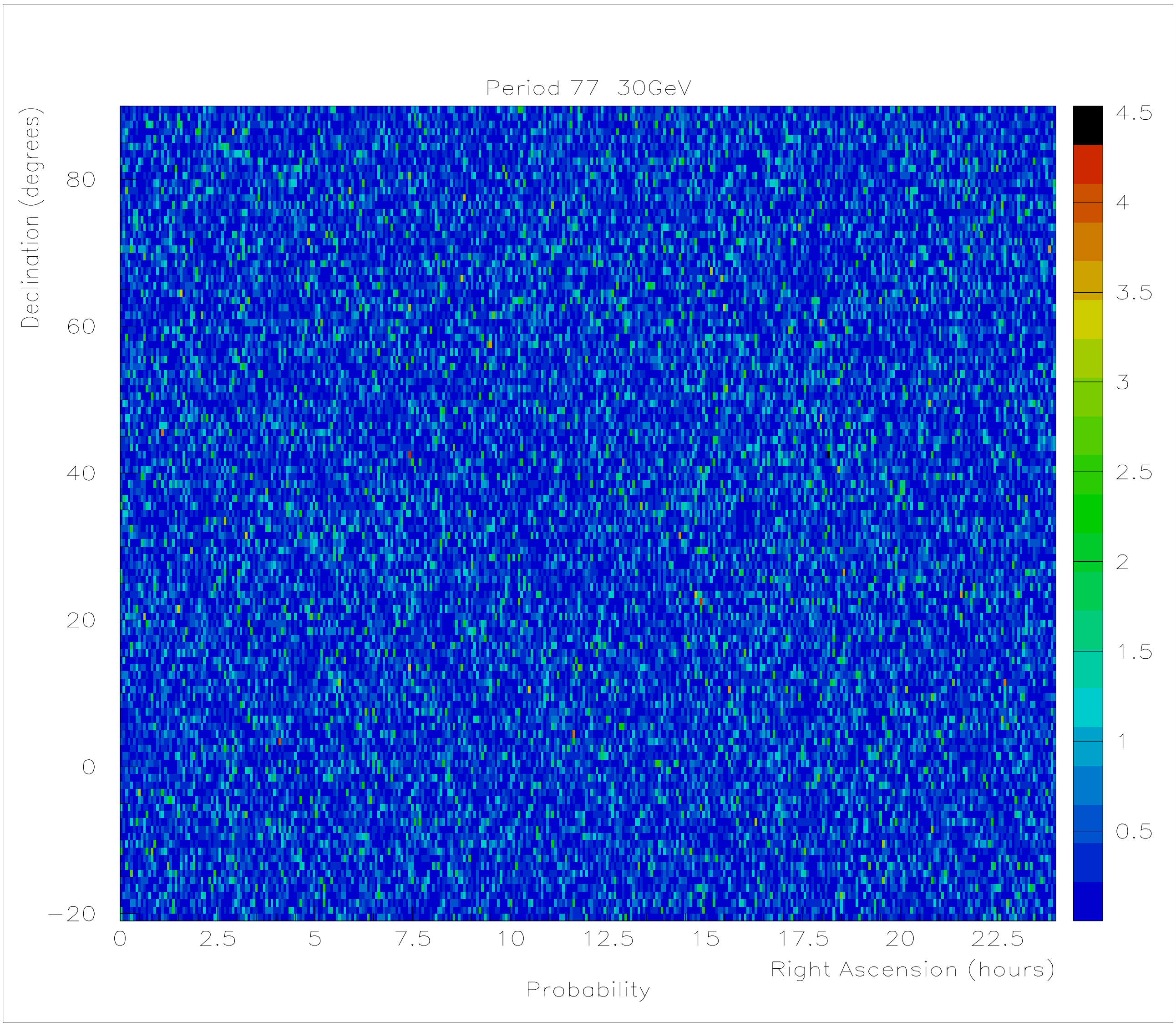
Probability distribution

Calculate probability that excesses are caused by statistical fluctuations. (Poisson statistics)

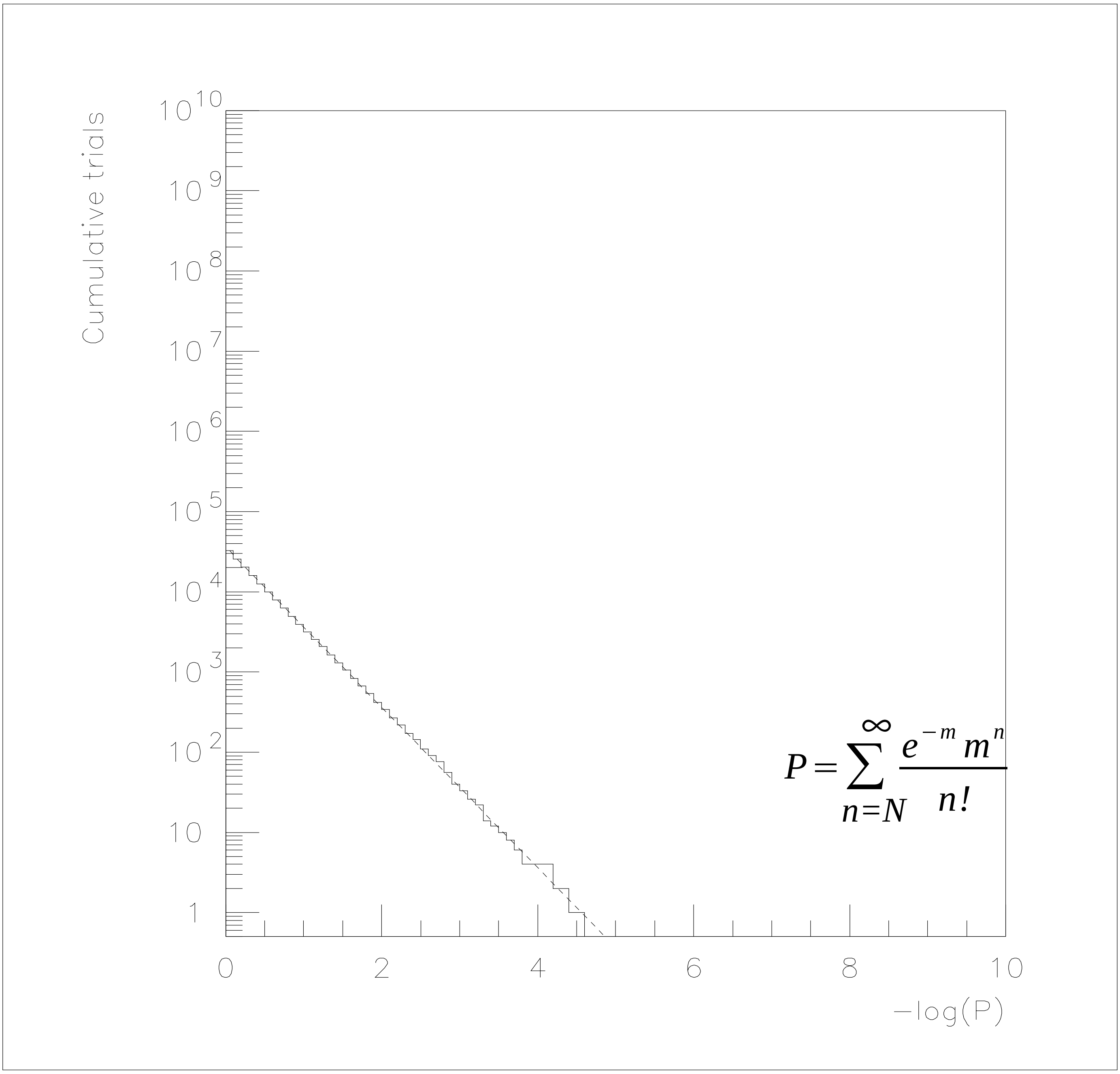
$$P = \sum_{n=N}^{\infty} \frac{e^{-m} m^n}{n!}$$

N: measured events
m: Background

Plot $-\log(P)$ on the sky map



− log (P) distribution



Drops exponentially as expected.

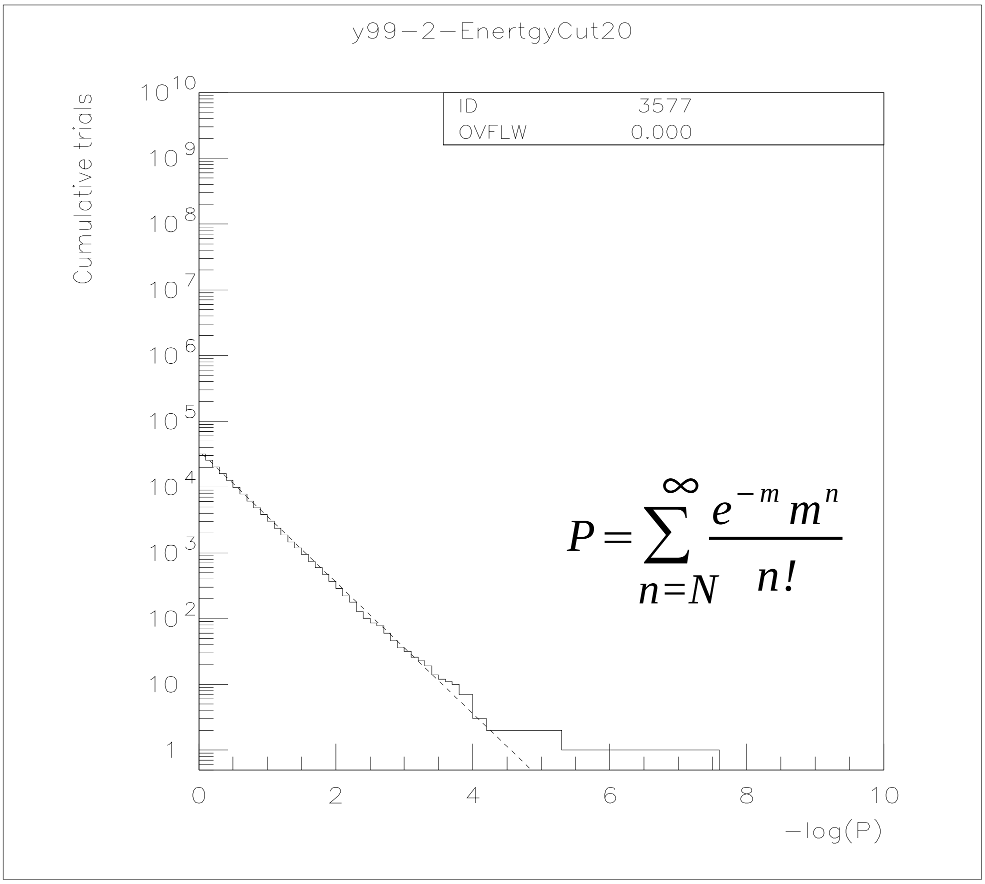
Analysis

- Different time scales:
  - 1 day, 1month, 1year, 2 years
- Different energy cuts:

  20 GeV, 30 GeV, 50 GeV, 100 GeV
- Bins: 1° x 1°, 2° x 2°, 3° x 3°
- Correct for high declination:

1° of Right Ascension corresponds to an effective arc of [cos(decl)]°
→ Sum more bins in Right Ascension direction to preserve solid angle.

20 GeV, 2° x 2° , 1999 (15 July –9 Nov)

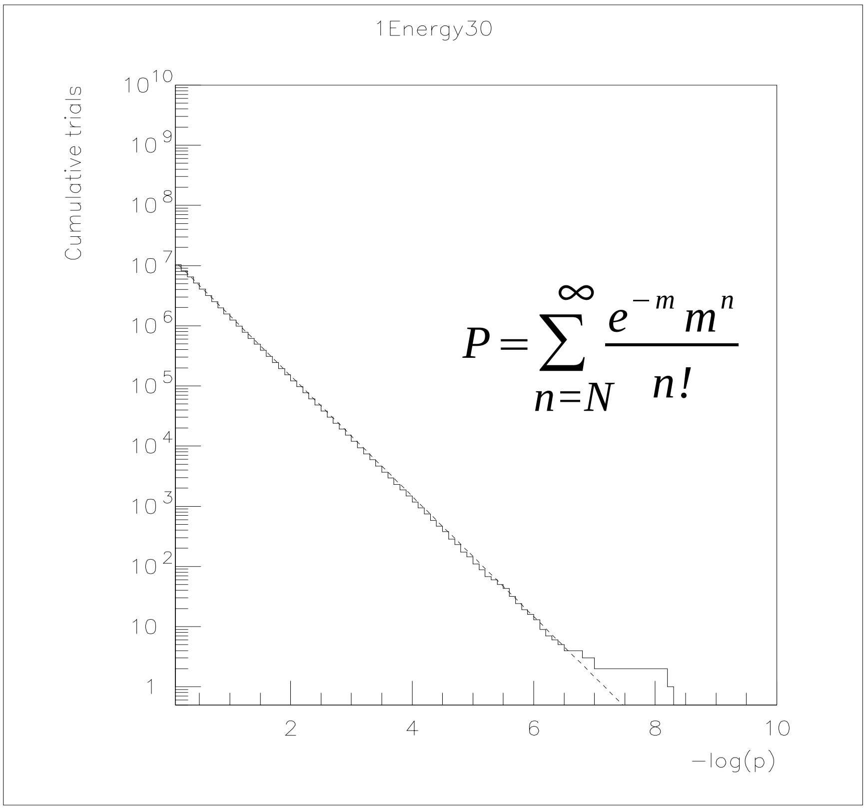


$$P = \sum_{n=N}^{\infty} \frac{e^{-m} m^n}{n!}$$

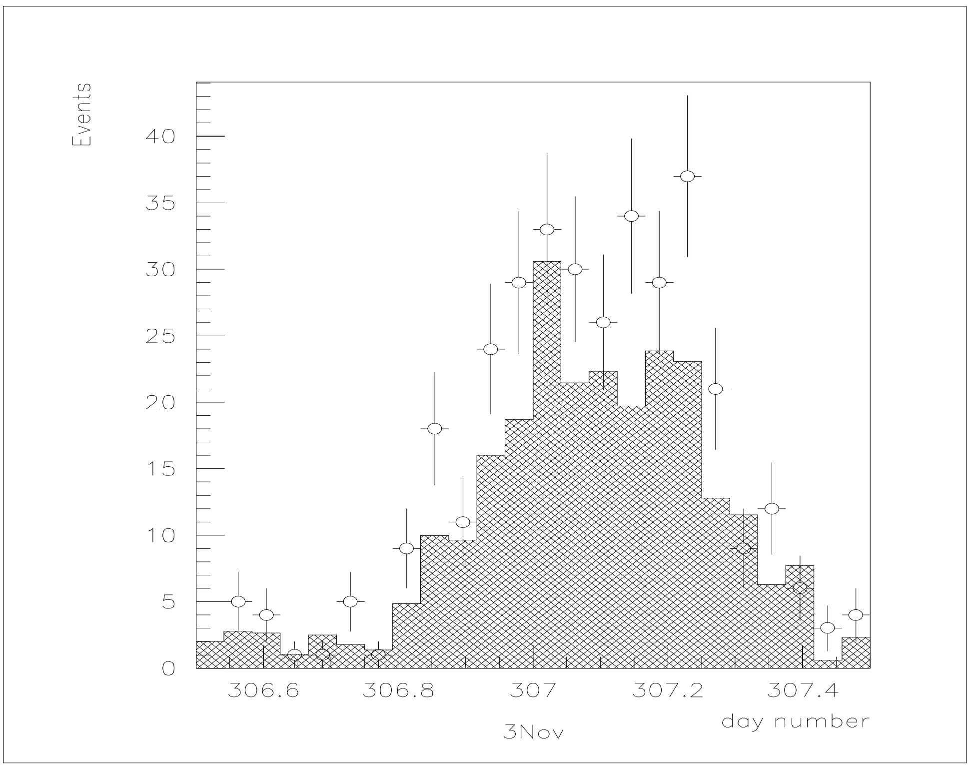
Probability that excess caused by stat. fluctuation: $1/(3.5\cdot 10^7)$
Number of trials: 40000

Time scale: 1 day

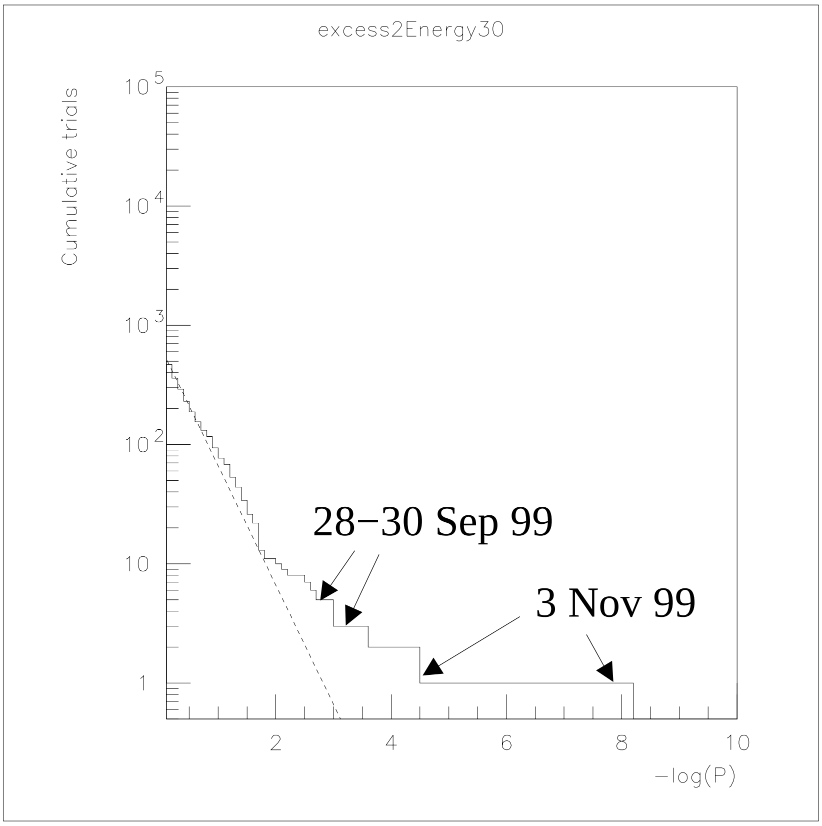
30 GeV, 1° x 1°



Example excess 3 November hour by hour



Other excesses in same direction



Summary of most significant excesses

E cut −log(p) measured backgr

****

31.7.1999 12:00 − 1.8.1999 12:00 decl:80−81 RA.: 15h44m−16h 8m

****

30 GeV 8.23 346. 250.16 (near BL Lac 1ES 1544+820) (<2°)
and γ−source 3EG J1621+8203

****

2.11.1999 12:00 − 3.11.1999 12:00 dec:75−76 RA:5h12' −5h 28'

****

20 GeV 8.49 379. 276.67
30 GeV 8.16 352. 255.68

****

1.5.2000 12:00 − 2.5.2000 12:00 dec:56−58 RA:17h56m−18h12m

****

20 GeV 7.57 1676. 1462.65 (near γ−source GRO J1753+57) (<2°)

****

1999 dec:21−23 RA 20h44m−20h52m

****

20 GeV 7.61 59651. 58327.91

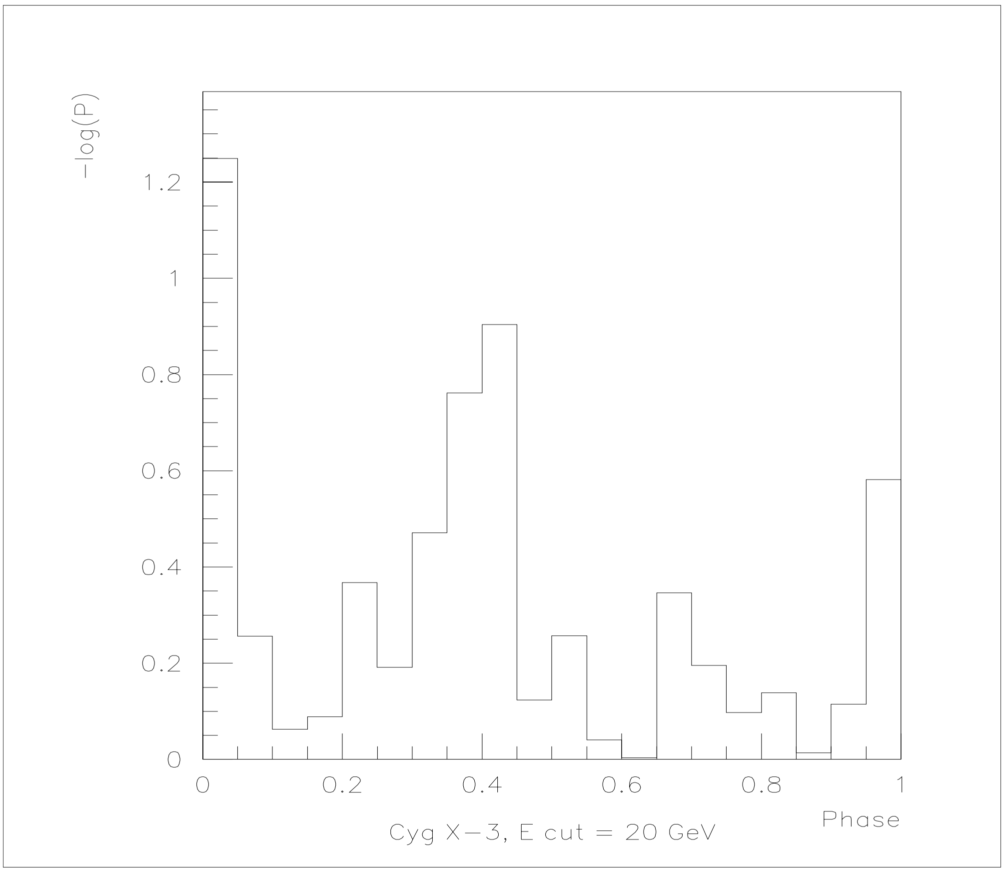
Known sources

Special plots for known sources:

1H 1430+423, Mrk 421, Mrk 501, Crab, Cyg X−1, Cyg X−3, Geminga, 3−C273, Her X−1, 1es2344+514

NO significant excess seen.

Cyg X−3: Plot −log(P) vs. phase



Conclusion

- Method has been developed to analyse anisotropy and to search for Point Sources with L3+C data.

- Large scale anisotropy < 0.05 % above 30 GeV

- No signal from known strongest γ−sources

- All sky survey: some excesses seen, despite of the fact that they are not forseen. (Statistical fluctuation or real source?)
  - Estimated μ−flux if source hypotesis is correct: ~ 10^{-8} s^{-1} cm^{-2}
  - Maximum μ−flux expected from known γ−sources at 20 GeV (Vela pulsar): ~ 10^{-9} s^{-1} cm^{-2} (**optimistic!**)
  - However Soudan−1 reported μ−flux 10^{-9} s^{-1} cm^{-2} from Cyg X−3 at E > 650 GeV (!)
  - (Maximum μ−flux expected from GRB at 20 GeV: ~ 10^{-5} s^{-1} cm^{-2} (for short period))