

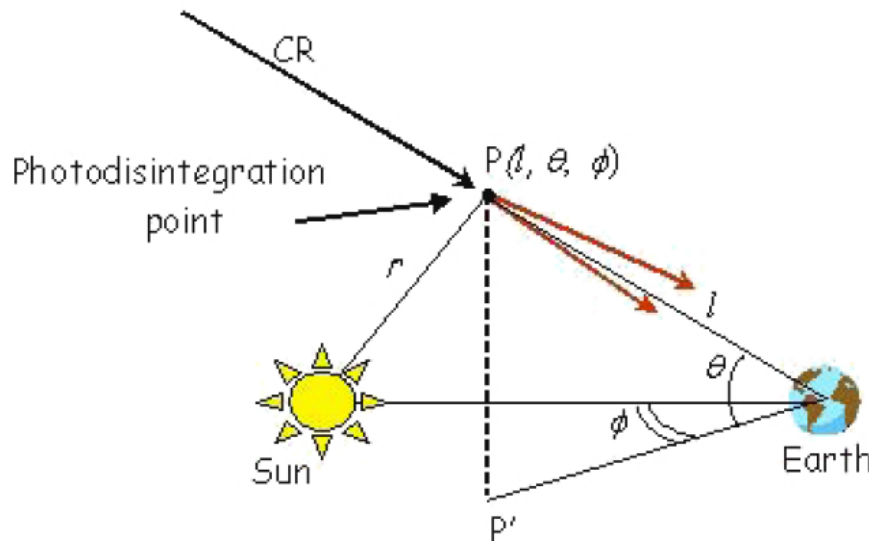
Preliminary search for long distance correlations in EEE

F.Riggi

Dept. of Physics & Astronomy, Catania

Physics processes for long distance correlations

Photodisintegration of cosmic ray nuclei in the solar field (GZ-effect)



Calculations of the probability of occurrence of such nuclei and of their separation distance carried out in the past with various results:

- Epele et al, 1999
- Medina-Tanco & Watson, 1999
- La Rocca & Riggi, 2006
- Fujwara et al, 2006
- Lafebre et al, 2008

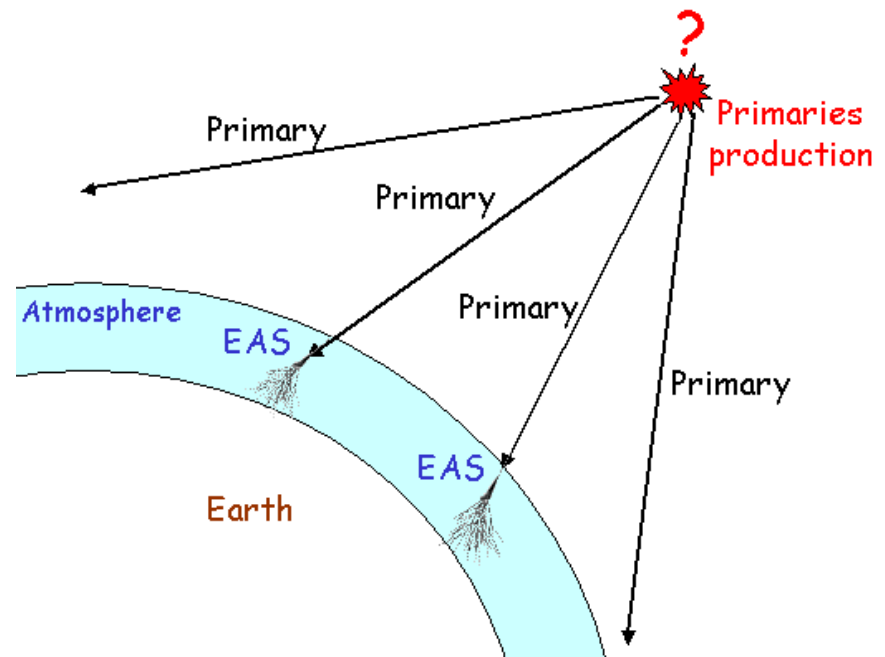
Estimated number of events per year $\ll 1$ (10^{-2} /year ?)

However, large uncertainties in such estimates, due to various factors

Physics processes for long distance correlations

Production of independent showers originating from a single primary

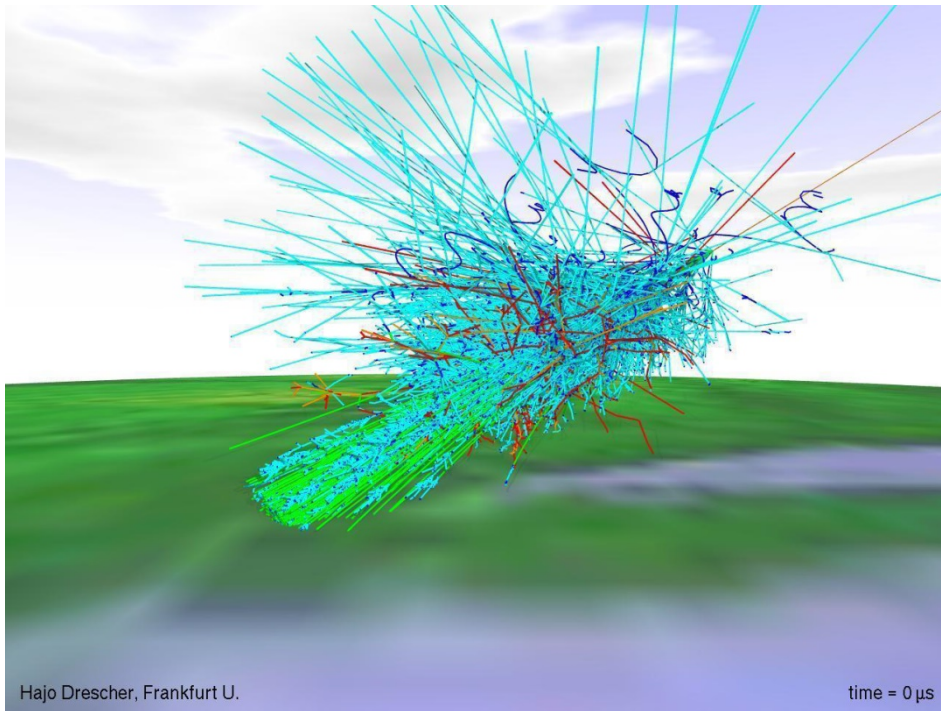
No quantitative estimation for such process available so far



Physics processes for long distance correlations

A single shower of extremely high energy, extending over tens/hundreds km ?

Likely ruled out by negative results from Auger Observatory (50 x 60 km wide)



Experimental searches so far

Observation of such events exploited by a few experiments:

LAAS (Japan)

A Large Area Air Shower experiment: a Japanese array with a few (10) sites (several scintillators in coincidence at 5-10 m distance) with relative distances between sites 0.1 - 1000 km.

One decade observations have shown some enhancement at small relative times (ms) between distant sites, but no significant excess due to such events.

CHICOS (USA)

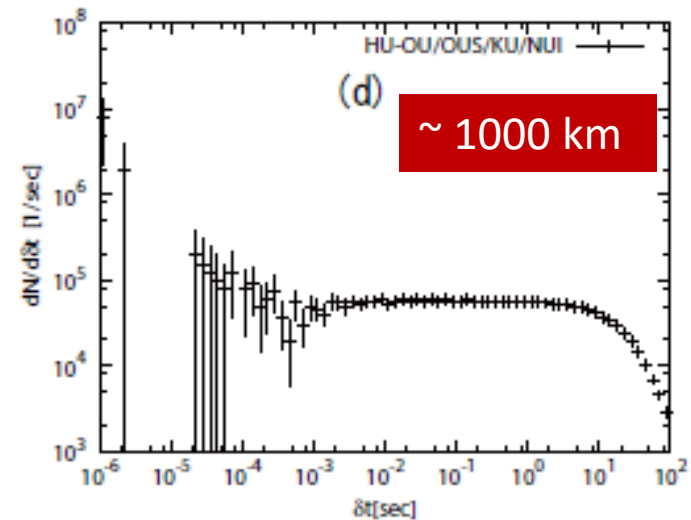
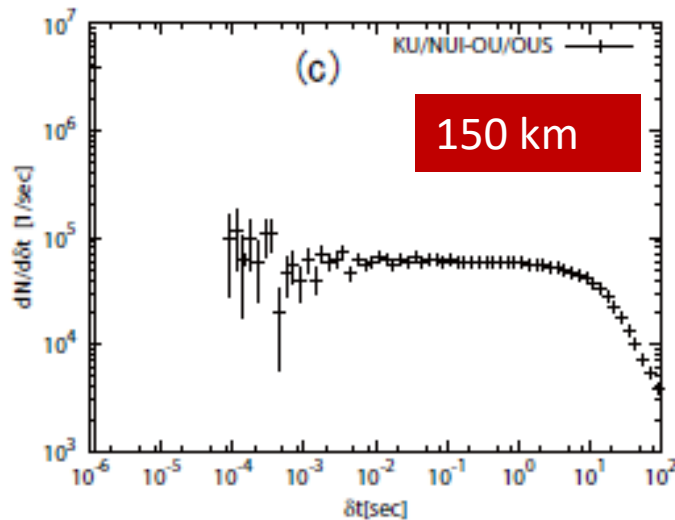
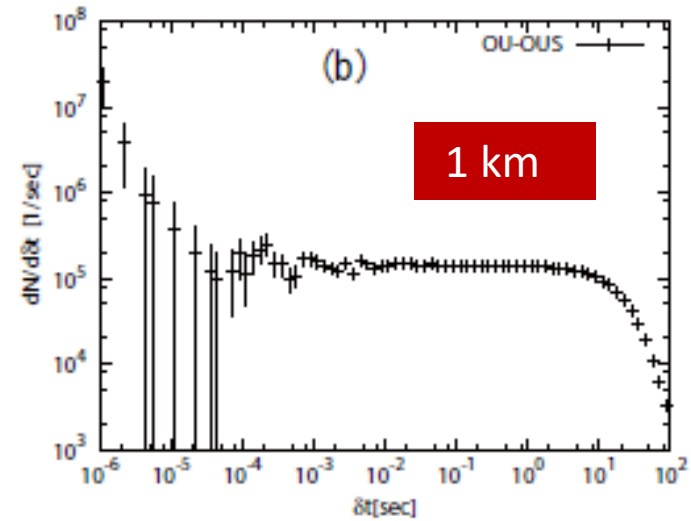
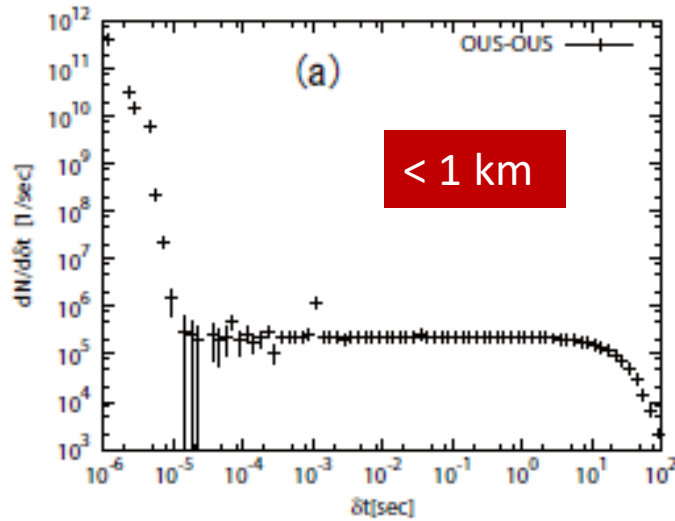
An educational network with 60 sites (2 scintillators in coincidence on each site at 3 m distance) with relative distances of the order of 50 km between sites.

Some small excess observed for time difference < 10 microseconds in a period of 17 months data taking.

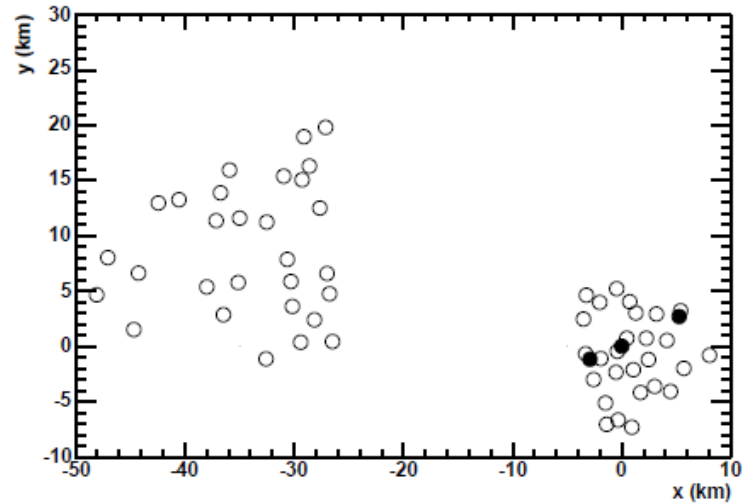
CZELTA (Czech Republic)

An educational network with 5 sites (3 scintillators at 10 m distance). Search for very long baseline correlations with the ALTA sites in Canada (7200 km distance). No events observed in a few years collecting time

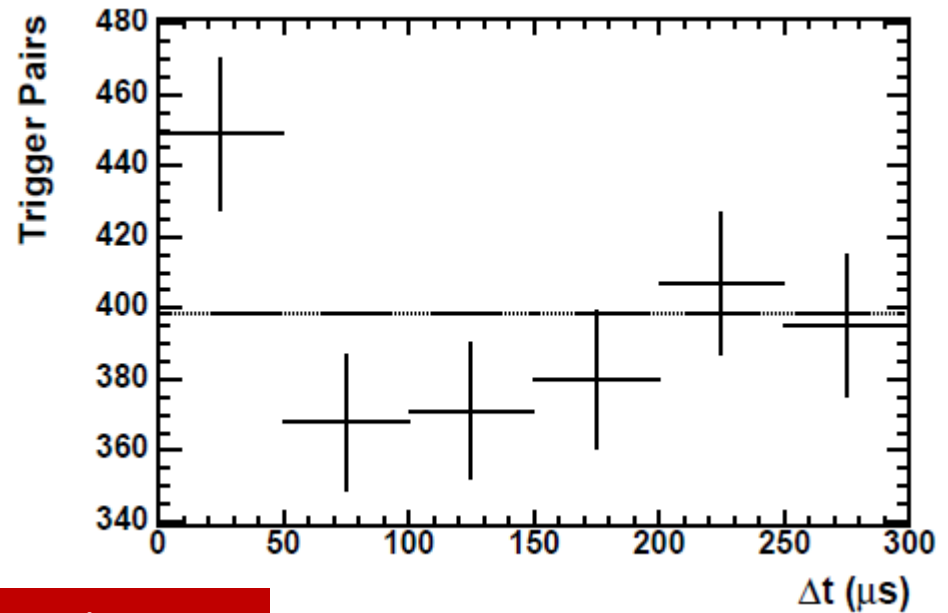
Results from LAAS experiment



Results from CHICOS experiment

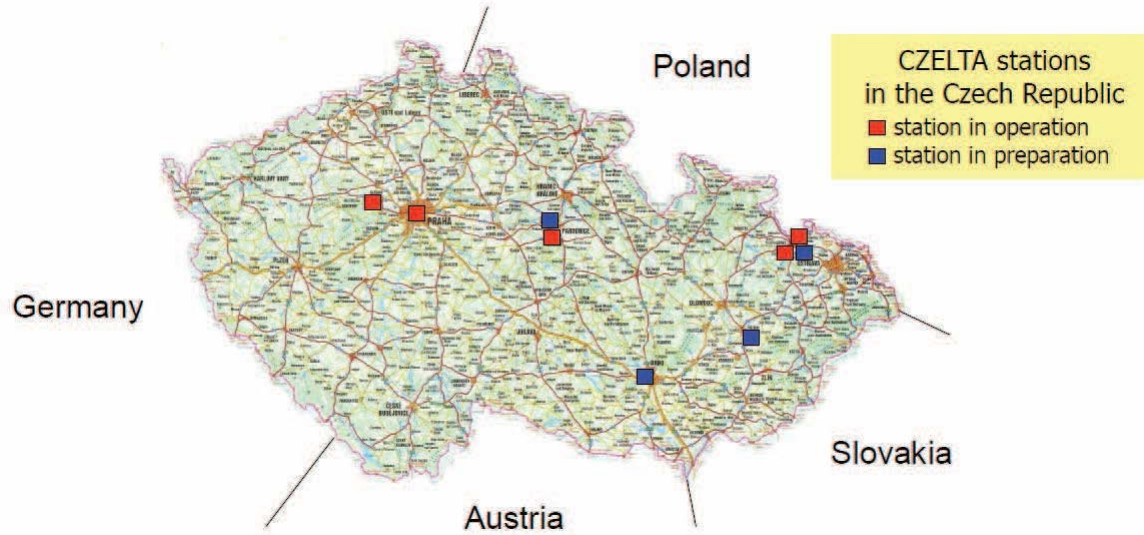


Distribution of sites in the CHICOS array



Some trigger pair excess at small time difference

Results from CZELTA experiment



A typical station of the CZELTA array

Distribution of sites in the CZELTA array

TABLE II
DOUBLE-COINCIDENCIES

ID ₁ & ID ₂	Dist ₁₂ [km]	t_{12} [ms]	τ [den]	n_{obs}	n_{exp}	p-value
2 & 14	7230	24.1	24	488	441.3	0.015
2 & 15	7200	24.0	265	1078	1018.8	0.034
2 & 21	7230	24.1	324	1461	1375.3	0.011
7 & 13	390	1.3	514	162	127.1	0.0016
15 & 18	90	0.3	511	52	38.0	0.018

Correlation with detectors located in US/Canada

The role of the EEE network in this context

The EEE sparse array could play a significant role in this context:

- **Large number of sites distributed over a large area**
- **Relative distances between sites up to 1200 km**
- **Large statistics collected so far and more expected in the future**
- **Time and orientation of muons/primary available on individual sites**
- **Individual showers already identified in several sites (clusters)**

The role of the EEE network in this context

Possible strategies for searching long distance correlations:

- **Correlations between single muons in individual telescopes**
Single rate = 10-40 Hz from site to site
Spurious rate in 1 ms time window: ~1 Hz (10^5 /day, too high!!)
- **Correlations between single muons and 2 track events**
Single rate = 10-40 Hz, 2tracks rate: 0.01 - 0.1 Hz
Spurious rate in 1 ms: $10^{-4} - 10^{-3}$ Hz (100-1000/day, still high)
- **Correlations between 2track events in both telescopes**
2tracks rate = 0.01 - 0.1 Hz
Spurious rate in 1 ms: $10^{-7} - 10^{-5}$ Hz (0.01 - 1 /day)
- **Correlations between individual showers in cluster telescopes**
Shower rate: 0.001 - 0.04 Hz (depending on cluster and S/N ratio)
Spurious rate in 1 ms: $10^{-8} - 10^{-7}$ Hz (0.001 - 0.01/day)

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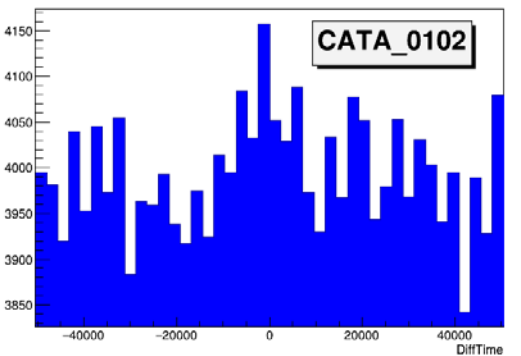
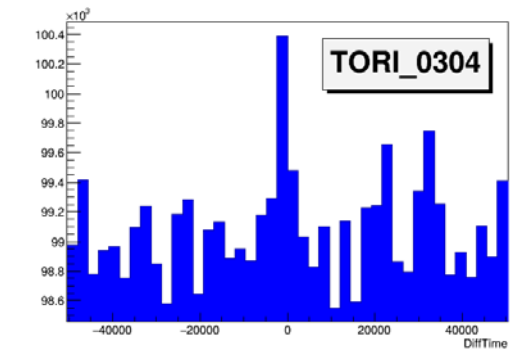
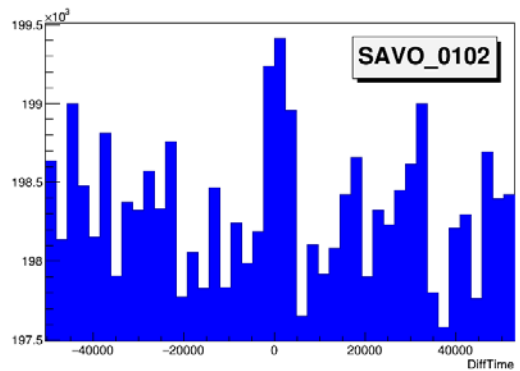
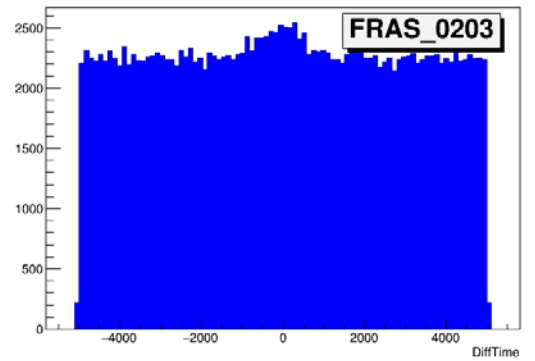
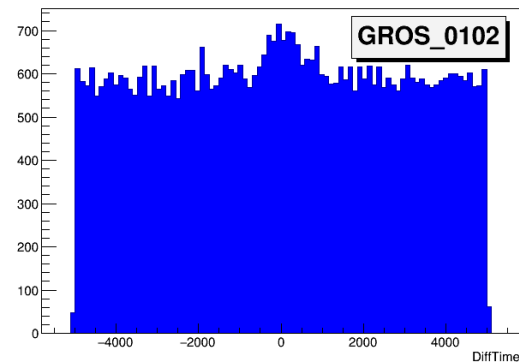
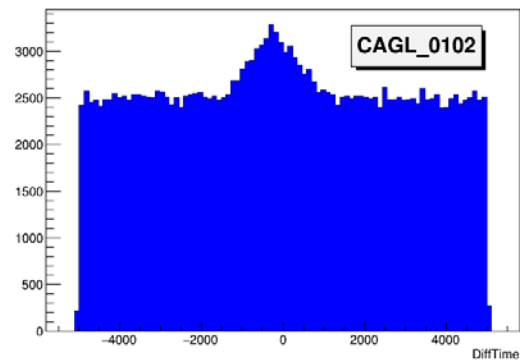
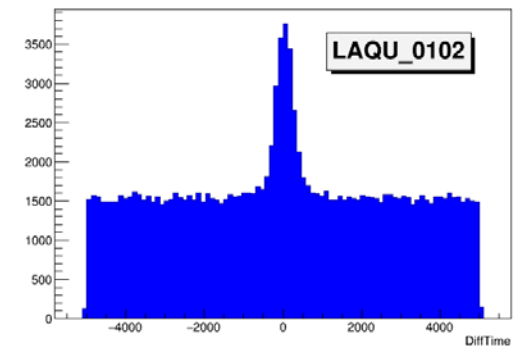
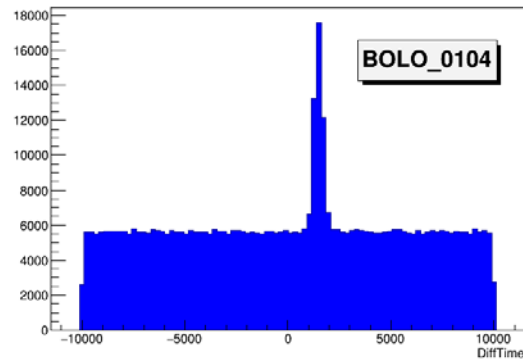
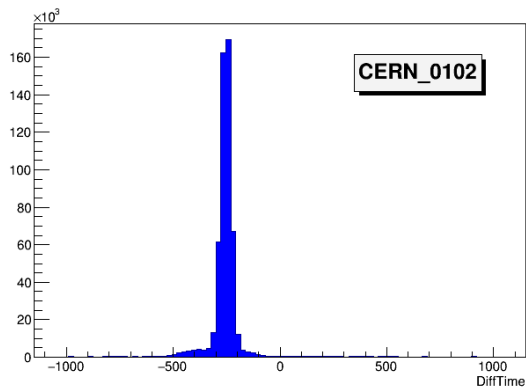
EEE Cluster sites

Site	Approx.Distance between telescopes (m)	Time window (ns)	Overall Rate in time window (Hz)	Live time (days)	Net Rate per day	
BOLO_0104	100	900-2100	0.0038	176	159	
CAGL_0102	530	-1400,1400	0.0017	474	17	
CATA_0102	3030	-10000, 10000	0.0031	127	2.9	
CERN_0102	30	-350, 150	0.0417	127	3549	
FRAS_0203	620	-1500, 1500	0.0068	104	27.8	
GROS_0102	500	-1000, 1000	0.0019	67	13.6	
LAQU_0102	200	-500, 500	0.0026	105	94	
SAVO_0102	1170	-5000, 5000	0.0272	353	10.7	
TORI_0304	1070	-7000, 7000	0.0412	163	12.2	
VIAR_0102	1340	-10000, 10000	0.0113	160	1	

Distribution of distances between cluster sites

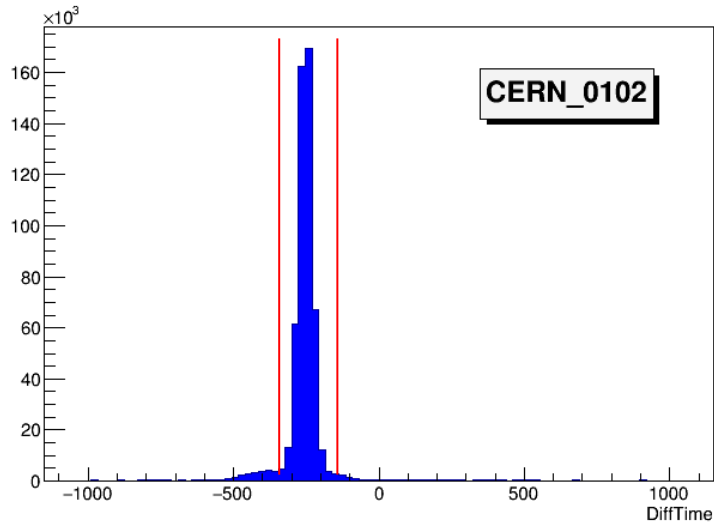
	BOLO	CAGL	CATA	CERN	FRAS	GROS	LAQU	SAVO	TORI	VIAR
BOLO	-									
CAGL		-								
CATA			-							
CERN	450	835	1200	-						
FRAS				725	-					
GROS				558		-				
LAQU				720			-			
SAVO				285				-		
TORI				180					-	
VIAR				425						-

S/N ratio over different sites

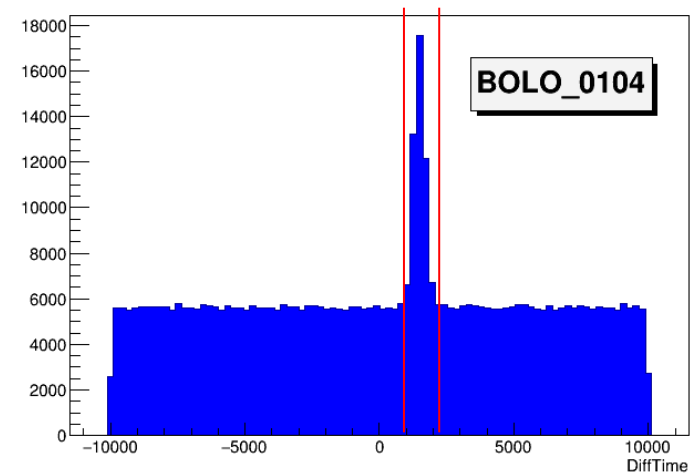


Correlation analysis

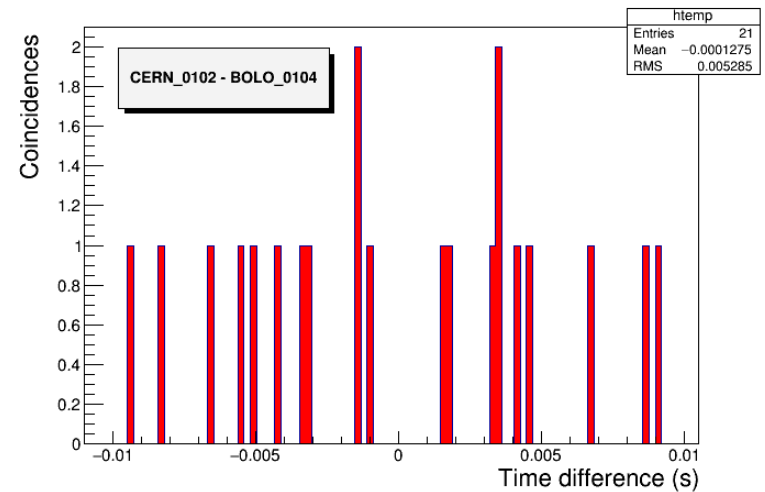
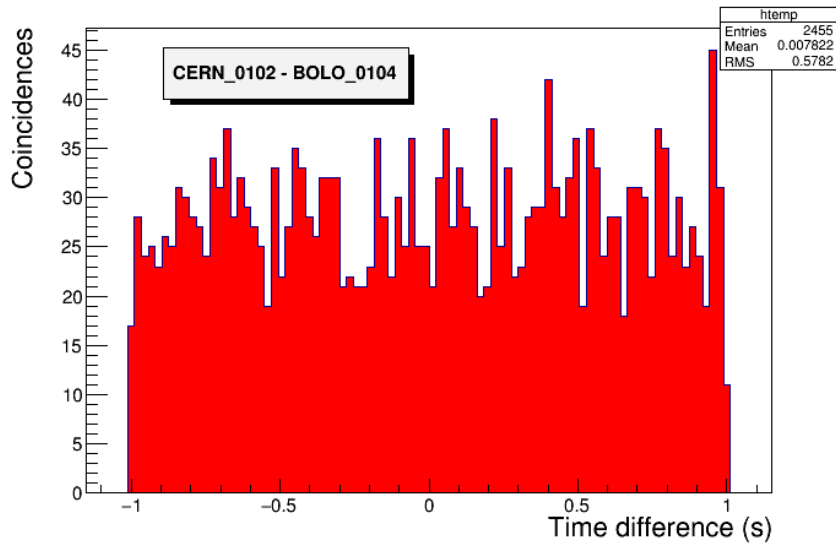
- Selected time window for each telescope
- No cut on relative angle between showers and track quality at the moment



- Build difference time spectra
- Estimate of common live time with a granularity of 5 minutes (thanks to Francesco Noferini for the help!)



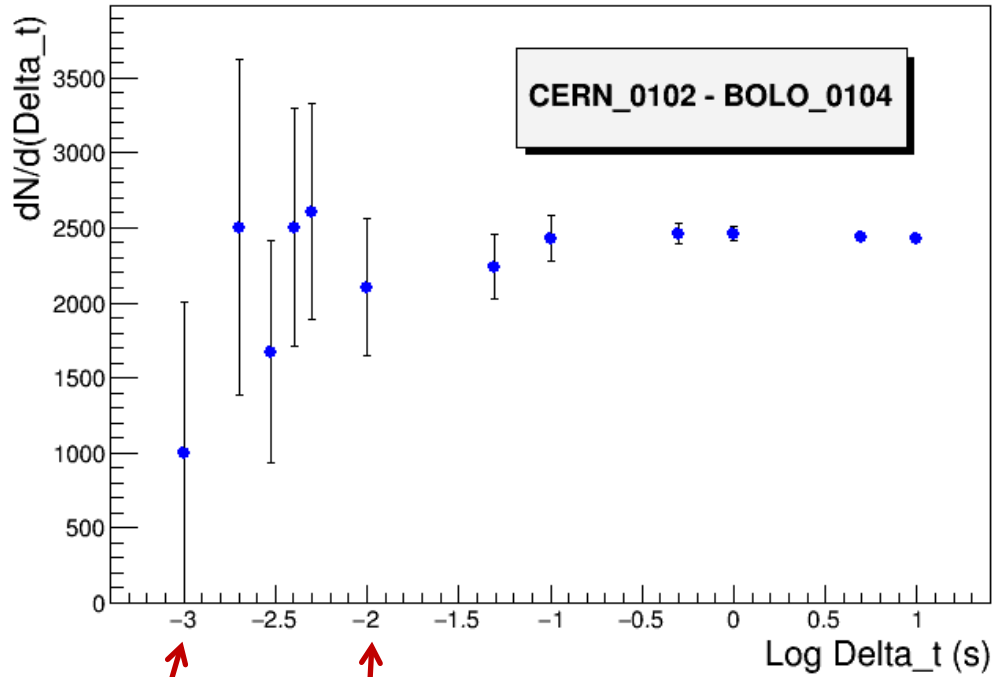
Typical time difference spectra between clusters



Time difference spectra between clusters, for various time windows (10 s, 1 s, 1 ms)

$dN/d(\Delta_t)$: Frequency of coincidence events

CERN_0102 – BOLO_0104 correlation



450 km distance

94.6 days live time

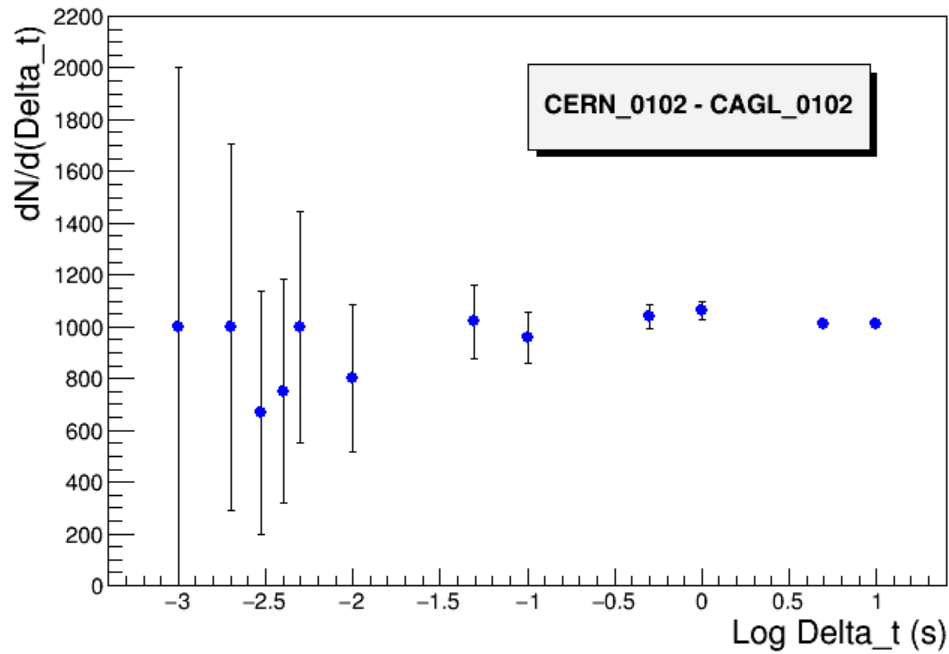
1 ms

10 ms

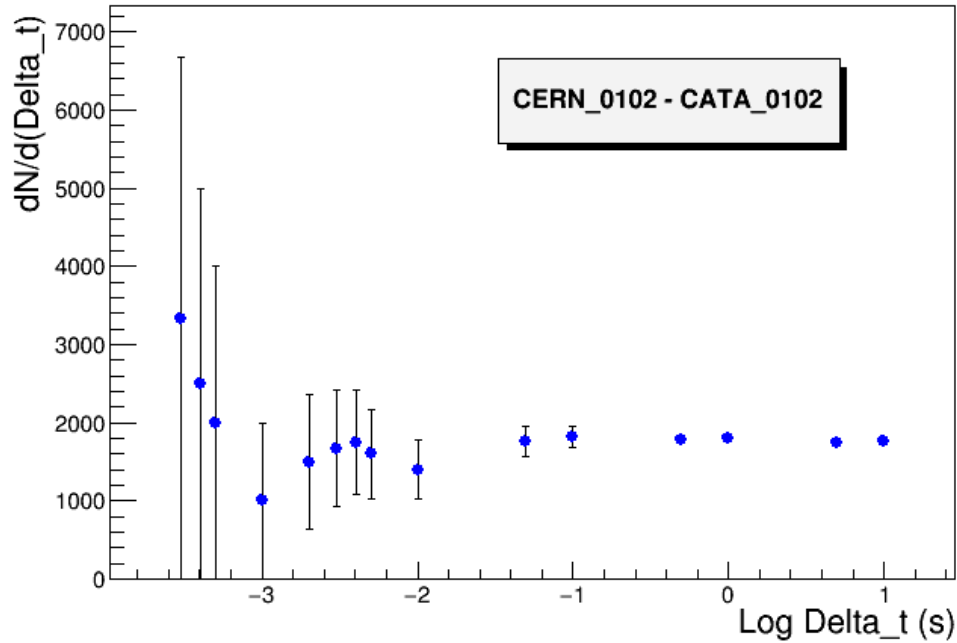
CERN_0102 – CAGL_0102 correlation

835 km distance

125.6 days live time



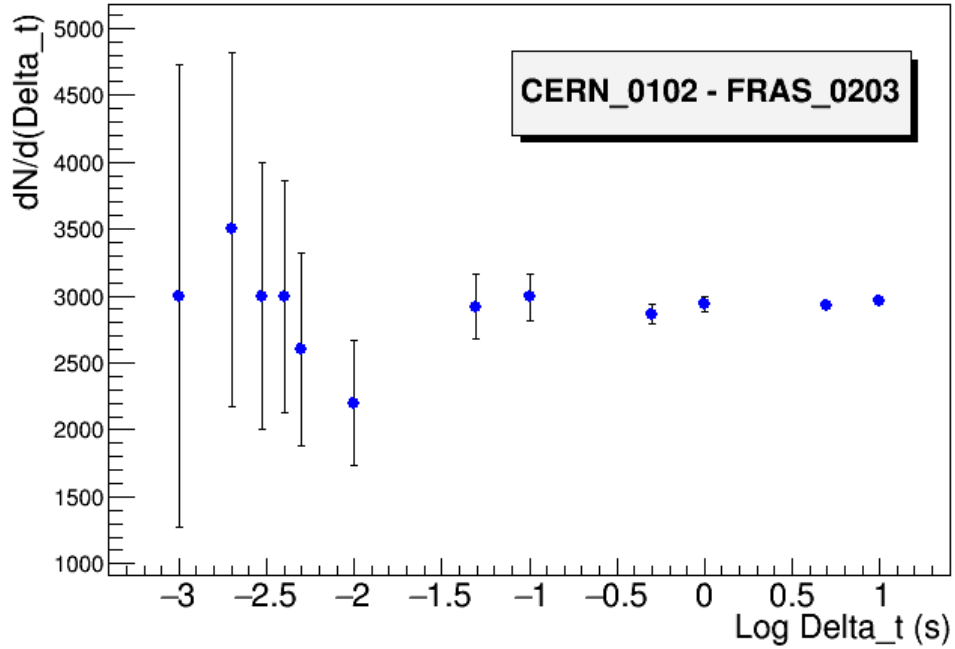
CERN_0102 – CATA_0102 correlation



1200 km distance

74.7 days live time

CERN_0102 – FRAS_0203 correlation



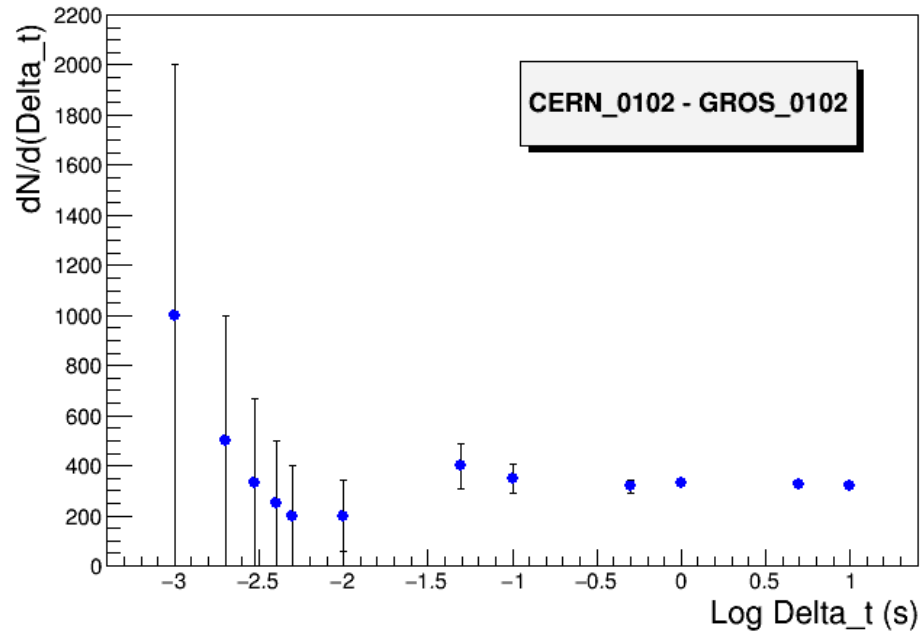
725 km distance

65.5 days live time

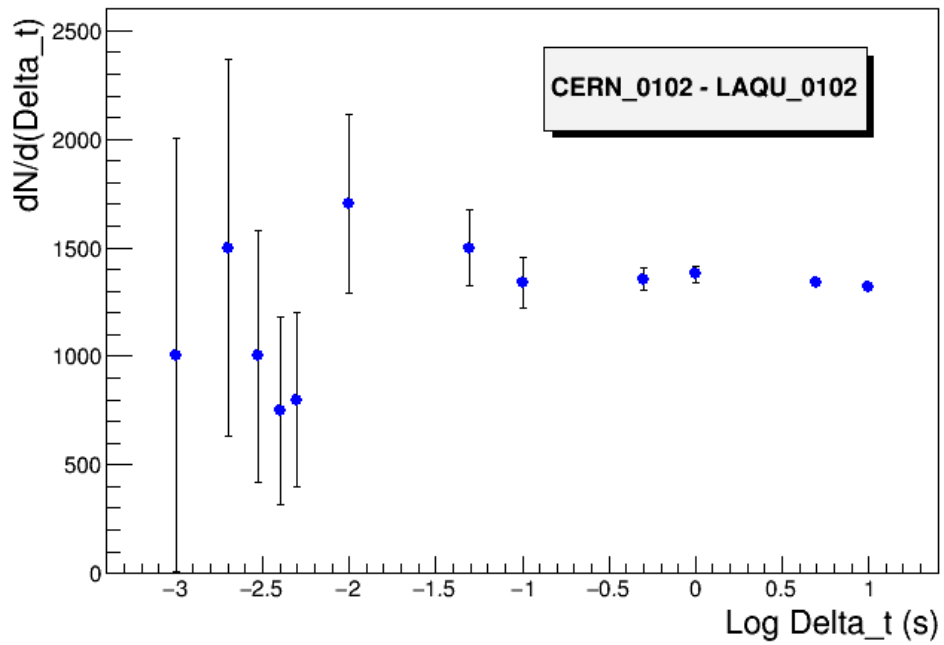
CERN_0102 – GROS_0102

560 km distance

26.7 days live time



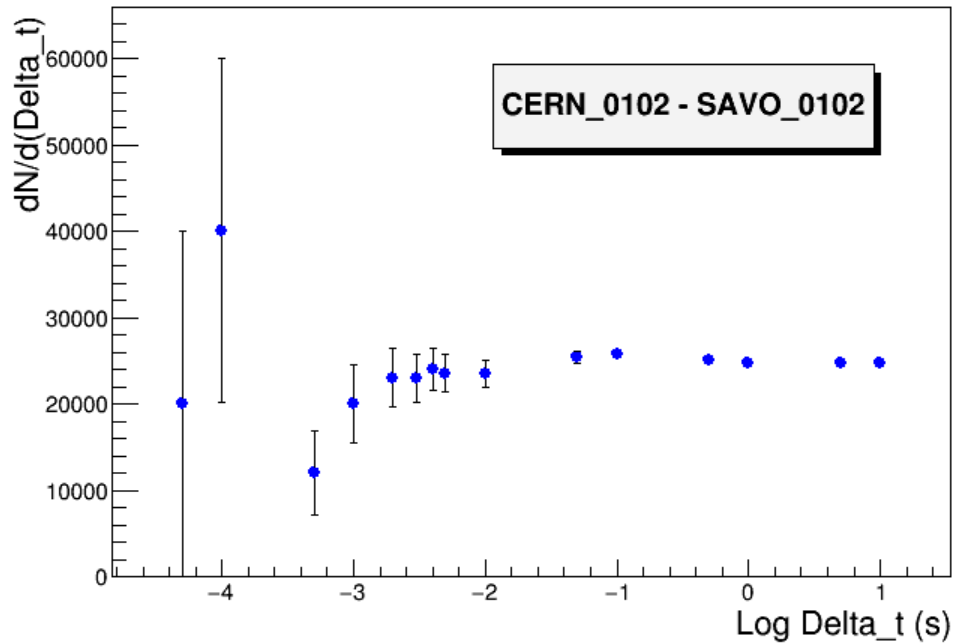
CERN_0102 – LAQU_0102



720 km distance

66.7 days live time

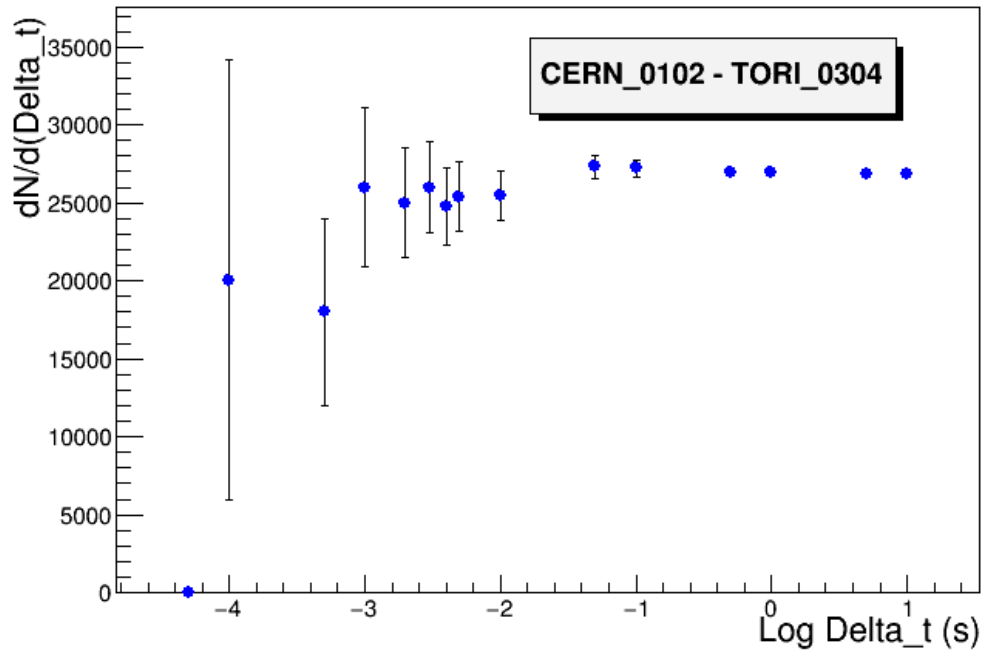
CERN_0102 – SAVO_0102



285 km distance

108.6 days live time

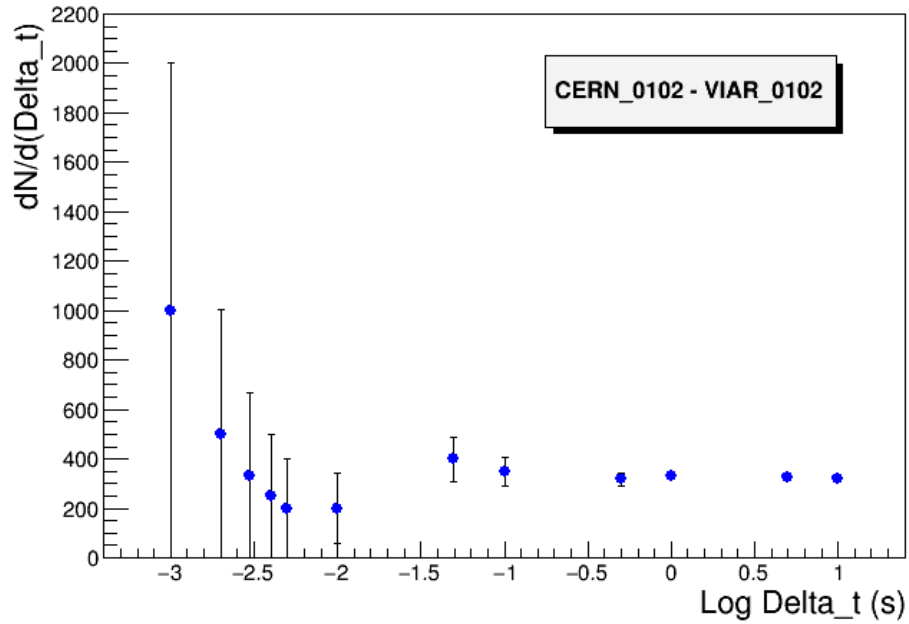
CERN_0102 – TORI_0304



180 km distance

86.4 days live time

CERN_0102 – VIAR_0102



425 km distance

103.2 days live time

Outlook

Analysis of long distance correlations between EEE cluster sites in progress

- **CERN- (any other site) correlation data analyzed (9 of 45 combinations)**
- **Relative distances probed so far: from 180 to 835 km**
- **Overall statistics roughly corresponding to 574 days live time**
- **No clear evidence so far of time correlations for distant sites**

Next to be done:

- **Analysis of remaining cluster combinations**
- **Estimate of upper limit, if any**