E.E.E.

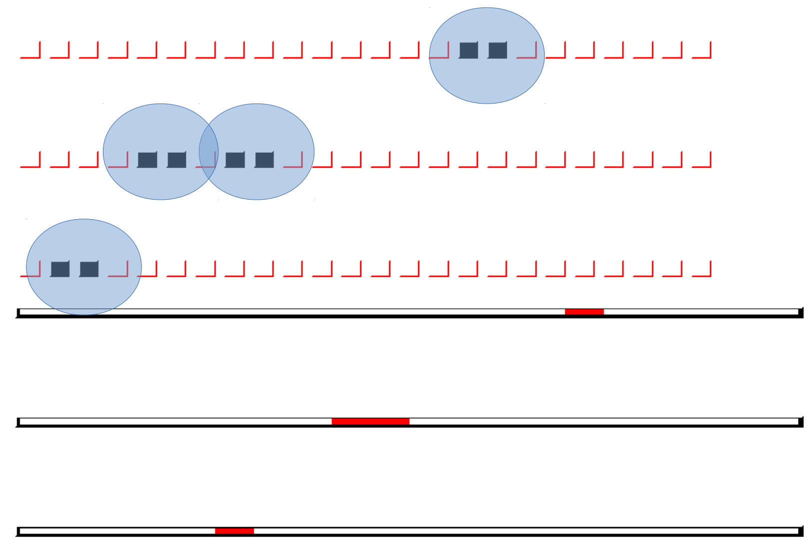
How to make a clever use of the DATA QUALITY MONITOR

(and understanding the path to a discovery)

DQM

RUN DQM

Run quality

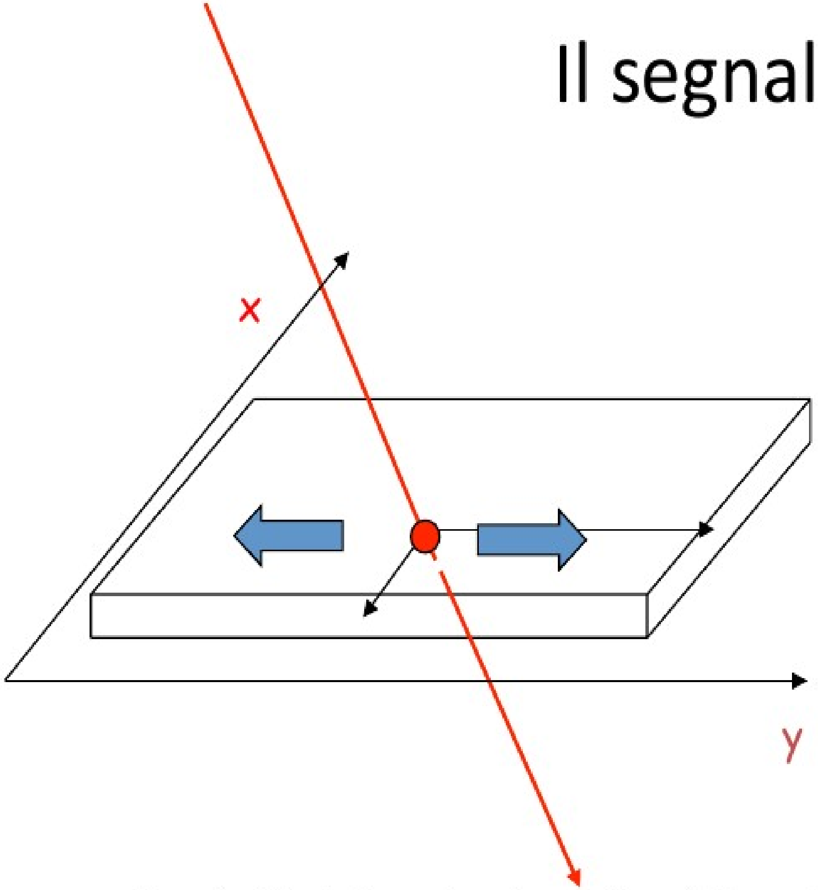


DQM histograms and alarms
Plenty of information
not to be left unused!

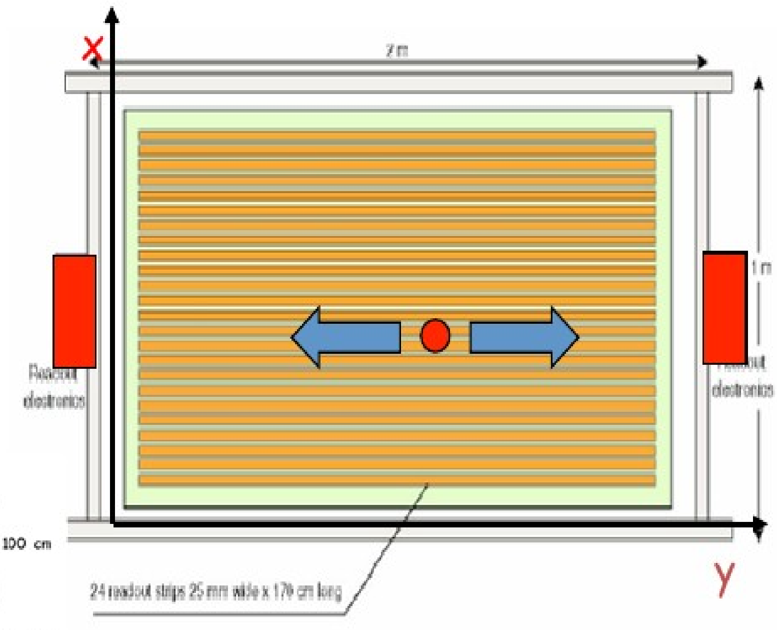
ALARM SUMMARY

PLOT	ALARM	STATUS	OUTPUT	LIMITS
RateHitEvents	y_values	Clean	31.41 +- 0.72	[10 / 20 – 60 / 80]
DeltaTime	exp_fit_lambda	Clean	33.32 +- 0.16	[5 / 10 – 50 / 75]
HitMultTop	x_average	Clean	1.0810 +- 0.0019	[0.500 / 0.750 – 2 / 3]
HitMultMid	x_average	Clean	1.0925 +- 0.0021	[0.500 / 0.750 – 2 / 3]
HitMultBot	x_average	Clean	1.0929 +- 0.0021	[0.500 / 0.750 – 2 / 3]
HitMultTotal	x_average	Clean	3.2614 +- 0.0052	[1.50 / 2.50 – 6 / 9]
ClusterMultTop	x_average	Clean	1.0810 +- 0.0019	[0.500 / 0.750 – 2 / 3]
ClusterMultMid	x_average	Clean	1.0925 +- 0.0021	[0.500 / 0.750 – 2 / 3]
ClusterMultBot	x_average	Clean	1.0927 +- 0.0021	[0.500 / 0.750 – 2 / 3]
ClusterMultTotal	x_average	Clean	3.2662 +- 0.0052	[1.50 / 2.50 – 6 / 9]
ChiSquare	x_average	Clean	2.735 +- 0.020	[1 / 2 – 6 / 10]
RateTrackEvents	y_values	Clean	29.85 +- 0.70	[10 / 20 – 60 / 80]
FractionTrackEvents	y_values	Clean	0.9642 +- 0.0042	[0.750 / 0.800 – 1 / 1]
Phi				
Theta				
TimeOfFlight				
TrackLength				

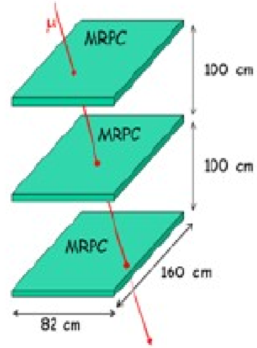
Il segnale delle MRPC



- 24 strip di rame per raccogliere il segnale
- trigger: coincidenza dei due lati di una camera e delle tre camere



- coordinata X determinata dalla strip colpita
- coordinata Y ottenuta dalla misura della differenza temporale di arrivo del segnale sui due lati della camera

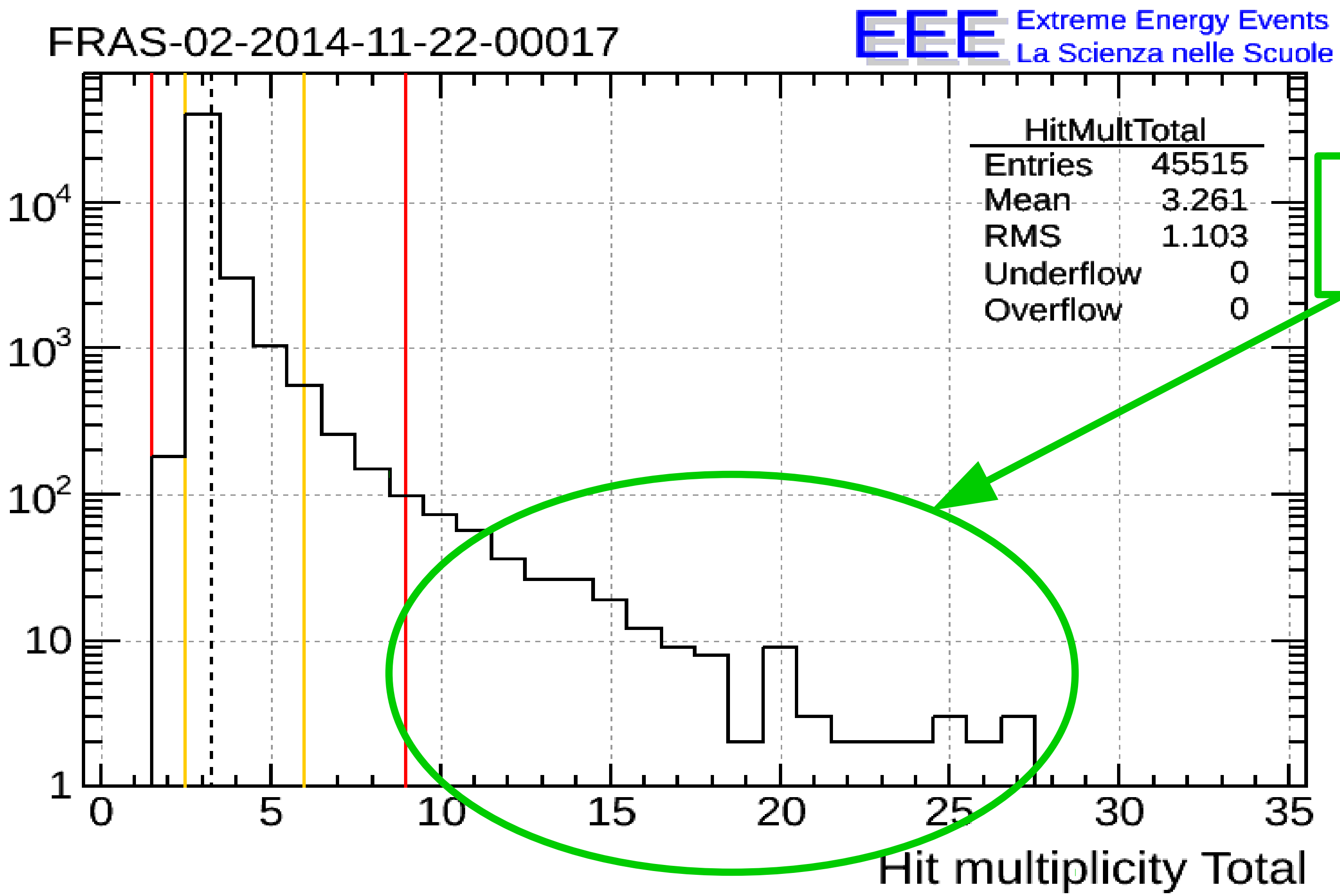


DQM

RUN DQM

Run quality

HIT MULTIPLICITY
distribution



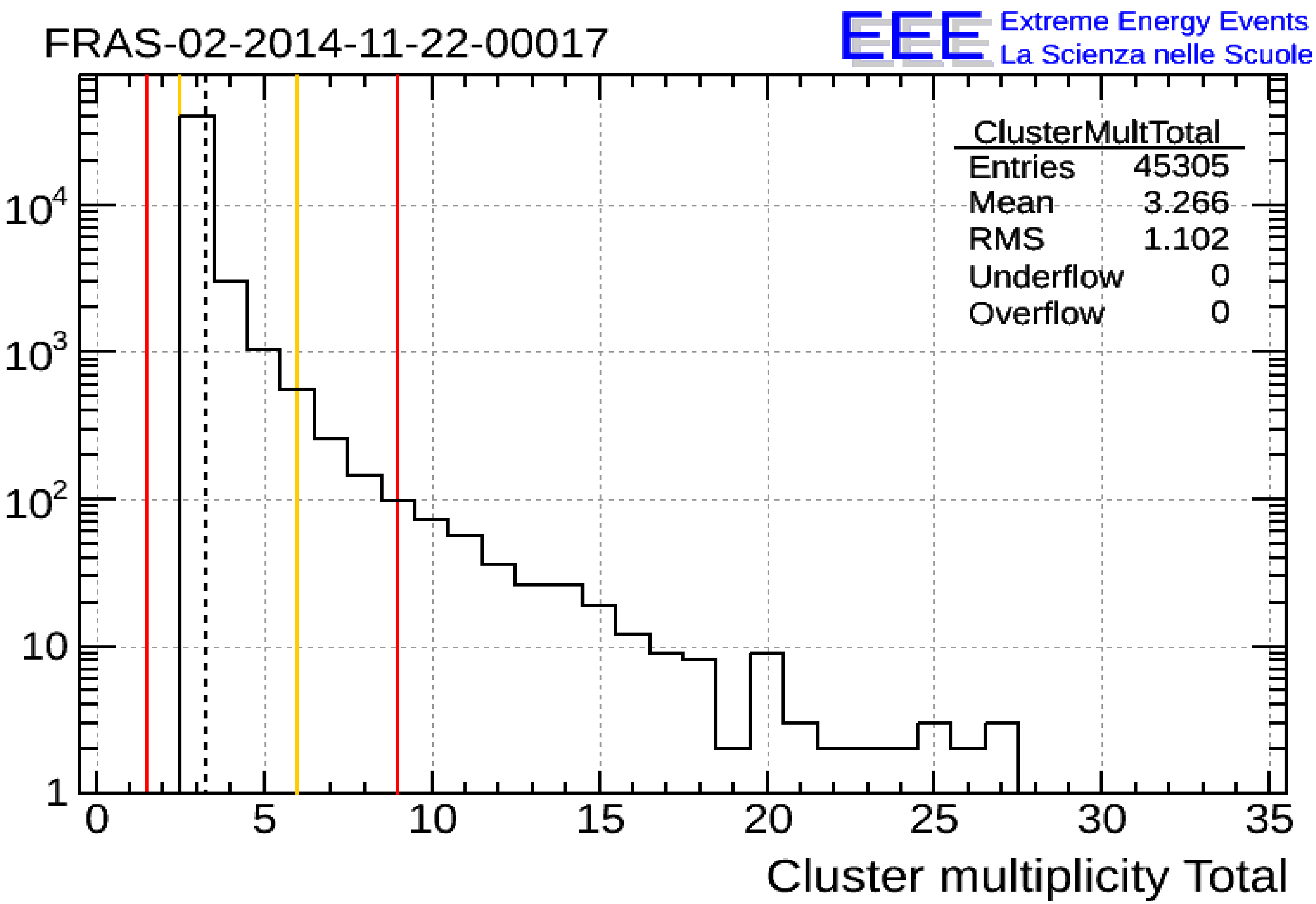
"noisy" events

DQM

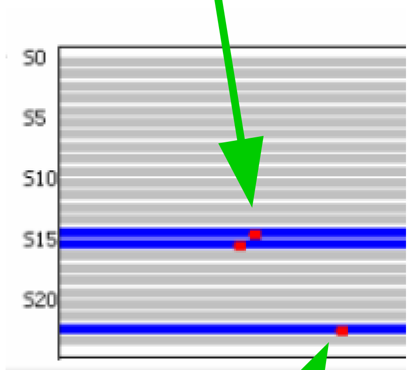
RUN DQM

Run quality

CLUSTER MULTIPLICITY
distribution



Cluster

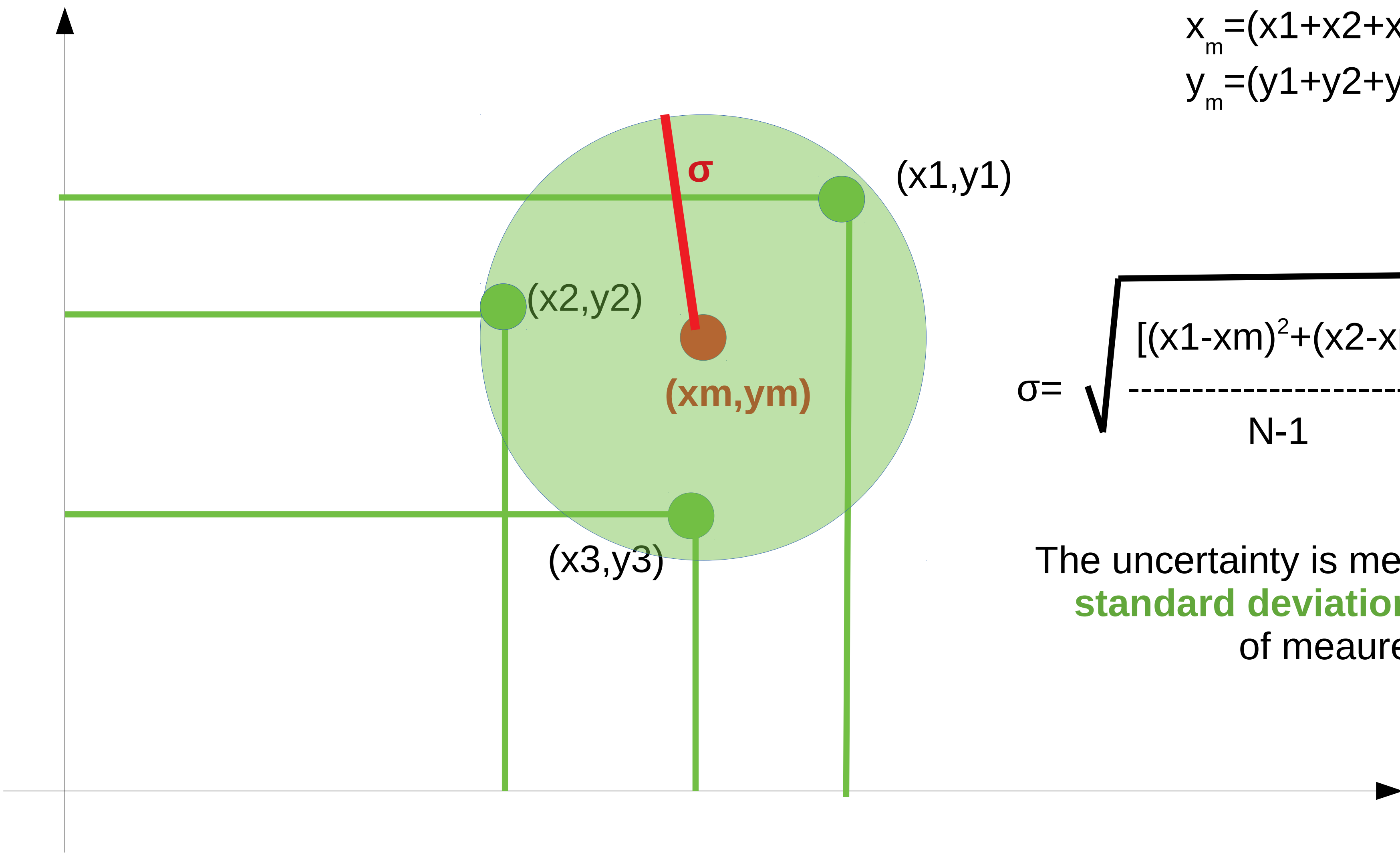


Single hit

Insights

How to get a cluster: the path to a muon track

The center of the cluster can be the simple average



$x_m=(x1+x2+x3)/3$

$y_m=(y1+y2+y3)/3$

$$\sigma = \sqrt{\frac{[(x1-xm)^2+(x2-xm)^2+(x3-xm)^2]}{N-1}}$$

The uncertainty is measured by the **standard deviation** of the set of meaures

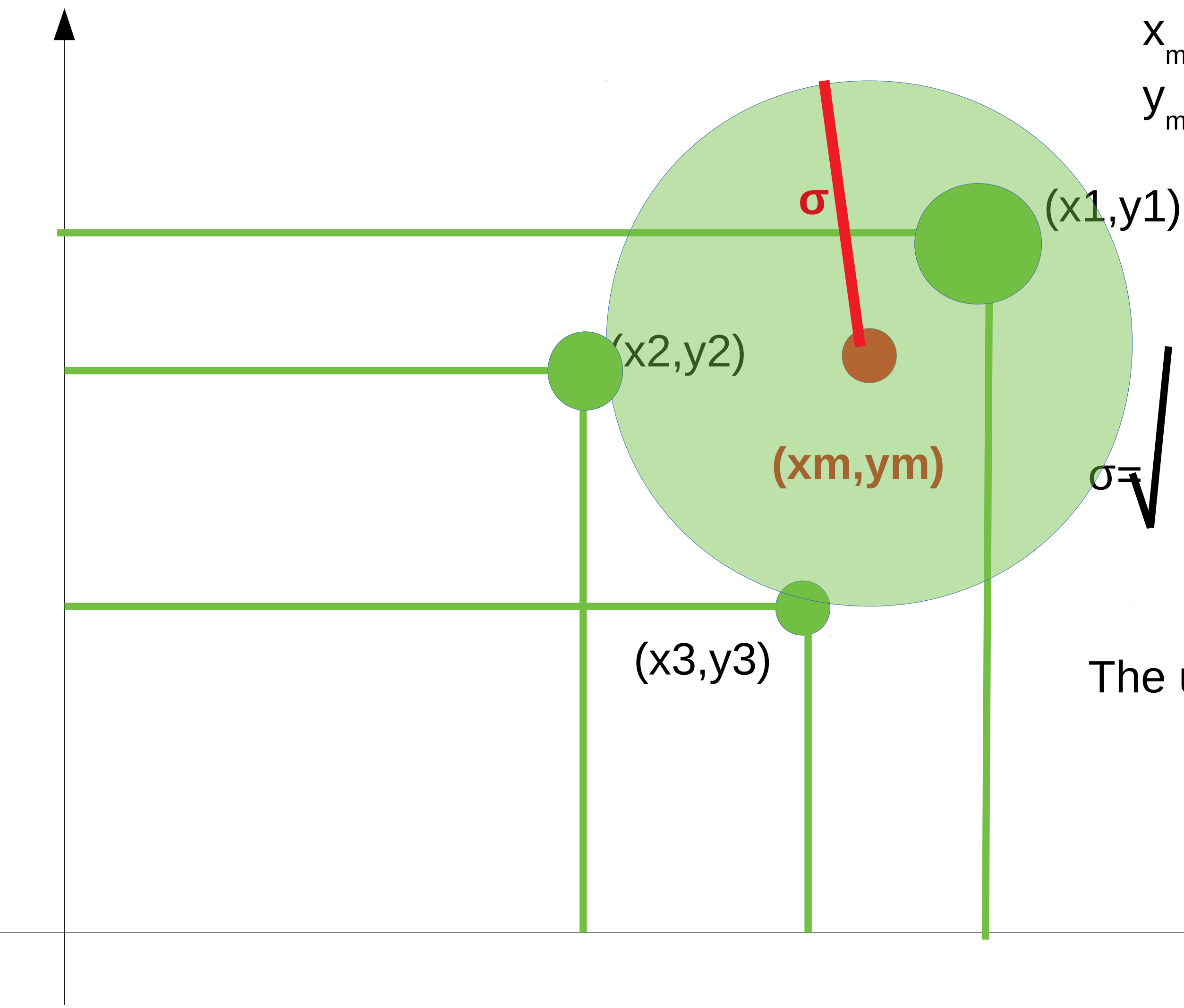
Insights

How to get a cluster: the path to a muon track

The center of the cluster can also be a weighted average

$$x_m=(w1x1+w2x2+w3x3)/3(w1+w2+w3)$$
$$y_m=(w1y1+w2y2+w3y3)/3(w1+w2+w3)$$

Where **wi** is the weight



$$\sigma=\sqrt{\frac{[w1(x1-xm)^2+w2(x2-xm)^2+w3(x3-xm)^2]}{(w1+w2+w3)(N-1)}}$$

The uncertainty is measured by a **weighted standard deviation** of the set of meaures

Insights

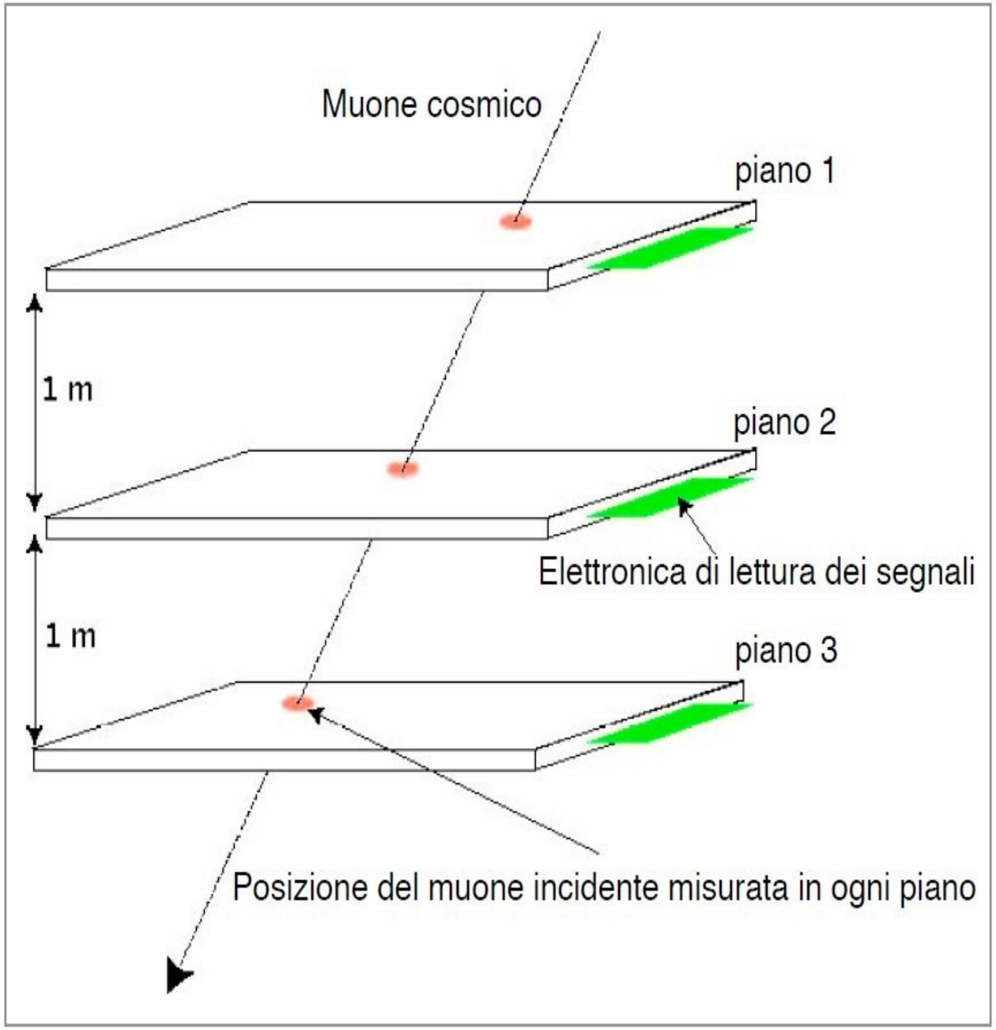
Two important parameters:
- the telescope efficiency
- the spurious coincidence rate

The efficiency is the Probabilty for a MRPC to detect a particle. On a high amount of particles travelling across a chamber the efficiency is

Eff =

N of particles detected

Number of particles actually travelled through the chamber



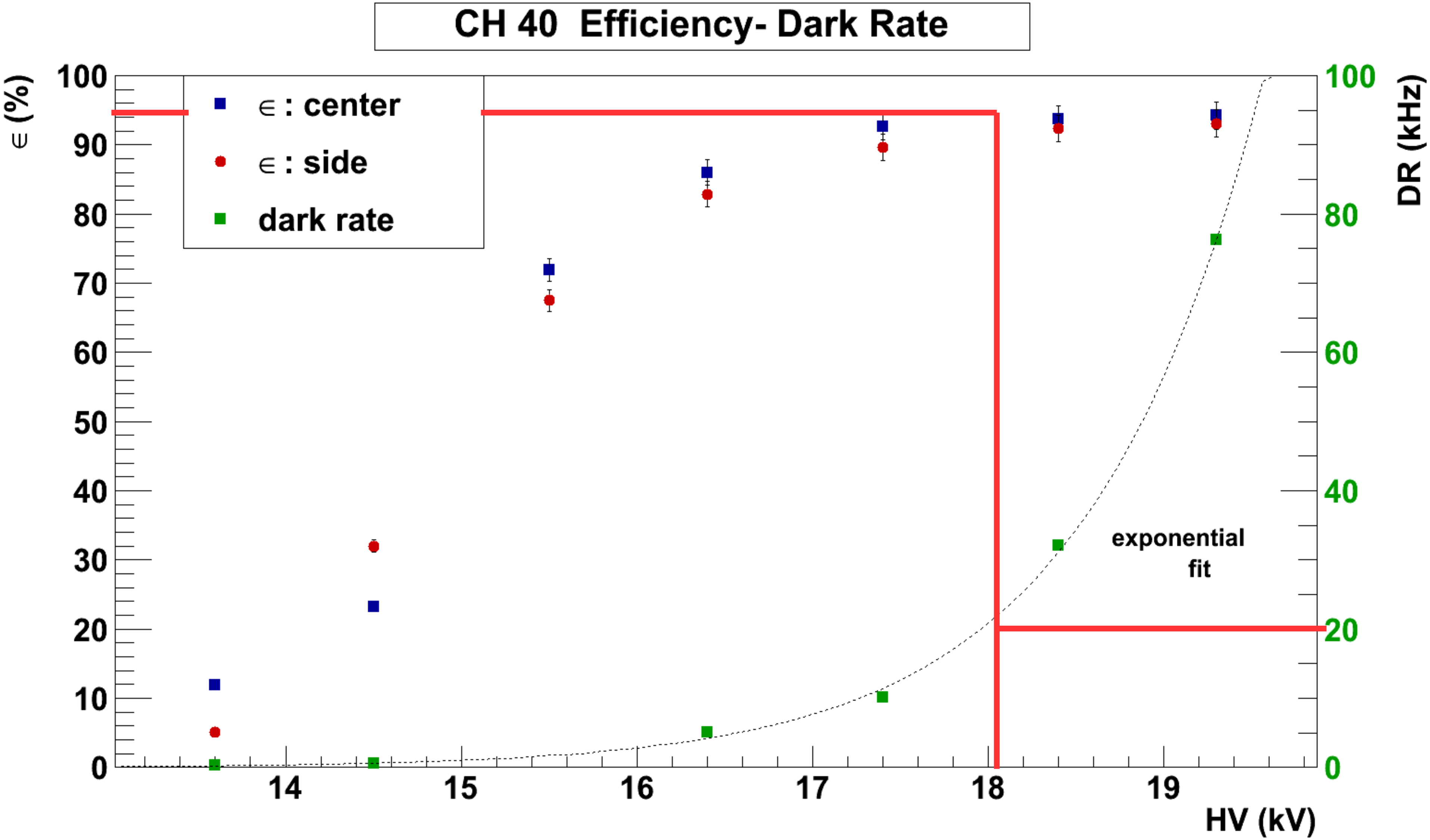
The **spurious rate** is the rate of signals seen by a MRPC (or a telescope) NOT CORRELATED with a real particle passing through the MRPC.

Insights

Dark Rate & Efficiency

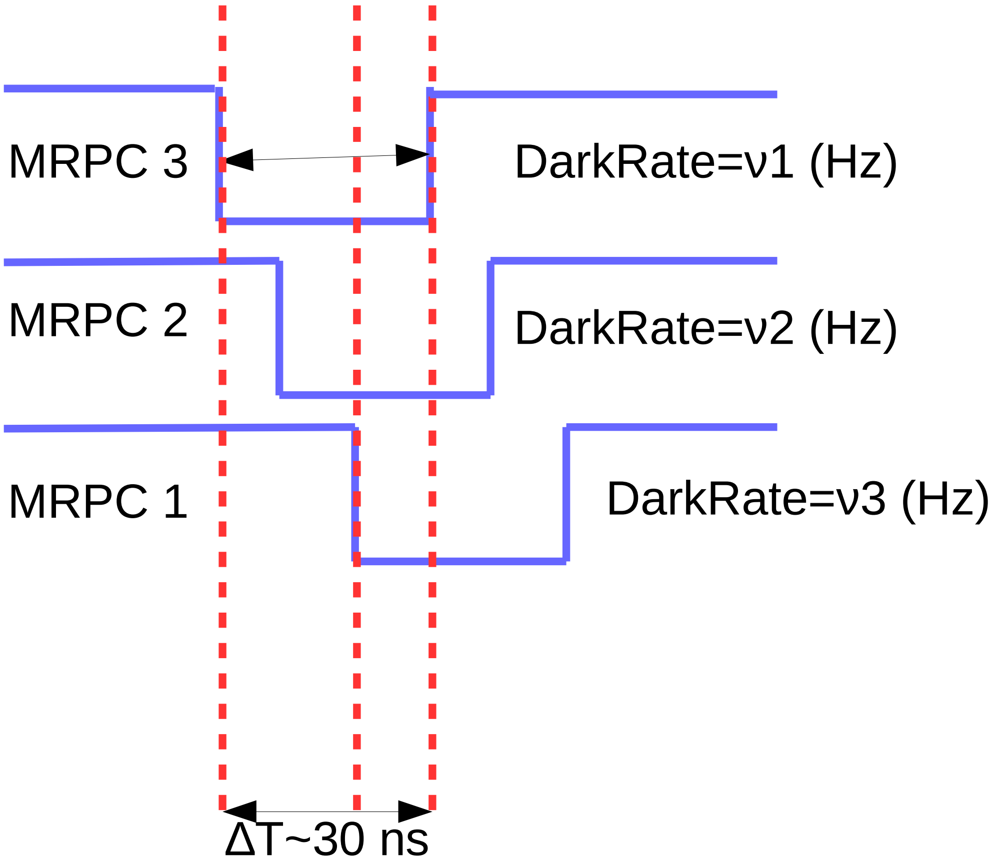
A telescope WORKING POINT:

- Efficiency
- Dark Rate (DR)



Insights

Dark Rate & Spurious



The time window keeps into account

- **Signal speed** along the strips (20 ns)
- **Time of Flight** between chambers

Spurious coincidences for a set of MRPC of a EEE telescope

P(A∩B)=P(A)P(B) non correlated

Spurios coincs in MRPC 2 in ΔT
$\nu 2 \cdot \Delta T$
Spurious coincs in MRPC 3 in ΔT
$\nu 3 \cdot \Delta T$

Spurious rate:

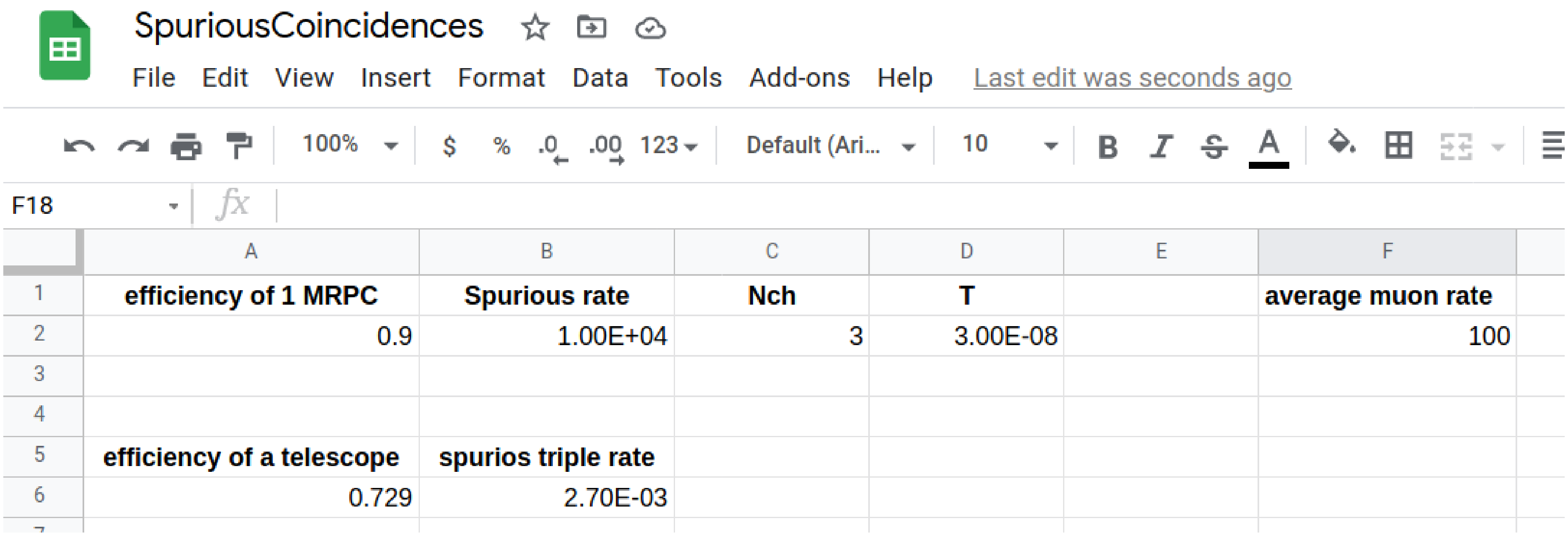
$\nu(\text{doubles}) = 2 \cdot (\nu 1 \cdot \Delta T) \cdot (\nu 2 \cdot \Delta T)/\Delta T = 2 \cdot \nu 1 \cdot \nu 2 \cdot \Delta T$

$\nu(\text{triples}) = 3 \cdot \nu 1 \cdot \nu 2 \cdot \nu 3 \cdot \Delta T^2 \sim 3 \cdot (2 \cdot 10^4 \text{ Hz})^3 \cdot (2 \cdot 10^{-8} \text{ s})^2 = \sim 10^{-2} \text{ Hz}$

Coincidences are fundamental tool to decrease the rate of spurious and allowing for the observation of real particles

Hands on!

Dark Rate & Spurious



	A	B	C	D	E	F
1	efficiency of 1 MRPC	Spurious rate	Nch	T		average muon rate
2	0.9	1.00E+04	3	3.00E-08		100
3						
4						
5	efficiency of a telescope	spurios triple rate				
6	0.729	2.70E-03				

Try to:

- evaluate the spurious telescope rate as a function of N chambers per telescope
- evaluate the efficiency of a telescope as a function of N chambers per telescope

- make plots showing this two quantitites vs N

- study the good track/false triggers over 1 year of data taking vs N

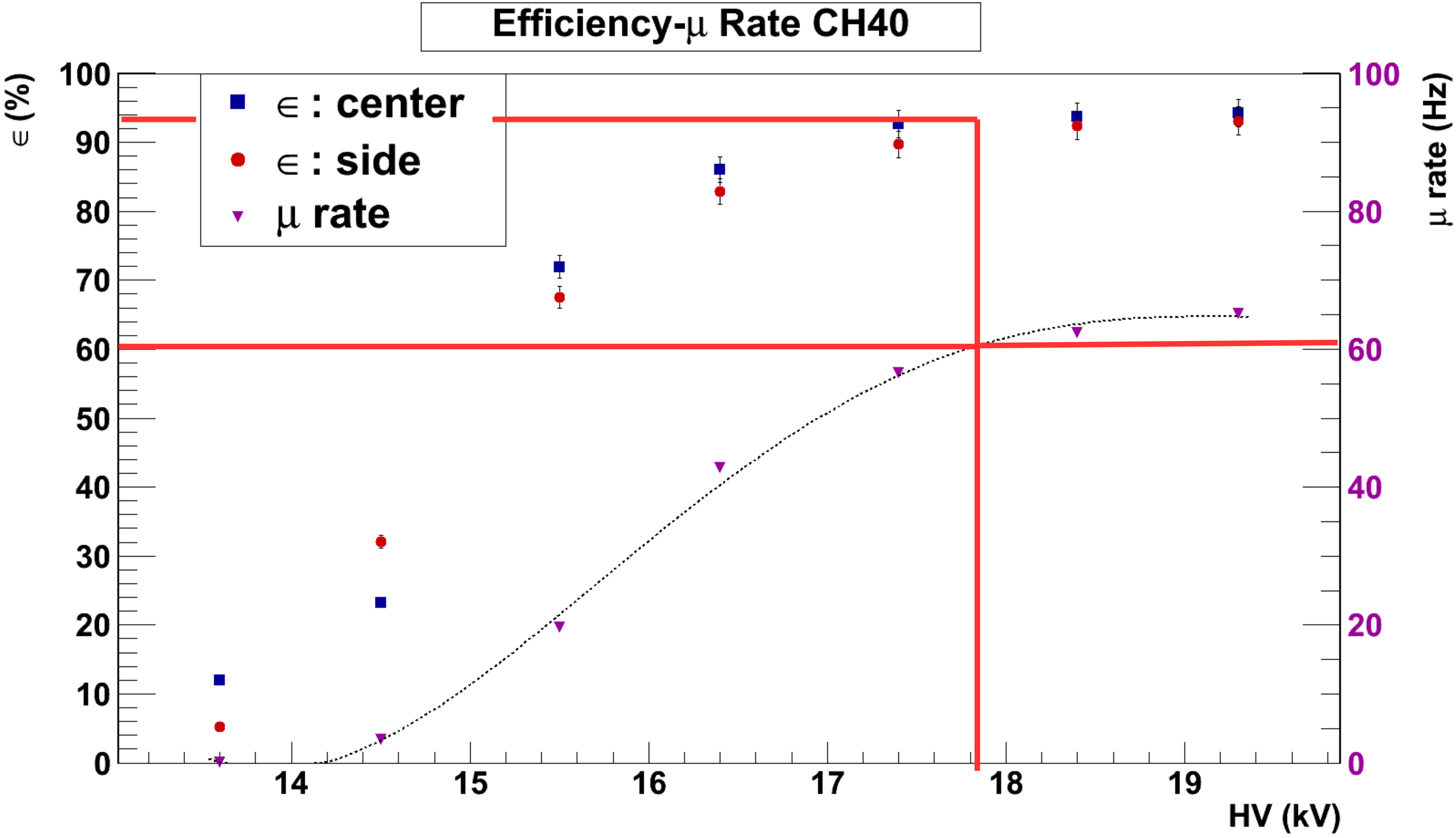
--------------------Define a proposal: which is the optimal number of MRPC for a telescope?

Insights

A telescope efficiency

A whole EEE telescope efficiency depends on the efficiency of the 3 MRPCs

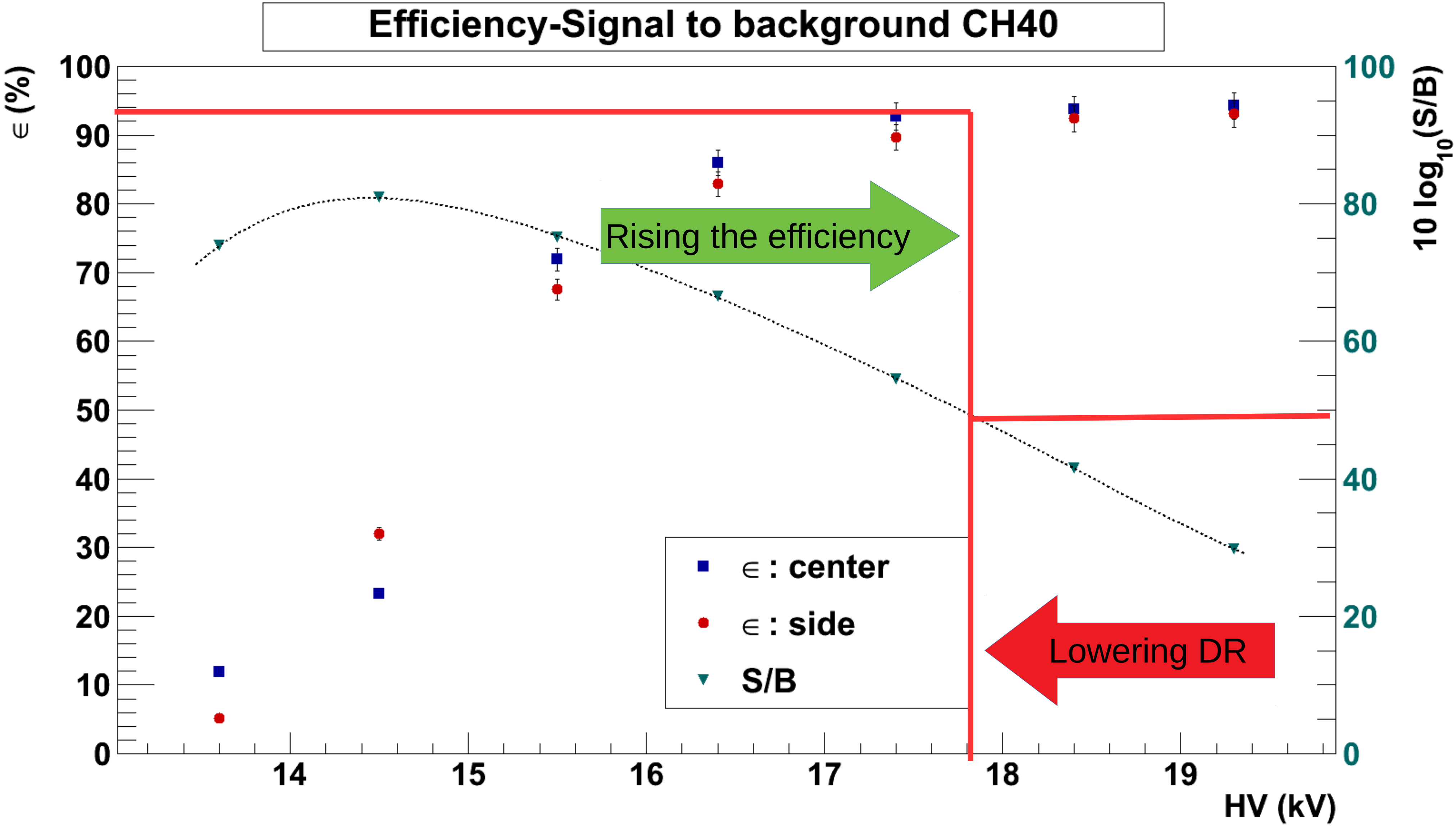
eff=effMRPC1 x effMRPC2 x effMRPC3



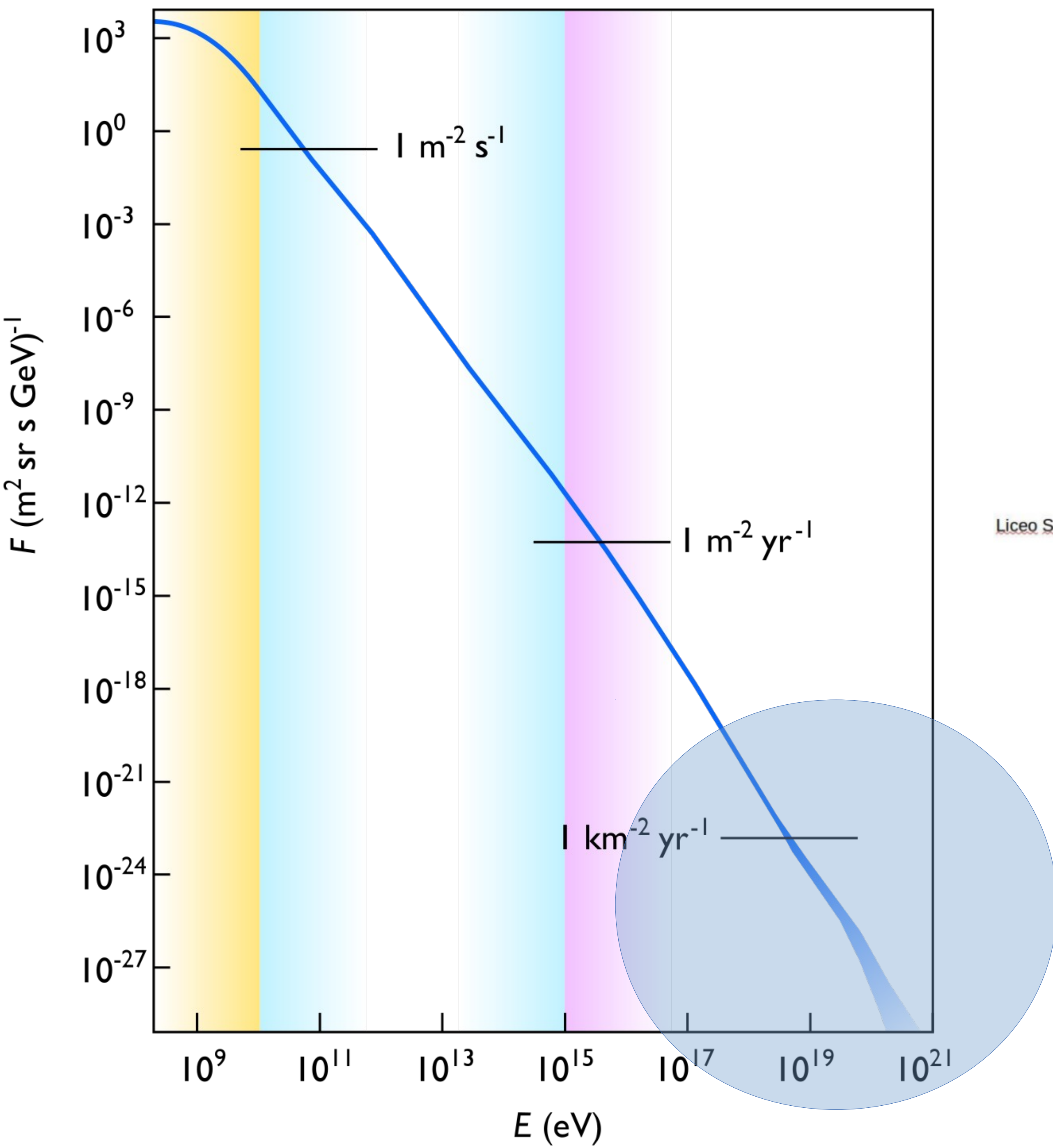
Insights

Dark Rate & Efficienza

The **best compromise** between spurious trigger and real particle triggers has to be found



Let's start to think what we need to come to a measurement of a shower and (possibly) to a discovery



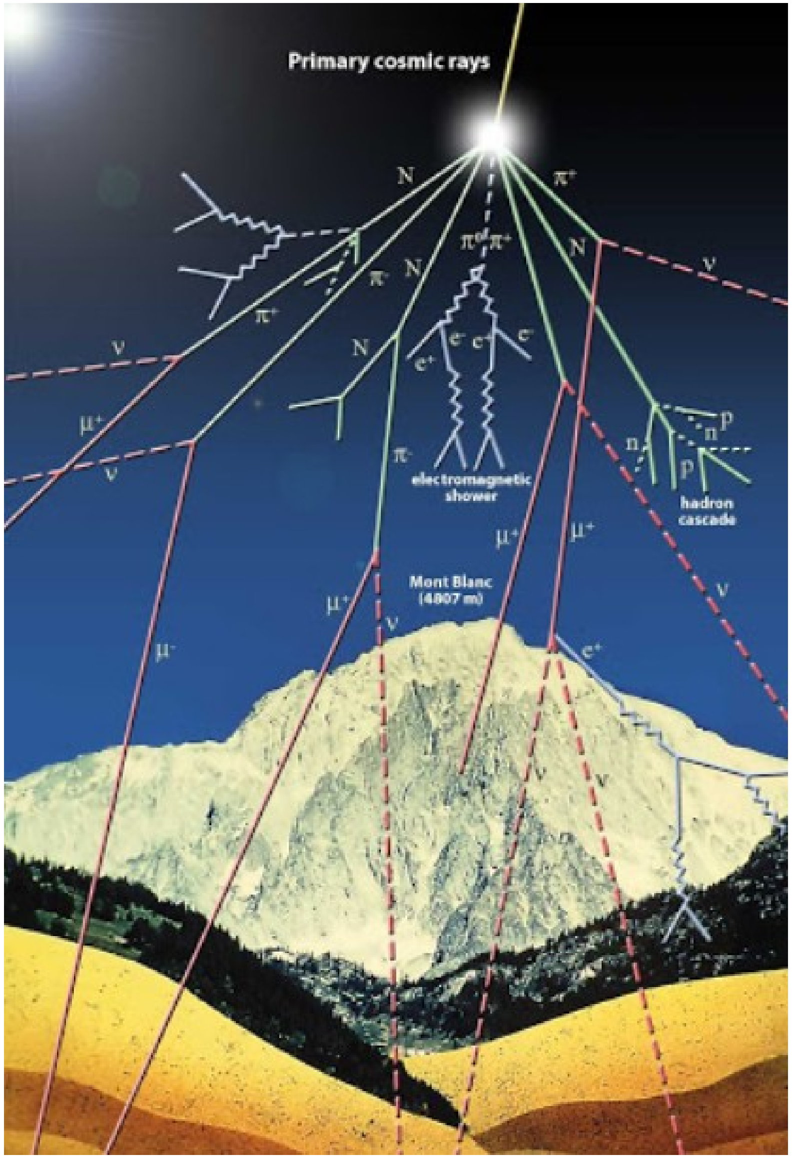
EEE expected rate at UHE

Tot ev / y =
$7.5 \pm 0.5_{stat} \pm 3.5_{syst}$

$10^{15} < E < 10^{20}$ eV

Insights

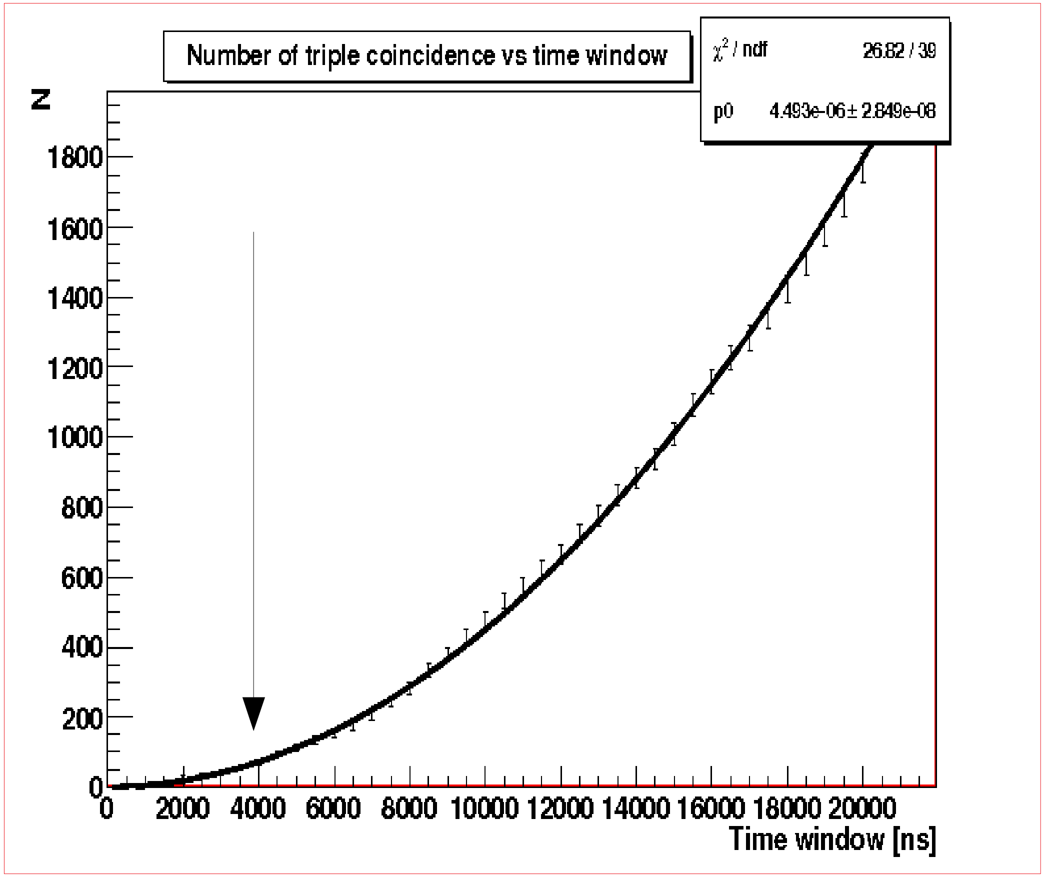
Spurious & Showers



The same approach can be used to understand the rate of coincidences between telescopes in a cluster

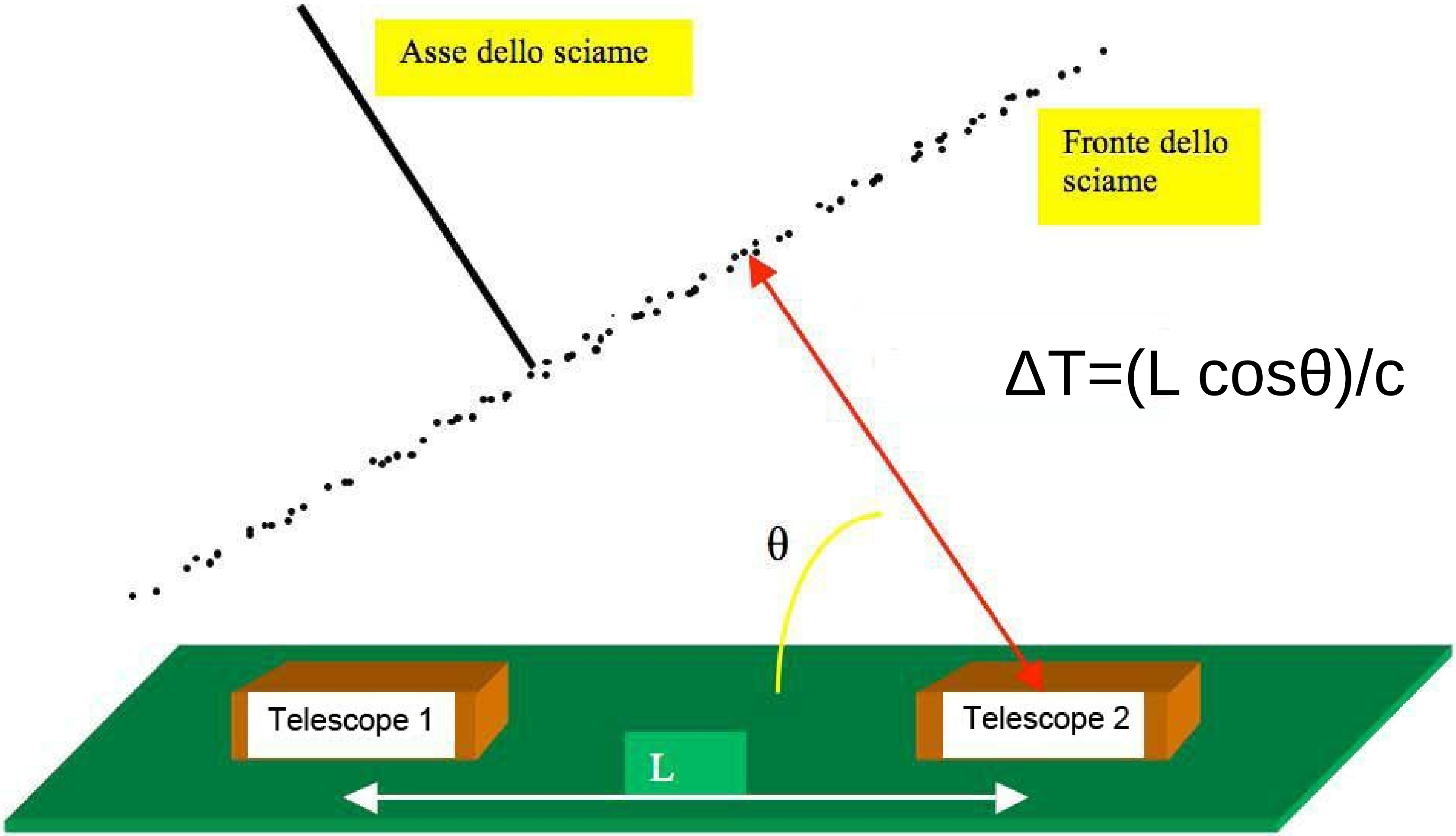
N(spurios showers) = $3\cdot\nu1\cdot\nu2\cdot\nu3\cdot\Delta T^2\cdot TDAQ\sim$
$=3\cdot(50\ Hz)^3\cdot(4\cdot10^{-6}\ s)^2\cdot3\cdot10^7 s=$
= 180 per year!

Things are more difficult than expected!



Hands on!

Showers timing



$$\Delta T = (L \cos\theta)/c$$

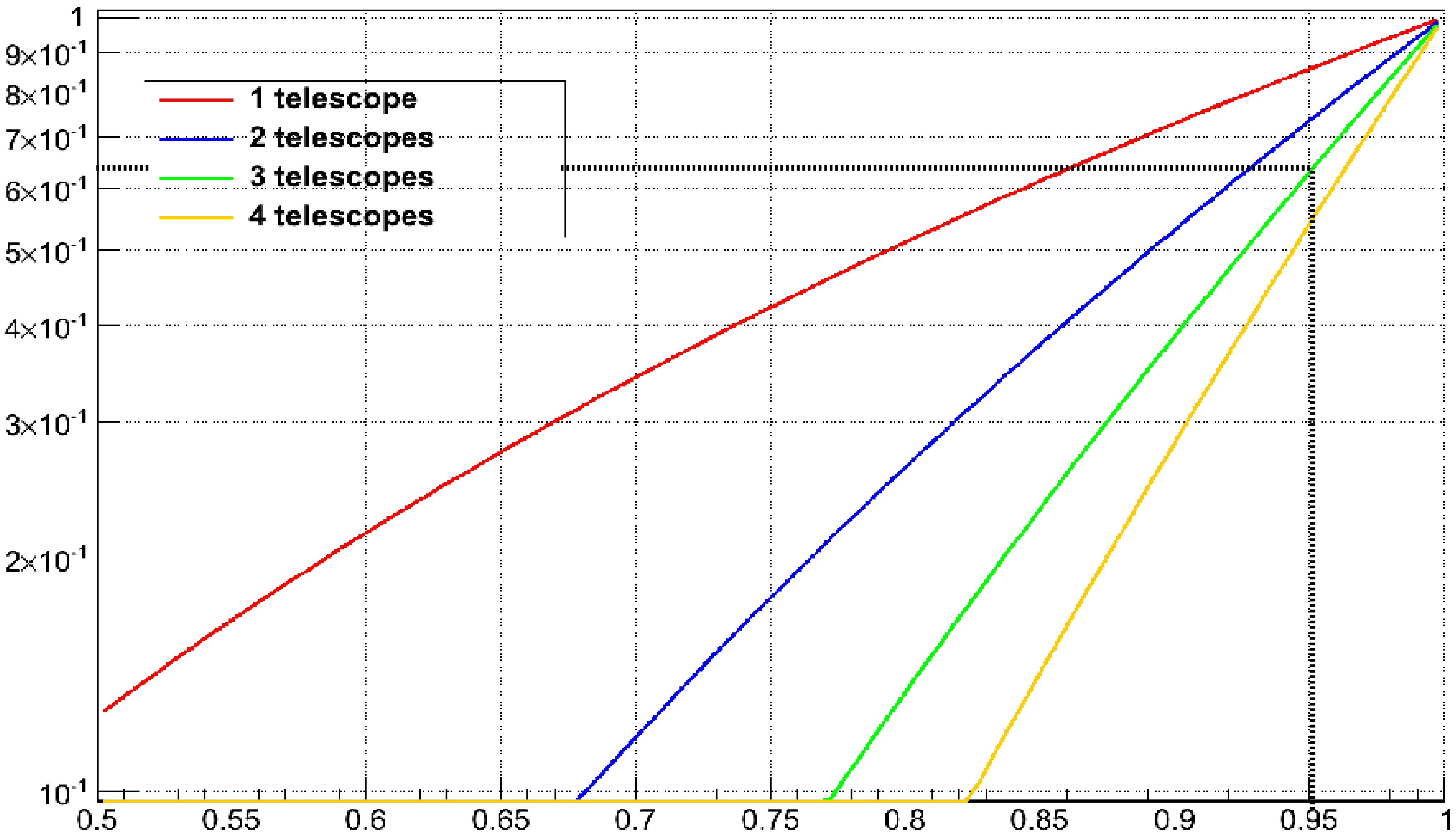
Can we decrease the time windows?
if yes, how?
How this decrease act on the spurious shower rate?

Insights

Telescope Cluster efficiency

A telescope cluster efficiency

eff=effTEL1 x effTEL2 x effTEL3



Hands on!

Spurious & Showers

Does not take into account the acceptance (next time topic!)

N telescopes per cluster	T	telescope rate
3	4.00E-06	72.9
efficiency of the cluster	**spurios shower rate**	
0.387420489	1.86E-05	

Try to:

- evaluate the spurious showers rate for N telescopes
- evaluate the efficiency of a cluster of N telescopes

- make plots showing this two quantitites vs N

- evaluate the spurious showers over 1 year
- discuss the limits to the discovery of high energy showers (rare ones)

- discuss the coincidence time T

- is there any approach to decrease the time window T?

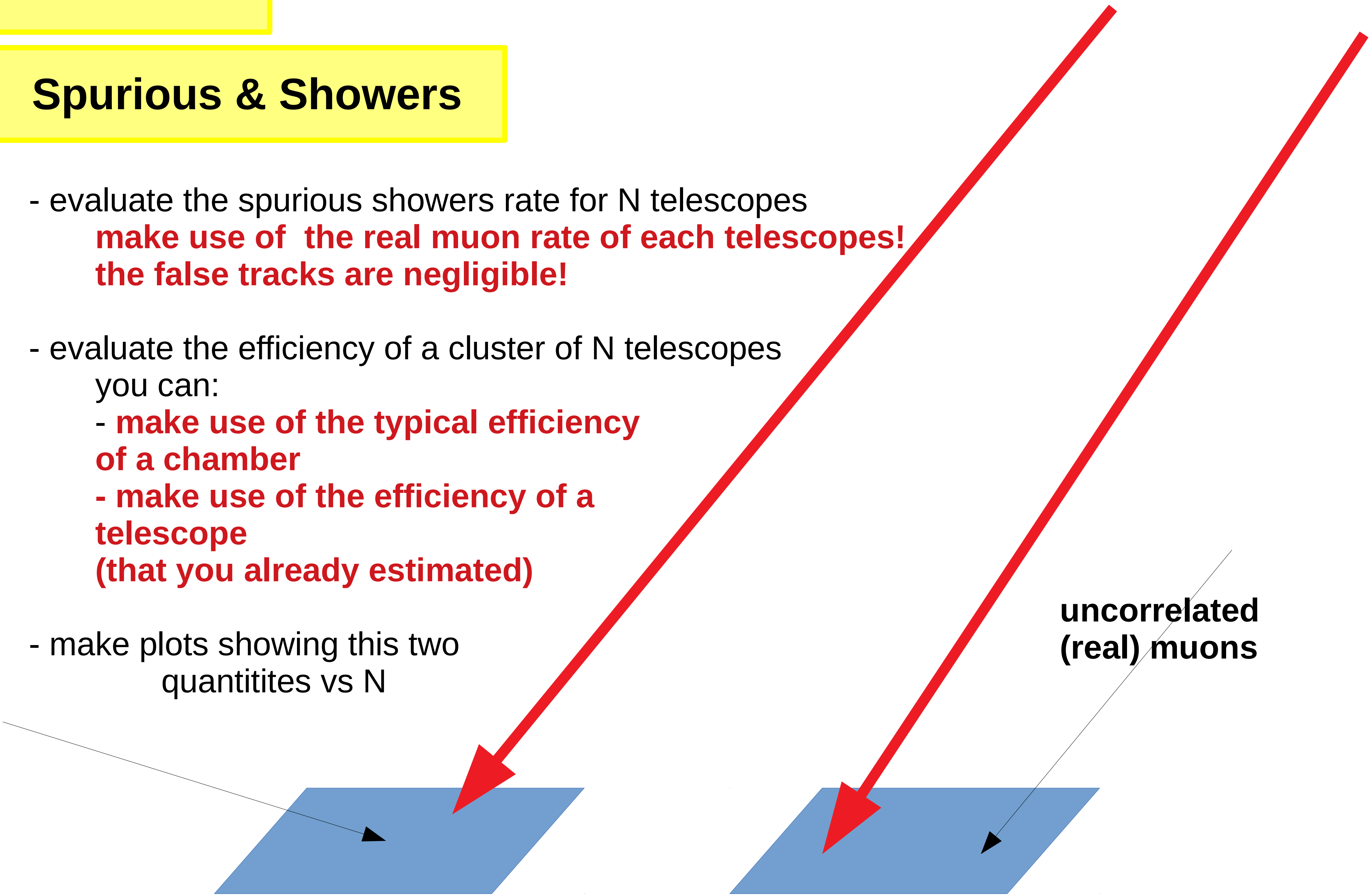
Hands on!

Spurious & Showers

- evaluate the spurious showers rate for N telescopes
  make use of the real muon rate of each telescopes!
  the false tracks are negligible!

- evaluate the efficiency of a cluster of N telescopes
  you can:
  - **make use of the typical efficiency of a chamber**
  - **make use of the efficiency of a telescope (that you already estimated)**

- make plots showing this two quantitites vs N



Hands on!

Spurious & Showers

- evaluate the spurious shower over 1 year
- compare it with the expected number of real showers at high energy

are the spurios showers negligible with respect to the real high energy ones?

- discuss the limits to the discovery of high energy showers (rare ones)

The ratio between the spurious and the real is not depending on the same parameters!

N_real = Real HECR rate x Exposure Time

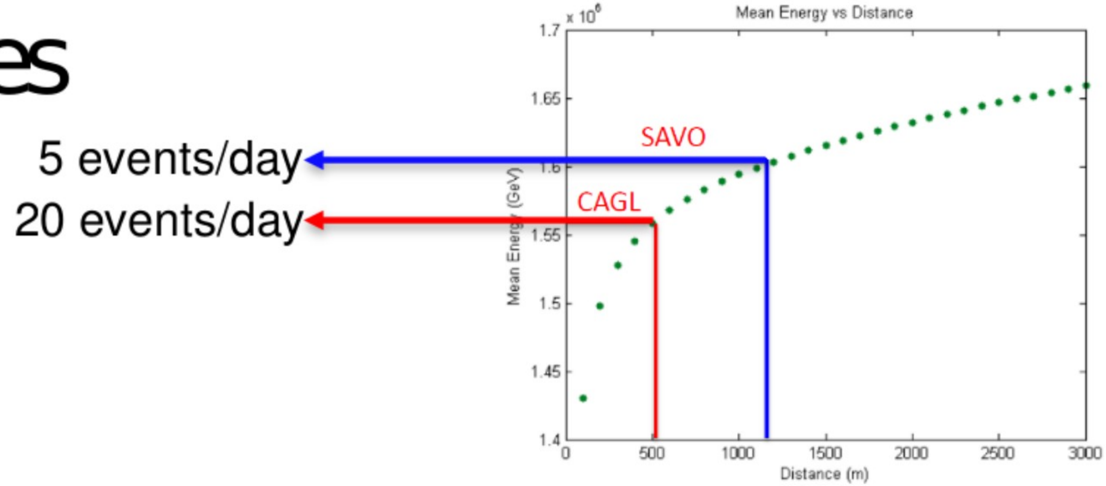
N_spurious =
N_tel x (Muon rate per telescope)$^{N\_tel-1}$ x Coincidence Windows x Exposure Time

At first order the Exposure Time do not play a role in defining the ratio between the real and spurious events (it plays an important role giving statistical significance to the observation, we'll see it in future)

Thus we have to play with the Coincidence Windows?

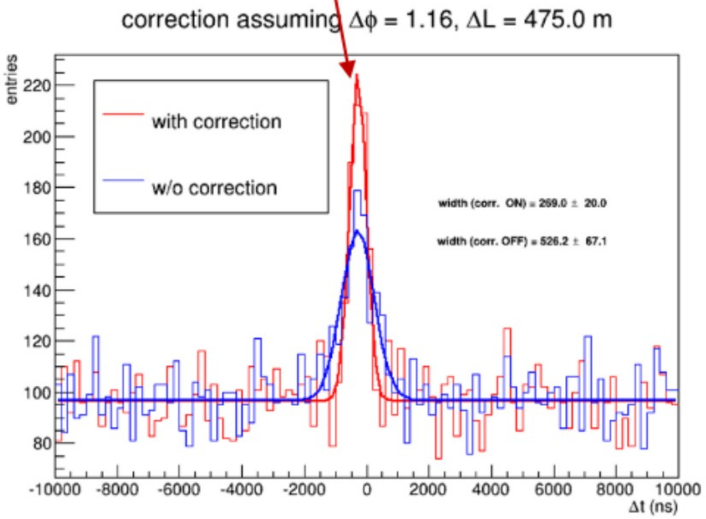
Multi-telescope analyses

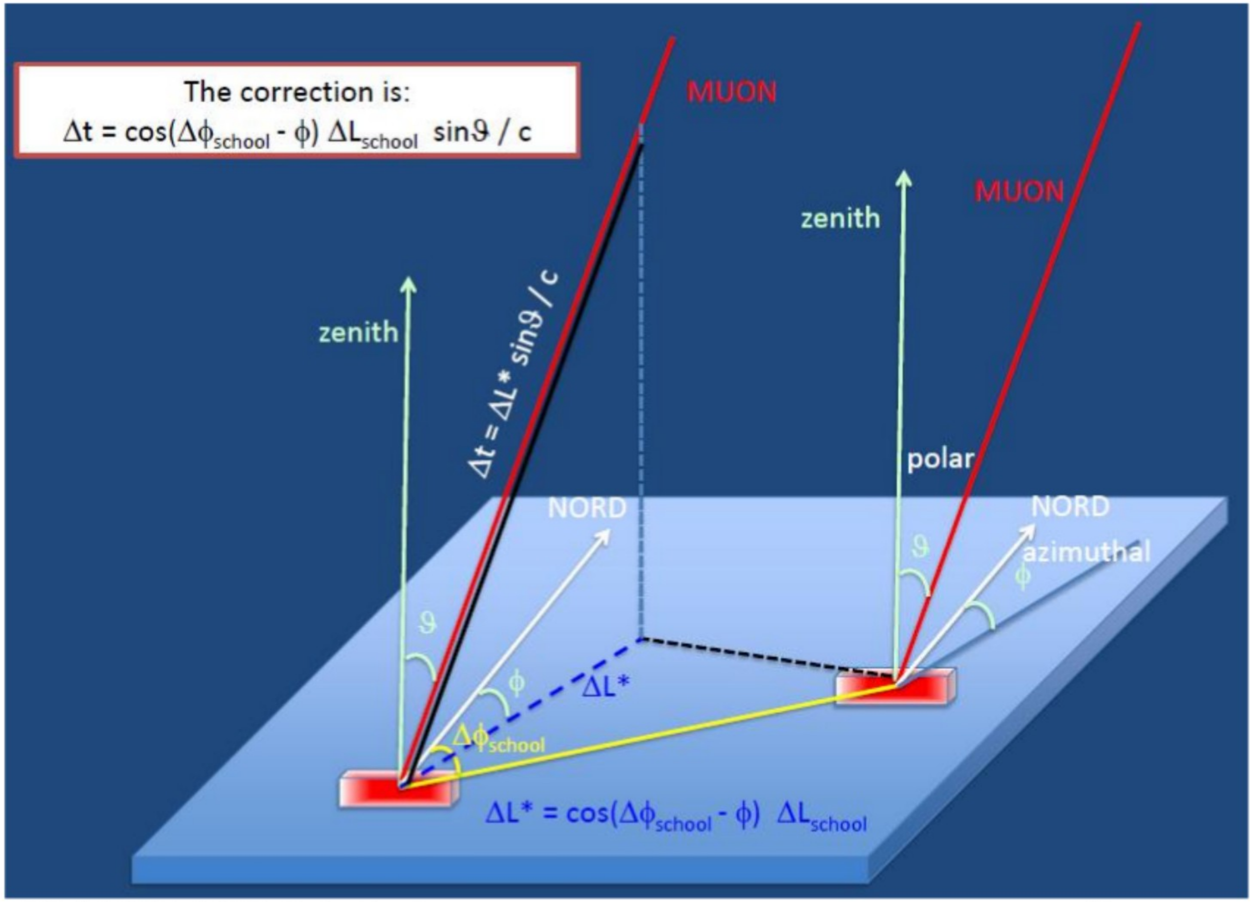
Corsika MC simulations



Multi-telescope analyses allow to select high-energy cosmic rays.

Muon tracking allows to reconstruct the direction of the wave front of the shower and then to correct for time delays.





Hands on!

Spurious & Showers

- discuss the coincidence time coincidence window

- plot
  - the real/spurios vs the time coincidence windows

Is there a limit to the improvement?

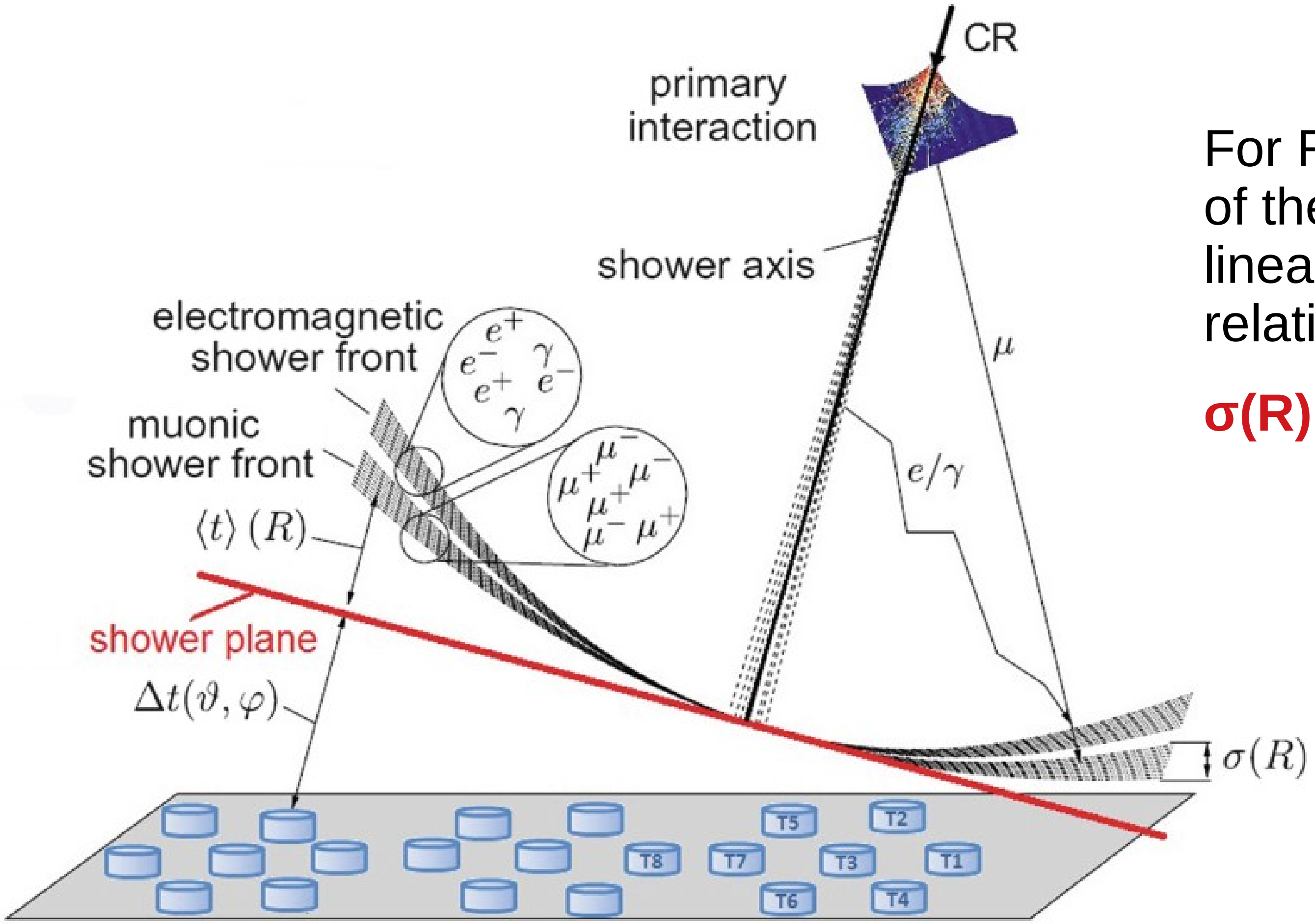
- Are we able to measure the time with infinite accuracy?
  - **physics of signal propagation and yield inside the detector (200 ps)**
  - **Time to Digital Converters accuracy (100 ps → 25 ps)**
  - **GPS time accuracy (nowadays can go down to few ns)**

  - an important source of time uncertainty is the **thickness of the shower disc**

Hands on!

Spurious & Showers

- an important source of time uncertainty is the **thickness of the shower disc**



For R < 400 m, the thickness of the EM shower increases linearly according to the relation

σ(R) [ns] ≃ 0.2R (R in [m])