International Workshop on a

Very Large Volume Neutrino Telescope for the Mediterranean Sea

VLVnT08

Toulon, Var, France, 22-24 April 2008

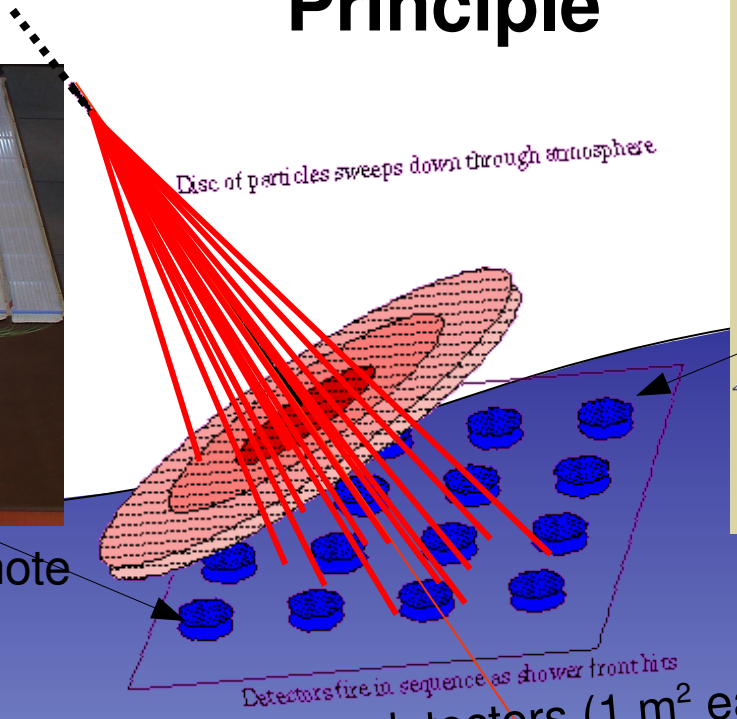
Study of the calibration potential of HELYCON detectors with ANTARES

G. Bourlis, J-P. Ernenwein*, A. Leisos, A. Tsirigotis, S. Tzamarias

* For the ANTARES collaboration

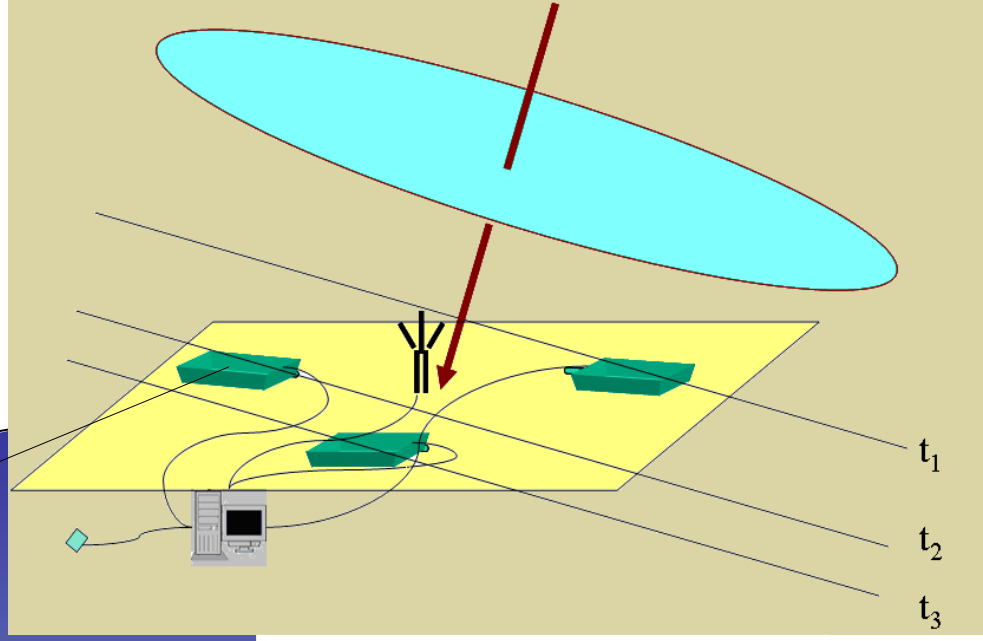
Principle

KM3NeT internal note



Set of Helycon detectors (1 m^2 each)

Atmospheric Muon(s)



Triangulation→ ShowerDirection

Stored on disk with GPS timestamp (< 1µs)

Principle

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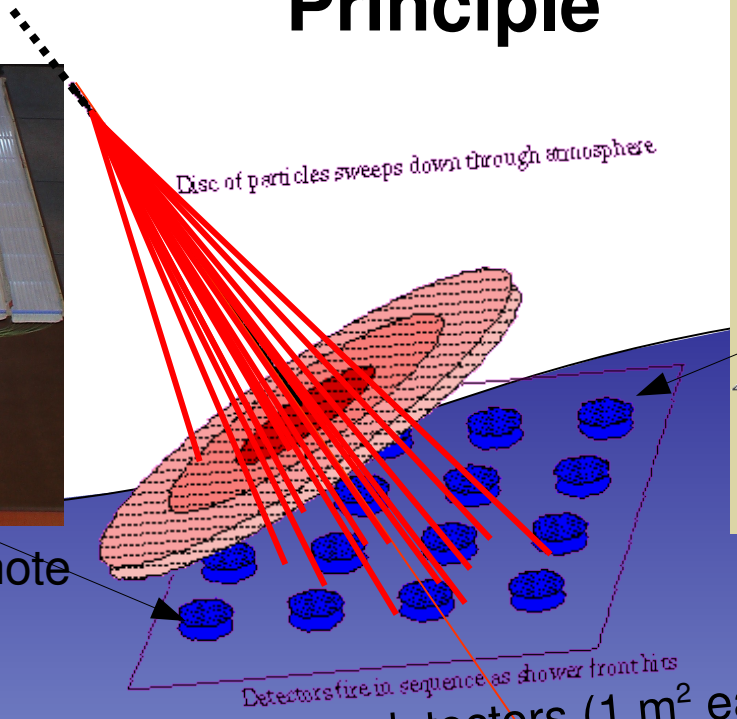

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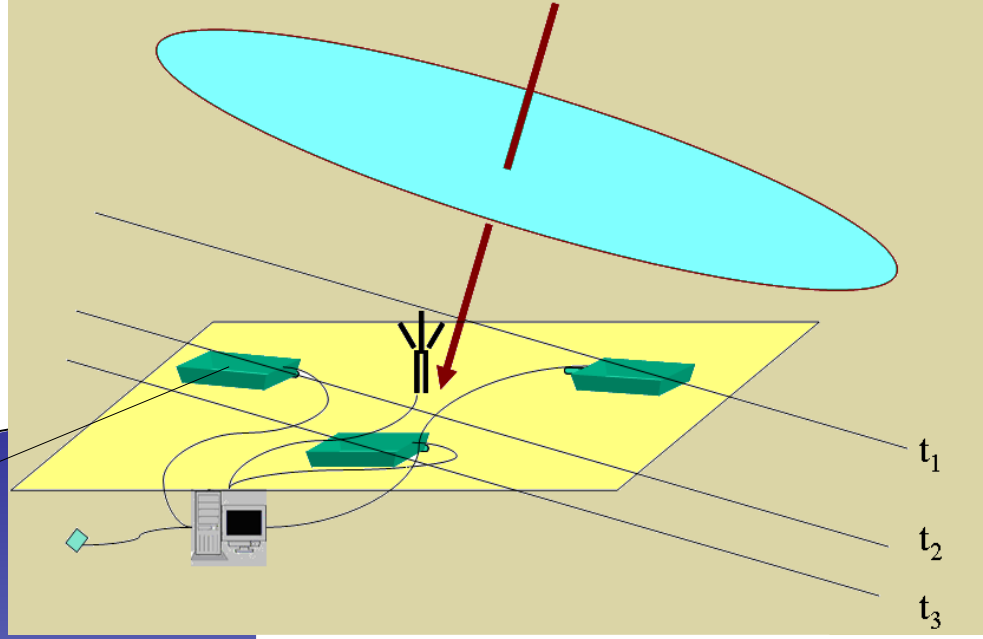

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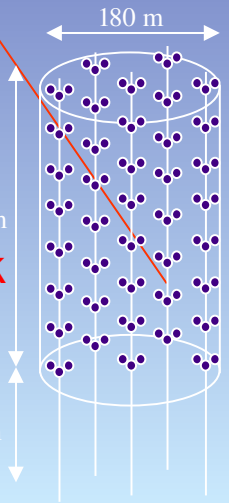


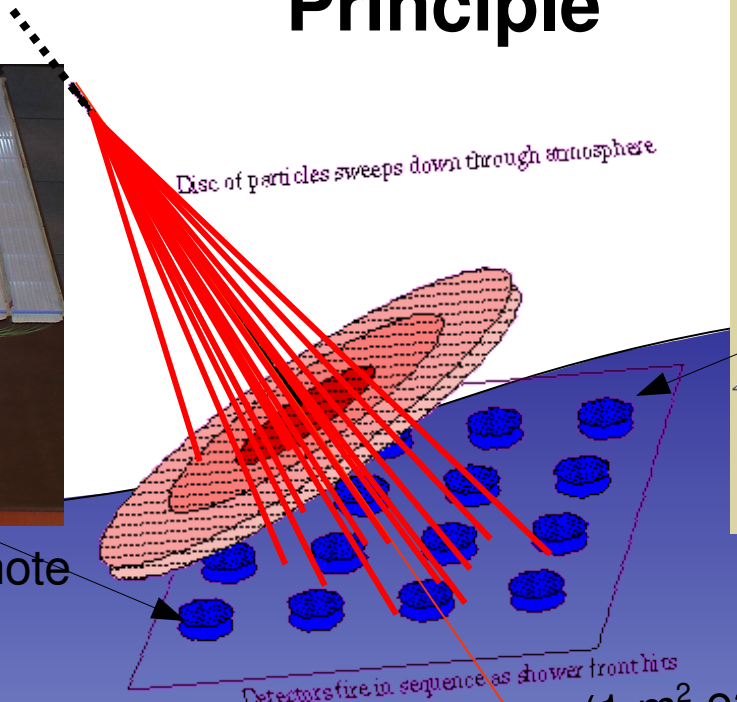
Reconstructed track

ANTARES
Events stored on disk with GPS timestamp (1 µs)

Matching in time and direction

Principle

KM3NeT internal note



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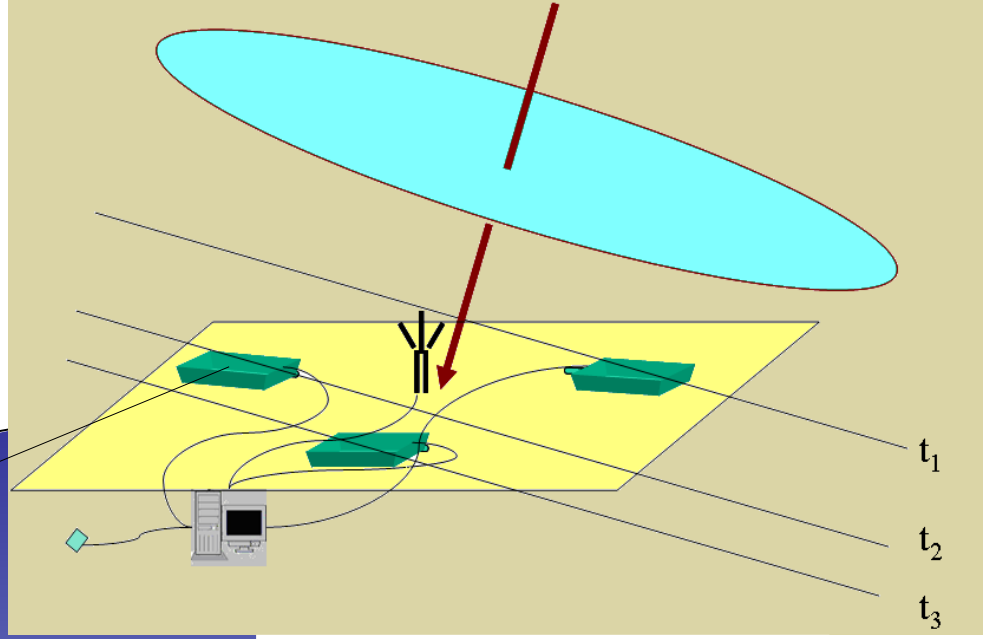

Triangulation→ ShowerDirection

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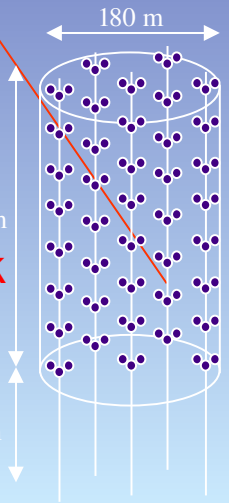
Atmospheric Muon(s)



Reconstructed track

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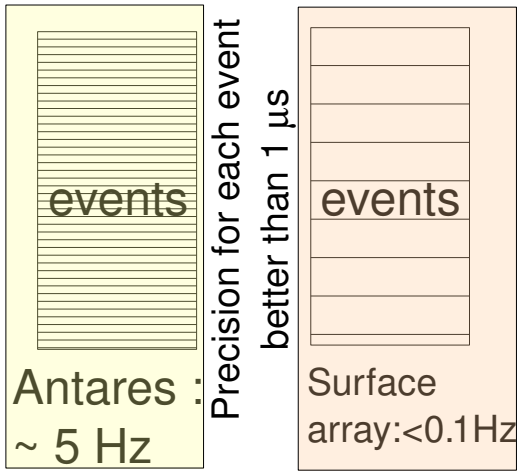
Matching in time and direction

Time matching



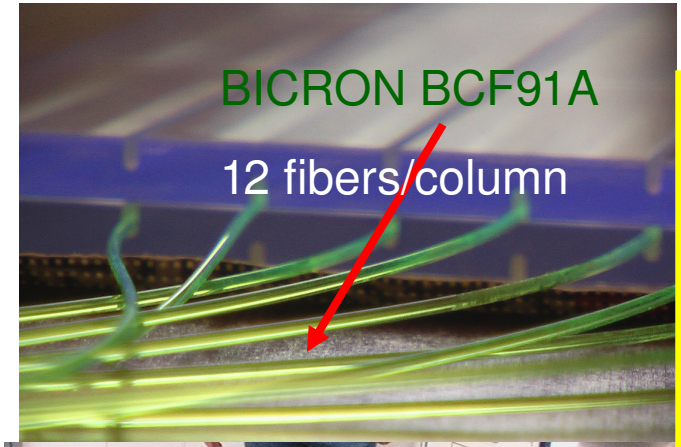
Possibility to match events a posteriori (using also directions)

HELYCON detectors (from S Tzamarias talk, HEP2008, 0lympia, April 19th)

TYVEC 4650B

10 x 12 cm tiles

2x80 tiles ~ 0.96 m²

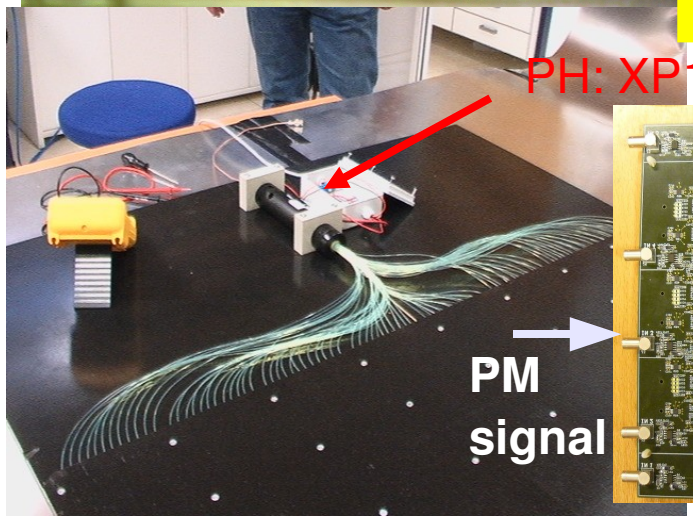


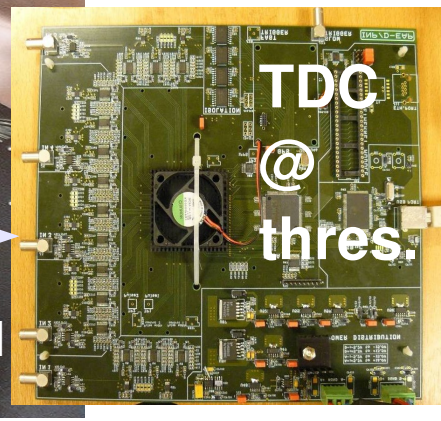
@ “nominal” H.V.

gain: ~ 4 10^5

0.07pCb / pe

1.05mV / pe





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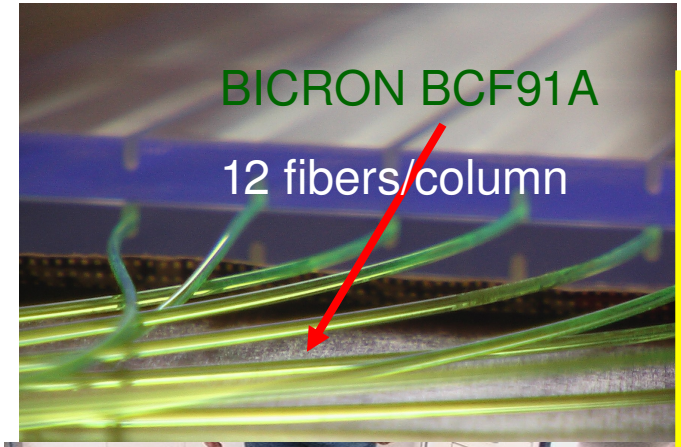

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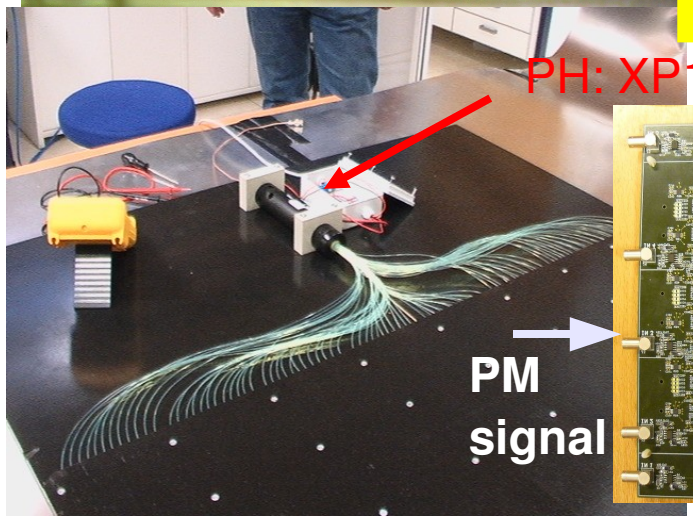
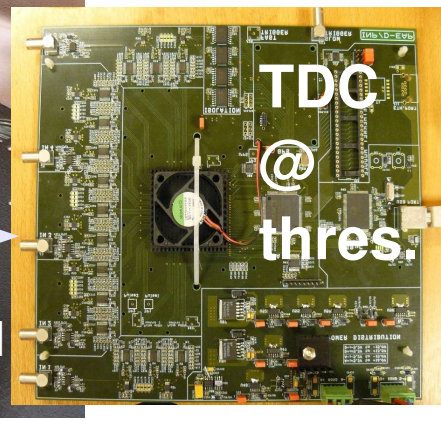
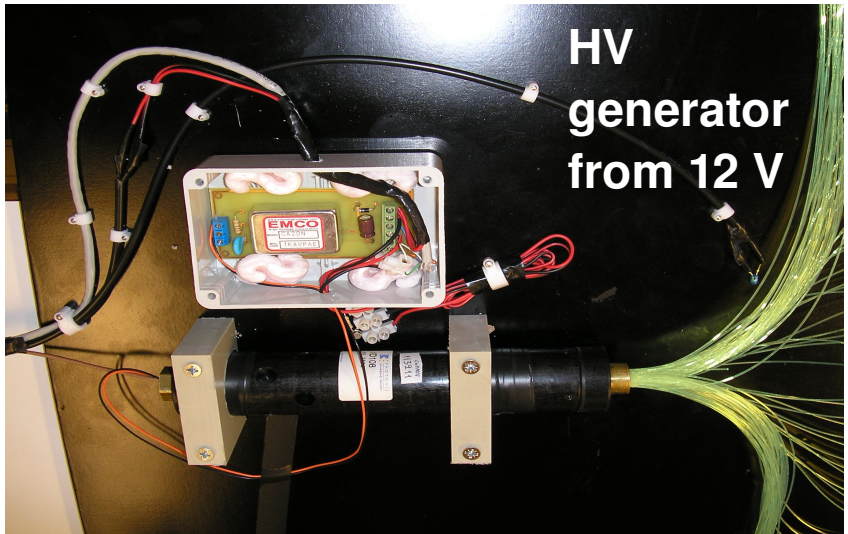
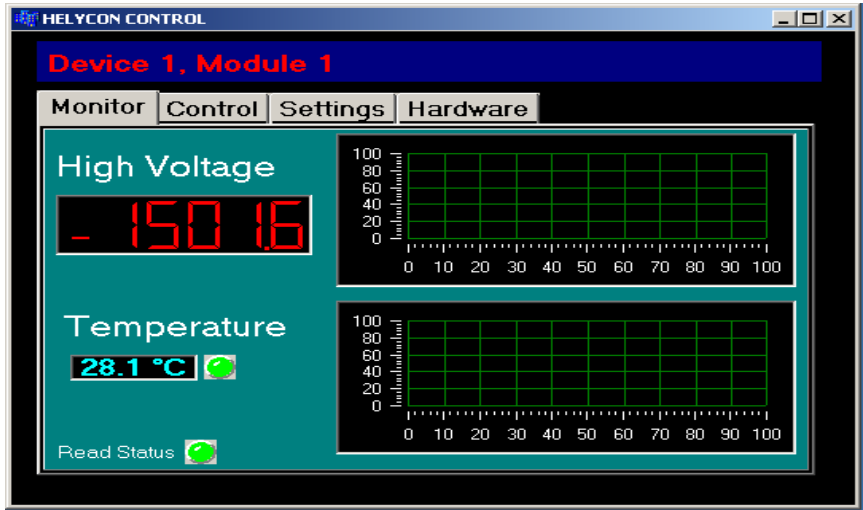






Slow Control through:

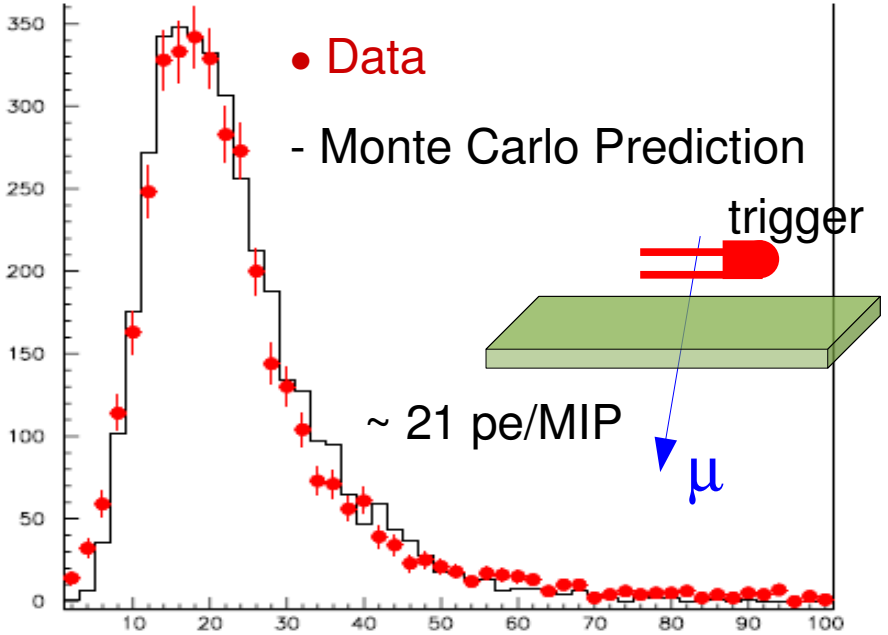
NI USB 6008



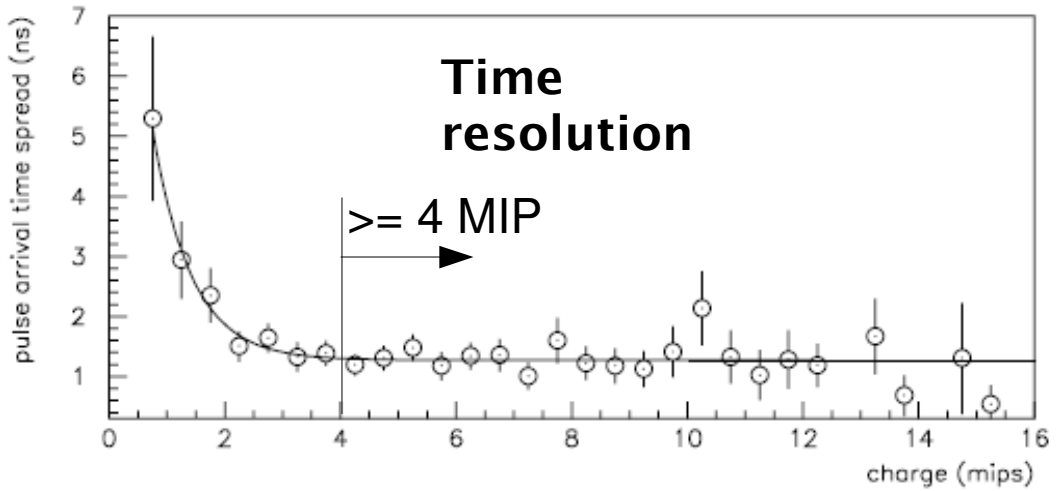
HELYCON detectors (from S Tzamarias talk, HEP2008, 0lympia, April 19th)

Cosmic μ test bench :

deposited charge at the detector center:



Charge (in units of mean p.e. charge)



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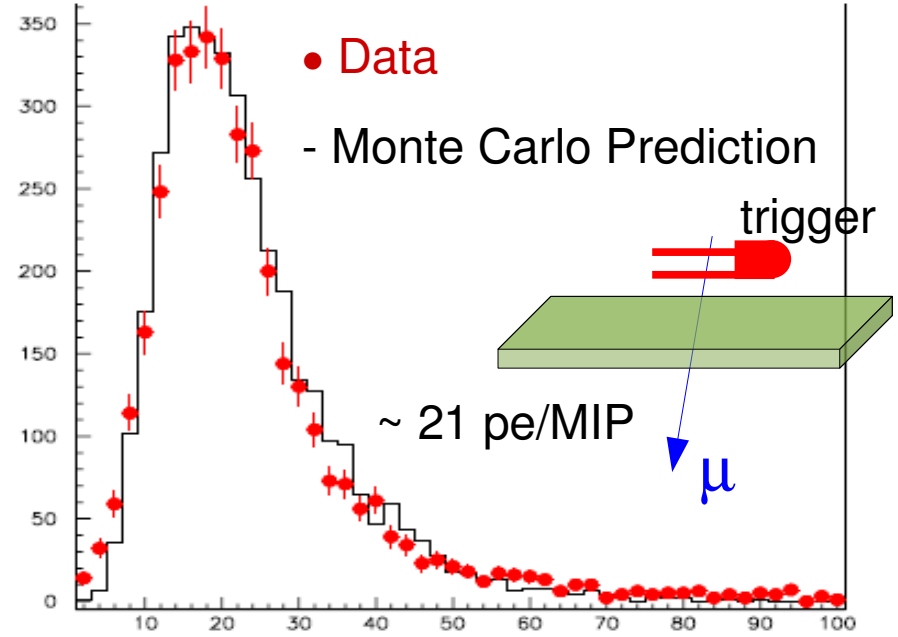
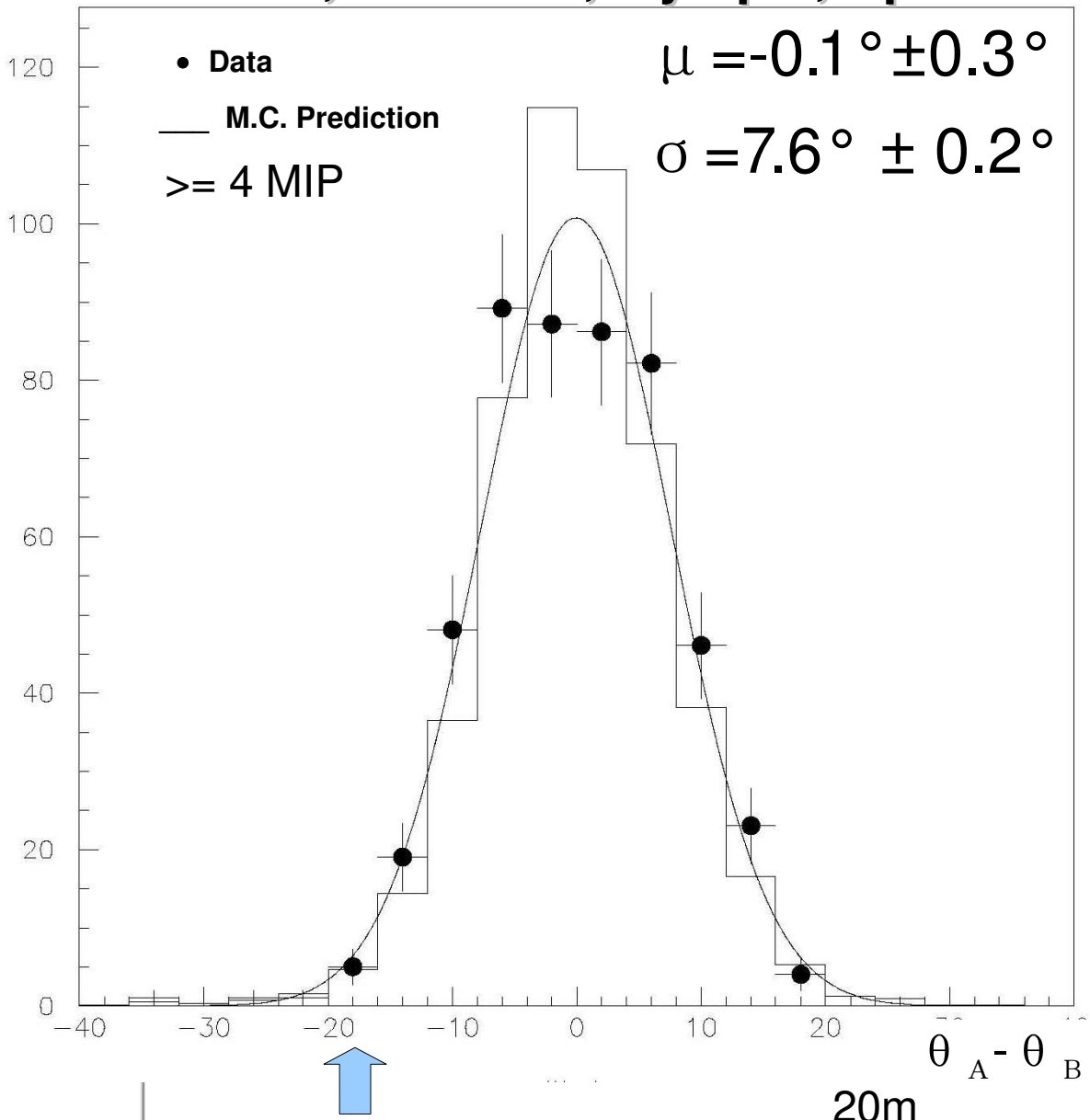
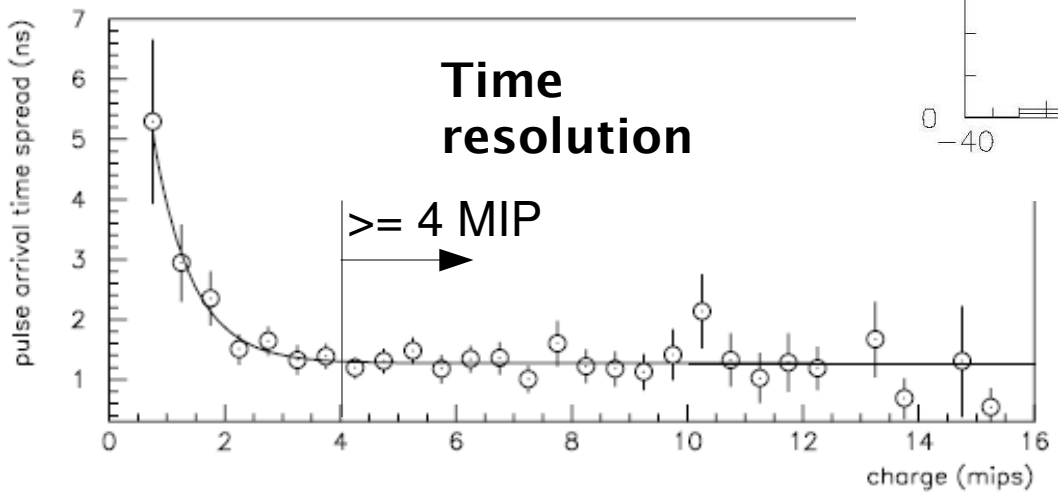
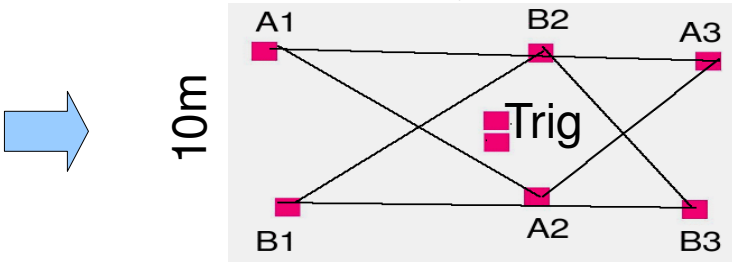






Test in the lab



Questions :

- Which parameters of ANTARES can we access
  - Zenith Offset ?
  - Absolute Position ?
  - Zenith Resolution (for down-going tracks) ?

- How many Helycon detectors are needed and with which lever arm ?

- How much time is required to accumulate enough statistics (linked to the previous point) ?

To try to answer :

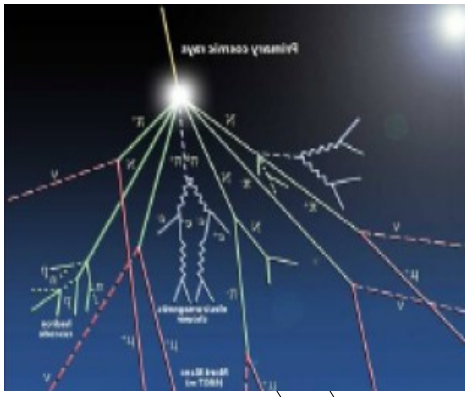
MC simulations of shower detection with HELYCON detectors (AT)

simulation of the detection with 12 lines ANTARES (JPE).

Then : event by event comparison of :

zenith, azimuth, position of reconstructed impact at sea level.

Estimate of the event rate.



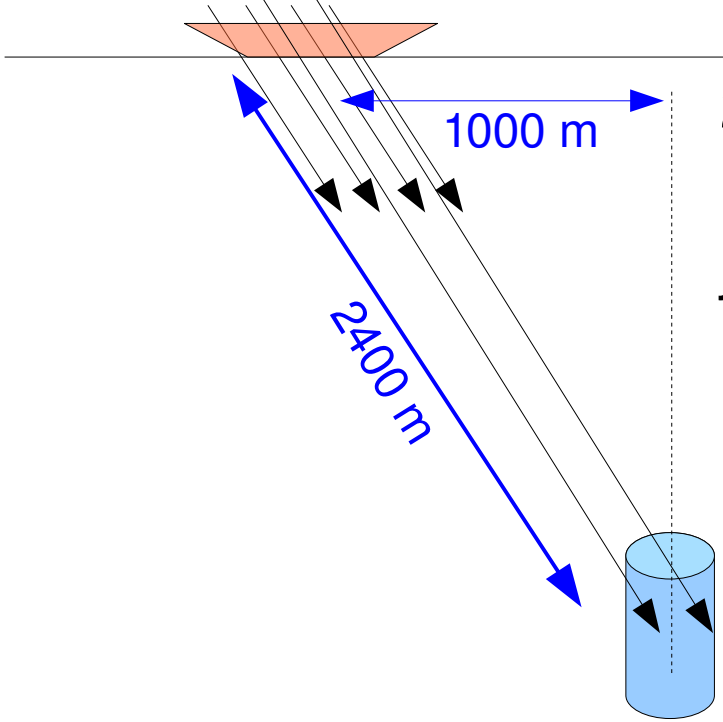
Corsika shower simulation :

protons with E in [10^5,5.10^6] GeV

5 or 8 days equivalent (55 10^4 showers / day).

Generation area = 100 m radius disk

Reconstruction based on Δt from a least 3 scintillators requiring 4 MIPs of threshold for each (angular resolution better than 1.5° -median- for setups with ~10 detectors) : ~3 rec evts / min.



2 tested distances :

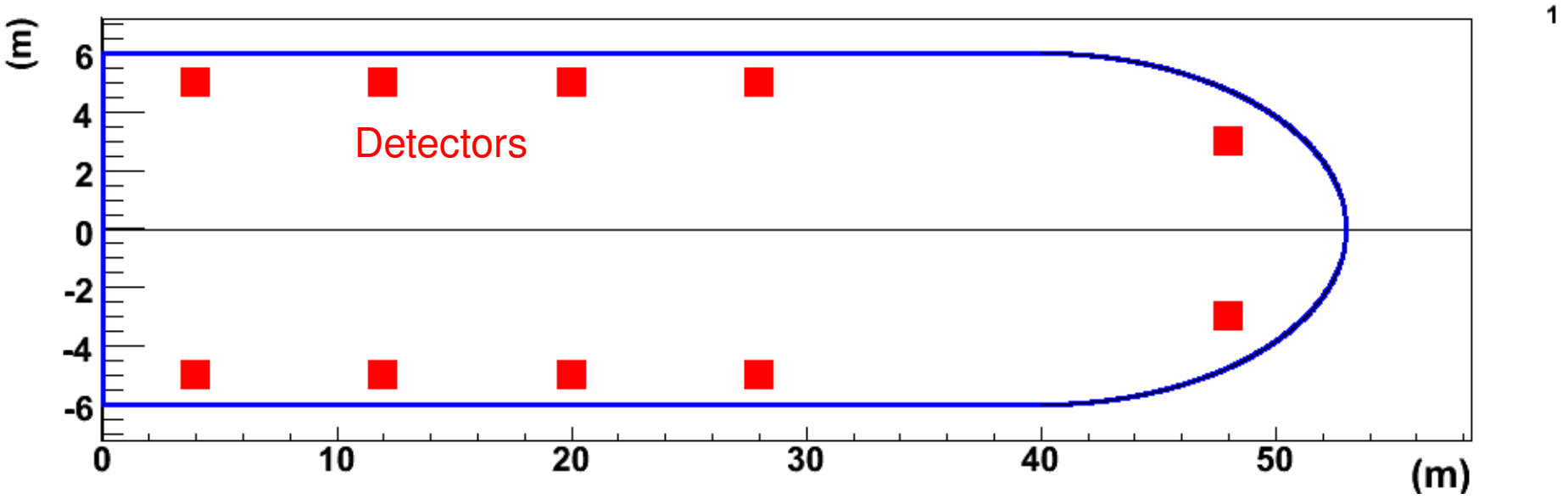
just above ANTARES (0m)

1 km apart (1000m, zenith ~ 24°)

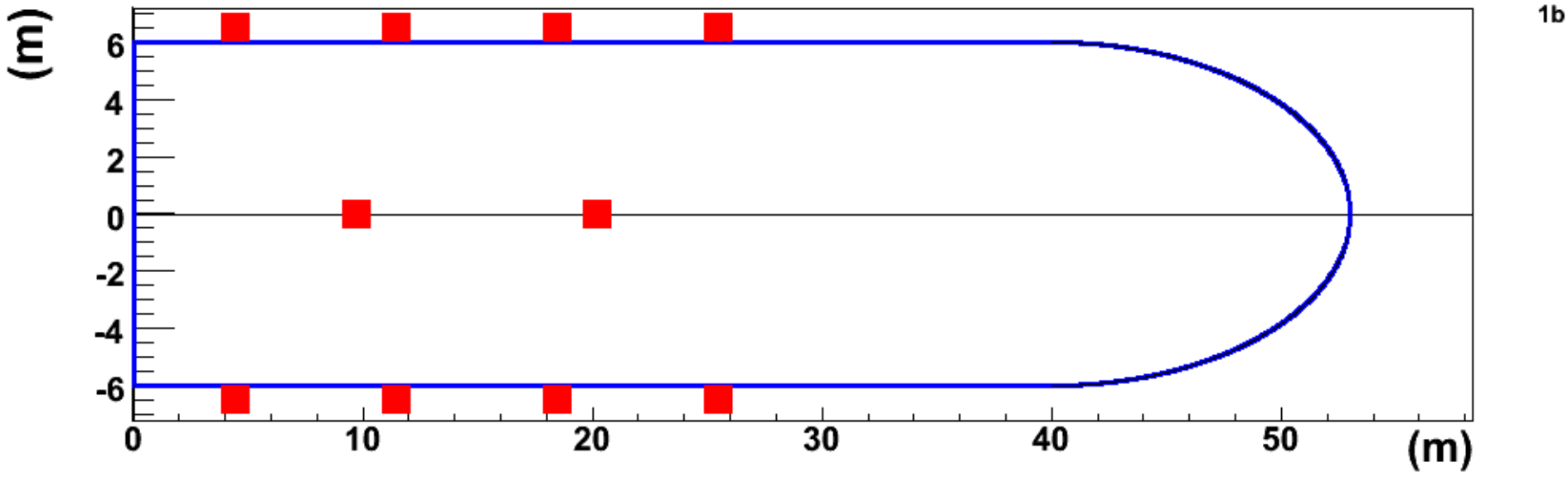
The castor :
boat used for ANTARES lines deployment

4 tested setups compatibles with the CASTOR boat ...

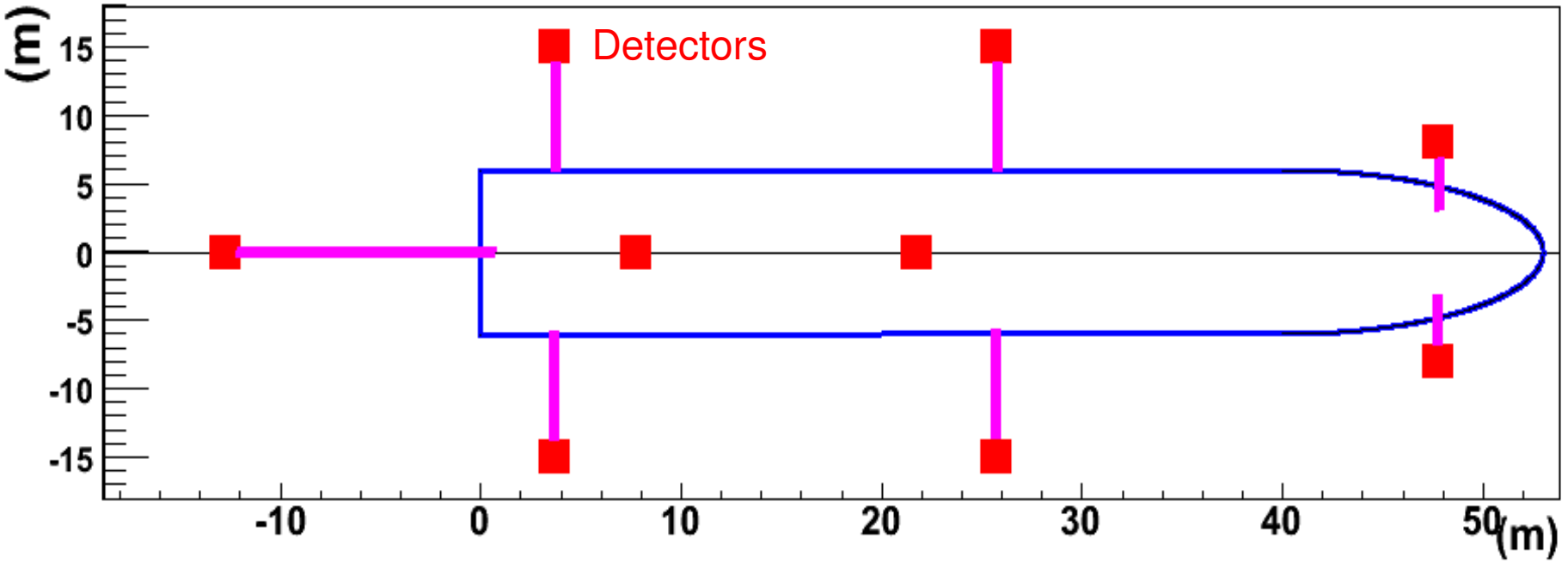
Tested setups 1 & 1b



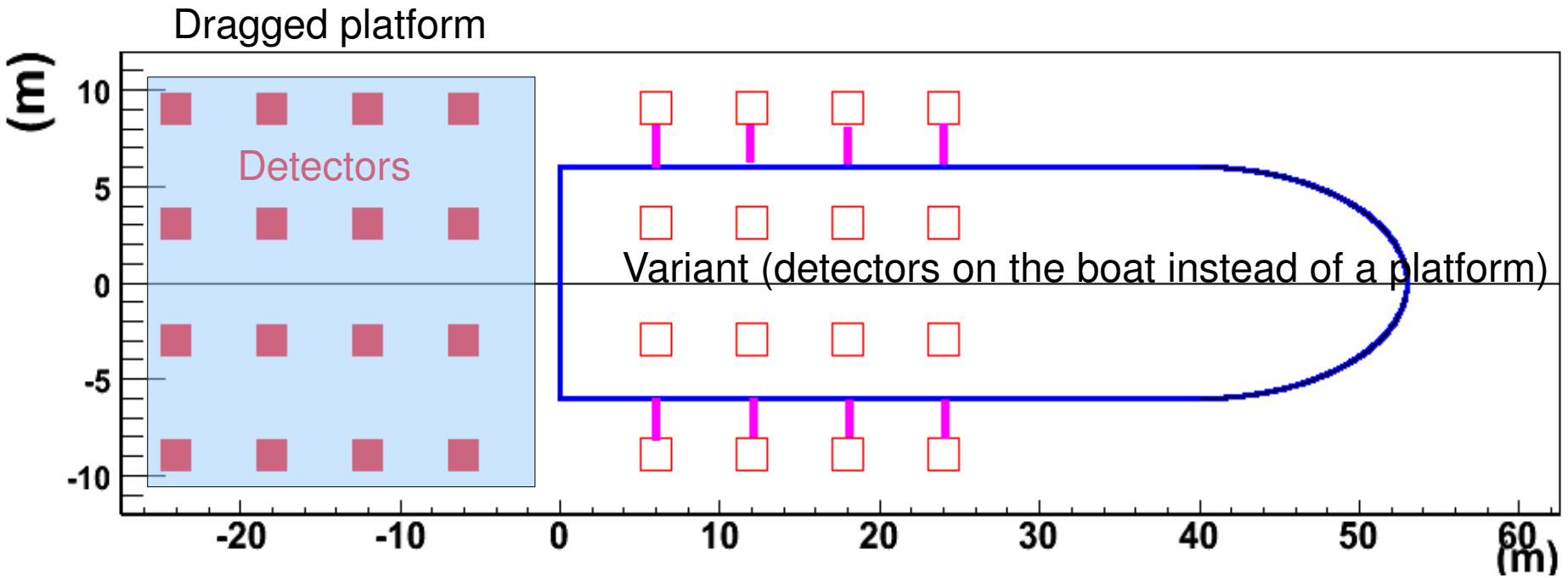
Variant



Tested setup 2

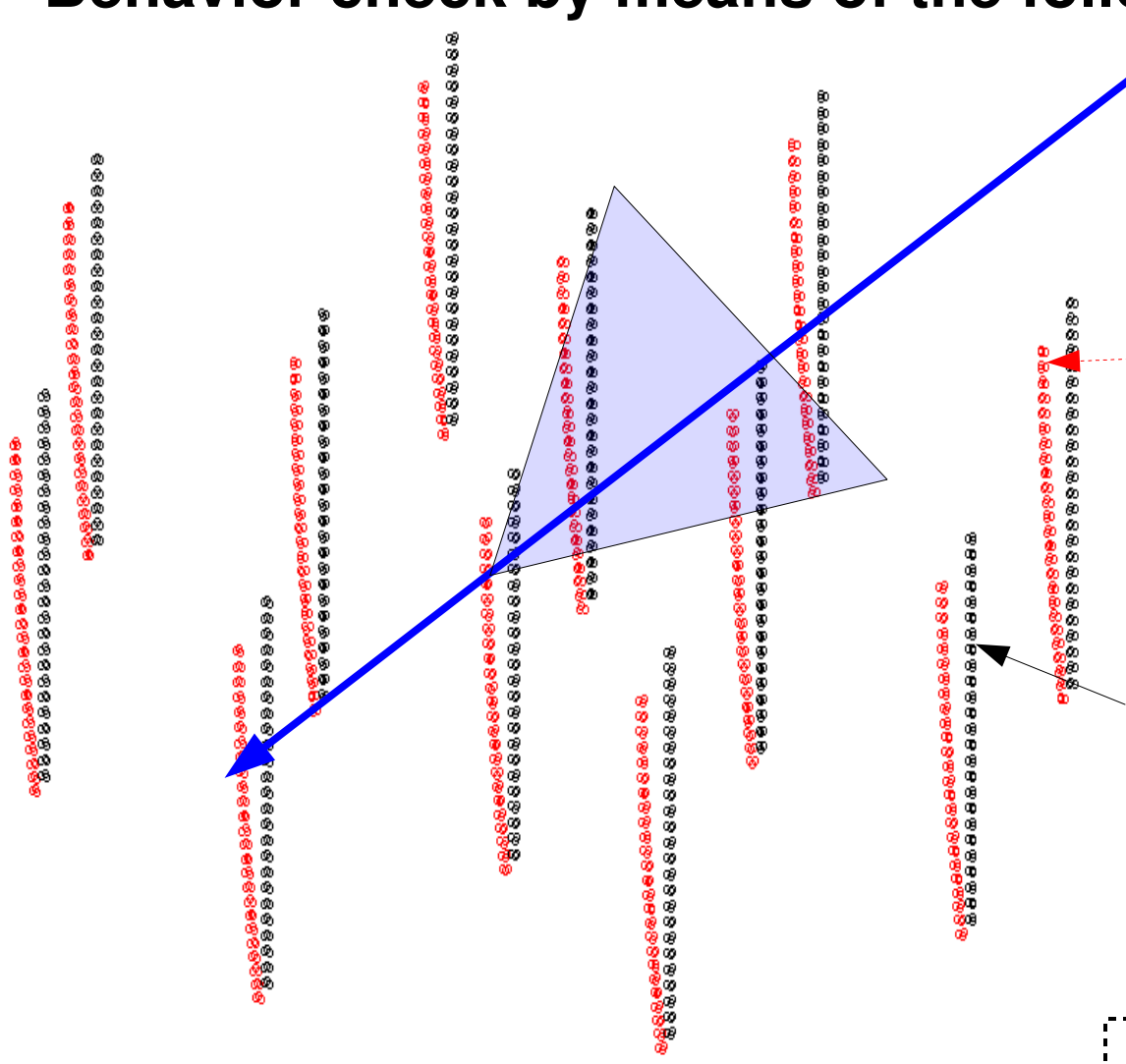


Tested setup 3



In the next plots :

Behavior check by means of the following simple test :



Cherenkov light simulated using non straight lines (sea current velocity of 20 cm/s along Y axis),

Reconstruction performed using straight lines (perfect detector)

dashed lines in all following plots

Observation of the effect on reconstrucetd zenith: $\Delta\theta$ = f(sea current speed)

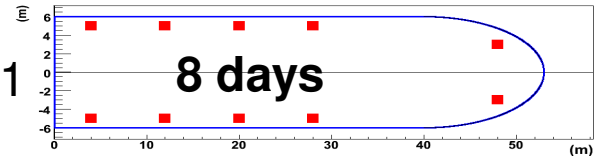
The plots with plain lines are made using perfect detector in both steps (simulation & reconstruction), they are our reference.

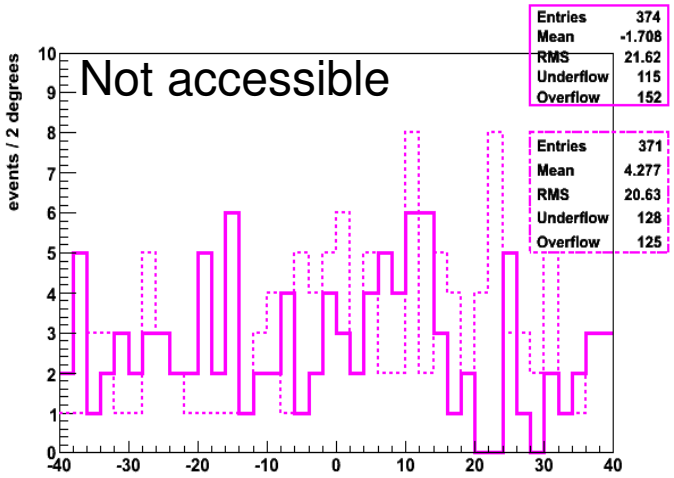
Preliminary simulation estimates : surface array reconstructed shower axis vs ANTARES 12 lines reconstructed track

60 kHz bkg

Above ANTARES

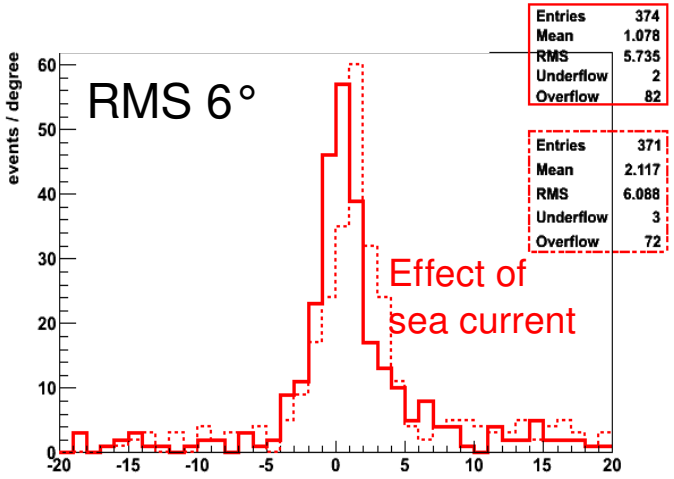
Setup 1



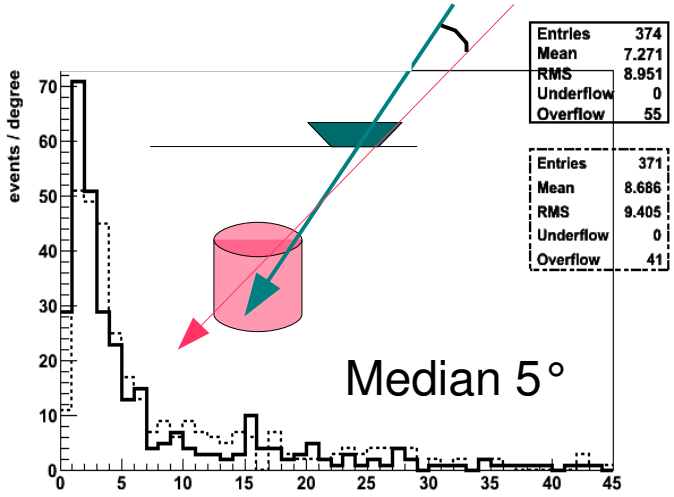


$\Delta\phi$ (°)

45 evts/day



$\Delta\theta$ (°)



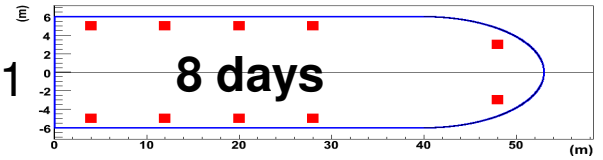
angle between tracks(°)

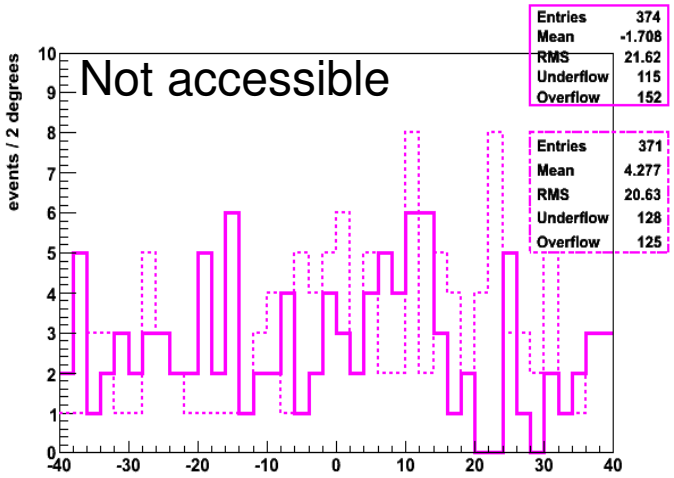
Preliminary simulation estimates : surface array reconstructed shower axis vs ANTARES 12 lines reconstructed track

60 kHz bkg

Above ANTARES

Setup 1





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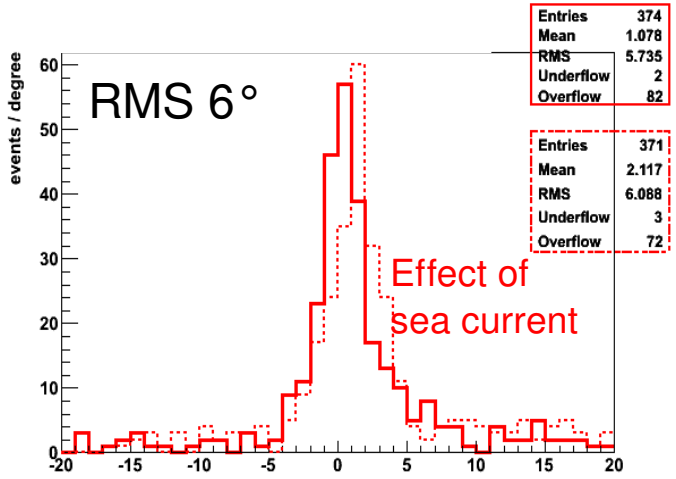
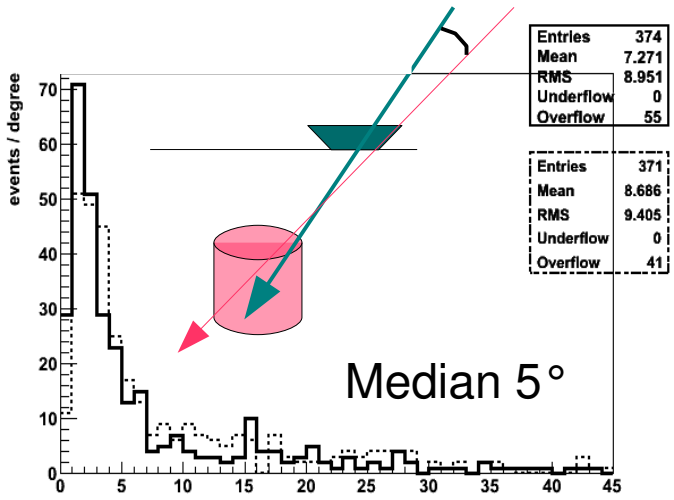
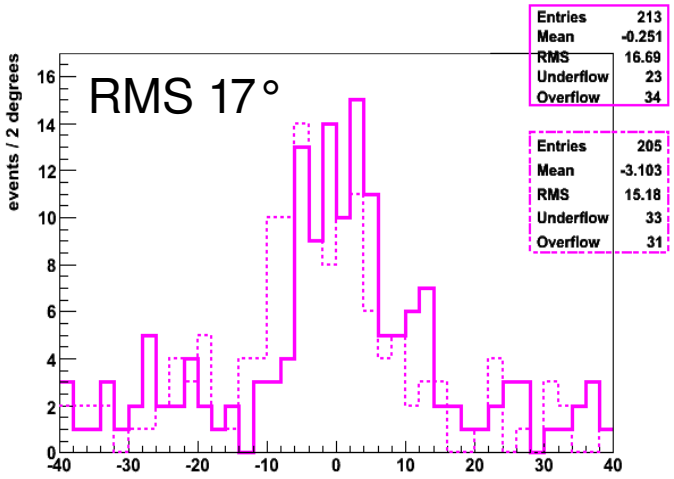


$\Delta\theta$ (°)

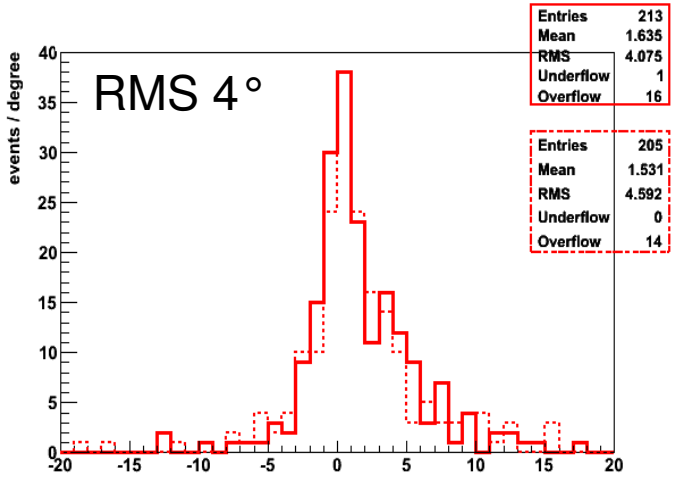


angle between tracks(°)

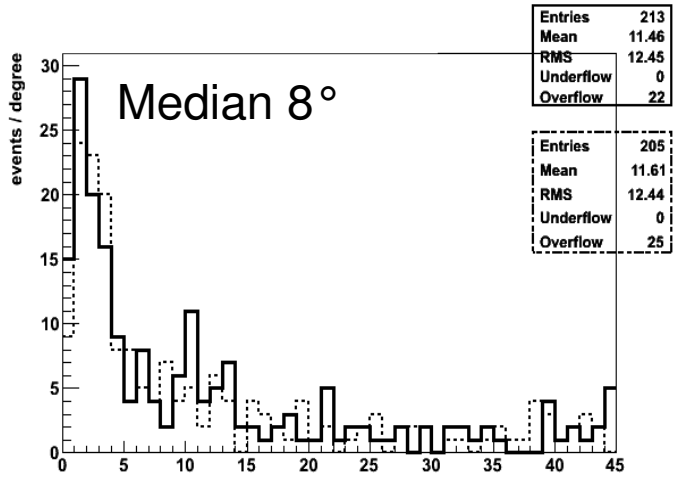


$\Delta\phi$ (°)

26 evts/day



$\Delta\theta$ (°)



angle between tracks(°)

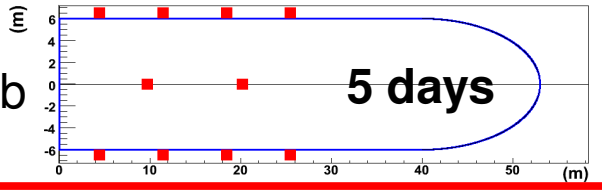
1 km from ANTARES

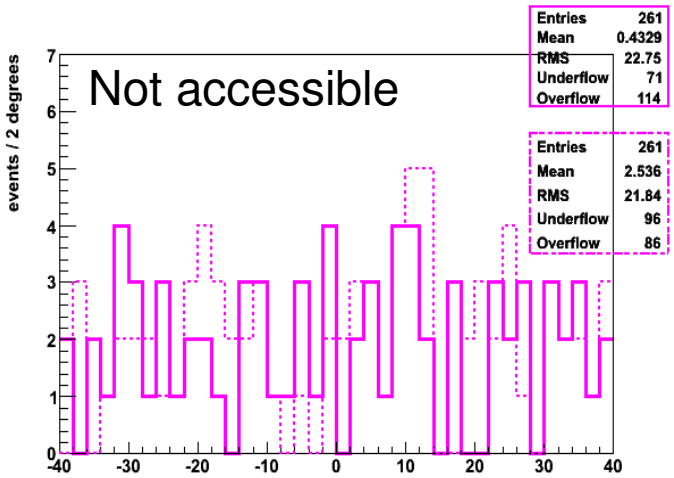
Preliminary simulation estimates : surface array reconstructed shower axis vs ANTARES 12 lines reconstructed track

60 kHz bkg

Above ANTARES

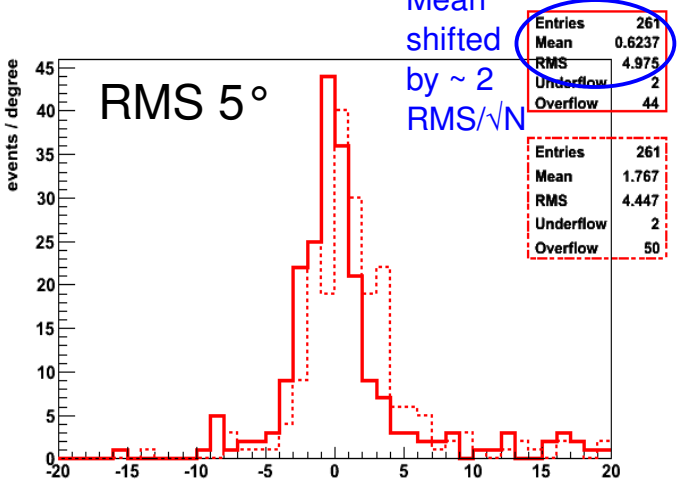
Setup 1b



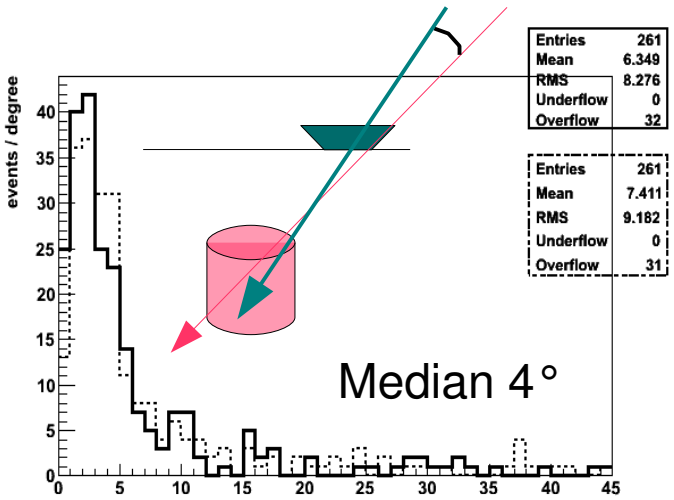


$\Delta\phi$ (°)

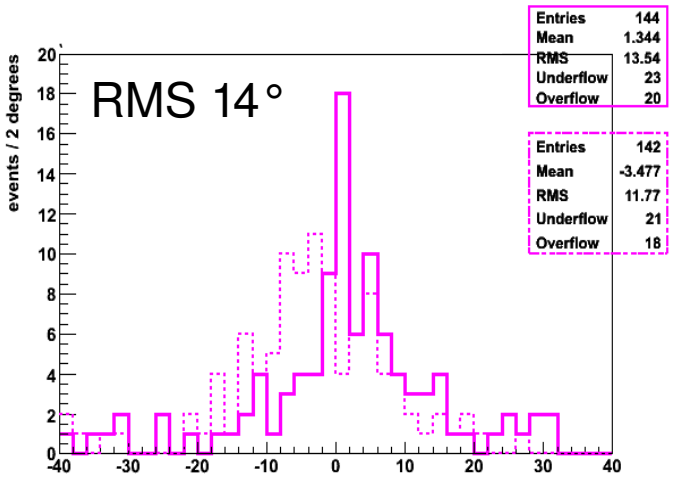
52 evts/day



$\Delta\theta$ (°)

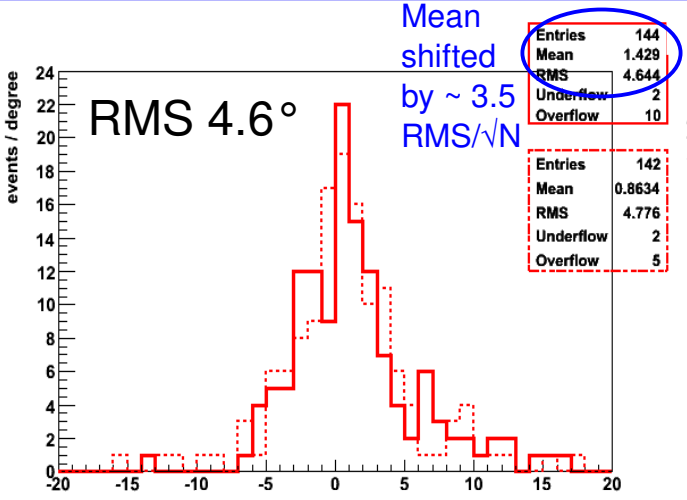


angle between tracks(°)

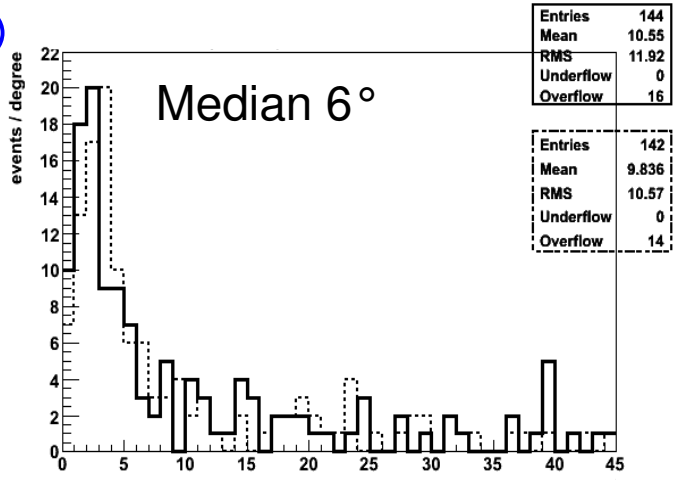


$\Delta\phi$ (°)

28 evts/day



$\Delta\theta$ (°)



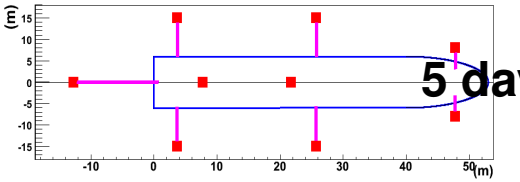
angle between tracks(°)

1 km from ANTARES

Preliminary simulation estimates : surface array reconstructed shower axis vs ANTARES 12 lines reconstructed track

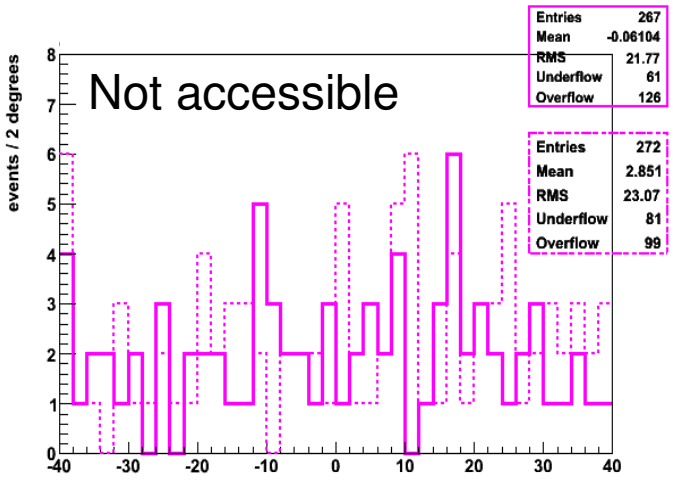
60 kHz bkg

Setup 2



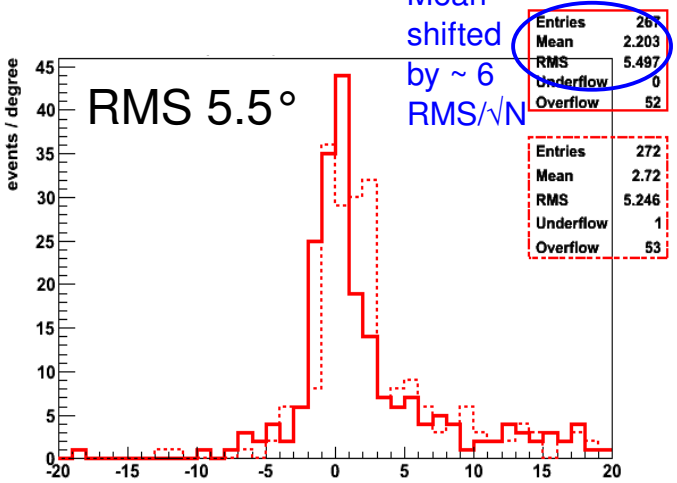
5 days

Above ANTARES

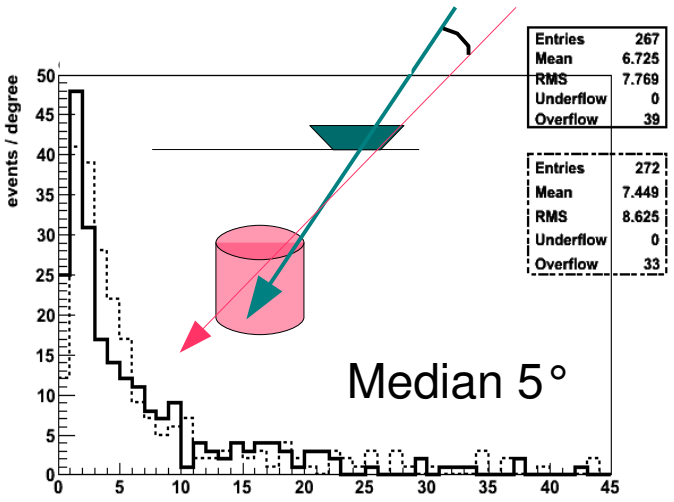


$\Delta\phi$ (°)

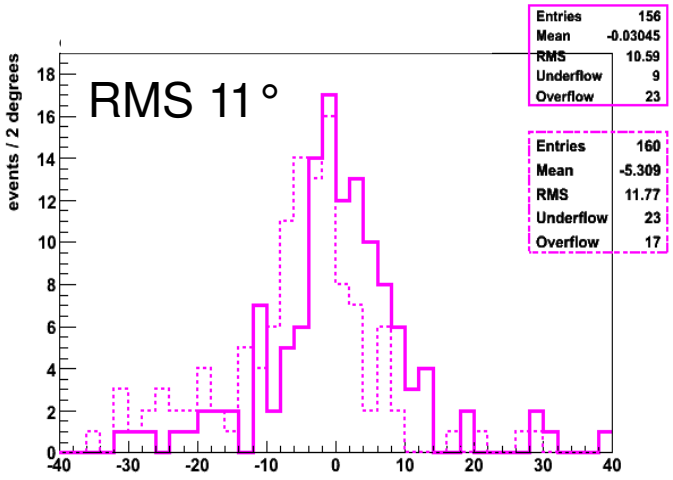
53 evts/day



$\Delta\theta$ (°)

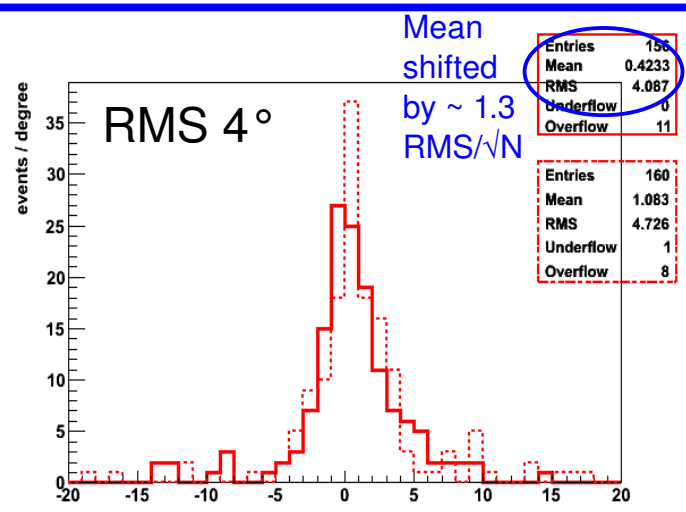


angle between tracks(°)

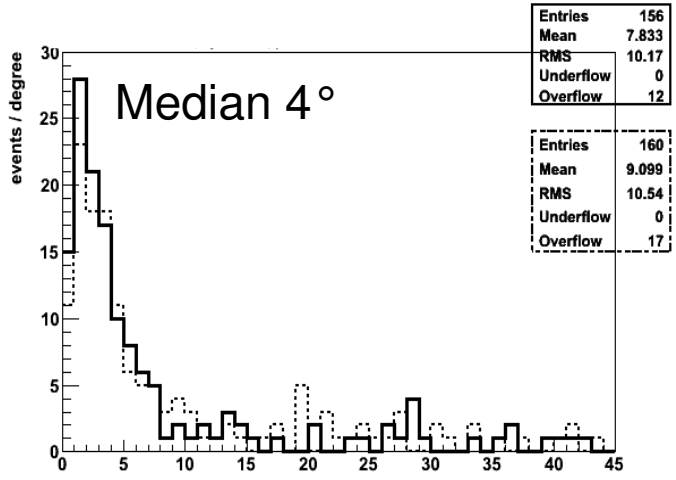


$\Delta\phi$ (°)

31 evts/day



$\Delta\theta$ (°)



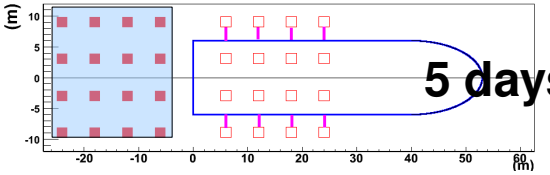
angle between tracks(°)

1 km from ANTARES

Preliminary simulation estimates : surface array reconstructed shower axis vs ANTARES 12 lines reconstructed track

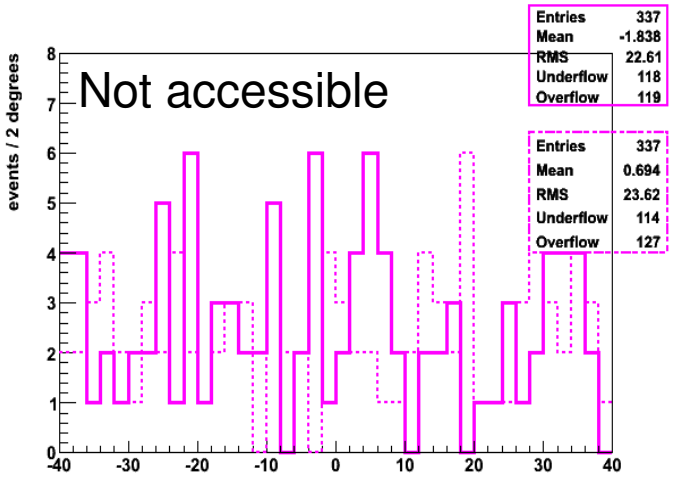
60 kHz bkg

Setup 3



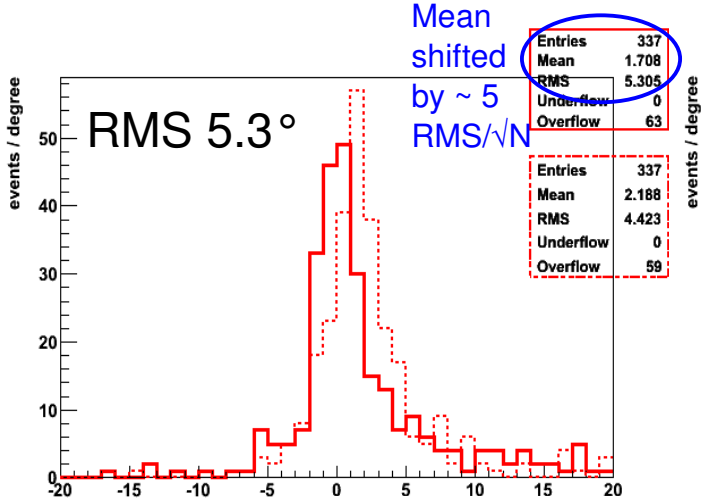
5 days

Above ANTARES

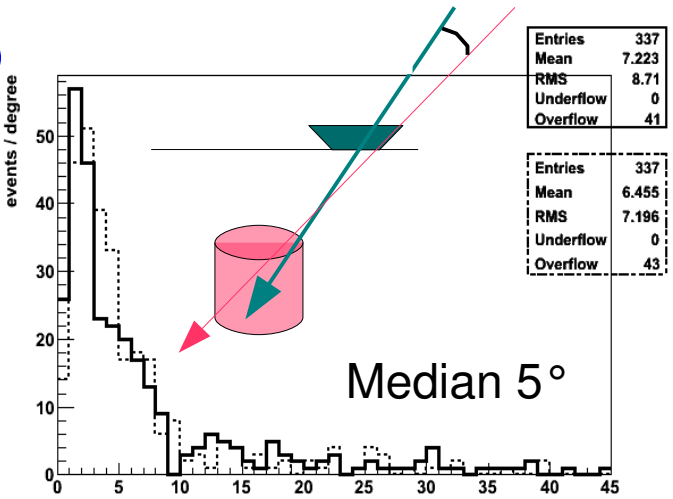


$\Delta\phi$ (°)

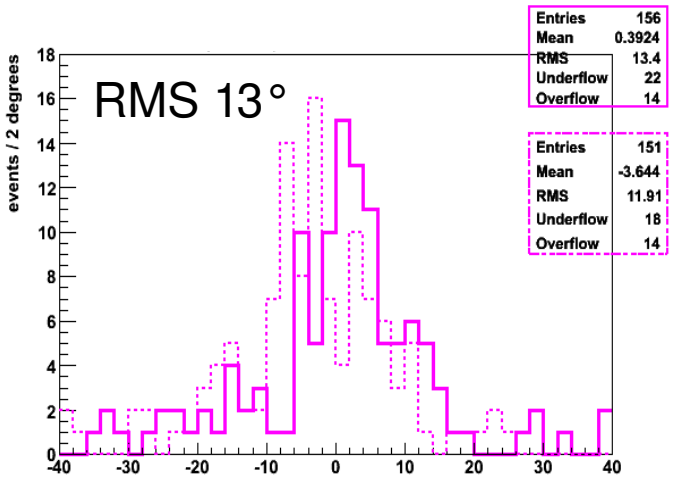
67 evts/day



$\Delta\theta$ (°)

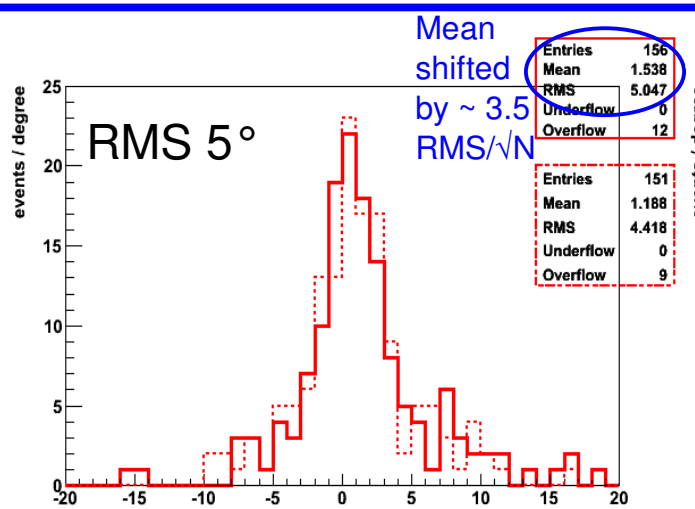


angle between tracks(°)

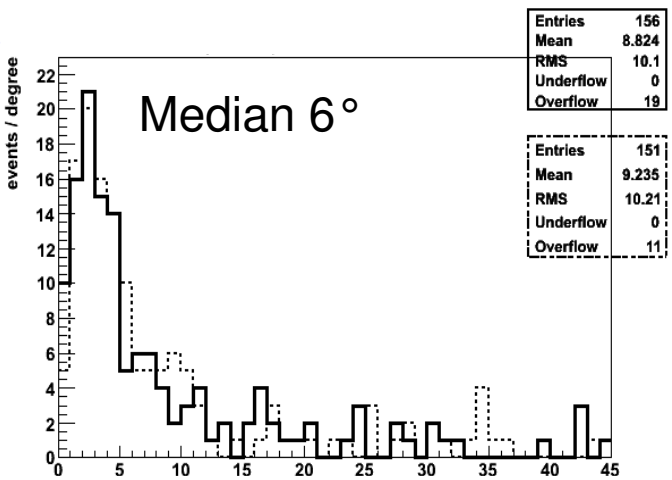


$\Delta\phi$ (°)

31 evts/day



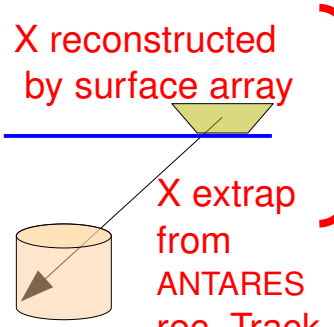
$\Delta\theta$ (°)

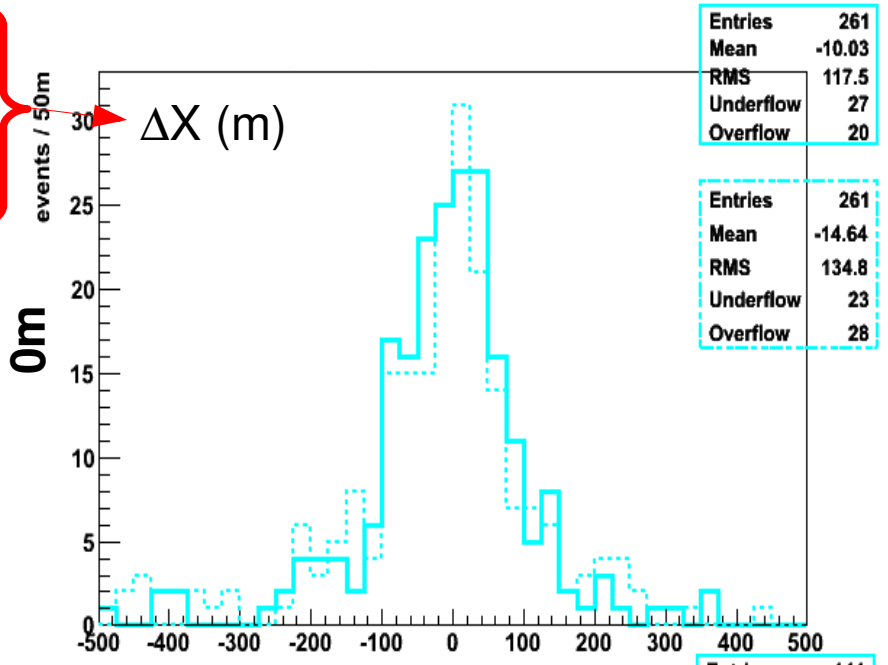


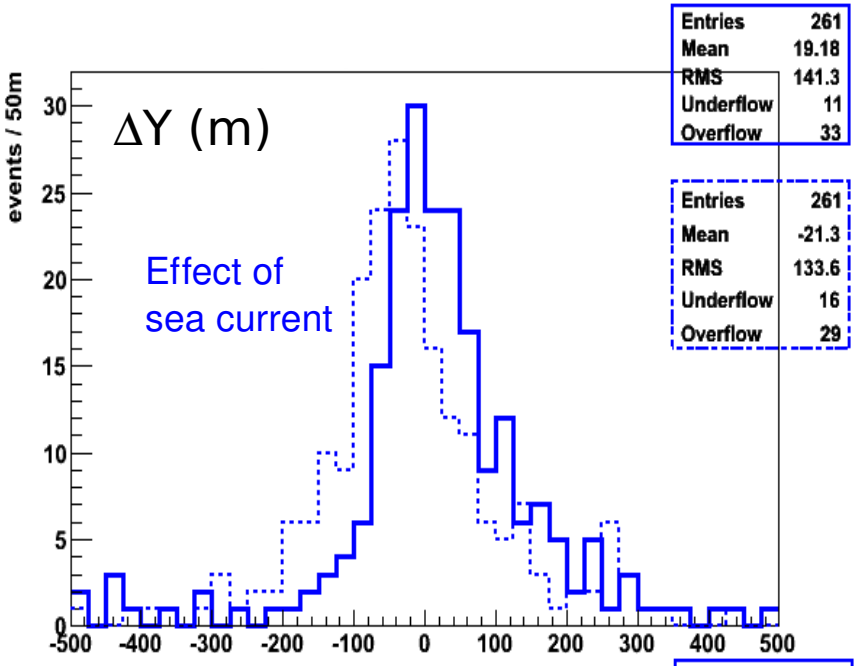
angle between tracks(°)

1 km from ANTARES

Difference between extrapolated X (Y) and shower reconstructed impact:

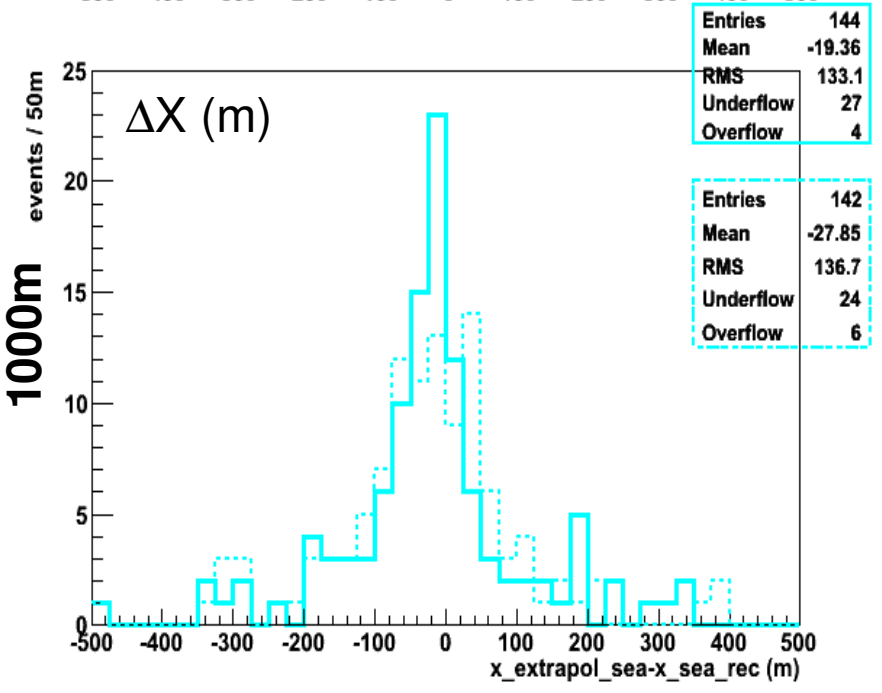


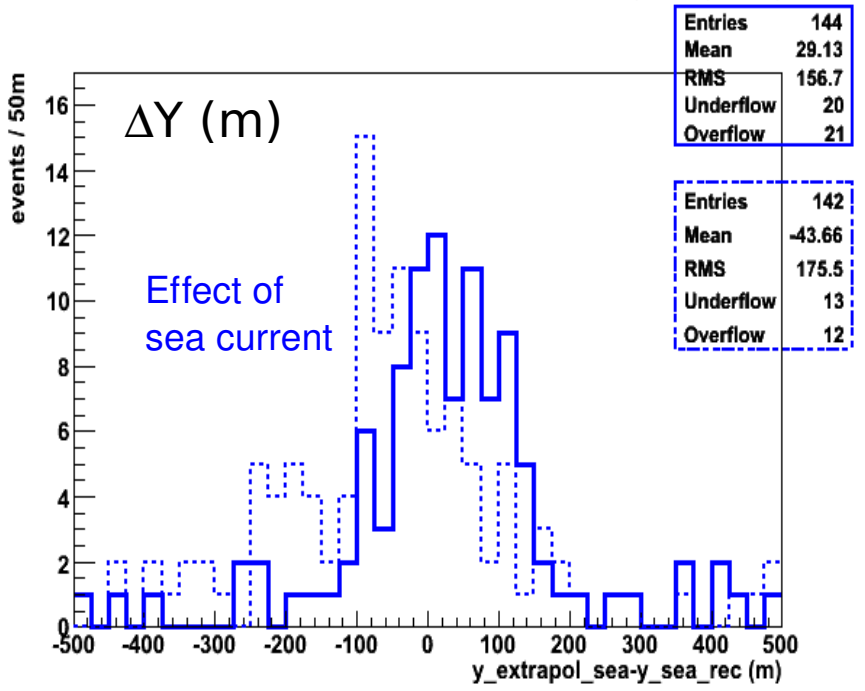




RMS~150 m

(similar for
all setups)





First conclusions :

RMS of 5° for $\Delta\theta$ (Δzenith) computed with event by event comparison.

No quality cut on reconstructed track :

RMS <Δzenith> ~ 0.5°, RMS <Δazimuth> ~ 1.5°

RMS <Δimpact at sea level> ~ 15 m

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In Δzenith distribution : shift of the mean of several sigmas: to be understood

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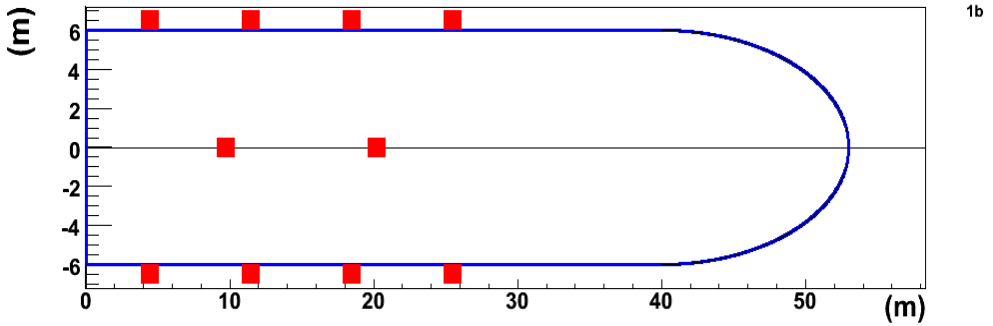
Setups rather equivalent for resolution, but not for rates :
a good compromise (easy to implement) is:



Rates
~50 evts/day @ 0m (43 used)
~30 evts/day @ 1 km (26 used)

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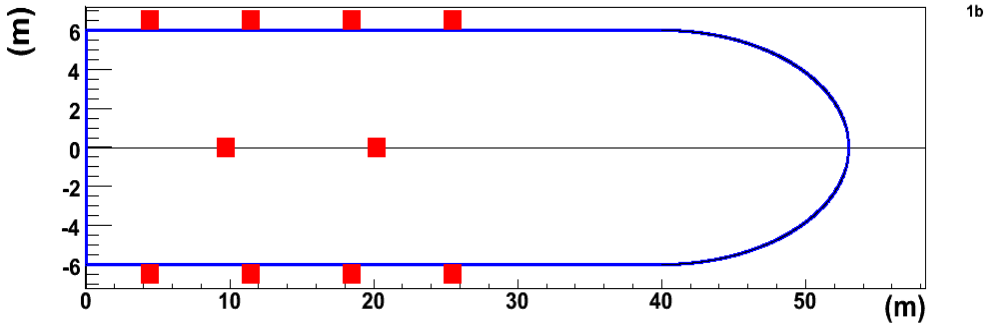


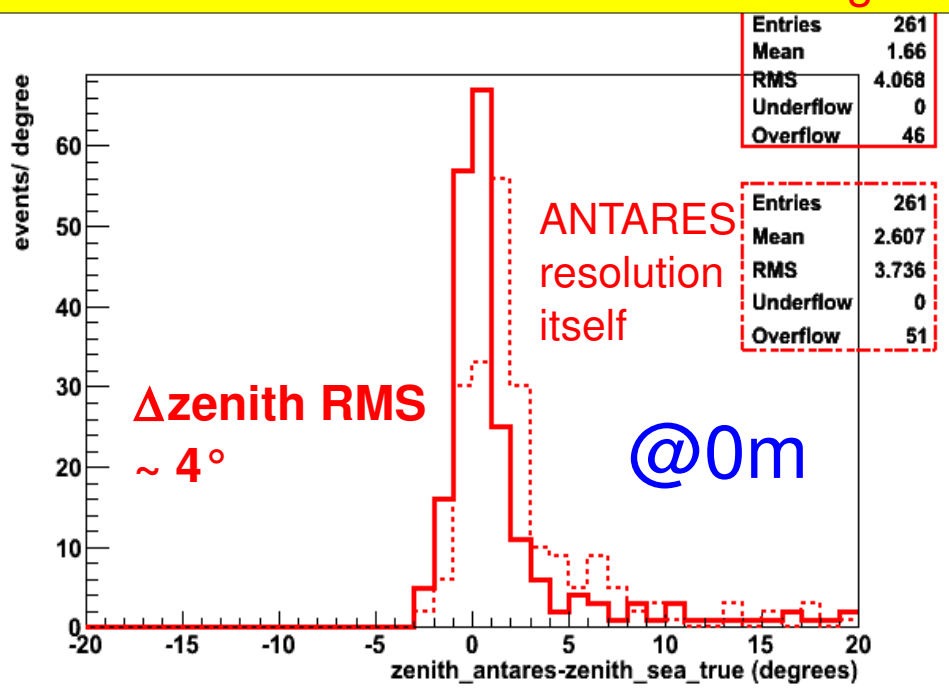
Rates
~50 evts/day @ 0m (43 used)
~30 evts/day @ 1 km (26 used)

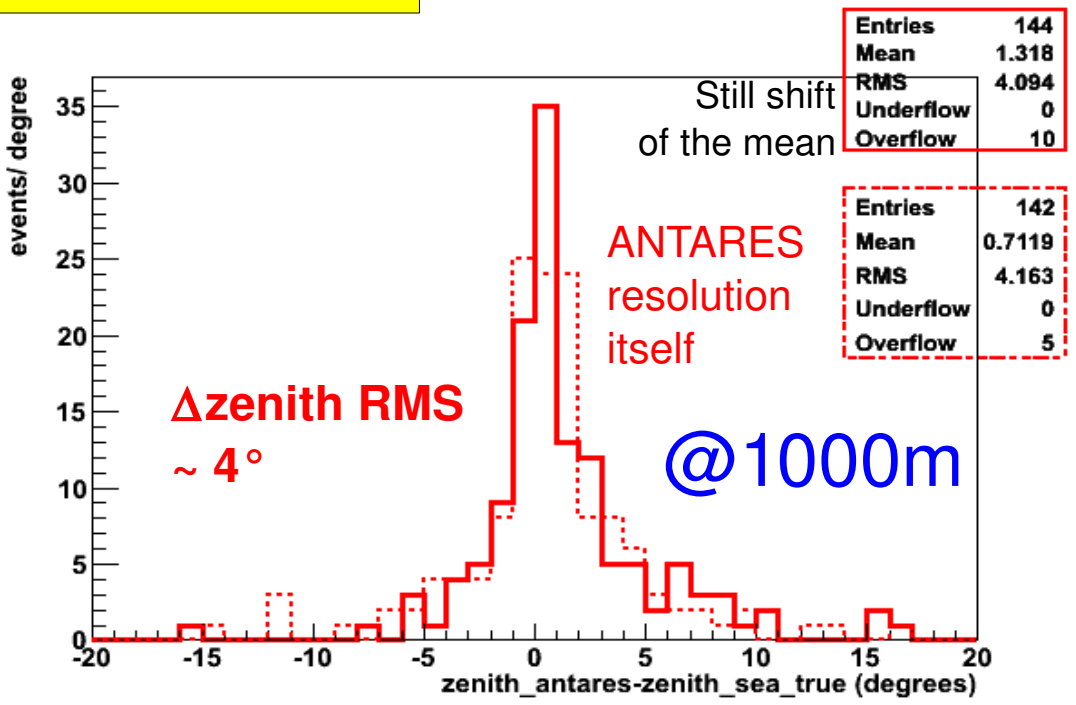
Propagation of muons & reconstruction efficiency :

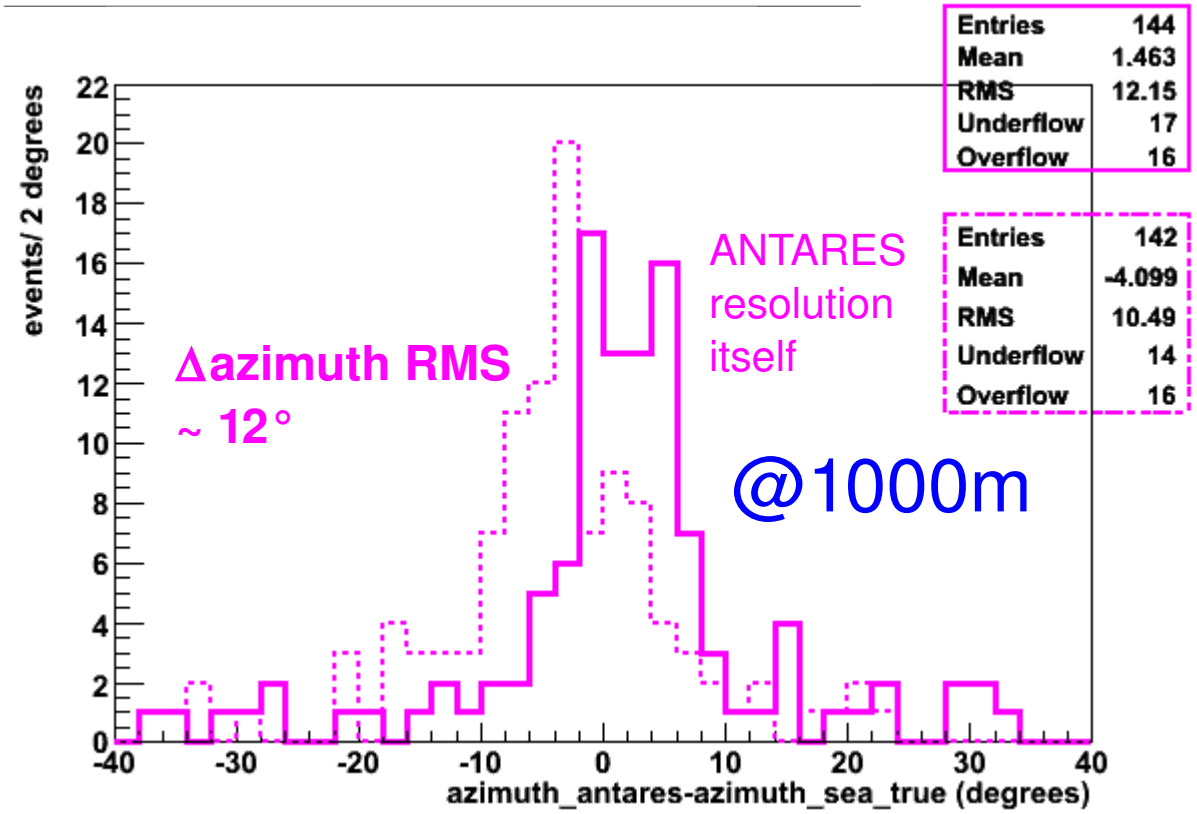
30% of showers measured by surface array @ 0 m and pointing to ANTARES give a reconstructed track in ANTARES,

20% of showers measured by surface array @ 1 km and pointing to ANTARES give a reconstructed track in ANTARES

Limit case : if we consider a full knowledge of shower axis ...







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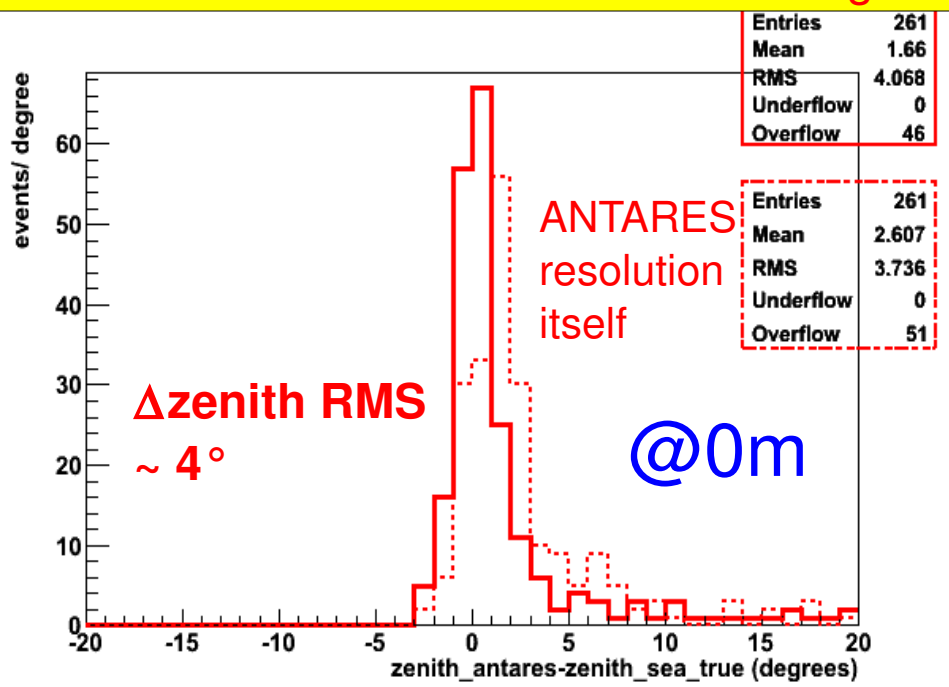
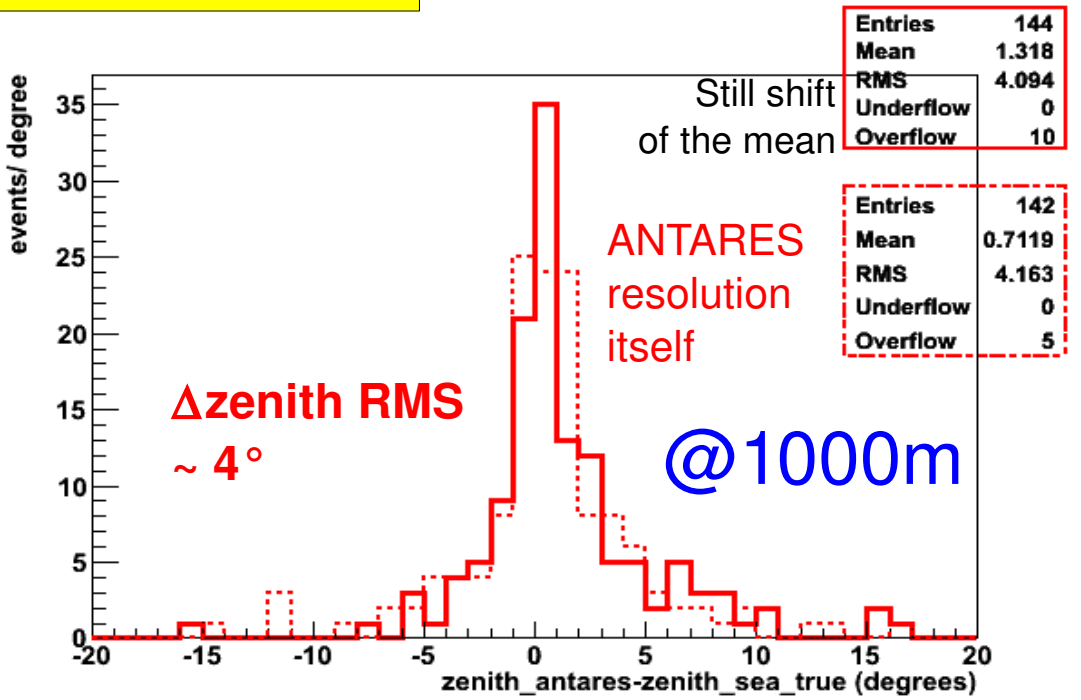
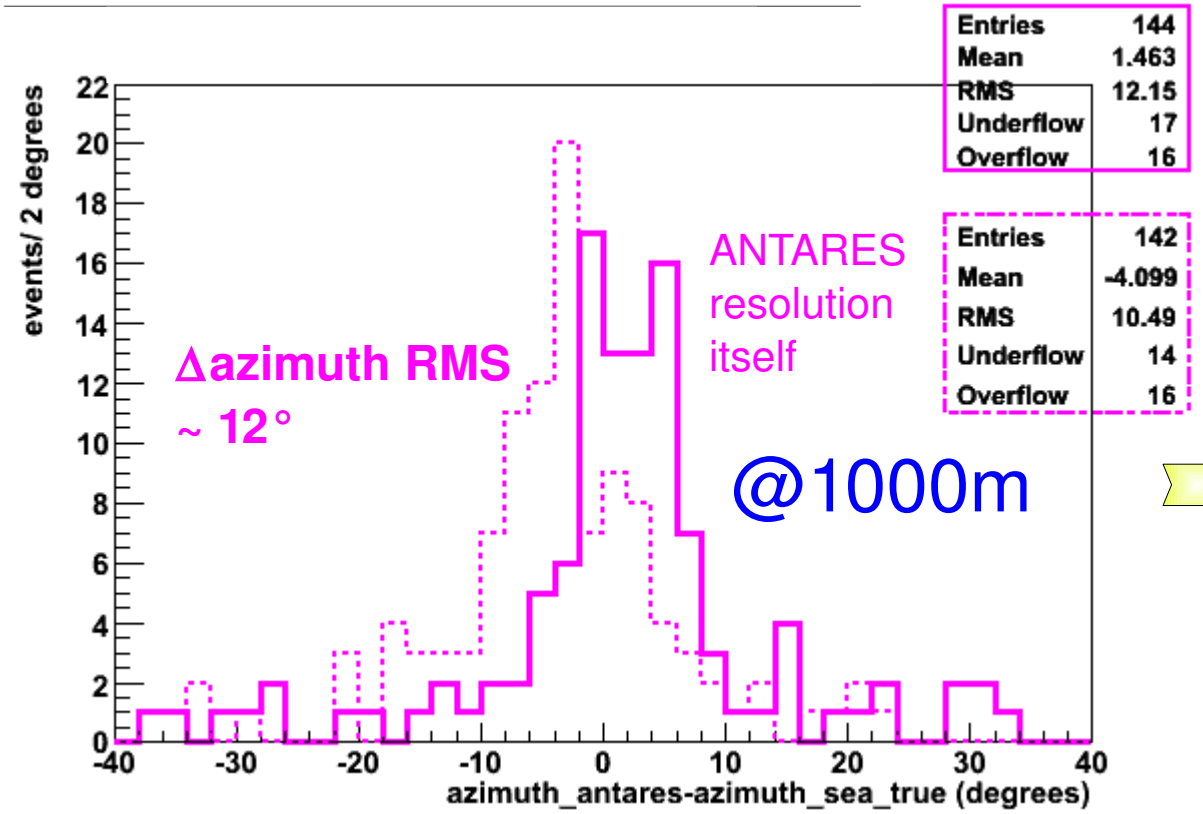






With a perfect shower axis knowledge at sea level (MC truth) we extract the ANTARES resolution itself for the considered tracks (down-going, no quality cuts):

RMS Δzenith ~ 4 °

RMS Δazimuth ~ 12°

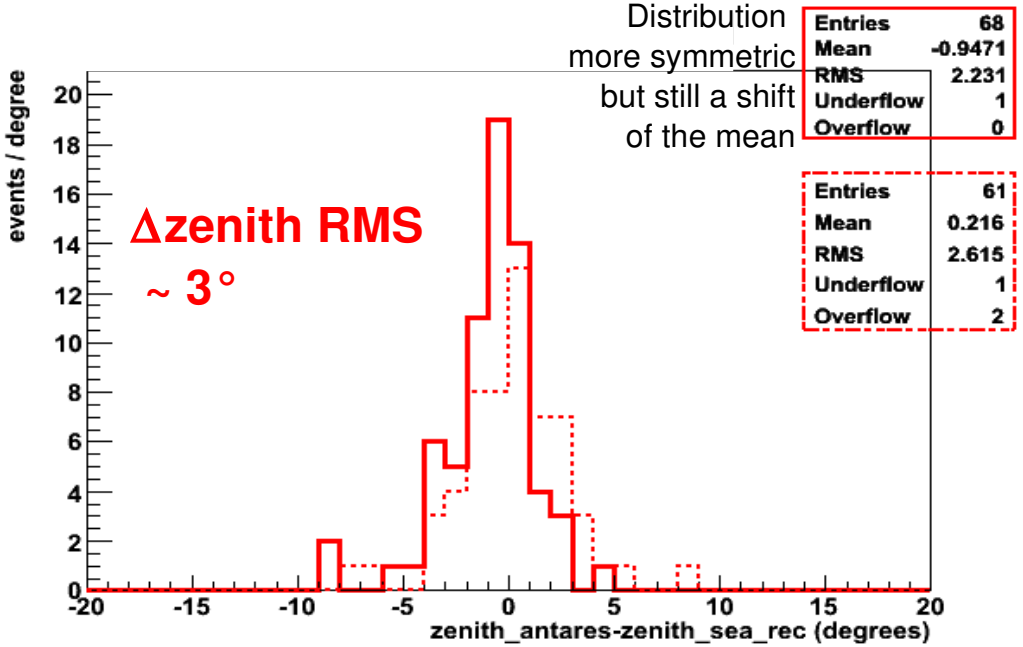
Surface array accuracy being slightly better (3° RMS on zenith, 1.5° for the median of space angle), it could allow the estimate of ANTARES angular resolution in this case (down going tracks, no quality cuts).

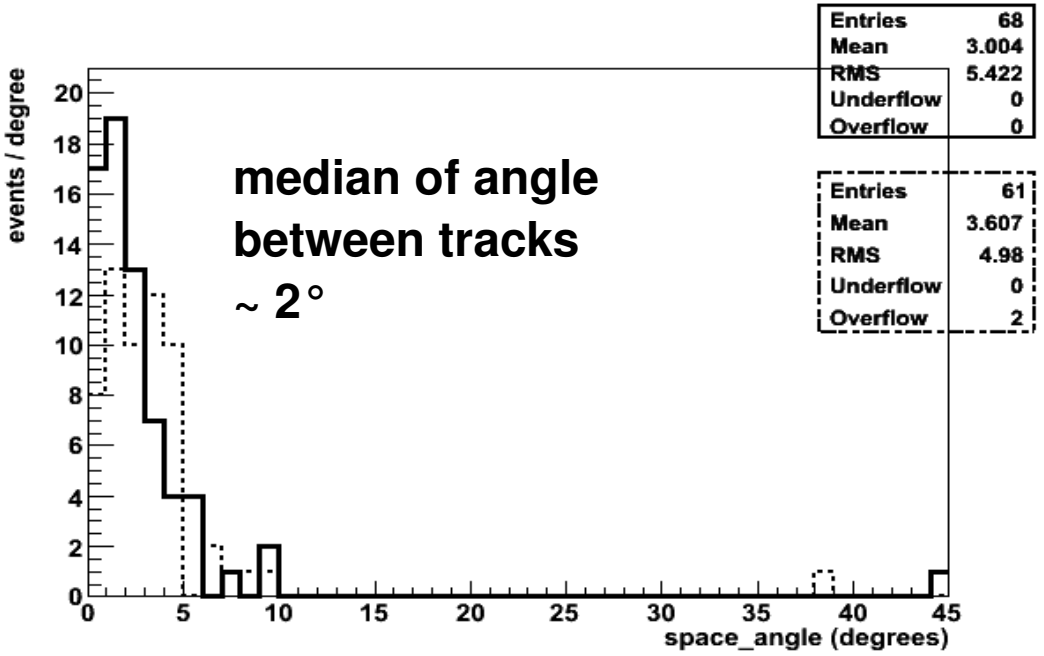
Applying quality cuts on ANTARES reconstructed track :

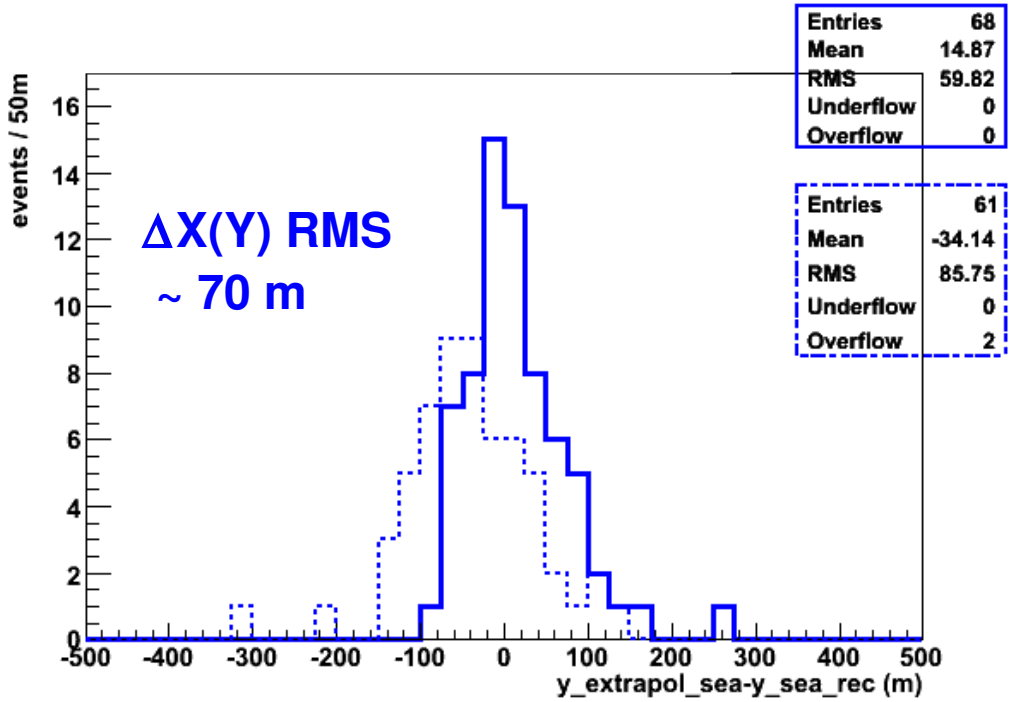
Rate falls to ~ 13 evts / day @ 0 m

but all of them are useful

Distribution more symmetric but still a shift of the mean







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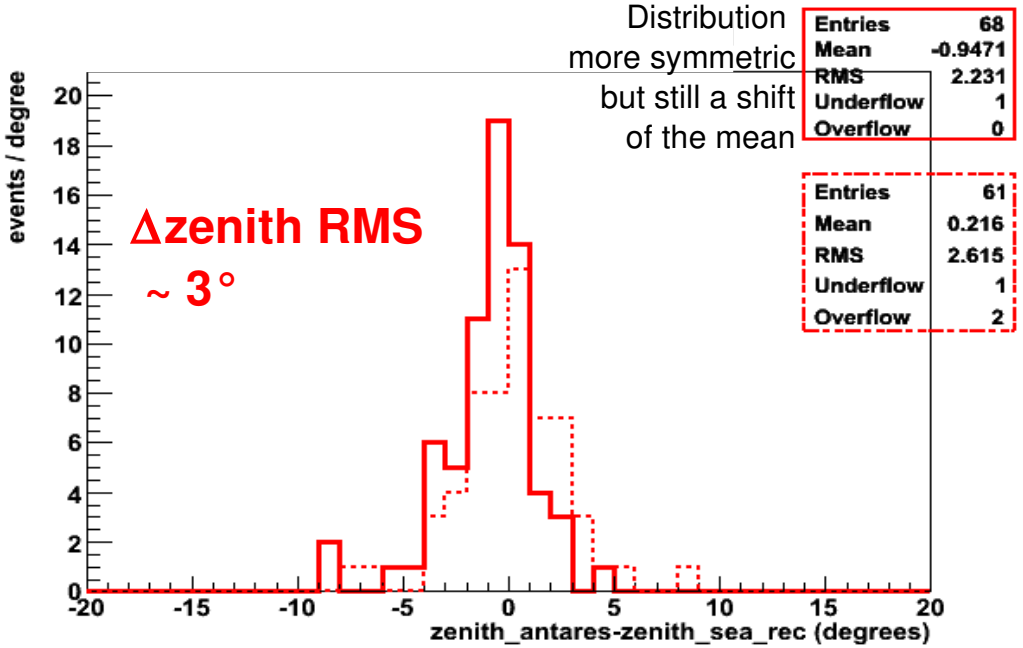
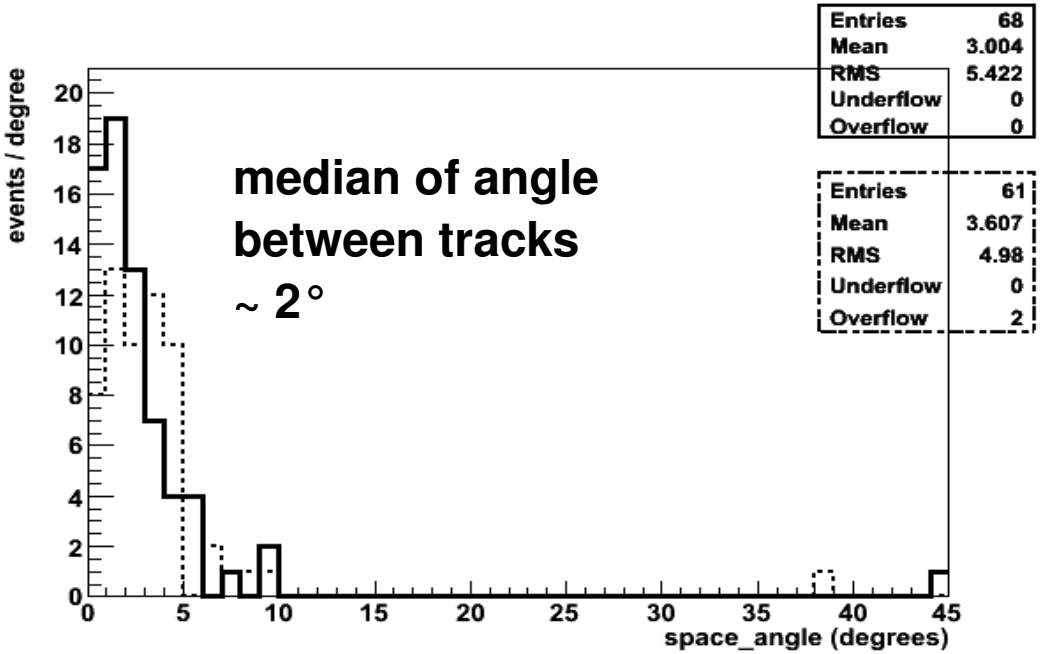
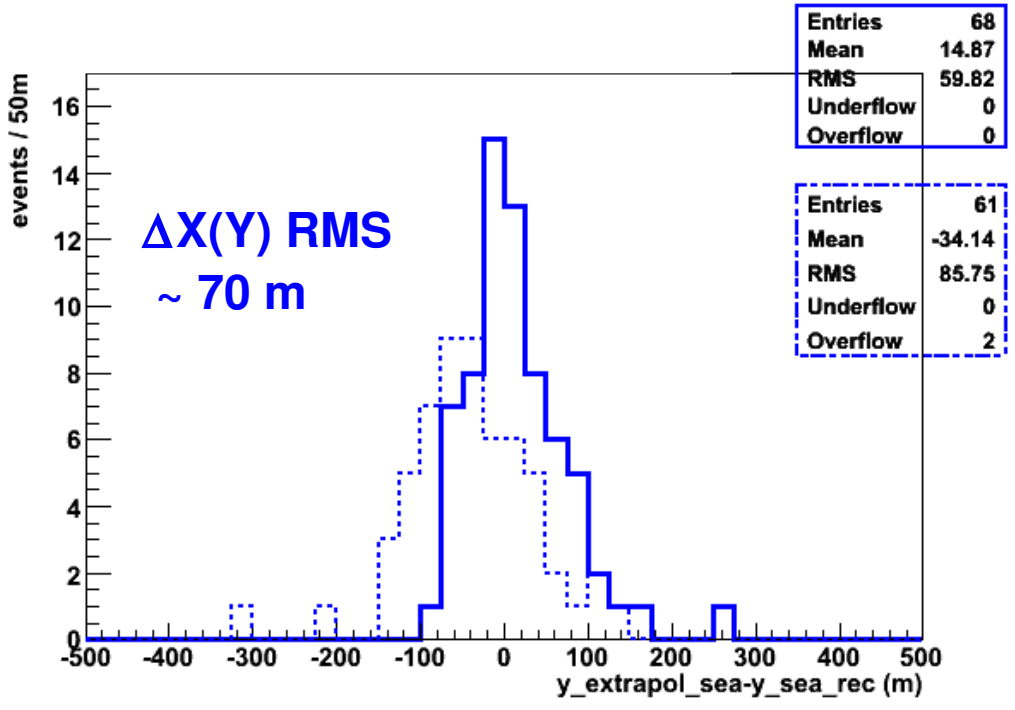
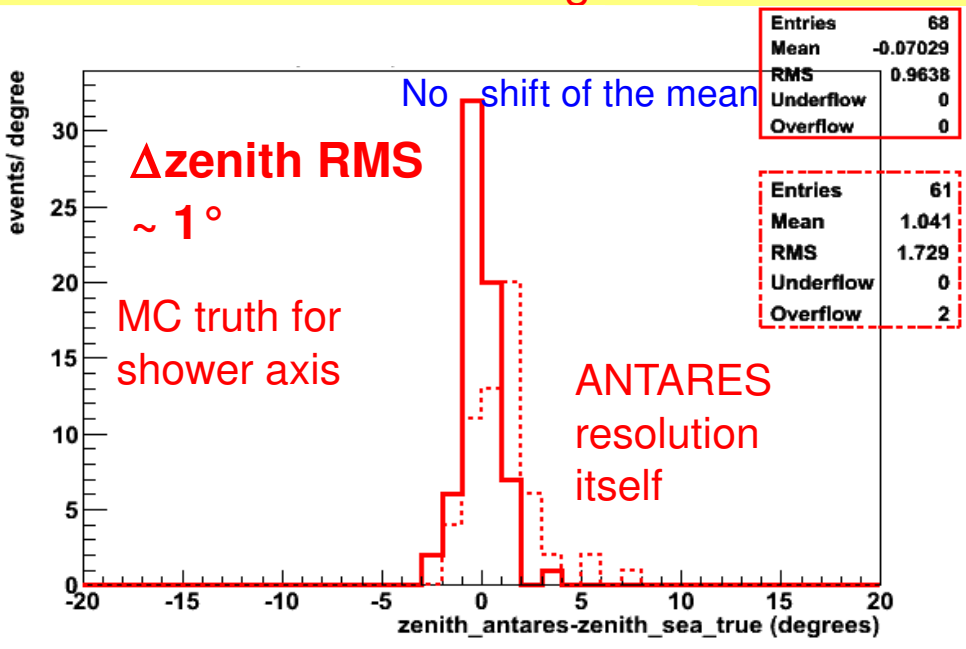
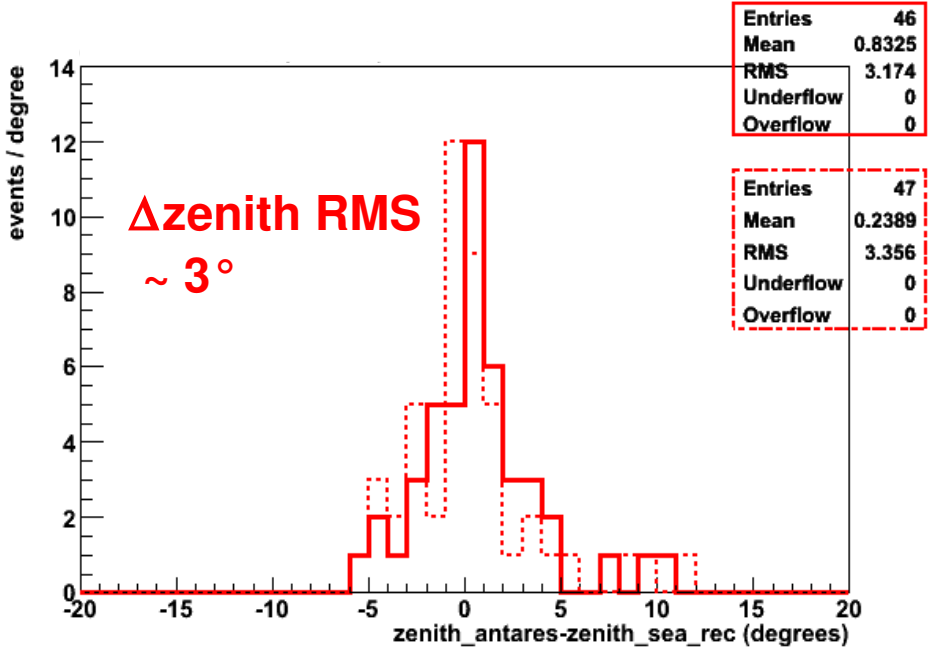


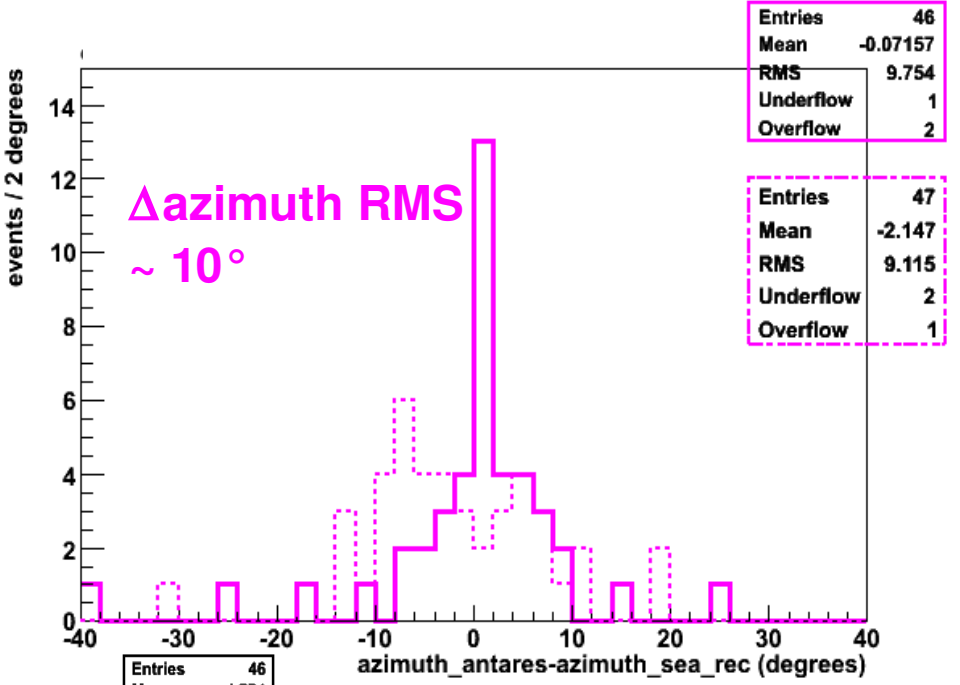




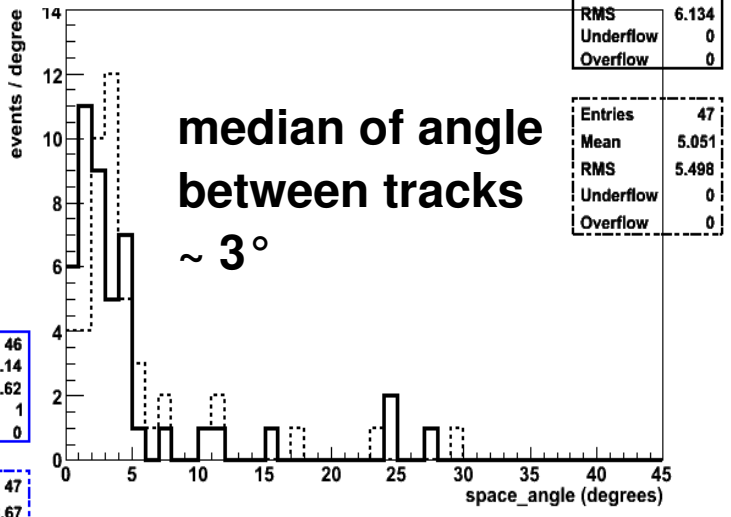
Limit case : full knowledge of shower axis

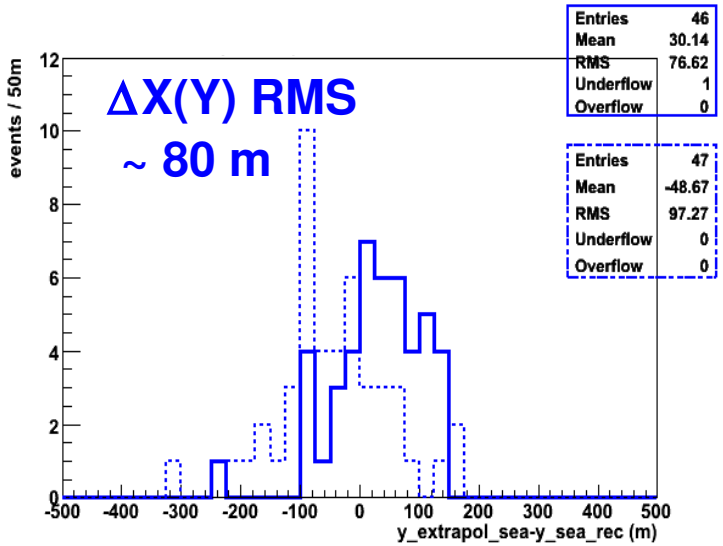


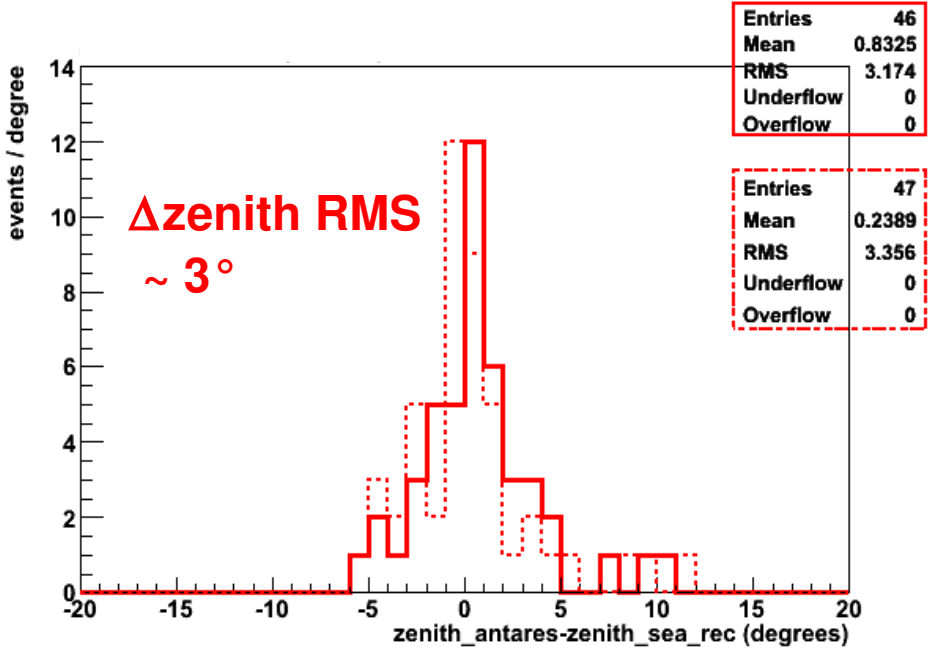


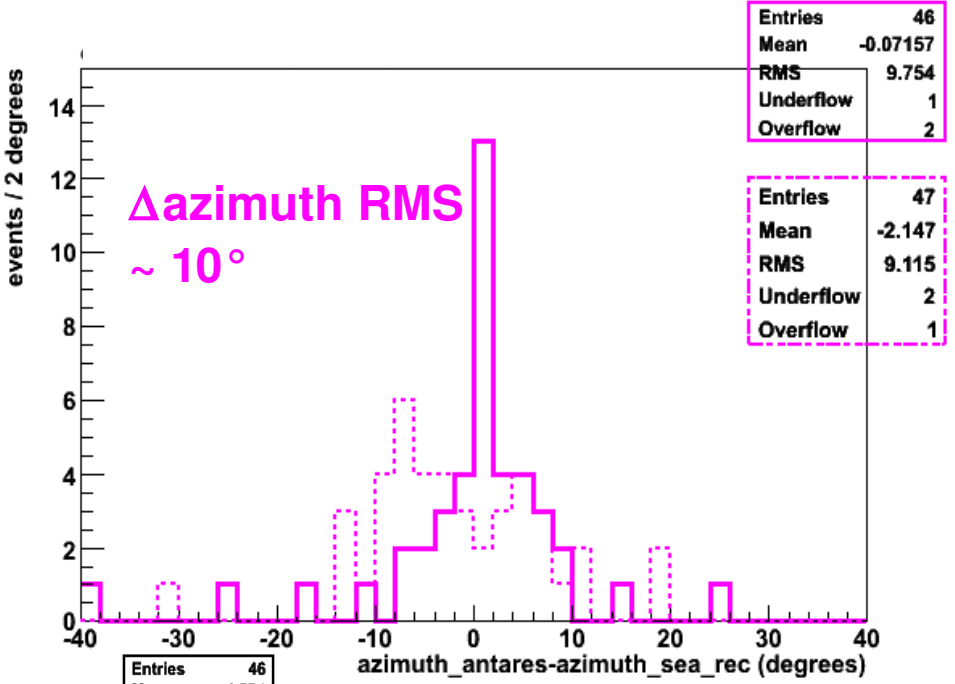


@ 1 km
(zenith ~ 24°)
~ 9 evts / day



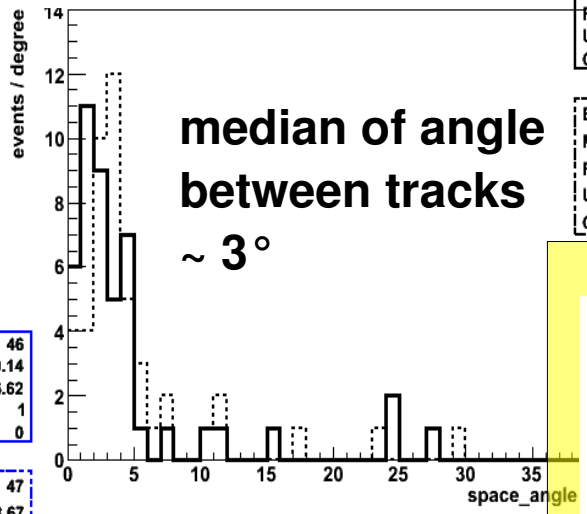




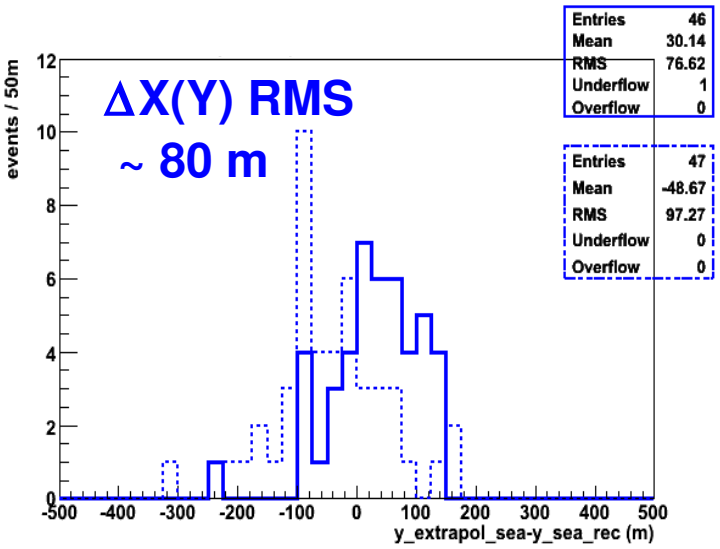


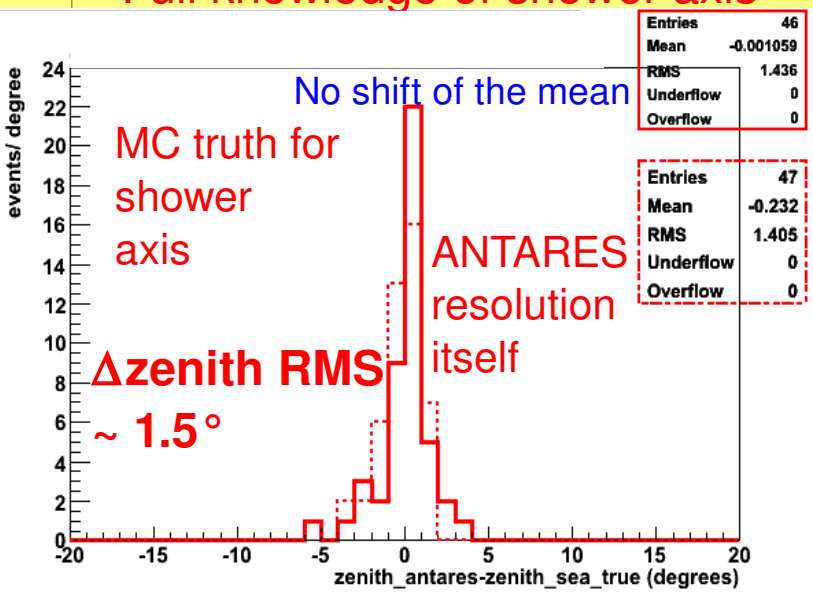
@ 1 km
(zenith ~ 24°)

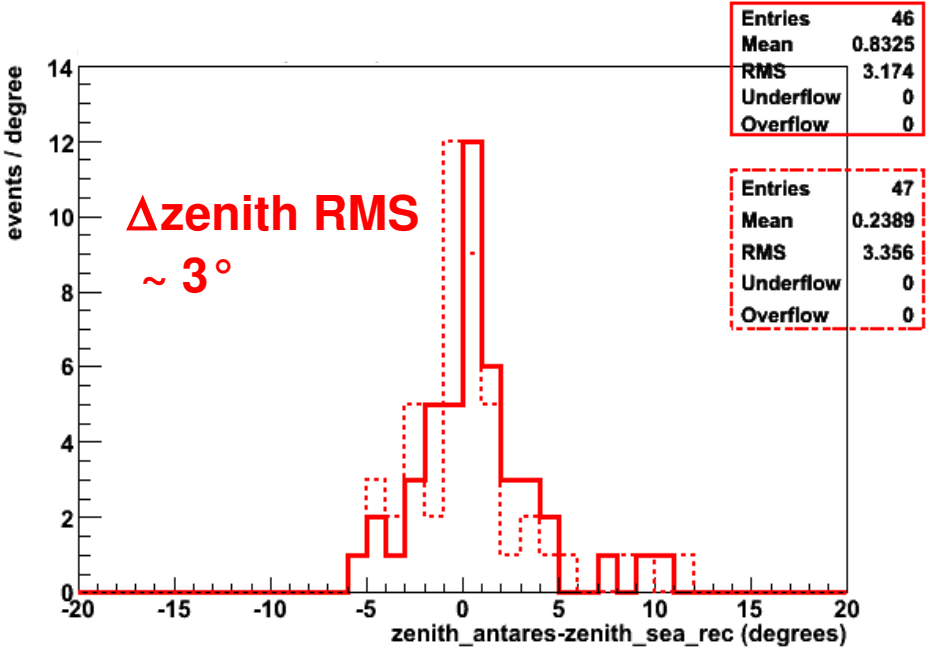
~ 9 evts / day



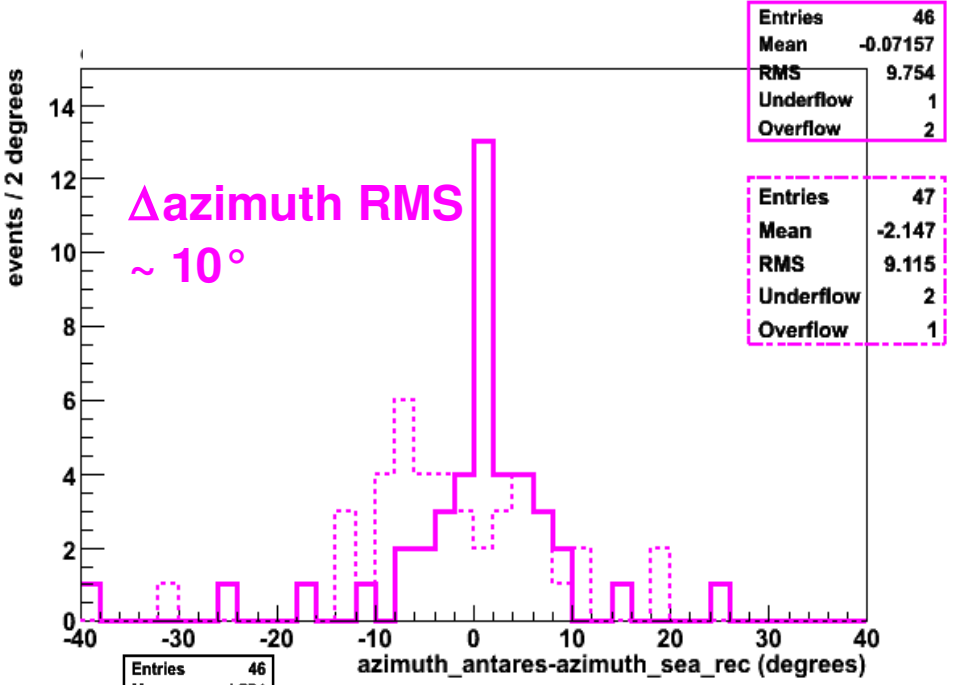
Full knowledge of shower axis







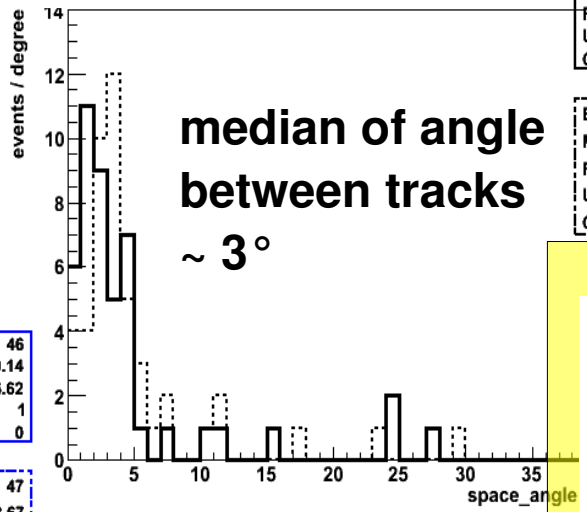
Δzenith RMS
~ 3°



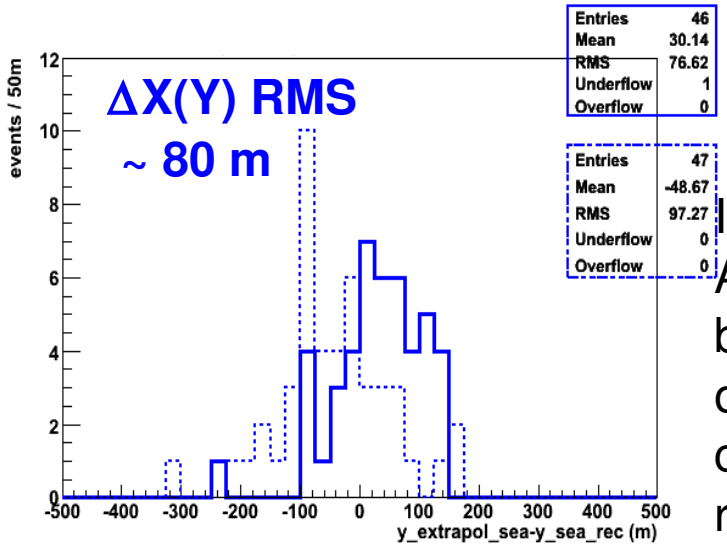
Δazimuth RMS
~ 10°

@ 1 km
(zenith ~ 24°)

~ 9 evts / day



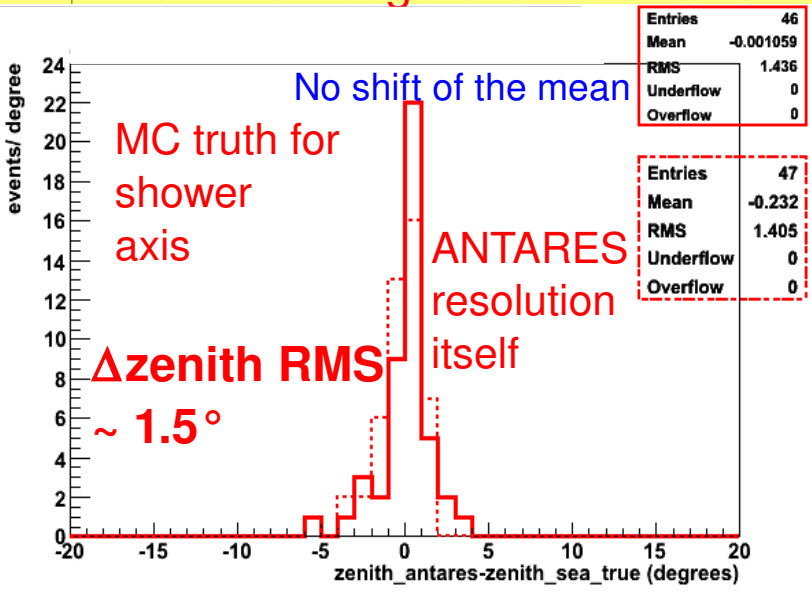
median of angle between tracks
~ 3°



ΔX(Y) RMS
~ 80 m

In case of quality cuts, ANTARES resolution is better than the surf array one: surf array can only check ANTARES resolution (upper bound).

Full knowledge of shower axis



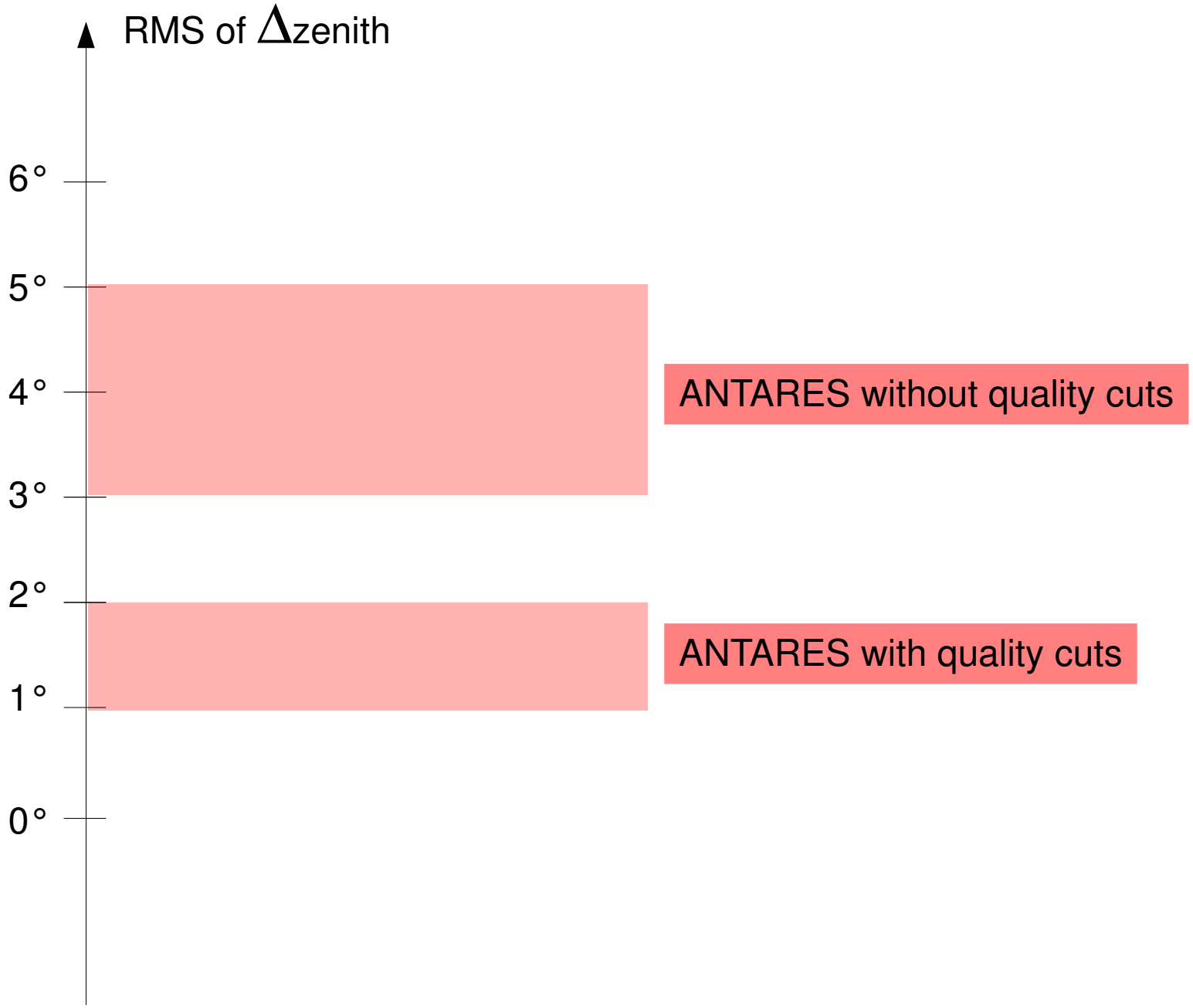
No shift of the mean

MC truth for shower axis

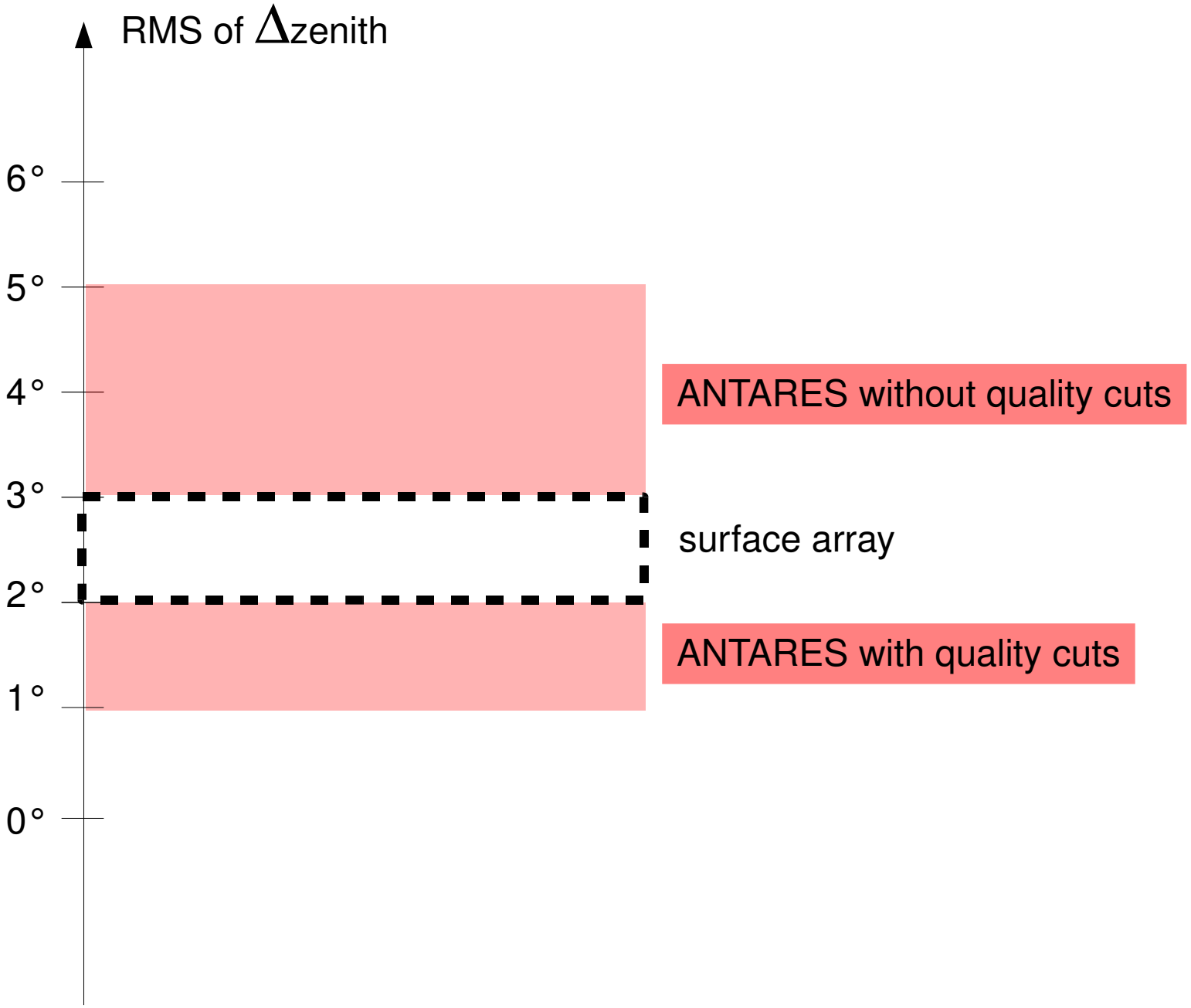
ANTARES resolution itself

Δzenith RMS
~ 1.5°

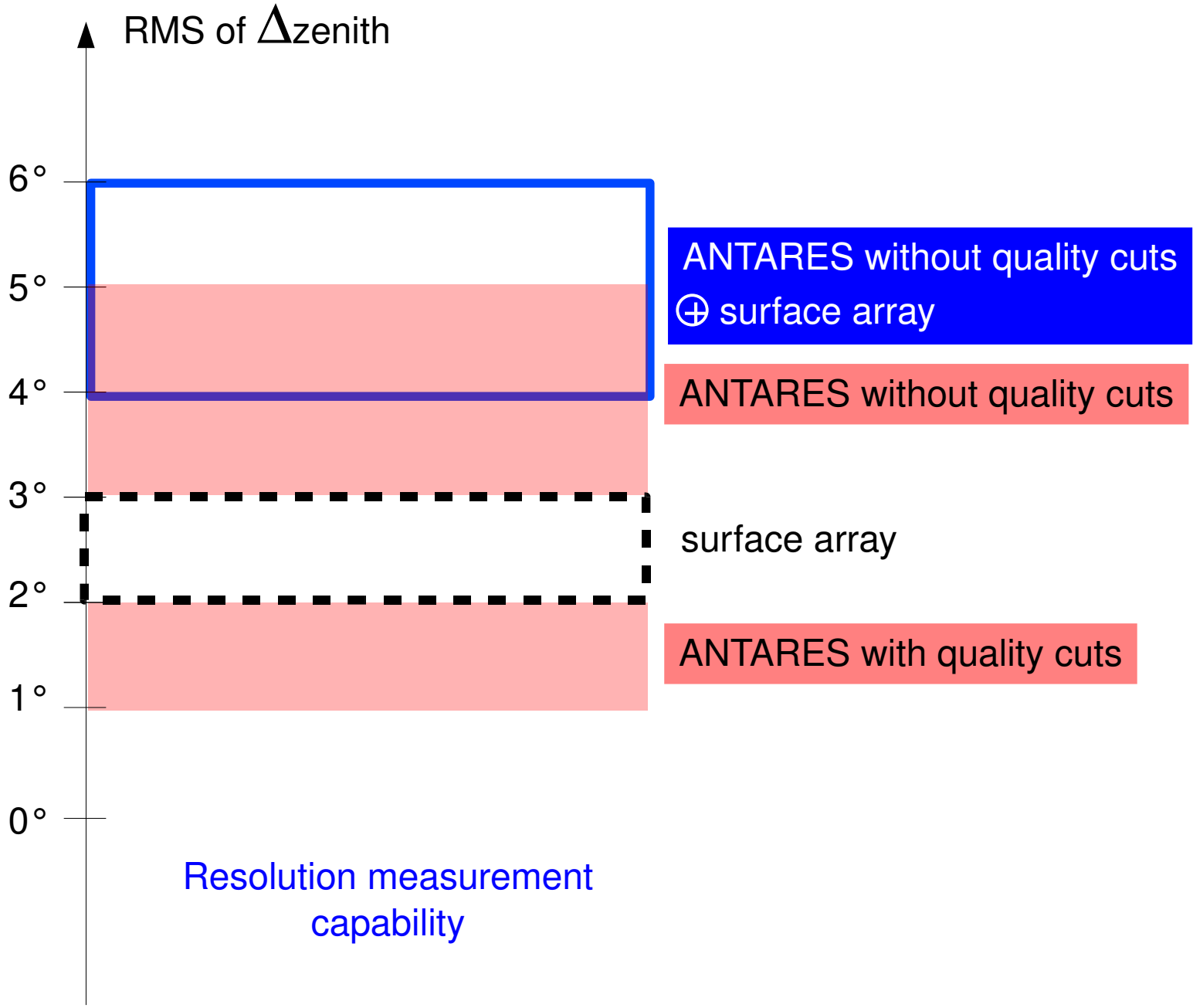
Summary


RMS of Δzenith
6°
5°
4°
3°
2°
1°
0°
ANTARES without quality cuts
ANTARES with quality cuts

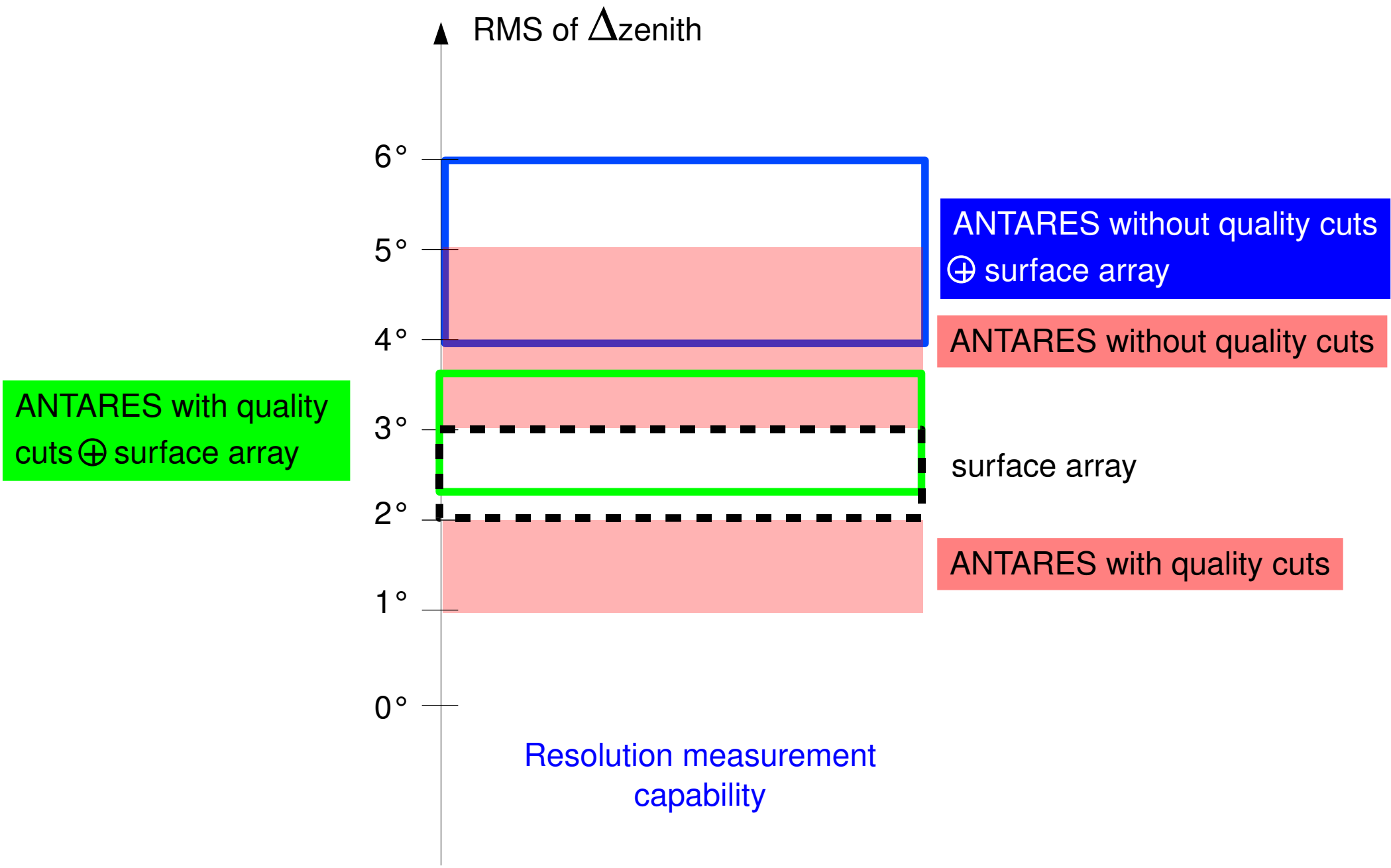
Summary


RMS of Δzenith
6°
5°
4°
3°
2°
1°
0°
ANTARES without quality cuts
surface array
ANTARES with quality cuts

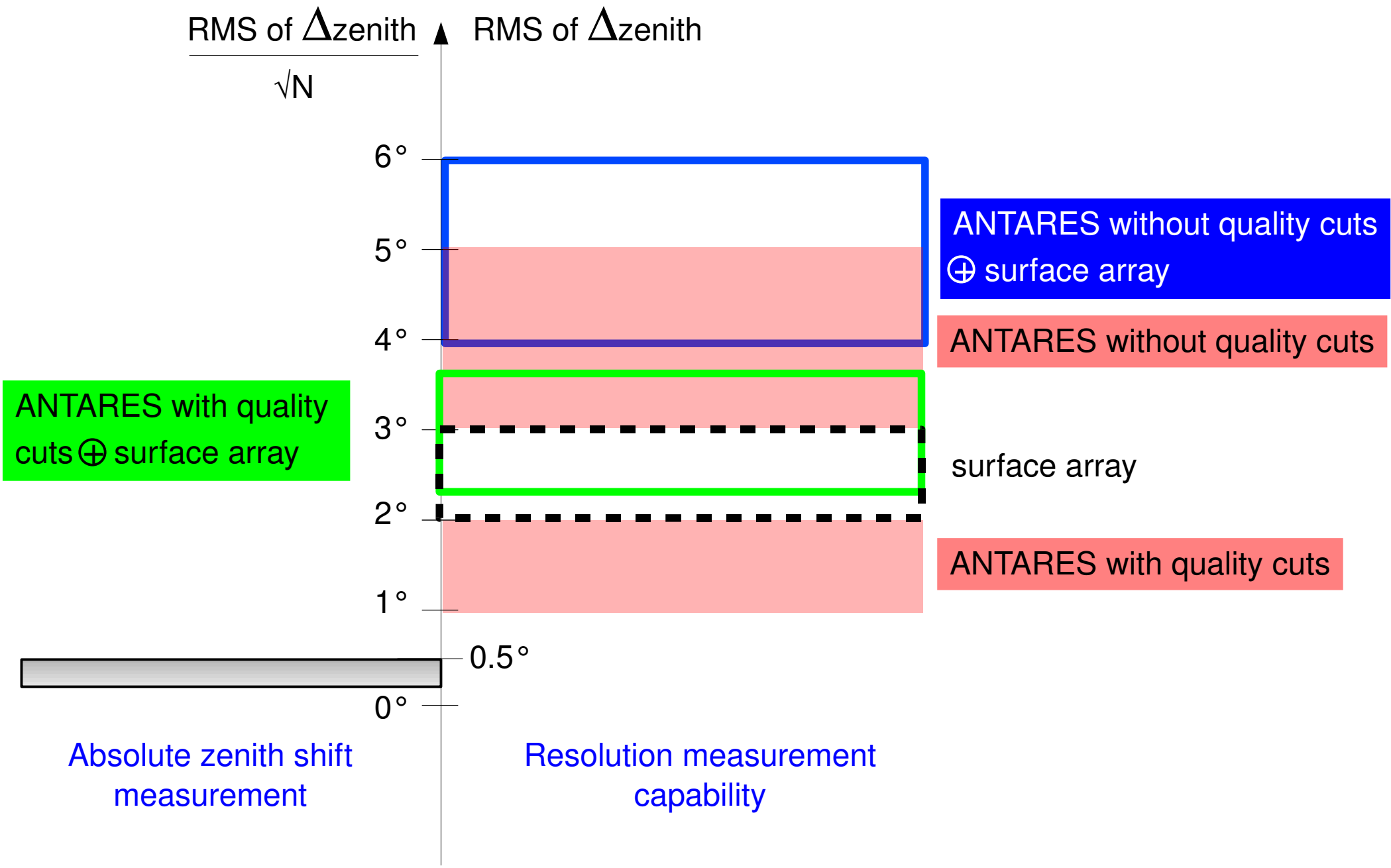
Summary


RMS of Δzenith
6°
5°
4°
3°
2°
1°
0°
ANTARES without quality cuts
⊕ surface array
ANTARES without quality cuts
surface array
ANTARES with quality cuts
Resolution measurement
capability

Summary


RMS of Δzenith
6°
5°
4°
3°
2°
1°
0°
ANTARES without quality cuts ⊕ surface array
ANTARES without quality cuts
ANTARES with quality cuts ⊕ surface array
surface array
ANTARES with quality cuts
Resolution measurement capability

Summary


RMS of Δzenith / √N
RMS of Δzenith
6°
5°
4°
3°
2°
1°
0.5°
0°
ANTARES without quality cuts ⊕ surface array
ANTARES without quality cuts
ANTARES with quality cuts ⊕ surface array
surface array
ANTARES with quality cuts
Absolute zenith shift measurement
Resolution measurement capability

Potential of the method :

For 5 days of operation,

resolution on $<\Delta zenith> \sim 0.5°$ and $<\Delta azimuth> \sim 1.5°$

resolution on $<\Delta X(Y)> \sim 12$ m (quality cuts)

⇒ possible to mesure shifts of this order of magnitude.

Effective area of the studied setups (ANTARES+surface array) ~ 3 m^2 wo cuts and 0.8 m^2 with quality cuts on ANTARES reconstructed track.

To check and improve :

Increase the statistics to study the repeatability of the method and to understand the shift of the mean of the zenith distribution,

Study other configurations to improve surface array resolution and effective area.

Investigate a way to check Optical Module angular acceptance considering the ratio of rates @ 0 m and @ 1000 m.