KM3NeT simulation: First steps in Erlangen

Sebastian Kuch
University Erlangen-Nürnberg
ANTARES

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bmb+f - Förderschwerpunkt
ANTARES
Großgeräte der physikalischen Grundlagenforschung

What ,Why , How ?

Full Simulation of different KM3 detector layouts and models.

Goal:

get a feeling for the influence of the detector parameters on the peformance of the detector.

Starting point:

Standard ANTARES Software tools
(similar to D.Zaborov, ANTARES-Soft-2002/008, 2004/004)

Simulation chain

Production → gentra

Simple production of muon tracks: Energy $10 - 10^6$ GeV, spectral index (-)1, whole solid angle, Surface drawing, can z = 1600m, r = 950m. → **No background!**

Detector simulation → km3

Including **hit** and **gen** to produce photon tables for different PM-types.

⇒ Some modifications of software were necessary!

Reconstruction → reco, Aartstartegy

Unmodified (In contrast to D.Zaborov)!

Analysis

Calculation of effective area and angular resolution:

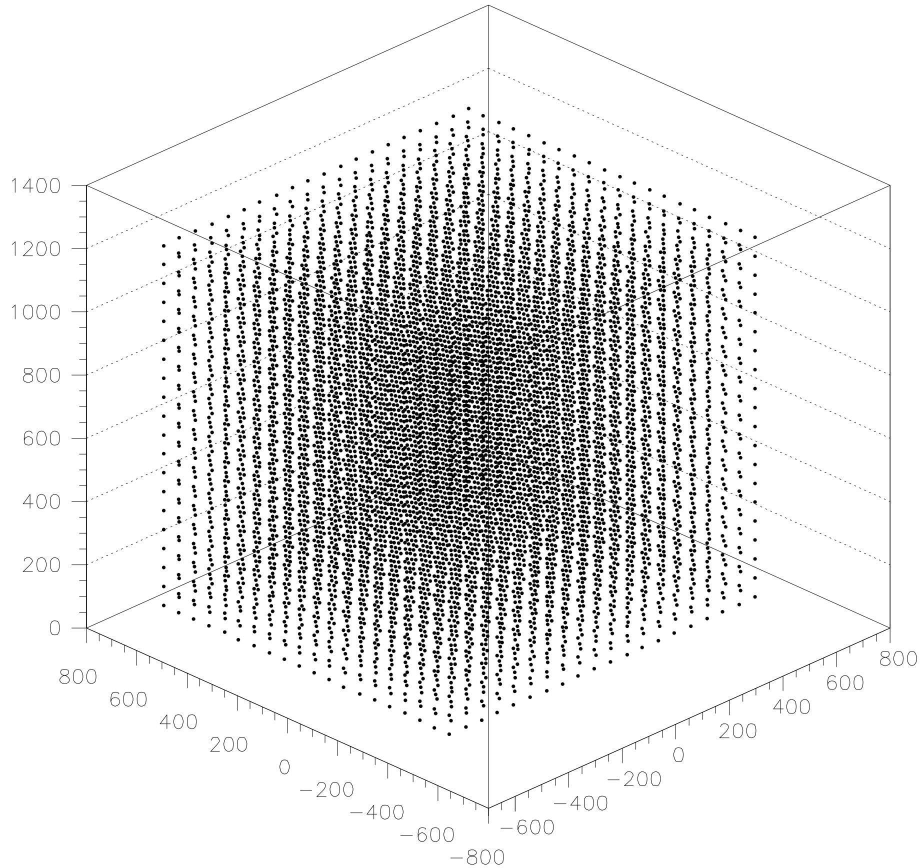
effective area: $A_{eff} = \frac{\sum_{n_{rec}} a_{eff}}{N_{sim}}$

n_{rec} number of reconstructed events, N_{sim} number of simulated events, a_{eff} visible geometric area of the cylindrical can volume for the particular muon track

angular resolution = median angular error

simple quality cut applied ('angular distance' Fit-Prefit $< 20°$)

General detector layout



cubic layout

20×20 strings

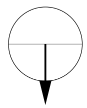
string-distance 60 m

storey-distance 60 m

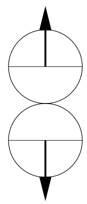
→ Used to compare storey layouts

cube detectors with ANTARES OM (10” Hamamatsu PM)

cube: 1 downward looking OM per storey (8000 OMs).

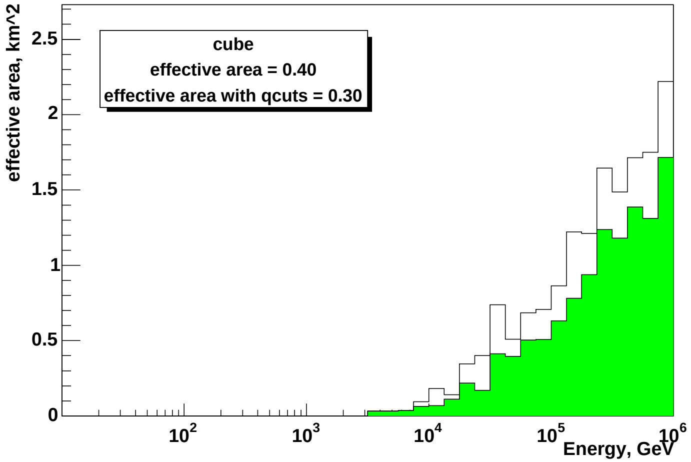


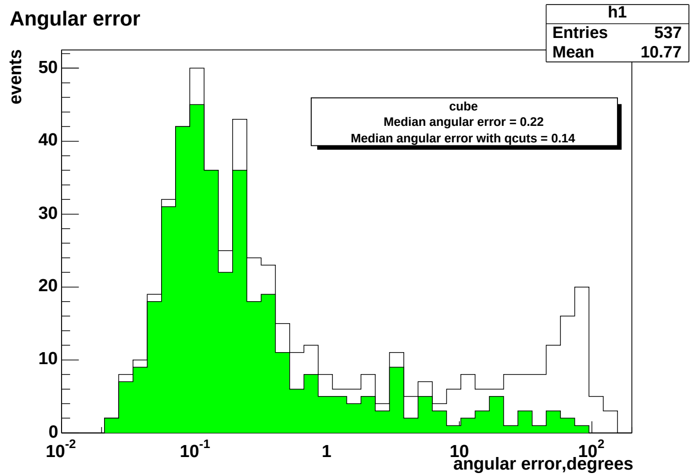
upcube: 1 downward looking and 1 upward looking OM per storey (16000 OMs).

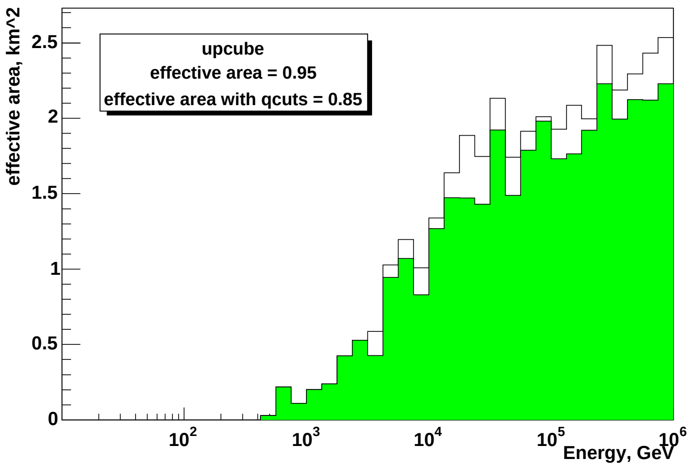


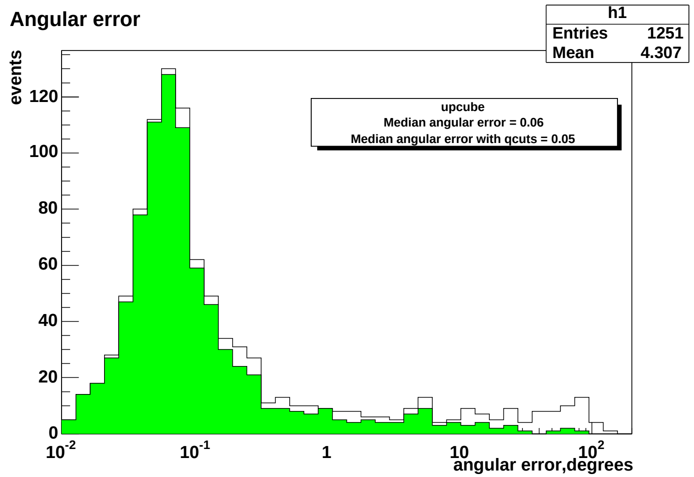
antcube: standard ANTARES storeys (24000 OMs).

results 1

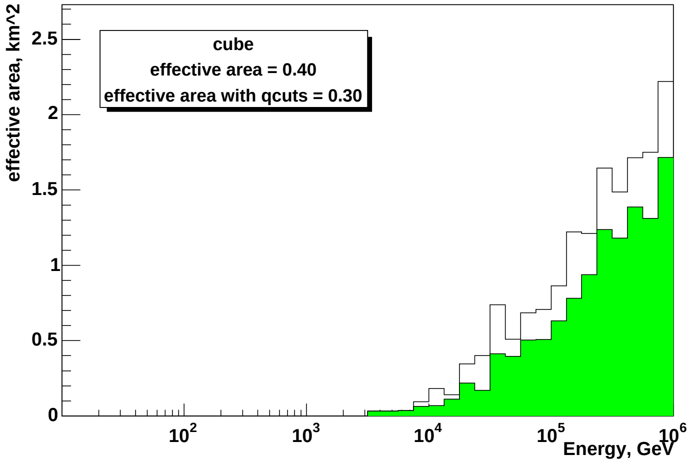

cube
effective area = 0.40
effective area with qcuts = 0.30
effective area, km^2
Energy, GeV

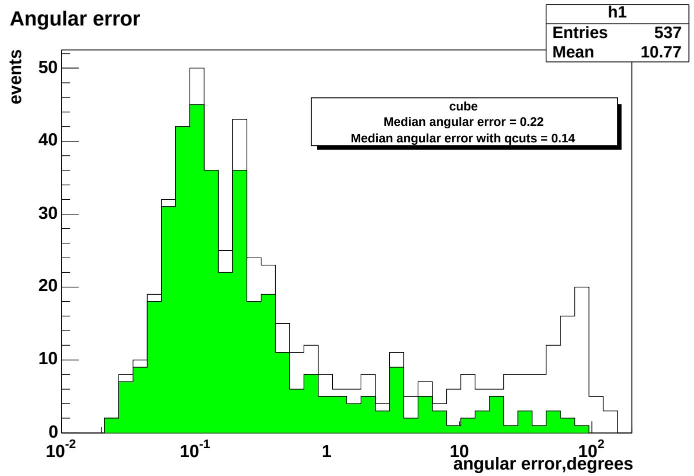

Angular error
h1
Entries 537
Mean 10.77
cube
Median angular error = 0.22
Median angular error with qcuts = 0.14
events
angular error,degrees

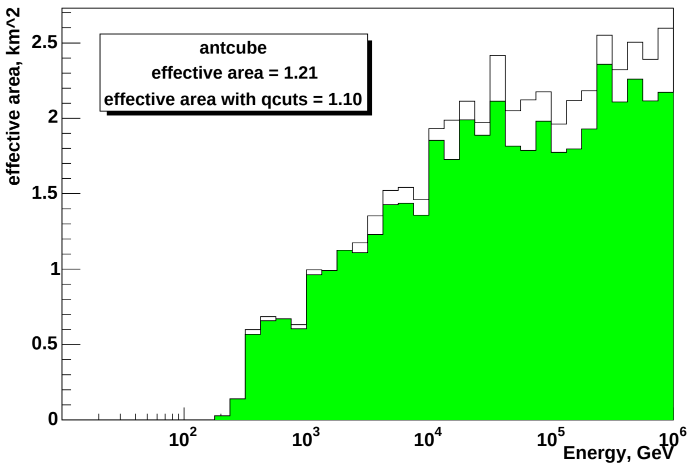

upcube
effective area = 0.95
effective area with qcuts = 0.85
effective area, km^2
Energy, GeV

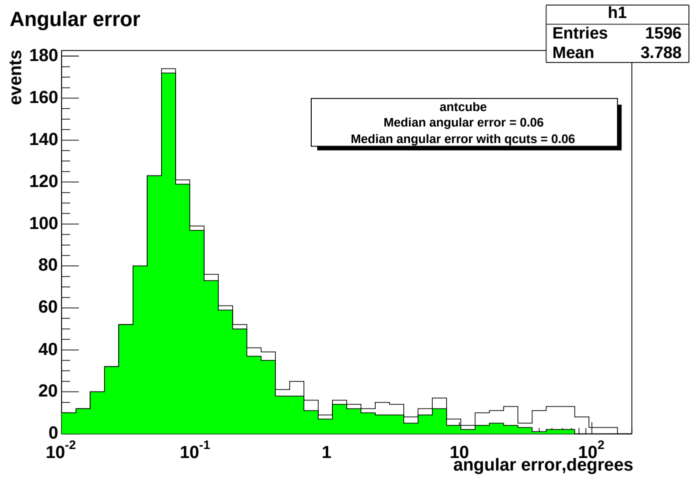

Angular error
h1
Entries 1251
Mean 4.307
upcube
Median angular error = 0.06
Median angular error with qcuts = 0.05
events
angular error,degrees

results 2


effective area, km^2
cube
effective area = 0.40
effective area with qcuts = 0.30
Energy, GeV


Angular error
h1
Entries 537
Mean 10.77
events
cube
Median angular error = 0.22
Median angular error with qcuts = 0.14
angular error,degrees


effective area, km^2
antcube
effective area = 1.21
effective area with qcuts = 1.10
Energy, GeV


Angular error
h1
Entries 1596
Mean 3.788
events
antcube
Median angular error = 0.06
Median angular error with qcuts = 0.06
angular error,degrees

result summary - cubes

detector	A_{eff} (km^2)	with qcuts	Energy Threshold (TeV)
cube	0.40	0.30	280
upcube	0.95	0.85	6.50
antcube	1.21	1.20	2.07

detector	angular error ($^\circ$)	with qcuts ($^\circ$)
cube	0.22	0.14
upcube	0.06	0.05
antcube	0.06	0.06

Energy Threshold $\rightarrow$ Center of bin where A_{eff} with qcuts larger than 1 km^2

cube detectors with cylindrical OM and 3.5" PM

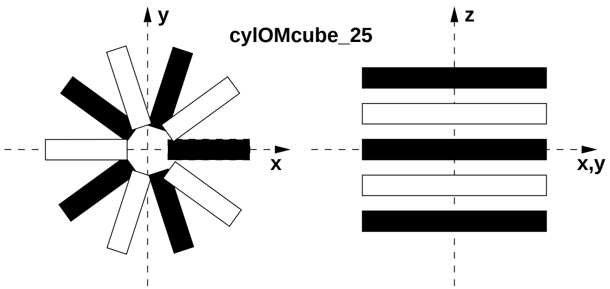
Properties of 3.5" PM used (the rest is unchanged!):

Diameter/ area (obviously!) = 3.5" / 0.0054 cm^2

Quantum efficiency $\sim$ 30 % Maximum (just scaled up)

Angular acceptance $\sim \cos(\theta)$

Storey layout:

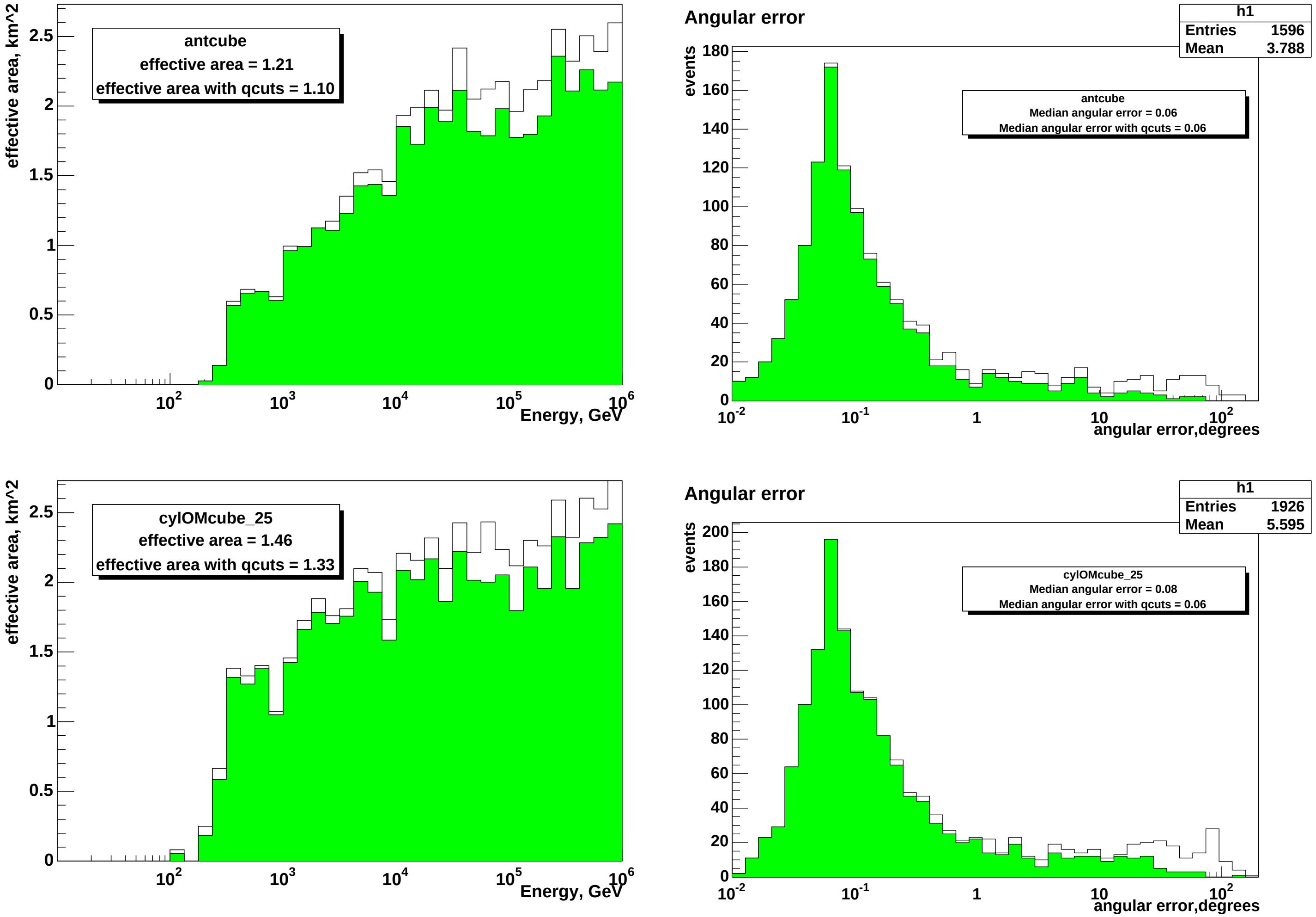


cylOMcube_x $\rightarrow \frac{x}{5}$ layers of 5 PMs

distance between layers $d = 7.5\,\mathrm{cm}$

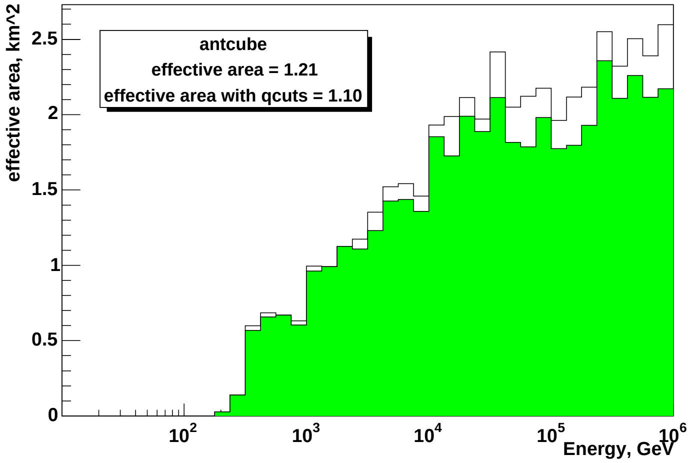
Every PM is treated as seperate OM!

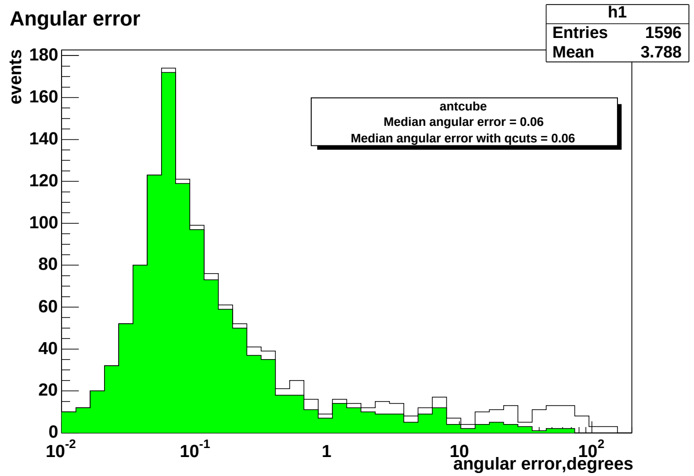
results 3

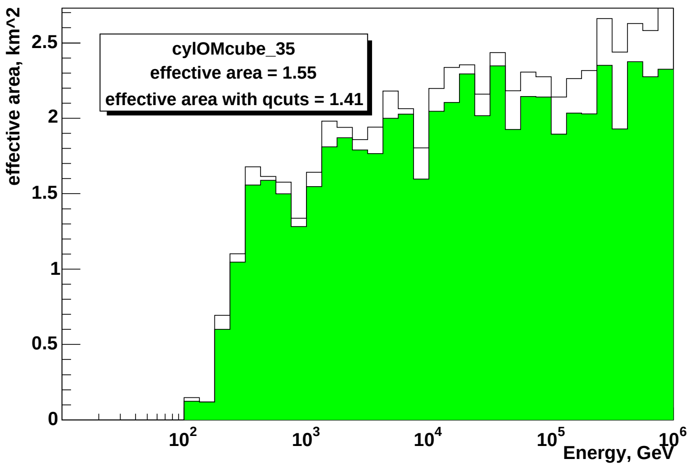


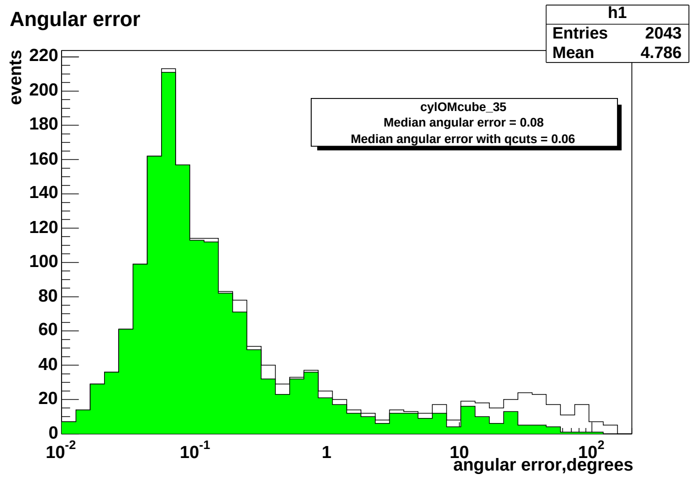
antcube
effective area = 1.21
effective area with qcuts = 1.10
effective area, km^2
Energy, GeV
Angular error
h1
Entries 1596
Mean 3.788
antcube
Median angular error = 0.06
Median angular error with qcuts = 0.06
events
angular error,degrees
cylOMcube_25
effective area = 1.46
effective area with qcuts = 1.33
effective area, km^2
Energy, GeV
Angular error
h1
Entries 1926
Mean 5.595
cylOMcube_25
Median angular error = 0.08
Median angular error with qcuts = 0.06
events
angular error,degrees

results 4


antcube
effective area = 1.21
effective area with qcuts = 1.10
effective area, km^2
Energy, GeV
0
0.5
1
1.5
2
2.5
10^2
10^3
10^4
10^5
10^6


Angular error
h1
Entries 1596
Mean 3.788
antcube
Median angular error = 0.06
Median angular error with qcuts = 0.06
events
angular error,degrees
0
20
40
60
80
100
120
140
160
180
10^{-2}
10^{-1}
1
10
10^2


cylOMcube_35
effective area = 1.55
effective area with qcuts = 1.41
effective area, km^2
Energy, GeV
0
0.5
1
1.5
2
2.5
10^2
10^3
10^4
10^5
10^6


Angular error
h1
Entries 2043
Mean 4.786
cylOMcube_35
Median angular error = 0.08
Median angular error with qcuts = 0.06
events
angular error,degrees
0
20
40
60
80
100
120
140
160
180
200
220
10^{-2}
10^{-1}
1
10
10^2

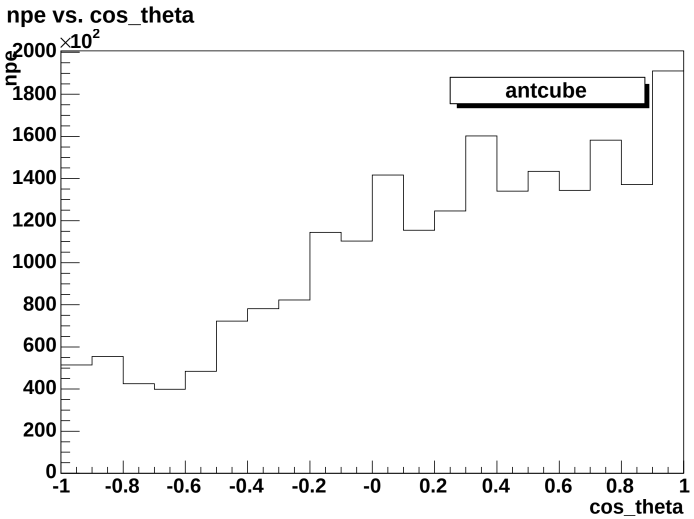
result summary - cylOMcubes

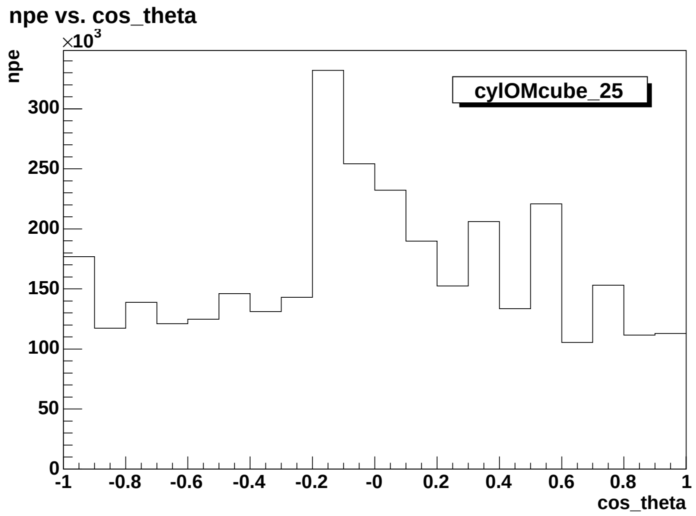
detector	A_{eff} (km^2)	with qcuts	Energy Threshold (TeV)
antcube	1.21	1.10	2.07
cylOMcube_25	1.46	1.33	0.37
cylOMcube_35	1.55	1.41	0.28

detector	angular error ($^\circ$)	with qcuts ($^\circ$)
antcube	0.06	0.06
cylOMcube_25	0.08	0.05
cylOMcube_35	0.08	0.06

npe vs. cos(θ)

Produced events with $E = 50\,\text{TeV}$, Plotted npe over cos(θ)



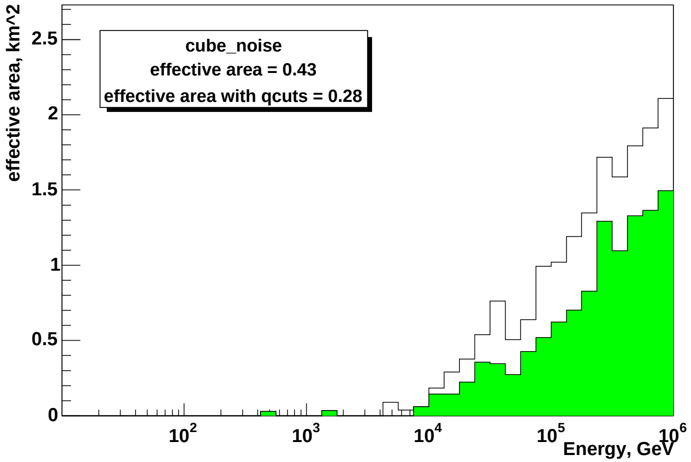


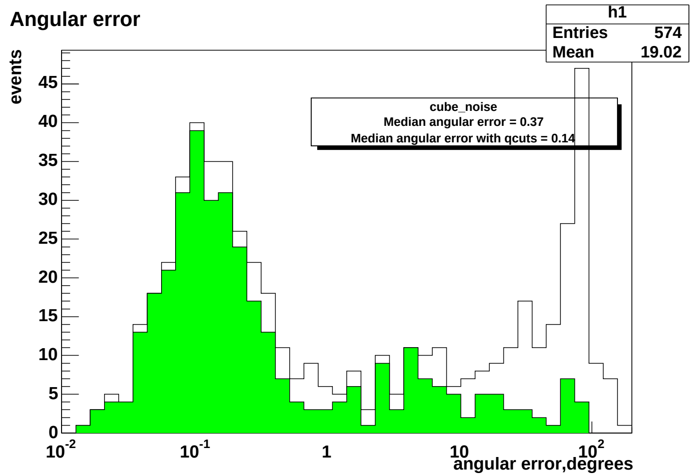
$\rightarrow$ Large statistical effects because of different d.o.c.a. !

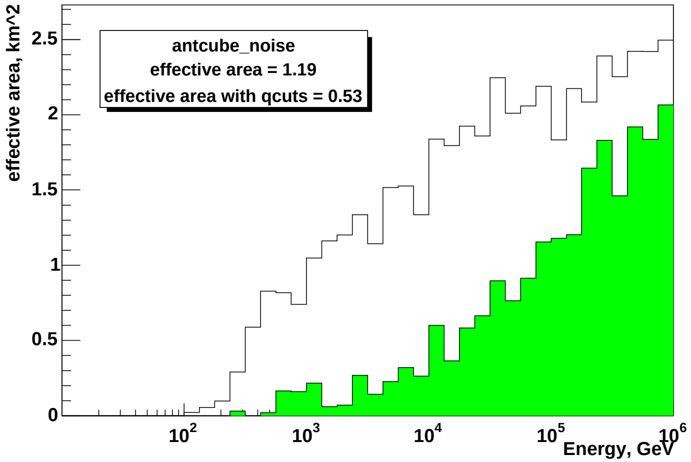
But the principle behaviour can be seen.

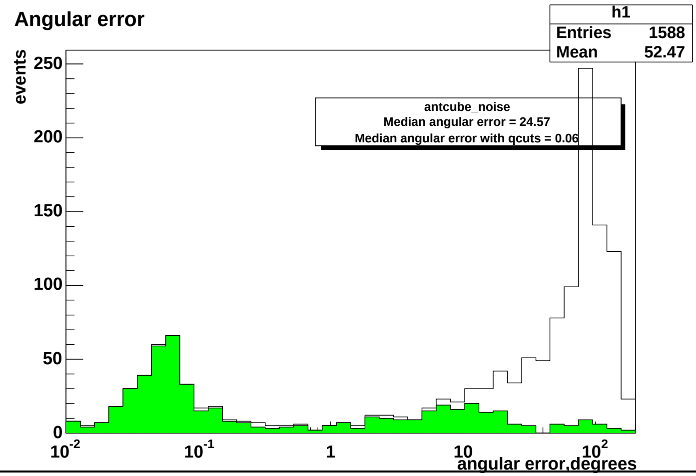
events with K40 noise 1

Rate 60 kHz per PM, scaled according to PM area!



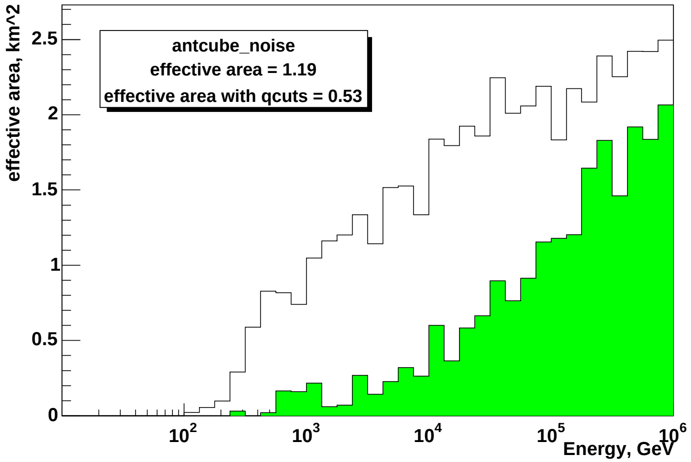


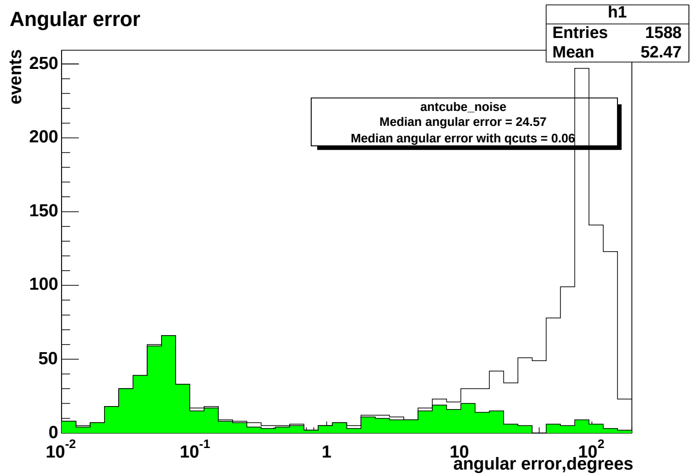


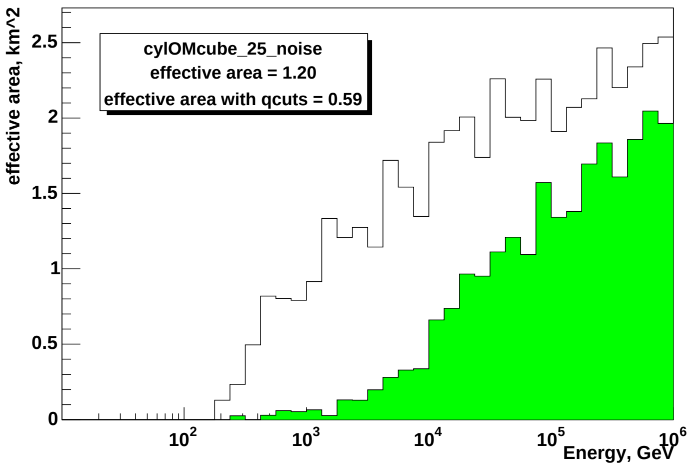


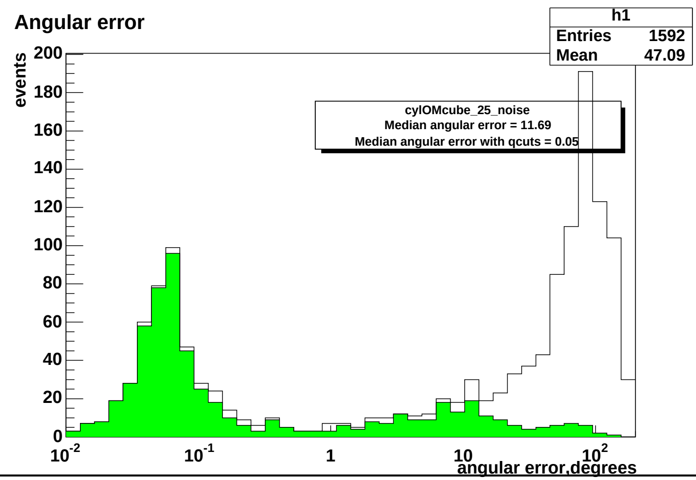
events with K40 noise 2

Rate 60 kHz per PM, scaled according to PM area!



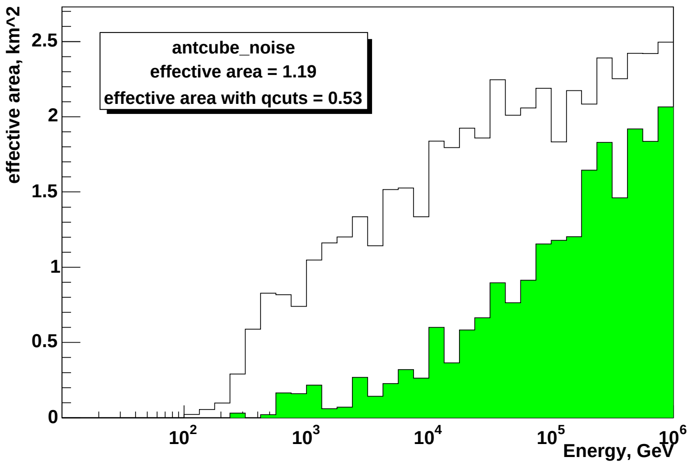


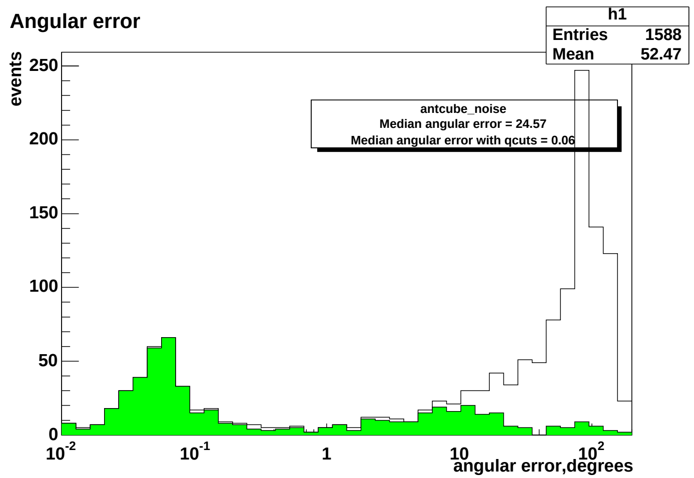


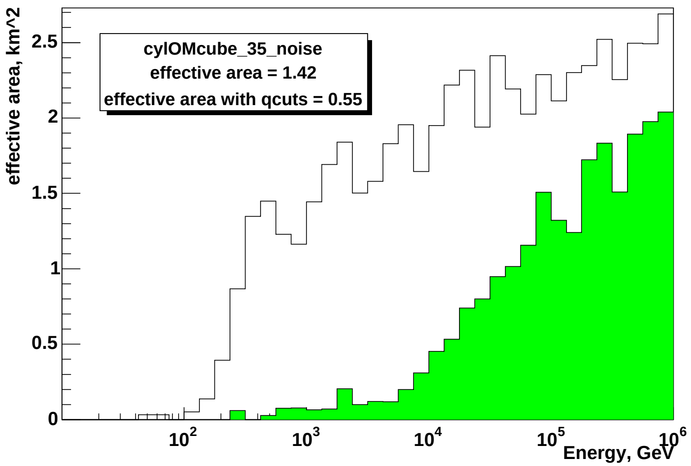


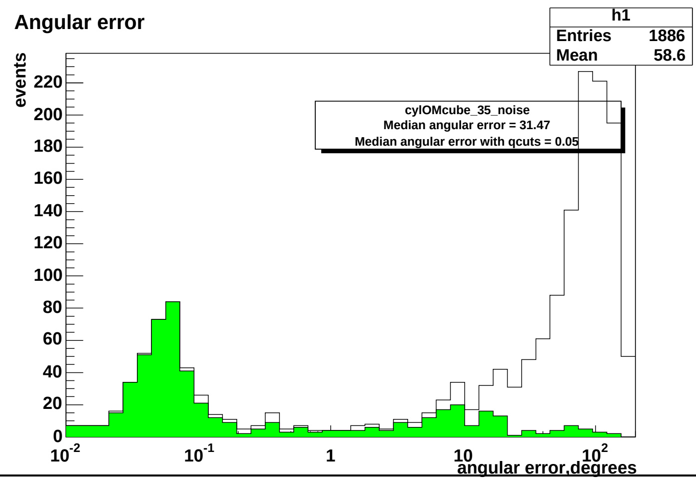
events with K40 noise 3

Rate 60 kHz per PM, scaled according to PM area!









result summary - K40 noise

detector	A_{eff} (km^2)	with qcuts
antcube	1.19	0.53
cylOMcube_25	1.20	0.59
cylOMcube_35	1.42	0.55

detector	angular error ($^\circ$)	with qcuts ($^\circ$)
antcube	24.57	0.06
cylOMcube_25	11.69	0.05
cylOMcube_35	31.47	0.05

Modification of causality filter

(D.Zaborov ANTARES-Soft 2002-08)

Standard causality filter:

$$| dt | - dr/v_{light} \leq 20\,\text{ns}$$

Large Detectors → Large Distances → Absorption has to be accounted for !

Two hits time separation defined by myon velocity (∼ c)

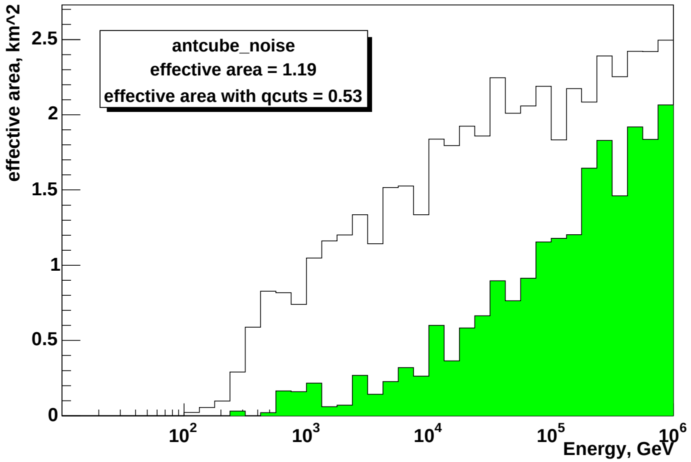
$$\Rightarrow$$

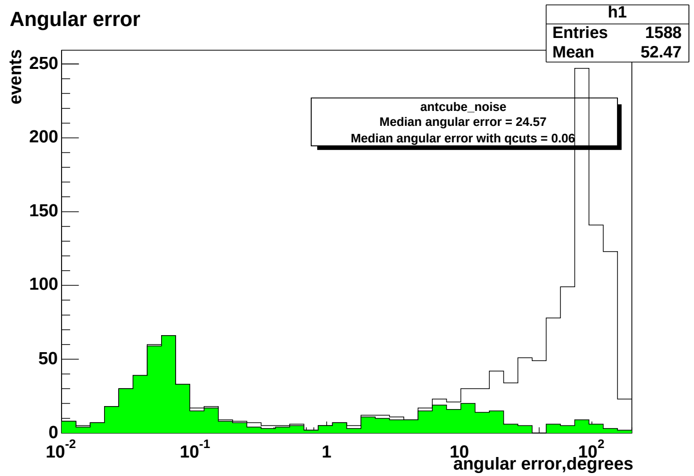
Additional causality condition:

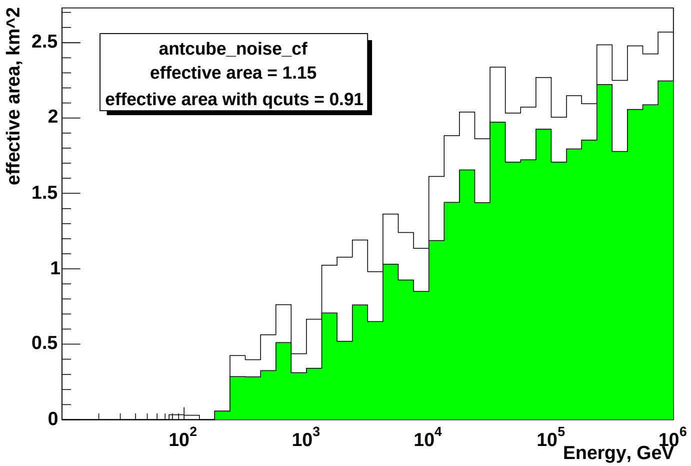
$$|| dt | - dr/c_{vacuum} | \leq 500 ns$$

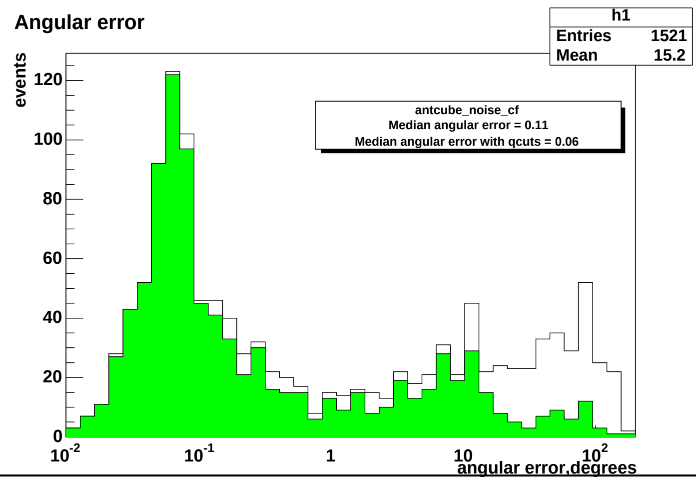
results with Dmitrys modified causality filter 1

rate 60 kHz per PM, scaled according to PM area!



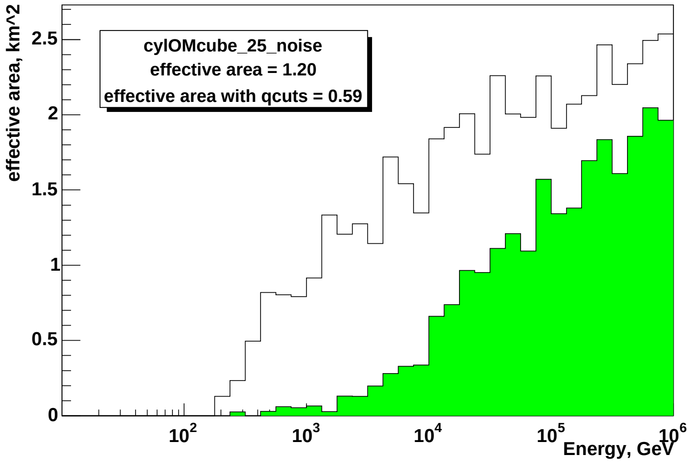


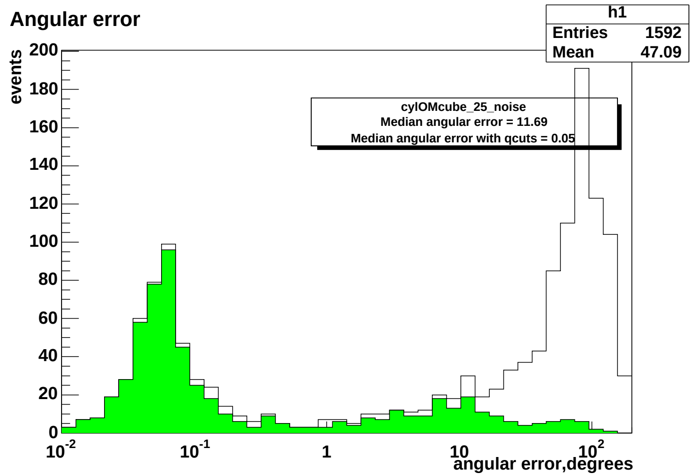


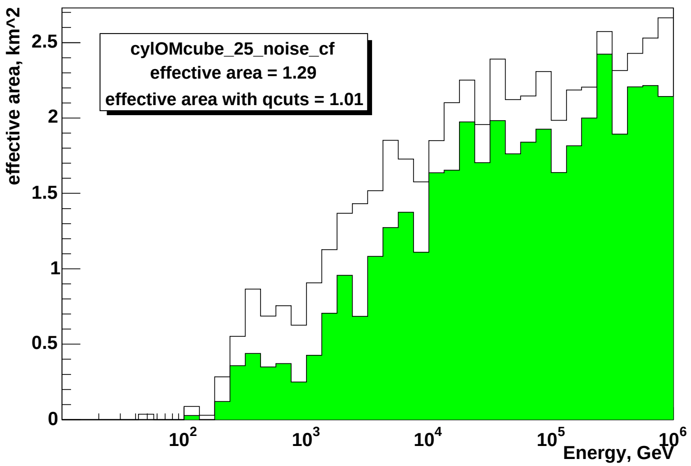


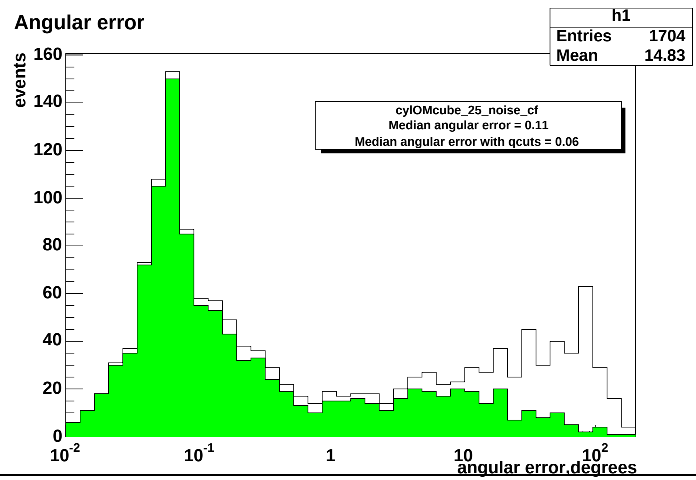
results with Dmitrys modified causality filter 2

rate 60 kHz per PM, scaled according to PM area!



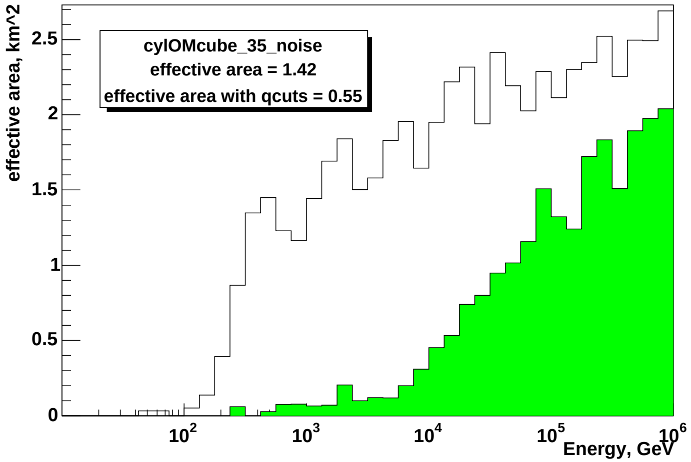


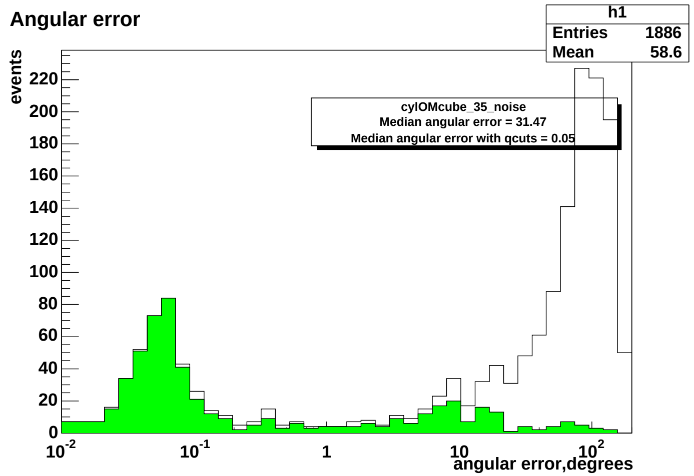


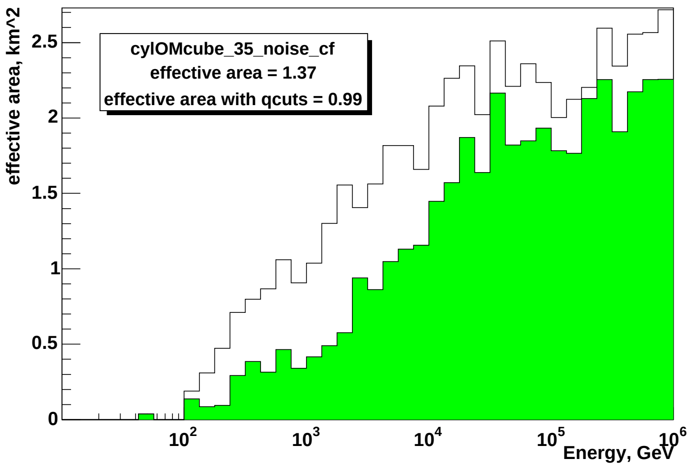


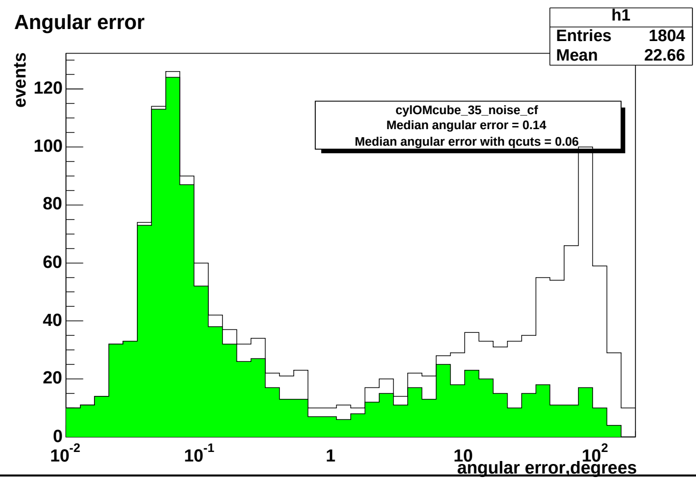
results with Dmitrys modified causality filter 3

rate 60 kHz per PM, scaled according to PM area!









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result summary - modified causality filter

detector	A_{eff} (km^2) with qcuts	A_{eff} with qcuts (km^2) modified filter
antcube	0.53	0.91
cylOMcube_25	0.59	1.01
cylOMcube_35	0.55	0.99

detector	angular error ($^\circ$) without qcuts	angular error without qcuts ($^\circ$) modified filter
antcube	24.57	0.11
cylOMcube_25	11.69	0.11
cylOMcube_35	31.47	0.14

summary and conclusions

- Antares Software has been modified for km3-detectors, with large numbers of PMs per storey.
- Cylindrical OM looks promising.
- Problems when including K40 noise, but...
- Modified causality filter seems to work fine.

next steps

- Realistic simulation of neutrino interactions (including atmosspehric background, showers, ...)
- Find decent(=realistic) geometry.
- Include site parameters in simulation.
- Experiment with heterogenous detector geometries.
- ...