Moon Shadow Observation by IceCube

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for the IceCube Collaboration

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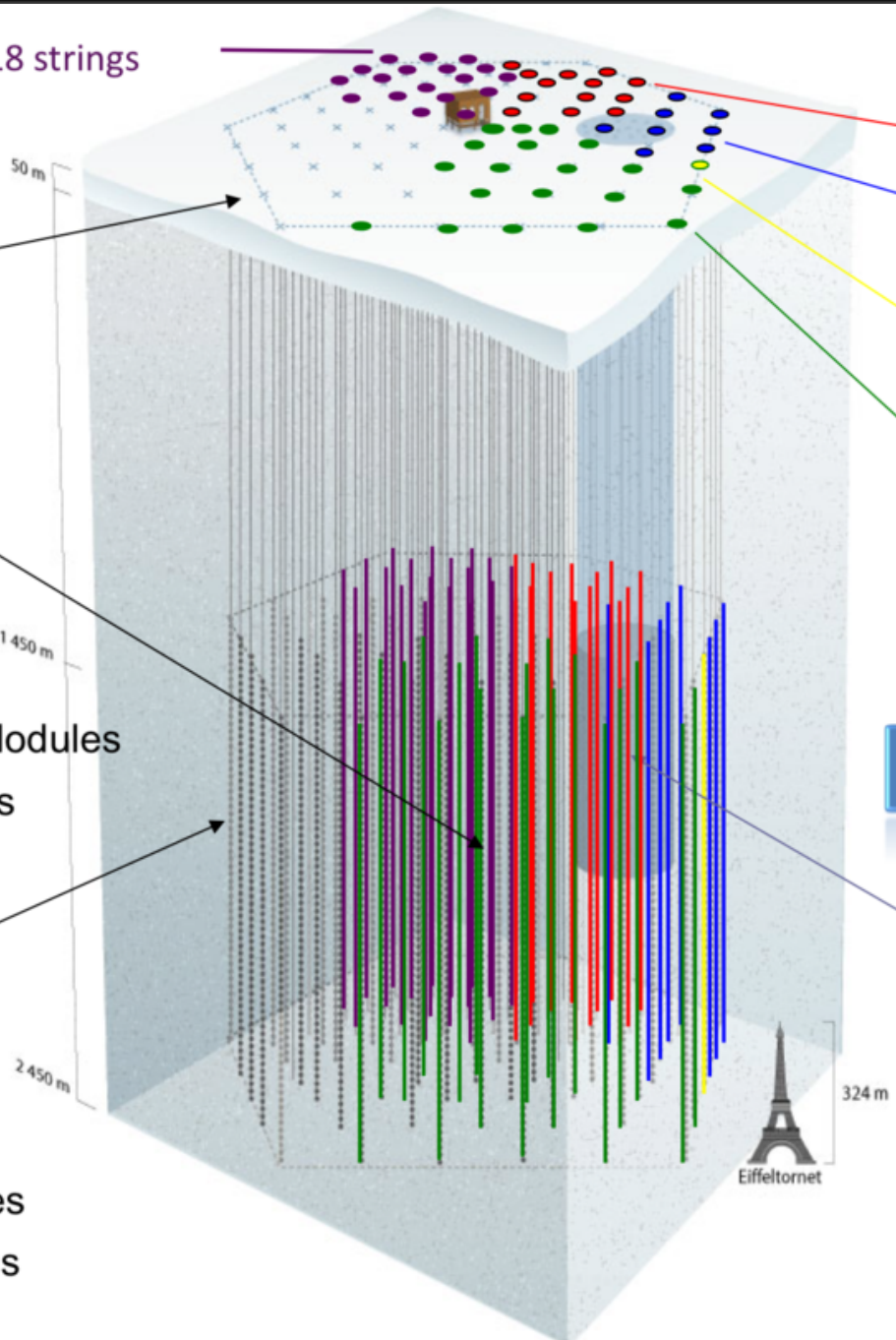
Mediteranian Antarctic Neutrino Telescope Symposium

Outline



IceTop

Air shower detetor

threshold ~ 300 TeV

DeepCore

6 additional strings ,

60 Optical Modules

7 or 10 m between Modules

72 m between Strings

InIce

70-80 Strings ,

60 Optical Modules

17 m between Modules

125 m between Strings

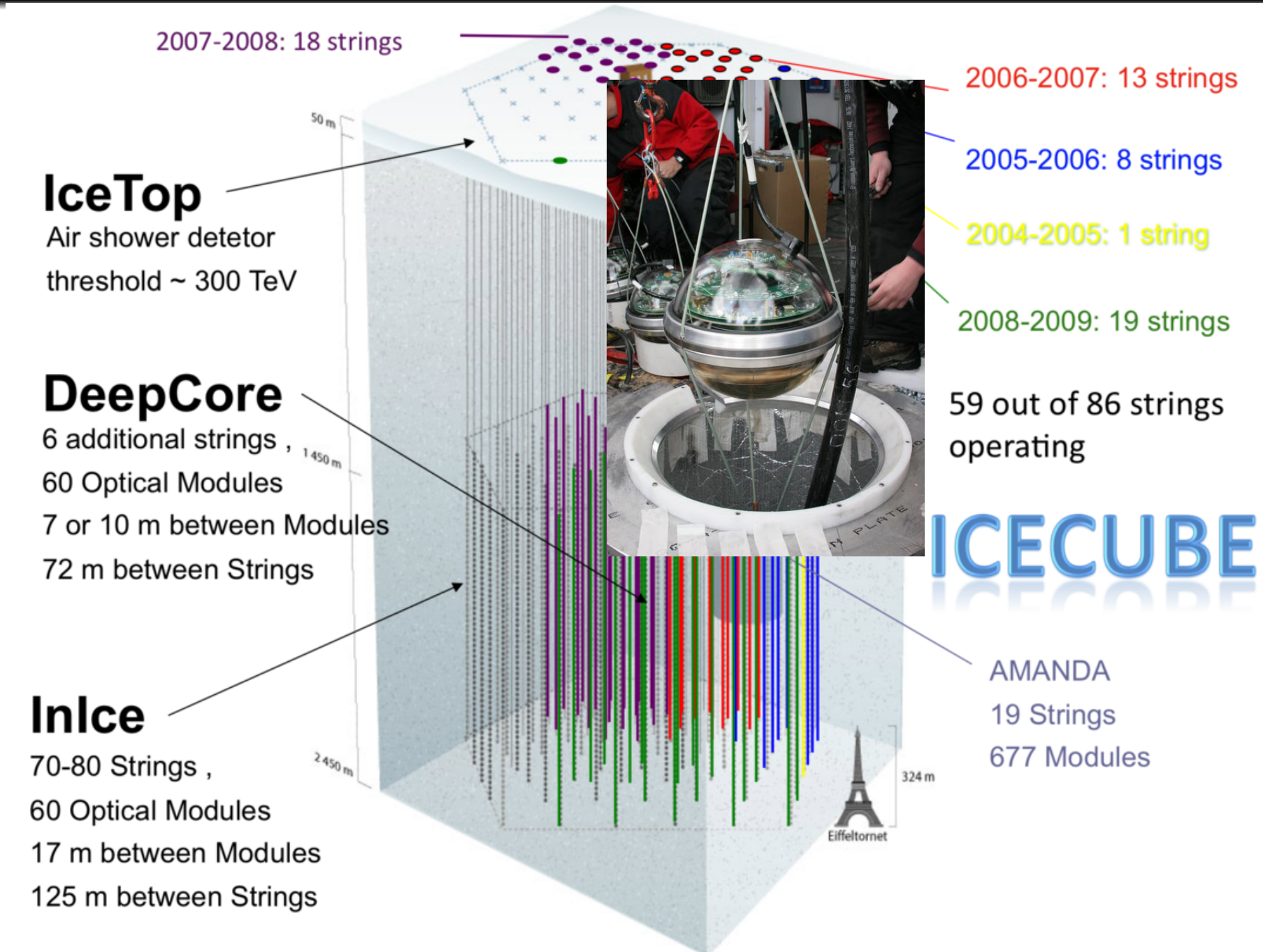
59 out of 86 strings operating

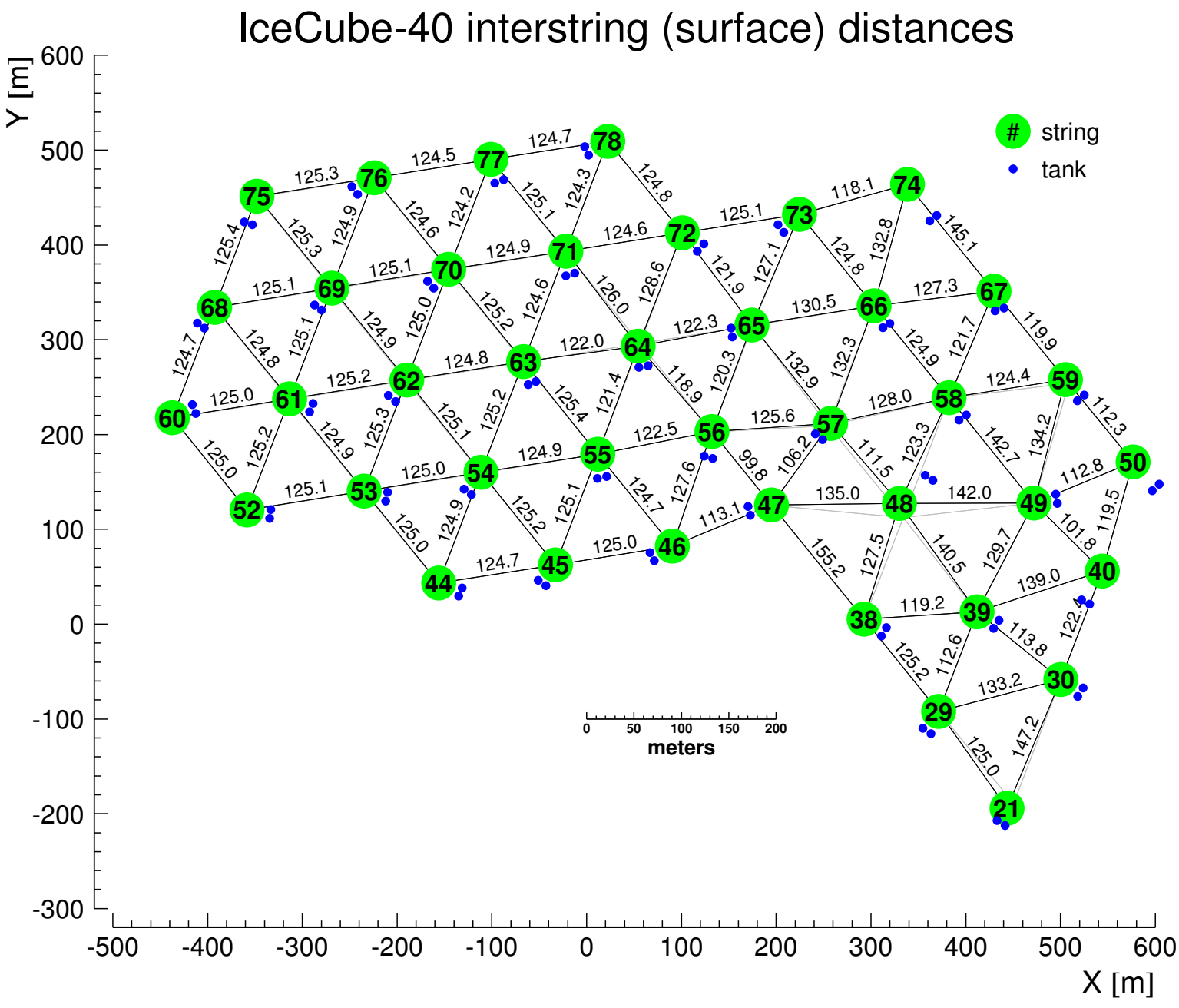
ICECUBE

AMANDA

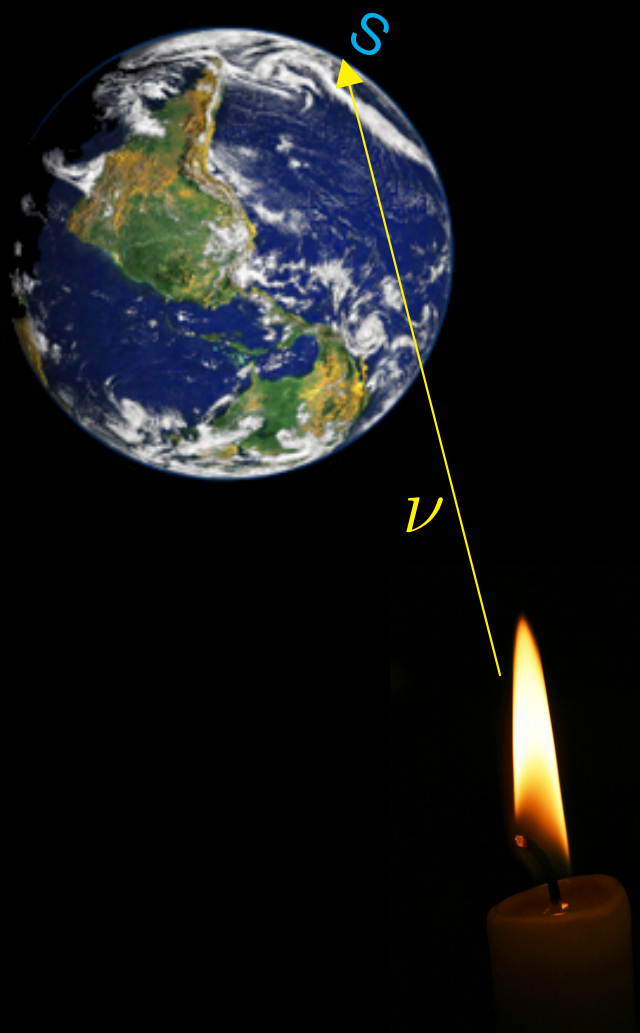
19 Strings

677 Modules

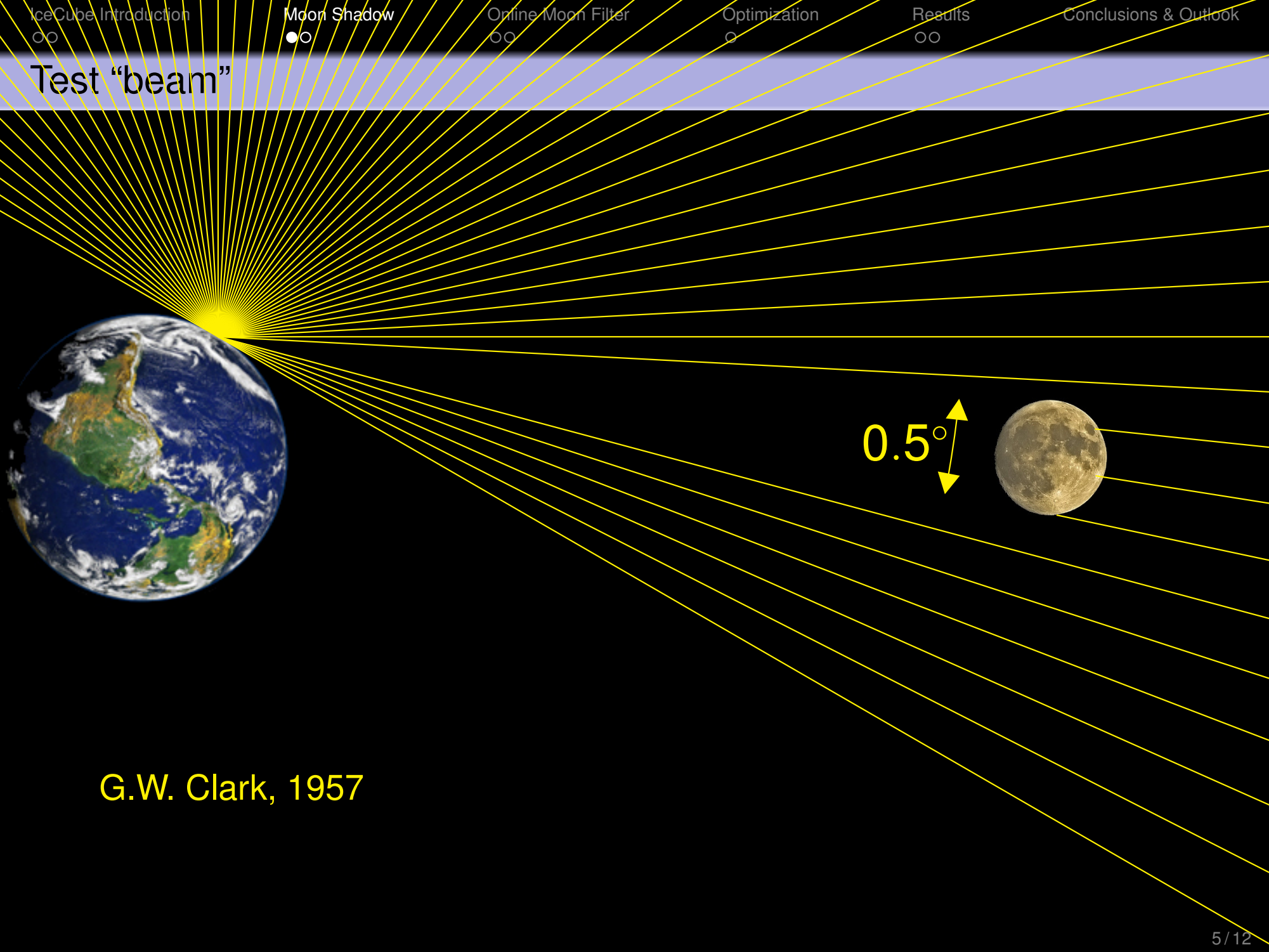

2007-2008: 18 strings
2006-2007: 13 strings
2005-2006: 8 strings
2004-2005: 1 string
2008-2009: 19 strings
IceTop
Air shower detetor
threshold ~ 300 TeV
DeepCore
6 additional strings ,
60 Optical Modules
7 or 10 m between Modules
72 m between Strings
InIce
70-80 Strings ,
60 Optical Modules
17 m between Modules
125 m between Strings
59 out of 86 strings operating
ICECUBE
AMANDA
19 Strings
677 Modules
50 m
1 450 m
2 450 m
324 m
Eiffeltornet


IceCube-40 interstring (surface) distances
string
tank
Y [m]
X [m]
meters
0 50 100 150 200

Test “beam”

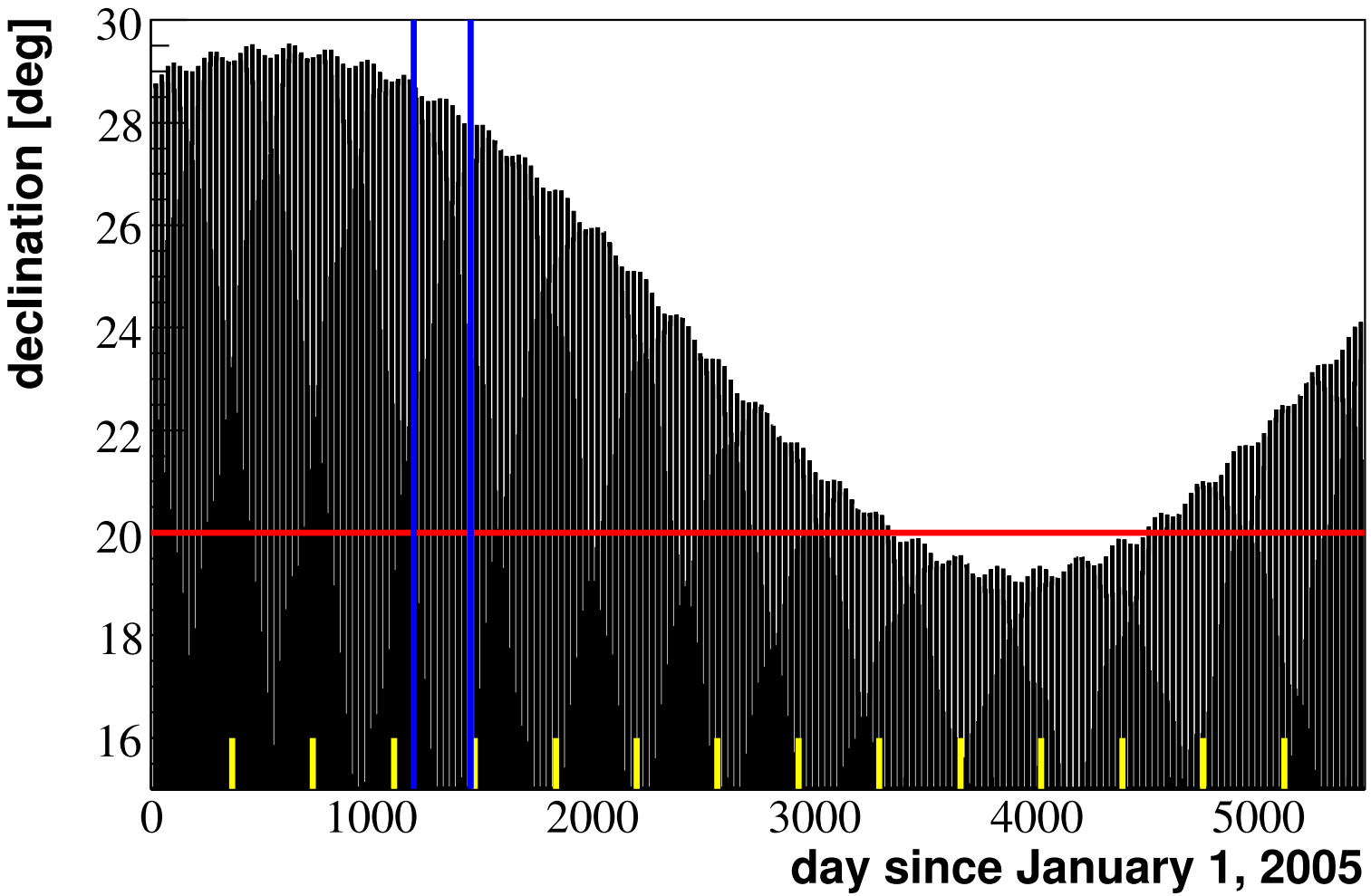


Test “beam”



G.W. Clark, 1957

Moon declination during IceCube's first 15 years



Online Filter Definition

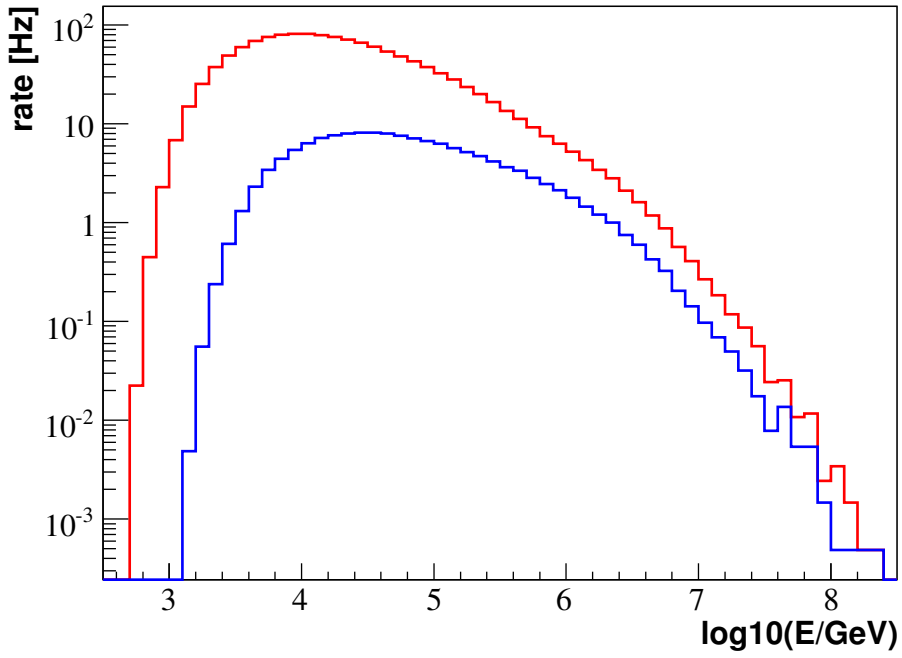
Definition:

- The Moon must be at least 15° above the horizon
- $N_{\mathrm{DOM}} \geq 12$
- $N_{\mathrm{string}} \geq 3$
- $|\theta_{\mathrm{trackfit}} - \theta_{\mathrm{Moon}}| < 10°$
- $|\phi_{\mathrm{trackfit}} - \phi_{\mathrm{Moon}}| < 40° / \cos\theta_{\mathrm{Moon}}$

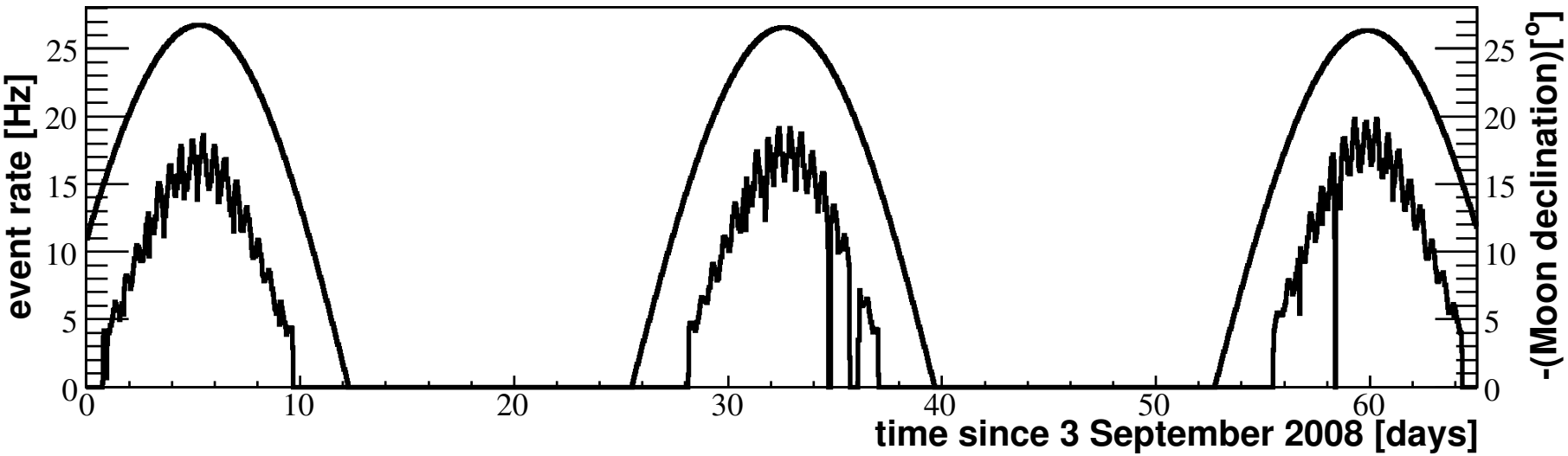
Characteristics:

- 8.5 days per Moon cycle
- max declination 27°
- rates
  - min: 4 Hertz
  - average: 12 Hertz
  - max: 20 Hertz
  - yearly average: 5 Hertz

Cosmic Ray primary energy spectrum (CORSIKA) for all events triggering IceCube and for all triggered events passing the online Moon filter.



Filter Rate (exp)



- higher rates for higher Moon elevations
- bi-daily fluctuation due to 40-string geometry

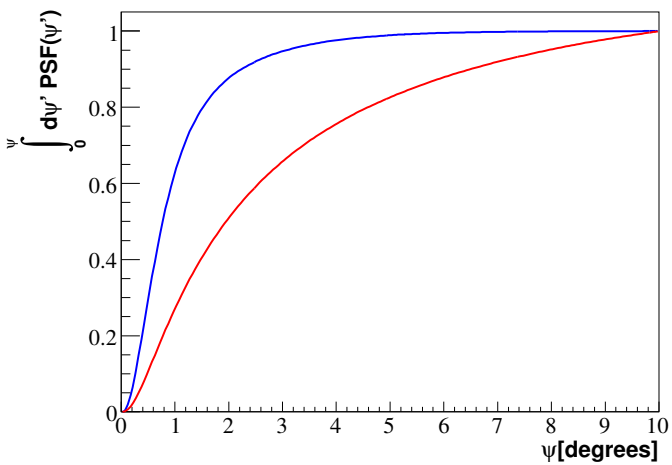
Optimizing Offline Event Selection and Search Bin Size

Maximizing:

$$S(\text{cuts}) = \frac{N_{\text{"signal"}}}{\sqrt{N_{\text{CR}\mu}}} \propto \frac{\sqrt{\eta(\text{cuts})}}{\Psi_{\text{med}}(\text{cuts})}$$

yields:

- $N_{\text{dir}} \geq 6$
- $L_{\text{dir}} \geq 400\,\text{m}$
- $\Psi_{\text{estimated}} \leq 1.3°$



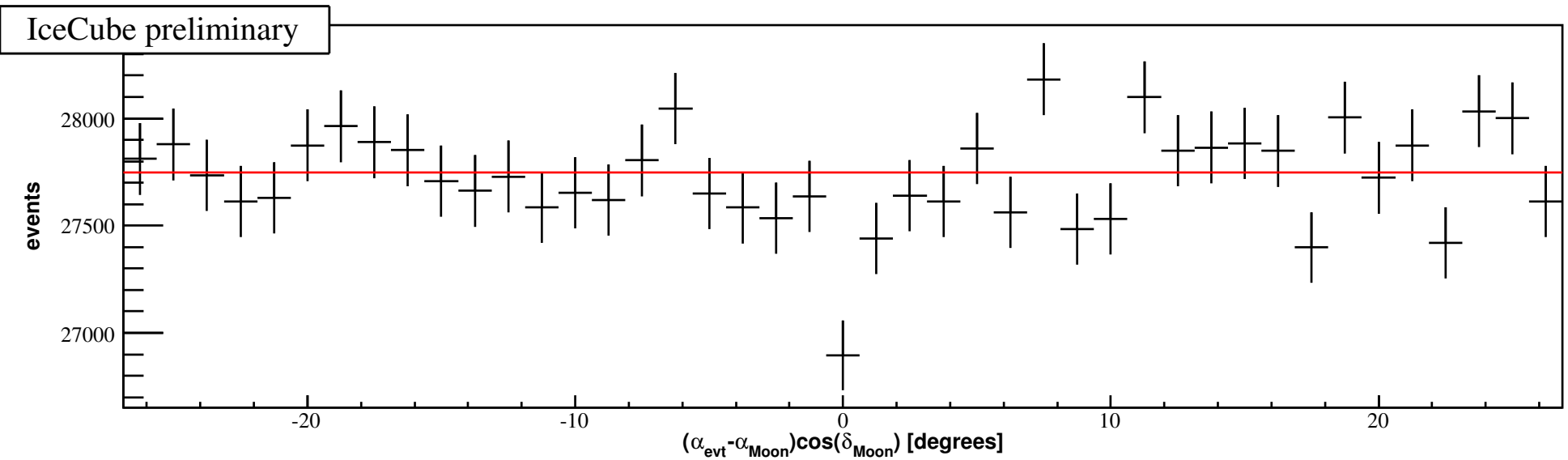
Maximizing:

$$S(\text{binsize}) \propto \frac{\int_0^{\text{binsize}} PSF(\Psi')d\Psi'}{\text{binsize}}$$

yields:

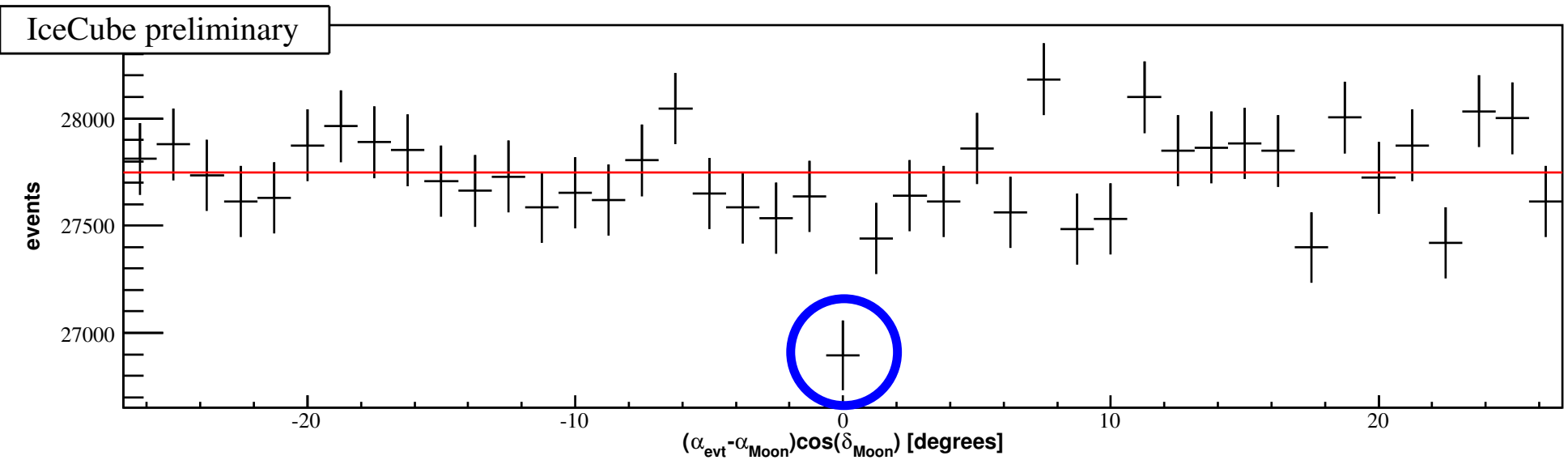
- Circular bin radius: 0.7°
- Square bin side: 1.25°

RA distribution relative to Moon



Moon zenith band: $|\theta_{\text{track}} - \theta_{\text{Moon}}| \leq 0.625°$.
RA binsize: 1.25°.

RA distribution relative to Moon



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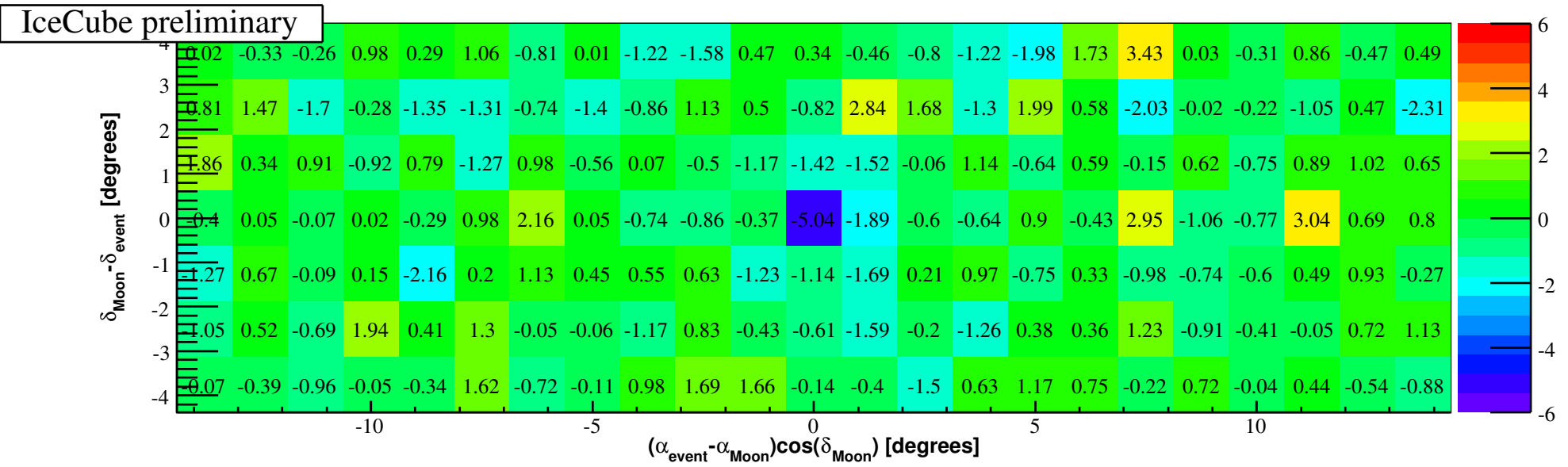
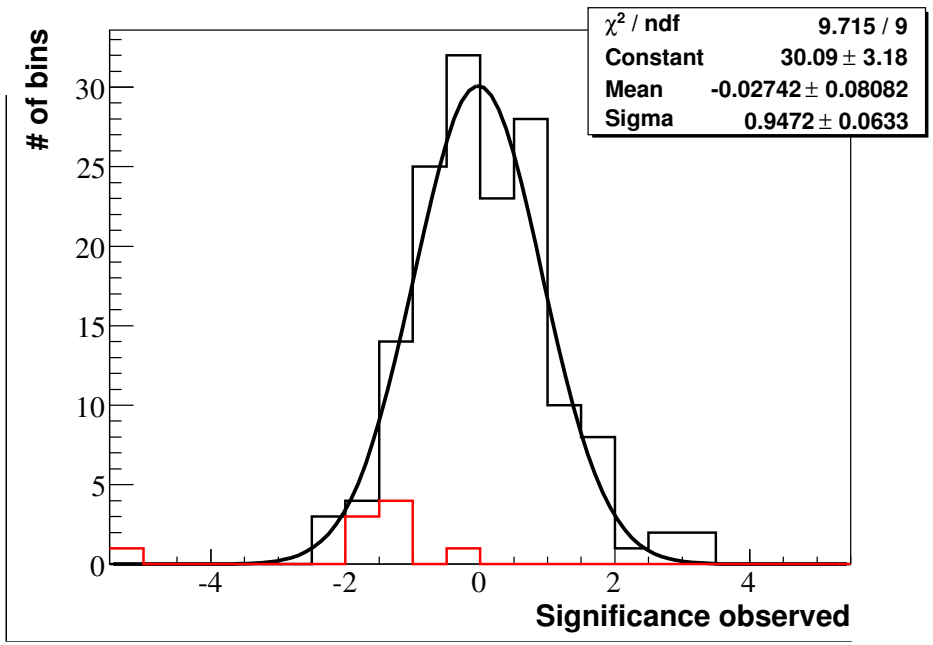
Li & Ma Significance Distribution



$$S_{\text{Li+Ma}} = \frac{N_{\text{on}} - \alpha N_{\text{off}}}{\sqrt{\alpha(N_{\text{on}} + N_{\text{off}})}}.$$



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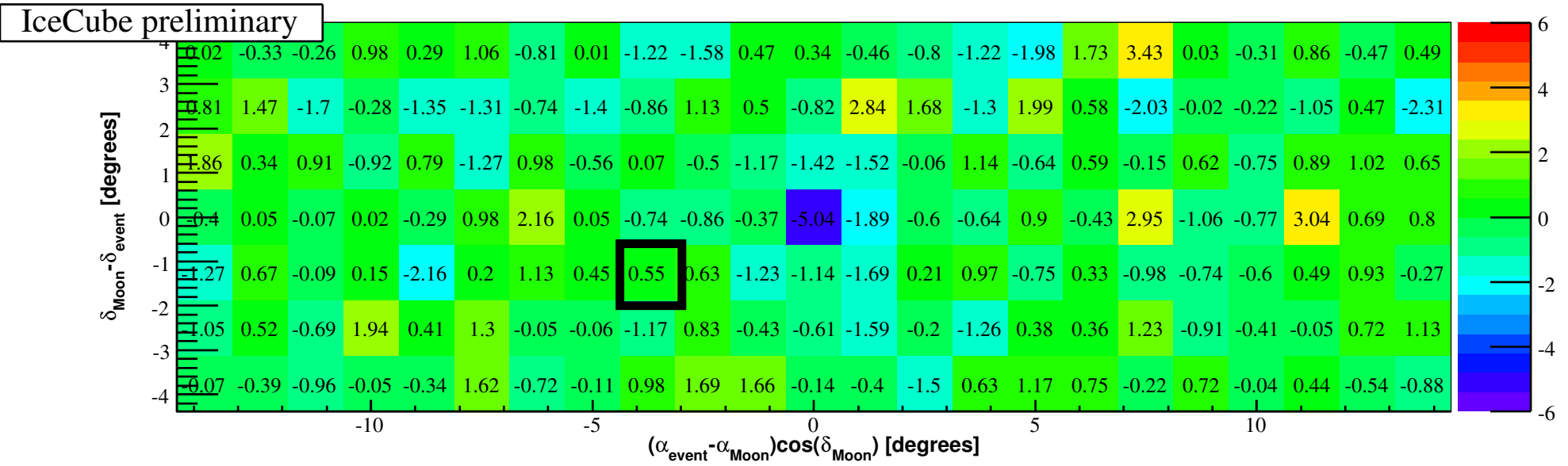

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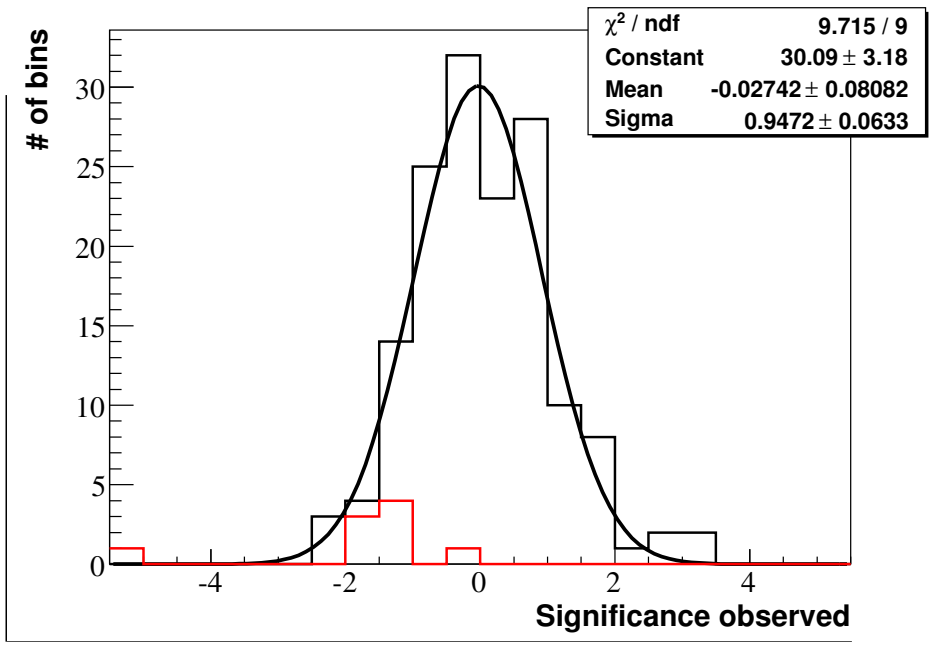

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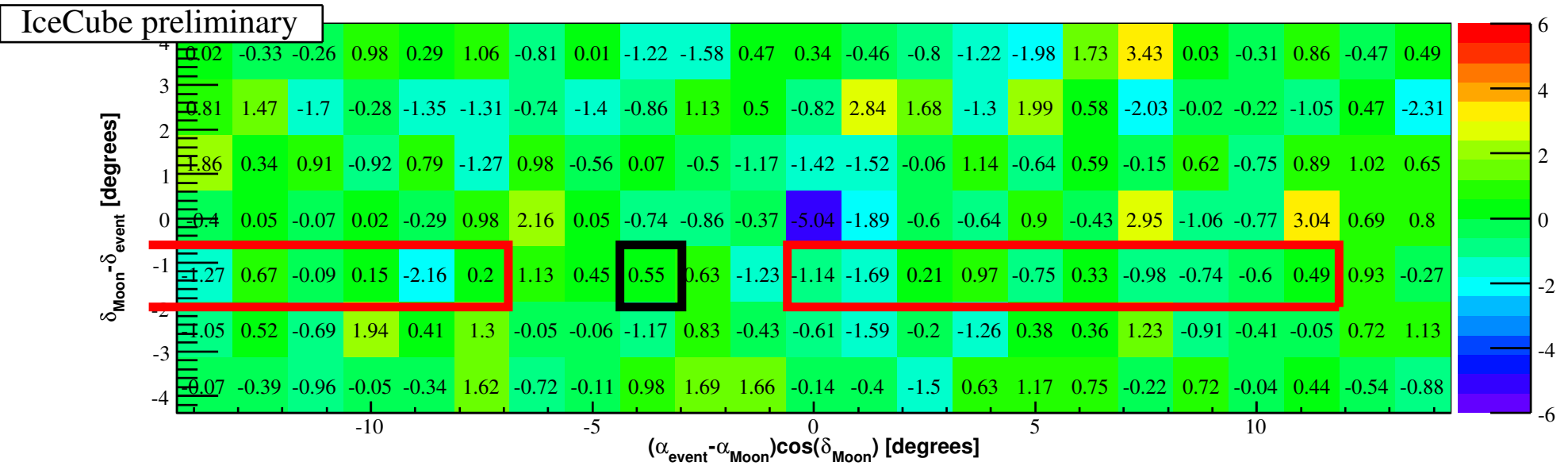

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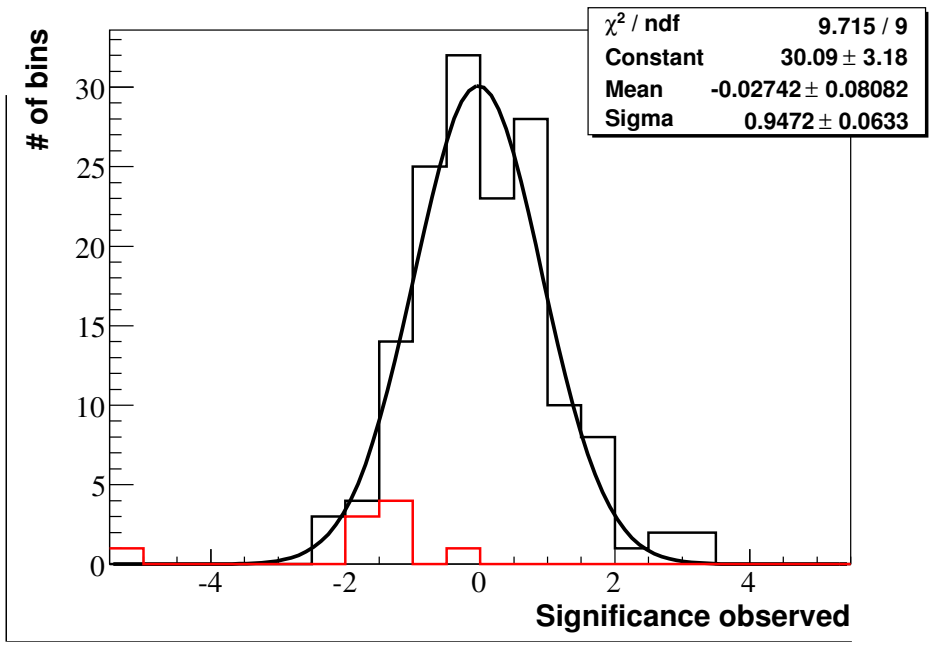

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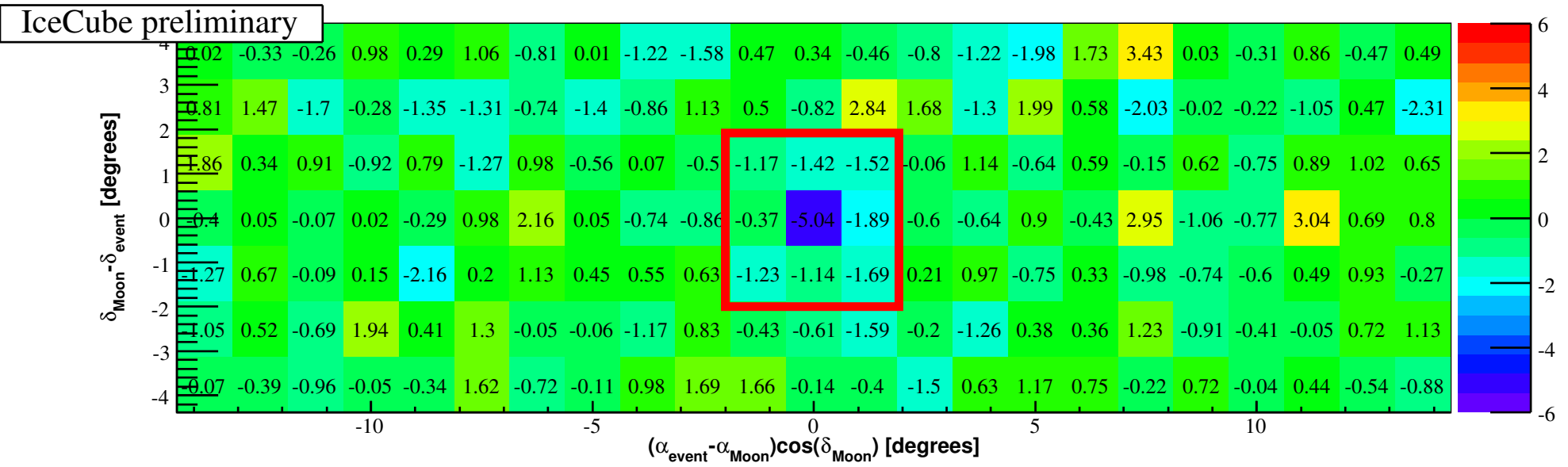

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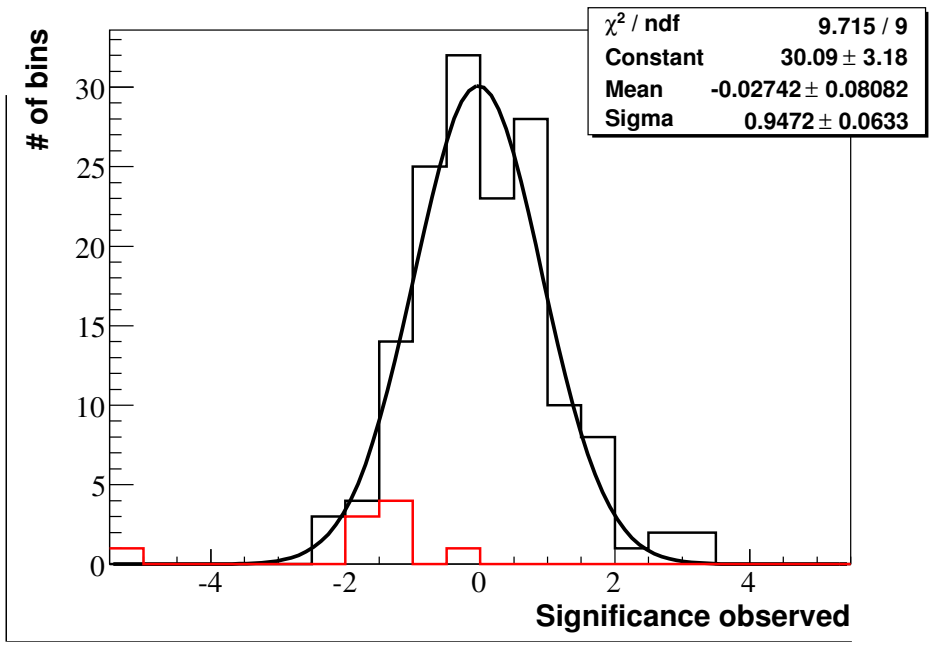

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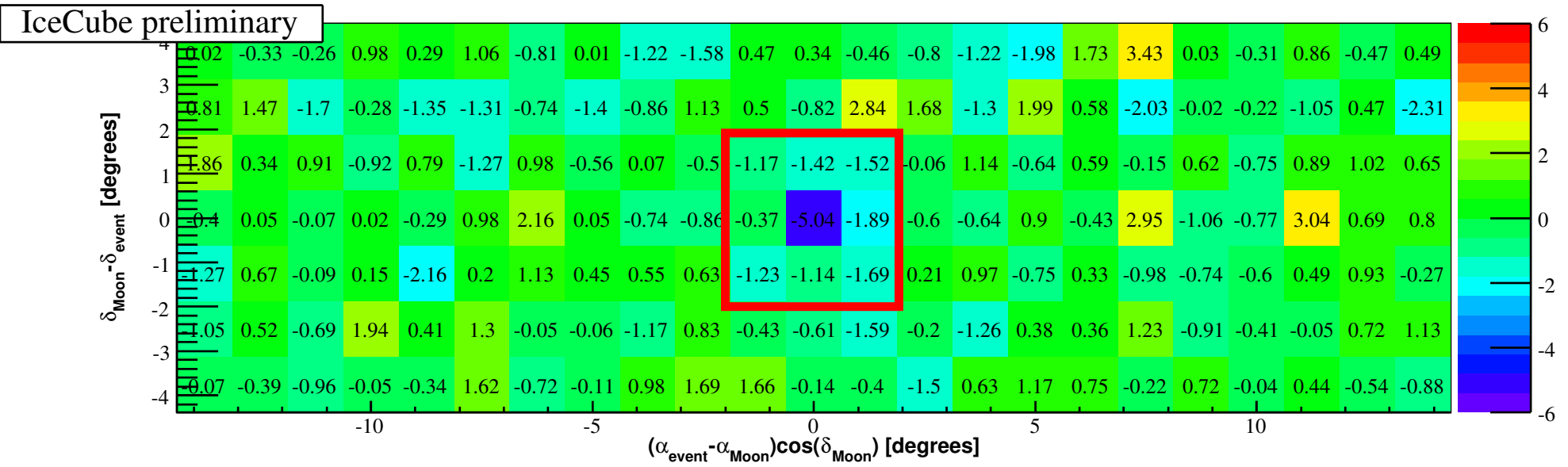

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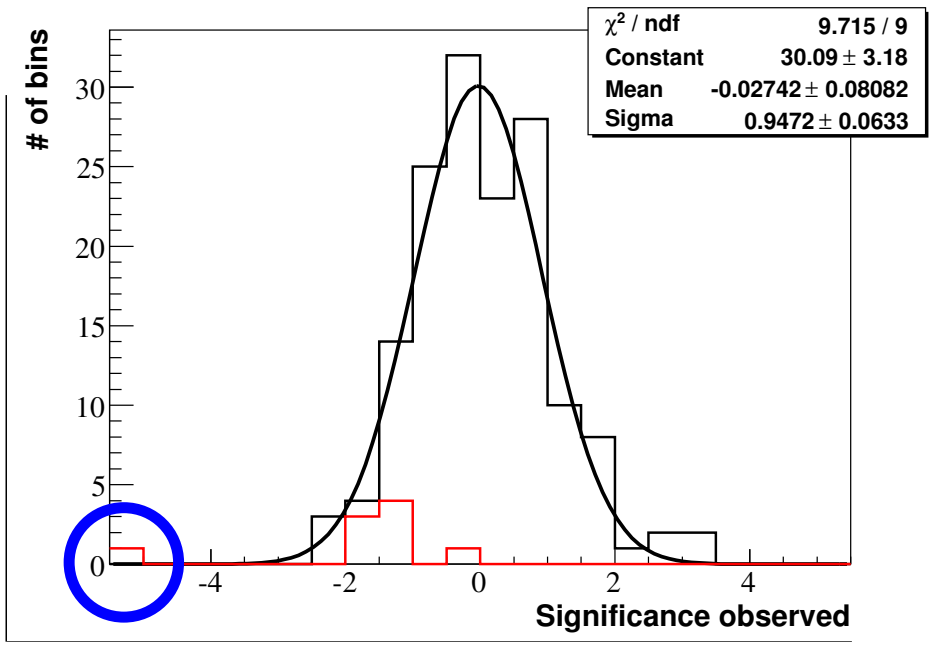

Conclusions

- Moon shadow observed as 5.0 σ deficit in the CR μ rate, using data taken during 8 Moon cycles in 40-string IceCube data, in a simple binned analysis
- There are no major issues with the pointing capability of IceCube

Outlook

- Data from 7 more Moon cycles in 40-string configuration to add
- Log-likelihood based analysis
- With more statistics, growing detector: measurement of offset and resolution
- Shadow of the Sun?