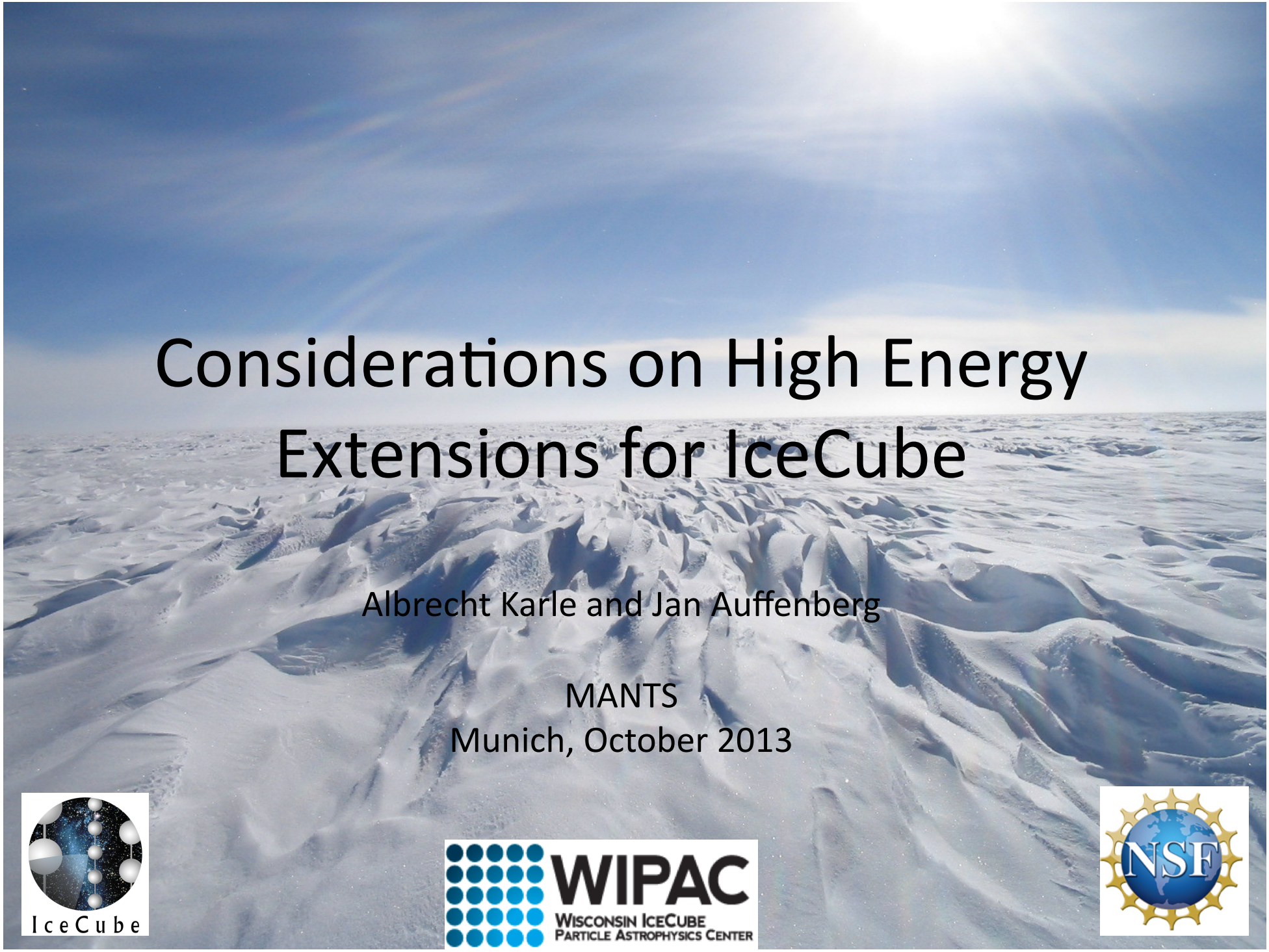


Considerations on High Energy Extensions for IceCube

Albrecht Karle and Jan Auffenberg

MANTS
Munich, October 2013

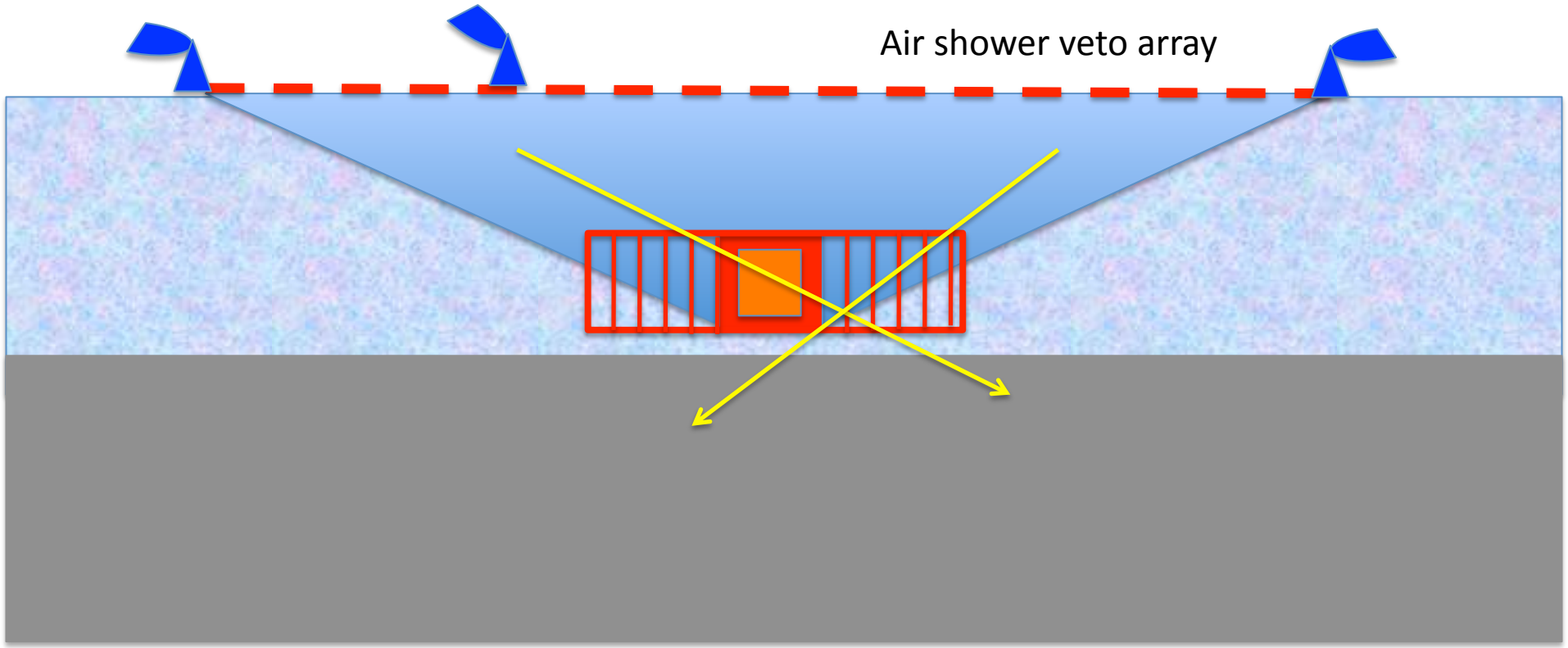
IceCube

WIPAC
Wisconsin IceCube Particle Astrophysics Center

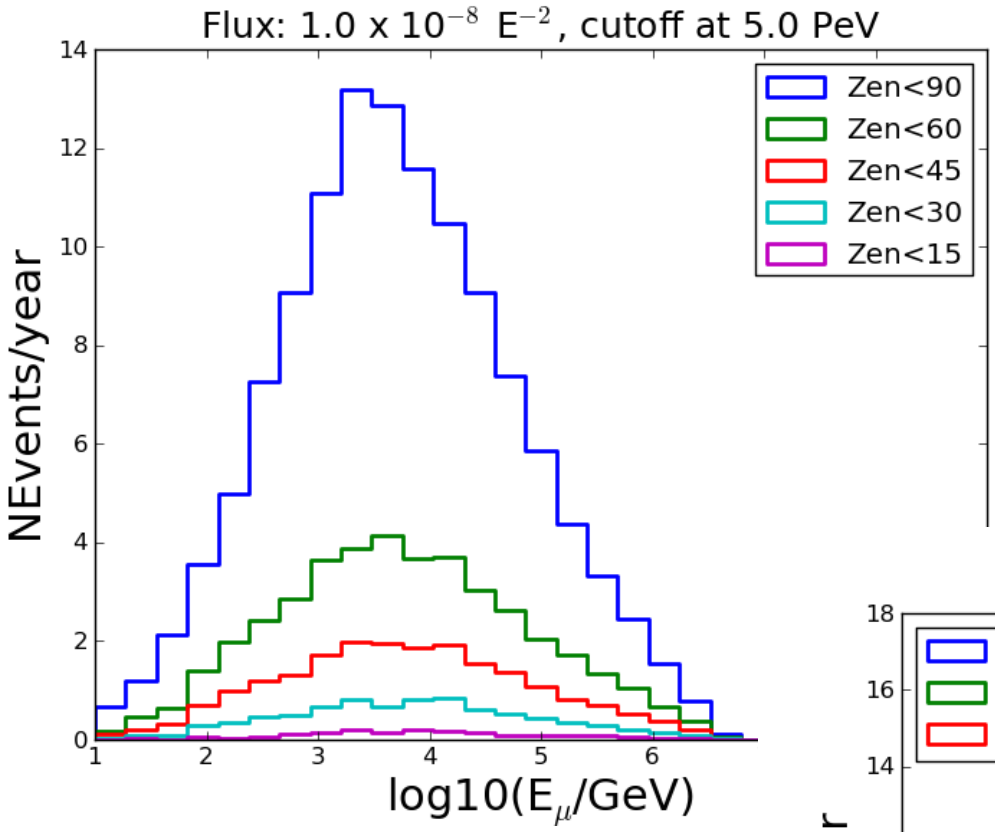
NSF

Upgrade strategies

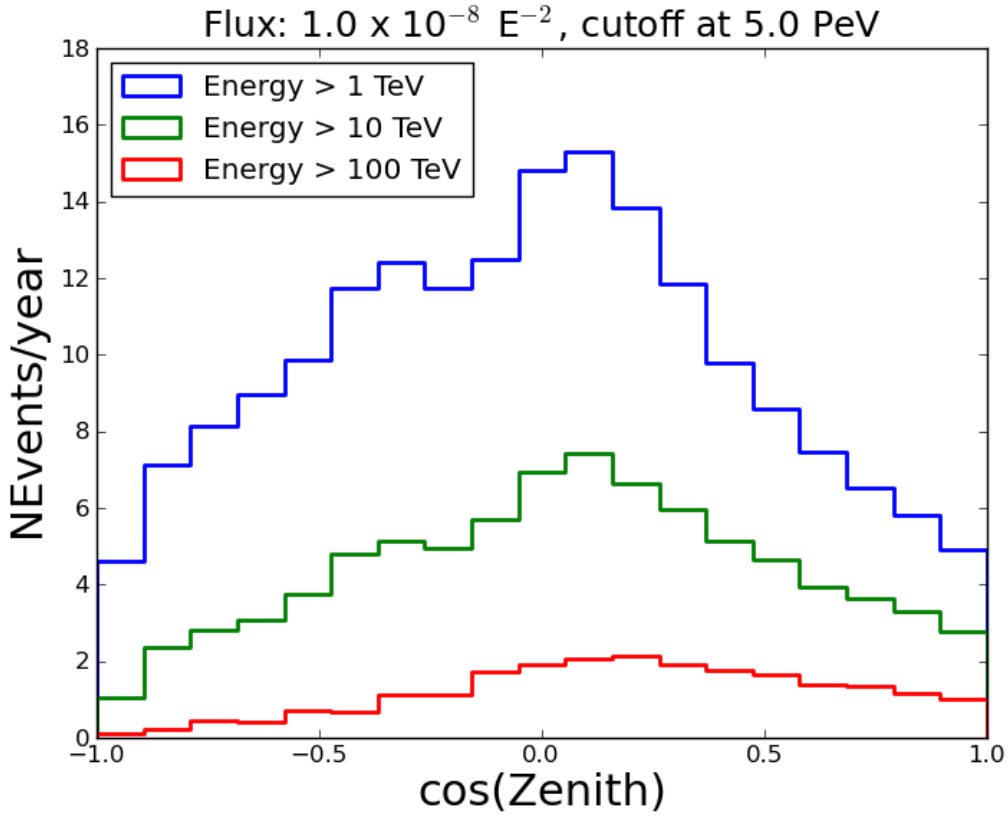
- Surface Veto: reject muon and possibly neutrino background up to 60 or 70° zenith
- Build a bigger detector
- Build a bigger detector with a full surface veto: don't need in-ice self veto (as much) once we have surface veto → large string spacing possible.



Event rates

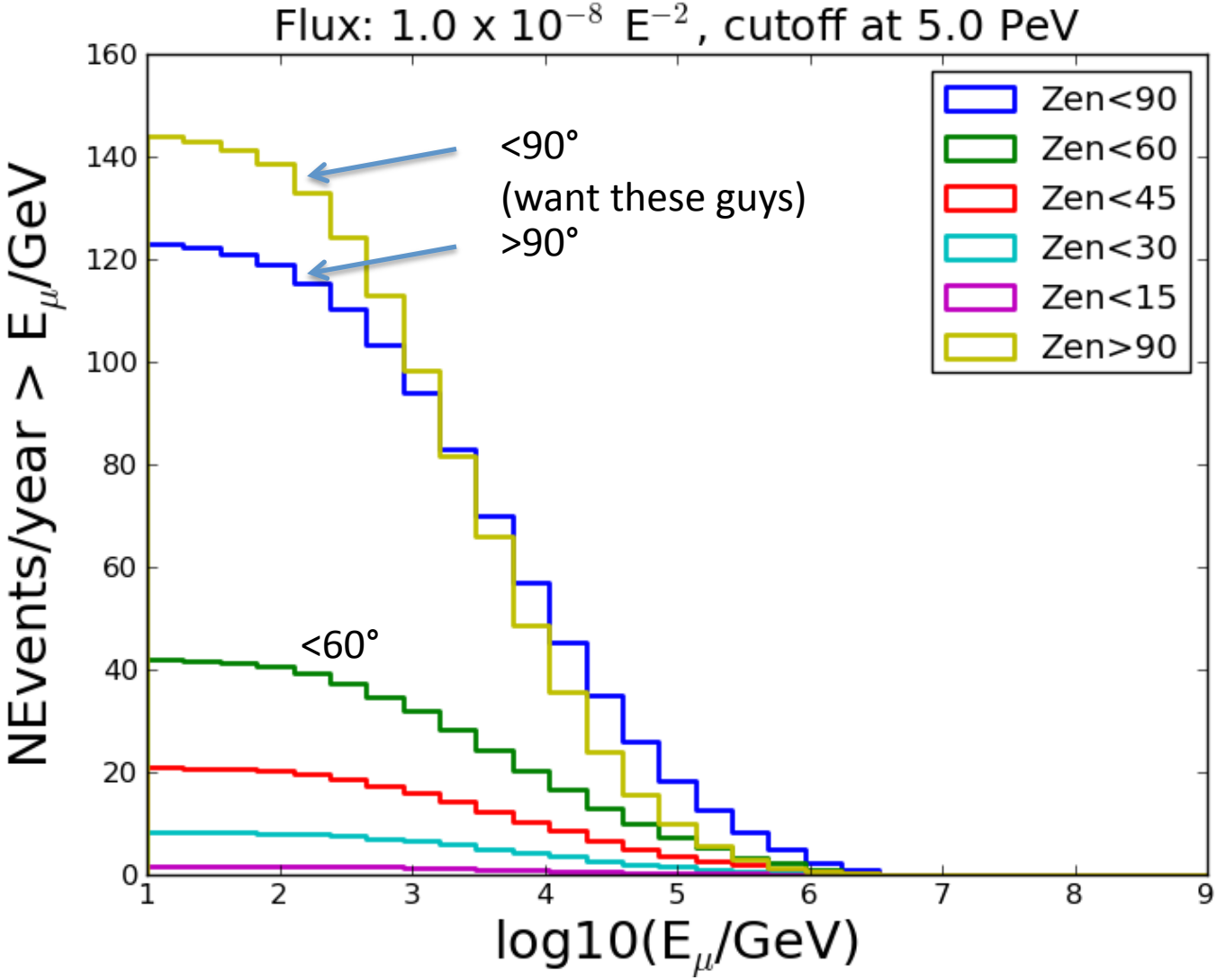


Injected Flux:
10^(-8) E^-2, cut-off at 5 PeV
(HESE flux,
Hypothesis here: all flavor isotropic,)



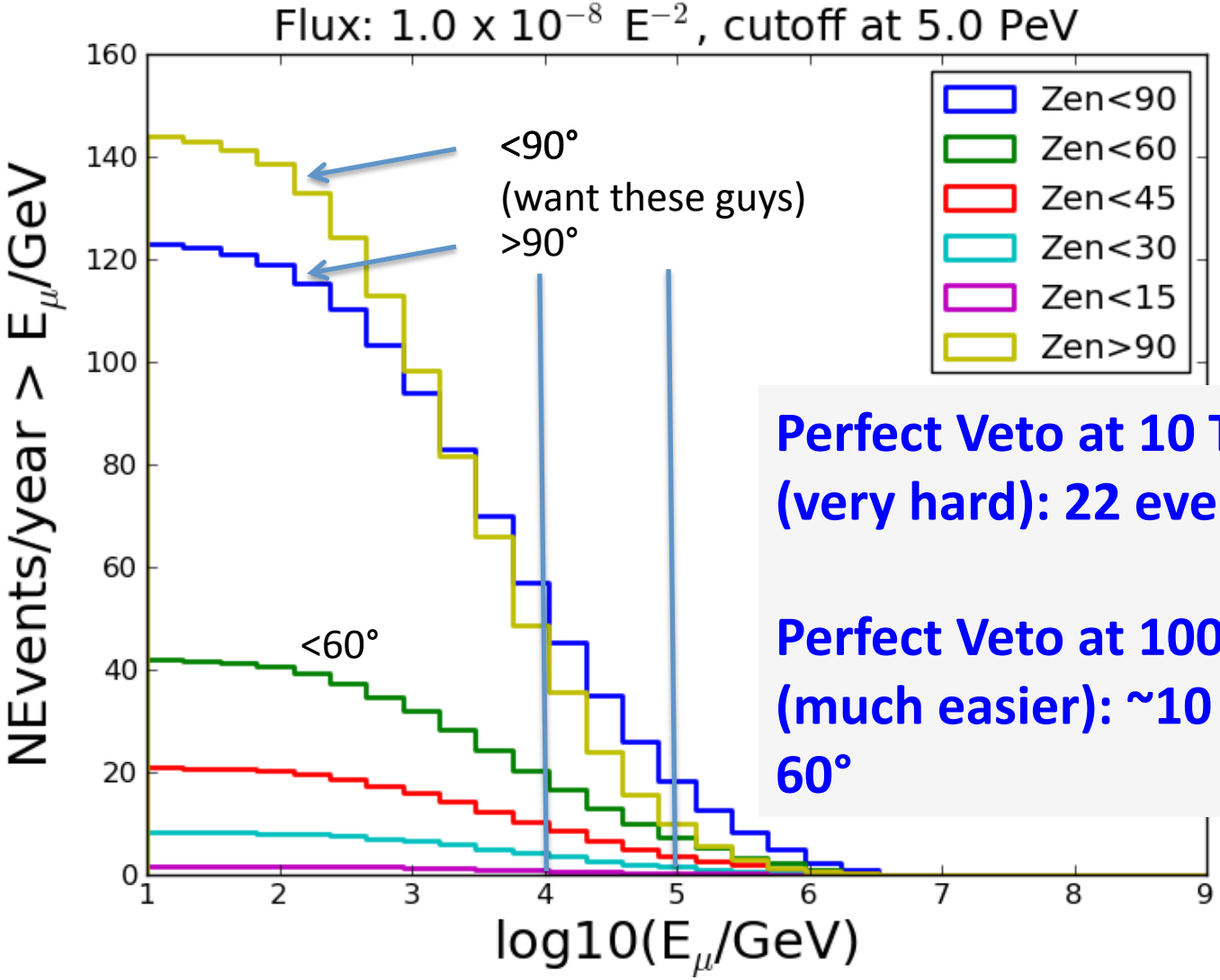
Figures by J. Feintzeig

Cumulative Event Rates



(muon energy in detector)

Event Rates



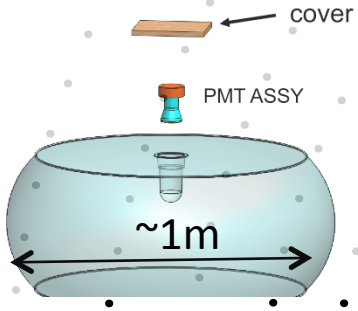
Perfect Veto at 10 TeV (very hard): 22 events < 60°

Perfect Veto at 100 TeV (much easier): ~10 events < 60°

IceVeto

See also: ICRC13 ID 0373 submitted by Jan Auffenberg:
IceVeto: An Extension of IceTop to Veto Horizontal Air Showers

Diameter: 12 km!



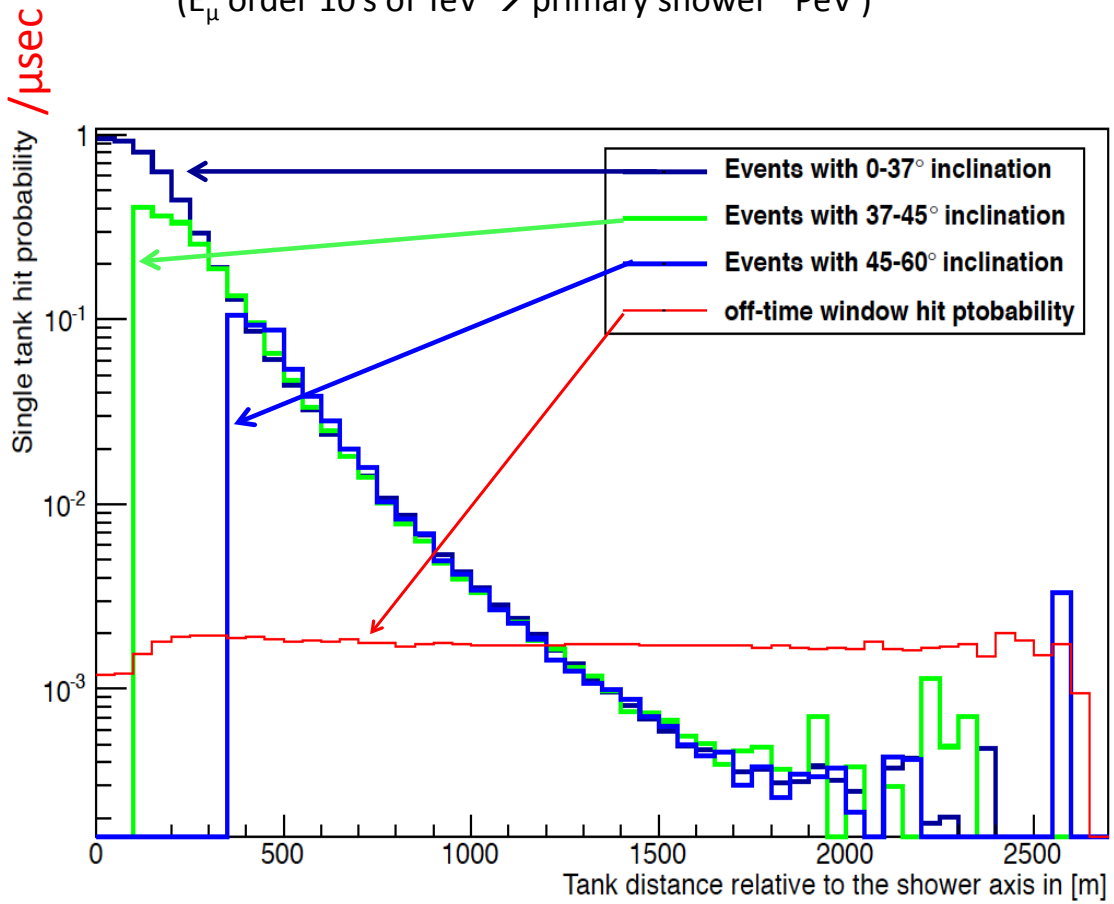
Distance to the center of IceCube grid north-south [m]

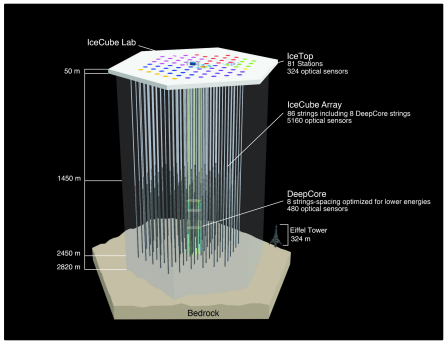
Distance to the center of IceCube grid east-west [m]

Graph

Single IceTop tank hit probability derived from data

Event selection in IceCube:
Good muon tracks (bundles) with N_{pe}> 1000
(E_μ order 10's of TeV → primary shower ~PeV)





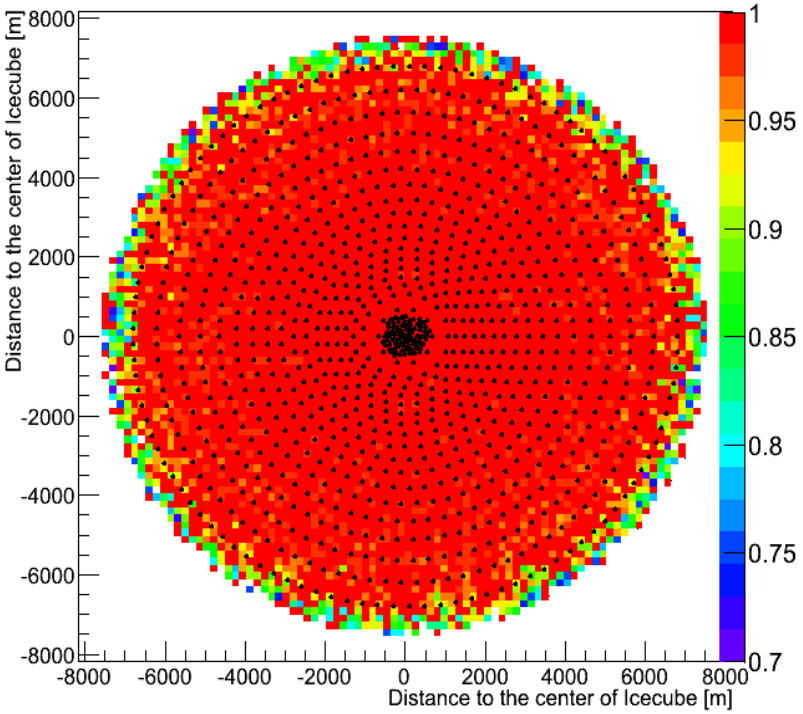
For a given energy of muons in the deep detector:

Tank hit probability is independent from inclination.

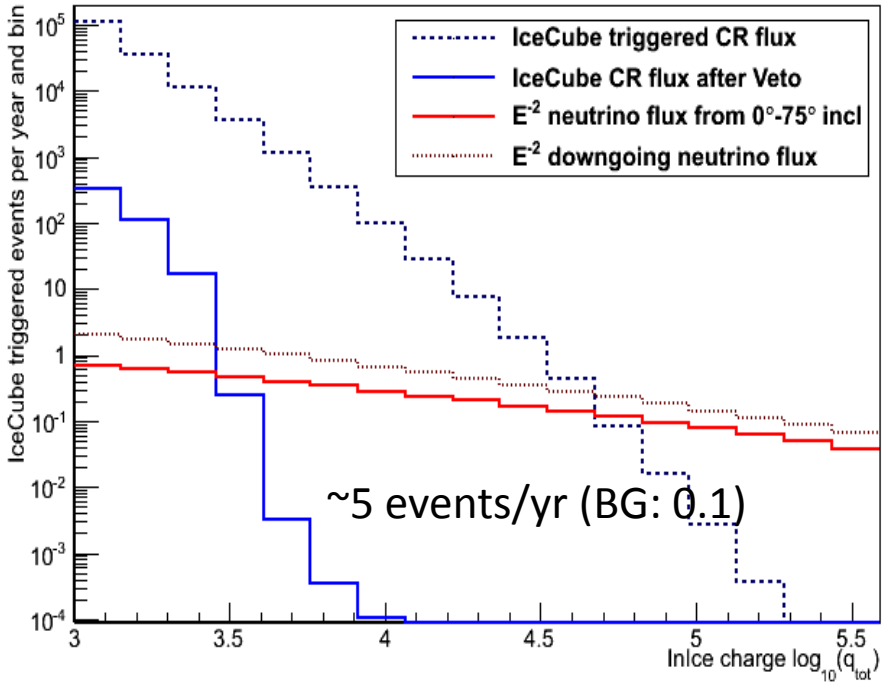
Background hit probability dominates at distances > 1200m

IceVeto

Ref.: J. Auffenberg et al. at ICRC (ID 0373)

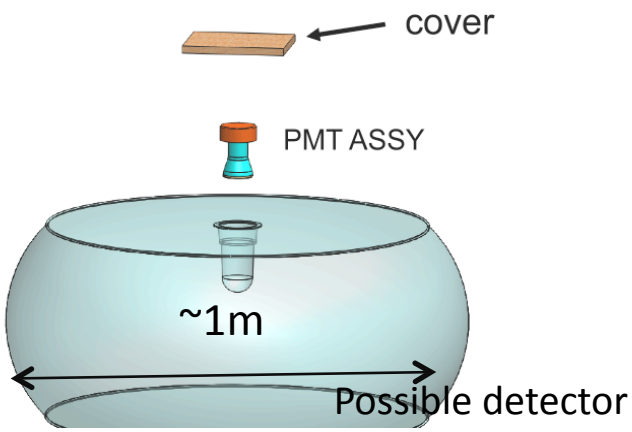


- Efficient to 72° inclination
- 943 Modules on the surface
- 6.7 km radius around IceCube
- Veto efficiency of 99.999% at 4000 PE (above ~100TeV)



Rough idea of cost

- Need 1000 to 2000 stations
  - Power 1 – 2 W
  - 300 km of cables
  - Cable Cost estimate $6M for 2000 stations
  - Station cost: $5M



Outlook

- Evidence in IceCube still coming in, namely numu result is not settled yet.
- Substantial increase in discovery potential in point sources will likely require an upgrade
- Clarify science goals
- Any In-Ice upgrade will benefit from surface veto and will likely be worth adding an extended surface detector to an upgrade of the deep detector.
- Surface veto alone may not do the job, but could get underway without drilling. The relative benefits will be more significant if part of a deep detector upgrade.
-

Science

- We know: HESE result
  - Astrophysical flux exists at the 1.0 x E-8 level
  - Looks like diffuse all flavor neutrino flux, not clustered.
- Data so far consistent with all flavor isotropic, but surely not clear yet.

If we assume that:

- Look in the point sources search for astrophysical source association, muon channel (northern hemisphere still the best channel)
- Measure (astrophysical) energy spectrum best with cascades
- However, upgoing point source limits are already very good, and they contain the astrophysical muon neutrinos.
  - If the muon neutrino flux is at the same level, we will have a nice number of astrophysical events in the high energy tail of the point source searches.
  - The point source results apply regarding search for clustering.

Neutrino Skymaps

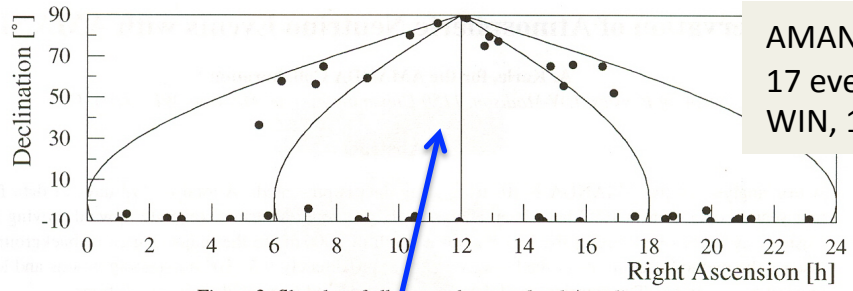
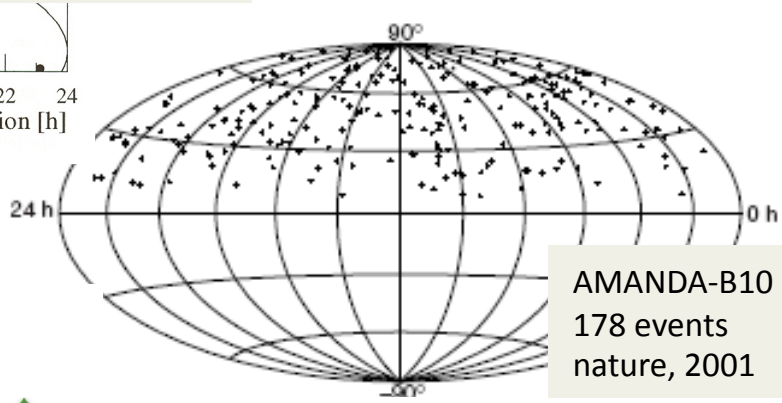
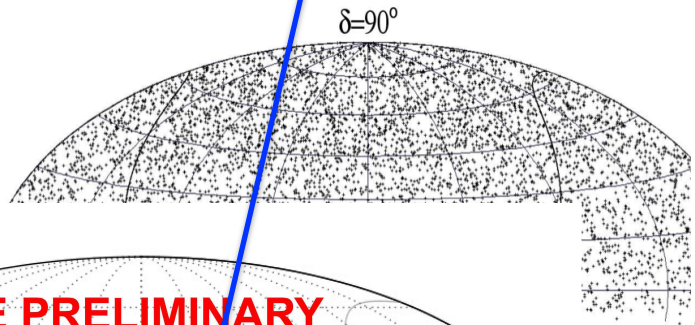


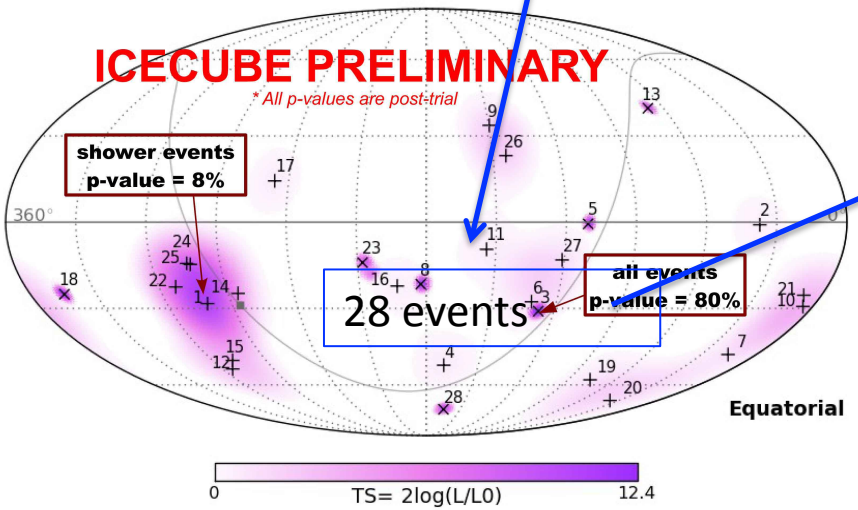
Figure 2: Sky plot of all events that pass level 4 quality cuts.

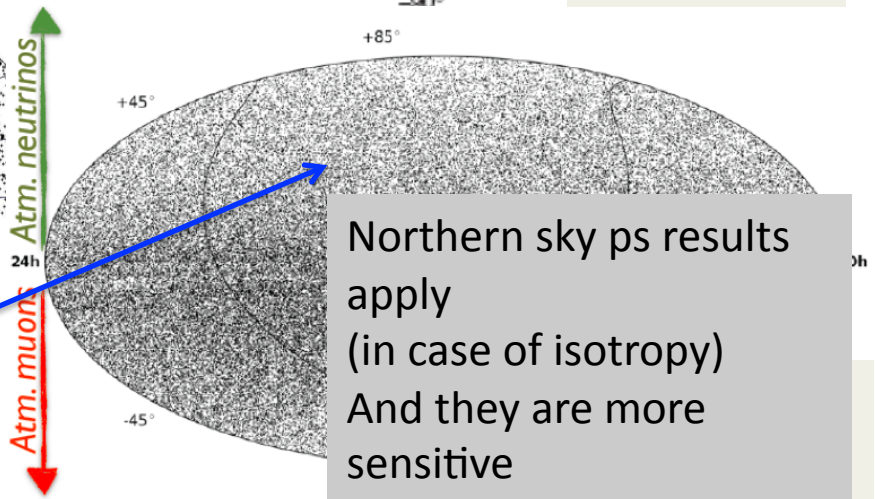
AMANDA-B10
17 events
WIN, 1999



AMANDA-B10
178 events
nature, 2001

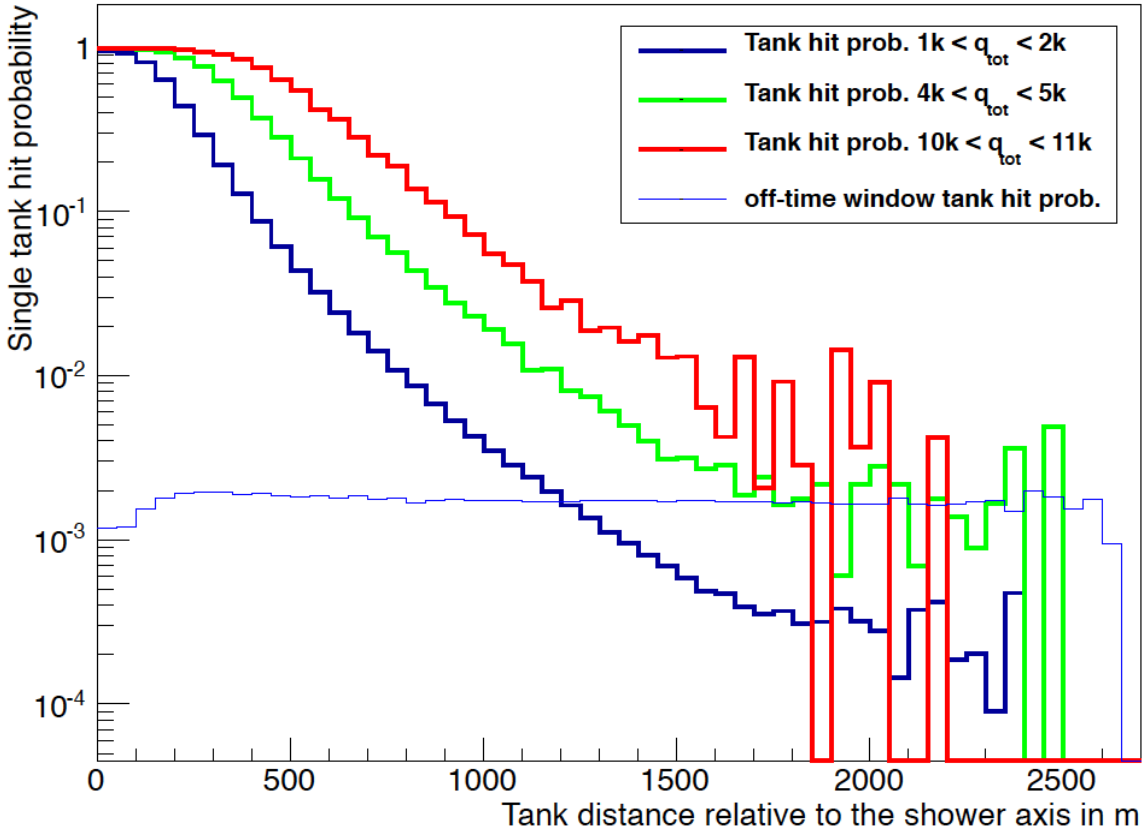


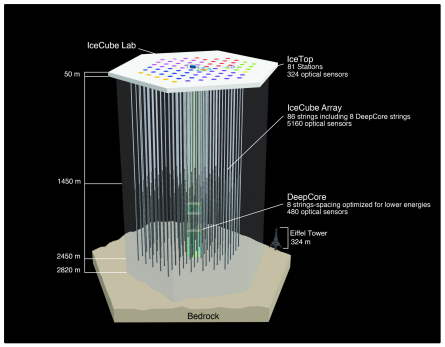




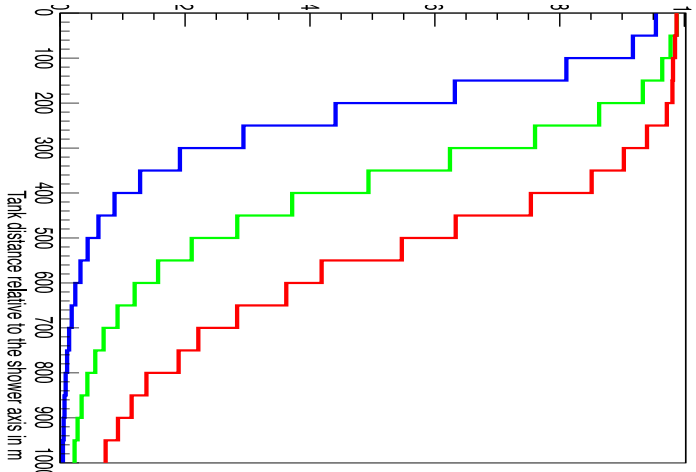
Northern sky ps results apply
(in case of isotropy)
And they are more sensitive

Single IceTop tank hit probability (real data)





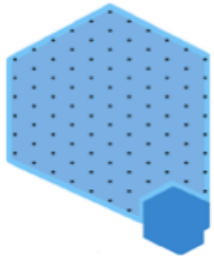
Tank hit probability increases with increasing NPE in the deep detector

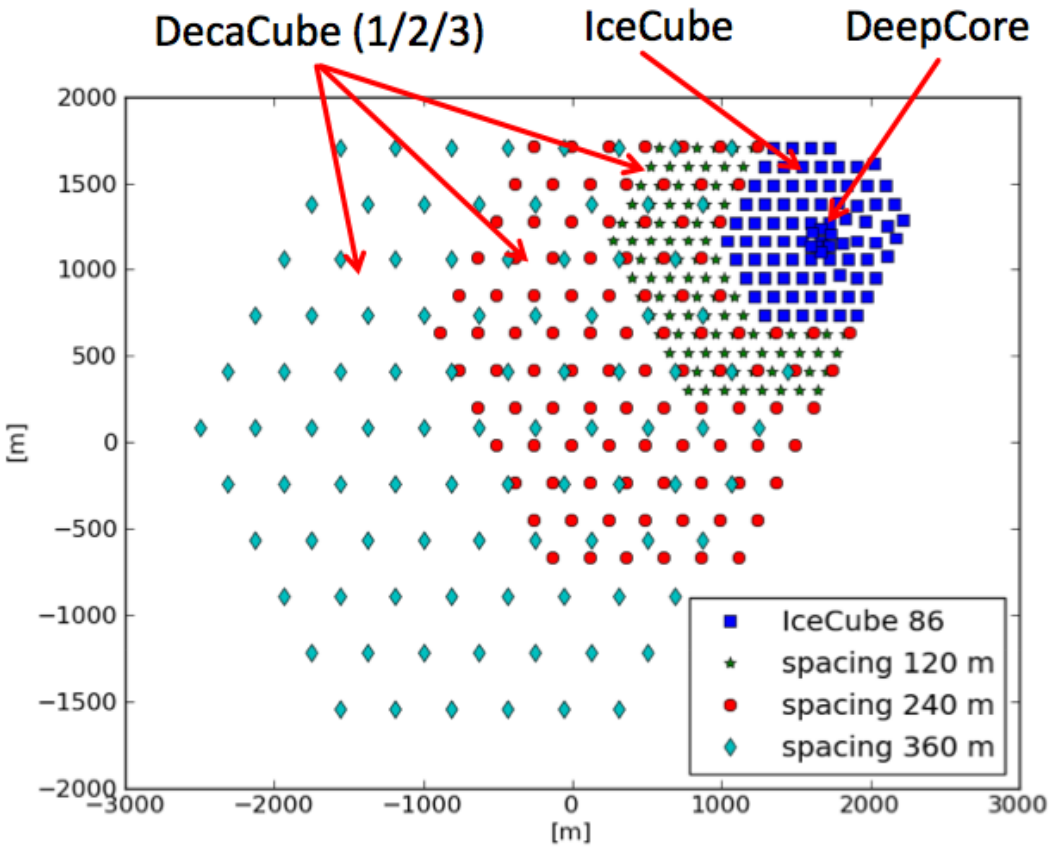


The background hit probability is at 2×10^{-3}

Christopher: *My favorite is 100 strings at medium spacing (250m)*

Studied geometries





Spacing 1 (120m):
IceCube (1 km^3)
+ 98 strings (1,3 km^3)
= 2,3 km^3

Spacing 2 (240m):
IceCube (1 km^3)
+ 99 strings (5,3 km^3)
= 6,3 km^3

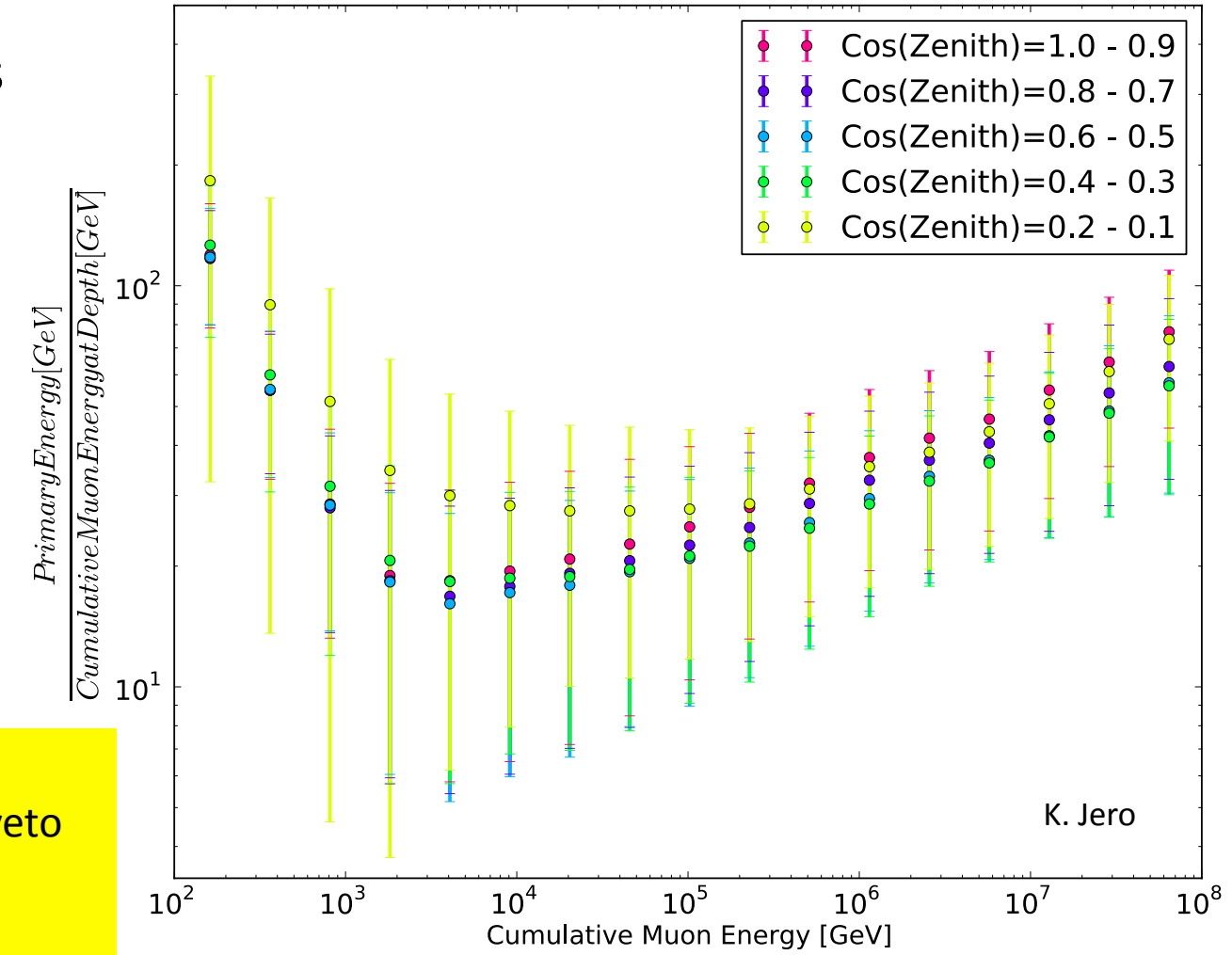
Spacing 3 (360m):
IceCube (1 km^3)
+ 95 strings (11,6 km^3)
= 12,6 km^3

Chosen geometry not optimum (i.e. for HESE)

… historically chosen to demonstrate that we do respect boundary conditions

Air shower energy vs muon energy in detector

Energy of primary is typically 20 to 30 times muon energy in detector



50 TeV muon energy in ice:
need 1 PeV air shower veto

5 TeV muon energy in ice
need 100 TeV airshower veto

How do the searches for a diffuse muon neutrino flux fit in?