Beyond IceCube

Design study for a multi-km^3 Cherenkov detector at the South Pole

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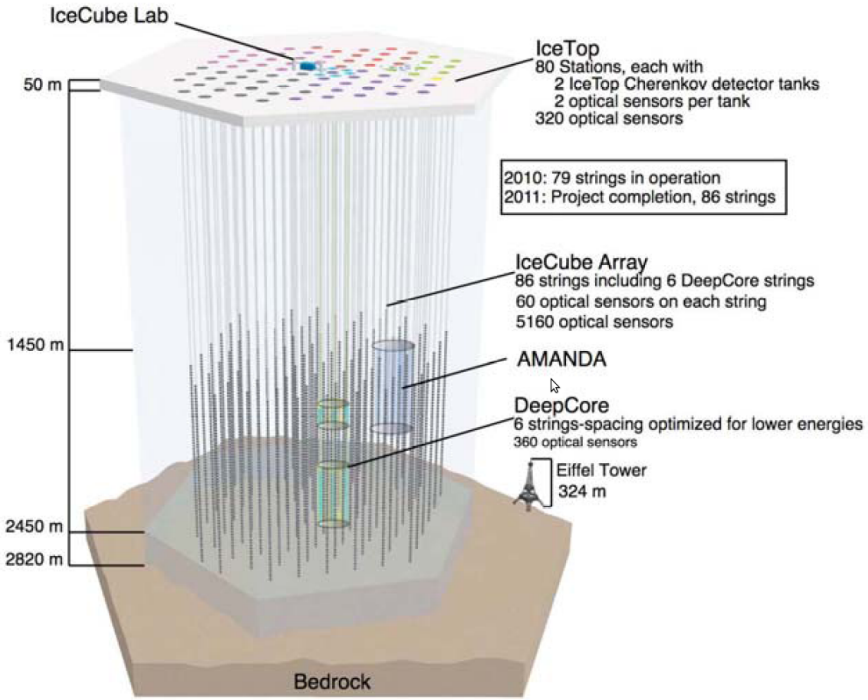
Agenda

Current and future ν-telecopes

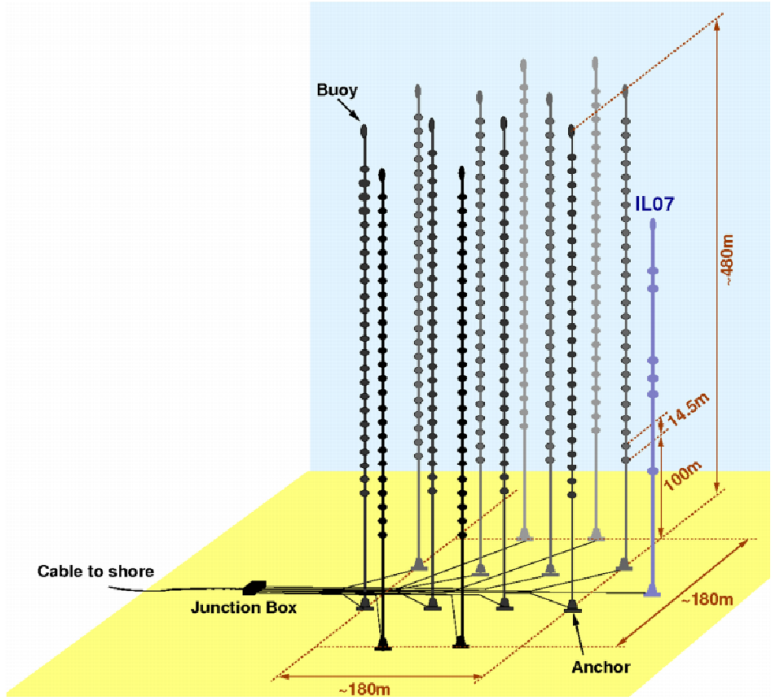
DecaCube

Conclusion & Outlook

Astrophysical-ν observatories today



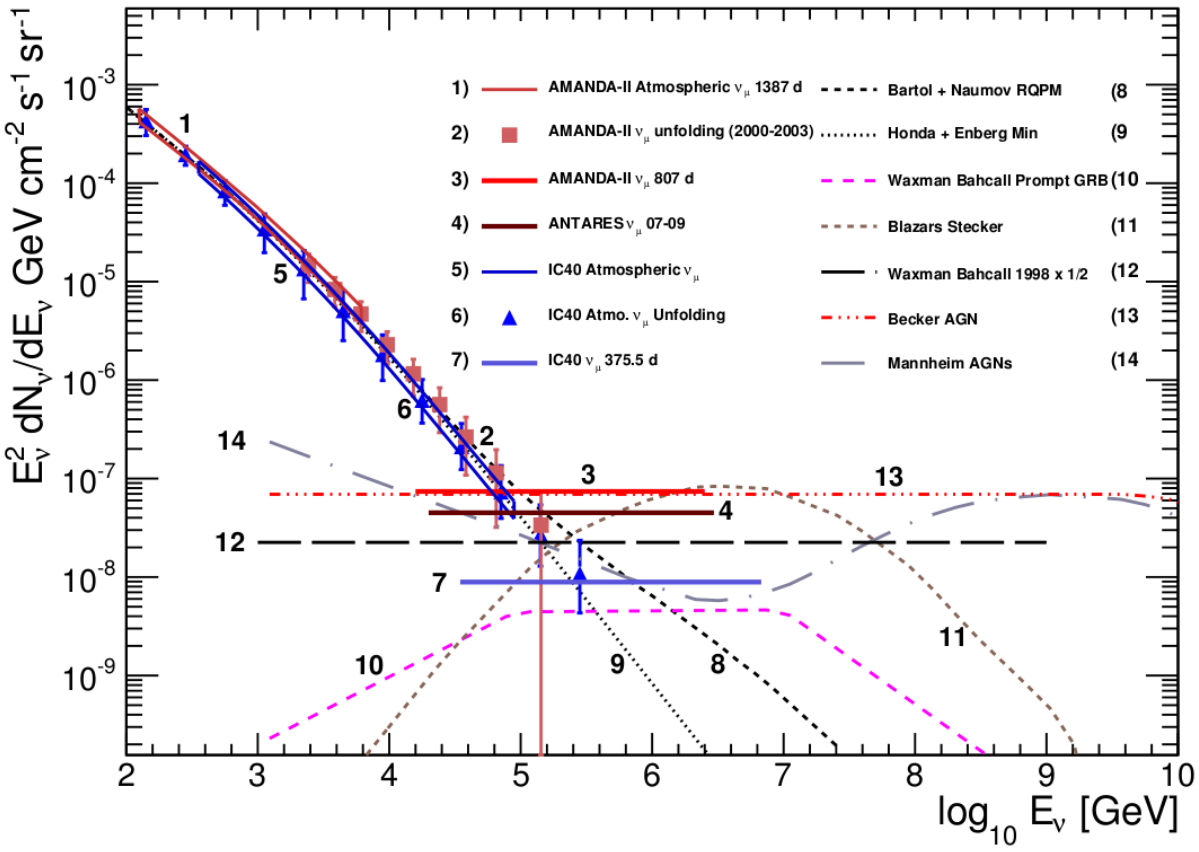
IceCube about 1 cubic kilometer



ANTARES about 0.01 cubic kilometer

Current limits

Best limits for diffuse ν-flux are measured with IceCube in the 40-string configuration

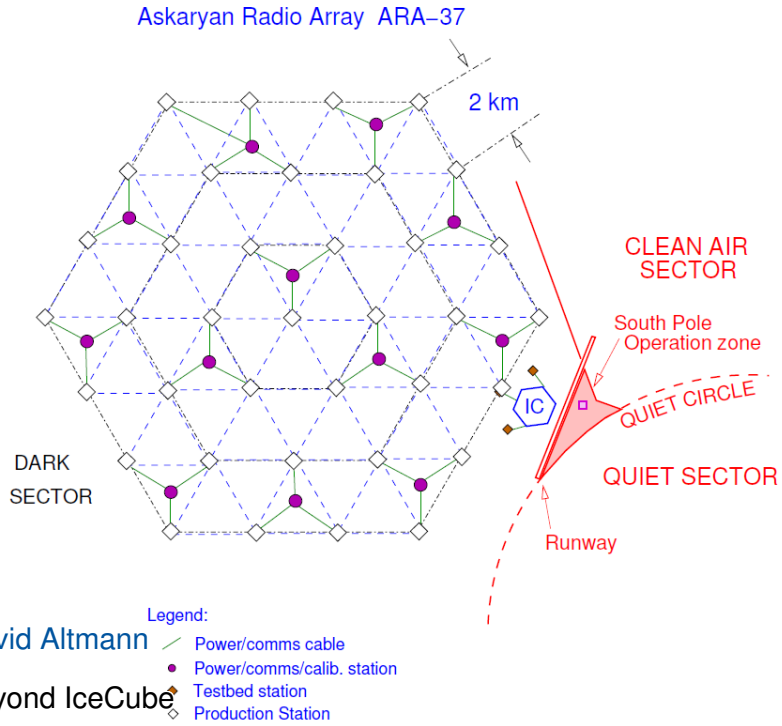


- So far only upper limit
- If full IceCube (86 strings) does see signal, statistic might not be large

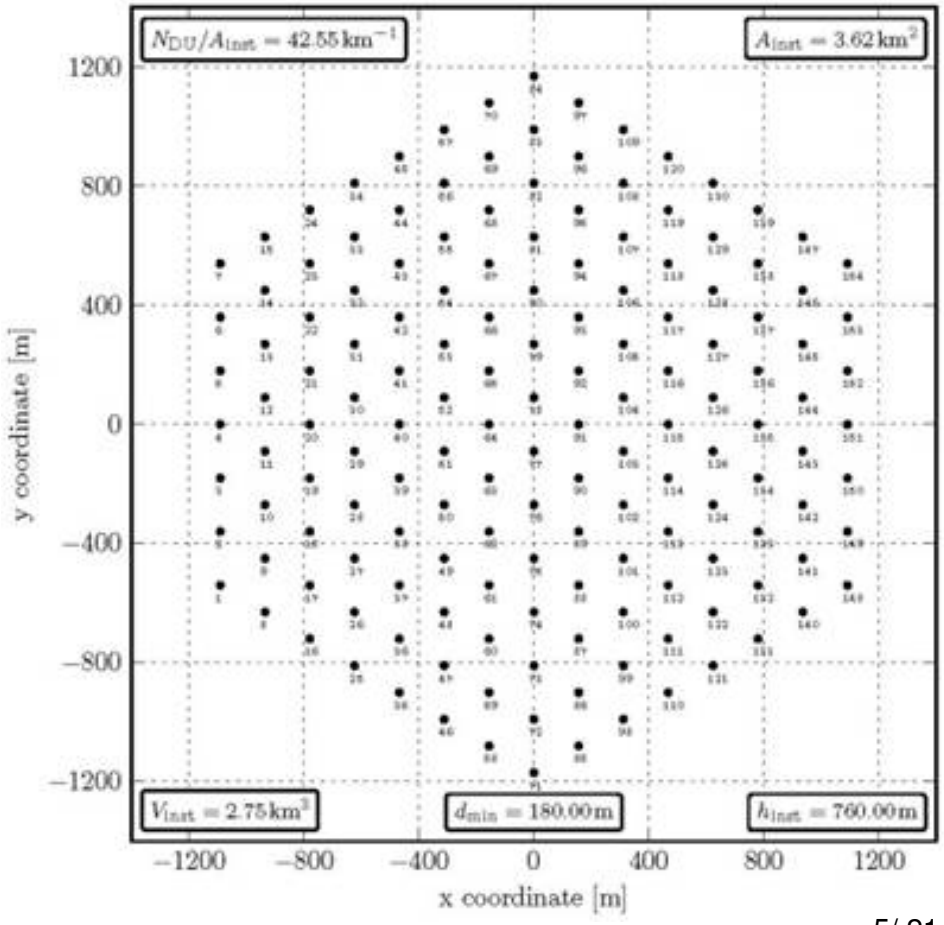
$\rightarrow$ How can we measure astrophysical ν **after** IceCube?

Future ν-telescopes

- IceCube extensions
  - ➔ Beyond DeepCore (low energy)
- Radio-Askaryan-telescopes
  - ➔ ARA
- KM3Net (2-6 km^3)



Possible KM3Net layout
Volume: 2.75 km^3
String spacing: 180 m



Why optical Cherenkov in deep ice?

- How can we improve ν measurement in the TeV & PeV realm?
  - ➔ Stick with IceCube technology – but increase the detector volume!
- The used technology is well understood
  - ➔ Experience in building IceCube DOMs
  - ➔ Experience in deploying IceCube DOMs
  - ➔ Experience in using IceCube DOMs

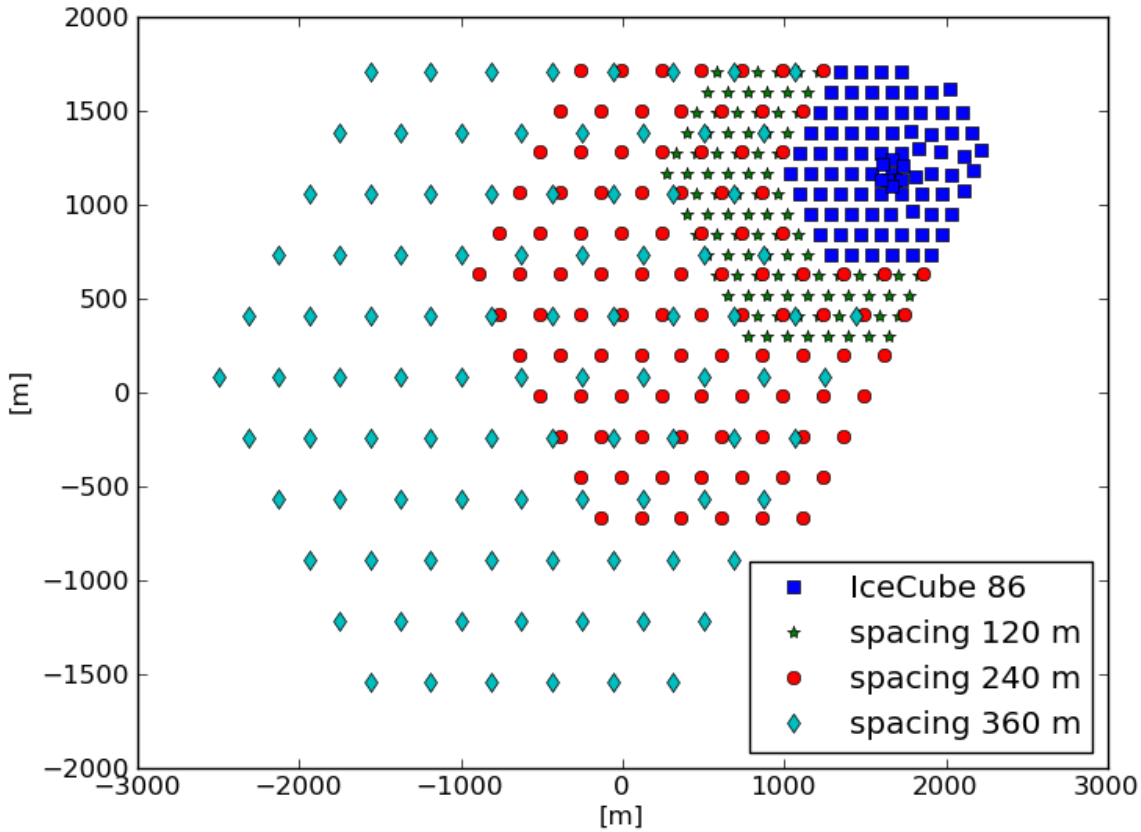
DecaCube: What do we need to build it?

- An extension to IceCube should increase the volume substantially
  - ➔ $\sim$ 100 additional strings
  - ➔ Increased distance between the strings
  - ➔ Same 60 DOMs per string design like IceCube
- 20 strings / year = 5 years deployment
- costs: roughly 80M€ (investment)

DecaCube: How does it look like?

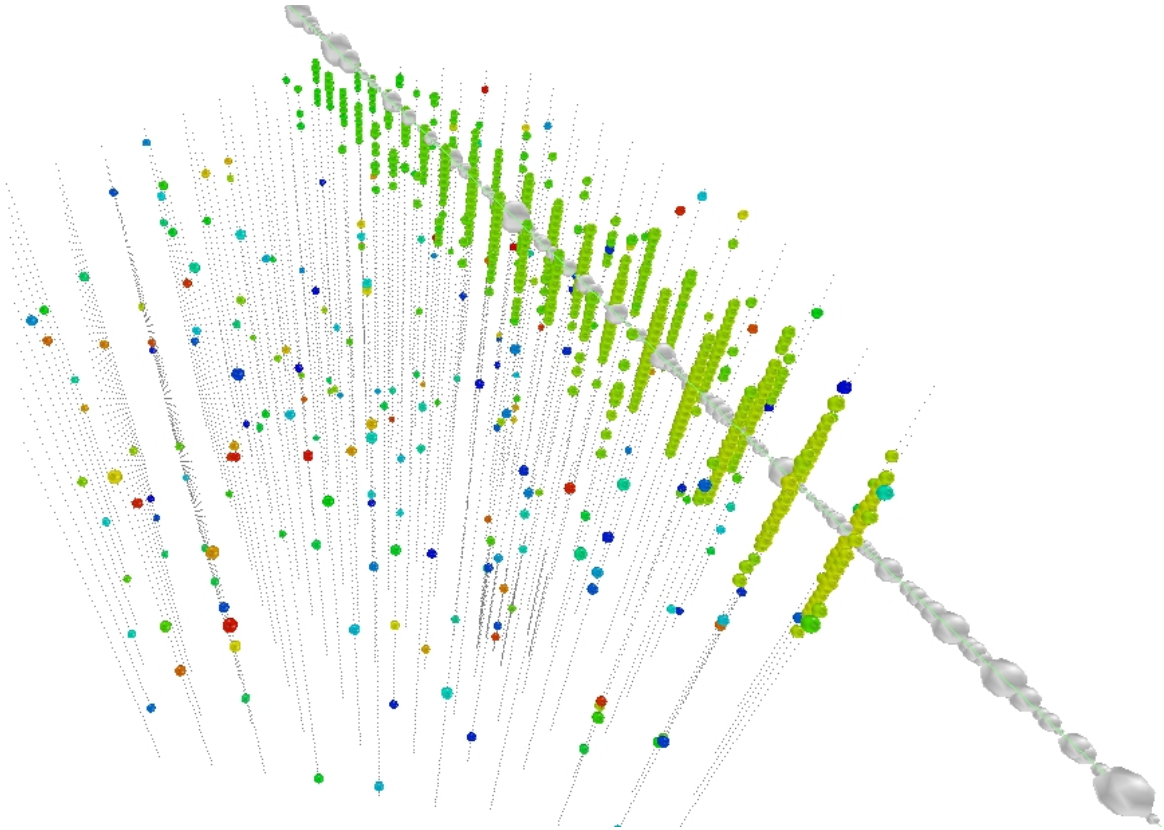
Design respects structures at the South Pole!

Detector	Total volume
IceCube	1 km^3
spacing 120 m	2,3 km^3
spacing 240 m	5,3 km^3
spacing 360 m	12,6 km^3



ν-simulation with standard IceCube software $\rightarrow$ Results are preliminary!

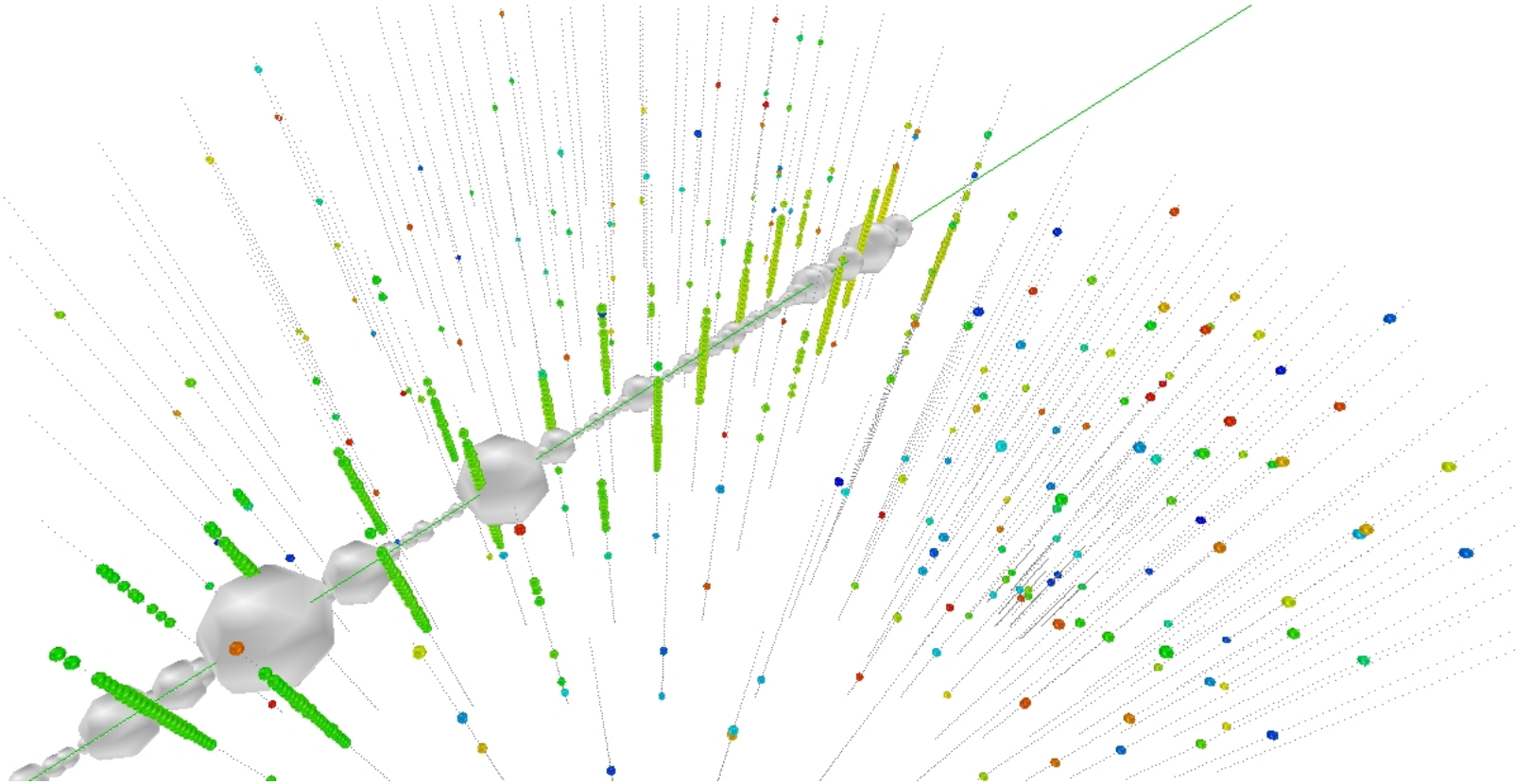
3 PeV-event in IceCube spacing extension



→ Looks like IceCube, only tracklength is longer

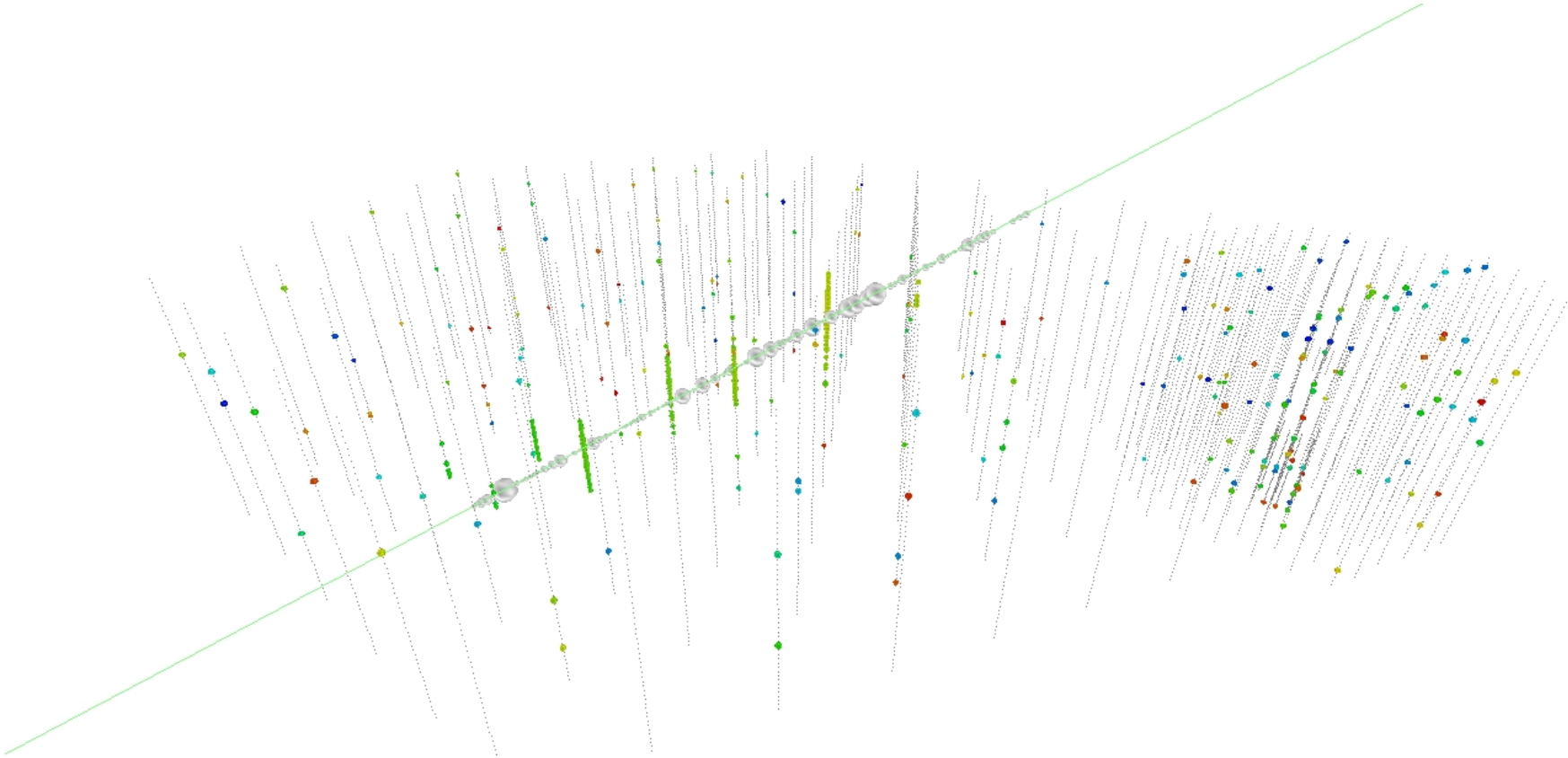
→ More information than necessary!

10 PeV-event in double spacing extension



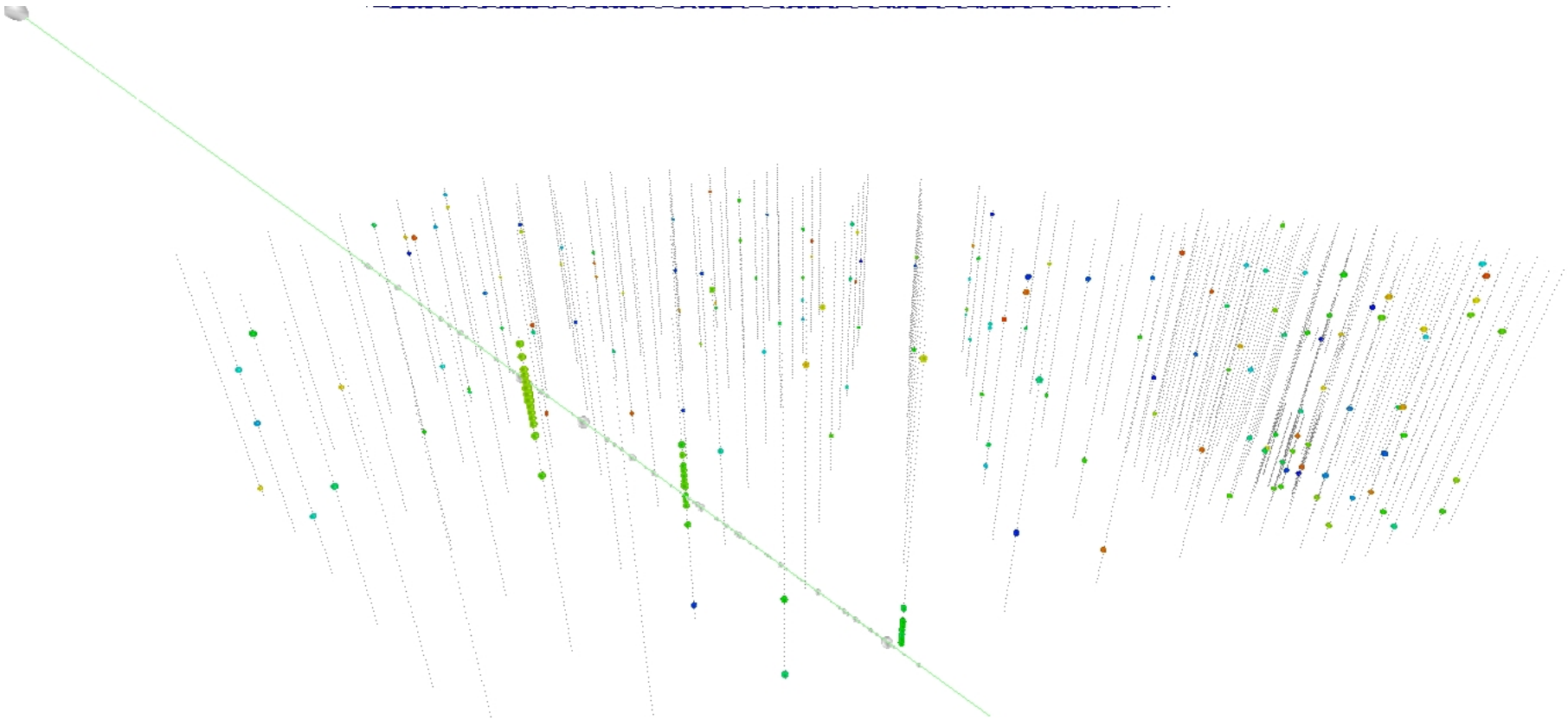
→ Maximal length in detector, more then one string row with hits

4 PeV-event in triple spacing extension



→ Long track, only one row of strings with hits.

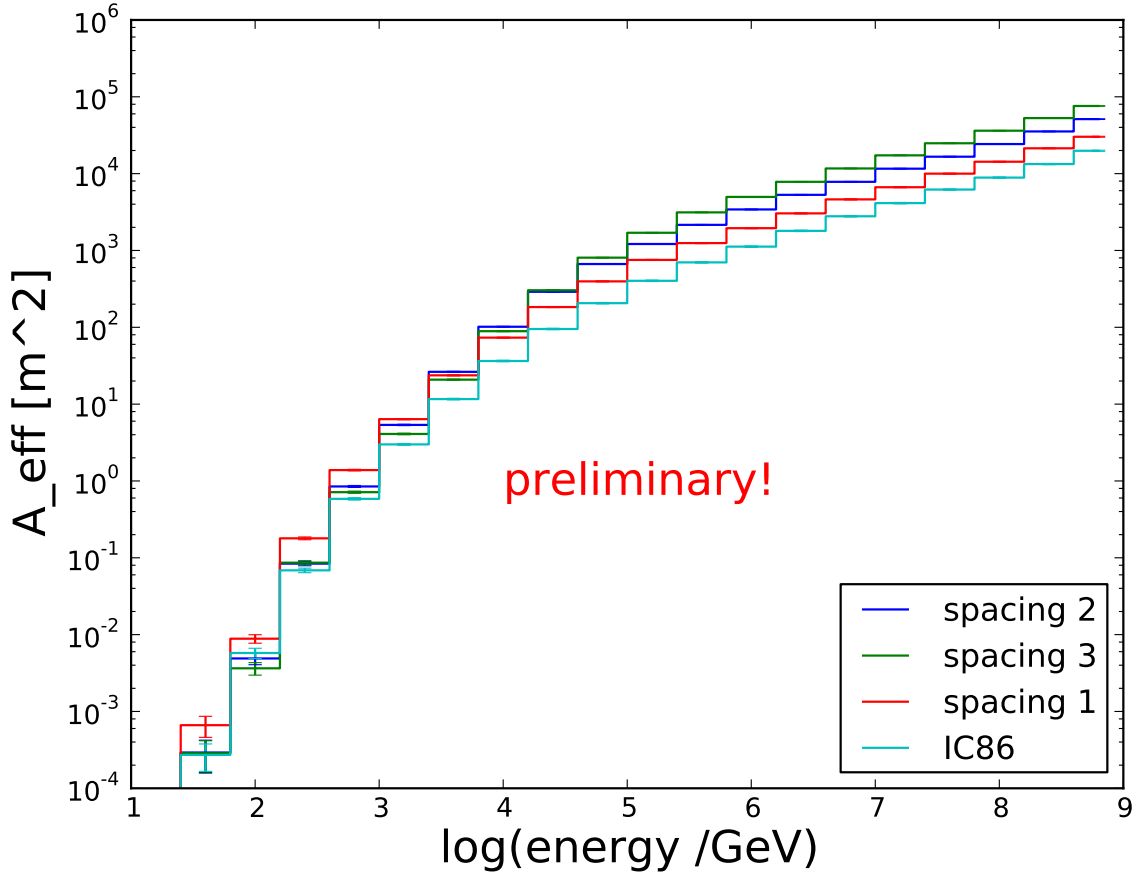
80 TeV-event in triple spacing extension



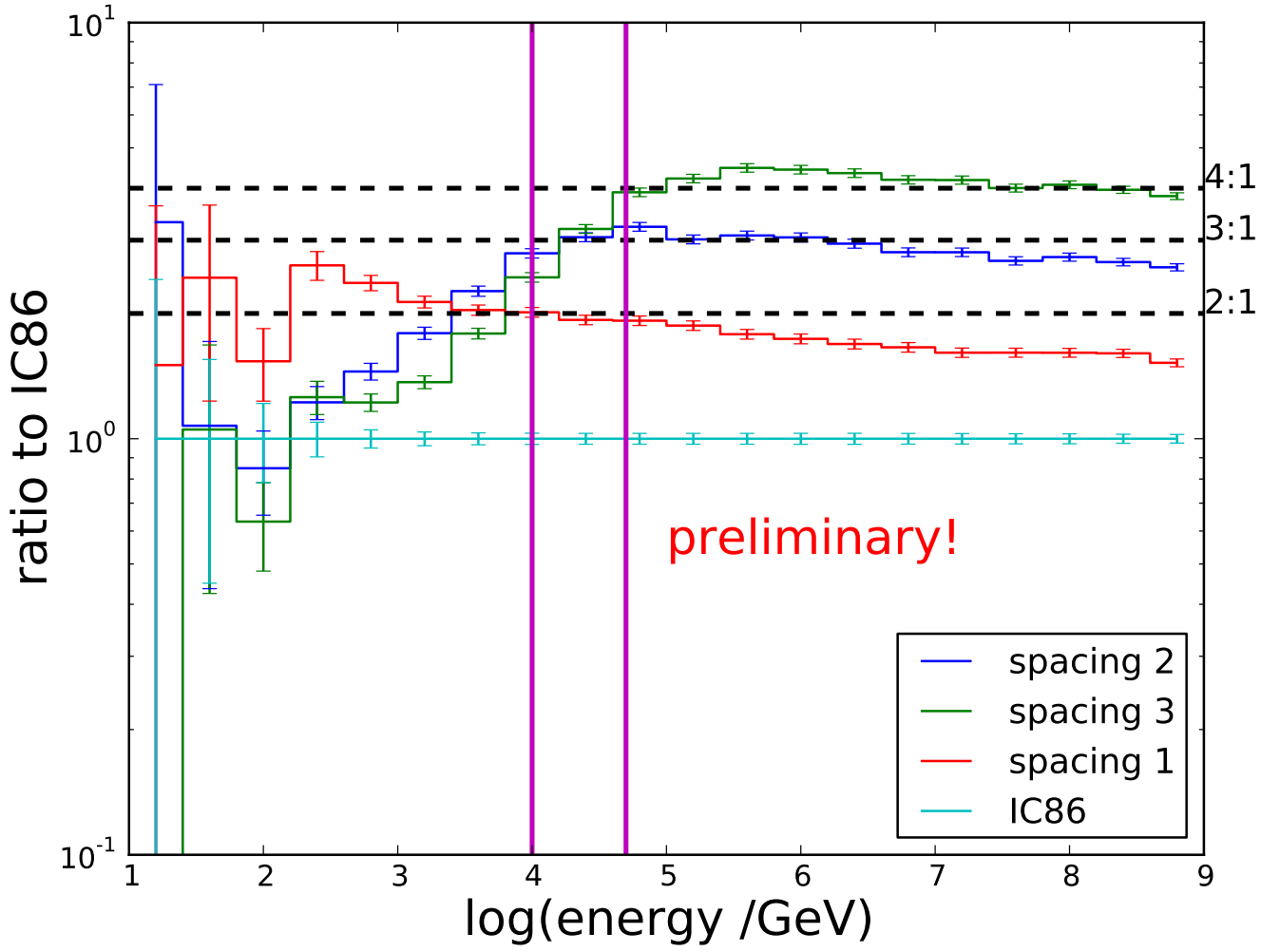
→ In the new detector volume, not many hits – but reconstructable!

Effective area

- $R(E_\nu) = A_{eff}(E_\nu) \cdot \Phi(E_\nu)$
- Which trigger condition?
  - ➔ 12 local coincidence hits
  - ➔ robust vs noise but very soft trigger



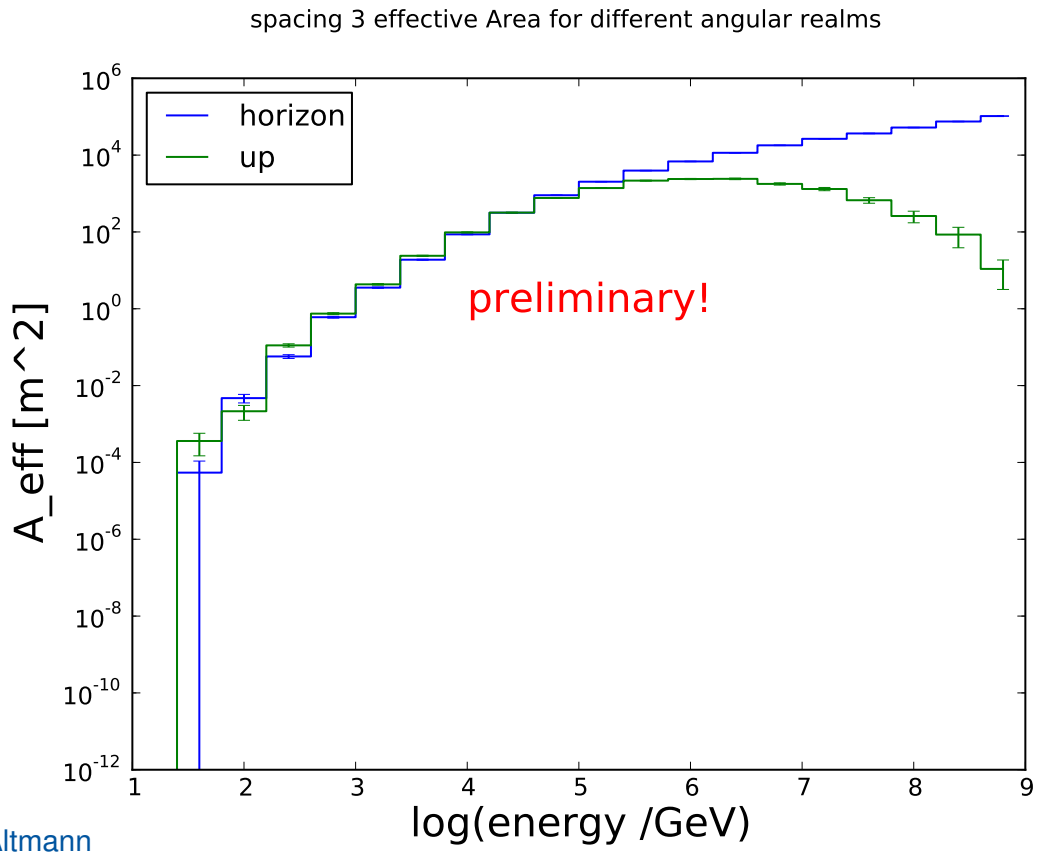
Effective area ratio



- Ratio does not scale with volume!
- Scales linear with spacing
- Threshold for double spacing at $\sim$ 10 TeV !
- Threshold for triple spacing at $\sim$ 50 TeV !

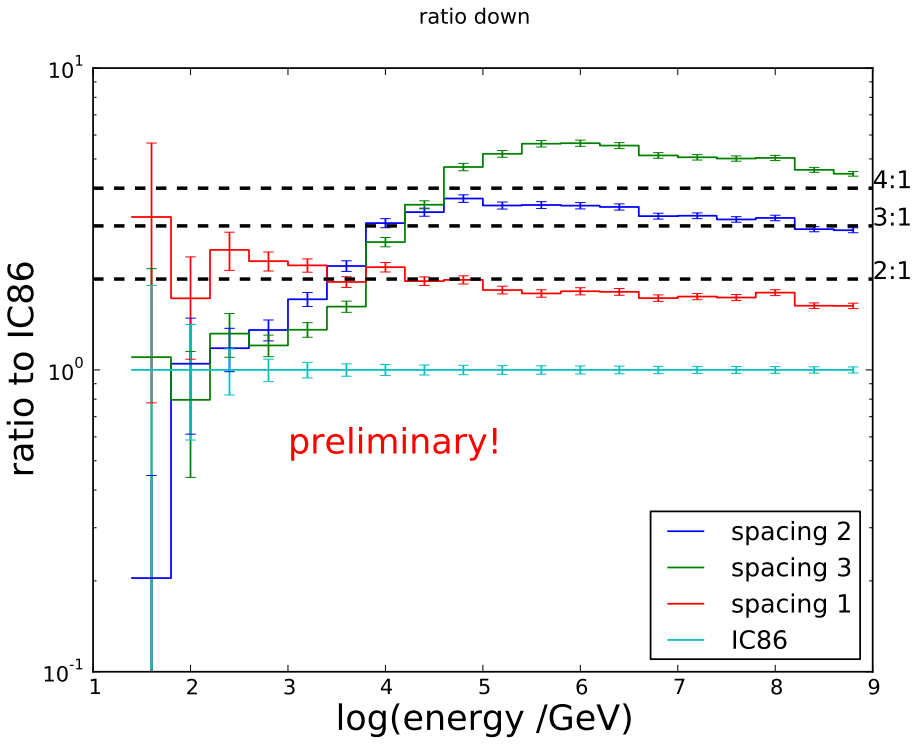
Effective area: Angular dependency

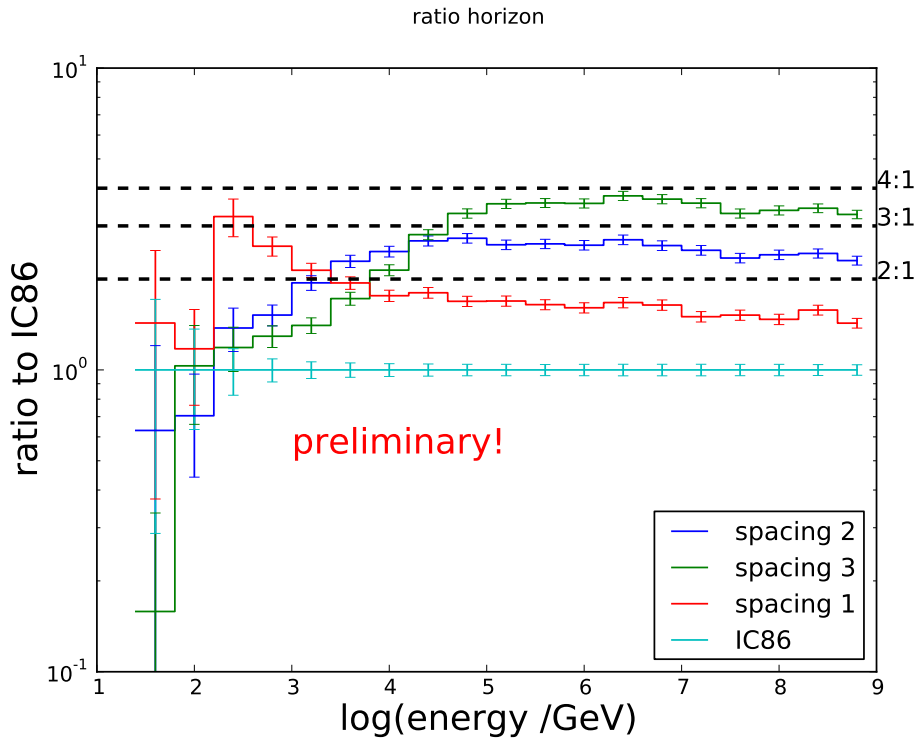
- up-going: cos(θ) < -0.33
- horizontal-going: -0.33 < cos(θ) < 0.33
- down-going: cos(θ) > 0.33



Earth becomes opaque!

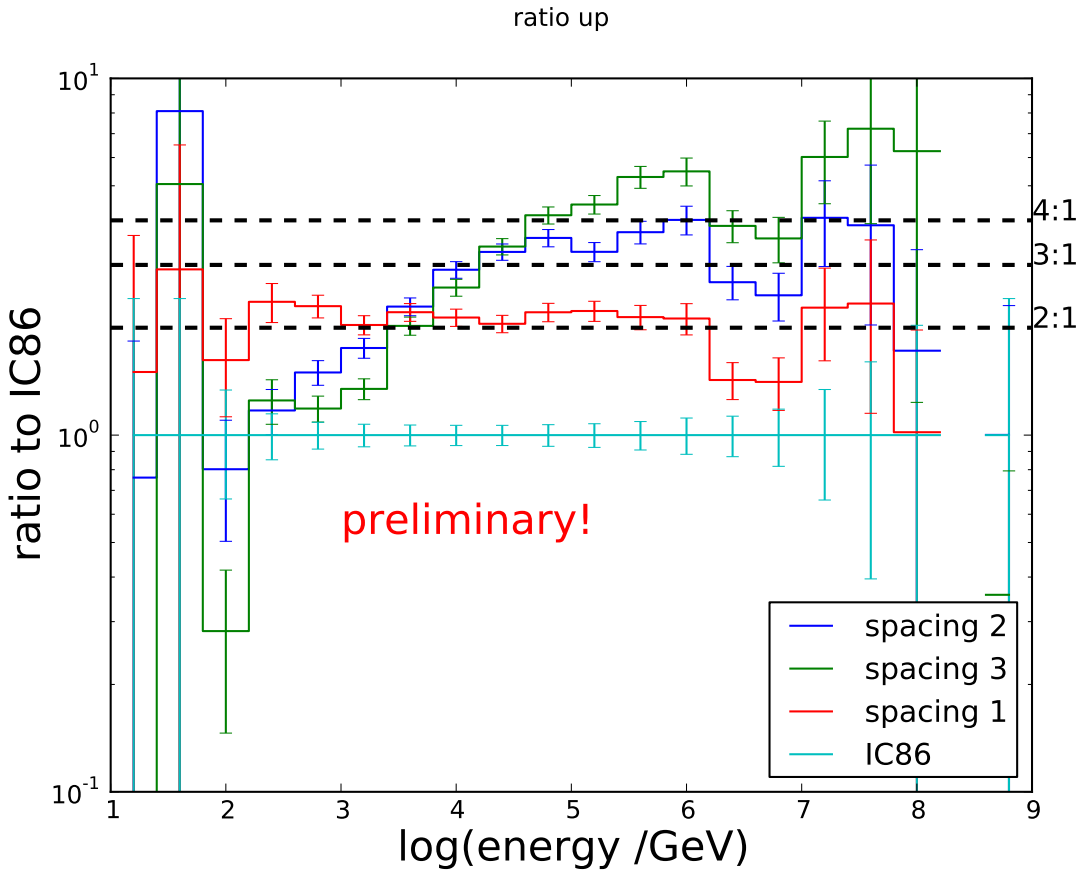
Effective area: Angular ratio down-going





Down-going ratio a bit better than horizontal ratio $\rightarrow$ preliminary simulation!

Effective area: Angular ratio up-going

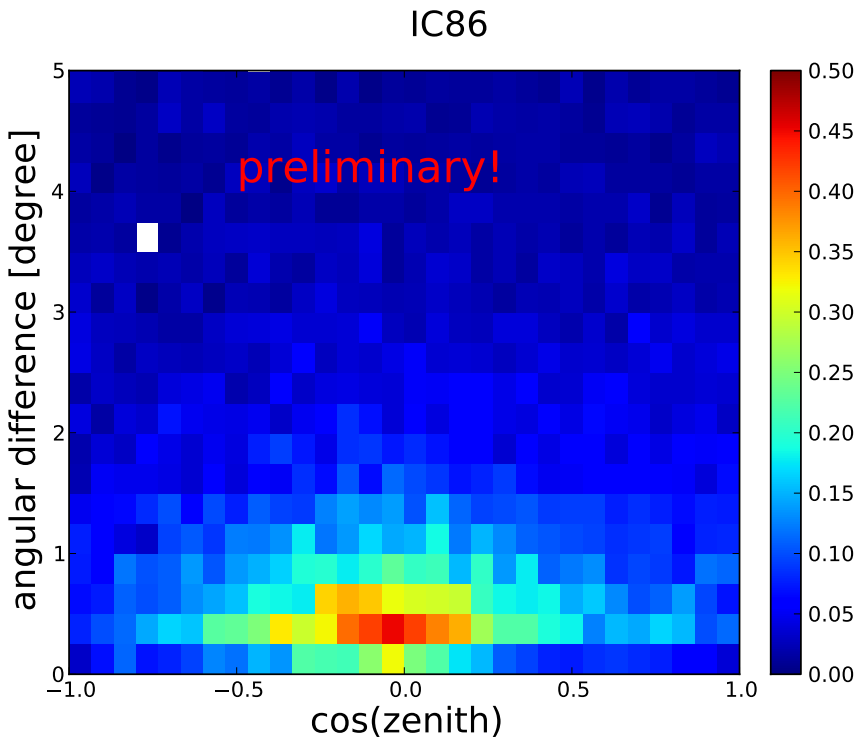


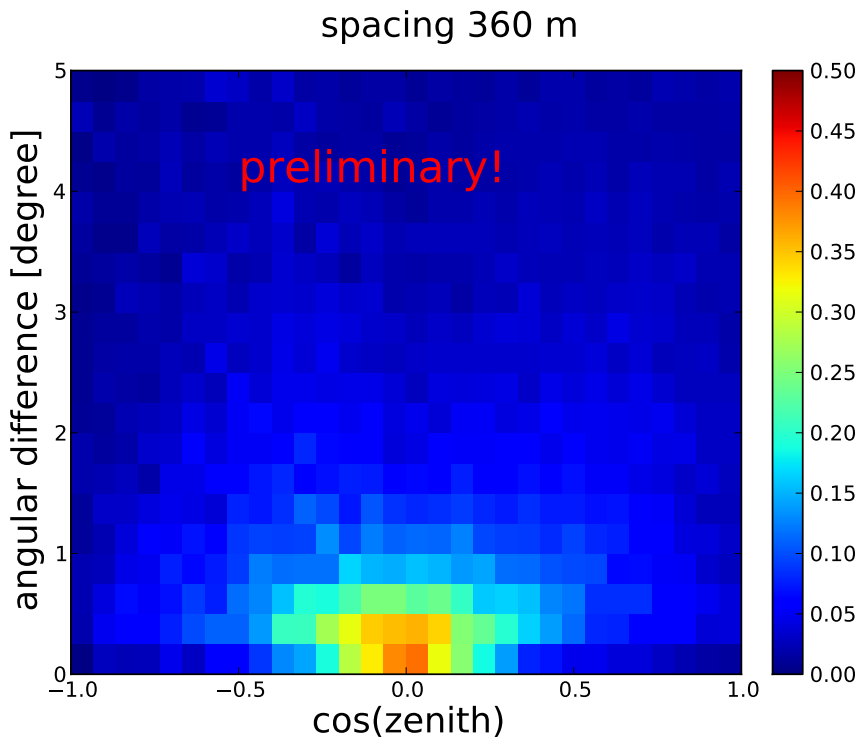
→ Low statistics make comparison at high energies difficult!

→ At lower energies similiar to down-going → expected!

Reconstruction with large spacing

Events (same trigger condition) with succesful reconstruction (SPE): Weighted with E_ν^{-2} and normalized





$\rightarrow$ Even though DOM density is much lower, resolution remains at a good level. Horizontal events can benefit from tracks in the detector volume with length of several km $\rightarrow$ Good Resolution!

Conclusion & Outlook

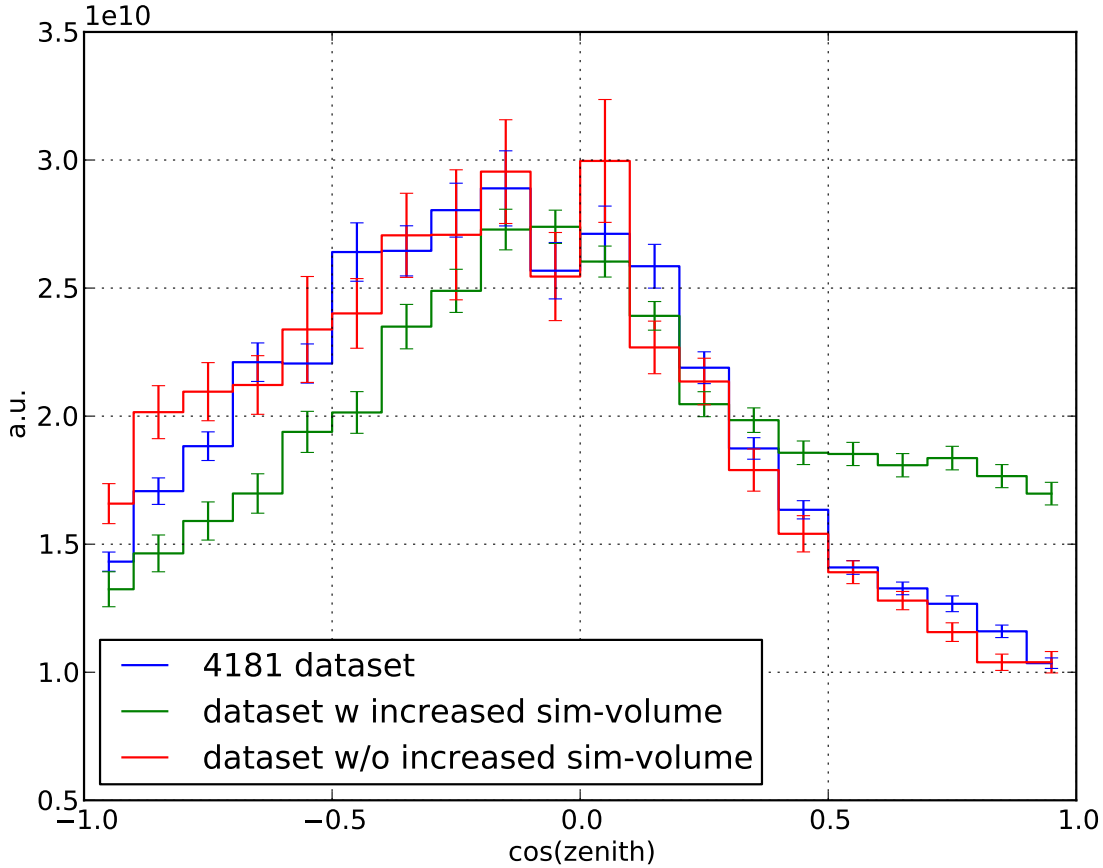
- An extension could improve A_{eff}, and resolution at least remains at a good level
- IceCube Software seems capable to simulate enlarged detector,
- **but** is not optimized for increased volume
  - ➔ Results are preliminary!
- Only ν_μ investigated (ν_τ and ν_e have to be investigated)
- Atmospheric background has to be simulated (first promising technical tests with CORSIKA)
- Investigation of sophisticated trigger and reconstruction algorithms seems necessary

Last slide!

Thank you for your attention!

Questions?

How **good** do we simulate ν?



- Increasing the simulated volume has impact on angular distribution!
- down-going events are overrated in the simulation!
  - ➔ All results are preliminary!
  - ➔ Weighting has to be fixed!