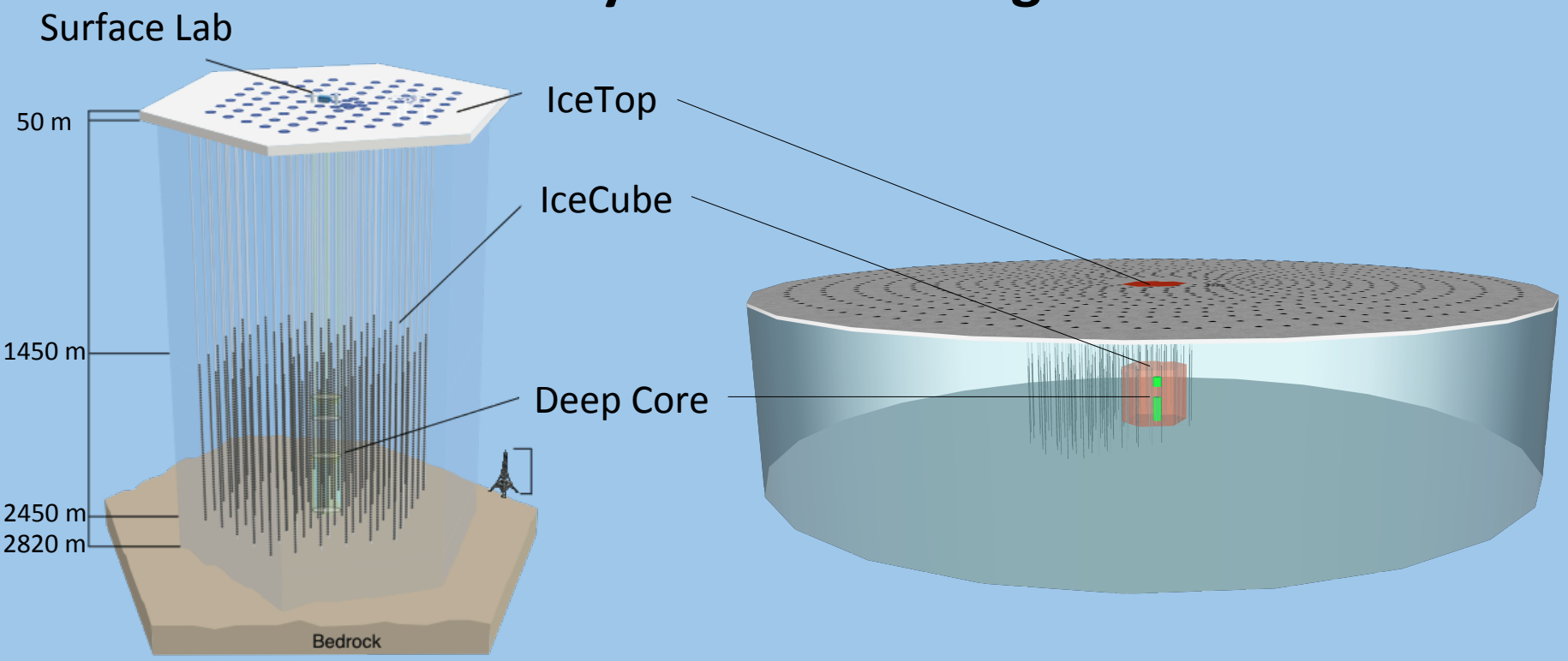
IceVeto

A high-energy extension for IceCube.

by Jan Auffenberg



R&D Proposal: IceVeto

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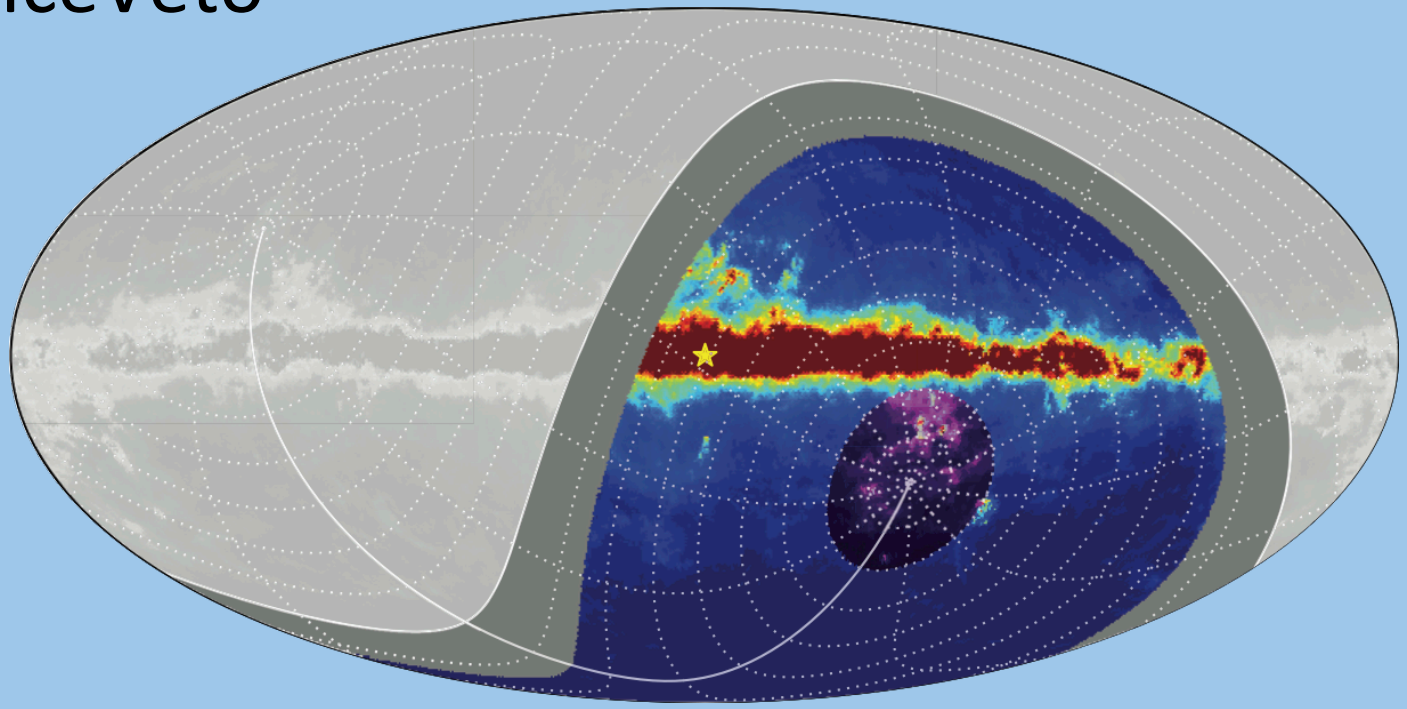

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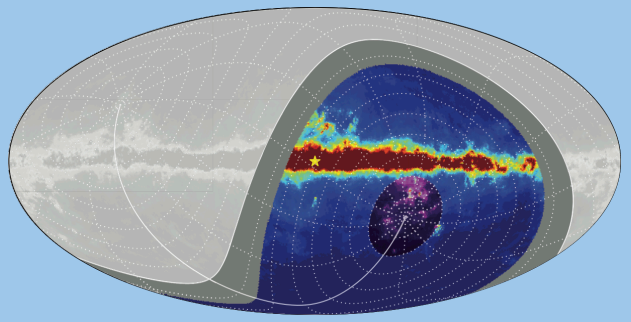
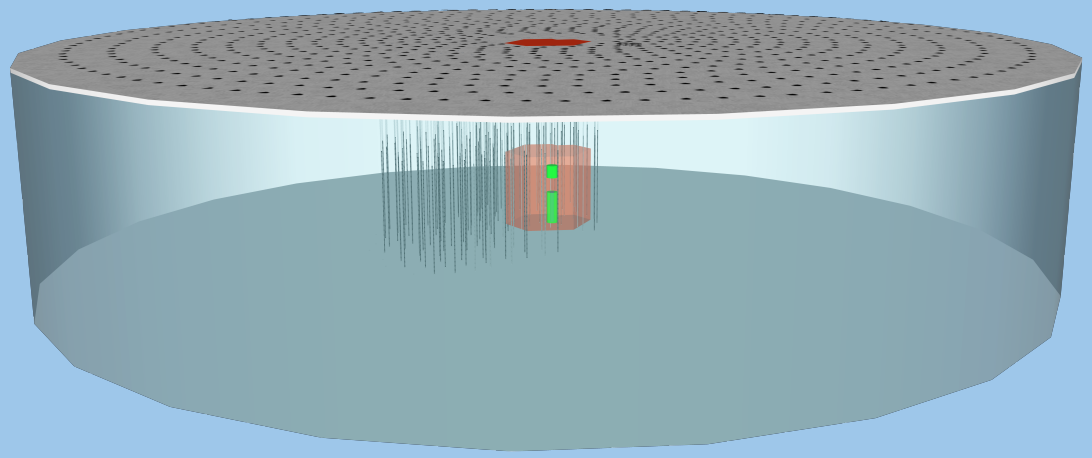
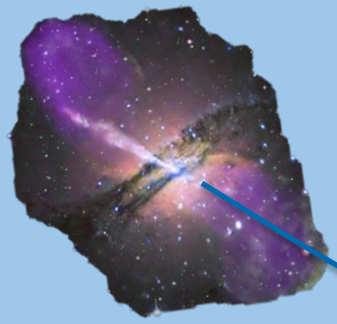




Why astrophysical neutrino search?



Cosmic-Rays: Unknown origin as they get bent in magnetic fields

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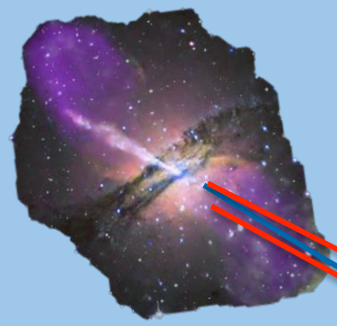

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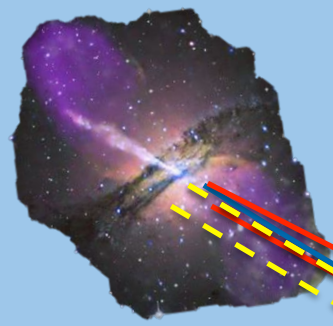

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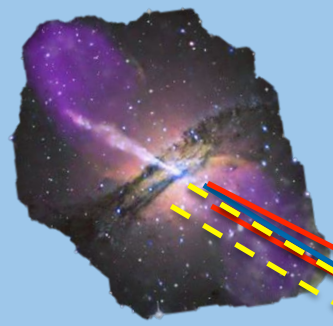

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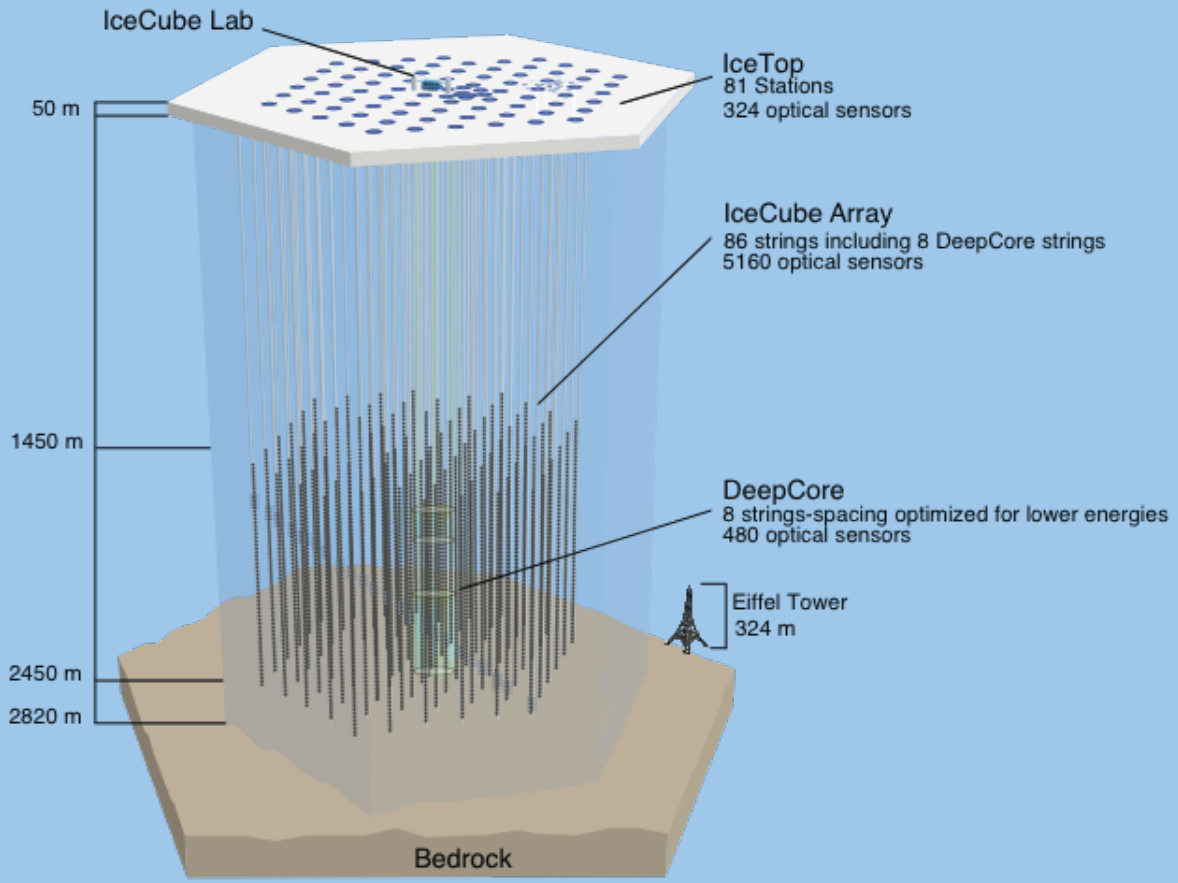
Neutrinos point back to their sources !

IceCube today



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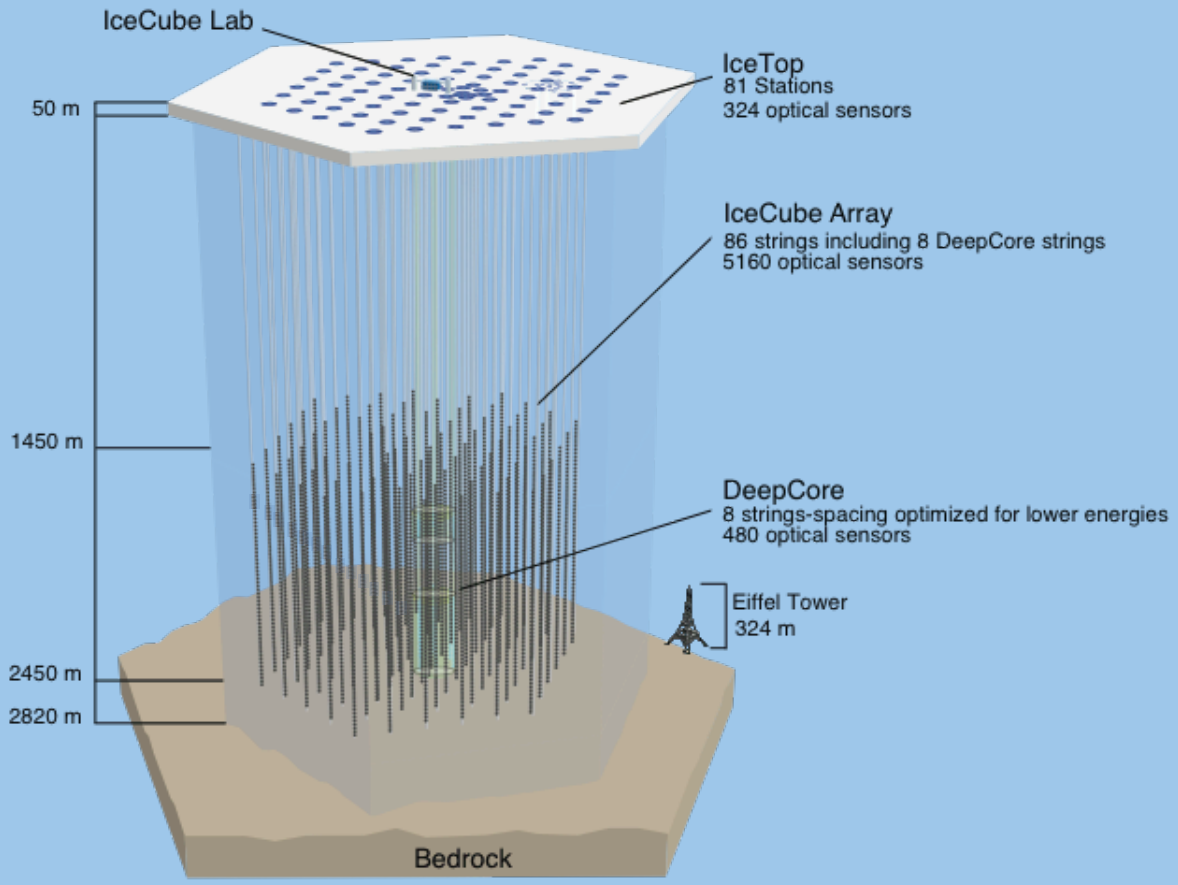

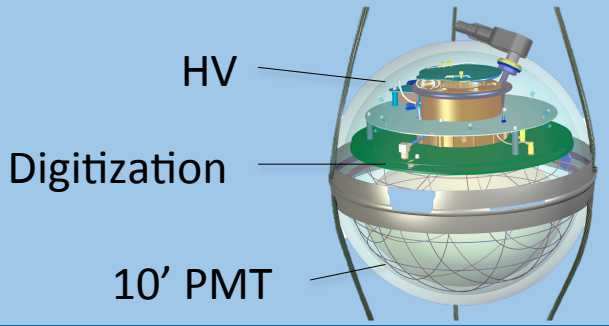

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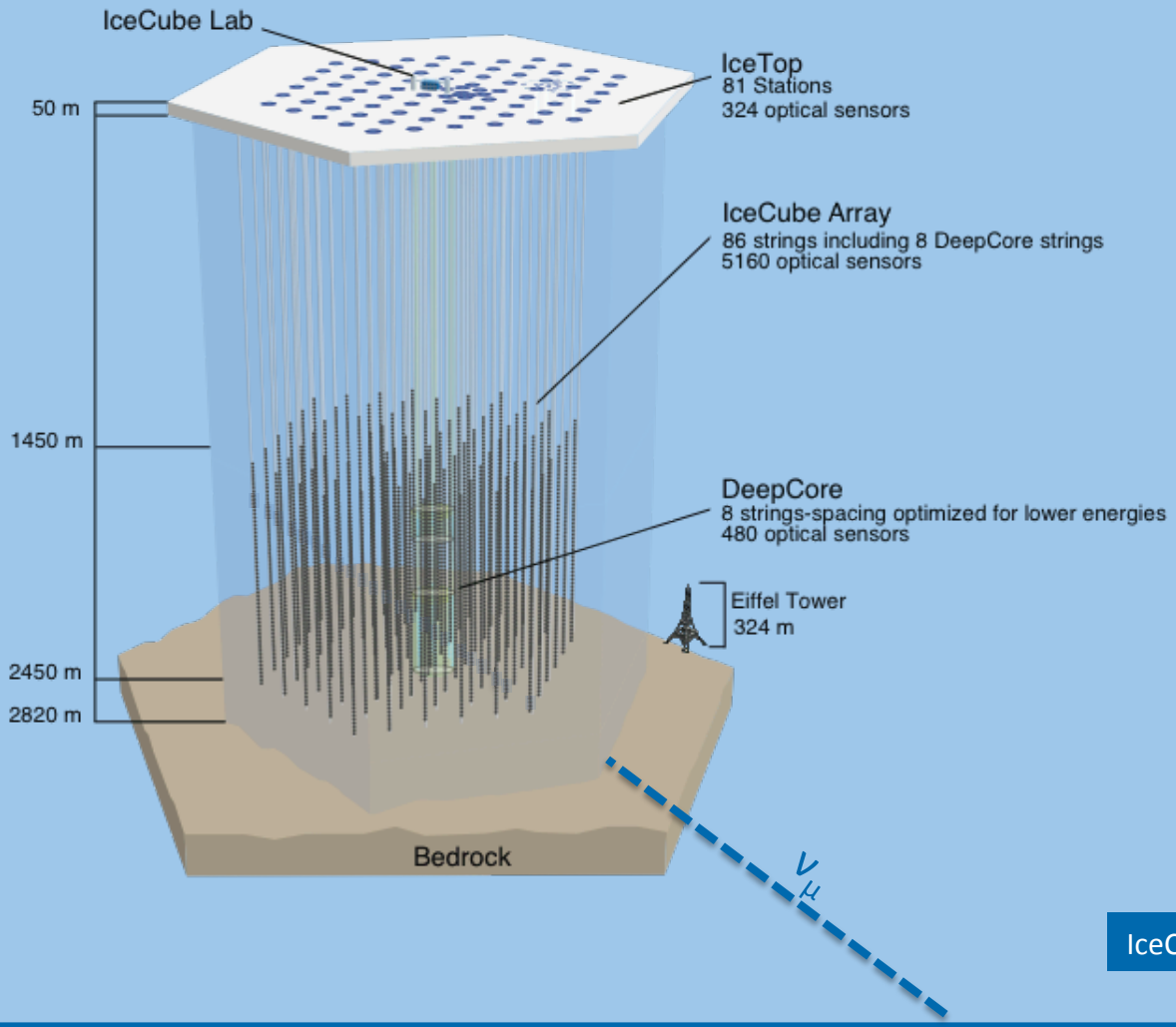

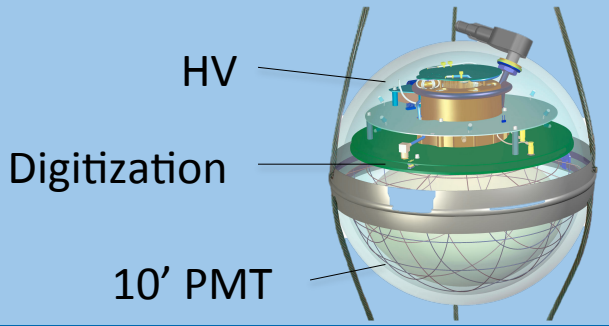

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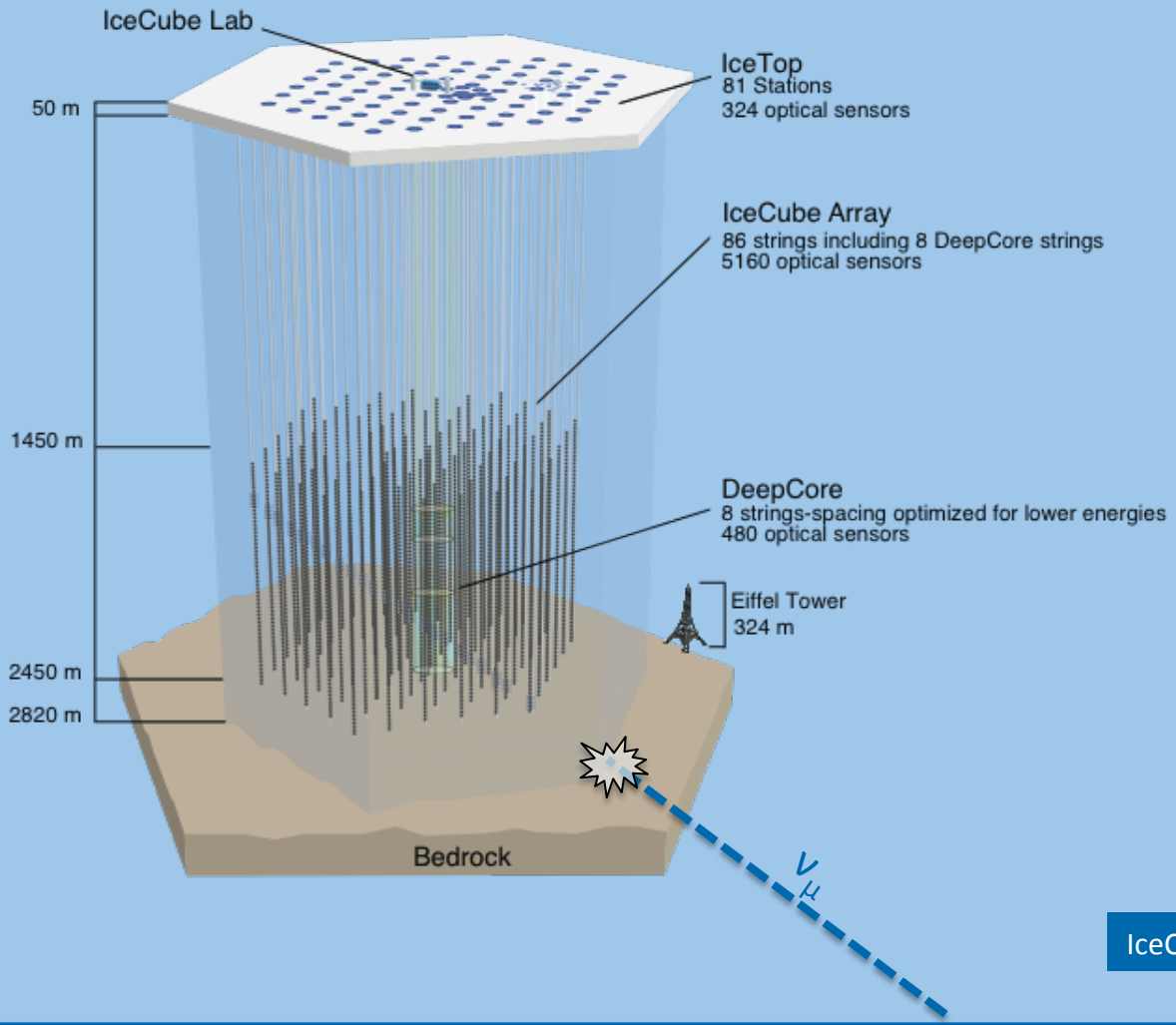

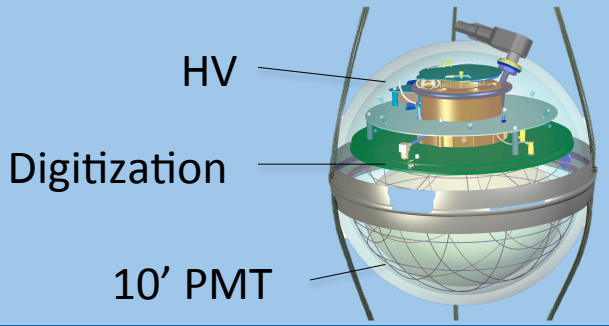

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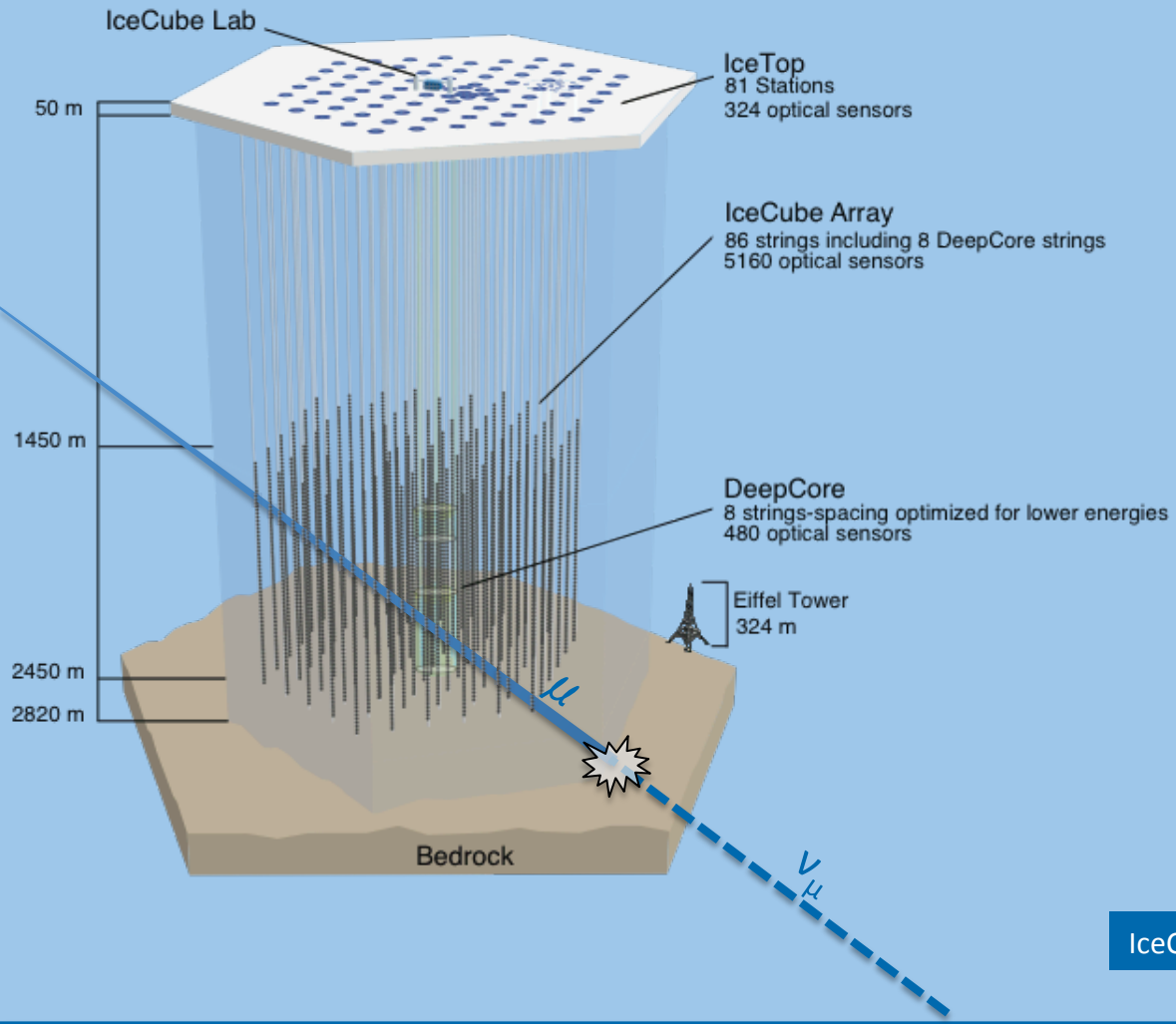

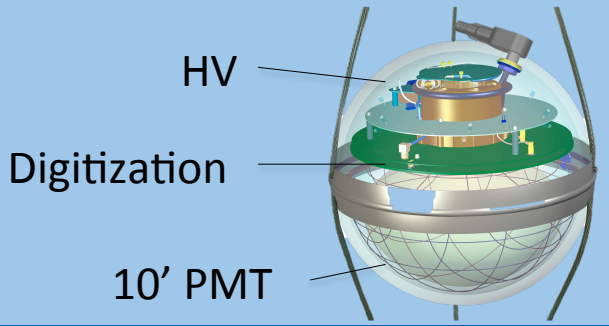

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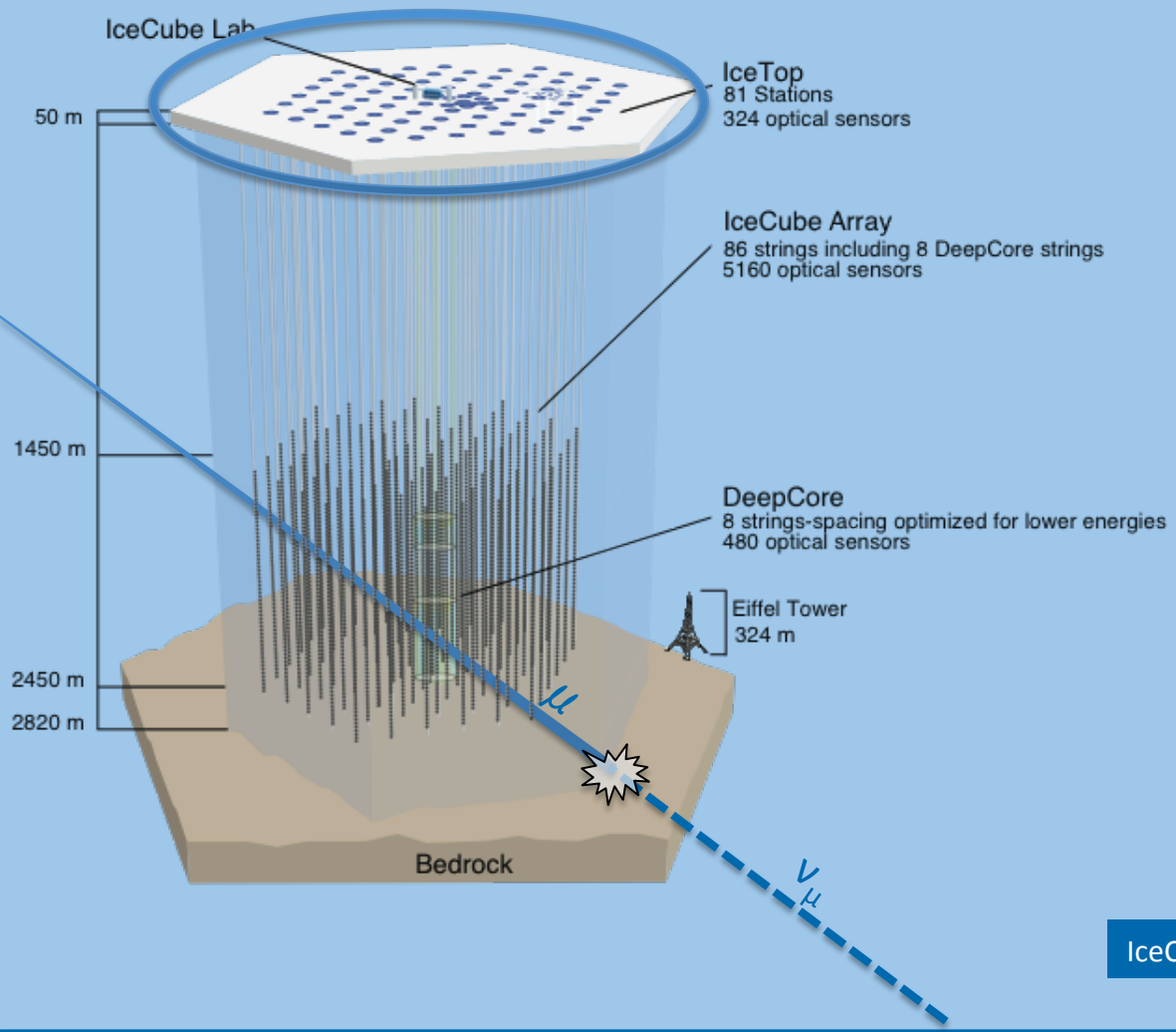

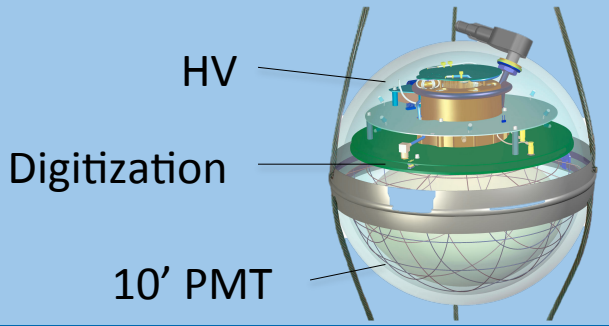

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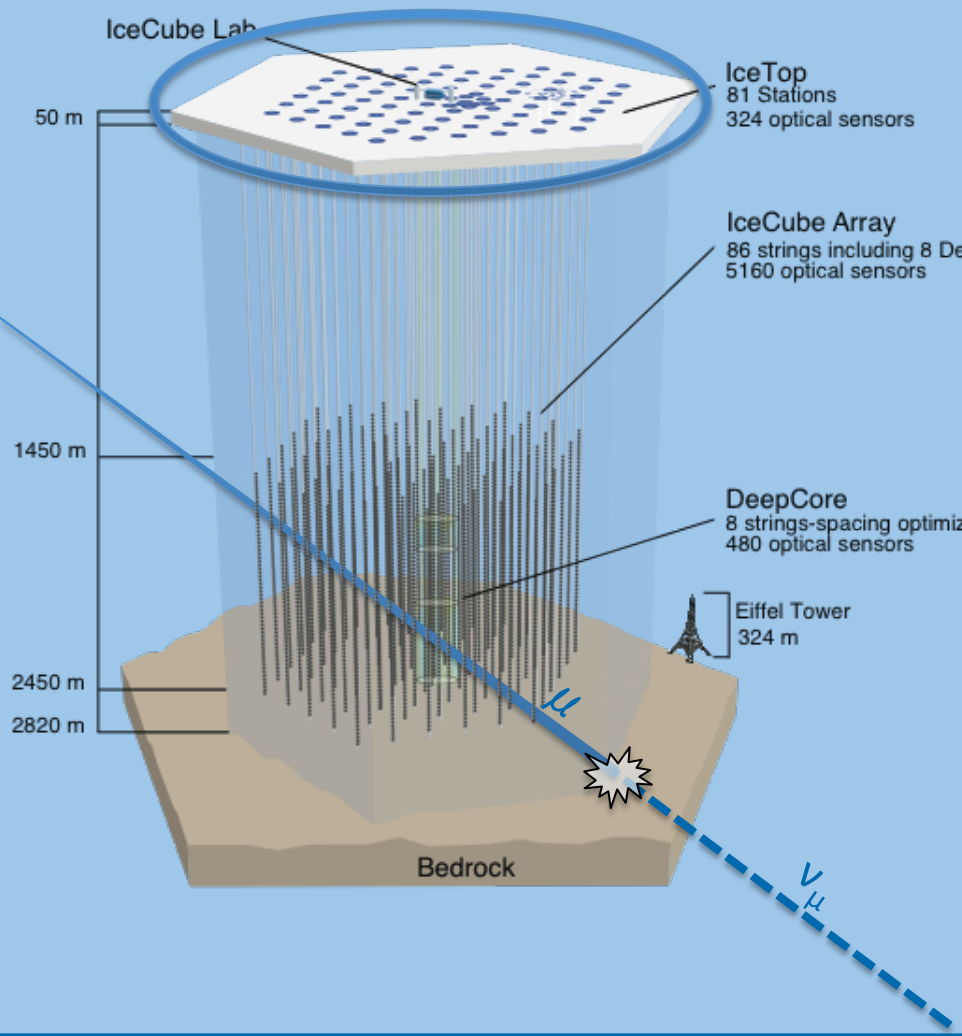

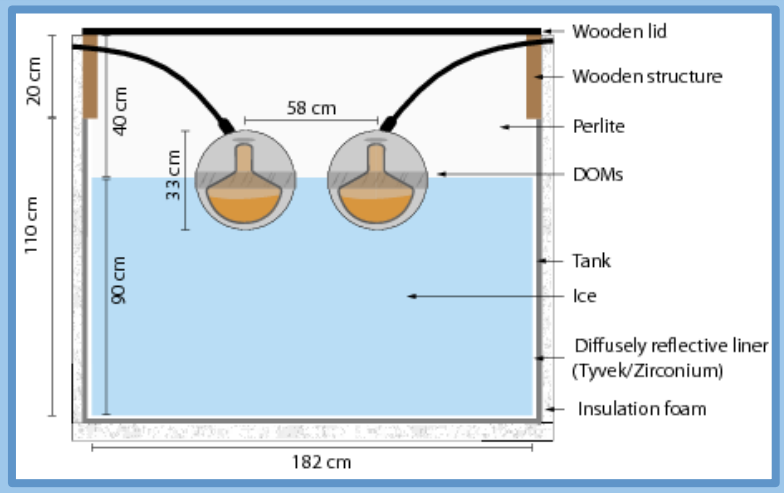

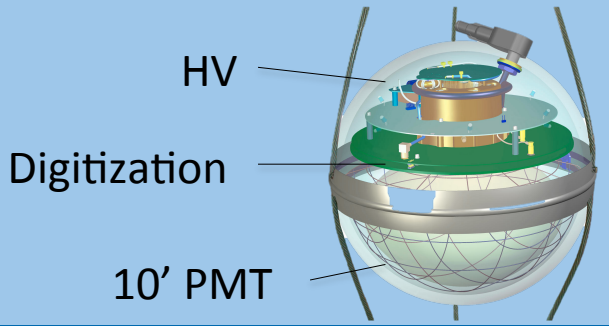

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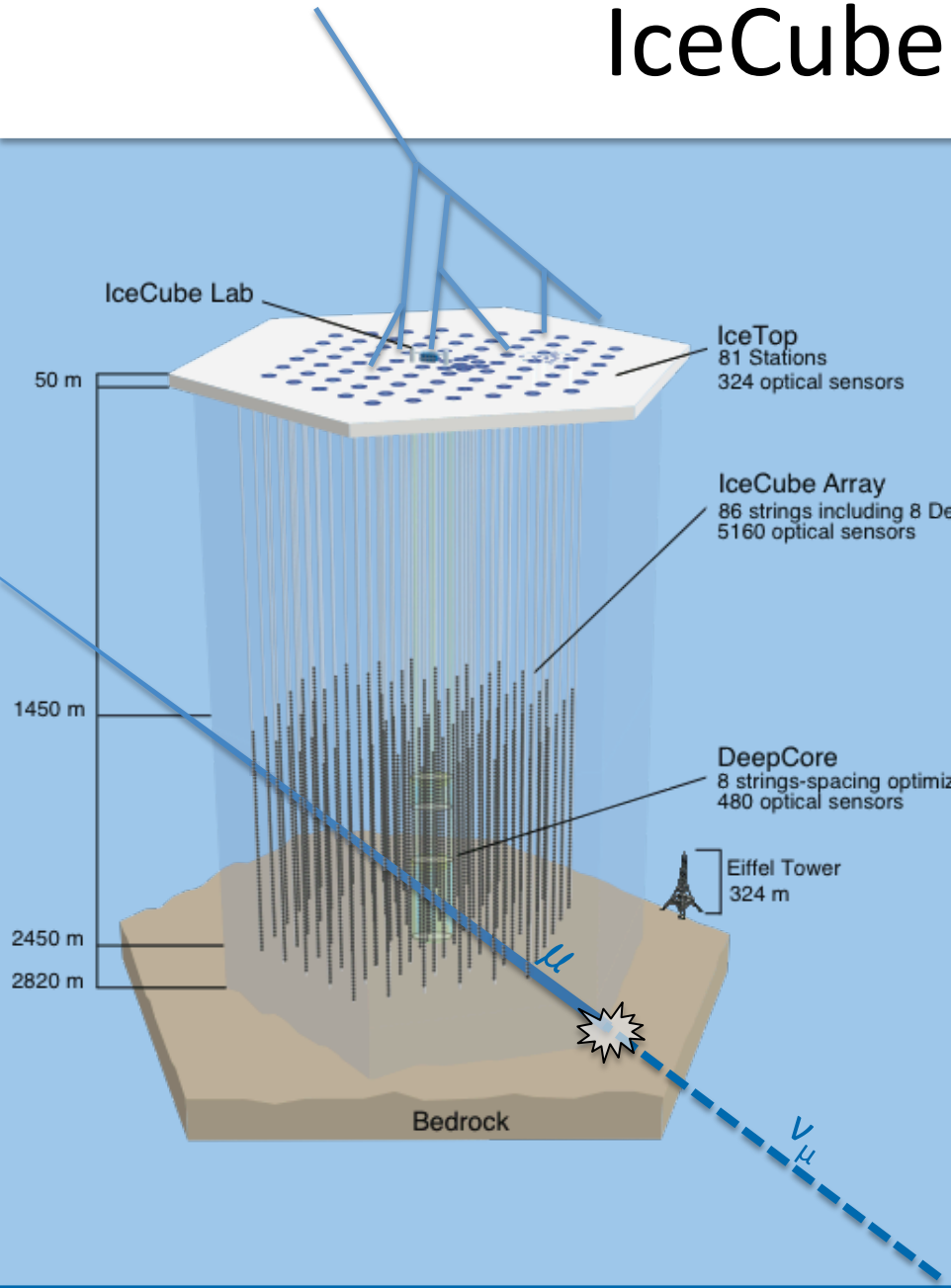

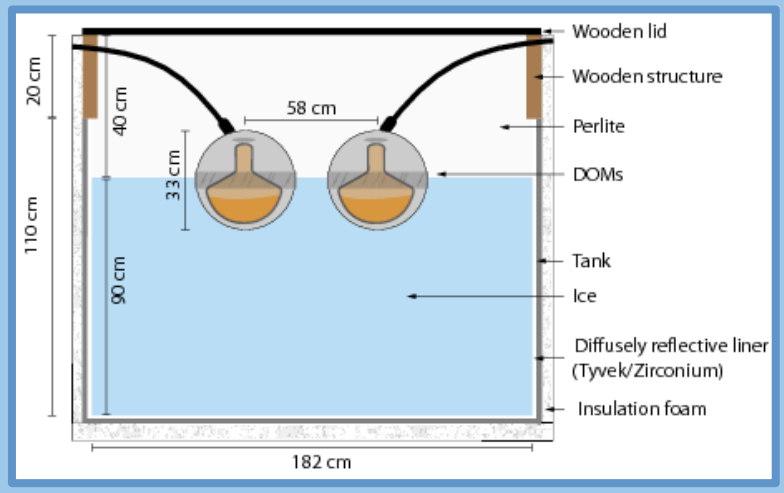

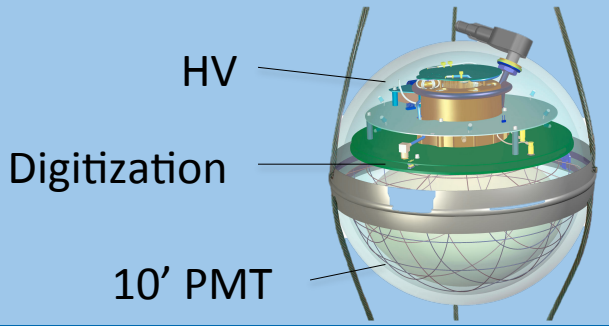

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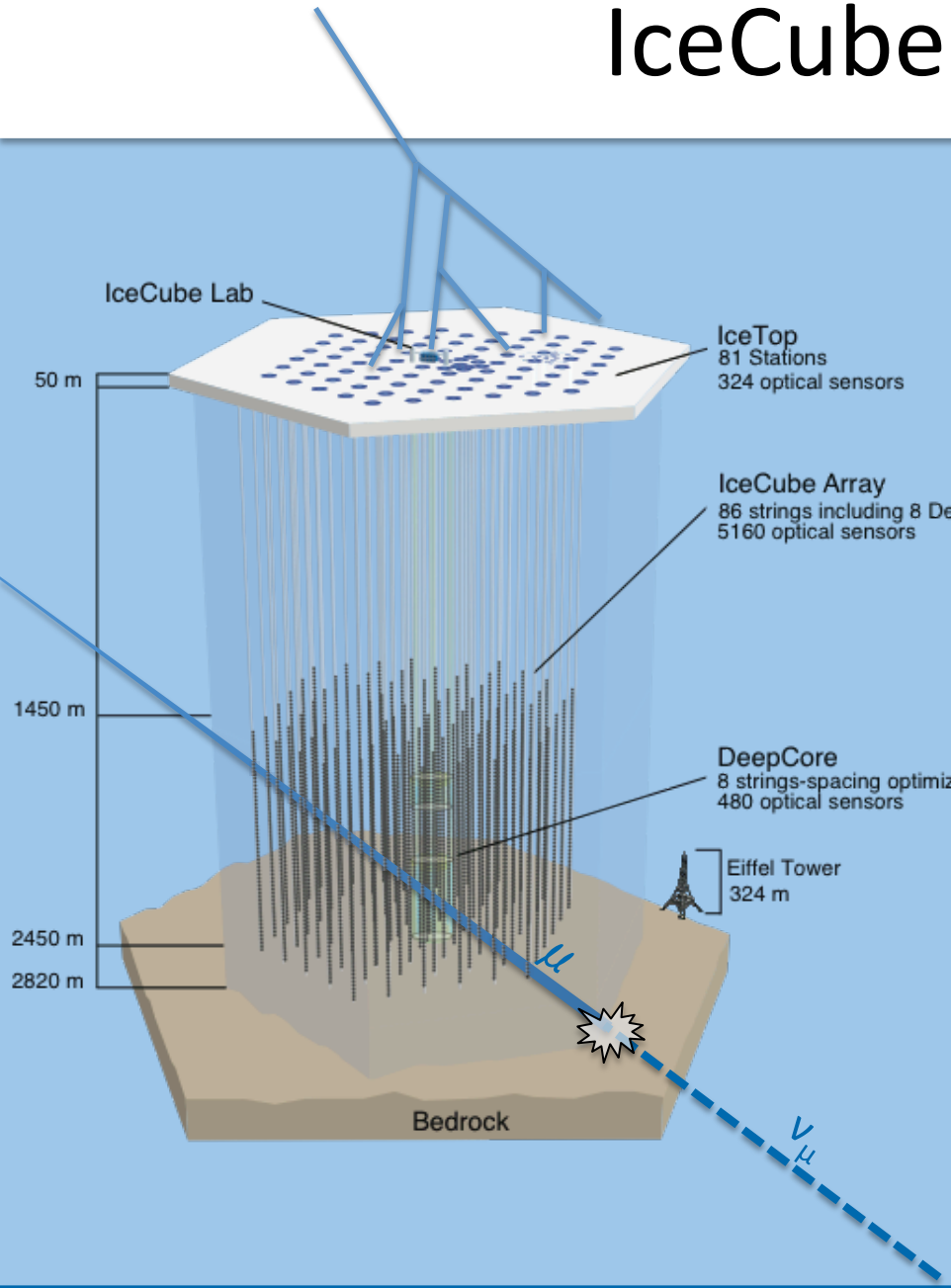

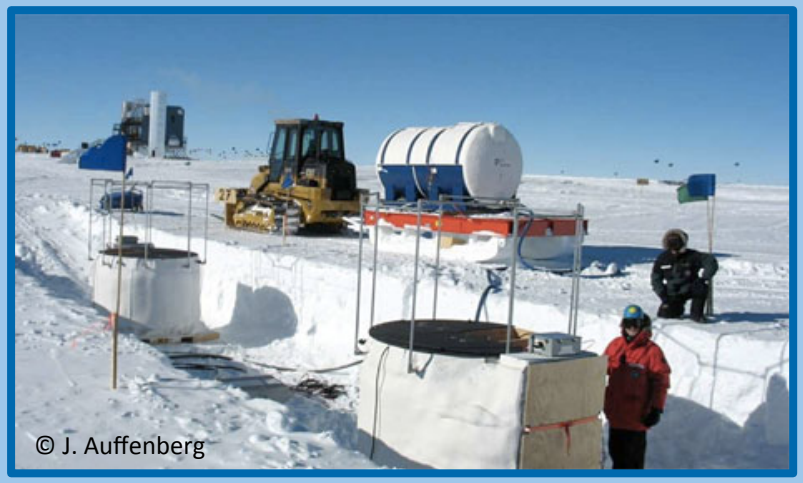
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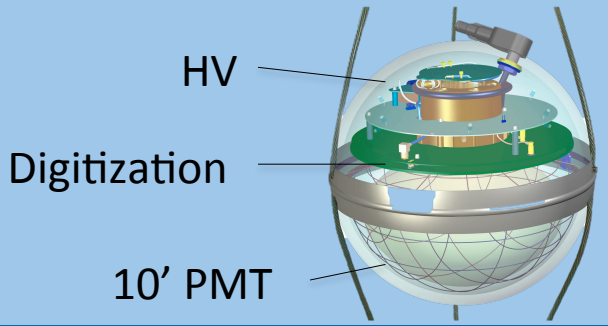

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Observed Neutrino Signatures

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Neutral Current /Electron Neutrino
so called “**shower**”

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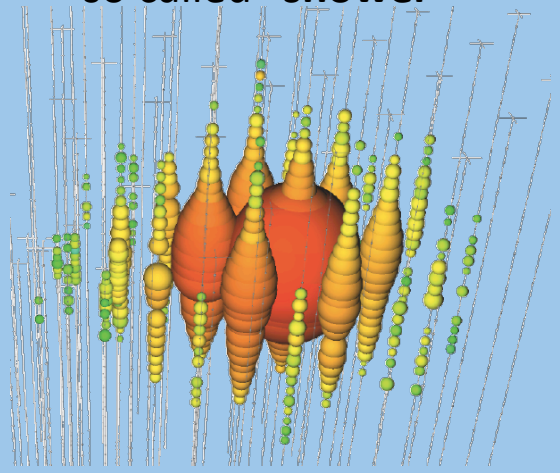

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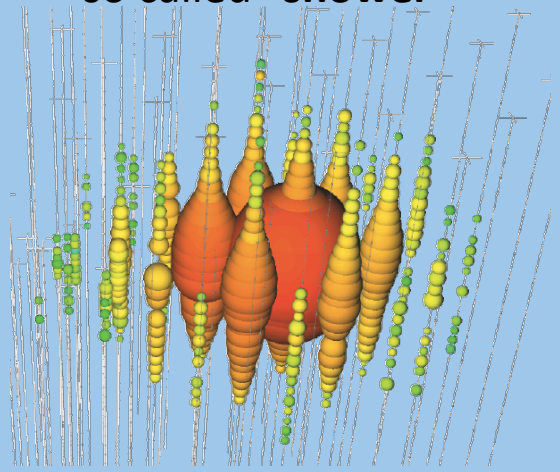

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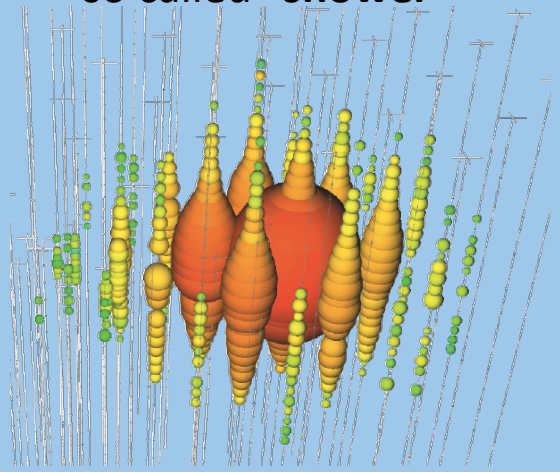

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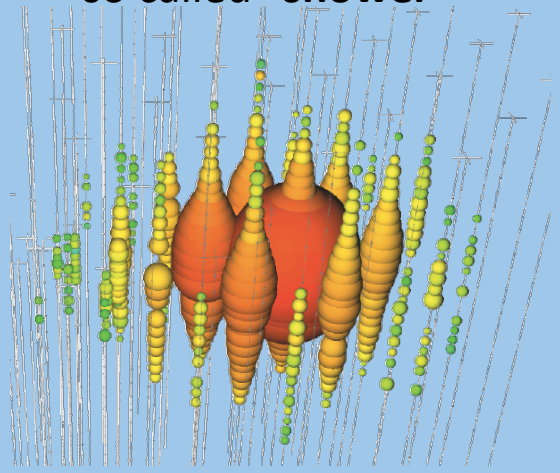

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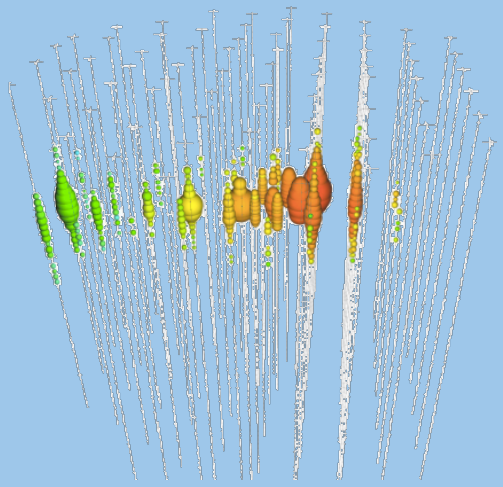

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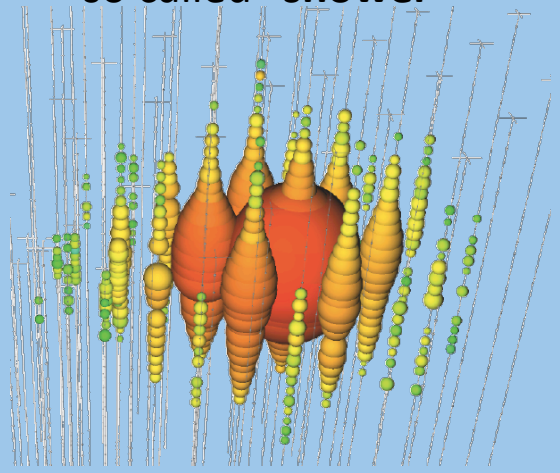

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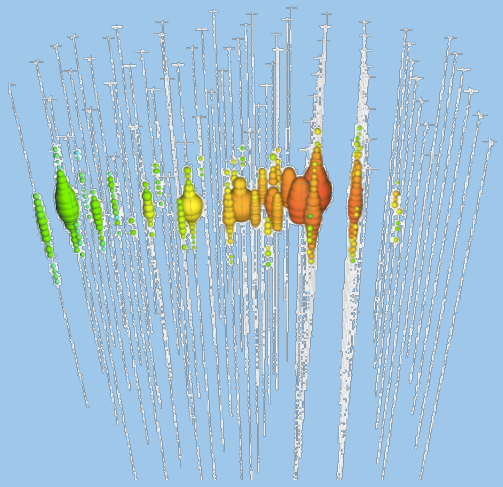

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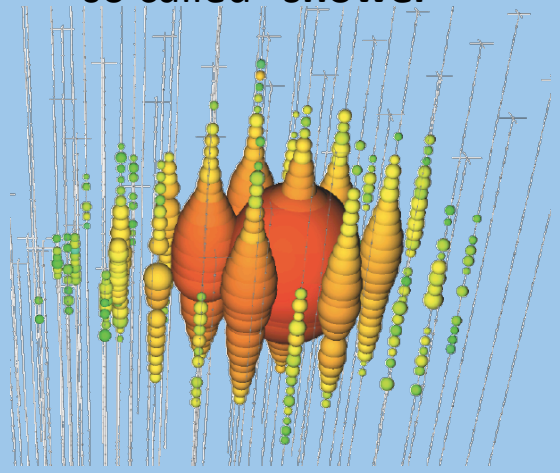

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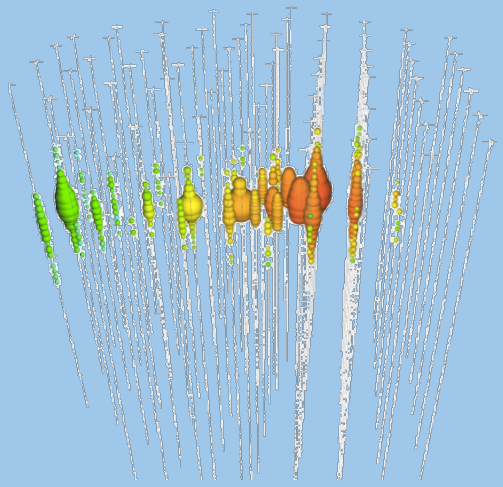

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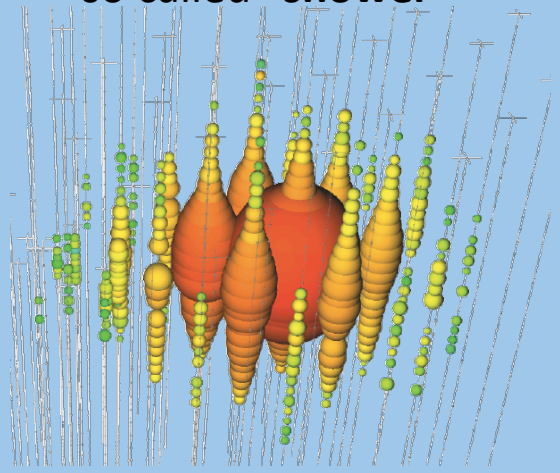

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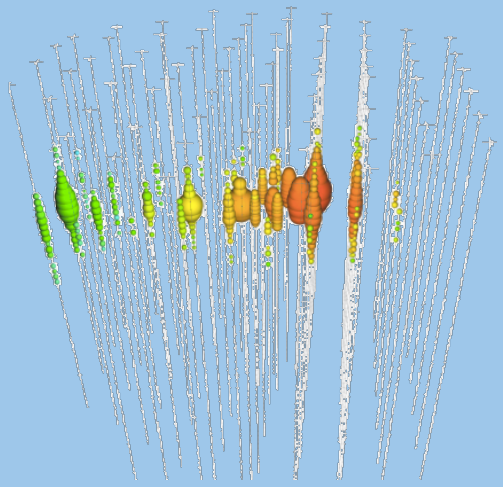

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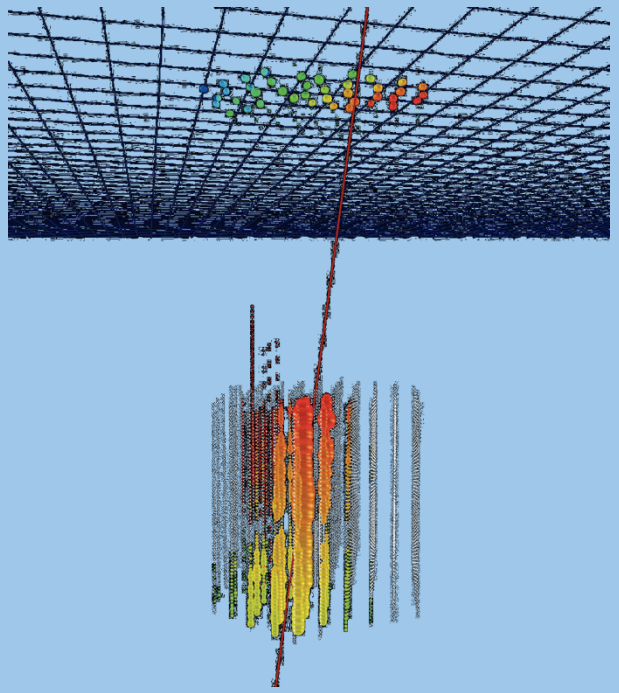
Cosmic-Ray background



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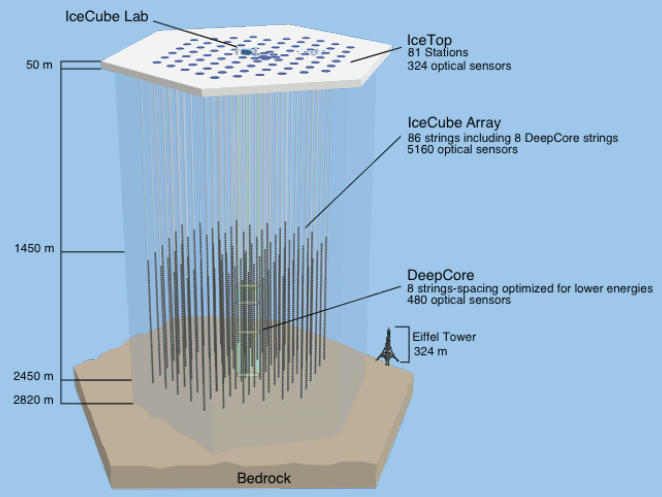
IceCube Results: Starting Events



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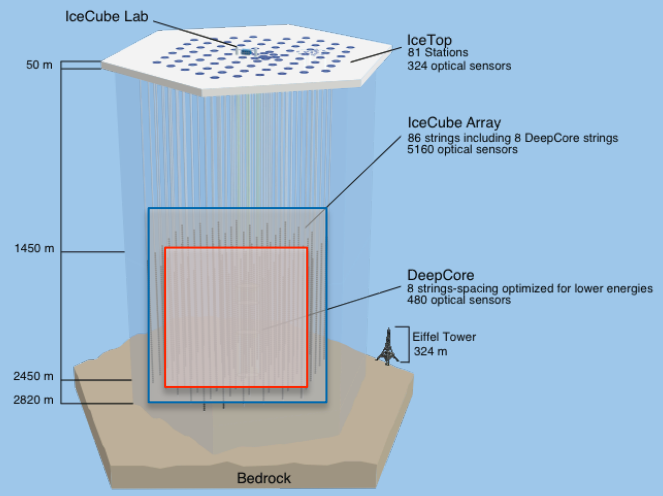

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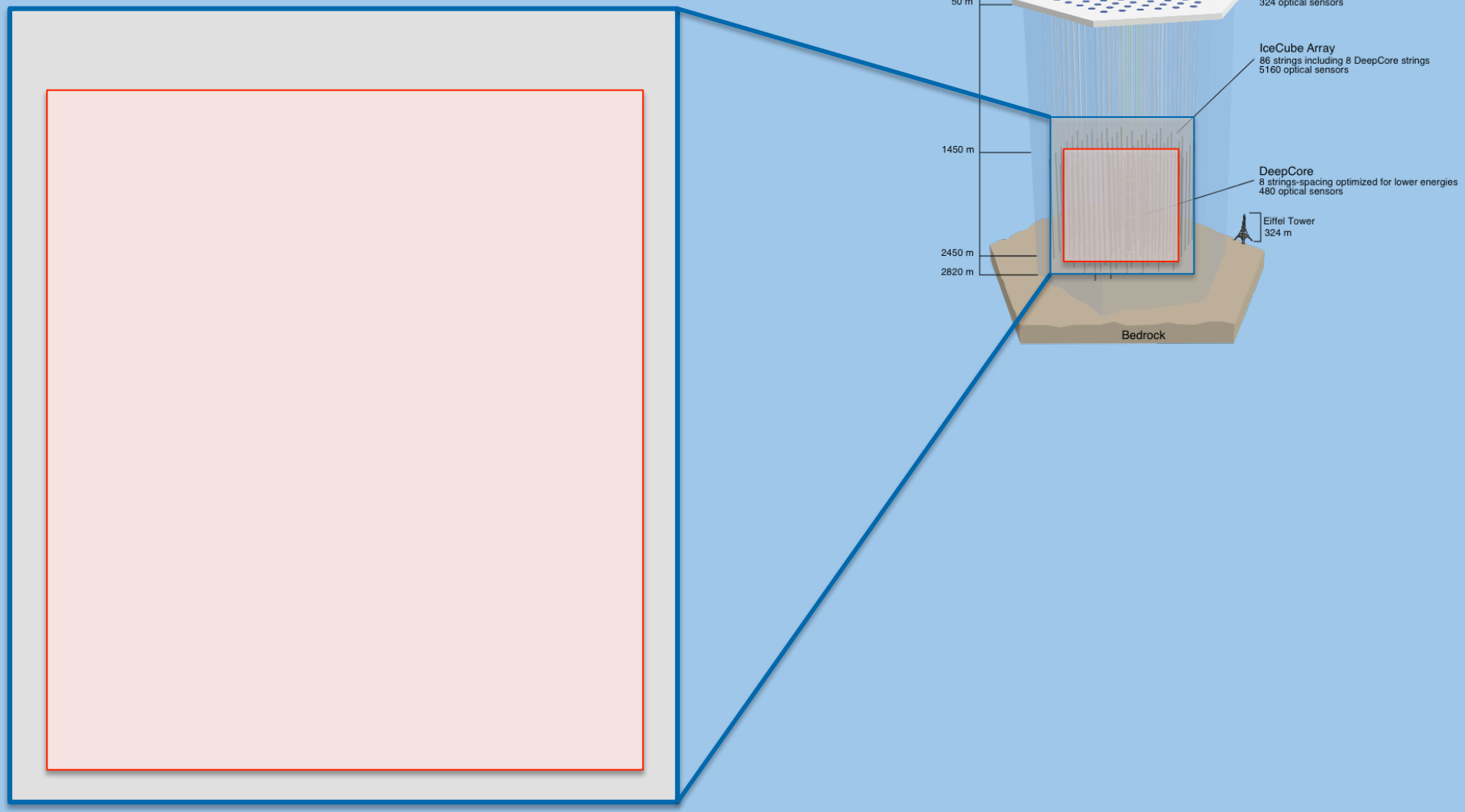

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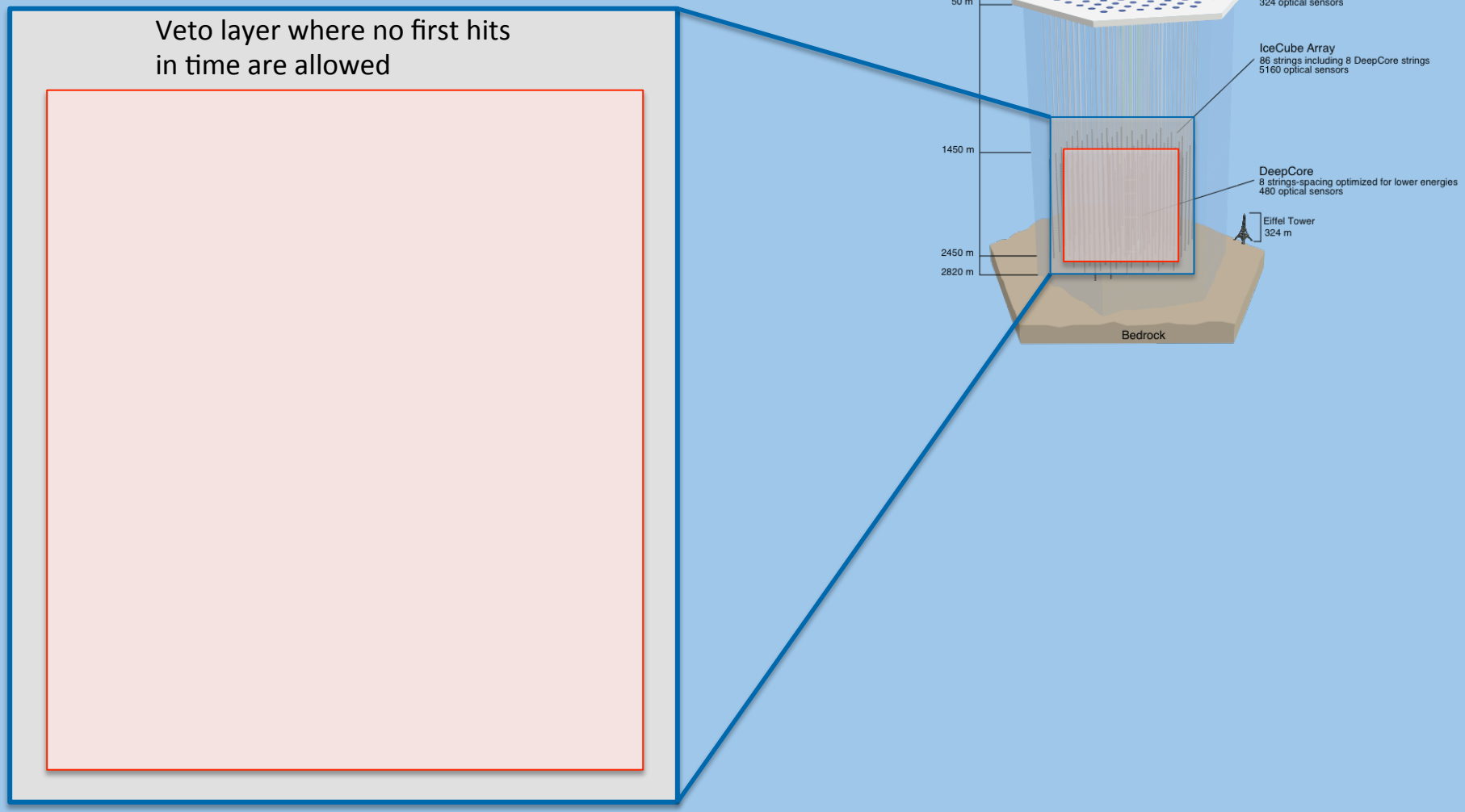
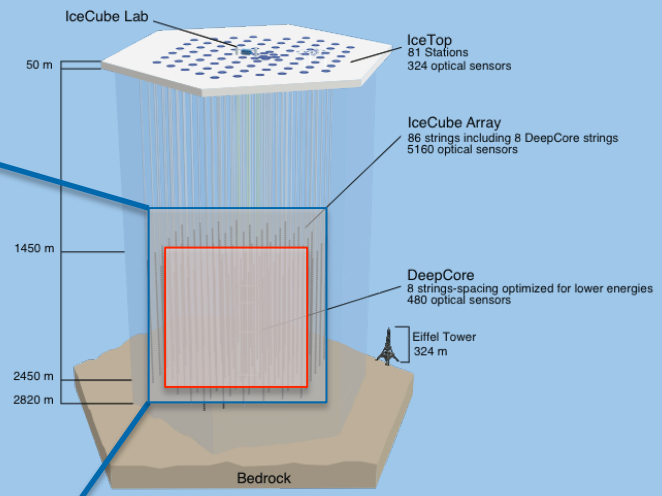


IceCube Results: Starting Events

Veto layer where no first hits in time are allowed

Vetoed Event



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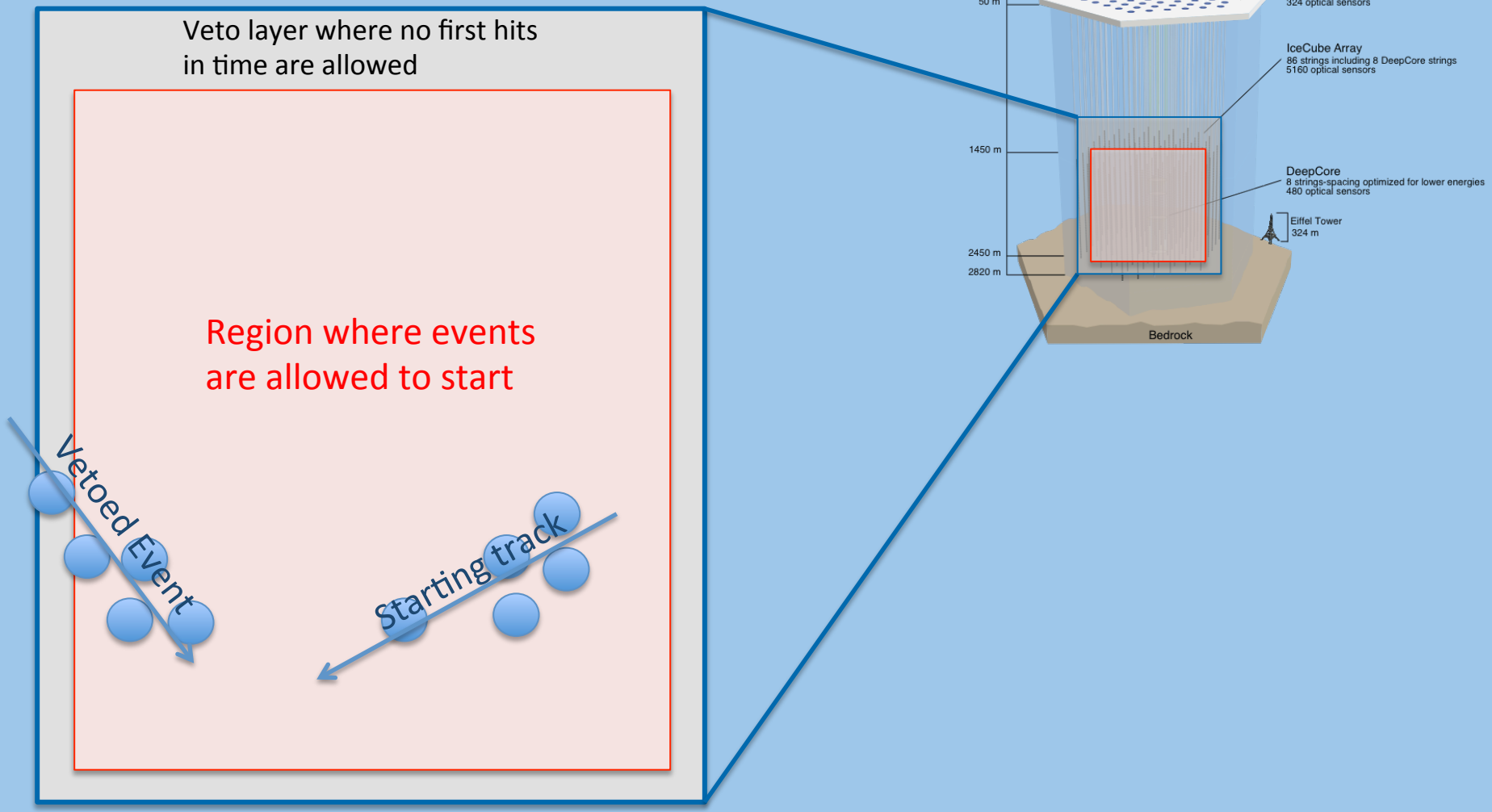

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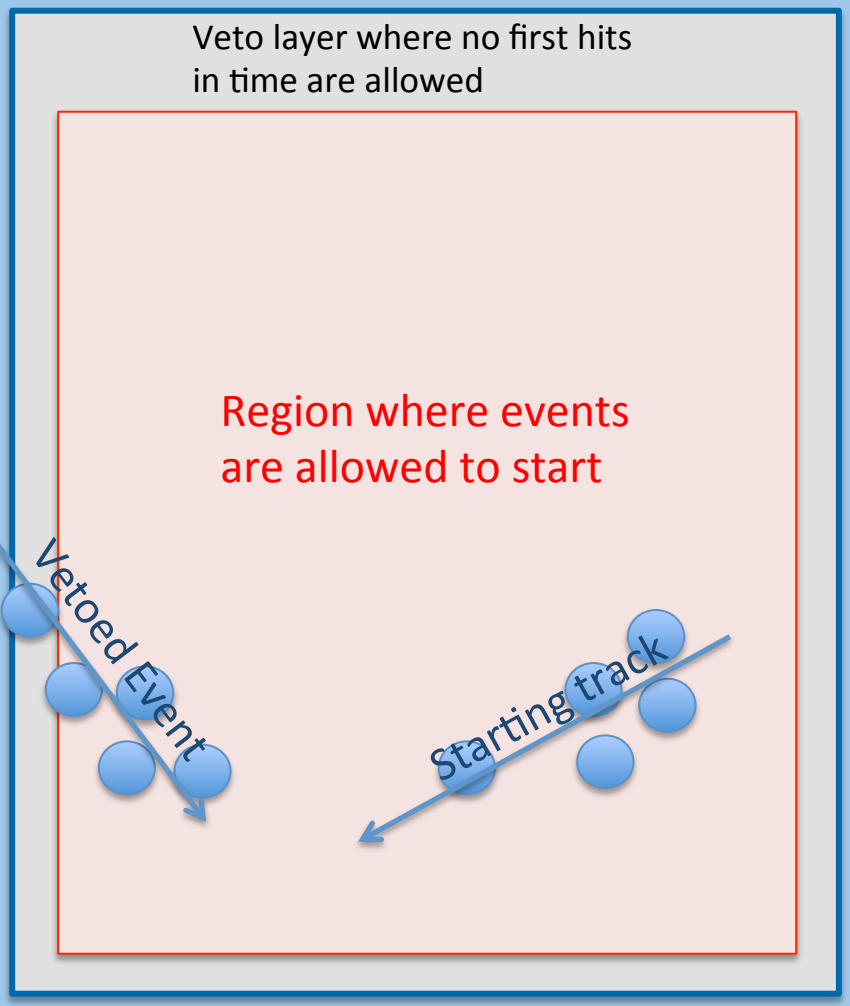

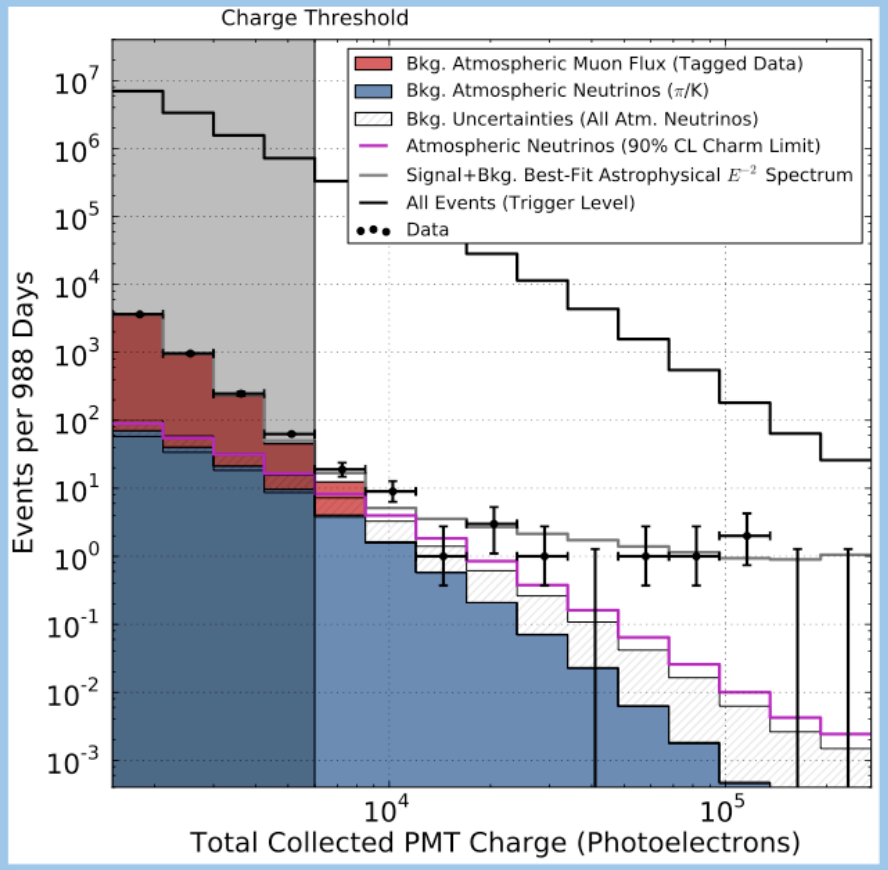

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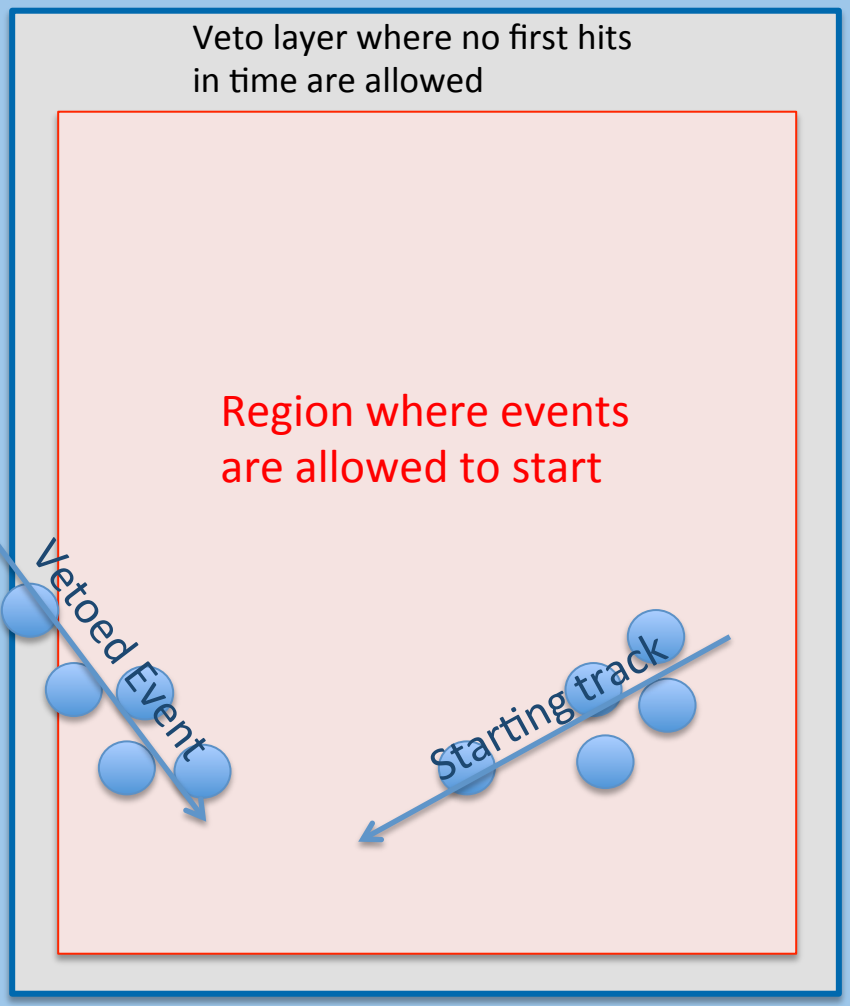

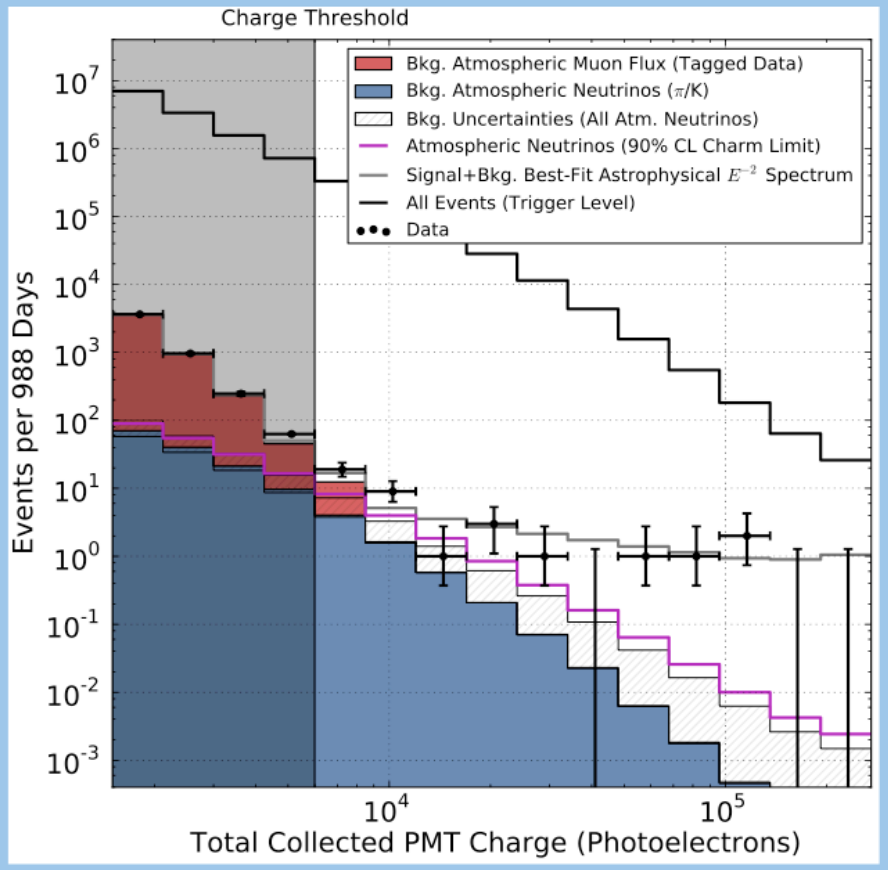

- null hypothesis rejected with 5.7σ after three years of data taking

IceCube Results: Starting Events

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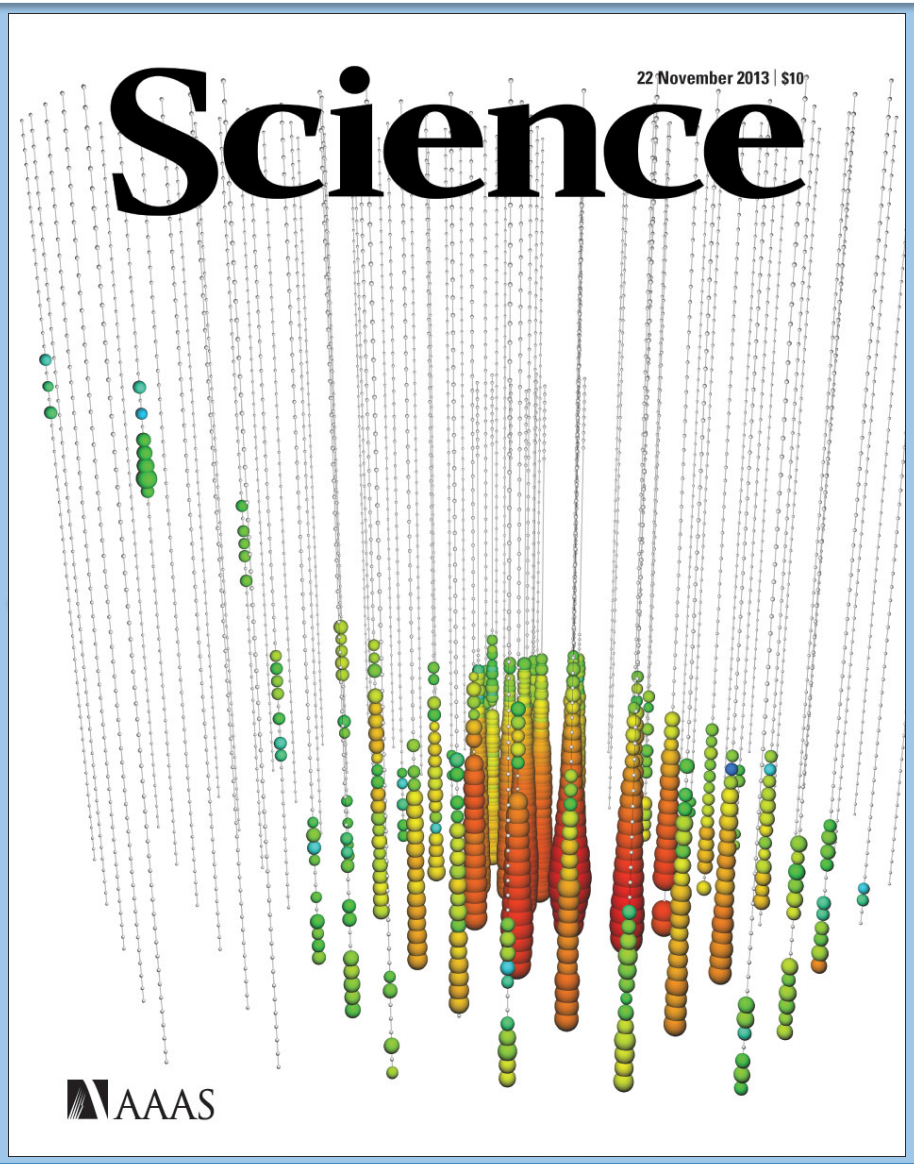
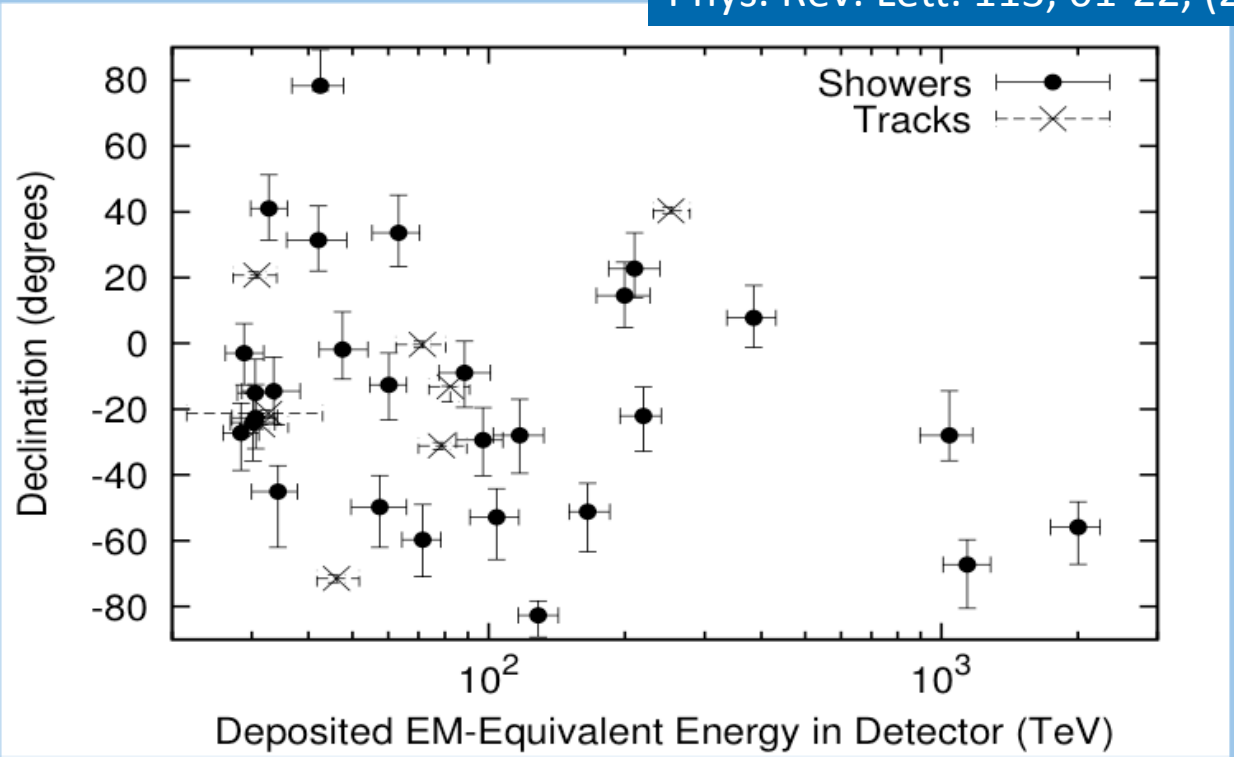


Where do the neutrinos come from?

Phys. Rev. Lett. 113, 01-22, (2014).



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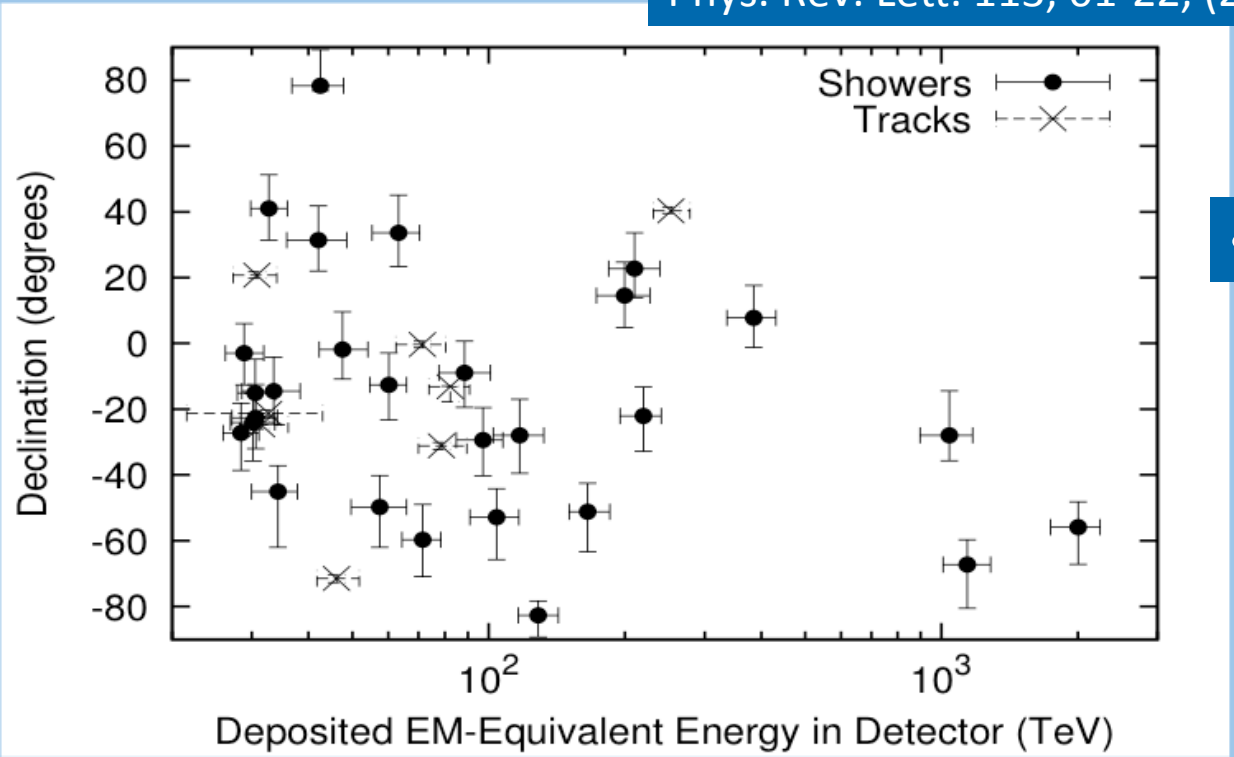

- only few tracks

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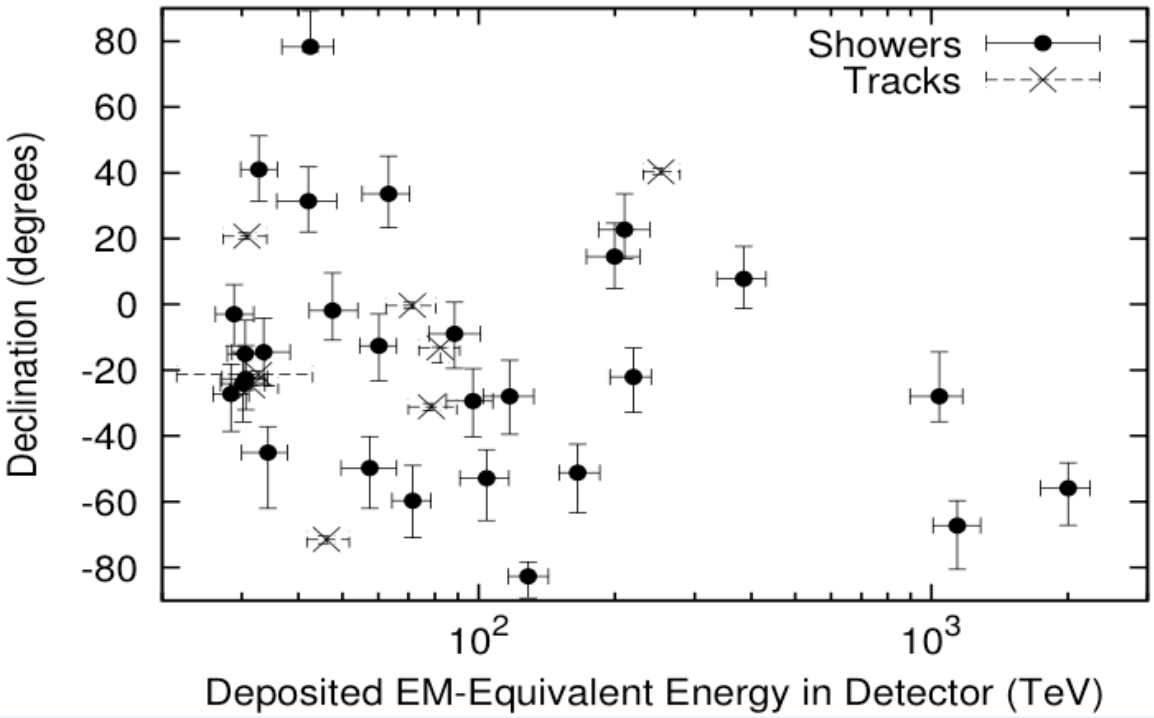

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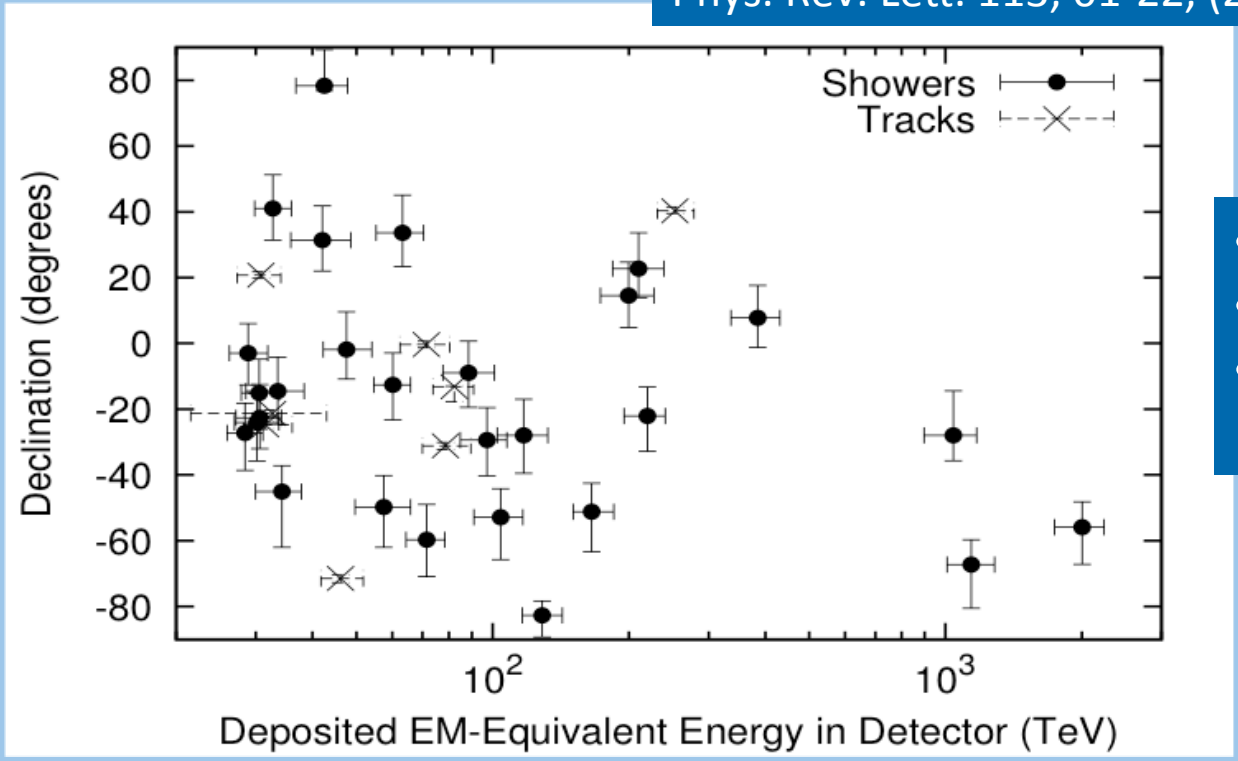

- only few tracks
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- PeV neutrinos only from the southern sky

Where do the neutrinos come from?

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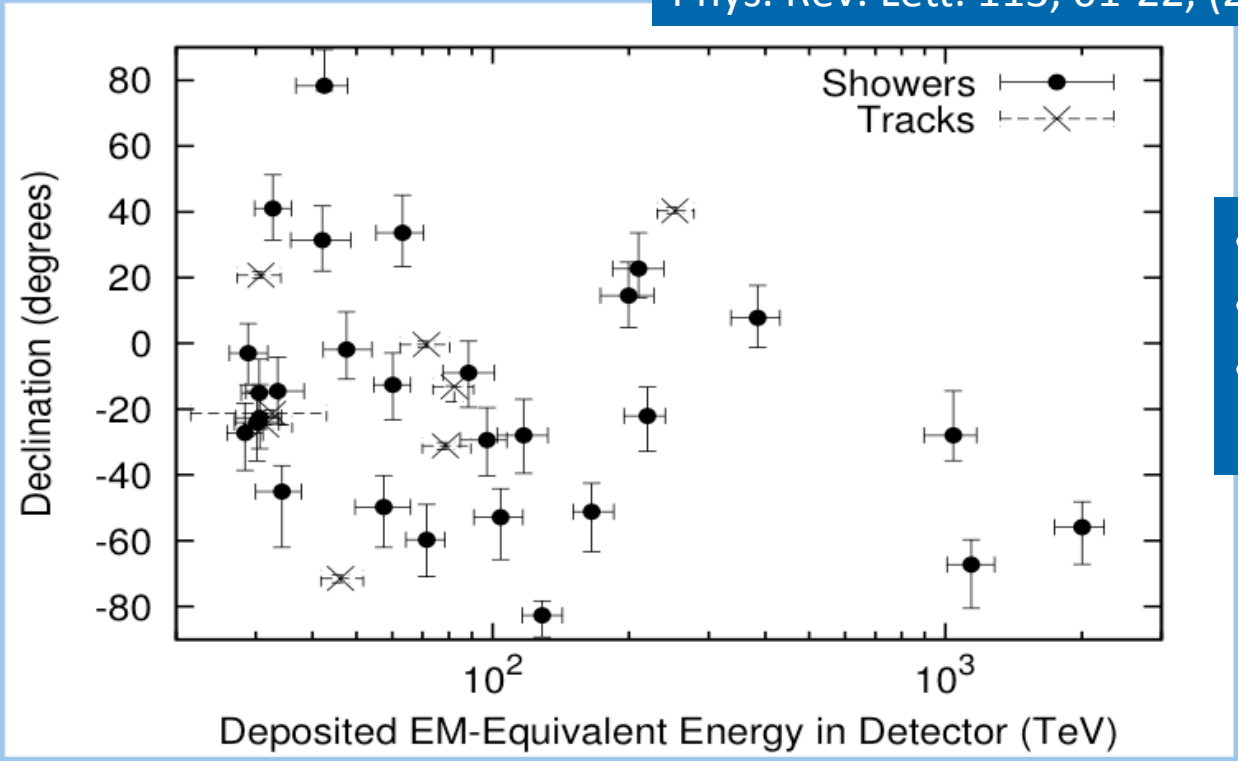

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We need more high energy tracks e.g. from the southern sky!

The future extension: IceVeto

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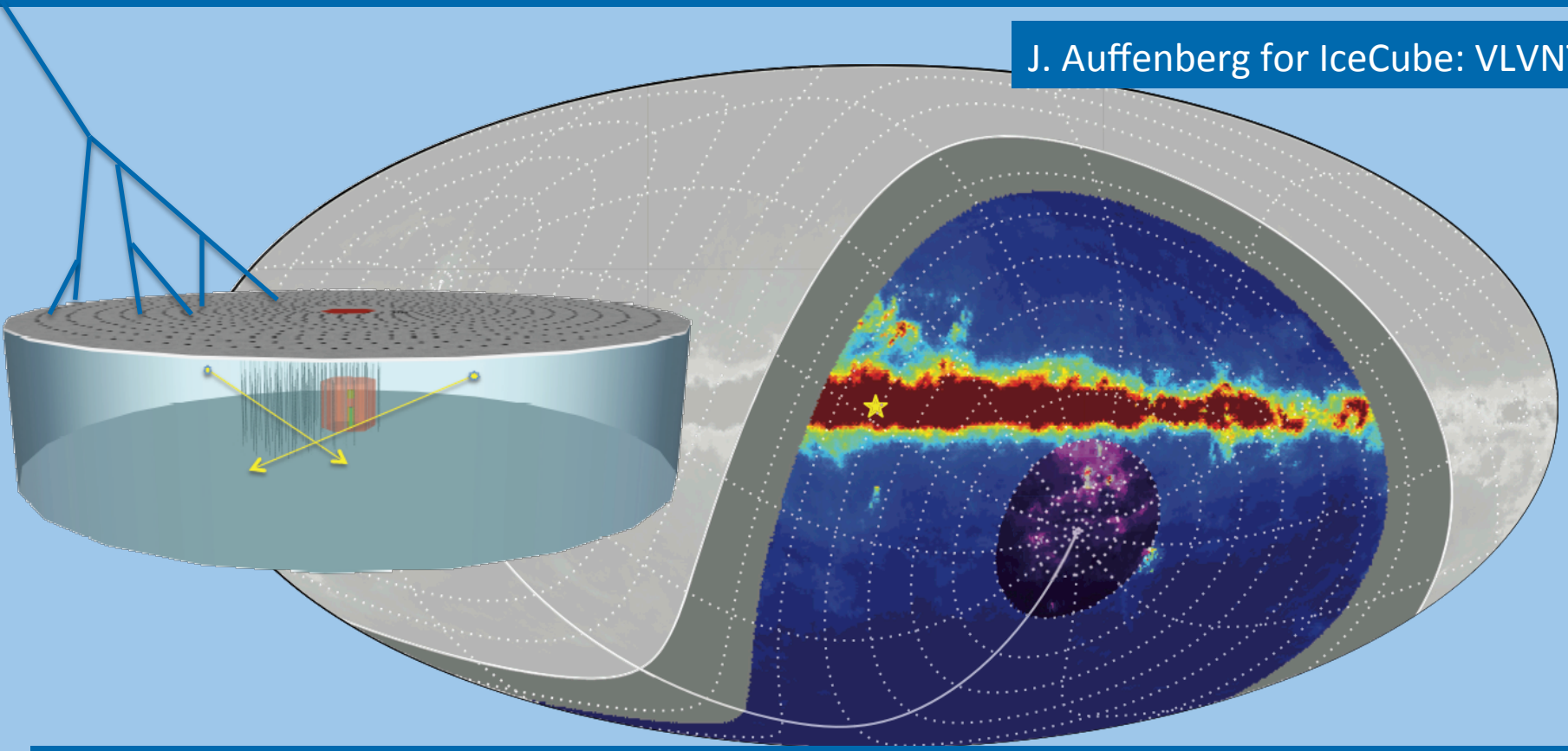


J. Auffenberg for IceCube: VLVNT13

Open the southern sky for E < 100 TeV Neutrino induced muon tracks by vetoing signals with coincident air showers

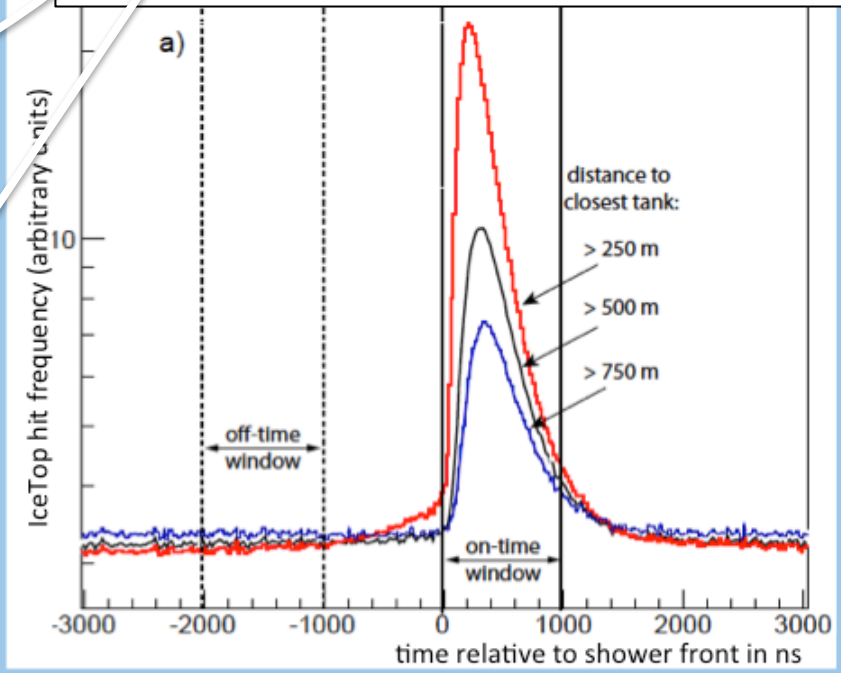
IceTop Veto

Air-Shower Front

Track

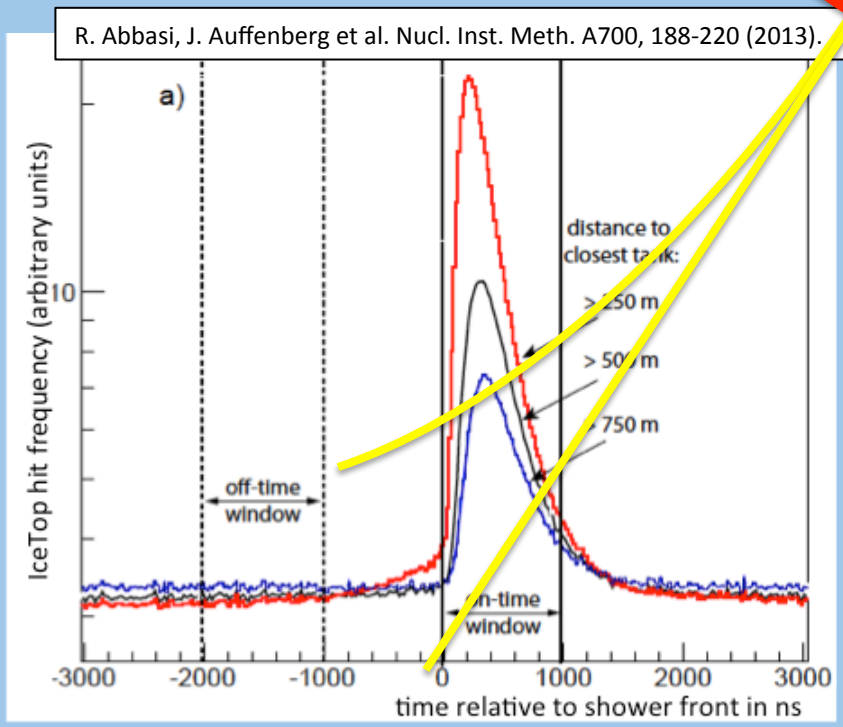
IceCube (InIce)

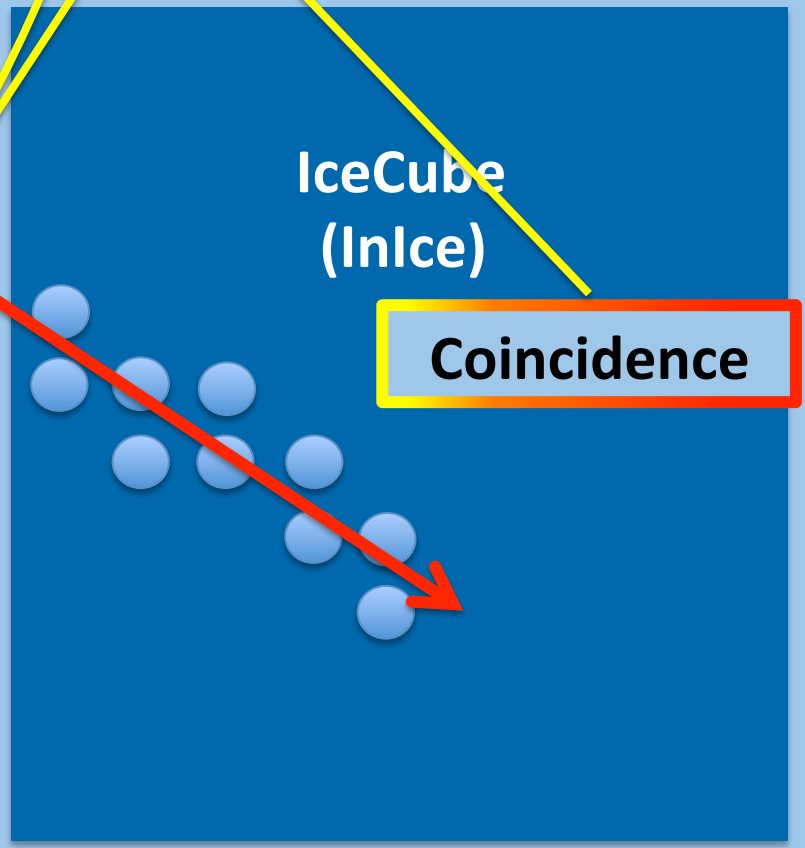
R. Abbasi, J. Auffenberg et al. Nucl. Inst. Meth. A700, 188-220 (2013).



J. Auffenberg for IceCube: ICRC13 ID 0373

IceTop Veto





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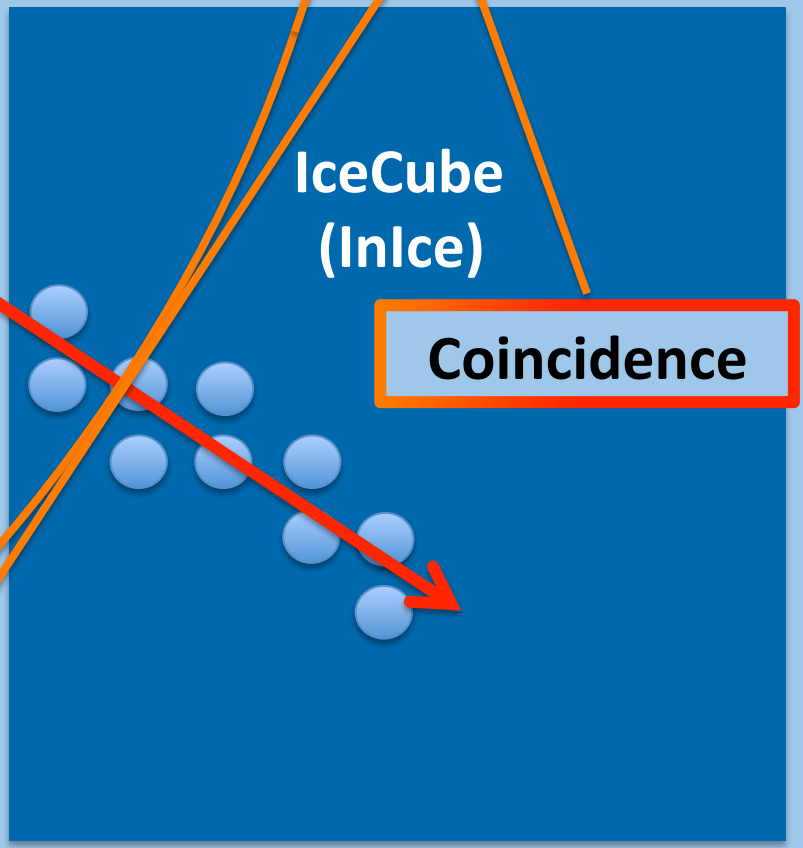

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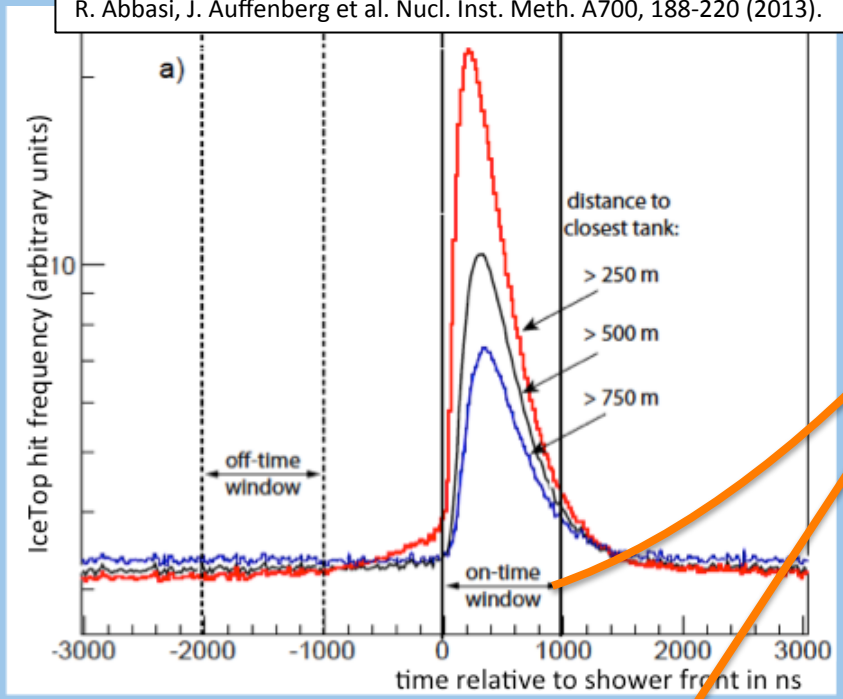

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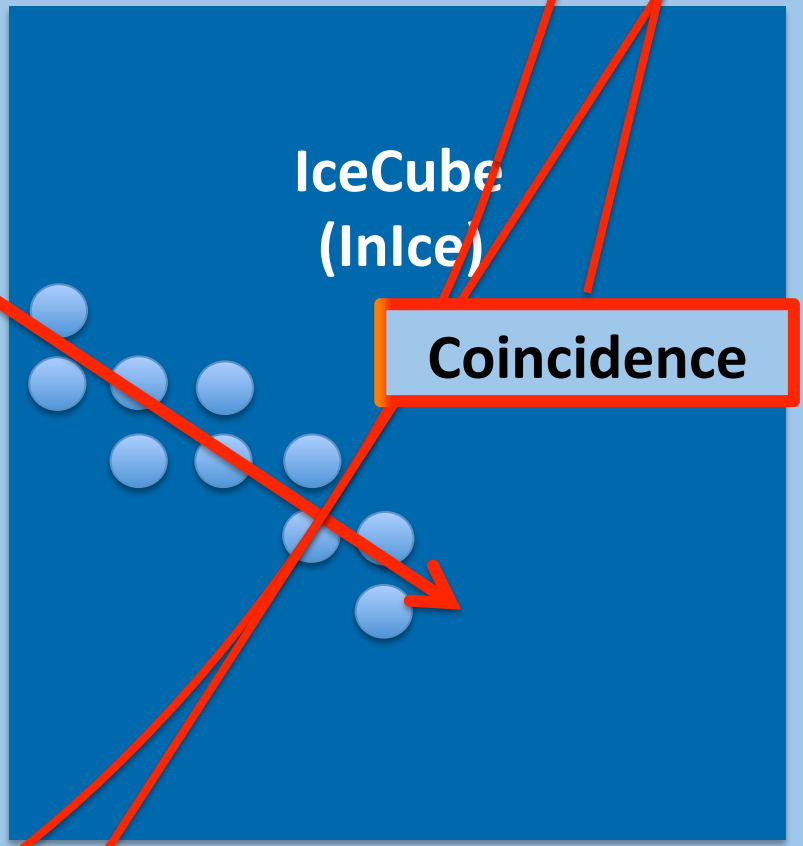

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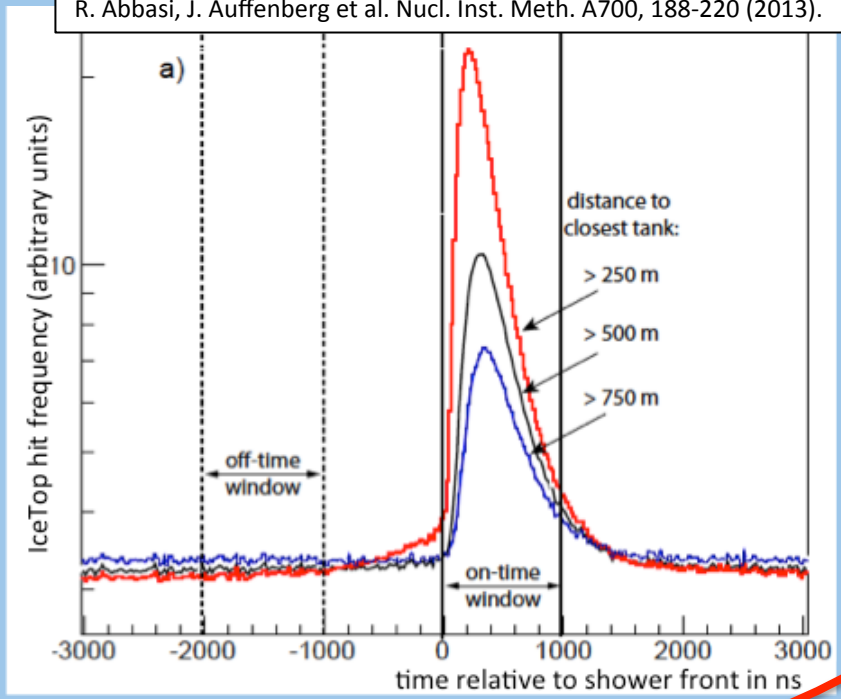

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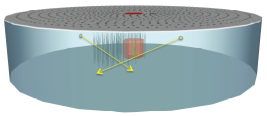
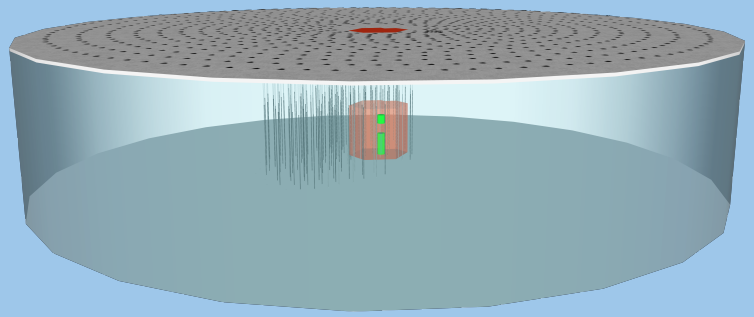
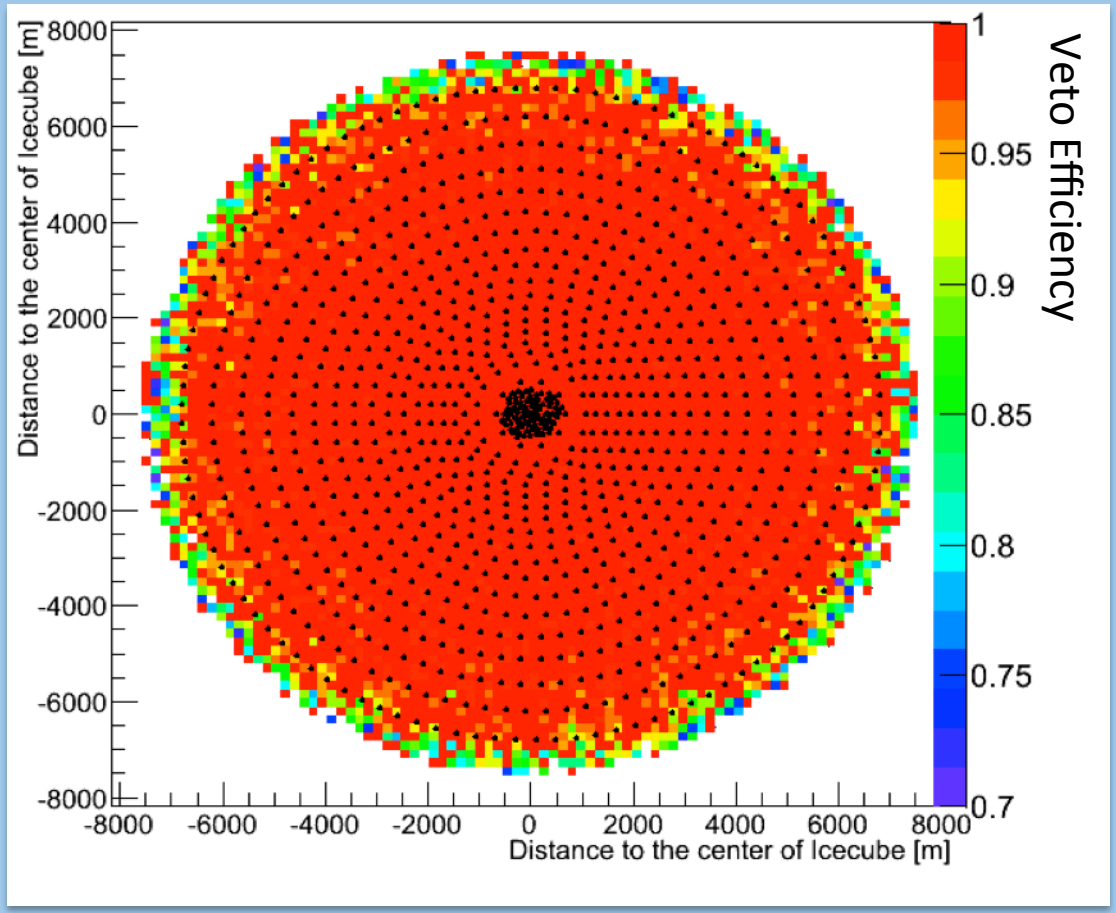
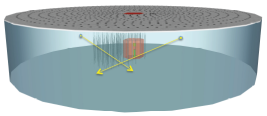


IceVeto Simulation

IceCube







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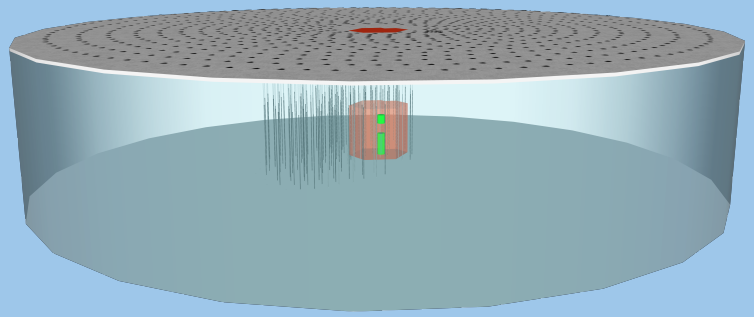
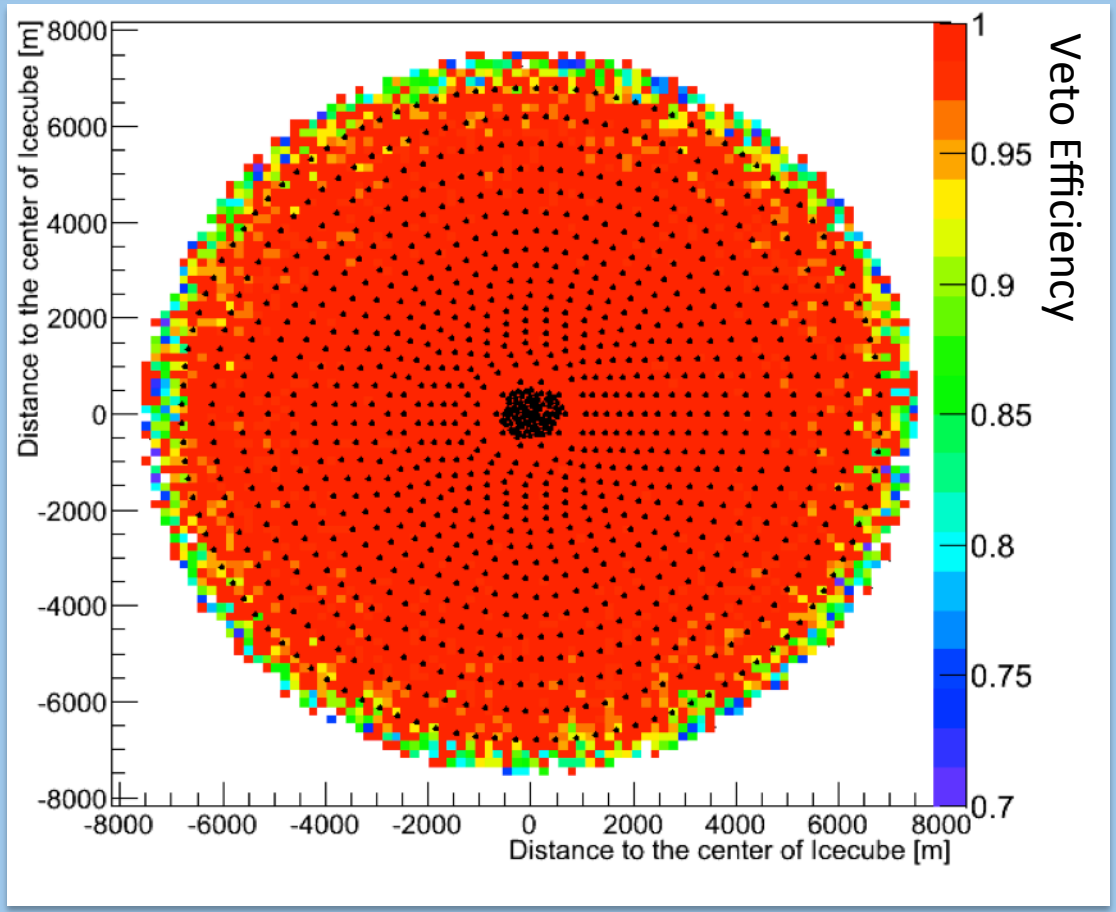
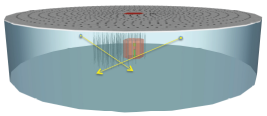


- **943 additional modules on surface**





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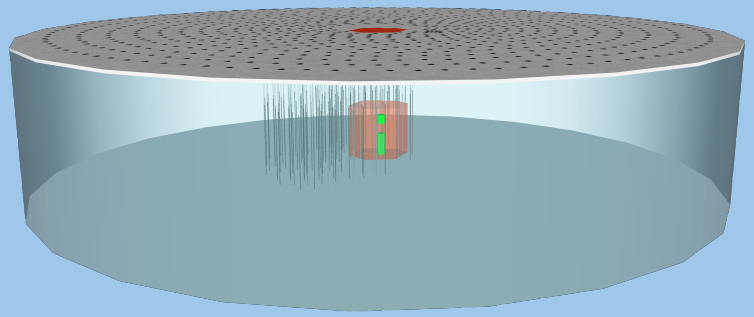
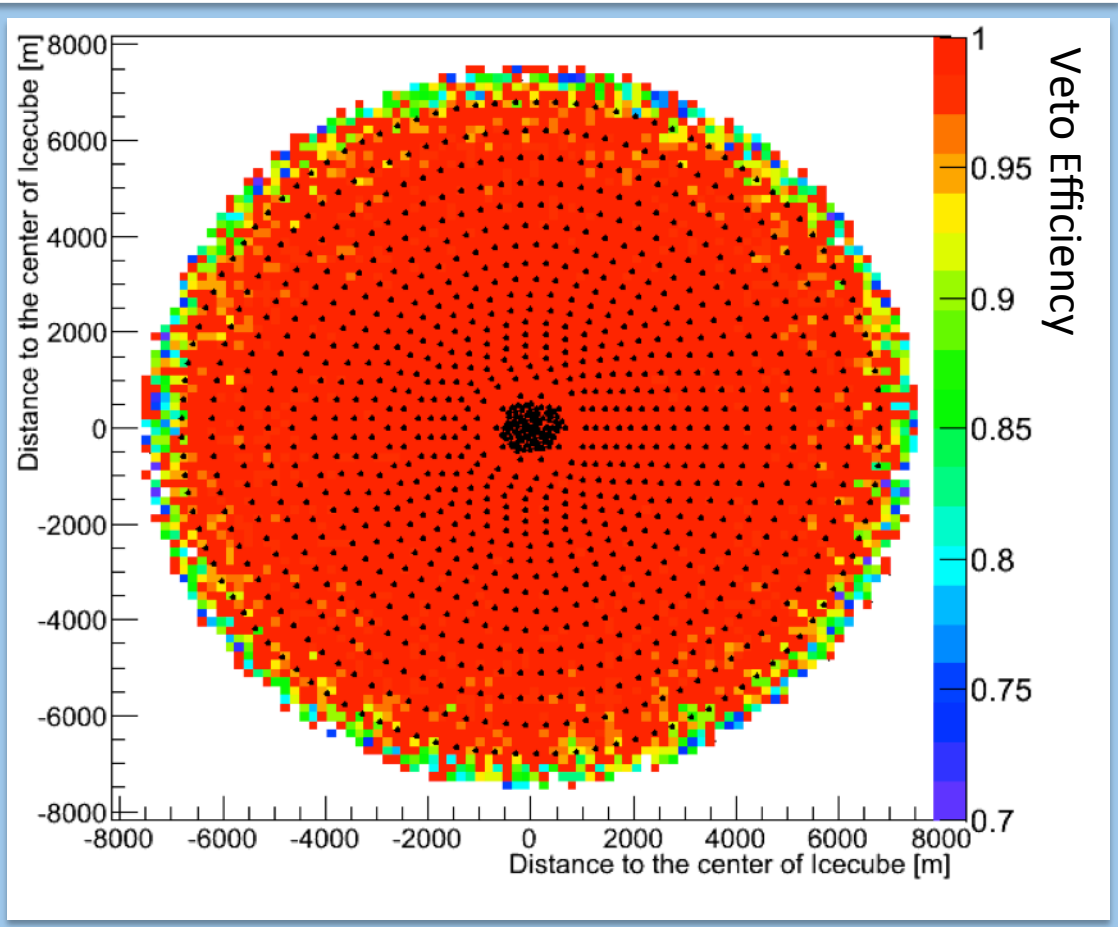
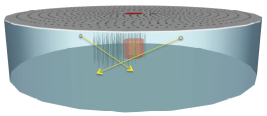


- **943 additional modules on surface**
- **99.999% Veto efficiency For PE > 4000**





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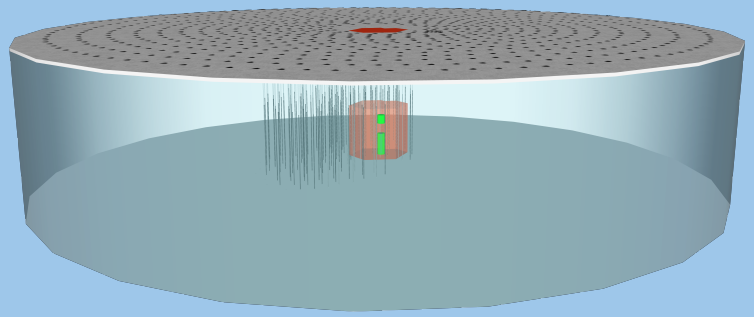

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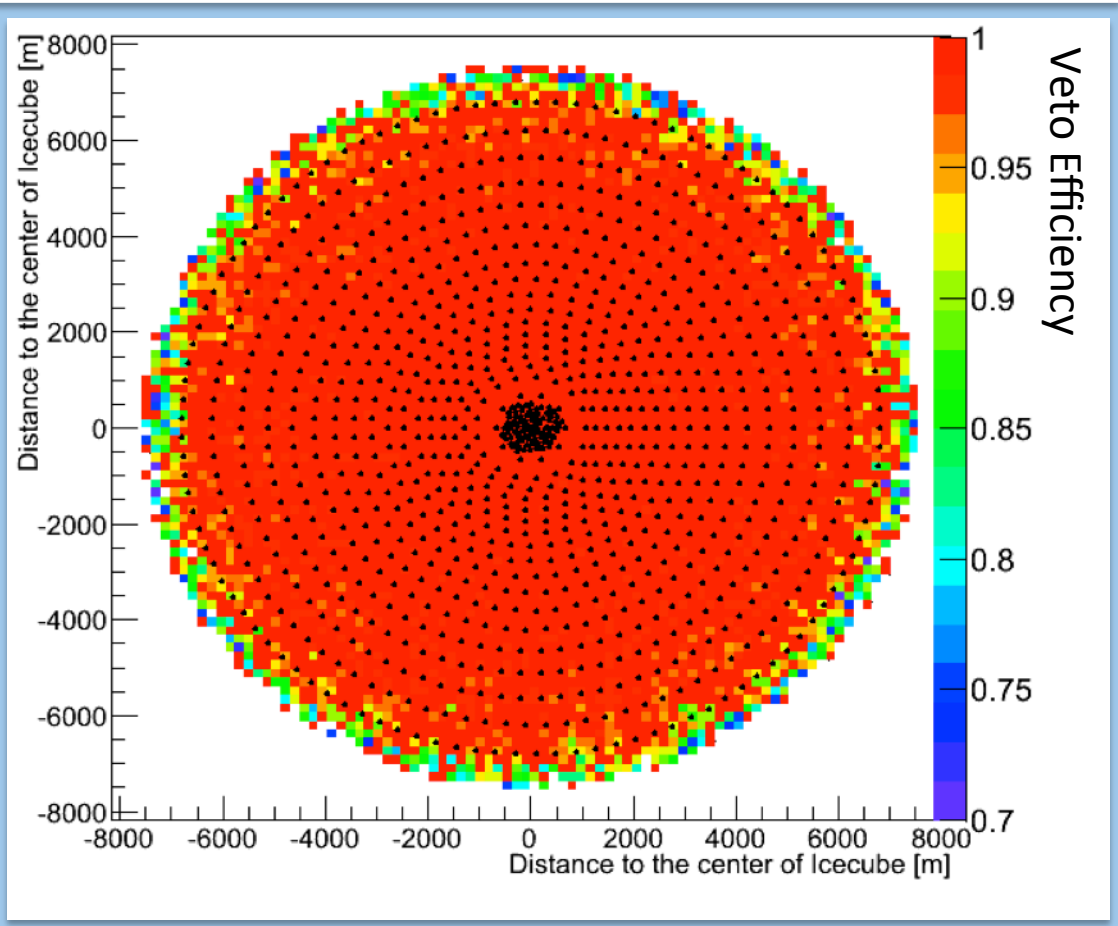
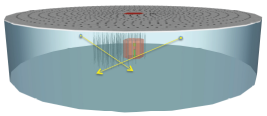
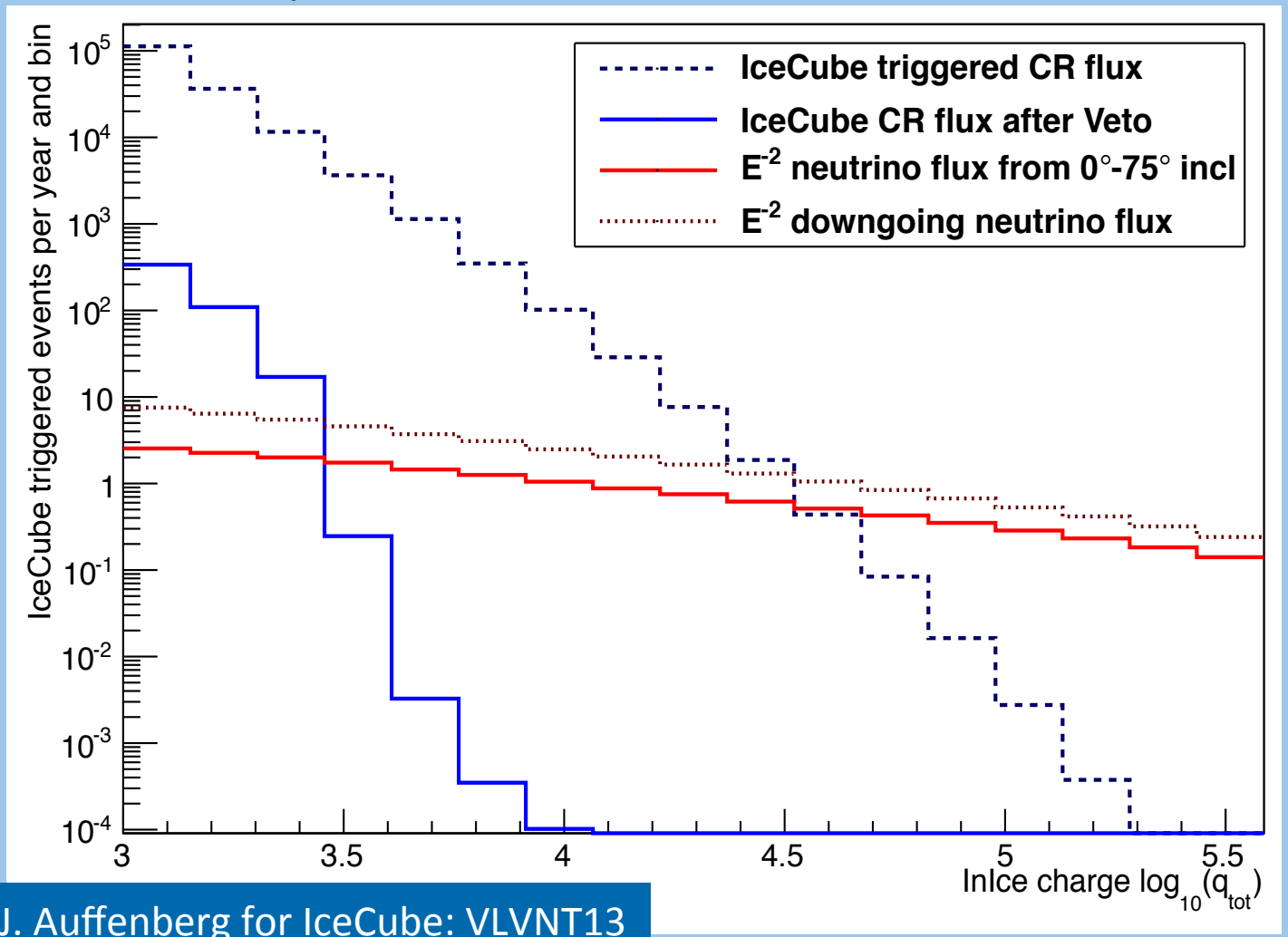


IceVeto is a sub-PeV cosmic-ray energy veto with 10^{-4} rejection power!



IceVeto Performance

Veto efficiency and neutrino flux calculated **based on real data**.



J. Auffenberg for IceCube: VLVNT13

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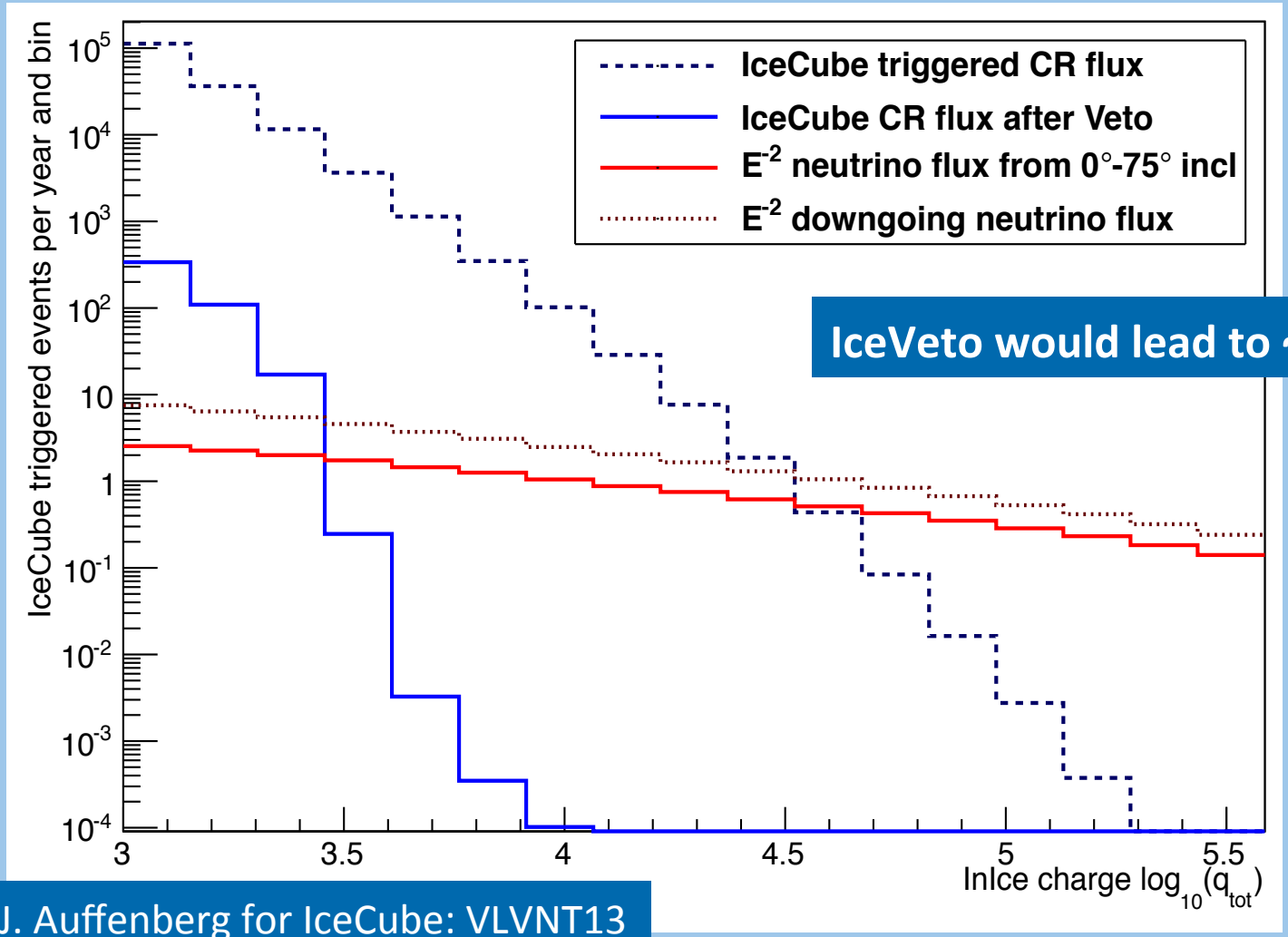
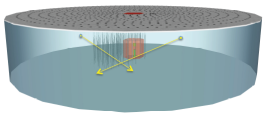


IceVeto would lead to ~10 tracks per year

J. Auffenberg for IceCube: VLVNT13



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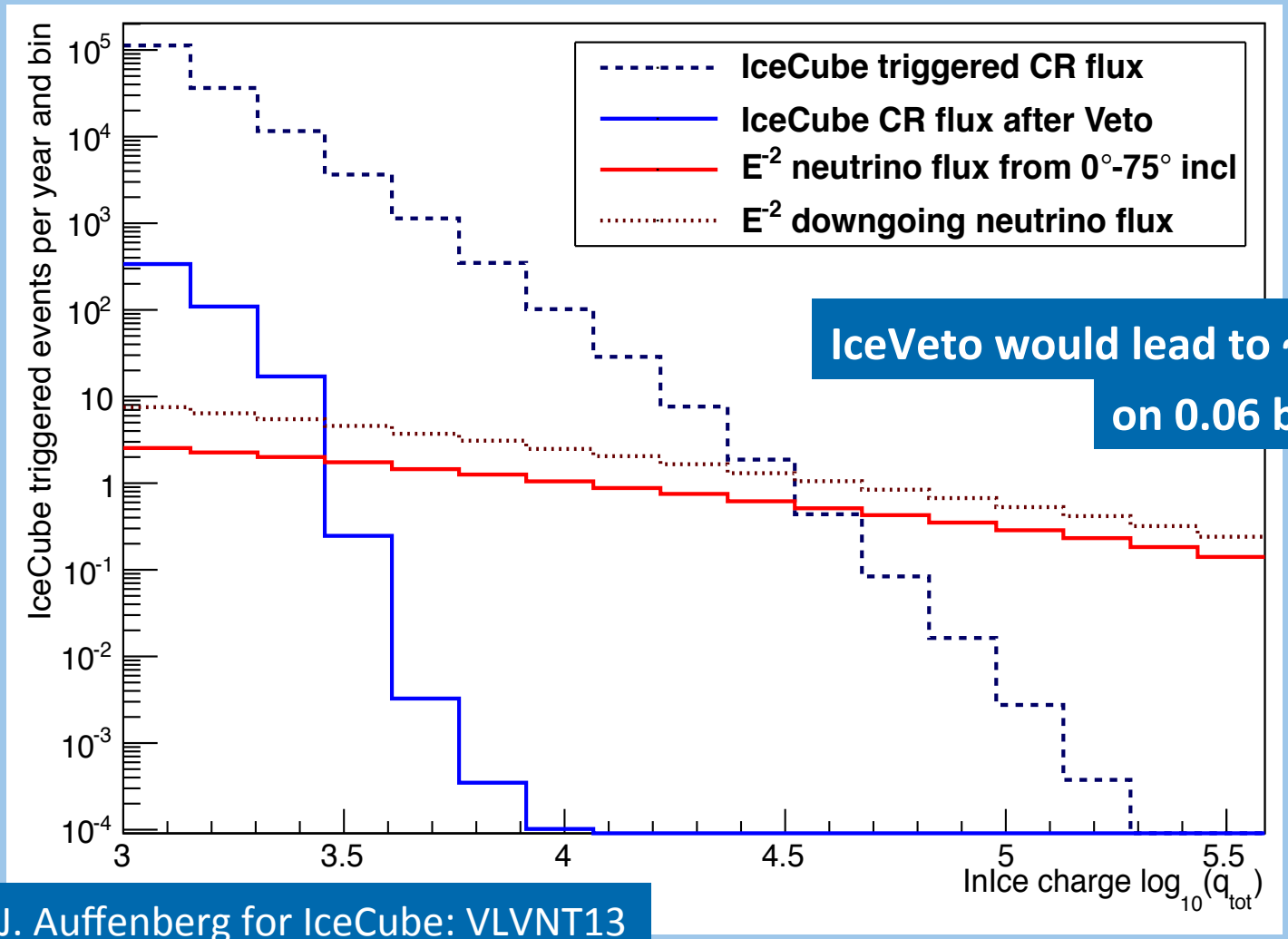

IceVeto would lead to ~10 tracks per year on 0.06 background events!

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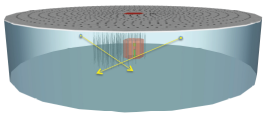

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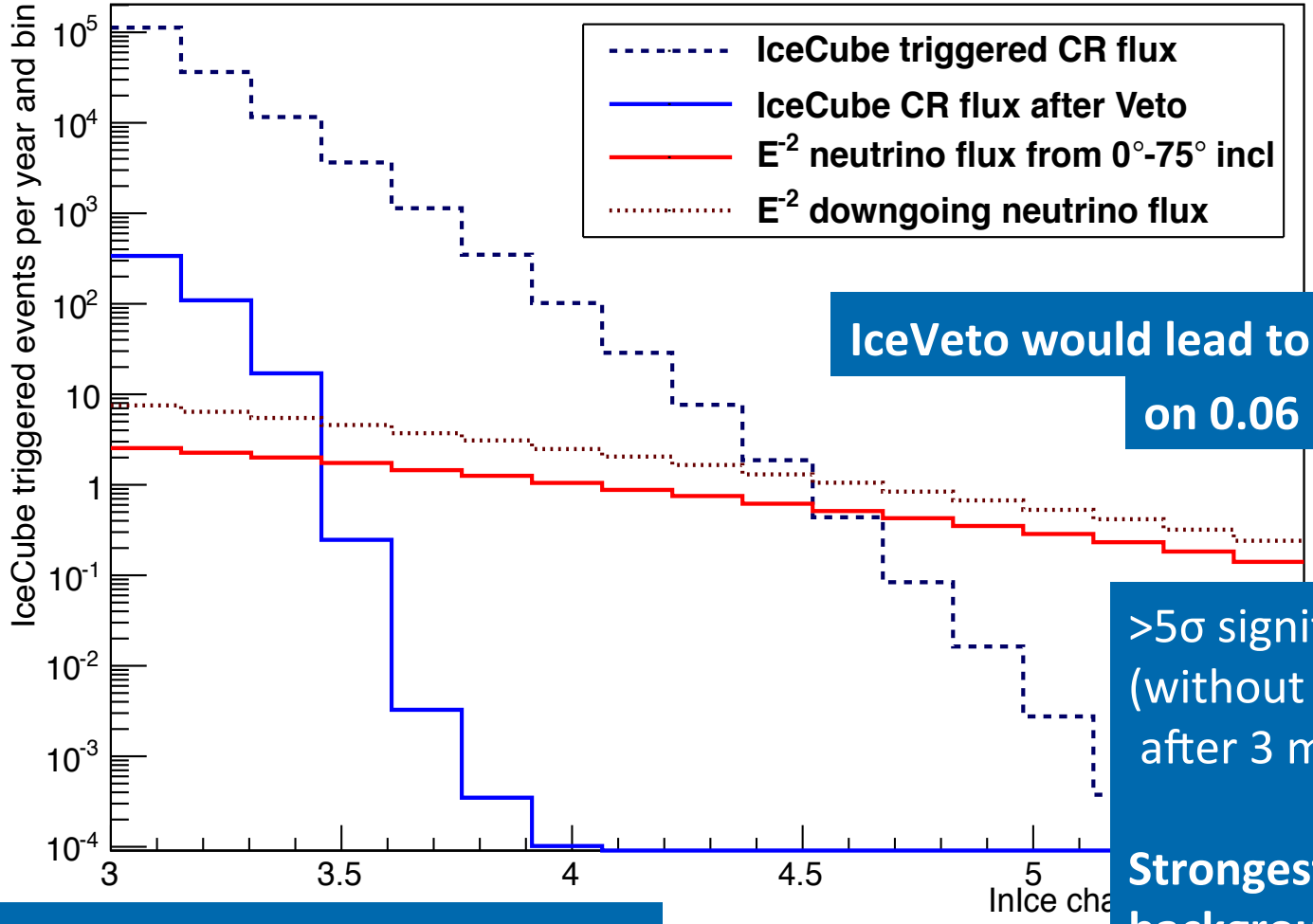
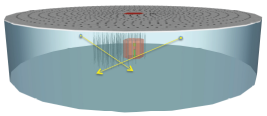


IceVeto would lead to ~10 tracks per year on 0.06 background events!

>5σ significance (without systematic errors) after 3 month!

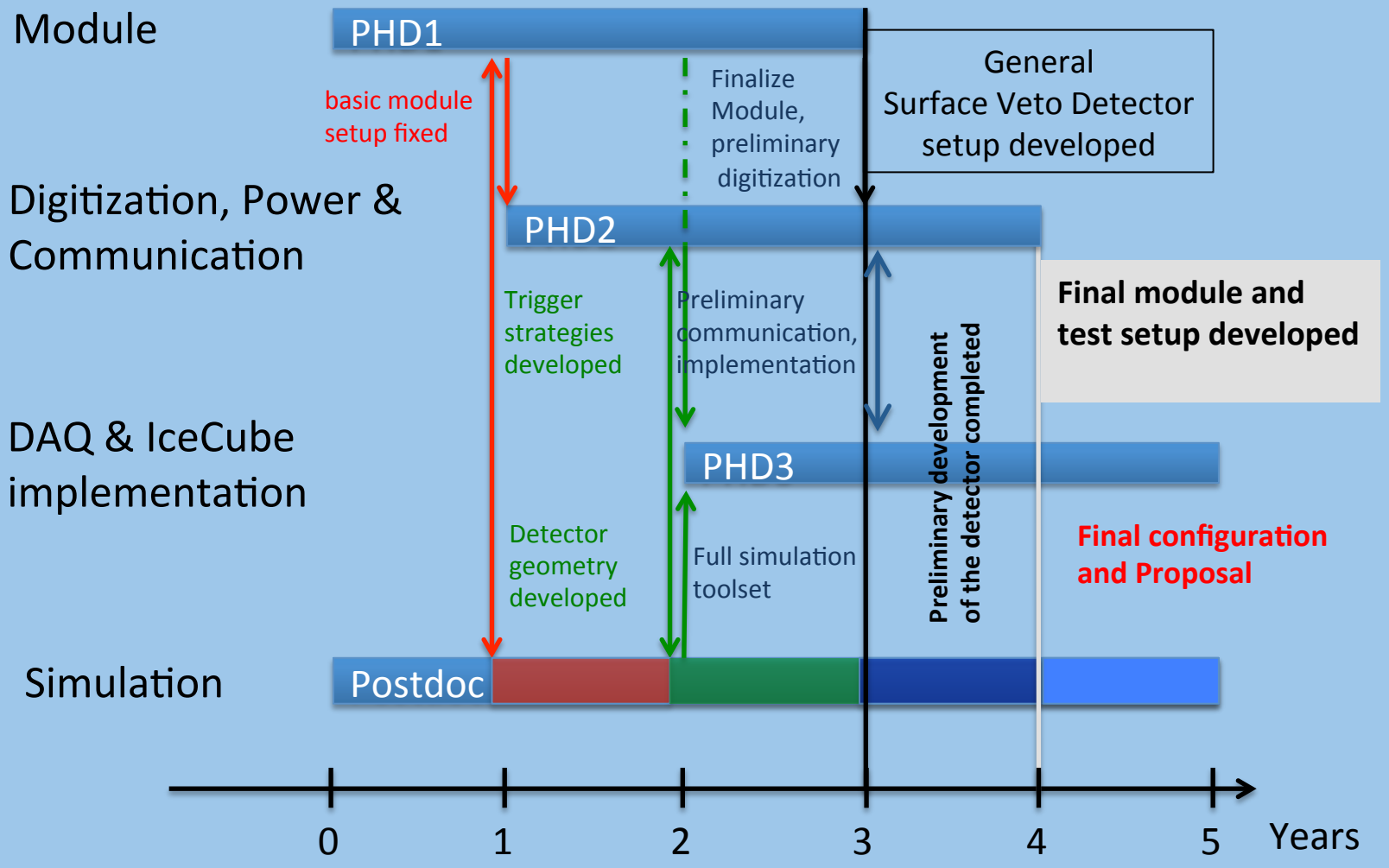
Strongest argument remains background free pointing

J. Auffenberg for IceCube: VLVNT13



The IceVeto Project

ICECUBE



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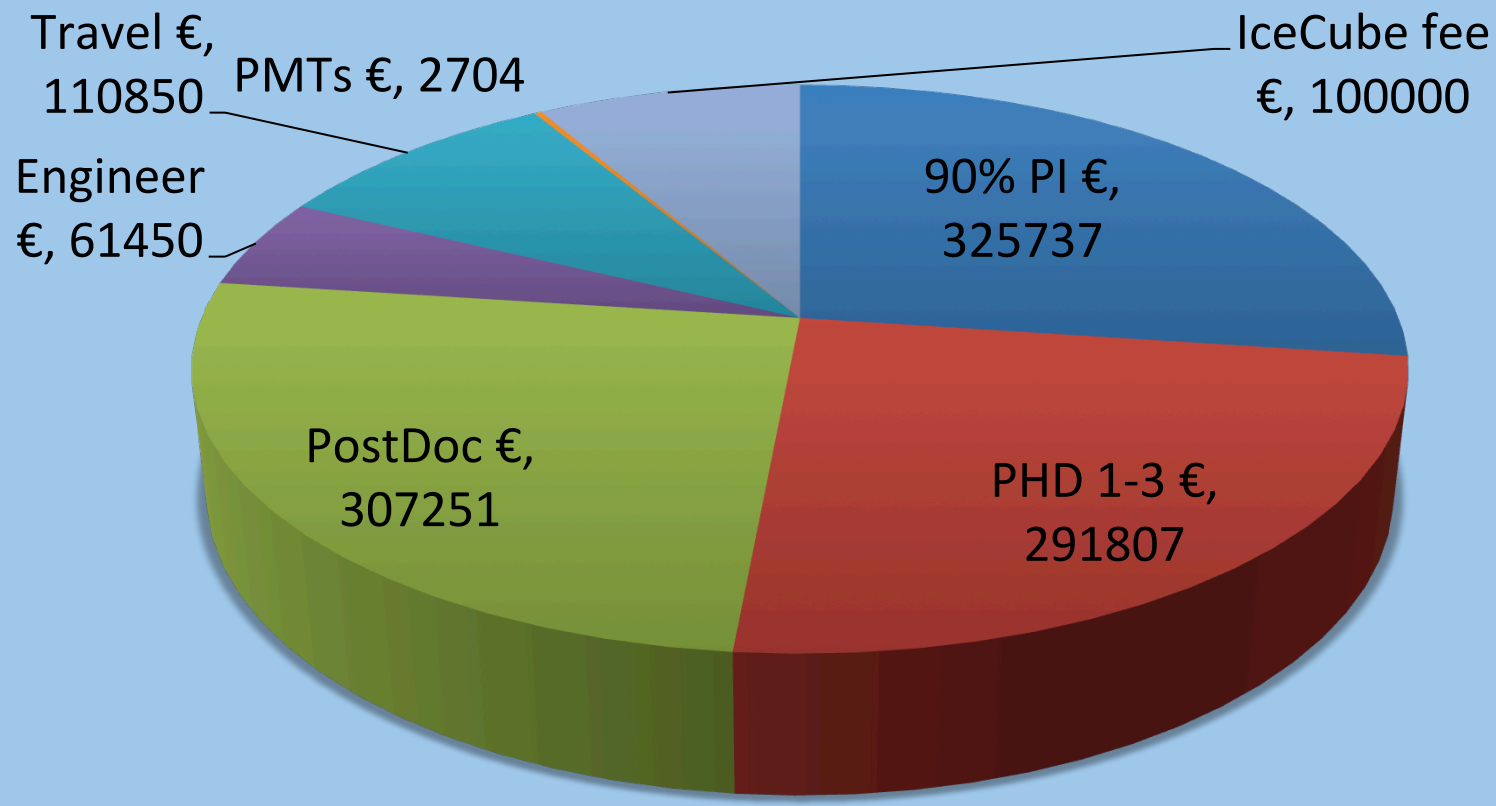
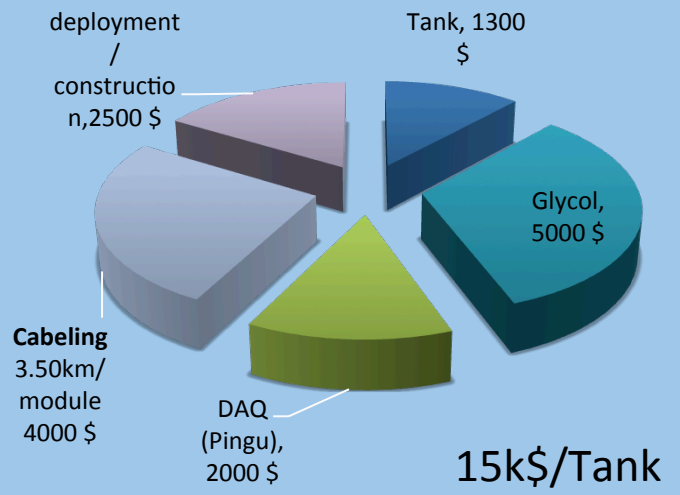
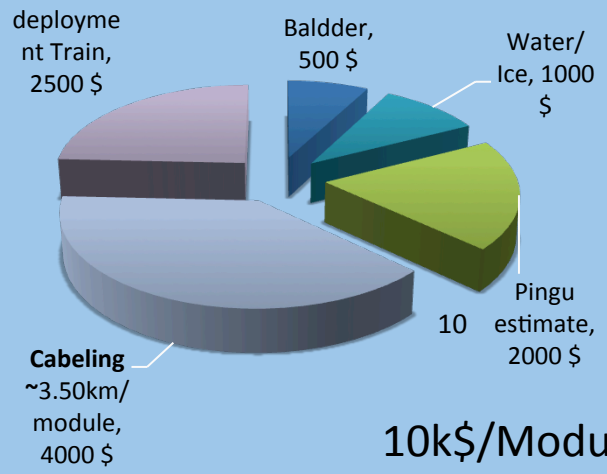


A- Total Direct cost (i + ii) €	**1199799**
B- indirect cost (overheads)) €	**299950**
Total Est. Cost & Requested EU contribution) €	**1499749**

Simple cost estimate based on IceTop



15k$/Tank



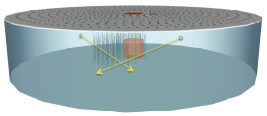
10k$/Module

- Tank: $1300 (2007: $1135) or just a bladder ($500)
- Tyvec Liner: $330 (2007: $300)
- Maybe Glyocol instead of Water: $5000 (price at the south pole vs. just south pole water $1000)
- DAQ + PMT: $2000 (PINGU estimate very likely less)
- Cabling (~3.50 km per module): ~$4 000 000
- Deployment $2500 per module or less?

Total: $8400 - $13500 per module

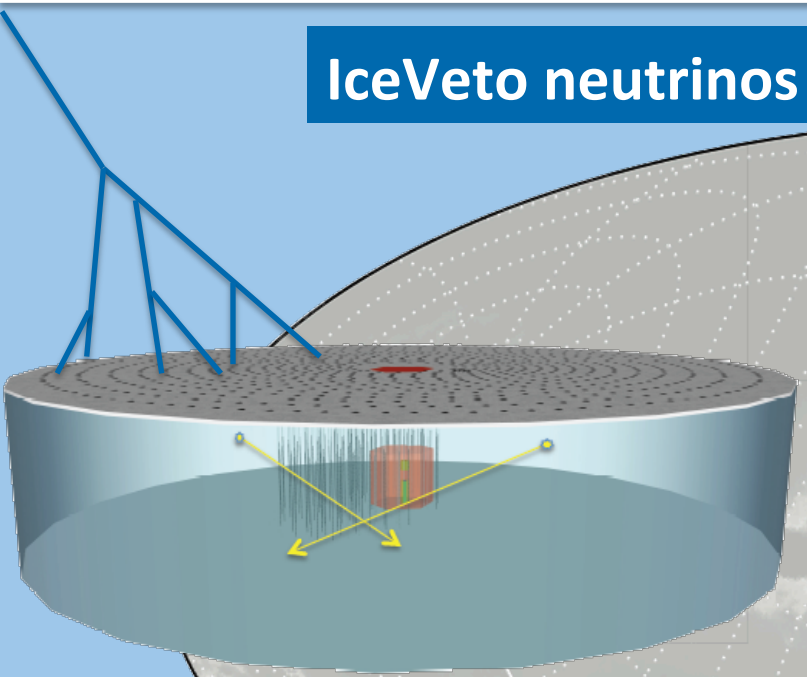
$ 10 – 20 Million for IceVeto

< 1/10 IceCube



IceVeto summary

IceVeto neutrinos will point to the sources of Cosmic Rays



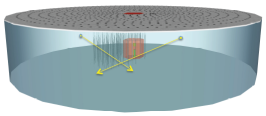
I propose:

- Develop IceVeto, an IceCube add on till 2020
- Use Ice Cherenkov tanks for cosmic-ray detection on the surface
- Move IceCube with IceVeto towards a multi component astroparticle detector
- Open the Southern Sky for PeV muon neutrinos

R&D Workshop

- Neutrino detection from MeV to EeV
- Air-shower physics with surface detectors
- Veto strategies
- Sensor Development and strategies
- Detector Design
- New Ideas

December 8th – 10th 2014
at RWTH Aachen University



Simulation results

ICECUBE

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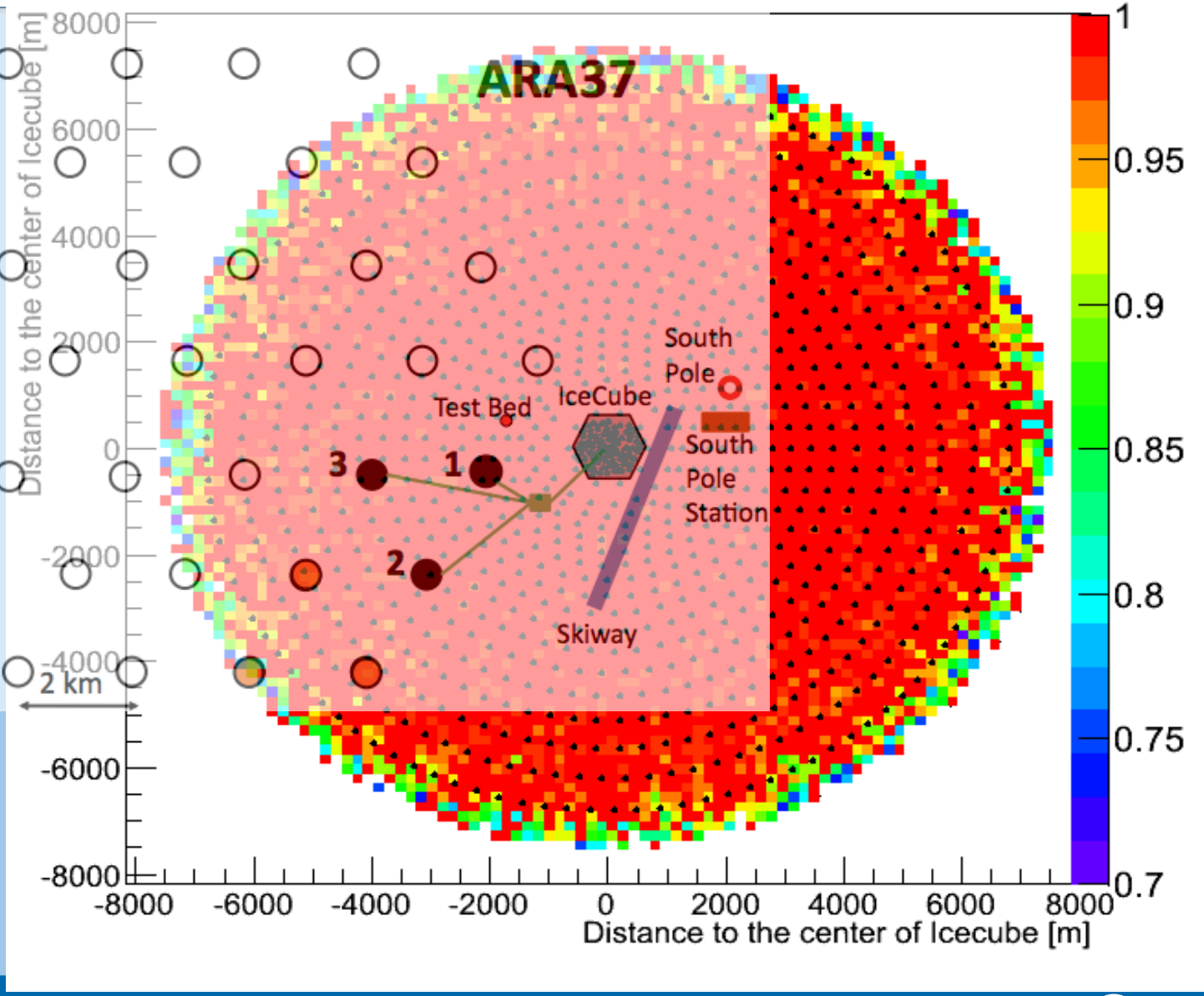
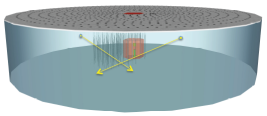
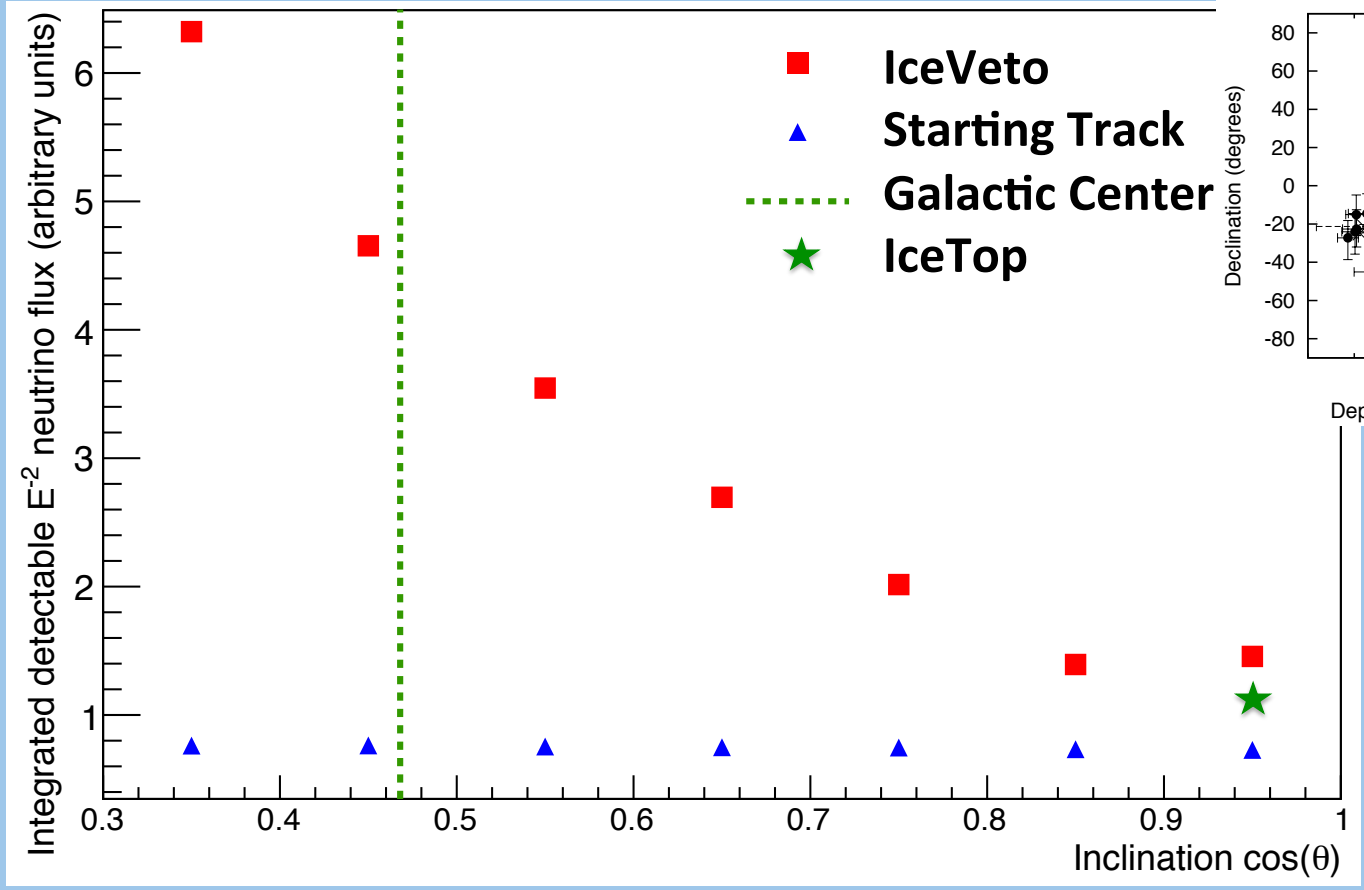
5

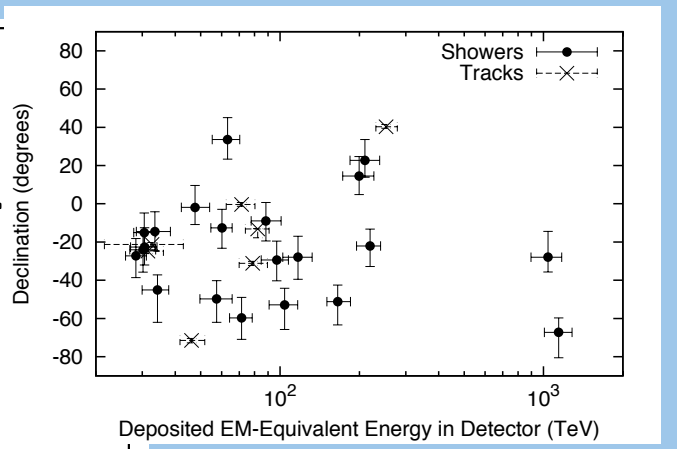




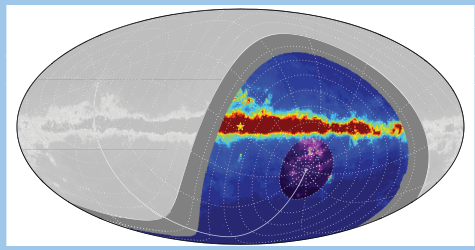
Many more tracks compared to starting track analyses

IceCube



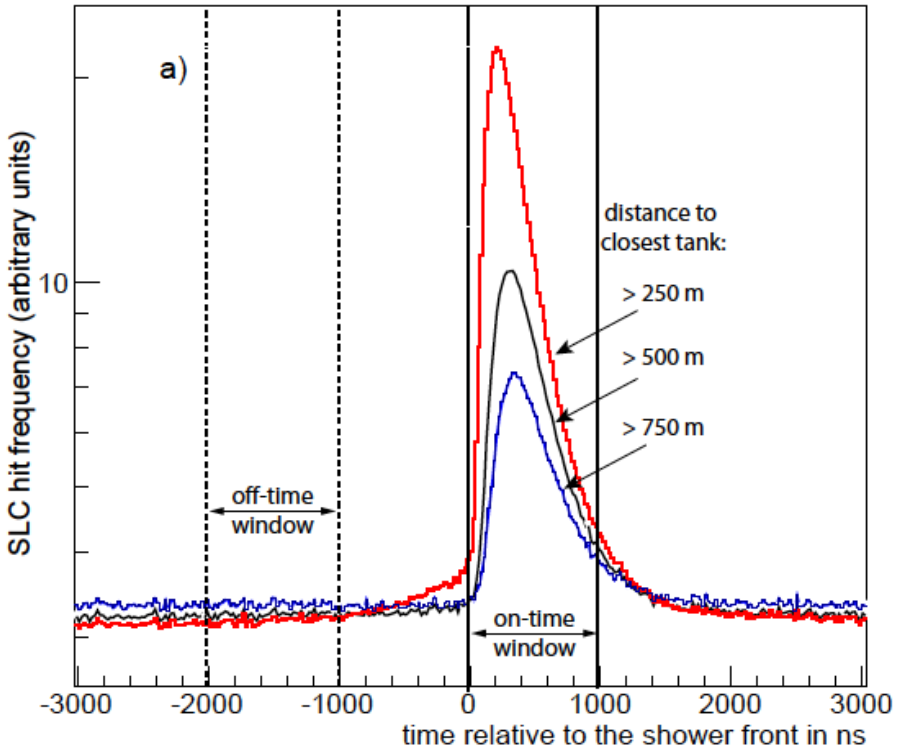


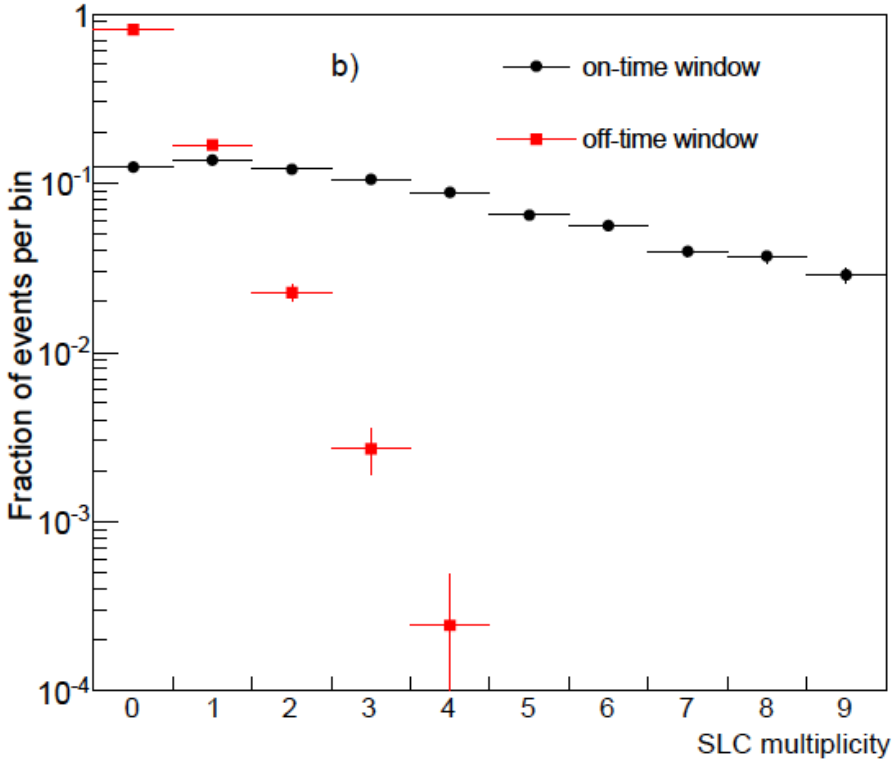
Only the crosses are tracks!



5.5 times more neutrino induced muon tracks from the Galactic Center (62° inclination) between 30 TeV -5 PeV based on an E^{-2} neutrino flux.

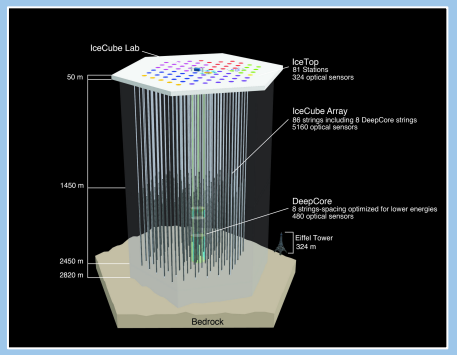
Signal Loss due to an IceTop Veto

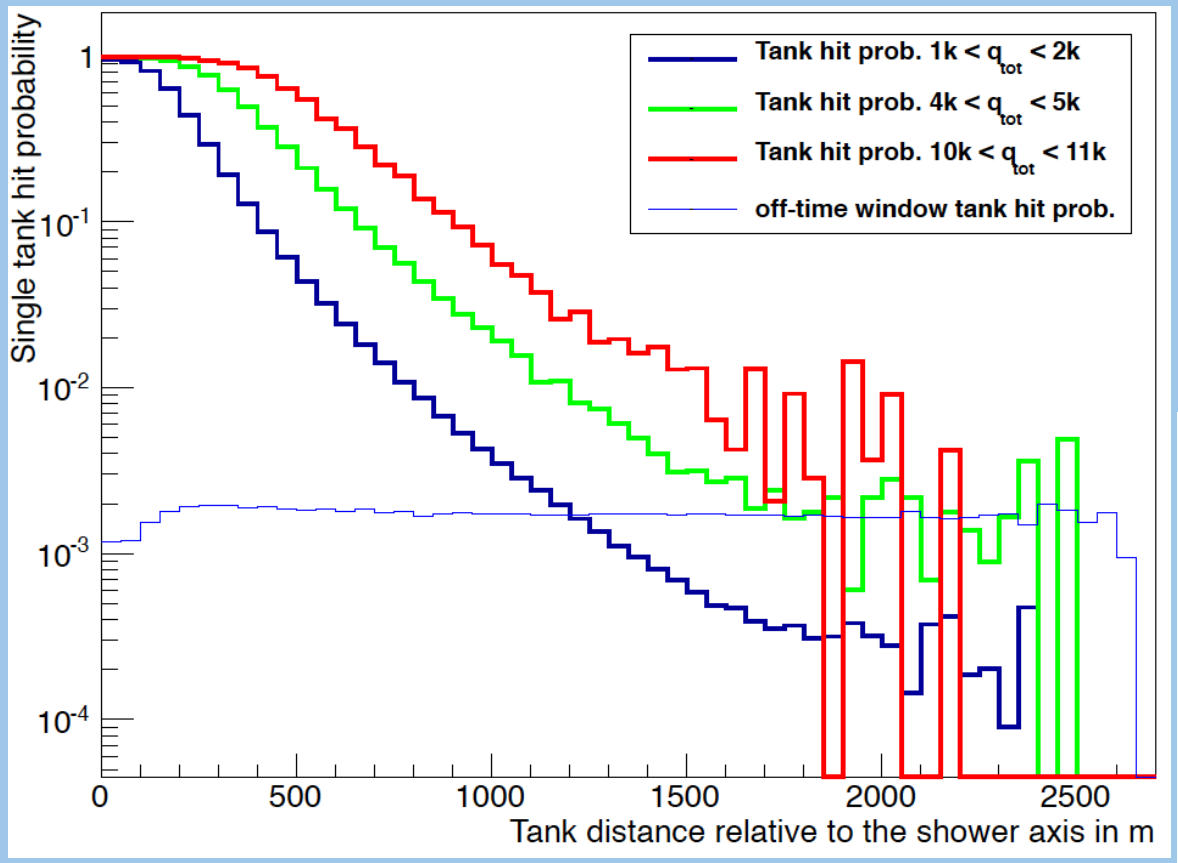




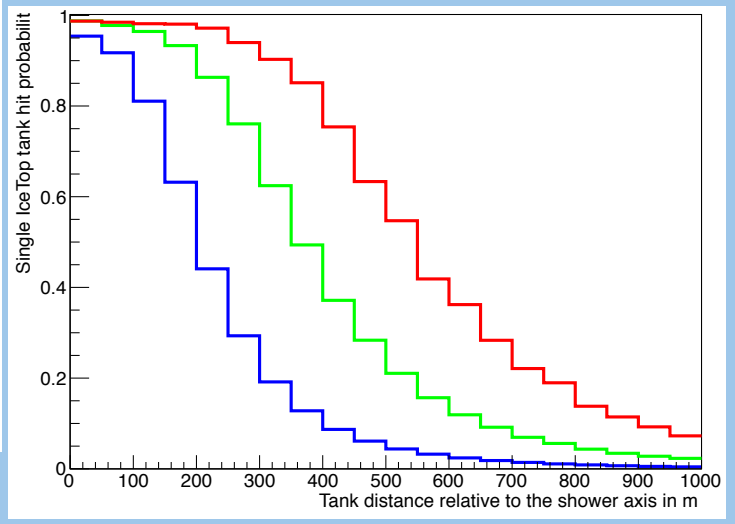
Signal loss below 2% for a >1 Hit cut !

Single IceTop tank hit probability

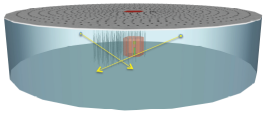




Tank hit probability increases with increasing NPE in the deep detector



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



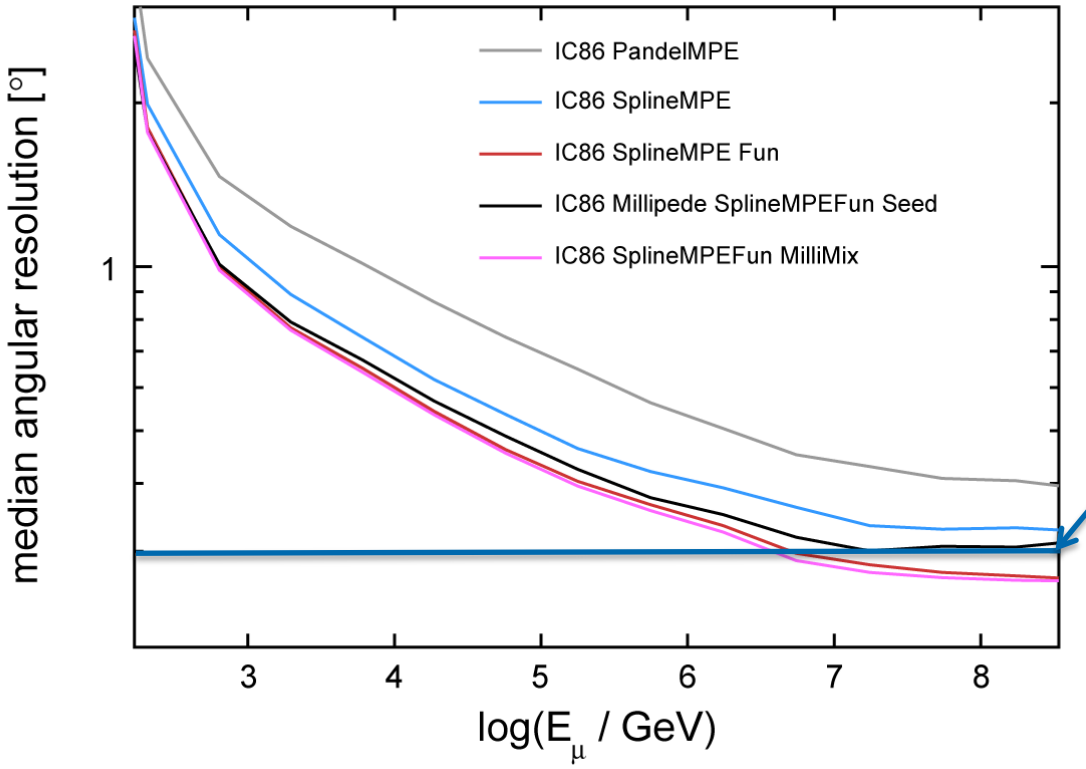
What about KM3NeT?

- KM3NeT has the same potential for a surface Veto. (due to good cascade direction reconstructions less important?)
- No high precision positioning for surface Veto modules necessary.
  (a floating buoy grid? Engineering is not trivial.)
- IceVeto for IceCube is a high energy extension for the observation space of KM3NeT. (Can't see PeV neutrinos from the south).

Pointing with IceCube

Slide and work credit to Kai Schatto

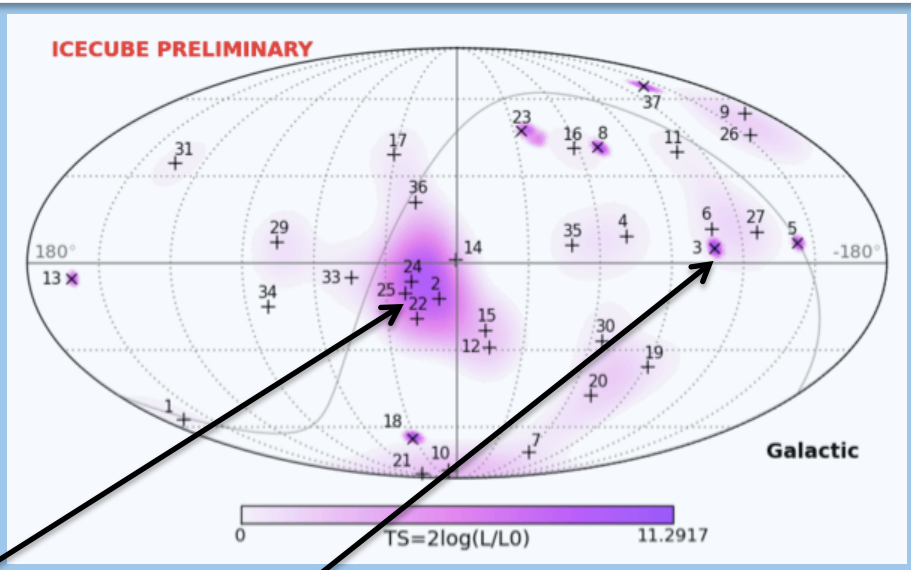
Averaging SplineMPE Fun and Millipede

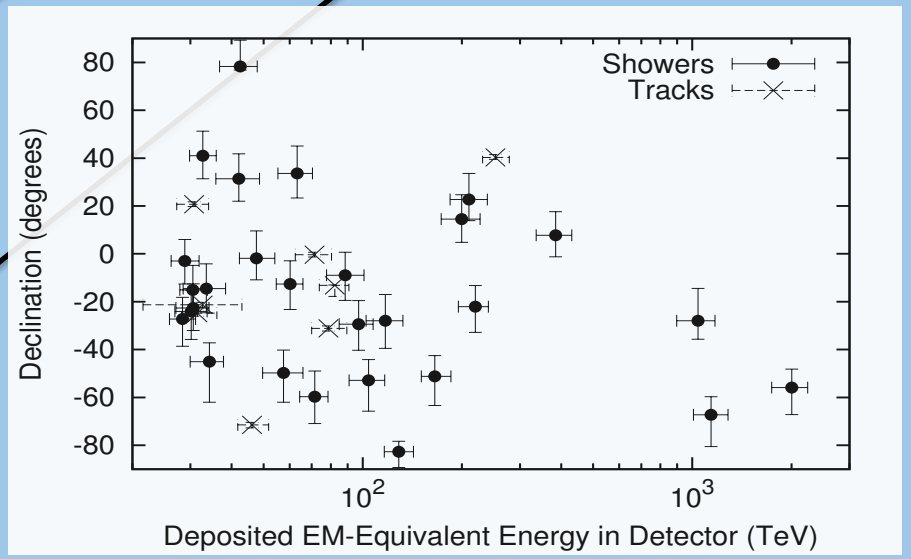


0.1° resolution

Where do the neutrinos come from?

ID	Dep. Energy (TeV)	Observation Time (MJD)	Decl. (deg.)	R.A. (deg.)	Med. Angular Error (deg.)	Event Topology
1	$47.6^{+6.5}_{-5.4}$	55351.3222143	−1.8	35.2	16.3	Shower
2	117^{+15}_{-15}	55351.4659661	−28.0	282.6	25.4	Shower
3	$78.7^{+10.8}_{-8.7}$	55451.0707482	−31.2	127.9	$\lesssim 1.4$	Track
4	165^{+20}_{-15}	55477.3930984	−51.2	169.5	7.1	Shower
5	$71.4^{+9.0}_{-9.0}$	55512.5516311	−0.4	110.6	$\lesssim 1.2$	Track
6	$28.4^{+2.7}_{-2.5}$	55567.6388127	−27.2	133.9	9.8	Shower
7	$34.3^{+3.5}_{-4.3}$	55571.2585362	−45.1	15.6	24.1	Shower
8	$32.6^{+10.3}_{-11.1}$	55608.8201315	−21.2	182.4	$\lesssim 1.3$	Track
9	$63.2^{+7.1}_{-8.0}$	55685.6629713	33.6	151.3	16.5	Shower
10	$97.2^{+10.4}_{-12.4}$	55695.2730461	−29.4	5.0	8.1	Shower
11	$88.4^{+12.5}_{-10.7}$	55714.5909345	−8.9	155.3	16.7	Shower
12	104^{+13}_{-13}	55739.4411232	−52.8	296.1	9.8	Shower
13	253^{+26}_{-29}	55756.1129844	40.3	67.9	$\lesssim 1.2$	Track
14	1041^{+132}_{-144}	55782.5161911	−27.9	265.6	13.2	Shower
15	$57.5^{+8.3}_{-7.8}$	55783.1854223	−49.7	287.3	19.7	Shower
16	$30.6^{+3.6}_{-3.5}$	55798.6271285	−22.6	192.1	19.4	Shower
17	200^{+27}_{-27}	55800.3755483	14.5	247.4	11.6	Shower
18	$31.5^{+4.6}_{-3.3}$	55923.5318204	−24.8	345.6	$\lesssim 1.3$	Track
19	$71.5^{+7.0}_{-7.2}$	55925.7958619	−59.7	76.9	9.7	Shower
20	1141^{+143}_{-133}	55929.3986279	−67.2	38.3	10.7	Shower
21	$30.2^{+3.5}_{-3.3}$	55936.5416484	−24.0	9.0	20.9	Shower
22	220^{+21}_{-24}	55941.9757813	−22.1	293.7	12.1	Shower
23	$82.2^{+8.6}_{-8.4}$	55949.5693228	−13.2	208.7	$\lesssim 1.9$	Track
24	$30.5^{+3.2}_{-2.6}$	55950.8474912	−15.1	282.2	15.5	Shower
25	$33.5^{+4.9}_{-5.0}$	55966.7422488	−14.5	286.0	46.3	Shower
26	210^{+29}_{-26}	55979.2551750	22.7	143.4	11.8	Shower
27	$60.2^{+5.6}_{-5.6}$	56008.6845644	−12.6	121.7	6.6	Shower
28	$46.1^{+5.7}_{-4.4}$	56048.5704209	−71.5	164.8	$\lesssim 1.3$	Track
29	$32.7^{+3.2}_{-2.9}$	56108.2572046	41.0	298.1	7.4	Shower
30	129^{+14}_{-12}	56115.7283574	−82.7	103.2	8.0	Shower
31	$42.5^{+5.4}_{-5.7}$	56176.3914143	78.3	146.1	26.0	Shower
32	—	56211.7401231	—	—	—	Coincident
33	385^{+46}_{-49}	56221.3424023	7.8	292.5	13.5	Shower
34	$42.1^{+6.5}_{-6.3}$	56228.6055226	31.3	323.4	42.7	Shower
35	2004^{+236}_{-262}	56265.1338677	−55.8	208.4	15.9	Shower
36	$28.9^{+3.0}_{-2.6}$	56308.1642740	−3.0	257.7	11.7	Shower
37	$30.8^{+3.3}_{-3.5}$	56390.1887627	20.7	167.3	$\lesssim 1.2$	Track





Hotspot of cascades only
p-value: 7%

All event Hotspot
p-value: 87%

MC simulation(based on real data)

Assumptions:
IceVeto detection module acts as a CR Veto similar to an IceTop tank.

Input parameters:
-Veto efficiency for events with reconstruction between 0-75° inclination with 1000 PE light deposit in the detector with >99.9% .
-IceVeto tanks are forced on rings around IceTop.

Input from real data:
-IceTop tank hit probability as function of PE.
-Geometrical event distribution.