A NEW PHYSICS INTERPRETATION OF THE ICECUBE DATA

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1. Is the IceCube signal atmospheric? Is it caused by a diffuse E^{-2} flux of cosmic neutrinos?

2. New NC ν interactions at UH energies

3. A better fit of the IceCube data

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● IceCube can measure the energy ($E \geq 30$ TeV in this analysis), direction ($\pm 15^o$ for showers), time development (sinchronized with IceTop) and topology (shower or track) of an event: 37 ν-events observed during a three year period
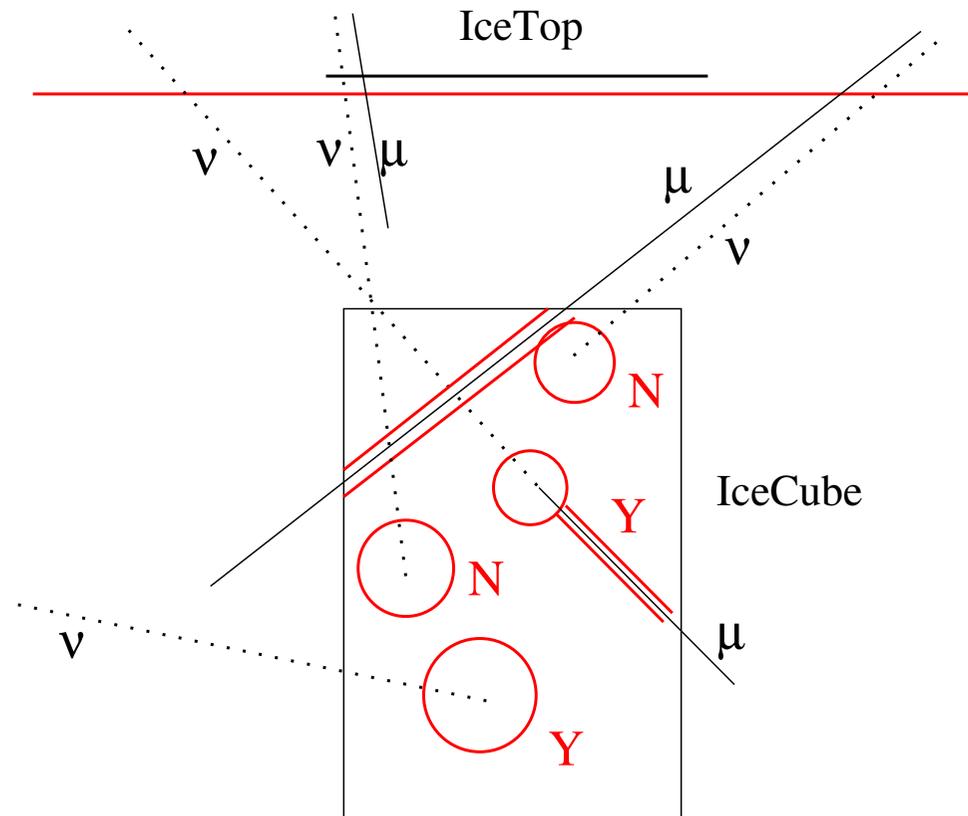
- Some track events may actually be atmospheric muons entering the detector from outside (5 *ambiguous* events, 8.4 ± 4.2 expected)

- Atm. π/K decays: $(\nu_e : \nu_\mu : \nu_\tau) \approx (1 : 17 : 0)$, larger flux from horizontal directions; Atm. charm decay: $(\nu_e : \nu_\mu : \nu_\tau) \approx (48 : 48 : 2)$, isotropic

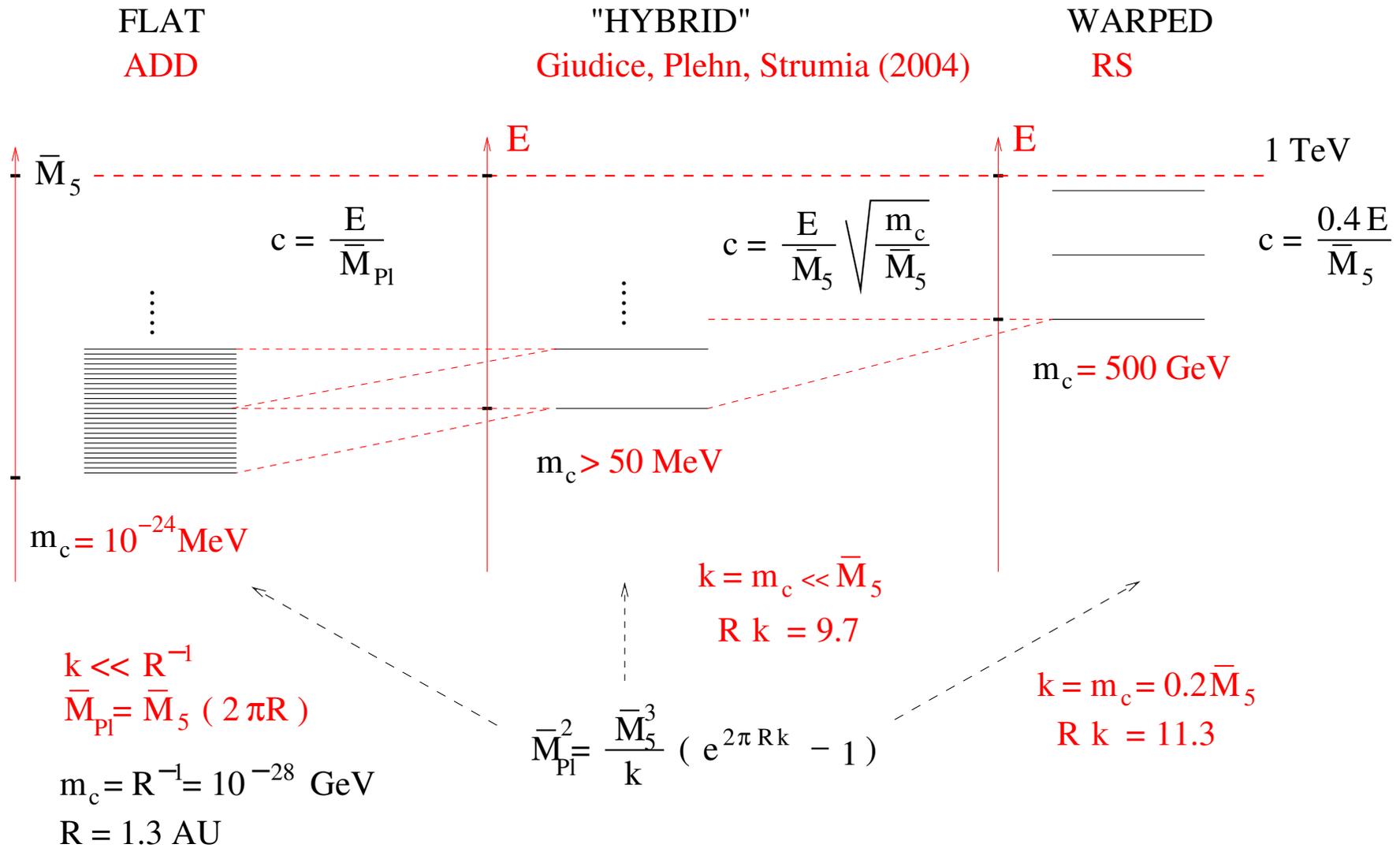- At high E_ν the Earth becomes opaque from large zenith angles
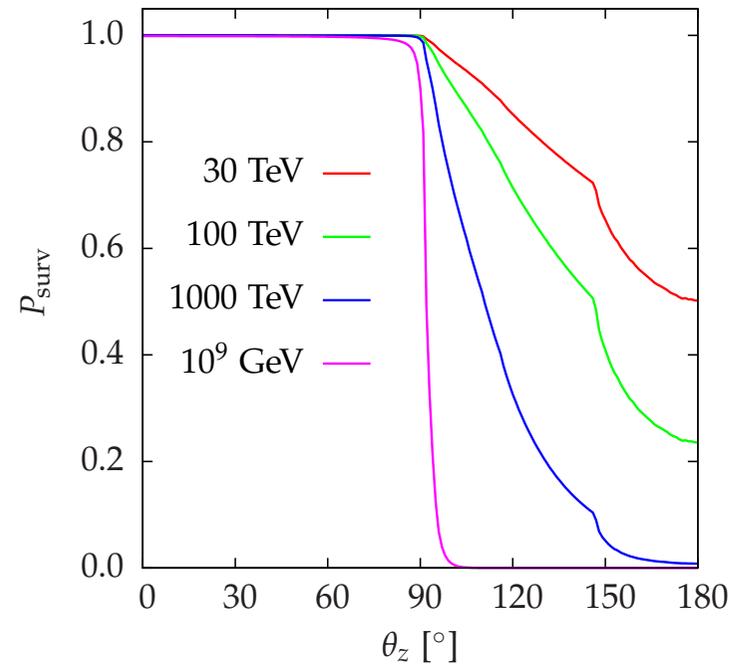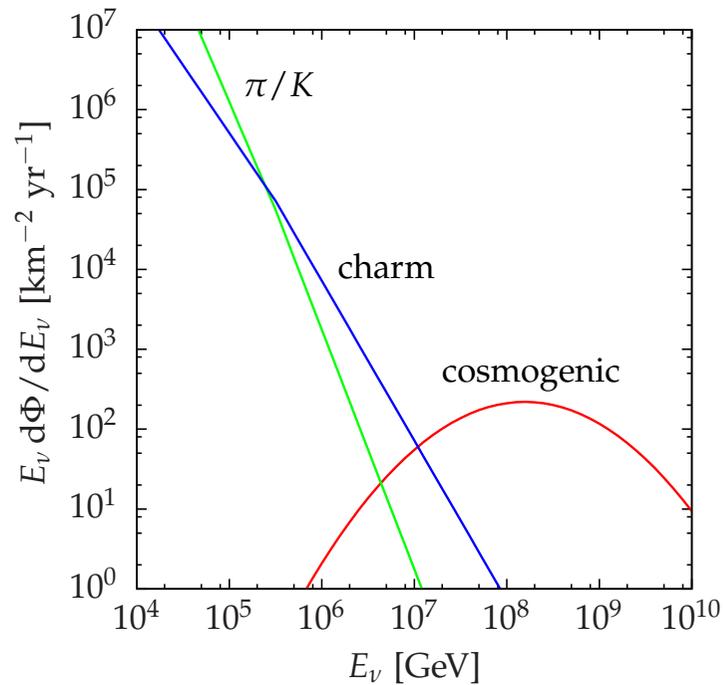
• IceCube has proposed a diffuse E^{-2} ν-flux to fit the excess: It gives 4.5 showers per track and a similar number of downgoing and horizontal events
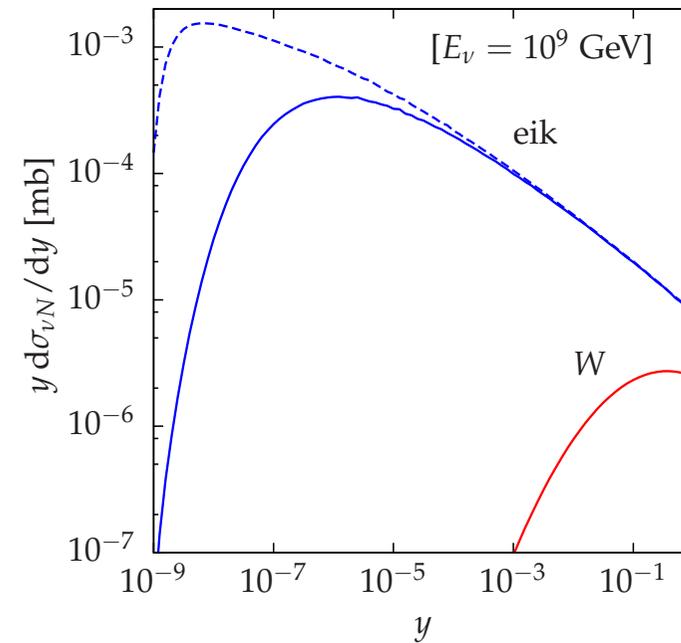
	Data	Atm	E^{-2}	Data	Atm	E^{-2}	
Tracks	2	0.8	0.6	0	0.0	0.1	UPGOING
Showers	5	2.7	3.6	0	0.0	0.7	$(+20° < \delta < +90°)$

	Data	Atm	E^{-2}	Data	Atm	E^{-2}	
Tracks	2	3.5	1.5	0	0.0	0.5	NEAR HORIZONTAL
Showers	8	5.9	6.4	1	0.2	2.6	$(-20° < \delta < +20°)$

	Data	Atm	E^{-2}	Data	Atm	E^{-2}	
Tracks	0/5	0.2/7.8	1.6	0	0.0	0.6	DOWNGOING
Showers	11	0.6/1.4	6.5	3	0.0	2.9	$(-90° < \delta < -20°)$

$30 - 300$ TeV $300 - 3000$ TeV

• The number and distribution of tracks is well explained by atmospheric neutrinos. In the low-energy bin there are 4 tracks from upgoing and near-horizontal directions for an expected background of 4.3, whereas at higher energies there are no events but just 0.06 tracks expected.

• There is an excess of showers that is especially significant from downgoing directions. At low energies we find 11 events for 0.6 expected, and in the 300–3000 TeV bin there are 3 showers for a 0.04 background. If we include near-horizontal directions we obtain a total of 23 events for just 6.7 expected

• We propose a new physics scenario that only introduces near-horizontal and downgoing showers (in a 1:2 ratio) with no new muon tracks from any directions

A consistent model of TeV gravity with 1 extra dimension

FLAT
ADD

"HYBRID"
Giudice, Plehn, Strumia (2004)

WARPED
RS

$\bar{M}_5$

1 TeV

$c = \dfrac{E}{\bar{M}_{Pl}}$

$c = \dfrac{E}{\bar{M}_5}\sqrt{\dfrac{m_c}{\bar{M}_5}}$

$c = \dfrac{0.4\,E}{\bar{M}_5}$

$m_c = 500$ GeV

$m_c > 50$ MeV

$m_c = 10^{-24}$ MeV

$k = m_c \ll \bar{M}_5$

$R\,k = 9.7$

$k \ll R^{-1}$

$\bar{M}_{Pl} = \bar{M}_5\,(2\pi R)$

$m_c = R^{-1} = 10^{-28}$ GeV

$R = 1.3$ AU

$\bar{M}_{Pl}^2 = \dfrac{\bar{M}_5^3}{k}\,(e^{2\pi R k} - 1)$

$k = m_c = 0.2\,\bar{M}_5$

$R\,k = 11.3$

- At $\sqrt{s} > \bar{M}_5$ the νN cross section becomes large (μb) but soft (inelasticity $y \approx 10^{-5}$)
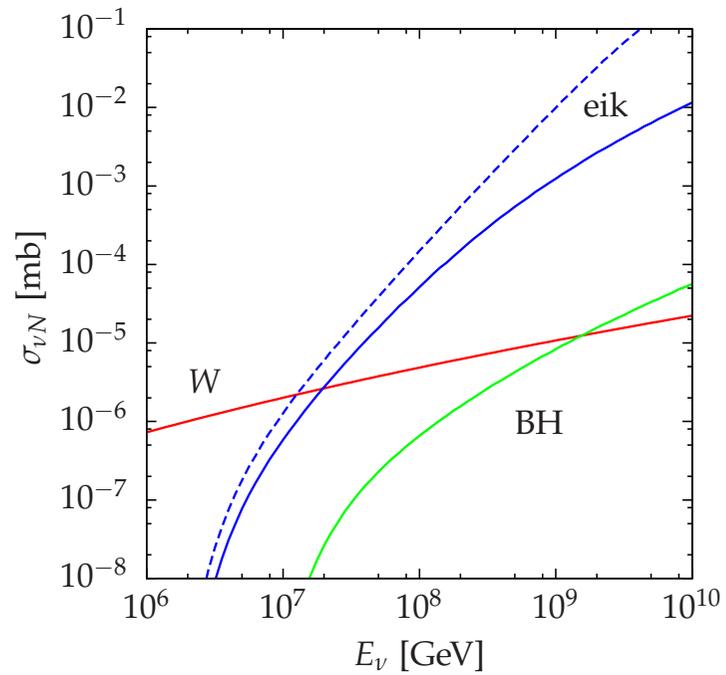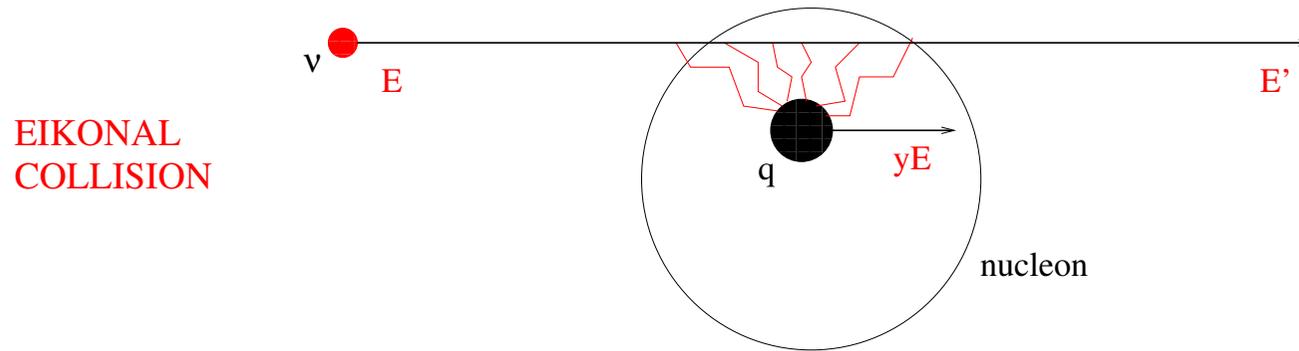
• Cosmogenic neutrinos –produced in collisions of CRs with the CMB radiation, a few hundred neutrinos of $E = 10^8$–10^{10} GeV per km^2 and year– may reach the center of IceCube and deposit there a small fraction of energy ($y \approx 10^{-5}$). Only shower events, no new tracks.

• Their large energy prevents these neutrinos from reaching IceCube from $\theta_z > 90^o$: Only downgoing and near-horizontal showers in a proportion of 2:1

• These soft collisions do not *destroy* the incident neutrino, which could actually interact once or several times in the ice before reaching the detector.

E^{-2} flux and standard physics versus cosmogenic flux and new physics

	Data	Atm	E^{-2}	NP	Data	Atm	E^{-2}	NP	
Tr	2	0.8	0.6	0.0	0	0.0	0.1	0.0	UP-GOING
Sh	5	2.7	3.6	0.0	0	0.0	0.7	0.0	$(+20° < \delta < +90°)$
Tr	2	3.5	1.5	0.0	0	0.0	0.5	0.0	NEAR-HORIZ
Sh	8	5.9	6.4	4.2	1	0.2	2.6	1.9	$(-20° < \delta < +20°)$
Tr	0	0.2	1.6	0.0	0	0.0	0.6	0.0	DOWN-GOING
Sh	11	0.6	6.5	8.0	3	0.0	2.9	3.5	$(-90° < \delta < -20°)$

$30 - 300$ TeV $\qquad\qquad$ $300 - 3000$ TeV

- $\sum_i^N 2 \left(E_i - X_i + X_i \ln \frac{X_i}{E_i} \right)$:   NP is 2.6 times more likely than E^{-2}

- Muon-track puzzle at IceCube?   Their analysis leaves the ν flux from charm *free,* and best fit gives a zero charm contribution (but crossover should be at 100–1000 TeV...). Some muons may look like showers (1410.1749).

  No extra muon tracks or 1 per 4.5 showers?

- The analysis using 3 direction bins (downgoing, near-horizontal, upgoing) is essential. It is motivated by the attenuation produced by the Earth, negligible in the down-going and near-horizontal bins. In these two bins the data gives 10.4:2.1 showers of 30–300 TeV and 3:1 showers of 300–3000 TeV

  Same excess from downgoing and near-horizontal directions or 2:1 ratio?

  How to discriminate between the E^{-2} and the NP hypotheses?

  more statistics or...

IceTop

IceCube
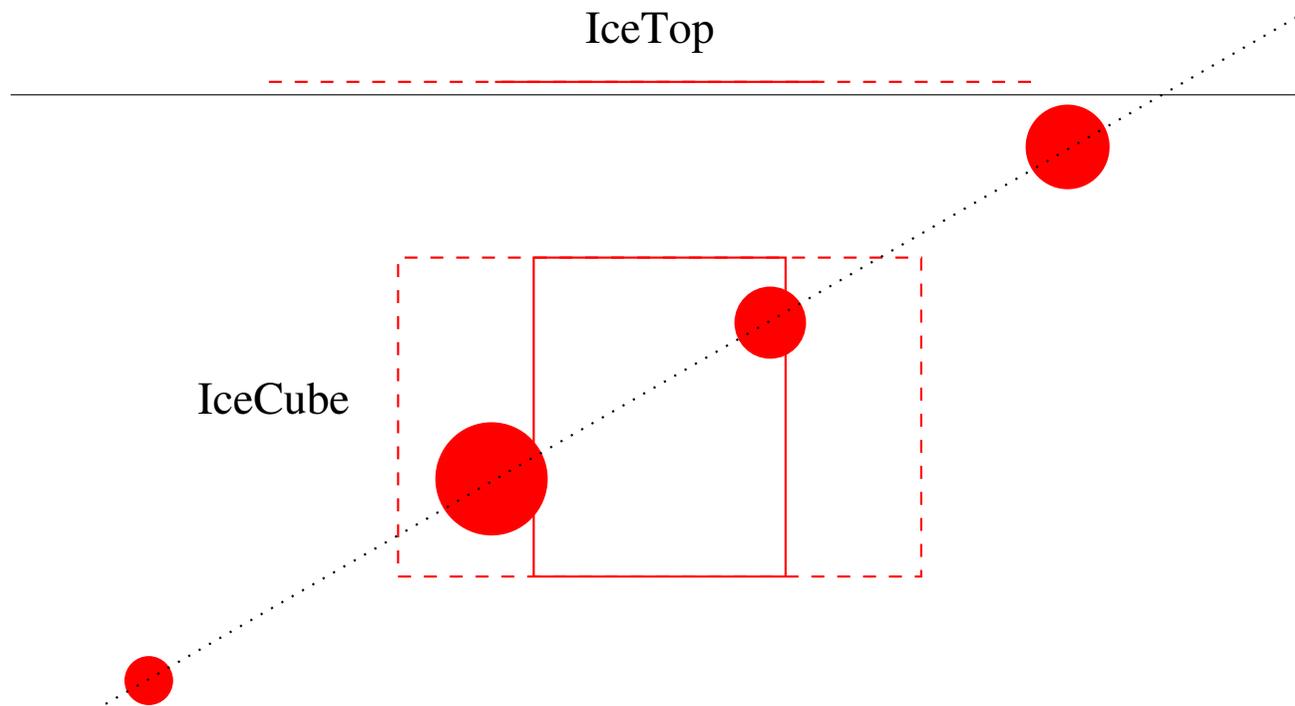
...near-horizontal double-shower events