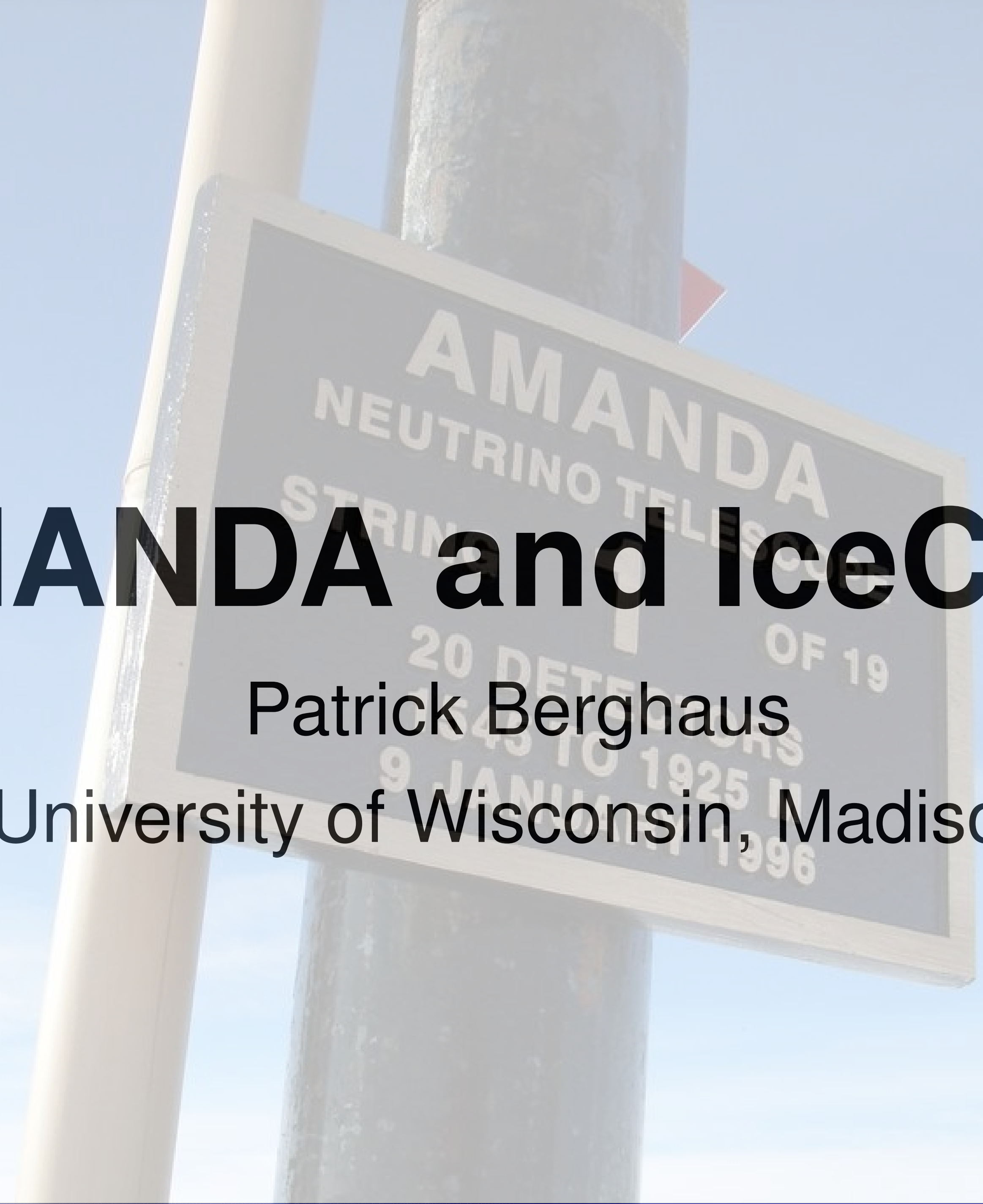
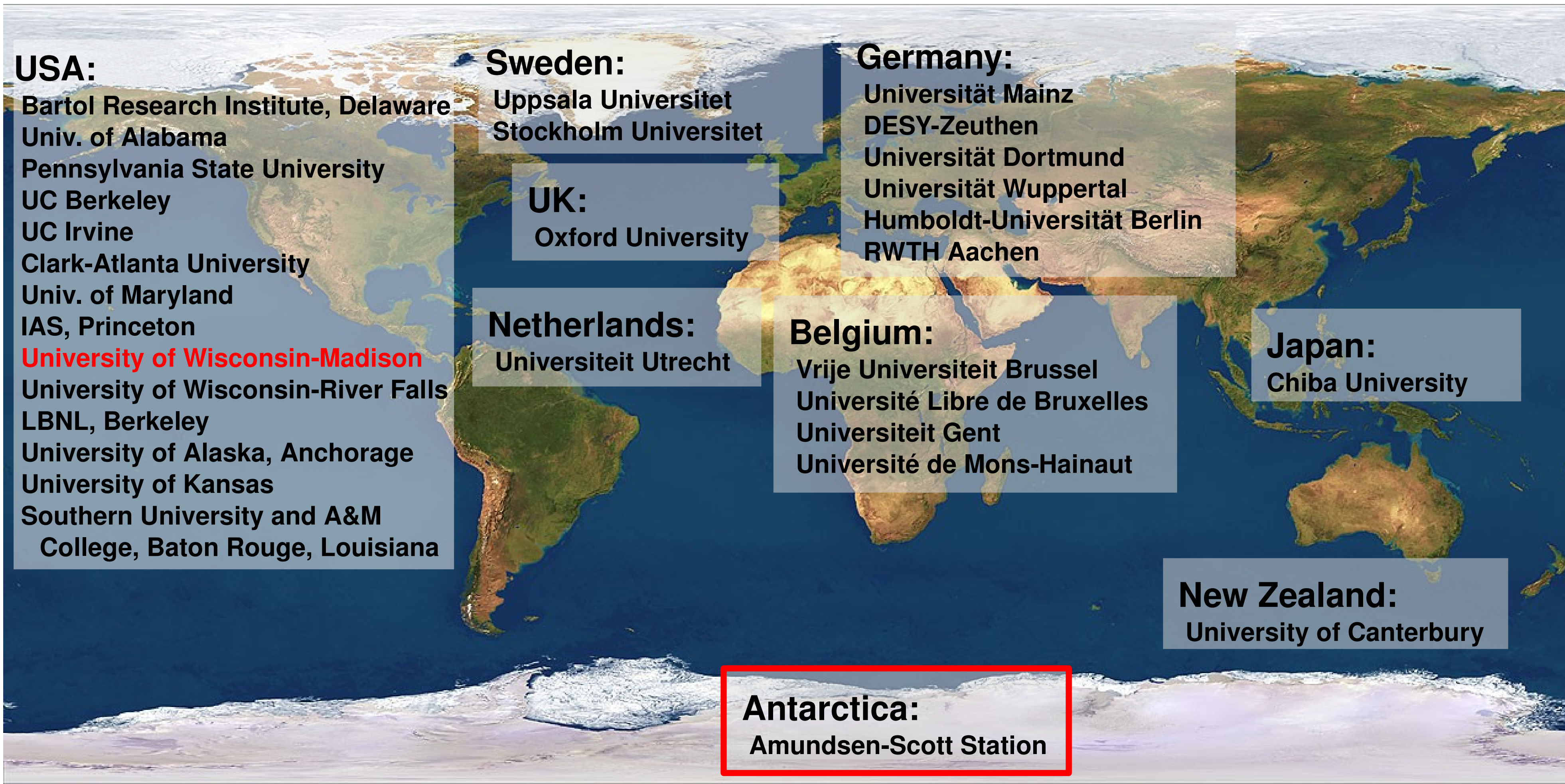


AMANDA and IceCube

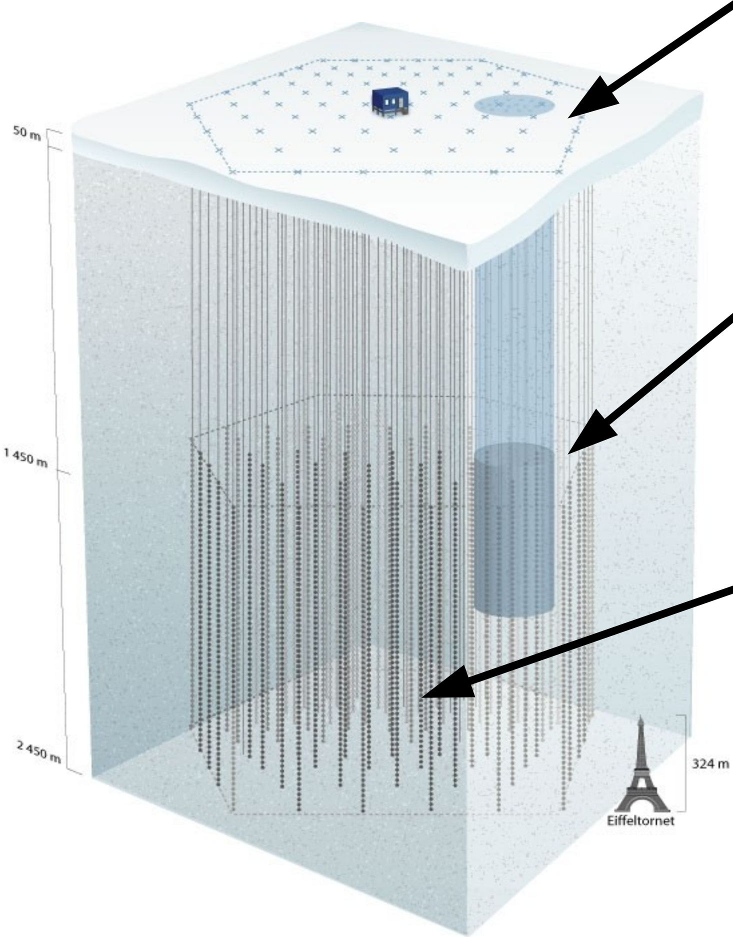
Patrick Berghaus

University of Wisconsin, Madison

IceCube: People



IceCube: Hardware



IceTop(Air Showers):

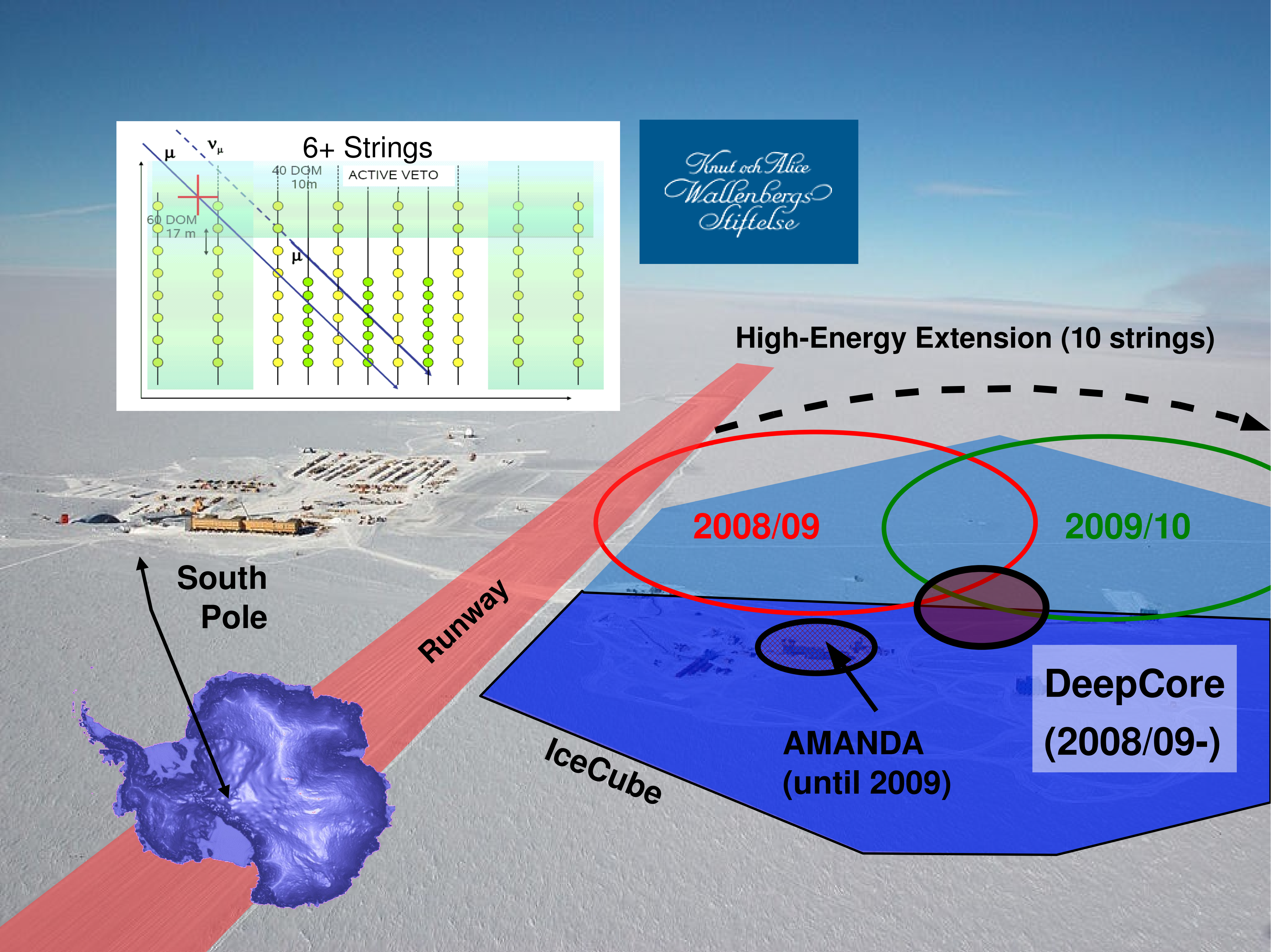
- 2 Surface Tanks per InIce String, 2 DOMs per Tank
- 2008: **80** Tanks Installed

Amanda:

- Ø=200m, h=500m (0.02 km³)
- 677 OMs on 19 Strings (from 2000)

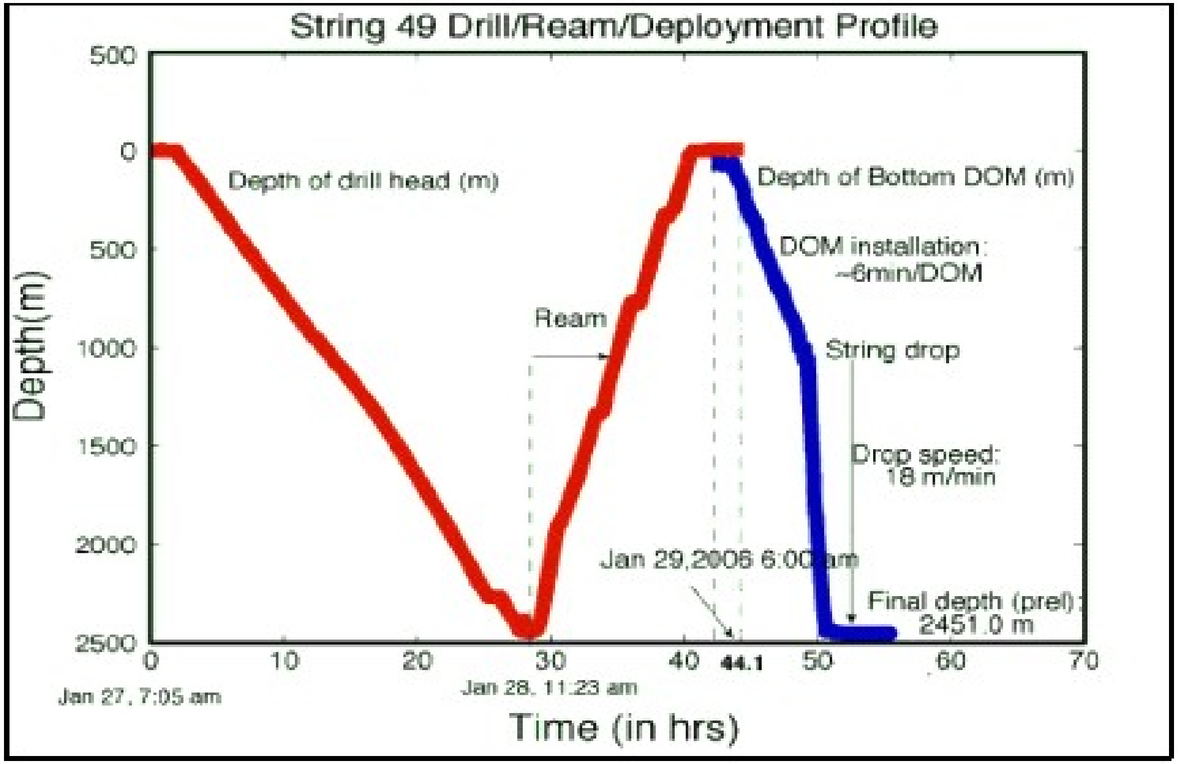
InIce:

- 1 km^3 instrumented
- 4800 Digital Optical Modules (DOMs) on 80 strings
- 2008: **40** Strings deployed (“**IC40**”)



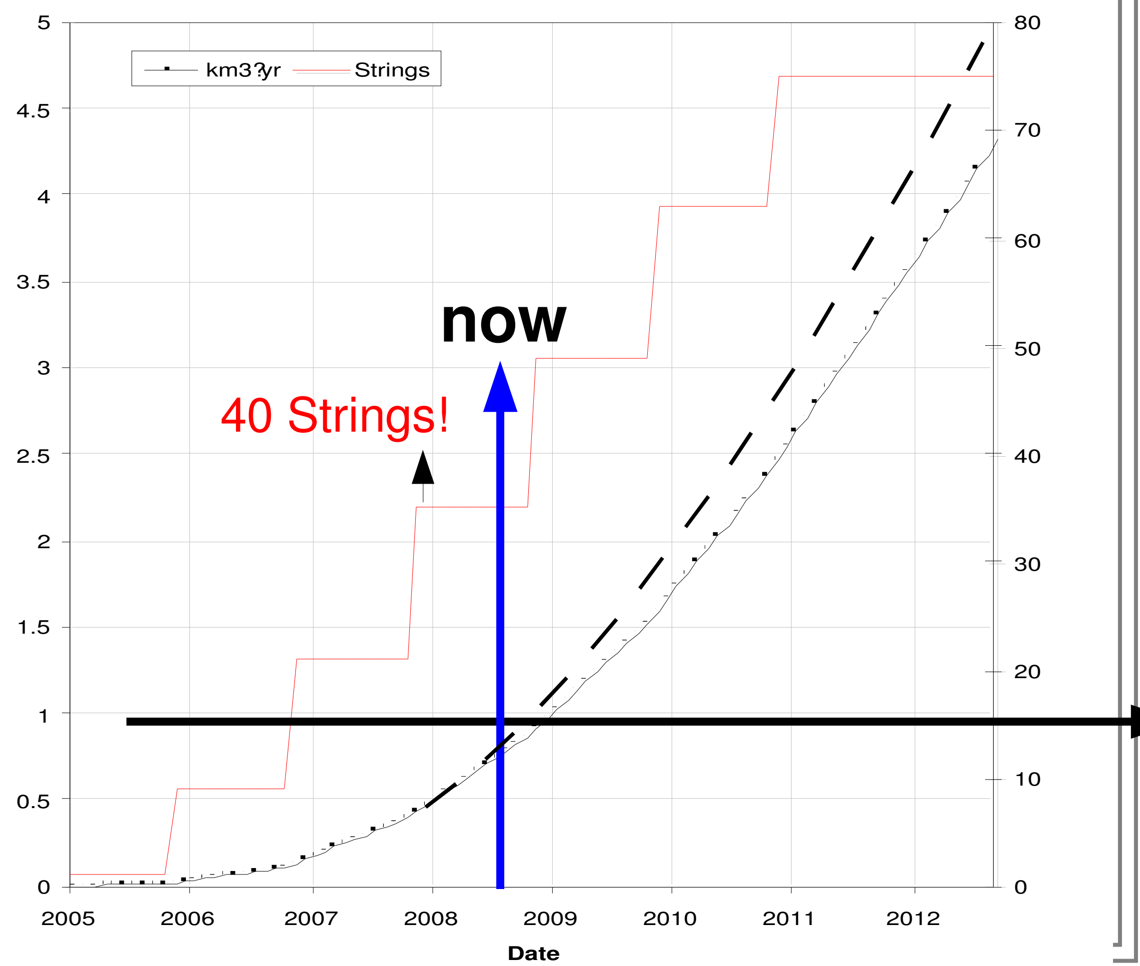
6+ Strings
μ
ν_μ
40 DOM
10m
ACTIVE VETO
60 DOM
17 m
μ
Knut och Alice
Wallenbergs
Stiftelse
High-Energy Extension (10 strings)
2008/09
2009/10
South
Pole
Runway
AMANDA
(until 2009)
DeepCore
(2008/09-)
IceCube

String Deployment



2 Days

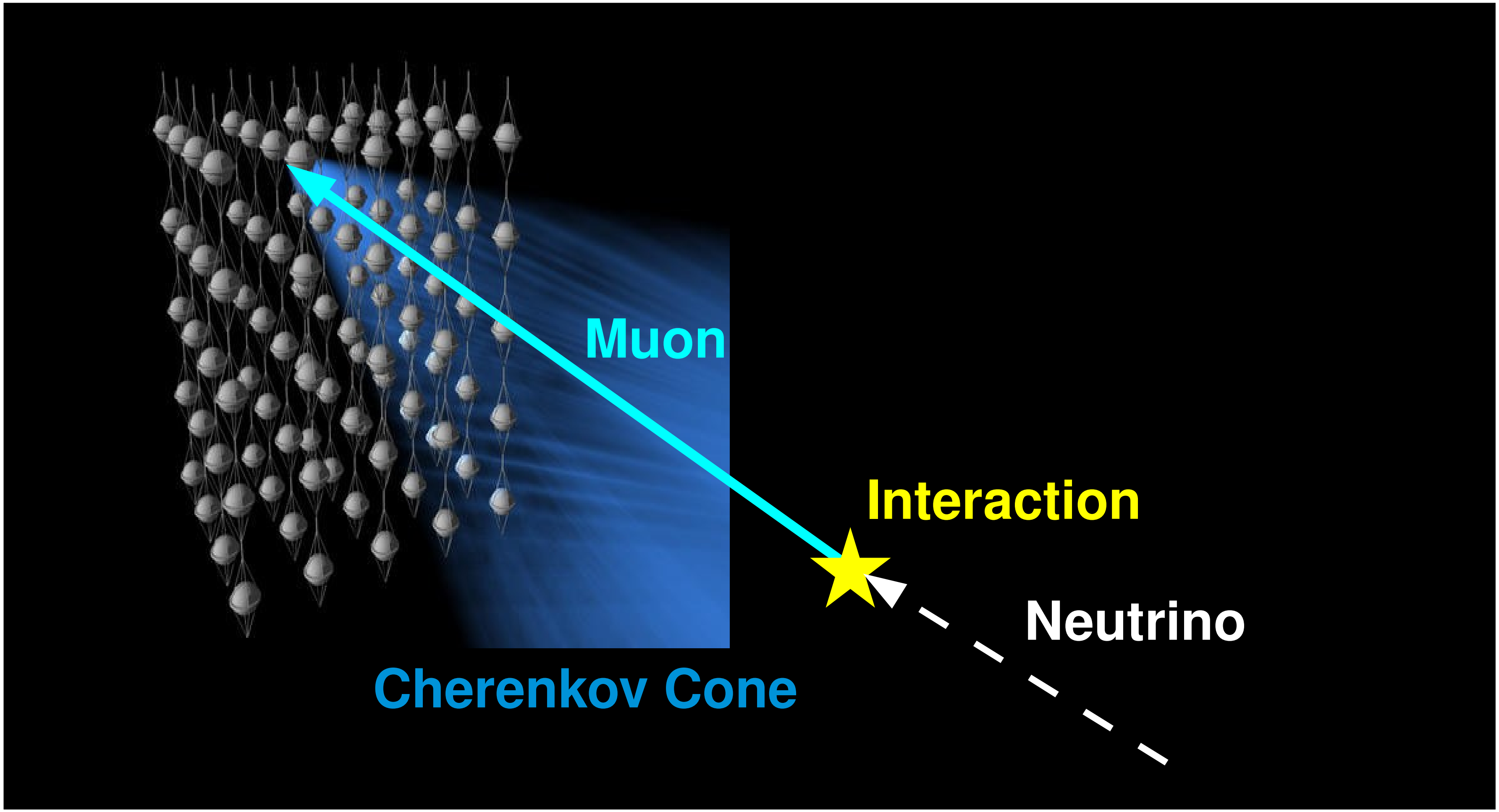
Integrated Exposure



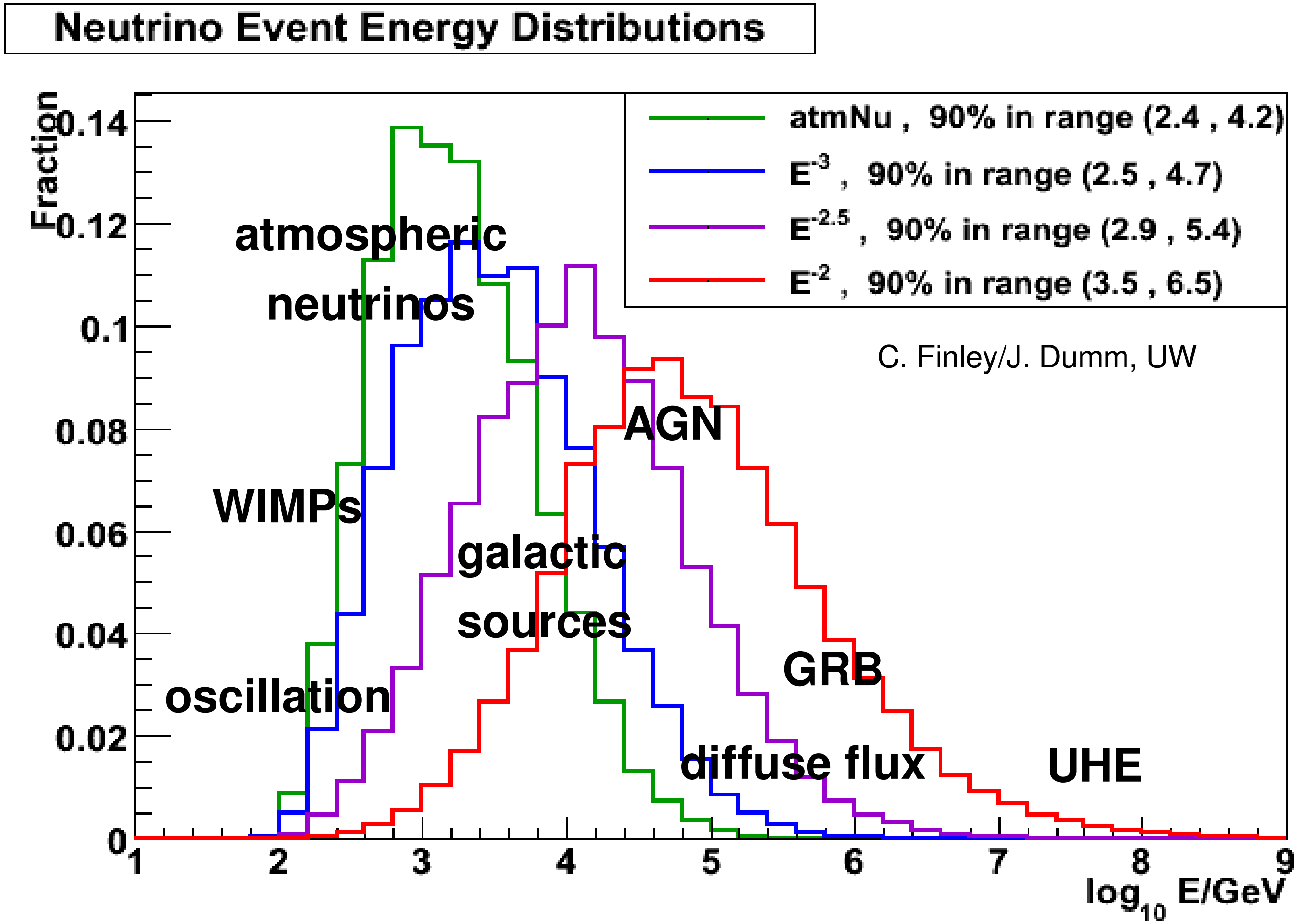
1 km^3 year by early 2009

Patrick Berghaus
University of Wisconsin, Madison

(Very Basic) Detection Principle

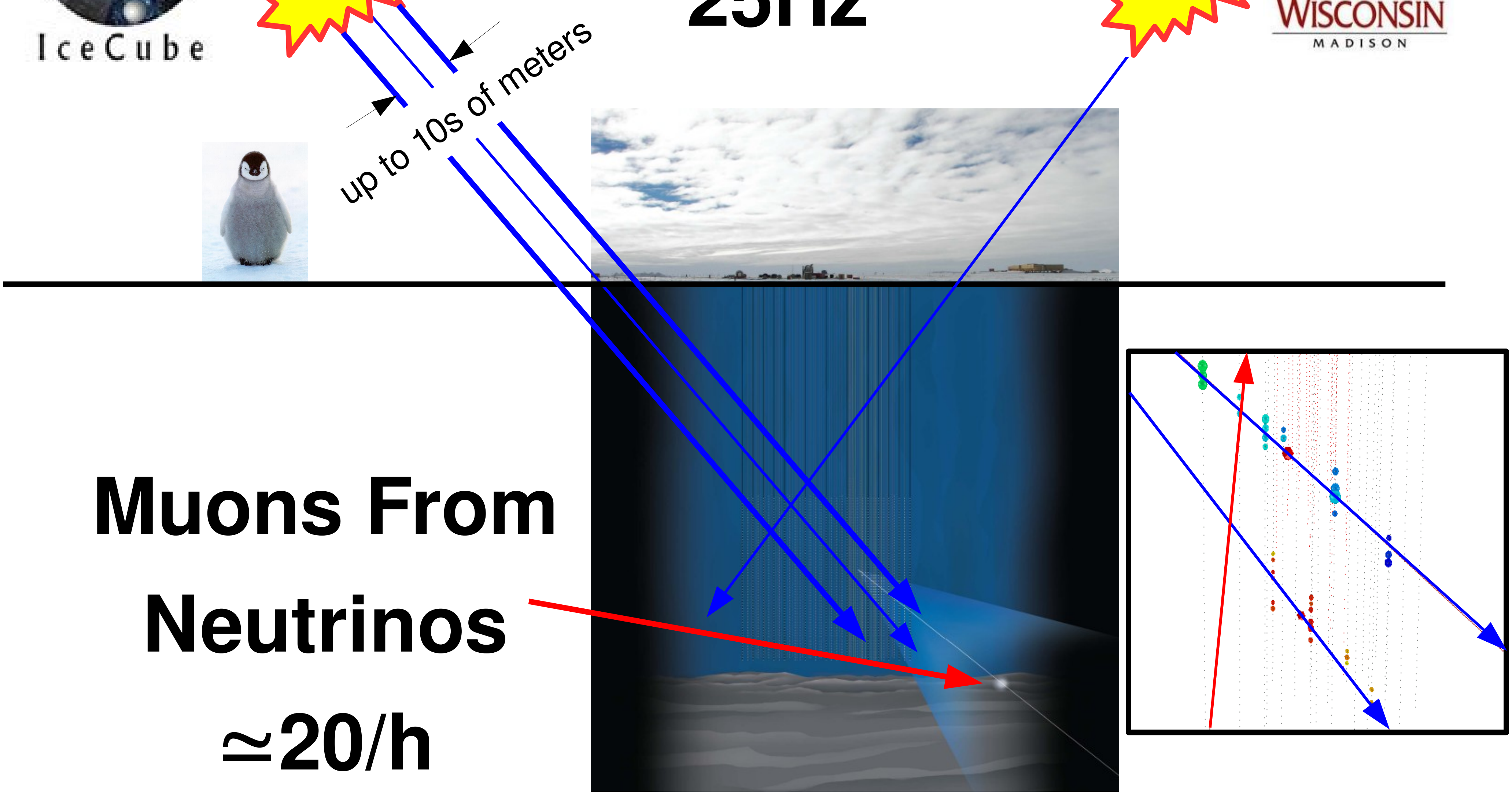


Neutrino Physics



Coincident Muons

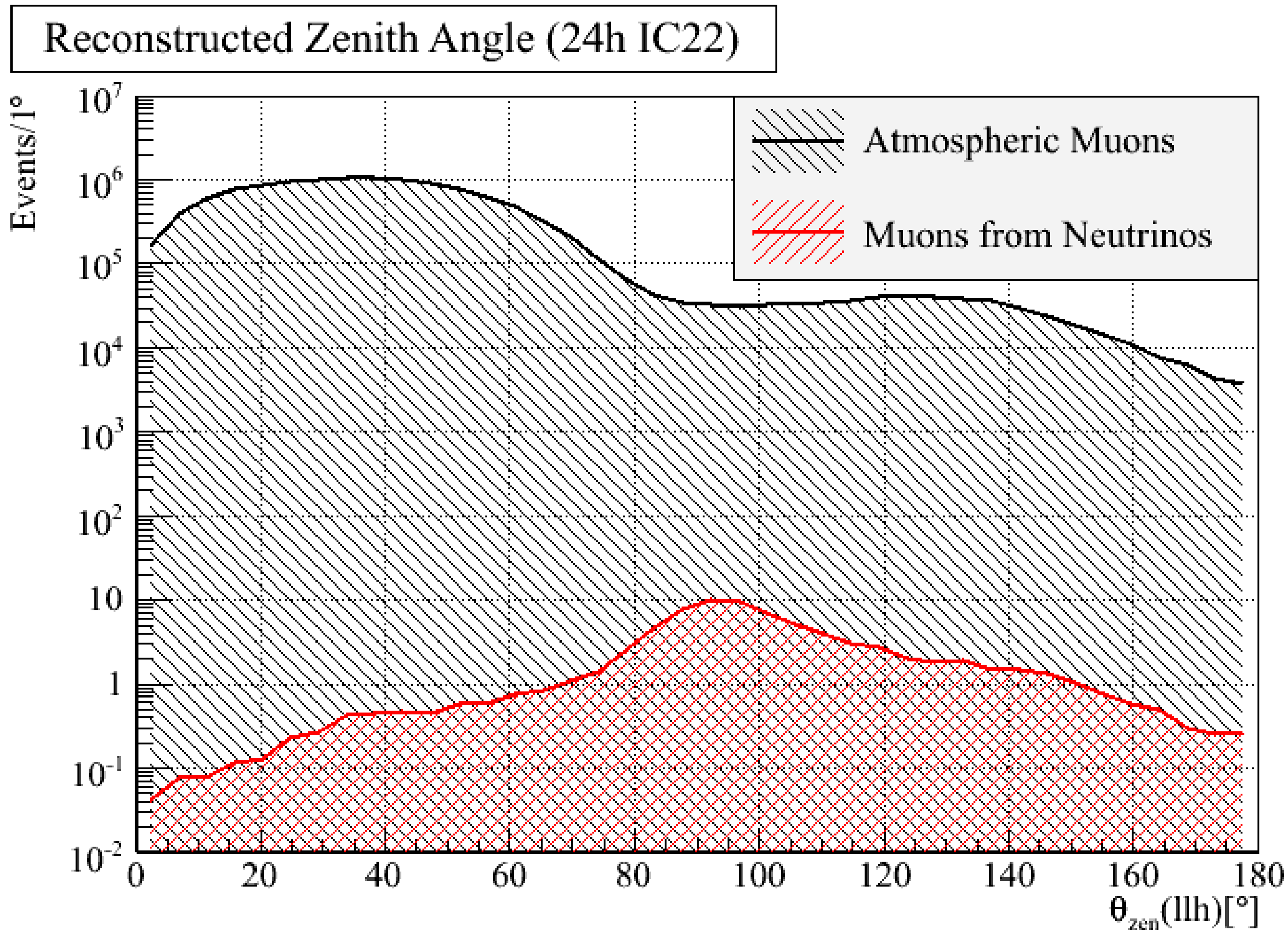
25Hz



Muons From Neutrinos

≃20/h

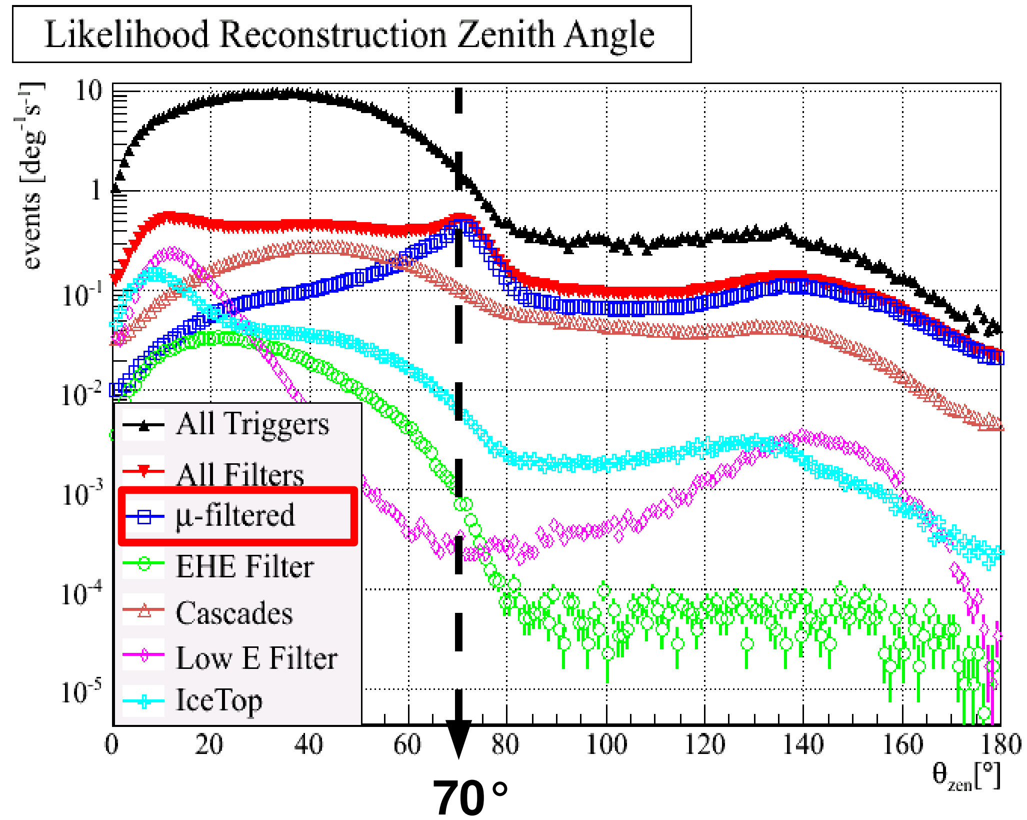
Background



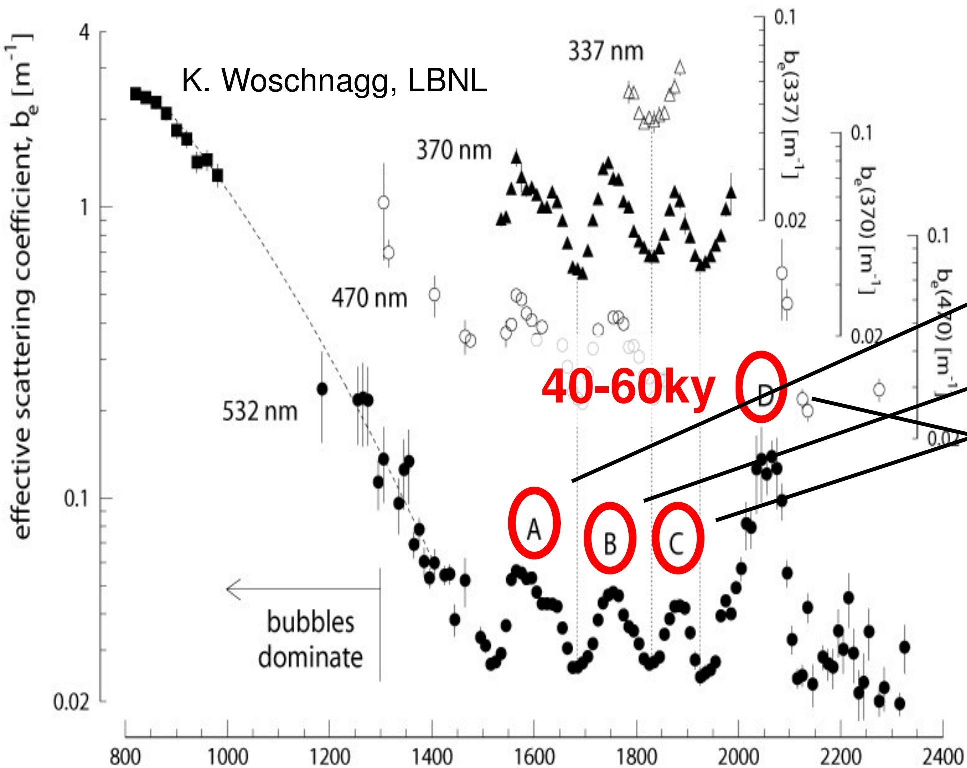
Reconstructed Zenith Angle (24h IC22)
Events/1°
Atmospheric Muons
Muons from Neutrinos
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
0
20
40
60
80
100
120
140
160
180
θ_{zen}(llh)[°]

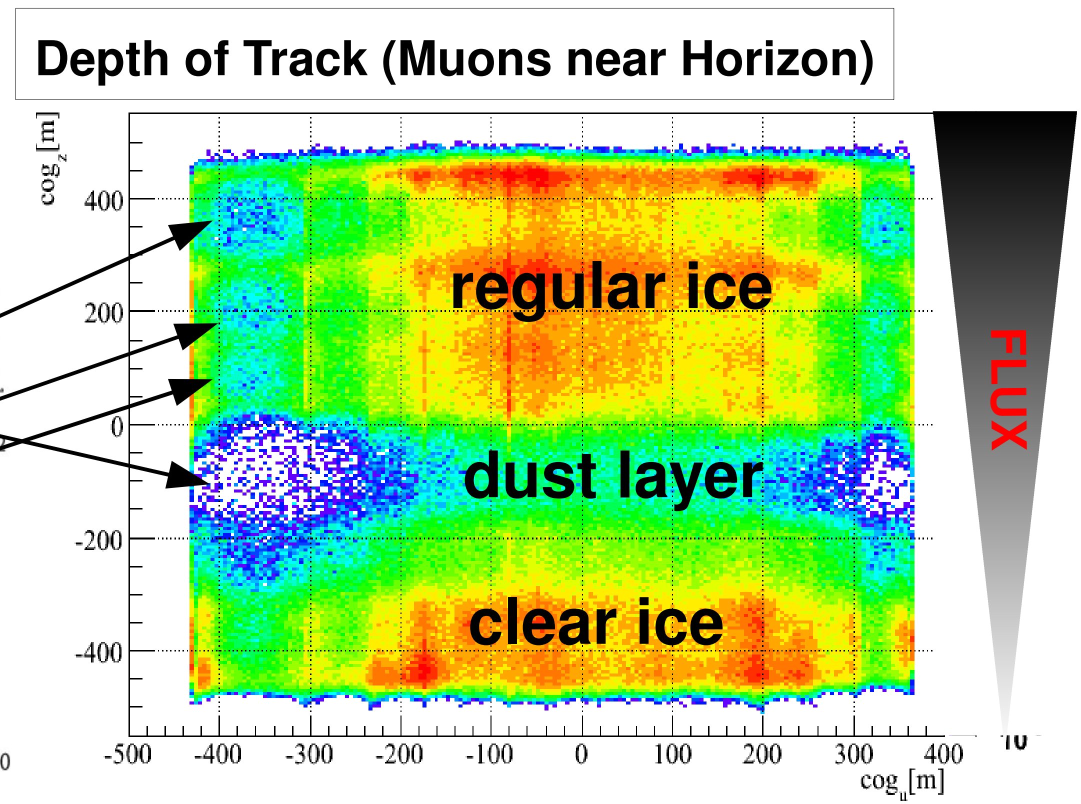
Event Filters

#Strings	Year	Run Length	CR μ Rate	ν rate	Trigger Rate
IC1	2005	-	-	2	-
IC9	2006	137 days	80 Hz	~ 1.5/day	150 Hz
IC22	2007	319 days	550 Hz	~ 20/day	670 Hz
IC40	2008	~ 1year	1000 Hz		1400 Hz
IC80	2011	10 years	1650 Hz	~ 200/day	TBD



Ice

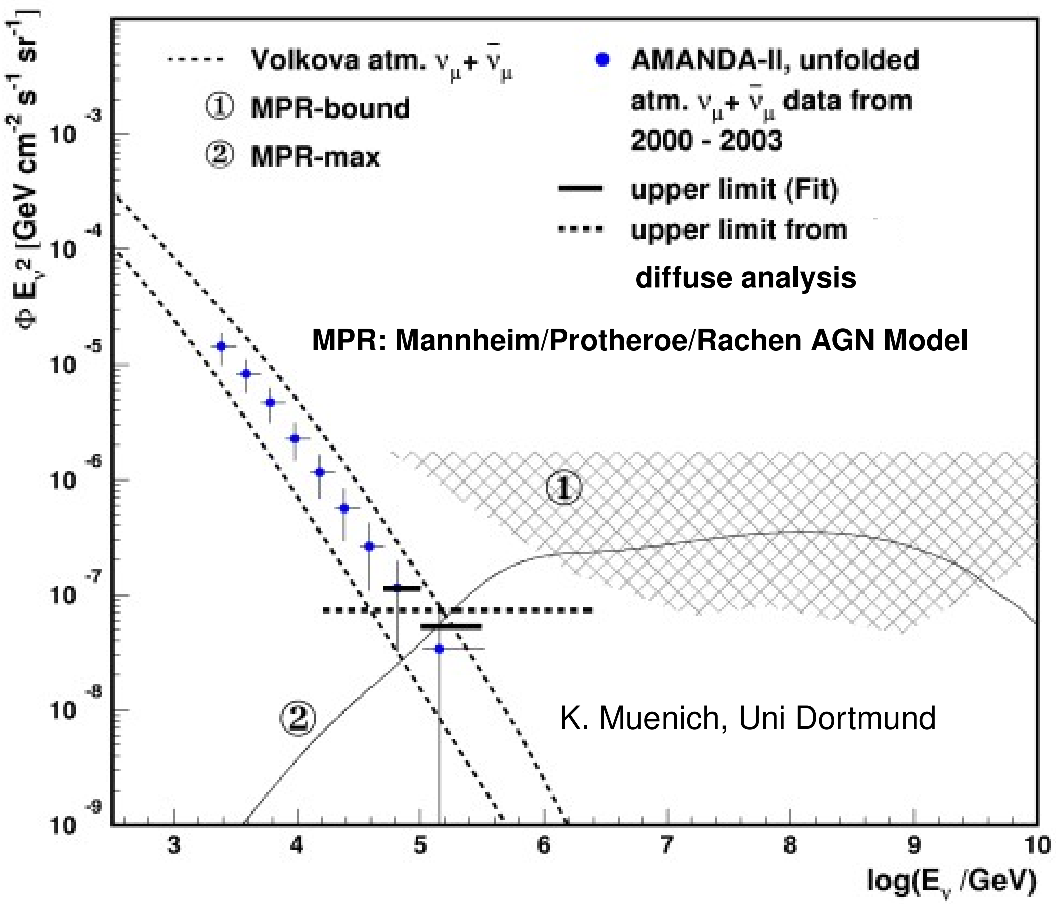




dust peaks correspond to cold periods during last Ice Age

Analyses

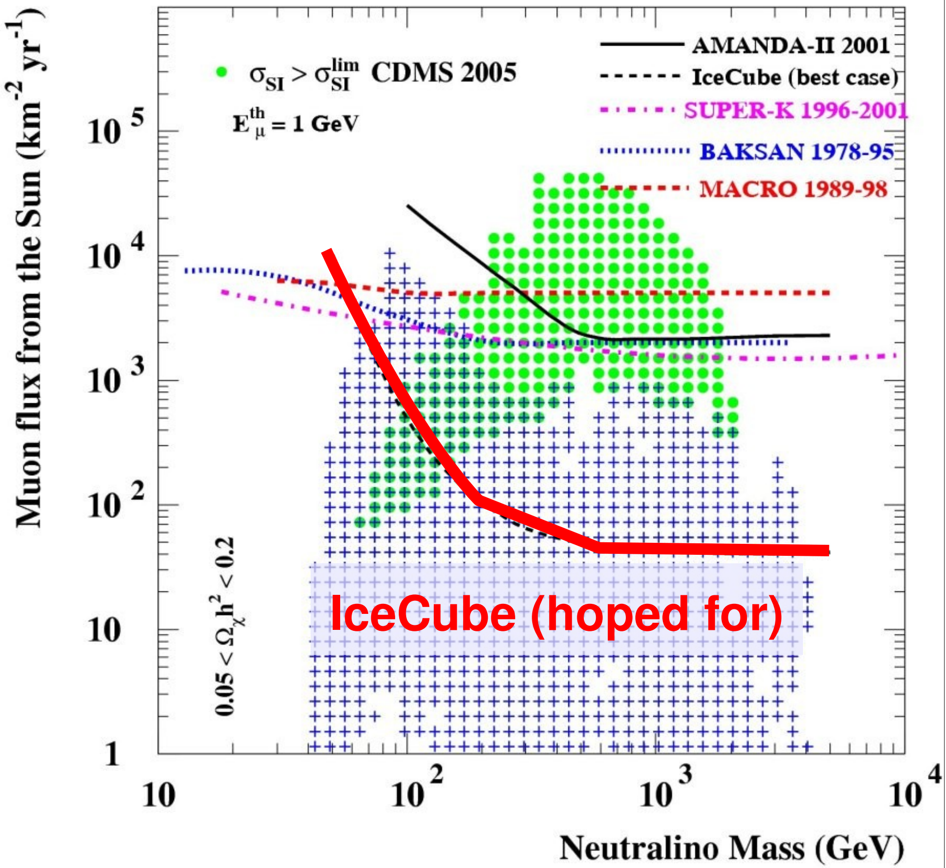
Atmospheric Neutrinos

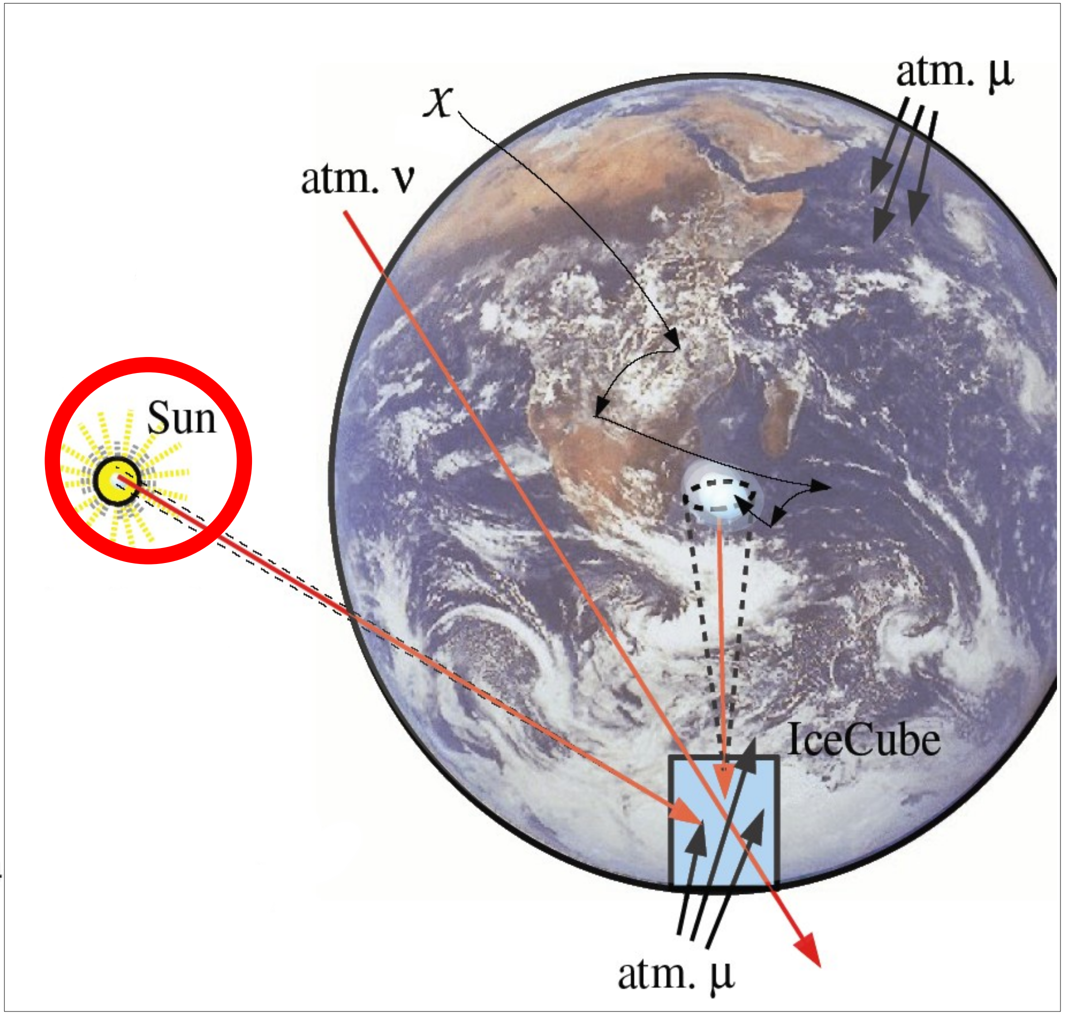


- Unfolded Energy Spectrum
- Consistent with Theory
- Only proven AMANDA/IceCube neutrino source

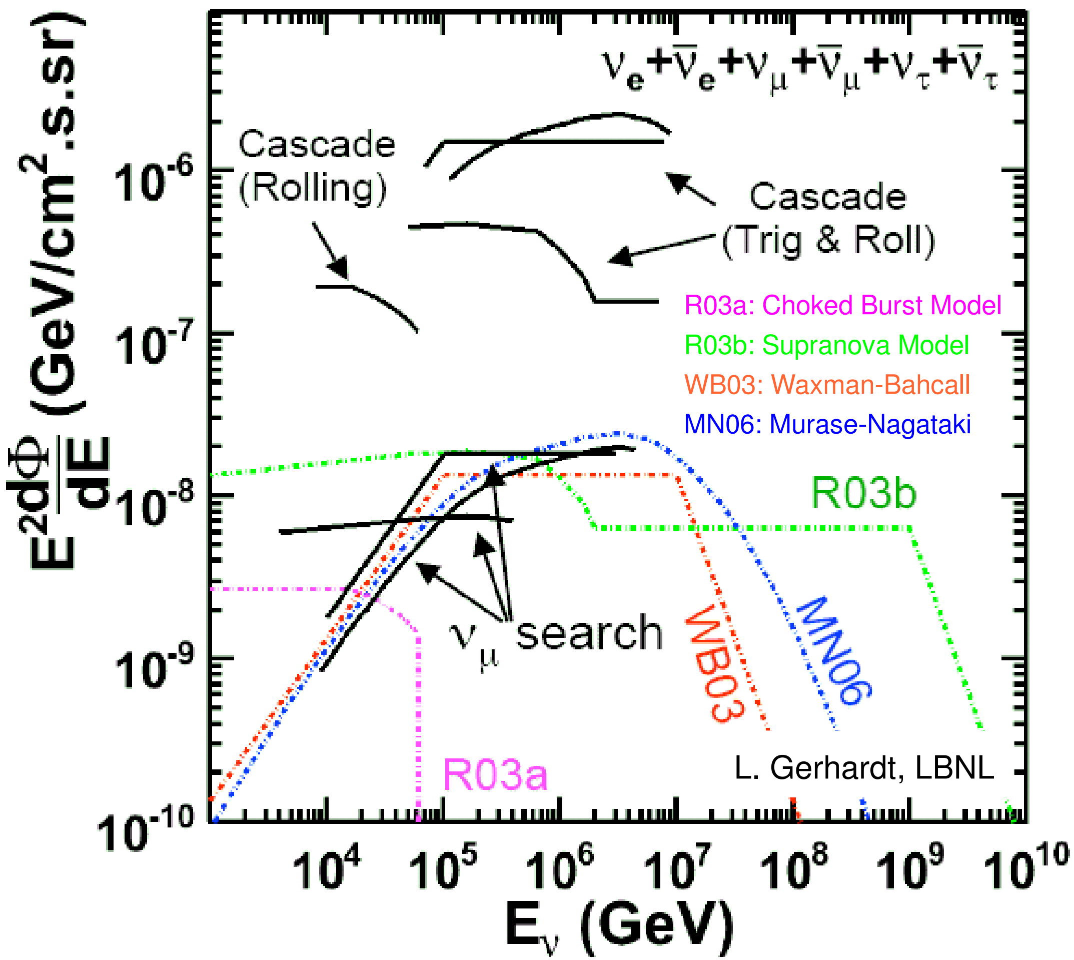
WIMPs

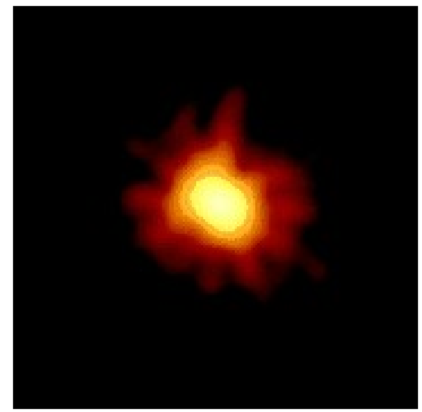
Neutralino Pair Annihilation





GRBs



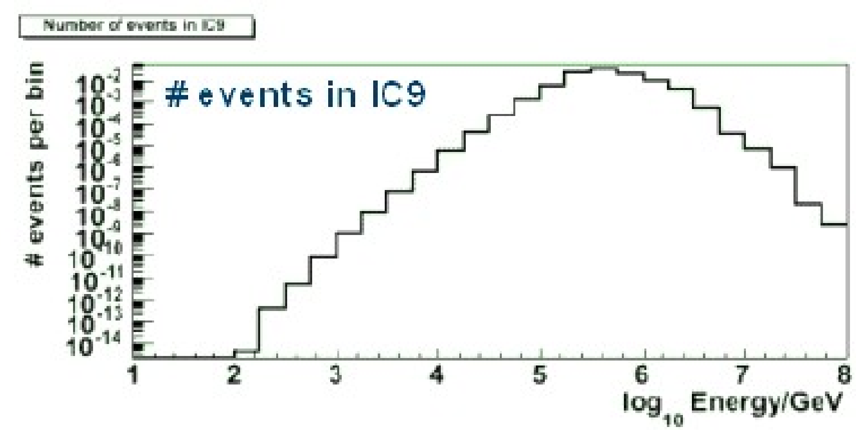


080319B

IC9 only

expected signal:

≈0.1 events

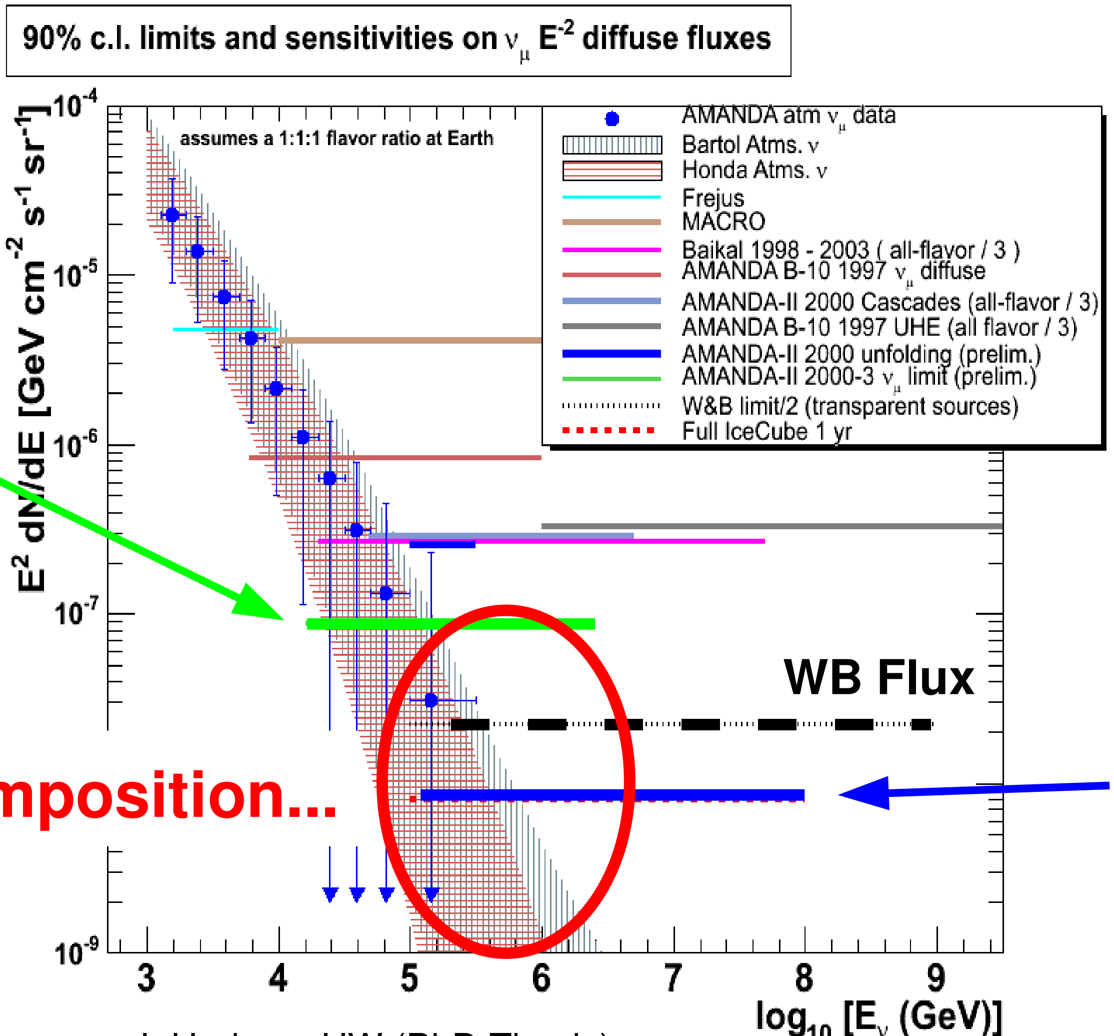


Diffuse Neutrino Flux

Latest Result

(4-year AMANDA)

astro-ph/0705.1315



Charm, Composition...

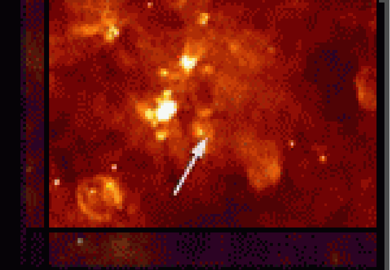
1 Year IC80

(estimated)

J. Hodges, UW (PhD Thesis)

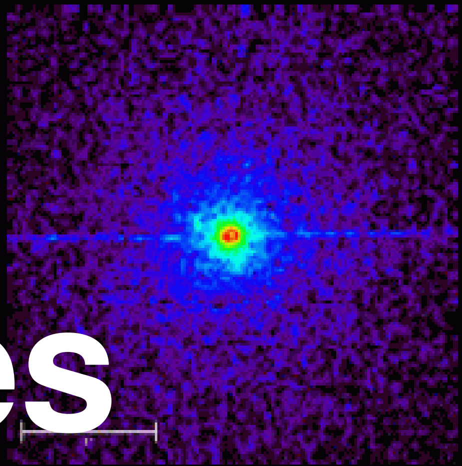
Potential Neutrino Sources

nearby AGN M87 (HST)



Magnetar SGR 1806-20

Quasar 3C273 Kitt Peak

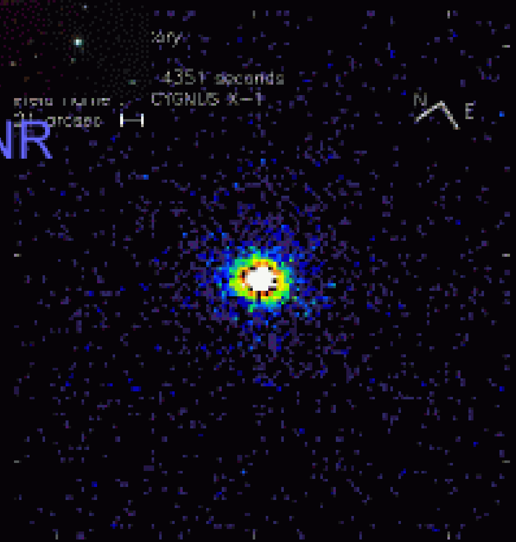


Cygnus X-3 x-ray (Chandra)

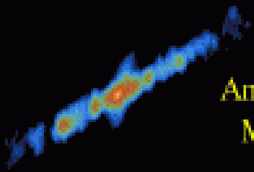
Point Sources

Crab nebula SNR

BL Lac Markarian 421



Cygnus X-1

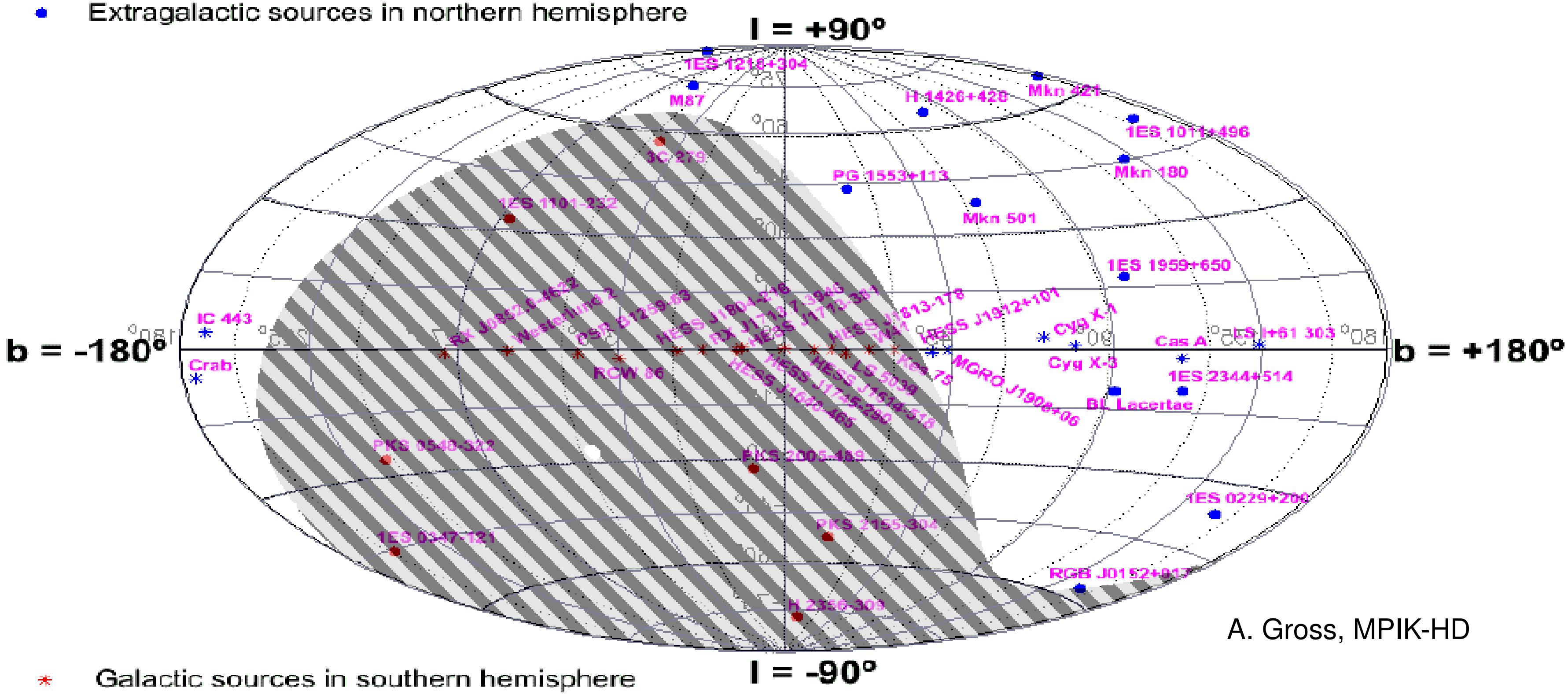


Amy Mioduszewski
Michael Rupen
Craig Walker
Greg Taylor

Microquasar SS433 (VLBA)

Sources: Sky Map

- Extragalactic sources in southern hemisphere
- Extragalactic sources in northern hemisphere



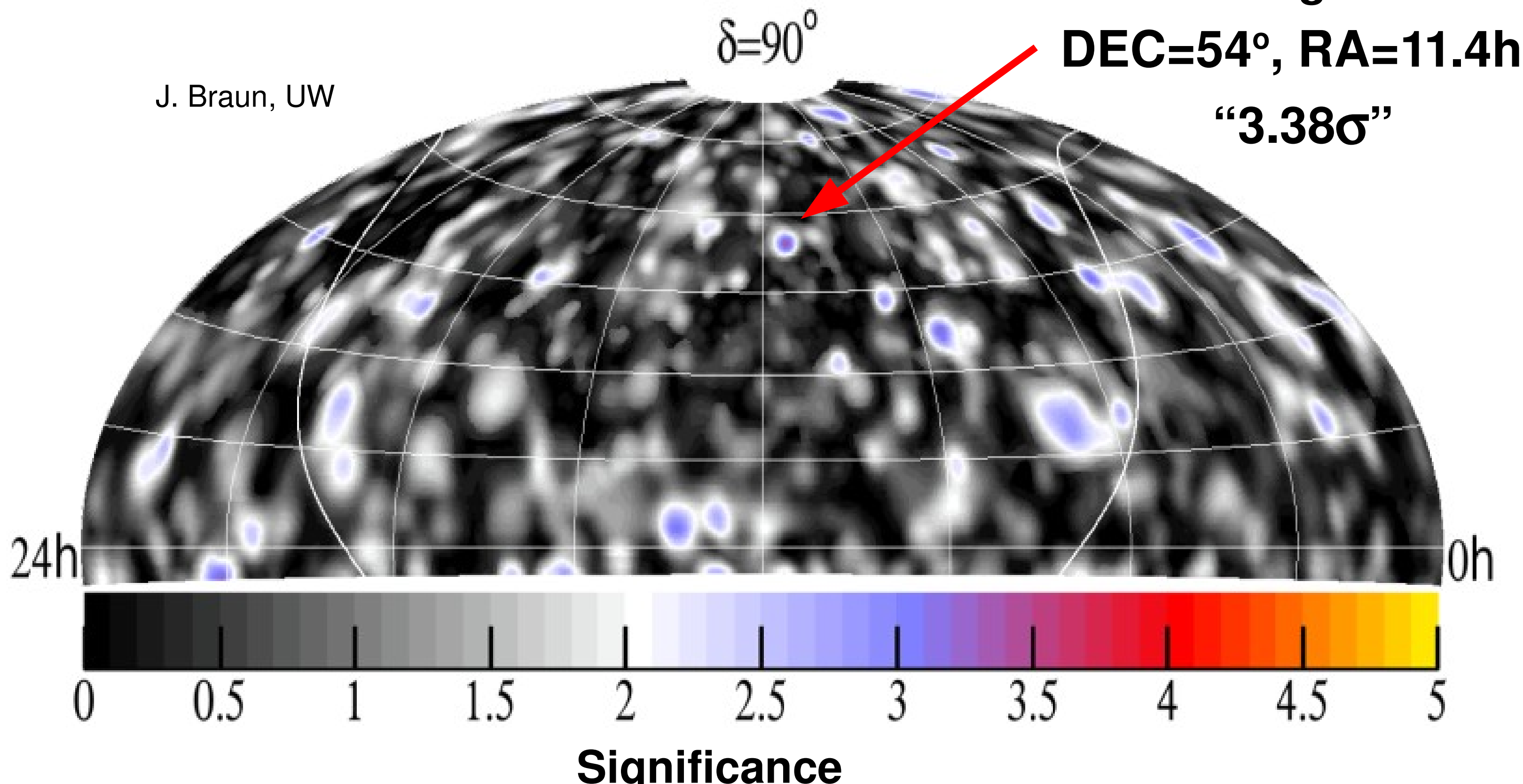
A. Gross, MPIK-HD

- Galactic sources in southern hemisphere
- Galactic sources in northern hemisphere

- not directly accessible for IceCube
- directly accessible for IceCube

Final AMANDA Result

2000-2006, 3.8y livetime



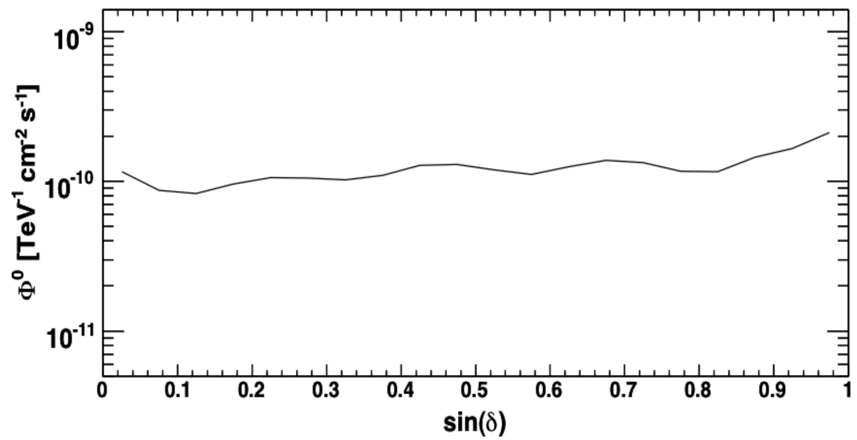
95% of randomized skies have a higher maximum significance!

- **26 sources** selected to reduce **trial factor**
- **No indication for neutrino point sources**
  (consistent with random sky)

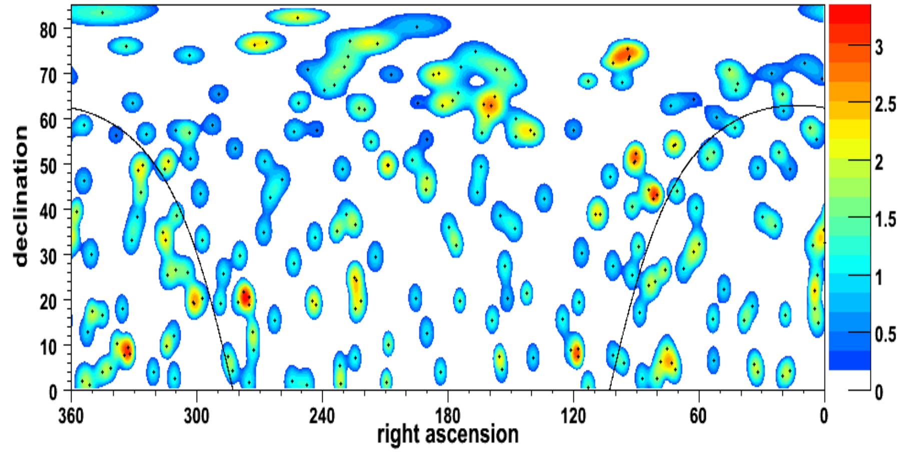
	Source	Excess parameter -log10 P	Flux upper limit for $\Phi = \Phi_0 E^{-2}$ 90% CL [10^{-11} TeV cm^{-2}s^{-1}]
AGN	Markarian 421	0.82	1.26
AGN	Markarian 501	0.22	3.56
AGN	1ES1959+650	0.44	3.38
AGN	M87	0.43	2.18
AGN	3C273	0.086	4.17
μ-QSO	SS433	0.64	1.57
μ-QSO	LSI +61 303	0.033	7.21
μ-QSO	Cygnus X-1	0.57	2.00
μ-QSO	Cygnus X-3	0.29	3.28
SNR	Cassiopeia A	0.67	1.93
SNR	Crab Nebula	0.10	4.47
SNR	**Geminga**	**0.0086**	6.07

Probability: 20%

IC9 Point Source Search



Source: C. Finley, UW



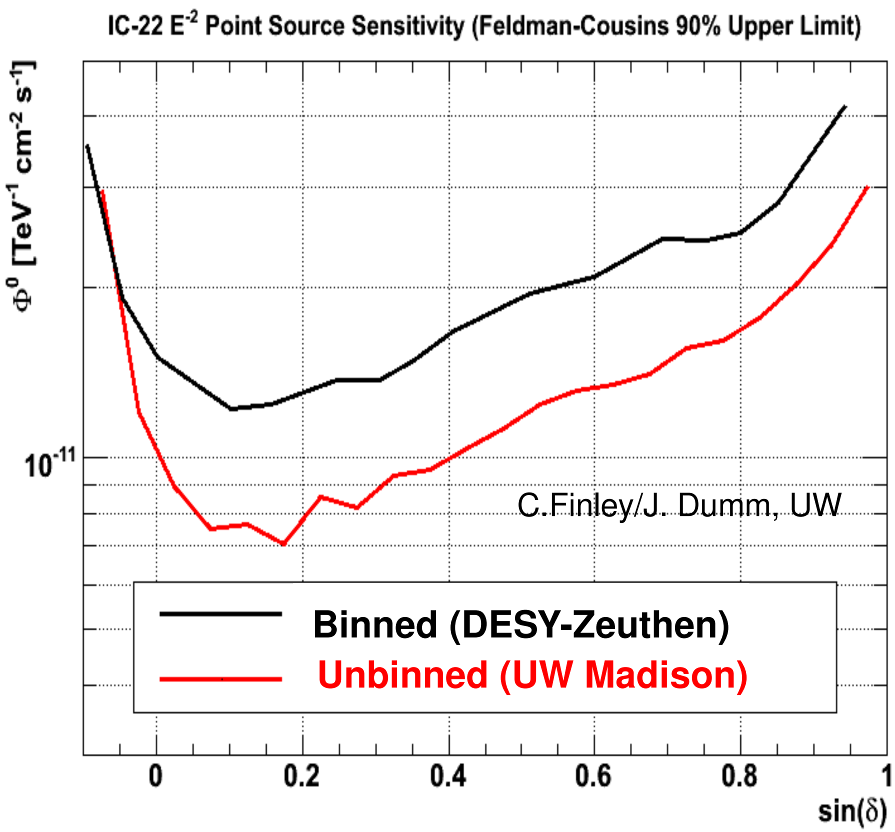
Flux limit:

IC9 ≃ AMANDA

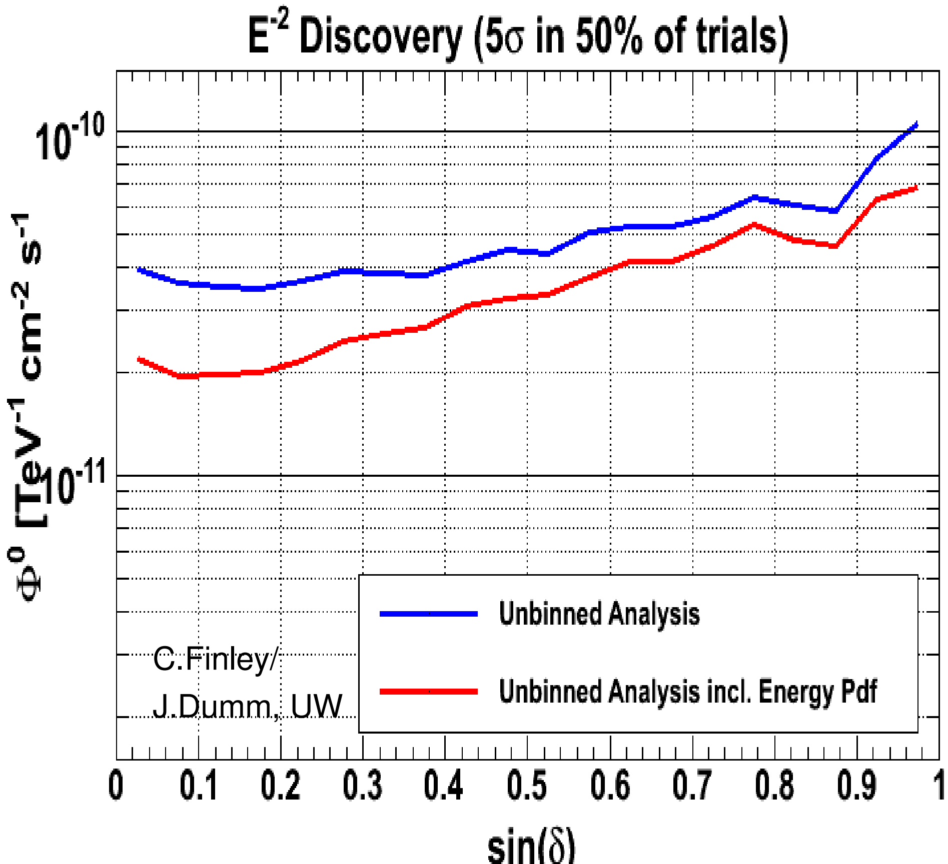
60% of random skies

have higher significance

IC22 Point Source Search

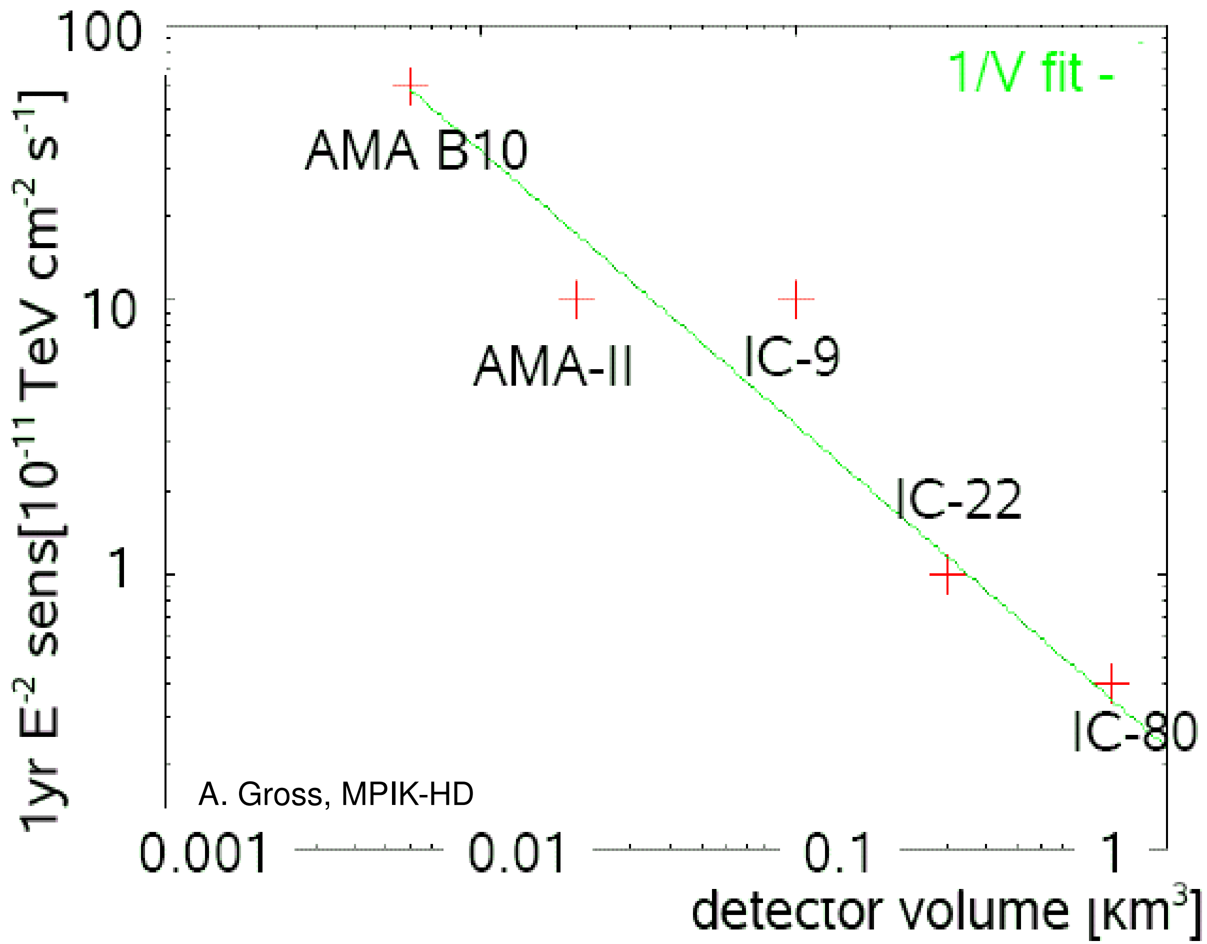


Sensitivity



Discovery

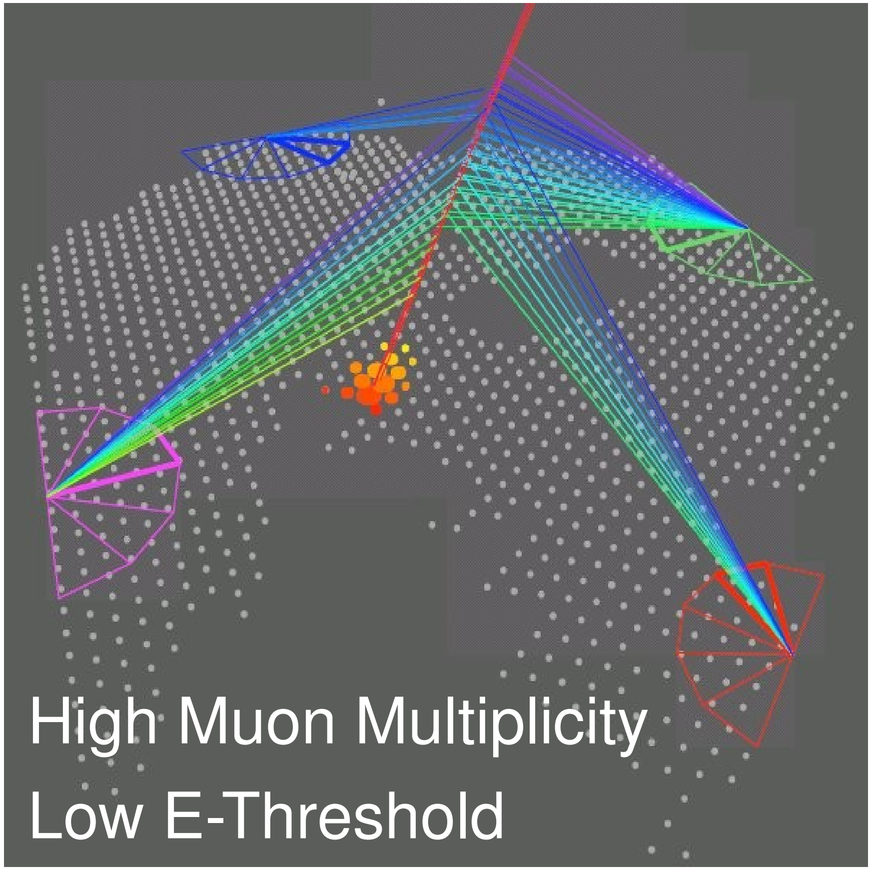
AMANDA/IceCube Evolution

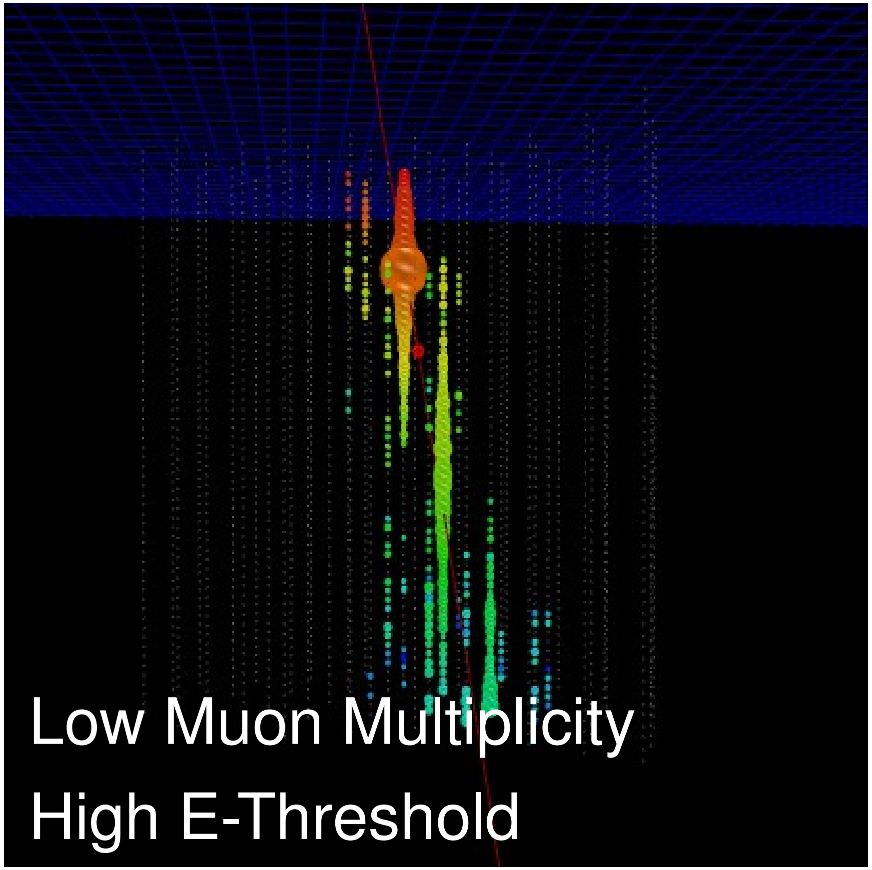


	PSF[°]
AMANDA B-10	4
IC9	2
AMANDA II	2.5
IC22	1.5
IC80 (pred.)	0.8
	(approx.)

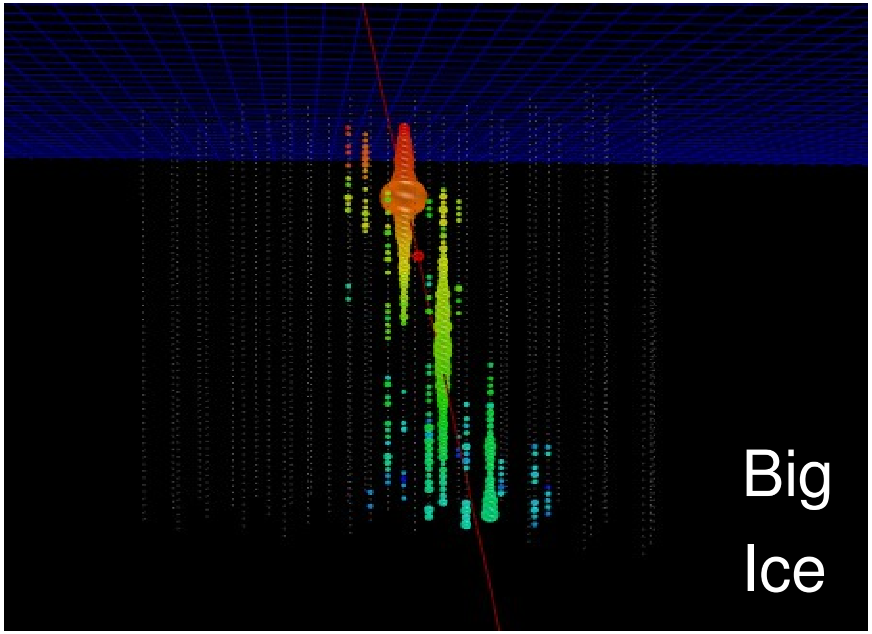
CR Connection

Auger vs. IceCube

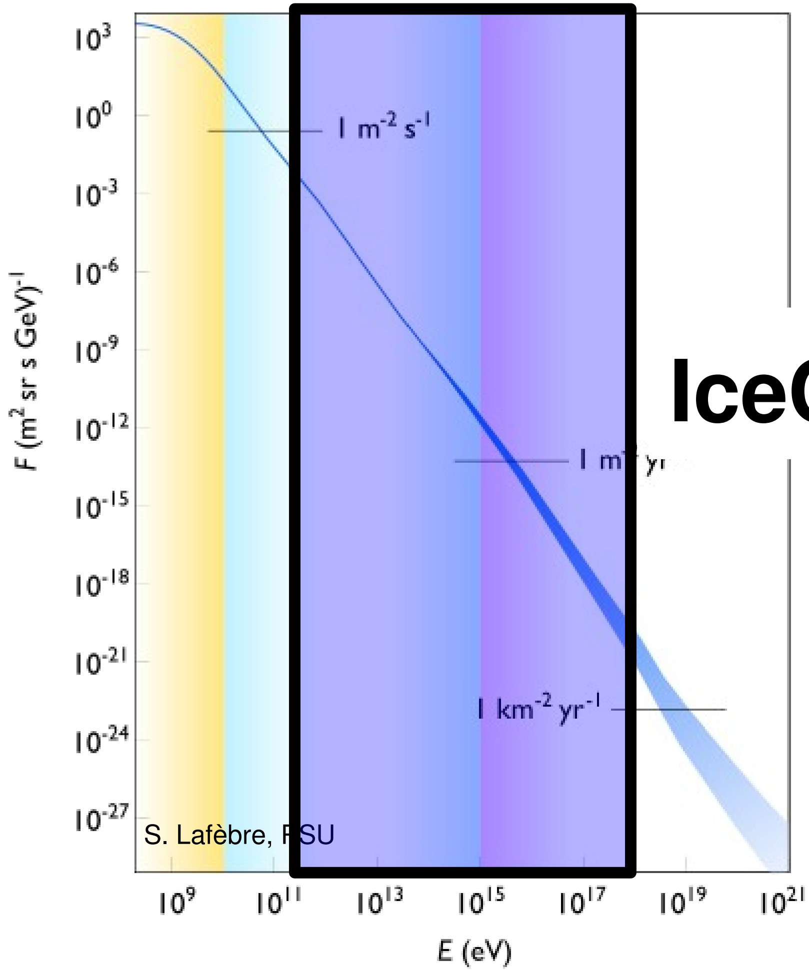




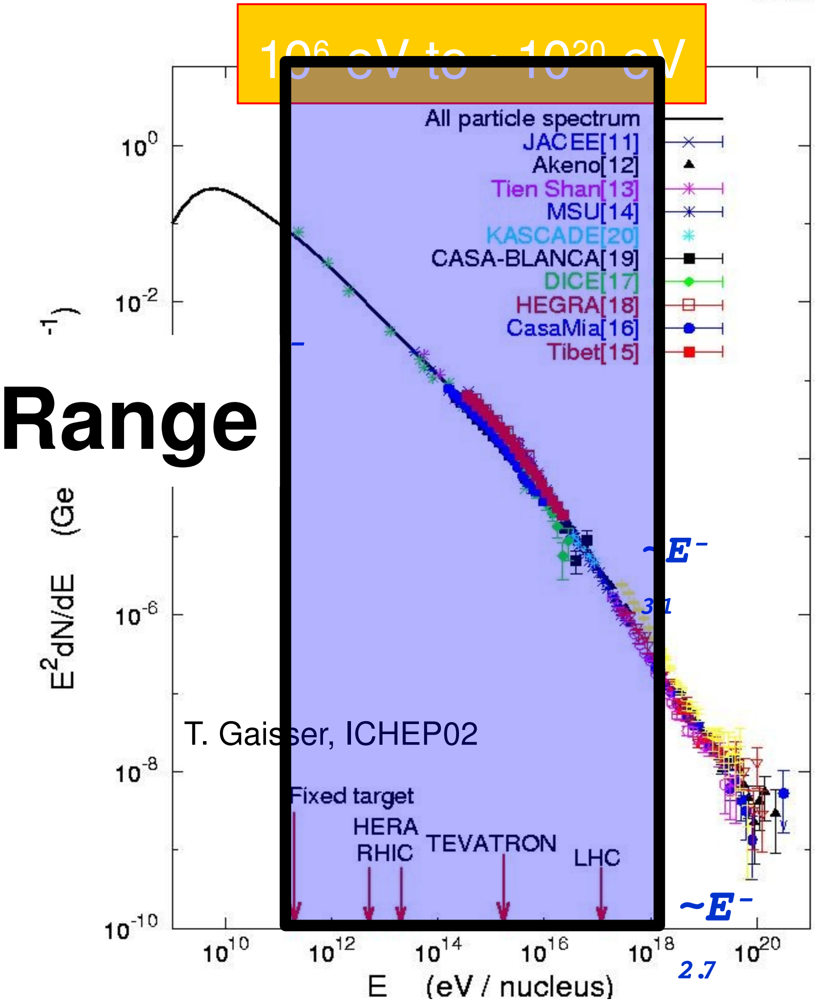
Macro vs. IceCube



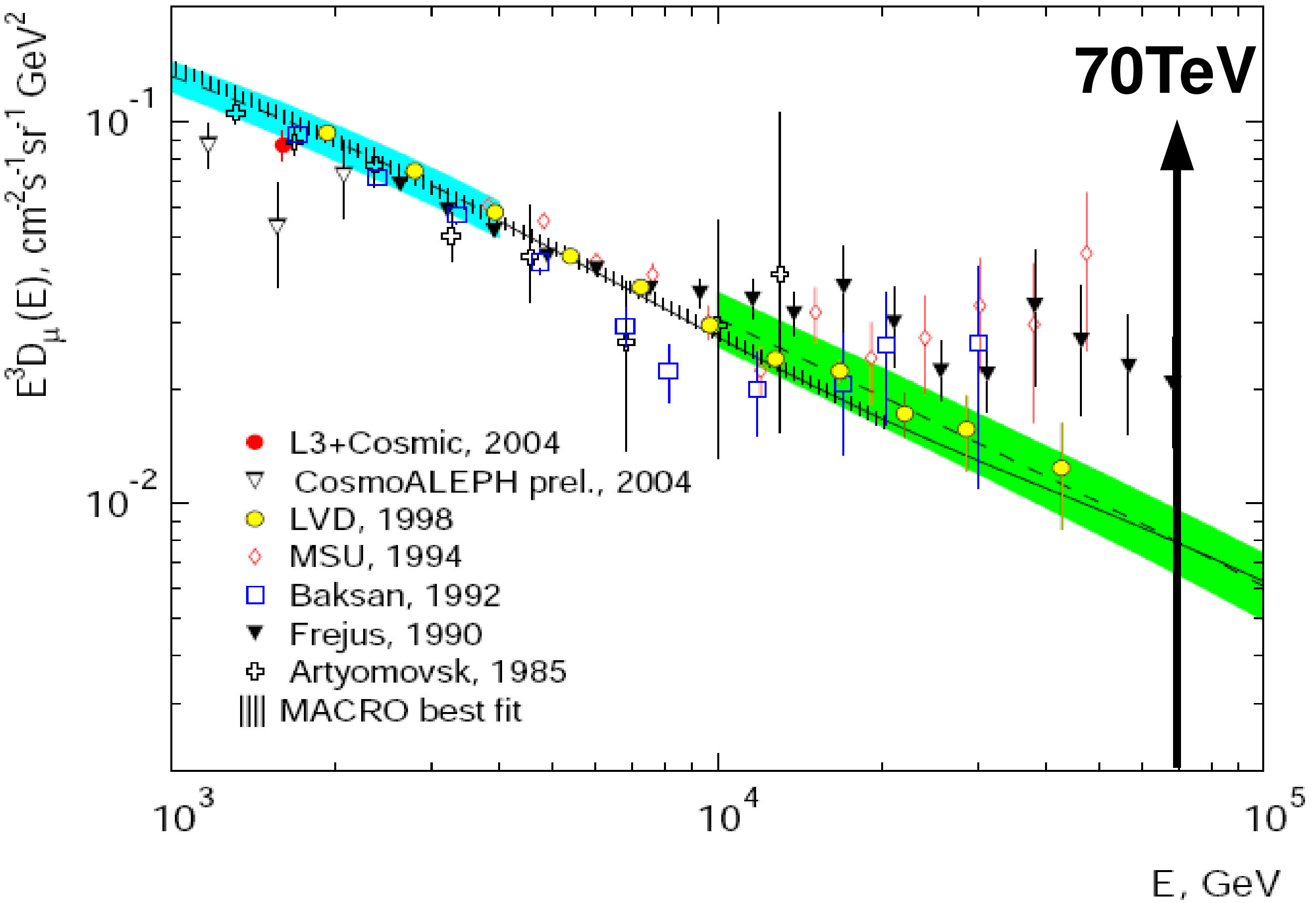
Cosmic Rays



IceCube Range



Muon Spectrum



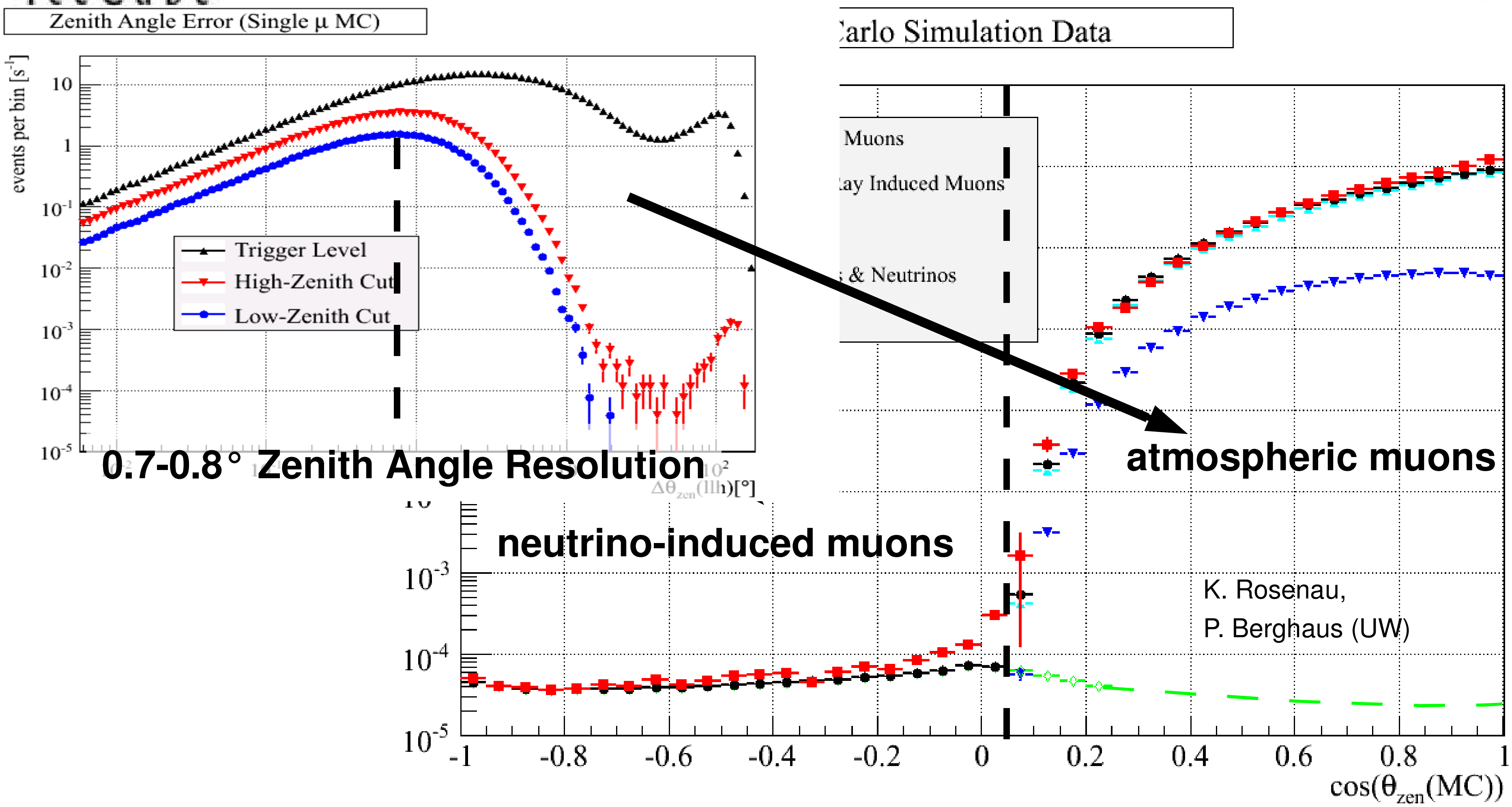
Calculation of the atmospheric muon flux motivated by the ATIC-2 experiment

A. A. Kochanov[1], A. D. Panov[2], T. S. Sinegovskaya[1] and S. I. Sinegovsky[1].

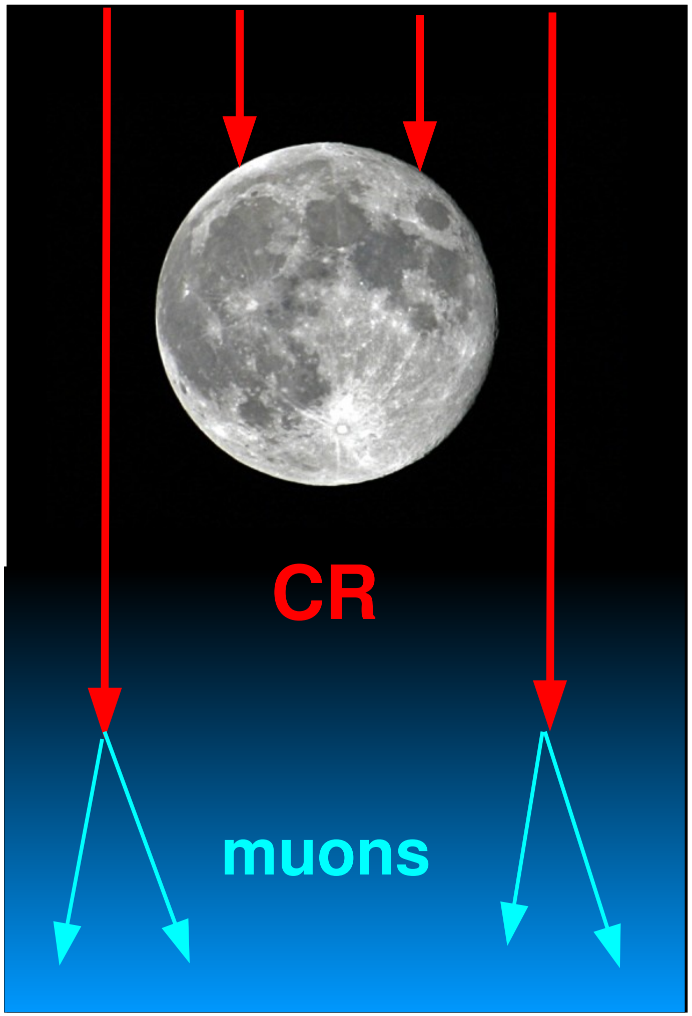
0706.4389

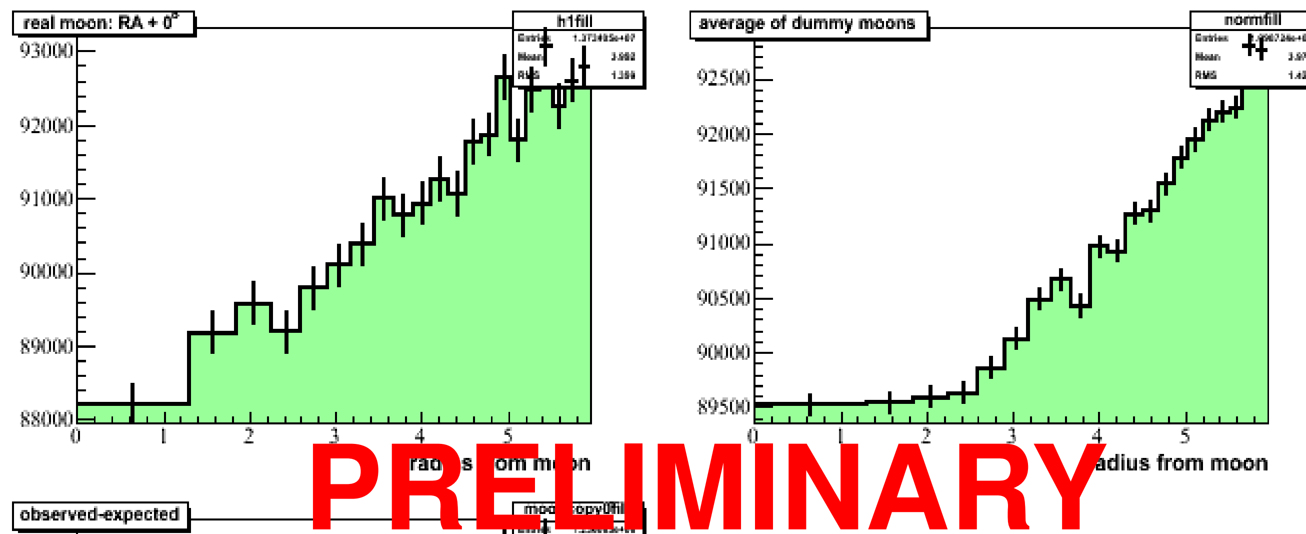
IceCube Muons

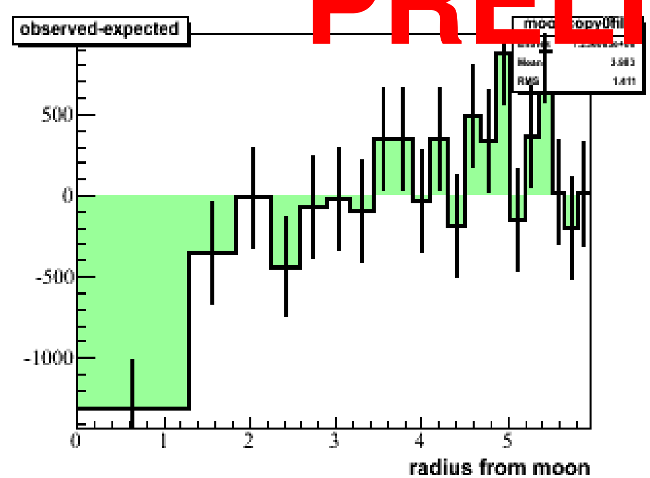
≃300 days IC22



Moon Shadow







observed: 88202 events

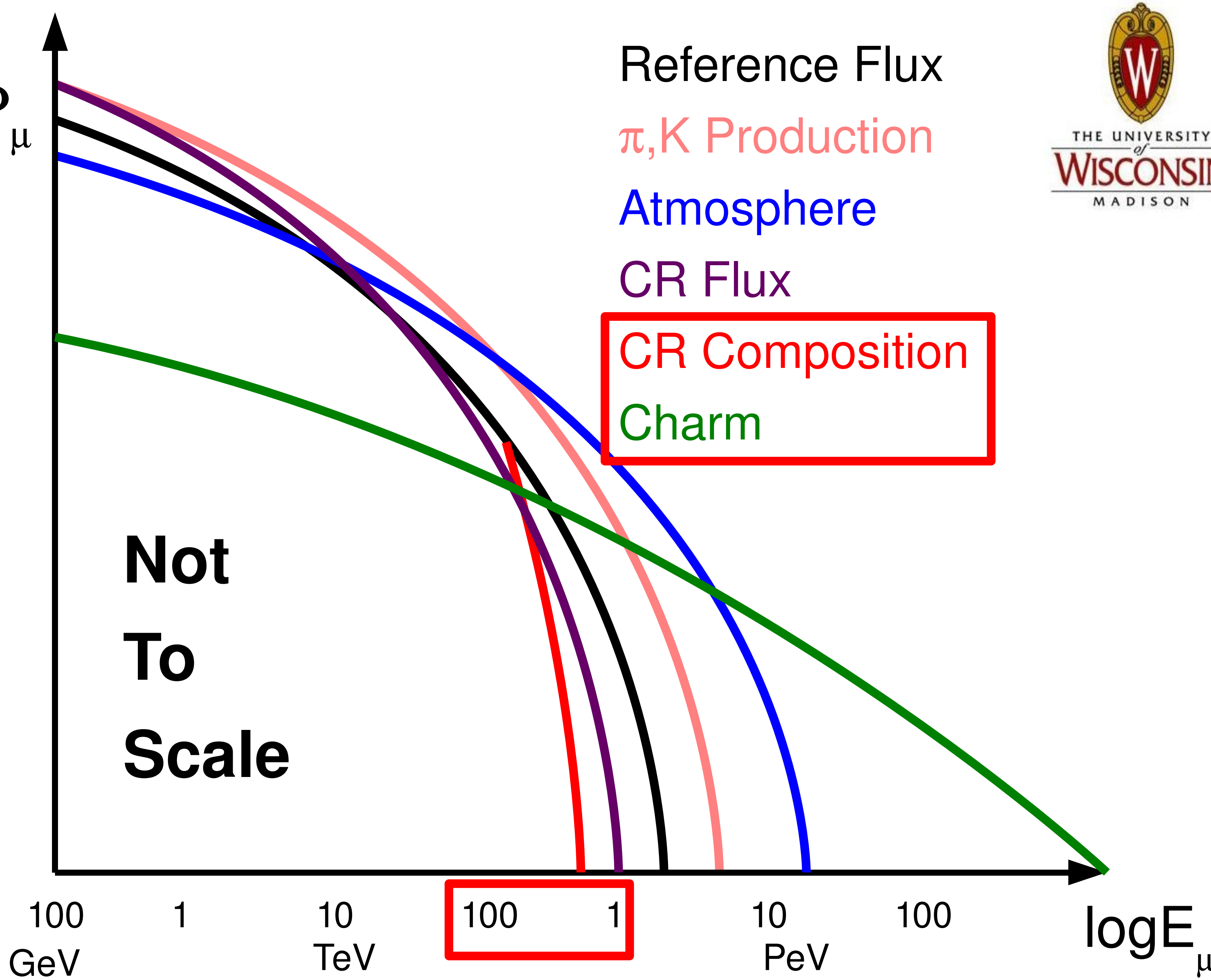
expected: 89521.6 events

deficit: -1319.62 events

error: 315.265 events

significance: -4.18576 σ

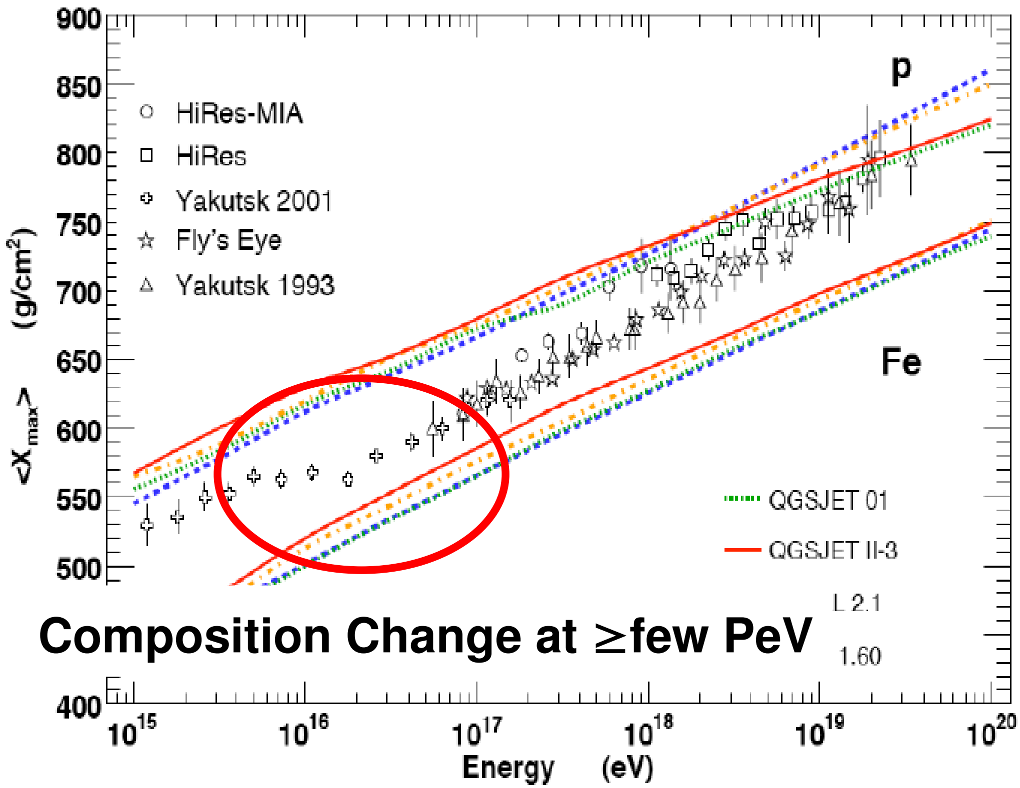
D. Boersma, L. Gladstone, UW

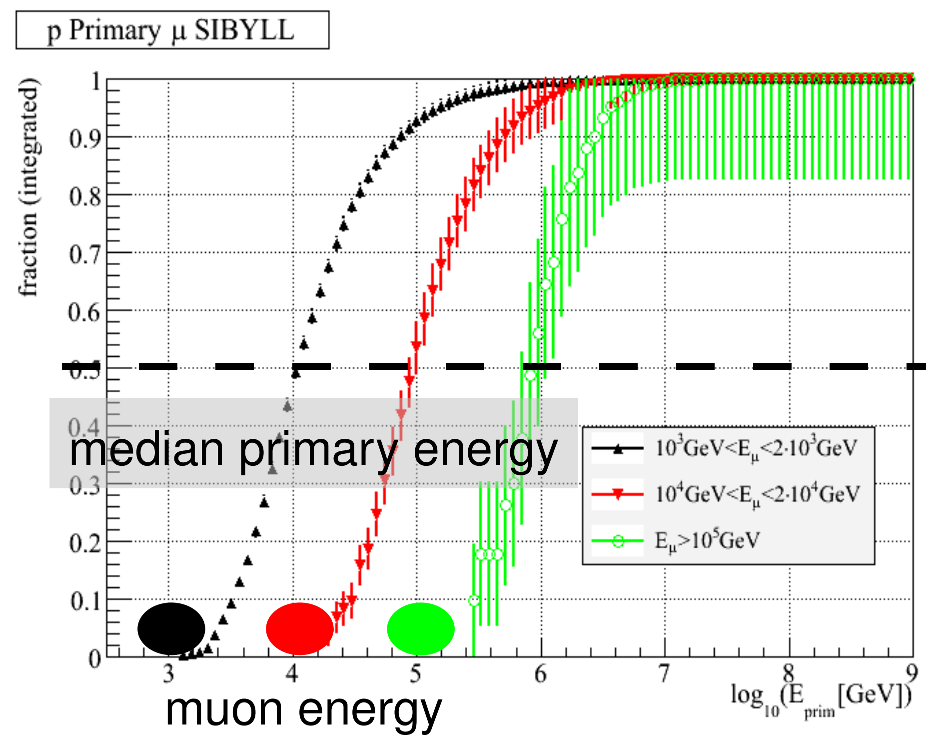

Φ
μ
Reference Flux
π,K Production
Atmosphere
CR Flux
CR Composition
Charm
Not
To
Scale
100
GeV
1
10
TeV
100
1
10
PeV
100
logE
μ

CR Composition

$\bar{E}_{prim,nucleon}/E_{\mu} \leq 10$!

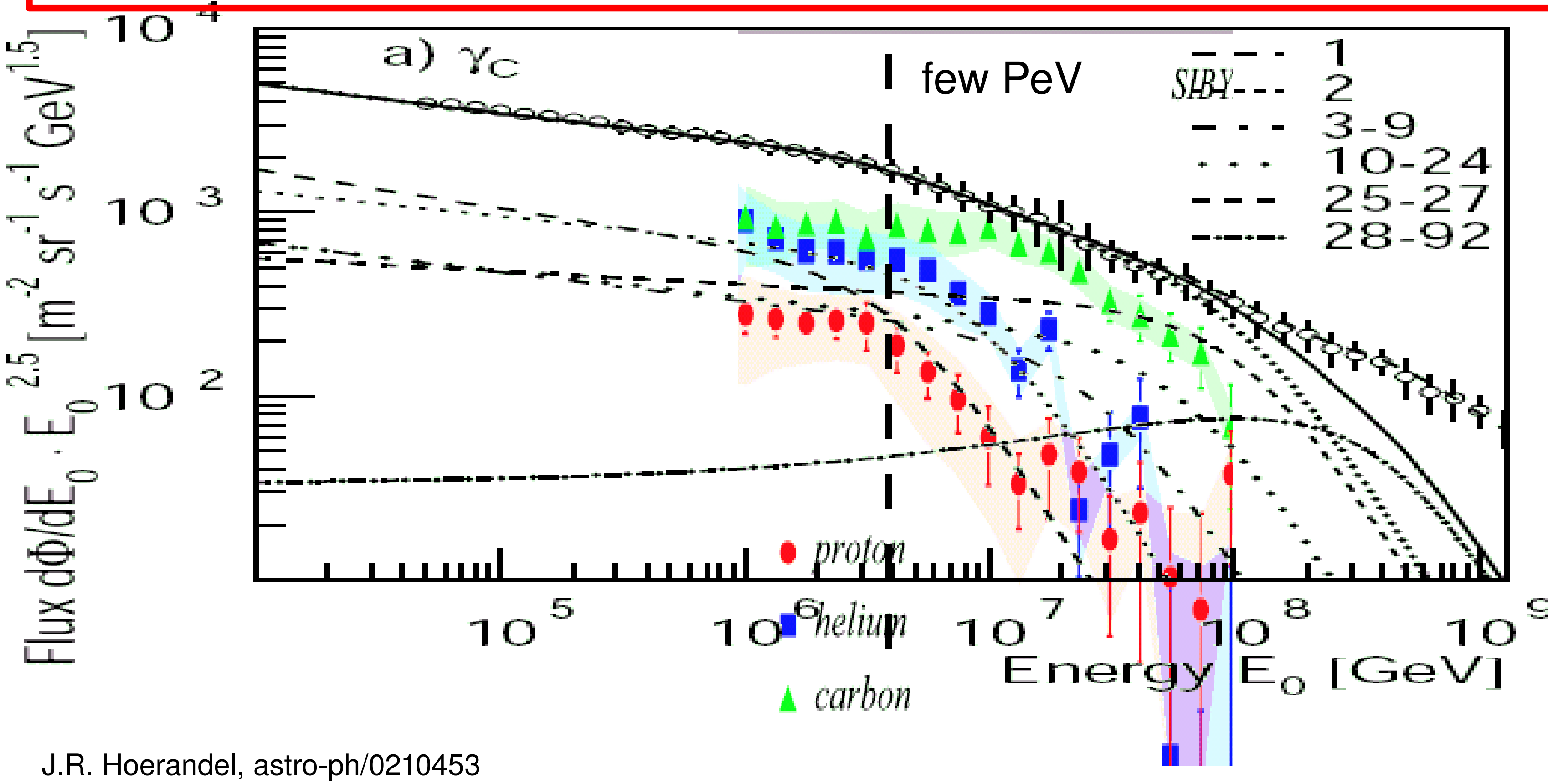
(T.K.Gaisser, "CR&Part.Phys.")





“Poly-Gonato” Model

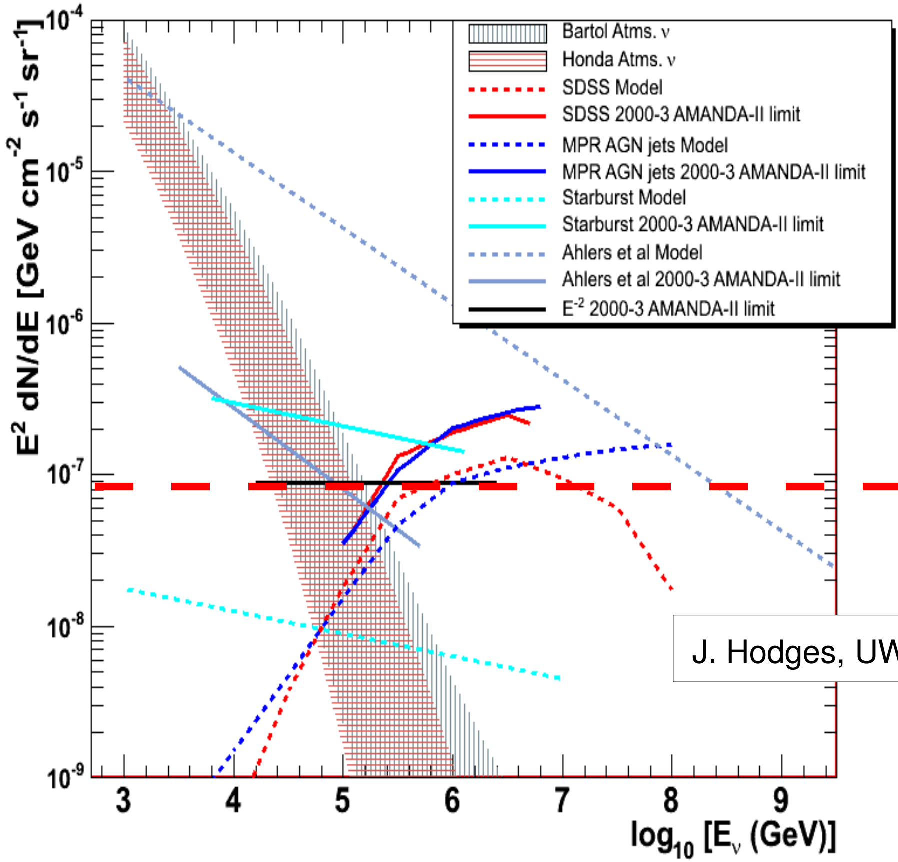
Steepening of Muon/Neutrino Spectrum above 100TeV



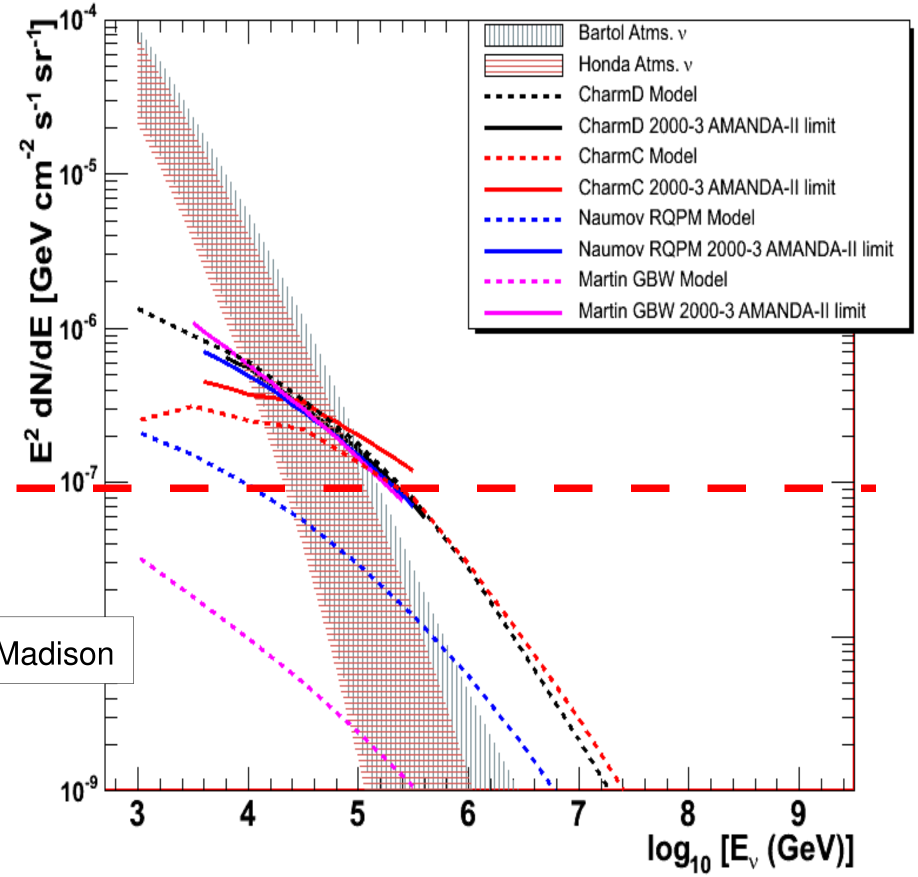
J.R. Hoerandel, astro-ph/0210453

Prompt Flux

Diffuse ν



Atmospheric ν

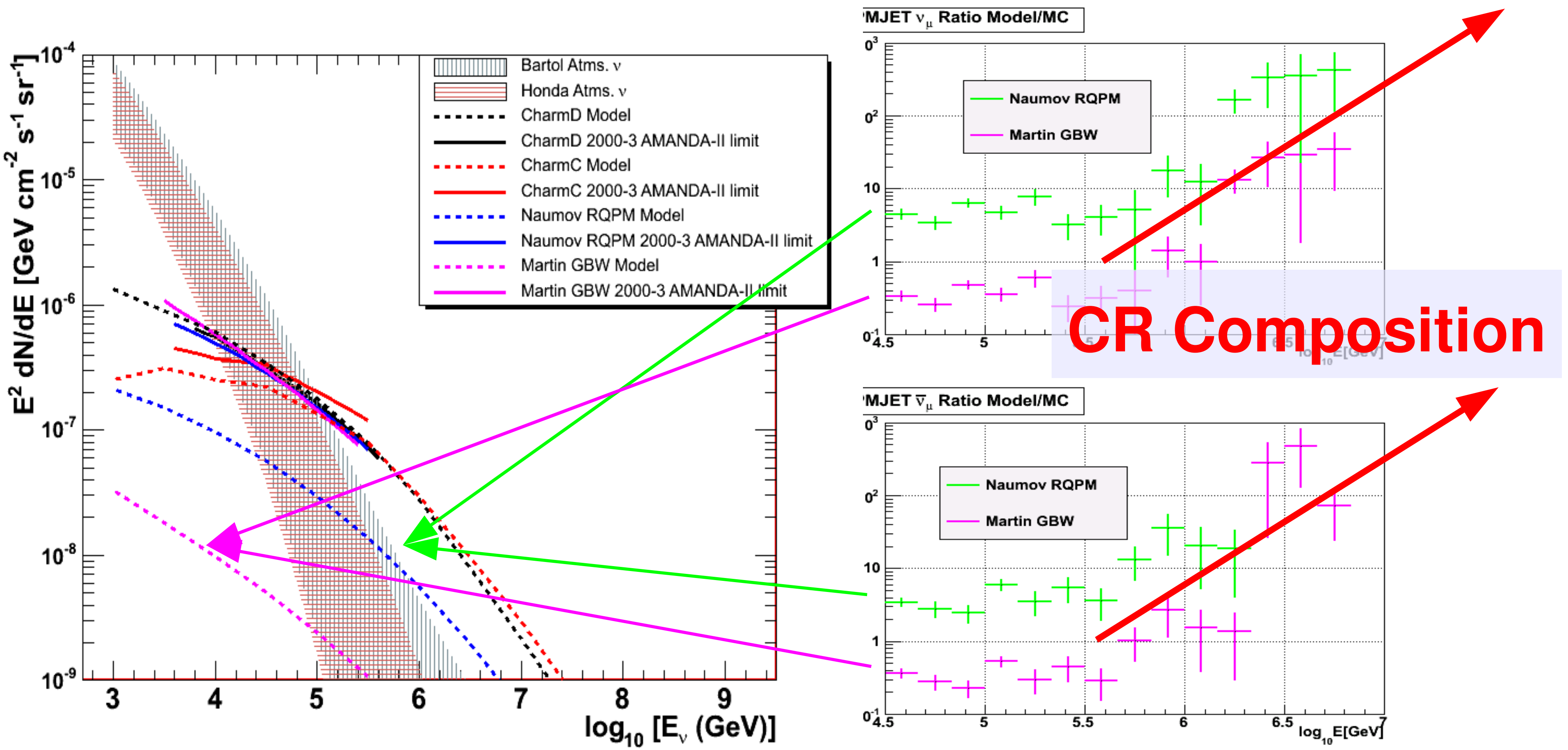


J. Hodges, UW Madison

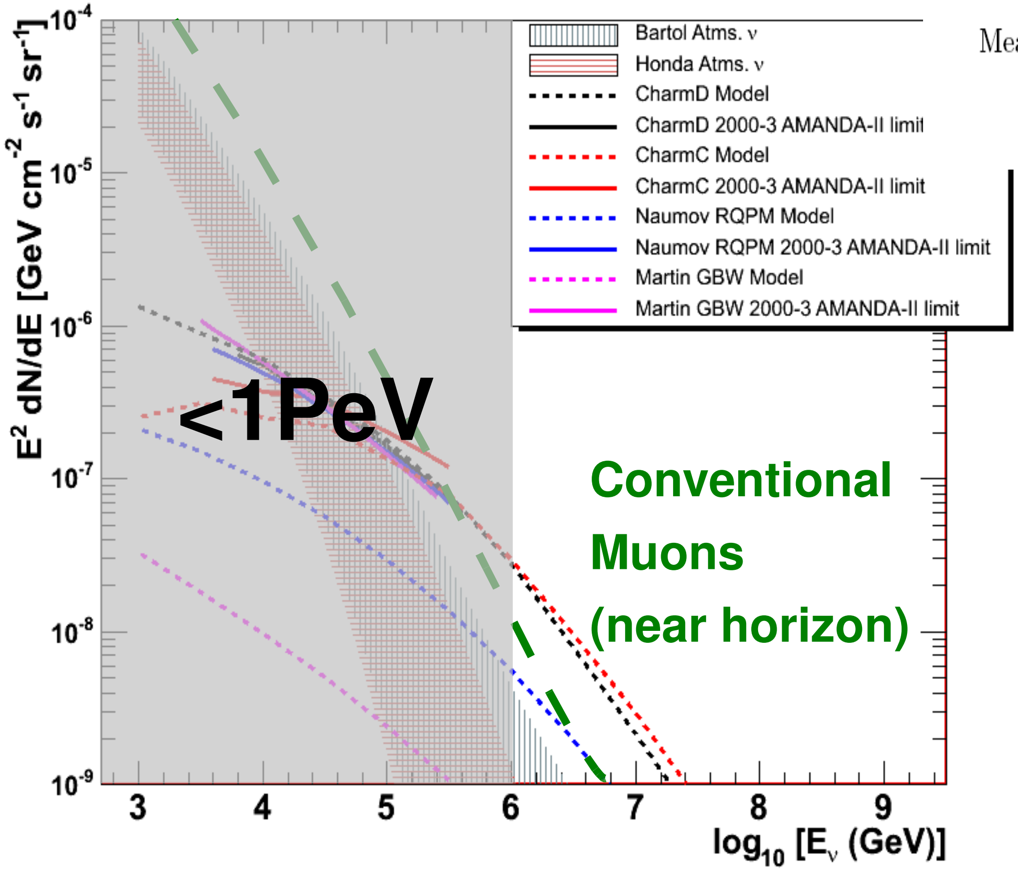
Prompt Neutrinos

Charm Production in DPMJET

P Berghaus[1], T Montaruli[1,2] and J Ranft[3]



Prompt Muons



UCLA/02/TEP/23, CWRU-P13-02, NSF-ITP-02-97

Measuring the prompt atmospheric neutrino flux with down-going muons in neutrino telescopes

Graciela Gelmini[1], Paolo Gondolo[2], and Gabriele Varieschi[3]

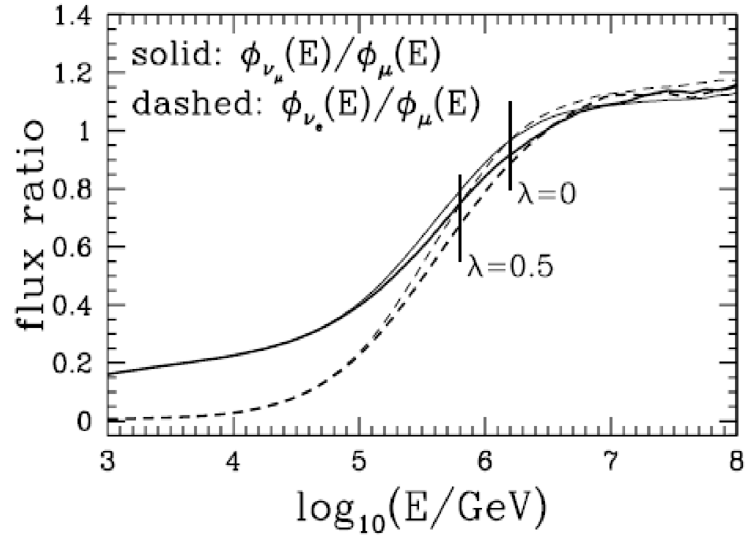


FIG. 4. Total neutrino-over-muon ratio as a function of lepton energy. Vertical marks denote the crossing energy from conventional to prompt muons.

Summary

IceCube can detect Muons from all zenith angles

Muon and Neutrino spectrum up to PeV region measurable

Sensitive to CR Composition around Knee

And perhaps Charm Production in Atmospheric Showers

Backup Slides

IceCube uses SIBYLL

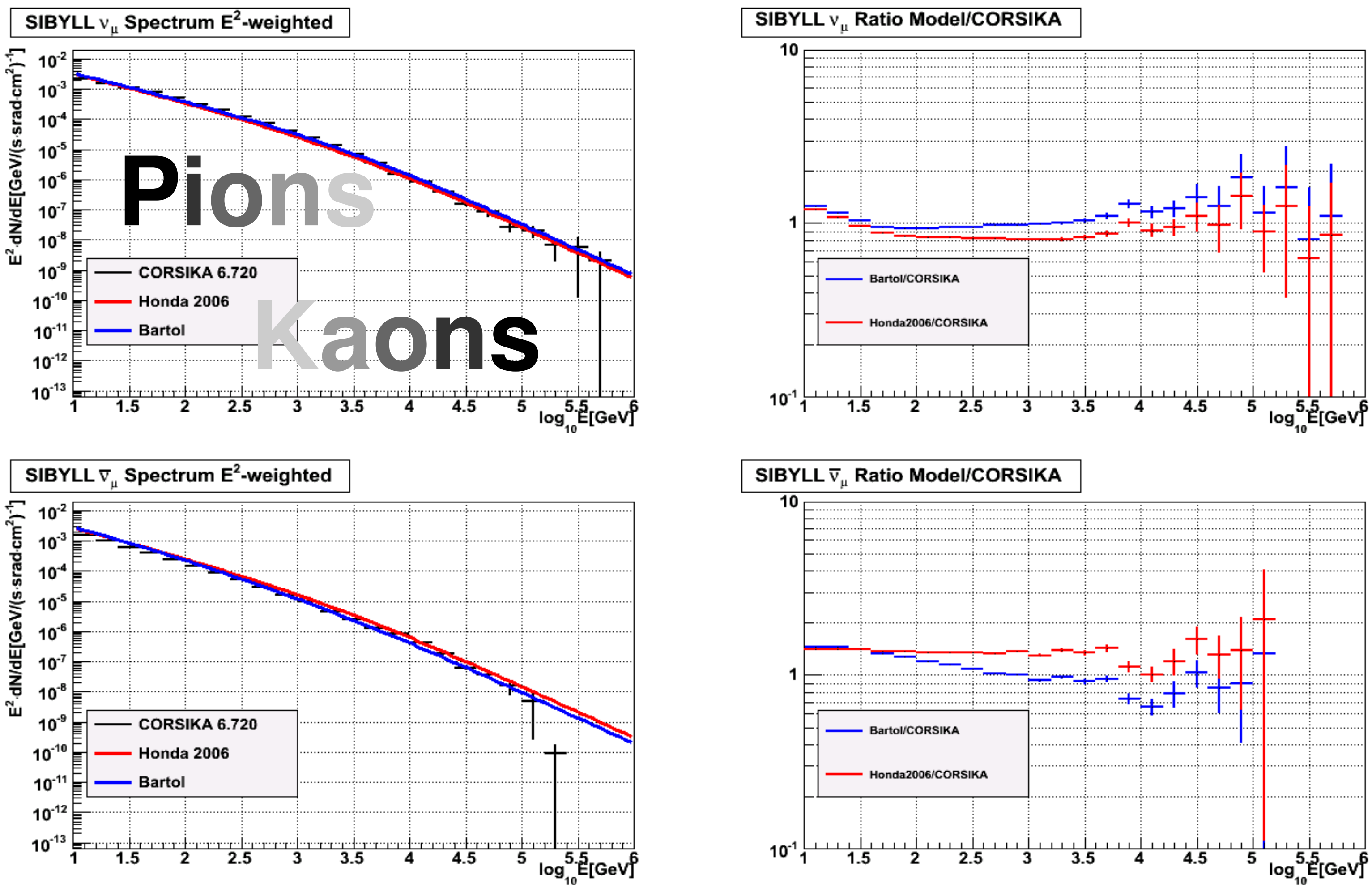
SIBYLL

≈

Bartol

≈

Honda '06



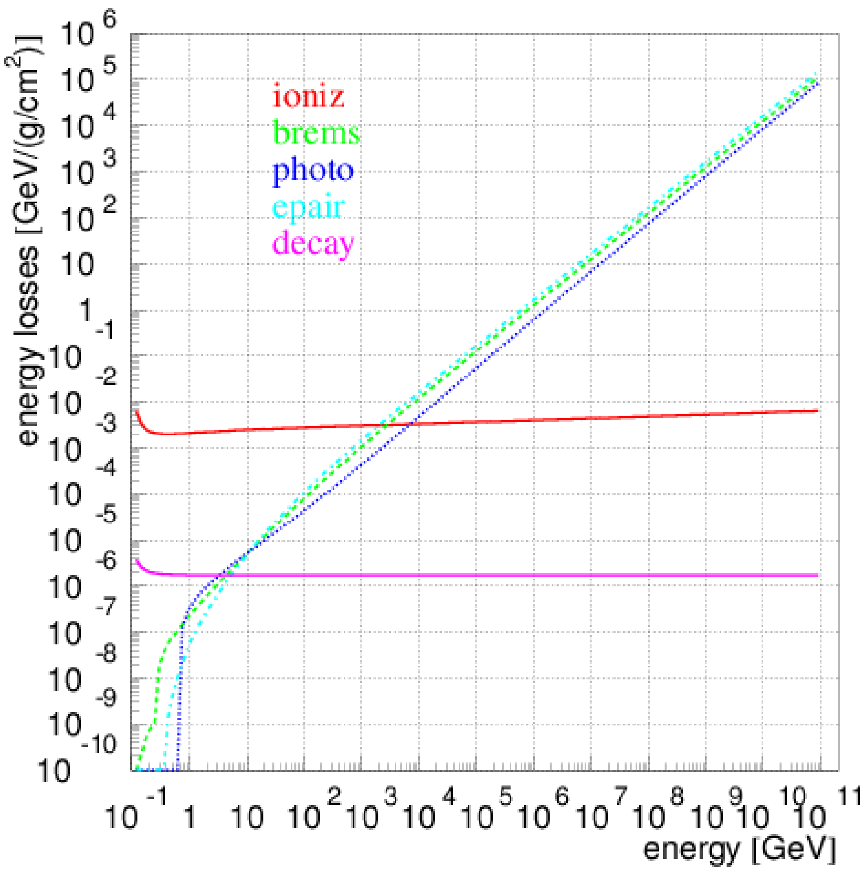
IceCube

Muon Monte Carlo: a high-precision tool for muon propagation through matter

hep-ph/0407075

THE UNIVERSITY of WISCONSIN MADISON

Dmitry Chirkin[1], Wolfgang Rhode[2]
chirkin@physics.berkeley.edu
rhode@uni-wuppertal.de



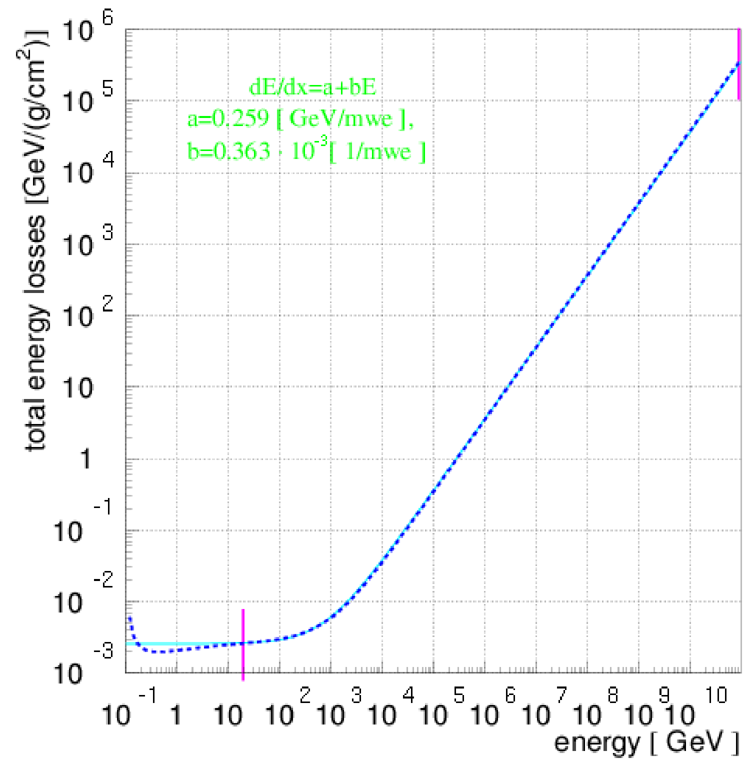
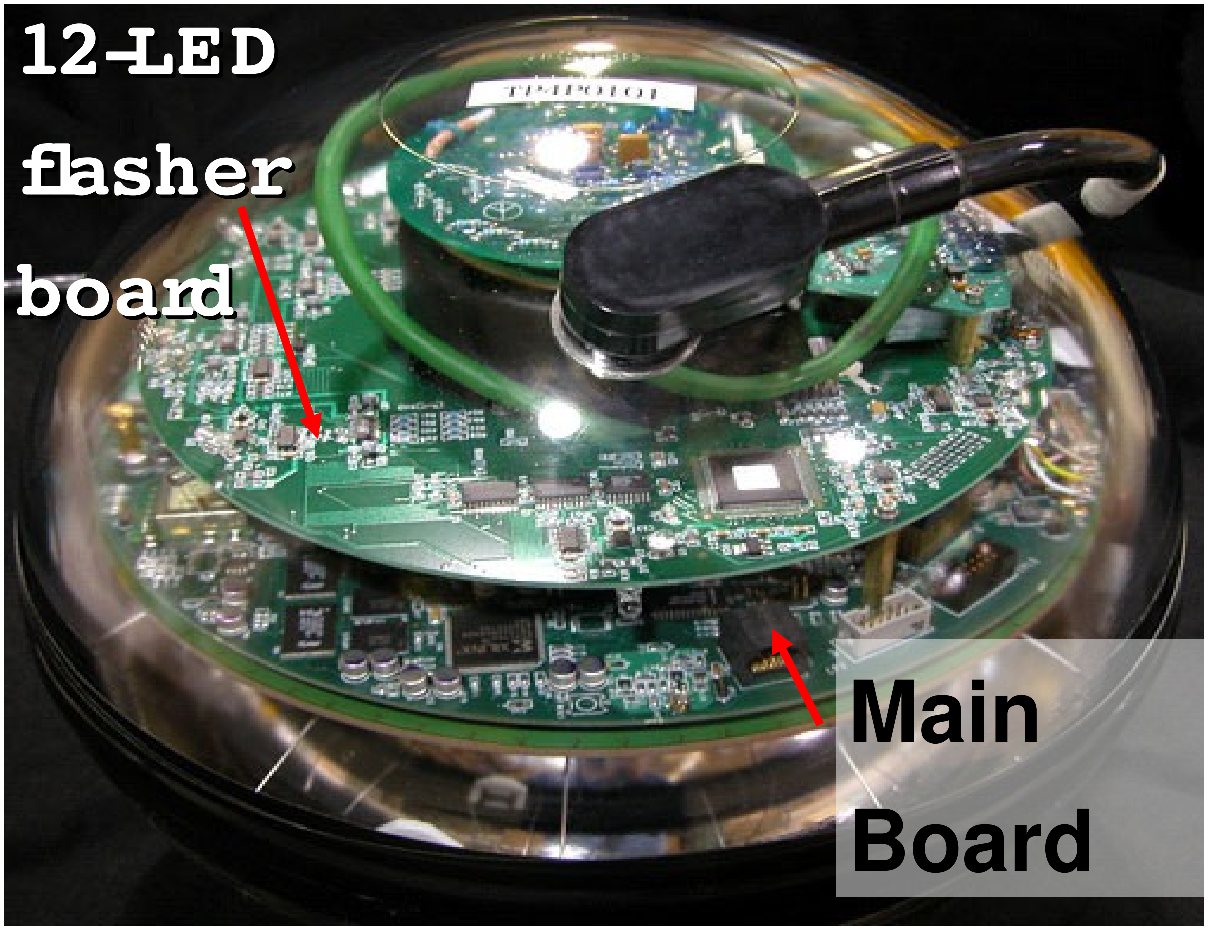
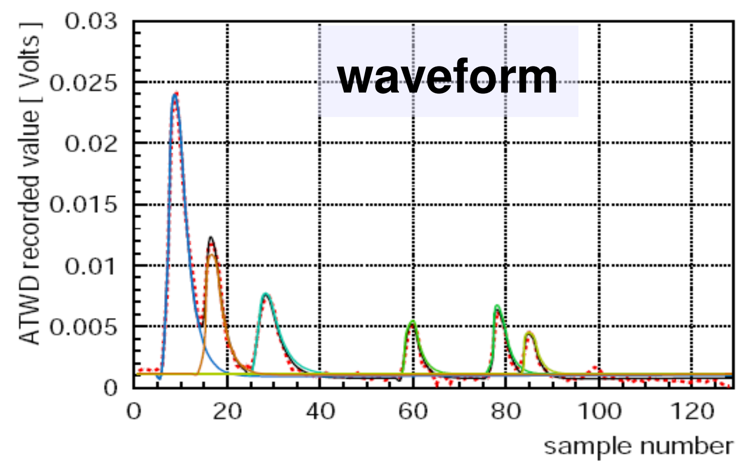


Fig. 21. Fit to the energy losses in ice

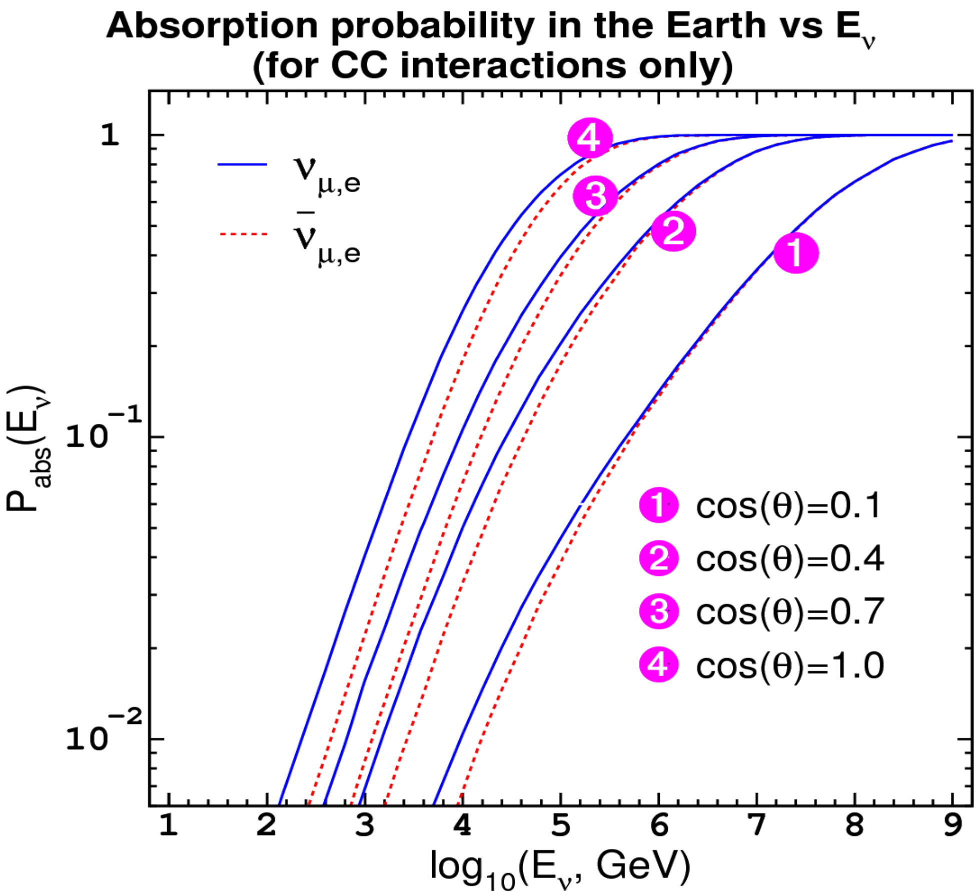
Digital Optical Module

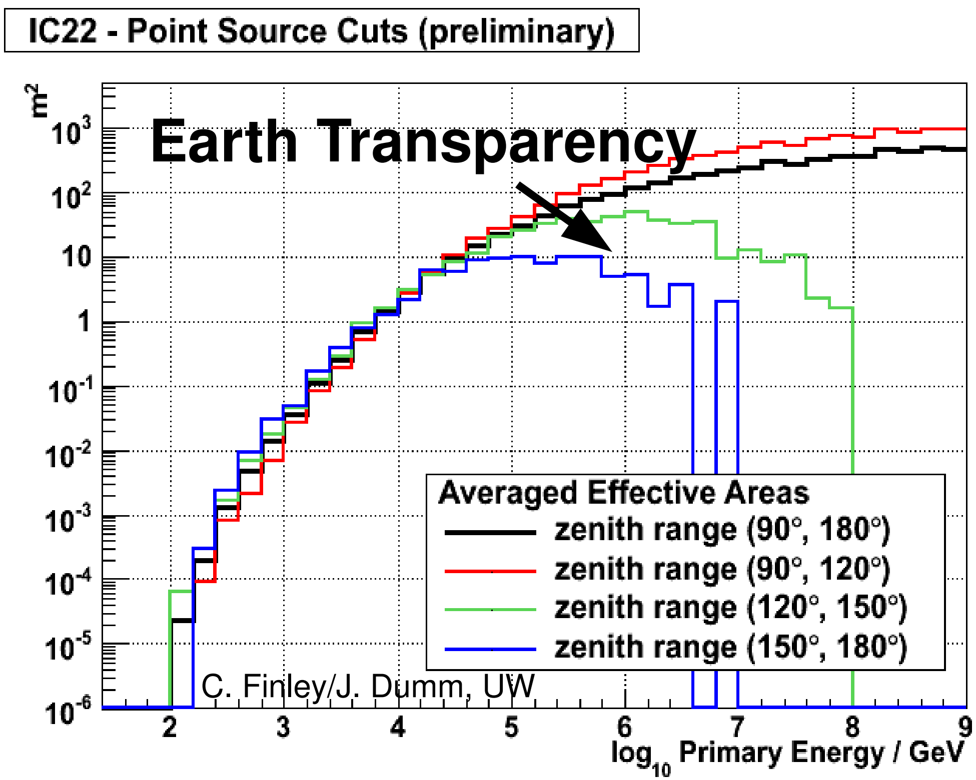


PMT:	10” Hamamatsu
Power:	3W
Digitization:	
ATWD (custom):	300 Mhz / 400ns
fADC:	40MHz / 6,400ns
Dynamic Range:	200pe / 15ns
Noise Rate:	650Hz



Effective Area





Muons in CORSIKA

MINOS Data

0705.3815

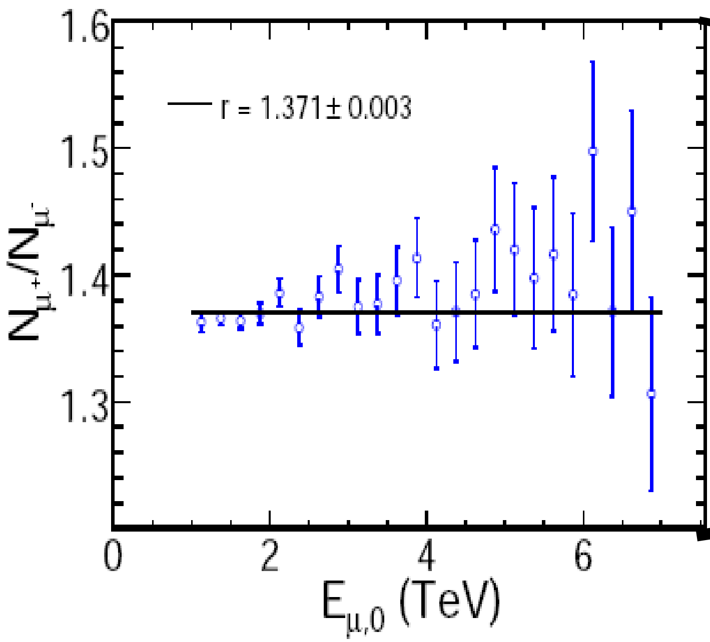
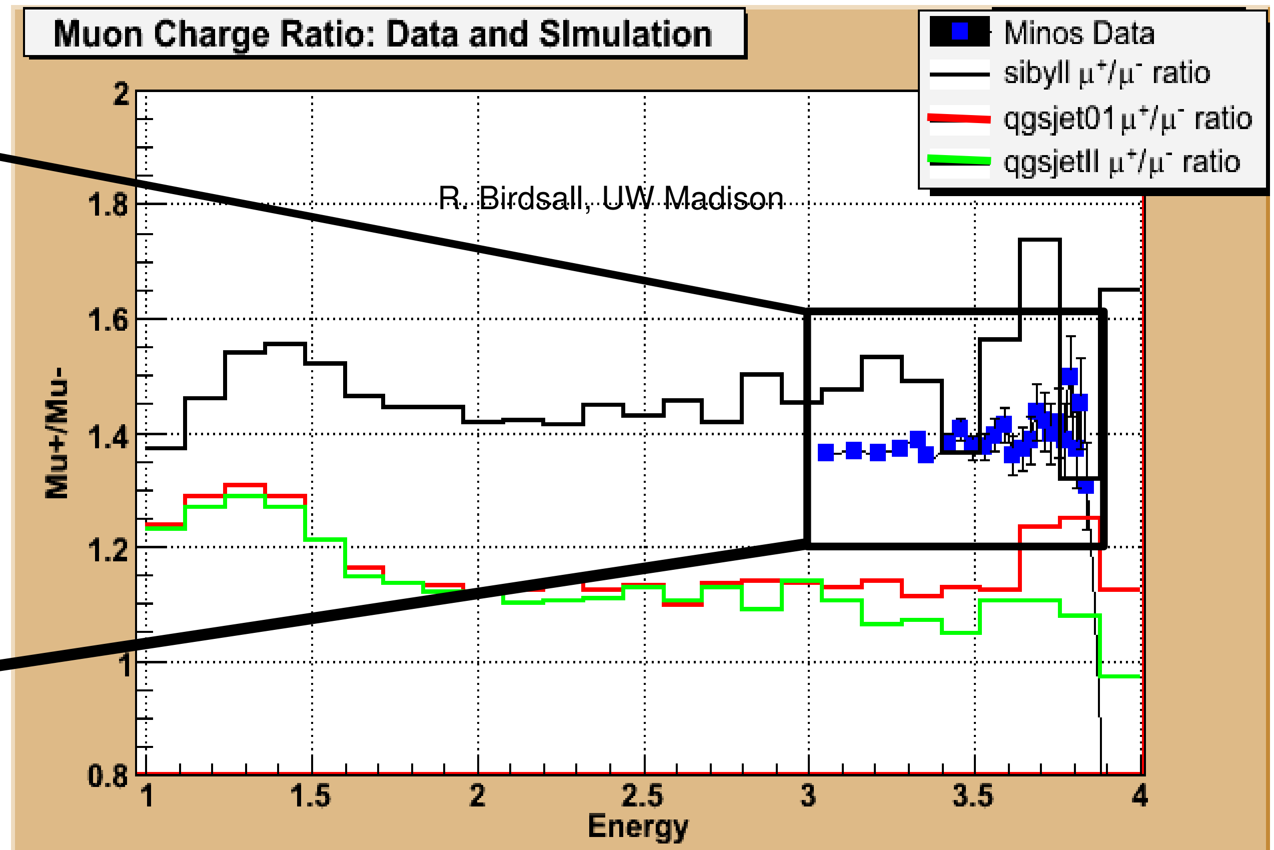
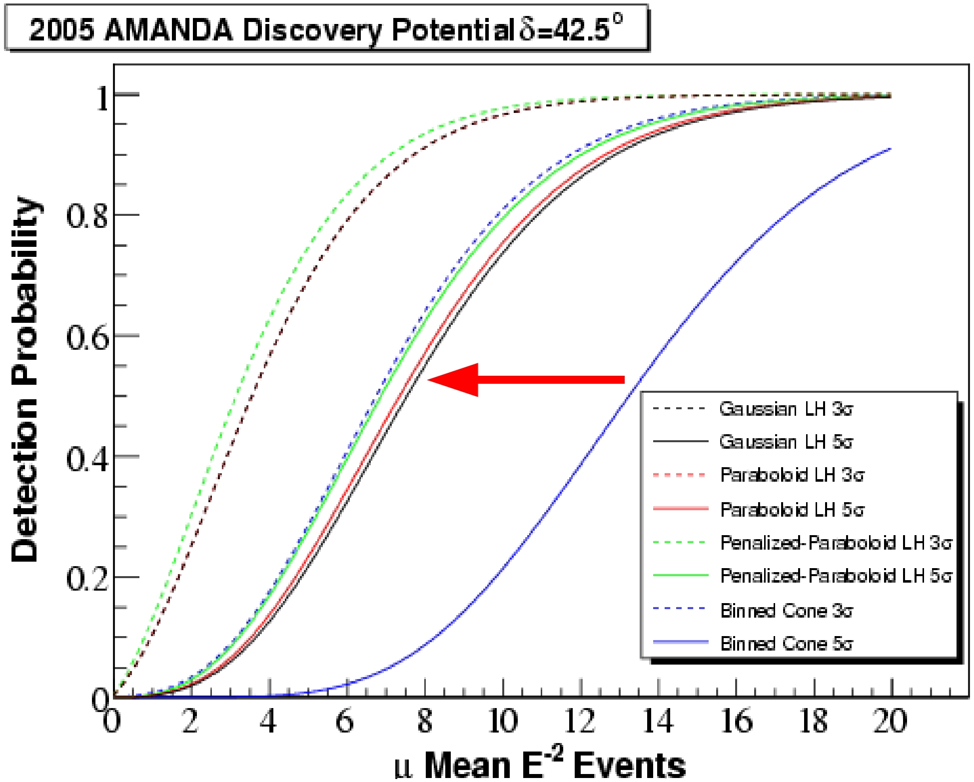
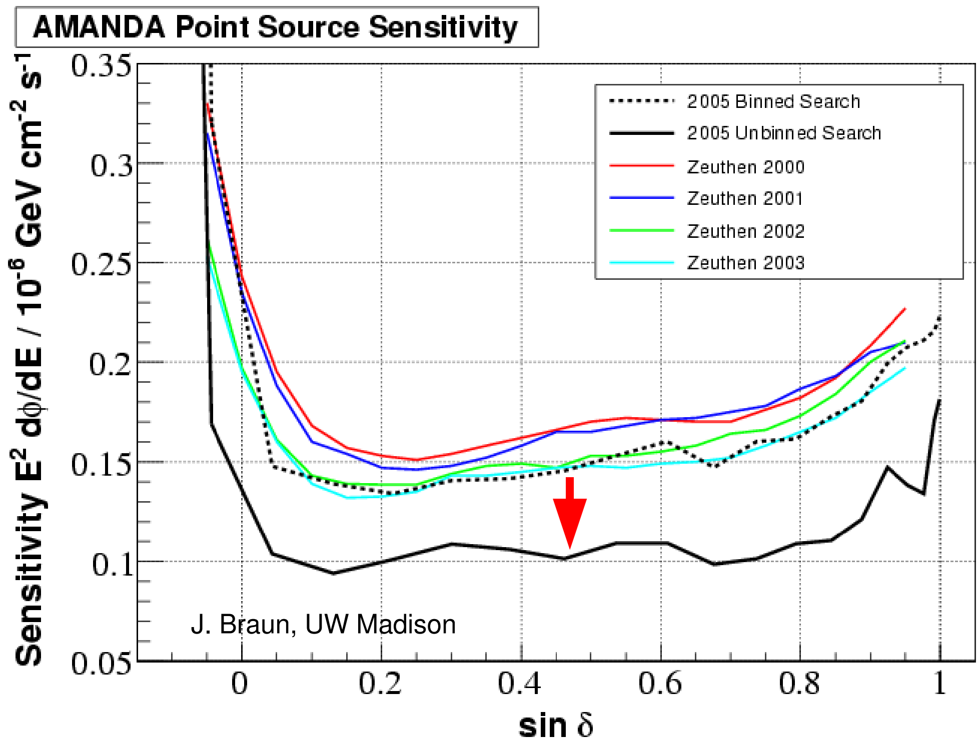


FIG. 15: The muon charge ratio $N_{\mu+}/N_{\mu-}$ at the Earth's surface. The errors shown are statistical.



Unbinned Search



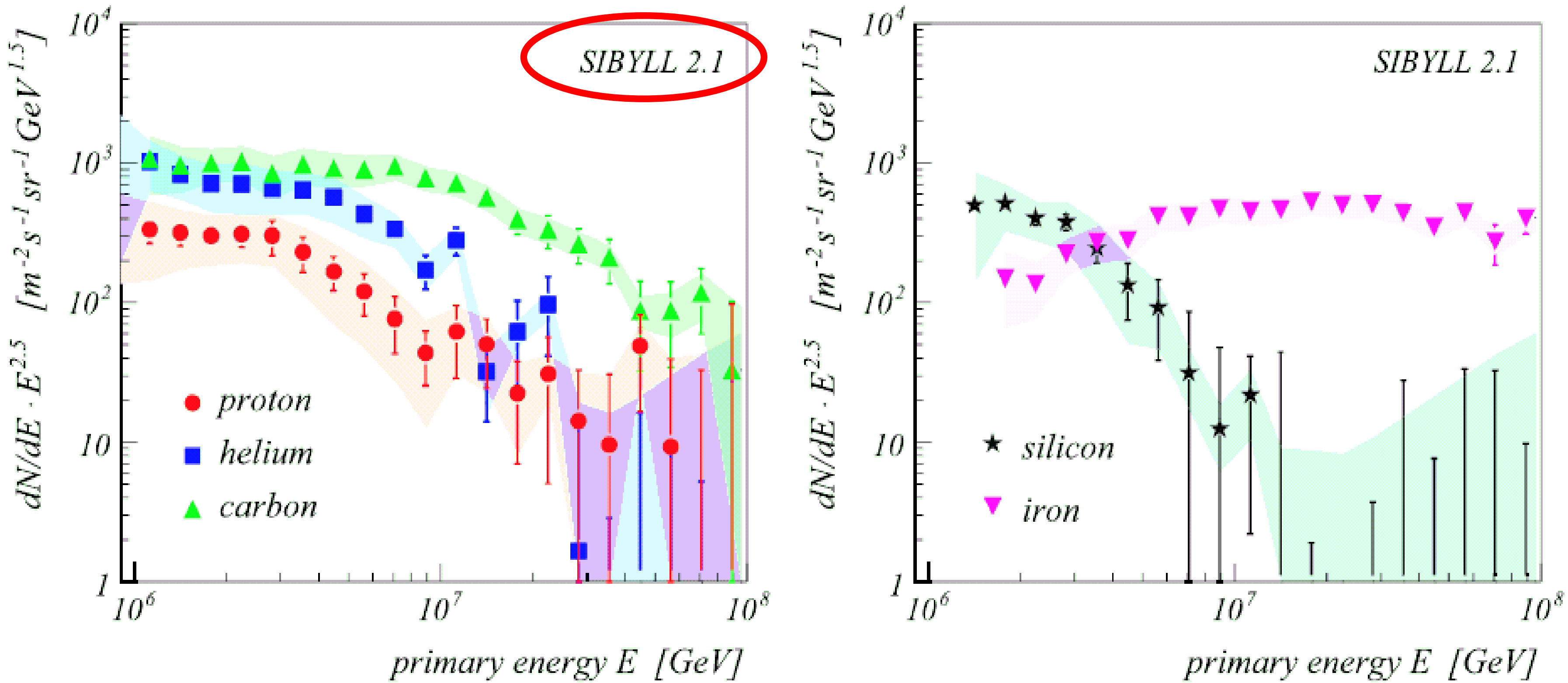


$$\mathcal{L}(\vec{x}_s, n_s, \gamma) = \prod_{i=1}^{N} \left(\frac{n_s}{N} \mathcal{S}_i + (1 - \frac{n_s}{N}) \mathcal{B}_i \right)$$

$$\lambda = -2 \cdot sign(\hat{n}_s) \cdot log \left[\frac{\mathcal{L}(\vec{x}_s, 0)}{\mathcal{L}(\vec{x}_s, \hat{n}_s, \hat{\gamma})} \right]$$

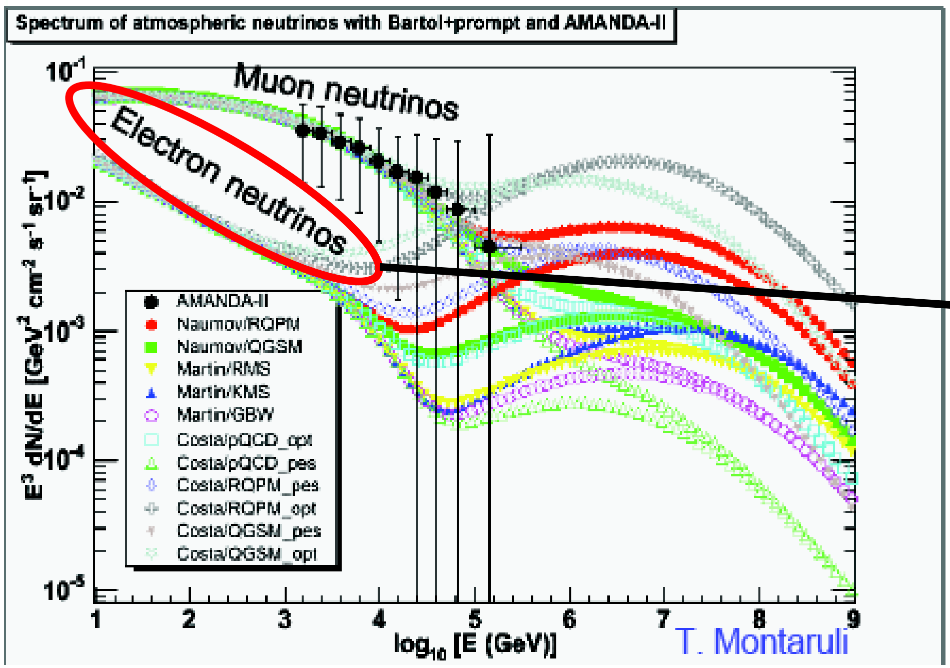
KASCADE Composition

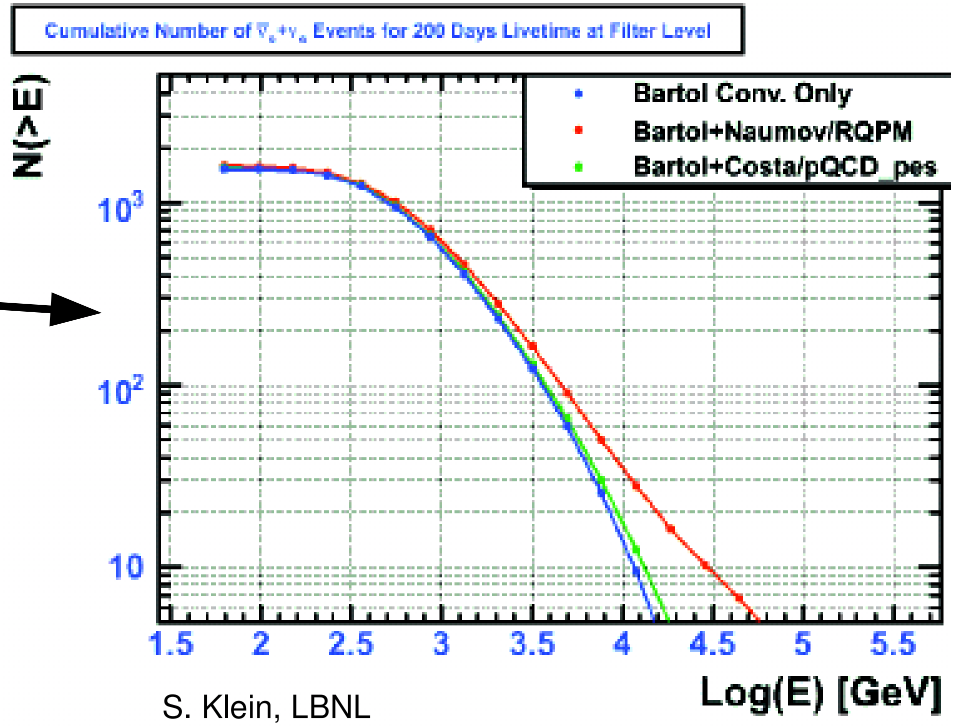
model-dependent



astro-ph/0505413

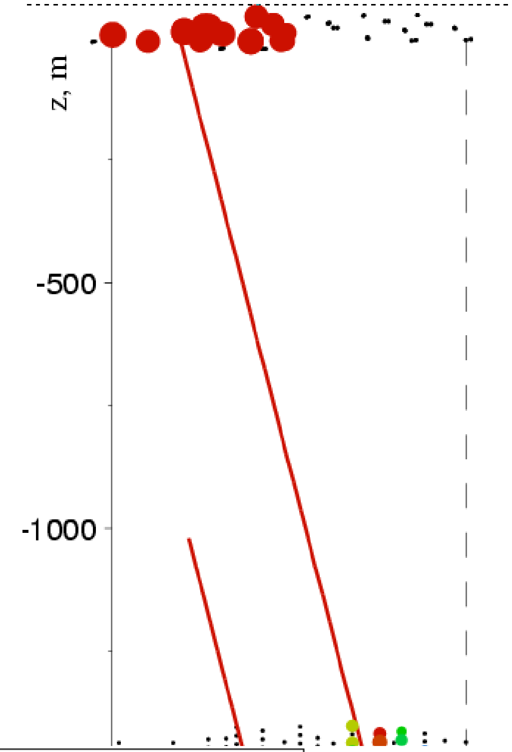
Prompt Neutrino Models





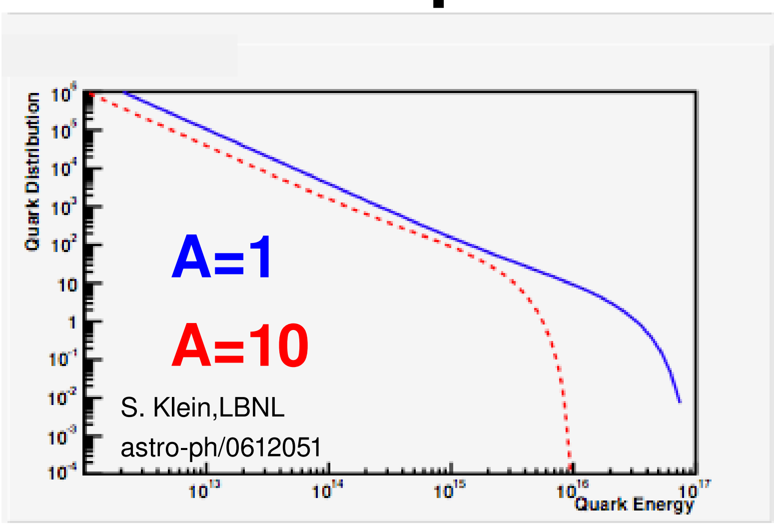
S. Klein, LBNL

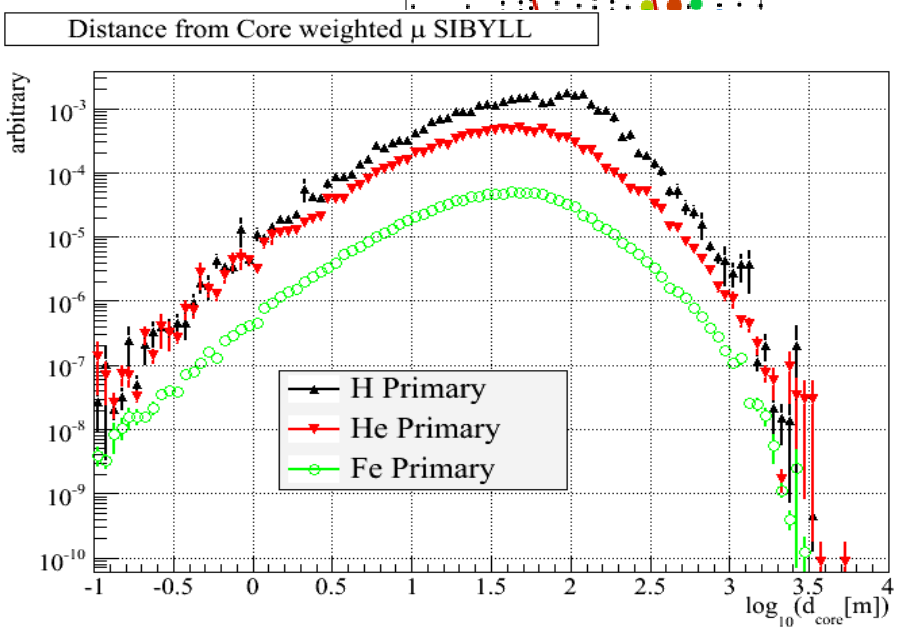
High-p_t Muons



- $p_t \geq 3$GeV/c
- $\geq$100m Separation
- 1000+ year^{-1} in IC80

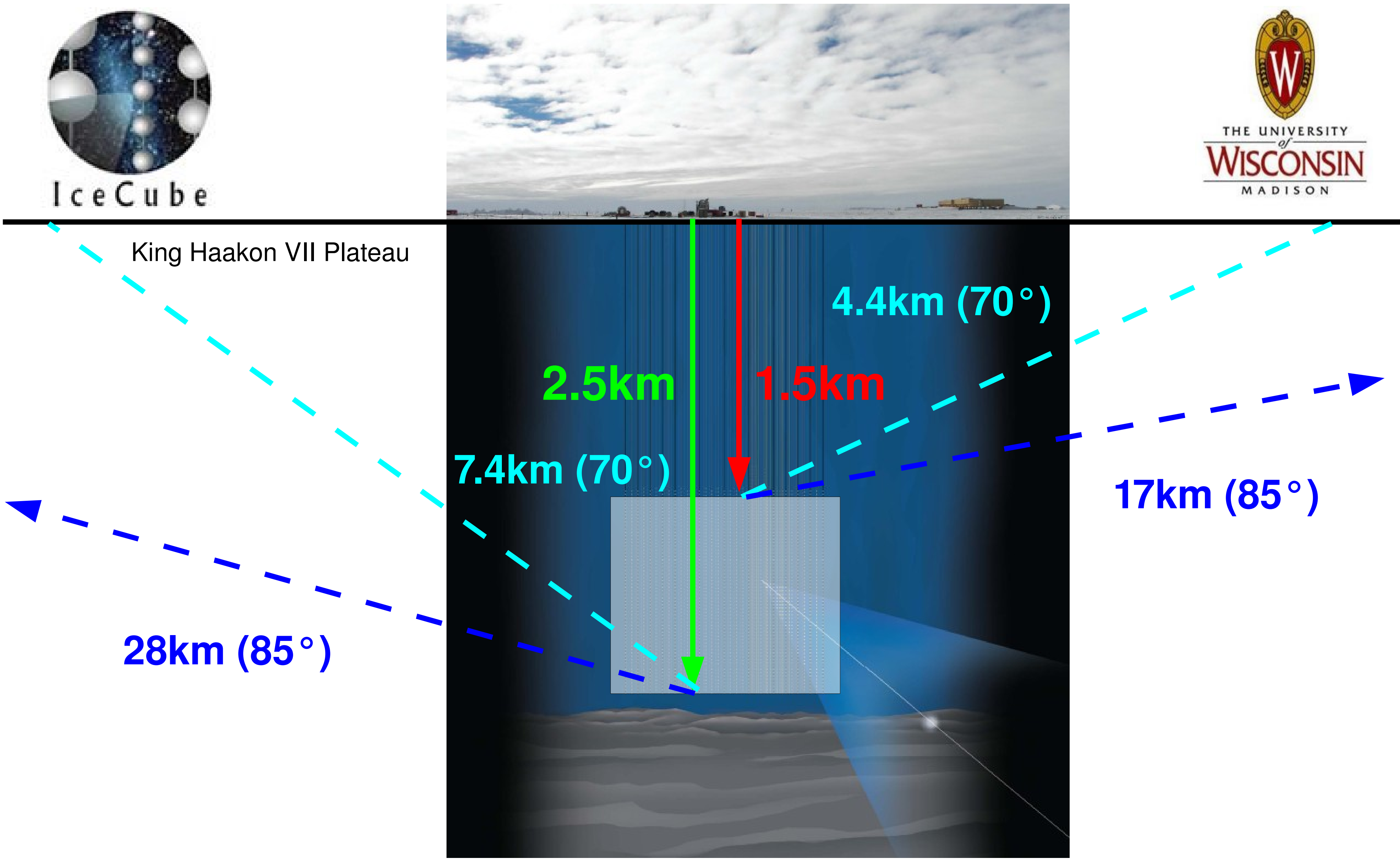
CR Composition





IceCube

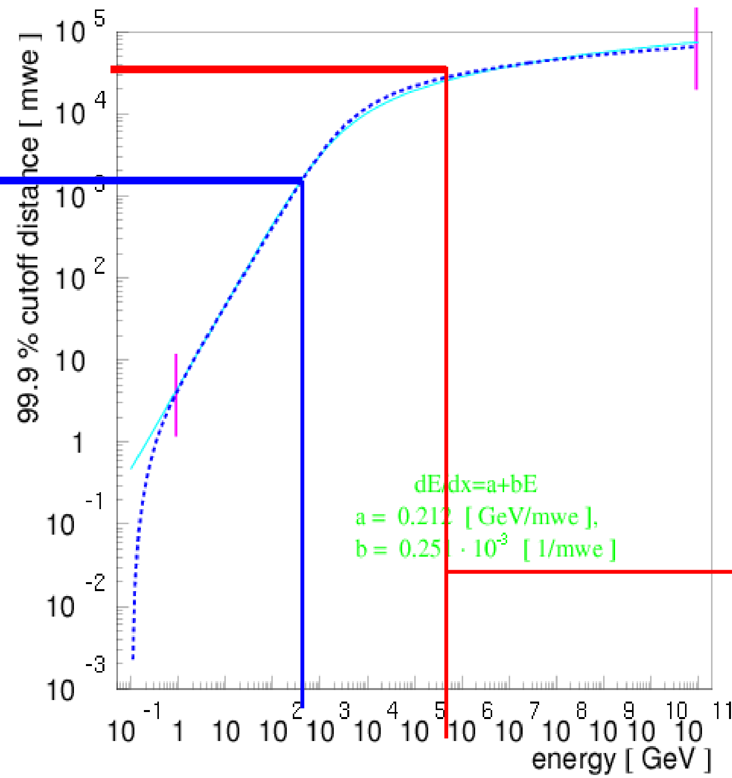
THE UNIVERSITY of WISCONSIN MADISON



Threshold Energy

Vertical

≃400GeV



Bottom (85°)

≃1PeV

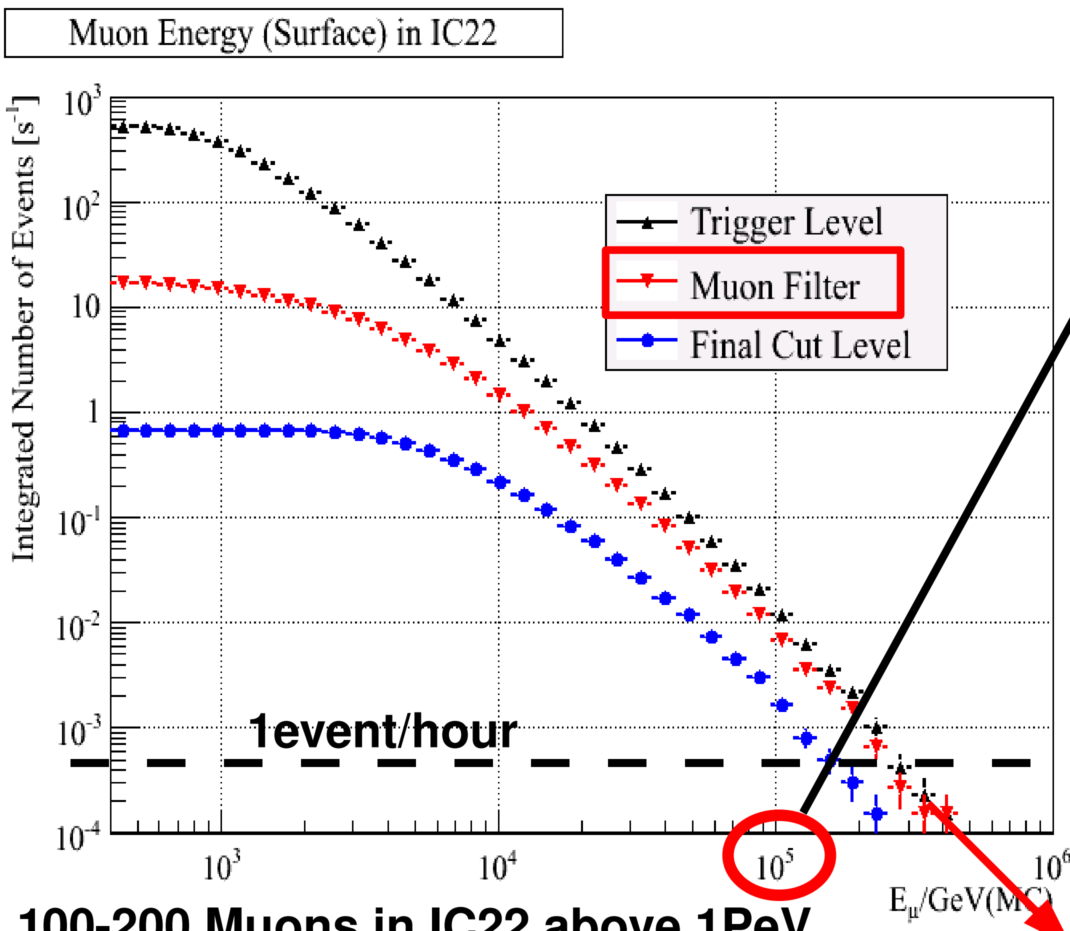
D. Chirkin, W. Rhode
hep-ph/0407075

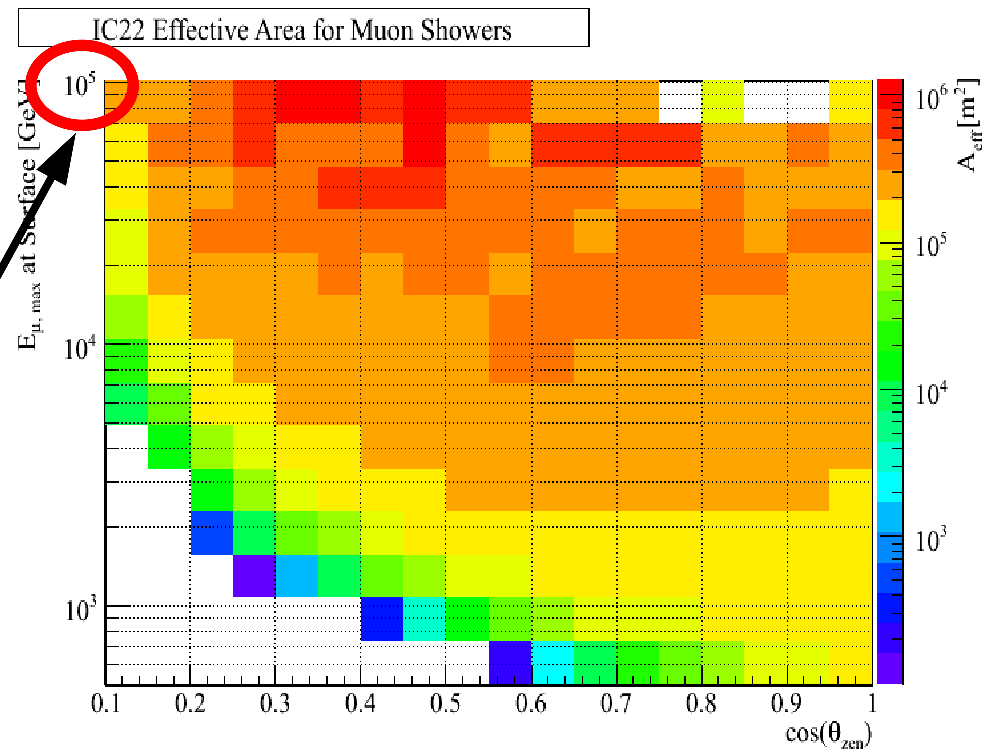
Fig. 29. Fit to the $E_{cut}(x)$

IceCube Muon Rates

IceCube

THE UNIVERSITY of WISCONSIN MADISON

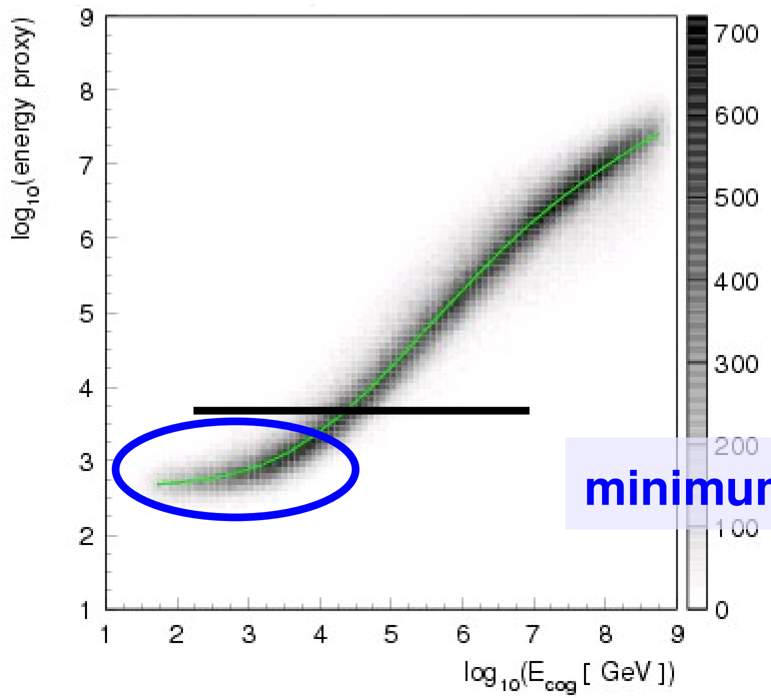




100-200 Muons in IC22 above 1PeV

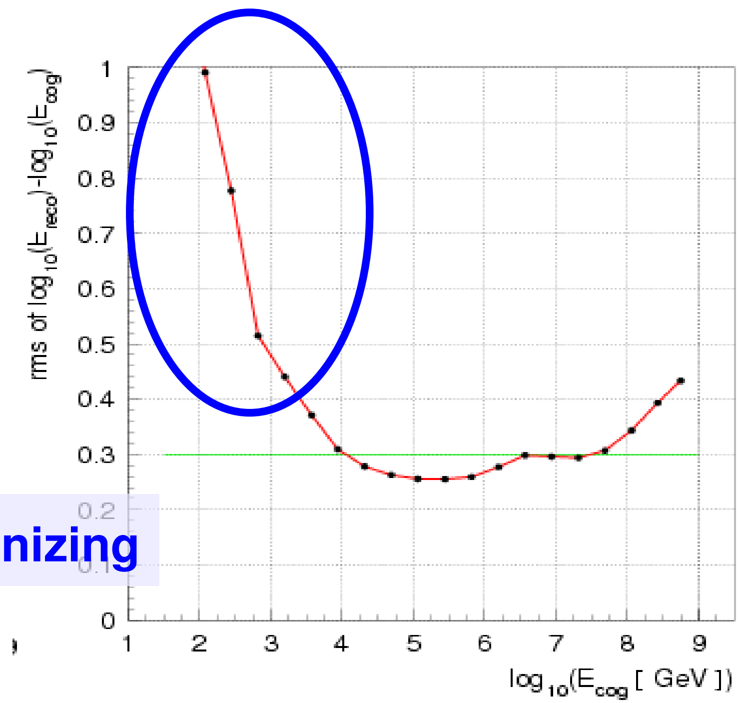
Energy Resolution

μ tracks, IC22



Source: D. Chirkin, UW

minimum ionizing



Energy Resolution
$\sigma(\log_{10}E) \sim 0.3$

Essential Observables for Muon Spectrum:

Slant Depth: mwe traversed

dE/dx: shower energy

Bundle Size: reject high-multiplicity showers