Summary of Cascade Session

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MANTS – Meeting
CERN
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ECAP ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS
FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Session contributions

Contributions

16:10	Search for a cosmic neutrino flux with showers in 6 years of ANTARES data	→ T. E., F. Folger
16:40	high energy cascade reconstruction in km3net	→ A. Heijboer
17:10	Cascade reconstruction and angular resolution in GVD	→ Zh.-A. Dzhilkibaev
17:35	IC79/86 Partially contained cascades	→ A. Stößl

Note: Cascade reconstruction for GeV energies covered in ORCA / PINGU session!

ANTARES

Search for a diffuse flux of cosmic neutrinos in 6 years of data

Cascade reconstruction: method and performance

- Cascade reconstruction factorizes in vertex time + position fit and energy + direction fit.

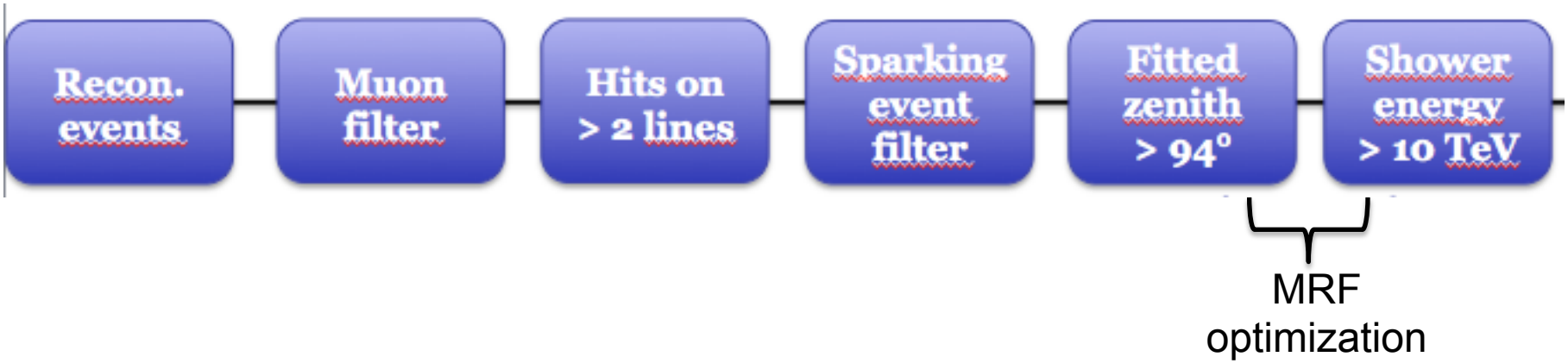
- Reconstruction based on likelihood method employing probability densities created from detailed MC simulations.

- Cascade reconstruction yields
  - median vertex resolution of 4 meters
  - median angular resolution of 6 degrees for E<100TeV
  - logarithmic energy error of 0.3

- Method has been ported successfully to KM3NeT for phase-1.5 studies

Diffuse flux analysis: data selection and sensitivity

Analysis chain for diffuse flux search:



Sensitivity
(1247 days livetime) per neutrino flavour:

$$E^2 \cdot \bar{\Phi}_{90\,\%} = 2.21^{+0.87}_{-0.73} \cdot 10^{-8}\,\mathrm{GeV/cm^2 \cdot sr \cdot s}$$

Result of data unblinding (1247 days)

Simulation atm. muons	Simulation atm. nu	Simulation astro nu	Unblinded Data
$1.9^{+/-\ 1.5}$	$3.1^{+1.3}_{-1.4}$	$2.8^{+0.6}_{-1.0}$	8

Upper limit (1247 days livetime) on cosmic diffuse neutrino flux (90% CL) per flavour, accounting for systematic uncertainties :

$$E^2 \cdot \Phi_{90\,\%} = 4.9 \cdot 10^{-8}\,\mathrm{GeV/cm^2 \cdot sr \cdot s}$$

Note: 1.5 sigma over background,
consistent with expectation from IceCube signal, but large uncertainites

KM3NeT

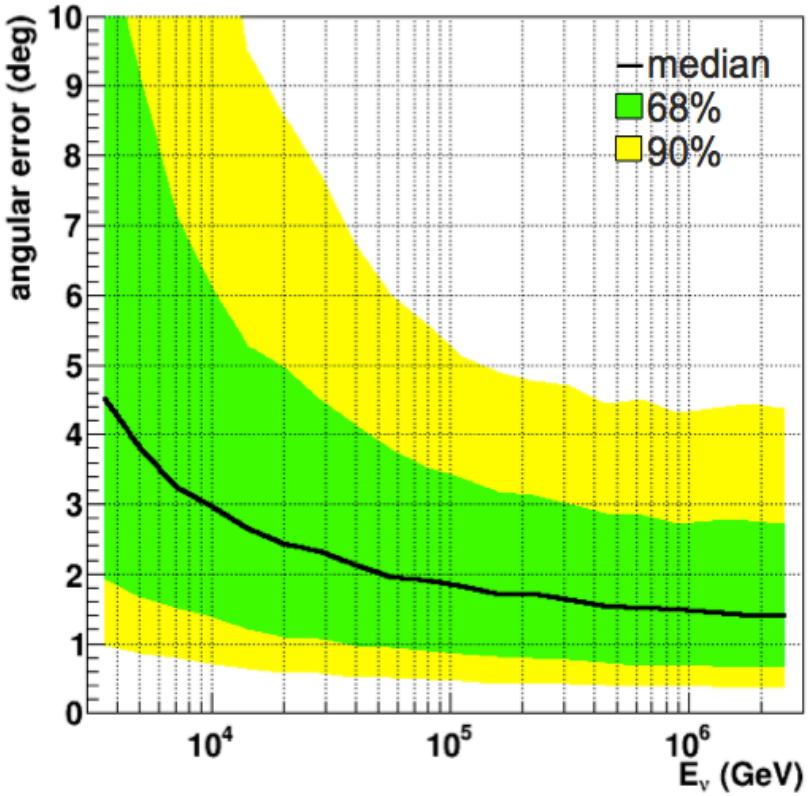
Cascade reconstruction

Cascade reconstruction in KM3NeT

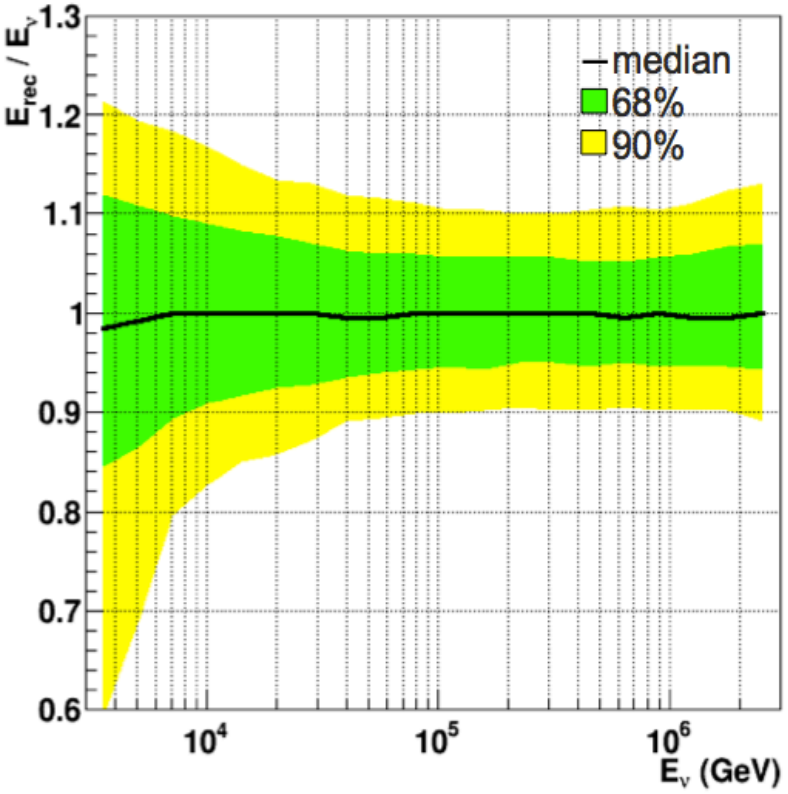
- position + time of the shower easily inferred from hit times, as nanosecond accuracy even at large distances!
- direction and energy of the shower inferred from light intensity, as Cherenkov light 'beaming' observed up to large distances
- vertex fit finds shower maximum to within 1 m
- direction + energy fit needs likelihood method
  and results sensitive to best likelihood formulation and accurate implementation.
- multi-PMT design allows photon counting
  → simple reconstruction by just using information on hit/empty PMTs.

Cascade reconstruction performance

direction resolution



energy resolution



Median resolutions

For *contained events* in KM3NeT:

- angular resolution: 4 – 1.5 degrees for 3 TeV – PeV
- energy resolution: < 10% for E > 3 TeV
- vertex resolution: < 0.5m for E > 4TeV

For *contained events* in ANTARES:

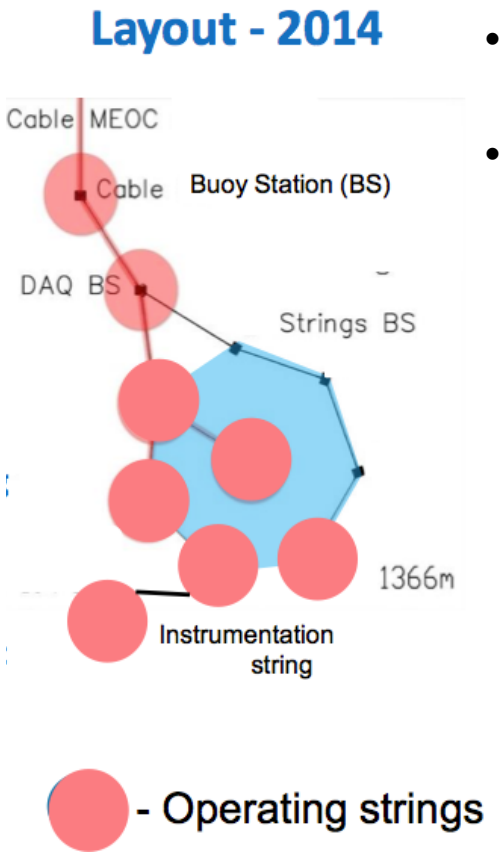
- angular resolution: 2 degrees for 10 TeV
- energy resolution: ~10% for 10 TeV

Very promising prospects for point source anlyses,
even with ANTARES!

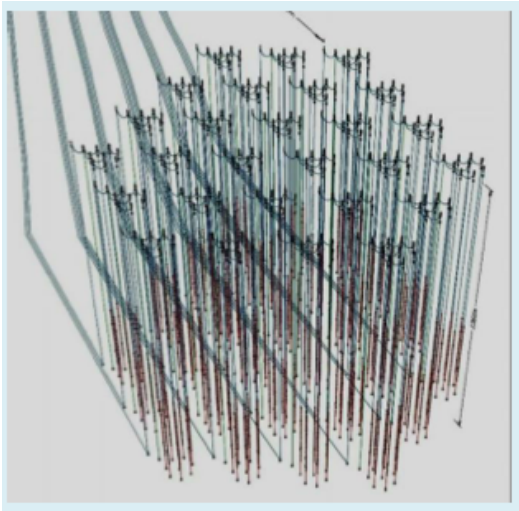
GVD

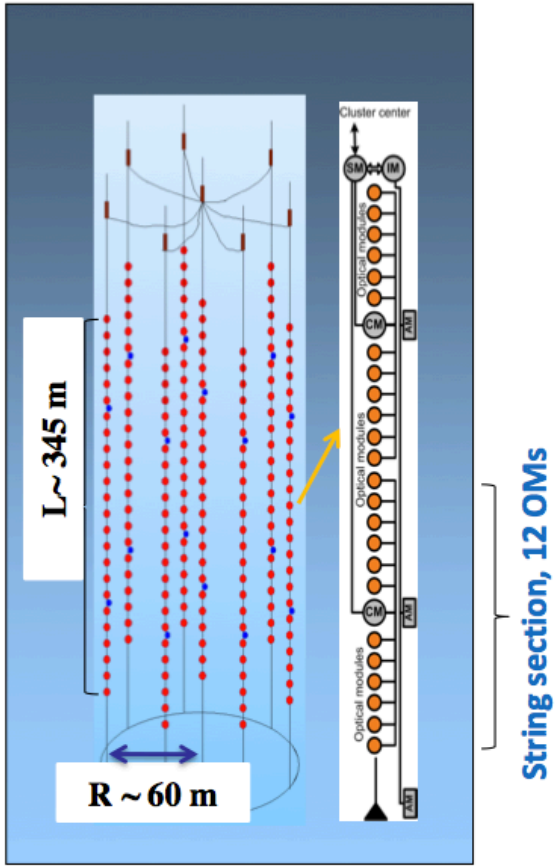
Cascade reconstruction

Cascade reconstruction in GVD



- First cluster will be completed in 2015
- Full GVD: 12 clusters with 8 strings and 192 Oms each





Reconstruction technique

Reconstruction of cascade position

$$\chi^2_t = \frac{1}{(N_{hit}-4)} \sum_{i=1}^{N_{hit}} \frac{(T_i(\vec{r}_{sh}, t_0) - t_i)^2}{\sigma^2_{ti}},$$

where $T_i(\vec{r}_{sh}, t_0)$ time of flight of unscattered photons

Reconstruction of cascade direction and energy

$$L_A = -\sum_{i=1}^{N_{hit}} \ln P_i(A_i, E_{sh}, \vec{\Omega}_{sh}(\theta, \varphi)),$$

where P_i calculates in respect of tabulated $\bar{n}_{pe}(\rho, z, \theta, \varphi, \tau)$

Performance prediction for 1 GVD cluster

- Predicted energy resolution ~ 30%,
  angular resolution ~ 4° for E_{sh} = 100 TeV

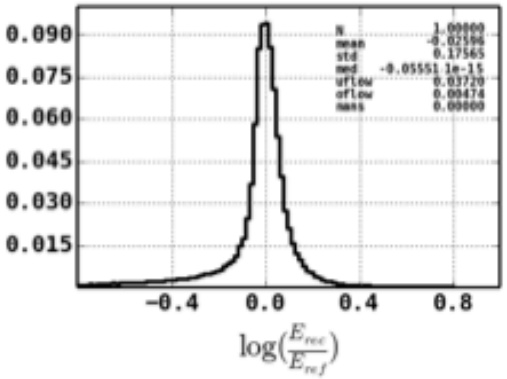
- 1 astrophysical neutrino event E > 100 TeV from „IceCube flux“ is expected in 1 year data sample

IceCube

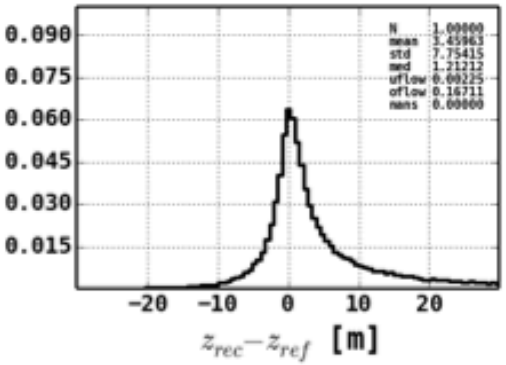
Search for partially contained cascades

Partially contained cascade search

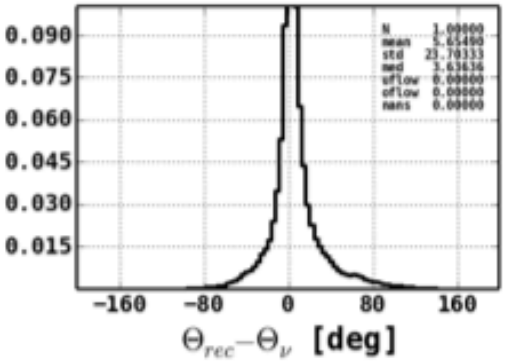
- IC diffuse flux search still in statistics limited regime
- Partially contained cascade volume: 347 Mton
- Reconstruction method: 7-parameter Poisson likelihood reconstruction (energy, vertex, direction), uses charge and timing information
- Resolutions for partially contained events slightly worse than contained



mean = -0.05, std = .17



mean = 3.45, std = 7.75



mean = 5.65, std = 23.70

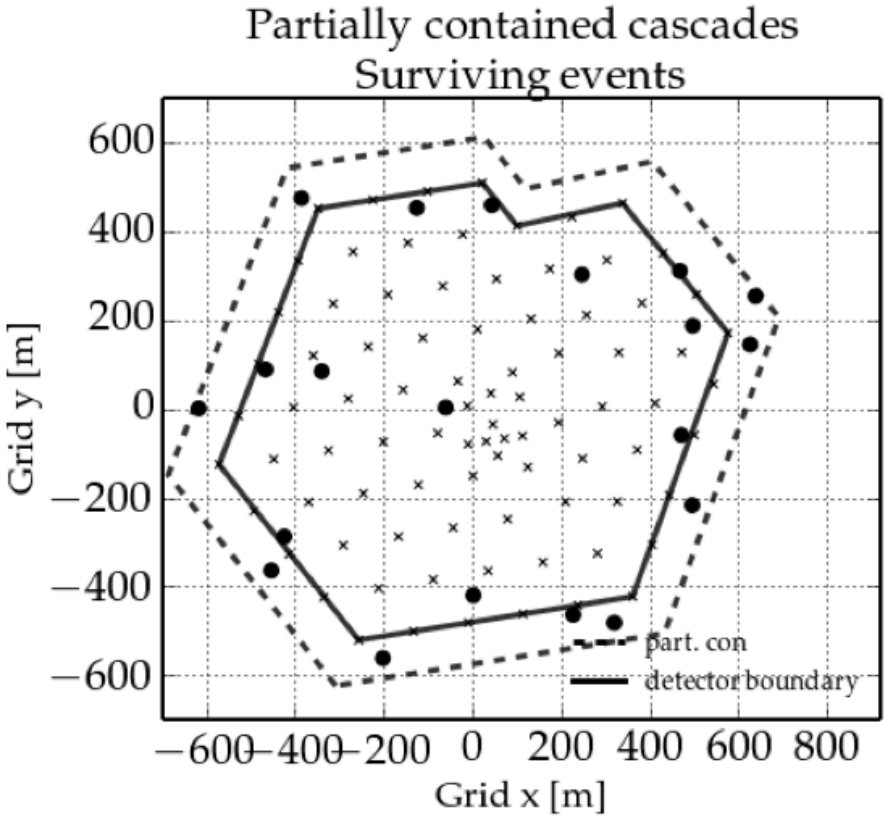
Analysis overview

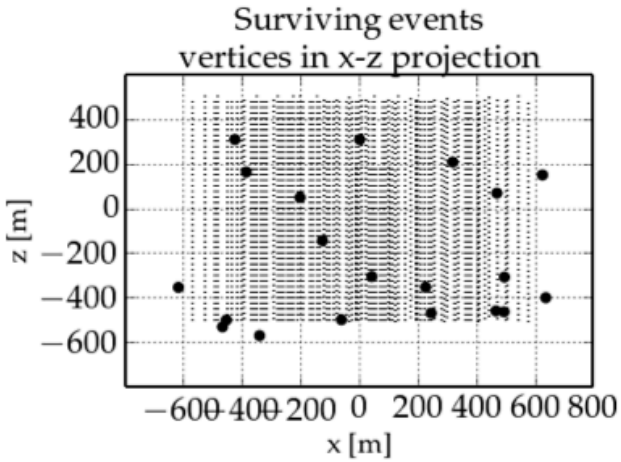
target	$E^{-2}\nu$ all-flavor, all-sky
technique	Straight cuts
method	Partially contained cascades
background	MC Background prediction

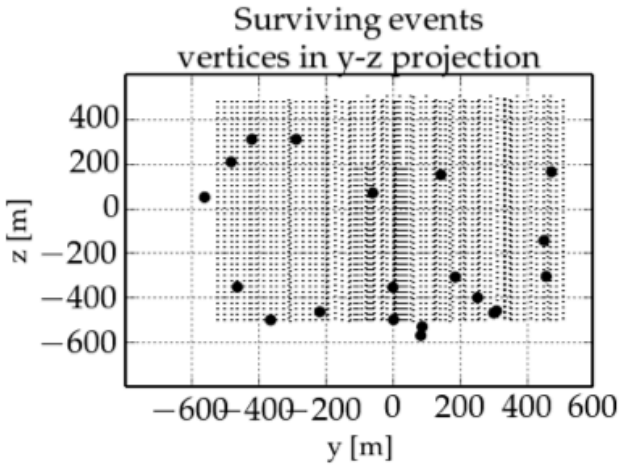
Analysis - IceCube data

- Data of 79/86 string configuration used ($\approx$ 660 days)
- 10% data used for cut development, 3-step unblinding

18 new events found, +2 events already in HESE



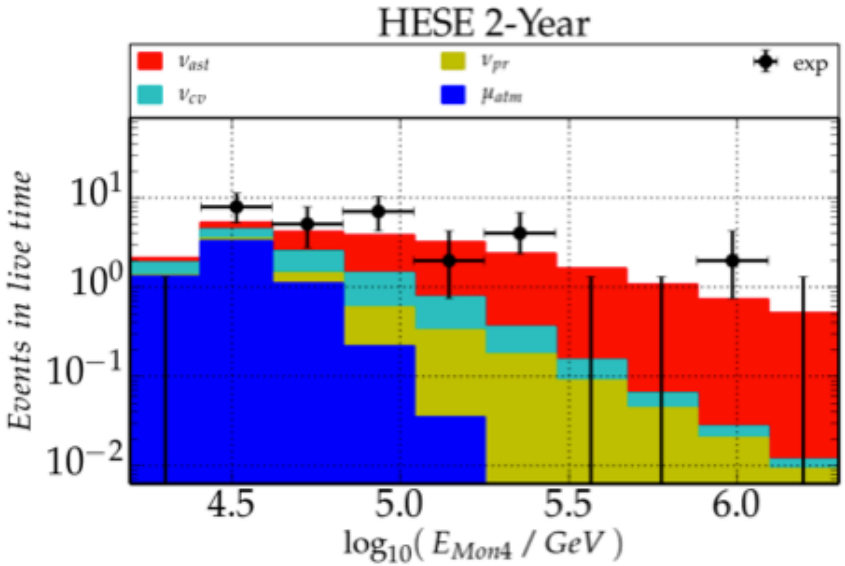


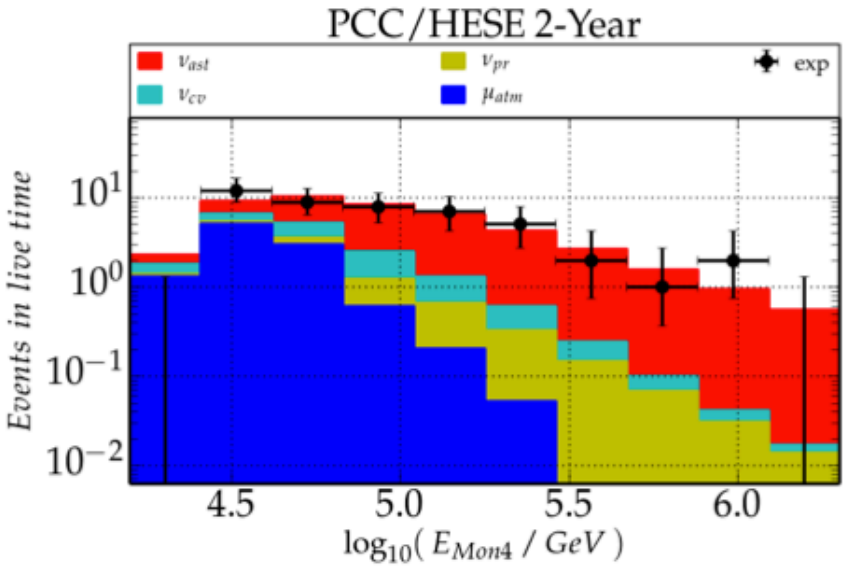


Consistency with HESE

IceCube: part. cont. cascades (A. Stößl)

- PCC. adds 19 additional events to 2-year HESE spectrum
- stacked MC expectations
- HESE only: $E^{-2}\Phi(E) = 1.2 \pm 0.4\ 10^{-8} GeV cm^{-2} s^{-1} sr^{-1}$
  best fit spectrum $E^{-2.2 \pm 0.3}$
- HESE/PCC: $E^{-2}\Phi(E) = 1.8 \pm 0.6\ 10^{-8} GeV cm^{-2} s^{-1} sr^{-1}$
  best fit spectrum $E^{-2.4 \pm 0.3}$





Summary

IceCube: part. cont. cascades (A. Stößl)

- Performed simple, straight cut search for partially contained cascade events
- MC background prediction
- 20 events found in 2 years of data
- events line up nicely in HESE-2-year spectrum - even partly filling up "the gap"
- indications for a softer index of 2.47
- joint publication with IC79/86 contained analysis in planning