WISCONSIN ICECUBE
PARTICLE ASTROPHYSICS CENTER

summary of charm production session

MANTS meeting 2014

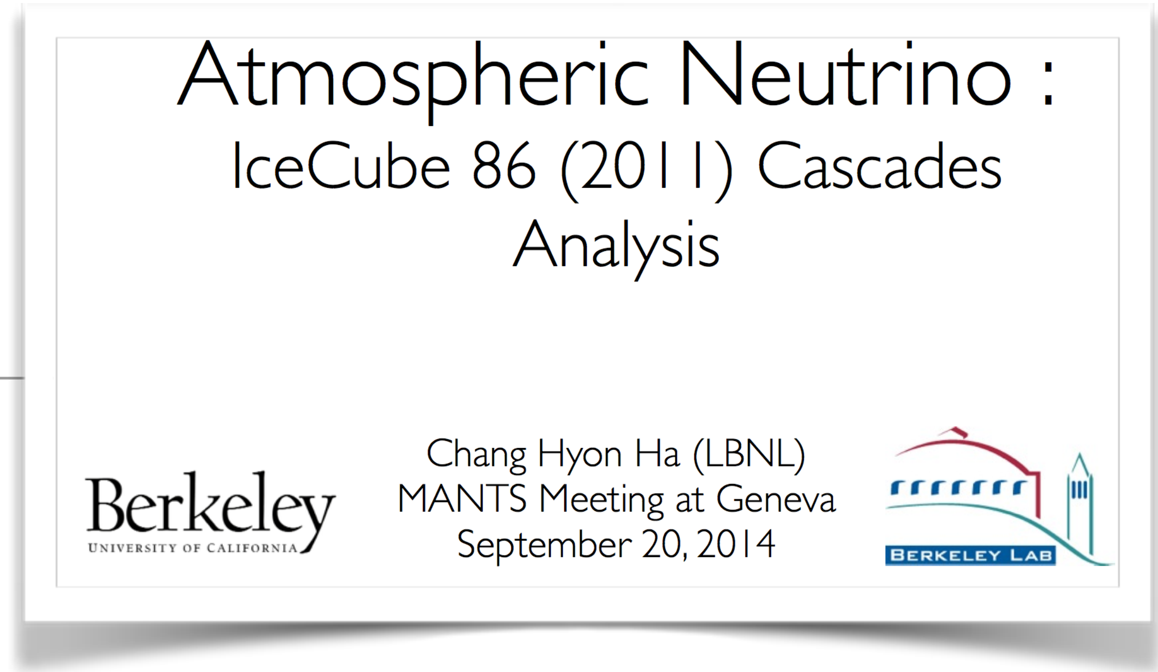
Paolo Desiati

Wisconsin IceCube Particle Astrophysics Center
& Department of Astronomy

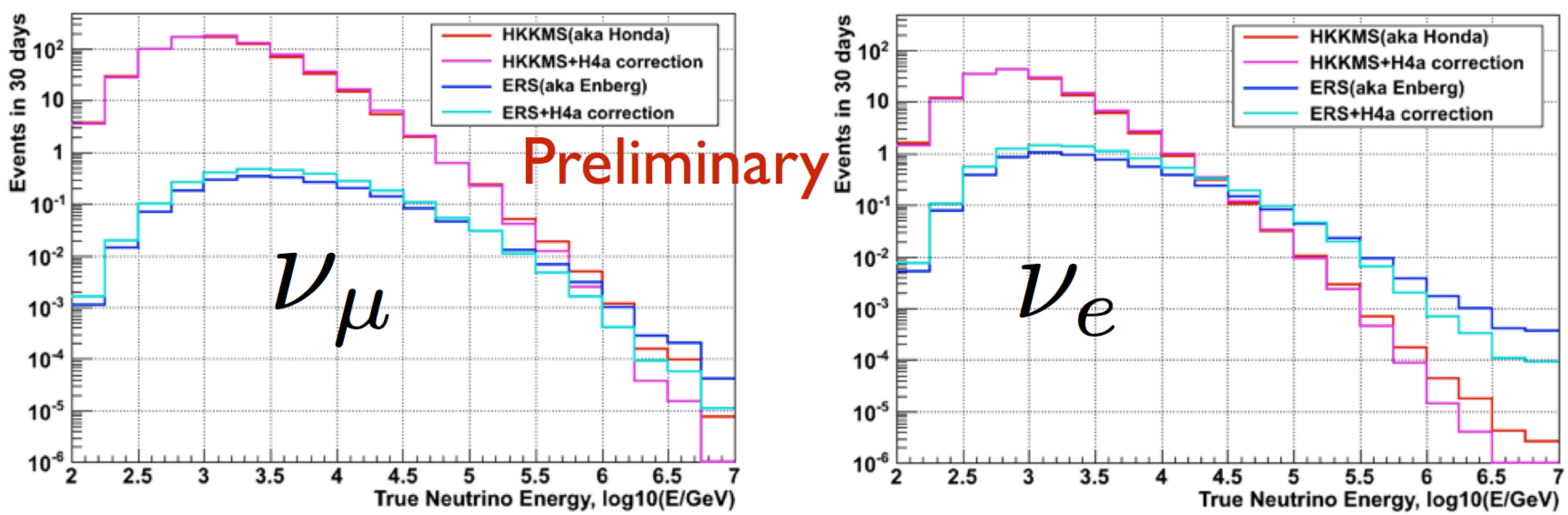
University of Wisconsin - Madison

MANTS Meeting 2014
CERN - September 21, 2014

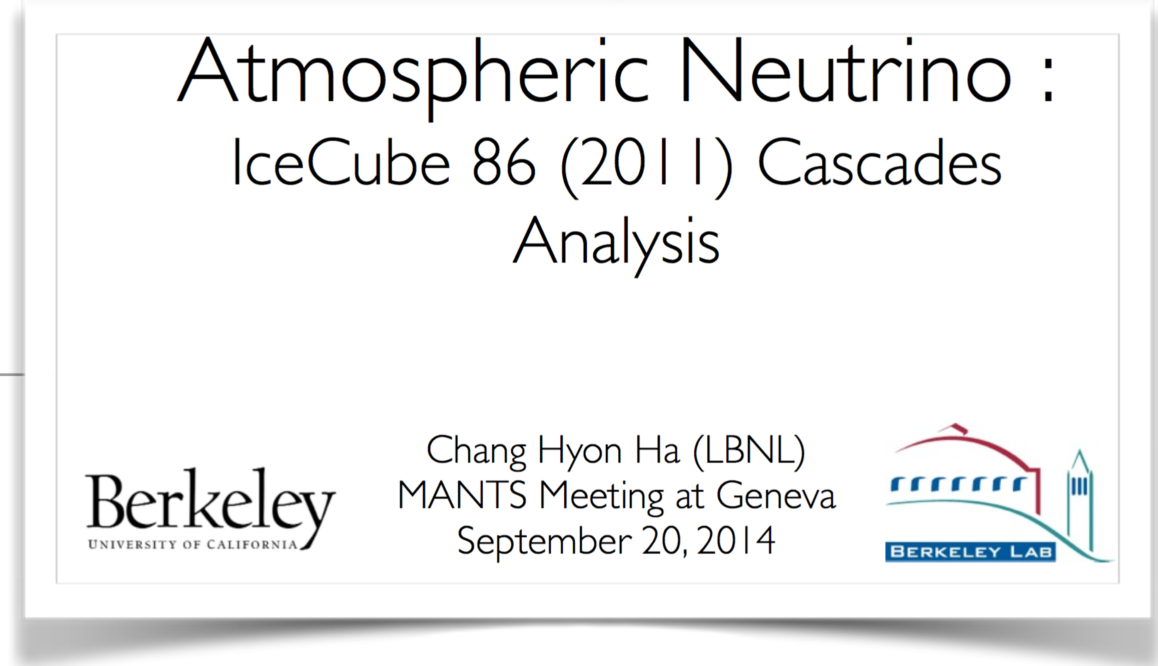
atmospheric neutrinos

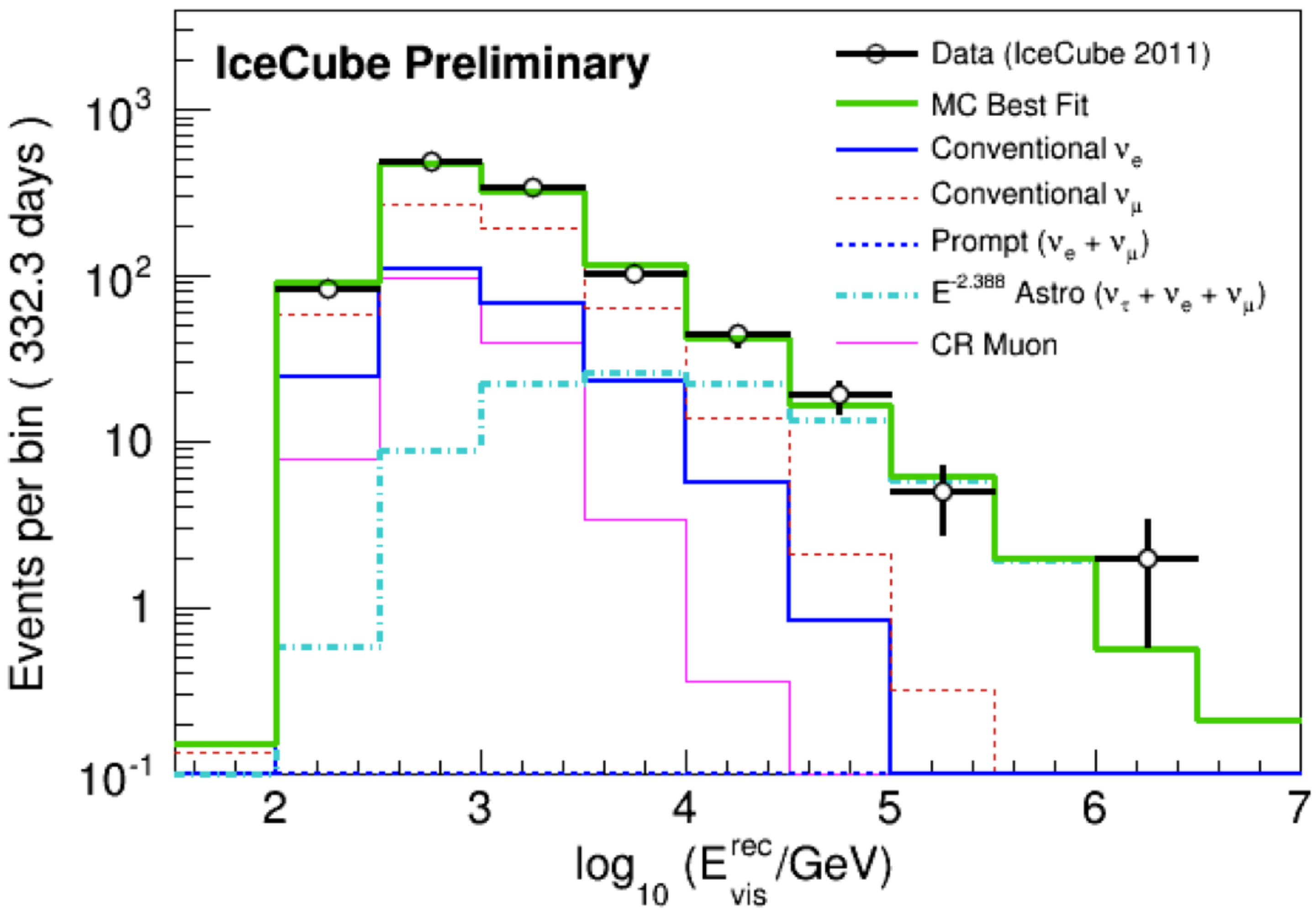


- determination of ν_e spectrum via **cascades**
- ν_μ / ν_e ~ 10 @ 1 TeV
- onset of prompt contribution from charm at lower energy

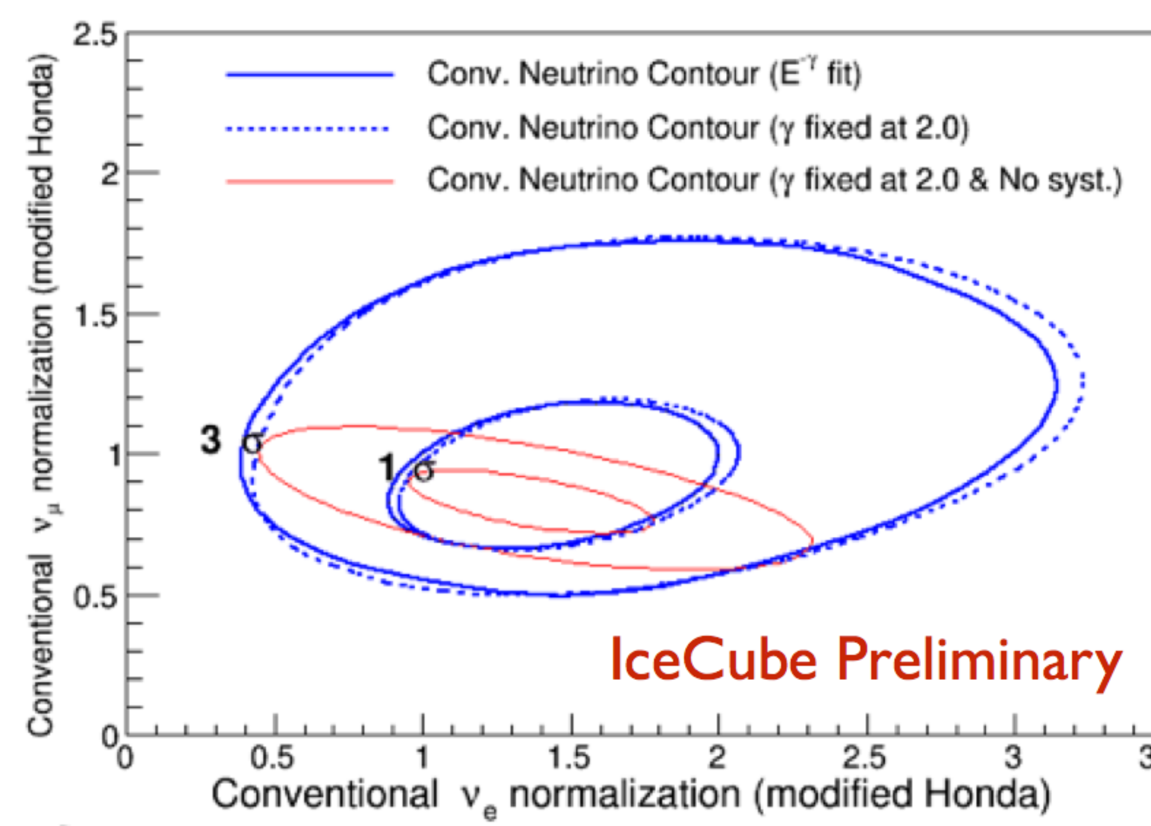


atmospheric neutrinos





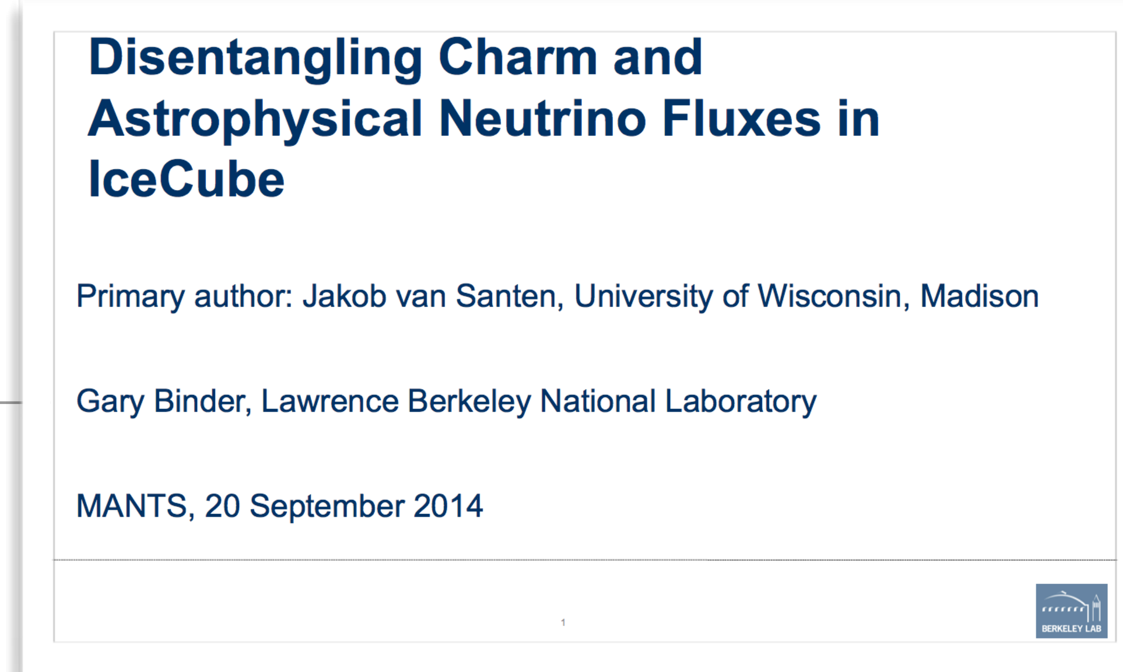
measurement of conventional neutrinos have NO impact on determination of charm & astrophysical contributions



- 1078 events / 332.3 days (0.3-14 TeV)
- 70 events > 10 TeV

atmospheric neutrinos

prompt & astrophysics

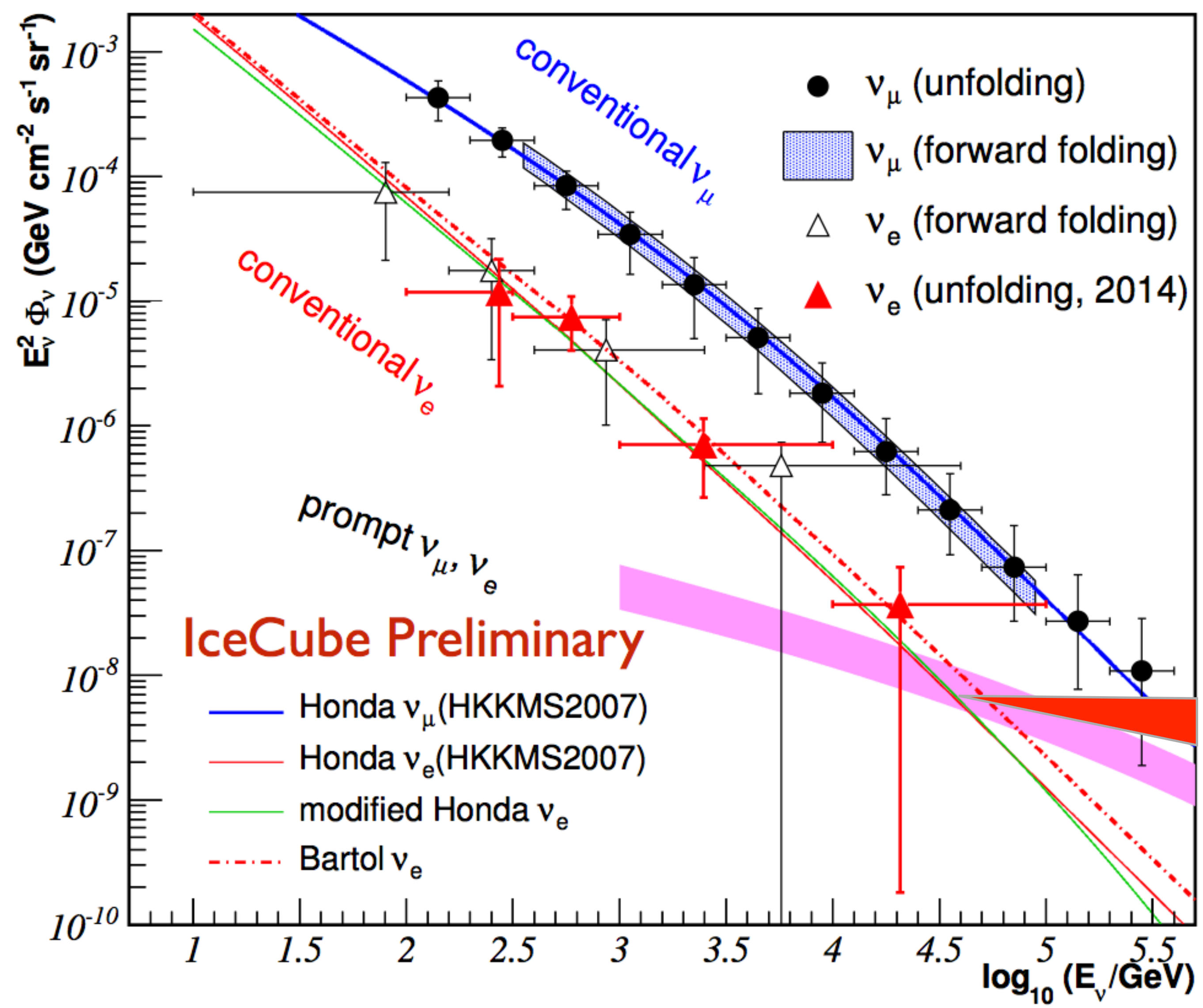

Disentangling Charm and Astrophysical Neutrino Fluxes in IceCube

Primary author: Jakob van Santen, University of Wisconsin, Madison

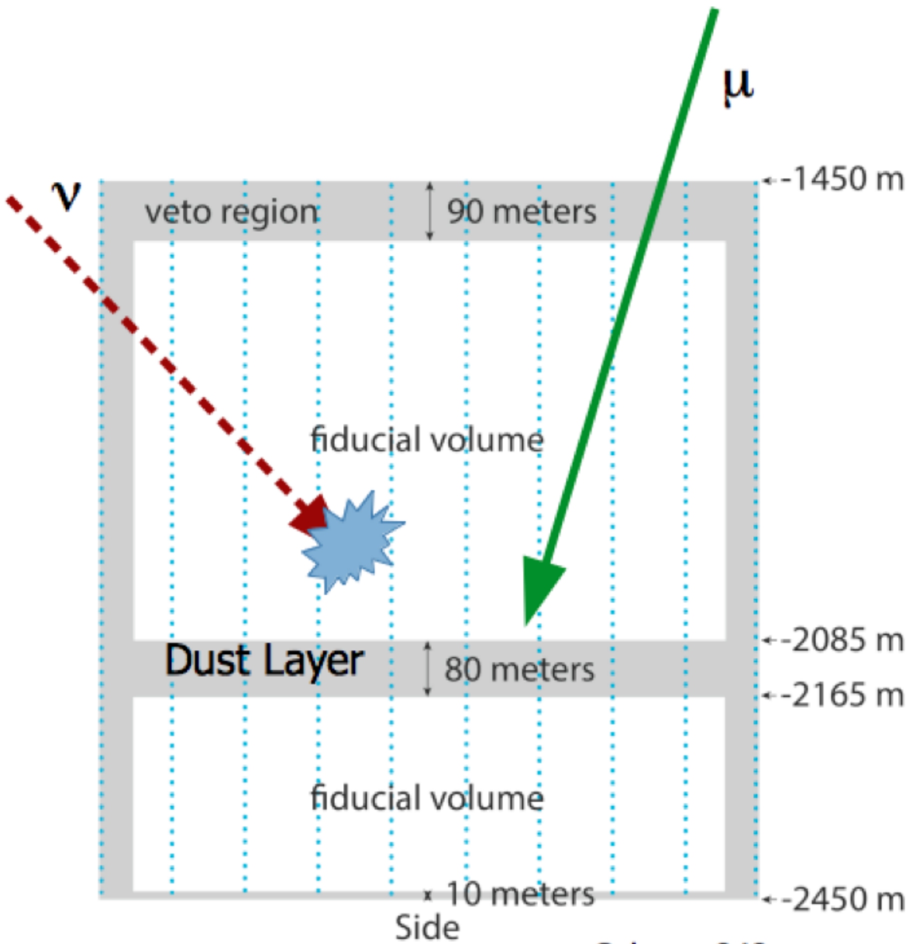
Gary Binder, Lawrence Berkeley National Laboratory

MANTS, 20 September 2014

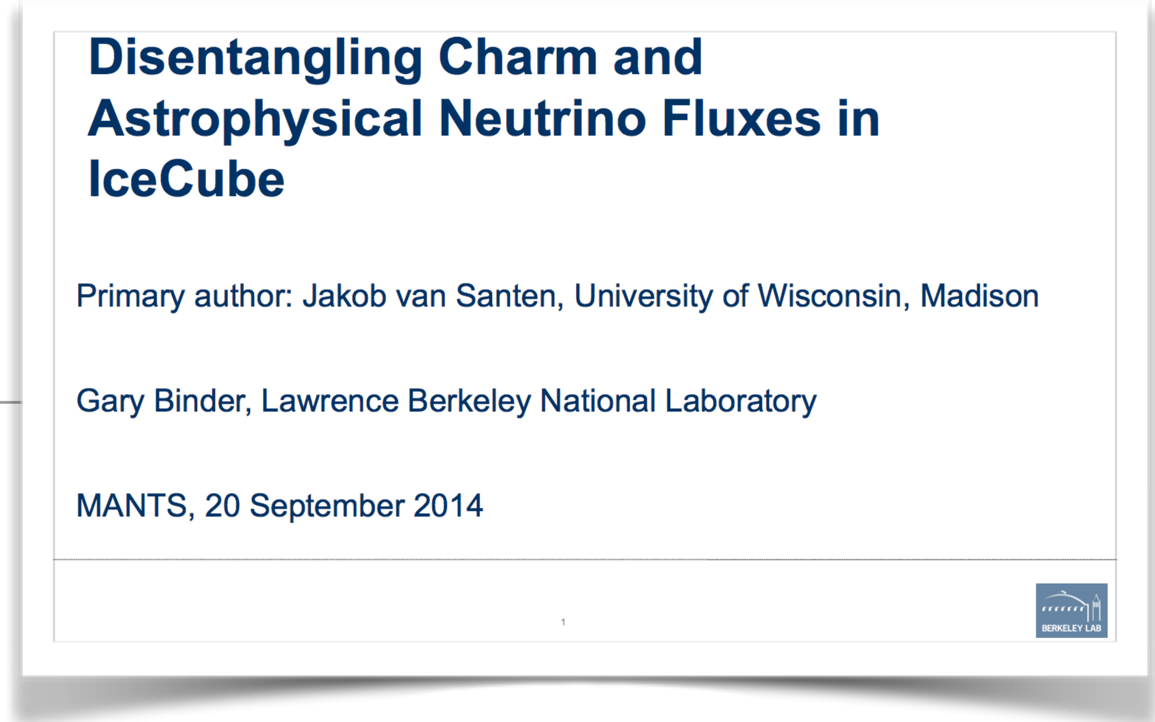
- charm production between conventional & astrophysical components
- is charm contribution **important** ?
- how much do we **know** about it ?
- is it possible to **measure** it ?



atmospheric neutrinos
prompt & astrophysics



Science 342, 1242856 (2013)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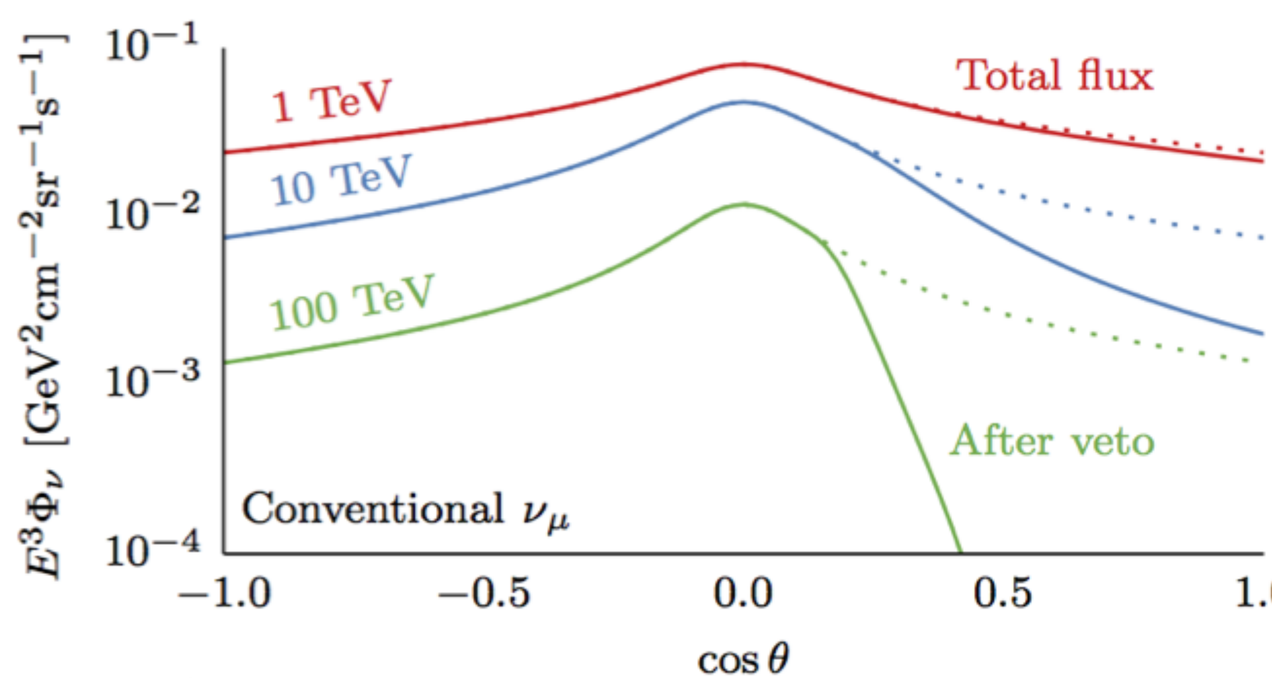
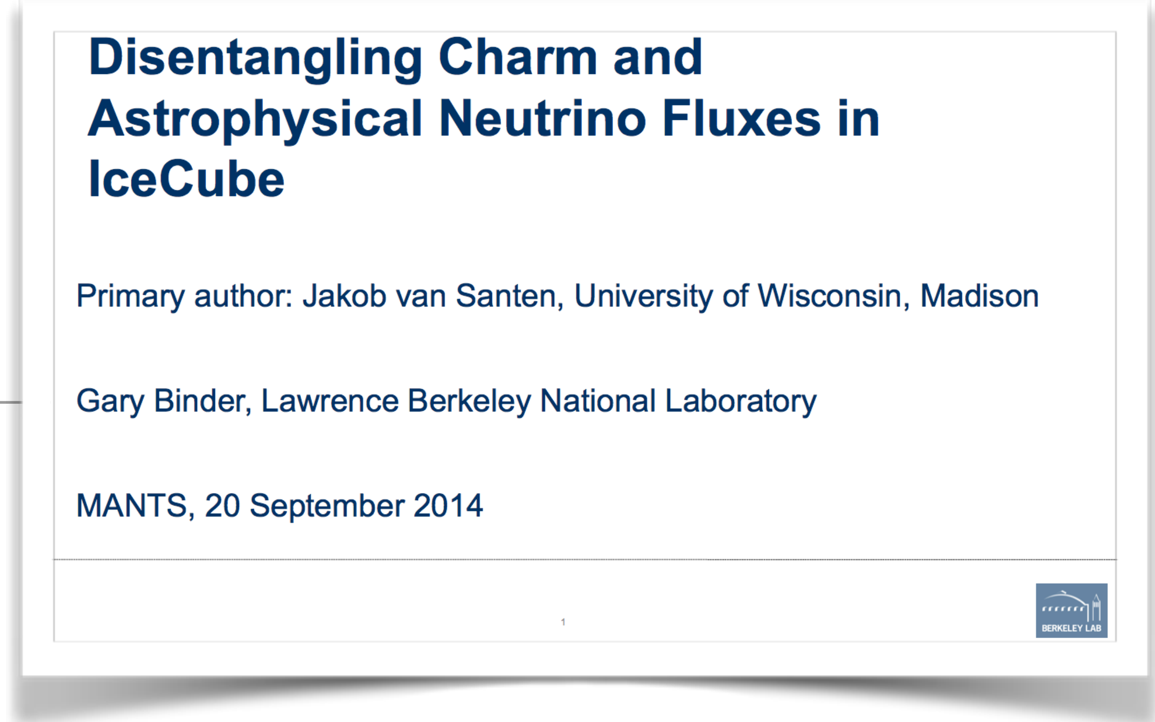
event veto with
low energy extension (60 TeV → 10 TeV)

self veto to reject
atmospheric neutrino contribution
from **southern hemisphere**



atmospheric neutrinos
prompt & astrophysics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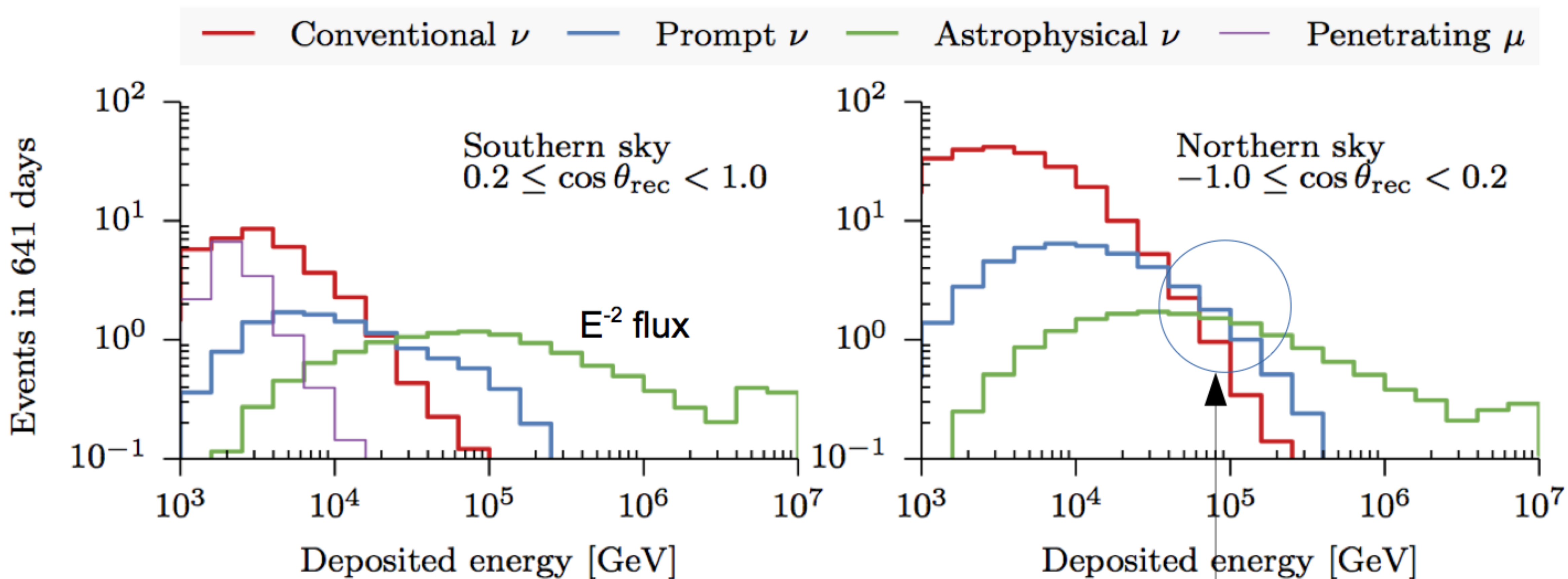
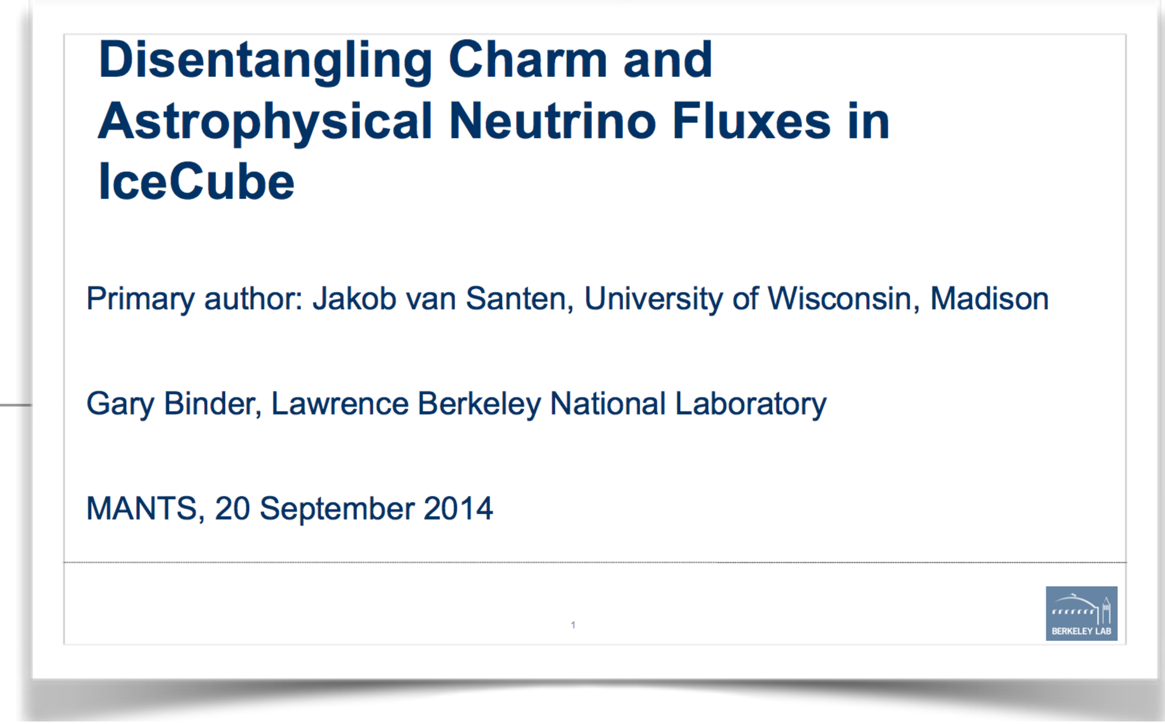


- Use energy, direction, and cascade/track ID information

Small window for prompt to appear

atmospheric neutrinos

prompt & astrophysics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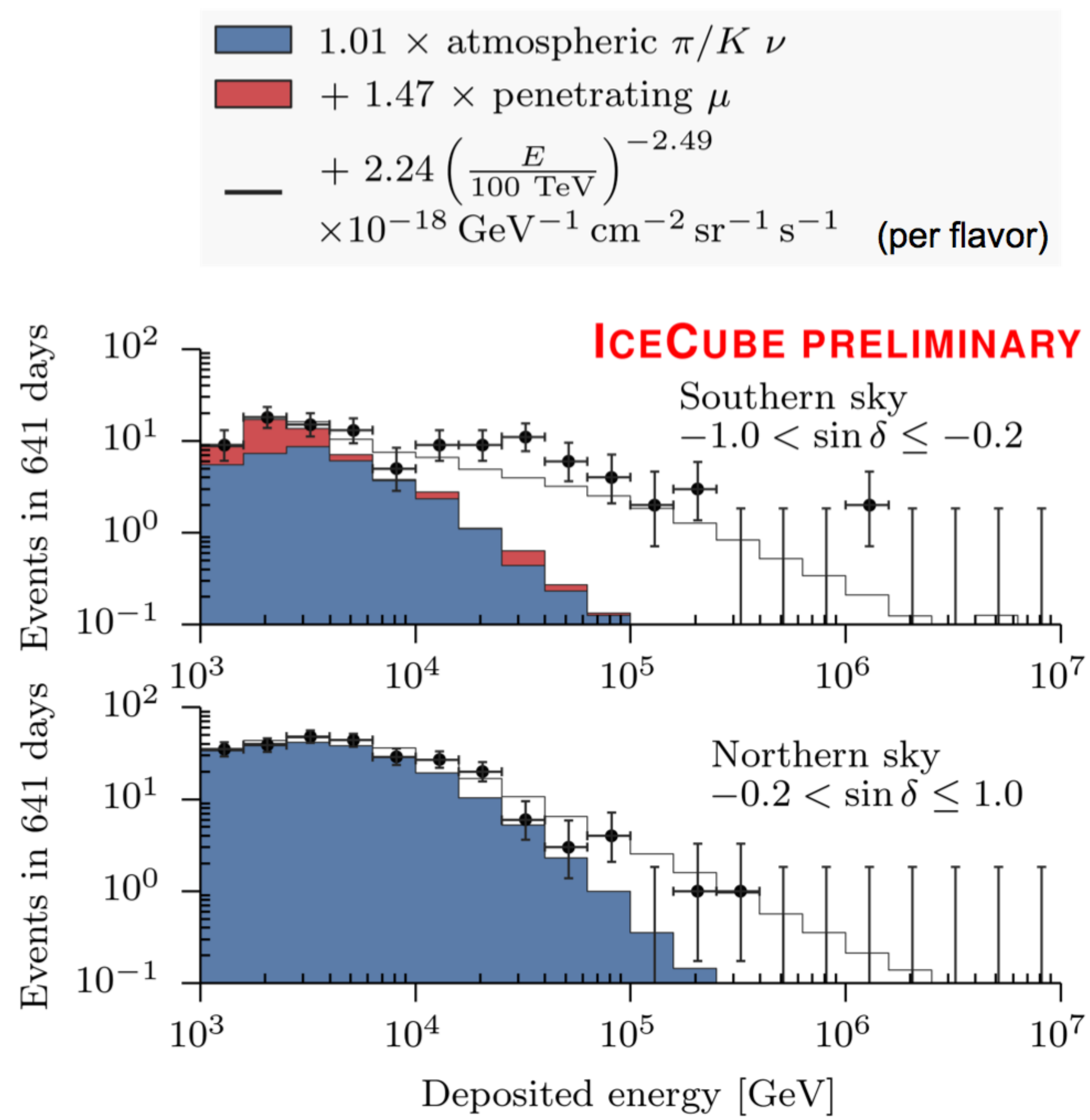
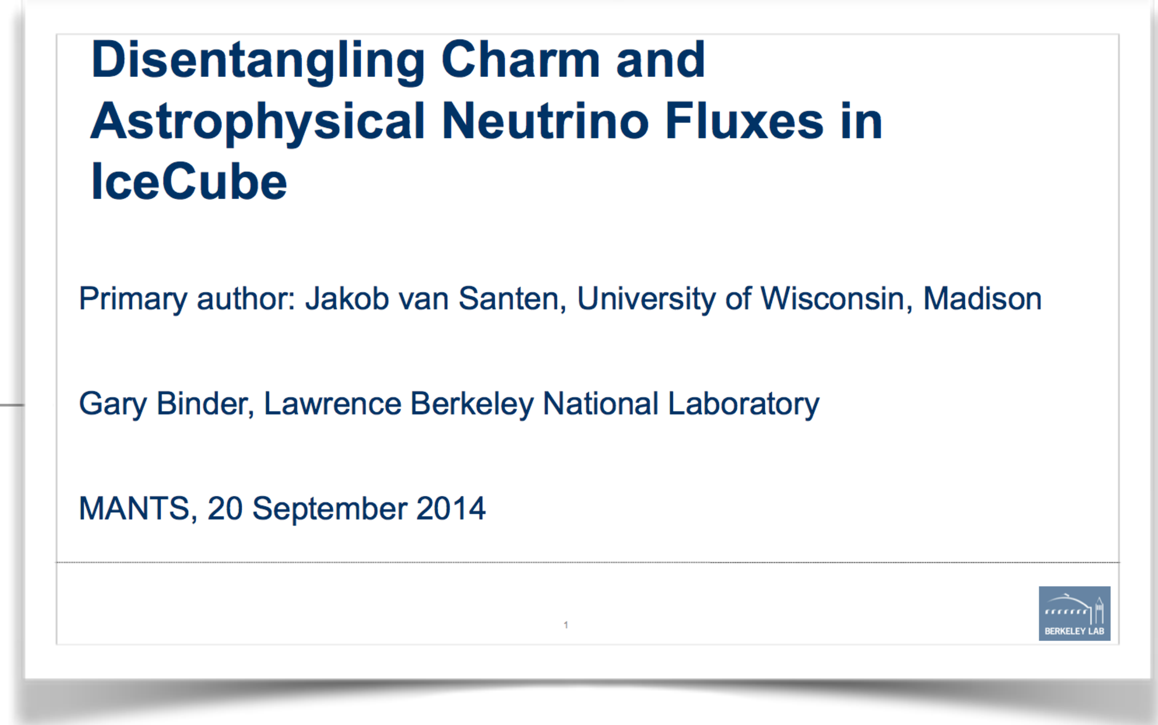
- 283 cascades + 105 tracks in 2 years
- best fit NO charm contribution
- *soft* astrophysical spectrum



atmospheric neutrinos
prompt & astrophysics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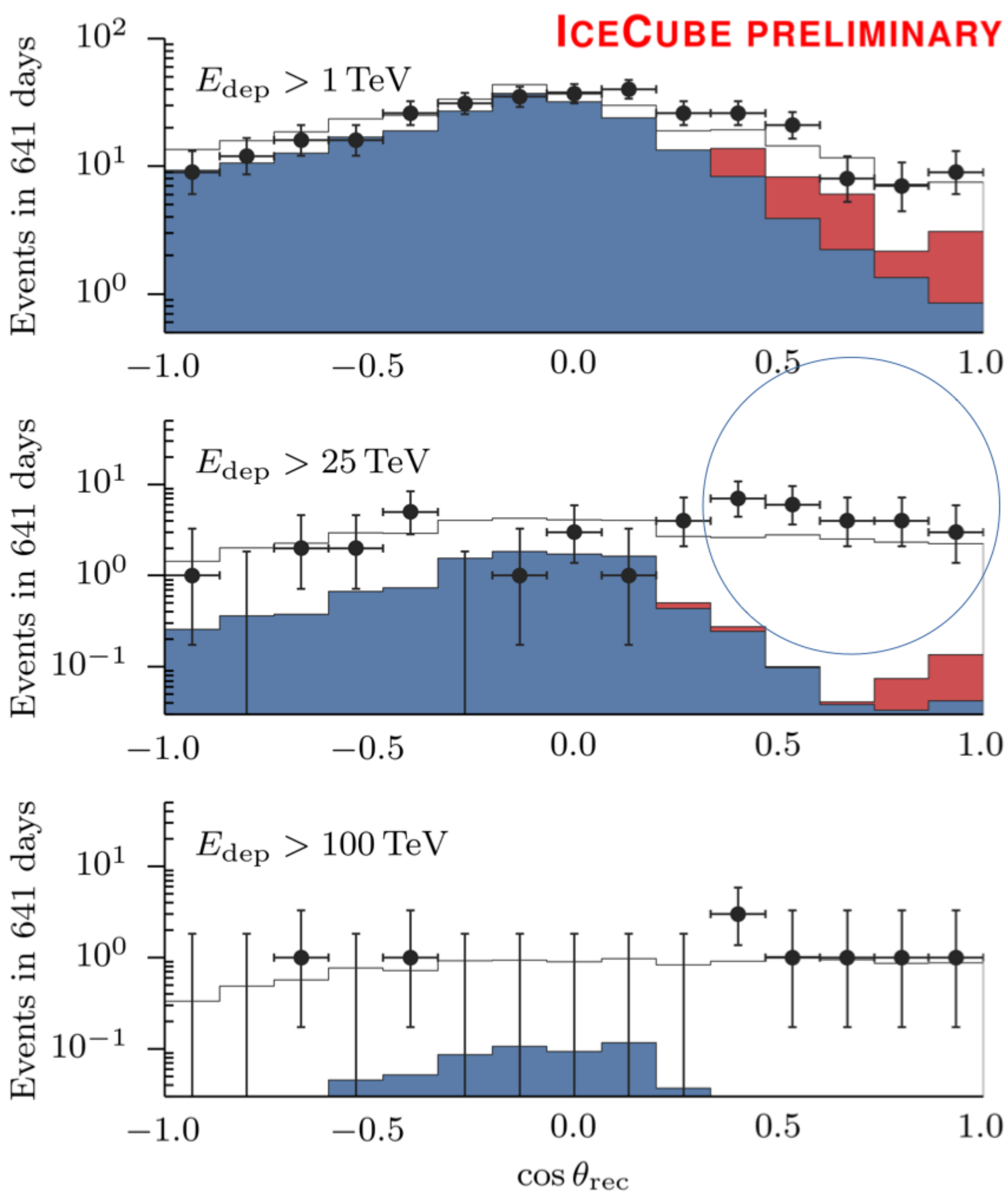
Zenith Distribution



- **all sky** 90% CL charm limit ~ 1.4 ERS
- **separate hemisphere** 90% CL charm limit ~ 3.6 ERS

atmospheric neutrinos
prompt & astrophysics

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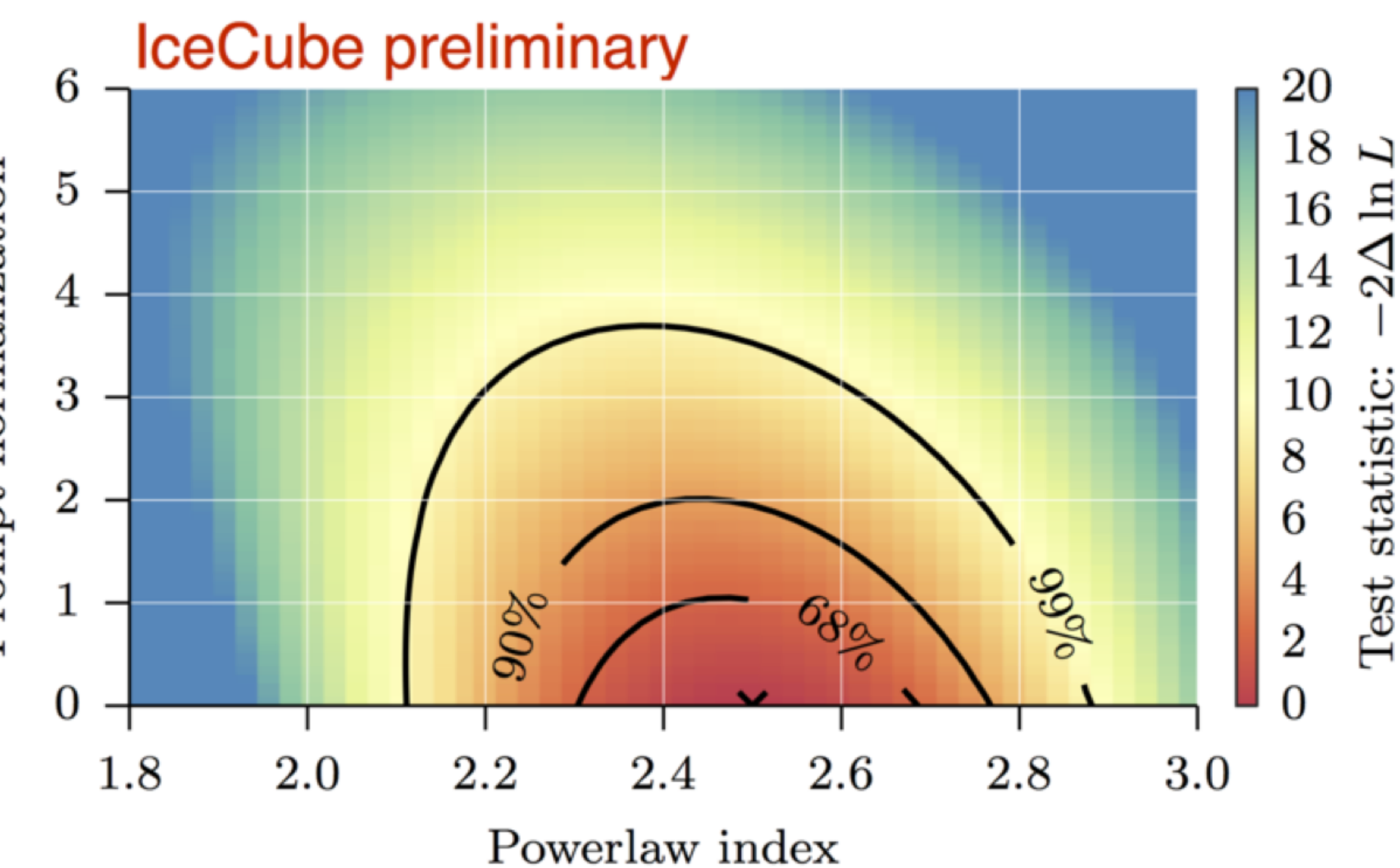
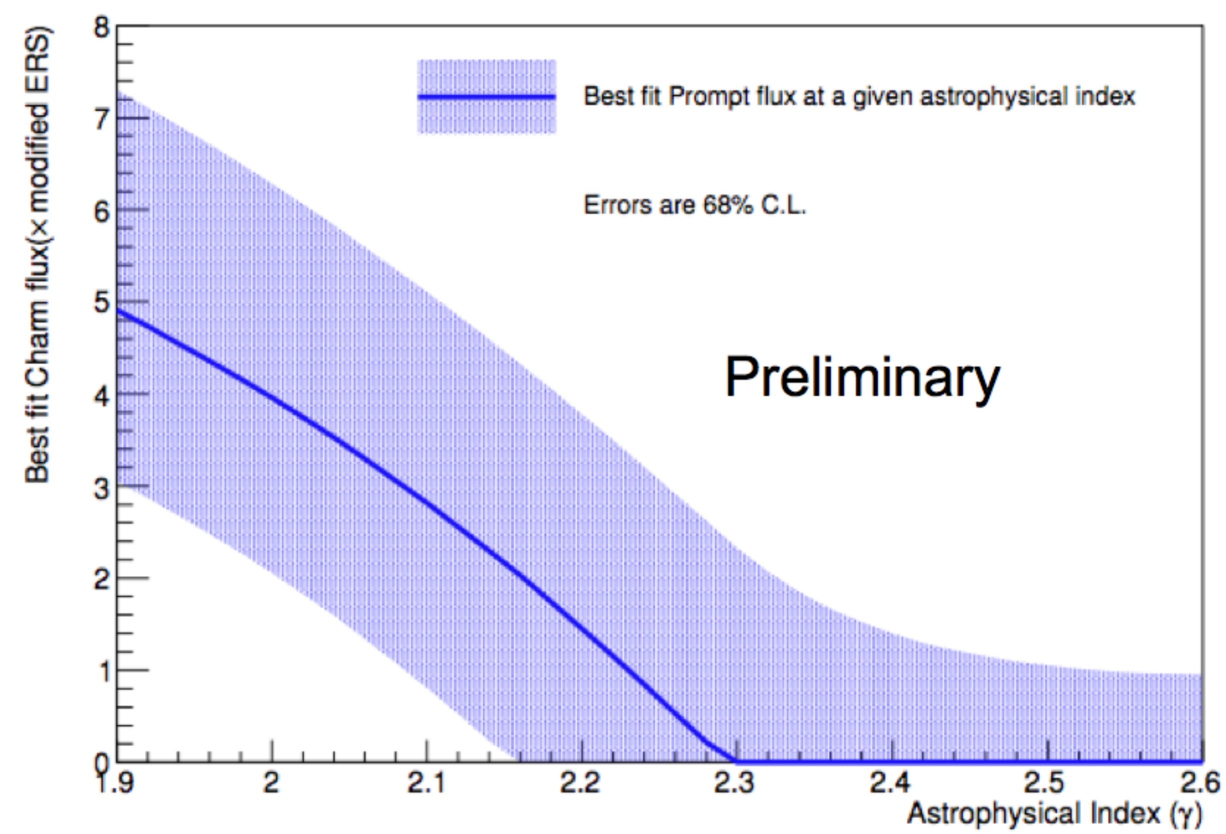


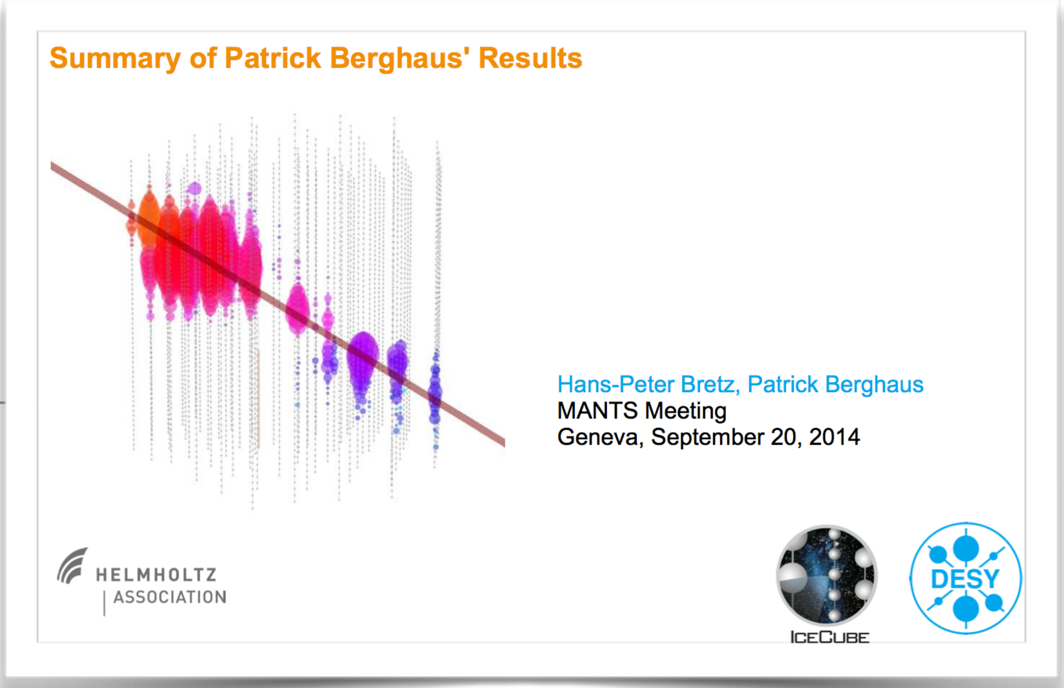
best fit is **NO charm**

anti-correlation between charm flux & astrophysical spectral index

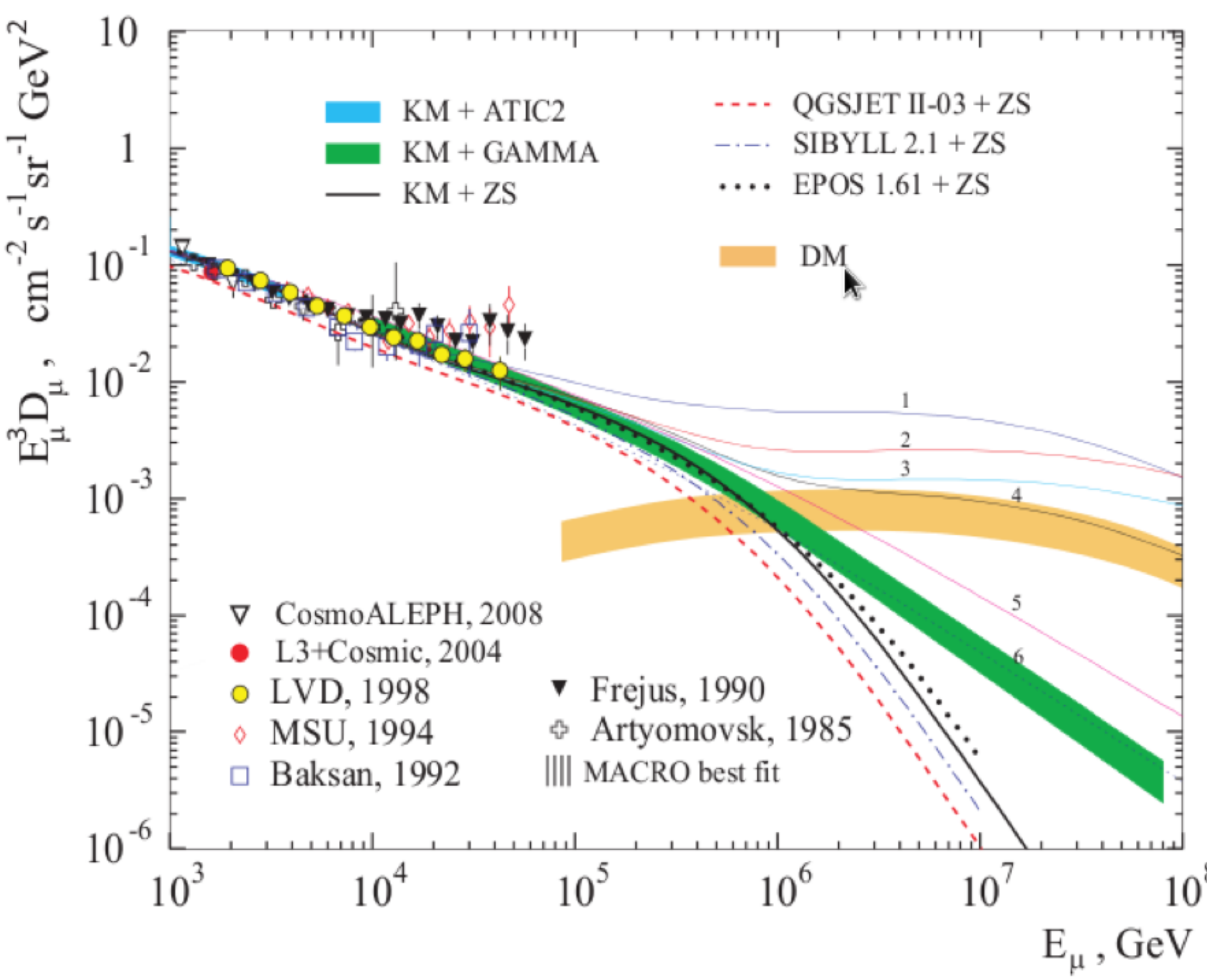
determine prompt component with muons ?



atmospheric neutrinos
and diffuse fluxes

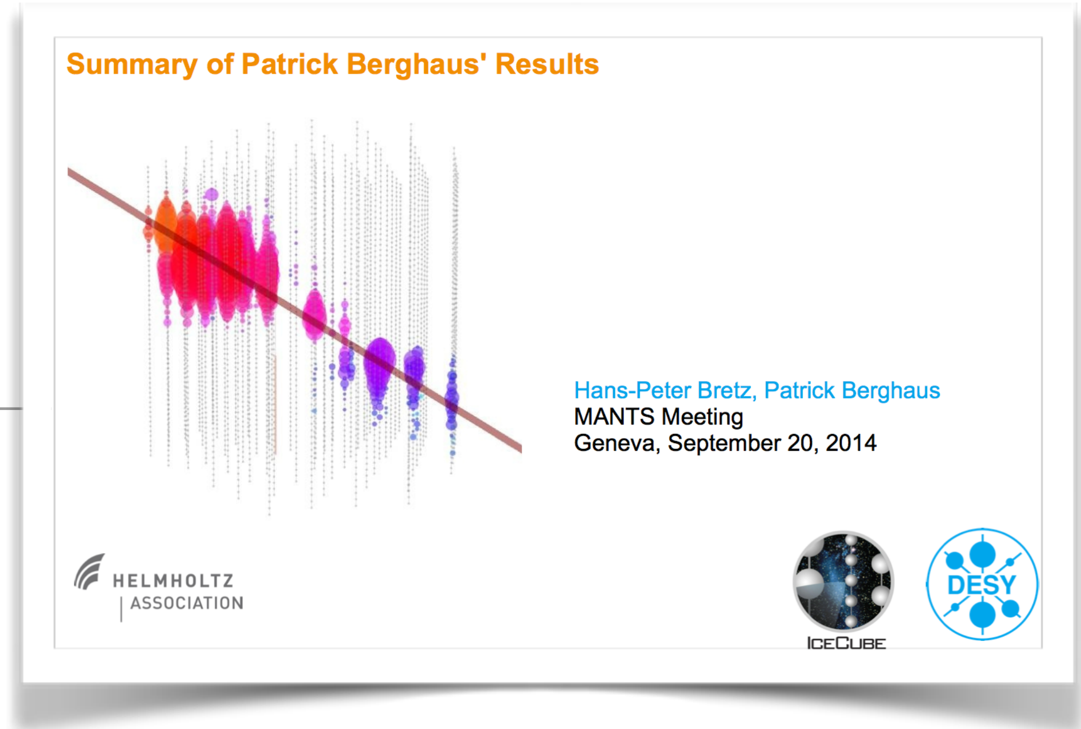


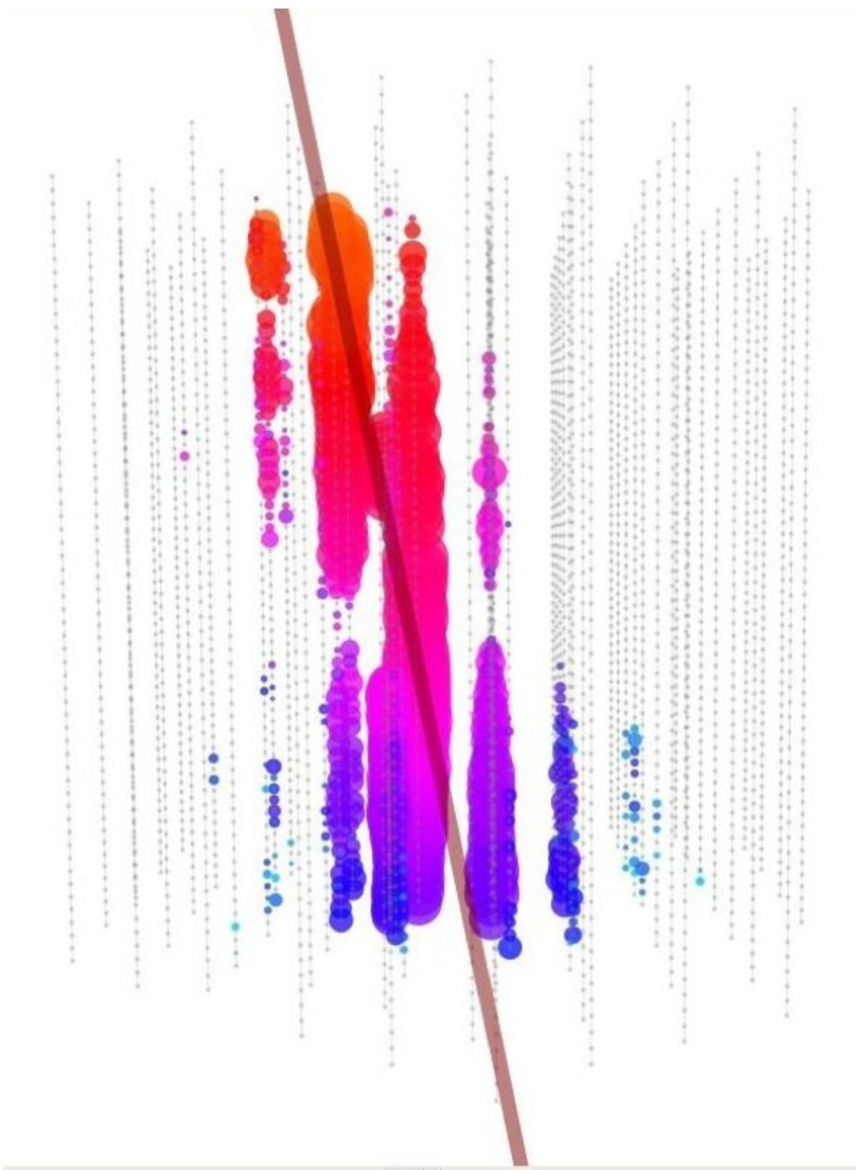
- large muon bundles of low energy muons
- high energy muons (leading muons, low multiplicity)
- stochastic energy losses to separate them

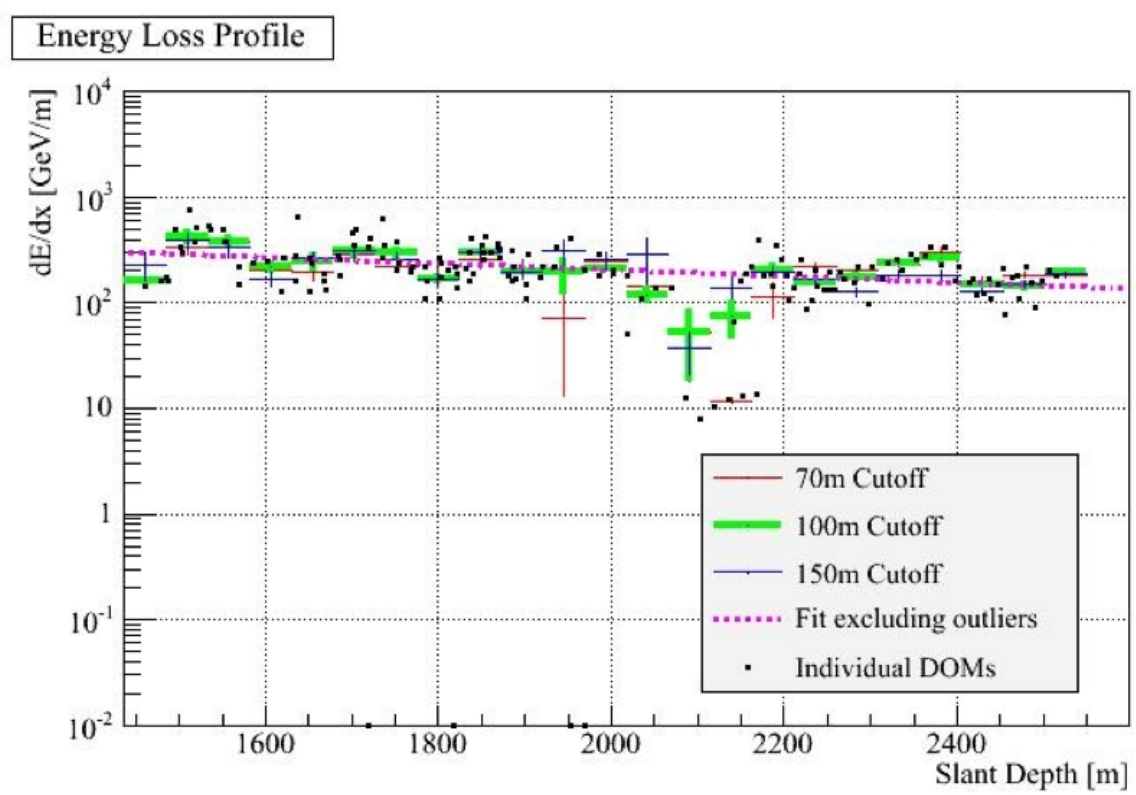


Sinegovsky et al. arXiv:0906.3791
Enberg et al. arXiv:0806.0418

atmospheric neutrinos
and diffuse fluxes

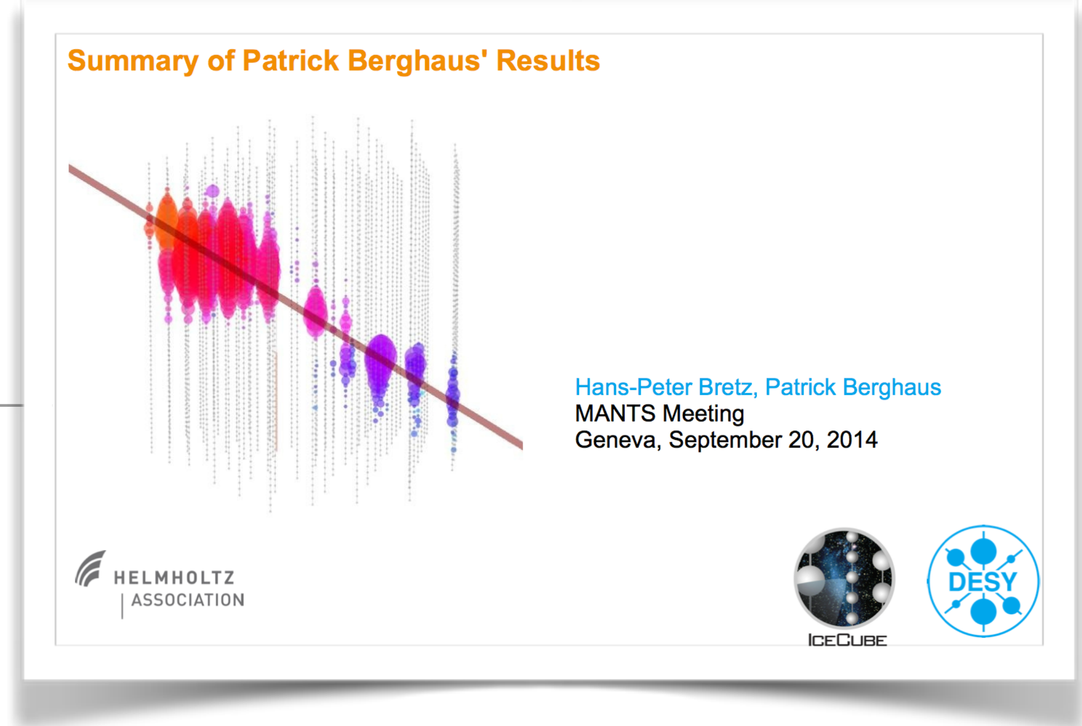


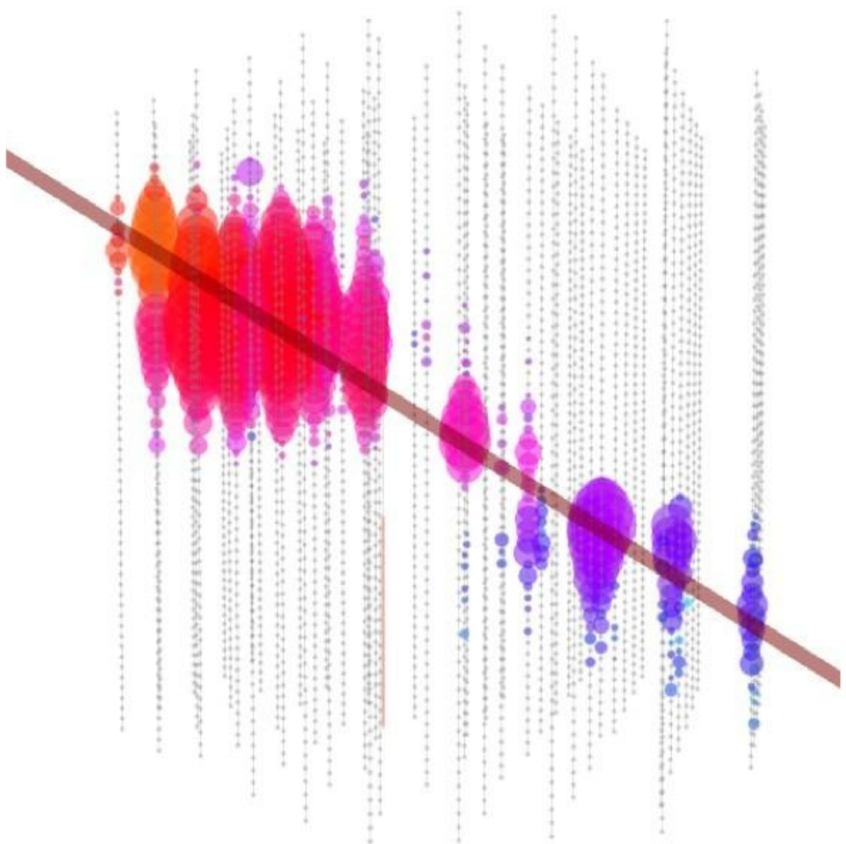


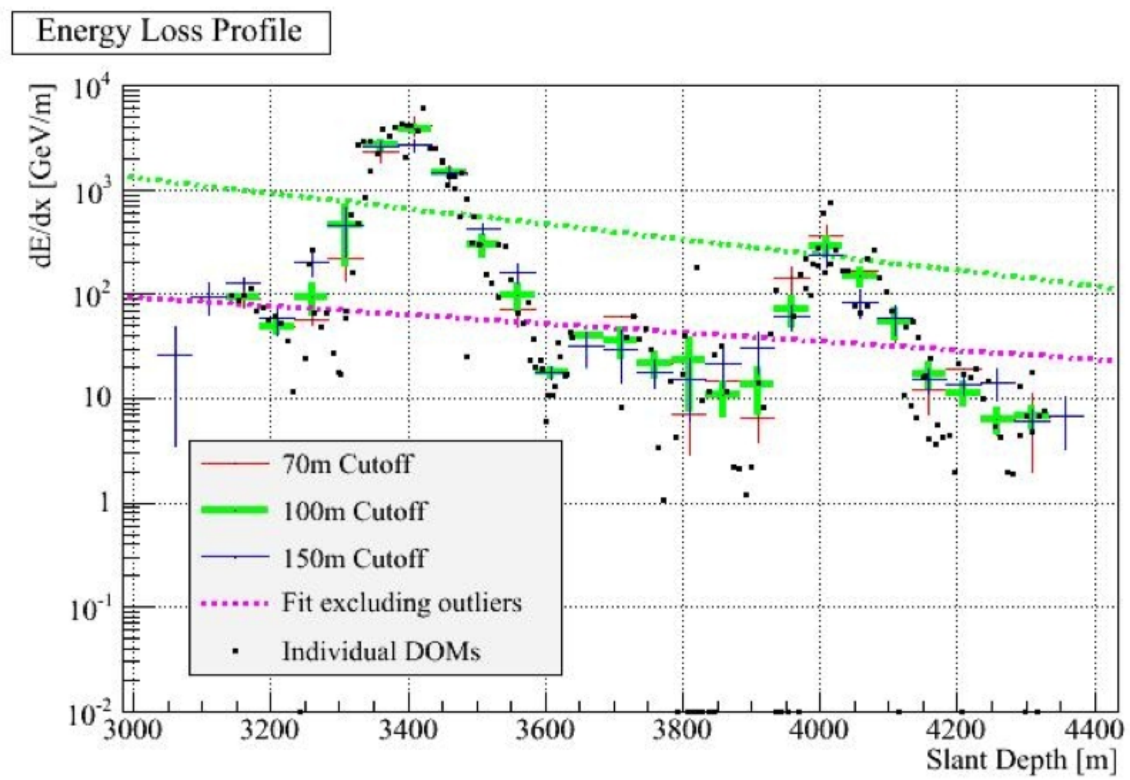


- Smooth energy loss profile

atmospheric neutrinos
and diffuse fluxes

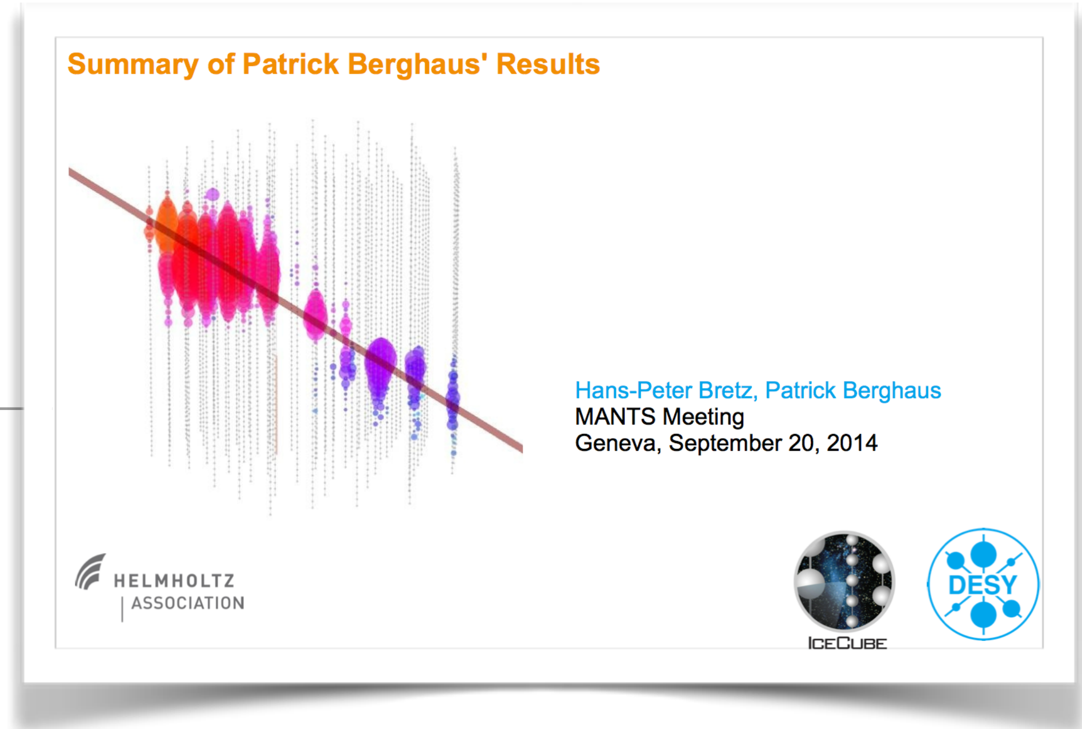


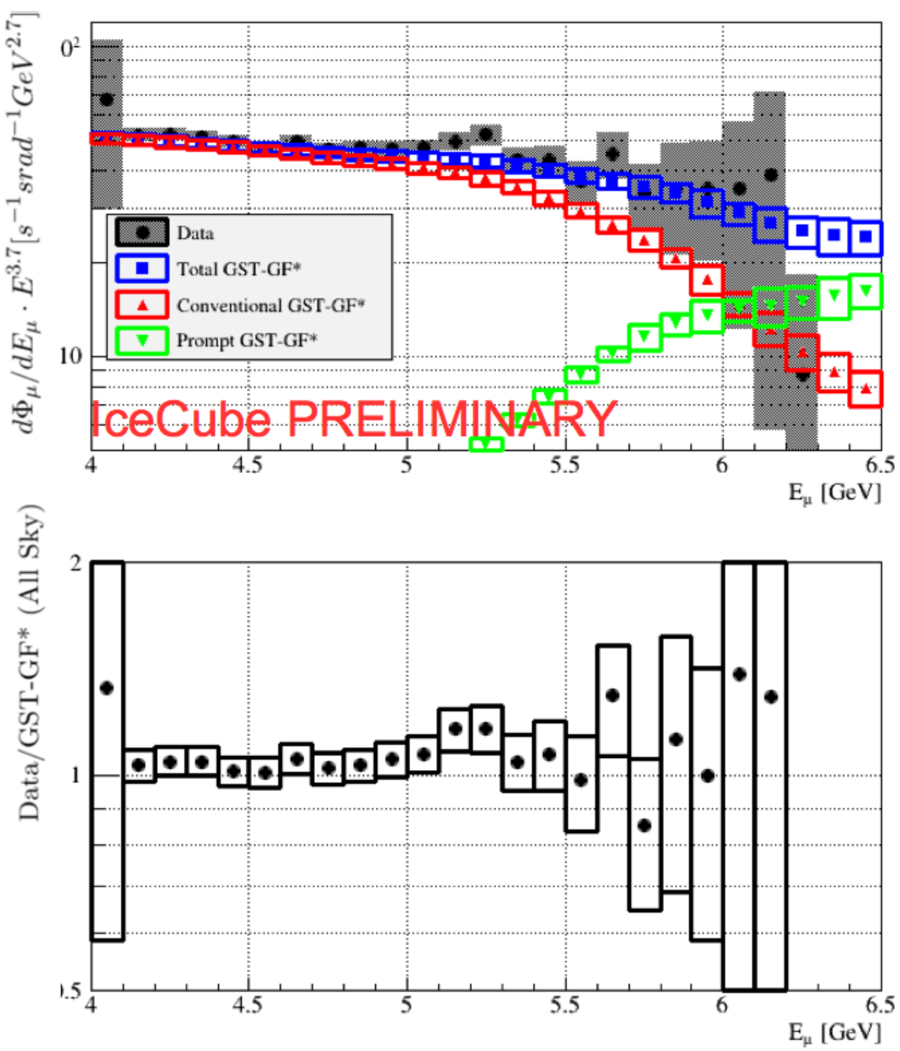




- Big stochastic losses
- Energy loss peaks can be used to distinguish high energy muons from muon bundles

atmospheric neutrinos
and diffuse fluxes



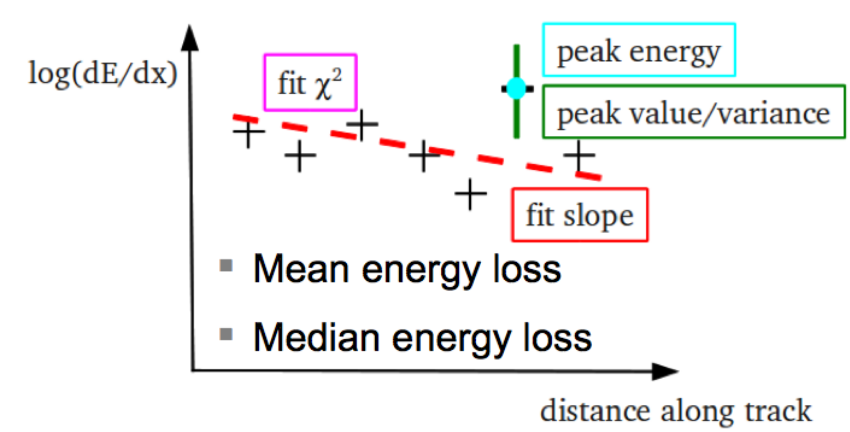


Model	Prompt (ERS)	p-value
GST-GF*	2.04	0.282
Poly-Gonato	7.49	0.149
H3a	8.32	0.075
ZS	7.82	0.014

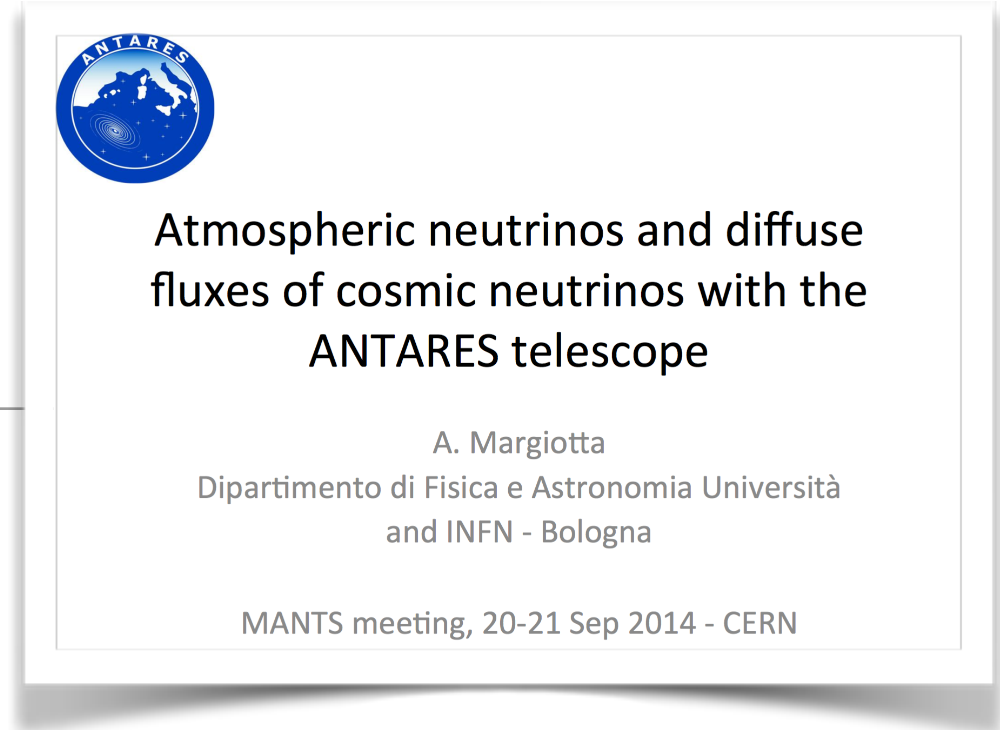
IceCube PRELIMINARY

- Best fit with prompt above neutrino analysis limits
- Some primary cosmic ray flux models favor high prompt contribution

GST-GF* (Gaisser et al.) arXiv:1303.3565



atmospheric neutrinos
and diffuse fluxes

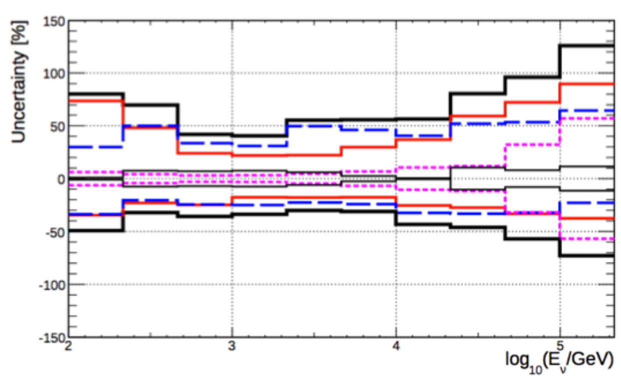

Atmospheric neutrinos and diffuse fluxes of cosmic neutrinos with the ANTARES telescope

A. Margiotta
Dipartimento di Fisica e Astronomia Università and INFN - Bologna

MANTS meeting, 20-21 Sep 2014 - CERN

- determination of atmospheric ν_μ spectrum
- 2 independent energy estimators & unfolding techniques

Systematic uncertainties



OM efficiency (+/- 10%)

water absorption length (+/- 10%)

statistical uncertainties

total uncertainties

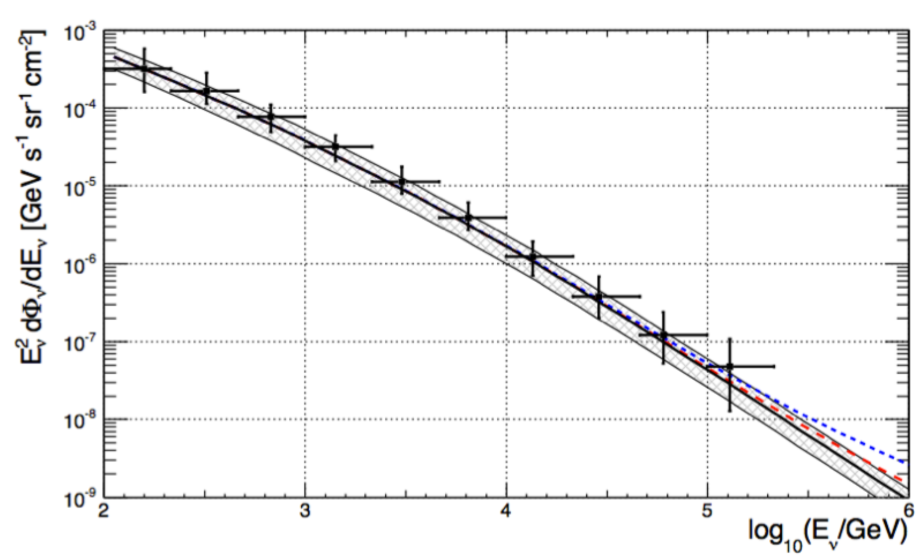
relative difference between unfolding methods

Bartol normalization + prompt contributions

A. Martin et al. - 2003

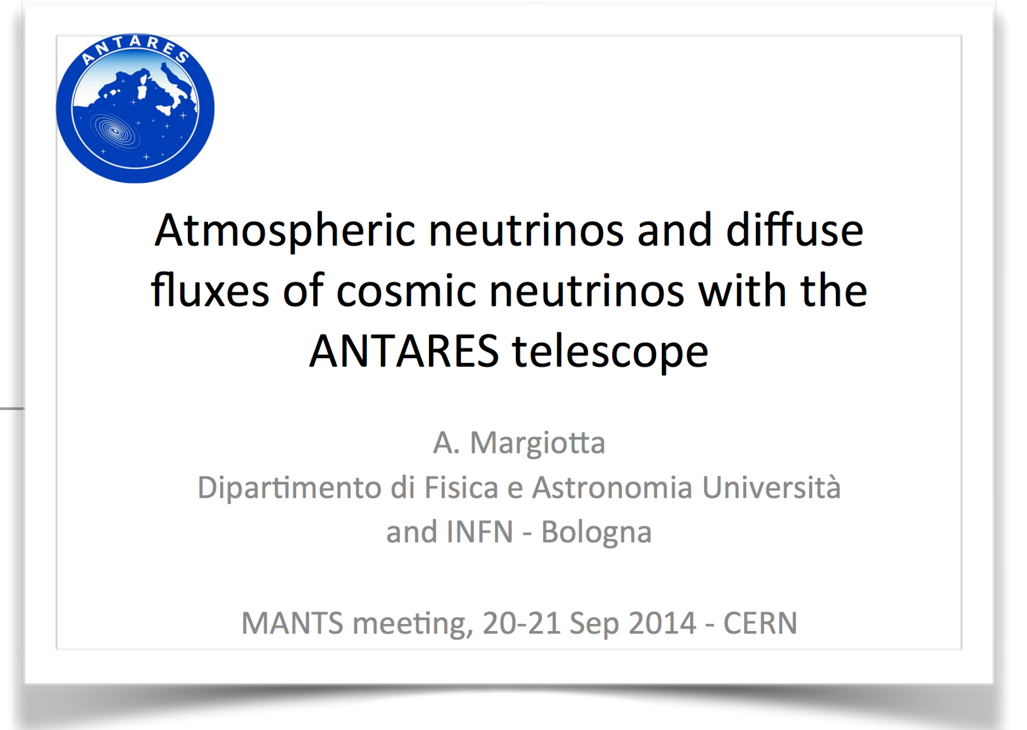
R. Engberg et al. - 2008

Barr et al. – 2004

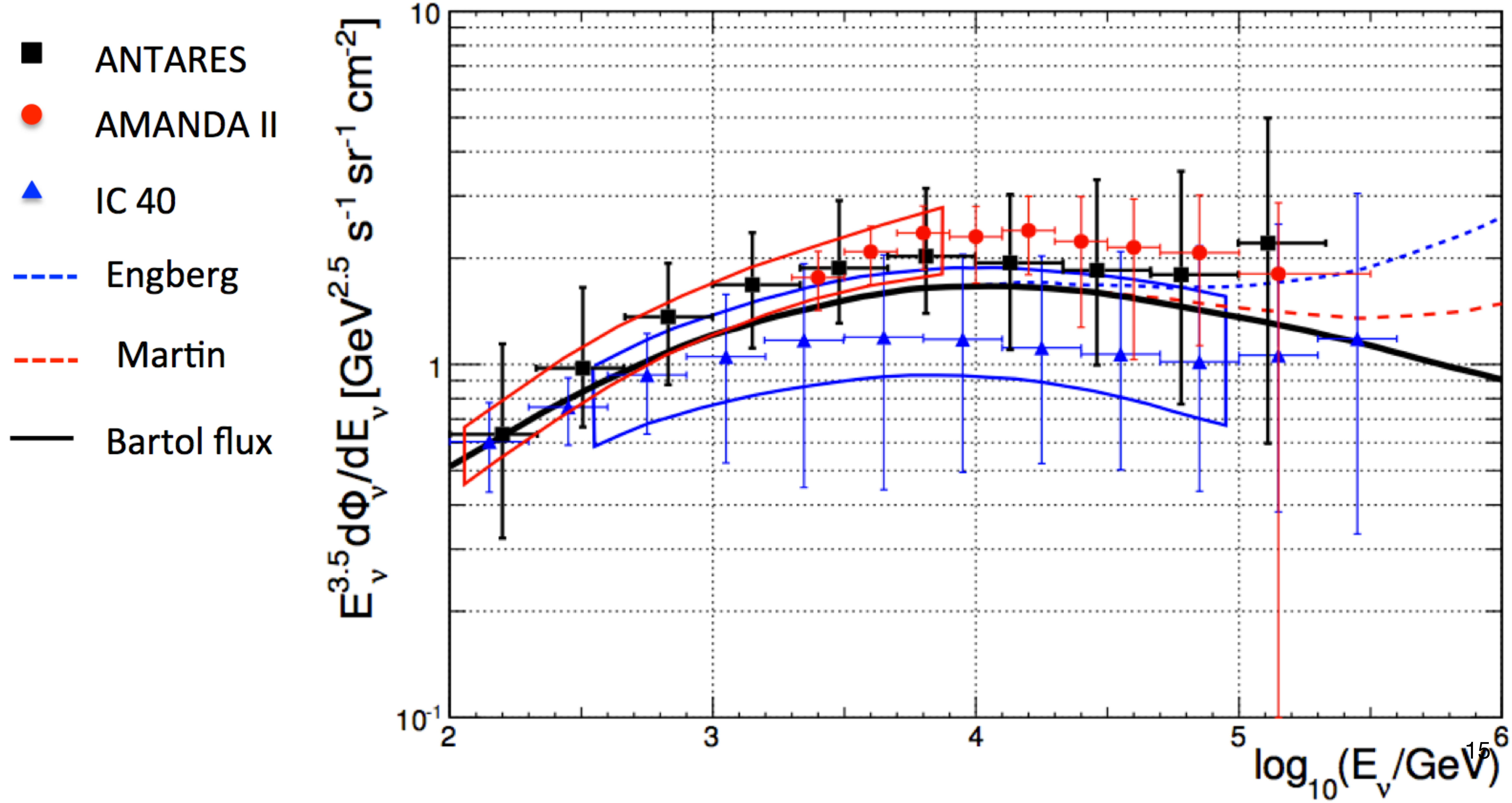


Adrian-Martinez et al.
Eur. Phys. J. C 73, 2006, 2013

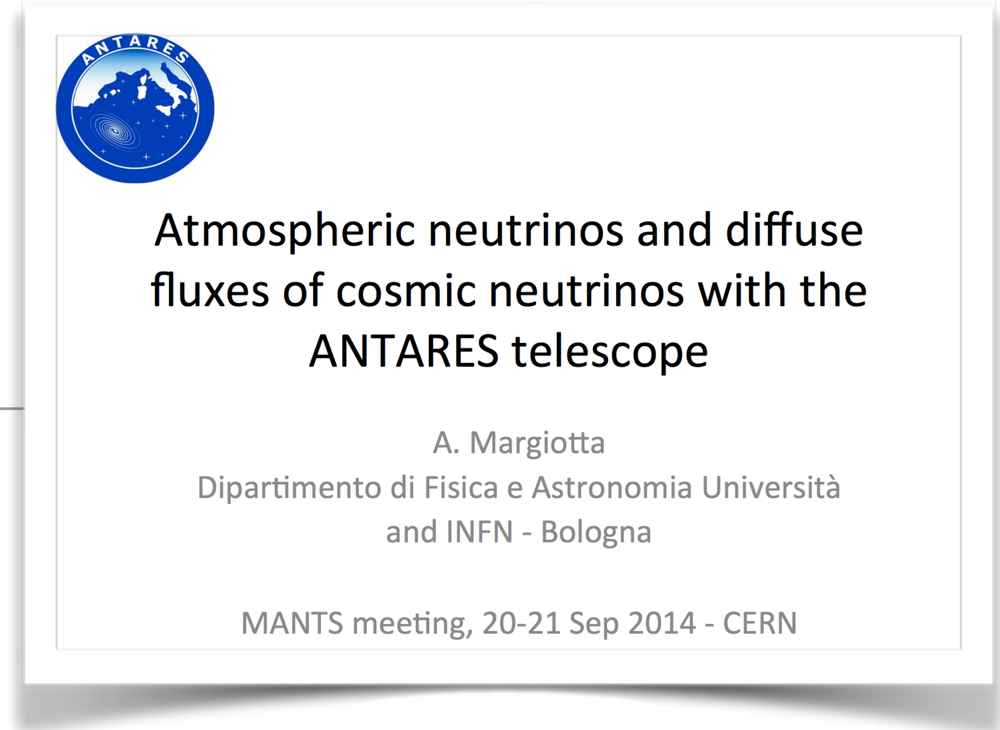
atmospheric neutrinos
and diffuse fluxes



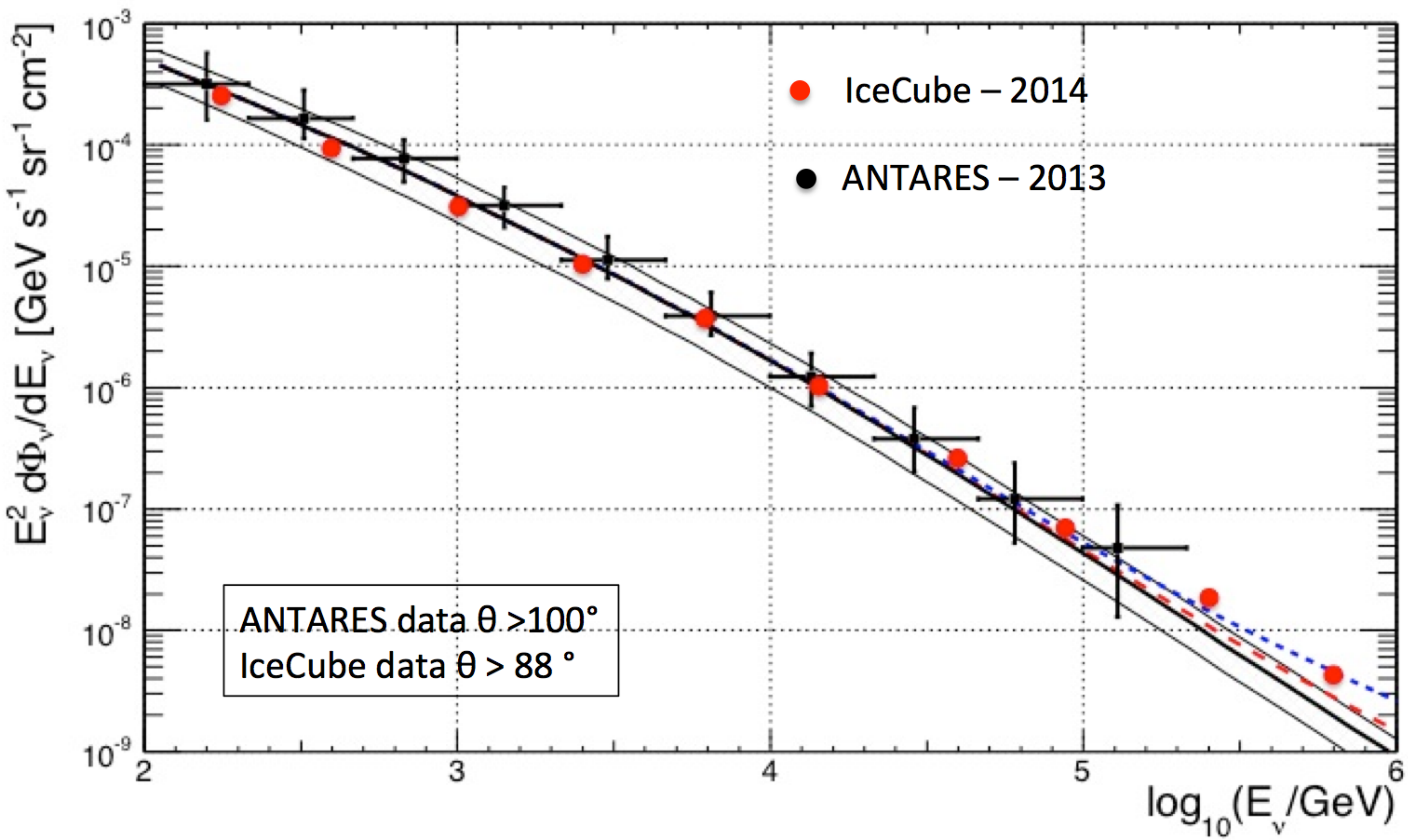
Adrian-Martinez et al.
Eur. Phys. J. C 73, 2006, 2013



atmospheric neutrinos
and diffuse fluxes

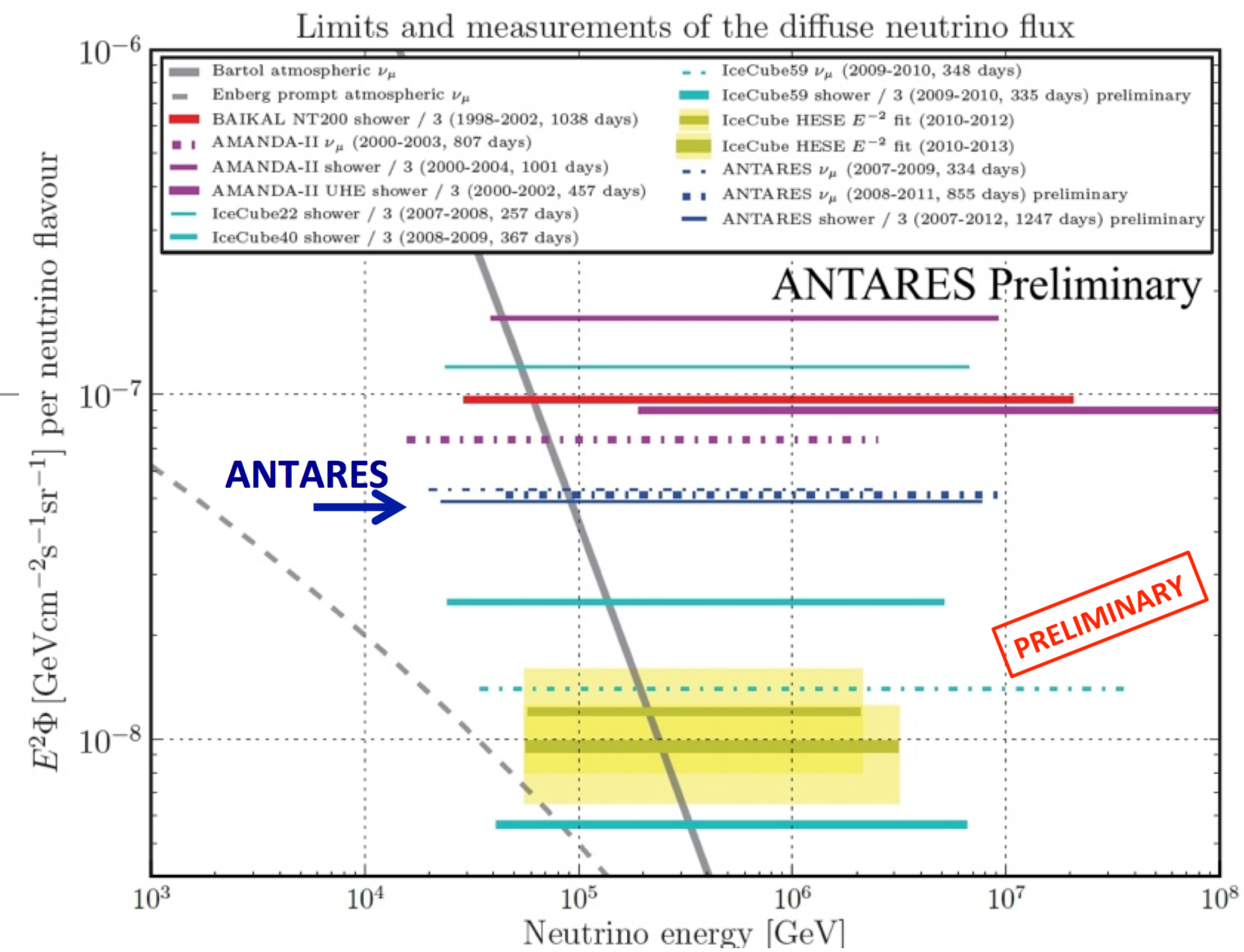


preliminary comparison with IC59



atmospheric neutrinos
and diffuse fluxes

3 years still to analyze will improve sensitivity



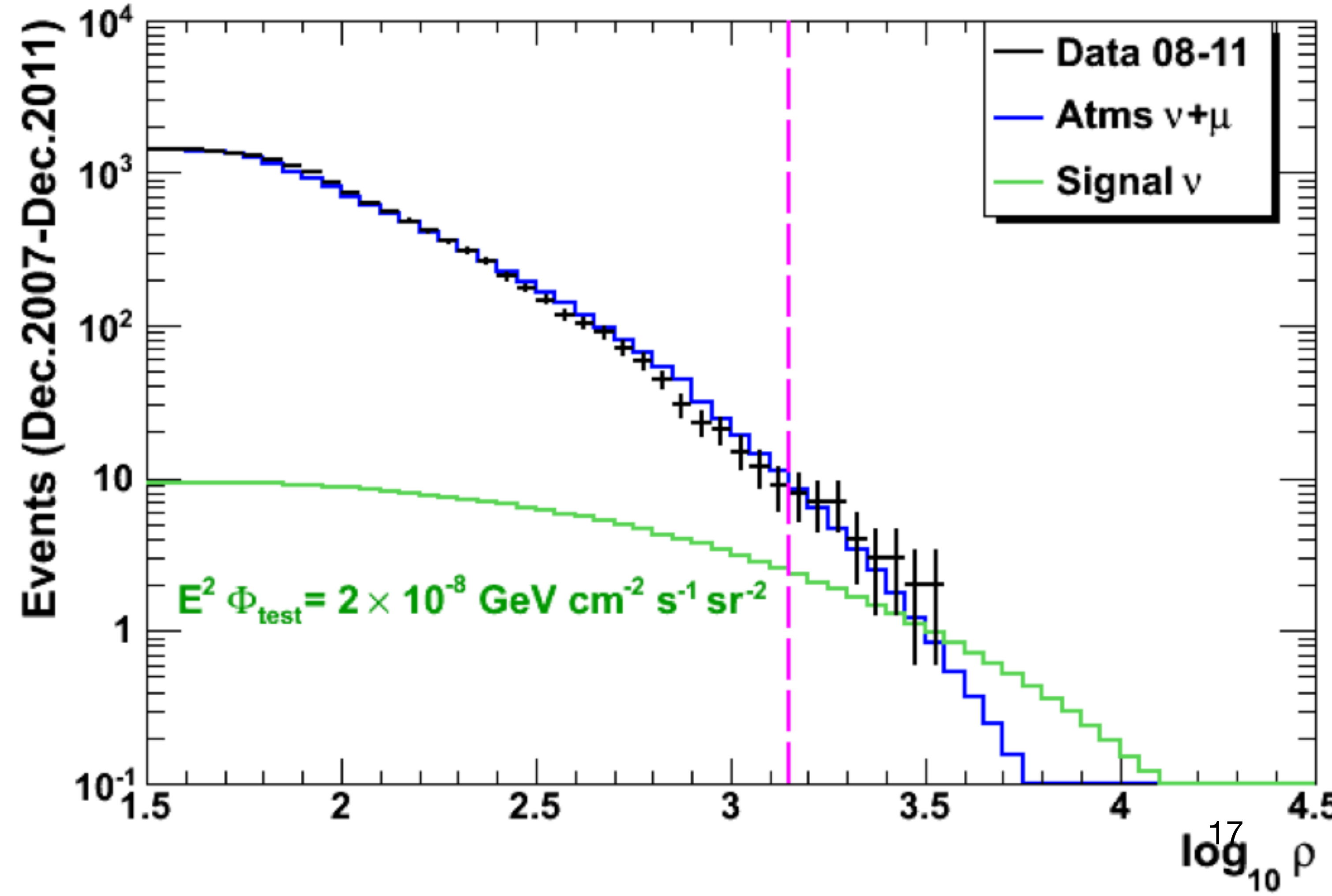
- Sensitivity :

$E^2\,\Phi_{90\%} = 4.7 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

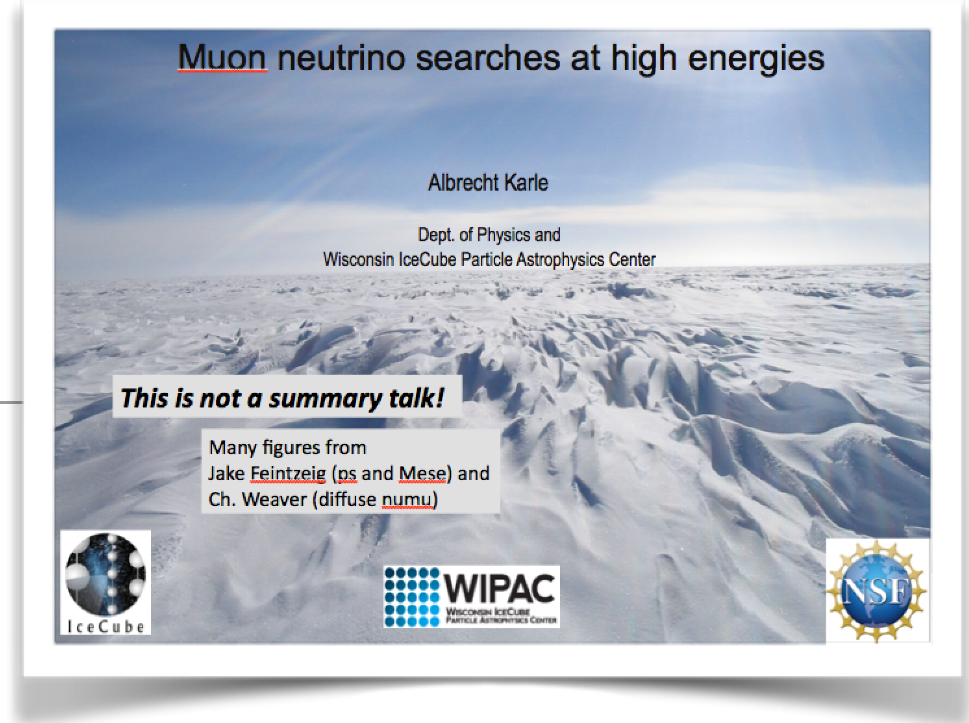
- $N_{bkg} = 8.4$; $N_{obs} = 8$

- Upper limit (45 GeV - 10 PeV) systematic included :

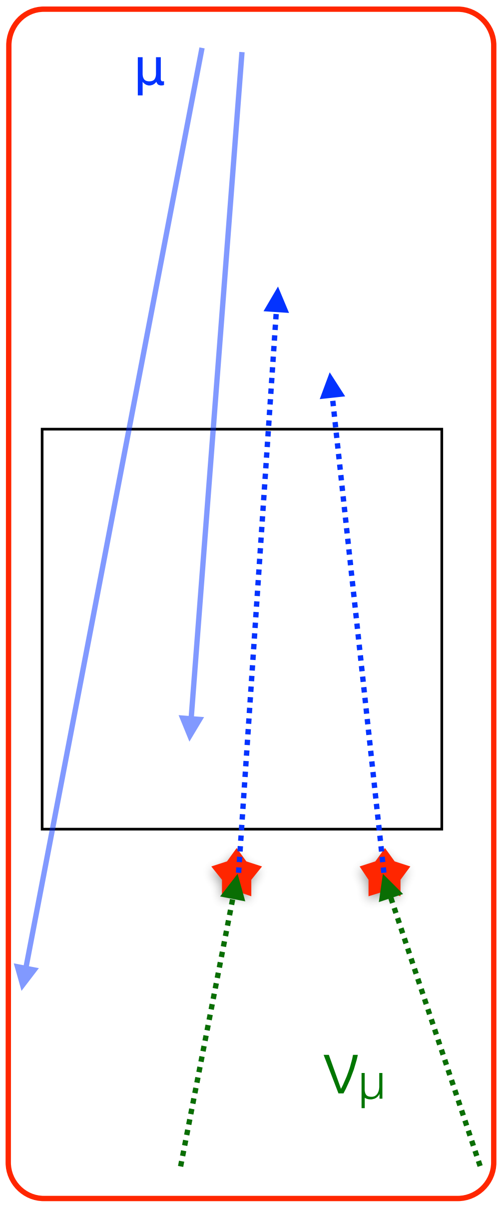
$E^2\,\Phi_{90\%} = 5.1 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

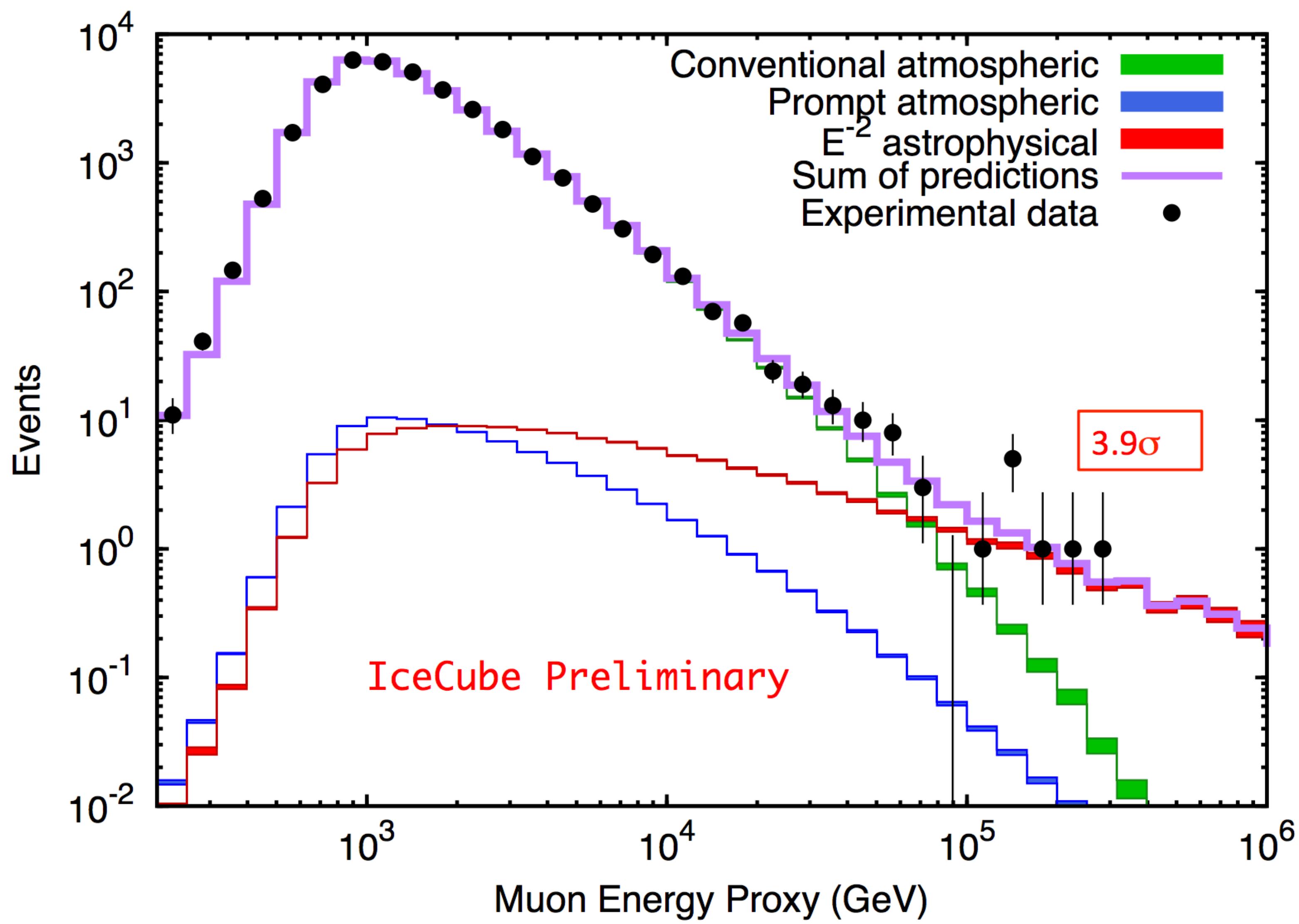


atmospheric neutrinos
and diffuse fluxes

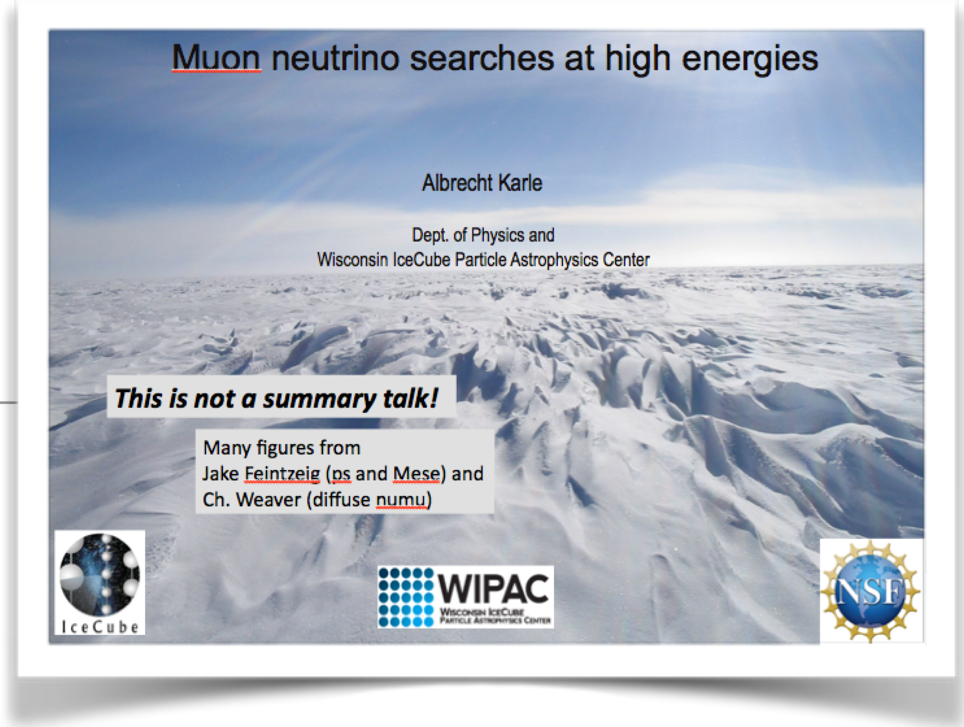


through-going

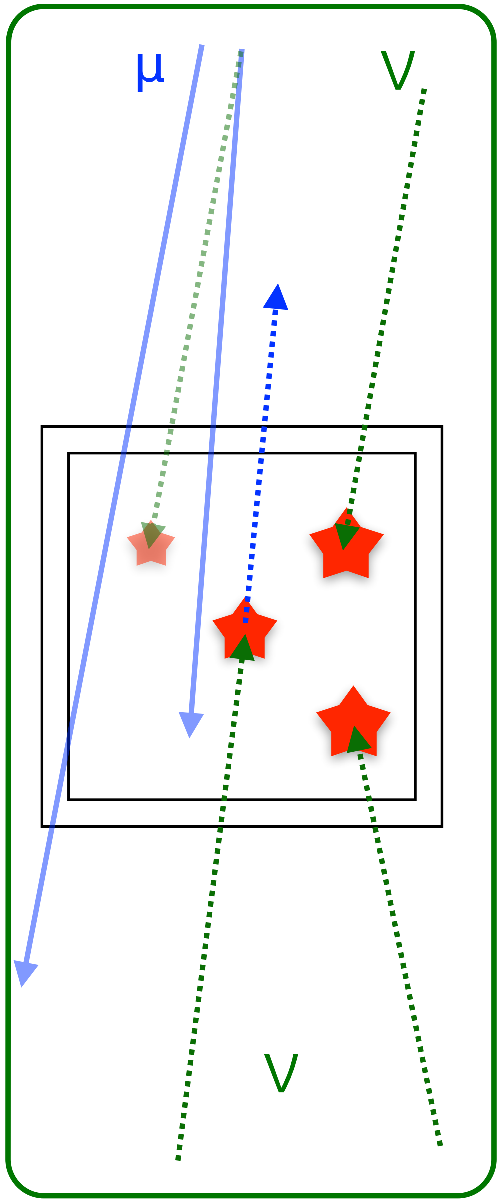


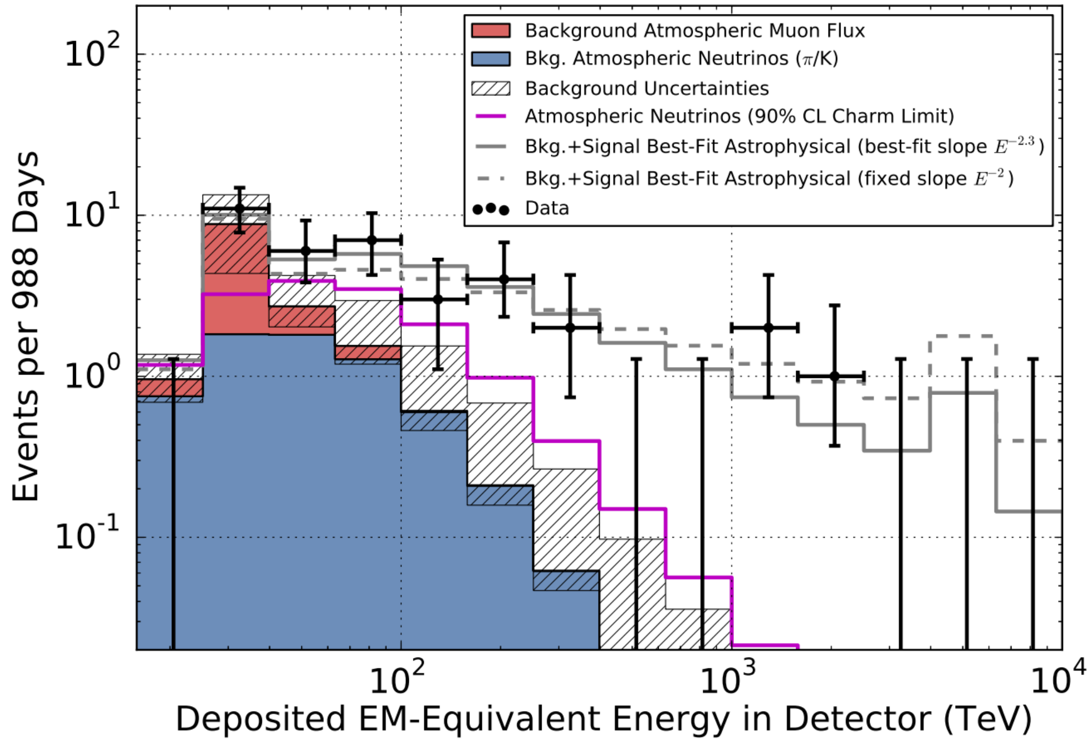


atmospheric neutrinos
and diffuse fluxes



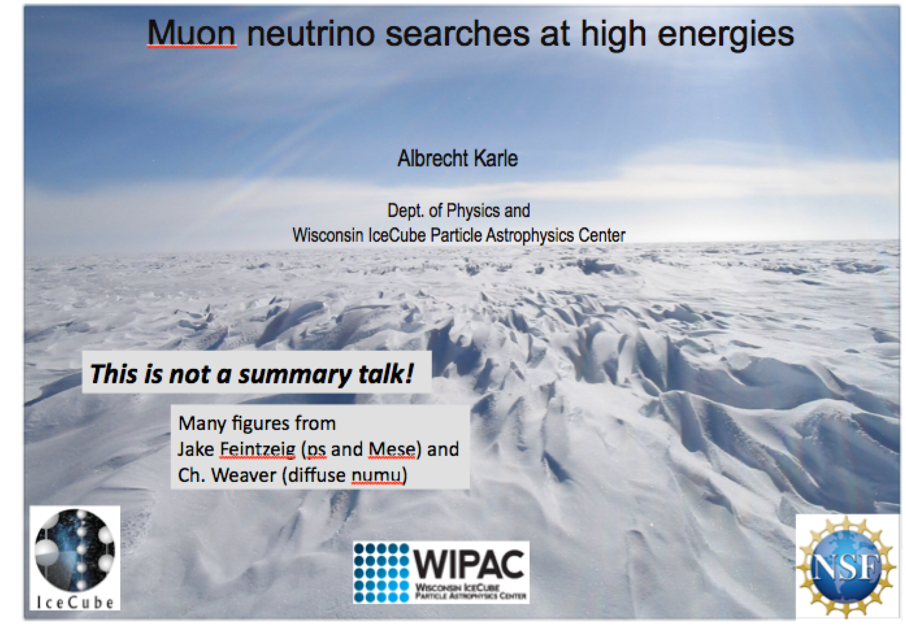
starting events
self veto



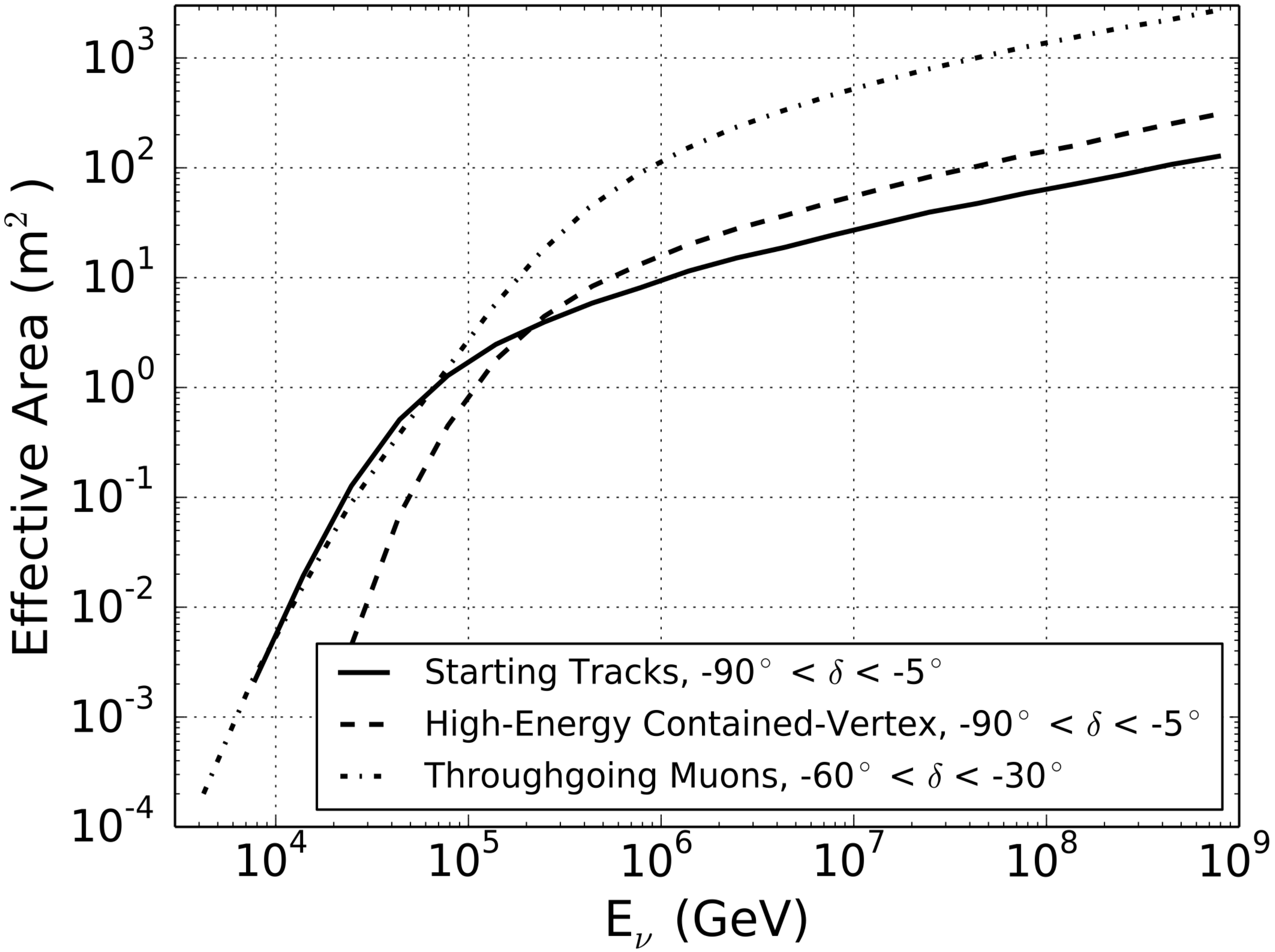


→ lower energy threshold

atmospheric neutrinos
and diffuse fluxes

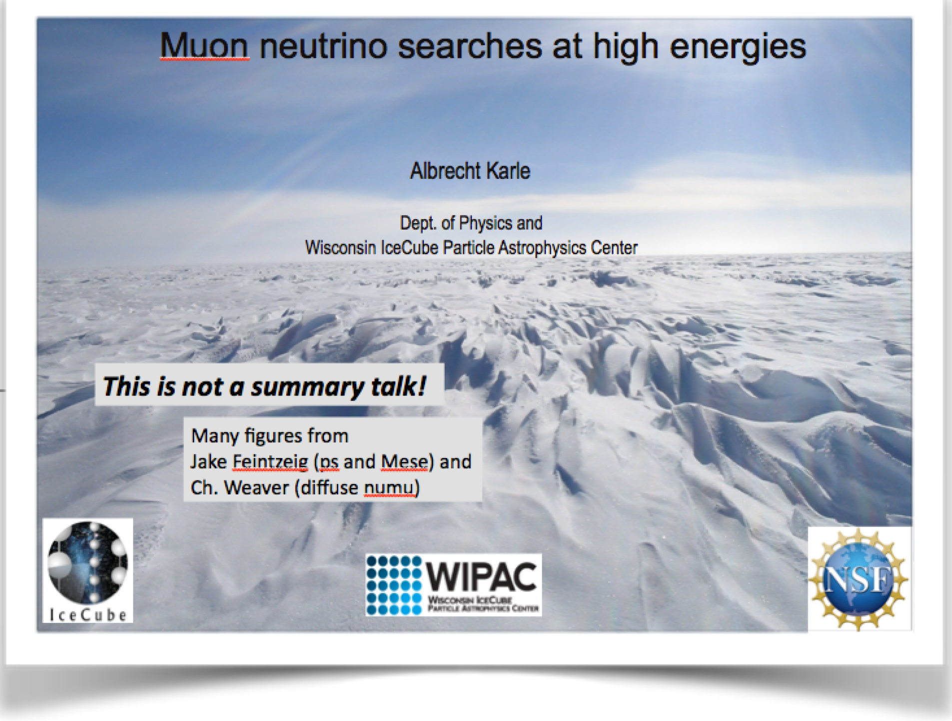


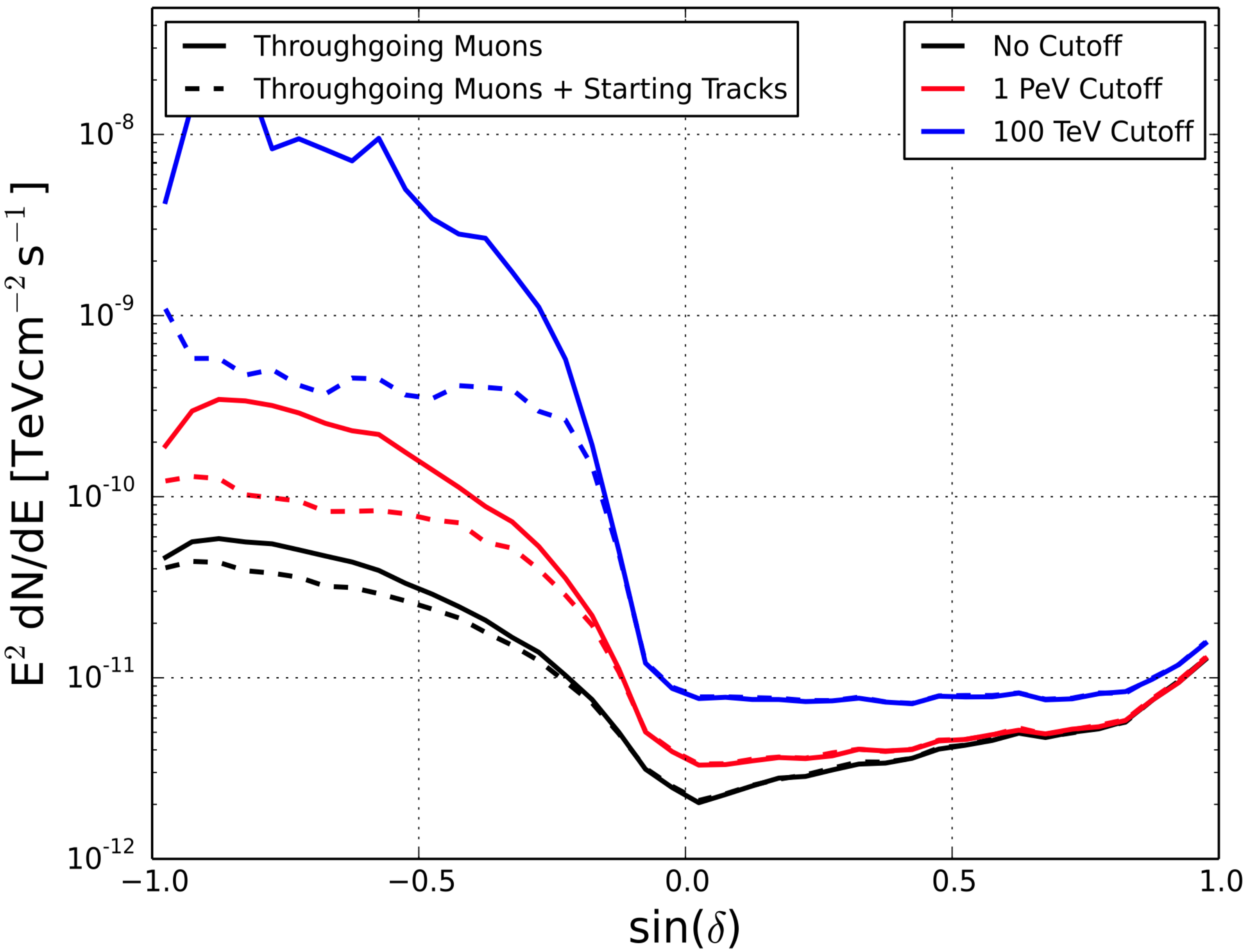
Medium Energy Starting Events - MESE



atmospheric neutrinos
and diffuse fluxes

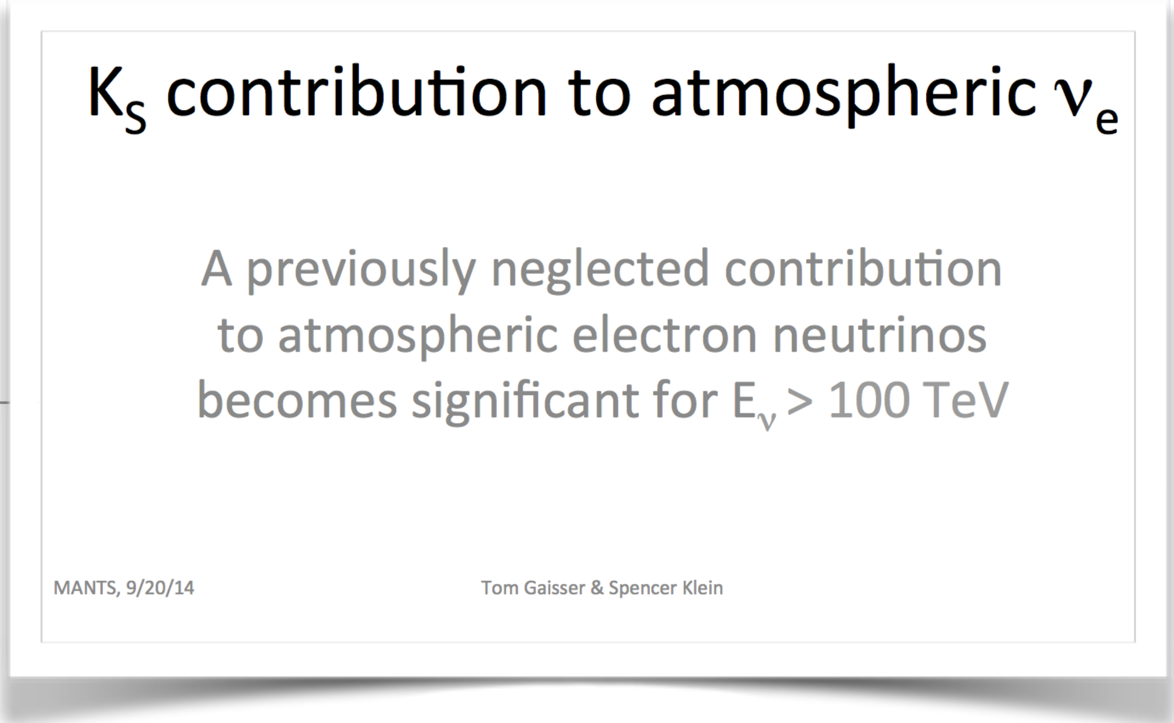
Data Stream	Livetime (days)	Dates
Throughgoing Muon	1372.4	4/2008 – 5/2012
Starting Track	988.5	5/2010 – 5/2013



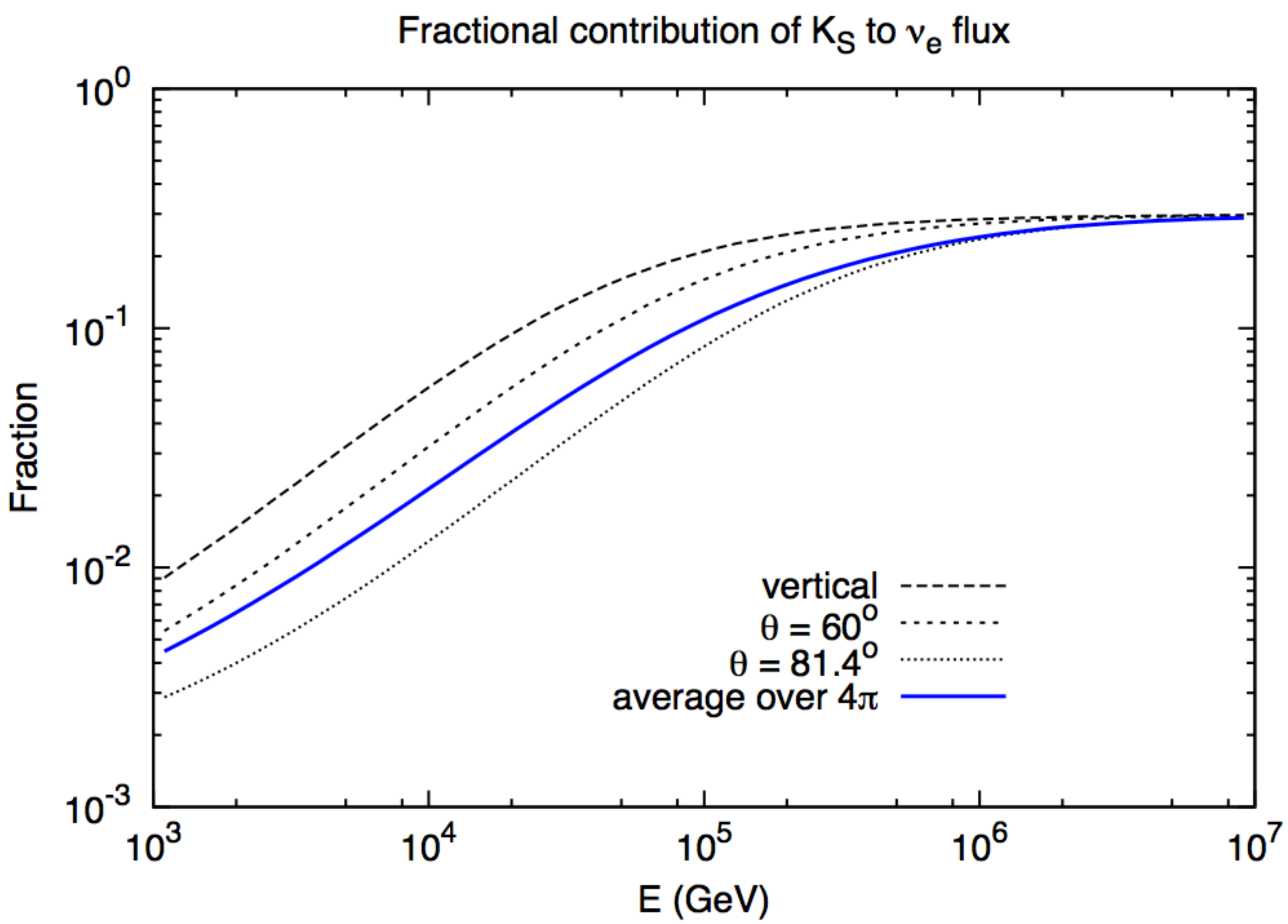


sensitivity **improvement** in northern hemisphere (up-going) with MESE event selection

atmospheric neutrinos
K short

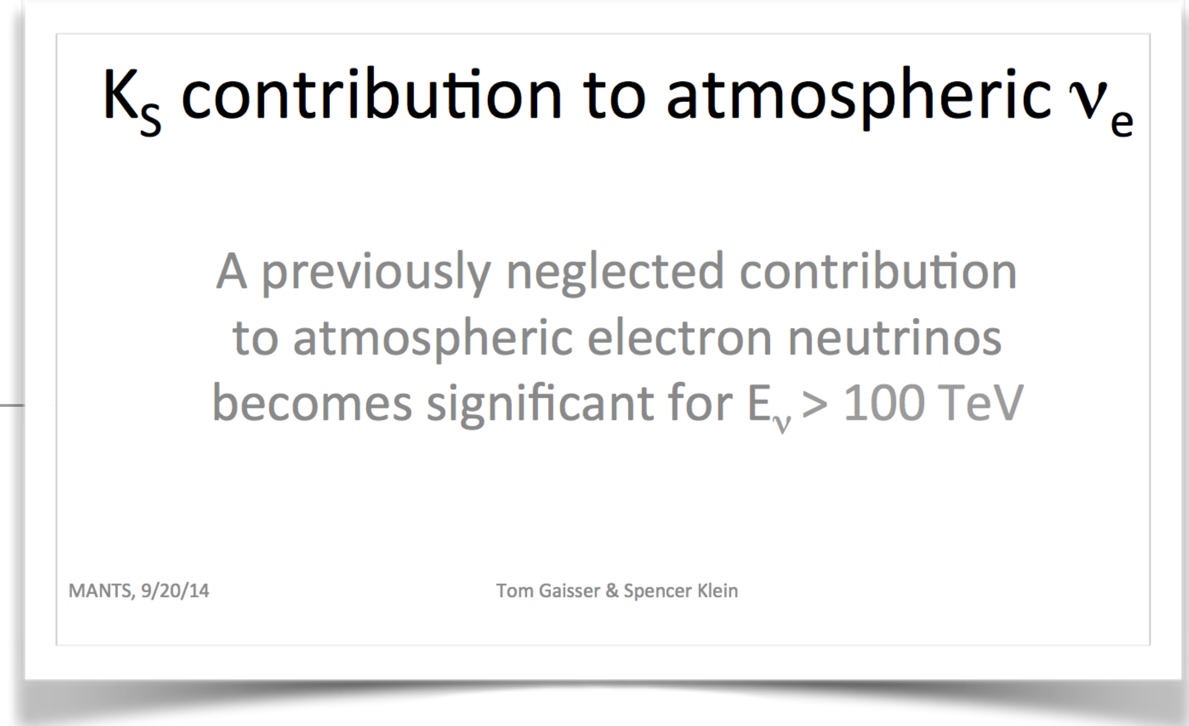


- Ks is usually neglected
- however it contributes to ν_e flux > 100 TeV: needs to be accounted for

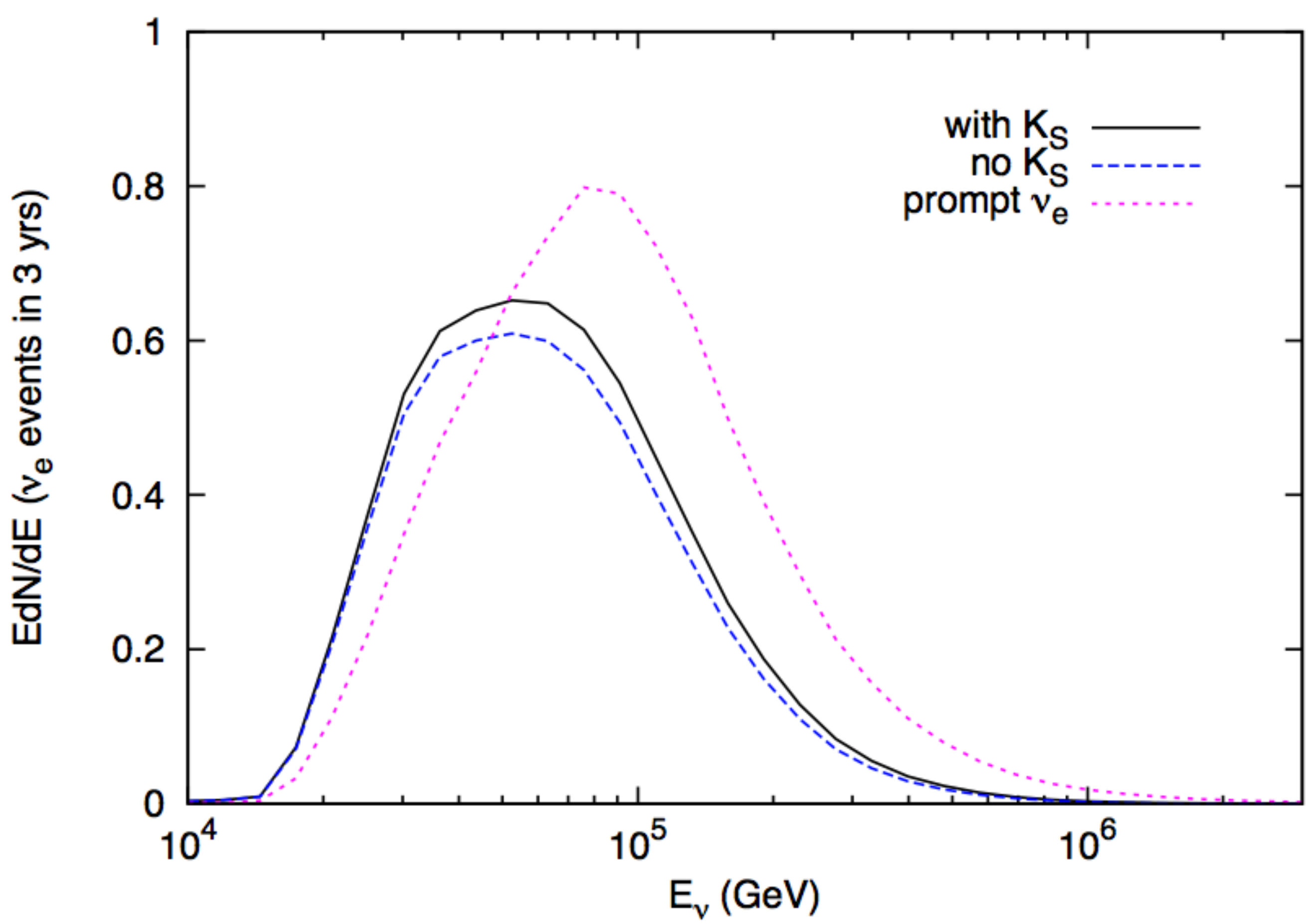


arXiv:1409.4924

atmospheric neutrinos
K short



- +<10% contribution to conventional ν_e
- flux is already small in the @100 TeV: 0.96 → 1.05 3 years of HESE sample
- neutrino/anti-neutrino ratio depends on energy

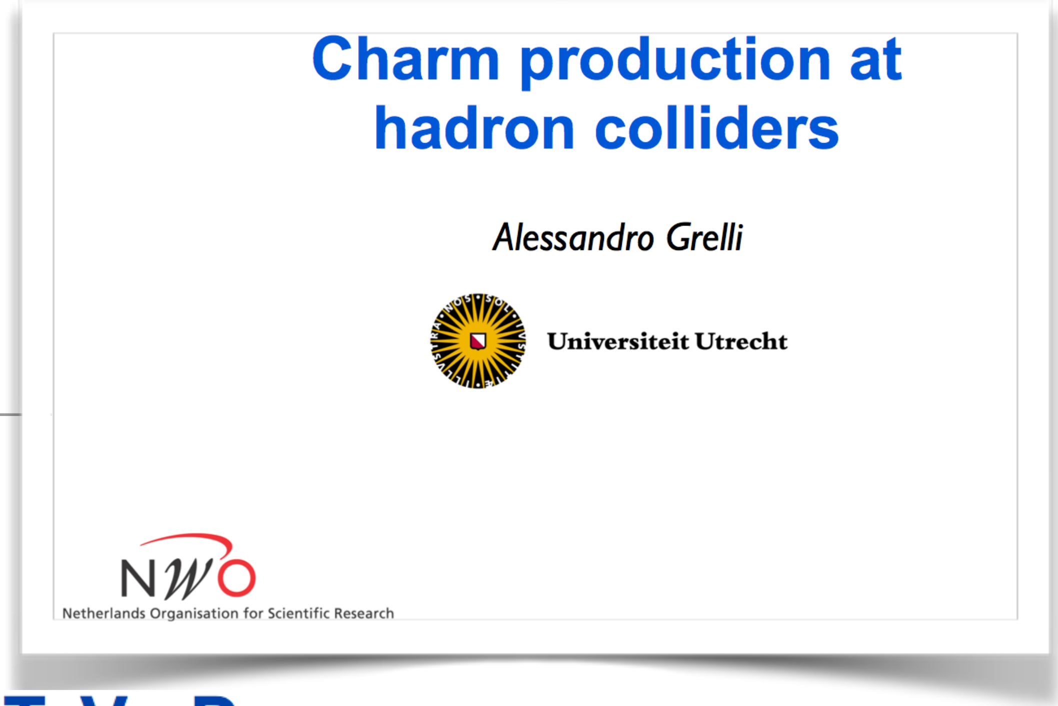


arXiv:1409.4924

atmospheric neutrinos

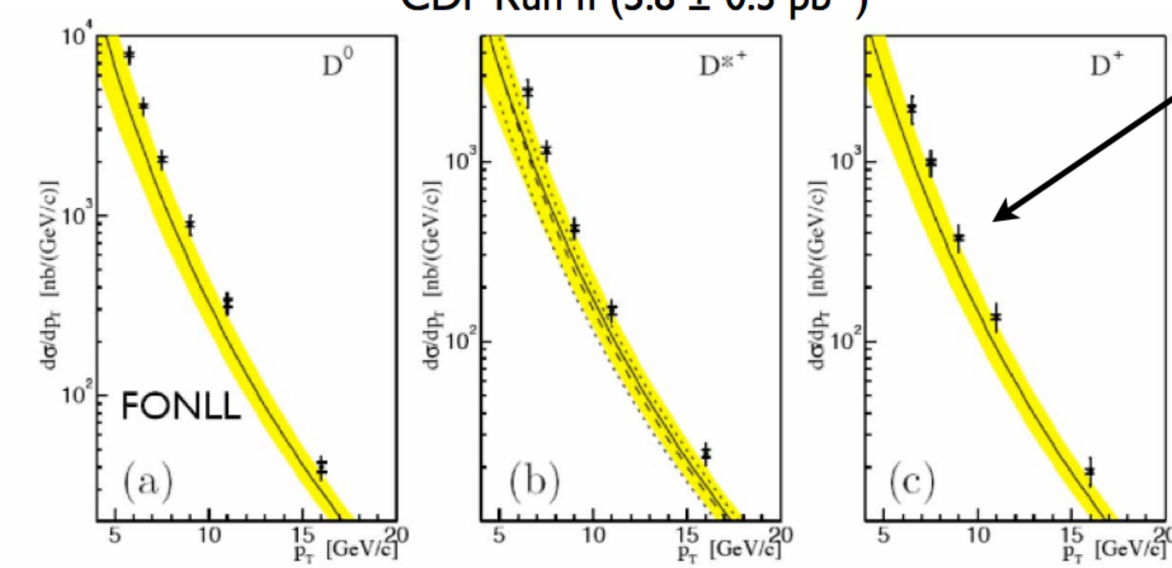
charm production in colliders

- pQCD + nuclear effects
- non-perturbative QCD & intrinsic charm



Charm at Tevatron in $p\bar{p}$ at $\sqrt{s}$ = 1.96 TeV - D mesons

CDF Run II (5.8 ± 0.3 pb^{-1})



Measurements are at the edge of theoretical uncertainties.

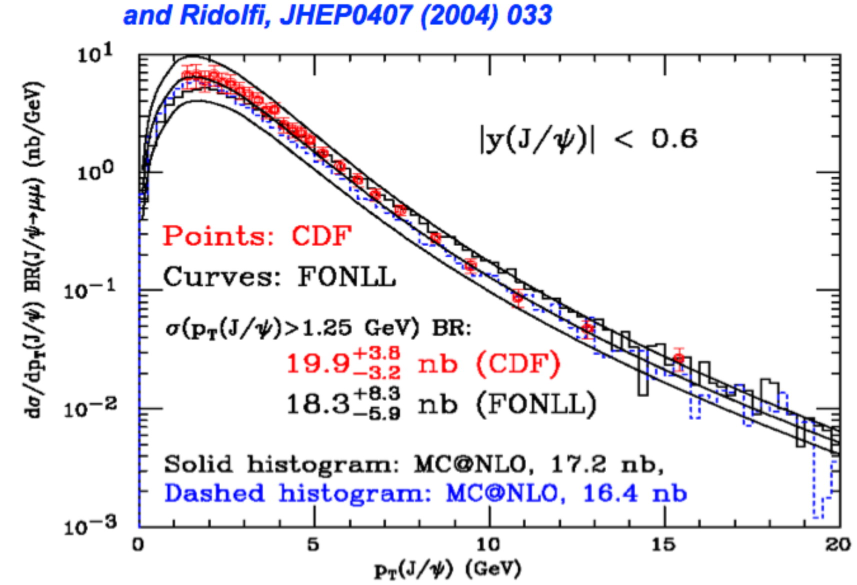
$D^0\,(cu) \rightarrow K^+\pi^-$ (BR ~3.89%),

$D^+\,(cu) \rightarrow K^-\pi^+\pi^+$ (BR ~9.13%),

$D^{*+}(cd) \rightarrow D^0(K^+\pi^-)\pi^+$ (BR~2.63%),

CDF, PRL91 (2003) 241804,
FONLL: M. Cacciari and P. Nason, JHEP 0309, 006 (2003)

FONLL, MC@NLO: Cacciari, Frixione, Mangano, Nason and Ridolfi, JHEP0407 (2004) 033



☑ Good understanding, within the errors, of b production at Tevatron (and LHC energies).

☑ Charm cross section studies, more complex, available since Tevatron Run II.

atmospheric neutrinos
pQCD

Charm production at hadron colliders

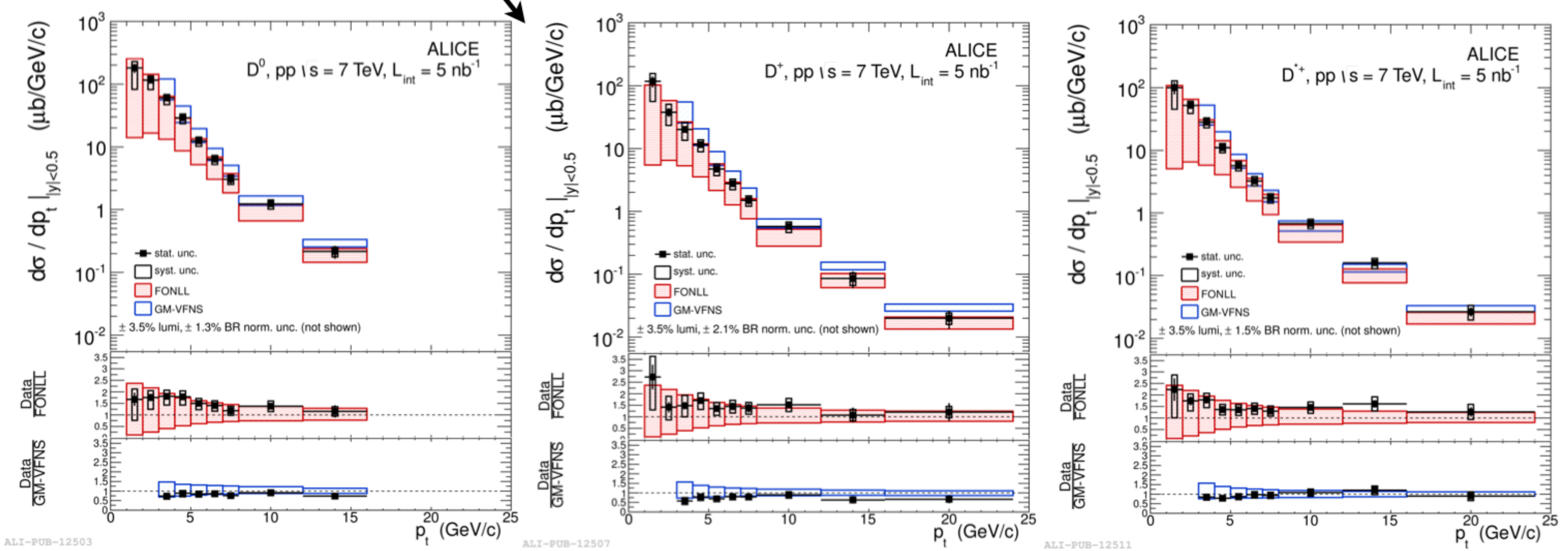
Alessandro Grelli

Universiteit Utrecht

Prompt D meson cross-section at mid-rapidity

D^0, D^+ and D^{*+} cross section at $\sqrt{s} = 7$ TeV, $|y|<0.5$

ALICE



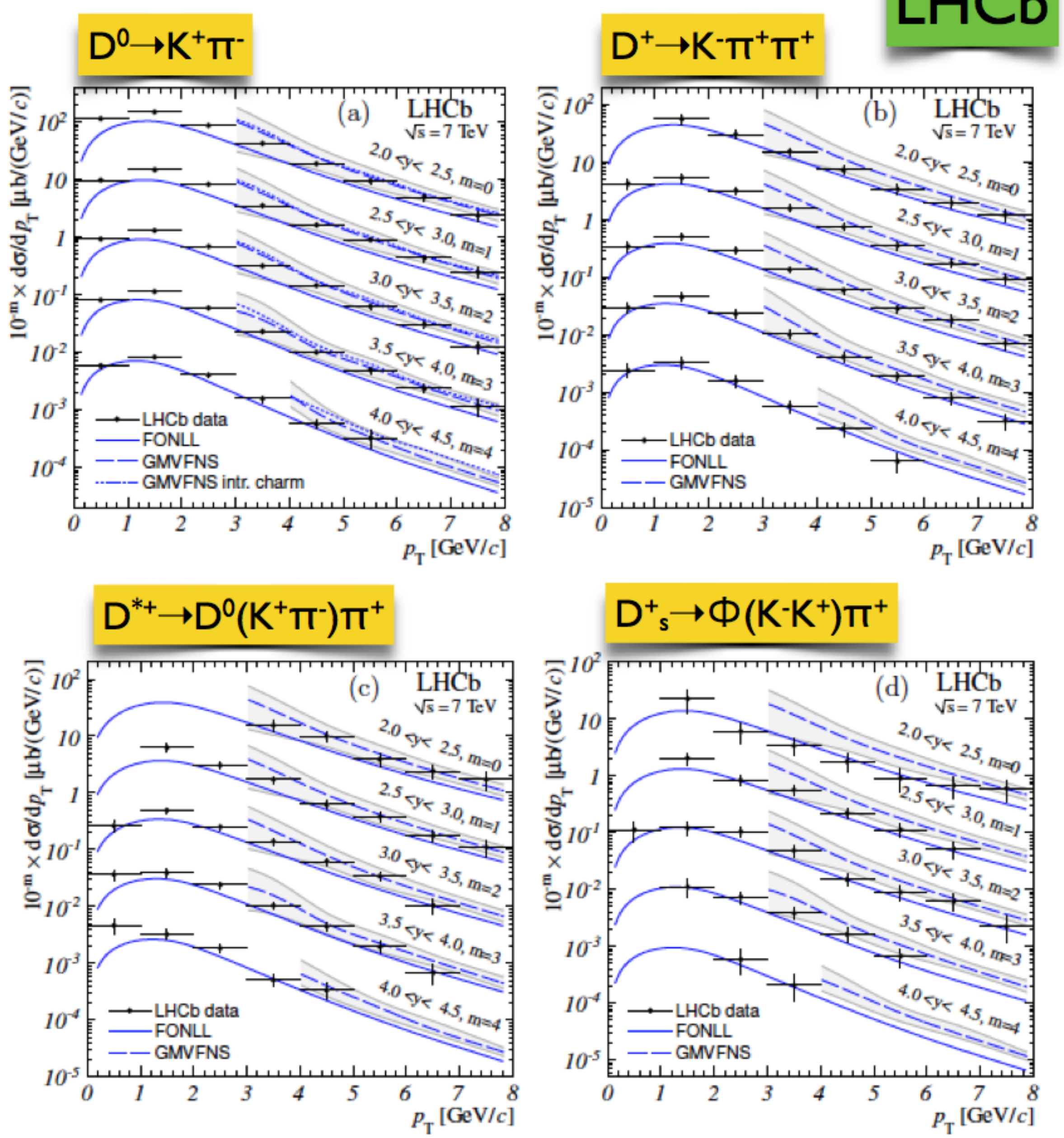
JHEP 1201 (2012) 128

atmospheric neutrinos
pQCD

Prompt D meson cross-section at forward rapidity

- LHCb analyzed D^0, D^+, D^{*+} and D^+_s hadronic decays in a data sample of **15nb^{-1}**
- Differential cross-section $d\sigma/dp_T$ analyzed in bins of pt and rapidity in the rapidity range **2.0<y<4.5**
- Charm cross-section evaluated in **2.0<y<4.5** and extrapolated to the full phase-space

Nuclear Physics, Section B 871 (2013)

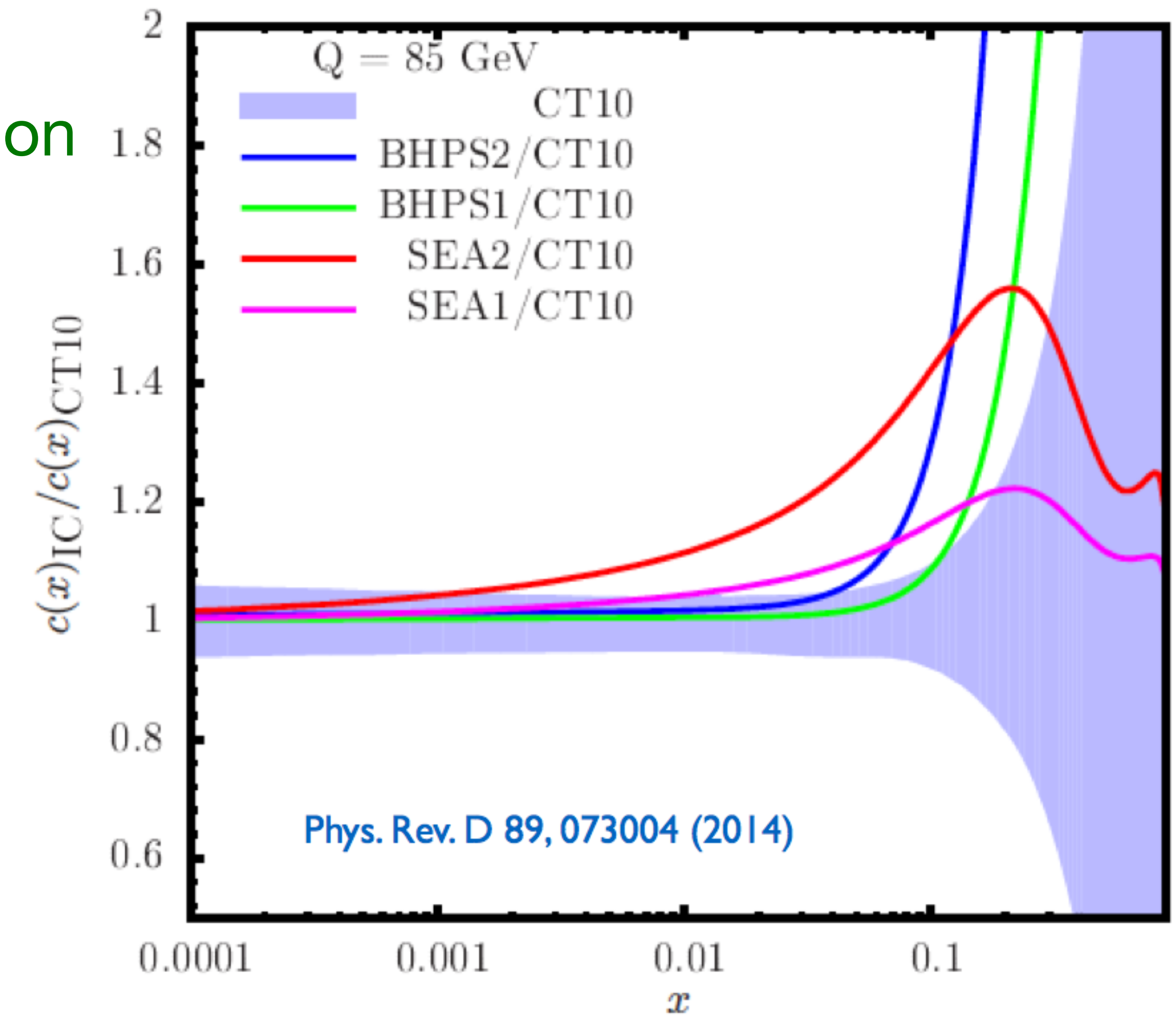


extrapolation to forward region FONLL

atmospheric neutrinos
intrinsic charm

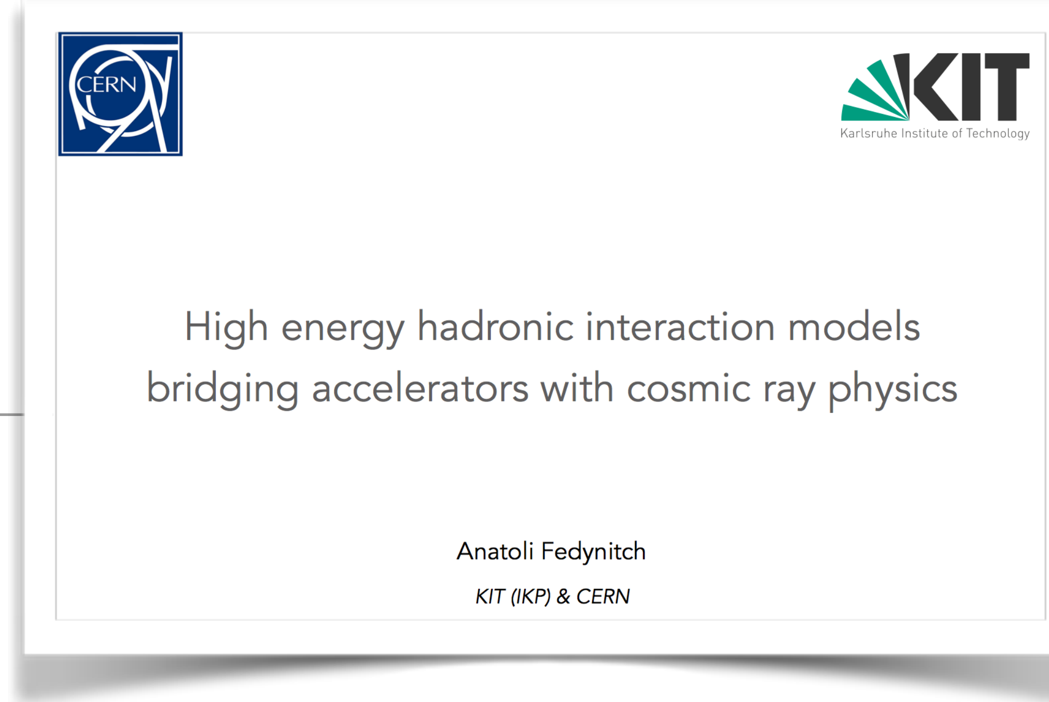
- proposed in 1980 to explain some observations
- virtual c-pair in nucleon: probability ~ 0.5% - 3% (wide range)
- modifications of charm distribution function

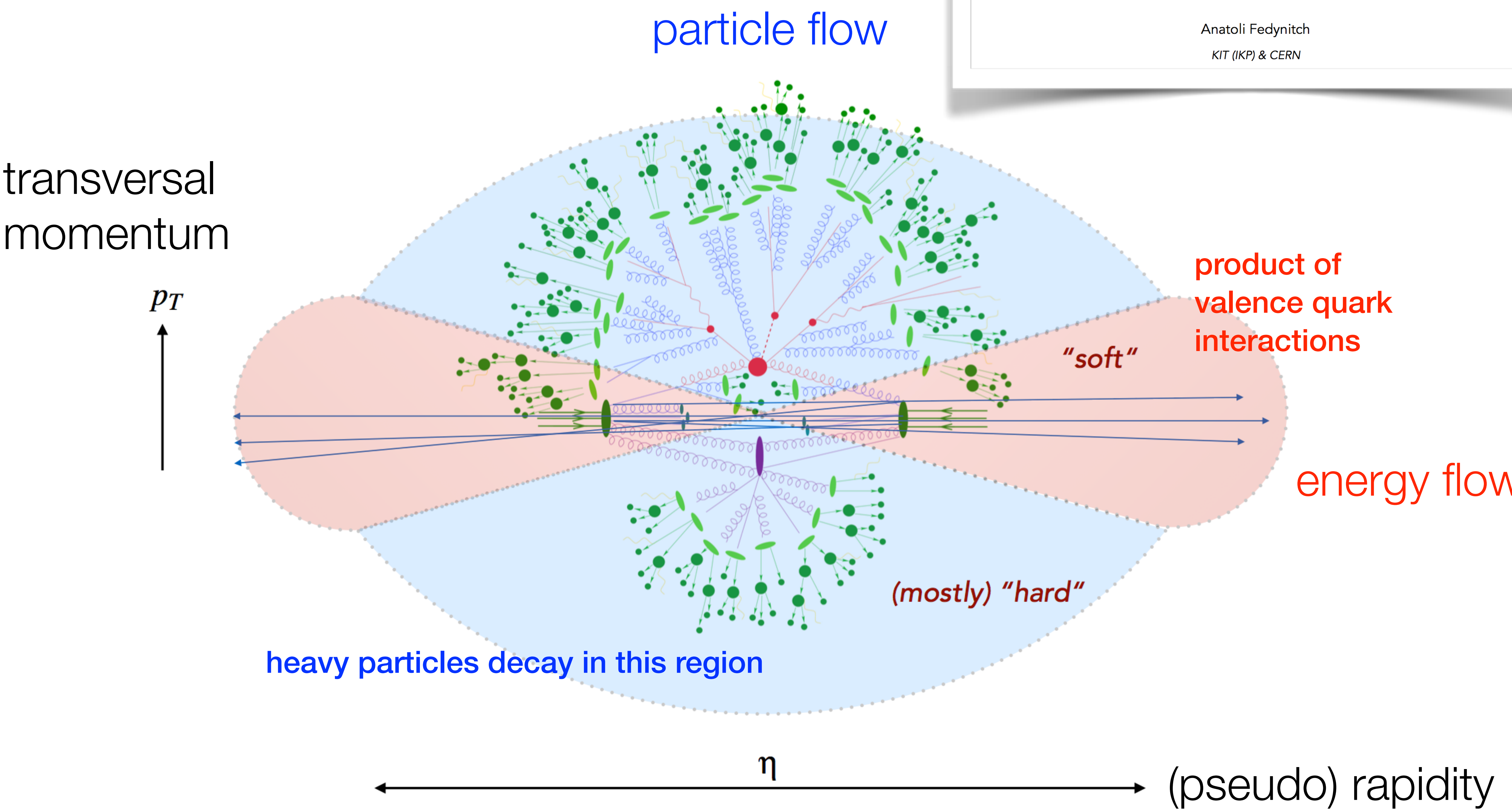
➡ could use new functions to estimate prompt neutrino contribution



atmospheric neutrinos

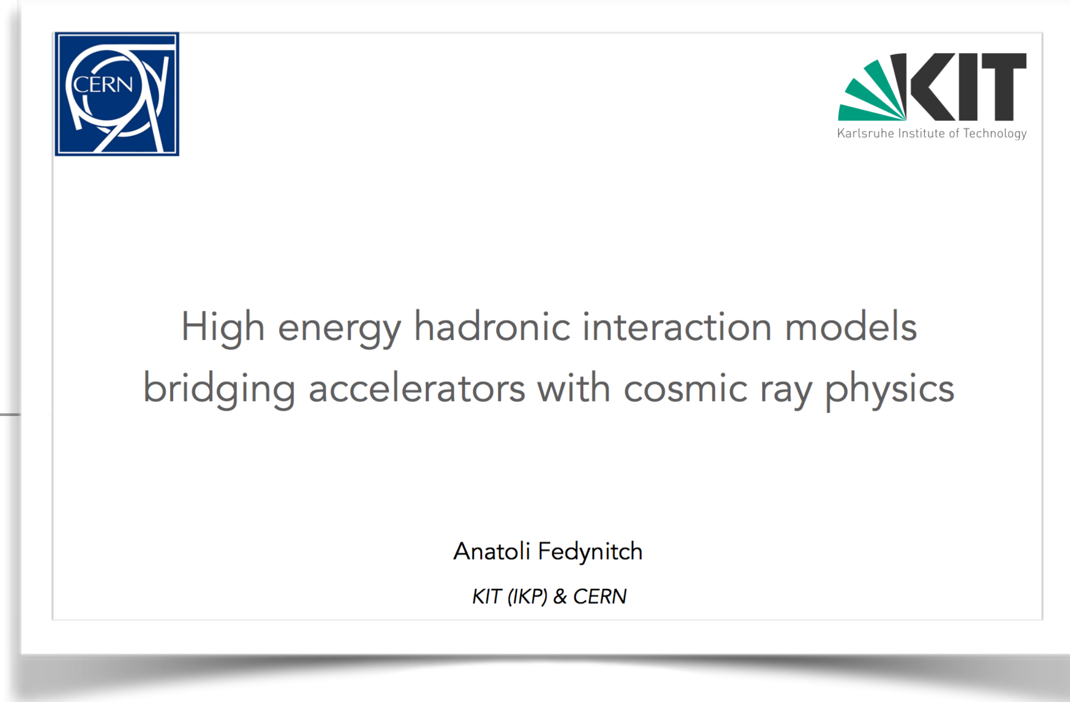
hadronic interaction models





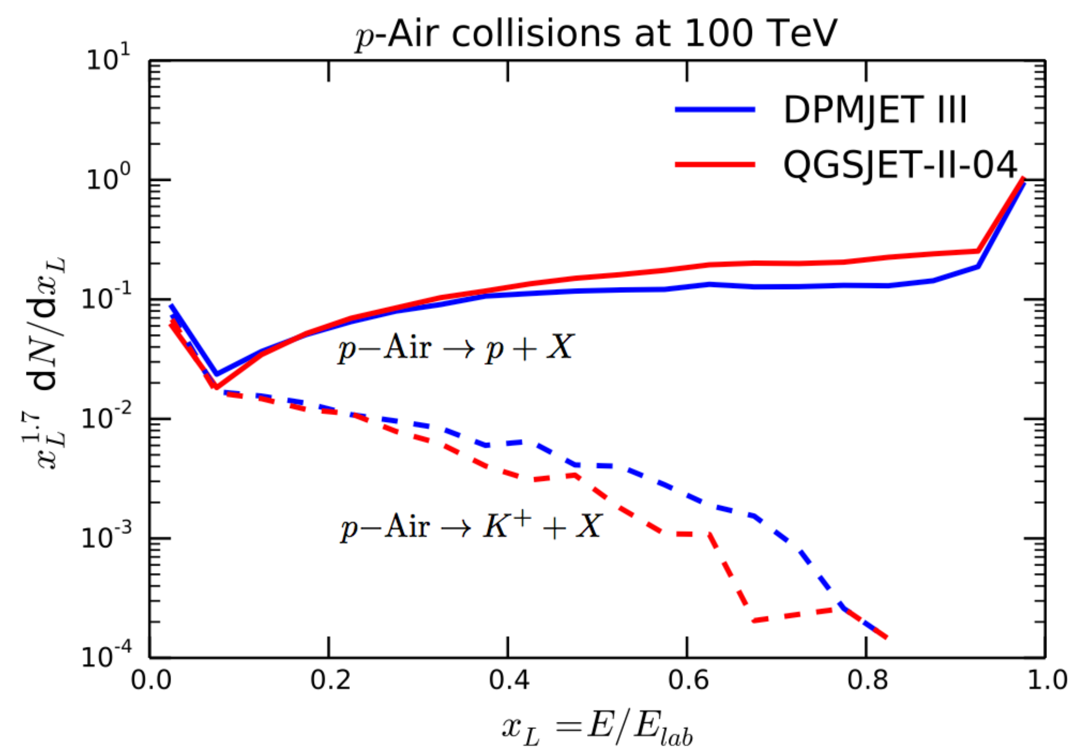
atmospheric neutrinos
hadronic interaction models

- models tuned only to about 10%



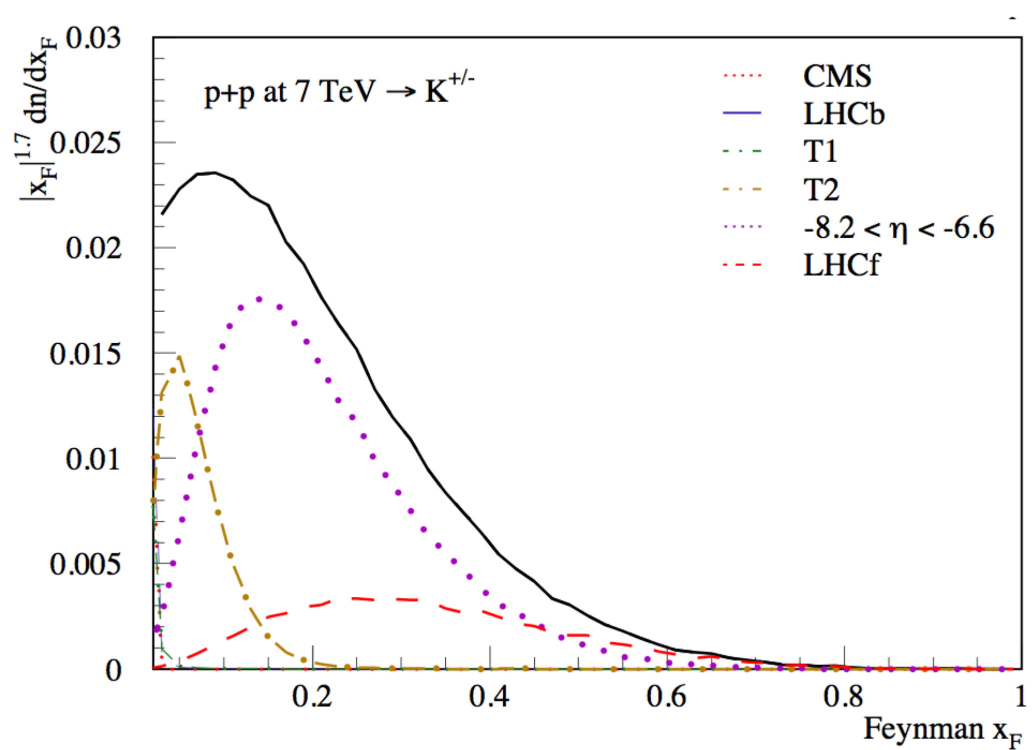
- forward detectors are crucial for **CRs** & **astrophysics**

Tanguy Pierog, ISVHECRI 2014

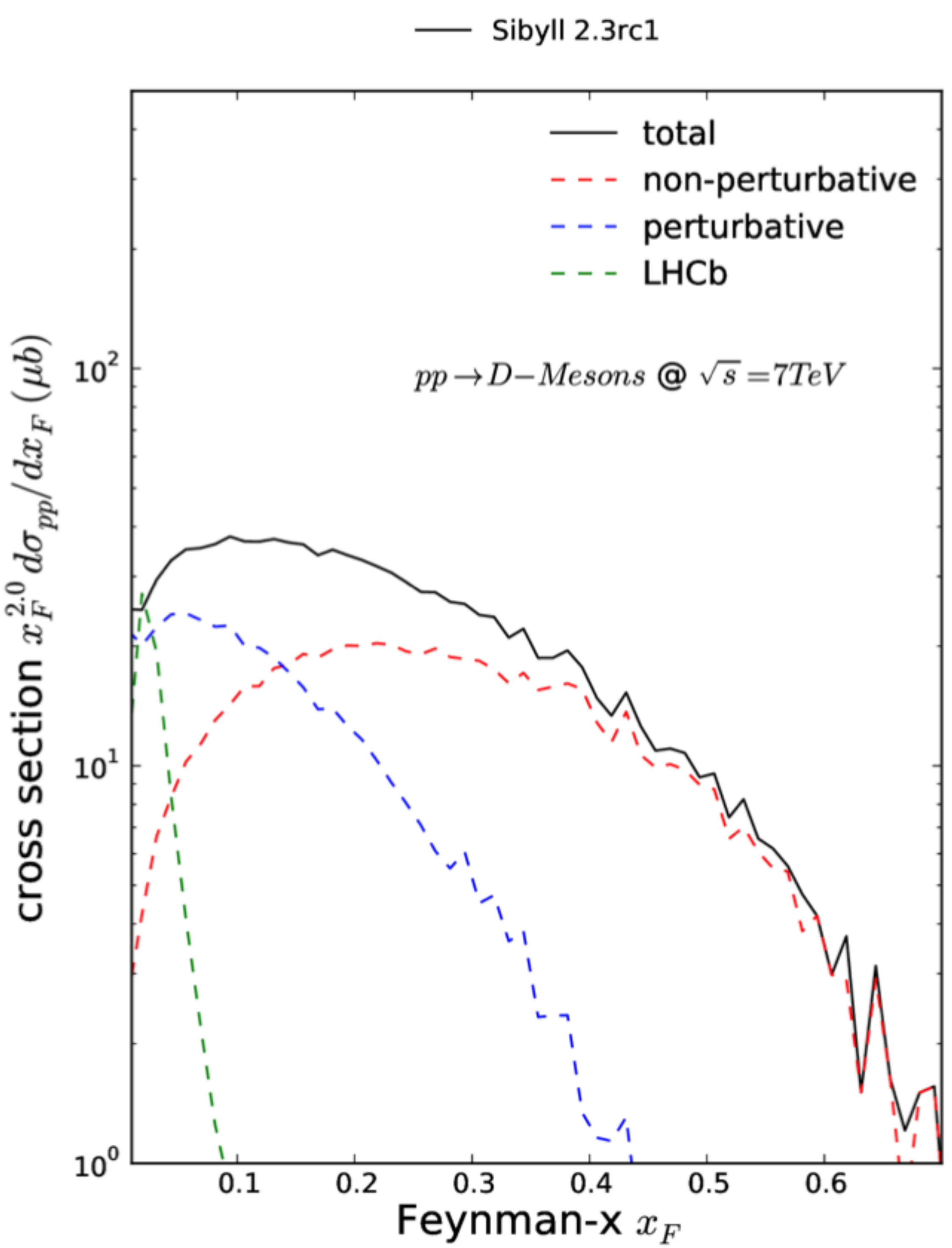


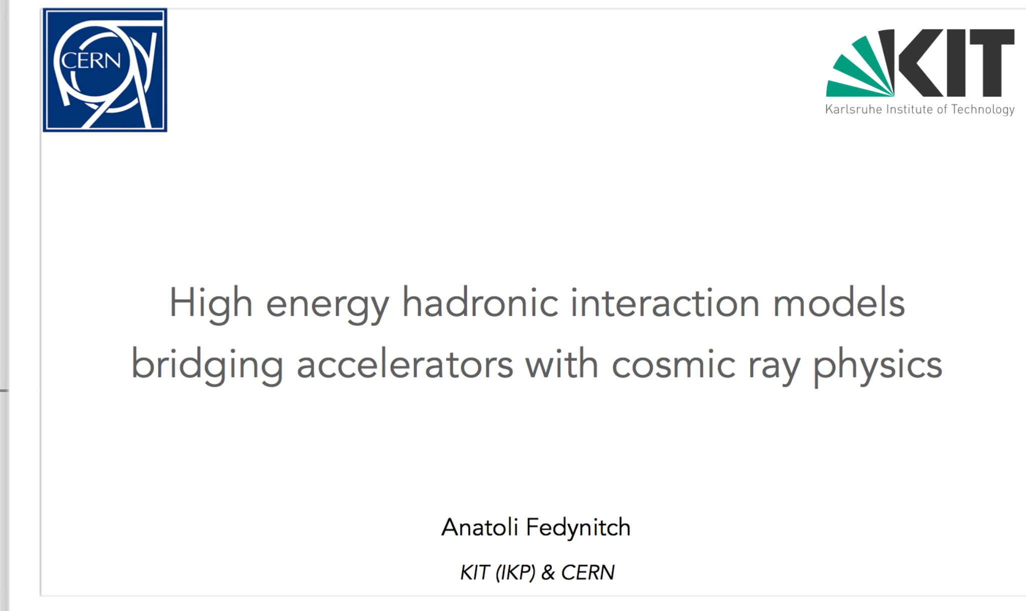
	DPMJET	QGSJet	Ratio
Z_{pp}	0.117	0.154	0.75
Z_{pK^+}	0.0067	0.0056	1.19

$$Z_{kh} = \int_0^1 dx\ x^{\gamma-1} \frac{dn(kA \to hY)}{dx}$$



atmospheric neutrinos
hadronic interaction models





- How much does LHCb phasespace contribute to integrated spectrum?

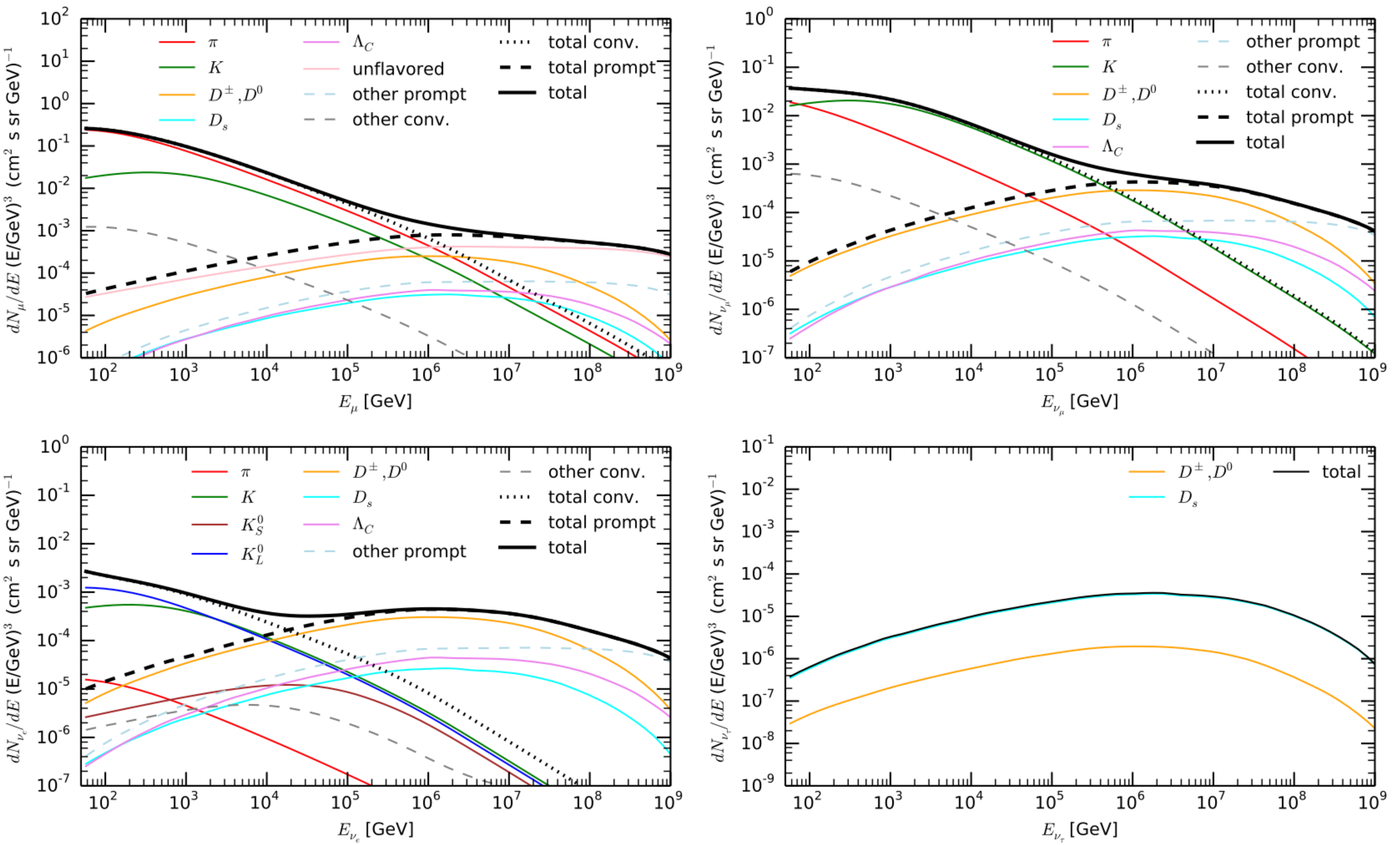
	%
LHCb	7
perturbative	37
Non-perturbative	59

→ LHC data **not** restrictive

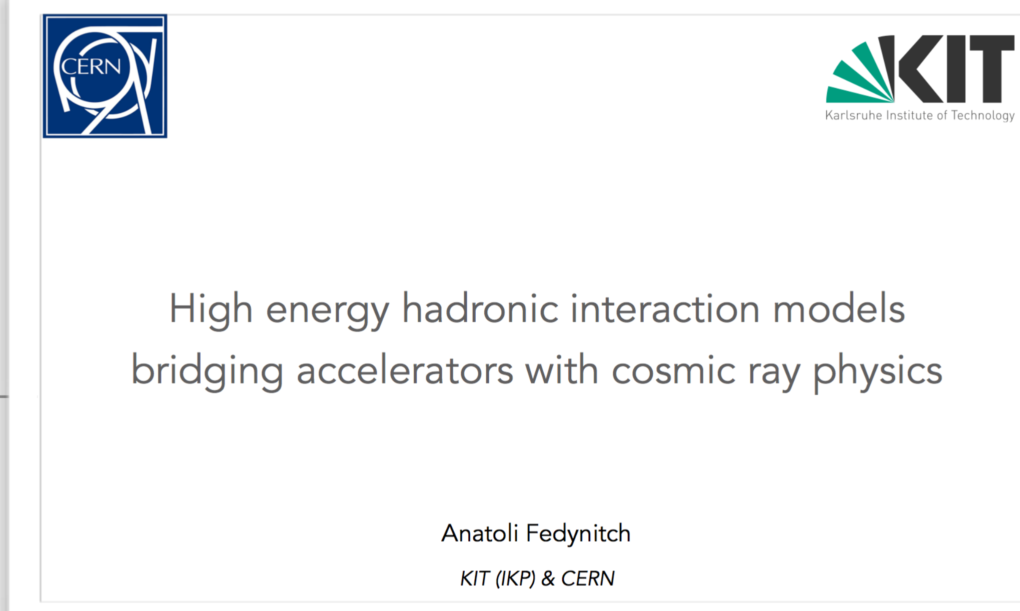
Paolo Desiati

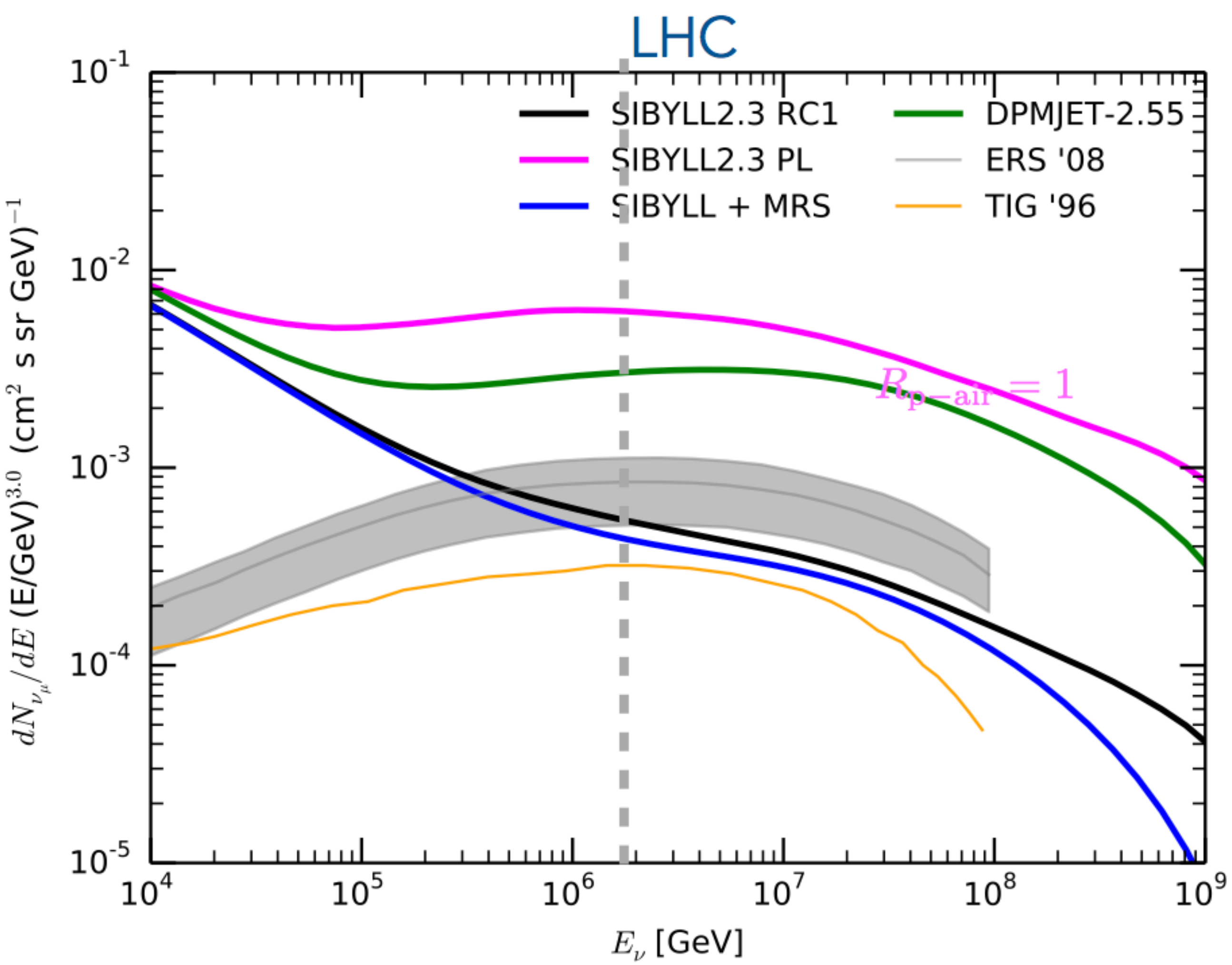
atmospheric neutrinos
hadronic interaction models

SIBYLL2.3_rc1 atmospheric lepton fluxes, TIG primary flux model.



atmospheric neutrinos
hadronic interaction models





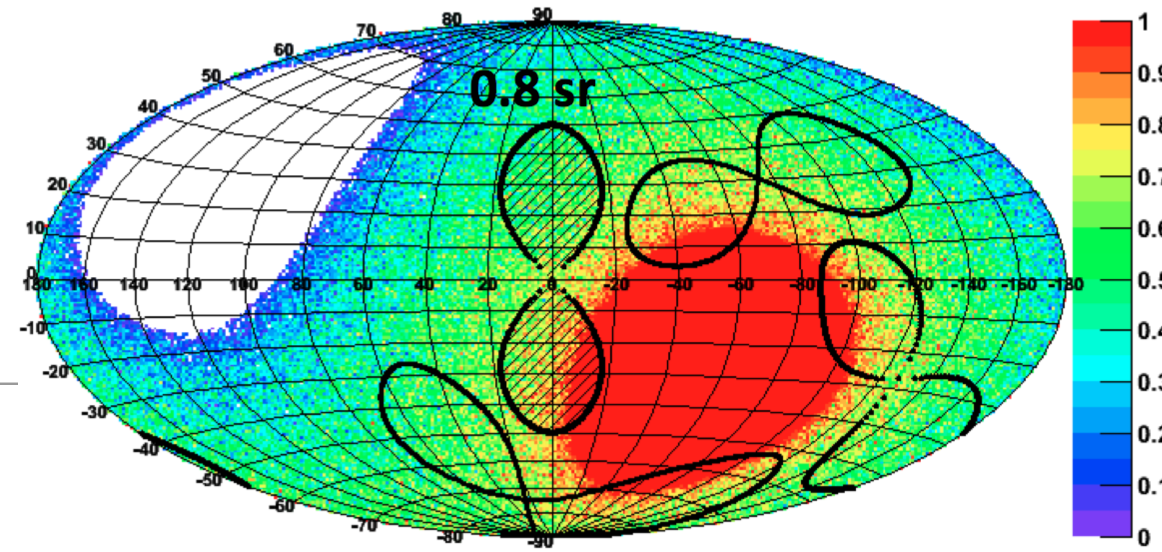
ERS - R. Enberg, M. H. Reno, and I. Sarcevic, Phys. Rev. D 78, 43005 (2008).

TIG - M. Thunman, G. Ingelman, and P. Gondolo, Astroparticle Physics 5, 309 (1996).

- nuclear effect are important but are uncertain
- pO, pC, pN data would be important for CRs and astrophysics

backup slides

atmospheric neutrinos
and diffuse fluxes

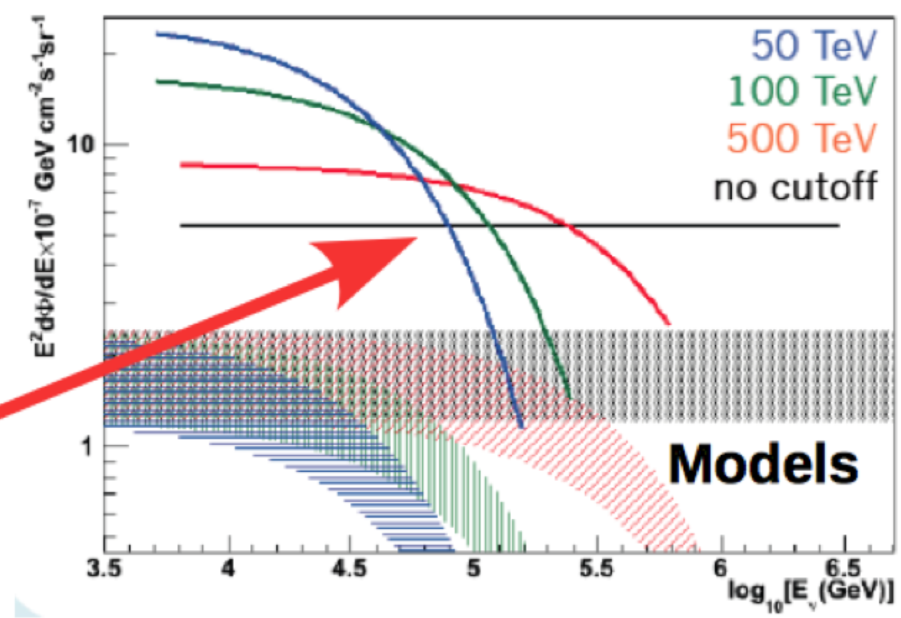


Fermi Bubble

compatible with the no-signal hypothesis

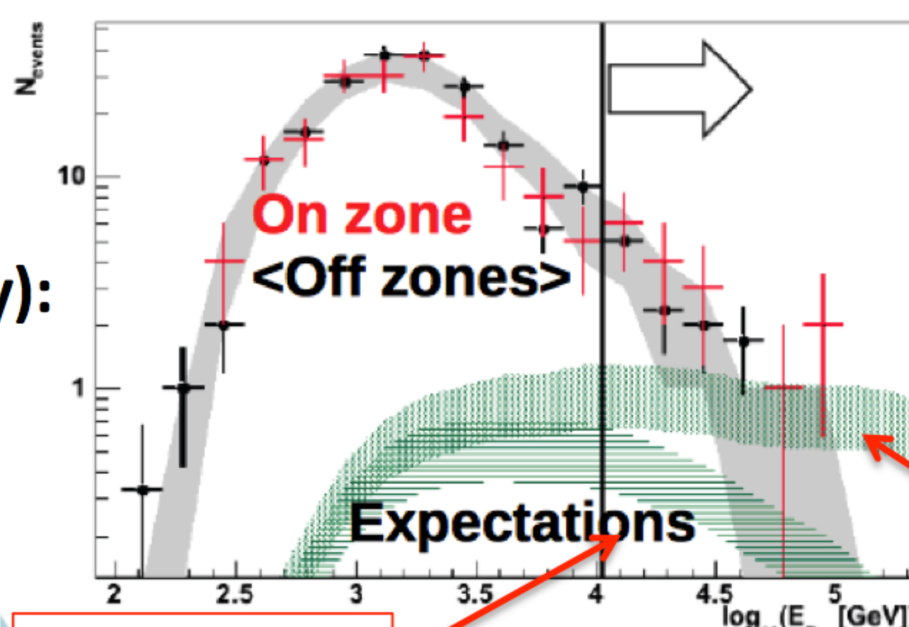
2008-2011 data
$N_{obs} = 16$
$\langle N_{bkg} \rangle = 11$
1.2σ excess

Upper Limits



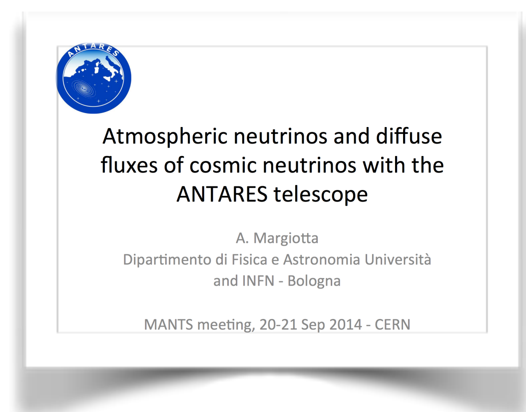
S. Adriàn-Martìnez et al., EPJ C 74(2014) 2

Energy estimator cut (high energy):
atmospheric event rejection



50 TeV cutoff

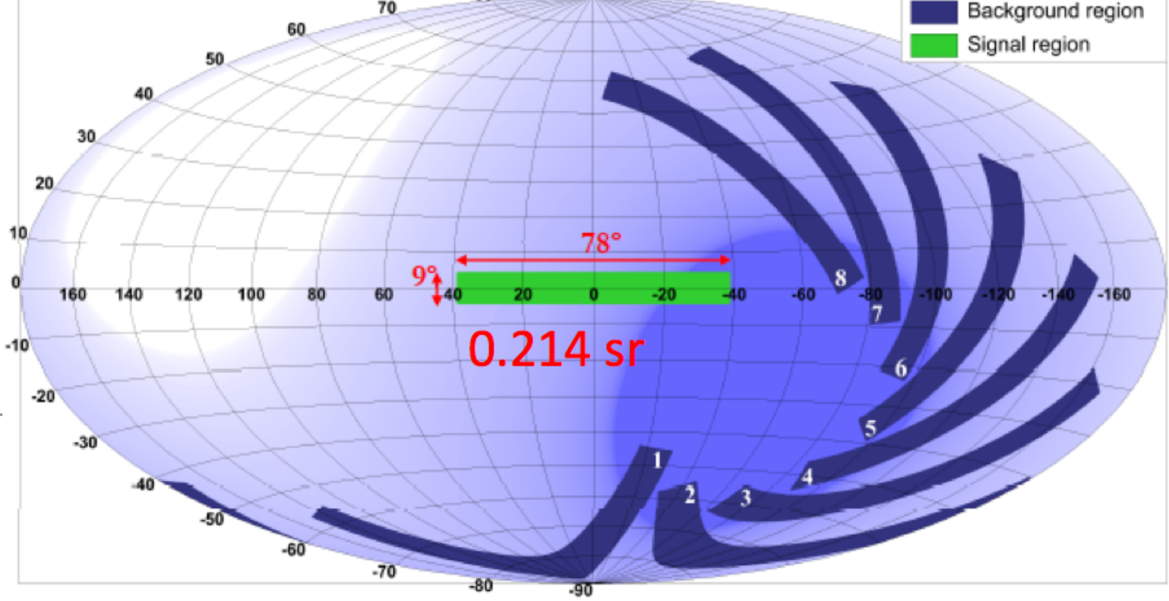
No cutoff


Atmospheric neutrinos and diffuse fluxes of cosmic neutrinos with the ANTARES telescope

A. Margiotta
Dipartimento di Fisica e Astronomia Università and INFN - Bologna

MANTS meeting, 20-21 Sep 2014 - CERN

atmospheric neutrinos
and diffuse fluxes



galactic plane

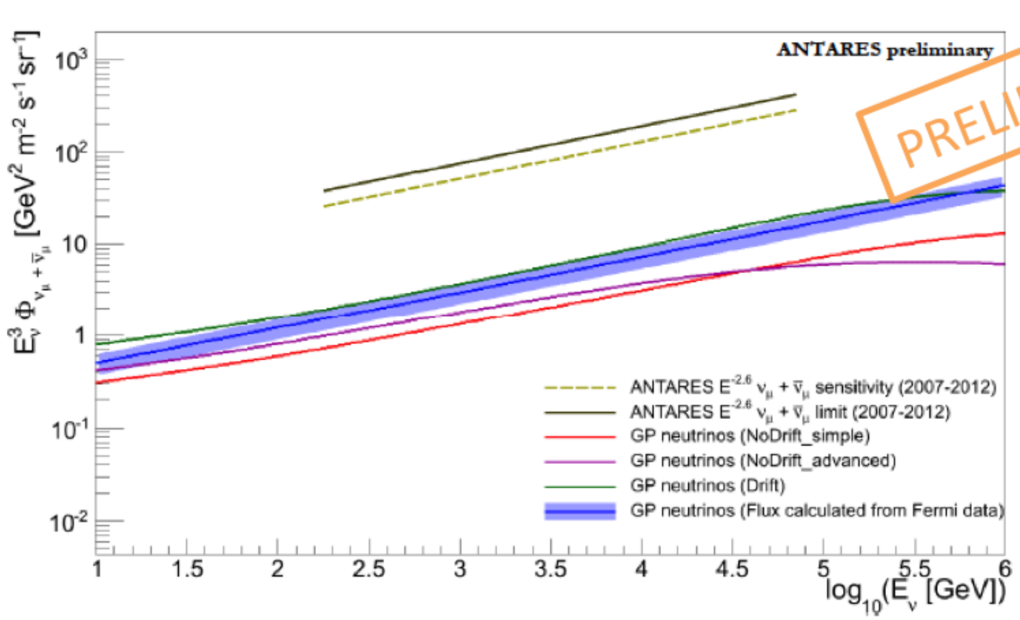
2007-2011 data:

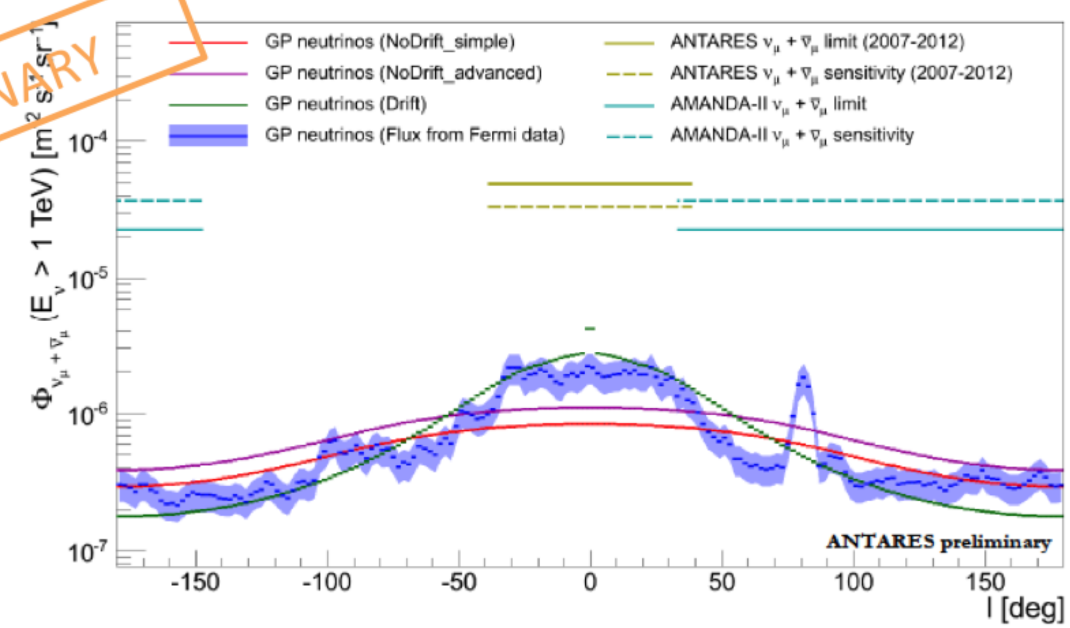
n_{obs}= 177, n_{exp}= 166

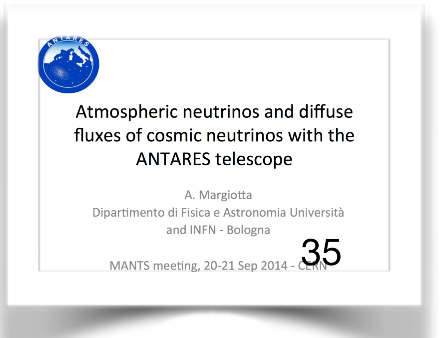
0.8σ excess and 90% upper limits set for different models

Model name	Reference	Matter density	Cosmic ray flux
NoDrift_simple	Ingelman and Thunman arXiv:hep-ph/9604286	constant: 1 nucleon / cm^3	constant
NoDrift_advanced	Candia and Roulet JCAP09(2003)005	constant: 1 nucleon / cm^3	constant
Drift	Candia JCAP11(2005)002	Radially dependent	Higher in GC due to drift of CRs

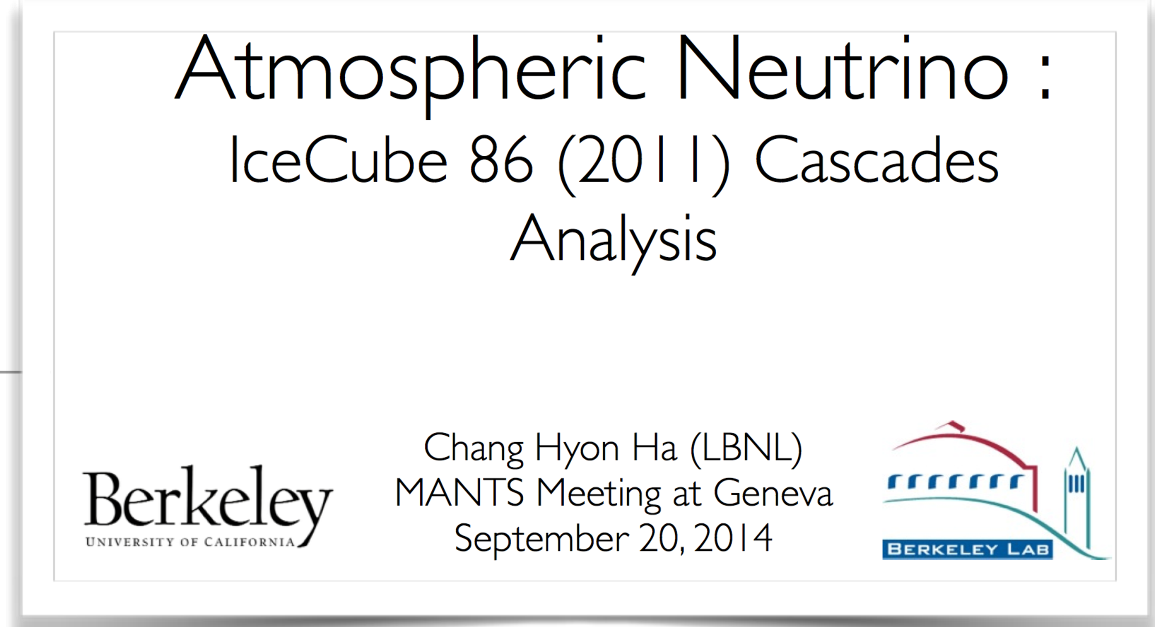
Upper limits for the neutrino flux from the Galactic Plane central (178 GeV < E_υ < 70.8 TeV)

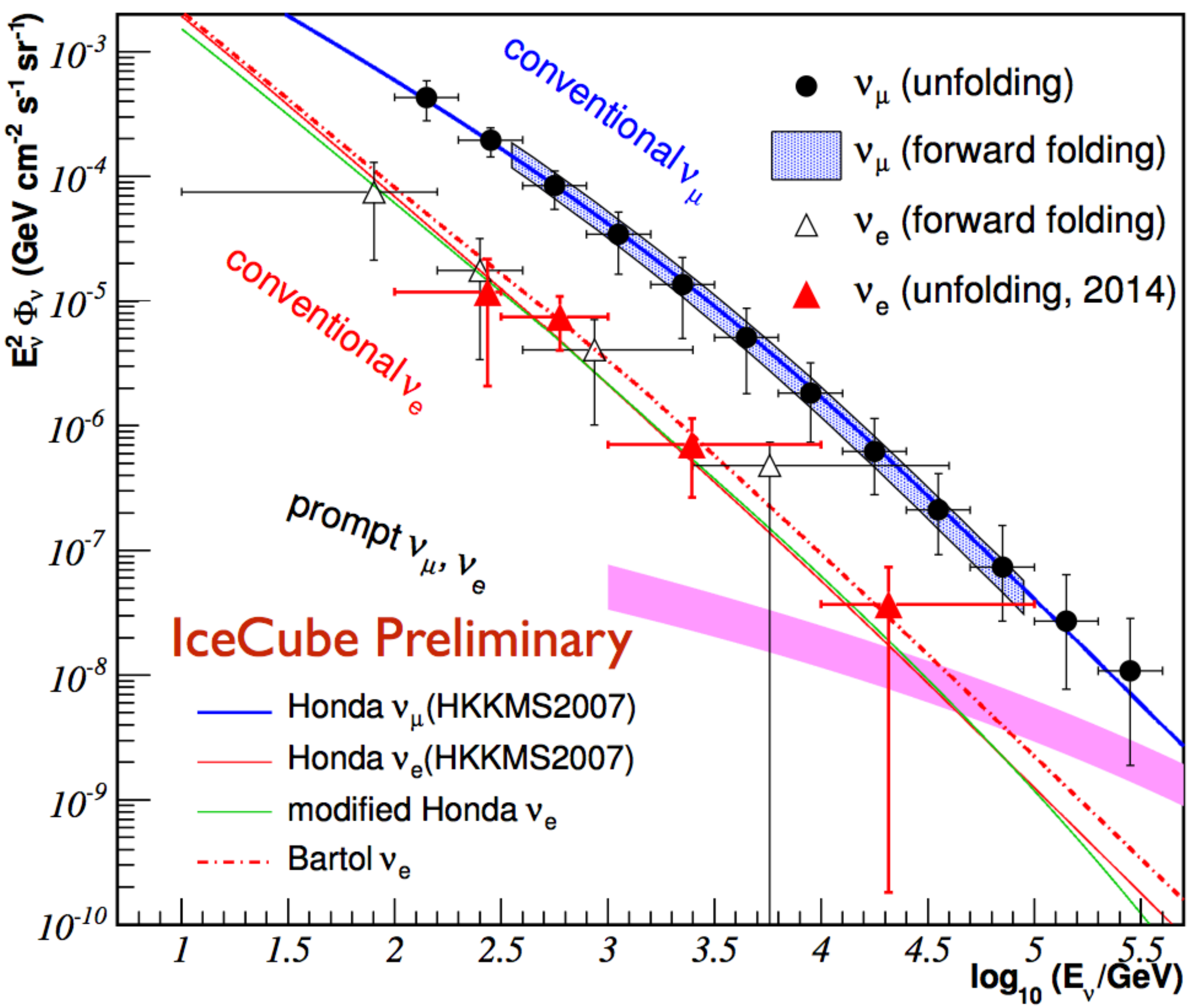




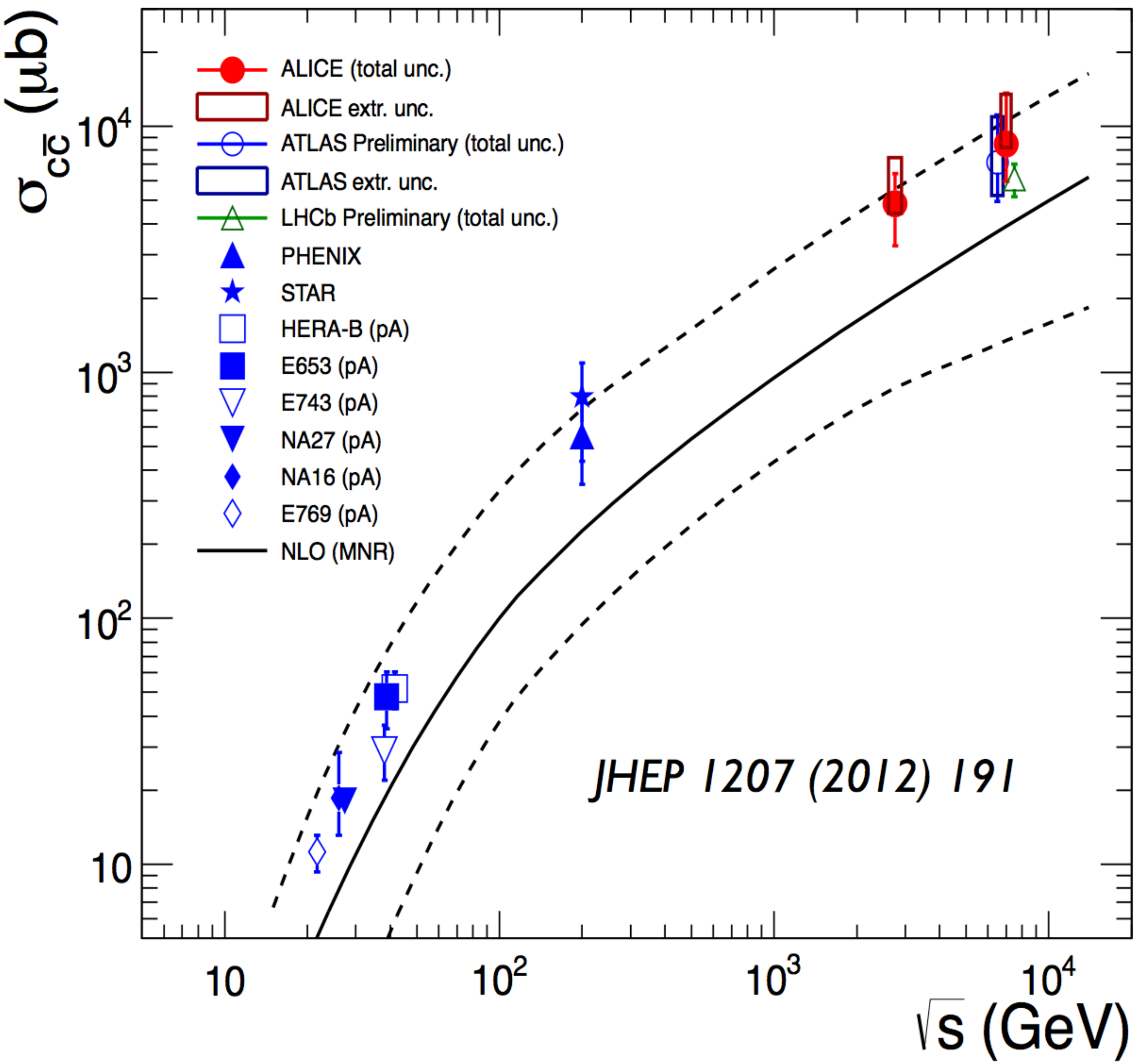


atmospheric neutrinos

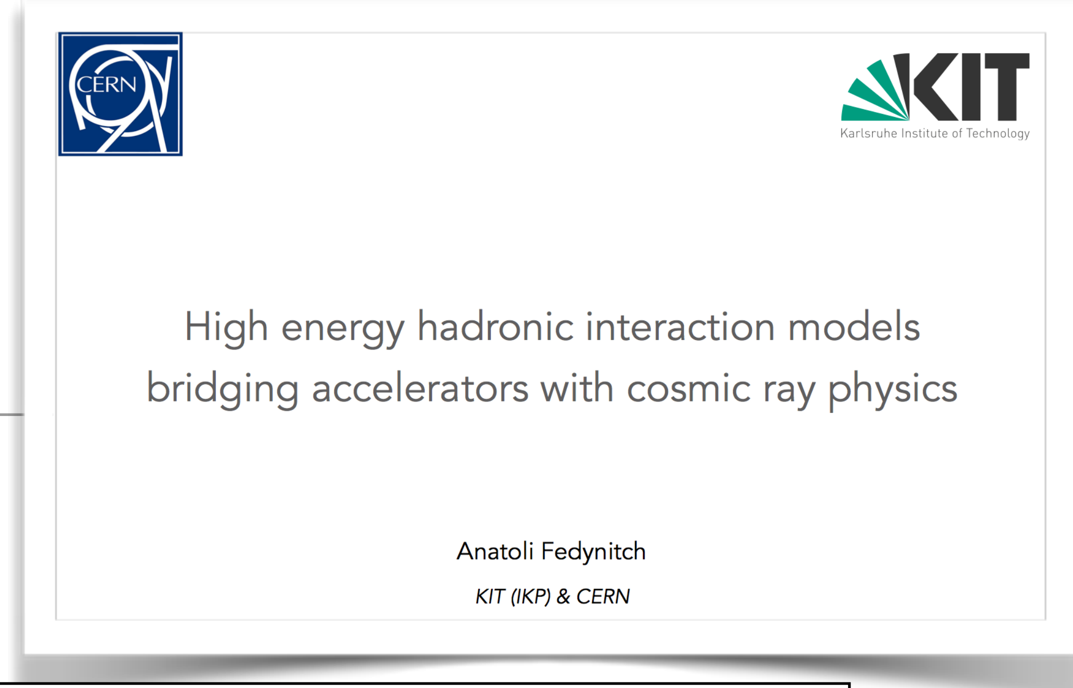


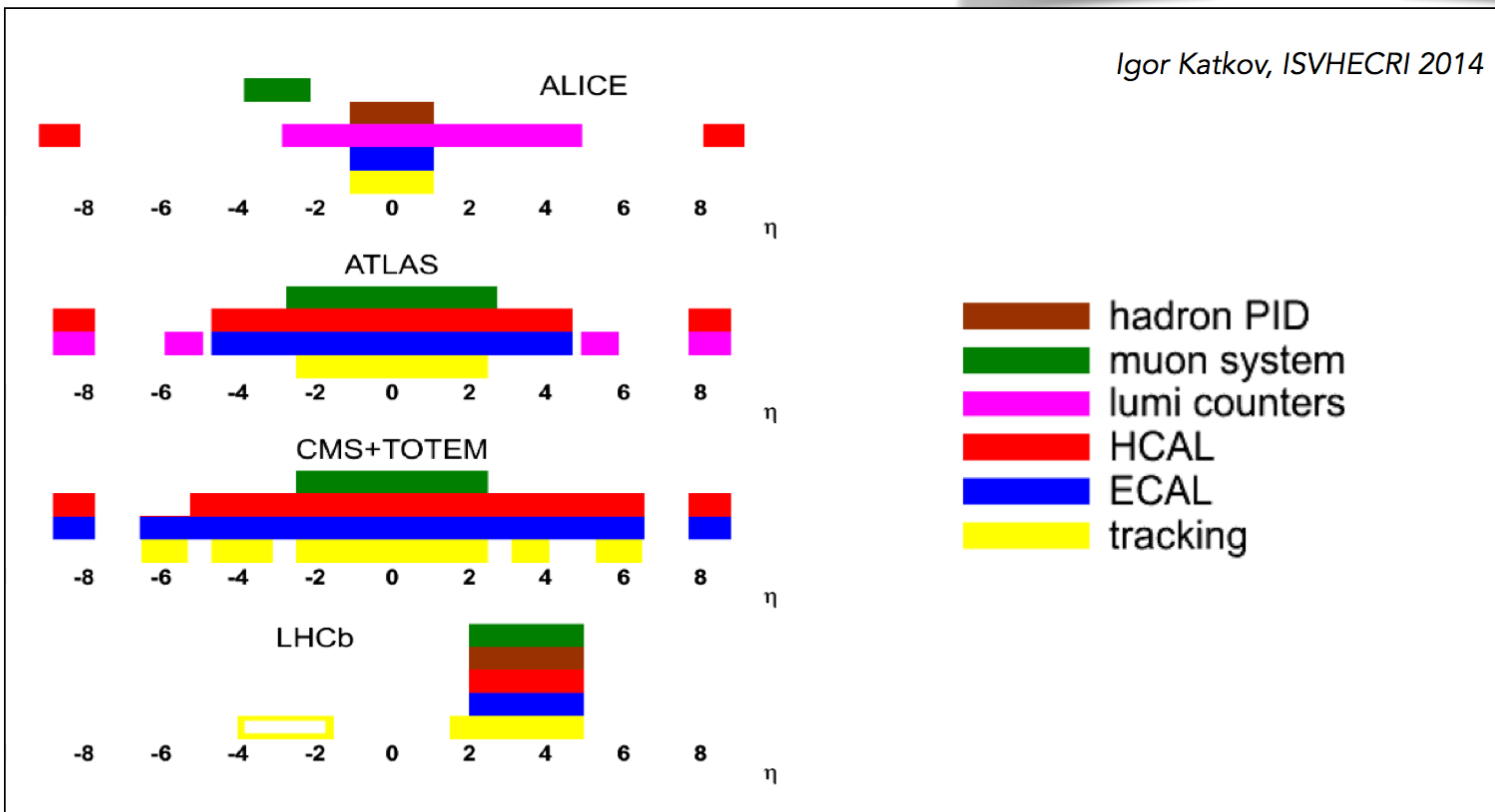


atmospheric neutrinos
pQCD



atmospheric neutrinos
hadronic interaction models





atmospheric neutrinos
hadronic interaction models

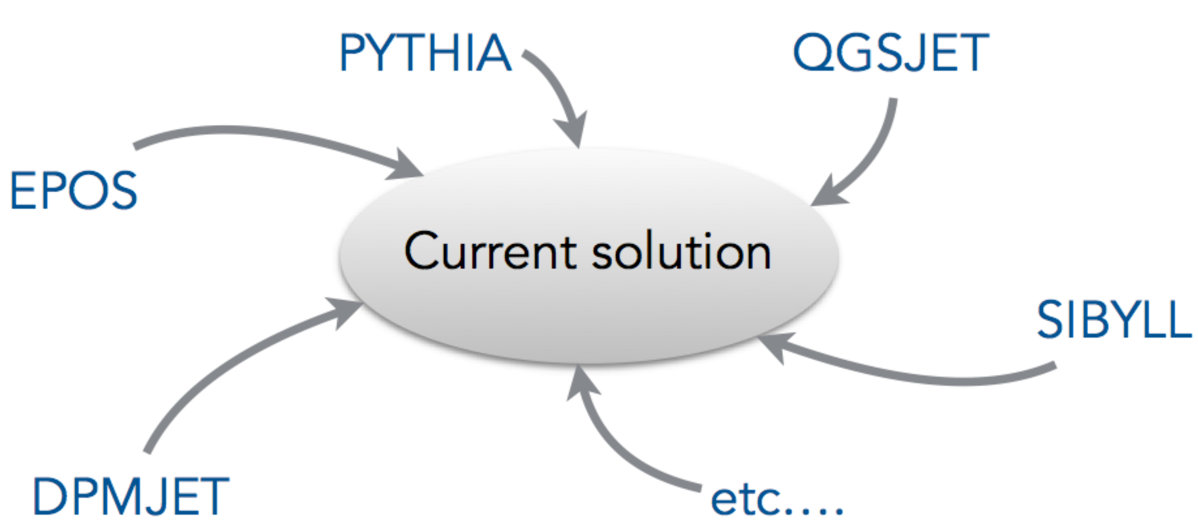
High energy hadronic interaction models
bridging accelerators with cosmic ray physics

Anatoli Fedynitch
KIT (IKP) & CERN

Desired behavior of an interaction model

Requirements
- describe soft and hard physics
- smooth transition between these two regimes
- extrapolation into unknown/-measured phase-space

But…
- separation between 'soft' and 'hard' not clearly defined
- pQCD minijet cross-section grows faster than $\ln^2 s$
- small-x behavior not well known
- other problems..



atmospheric neutrinos
hadronic interaction models

High energy hadronic interaction models bridging accelerators with cosmic ray physics

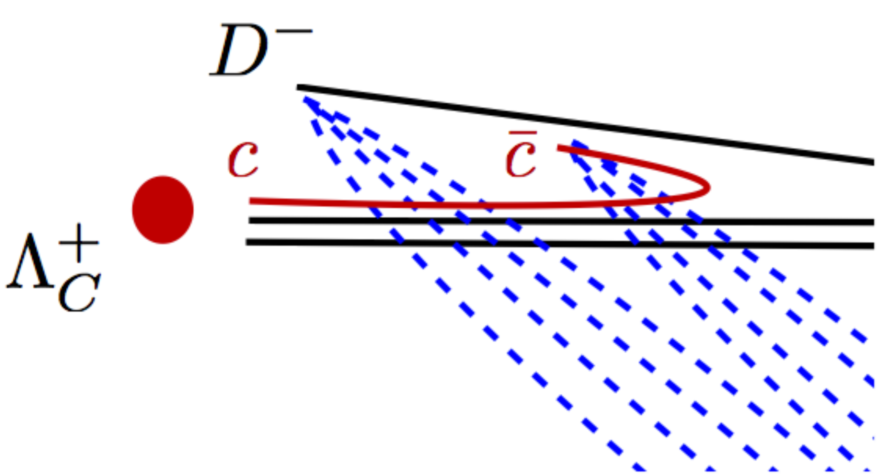
atoli Fedynitch

T (IKP) & CERN

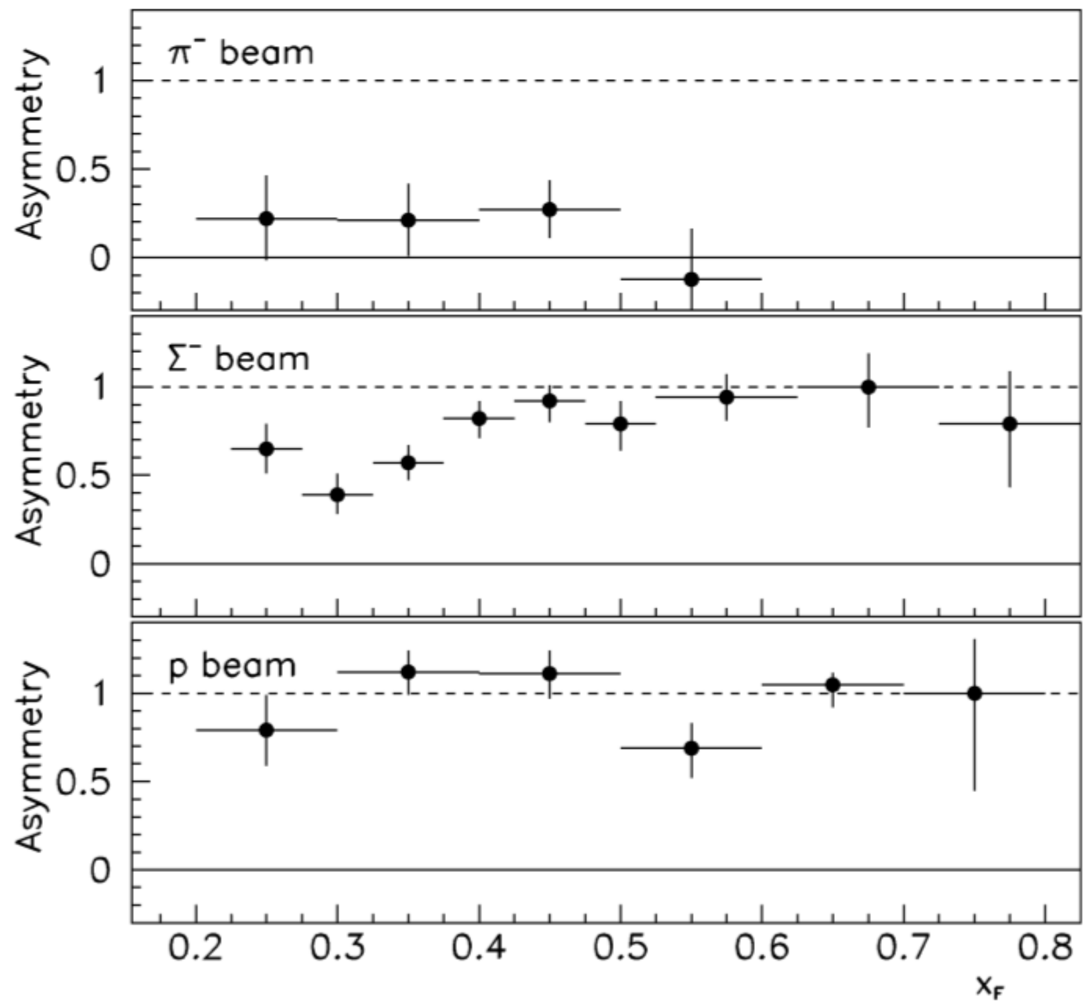
Origin of non-perturbative component

Asymmetry

$$A \equiv \frac{\Lambda_C - \bar{\Lambda}_c}{\Lambda_C + \bar{\Lambda}_c}$$



SELEX Collaboration, F. G. Garcia et al., Physics Letters B 528, 49 (2002).



atmospheric neutrinos
hadronic interaction models

High energy hadronic interaction models
bridging accelerators with cosmic ray physics

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LHCb D-mesons and charmed Lambda