Neutrinos from cosmic ray interactions in the Sun

Carl Niblaeus

astro-ph/1704.02892

with Joakim Edsjö[a], Jessica Elevant[a], Rikard Enberg[b]

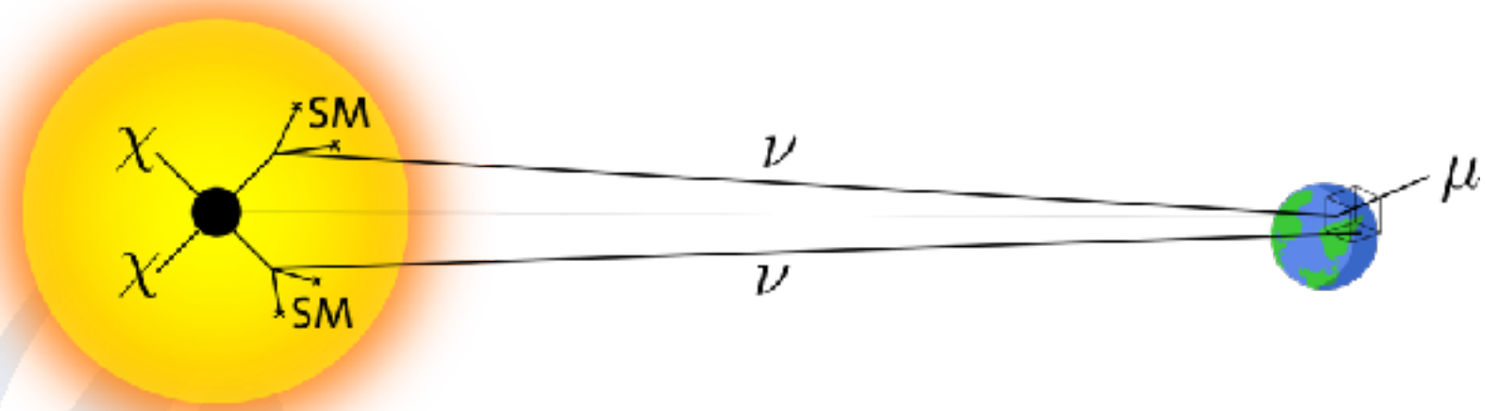
[a]Stockholm University & OKC, [b]Uppsala University

Stockholm University

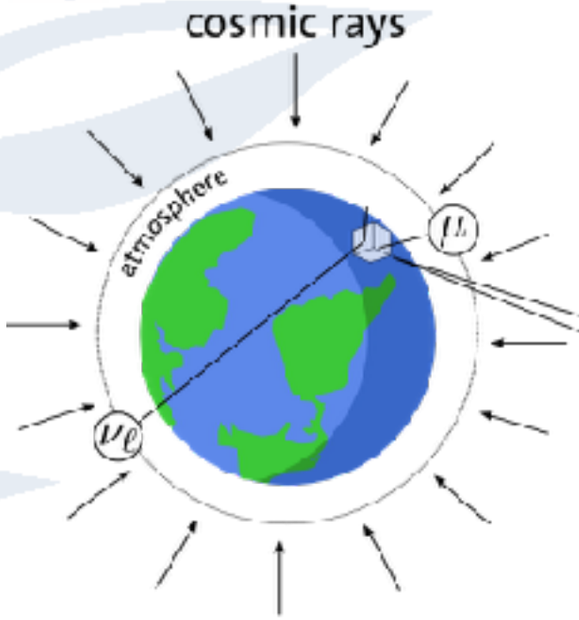
Oskar Klein centre

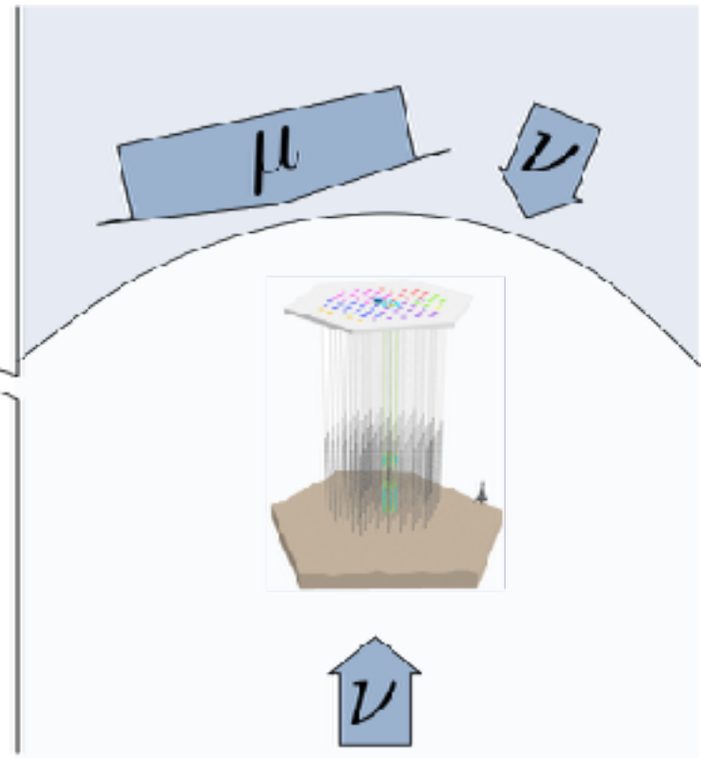
When solar WIMP searches become more sensitive, an additional background source becomes relevant

The signal



The main background





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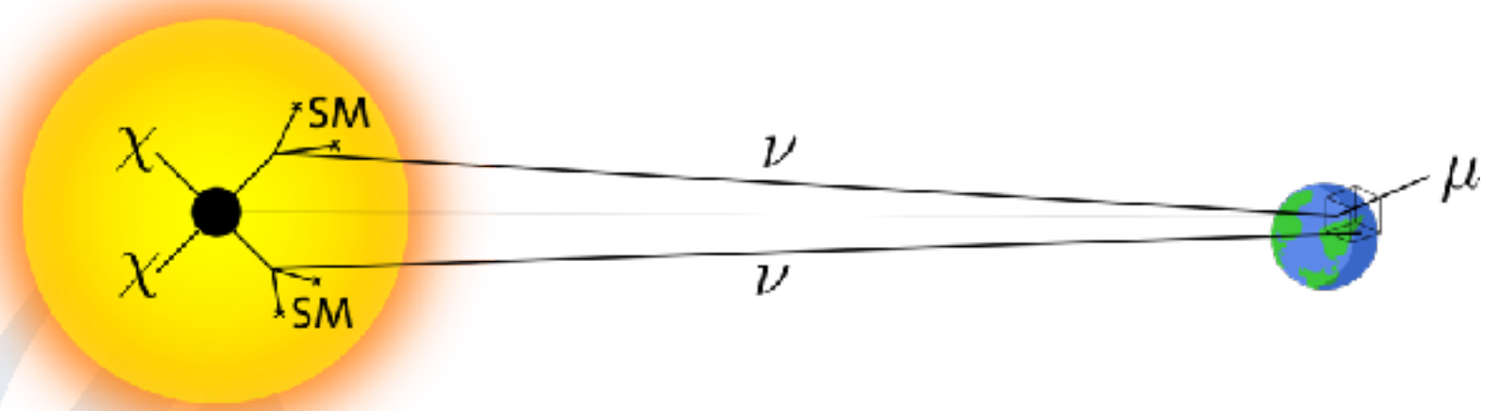
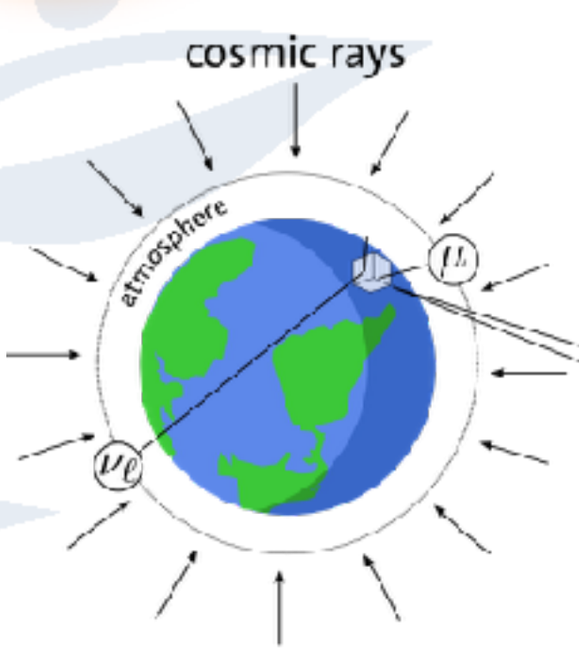
The signal

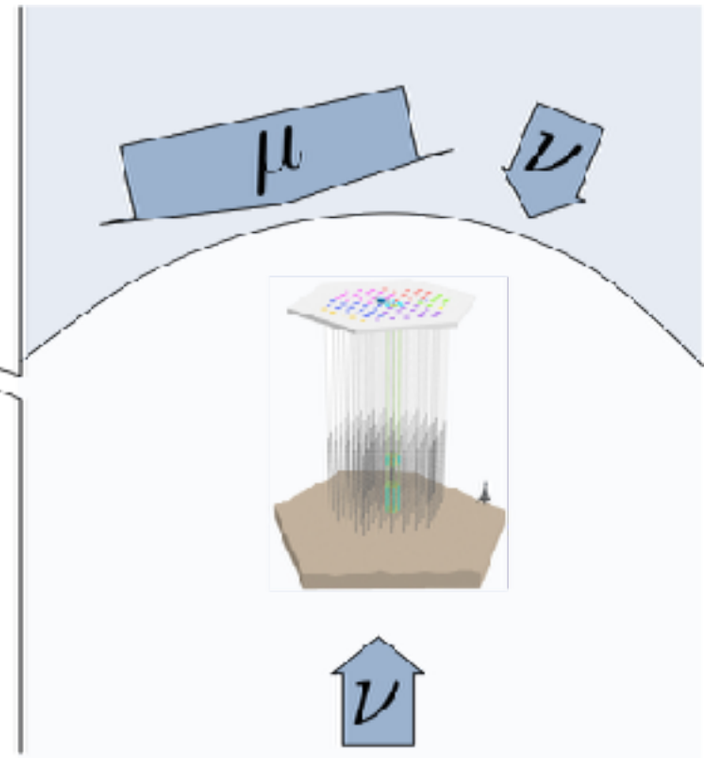


The main background

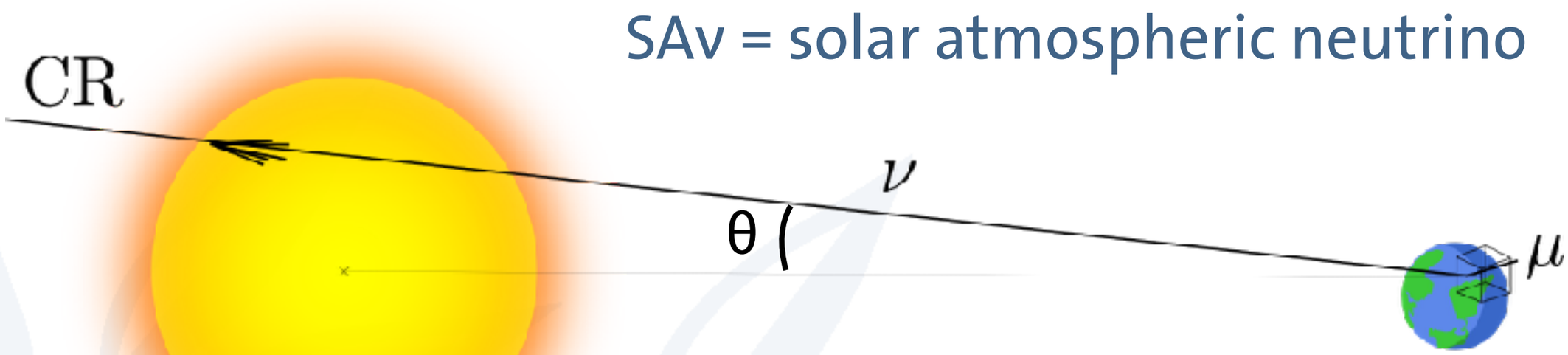
… but also

solar atmospheric ν (SAν)





We calculate the SAν flux at Earth and study impact on solar WIMP searches



SAν = solar atmospheric neutrino

Moskalenko (1991)

Seckel et al. (1991)

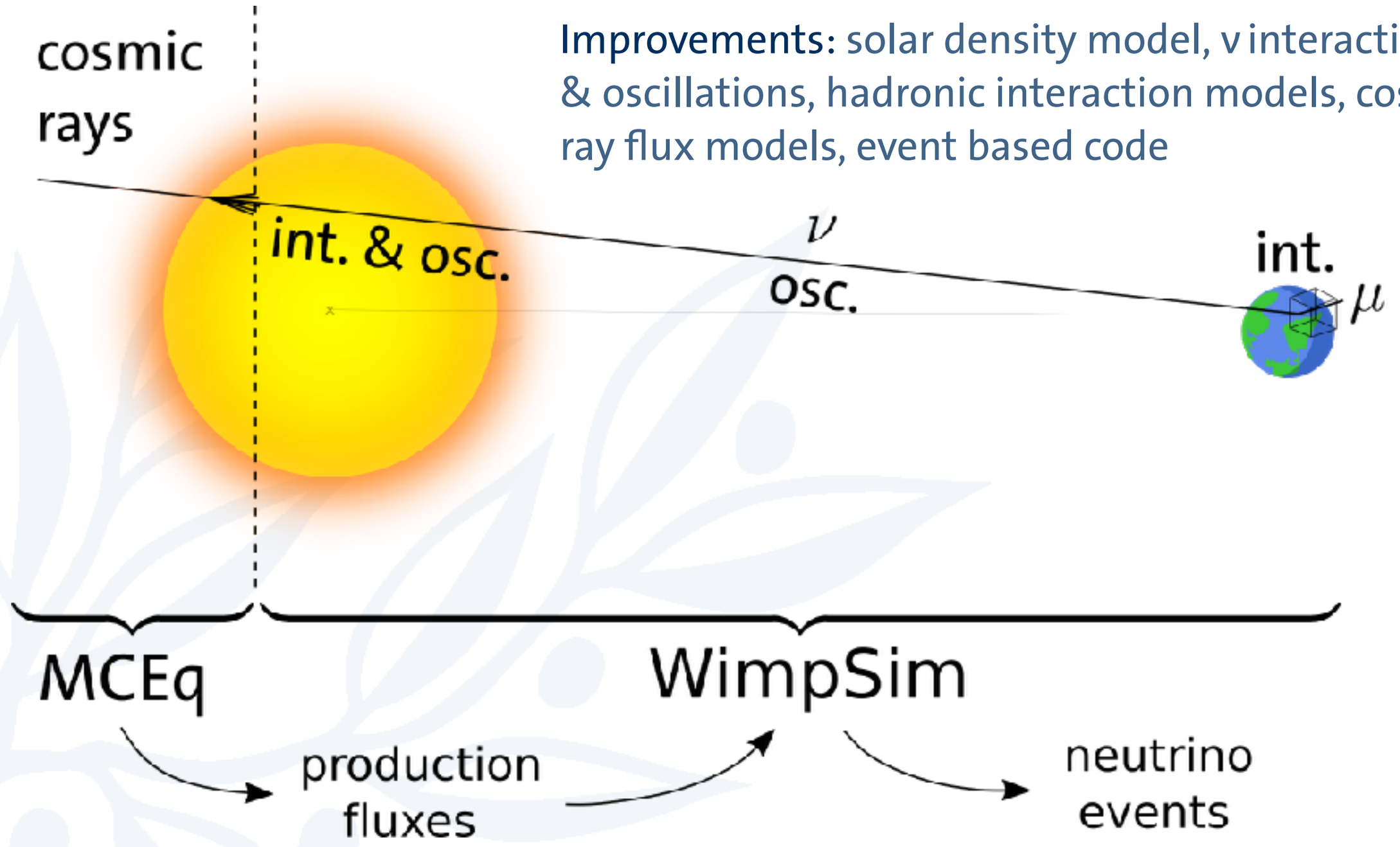
Ingelman, Thunman (1996)

Argüelles et al. (2017)

The SAν flux is quite small (2-3 events/year) but can be a tricky background in solar WIMP searches since with increasing sensitivity in 100-1000 GeV energy range

We have calculated the SAν flux at Earth with **MCEq** & **WimpSim**

Improvements: solar density model, ν interactions & oscillations, hadronic interaction models, cosmic ray flux models, event based code

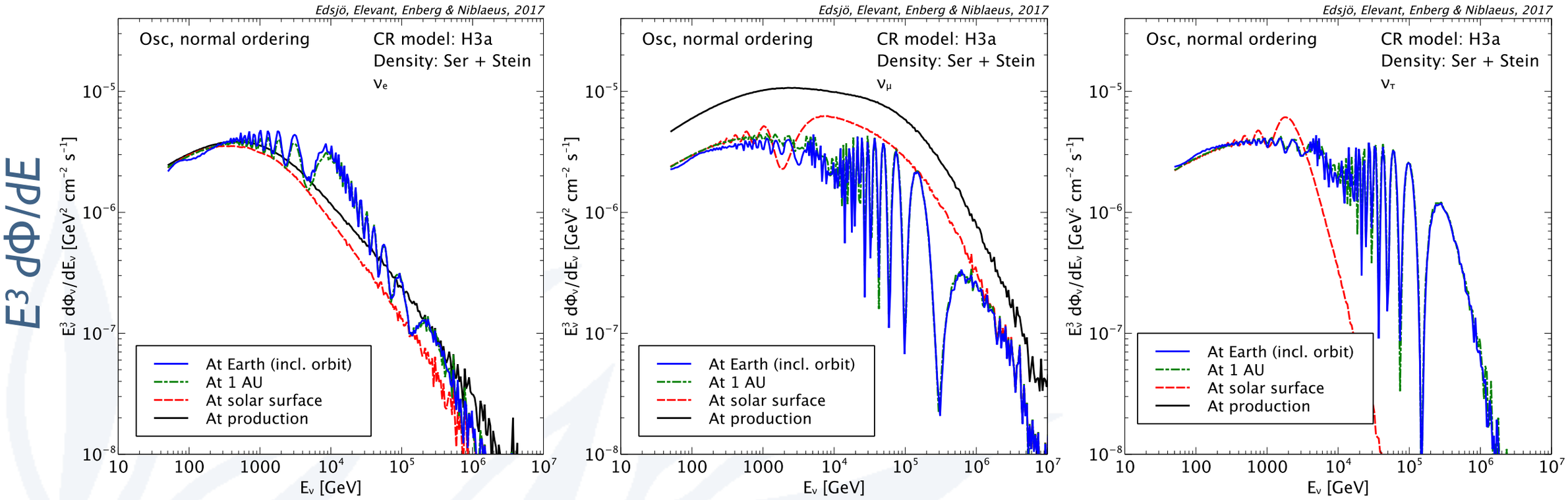


https://github.com/afedynitch/MCEq

http://copsosx03.fysik.su.se/wimpsim/

We predict a few events per year from the SA**ν** flux

ν_e ν_μ ν_τ

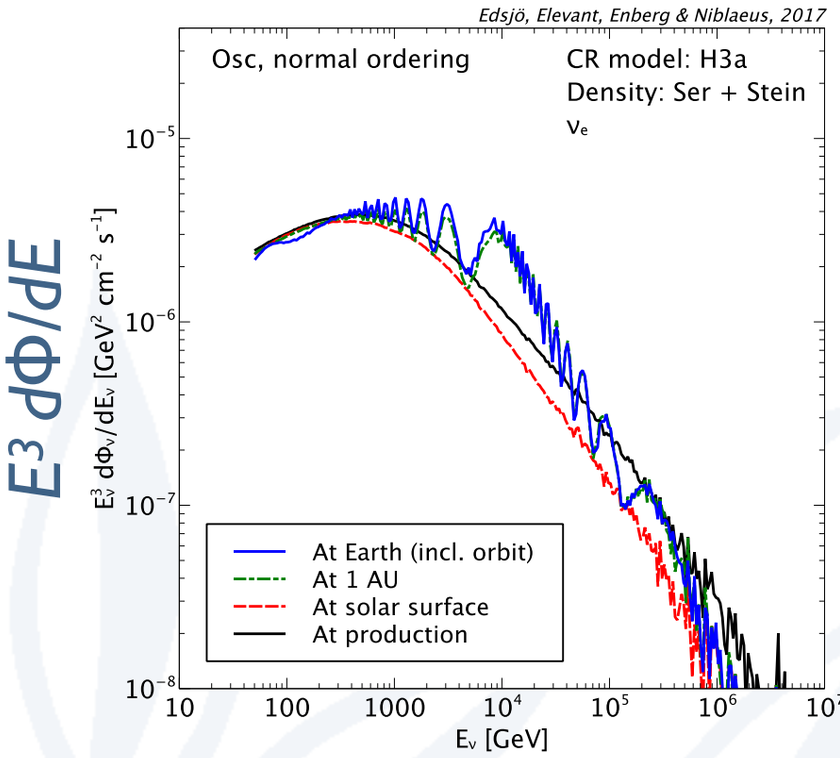


E_ν

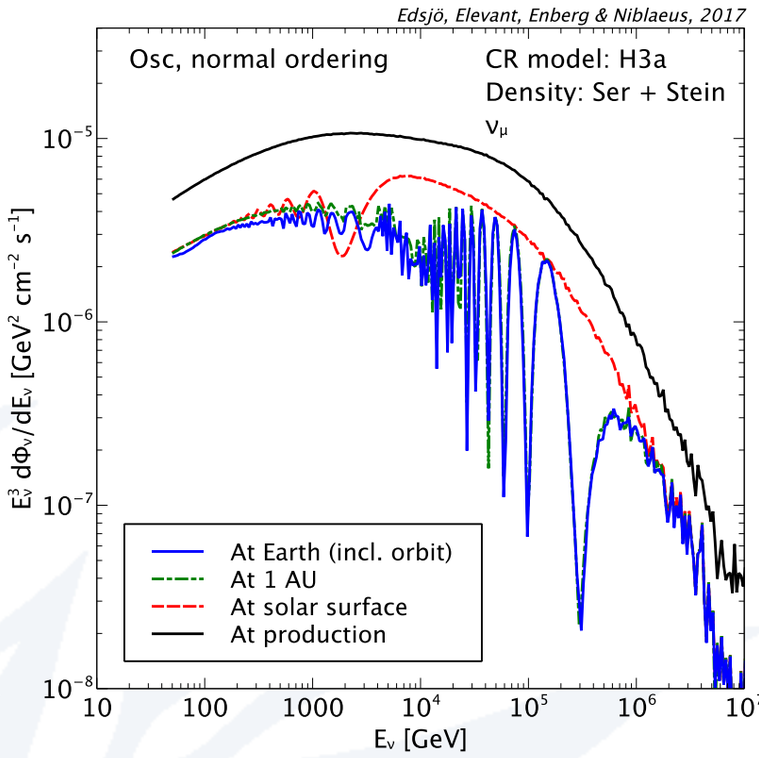
Interactions in Sun damp flux at E_ν >1 TeV, oscillations change flavour ratio and cause wiggles

We predict a few events per year from the SAν flux

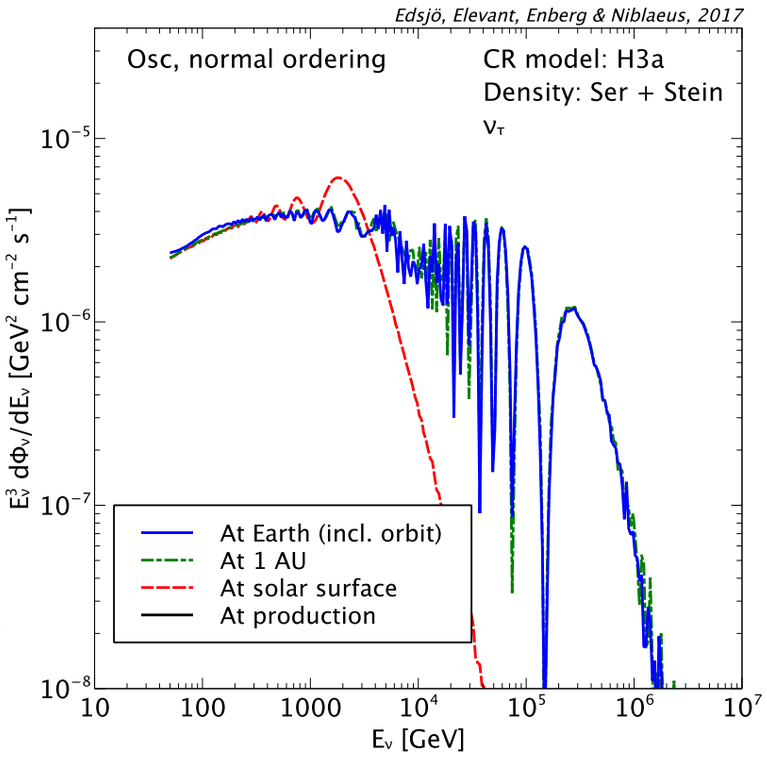
ν_e



ν_μ



ν_τ



$E^3\, d\Phi/dE$

E_ν

Interactions in Sun damp flux at E_ν >1 TeV, oscillations change flavour ratio and cause wiggles

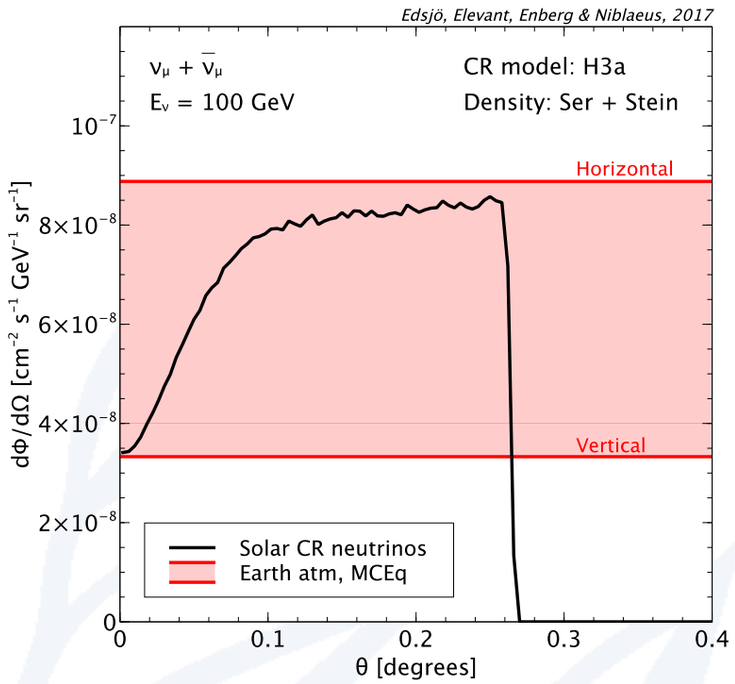
$$\int A_{\text{eff}}(E)\,\frac{d\Phi}{dE}(E)\;dE$$

$\Rightarrow$ 2-3 events/year

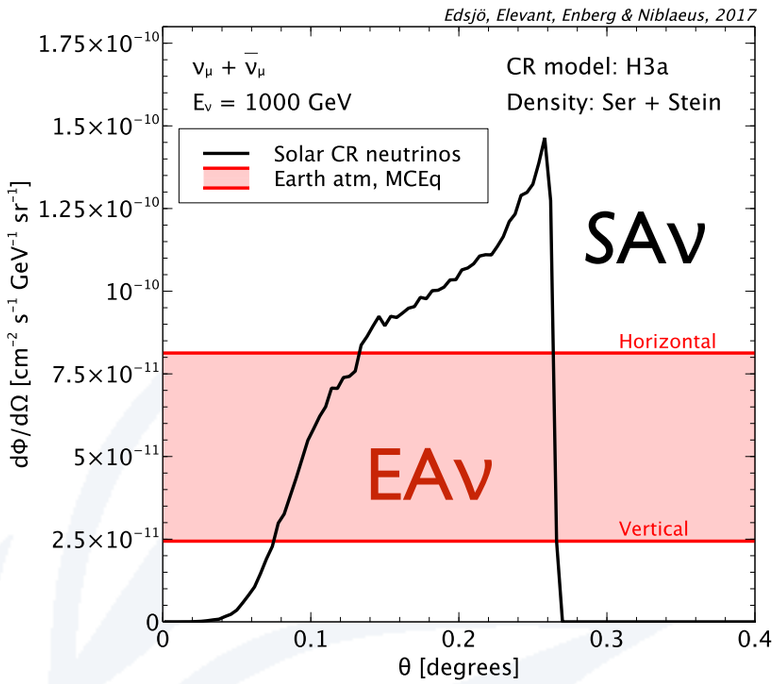
A_{eff} from IceCube [1612.05949]

The SAν flux can be larger than the Earth atmospheric near the Sun

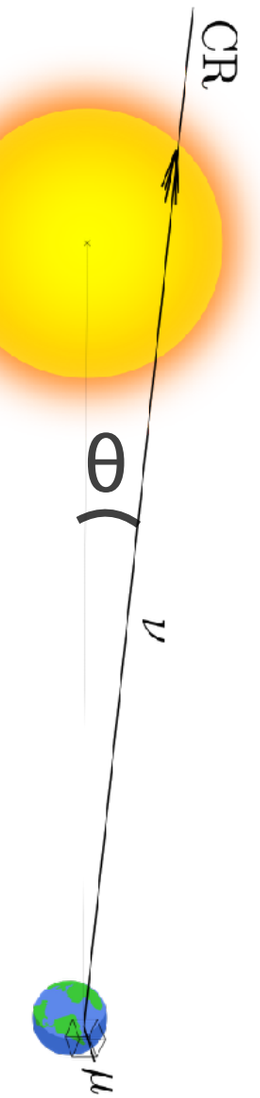
E_ν=100 GeV



E_ν=1000 GeV



Solar radius: 0.26°



θ

Smeared in ν telescope by:

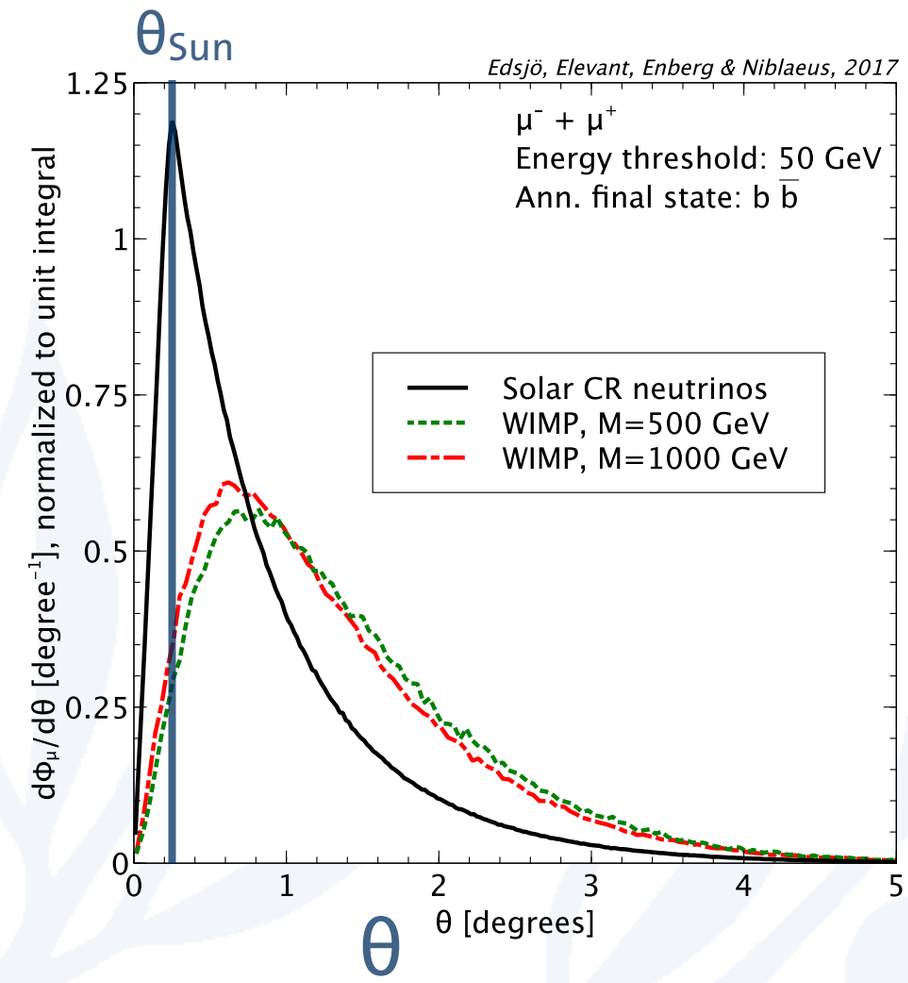
(i) neutrino-muon scattering angle

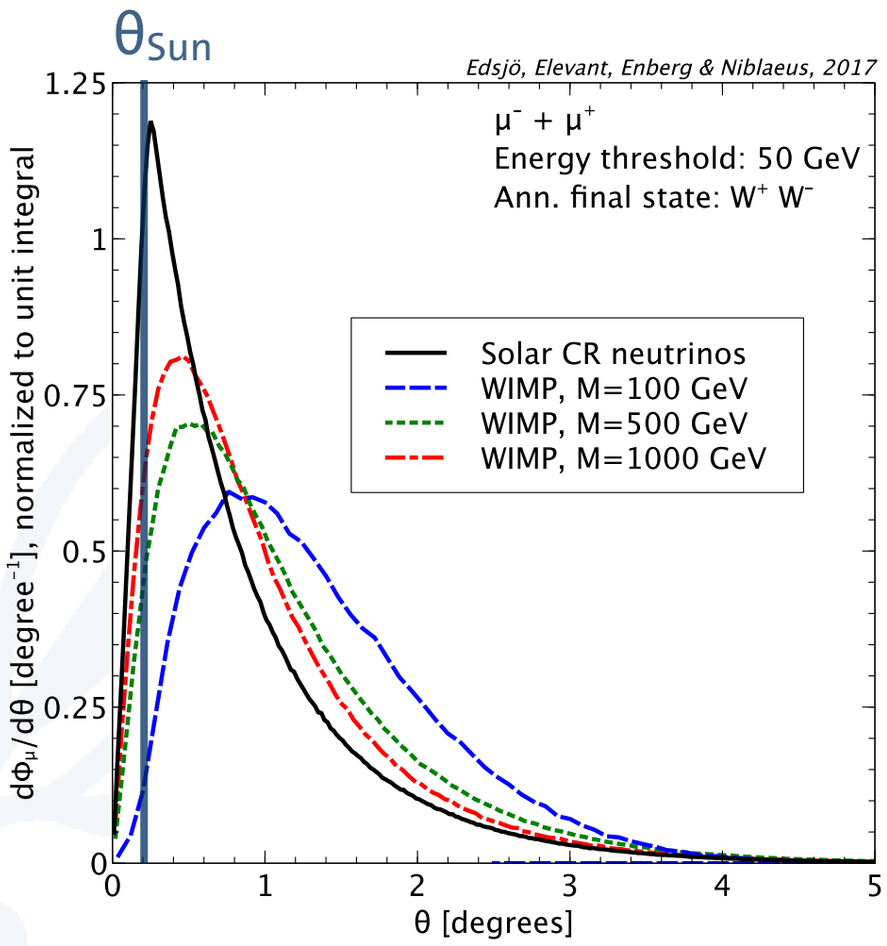
(ii) multiple Coulomb scattering

(iii) angular resolution

The SAν flux can be tricky do distinguish from WIMP-induced neutrinos

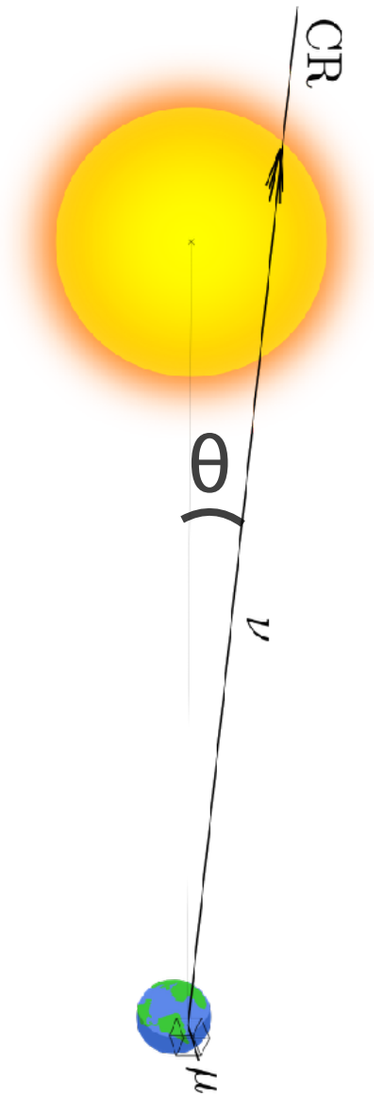
The neutrino-induced **muon** flux (normalised to unit integral):





IC ang. resolution:

- 6° for E_ν=100 GeV
- 2° for E_ν=1000 GeV



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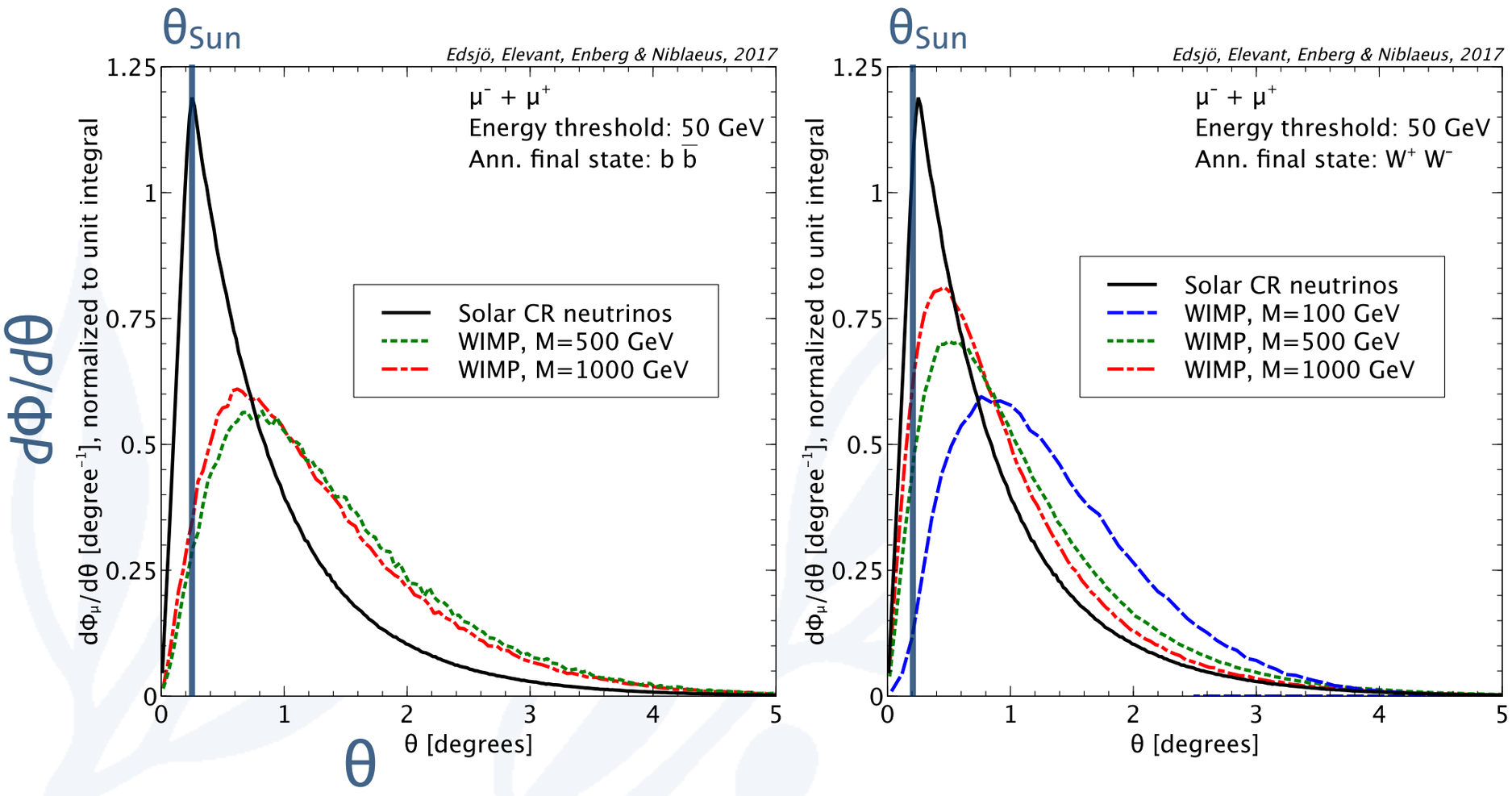

dΦ/dθ

θ

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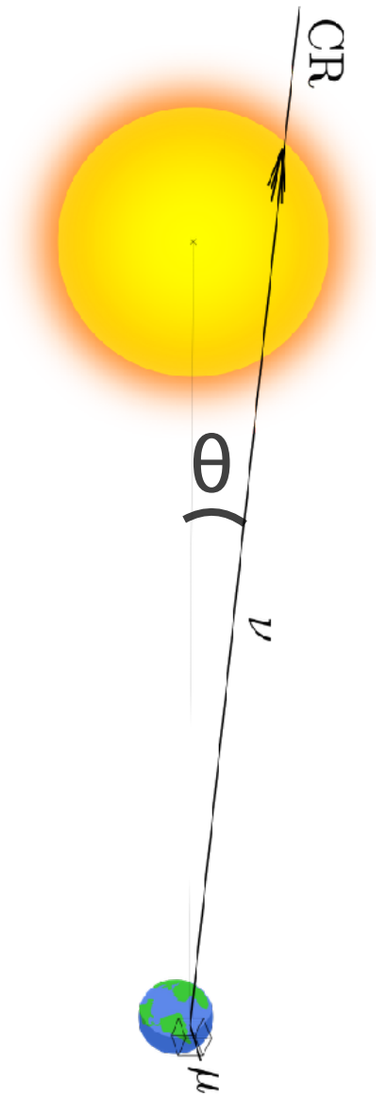
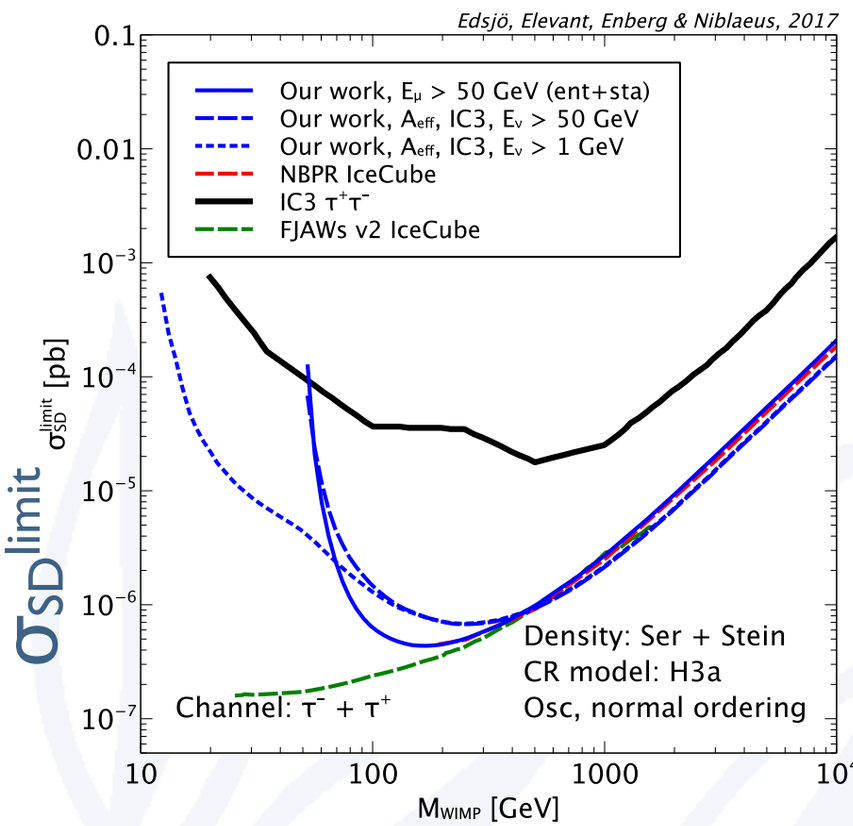


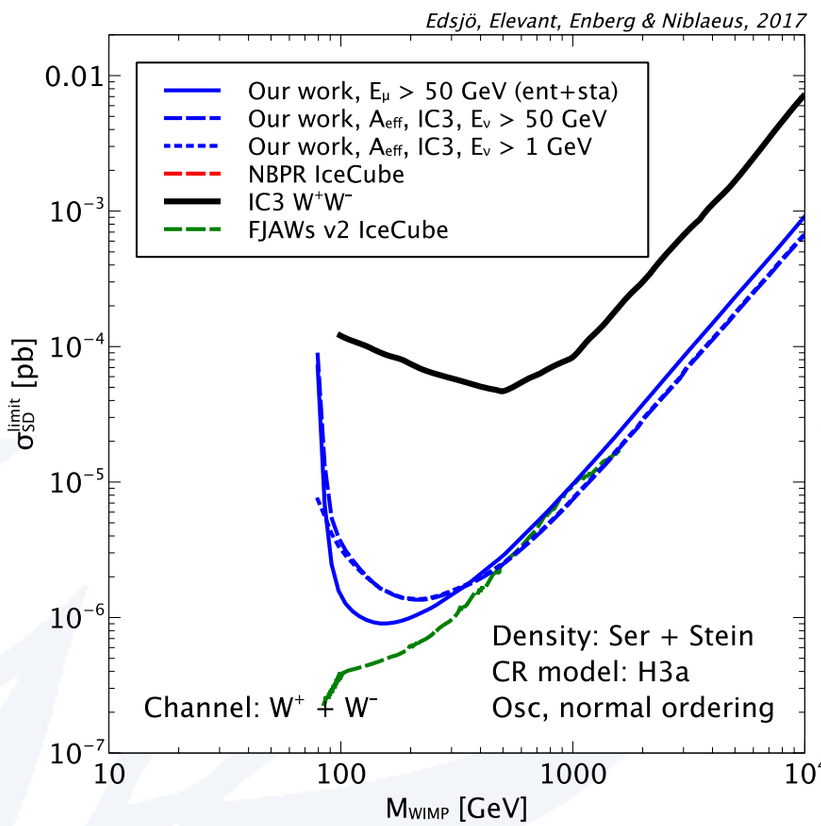
Energy spectra are different (power-law vs bump) but energy estimate for muons is poor at these energies

SAν dominate below this sensitivity floor for the WIMP-proton cross section

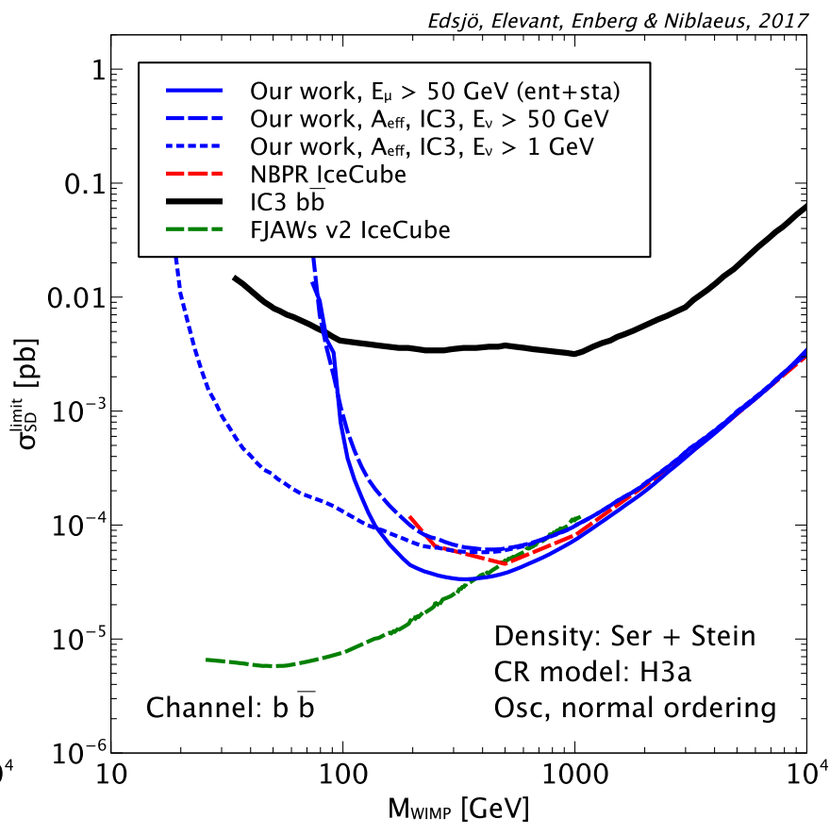
$\tau^+\tau^-$



W^+W^-



$b\bar{b}$



M_{WIMP}

We adjust $\sigma_{\chi p}^{SD}$ for each m_χ to get N_{evt}(WIMP ann.) = N_{evt}(SAν)

NBPR: astro-ph/1703.10280 FJAWs v2: astro-ph/1703.07798

Review

Neutrino telescopes look for a neutrino flux from DM annihilations in the Sun

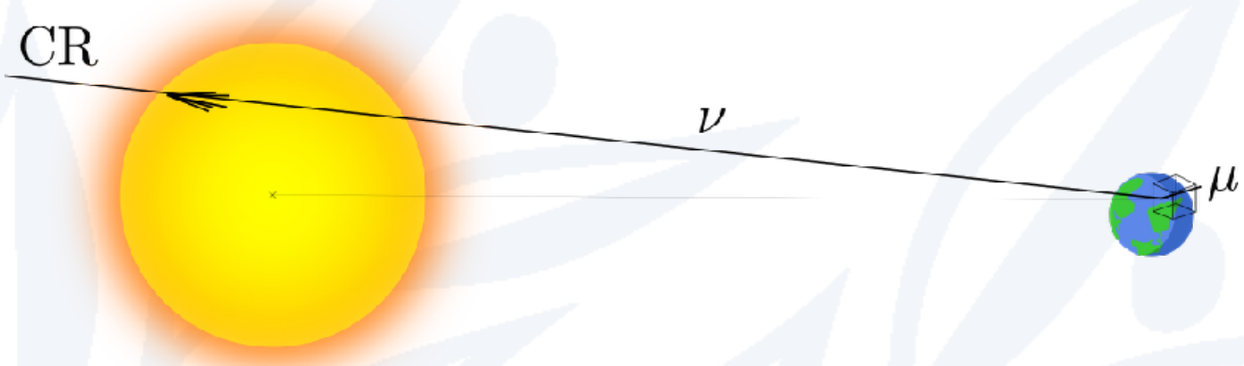
SAv, created by cosmic ray interactions in the Sun is a background that is currently neglected

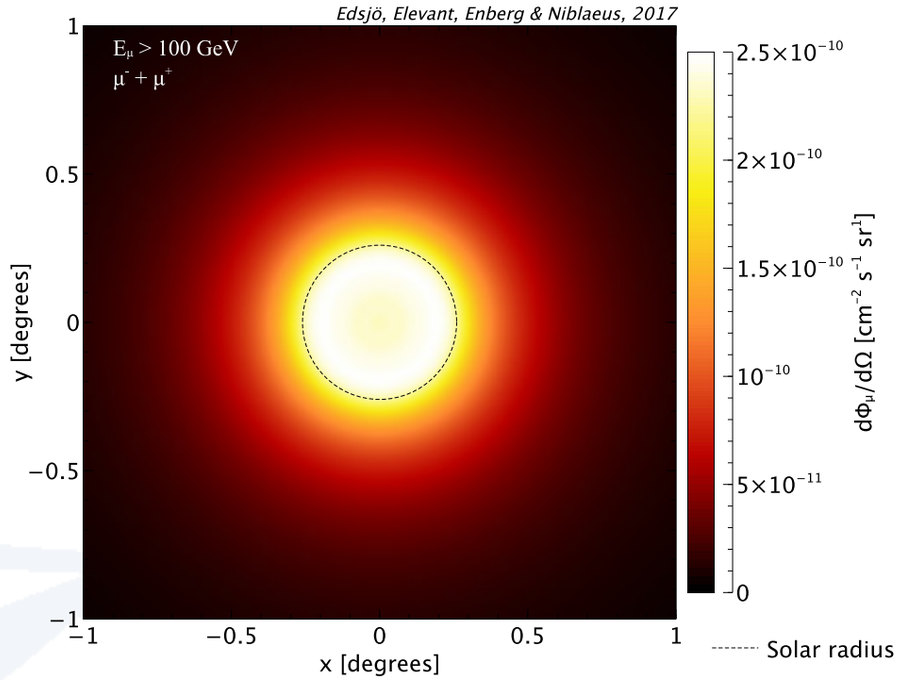
We have calculated the SAv flux at Earth

It can be tough to distinguish a dark matter signal from the SAv

We have calculated the flux of **solar atmospheric neutrinos** and studied the effect on **dark matter searches**

astro-ph/1704.02892





Future prospects:

More detailed studies of detection possibilities

Refined modeling of e.g. magnetic fields

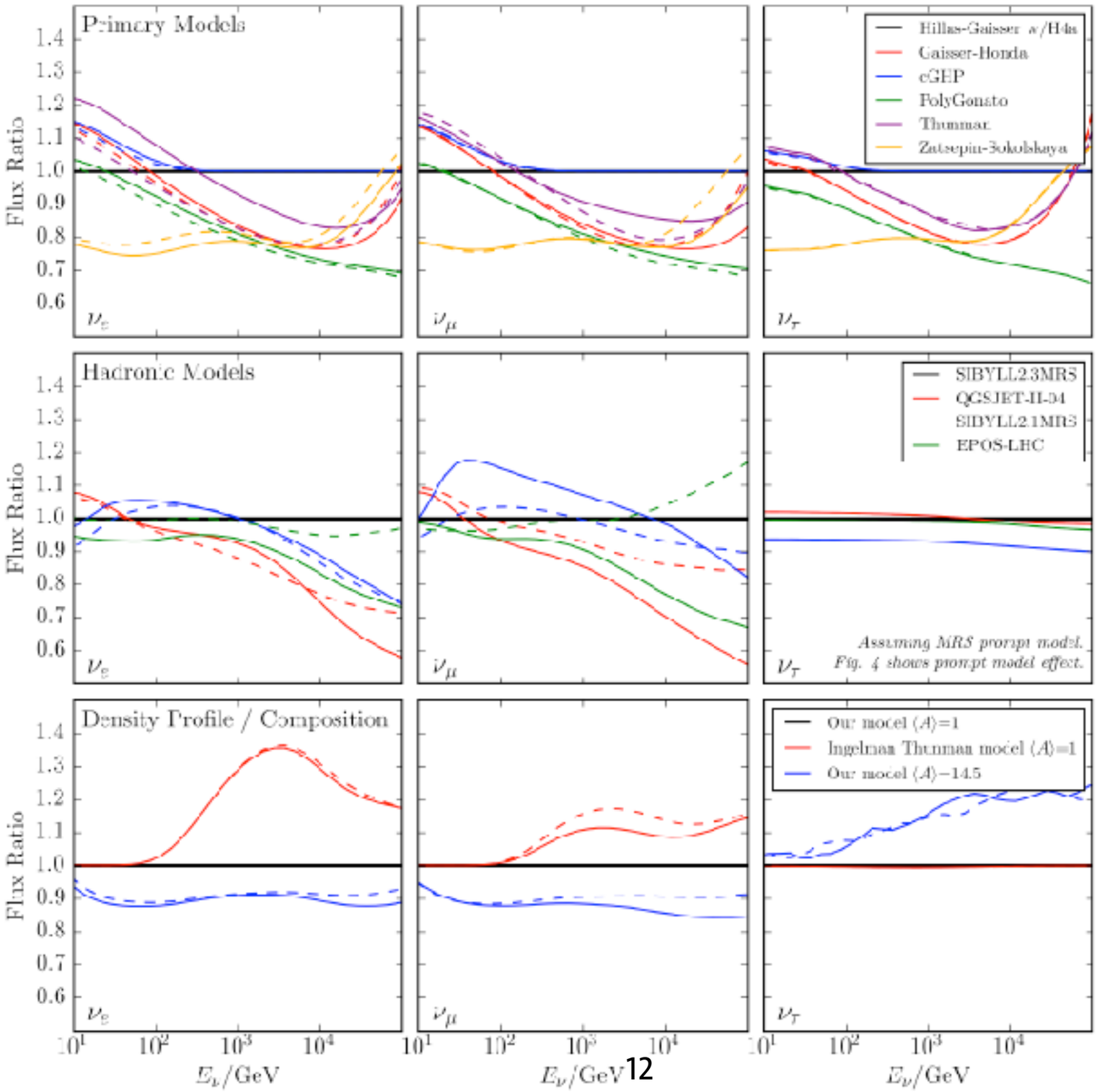
Extra

Systematics on production fluxes from Argüelles et al., astro-ph/1703.07798

CR flux model

Hadr. int. model

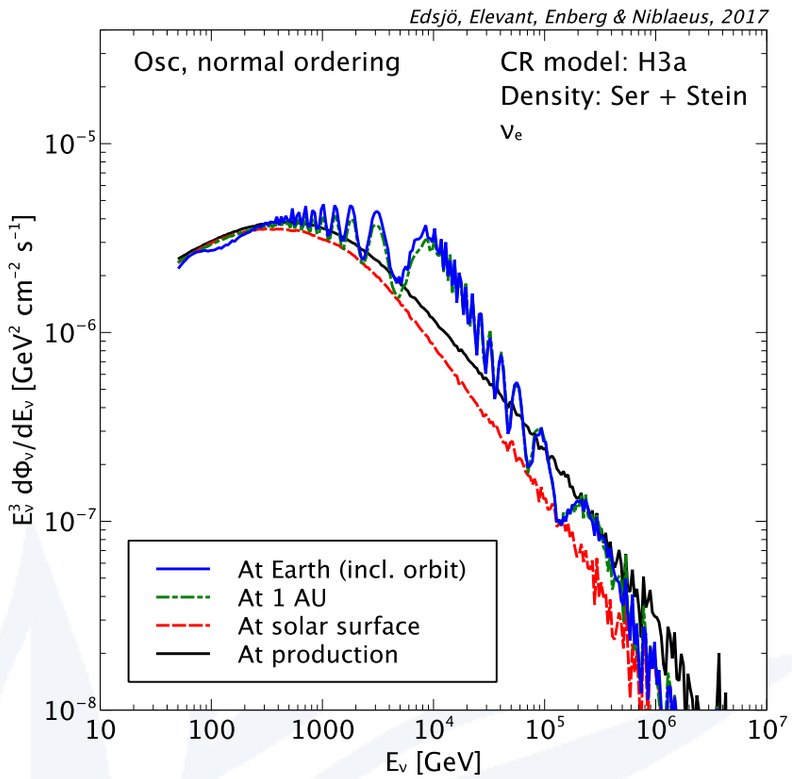
Density profile

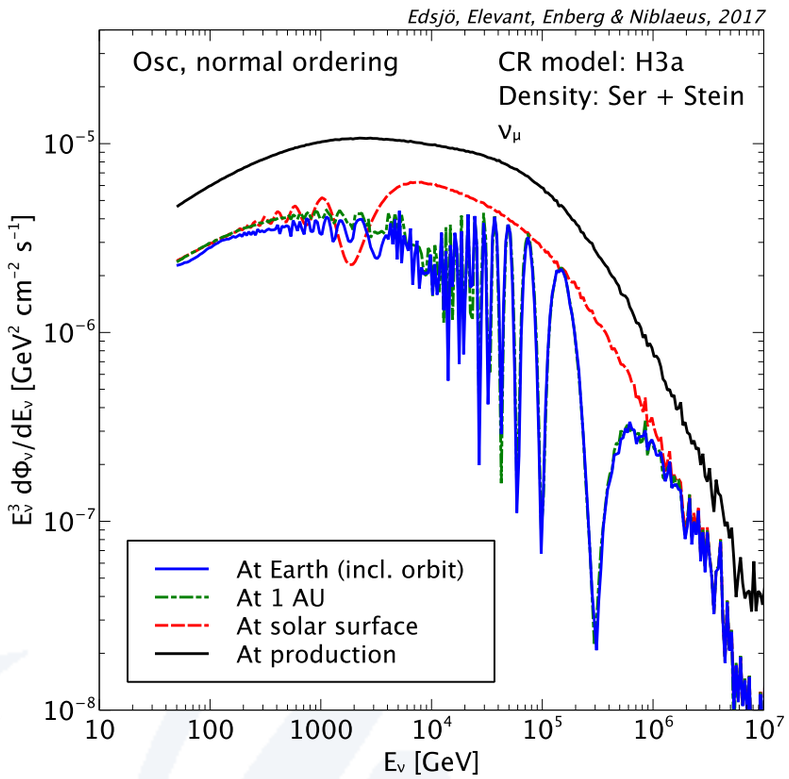


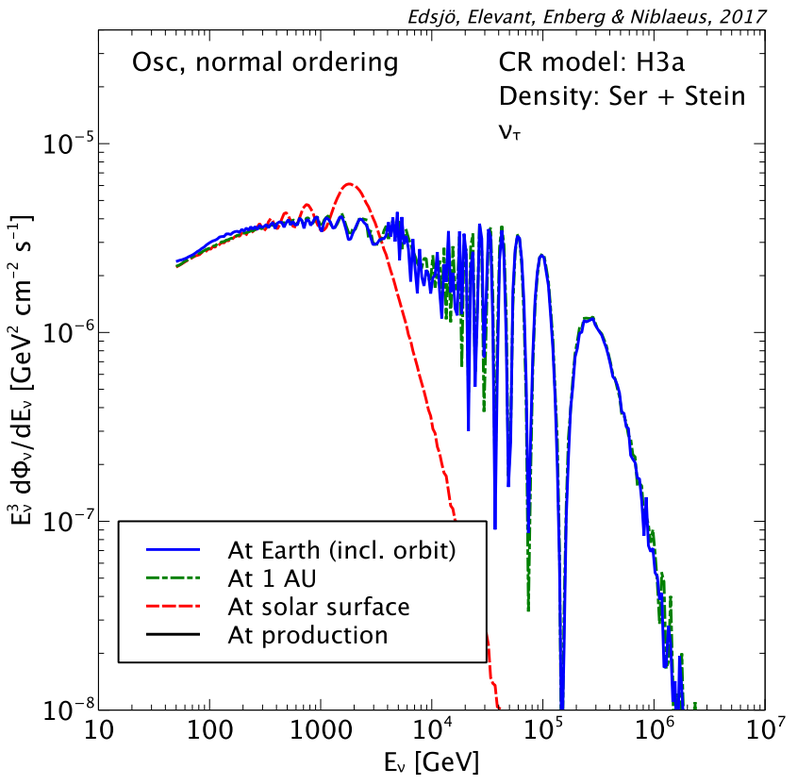
Final effect: factor≈2

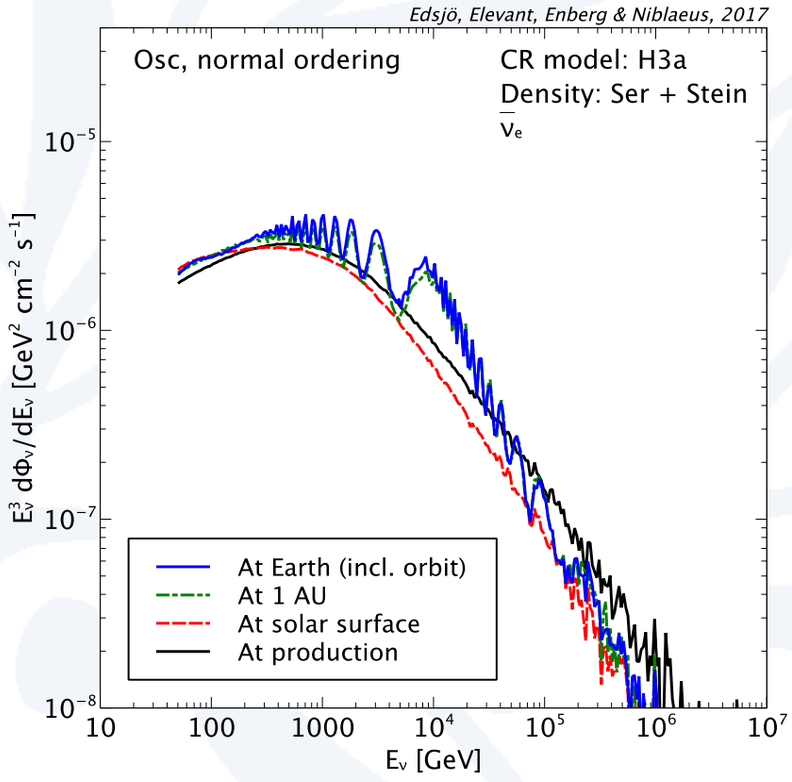
Magnetic field neglected

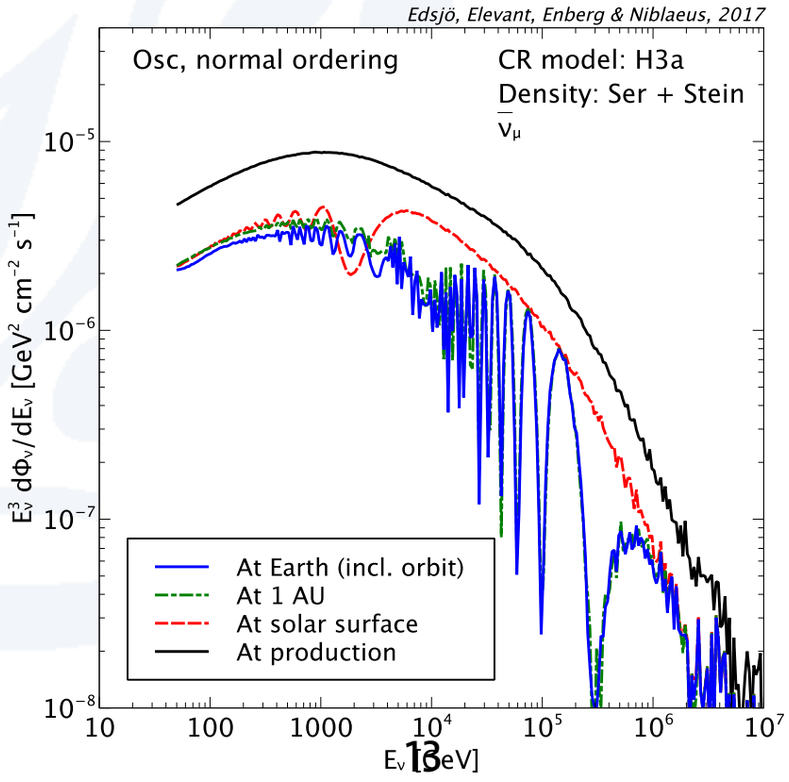
Fluxes for all flavours

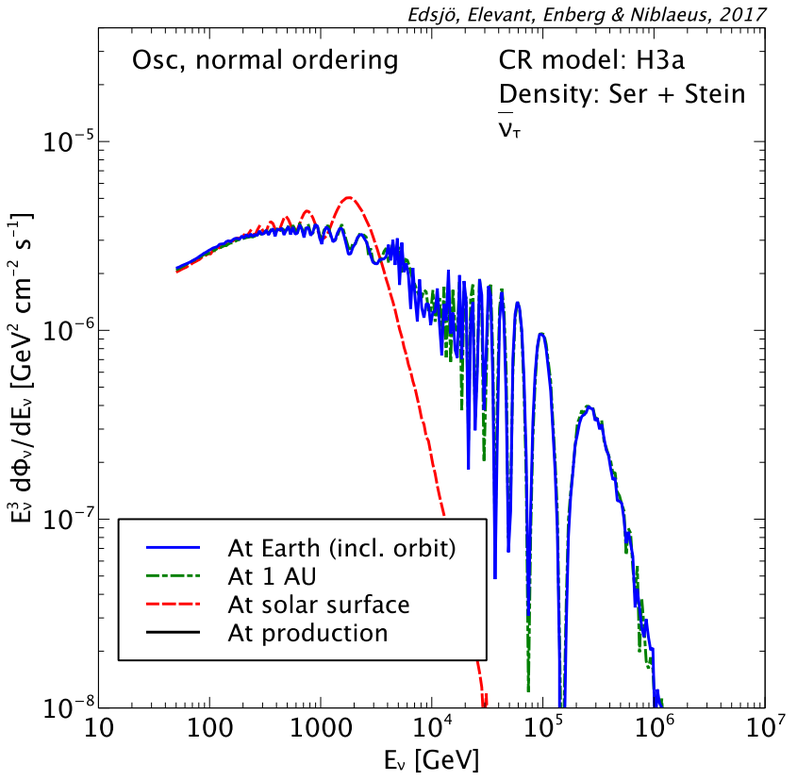




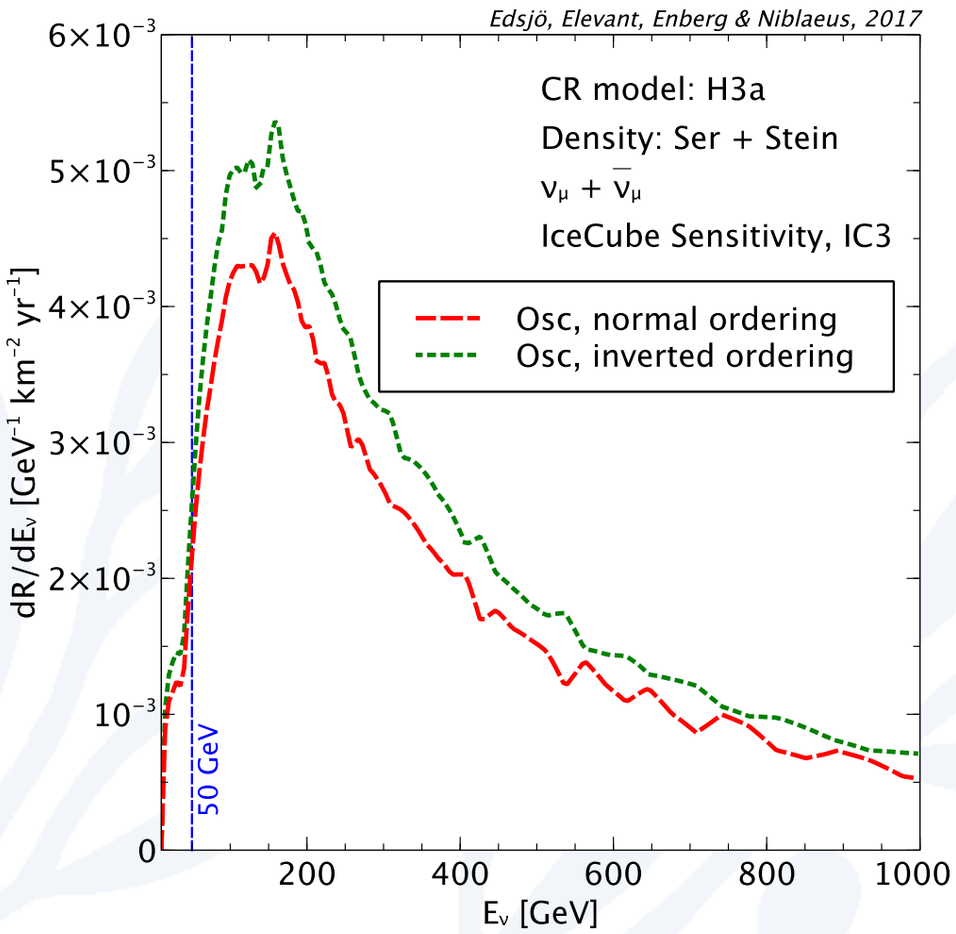




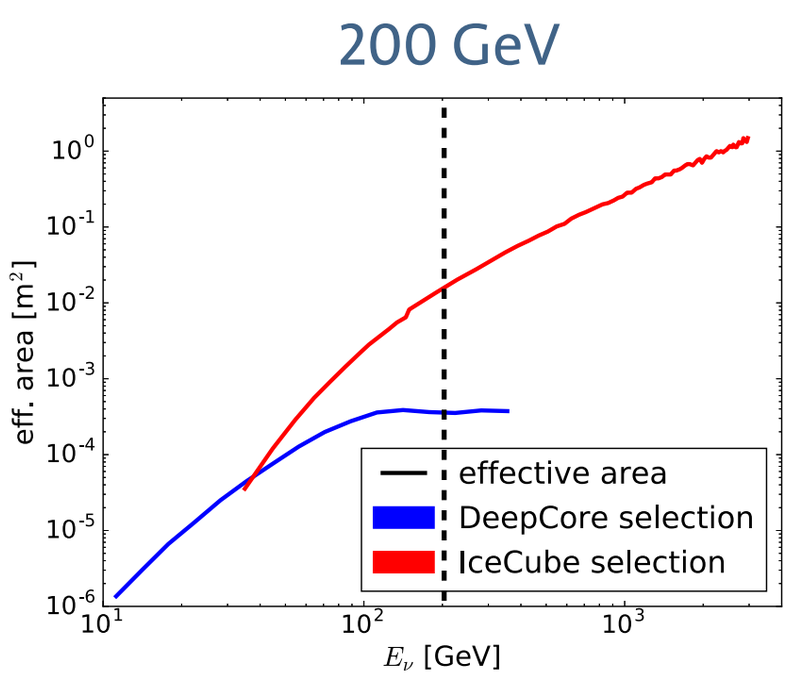




The event rate is dominated by neutrino energies around 200 GeV



$$\frac{dR}{dE} = A_{\text{eff}}(E)\frac{d\Phi}{dE}$$



IC 3y analysis, astro-ph/1612.05949

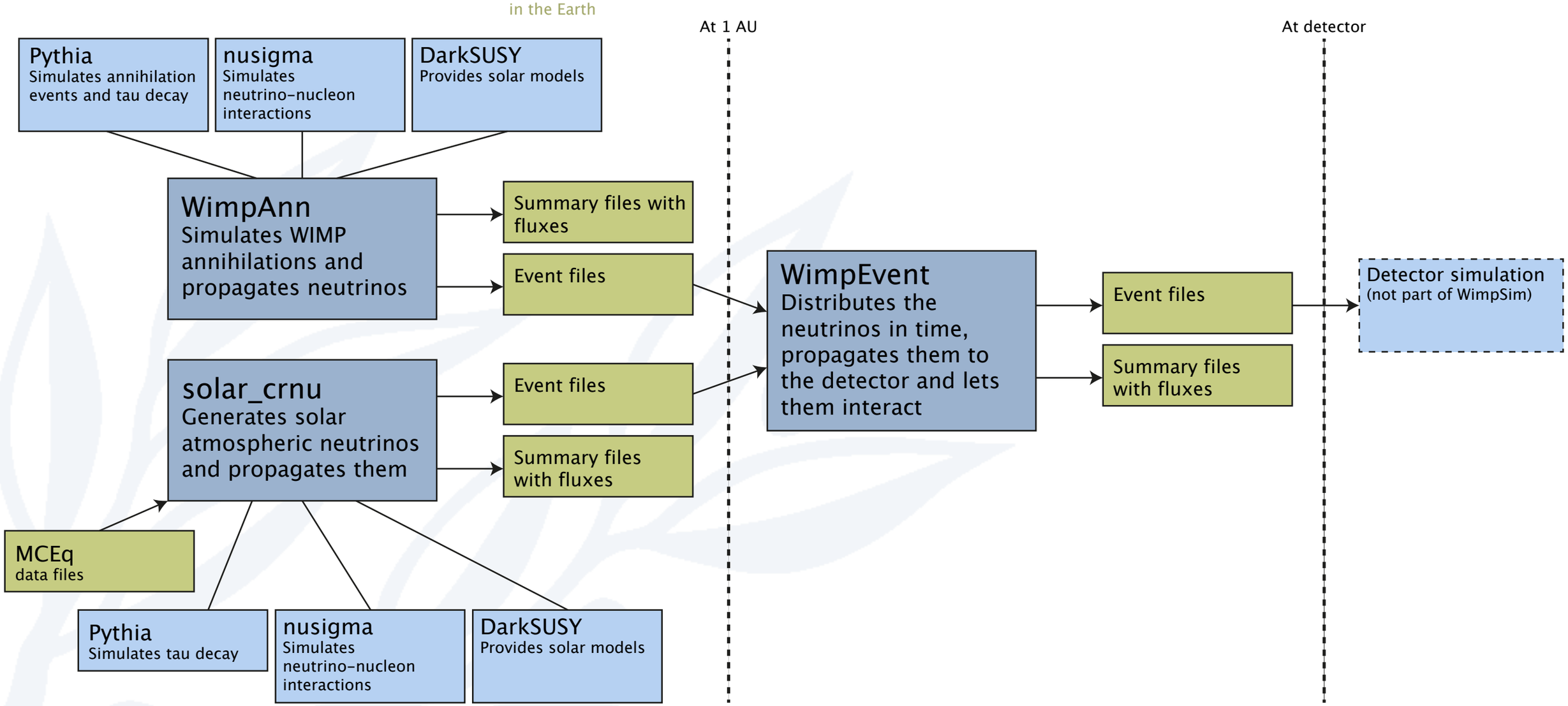
Effective area drops faster than flux increases as energy is lowered

WimpSim code layout

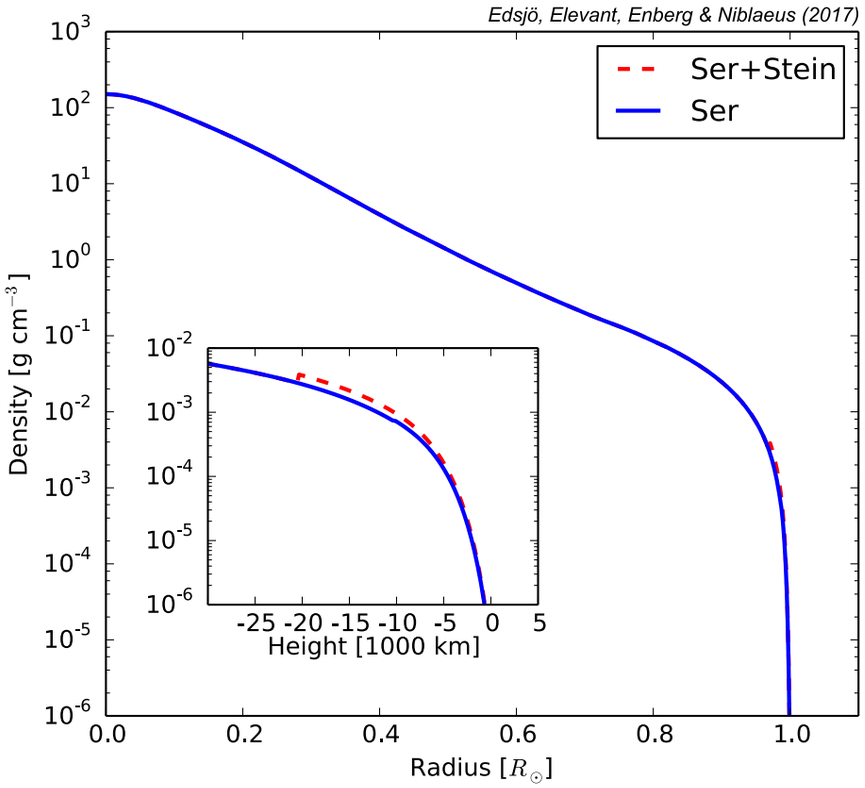
In the Sun*

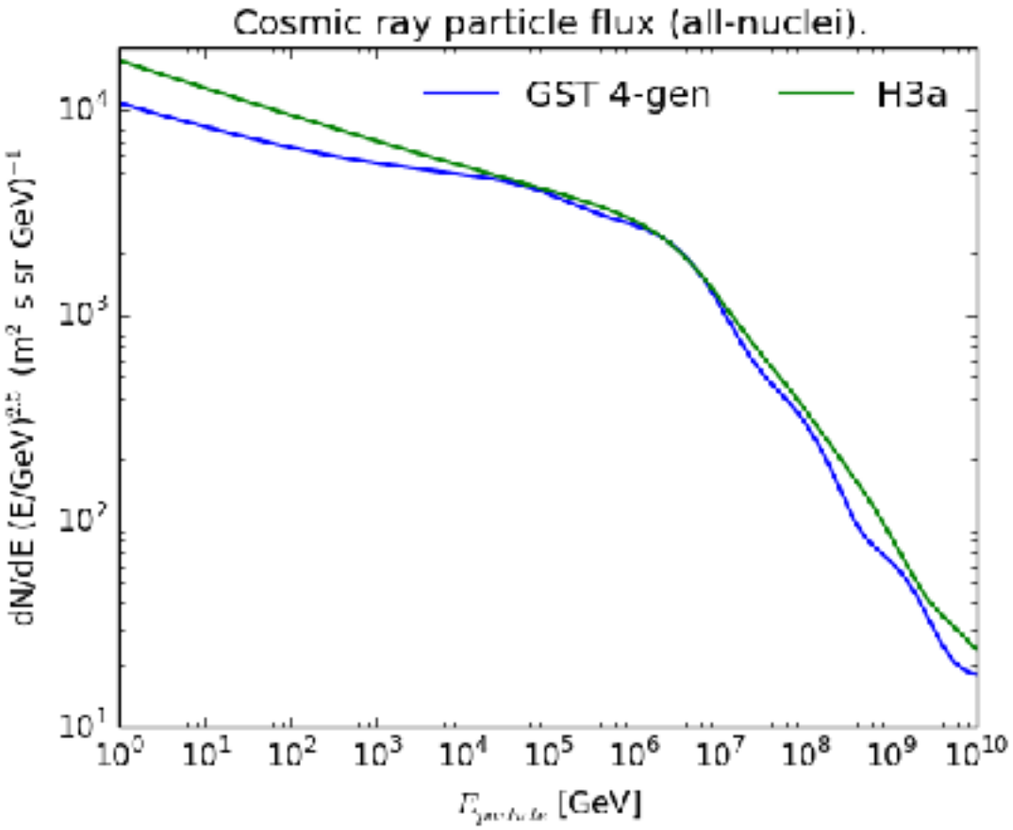
*) WimpAnn can also be run for annihilations in the Earth

At the Earth



We have varied density profile, CR flux model and neutrino mass hierarchy

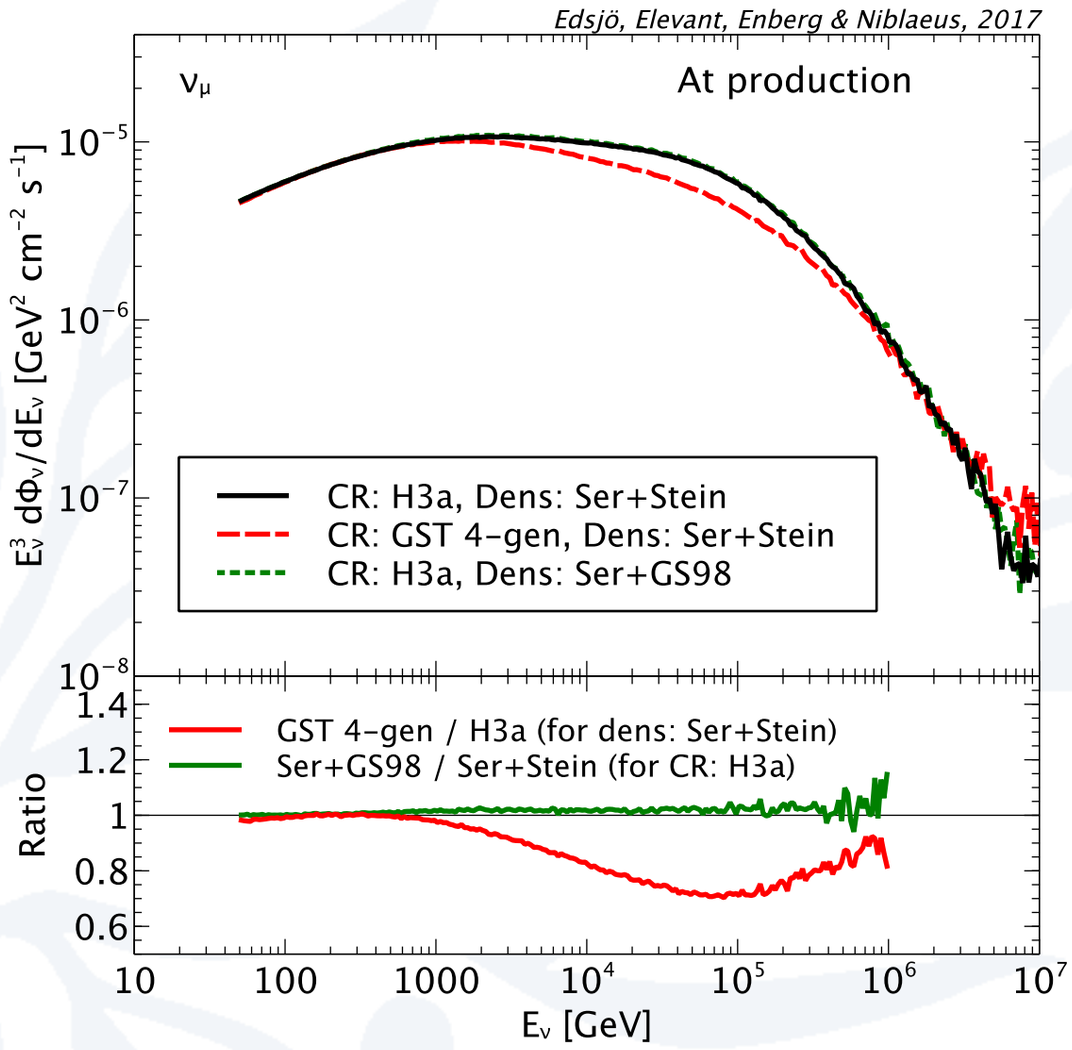




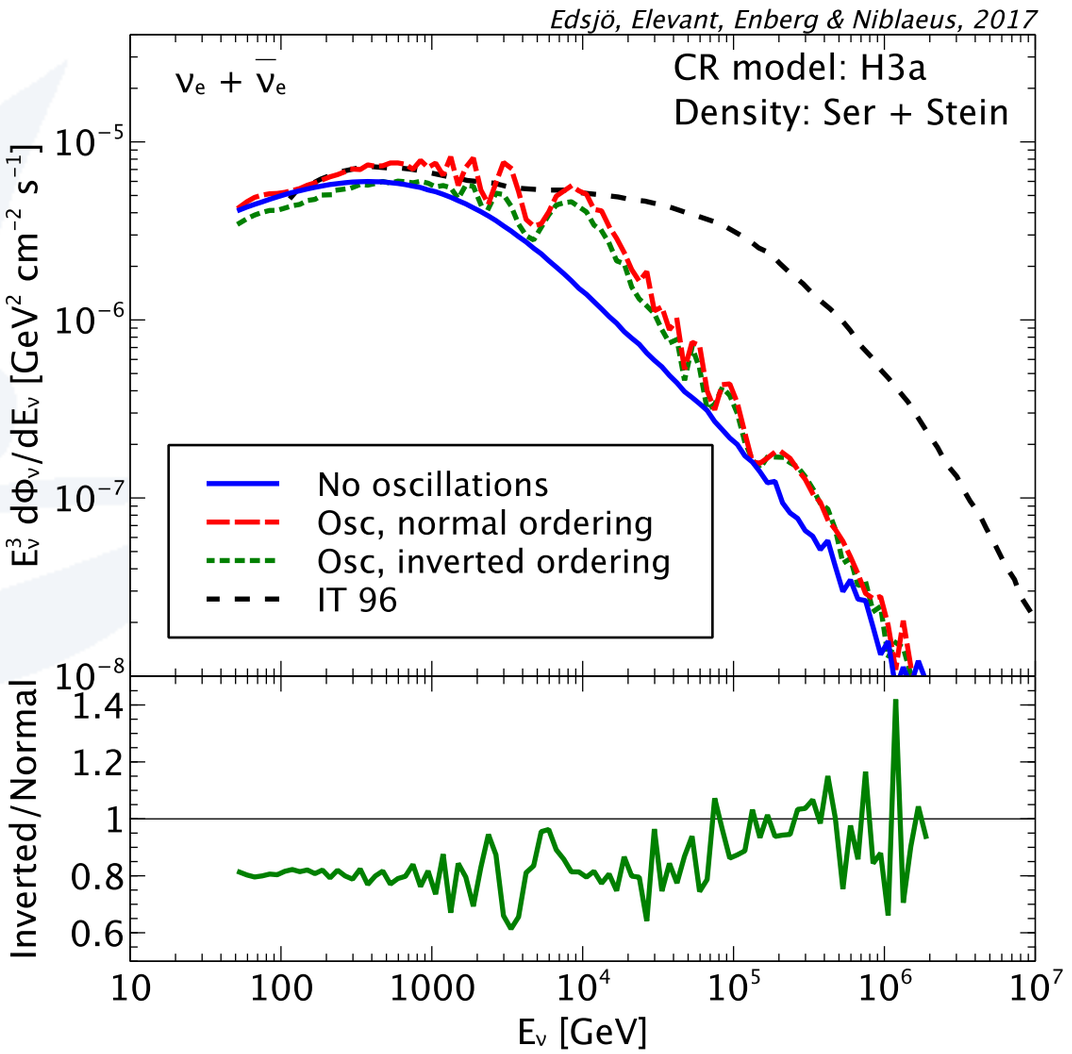
Mass hierarchy affects matter oscillations and best-fit values of oscillation parameters

Resulting flux differences are rather small

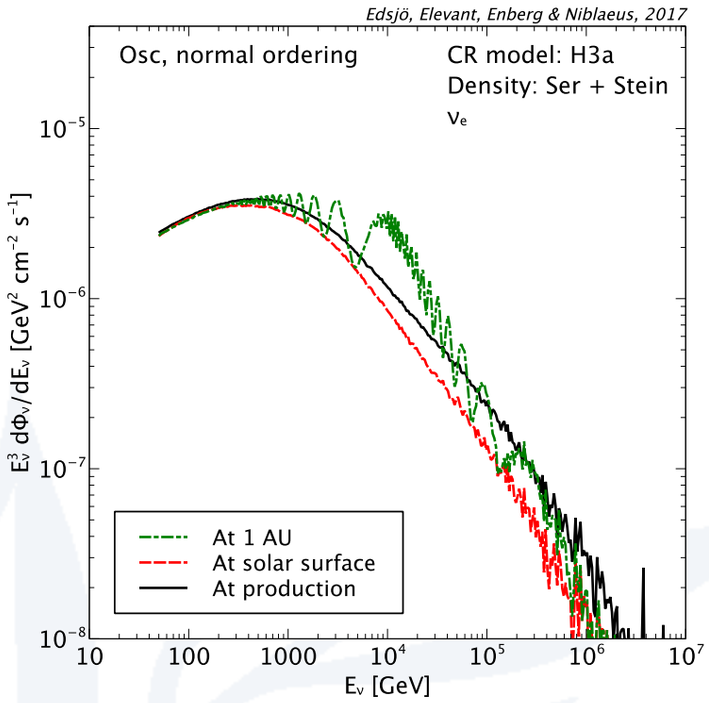
Density/CR model

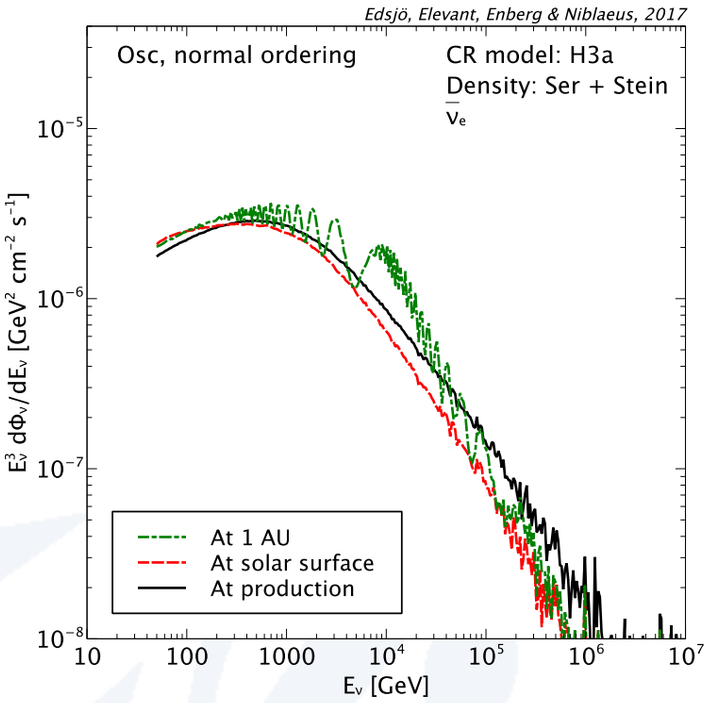


Mass hierarchy

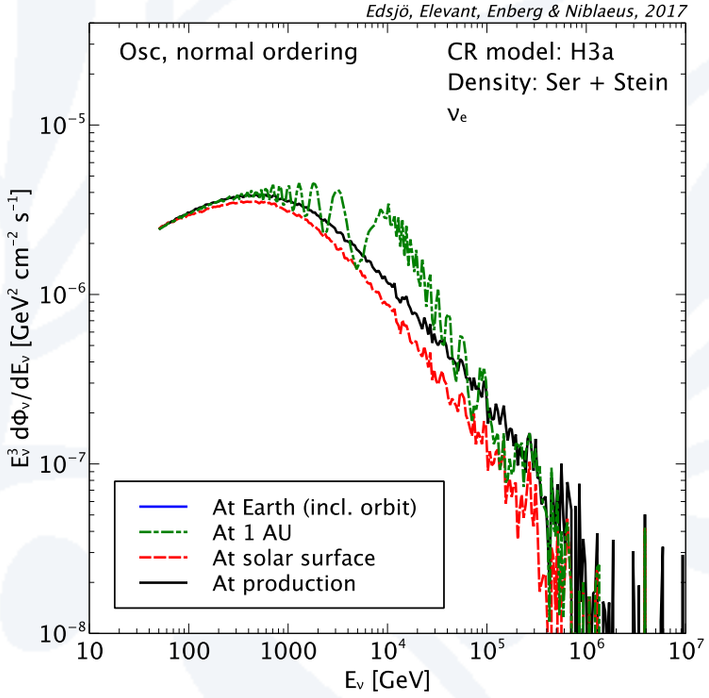


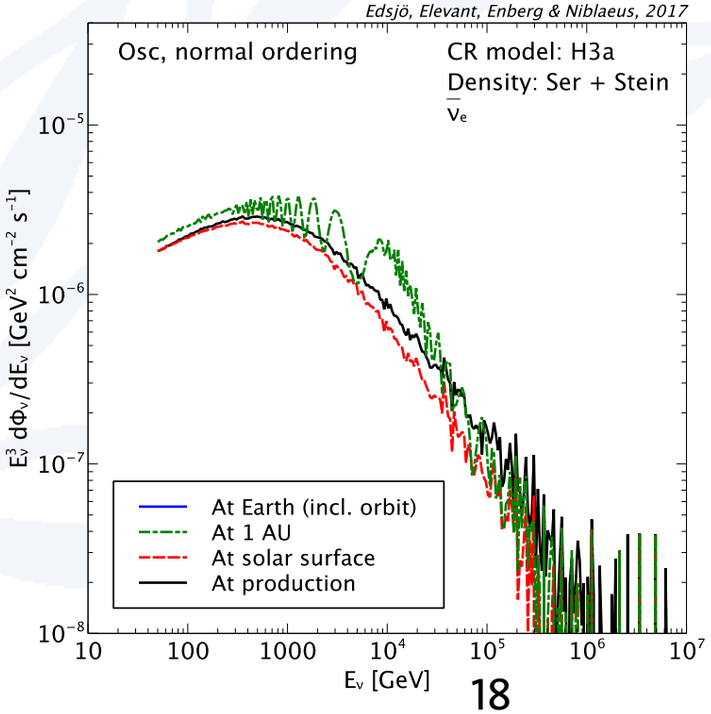
Matter oscillation effects (MSW) are small





Standard





No MSW effect