Screening effects in the ultrahigh energy neutrino nucleon interactions

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based on:
Eur.Phys.J. C29 (2003) 521 K.Kutak, J. Kwieciński

Why neutrinos?

Cosmic space

$$\swarrow \qquad \downarrow \qquad \searrow$$

$$photons \quad hadrons \quad neutrinos$$

- photons

$$\gamma(E = 10^{15} eV) + CMB \rightarrow \quad absorption < 10^8 pc$$

$$\swarrow$$

not very distant sources(dist. between galaxies $10^7 pc$)

- hadrons

$$p(E = 10^{20} eV) + CMB \rightarrow \quad absorption < 10^{7} pc$$

Universe is not transparent also to high energy hadrons

low energy hadrons + $\vec{B}$

$\downarrow$

scrambled by magnetic field

$\downarrow$

no useful information about source(direction)

- neutrinos

they interact weakly W^+, W^-, Z^0

$\downarrow$

range $10^9 pc$

Only neutrinos can reach us without attenuation from extragalactic sources. They test QCD at very high energies.

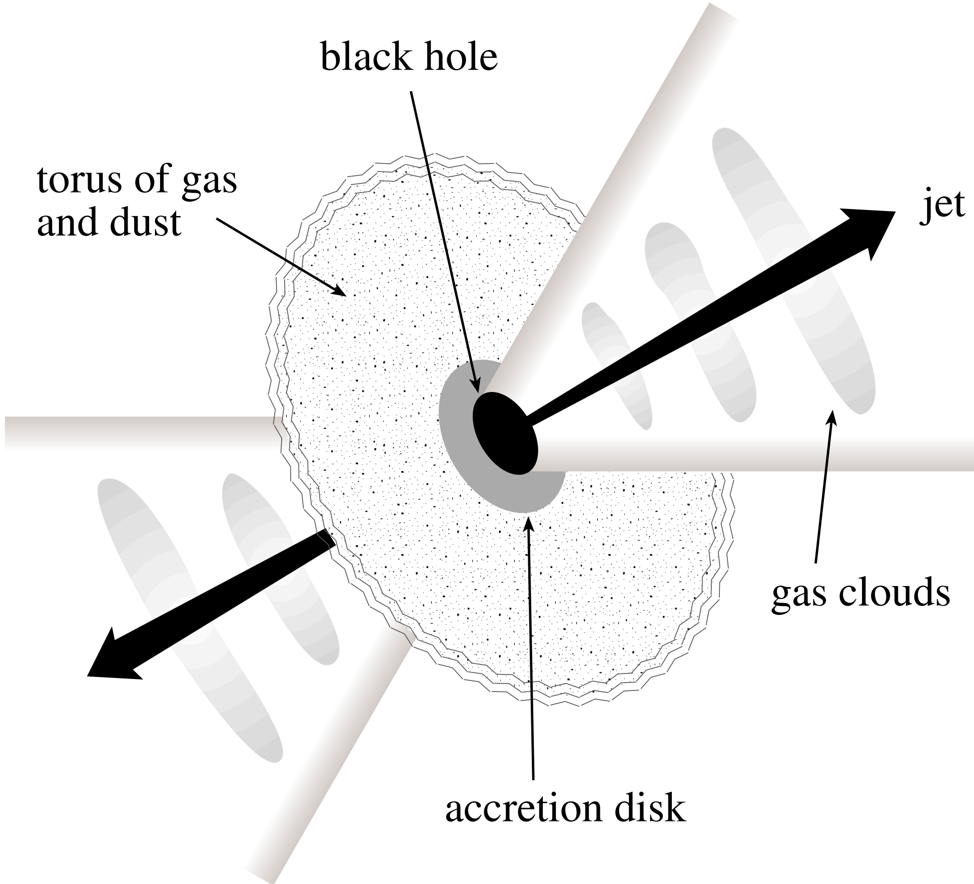
Sources of UHE neutrinos

- Active Galactic Nuclei

This is how we get neutrinos:

$$p+\gamma \to \pi \to \mu+\nu_\mu \to e+\nu_\mu+\nu_e+\overline{\nu_\mu}$$

$$E_\nu \approx 10^{19} eV$$

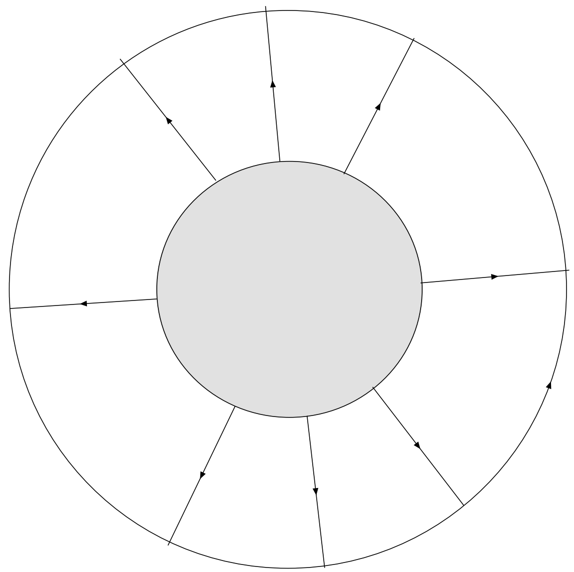


Sources of UHE neutrinos

- Gamma Ray Bursts
  Expanding neutron star $\longrightarrow$

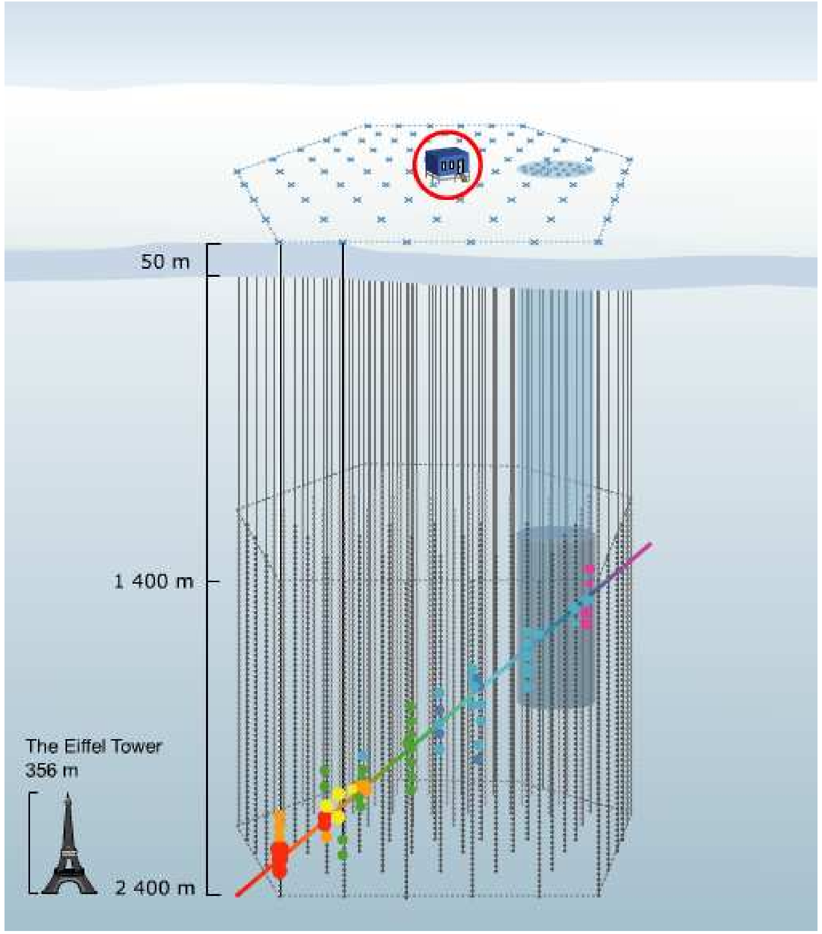
$$p+\gamma \rightarrow \pi \rightarrow \mu+\nu_\mu \rightarrow e+\nu_\mu+\nu_e+\overline{\nu_\mu}$$

$$E_\nu \approx 10^{14} eV$$



Detection

- neutrino production
- propagation through Cosmic Space
- propagation through Earth
- decay to muon close to the detector
- muon produces Cherenkov light in Ice Cube(South Pole)



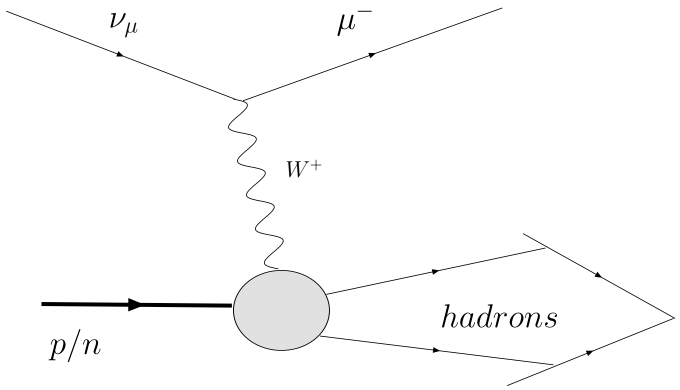
Ice Cube fully operational in 2011.
Volume $1km^3$
4200 optical modules

Interaction with nucleons

$$\frac{\partial^2\sigma^{CC,NC}_{\nu,\bar{\nu}}}{\partial x\partial y} = \frac{G_F^2 M E}{\pi}\left(\frac{M_i^2}{Q^2+M_i^2}\right)$$

$$[\frac{1+(1-y)^2}{2}F_2^{CC,NC}(x,Q^2) - \frac{y^2}{2}F_L^{CC,NC}(x,Q^2)$$

$$\pm y\left(1-\frac{y}{2}\right)xF_3^{CC,NC}(x,Q^2)]$$



G_F Fermi constant, M nucleon mass, M_i boson mass, E energy of the neutrino, x Bjorken variable, y inelasticity.
The dominant contribution $\rightarrow$ $Q^2 = M_W^2$.
At highest energies $x \simeq 10^{-8}$ $\rightarrow$ gluon dominated process. $F2$ gives dominant contribution.

Cross section in k_t factorisation approach

At $x \simeq 10^{-8} \rightarrow$ gluon dominated process. Realistic estimate should include:

- nonlinear dynamics(BFKL + screening)
- effects coming from DGLAP(large Q^2)

Basic quantity: unintegrated gluon distribution $f(x, k^2)$

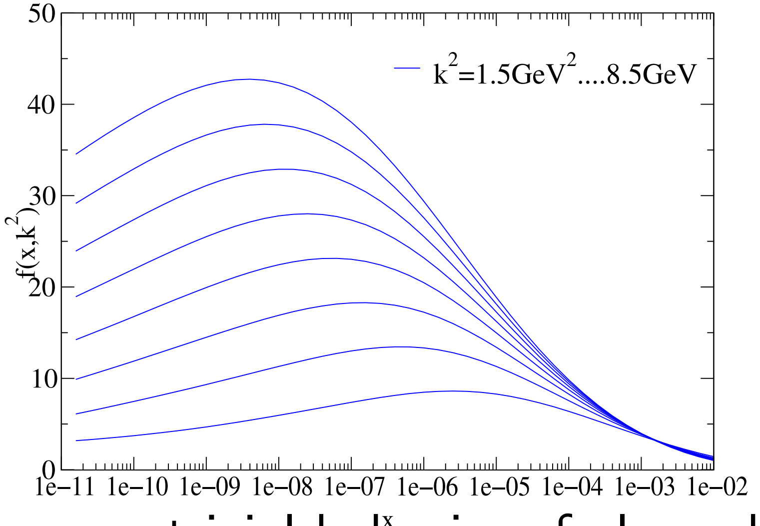
$$F_2 \simeq S \otimes f$$

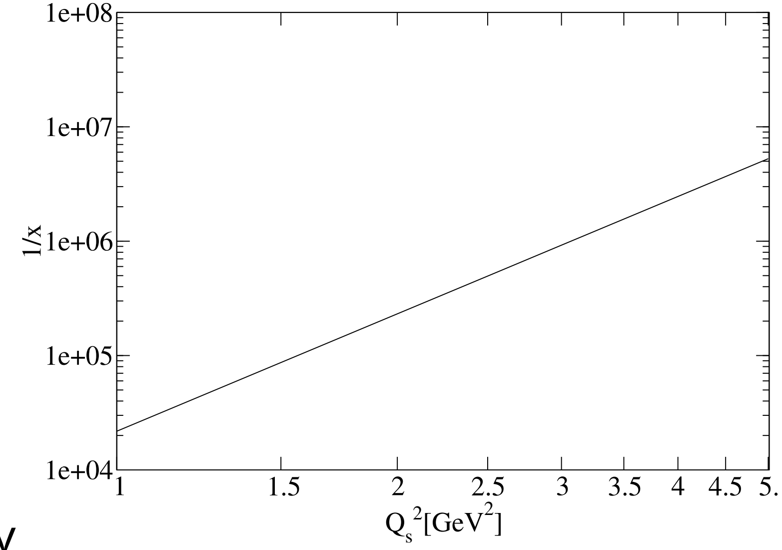
S$\rightarrow$quark loop, f satisfies:

$$f = f_0 + K_1 \otimes f - K_2 \otimes f^2$$

K_1 BFKL kernel with subleading effects, K_2 Triple Pomeron Vertex.
Proton is assumed to have sharp edge.

Properties of gluon coming from nonlinear equation





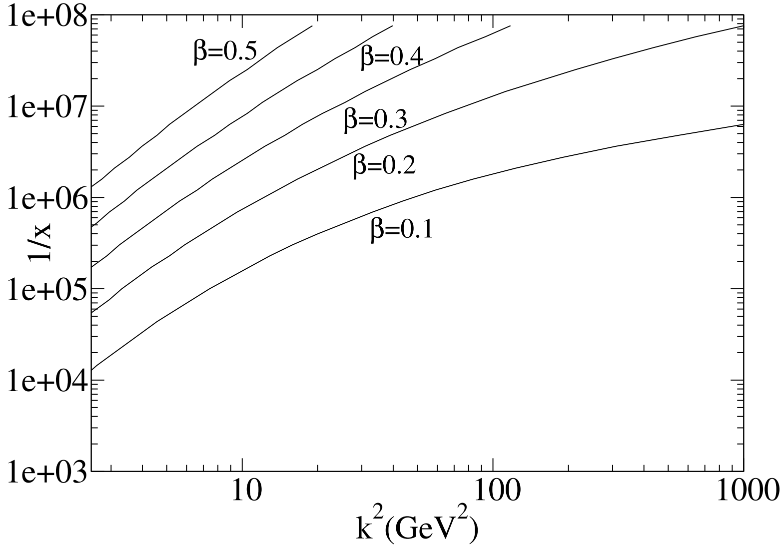
- nontrivial behavior of gluon density
- emergence of saturation scale

Saturation alternatively

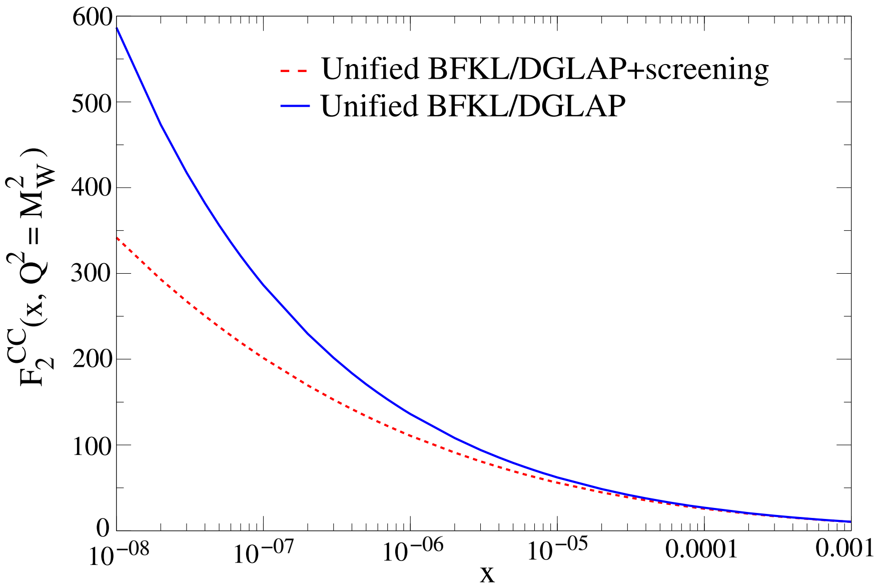
Relative difference:

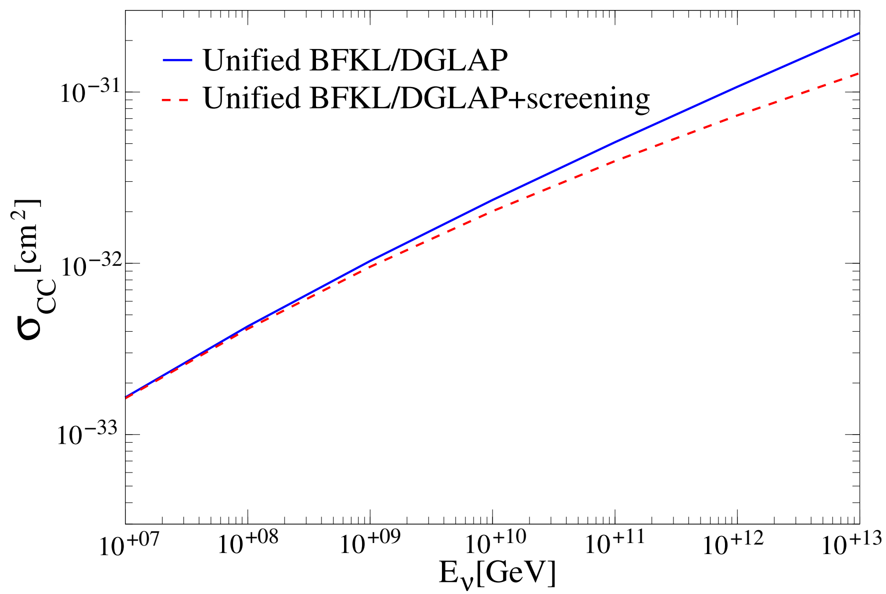
$$\frac{|f^{lin}(x,\tilde{Q}_s^2(x,\beta)) - f^{nlin}(x,\tilde{Q}_s^2(x,\beta))|}{f^{lin}(x,\tilde{Q}_s^2(x,\beta))} = \beta$$

Difference not negligible at large k^2



Results for F_2^{cc} and xsection





- screening corrections slow down growth of F_2^{cc}
- screening corrections reduce $\sigma^{\nu N}$ by factor lass than 2 at ultrahigh energies

Conclusions and outlook

- Neutrinos test QCD at very small $x \simeq 10^{-8}$.
- Screening corrections are relevant for ultrahigh energy neutrinos.
- Screening corrections reduce $\sigma^{\nu N}$ by factor less than 2 at ultrahigh energies.
- Possible small reduction of screening when more realistic proton profile is assumed.
- Update with more recent HERA data? Another approach to take into account DGLAP effects?

Dodatek

Screening effects for nucleai.