technische universität dortmund

Experimentelle Physik V
Teilchenphysik

Neutrino cross sections

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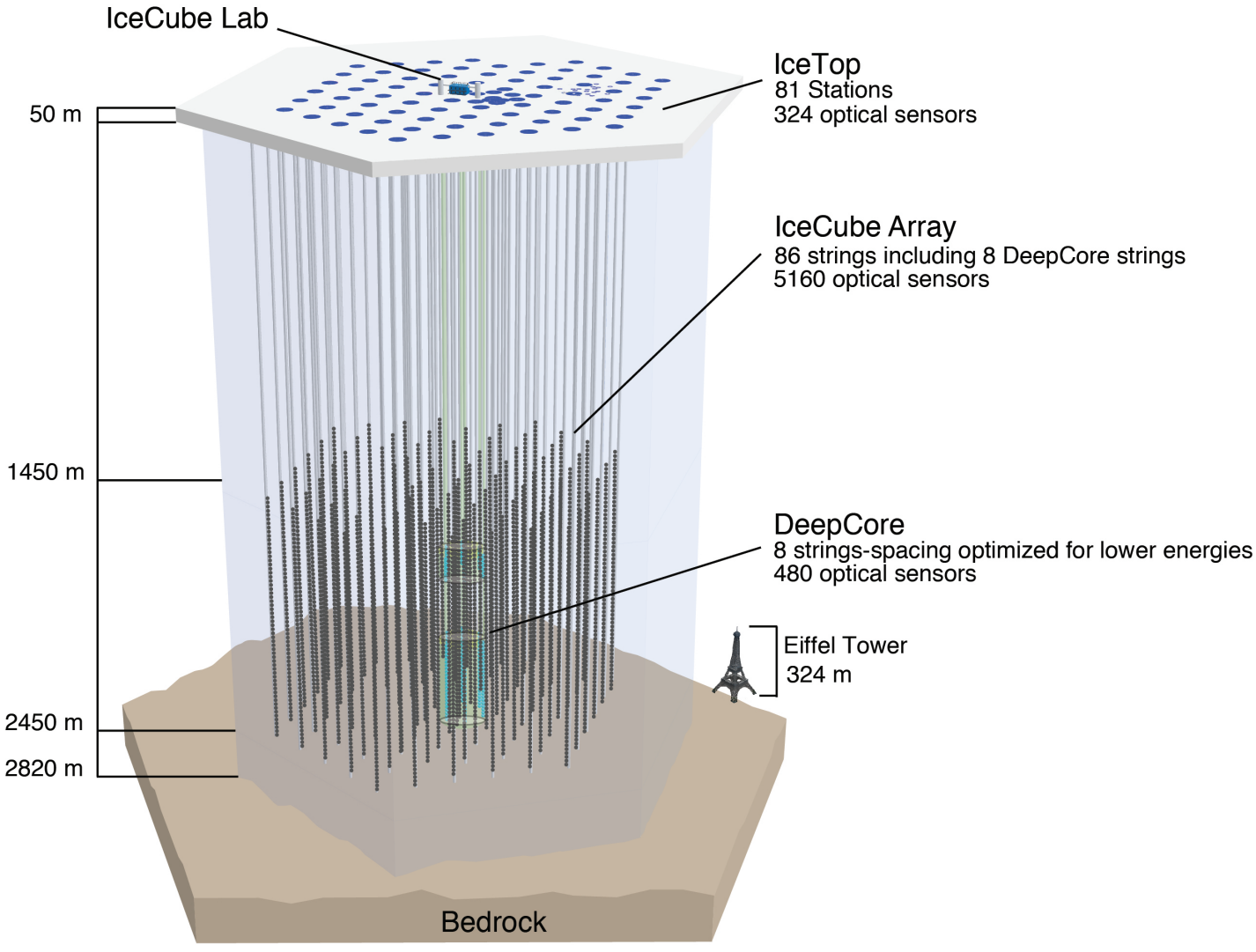
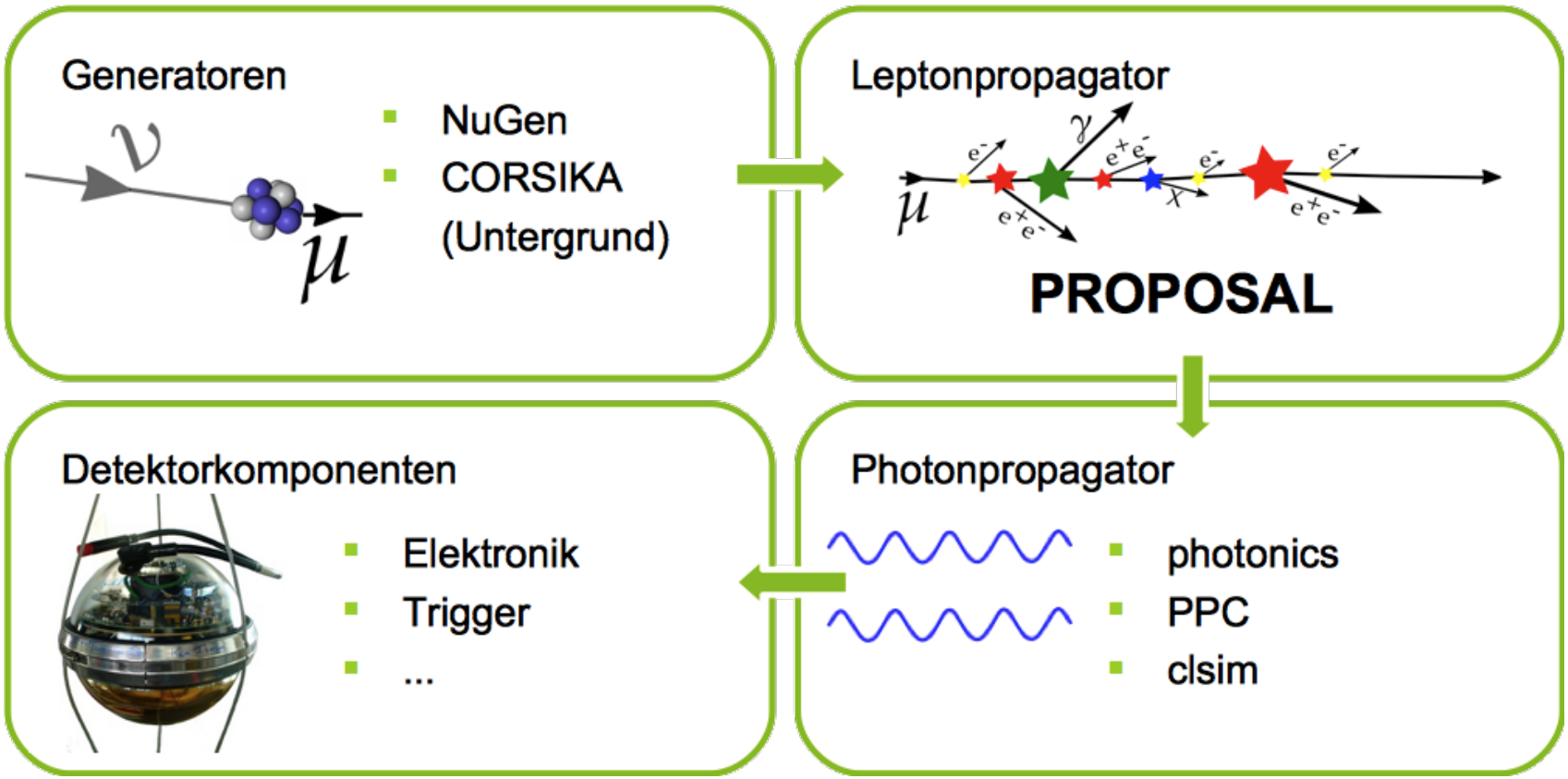
IceCube Detector



[1]

IceCube Simulation Chain



Neutrino Interactions

- Charged Current

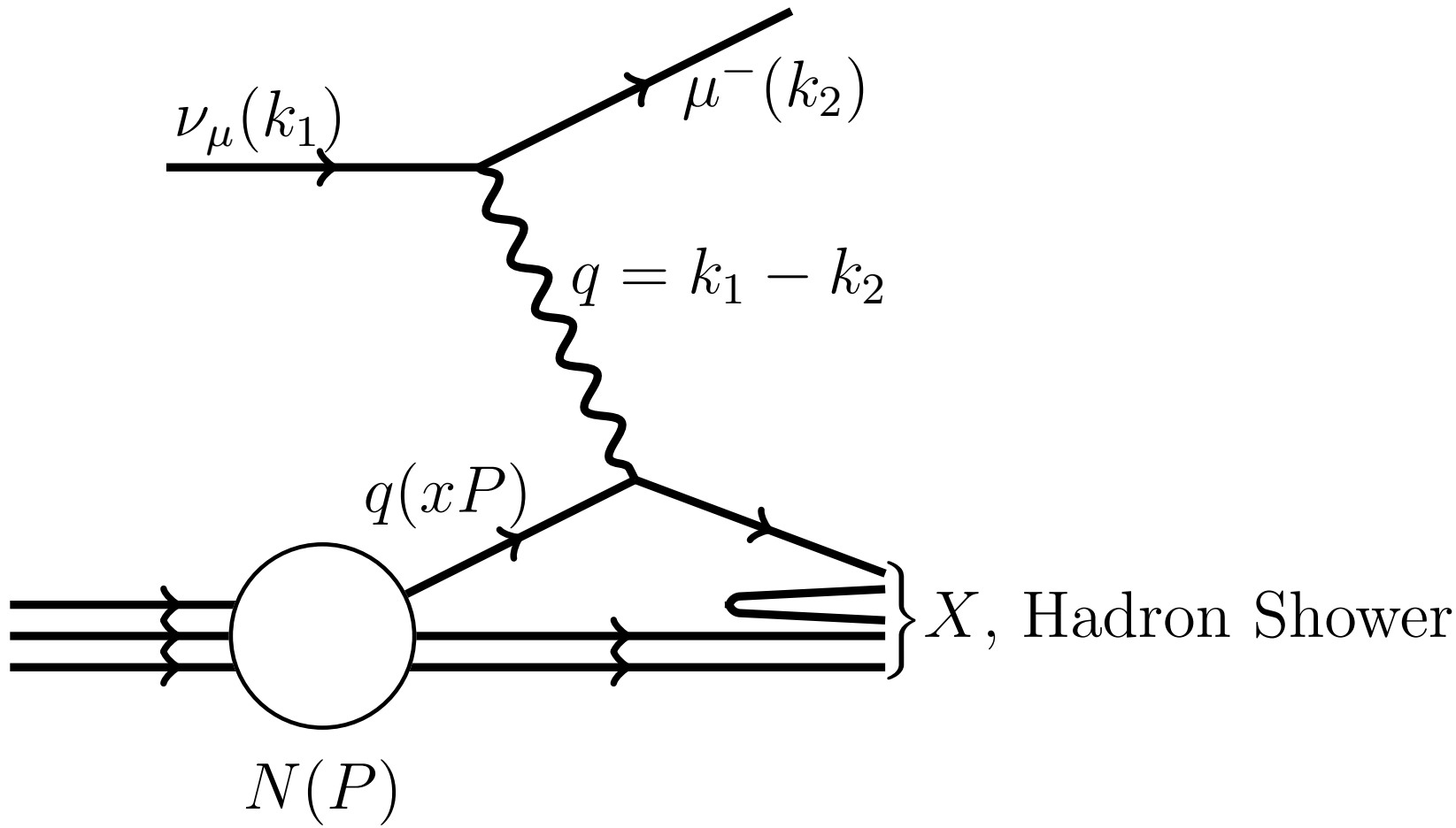
$$\nu_\ell + N \to \ell^- + X$$
$$\bar{\nu}_\ell + N \to \ell^+ + X$$

- Neutral Current

$$\nu_\ell + N \to \nu_\ell + X$$
$$\bar{\nu}_\ell + N \to \bar{\nu}_\ell + X$$

At relevant energies for IceCube the process of deep inelastic scattering is dominating ($E > 5\,\mathrm{GeV}$).

Deep Inelastic Scattering



DIS Kinematic Invariants

- Bjorken scaling variable

$$x = \frac{Q^2}{2M\nu}$$

- Inelasticity in laboratory frame

$$y = \frac{\nu}{E}$$

- Four-momentum transfer

$$q = k_1 - k_2$$
$$Q^2 = -q^2 = -(k_1 - k_2)^2$$

Inclusive Leading Order CC Cross Section

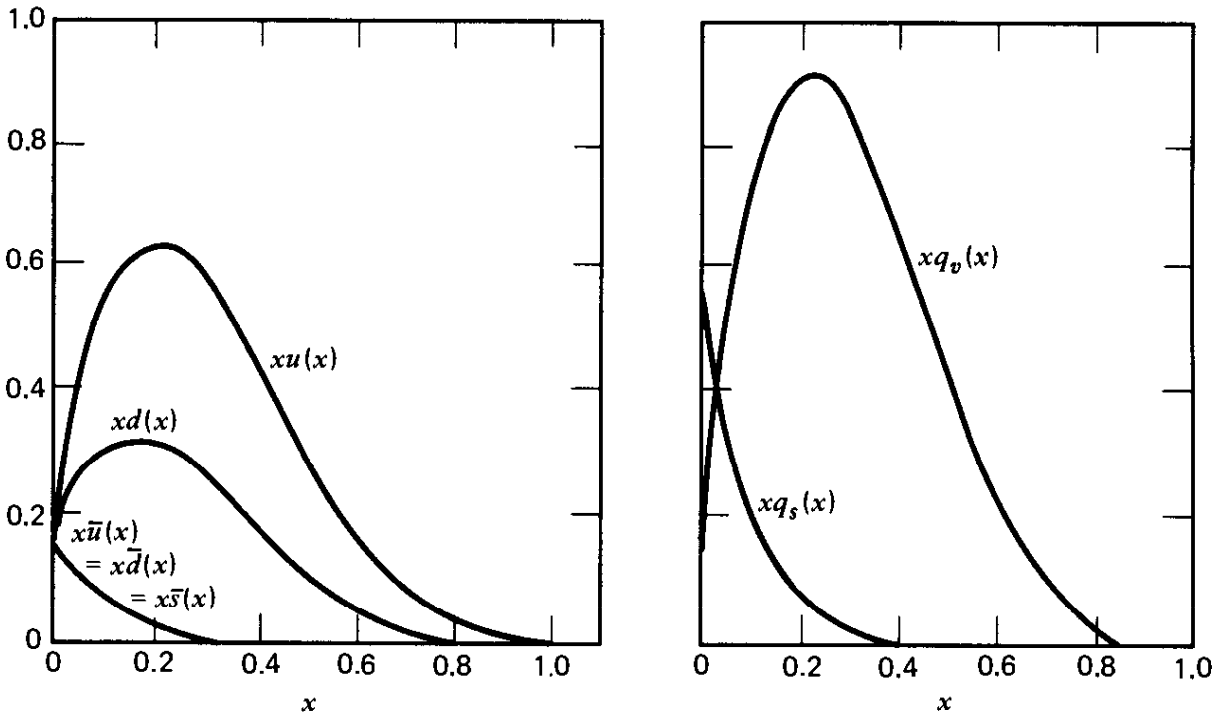
$$\frac{\mathrm{d}^2\sigma\left(\nu N, \bar{\nu} N\right)}{\mathrm{d}x\mathrm{d}Q^2} = \frac{G_F^2 M_W^4}{4\pi(Q^2 + M_W^2)^2 x}\sigma_r\left(\nu N, \bar{\nu} N\right)$$

$$\sigma_r\left(\nu N\right) = \left[Y_+ F_2^{\nu}(x, Q^2) - y^2 F_L^{\nu}(x, Q^2) + Y_- x F_3^{\nu}(x, Q^2)\right]$$
$$\sigma_r\left(\bar{\nu} N\right) = \left[Y_+ F_2^{\bar{\nu}}(x, Q^2) - y^2 F_L^{\bar{\nu}}(x, Q^2) - Y_- x F_3^{\bar{\nu}}(x, Q^2)\right]$$

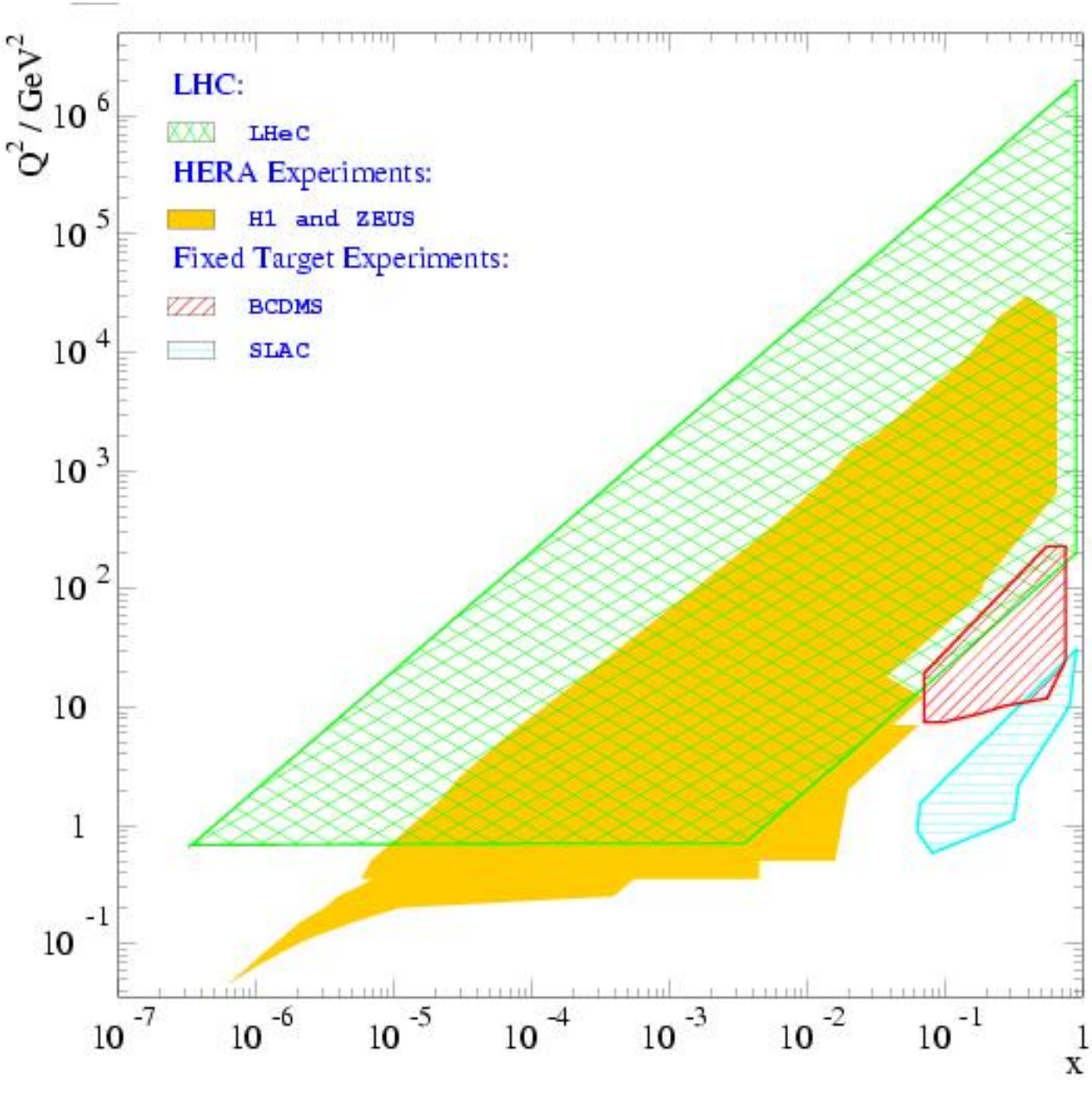
$$\text{with } Y_\pm = 1 \pm (1 - y)^2$$
$$F_2^{\nu,\bar{\nu}}(x, Q^2) = 2 \sum_{i=u,d,\ldots} \left[xq(x, Q^2) + x\bar{q}(x, Q^2)\right]$$
$$xF_3^{\nu,\bar{\nu}}(x, Q^2) = 2 \sum_{i=u,d,\ldots} \left[xq(x, Q^2) - x\bar{q}(x, Q^2)\right]$$

Parton Distribution Functions

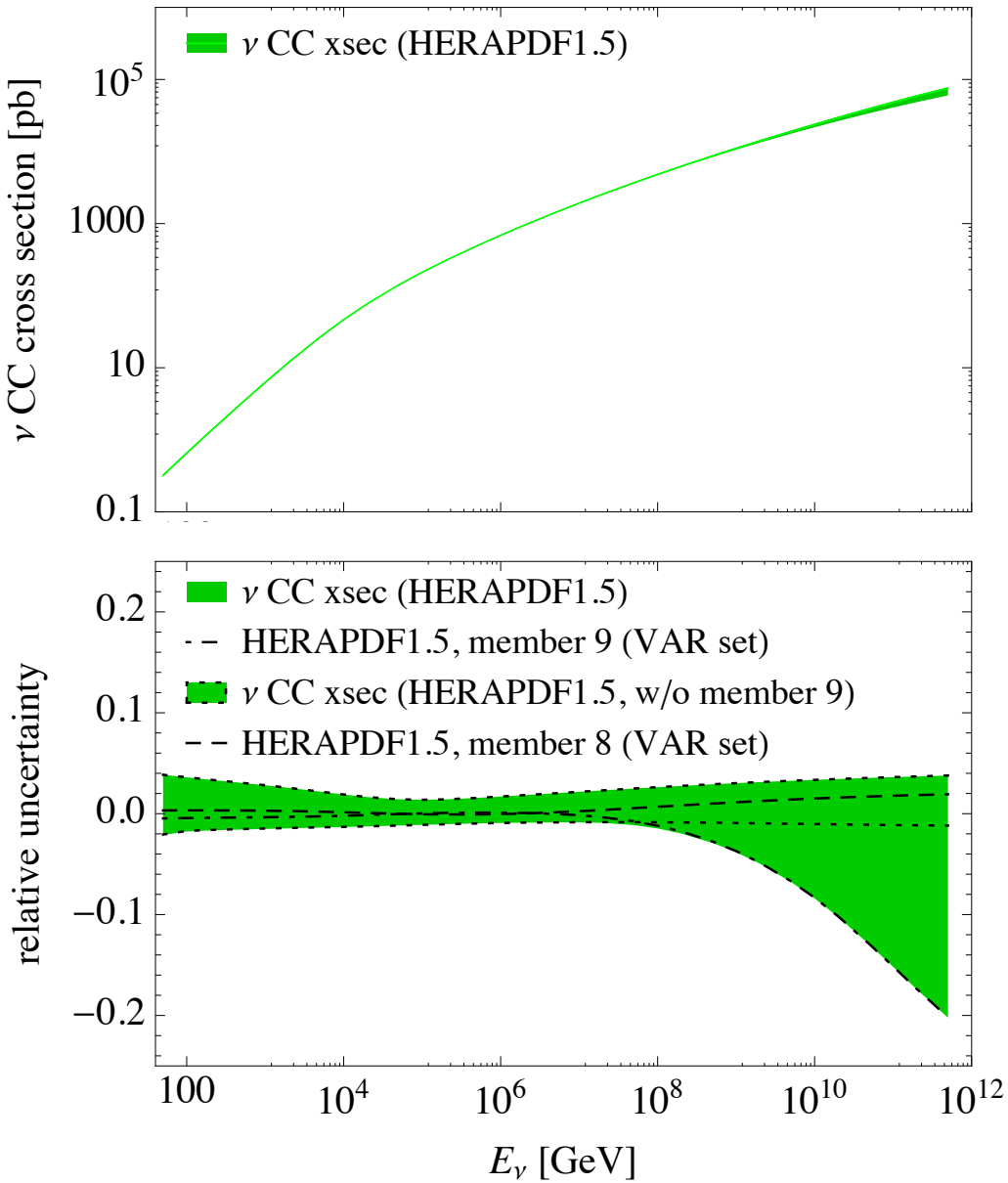
- PDFs (e.g. in F_2, F_3, F_L) can be measured in accelerator experiments.
- Different experiments probe different kinematical regions.
- Extrapolate PDFs to regions of smaller x to describe the cross section at highest energies.



[2]


LHC:
LHeC
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
BCDMS
SLAC
Q^2 / GeV^2
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
[3]

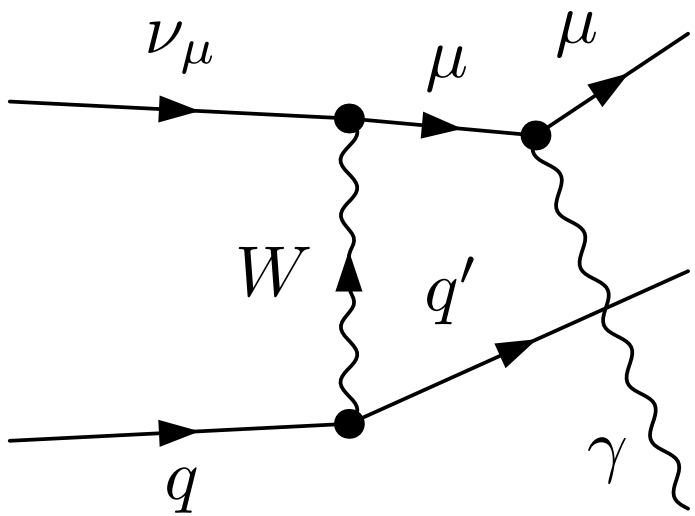
Currently Implemented Cross Section



[4]

Include Corrections

- Lepton masses
- Higher order QCD processes
- Nuclear effects
- Radiative corrections
- Target mass effects
- Heavy quark production



References

[1] http://2.bp.blogspot.com/_0mpmpuJV3hw/TT8G7cqHlXI/AAAAAAAAABE/SjblMYF4mpY/s1600/IceCube-schema.jpg.

[2] F. Halzen und A.D. Martin. *Quarks and leptons: an introductory course in modern particle physics*. Wiley, 1984.

[3] P. Newman. „Deep Inelastic Scattering at the TeV Energy Scale and the LHeC Project“. In: *Nucl.Phys.Proc.Suppl. 191* (2009).

[4] Cooper-Sarkar, Amanda, Philipp Mertsch, and Subir Sarkar. „The high energy neutrino cross-section in the Standard Model and its uncertainty.“ Journal of High Energy Physics 2011.8 (2011).

Parton Distribution Functions

- Convolute NLO matrix element with PDFs to obtain cross section.
- Parametrize PDFs in x at a scale Q_0^2, which is large enough to apply perturbative QCD.
- PDFs at scales $Q^2 > Q_0^2$ can be calculated with the DGLAP equations.
- Predict PDF values at unmeasured values of x.
- Uncertainties naturally increase outside the fitted region.