HELMHOLTZ GEMEINSCHAFT

HGF-VH-NG-401

DESY

Physics of gluons and heavy quarks from HERA to the LHC

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Motivation: starting from top

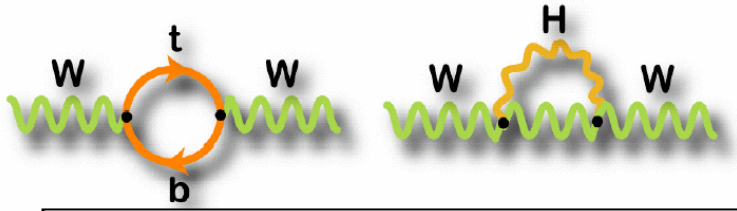
heaviest fundamental particle

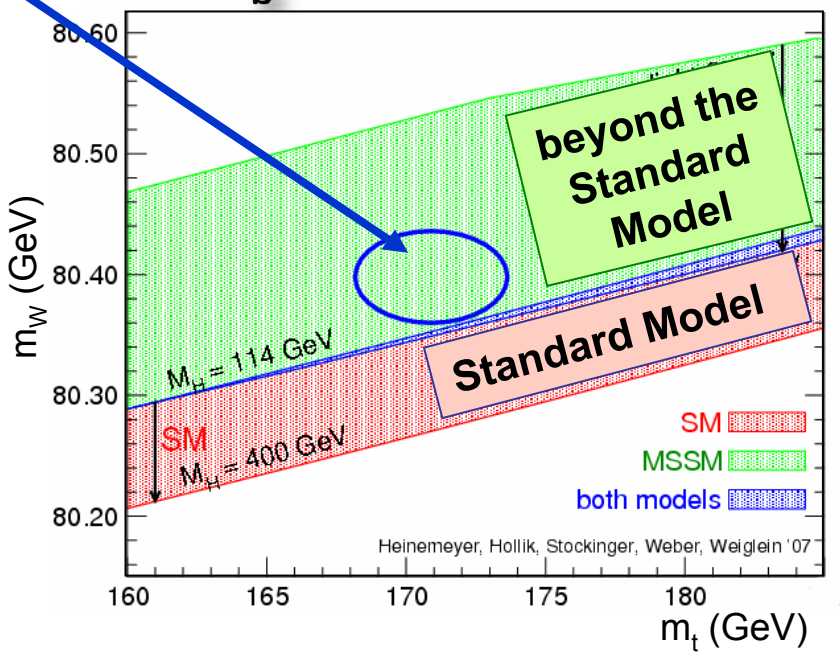
decays before forming hadrons

m_t – fundamental parameter of the SM

together with m_W constrains Higgs mass

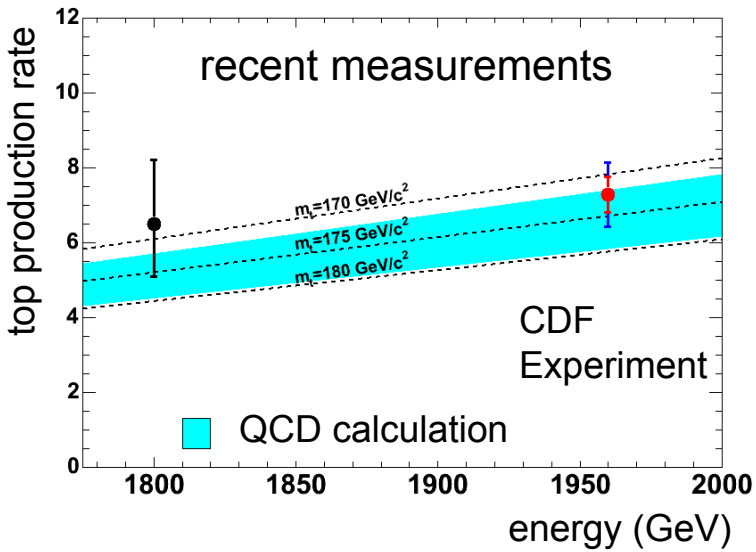
current knowledge: m_t=171 ± 2 GeV





production rate (cross section)

precision test of the QCD



need high sensitivity → high precision !

LHC: proton collisions at 14 TeV

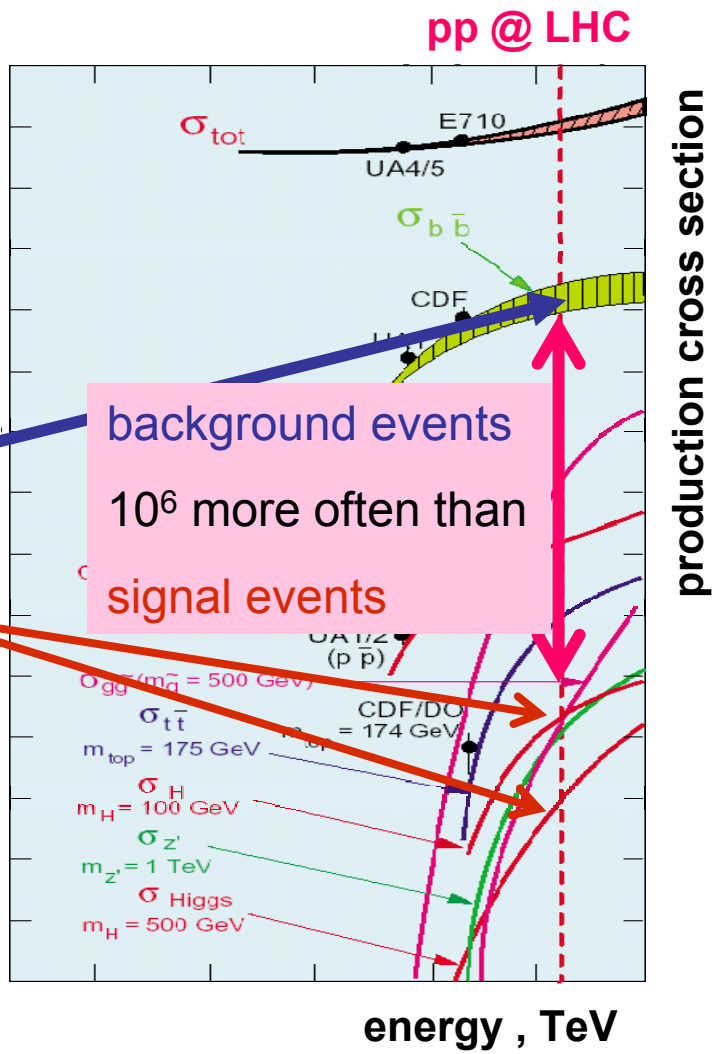
LHC needs precise understanding of the proton

collision at the LHC:

90% gluon-gluon fusion, 10% quark-quark

$\sigma(gg \rightarrow tt)$ 833 pb,

challenge: separate signal from background

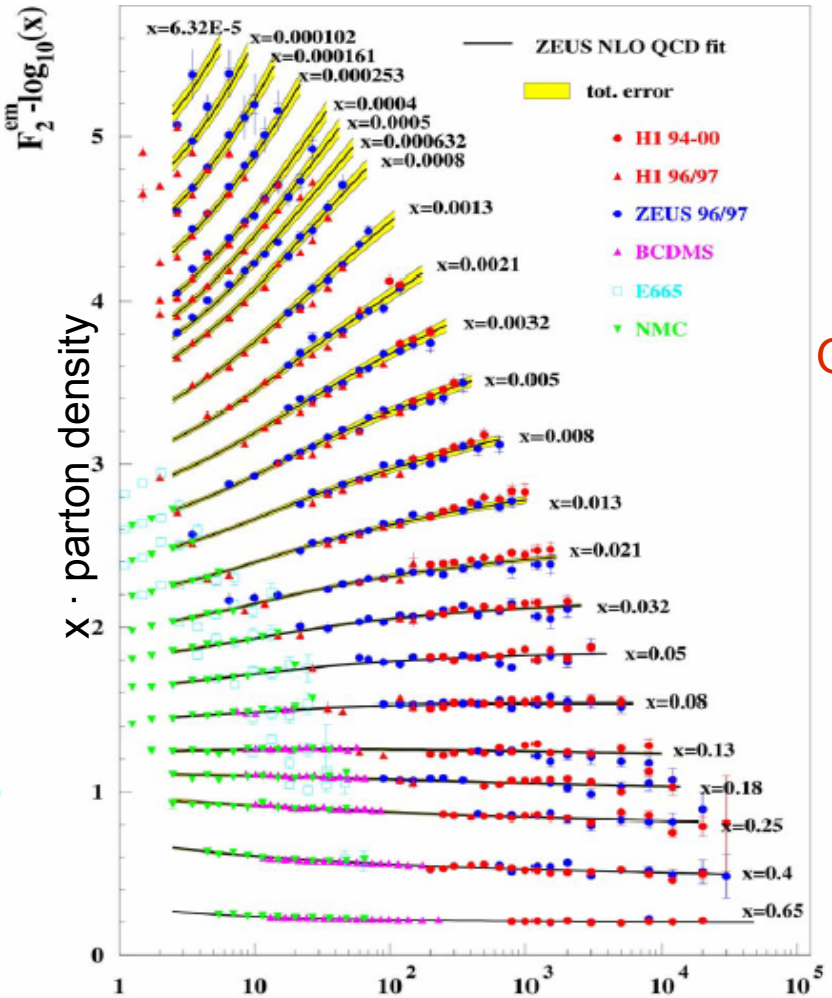


90% of cross section
~ (gluon density in the proton)^2

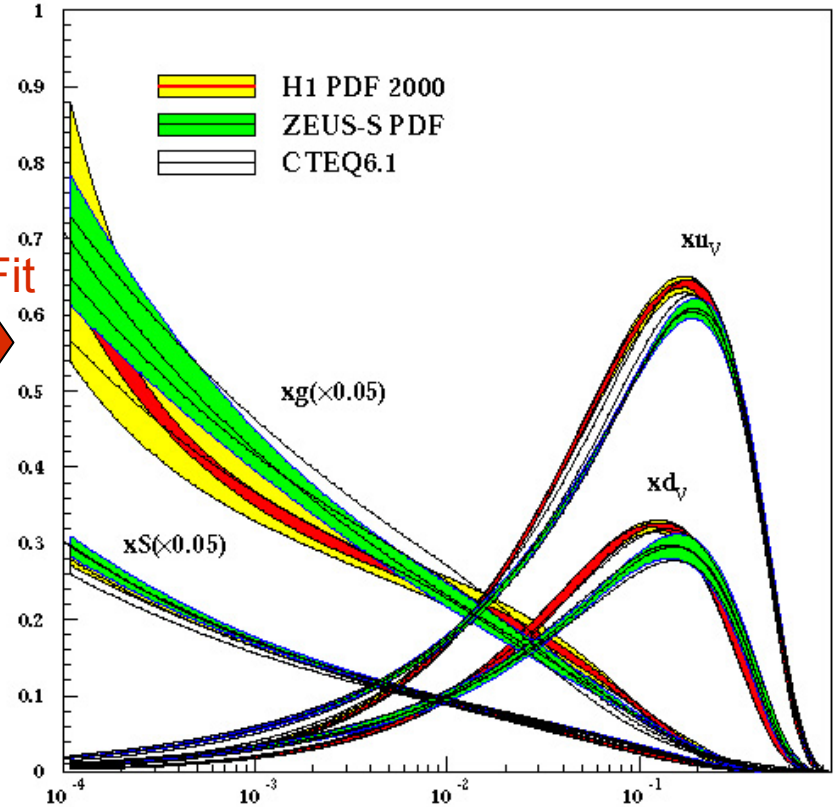
Precise understanding of gluon content of the proton necessary !

This we get only at HERA

World-only machine to study the proton with high precision



QCD Fit



Uncertainties : Largest problem - QCD Fit (starting parameters, parameterization)

Gluon density and physics of heavy quarks

LHC needs precise measurements of the parton densities from HERA

- PDF uncertainties: largest uncertainty for most LHC analyses

need a direct gluon measurement

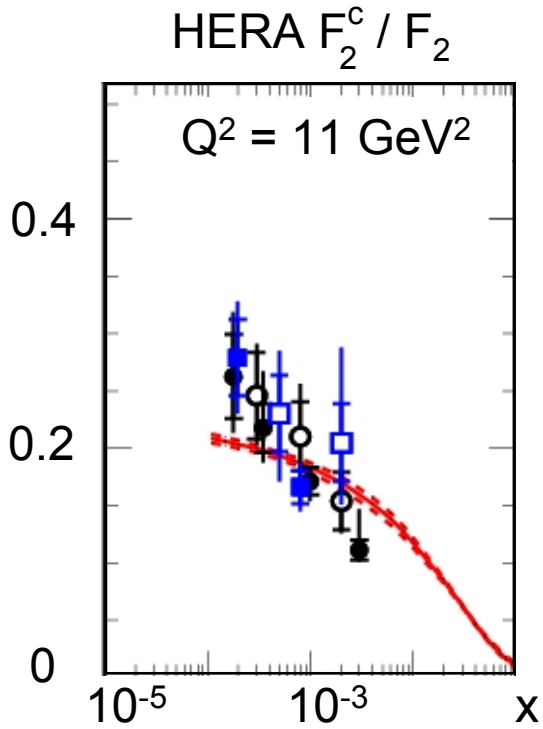
heavy quark (c/b) production at HERA

e.g. charm contribution F_2^c

to the proton structure function F_2

previous measurements

- charm contribution high
- large experimental and theory uncertainties

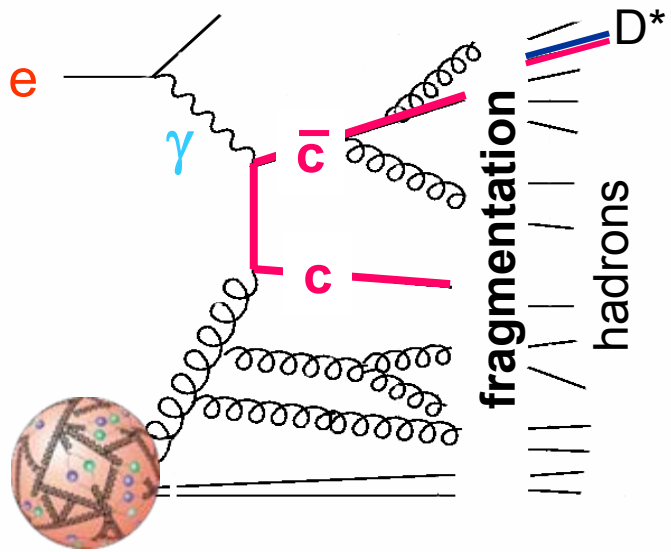


We will do this, but 6x more precise

Our first task

Directly access the gluon via heavy quarks at HERA

heavy quarks (charm and beauty) produced in Boson-Gluon Fusion



Experimentally:

tag charm via D*, extract F^{c}_{2}, include in PDF fits

Problems:

- not yet final precision
- extrapolation models not optimal
- large extrapolation uncertainties
- no consistent model yet to include in PDF fits

ToDo in Experiment:

study charm fragmentation

expand the phase space for D*

combine the charm tag methods

KL, B. Pokorny, K. Daum

ToDo in Theory:

understand fragmentation

develop consistent model

MC@NLO

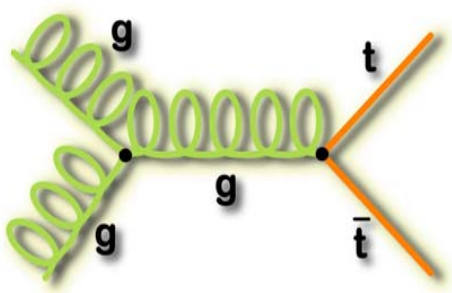
A. Kadeer, H.Spiesberger

Our second task

top mass and cross section @ CMS: Maria Aldaya, Ewelina Kosior

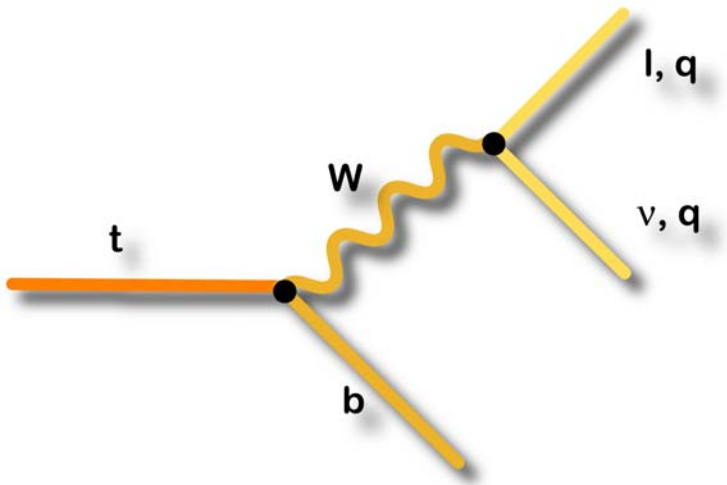
Production: 90% gluon-gluon fusion

e.g. LO:



Decay: electroweak, ~100% Wb

Final state characterized by W decay



Kinematics: top rest frame: $p^*_W = p^*_b$

$$E_b^* = \frac{m_t^2 - m_W^2 + m_b^2}{2m_t} = \frac{1}{2}m_t + \frac{m_b^2 - m_W^2}{2}\frac{1}{m_t}$$

Relativistic boost of b : $\gamma_b \sim 0.4\ (m_t/m_b)$

b-momentum sensitive to the top mass

Top mass measurement via:

- top mass via b-jet energy
- top mass via B decay length $\langle L \rangle = \tau^* \frac{p_B}{m_B}$

  τ^* lifetime of B-hadron (at rest)

  L: average measured distance from the primary vertex to the B decay vertex

Almost linear dependence of m_t on L

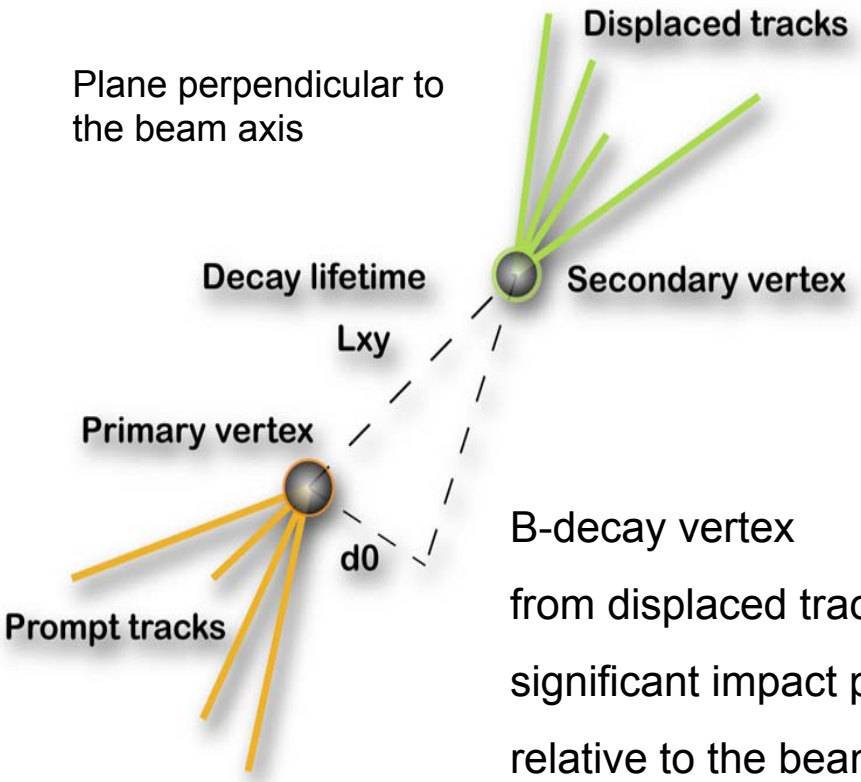
L ~ several mm

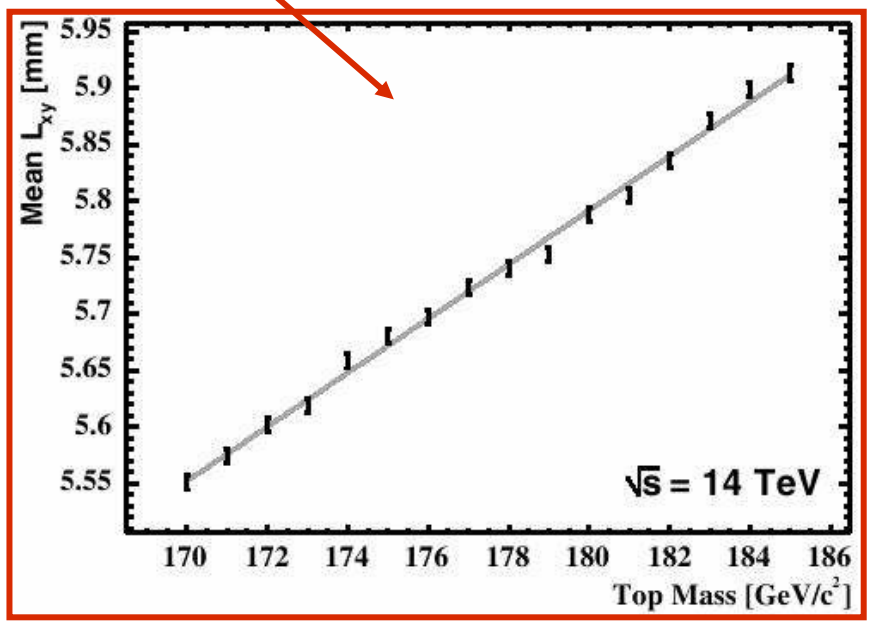
Top mass via B-decay length

Longitudinal momentum of the tt pair not well known in pp collisions

Use transverse decay length $L_{xy}=L\,|\sin\theta|$ → get this

θ– angle of the B flight wrt beam axis





B-decay vertex

from displaced tracks:

significant impact parameters d0

relative to the beam axis.

Significance $Sd=d0/\sigma_{d0}$

CDF: Sd>2.5

Summary: Scope of the research group

Gluon density in the proton using heavy quarks at HERA:

- duration: 2008-2010, ongoing
- measurement of D* cross section in DIS at H1
- combination of H1 and ZEUS results, different charm tag methods
- extraction of charm contribution to the structure function, F^{c}_{2}
- publication 2011, inclusion of the results into the global PDF fit

Top quark mass and cross section with the first LHC data

- duration: 2008-2013, starting fall 2008
- validation of SV reconstruction for b-tagging at CMS
- simulation of top-pairs in dileptonic decays
- measurement of top cross section using b-tagging
- measurement of top mass using B decay length