HELMHOLTZ GEMEINSCHAFT

HGF-VH-NG-401

DESY

Physics of gluons and heavy quarks from HERA to the LHC

Maria Aldaya, Alimjan Kadeer, Ewelina Kosior, Katerina Lipka, Boris Pokorny

Helmholtz Host	Prof. R.-D. Heuer	DESY
University Partners	Prof. R. Klanner	University of Hamburg
	Prof. H. Spiesberger	University of Mainz
	PD. K. Daum	University of Wuppertal

Universität Hamburg

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

BERGISCHE UNIVERSITÄT WUPPERTAL

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

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- measurement of top cross section using b-tagging
- measurement of top mass using B decay length

Motivation: starting from top

heaviest fundamental particle

decays before forming hadrons

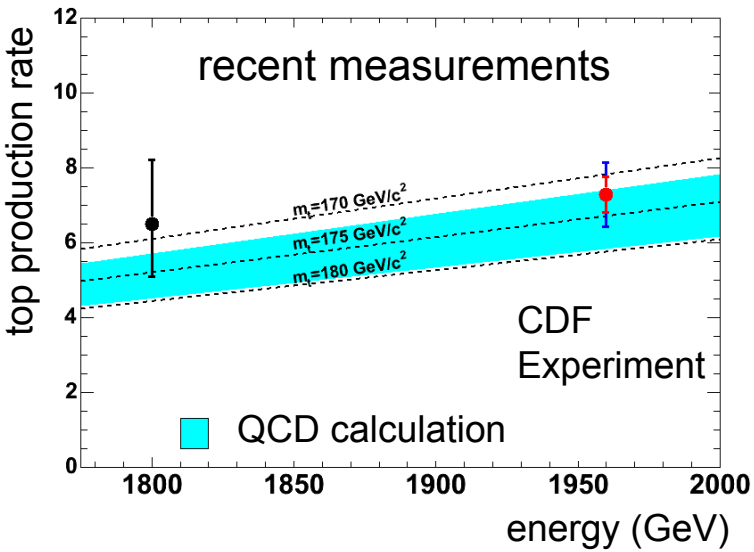
m_t – fundamental parameter of the SM

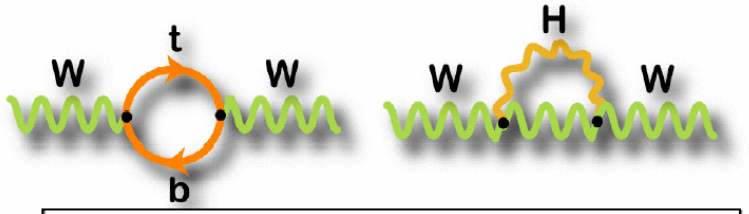
together with m_W constrains Higgs mass

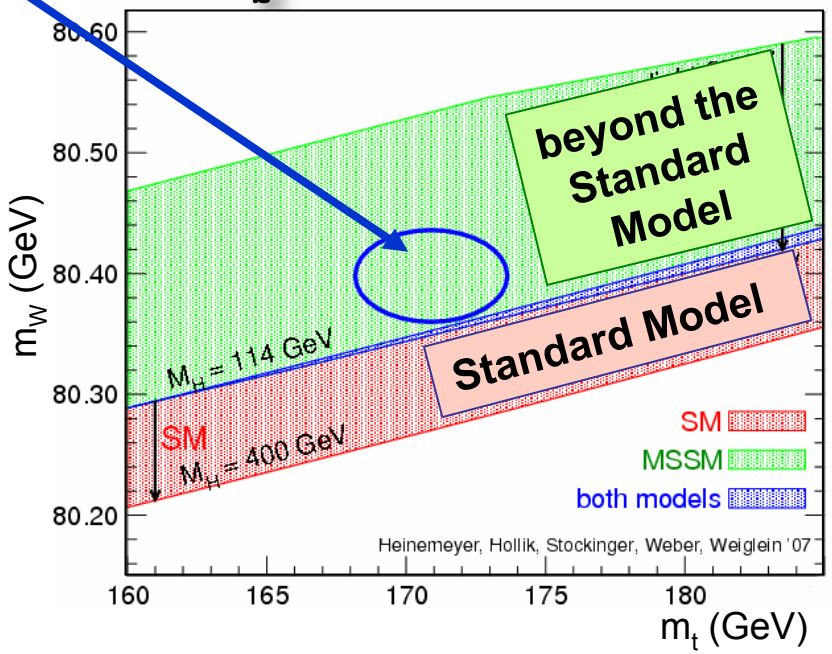
current knowledge: m_t=171 ± 2 GeV

production rate (cross section)

precision test of the QCD







need high sensitivity → high precision !

LHC: proton collisions at 14 TeV

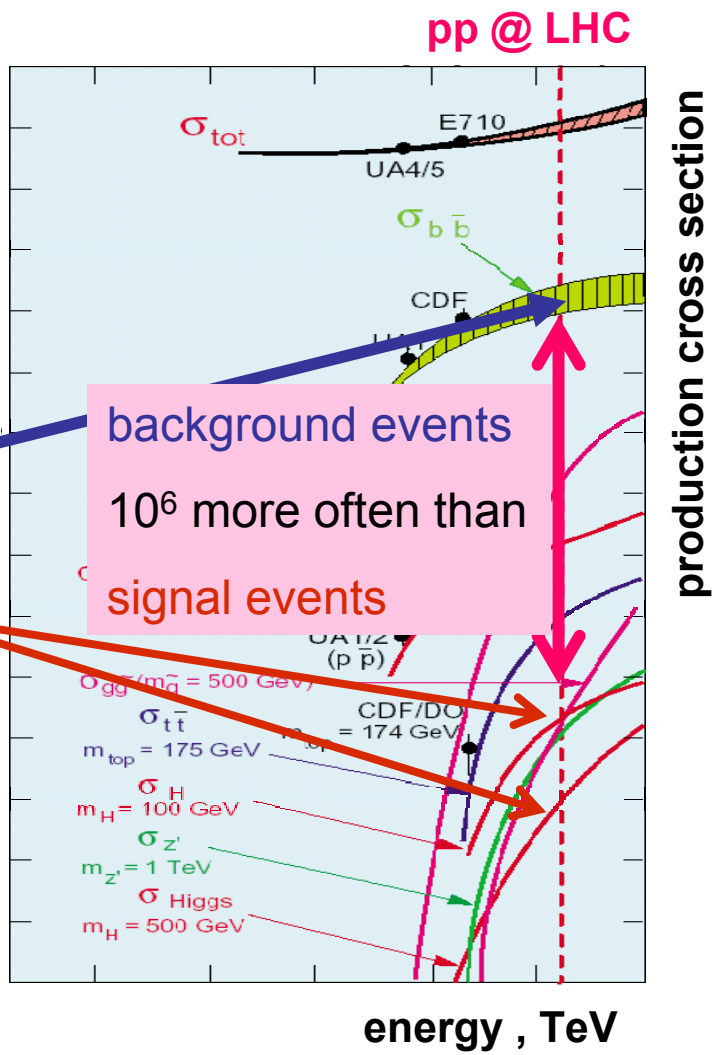
LHC needs precise understanding of the proton

collision at the LHC:

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

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

challenge: separate signal from background

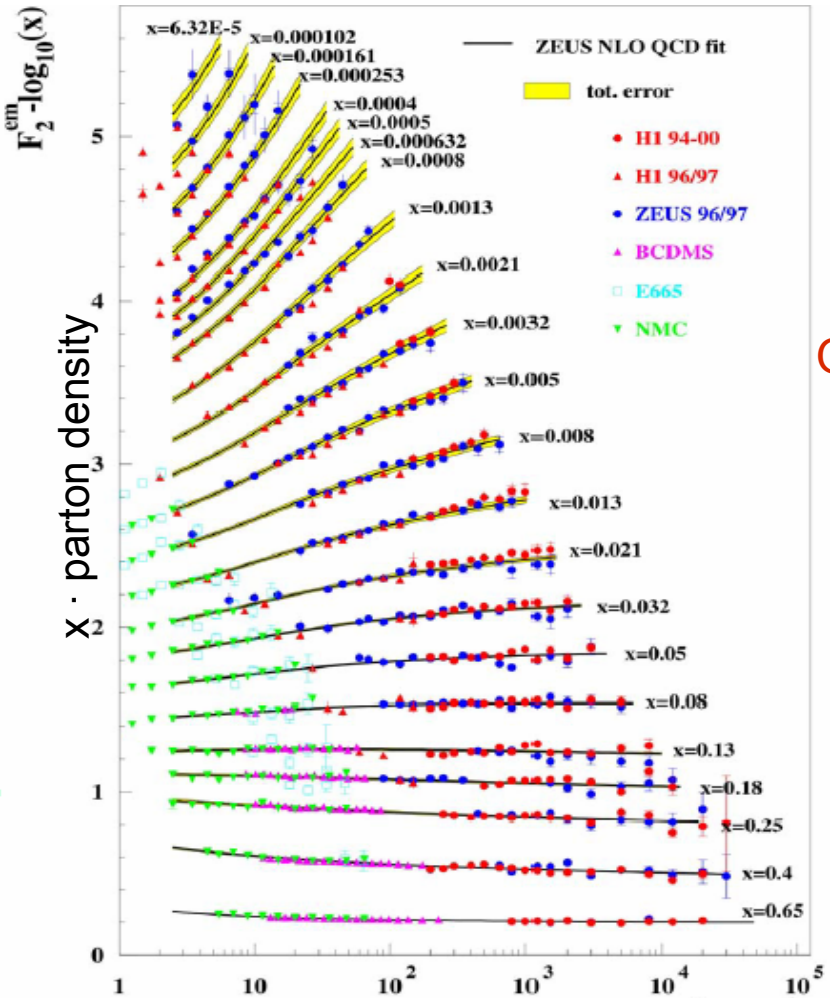


90% of cross section
~ (gluon density in the proton)^2

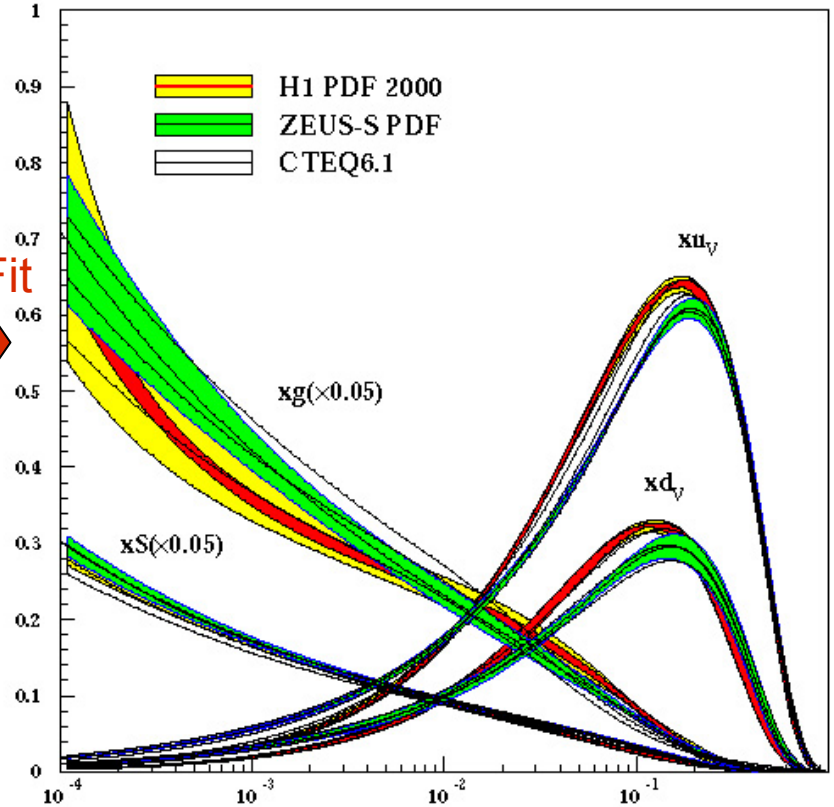
Precise understanding of gluon content of the proton necessary !

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

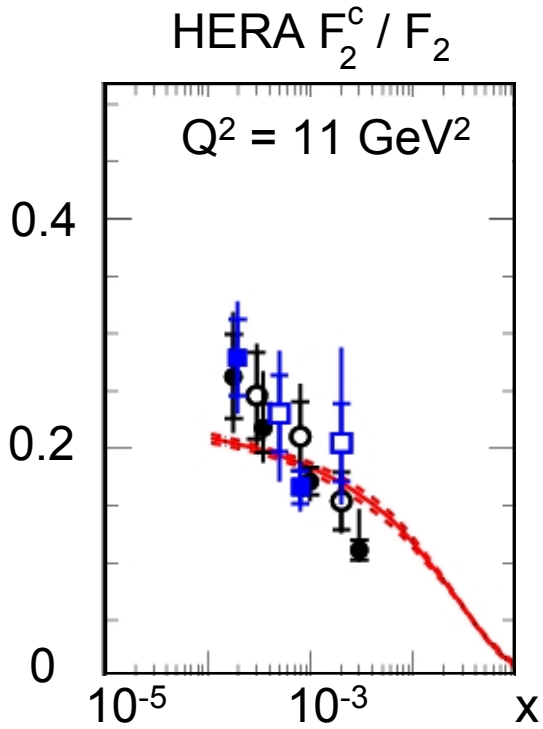
heavy quark (c/b) production at HERA

e.g. charm contribution F_2^c

to the proton structure function F_2

previous measurements

- charm contribution high
- large experimental and theory uncertainties

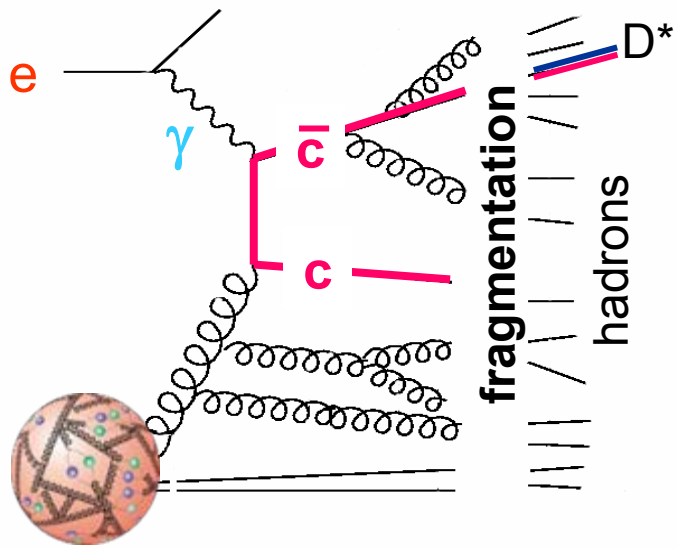


We will do this, but 6x more precise

Our first task

2008-2010 Direct access to 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

ToDo in Theory:

understand fragmentation

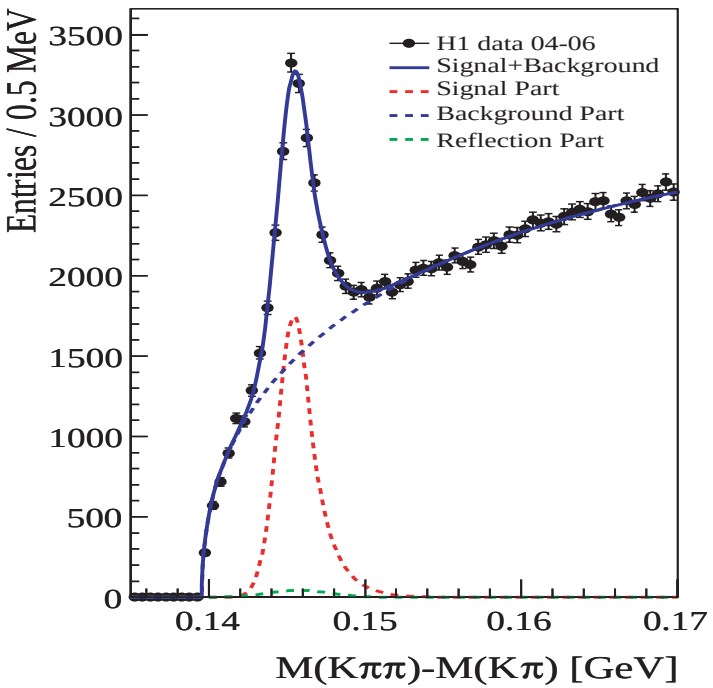
develop consistent model

MC@NLO

In more details…

Measurement of the charm contribution to the proton structure function

1. Tag charm events via $D^* \rightarrow K \pi \pi_s$



2. Measurement of $\sigma_{visible}(D^*)$ in DIS

detector "sees" only part of the D*s due to limited acceptance

3. Extrapolation to full phase space

use models of charm production and fragmentation models:

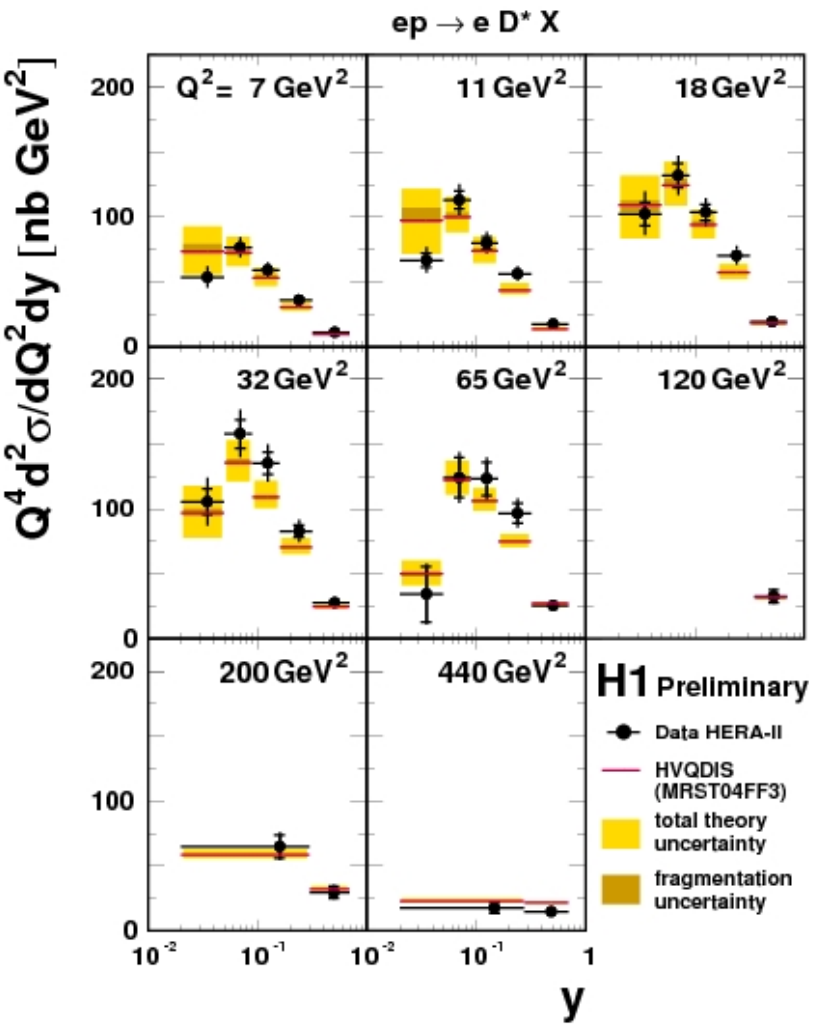
$$F_2^{c\bar{c}}(\exp) = \frac{\sigma_{vis}(\exp)}{\sigma_{vis}(theory)} F_2^{c\bar{c}}(theory)$$

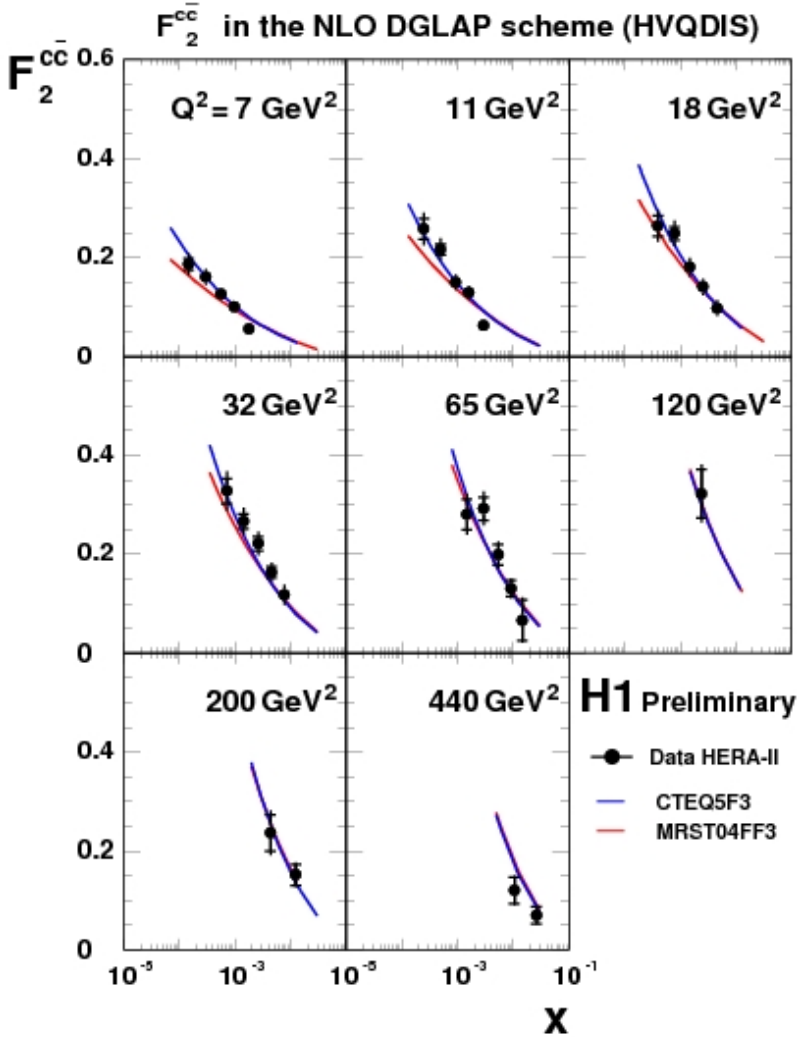
People:

Experiment K. Daum, K. Lipka, B. Pokorny; Theory: A. Kadeer, H. Spiesberger

Where we are

Cross sections vs NLO, F^{c}_{2} from D*





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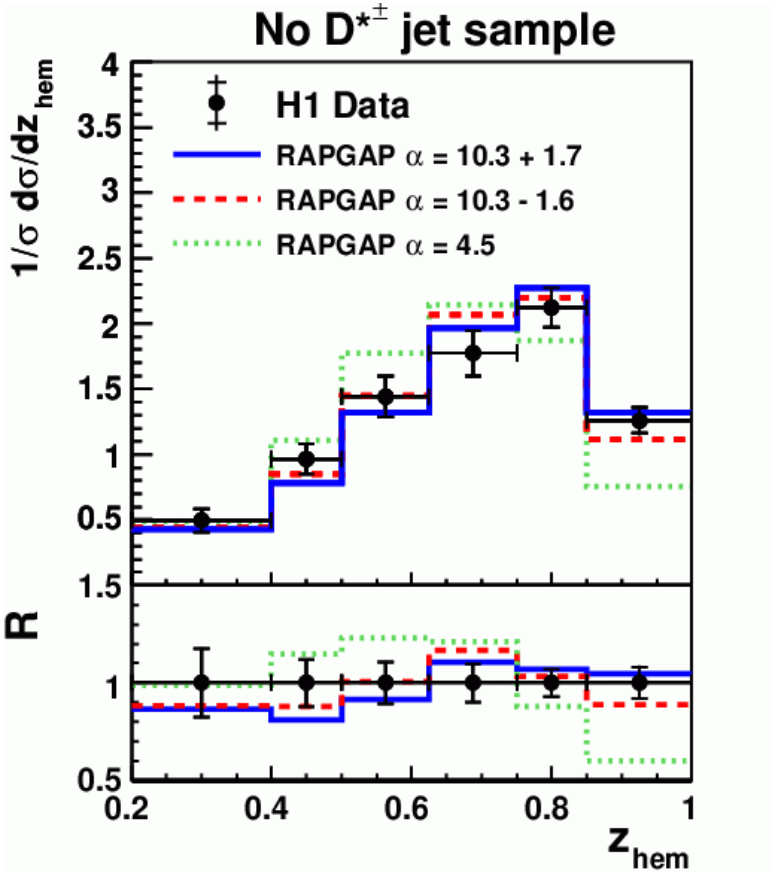
To be done in experiment

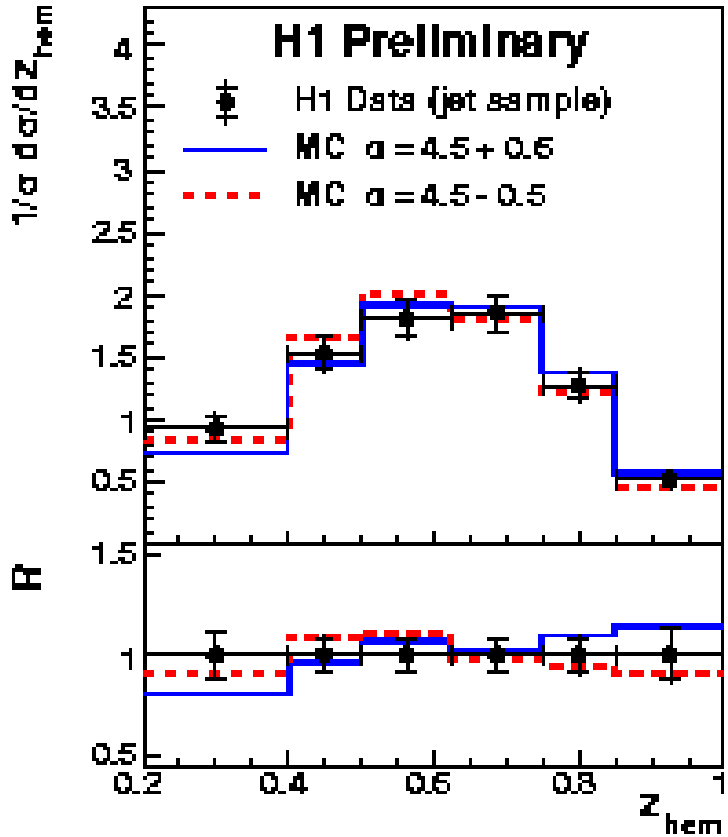
Fragmentation c (E_c) → D* (z E_c) (Boris Pokorny)

H1 measurement (HERA-I): do we understand fragmentation close to threshold?

Close to threshold



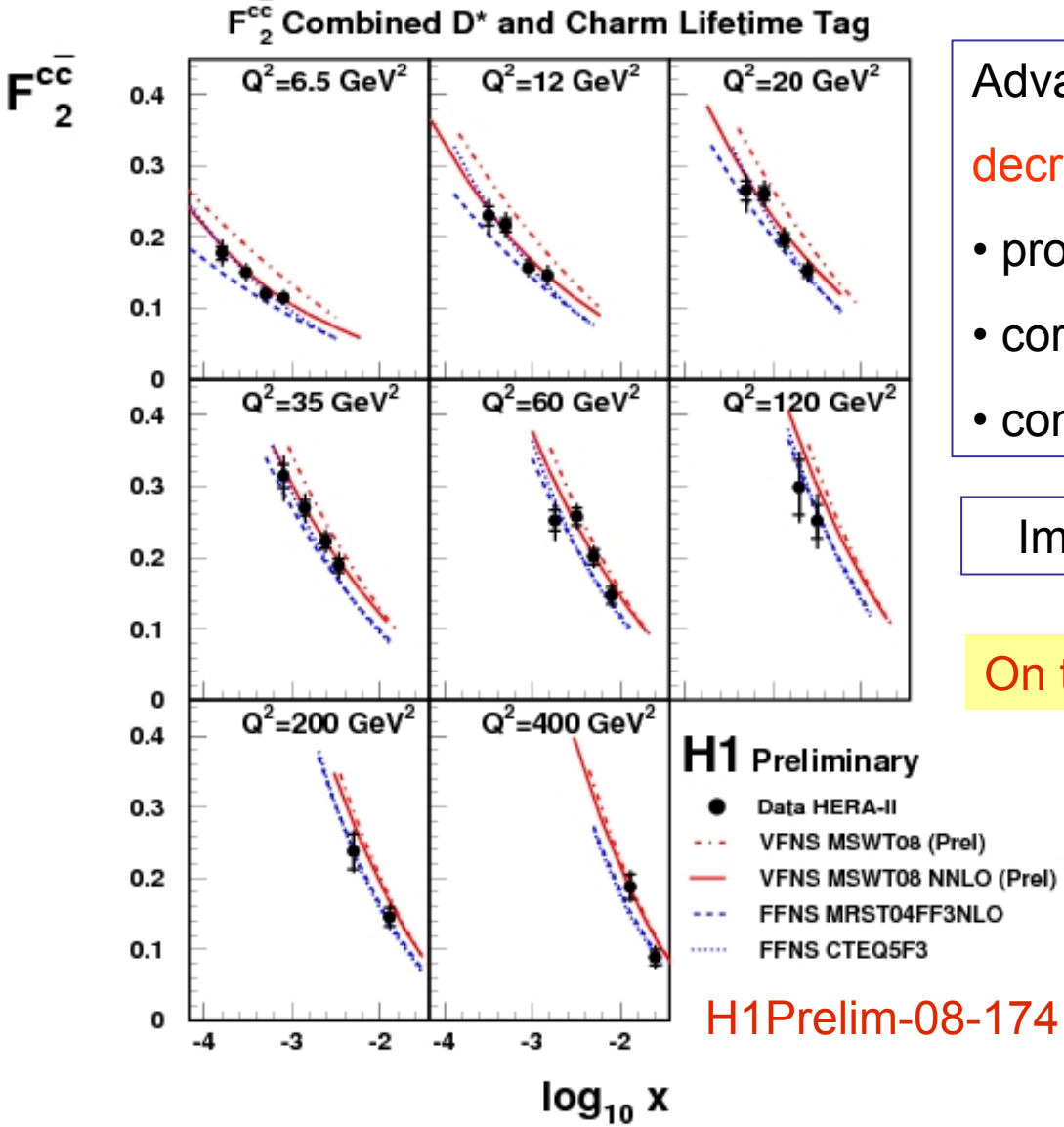
Far above the threshold



Different results in different phase space regions: more studies with more precise data

To be done in experiment

Combination of different charm tag methods and experiments (K. Lipka)



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Advantages wrt. to a combined plot:

decreased uncertainty due to

- proper combination
- correct treatment of correlations
- common extrapolation method

Improved sensitivity to the theory

On the way: H1-ZEUS combination

To be done in theory

Address the experimental needs in the theory (Alimjan Kadeer, K. Lipka)

Enhance the experiment/theory dialog on the subject

- August: informal theory/experimental meeting on F^c_2 issues
- September: John Smith vs Kramer & Kniehl
- Tomorrow: seminar by J. Bluemlein - heavy quarks in 3 loops

Proper theory (treatment):

- Consistent parameters in the models, fragmentation
- Proper PDFs for existing NLO (KL together with Fred Olness)
- NLO + PS : MC@NLO (Alimjan Kadeer)
- development of GMVFNS (Alimjan Kadeer, Hubert Spiesberger)
- NLO vs PS, Fragmentation: workshop next year at DESY

  (with help of Hannes Jung via Analysis Center)

Our second task

2008-2013 Precision measurements of top quark production at the LHC

Goal: Precision tests of the Standard Model:

measurement of mass and cross section in di-leptonic channel

Network:

CMS group of DESY: top quark physics

CMS group of Hamburg University: already integrated in the “top group” (Roger)

Our contribution :

Simulations and analysis of top quark production

Development of analysis tools

Validation of Secondary Vertex reconstruction

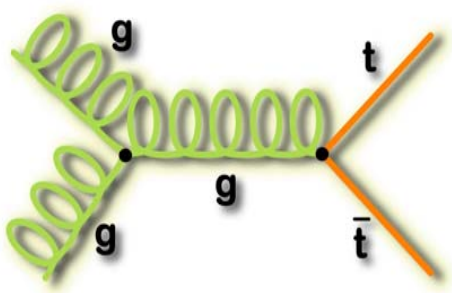
Influence of the Alignment

In more details…

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

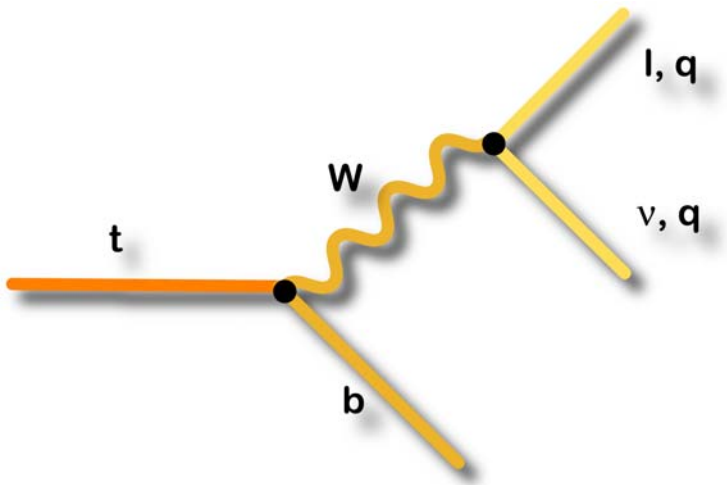
Production: 90% gluon-gluon fusion

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

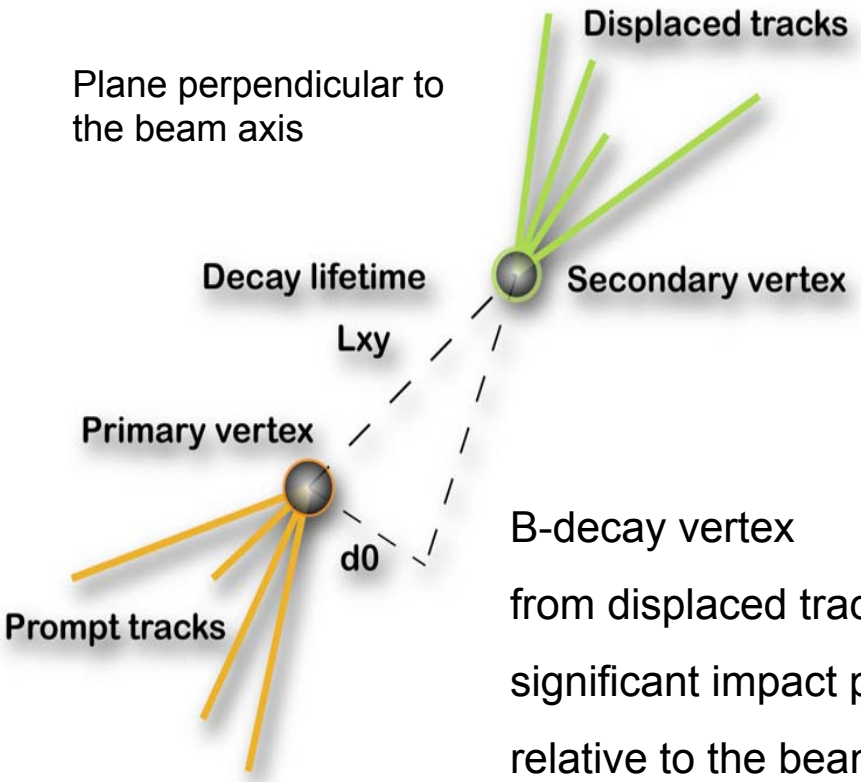
L ~ several mm

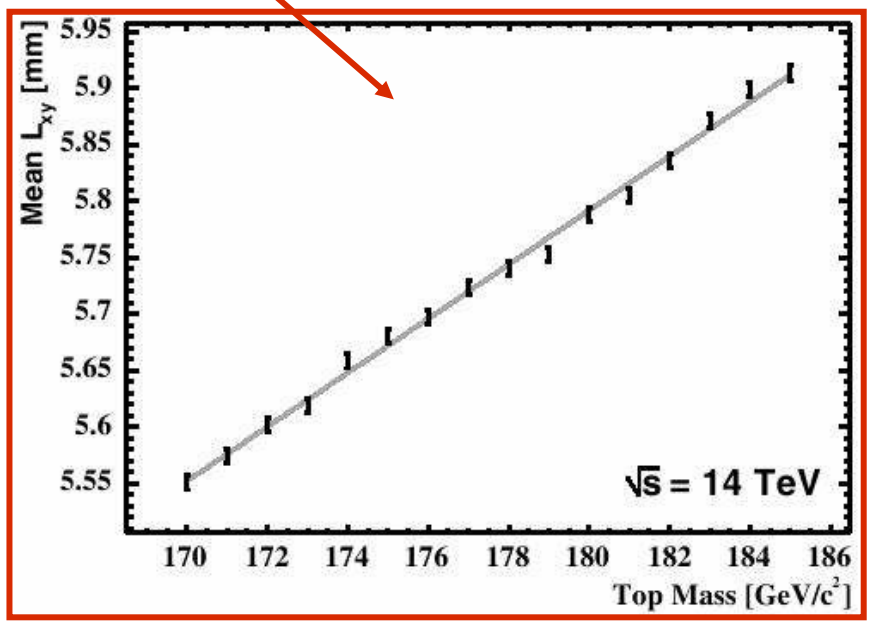
Top mass via B-decay length

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

Top mass via B-decay length

Correlation between top mass and B-decay length affected by:

Estimate of systematic uncertainties for LHC (CMS)

Hill, Incandela, Lamb, Phys. Rev. D71, 054029 (2005)

L=10 fb^{-1}, di-lepton events, b tagging 20-40% efficient, resolution CMS TDR

Source	Uncertainty, GeV
Initial state QCD radiation	1.3
Final state radiation (variation of Λ_{QCD} in PYTHIA)	0.5
PDF (MRST vs CTEQ5)	0.7
B lifetime (LEP measurements)	1.3
B fragmentation (LEP measurements)	1.2
Jet energy scale	0.2
TOTAL	2.4

Top shopping list

- Use di-leptonic events, understand the lepton objects
- Contribution the b-tagging @ CMS:
- Validation package for secondary vertex reconstruction
- Use MC : estimate the uncertainties of m_t using B decay length method
- Use first data – understanding of the detector, aim: top cross section
- Measurement of top mass in di-leptonic channel

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