Probing Strangeness via Charm Production in CC DIS at HERA

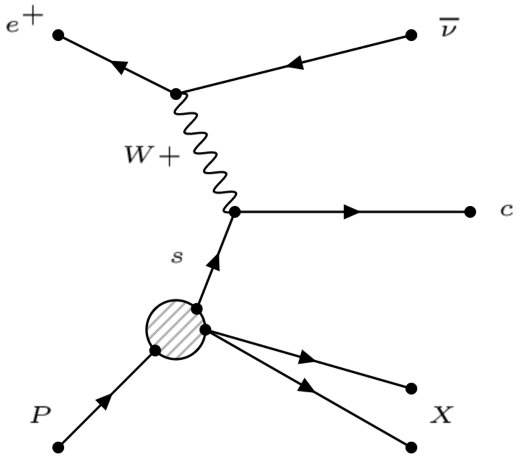
Jae D. Nam

Temple University

Introduction

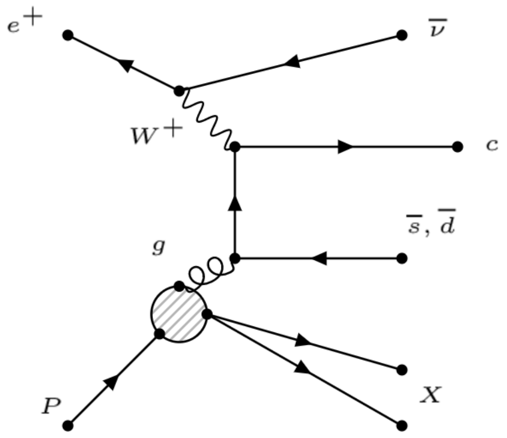
Charm productions in Charged Current DIS

Quark Initiated Process (QI, LO)



- Via *d/b* is Cabibbo-suppressed
- Probes the strangeness in the sea

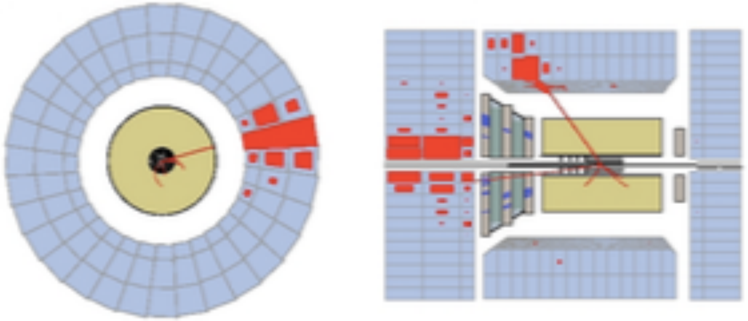
Boson-Gluon Fusion (BGF, NLO)



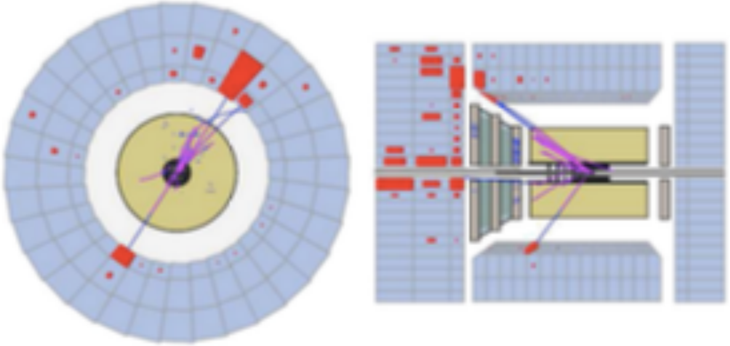
- Its contribution becomes larger at low x
- Background to be suppressed

Introduction

CC DIS



NC DIS



Neutrino in the final state

- Due to the final state neutrino, a large missing P_T is observed.
- No charged lepton in the final state & the kinematic variables reconstructed using the hadronic final state.
- Kinematic variables (x, y, Q^2) defined by using Jacquet Blondel Method.

$$y_{JB} = \frac{\sum_h (E - p_z)_h}{2E_{e,beam}} \qquad Q^2_{JB} = \frac{p^2_{T,h}}{1 - y_{JB}} \qquad x = \frac{Q^2}{sy}$$

Introduction

Charged current events are always weak interactions.

$$\frac{d\sigma^{e^{\pm}+p}_{CC,P_e}}{dxdQ^2} = (1 \pm P_e)\frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{M_W^2 + Q^2}\right)^2 \tilde{\sigma}^{e^{\pm}+p}_{CC}$$

$$** \; G_F = \frac{\pi\alpha}{\sqrt{2}\, M_W^2\left(1 - \frac{M_W^2}{M_Z^2}\right)}$$

where,

$$\tilde{\sigma}^{e^{\pm}+p}_{CC} = Y_+ W_2^{\pm}(x,Q^2) - y^2 W_L^{\pm}(x,Q^2) \mp Y_- x W_3^{\pm}(x,Q^2)$$

$$W_2(x,Q^2) = \sum_i x(q_i(x,Q^2) + \bar{q}_i(x,Q^2))$$

$$xW_3(x,Q^2) = \sum_i x(q_i(x,Q^2) - \bar{q}_i(x,Q^2))$$

W^+ and W^- (e^+ and e^-) are sensitive to different quark densities,

$$\tilde{\sigma}^{e^{+}+p}_{CC} = x[\bar{u} + \bar{c} + (1-y)^2(d + s)]$$
$$\tilde{\sigma}^{e^{-}+p}_{CC} = x[u + c + (1-y)^2(\bar{d} + \bar{s})]$$

The resulting charm [anti-charm] from $s(x,Q^2)$ [$\bar{s}(x,Q^2)$] will be tagged by using Secondary Vertexing Method

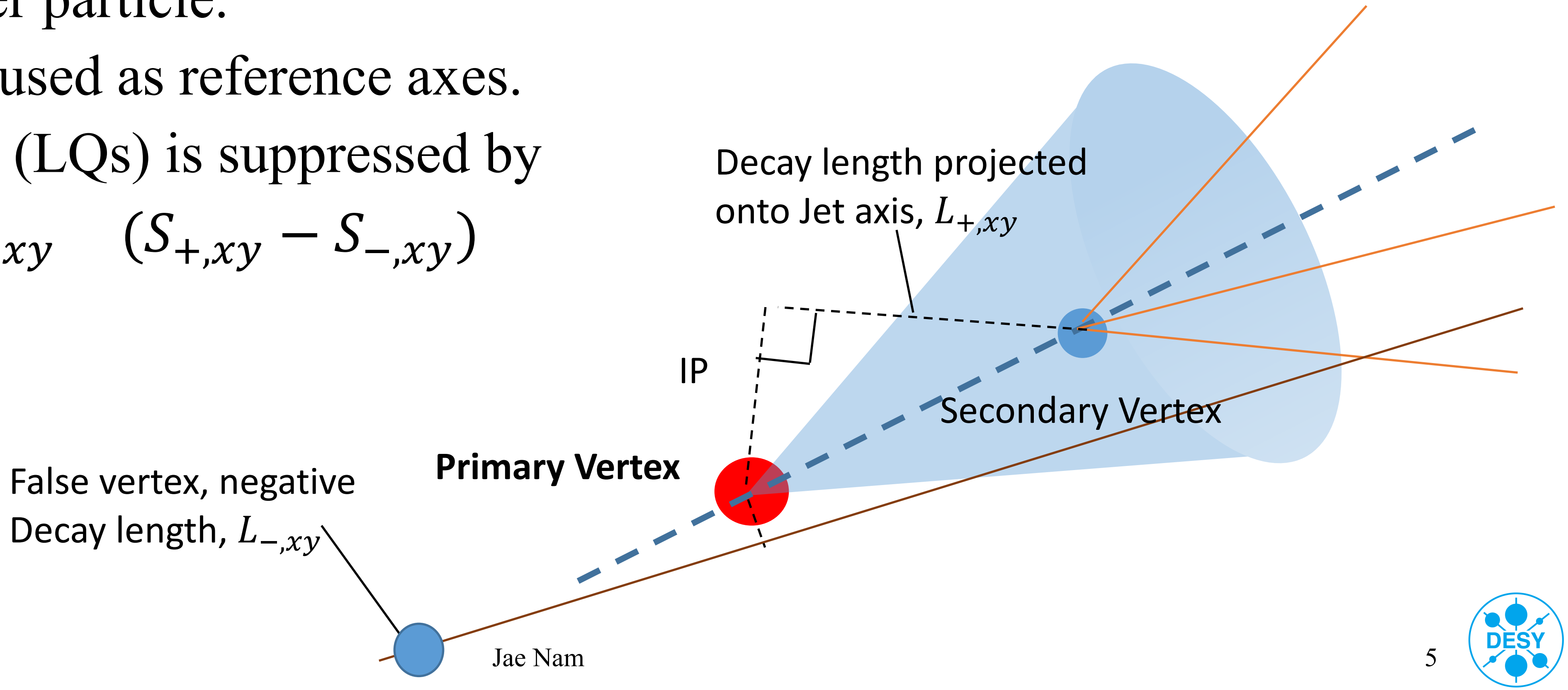
Secondary Vertex Extraction

Second Vertex Extraction

- True vertices allow reconstruction of the life time, momentum, and energy of the mother particle.
- Jet axes are used as reference axes.
- Background (LQs) is suppressed by

$$L_{+,xy} - L_{-,xy} \quad (S_{+,xy} - S_{-,xy})$$

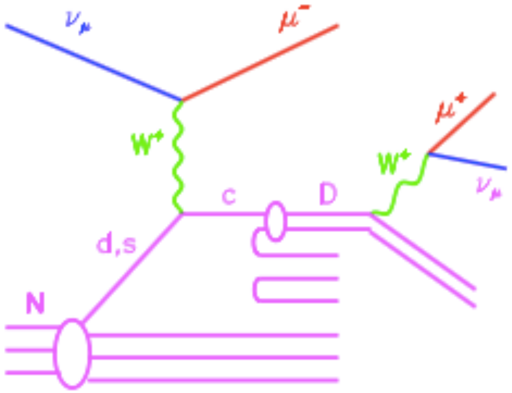
*S = significance



Previous Results (CCFR/NuTeV)

CCFR/NuTeV (Z.Phys.C65:189-198,1995)

- Opposite sign dimuon events in neutrino-nucleon collisions
- $\nu + N \rightarrow \mu^- + c + X \rightarrow \mu^- + (\mu^+ + \nu_\mu + X_c) + X$
- $\kappa = \frac{\int_0^1 dx[xs + x\bar{s}]}{\int_0^1 dx[x\bar{u} + x\bar{d}]} = 0.477^{+0.063}_{-0.053}$



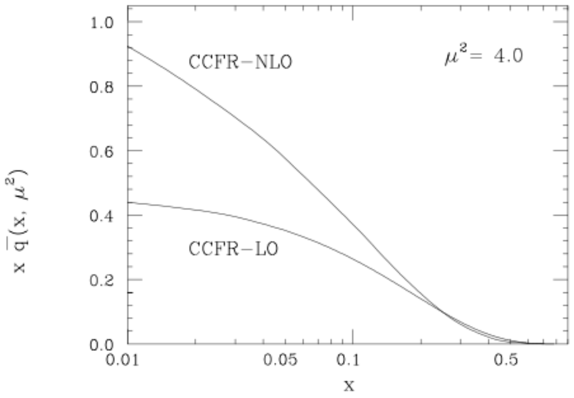


Figure 3: The quark sea distribution $x\bar{q}(x, \mu^2 = 4.0\ \mathrm{GeV}^2/c^2)$ determined at next-to-leading order and leading order.

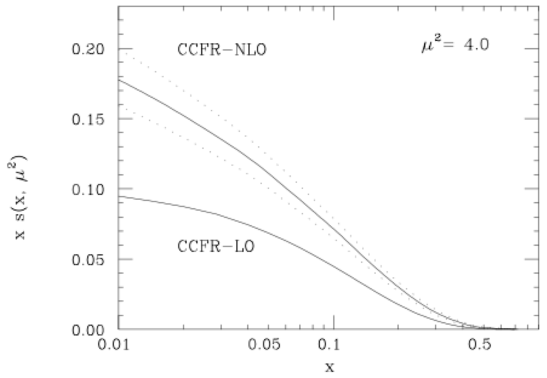


Figure 4: The strange quark distribution $xs(x, \mu^2 = 4.0\,\mathrm{GeV}^2/c^2)$ determined at next-to-leading order (described in section 4.1) and leading order. The band around the NLO curve indicates the $\pm 1\sigma$ uncertainty in the distribution.

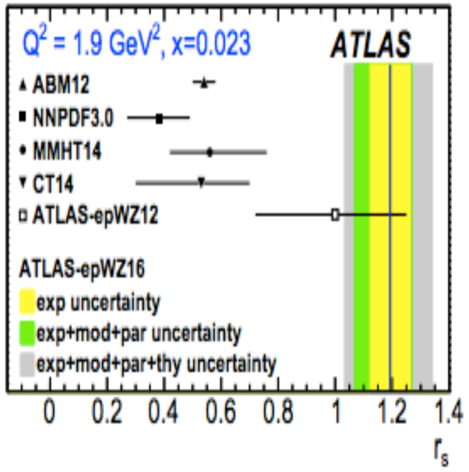
Previous Results (ATLAS)

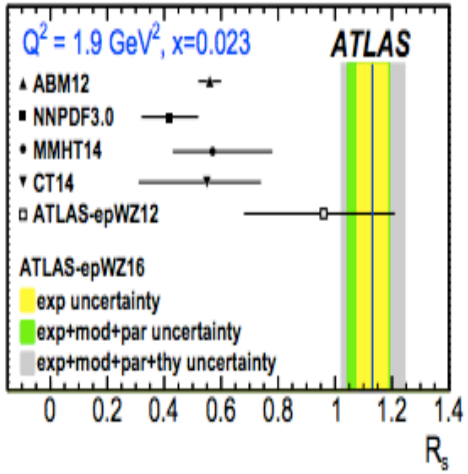
ATLAS (Eur. Phys. J. C 77 (2017) 367)

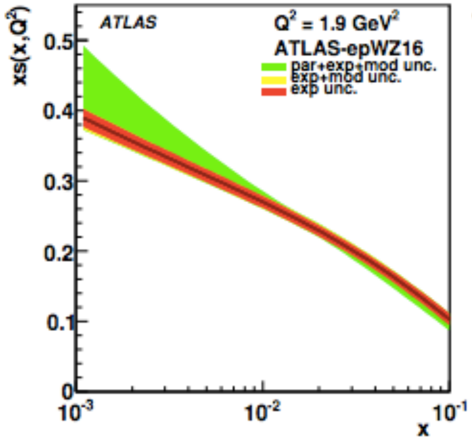
- $p + p$ collisions at $\sqrt{s} = 7\ TeV$
- $r_s = \frac{s+\bar{s}}{2\bar{d}} = 1.19 \pm 0.07$
- $R_s = \frac{s+\bar{s}}{\bar{u}+\bar{d}} = 1.13 \pm 0.05$

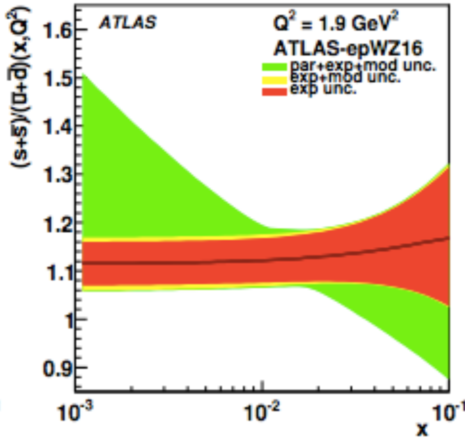
  ** $Q^2 = 1.9\ GeV^2, x = 0.023$

- The large discrepancy between the previous (CCFR/NuTeV) and the new (ATLAS) analyses brings the need to revisit this topic with a different approach.

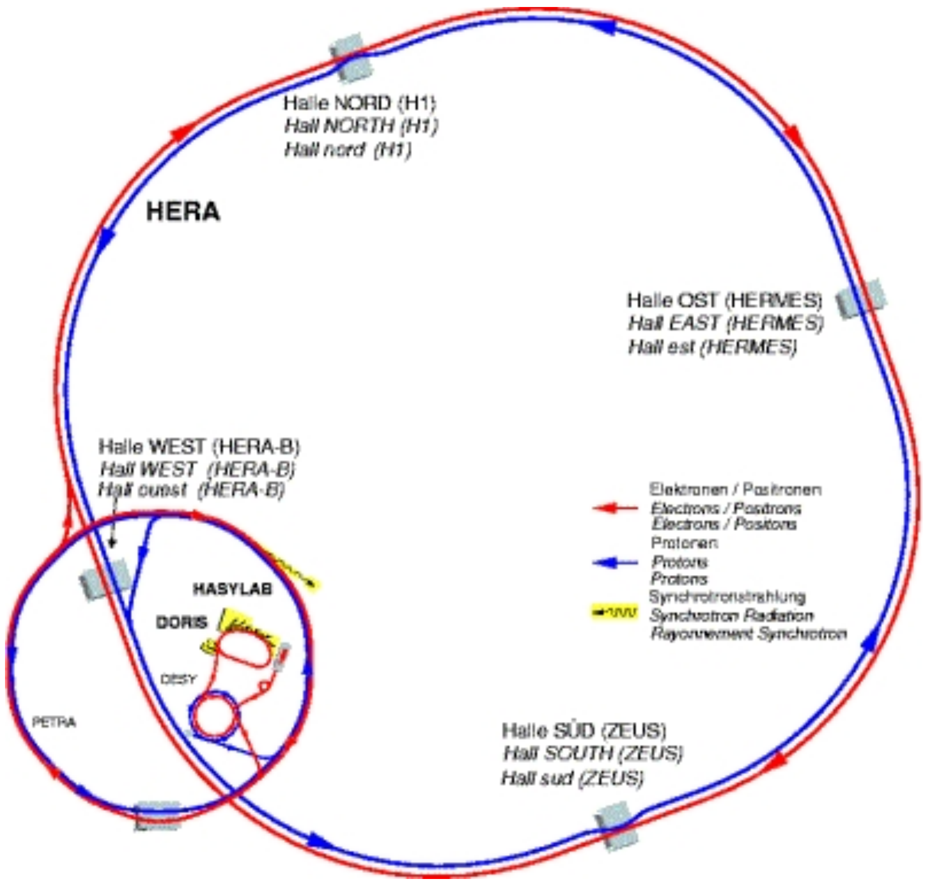




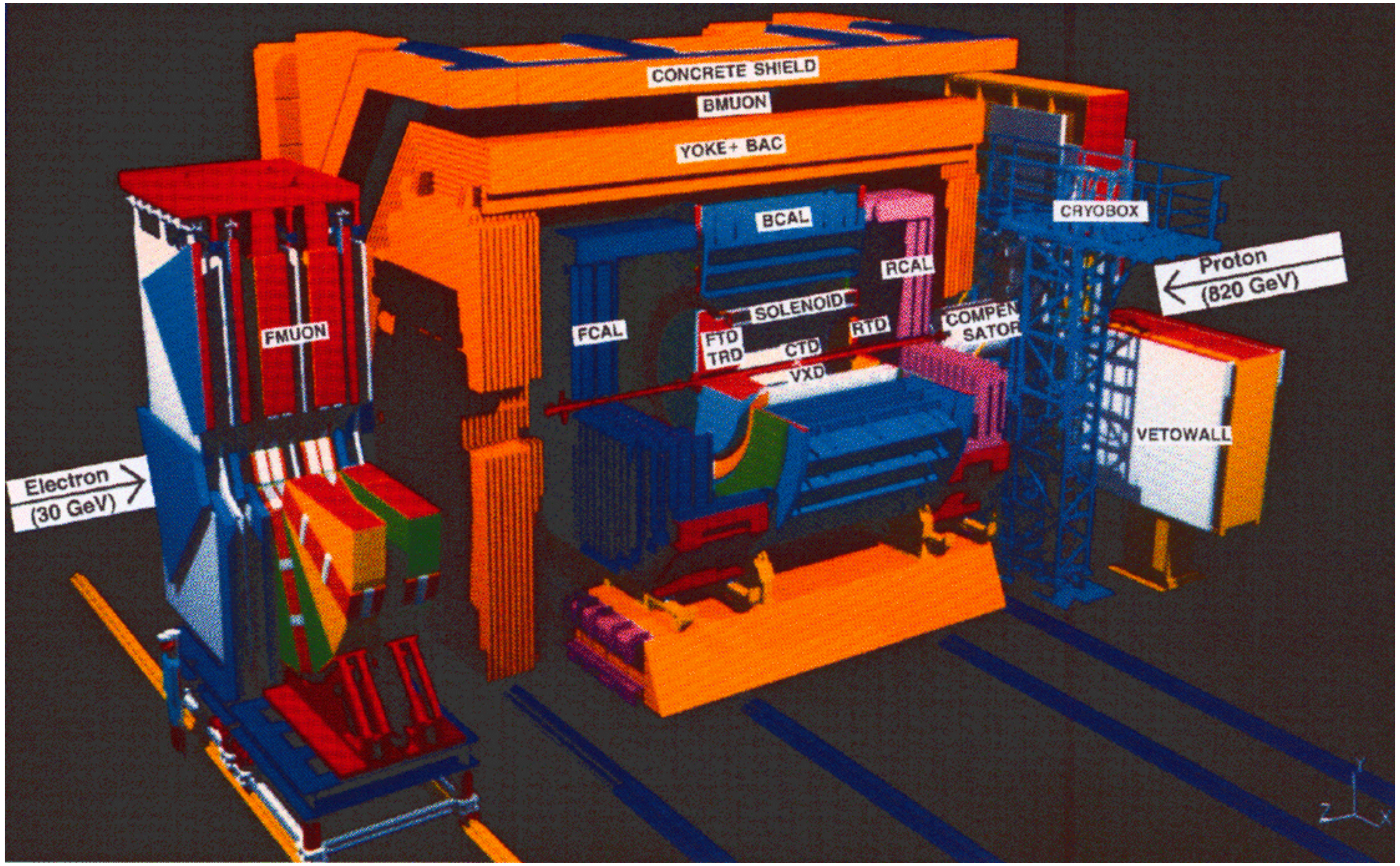




The Hadron Electron Ring Accelerator, HERA

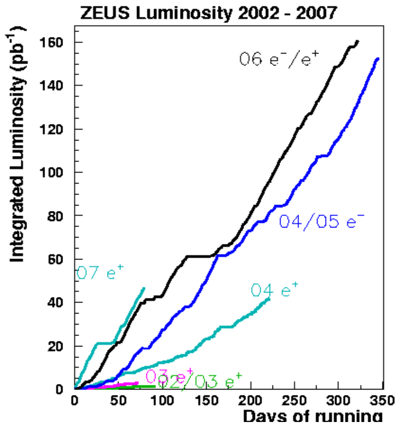


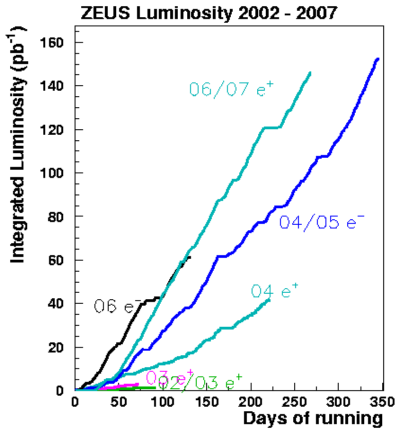
ZEUS Detector



- Run period 1992 – 2007
- Uranium Plastic-scintillator Calorimeter (CAL)
- Wire chamber (CTD)
- Silicon Microvertex Detector (MVD, installed in 2000)

HERA II Data





- Unpolarized events ~ 3%
- Integrated luminosity ~ 370 pb^{-1}
- Data & pre-generated MC stored in ZEUS Common nTuple
- Expect to see N_{CC} ~ 10,000 & N_{Charm} ~ 100 after decay length subtraction

Year	Collision	e^+ / e^- Energy (GeV)	P Energy (GeV)	Integrated Luminosity (pb^{-1})
2003/04	$e^+ + P$	27.5	920	~ 41
2004/05	$e^- + P$	27.5	920	~ 134
2006	$e^- + P$	27.5	920	~ 55
2006/07	$e^+ + P$	27.5	920	~ 142

ZEUS Online Trigger System

Trigger Selection

- Coarse selection by ZEUS three-level trigger system.
  - FLT : Energy, E_T, P_T in CAL.
  - SLT : Bunch-crossing time, Topology of calorimeter energy deposits and P_T.
  - TLT : Track reconstruction and vertex finding

- DST : Further pseudo-trigger level at event reconstruction stage

Charged Current Event Selection (Offline)

CC Selection	$P_{T,miss} > 12\ GeV$ and $P'_{T,miss} > 10\ GeV$ ** $P'_{T,miss} = P_{T,miss}$ measurement excluding ones from cells adjacent to the forward beam hole
Kinematic cut (Optiomal resolution/low BG)	$Q^2_{JB} > 200\ GeV^2$ and $y_{JB} < 0.9$ ** Q^2_{JB} and y_{JB} preset variables in common nTuple
PhP rejection	$V_{AP}/V_P < 0.25$ (for $P_{T,miss} < 20\ GeV$) $V_{AP}/V_P < 0.35$ (else) ** $\frac{V_{AP}}{V_P}$ = ratio of antiparallel/parallel components of hadronic transverse momentum ** $V_{AP} = -\sum_i \vec{P}_{T,i} * \hat{n}$, $V_P = \sum_i \vec{P}_{T,i} * \hat{n}$, $\hat{n} = \overrightarrow{P_T}/P_T$
NC DIS rejection	reject if $\delta > 30\ GeV$ && $P_T > 30\ GeV$ && … ** $\delta = \sum_h (E - P_z)_h$

** These selection cuts are from the previous CC analysis. Eur. Phys. J. C (2010) 70: 945–963

Jet/Track/Secondary Vertex Selection

Jet Selection	At least 1 jet, each with $E_T > 5\ GeV$
	$-2.5 < \eta < 2.5$
Track Selection	$P_{T,track} > 0.5\ GeV$
	$(N_{CTD} \geq 3 \mid\mid N_{STT} \geq 1) \&\& N_{MVD} \geq 4$
	Distance to closest jet $R = \sqrt{\Delta\varphi^2 + \Delta\eta^2} < 1$
Secondary Vertex Selection	$\chi^2/N_{dof} < 6$
	$\lvert Z_{secvtx}\rvert < 30\ cm$
	Distance to beamspot $\sqrt{\Delta x^2 + \Delta y^2} < 1\ cm$

** These selection cuts are from the previous HF analysis. JHEP 1409 (2014) 127, Eur.Phys.J.C71:1659,2011

Current Status & Summary

- CC events have been selected from all HERA II data.
- Charm signal with suppressed LQ contribution has been observed in the mirrored L_{xy} and S_{xy} plots.
- Detector-level & Reconstruction-level corrections will be quantified along with analysis on systematic uncertainty
- The charm cross section will be extracted by sub-dividing the kinematic plane into Q^2 bins.

Thank you

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