Probing nuclear gluons with heavy flavors at an Electron-Ion Collider

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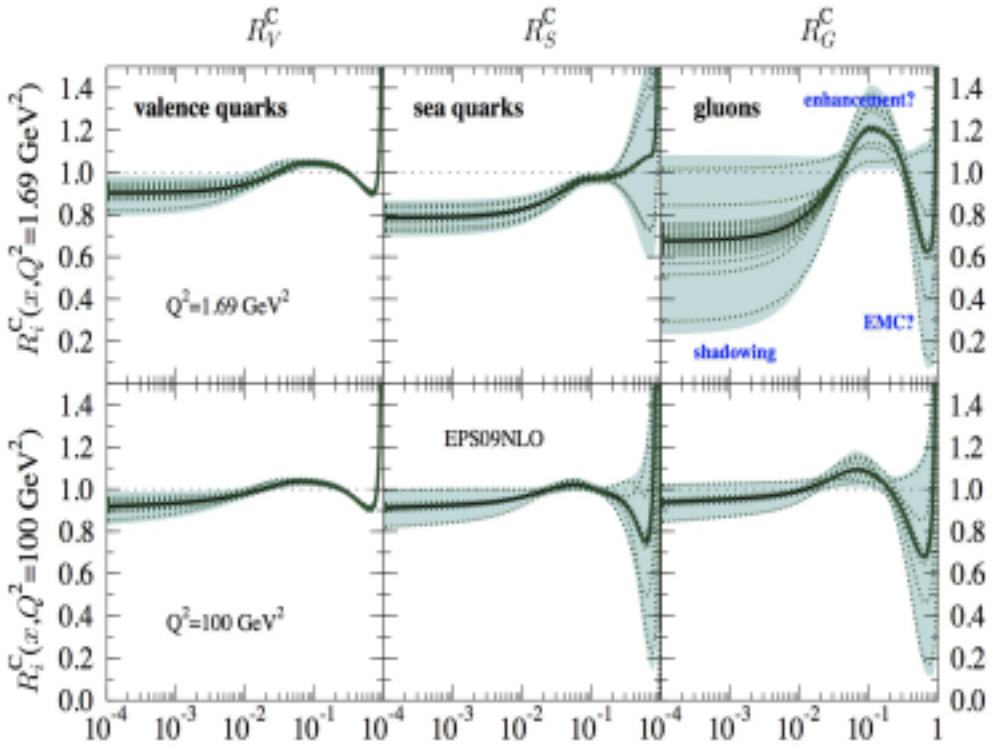
Overview

AIM: Study feasibility of direct measurements of nuclear gluons at $x \gtrsim 0.1$ using heavy quark probes with a future Electron-Ion Collider

- Nuclear modification of gluons
- Open charm/beauty as direct probe
- Simulation tools and methods
- EIC simulation results

Nuclear modification of partonic structure

Investigate feasibility of direct measurements of nuclear gluons at x > 0.1 using heavy quark probes — open charm, beauty — with EIC



Nuclear PDF parametrization EPS09 Eskola et al. 2009

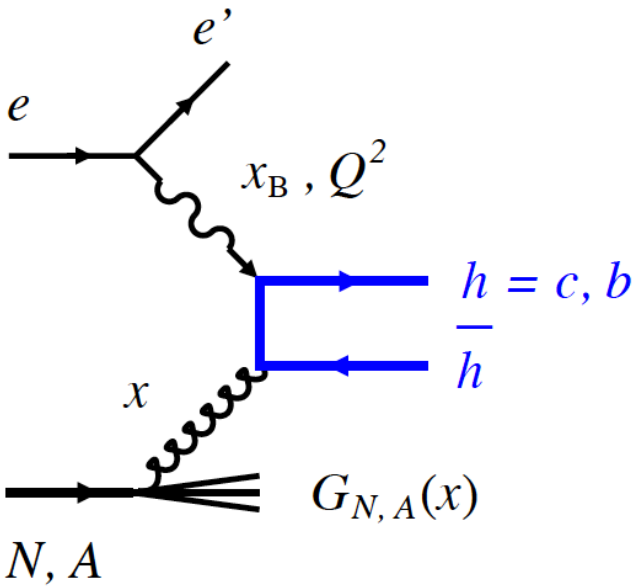
Strong gluon shadowing observed at x < 0.01 suggests compensating antishadowing at x ~ 0.1
(LHC ALICE J/Ψ in ultraperipheral AA)

At EIC - trying to get an answer on two outstanding questions regarding nuclear modifications of the nucleon's gluonic structure:

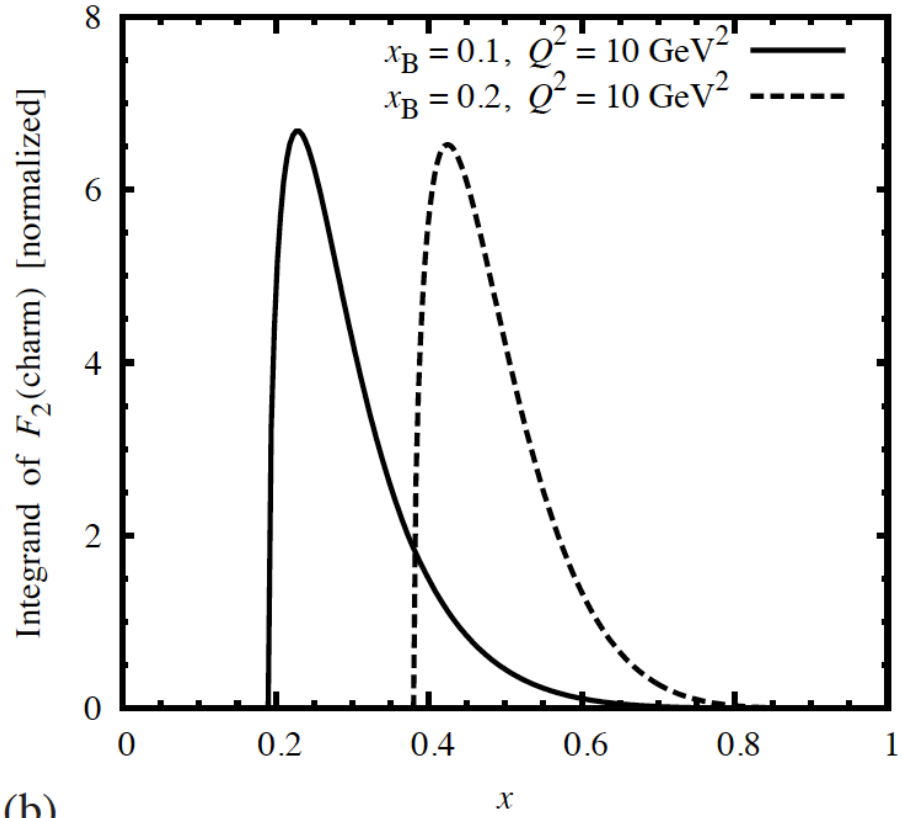
1. Is the nuclear gluon density suppressed at x > 0.3 (EMC) ?

2.What is the quark/gluon structure of the nuclear enhancement at x ~ 0.1 ?

Charm and DIS cross-sections I



(a)



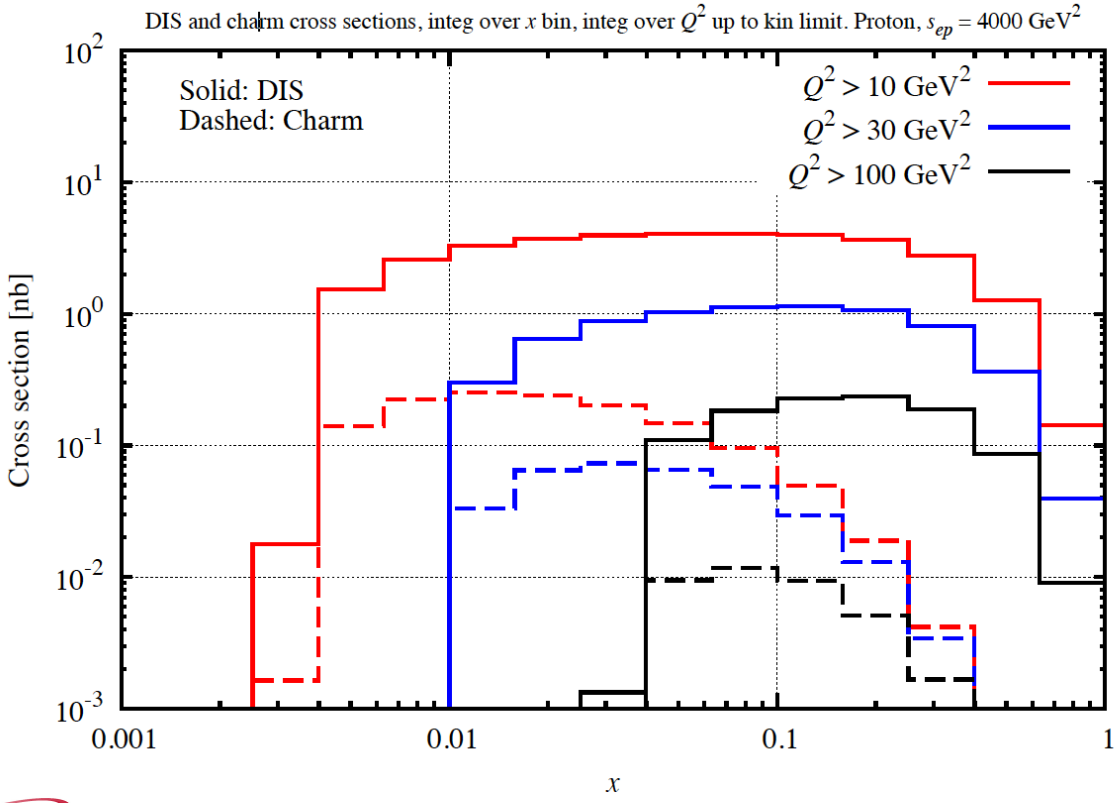
(b)

Charm and DIS cross-sections

Calculate differential cross sections using LO QCD formulas and integrate cross section over defined x and Q2 bins

$$d\sigma(e + N \to e' + X) = \mathrm{Flux}(x, y, Q^2)\, F_2(x, Q^2)\, dx\, dQ^2 \quad (1)$$

$$d\sigma(e + N \to e' + c\bar{c} + X') = \mathrm{Flux}(x, y, Q^2)\, F_2^{c\bar{c}}(x, Q^2)\, dx\, dQ^2 \quad (2)$$



Here s(eN) = 4000 GeV², corresponding to 10 on 100 GeV

Methods of Charm reconstruction

1. Exclusive D-mesons decays using PID and Vertex cut
    - Decays into charged hadrons
    - Semi-leptonic decays

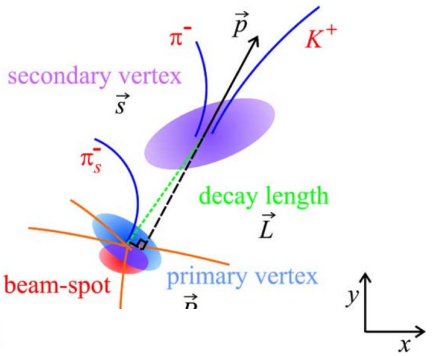
2. Decay length significance
    - Kaons or pions vertex displacement

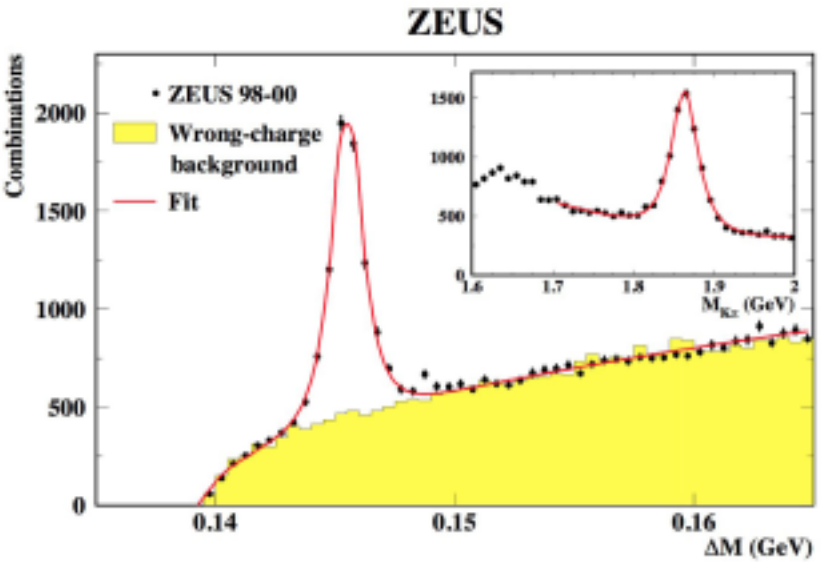
3. Charm with large PT in photoproduction. ???

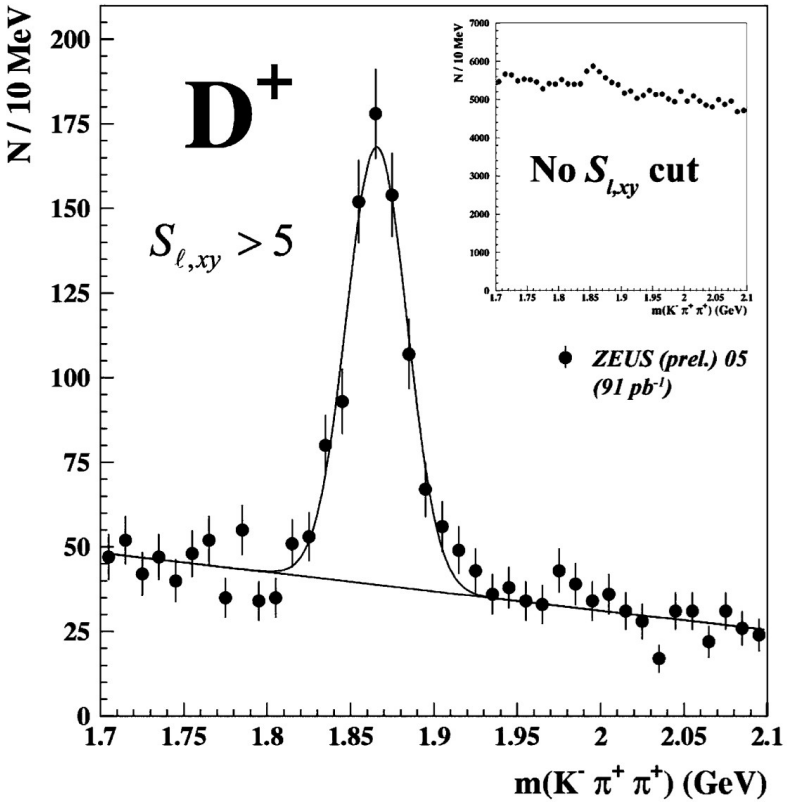
Charm at HERA

- Charm fragmentation to other mesons is measured.
- First measurements without microvertex – D* golden channel
- Later measurements with microvertex to resolve primary and secondary vertices.

$D^{*+} \to D^o \pi_s^+$, $D^o \to K^- \pi^+$







N. Coppola, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 54, NO. 5, OCTOBER 2007

Charm identification at EIC

- High intensity beam (L~ 10^{34})
- 100% Total acceptance including far-forward area
- Excellent Vertex detector resolution
- PID for charged hadrons

h_c	f	Decay	BR
D^0	59%	$K^-\pi^+$	3.9%
		$K^-\pi^+\pi^+\pi^-$	8.1%
D^+	23%	$K^-\pi^+\pi^+$	9.2%
D^{*+}	23%	$(K^-\pi^+)_{D0}\ \pi^+_{\rm slow}$	2.6%
		$(K^-\pi^+\pi^+\pi^-)_{D0}\ \pi^+_{\rm slow}$	5.5%
D_s^+	9%	$(K^+K^-)_\phi\ \pi^+$	2.3%
Λ_c^+	8%	$pK^-\pi^+$	5.0%

D0 : 2.3 % + 4.8%
D+ : 2.1 %
D*: 0.6% + 1.2%
Ds: 0.2 %
Λc: 0.4%

Total: ~10%

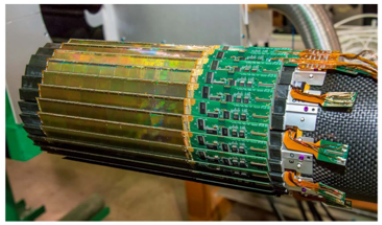
Vertex

-Reconstruction of a primary vertex
-Reconstruct secondary vtx: Tagging of c and b quarks (decay length ~100-500μm)
-improve momentum resolution of outer tracker
-provide stand-alone measurements of low-Pt particles
-dE/dx measurements (PID) for low Pt particles

- MAPS (STAR, ALICE) EIC R&D is ongoing

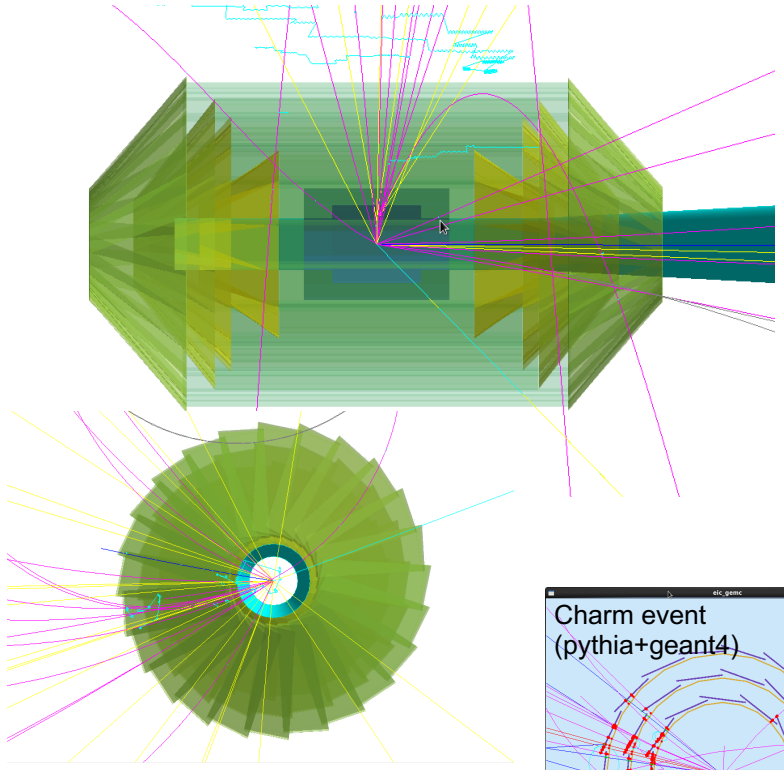
- DEPFET: BelleII PXD

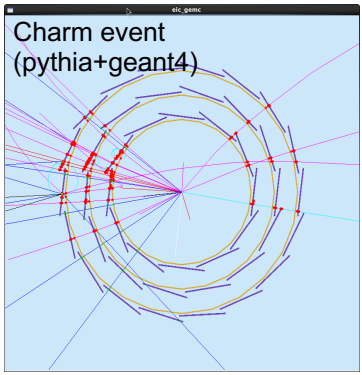
1 ladder : 0.19 % X_0
-thickness 50μm
-Integration time ~10μs
-Vertex resolution ~23μm

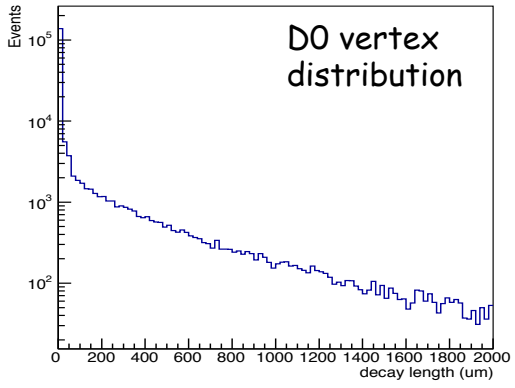


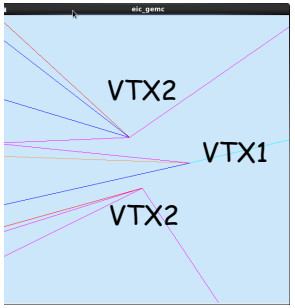
- Vertex detector is a closest to IP detector. Background increase an occupancy, therefore a high granularity detector is needed (pixels).
- Multiple scattering: low material budget detector
- Beam related background could cause a radiation damage.

GEANT4 vertex detector



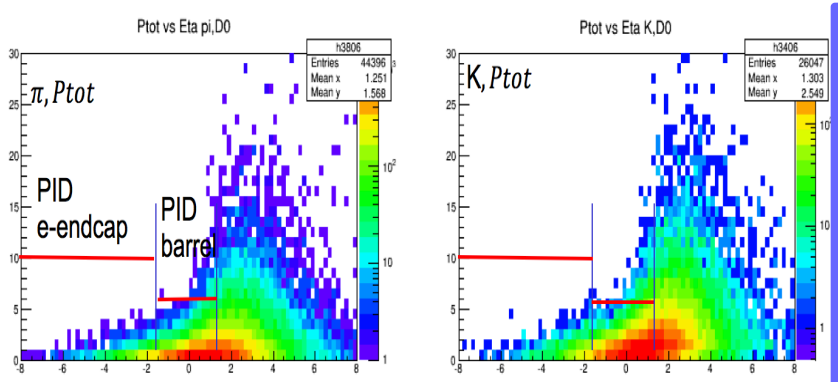




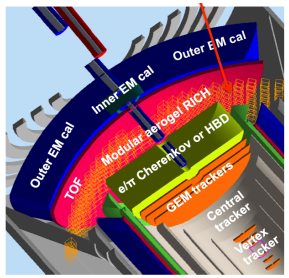


Particle identification

π and K from D0 decay
Total momentum and PT vs pseudorapidity

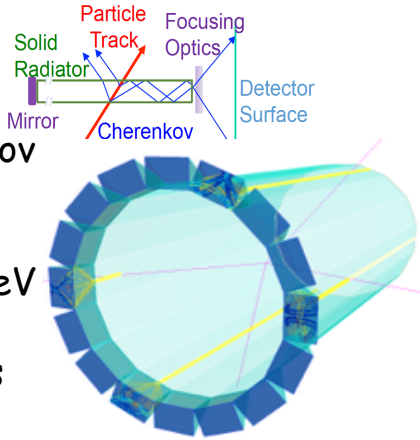


Electron end-cap: Modular RICH



- Modular aerogel RICH (eRD14 detector R&D)
- π/K separation up to ~10 GeV

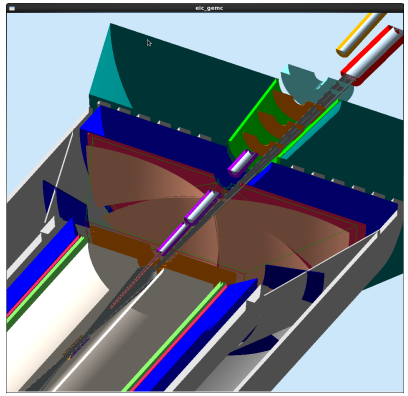
Barrel: DIRC



- radially compact (2 cm) Cherenkov detector
- Particle identification (3σ) p/K < 10 GeV, π/K < 6 GeV, e/π < 1.8 GeV
- eRD14 R&D program (test beam with PANDA), radiation hardness test

Hadron end-cap: dual-radiator RICH

- JLEIC design geometry constraint: ~160 cm length
- Aerogel in front, followed by CF4
- covers energy for π/K up to 50GeV
- Sensitive to magnetic field=>
- New 3T solenoid minimized a field in RICH region



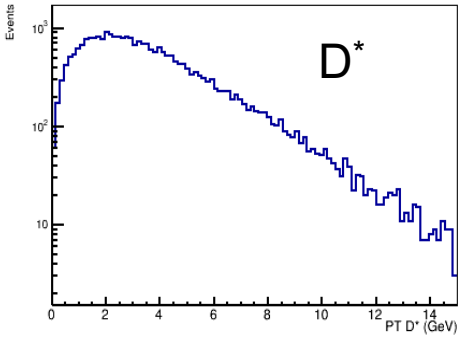
Yulia Furletova

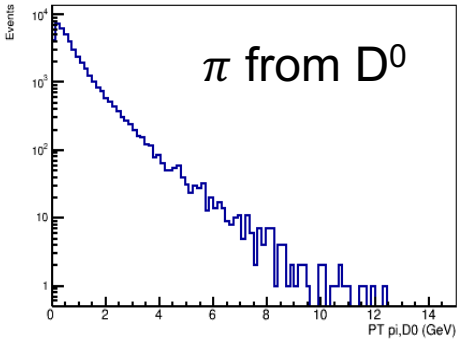
Selection Cuts

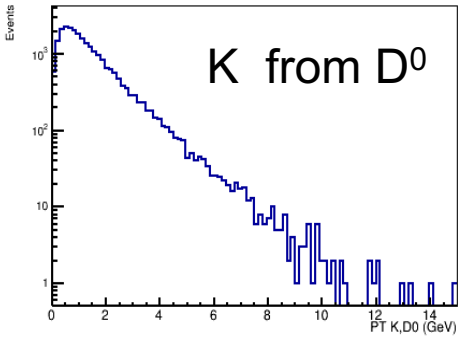
$D^{*+} \to D^o \pi_s^+$, $D^o \to K^- \pi^+$

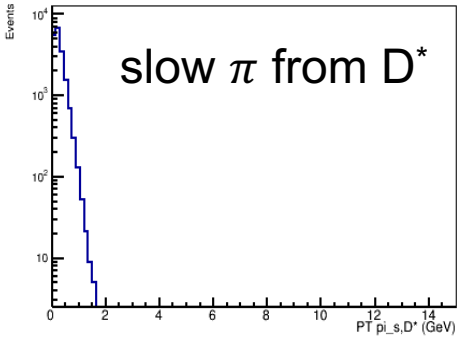
- Pythia 6 (ep 10 GeV x 100 GeV)
- Kinematic cuts: Q^2>10 GeV^2, x>0.05
- L~0.01 fb^{-1}
- Pt >0.1 GeV
- VTX cut (D0~ 100 μm, D+ ~300 μm Ds ~150 μm)
- PID cut:

-4 < η <-1.5
pt<10 GeV (e-endcap, Modular RICH
-1.5 < η <1.5
pt<6 GeV (barrel, DIRC)
1.5 < η <4
pt<50GeV (h-endcap, dual-RICH)



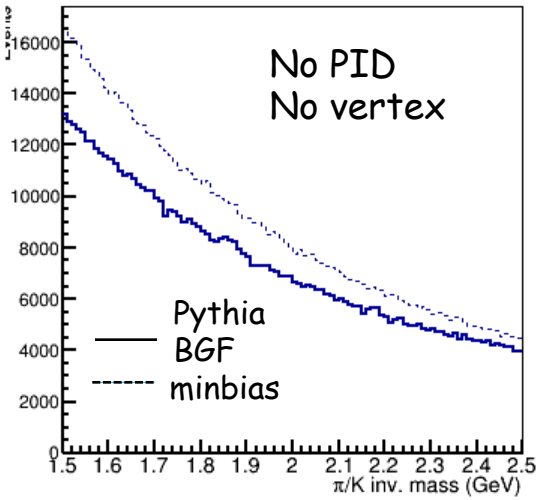


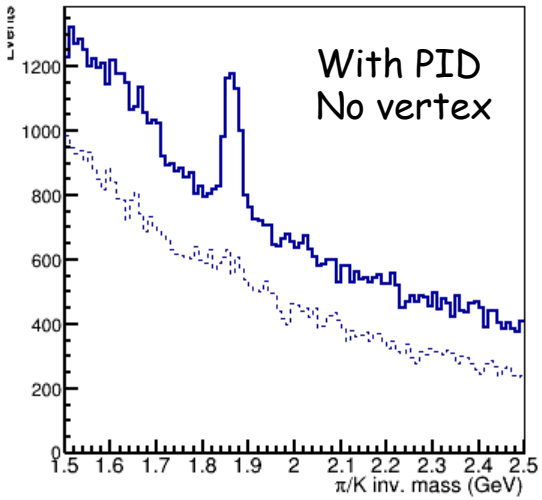


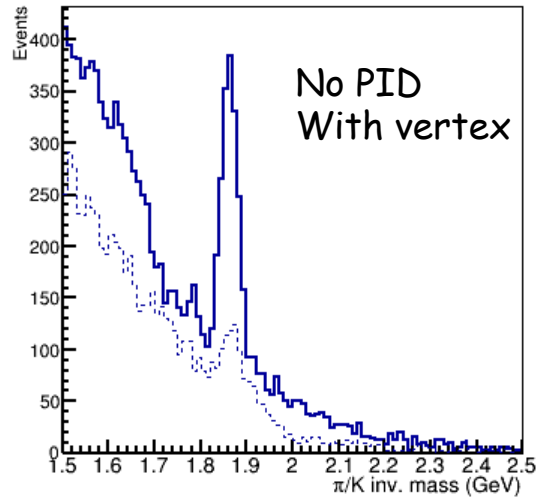


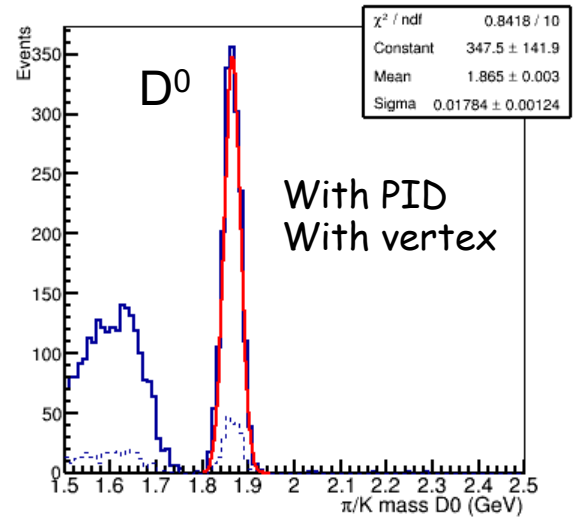
Charm direction:
Electron end-cap: ~1.5%
Barrel: ~78%
Hadron end-cap: ~20%
Far-forward: < 0.5 %

D0 mass plots







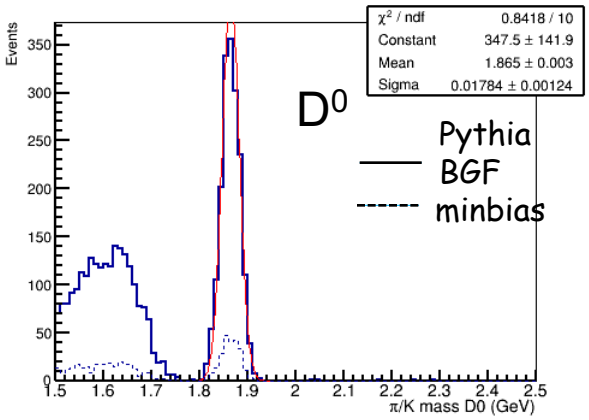


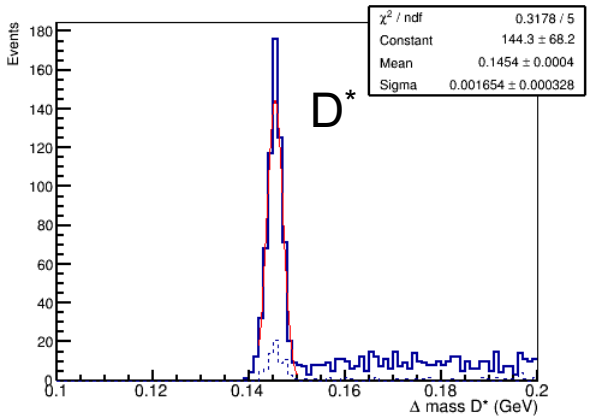
- Pythia6
- D0->π + K

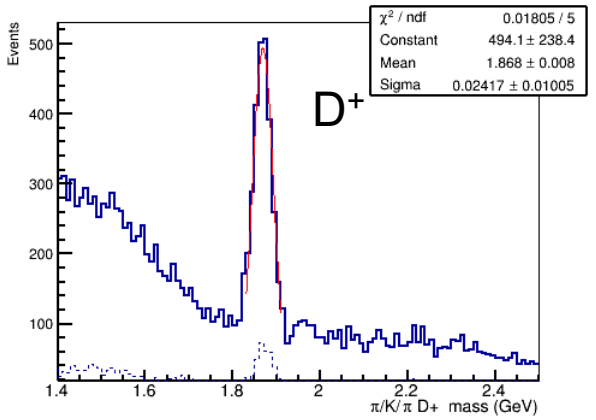
- Q2>10 GeV, x>0.05
- L~0.01 fb^{-1}
- Pt >0.1 GeV

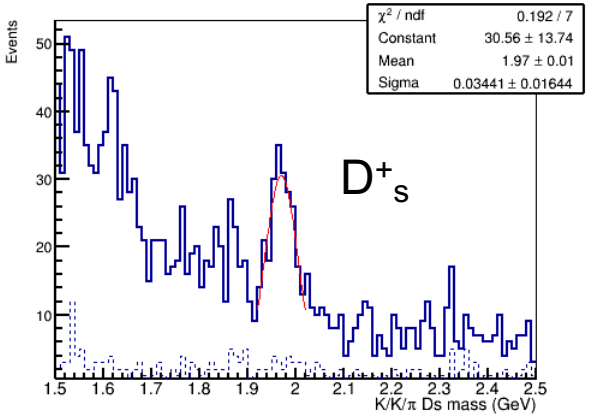
- VTX>100μm
- PID

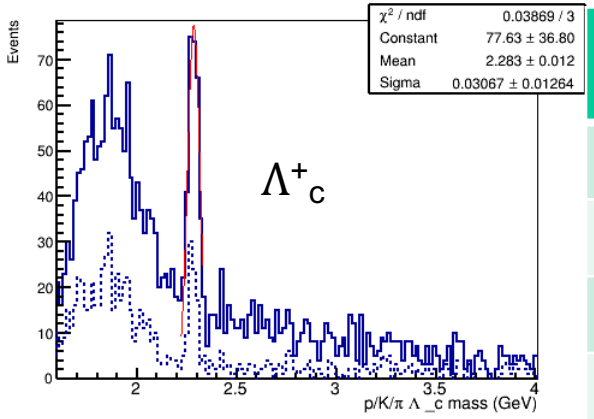
DIS (Q2>10 GeV, x>0.05, L~0.01fb^{-1})





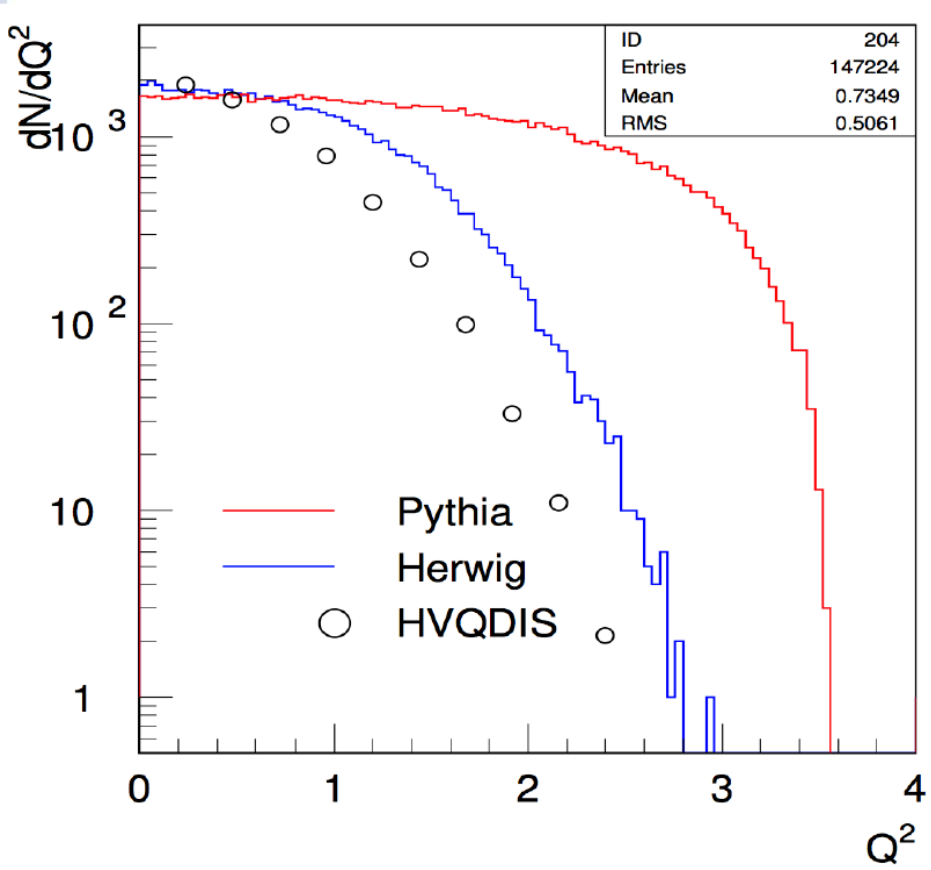


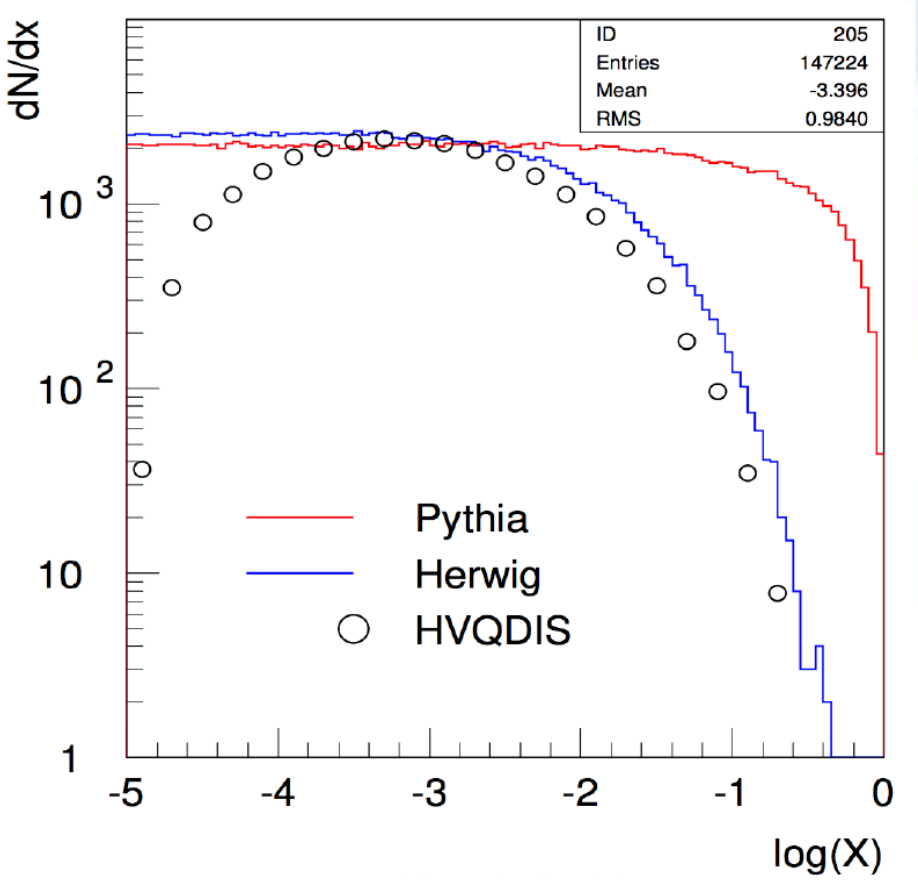




	expected	without Acceptance cut	With Acceptance cut
D0	2.3%	1.01%	0.88%
D*	0.6%	0.32%	0.32%
D+	2.1%	1.2%	1.14%
Ds	0.2%	0.08%	0.07%
Λ^+_c	0.4%	0.19%	0.13%

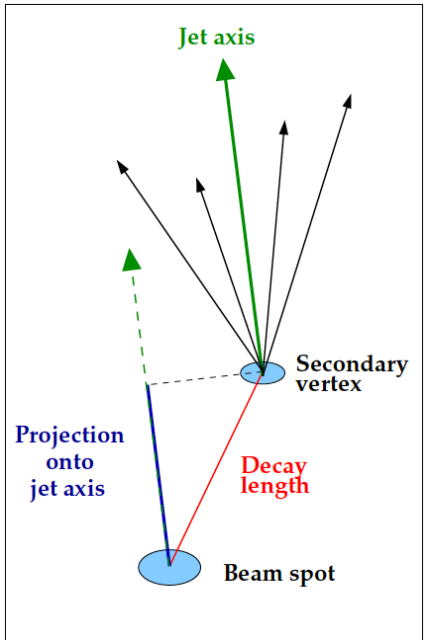
HVQDIS, Pythia and HERWIG





HVQDIS, Pythia and HERWIG comparison at high-x is ongoing

Decay length significance at ZEUS



$$
\begin{aligned}
d &= \vec{d}_{2D} \cdot \frac{\vec{j}_{2D}}{|\vec{j}_{2D}|} \\
&= \begin{pmatrix} \Delta X \\ \Delta Y \end{pmatrix} \cdot \frac{\vec{j}_{2D}}{|\vec{j}_{2D}|} \\
&= \begin{pmatrix} X_{vtx} - X_{bsp} \\ Y_{vtx} - Y_{bsp} \end{pmatrix} \cdot \frac{\vec{j}_{2D}}{|\vec{j}_{2D}|}.
\end{aligned}
$$

- Reconstruct jet
- Reconstruct vtx
- Decay length projection on jet axis
- (-) if in wrong semisphere
- Decay length significance $S=d/\delta d$
- M_{vxt} (assuming all tracks are charged pions)
- Subtract LF from wrong sign
- S in Mvtx bin

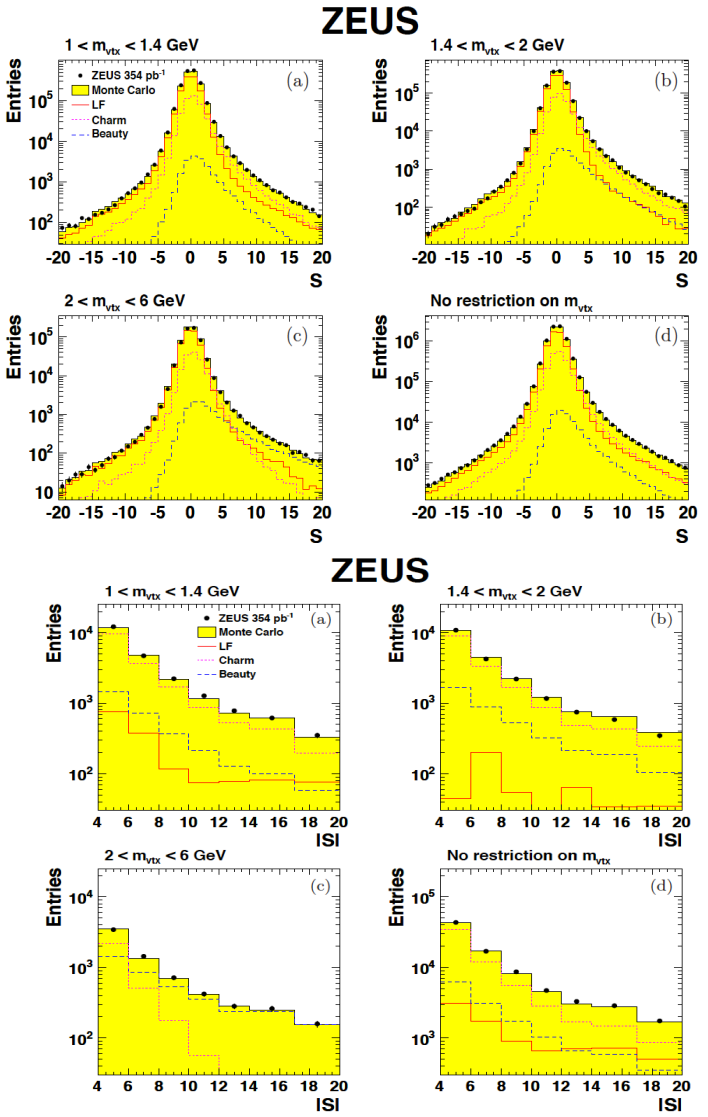
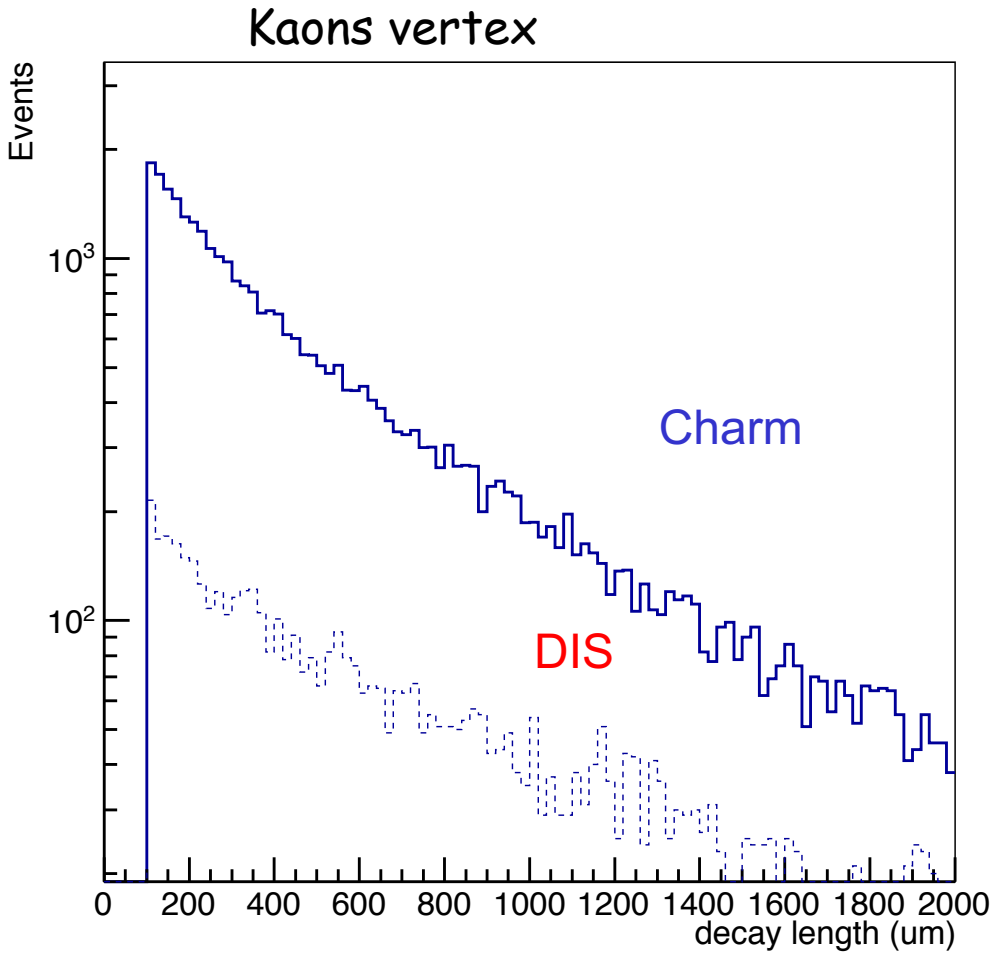


Figure 2: *Distribution of the subtracted decay-length significance in four ranges of m_{vtx}. For more details, see the caption of Fig. 1.*

2014 ZEUS paper:JHEP09(2014)127

Decay length significance



Q2>10, x>0.05
VTX > 100 um

BGF (charm)

Eff: ~ 20.5 %

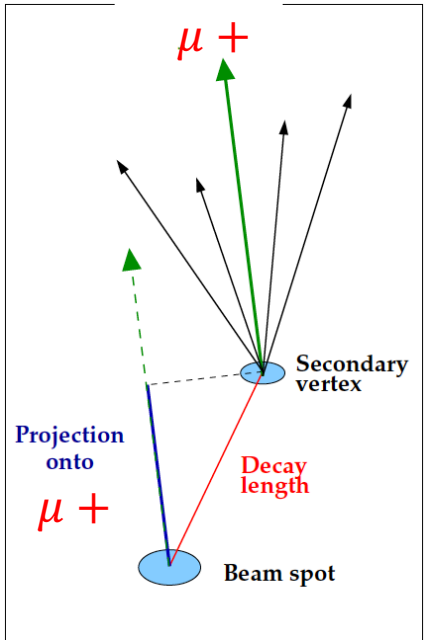
Minbias:

Eff: 3.5%

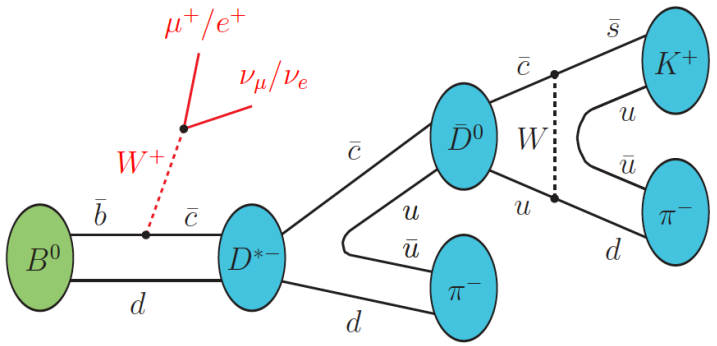
S/B = 5

To do: Number of charm in DIS sample !!!

B-tragging



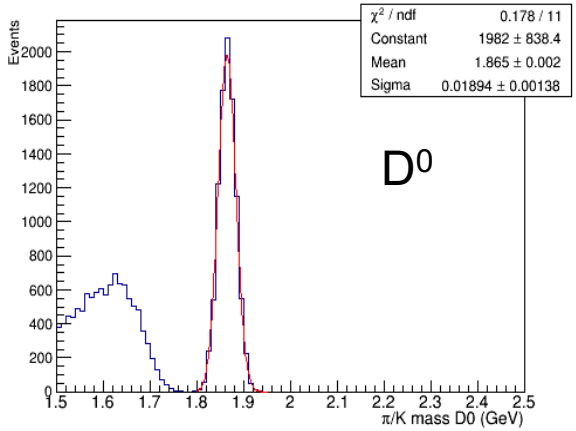
"Measurement of beauty and charm Photoproduction using inclusive secondary vertexing with the ZEUS detector at HERA" Verena Ellen Schoenberg

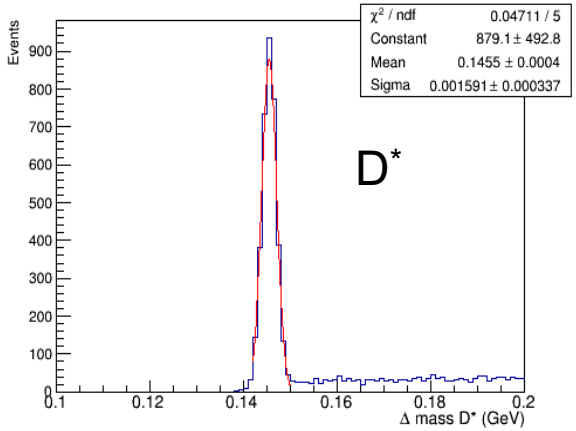


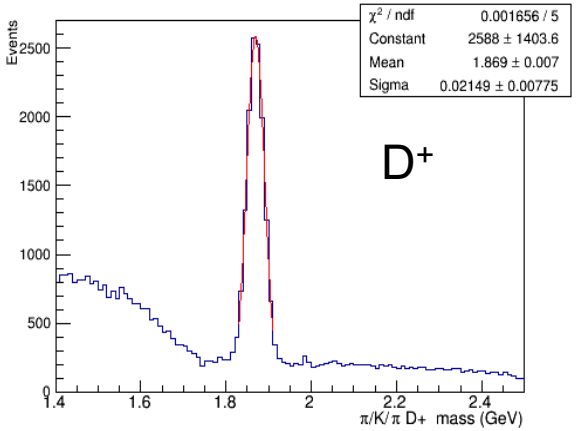
- Reconstruct jet
- Reconstruct vtx
- Decay length projection on jet axis
- (-) if in wrong semisphere
- Decay length significance S=d/δd
- Reconstruct the mass of D*
- Subtract LF from wrong sign
- S in Mvtx bin

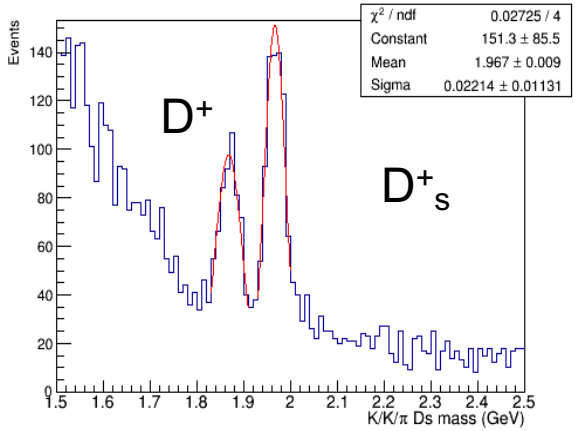
Charm in PHP

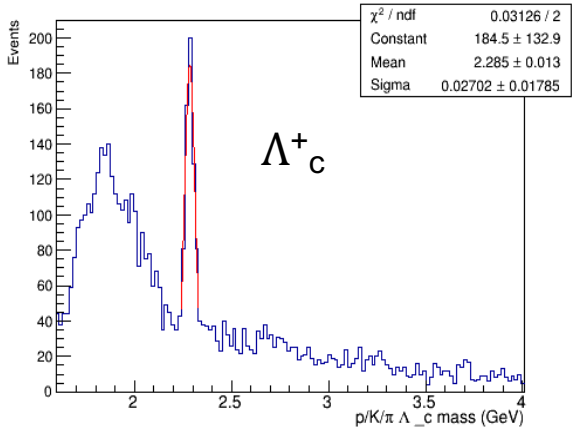
PHP (Q2<1 GeV, PT> 1 GeV)











- Q2 < 1 GeV
- L~0.01 fb^{-1}
- Pt >1 GeV
- Vtx + PID

Summary

- Study feasibility of direct measurements of nuclear gluons at $x \gtrsim 0.1$ using heavy quark probes with a future Electron-Ion Collider

Summary

- Backup