Reconstruction of VMs
(ZEUS experience)

Y. Furletova

Detector for VM

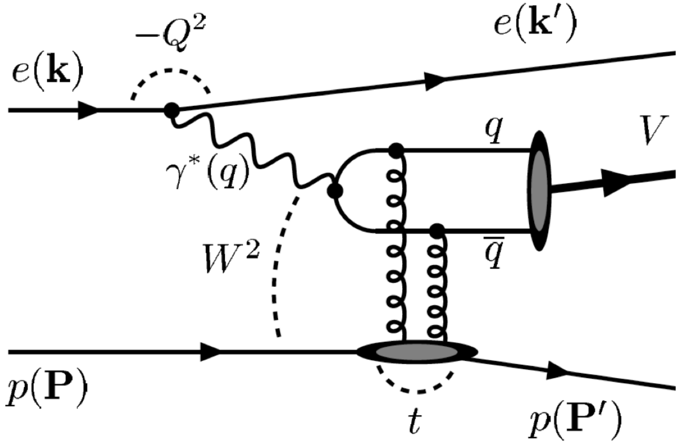


Figure 2. Exclusive vector meson production described by perturbative quantum chromodynamics.

Need to understand how the design of past detectors (ZEUS,H1,etc) impacted the observation of VMs to guide optimal designs for the EIC detector.

Need to know the background.

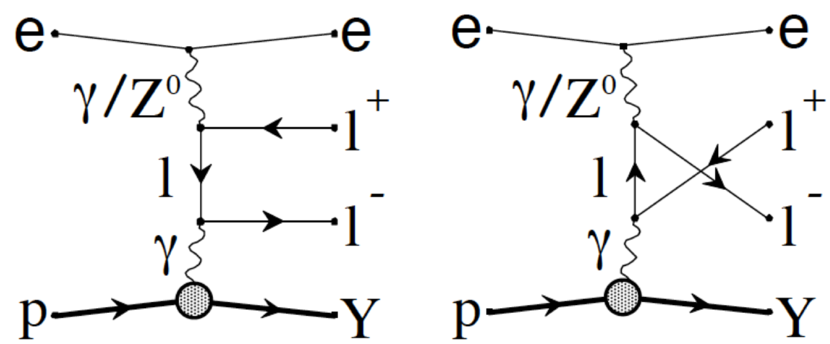
-Scattered electron
-decay products of VM
-recoil proton

ZEUS paper by Robert Ciesielsky

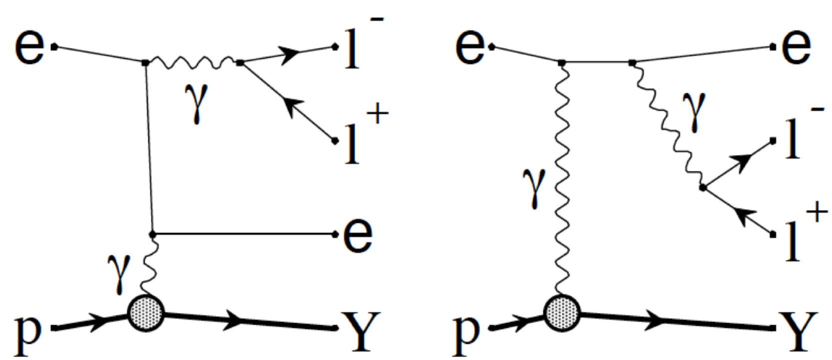
JLAB/EIC^2 summer student Brent Lawson

Detector for VM (J/ψ)

Main non-resonant background process is a di-lepton production



(a) Bethe-Heitler type diagrams



(b) QED-Compton type diagrams

VM at ZEUS

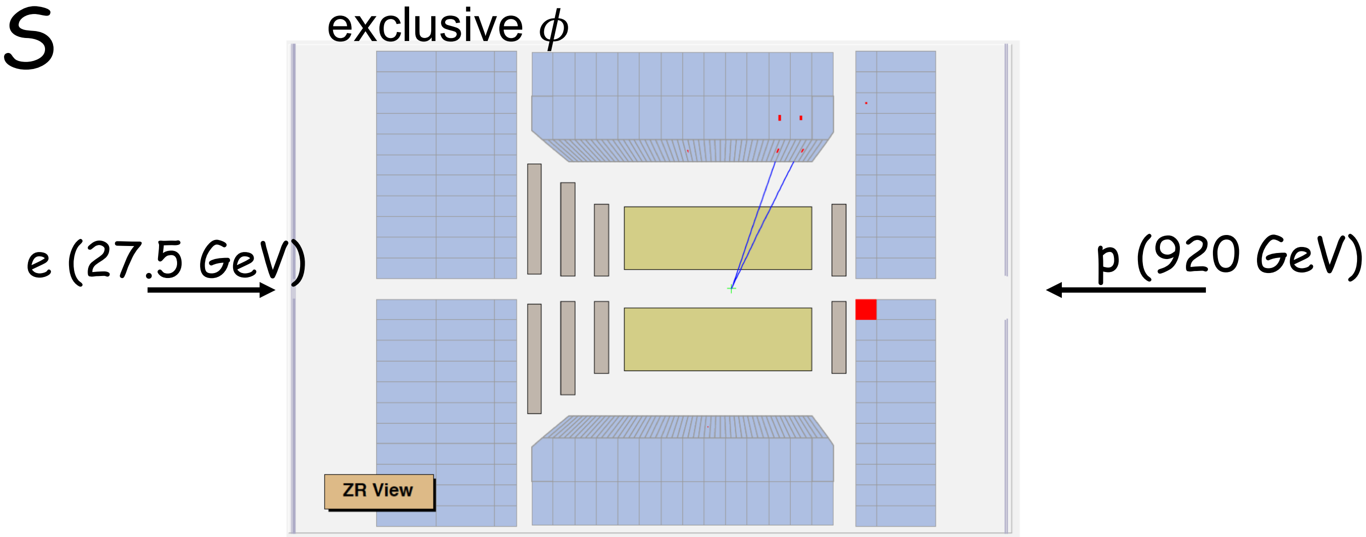
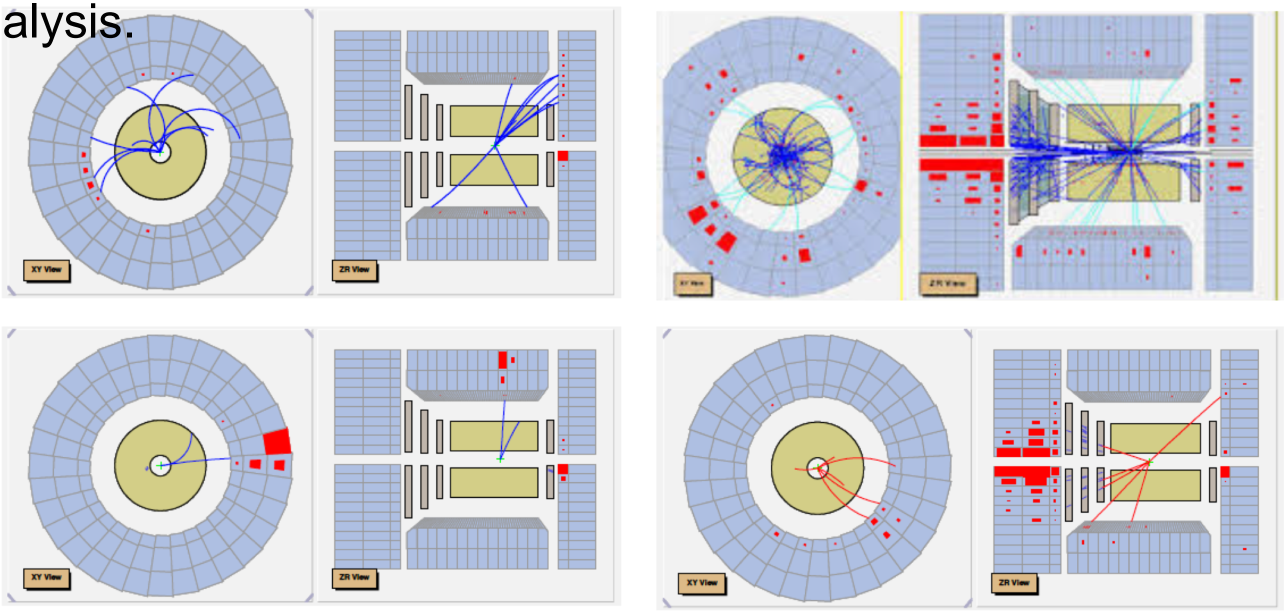


Figure 3. Example of the tracks and energy deposits for exclusive ϕ production.

Background: Examples of events that are not exclusive ϕ production, that needs to be removed during the analysis.



Yulia Furletova

VM ($\phi \to K^+ K^-$) at ZEUS

Cuts used for data selection

1. 2 < # of tracks in CTD < 5
2. Tracks must have opposite charges and be associated with primary vertex
3. $E'_e > 10\ GeV$ in a reliable region of detector
4. Tracks must pass through > 3 superlayers in the CTD
5. Tracks must have trans. momentum > 0.15 GeV
6. Tracks must be within $|\eta| < 1.7$ (angle)
7. $|Vtx_z| < 50$ cm and $Vtx_r < 0.8$ cm
8. Energy in inner ring of forward calorimeter < 1 GeV
9. No extraneous tracks with E > 0.3 GeV
10. $2 < Q^2 < 70\ GeV^2$
11. $45 < E\text{-}p_z < 65$ GeV
12. 35 < W < 200 GeV
13. $|t| < 0.6$
14. $1.01 < M_{KK} < 1.10$ GeV

No PID

at HERA- initial e: 27.5GeV

For track reconstruction (no vertex for HERA-1)

Only CTD area

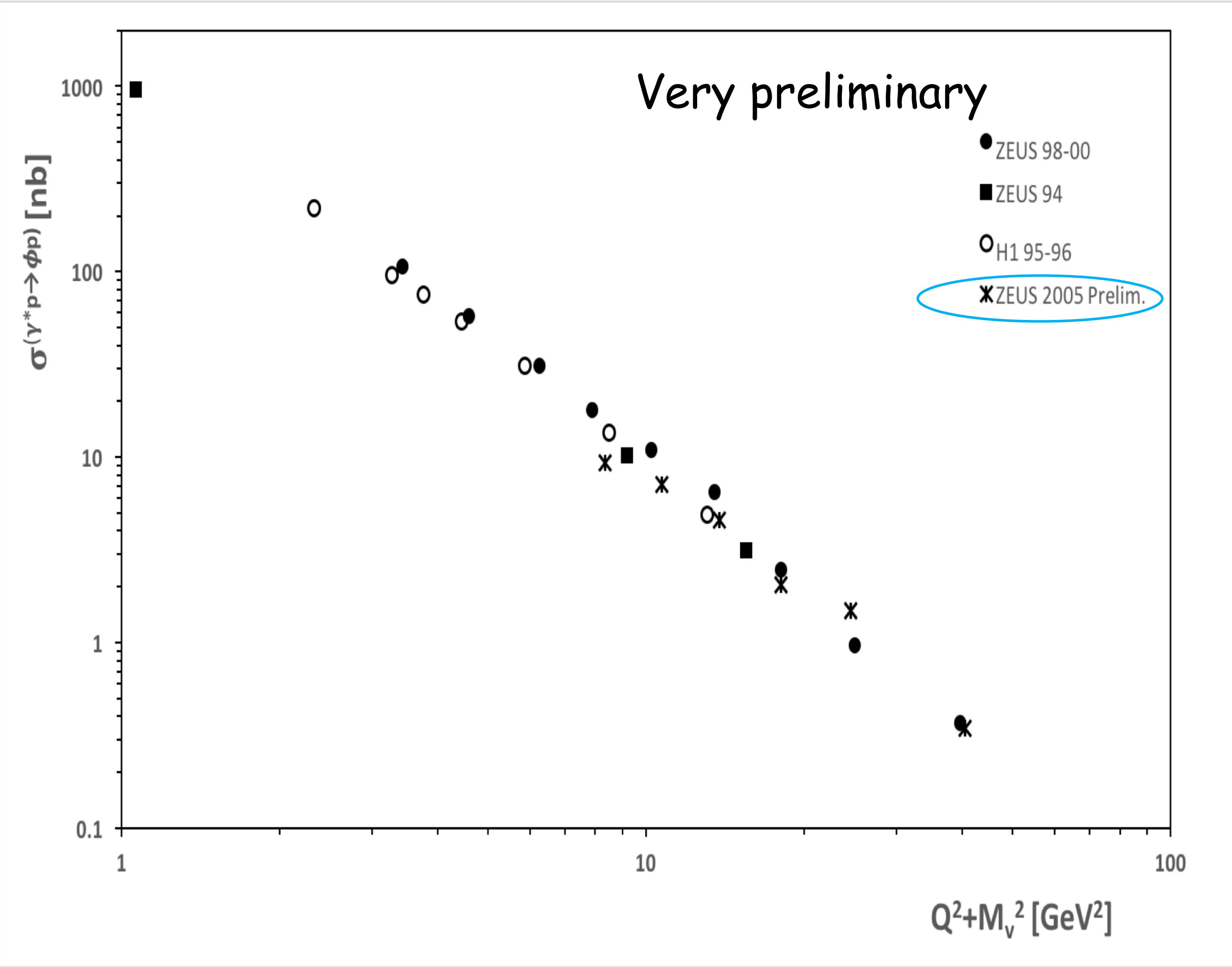
Beam background rejection

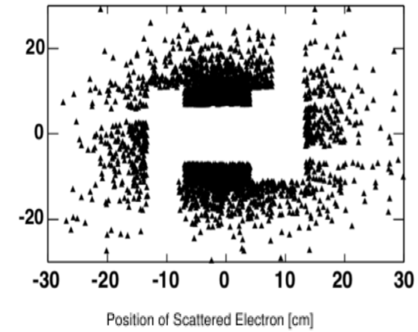
"Exclusivity" cut, no forward detection at HERA.

NC DIS: E-pz ~ 2Ee ~ 55 GeV
(for EIC ~ 20 GeV (2x10)

VM ($\phi \rightarrow K^+ K^-$) at ZEUS

Brent Lawson





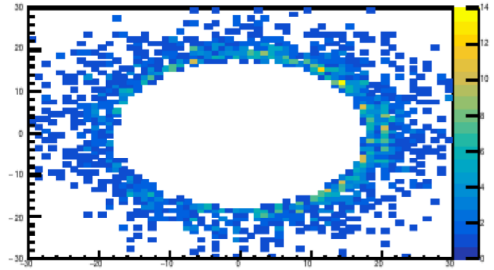
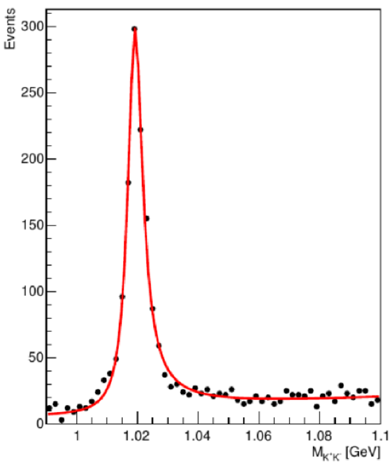


Figure 9. Electron position cuts from ZEUS detector during HERA-I[4] and HERA-II

Invariant mass peak for ϕ vector meson fit with a Relativistic Breit-Wigner distribution and a second order polynomial to describe the background



Yulia Furletova

Decay products of VMs: momentum reconstruction

ϕ-mesons

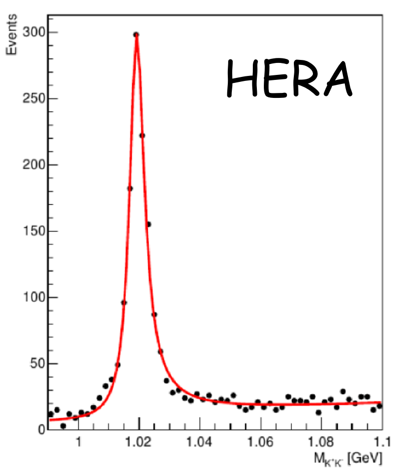
Br (ϕ->K+K-) ~49%

ρ-mesons

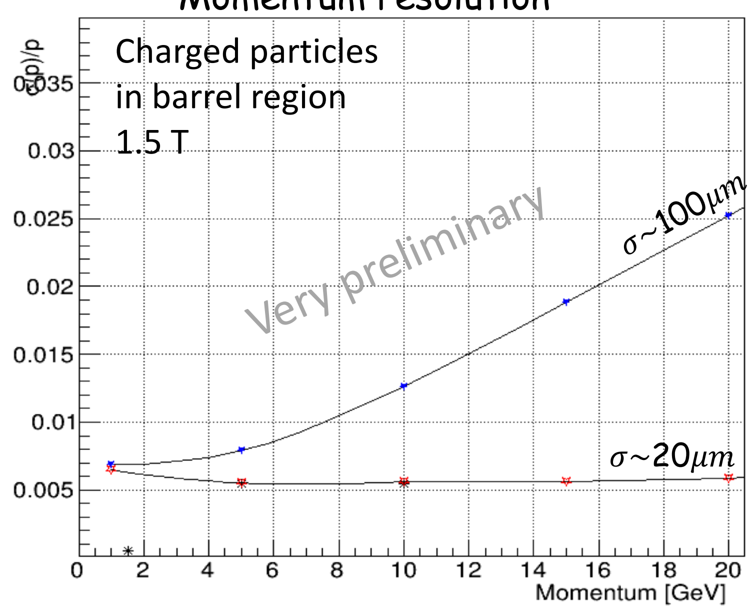
Br (ρ->π+π-) ~ 100%

- Momentum resolution affects invariant mass spectrum width
- At EIC, momentum resolution below few % is required
- Need PID!!

Invariant mass peak for ϕ vector meson fit with a Relativistic Breit-Wigner distribution and a second order polynomial to describe the background



Momentum resolution



Yulia Furletova

J/ψ identification

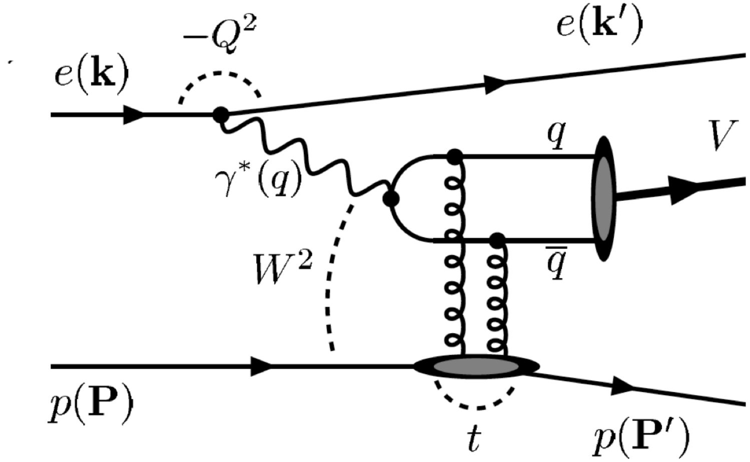


Figure 2. Exclusive vector meson production described by perturbative quantum chromodynamics.

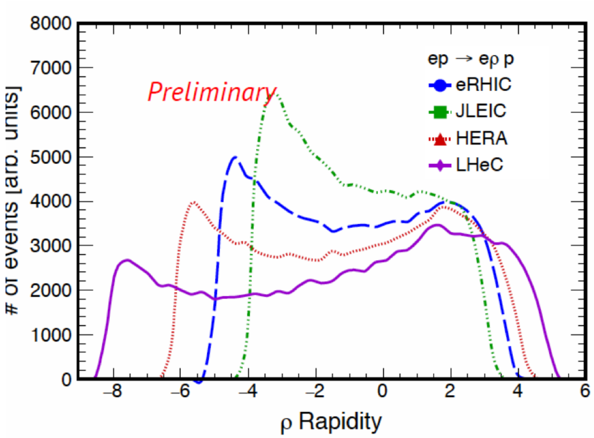
J/ψ

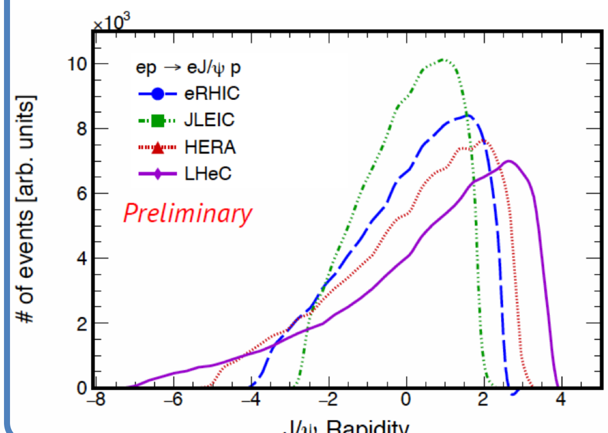
Br (J/ψ->e+e-) ~6%

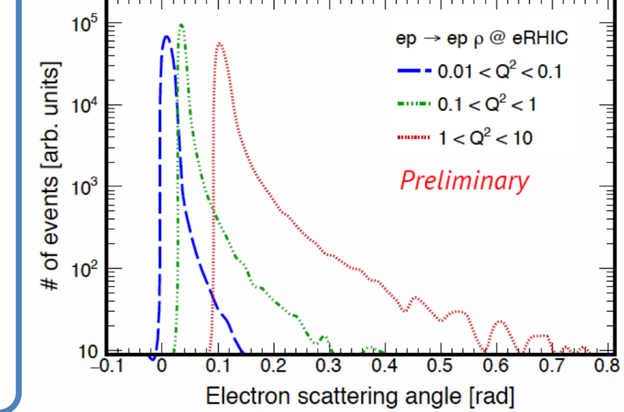
Br (J/ψ->μ+μ-) ~6%

Need lepton identification

Michael Lomnitz - DIS 2018







Yulia Furletova

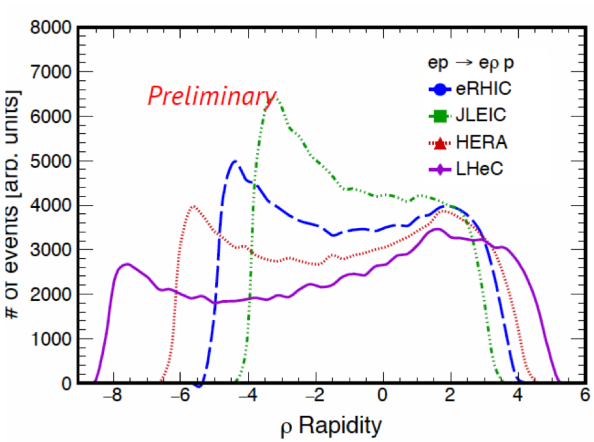
Electron identification (e/hadron separation)

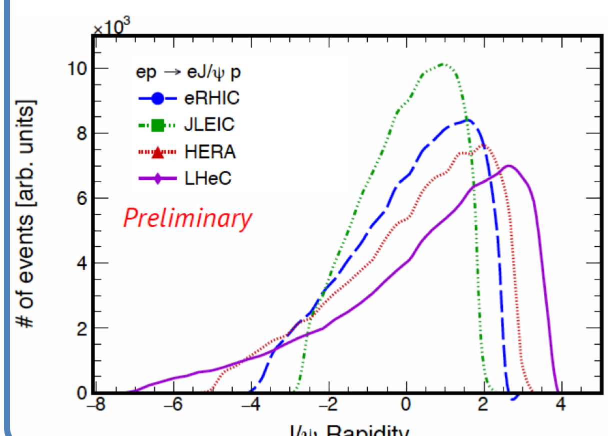
Br (J/ψ->e+e-) ~6%

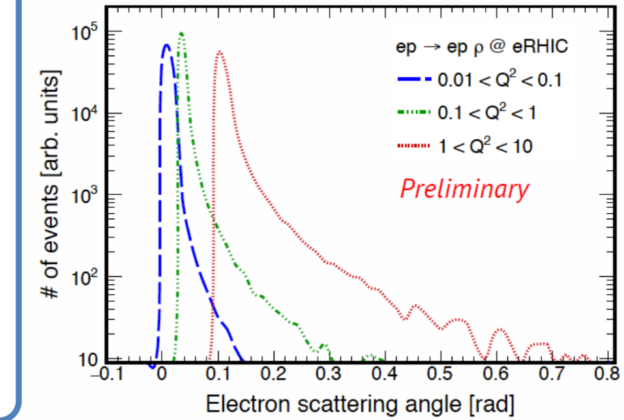
- ✓ For electron identification we use mainly calorimeter
- ✓ e/π rejection for EMCAL is 50 (100)
- ✓ HCAL e/π rejection ~ 5.
- ✓ TRD e/π rejection ~ 5-10/layer

- ✓ Kinematics: boosted towards hadron- endcap
- ✓ Very high hadron background
- ✓ Need hadron suppression by 10^4
- ✓ Need additional tools for electron identification

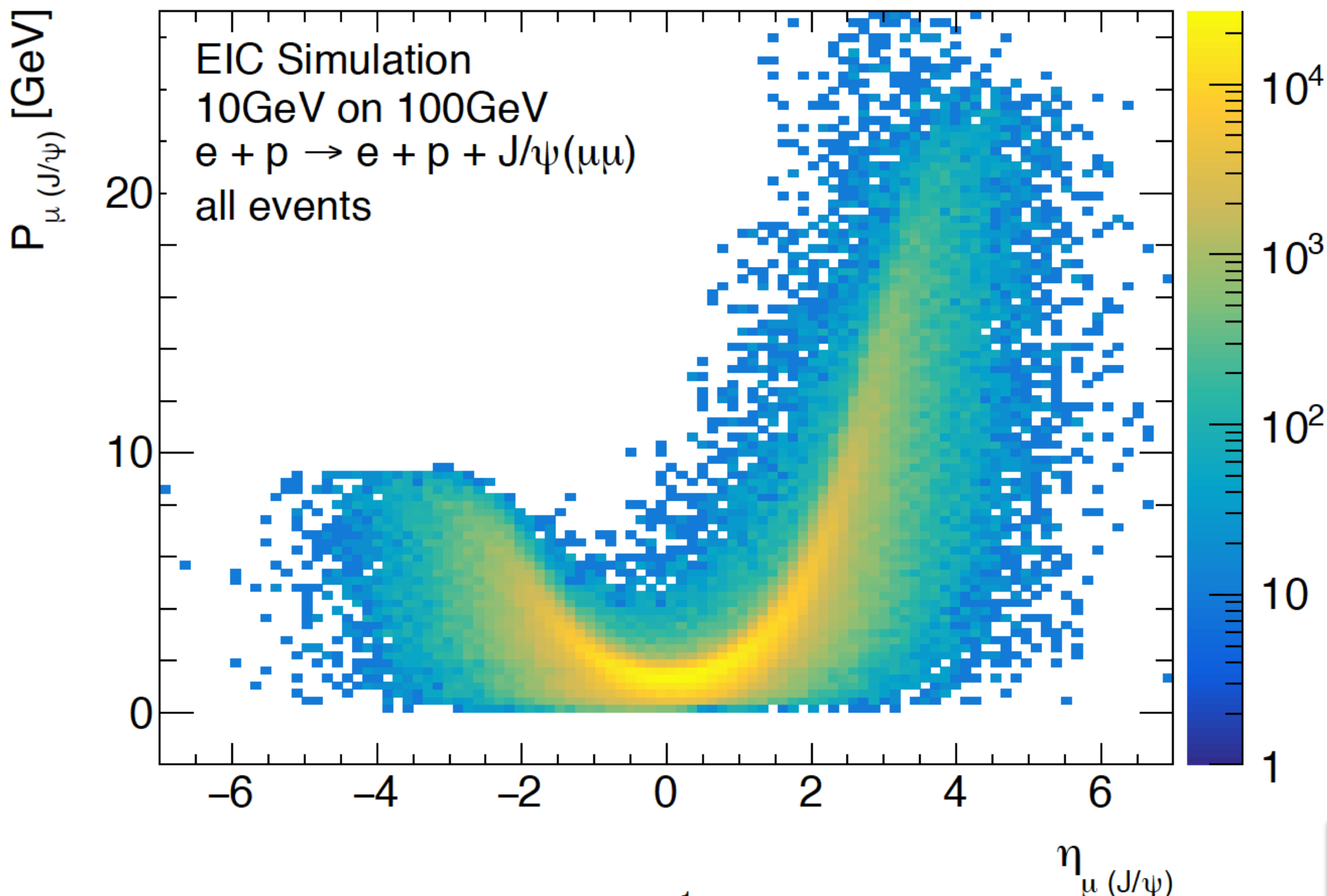
Michael Lomnitz - DIS 2018







Muons from J/ψ



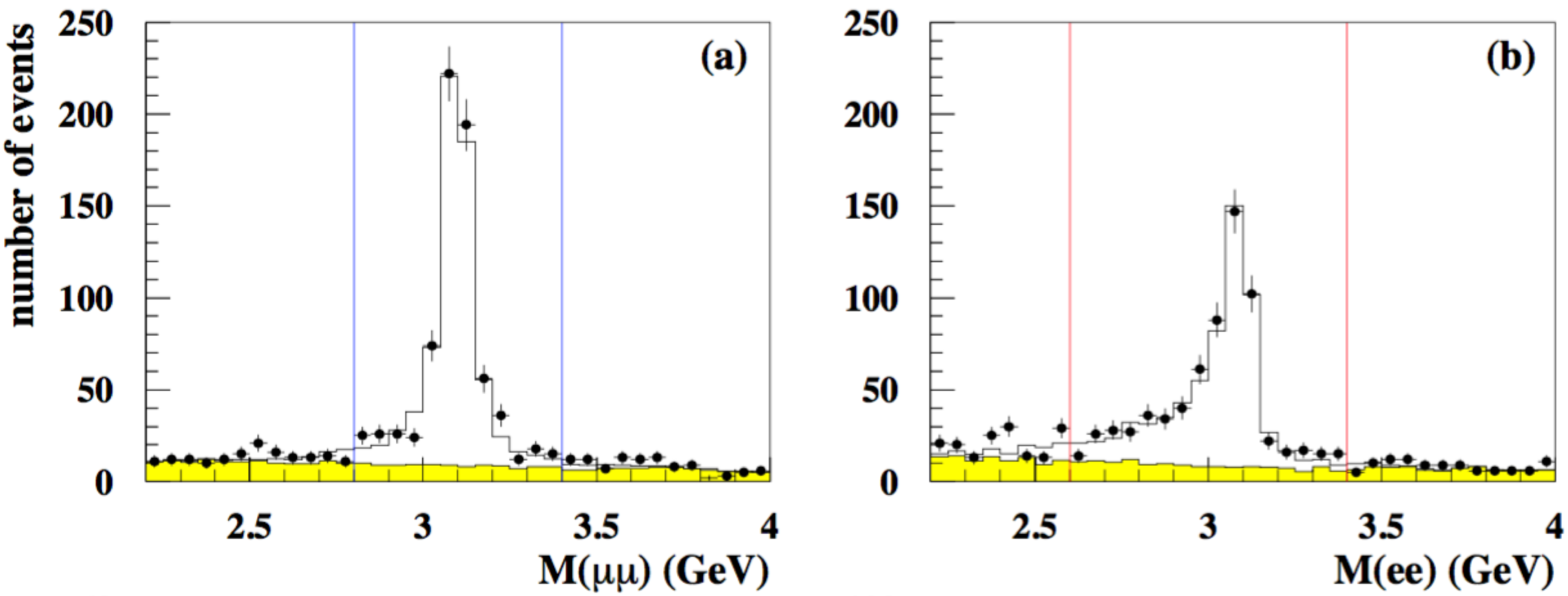
1

Sylvester Joosten

Muon identification

ZEUS/HERA data
(Robert Ciesielsky)

Br ($J/\psi \to \mu^+\mu^-$) ~6%



- Much cleaner sample from muon decay channel
- $e^-p \to e^-p\,(J/\psi \to e^+e^-) \to e^- e^- e^+ p$

From other fields(Heavy flavor physics)

Semi-leptonic channels

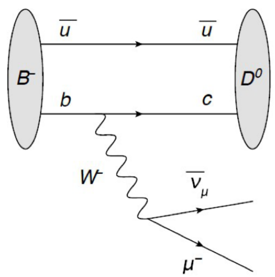


Figure 2.15.: Quark level diagram for the decay $B^- \to D^0\mu^-\nu_\mu$.

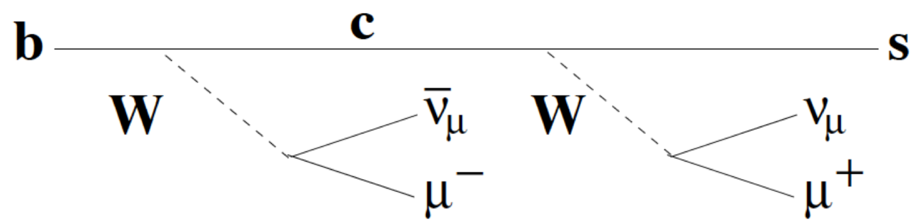
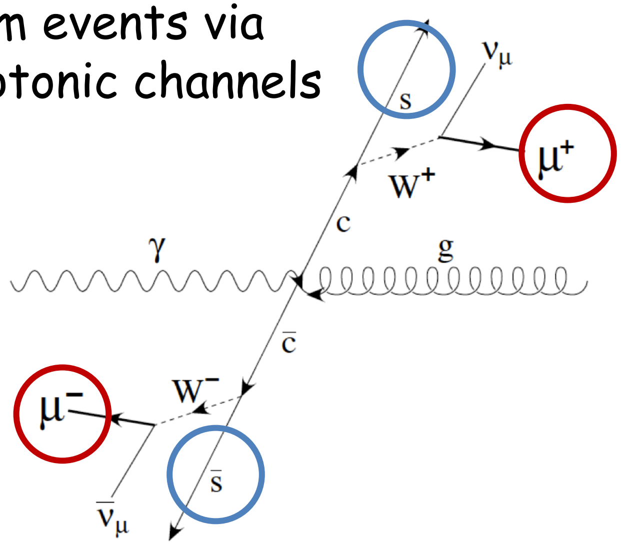
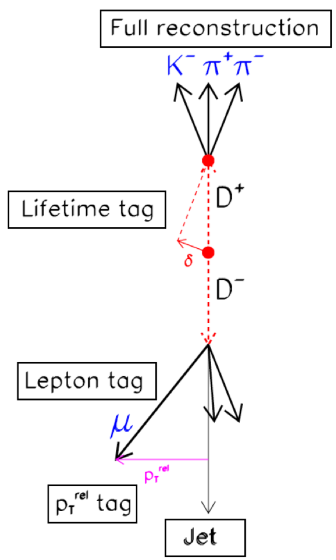


Figure 2.12: *Cascade decay of a beauty quark.*

Di-charm events via semi-leptonic channels



Di-charm events,
Combination of inclusive and exclusive decays



BR: c-> lepton + X (~ 17% ?)

Muon identification/instrumentation

For high energy (above a few GeV), muons identification is based on **low rate of interaction** of muons with matter…

If charged particle penetrates large amount of absorbers with minor energy losses and small angular displacement -- such particle is considered a muon

Problem: Hadrons create shower in absorber. If the absorber is too thin the shower can leak through….

- E_{emcal}/E_{tot} , for muons Min energy in EMCAL and HCAL
- p/E (momentum vs total energy)
- dE/dx, cluster counting in tracking detectors (need electronics?)
- Do we need additional instrumentation: muon chambers behind HCAL ?

Forward instrumentation

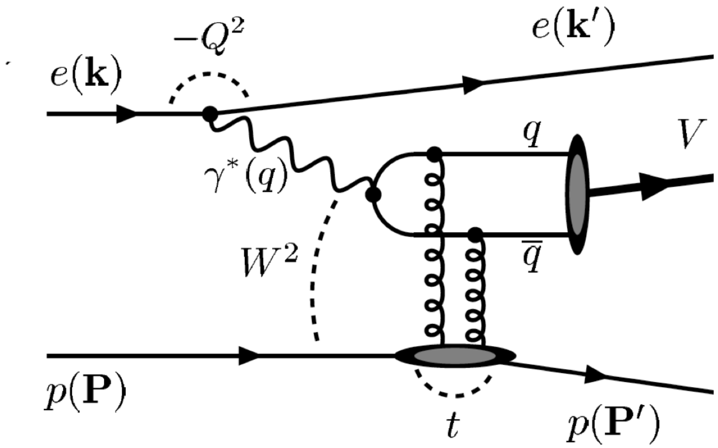


Figure 2. Exclusive vector meson production described by perturbative quantum chromodynamics.

$t=(P_p - P_{p'})^2=-P^2_{T\,J/\psi}$ (for PHP)

At HERA (no detection for p') :

$$|t| \approx (p_x^e + p_x^{l+} + p_x^{l-})^2 + ((p_y^e + p_y^{l+} + p_y^{l-})^2,$$

For EIC : far-forward proton detection!

Conclusion

- Kinematic coverage (including PHP)
- Background (identify sources of background, proper cuts/selection
- Far-Forward instrumentation
- Hadron identification π/K(ϕ,etc…)
- Lepton identification (J/ψ)
  - Additional tools for e/π rejection
  - Muon identification