Detector requirement of studying photon PDFs at EIC

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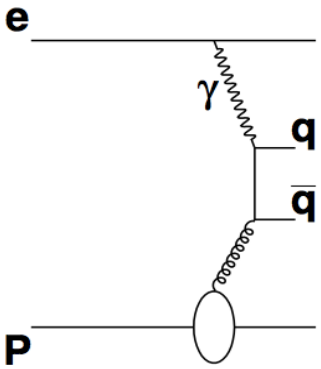
05/04/20

Outline

- **Introduction**
- **Photon structure at EIC from detector aspects**
  - Detector requirements on how to separate direct and resolved process
  - Select Jets from photon side
  - Flavor tagging in photon side jet
- **Summary**

Di-jet in resolved/direct process



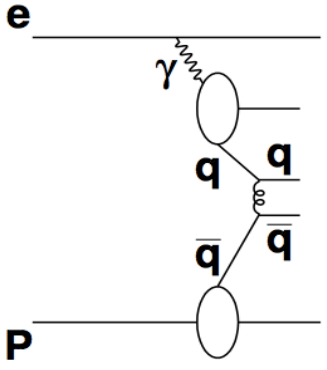
PGF: Di-jet produced

"Direct process"

- Point-like photon (no substructure)
- x_γ is equal to 1
- Di-jet production

"Resolved process"

- Hadronic photon (with structure)
- x_γ is smaller than 1
- Di-jet production

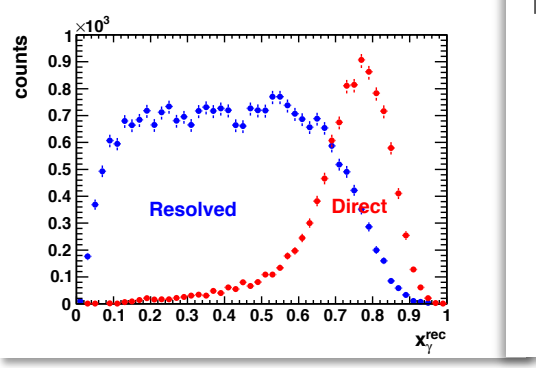


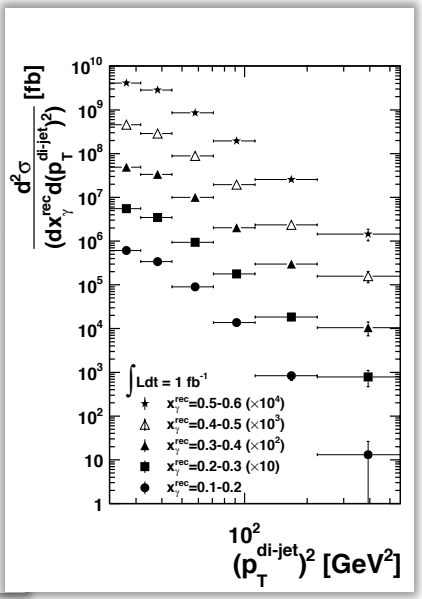
Similar with pp collision

- **Separate di-jet produced in resolved and direct processes,** to get clear resolved process, x_γ <0.6
- Reconstruct x_γ by using di-jet as observables:
  - Two jets with highest p_T
  - Parton densities in the photon can be extracted by measuring **di-jet cross section**

$$\frac{d^2\sigma}{dx_\gamma dp_T} = \gamma_{flux} \otimes PDF_\gamma(x_\gamma, Q^2, \mu) \otimes PDF_p(x_p, \mu) \otimes d\sigma_{ij}(\theta^*, Q^2, \mu)$$

$$x_\gamma^{rec} = \frac{1}{2E_e y}(p_{T1}e^{-\eta_1} + p_{T2}e^{-\eta_2})$$

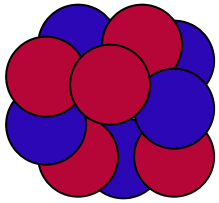




Identify the flavor

$$\frac{d\sigma}{dx_\gamma dp_T} = \gamma_{flux} \otimes PDF_\gamma(x_\gamma, Q^2, \mu) \otimes PDF_p(x_p, \mu) \otimes d\sigma_{ij}(\theta^*, Q^2, \mu)$$

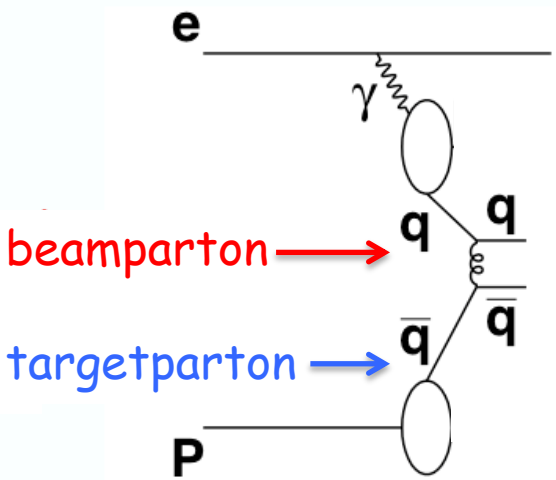
From measuring the cross section, we can extract the total PDFs of the photon



What if we want to separate the contribution depending on different flavor partons?

Flavor tagging need to be achieved

Select jet from the photon side

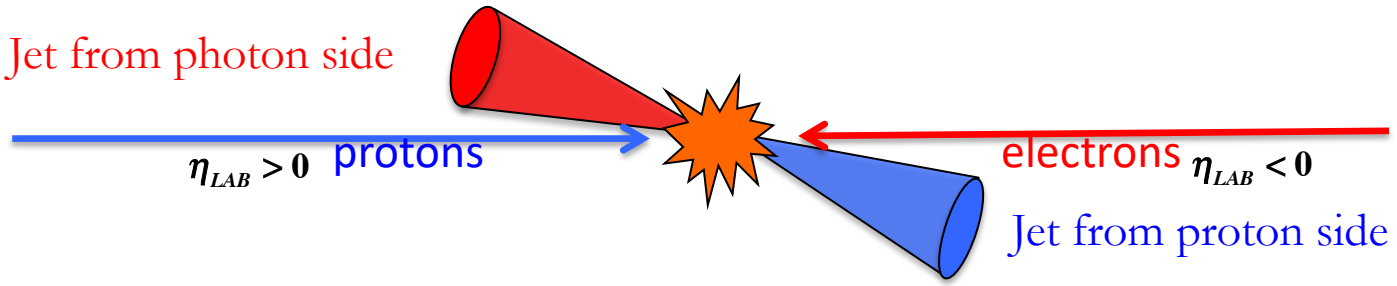


In PYTHIA, beamparton, targetparton

- As we have known how to separate "direct" and "resolved" process, then we measure jet kinematics in resolved process
- "Path" to do parton-jet match: Geometric match
  - beamparton - one final parton - one jet of di-jet ⟹ Jet from photon side
  - tgtparton - another final parton - another jet of di-jet ⟹ Jet from proton side

$$\Delta E\{parton - jet\}$$

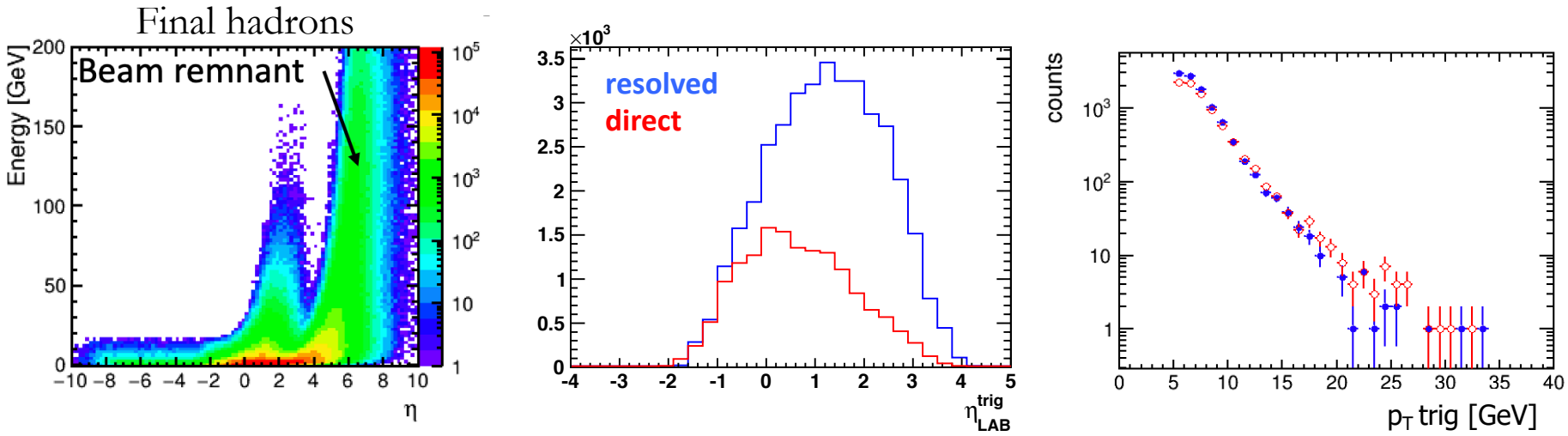
$$\Delta R\{parton - jet\} = \sqrt{\Delta\phi^2 + \Delta y^2}$$



Di-jet Kinematics

$$x_\gamma^{rec} = \frac{1}{2E_e y}(p_{T1}e^{-\eta_1} + p_{T2}e^{-\eta_2})$$

20GeV×250GeV, 0.01<y<0.95, two highest p_T jets, , $p^{jet1}{}_T$>5 GeV, $p^{jet1}{}_T$>$p^{jet2}{}_T$>4.5 GeV,
Inside the jet, stable particle p_T>250MeV, $|\eta^{particles}|$<4.5

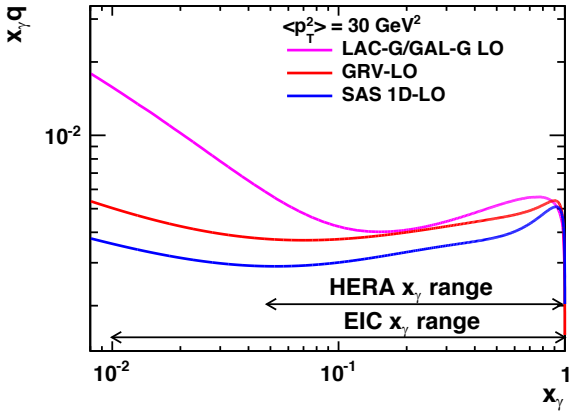


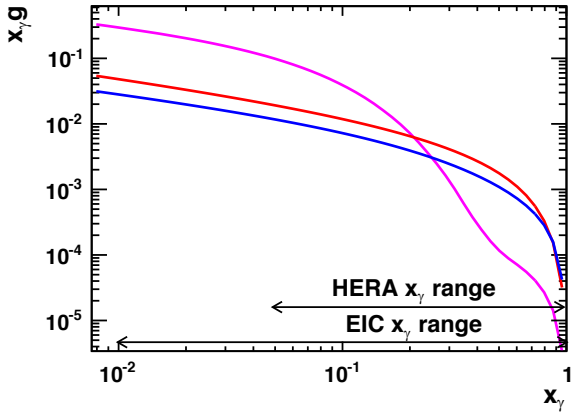
Detector requirement of measuring di-jets:

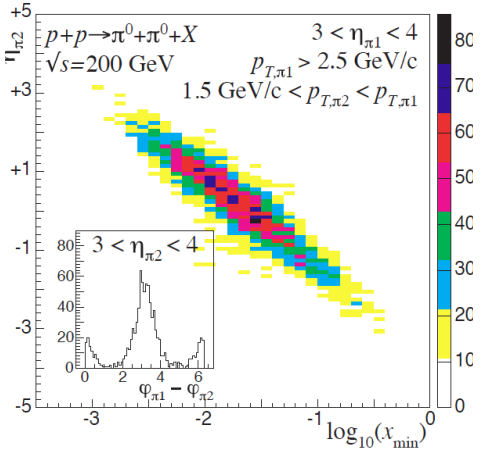
- Resolved process dominates at forward region, the rapidity coverage needs to be -2 to 4.
- Trigger jet p_T range is from 5 to 33 GeV.
- Kinematics distribution of associate jet shows the same result.

Phase space

$$x_\gamma^{rec} = \frac{1}{2E_e y}(p_{T1}e^{-\eta_1} + p_{T2}e^{-\eta_2})$$





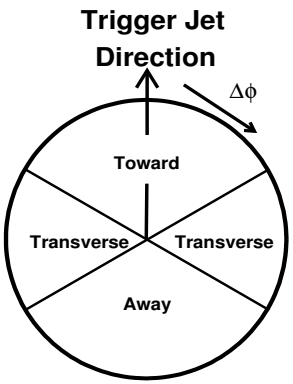


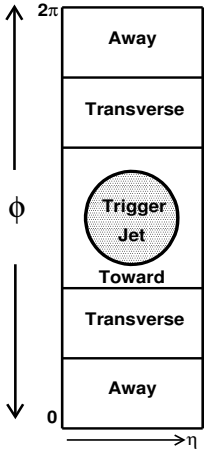
Advantages of EIC with larger acceptance compared with HERA:

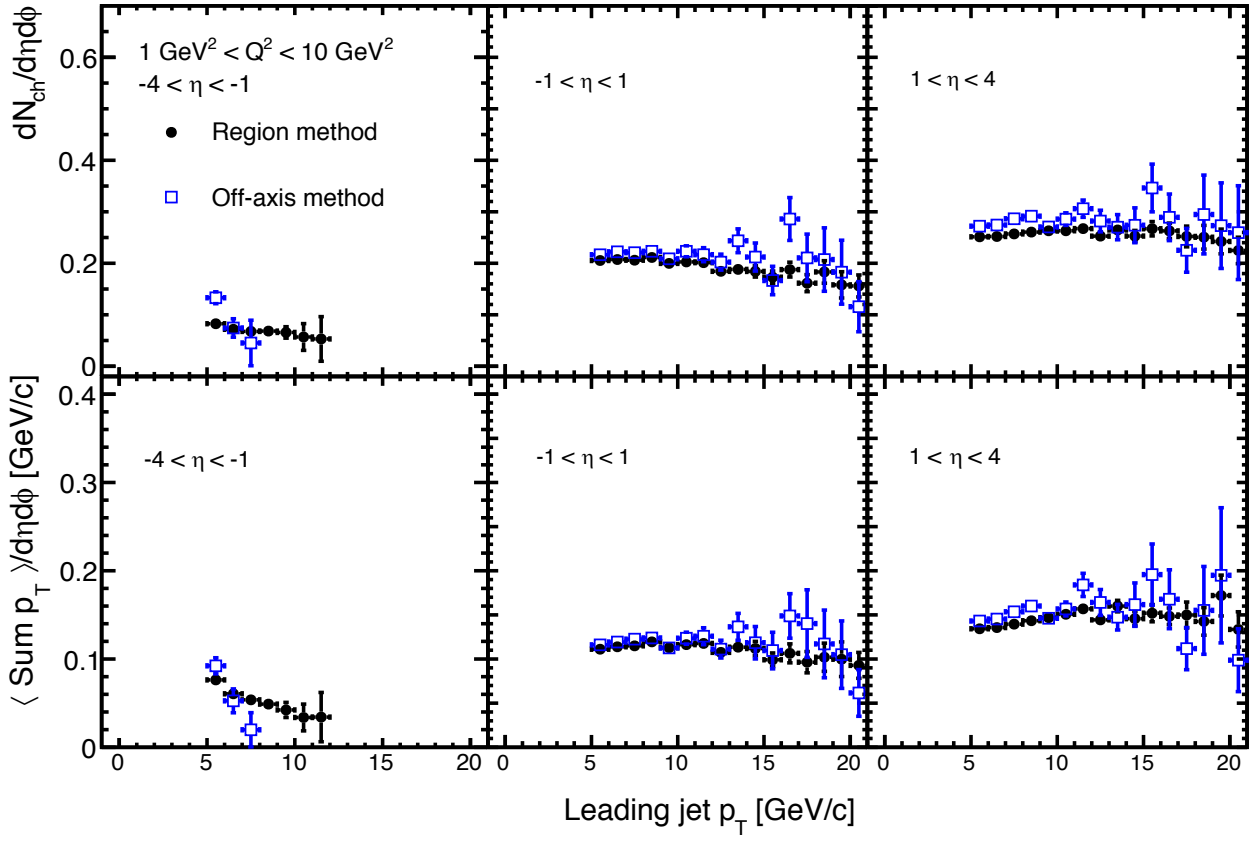
- Photon PDF is not constraint well especially in small x_γ region, more forward rapidity detection is required to access small x region.
- At HERA: $-1.125 < \eta^{cal} < 1.875$ from ZEUS [DESY-95-033]. Even through, the energy is higher at HERA, the phase space is larger with higher energy, however EIC can probe extended region by detecting more forward particles and high luminosity.
- Similar with Proton structure measurement.

Forward UE

$$x_\gamma^{rec} = \frac{1}{2E_e y}(p_{T1}e^{-\eta_1} + p_{T2}e^{-\eta_2})$$



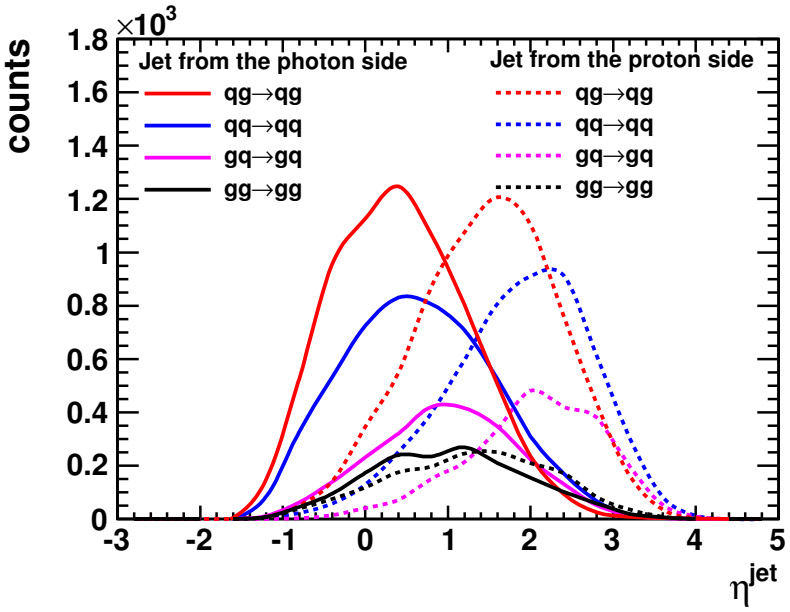


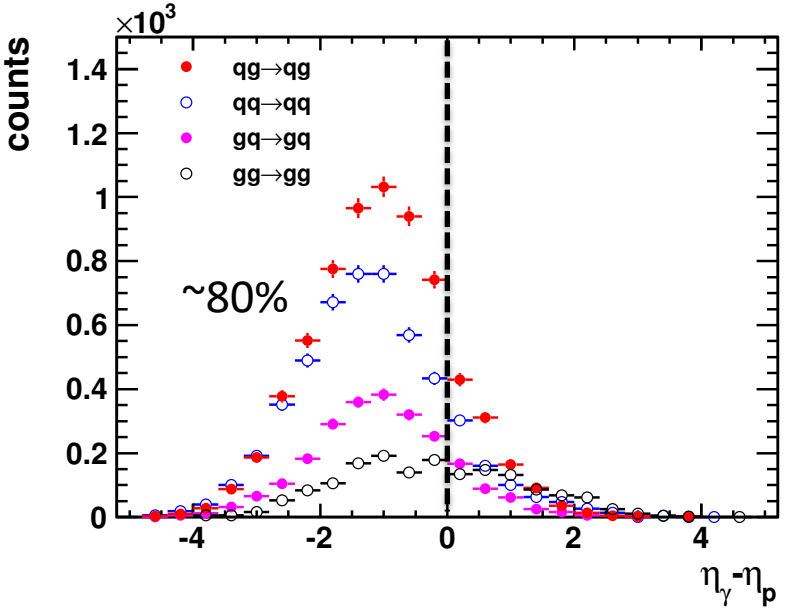


We see at high rapidity, underlying events effect can not be ignored. That will also require precious PID in forward direction to estimate the influence of underlying events.

Select jet from the photon side

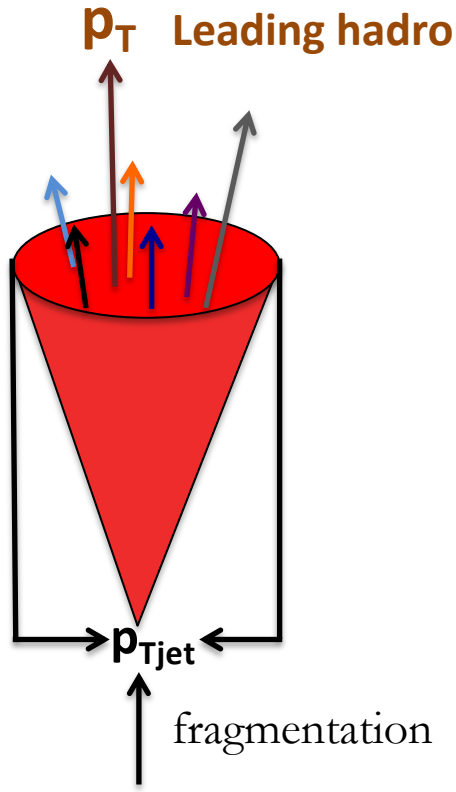
hadrons $\eta_{LAB} > 0$ → ← electrons $\eta_{LAB} < 0$





The photon side jet rapidity is more backward influenced by the electron beam direction. In the experiment, we can identify a jet with more negative rapidity to be the photon side jet, with the requirement of high precious of jet reconstruction.

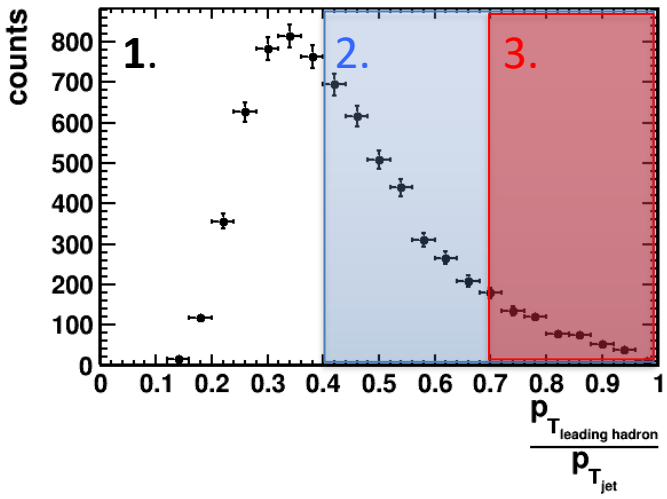
Flavor tagging



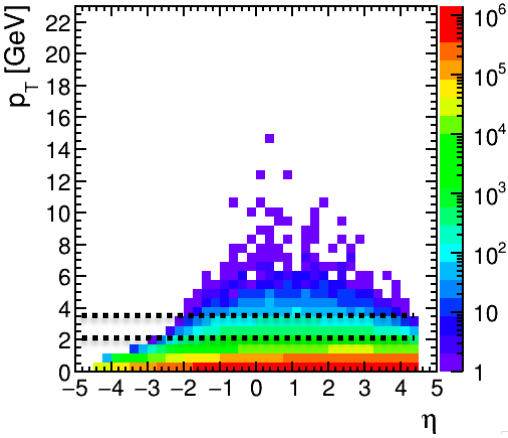
parton: g/q

Leading charged hadron inside (Kaon, pion, proton)

Photon side jet: highest p_T hadron

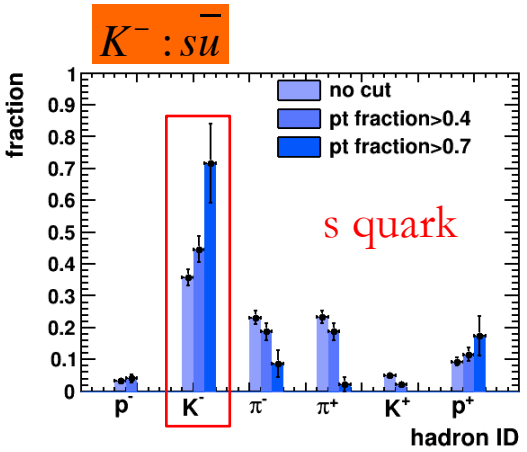


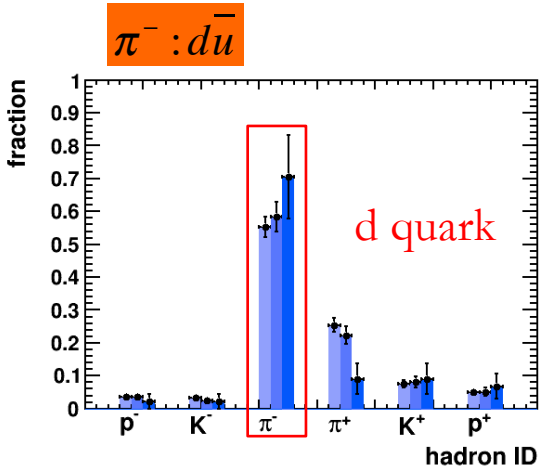
Final charged hadrons

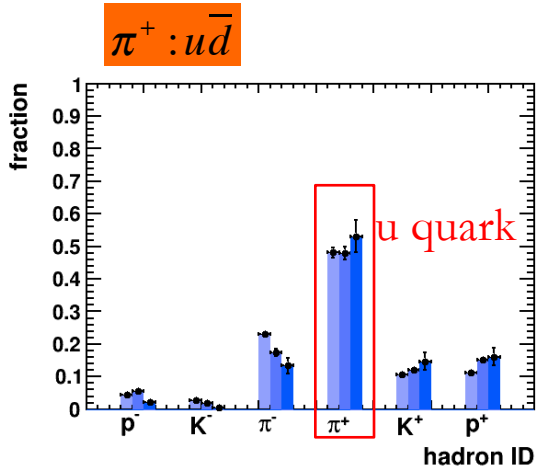


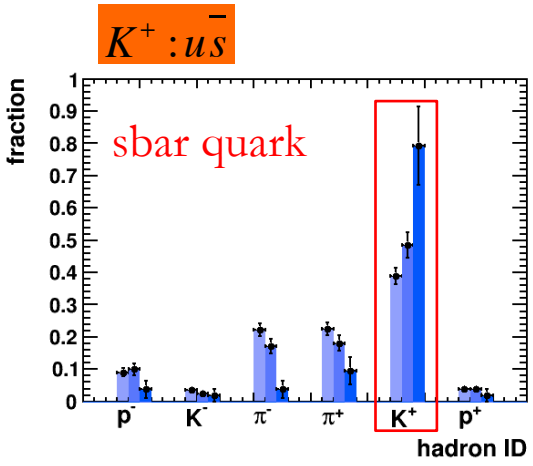
1. p_T fraction: no cut
2. p_T fraction: >0.4, ~p_T of leading hadron>2-2.4 GeV, -3<eta<4
3. p_T fraction: >0.7, ~p_T of leading hadron>3.5-4 GeV, -2<eta<3.5

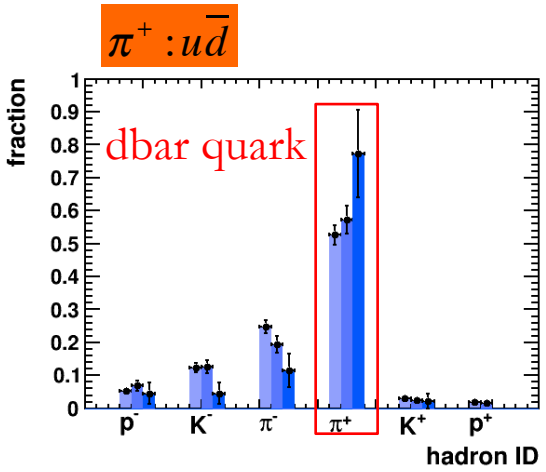
Flavor tagging (1)

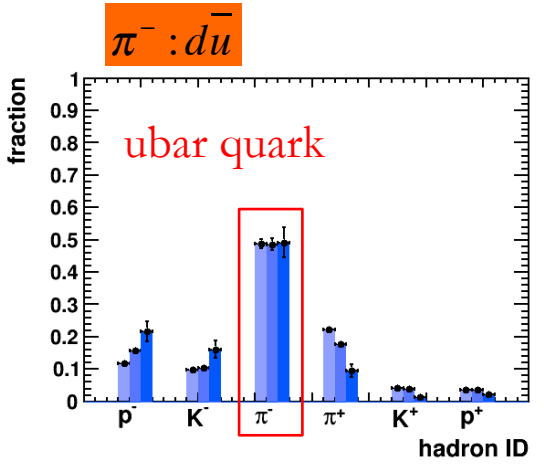






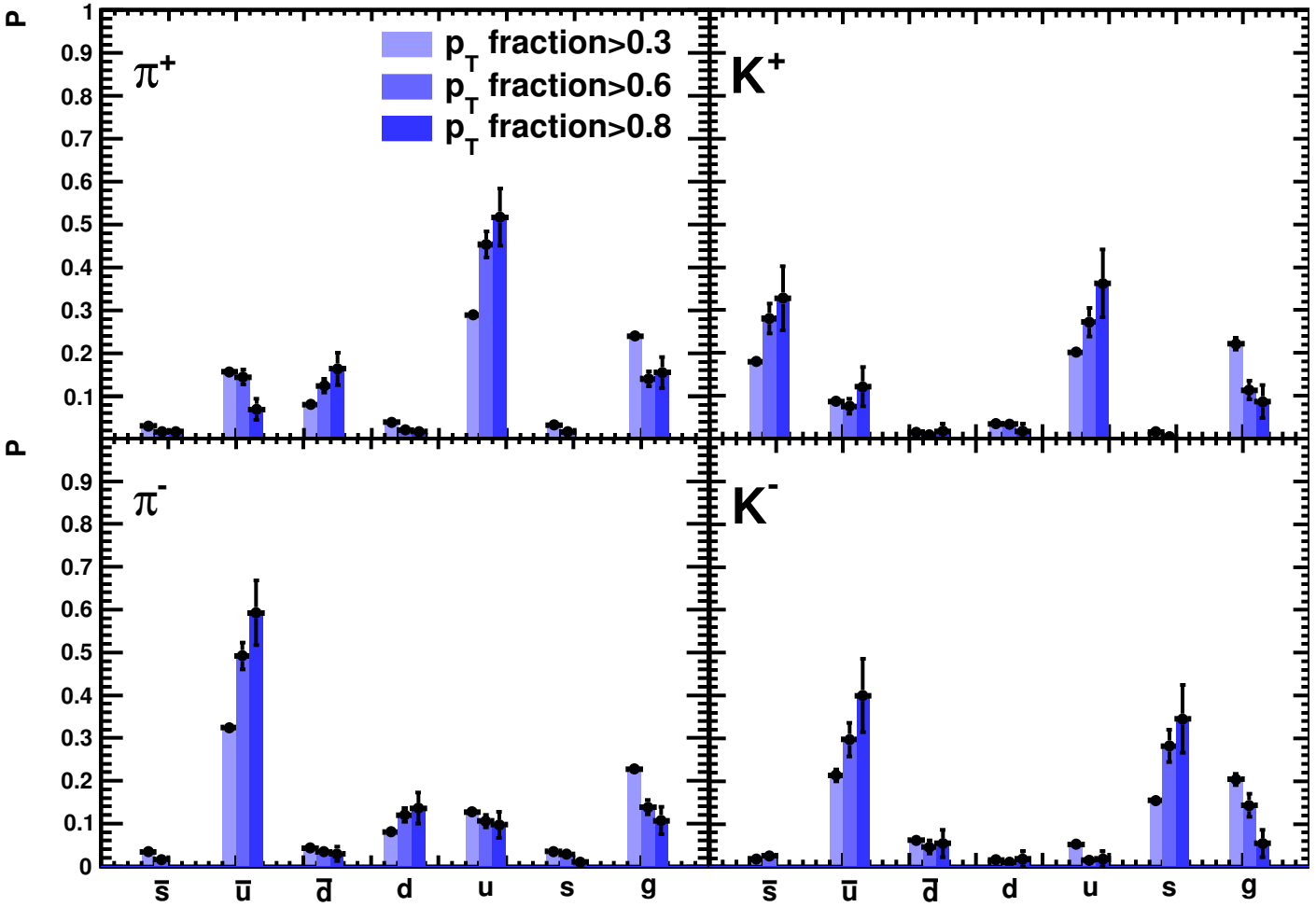






Flavor tagging (2)

The correlation between the beamparton flavor and the type of the leading hadron inside photon side jet.



Precious PID is needed. Measuring high p_T of leading particle is also required.

Summary

- Di-jet produced in resolved and direct process can be well separated at EIC by reconstructing x_γ, we measured di-jets with acceptance of -4.5 to 4.5, more forward rapidity helps to access smaller x_γ region in comparison with HERA results.
- The current simulation shows that x^{rec}_γ<0.6 is the optimized cut to select our target channel, that requires hadron acceptance in forward direction goes to 4.
- High resolution tracker is also required to reconstruct jets, the jets kinematics is directly related with accuracy of di-jet cross section: x_γ reconstructing, underlying events subtraction…
- We can provide possibility of identifying the flavor of the parton from the photon. PID with high precision is needed at EIC.
- Measuring leading hadron momentum fraction is required, especially for high p_T (3.5 GeV) charged hadrons, they enhance the sensitivity between hadron type and beamparton flavor.

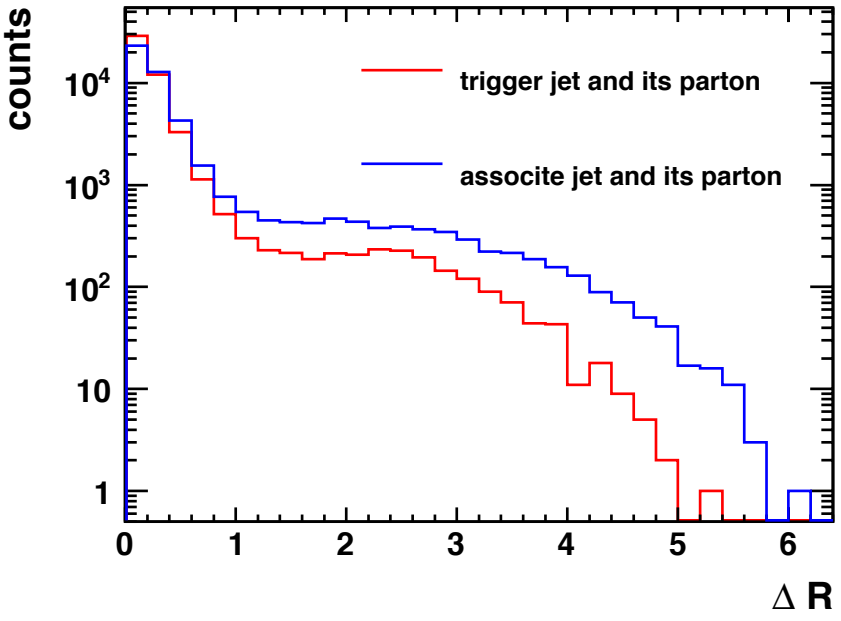
Back up

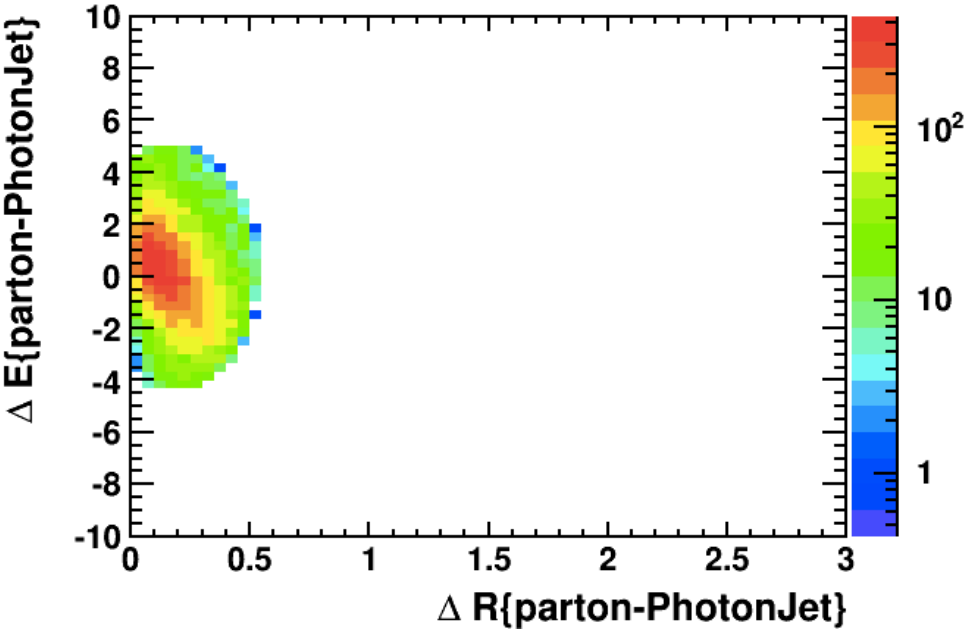
How to match di-jet with two final partons

Geometric match:

$$\Delta R\{parton - jet\} = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$

$$\Delta E\{parton - jet\}$$





beamparton

tgtparton

→ **Two final partons** → ✓ **match** → **Di-jet**