Study of Pion and Kaon Distribution Amplitudes at AMBER

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Possible Approaches for Probing Meson Distribution Amplitudes at AMBER

- Diffractive Dissociation of Pions and Kaons
  - * $\pi^- + A \to 2$ forward jets
  - * $K^- + A \to 2$ forward jets
- Angular Distribution of Inclusive Drell-Yan at large x_1
  - * $\lambda,\ \mu,\ \nu$ of $\pi^- + p \to \mu^+ + \mu^- + X$
  - * $\lambda,\ \mu,\ \nu$ of $K^- + p \to \mu^+ + \mu^- + X$
  - * $d\sigma / dx_1$ at large x_1 ?
- Exclusive Drell-Yan with Pions and Kaons
  - * $\pi^- + p \to \mu^+ + \mu^- + n$
  - * $K^- + p \to \mu^+ + \mu^- + \Lambda$

Diffractive Dissociation of Pions and Kaons

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Direct Measurement of the Pion Valence-Quark Momentum Distribution, the Pion Light-Cone Wave Function Squared

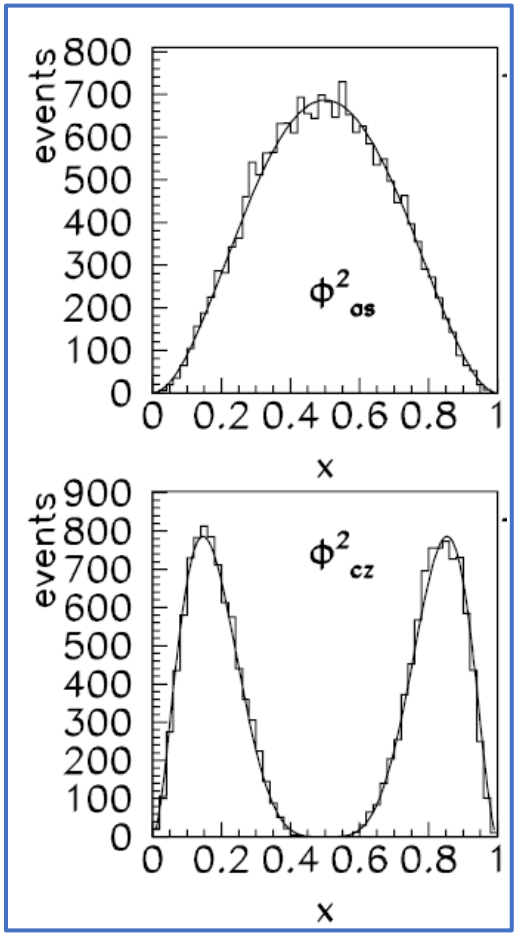
Fermilab E791 recorded 2×10^{10} events from interactions of a 500 GeV/c π^- beam with carbon and platinum targets

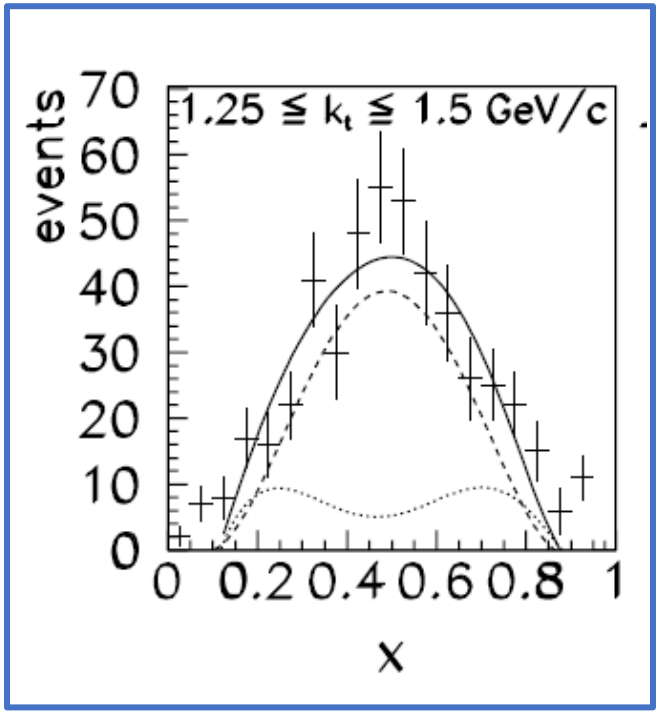
Each candidate event carries at least 90% of the beam momentum. The selected events were subjected to the JADE jet-fnding algorithm

The dijet nature of these events was verified from their relative azimuthal angle, which peaks at 180^0.

Diffractive Dissociation of Pions and Kaons

$$x_{\text{measured}} = \frac{p_{\text{jet}1}}{p_{\text{jet}1} + p_{\text{jet}2}} .$$





Diffractive Dissociation of Pions and Kaons

E791 Spectrometer

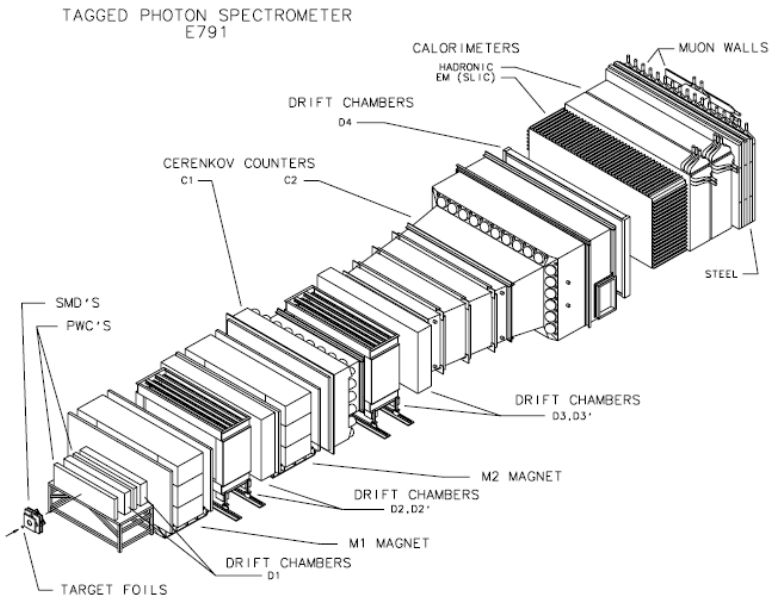


Fig. 2. The E791 spectrometer.

- E791 spectrometer is not too different from AMBER.
- Only 10% of the E791 data were used for the analysis (rate seems to be quite high)
- Perhaps one could check if dijets could be reconstructed from COMPASS data with pion beam?
- Dissociation of kaon would be new measurement at AMBER

Angular Distribution of Inclusive Drell-Yan at Large X_1

PHYSICAL REVIEW D **76,** 074032 (2007)

Polarized and unpolarized μ-pair meson-induced Drell-Yan production and the pion distribution amplitude

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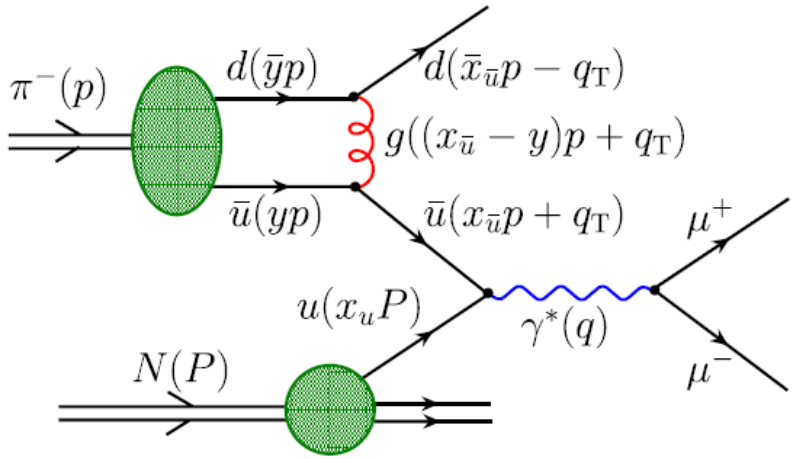


Angular Distribution of Inclusive Drell-Yan at Large X_1

$$\frac{d^5\sigma(\pi^- + N \to \mu^+ + \mu^- + X)}{dQ^2 dQ_T^2 dx_L d\cos\theta d\phi}$$

$$\propto N(\tilde{x},\rho)\left(1 + \lambda\cos^2\theta + \mu\sin 2\theta\cos\phi + \frac{\nu}{2}\sin^2\theta\cos 2\phi\right), \quad (2.18)$$

where [5]

$$\lambda(\tilde{x},\rho) = \frac{2}{N}\{(1-\tilde{x})^2[(>\mathrm{Im}I(\tilde{x}))^2 + (F + \mathrm{Re}I(\tilde{x}))^2] - (4-\rho^2)\rho^2\tilde{x}^2F^2\}, \quad (2.19)$$

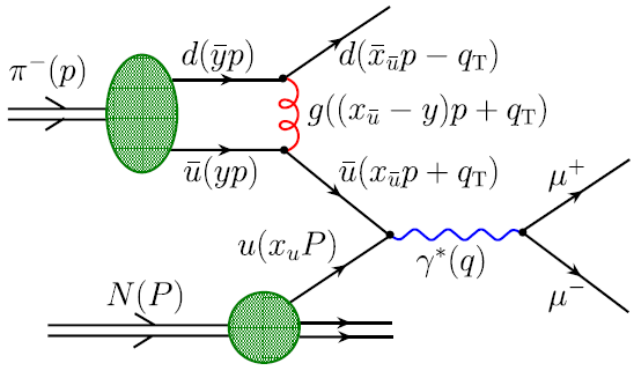
$$\mu(\tilde{x},\rho) = -\frac{4}{N}\rho\tilde{x}F\{(1-\tilde{x})[F + \mathrm{Re}I(\tilde{x})] + \rho^2\tilde{x}F\}, \quad (2.20)$$

$$\nu(\tilde{x},\rho) = -\frac{8}{N}\rho^2\tilde{x}(1-\tilde{x})F[F + \mathrm{Re}I(\tilde{x})], \quad (2.21)$$

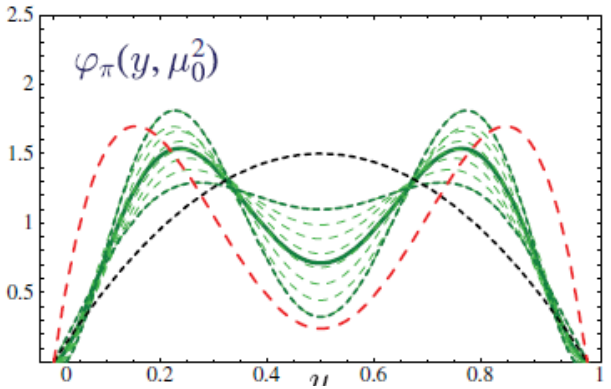
$$N(\tilde{x},\rho) = 2\{(1-\tilde{x})^2[(\mathrm{Im}I(\tilde{x}))^2 + (F + \mathrm{Re}I(\tilde{x}))^2] + (4+\rho^2)\rho^2\tilde{x}^2F^2\} \quad (2.22)$$

$$F = \int_0^1 dy \frac{\varphi(y,\tilde{Q}^2)}{y}, \quad (2.24)$$

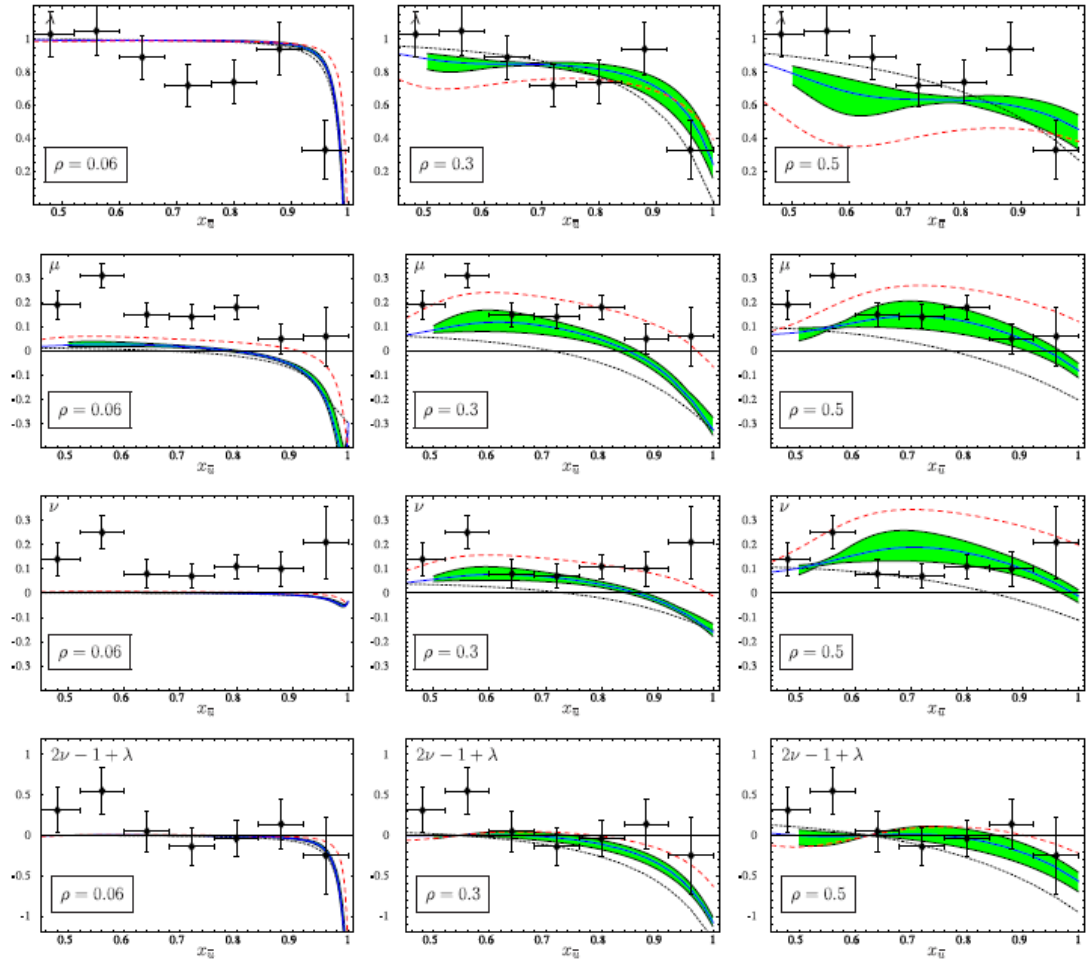
$$I(\tilde{x}) = \int_0^1 dy \frac{\varphi(y,\tilde{Q}^2)}{y(y+\tilde{x}-1+i\varepsilon)} \quad (2.25)$$



- The lepton angular distribution λ, μ, ν can be expressed as functions of pion's distribution amplitude $\varphi(y, Q^2)$, rather than pion's PDF.



Angular Distribution of Inclusive Drell-Yan at Large X_1



Different curves correpsond to different pion distribution amplitudes

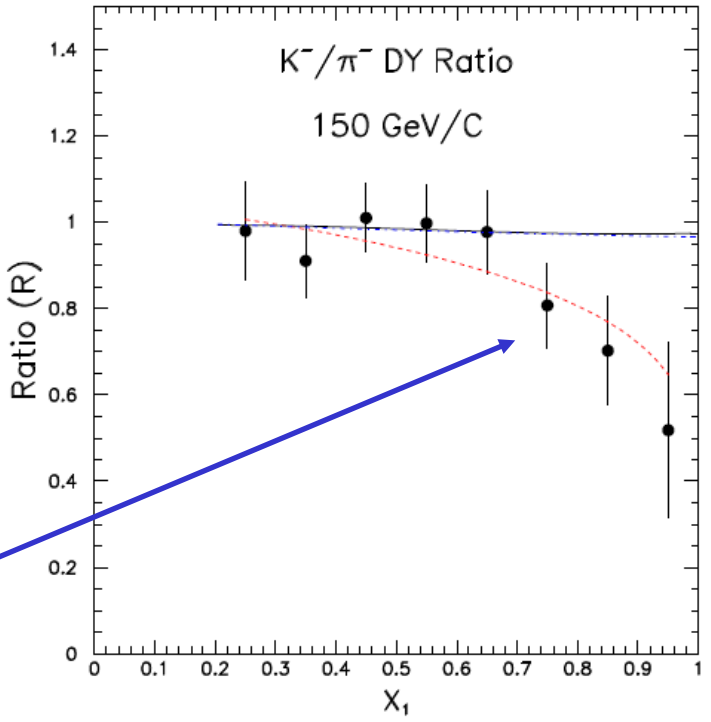
Angular Distribution of Inclusive Drell-Yan at Large X_1

- One can extend this approach to predict the λ, μ, ν coefficients for kaon-induced Drell-Yan
- Can one calculate the absolute Drell-Yan cross sections, using this approach?
- Can one calculate the K^-/π^- Drell-Yan ratios using the kaon and pion dsitribution amplirudes?

Angular Distribution of Inclusive Drell-Yan at Large X_1

$$\frac{d^5\sigma(\pi^- + N \to \mu^+ + \mu^- + X)}{dQ^2 dQ_T^2 dx_L d\cos\theta d\phi}$$
$$\propto N(\tilde{x}, \rho)\left(1 + \lambda\cos^2\theta + \mu \sin 2\theta \cos\phi + \frac{\nu}{2}\sin^2\theta \cos 2\phi\right),$$

$$N(\tilde{x}, \rho) = 2\{(1 - \tilde{x})^2[(\mathrm{Im}I(\tilde{x}))^2 + (F + \mathrm{Re}I(\tilde{x}))^2] + (4 + \rho^2)\rho^2\tilde{x}^2F^2\} \quad (2.22)$$



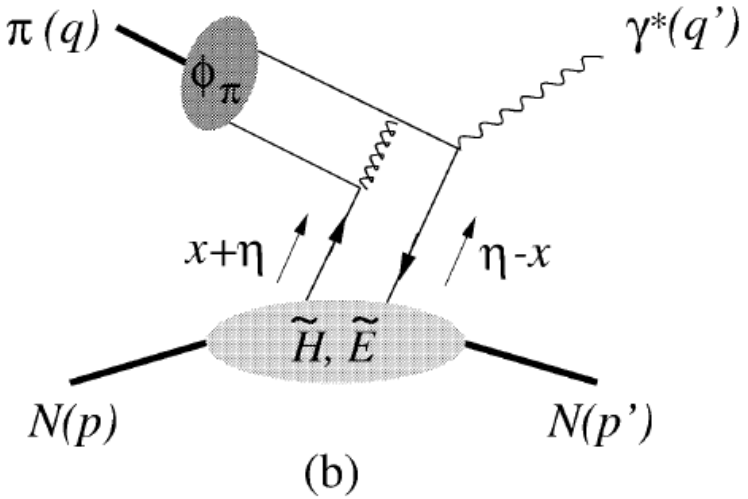
The curves are obtained with the pion and kaon PDFs. Can one use the DA of pion and kaon to calculate these ratios and compare with the data (at the $x_1 > 0.5$ region)?

Exclusive dilepton production in πN interaction

$$\pi^- p \to \gamma^* n \to \mu^+ \mu^- n$$

E. Berger, M. Diehl, B. Pire, Phys. Lett. B523 (2001) 265

Probe pion distribution amplitude (ϕ_π) and nucleon GPD ($\tilde{H}, \tilde{E}$)



(b)

Bjorken variable $\tau = \frac{Q'^2}{s - M^2}$

skewness $\eta = \frac{(p-p')^+}{(p+p')^+} = \frac{\tau}{2-\tau}$

$$\frac{d\sigma}{dQ'^2\, dt\, d(\cos\theta)\, d\varphi} = \frac{\alpha_{em}}{256\,\pi^3}\frac{\tau^2}{Q'^6}\sum_{\lambda',\lambda}|M^{0\lambda',\lambda}|^2 \sin^2\theta$$

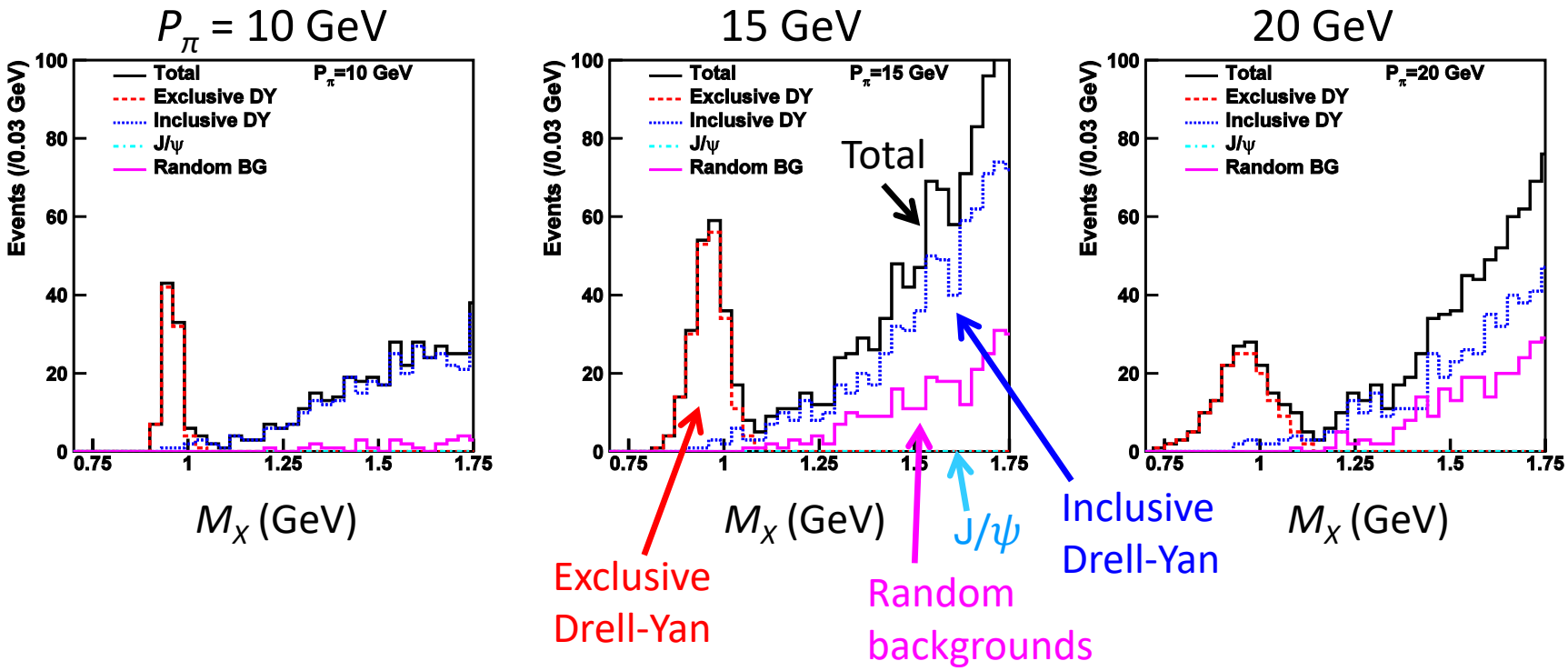
$$M^{0\lambda',\lambda}(\pi^- p \to \gamma^* n) = -ie\frac{4\pi}{3}\frac{f_\pi}{Q'}\frac{1}{(p+p')^+}\bar{u}(p',\lambda')\left[\gamma^+\gamma_5\,\tilde{\mathcal{H}}^{du}(\eta,t) + \gamma_5\frac{(p'-p)^+}{2M}\,\tilde{\mathcal{E}}^{du}(\eta,t)\right]u(p,\lambda)$$

$$\tilde{\mathcal{H}}^{du}(\eta,t) = \frac{8\alpha_S}{3}\int_{-1}^{1} dz\,\frac{\phi_\pi(z)}{1-z^2}\int_{-1}^{1} dx\left[\frac{e_d}{-\eta-x-i\epsilon} - \frac{e_u}{-\eta+x-i\epsilon}\right]\left[\tilde{H}^d(x,\eta,t) - \tilde{H}^u(x,\eta,t)\right]$$

Some simulation for exclusive Drell-Yan with pion beam is available

Takahiro Sawada, Wen-Chen Chang, Shunzo Kumano, Jen-Chieh Peng, Shinya Sawada, Kazuhiro Tanaka, Phys. Rev. D93 (2016) 114034

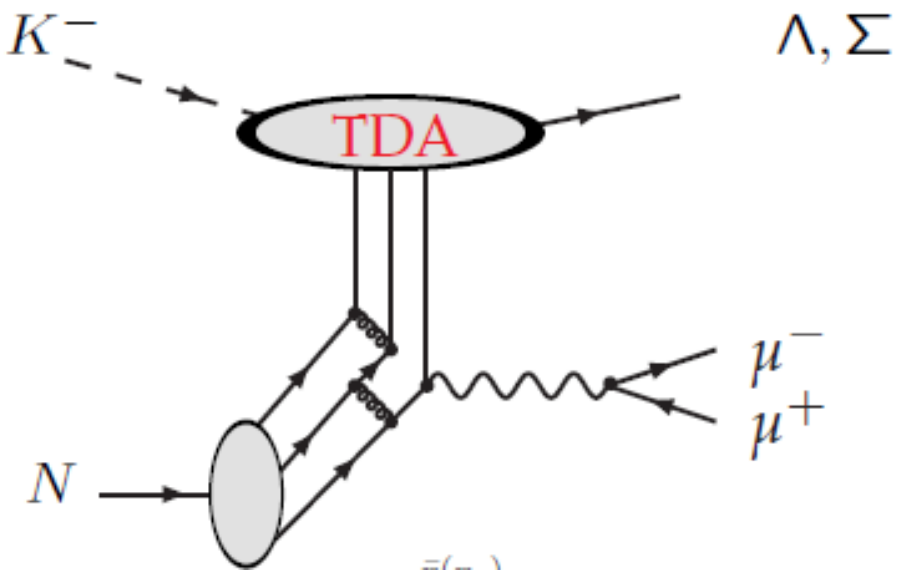
π^- Beam Momentum



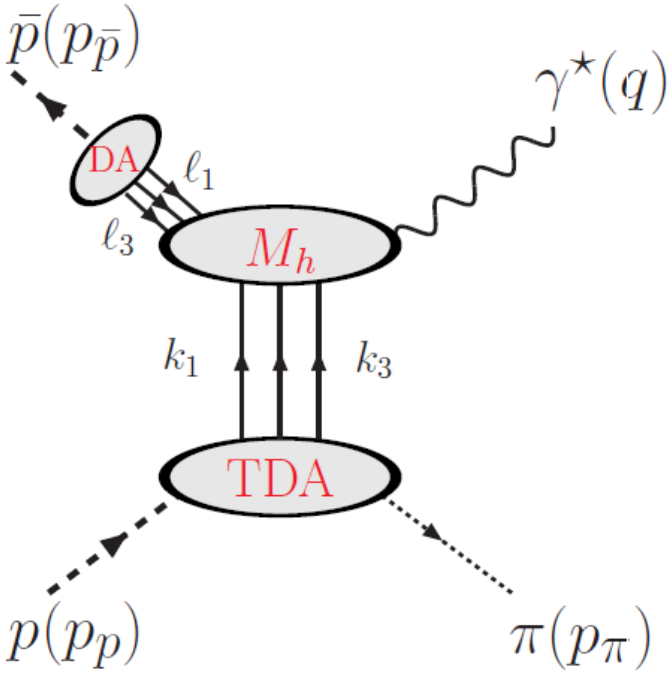
* Cross section increases as beam energy decreases. RF separated kaon or antiproton beam would be more favorable
* Simulations for AMBER with pion and kaon beams are needed

Other exclusive dilepton reactions sensitive to kaon and antiproton DA and meson-baryon TDA

$K^- N \to \Lambda \gamma^*$



$\bar{p}N \to \gamma^* \pi$



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More detailed studies are needed