Diffractive scattering at AMBER to access meson DA? Some input for discussion

Oleg Denisov CERN, 2021/04/27

Outline

1. Intro
2. PDA & PDF
3. Experimental data (E791)
4. AMBER?

PDAs & PDFs

- Relationship between leading-twist PDAs and valence-quark PDFs, expressed via a meson's light-front wave function (LFWF):

$$\varphi(x) \sim \int d^2k_\perp \psi(x, k_\perp^2)\,,$$

$$q(x) \sim \int d^2k_\perp |\psi(x, k_\perp^2)|^2$$

- Given that factorization of LFWF is a good approximation for integrated quantities, then at the hadronic scale, ζ_H:

$$q_{\pi,K}(x;\zeta_H) \propto \varphi^q_{\pi,K}(x;\zeta_H)^2$$

Proportionality constant is fixed by baryon number conservation

- Owing to parton splitting effects, this identity is not valid on $\zeta > \zeta_H$.

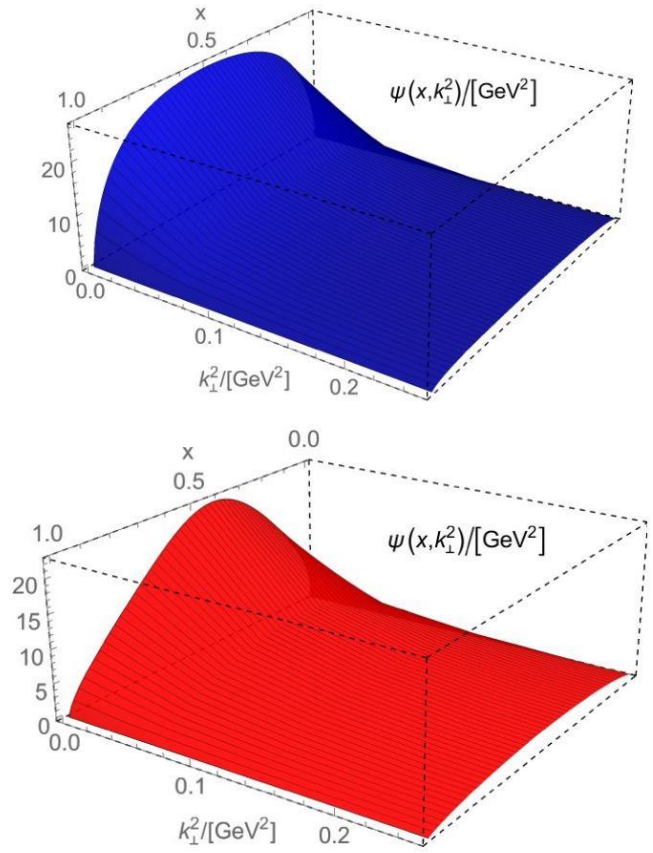
(Think about DGLAP and ERBL regions for a GPD.)

- Nevertheless, evolution equations are known; so the connection is not lost, it just metamorphoses.

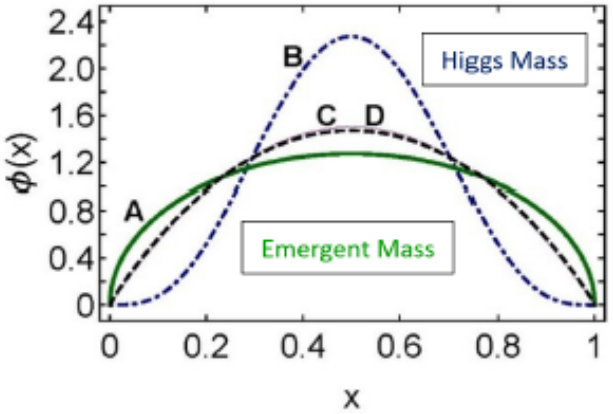
Light Front Wave Function

- In many respects, a hadron's LFWF is the key.
- LFWF correlates all observables
- EHM is expressed in every hadron LFWF
- The "trick" is to find a way to compute the LFWF

- Experiments sensitive to differences in LFWFs are sensitive to EHM
- Excellent examples are π & K PDAs and PDFs
  - Two sides of the same coin
  - Accessible via different processes
  - Independent measurements of the same thing
  - Great check on consistency

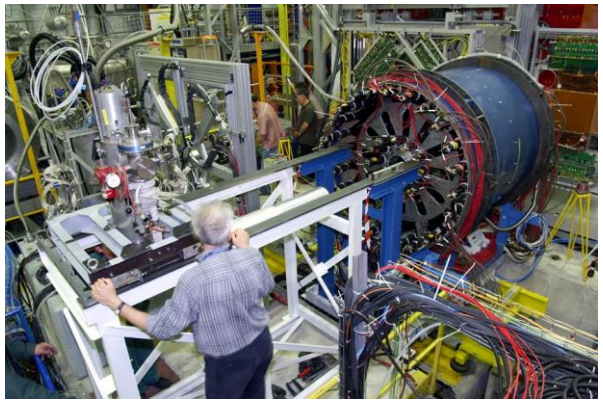


AMBER - New EHM-related ideas: PDA



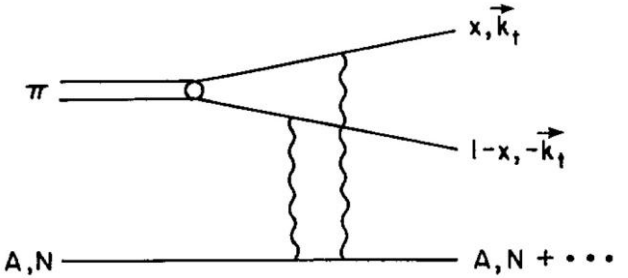
Where *x* is a fraction of hadron's longitudinal momentum carried by the quark in the imf.

Craig Roberts: Pion and kaon distribution amplitudes (DAs) nearest thing in quantum field theory to a Schredinger wave function; consequently, fundamental to understanding π and K structure. Modern theory predicts that EHM is expressed in the x-dependence of pion and kaon DAs.



Fermilab E791 the only experimental data In di-jets production by 500 GeV π^- beam

A solid (green) emergent mass generation is dominant (pion);
B dot-dashed (blue) curve: Higgs mechanism is the primary source of mass generation (C-meson);
C solid (thin, purple) curve (asymptotic prole, 6x(1 - x);



L.L. Frankfurt, G.A. Miller, and M. Strikman, Phys. Lett. B304, 1 (1993).

AMBER robe: diffractive pion dissociation on a heavy target with very small *t'*, this is a coherent process where two quarks break apart producing hadron in the final state

E791

The only experiment with two jets in the final state which has been done so far is Fermilab experiment E791 (E791 Collaboration, E.M. Aitala et al., EPJ direct C4, 1 (1999)), recorded 2×10^{10} events from interactions of a 500 GeV/c π^- beam with carbon (C) and platinum (Pt) targets. The trigger included a loose requirement on transverse energy deposited in the calorimeters.

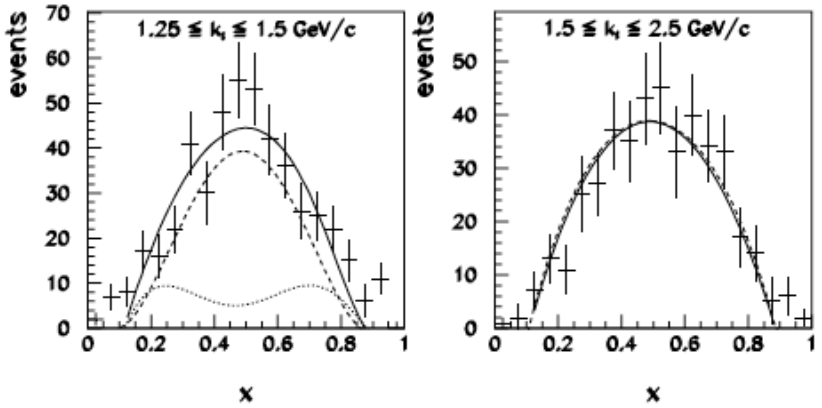


FIG. 3. The x distribution of diffractive di-jets from the platinum target for $1.25 \leq k_t \leq 1.5$ GeV/c (left) and for $1.5 \leq k_t \leq 2.5$ GeV/c (right). The solid line is a fit to a combination of the asymptotic and CZ wave functions. The dashed line shows the contribution from the asymptotic function and the dotted line that of the CZ function.

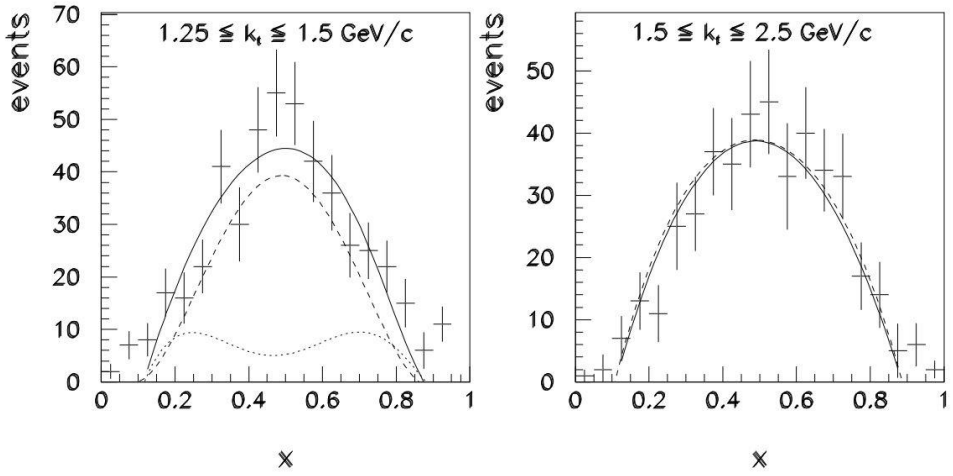
FERMILAB-Pub-00/221-E E791 October 2000

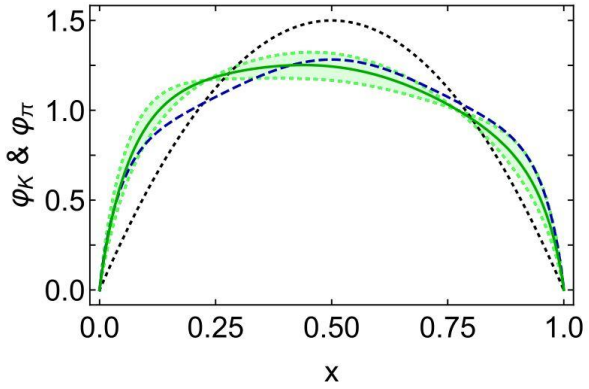
Two-jet events were identified analysing by a number of selection critereas, for example all charged particles carried out 90% of beam particle momentum, cut on k_T, angular distributions analysis etc.

Controversy over PDAs

Left: Nonpertubative (broadening) important
Right: Asymptotic profile sufficient

- E791 Collaboration, E. Aitala *et al.*, Phys. Rev. Lett. 86, 4768 (2001).
  - Claim: $\varphi_\pi(x)$ is well represented by the asymptotic profile for $\zeta^2 > 10$ GeV^2
- Modern continuum predictions and analyses of lQCD
  - PDAs are broadened at ζ^2=4 GeV^2
  - Evolution is logarithmic ⇒ if true at ζ^2=4 GeV^2, then true at ζ^2=10 GeV^2
- Simple theory shows that E791 conclusion cannot be correct
  - The E791 images cannot represent the same pion property
  - Not credible to assert that $\varphi_\pi(x)$ is well represented by the asymptotic distribution for $\zeta^2 > 10$ GeV^2

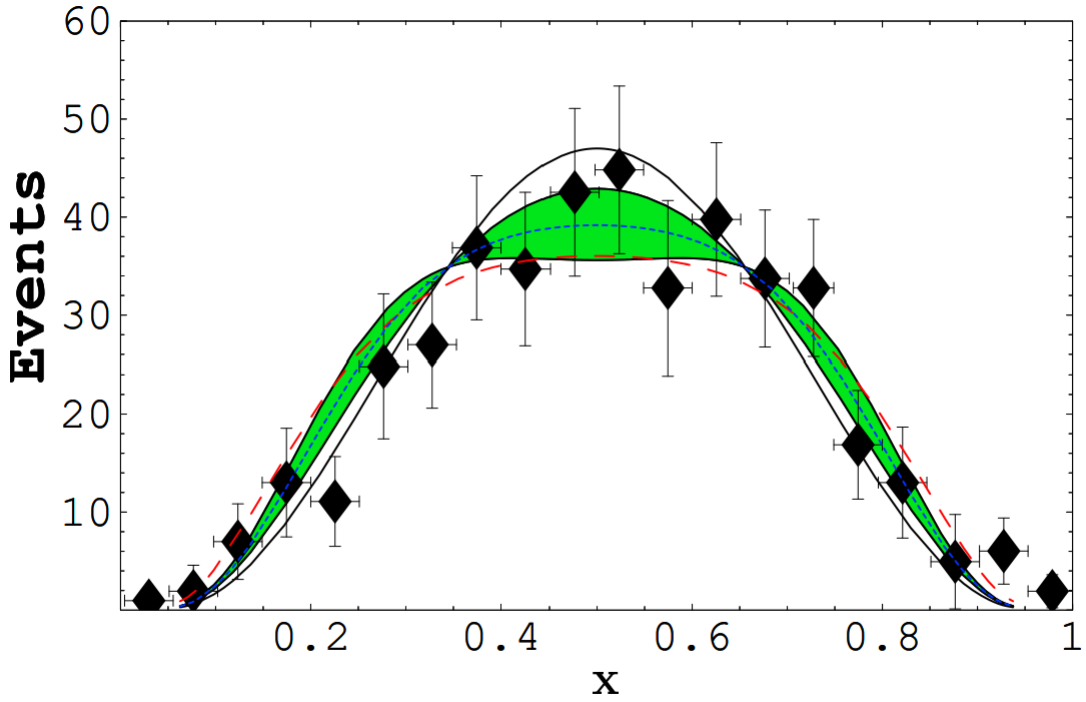




- Hard exclusive processes only sensitive to low-order PDA moments.
- Diffractive processes much better because sensitive to x-dependence (check this claim)

Diffractive Dissociation of Meson into di-jets

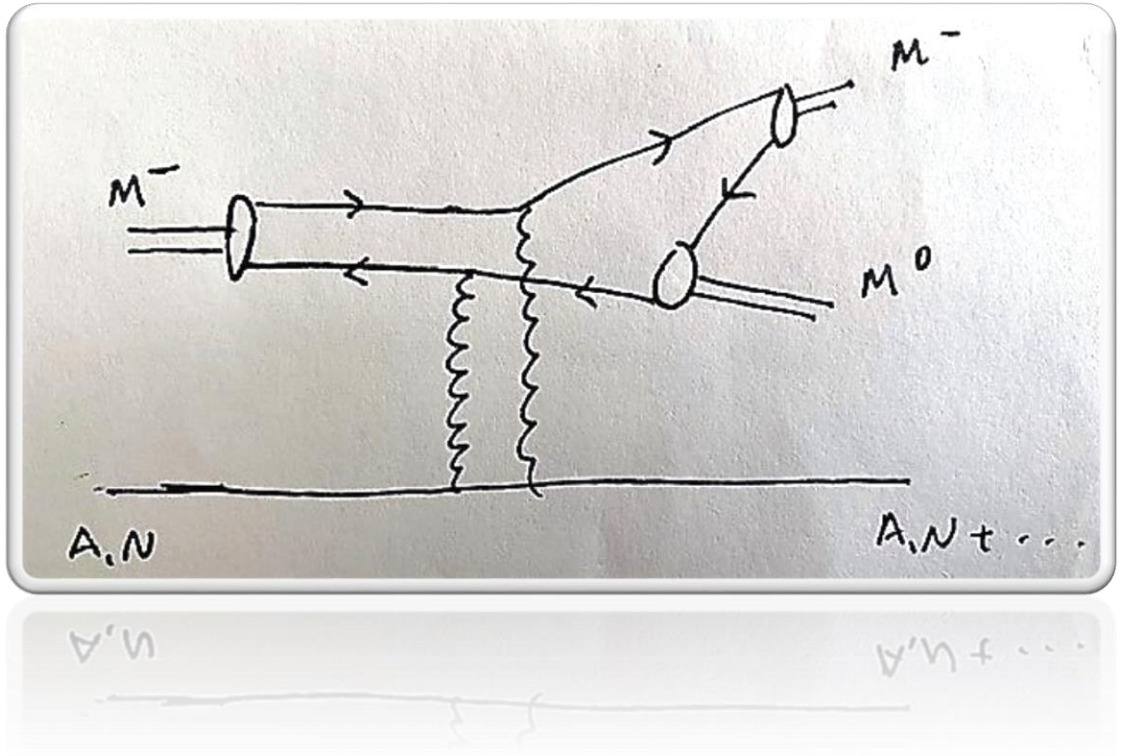
- Another perspective: *CLEO and E791 data: A Smoking gun for the pion distribution amplitude?* A. Bakulev, S. Mikhailov, N. Stefanis, Phys. Lett. B **578** (2004) 91-98
- One might be sceptical of the simple arguments used to relate diffractive dissociation into di-jets – at least, one can look deeper
- Notwithstanding that, the E791 data and analysis can and should be improved



E791 data are consistent with a large variety of DAs, including the asymptotic DA

Diffractive Dissociation of Meson into di-meson final states

- Can one obtain information on meson DAs via di-meson final states
- 1st guess answer = No
- If the diagram at right is the sort of thing one would look for, then following problems are encountered:
  - Two additional LFWFs ⇒ additional $\frac{1}{k_t^8}$ suppression introduced to cross-section
  - Integration over the loop means pointwise information on x-dependence is lost



Di-jets in AMBER

Thus the main question remains :

Can we access di-jets regime in AMBER?

What is a signature of di-jet event with 190 GeV hadron beam?

Definition of the “jet” in AMBER kinematics

BACK UP