SPACE-TIME PROPERTIES OF HADRONIZATION:

WHAT PHYSICS CAN BE GAINED FROM A CLAS12 RICH?

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CONTEXT

EXPERIMENTS

- New experiments to study hadronization and quark energy loss (now, +/- 10 years):
  - HERMES, CLAS, CLAS12
- Close connections to topics from other communities:
  - Fermlab (Drell-Yan), RHIC/LHC (jet quenching)
- Early stage of understanding:
  - comprehensive experimental survey is critical

HERMES, CLAS, CLAS12

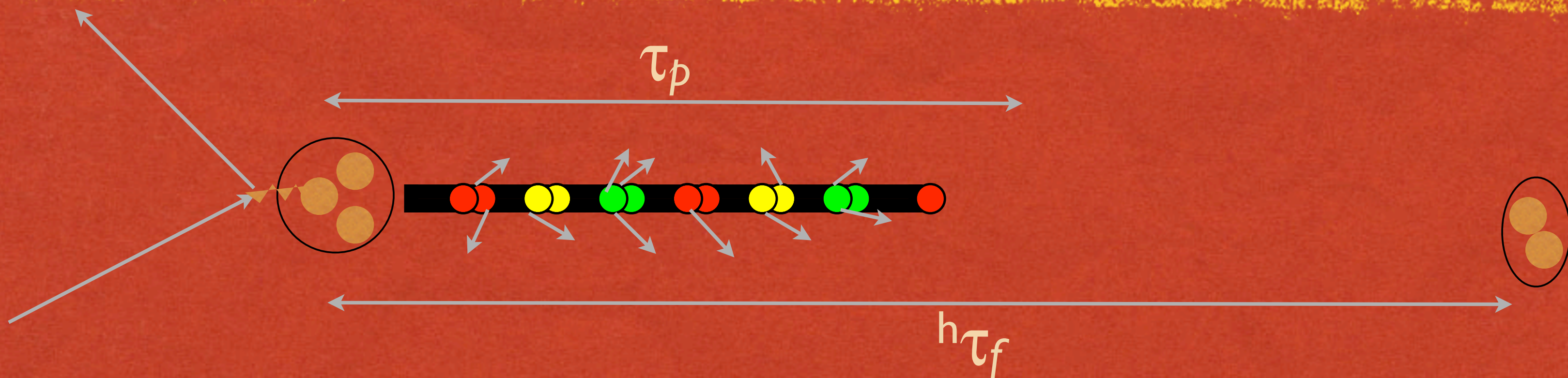
- HERMES took data 1997-2005, 7 nuclear targets, most of data with RICH.
  - 231 pb^{-1} on He+Ne+Kr+Xe at 27 GeV
- CLAS took data 2003, 4 primary nuclear targets
  - ~25,000 pb^{-1} on C+Fe+Pb, at 5.0 GeV
- CLAS12: approved experiment, ~10x CLAS luminosity

PHYSICS FOCUS
EXPERIMENTAL METHOD

REMINDER: PHYSICS FOCUS

- Determine hadronization mechanisms and time constants:
  - Production time, τ_p
  - Formation time, ${}^{h}\tau_f$

PHYSICAL PICTURE



- production time τ_p is time required to form color singlet pre-hadron; 'lifetime of deconfined quark'
- formation time $^h\tau_f$ is time required to form full-sized hadron

INTERACTIONS IN NUCLEUS

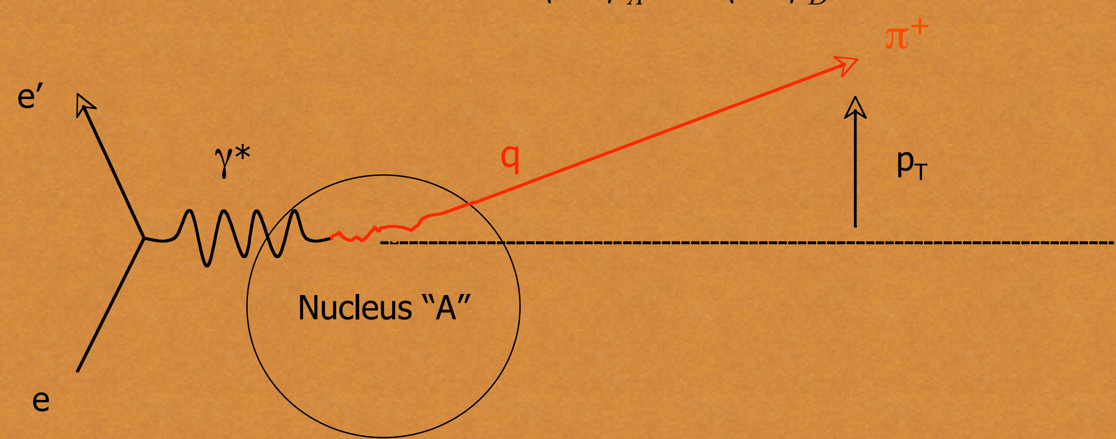
- ‘Gentle’ interactions: medium-stimulated gluon emission; results in:
  - small energy loss of propagating quark
  - slightly *broadened* transverse momentum distribution - small but measurable
- ‘Violent’ inelastic reaction - prehadron or hadron interacts with medium:
  - results in *attenuation* of hadron flux

REMINDER: EXPERIMENTAL TECHNIQUE

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

Hadronic multiplicity ratio

$$p_T \text{ } \mathit{broadening}: \quad \Delta p_T^2 \equiv \left\langle p_T^2 \right\rangle_A^{DIS} - \left\langle p_T^2 \right\rangle_D^{DIS}$$

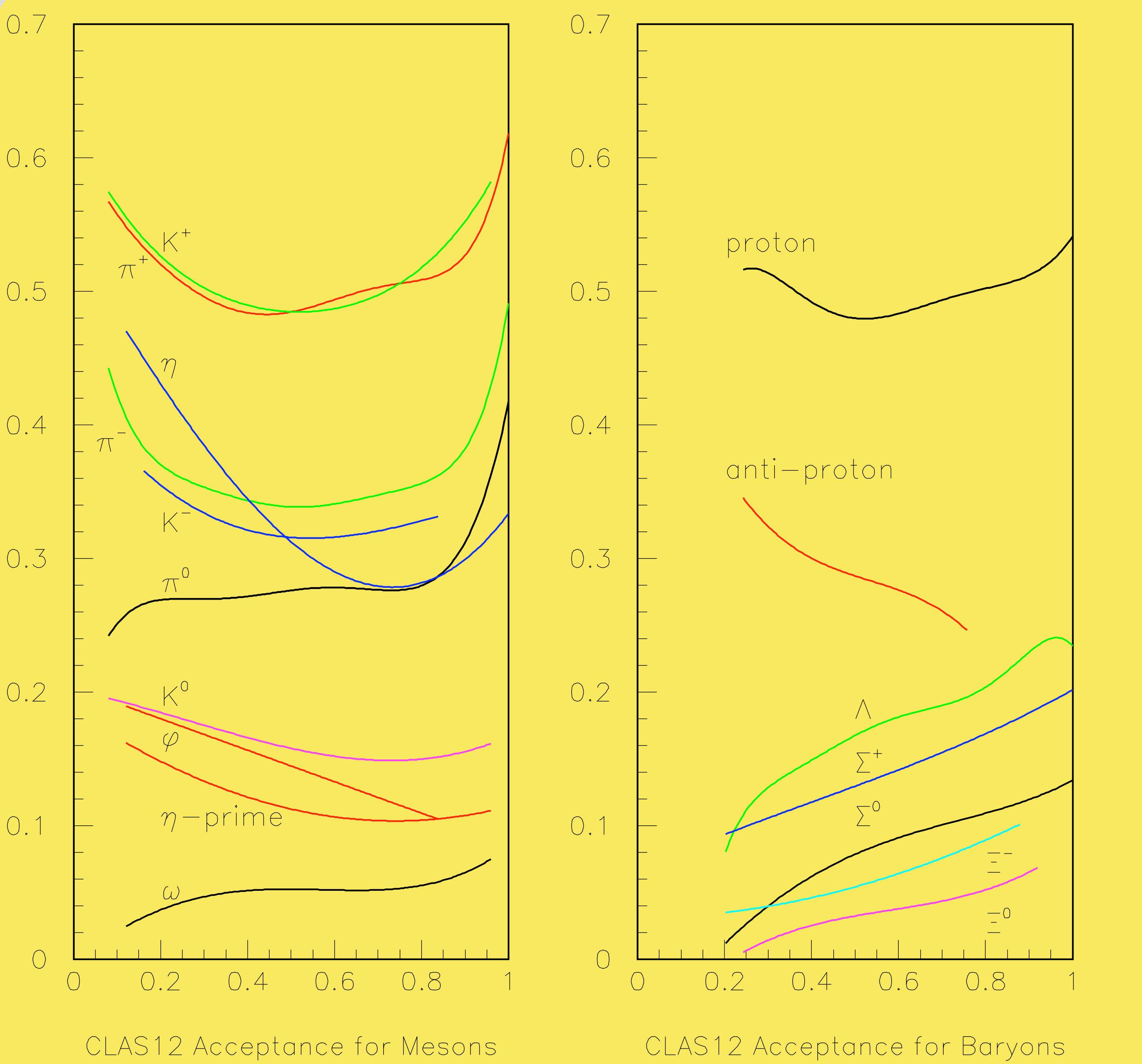


CLAS12 EXPERIMENT

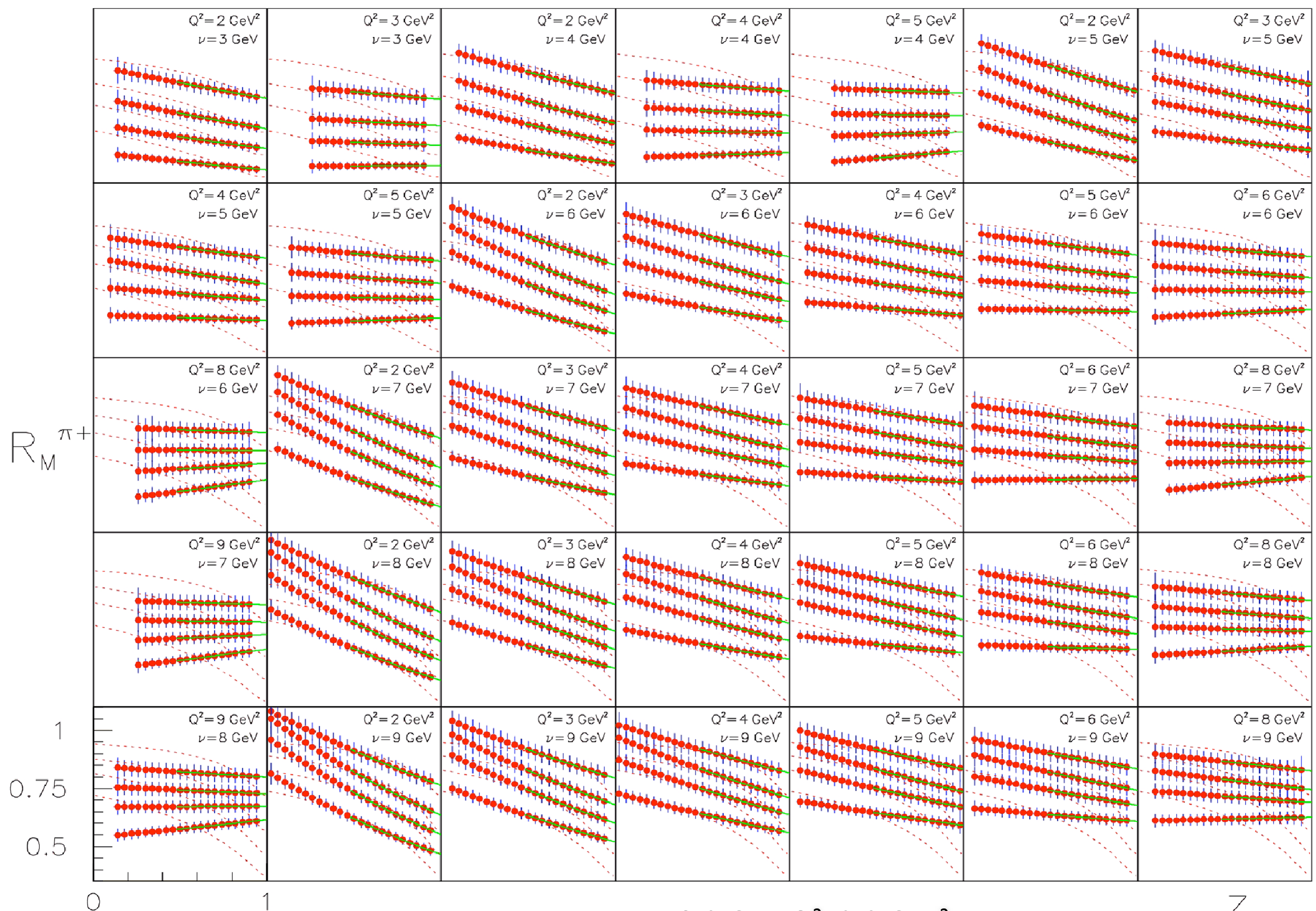
CLAS12 Hadrons

hadron	$c\tau$	mass (GeV)	flavor content	detection channel	Production rate per 1k DIS events
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	$\gamma\gamma$	1100
π^+	7.8 m	0.14	$u\bar{d}$	direct	1000
π^-	7.8 m	0.14	$d\bar{u}$	direct	1000
η	0.17 nm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	$\gamma\gamma$	120
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\pi^0$	170
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\eta$	27
ϕ	44 fm	1.0	$u\bar{u}d\bar{d}s\bar{s}$	K^+K^-	0.8
$f1$	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$	$\pi\pi\pi\pi$	-
K^+	3.7 m	0.49	$u\bar{s}$	direct	75
K^-	3.7 m	0.49	$\bar{u}s$	direct	25
K^0	27 mm	0.50	$d\bar{s}$	$\pi^+\pi^-$	42
p	stable	0.94	ud	direct	530
$\bar{p}$	stable	0.94	$\bar{u}\bar{d}$	direct	3
Λ	79 mm	1.1	uds	$p\pi^-$	72
$\Lambda(1520)$	13 fm	1.5	uds	$p\pi^-$	-
Σ^+	24 mm	1.2	us	$p\pi^0$	6
Σ^0	22 pm	1.2	uds	$\Lambda\gamma$	11
Ξ^0	87 mm	1.3	us	$\Lambda\pi^0$	0.6
Ξ^-	49 mm	1.3	ds	$\Lambda\pi^-$	0.9

CLAS12 Geometric Acceptances for Mesons and Baryons



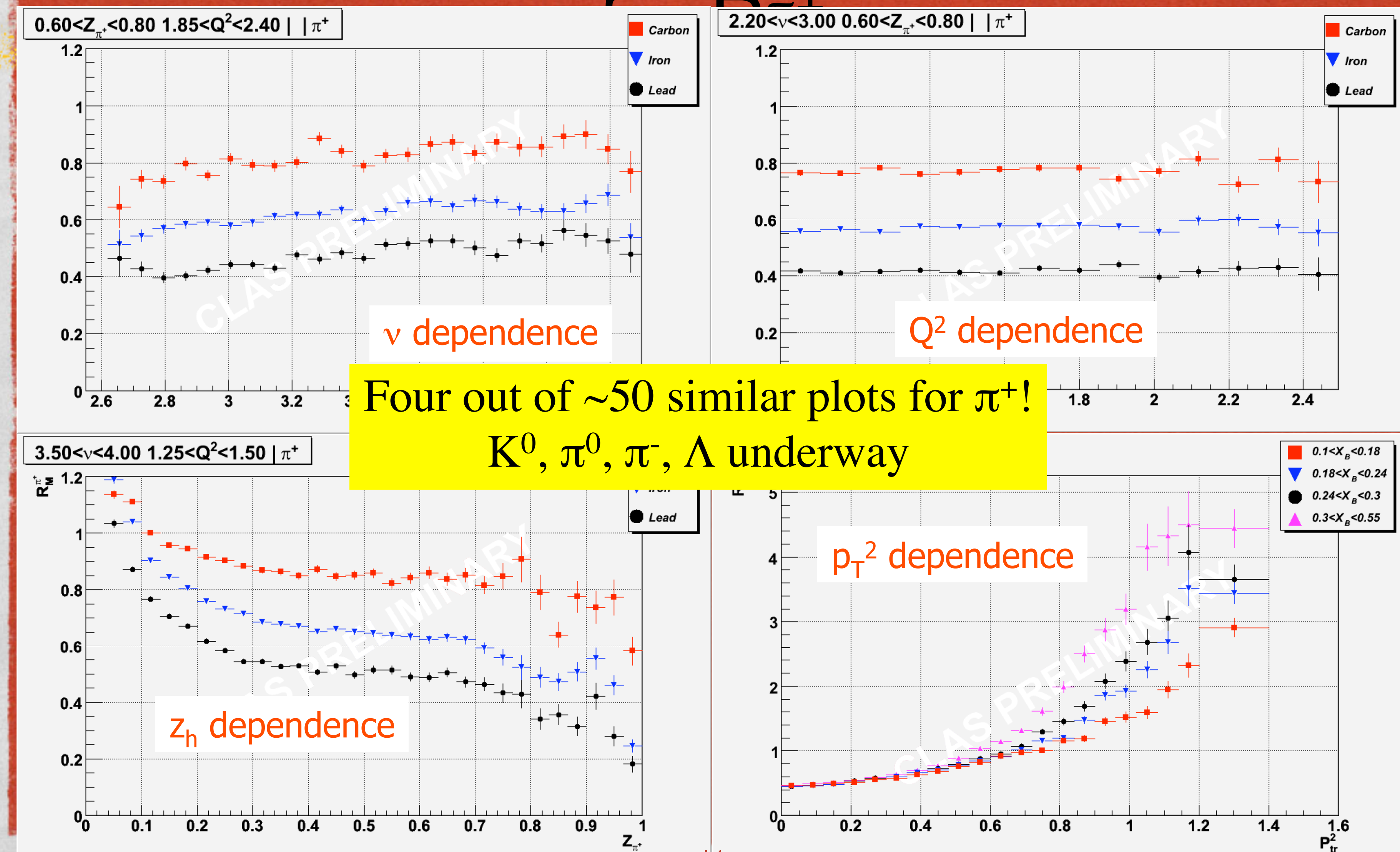
Examples of Experimental Data and Theoretical Predictions



ν=3-9 GeV, Q^2=2-8 GeV^2

CLAS12 Multiplicity Ratio vs. Z_h, π^+

Examples of multi-variable slices of preliminary CLAS 5 GeV data



IMPACTS OF RICH

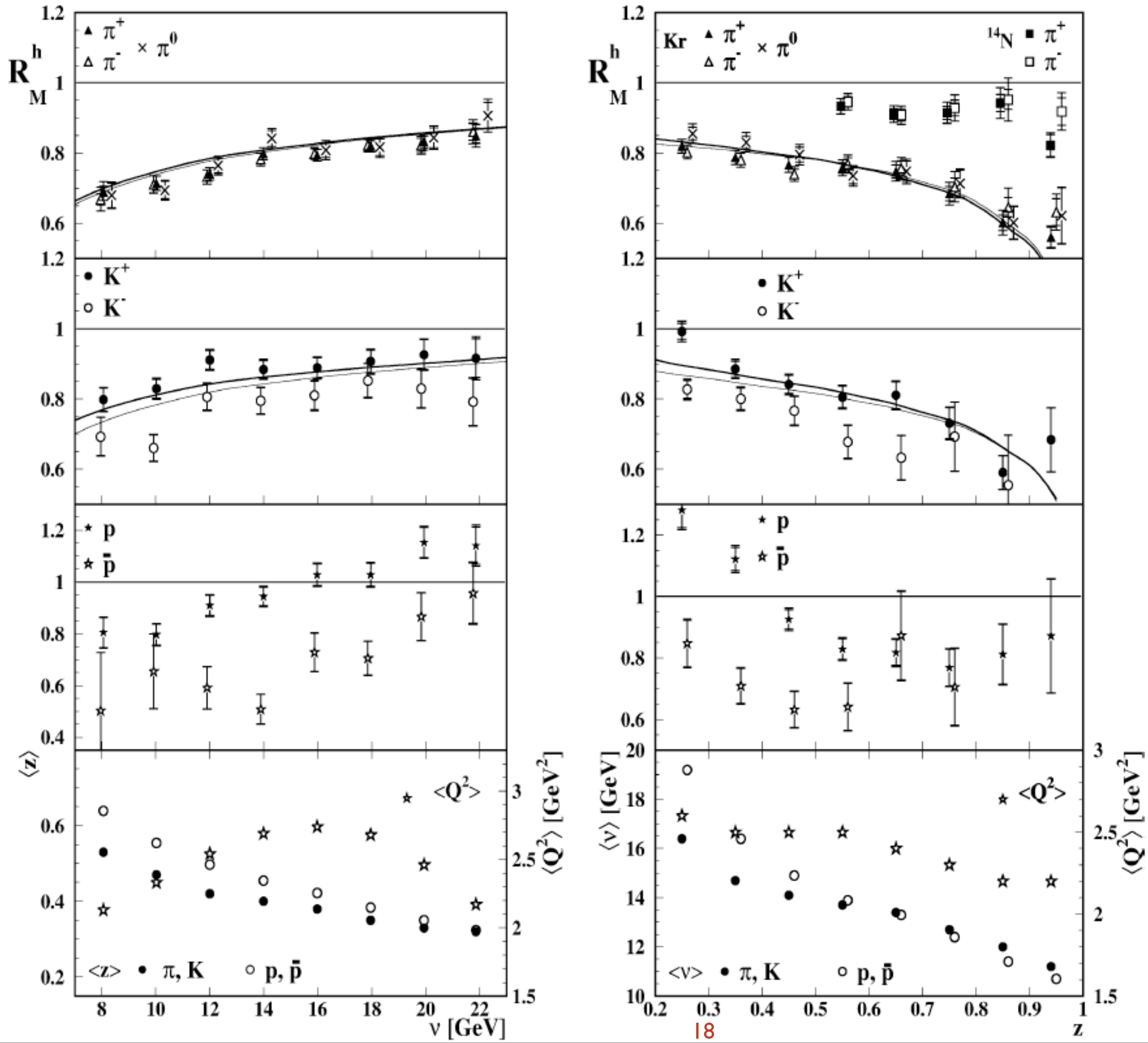
MAJOR IMPACTS OF RICH

- Continuity with HERMES: π^{+-0}, K^{+-}, baryons
- Compare isospin partners over full multi-dimensional space available with CLAS12
- Test universality of production time τ_p
- Double the constraints on mass/size dependence of ${}^{h}\tau_f$
- Probe reaction mechanism using known cross sections

CONTINUITY WITH HERMES

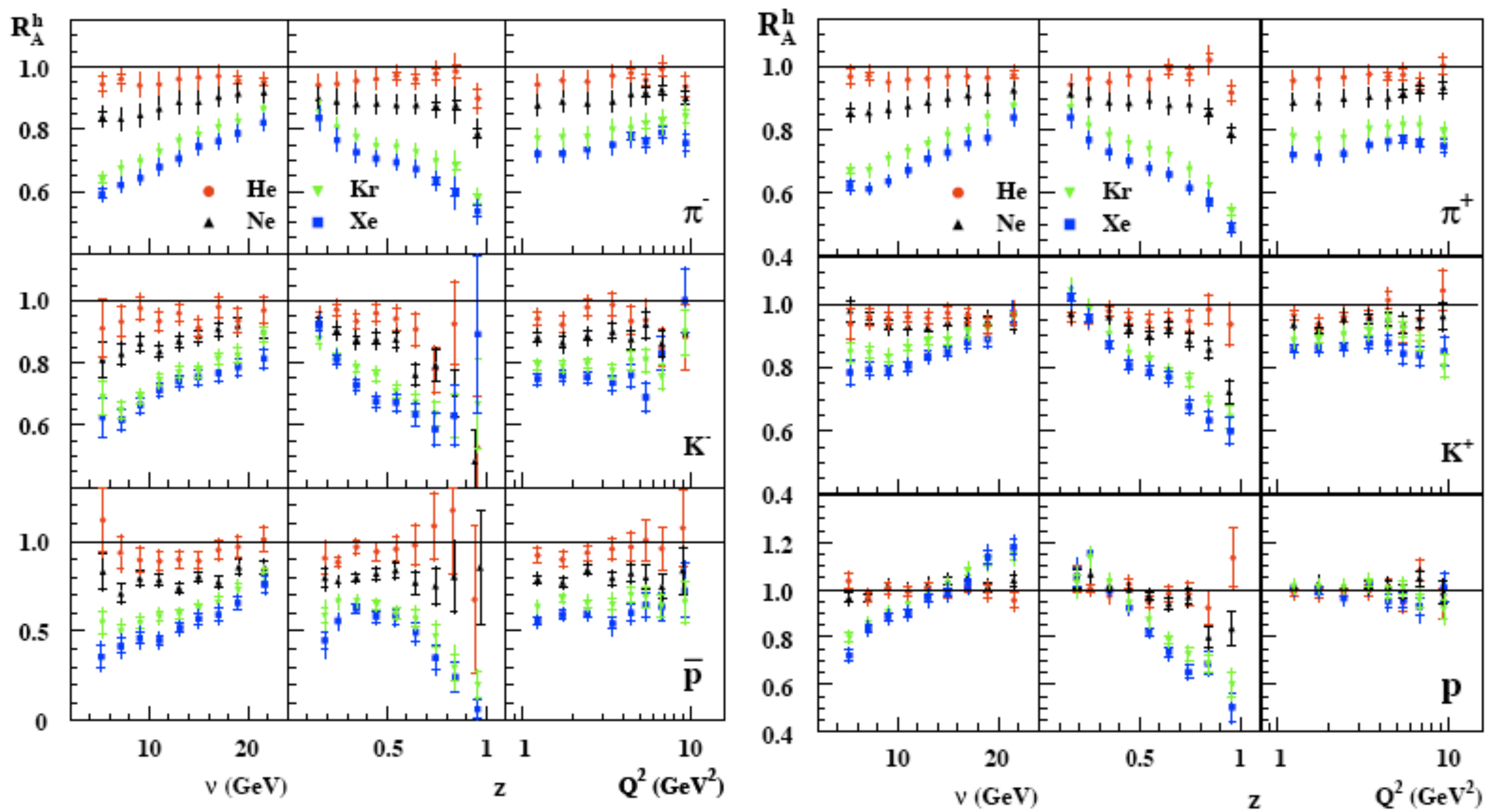
- HERMES has measured attenuation of identified hadrons with a range of nuclear target masses:
  - Eur. Phys. J. C 20, 479–486 (2001); Phys. Letts. B 577(2003)37; Nucl. Phys. B 780 (2007) 1
    - π^{+-0}, K^{+-}, proton, antiproton
    - Targets: D, He, (N), Ne, Kr, Xe

HERMES Collaboration / Physics Letters B 577 (2003) 37–46



HERMES

Krypton Target (mostly)



HERMES data for He, Ne, Kr, Xe: π^{+-}, K^{+-}, p, antiproton

CONTINUITY WITH HERMES

Important to have continuity because:

- Exploratory surveys: avoid extrapolations and modeling in making basic cross-checks of the data
- Need to demonstrate consistency with the HERMES 1-D and 2-D analyses before drawing conclusions from 5-D analyses
- Extrapolation of higher-level analyses (e.g., for τ_p and ${}^{h}\tau_f$) to higher ν where only HERMES has coverage

COMPARE ISOSPIN PARTNERS OVER FULL 5-D SPACE

- CLAS12 allows studies in 5-dimensional bins; this is critical for 2nd generation study.
- Naive picture: isospin partners should have nearly identical formation properties. Crucial cross-check on validity of physical picture. Consistent with HERMES pion observations for 1-D distributions.
- Can also assess impact of alternate initial state mechanisms (e.g., K^- vs. K^+).

TEST UNIVERSALITY OF PRODUCTION TIME

- If physical picture of struck quark propagating is correct, then p_T broadening should naively be identical for π^{+-0}, K^{+0}. (K^- should be different.) (Baryons?)
- Need to test over wide kinematic range.
- Without RICH, lose important mesons & kinematics

Constraints on mass/size dependence of ${}^{h}\tau_f$

- Naive picture: larger hadrons take longer to form than smaller hadrons, and baryons (3q) take longer to form than mesons (2q).
- Based on arguments from Fourier components and from formation mechanisms.
- Need the broadest possible kinematic range for the largest range of hadron masses/sizes

Probe Reaction Mechanism with Known Cross Sections

- Compare π^+ to K^+: total cross section on D is different by factor 2.
- Can discriminate between hadronization inside nucleus and hadronization outside the nucleus?
- Shed light on the most basic controversy over reaction mechanism.