Physics motivations for spectroscopy, prompt photons and Primakoff

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RF-separated beams for Amber- Kick Off Meeting

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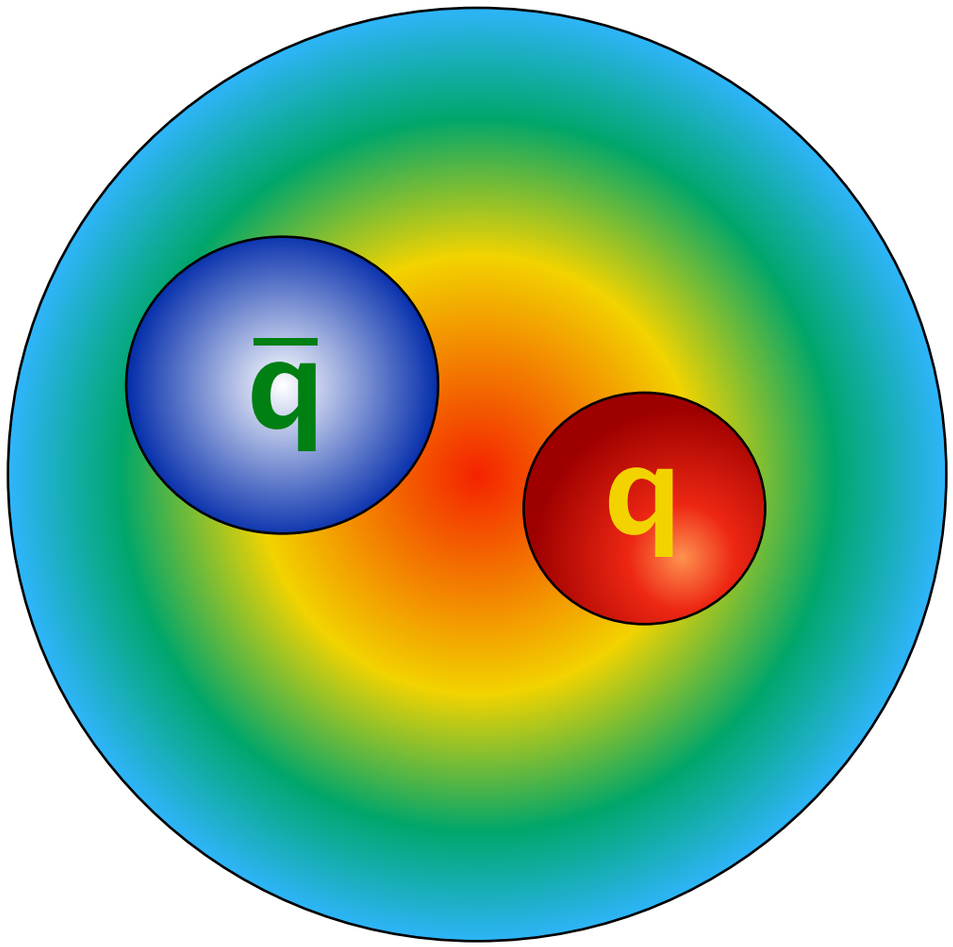
Meson as a complex QCD system



Emergence of hadronic mass

Partonic structure

Drell-Yan

Charmonia

Prompt photons

π K

π K

π K

Resonant and dynamical properties of mesons

Pion and kaon as Nambu-Goldstone bosons

"Rigidity" of the meson as a complex system

Spectroscopy

COMPASS π K

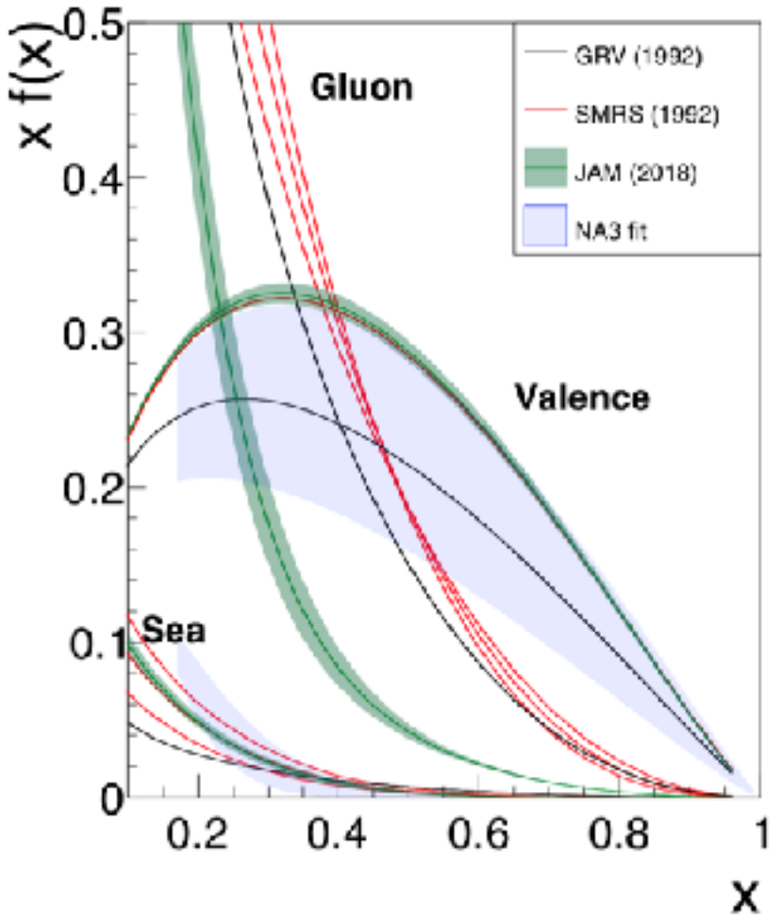
Low-t (Primakoff) reactions

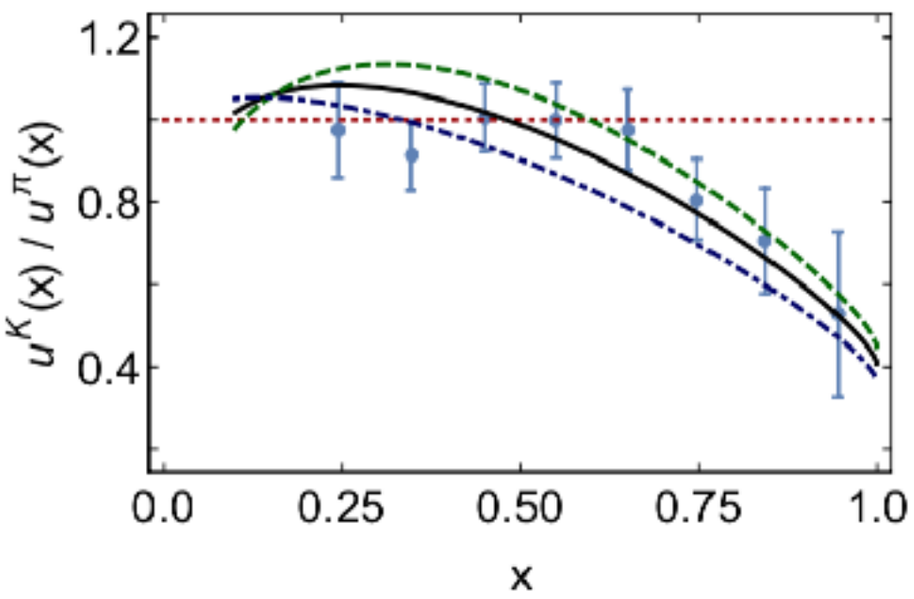
COMPASS π K

Polarizability

COMPASS π K

Meson PDFs



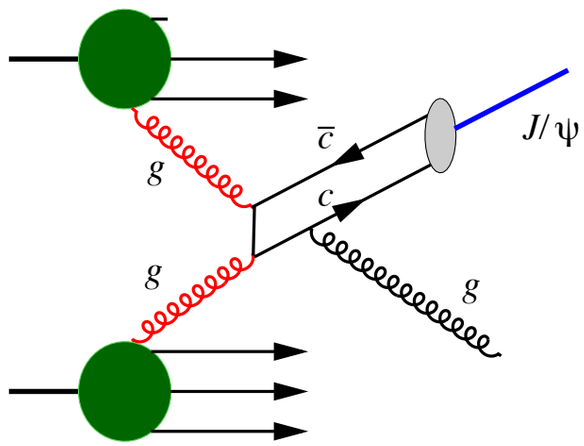


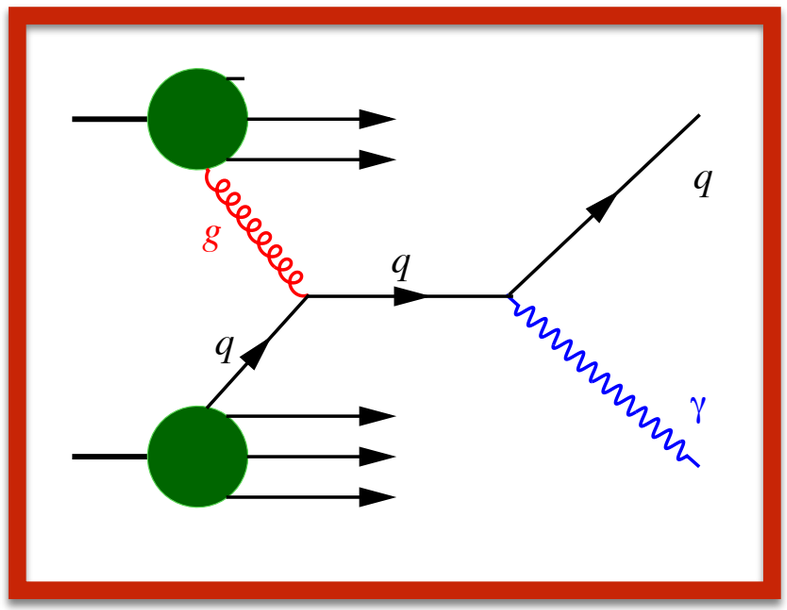
GRV (1992) *set of pion PDFs: Drell-Yan, charmonia and prompt photon production experiments (**E615, NA10, WA70, NA24**).*

SMRS (1992)*: basically the same old data.*

JAM (2018) *set: production of leading neutrons in DIS at HERA (**ZEUS, H1**).*

Kaon PDFs*: just 700 kaon-induced DY events at **NA3***



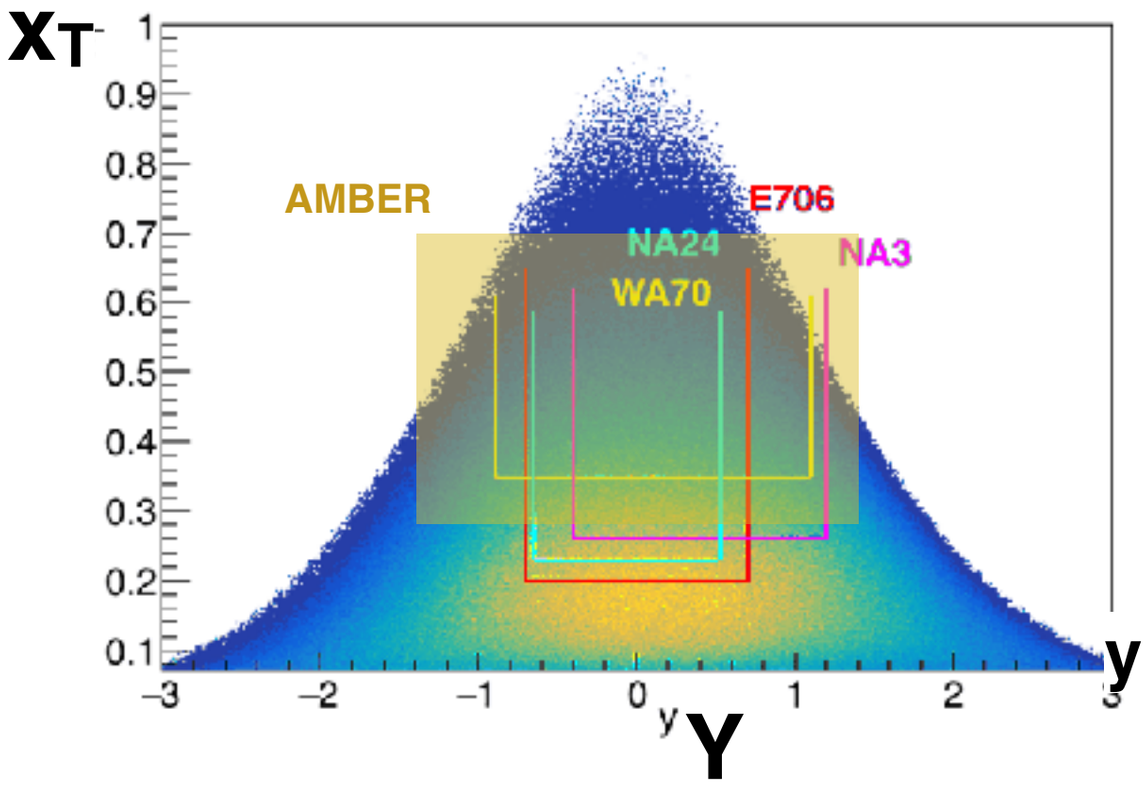


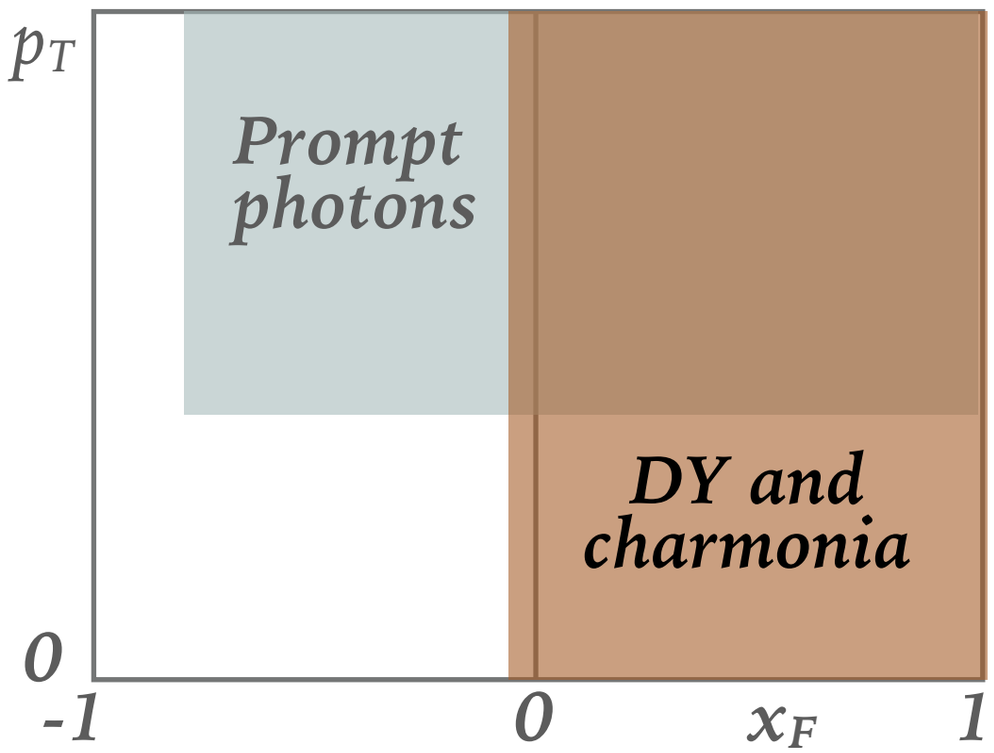
Experiments with prompt photons at low energies

Experiment	Beam and target	$\sqrt{s}$, GeV	y range	x_T range
E95 (1979)	p; Be	19.4, 23.75	-0.7 – 0.7	0.15 – 0.45
E629 (1983)	p, π^+; C	19.4	-0.75 – 0.2	0.22 – 0.52
NA3 (1986)	p, π^+, π^-; C	19.4	-0.4 – 1.2	0.26 – 0.62
NA24 (1987)	p, π^+, π^-; p	23.75	-0.65 – 0.52	0.23 – 0.59
WA70 (1988)	p, π^+, π^-; p	22.96	-0.9 – 1.1	0.35 – 0.61
E706 (1993)	p, π^-; Be	30.63	-0.7 – 0.7	0.20 – 0.65
E704 (1995)	p; p$\uparrow$	19.4	<0.74	0.26 – 0.39
UA6 (1993,1998)	$\bar{p}$; p	24.3	-0.2 – 1.0	0.34 – 0.50

were used for pion PDFs extraction

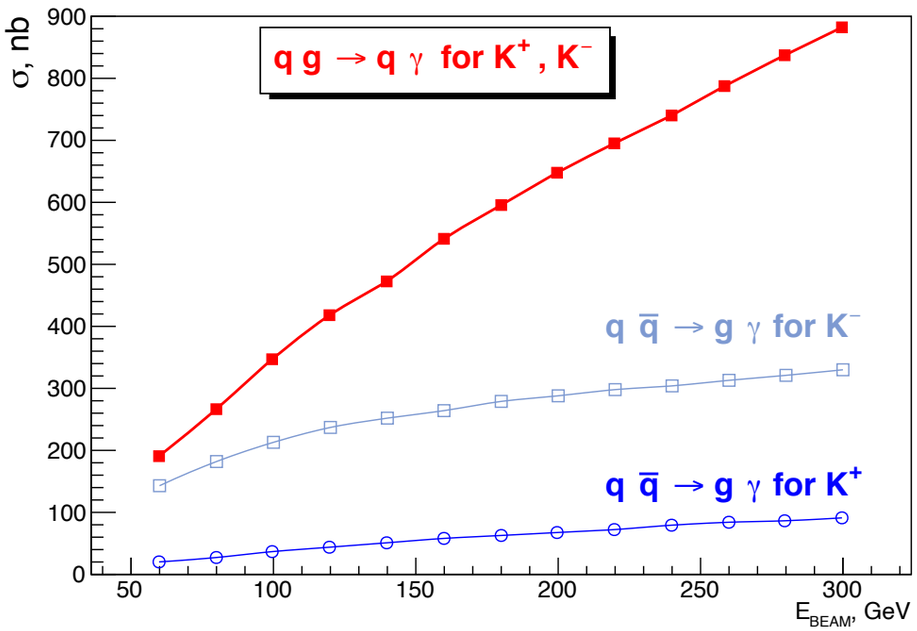
$$x_T = \frac{2p_T}{\sqrt{s}}$$



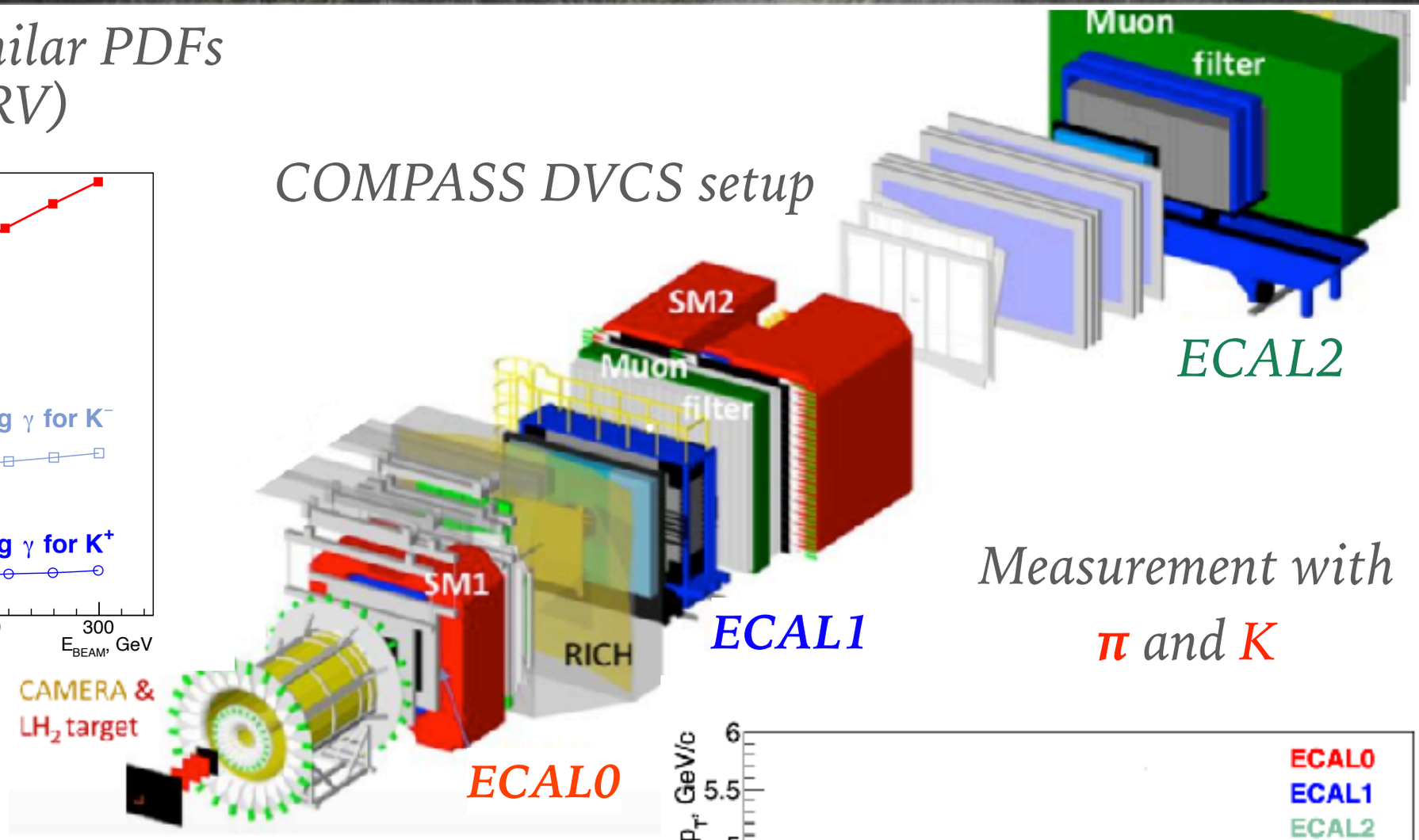


Prompt photons at COMPASS++/AMBER

Assumed for kaon similar PDFs as for pion (GRV)



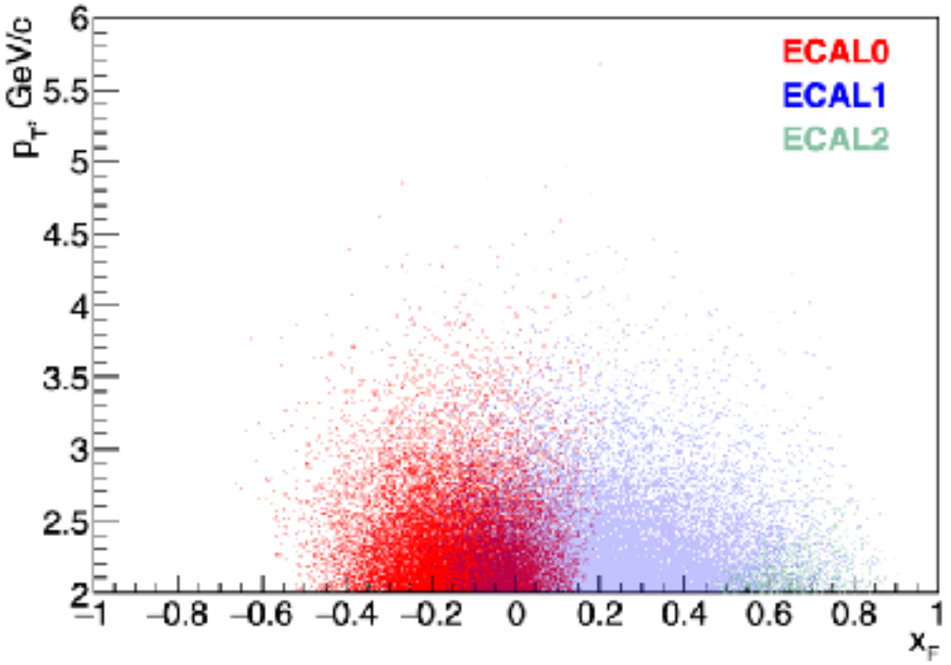
COMPASS DVCS setup



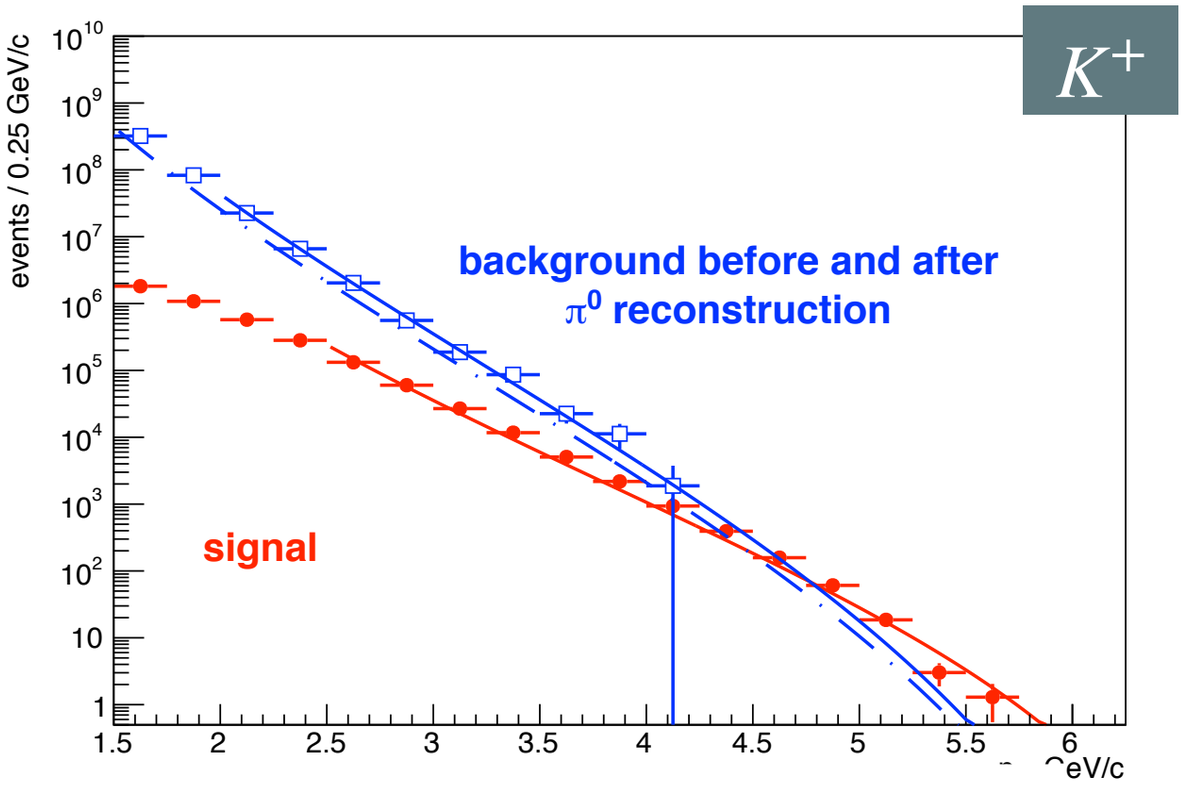
Measurement with π *and* K

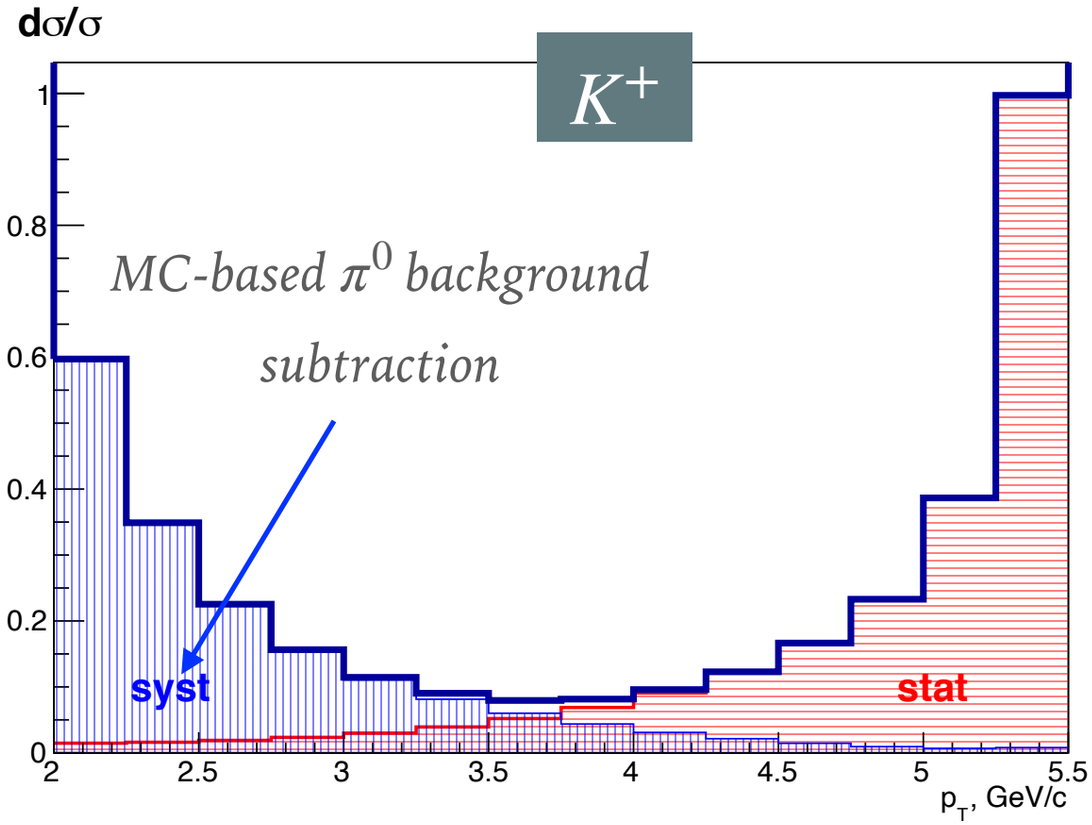
100 GeV kaon-enriched hadron beam!

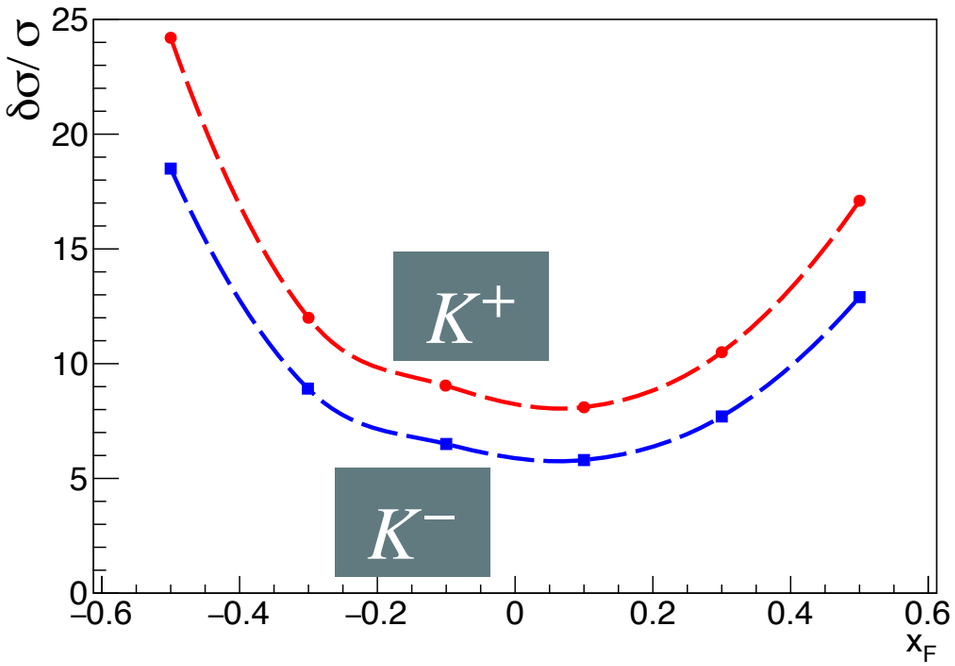
Open setup *- possibility for semi-inclusive and exclusive reactions!*



Expectations







# of photons	p_T>2 GeV/c	p_T>3 GeV/c
π^- total	3.1×10^7	3.7×10^5
π^- prompt	1.3×10^6	6.8×10^4
π^+ total	3.3×10^7	3.6×10^5
π^+ prompt	1.1×10^6	4.7×10^4

This experiment (100 GeV): 50 pb^{-1} (1 year)

WA70 (280 GeV): *1.3 pb^{-1} for π^+ and 3.5 pb^{-1} for π^-*

Primakoff physics

Polarizability

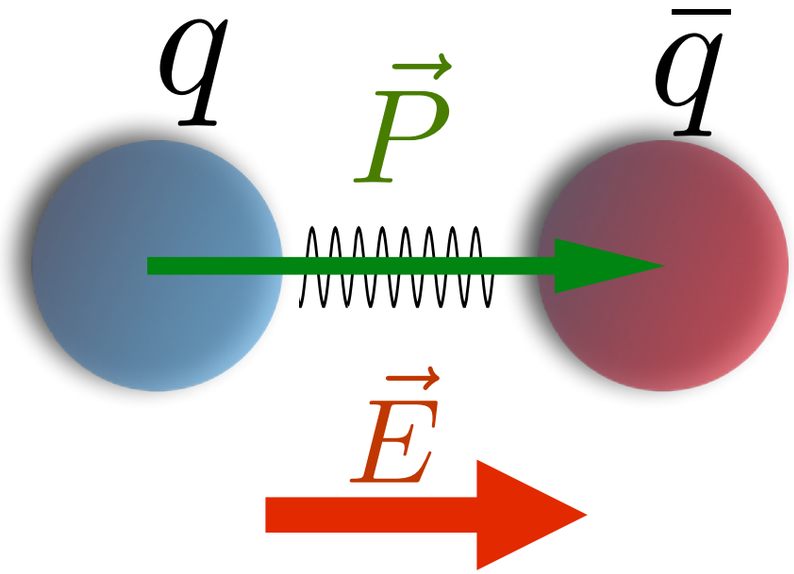
$$\vec{P} = \alpha_X \vec{E}$$

$$\vec{\mu} = \beta_X \vec{H}$$

$$A(\gamma X \to \gamma X) =$$

$$(-\frac{\alpha}{m}\delta_{o\pm} + \alpha_X \omega_1 \omega_2)\hat{e}_1 \cdot \hat{e}_2 +$$

$$+\beta_X \omega_1 \omega_2 (\hat{e}_1 \times \hat{q}_1)(\hat{e}_2 \times \hat{q}_2) + ...$$



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

PDG data:

	α_X, 10^{-4} fm^3	β_X, 10^{-4} fm^3
p	12.0±0.6	1.9∓0.6
n	12.5±1.7	2.7∓1.8
π	2.0±0.9	~2.0∓0.9

K ?

Chiral anomaly

Constants for reactions:

$$\gamma^* K^- \to K^- \pi^0$$
$$\gamma^* K^- \to K^- \eta$$
$$\gamma^* K^- \to K^0 \pi^-$$

Radiative widths of K* mesons

$$\gamma^* K^- \to K^{*-}$$

Particle	BR(→Kγ)	Full width, MeV
K*(892)$^-$	(9.9±0.9)×10^{-4}	50
K_2*(1430)$^-$	(2.4±0.5)×10^{-3}	100
...		

Kaon polarizabilities

Theoretical predictions:

χPT prediction $O(p^4)$:

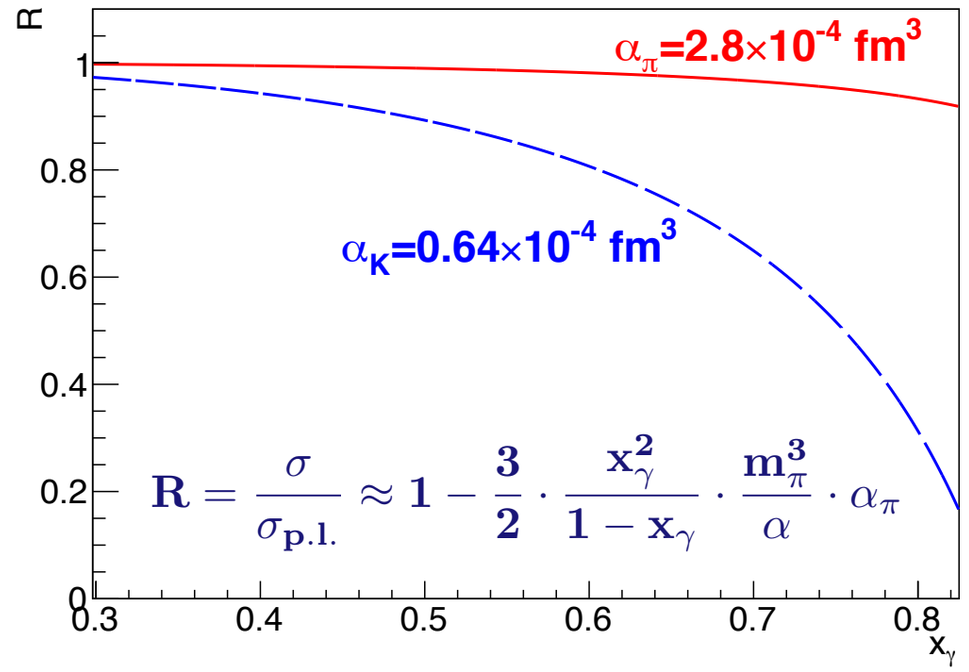
$$\alpha_K + \beta_K = 0$$

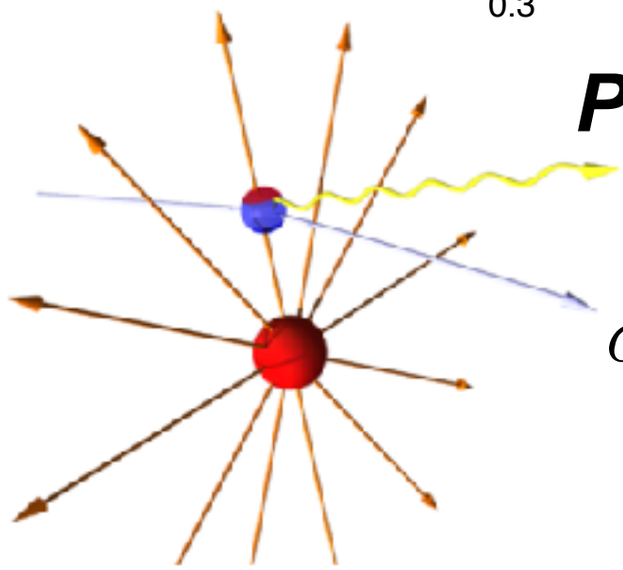
$$\alpha_K = \alpha_\pi \times \frac{m_\pi F_\pi^2}{m_K F_K^2} \approx \frac{\alpha_\pi}{5} \approx 0.6 \times 10^{-4} fm^3$$

Quark confinement model:

$$\alpha_K + \beta_K = 1.0 \times 10^{-4} fm^3$$

$$\alpha_K = 2.3 \times 10^{-4} fm^3$$





Polarization effects

~m^3

$$\sigma_{Prim} \sim \frac{1}{m^2}$$

Experimental results:

α_K<200×10^{-4} fm^3 (1973)

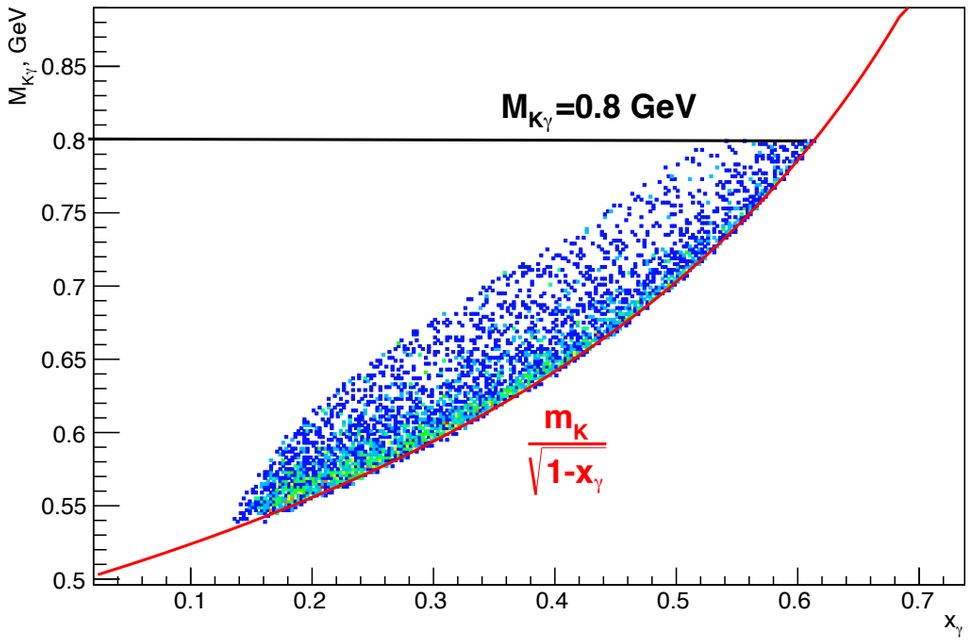
- from kaonic atoms spectra

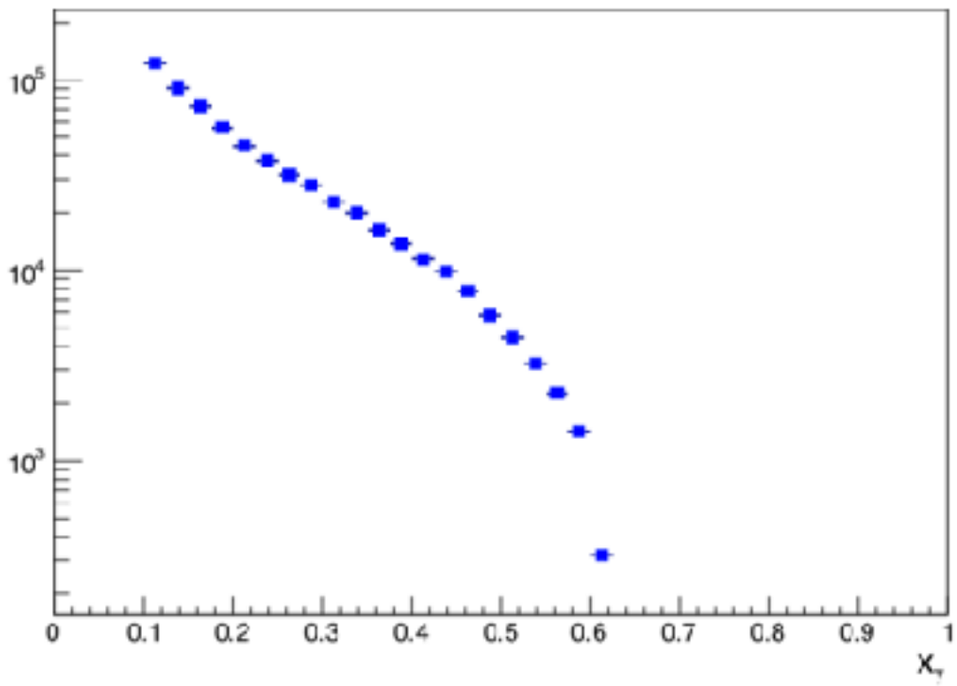
At COMPASS:

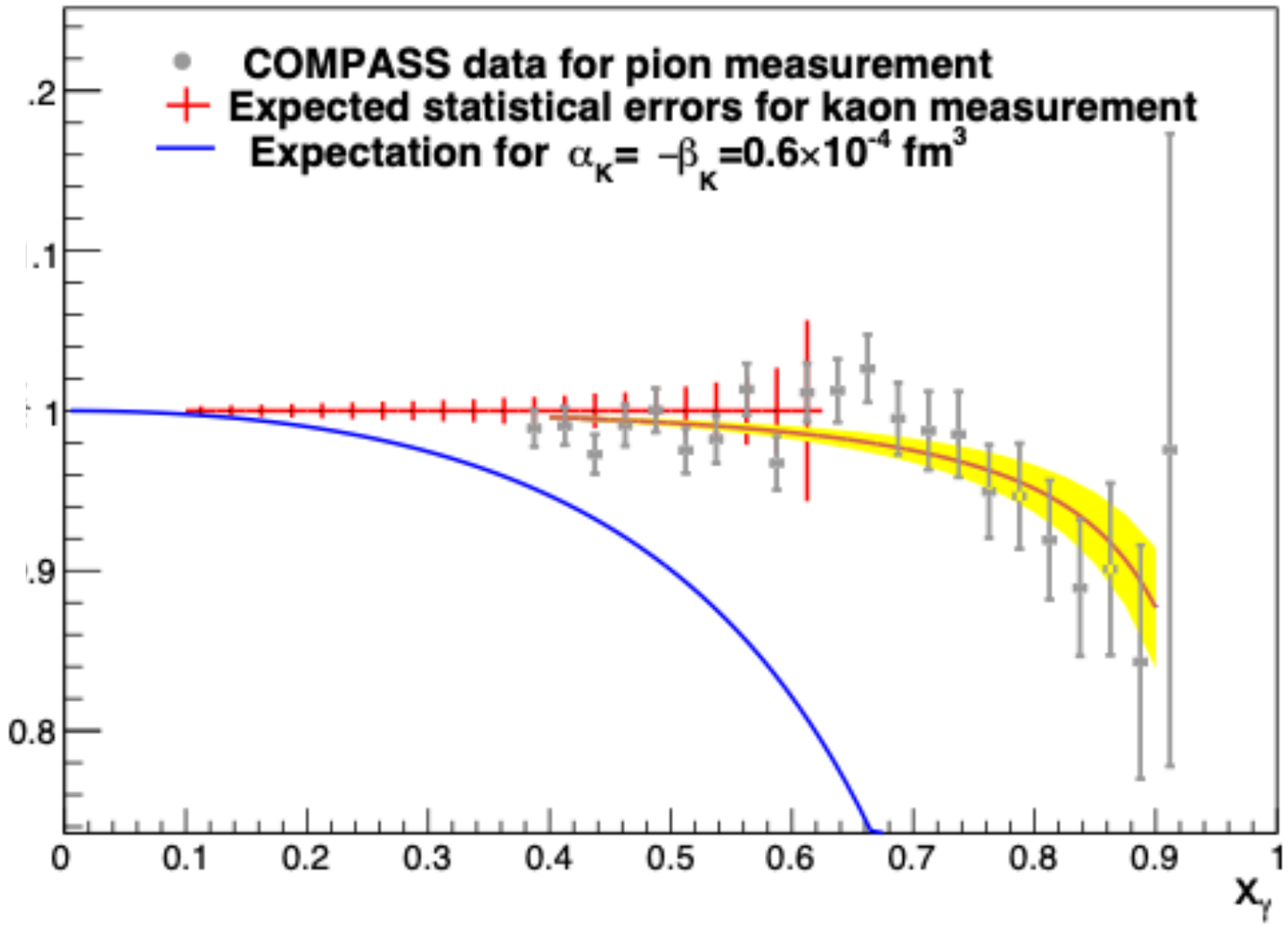
- ~2.4% of kaons in hadron beam
- CEDARs for beam kaons identification

1 Kγ event per 500 $\pi\gamma$

Expectations



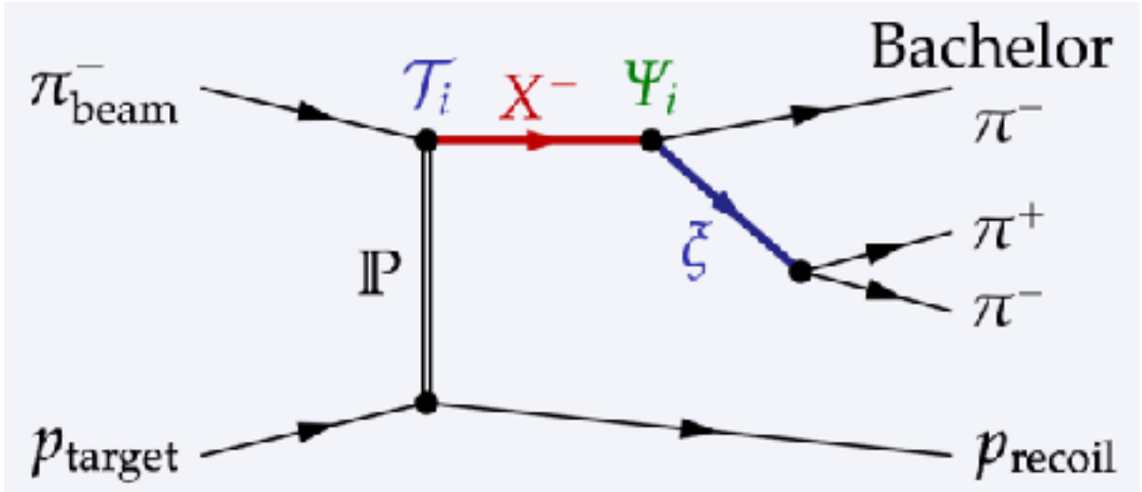


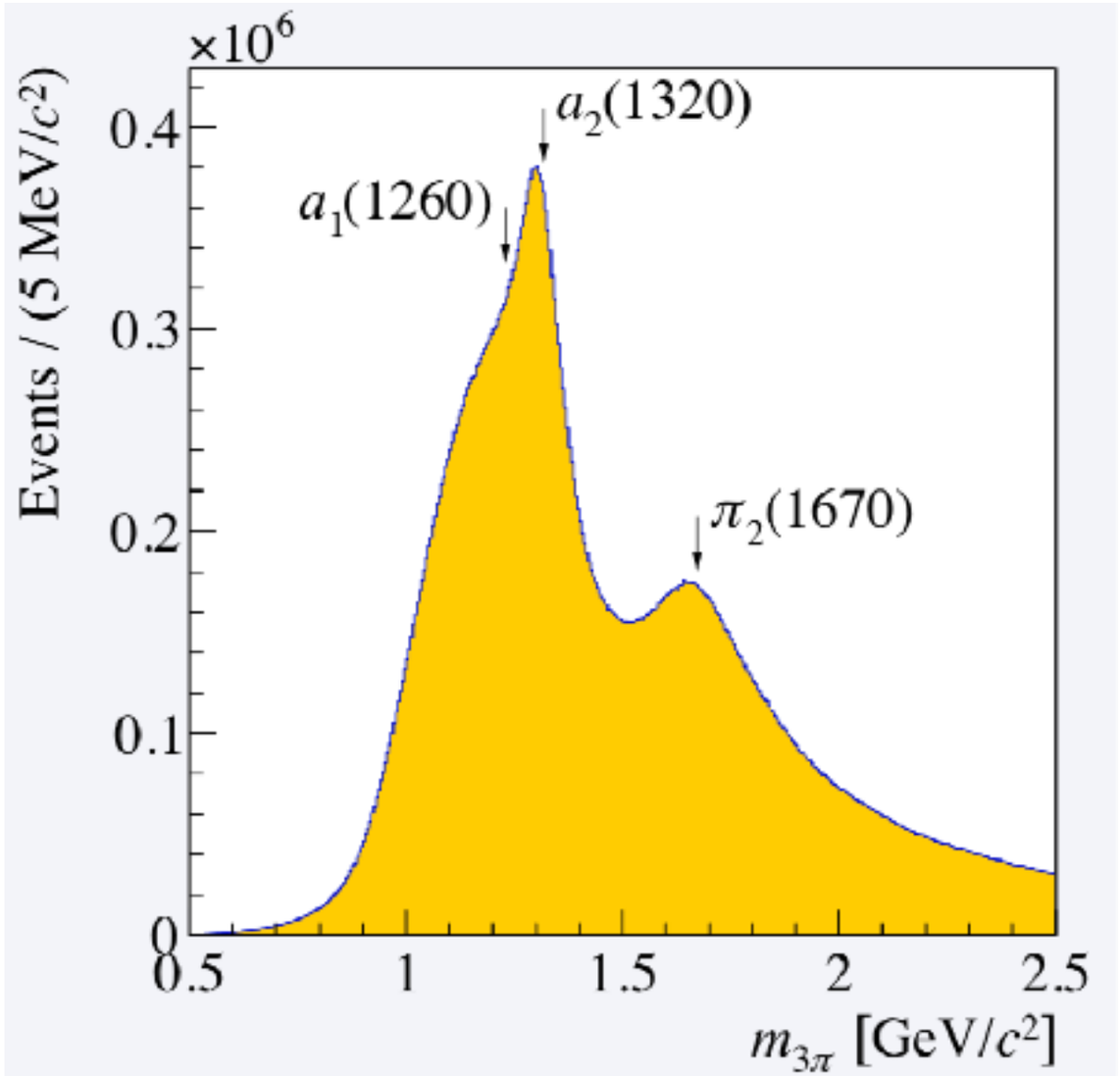


$$5 \times 10^{12}\ K^- \ \rightarrow\ 6 \times 10^5\ K\gamma\ events$$

$$\sigma_{\alpha_K\ stat} = 0.03 \times 10^{-4}\ fm^3$$

COMPASS with pions

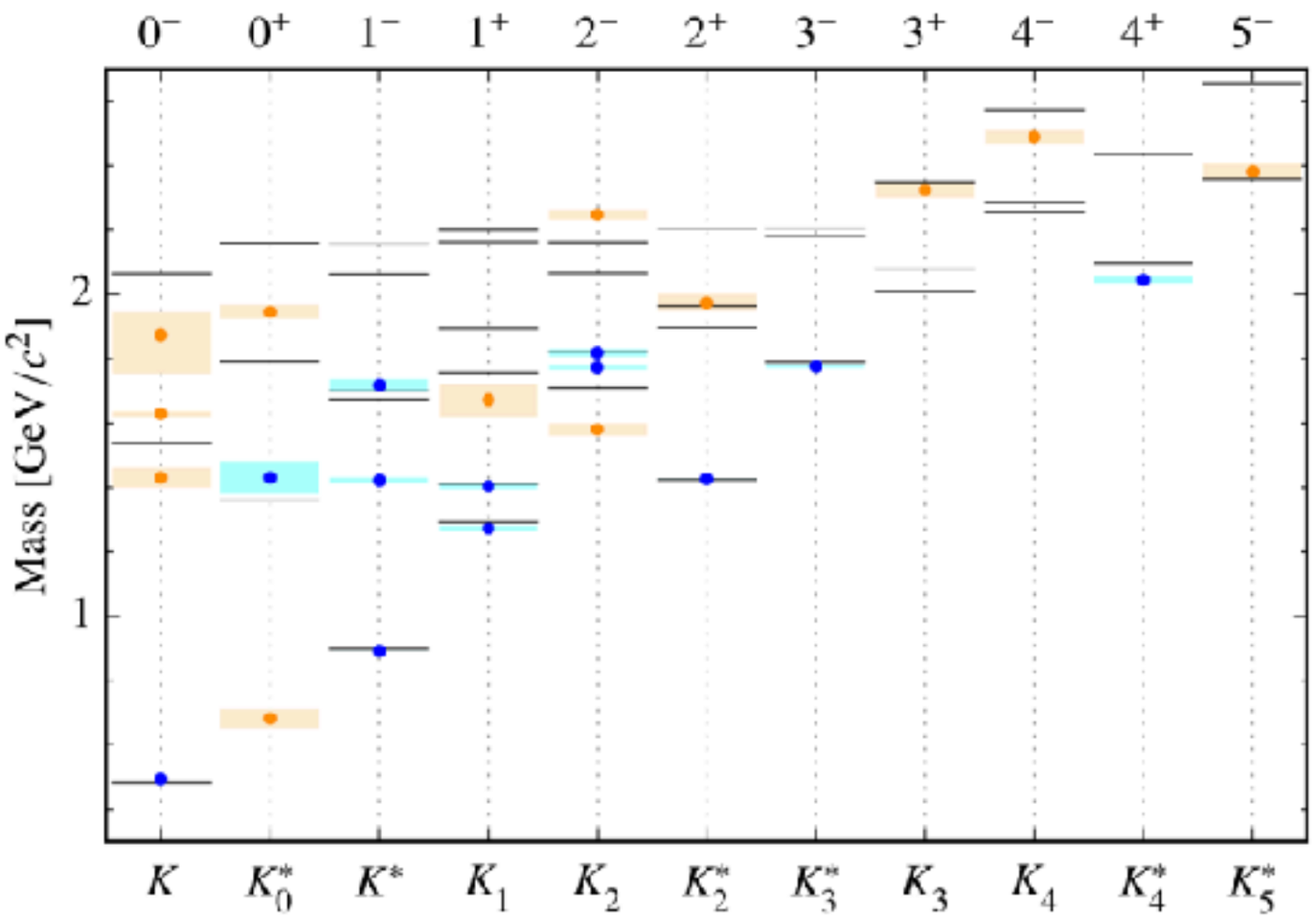


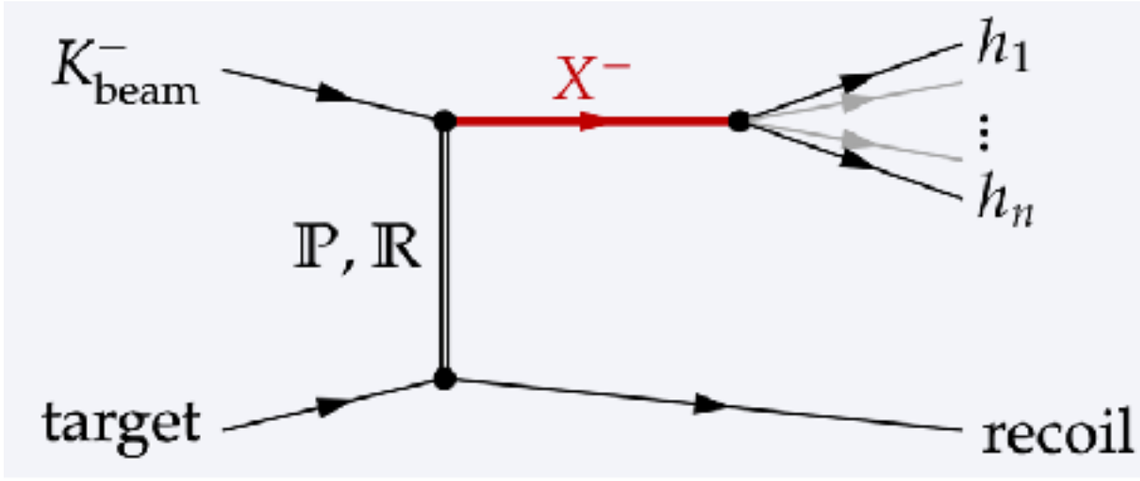


World largest sample:
46×10^6 $\pi^-\pi^+\pi^-$ events

Sophisticated PWA: 87 partial waves, J and L up to 6

Kaon spectroscopy





- Most PDG entries more than 30 years old
- Since 1990 only 4 kaon states added to PDG

We intend to rewrite completely the kaon section of PDG

Summary

- **AMBER is a unique instrument for comprehensive study of kaon as a complex QCD system.**
- **Prompt-photon production is an instrument, complimentary to the charmonia production, for access gluon content of kaon.**
- **Kaon-induced spectroscopy with AMBER could rewrite completely the kaon section of PDG**
- **Kaon polarizability measurement and study of kaon-induced low-t electromagnetic reactions is a way to study the properties pf kaon as a Goldstone boson.**

So, a new kaon-enriched beam for AMBER is welcome!