ϕ meson photo-production at 9 GeV on nuclear targets with GlueX

Frontiers Workshop
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Introduction

Vector mesons

- J. J. Sakurai predicted existence in 1960[1]
- Experimentally established in 1960s
- Vector meson dominance (VMD) model
- Physical photon: bare photon and ρ, ω, ϕ
- Important to study hadron interactions and photon's hadronic properties[2]

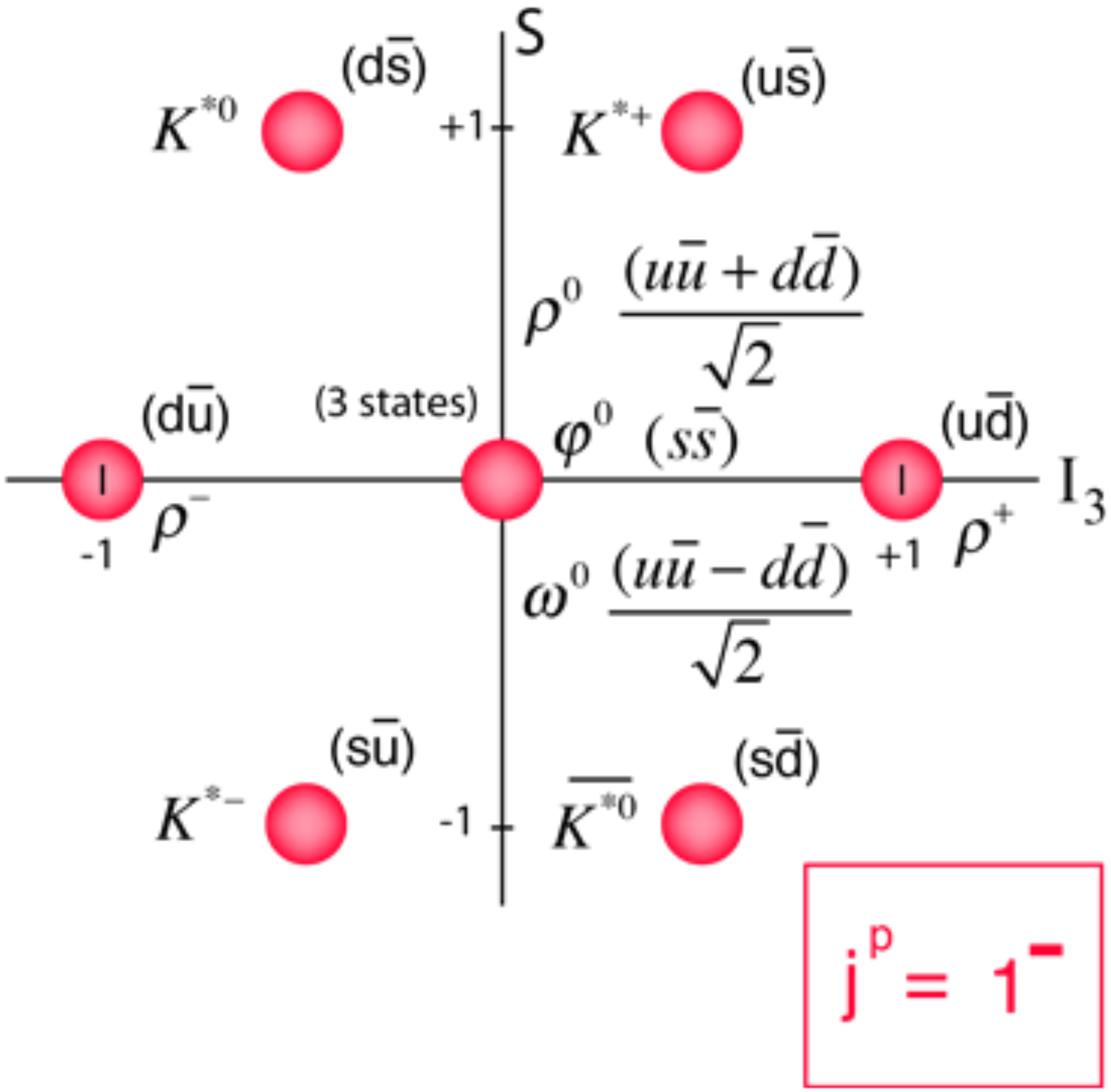

Fig. 2: $J^{PC} = 1^{--}$ vector meson nonet in the $SU(3)_{flavor}$.[3]

Physics motivation

Scattering in Regge theory

- Phenomenology before the advent of QCD
- Complex angular momenta in scattering
- Regge trajectory: collection of poles in PWA
- $J =$ spin, $t =$ mass of exchanged particle
- All known trajectories are found linear $\alpha(t) = \alpha(0) + \alpha' t$
- $\dfrac{d\sigma_{elastic}}{dt} \sim s^{2\alpha(0)-2} e^{-b|t|}, b = b_0 + 2\alpha' \ln(s)$

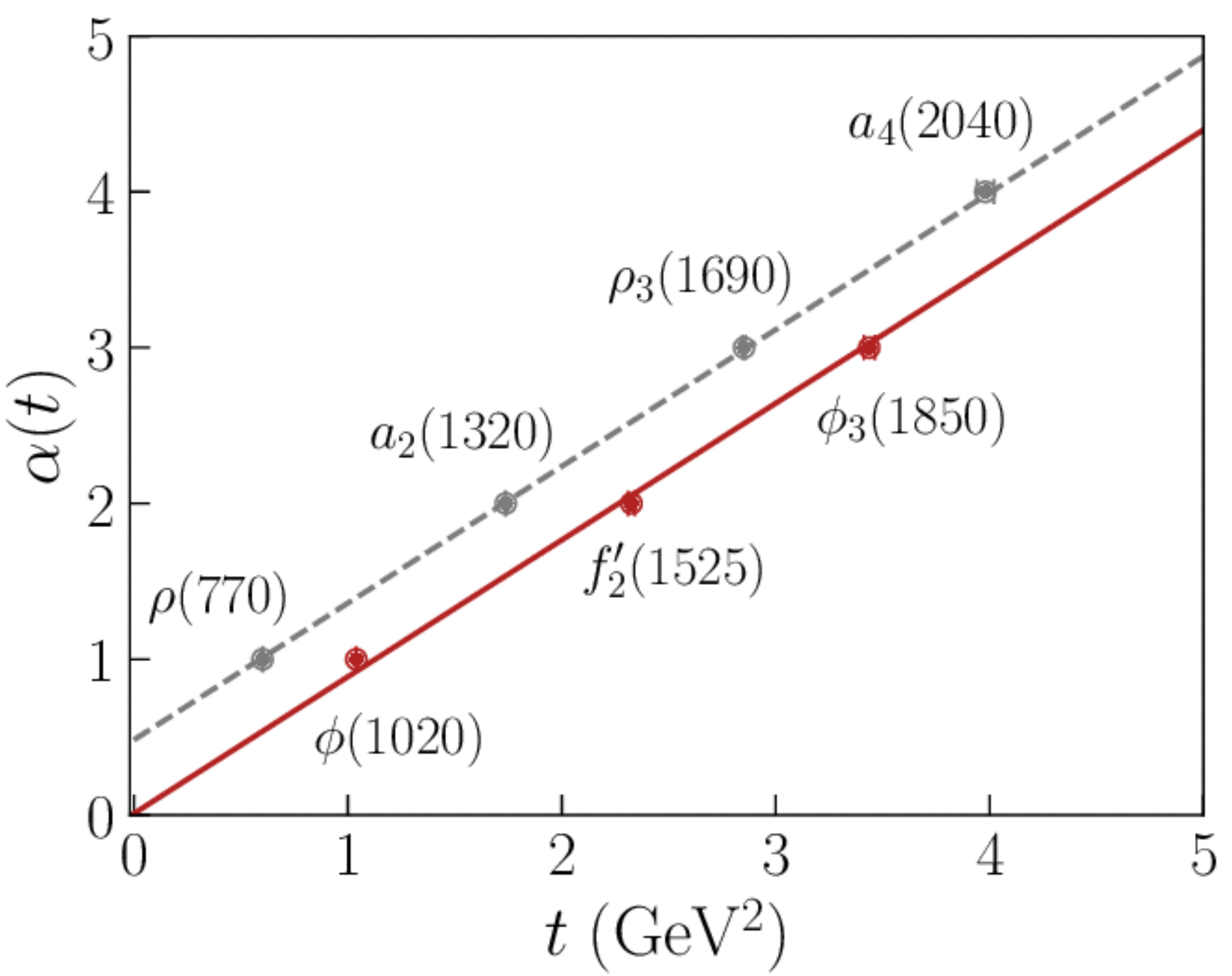

Fig. 3:Chew-Frautschi plot of some mesonic trajectories[4]

Physics motivation

Soft Pomeron in Regge theory

- For all hadronic interactions, cross sections flatten at high energies
- Pomeron trajectory is introduced
- $\alpha' = 0.25, \alpha(0) = 1.0808$ [5,6]
- “Soft” Pomeron trajectory

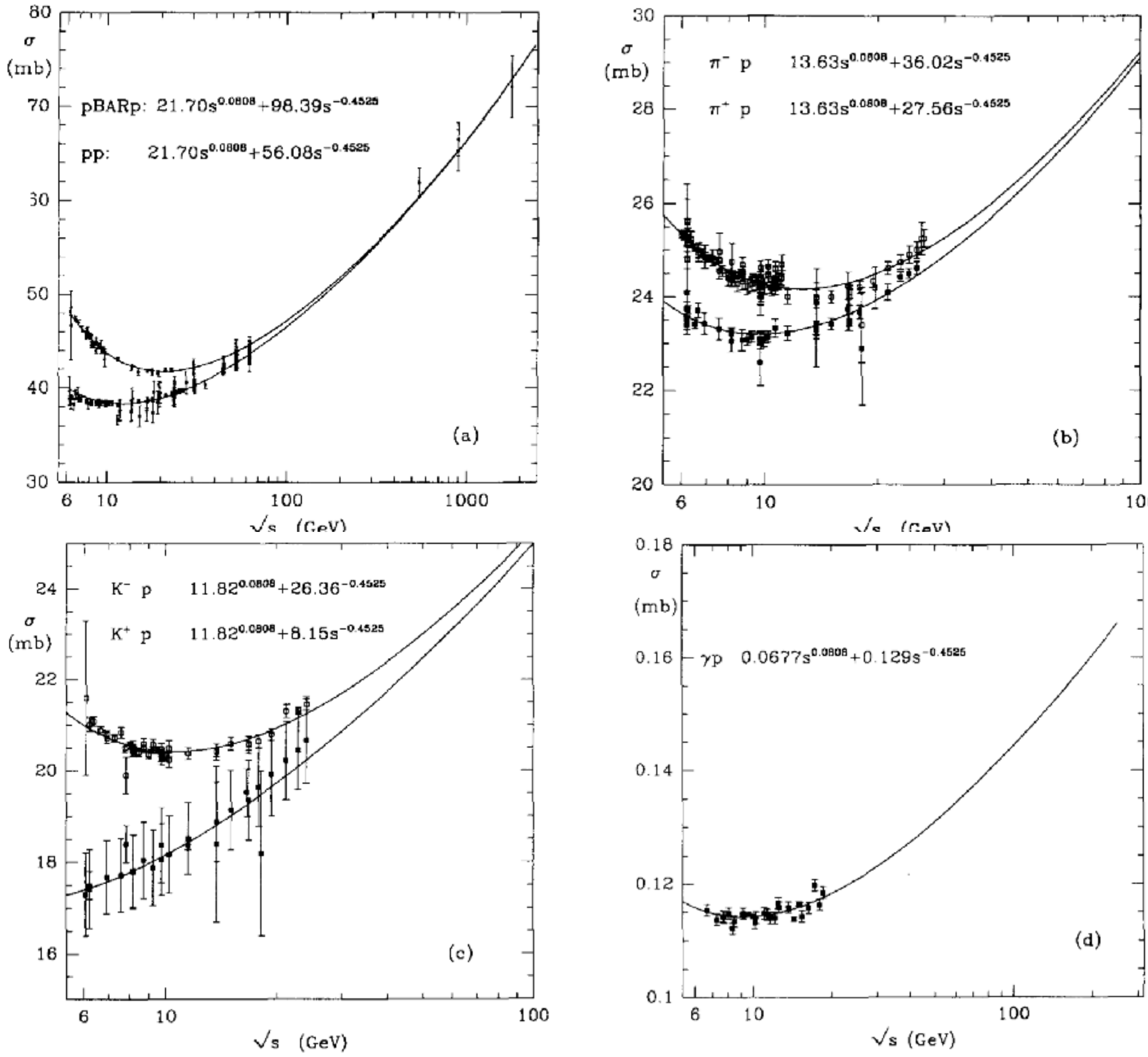

Fig. 4: Determination of the intercept of the Pomeron[5]

Physics motivation

Hard Pomeron in QCD

- Objects without valence quarks
- Generally believed to originate from multi-gluon exchange[7]
- Quantitative predictions require a hard scale
- large $Q^2, |t|$ or vector meson mass[8,9]
- Different from the soft behaviors

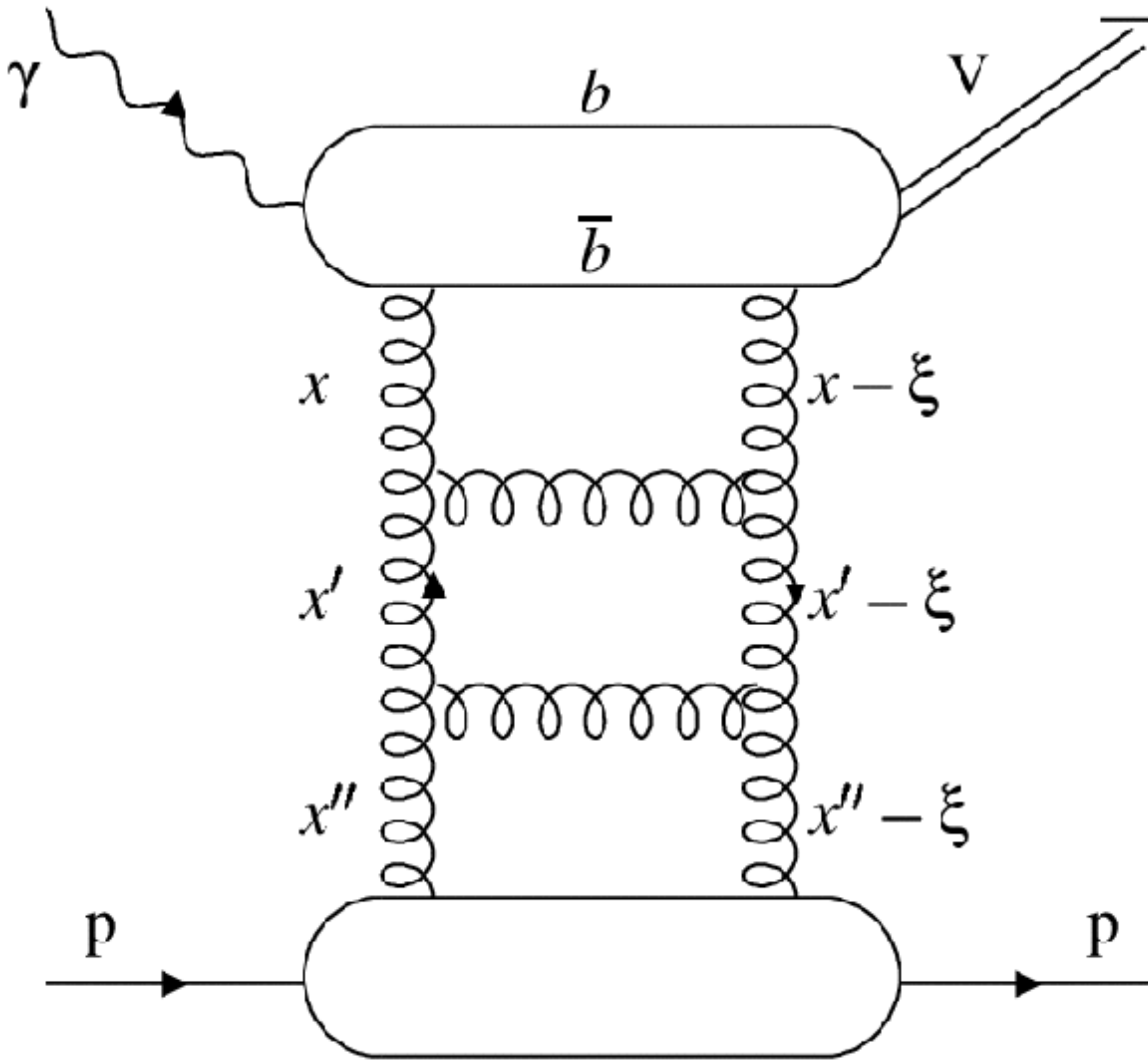

Fig. 5: Gluon ladder picture of vector meson production[10]

Physics motivation

Uniqueness of ϕ meson production

- At low energies, gluon dynamics are hard to study
- In general, quark exchanges are more significant
- For $\phi(s\bar{s})$, OZI rule suppresses quark exchanges
- Unique to study gluon exchanges at low energies
- Data is higher than Pomeron predictions near threshold

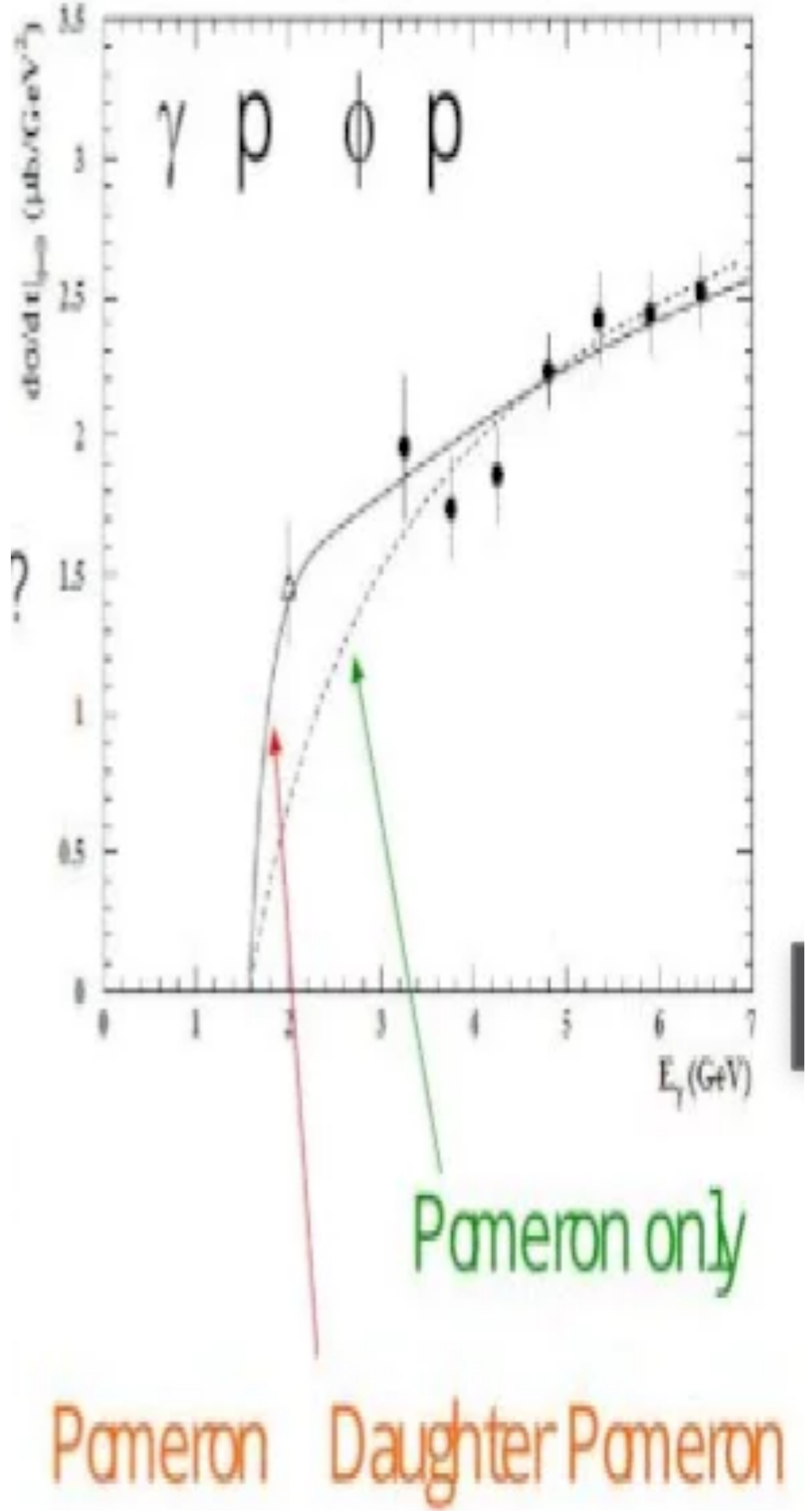

Fig. 7: $\gamma p \rightarrow \phi p$ data at low energies[11]

Physics motivation

Probe strangeness in the nucleons

- $s\bar{s}$ pair can be knocked out to produce ϕ meson
- Interference between strange and non-strange amplitude
- Polarization observables can provide some signature of the strange admixture[12]

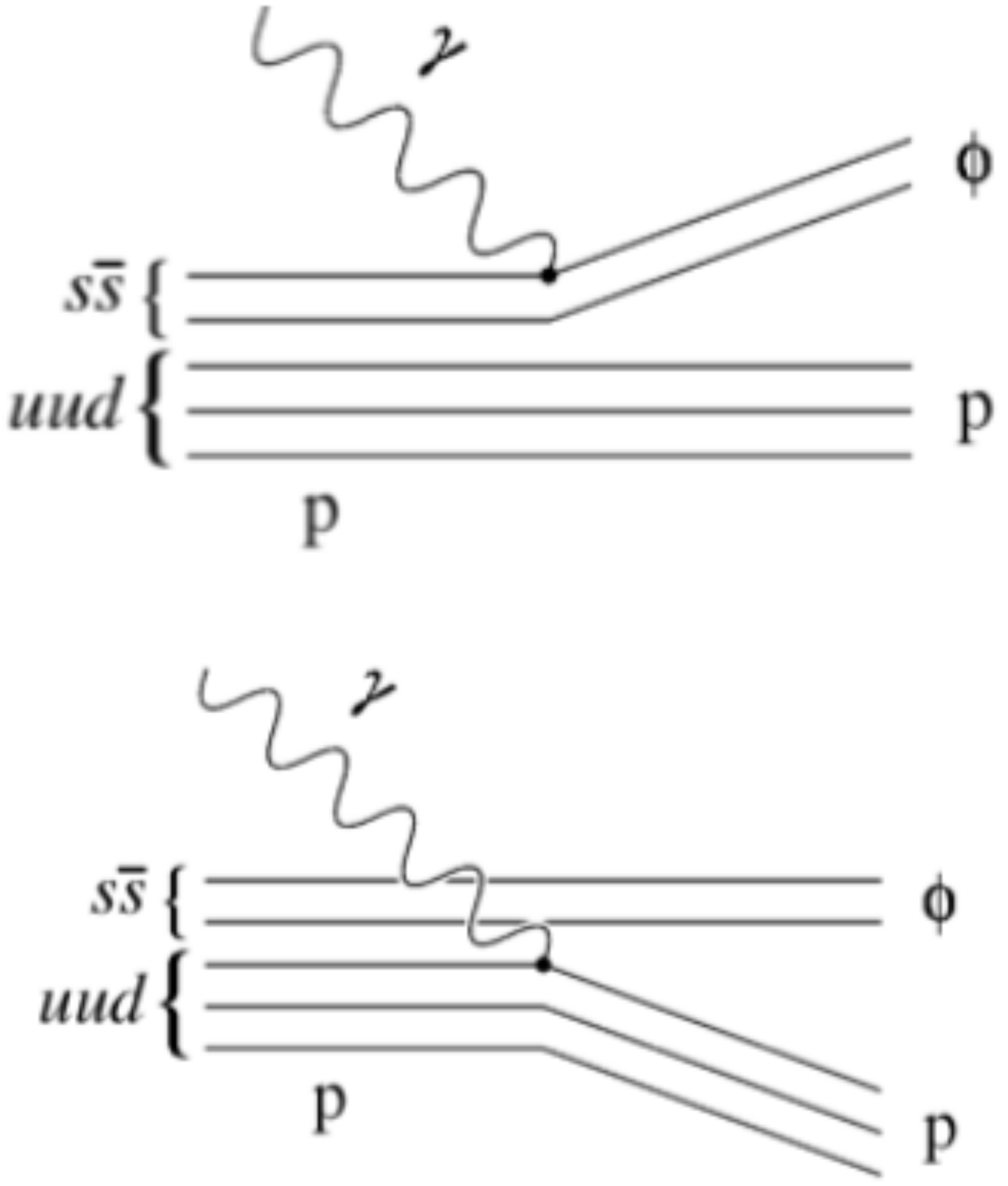

Fig. 10: Direct knockout of the $s\bar{s}$ pair[12]

Experimental details

Run conditions

- SRC/CT (E12-19-003), Nov 6 to Dec 21 2021
- Jefferson Lab, Hall D
- Topics

    -short range correlation (SRC)

    -color transparency (CT)

    -bound nucleon structure
- Linearly polarized photon, ~9 GeV coherent peak
- Targets: D_2,^{4}He,^{12}C

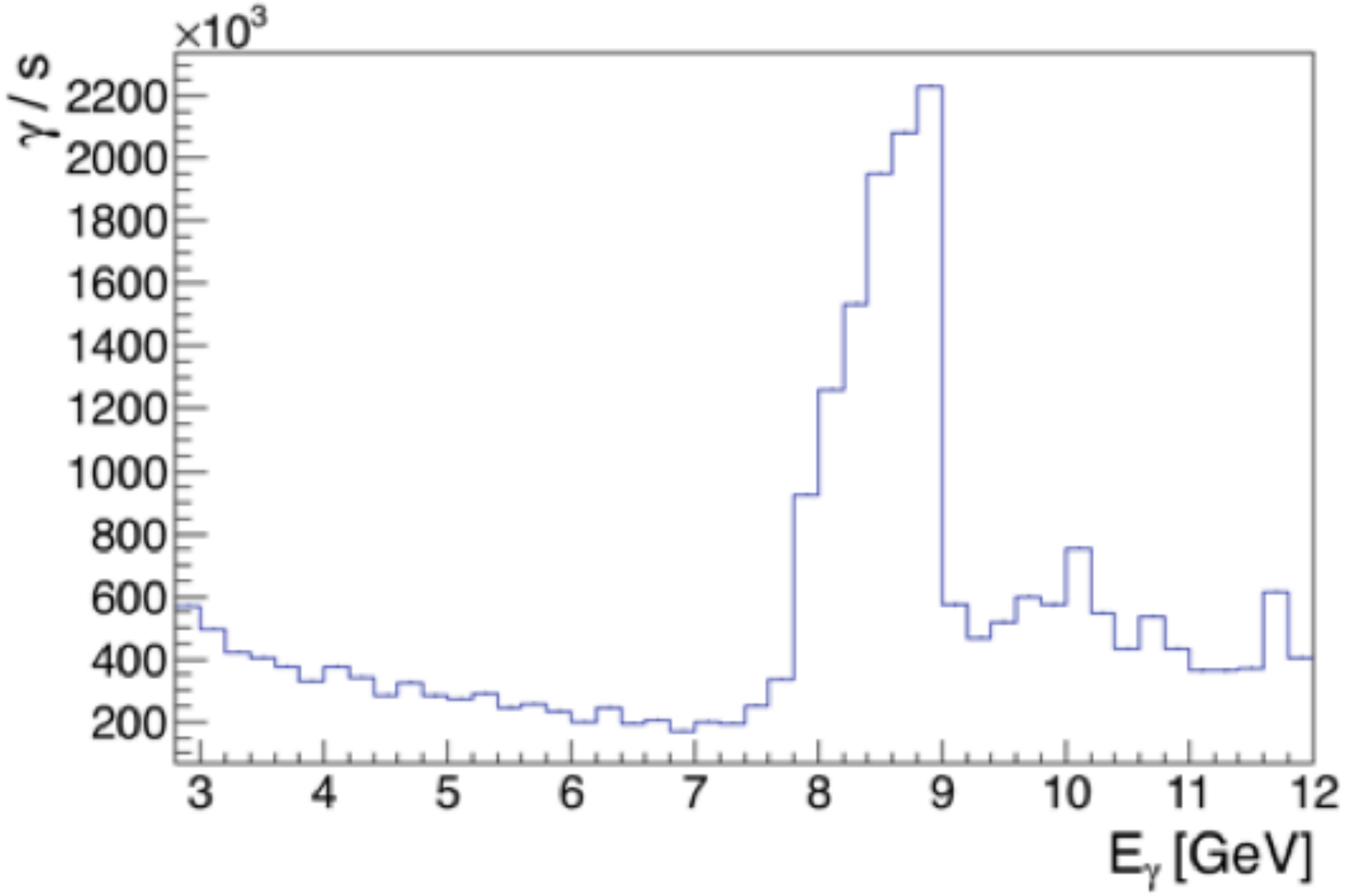

Fig. 11: Photon energy spectrum
In the standard GlueX software[13]

Targets	D_2	^{4}He	^{12}C
Beam energy		10.8 GeV	
Beam current	140 nA	150 nA	150 nA
Radiator		3.9×10^{-4} R.L. diamond	
Photon polarization		0°, 45°, 90°, 135°	
Collimator aperture		5.0 mm	
Photon flux		$\sim 2 \times 10^7$/s	
Duration of production	3.8 days	9.0 days	13.5 days
Event triggers	16.0 B	26.6 B	44.8 B
Luminosity ($E_\gamma > 7$ GeV)	17.1 pb^{-1}	16.1 pb^{-1}	6.9 pb^{-1}

Table 1: Summary of the SRC/CT experiment

Experimental details
GlueX detector

- Tagged photon beam
- Pair spectrometer
- Targets
- Tracking detectors
- Electromagnetic calorimeters
- Scintillation detectors

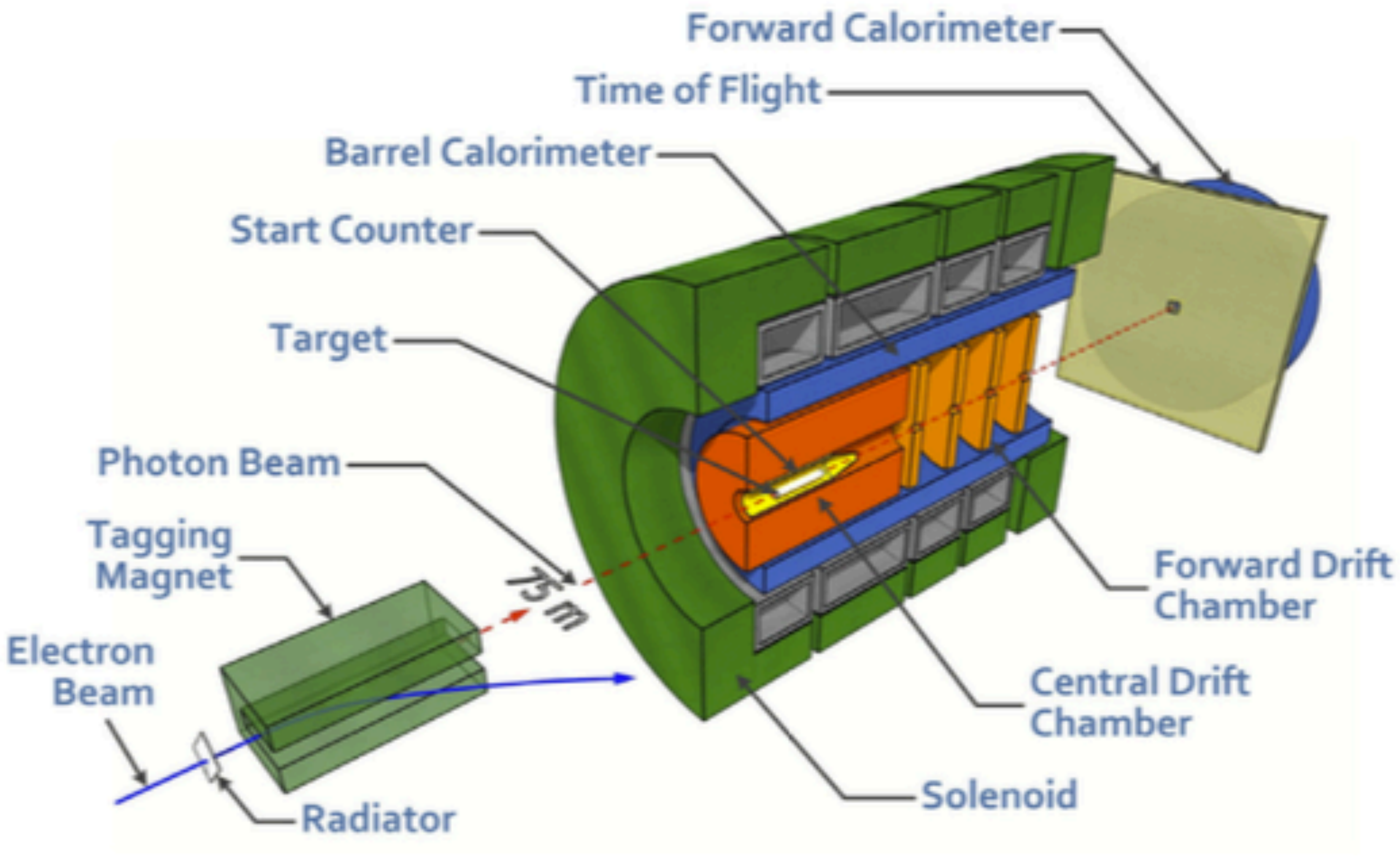

Fig. 13: A cut-away drawing of the GlueX detector, not to scale[14]

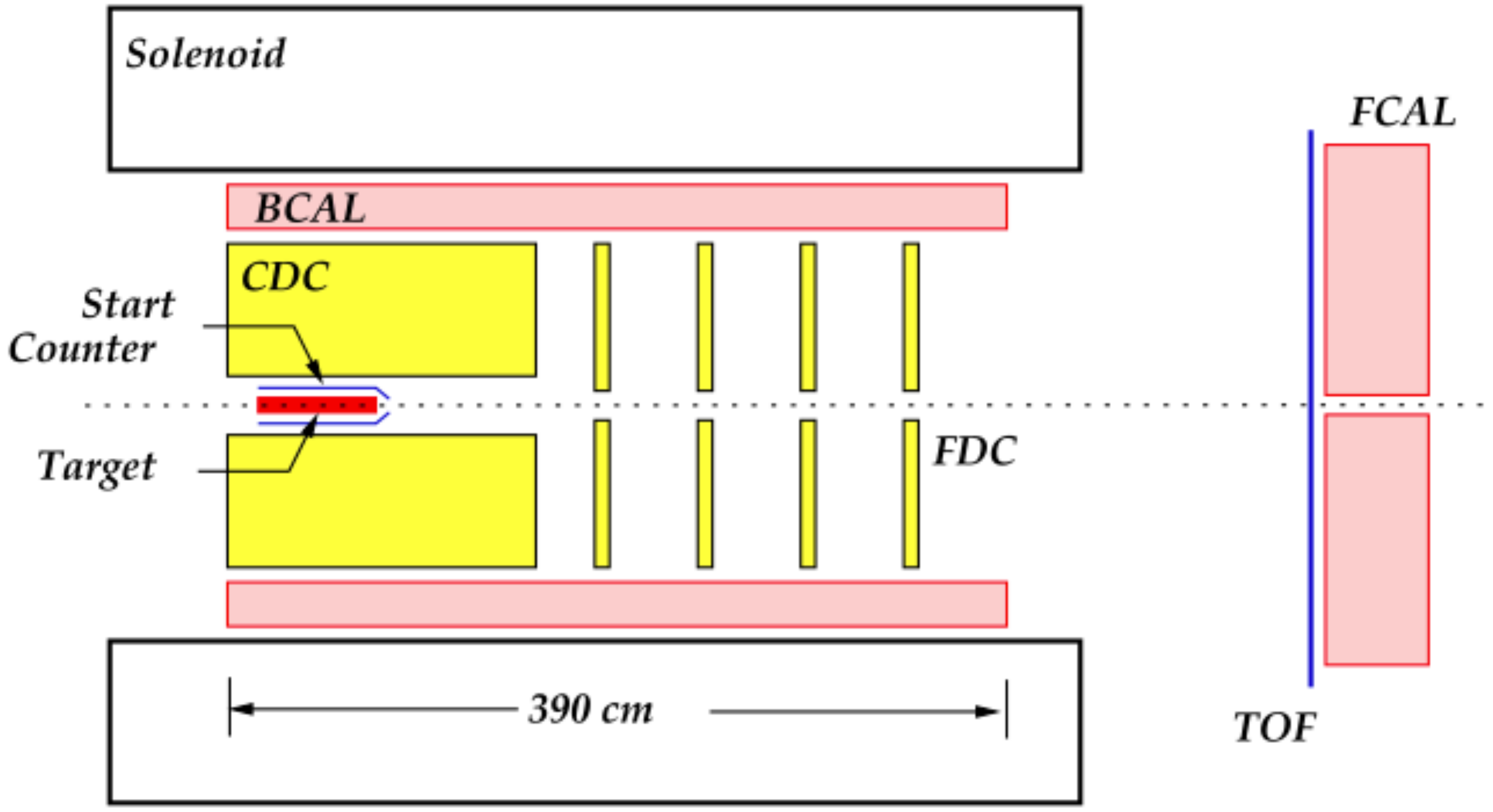

Fig. 14: Cross section view of the GlueX detector[15]

Preliminary analysis

$\gamma d \rightarrow \phi p(n) \rightarrow K^+K^- p(n)$ channel

- Cuts applied
- Detector timing cuts
- Confidence level cut: CL>0.1
- Missing mass squared cut:
  0.85 GeV$^2 < MM^2 < 0.95$ GeV^2
- Coplanarity cut:
  $170^\circ < |\phi_\phi - \phi_p| < 190^\circ$

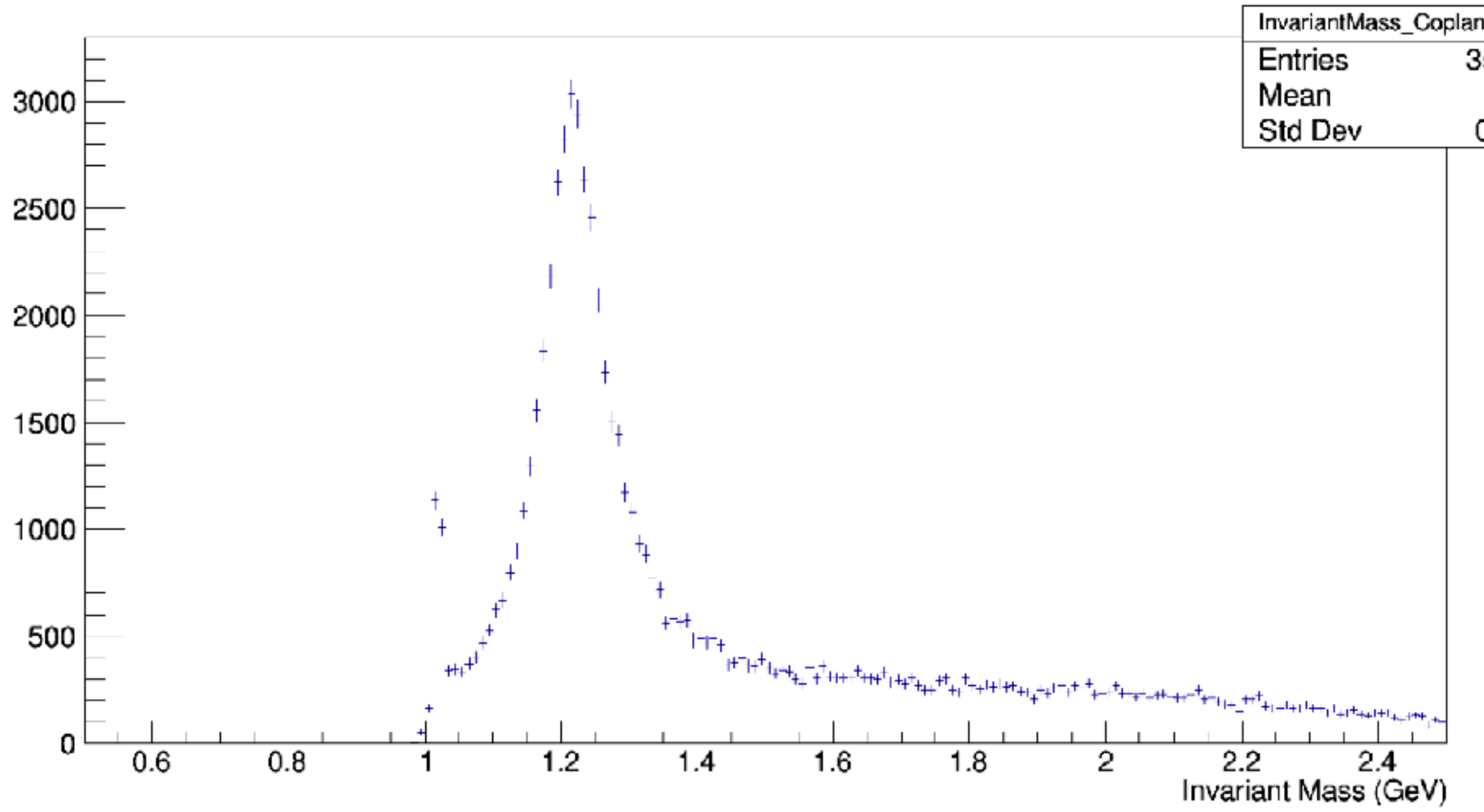

Fig. 29: K^+K^- invariant mass after the cuts

Preliminary analysis

Under development

- $\gamma n \to \phi n$ channel : leading neutron detection with the calorimeters
- $\gamma A \to \phi A$: coherent production on nucleus

Summary

- ϕ meson is unique to study gluon exchange at low energies and probe the hidden strangeness in the nucleons
- SRC/CT experiment offers great opportunity to measure its photo-production on different nuclear targets
- Production on proton, neutron and coherent are being investigated

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