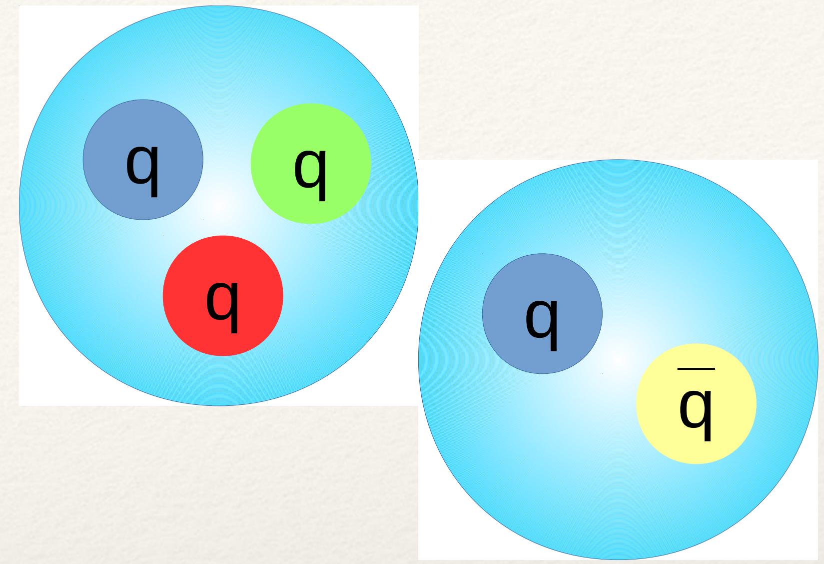
Peter Hurck

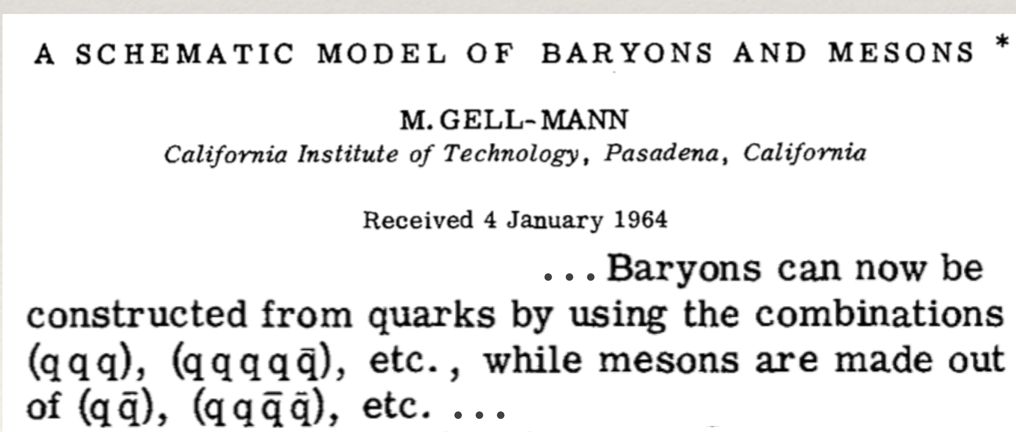
Strange physics at GlueX

JLUO Annual Meeting 2023

Introduction

- QCD gives rise to spectrum of hadrons
  - Study quarks as degrees of freedom
  - Many $q\bar{q}$ and qqq states have been observed
  - $q\bar{q}q\bar{q}$, $qqqq\bar{q}$, … are not forbidden!




A SCHEMATIC MODEL OF BARYONS AND MESONS *

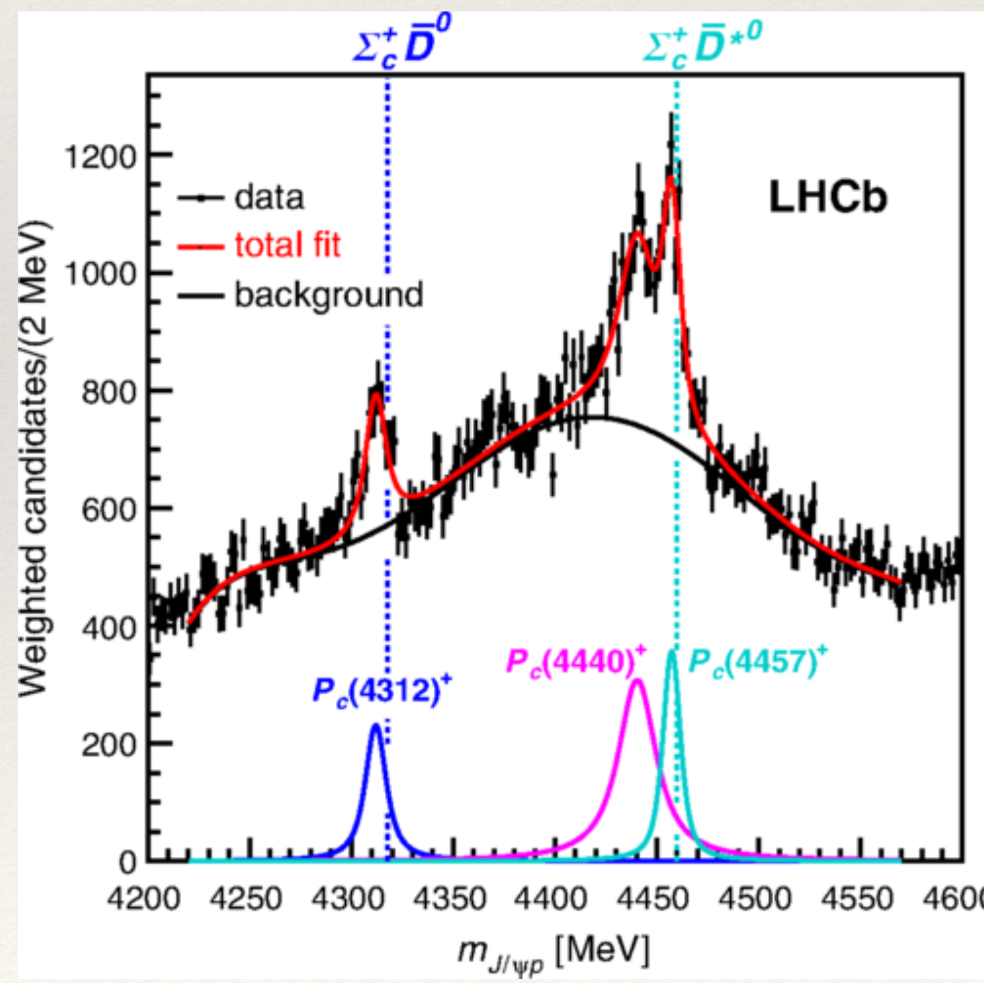
M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

. . . Baryons can now be constructed from quarks by using the combinations $(q\,q\,q)$, $(q\,q\,q\,q\,\bar{q})$, etc., while mesons are made out of $(q\,\bar{q})$, $(q\,q\,\bar{q}\,\bar{q})$, etc. . . .

Phys. Lett. 8 (1964) 214

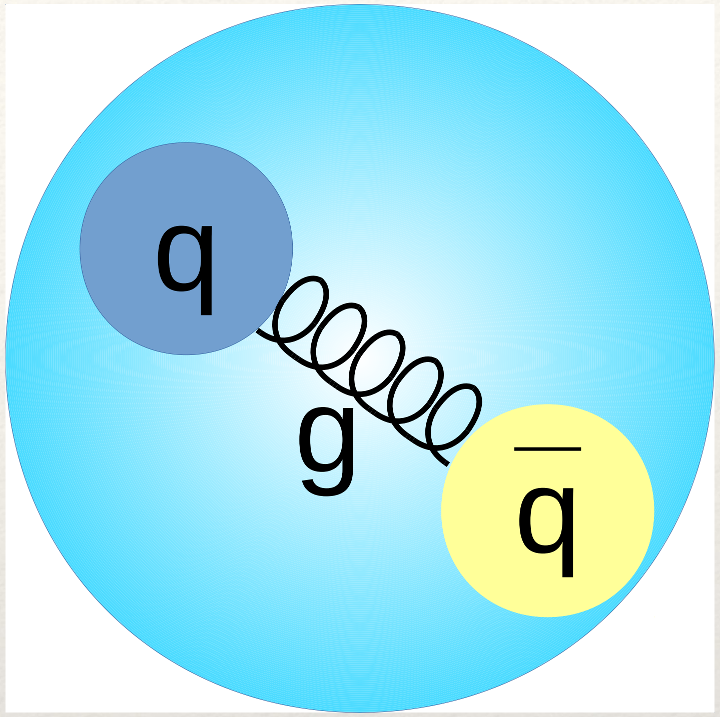
Evidence exists for pentaquark states:



LHCb, Phys. Rev. Lett. **122**, 222001

Hybrid mesons

- main objective for GlueX:
  Search and study of hybrid mesons



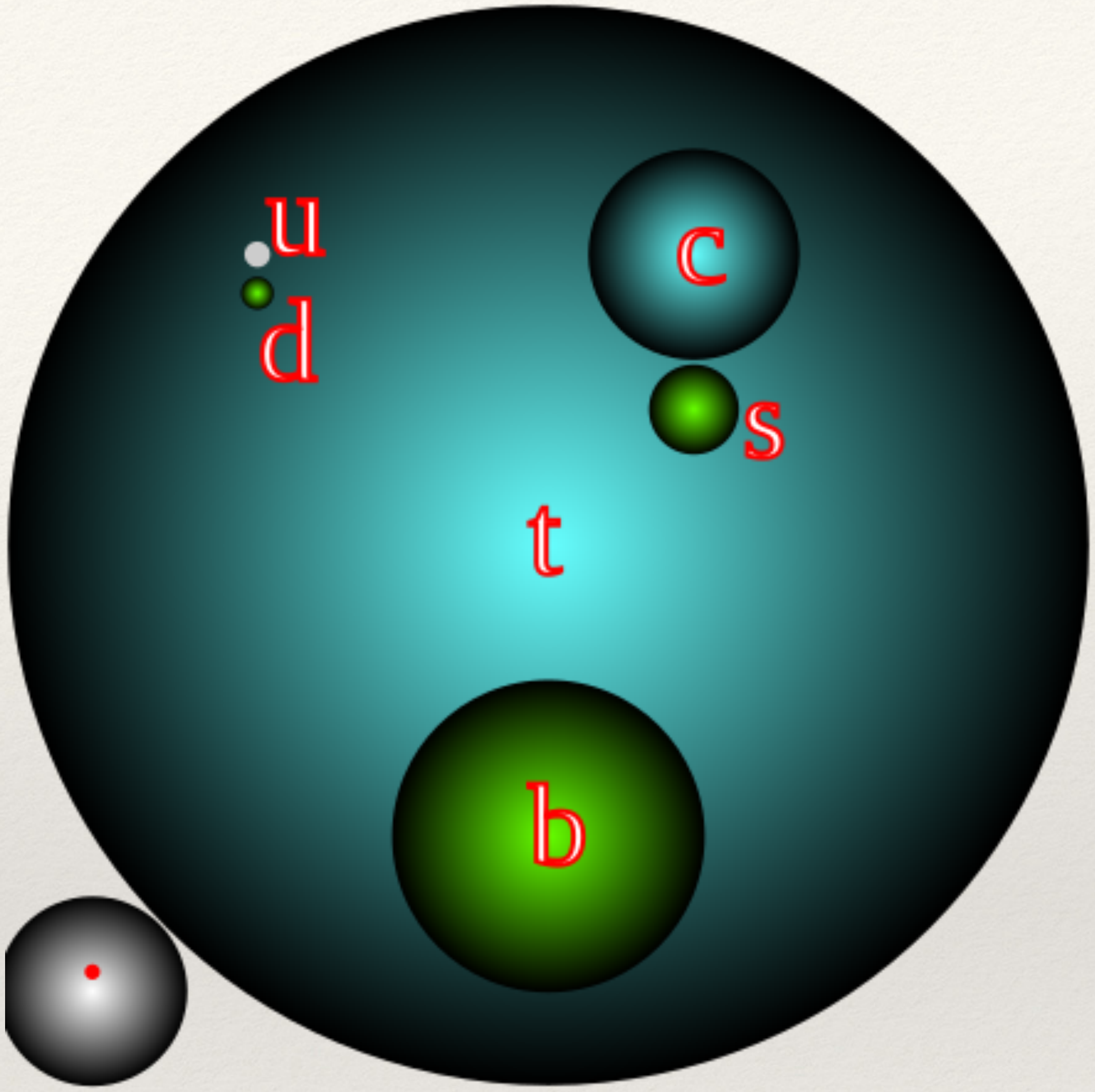
- In quark model:
  $\vec{J} = \overrightarrow{L} + \vec{S}$, $P = (-1)^{L+1}$, $C = (-1)^{L+S}$

  → <u>not</u> allowed:
  $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, \ldots$

- "Exotic" quantum numbers are "smoking gun" for something not being pure $q\bar{q}$

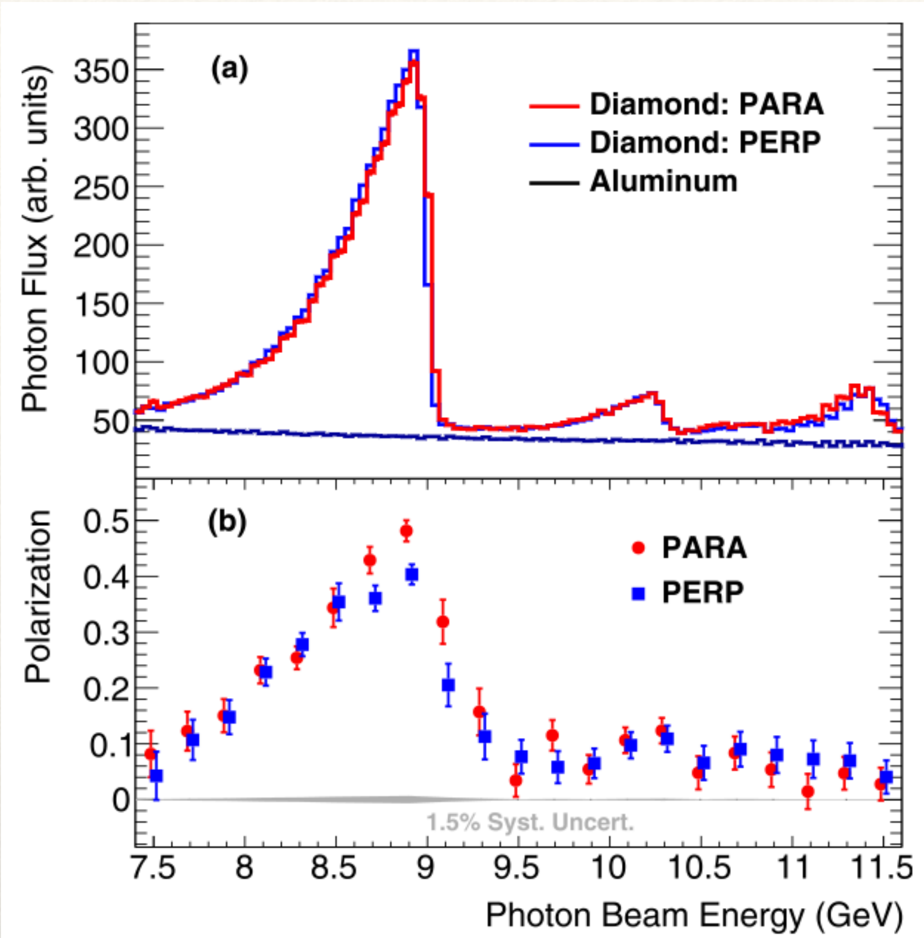
Strange quark

- Considered a light quark
  - SU(3) flavour symmetry
- Mass approx. 90-95 MeV
- $$\frac{m_s}{(m_u + m_d)/2} \approx 27.5$$
- $$\frac{m_c}{m_s} \approx 12$$
- A potential bridge to connect QCD with light (u, d) and heavy (c, b) quarks



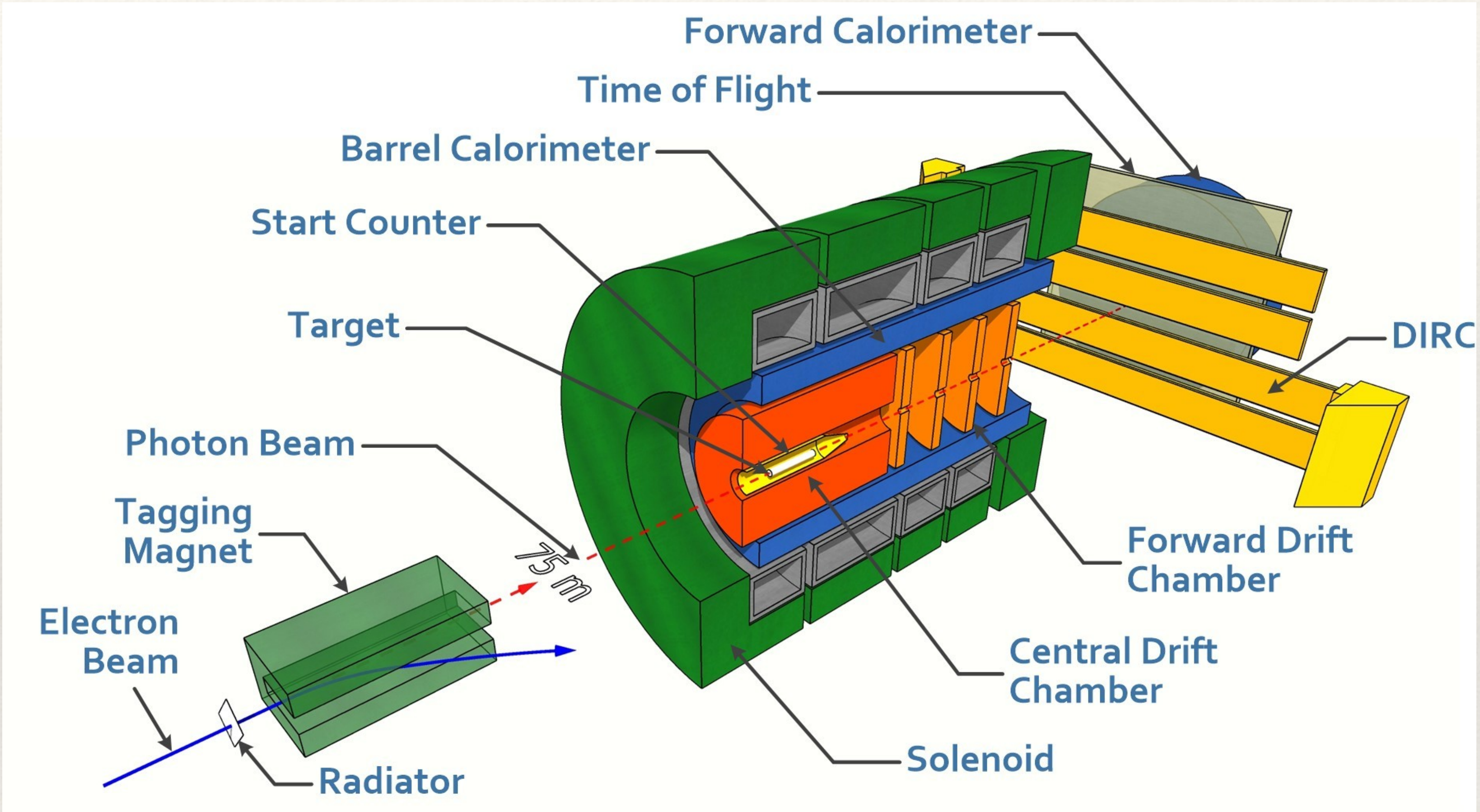
https://commons.wikimedia.org/wiki/File:Quark_masses_as_balls.svg

GlueX experiment in Hall D



GlueX, Nucl. Instrum. Meth. A 987 (2021) 164807

- produce linearly polarized photon beam via coherent bremsstrahlung on thin diamond



- tag electrons to determine photon energy

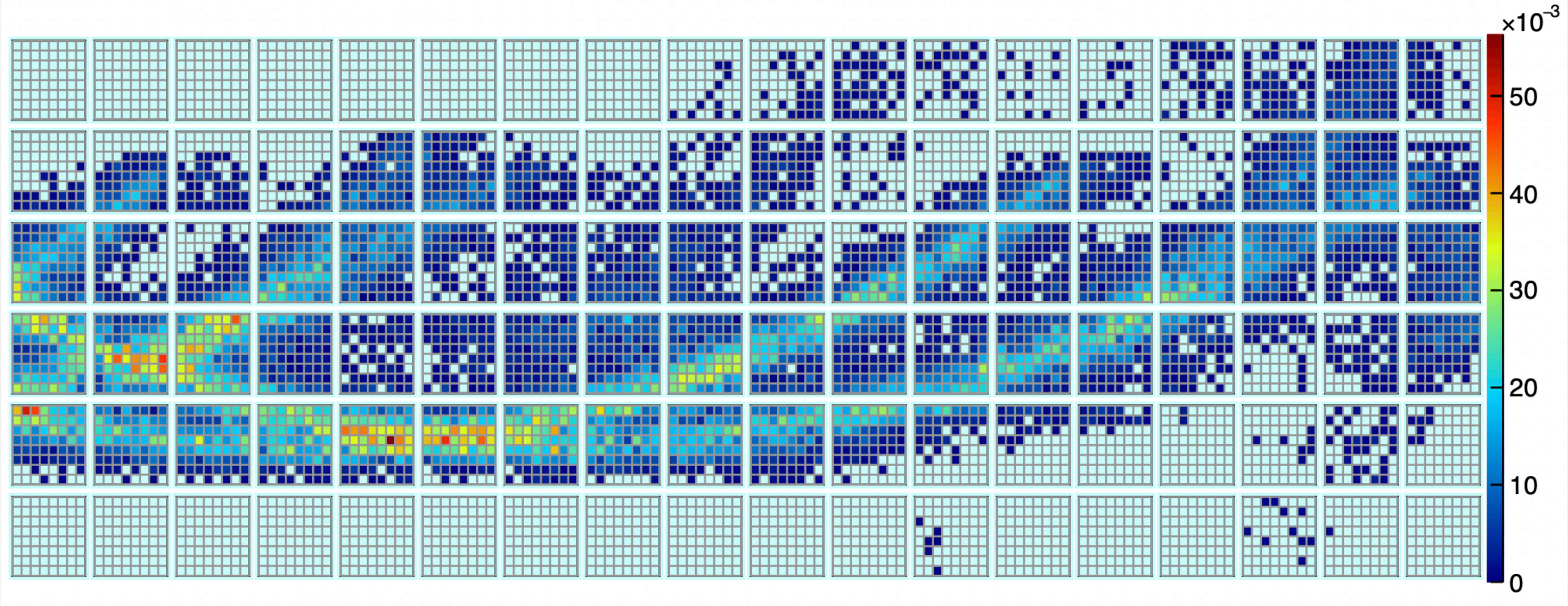
2017-2018 GlueX-I
Since 2019 GlueX-II

- Acceptance: $\theta_{lab} \approx 1^\circ - 120^\circ$
- Charged particles: $\sigma_p/p \approx 1\% - 3\,\%$ ($8\% - 9\,\%$ very-forward high-momentum tracks)
- Photons: $\sigma_E/E = 6\,\%/\sqrt{E} \oplus 2\,\%$

DIRC

- Detection of Internally Reflected Cherenkov light
- Installed and commissioned in 2019

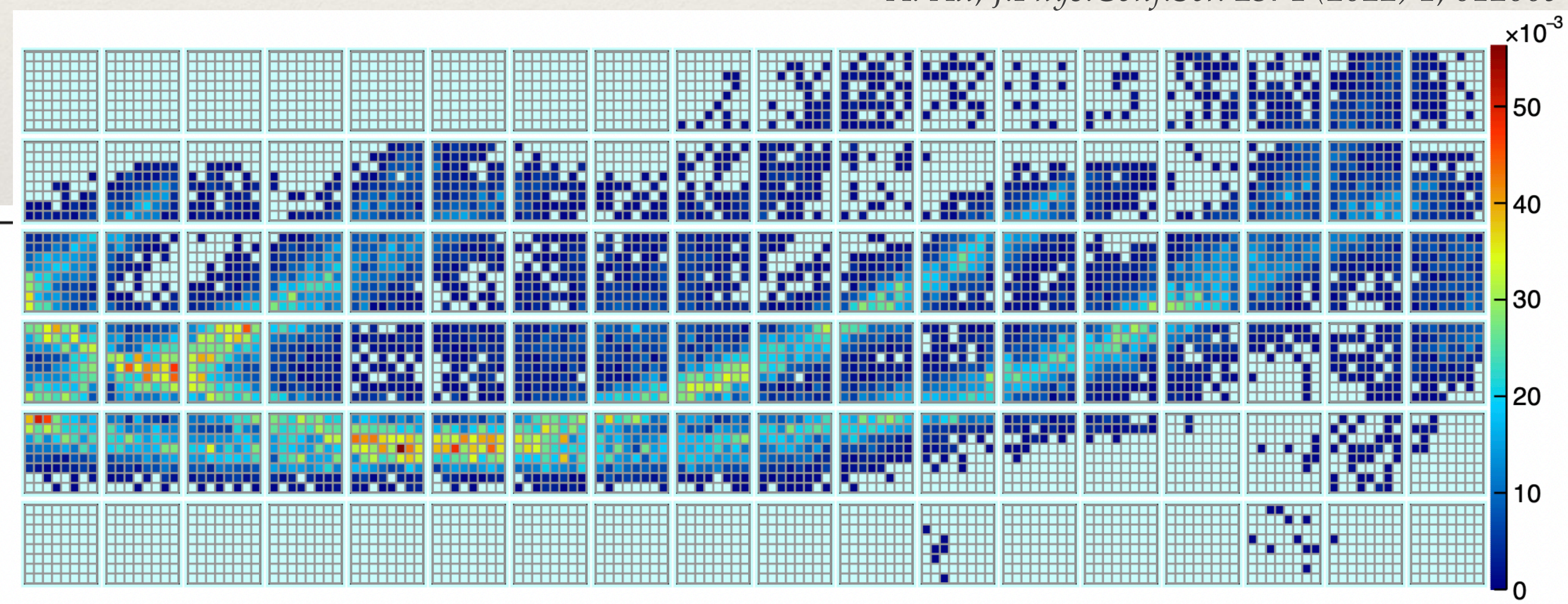
A. Ali, J.Phys.Conf.Ser. 2374 (2022) 1, 012009

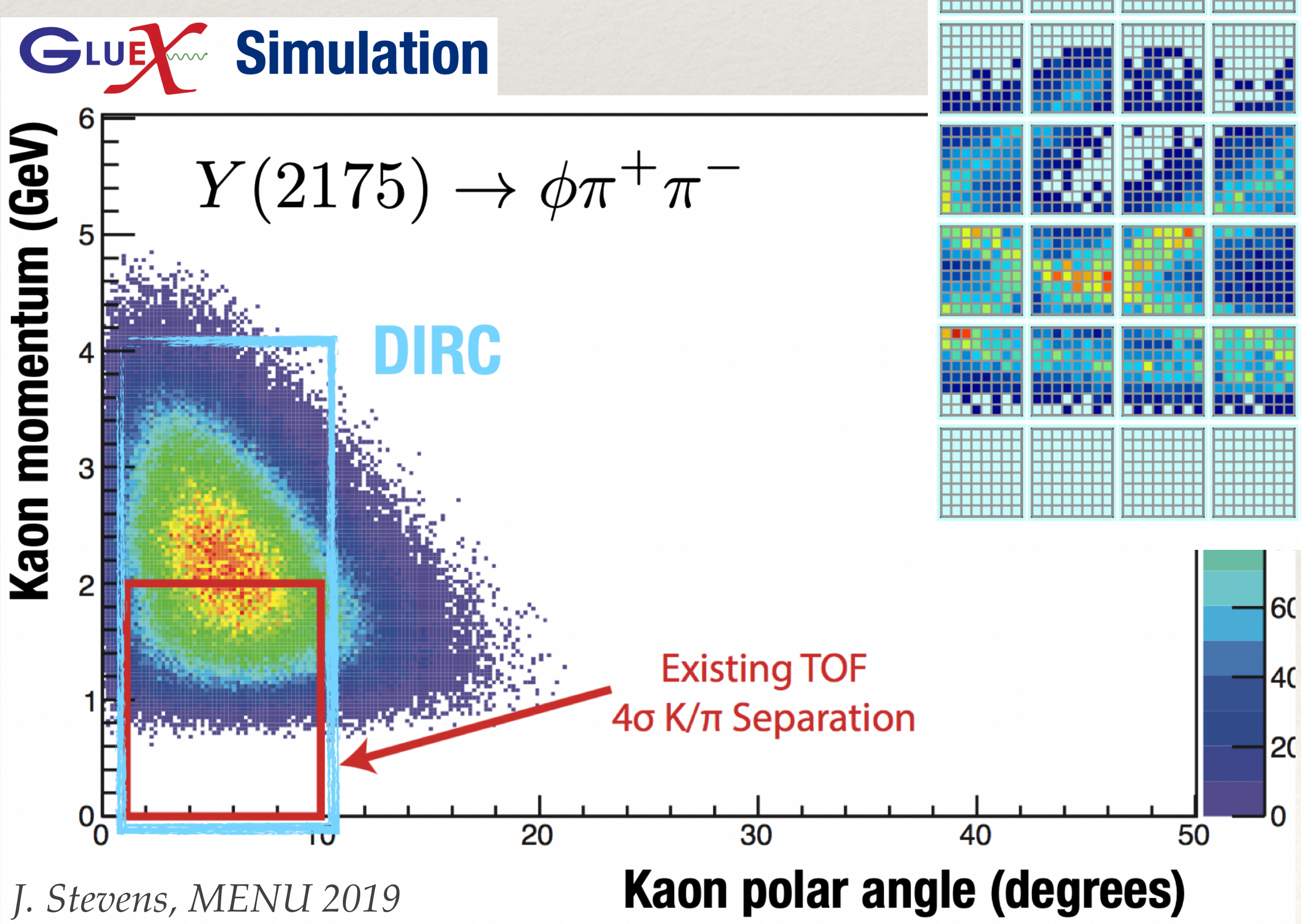


DIRC

- Detection of Internally Reflected Cherenkov light
- Installed and commissioned in 2019
- Aiming to improve pion kaon separation up to 3.5 - 4.0 GeV
    - Key for strangeness program at GlueX

A. Ali, J.Phys.Conf.Ser. 2374 (2022) 1, 012009

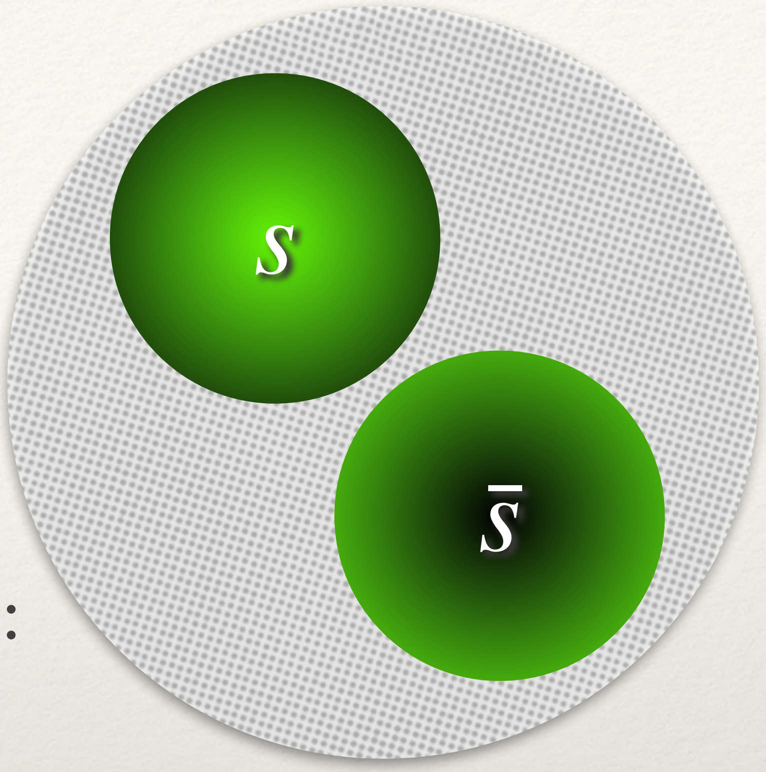




J. Stevens, MENU 2019

Strangeonium

- $s\bar{s}$ state
- Are there parallels to charmonium ($c\bar{c}$) ?

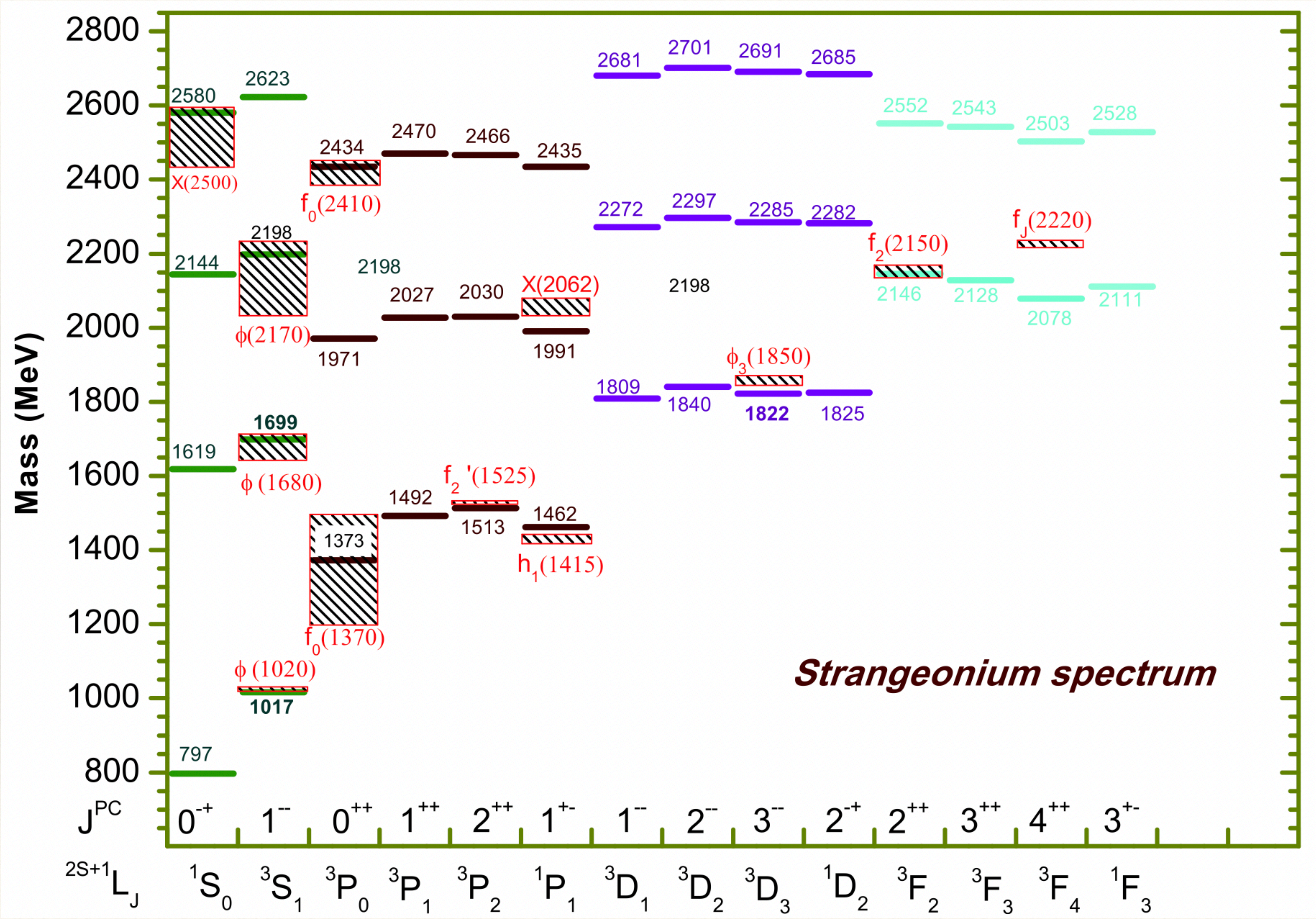


- There are only few accepted strangeonium states: $\phi(1020)$, $\phi(1680)$, $\phi_3(1850)$, $h_1(1415)$, $f_2'(1525)$
- A few candidates show dominant decays to $\phi\eta$, $\phi\eta'$, $\phi\phi$
  - Are these tetraquarks ($ss\bar{s}\bar{s}$) ?
- We need more measurements to establish a proper strangeonium spectrum

Strangeonium spectrum

nonrelativistic linear potential quark model

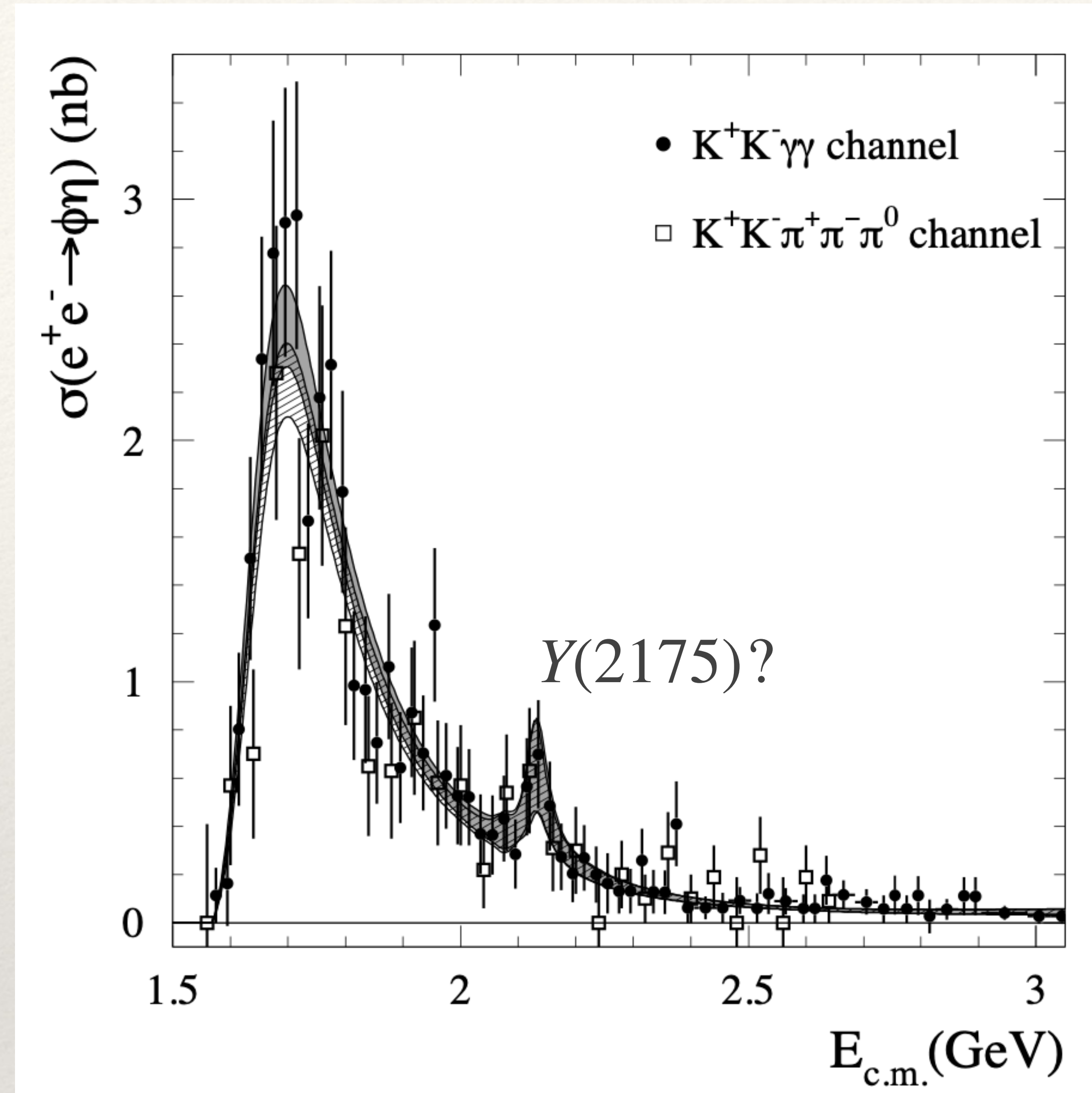
Qi Li et al 2021 Chinese Phys. C 45 023116



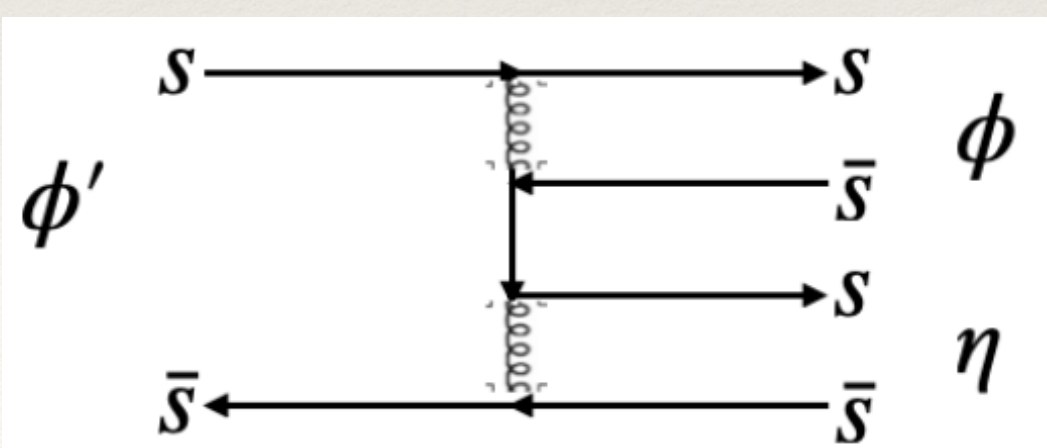
Y(2175) aka $\phi(2170)$

BaBar: Phys. Rev. D 77, 092002 (2008)

- BaBar (ISR):
  - Peaking structure at around 2175 MeV in $e^+e^- \to \phi f_0(980) \to \phi\pi\pi$
  - Peaking structure at around 2130 MeV in $e^+e^- \to \phi\eta$
- BES III in $J/\psi \to \phi f_0(980) \to \phi\pi\pi$:
  - Observed peak at 2170 MeV
- Strangeness rich environment
- Interpretation not clear, masses vary a lot

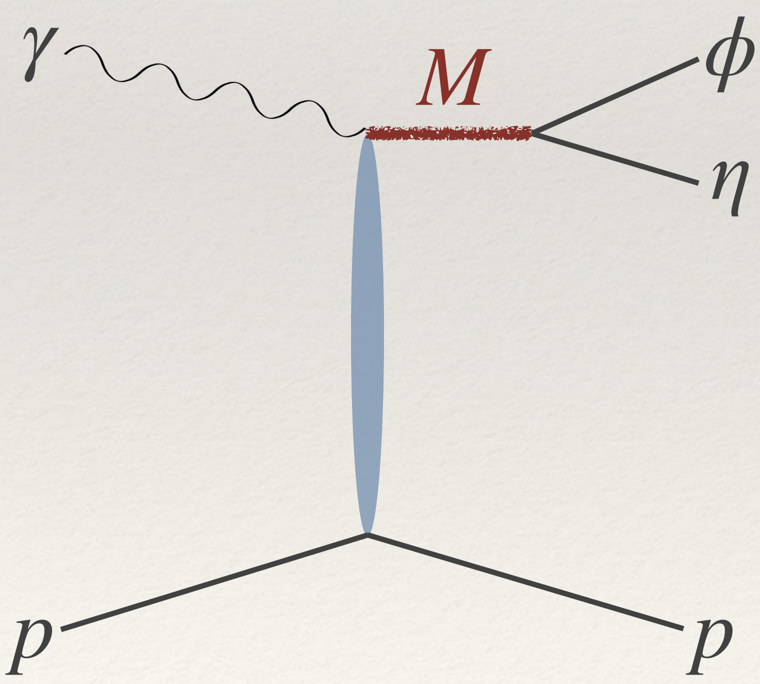


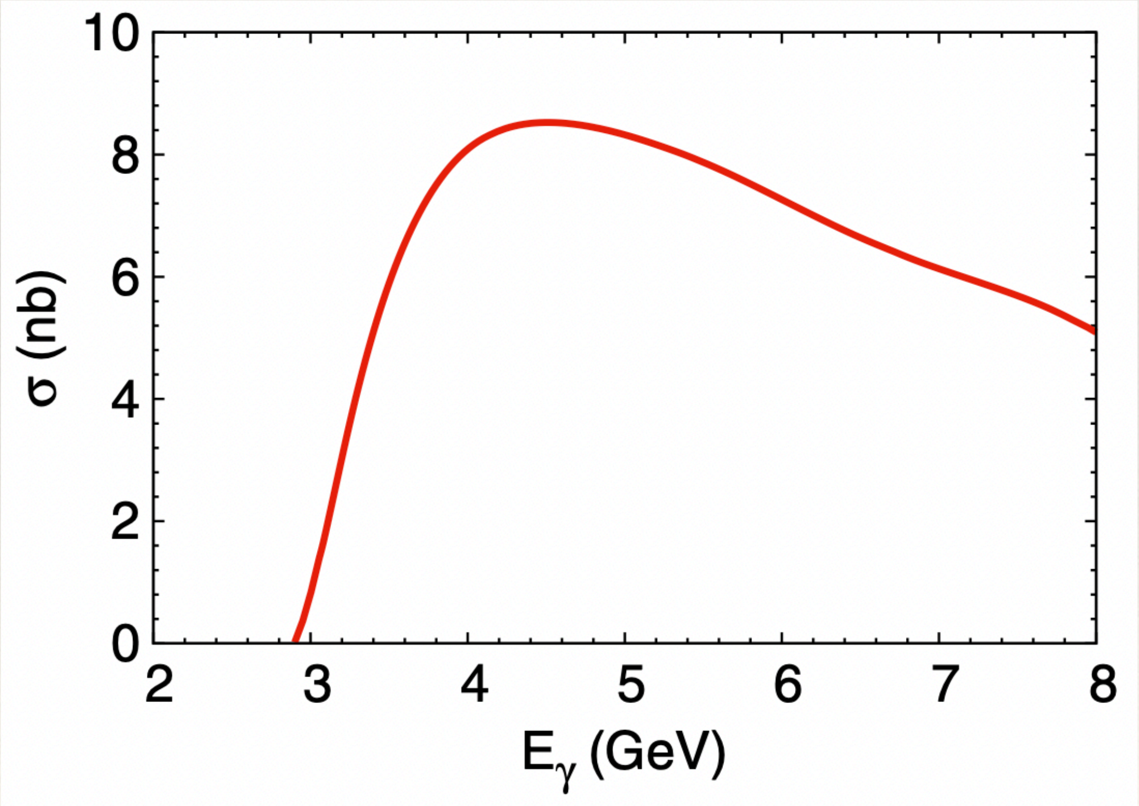
	$\frac{\chi^2}{\text{n.d.f.}} = \frac{184.9}{160-16} = 1.28$	
R with $I=0$	ϕ'	ϕ''
$\Gamma^R_{ee}\mathcal{B}^R_{KK^*(892)}$(eV)	367±47	-
$\Gamma^R_{ee}\mathcal{B}^R_{\phi\eta}$(eV)	154±32	1.7±0.8
$1-\mathcal{B}^R_{KK^*(892)}-\mathcal{B}^R_{\phi\eta}$	0.33±0.14	-
M_R(MeV)	1709±19	2127±24
Γ_R(MeV)	325±68	60±50



$\gamma p \to \phi \eta p$

- Study $\gamma p \to \phi \eta p$ with $\phi \to K^+K^-$ and $\eta \to \gamma\gamma$
  - Vector-pseudoscalar: same spin-structure as $\omega\pi$
  - Make use of well developed formalisms
  - Access to exotic quantum numbers 0^{--} and 2^{+-}





Phys. Rev. D 99, 114014

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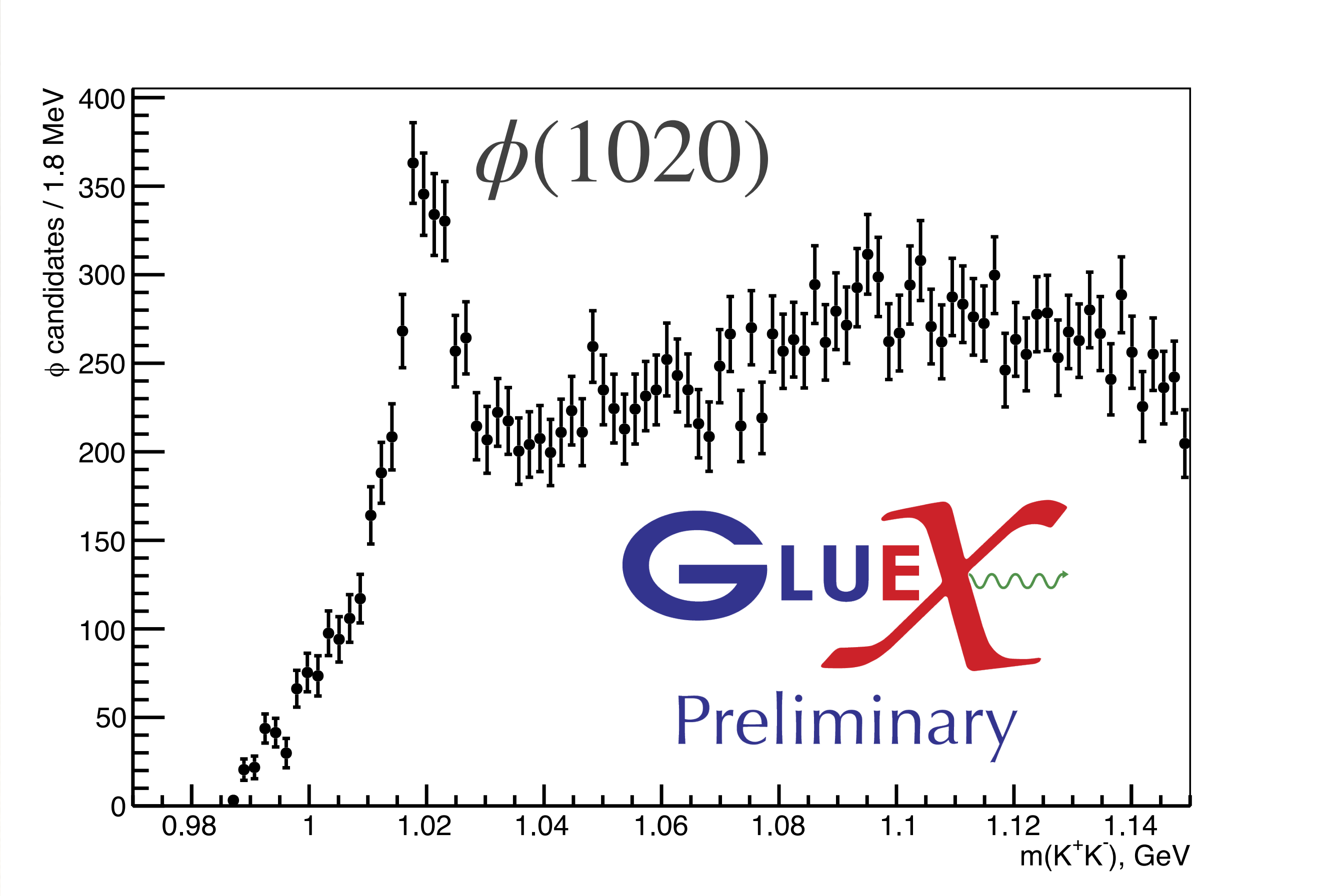
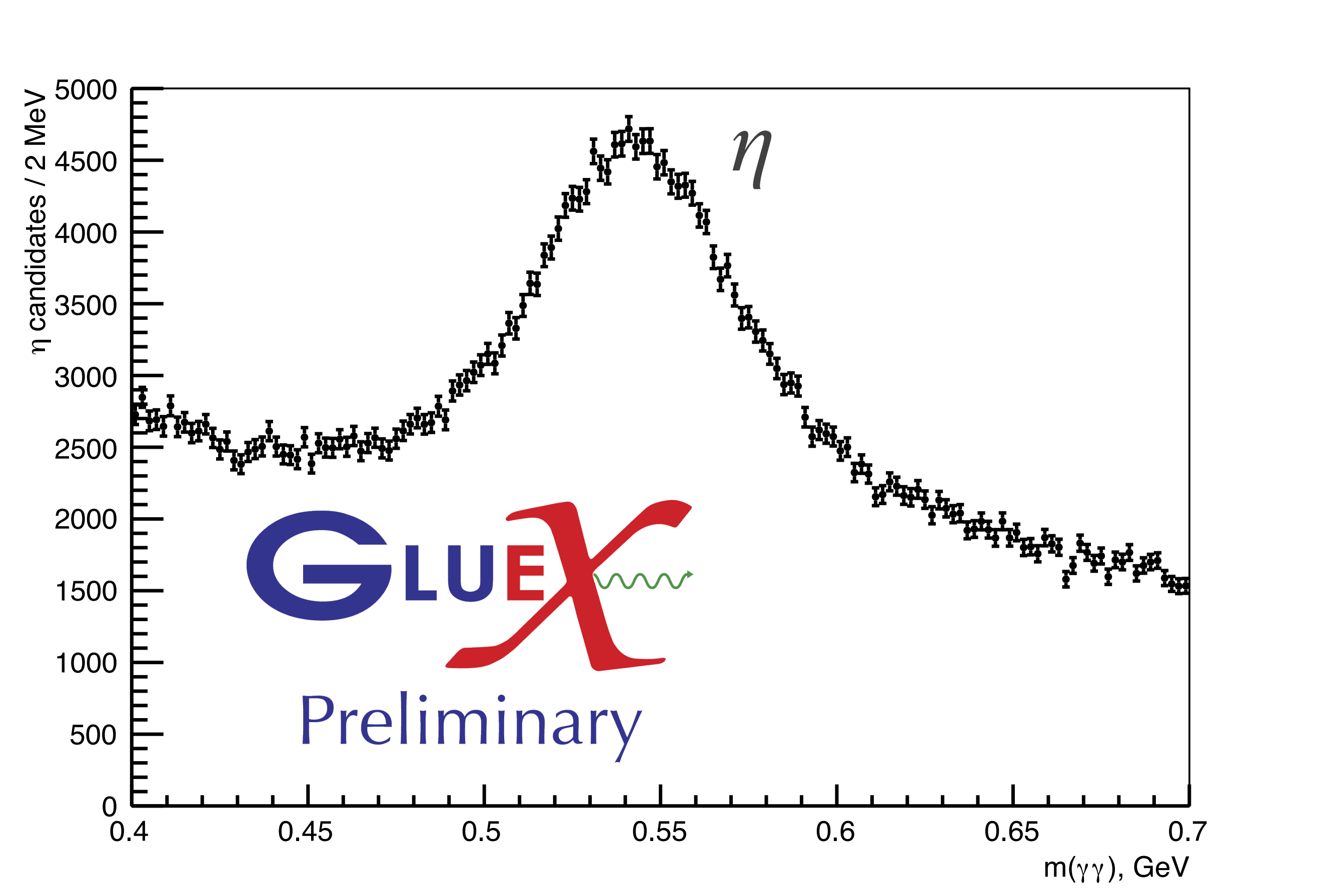
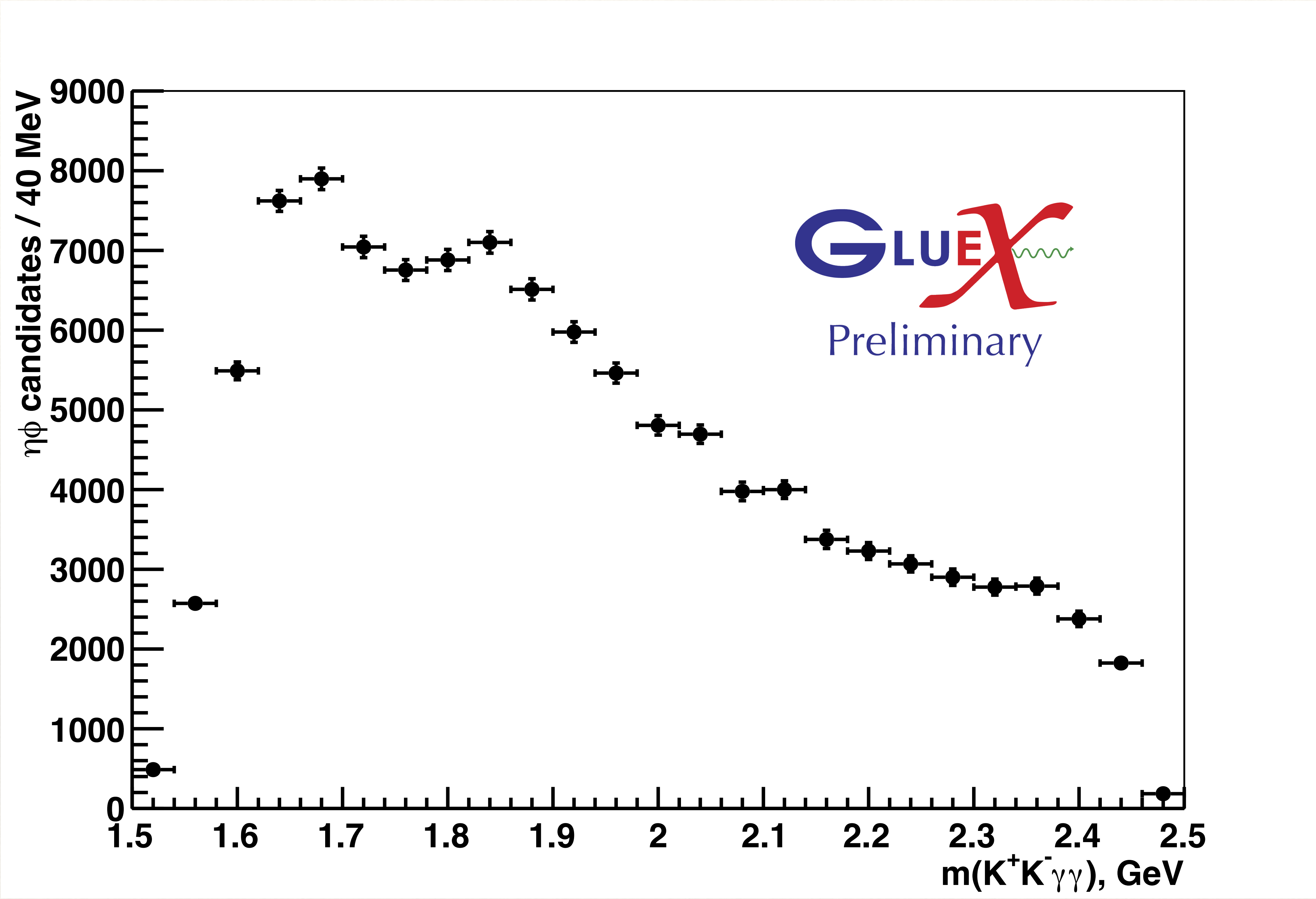




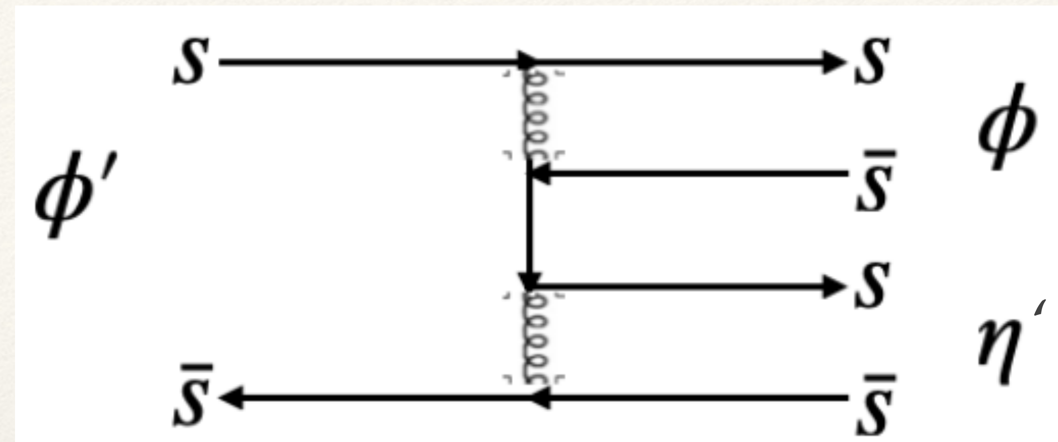
$\gamma p \to \phi \eta p$



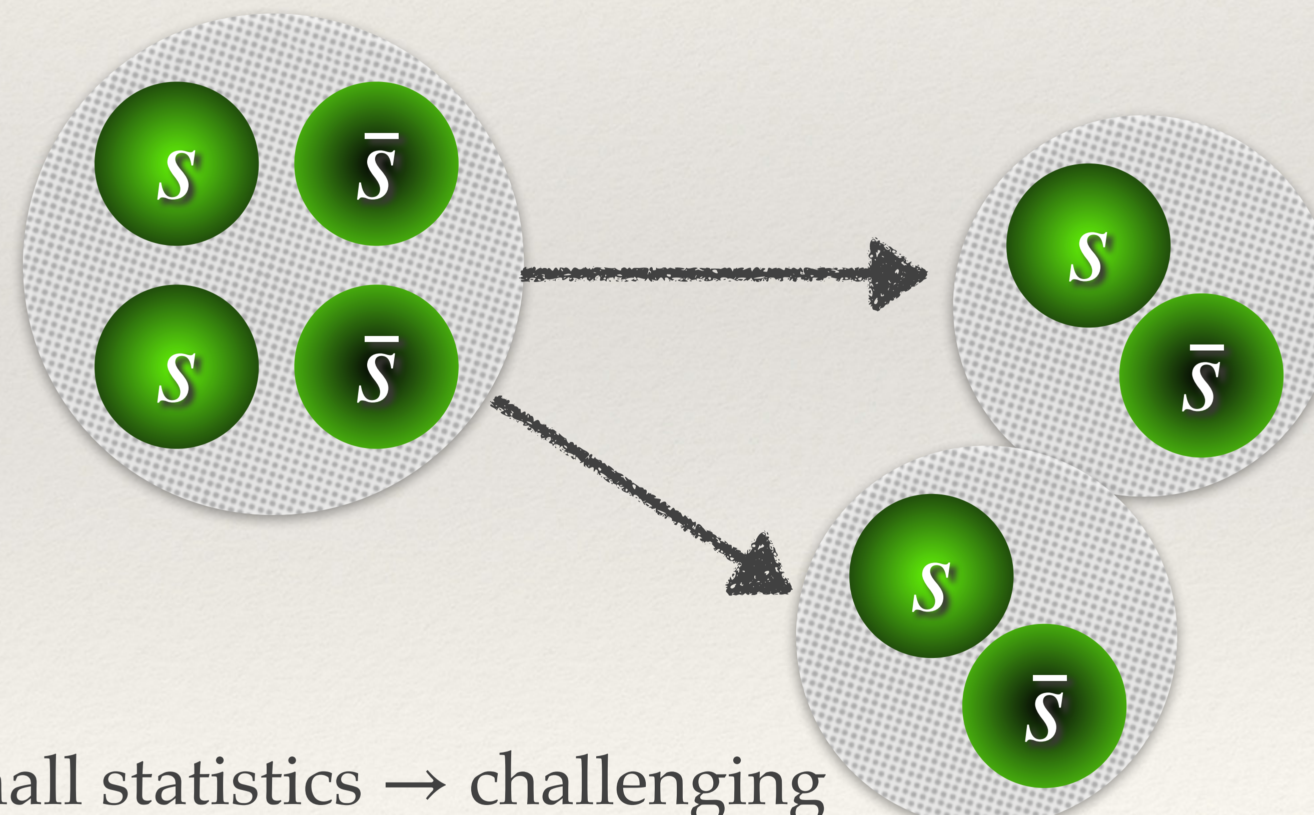
- Increase stats with alternative decay channels $\phi \to K_S K_L$ and $\eta \to \pi^+\pi^-\pi^0$
- (Mass dependent) partial wave analysis needed to identify resonances

Other interesting reactions

- $\gamma p \to \phi \eta' p$
  - η' also has $s\bar{s}$ component
  - Same spins involved
  - Smaller statistics
  - Will come into reach with complete GlueX-II data set

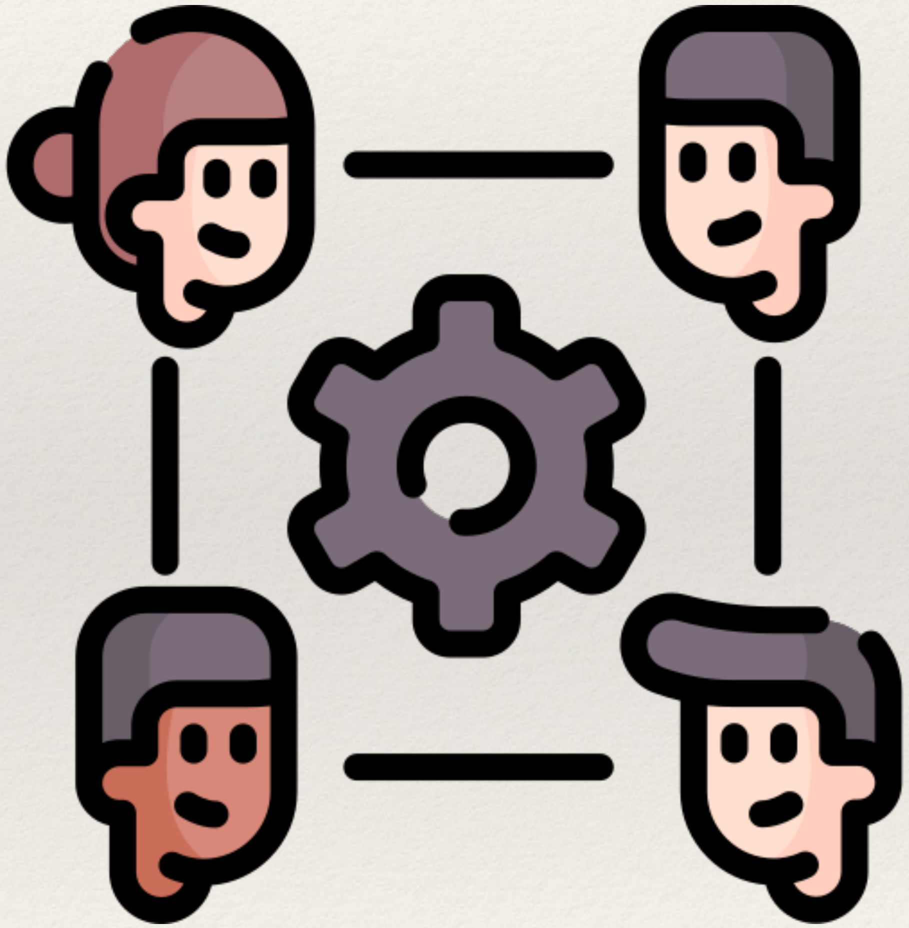


- $\gamma p \to \phi \phi p$
  - Potential for tetra quark discovery
  - Parallels to $T_{cc\bar{c}\bar{c}} \to J/\psi \; J/\psi$
  - More complicated analysis and small statistics → challenging



Workshop

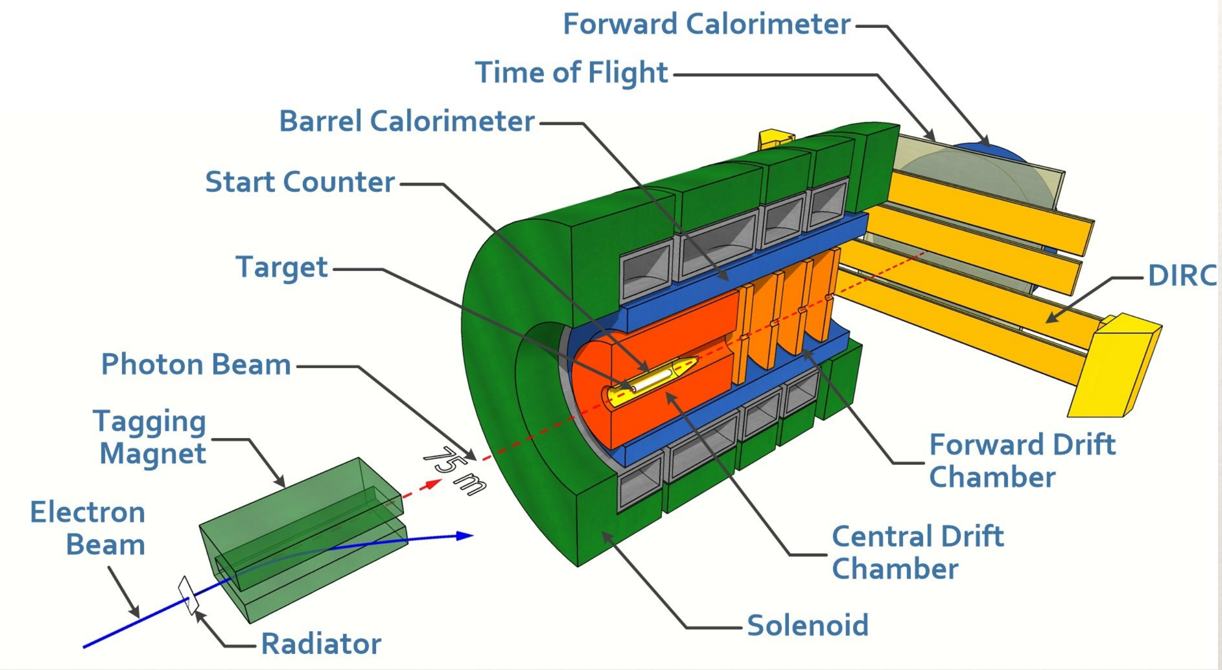
- Use prize money to organise a workshop on strange physics
- Bring theory and experiment together to identify key measurements as well as stumbling blocks
- Tentatively aimed for early 2024
- Possible topics:
  - Strangeonia and excited kaons
  - Hyperon spectroscopy
  - $\Lambda(1405)$
  - Analysis techniques
  - New experiments
  - …



Workshop icons created by Freepik - Flaticon

Summary and outlook

- This is an exciting time to study hadrons containing strange quarks
- GlueX is accumulating a world leading data set for photo production
- DIRC is extending our reach to strange sector
  - Study strangeonia and hyperons



- In the future KLong in Hall D will provide new opportunities for studying the spectrum of strange mesons and baryons

Thank You!

gluex.org/thanks