Hadron Spectroscopy with the GlueX Experiment

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Florida State U.
[For the GlueX Collaboration]

Snowmass21 RPF Townhall, Oct. 2, 2020
LOI: https://www.snowmass21.org/docs/files/summaries/RF/SNOWMASS21-RF7_RF0_Dobbs-079.pdf

GlueX and Hadron Spectroscopy

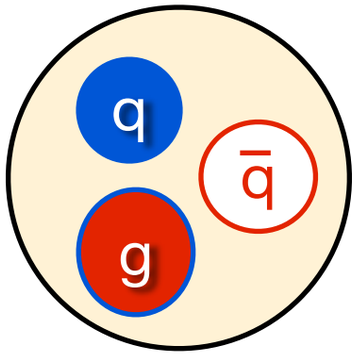
- Key question: How do gluons contribute to the spectrum and structure of hadrons?
  - Do gluonic degrees of freedom manifest in the hadronic spectrum?
  - Look for states with non-qq QNs

$J=L+S \quad P=(-1)^{L+1} \quad C=(-1)^{L+S}$

meson

Allowed J^{PC} :
0^{-+}, 0^{++}, 1^{--}, 1^{+-}, 2^{++}, …

Forbidden J^{PC}:
0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, …



hybrid meson

Hybrid J^{PC} : **0^{-+}, 0^{+-}, 1^{--}, 1^{-+}, 2^{-+}, 2^{+-},** …

GlueX and Hadron Spectroscopy

- Key question: How do gluons contribute to the spectrum and structure of hadrons?
  - Do gluonic degrees of freedom manifest in the hadronic spectrum?
  - Look for states with non-qq QNs
- The GlueX Experiment is designed for hadron spectroscopy: comprehensive studies of the hybrid meson spectrum and more!
  - Fixed target, large statistics for all final states
  - Linearly polarized photon beam
  - Access to strange and charm quark states
  - Utilize scattering theory to extract resonance poles from measured amplitudes—same as state-of-the-art in the heavy quark sector

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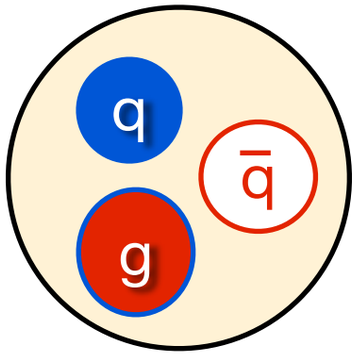

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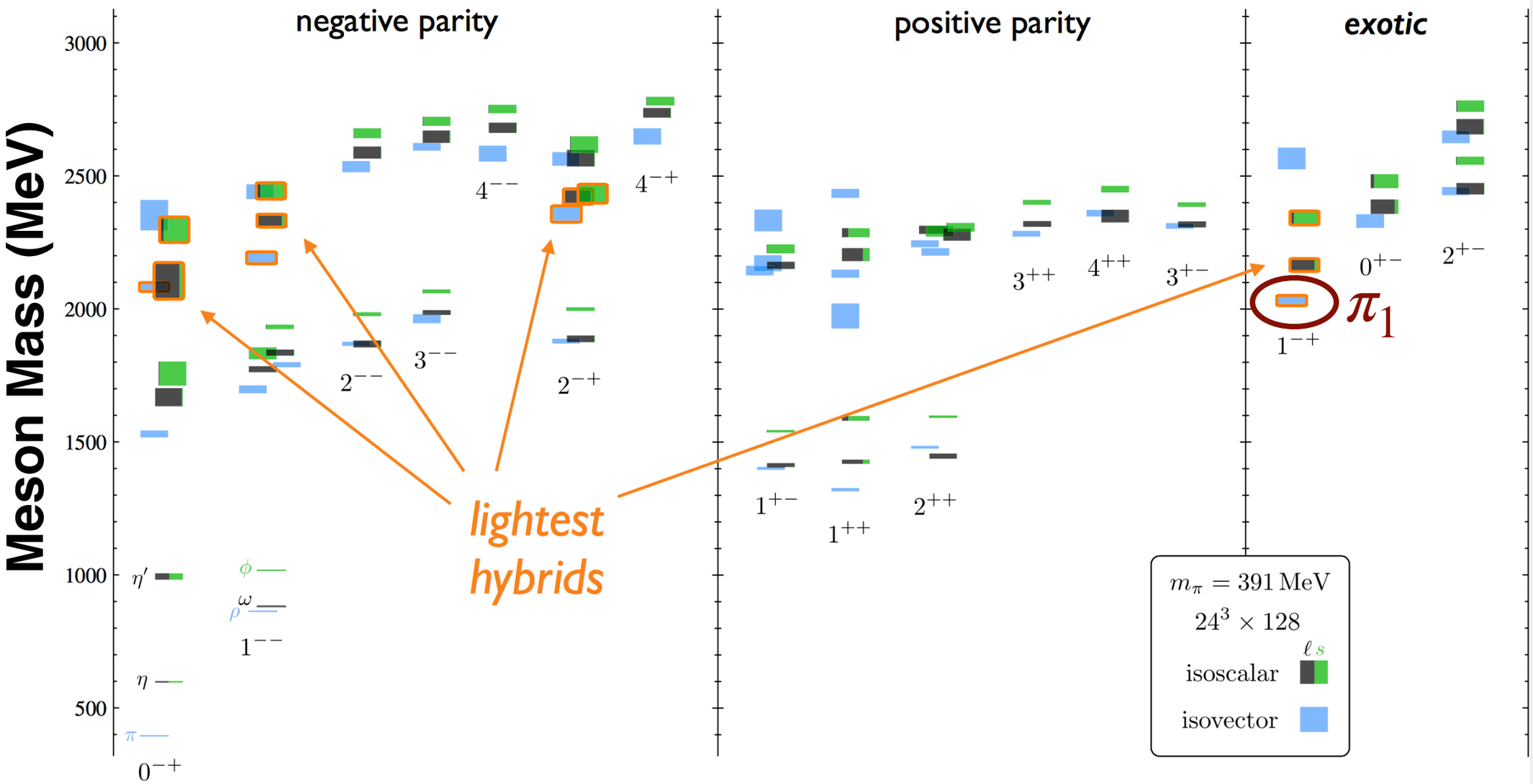
Light Meson Spectrum from Lattice QCD

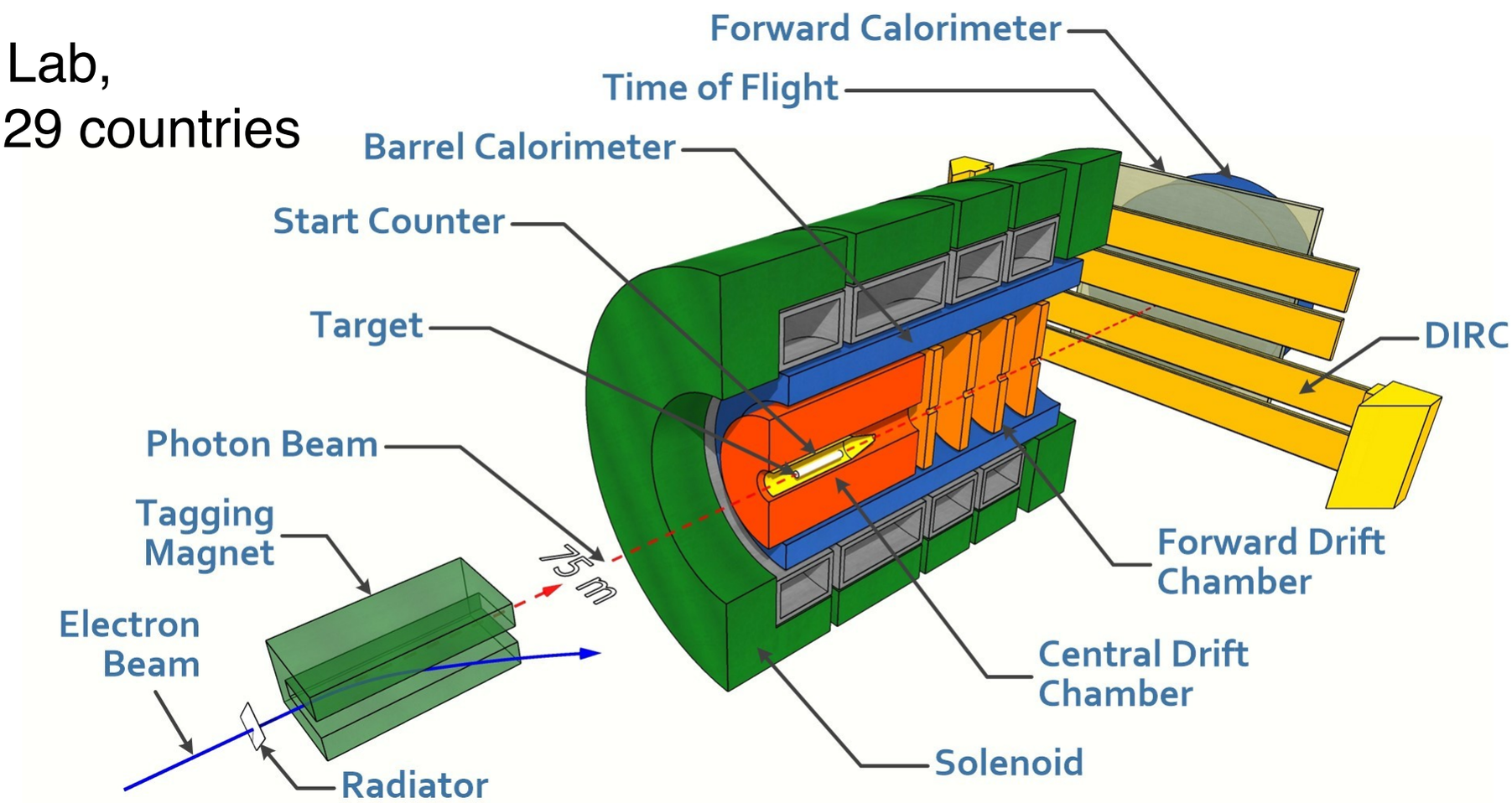
HadSpec: Dudek, Edwards, Guo, Thomas, PRD 88, 094505 (2013)

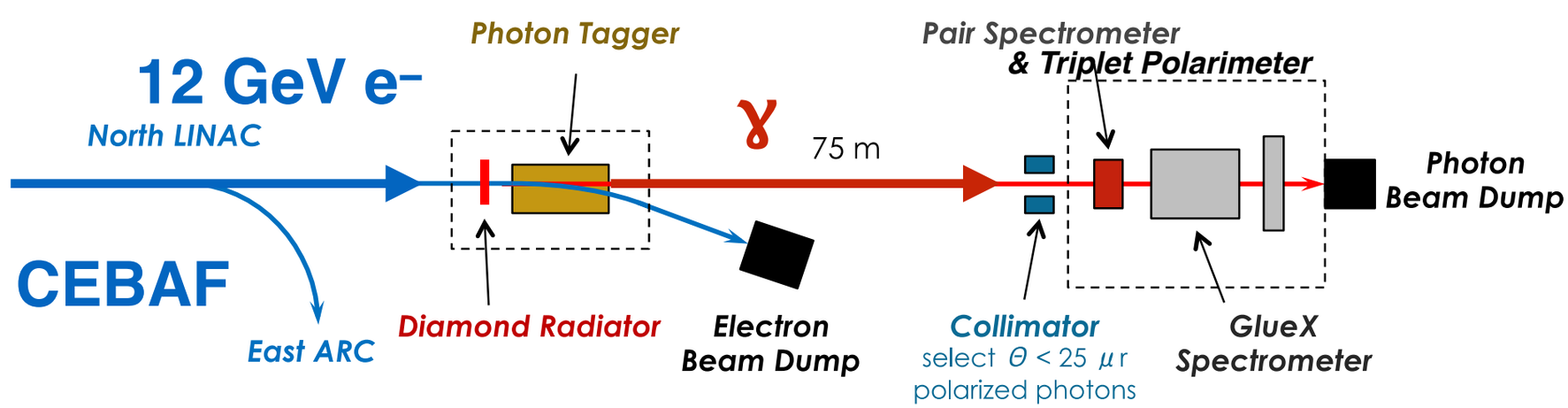


- Need to study spectrum of “exotic” and “normal” QN hybrid mesons
- Need to understand hybrid flavor structure
- Hybrid mass range also populated by strangeonia

The GlueX Experiment

- Located at Jefferson Lab, 120+ members from 29 countries
- Full acceptance, reconstruction and identification for all final state particles
- Photon beam via coherent bremsstrahlung
- Neutral final states at these energies mostly unexplored
- 2017-8 run collected 4 PB data, plan to collect at least 4 times more





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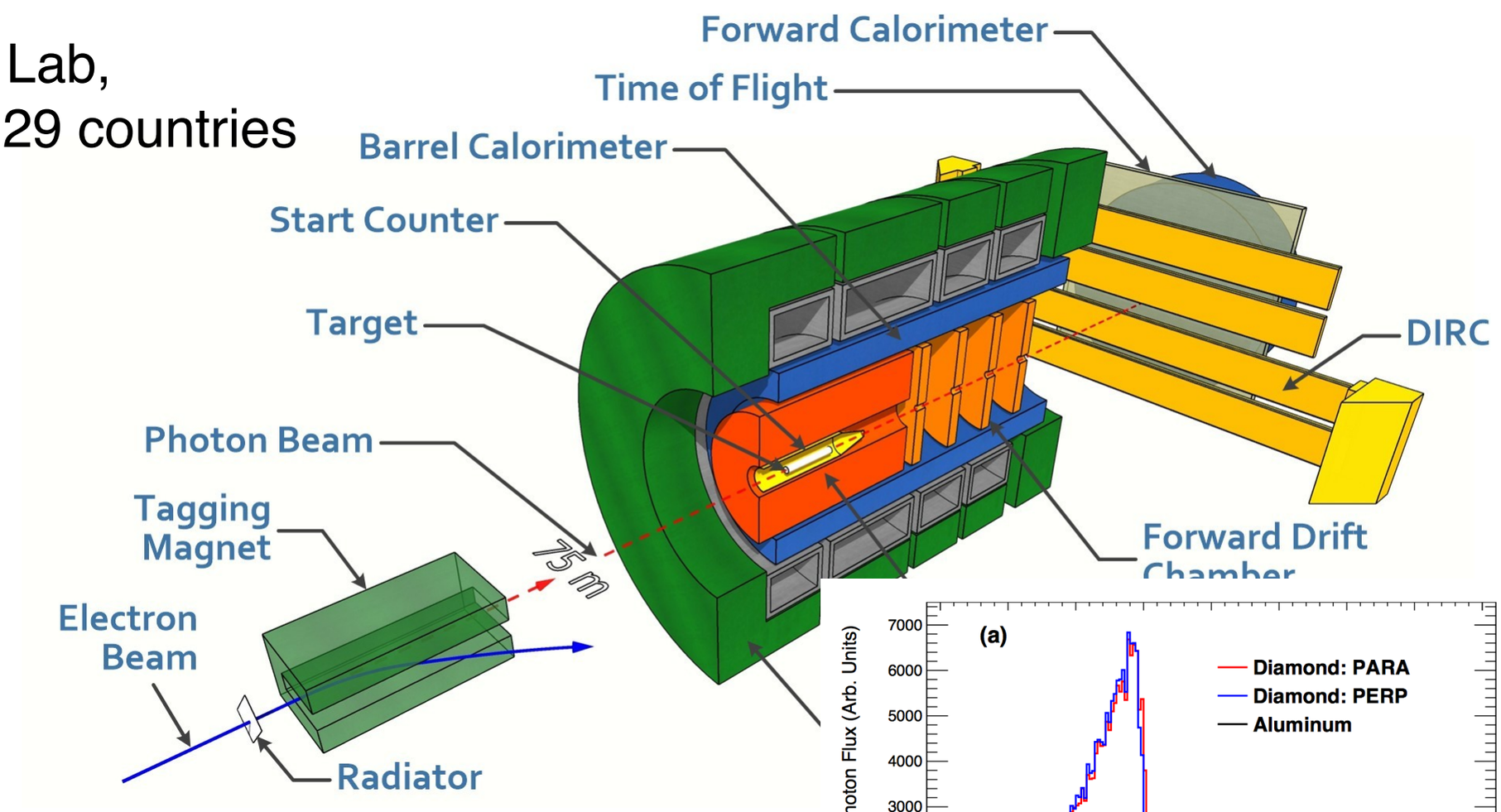
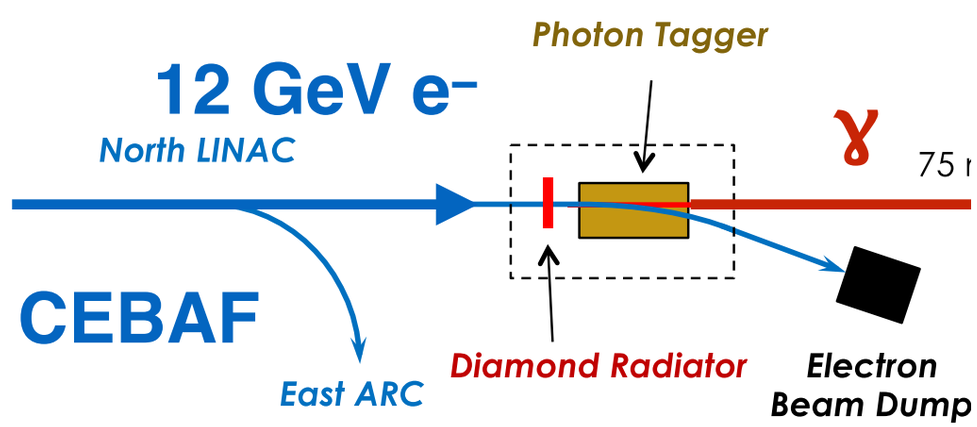
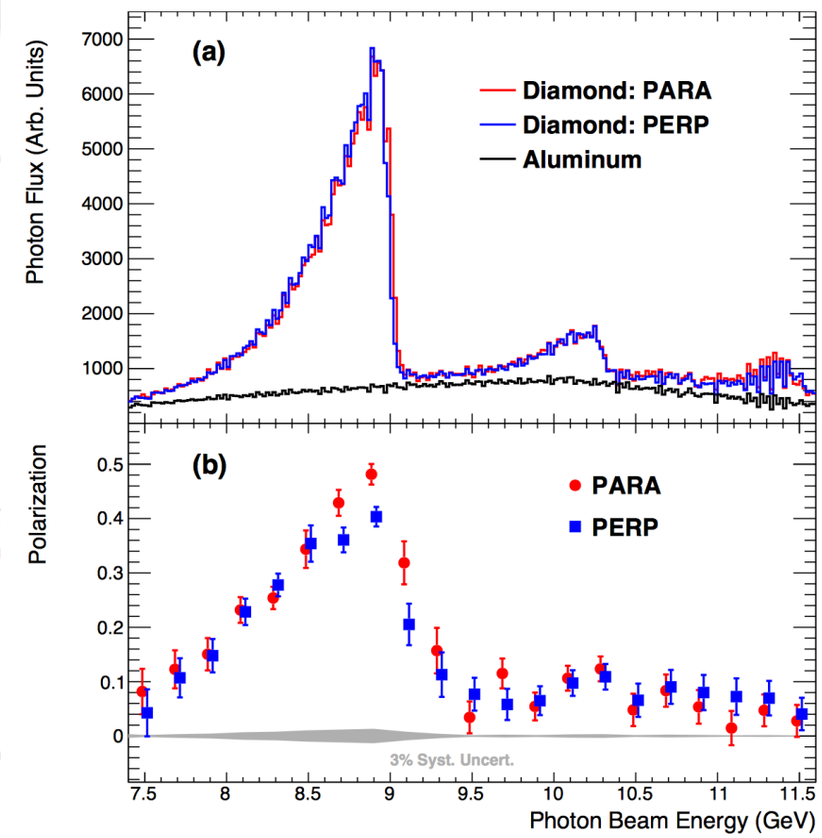
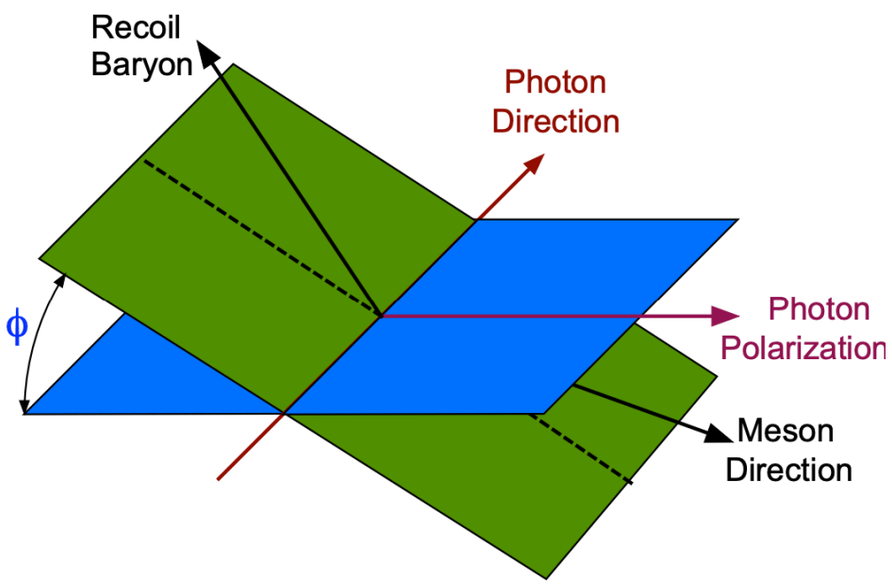






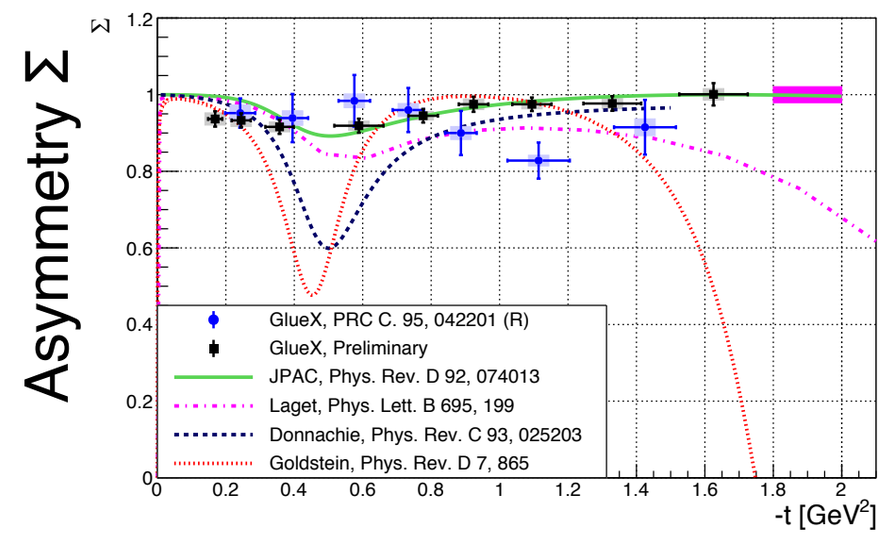
Meson Photoproduction: Beam Asymmetries

- Use photon polarization to study production mechanisms and develop models, use as input to hybrid searches—wide program underway

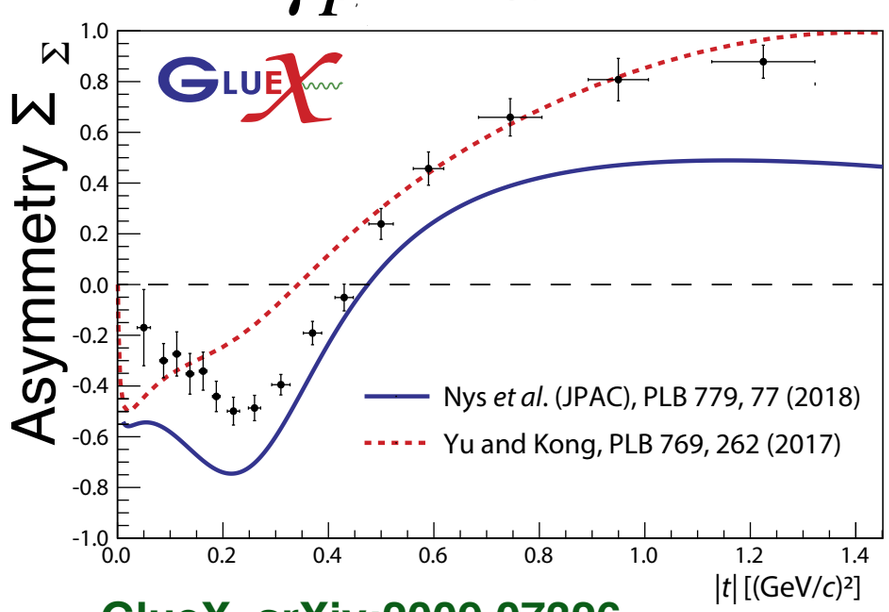


$$\vec{\gamma}p \rightarrow \pi^0 p$$

W. McGinley, MENU2019

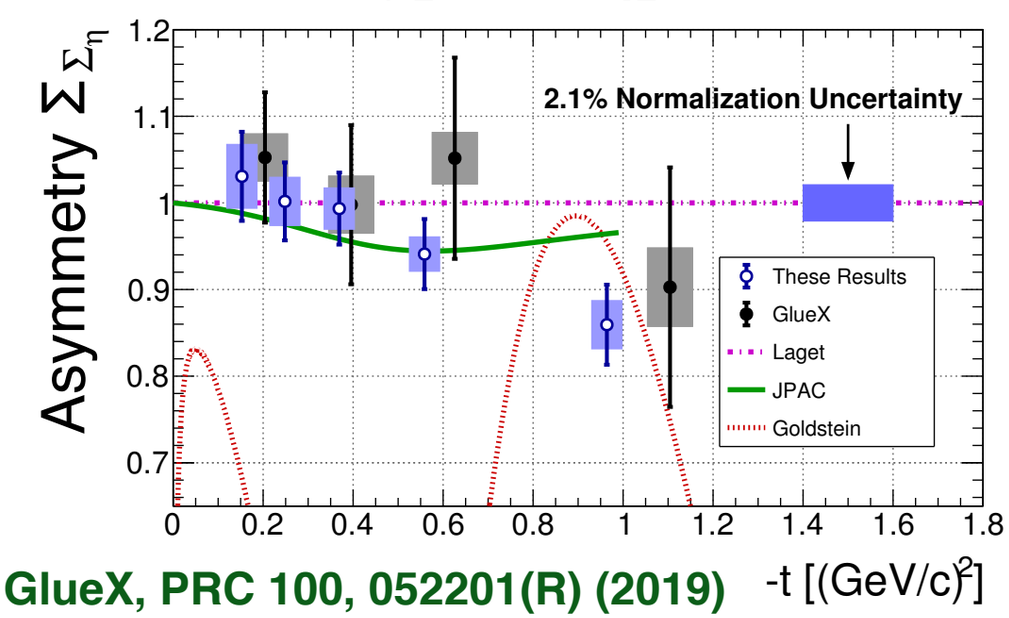


$$\vec{\gamma}p \rightarrow \pi^- \Delta^{++}$$



GlueX, arXiv:2009.07326

$$\vec{\gamma}p \rightarrow \eta p$$



GlueX, PRC 100, 052201(R) (2019)

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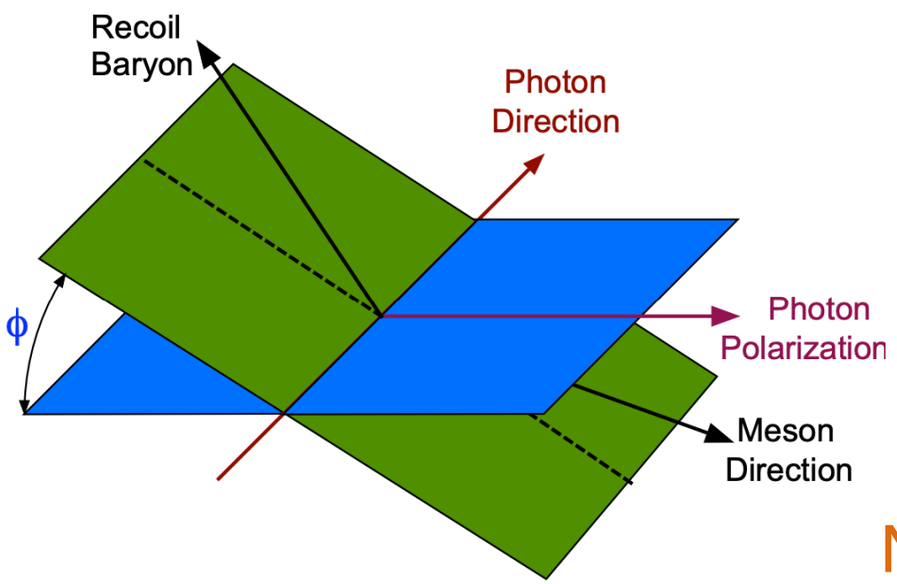

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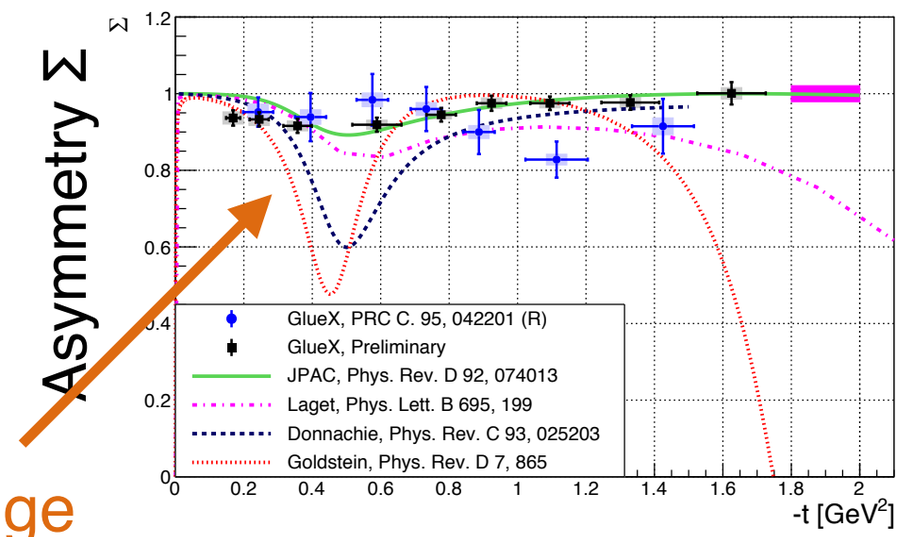
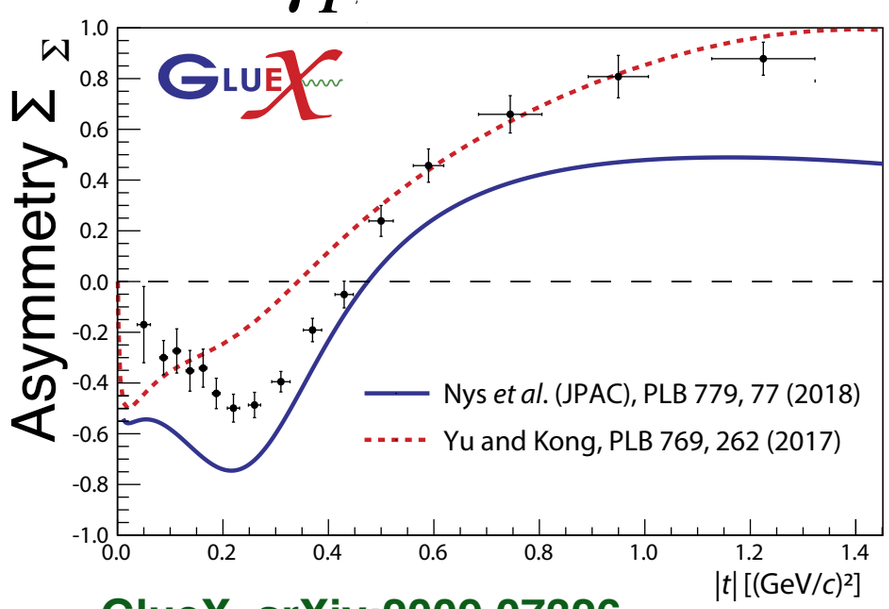


Near unity, natural exchange dominant

$\vec{\gamma}p \rightarrow \pi^- \Delta^{++}$



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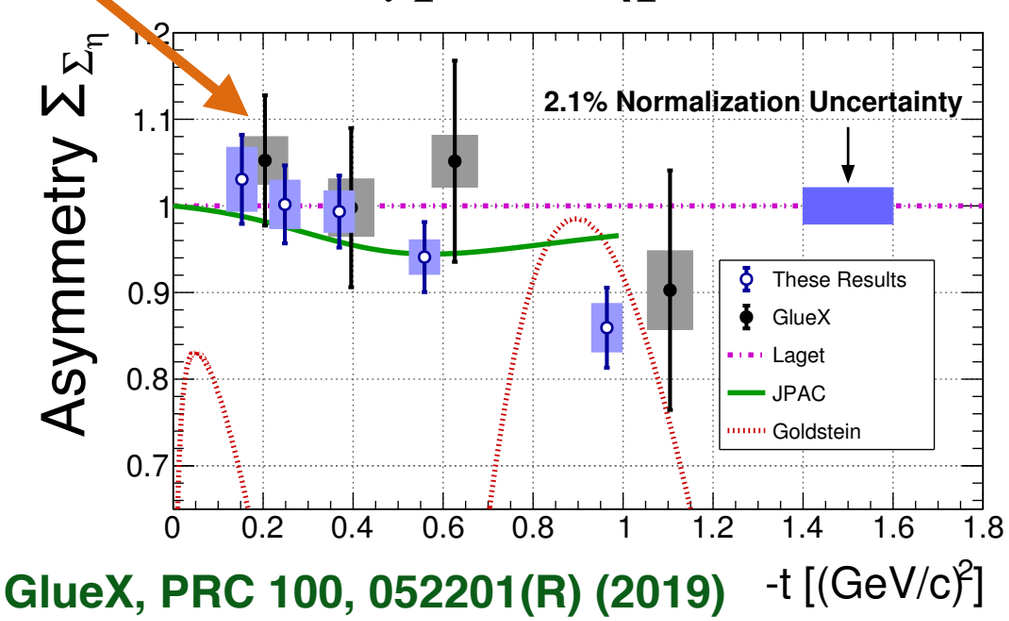

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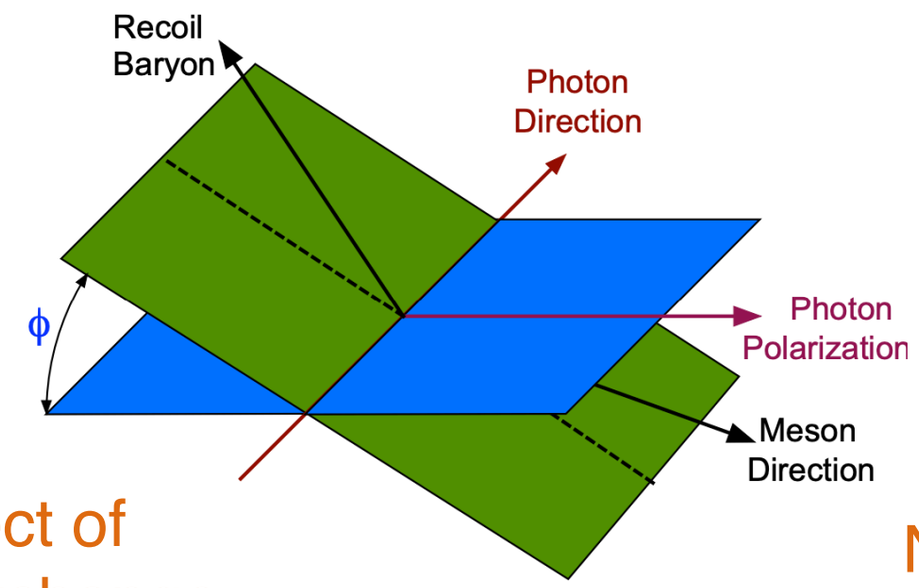

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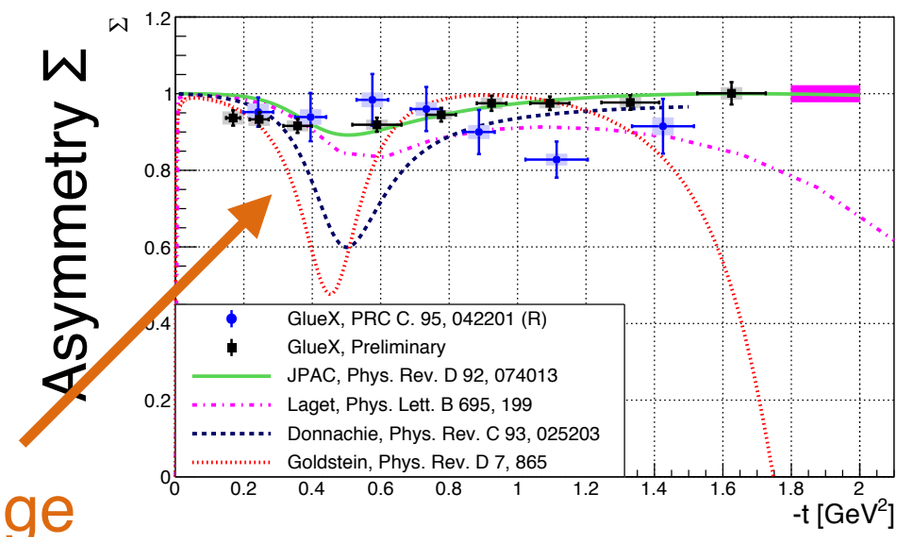
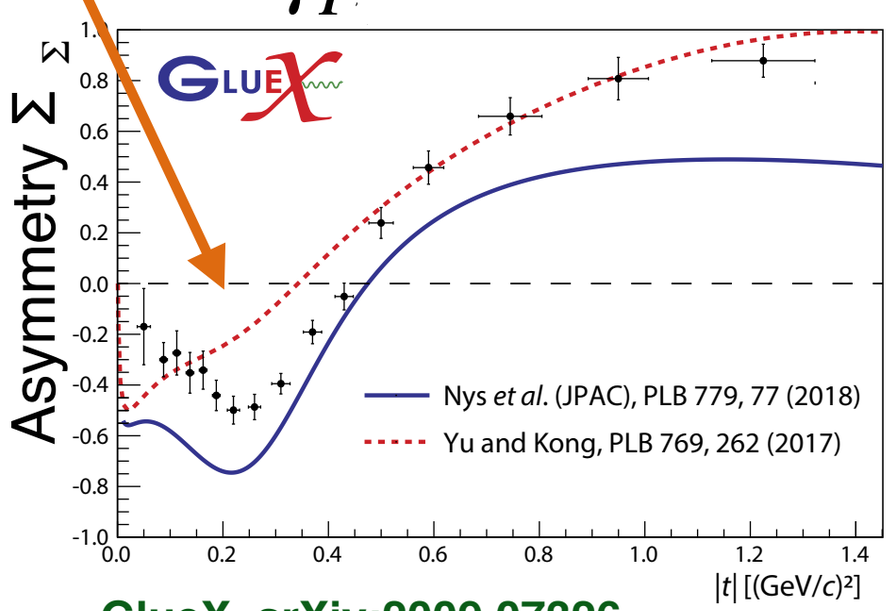


Effect of pion exchange

Near unity, natural exchange dominant

$\vec{\gamma}p \rightarrow \pi^- \Delta^{++}$



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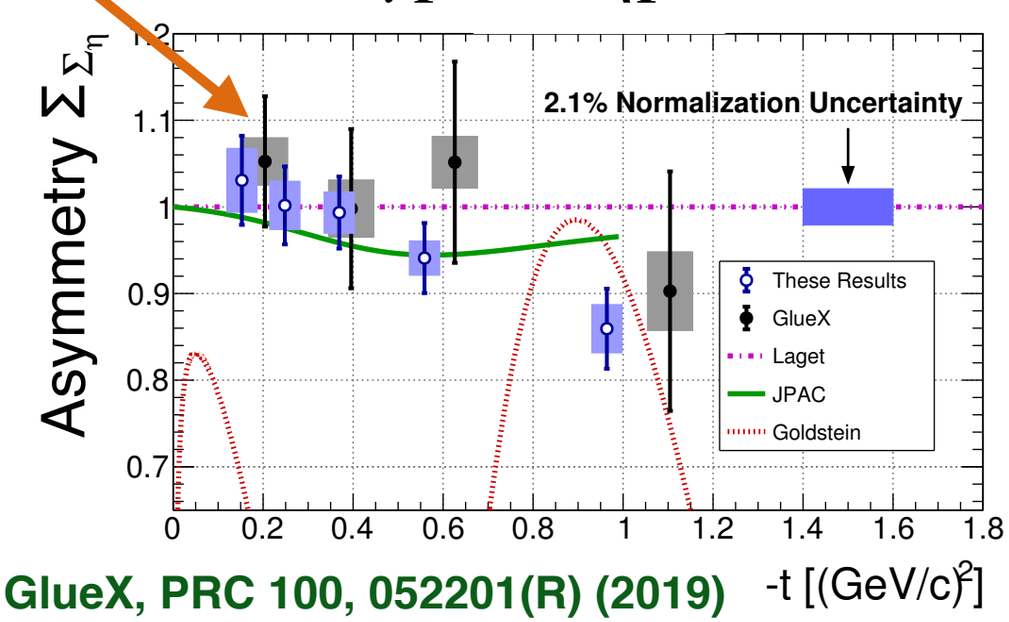
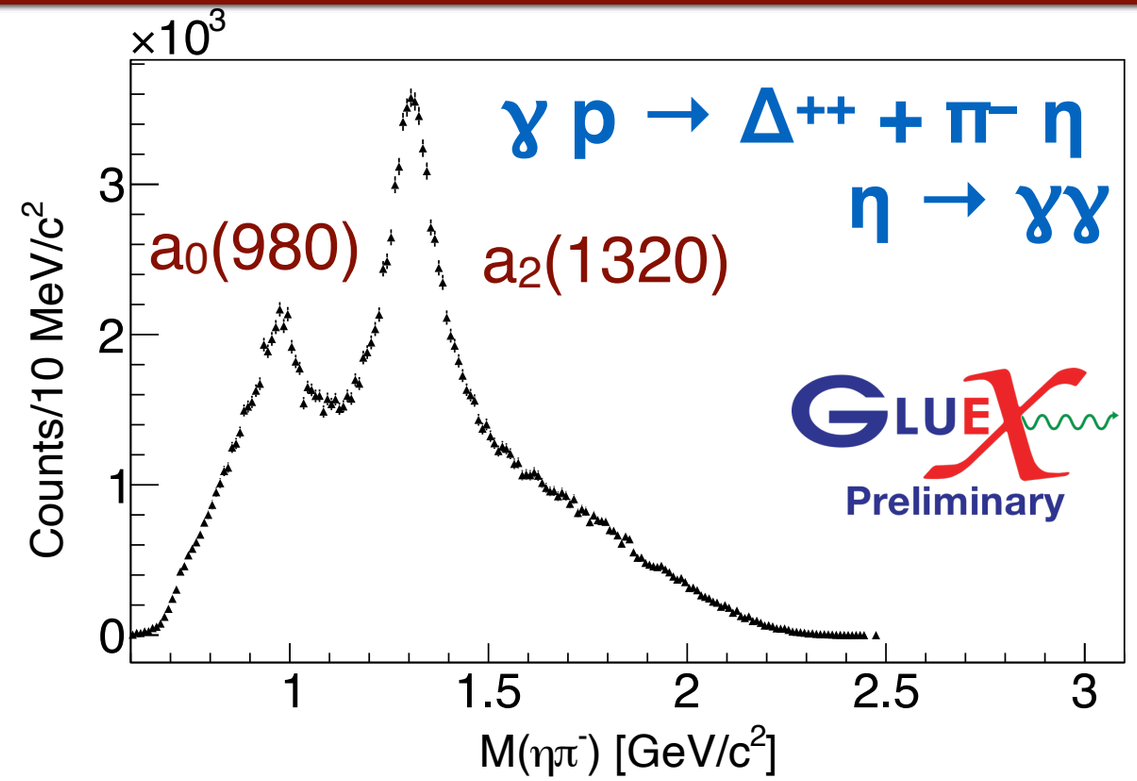
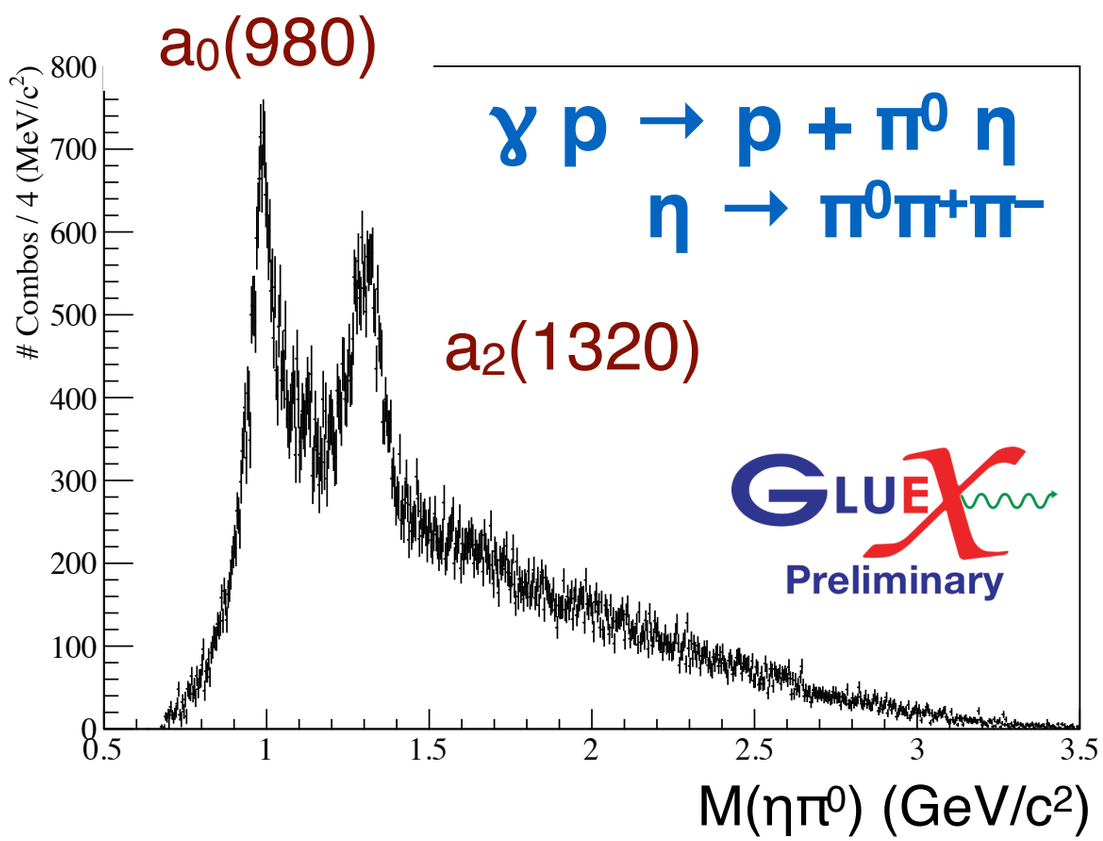


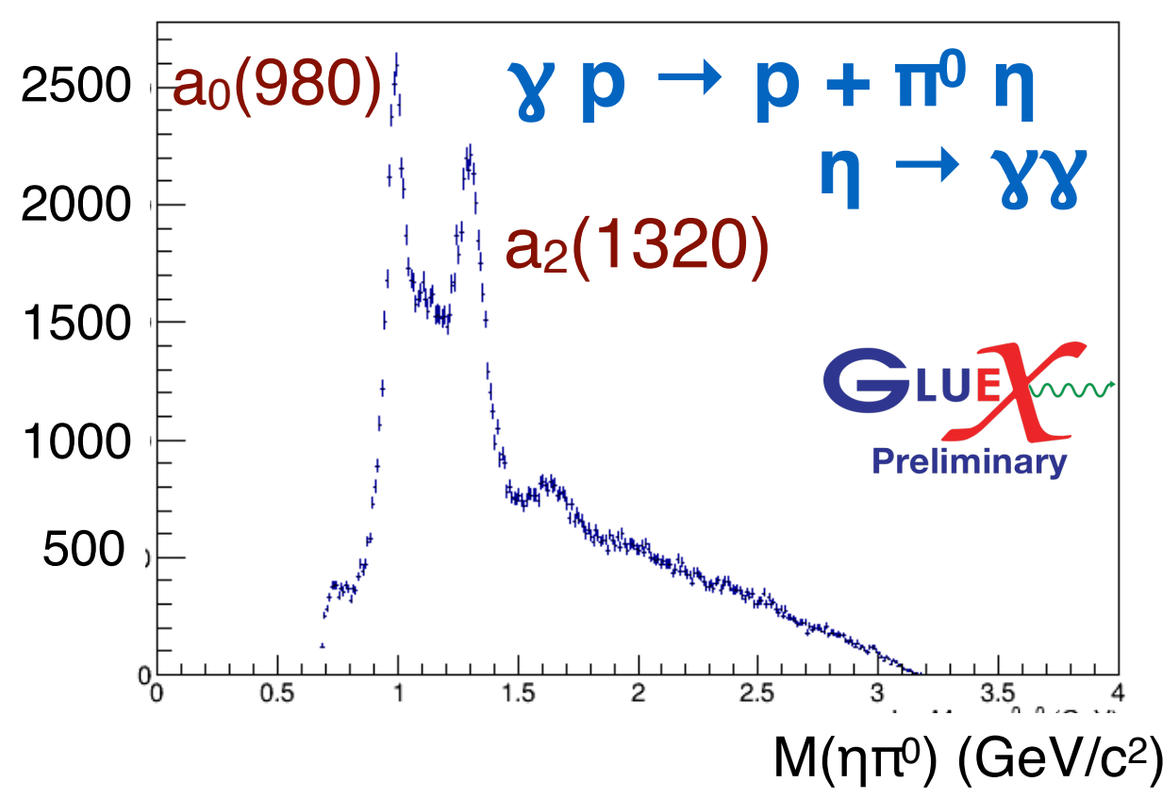
GlueX, PRC 100, 052201(R) (2019)

Searching for the lightest exotic hybrid π_1: $\gamma p \to p + \pi\eta$

- Next step: search for π_1 in $\eta\pi$ / $\eta'\pi$ channels
- Multiple production and decay modes accessible with world-leading statistical precision
- Amplitude analysis techniques using beam polarization push state-of-the-art

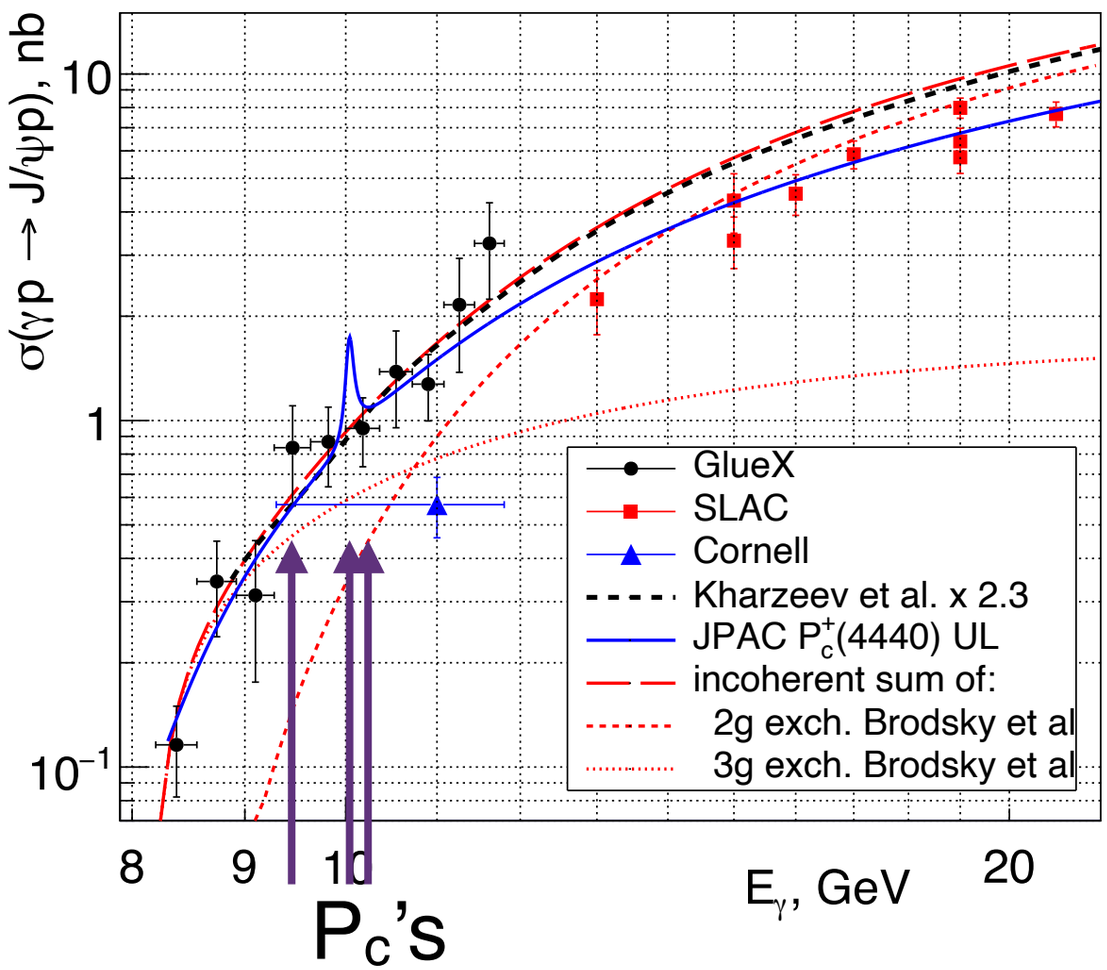




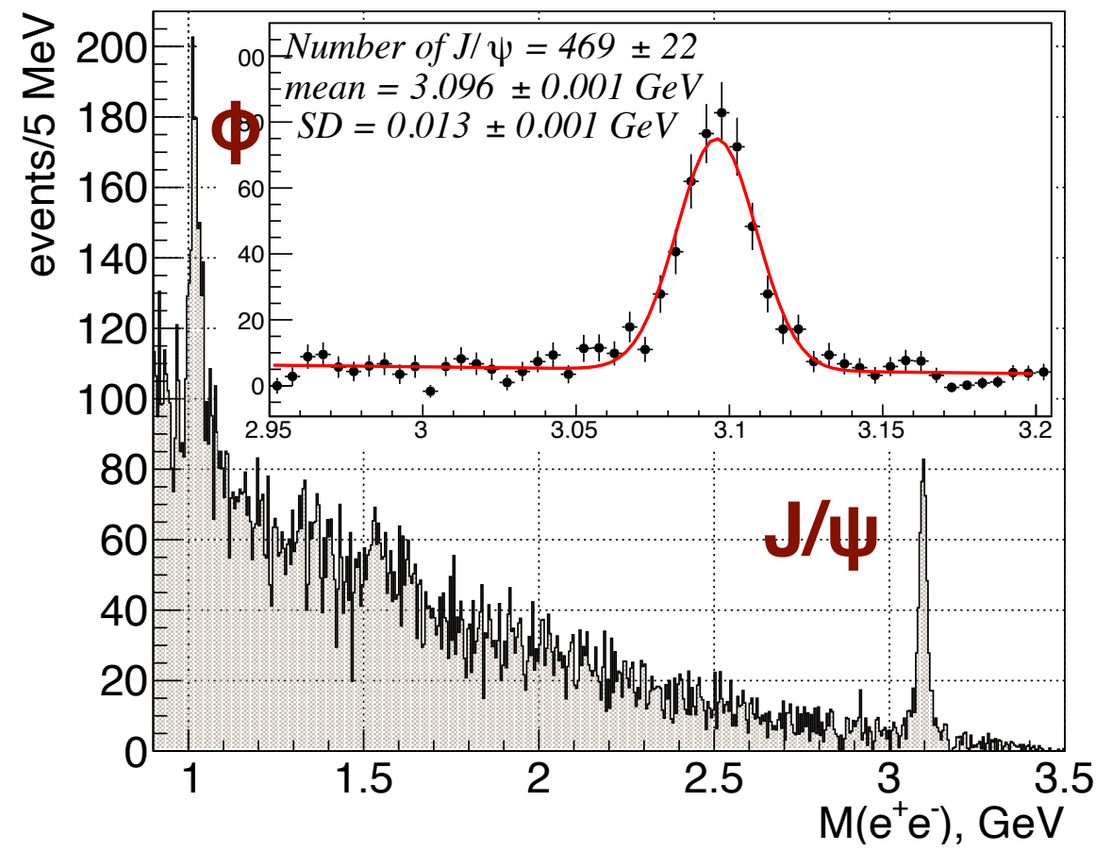


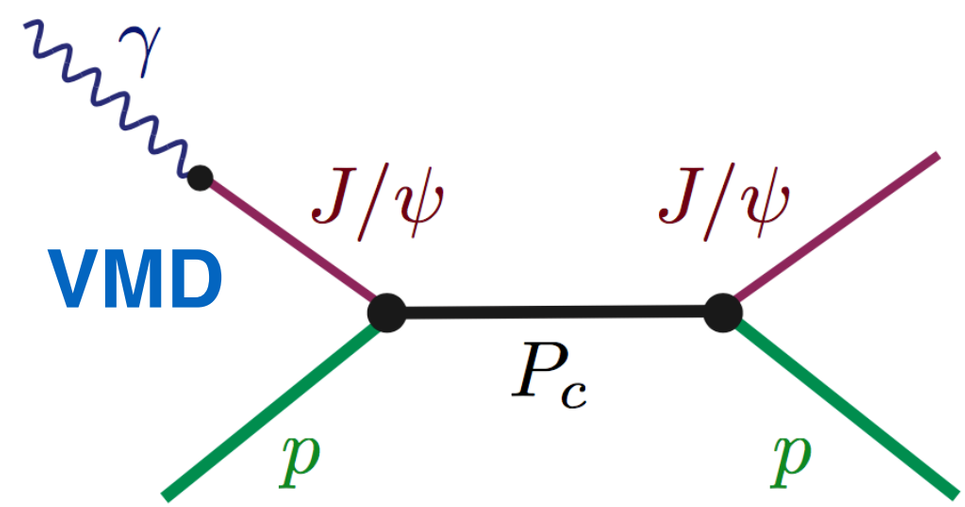
J/ψ Photoproduction at GlueX

- Study production dynamics through cross section shape
- Search for s-channel production of LHCb Pc states
- Other charmonia also accessible



GlueX, PRL 123, 072001 (2019)





γ p → P_c → J/ψ p

Future Plans

- The GlueX detector and beam line enable a broad physics program
  - Other Snowmass LoIs: JEF, Light BSM searches
  - 2019 White paper: Future Physics in Hall D with the GlueX Detector
    - **Continuation of spectroscopy program**
      - Potential for different beam conditions, deuterium target
      - Strangeonia and strange-quark X,Y,Z analogues
    - **Closed- and open-charm production near threshold, P_c search**
    - Polarized target measurements
    - Nuclear targets
    - Pion polarizabilities
    - Physics with a K_L beam

GlueX-doc 3870 v11

Future Physics in Hall D with the GlueX Detector

A. Ali,[10] M. Amaryan,[22] E. G. Anassontzis,[2] A. Austregesilo,[3] M. Baalouch,[22] F. Barbosa,[14] J. Barlow,[7] A. Barnes,[3] E. Barriga,[7] T. D. Beattie,[23] V. V. Berdnikov,[17] T. Black,[20] W. Boeglin,[6] M. Boer,[4] W. J. Briscoe,[8] T. Britton,[14] W. K. Brooks,[24] B. E. Cannon,[7] N. Cao,[11] E. Chudakov,[14] S. Cole,[1] O. Cortes,[8] V. Crede,[7] M. M. Dalton,[14] T. Daniels,[20] A. Deur,[14] S. Dobbs,[7] A. Dolgolenko,[13] R. Dotel,[6] M. Dugger,[1] R. Dzhygadlo,[10] H. Egiyan,[14] A. Ernst,[7] P. Eugenio,[7] C. Fanelli,[16] S. Fegan,[8] A. M. Foda,[23] J. Foote,[12] J. Frye,[12] S. Furletov,[14] L. Gan,[20] A. Gasparian,[19] V. Gauzshtein,[25,26] N. Gevorgyan,[27] C. Gleason,[12] K. Goetzen,[10] A. Goncalves,[7] V. S. Goryachev,[13] L. Guo,[6] H. Hakobyan,[24] A. Hamdi,[10] S. Han,[29] J. Hardin,[16] G. M. Huber,[23] A. Hurley,[28] D. G. Ireland,[9] M. M. Ito,[14] N. S. Jarvis,[3] R. T. Jones,[5] V. Kakoyan,[27] G. Kalicy,[4] M. Kamel,[6] C. Kourkoumeli,[2] S. Kuleshov,[24] I. Kuznetsov,[25,26] I. Larin,[15] D. Lawrence,[14] D. I. Lersch,[7] H. Li,[3] W. Li,[28] B. Liu,[11] K. Livingston,[9] G. J. Lolos,[23] V. Lyubovitskij,[25,26] D. Mack,[14] H. Marukyan,[27] V. Matveev,[13] M. McCaughan,[14] M. McCracken,[3] W. McGinley,[3] J. McIntyre,[5] C. A. Meyer,[3] R. Miskimen,[15] R. E. Mitchell,[12] F. Mokaya,[5] F. Nerling,[10] L. Ng,[7] A. I. Ostrovidov,[7] Z. Papandreou,[23] M. Patsyuk,[16] P. Pauli,[9] R. Pedroni,[19] L. Pentchev,[14] K. J. Peters,[10] W. Phelps,[8] E. Pooser,[14] N. Qin,[21] J. Reinhold,[6] B. G. Ritchie,[1] L. Robison,[21] D. Romanov,[17] C. Romero,[24] C. Salgado,[18] A. M. Schertz,[28] R. A. Schumacher,[3] J. Schwiening,[10] K. K. Seth,[21] X. Shen,[11] M. R. Shepherd,[12] E. S. Smith,[14] D. I. Sober,[4] A. Somov,[14] S. Somov,[17] O. Soto,[24] J. R. Stevens,[28] I. I. Strakovsky,[8] V. Tarasov,[13] S. Taylor,[14] A. Teymurazyan,[23] A. Thiel,[9] G. Vasileiadis,[2] D. Werthmüller,[9] T. Whitlatch,[14] N. Wickramaarachchi,[22] M. Williams,[16] T. Xiao,[21] Y. Yang,[16] J. Zarling,[12] Z. Zhang,[29] G. Zhao,[11] Q. Zhou,[11] X. Zhou,[29] and B. Zihlmann[14]

(The GlueX Collaboration)

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[2] *National and Kapodistrian University of Athens, 15771 Athens, Greece*
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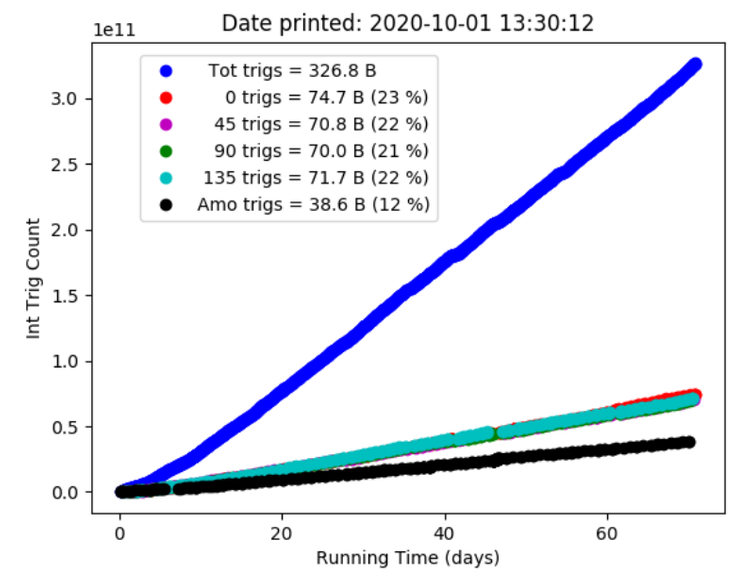
[4] *The Catholic University of America, Washington, D.C. 20064, USA*

GlueX and the Snowmass Process



- GlueX-II run with higher beam intensity and improved PID underway. Can update expectations for the sensitivity of this data.
  - Relevant example: evaluate physics reach for production of charm quark hadrons
- Understand impact of GlueX in context of global experimental and theoretical spectroscopy effort
  - Contribute to relevant topical white papers
  - Update list of priority measurements, particularly those having a synergy with HEP experiments
  - Develop lines of communication over which analysis techniques and information can flow
  - Raise awareness of hadron spectroscopy among the wider community, and of the unique contributions of GlueX in particular