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Feasibility Study of Kaon Identification for Hyperon Photoproduction in JLab's Hall B CLAS12

Isabella Illari[1], William Phelps[2]
[1]The George Washington University, Washington, D.C. 20052
[2]Christopher Newport University, Newport News, VA 23606

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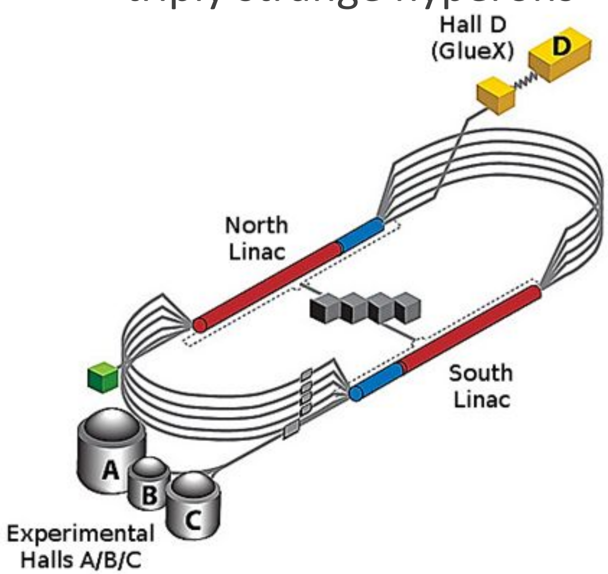
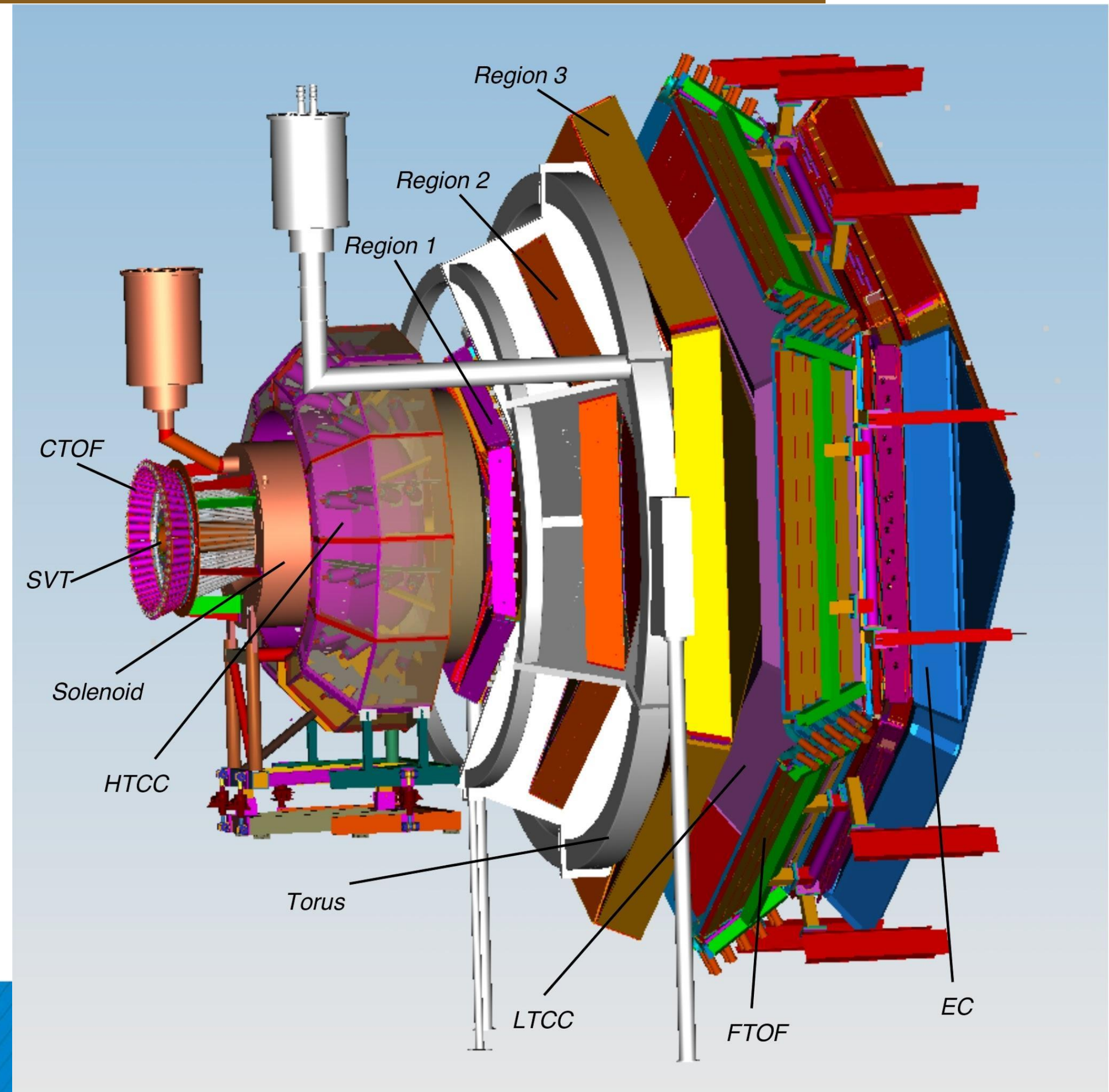
Jefferson Lab

Jefferson Lab CLAS12 detector

- large acceptance spectrometer in Hall B
- measure reactions w/ multi-particle final states & high luminosity using unpolarized & polarized targets
- 11 GeV electron beam (CEBAF)
- baryon spectroscopy in quasi-real photoproduction of a large variety of final states
    - includes singly, doubly & triply strange hyperons





High energy photoproduction

To study high energy photoproduction w/ CLAS12:

1. Untagged photon beams
2. Electron scattering at very small angles (polar angles <4°)
   a. Quasi-real photons produced by electrons scattered at very forward angles
   b. Electroproduction at very small vals of Q^2 using unpolarized electrons
   c. Equivalent to photoproduction using partially linearly polarized photons
   d. Photon beams w/ small virtualities, $Q^2 < 0.05\ [\mathrm{GeV}]^2$

Stepanyan, Stepan et al. "Hadron Physics with CLAS12." (2010).

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Motivation

- Photoproduction of very strange hyperon, Ω^-
  - Photoproduction cross section is unknown
  - Dynamics of Ω^- photoproduction is unclear
    - No strange quarks in initial state
    - Three in the final state
- Available theoretical predictions for Ω^- hyperon photo- & electroproduction cross section vary from 1-300 pb
- Only an upper limit of cross section (σ_{tot}< 17 nb @ 20 GeV) reported by SLAC
- Is it possible to study Ω^- photoproduction with CLAS12?
  - K id at energy ranges in CLAS12

Reaction: Ω^- photoproduction

- Production & decay chain for Ω^- photoproduction

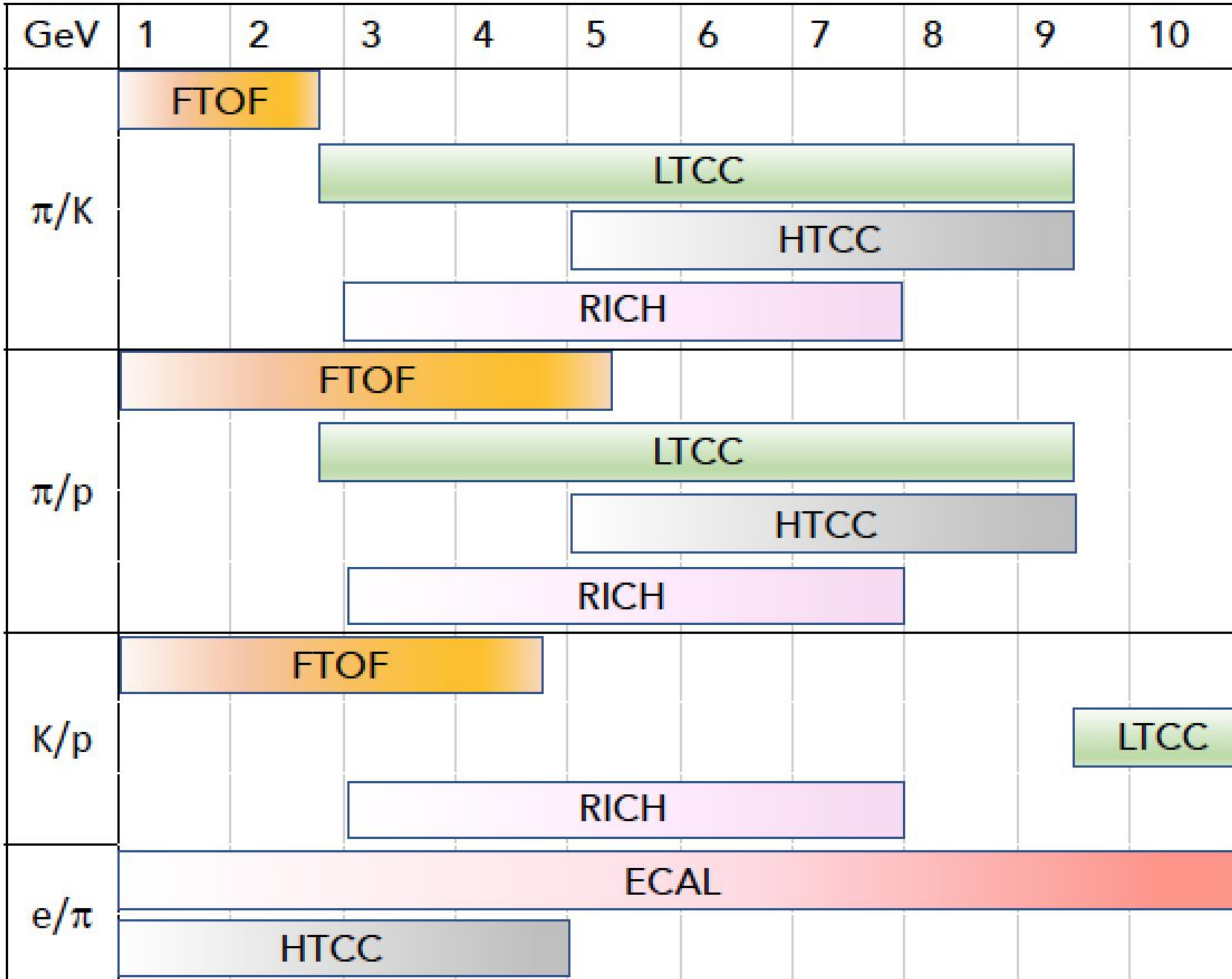
$$\gamma p \rightarrow K^+ K^+ K^0 \Omega^-$$

$$K^0_{\mathrm{s}} \rightarrow \pi^+ \pi^-$$

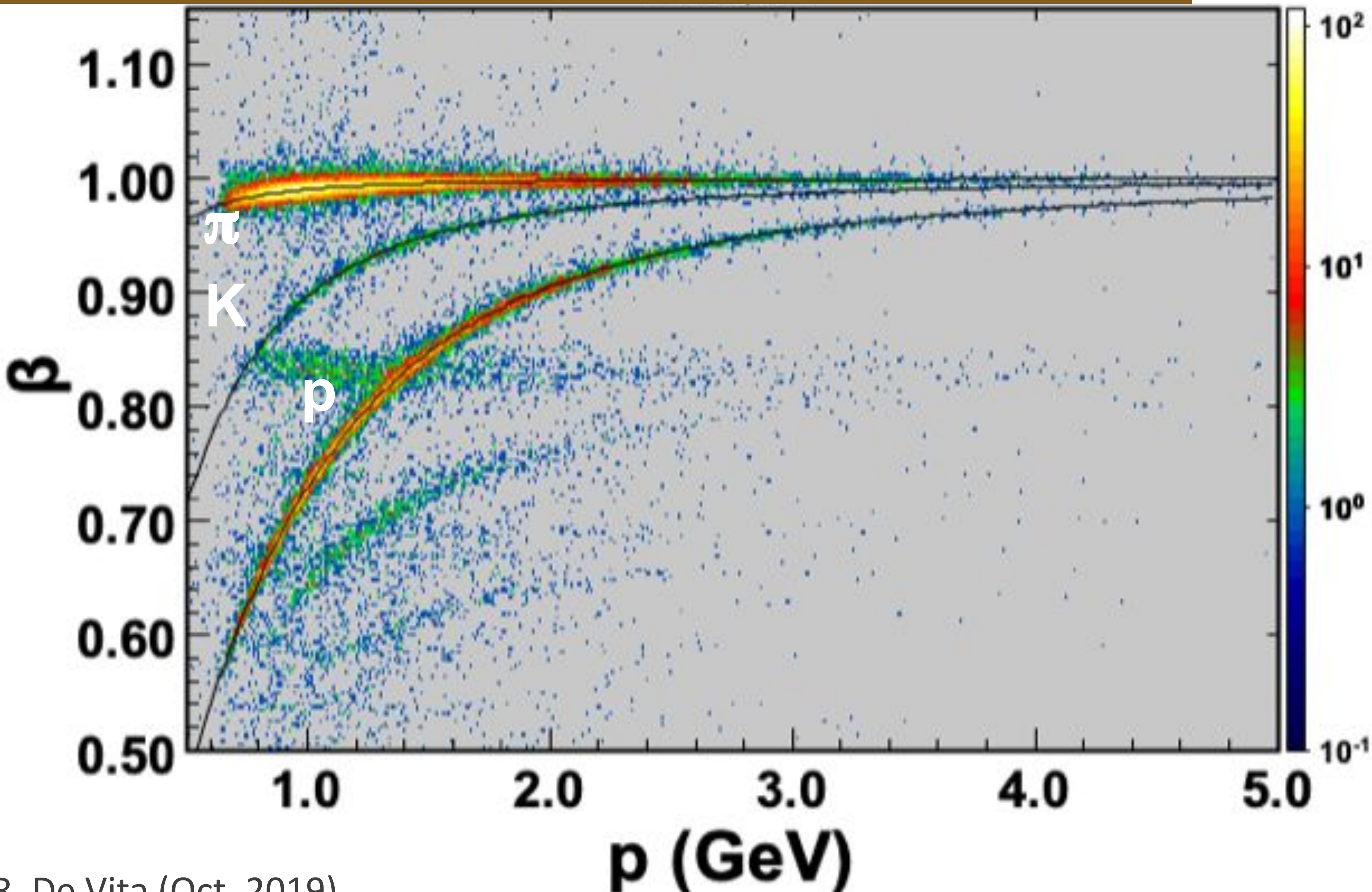
- **To identify final state the min req is to detect 3 kaons**:
  - 2 K^+ & 1 K^0_s
  - Latter identified by decay $\rightarrow \pi^+\pi^-$
- studies of kaon identification in CLAS12
  - **Monte Carlo simulations**
  - Real data collected by Run Group A (RG-A)

"Photoproduction of the very strangest baryons on the proton target in CLAS12" by L. Guo et al. JLab Proposal E12-11-005a, Newport News, VA, USA, 2011.

Particle IDentification in CLAS12



ID of charged hadrons in CLAS12



R. De Vita (Oct. 2019).

Reaction: $K^0\Sigma^+$ photoproduction

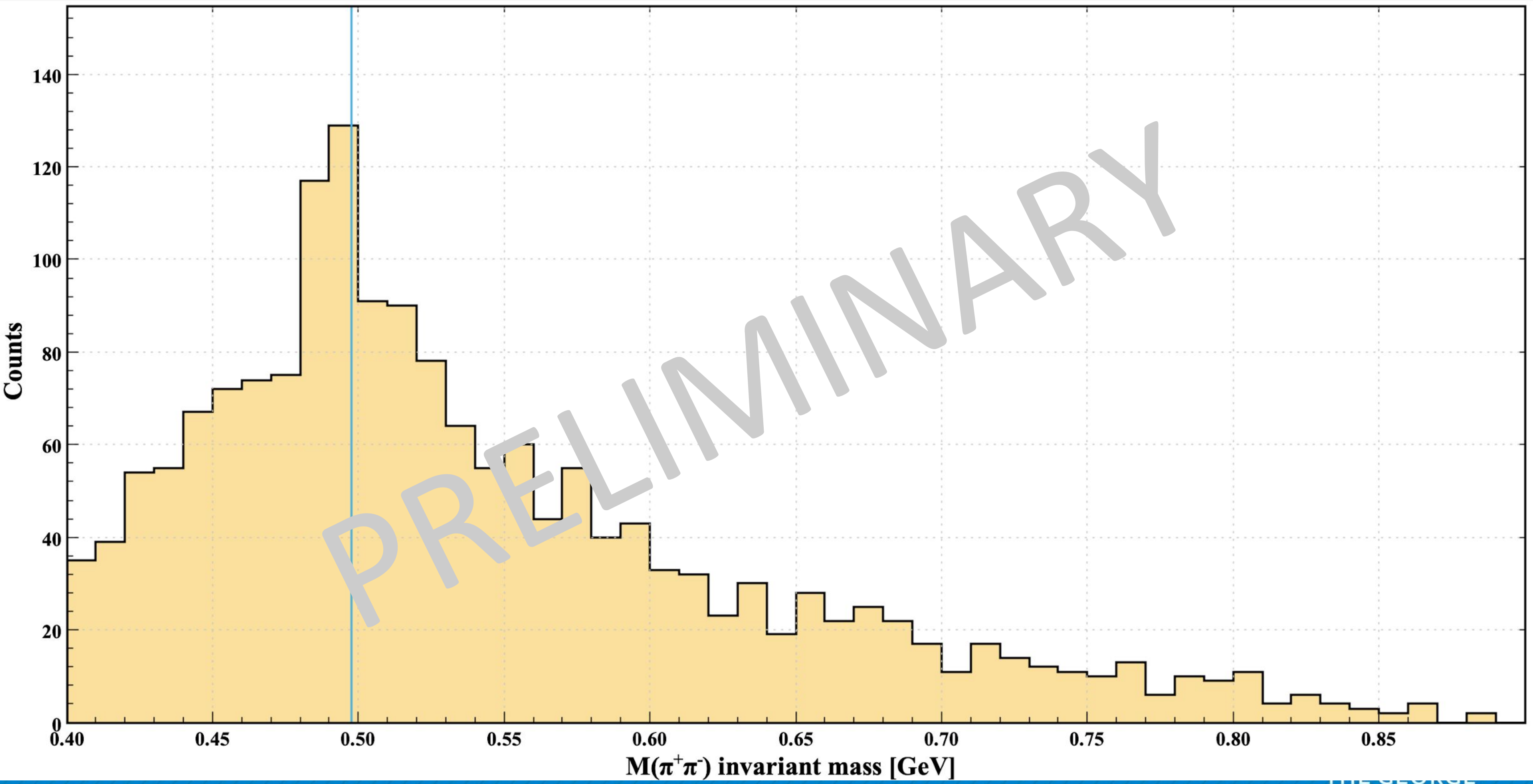
- To identify final state the min req is to detect 3 kaons:
  - 2 K^+ & **1 K^0_s**
  - Latter identified by decay → $\pi^+\pi^-$
- **For K^0** examine the following reaction: $\gamma p \rightarrow K^0\boldsymbol{\Sigma}^+$

$$\gamma p \rightarrow K^0_s \Sigma^+ \rightarrow \gamma\gamma p \pi^+ \pi^-$$

$$\begin{aligned}
\Sigma^+ &\rightarrow p\pi^0 && (\mathrm{BR} = 52\%) \\
&\rightarrow n\pi^+ && (\mathrm{BR} = 48\%) \\
K^0_s &\rightarrow \pi^0\pi^0 && (\mathrm{BR} = 69\%) \\
&\rightarrow \pi^+\pi^- && (\mathrm{BR} = 31\%) \\
\pi^0 &\rightarrow 2\gamma && (\mathrm{BR} = 99\%)
\end{aligned}$$

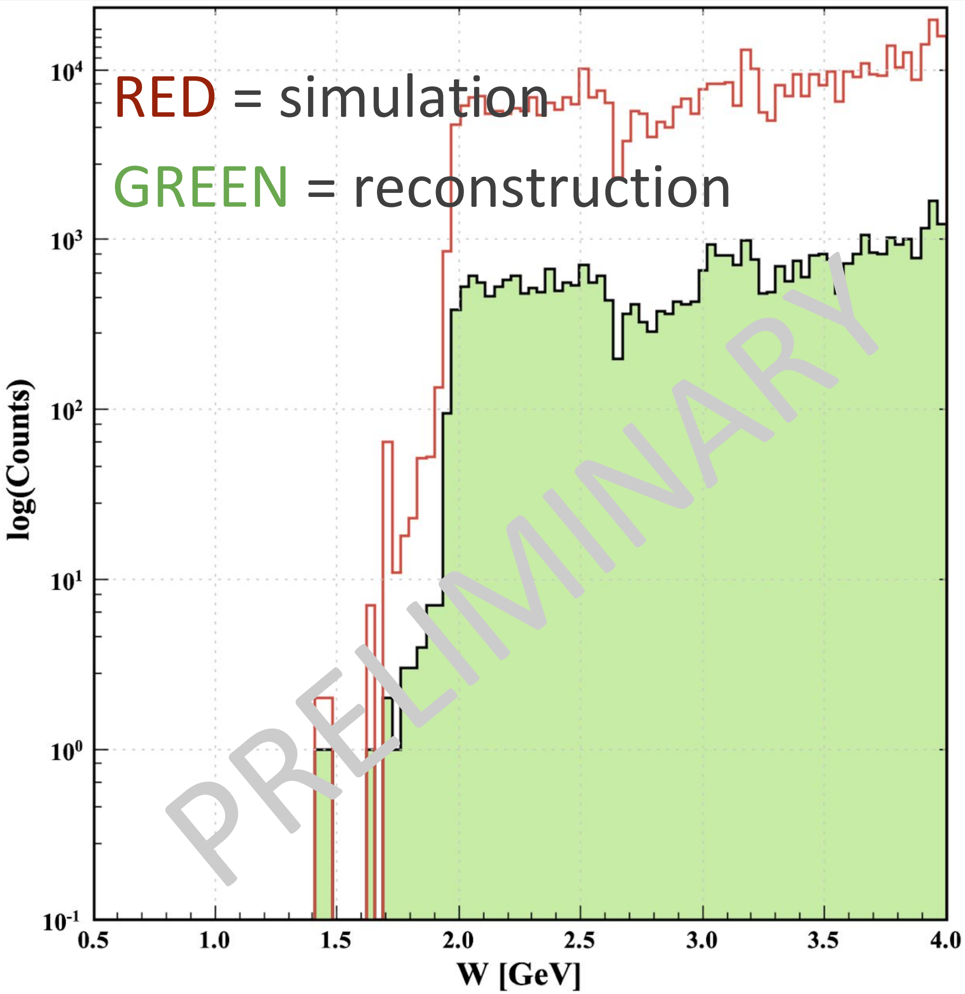
Simulating just K^0_s events in GEMC

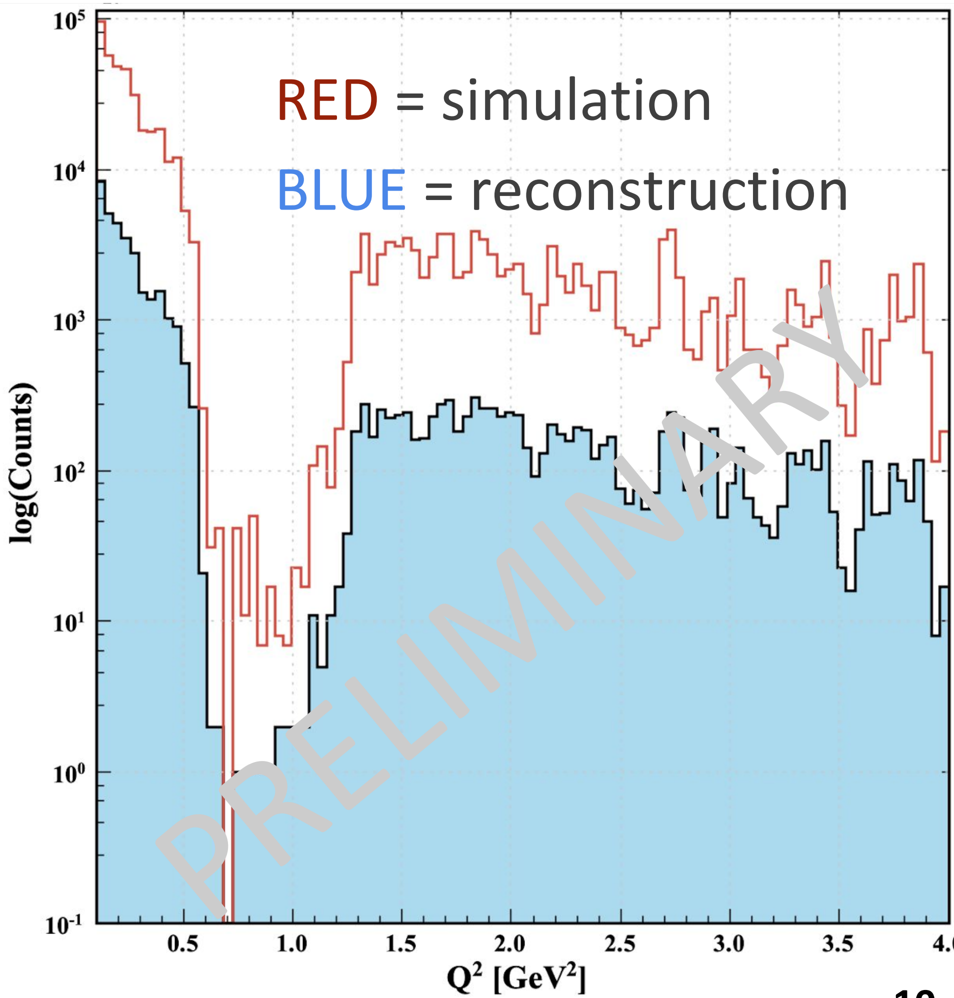
K^0_S mass = 0.498 GeV



Monte Carlo sims: PYTHIA

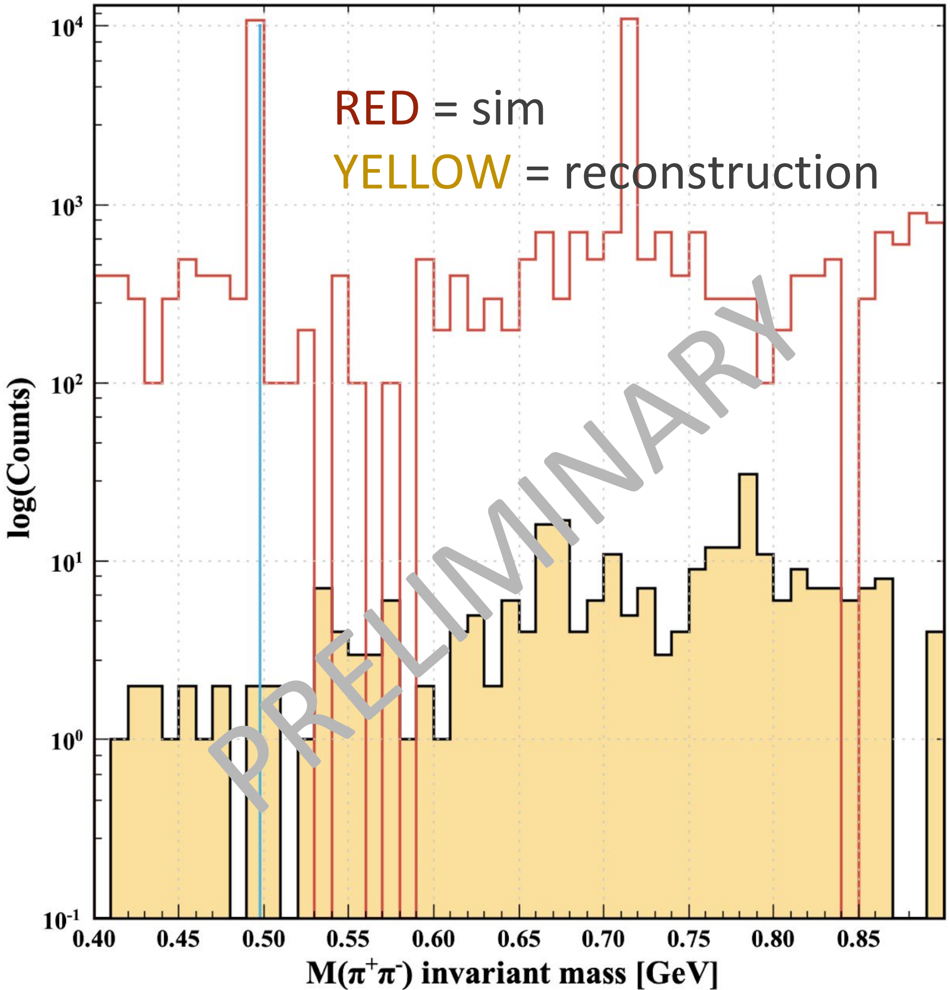
Initial state: γp; **Set:** Q^2_{min} = 0.00001 GeV^2 & Q^2_{max} = 15.0 GeV^2; ~1 billion events; event generator & input file from Harut Avagyan

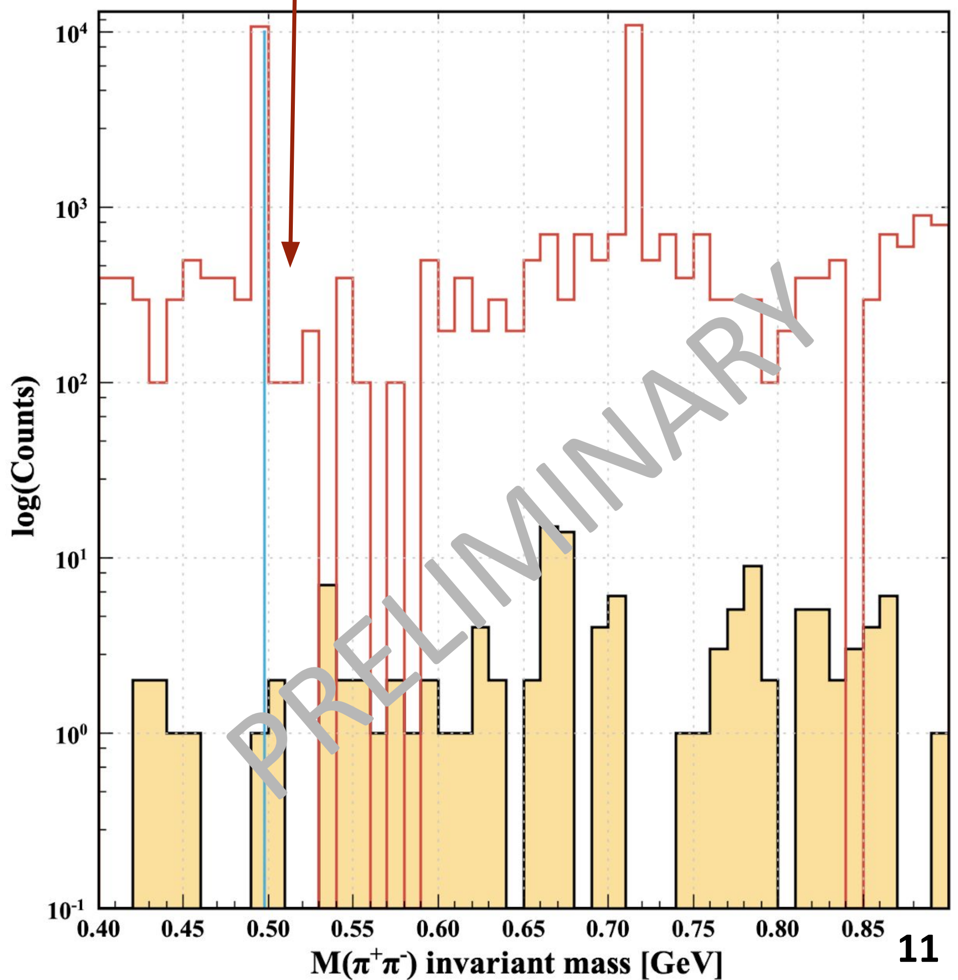




FILTER 1: K^0_s Invariant Mass (MC)

K^0_s mass = 0.498 GeV, visible shift to right; Right: **cut** around "pro" particle w/in 0.1 GeV; org.jlab.jnp.physics.Particle pro = physEvent.getParticle("[b]+[t]-[11,0]-[2212,0]-[211,0]-[-211,0]"); (4-vector taking beam + target - end products)

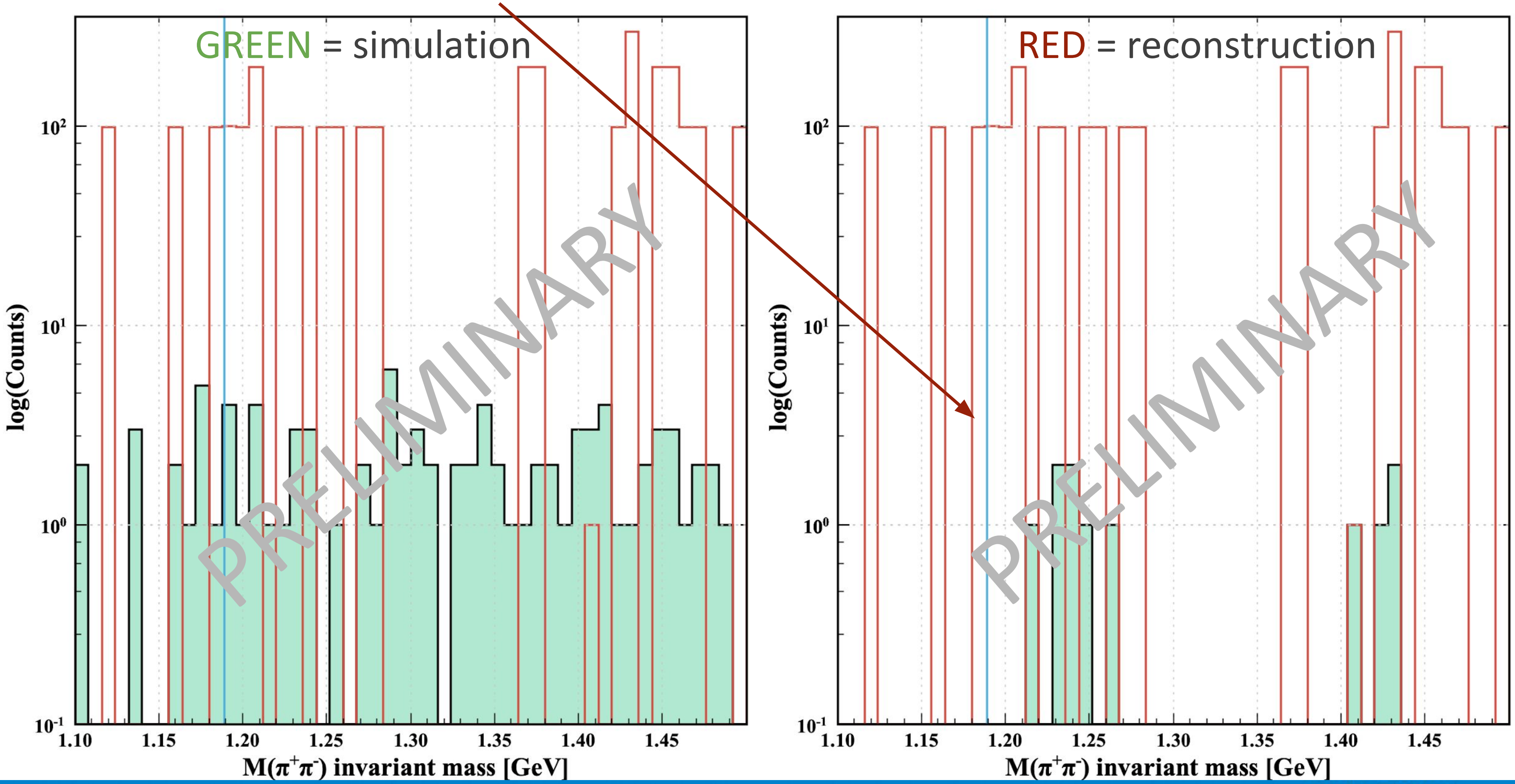




FILTER 1: Σ^+ Invariant Mass (MC)

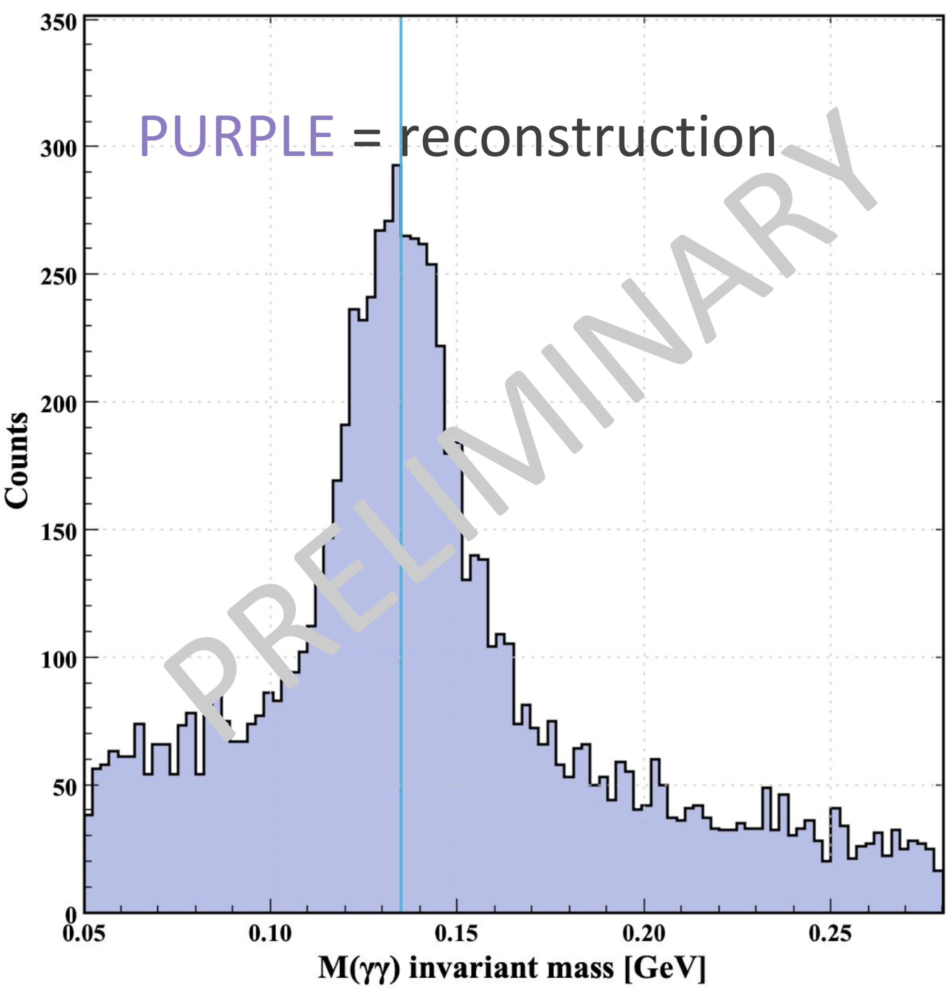
Σ^+ mass = 1.189 GeV, visible shift to right

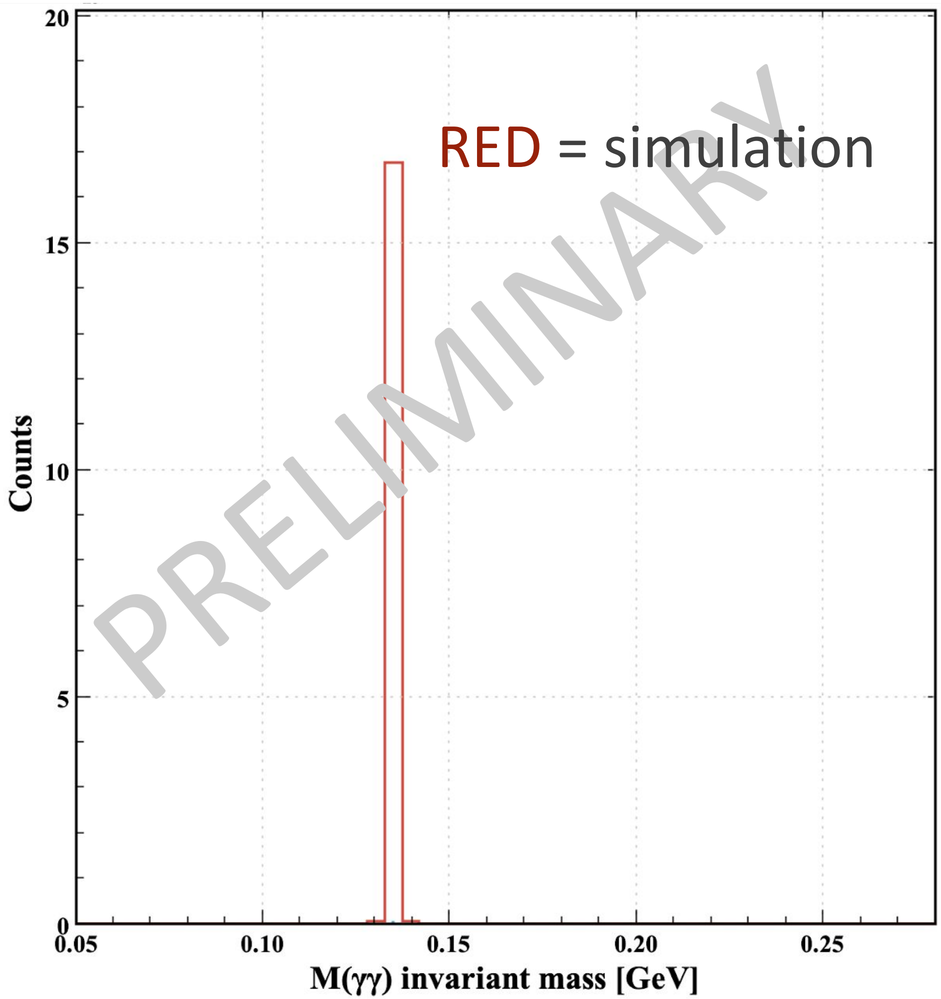
Right: same cut as previous slide



FILTER 2: π^0 Invariant Mass (MC)

π^0 mass: 0.135 GeV





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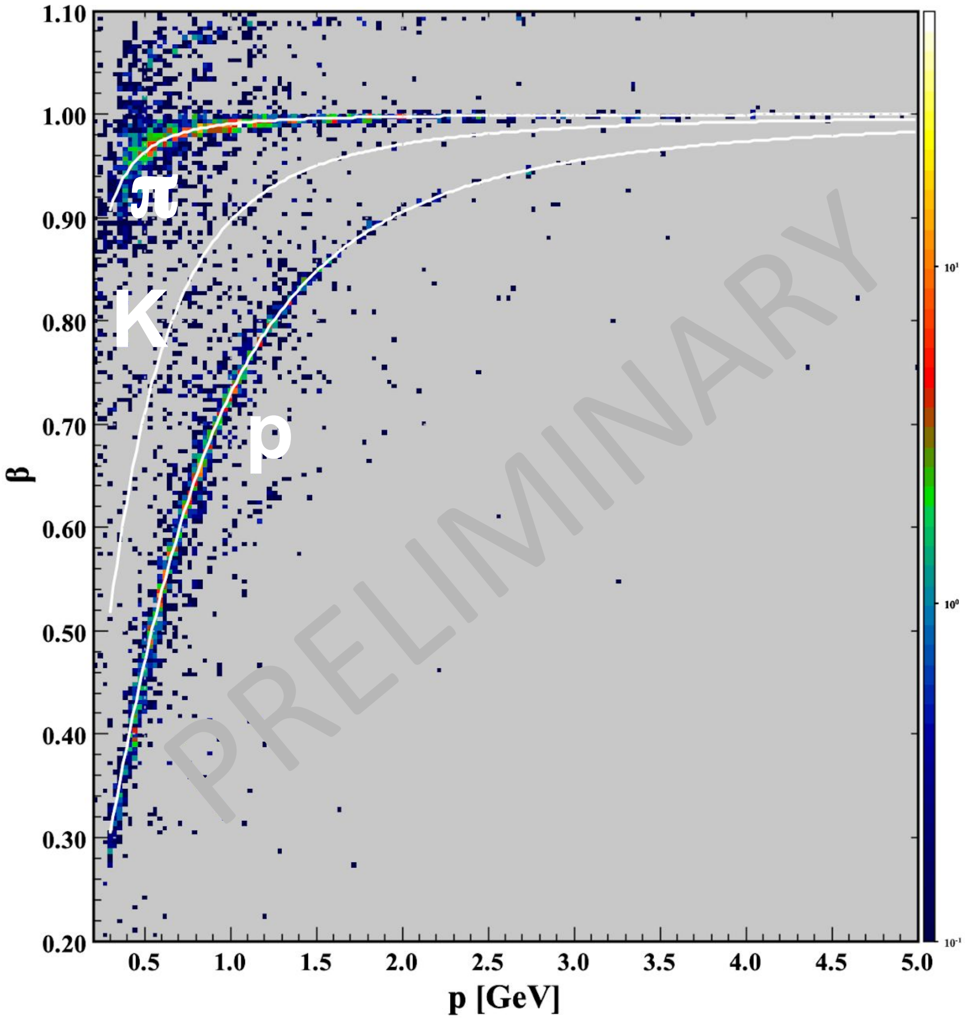
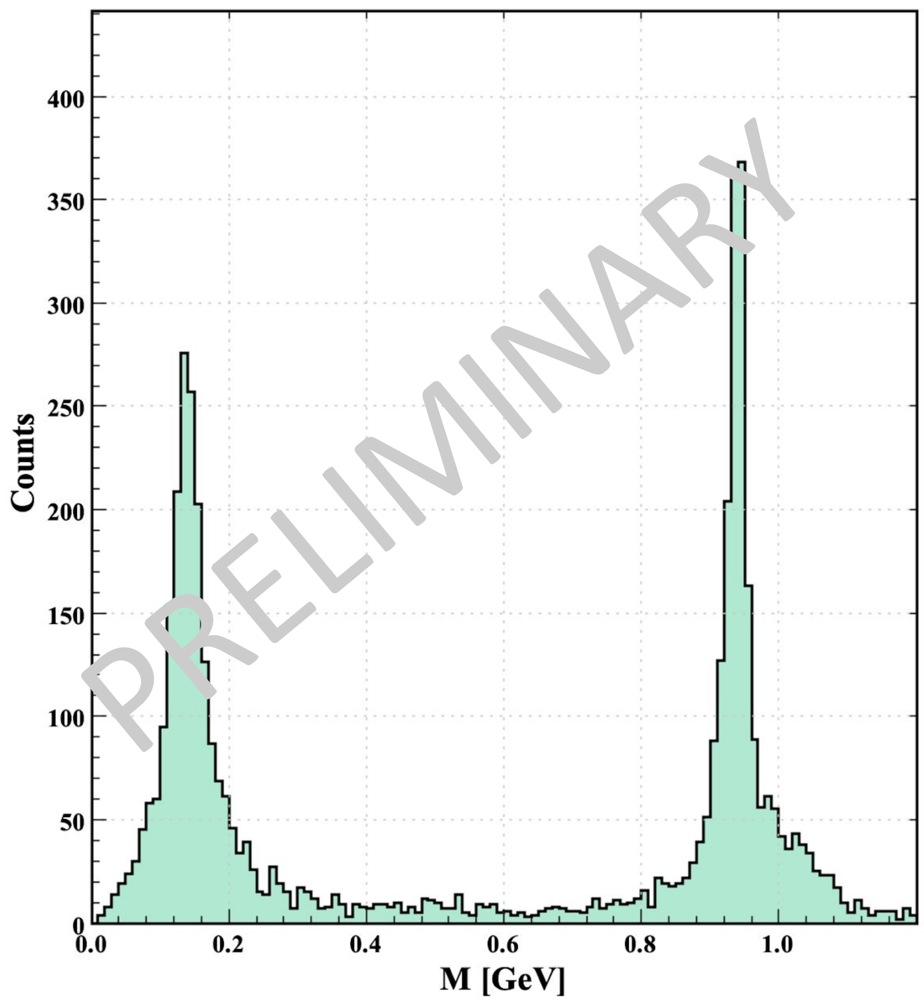
Filter 2: *β*, P, mass calc (MC)





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What we've covered…

- High energy photoproduction
  - Very forward electron scattering, low $Q^2 \to$ quasi-real photoproduction
  - Large variety of final states
  - Photoproduction of singly, doubly & triply strange hyperons
- Dynamics of the Ω^- photoproduction is unclear
  - Final state $\gamma p \to K^+K^+K^0_s\Omega^-$
  - Detect 3 kaons: 2 K^+ & 1 K^0_s
- General capabilities of CLAS12: separation of e^-, π, & K
  - Data taken in RG-A & existing software in Forward & Central Detectors
  - K^+ & π^+, π^- id possible in large momentum range
- MC simulations for $K^0_s \to \pi^+\pi^-$
  - Understanding simulated & reconstructed events

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What next?

- Compare to different MC (EdGen)
- Refine simulation and reconstruction results
  - Read from different banks, etc.
- Compare to real data
  - RG-A: skim4
    - Electron in Forward Detector
    - Compare to MC results

Acknowledgments

This work was performed with partial support from US DOE DE-SC001658, The George Washington University, and Thomas Jefferson National Accelerator Facility. A special thank you to Igor Strakovsky, Giovanni Angelini, and Raffaella De Vita.

Thank You.

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Any Questions?

END

EXTRA SLIDES

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Abstract

The CLAS12 physics program is involved in the study of baryon spectroscopy in quasi-real photoproduction of a large variety of final states, and includes the photoproduction of singly, doubly and triply strange hyperons. The photoproduction of the very strange hyperon, the Ω^-, is of particular interest. Its photoproduction cross section is unknown. Furthermore, the dynamics of the Ω^- photoproduction is unclear, as there are no strange quarks in the initial state while there are three in the final state. The available theoretical predictions for the Ω^- hyperon photo- and electroproduction cross section vary from 1 to 300 pb. As of today, there is only an upper limit of the cross section ($\sigma_{tot} < 17$ nb at 20 GeV) reported by SLAC. To identify the final state for $\gamma p \to \Omega^- K^+ K^+K^0$ the minimal requirement is to detect three kaons: two K^+ and one K^0_s. The latter is identified by its decay to $\pi^+\pi^-$. We will discuss our study of kaon identification in CLAS12 based on Monte Carlo simulations and real data collected by Run Group A, which used a $\sim$11 GeV beam incident on a liquid hydrogen target.

CLAS12

CLAS12 is a large acceptance spectrometer located in the Hall-B of the JLab and designed to measure reactions with multi-particle final states and high luminosity using unpolarized and polarized targets. The electron beam is provided by the CEBAF electron accelerator with an energy up to 11 GeV in the Hall B, and a maximum longitudinal polarization of 85%. The maximum luminosity expected in CLAS12 is 1035cm−2s−1. The detector is divided into two major detectors: a forward detector that measures high momentum particles from 5◦ to 35◦, and a central detector able to measure particles with an angle between 40◦ and 135◦. The CLAS12 spectrometer system is based on two superconducting magnets, a 5-T solenoid magnet and a toroid magnet with a maximum field of 2.5 T. The two magnets provide magnetic analysis of charged particles in the large-angle range and the forward-angle range, respectively. Layers of drift chambers are used for charged particle tracking with a momentum resolution $\Delta p/p$ better than 1%. A series of micromegas vertex trackers are used to improve the track reconstruction in the vicinity of the target. A silicon vertex tracker is also used to measure the momentum and determine the vertex of the charged particle, and scintillators for time-of-flight measurements. Electron and pion Particle IDentification (PID) in CLAS12 is performed by Electromagnetic Calorimeters, Time-Of-Flight (TOF) and Low and High Threshold Cherenkov Counters (LTCC, HTCC) detectors.

Diagram: Ω^- photoproduction

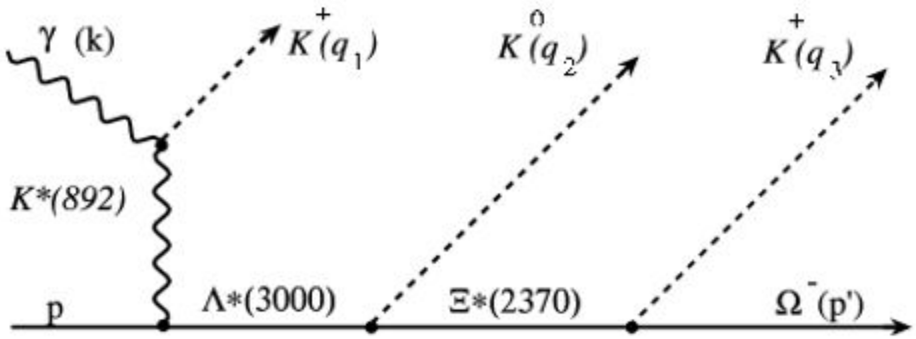

FIG. 10: Feynman diagram for the $\gamma p \to K^+ K^0 K^+ \Omega^-$ transition in the effective Lagrangian approach of Shklyar.

"Photoproduction of the Very Strangest Baryons on a Proton Target in CLAS12" by A. Afanasev et al. (2012)

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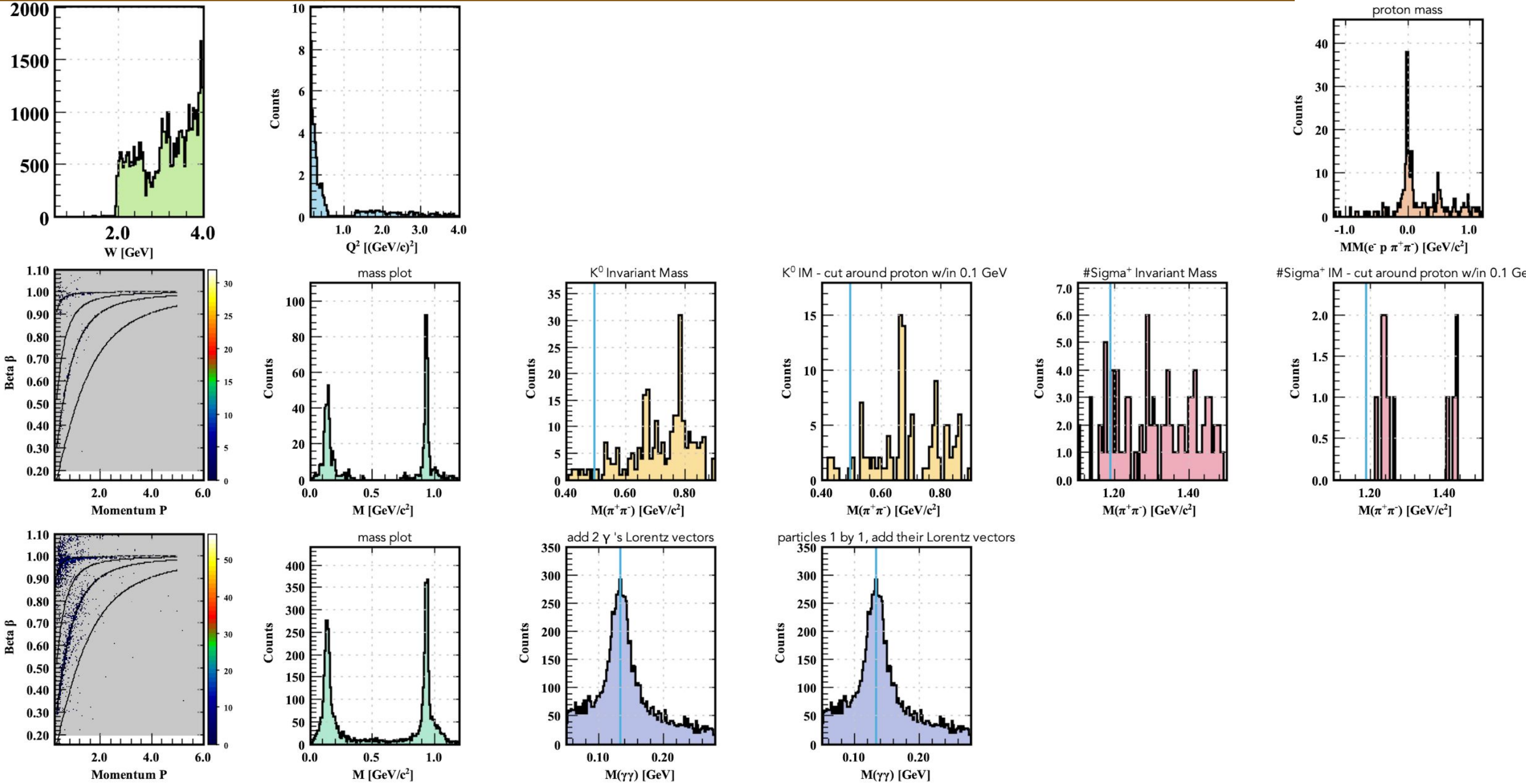
Reconstruction



FILTER 1: K^0 (yellow), Σ^+ (red), proton mass (orange)

FILTER 2: π^0 (purple)

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Analysis Code

- **Java/Jupyter Notebook**
- **Event Selection/Filters:**
    - $\gamma\gamma p\pi^+\pi^-$ (& any other pos/neg particle)
    - $\gamma\gamma$ (& any other pos/neg particle $\longrightarrow 2\gamma$ inclusive)
- **Shema/Banks:**
    - for simulations
        - MC::Lund
        - MC::Particle
    - for reconstruction
        - REC::Particle
        - REC::Event
        - REC::Scintillator
        - REC::ForwardTagger

REC::* Banks

- all detectors’ reconstructions
- retrieve event-based quantities
  - e.g. RF, helicity, live-time
- associate detector response ⟶ “particles”
  - Forward Detectors, Central Detector, Forward Tagger
- define event start time based on CLAS12 & FR
- Particle IDentification (PID)
- REC::Event
  - run/event #, helicity, event time, live time, etc
- REC::Particle
- REC::”ResponseType”
  - e.g. Calorimeter, Scintillator, Cherenkov
- REC::Trajectory, etc

“Structure and content of EB banks” by N. Baltzell. CLAS Collaboration Meeting. (October 2017)