

Exclusive Experimental Analysis of $\gamma n \rightarrow K^+ \Sigma^-$: Quasi-free and Rescattering Reactions

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June 19, 2017

2017 International Summer Workshop on Reaction Theory
June 12-22, 2017 Bloomington, Indiana - USA

Motivation

- Constituent quark models predict N^* states that have not yet been found experimentally.

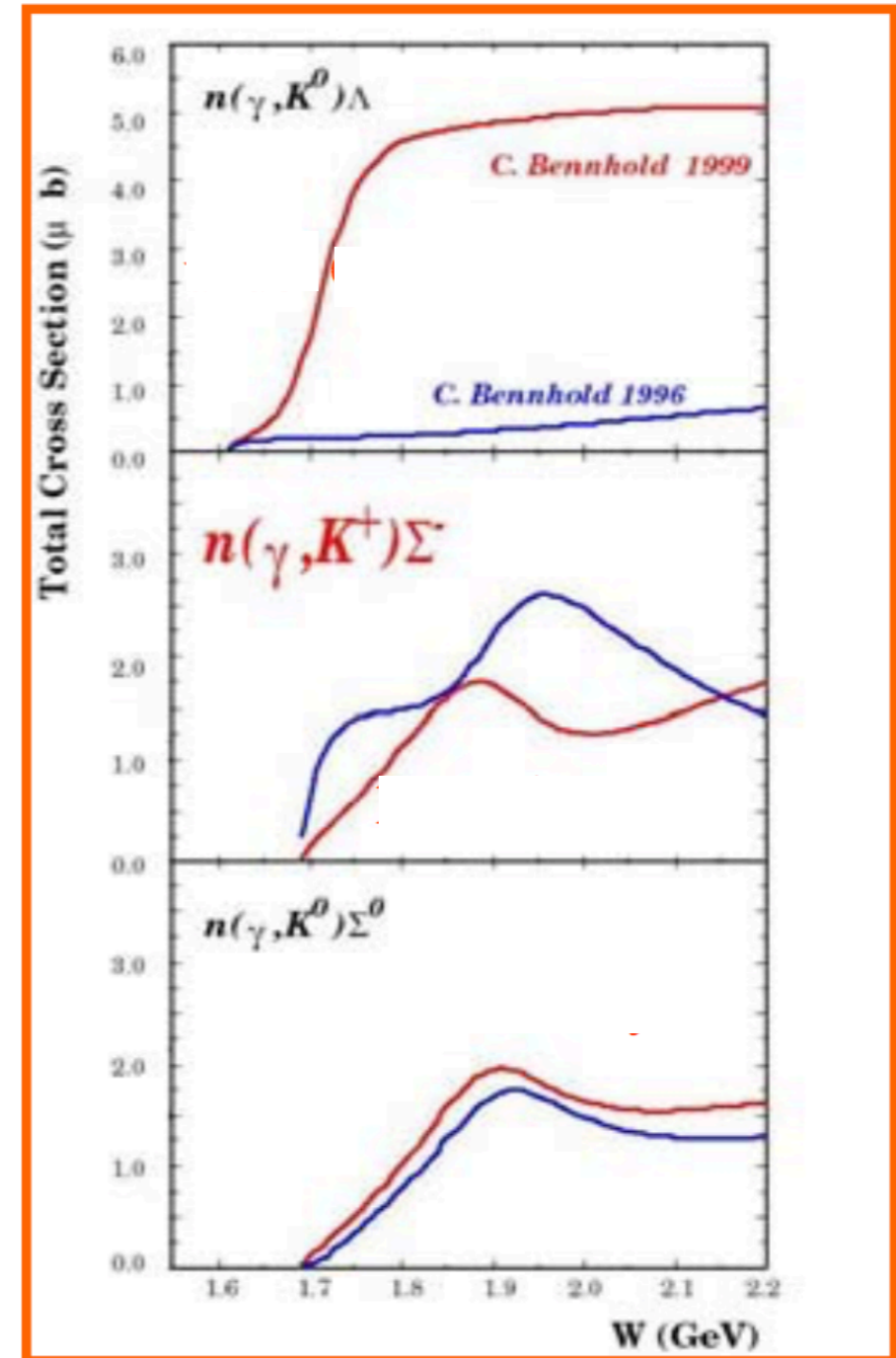
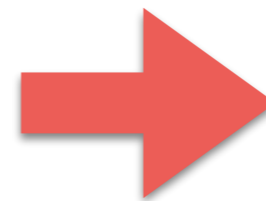
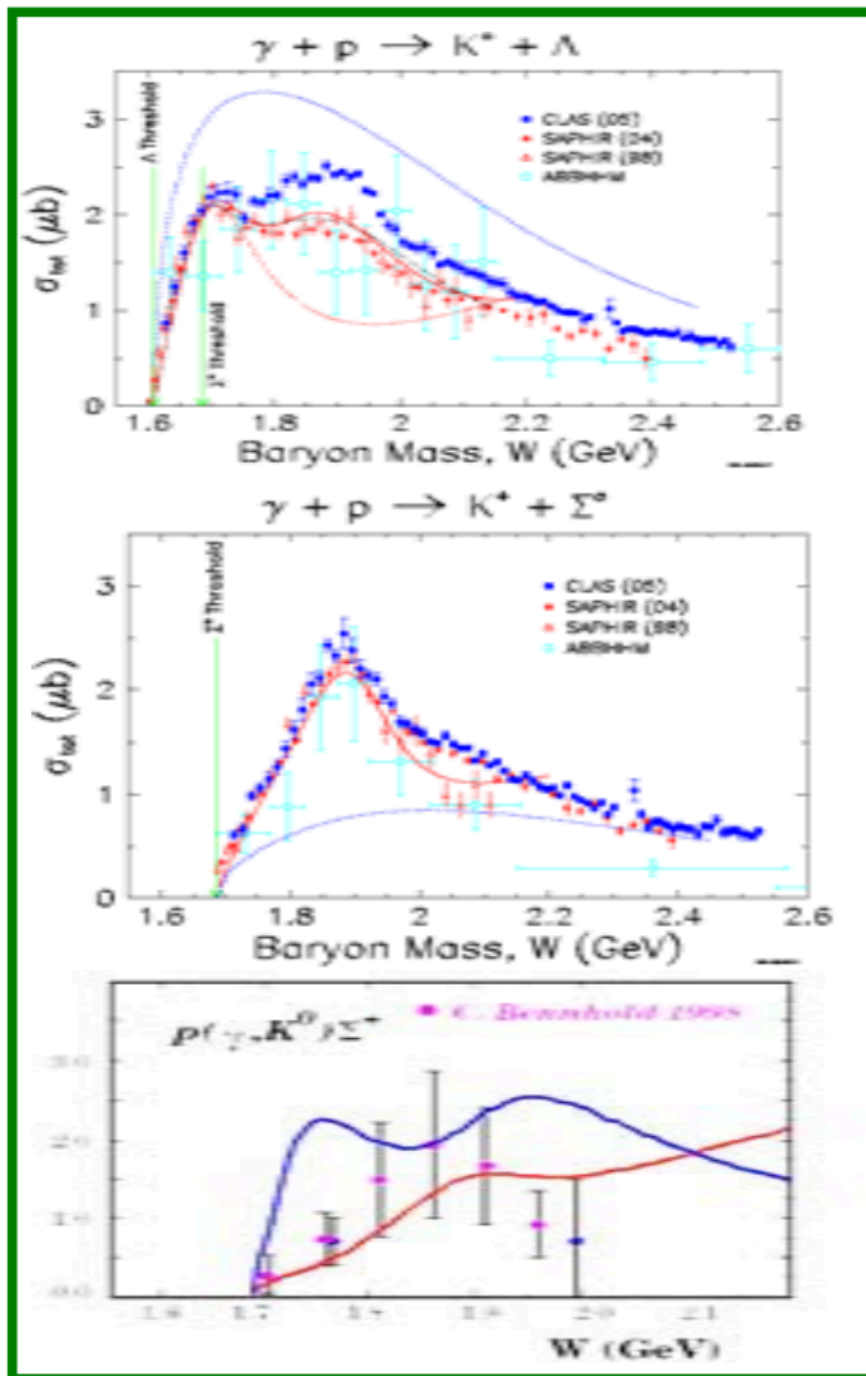
Motivation

- Constituent quark models predict N^* states that have not yet been found experimentally.
- Model issue or experimental issue?
- These states could couple more strongly to strange channels.
- It is important to provide data to investigate the spectrum of baryon (N^* and Δ) resonances that decay into KY ($Y \equiv \Lambda$ or Σ) and not into π channels.

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- It is important to provide data to investigate the spectrum of baryon (N^* and Δ) resonances that decay into KY ($Y \equiv \Lambda$ or Σ) and not into π channels.
- In particular, strangeness data on the neutron is scarce

Reactions on the neutron



CLAS g13 Run Period

Polarized photon beam

Circular (g13a) and linear (g13b) polarization

Photon energy range

0.8-2.5 GeV, 1.1-2.3 GeV

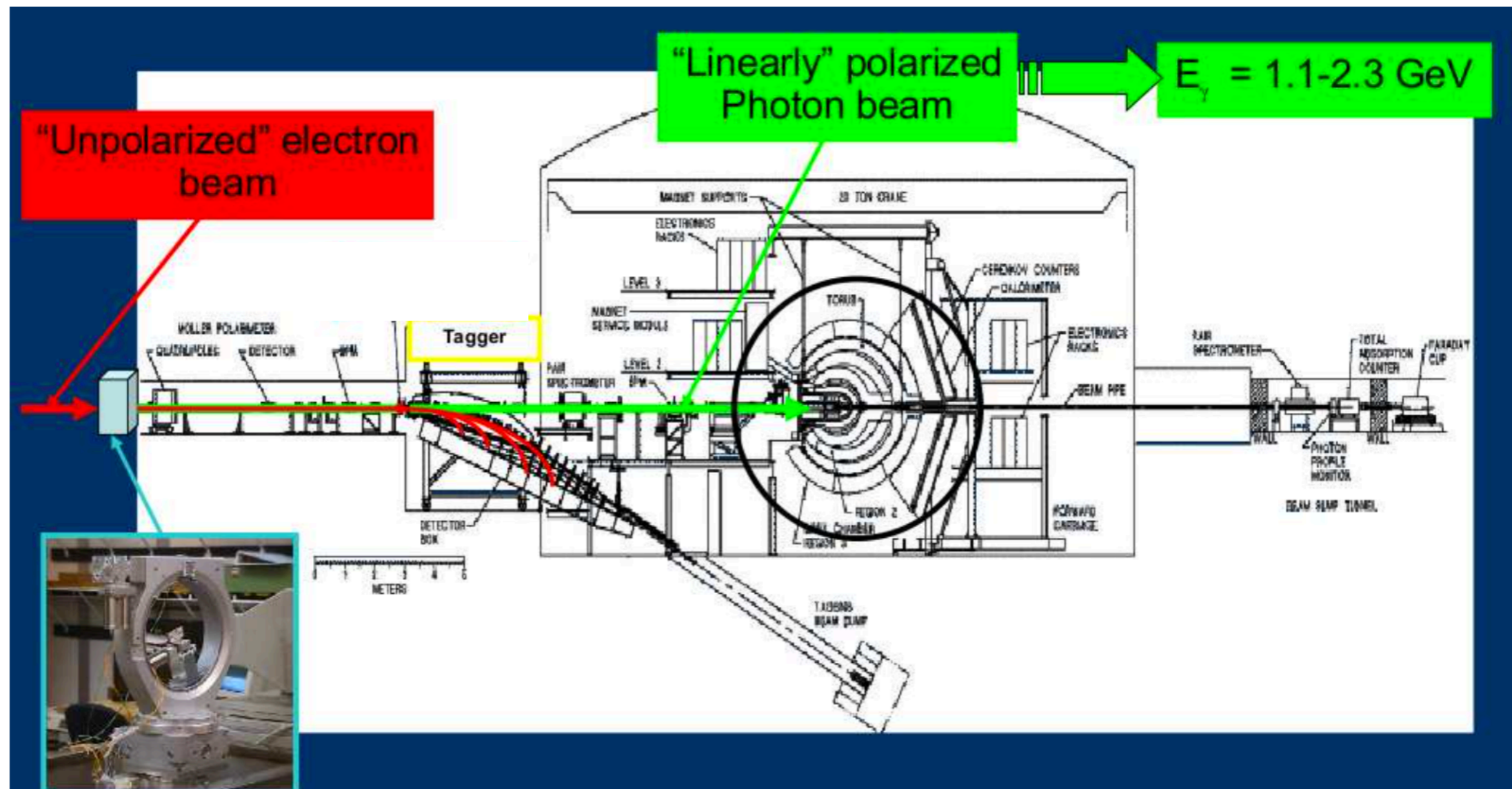
Target

Liquid Deuterium (40-cm length)

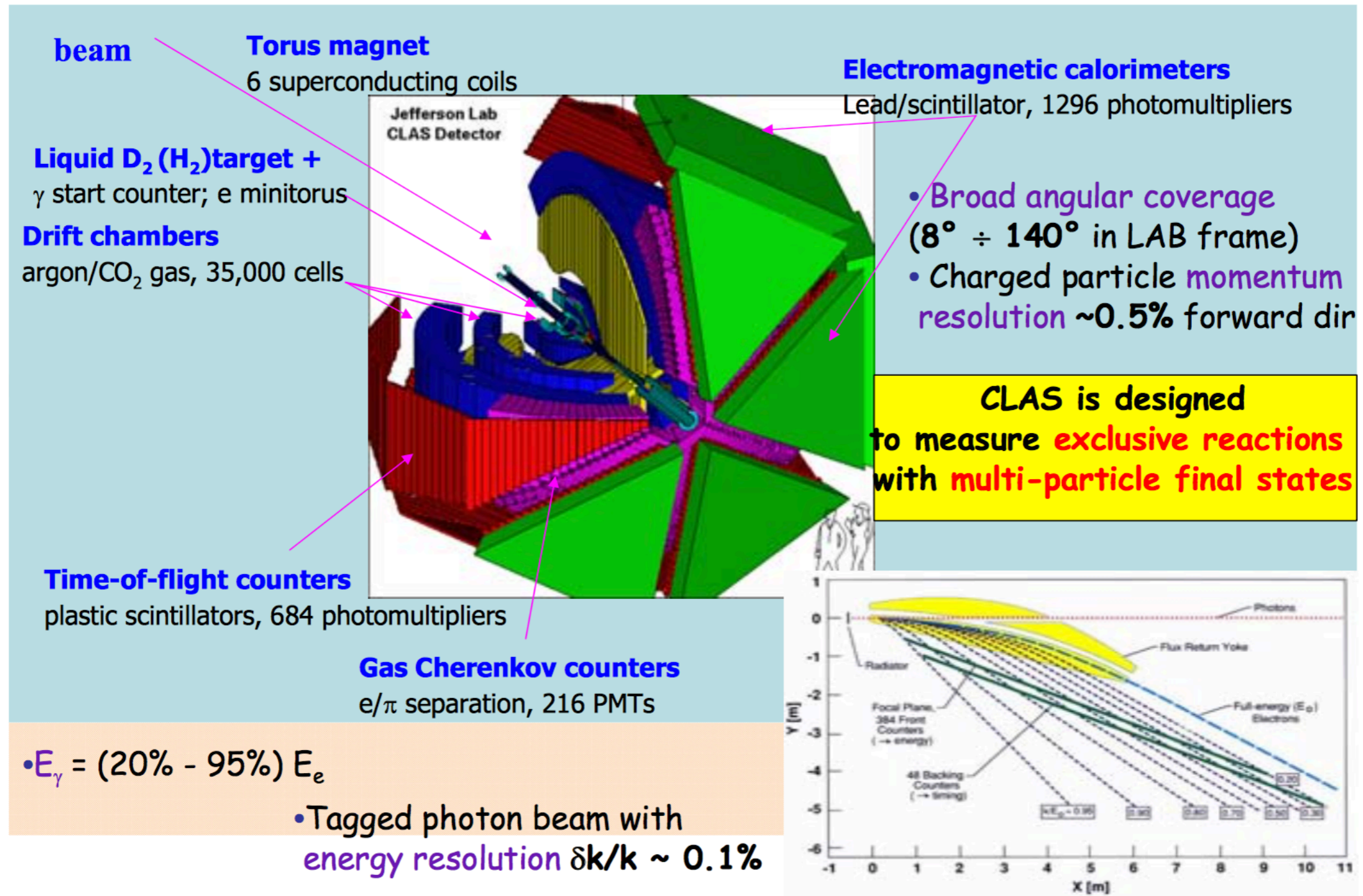
Triggers

About a total of 52 billion triggers

CLAS g13 Run Period

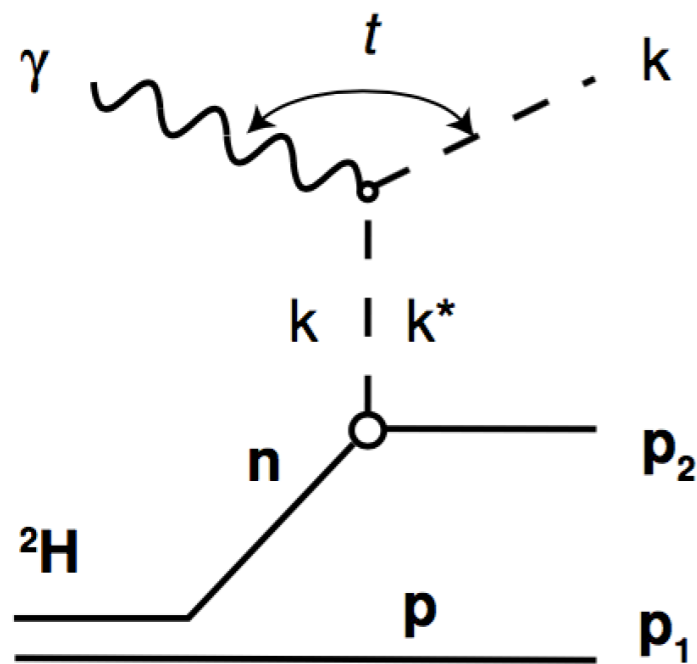


CLAS: CEBAF Large Acceptance Spectrometer

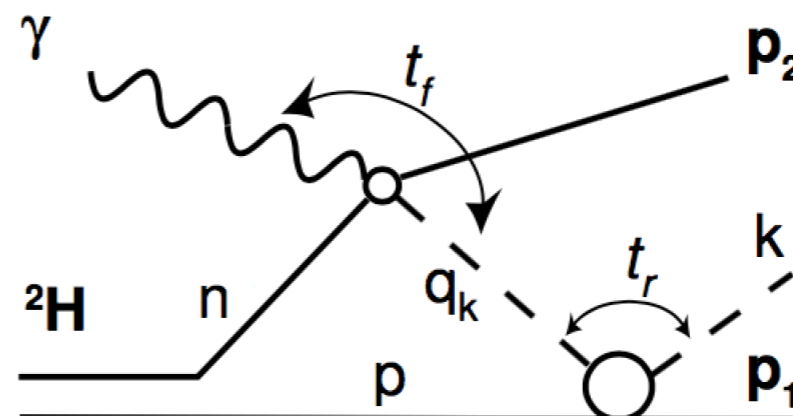
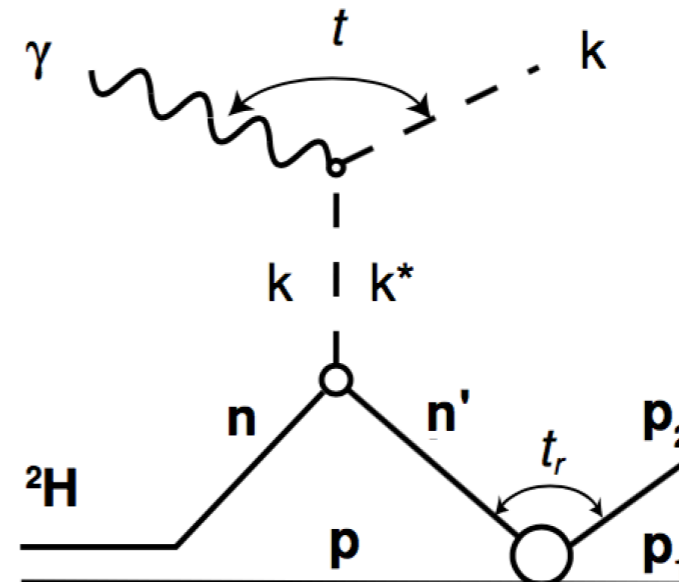


Reaction $\gamma n \rightarrow KY$

Quasi free



Rescattering



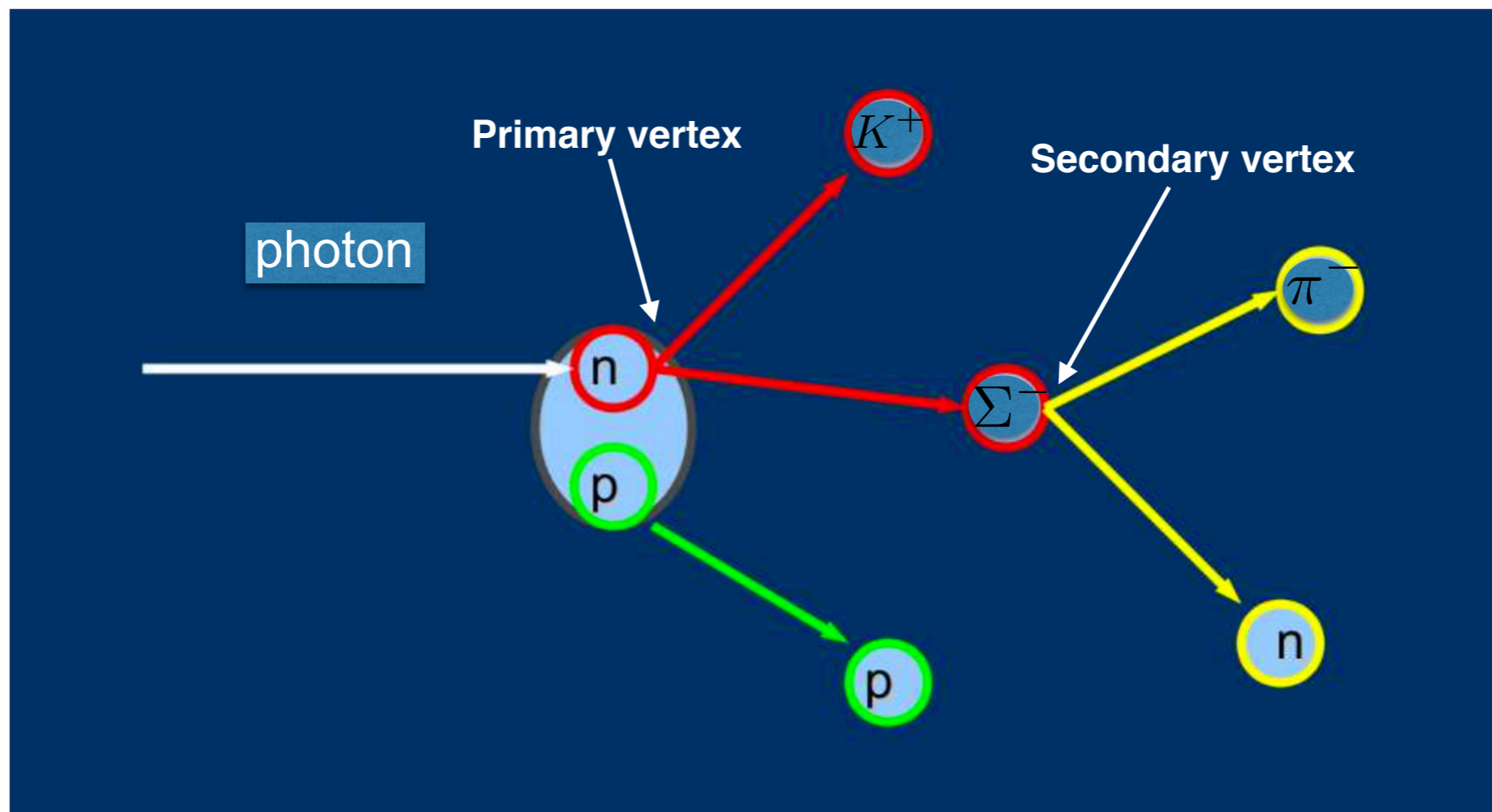
Experimental Analysis

- **Quasi-free reaction:** π^- , K^+ , n *detected*

Σ^- from Invariants mass

p from Missing mass

Reaction $\gamma d \rightarrow K^+ \Sigma^- p$



Experimental Analysis

- **Quasi-free reaction:** π^{-}, K^{+}, n *detected*

Σ^{-} from Invariants mass

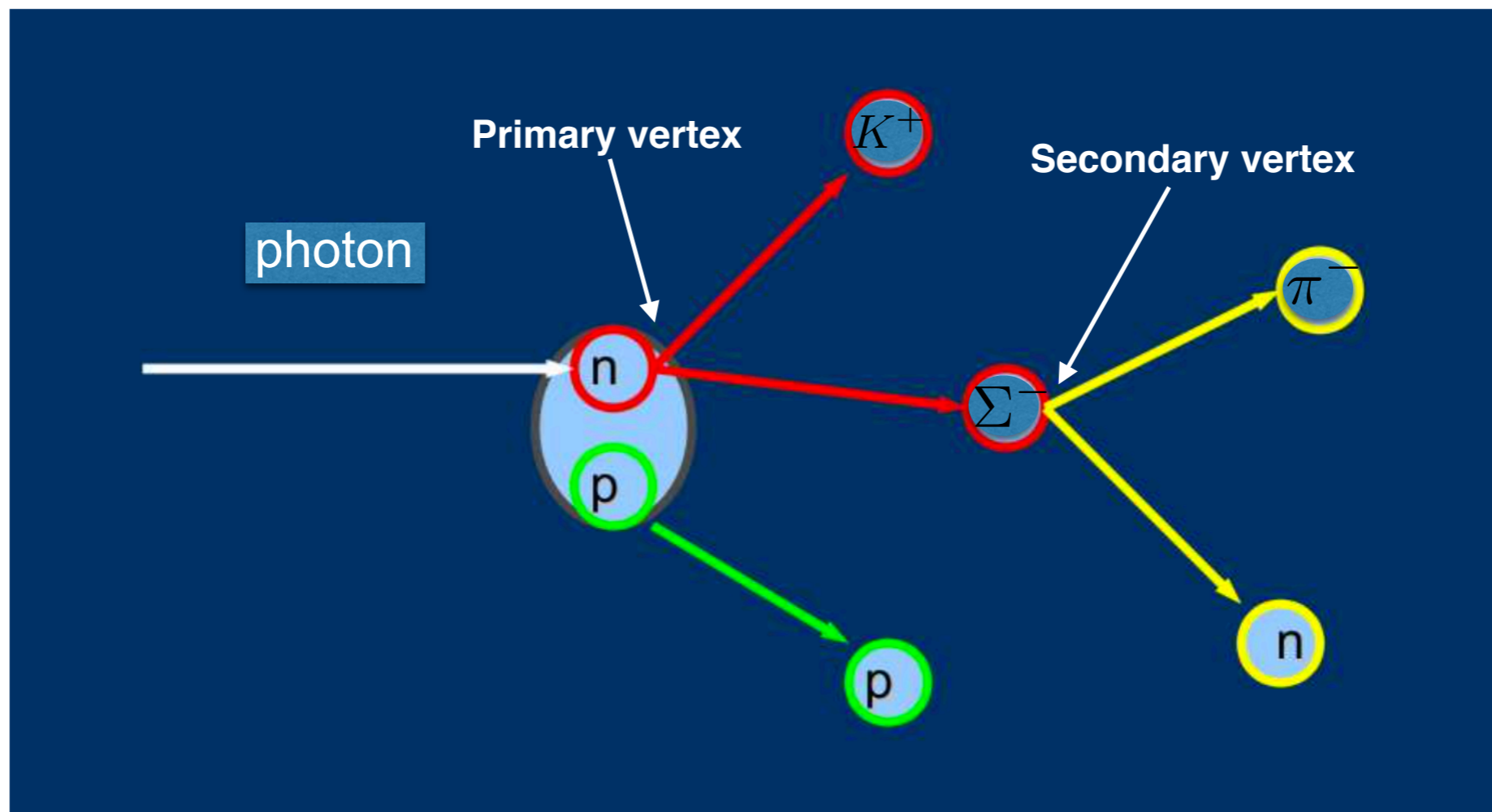
p from Missing mass

- **Rescattering reaction:** π^{-}, K^{+}, p *detected*

n from Missing mass

Σ^{-} from Invariants mass

Reaction $\gamma d \rightarrow K^+ \Sigma^- p$

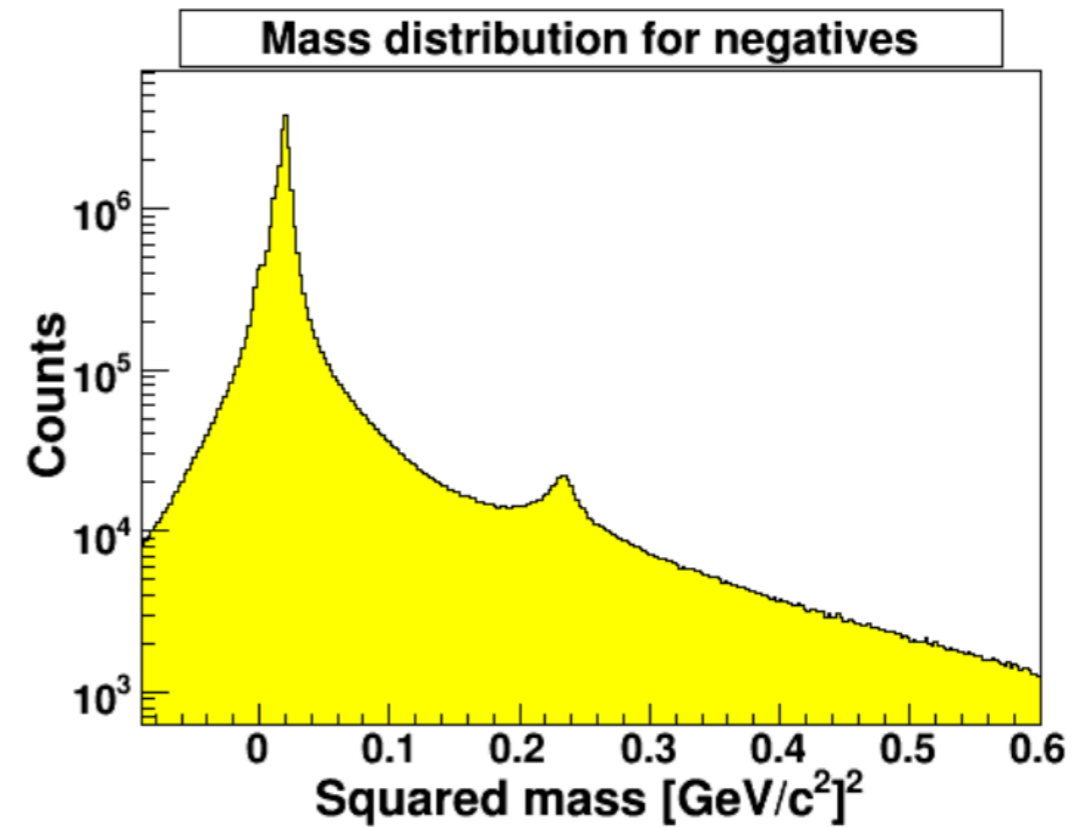
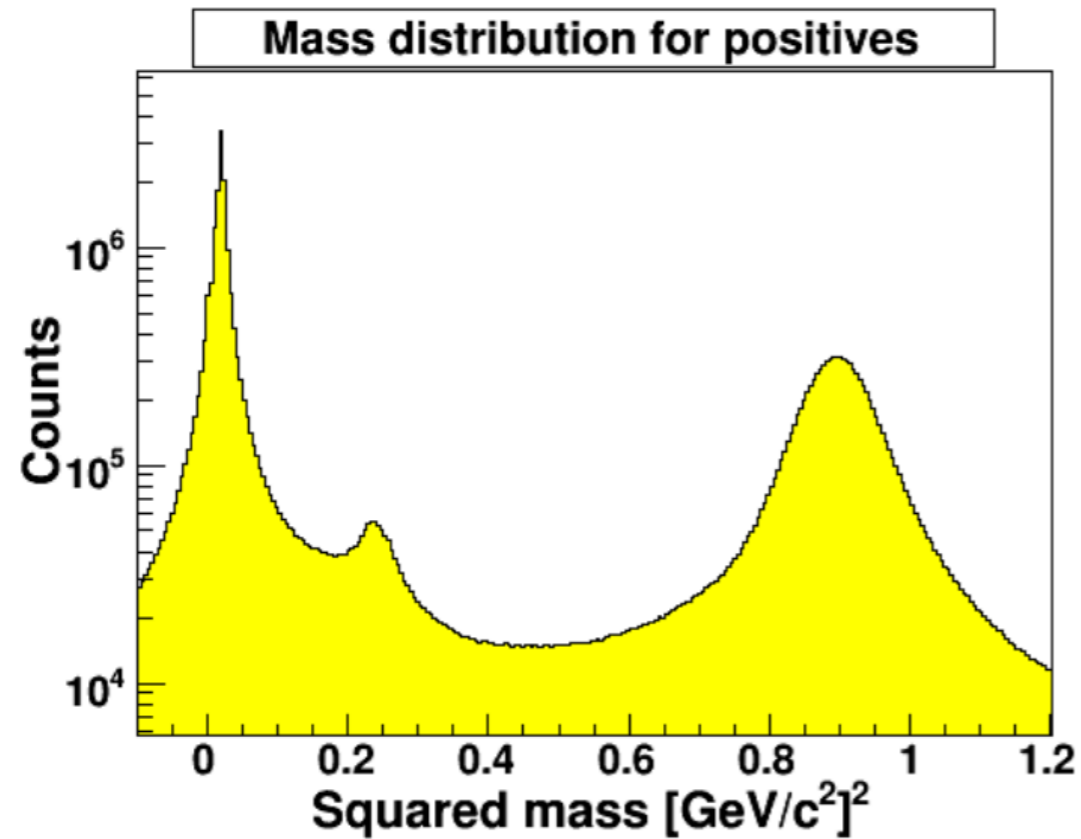


Experimental Analysis

Analysis strategy:

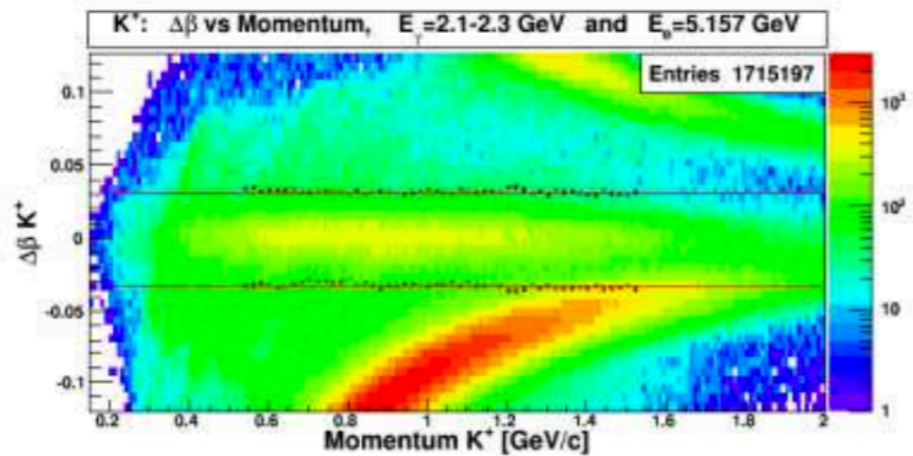
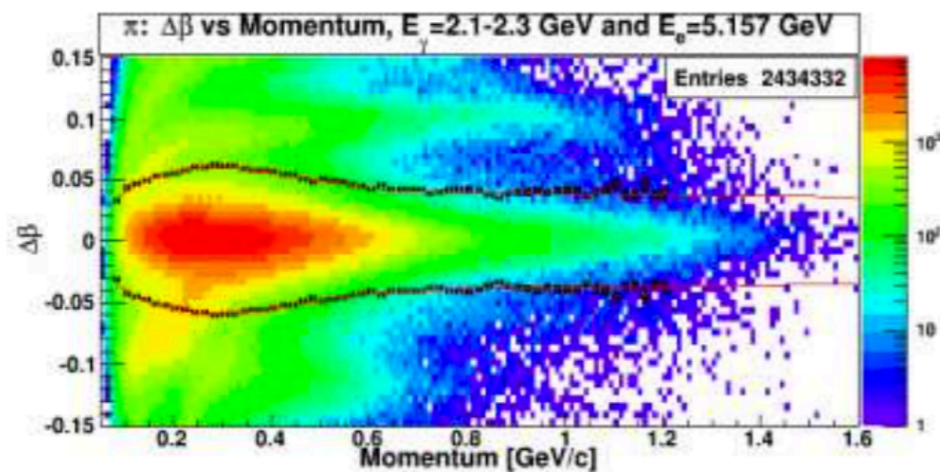
- PID cuts
- Fiducial cuts
- Energy-loss corrections
- Background subtraction

Charged part. reconstruction



Charged part.reconstruction

$$\Delta\beta = \beta_{calc} - \beta_{meas} \text{ (3-}\sigma \text{ cuts)}$$



β_{calc}

$$\frac{p}{\sqrt{p^2 + m^2}}$$

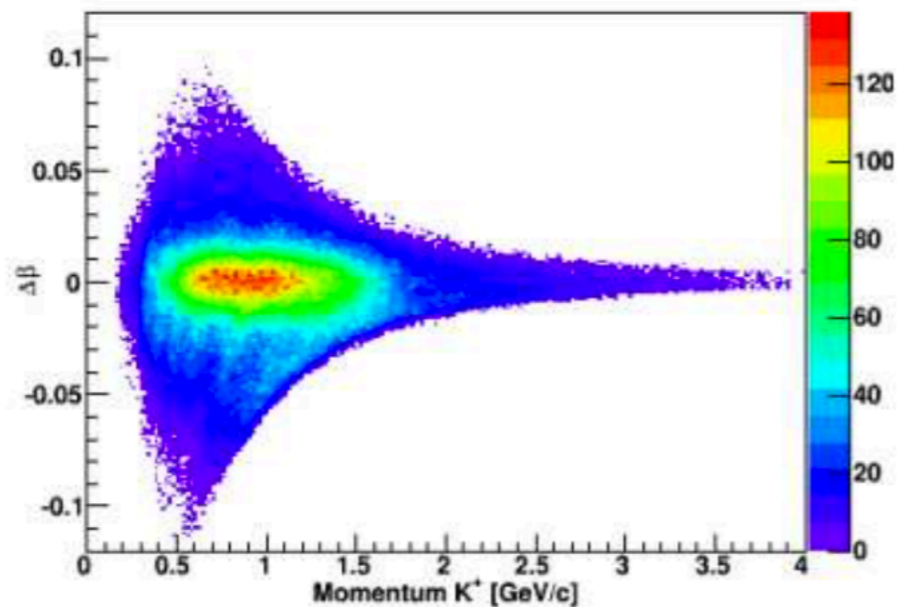
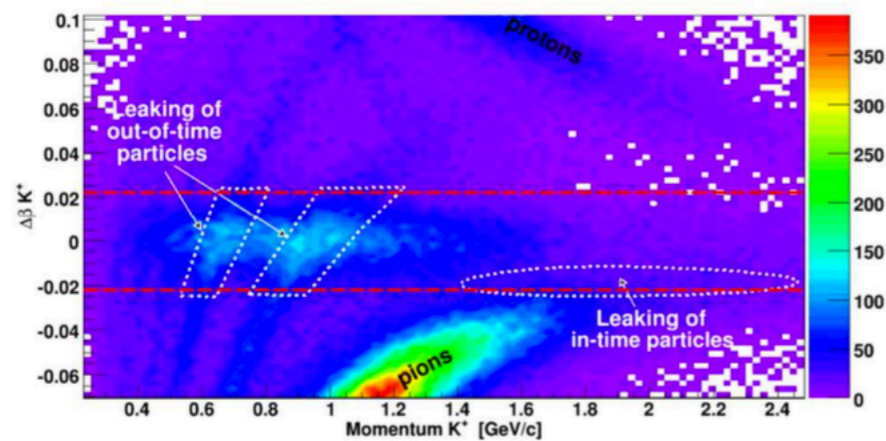
p : reconstructed momentum,
 m : input mass of the particle

β_{meas}

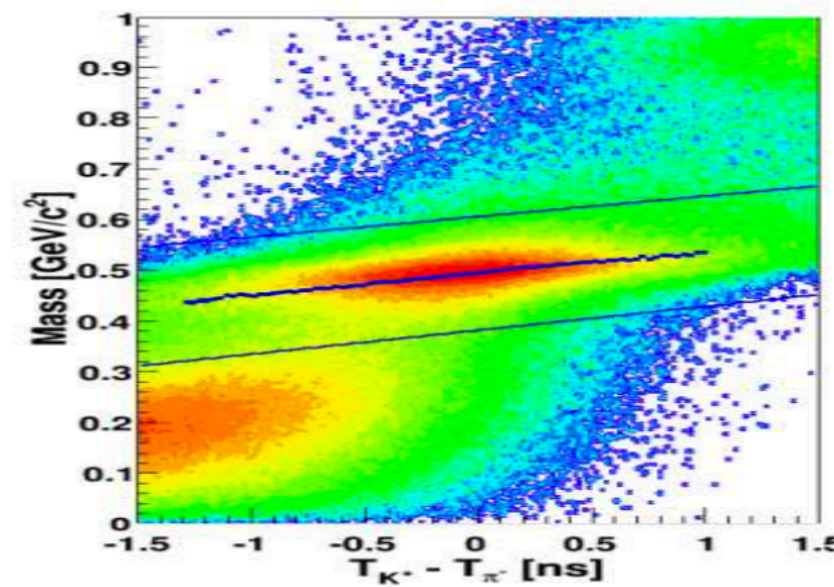
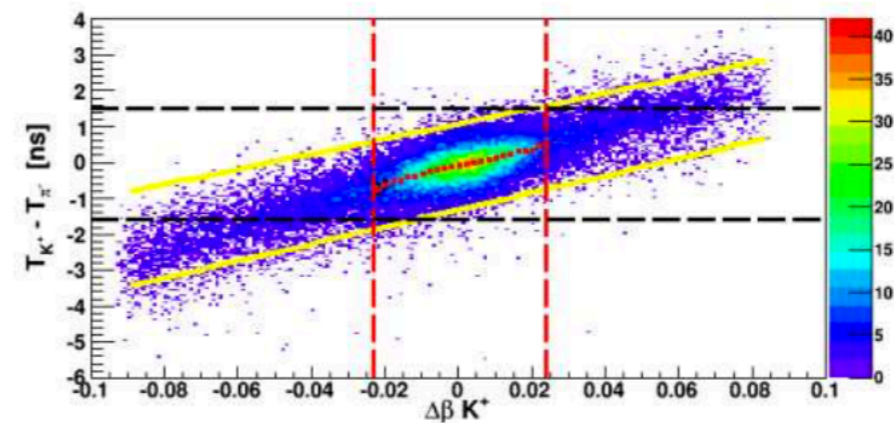
Reconstructed in the CLAS
software

Charged part. reconstruction

β and momentum distribution

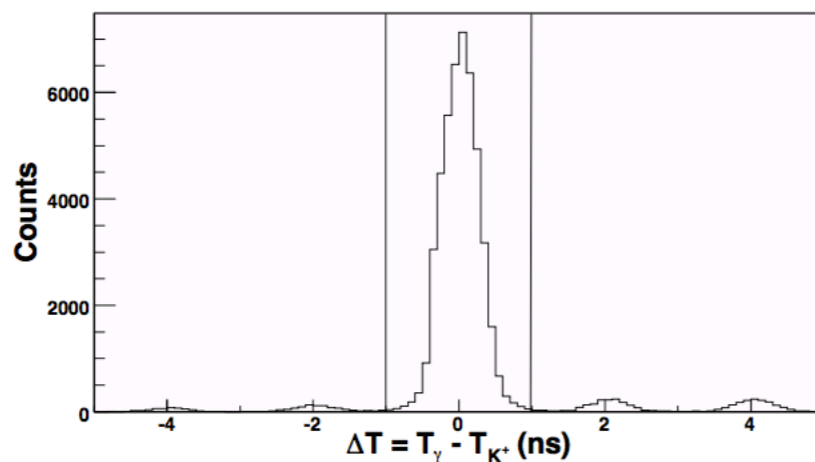
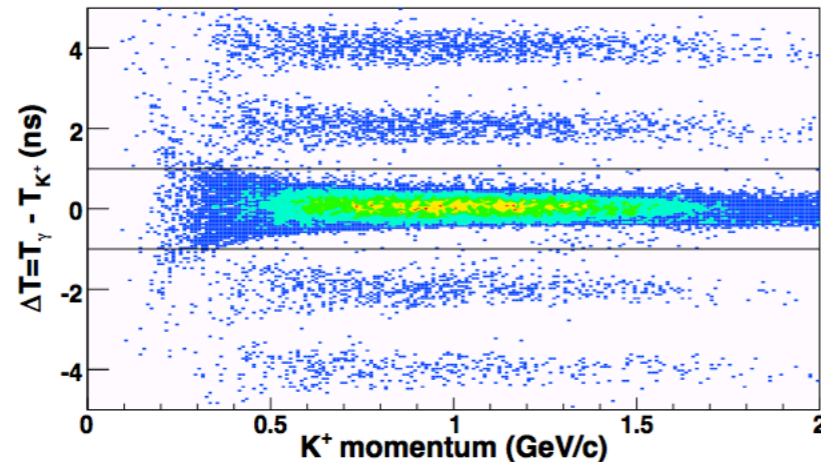


β and momentum distribution



Incident photon selection

Best photon: $\Delta T = T_\gamma - T_{K^+}$



T_γ

Photon arrival time (tagger)

T_{K^+}

Photon arrival time (TOF)

Good photons rejected

Multiple-good-photon events were rejected ($\approx 2.60\%$)

Quasi-free reaction

Neutron reconstruction

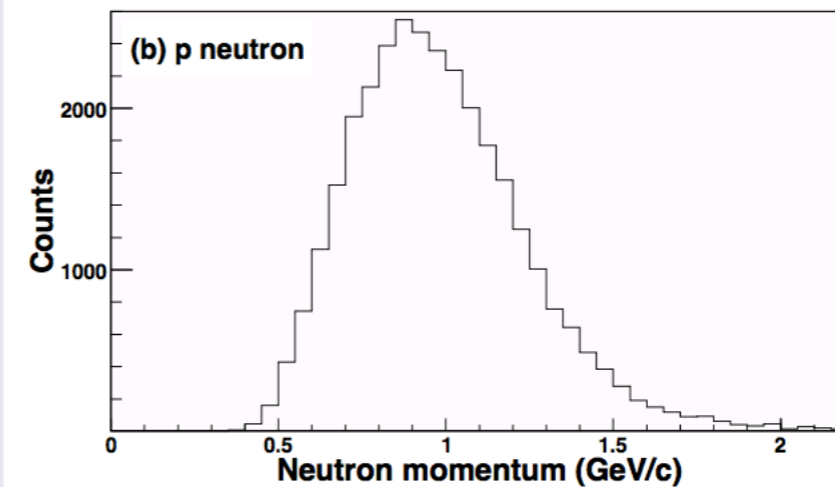
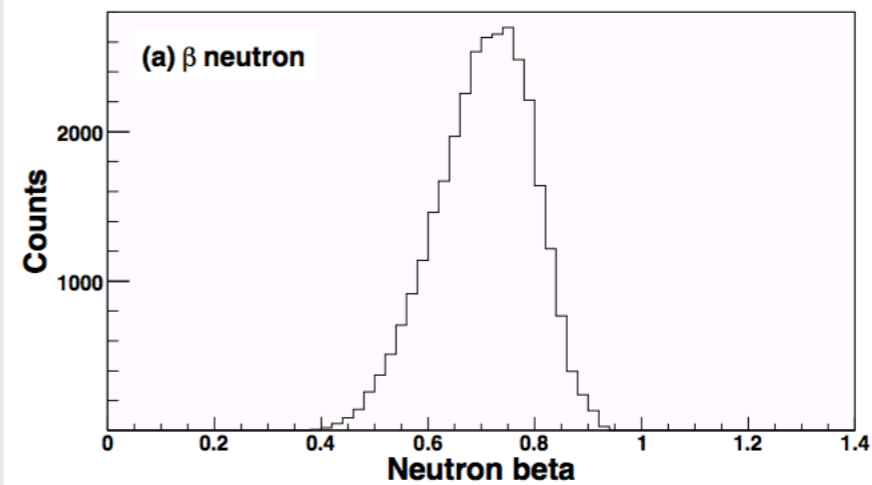
Neutron detection

Signal in the Calorimeter (EC)

Neutron time

EC time calibrated. No need for correction

β and momentum distribution



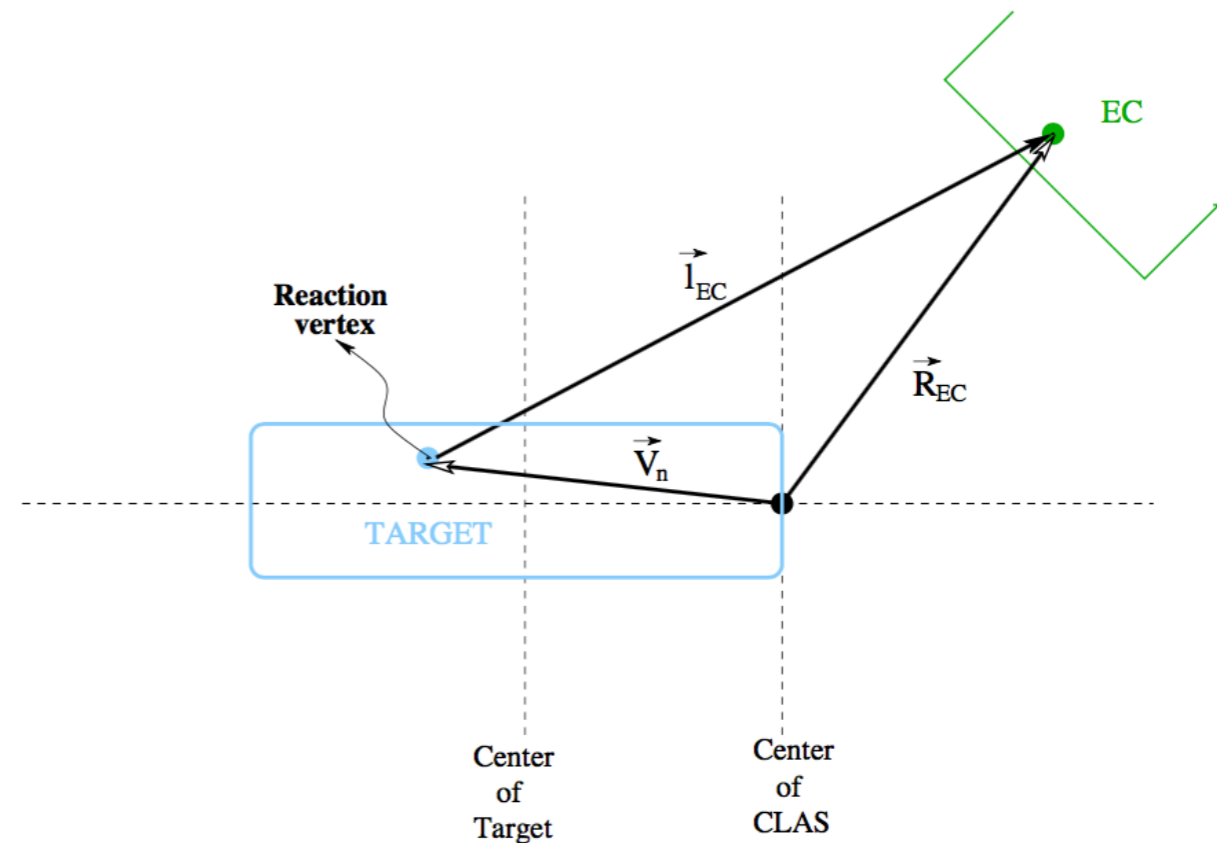
Neutron reconstruction

Interaction layer in EC

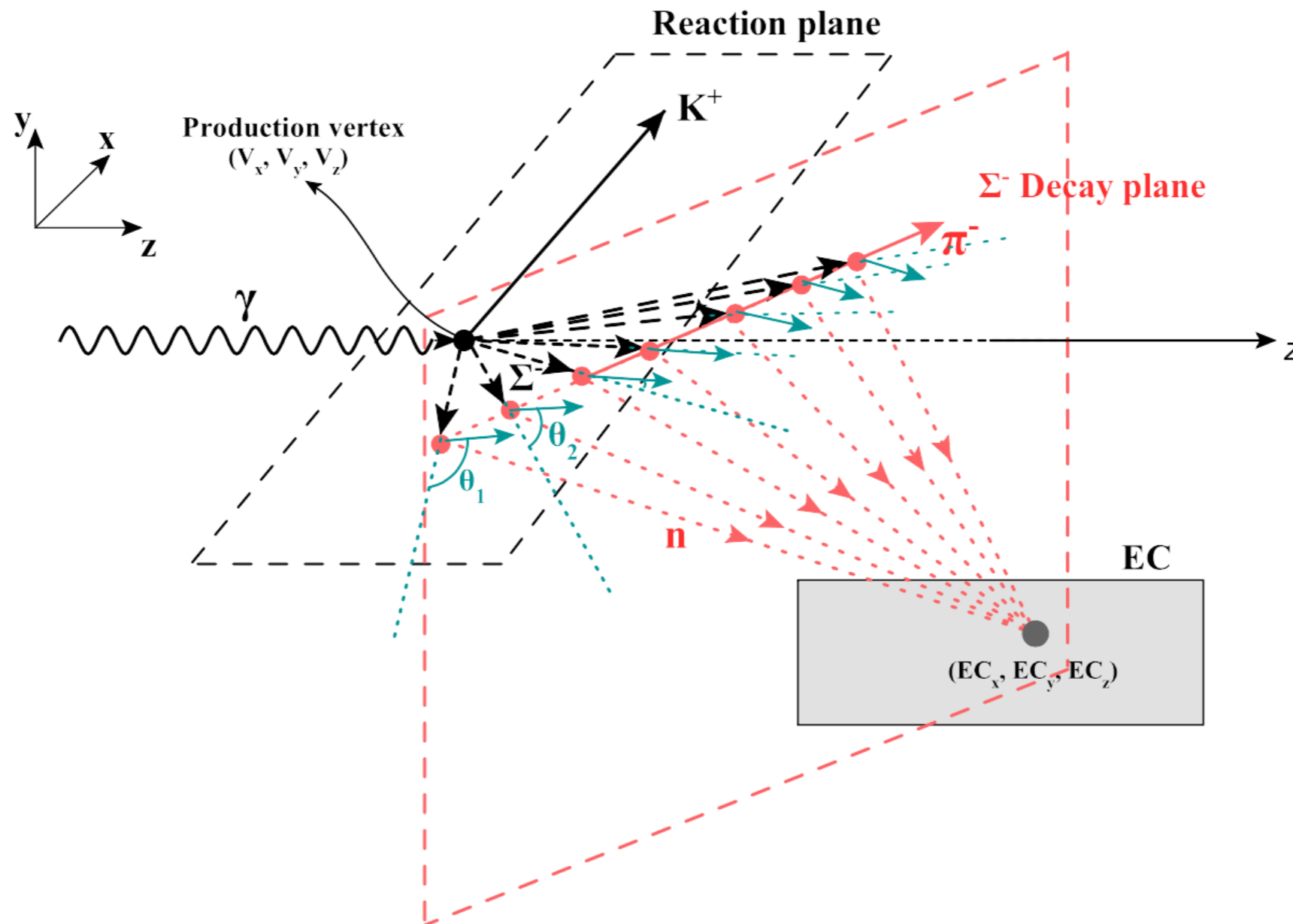
- From $\gamma d \rightarrow \pi^+ \pi^- p n$

Reconstructed neutron vertex

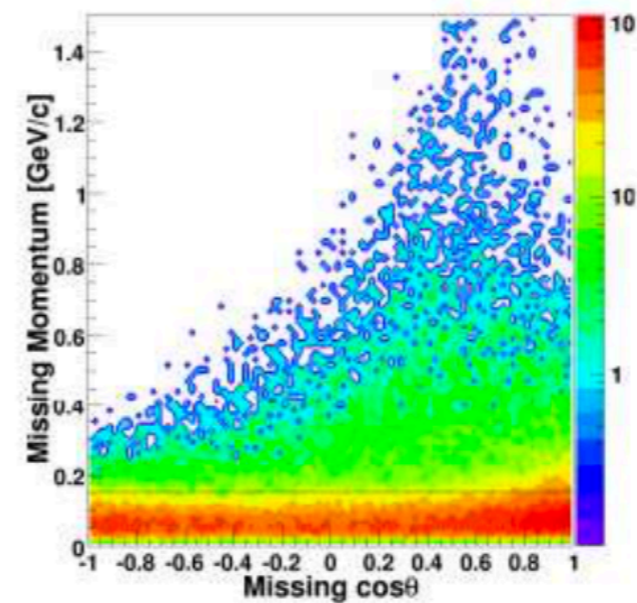
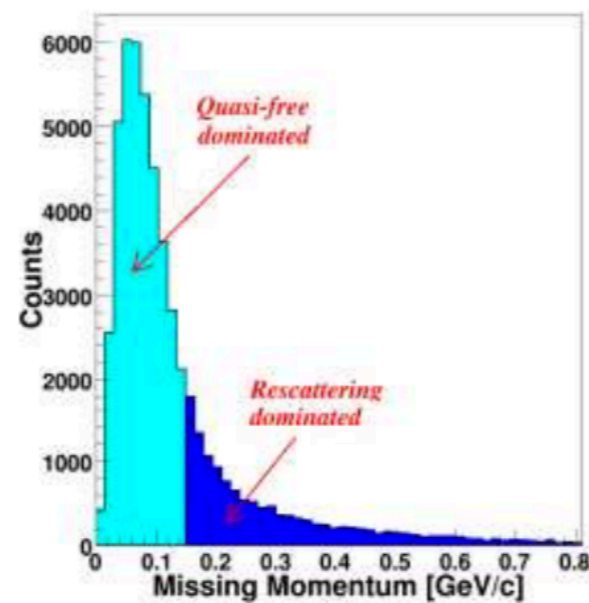
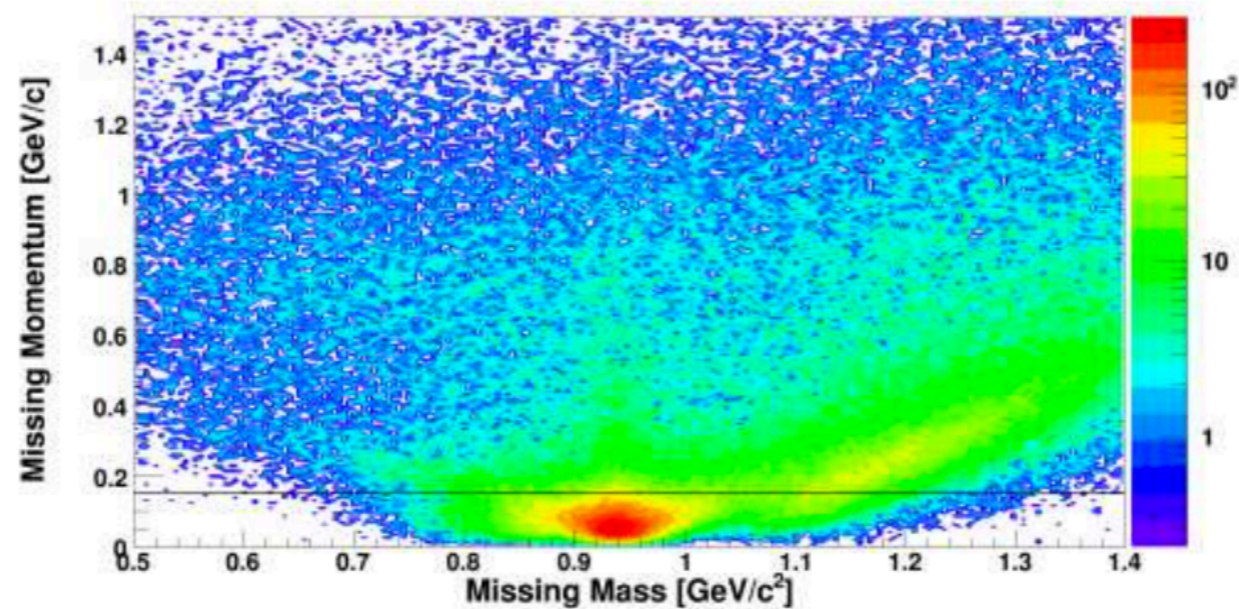
- $c\tau_{\Sigma^-} \approx 4.4 \text{ cm}$



Neutron reconstruction



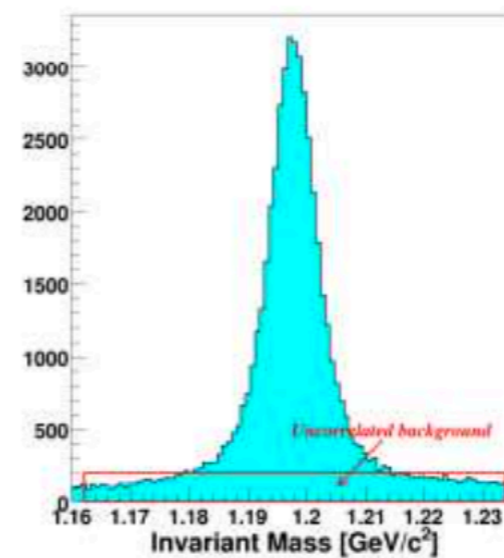
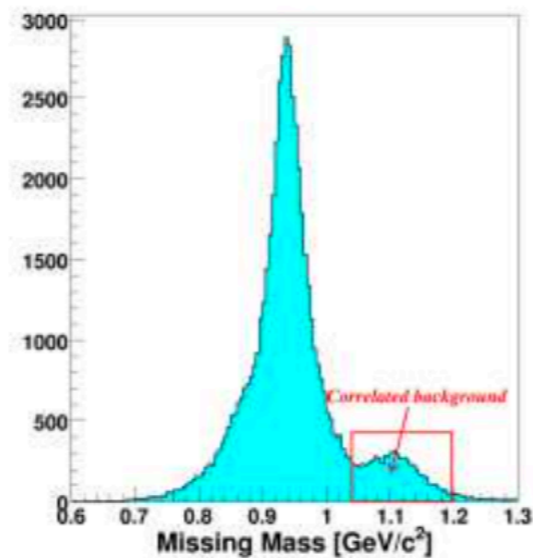
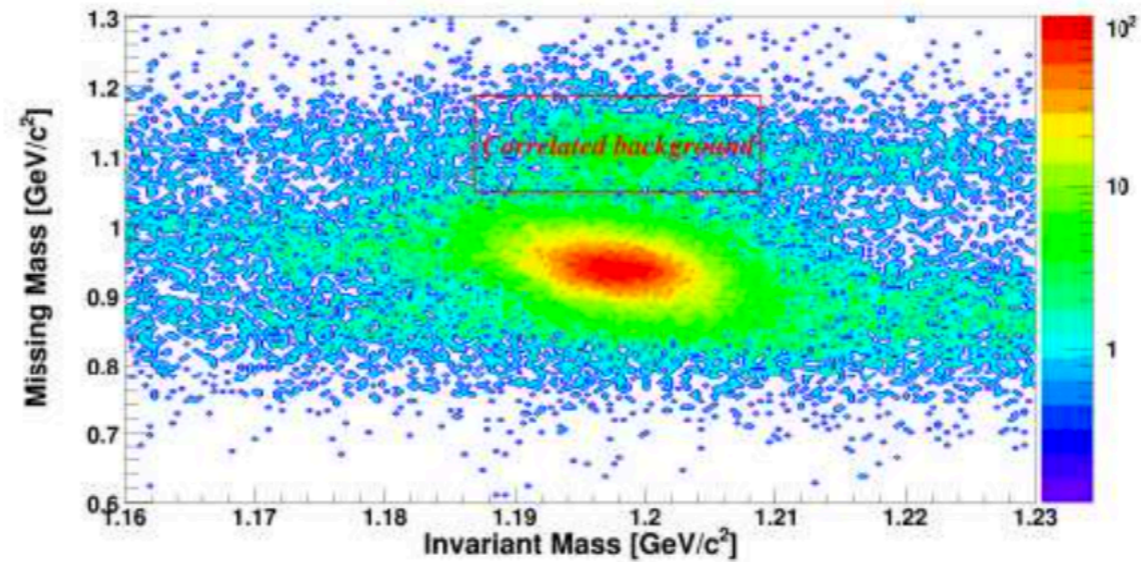
Missing mass (proton)



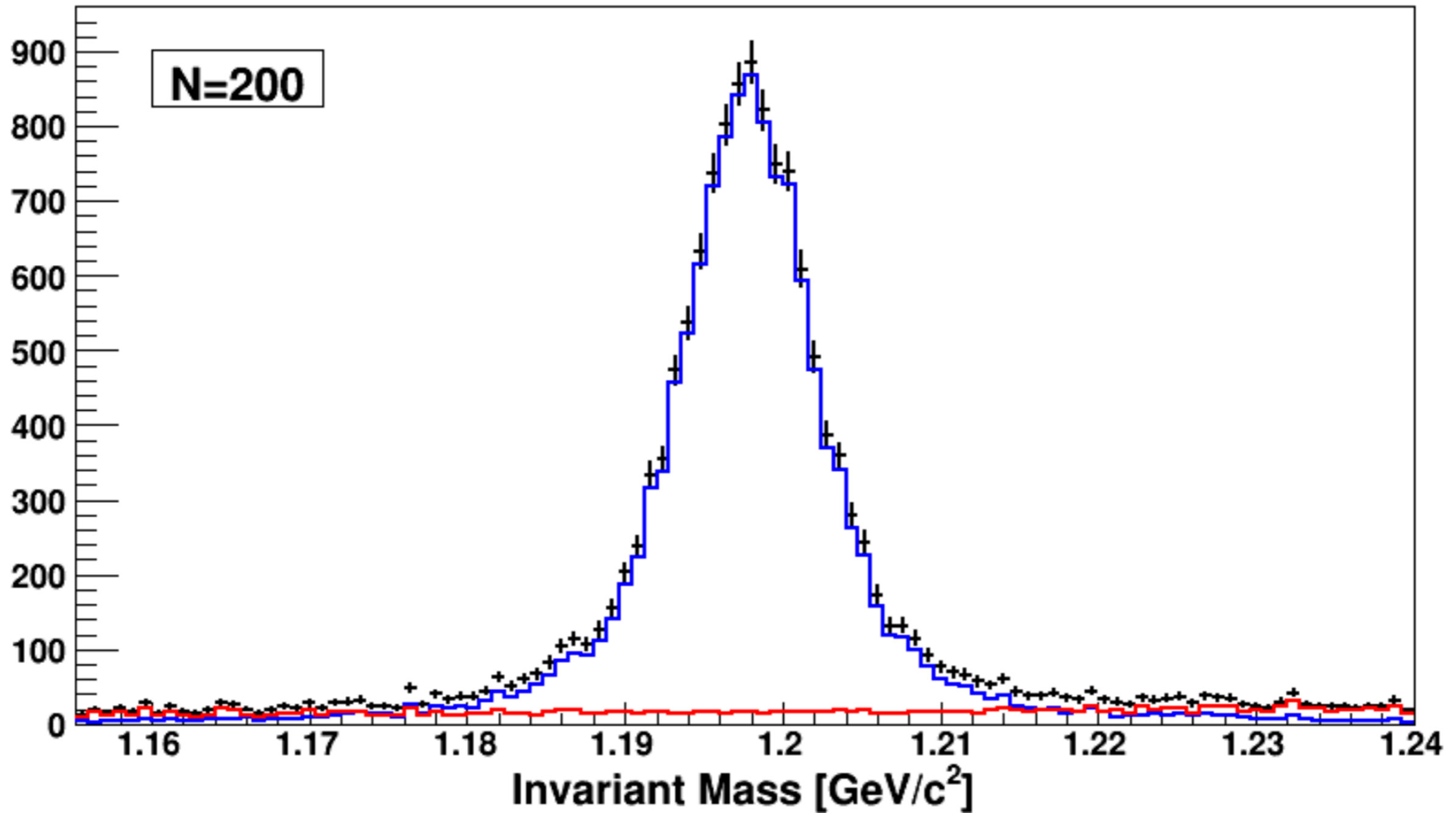
Background

Correlated background: $\gamma d \rightarrow K^+ \Sigma^- (p) \pi^0$

Uncorrelated background: $\gamma d \rightarrow \pi^+ \pi^- n p$

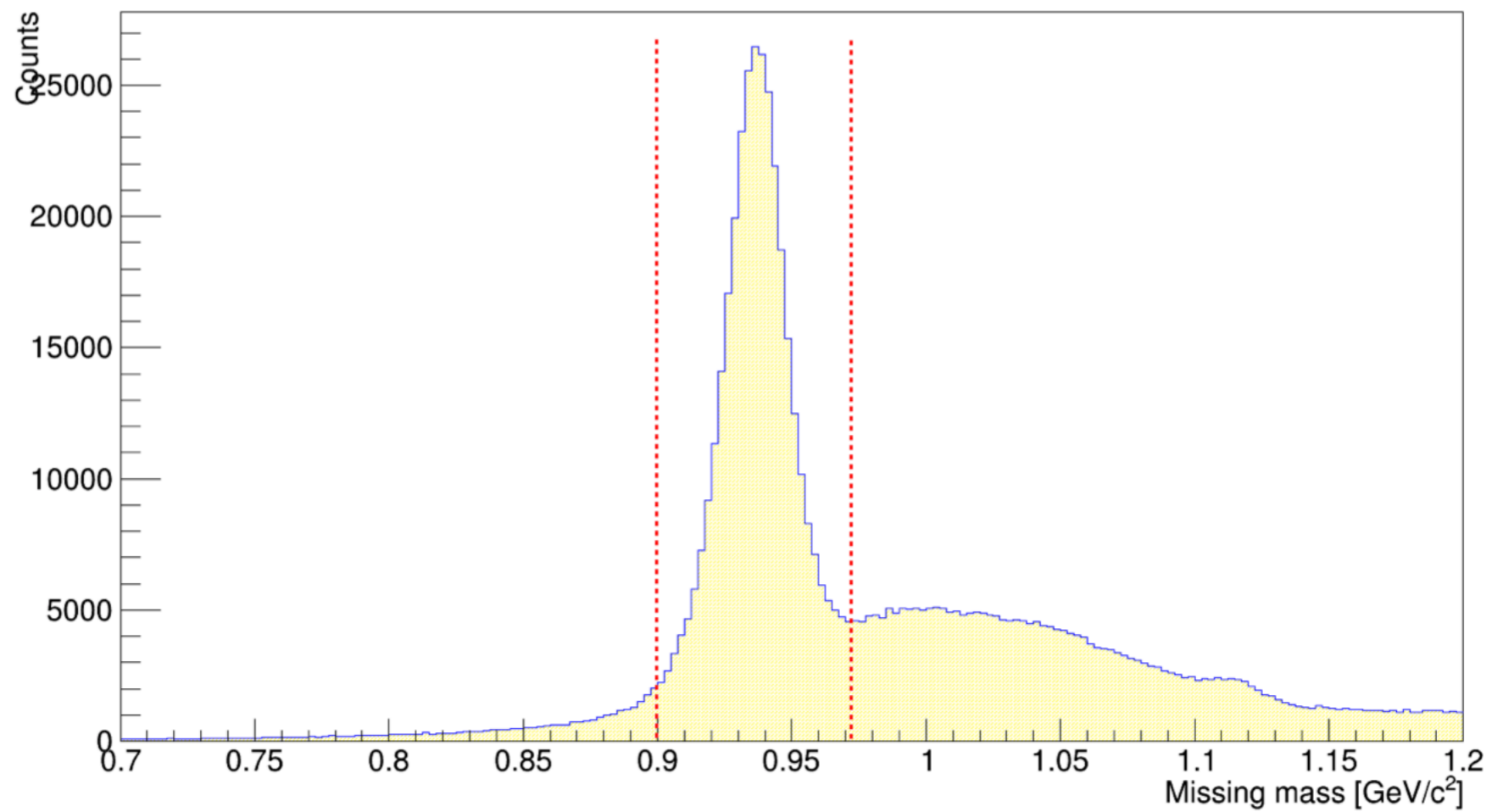


Invariant mass (Σ^-)

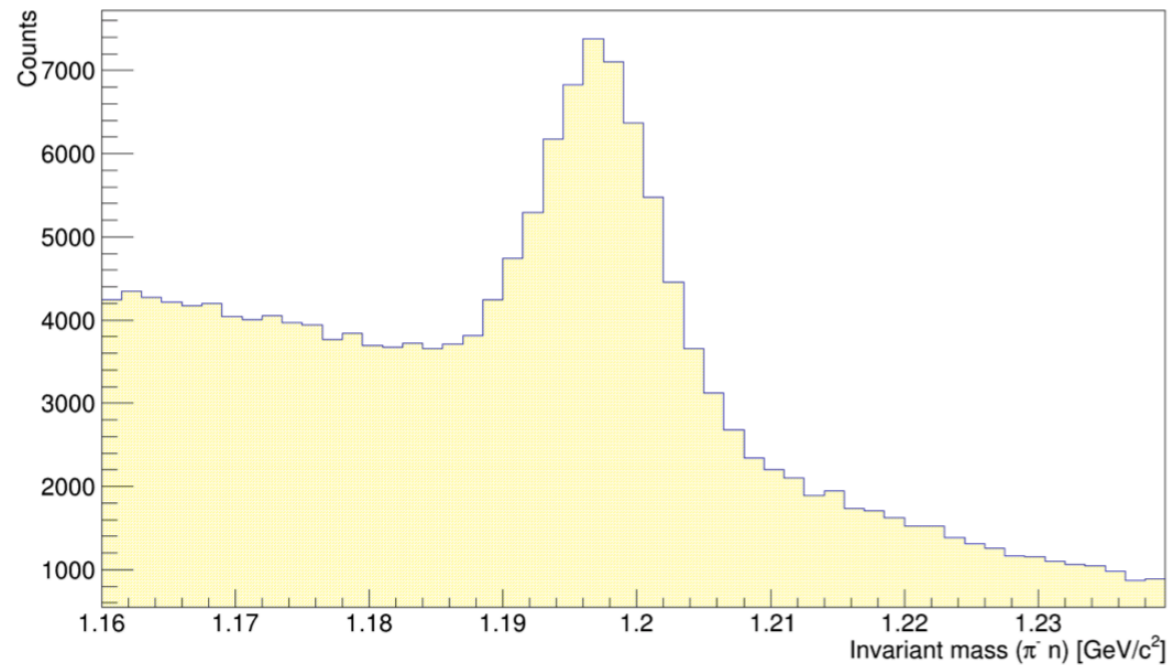


Rescattering reaction

Missing mass (neutron)



Background subtraction

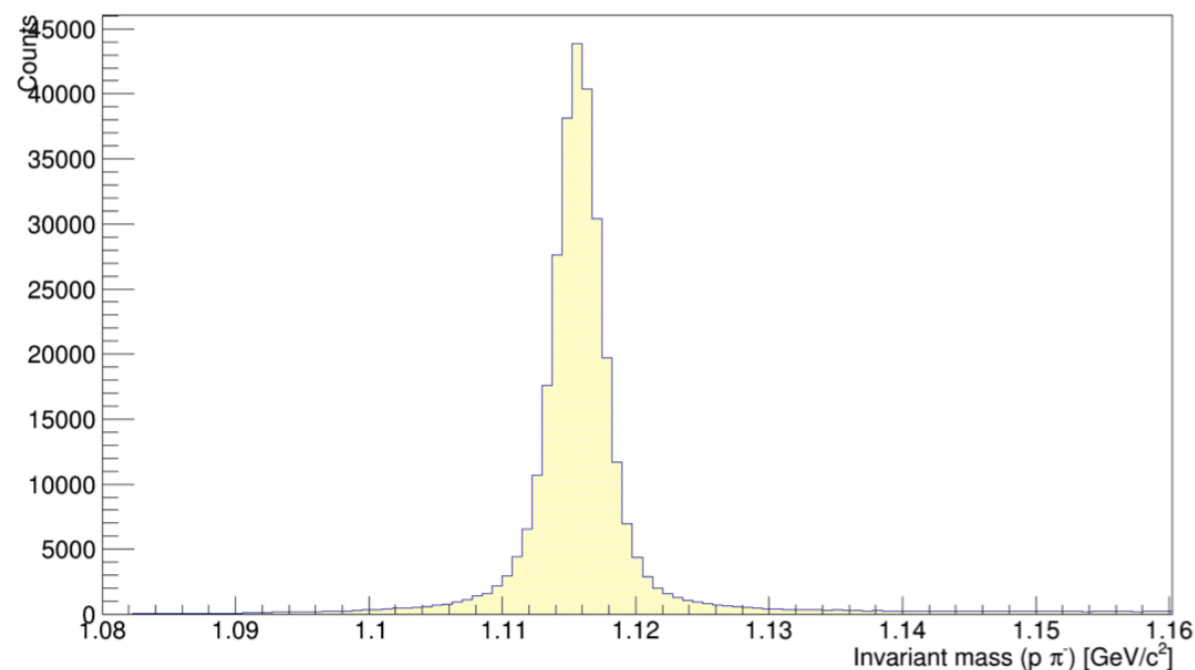


$$\gamma d \rightarrow K^+ \Sigma^- p \rightarrow K^+ \pi^- np$$

- $MM(\pi^- n)$

$$MM(\pi^- p) < 1.05 \text{ GeV}$$

$$MM(\pi^- p) > 1.20 \text{ GeV}$$



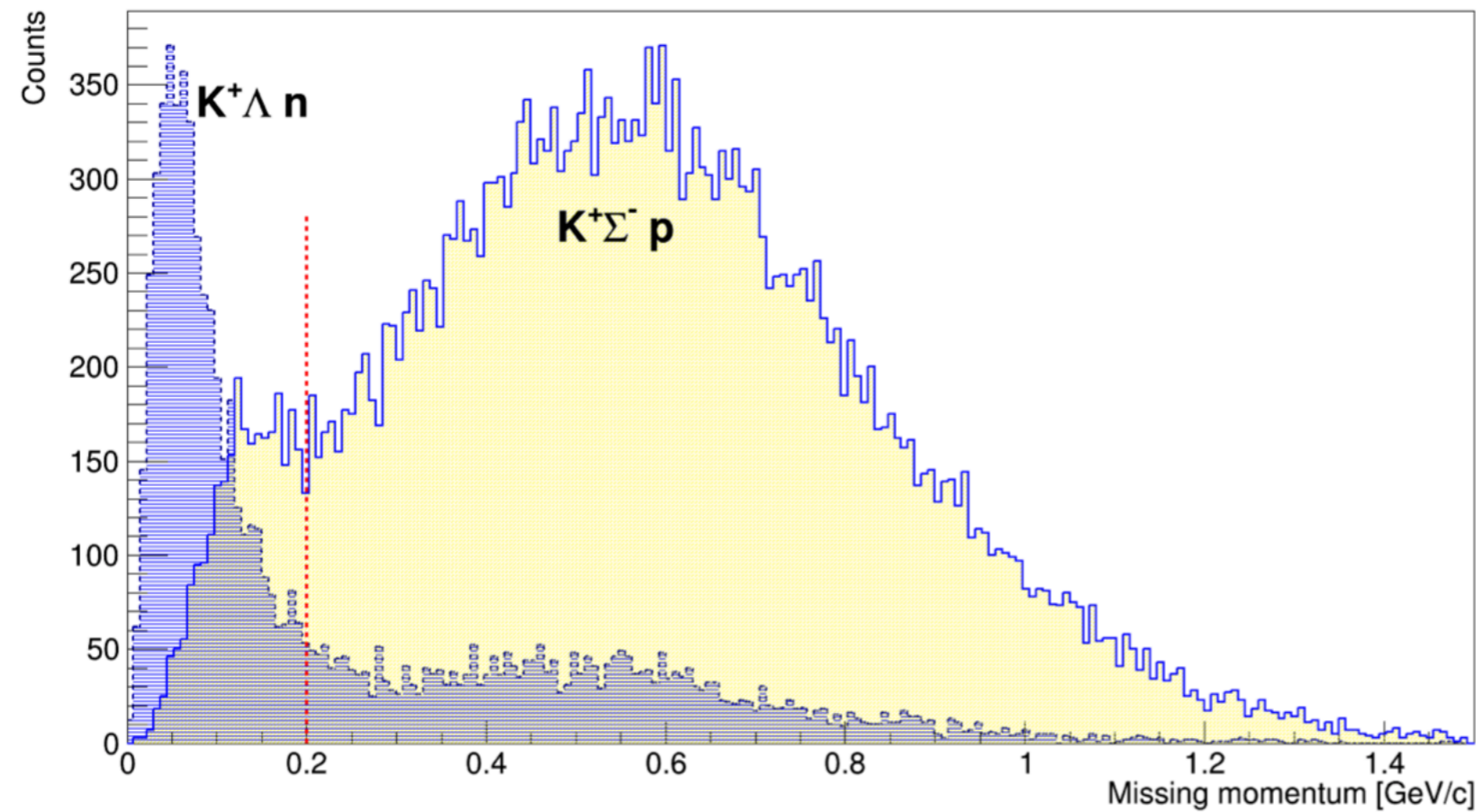
$$\gamma d \rightarrow K^+ \Lambda n \rightarrow K^+ \pi^- pn$$

- $MM(\pi^- p)$

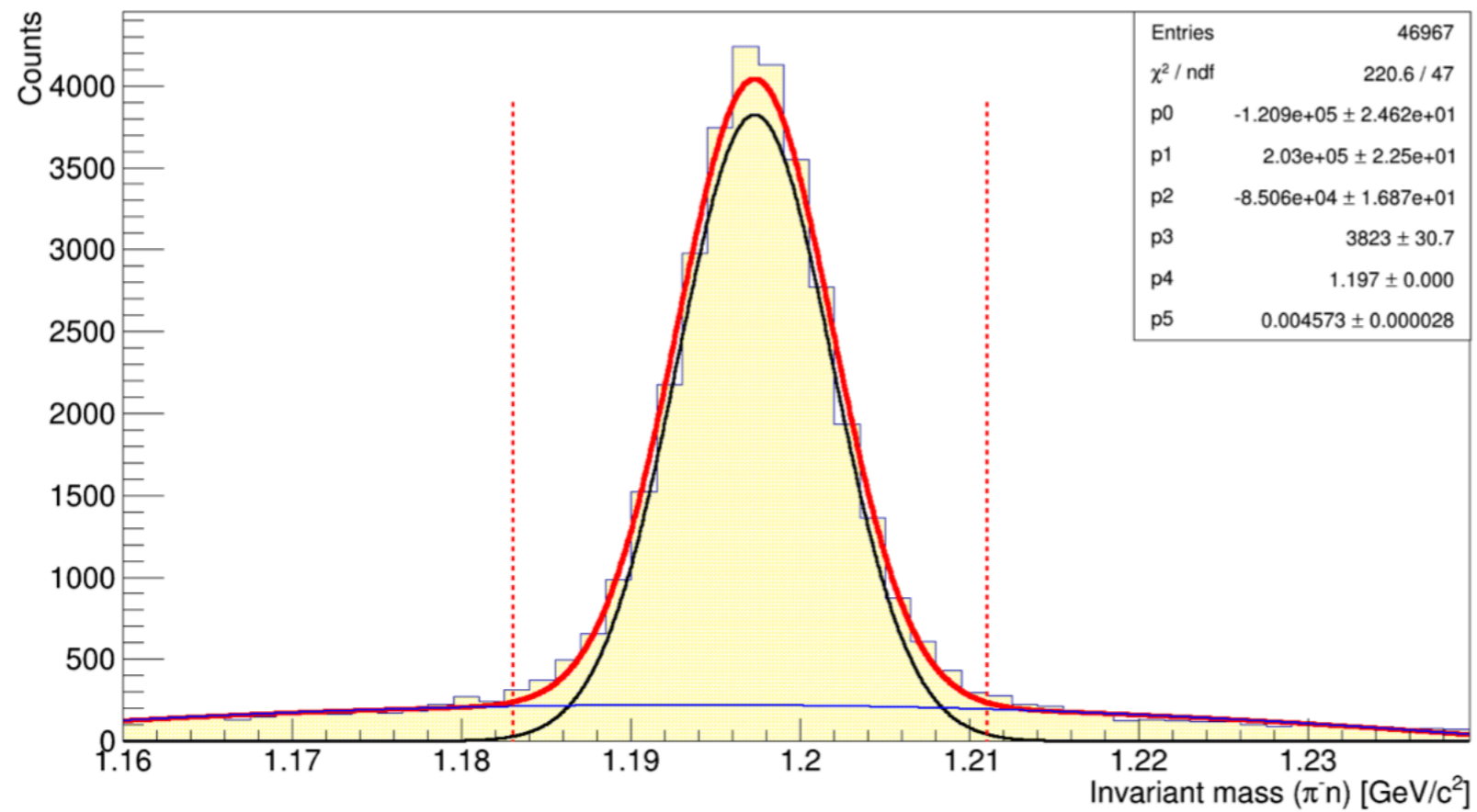
$$MM(\pi^- n) < 1.10 \text{ GeV}$$

$$MM(\pi^- n) > 1.30 \text{ GeV}$$

Background subtraction



Invariant mass (Σ^-)



Conclusions

- An exclusive analysis of the $\gamma d \rightarrow K^+ \Sigma^- (p)$ quasi-free reaction has been performed
- An exclusive analysis of the $\gamma d \rightarrow K^+ \Sigma^- p$ rescattering reaction is ongoing
- The results of this work provides new high-quality beam-asymmetry data for N^* resonances built on the neutron that decay into strange channels

Thanks

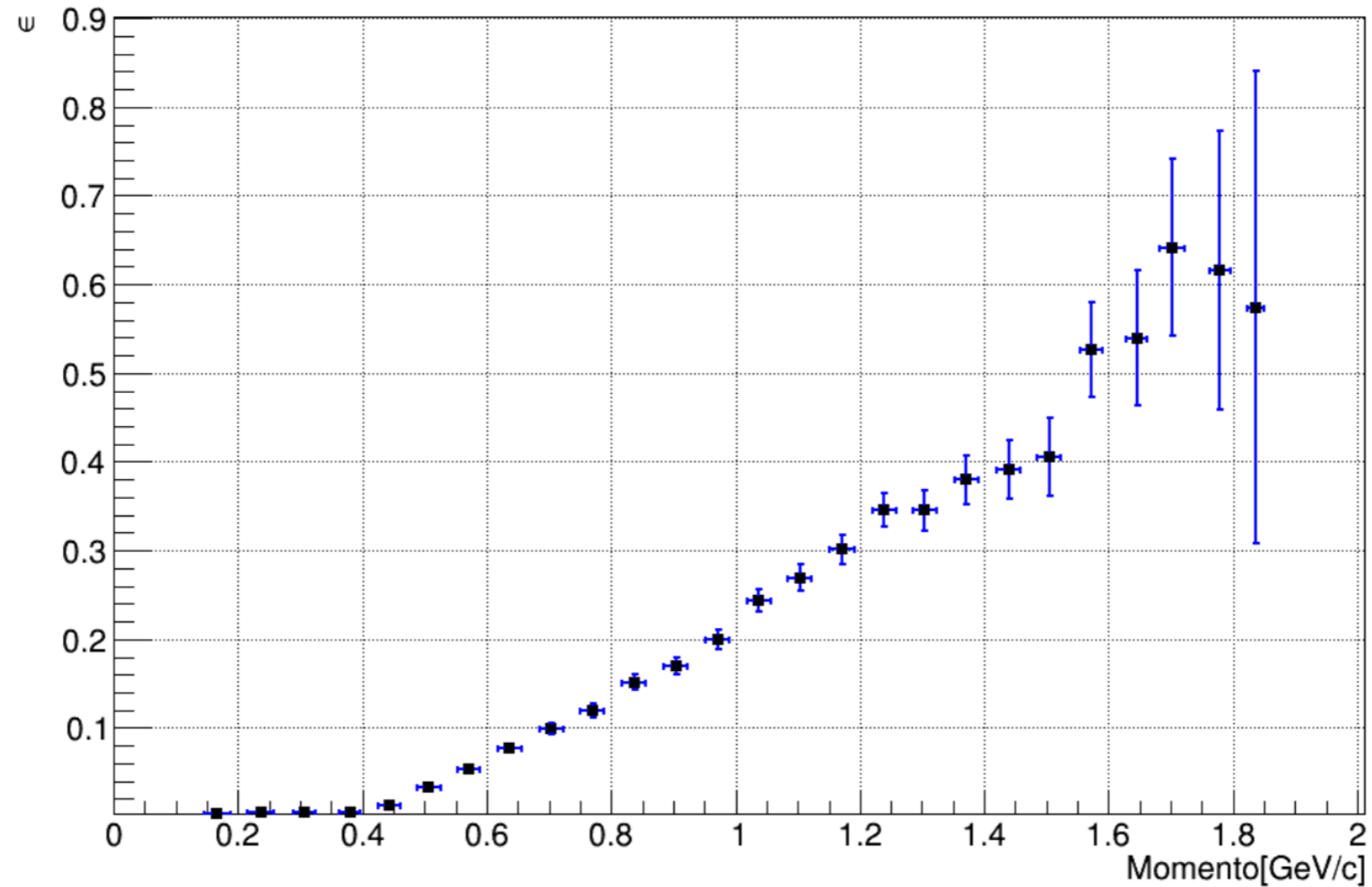
Backup slides

Summary of the CLAS detector characteristics

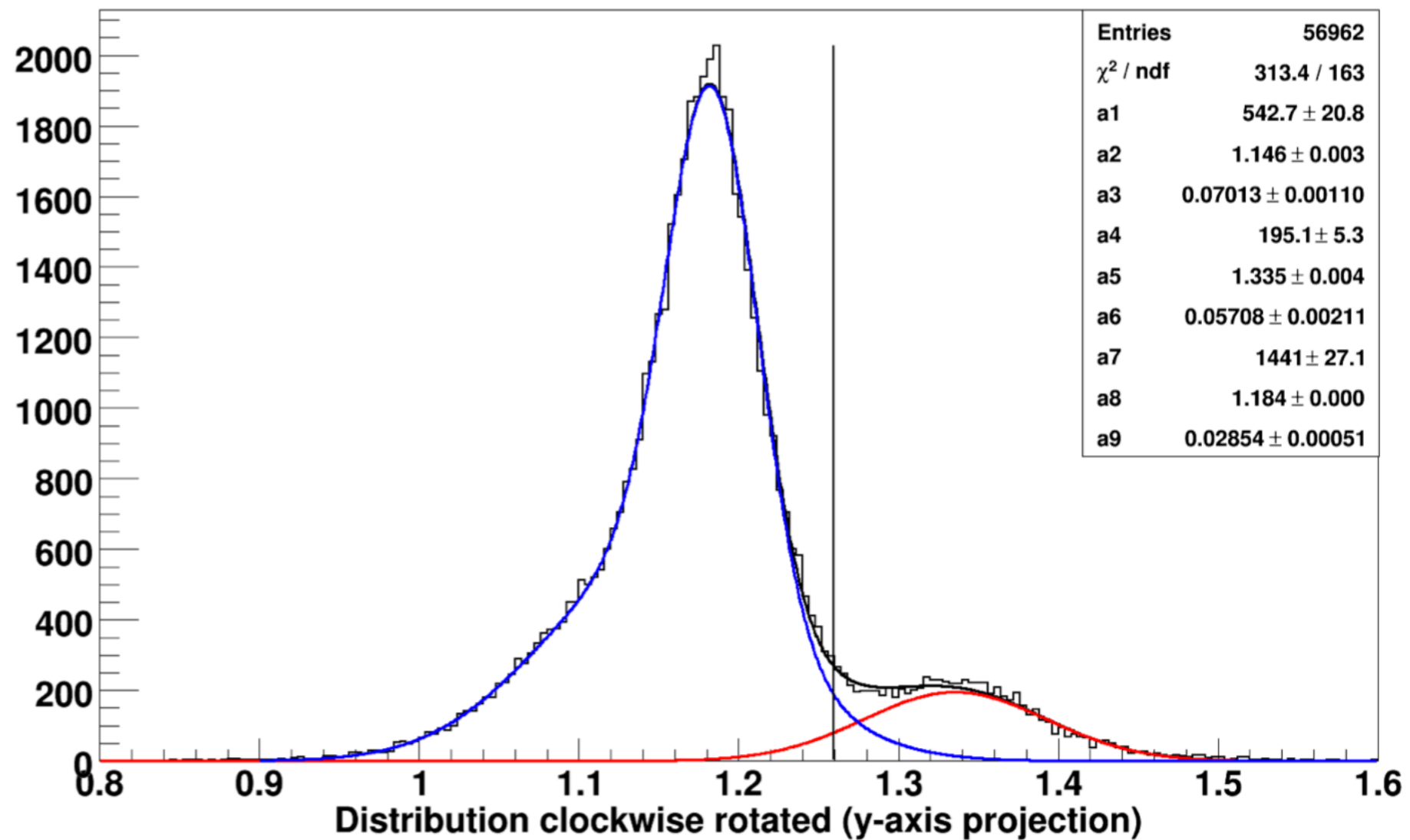
Capability	Quantity	Range
Coverage	Charged-particle angle	$8^\circ \leq \theta \leq 140^\circ$
	Charged-particle momentum	$p \geq 0.2 \text{ GeV}/c$
	Photon angle (4 sectors)	$8^\circ \leq \theta \leq 45^\circ$
	Photon angle (2 sectors)	$8^\circ \leq \theta \leq 75^\circ$
	Photon energy	$E_\gamma \geq 0.1 \text{ GeV}$
Resolution	Momentum ($\theta \lesssim 30^\circ$)	$\sigma_p/p \approx 0.5\%$
	Momentum ($\theta \gtrsim 30^\circ$)	$\sigma_p/p \approx (1-2)\%$
	Polar angle	$\sigma_\theta \approx 1 \text{ mrad}$
	Azimuthal angle	$\sigma_\phi \approx 4 \text{ mrad}$
	Time (charged particles)	$\sigma_t \approx (100-250) \text{ ps}$
	Photon energy	$\sigma_E/E \approx 10\%/\sqrt{E}$
Particle ID	π/K separation	$p \leq 2 \text{ GeV}/c$
	π/p separation	$p \leq 3.5 \text{ GeV}/c$
	π^- misidentified as e^-	$\leq 10^{-3}$
Luminosity	Electron beam	$L \approx 10^{34} \text{ nucleon cm}^{-2} \text{ s}^{-1}$
	Photon beam	$L \approx 5 \times 10^{31} \text{ nucleon cm}^{-2} \text{ s}^{-1}$
Data acquisition	Event rate	4 kHz
	Data rate	25 MB/s
Polarized target	Magnetic field	$B_{\text{max}} = 5 \text{ T}$

EC neutron efficiency

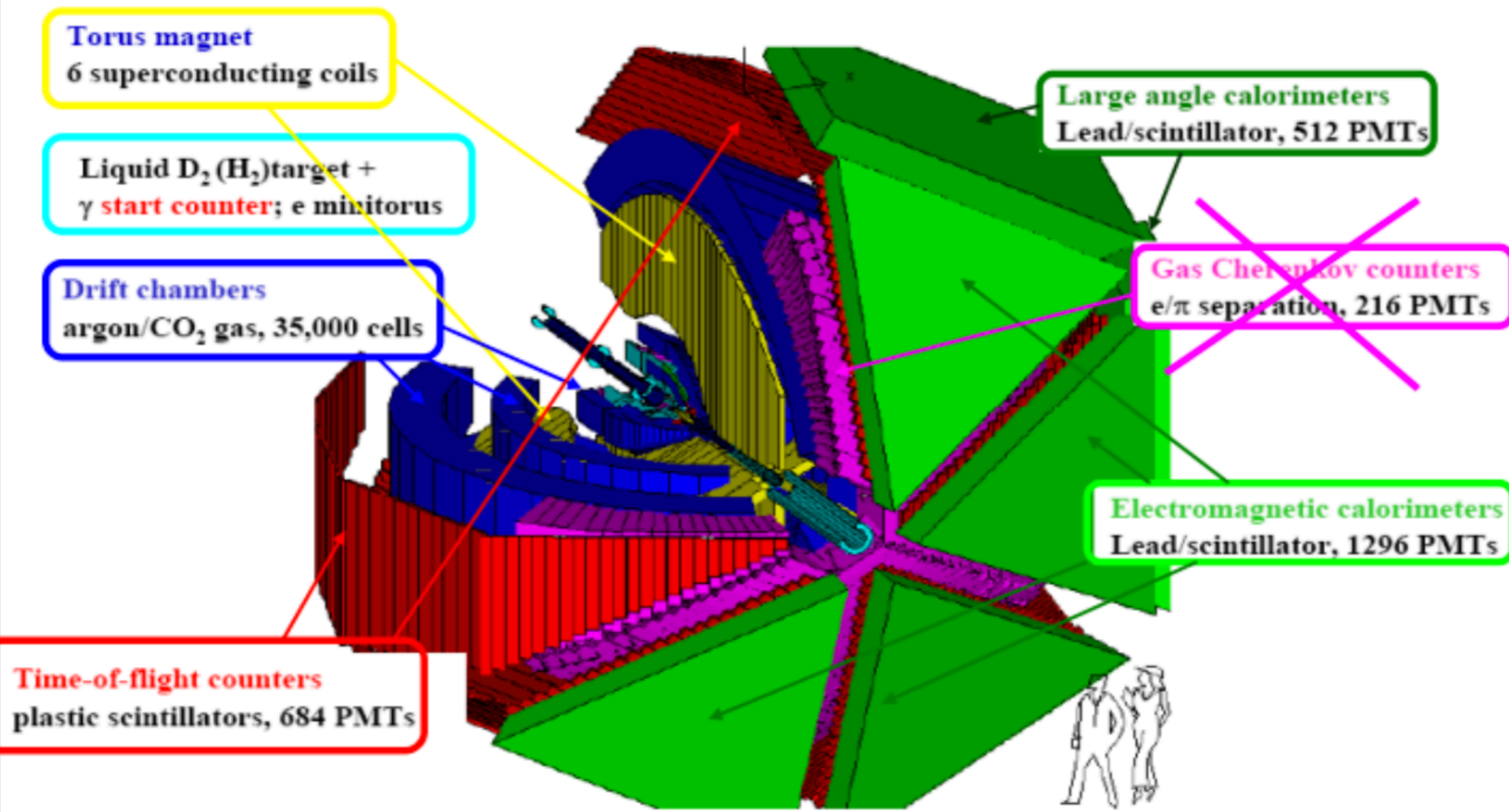
Eficiencia ϵ Vs Momento del neutron

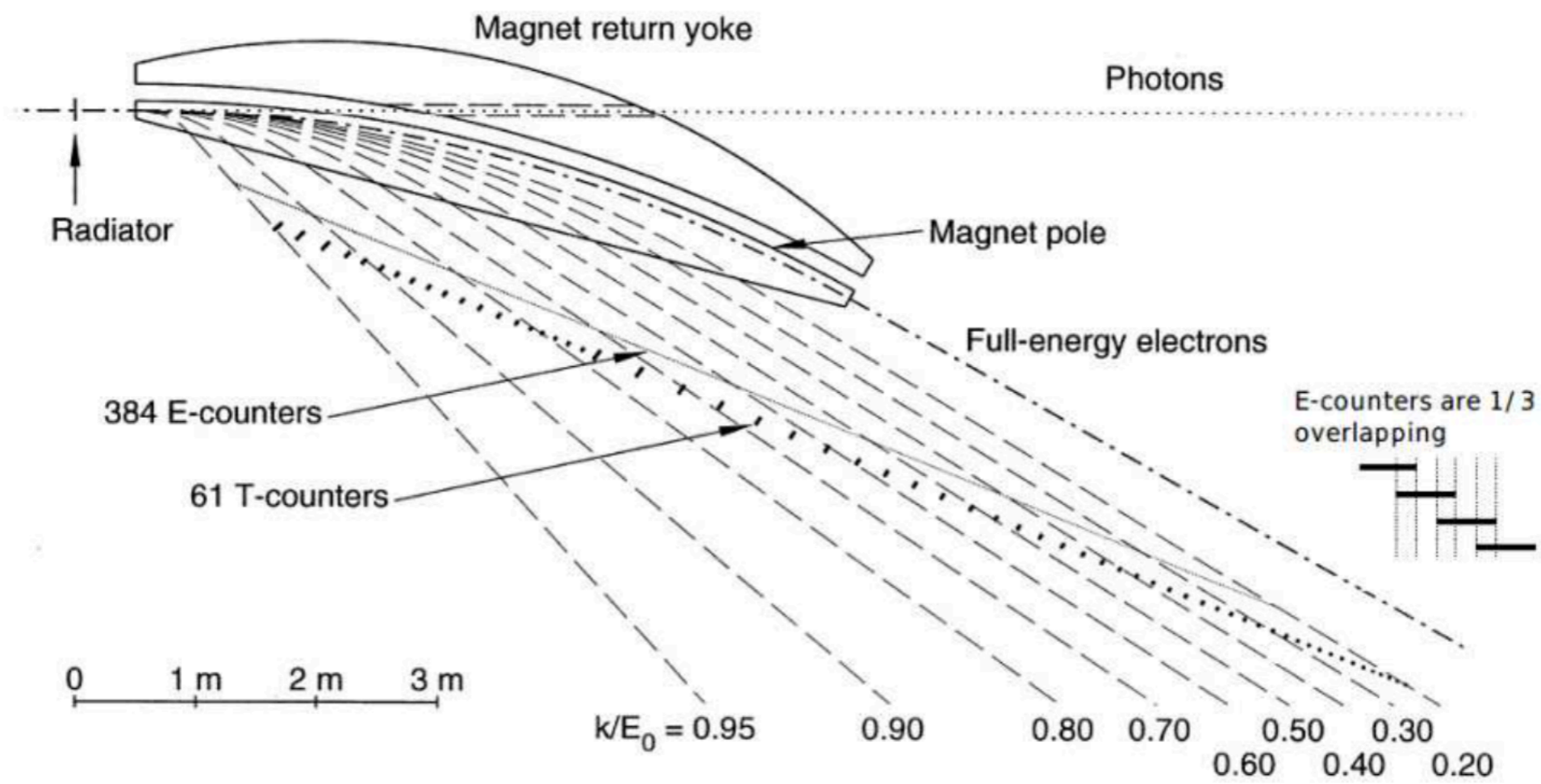


Correlated background



CEBAF Large Acceptance Spectrometer





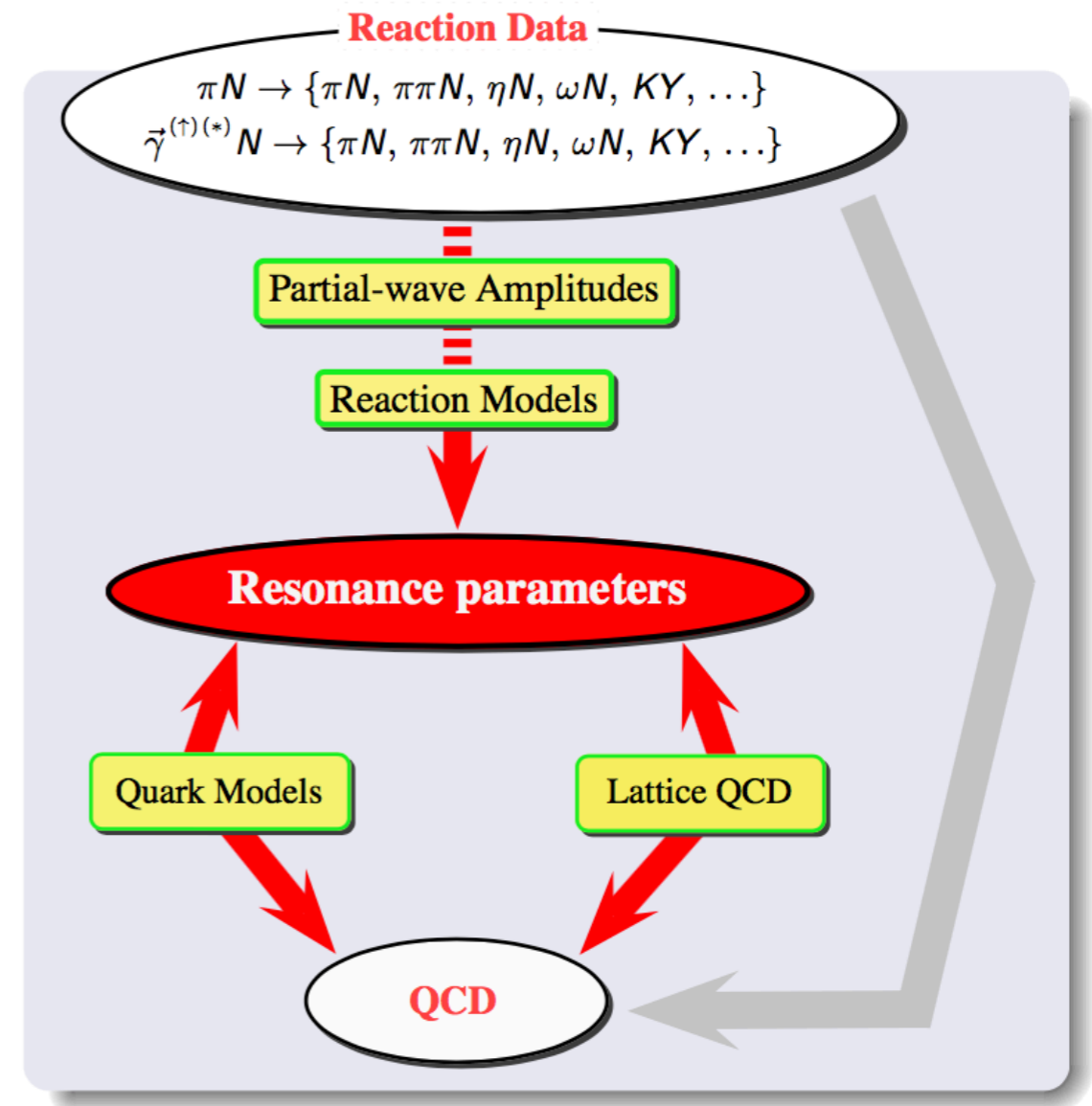
Excited States

Experimentally

- Data
- PWA
- Reaction models

Approximate solutions

- Lattice QCD
- Constituent quark model



Understand some of the QCD features

- Non-perturbative regime
- Confinement
- Nucleon structure
- Nucleon excited states

Previous Measurements

- g10: **Exclusive** cross section.
 - ✓ High statistics
 - ✗ Unpolarized beam
- LEPS Spring-8: **Inclusive** cross section and beam asymmetry.
 - ✓ High degree of linear polarization
 - ✗ Coverage limited to very forward angles

Reaction $\gamma d \rightarrow K^+ \Sigma^- p$

