Determination of double polarization observable E for $\gamma d \rightarrow K^{+}\Sigma^{-}(p)$

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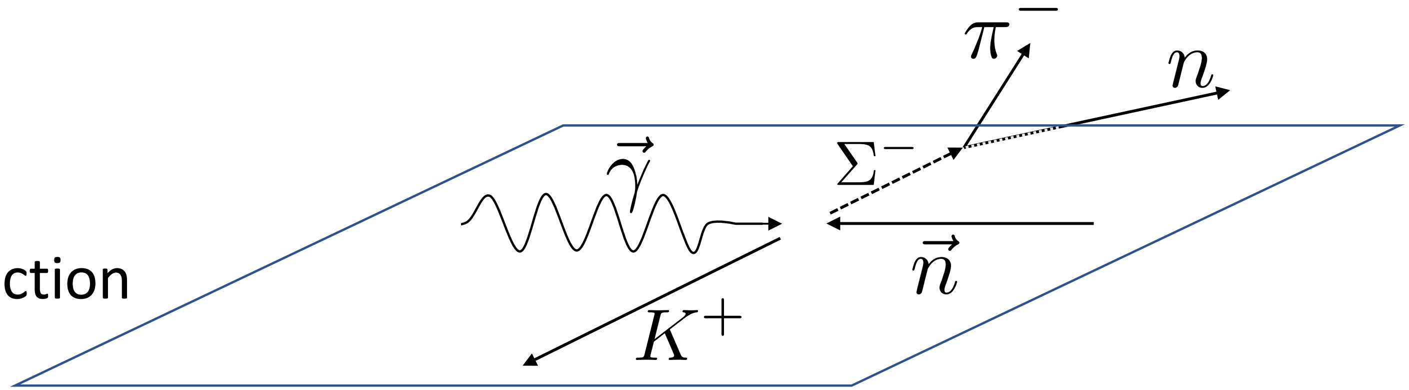
Outline

- Determination of E
- g14 Run period
- Reaction reconstruction
- Systematic studies
- Results



$$\tau_{\Sigma^-} = 0.1475 \text{ ns}$$

$$\Sigma^- \to n\pi^- \quad \text{BR: } 99.85\%$$

Determination of E

$$\begin{aligned}\frac{d\sigma}{dt} &= \left(\frac{d\sigma}{dt}\right)_0 [1 - P_{lin}\Sigma\cos(2\phi) \\ &+P_x(-P_{lin}\mathbb{H}\sin(2\phi) + P_\odot\mathbb{F}) \\ &+P_y(\mathbb{T} - P_{lin}\mathbb{P}\cos(2\phi)) \\ &+P_z(P_{lin}\mathbb{G}\sin(2\phi) - P_\odot\mathbb{E})],\end{aligned}$$

$$\boxed{\frac{d\sigma}{dt} = \left(\frac{d\sigma}{dt}\right)_0 [1 - P_z P_\odot \mathbb{E}].}$$

$$\begin{aligned}Y^{\rightrightarrows} &\sim cF^{\rightrightarrows}[1 - |P_z||P_\odot|\mathbb{E})]A(\Omega, p, ...) \\ Y^{\rightleftarrows} &\sim cF^{\rightleftarrows}[1 + |P_z||P_\odot|\mathbb{E})]A(\Omega, p, ...)\end{aligned}$$

$$P_\odot = P_{el}\frac{4x - x^2}{4 - 4x + 3x^2}, \text{ with } x = \frac{E\gamma}{E_{el}}$$

Method 1

$$\mathbb{E} = \frac{1}{|P_z||P_\odot|}\frac{Y^{\rightleftarrows} - Y^{\rightrightarrows}}{Y^{\rightleftarrows} + Y^{\rightrightarrows}}.$$

$$\sigma_{\mathbb{E}} = \frac{2}{|P_z||P_\odot|}\sqrt{\frac{Y^{\rightleftarrows}Y^{\rightrightarrows}}{(Y^{\rightleftarrows} + Y^{\rightrightarrows})^3}}.$$

Method 2

$$\log L = b + \sum_{i=1}^{Y^{\rightrightarrows}} \log(1 - |P_z^i||P_\odot^i|\mathbb{E}) + \sum_{i=1}^{Y^{\rightleftarrows}} \log(1 + |P_z^i||P_\odot^i|\mathbb{E})$$

g14 Run Period

- Run December 1, 2011 – May 27 2012
- Frozen-spin Hydrogen-Deuteride (HDice)
- Circularly and linearly polarized photon beam

Period	Beam Energy (MeV)	Beam Pol (%) [2]	Run Range	Events (10^6)	Target Pol (%) [2]
Silver 1	2280.96	81.7	68021-68092	830	$+25.6 \pm 0.7$
Silver 2a	2280.96	81.7	68094-68123	393	$+23.0 \pm 0.6$
Silver 2b	2280.96	76.2	68124 - 68176	777	$+23.0 \pm 0.6$
Silver 3	2280.96	76.2	68188 - 68230	250	(+20.9)?
Silver 4	2280.96	76.2	68232 - 68305	820	(−17.2)?
Silver 5	2280.96	88.8	68335 - 68526	4832	(−15.5)?
Gold 2a	2541.31	88.2	69227-69254	470	$+26.8 \pm 0.9$
Gold 2b	2541.31	83.4	69255-69364	1626	$+26.8 \pm 0.9$
Empty A	3355.75	82.4	68995-69036	660	0.0
Empty B	3355.75	82.4	69038-69044	120	0.0

[2] CLAS Analysis Note 2016-104, 2016

SKIM

1 positive kaon

1 negative pion

Based on wide beta cuts

Any number of neutrals

Analysis: Particle ID

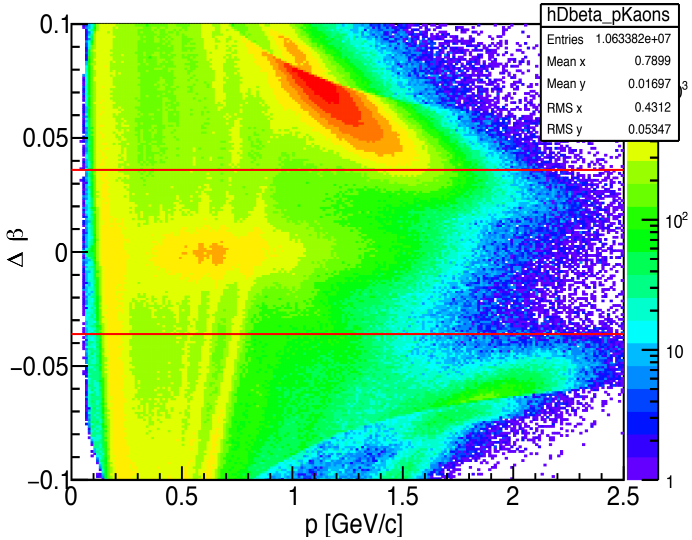
- Based on 2 independent measurements of particles speed

$$\Delta\beta = \beta^{DC} - \beta^{TOF}$$

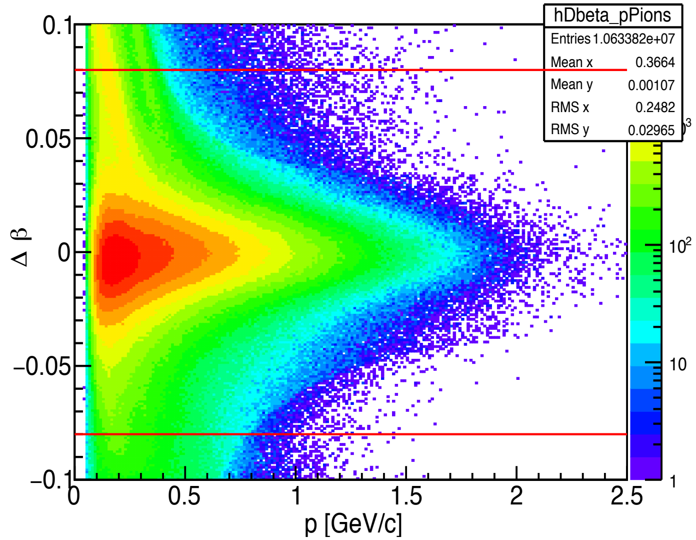
$$\beta^{DC} = \frac{p}{\sqrt{p^2 + (m^i_{PDG}c^2)^2}}$$

$$\beta^{TOF} = \frac{d^{TOF}}{(t^{TOF} - t^{start})c}$$

Positive tracks
Kaon mass assumption



Negative tracks
Pion mass assumption



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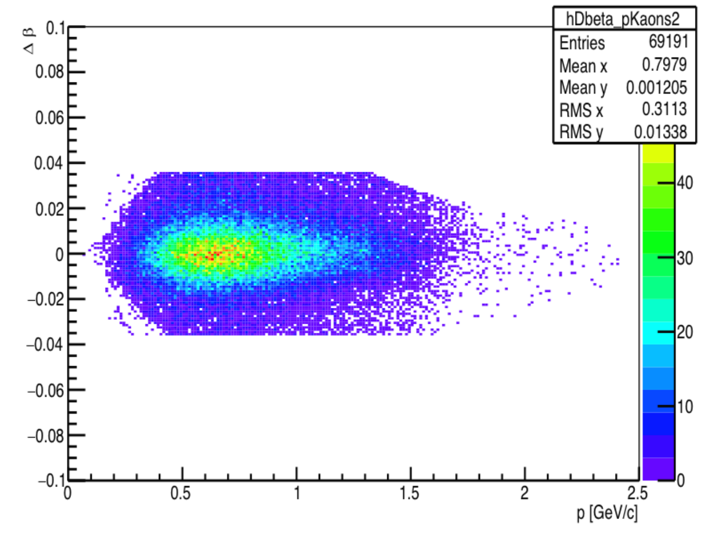
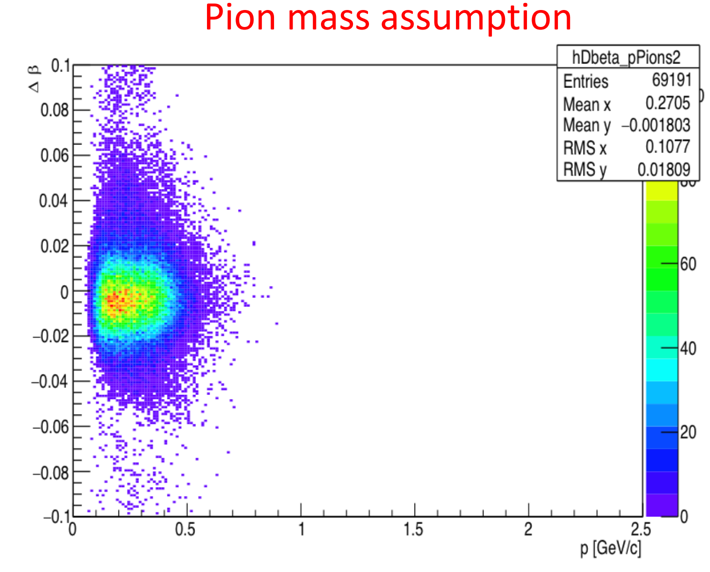
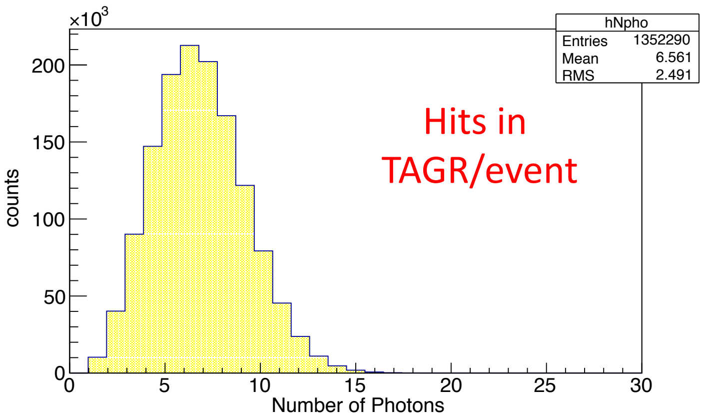


Negative tracks
Pion mass assumption



Analysis: Photon selection

- Photon-reconstructed track coincidence time at vertex

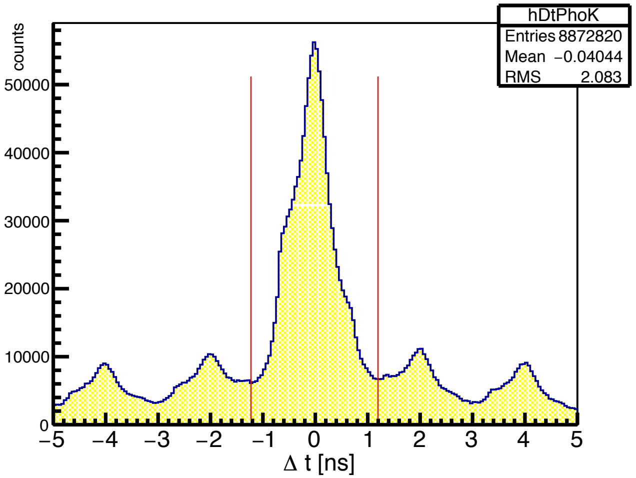


$$\Delta t = t_{track} - t_{\gamma}$$

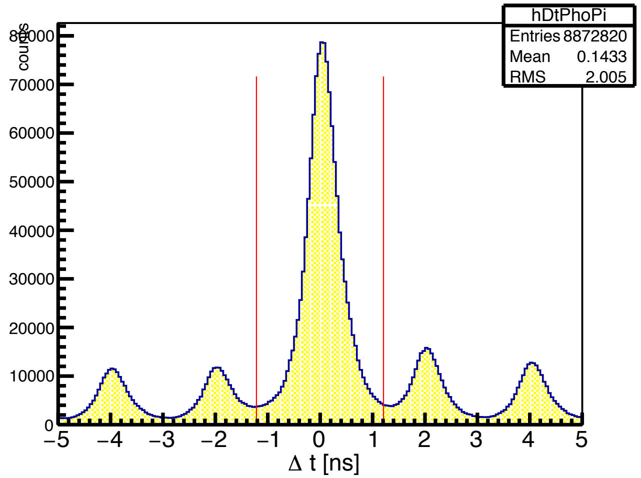
$$t_{\gamma} = t_{pho} + \frac{7.5\ cm + z_{vertex}}{c}$$

$$t_{track} = t^{TOF} - \frac{d^{TOF}}{\beta^{DC} c}$$

Kaon-photon Coincidence time



Pion-photon Coincidence time



$$|\Delta t_{K+}| < 1.2\ \mathrm{ns\ and}\ |\Delta t_{\pi-}| < 1.2\ \mathrm{ns}$$

met by the same photon

Analysis: Photon selection

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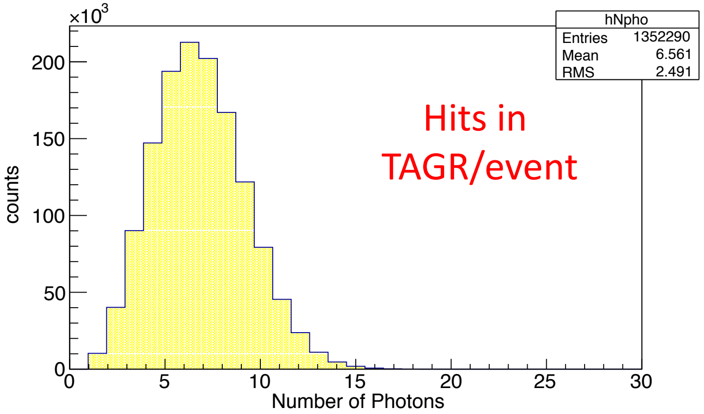

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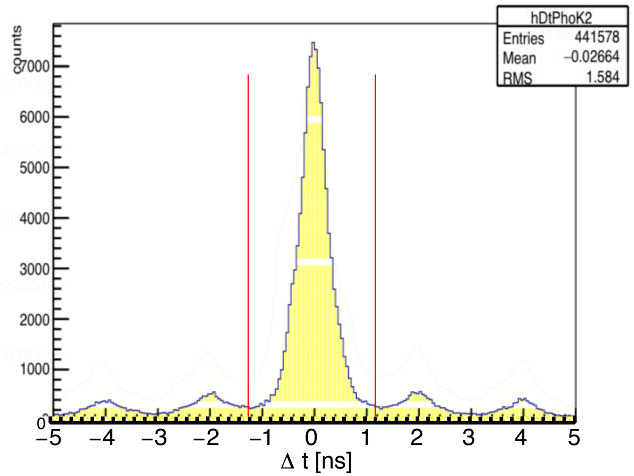
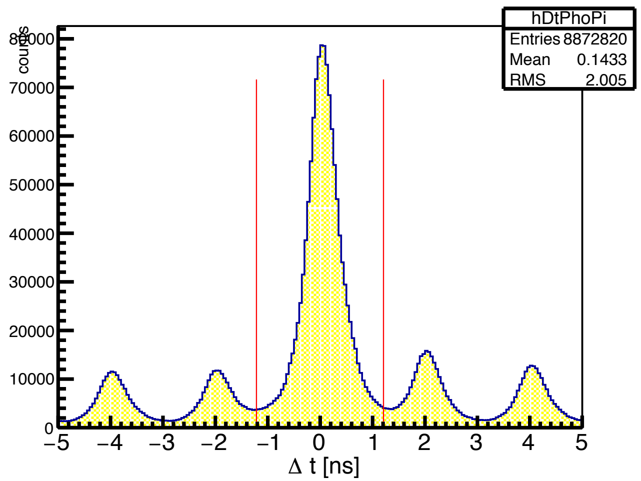


Pion-photon Coincidence time



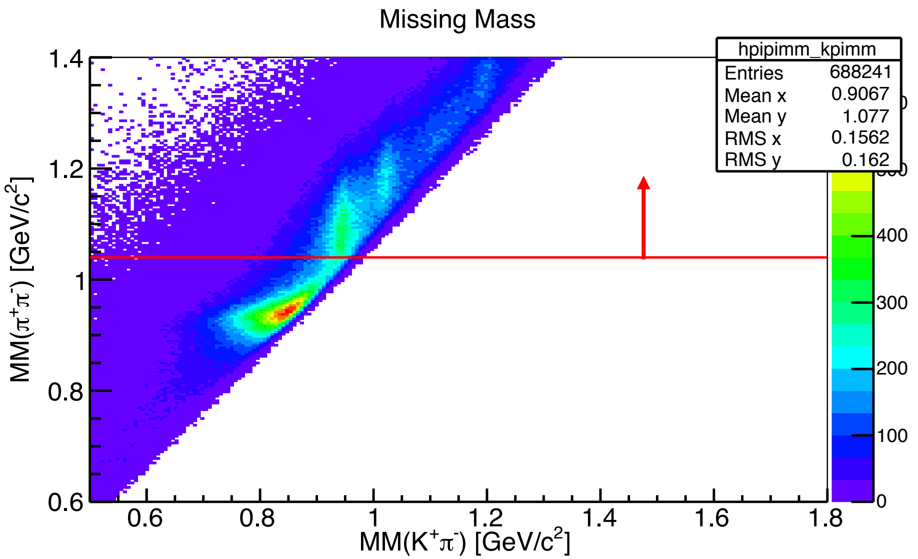
$$|\Delta t_{K+}| < 1.2 \text{ ns and } |\Delta t_{\pi-}| < 1.2 \text{ ns}$$

met by the same photon

Analysis: Particle misidentification

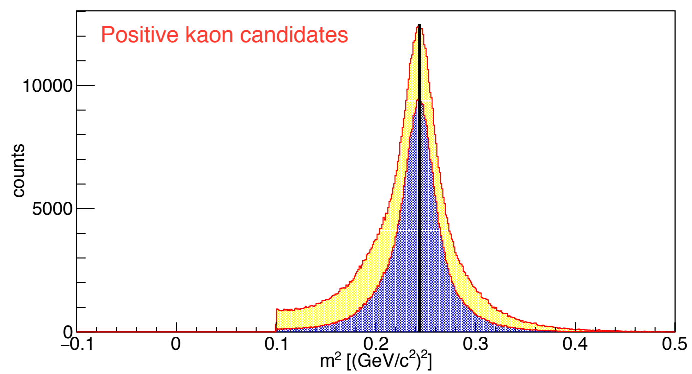
- Large fraction of positive pions is misidentified as kaons

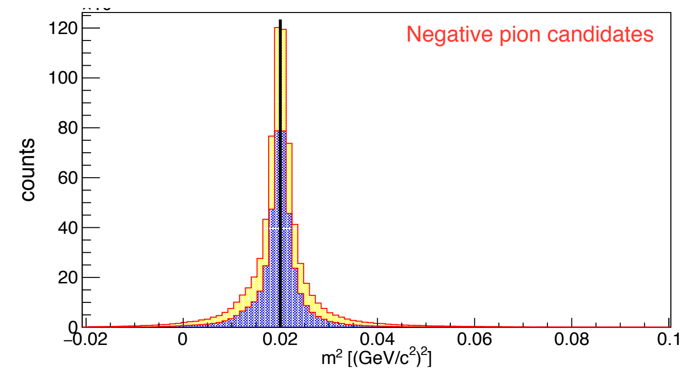
$$\gamma n \to \pi^+ \pi^- X$$



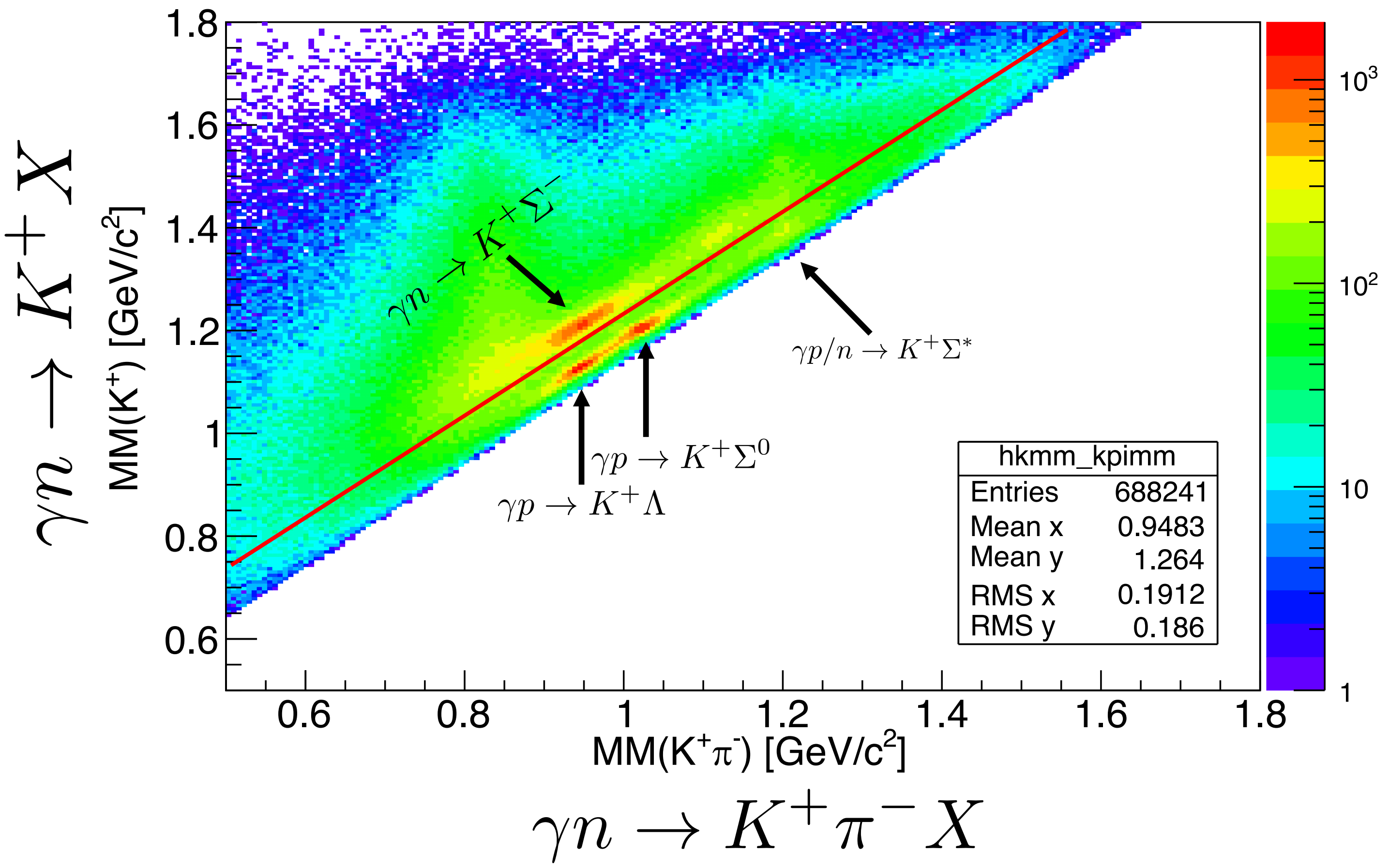
$$\gamma n \to K^+ \pi^- X$$

$$m^2_{calc} = p^2\left(\frac{1}{\beta^2} - 1.0\right)$$



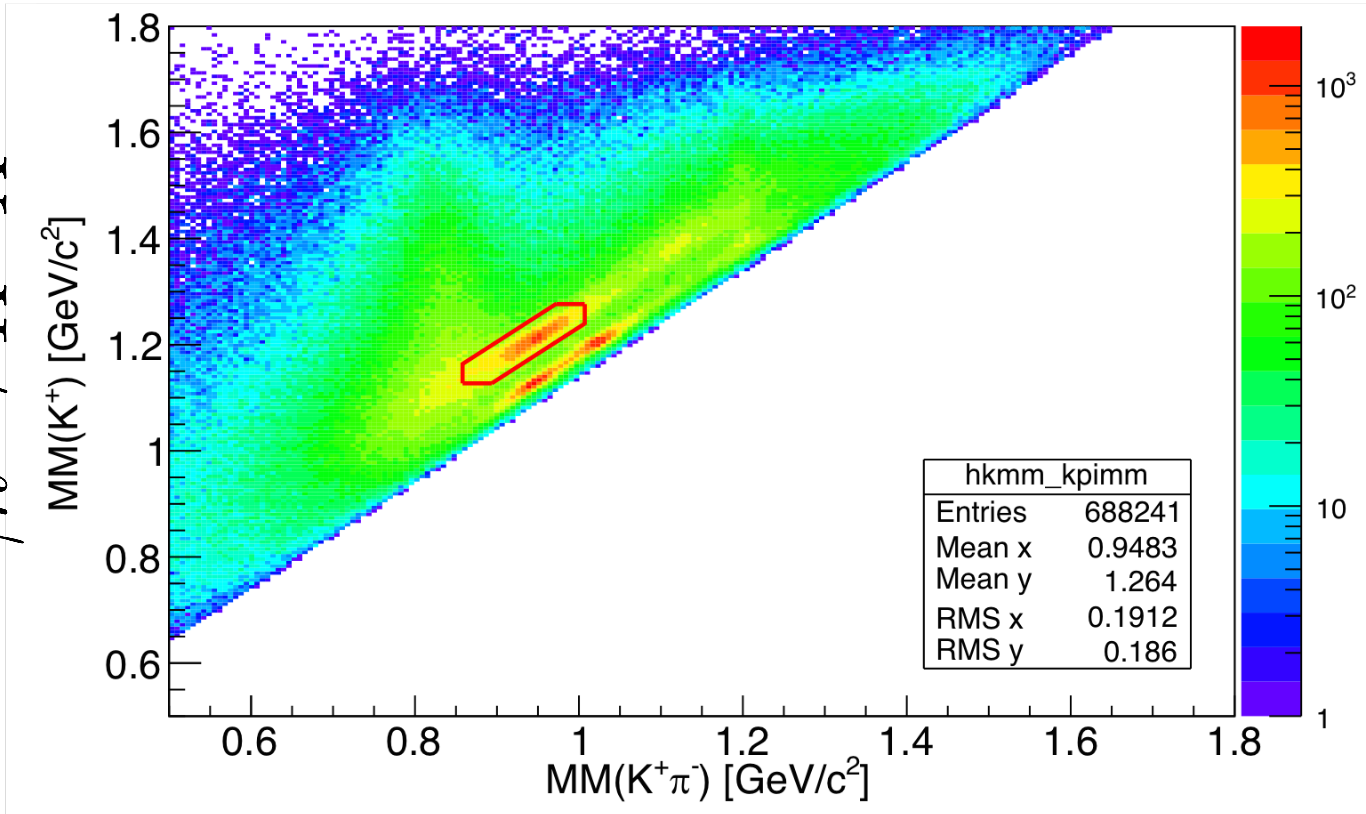


Analysis: Reaction reconstruction



Analysis: Reaction reconstruction

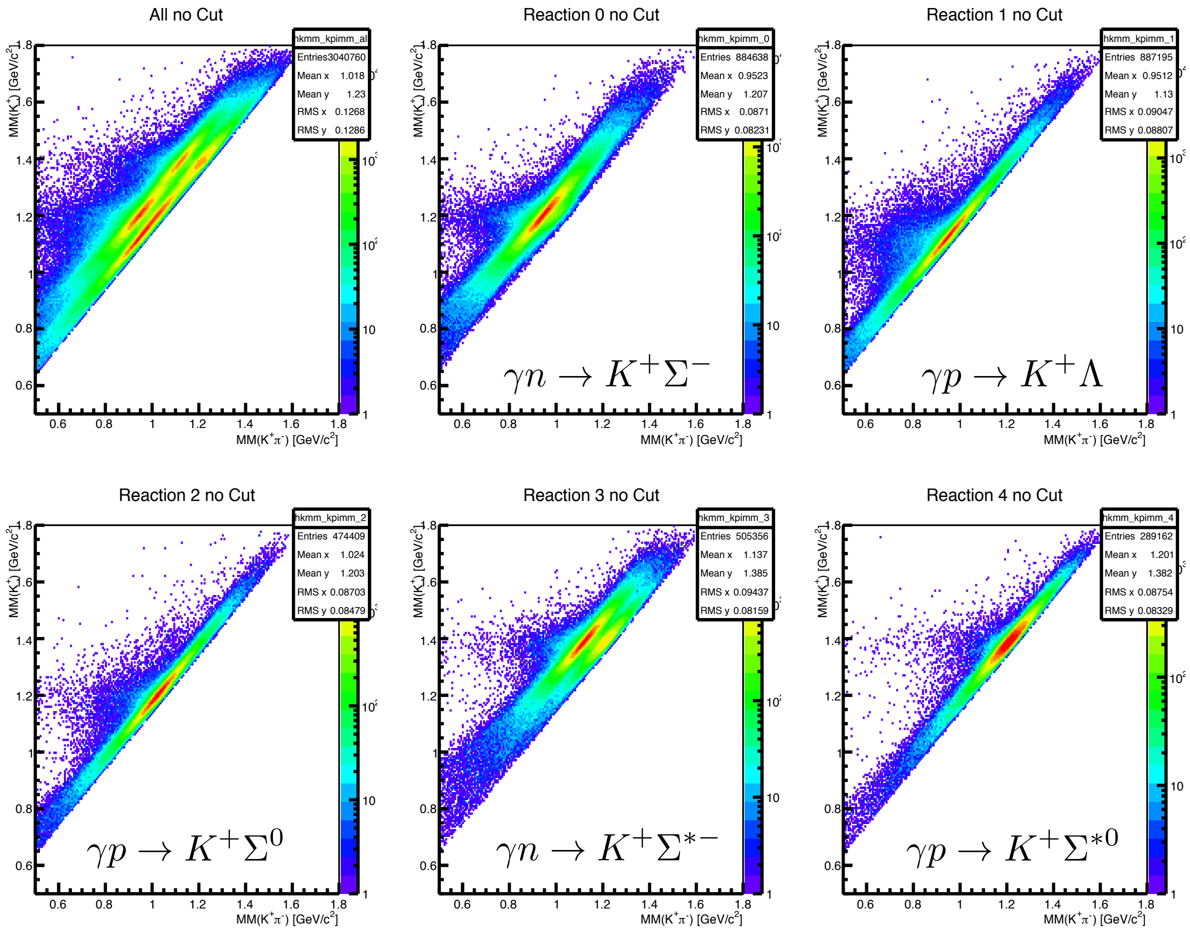
$\gamma n \rightarrow K^+ X$



$\gamma n \rightarrow K^+ \pi^- X$

Analysis: Background studies

- Generated data for 5 different reactions with equal weights
  - Fermi distribution of target nucleon
- Processed through GSIM
- Reconstructed in identical way as real data



Reaction Reconstruction cuts

Reaction 0: 48%

Reaction 1: 0.1%

Reaction 2: 0.2%

Reaction 3: 1.4%

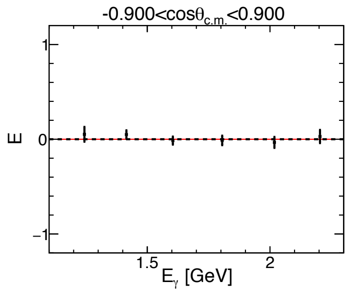
Reaction 4: 0.1%.

Analysis: Empty target subtraction

$$Y_T^{\rightrightarrows/\rightleftarrows} = Y_S^{\rightrightarrows/\rightleftarrows} + Y_B^{\rightrightarrows/\rightleftarrows}.$$

$$\begin{aligned} Y_S^{\rightrightarrows} &= \alpha_S F^{\rightrightarrows}[1 - |P_z||P_\odot|\mathbb{E}_S)]A(\Omega, p, \ldots) \\ Y_S^{\rightleftarrows} &= \alpha_S F^{\rightleftarrows}[1 + |P_z||P_\odot|\mathbb{E}_S)]A(\Omega, p, \ldots) \end{aligned}$$

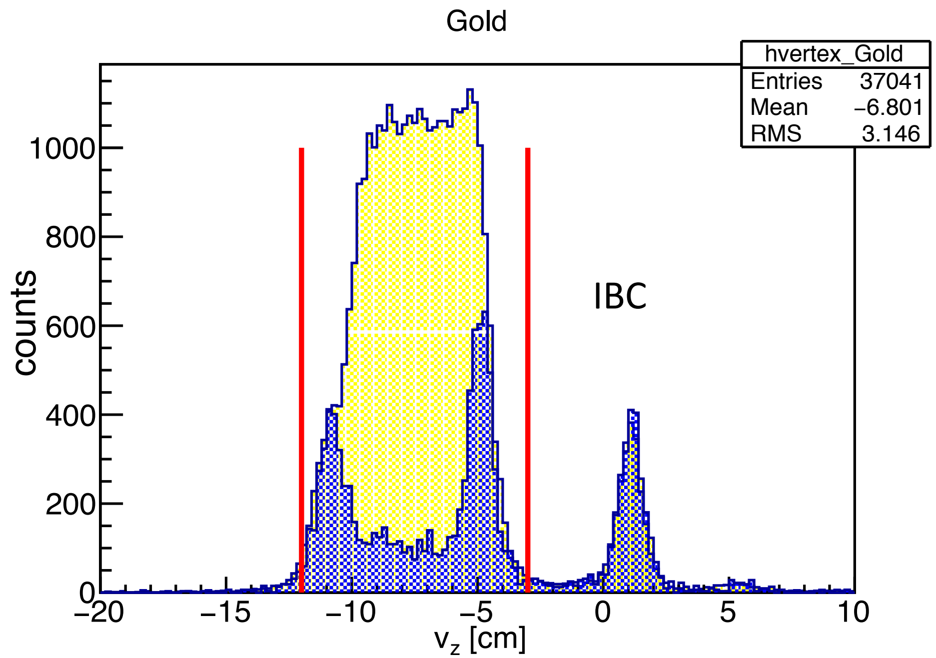
$$Y_B^{\rightrightarrows/\rightleftarrows} = \alpha_B F^{\rightrightarrows/\rightleftarrows} A(\Omega, p, \ldots)$$



$$\mathcal{A}_\mathcal{T} = \frac{Y_T^{\rightleftarrows} - Y_T^{\rightrightarrows}}{Y_T^{\rightleftarrows} + Y_T^{\rightrightarrows}} = \frac{\alpha_S}{\alpha_S + \alpha_B}|P_z||P_\odot|\mathbb{E}_S$$

$$\mathbb{E}_S = \frac{1}{d}\frac{1}{|P_z||P_\odot|}\mathcal{A}_\mathcal{T},$$

$$\begin{aligned} d &= \frac{\alpha_S}{\alpha_S + \alpha_B} \\ &= \frac{\alpha_T - \alpha_B}{\alpha_T} \\ &= 1 - \frac{\alpha_B}{\alpha_T}. \end{aligned}$$



- Due to low statistics a kinematic independent dilution factor was determined.
- Studies using wide kinematic bins showed statistically insignificant variations of the dilution factor

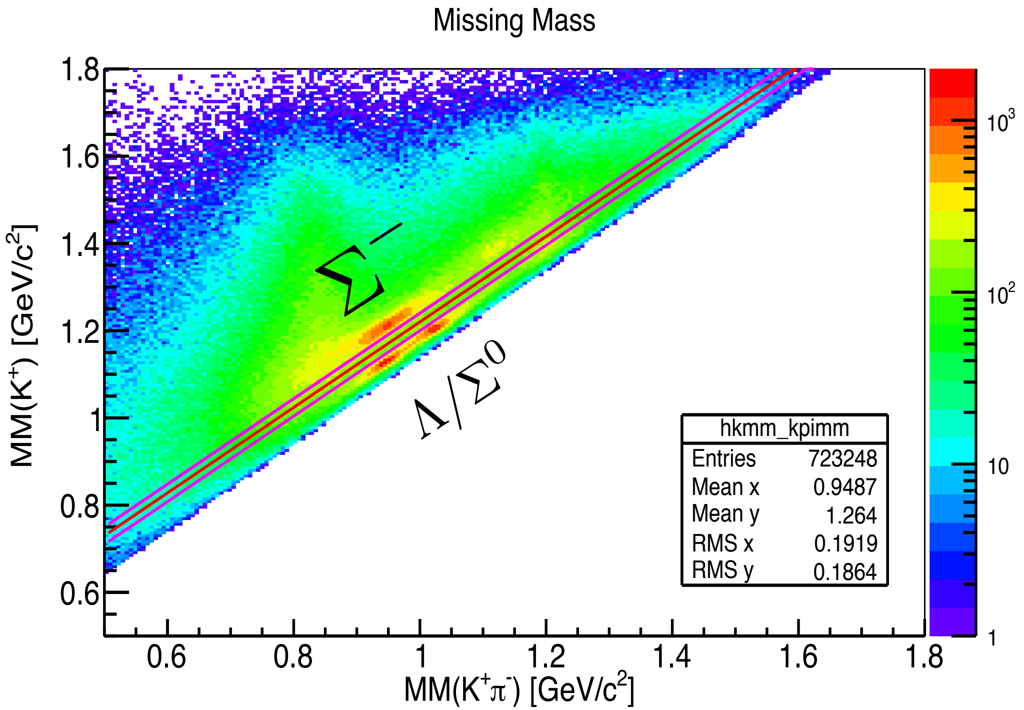
Systematic studies

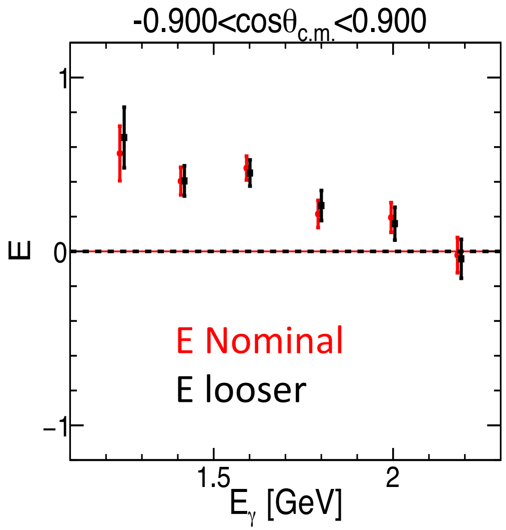
- Estimation of systematic uncertainties:
  - Variation of nominal cuts
  - Comparison between extracted observables
  - Difference and spread of difference reflects *upper estimate* of systematic uncertainty

Source	σ^{sys}
Kaon PID	0.013
Pion PID	0.024
Photon Selection	0.06
Particle Misidentification	0.005
Λ/Σ^0 separation	0.055
Kaon decayed events	0.048
Σ^* background subtraction	0.047
z-vertex cut	0.025
Fiducial cuts	0.029
Method of extraction observable	0.005
Total Absolute Systematic	**0.11**
Target Polarization	6%
Photon Polarization	3.4%
Empty target subtraction	1.0%
Total Scale Systematic	**6.9%**

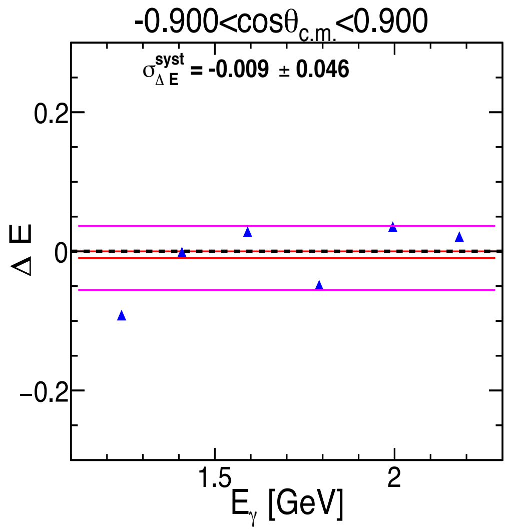
Systematic studies

$$\Lambda/\Sigma^0 \text{ separation}$$

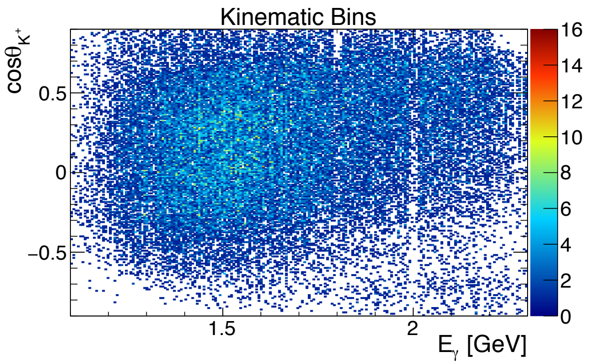


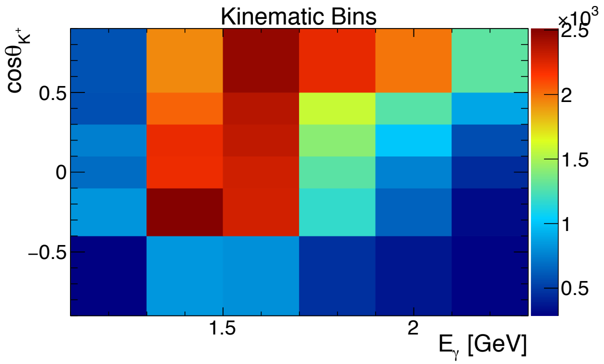


$$\Delta E = E_{nominal} - E_{looser}$$



Results

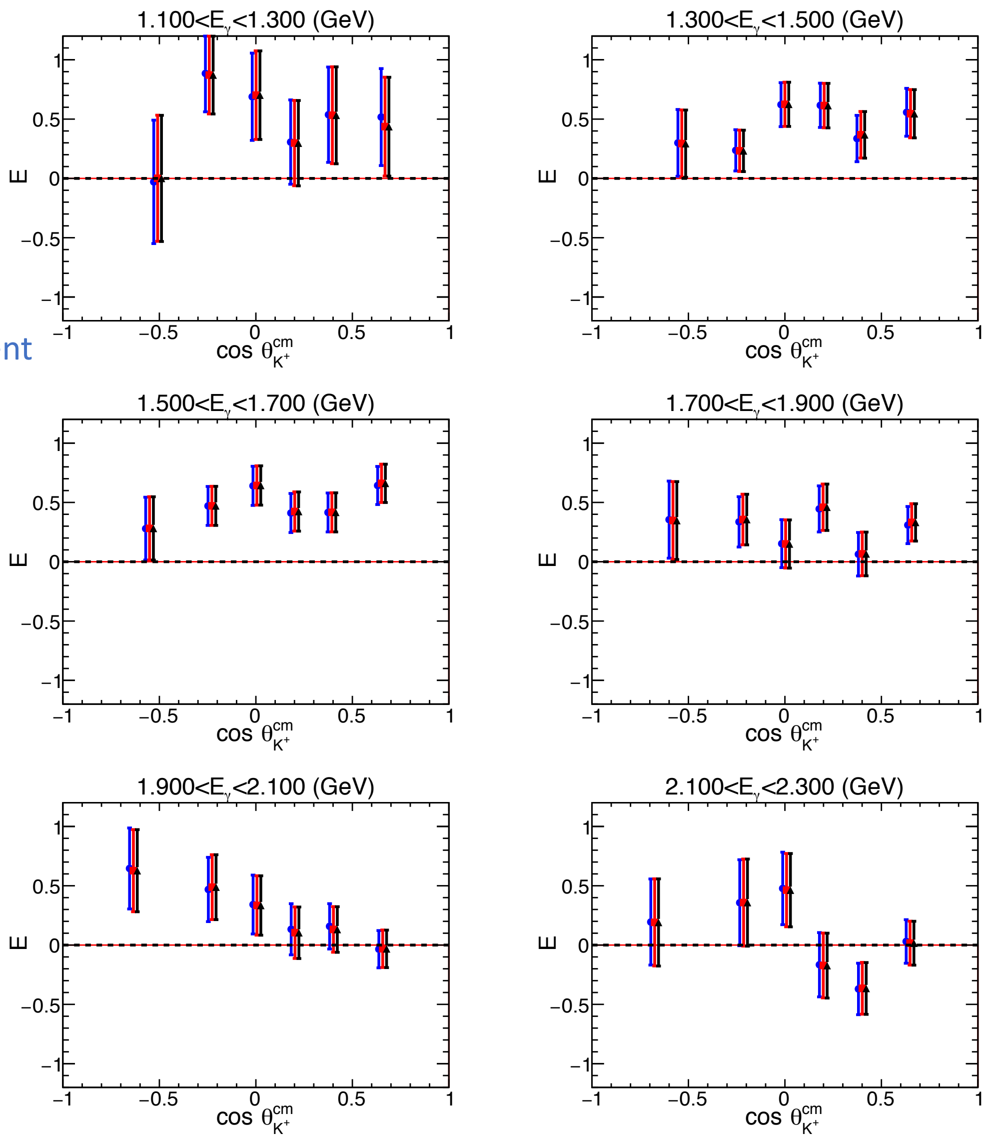




$ML_{event-by-event}$

$ML_{average}$

Asymmetry



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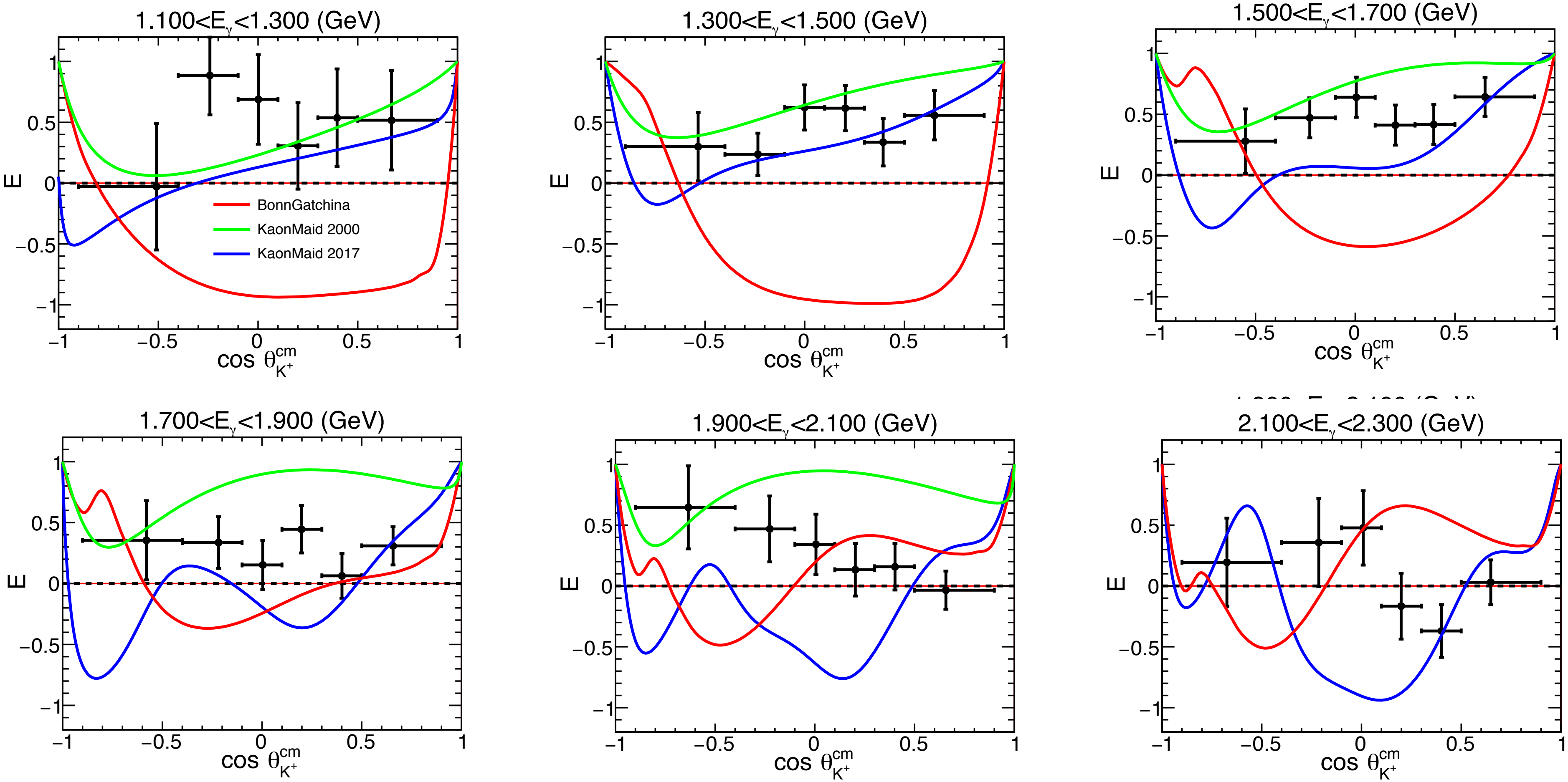

1.100<Eγ<1.300 (GeV)
1.300<Eγ<1.500 (GeV)
1.500<Eγ<1.700 (GeV)
1.700<Eγ<1.900 (GeV)
1.900<Eγ<2.100 (GeV)
2.100<Eγ<2.300 (GeV)
BonnGatchina
KaonMaid 2000
KaonMaid 2017
E
cos θ cm K+
−1
−0.5
0
0.5
1

Summary

- First draft of paper will be completed soon
- In contact with theorist for inclusion of the data to PWA

- Analysis review initiated on November 9 2017
- First round of comments provided on January 4th 2018 with no major issues
- Reply from author and updated note was released to committee members on January 12th
- Second round of comments (and hopefully final) will be released soon.