Hadron Spectroscopy
CLAS g12

D. P. Weygand

High Energy (E_γ> 4.4 GeV) Luminosity: 27 pb^{-1}

Total Integrated Luminosity: 68 pb^{-1}

Topics

Meson Spectroscopy

$\gamma p \to \pi^+ \pi^+ \pi^- (n)$ See C. Bookwalter

$\gamma p \to \eta \pi^- \Delta^{++}$

$\gamma p \to (\phi \eta) p$ $\gamma p \to (\phi \pi^0) p$

Cascade, Exotic Baryon and N* Spectroscopy

$\gamma p \to \theta^+ K^- \pi^+$ $\theta^+ \to K^+ n$

$\gamma p \to K^+ K^+ X$

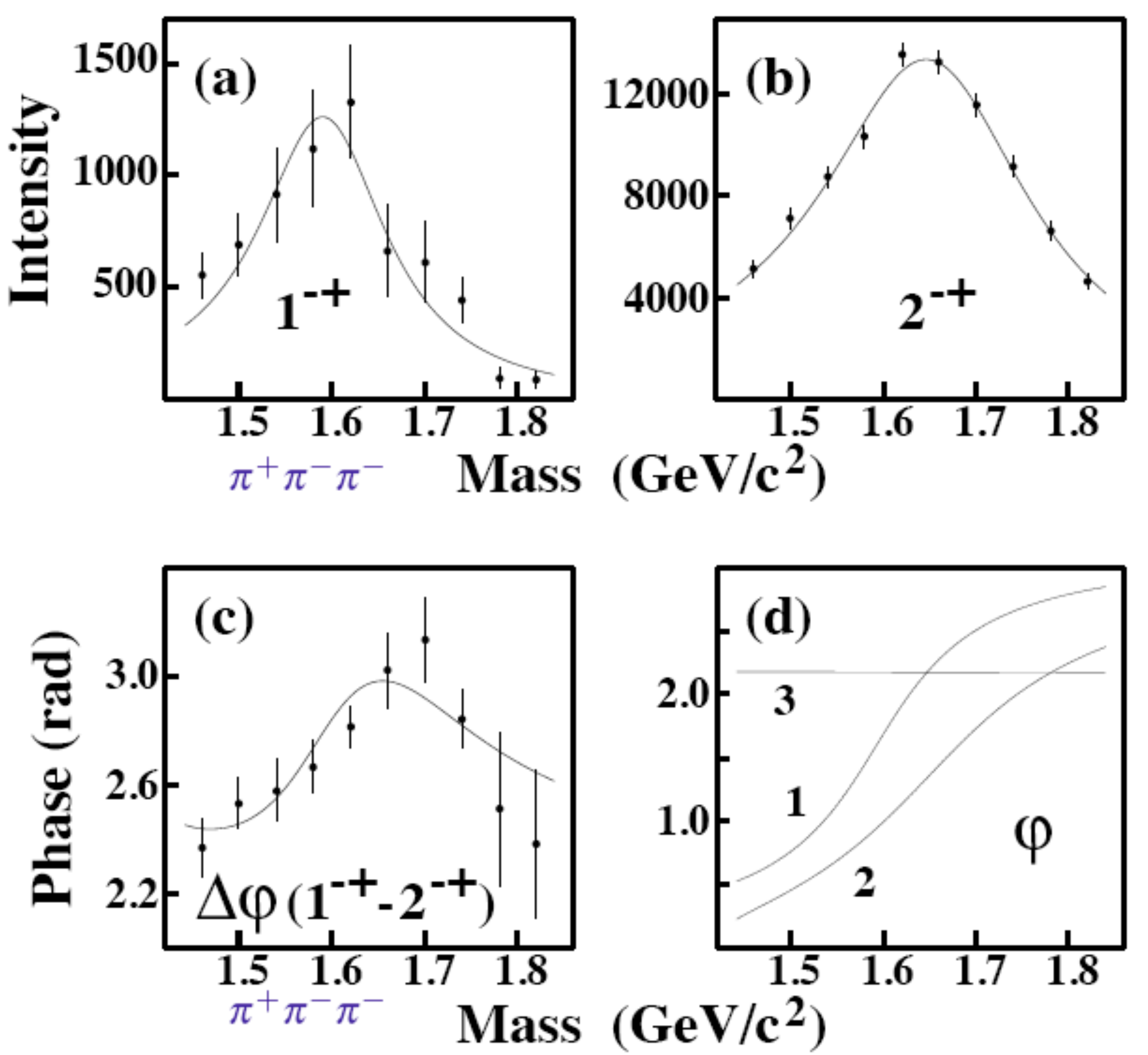
$\gamma p \to \phi(\omega p)$

e^+e^-

$\rho - \omega$ Interference See following talk, D. Djalali

$\pi^0, \eta, \eta' \to e^+ e^- \gamma$

E852 250000 events/1997



PRL 81, 5760 (1998)
PRD 65, 072001 (2002)

COMPASS

CERN-SPS fixed target

2004: 2 days, 190 GeVπ^- beam   Pb target

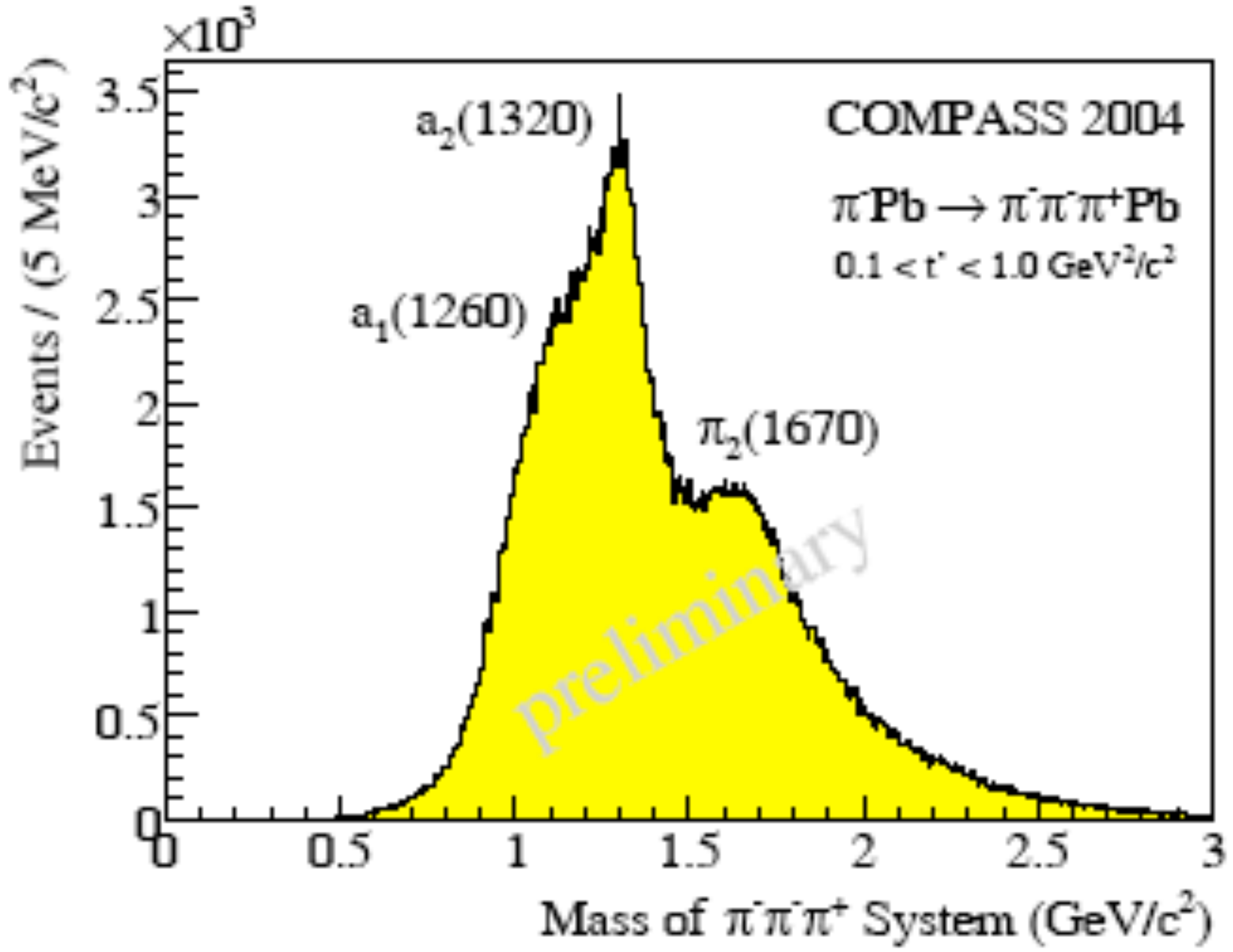


Fig. 1. Invariant mass of $\pi^-\pi^-\pi^+$ final states for $0.1 < t' < 1.0\,\mathrm{GeV}^2/c^2$.

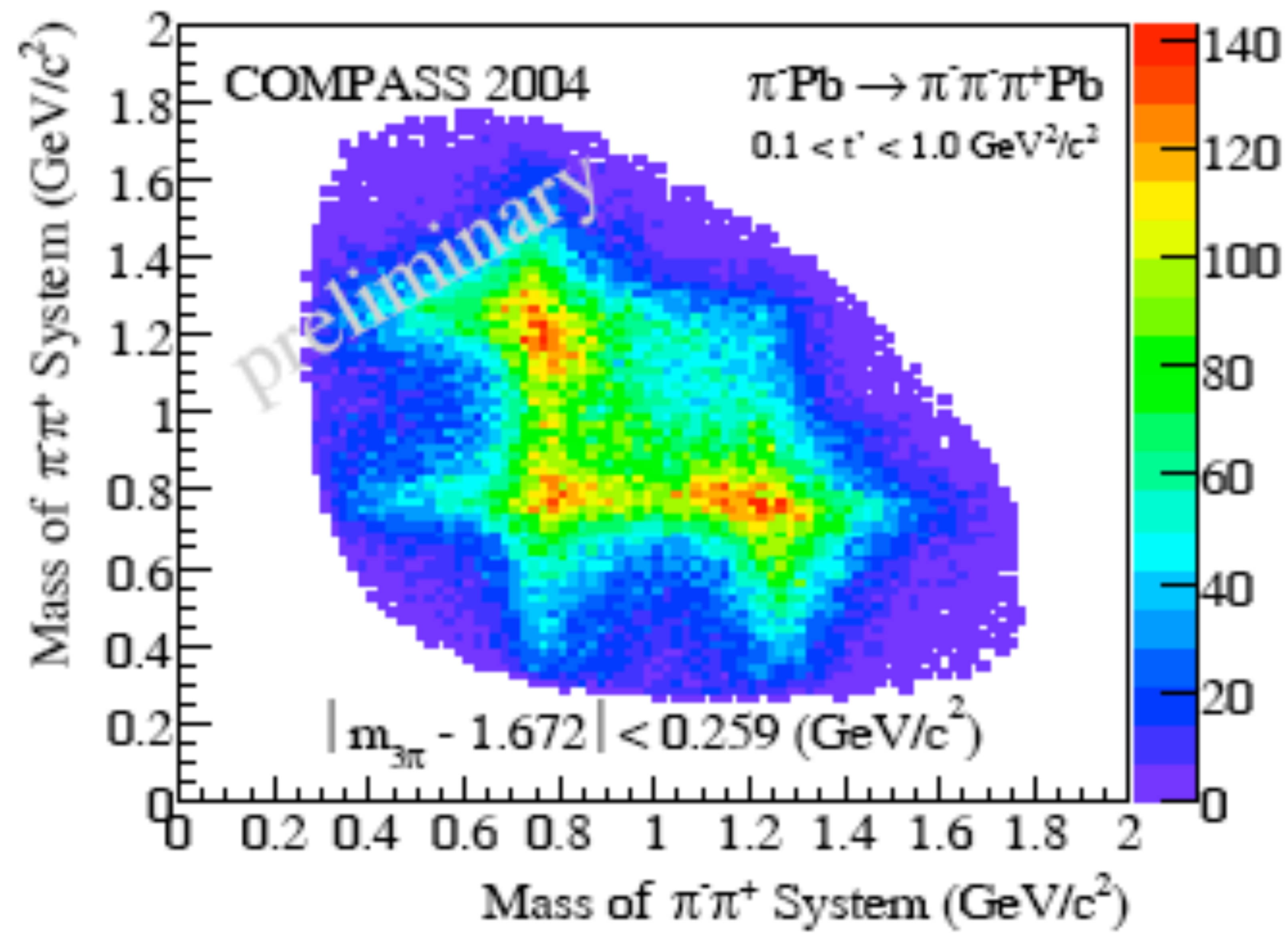


Fig. 2. Dalitz plot for $\pi_2(1670)$, selected by a $\pm 1\Gamma$ cut around its nominal mass.

COMPASS

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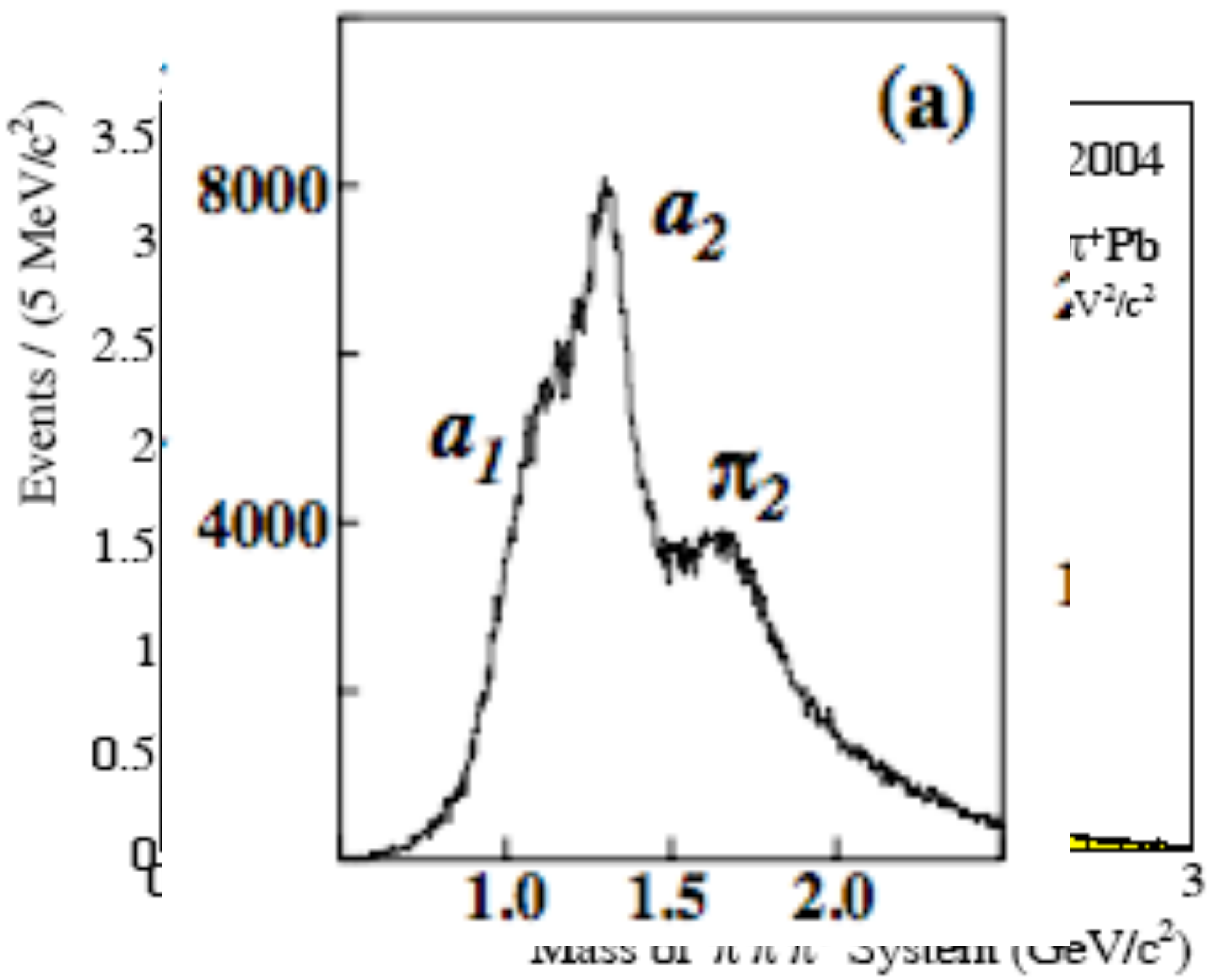

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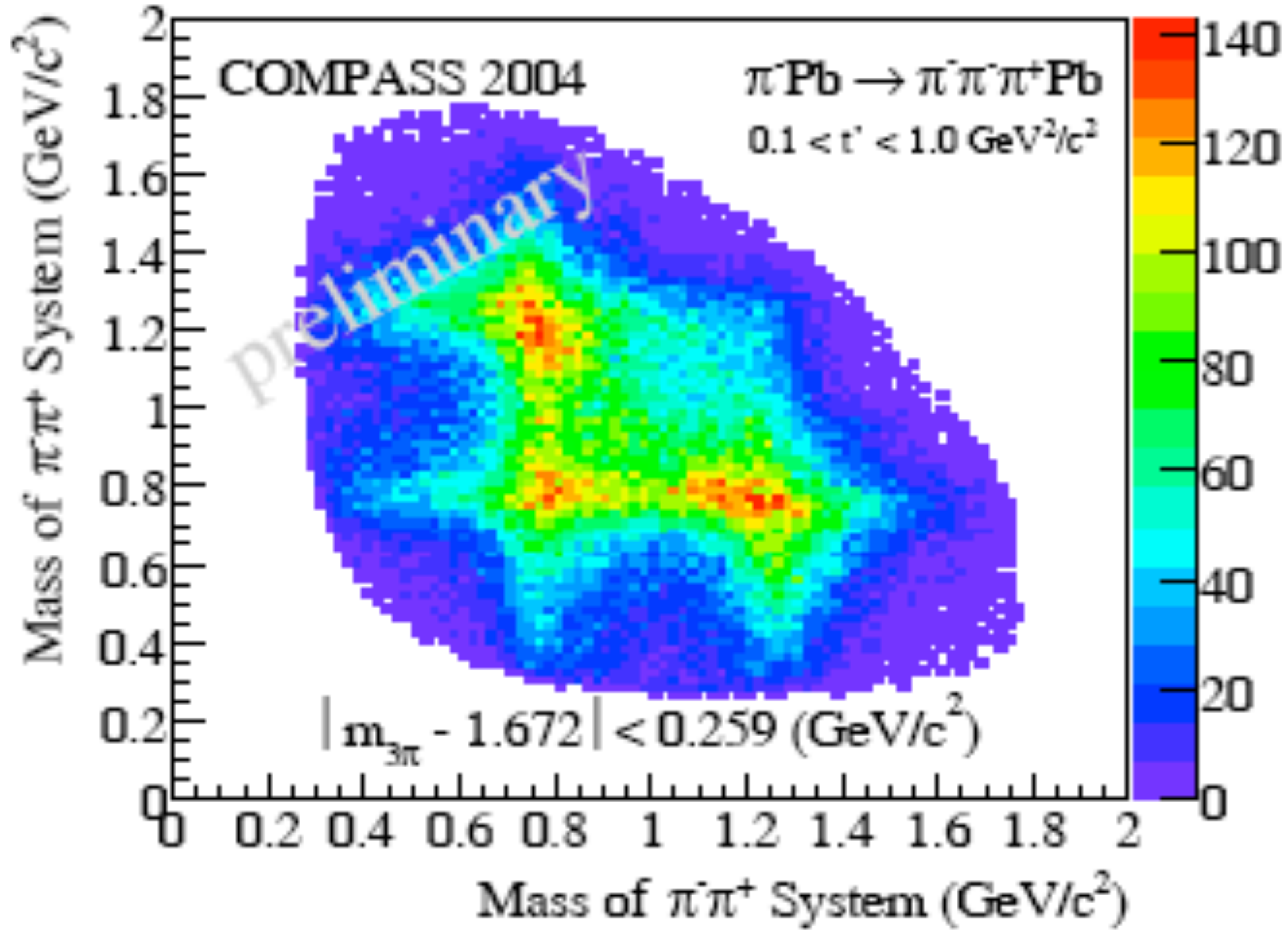

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COMPASS

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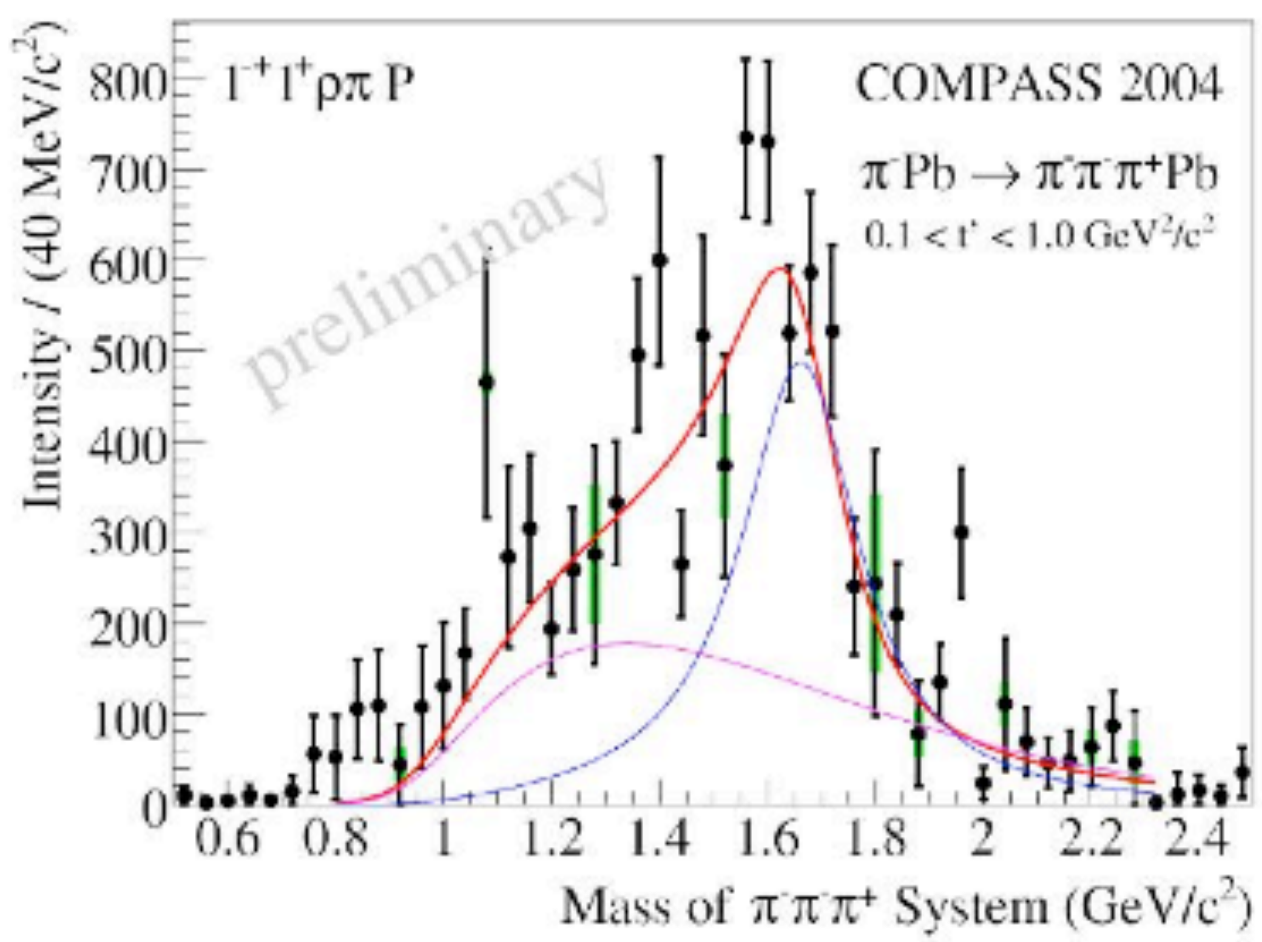
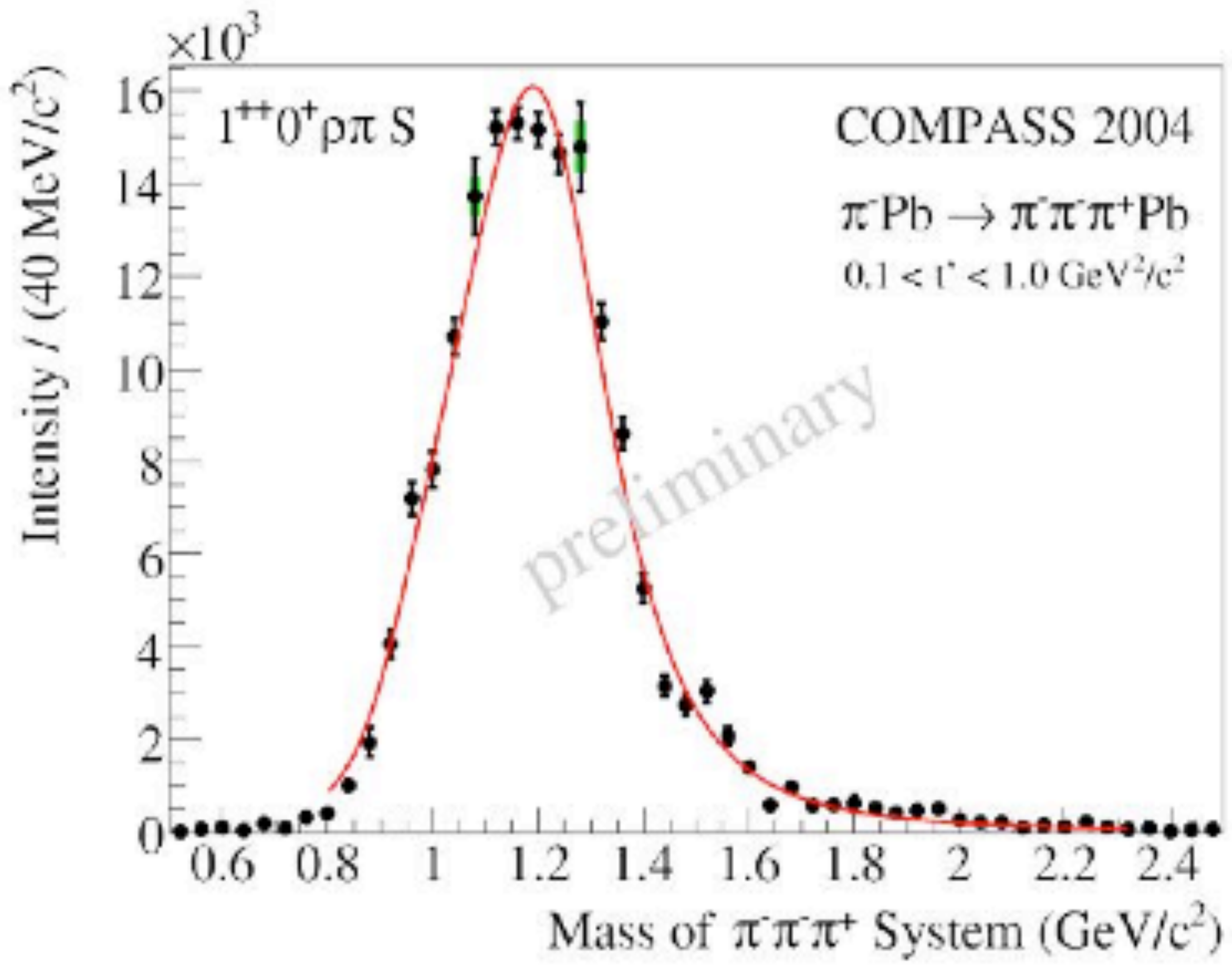
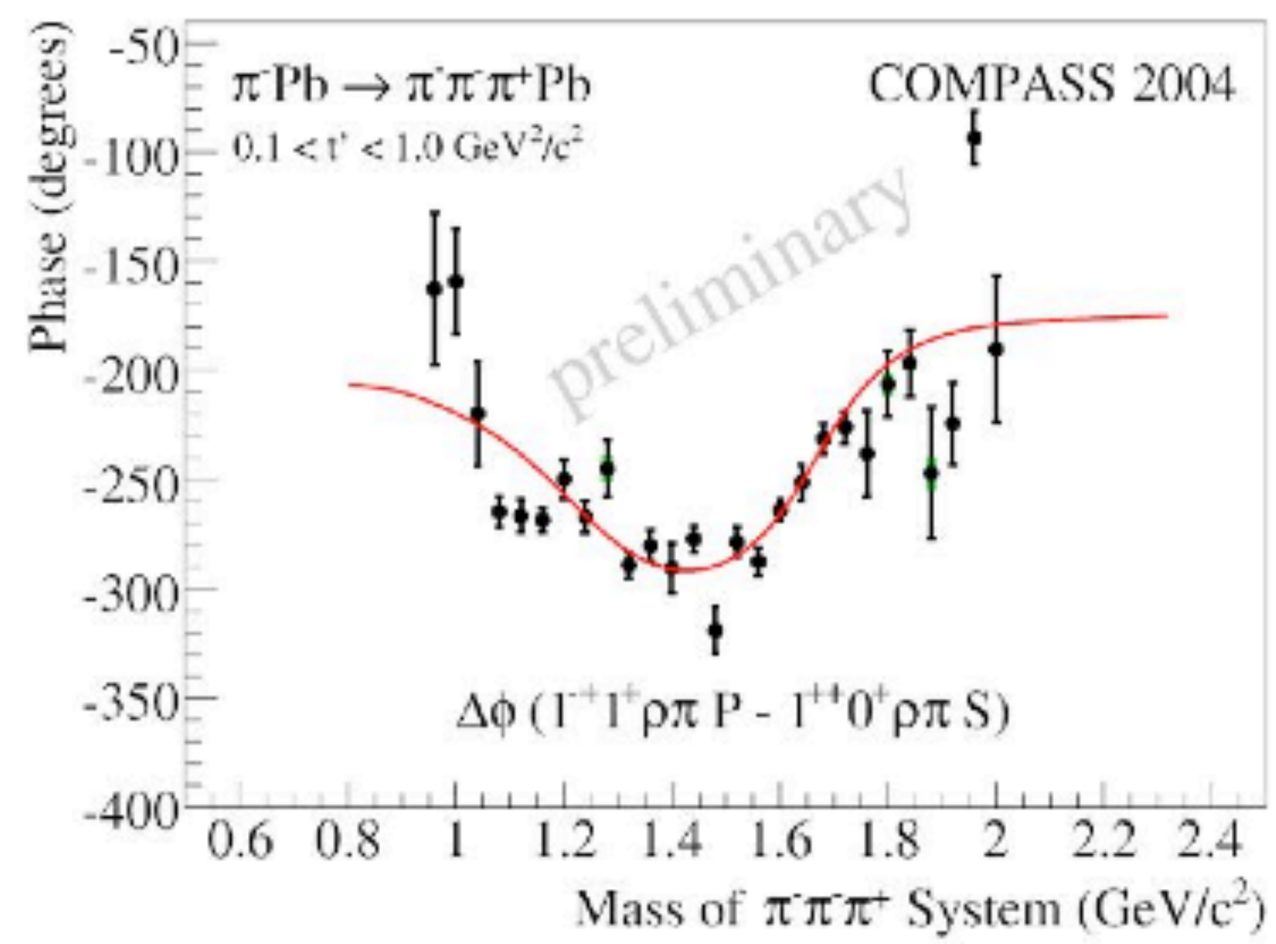


- BW parameters for $\pi_1(1600)$
  $M = (1660 \pm 10^{+0}_{-64})\,\mathrm{MeV/c^2}$
  $\Gamma = (269 \pm 21^{+42}_{-64})\,\mathrm{MeV/c^2}$
- Leakage negligible: $< 5\%$





COMPASS

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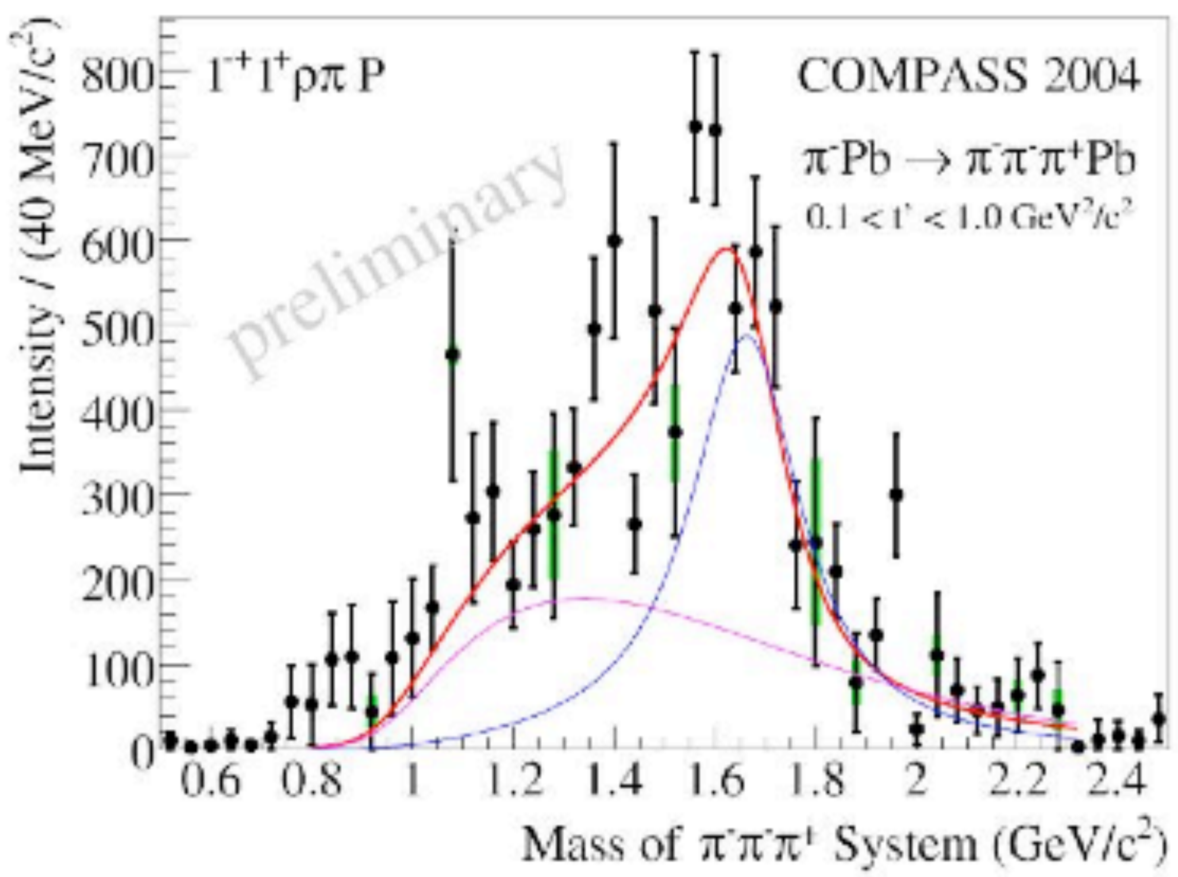
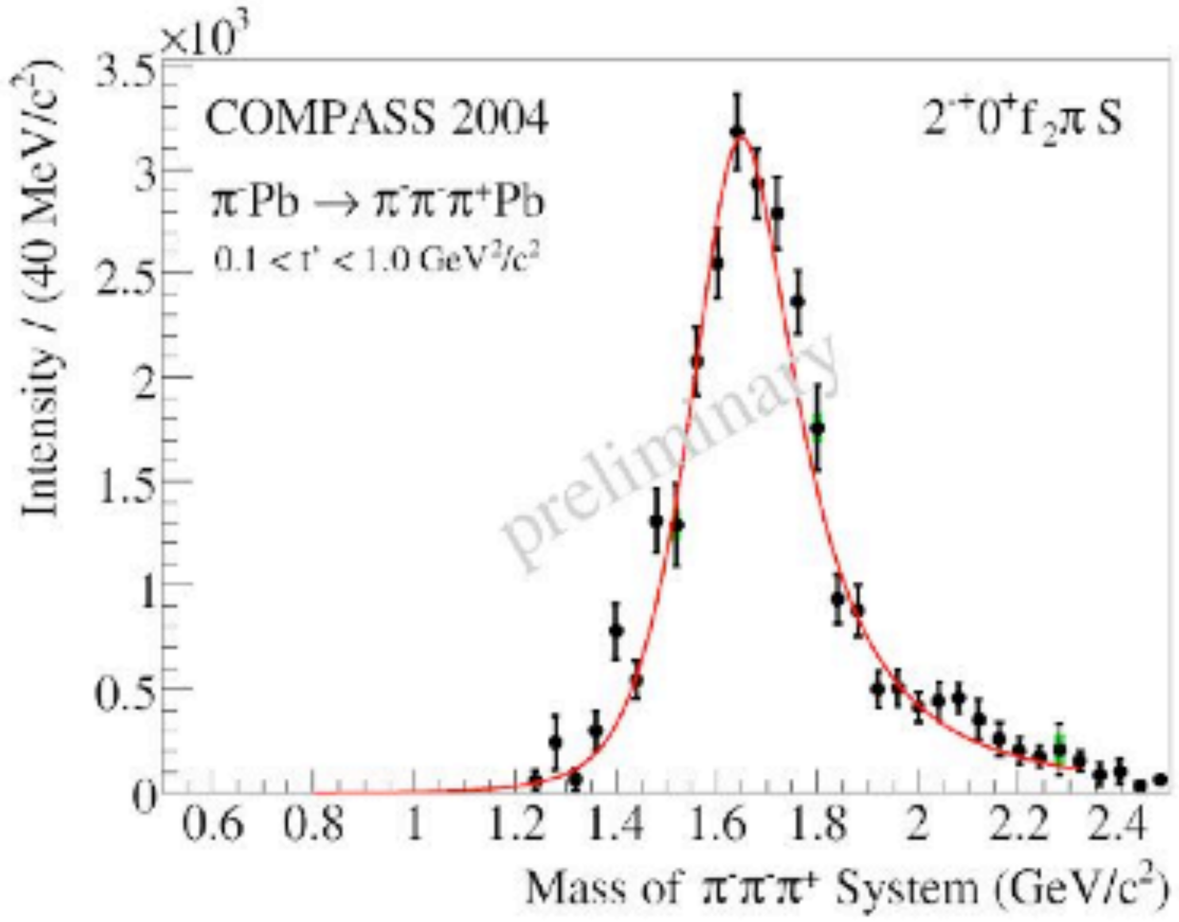
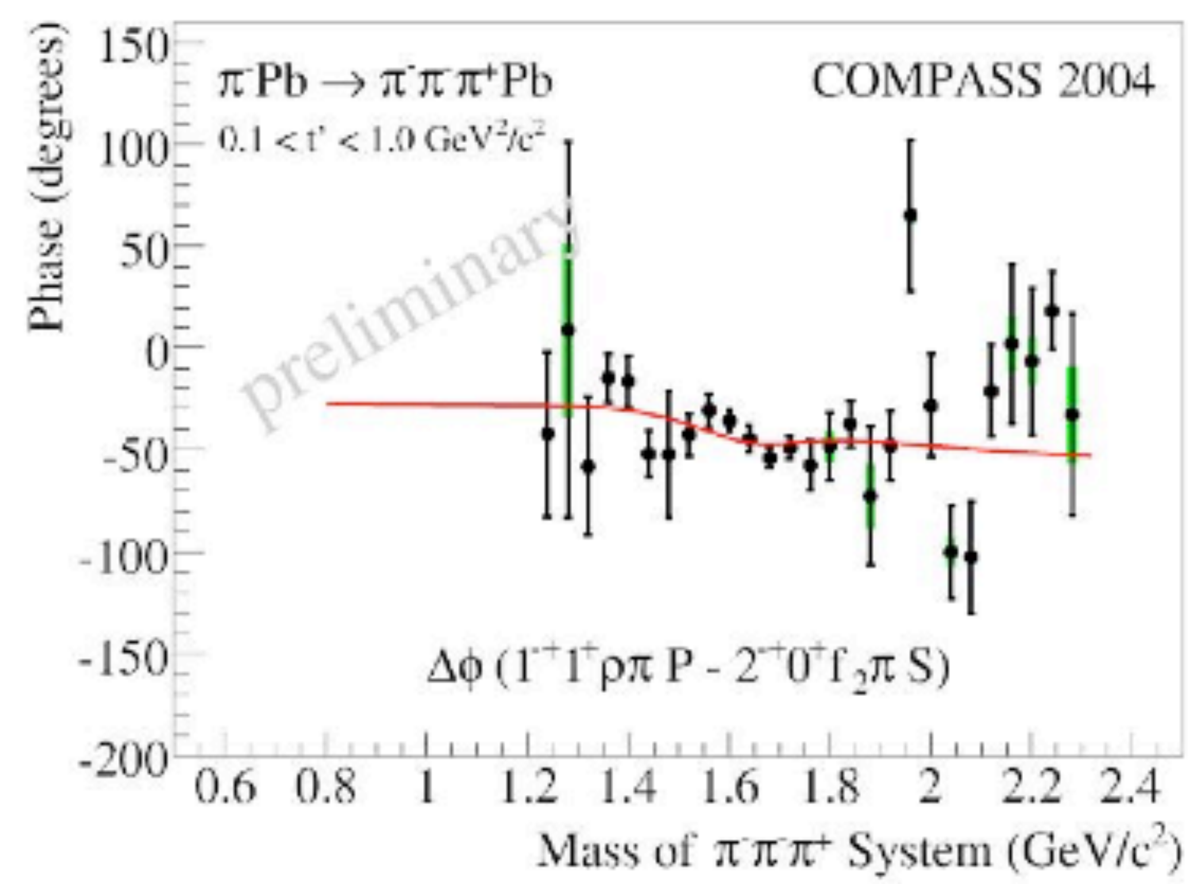


$J^{PC} = 1^{-+}$





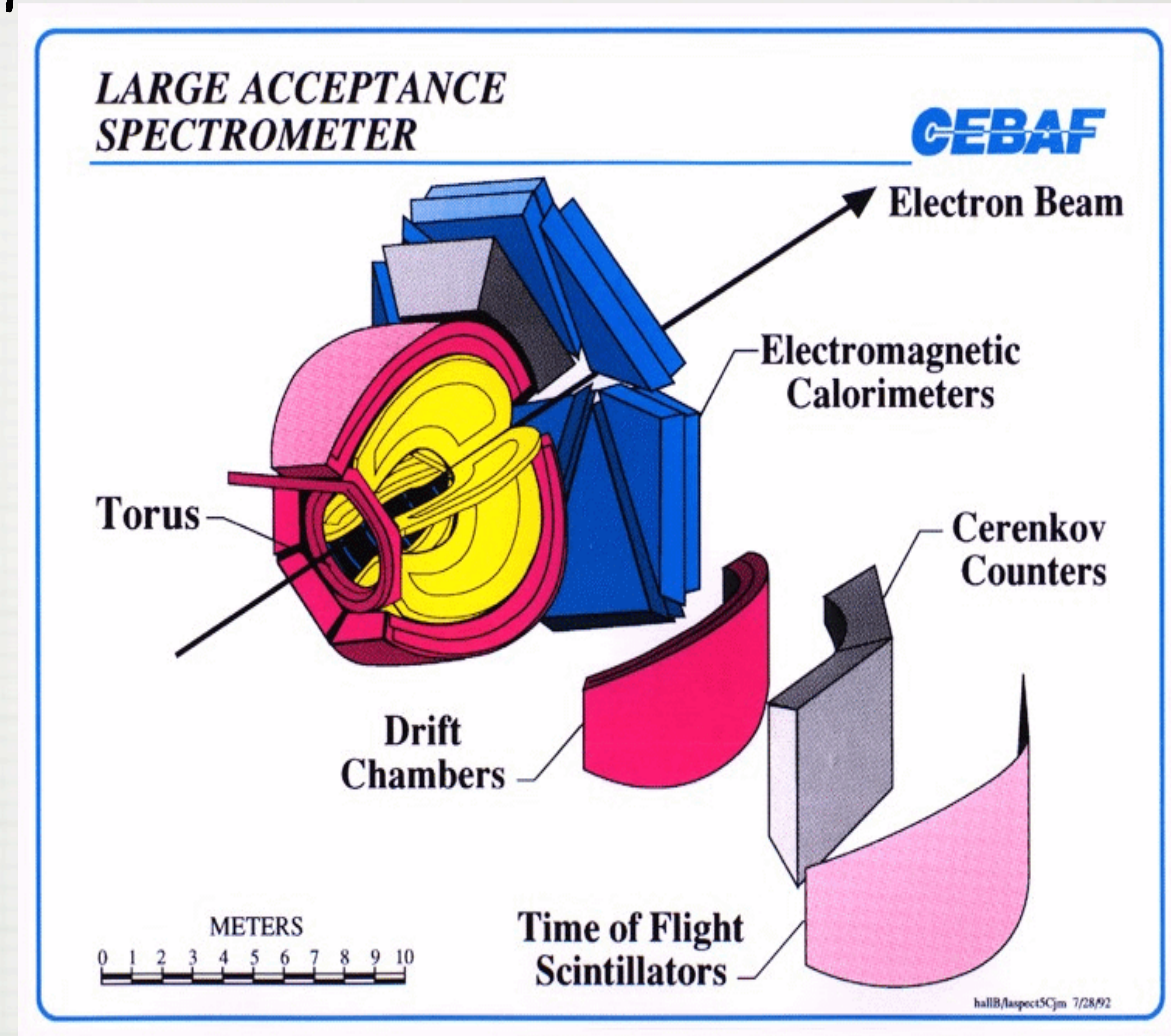
Why photoproduction?

Isgur & Paton
Phys. Rev. Lett. 54, 869–872 (1985)

We would suggest that high-mass meson diffractive scattering will be particularly rich in hybrids. In the case where the beam flux tube is simply "plucked" by the target one will produce hybrids with the flavor and spin of the beam: A π beam would, for example, produce by this mechanism the nonexotic $I=1$, $J^{PC}=1^{++}$ and 1^{--} hybrids. More complicated spin-flip and quantum-number exchange mechanisms in which the hybrid is produced by quark scattering rather than pure glue scattering could produce the other hybrids, including the desirable exotic ones. Diffractive photoproduction, on the other hand, can produce "plucked" ρ, ω, and ϕ states and so could be a good source for all four of the desirable exotics y_2^{+-}, z_2^{+-}, x_1^{-+}, and y_0^{+-}. Traditional "gluon-rich" channels

Cebaf Large Acceptance Spectrometer

Particle Detection in CLAS



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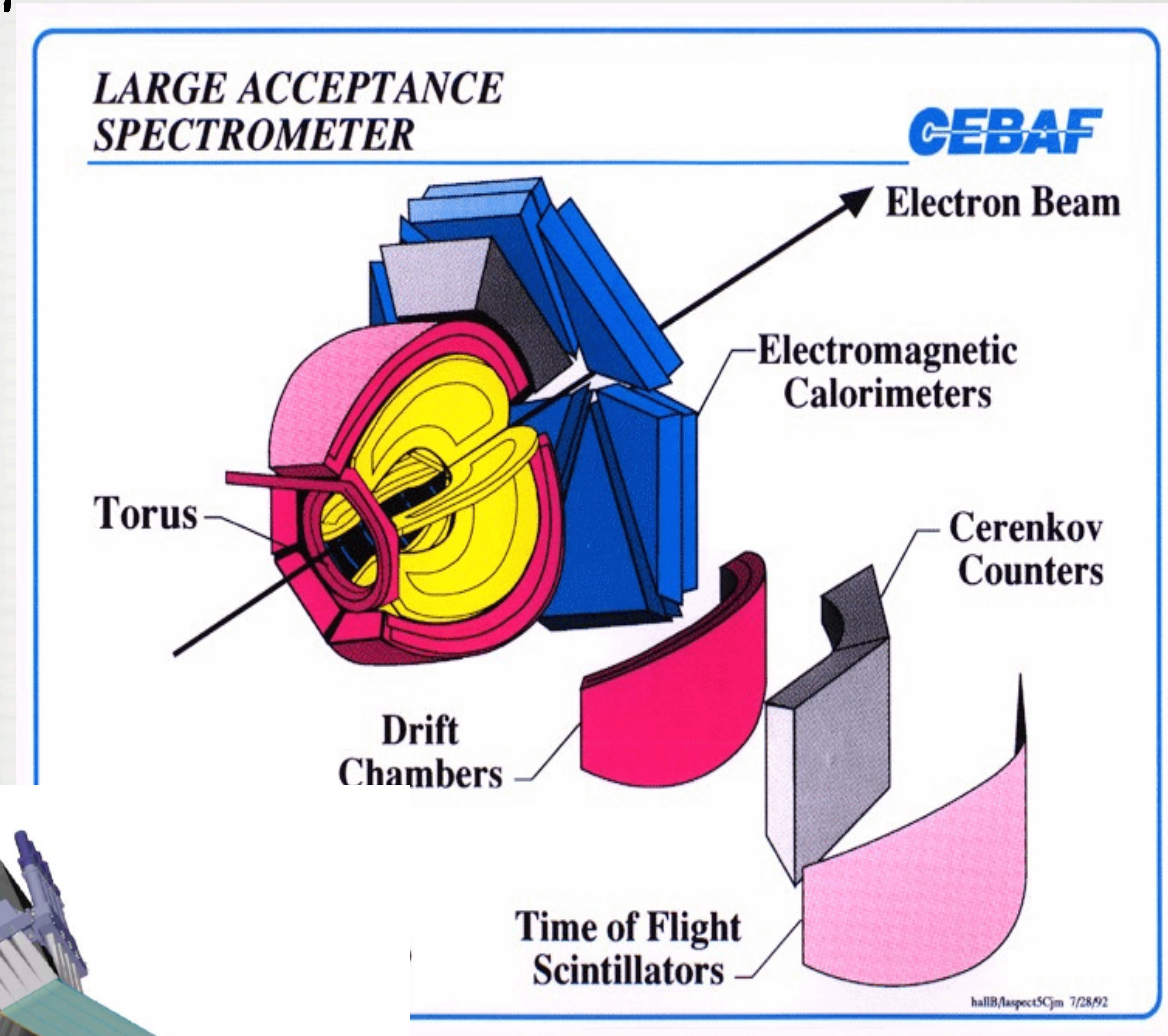
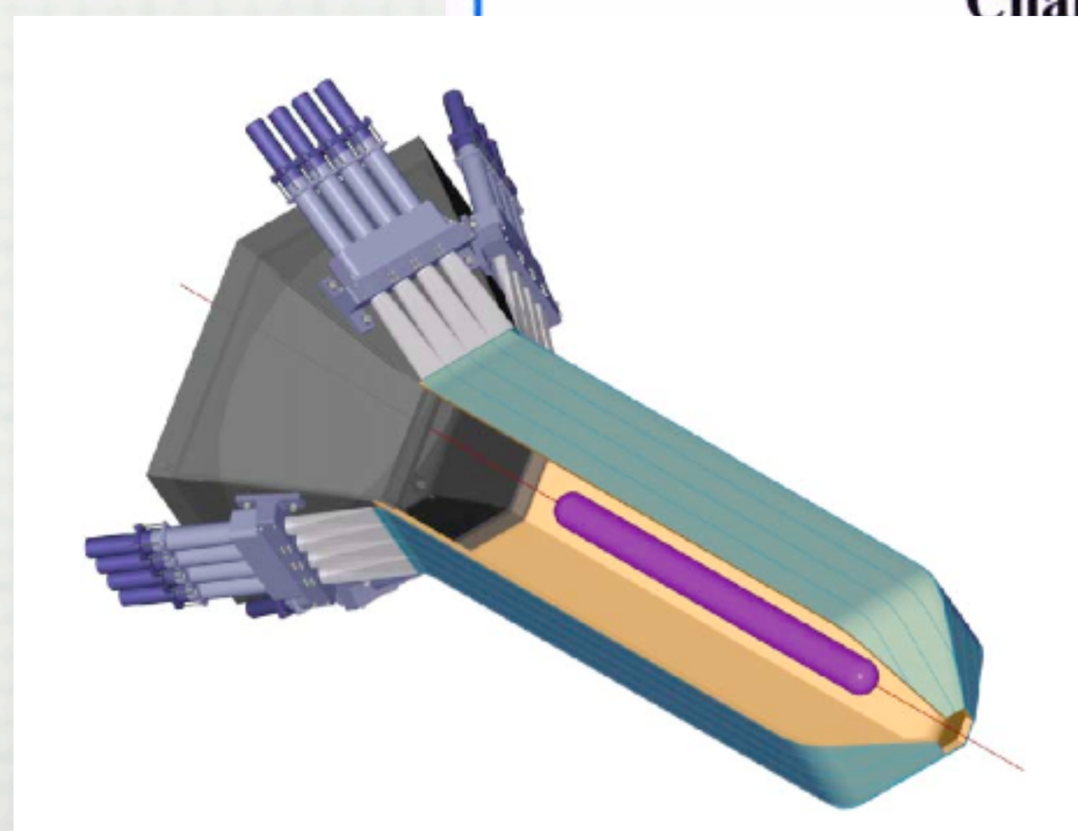
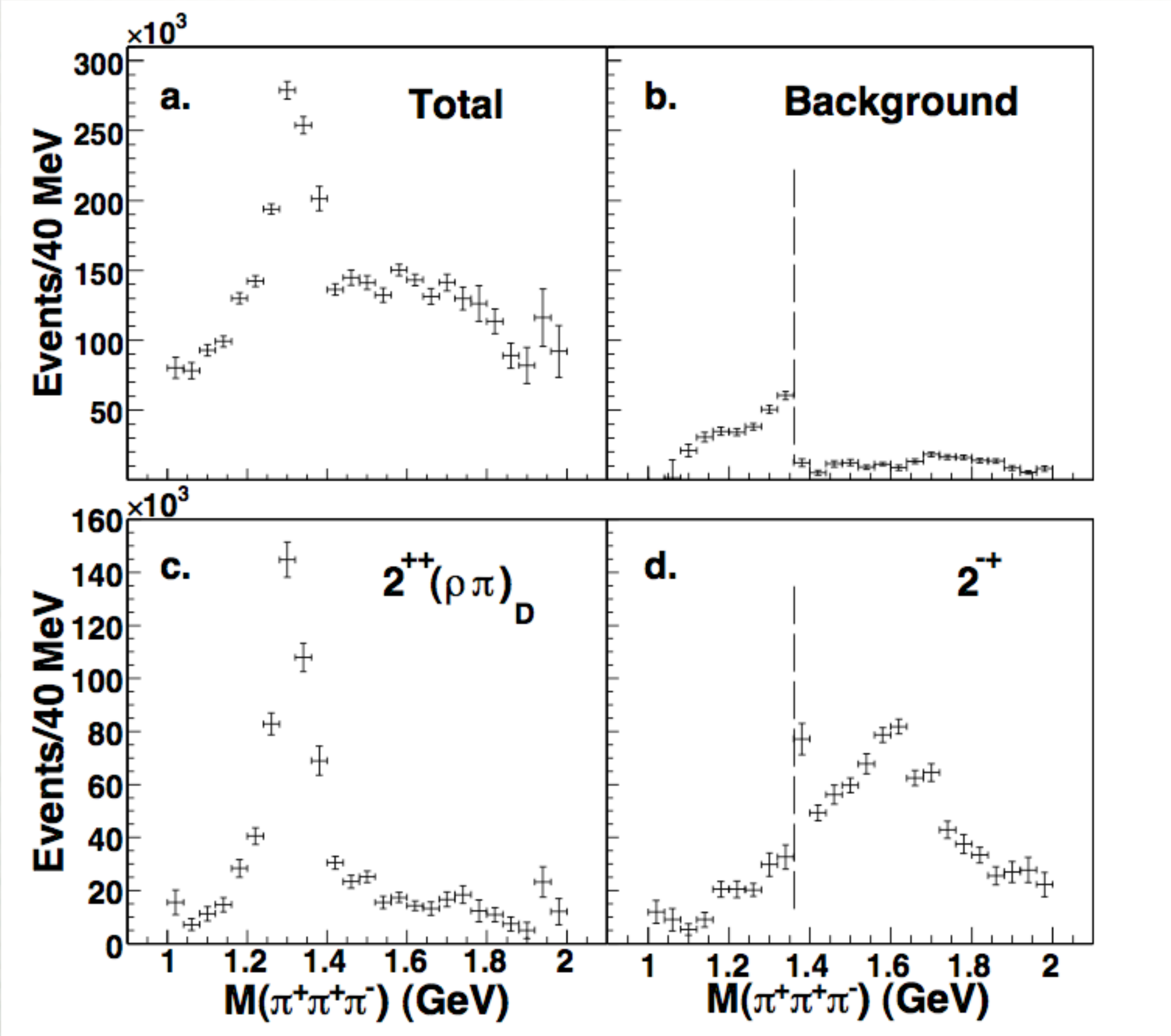
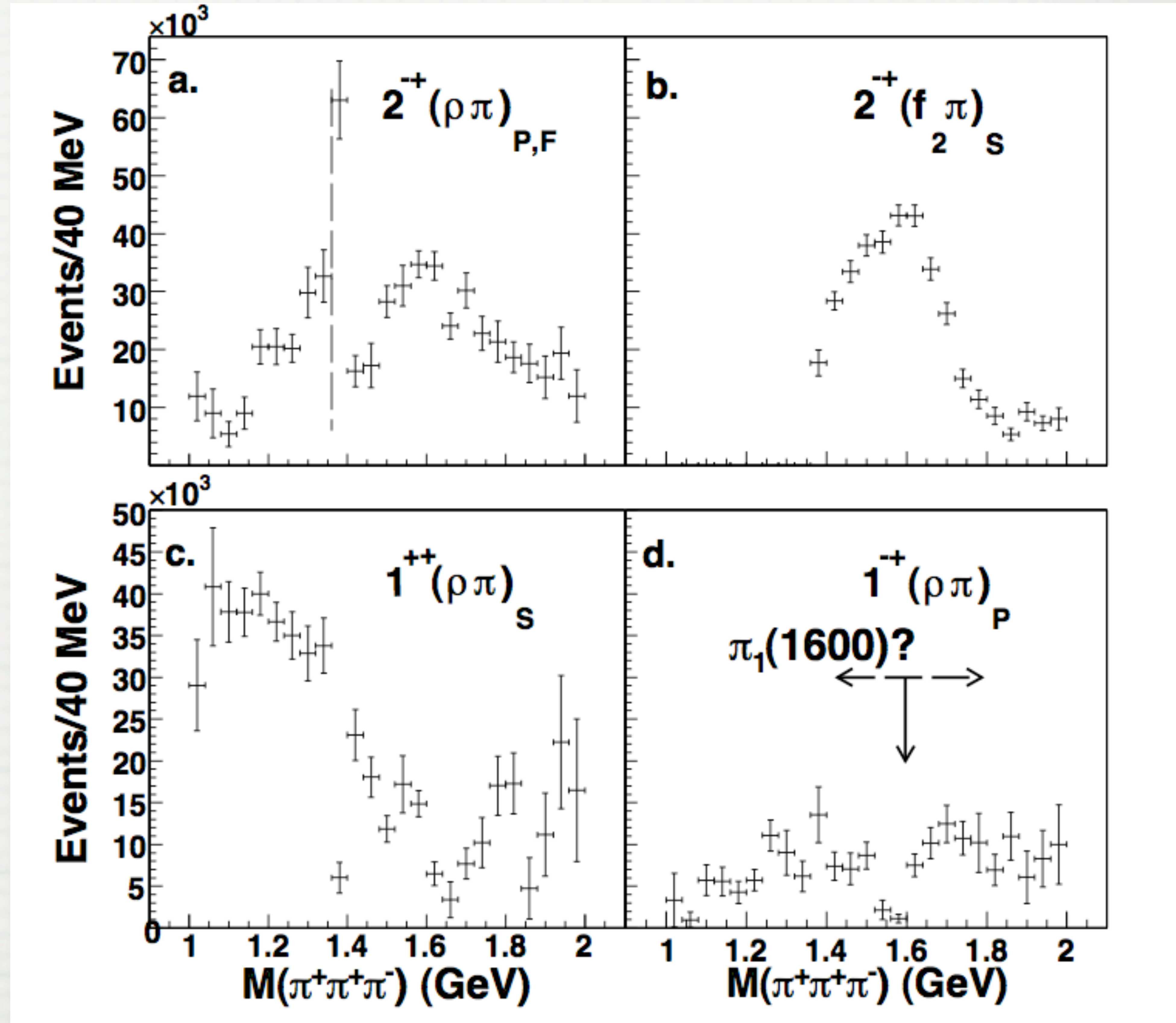




Thursday, June 16, 2011

CLAS/g6c (Nozar et al.). Phys.Rev.Lett. 102 (2009) 102002



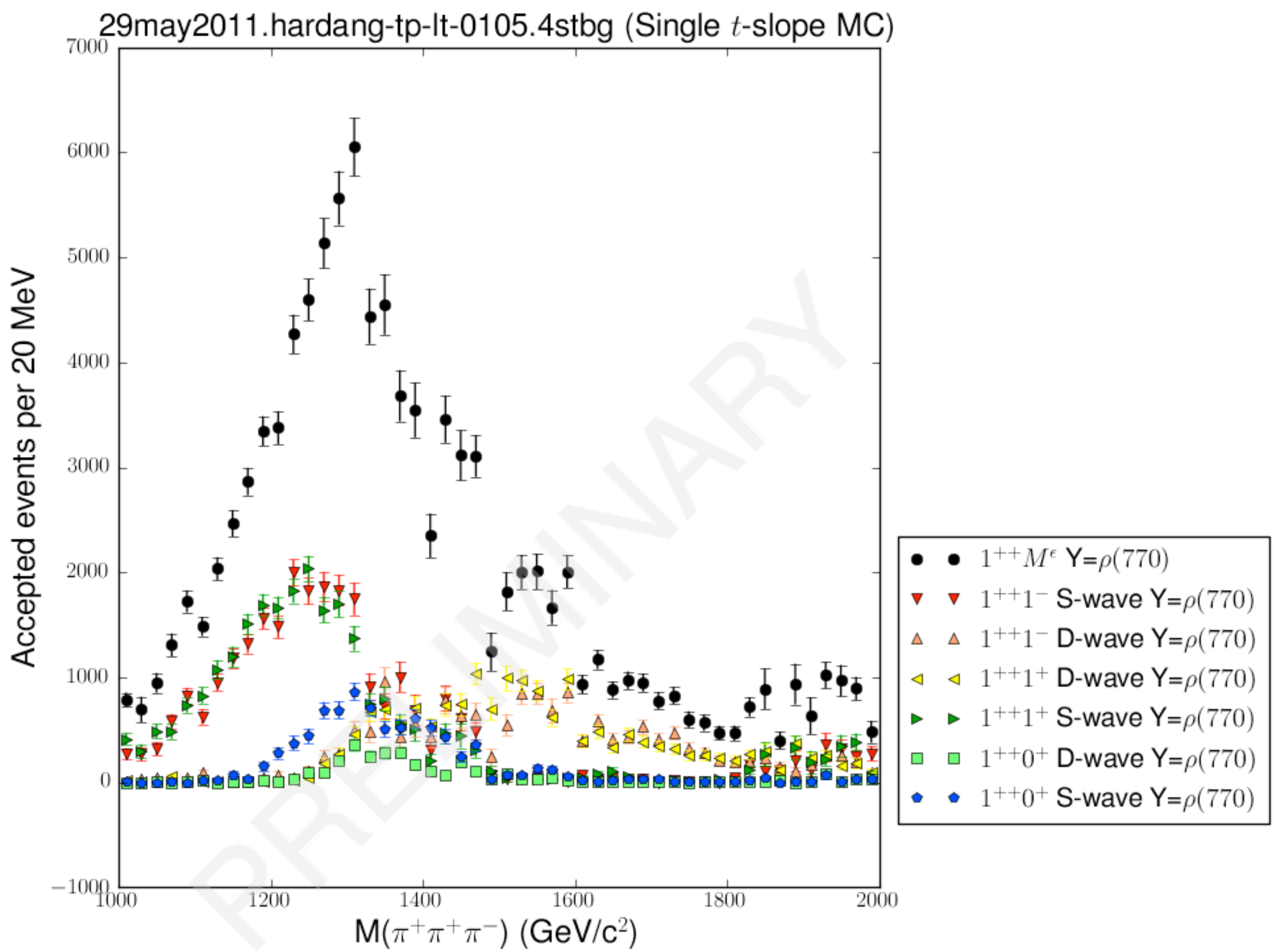


g12

Craig Bookwalter, Paul Eugenio FSU

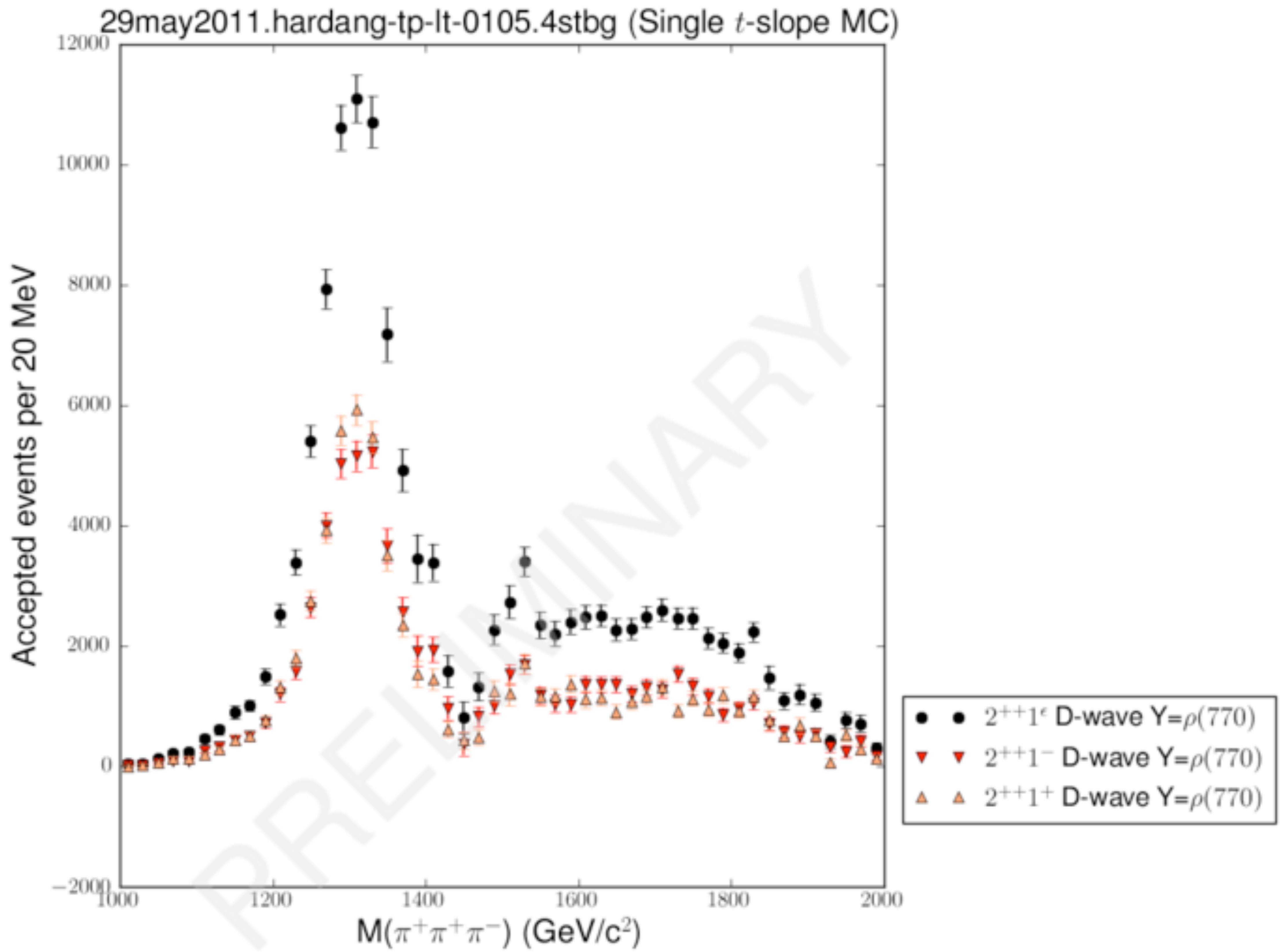
$\gamma p \rightarrow \pi^+\pi^+\pi^- n$

$J^{PC} = 1^{++}$



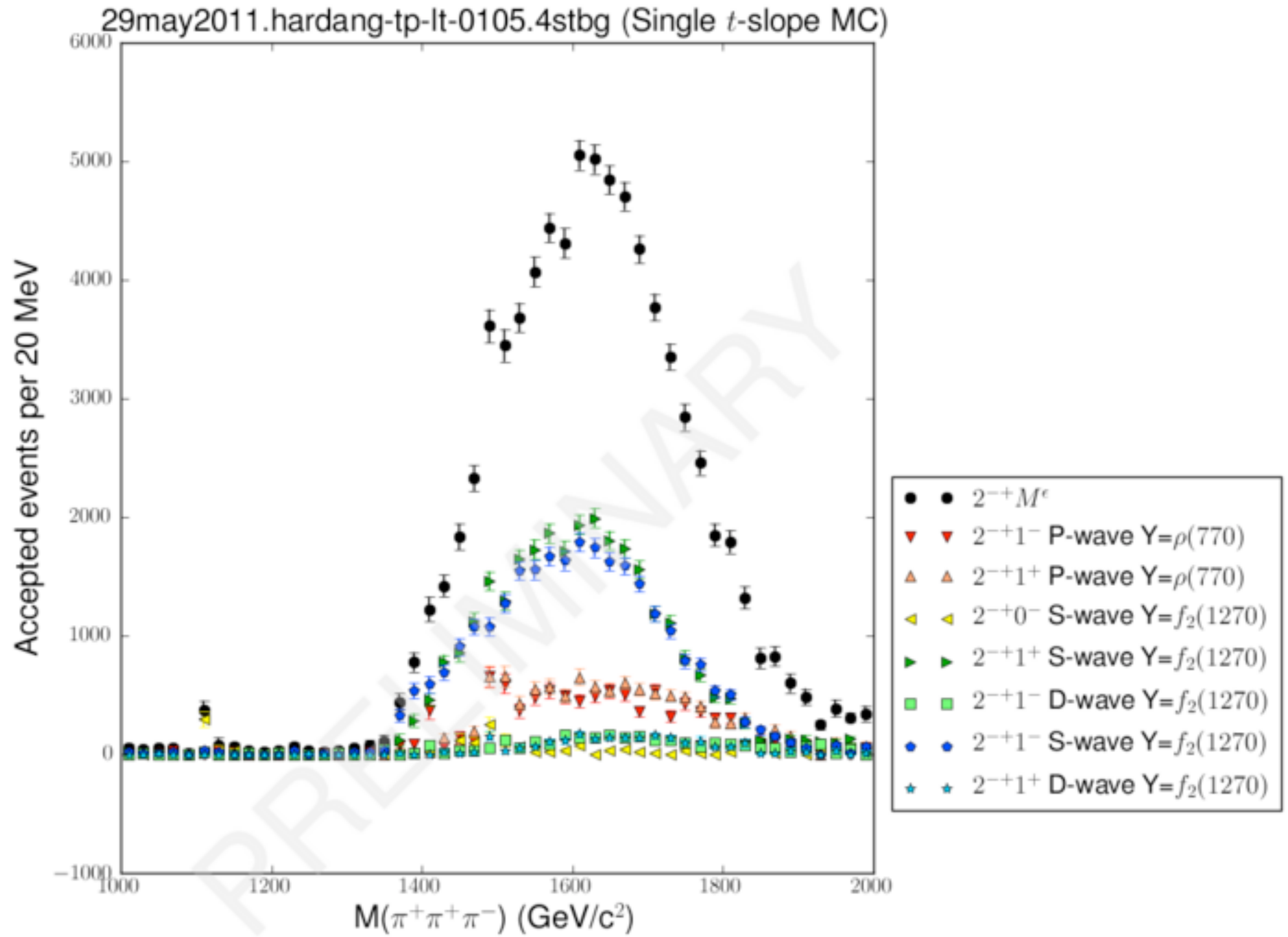
$$\gamma p \to \pi^+\pi^+\pi^- n$$

$$J^{PC} = 2^{++}$$



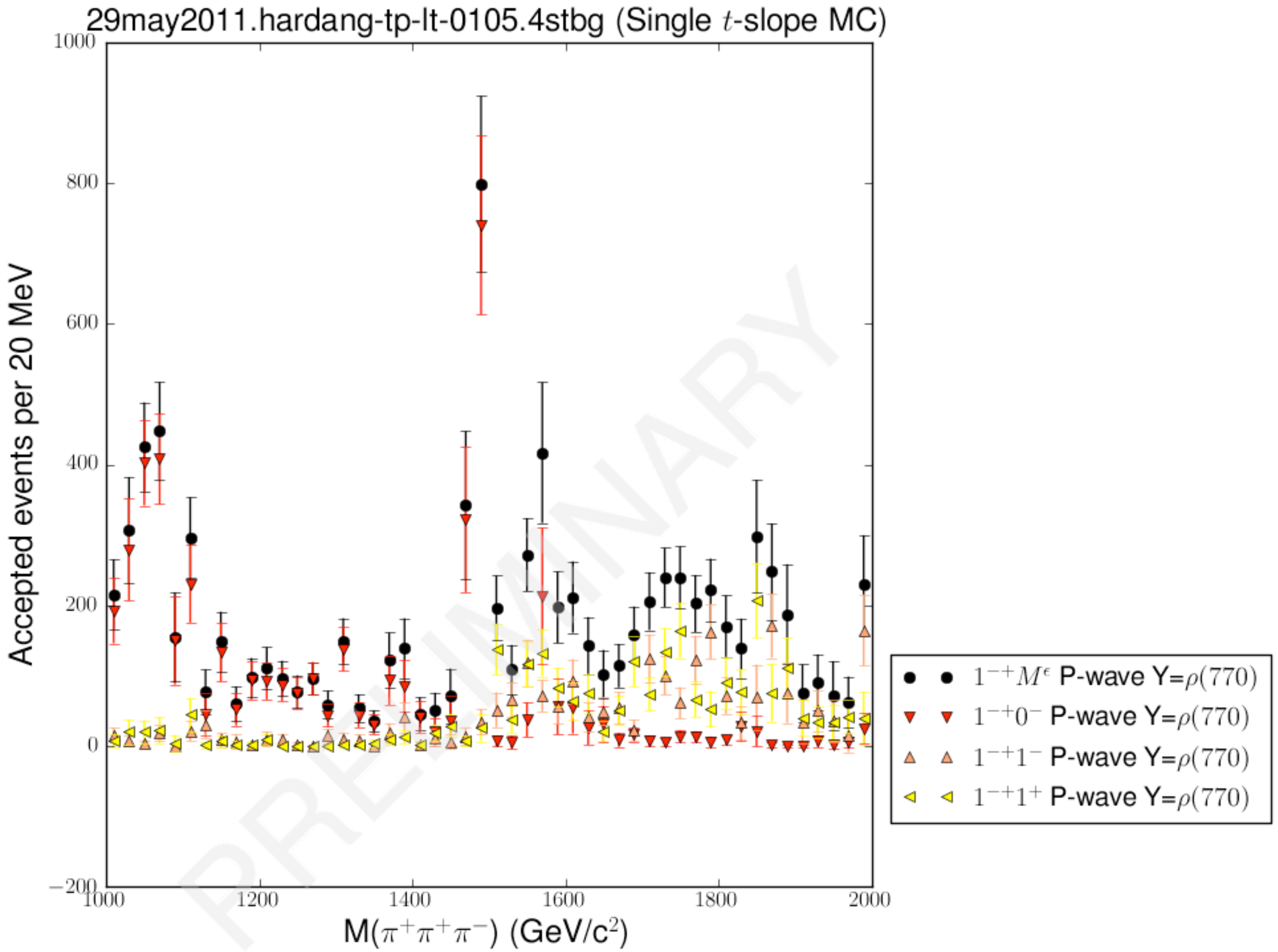
$$J^{PC} = 2^{-+}$$

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

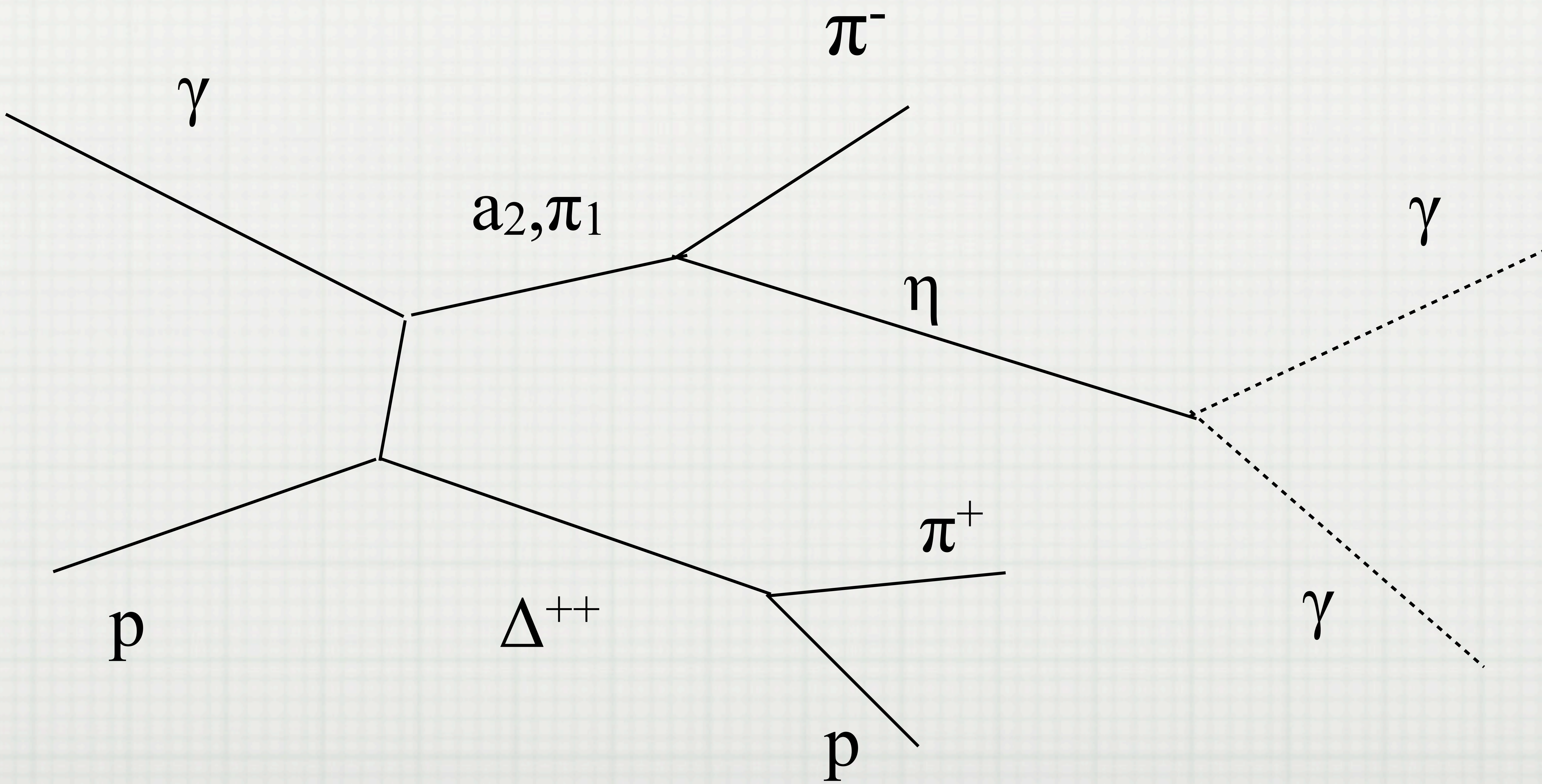


$$\gamma p \to \pi^+\pi^+\pi^- n$$

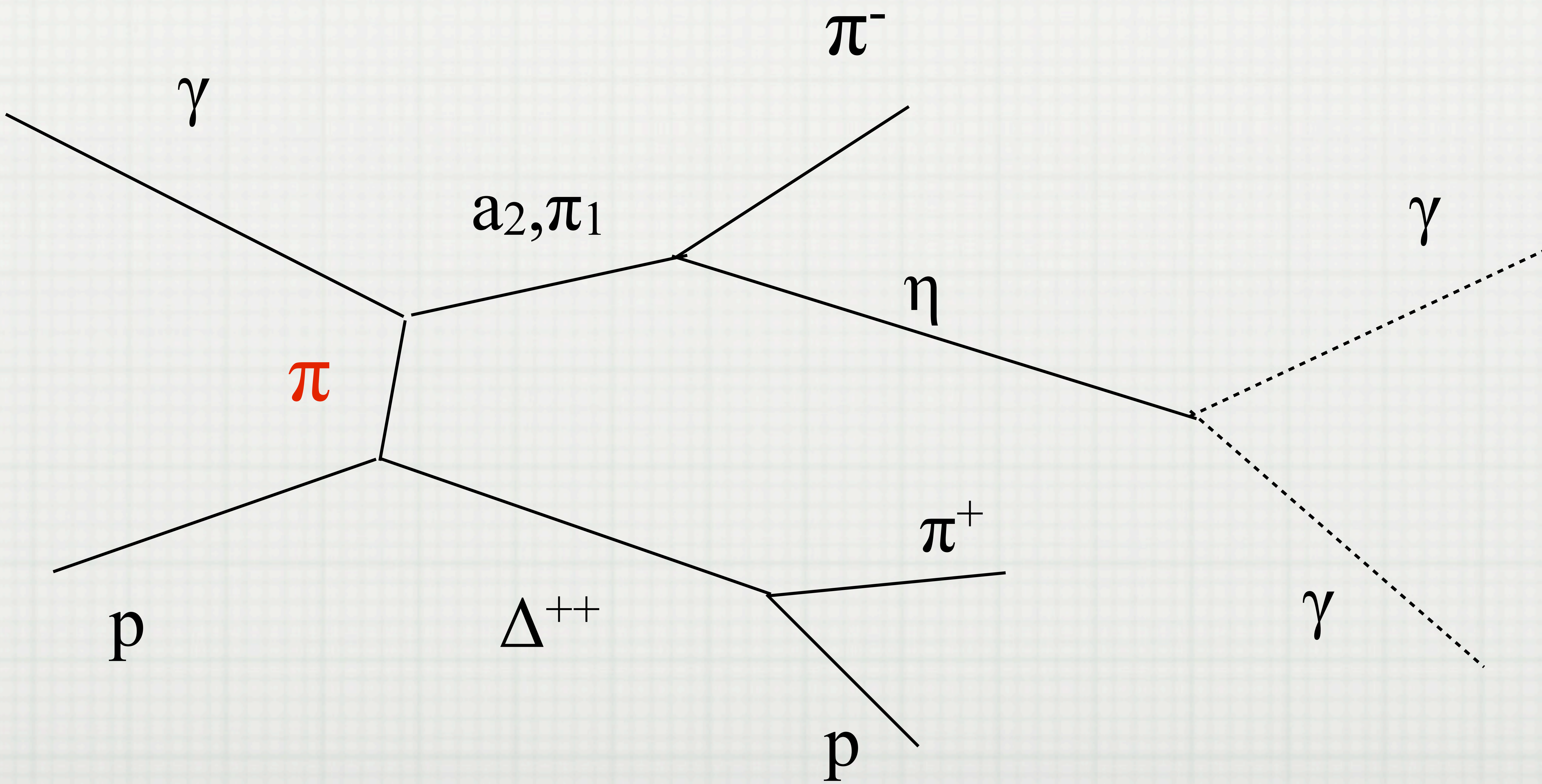
$$J^{PC} = 1^{-+}$$



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

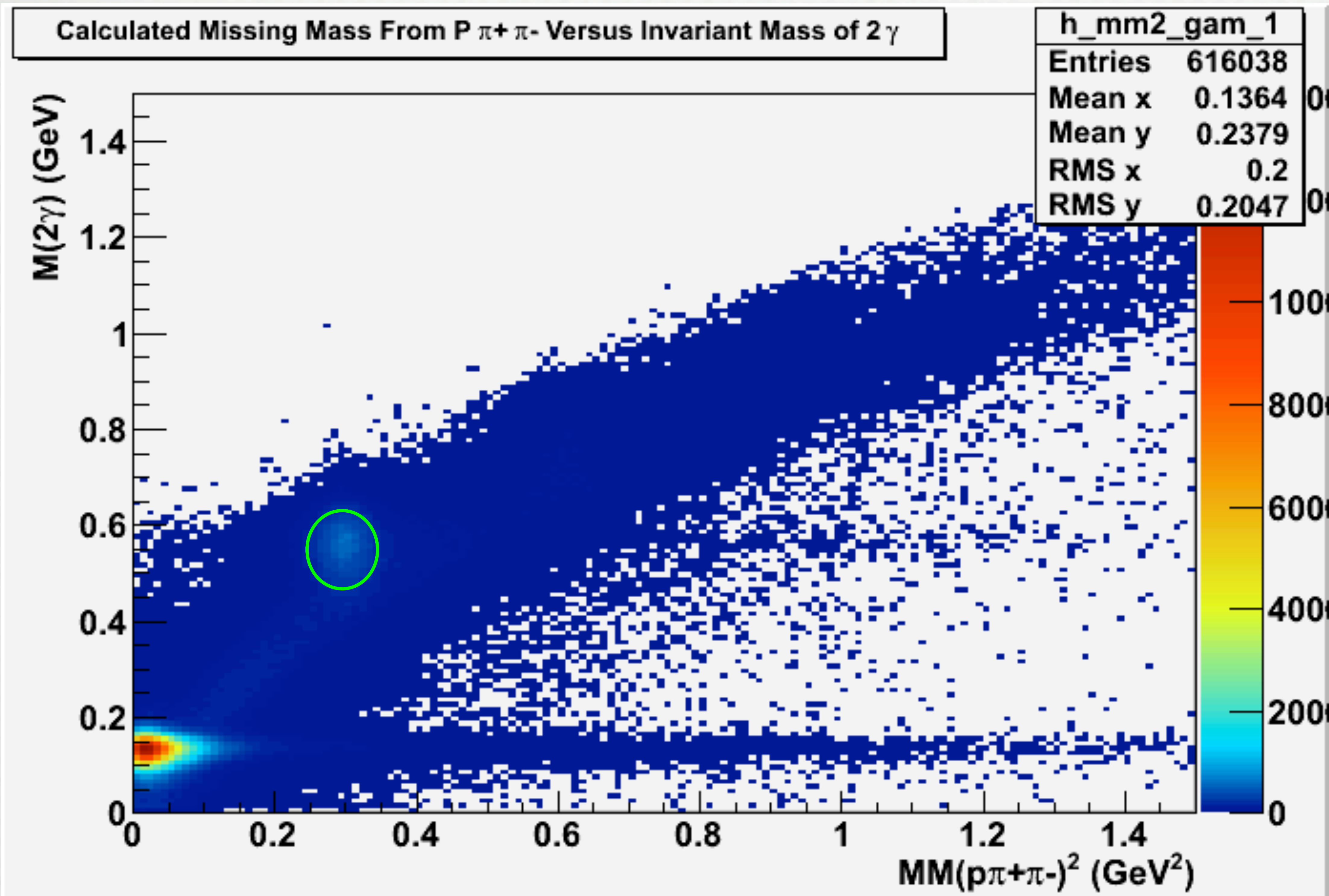


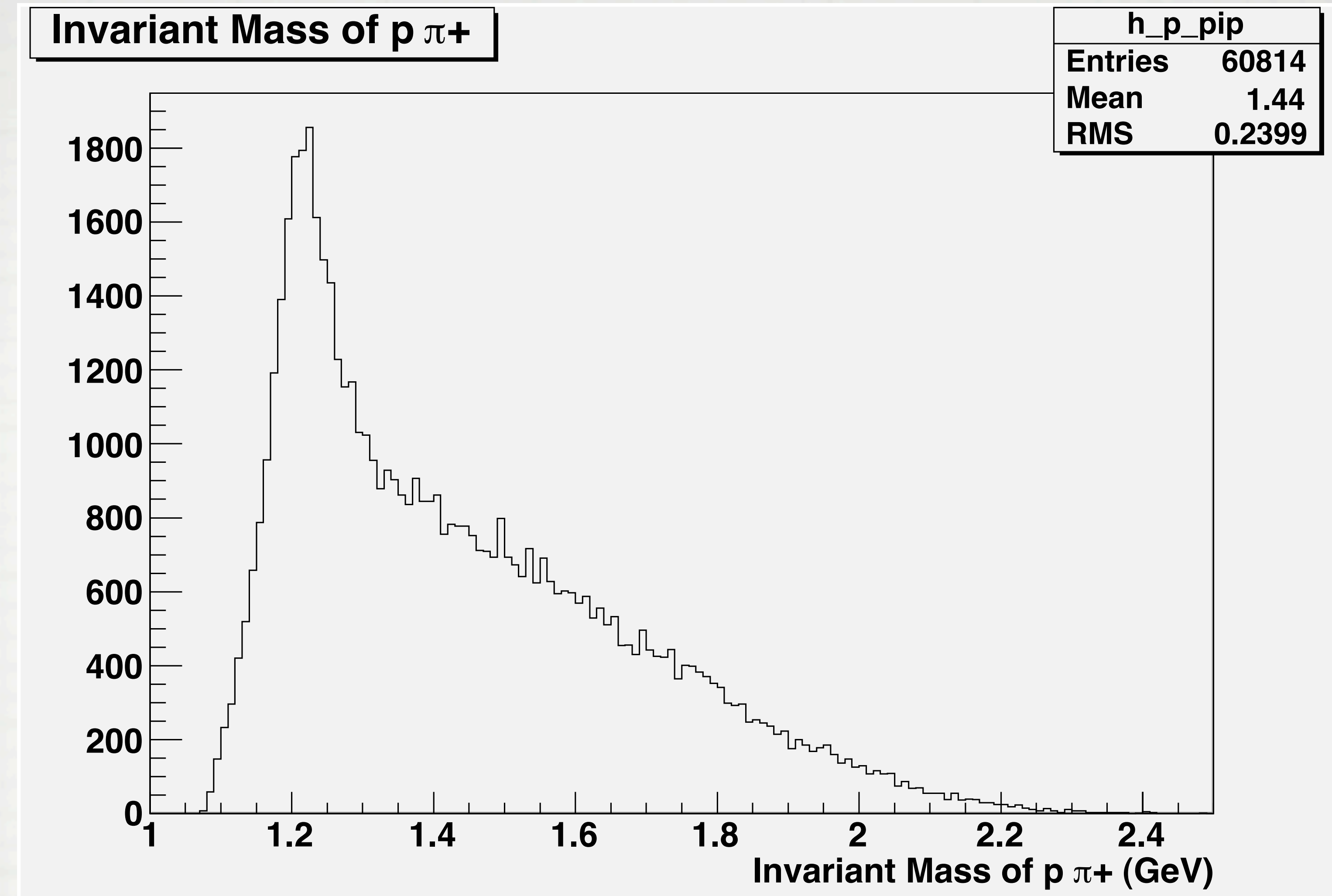
$$\gamma p \rightarrow \eta \pi^- \Delta^{++}$$

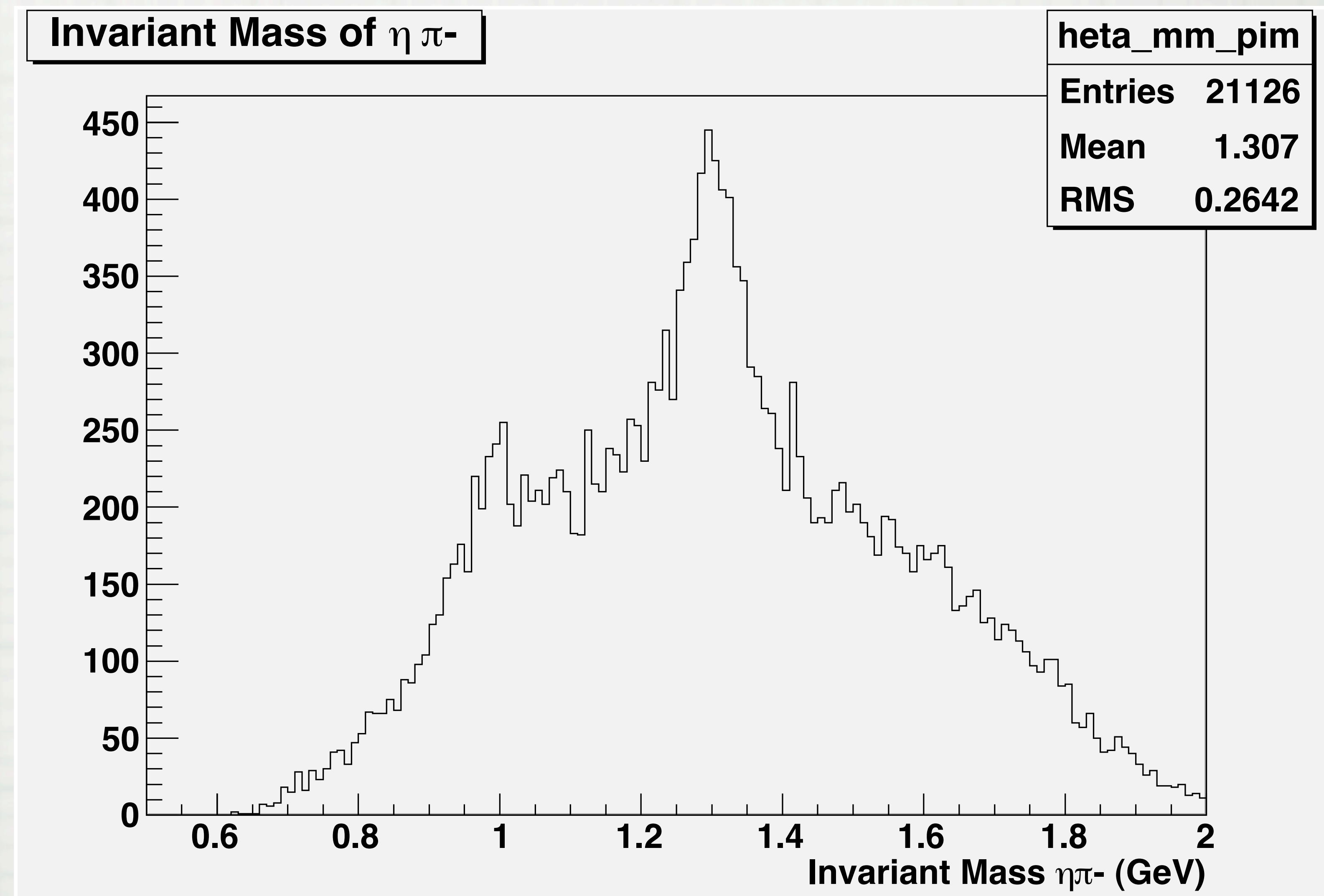


$$p\gamma \rightarrow \pi^- \eta(\gamma\gamma)\Delta^{++}(p\pi^+)$$

Diane Schott

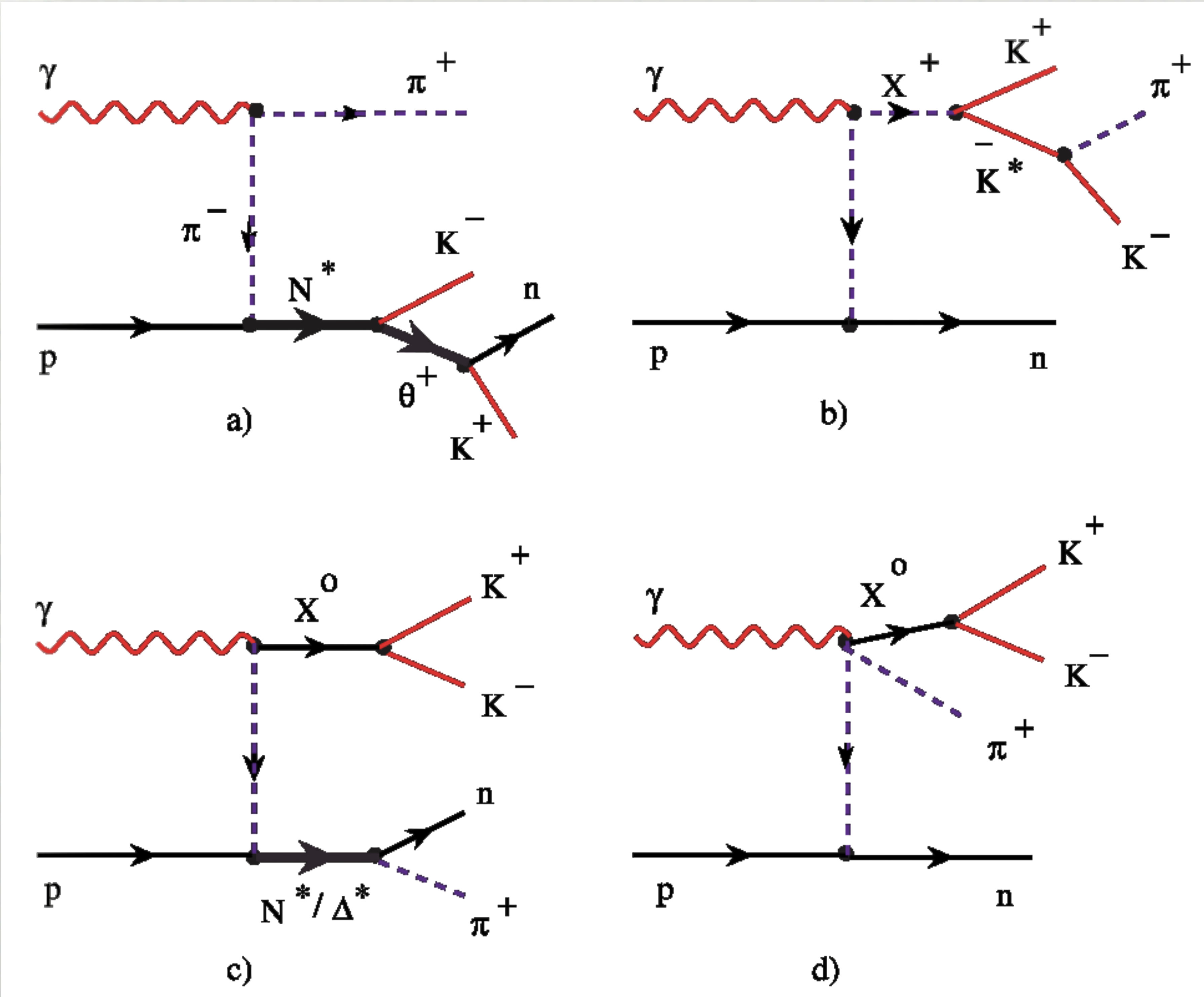






Exotic Baryons $g6_c$

$$\gamma p \to (K^+ n) K^- \pi +$$



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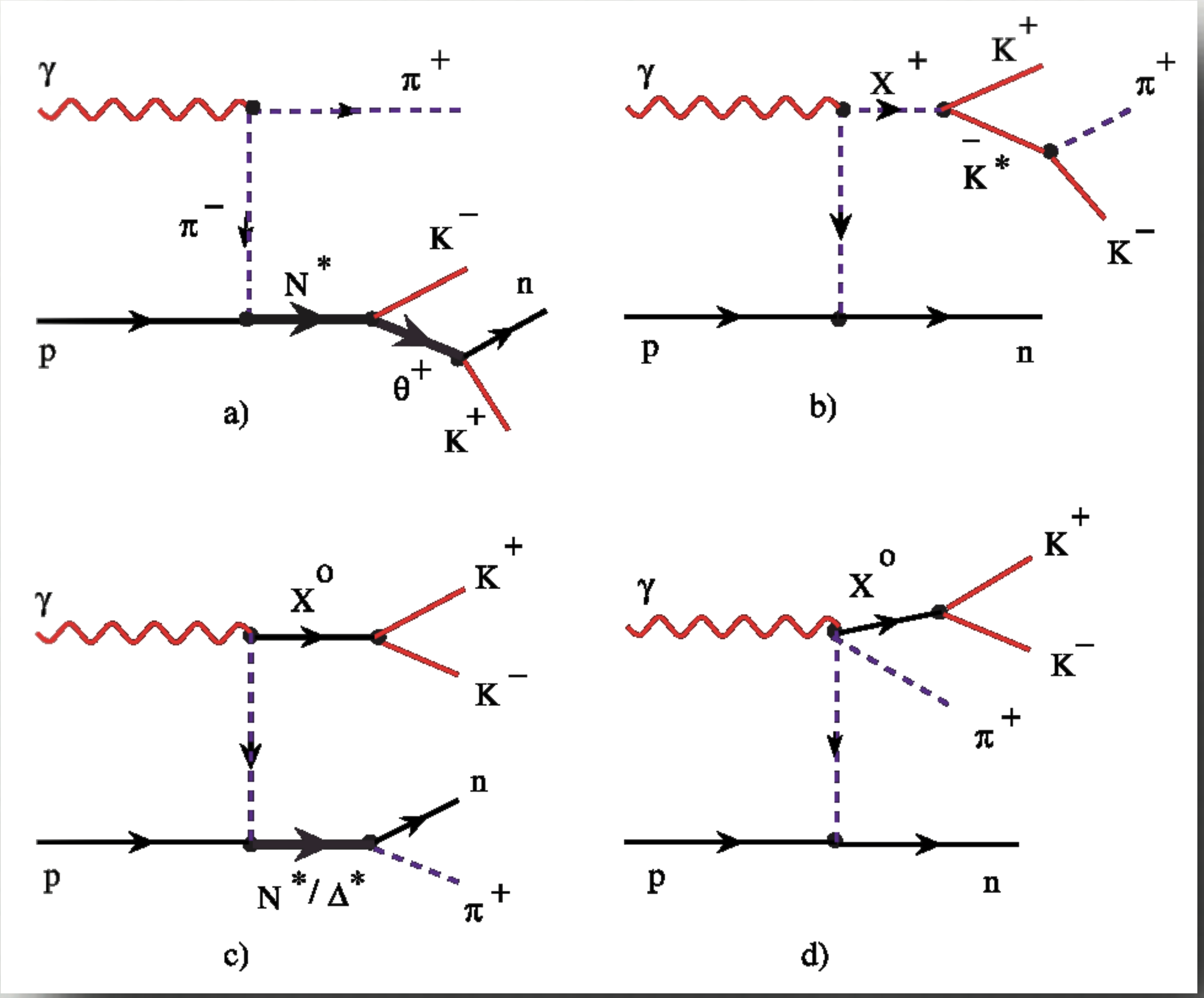
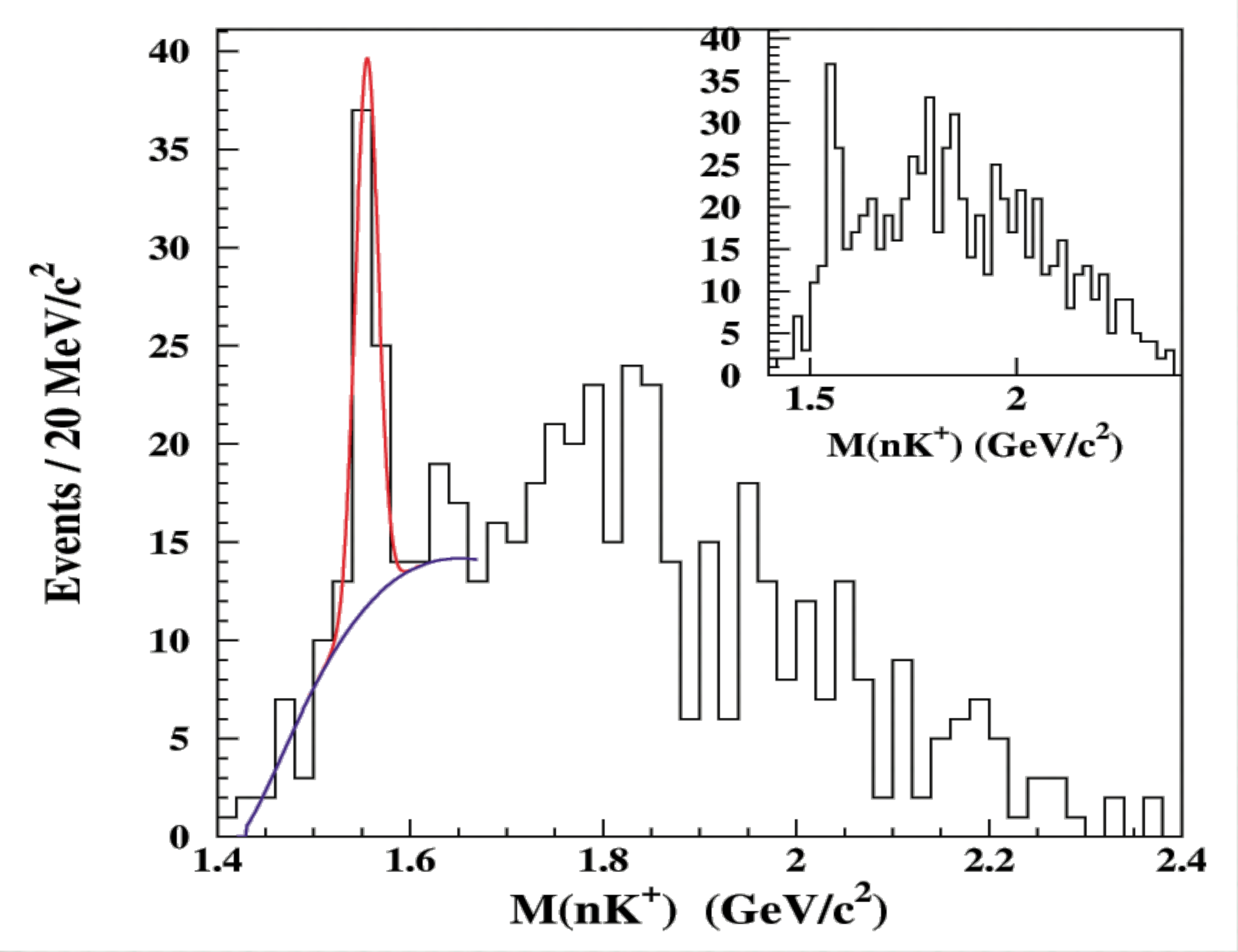
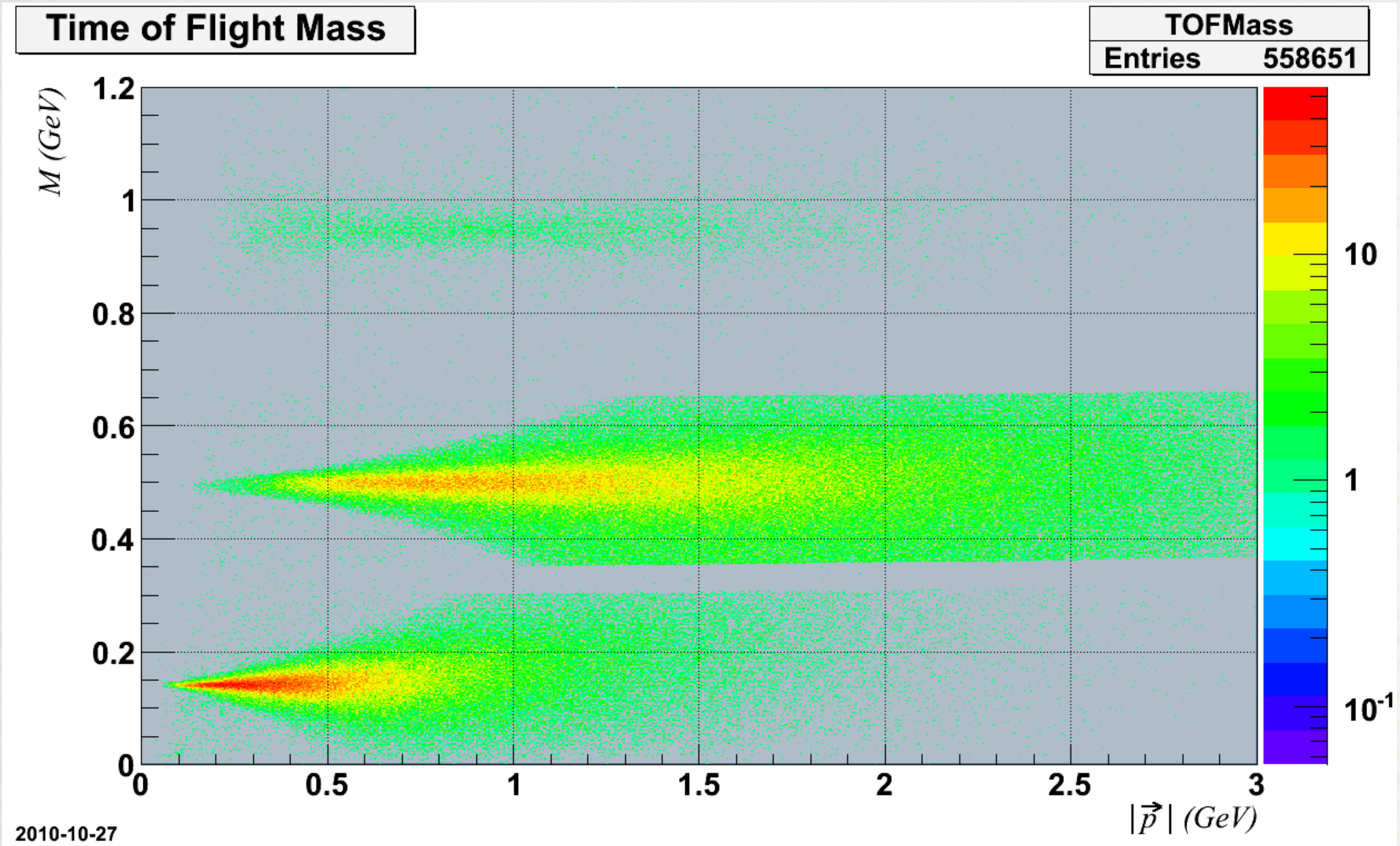
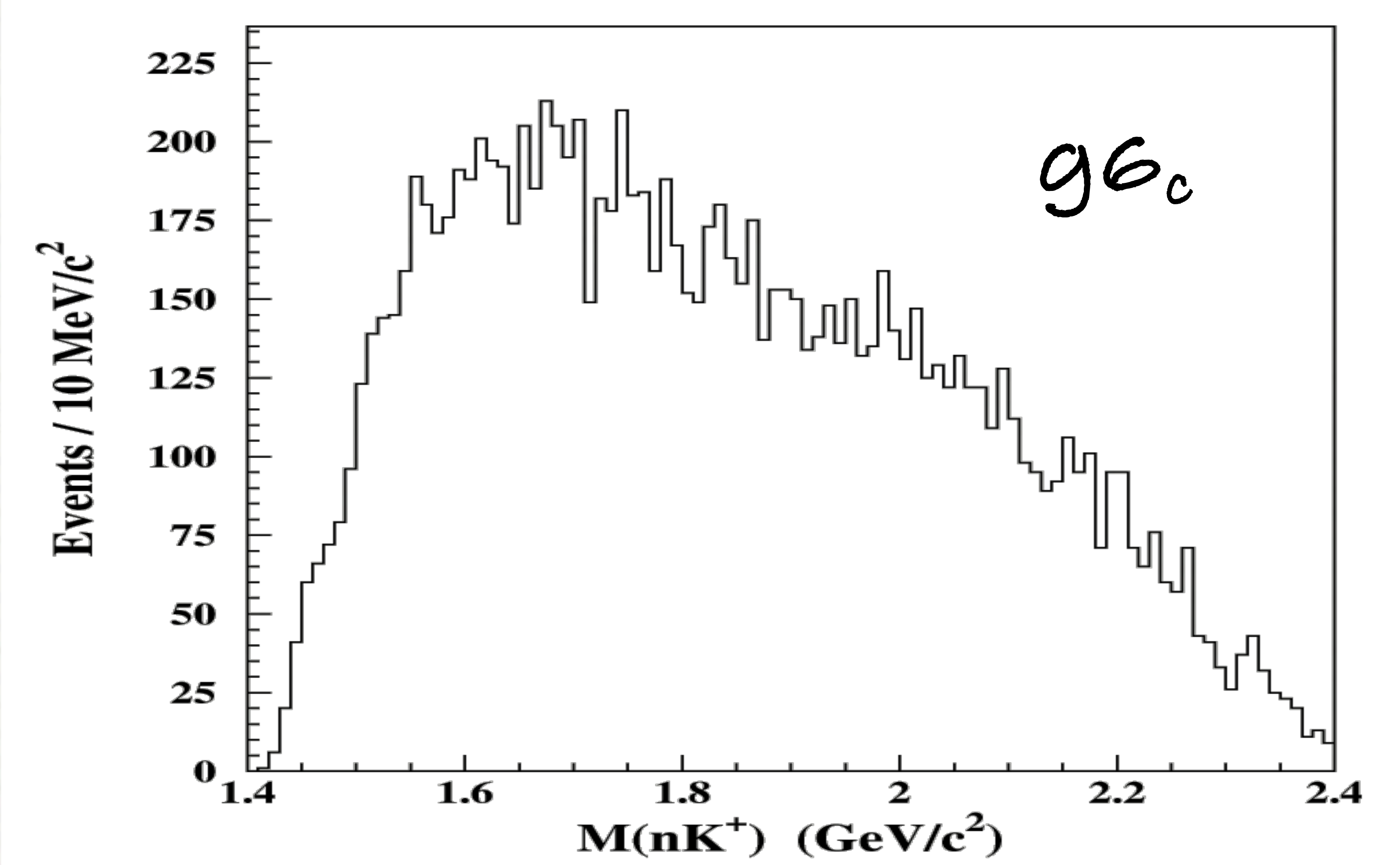


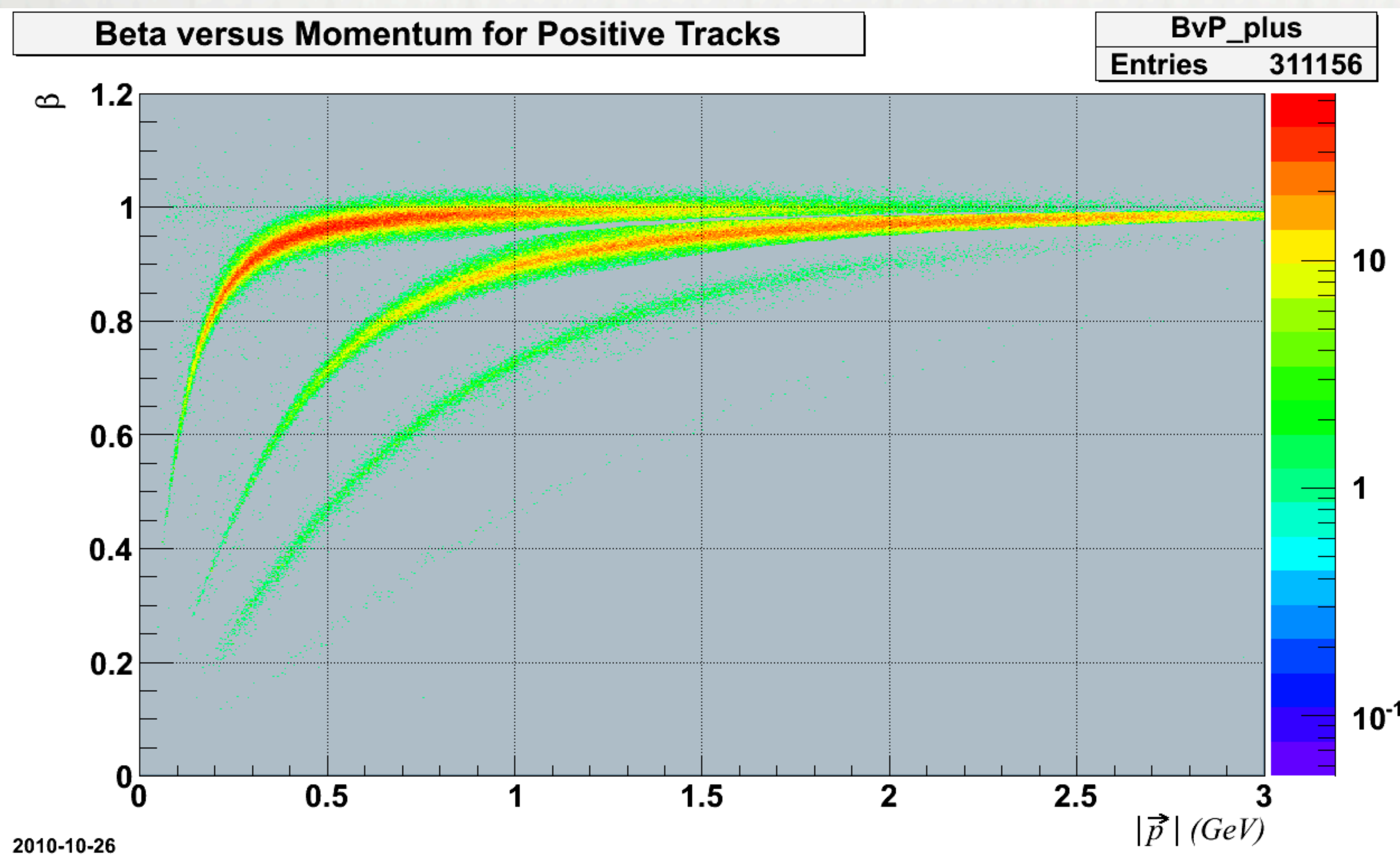


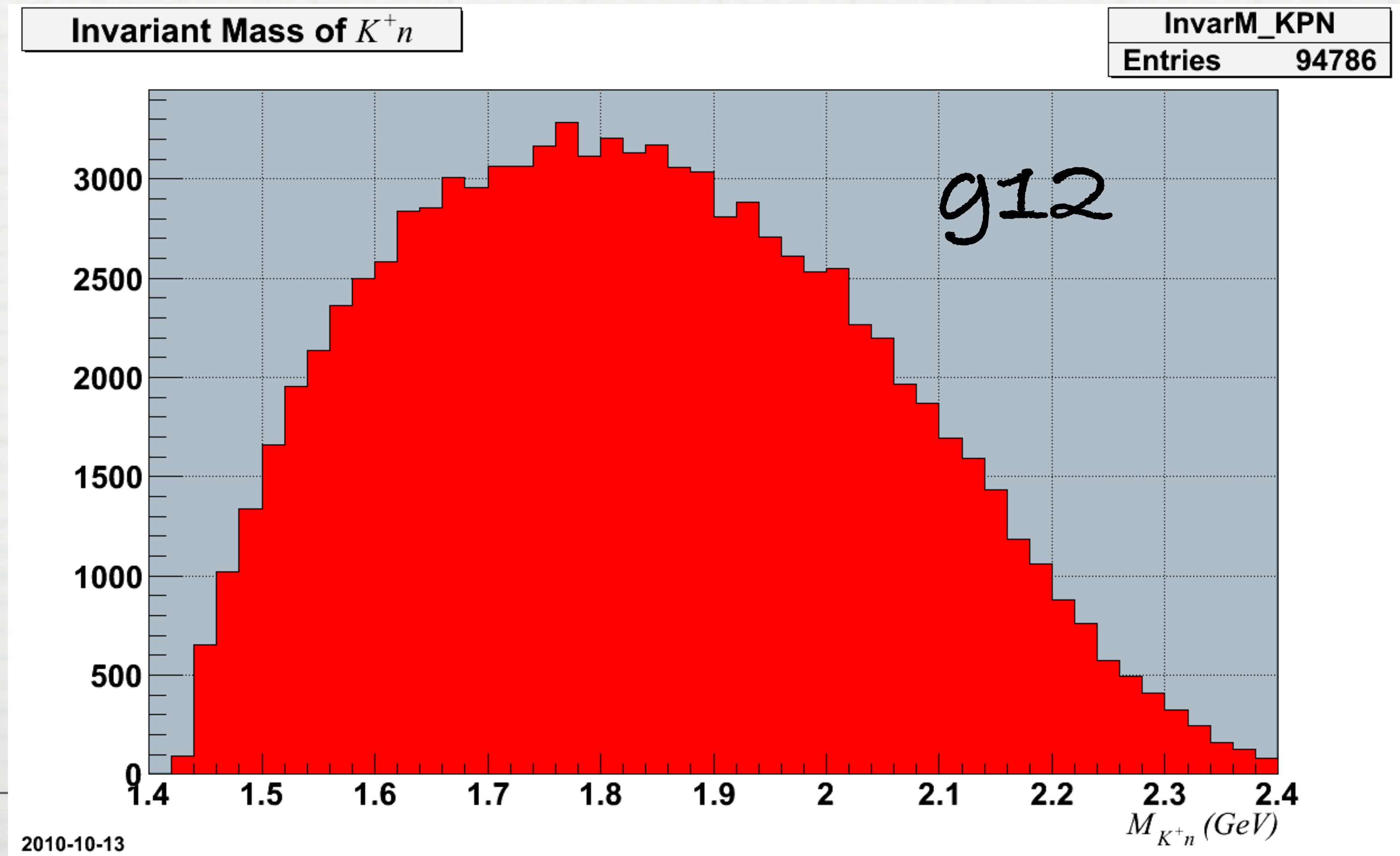
g12 Miles Price and Paul Stoler

Rensselaer









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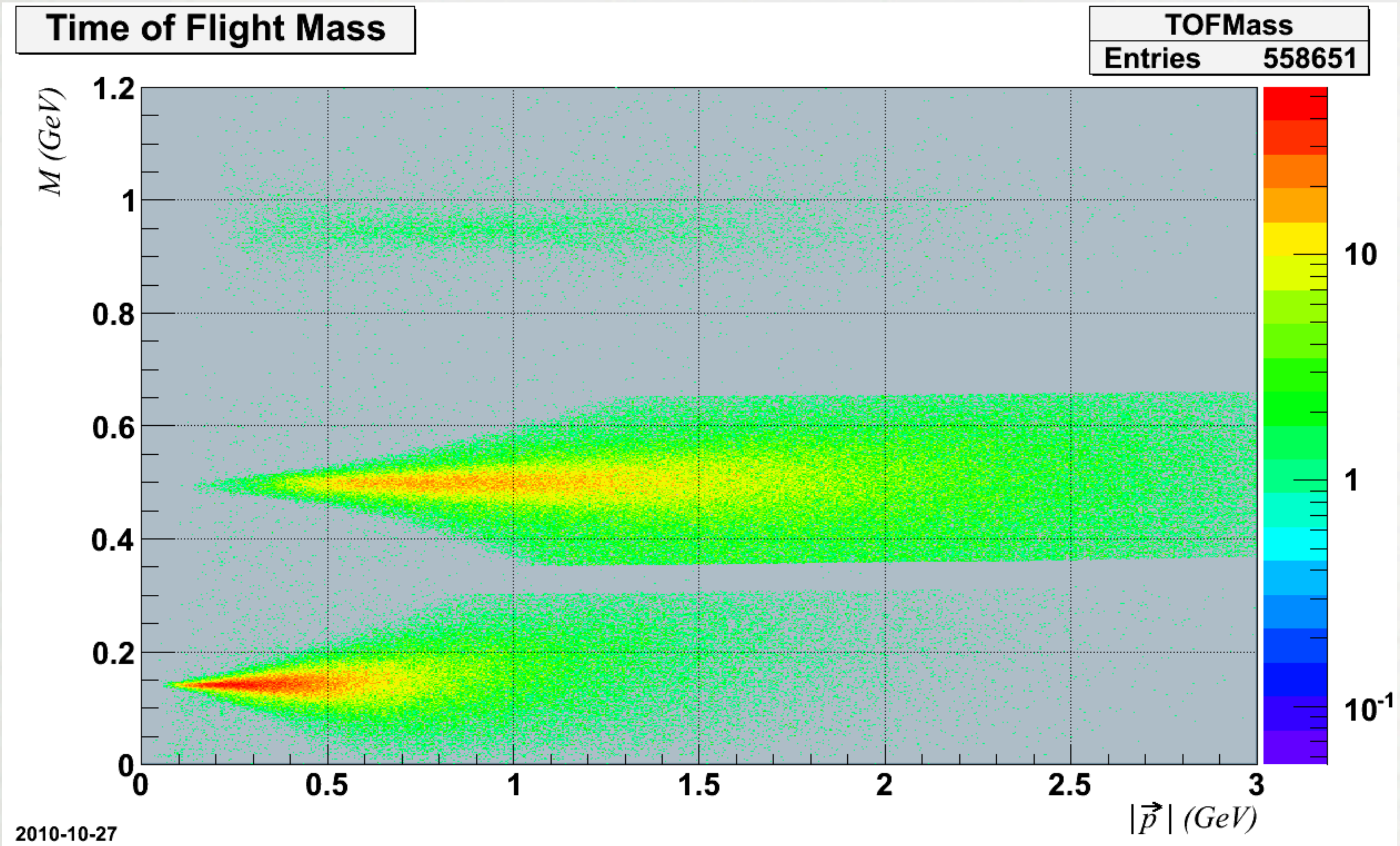

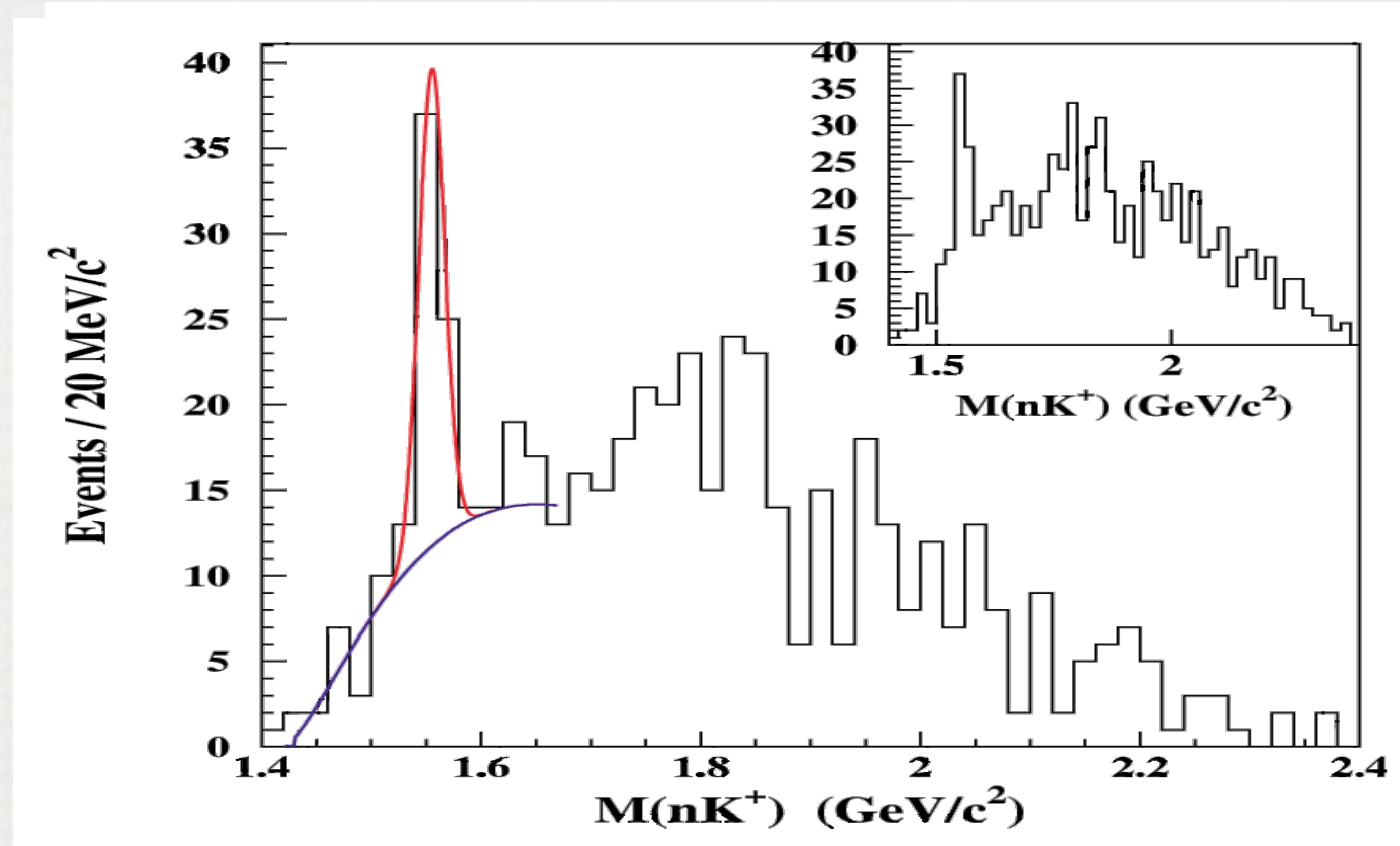

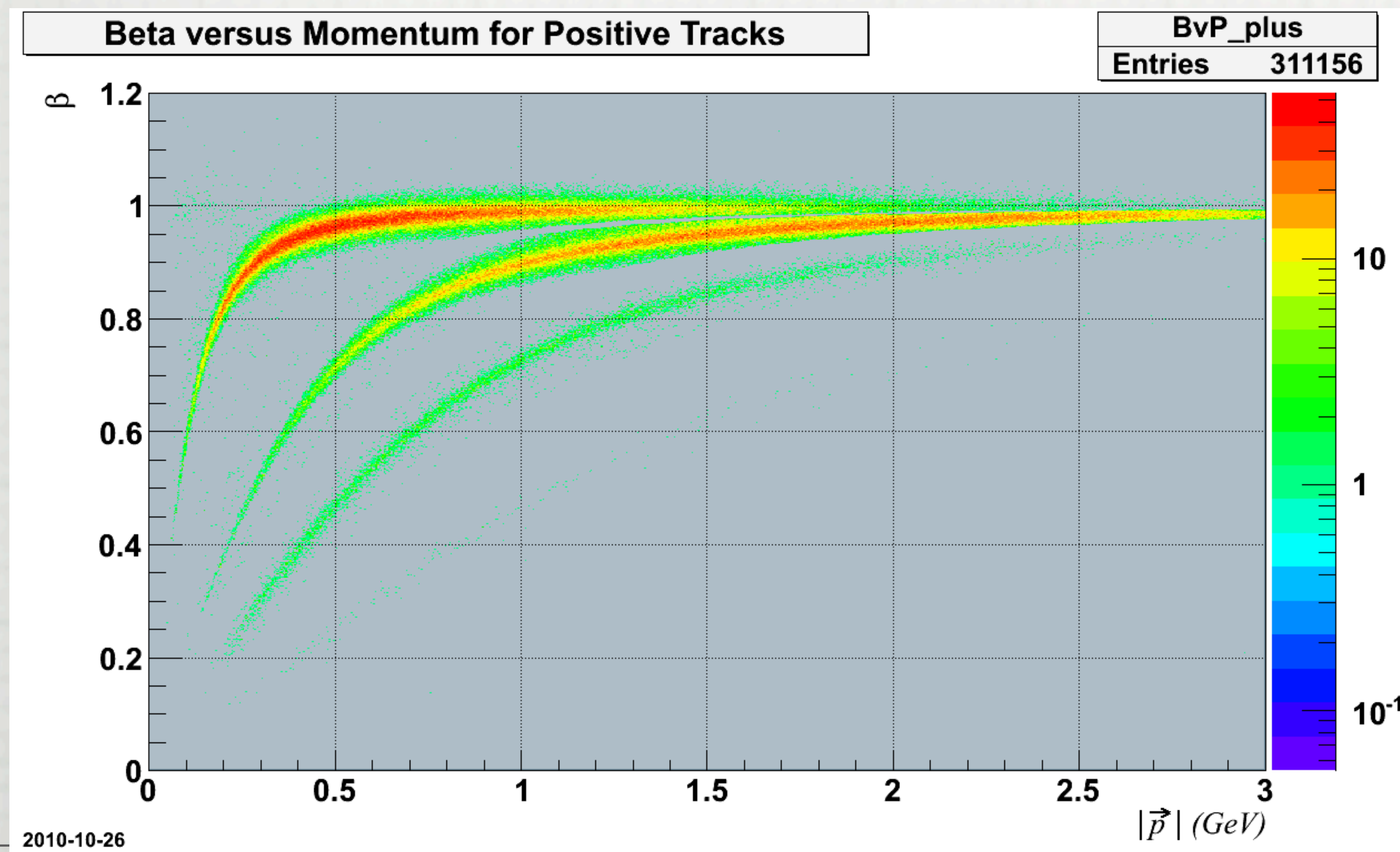

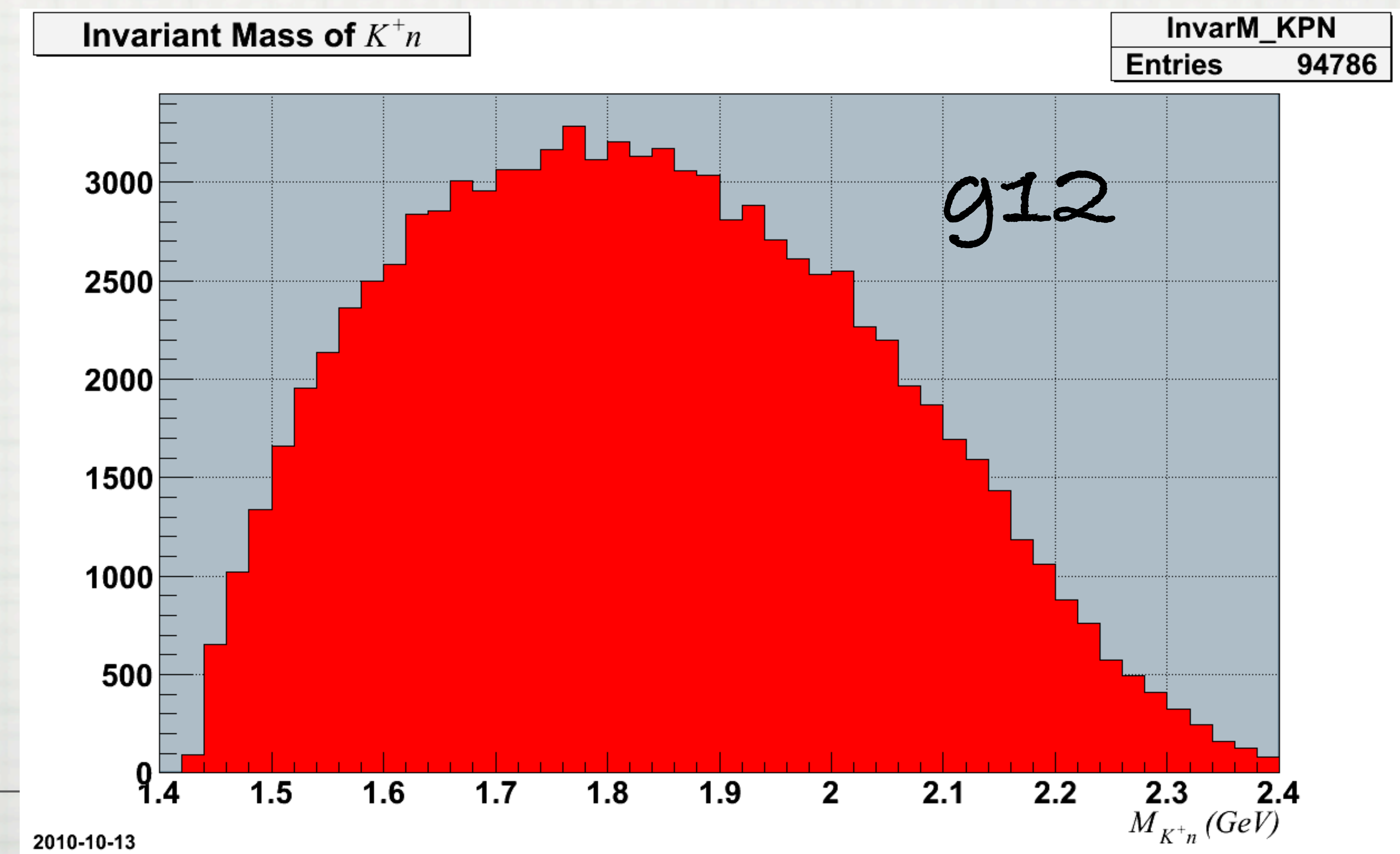

g12 Miles Price and Paul Stoler

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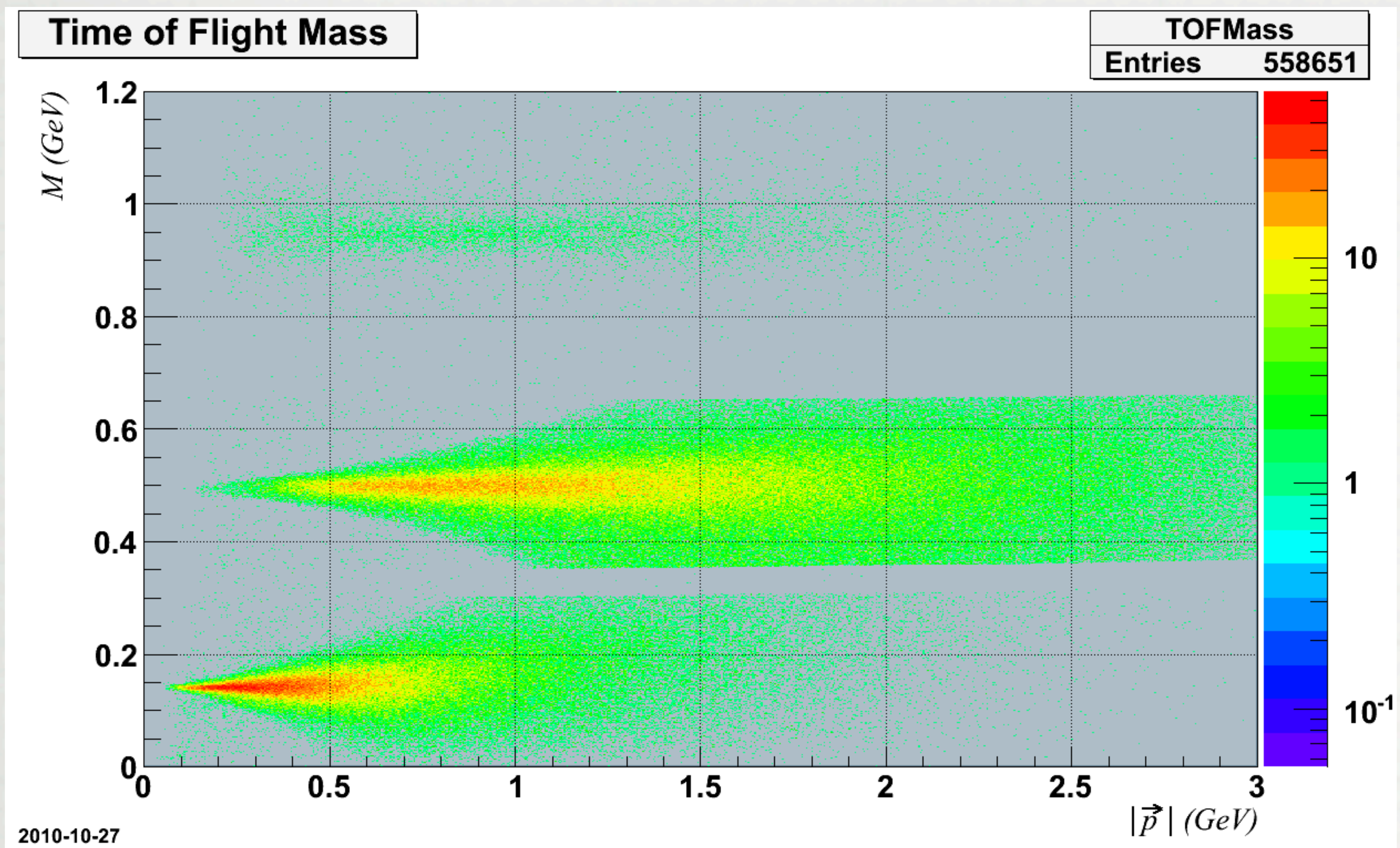
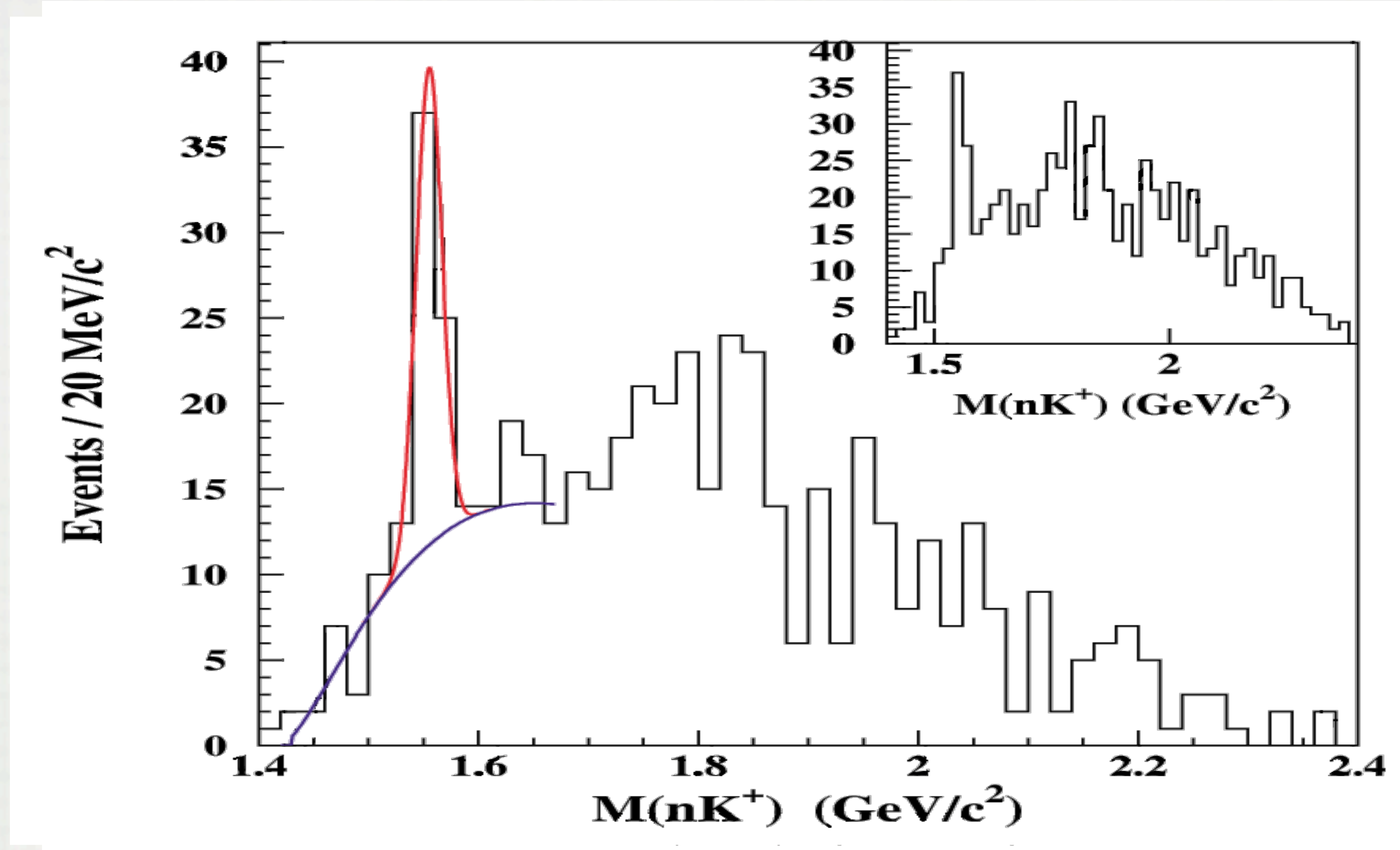
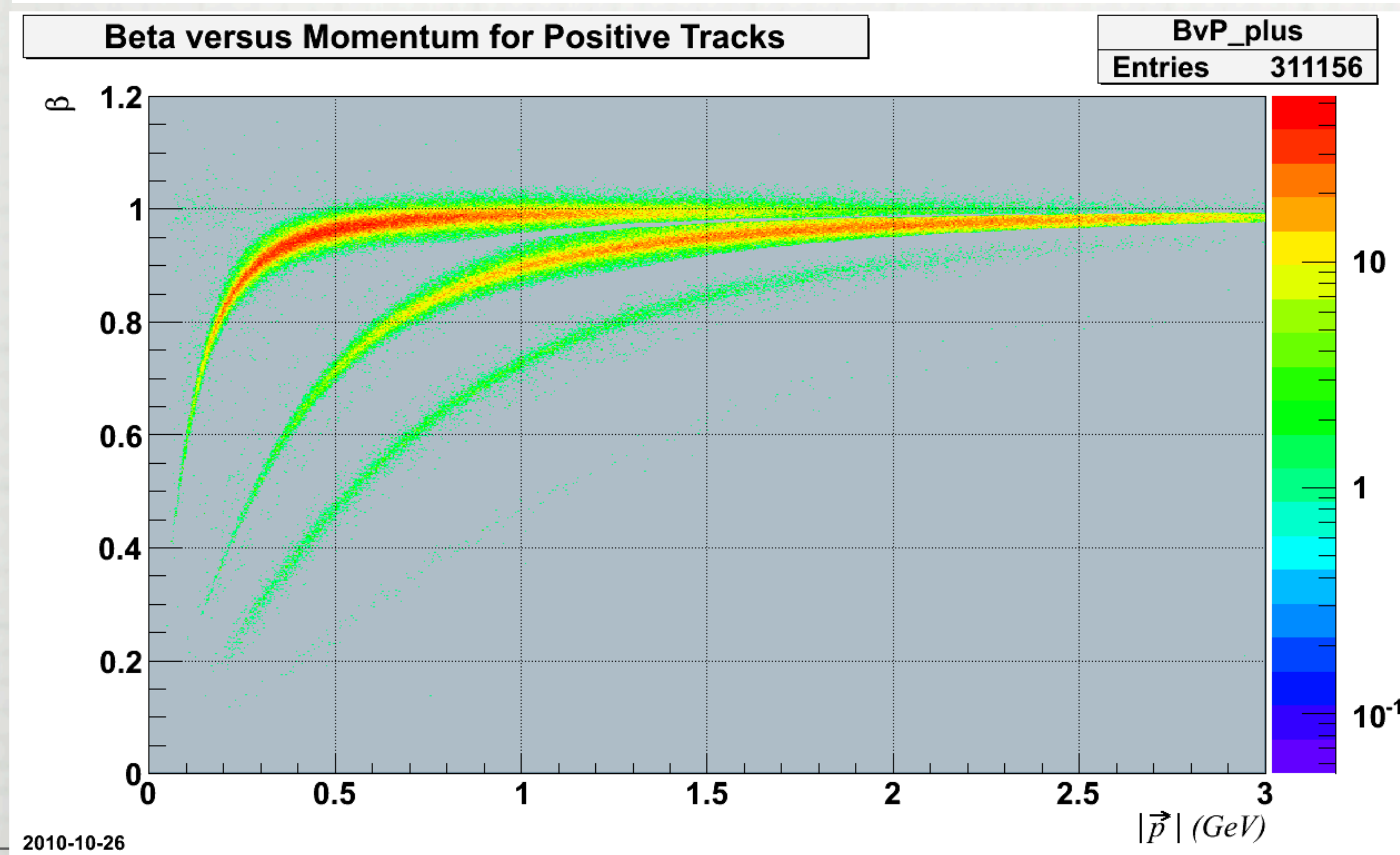
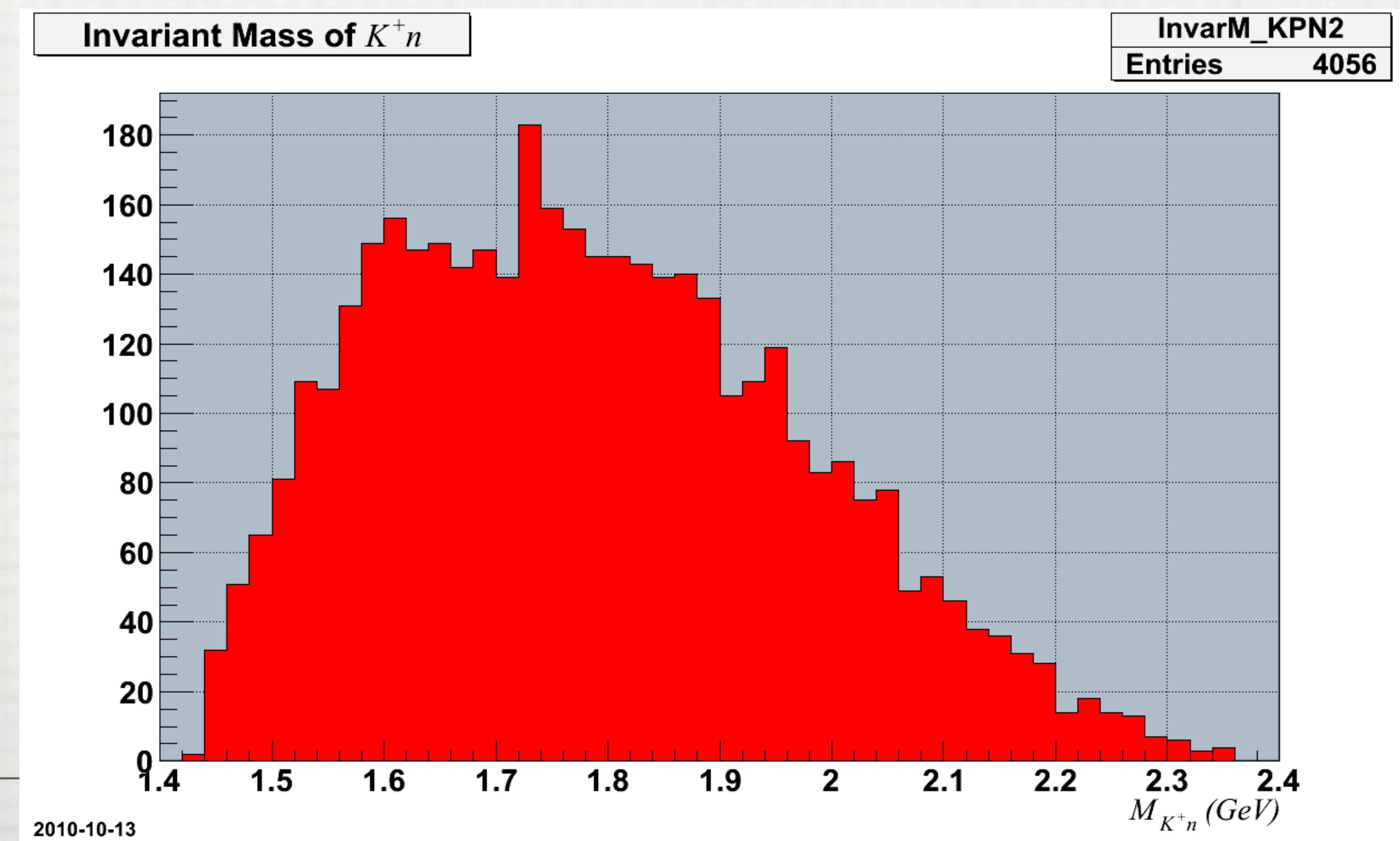


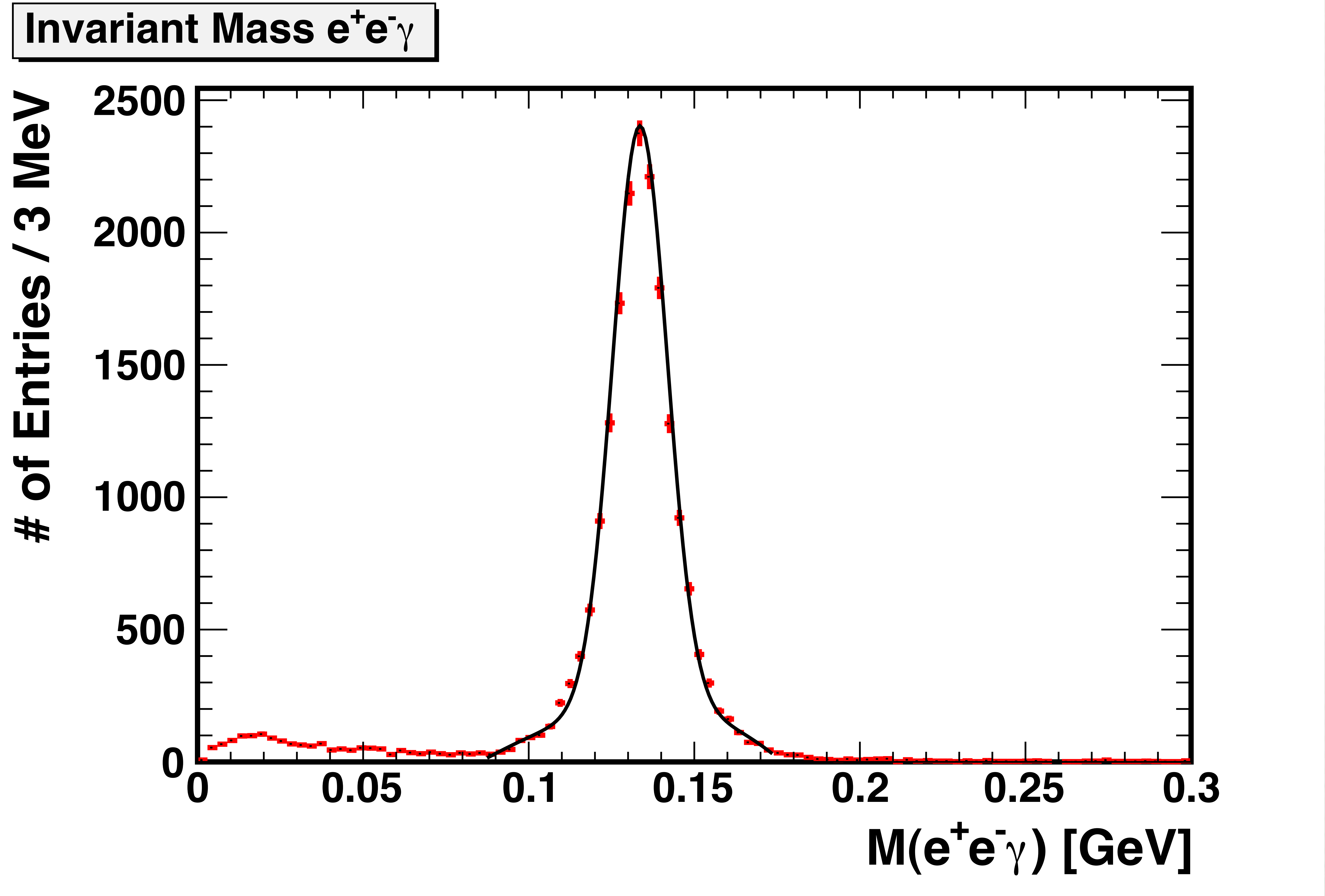






g7/g12 $e^+ e^-$ π^0 Dalitz Decay

Mike Kunkel/ODU
Moskov Amarian



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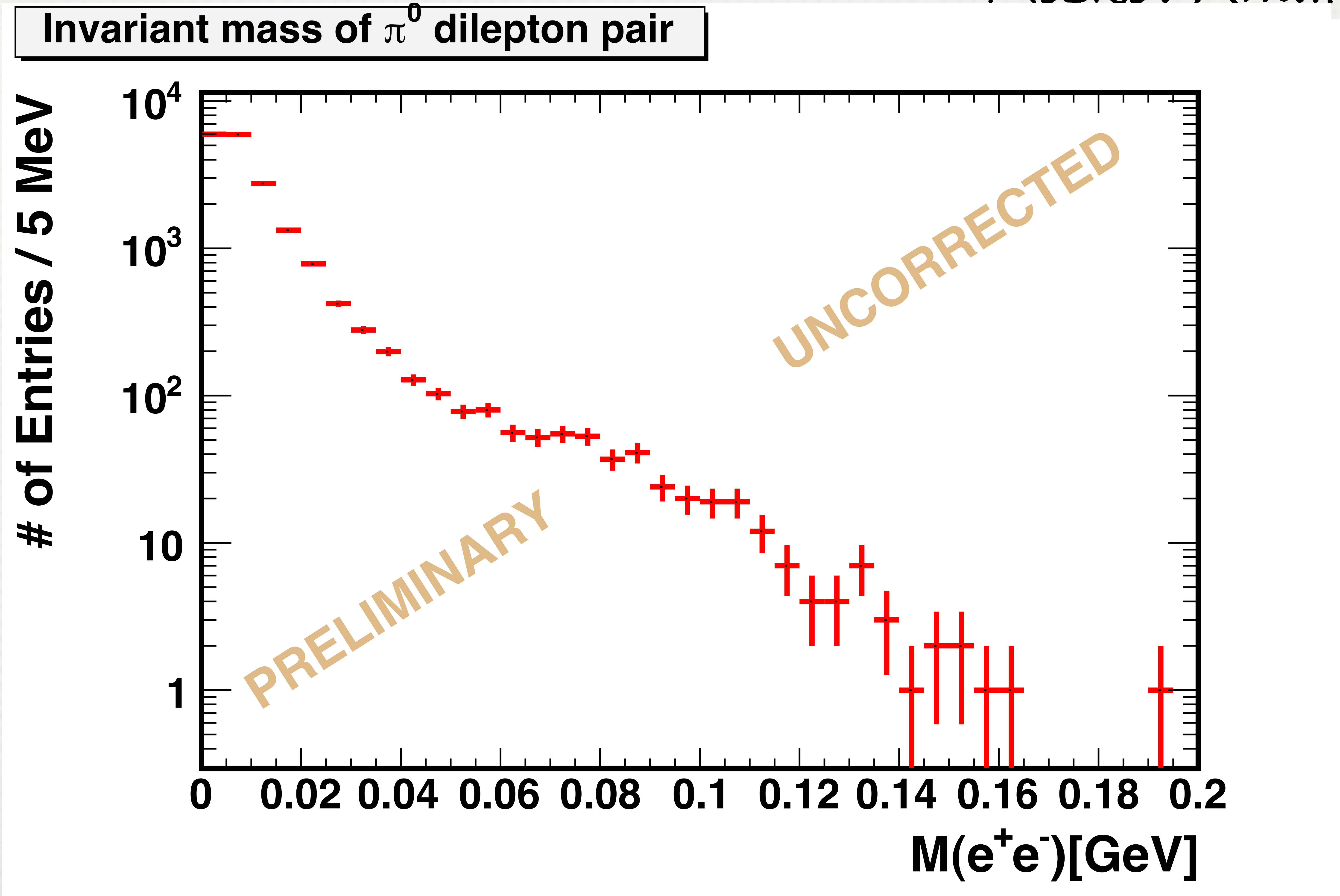


η Dalitz Decay

WASA/Celcius

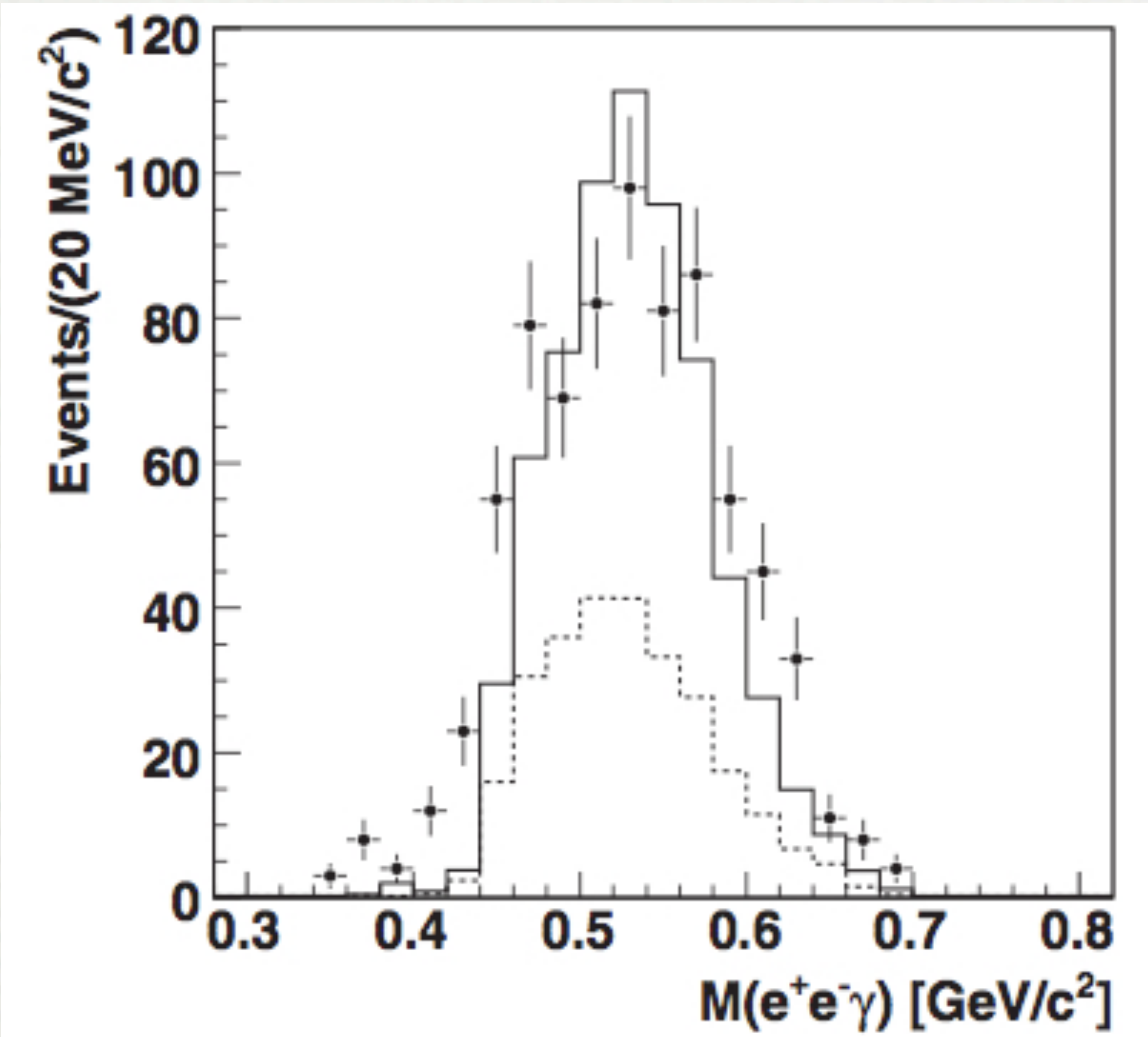
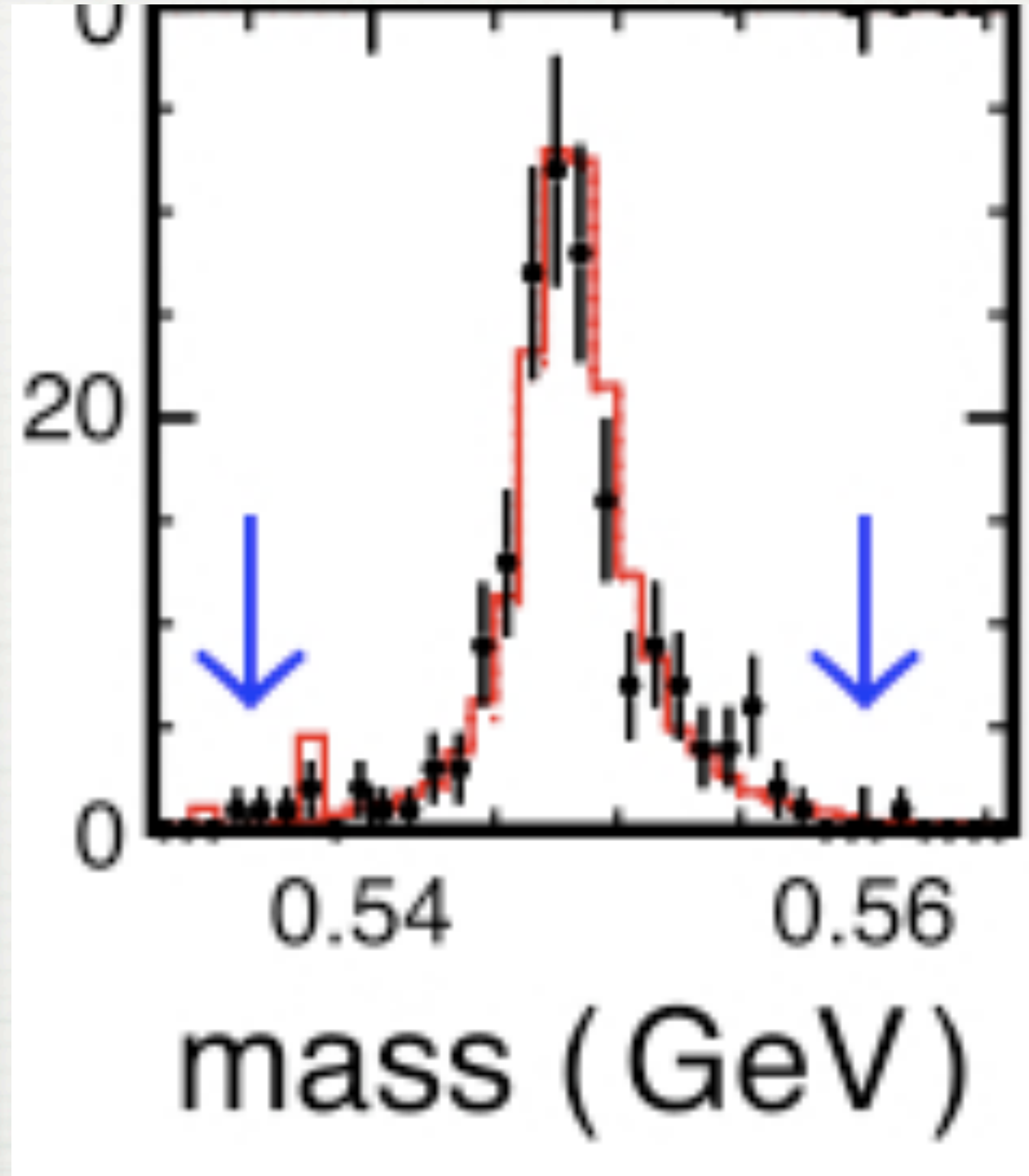
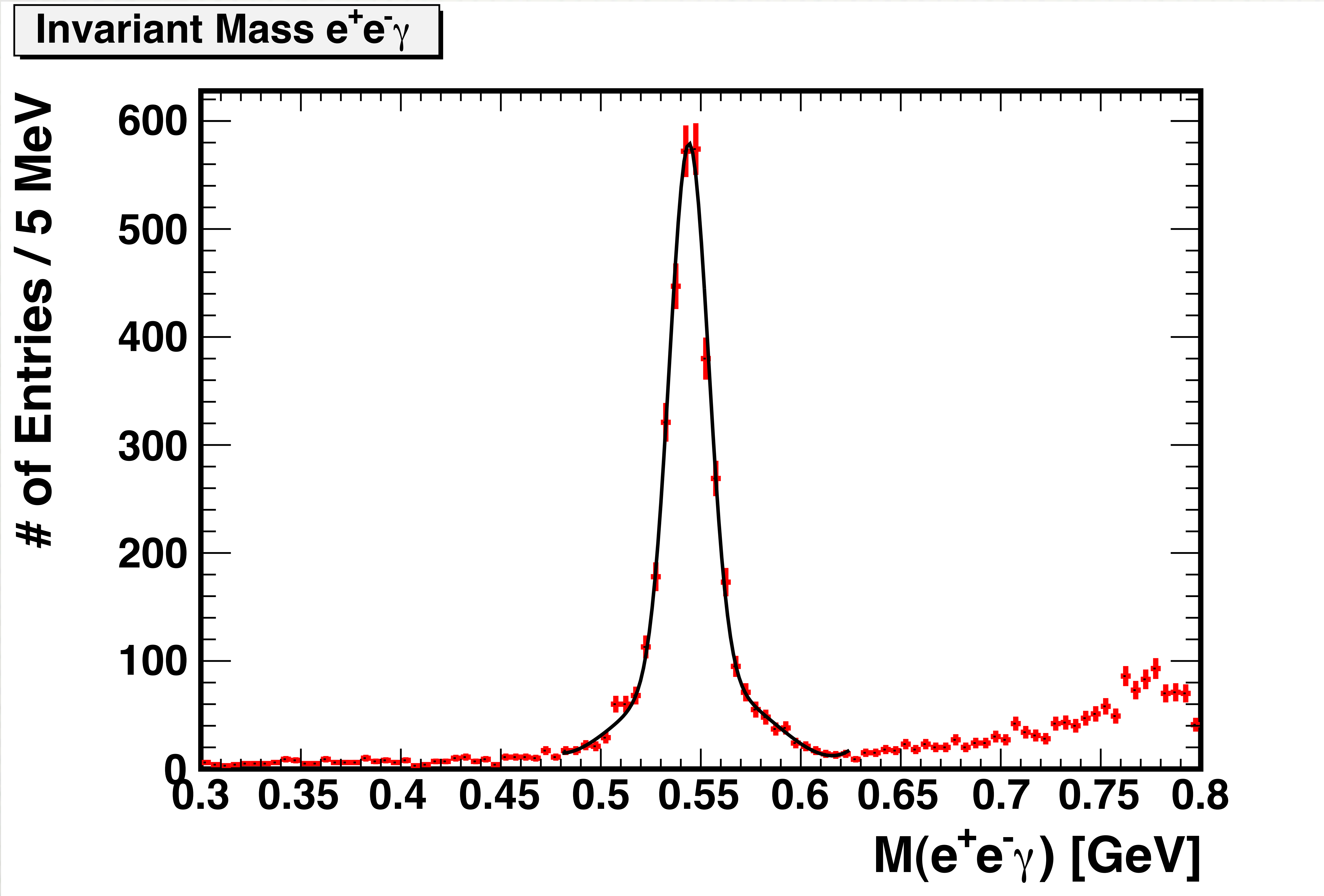


FIG. 8. The $M(e^+e^-\gamma)$ distribution after the final selection. Points—experimental data, solid line—MC simulation of $\eta \to e^+e^-\gamma$, dotted line—MC simulation of $\eta \to \gamma\gamma$ with photon conversion in the detector material.

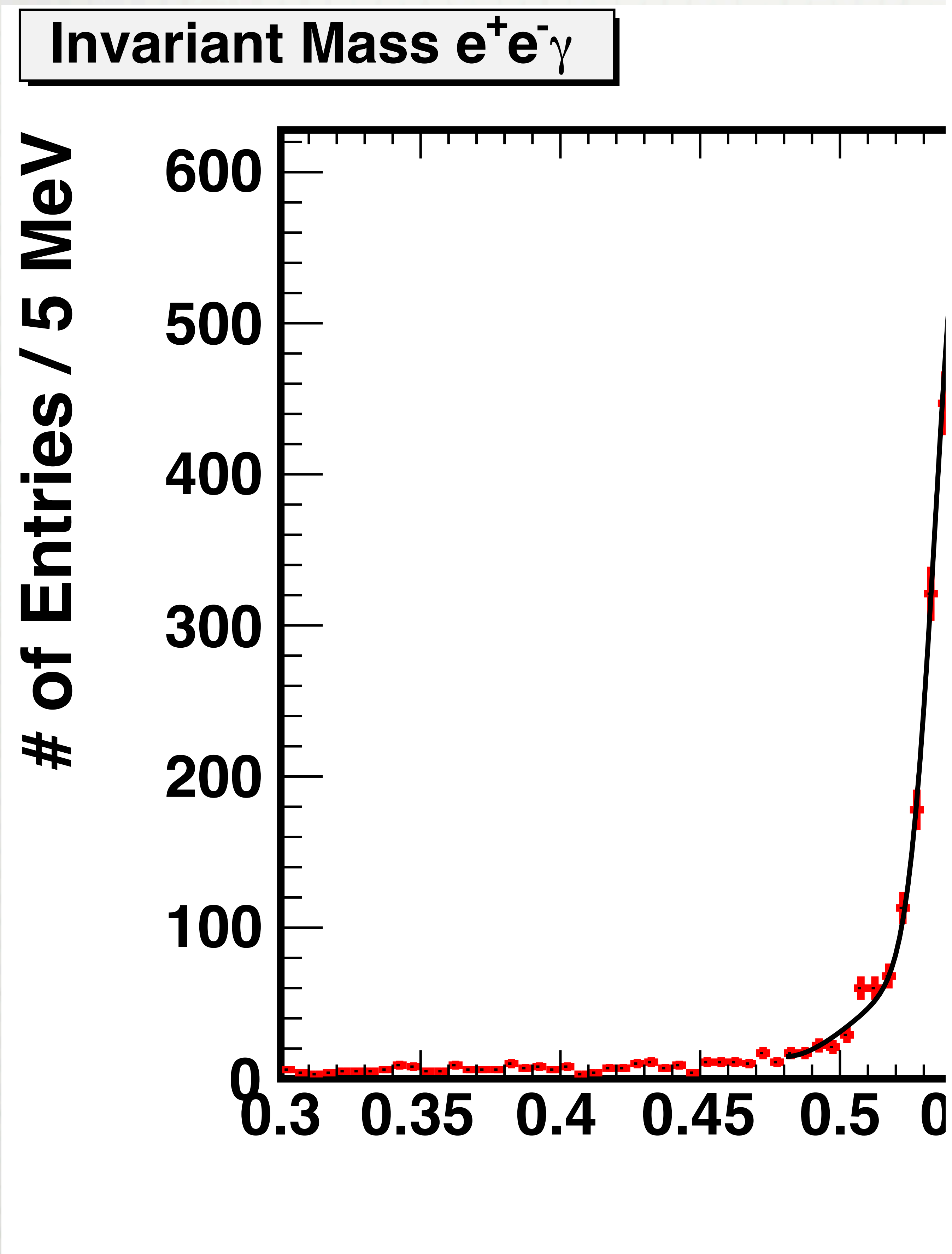
Cleo

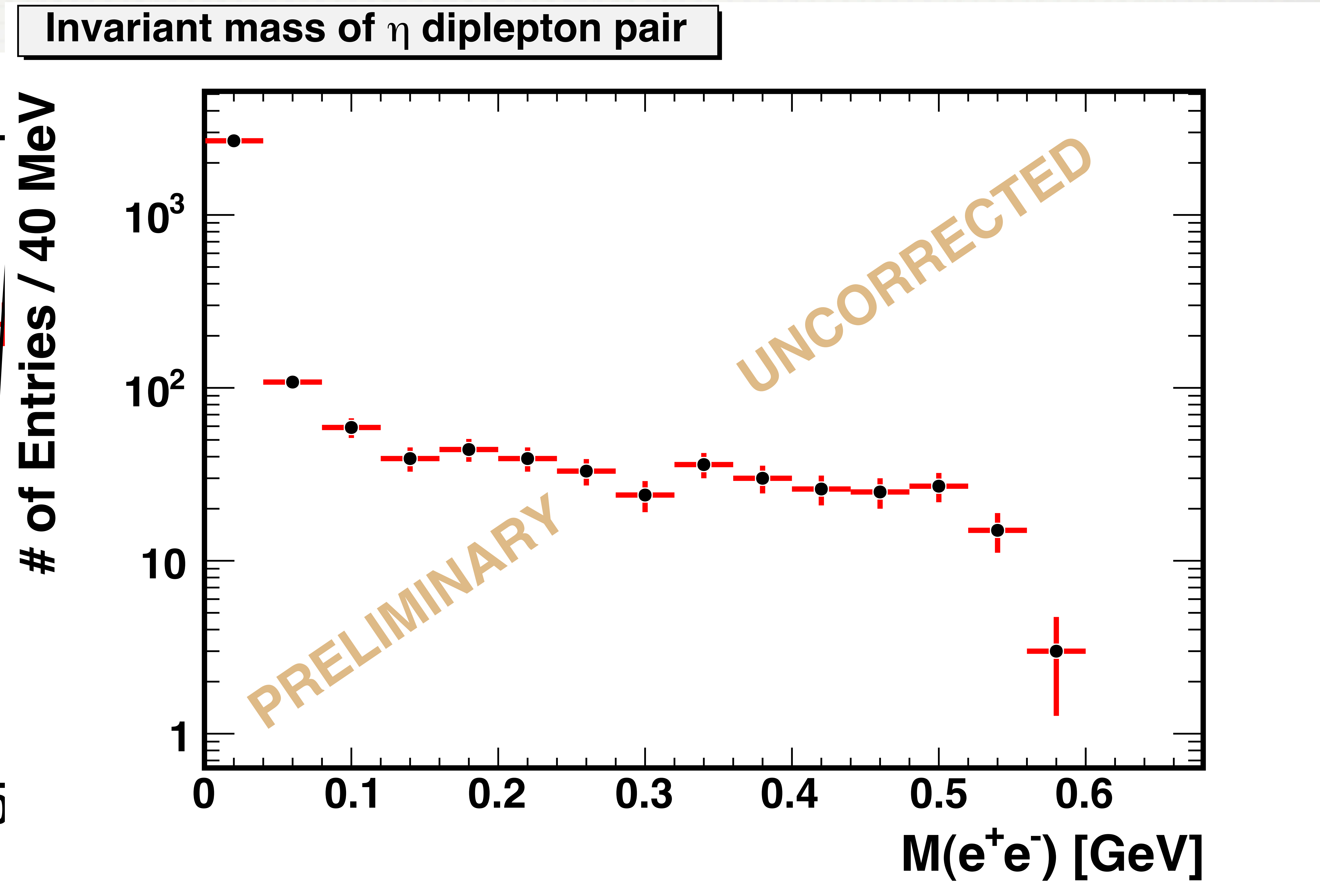


g12 η Dalitz Decay



g12 η Dalitz Decay

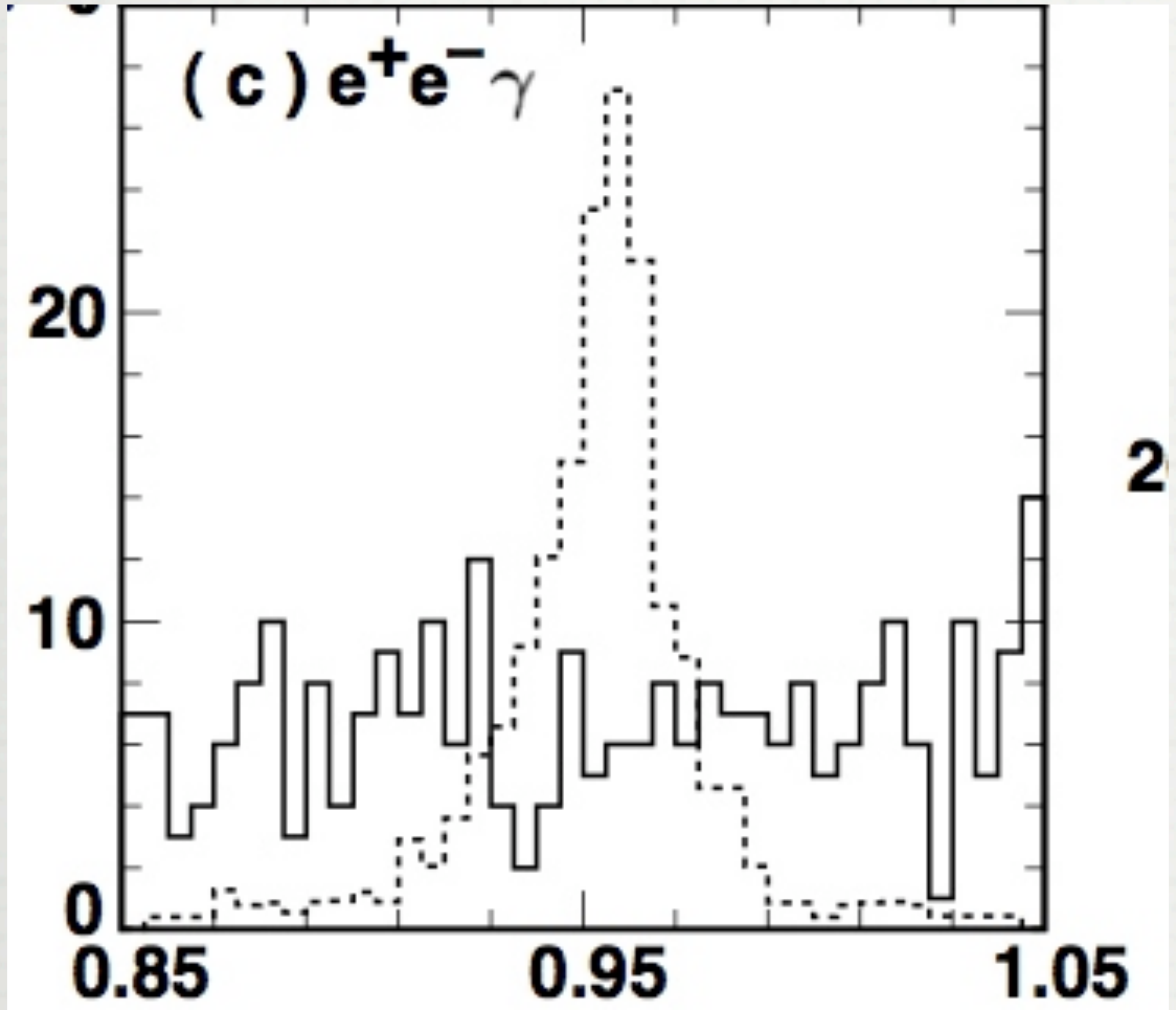


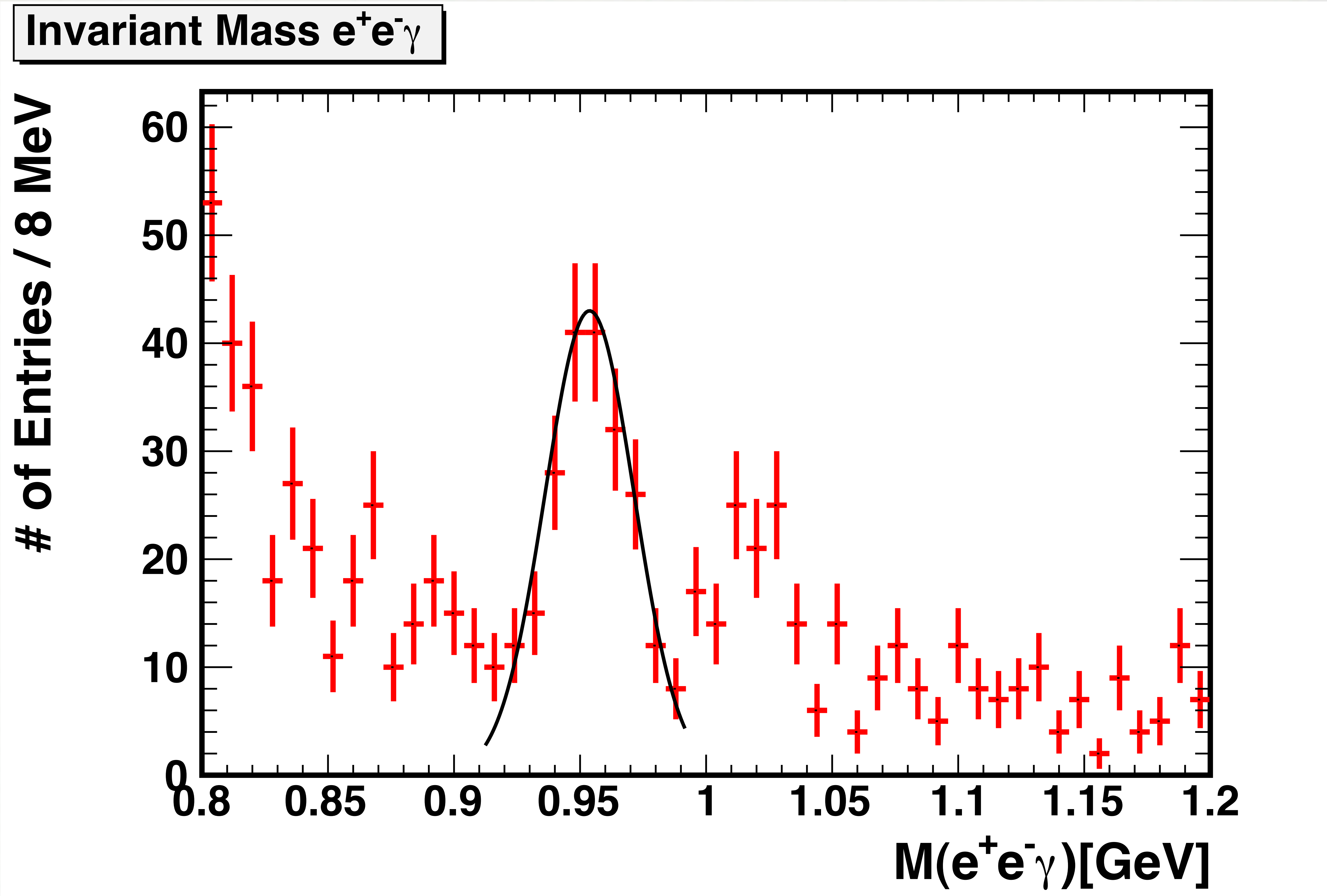


η' Dalitz Decay

g12

Cleo





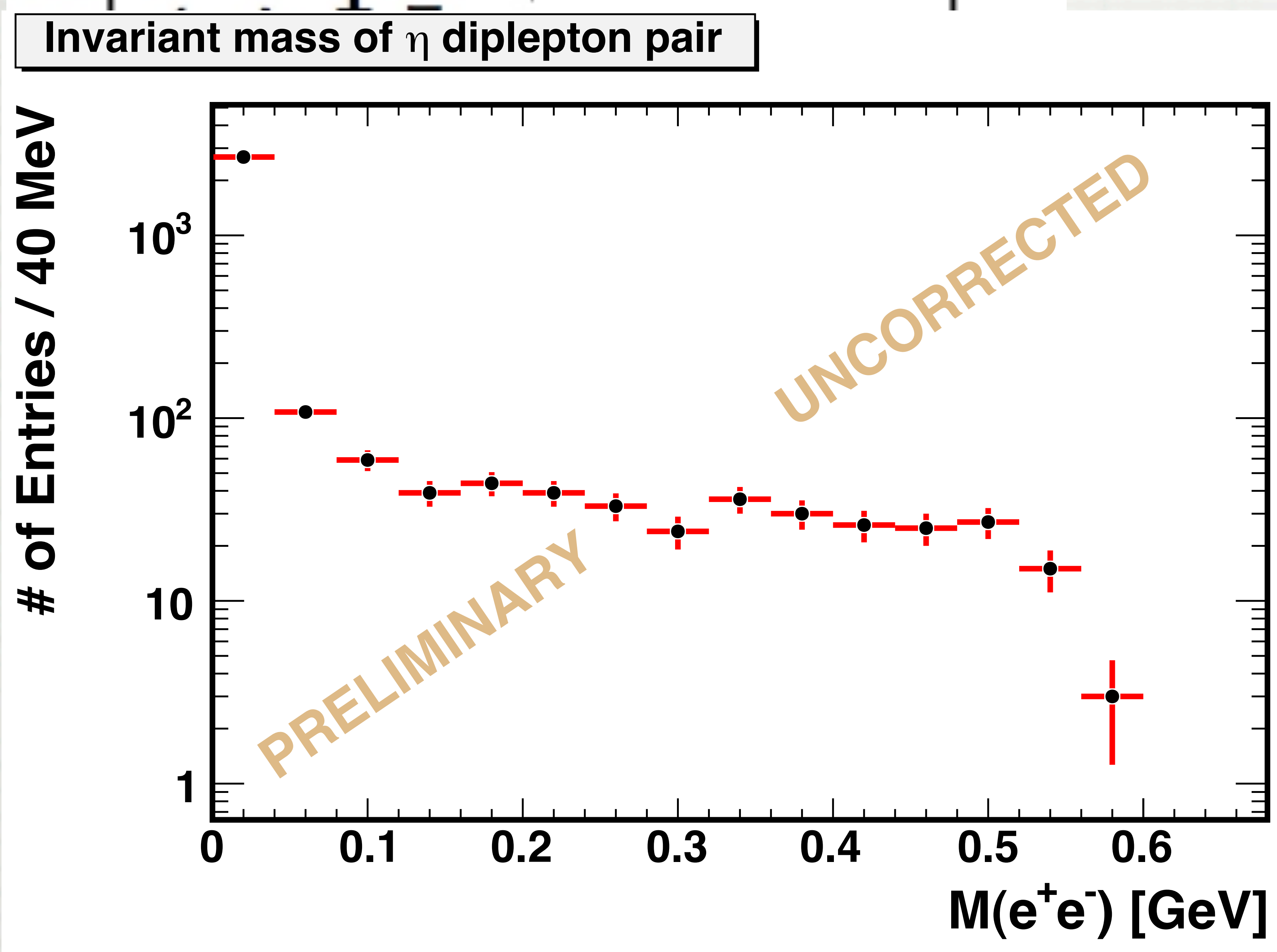
Dashed Lines are Monte-Carlo Prediction.

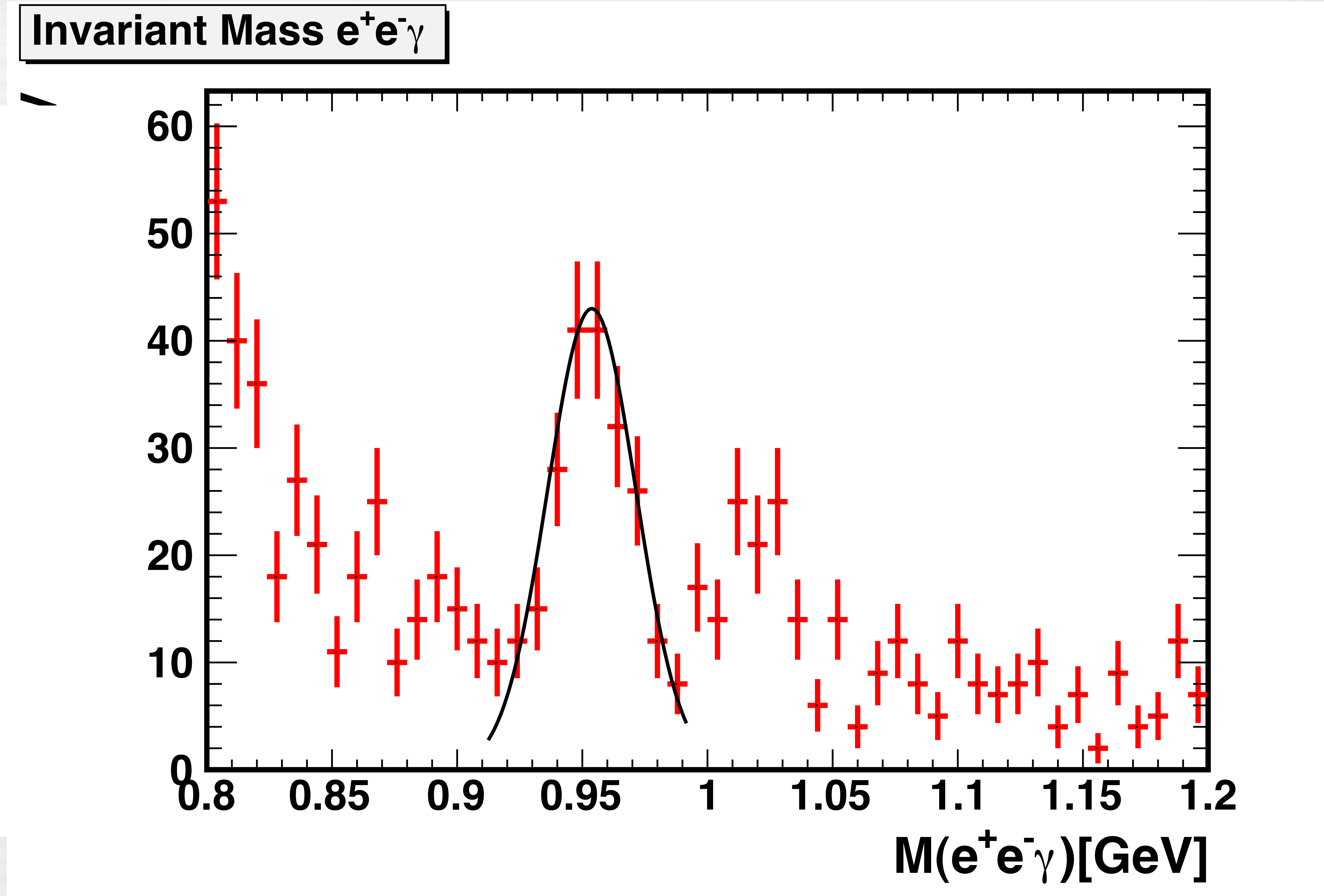
Solid Line is measured result.

η' Dalitz Decay

g12

Cleo



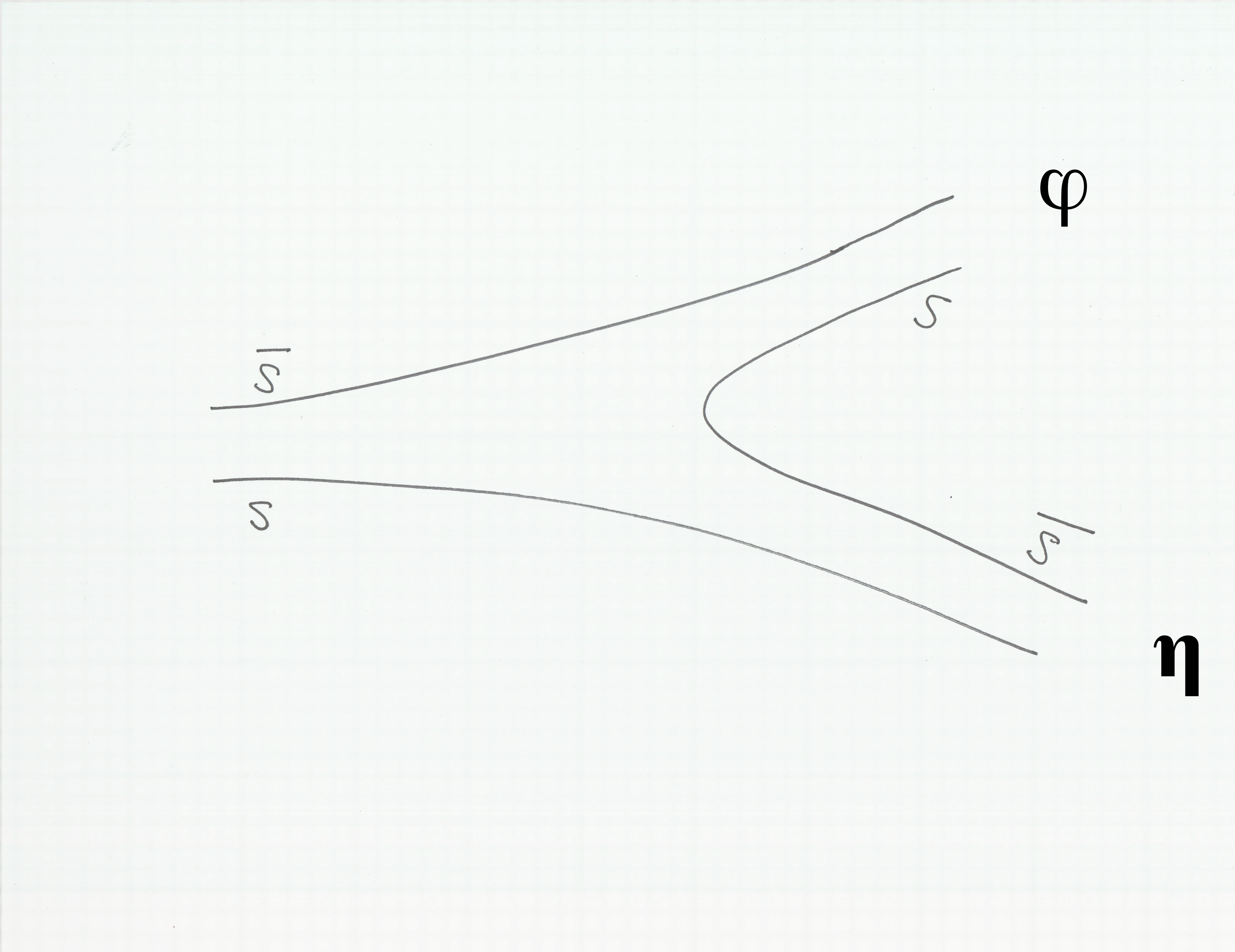


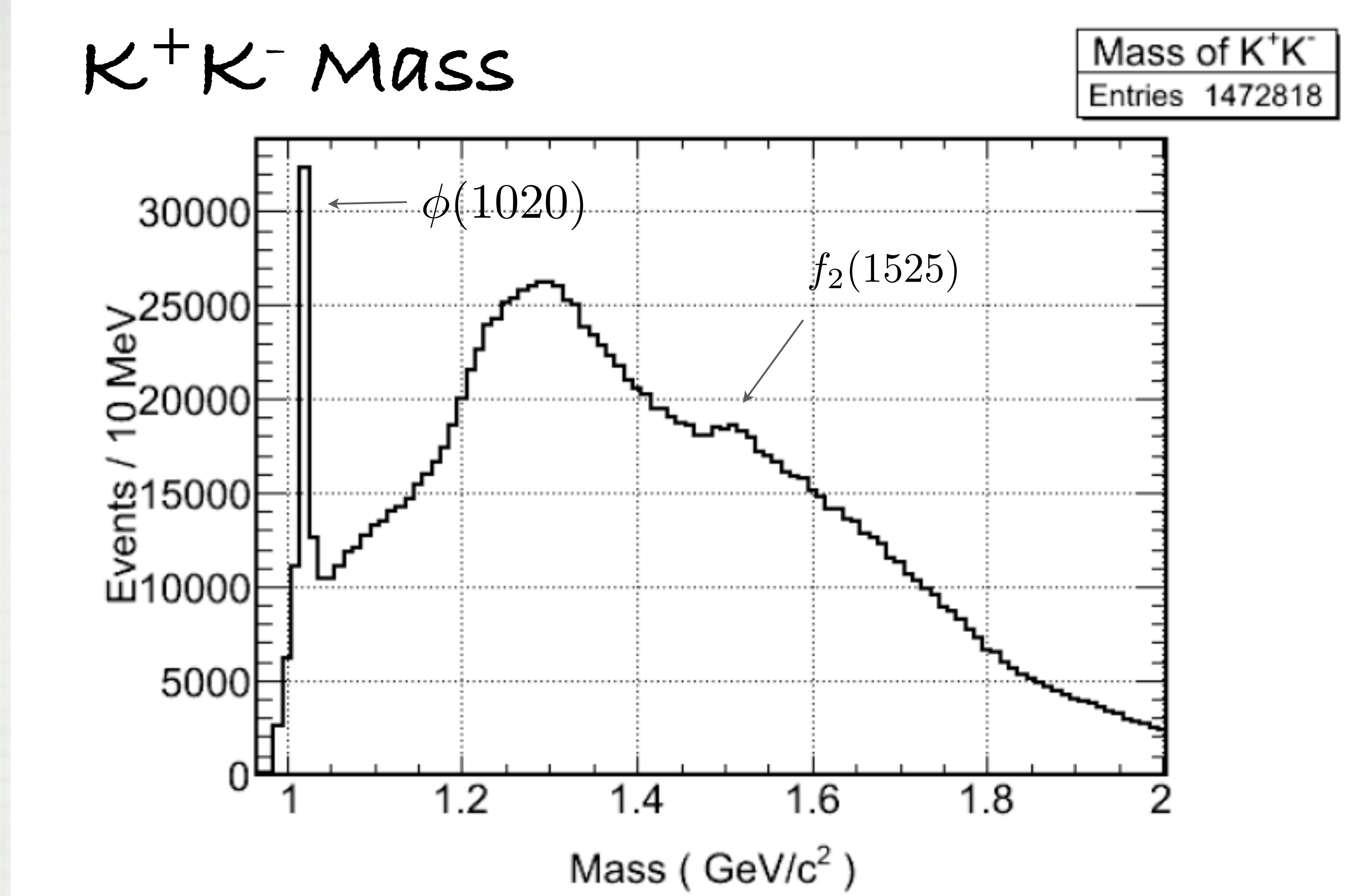
Dashed Lines are Monte-Carlo Prediction.

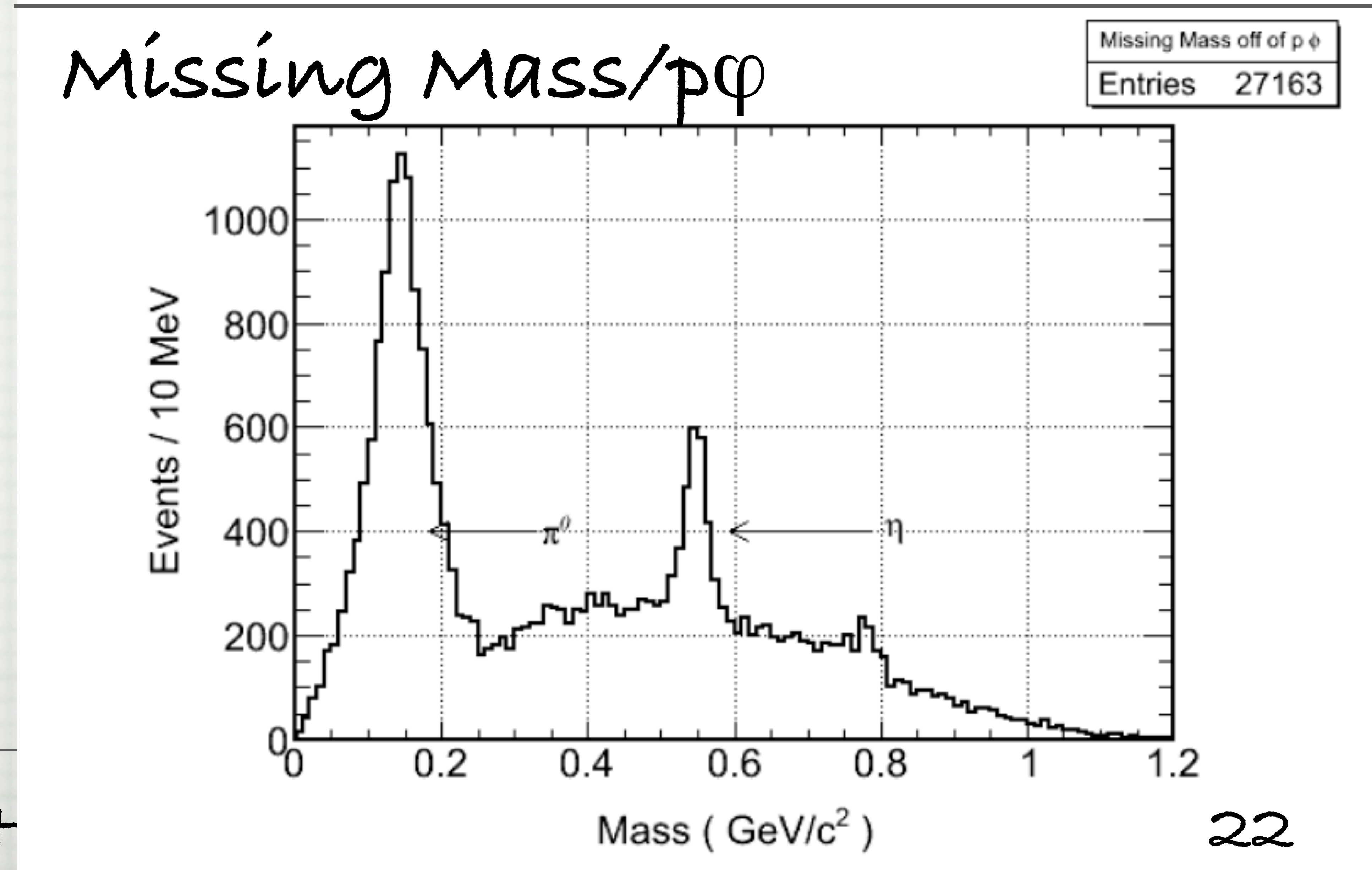
Solid Line is measured result.

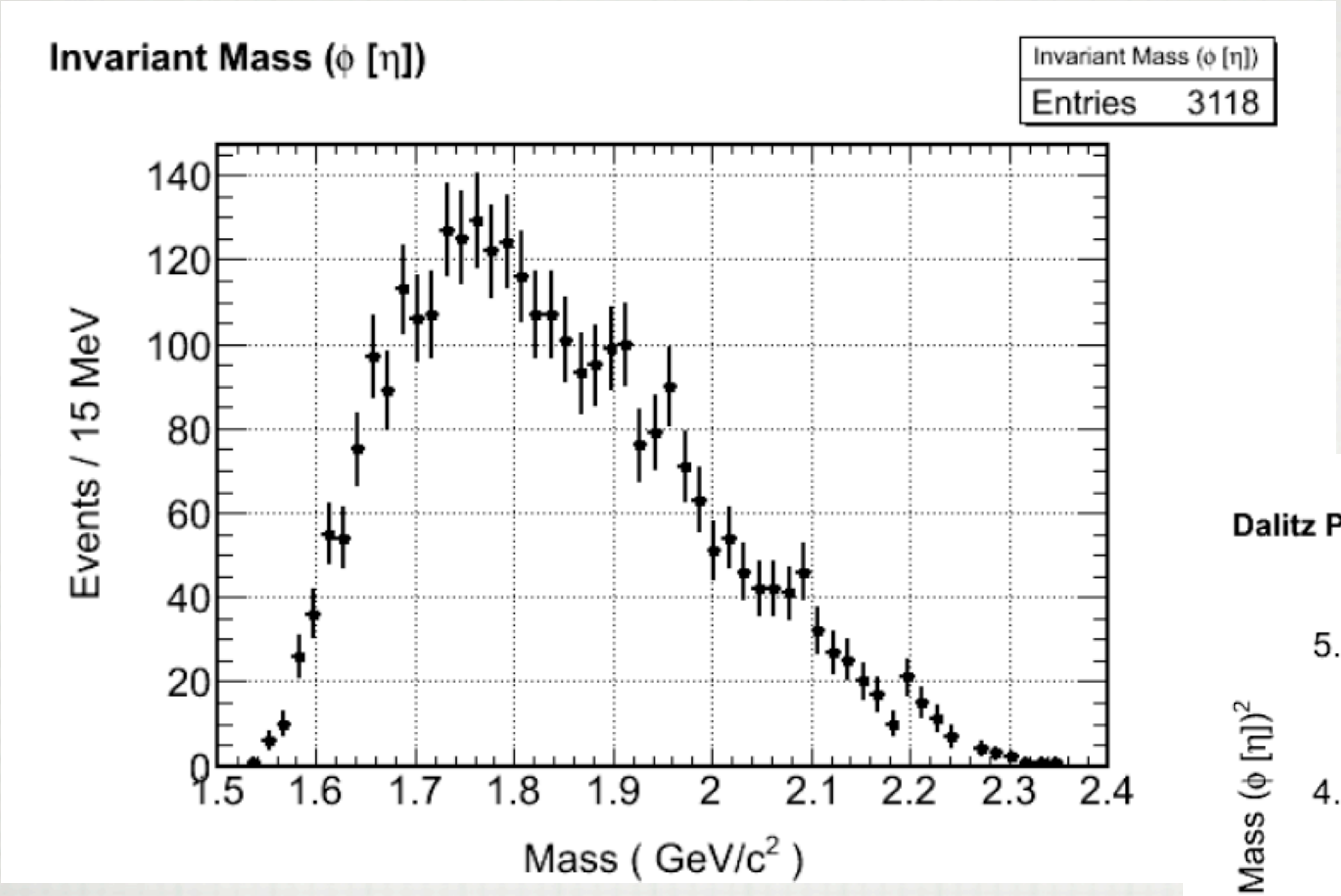
$X \to \phi\eta$

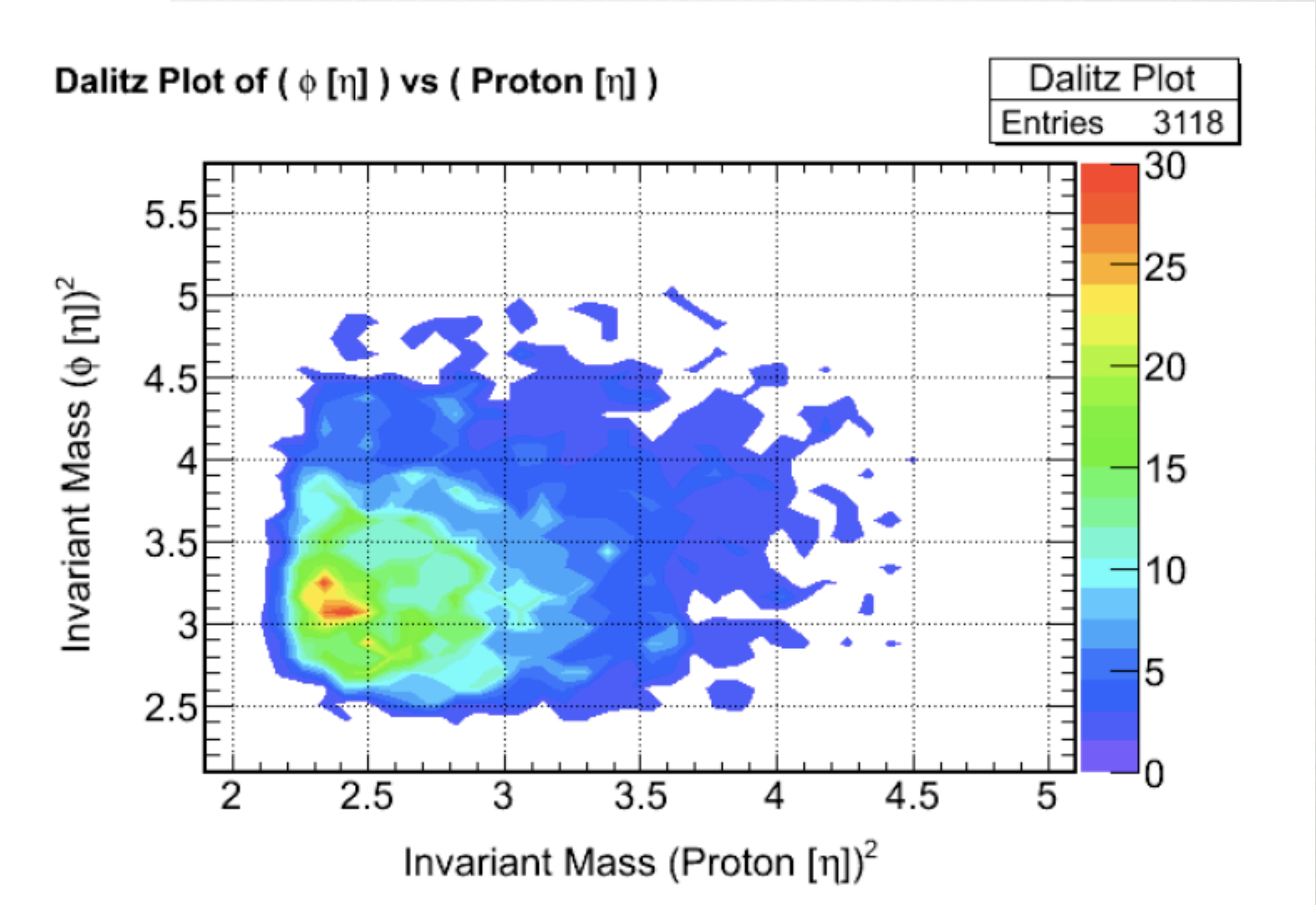
Mukesh Saini/FSU
Paul Eugenio



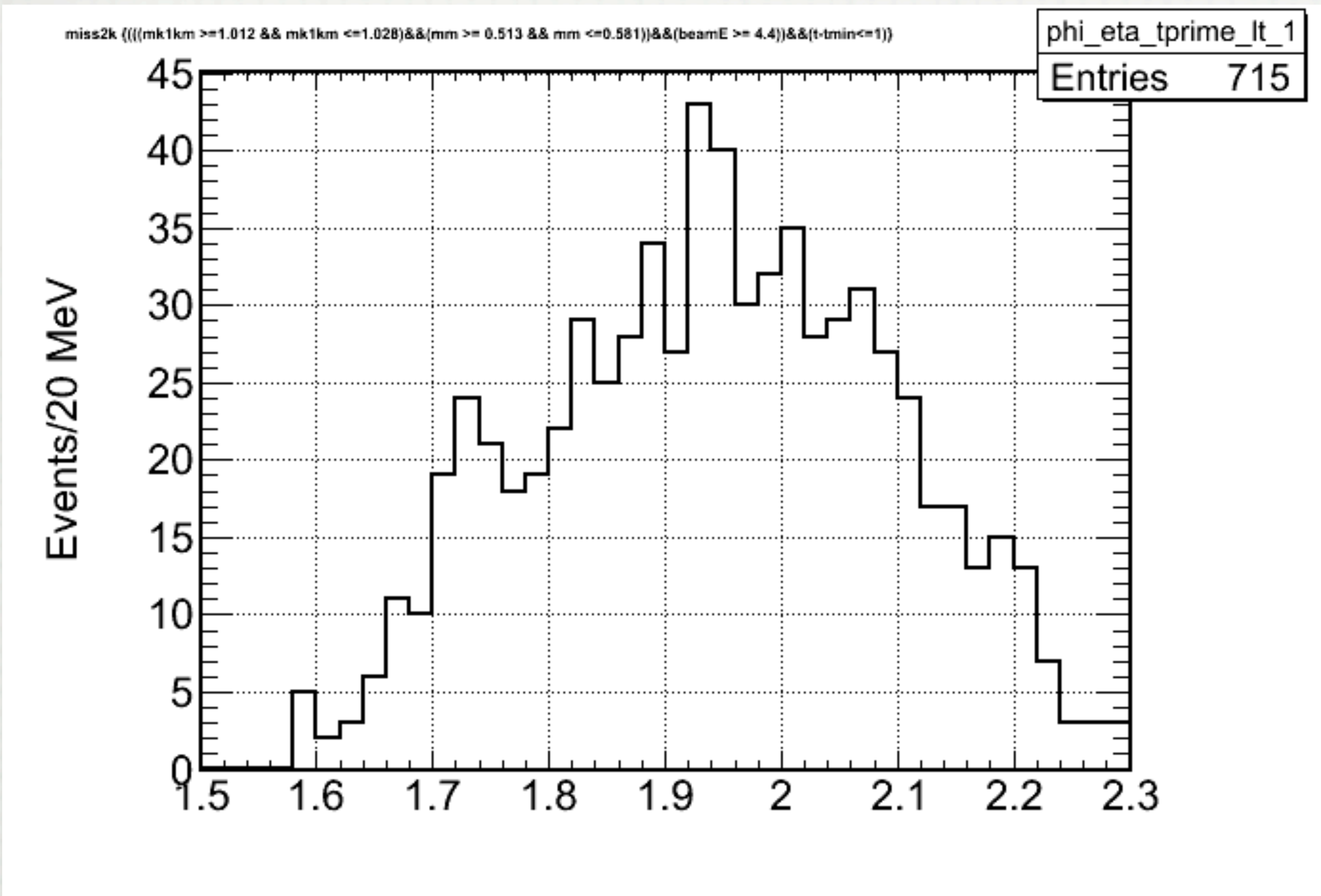


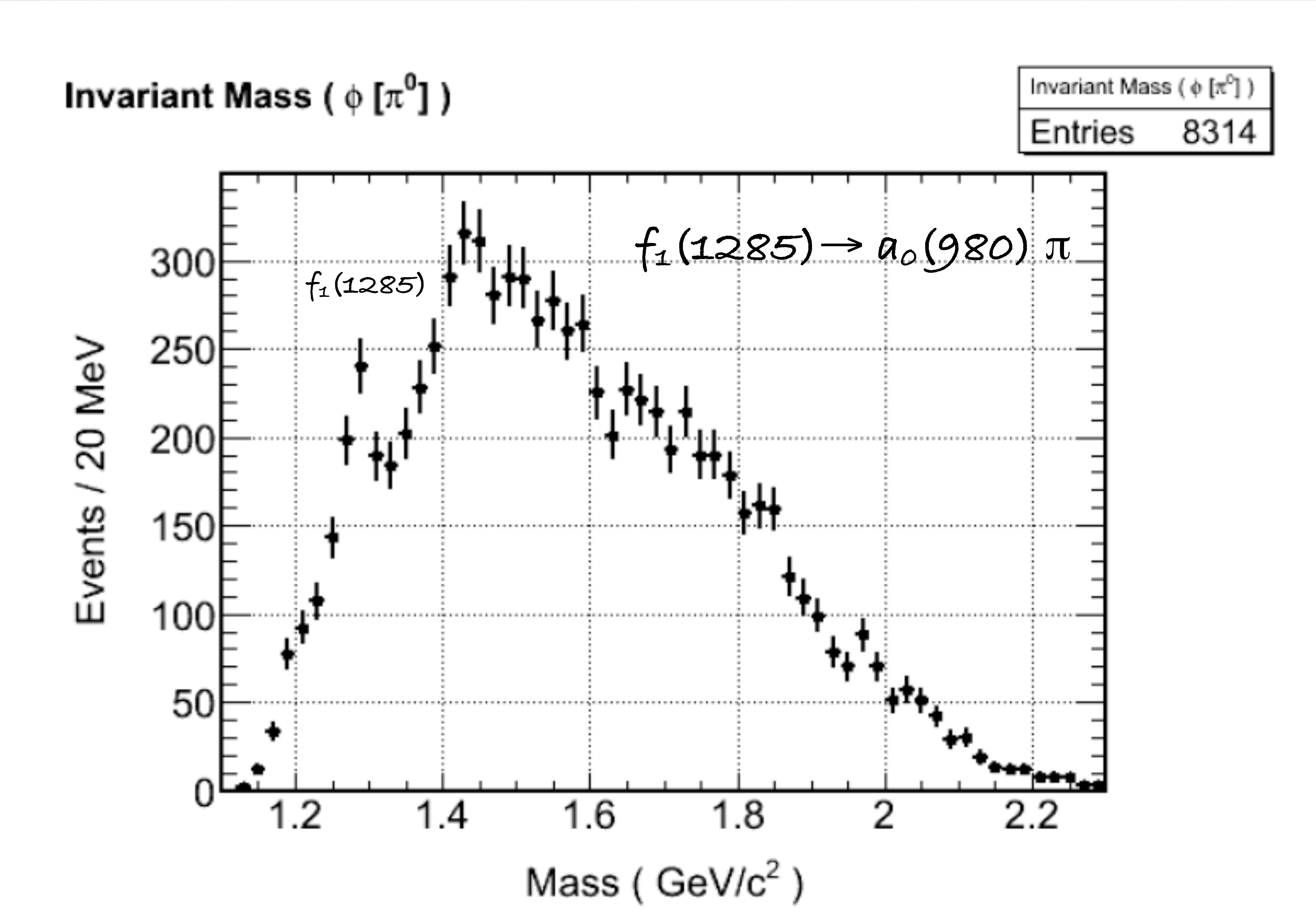


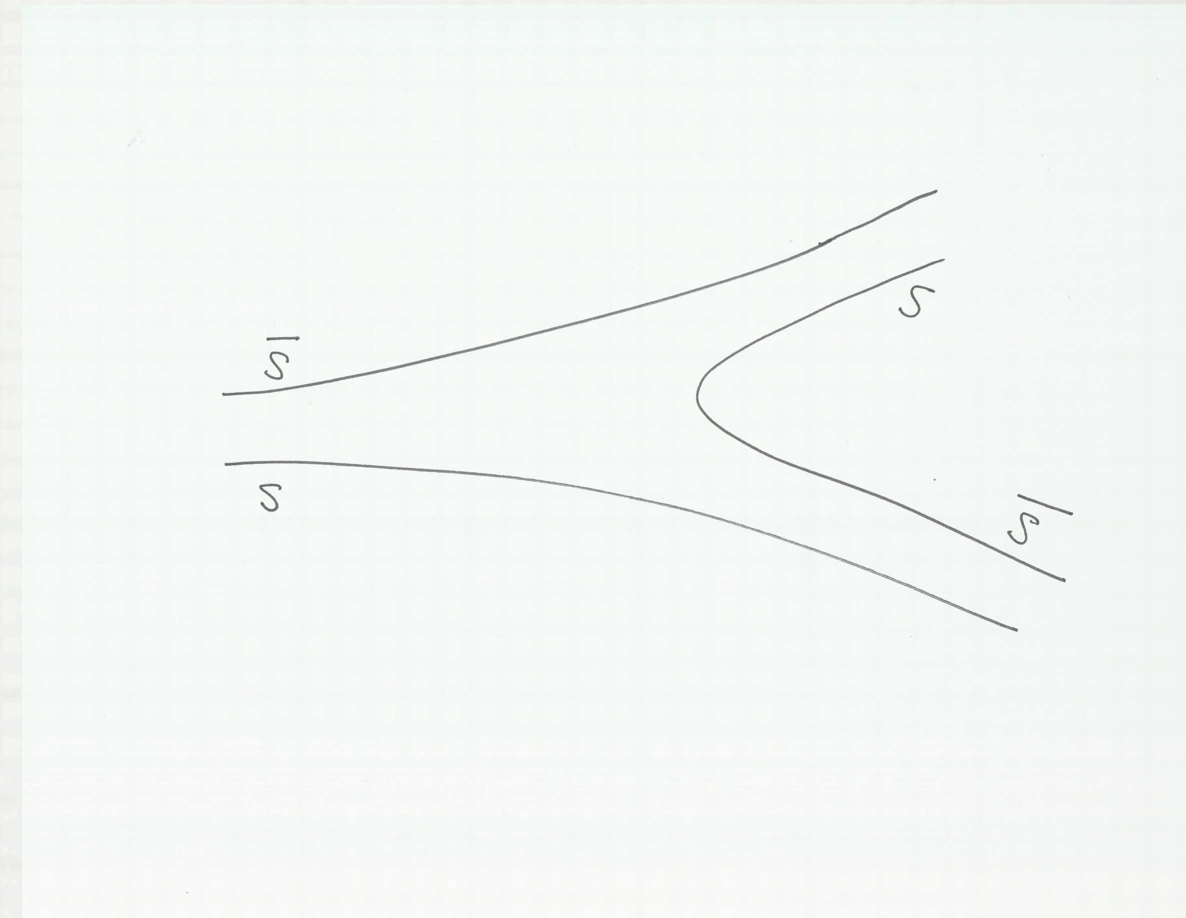

Invariant Mass (φ [η])
Invariant Mass (φ [η])
Entries 3118
Events / 15 MeV
Mass (GeV/c2)

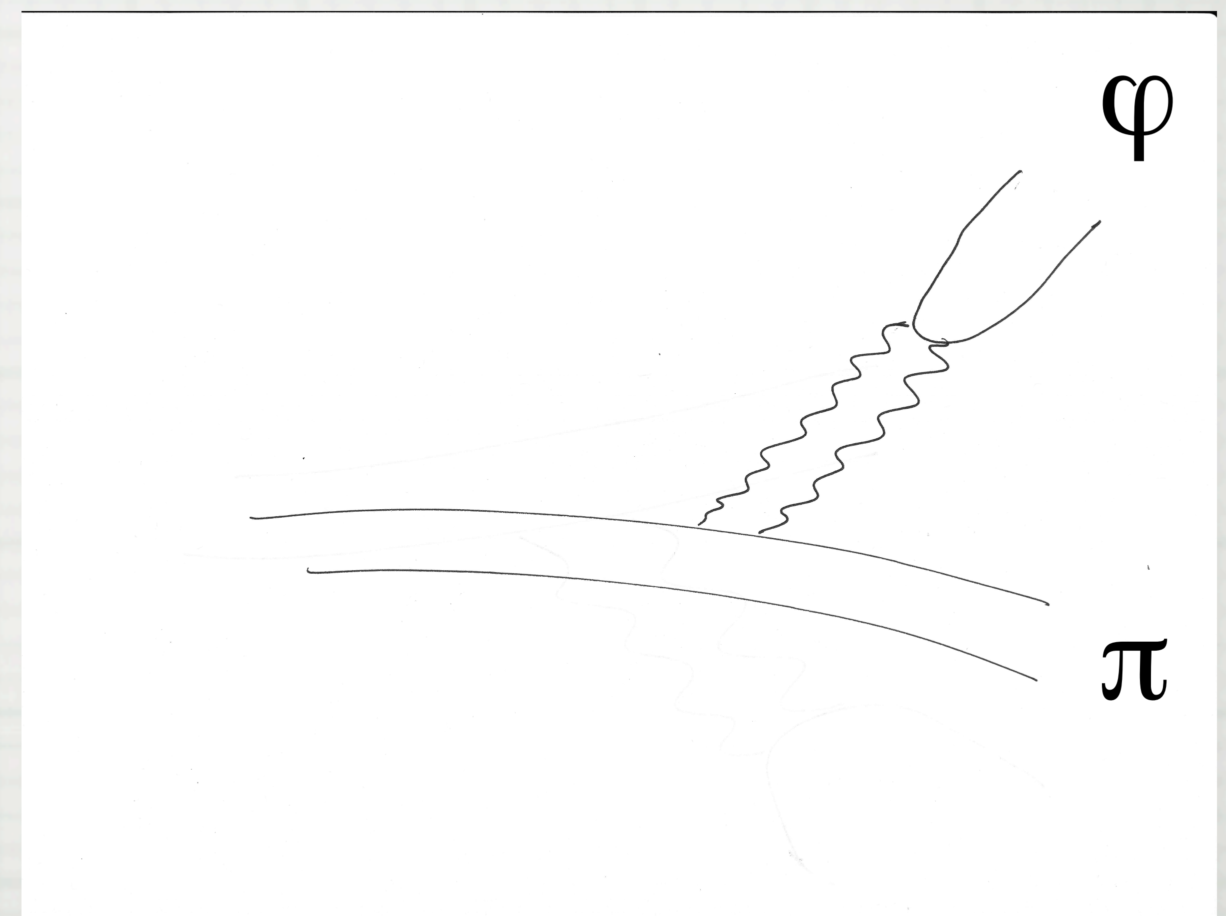

Dalitz Plot of (φ [η]) vs (Proton [η])
Dalitz Plot
Entries 3118
Invariant Mass (φ [η])2
Invariant Mass (Proton [η])2

$$\gamma p \rightarrow (\phi\eta)p \ \ |t'| < 0.1 \ \ \text{GeV}^2$$




Invariant Mass (φ [π^0])
Invariant Mass (φ [π^0])
Entries 8314
f1(1285) → a0(980) π
f1(1285)
Events / 20 MeV
Mass (GeV/c^2)
0
50
100
150
200
250
300
1.2
1.4
1.6
1.8
2
2.2


s̄
s
s
s̄


φ
π

$N^* \to \omega p$

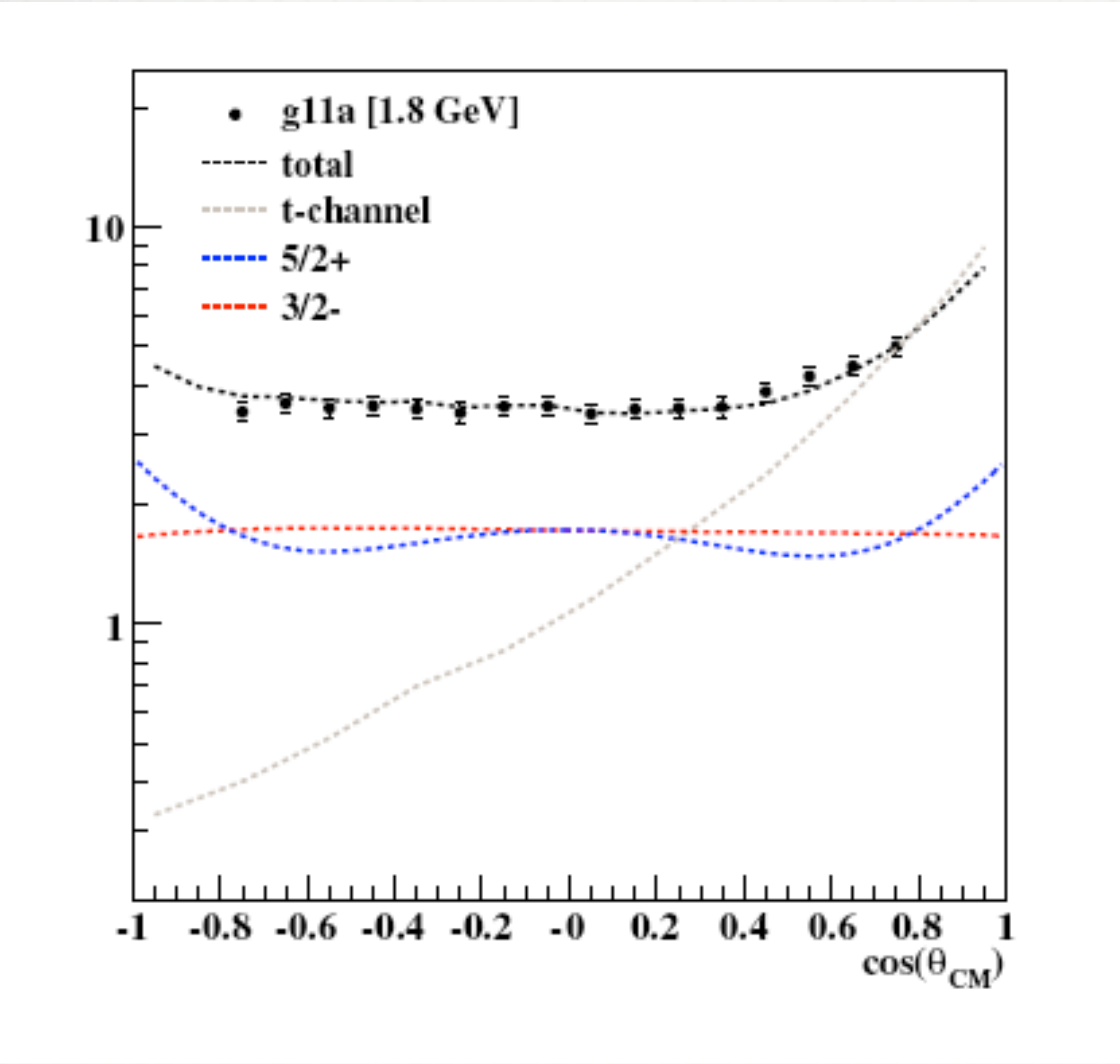
CLAS g_{11}

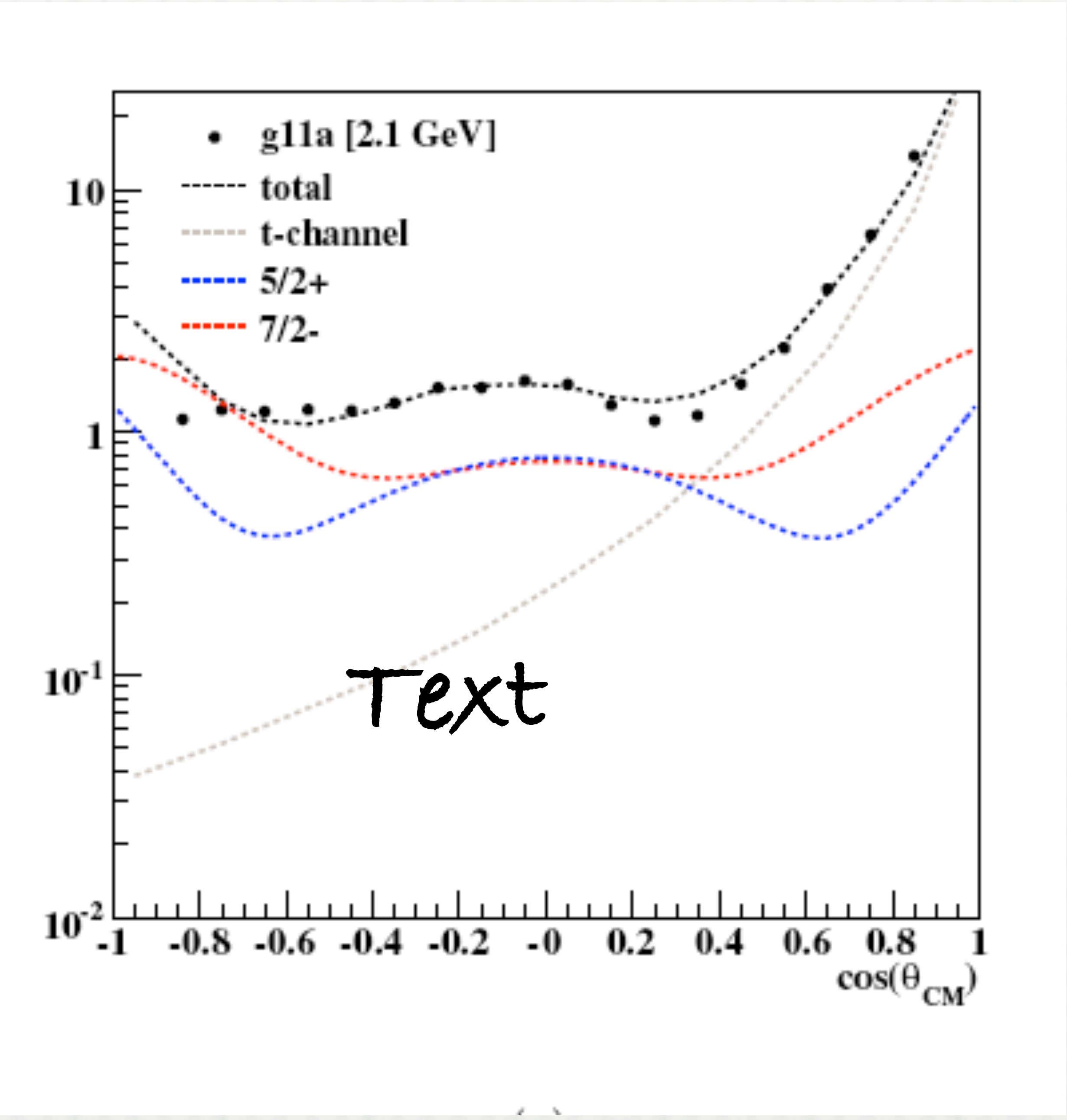
$E_e = 4$ GeV

Mike Williams

Curtis Meyer (CMU)

N* (s-channel) + ω (t-channel)





$\sqrt{s} = 1.8$ GeV

$\sqrt{s} = 2.1$ GeV

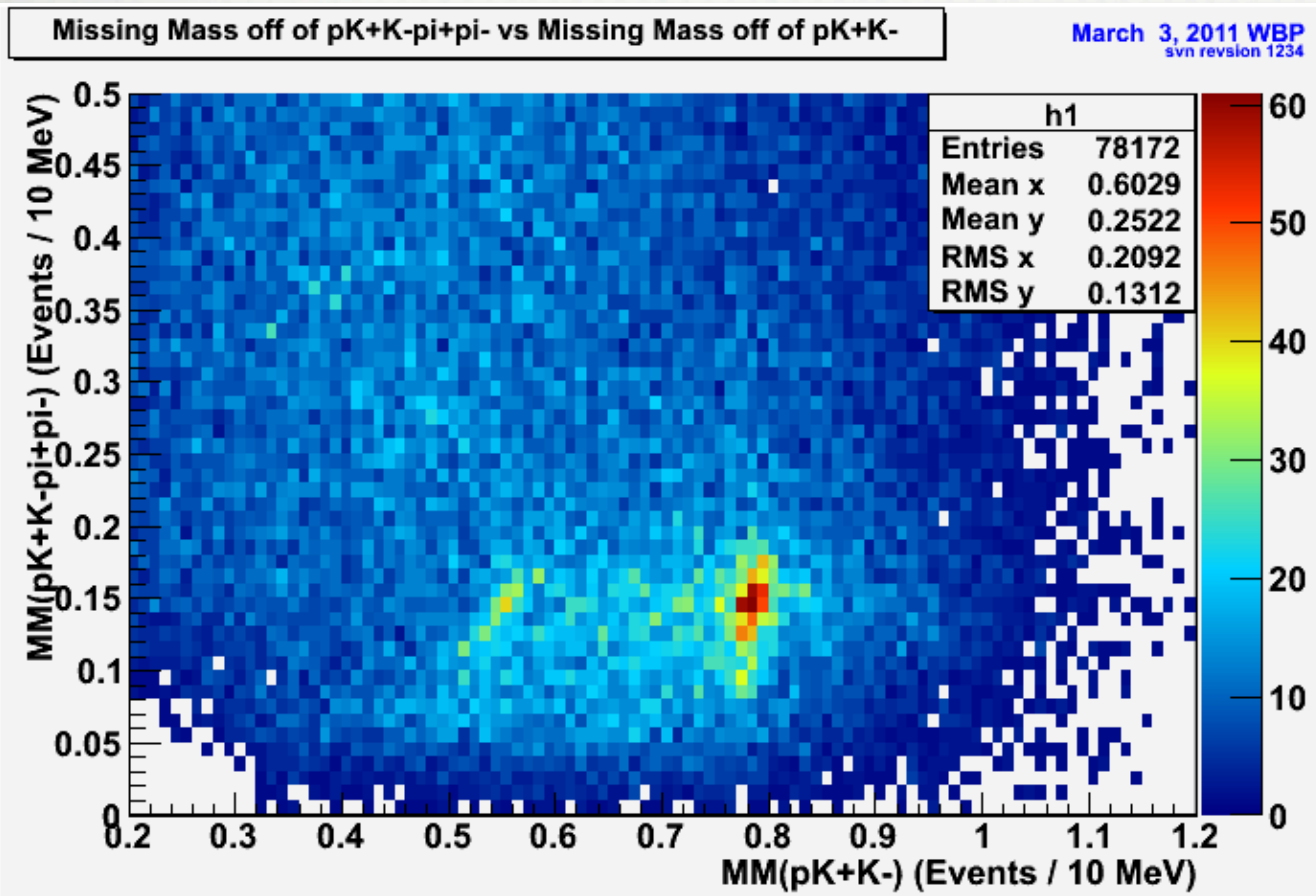
Furthermore, the ability of the PWA fit, which contains only the F15(1680) and D13(1700) s-channel amplitudes and the 0 t-channel amplitude, to reproduce both our dσ/d cos ϑ spin density matrix for √s < 2 GeV is truly remarkable. It is also
important to note that the large angle cross section for √s < 1.85 GeV is virtually flat. This demonstrates the importance of the spin-density measurements.
At higher energies, we have found fairly strong evidence for the presence of the **** G17(2190) resonance. The cross sections extracted for the $J^P = 7/2^-$ partial wave are in excellent agreement with this hypothesis.

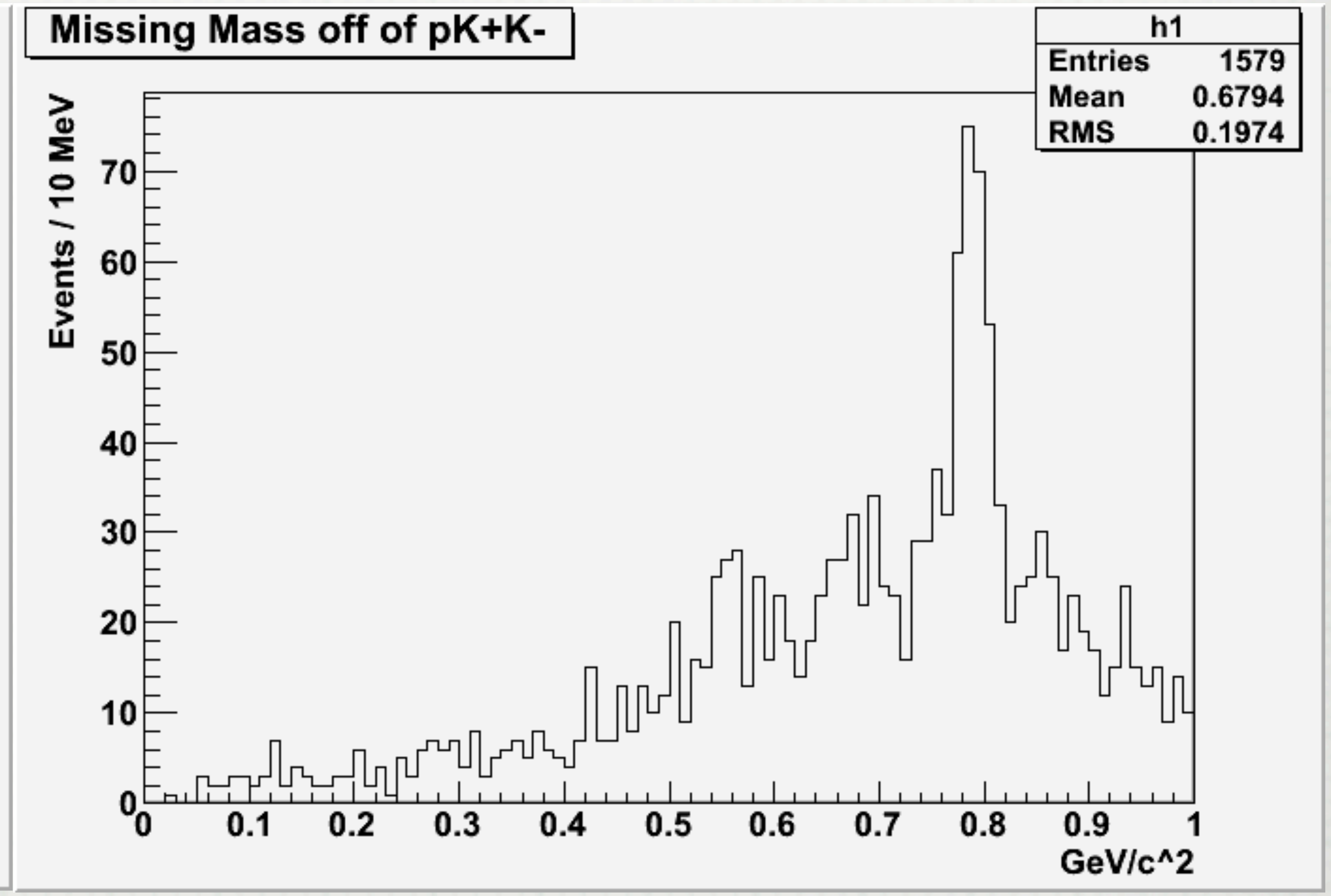
$$p\gamma \to pK^+K^-\pi^+\pi^-(\pi^0)$$

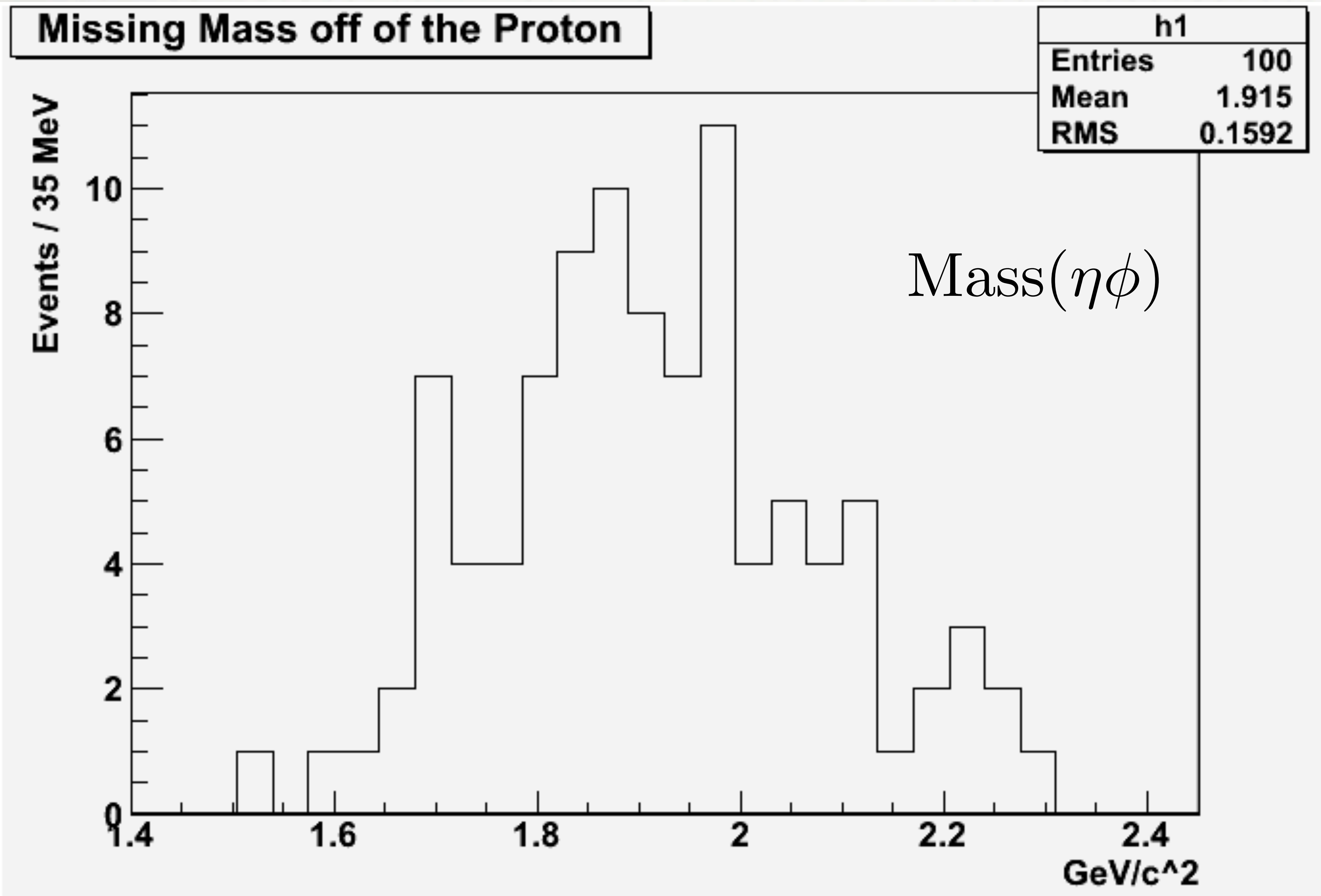
$$\phi \to K^+K^-$$

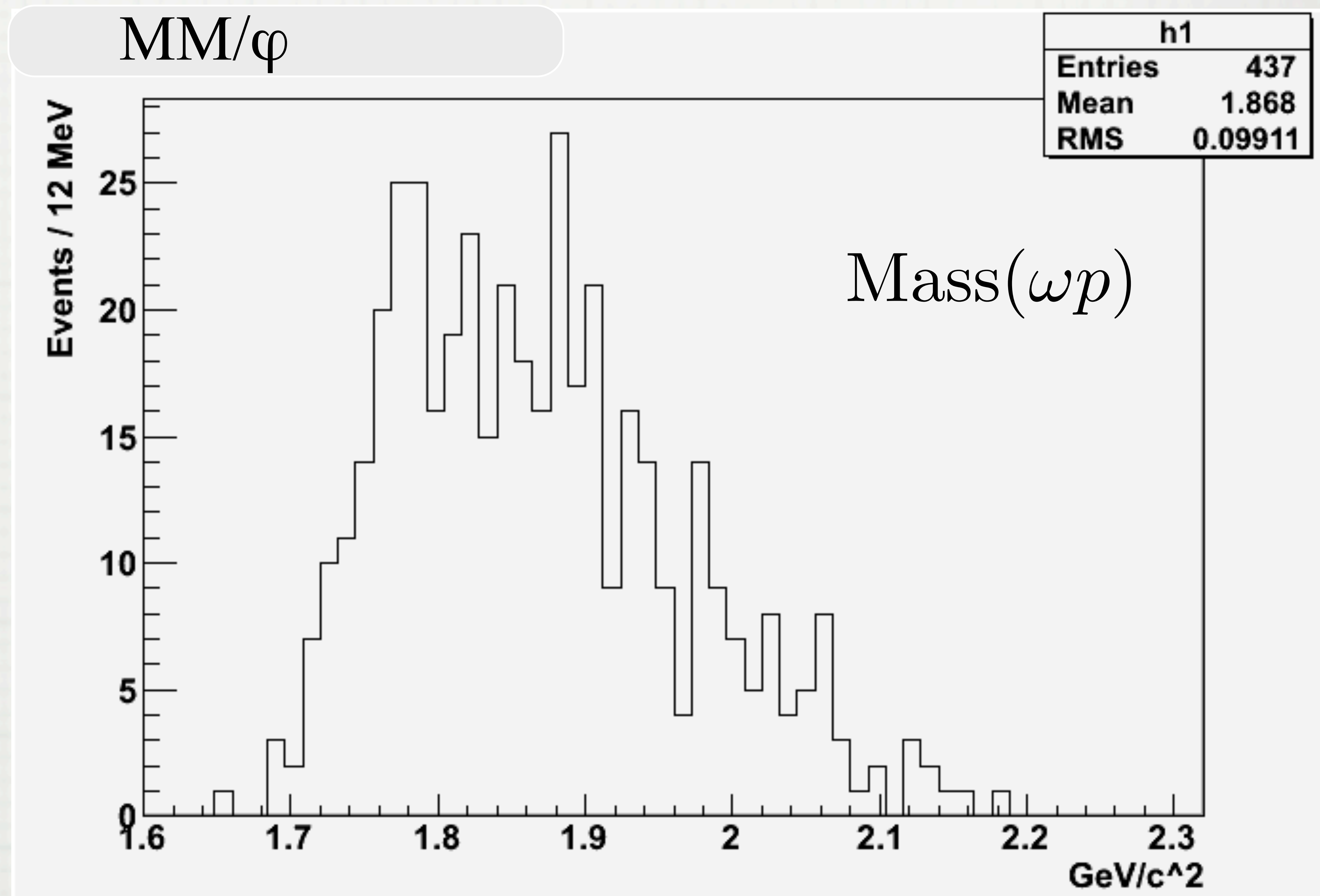
Carlo Salgado

W. Phelps/CNU and NSU

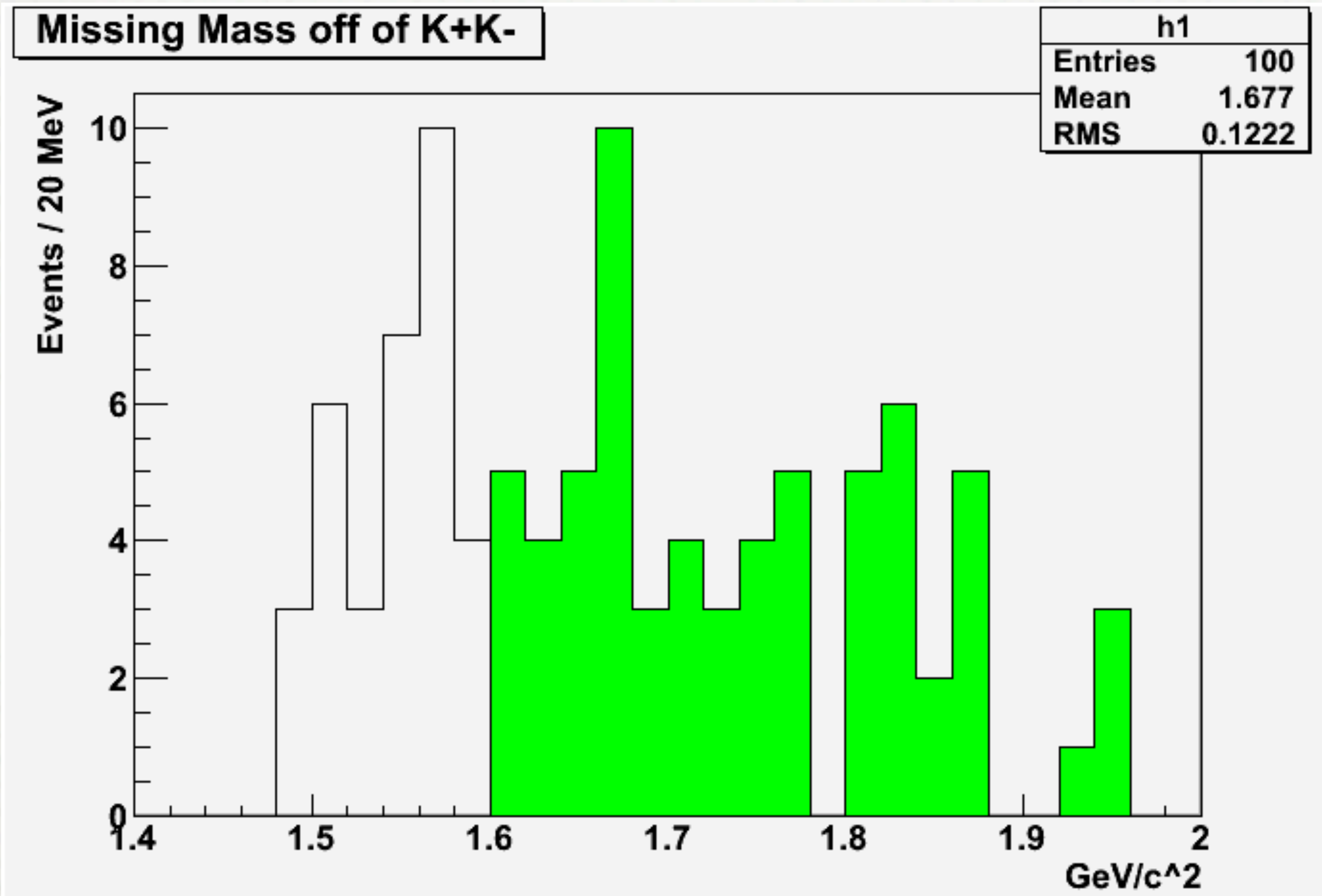




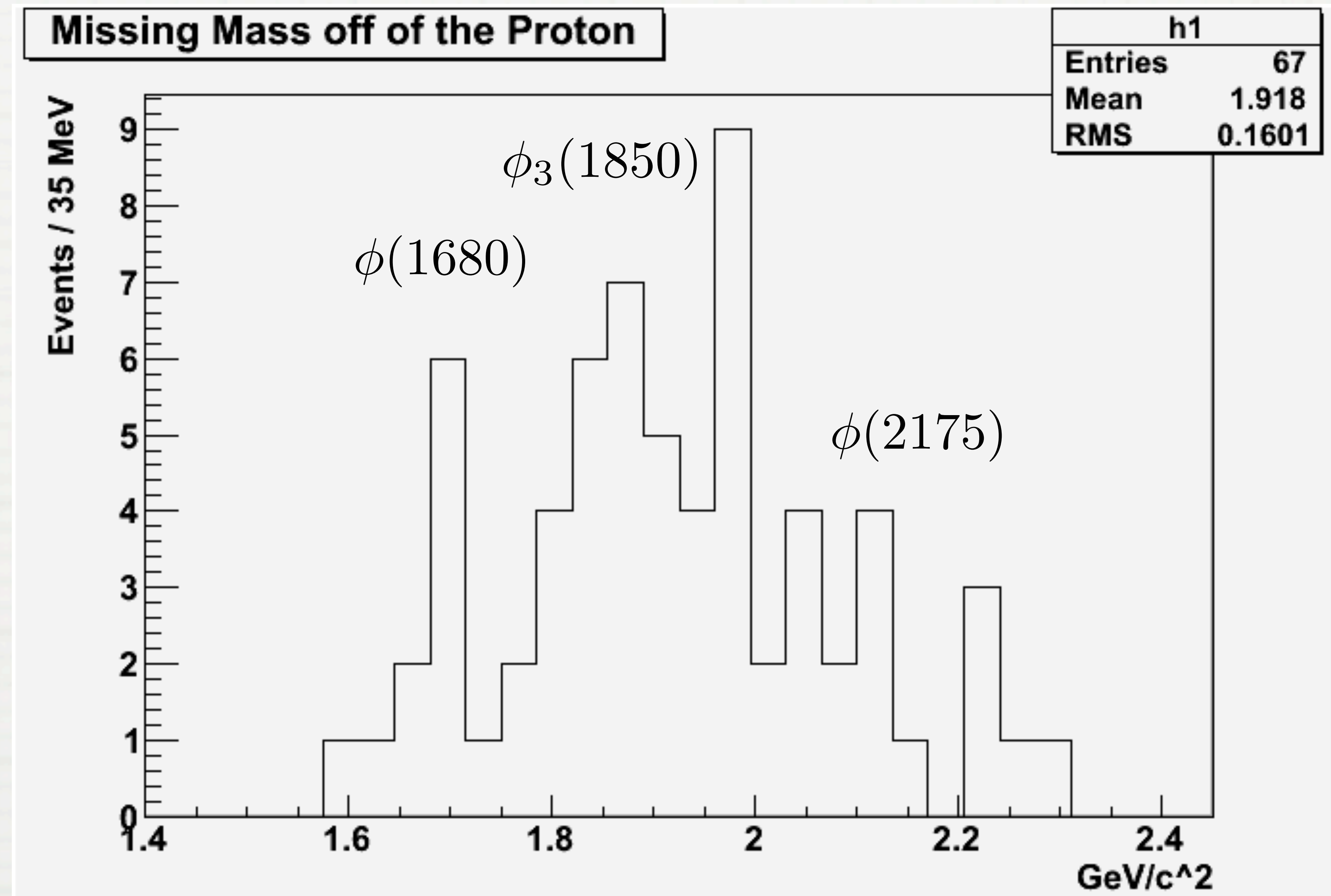

Missing Mass off of the Proton
h1
Entries 100
Mean 1.915
RMS 0.1592
Events / 35 MeV
Mass($\eta\phi$)
GeV/c^2


MM/φ
h1
Entries 437
Mean 1.868
RMS 0.09911
Events / 12 MeV
Mass(ωp)
GeV/c^2

$N^* \rightarrow p\eta$



$\phi' \rightarrow \phi\eta$



Ξ^* Spectroscopy

Ξ Ground State Mass difference: 6.48 ± 0.24 MeV

Only one measurement of Ξ^0 mass has more than 50 events

SU(3) flavor symmetry requires one Ξ I=1/2 per octet and per decuplet:
$n(\Xi^*)=n(N^*)+n(\Delta^*)$

QM predicts 45 cascades with mass below 2.5 GeV (S.Capstick and N. Isgur PRD 34 2809 (1986))

Algebraic model predicts 33 states with mass below 2.5 GeV (A.R. Bijker, F.Iachello, and A. Leviatan Ann. Phys. 284 89 (2000)

Suggests many states missing experimentally

Of the 6 **** & *** PDG Ξ states, J^P determined for only 3

Ξ Production Mechanisms not well understood

Jenkins et. al, Phys.Rev.Lett. 51 (1983) 951-954
BNL MPS

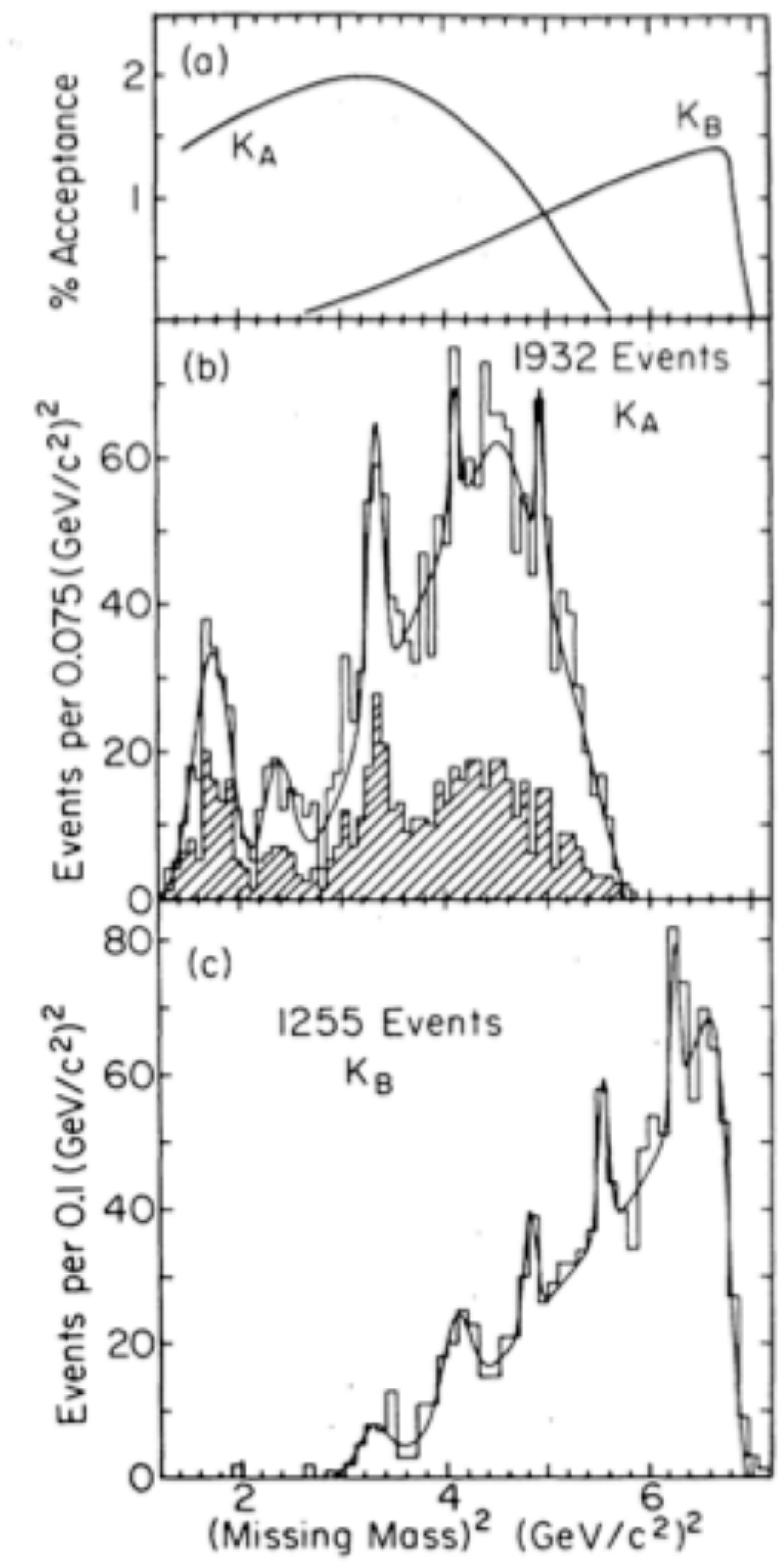


FIG. 3. Missing mass squared (X) for $K^- + p \to K^+ + X$. (a) Acceptance. (b) K_A; cross hatched areas are events with detected $\Lambda \to p\pi$. (c) K_B. Smooth curves in (b) and (c) are fits to background plus resonances.

Jenkins et. al, Phys.Rev.Lett. 51 (1983) 951-954

BNL MPS

State	PGD	K_A Mass (MeV)	K_A FWHM (MeV)	K_A σ (μb)	K_B Mass (MeV)	K_B FWHM (MeV)	K_B σ (μb)	σ_{extrap} (μb)	K_A and/or K_B σ (μb)	K_A and/or K_B Mass (MeV)
Ξ(1320)	4	1320 ± 6	158	7.2 ± 0.6 ± 0.6				7.4	7.2 ± 0.6	1320 ± 6
Ξ(1530)	4	1541 ± 12	106	2.8 ± 0.6 ± 0.2				2.7	2.8 ± 0.6	1541 ± 12
Ξ(1630)	2			< 1.0					< 1.0	
Ξ(1680)	2									
Ξ(1820)	3	1823 ± 6	49	3.4 ± 0.6 ± 0.3	1813 ± 15	92	2.7 ± 0.7 ± 0.2	3.0	3.1 ± 0.5	1822 ± 6
Ξ(1940)	2			< 1.3			< 0.8		< 0.8	
Ξ(2030)	3	2022 ± 9	26	1.1 ± 0.6 ± 0.1	2022 ± 12	63	2.1 ± 0.5 ± 0.2	1.5	1.7 ± 0.4	2022 ± 7
Ξ(2120)	1			< 1.1			< 1.4		< 1.1	
Ξ(2250)	1	2218 ± 6	28	2.0 ± 1.0 ± 0.2	2197 ± 12	32	1.0 ± 0.3 ± 0.1		1.0 ± 0.3	2214 ± 5
Ξ(2370)	2				2356 ± 10	36	0.9 ± 0.3 ± 0.1		0.9 ± 0.3	2356 ± 10
Ξ(2500)	2				2505 ± 10	36	1.0 ± 0.5 ± 0.1		1.0 ± 0.5	2505 ± 10

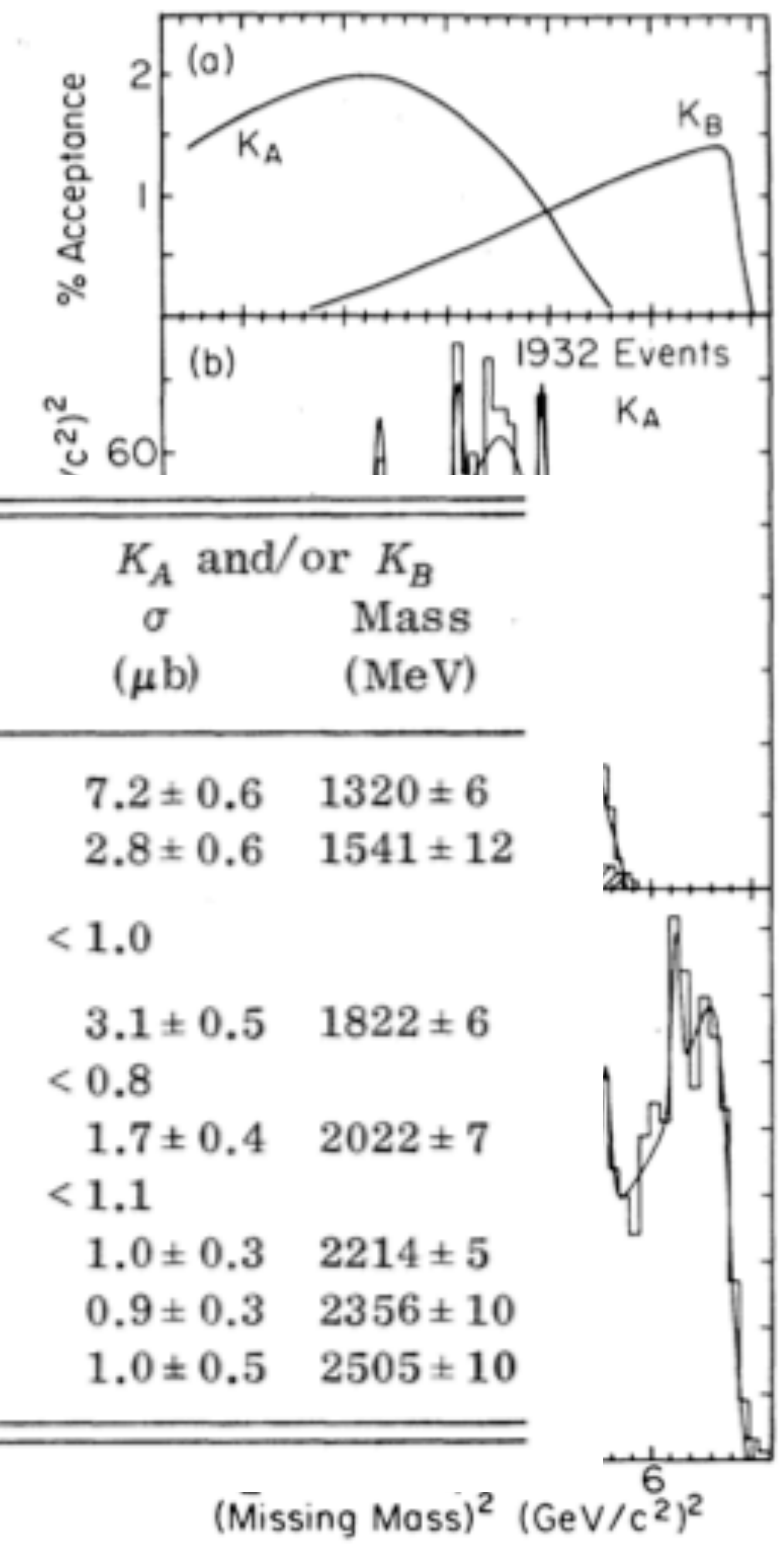


FIG. 3. Missing mass squared (X) for $K^- + p \rightarrow K^+ + X$. (a) Acceptance. (b) K_A; cross hatched areas are events with detected $\Lambda \rightarrow p\pi$. (c) K_B. Smooth curves in (b) and (c) are fits to background plus resonances.

Jenkins et. al,Phys.Rev.Lett. 51 (1983) 951-954

BNL MPS

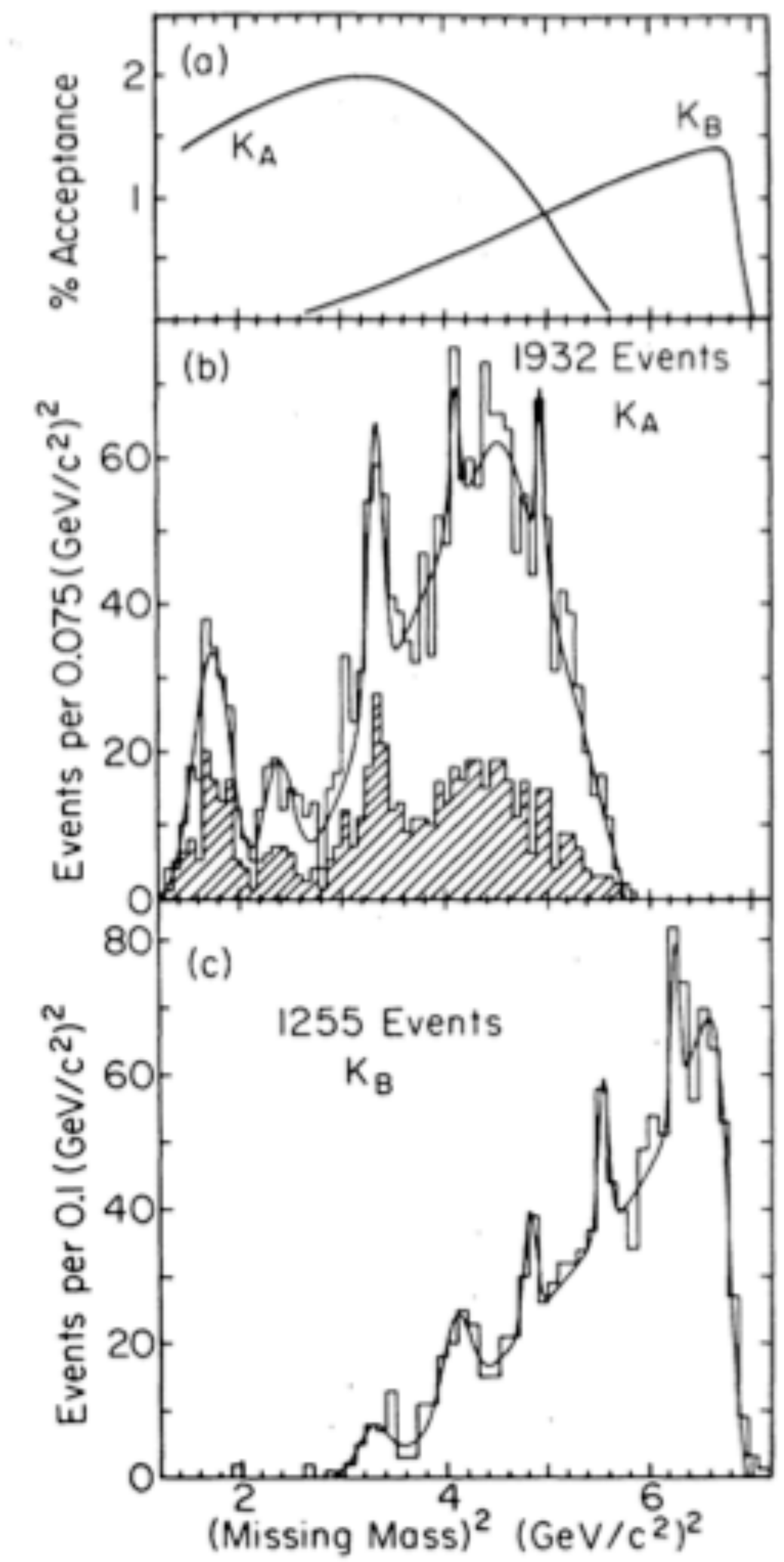
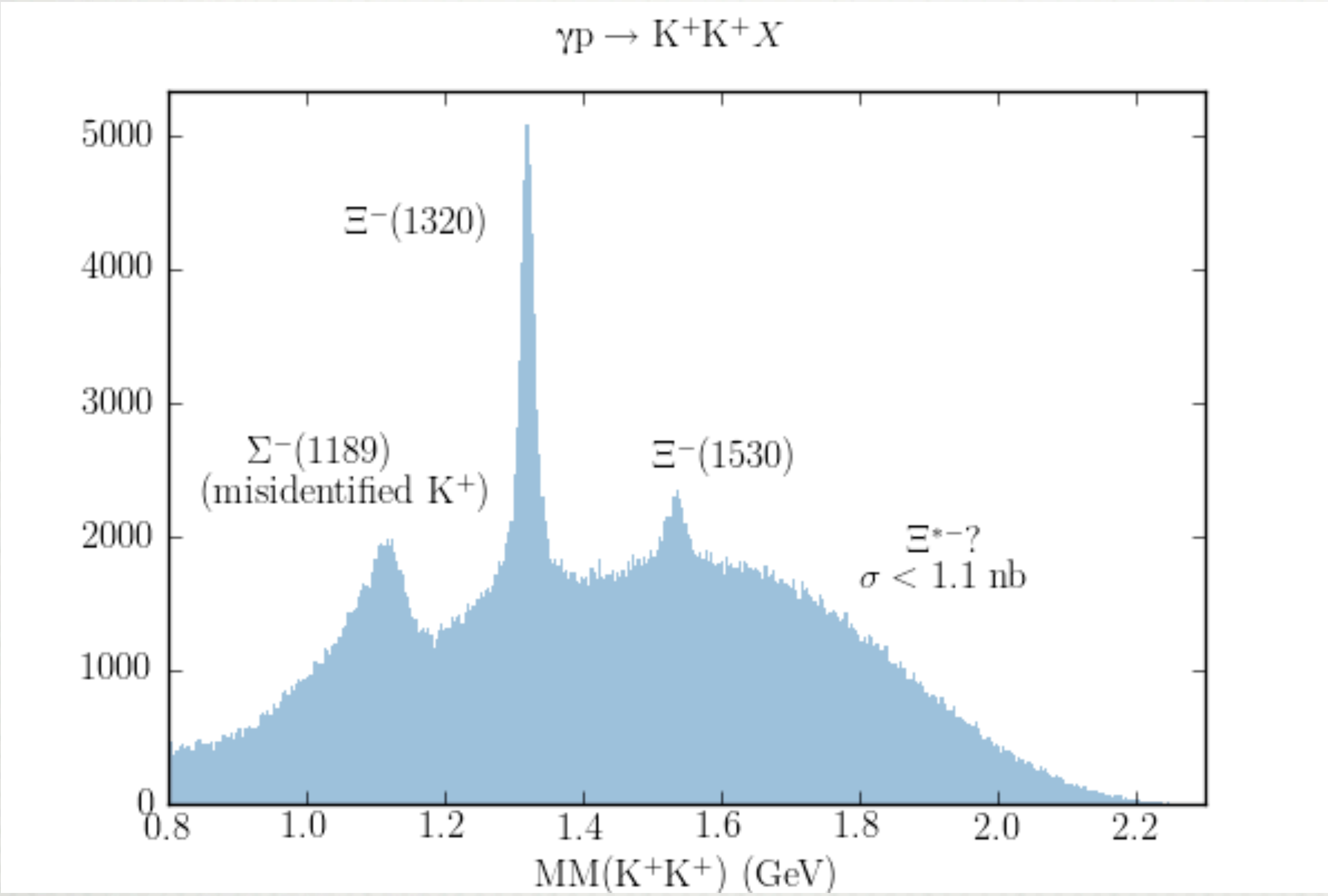


FIG. 3. Missing mass squared (X) for $K^- + p \to K^+ + X$. (a) Acceptance. (b) K_A; cross hatched areas are events with detected $\Lambda \to p\pi$. (c) K_B. Smooth curves in (b) and (c) are fits to background plus resonances.

$$\gamma p \rightarrow K^+ K^+ X$$

Jenkins et. al, Phys.Rev.Lett. 51 (1983) 951-954

BNL MPS



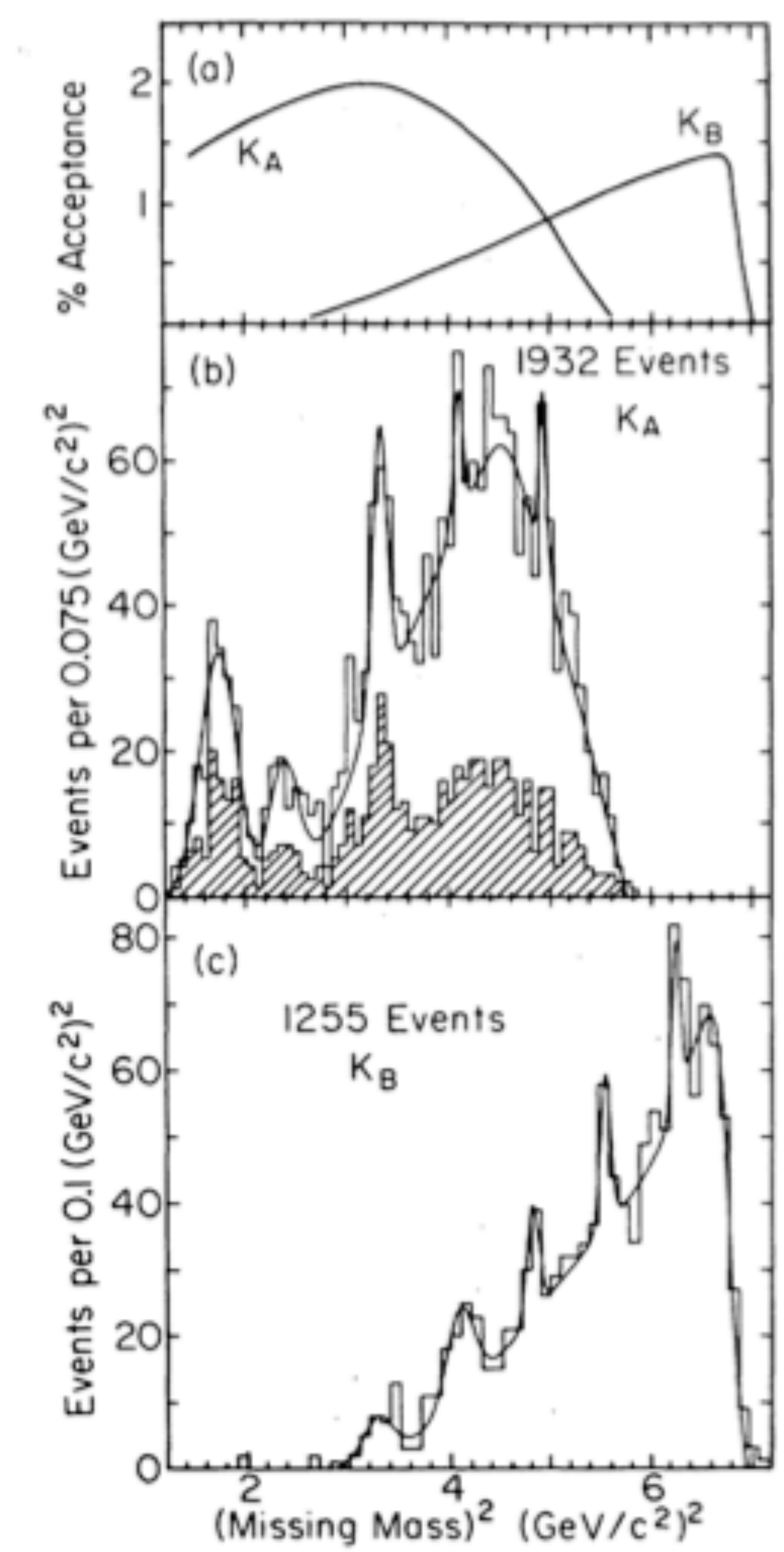
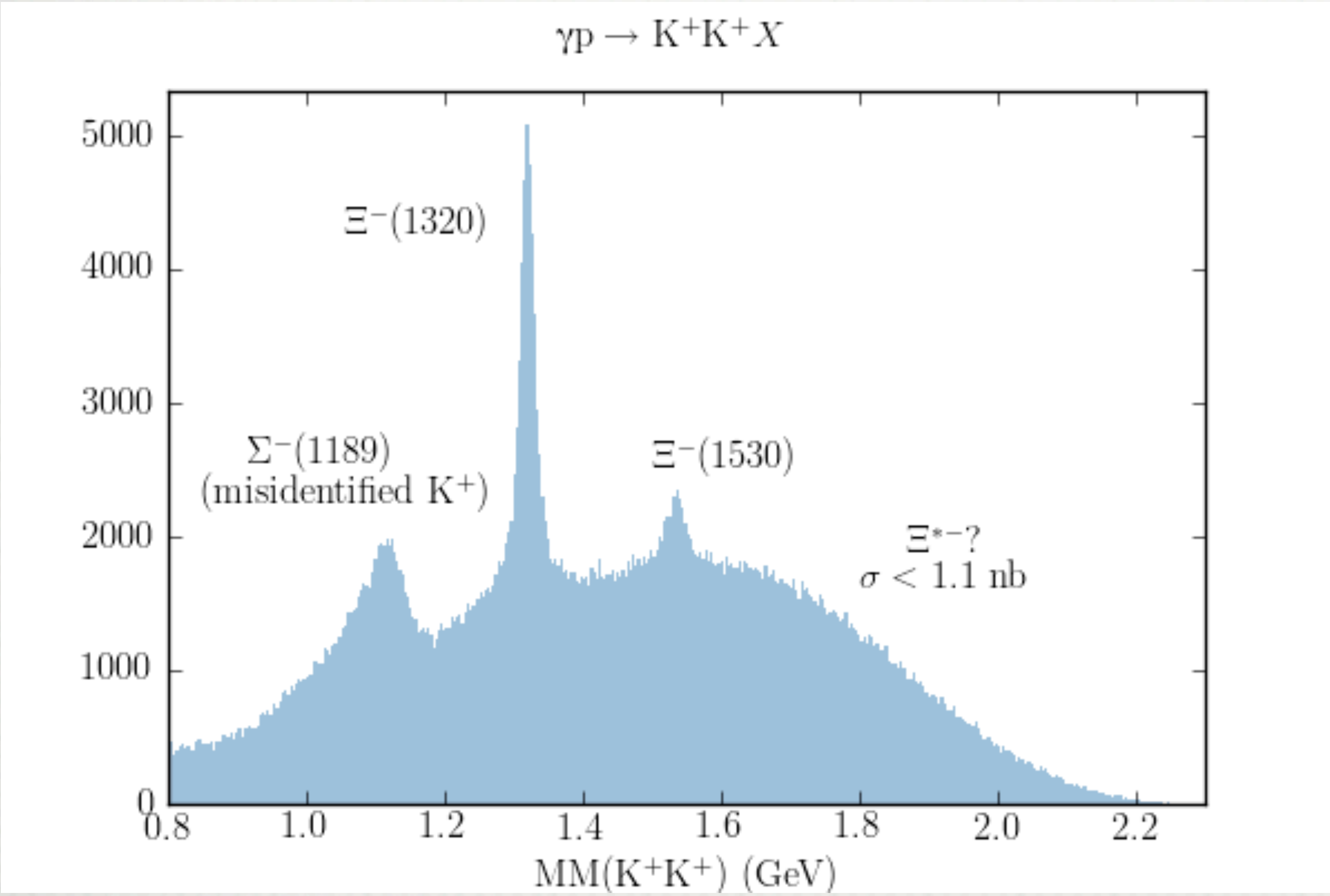
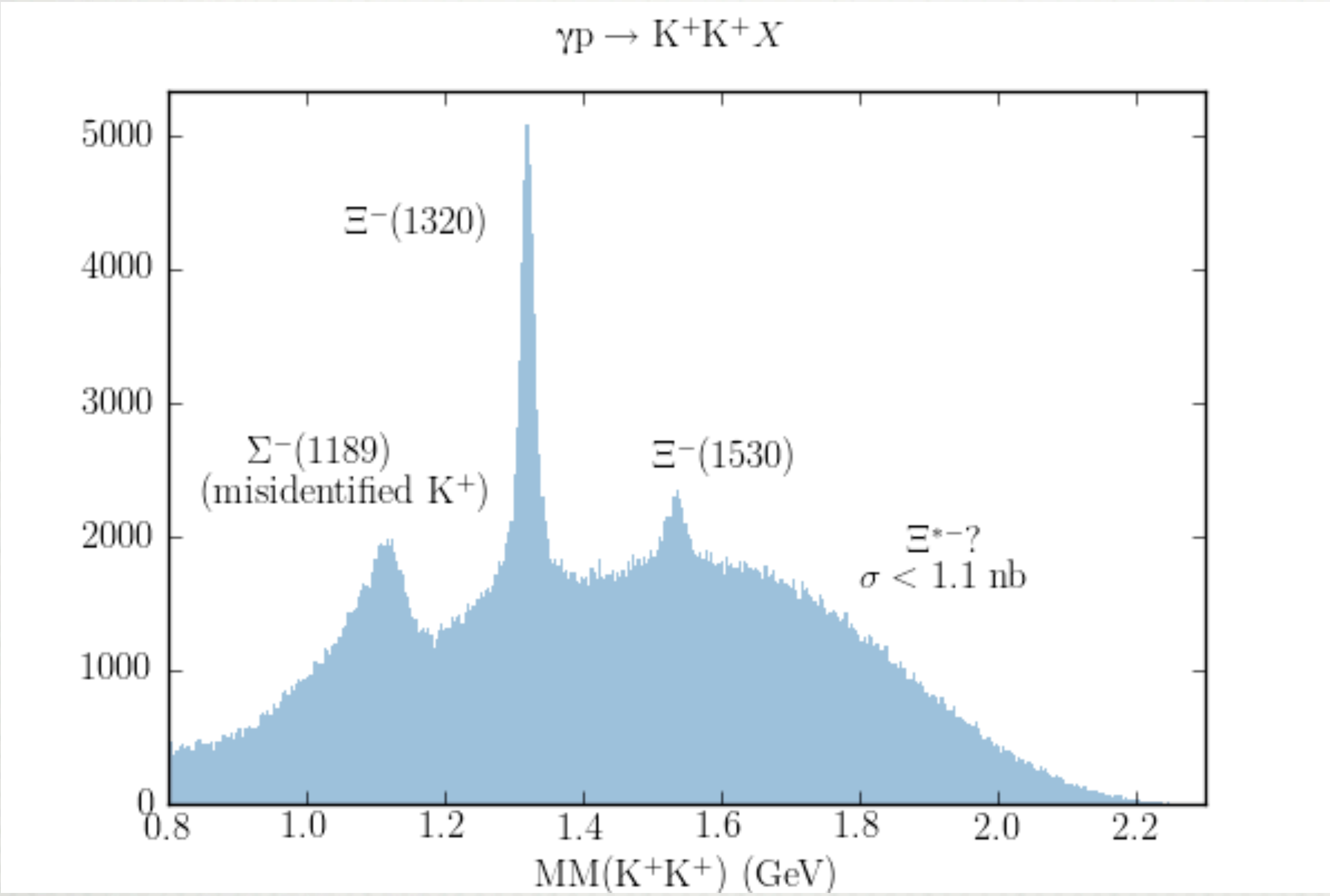


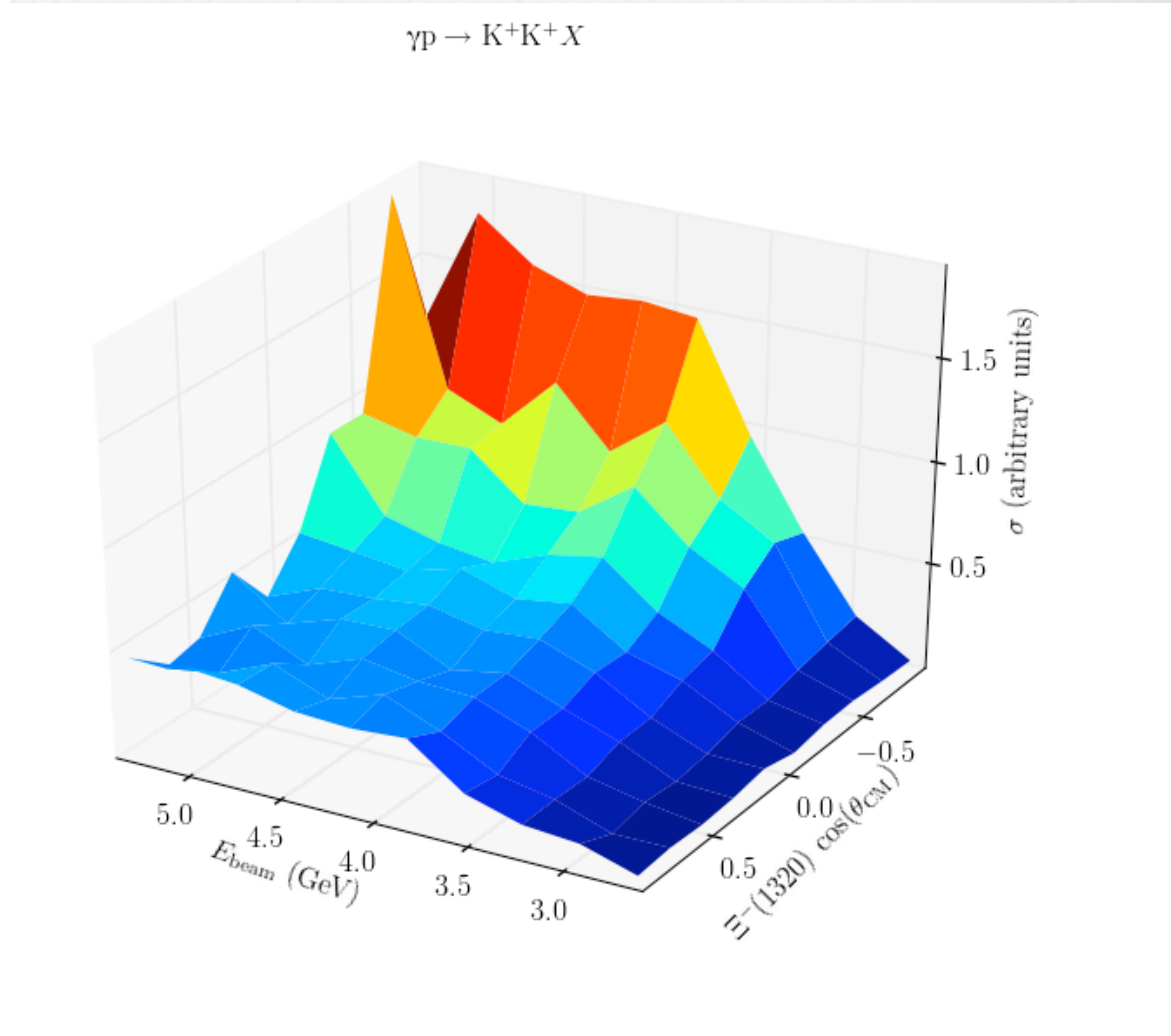
FIG. 3. Missing mass squared (X) for $K^- + p \rightarrow K^+ + X$. (a) Acceptance. (b) K_A; cross hatched areas are events with detected $\Lambda \rightarrow p\pi$. (c) K_B. Smooth curves in (b) and (c) are fits to background plus resonances.

$\gamma p \rightarrow K^+ K^+ X$

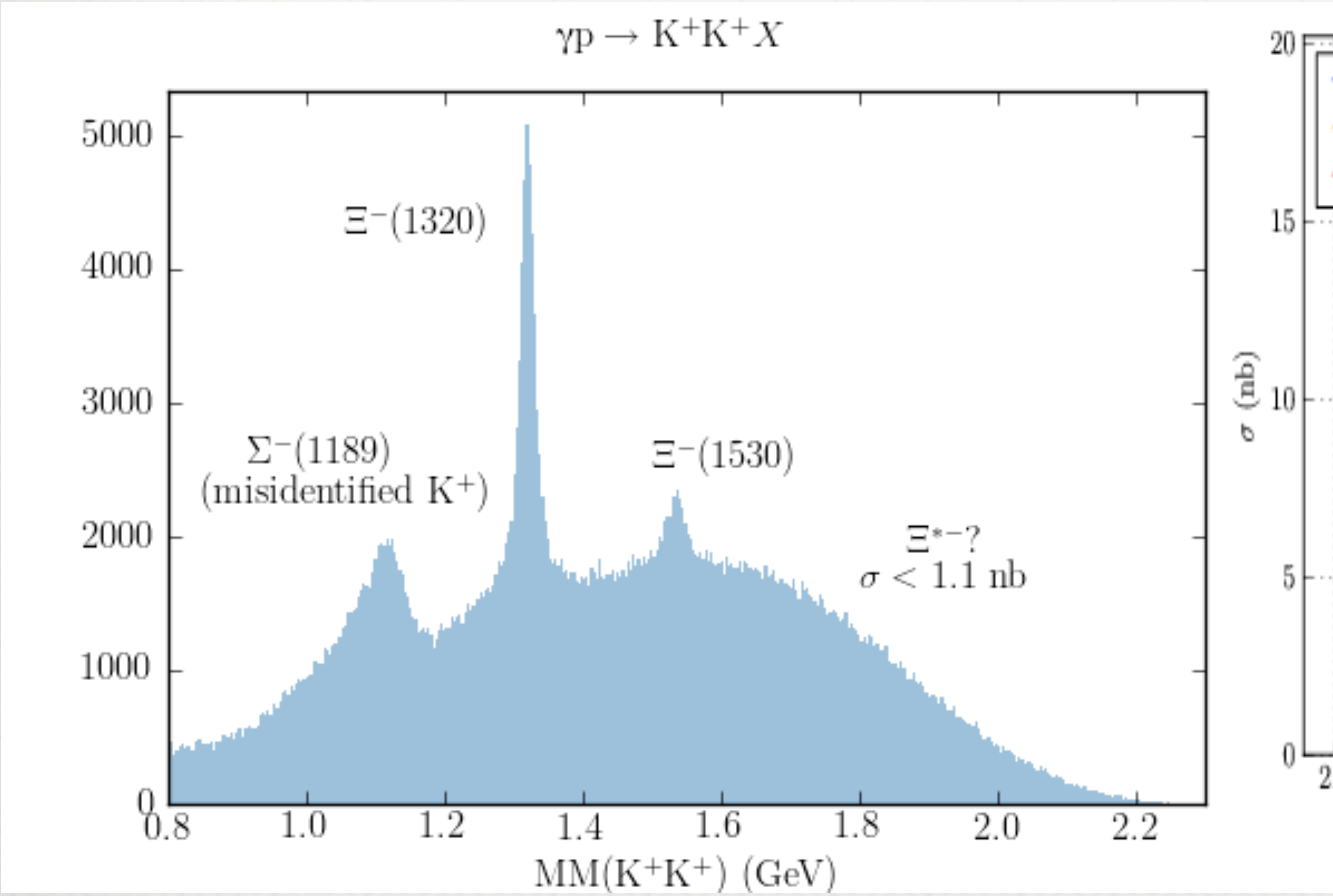


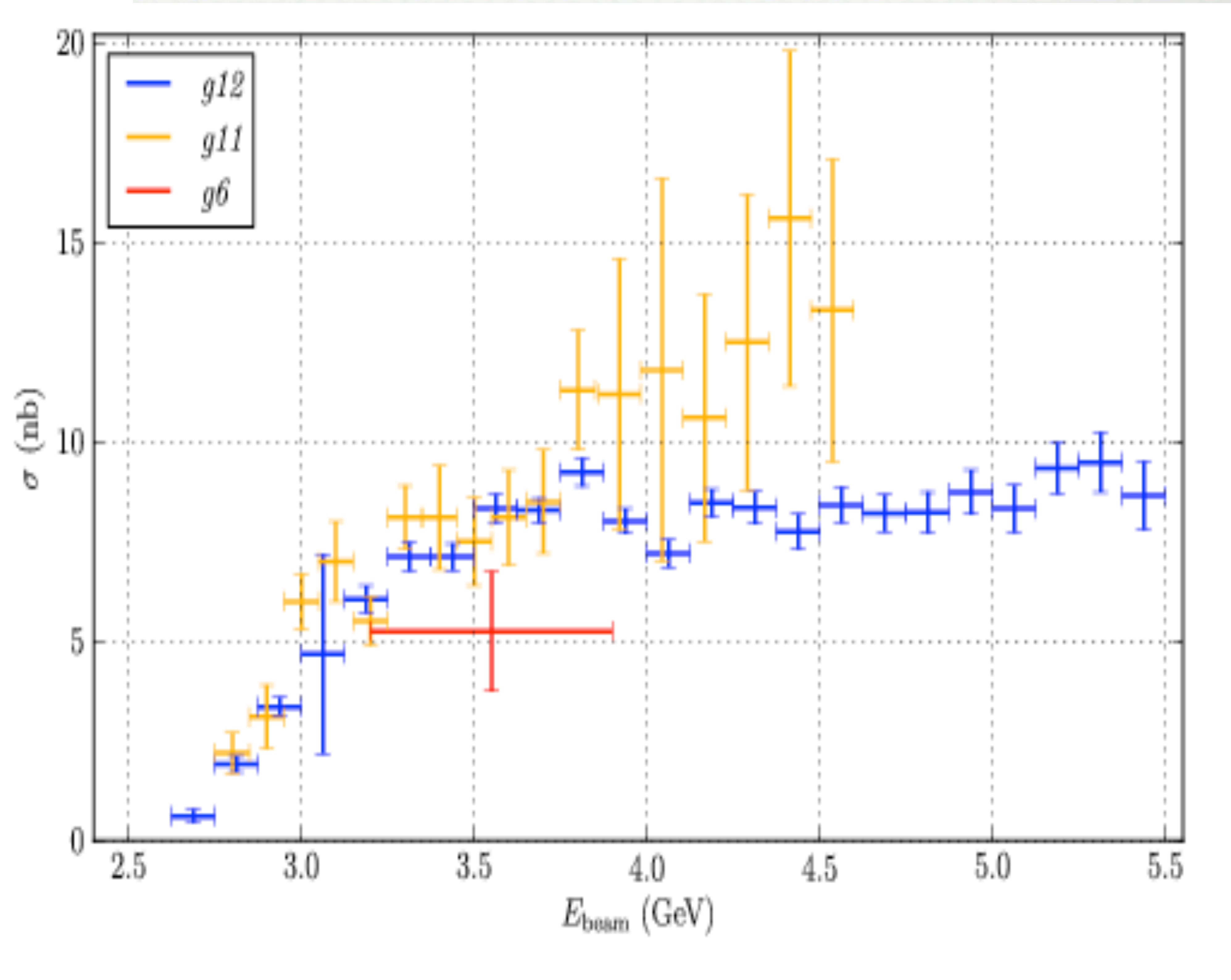
$\gamma p \to K^+ K^+ X$





$$\gamma p \to K^+ K^+ X$$





Conclusions

Previous CLAS result on exotic $\pi_1(1600)/a_2(1320)$ in photoproduction confirmed with higher statistics

Previous CLAS result on $\gamma p \rightarrow$ pentaquark not confirmed with higher statistics

High luminosity allows exploitation of 'rare' topologies

$$\gamma p \rightarrow \phi\pi^0 p, \quad \phi\eta p, \quad \phi\omega p$$

No observation of any Ξ^* states above 1530 MeV recoiling off of K^+K^+

Lepton detection permits high statistic study of pseudoscalar Dalitz decay

first observation of η' Dalitz decay; ρ-ω interference via e^+e^- channel