Strangeonia Spectroscopy with CLAS

(g12 run data)

(work in progress)

Carlos Salgado, Norfolk State University – Hadron Spectroscopy Meet June17, 2010

Strangeonia Spectroscopy with CLAS

Strange quarkonia: (light mesons with a least one strange (anti) quark in the dominant (q,qbar) valence components:

- Kaonia (n,sbar) where n=u,d (K…
- Anti-Kaonia (nbar,s) (Kbar,…
- **Strangeonia (s,sbar) (Φ,f,…**

G12 – look at 1 - 2 GeV mass range

Radial Excitations of S: the Φ

	State	KK	KK*	$\eta\varphi$	K*K*, $KK_{1(2)}$, $\eta'\varphi$, …
1S	1019 (Φ) Γ_{th}=2.5MeV Γ_{exp}=4.26MeV	Γ_{th}=2.5MeV			
2S	1680 (Φ) Γ_{th}=378MeV Γ_{exp}=150MeV	Γ_{th}=89MeV	Γ_{th}=245MeV	Γ_{th}=44MeV	
3S	2050 (Φ) Γ_{th}=378MeV		Γ_{th}=20MeV	Γ_{th}=21MeV	Γ_{th}=337MeV

($^3P_0$ decay model:Barnes,Black,Page:2002)

First orbital excitations

		KK	KK*	ηη
1^1P_1	1440 (h_1) Γ_{th}=160MeV Γ_{exp}=91MeV		Γ_{th}=160MeV	
1^3P_0	1500 (f_0) Γ_{th}=279MeV	Γ_{th}=214MeV		Γ_{th}=60MeV
1^3P_1	1530 (f_1) Γ_{th}=254MeV		Γ_{th}=254(?)MeV	
1^3P_2	1525 (f'_2) Γ_{th}=80MeV Γ_{exp}=76MeV	Γ_{th}=61MeV	Γ_{th}=9MeV	Γ_{th}=10MeV

($^3P_0$ decay model:Barnes,Black,Page:2002)

Radial of P

		KK	KK*	ηφ	K*K*	K*K$_1$ …
2^1P_1	1850 (h_1) Γ_{th}=193MeV		Γ_{th}=95MeV	Γ_{th}=33MeV	Γ_{th}=64MeV	Γ_{th}=1MeV
2^3P_0	2000 (f_0) Γ_{th}=782MeV	Γ_{th}=47MeV		Γ_{th}=9MeV ηη	Γ_{th}=89MeV	Γ_{th}=548MeV
2^3P_1	1950 (f_1) Γ_{th}=296MeV		Γ_{th}=68MeV		Γ_{th}=29MeV	Γ_{th}=198MeV
2^3P_2	2000 (f_2) Γ_{th}=403MeV	Γ_{th}=64MeV	Γ_{th}=142MeV	Γ_{th}=16MeV ηη	Γ_{th}=101MeV	Γ_{th}=60MeV

($^3P_0$ decay model:Barnes,Black,Page:2002)

Second orbital excitations

		KK	KK*	K*K*	$KK_1(1273)$	$\eta\varphi$
1^1D_1	**1850** (η_2) Γ_{th}=129MeV		Γ_{th}=114MeV	Γ_{th}=15MeV		
1^3D_1	**1850** (φ) Γ_{th}=652MeV	Γ_{th}=65MeV	Γ_{th}=75MeV	Γ_{th}=5MeV	Γ_{th}=478MeV	Γ_{th}=29MeV
1^3D_2	**1850** (φ_2) Γ_{th}=214MeV		Γ_{th}=151MeV	Γ_{th}=7MeV	Γ_{th}=2MeV	Γ_{th}=53MeV
1^3D_3	**1854** (φ_3) Γ_{th}=104MeV Γ_{exp}=87MeV	Γ_{th}=45MeV	Γ_{th}=24MeV	Γ_{th}=32MeV		Γ_{th}=3MeV

($^3P_0$ decay model:Barnes,Black,Page:2002)

Possible meson resonances decaying to:

K^+K^-	
$\Phi(1020)$	49%
$f_2(1270)$	46%
$f_1(1285)$	9%
$a_2(1320)$	49%
$f_0(1370)$	seen
$f_1(1420)$	dominant
$\eta(1440)$	seen
$a_0(1450)$	seen
$f_0(1500)$	seen
$f'_2(1525)$	89%
$\Phi(1680)$	seen
$\rho3(1690)$	1.6%
ρ (1700)	seen
$f_0(1710)$	seen
$\Phi_3(1850)$	seen
$a_4(1450)$	seen
$f_4(2050)$	7%

K^*K	
$f_1(1285)$	9%
$f_1(1285)$	9%
$\eta(1440)$	seen
$\Phi(1680)$)	seen
$\pi(1800)$	seen
$\Phi_3(1850)$	seen

Experiments in Strangeonia

LASS (SLAC E135) – K beam (11 GeV) (1980's)

$$K^- p \to K^+ K^- \Lambda$$
$$K^- p \to K_s K_s \Lambda$$
$$K^- p \to K_s K^\pm \pi^\mp \Lambda$$

Ω- Spectrometer (CERN) – Photon beam (25-70 GeV) (1980's)

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

DM2 (Orsay) – e+e- (1.35-2.4 GeV) (late 1980's)

$$e^+ e^- \to K^+ K^- \pi^0$$
$$e^+ e^- \to K_s K^\pm \pi^\mp$$

E771 (BNL) – Pion beam (8 GeV) (mid 1980's)

$$\pi^- p \to K^+ K_s \pi^- n$$

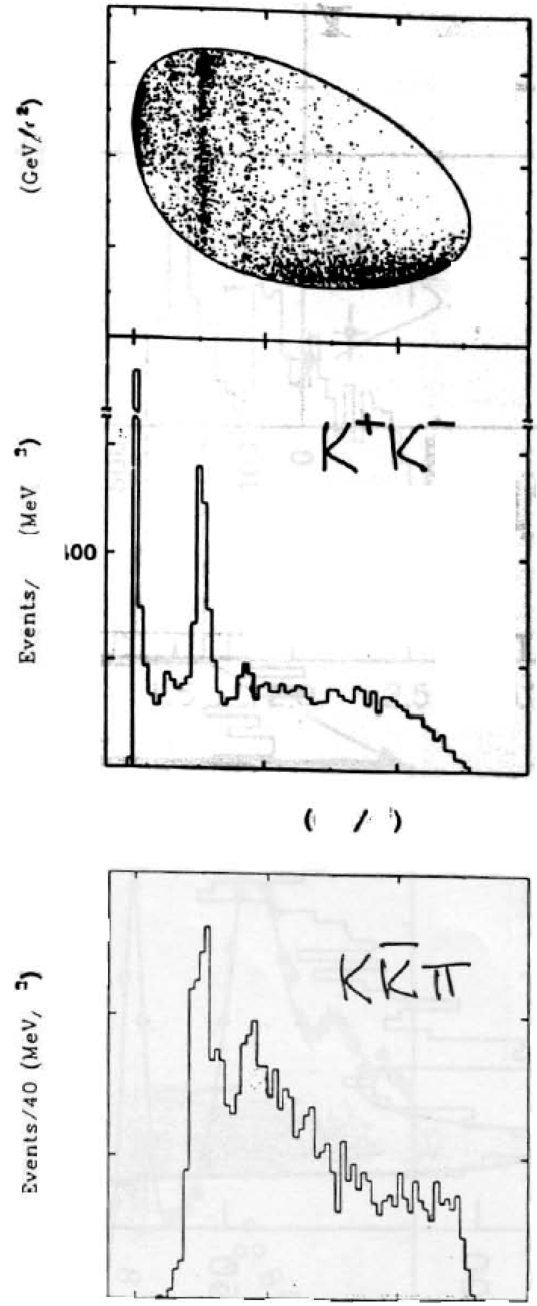
E401 (FNAL) – Photon beam (75 GeV) (late 1980s)

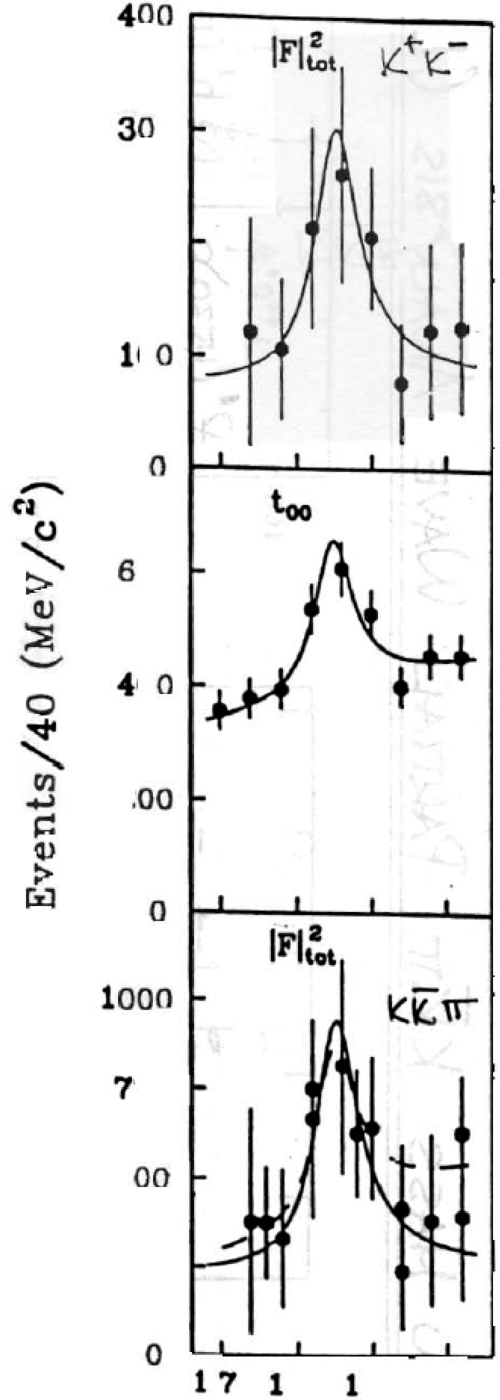
$$\gamma p \to K^+ K^- p$$

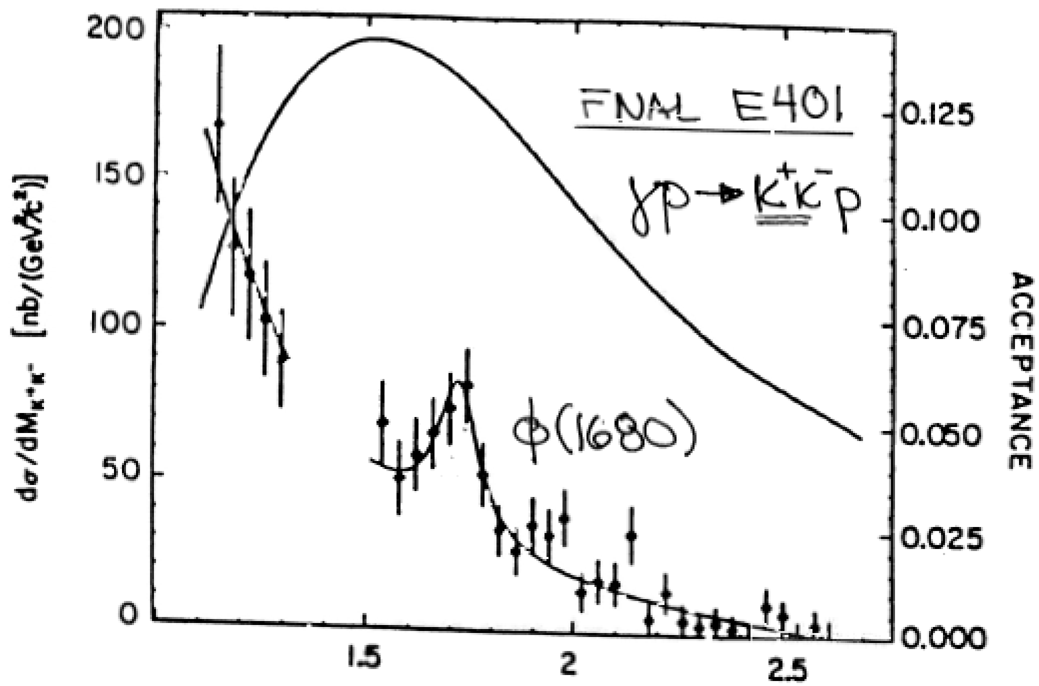
Focus (FNAL) – Photon beam (300 GeV) (pub.2002)

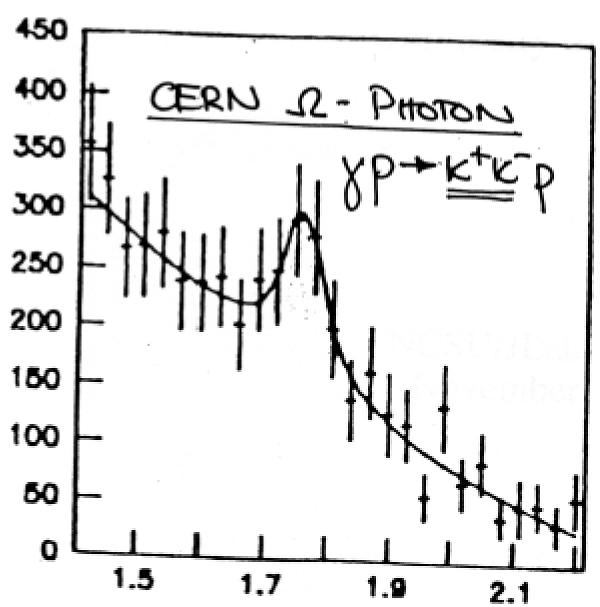
$$\gamma p \to K^+ K^- p$$

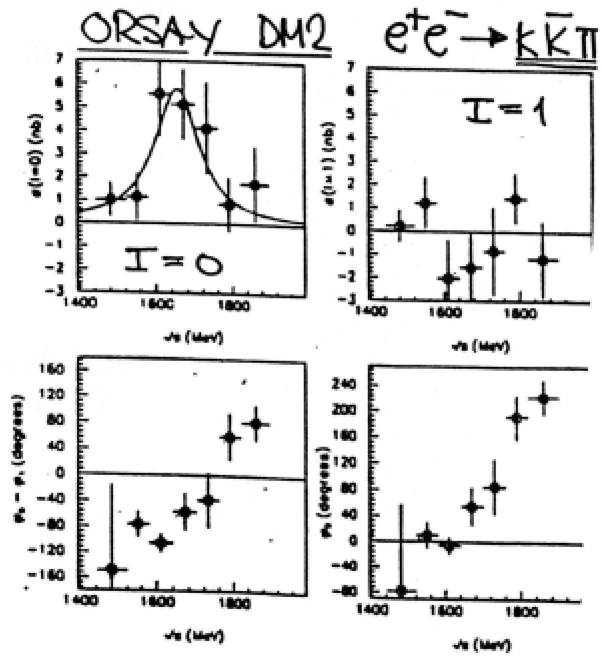
LASS PWA of $\Phi_3(1850)$






FNAL E401
$\gamma p \to K^+K^- p$
$\phi(1680)$
$d\sigma/dM_{K^+K^-}$ [nb/(GeV/c^2)]
ACCEPTANCE
0
50
100
150
200
1.5
2
2.5
0.000
0.025
0.050
0.075
0.100
0.125


CERN Ω - PHOTON
$\gamma p \to K^+K^- p$
0
50
100
150
200
250
300
350
400
450
1.5
1.7
1.9
2.1


ORSAY DM2
$e^+e^- \to K\bar{K}\pi$
I = 0
I = 1
$\sqrt{s}$ (MeV)
1400
1600
1800

Focus (FNAL)

m(1680)=1753.5±3.8 MeV

Γ=122.2±14 MeV

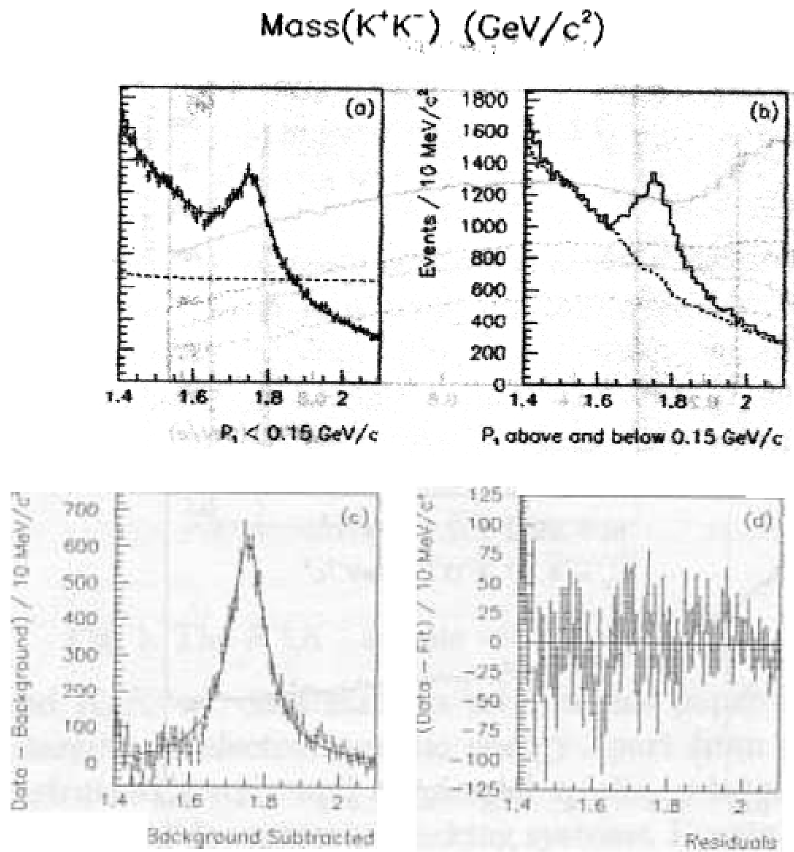


Fig. 3. (a) The K^+K^- mass spectrum with the requirement that $p_T < 0.15$ GeV/c. The spectrum is fit with a non-relativistic Breit-Wigner distribution and a quadratic background. The dotted line is the Monte Carlo efficiency on a scale from 0 to 100%. (b) The solid line is the K^+K^- mass spectrum with the requirement that $p_T < 0.15$ GeV/c. The dotted line is the K^+K^- mass spectrum with $p_T > 0.15$ GeV/c scaled to the size of the low p_T spectrum for comparison. (c) The data and fit after subtracting the quadratic polynomial background shape. (d) The data minus the fit.

G12 run – photoproduction

Event Selection

K Skim (at least one K selected by reconstruction a1c)

We are looking at

•pK+	KK
•pK-	KK,KK*
•pK+K-	KK,KK*,ηφ
•K+K-	KK

Selection cuts

→ **Beam energy > 4.4 GeV**

→ **Inside target (vertex cut)** $-1.1<x_v<0.9$ cm

$-1.<y_v<1.$ cm

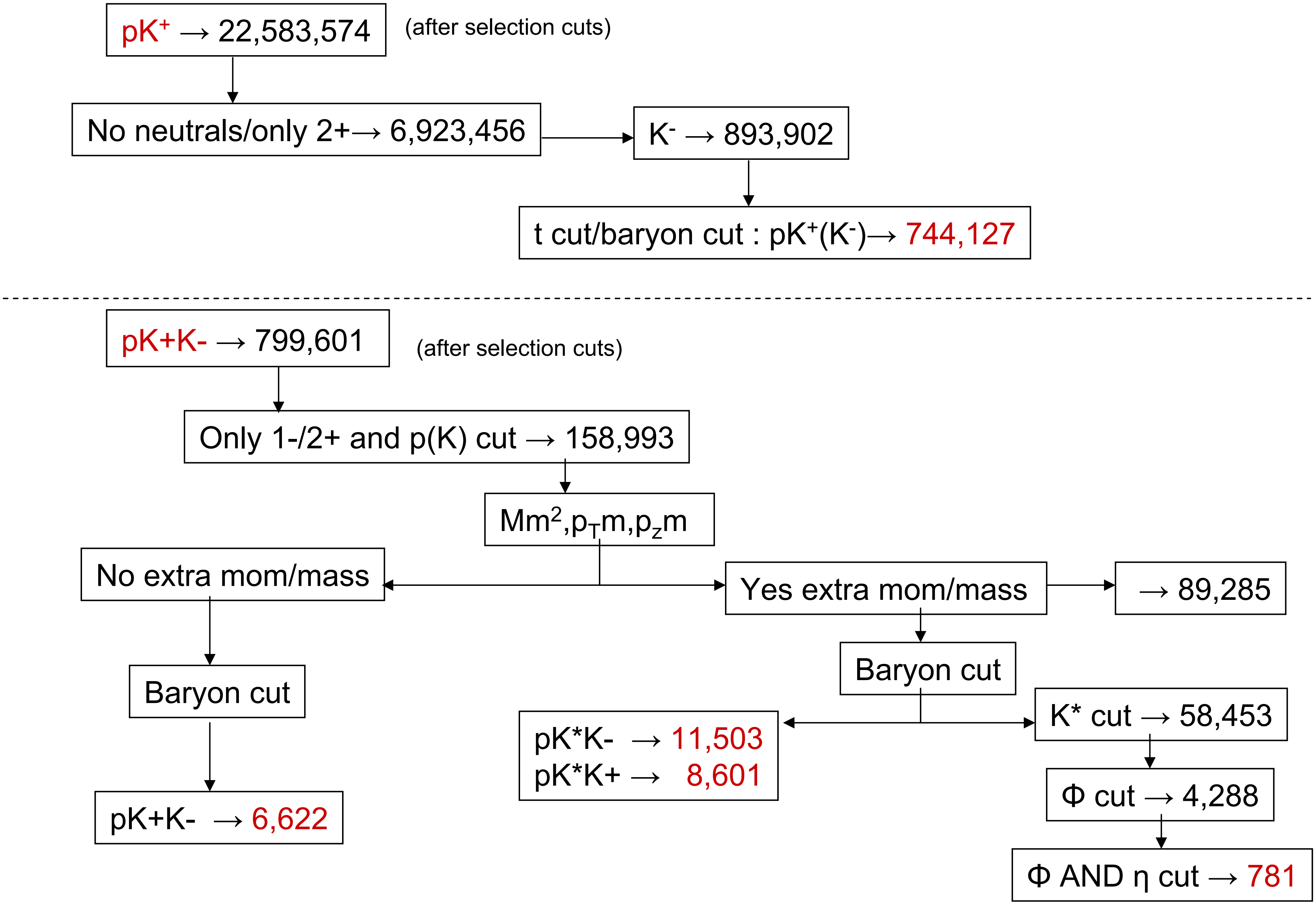
$-70<z_v<-110$ cm

→ **Particle Timing**

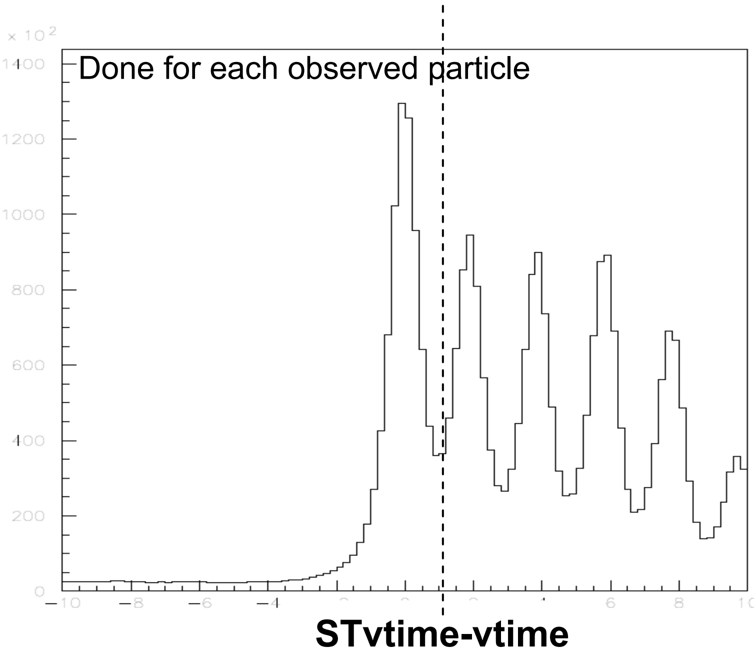
$|STVtime-Vtime|_K < 1$ ns

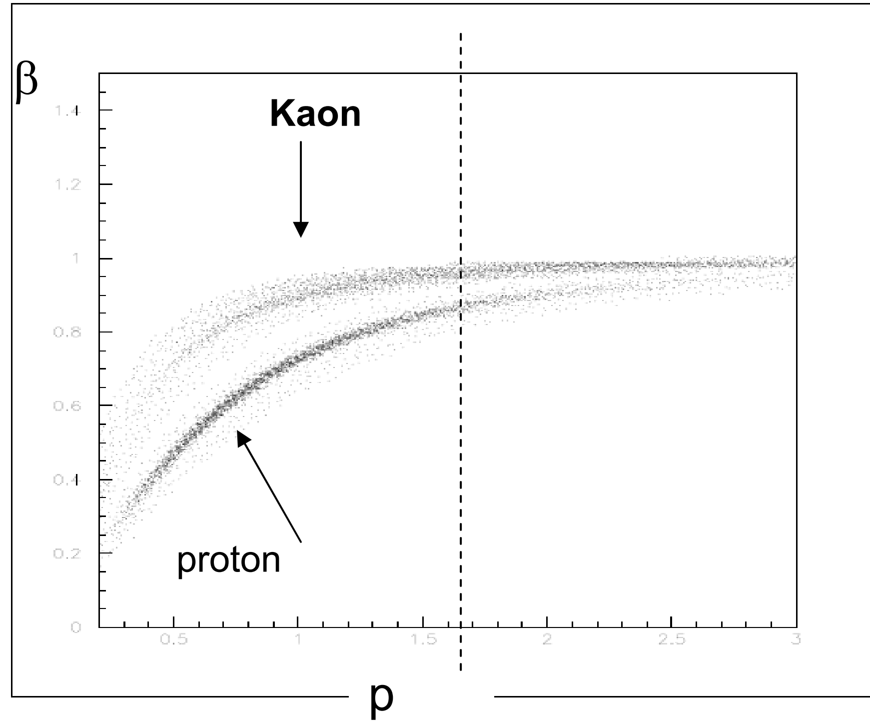
$|STVtime-Vtime|_p < 1$ ns

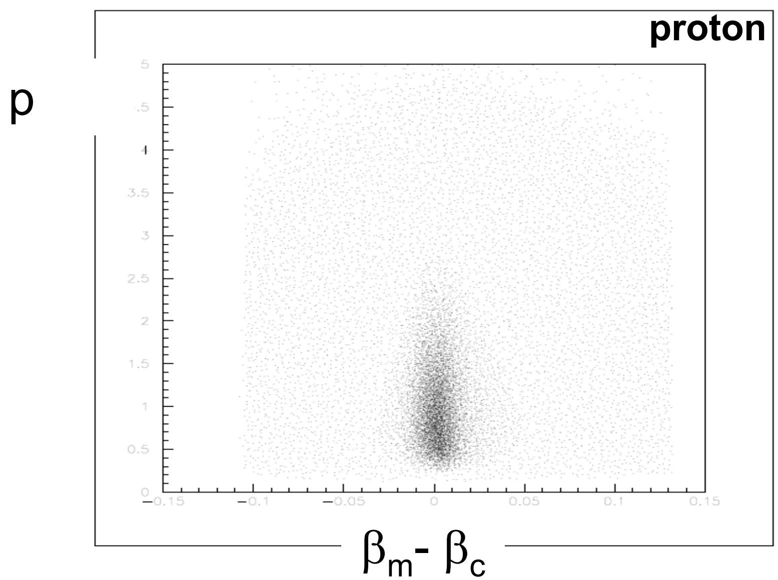
Event counting (all g12 data)

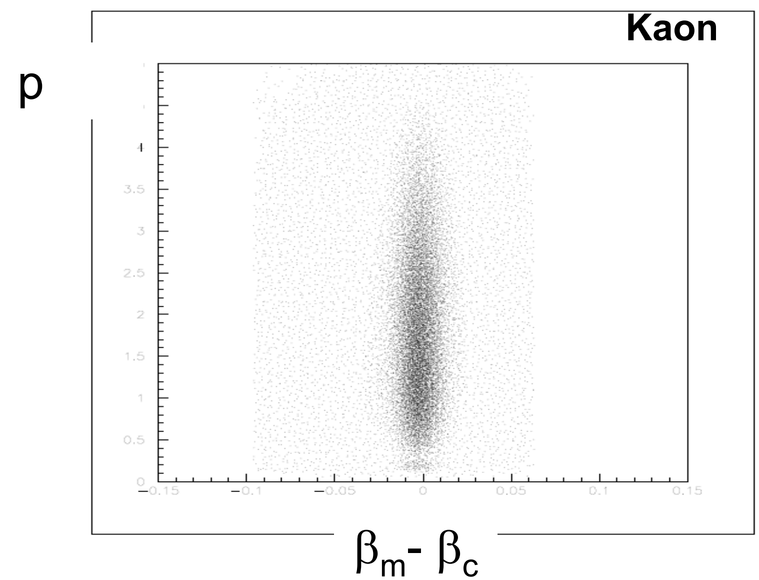


Kaon selection



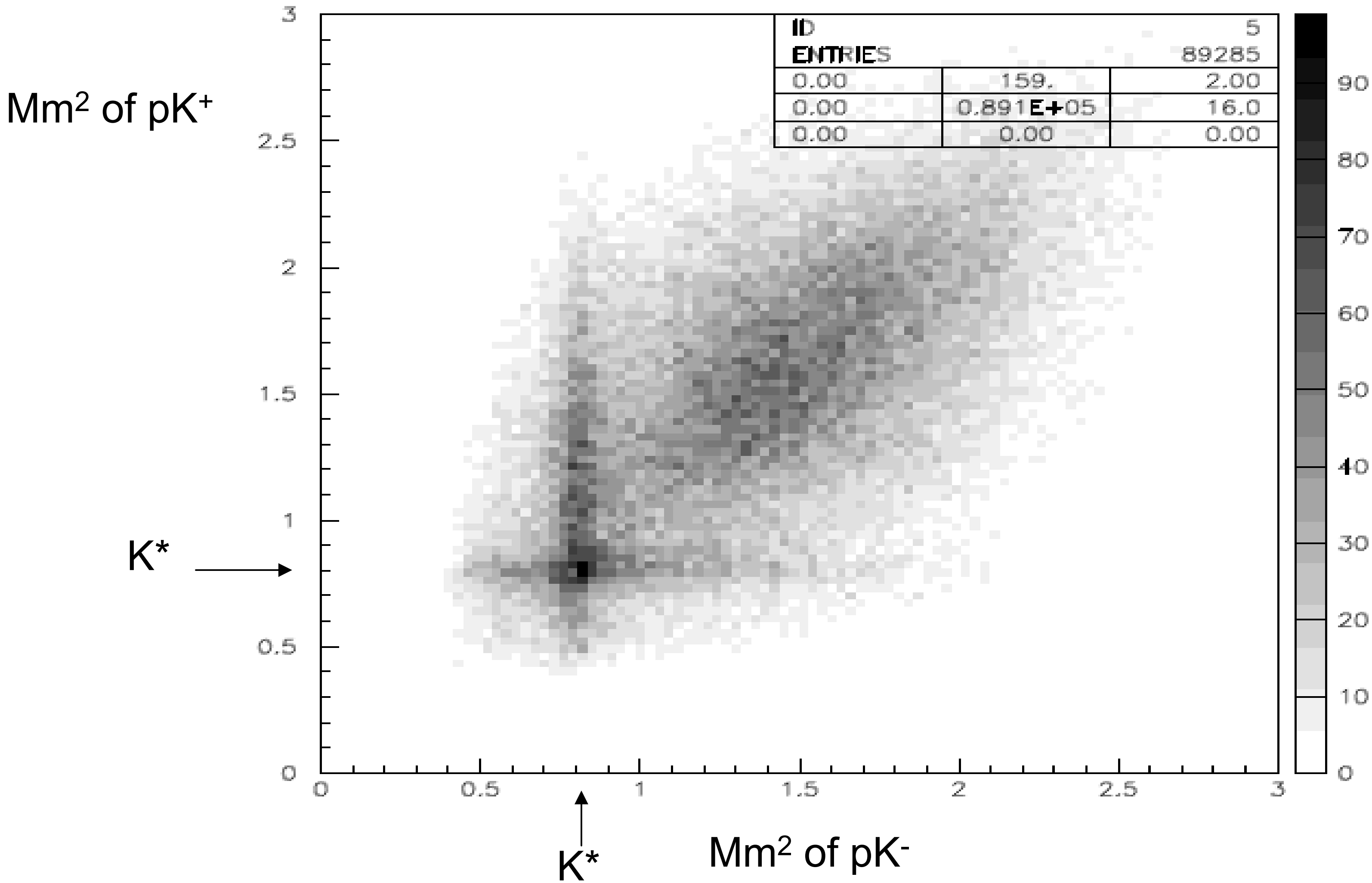


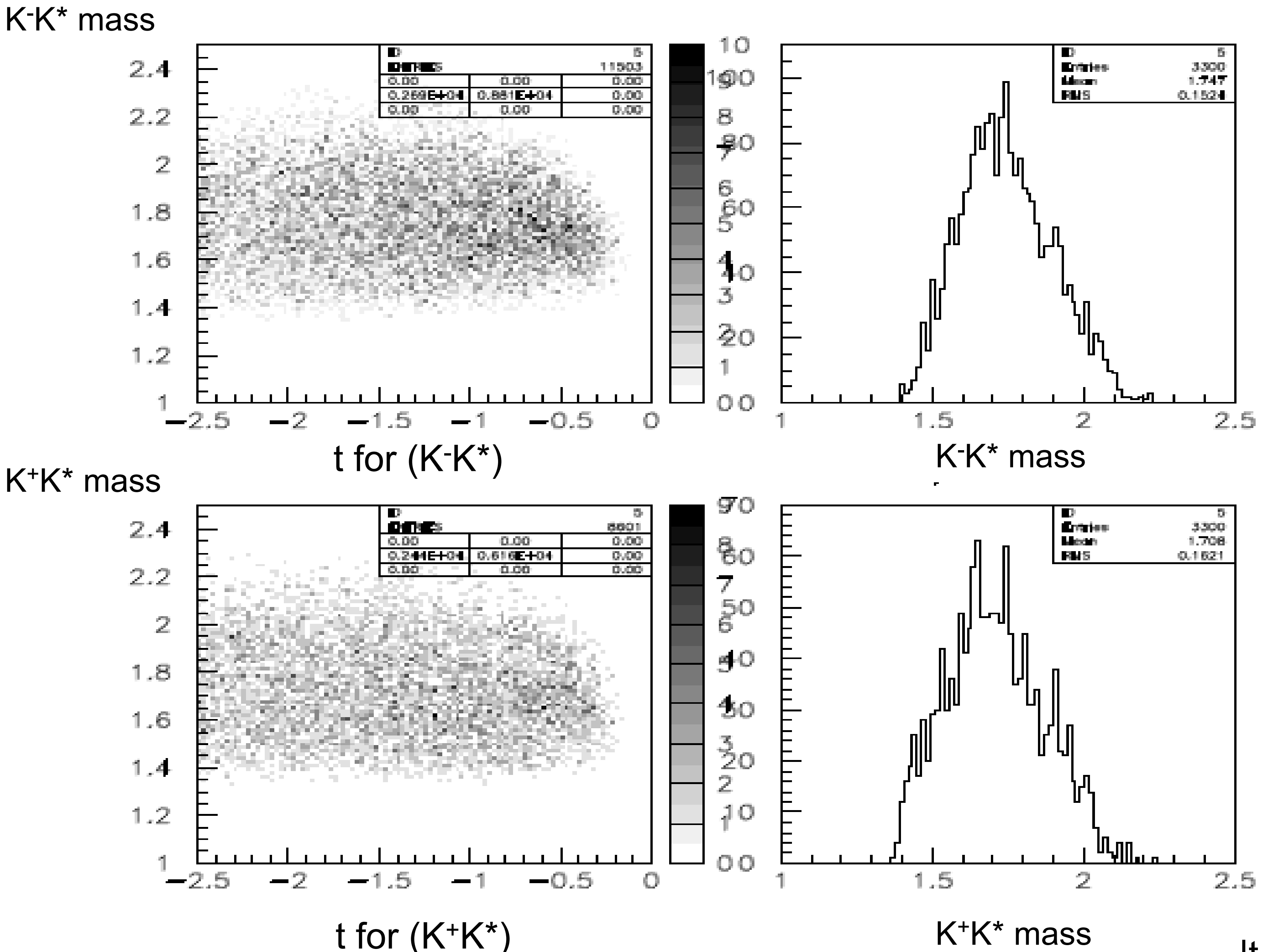




pK±(K*) $\gamma p \to pK^{\pm}K^{*\mp} \to pK^{\pm}K^{\mp}\pi^{0}$

(PK+K- observed)

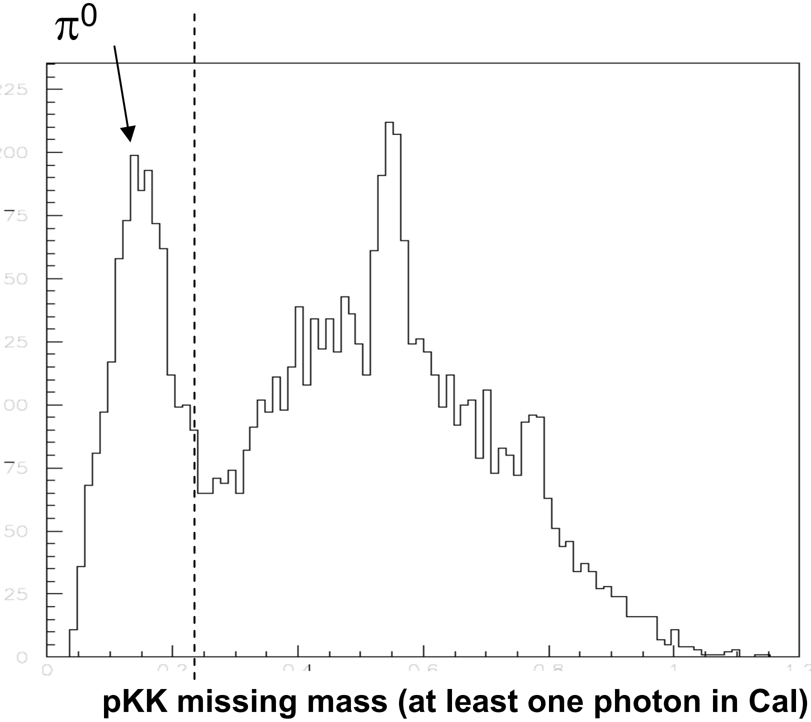


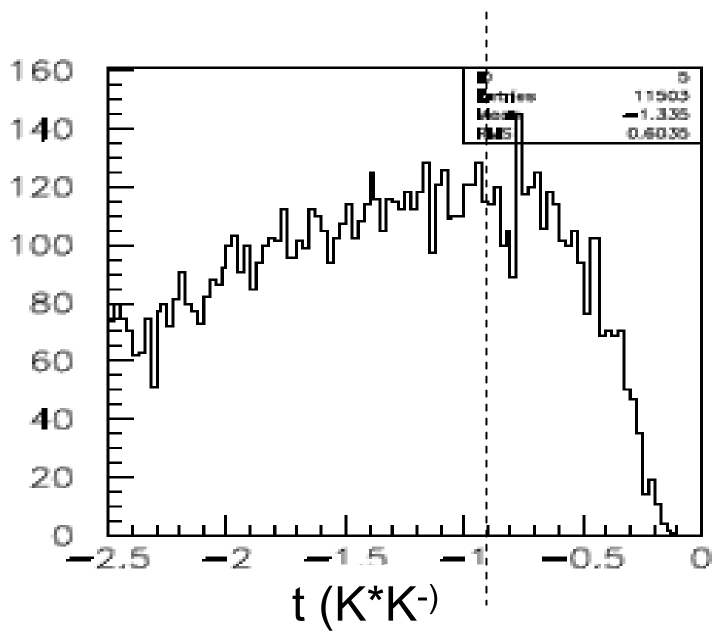


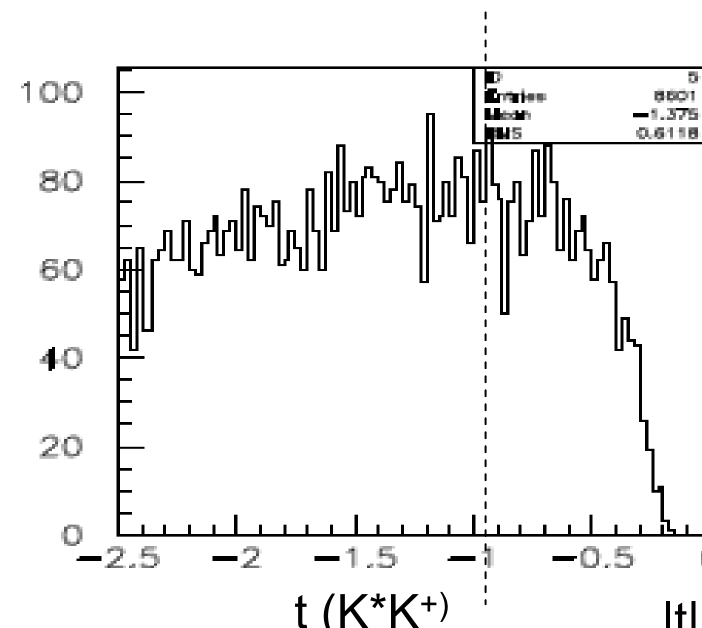
K-K* mass
t for (K-K*)
K-K* mass
Entries 3300
Mean 1.747
RMS 0.1524
K+K* mass
t for (K+K*)
K+K* mass
Entries 3300
Mean 1.708
RMS 0.1621

|t|<0.9

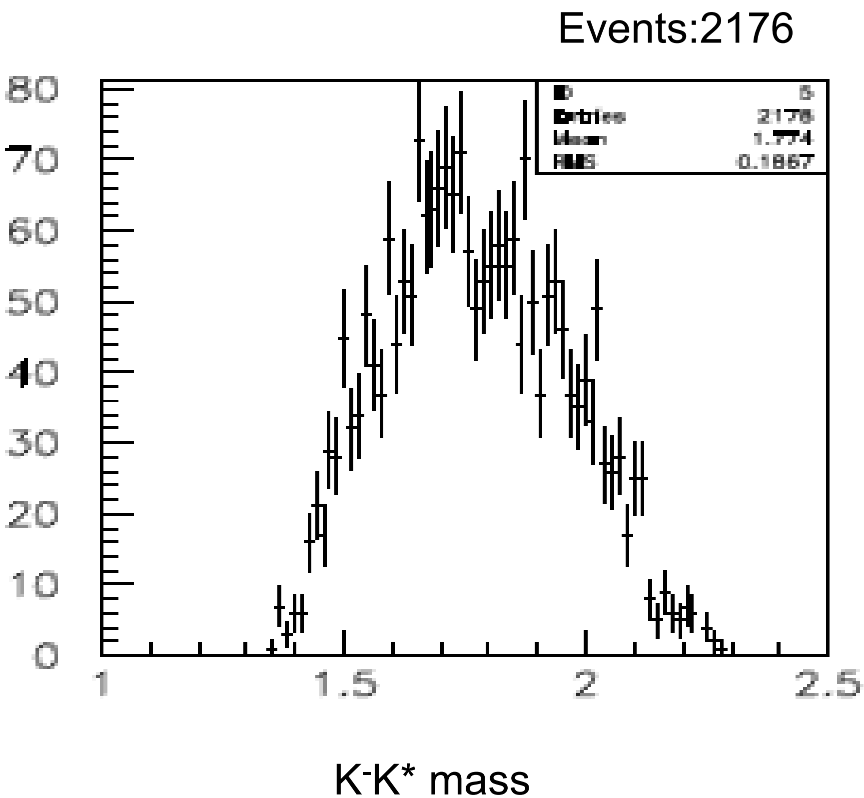
K* with a π^0

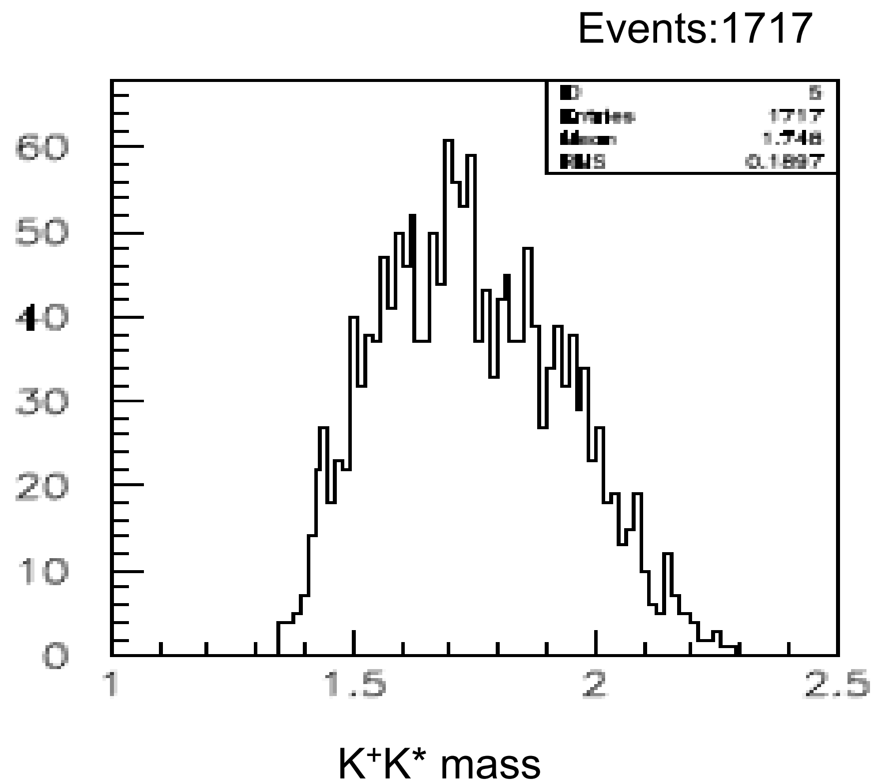






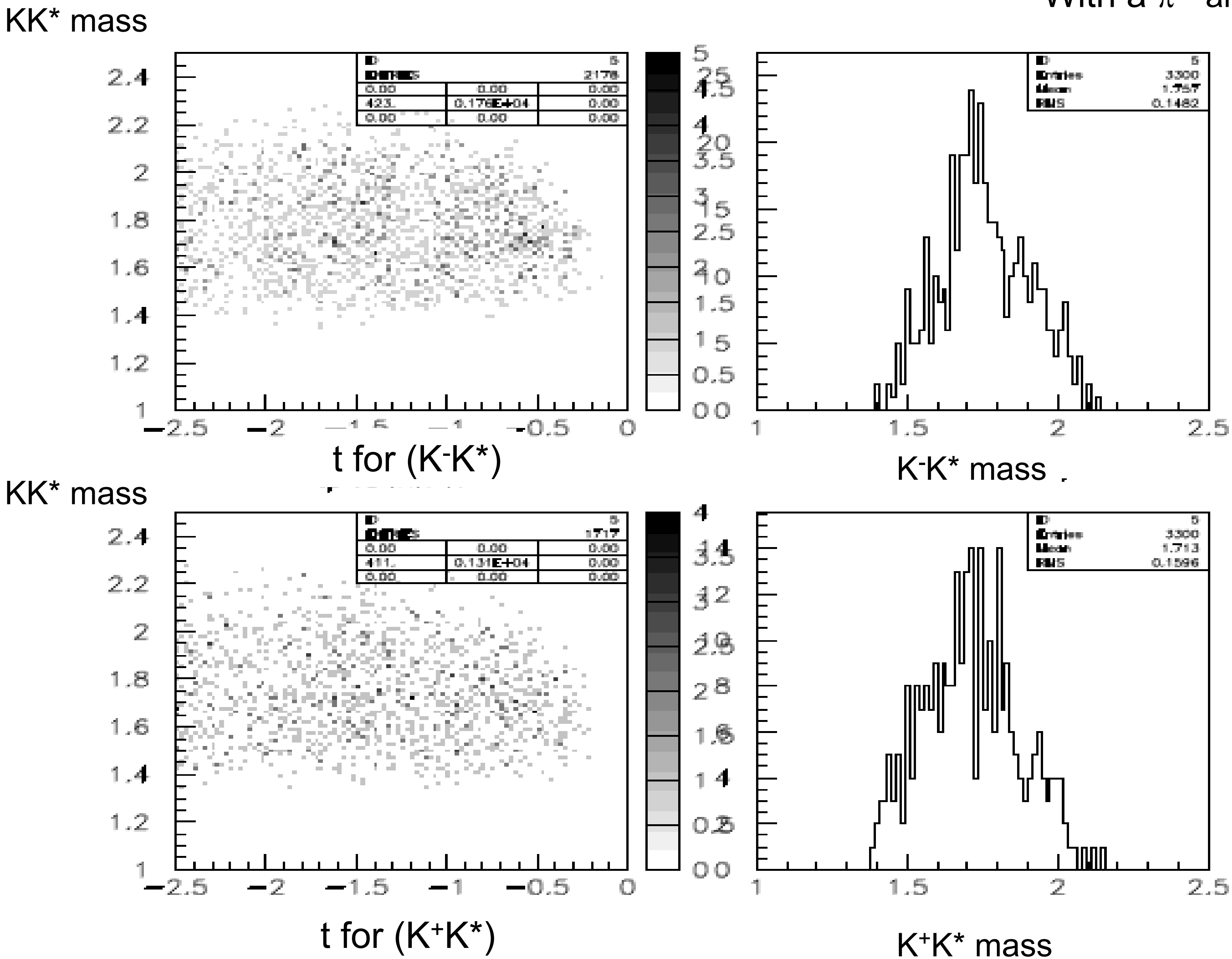
|t|<0.9



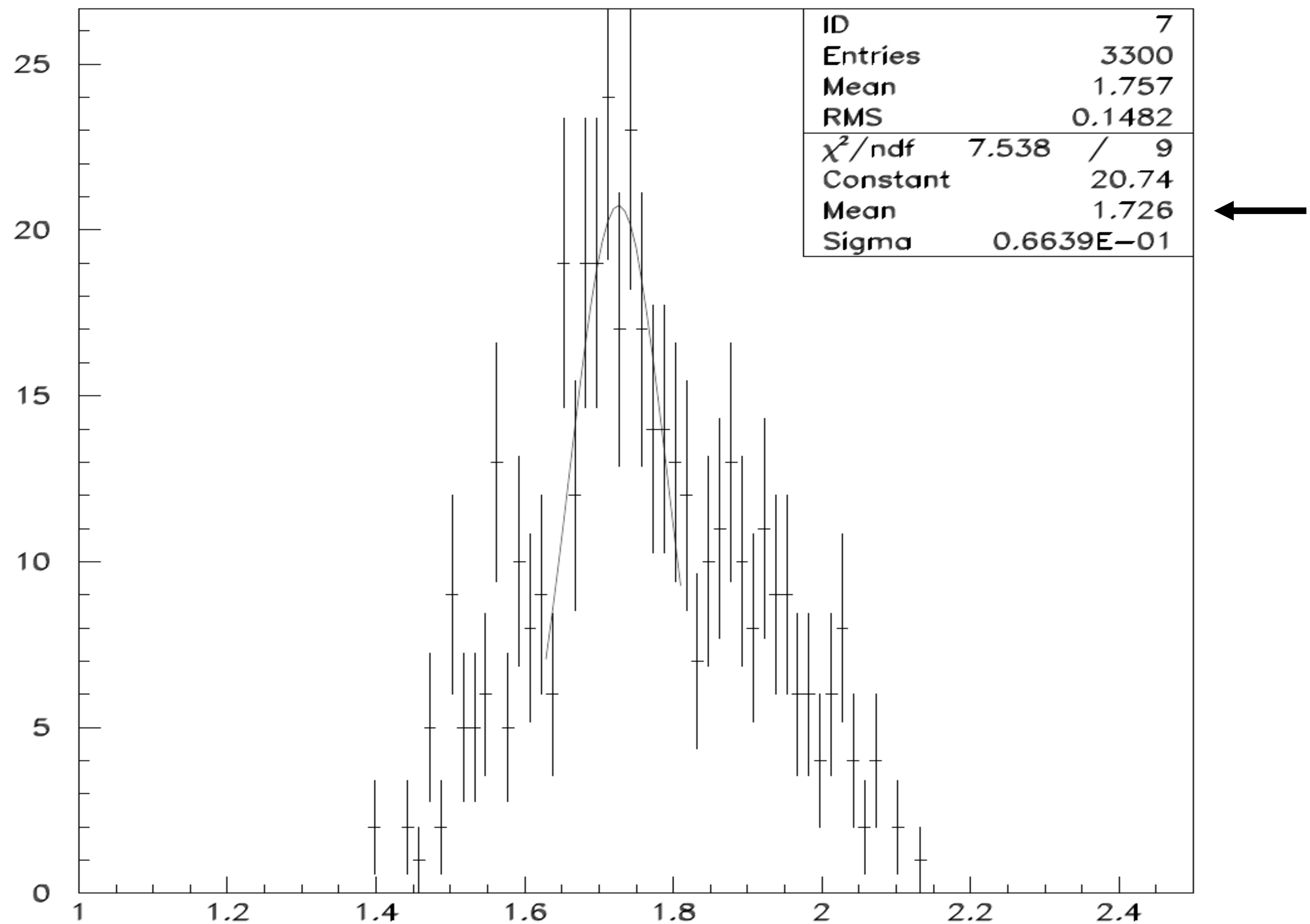


(no t cut, π^0 cut)

With a π^0 and |t|<0.9



See next slide

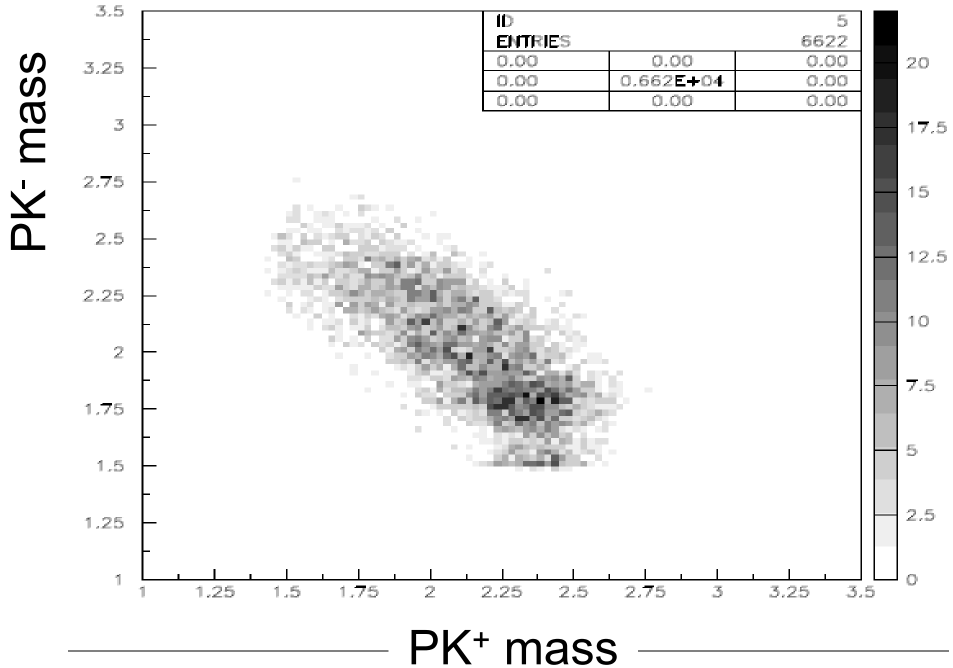

ID 7
Entries 3300
Mean 1.757
RMS 0.1482
χ²/ndf 7.538 / 9
Constant 20.74
Mean 1.726
Sigma 0.6639E−01
0
5
10
15
20
25
1
1.2
1.4
1.6
1.8
2
2.2
2.4

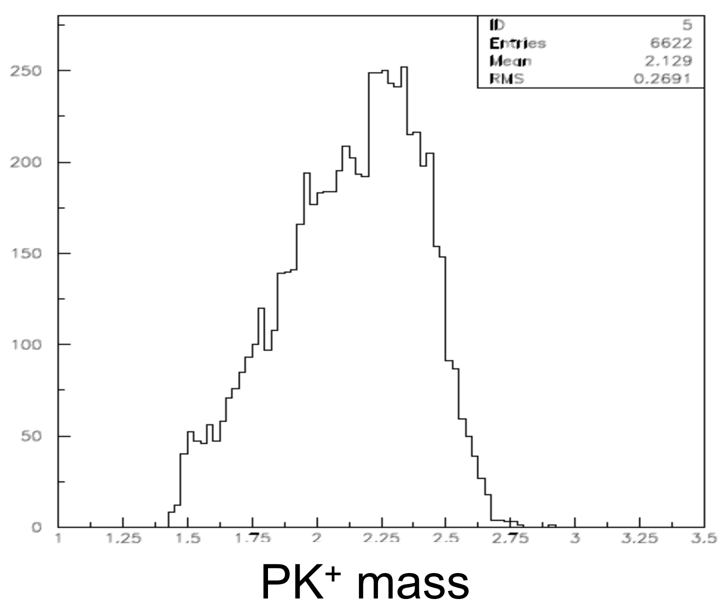
K⁻K* mass

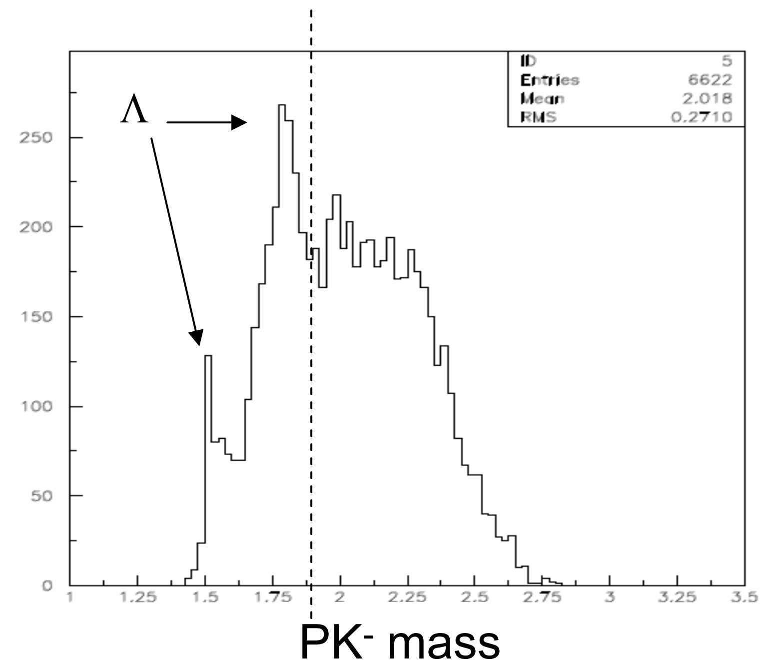
pK⁺K⁻

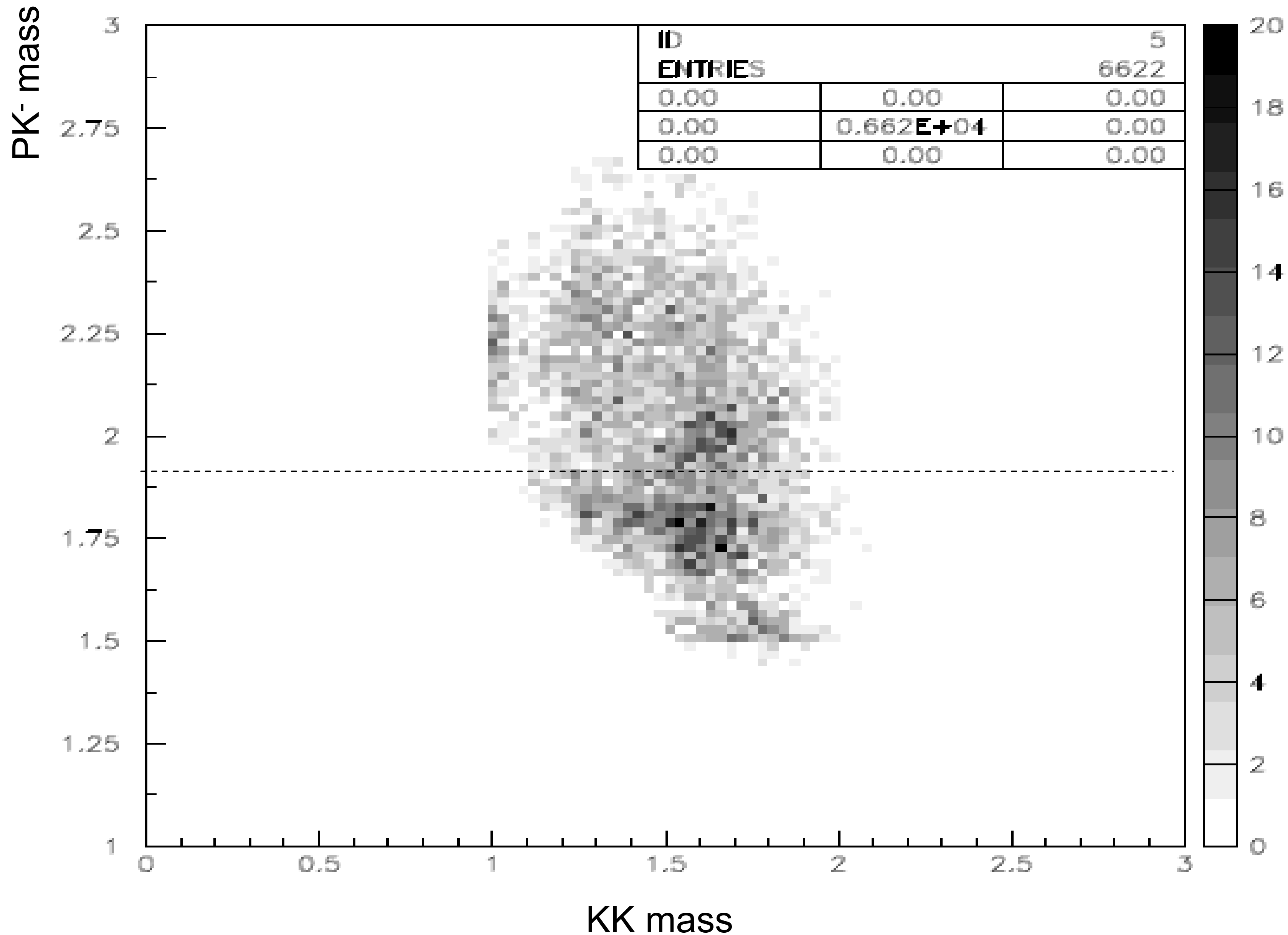
(PK⁺K⁻ observed)

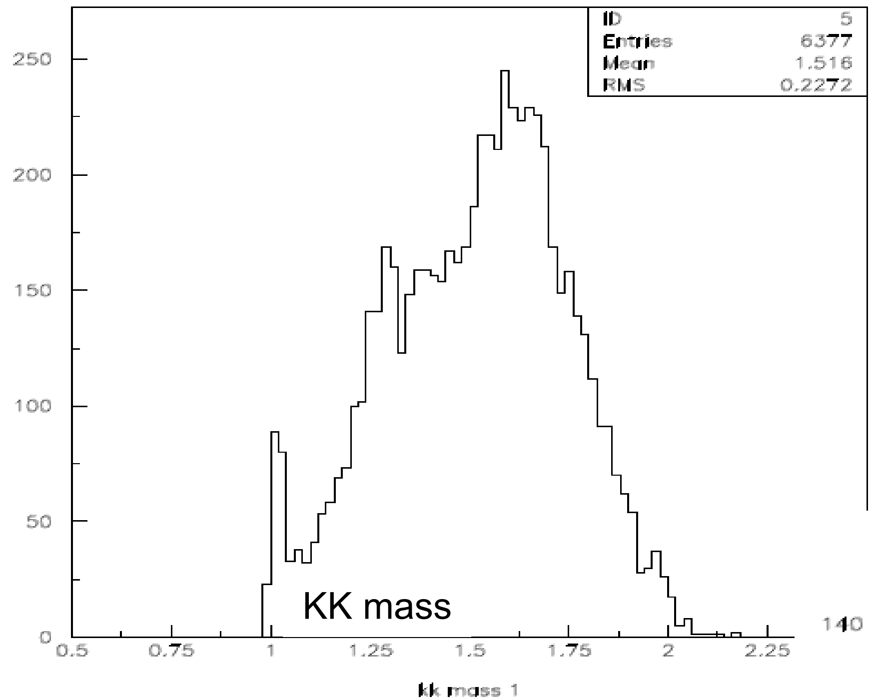
$$\gamma p \to p K^+ K^-$$



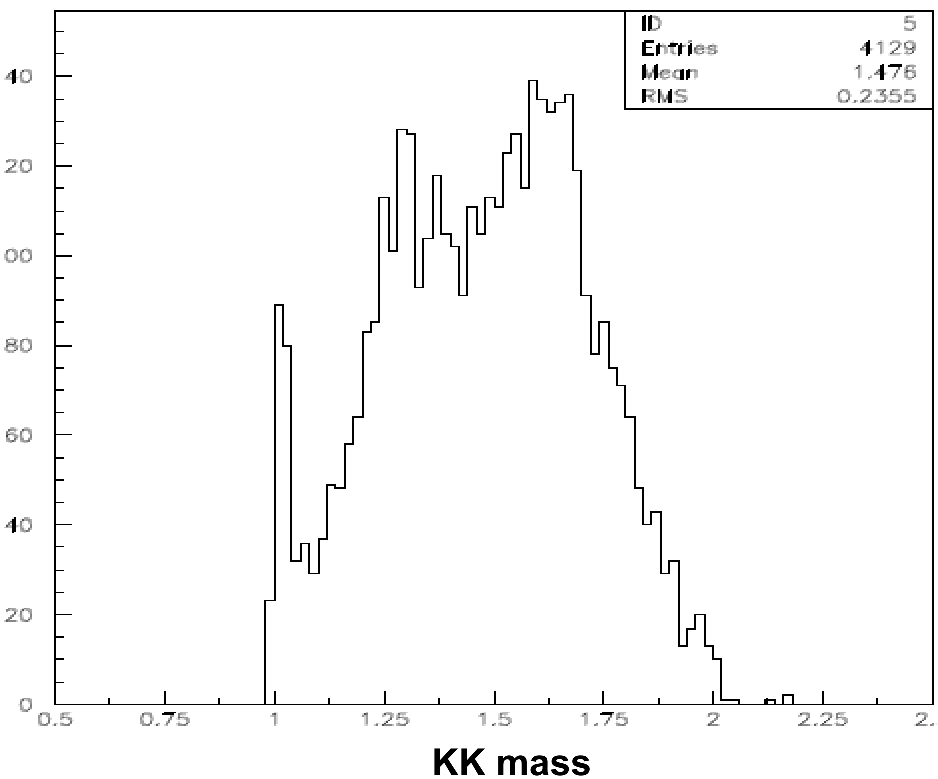





PK- mass
KK mass
ID 5
ENTRIES 6622
0.00 0.00 0.00
0.00 0.662E+04 0.00
0.00 0.00 0.00
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
0
0.5
1
1.5
2
2.5
3
0
2
4
6
8
10
12
14
16
18
20



Baryon cut - m(pK$^-$)>2 GeV



Moments Of KK

$$H_x(LM) = \sum_i^n D^L_{M0}(\phi_i, \theta_i, 0)$$

→

$$H(00) = S_0^2 + P_0^2 + P_-^2 + D_0^2 + D_-^2 + P_+^2 + D_+^2$$

$$H(10) = \frac{1}{\sqrt{3}}S_0P_0 + \frac{2}{\sqrt{15}}P_0D_0 + \frac{1}{\sqrt{5}}(P_-D_- + P_+D_+)$$

$$H(11) = \frac{1}{\sqrt{6}}S_0P_- + \frac{1}{\sqrt{10}}P_0D_- - \frac{1}{\sqrt{30}}P_-D_0$$

$$H(20) = \frac{1}{\sqrt{5}}S_0D_0 + \frac{2}{5}P_0^2 - \frac{1}{5}(P_-^2 + P_+^2) + \frac{2}{7}D_0^2 + \frac{1}{7}(D_-^2 + D_+^2)$$

$$H(21) = \frac{1}{\sqrt{10}}S_0D_- + \frac{1}{5}\sqrt{\frac{3}{2}}P_0P_- + \frac{1}{7\sqrt{2}}D_0D_-$$

$$H(22) = \frac{1}{5}\sqrt{\frac{3}{2}}(P_-^2 - P_+^2) + \frac{1}{7}\sqrt{\frac{3}{2}}(D_-^2 - D_+^2)$$

$$H(30) = \frac{3}{7\sqrt{5}}(\sqrt{3}P_0D_0 - P_-D_- - P_+D_+)$$

$$H(31) = \frac{1}{7}\sqrt{\frac{3}{5}}(2P_0D_- + \sqrt{3}P_-D_0)$$

$$H(32) = \frac{1}{7}\sqrt{\frac{3}{2}}(P_-D_- - P_+D_+)$$

$$H(40) = \frac{2}{7}D_0^2 - \frac{4}{21}(D_-^2 + D_+^2)$$

$$H(41) = \frac{1}{7}\sqrt{\frac{5}{3}}D_0D_-$$

$$H(42) = \frac{\sqrt{10}}{21}(D_-^2 - D_+^2)$$

the partial waves $[\ell]$ are, for unnatural-parity exchange,

$$S_0, \quad P_0, \quad P_-, \quad D_0, \quad D_-$$

and, for natural-parity exchange,

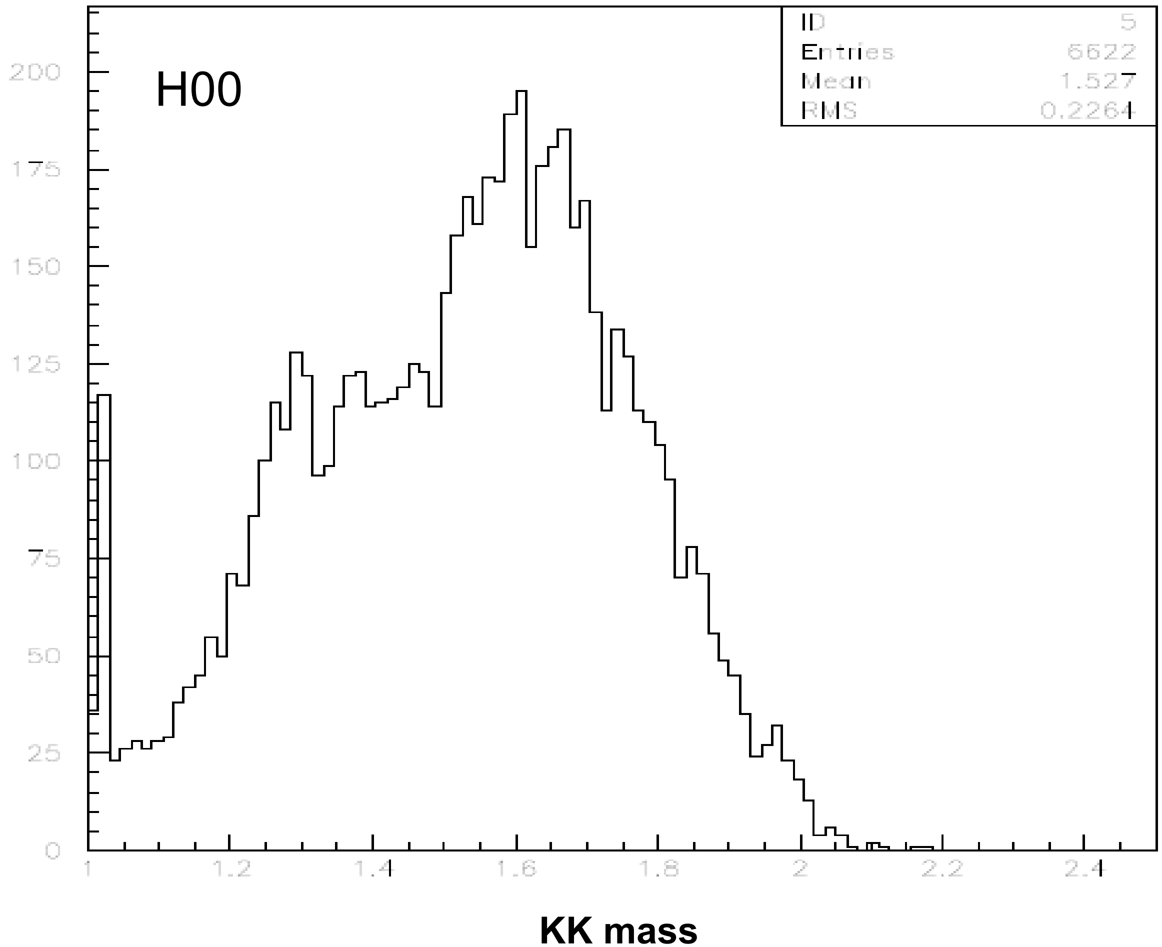
$$P_+, \quad D_+$$

From 852:ηπ analysis

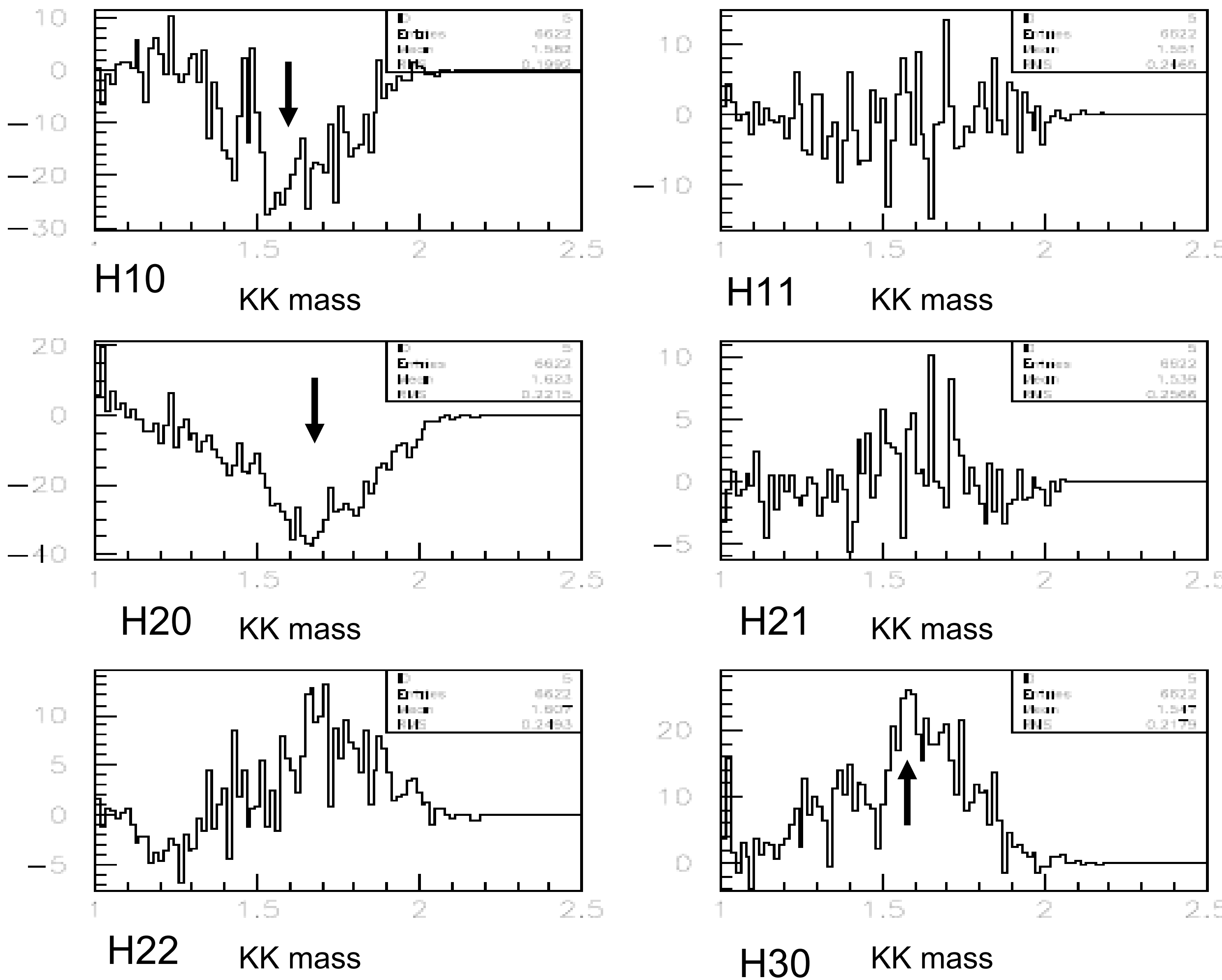
pK^+K^- sample

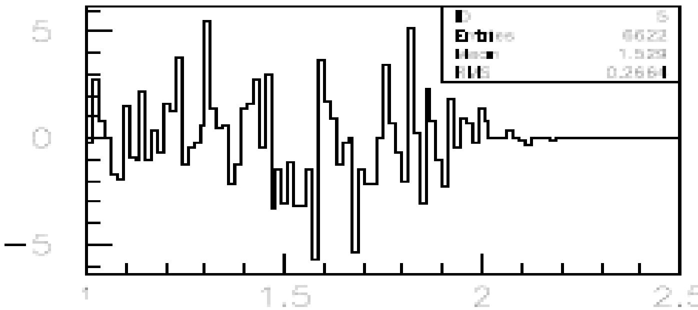
Events=6622

Adding |t|< 0.5

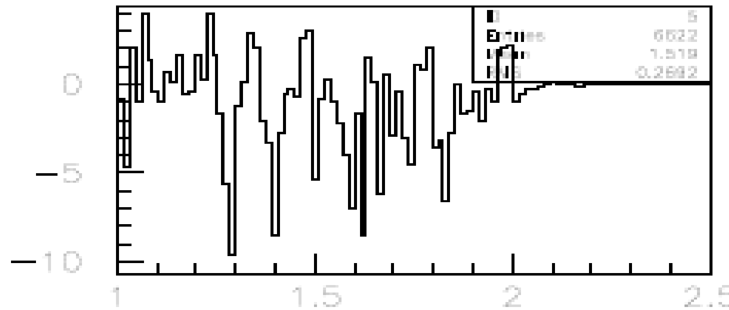


$f'_2(1525)$?

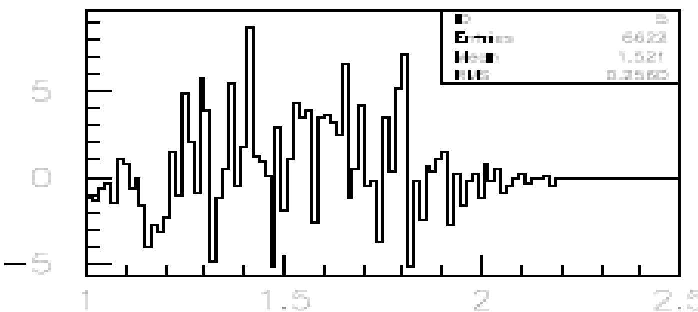

H10
KK mass
H11
KK mass
H20
KK mass
H21
KK mass
H22
KK mass
H30
KK mass



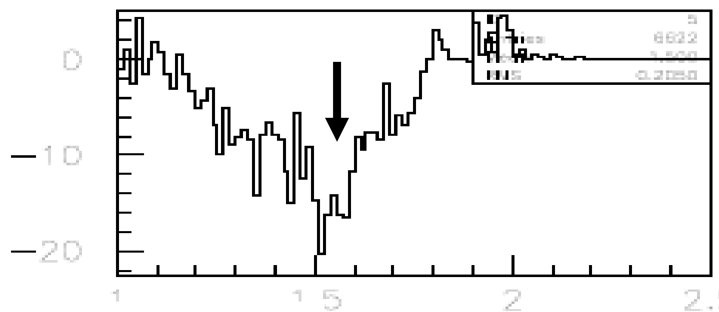
H31 KK mass



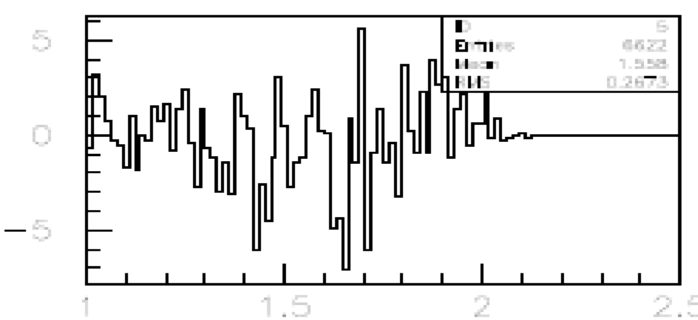
H32 KK mass



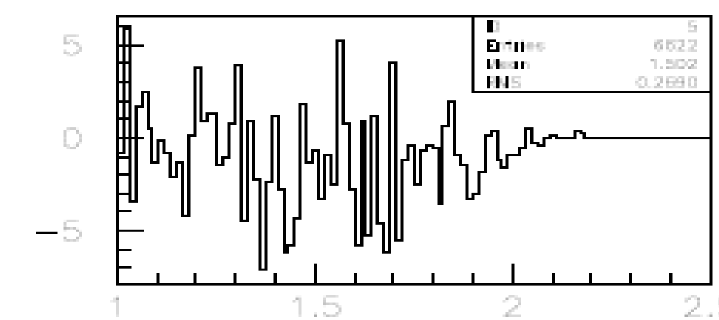
H33 KK mass



H40 KK mass



H41 KK mass

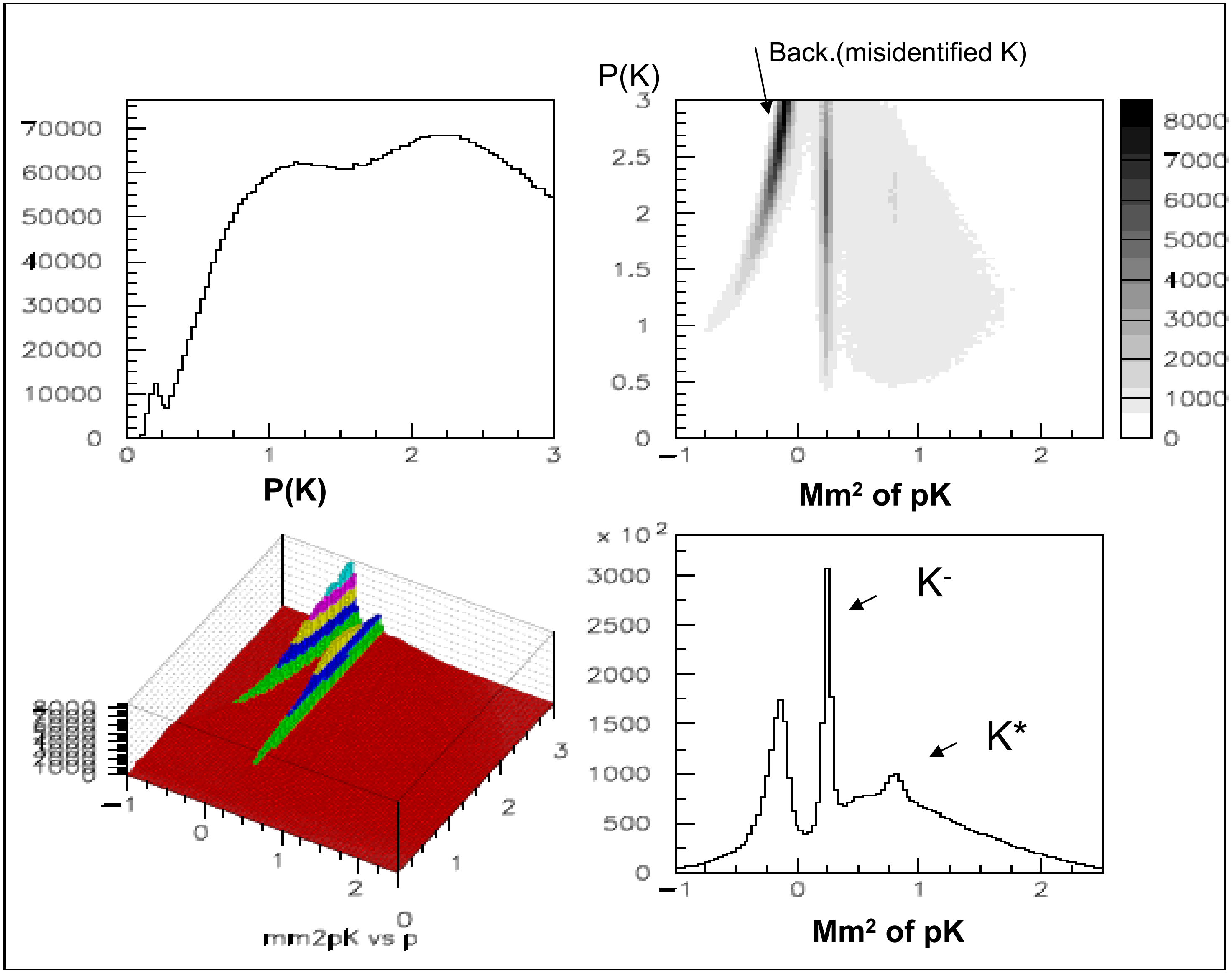


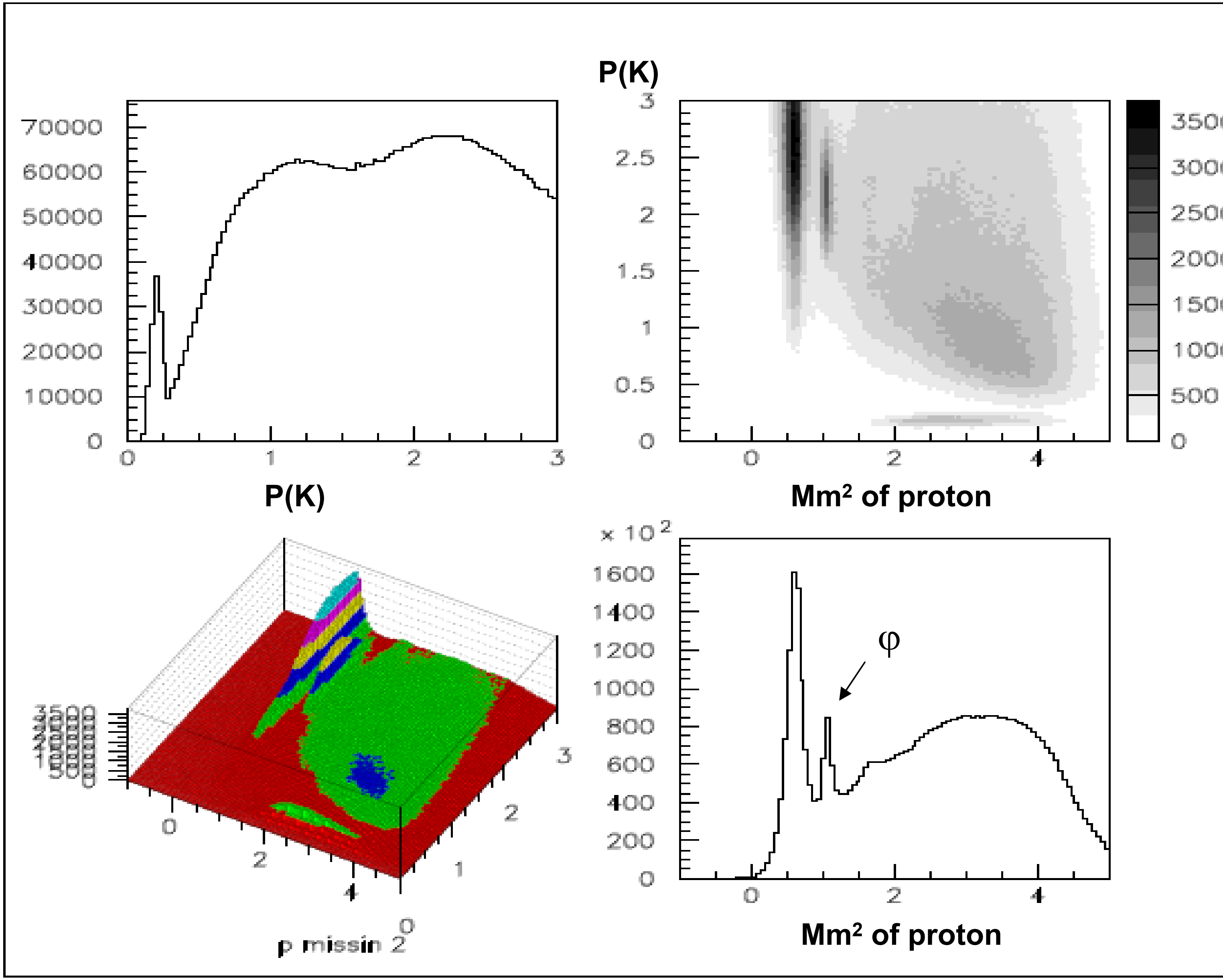
H42 KK mass

pK+(K-)

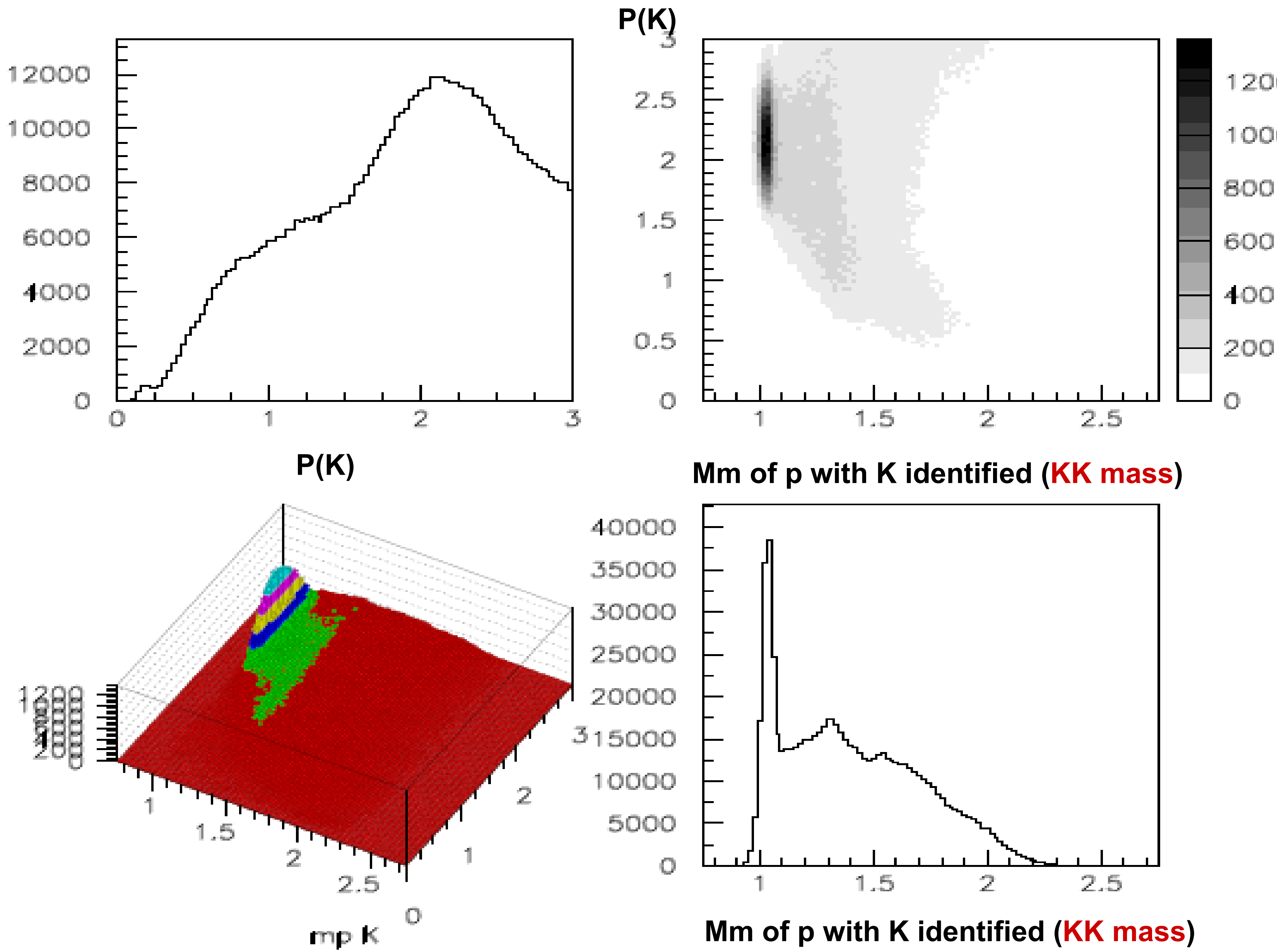
(pK+ observed)

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

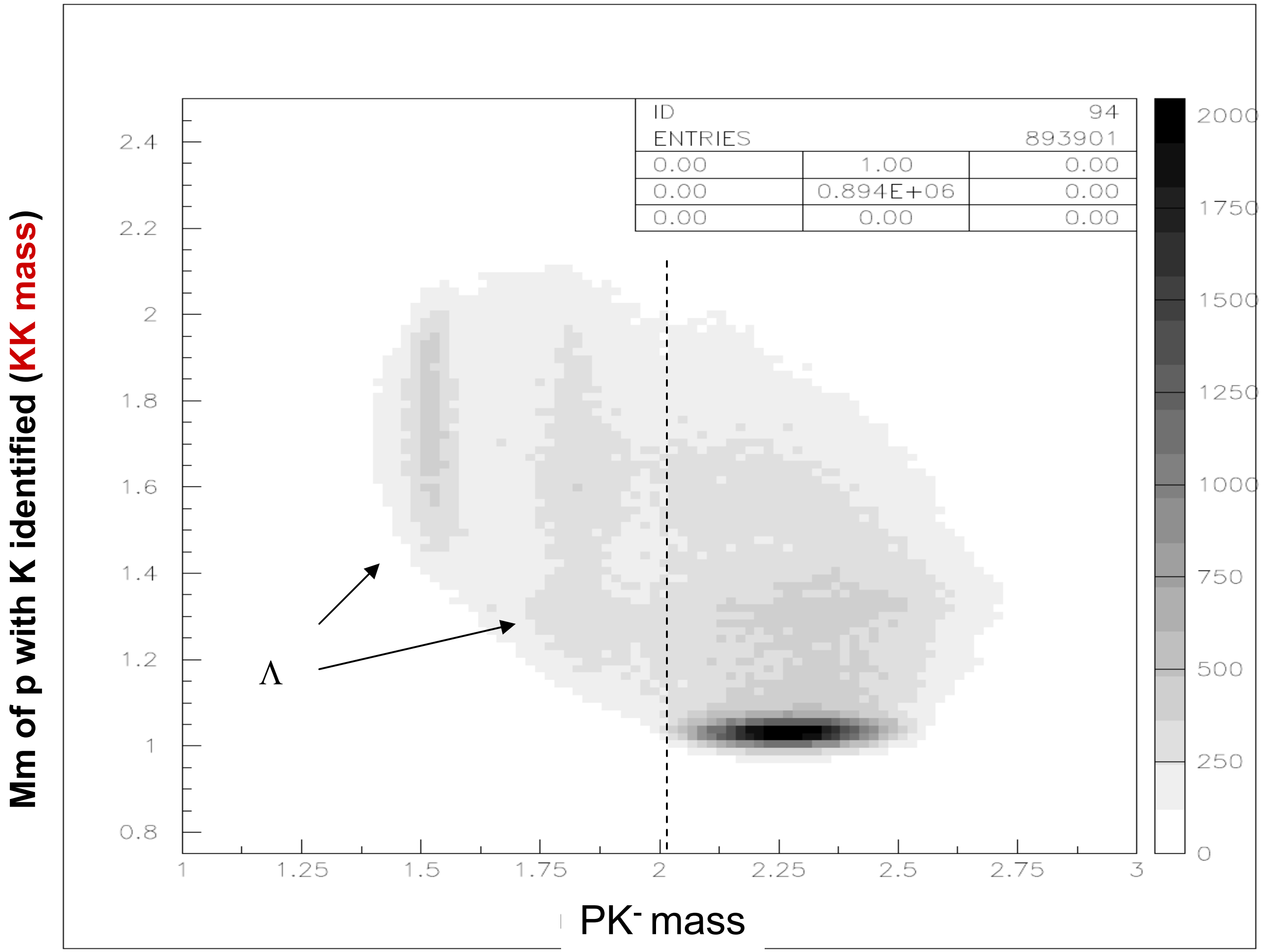




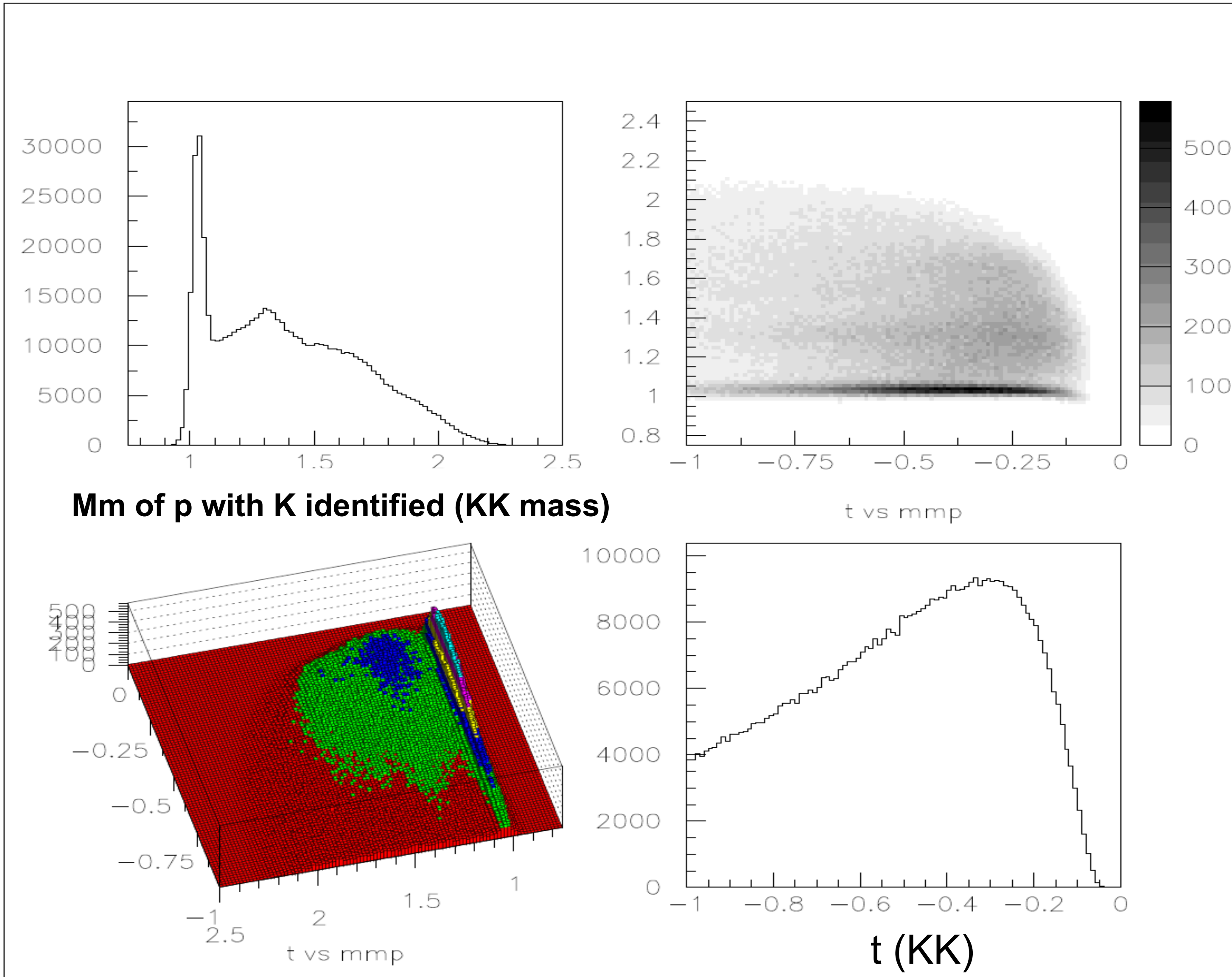
P(K)
Mm² of proton
P(K)
φ
Mm² of proton
p missin 2
× 10²



P(K)
Mm of p with K identified (KK mass)
P(K)
mp K
Mm of p with K identified (KK mass)



Baryon cut: m(PK-)>2 GeV)


Mm of p with K identified (KK mass)
t vs mmp
t vs mmp
t (KK)
30000
25000
20000
15000
10000
5000
0
1
1.5
2
2.5
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
−1
−0.75
−0.5
−0.25
0
500
400
300
200
100
0
10000
8000
6000
4000
2000
0
−1
−0.8
−0.6
−0.4
−0.2
0

t cut: |t|<0.4

Moments Of KK

$$H_x(LM) = \sum_i^n D^L_{M0}(\phi_i, \theta_i, 0)$$

the partial waves $[\ell]$ are, for unnatural-parity exchange,

$$S_0, \quad P_0, \quad P_-, \quad D_0, \quad D_-$$

and, for natural-parity exchange,

$$P_+, \quad D_+$$

→

$$H(00) = S_0^2 + P_0^2 + P_-^2 + D_0^2 + D_-^2 + P_+^2 + D_+^2$$

$$H(10) = \frac{1}{\sqrt{3}} S_0 P_0 + \frac{2}{\sqrt{15}} P_0 D_0 + \frac{1}{\sqrt{5}} (P_- D_- + P_+ D_+)$$

$$H(11) = \frac{1}{\sqrt{6}} S_0 P_- + \frac{1}{\sqrt{10}} P_0 D_- - \frac{1}{\sqrt{30}} P_- D_0$$

$$H(20) = \frac{1}{\sqrt{5}} S_0 D_0 + \frac{2}{5} P_0^2 - \frac{1}{5}(P_-^2 + P_+^2) + \frac{2}{7} D_0^2 + \frac{1}{7}(D_-^2 + D_+^2)$$

$$H(21) = \frac{1}{\sqrt{10}} S_0 D_- + \frac{1}{5}\sqrt{\frac{3}{2}} P_0 P_- + \frac{1}{7\sqrt{2}} D_0 D_-$$

$$H(22) = \frac{1}{5}\sqrt{\frac{3}{2}}(P_-^2 - P_+^2) + \frac{1}{7}\sqrt{\frac{3}{2}}(D_-^2 - D_+^2)$$

$$H(30) = \frac{3}{7\sqrt{5}}(\sqrt{3} P_0 D_0 - P_- D_- - P_+ D_+)$$

$$H(31) = \frac{1}{7}\sqrt{\frac{3}{5}}(2 P_0 D_- + \sqrt{3} P_- D_0)$$

$$H(32) = \frac{1}{7}\sqrt{\frac{3}{2}}(P_- D_- - P_+ D_+)$$

$$H(40) = \frac{2}{7} D_0^2 - \frac{4}{21}(D_-^2 + D_+^2)$$

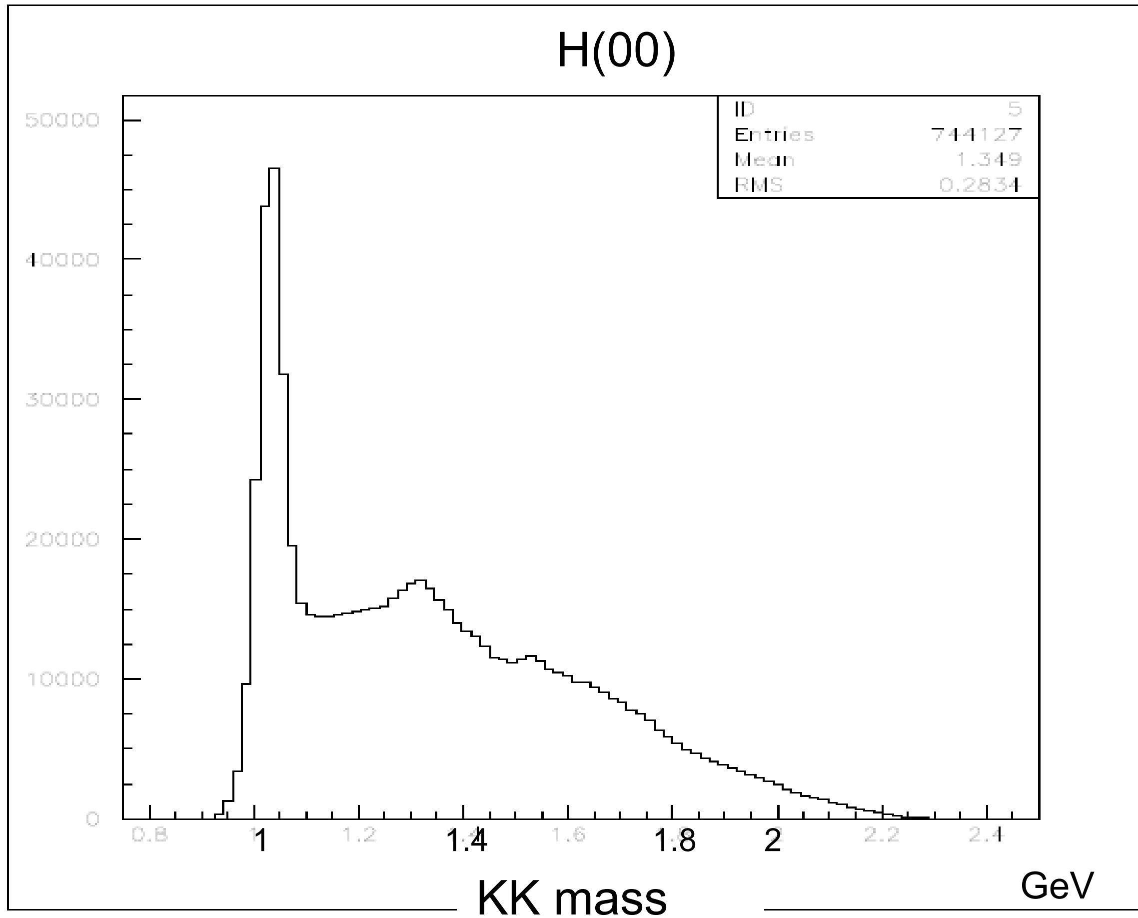
$$H(41) = \frac{1}{7}\sqrt{\frac{5}{3}} D_0 D_-$$

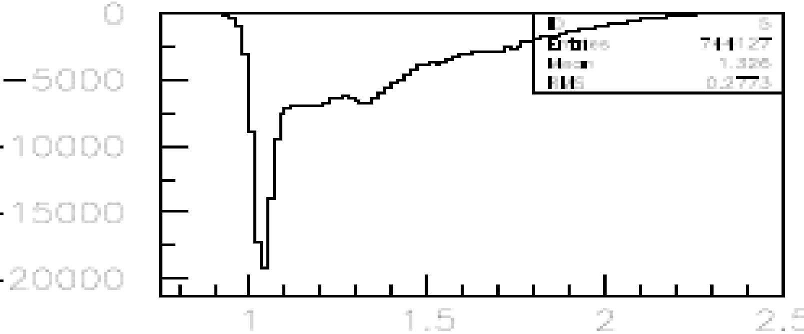
$$H(42) = \frac{\sqrt{10}}{21}(D_-^2 - D_+^2)$$

$pK^+(K^-)$ sample

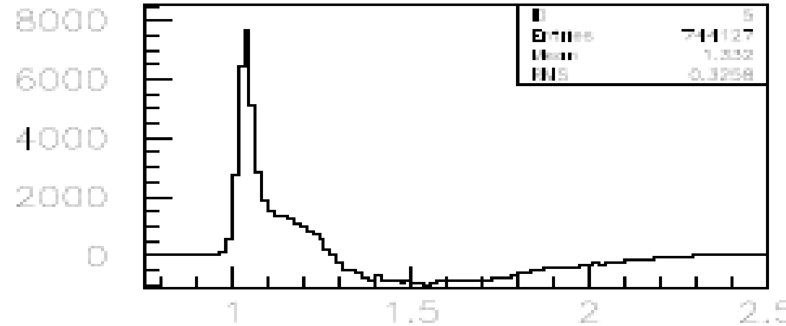
Events=744,127

With baryon and t cut





H(10)



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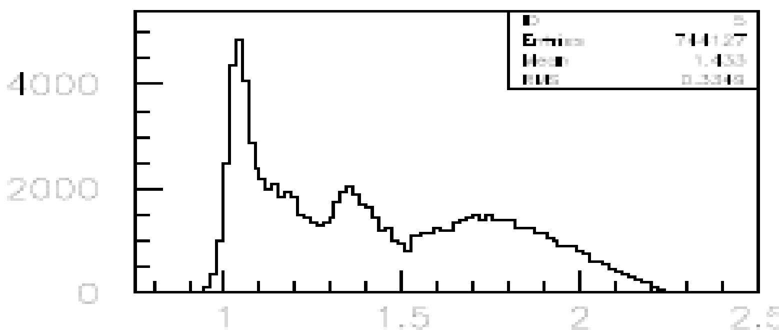

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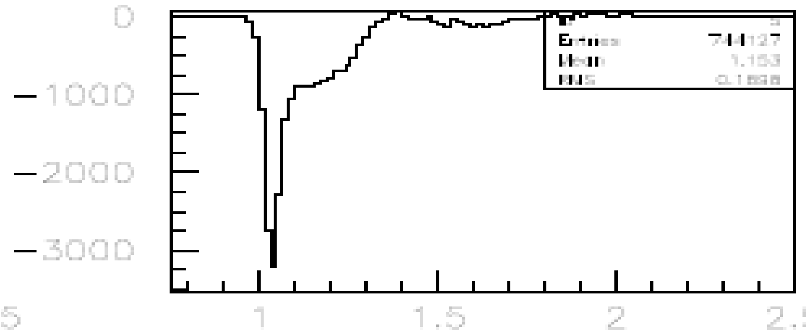

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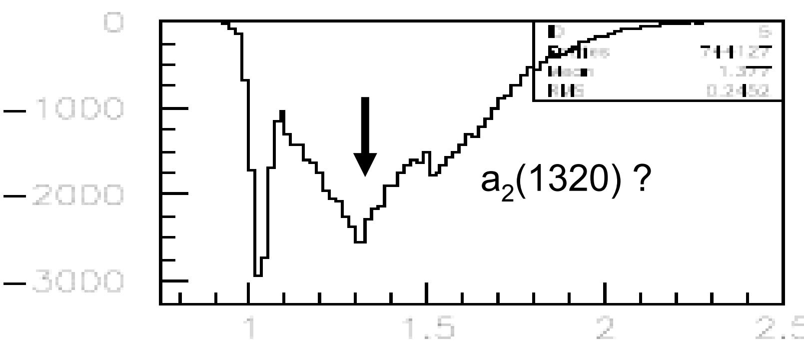

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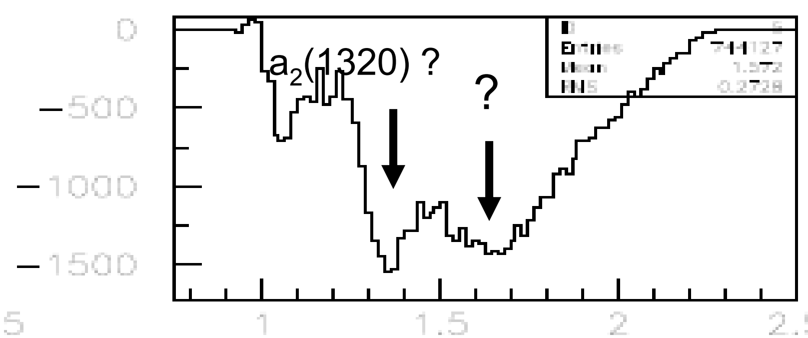
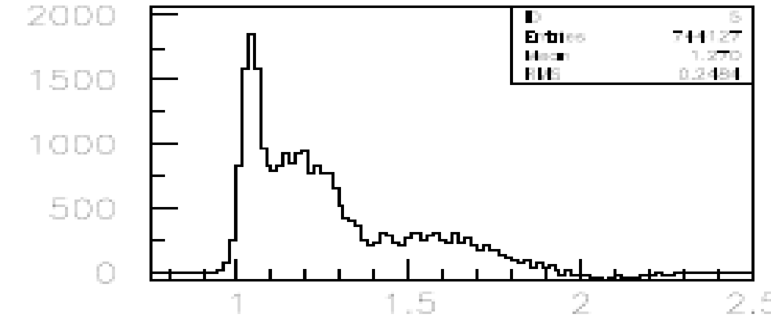
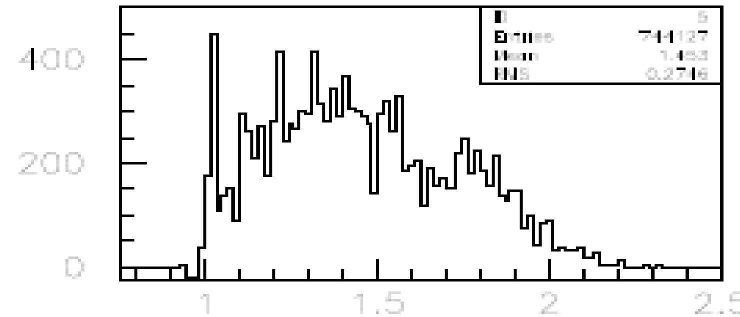


H(30)



H(31)



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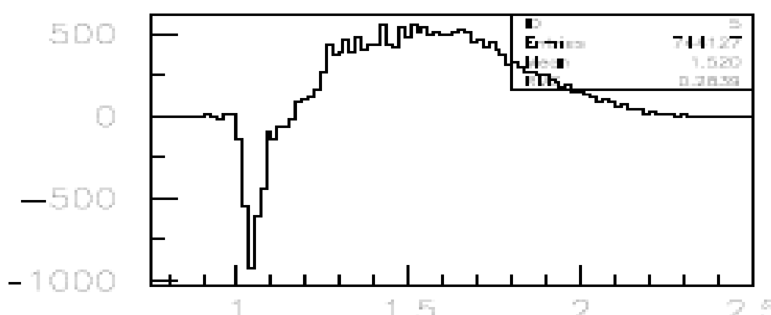
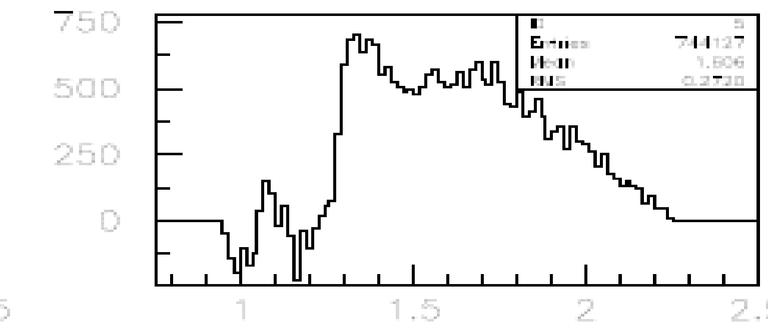
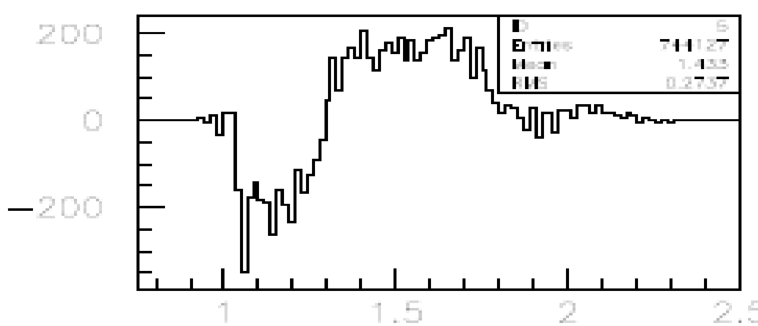


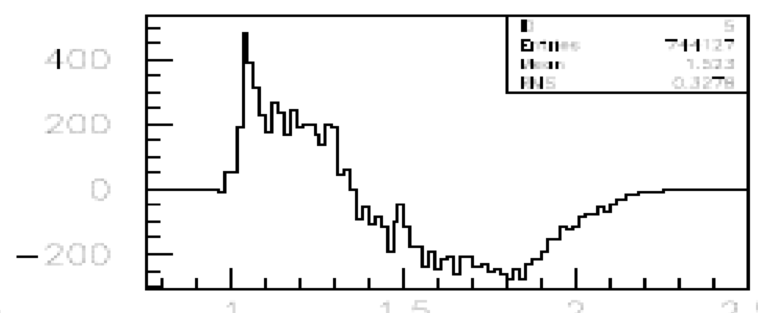
H(33)



H(40)



H(41)



H(42)

Next:

- Tune/relax selection cuts
- Look at pK^- and KK topologies
- start PWA