Electroproduction of Kaons and Light Hypernuclei on ^{3}He and ^{4}He

Jefferson Lab(E91016)Collaboration

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MOTIVATION

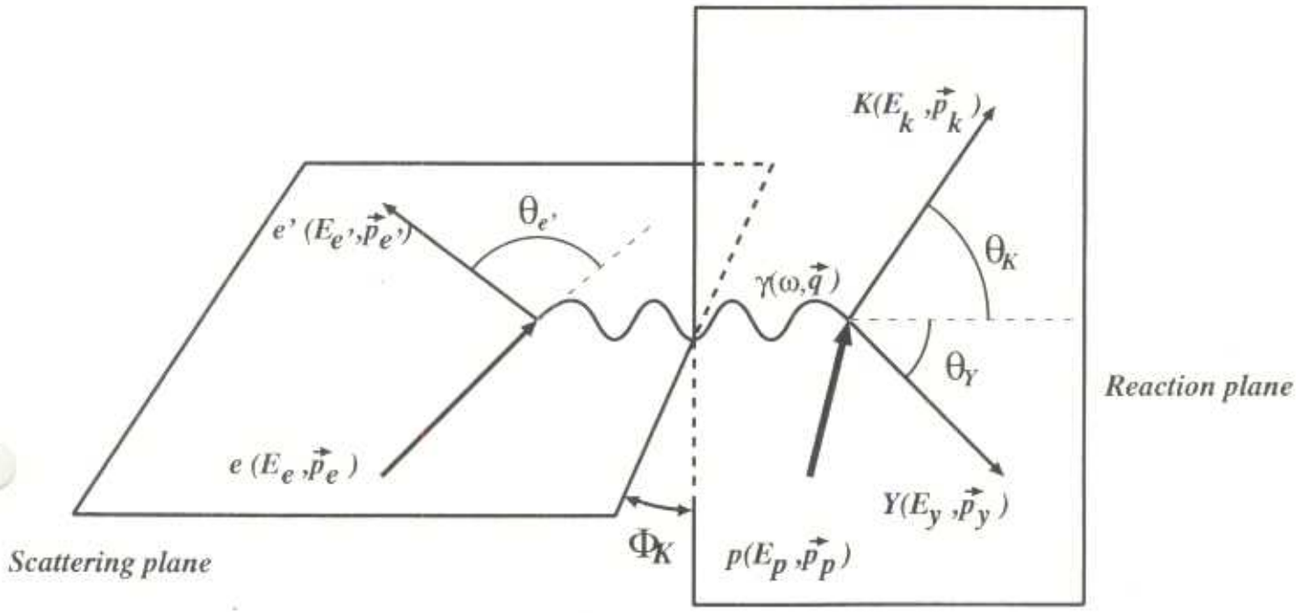
- Study hyperon–nucleon interactions via:

  $e + A \Rightarrow e' + K^+ + X$

  A : ^1H, ^3He, ^4He

  X : Y,Y(A–1)

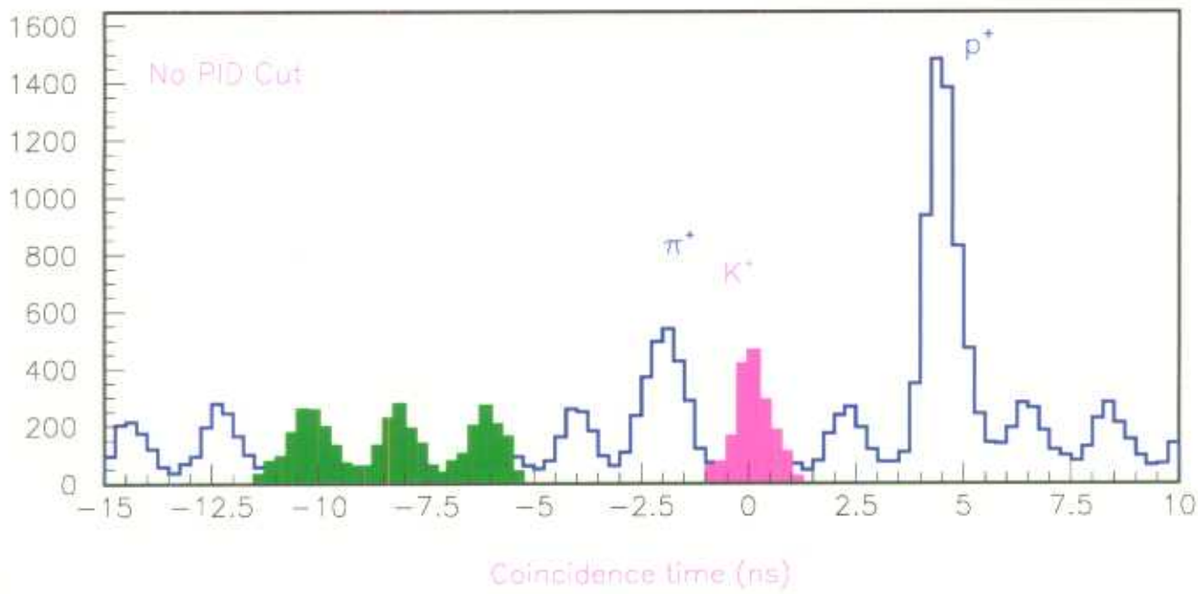
  Y : Λ, Σ^o, Σ^-
- Quasi–free kaon electroproduction on nuclei to study A–dependence and angular distribution
  - hyperon cross sections
  - production ratios
- Investigation of possible Λ bound state
- Attempt FSI model

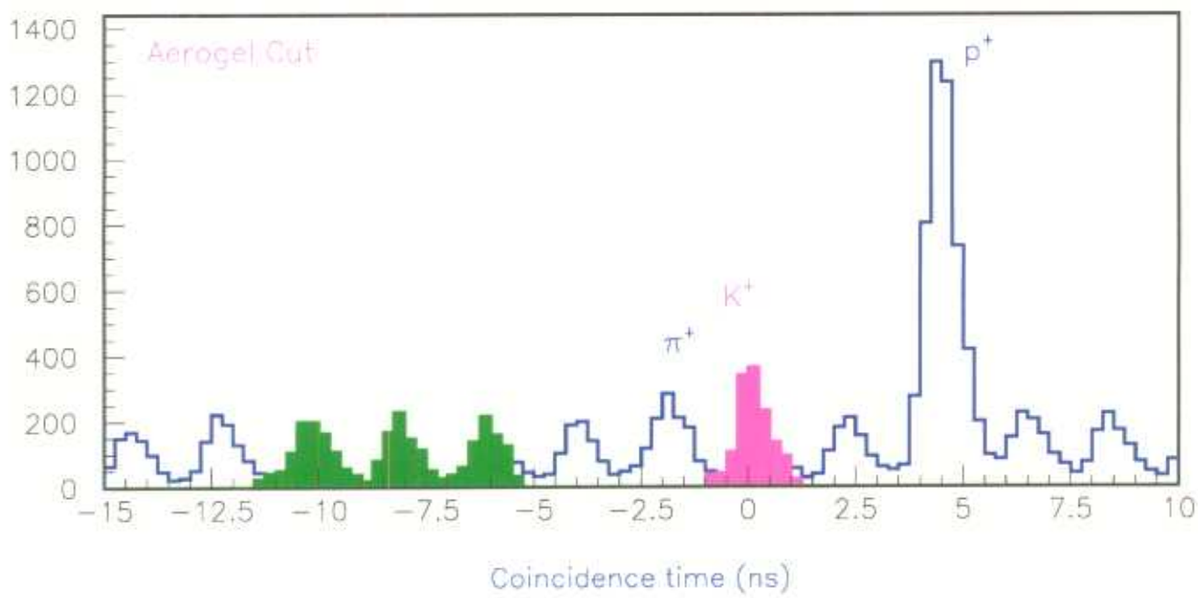


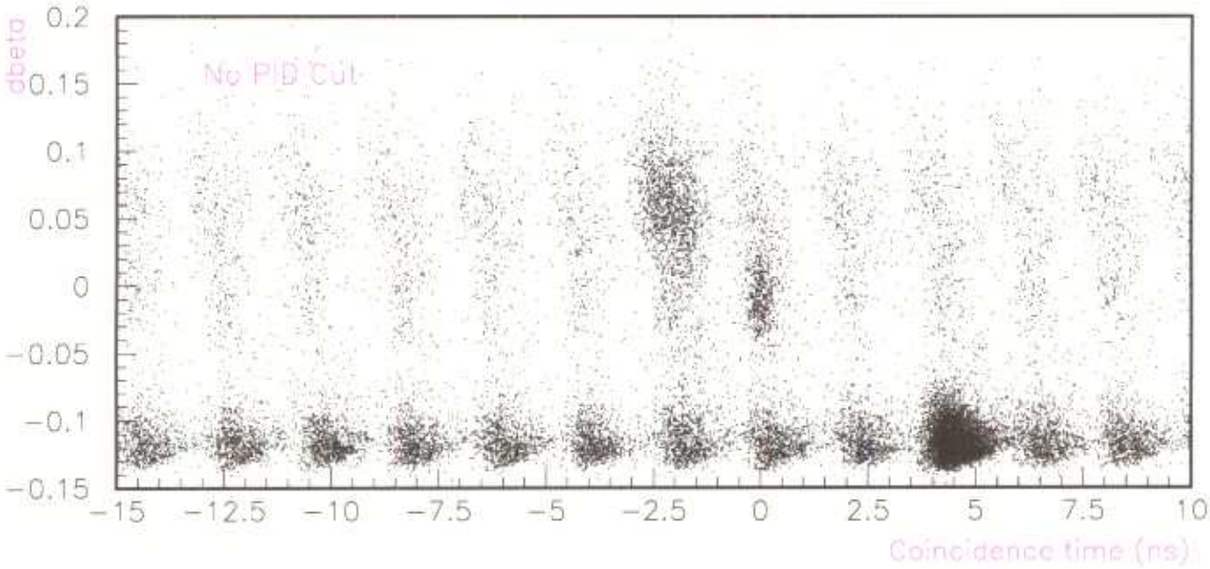
Kinematic Settings

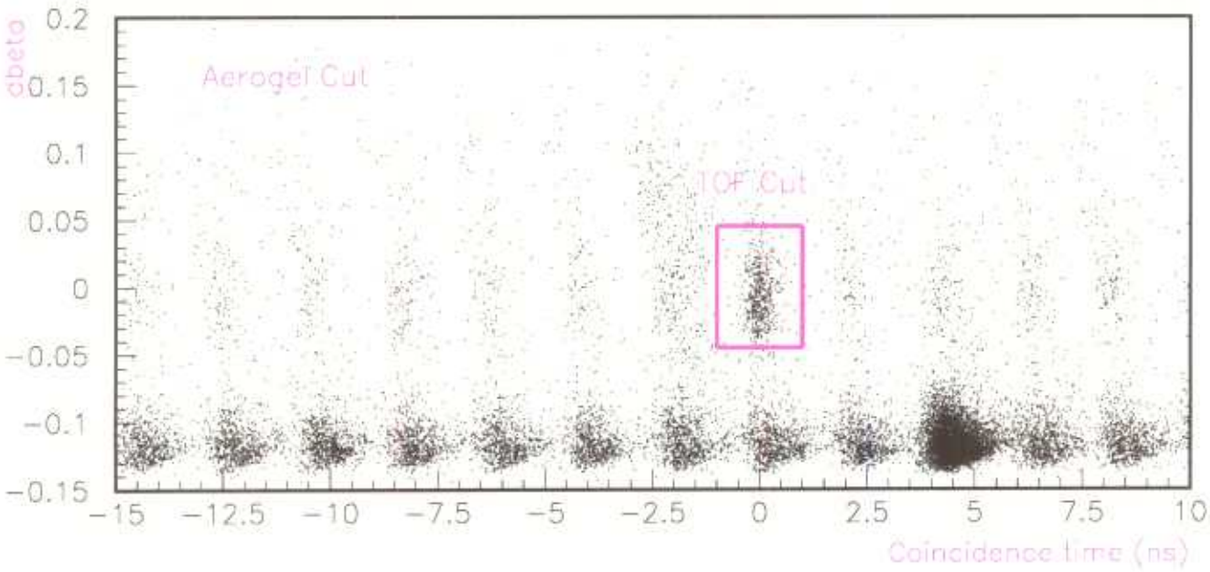
Beam energy: 3.245 GeV
Momentum transfer, Q^2: 0.35 GeV^2/c^2
Invariant mass, W: 1.91 GeV

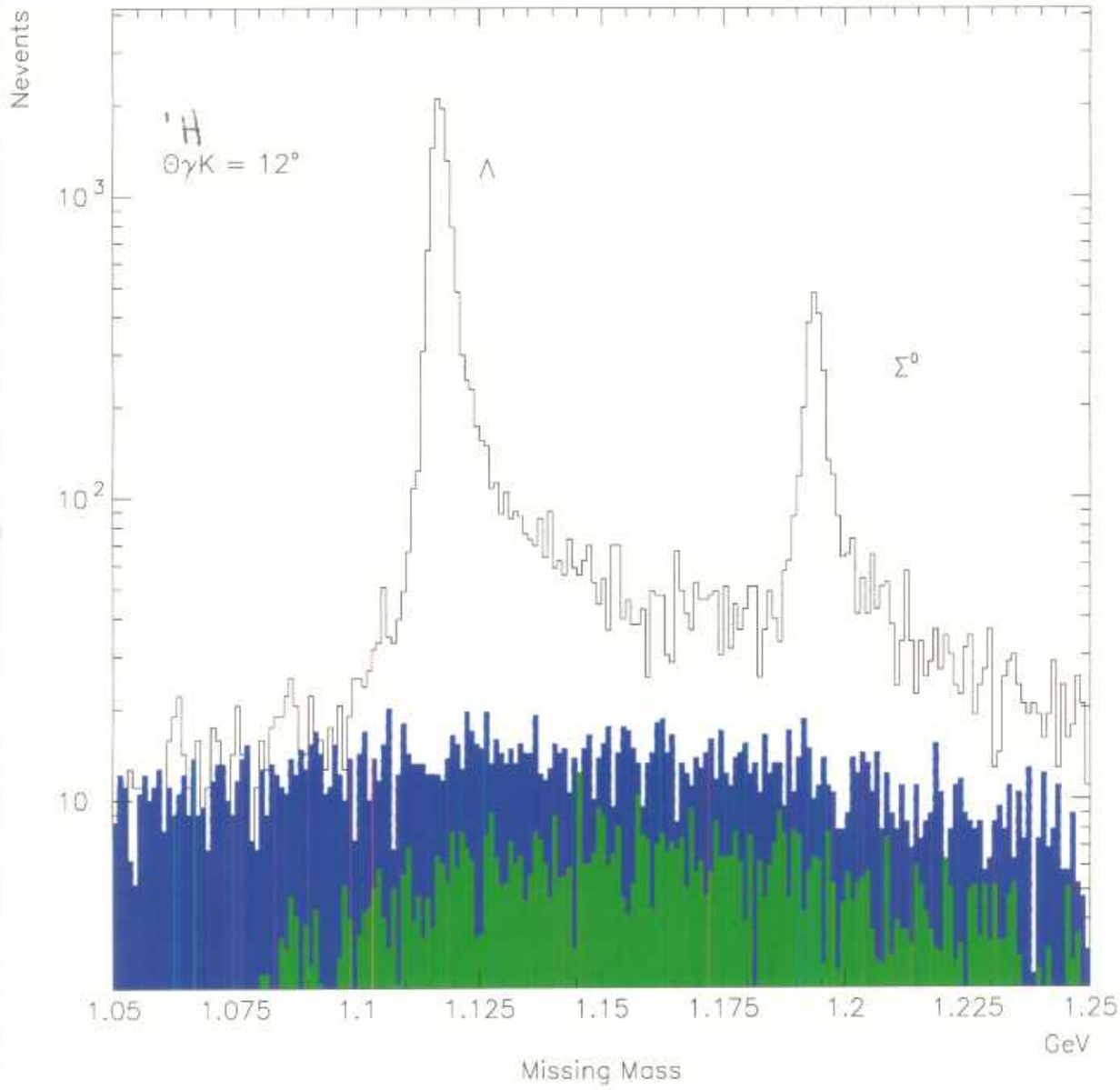
	SOS(K^+)	HMS(e^-)
P_o (GeV/c)	1.290	1.576
δP	+/- 20%	+/- 10%
$\theta_{\gamma K}$ (lab)	0°, 6°, 12°	

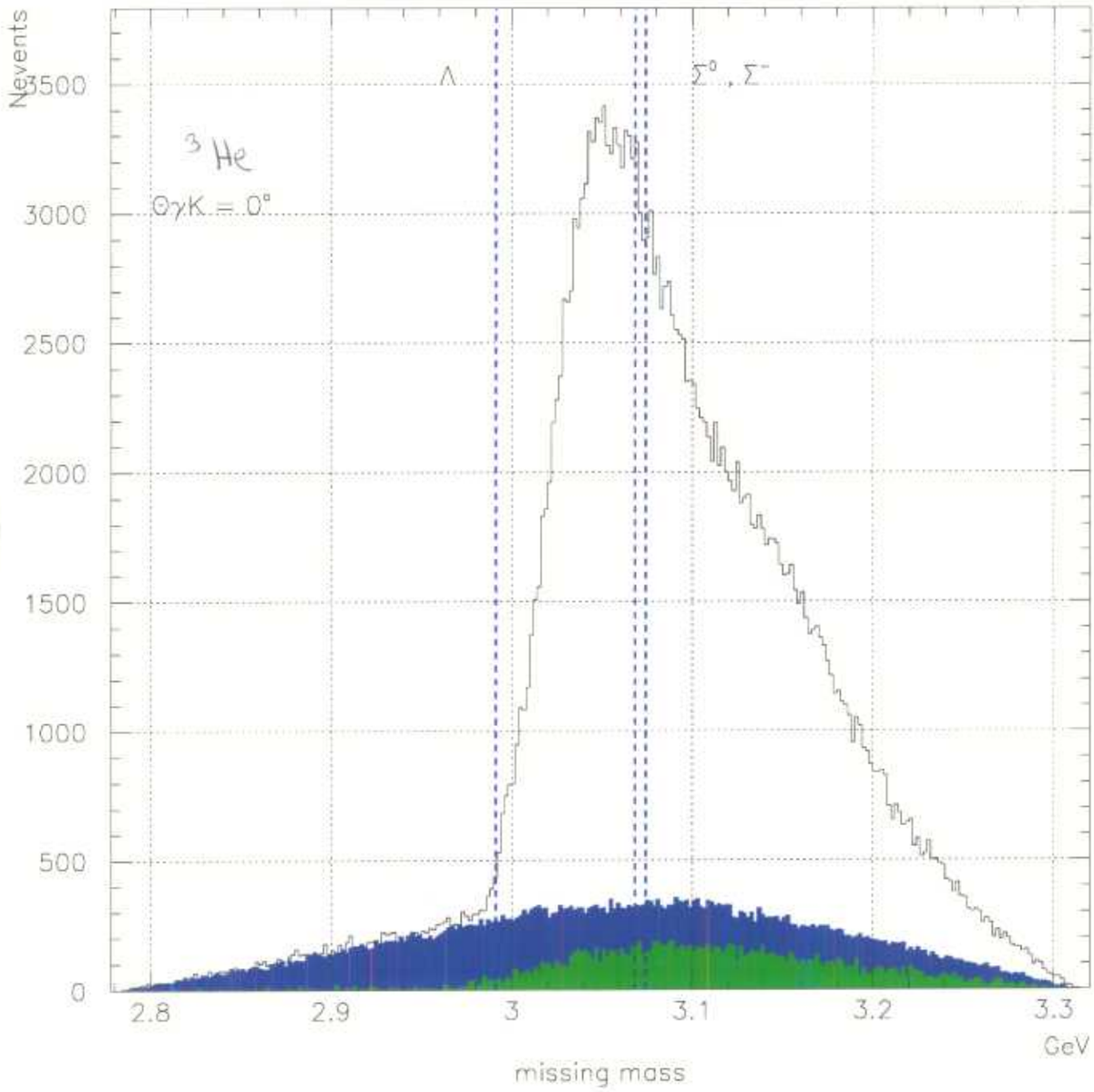

No PID Cut
p^+
π^+
K^+
1600
1400
1200
1000
800
600
400
200
0
−15
−12.5
−10
−7.5
−5
−2.5
0
2.5
5
7.5
10
Coincidence time (ns)

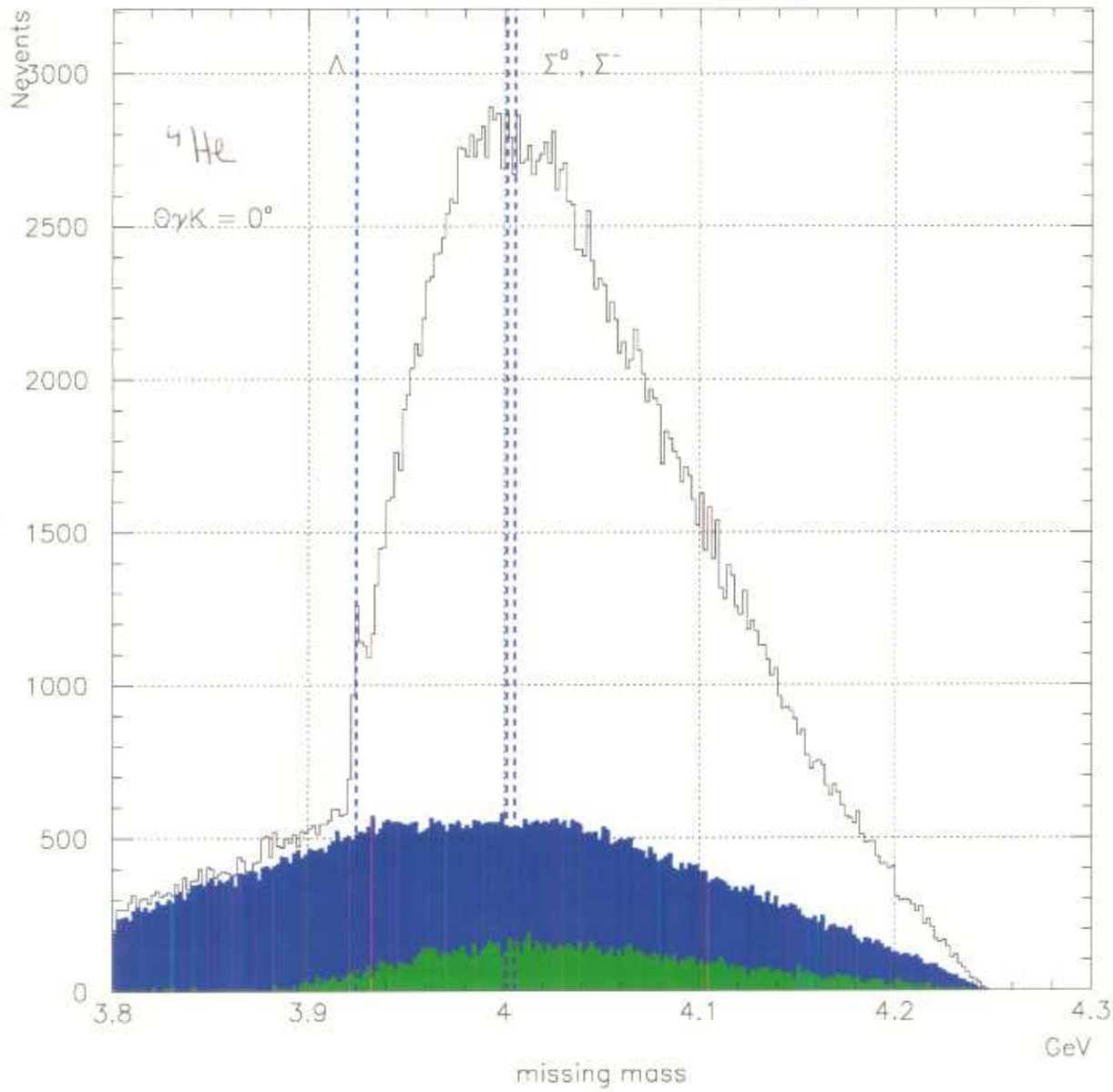

Aerogel Cut
p^+
K^+
π^+
1400
1200
1000
800
600
400
200
0
−15
−12.5
−10
−7.5
−5
−2.5
0
2.5
5
7.5
10
Coincidence time (ns)

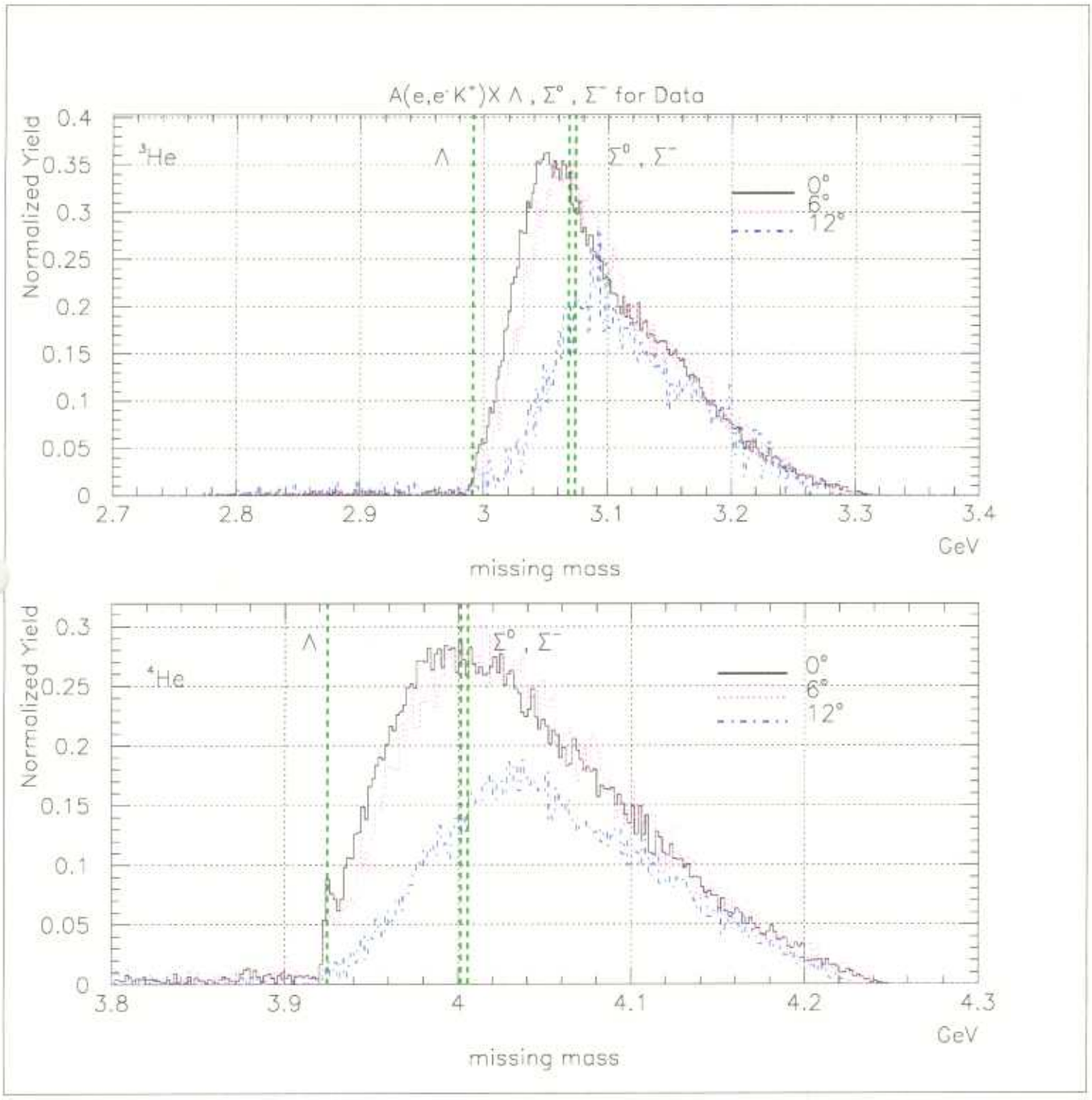

dbeta
No PID Cut
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−15
−12.5
−10
−7.5
−5
−2.5
0
2.5
5
7.5
10
Coincidence time (ns)

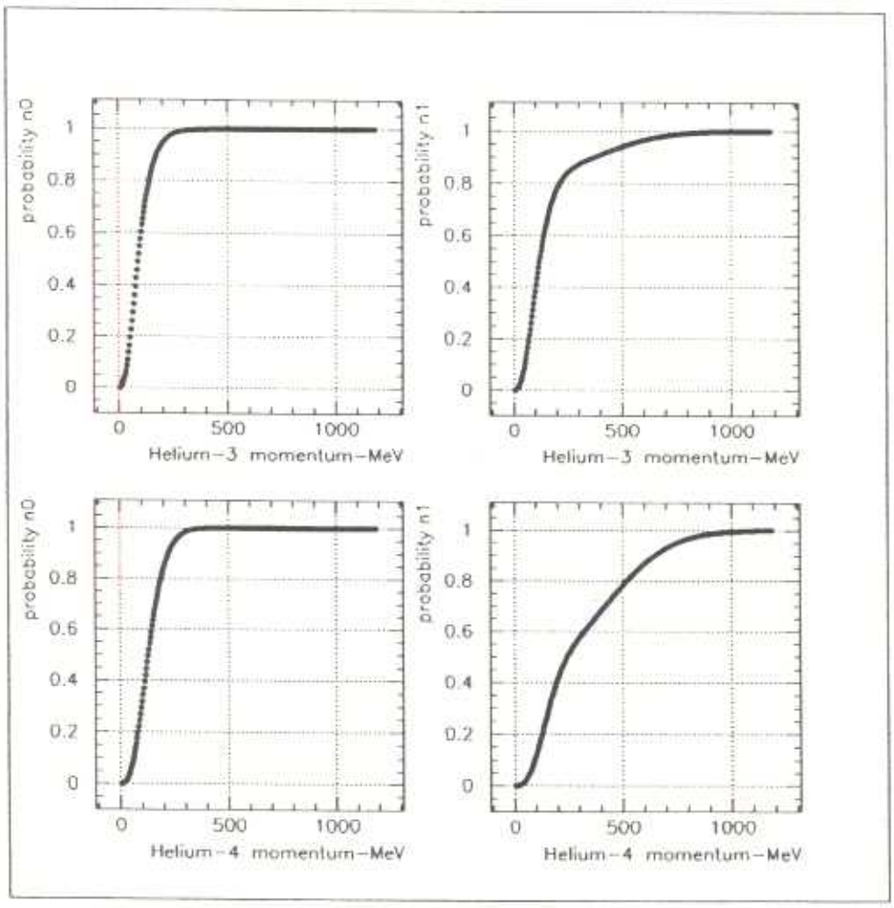

dbeta
Aerogel Cut
TOF Cut
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−15
−12.5
−10
−7.5
−5
−2.5
0
2.5
5
7.5
10
Coincidence time (ns)


Nevents
^1H
$\Theta\gamma K = 12°$
Λ
Σ^0
10^3
10^2
10
1.05
1.075
1.1
1.125
1.15
1.175
1.2
1.225
1.25
GeV
Missing Mass


Nevents
3500
3000
2500
2000
1500
1000
500
0
2.8
2.9
3
3.1
3.2
3.3
GeV
missing mass
Λ
Σ°, Σ⁻
³He
ΘγK = 0°


Nevents
3000
2500
2000
1500
1000
500
0
3.8
3.9
4
4.1
4.2
4.3
GeV
missing mass
Λ
Σ°, Σ⁻
⁴He
θγK = 0°


A(e,e'K⁺)X Λ , Σ° , Σ⁻ for Data
Normalized Yield
³He
Λ
Σ° , Σ⁻
0°
6°
12°
missing mass
GeV
⁴He
Λ
Σ° , Σ⁻
0°
6°
12°
Normalized Yield
missing mass
GeV

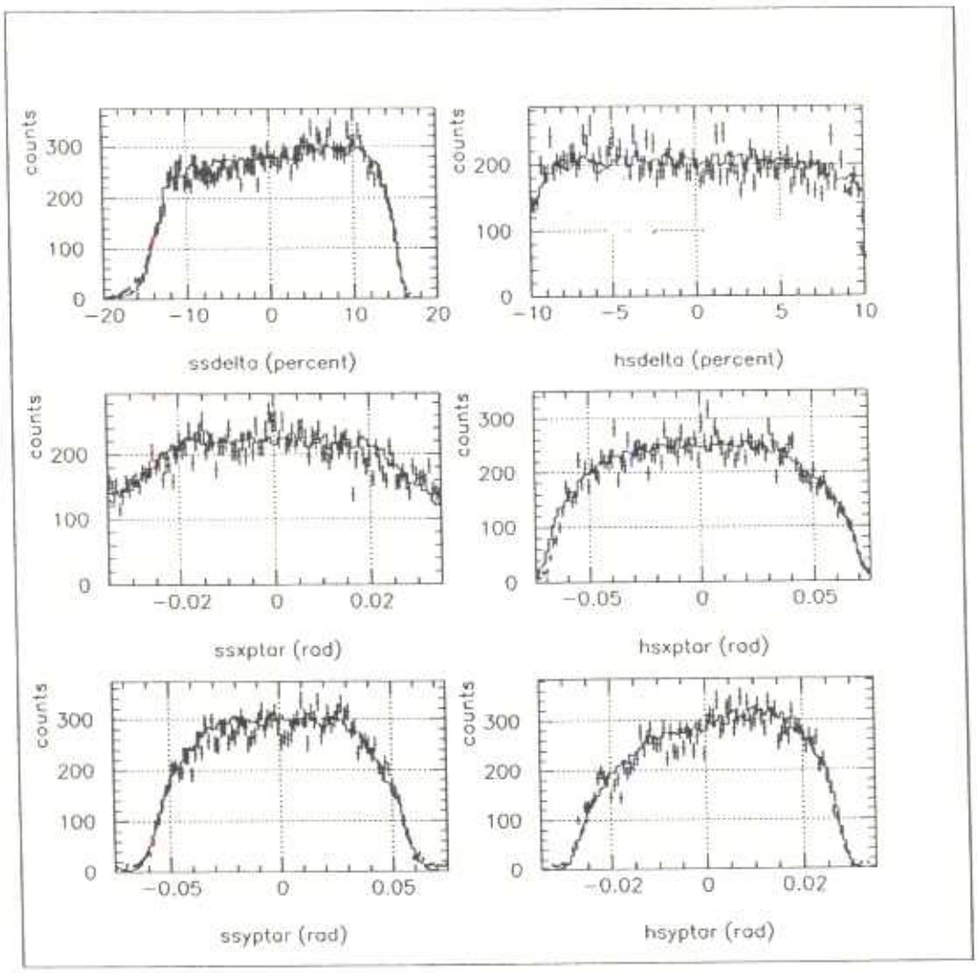


Momentum distribution for ^{3}He and ^{4}He.

C. Ciofi degli Atti Phys. Rev. C 53, 1689-1710 (1996)

	Hyperon	Final States	% Contribution	
^{3}He	Λ, Σ^0	(pn)	65.3	→ n0
	Λ, Σ^0	pn	34.7	→ n1
	Σ^-	pp	100.0	→ n1
^{4}He	Λ, Σ^0	(pnn)	80.0	
	Λ, Σ^0	(pn)n,pnn	20.0	
	Σ^-	(ppn)	80.0	
	Σ^-	p(pn),ppn	20.0	

This table shows the contribution for each final state for the helium simulation. Production from ^{3}He is shown in the top portion and ^{4}He in the bottom. The parentheses inidicates a bound system. One weight is applied to the indistinguishable systems.



Hydrogen Λ production data vs. SIMC comparison for reconstructed quantities. The solid line is SIMC and the data is shown with statistical error bars. The proper normalization has been applied to SIMC to match the data.

Λ cross section model

Jinseok Cha, PhD thesis, Hampton University, 2000

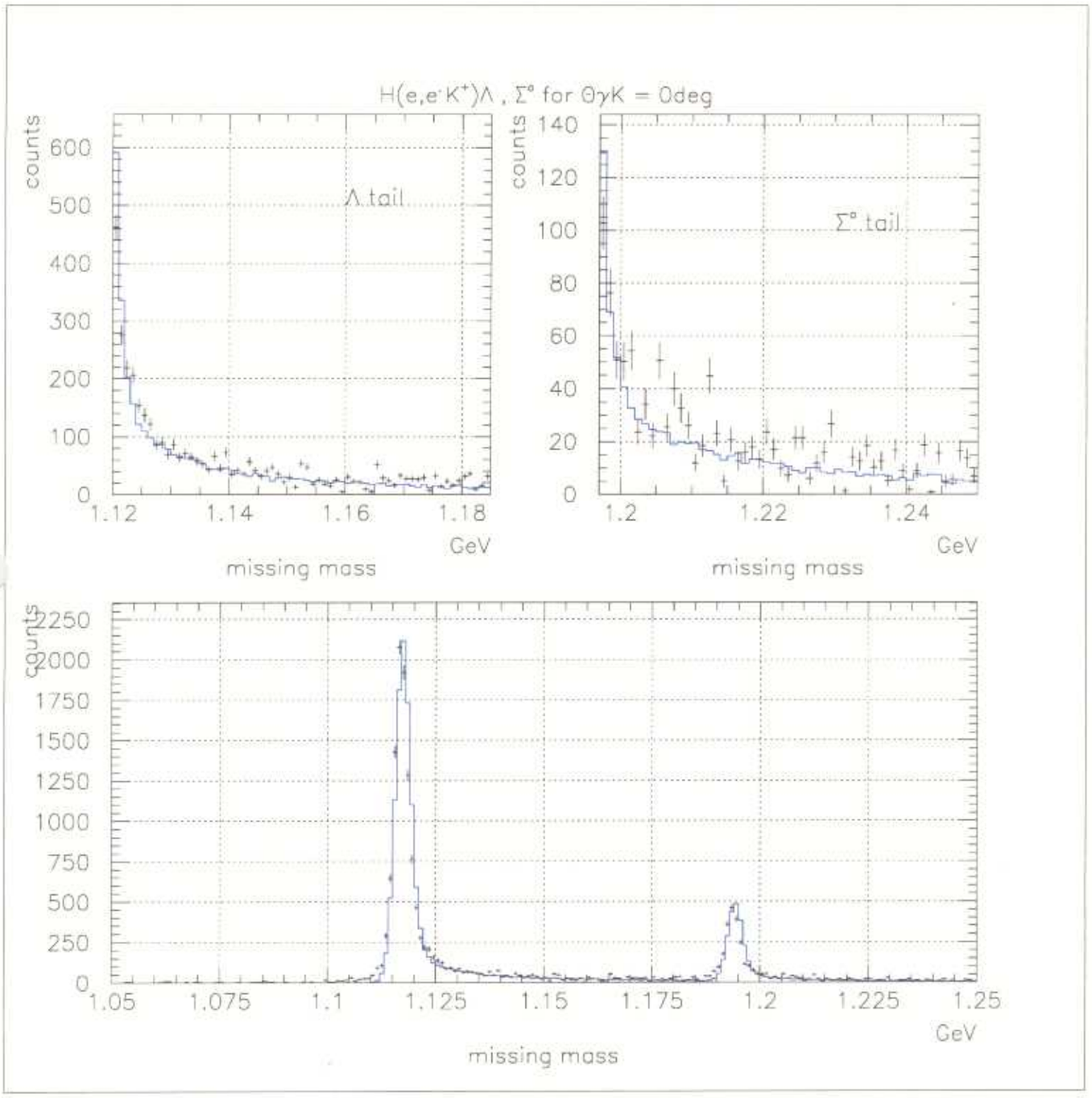
$$\frac{d\sigma}{d\Omega^*}(Q^2, W, t, \phi) = f(Q^2)g(W)h(t)i(\phi),$$

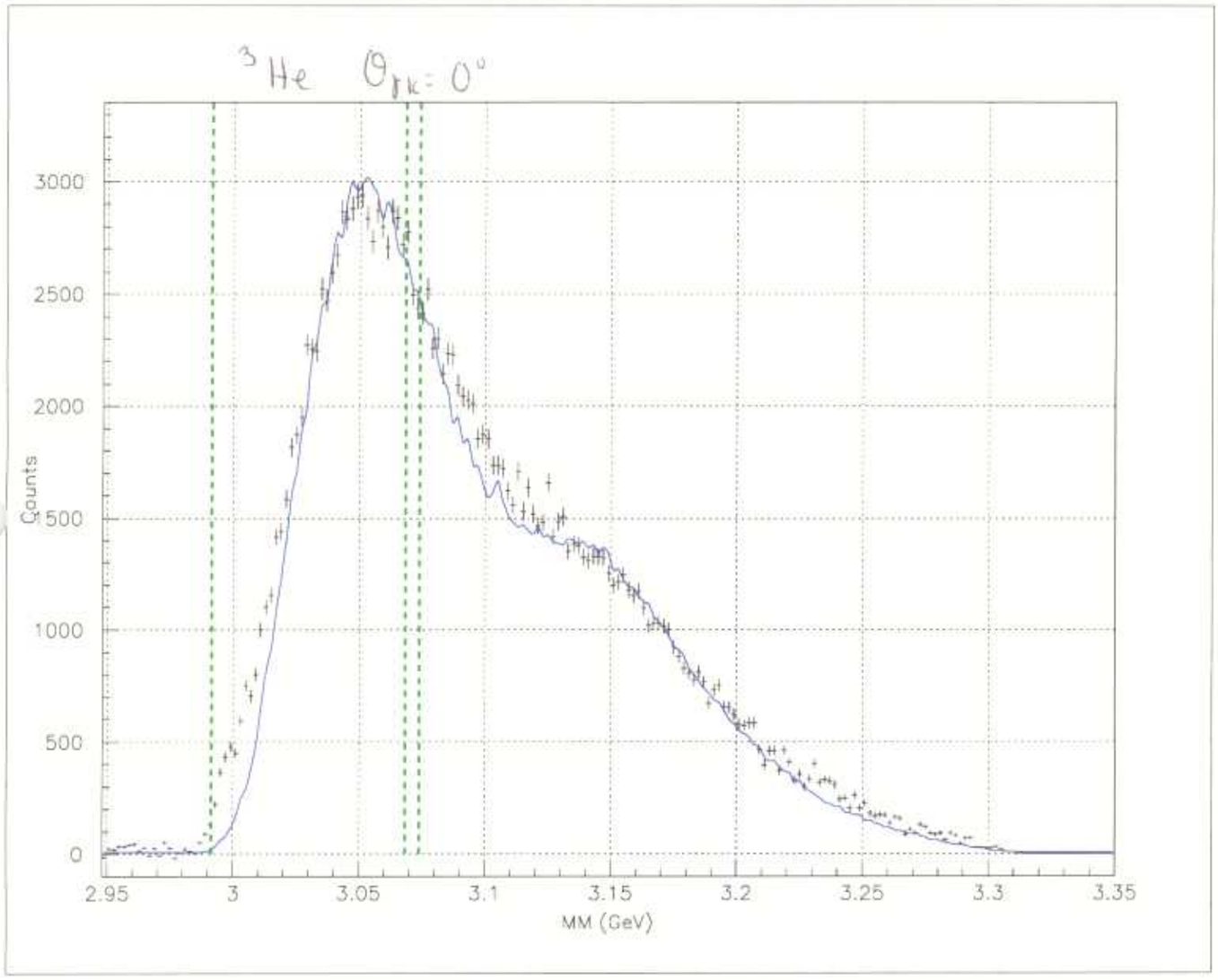
* center-of-mass

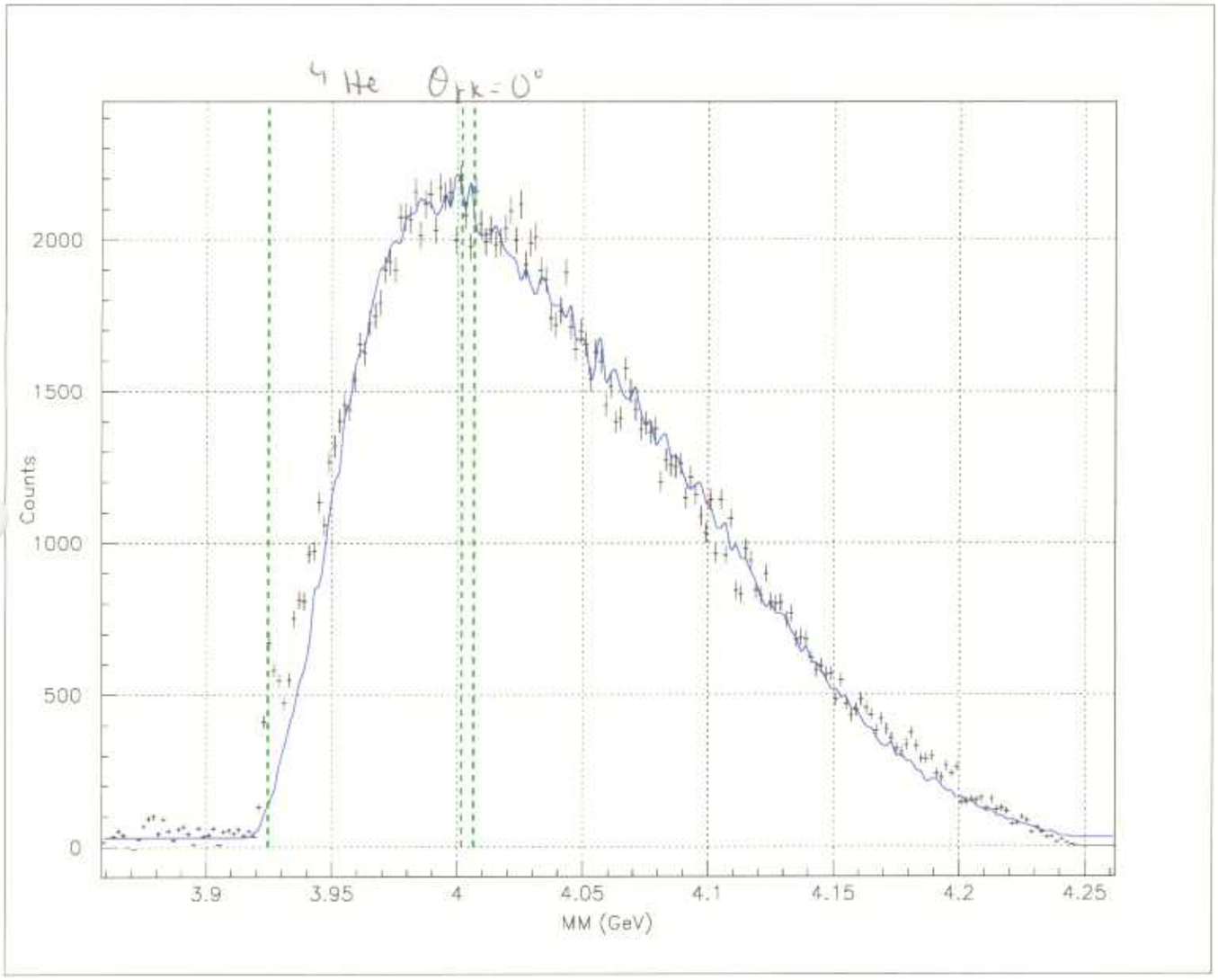
$$\begin{aligned}
f(Q^2) &= Constant \\
g(W) &= \frac{P_1 P_k^{CM}}{(W^2 - M_p^2)W} + \frac{P_2 W^2}{(P_3 W)^2 + (W^2 - P_4^2)^2} \\
h(t_{min} - t) &= P_1 e^{P_2(t_{min} - t)} \\
i(\phi) &= P_1 + P_2 \cos(\phi) + P_3 \cos(2\phi)
\end{aligned}$$

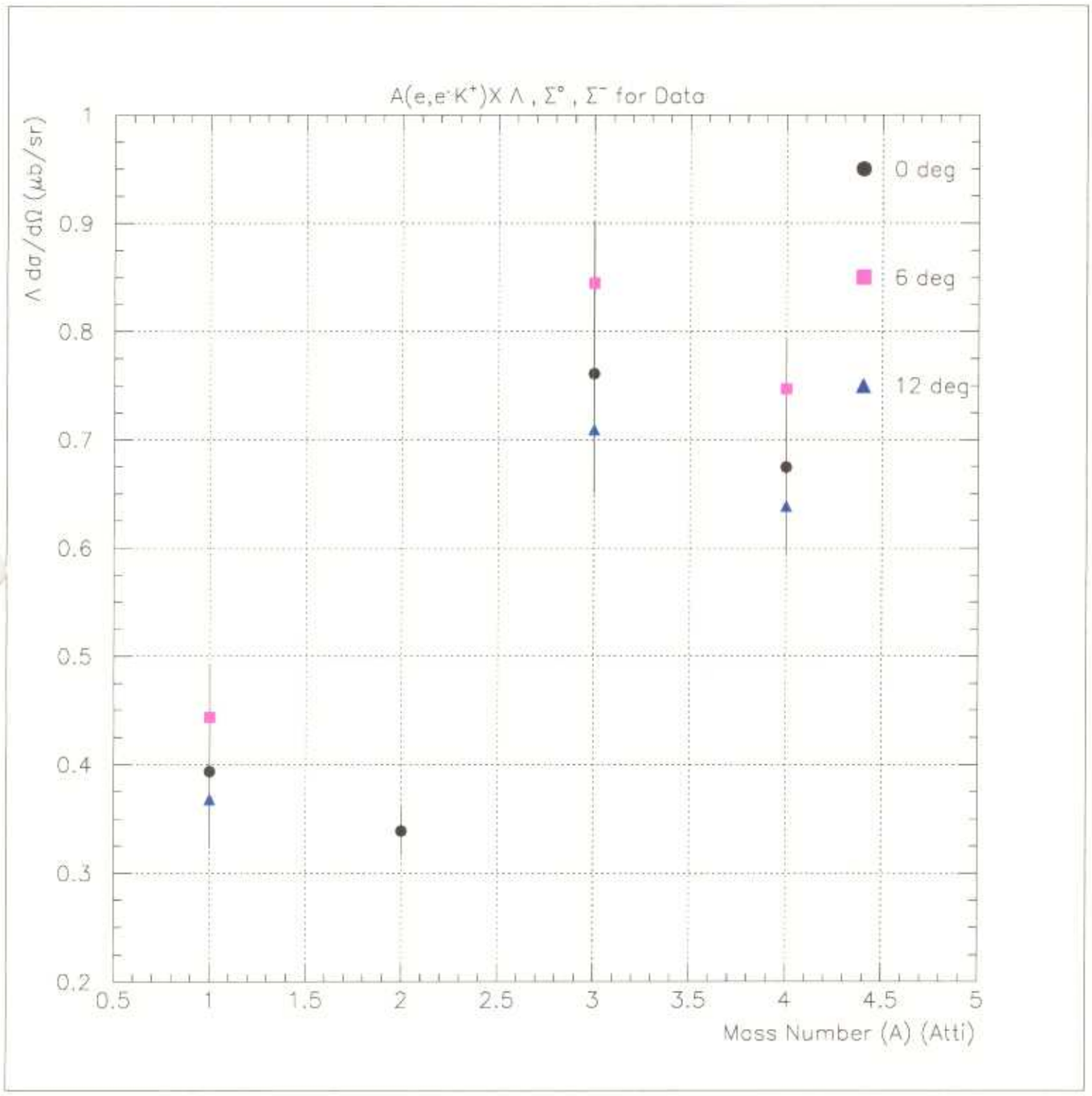
Functions	P_1	P_2	P_3	P_4
$f(Q^2)$	0.430 ± 0.005			
$g(W)$	4.470 ± 0.005	0.00089 ± 0.00086	$0.0787 \pm .02458$	1.72 (fixed)
$h(t_{min} - t)$	0.4262 ± 0.0056	-2.144 ± 0.211		
$i(\phi)$	0.438 ± 0.006	$-0.048 \pm .009$	0.008 ± 0.009	

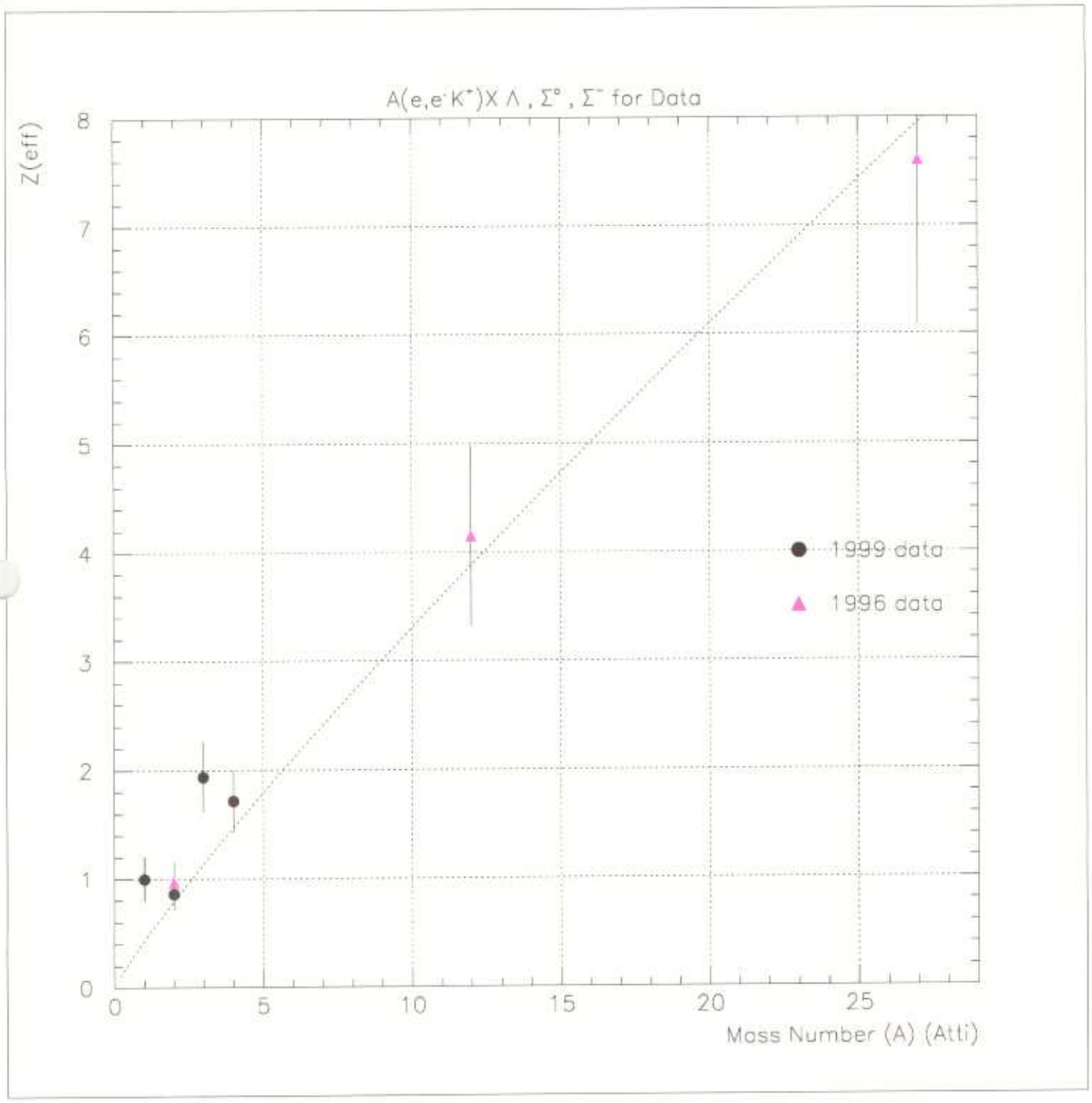
The constants of the cross section parameterization.

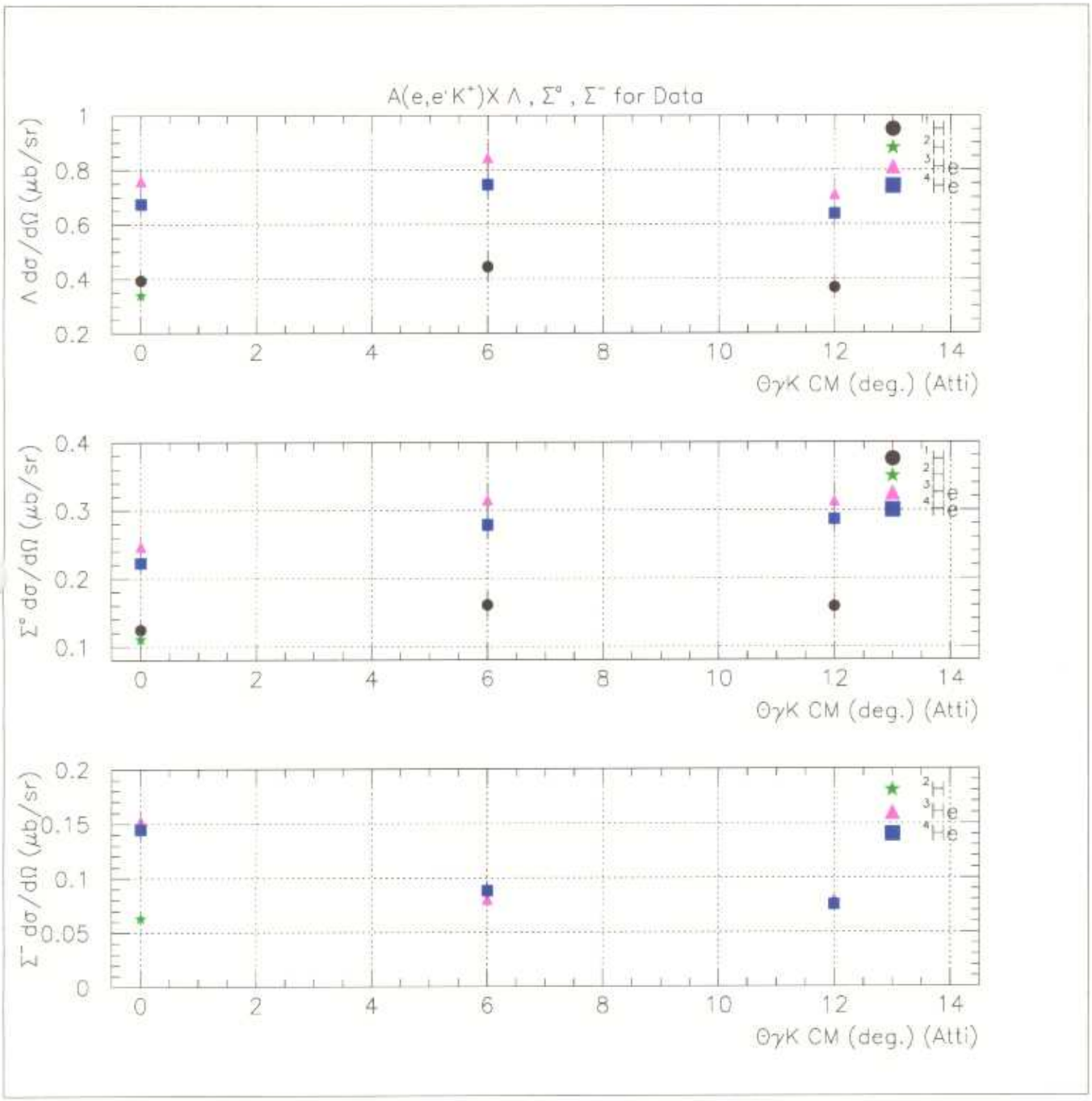

H(e,e'K+)Λ , Σ° for ΘγK = 0deg
counts
Λ tail
missing mass
GeV
Σ° tail
missing mass
GeV
counts
missing mass
GeV

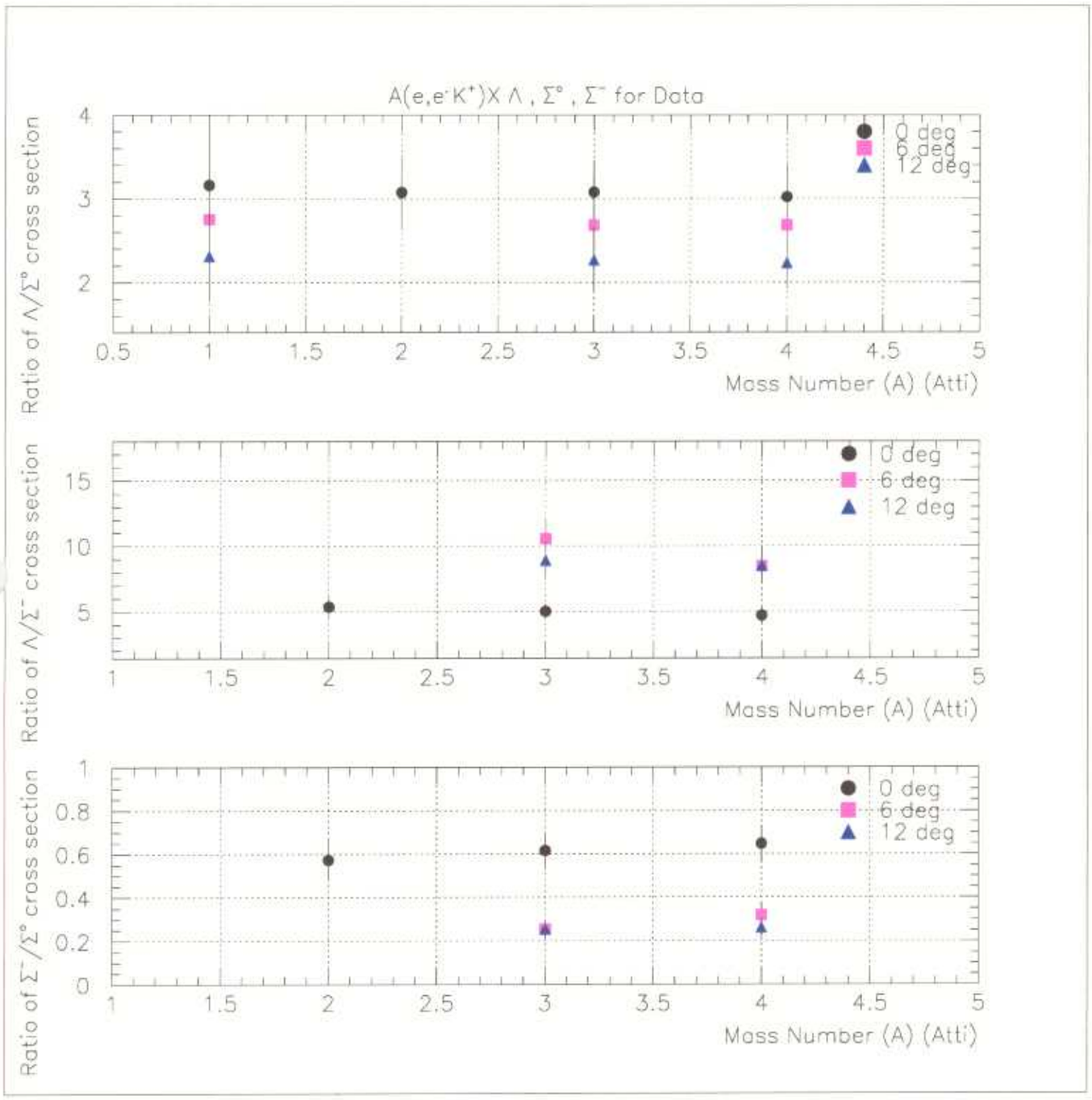

^{3}He $\theta_{\gamma K} = 0°$
Counts
3000
2500
2000
1500
1000
500
0
2.95
3
3.05
3.1
3.15
3.2
3.25
3.3
3.35
MM (GeV)

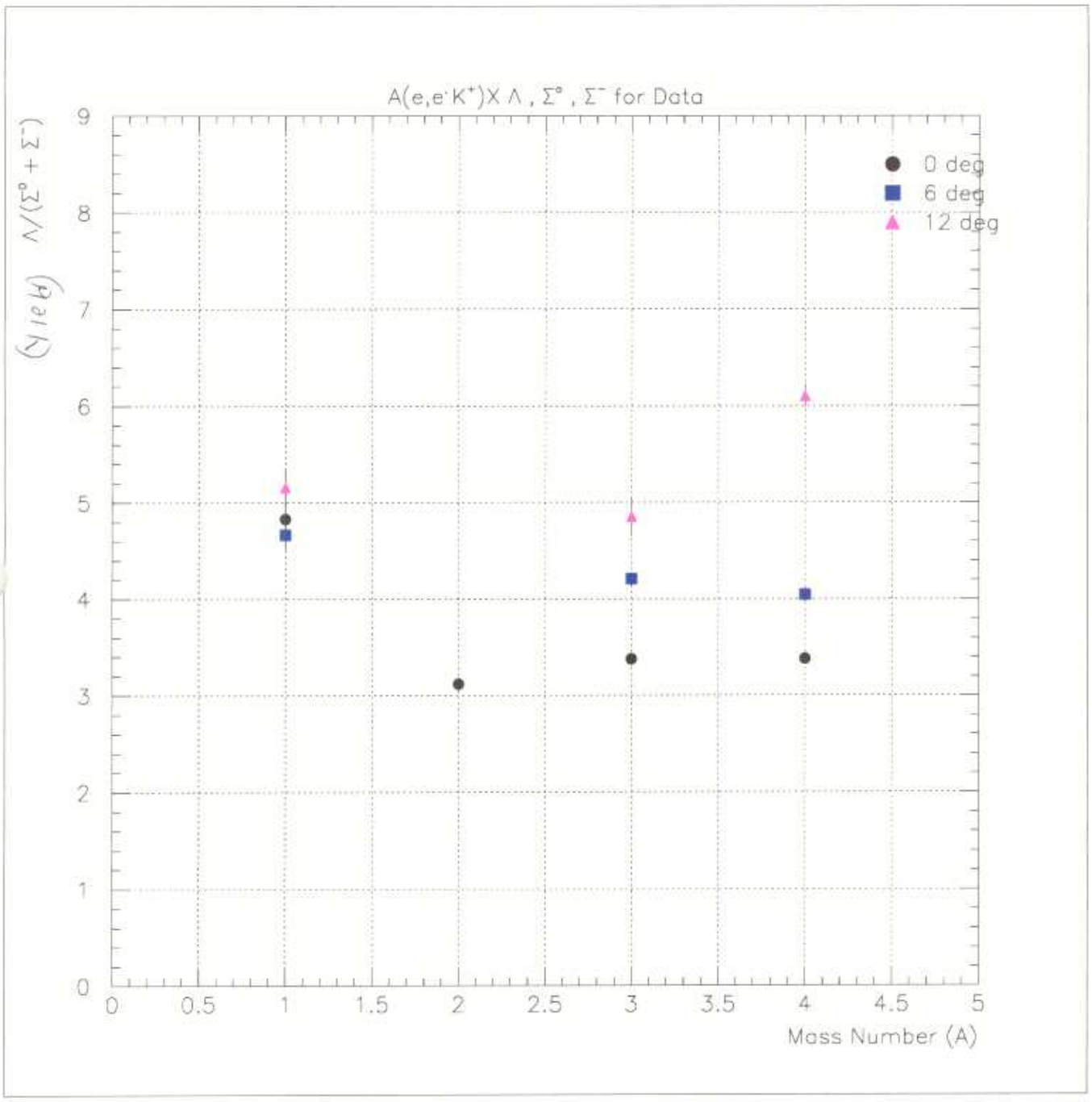

4 He θ_RK = 0°
Counts
2000
1500
1000
500
0
3.9
3.95
4
4.05
4.1
4.15
4.2
4.25
MM (GeV)


A(e,e'K+)X Λ , Σ° , Σ- for Data
Λ dσ/dΩ (μb/sr)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Mass Number (A) (Atti)
0 deg
6 deg
12 deg

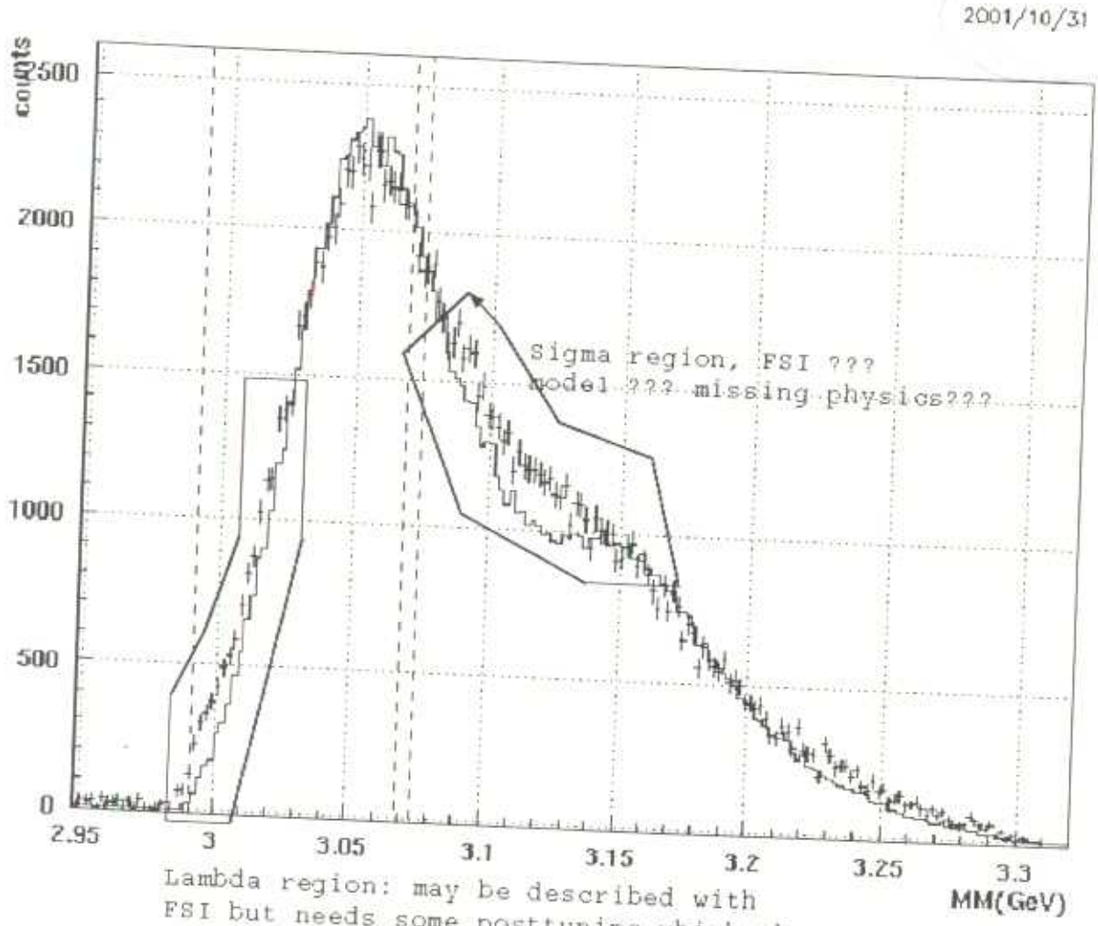

A(e,e'K⁺)X Λ , Σ° , Σ⁻ for Data
Z(eff)
Mass Number (A) (Atti)
1999 data
1996 data
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25


A(e,e'K+)X Λ , Σ° , Σ- for Data
Λ dσ/dΩ (μb/sr)
Σ° dσ/dΩ (μb/sr)
Σ- dσ/dΩ (μb/sr)
ΘγK CM (deg.) (Atti)
1H
2H
3He
4He


A(e,e⁻K⁺)X Λ , Σ° , Σ⁻ for Data
Ratio of Λ/Σ° cross section
Ratio of Λ/Σ⁻ cross section
Ratio of Σ⁻/Σ° cross section
Mass Number (A) (Atti)
0 deg
6 deg
12 deg


A(e,e'K+)X Λ , Σ° , Σ- for Data
Λ/(Σ° + Σ-)
(Yield Λ)
0 deg
6 deg
12 deg
Mass Number (A)
0
1
2
3
4
5
6
7
8
9
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

^{3}He



Lambda region: may be described with FSI but needs some posttuning which obscures any statements on the input YN models for effective range. May improve by considering to include Hypertriton

FIGURE 2

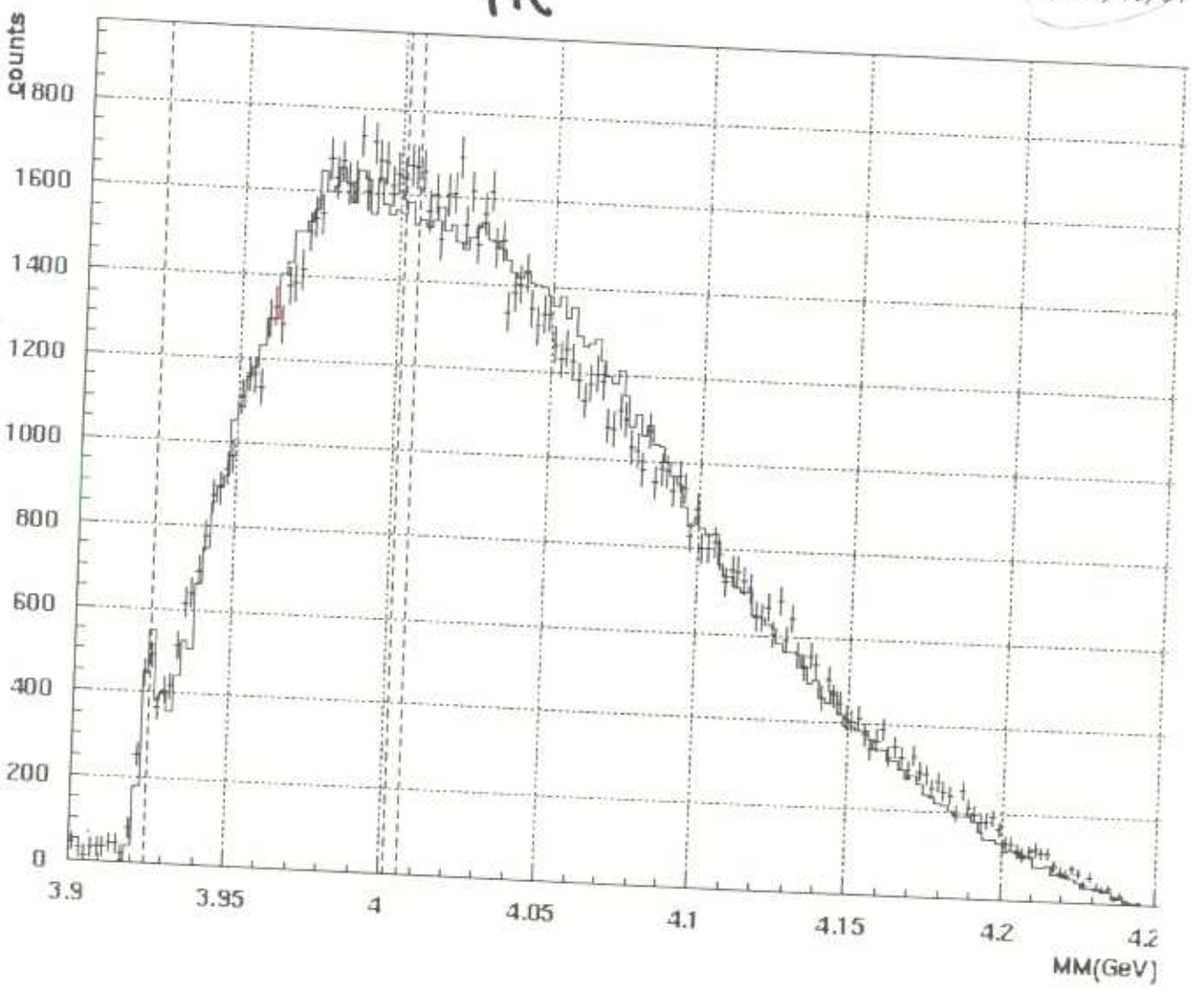
Effective range FSI w/ Nijmegen hardcore applied - Contains full Spectral Function taken from Benhar

(not most recent)

(Frank Dohrmann)

^{4}He

2001/10/31



Effective range w/ Nijmegen hardcore applied. (Fitrange - full spectrum)

- Contains full spectral function taken from Benhar (not most recent)

(Frank Dohrmann)

SUMMARY

- **Reasonable agreement between Monte Carlo and data using the Atti momentum distribution for quasi–free ^{3}He and ^{4}He.**

- **Measured center–of–mass $\frac{d\sigma}{d\Omega}$ for quasi–free Λ, Σ^0, Σ^- for $\Theta_{\gamma K} = 0^0, 6^\circ$, and 12°.**

- **Possible Λ bound state on ^{4}He**

- **Attempted models of Λ FSI on ^{3}He and ^{4}He.**