The Crystal Ball Program
At
Brookhaven National Laboratory

The BNL Crystal Ball Collaboration

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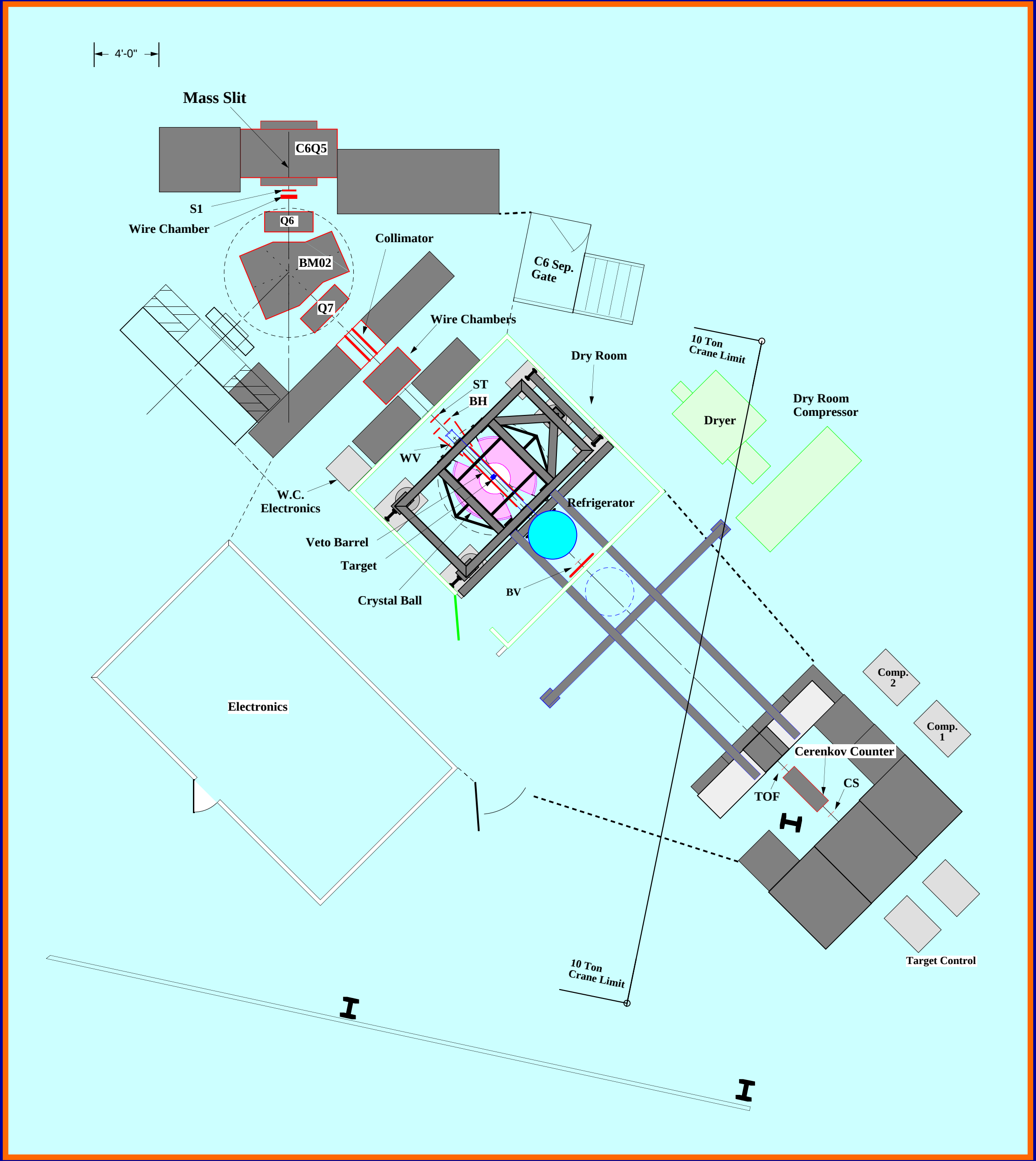
- Argonne National Lab: C.E. Allgower, H. Spinka;
- Arizona St. Univ., K.Craig, J.Comfort A. Ramirez;
- George Washington Univ.: W.Briscoe, I. Strakovsky, A. Shafi;
- Kent State Univ.: D.M. Manley, J. Olmsted;
- Petersburg Nuclear Physics Institute: V.S. Bekrenev, N.G. Kozlenko, S. Kruglov, A.A. Kulbardis, V. Lopatin, A. Starostin;
- Rudjer Boskovic Institute: A. Marusic, I. Supek;
- UCLA: M. Clajus, S. Prakhov, B.M.K. Nefkens, W. B. Tippens, J. W. Price, N. Phaisangittisakul, S. McDonald;
- Universitat Karlsruhe: H.M. Staudenmaier;
- Univ. of Regina: N. Knecht, G. Lolos, Z. Papandreou;
- Univ. of Maryland D. C. Peaslee
- Valparaiso Univ.: D. Grosnick, D. Koetke, R. Manweiler, D.S. Stanislaus.

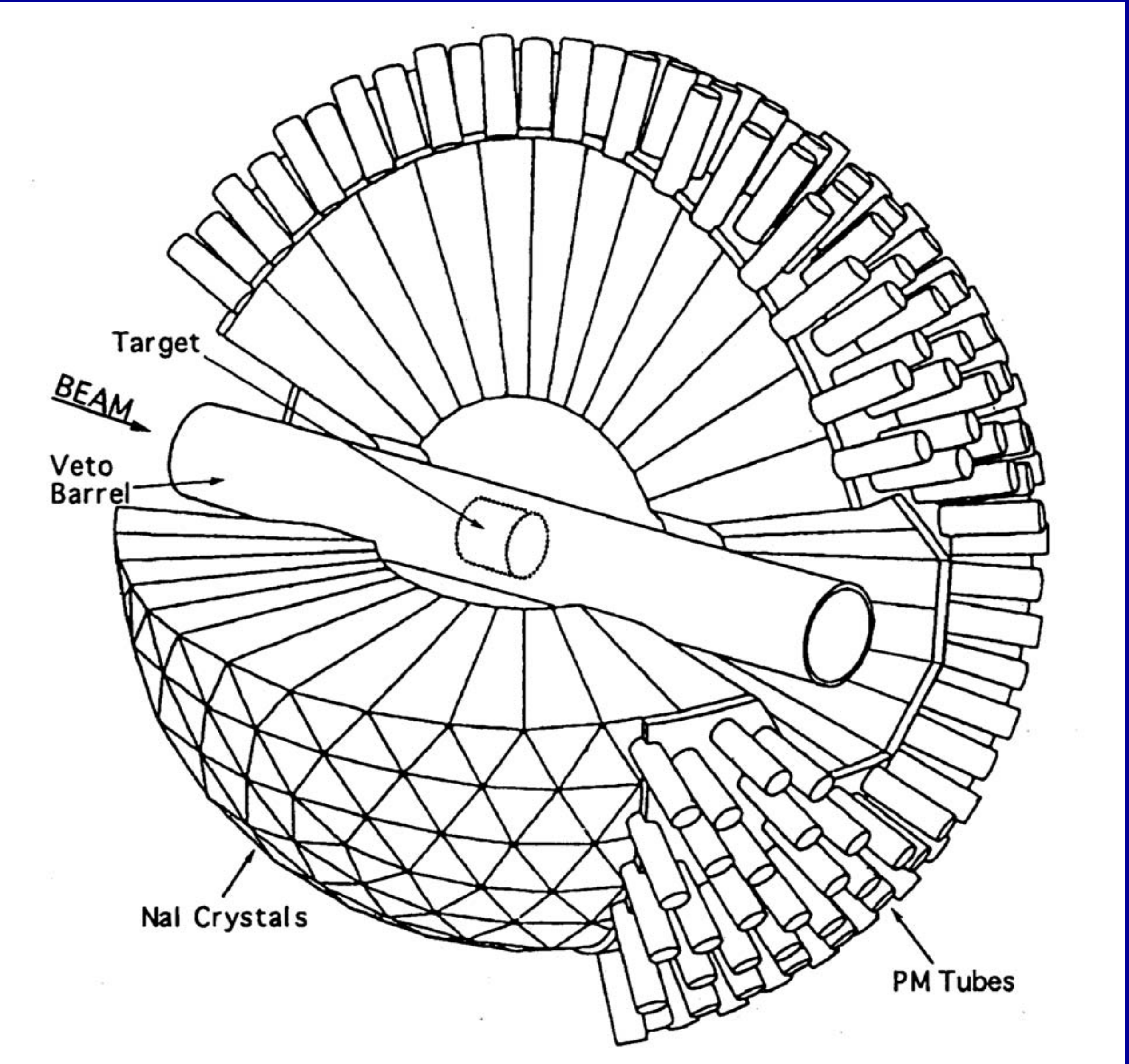
The Crystal Ball

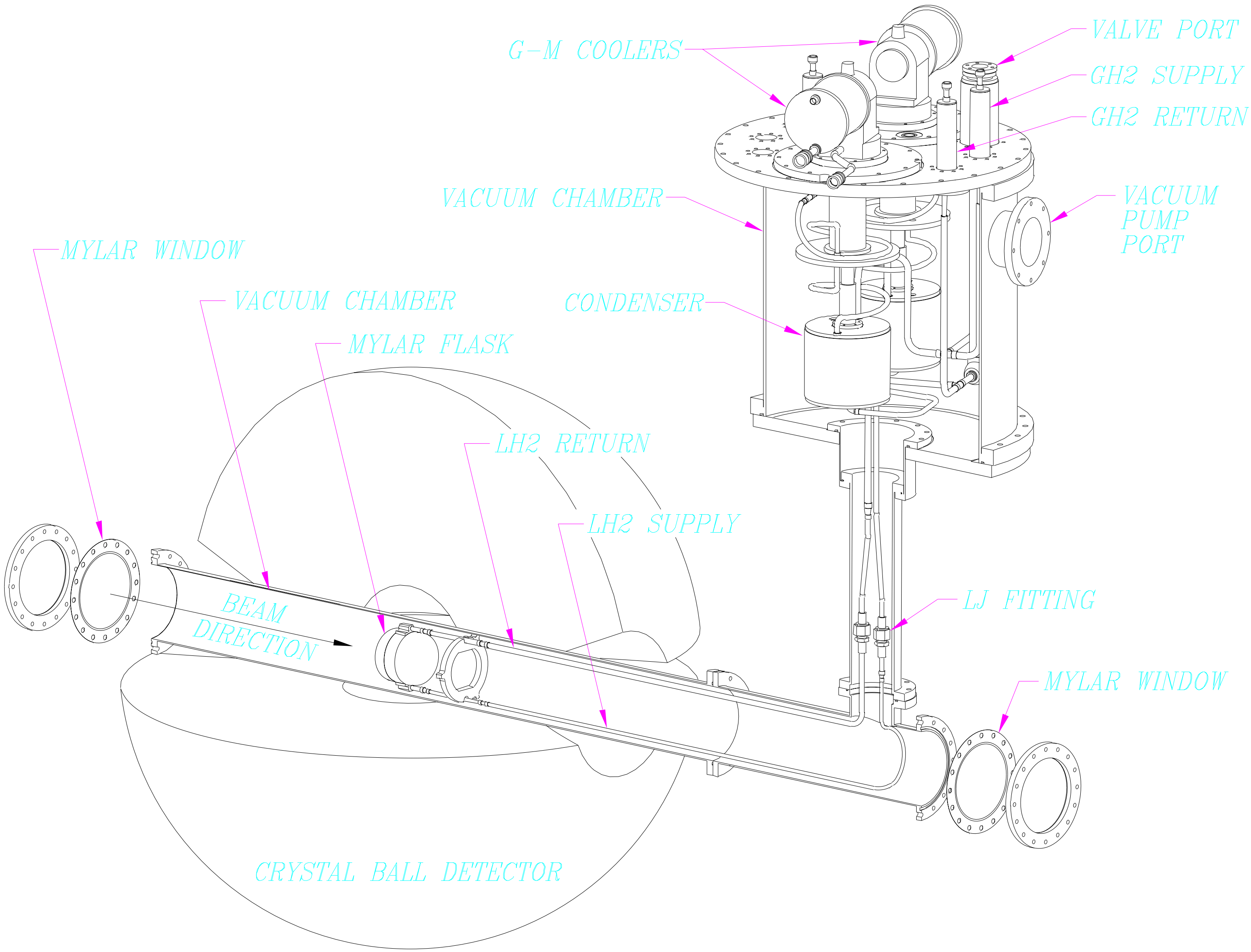
- Segmented, electromagnetic calorimeter
- 94% of 4π
- 672 NaI Crystal
- High efficiency for photons and neutrons

- Xtal Ball Layout at BNL C6 beam line.
- 1998 – 2002
- Never made it to the D Line!



The Crystal Ball





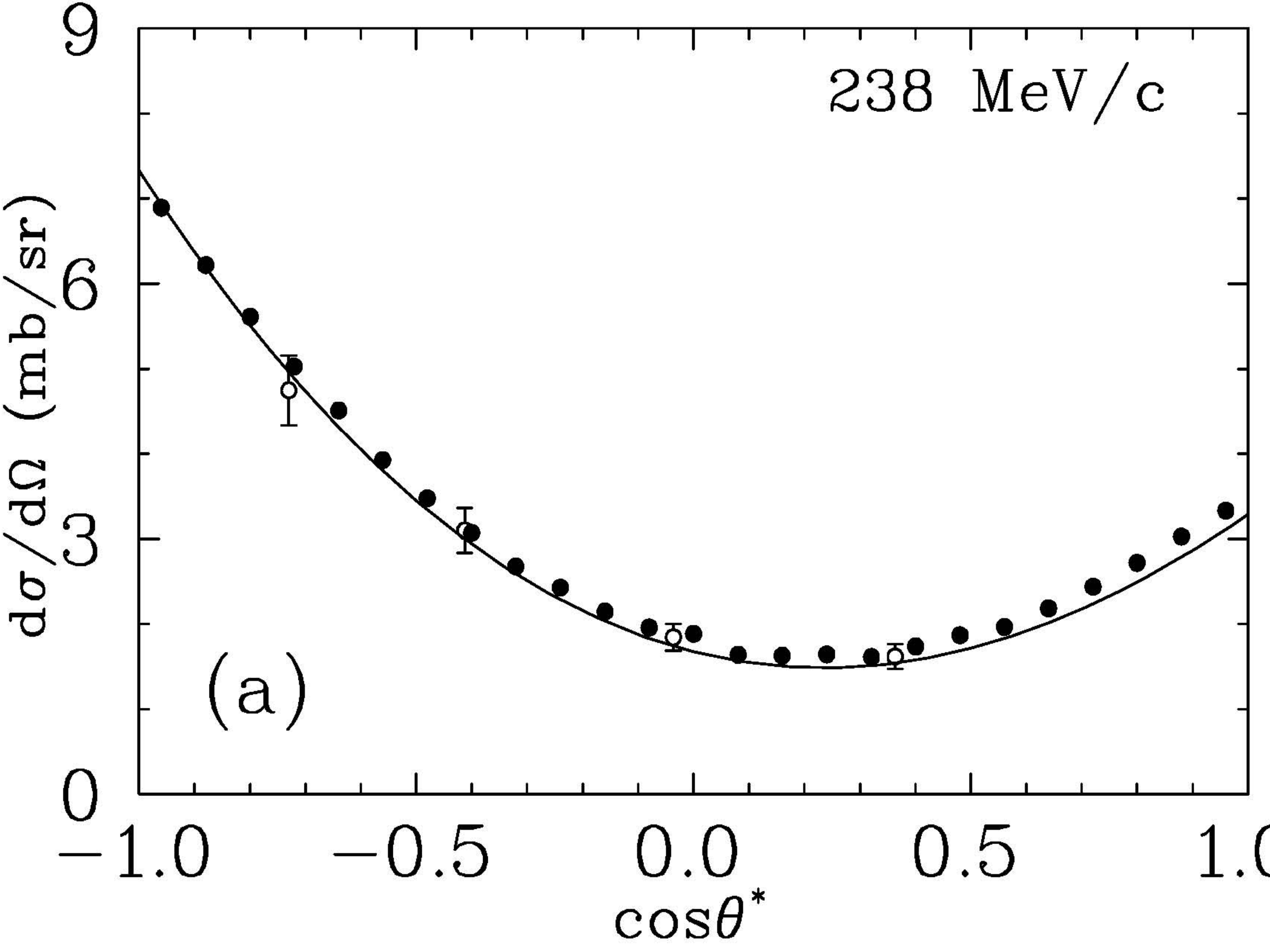
BROOKHAVEN NATIONAL LABORATORY

AGS CRYOGENIC GROUP

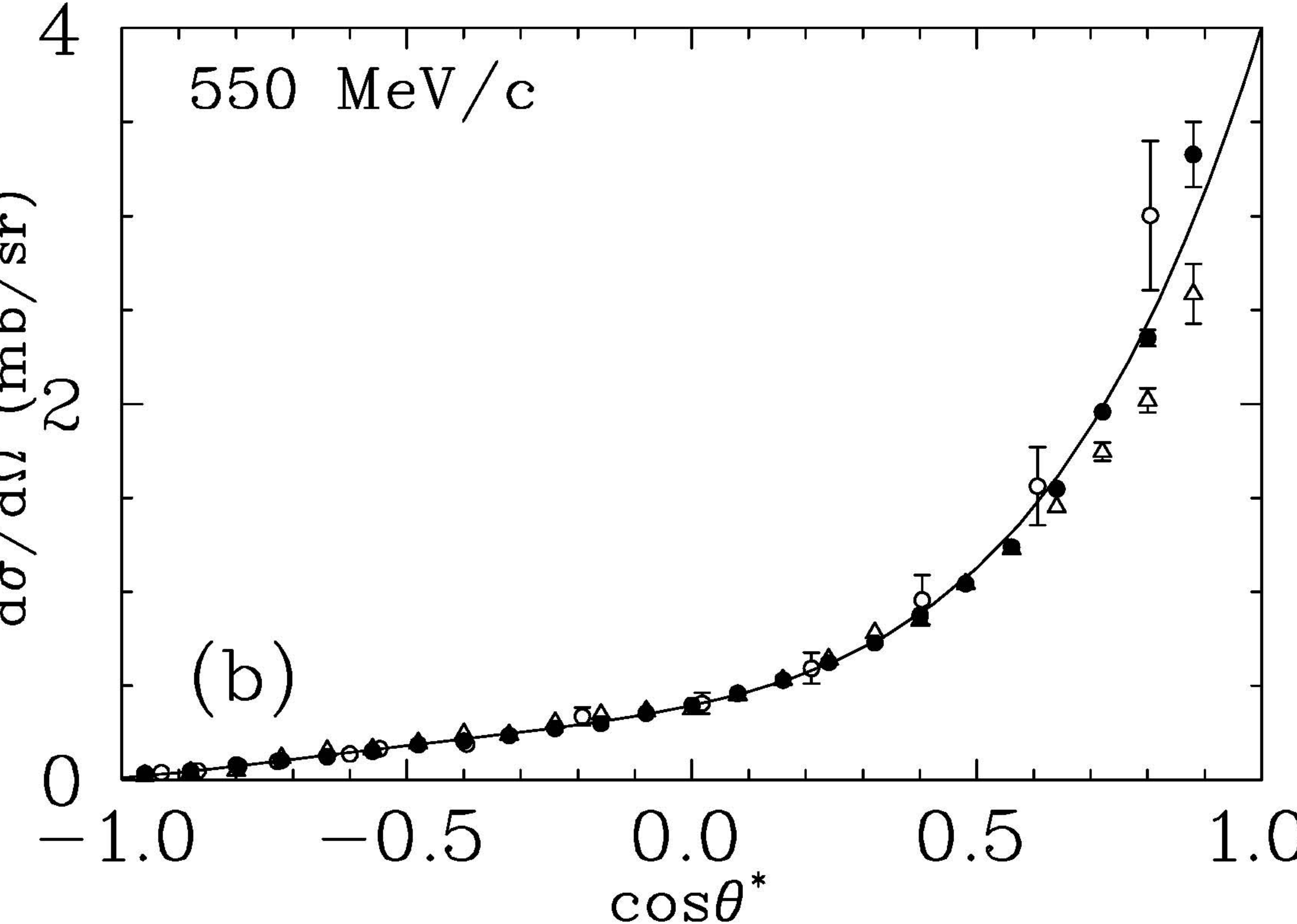
Charge Exchange

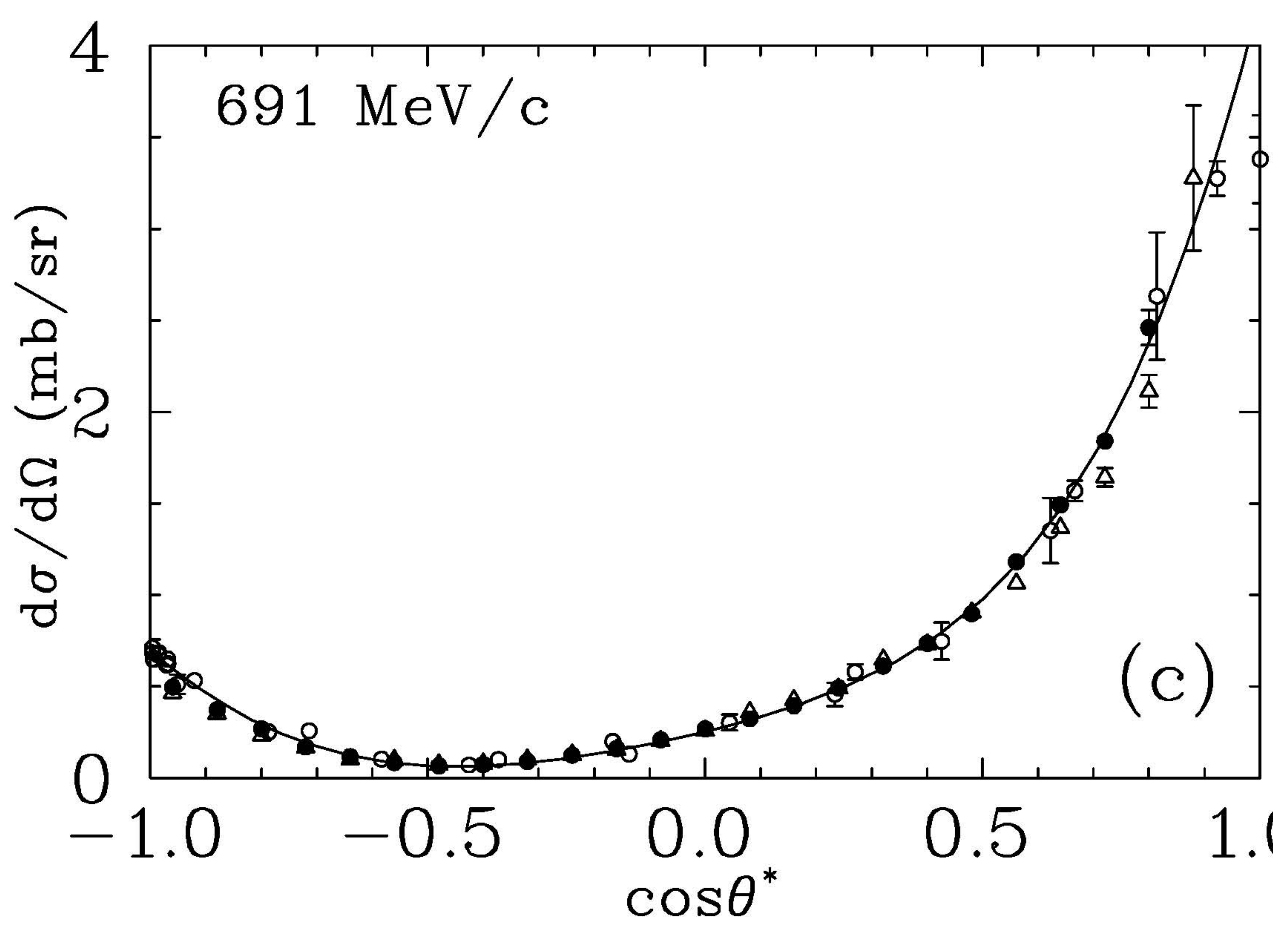
$\pi^{-}p \rightarrow \pi^{0}n$

Alexander Starotsin, UCLA
Mike Sadler, Abilene Christian University



238 MeV/c
(a)
dσ/dΩ (mb/sr)
cosθ*
0
3
6
9
−1.0
−0.5
0.0
0.5
1.0


550 MeV/c
(b)
dσ/dΩ (mb/sr)
cosθ*
4
2
0
−1.0
−0.5
0.0
0.5
1.0



691 MeV/c
(c)
dσ/dΩ (mb/sr)
cosθ*
0
2
4
−1.0
−0.5
0.0
0.5
1.0

Radiative Capture of Pions on Protons

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

Thesis of Aziz Shafi

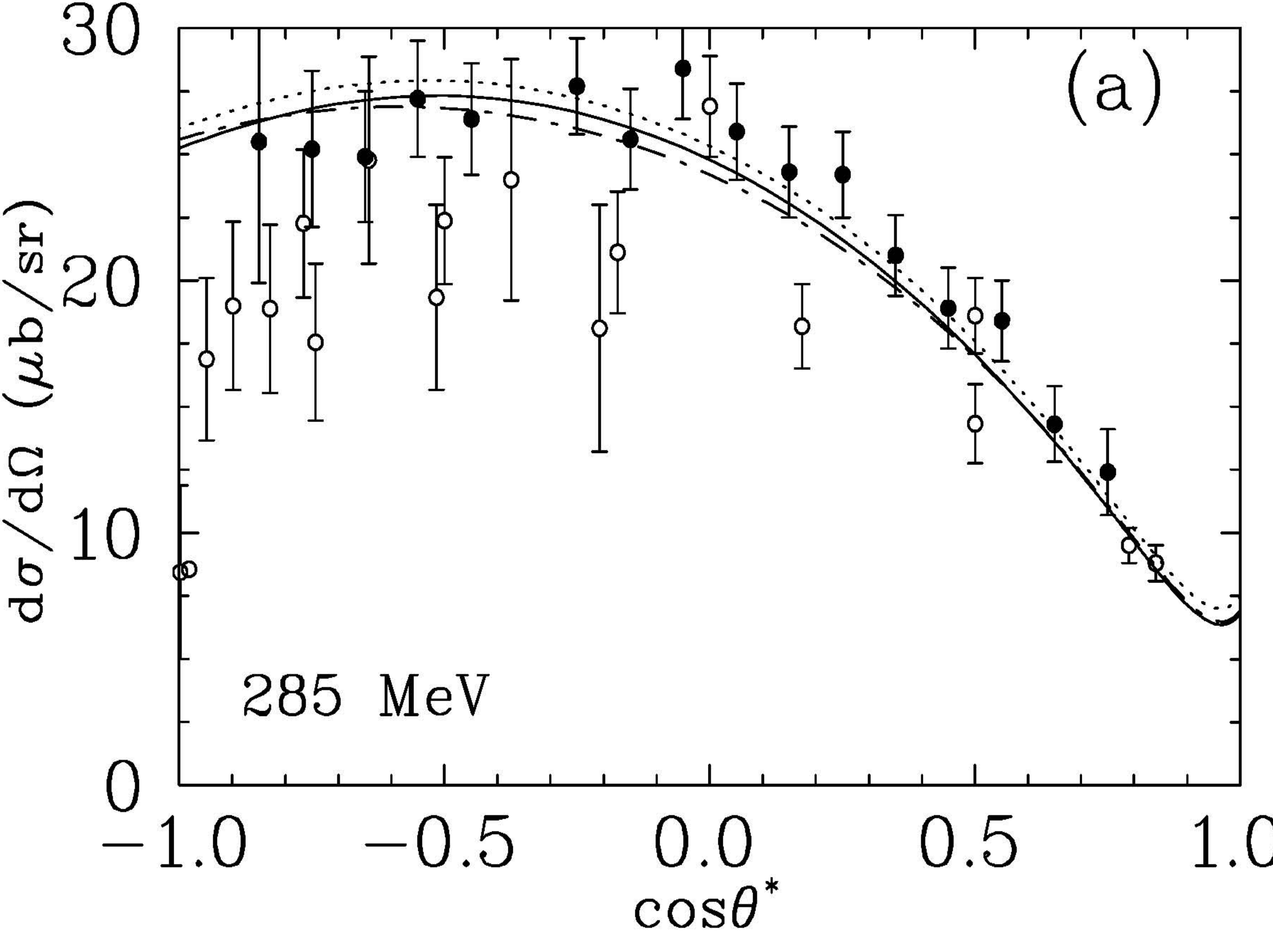
The George Washington University

Advantages of Radiative Capture Experiments

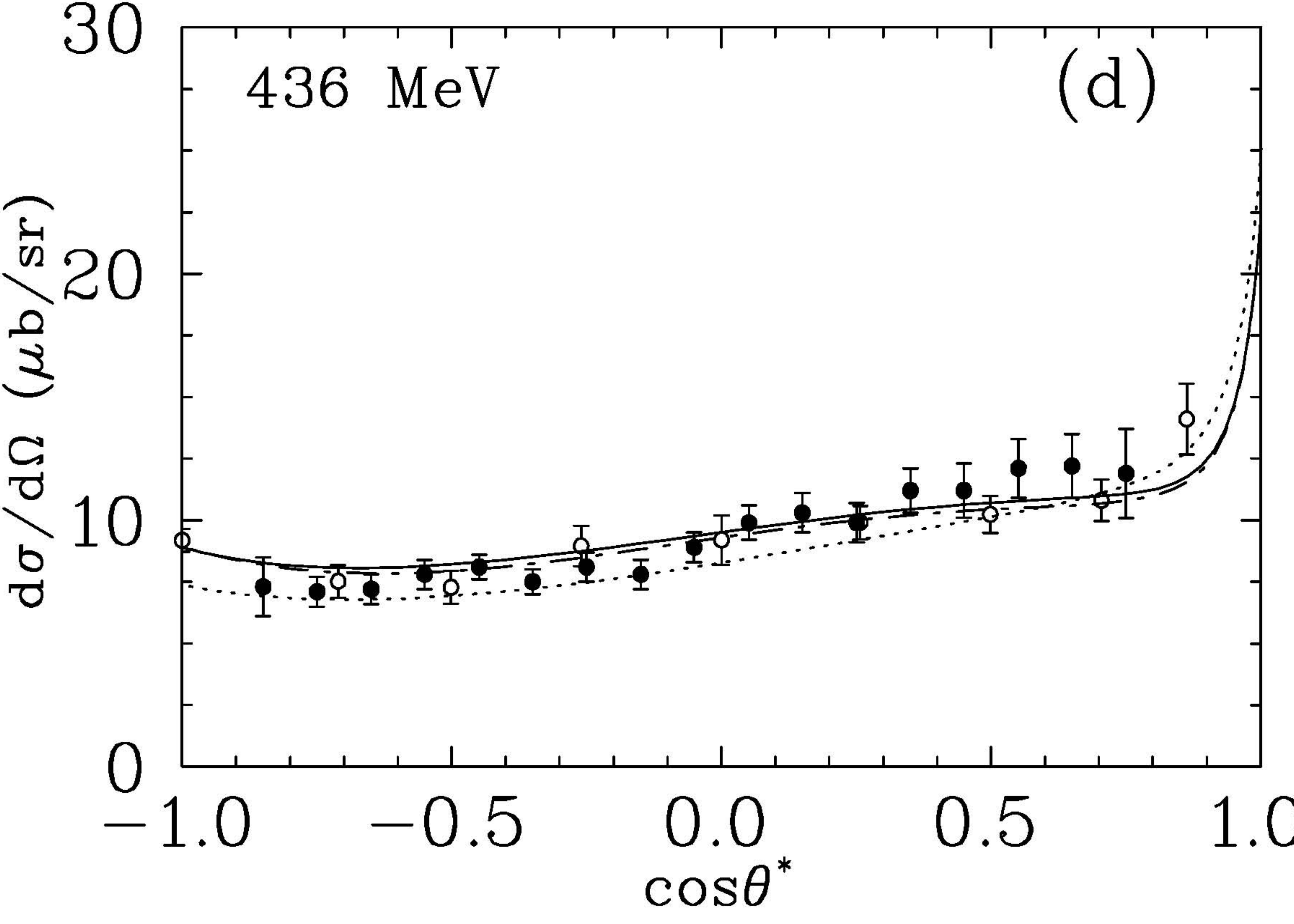
- As in photoproduction it fixes the $q^2 = 0$ point, important for understanding the behavior of baryon resonances at higher momentum transfer.
- The inverse photoproduction reaction $\gamma n \rightarrow \pi^- p$ has the disadvantage of requiring corrections due to the lack of a free neutron target. Must use $\gamma d \rightarrow \pi^- pp$ and make “deuteron” corrections.

Final Results

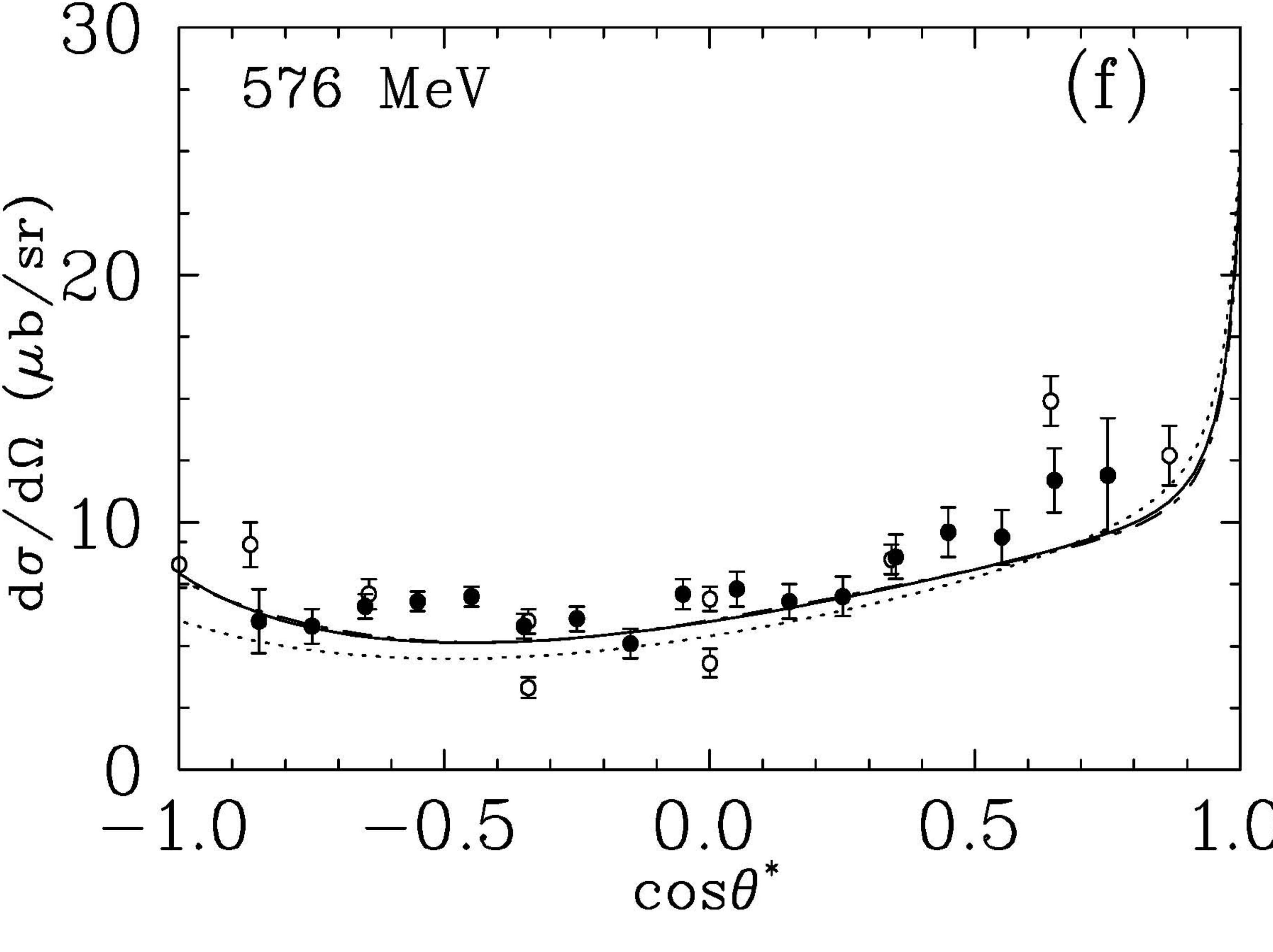
- 18 Differential Cross Sections with 10% Statistics.
- Large angular range: 18 angular bins.
- Large range in momentum
- $p_\pi = 238$ MeV/c – 748 MeV/c



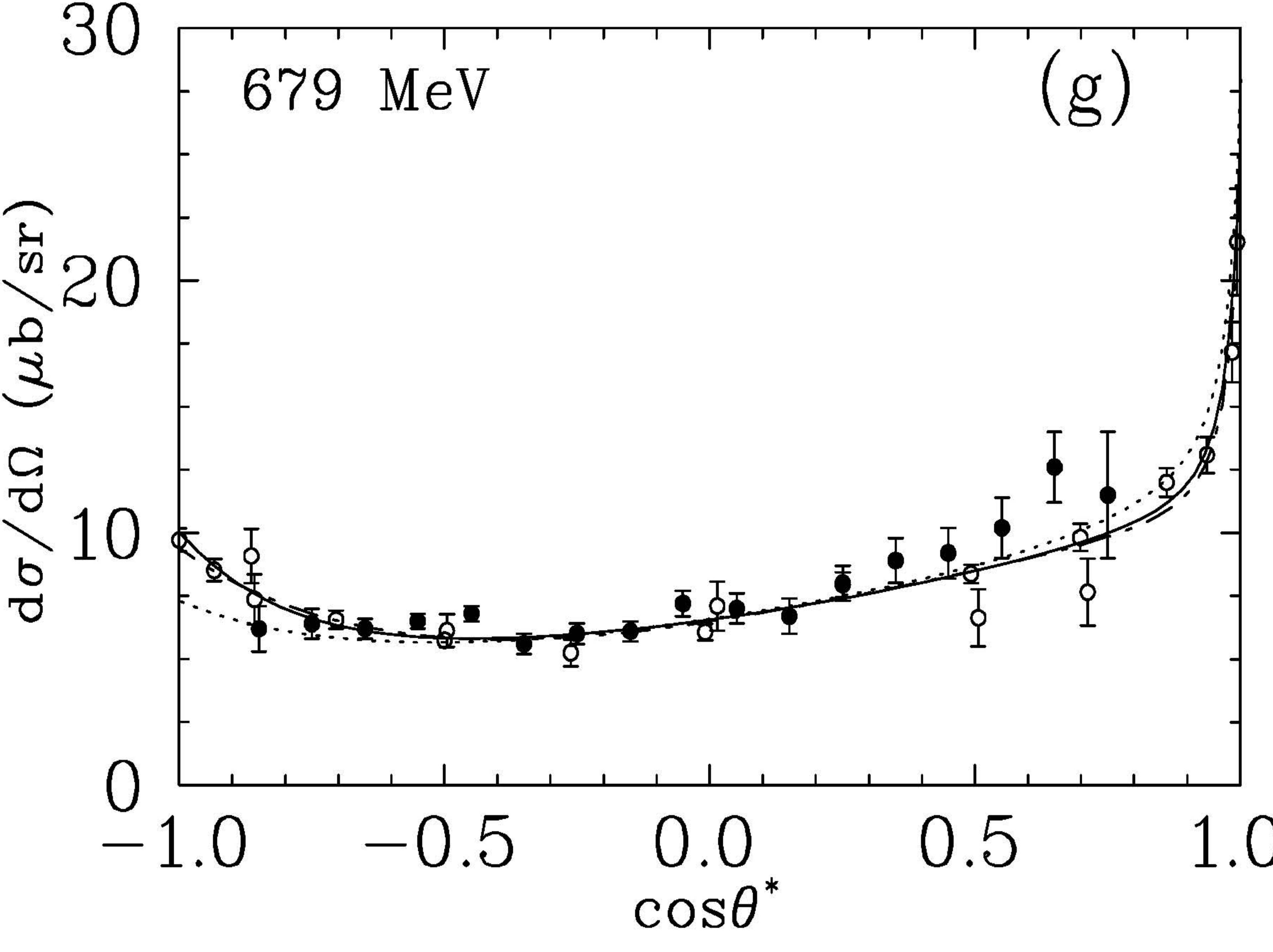
(a)
285 MeV
dσ/dΩ (μb/sr)
cosθ*
0
10
20
30
−1.0
−0.5
0.0
0.5
1.0

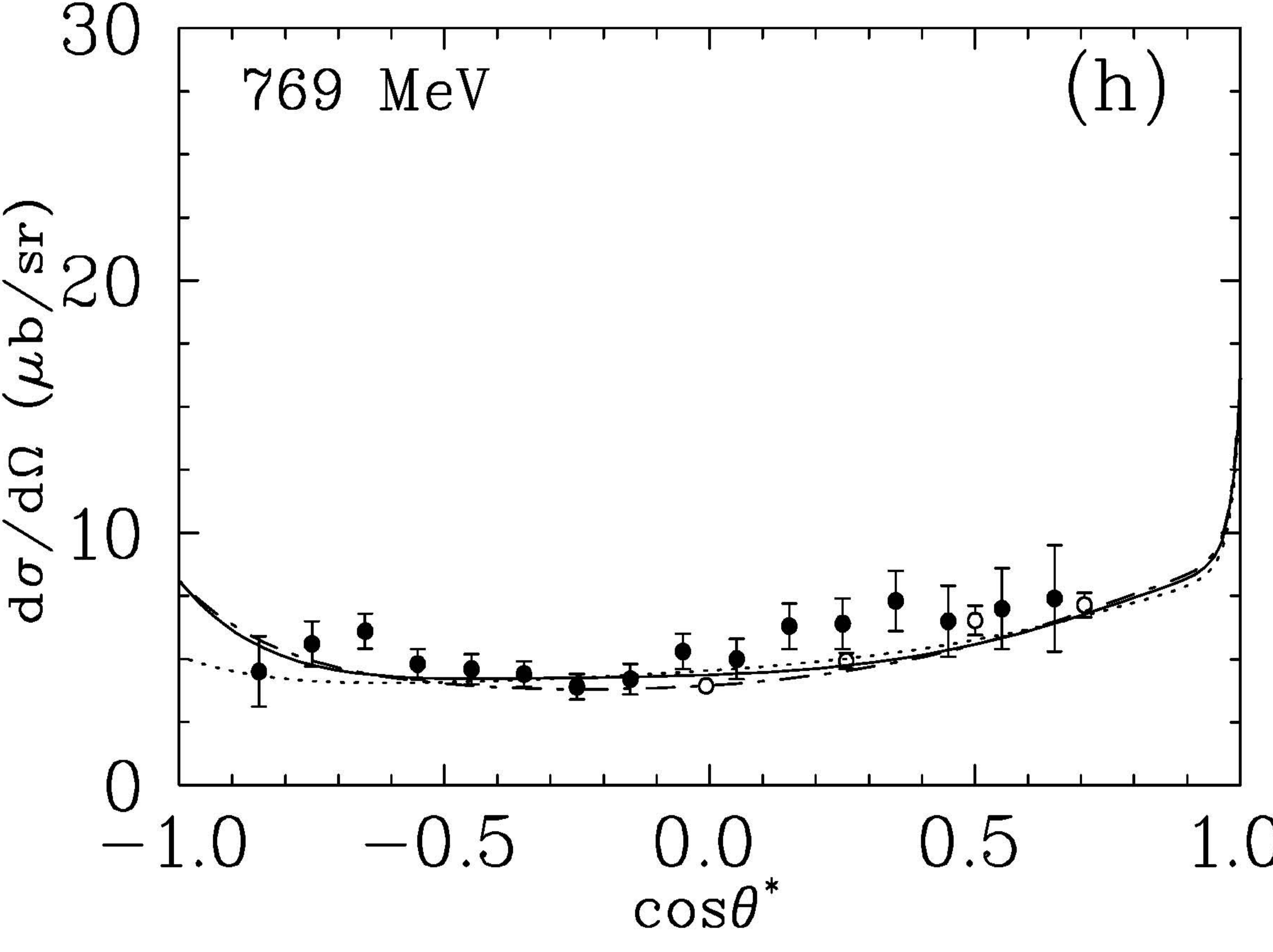


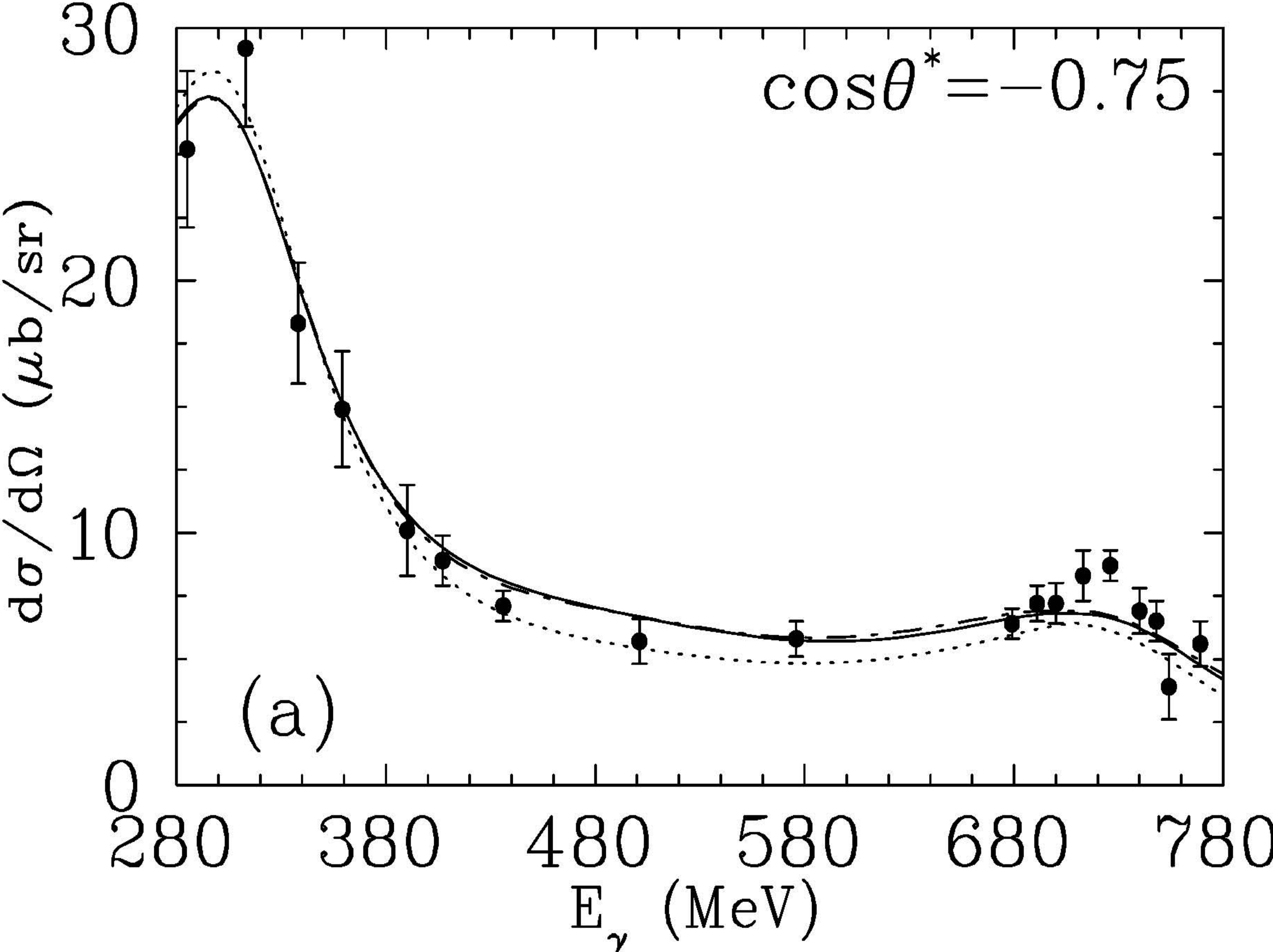
436 MeV
(d)
dσ/dΩ (μb/sr)
cosθ*
0
10
20
30
−1.0
−0.5
0.0
0.5
1.0



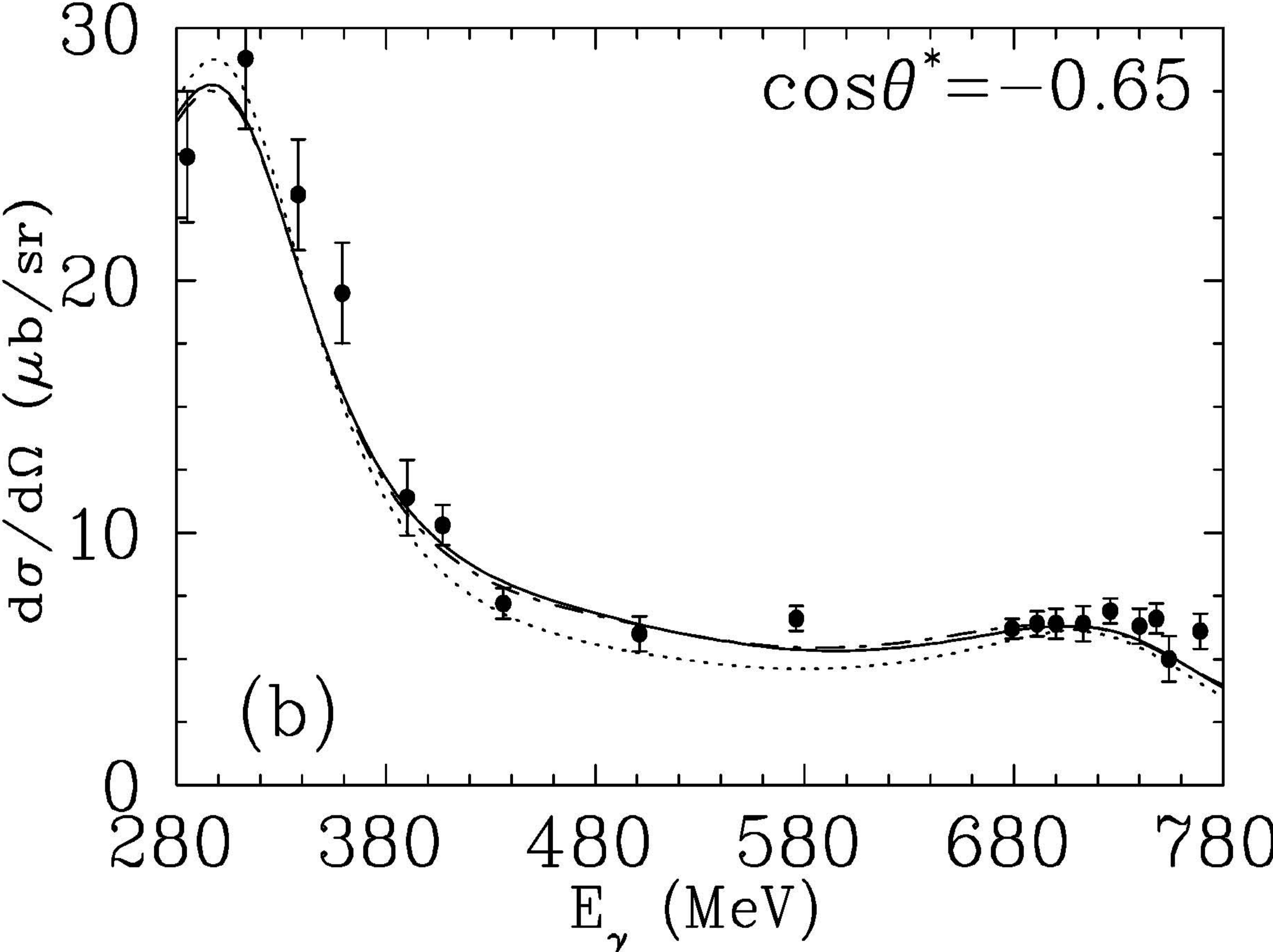
576 MeV
(f)
dσ/dΩ (μb/sr)
cosθ*
0
10
20
30
−1.0
−0.5
0.0
0.5
1.0


679 MeV
(g)
dσ/dΩ (μb/sr)
cosθ*
0
10
20
30
−1.0
−0.5
0.0
0.5
1.0

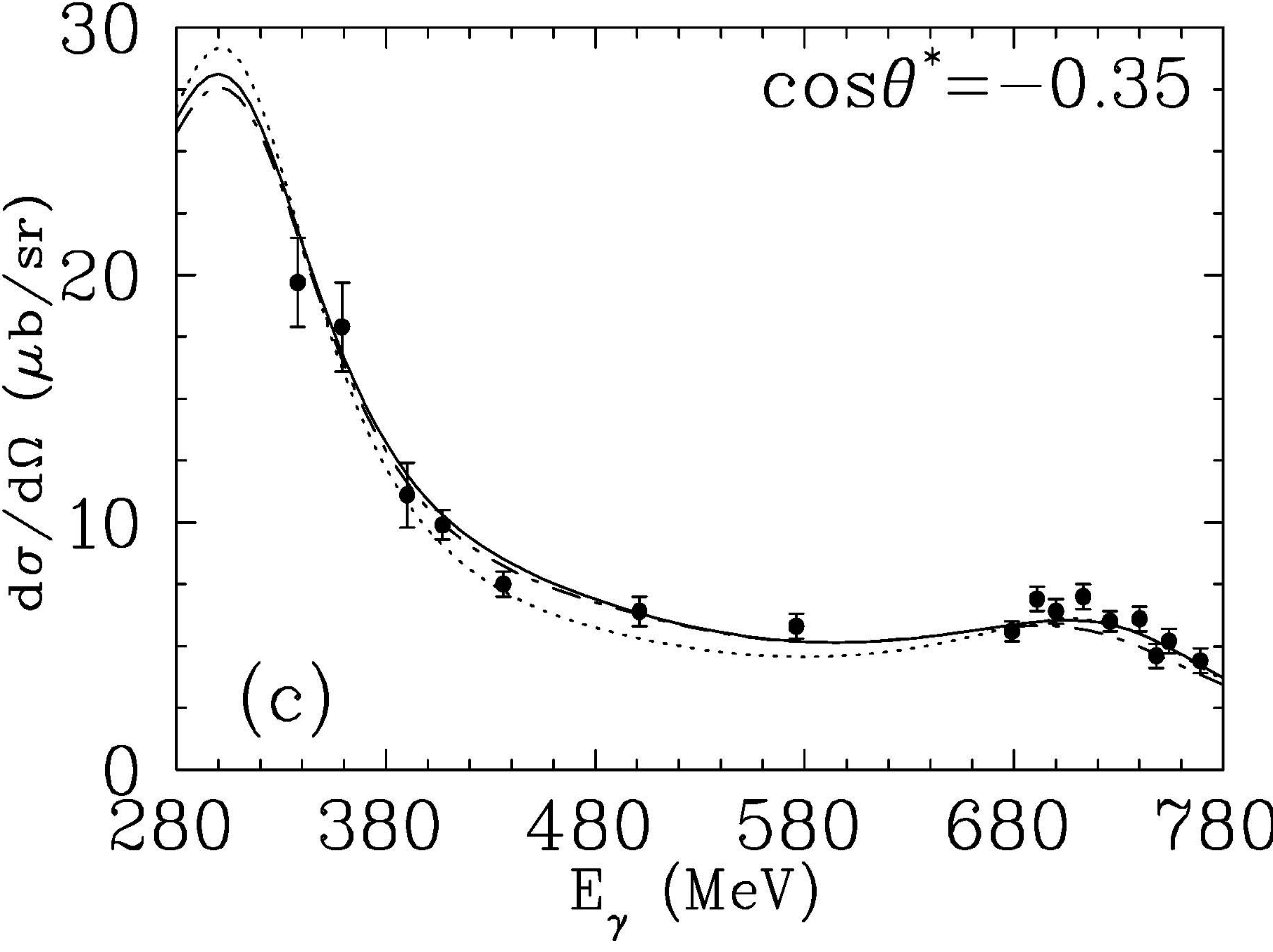

769 MeV
(h)
dσ/dΩ (μb/sr)
cosθ*
30
20
10
0
−1.0
−0.5
0.0
0.5
1.0



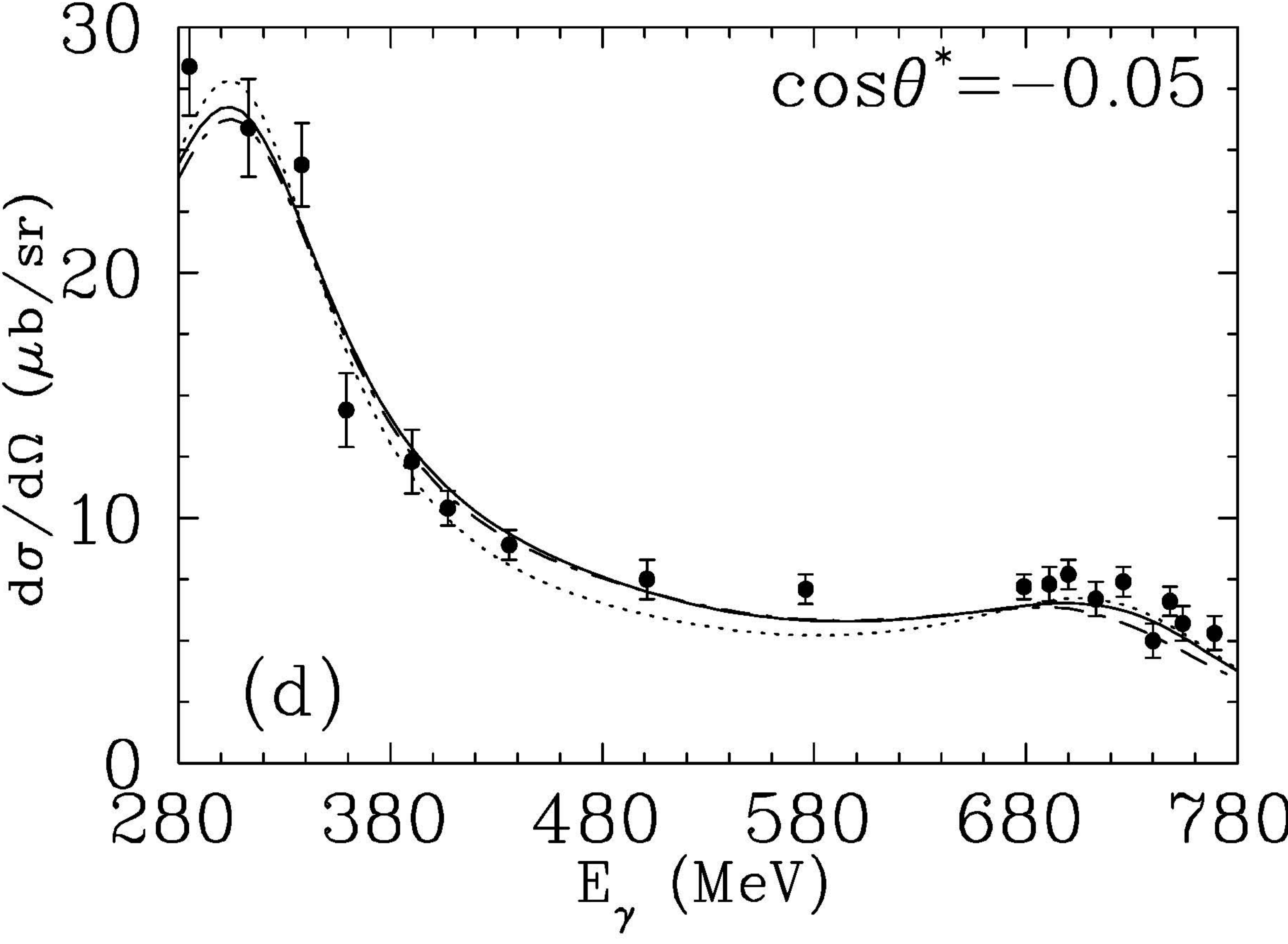
cosθ^*=−0.75
(a)
dσ/dΩ (μb/sr)
0
10
20
30
280
380
480
580
680
780
E$_\gamma$ (MeV)



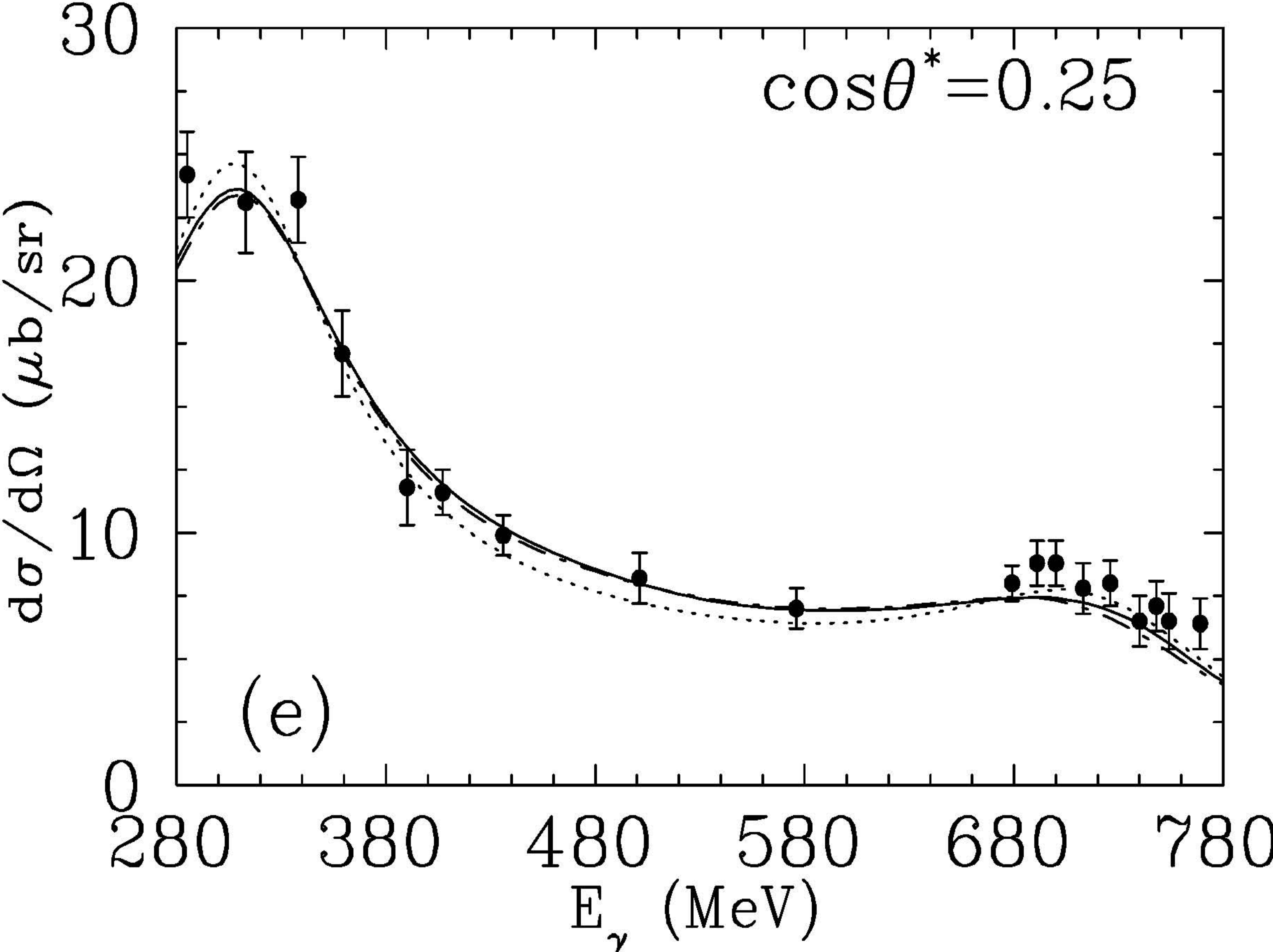
cosθ* = −0.65
(b)
dσ/dΩ (μb/sr)
E_γ (MeV)
0
10
20
30
280
380
480
580
680
780



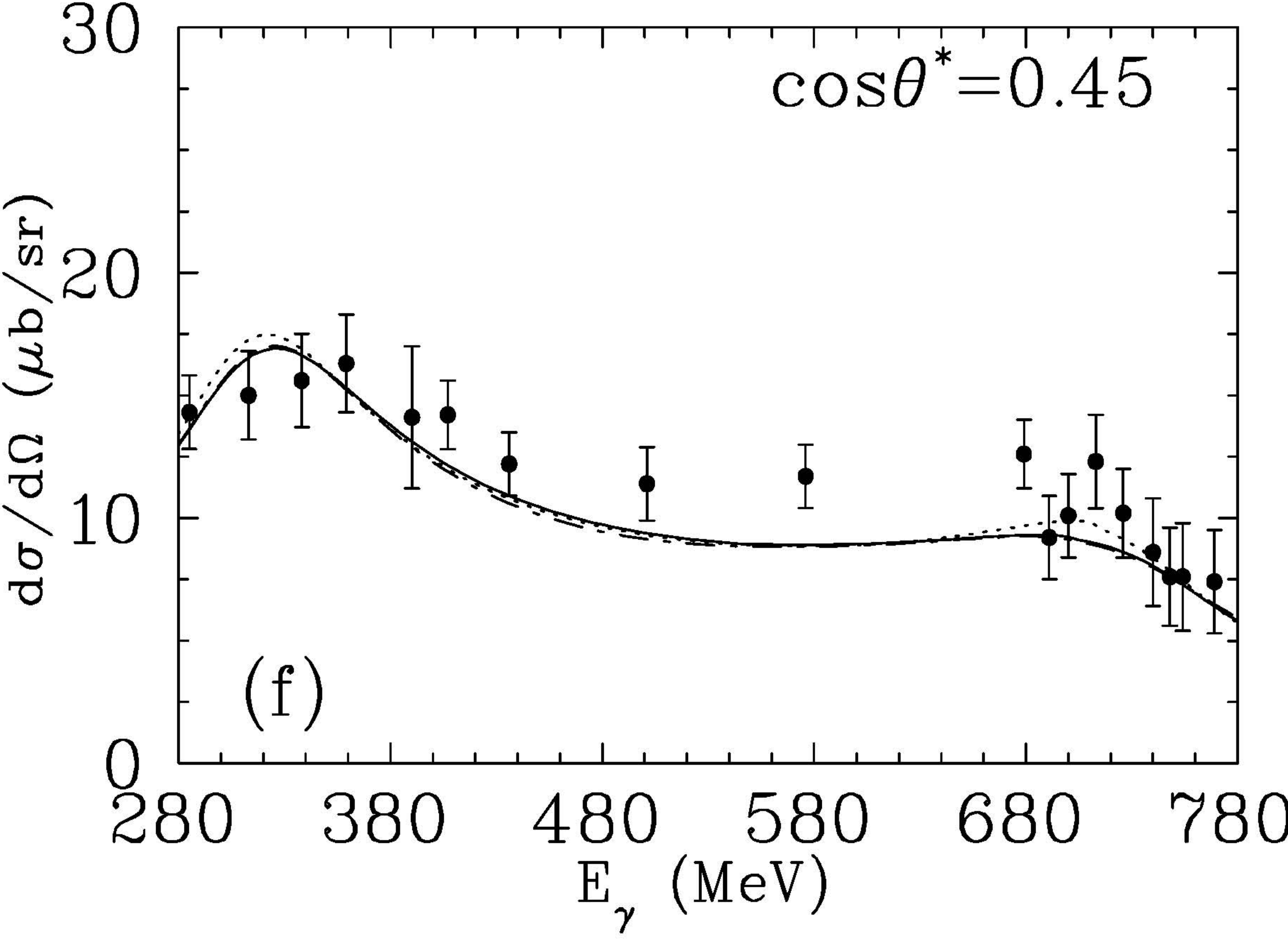
cosθ* = −0.35
(c)
dσ/dΩ (μb/sr)
E_γ (MeV)
0
10
20
30
280
380
480
580
680
780

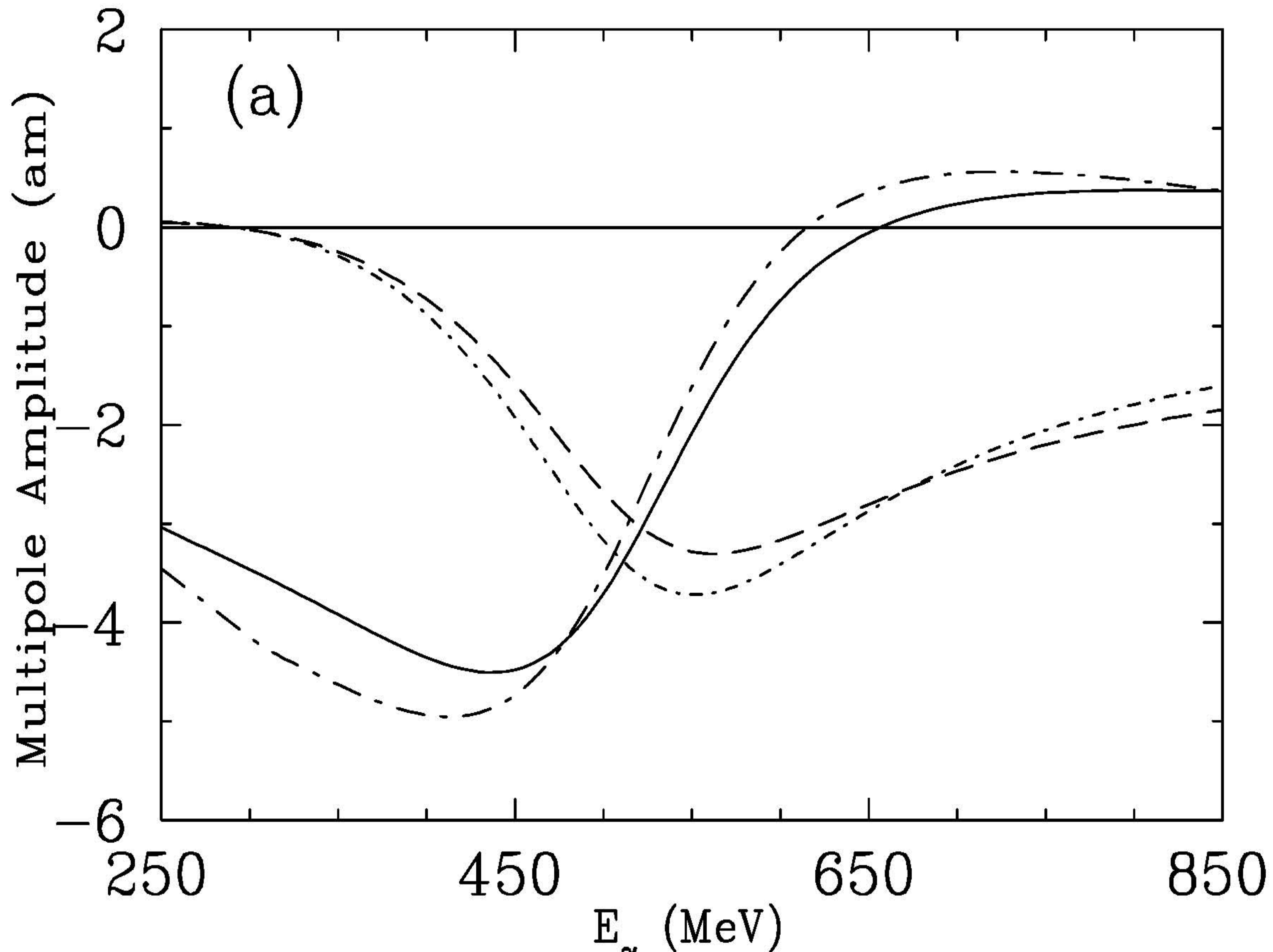


cosθ* = −0.05
(d)
dσ/dΩ (μb/sr)
E_γ (MeV)
0
10
20
30
280
380
480
580
680
780

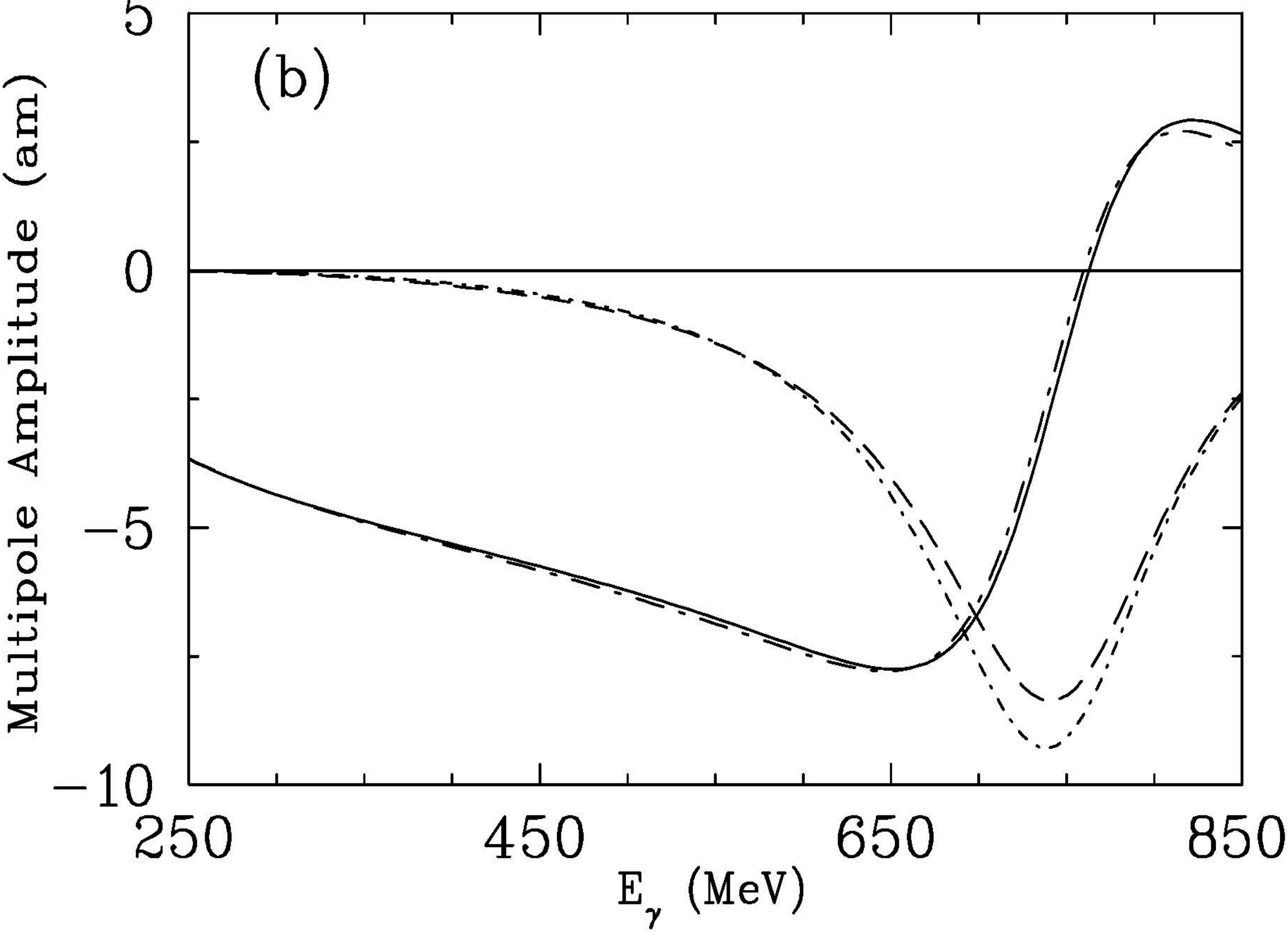


cosθ* = 0.25
(e)
dσ/dΩ (μb/sr)
0
10
20
30
280
380
480
580
680
780
E_γ (MeV)


cosθ* = 0.45
(f)
dσ/dΩ (μb/sr)
E_γ (MeV)
0
10
20
30
280
380
480
580
680
780



(a)
Multipole Amplitude (am)
2
0
−2
−4
−6
250
450
650
850
E_γ (MeV)



(b)
Multipole Amplitude (am)
5
0
−5
−10
250
450
650
850
E_γ (MeV)

Results

- 324 data points: largest number of data from and single experiment spanning this energy range.
- The largest (yet relatively small) effect on the SAID analysis shows up in the Neutron Magnetic Multipoles.

Production of Etas on Protons

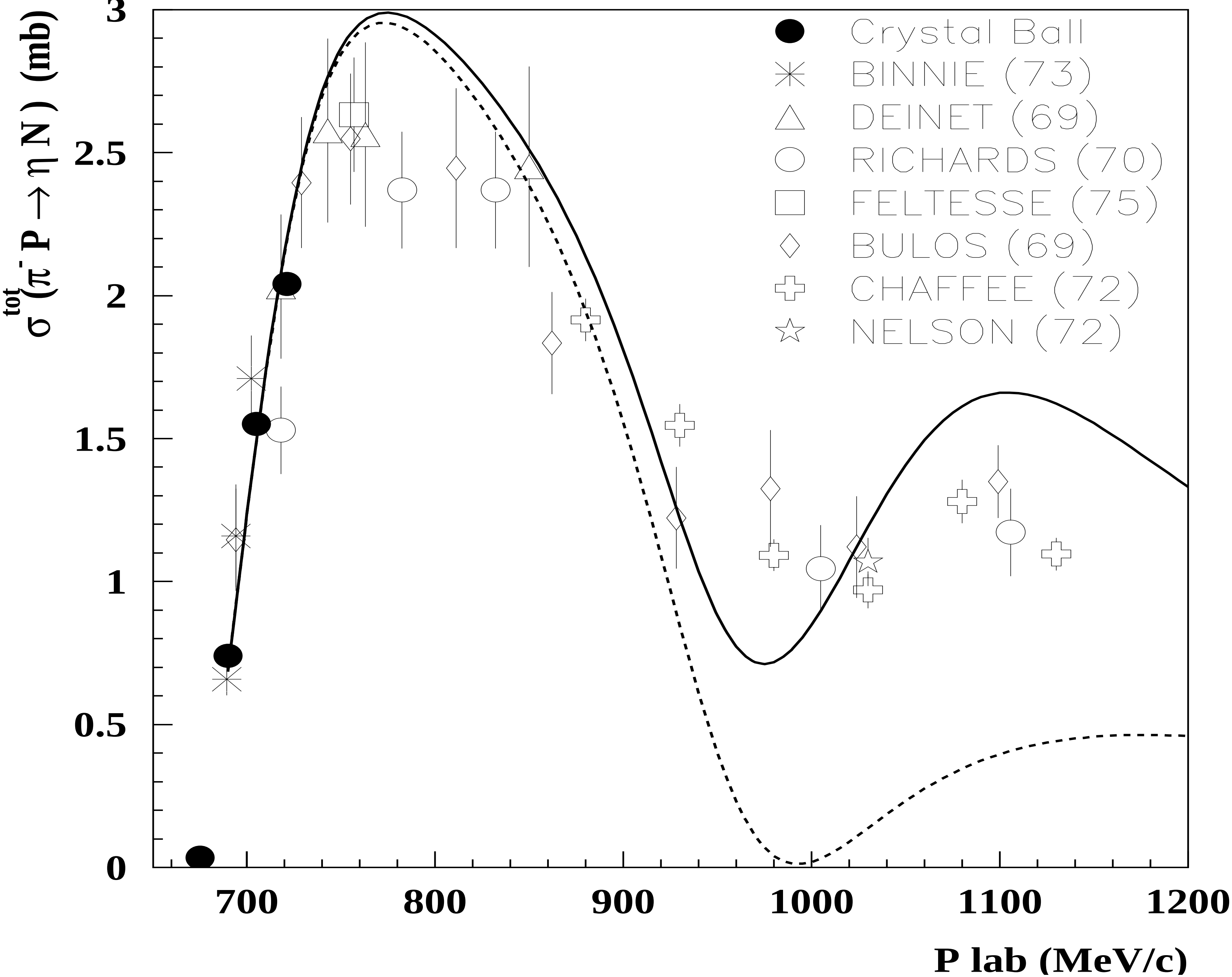
$\pi^- p \rightarrow \eta n$

Thesis of Nicholas G. Kozlenko, PNPI

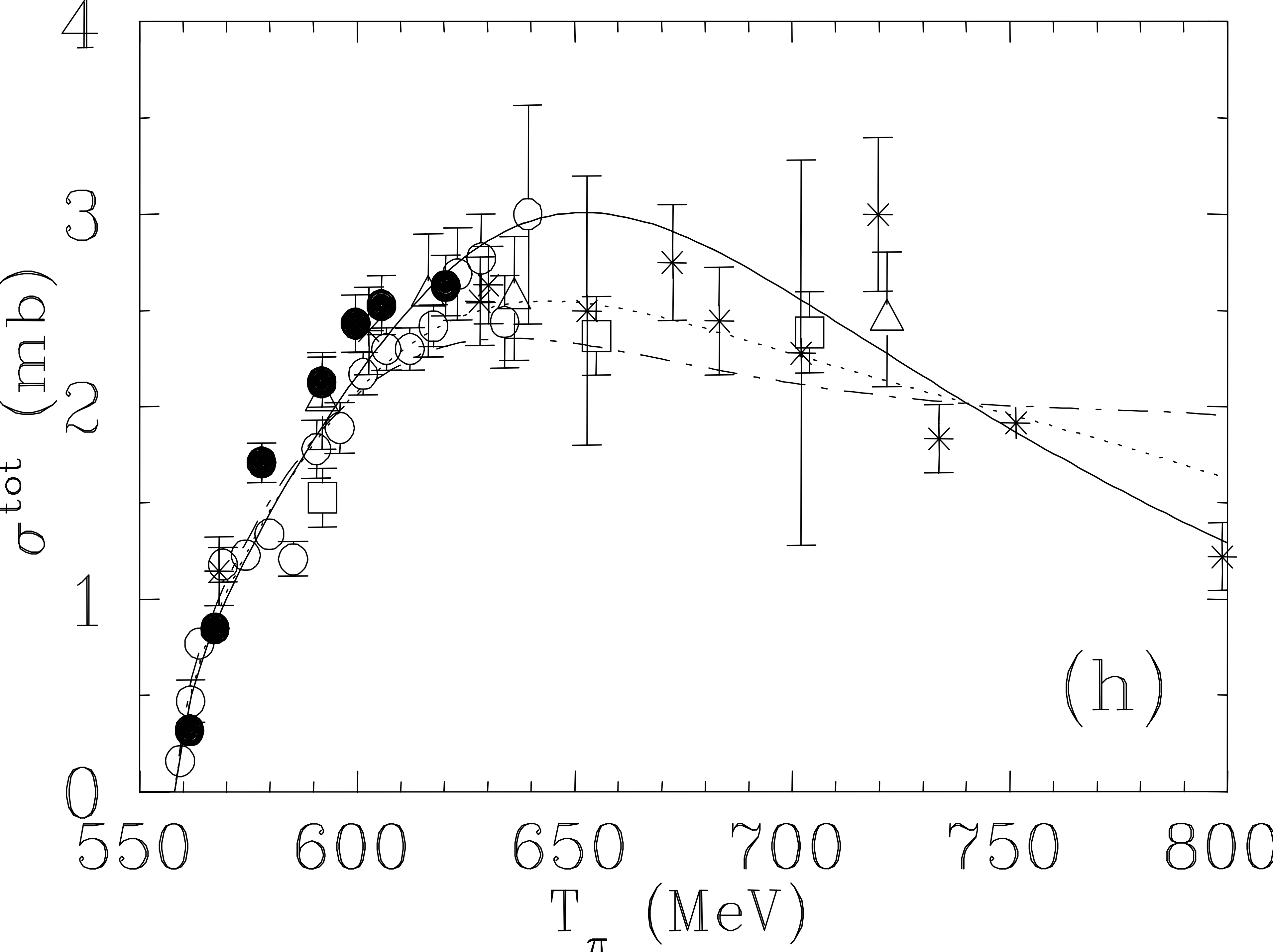
Analysis of Serguei Prakhov, UCLA

Thesis of Thomas W. Morrison, GWU*

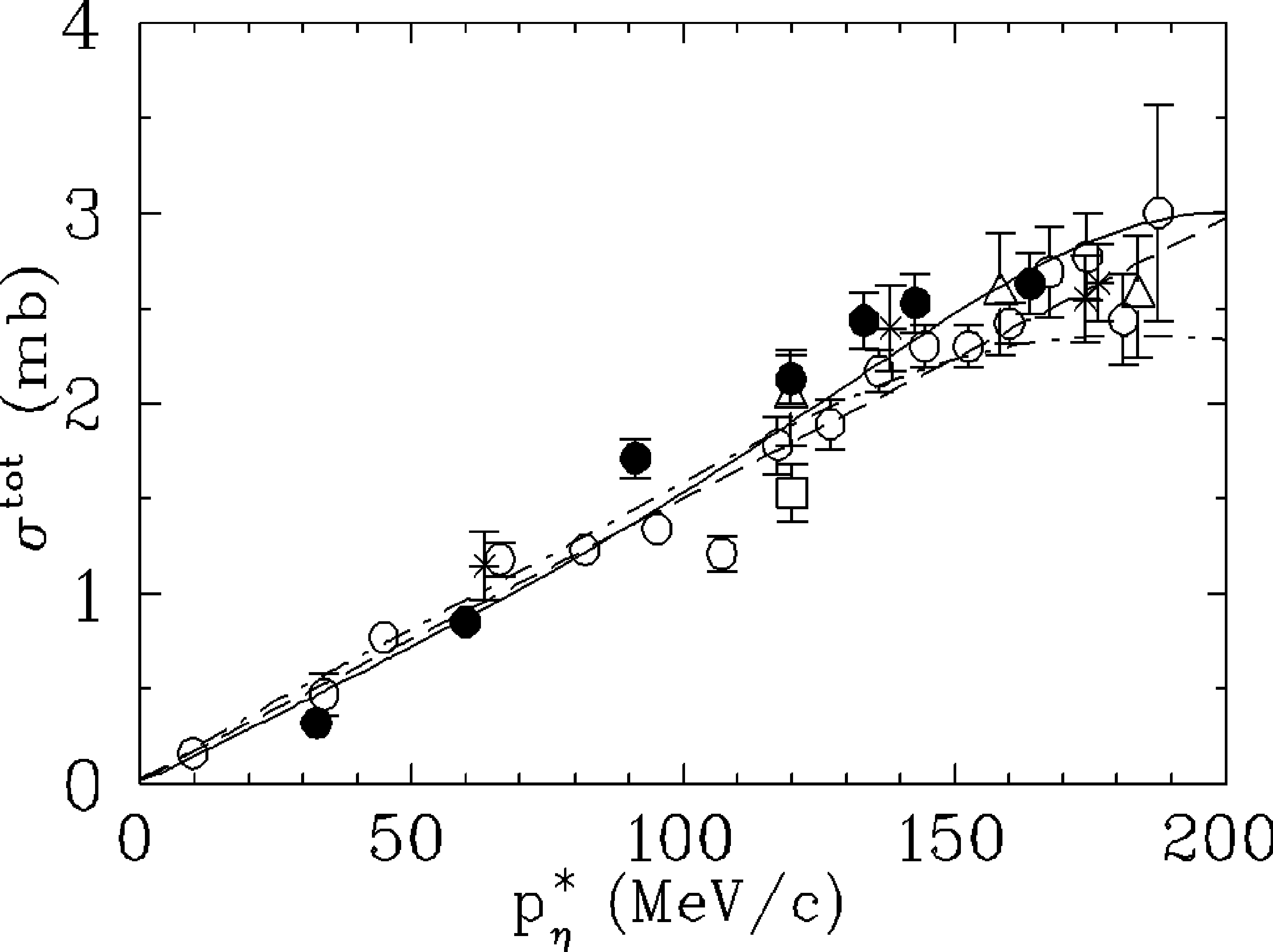
*used LAMPF Neutral Meson Spectrometer in feasibility study



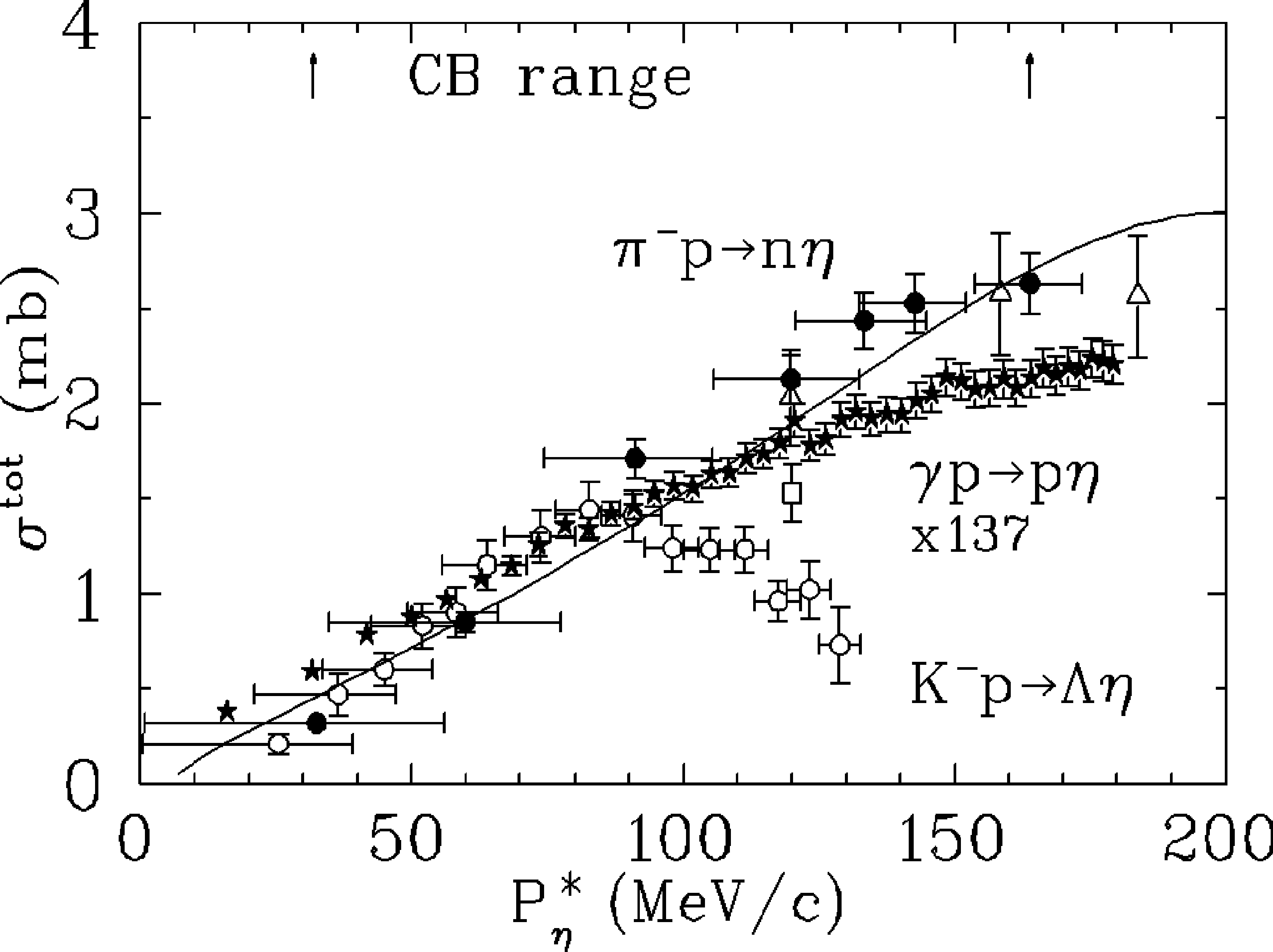
Crystal Ball
BINNIE (73)
DEINET (69)
RICHARDS (70)
FELTESSE (75)
BULOS (69)
CHAFFEE (72)
NELSON (72)
$\sigma^{tot}(\pi^- P \to \eta N)$ (mb)
P lab (MeV/c)
0
0.5
1
1.5
2
2.5
3
700
800
900
1000
1100
1200



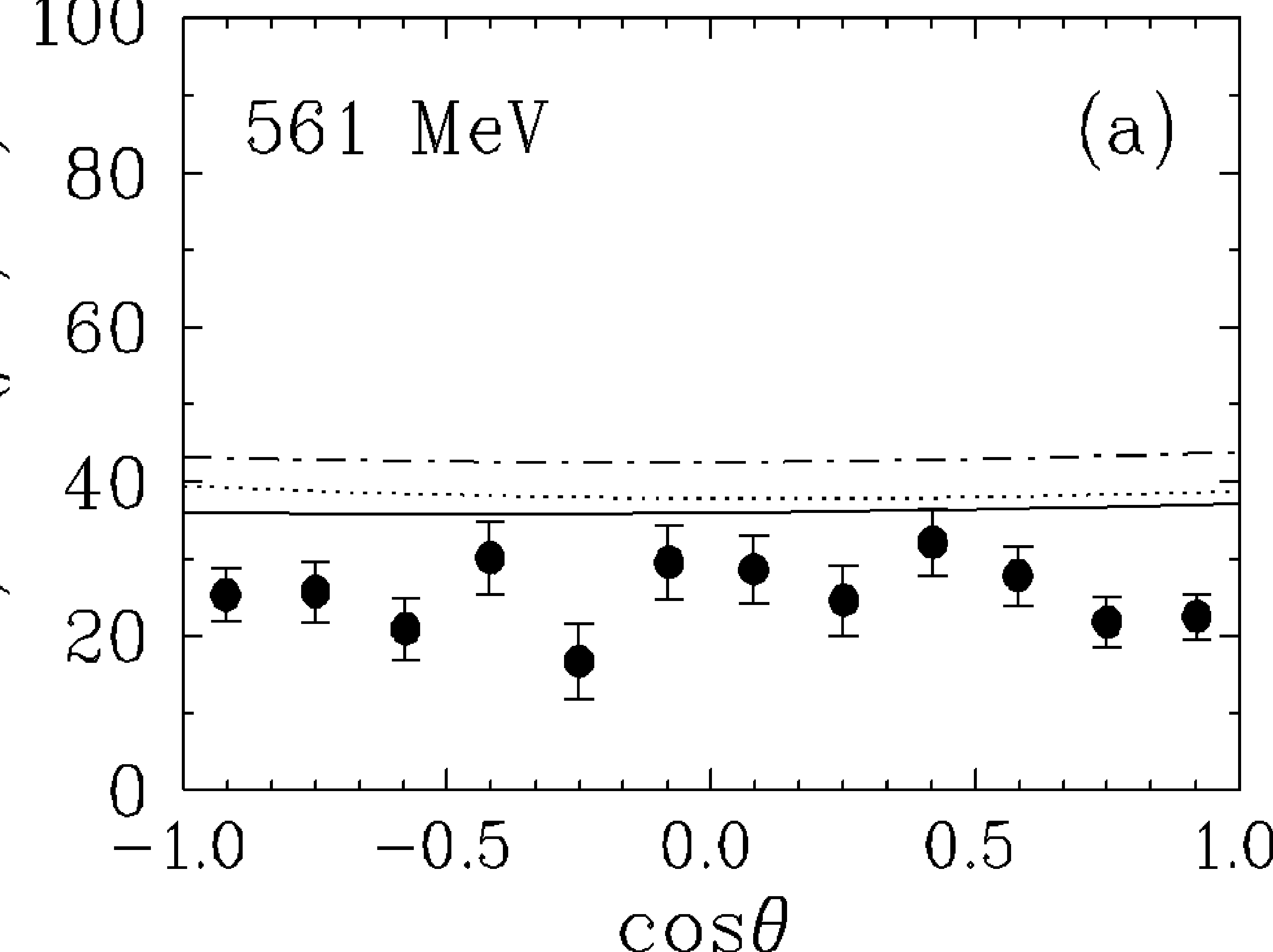
σ^{tot} (mb)
0
1
2
3
4
550
600
650
700
750
800
T_π (MeV)
(h)



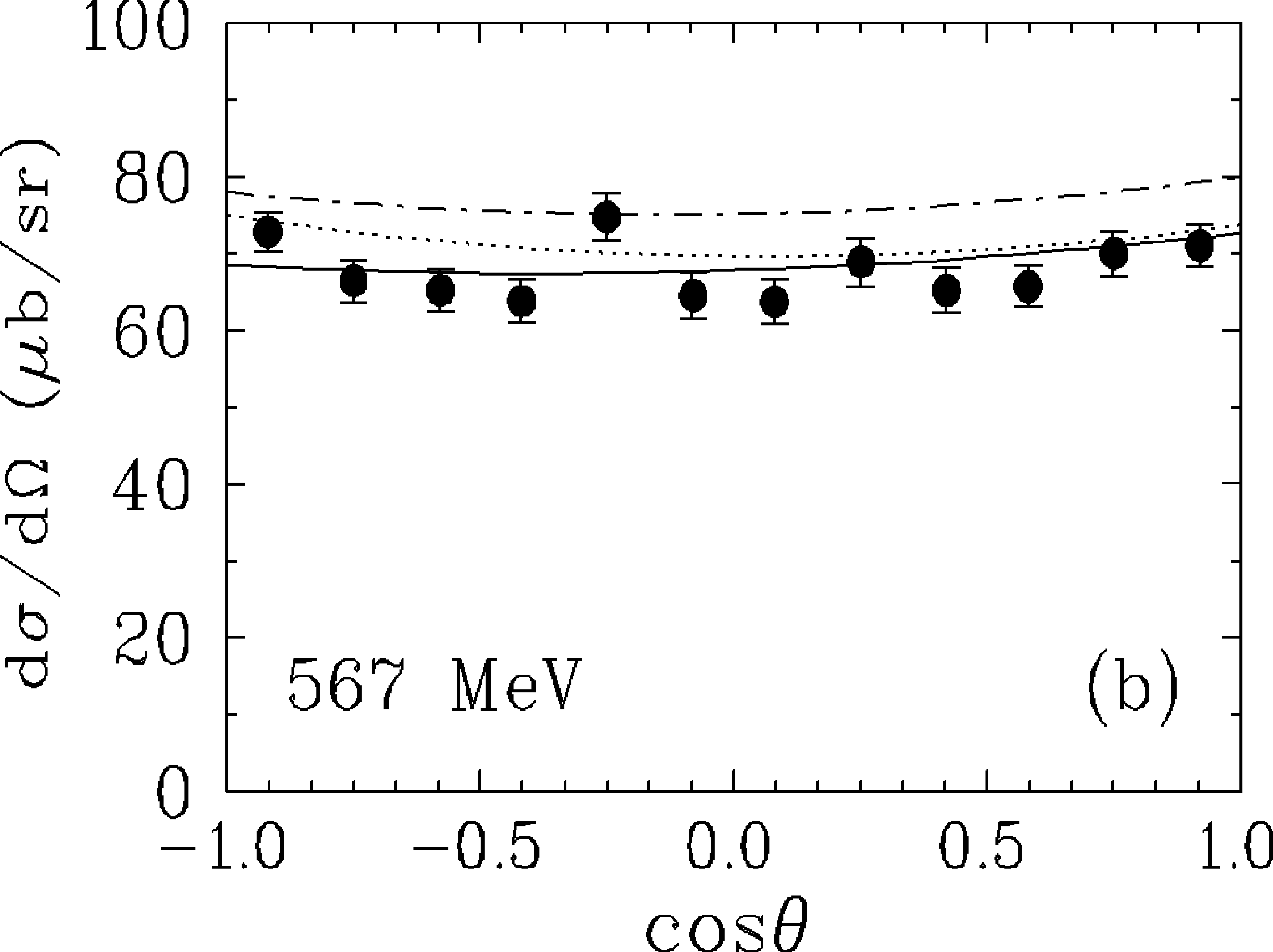
4
3
2
1
0
σ^tot (mb)
0
50
100
150
200
p*_η (MeV/c)



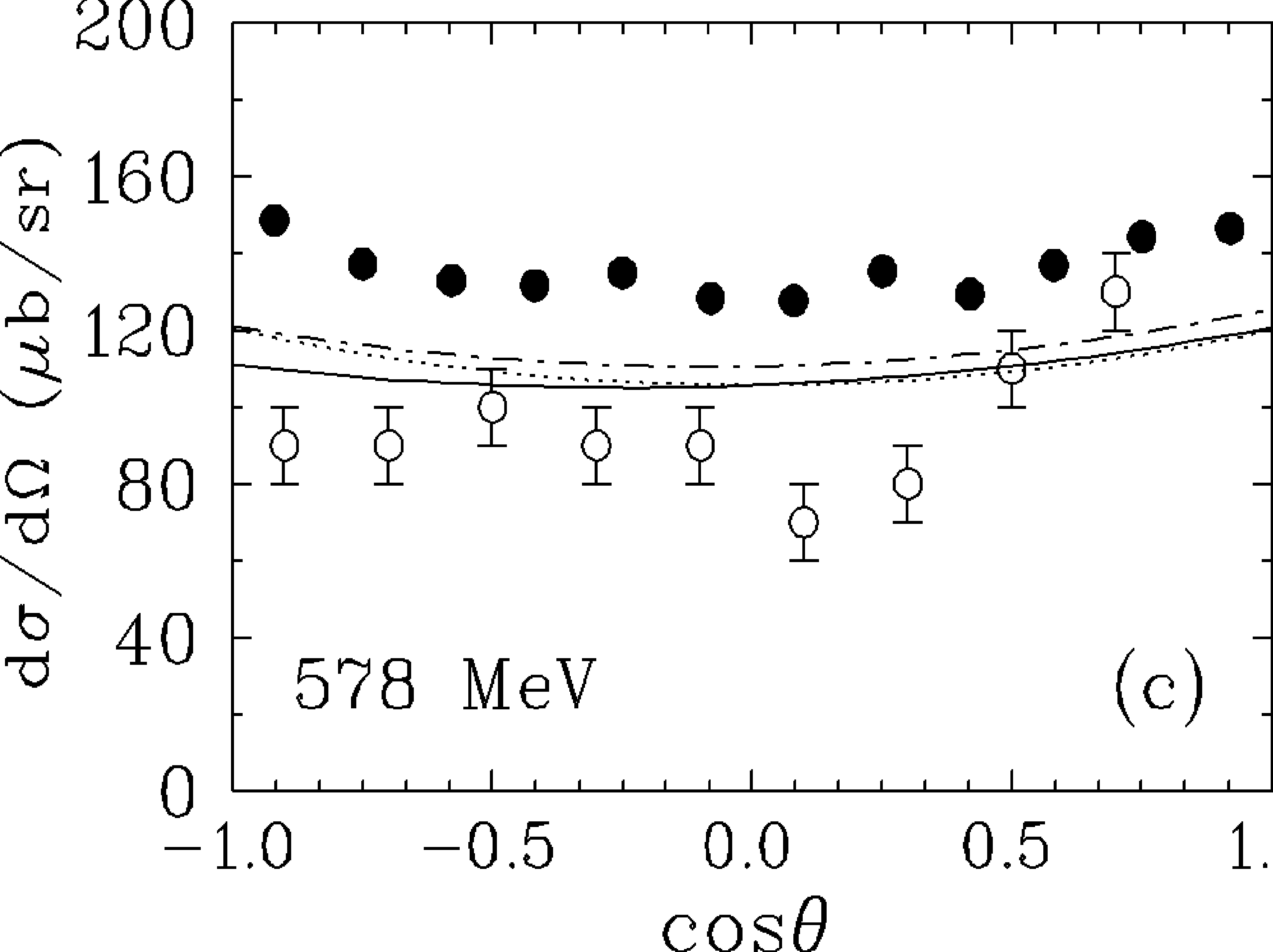
CB range
π⁻p→nη
γp→pη
x137
K⁻p→Λη
σ^tot (mb)
P*_η (MeV/c)
0
1
2
3
4
0
50
100
150
200



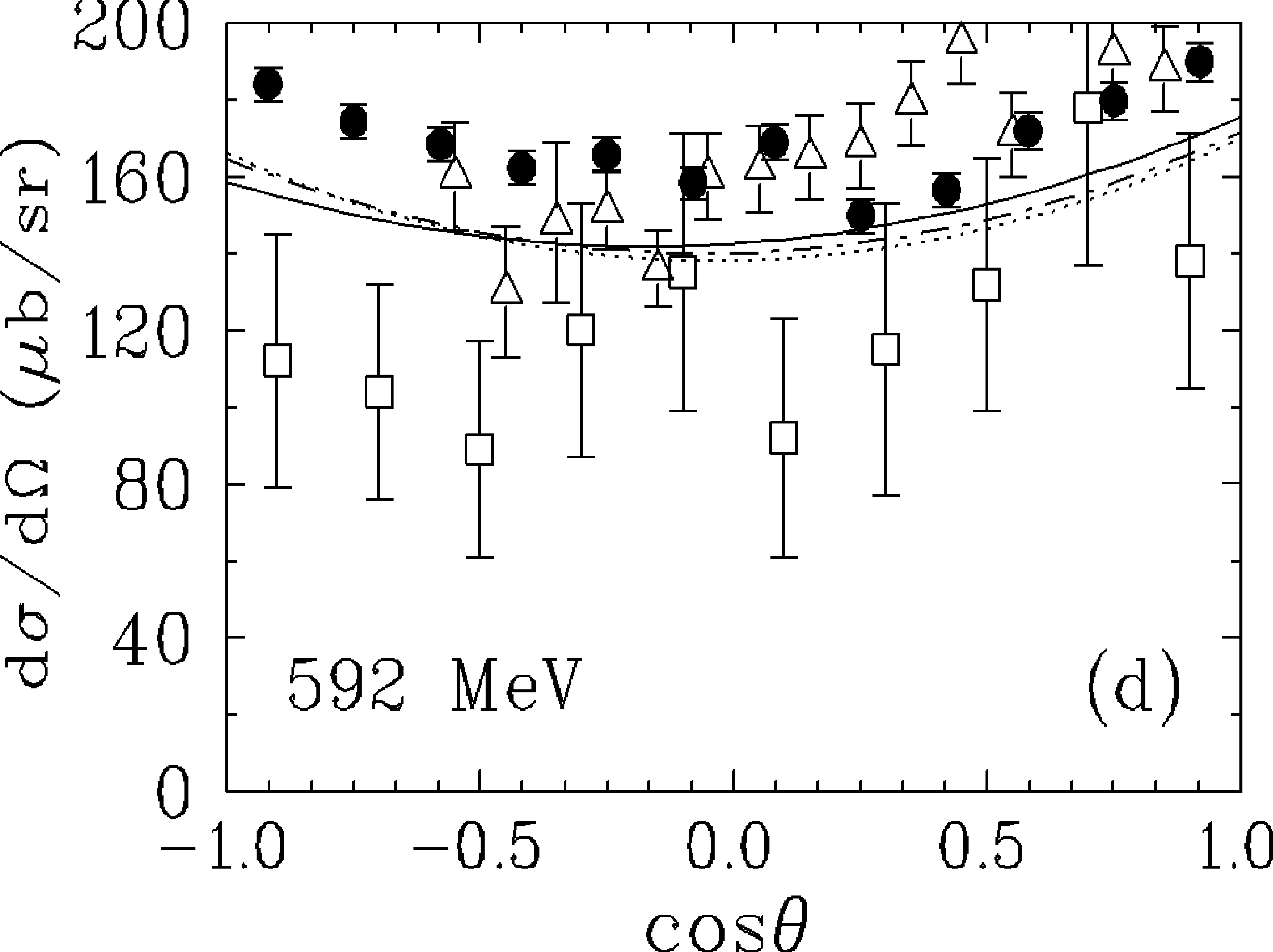
561 MeV
(a)
100
80
60
40
20
0
−1.0
−0.5
0.0
0.5
1.0
cosθ



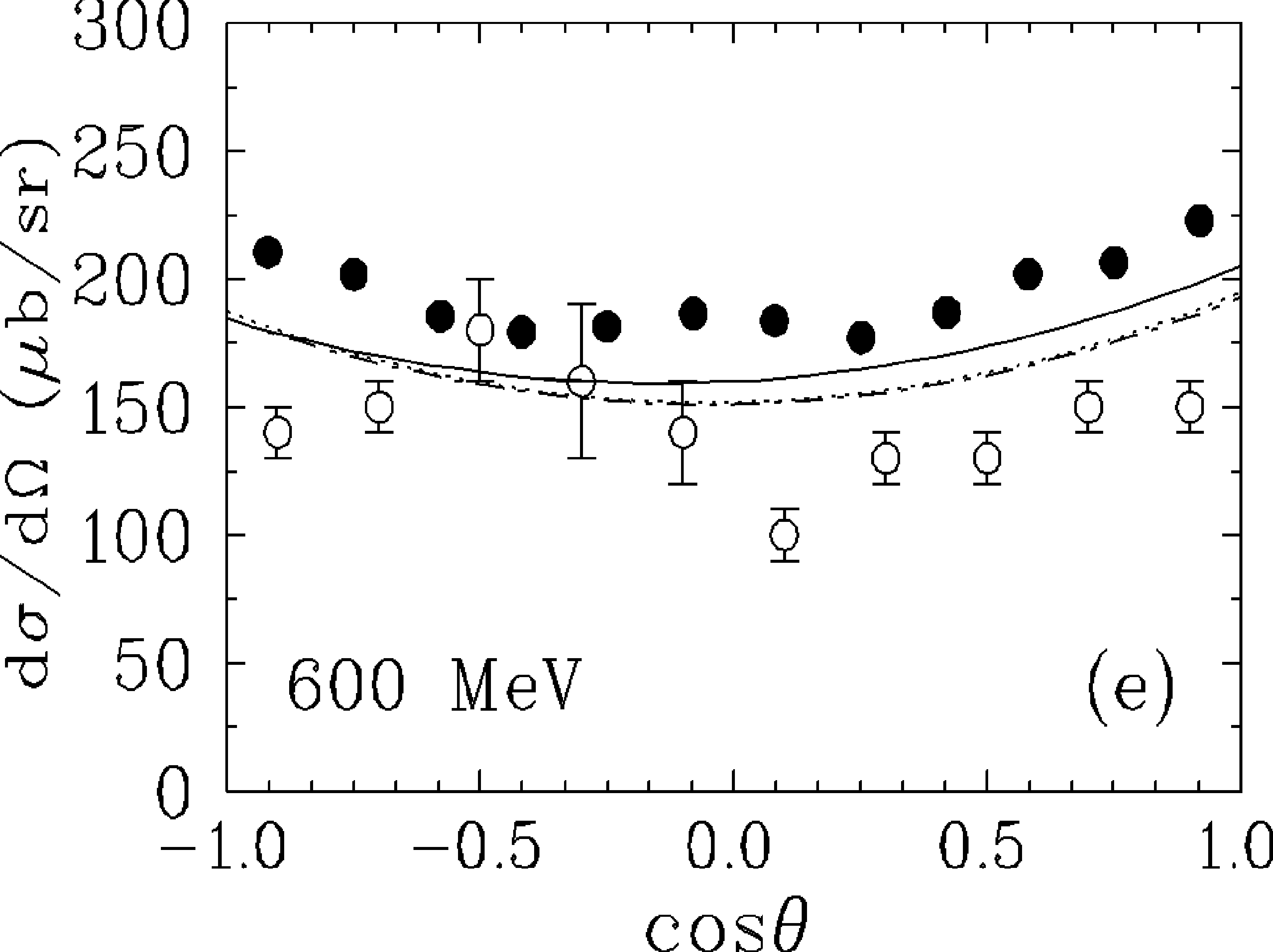
100
80
60
40
20
0
dσ/dΩ (μb/sr)
567 MeV
(b)
−1.0
−0.5
0.0
0.5
1.0
cosθ



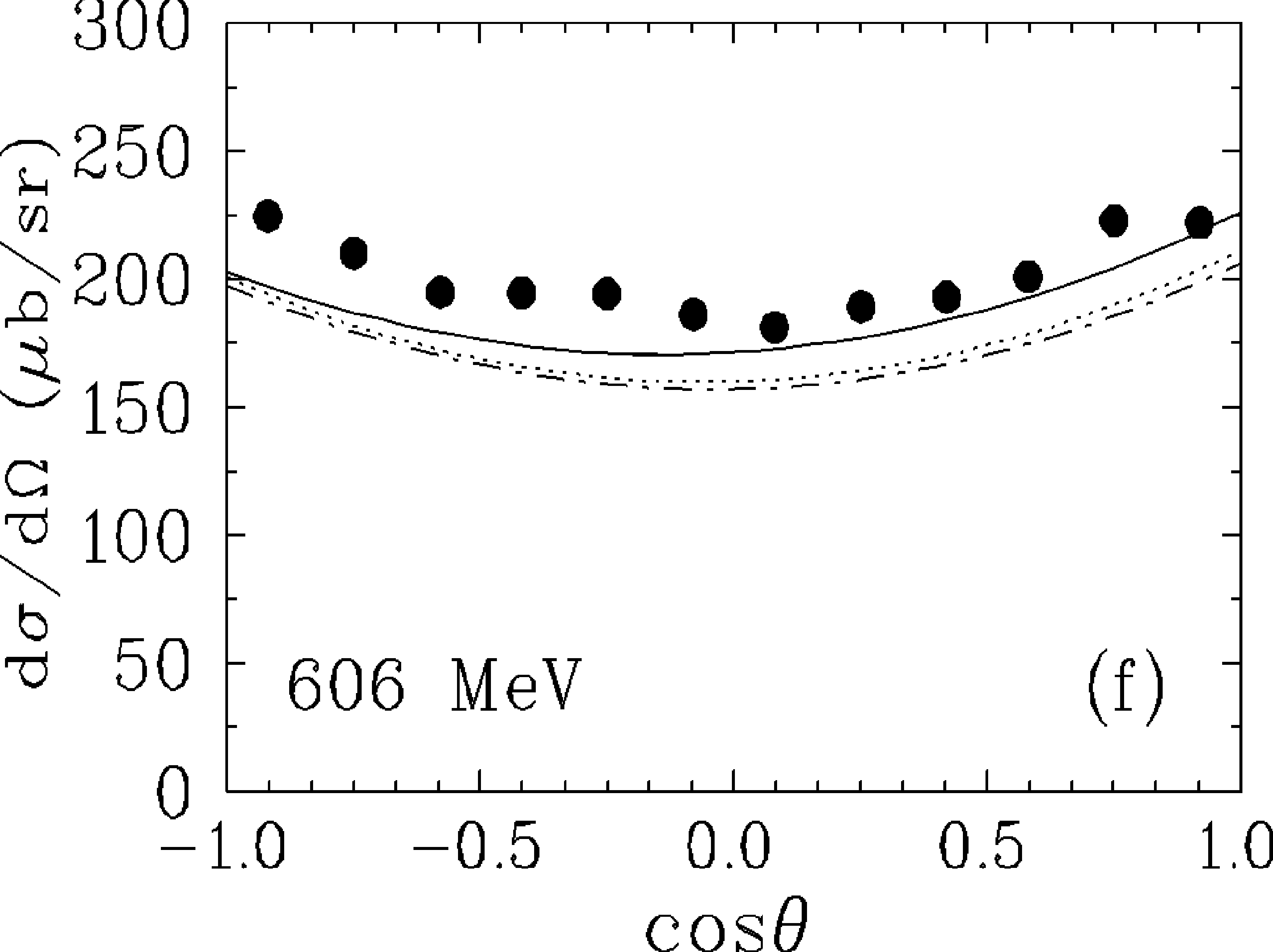
200
160
120
80
40
0
dσ/dΩ (μb/sr)
578 MeV
(c)
−1.0
−0.5
0.0
0.5
1.
cosθ



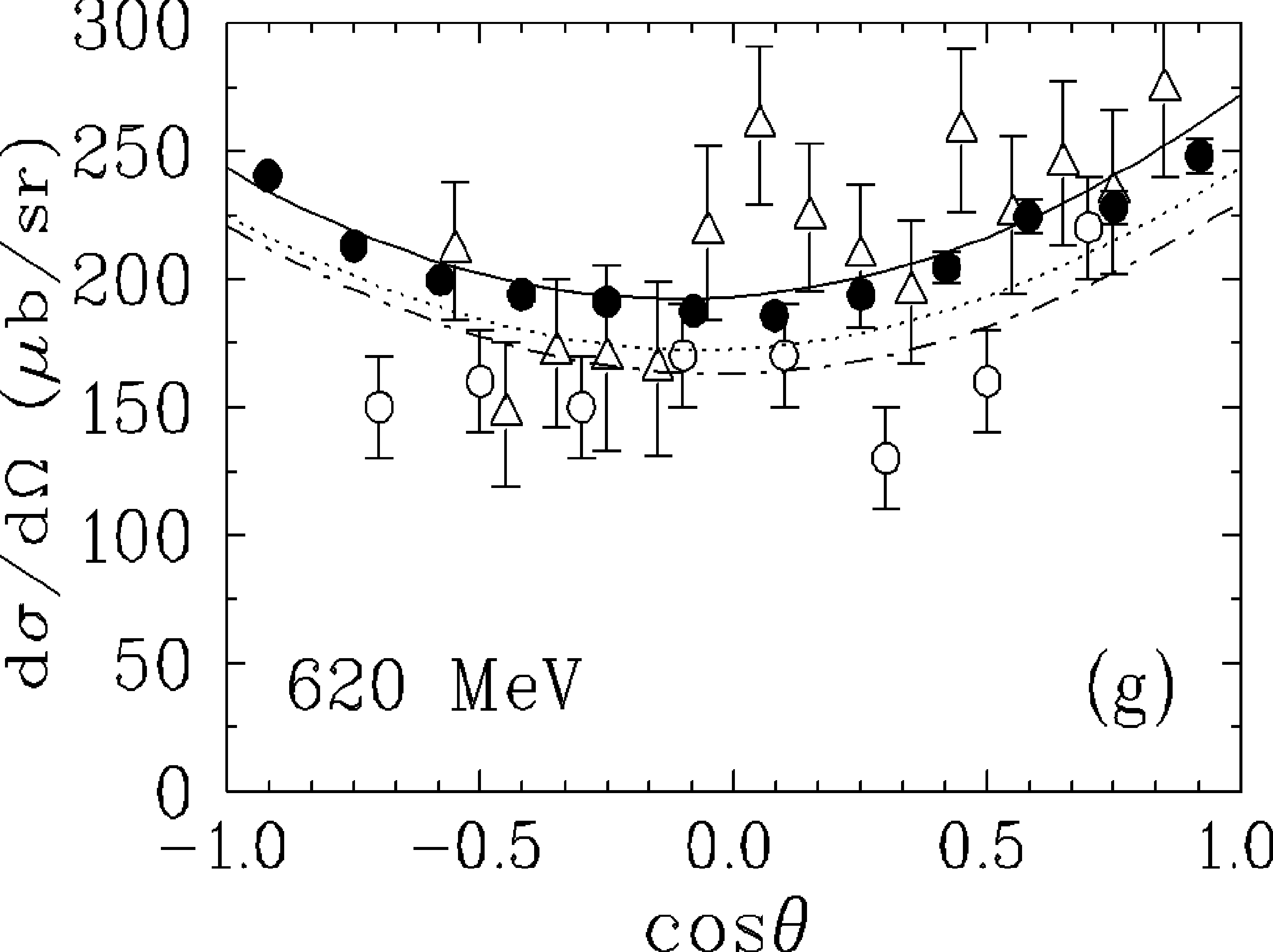
dσ/dΩ (μb/sr)
200
160
120
80
40
0
592 MeV
(d)
−1.0
−0.5
0.0
0.5
1.0
cosθ



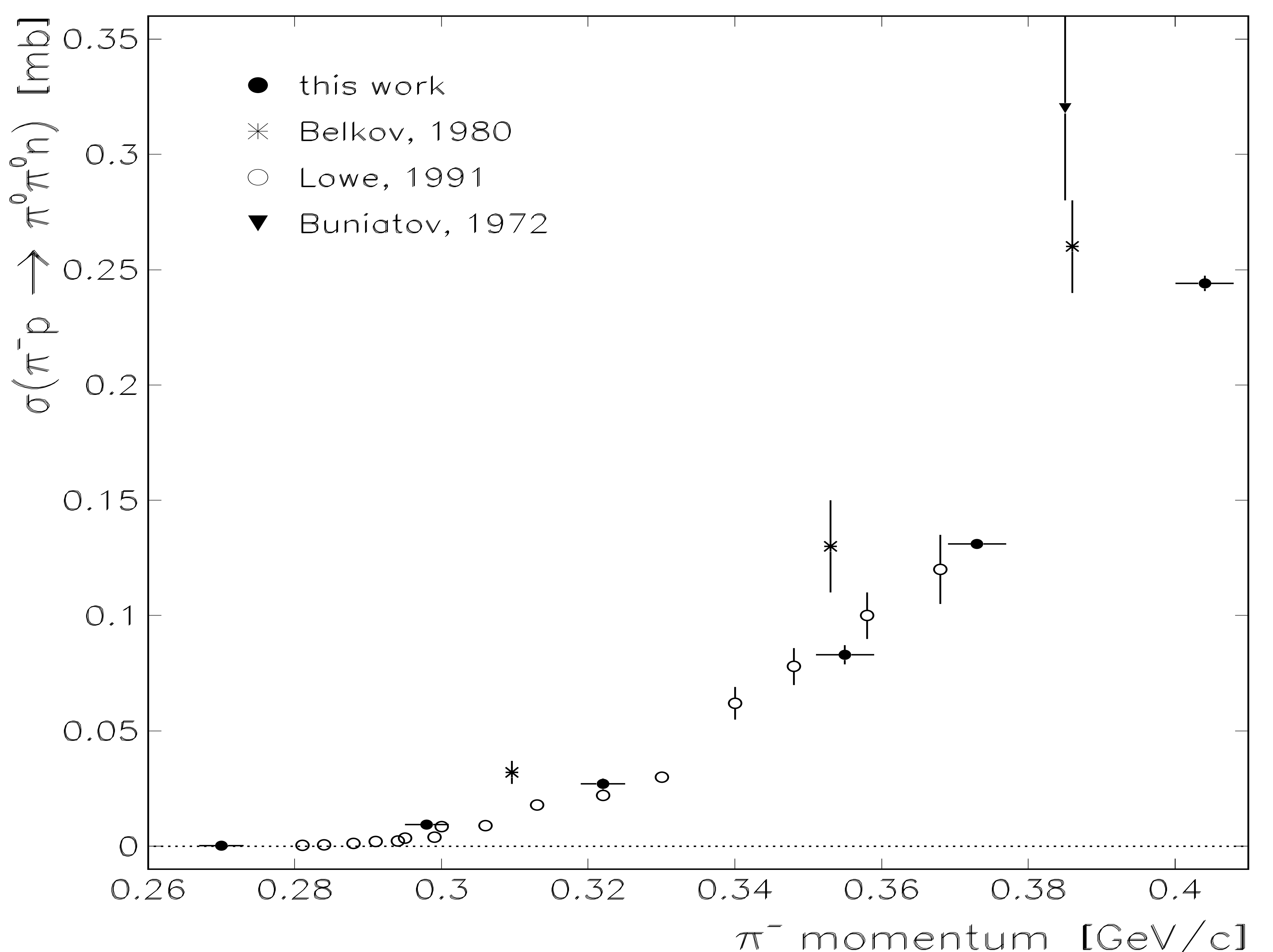
dσ/dΩ (μb/sr)
0
50
100
150
200
250
300
−1.0
−0.5
0.0
0.5
1.0
cosθ
600 MeV
(e)



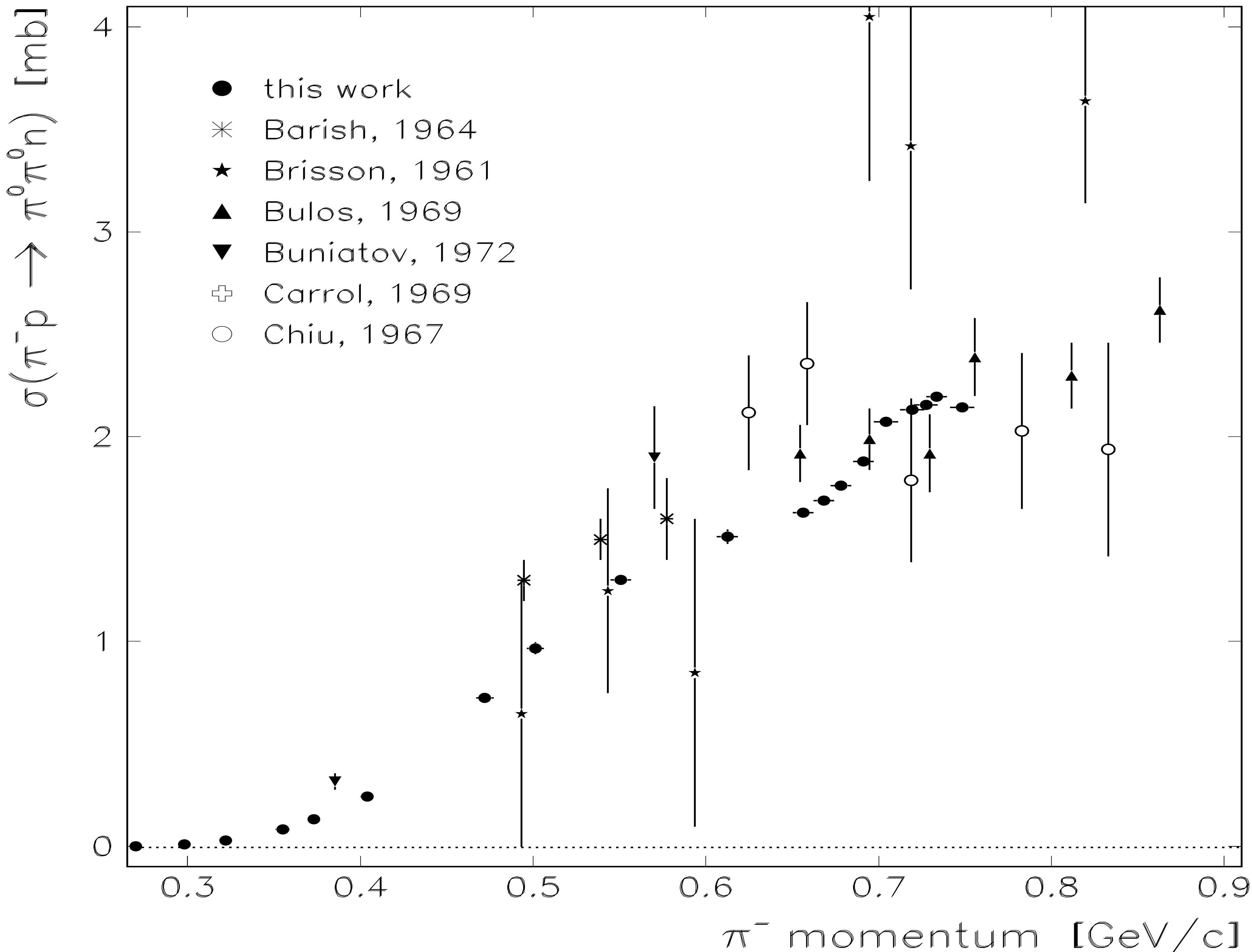
dσ/dΩ (μb/sr)
300
250
200
150
100
50
0
−1.0
−0.5
0.0
0.5
1.0
cosθ
606 MeV
(f)



300
250
200
150
100
50
0
dσ/dΩ (μb/sr)
−1.0
−0.5
0.0
0.5
1.0
cosθ
620 MeV
(g)



this work
Belkov, 1980
Lowe, 1991
Buniatov, 1972
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
$\sigma(\pi^- p \rightarrow \pi^0\pi^0 n)$ [mb]
π^- momentum [GeV/c]



σ(π⁻p → π⁰π⁰n) [mb]
this work
Barish, 1964
Brisson, 1961
Bulos, 1969
Buniatov, 1972
Carrol, 1969
Chiu, 1967
0
1
2
3
4
0.3
0.4
0.5
0.6
0.7
0.8
0.9
π⁻ momentum [GeV/c]

Summary

- Crystal Ball at BNL collected several hundreds of data points over a large energy and angular range.
- These data the latest and maybe the last set of points for the foreseeable future.
- While tightening error bars, the SAID fits did not change significantly.
- We at the DAC see this as a good thing!

The Crystal Ball at MAMI

A program exploiting the high photon and neutron detection efficiency of the Crystal Ball and Taps

The Crystal Ball

- Segmented, electromagnetic calorimeter
- 94% of 4π
- 672 NaI Crystal
- High efficiency for photons and neutrons
- PLUS
- The forward TAPS detector will be used as an end cap $\rightarrow$ 98% of 4π
- TAPS also efficient for neutrons

MAMI

- *Ma*inz *Mi*crotron
- MAMI B Tagged Photons to 800 MeV
- MAMI C Tagged Photons to 1500 MeV
- Circularly polarized photons
- Linearly polarized photons
- LH2 and LD2 targets fit in Xtal Ball now
- Polarized H2, D2 available next year

Collaboration Physics Program

- Phase One: Present MAMI-B conditions

  $\mu(\Delta^+)$ from $\gamma p \rightarrow \gamma' \pi^o p$ Done!

  $\gamma p(n) \rightarrow$ neutral mesons p(n) Analysis!

- Phase Two: MAMI C

  $\mu(S11)$ from $\gamma p \rightarrow \gamma' \eta p$

  γ_{pol} p(n) $\rightarrow$ neutral and charge mesons p(n)

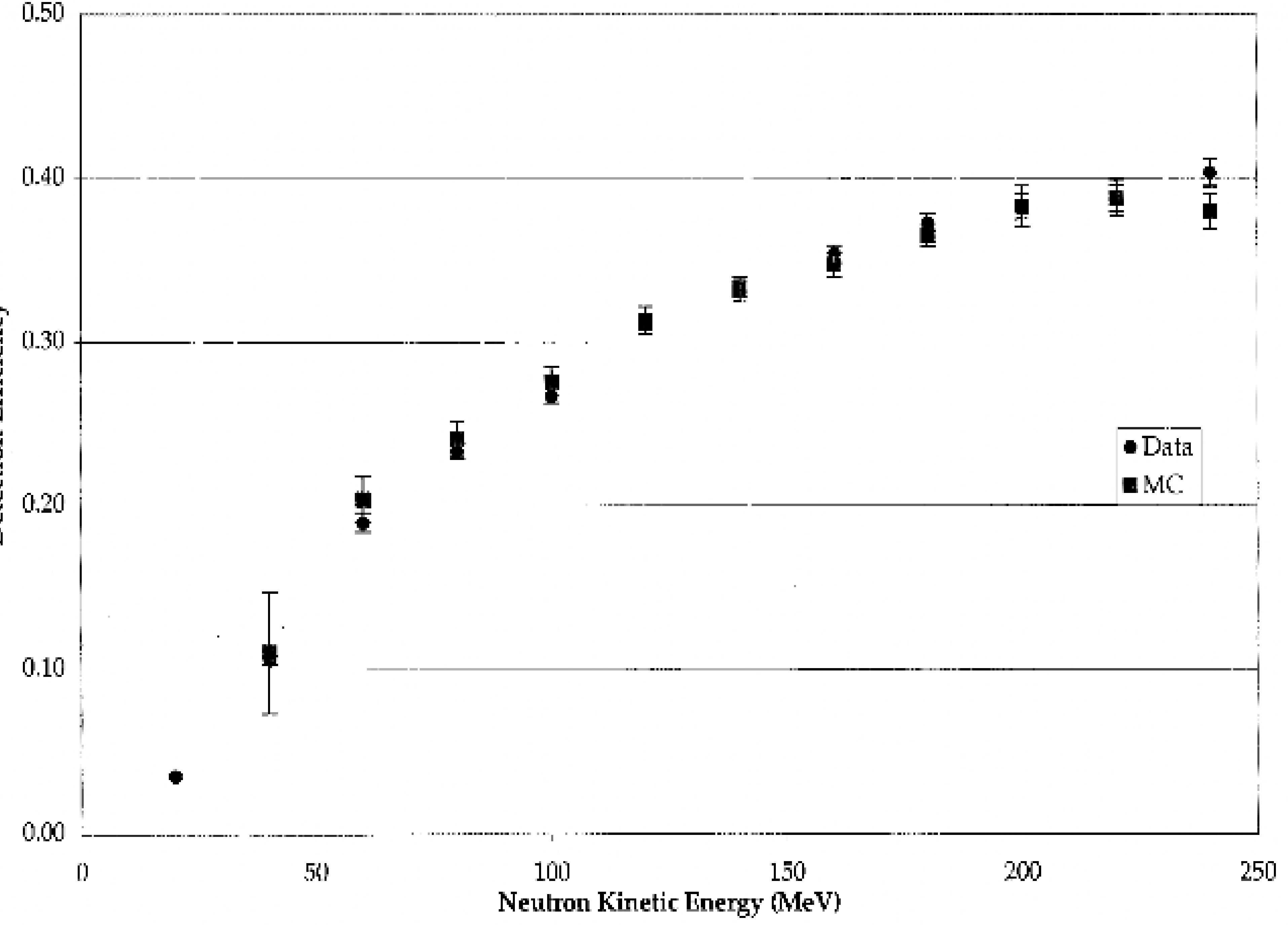
- Phase Three: MAMI C & Polarized Targets

  $\gamma_{pol}\ p_{pol}(n_{pol}) \rightarrow$ neutral and charged mesons p(n)

Tracker and Target Counter

- Reduces background
- Allows charged particle detection
- Tracker
  - Cylindrical Wire Chamber
- Target Counter
  - Scintillation Counters

- First Thing – Measure Neutron Efficiency



0.50
0.40
0.30
0.20
0.10
0.00
0
50
100
150
200
250
Neutron Kinetic Energy (MeV)
Data
MC

The Photoproduction of Neutral Mesons from the Neutron

We plan to exploit the unique photon and neutron detection properties of the Crystal Ball and TAPS at MAMI by measuring the simple photoproduction reactions

γ n –> π^0n

γ n –> ηn

γ n –> η'n

γ n –> ωn

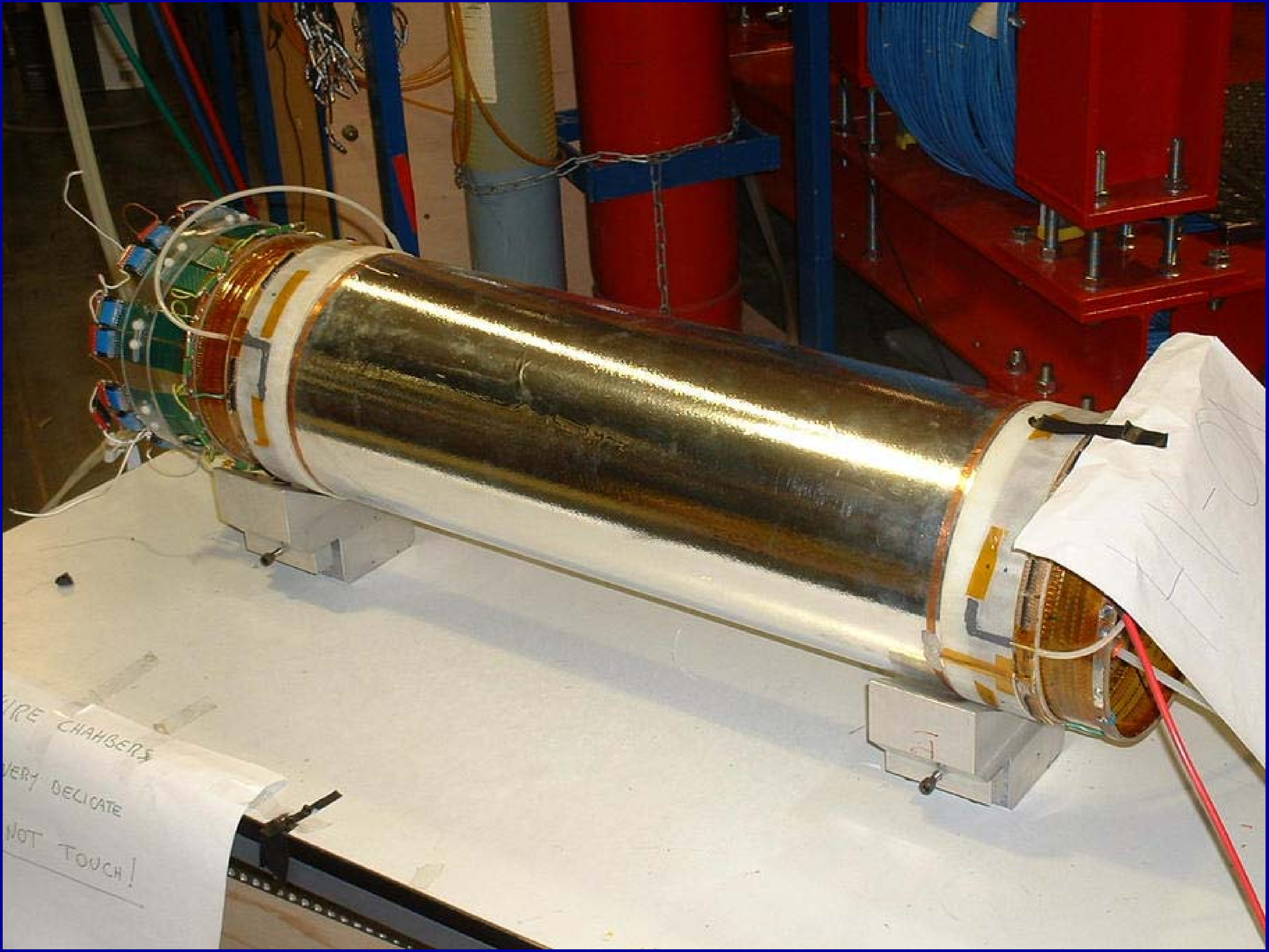
In this same energy region we plan to study

- the cascade decays

$$\gamma\, n \to \pi^0 \pi^0\, n$$

$$\gamma\, n \to \pi^0 \eta\, n$$

- electromagnetic properties of resonances by searching for radiative decay chains that result in a $\pi^0\gamma$ or $\eta\ \gamma$ final state
- $N^* \to \gamma\Delta$
- $N^* \to \gamma\ S_{11}(1535)$


IRE CHAMBERS
VERY DELICATE
NOT TOUCH!