Observation of a structure in the $M_{p\eta}$ invariant mass distribution near 1700 MeV in the $\gamma p \rightarrow p\pi^0\eta$ reaction

Mariana Nanova, Volker Metag

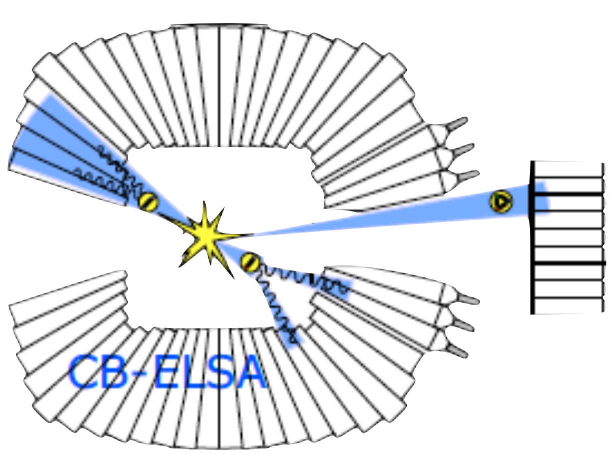
for the CBELSA/TAPS Collaboration

II. Physikalisches Institut

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Outline:

- motivation
- experimental result
- interpretation of the results
- summary



HADRON 2021

26th - 31th July 2021, Mexico City

*funded by the DFG within SFB/TR16

motivation:
observation of narrow N(1685) resonances in $\gamma N \to \eta\pi N$ reactions

V. Kuznetsov et al.,
JETP Lett. 106 (2017) 693
exotic state predicted by
Chiral Soliton Model

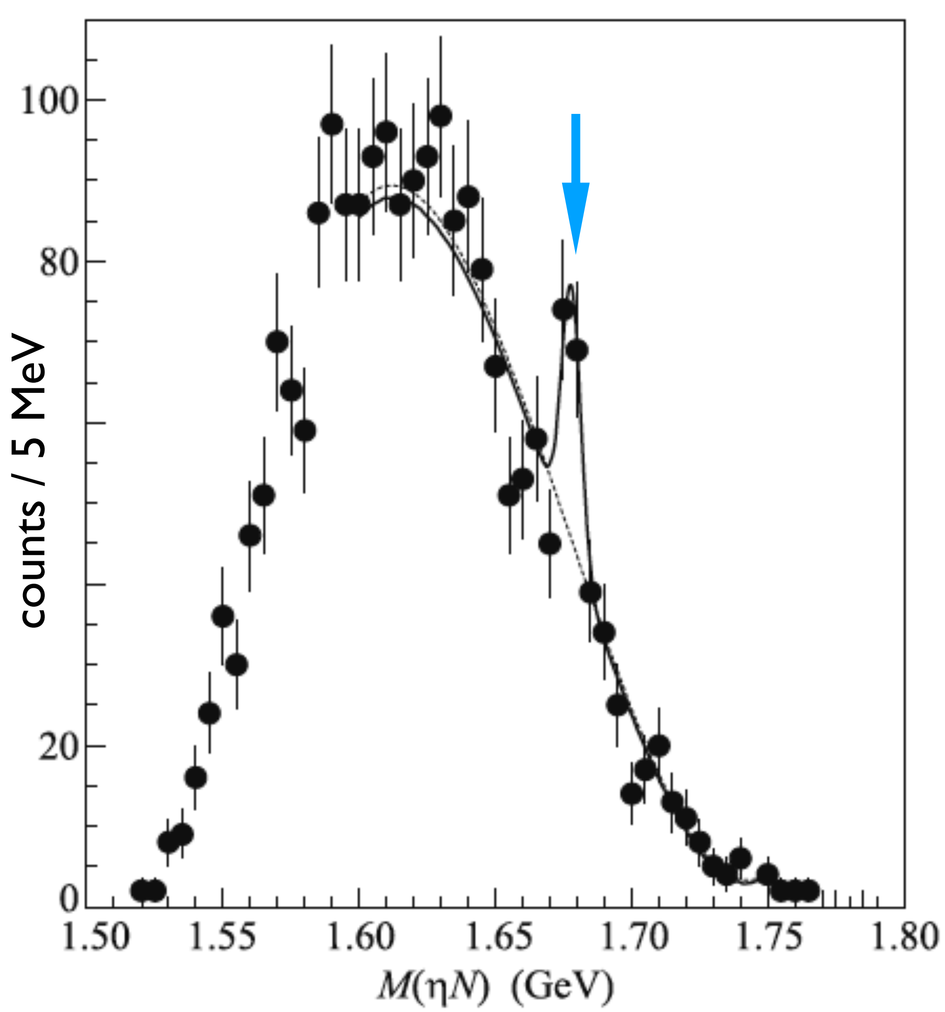
D. Diakonov, V. Petrov, and M.V. Polyakov,
Z. Phys. A 359 (1997) 305

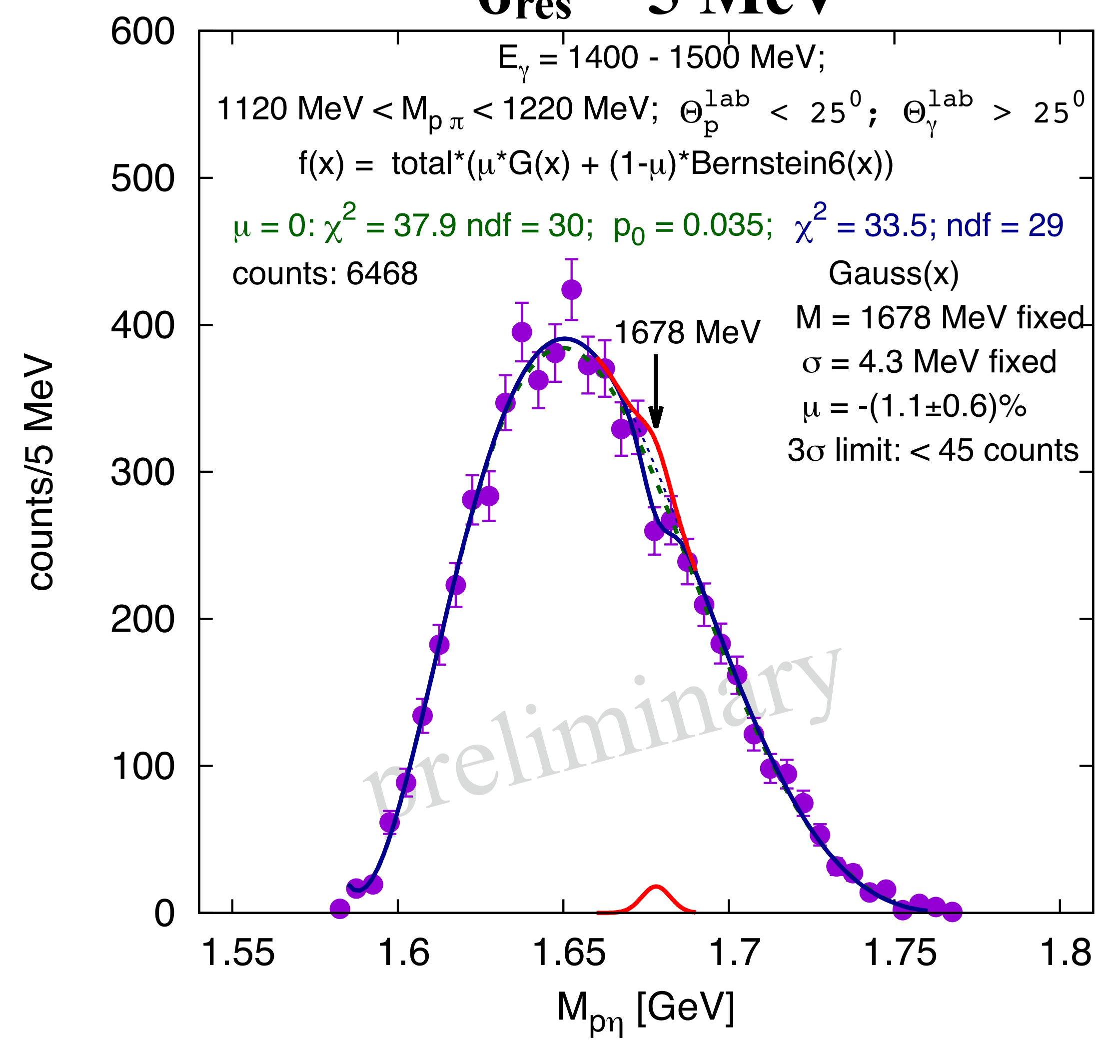
identical conditions:

E_γ = 1400 - 1500 MeV
1120 < $M_{p\pi}$ < 1220 MeV
$\theta_p < 25^0$; $25^0 < \theta_\gamma < 165^0$

$\gamma\, p \to p\, \pi^0\, \eta$
CBELSA/TAPS

4.5 times higher statistics;
σ_{res} = 5 MeV





$M_{\eta N}$ = (1678±0.8(stat)±10(syst)) MeV;
Γ≈ 10 MeV; significance 4.6 σ

< 45 counts: $\sigma_{structure}$ < 6 nb (3σ)
structure cannot be confirmed !!!

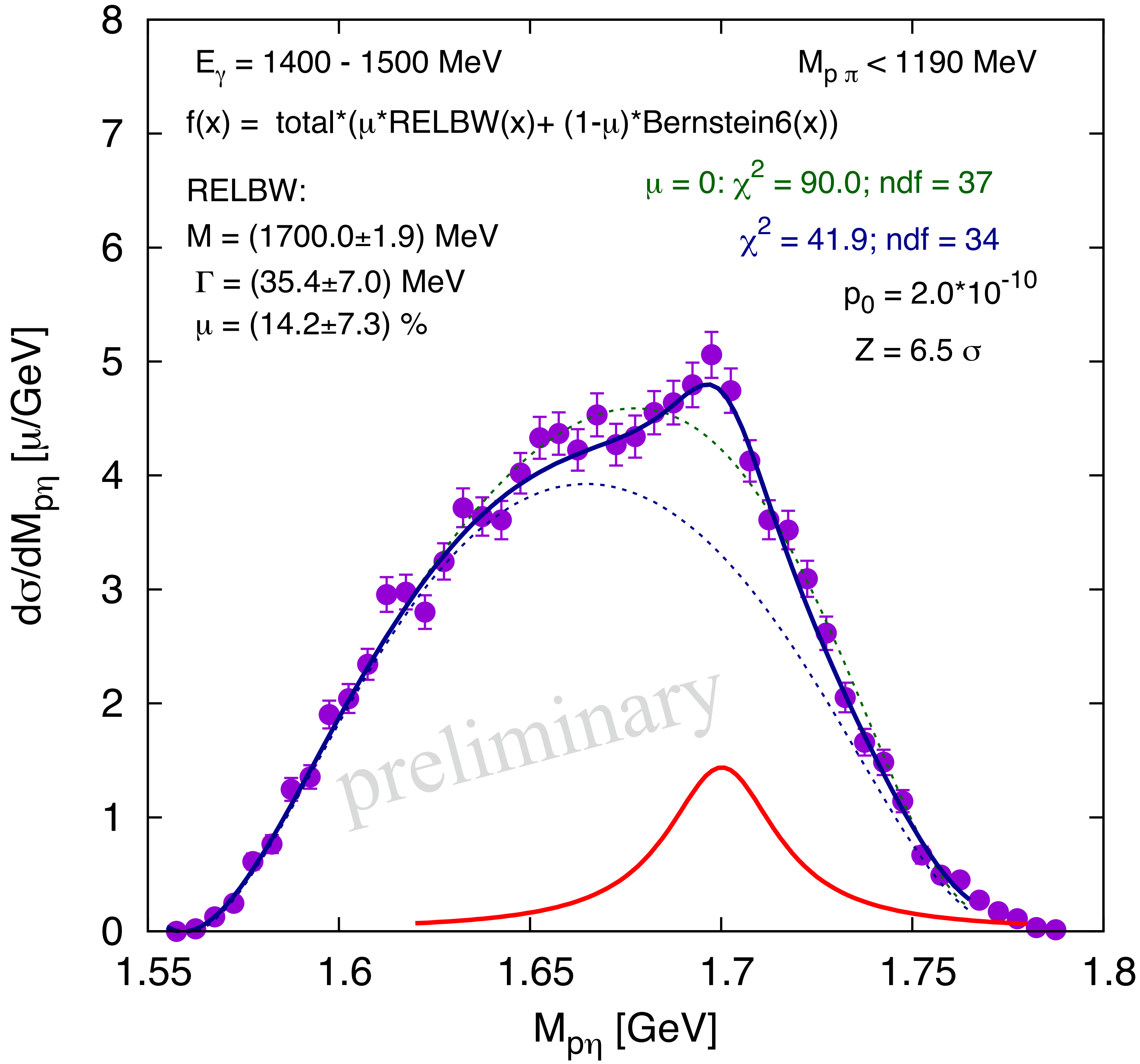
$\gamma\, p \rightarrow p\, \pi^0\, \eta$

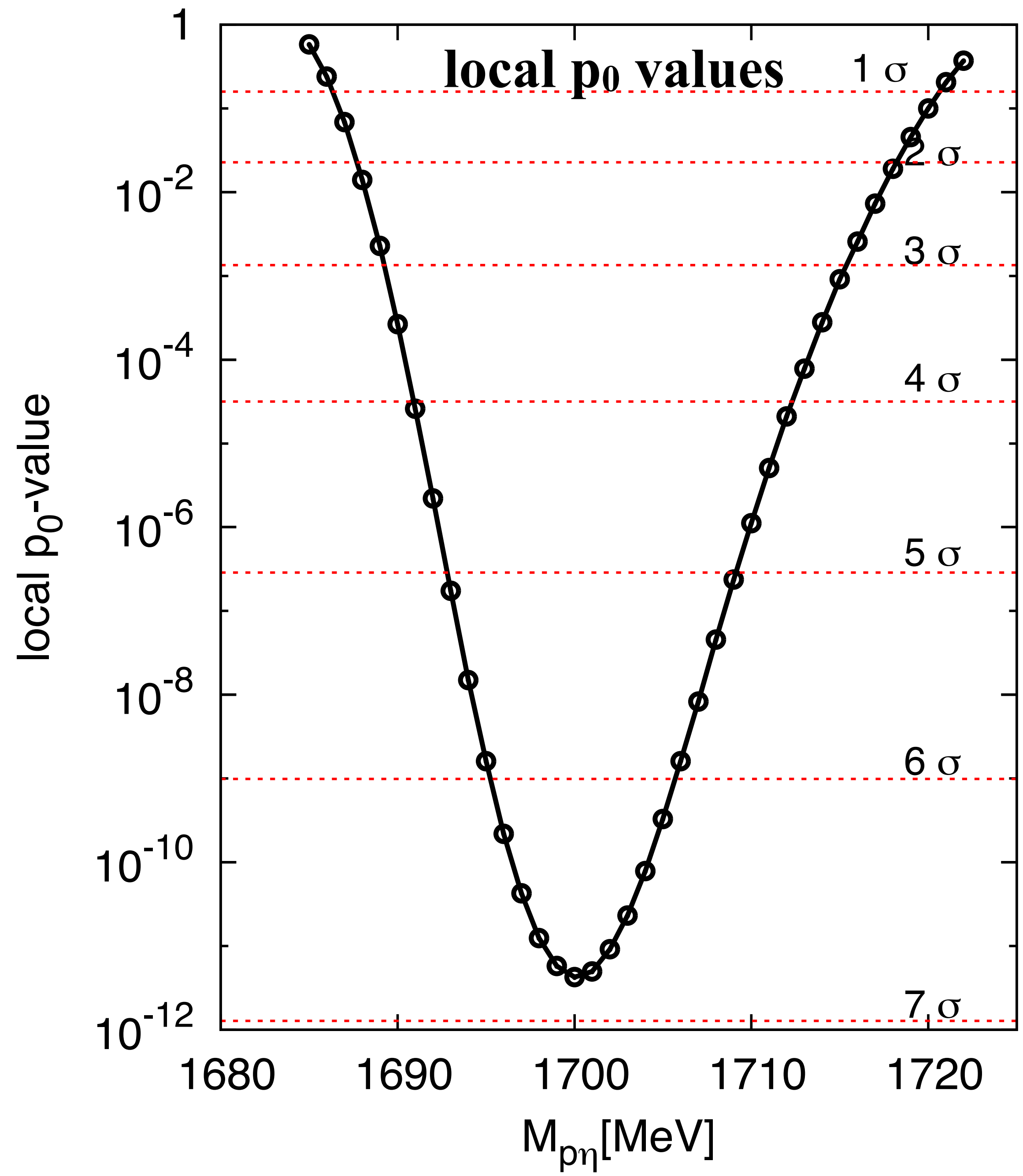
E_γ = 1400 - 1500 MeV

$M_{p\pi}$ < 1190 MeV

$\theta_p > 1^0$; $1^0 < \theta_\gamma < 165^0$

statistical significant structure observed at $M_{p\eta} \approx 1700$ MeV





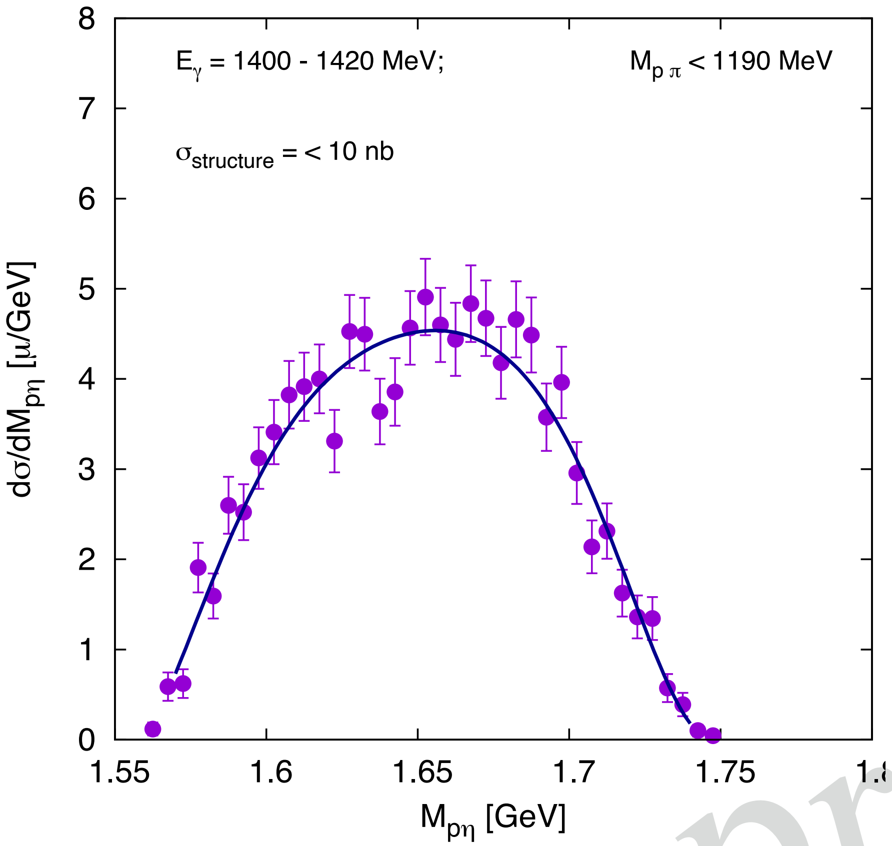
$M_{p\eta}$ = (1700±1.9) MeV; Γ = (35.4±7.0)MeV

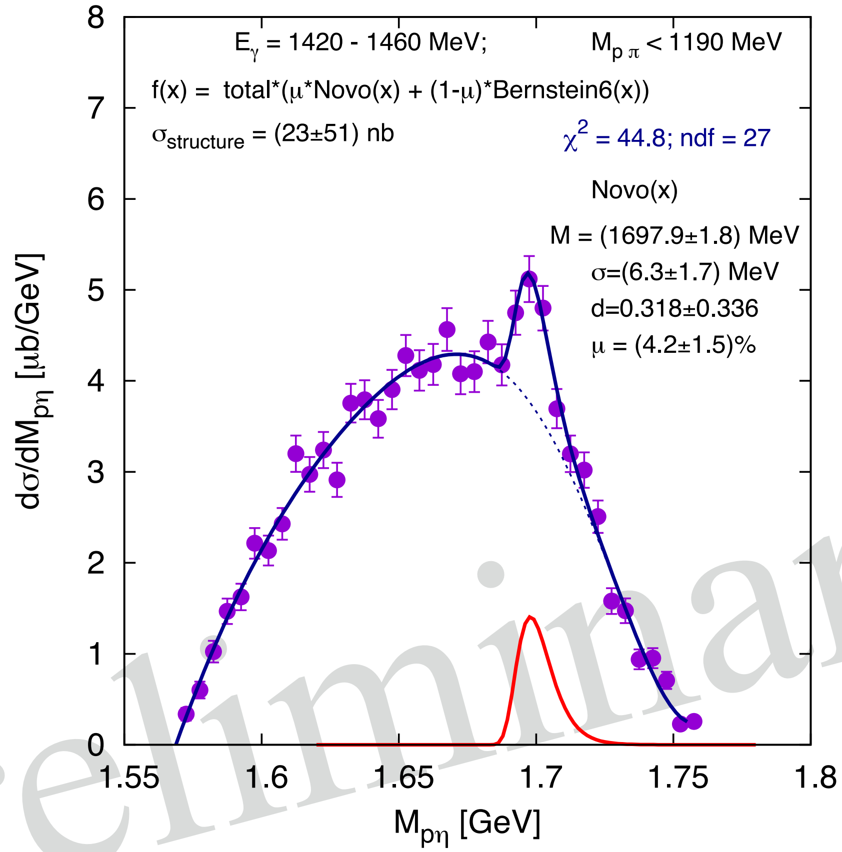
structure established at 6.8 σ

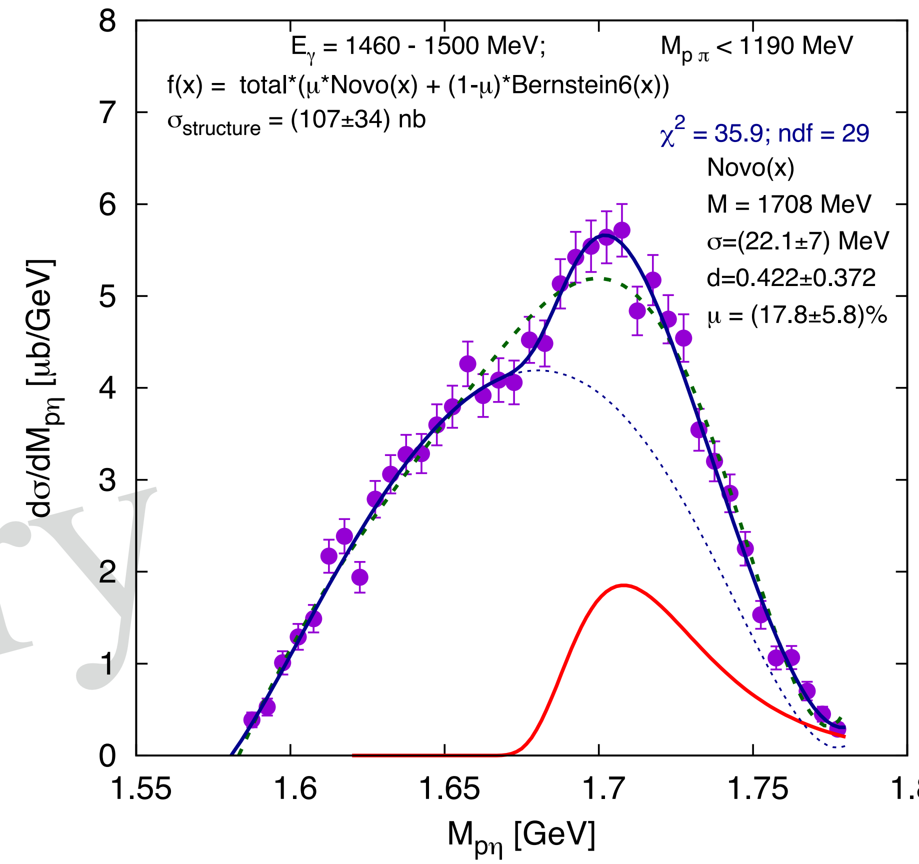
$\gamma\, p \rightarrow p\, \pi^0\, \eta$

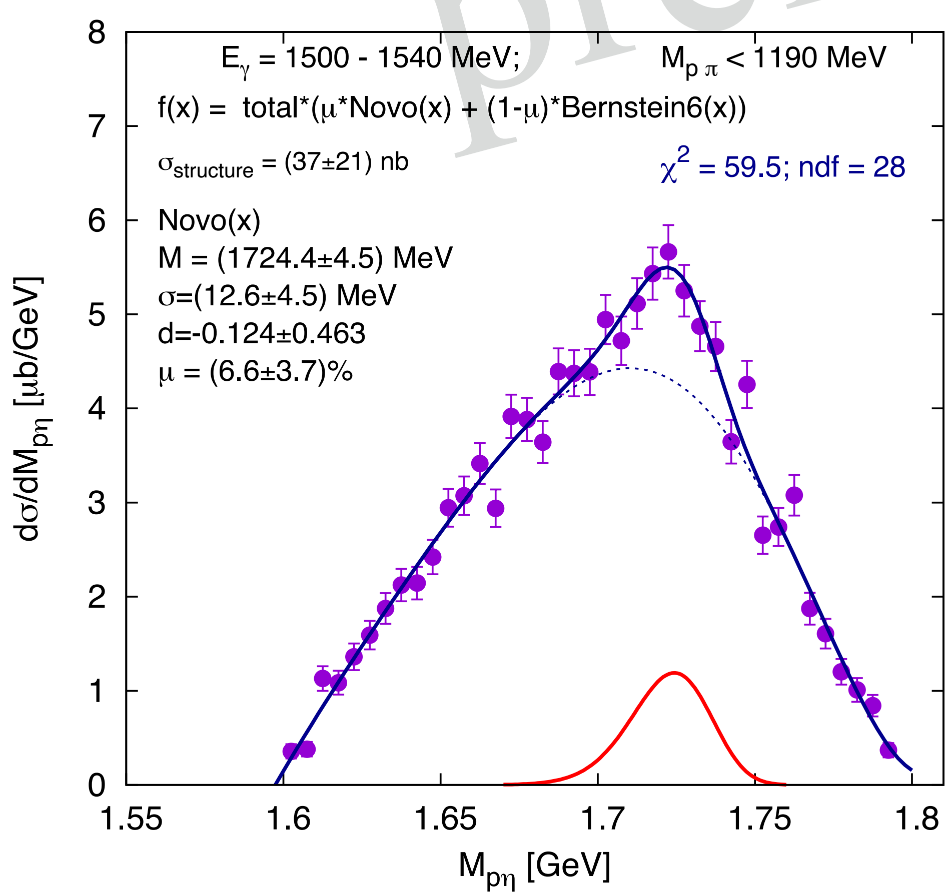
E_γ = 1400 - 1600 MeV

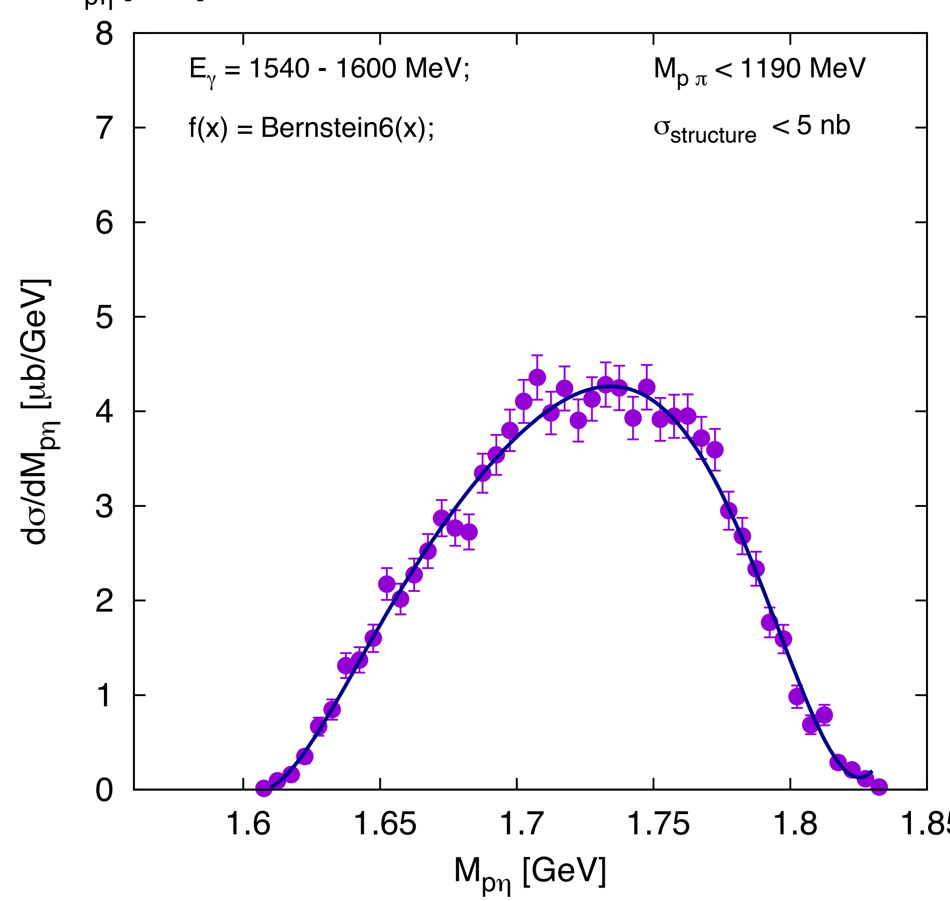
properties of structures as function of the incident photon energy











signal only seen for E_γ = 1420 - 1540 MeV

$\gamma\, p \rightarrow p\, \pi^0\, \eta$

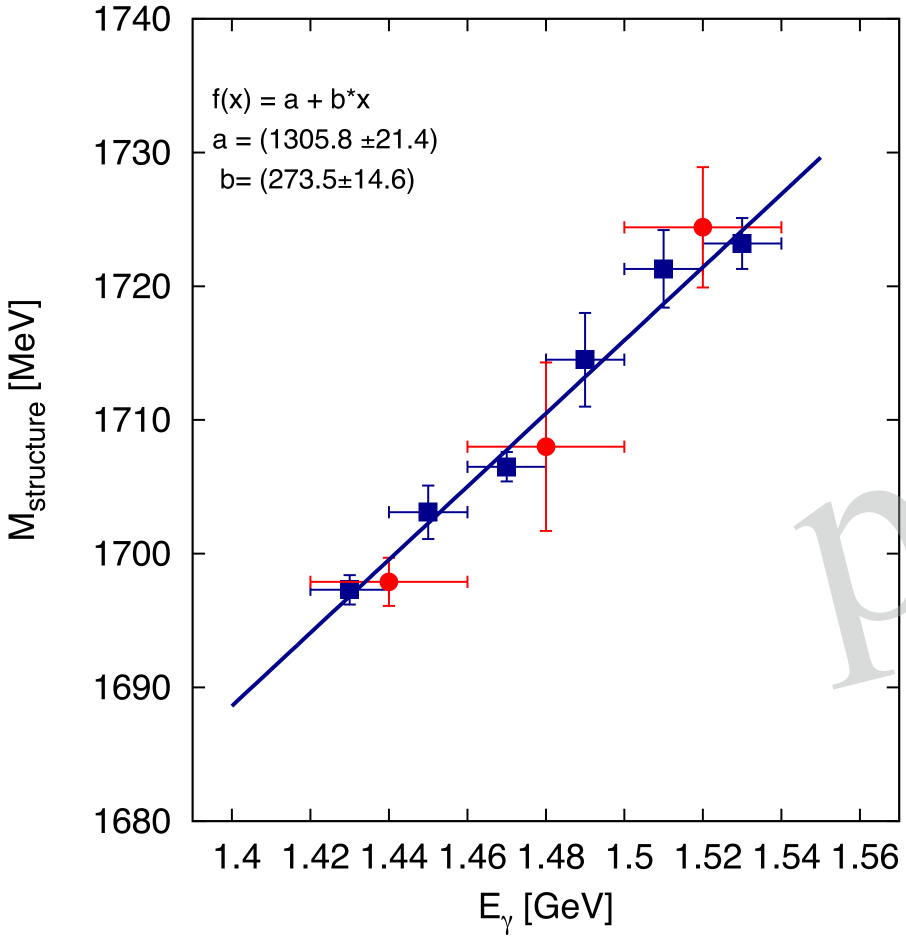
properties of the structure as function of the excitation energy

signal fitted with Novosibirsk function

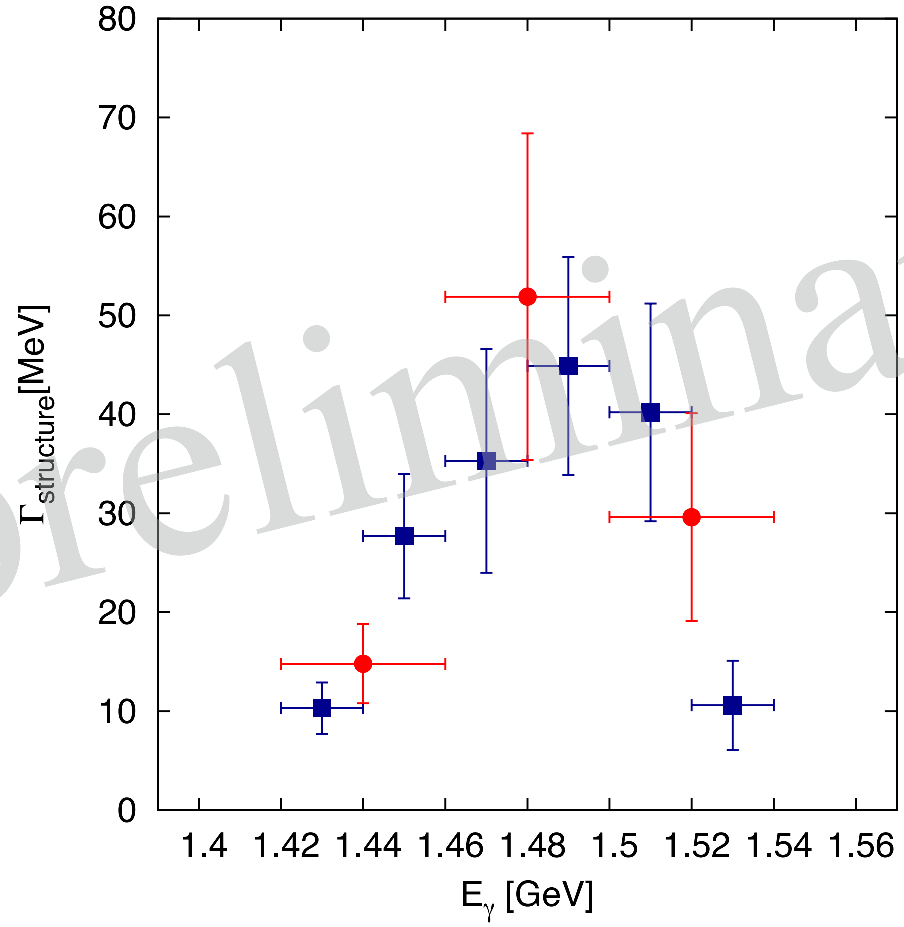
signal fitted with Gaussian function

systematic error of fits (different fit functions): $\leq 15\%$

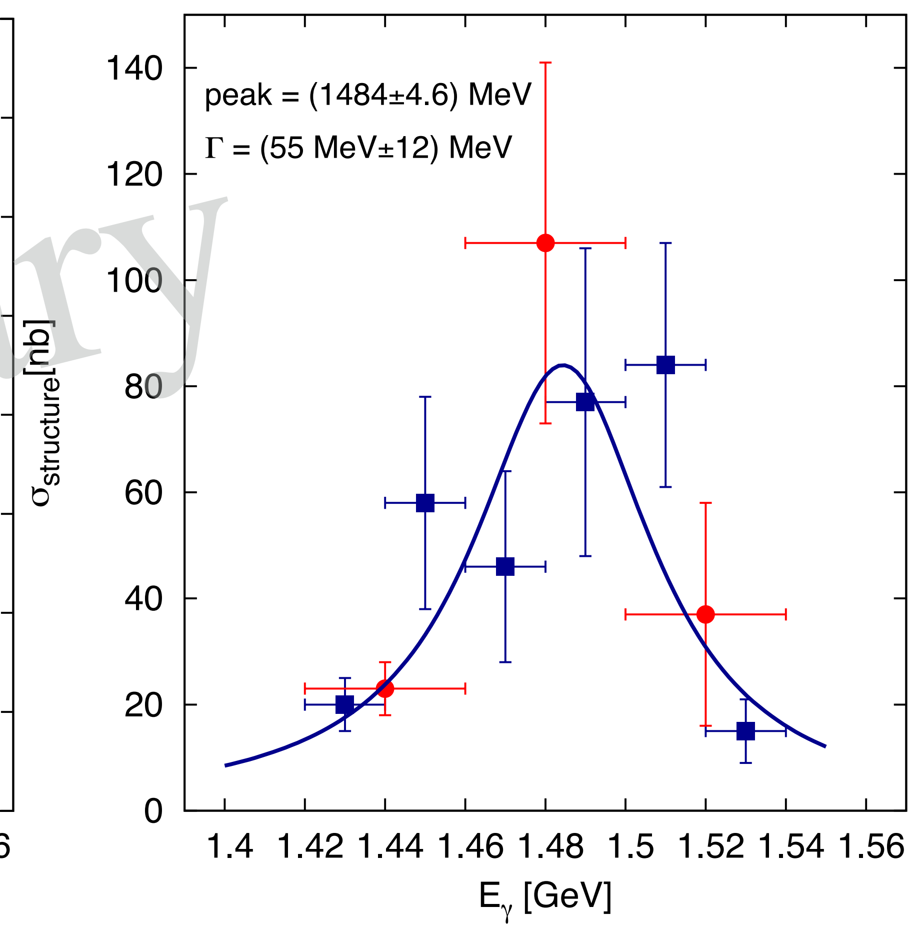
peak position



width



cross section



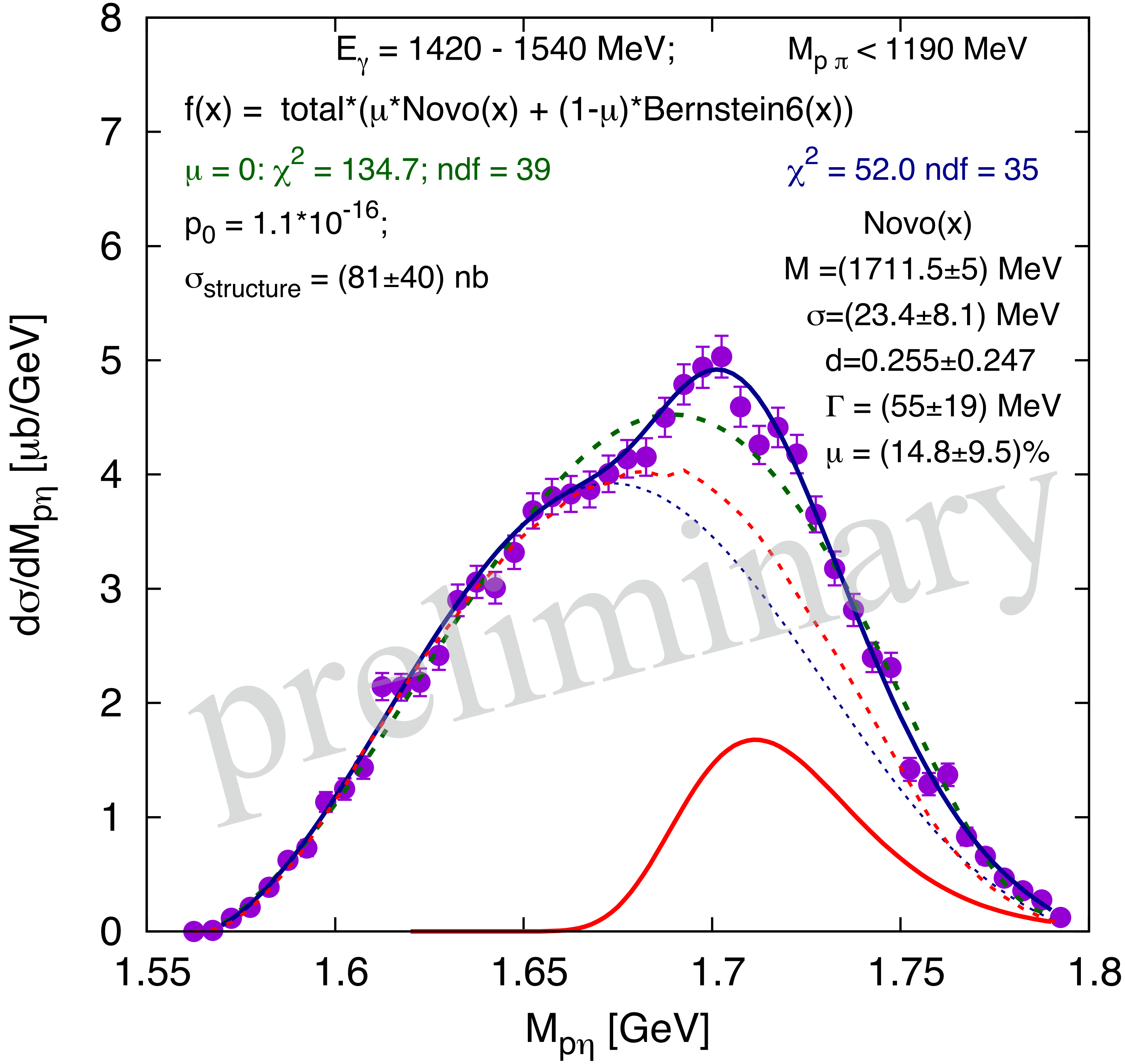
I. peak shifts with incident energy

II. width: $\Gamma \leq 50$ MeV

III. resonance-like cross section peaking at
E_γ = 1490 MeV ($\gamma p \rightarrow p\, a_0 \rightarrow p\, \pi^0\, \eta$ threshold)

comparison to partial wave analysis (PWA)

PWA: BnGa 2016-02 (normalized to data in 1550 MeV < $M_{p\eta}$ < 1680 MeV)

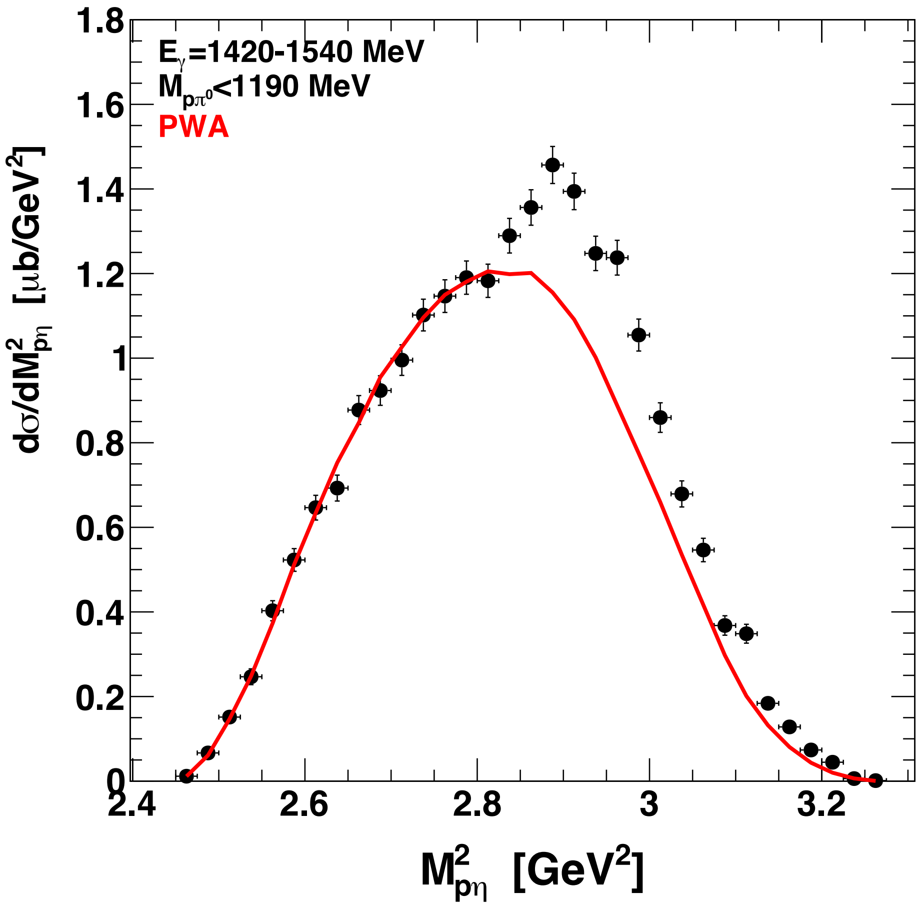


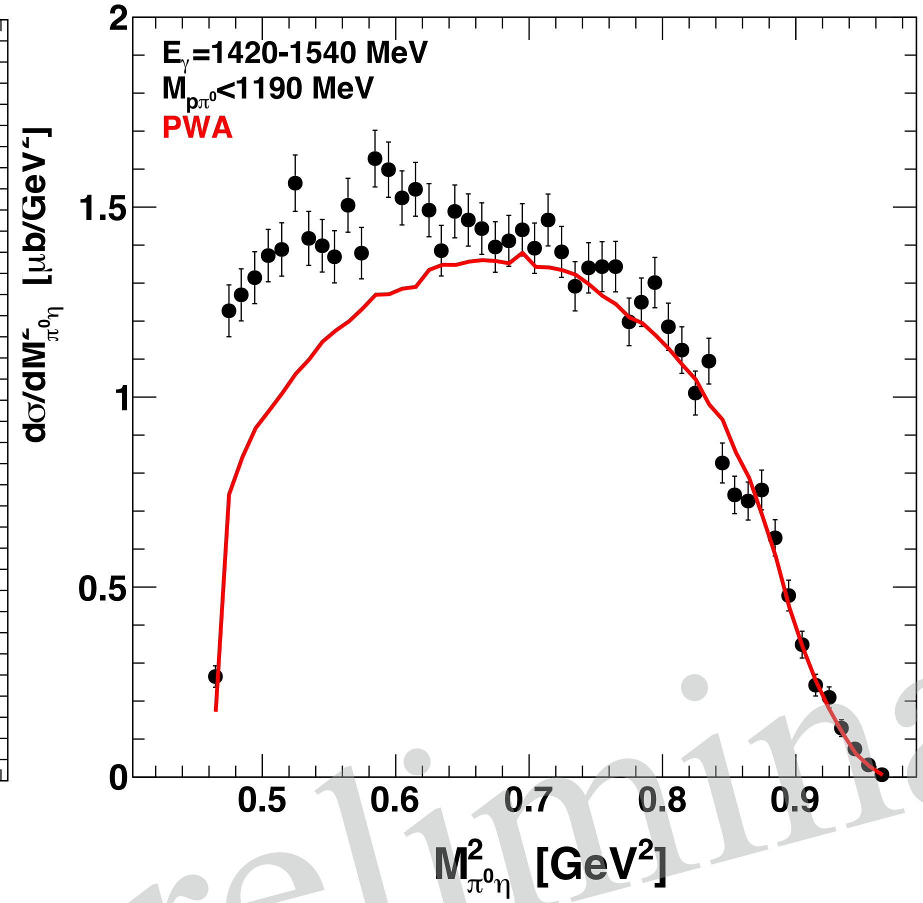
characterisation of structure not only by fit but also by deviation from PWA

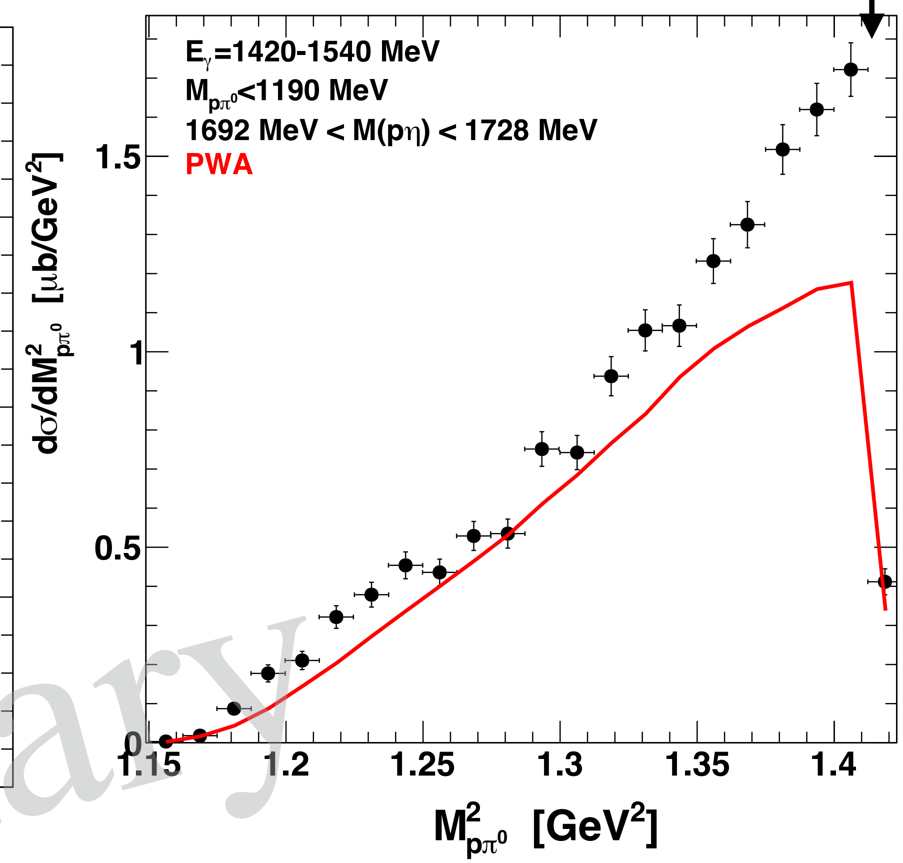
$\gamma\, p \rightarrow p\, \pi^0\, \eta$

(1190 MeV)²

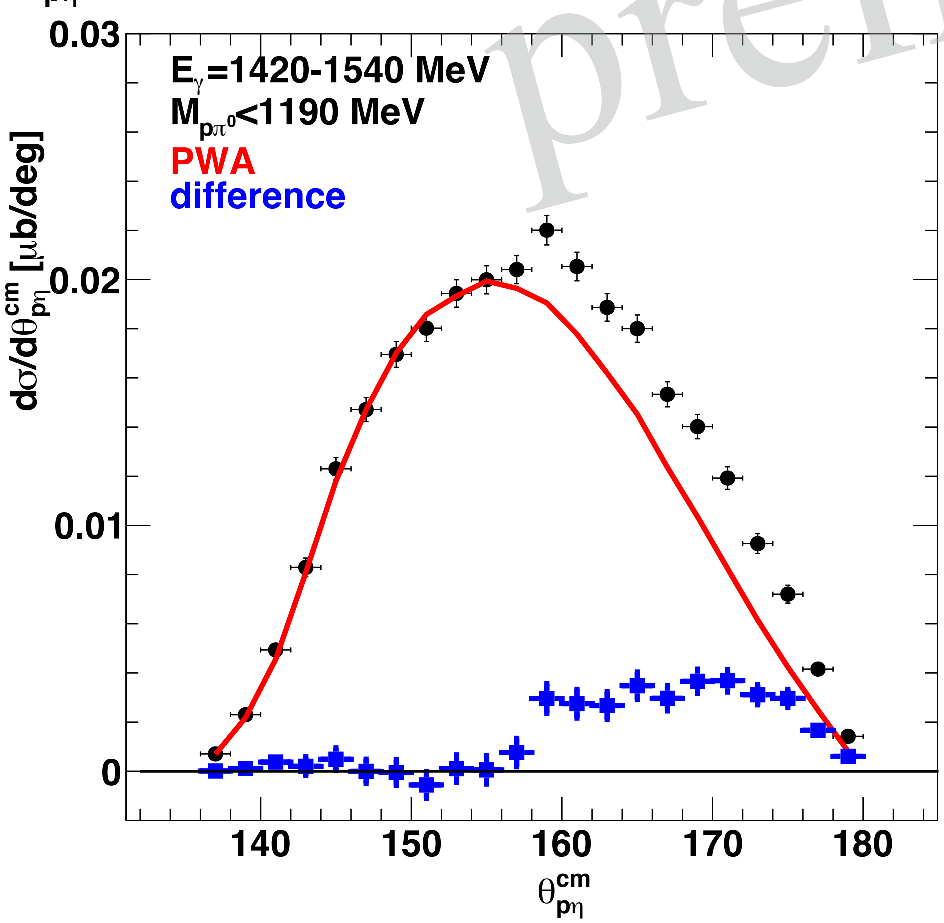
signal = deviation from PWA

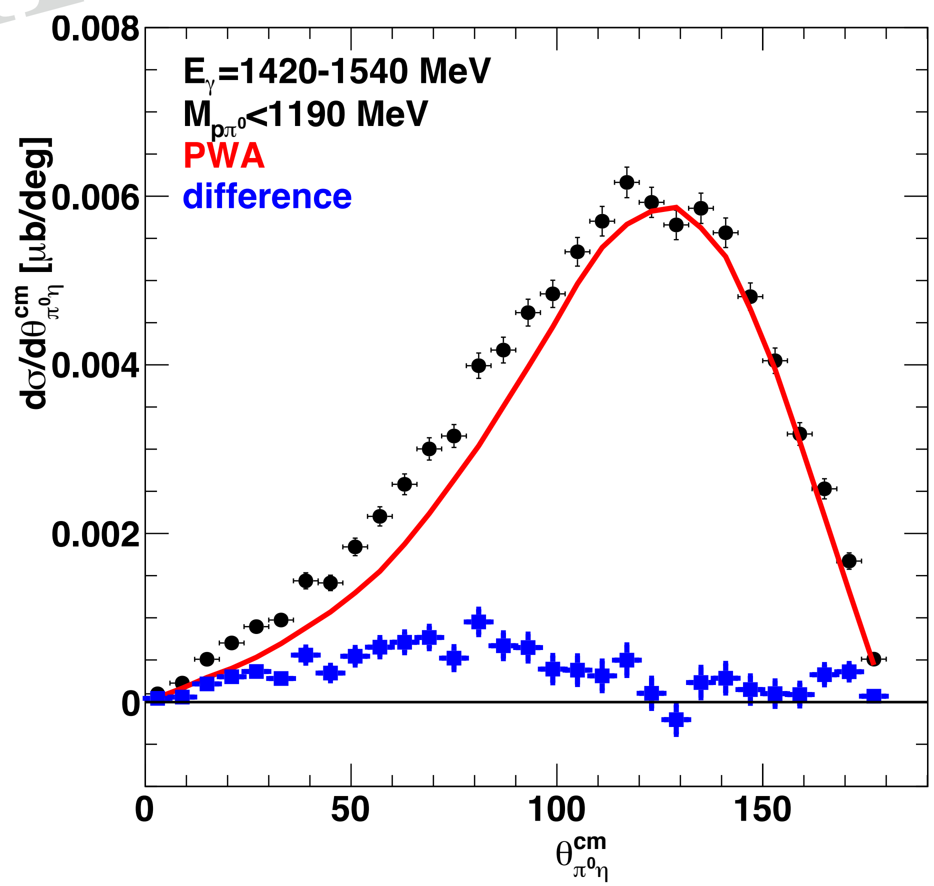






predominant back-to-back emission





deviation for $\theta_{\pi 0\eta} \approx 20^0$ - 90^0 in cms

what is the origin of the observed structure?

three scenarios:

I. Decay cascade

not possible to reproduce narrow width of the structure
but interference effects not excluded

II. State in the exotic baryon anti-decuplet

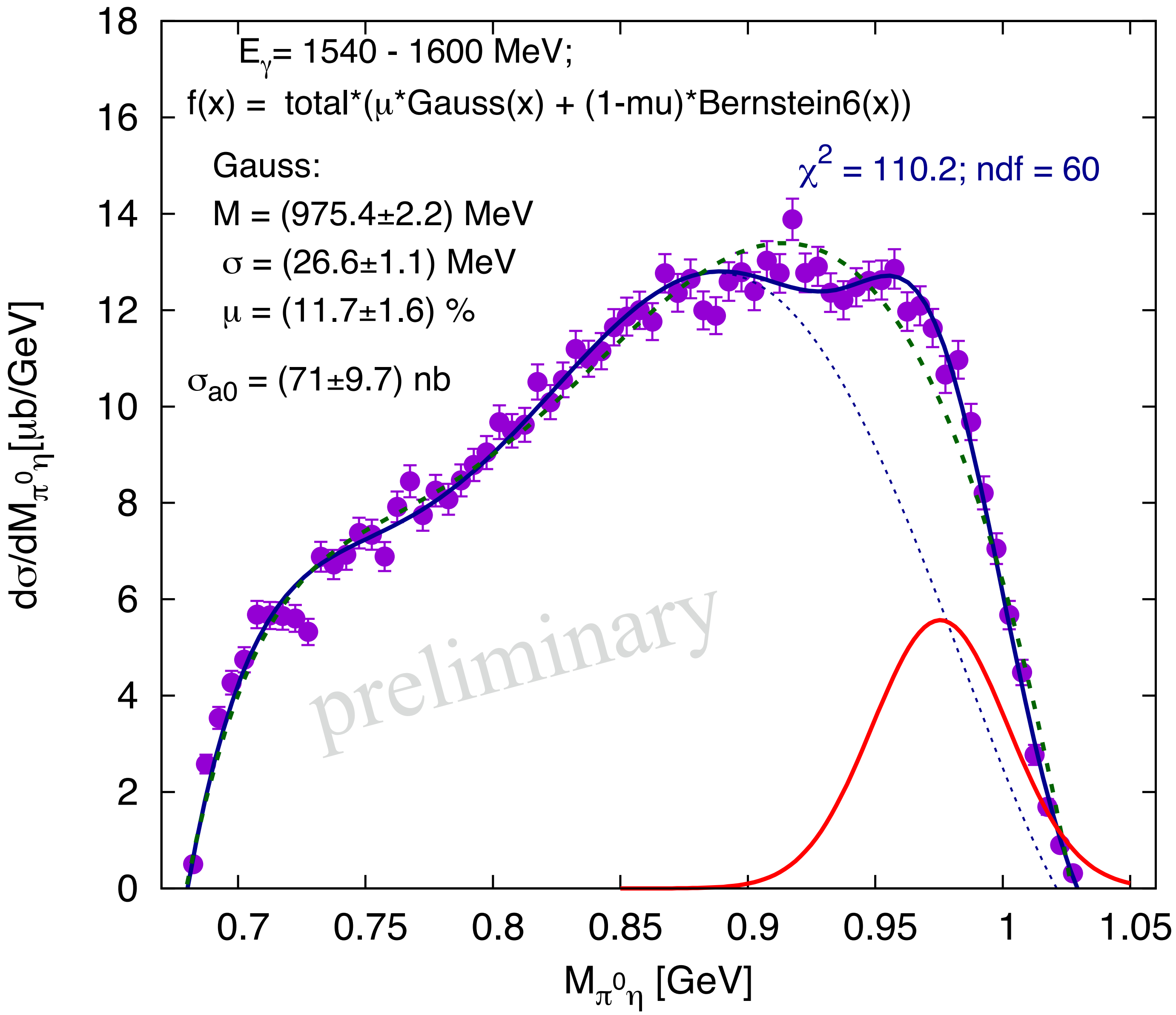
unlikely because structure is associated with the p-a_0 threshold

III. Triangular singularity

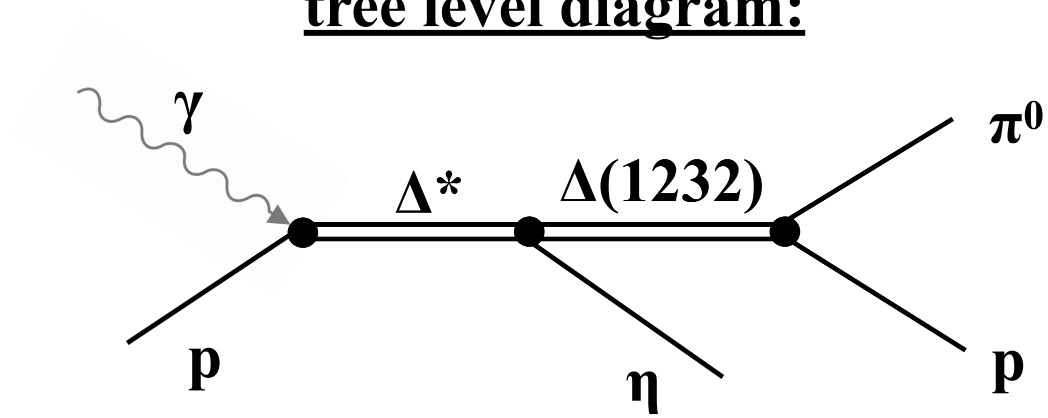
associated with the $\gamma p \to p\text{-}a_0(980) \to p\pi^0\eta$ threshold

$\gamma\, p \rightarrow p\, \pi^0\, \eta$

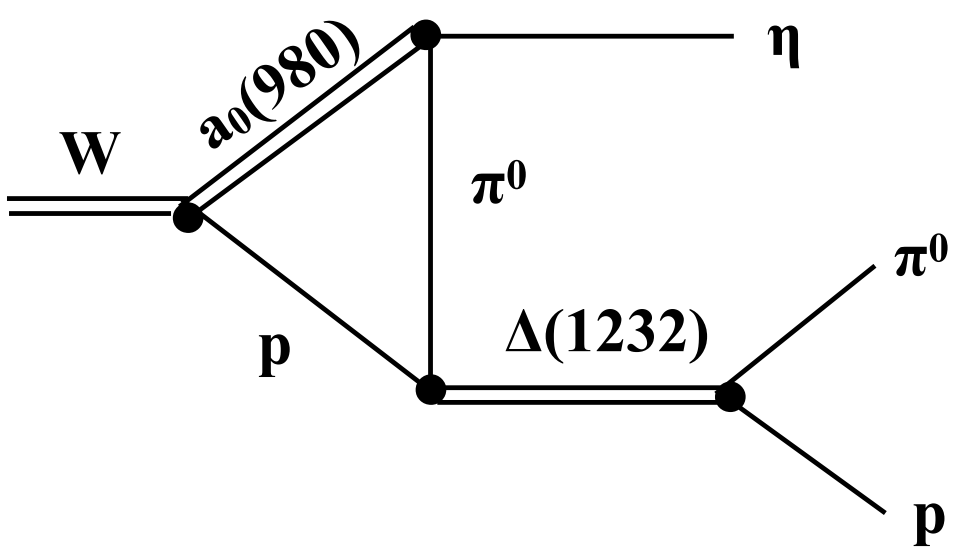
direct observation of an a_0 signal



tree level diagram:



triangular diagram:



m_{a0} = 975±2.2 MeV ; Γ_{a0} = 62±2.6 MeV

PDG: m_{a0} = 980±20MeV ; Γ_{a0} = 50 - 100 MeV

specific kinematic conditions

a_0, Δ close to pole mass

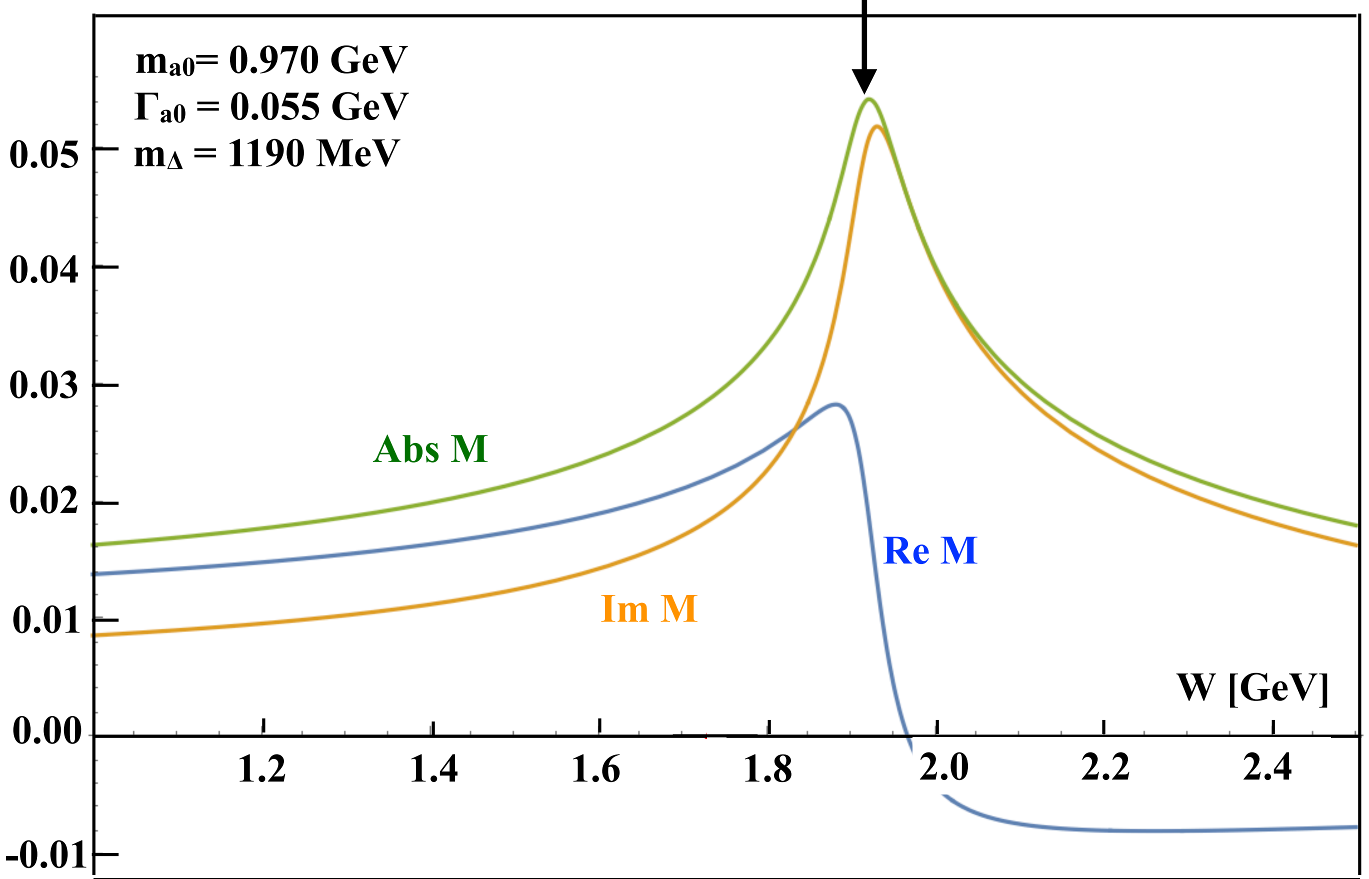
p, π^0, η - collinear

calculation of triangular amplitude

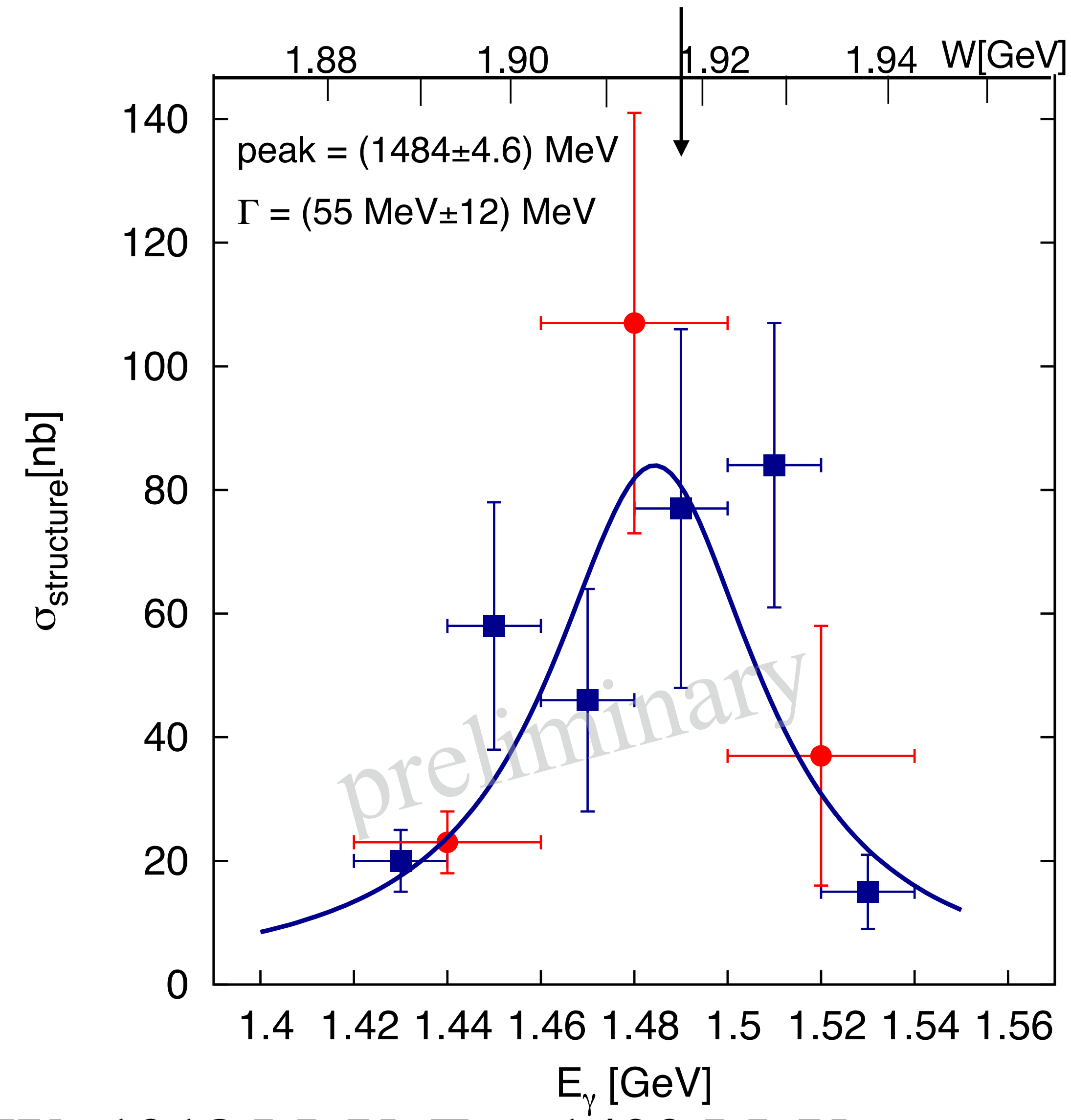
comparison to data

W=1918 MeV
E_γ= 1492 MeV

thanks to Matthias Wagner and Bernhard Ketzer (Uni. Bonn)
M. Mikhasenko et al., PRD 91 (2015) 094015



W=1918 MeV
E_γ=1492 MeV



calculation shows enhancement at W=1918 MeV; E_γ= 1492 MeV
as observed experimentally

following M. Bayar et al.
PRD 94 (2016) 074039

singularities at
$M_{\pi 0\eta} \approx$ 960 - 990 MeV
$M_{p\pi 0} \approx$ 1190 MeV
$M_{p\eta} \approx$ 1550- 1600 MeV

but

structure at
$M_{p\eta} \approx$ 1700 - 1720 MeV

following M. Bayar et al.
PRD 94 (2016) 074039

π^0 p - rescattering

cm system

kinematics: singularity

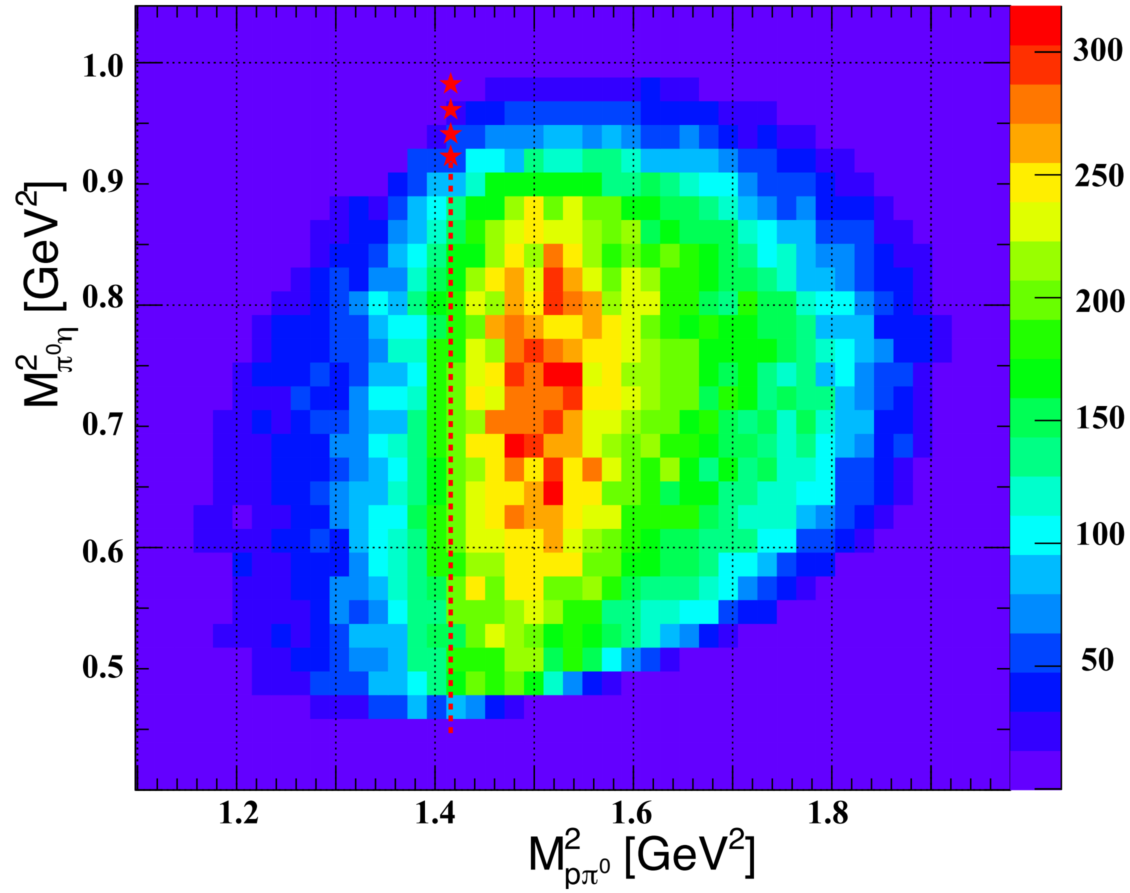
W= 1934 MeV; m_{a0}= 980 MeV

p_p= 122.9 MeV; β_p=0.130

β_η = -0.590

p_π= 277.8 MeV; β_π=0.899 **p_η= -400.7MeV**

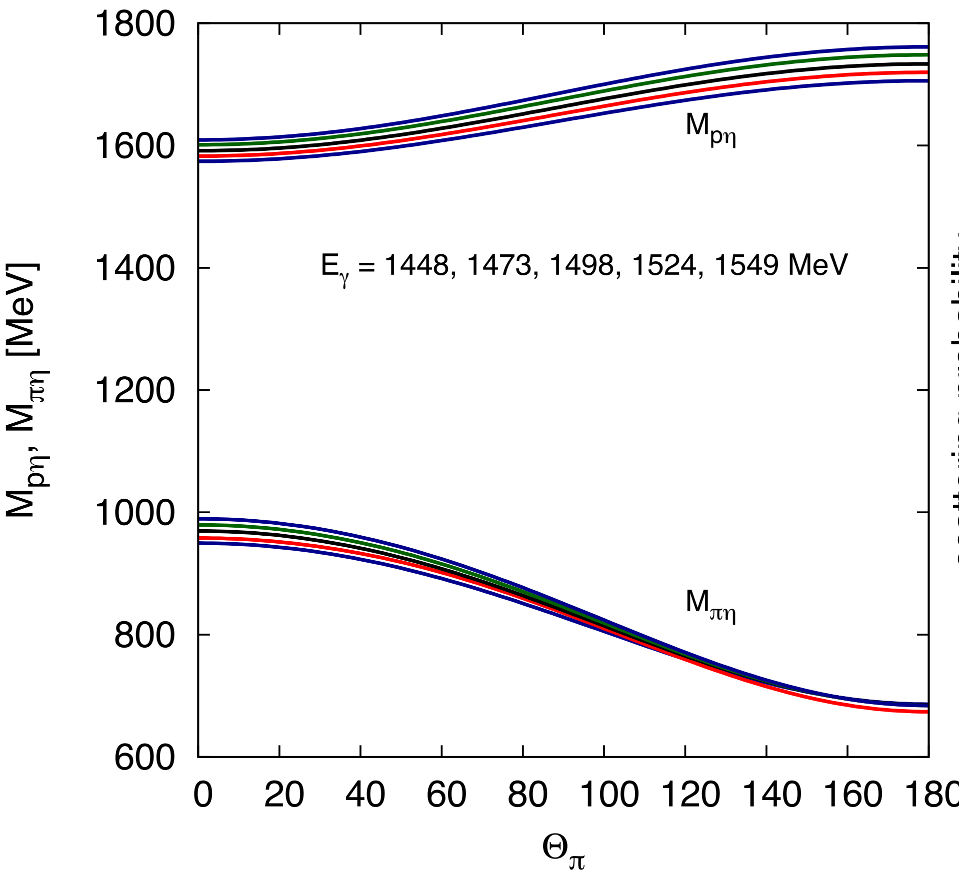
$M_{p\eta}$ = 1601 MeV; $M_{p\pi 0}$ = 1190 MeV



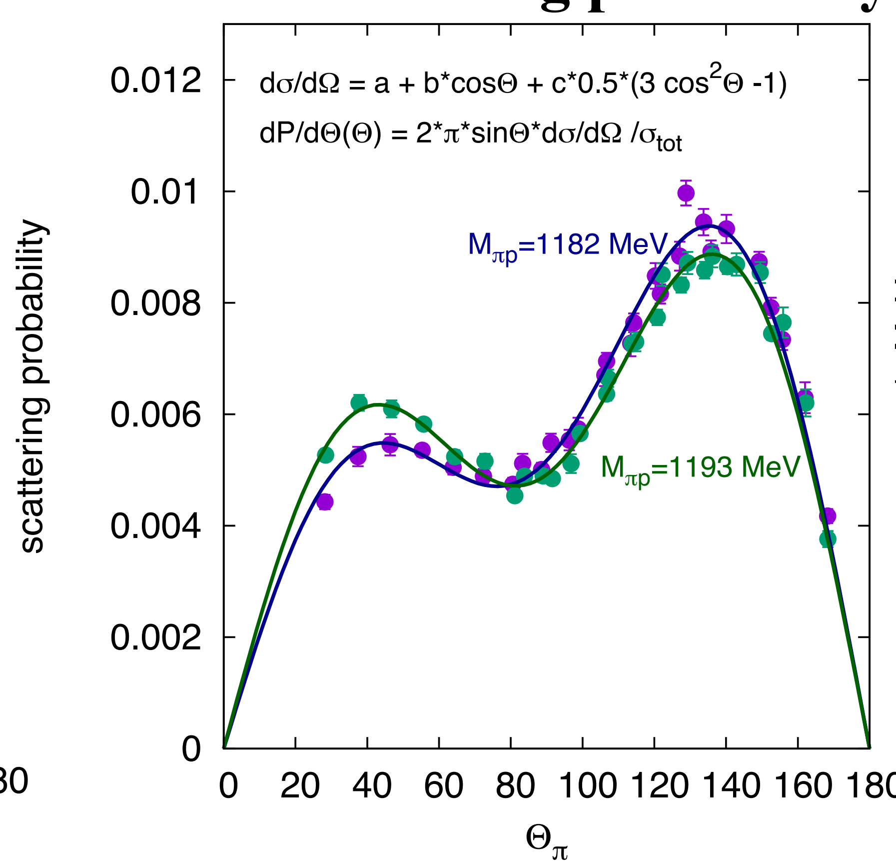
singularity events are re-distributed along the dashed red line by π^0-p - rescattering

π^0 p - rescattering:

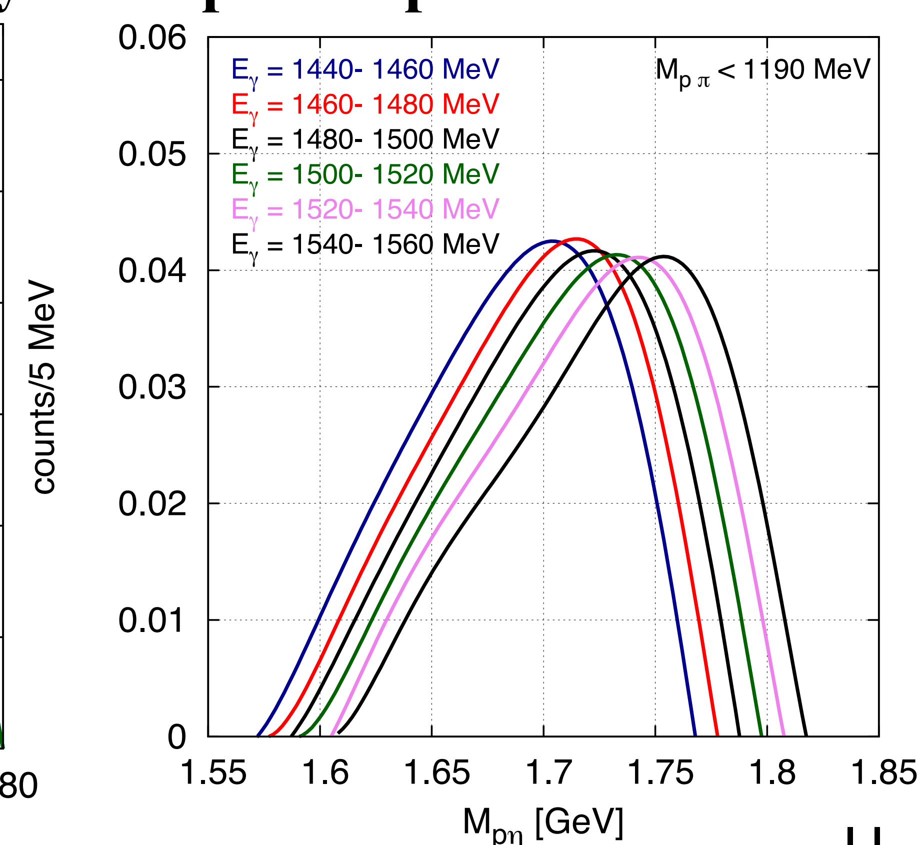
$M_{p\eta} \approx$ 1600 → 1700 MeV
$M_{\pi 0\eta} \approx$ 980 → 682 MeV



re-scattering probability

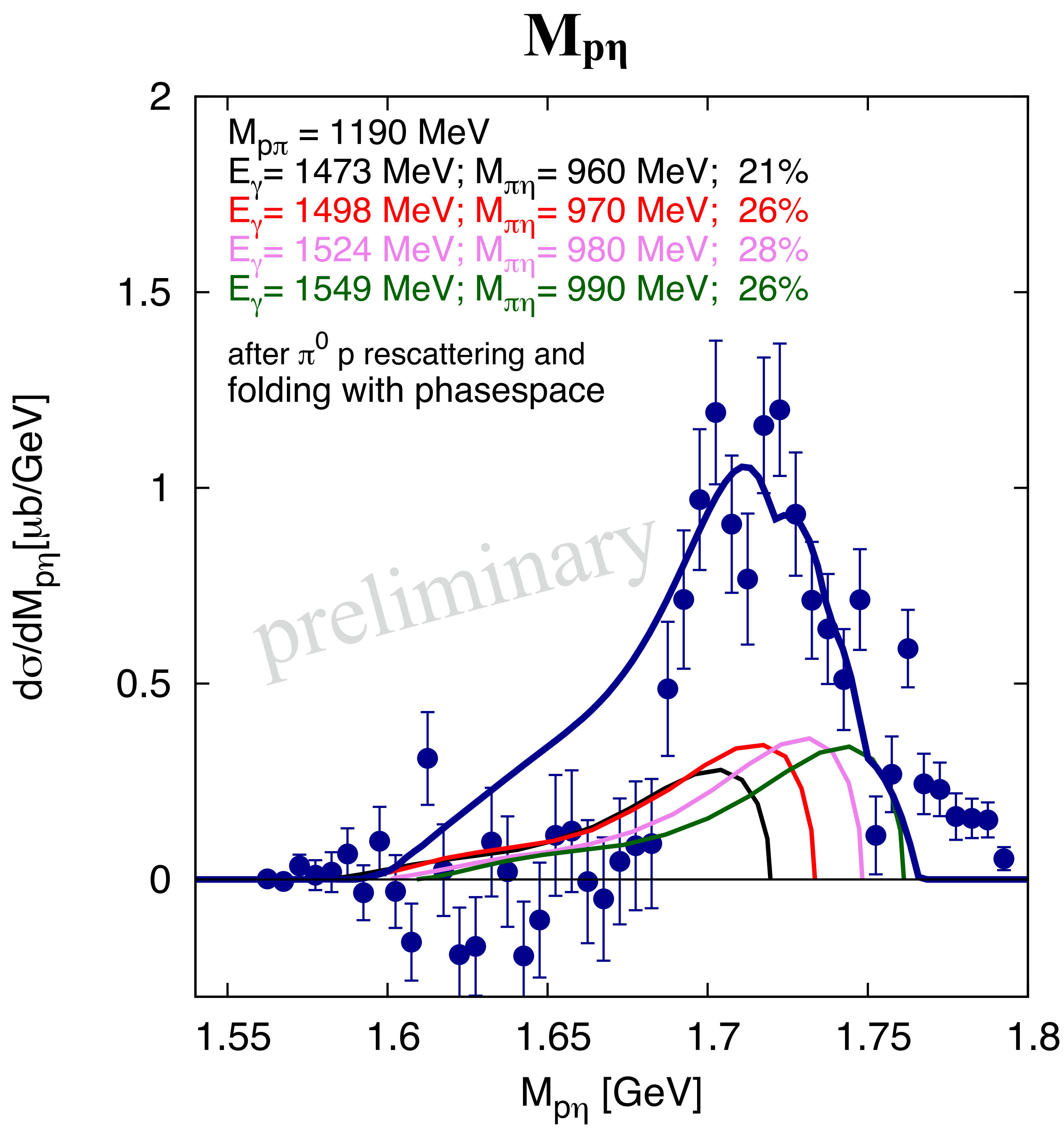


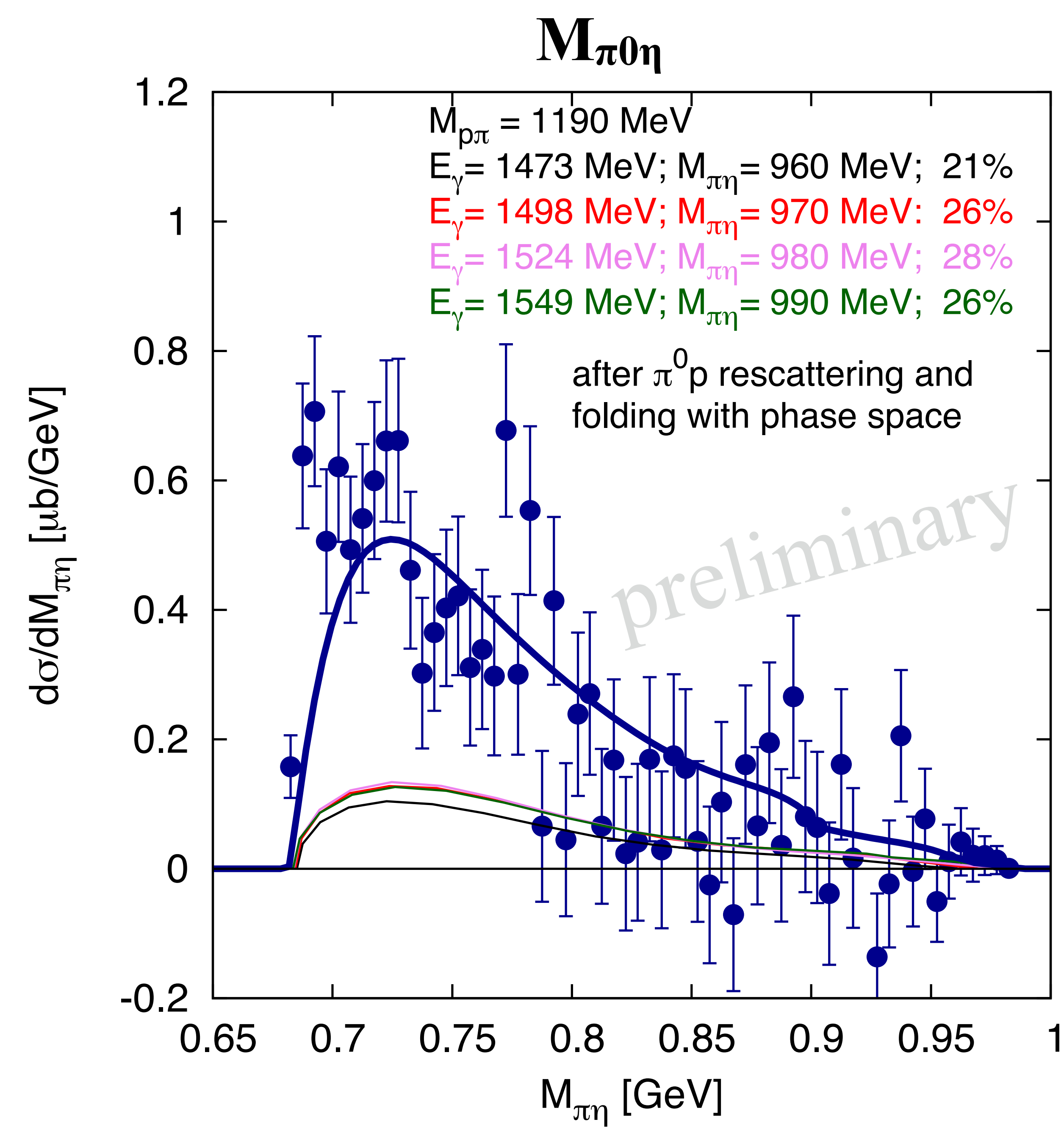
phase-space distribution



comparison data (difference to PWA) ⟷ calculation

contributions of the 4 selected singularity points with weight given by a_0 line shape





peak moves with excitation energy as observed experimentally

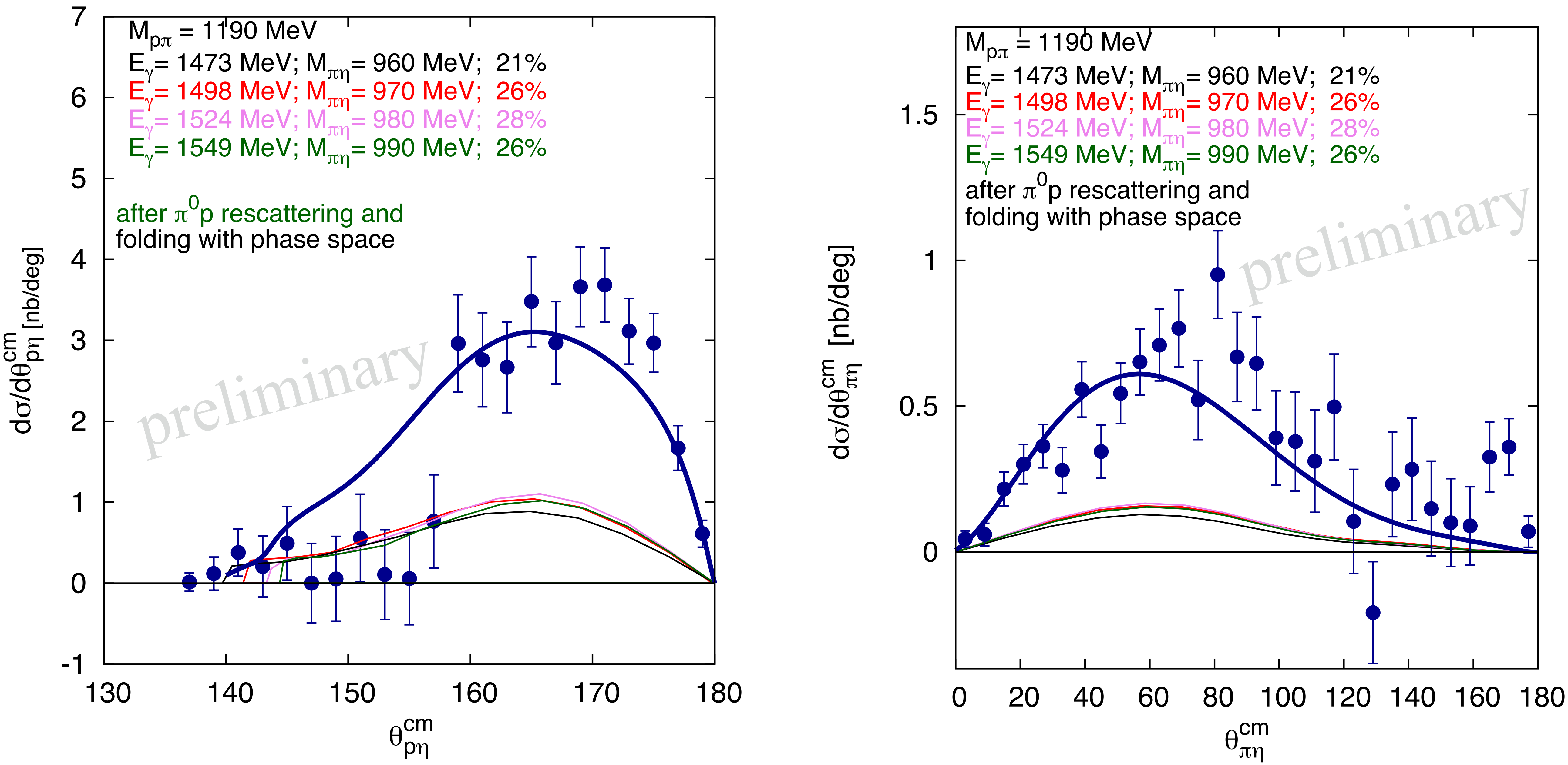
$M_{\pi 0\eta}$ distribution shifted towards kinematical limit $m_{\pi 0} + m_\eta$ = 682 MeV

blue curve (sum of the 4 contributions) fitted to the data

comparison data (difference to PWA) ⟷ calculation

contributions from the 4 selected singularity points with weight given by a_0 line shape

opening angle $\theta_{p\eta}$ in cm system | **opening angle $\theta_{\pi^0\eta}$ in cm system**



opening angles $\theta_{p\eta}$ confined to 150^0 - 180^0 | **opening angles $\theta_{\pi^0\eta}$ show max at ≈ 60^0**

blue curve (sum of the 4 contributions) fitted to the data

conclusions

- **the structure reported by Kuznetsov et al., JETP Lett. (2017) 693, not confirmed**

- **structure at $M_{p\eta} \approx 1710$ MeV almost quantitatively reproduced by calculation based on the triangular loop in the $\gamma p \rightarrow p\ a_0 \rightarrow p\ \pi_0\ \eta$ reaction**

- **loop diagrams and rescattering effects play an important role in the interpretation of structures in the excitation spectrum of the nucleon**

- **not every bump in an invariant mass spectrum is a resonance !!**

- **improvements:**

  calculation not only for 4 selected singularity points
  take interference of tree-level and triangular amplitude into account

  → **full partial wave analysis including the present data**

V. Metag, M. Nanova et al,
to be submitted to EPJA