Photoproduction of η‘ Mesons from Nuclei

recent results on in-medium properties of η’ meson from CBELSA/TAPS

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for CBELSA/TAPS Collaboration

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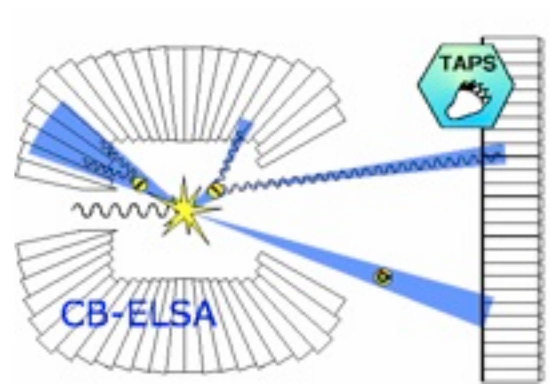
***funded by the DFG within SFB/TR16**



outline

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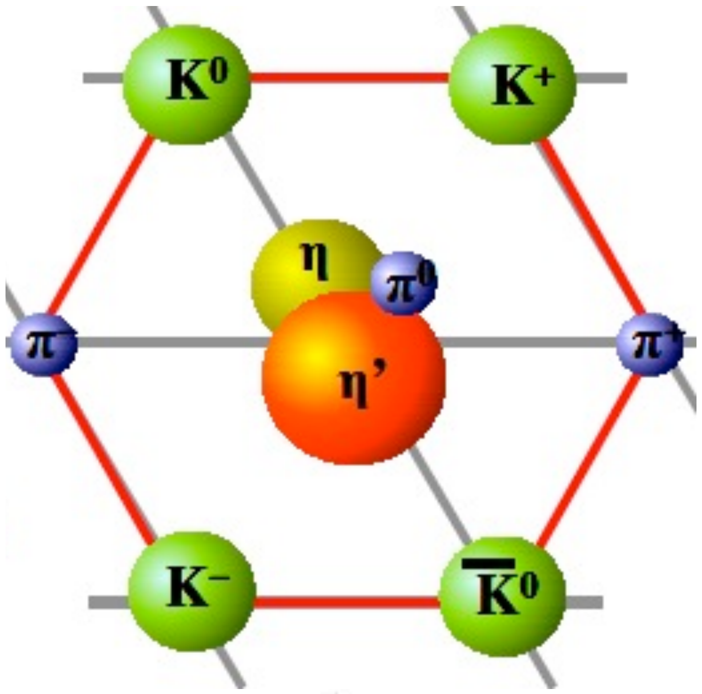
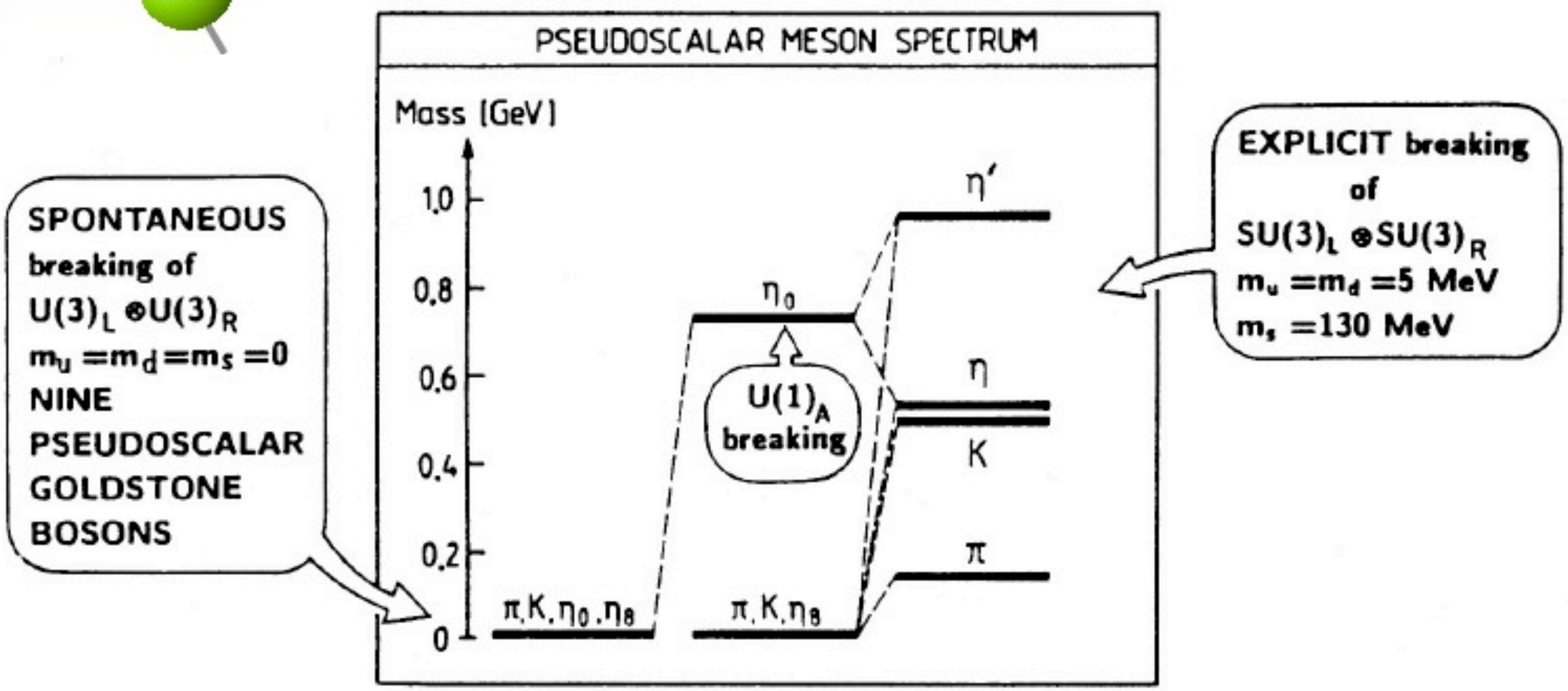
- motivation
- experimental approaches for studying the in-medium properties of η' meson
- experimental setup
- η' photoproduction on proton and deuteron
- η' photoproduction on nuclei
  - reconstruction of the η' meson
  - transparency ratio (T_A) measurements
  - comparison with the T_A of other mesons
- summary & outlook

pseudoscalar meson nonet



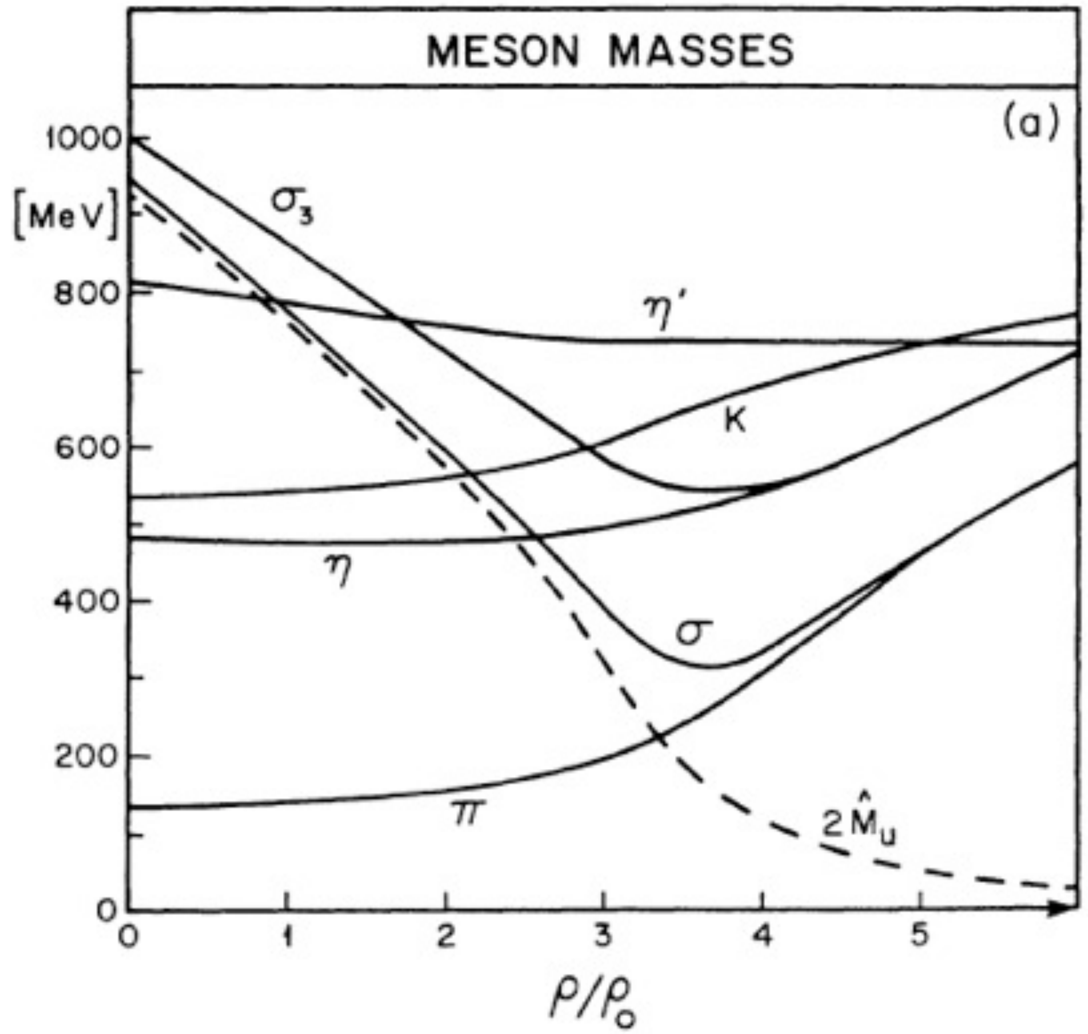
W. Weise



masses as a result of symmetry breaking

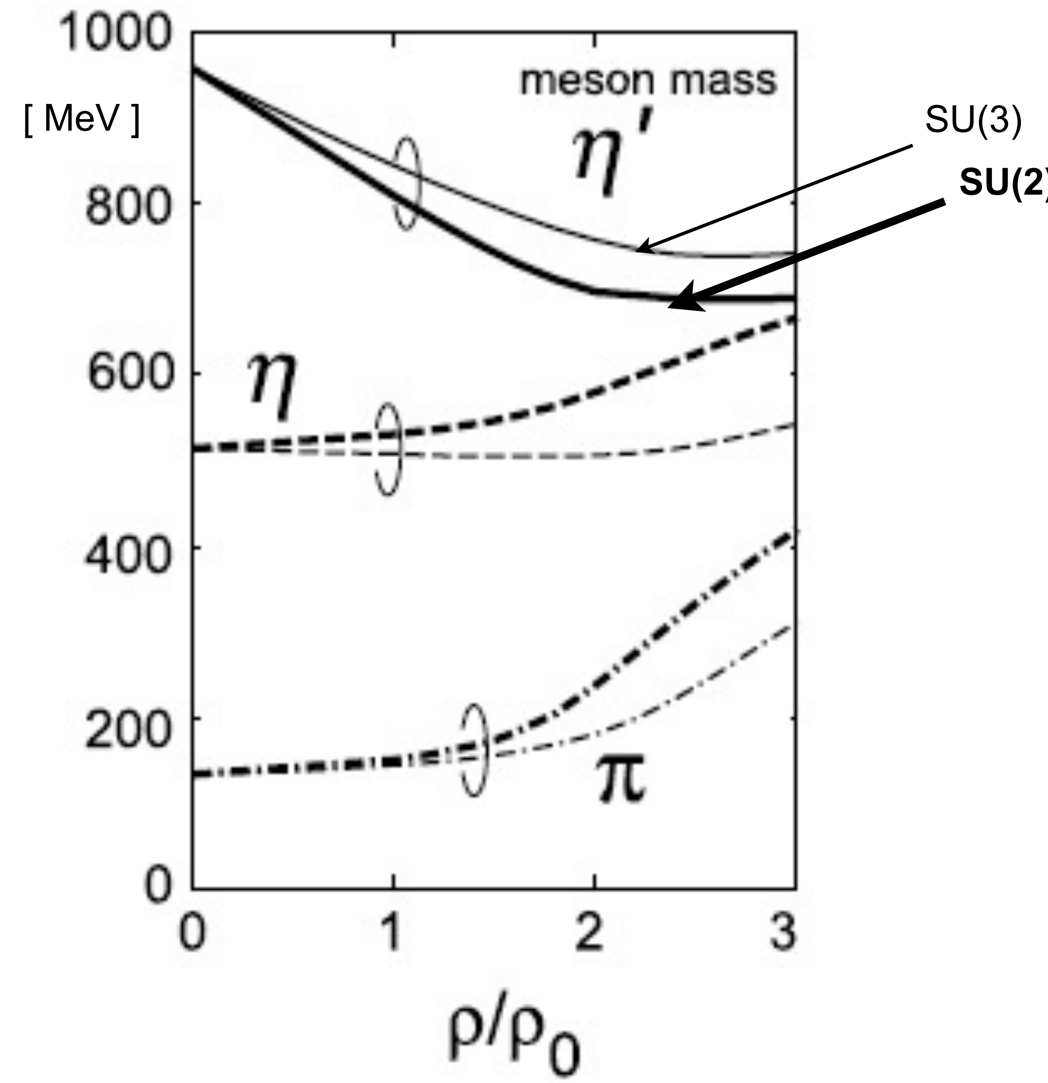
predicted in-medium properties of the η' meson

V. Bernard und U.G. Meissner,
Phys. Rev. D 38 (1988) 1551



the mass of the η' meson is almost independent of density

H. Nagahiro, M. Takizawa and S. Hirenzaki,
Phys. Rev. C 74 (2006) 045203



mass changes of η and η' mesons in the nuclear medium

(talk Hirenzaki on Thursday, at 16:50 in the HHCM session)

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line shape analysis: not applicable;

η' meson decays outside of nucleus;

$$\lambda_{dec} = \hbar c/\Gamma_0 = 1000 fm >>> R_{nucl}$$

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indirect evidence for reduction of η' mass in the hot medium (PHENIX & STAR data)
T. Csörgö, R. Vèrtesi and J. Szklai
Phys. Rev. Lett. 105 (2010) 182301
Phys. Rev. C 83 (2011) 054903

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  attenuation measurement of the η' meson flux

  experimental observable to extract the in-medium witdh of the meson:

  transparency ratio:

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measure for the loss of meson flux through inelastic processes in the nucleus
applicable for any meson irrespective of lifetime

ω: M. Kotulla et al., (CBELSA/TAPS), PRL 100 (2008)192302
M. H. Wood et al., (CLAS), PRL 105 (2010) 112301

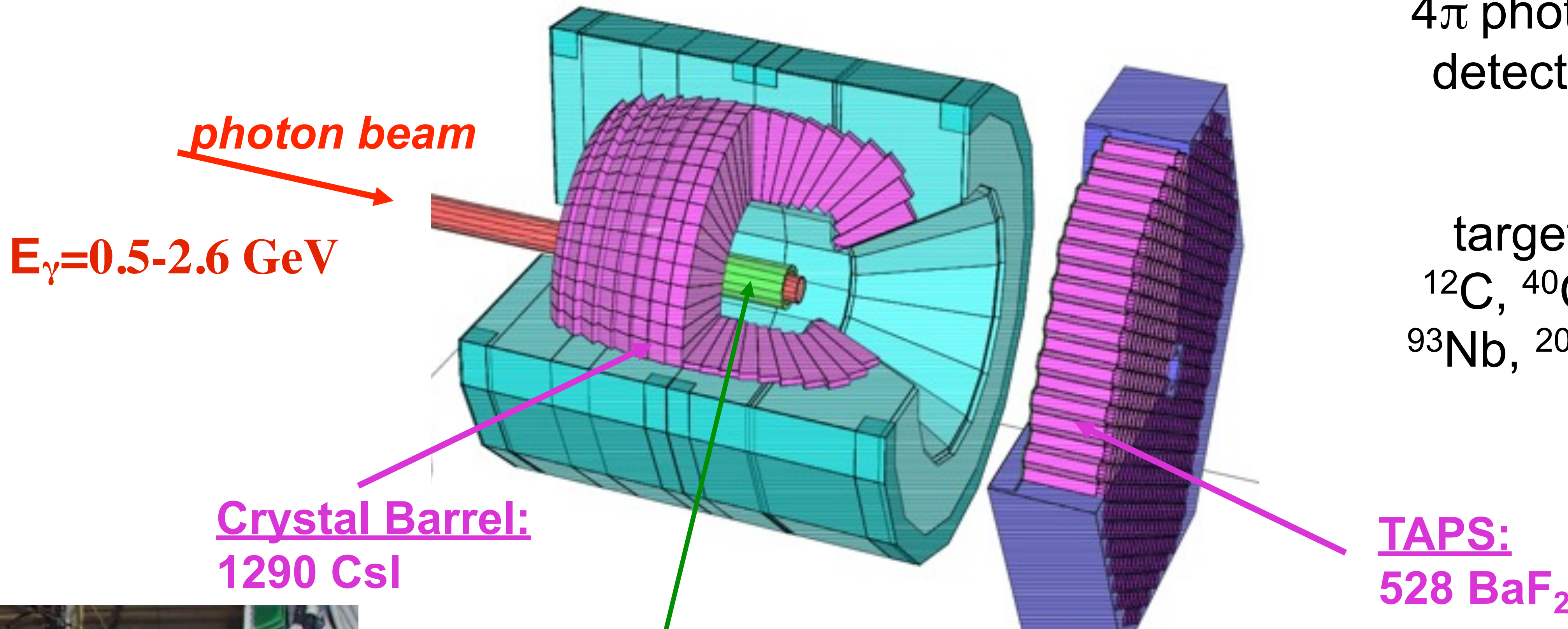
Φ: T. Ishikawa et al., (Spring8), PLB 608 (2005) 215
A. Polyanskiy et. al., (COSY-ANKE), (talk later in this session)
P. Salabura (plenary session, Friday 12:00)

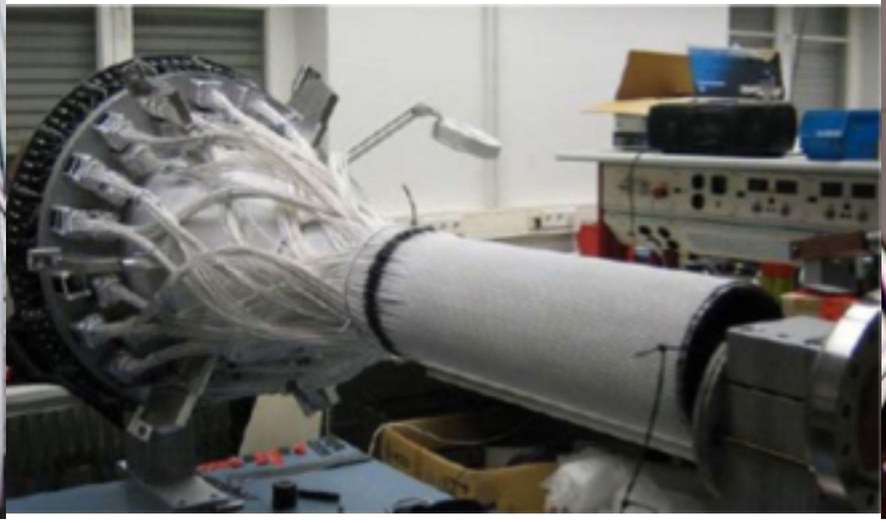
Crystal Barrel/TAPS@ELSA Experiment

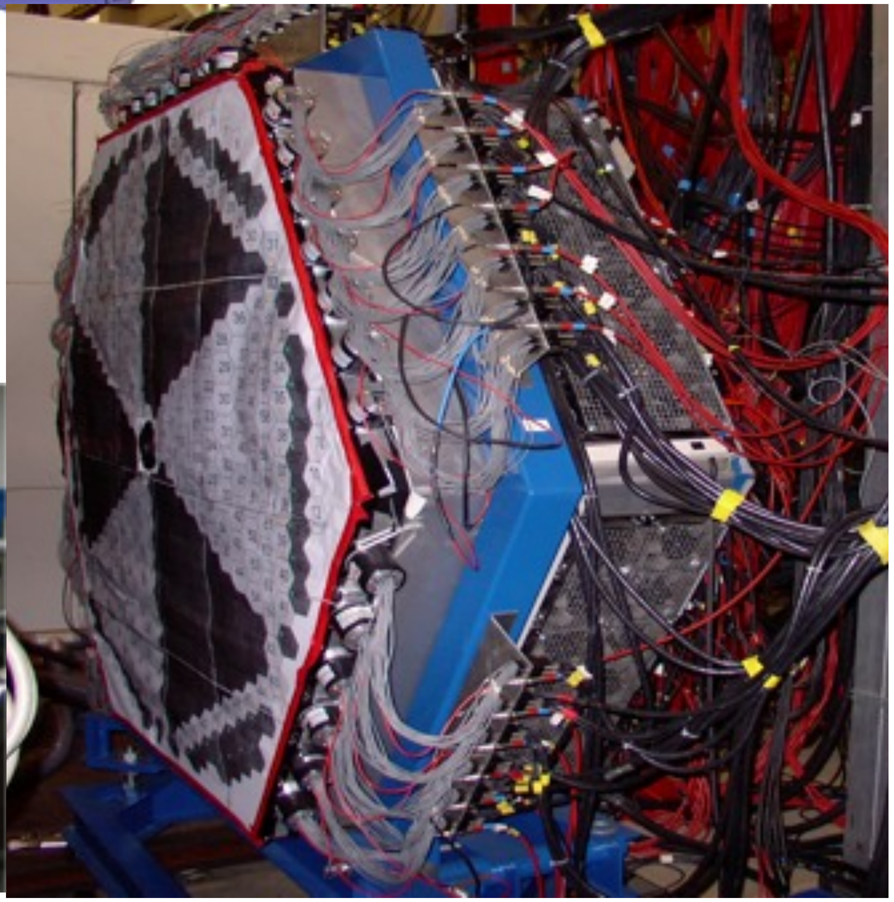
http://www.cb.uni-bonn.de

4π photon detector

targets:
^{12}C, ^{40}Ca, ^{93}Nb, ^{208}Pb



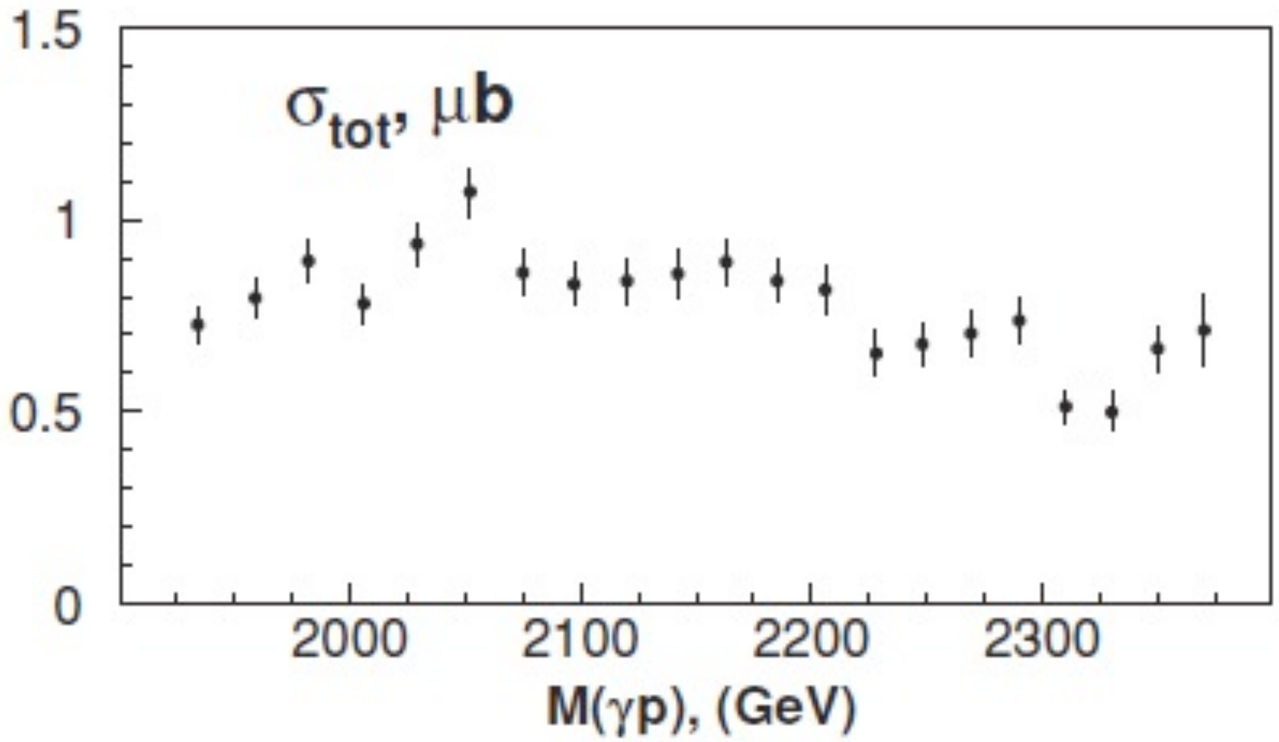




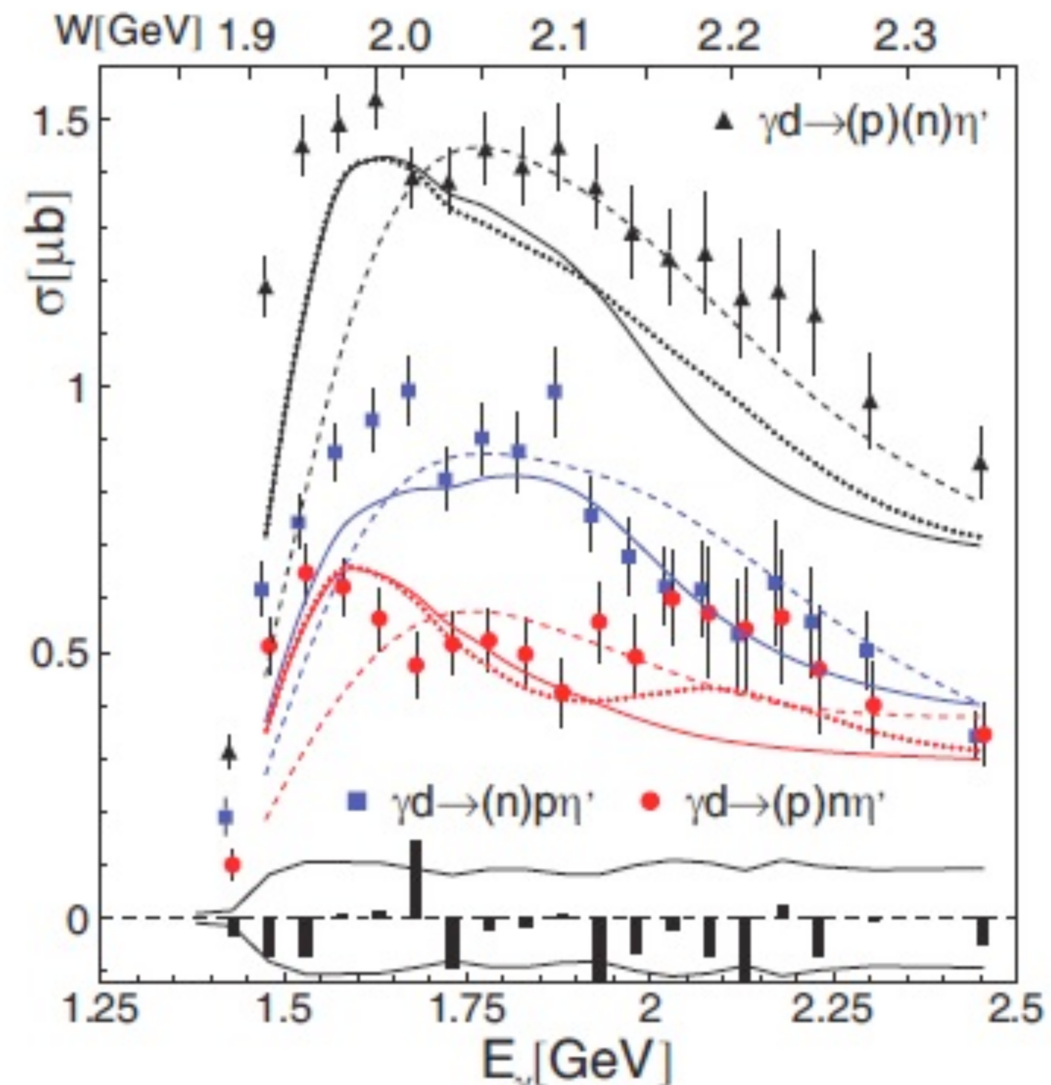
photoproduction of η‘ meson on proton and deuteron

I. Jaegle et al., Eur. Phys. J. A 47(2011) 11

V. Crede et al.,
Phys. Rev. C 80 (2009) 055202



total cross section determined exploiting full angular coverage



--- **η’-MAID model**
W.T. Chiang et al.,
*PRC **68** (2003) 045202*
P_{11}, P_{13} (1950 MeV), D_{13}

NH model
K. Nakayama, H. Haberzettl,
*PRC **73** (2006) 045211,*
*PRC **69** (2004) 065212*

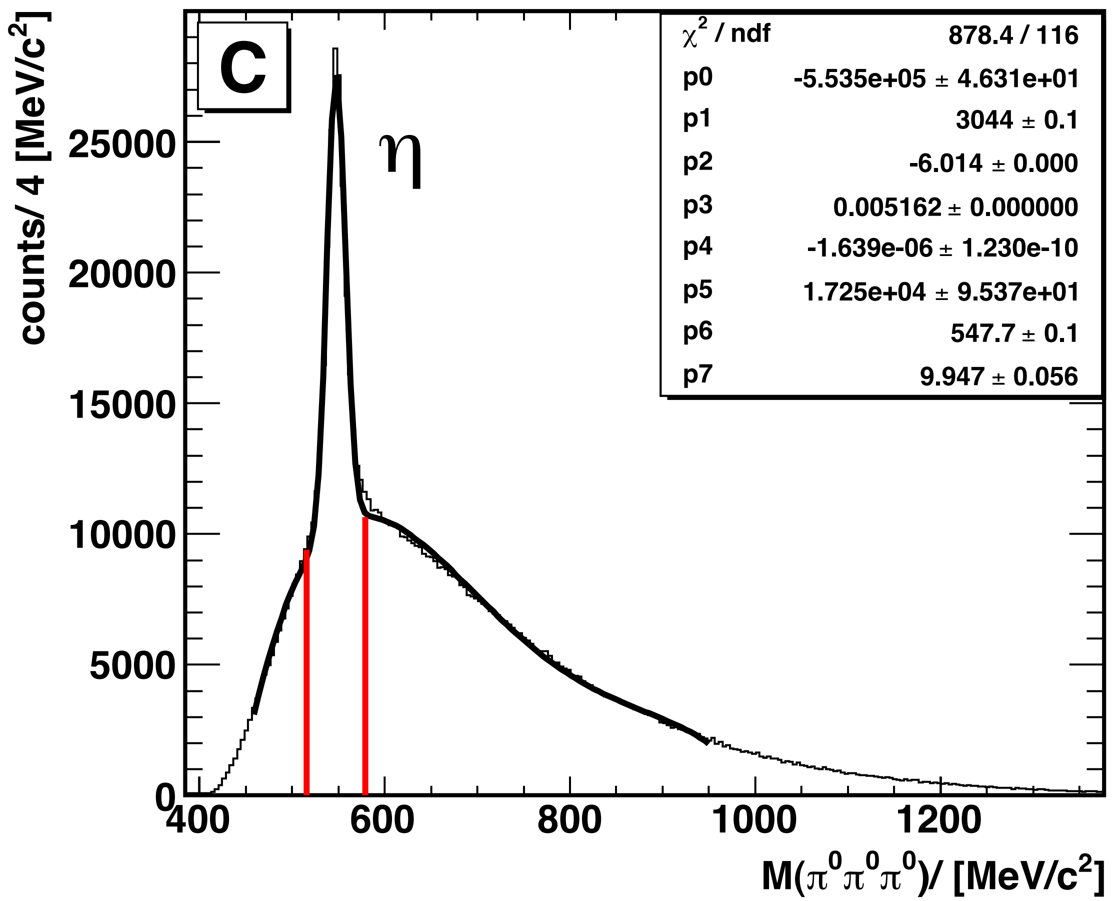
η’ coupling to different resonances

photoproduction of η‘ mesons on nuclei

$\eta' \to \pi^0\pi^0\eta \to 6\gamma$ BR: 8.1% **CB/TAPS@ELSA**

- solid targets: ^{12}C, ^{40}Ca, ^{93}Nb and ^{208}Pb;
  20 mm, 10 mm, 1 mm and 0.6 mm ≲ (6-9)% X_0

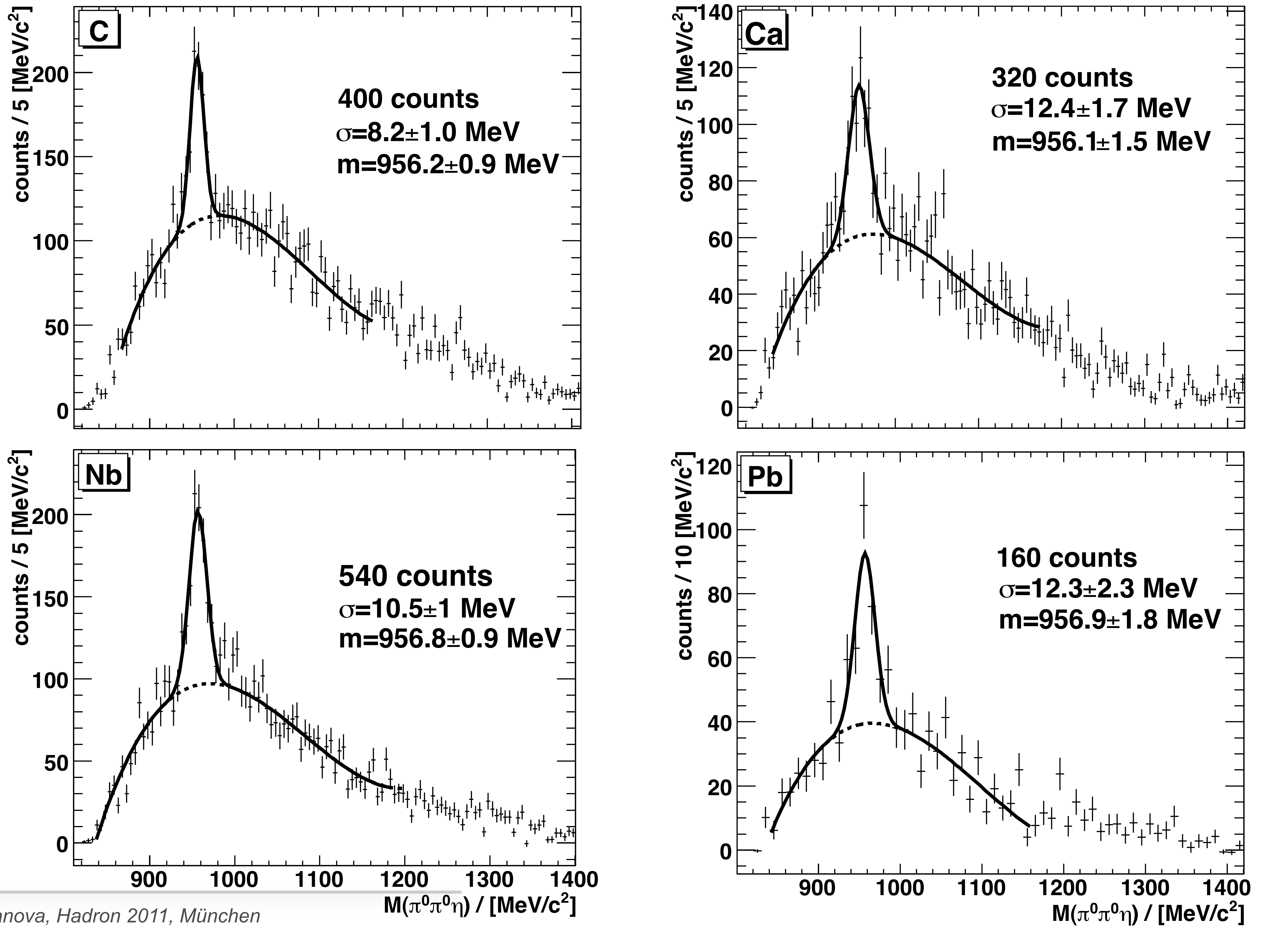
- event selection: ≥ 6 neutral particles AND/OR 6n + 1ch
- sum energy of 6 neutral particles > 600 MeV
- competing channel with same final state: $\eta \to \pi^0\pi^0\pi^0 \to 6\gamma$
  reconstructed and removed in further analysis



photoproduction of η‘ mesons on nuclei (E_γ=1200-2200 MeV)

$$\gamma A \rightarrow \eta^{'} A' \rightarrow \pi^0\pi^0\eta \rightarrow 6\gamma A'$$

A=^{12}C, ^{40}Ca, ^{93}Nb, ^{208}Pb



acceptance

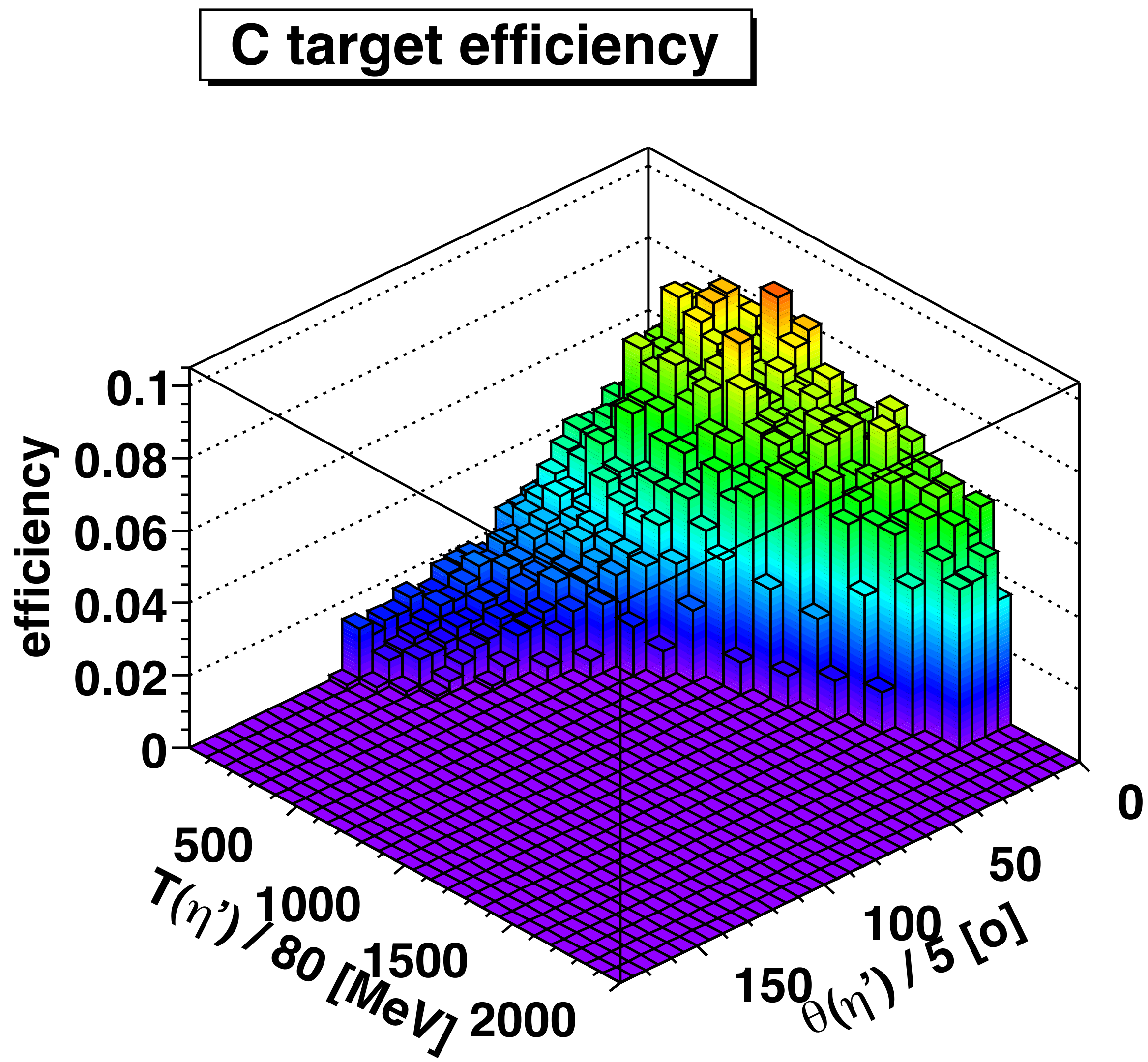
E_γ = 1200 - 2200 MeV

η’ MC simulation

acceptance (T_{kin}, θ^{lab})

independent of any reaction model

‘grid method’ for acceptance correction (I. Jaegle)



efficiency correction of the data - event by event in (T_{kin}, θ^{lab}) plane

efficiency is slightly different for different solid targets

transparency ratio measurements

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$\Rightarrow$ shortening of lifetime of the meson; increase the width: $\Gamma(\rho, |p_{\eta'}|) \propto \rho . v . \sigma_{abs}$

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  N. Bianchi et. al, PRC 54 (1996) 1688

T. Falter, S. Leupold and U. Mosel, 0102058 [nucl-th]

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normalization to light nucleus (^{12}C) - helps to suppress these effects

in-medium width of the η‘ meson

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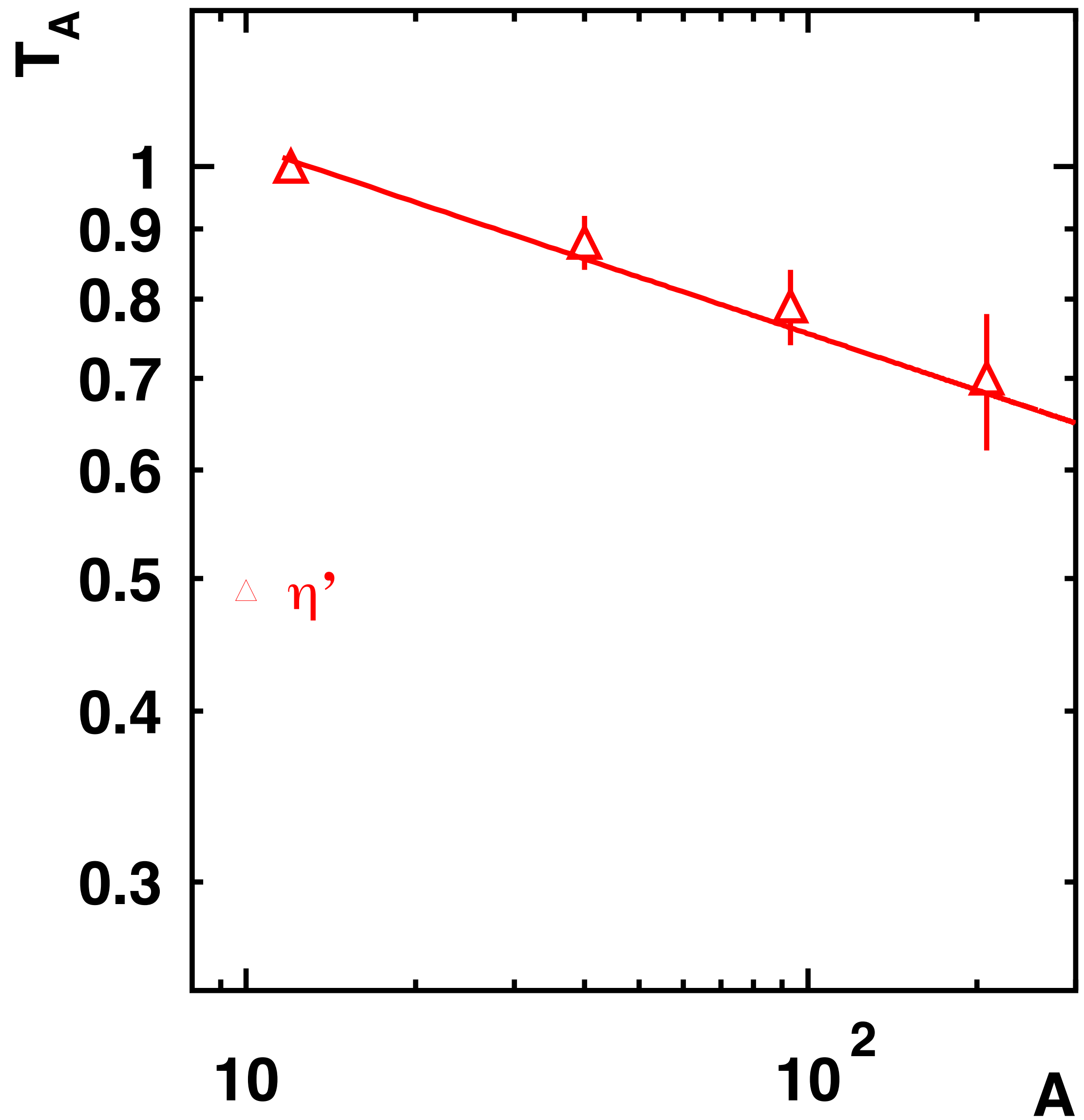
transparency ratio:

$$T_A = \frac{12 \cdot \sigma_{\gamma A \to \eta' X}}{A \cdot \sigma_{\gamma C \to \eta' X}}$$

normalized to C



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$$\sigma(A) = \sigma_0 \cdot A^{\alpha}$$

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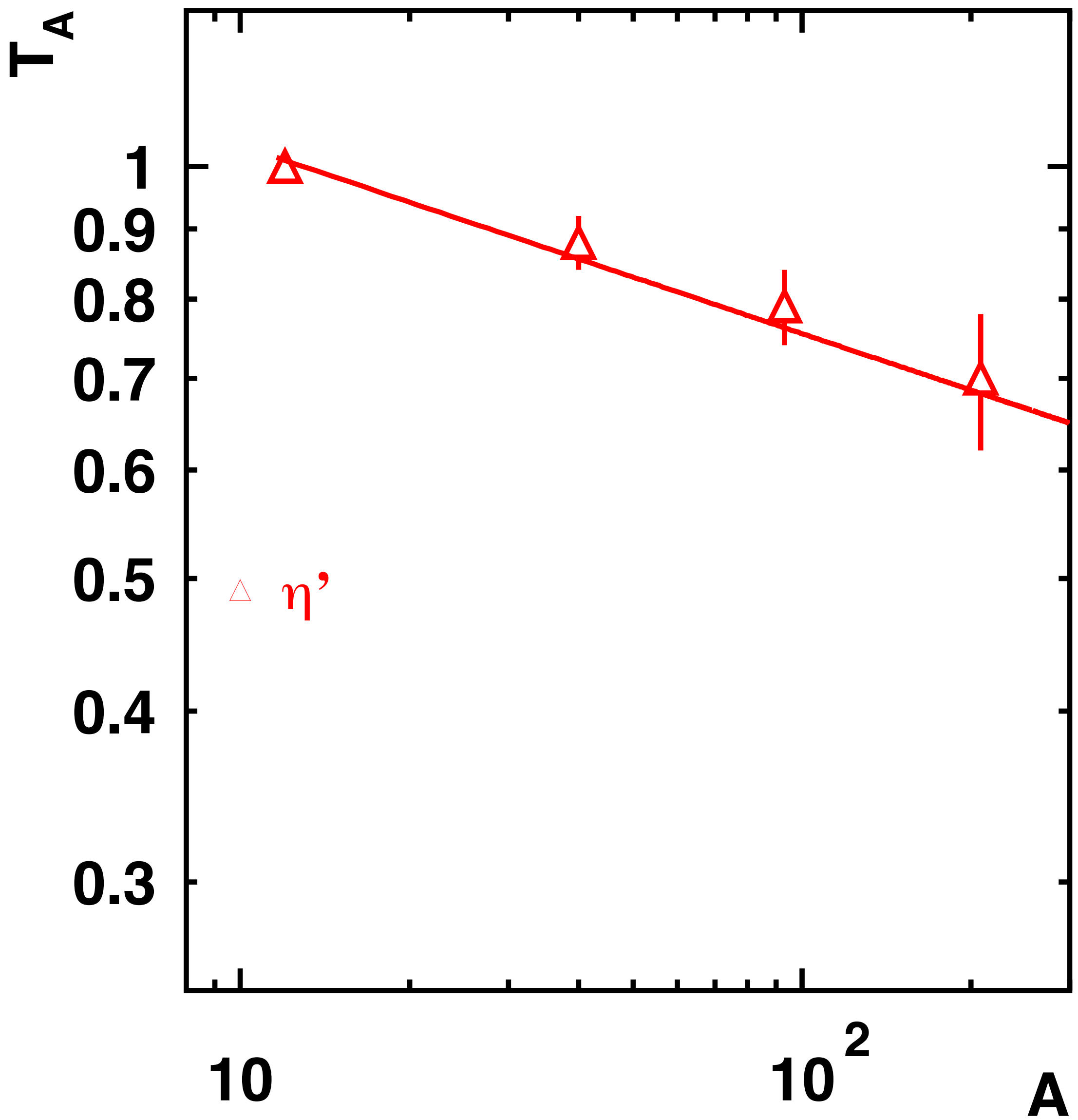

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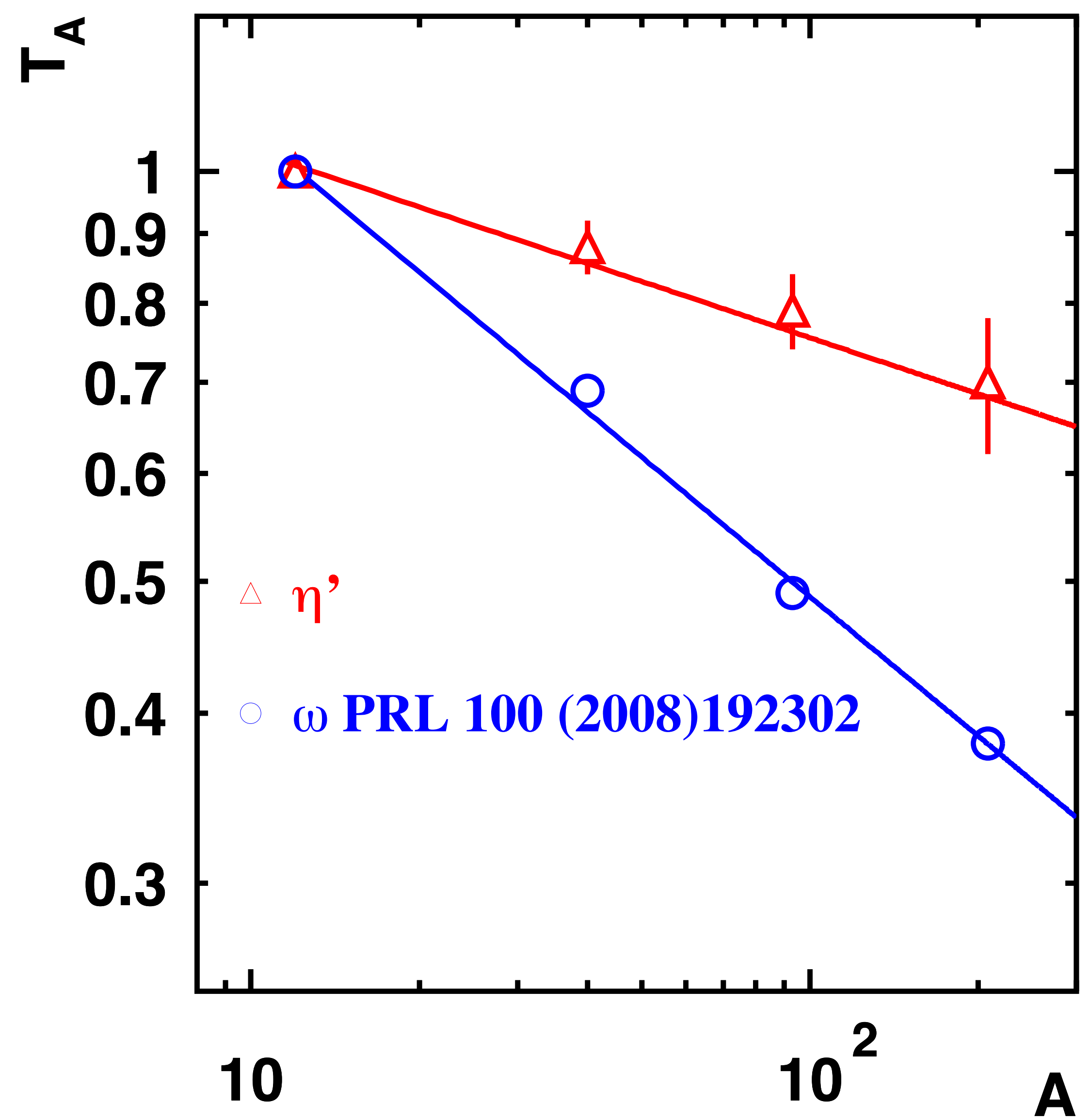
comparison with T_A for **ω** meson

$\Gamma(\rho_0, <|p_\omega|> \approx 1.1$ GeV/c$) \approx$ 130-150 MeV

M. Kotulla et al. PRL 100 (2008) 192302



η′ absorption weaker than ω absorption!!

but how large is the width??

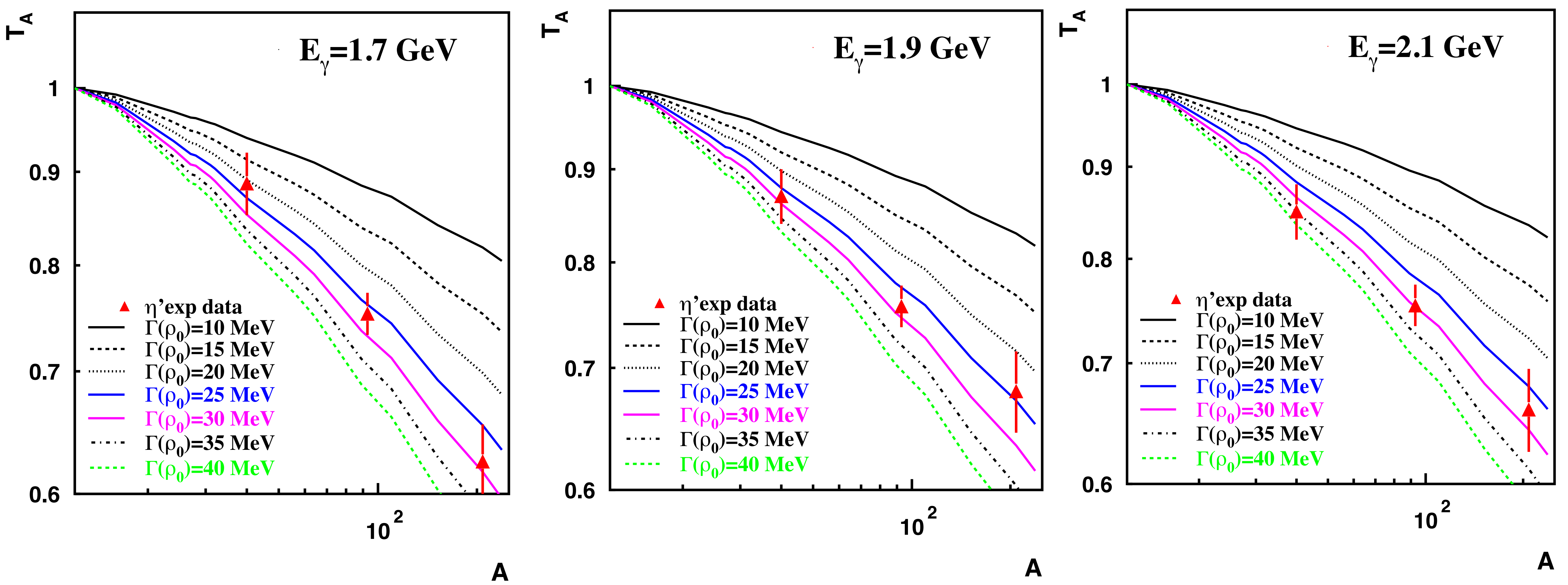
➜ comparison to transport model calculations

η′ in-medium width and absorption cross section

η′ transparency ratio compared with the calculations by *A.Ramos and E. Oset*

$$\sigma_{\gamma A\to\eta' A'} = C\int d^3r\rho(\vec{r})\frac{1}{2\pi}\int_0^{2\pi} d(\phi^{\eta'}_{\rm c.m.})\frac{1}{2}\int_{-1}^{1} d(\cos\theta^{\eta'}_{\rm c.m.})\frac{d\sigma}{d\Omega}(\gamma p\to\eta' p)P_s(\vec{r})$$

where $P_s(\vec{r})$ is the survival probability $P_s(\vec{r}) = \exp\left[\int_0^\infty dl\frac{\mathrm{Im}\,\Pi_{\eta'}(\rho(\vec{r}\,'))}{|\vec{k}_{\eta'}|}\right]$ with $\vec{r}\,' = \vec{r} + l\frac{\vec{k}_{\eta'}}{|\vec{k}_{\eta'}|}$



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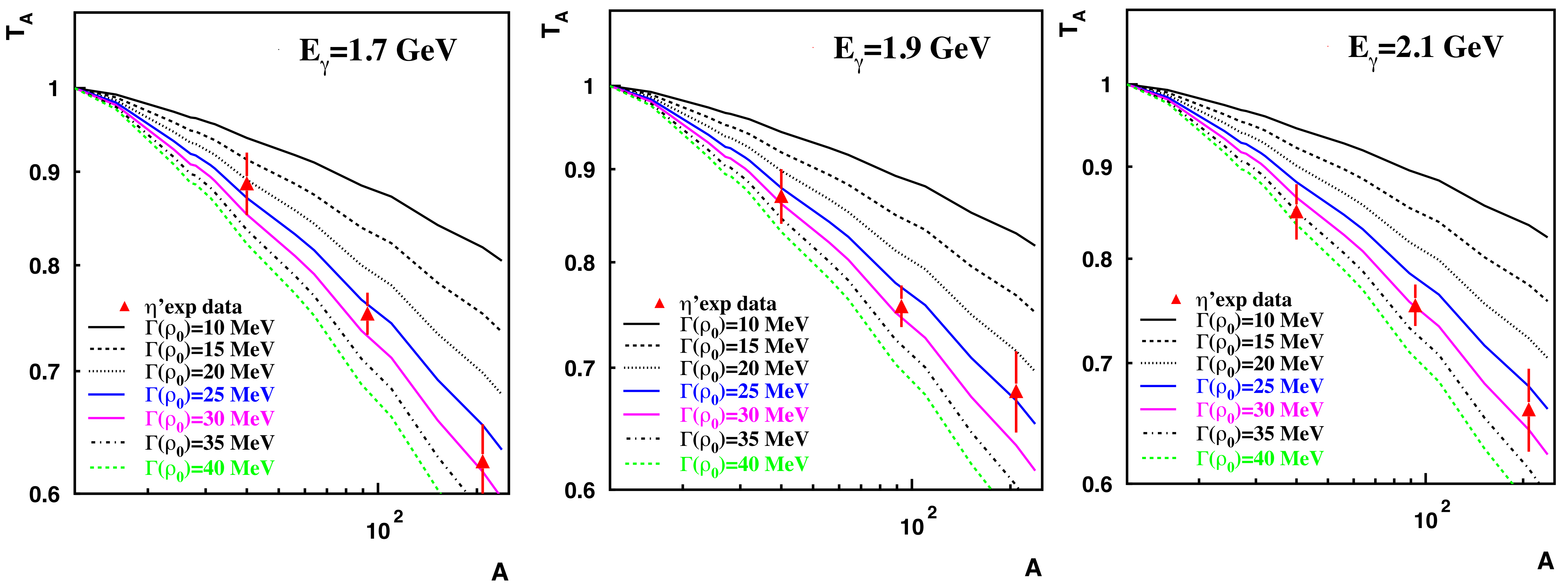

comparison to data $\Gamma(\rho_0,\langle|\vec{p}_{\eta'}|\rangle \approx 1.05\ \mathrm{GeV/c}) \approx 25\text{-}30\ \mathrm{MeV}$

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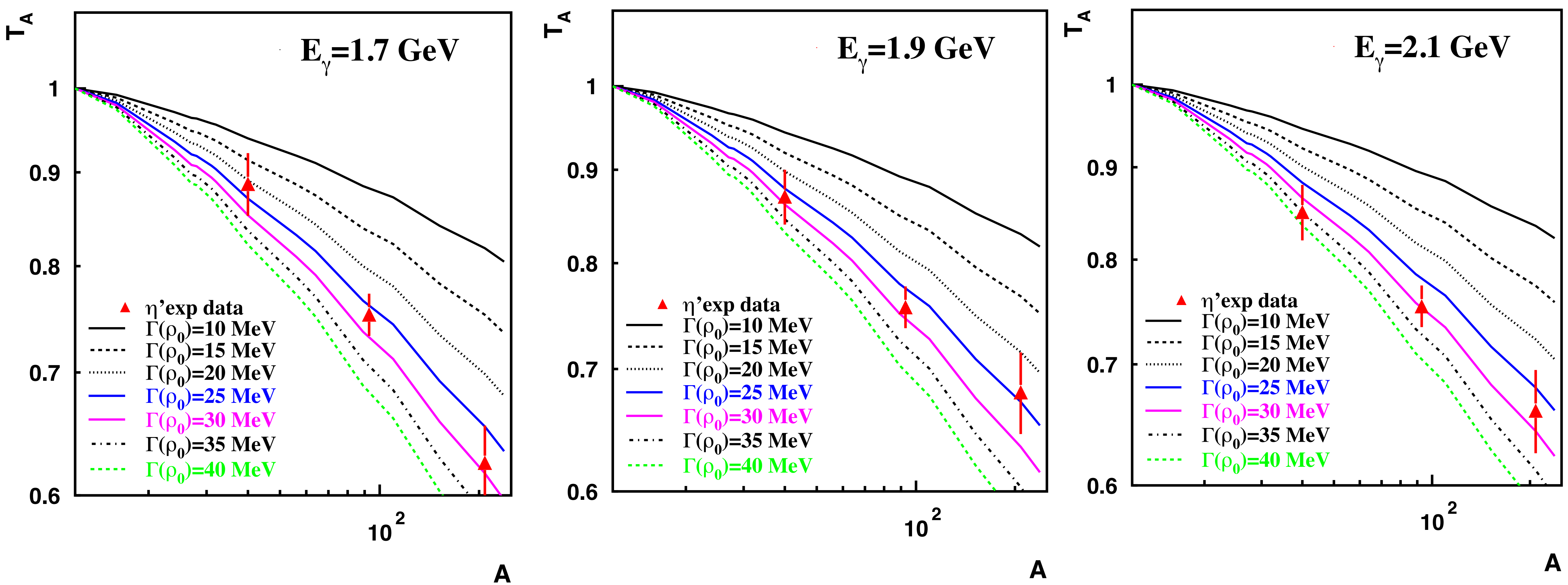

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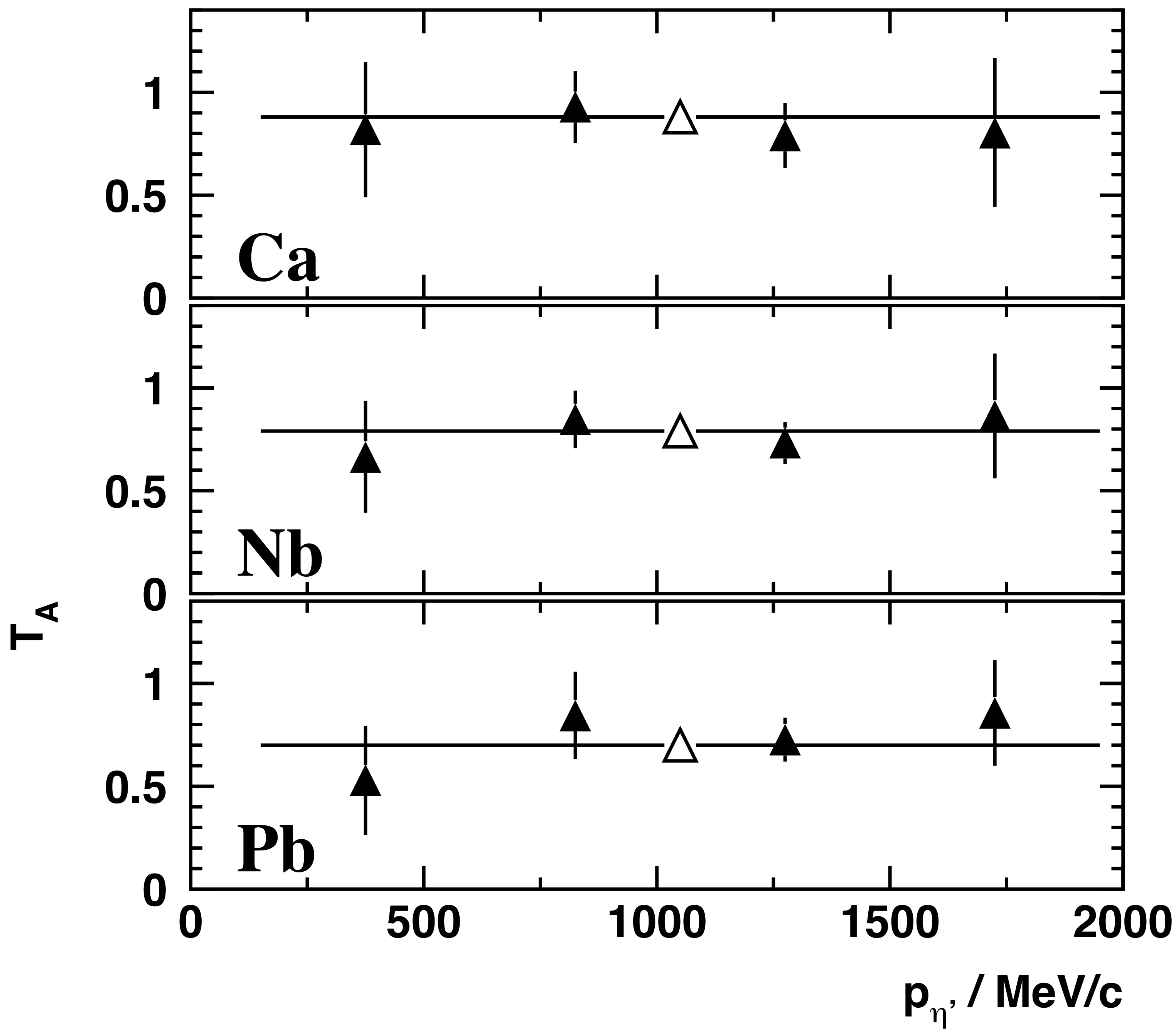
absorption cross section: $\sigma_{\eta' N} = \frac{\Gamma_{inel}}{\rho_0 \cdot \beta \cdot \hbar \cdot c} \approx 11\ \mathrm{mb}$

momentum dependence of the η′ transparency ratio



Δ - over all momenta

weak variation of T_A with the $p_{\eta'}$
no contribution from the two-step processes

problems in transparency ratio measurements

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- **two-step processes -**

  increase the number of mesons:

  a) $\gamma N \to \pi N$ and then:

  $\pi N \to \eta' N$ / σ = 0.1 mb @ $p_\pi \approx 1.5$ GeV/c

  $\pi N \to \omega N$ / σ = 2.5 mb @ $p_\pi \approx 1.1$ GeV/c

  $\pi N \to \eta N$ / σ = 3 mb @ $p_\pi \approx 0.8$ GeV/c

  Landolt-Börnstein, New Series Vol. I/12 a (1988)

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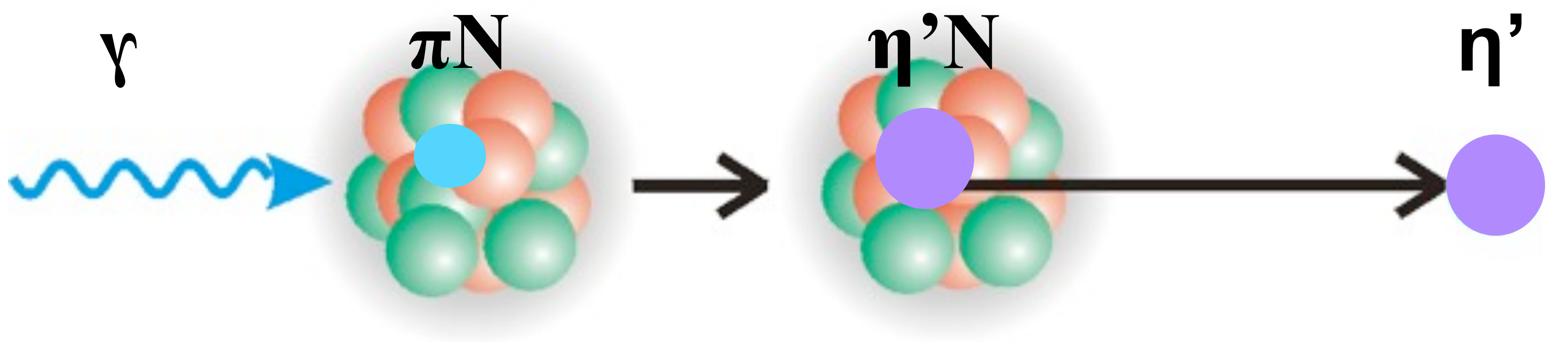

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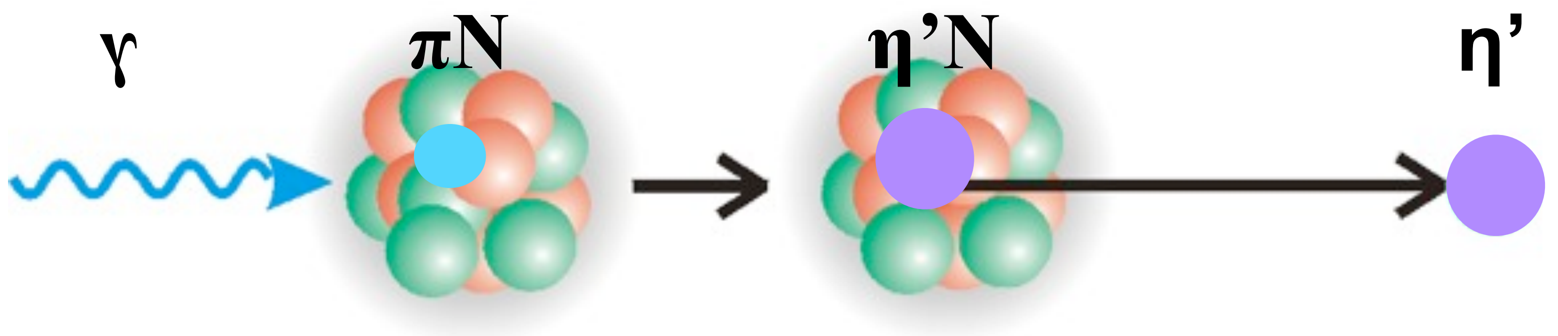
⇨ absorption measurement distorted by two-step production processes



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  increase the number of mesons:

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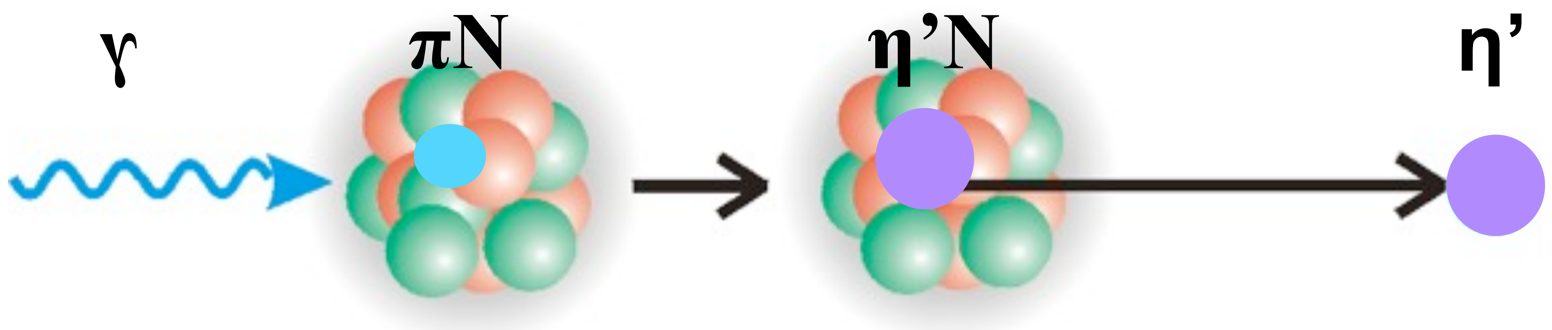

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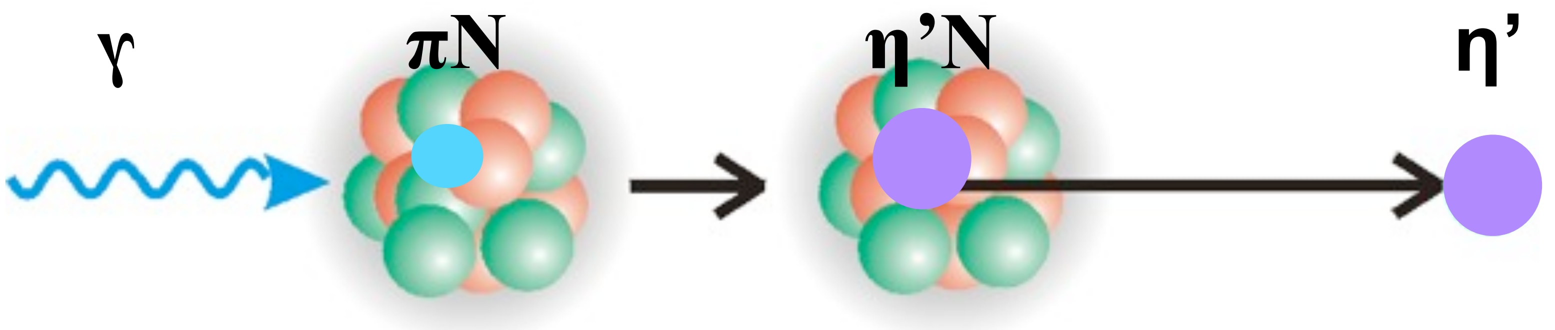

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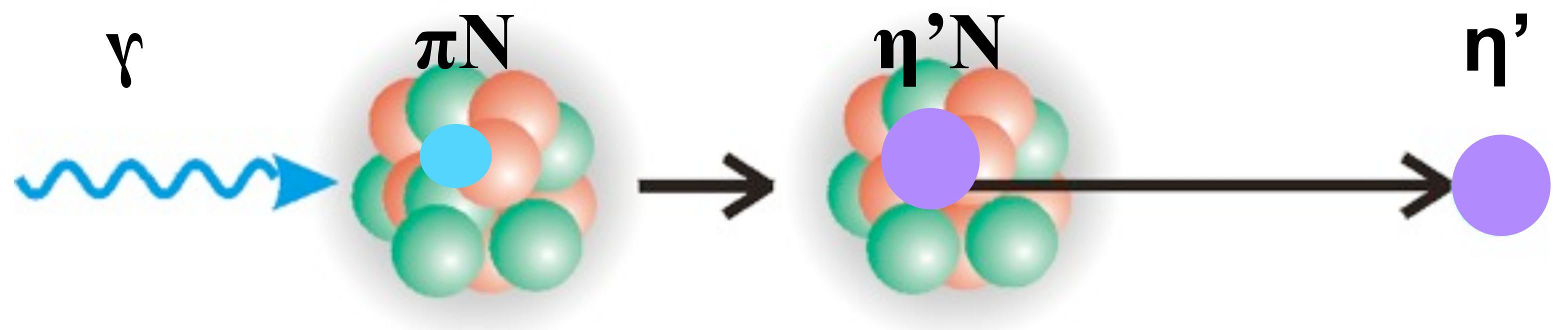

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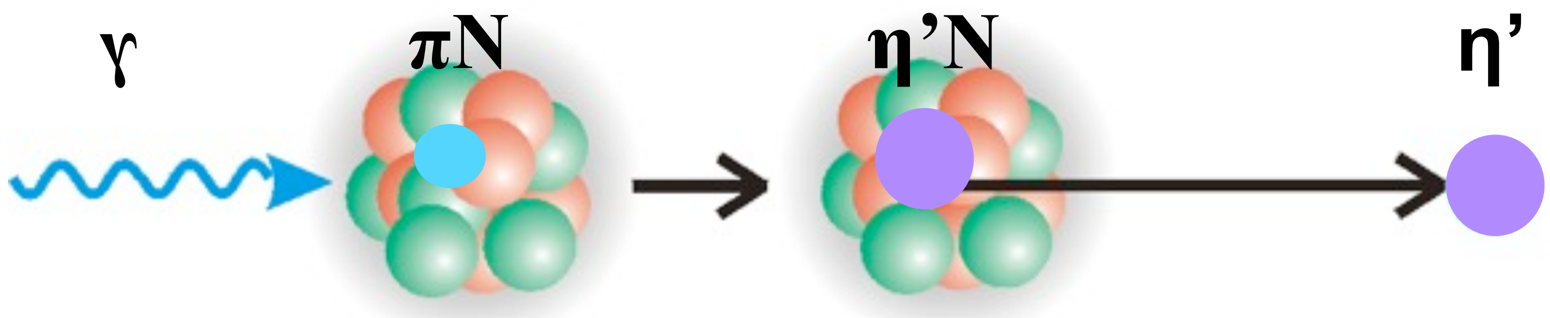

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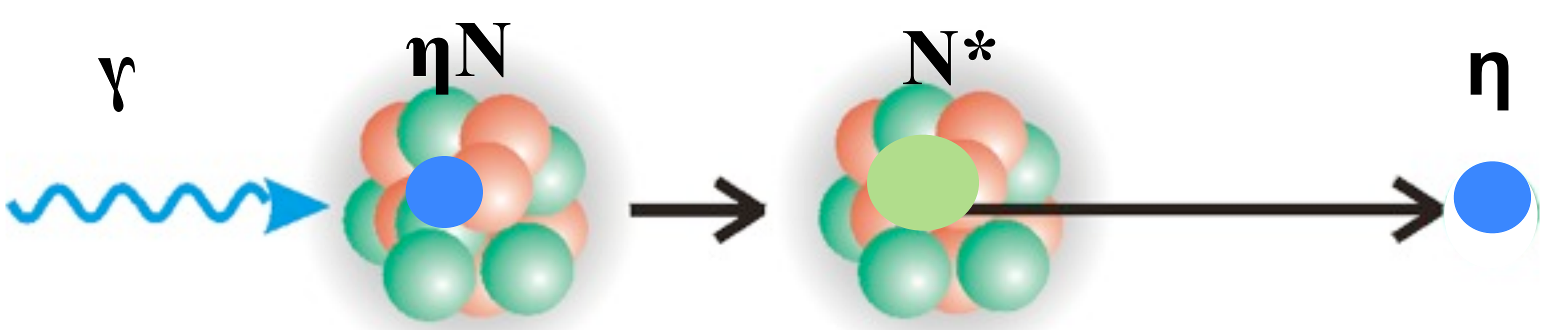

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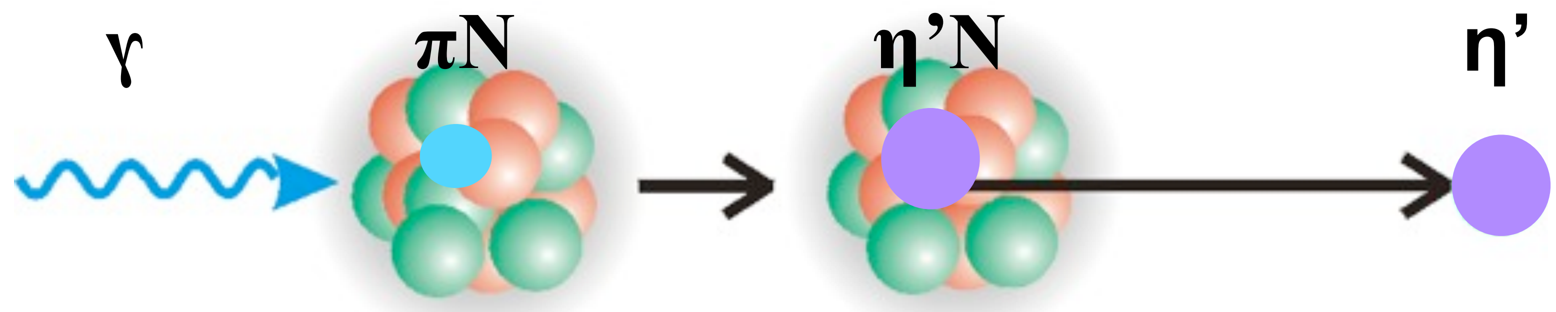
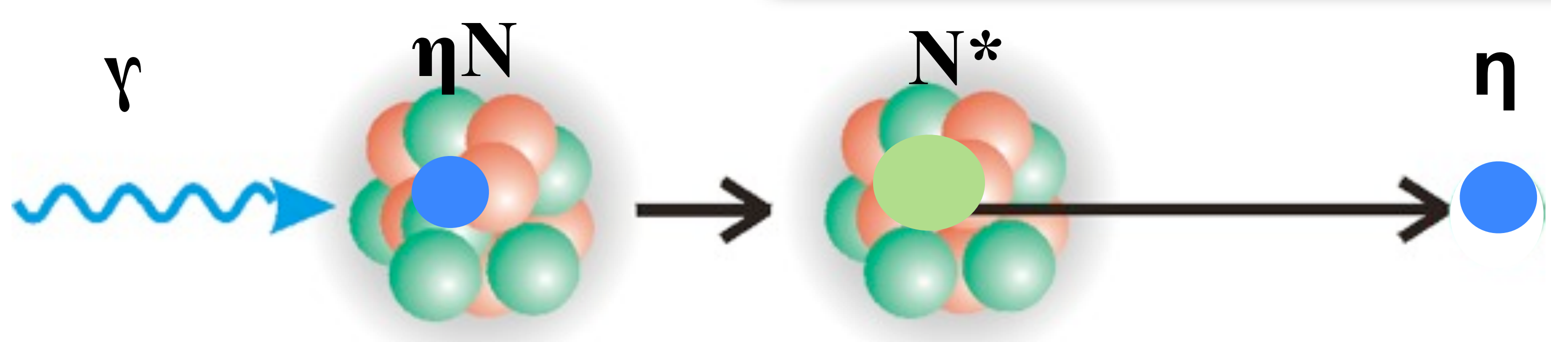


suppressing this process ⇨ select only mesons with higher T_{kin}

b) via resonances: η N→N*→ η N ⇨ slowing down by absorption and reemission



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T. Mertens et al., EPJA 38 (2008) 195
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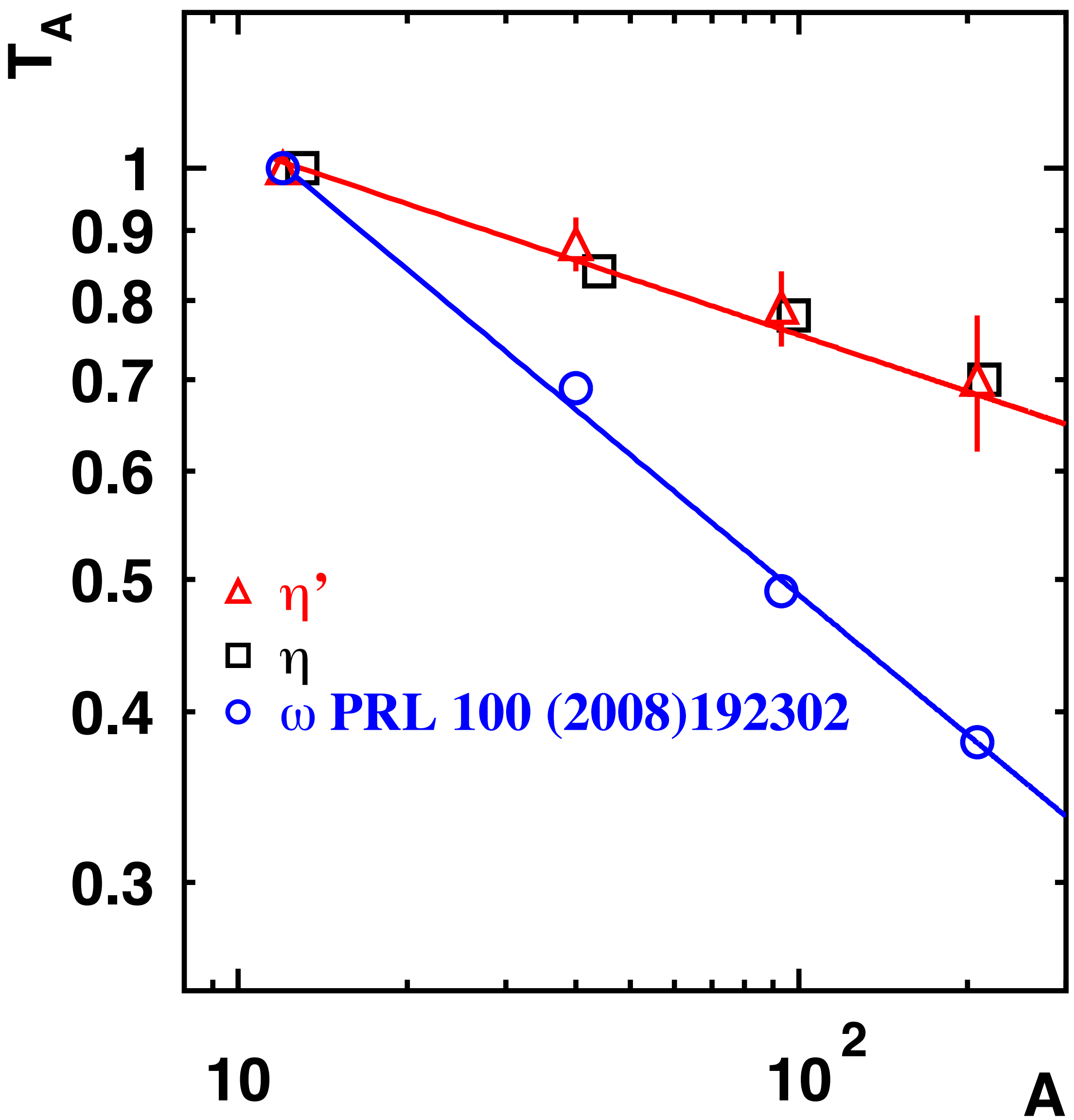

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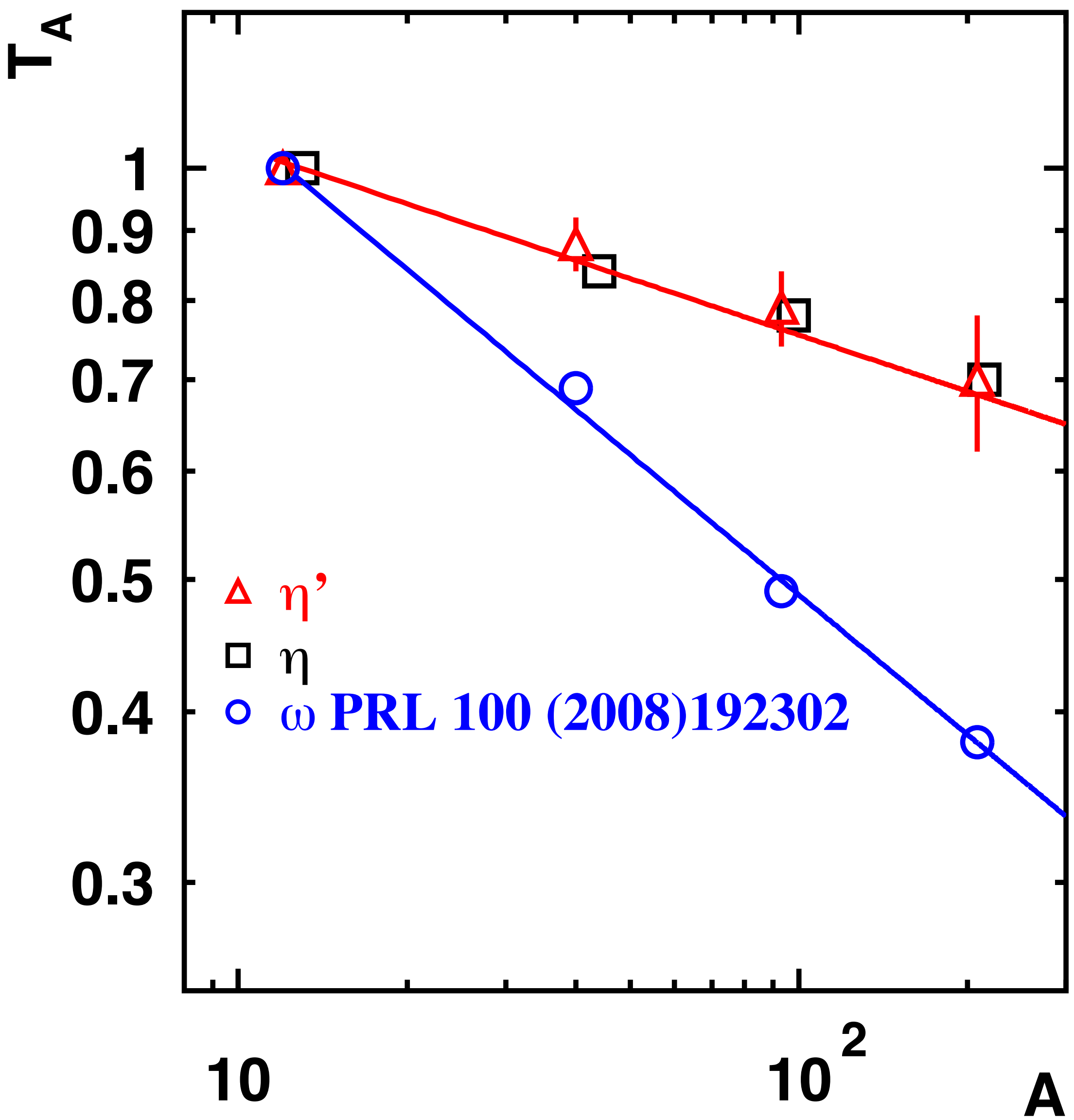

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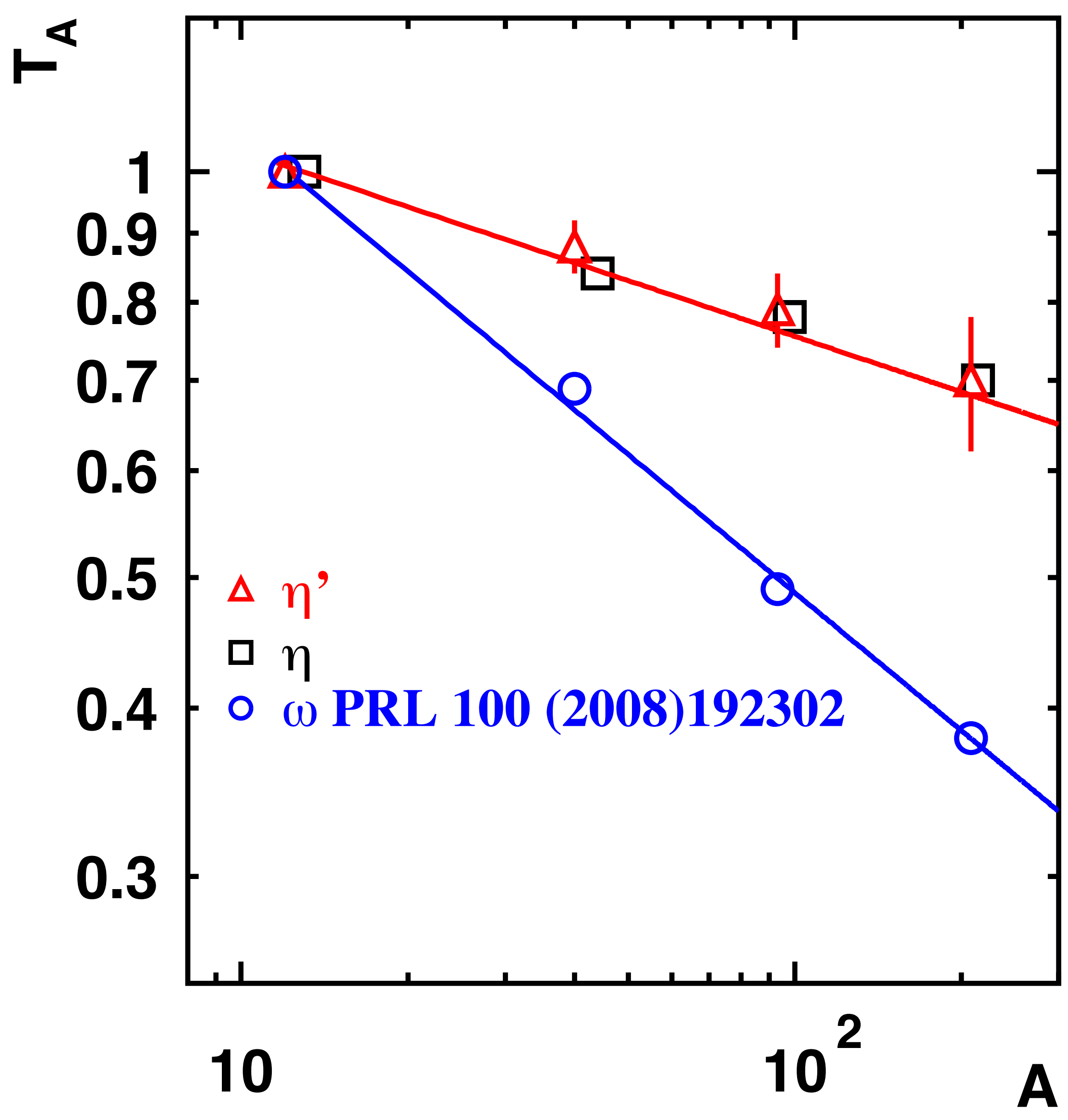

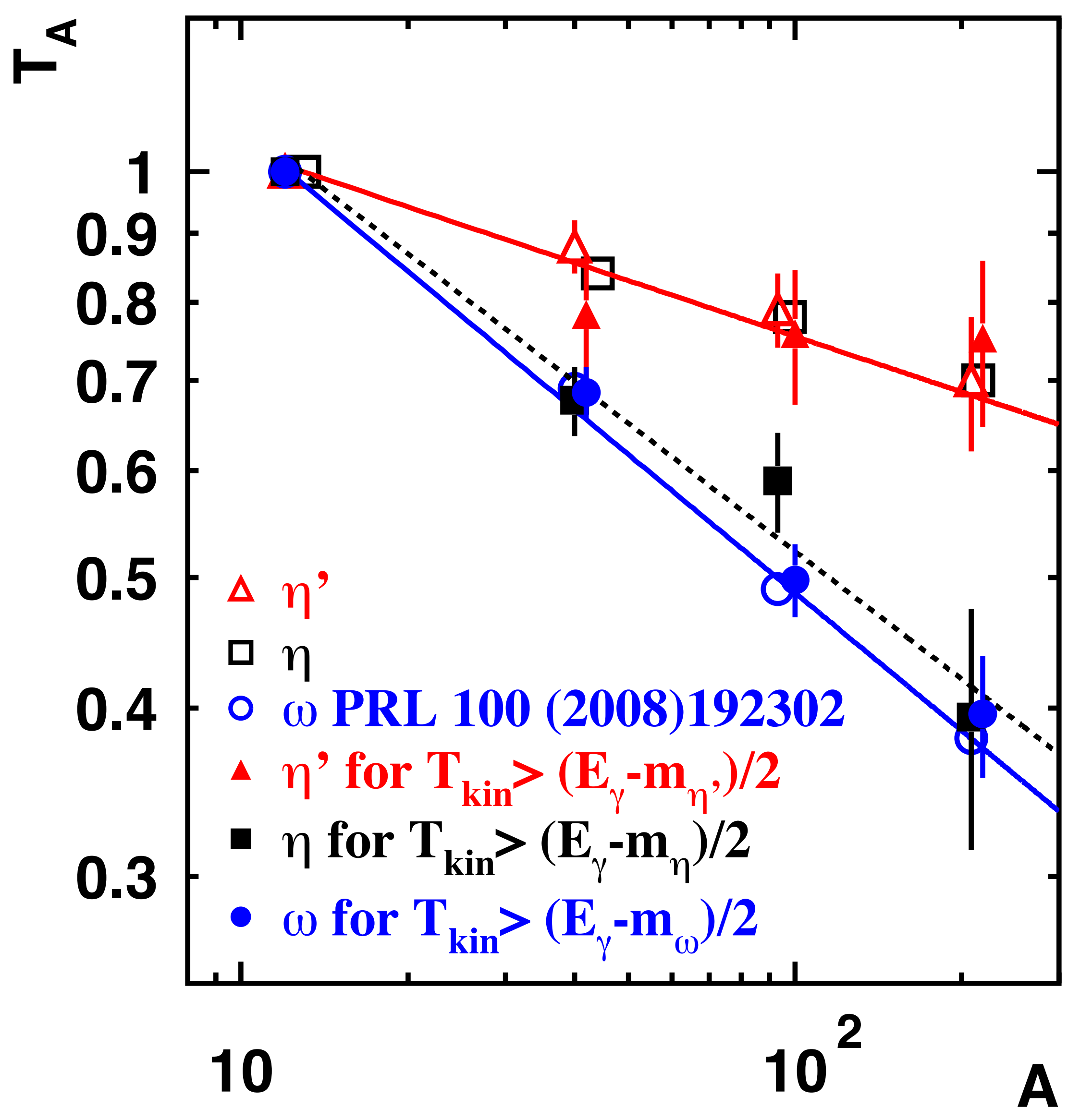

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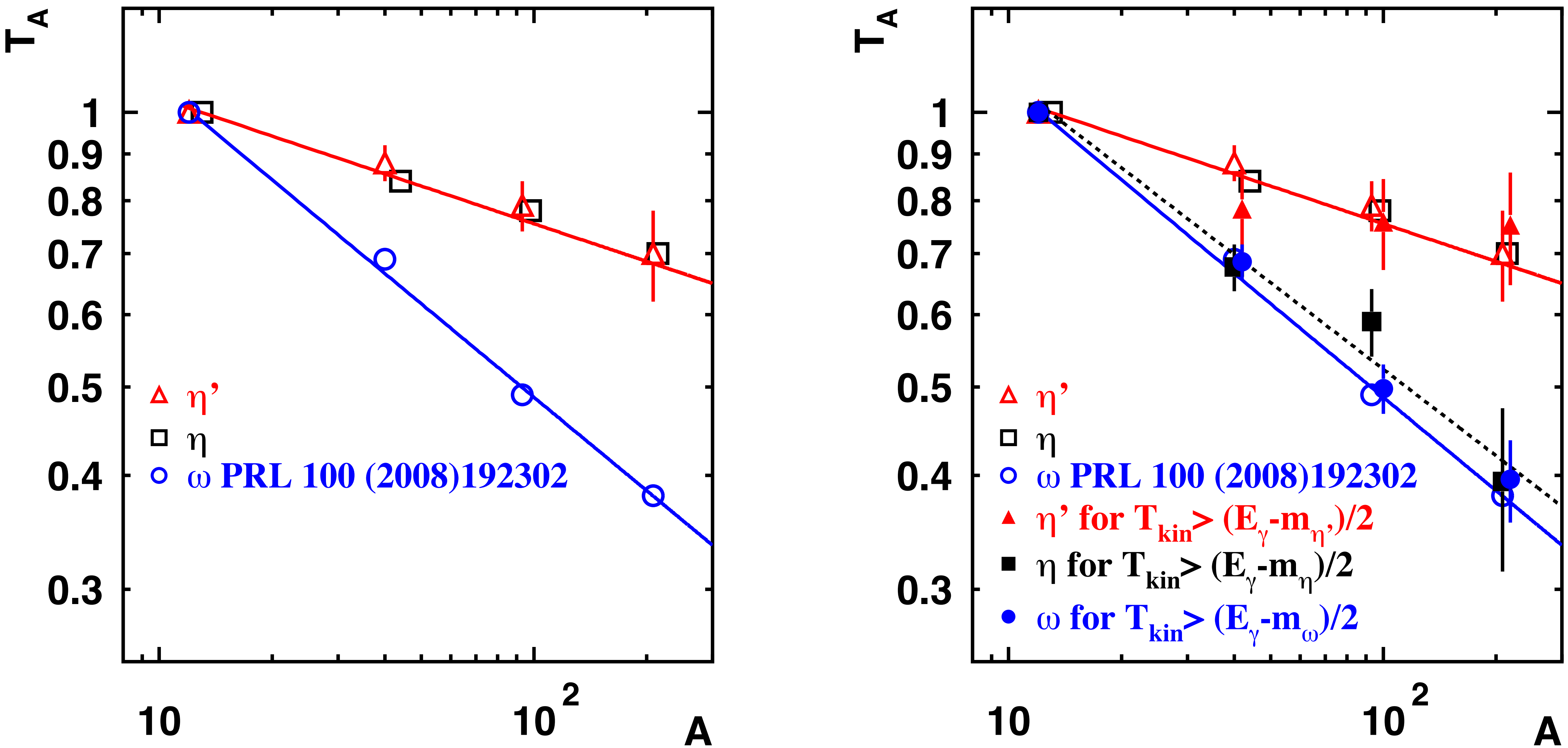

T_A measurement for η meson strongly affected by two-step processes; only little effect for η' and ω mesons

interaction of mesons in nuclear medium

A-scaling of production cross sections as a function of the meson kinetic energy

$\sigma(A) = \sigma_0 \cdot A^{\alpha(T)}$ $\alpha \approx 1.0$: mesons escape from the full **volume**

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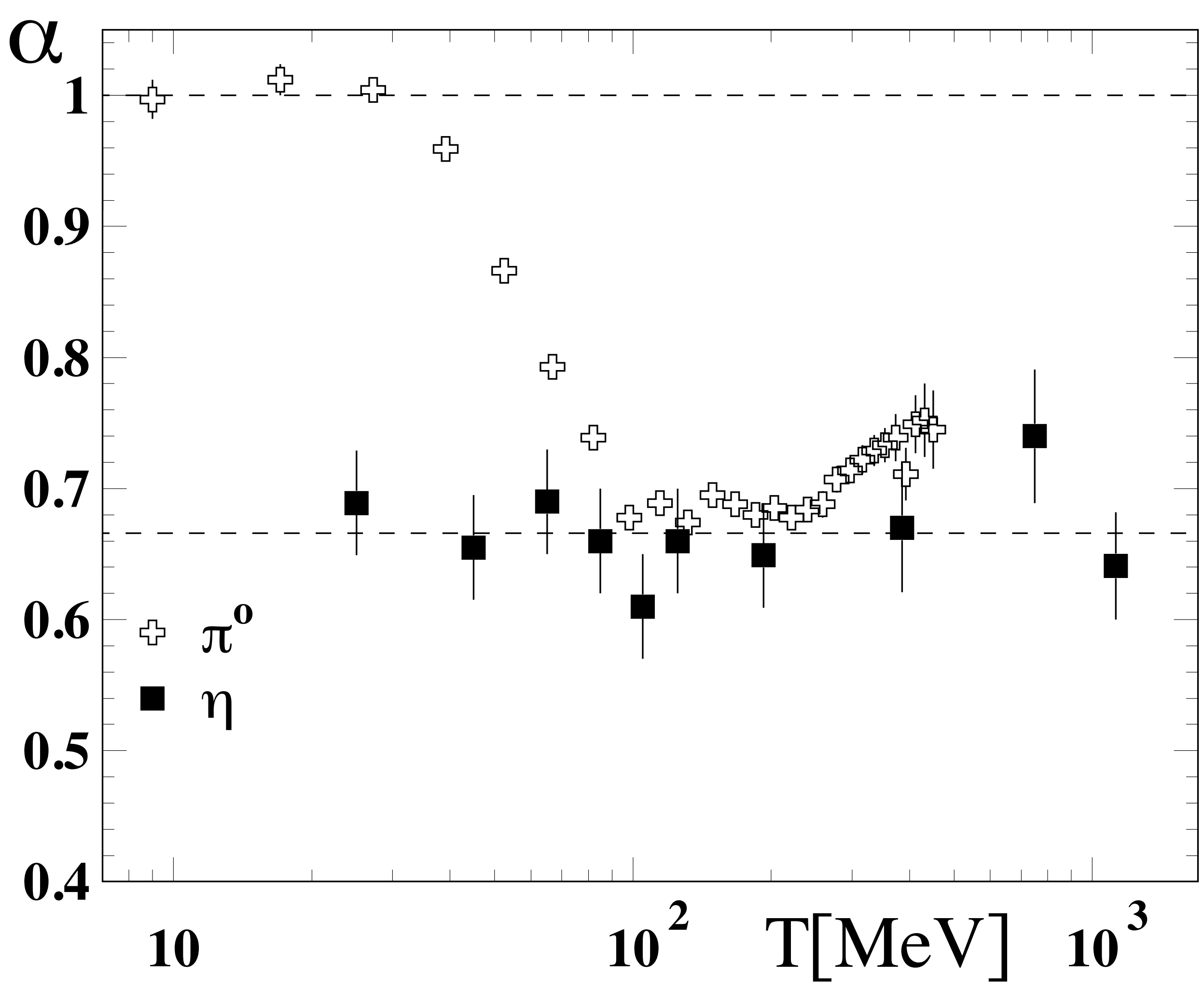

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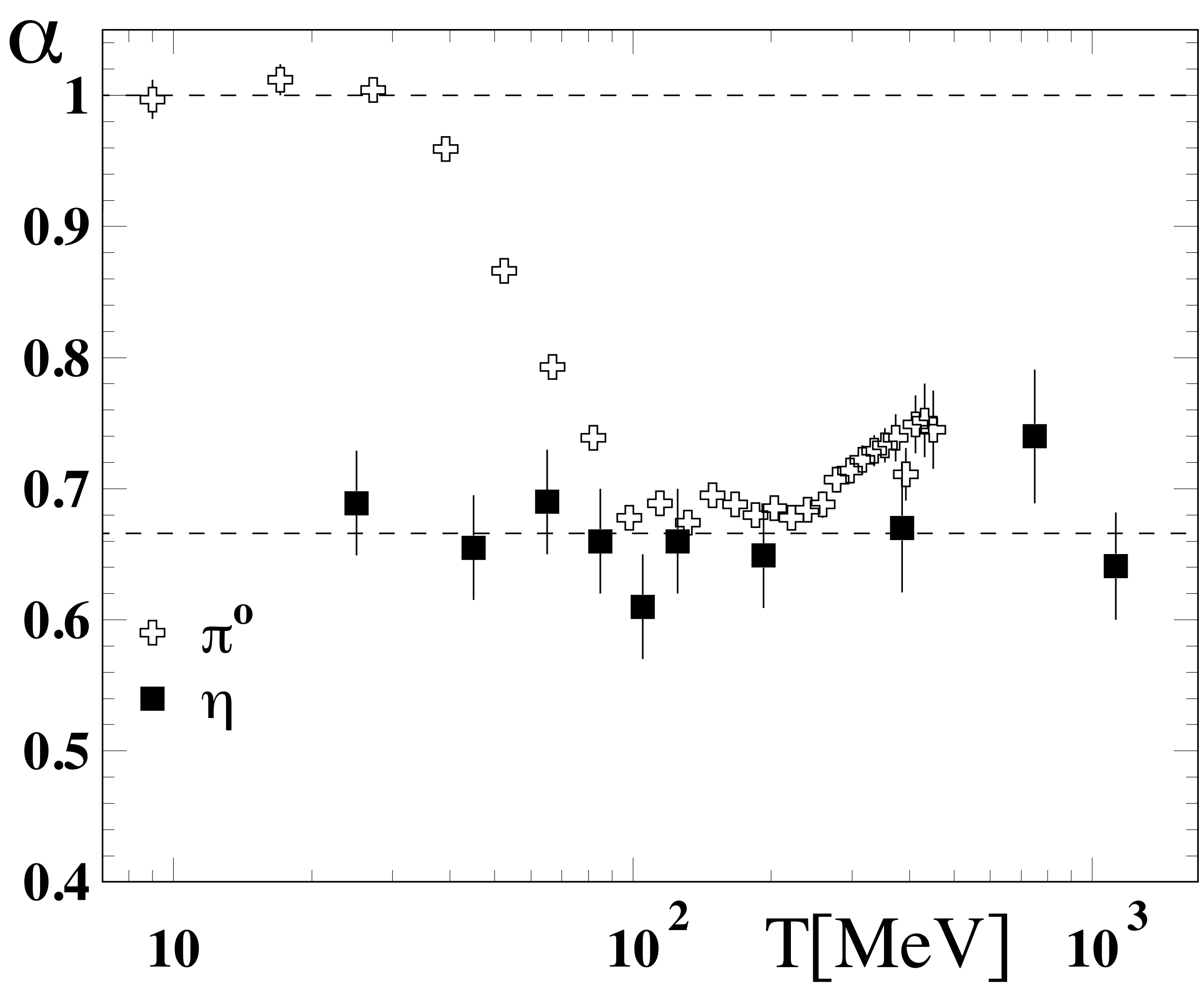

π^0 mesons:

low energies: only very weak interaction;
strong absorption for higher energies:
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B. Krusche et al., Eur. Phys. J. A ***22****, 277 (2004).*

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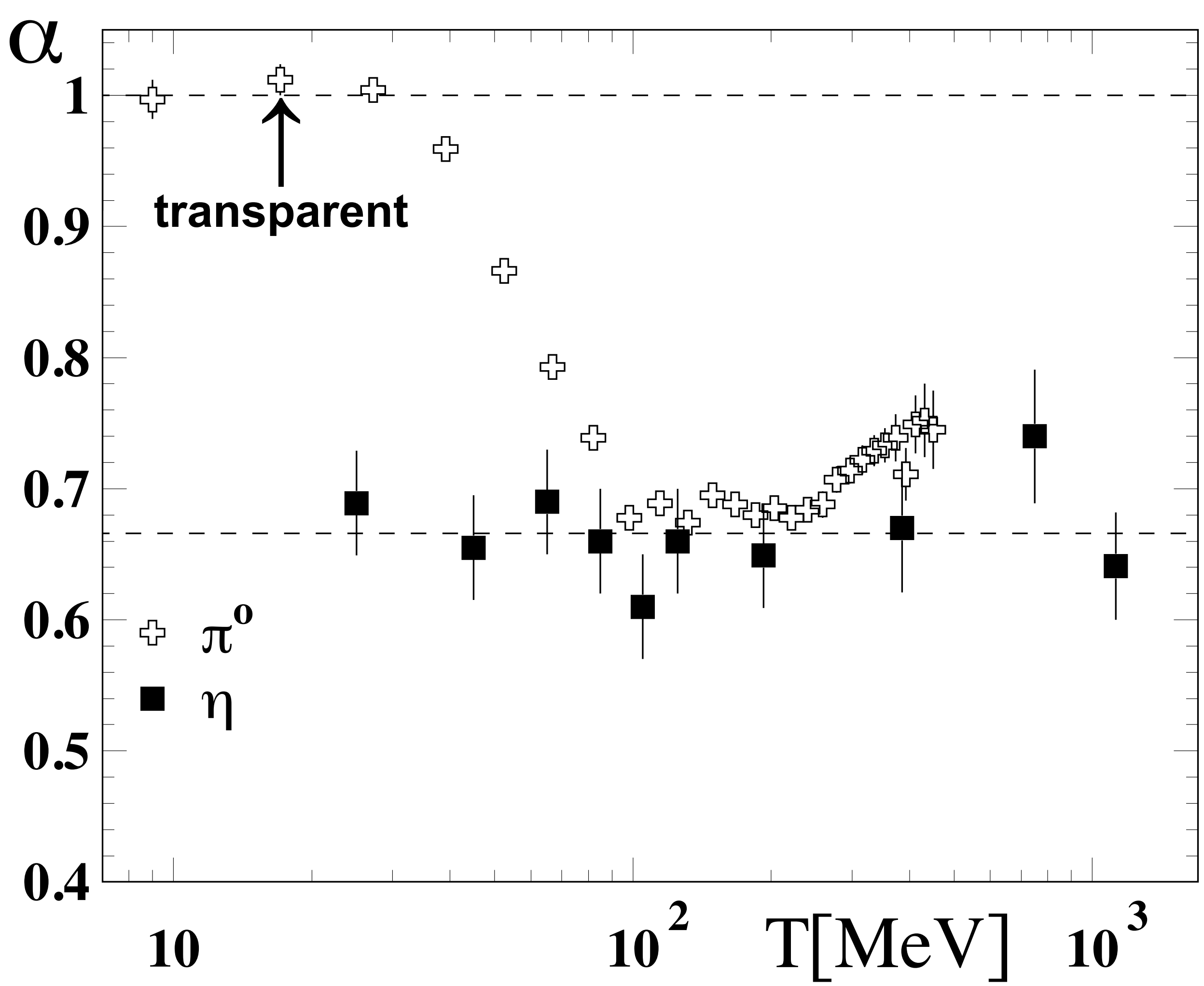

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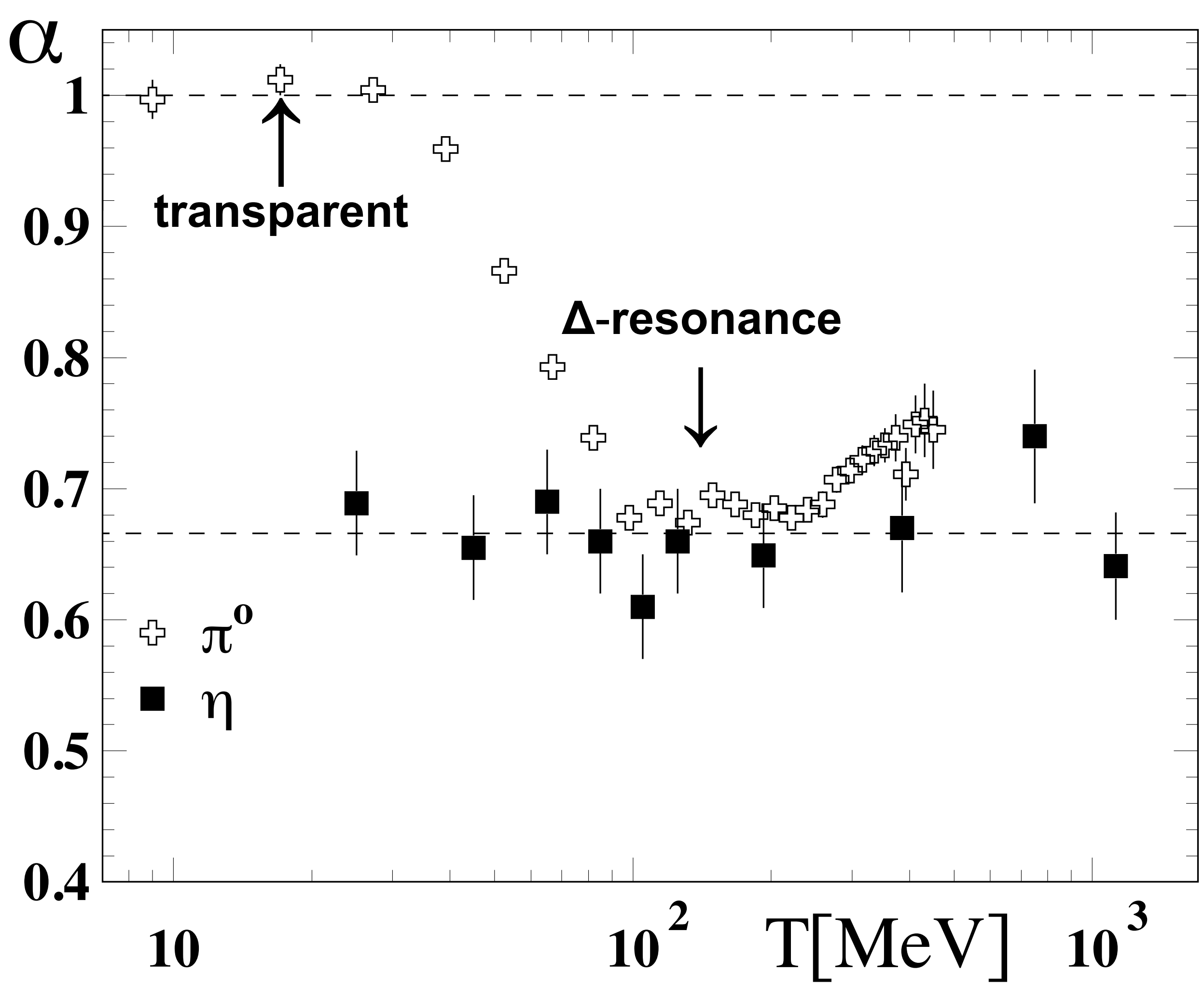

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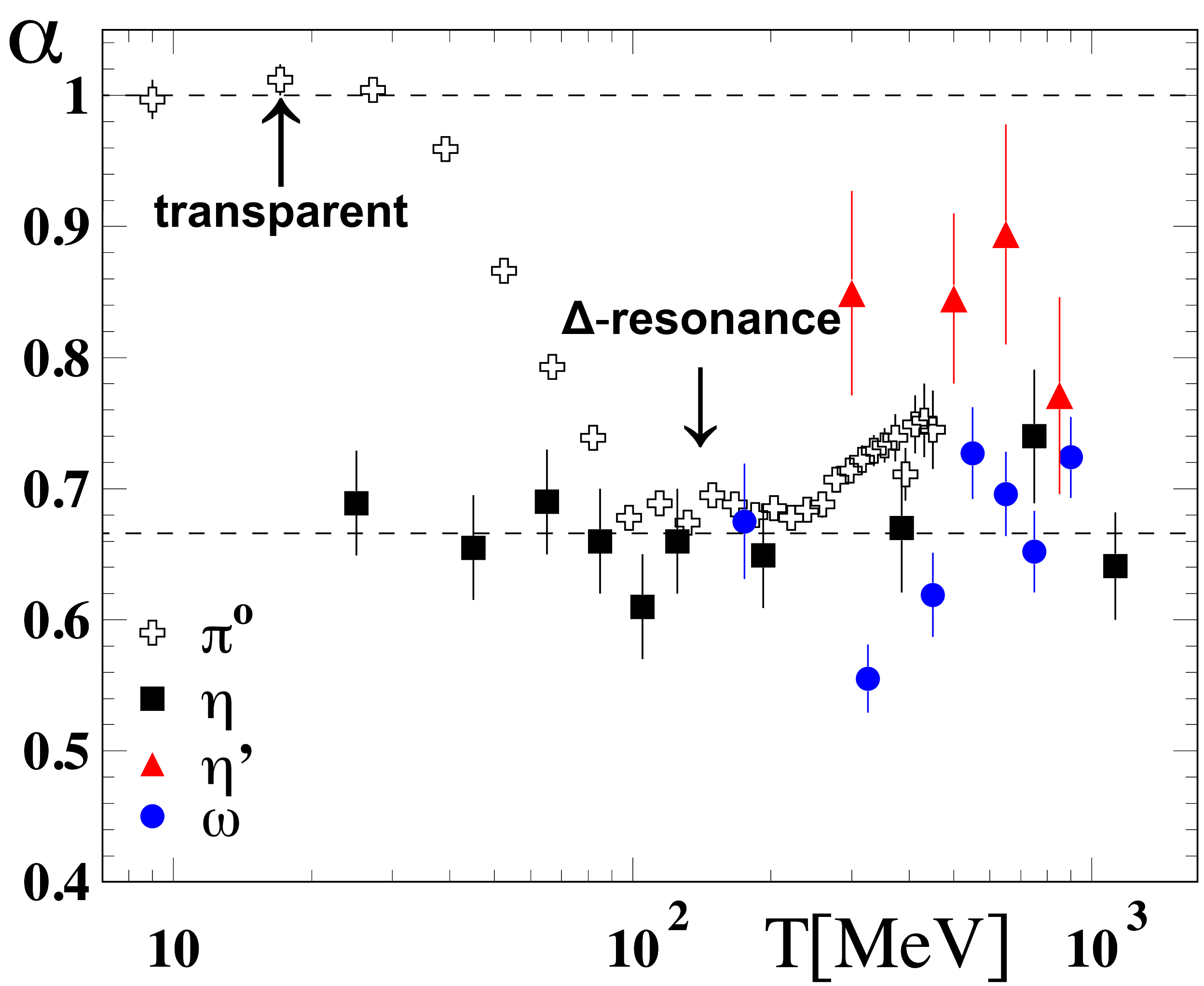

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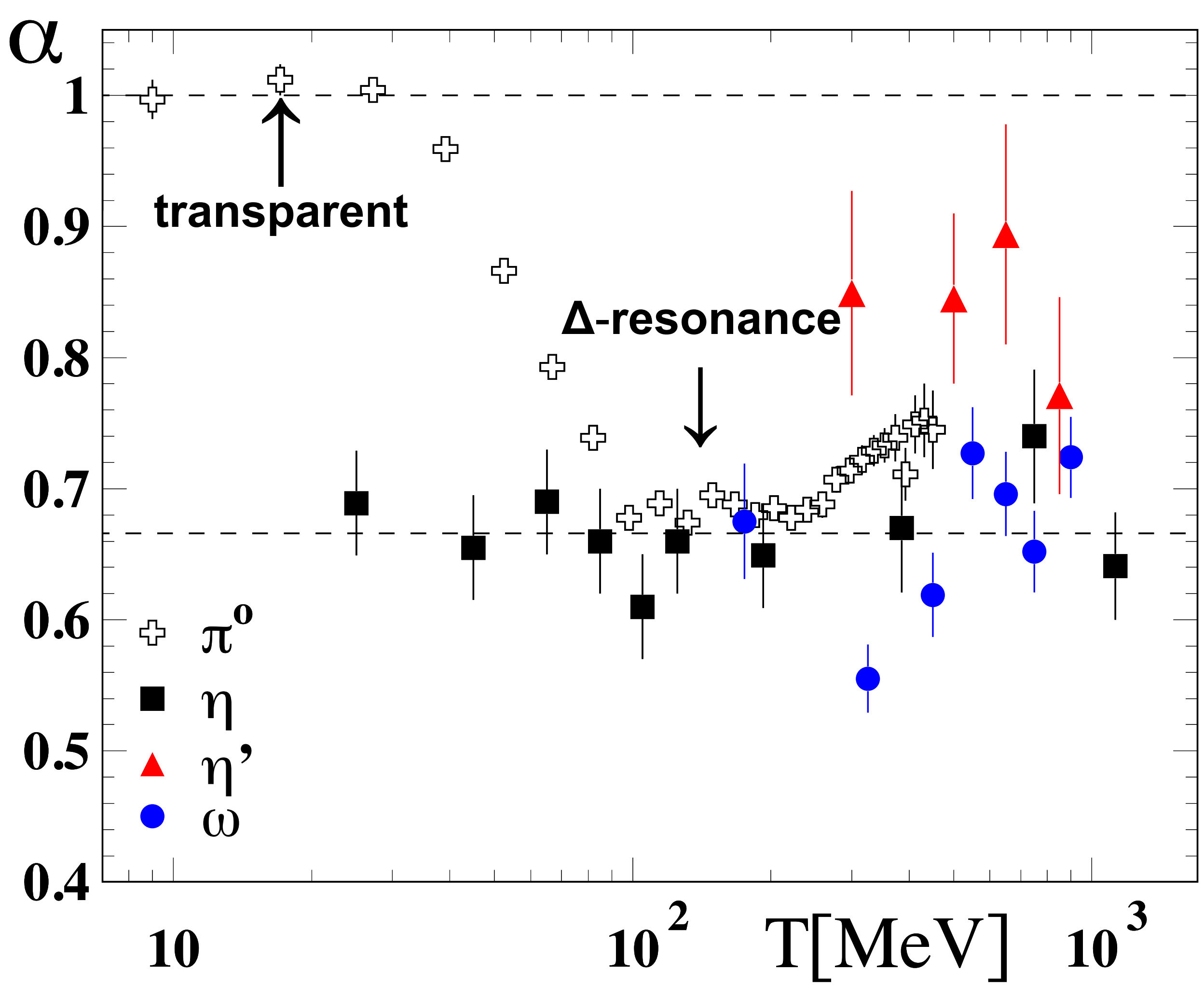

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*T. Mertens et al., Eur. Phys. J. A **38**, 195 (2008).*

ω mesons:

strong absorption: $\langle\alpha\rangle_T \approx 0.67$;

M. Kotulla et al., Phys. Rev. Lett. 100, 192302 (2008)

η' mesons:

$\langle\alpha\rangle_T \approx 0.84$

η'N interaction weaker than ηN

M. Nanova et al. to be published

summary & outlook

preliminary results about the in-medium properties of η' meson:

- transparency ratio measurement:

in-medium width 25-30 MeV at $p_{\eta'} \approx 1.05$ GeV/c and $\rho=\rho_0$ $\Rightarrow \sigma_{\eta' N} \approx 11$ mb

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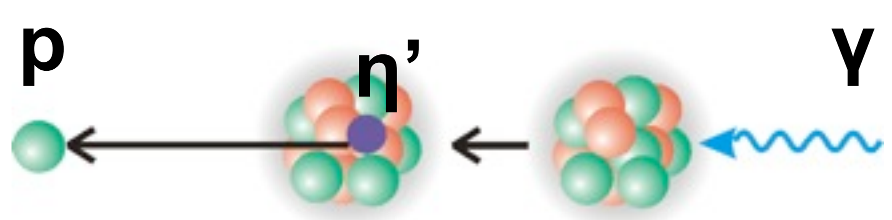
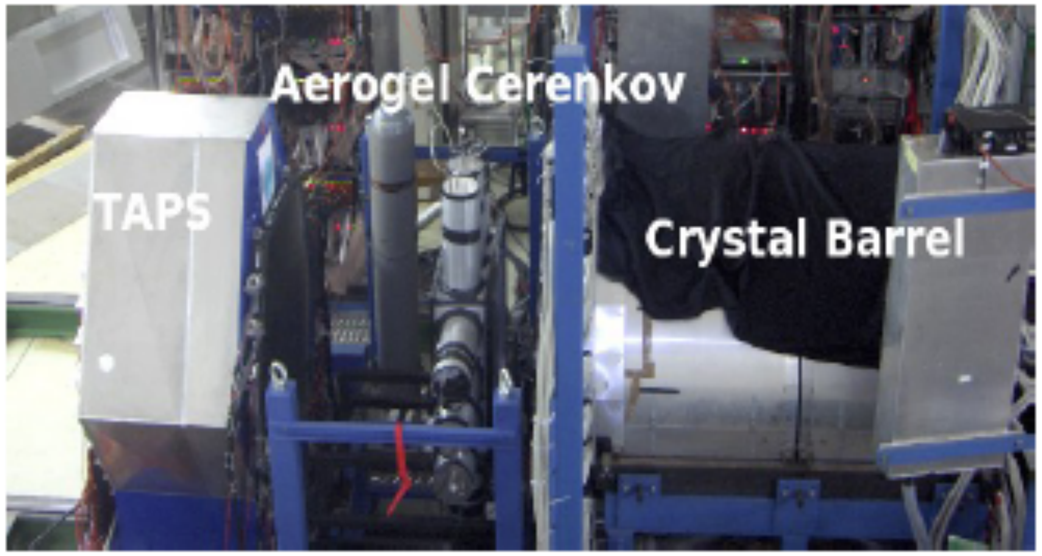
next step: CB/TAPS@ ELSA data on ^{12}C target (E_γ up to 2.9 GeV)

- searching for η'- bound states





H. Nagahiro, M. Takizawa and S. Hirenzaki, Phys. Rev. C 74 (2006) 045203