In-medium properties of the η' meson from photonuclear reactions

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for CBELSA/TAPS Collaboration

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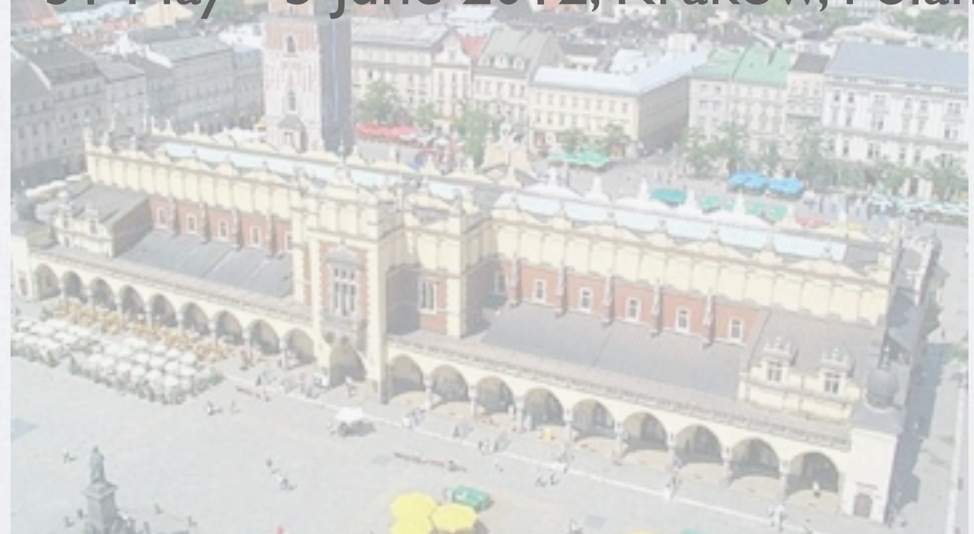
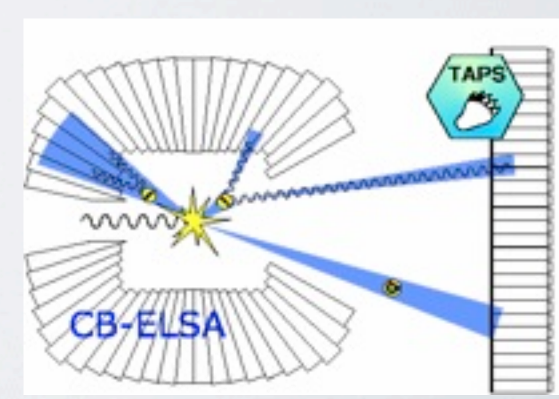
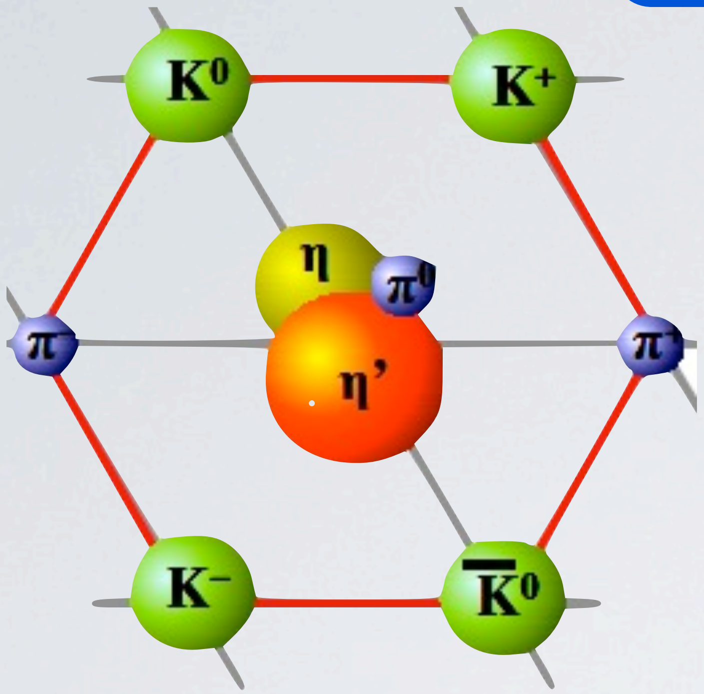
*funded by the DFG within SFB/TR16



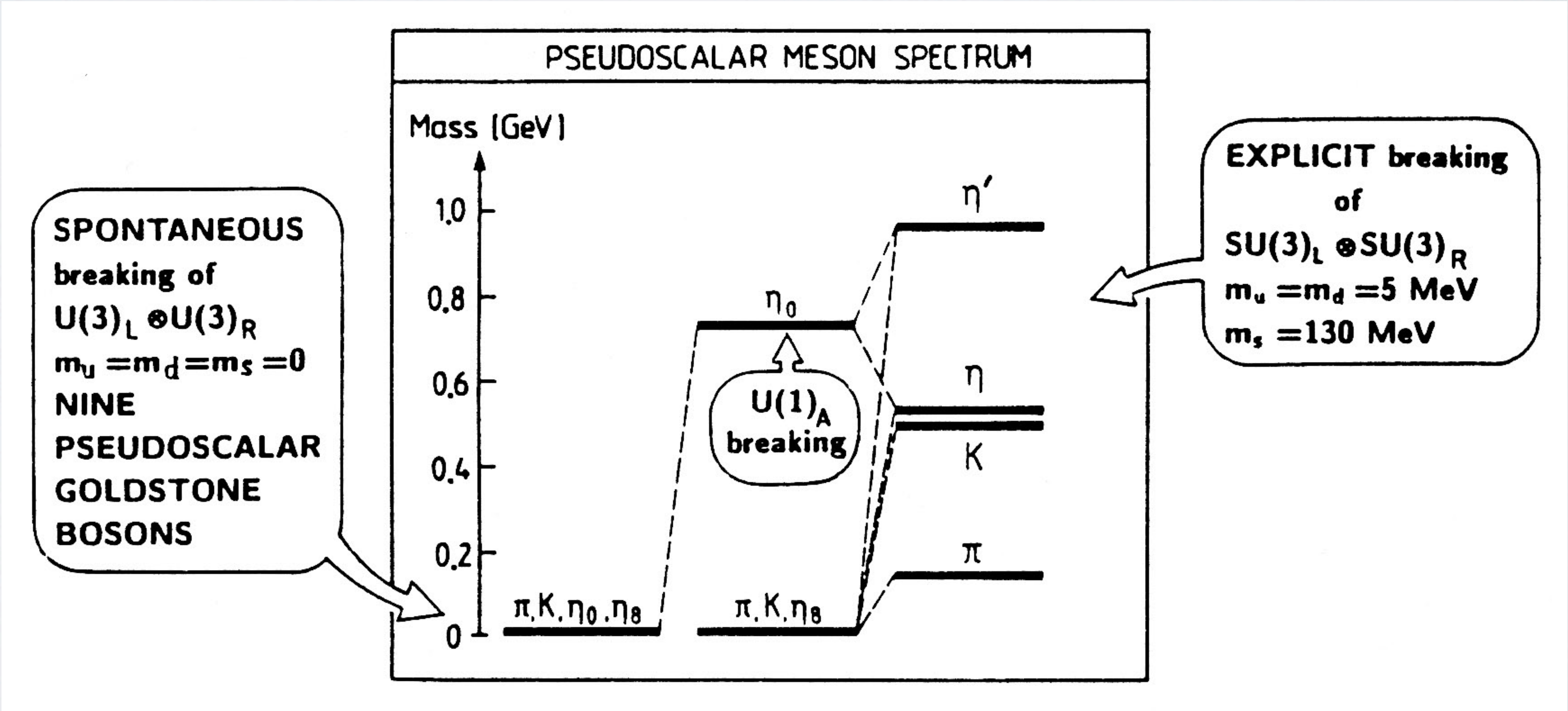


motivation



S. Klimt et al., Nucl. Phys. A516 (1990) 429

The NJL Model

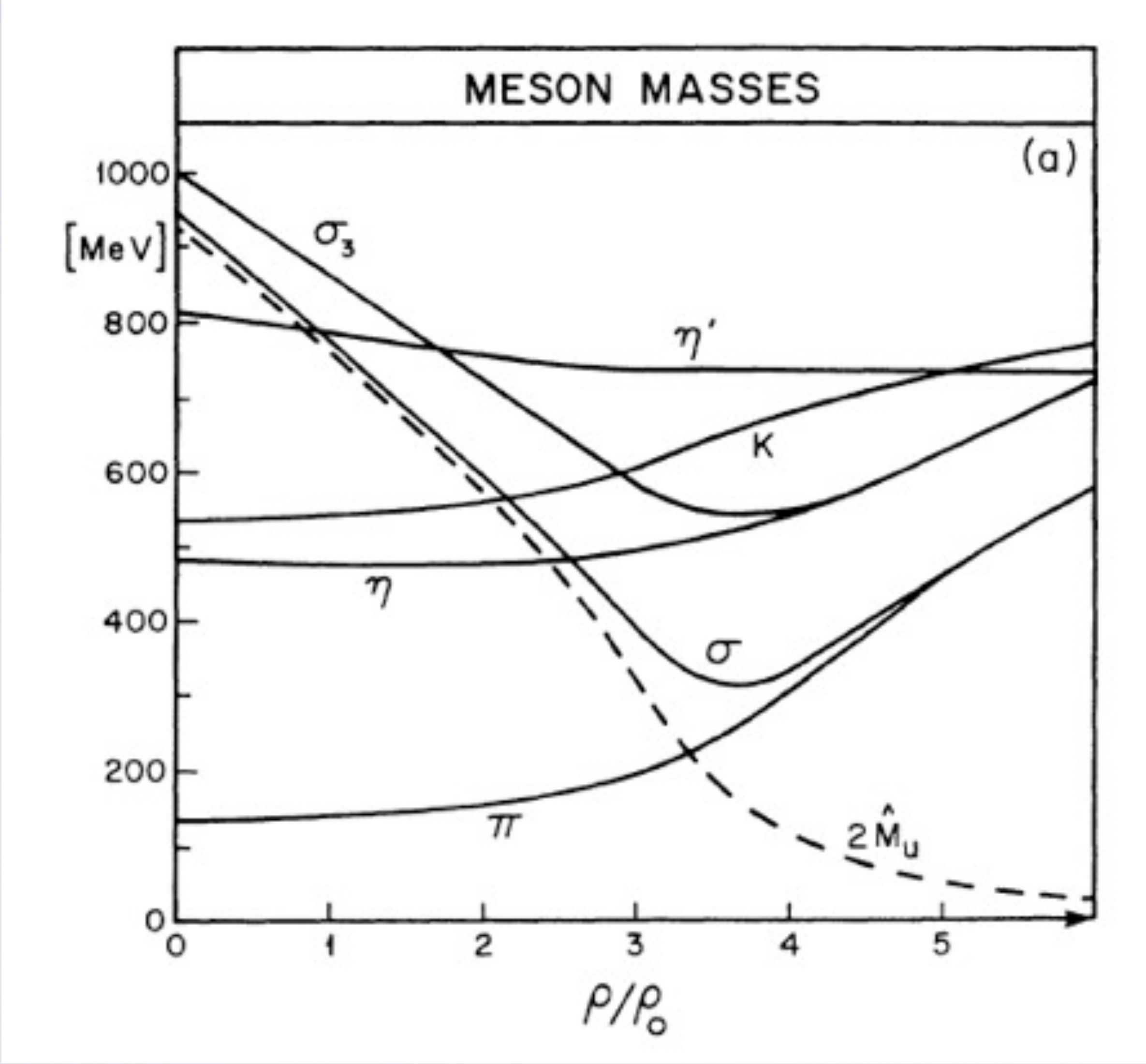


masses as a result of symmetry breaking

spectral function of the η' meson

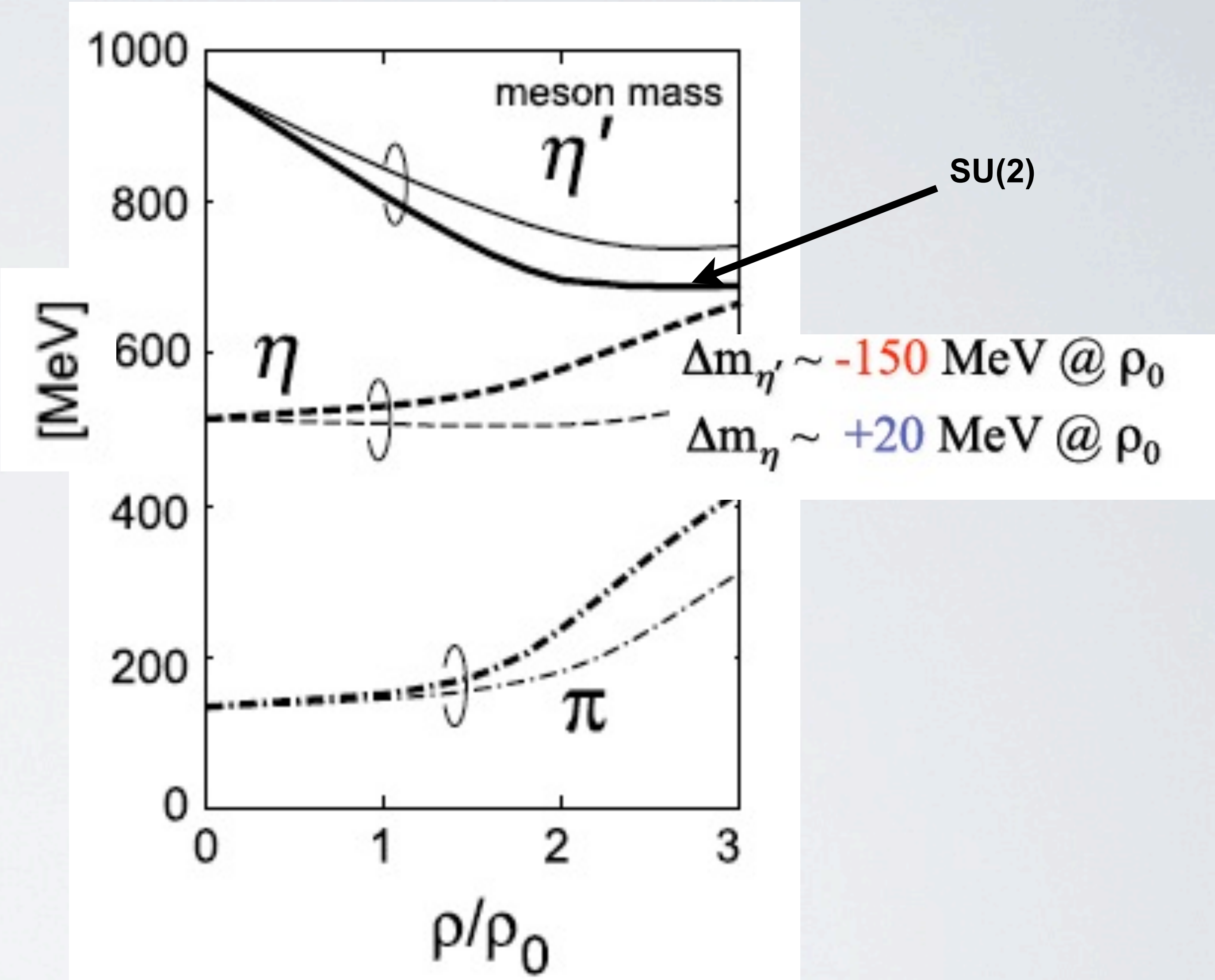
- model predictions - based on NJL

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



large medium effect could be seen even at normal nuclear density

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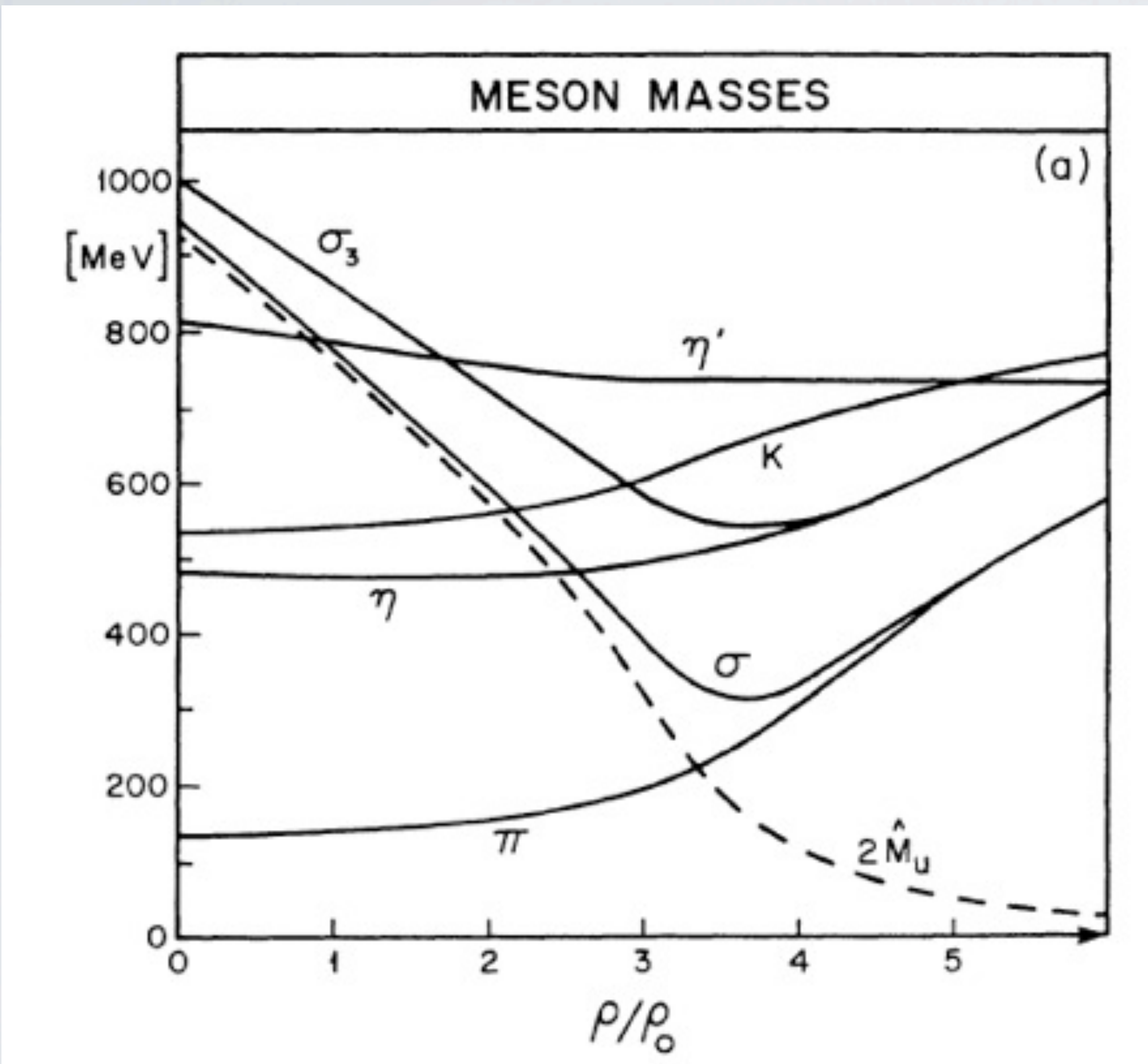

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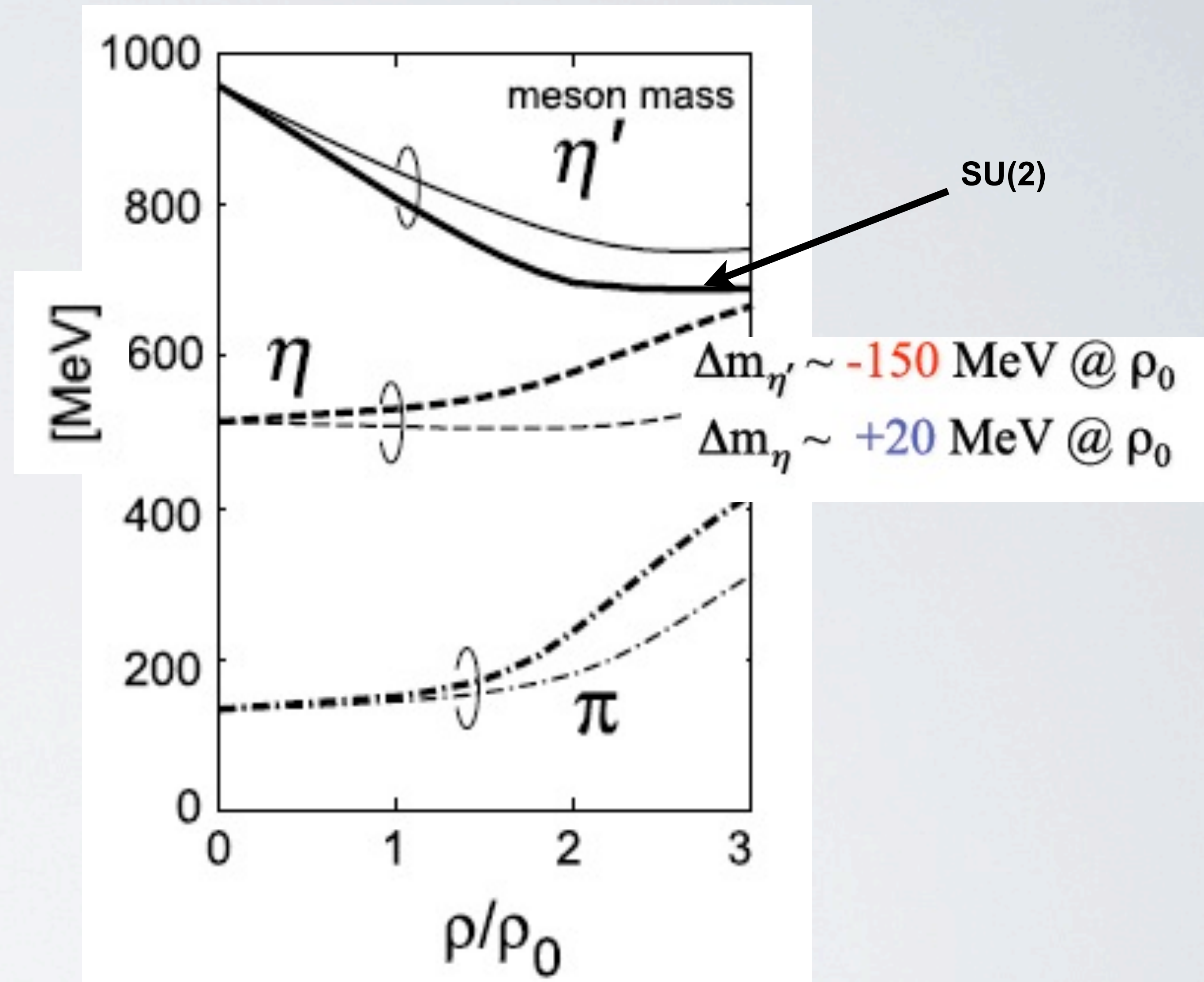

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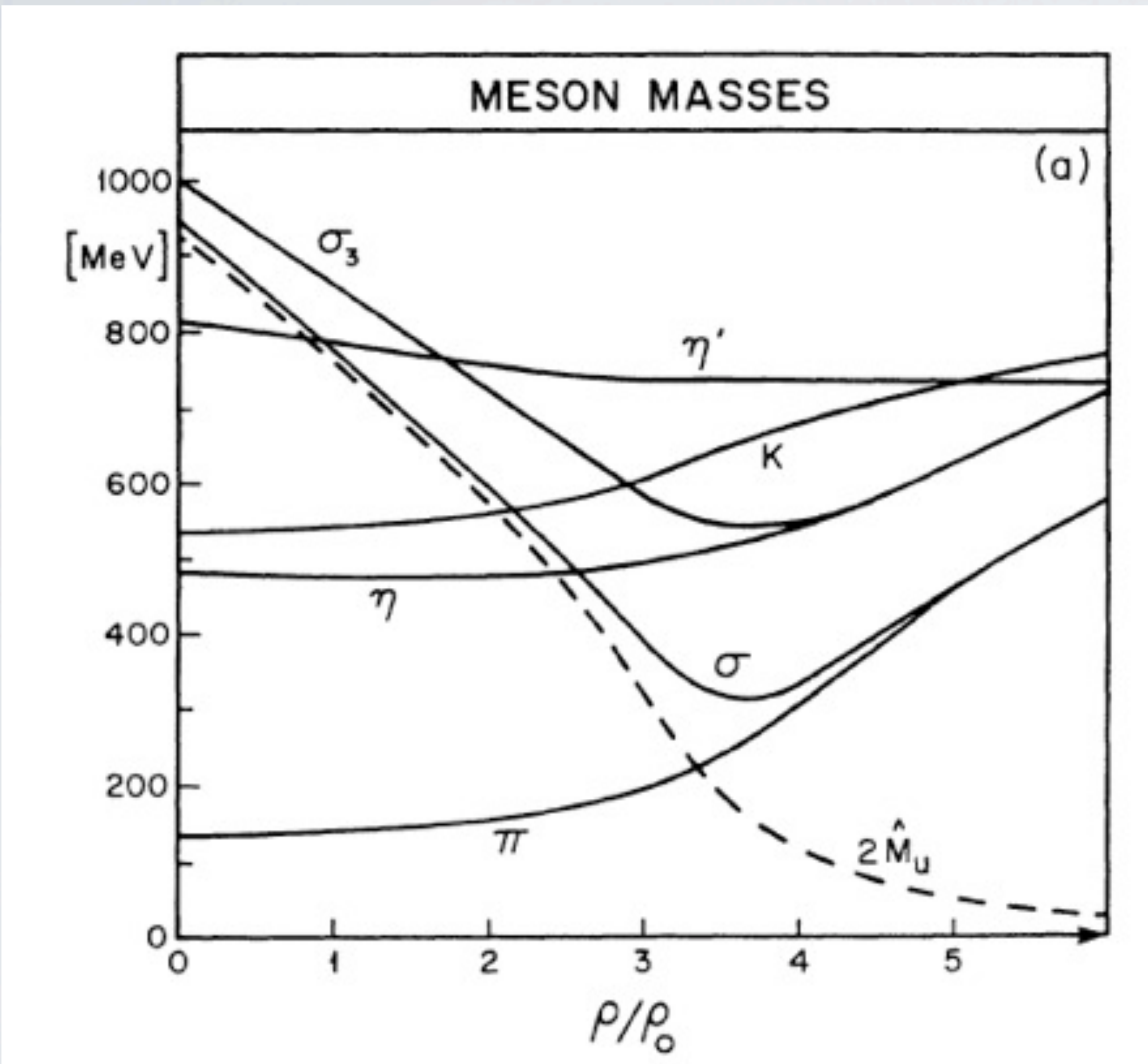

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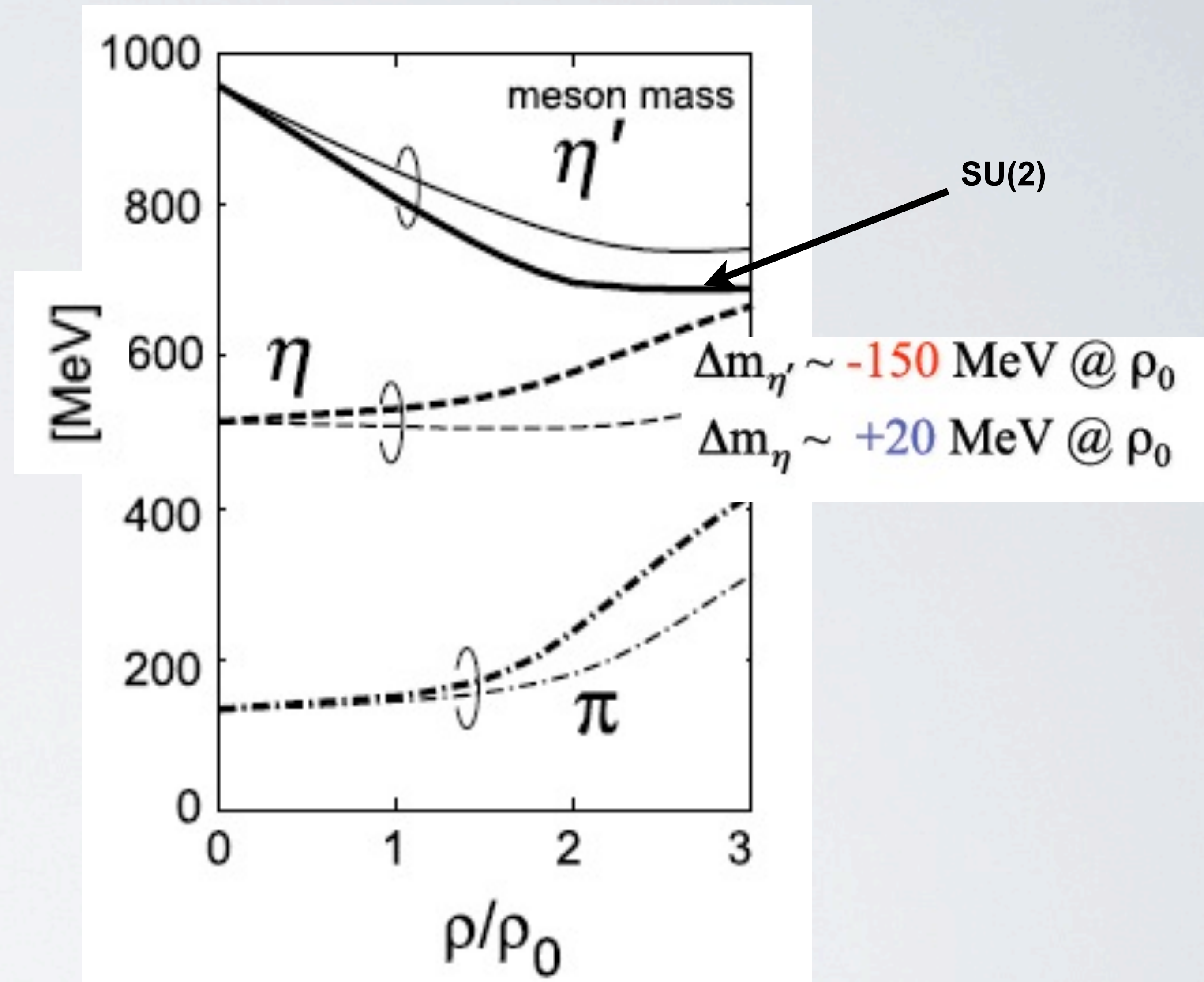

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- experiment:

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

η'N interaction

- theoretical study: η'N inelastic cross section

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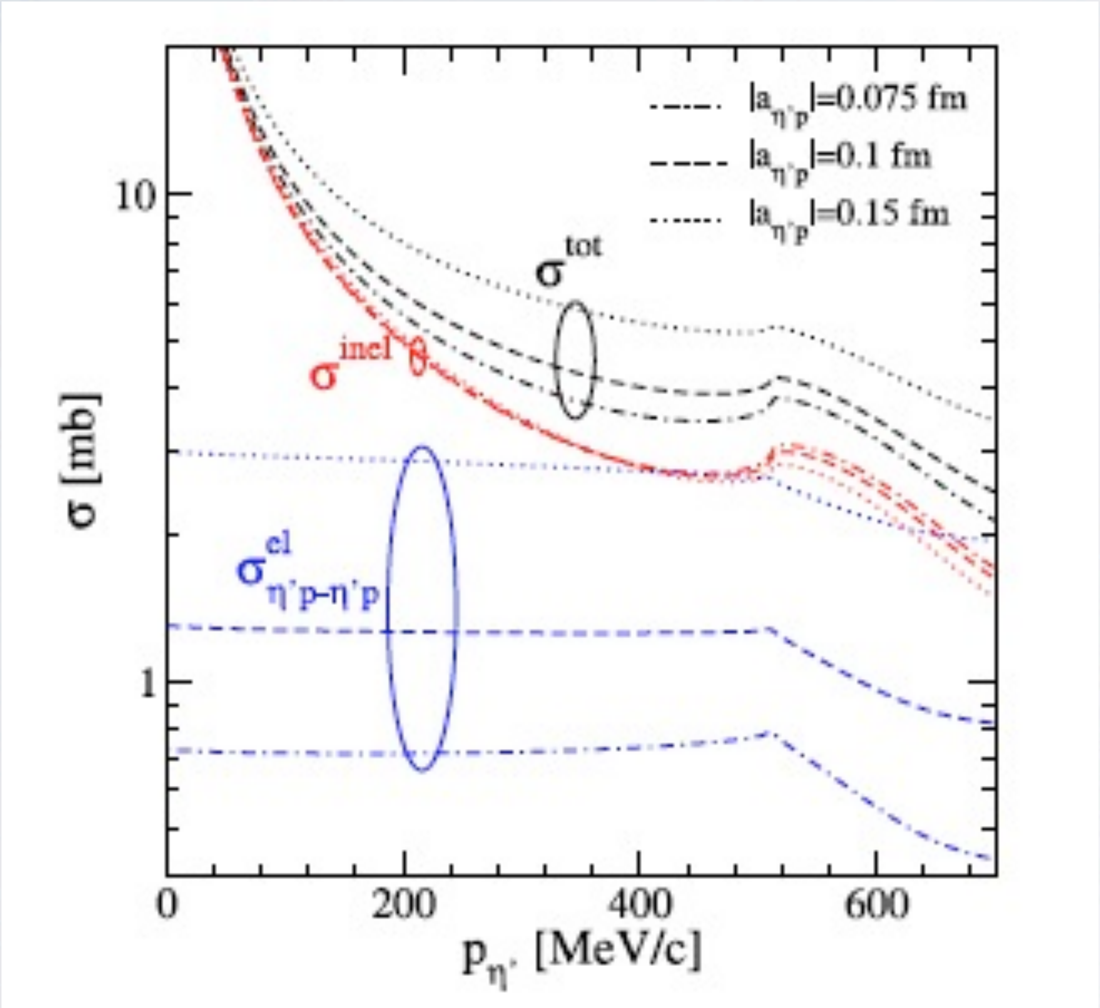
E. Oset, A. Ramos, PLB 704 (2011) 334



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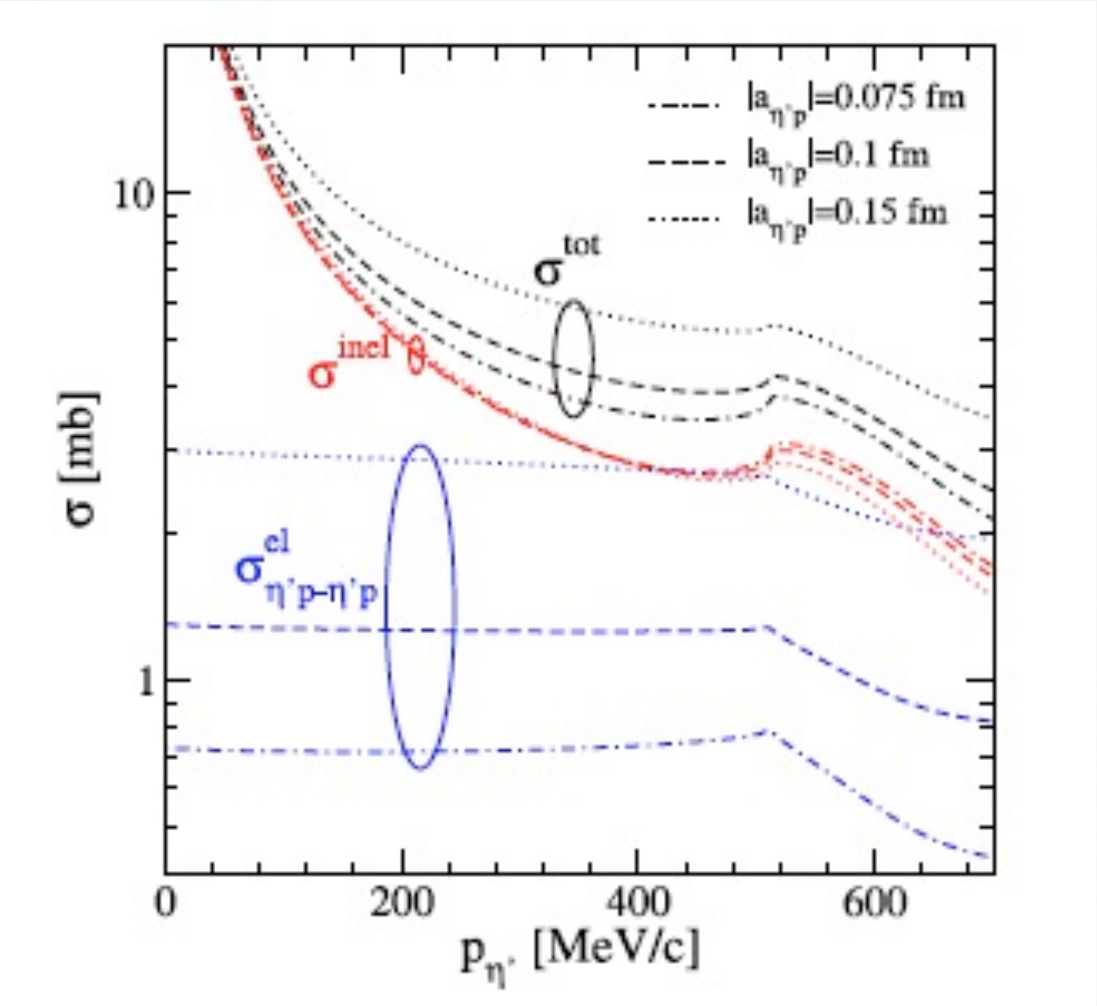
E. Oset, A. Ramos, PLB 704 (2011) 334



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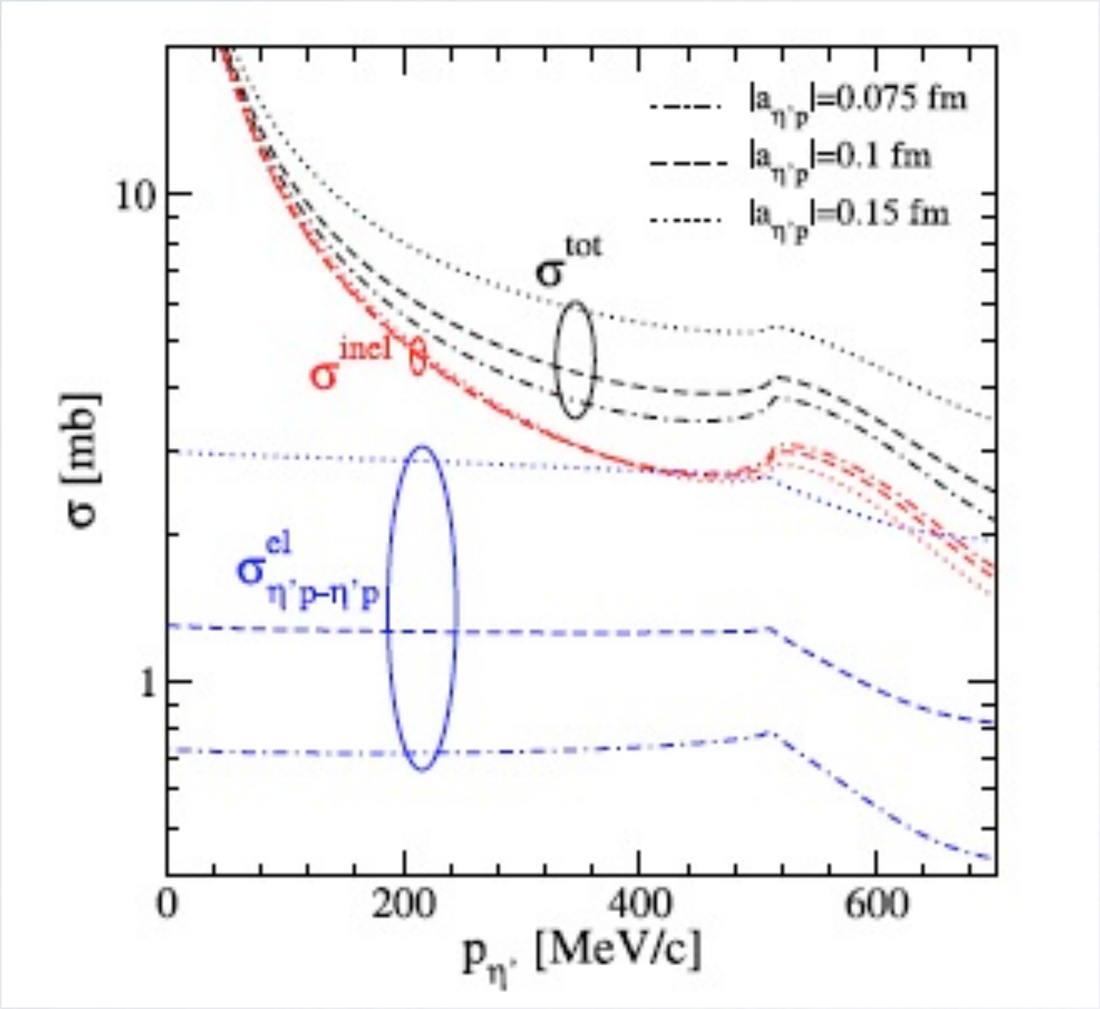

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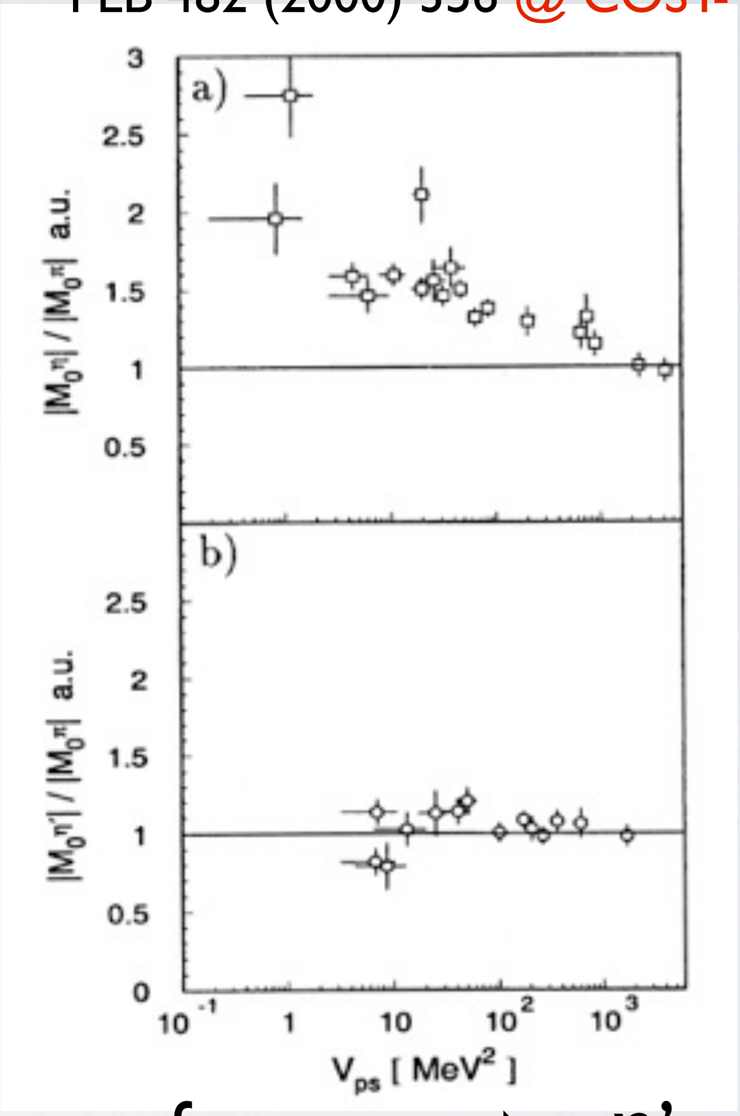
P. Moskal et al., PLB 474 (2000) 416, PLB 482 (2000) 356 @ COSY-11



from pp → ppη'
compared to pp→ppπ^0
to minimize FSI effects

⇨ $|a_{\eta'N}| \sim 0.1$ fm

experimental study of η'N interaction with CB/TAPS@ELSA

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- **in-medium width:**

attenuation measurement of the η' meson flux:

transparency ratio

experimental observable to extract the
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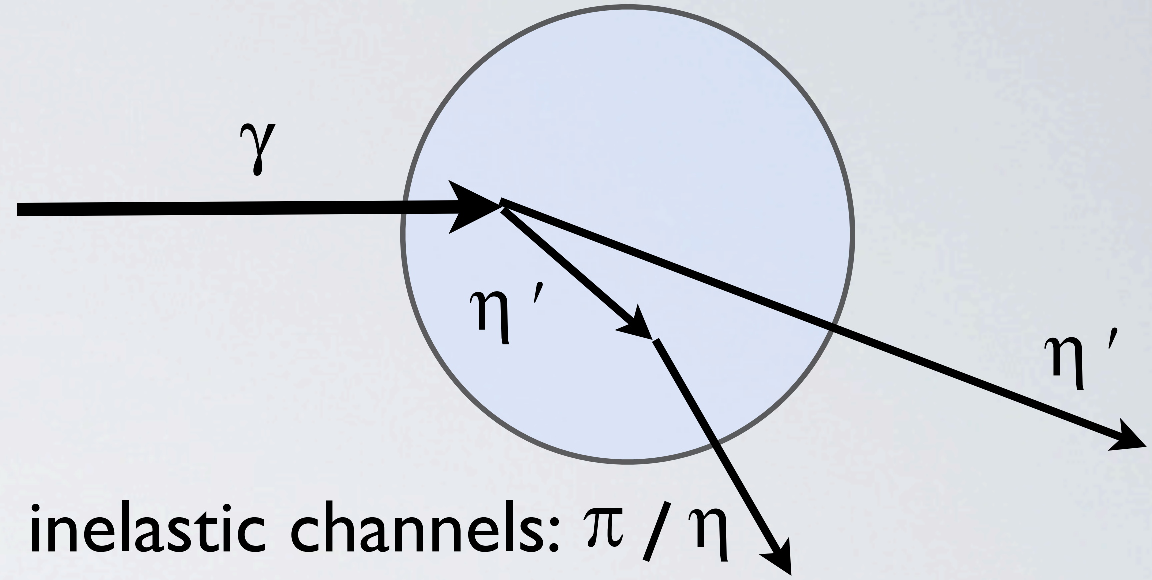

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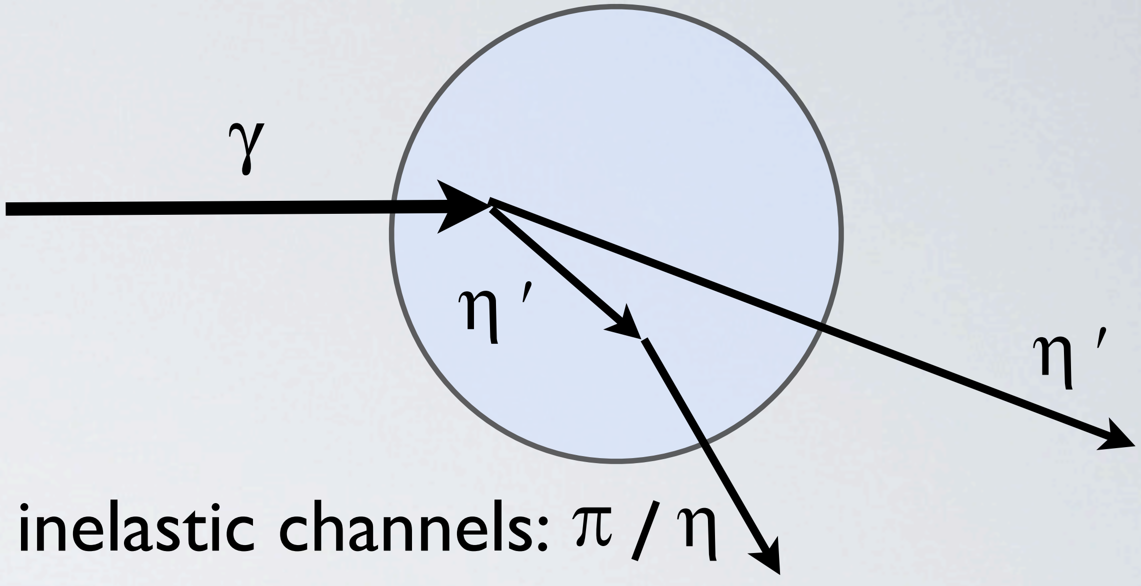

<u>transparency ratio</u>

experimental observable to extract the in-medium width of the meson

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

production probability per nucleon within the nucleus compared to production probability on the free nucleon

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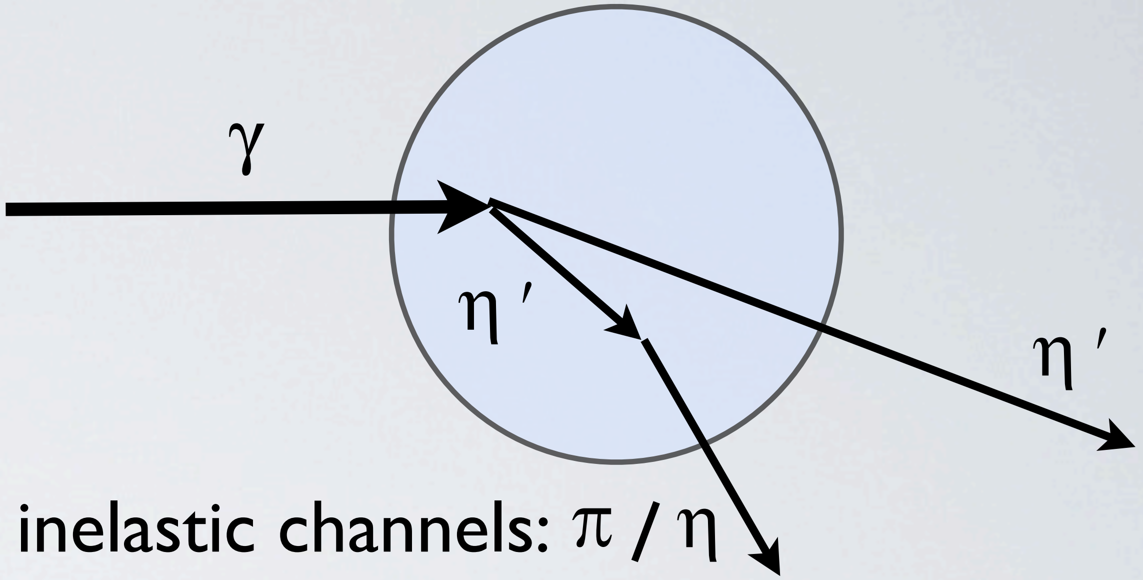

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inelastic reactions remove η' mesons, e.g. η' N → π N
shortening of η' lifetime in the medium ⇒ increase in width

low density approximation: $\Gamma(\rho) = -\frac{Im\Pi(\rho)}{E} \sim \rho v \sigma_{inel}$; $\Gamma(\rho) = \Gamma(\rho_0)\frac{\rho}{\rho_0}$

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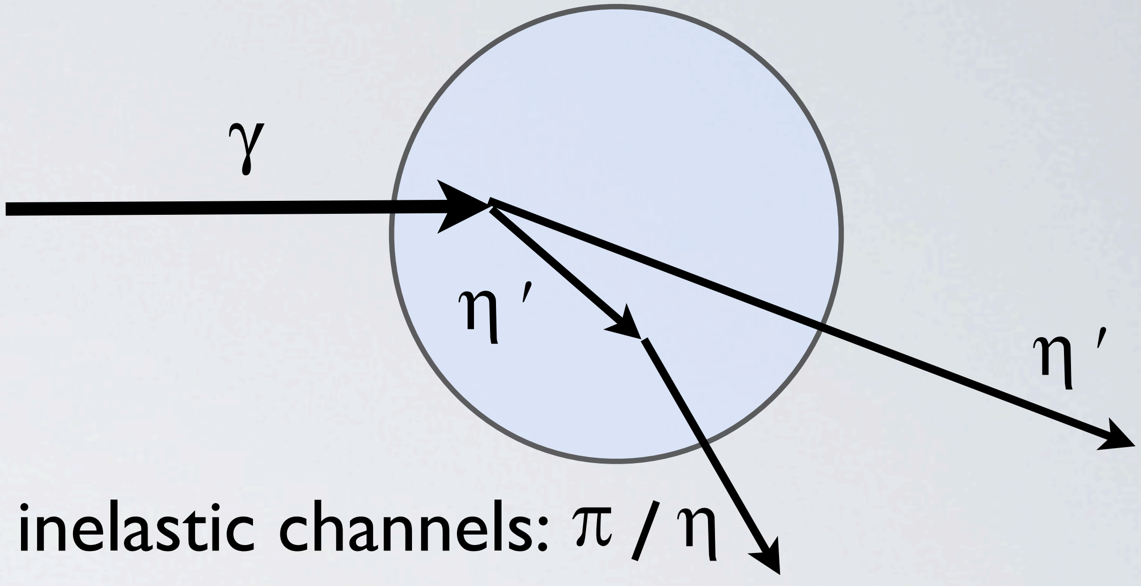

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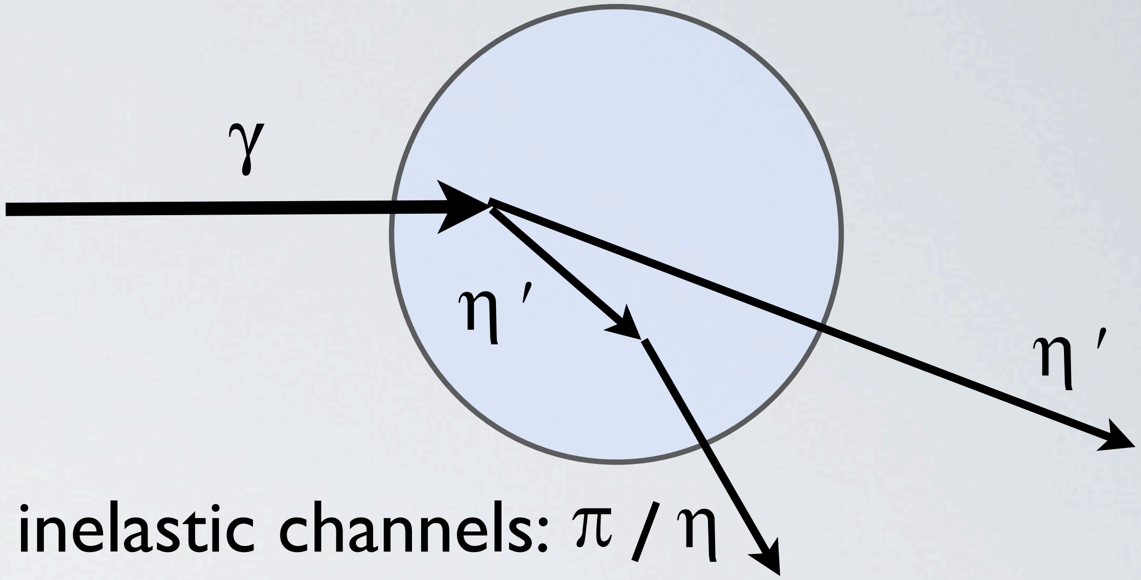

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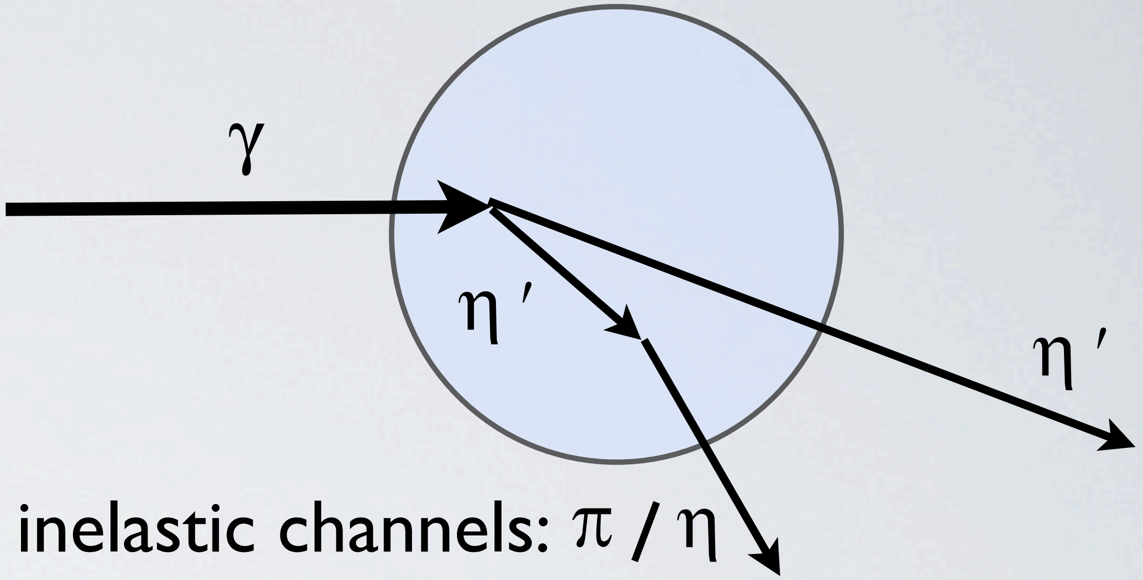

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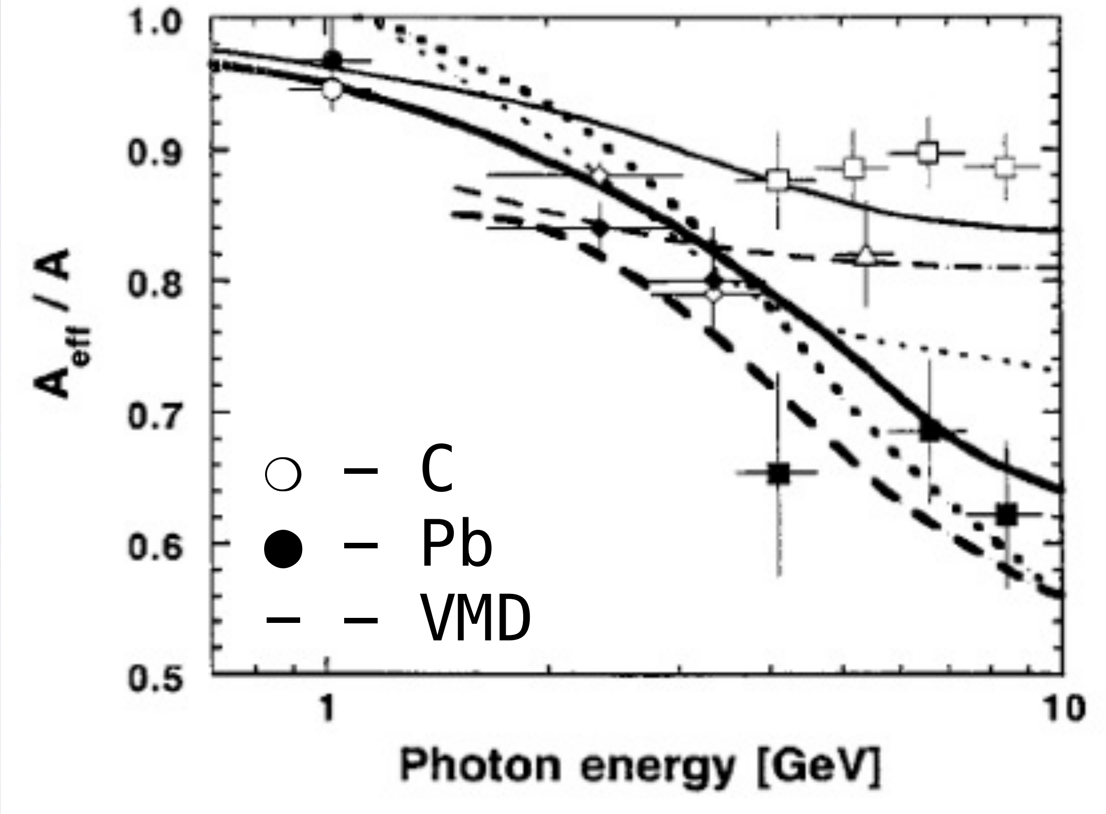
information on in-medium properties of mesons from measurement of their decay outside of the nucleus

systematic uncertainties in transparency ratio measurements

1.) photon shadowing:

N. Bianchi et al., Phys. Rev. C 54 (1996)1688



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2.) multi-step processes:

e.g. $\gamma N_1 \rightarrow \pi N_1$

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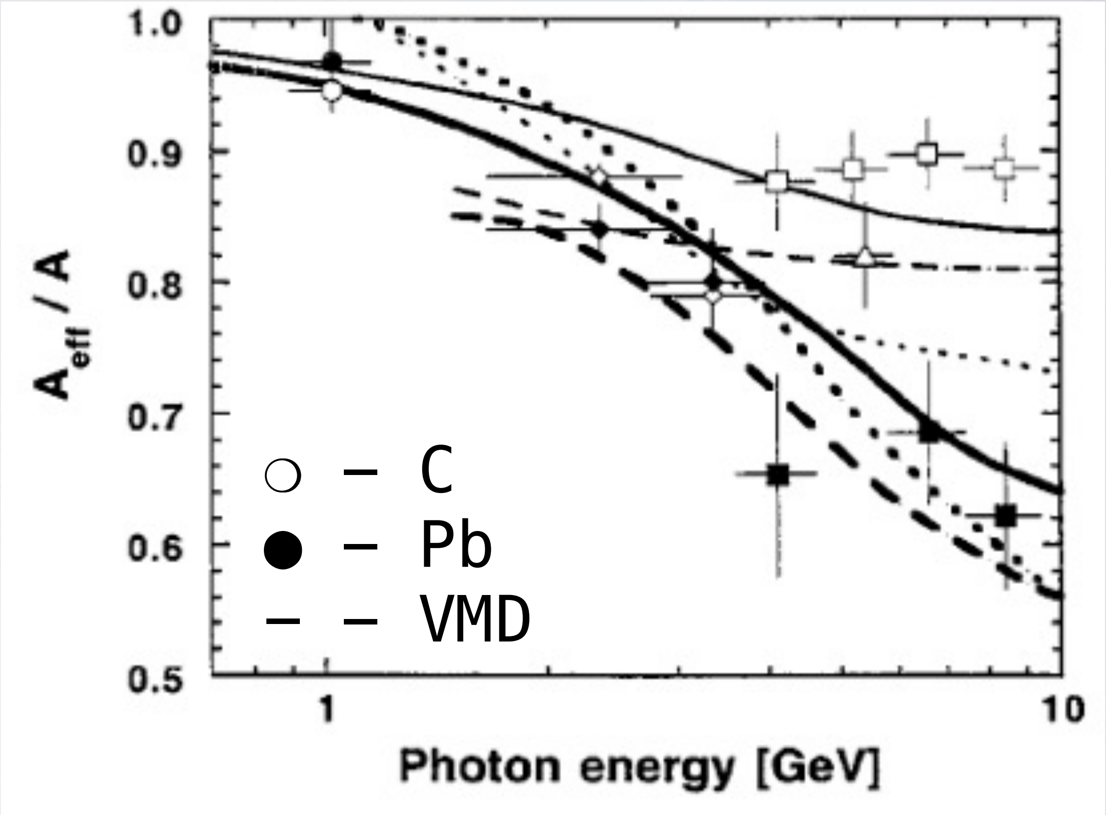

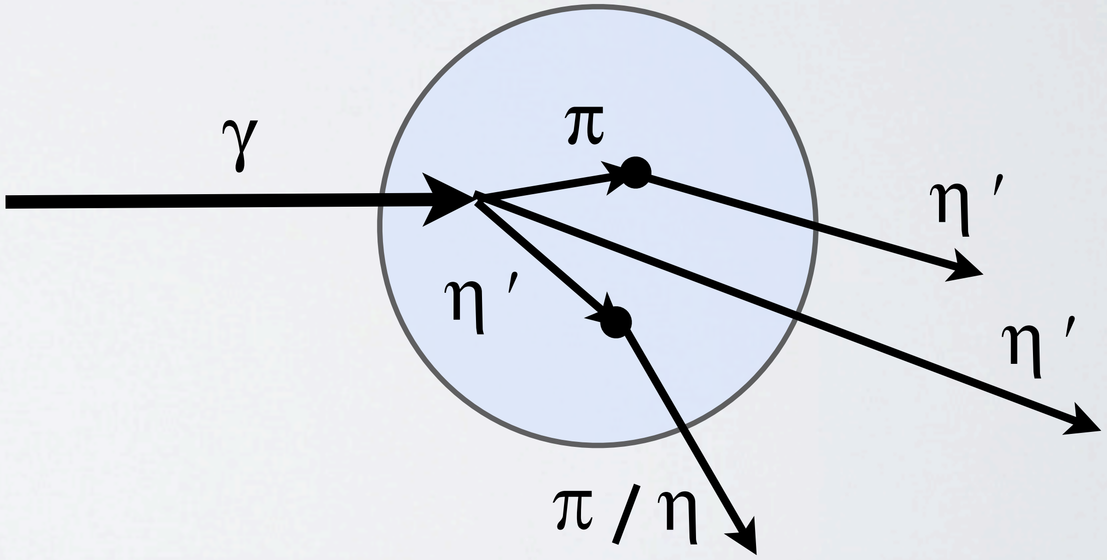

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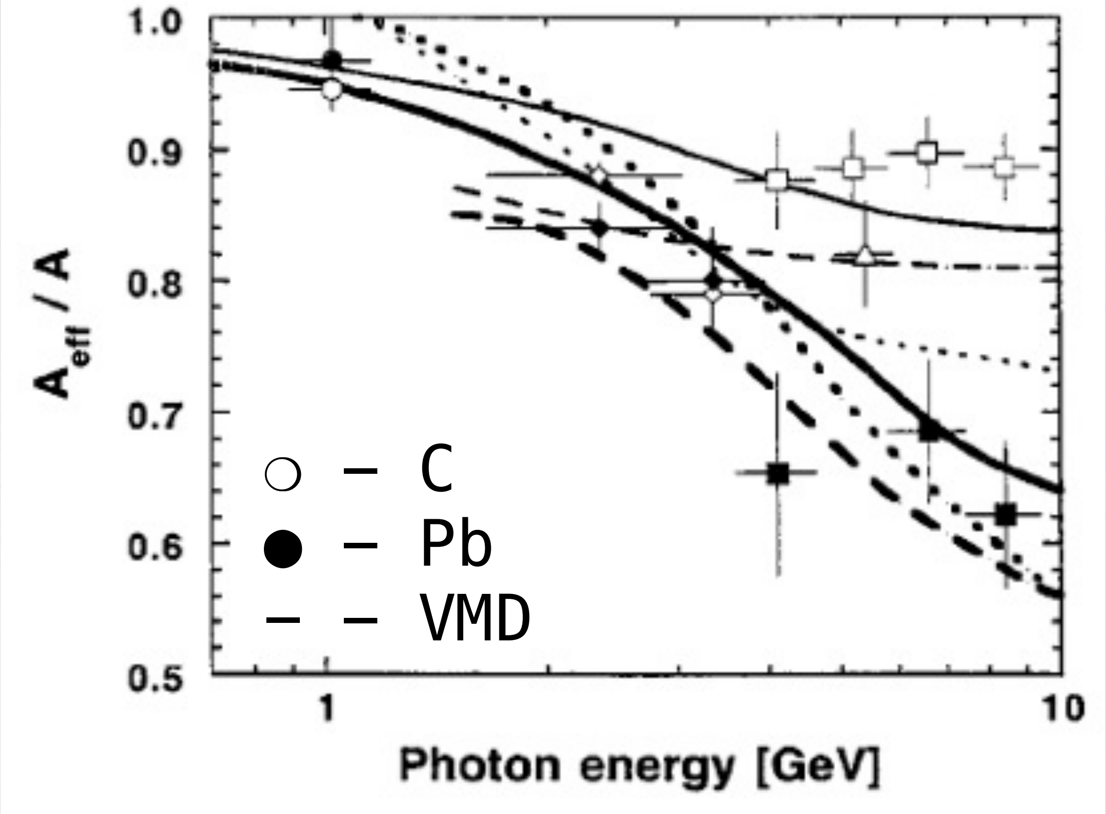

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less energy available for final state ω, η' meson;
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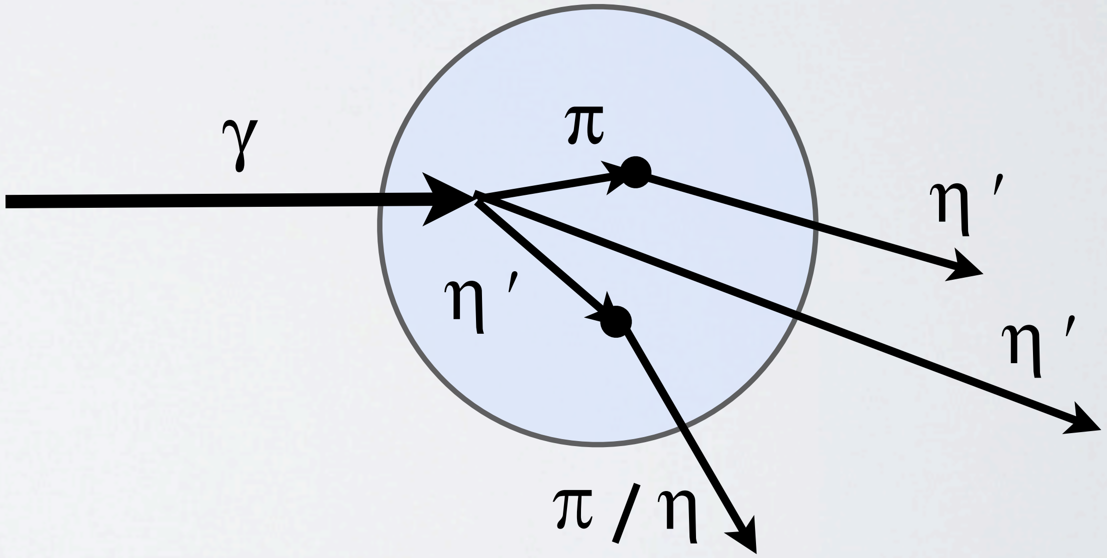

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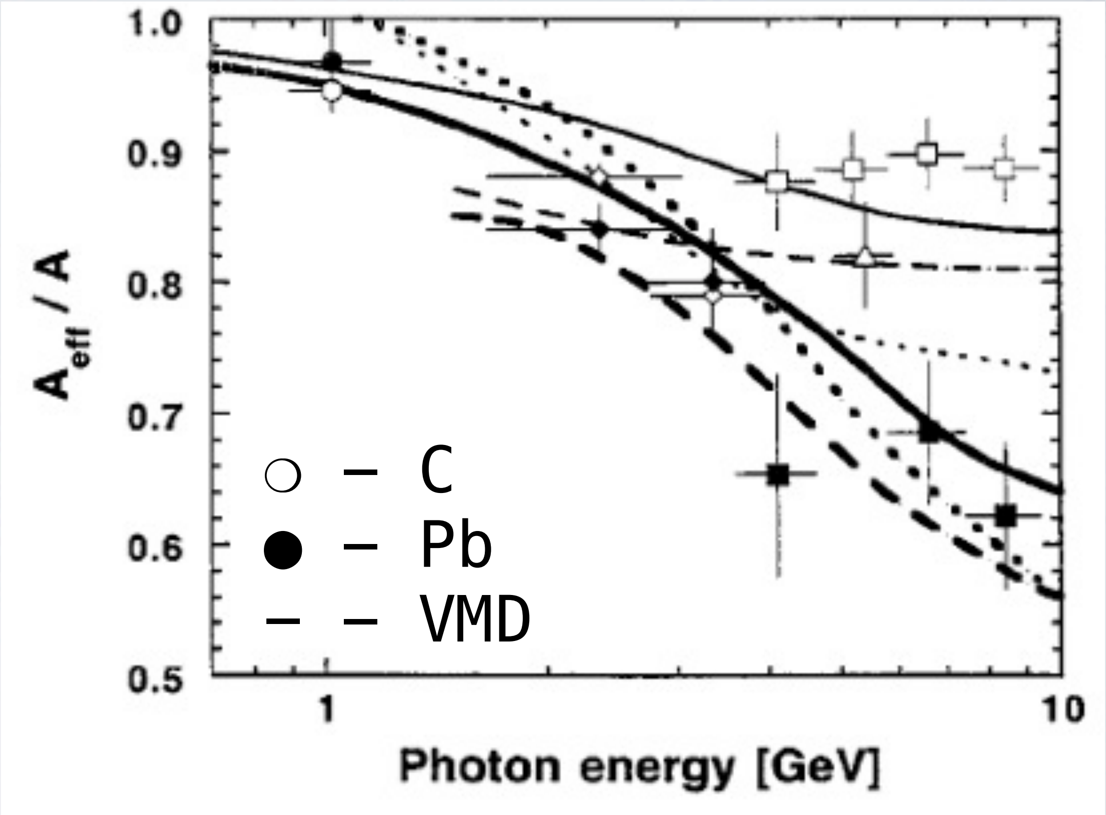

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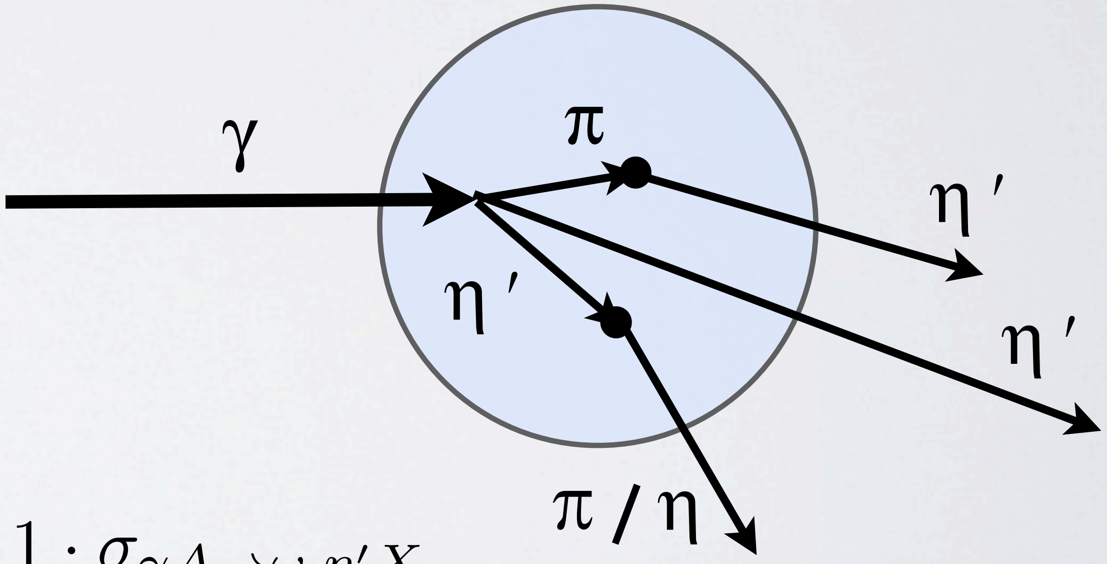

both distortions can be reduced by
taking light nucleus like C as reference:

$$T_A^C = \frac{11 \cdot \sigma_{\gamma A \to \omega,\eta' X}}{A_{eff} \cdot \sigma_{\gamma C \to \omega,\eta' X}}$$

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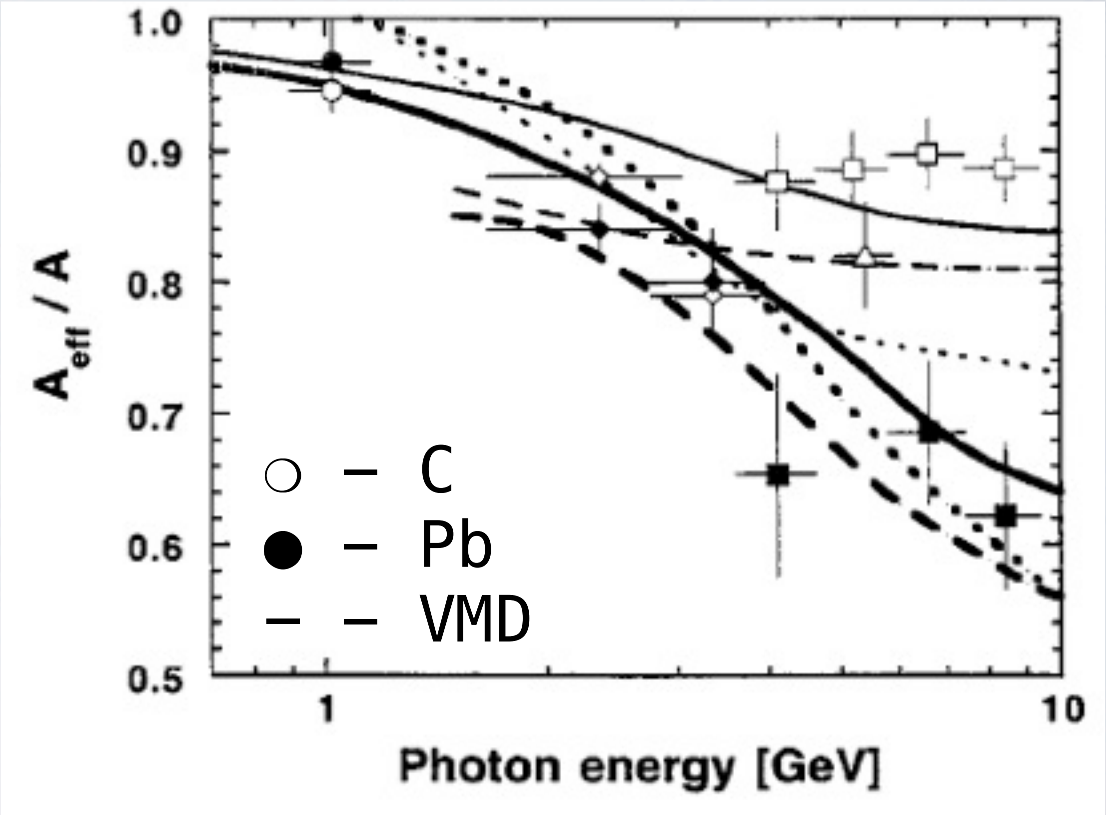

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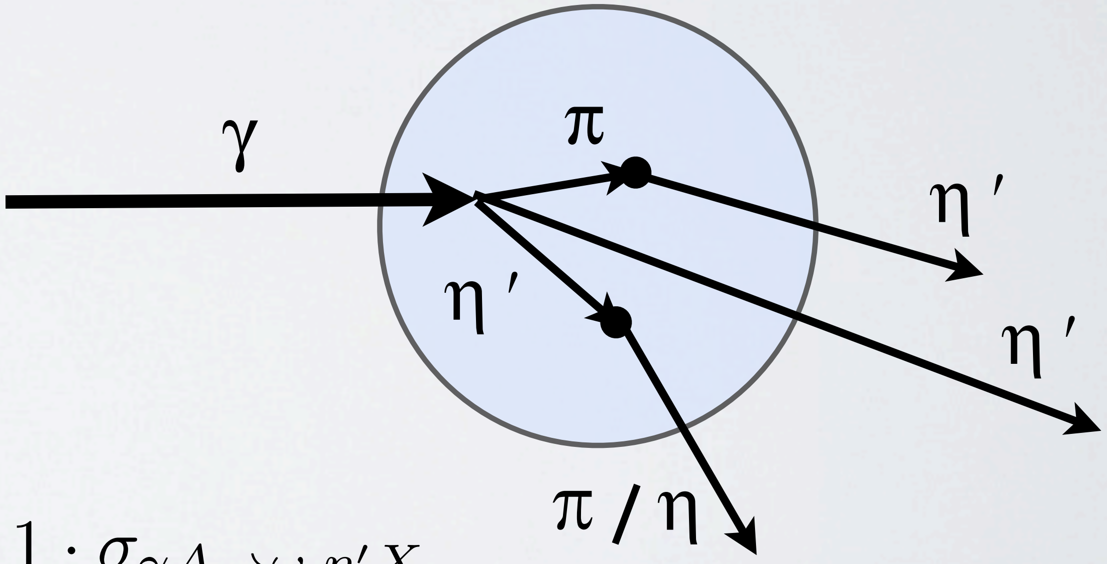

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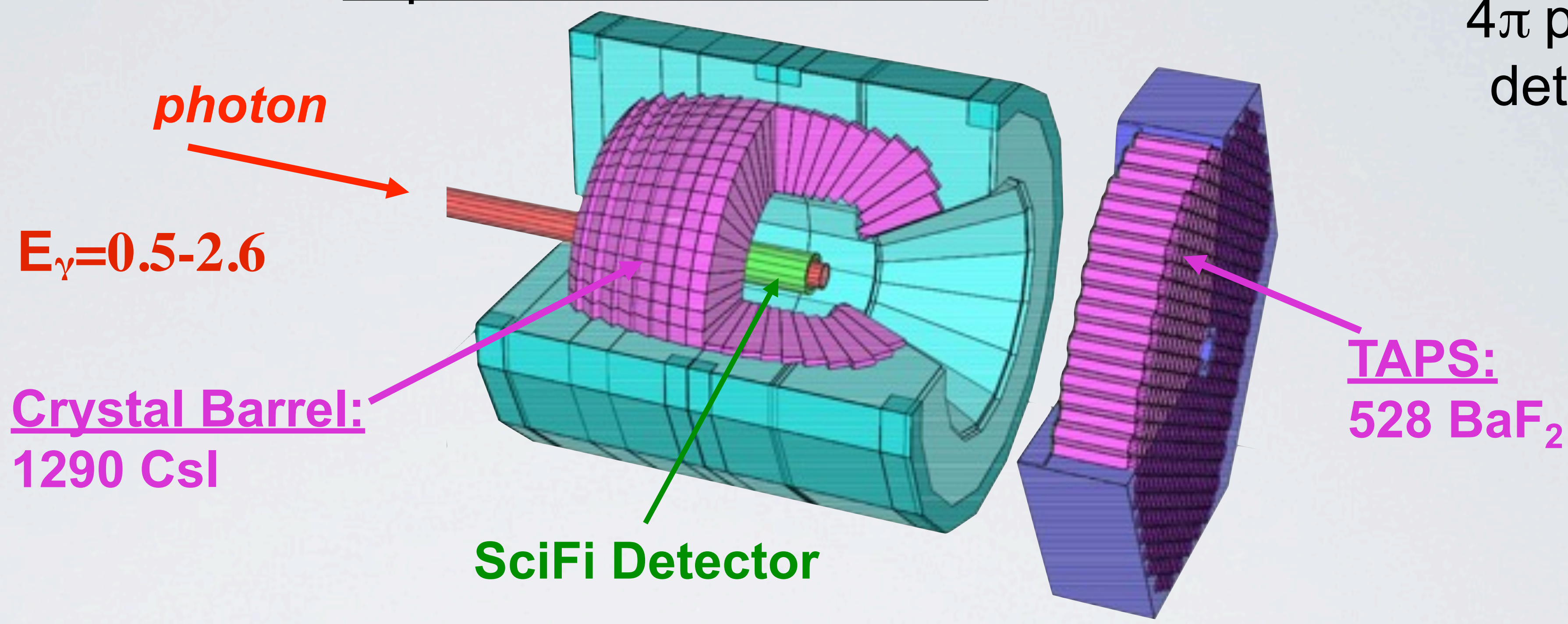
3.) two-body absorption processes:

absorption processs involving 2 nucleons distort $\Gamma \rightarrow \sigma_{inel}$ conversion

Crystal Barrel/TAPS@ELSA Experiment

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

4π photon detector



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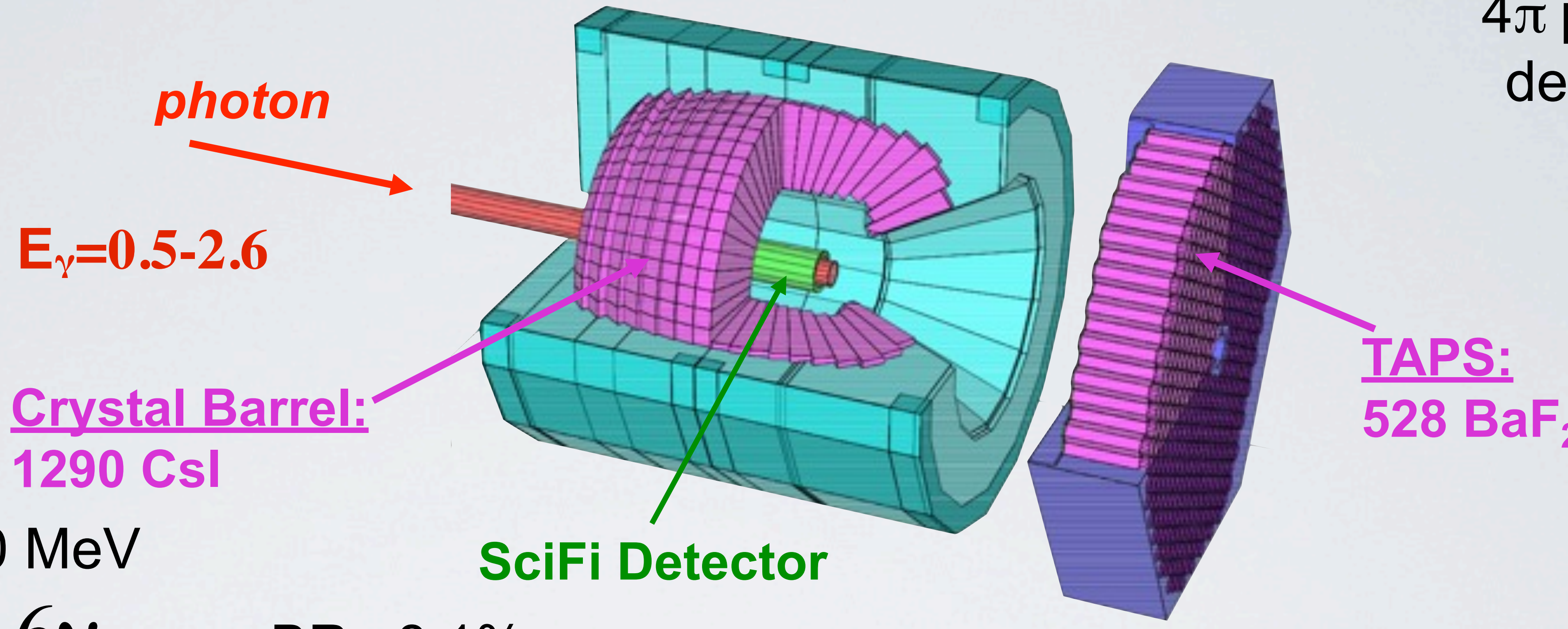

E_γ = 1500 - 2200 MeV

$\eta' \to \pi^0\pi^0\eta \to 6\gamma$ BR: 8.1%

photoproduction of η' meson off ^{12}C, ^{40}Ca, ^{93}Nb and ^{208}Pb

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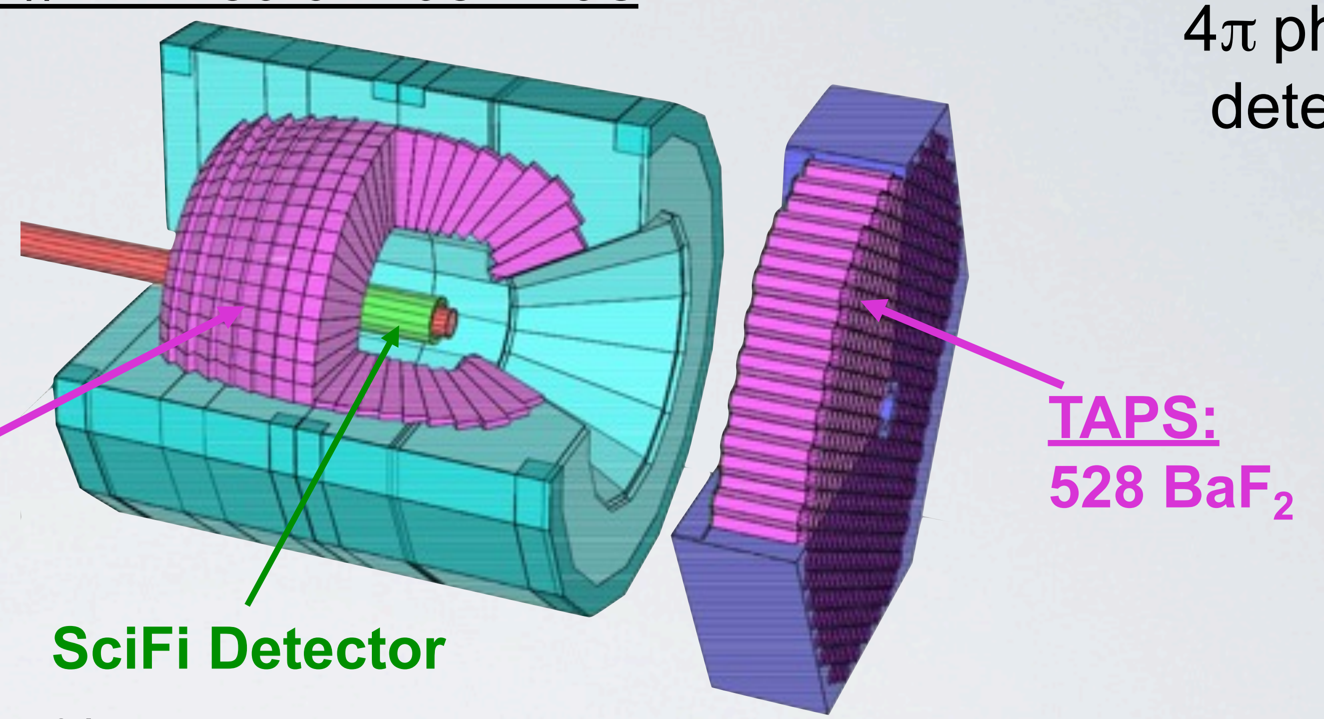

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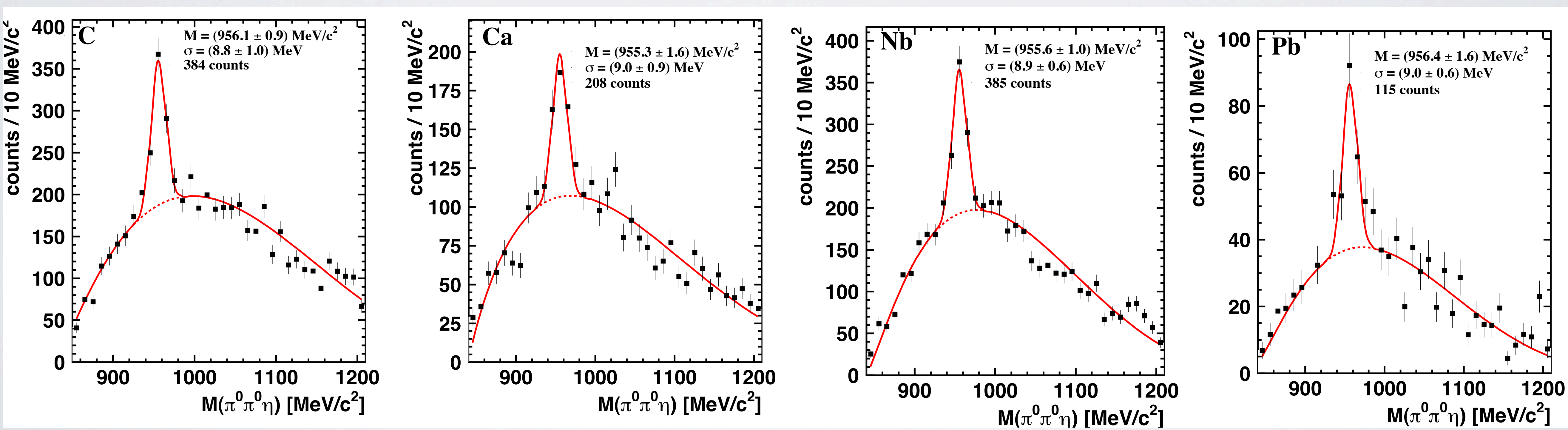

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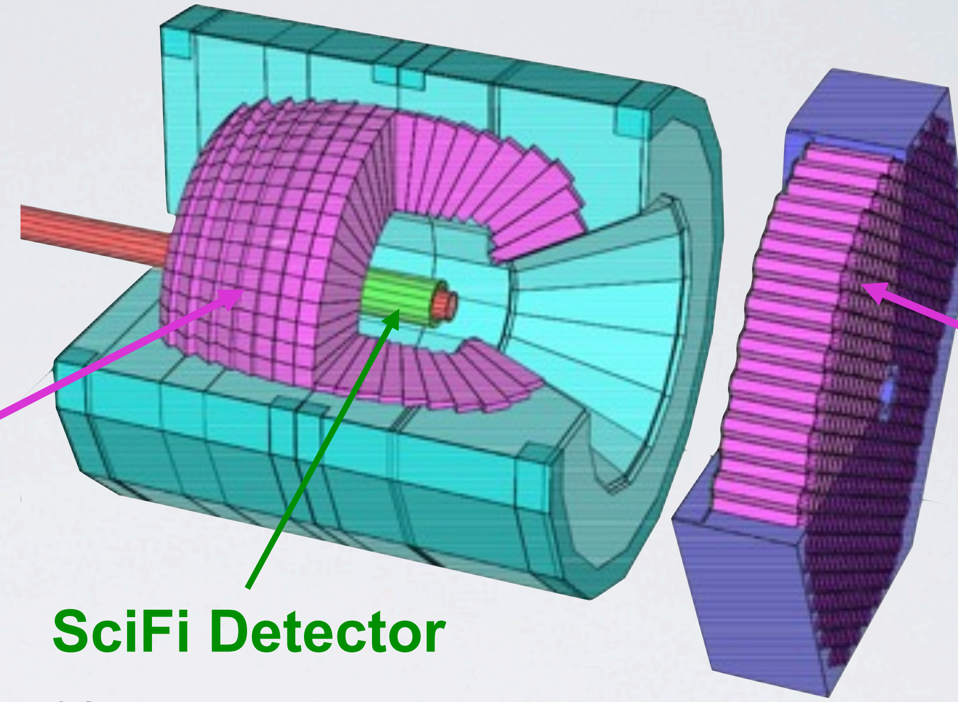

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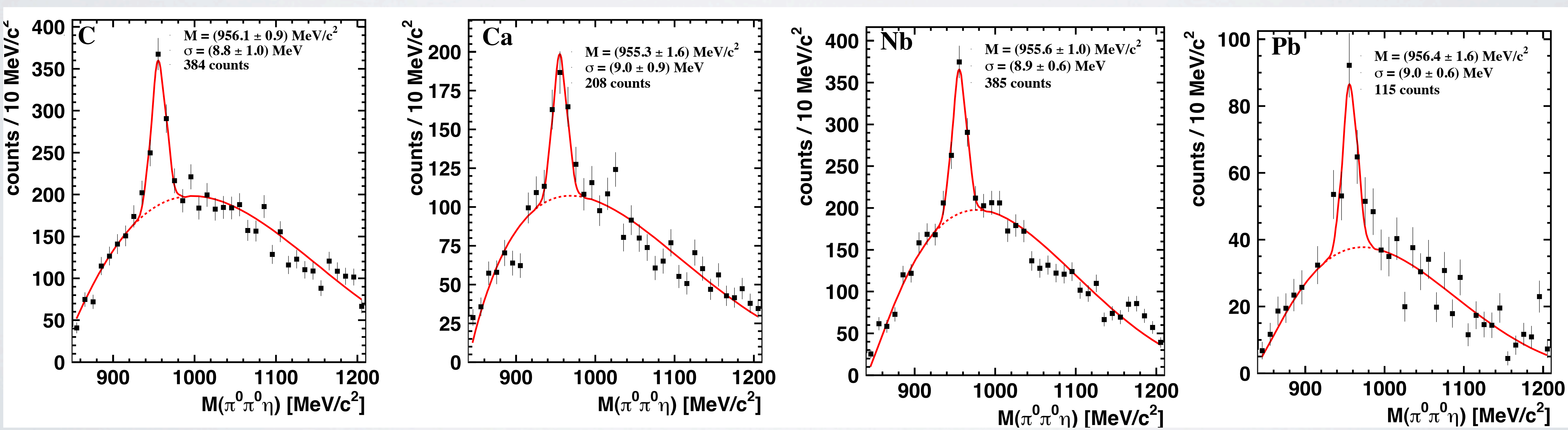

competing channels with same final states ($\pi^0\pi^0\pi^0 \to 6\gamma$) reconstructed and removed

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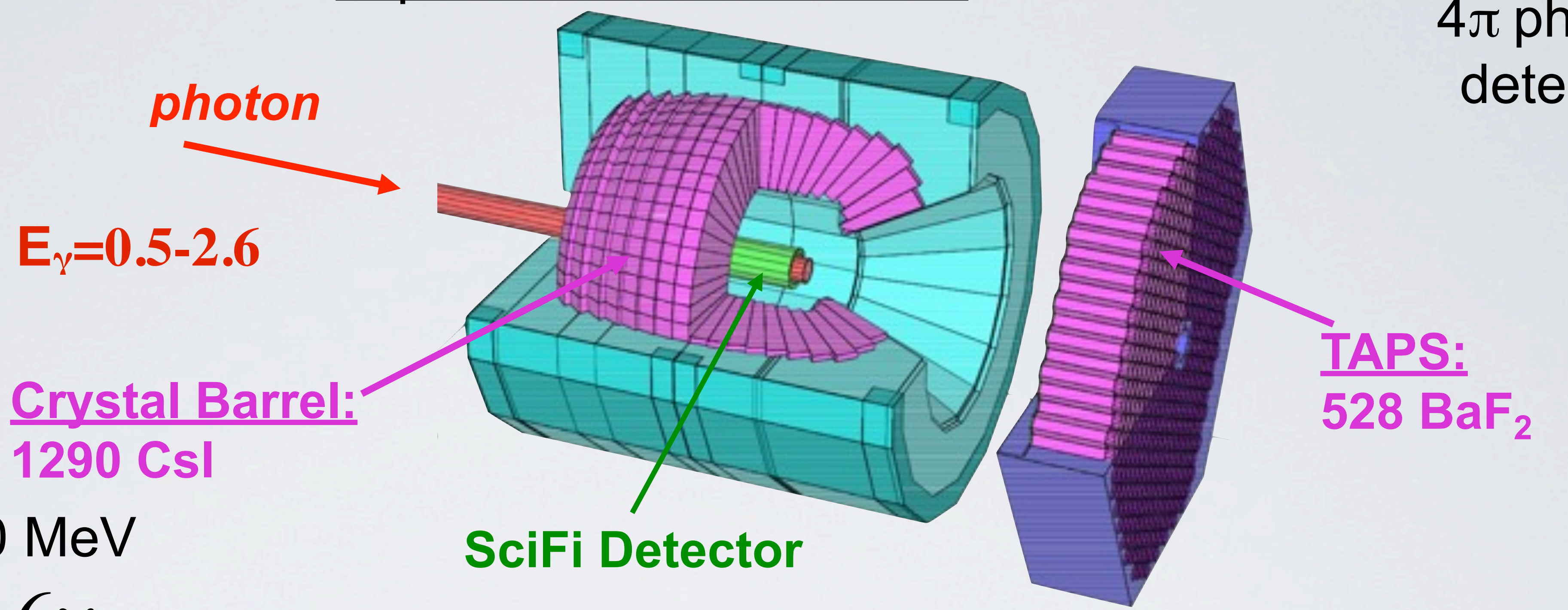

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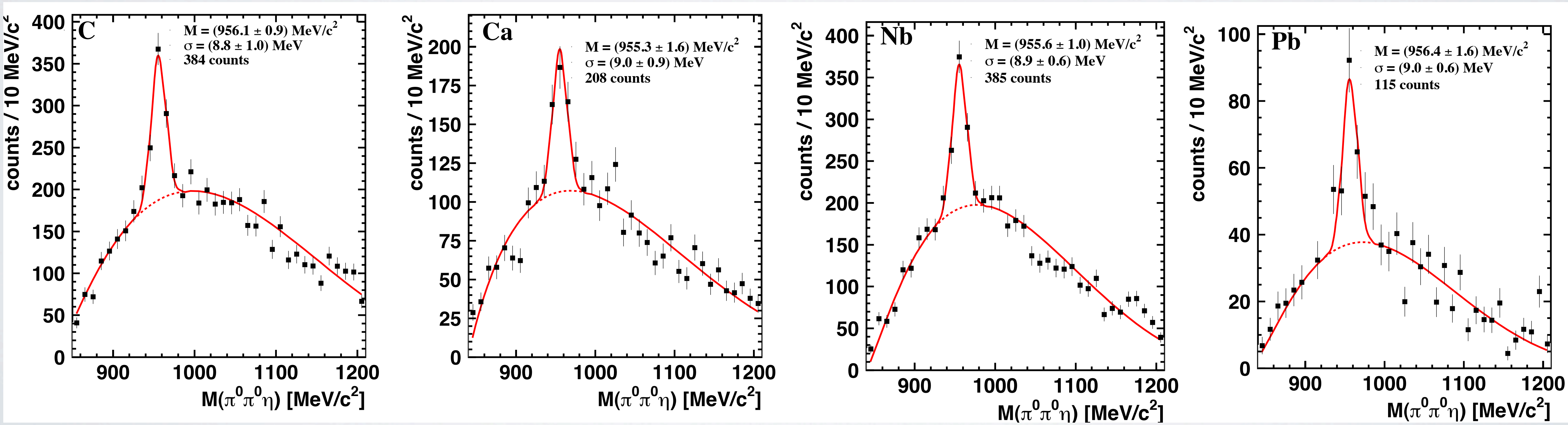

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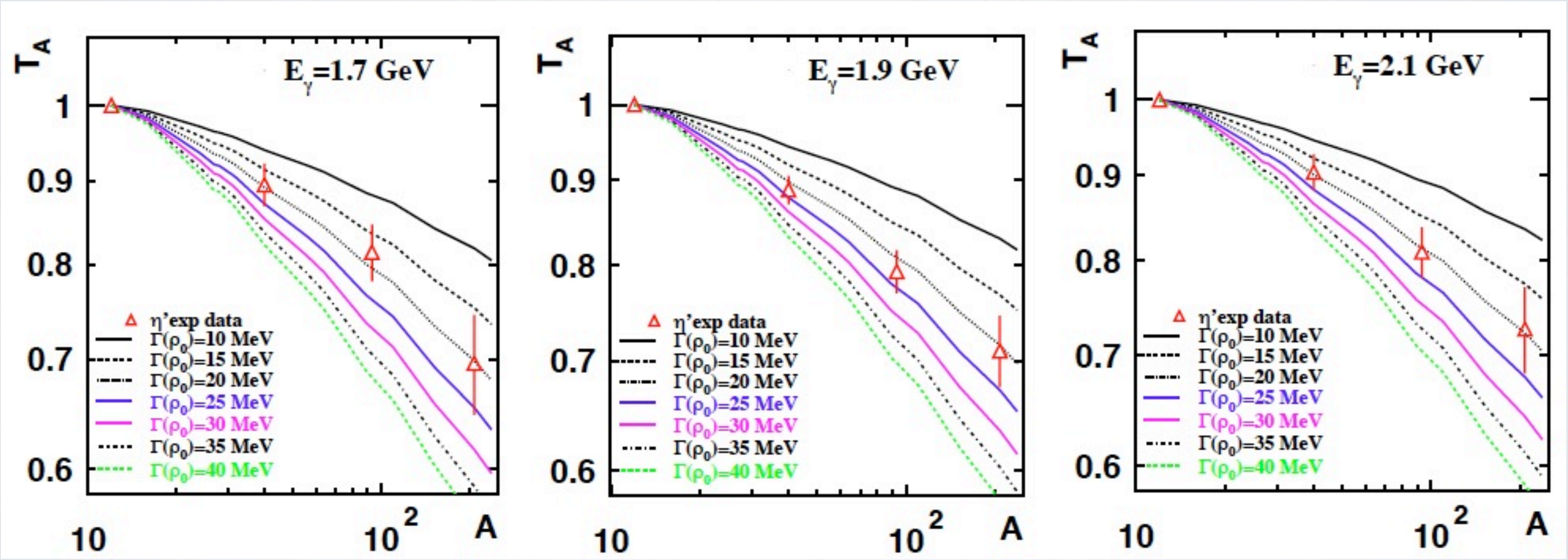
efficiency correction of the data - event by event in (T_{kin}, θ^{lab}) plane

in-medium width of η’ meson

M. Nanova et al., PLB 710 (2012) 600



in-medium width of η' meson

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

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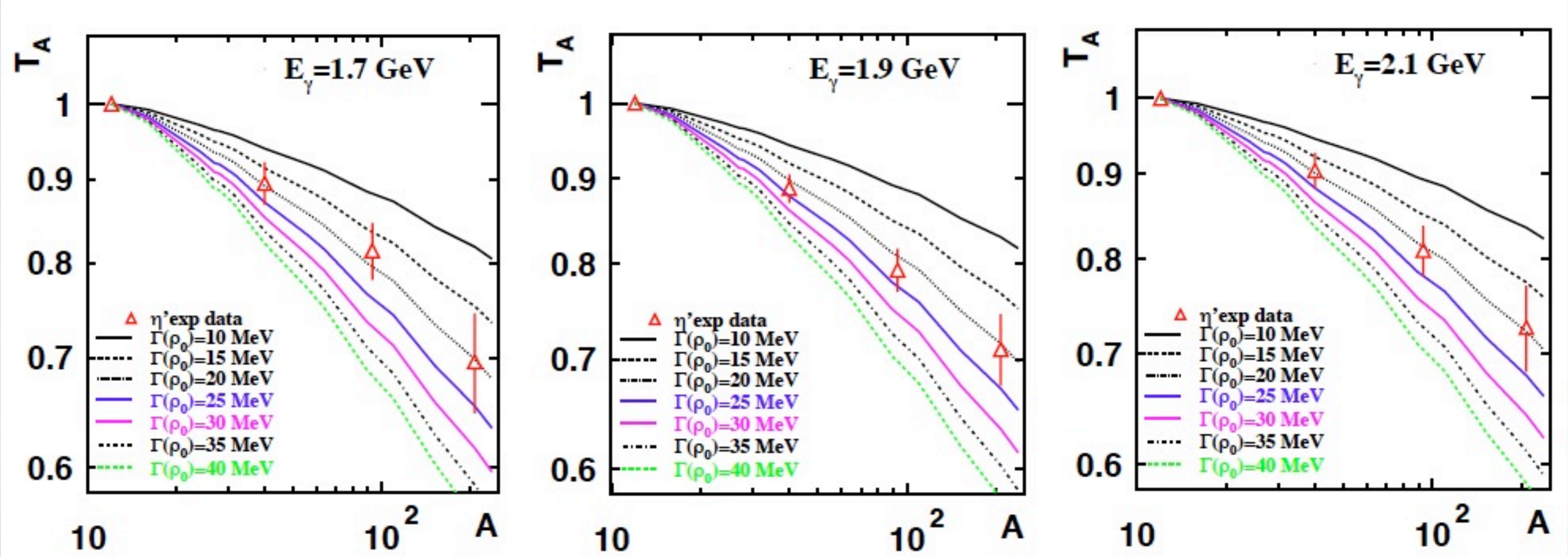

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$\frac{d\sigma}{d\Omega}(\gamma p\to\eta' p)$ ⇨ V. Crede et. al, PRC 80 (2009) 055202

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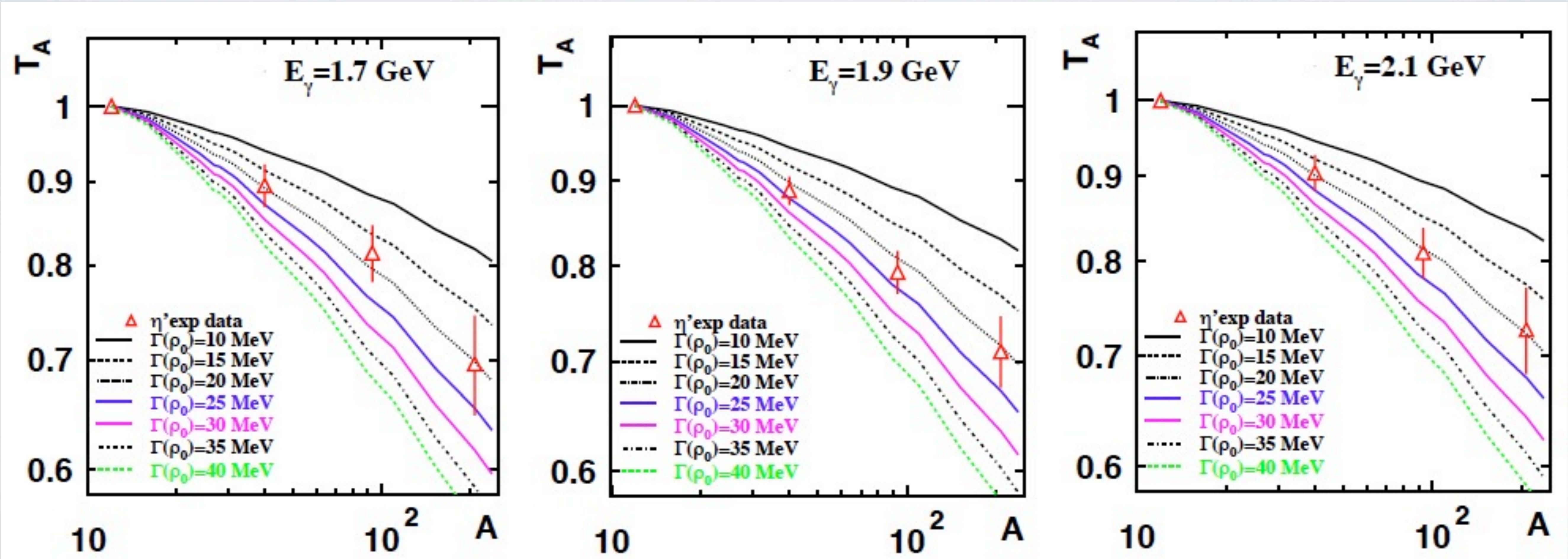

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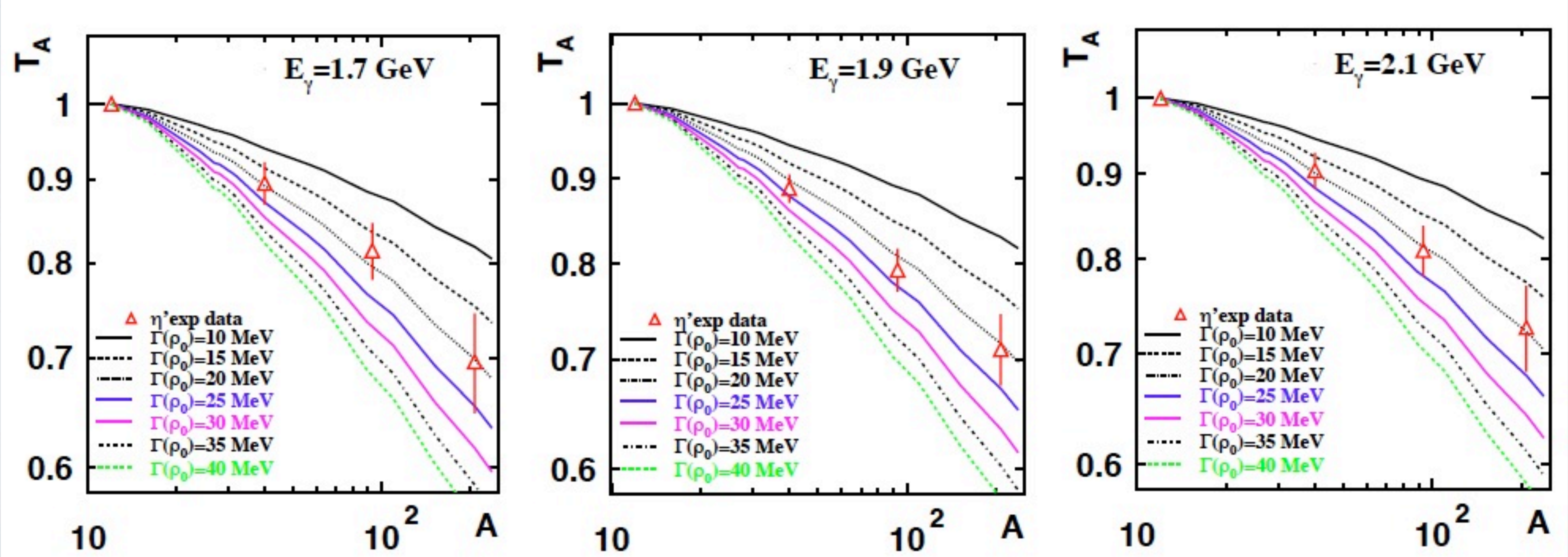
where $P_s(\vec{r})$ is the survival probability $P_s(\vec{k}_{\eta'}, \vec{r}) = \exp\left[\int_0^\infty dl \frac{\mathrm{Im}\,\Pi_{\eta'}(\rho(\vec{r}\,'))}{|\vec{k}_{\eta'}|}\right]$ with $\vec{r}\,' = \vec{r} + l\frac{\vec{k}_{\eta'}}{|\vec{k}_{\eta'}|}$

$\frac{d\sigma}{d\Omega}(\gamma p \to \eta' p)$ ⇨ V. Crede et. al, PRC 80 (2009) 055202

M. Nanova et al., PLB 710 (2012) 600



in-medium width of η' meson

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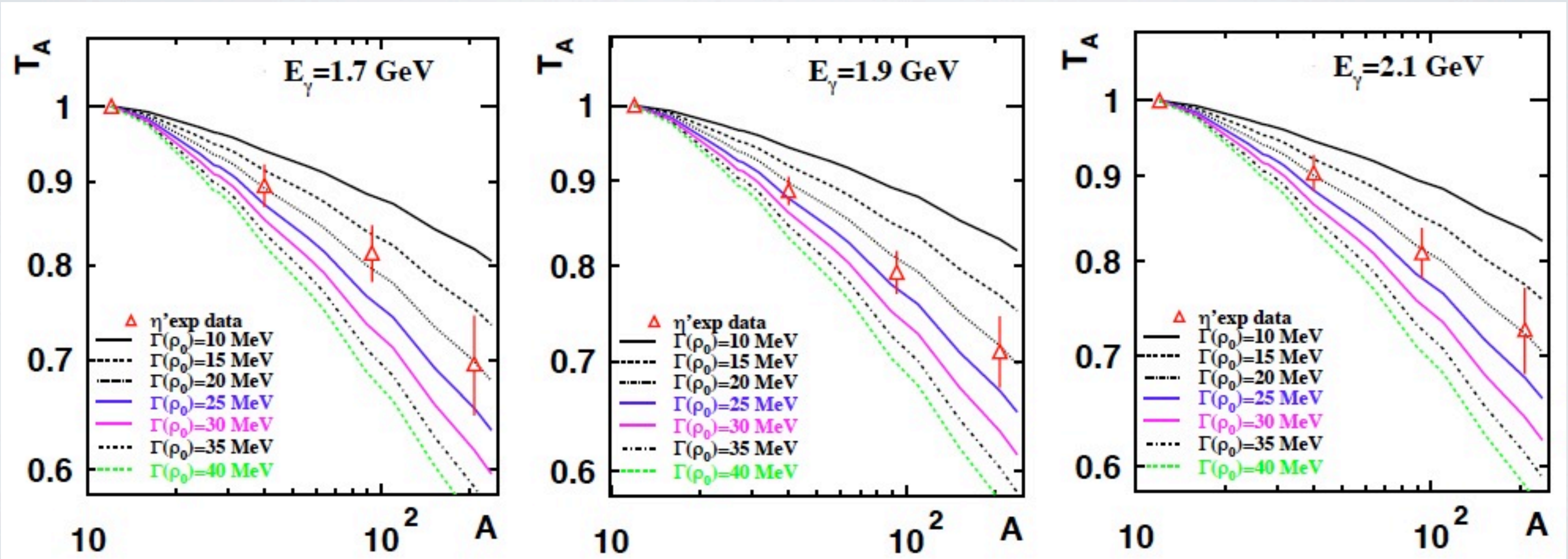

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Glauber analysis for extraction of inelastic cross section

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approximation of nuclear density distribution:

nucleus = a sphere with radius $R = r_0 \cdot A^{\frac{1}{3}}$ homogeneously filled with A nucleons

r_0=1.143 fm; ρ_0=0.17 fm^{-3}

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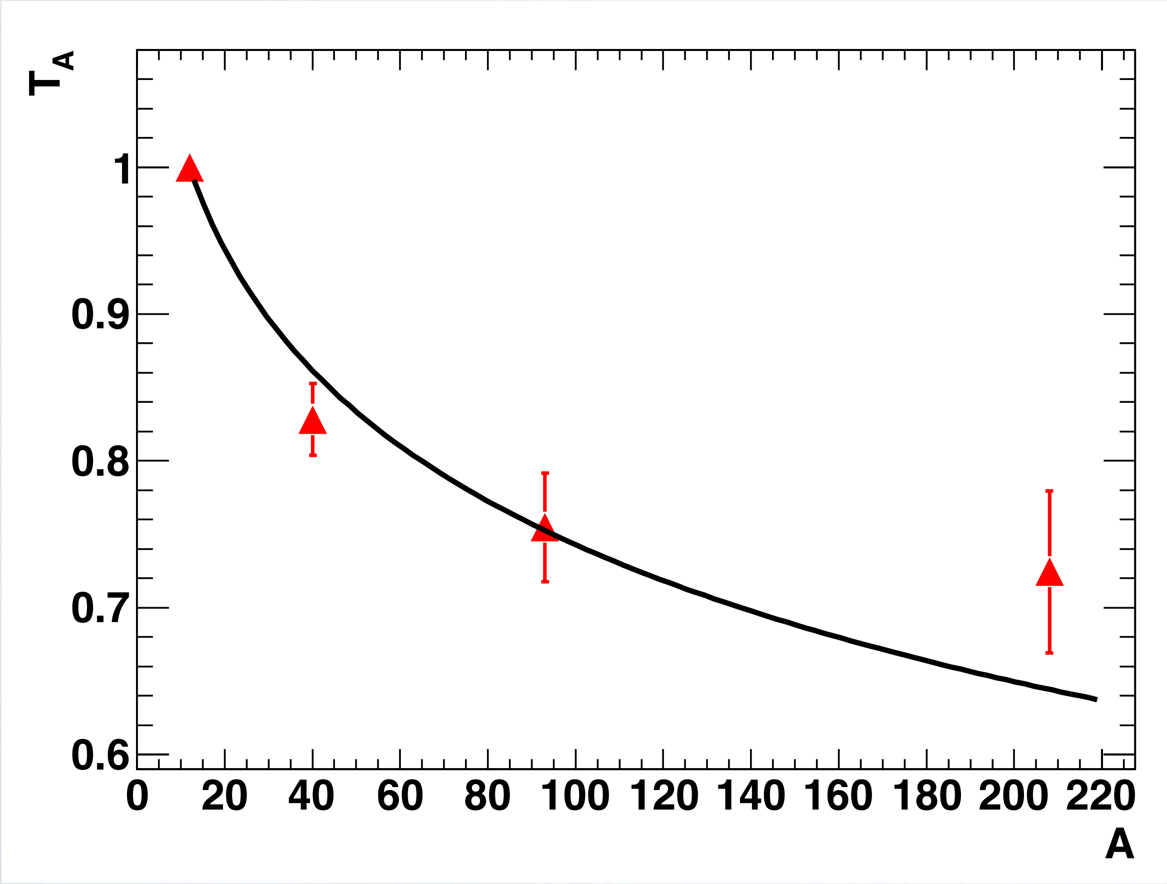

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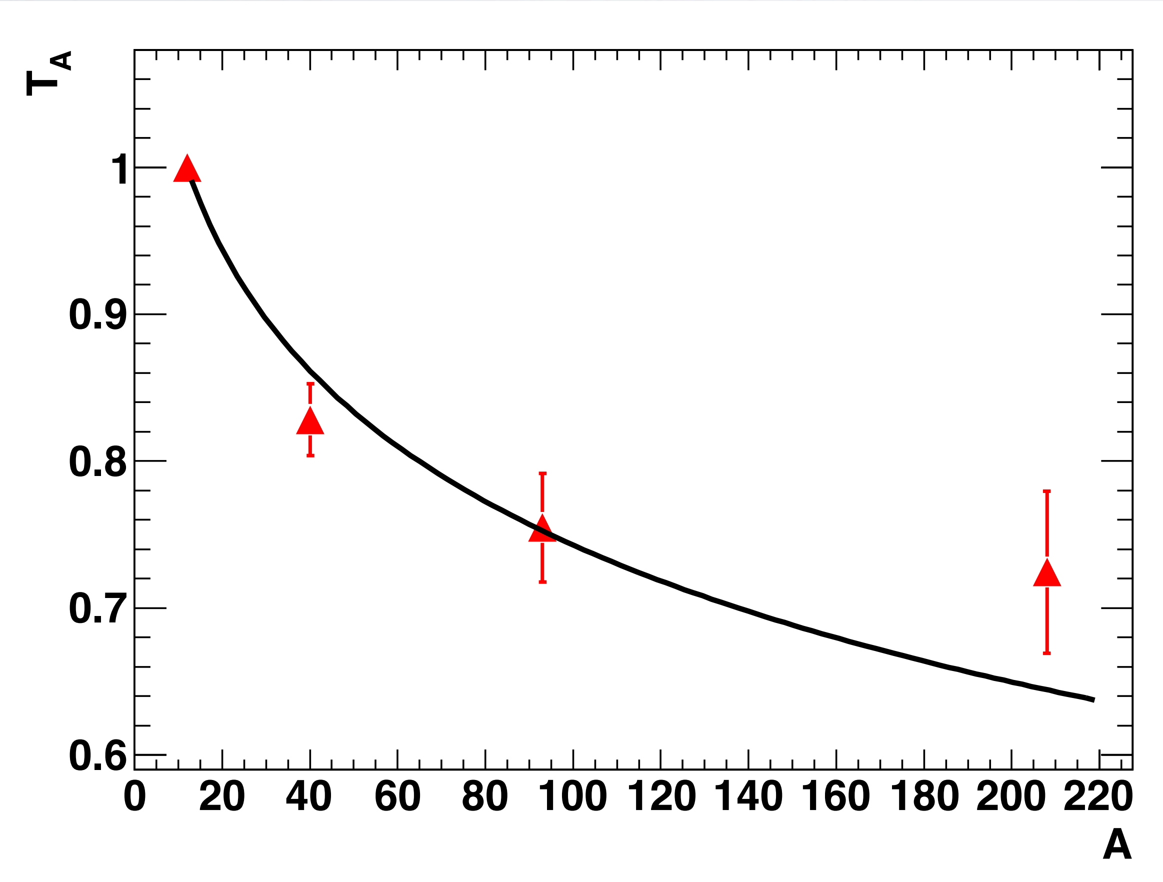

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$\sigma_{\eta' N}$ =(11.0±1.5) mb

$\Gamma_{\eta'} \approx$ 25 MeV

$$\Gamma = \hbar c \cdot \rho_0 \cdot \sigma_{inel} \cdot \beta$$

$$\Gamma(\rho) = \Gamma(\rho_0) \cdot \frac{\rho}{\rho_0}$$

impact of two-step processes ??

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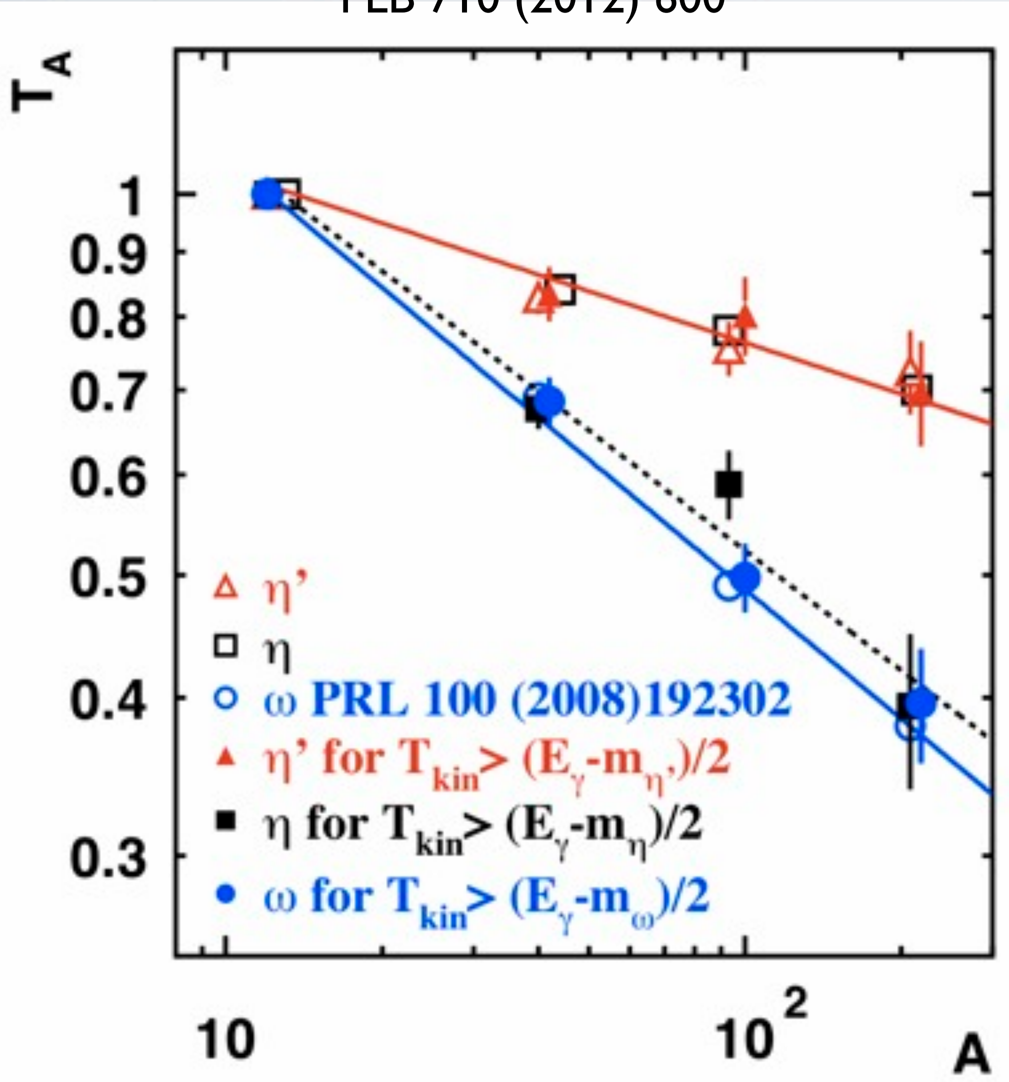

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⇒ little secondary production;

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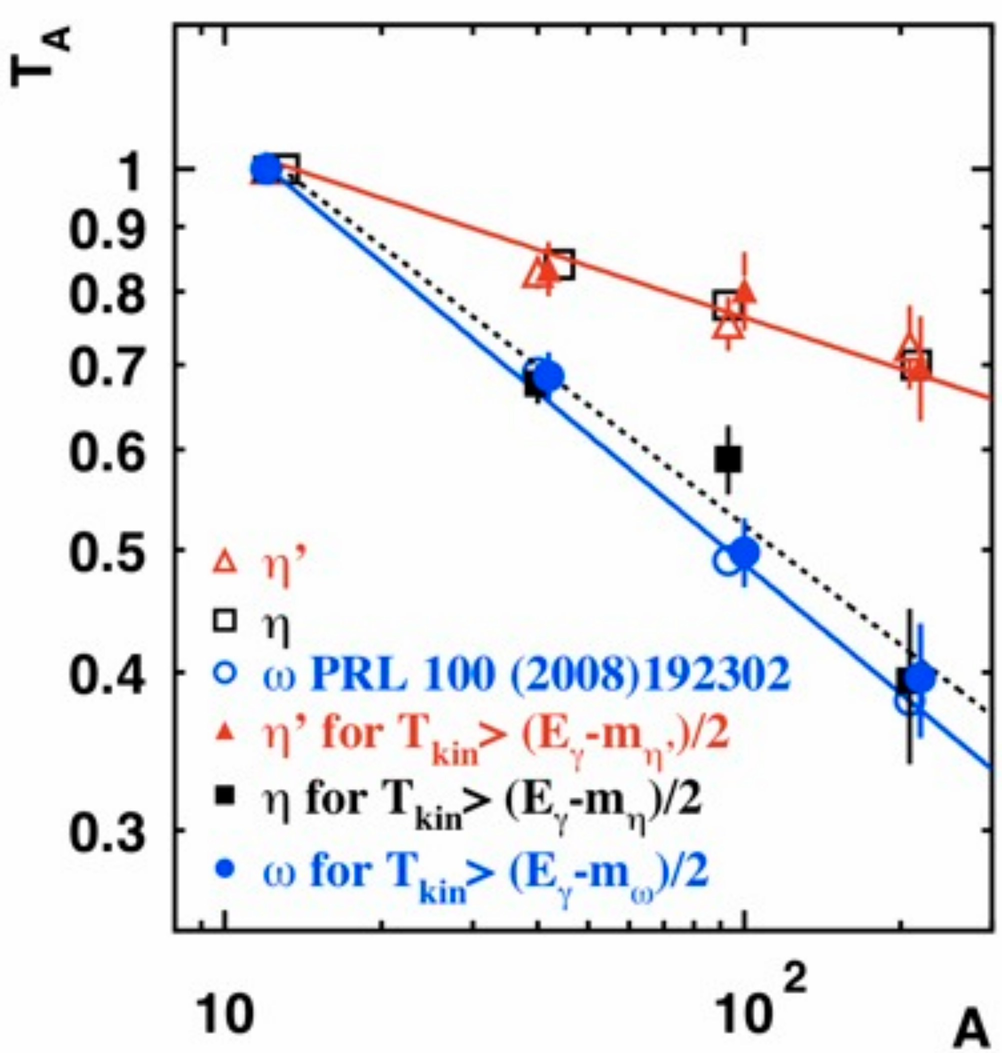

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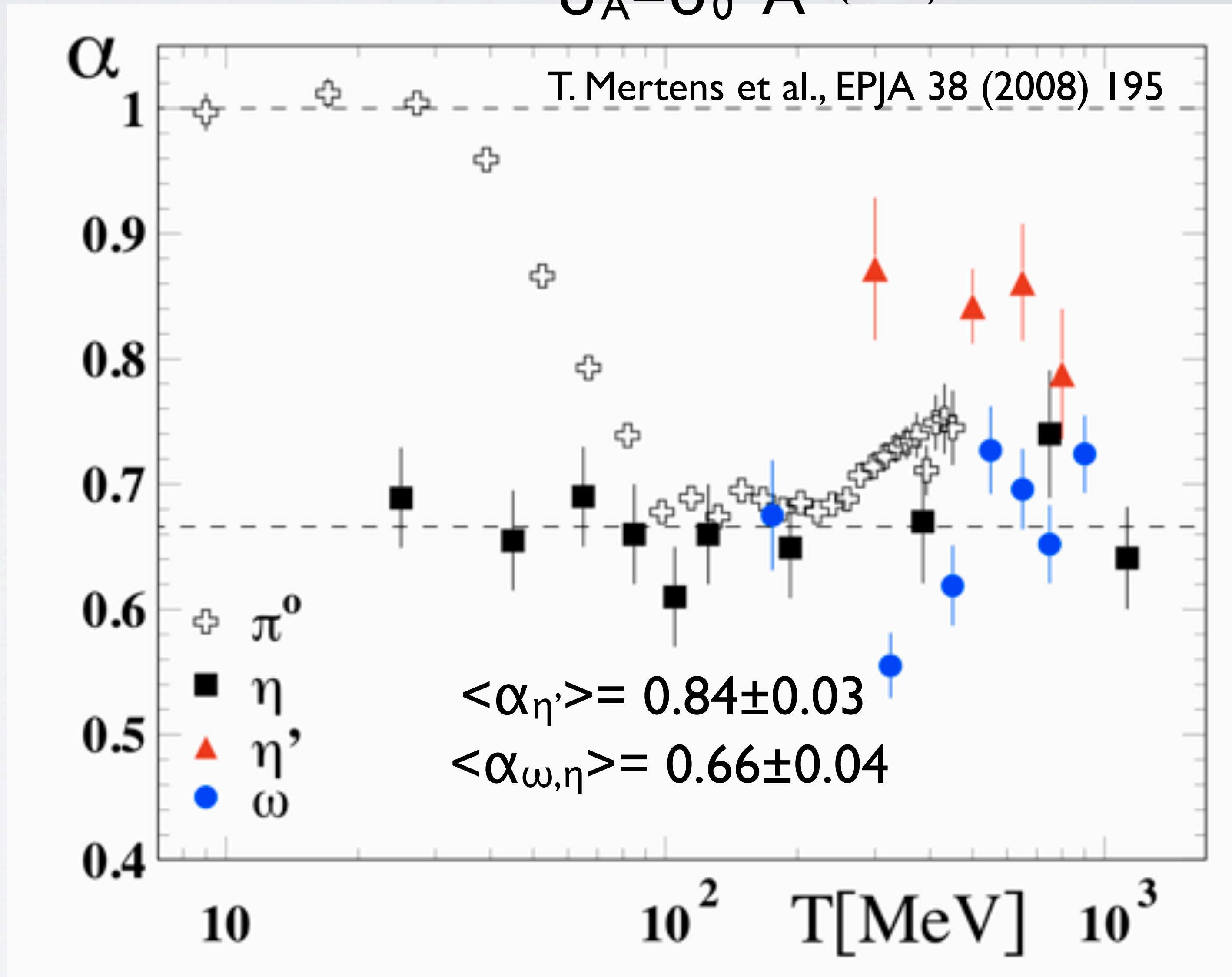

η' interaction with nuclear matter
much weaker than for π, η, ω mesons

momentum distribution

E_γ = 1500-2200 MeV

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PLB 710 (2012) 600

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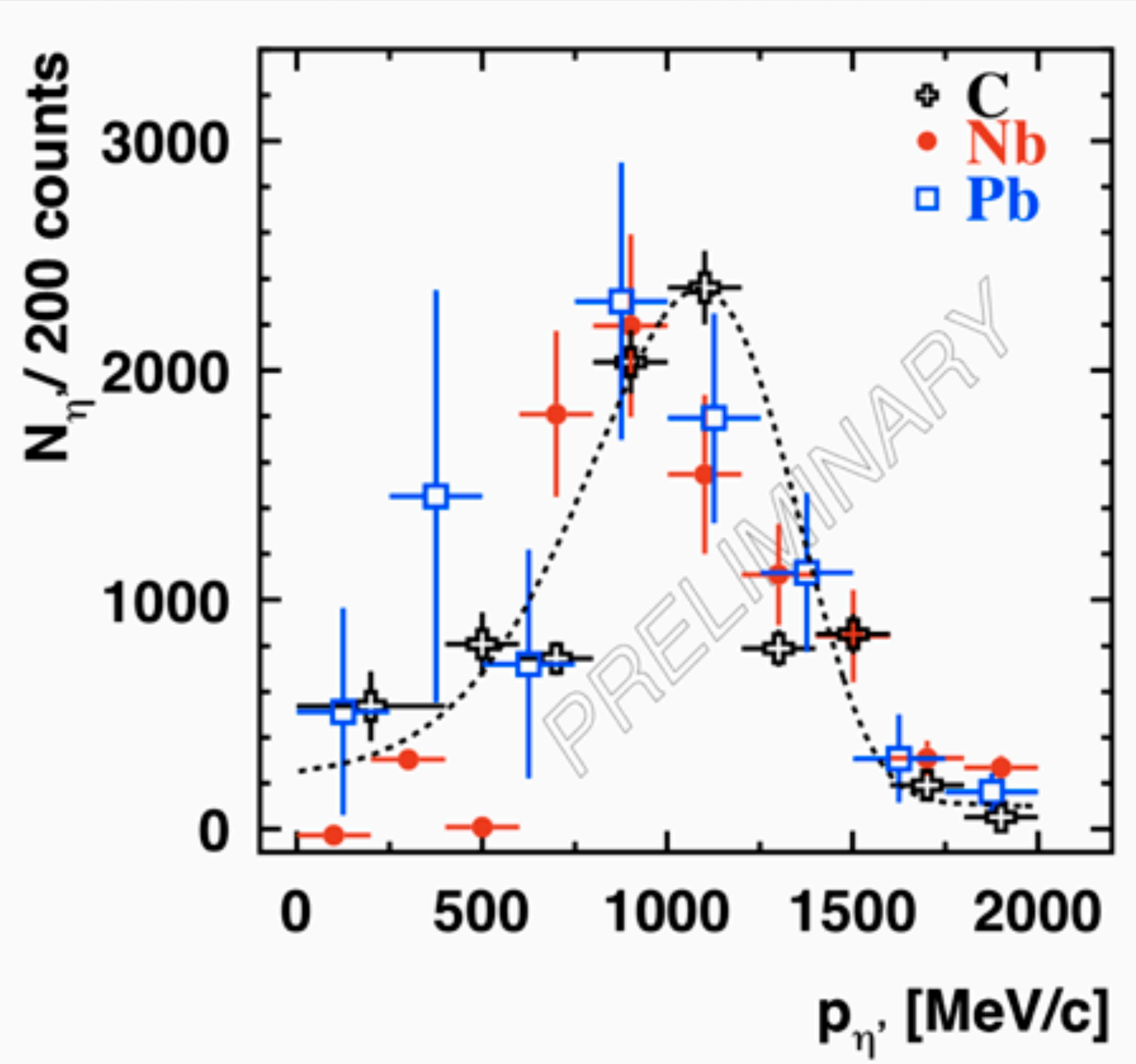

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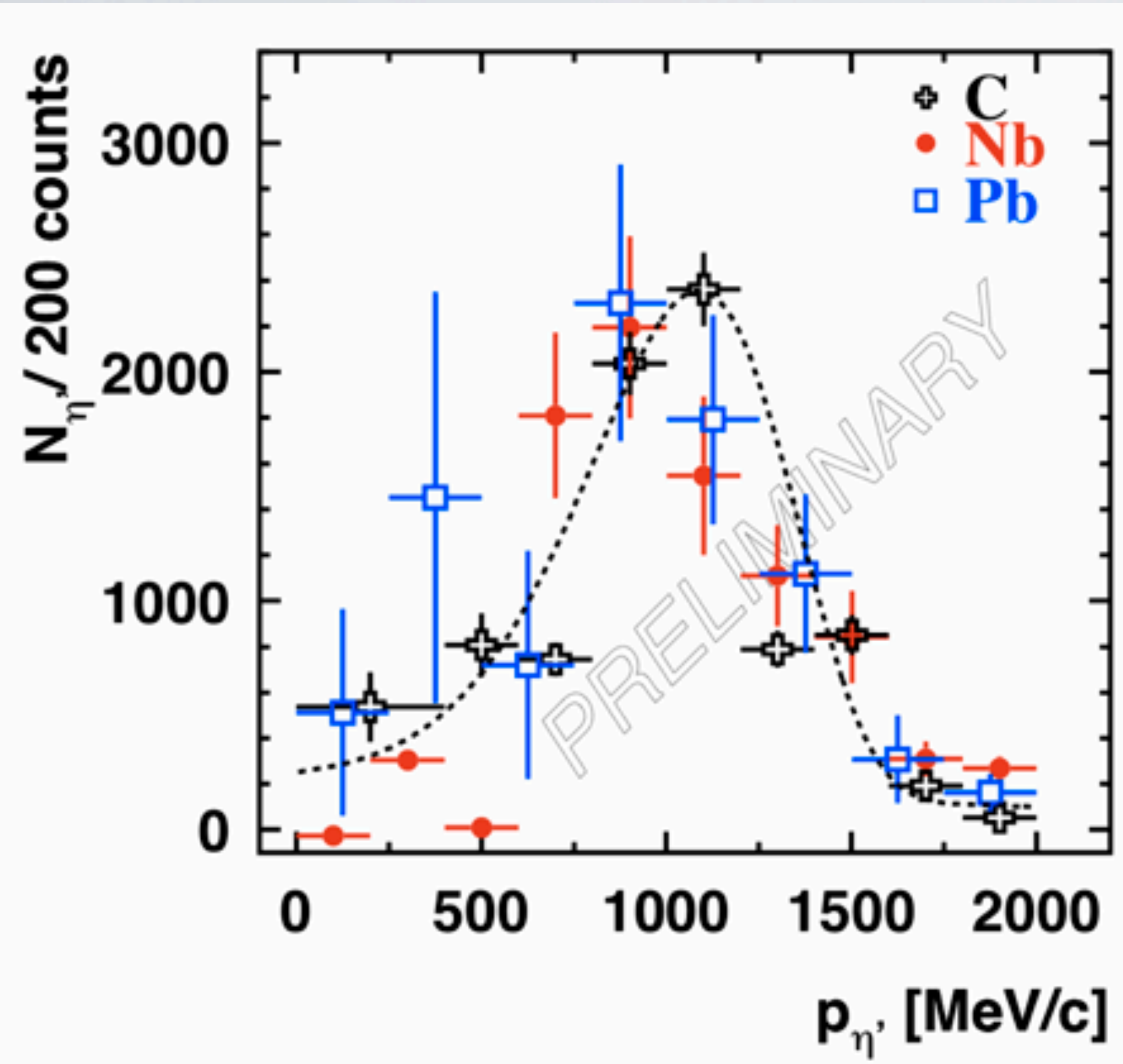

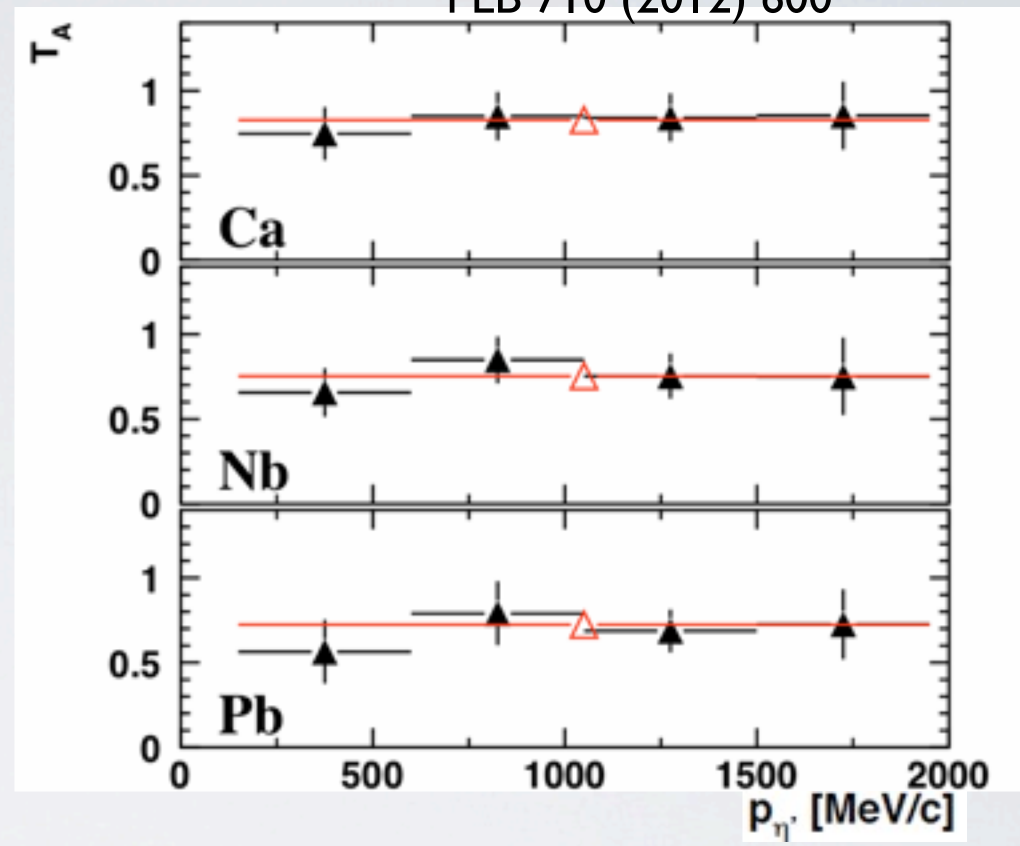

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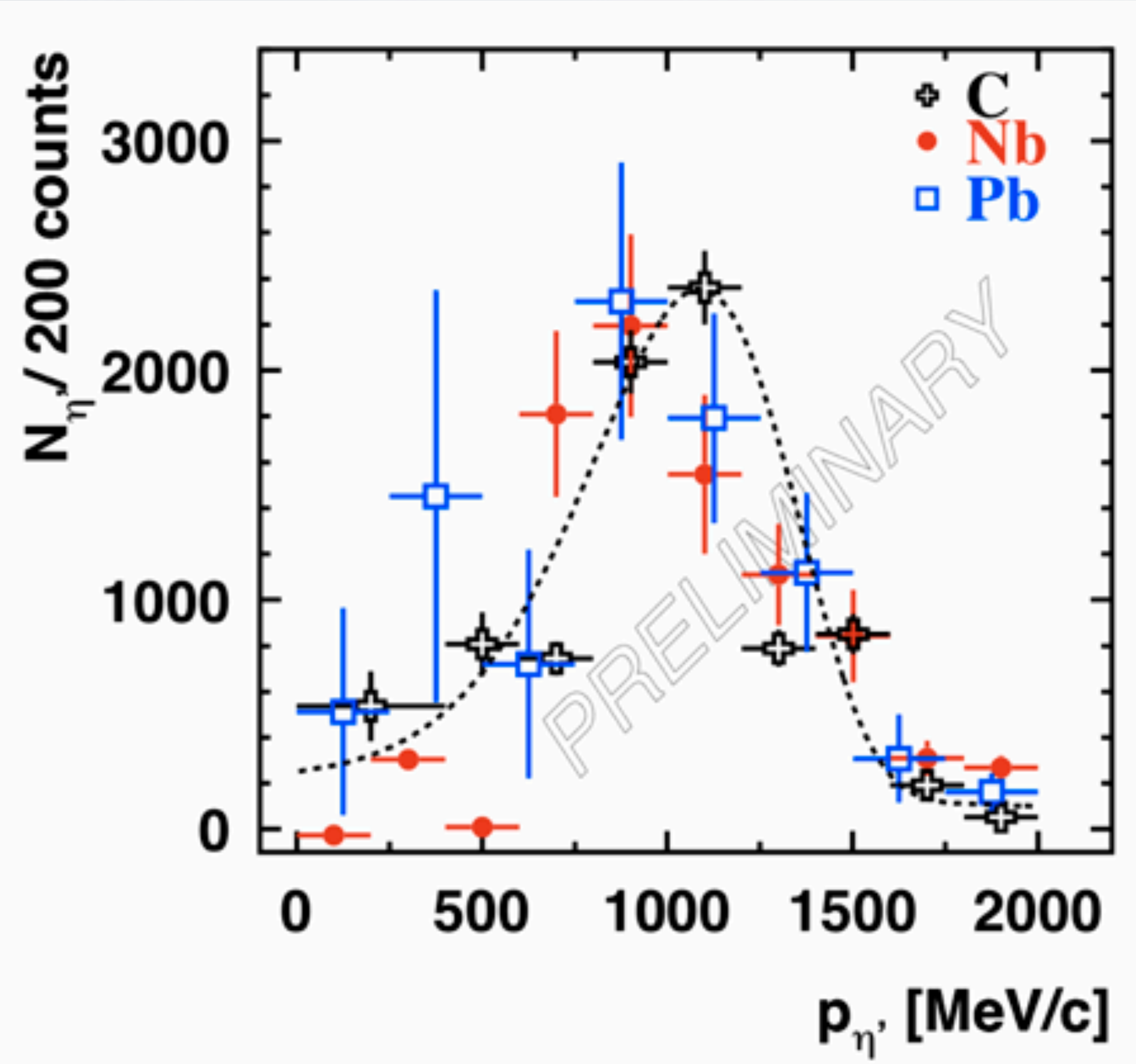

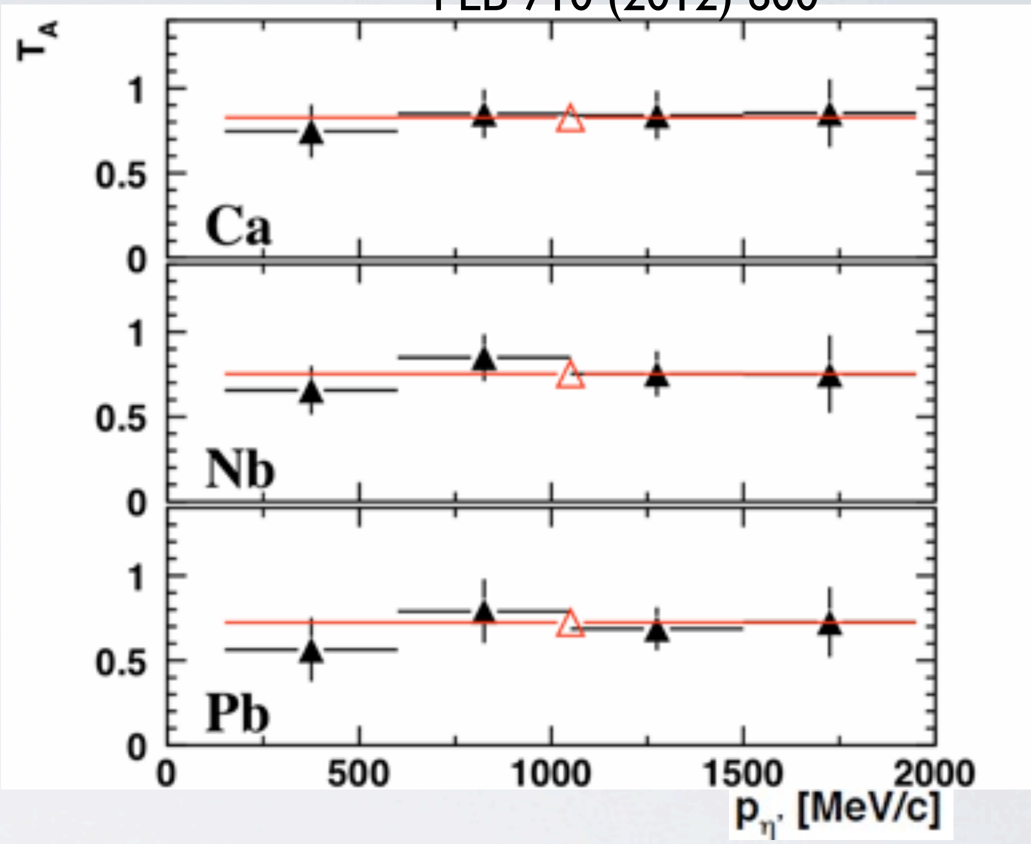

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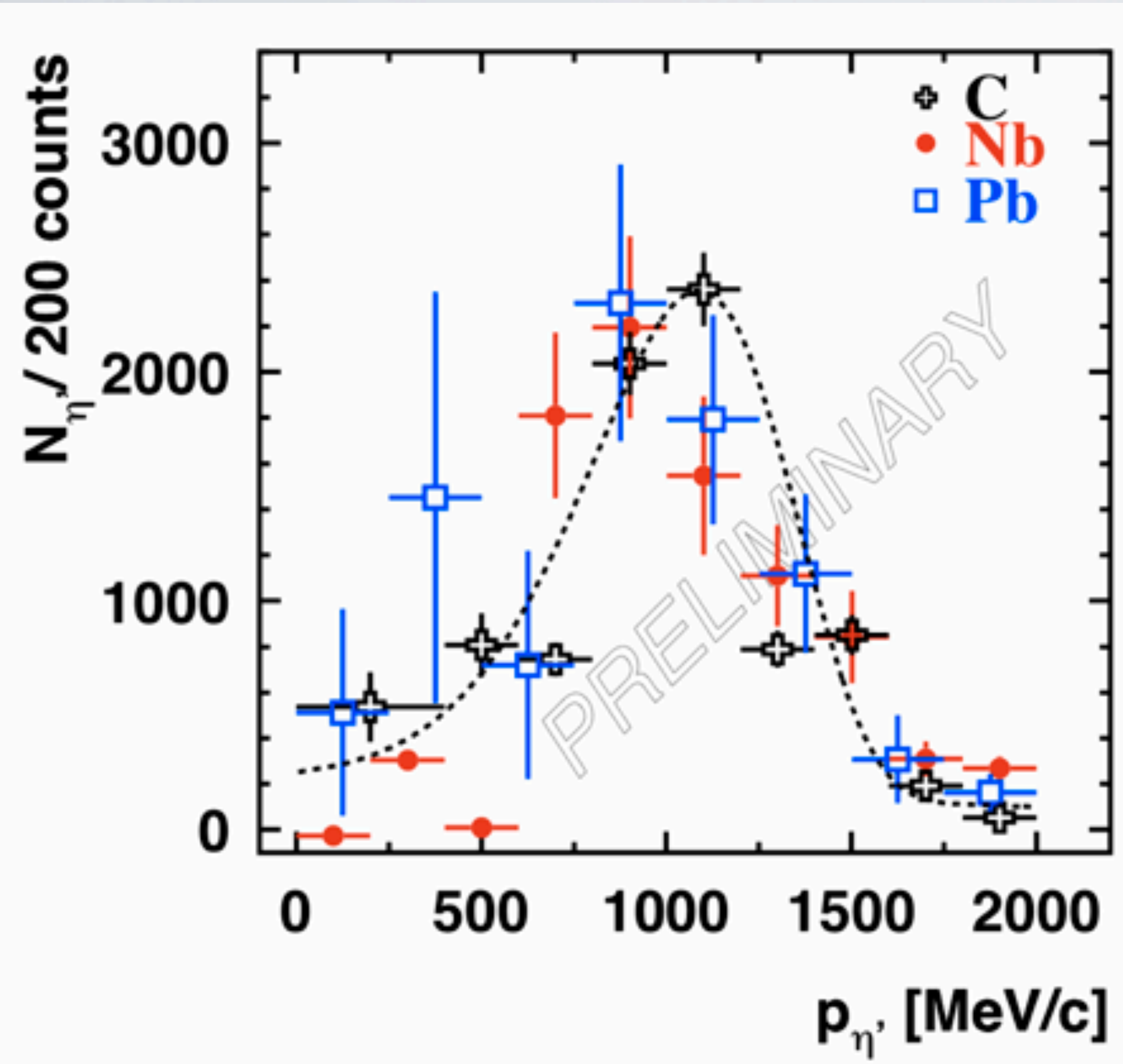

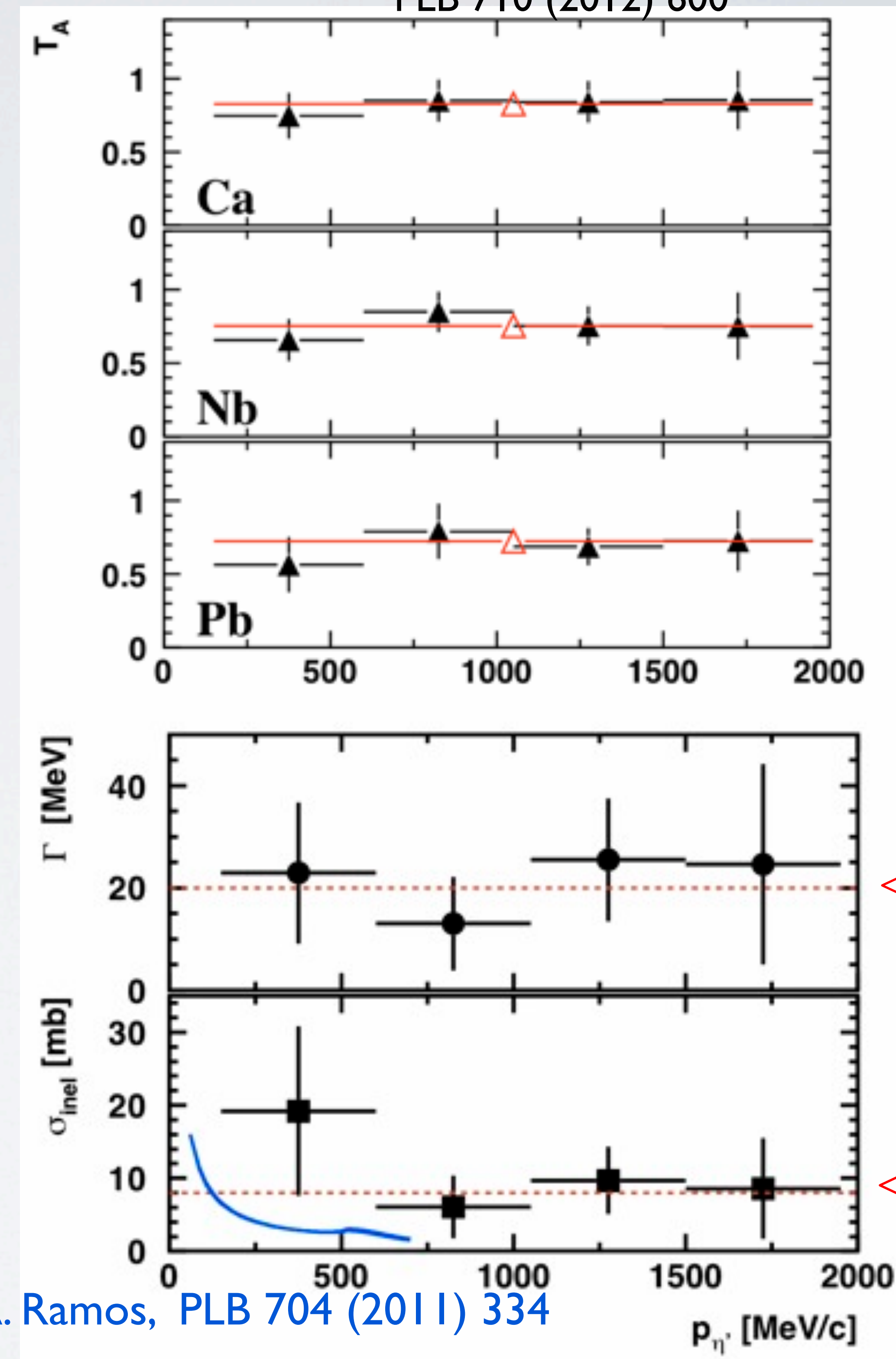

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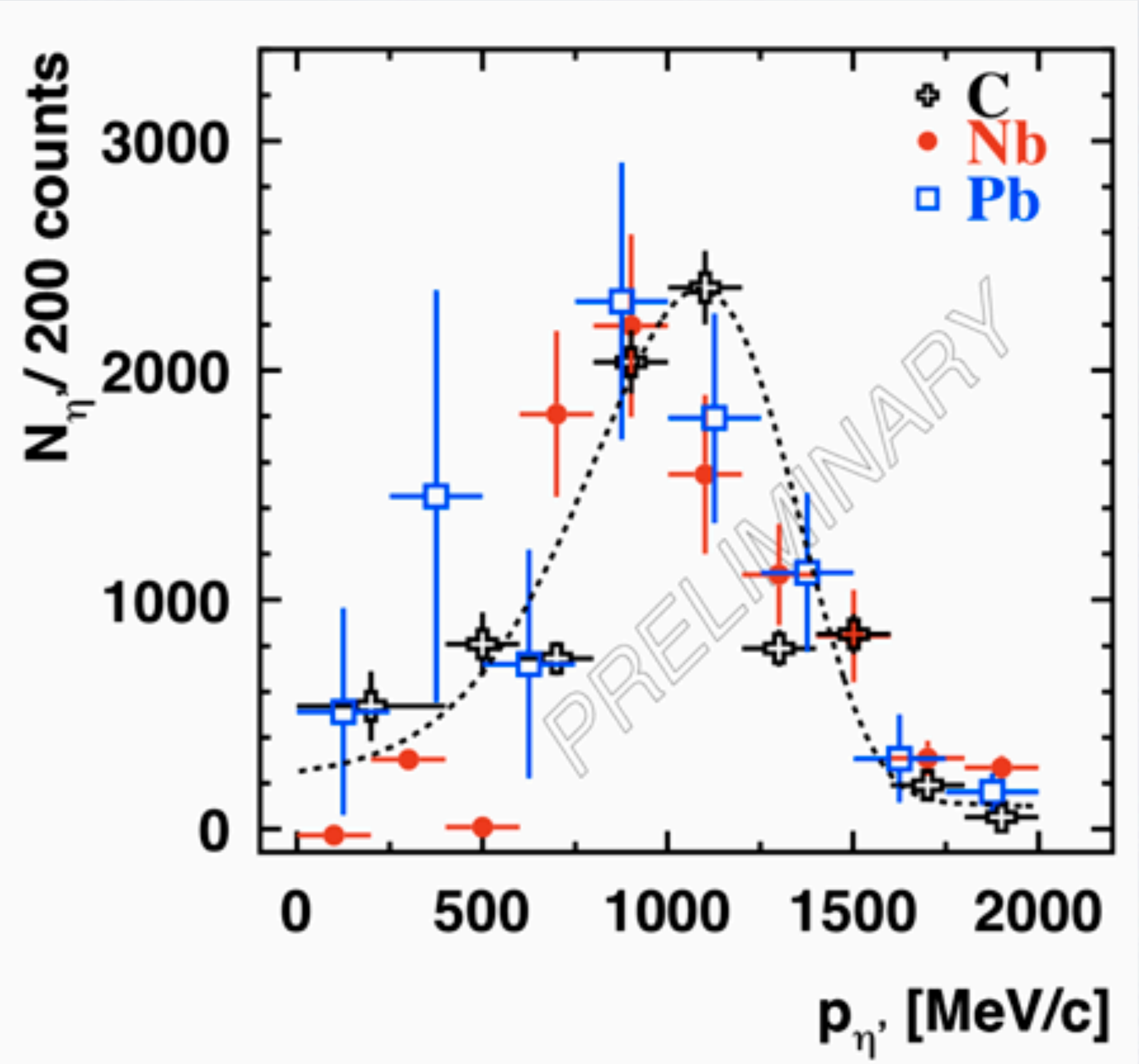

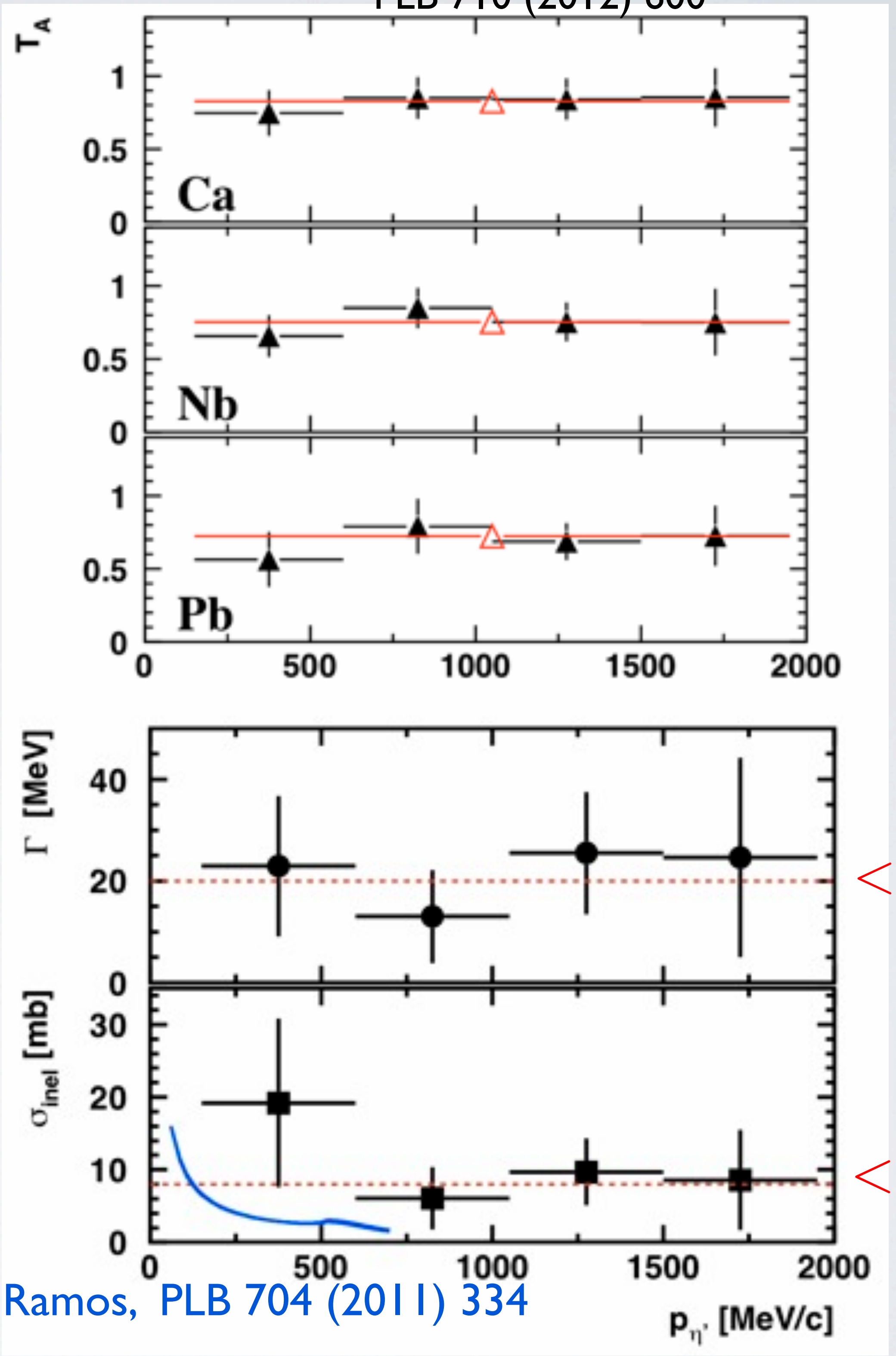

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T_A - no strong variation with momentum
indication for a little effect of two-step processes

summary and outlook

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transparency ratio: in-medium broadening η' meson;

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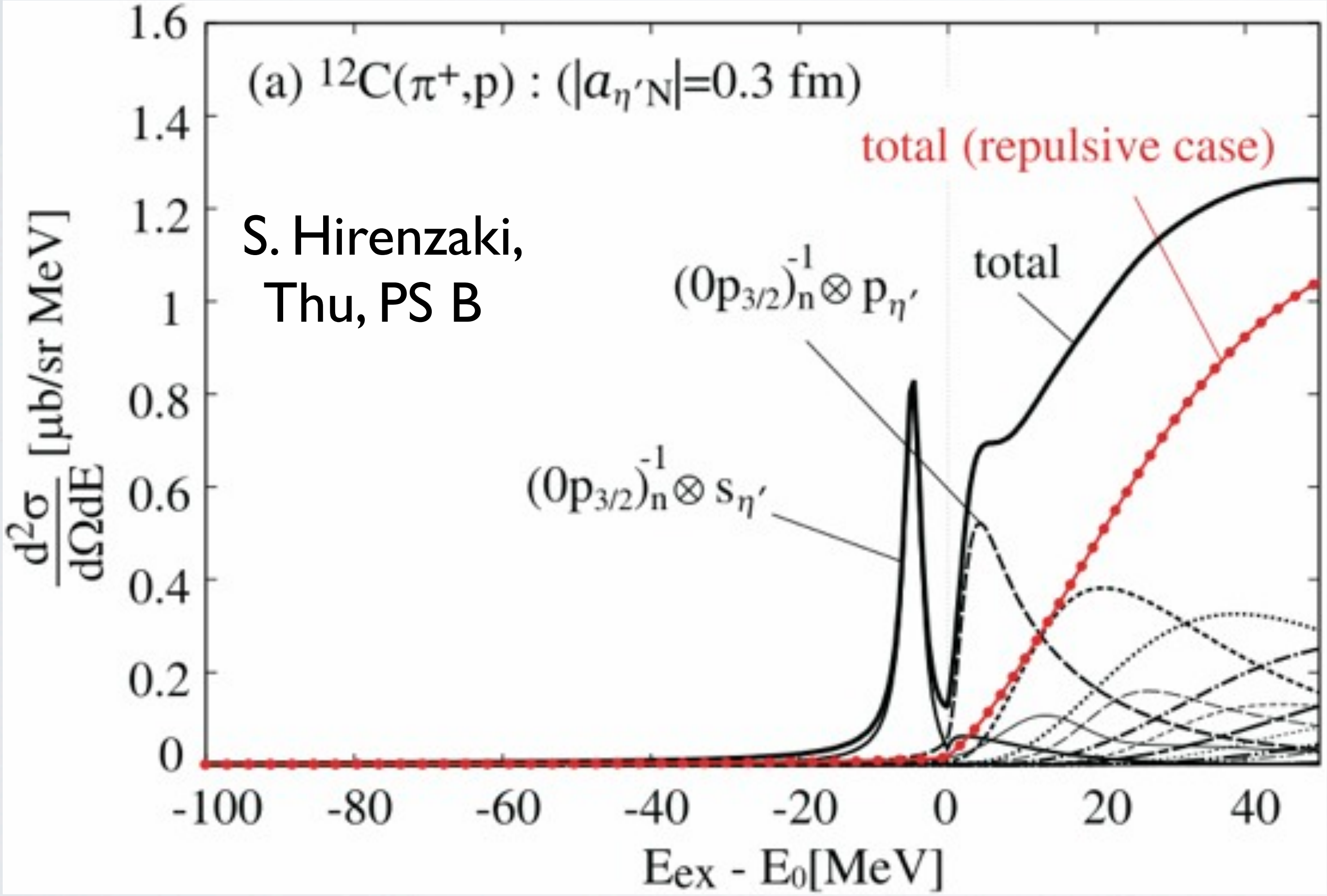

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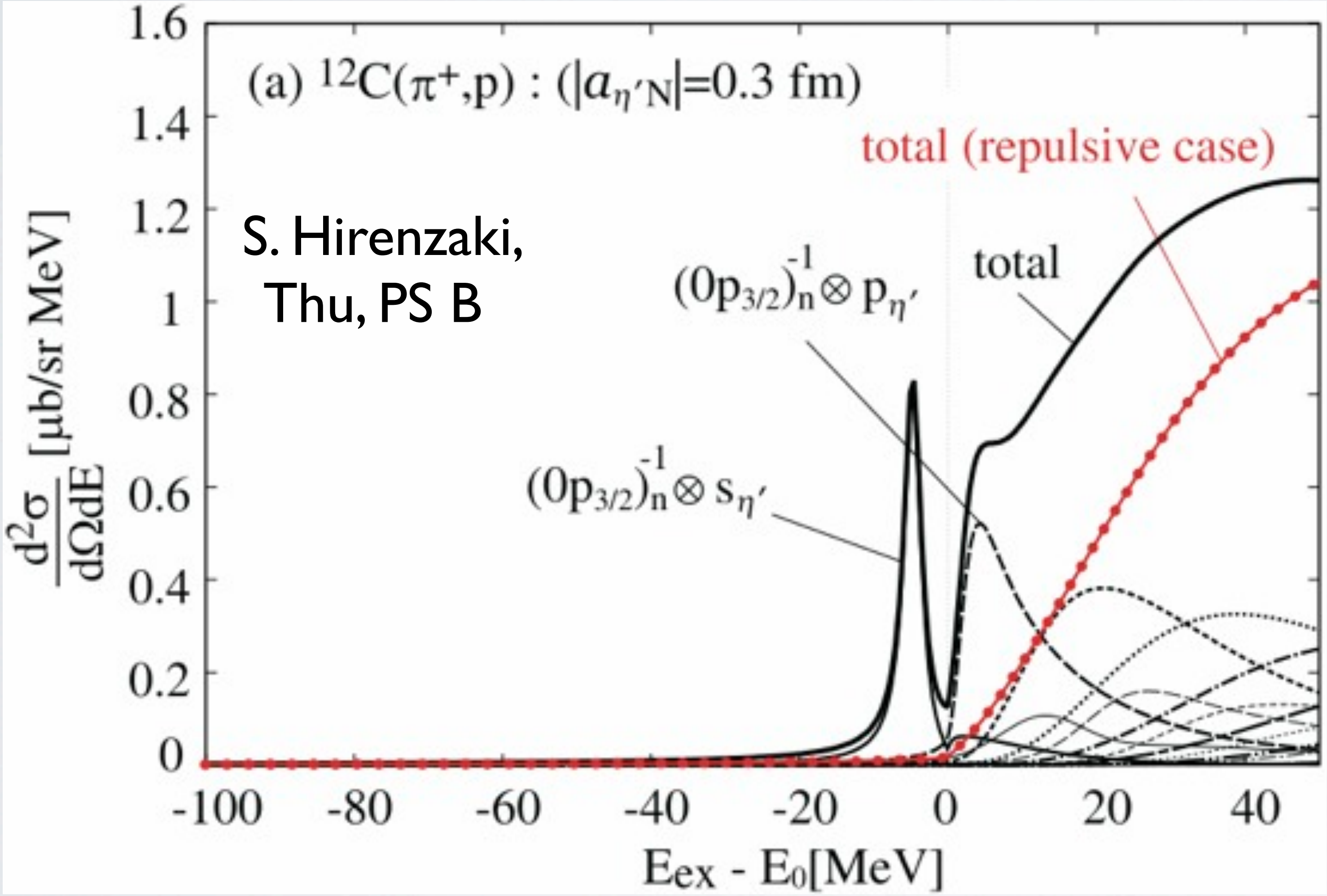

J-PARC

$^{12}C(\pi^+,p)\,\eta' X$ @ 1.8 GeV/c

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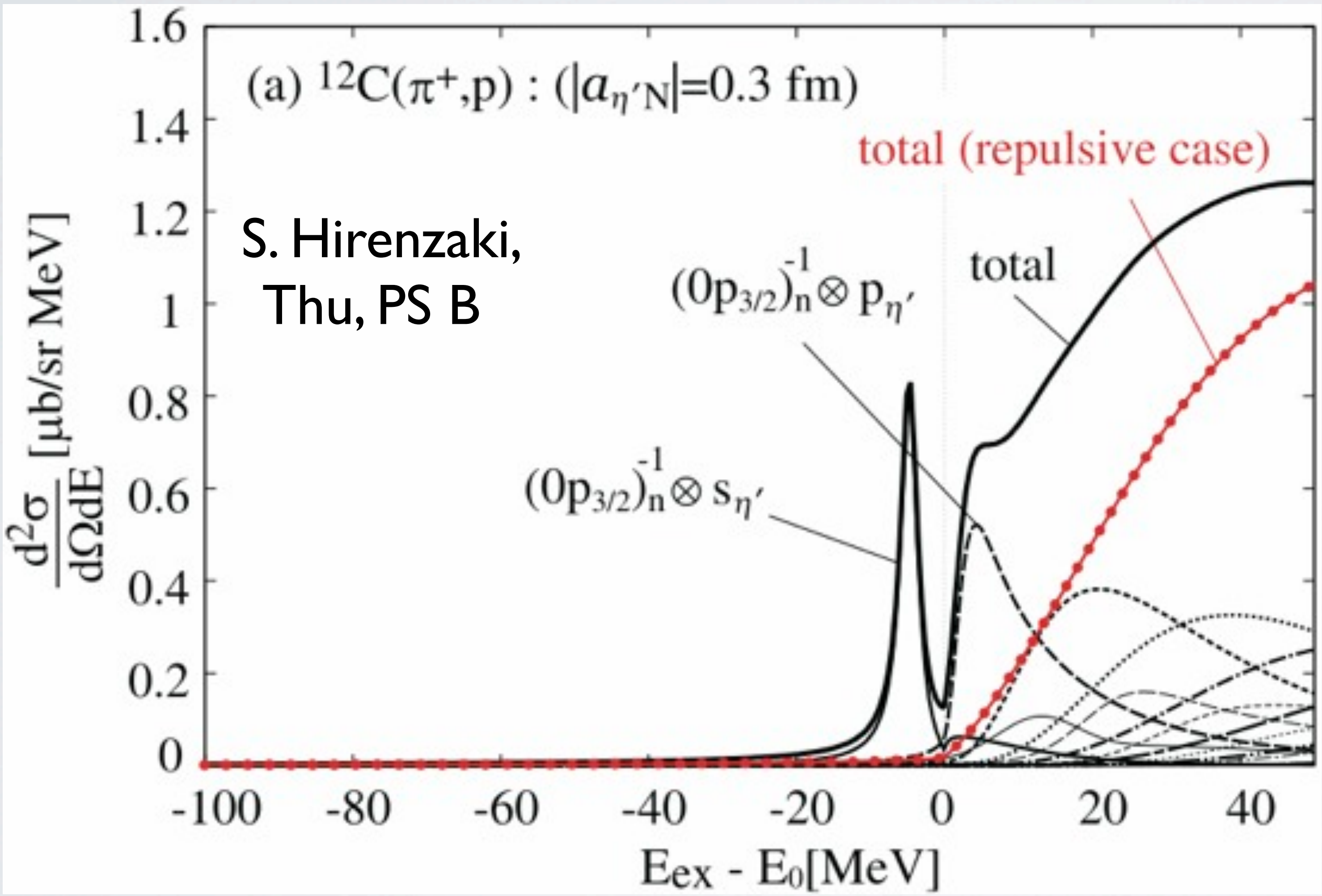

J-PARC

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GSI

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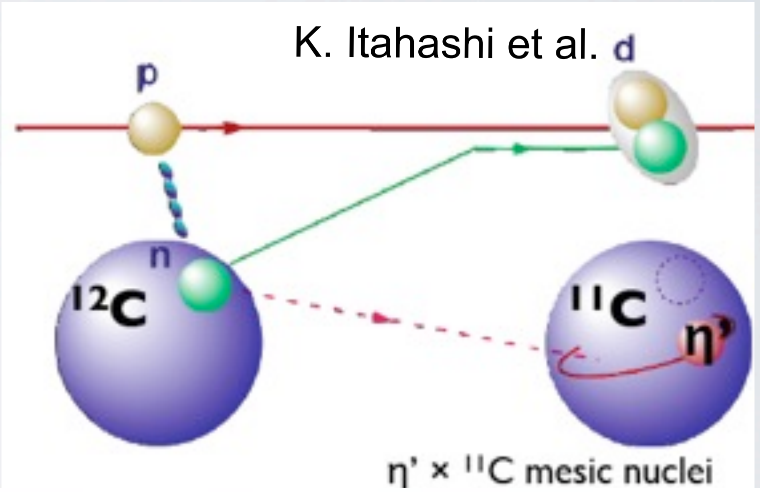

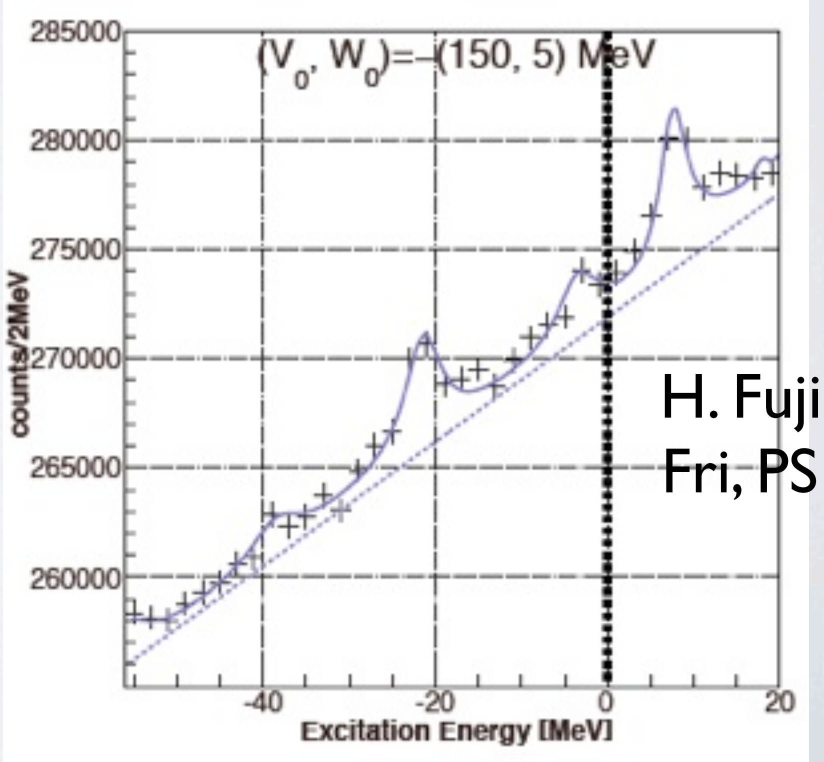

search for η’-bound states @ ELSA

$^{12}C(\gamma,\eta')X$ @ 1.5-3.1 GeV

estimated cross section: 5-10 nb/sr/MeV

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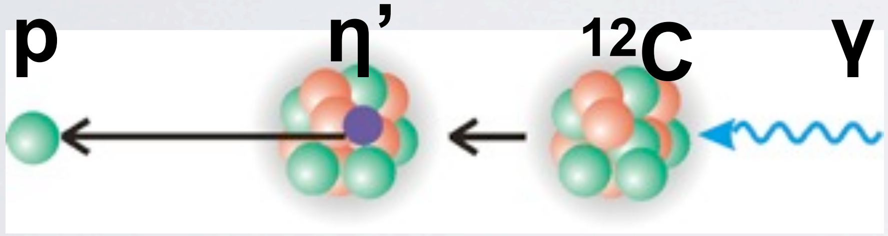

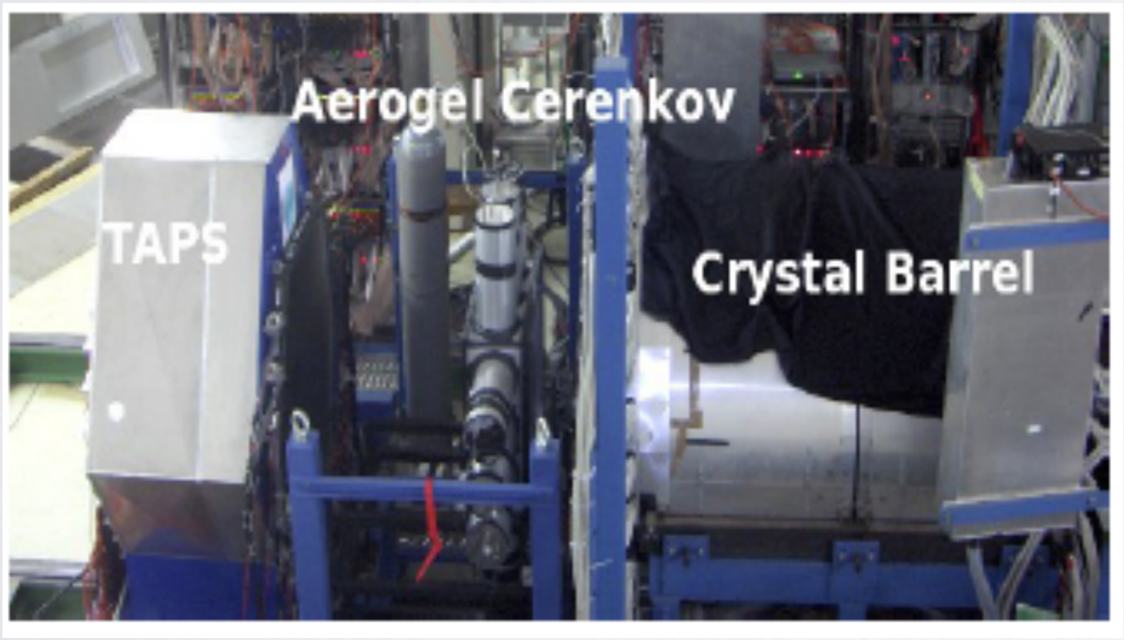

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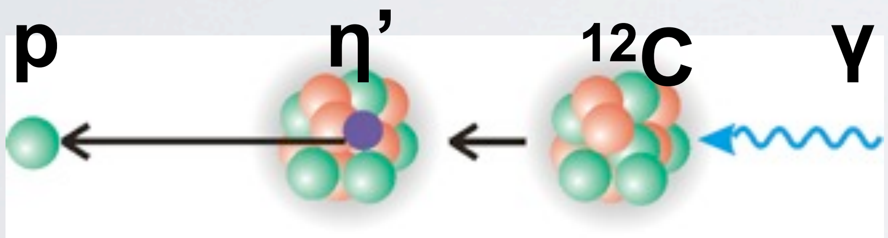

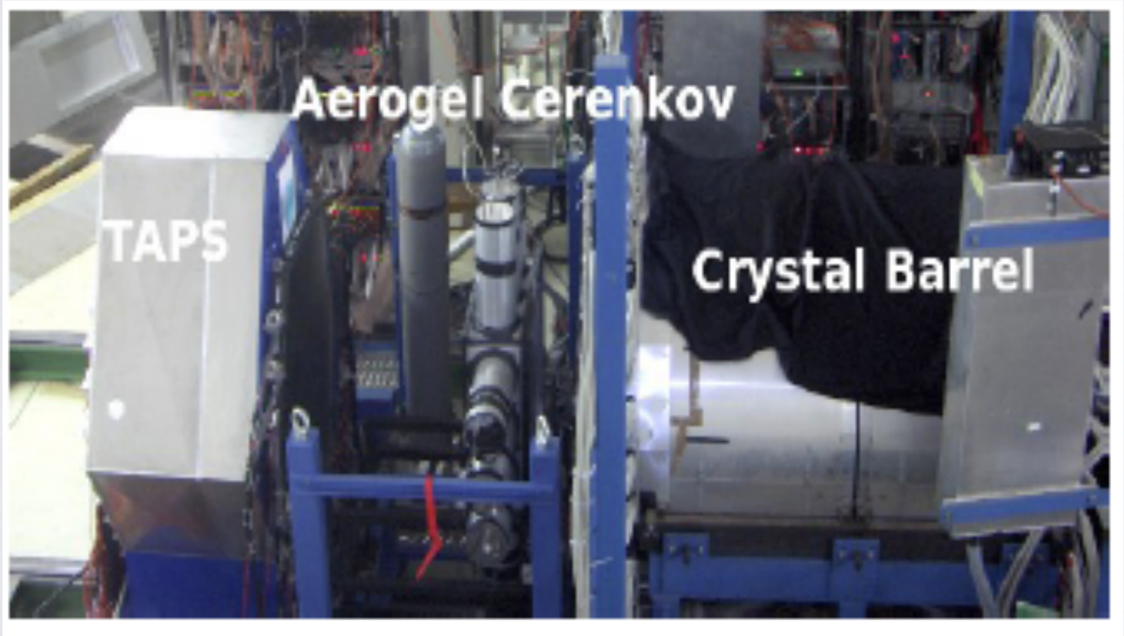

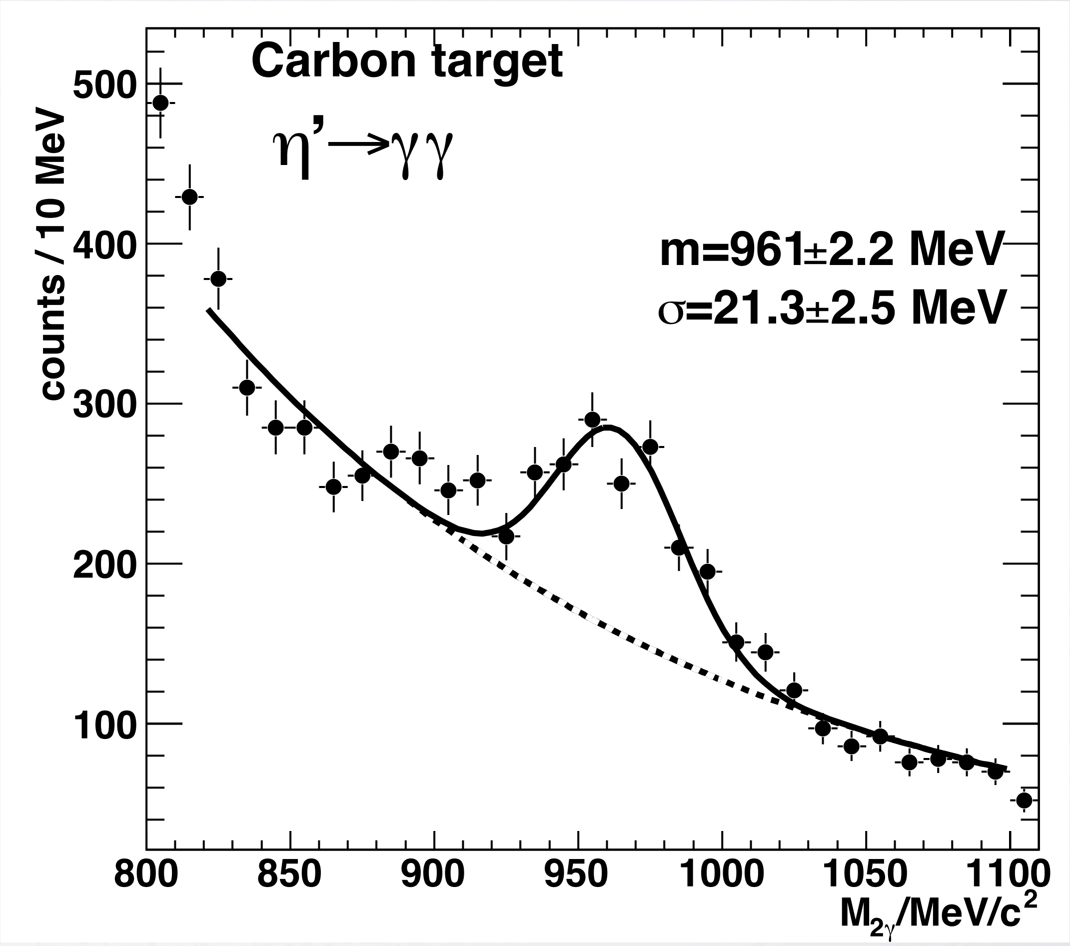

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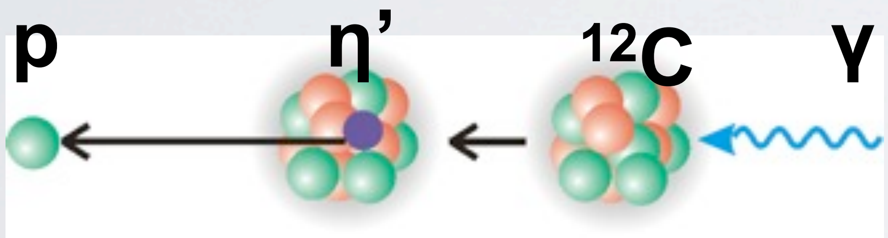

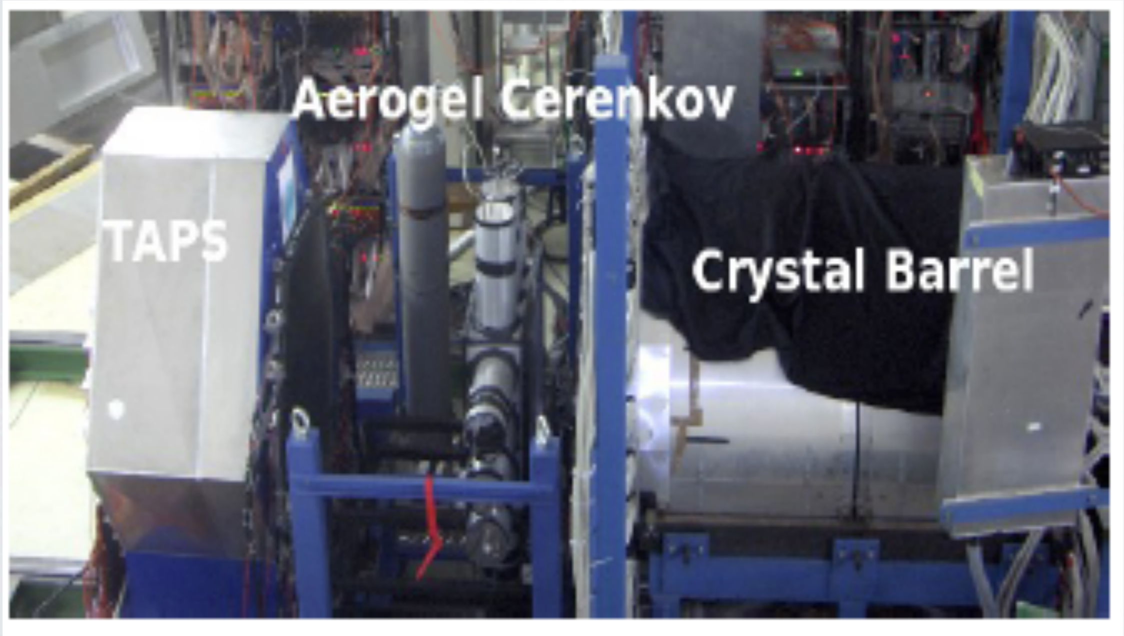

Experiment in 3rd.
TR16 funding period?