Joint SPHERE and JSPS Meeting 2010

September 4-6, 2010, Prague, Czech Republic

Volodymyr Magas

University of Barcelona, Spain

On the A dependence of the K* production in nuclei

In collaboration with

A. Ramos (Barcelona), E. Oset (Valencia)

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Project is in progress

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Main points

-The aim of this work is to propose a method to study the K* width in the medium

-Theoretical models predict a large increase of K* width in the medium (by the factor of 5 at $\rho = \rho_0$)

- Our approach is to study the *A* dependence of K* production in K- reactions with different nuclei

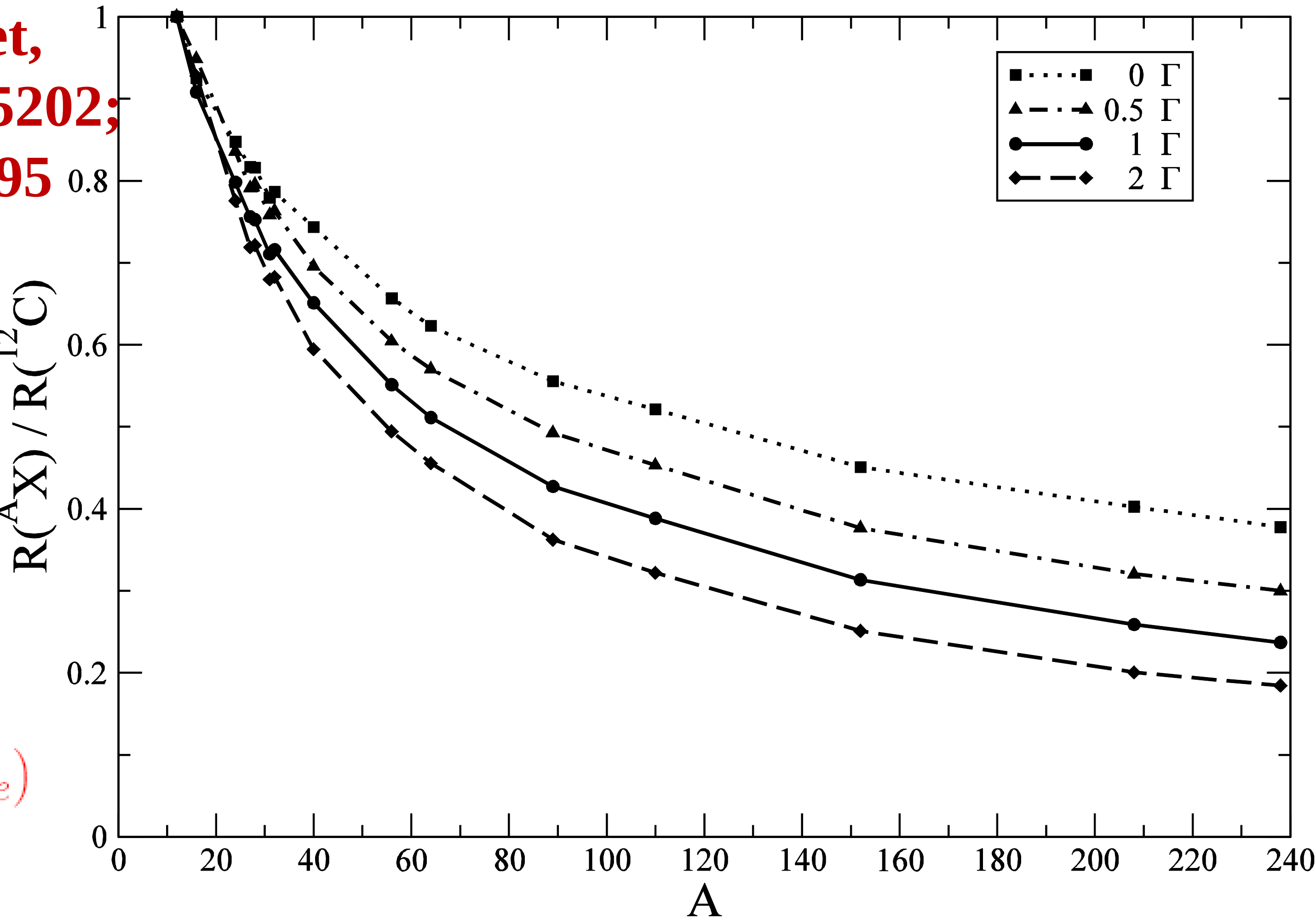
- We propose to use K- with momenta around 1500 MeV (slightly above threshold). This energy range is accessible at experimental facilities like J-PARC

Our earlier proposal:

"Measuring the φ meson width in the medium from p induced φ production in nuclei"

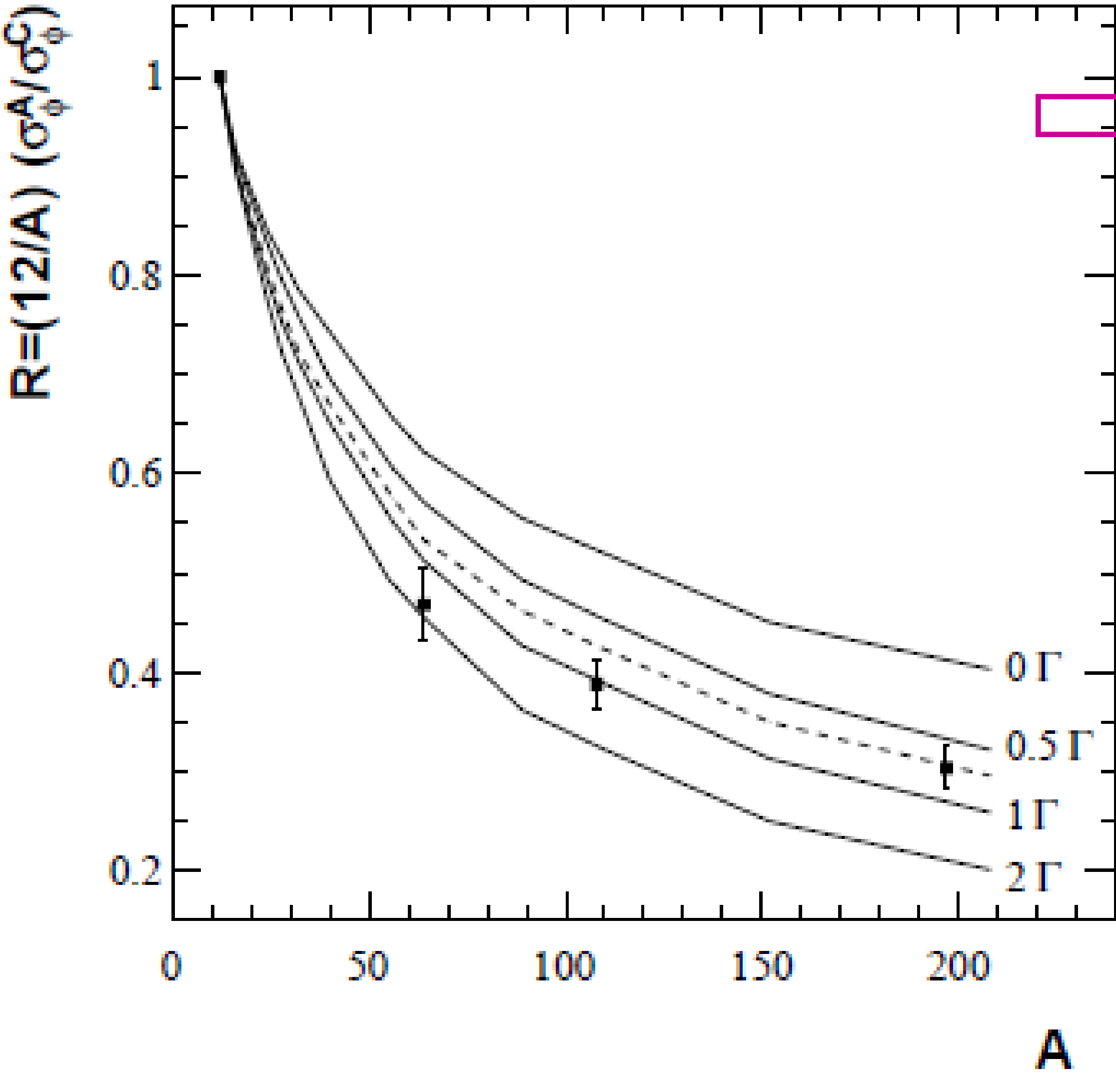
was based on similar philosophy

Magas, Roca, Oset, PRC71 (2005) 065202; NP A755 (2005) 495



$R \equiv \sigma_A/(A\sigma_{free})$

Such an experiment has been done at ANKE-COSY



$$\Gamma\left(p_{\varphi}=0,\rho=\rho_0\right)=27^{+5}_{-3}\,MeV$$

A. Polyanskiy et al., arXiv:1008.0232 [nucl-ex]

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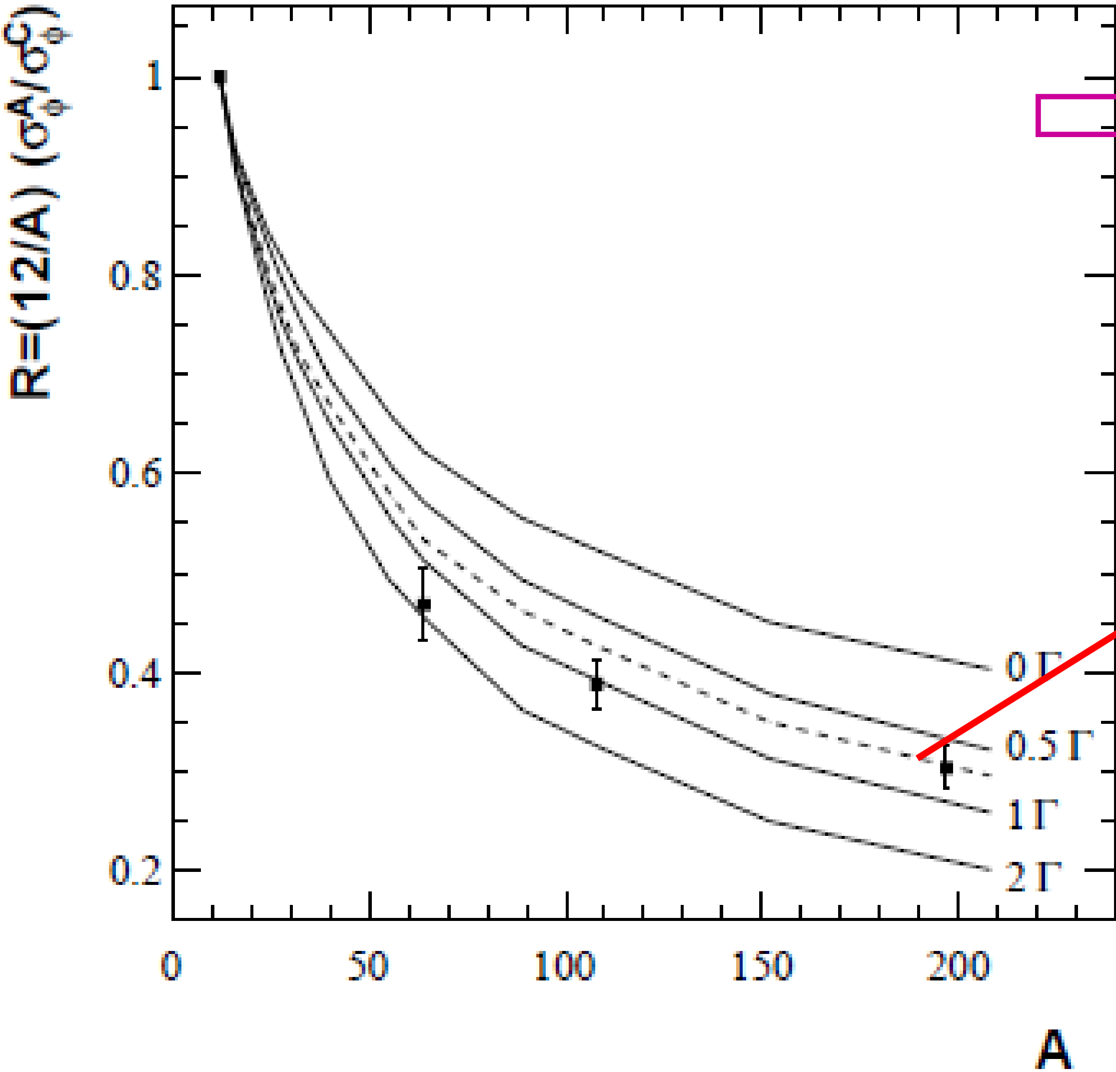

$$\Gamma\left(p_\varphi = 0, \rho = \rho_0\right) = 27^{+5}_{-3}\, MeV$$

$$\Gamma\left(p_\varphi = 0, \rho = \rho_0\right) = 45^{+17}_{-9}\, MeV$$

A. Polyanskiy et al., arXiv:1008.0232 [nucl-ex]

Monte Carlo simulation

$$\overline{K}^{-} + A \rightarrow \overline{K}^{*} + X$$

p_K = 1.5 GeV/c

- **K- propagation in the nucleus**
  - Quasi elastic scattering
  - One nucleon absorption
  - Two nucleon absorption

- **K* production**

  $K^- p \rightarrow K^{*-} p$ $K^- n \rightarrow K^{*-} n$

  $K^- p \rightarrow K^{*0} n$

- **K* propagation in the nucleus**
  - Free decay
  - Quasi elastic scattering
  - Absorption

- **K- propagation in the nucleus**
  - Quasi elastic scattering
  - One nucleon absorption
  - Two nucleon absorption

We can make use of a MC code developed for the
"The (K-,p) reaction on nuclei with in-flight kaons“
Magas, Yamagata-Sekihara, Hirenzaki, Oset, Ramos, PRC81 (2010) 024609; NP A835 (2010) 382

Our Monte Carlo simulation

Our input cross section are taken from Particle Data Group.

Quasielastic scatterings

$$\sigma_{K^-p\to K^-p} = 21.22 \text{ mb}\,, \quad \sigma_{K^-p\to K^0 n} = 7.15 \text{ mb}\,, \quad \sigma_{K^-n\to K^-n} = 18.5 \text{ mb}$$

One body kaon absorption

$$\sigma_{K^-p\to\pi^0\Lambda} = 4.32 \text{ mb}\,, \quad \sigma_{K^-p\to\pi^+\Sigma^-} = 1.76 \text{ mb}$$

$$\sigma_{K^-p\to\pi^-\Sigma^+} = 1.4 \text{ mb}\,, \quad \sigma_{K^-p\to\pi^0\Sigma^0} = 1.58 \text{ mb}$$

$$\sigma_{K^-n\to\pi^-\Lambda} = 6.35 \text{ mb}\,, \quad \sigma_{K^-n\to\pi^-\Sigma^0} = 0.97 \text{ mb}\,, \quad \sigma_{K^-n\to\pi^0\Sigma^-} = 1.15 \text{ mb}$$

Total: $\sigma_{total\,K^-p} = 51.7 \text{ mb}\,, \quad \sigma_{total\,K^-n} = 38 \text{ mb}\,.$

Since the total cross sections are larger than the sum of the channels we are using explicitly, we define

$$\sigma_{K^-p,n\to X} = 14.27 \text{ mb}\,, \quad \sigma_{K^-p,n\to X} = 10.0 \text{ mb}\,,$$

which take care about all the other possible reaction channels where no fast nucleons come out.

- **K* production**

  $K^- p \rightarrow K^{*-} p$　　　$K^- n \rightarrow K^{*-} n$

  $K^- p \rightarrow K^{*0} n$

Cross sections are unknown!!!

- **K* production**

  $K^- p \rightarrow K^{*-} p$ $K^- n \rightarrow K^{*-} n$

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as a first step

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- **K* production**

$K^- p \rightarrow K^{*-} p$ $K^- n \rightarrow K^{*-} n$

$K^- p \rightarrow K^{*0} n$

as a first step

$$R_A = \sigma_A^{K^*} / A$$

-The prime observable, depend on K* production cross section

Cross sections are unknown!!!

- **K* production**

$K^- p \rightarrow K^{*-} p$ $K^- n \rightarrow K^{*-} n$

$K^- p \rightarrow K^{*0} n$

as a first step

$$R_A = \sigma_A^{K^*} \big/ A$$

-The prime observable, depend on K* production cross section

*Staying **close to K* production threshold** and using **ratio of R's of different nuclei** we can remove dependence on the unknown K* production cross section*

$$R_A \big/ R_{^{12}C}$$

Also such a ratio strongly reduces experimental uncertancies

Monte Carlo simulation

K- propagation:

The probability of different reactions in a **δl** distance is given by

$\sigma_{QE}\rho\delta l$

$K^- p \to K^- p$

$K^- p \to K^0 n$

$K^- n \to K^- n$

$\sigma_{1N}^{abs}\rho\delta l$

$K^- N \to X / K^{*0}$

$C_{2N}^{abs}\rho^2\delta l$

$K^- NN \to \Lambda N$

$K^- NN \to \Sigma N$

$\sigma_{K^*}\rho\delta l$

$K^- p \to K^{*0} n$

$\cancel{K^-}$

close to threshold

$\cancel{K^-}$

$\cancel{K^-}$

$K^- \to K^{*0}$

Monte Carlo simulation

K- propagation:

The probability of different reactions in a **δl** distance is given by

$\sigma_{QE}\rho\delta l$

$K^- p \to K^- p$

$K^- p \to K^0 n$

$K^- n \to K^- n$

$\sigma_{1N}^{abs}\rho\delta l$

$K^- N \to X / K^{*0}$

$C_{2N}^{abs}\rho^2\delta l$

$K^- NN \to \Lambda N$

$K^- NN \to \Sigma N$

$\sigma_{K*}\rho\delta l$

$K^- p \to K^{*0} n$

$$\sigma_A^{K^*} = \int d^2 b dz \,\_\, \mathrm{P}_{K^- in}(b,z) \,\_\, \sigma_{K^*}\rho \,\_\, \mathrm{P}_{K^* out}(b,z) \sim$$

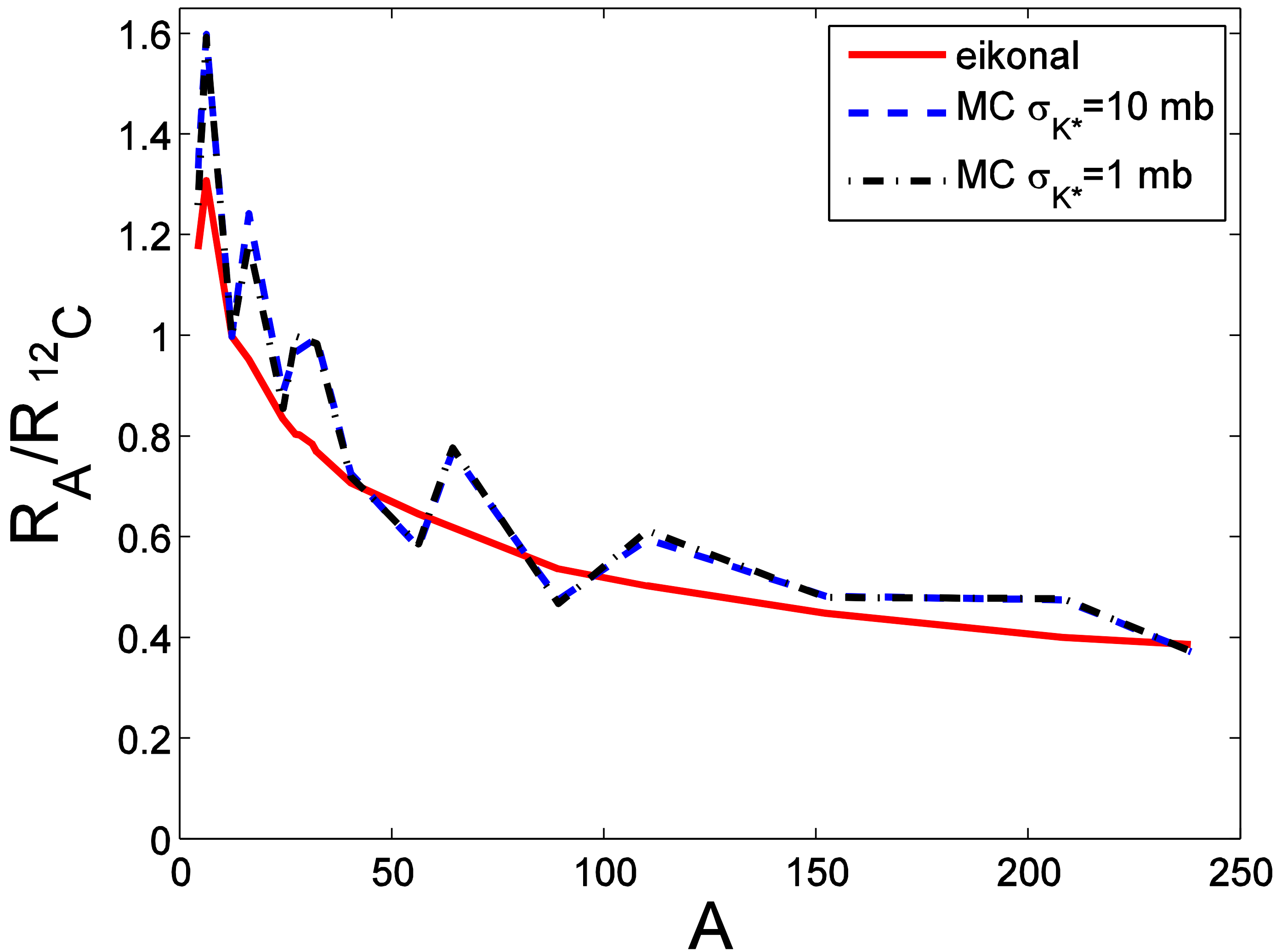
// eikonal

$$\sim \sigma_{K*} \cdot \int d^2 b dz \cdot e^{-\int_{-\infty}^{z} dz' (\sigma_{QE}\rho + \sigma_{1N}^{abs}\rho + C_{2N}^{abs}\rho^2)} \cdot \rho \cdot \mathrm{P}_{K* out}(b,z)$$

Monte Carlo simulation

K- propagation

$p_K = 1.5$ GeV/c



➢ K* propagation in the nucleus

- Free decay → probability to reconstruct K* is given by

$$P_{\pi}^{out} * P_{K}^{out}$$

- Quasi elastic scattering
- Absorption

Monte Carlo simulation

$\Pi(p_{K^*}, \rho)$ - is K* selfenergy in nuclear medium

$$\Gamma = -\frac{\Im m \Pi}{E_{K^*}} \equiv \frac{dP}{dt}$$

The probability of loss of flux per unit length

$$\frac{dP}{d\ell} = \frac{dP}{v dt} = -\frac{\Im m \Pi}{p_{K^*}}$$

Monte Carlo simulation

$$\Im m\Pi_{tot} = \Im m\Pi_{free} + \Im m\Pi_{QE} + \Im m\Pi_{abs}$$

$$\Im m\Pi_{free} = -\Gamma \cdot E_{K^*}, \quad \Gamma_{free}=50\ \text{MeV}$$

K* selfenergy in nuclear medium

Basic model:

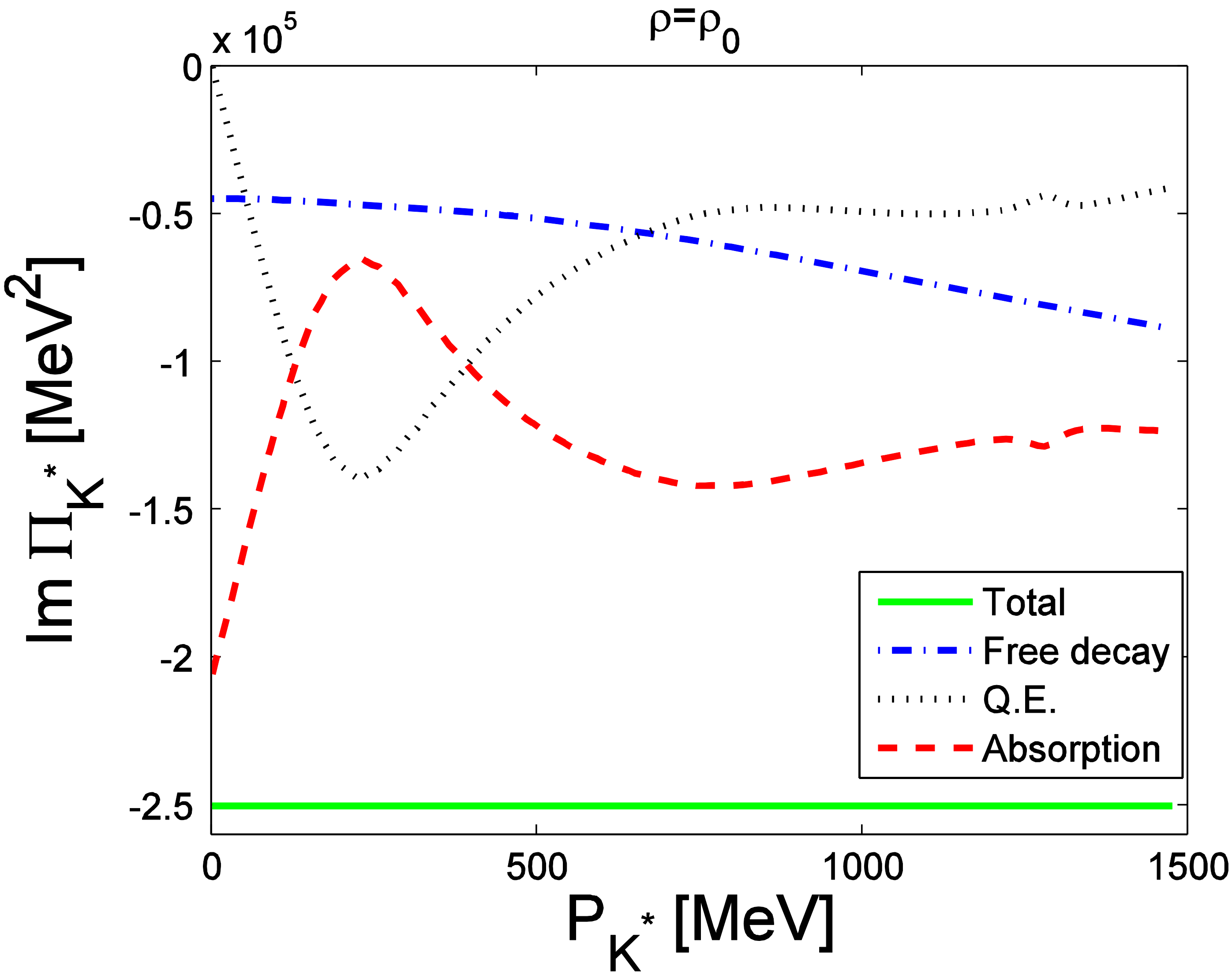
Oset, Ramos, EPJ A44 (2010) 445

K* in the medium:

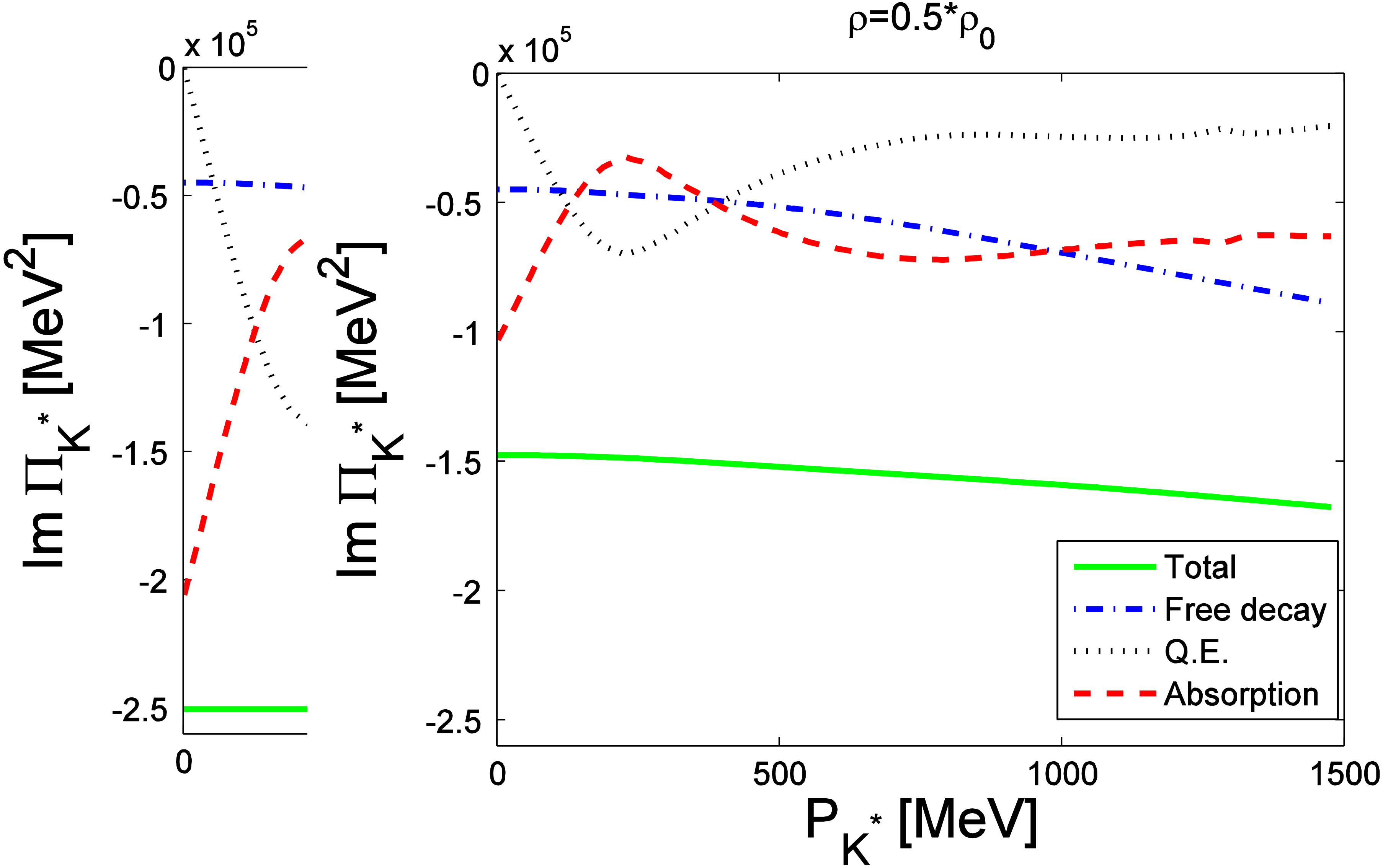
Tolos, Molina, Oset, Ramos, arXiv:1006.3454 [nucl-th]

$$\left.\begin{aligned}
&\Im m\Pi_{tot} = \Im m\Pi_{free} + (-2.5\cdot 10^5 - \Im m\Pi_{free})\,\rho/\rho_0 \\
&\Im m\Pi_{QE} = -\frac{q^{CM} M_N}{4\pi\sqrt{s_{K^*N}}}\left|t_{\bar{K}^*N\to\bar{K}^*N}\right|^2 \rho \\
&\Im m\Pi_{abs} = \Im m\Pi_{tot} - \Im m\Pi_{QE} - \Im m\Pi_{abs}
\end{aligned}\right\}\ \text{simplified model}$$

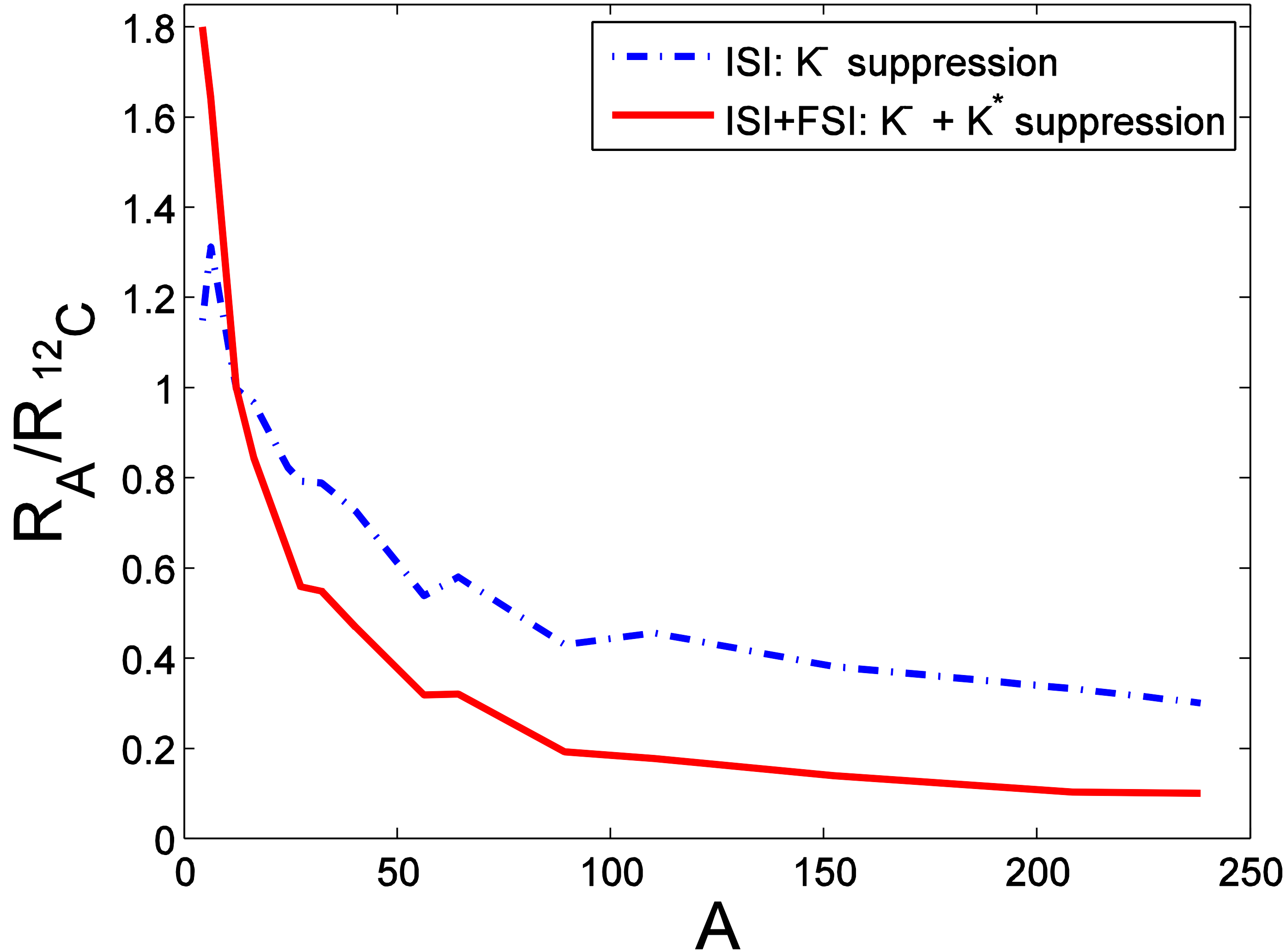
K* selfenergy in nuclear medium



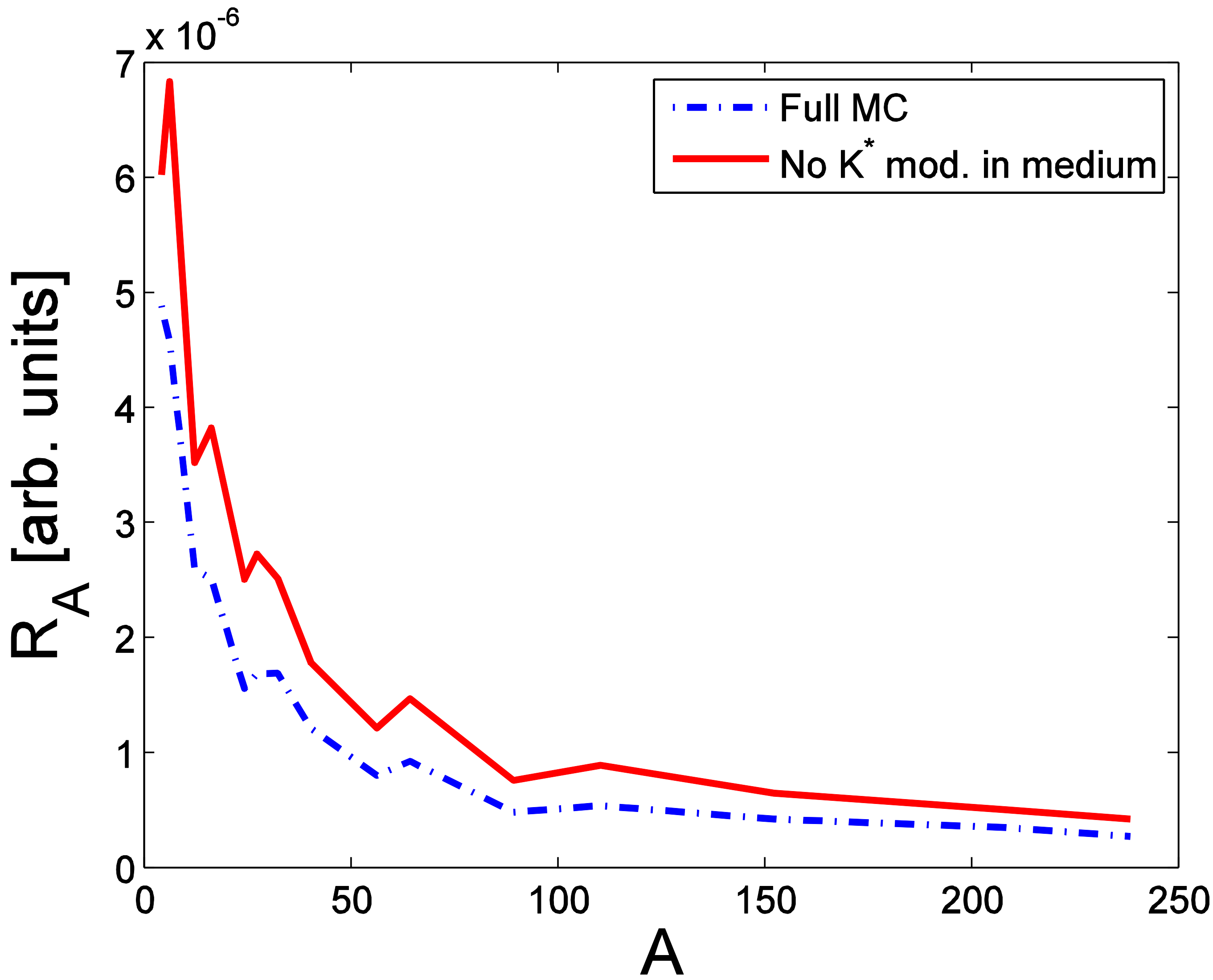
K* selfenergy in nuclear medium



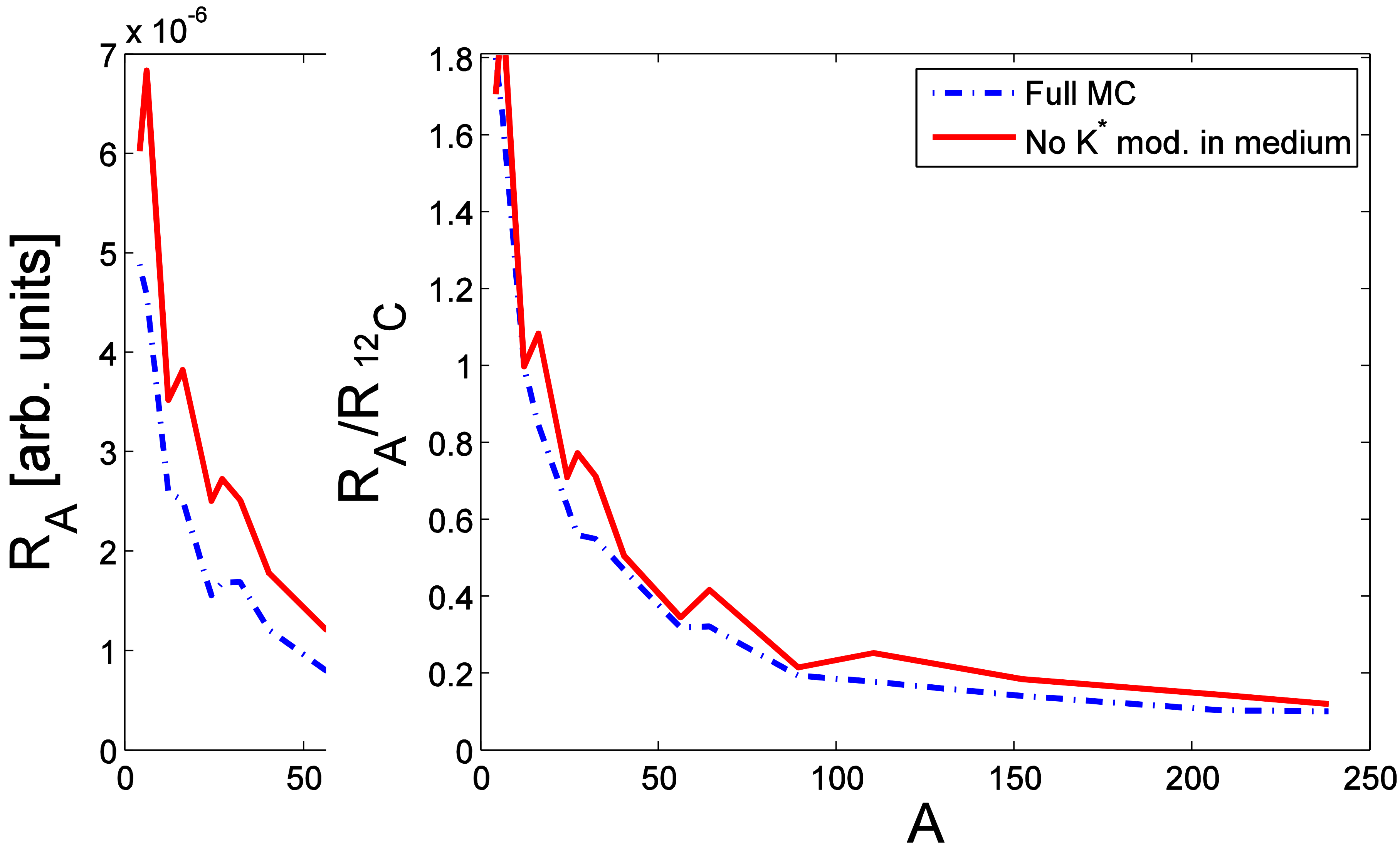
Monte Carlo simulation - Results



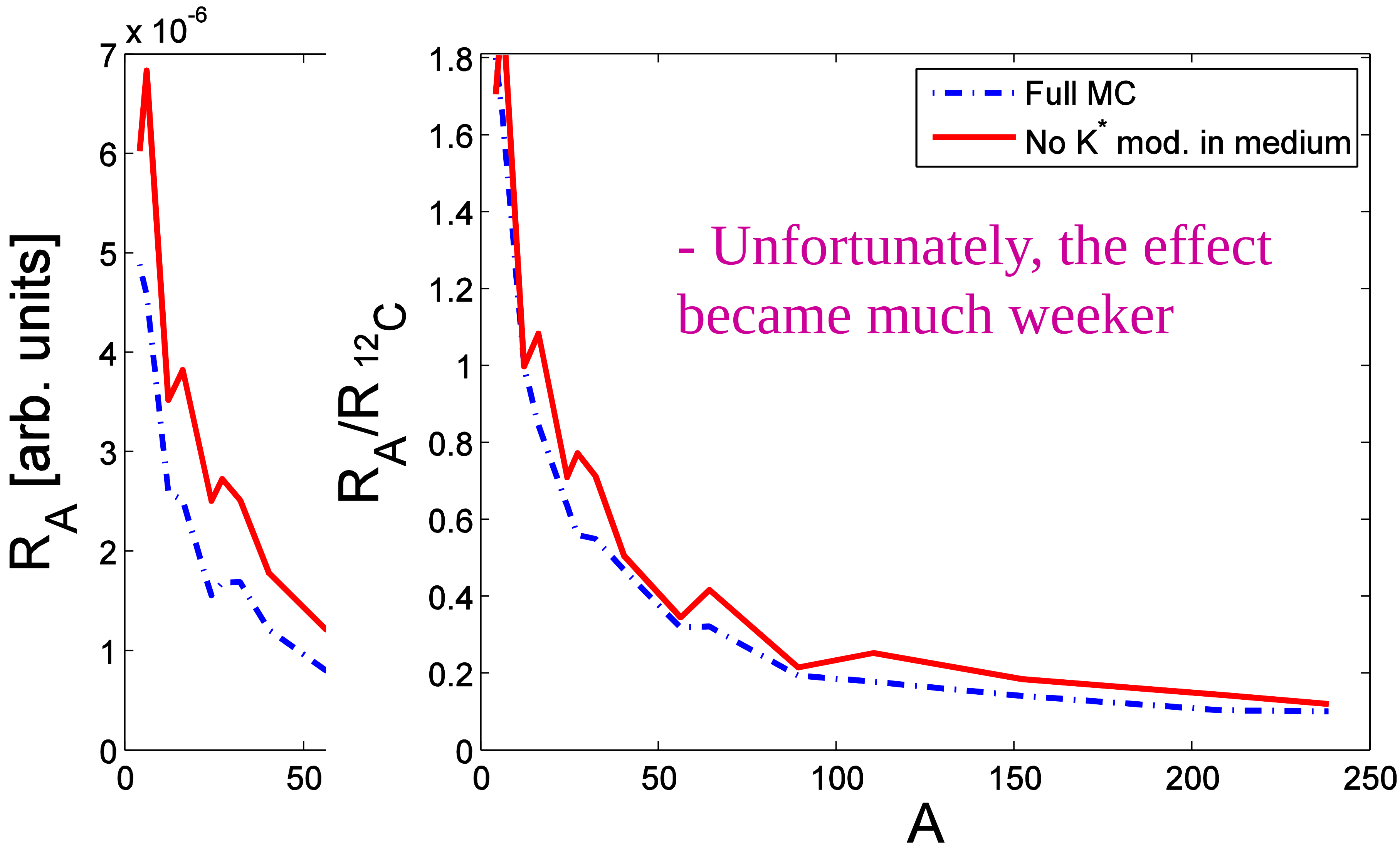
Monte Carlo simulation - Results



Monte Carlo simulation - Results

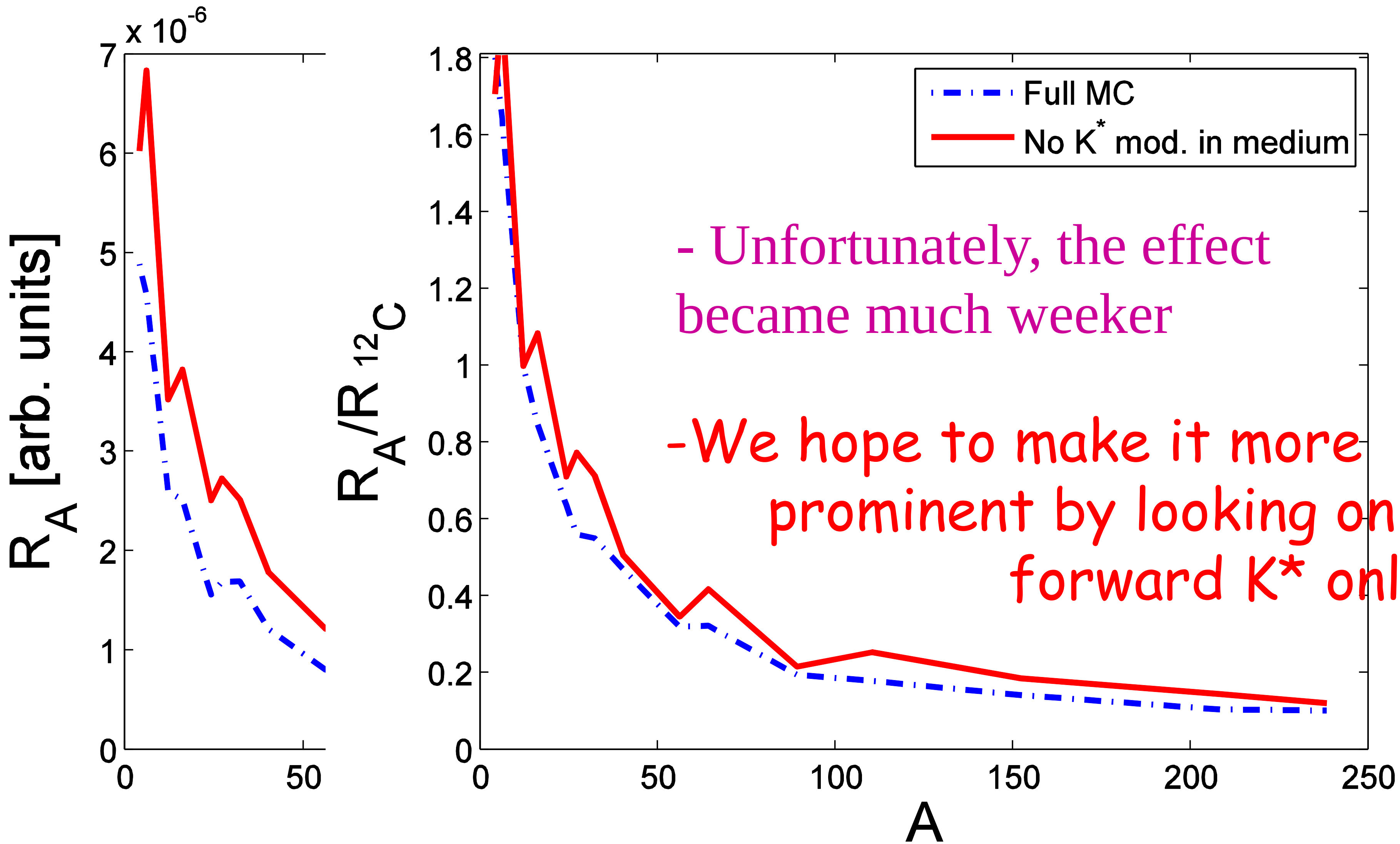


Monte Carlo simulation - Results



- Unfortunately, the effect became much weeker

Monte Carlo simulation - Results



- Unfortunately, the effect became much weeker

-We hope to make it more prominent by looking on forward K* only

Conclusion

We are exploring the A dependence of the relative K* production in nuclei in K- A collisions

We suggest for the experiment an energy range accessible at J-PARC

Our results show that the modification of K* width in nuclear medium may have sizeable effect in such reactions

Project is in progress

Results

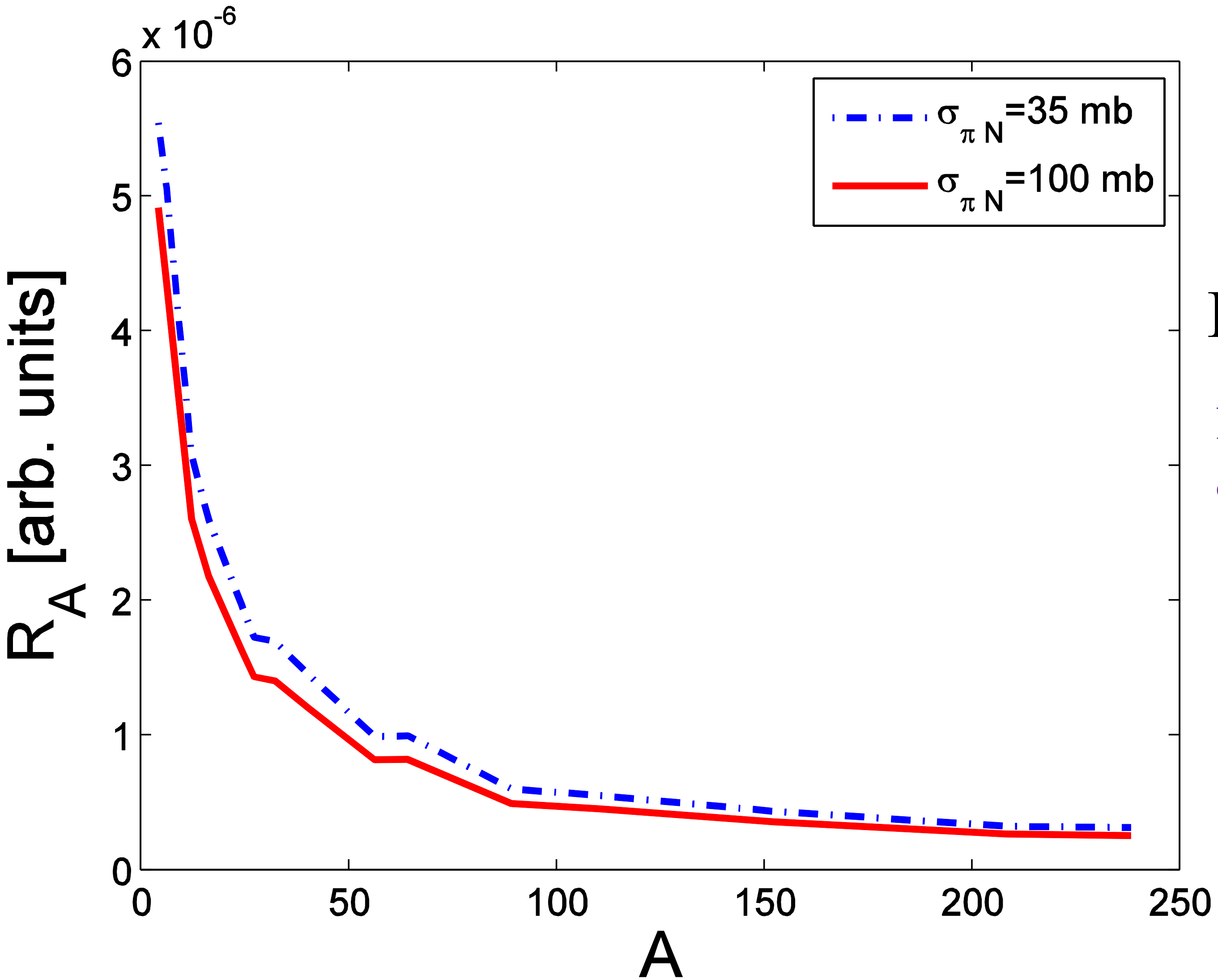
For the asymmetric nuclei $N \neq Z$ we need a weighting factor

$$\frac{(N\sigma_{pn,\phi} + Z\sigma_{pp,\phi})/A}{(\sigma_{pn,\phi} + \sigma_{pp,\phi})/2}$$

Some models predict $\sigma_{pn,\phi}/\sigma_{pp,\phi} \approx 5$
(A. I. Titov et al., EPJ A **7** (2000) 543)

Then for very asymmetric nucleus like ^{238}U the weighting factor is 1.15

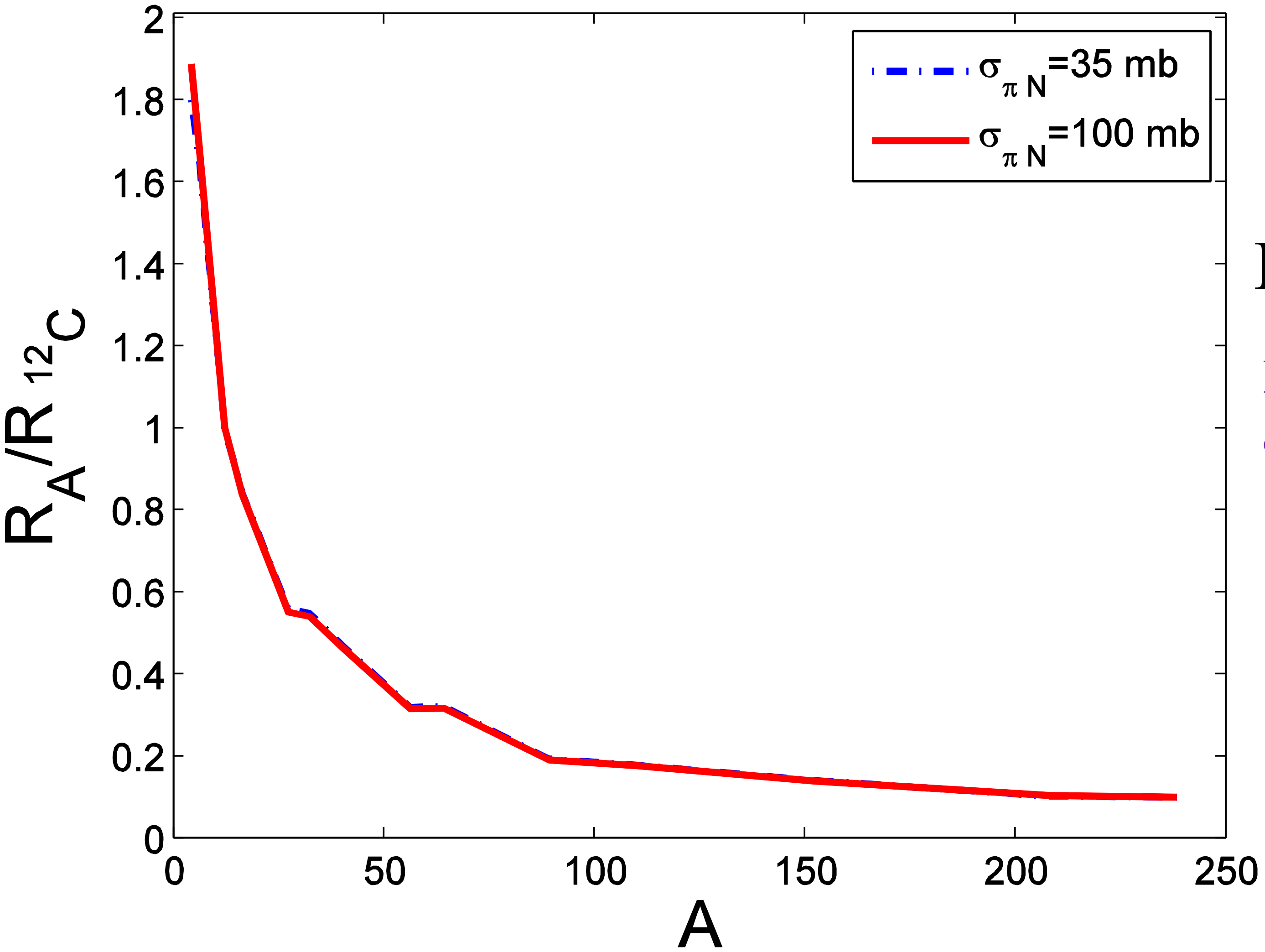
Monte Carlo simulation - tests



$$P_\pi = e^{-\int d\ell \sigma_{\pi N} \rho}$$

Pion survival prob.
after K* → πK decay

Monte Carlo simulation - tests



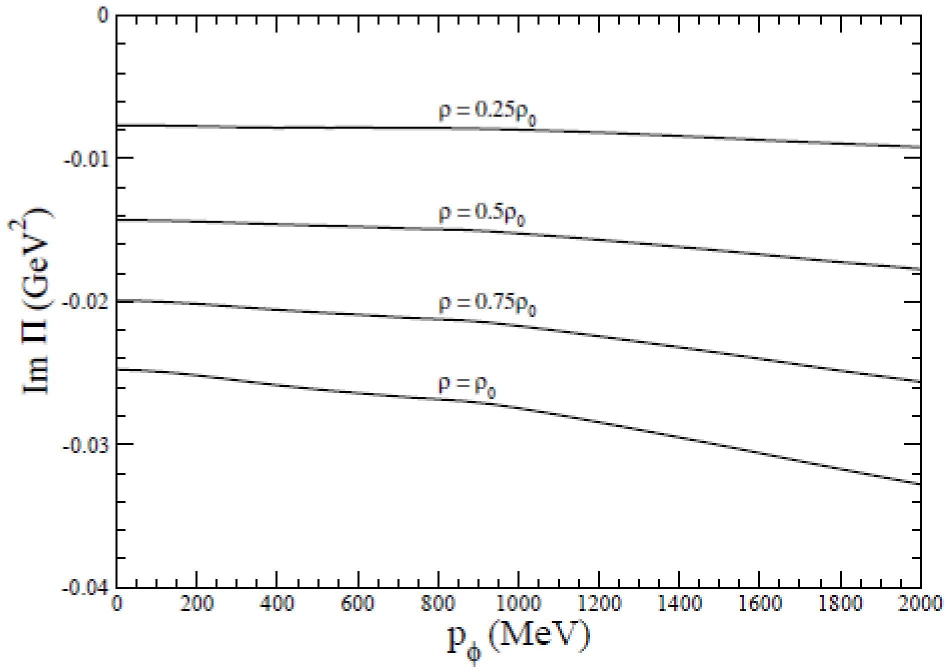
$$P_\pi = e^{-\int d\ell\, \sigma_{\pi N}\, \rho}$$

Pion survival prob. after K* → πK decay

$$R_A \big/ R_{^{12}C}$$

ratio strongly reduces experimental uncertancies

Imaginary part of ϕ selfenergy in medium



Imaginary part of the in medium ϕ selfenergy (does not include a free part) as a function of the momentum of the ϕ and the nuclear density. For a ϕ at rest and $\rho = \rho_0$ this corresponds to a ϕ in the medium width correction of 24 MeV. From D. Cabrera et al., NPA **733** (2004) 130.

Our Monte Carlo simulation

Two nucleon kaon absorption:
$K^- NN \to \Lambda N$ and $K^- NN \to \Sigma N$,
with all possible charge combinations

We assume:

1) The probability per unit length of the two nucleon absorption is given by:

$$P_{K^-NN} = C_{abs}\rho_N^2$$

2) Total two body absorption is 20 % of the one body absorption at about nuclear matter density (this can be guessed from data of K^- absorption in ^4He - Katz, et al., PRD 1(70) 1267)

$$\Rightarrow C_{abs} \approx 6\ fm^5$$

Monte Carlo simulation - Results