Measuring the J/Ψ-Nucleon dissociation cross section with PANDA

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on behalf of
PANDA collaboration

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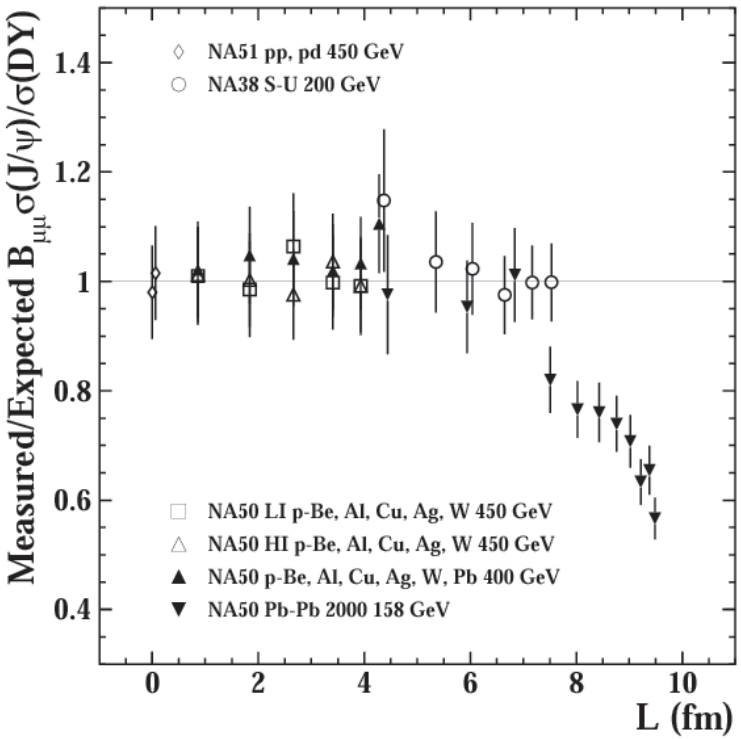
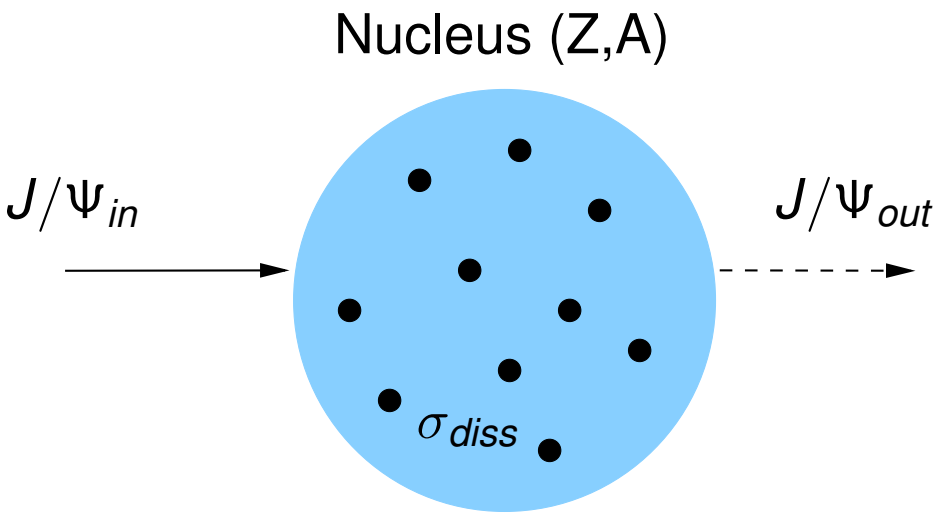
Motivation

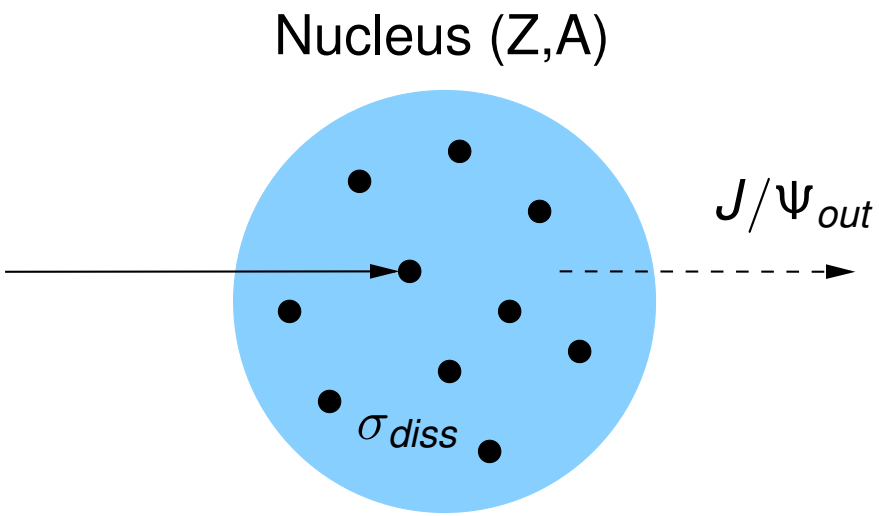
- J/Ψ-nucleon dissociation cross:
  Probability of J/Ψ to break up when moving through nuclear matter.
- Charme in medium - fundamental parameter
- Issue in heavy ion research
  Anomalous suppression observed in central HI collisions
  Probable indication of existence of Quark-Gluon-Plasma



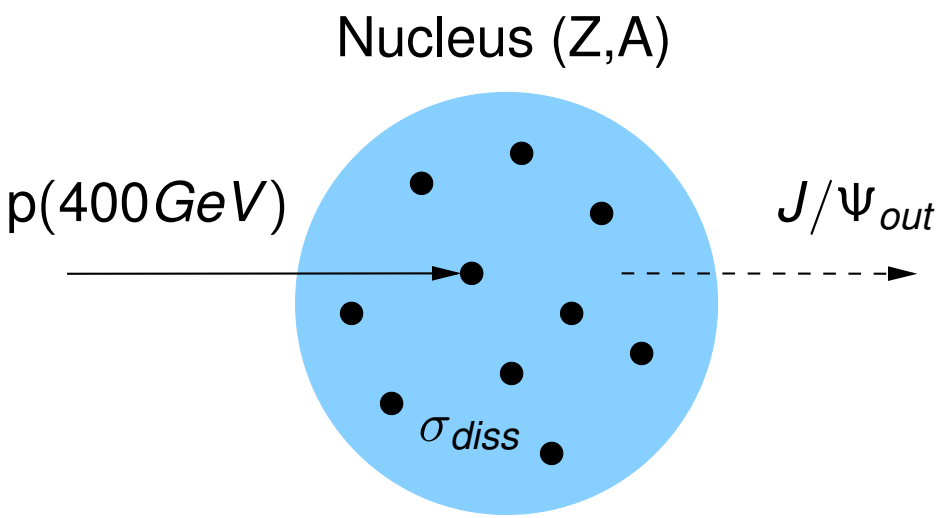
Experimental approaches



Experimental approaches

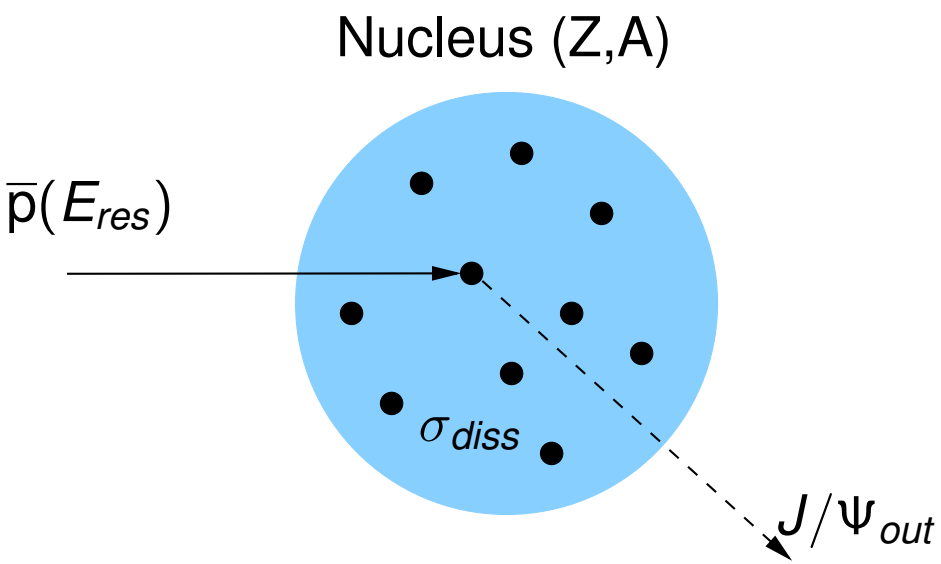


Experimental approaches



- *NA50 collaboration*, Eur. Phys.J.C 48 (2006) 329
- Production of J/Ψ
- Interpretation of results ambiguous because mixed with other effects
- Large momenta, feed down from other states, interaction with co-movers
- $\sigma_{diss} \approx 4.5\ mb\ (1 - 7\ mb)$

Experimental approaches



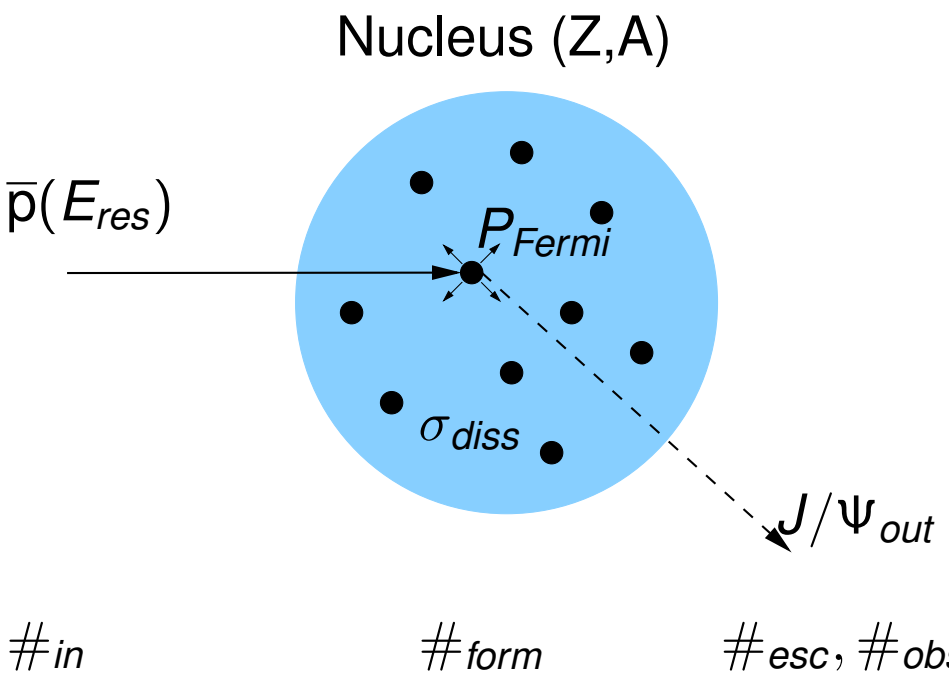
- *K.K. Seth*, A Unique way to Measure Charmonium-Nucleon Cross Sections, Hirschegg, 2001
- Formation of J/Ψ
- Avoid effects from large momenta, feed down, co-movers
- **At FAIR with PANDA**

Measurement of σ_{diss}

$$\#_{esc} = \#_{form} \cdot (1 - \sigma_{diss} \cdot \langle \rho L \rangle)$$

$$\sigma_{diss} = \frac{1}{\langle \rho L \rangle} \cdot \left[1 - \frac{\#_{esc}}{\#_{form}} \right]$$

modeling
measurement



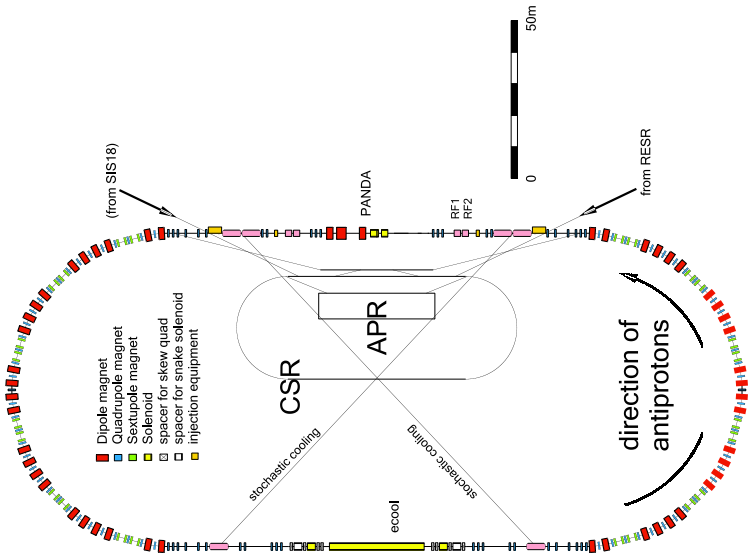
$$\#_{obs} = \#_{esc} \cdot br \cdot f_{eff}$$

$$\#_{form} = \mathcal{F}(.,.,.,.) \cdot \#_{in}$$

HESR and PANDA at FAIR

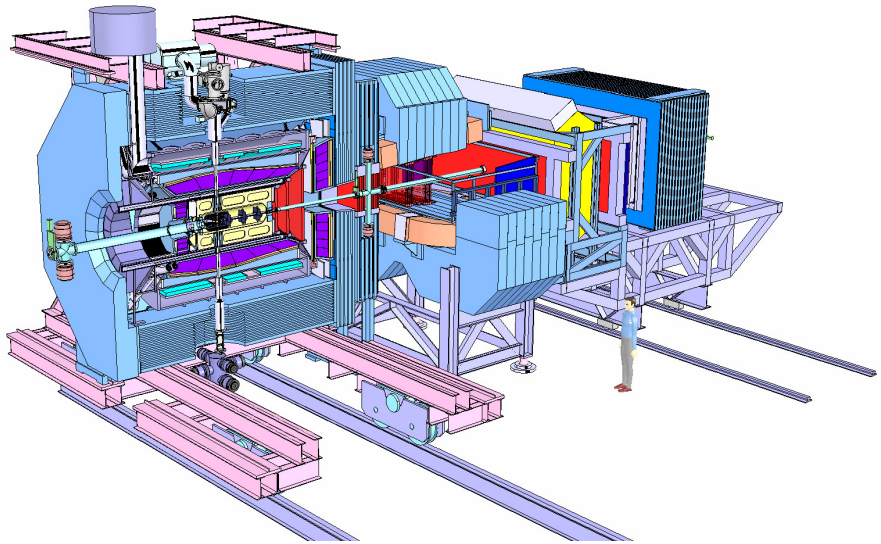
HESR

- $P_{\bar{p}}$: 1.5 - 15 GeV/c
- HI and HR mode
- $\frac{\Delta P_{\bar{p}}}{P_{\bar{p}}} \geq 2 \cdot 10^{-5}$
- $L \leq 10^{32}\ 1/cm^2/s$



PANDA

- 4π coverage
- Charged and neutral particle identification
- Cluster jet and solid targets



Questions to answer

- How can $\#_{in}$ be determined
- How can $\#_{esc}$ be measured
- How accurately can $\#_{form}$ and $\langle \rho L \rangle$ be computed

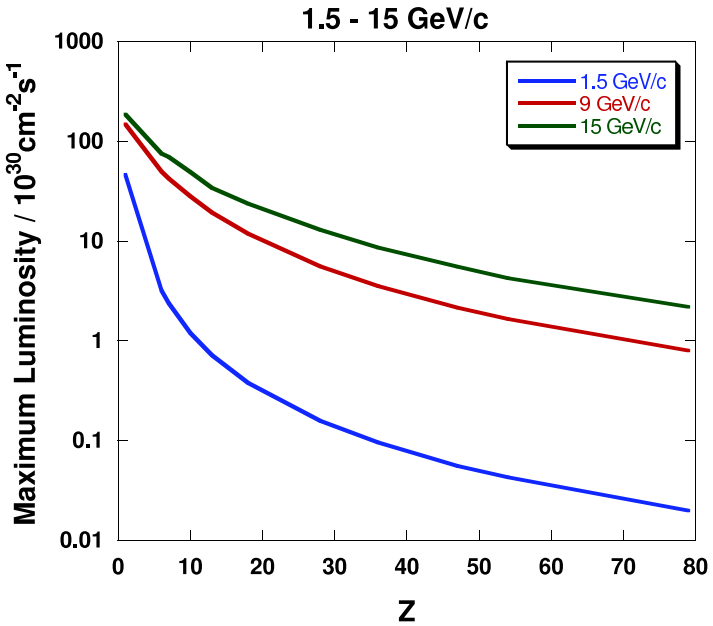
Measurement of $\#_{esc}$

- $\overline{p} + A \rightarrow J/\Psi \rightarrow l^+ l^-$
- cross sections in the order of 100 pb
- total cross section in the order of 1 b
- $\rightarrow$ need background suppression of $> 10^{10}$
- exploit topology of signal events to enhance S/N
- Combination of cuts allows to efficiently suppress background ($< 10^{-10}$)

PANDA Physics Performance Report, arXiv:0903.3905

- How long will it take?
  - $\sigma_{obs} \approx 100\ pb$, $L \approx 10^{30}$

$\rightarrow$ a few J/Ψ per day!



Computation of $\#_{form}$

ideal case: $\Delta P_{\overline{p}} = 0$, $P_p = 0$

$$\sigma_{BW}(E_{cm}) = \frac{2J+1}{(2S_1+1)(2S_2+1)} \frac{4\pi}{k^2} \left[\frac{(\Gamma/2)^2}{(E_{cm} - m_{J/\psi})^2 + (\Gamma/2)^2} \right] B_{in} B_{out}$$

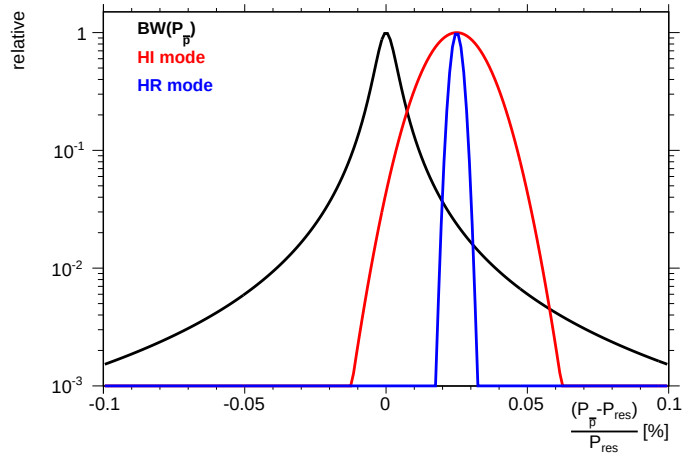
- $m_{J/\psi} = 3096.916 \pm 0.011$ MeV, $\Gamma = 0.0932 \pm 0.0021$ MeV

  (*Particle Data Group*, Physics Letters B667, 1 (2008)
- $B_{in} B_{out} = (1.14 \pm 0.2) \times 10^{-4}$

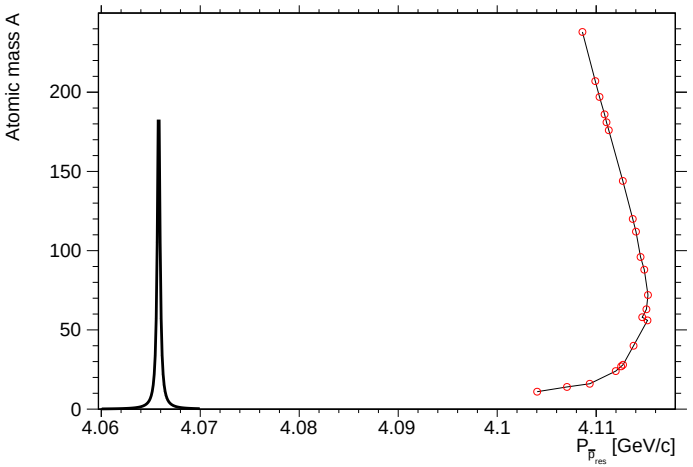
  (*E760 collaboration*, Phys. Rev. D 47 (1993) 772)
- $\rightarrow BW(m_{J/\psi}) = 280$ nb

Computation of $\#_{form}$

1. complication: $\Delta P_{\bar{p}} \neq 0$



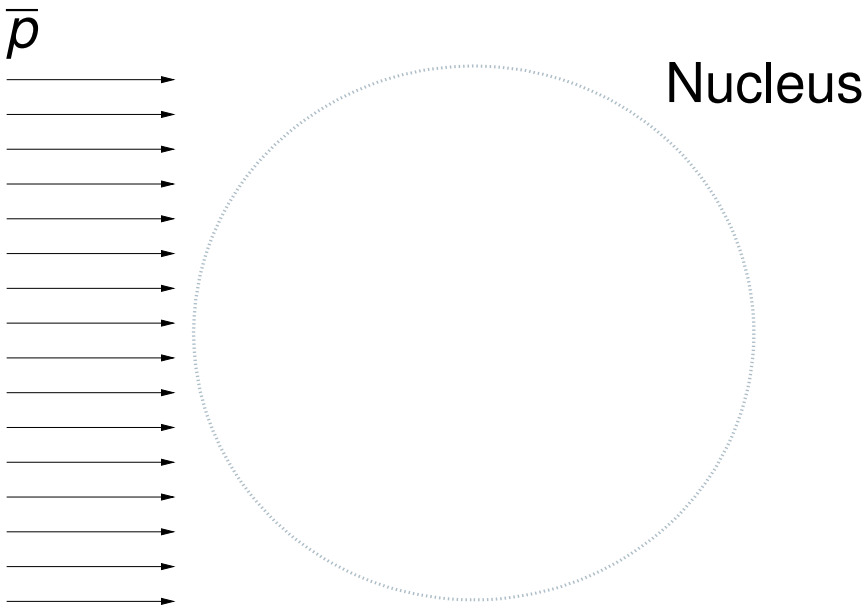
2. complication: Nuclear binding energy, in-medium mass shift?



3. complication: $P_{\bar{p}} \neq 0$, Fermi motion

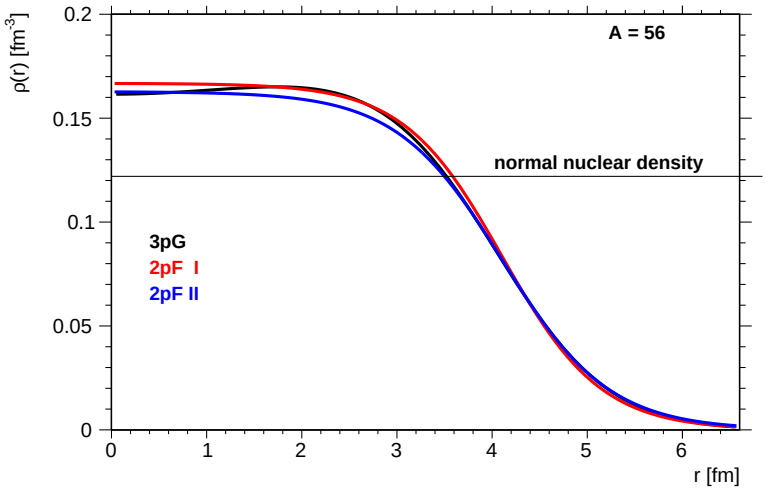
$$P_F = \hbar(3\pi^2 \frac{Z}{V})^{1/3} \approx 250 MeV/c$$

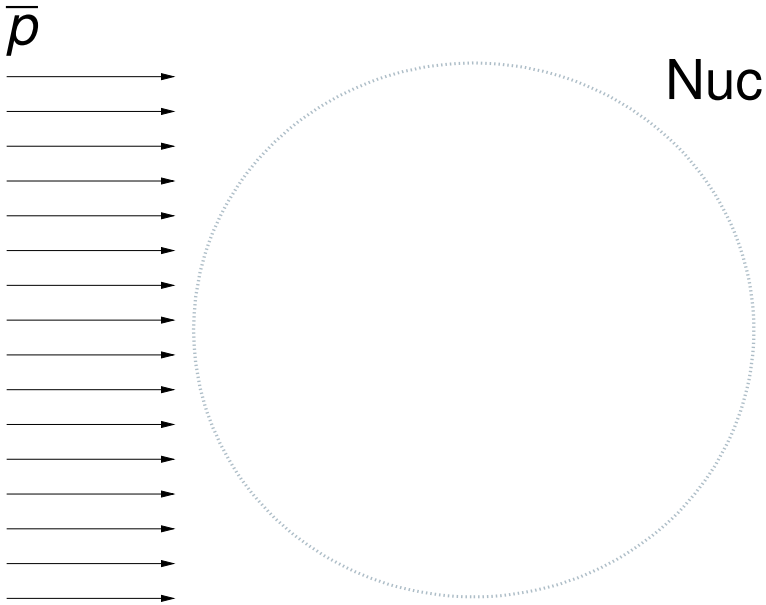
Computation of $\#_{form}$



Computation of $\#_{form}$

H. de Vries et al. *Atomic Data and Nuclear Tables* **36** (1987) 495





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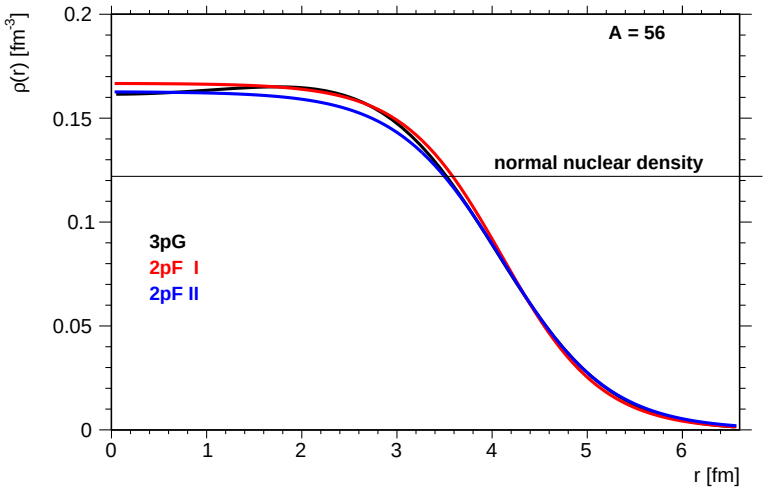

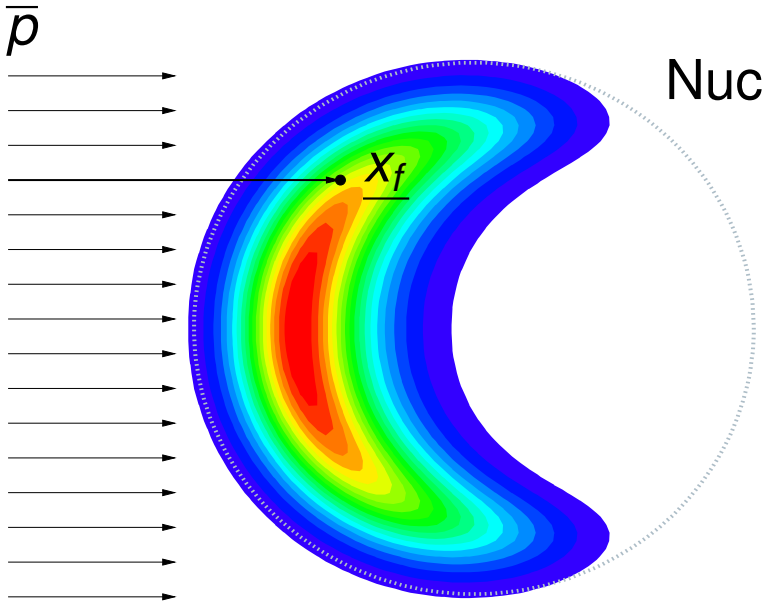

$$dx_f \propto dN/dz$$

Computation of $\#_{form}$

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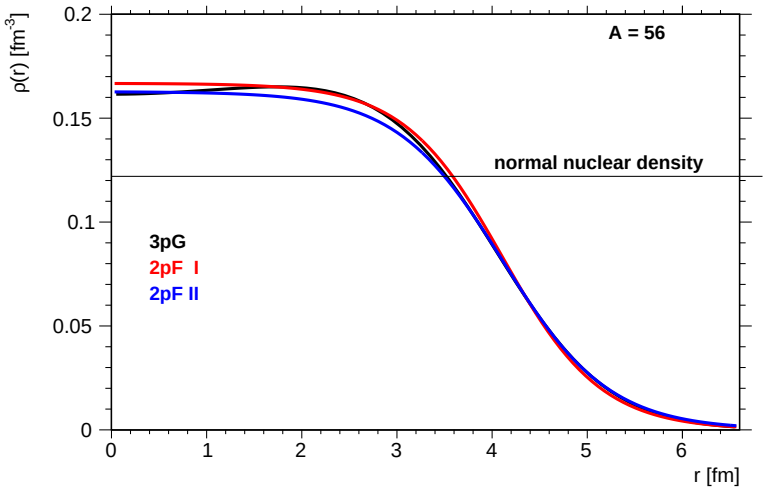
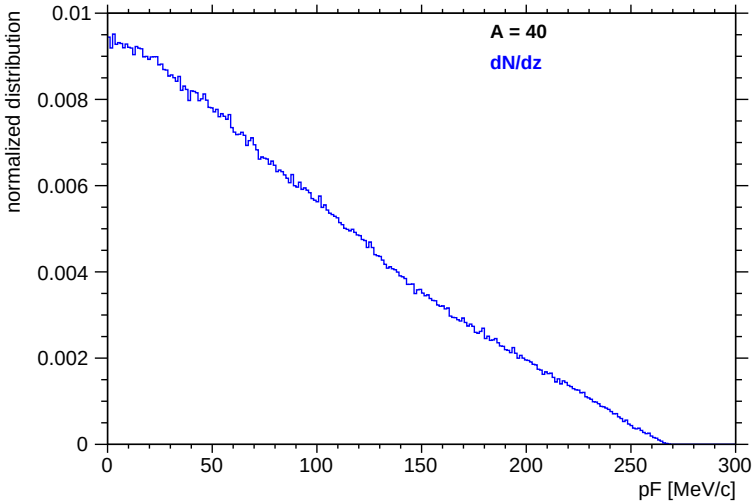
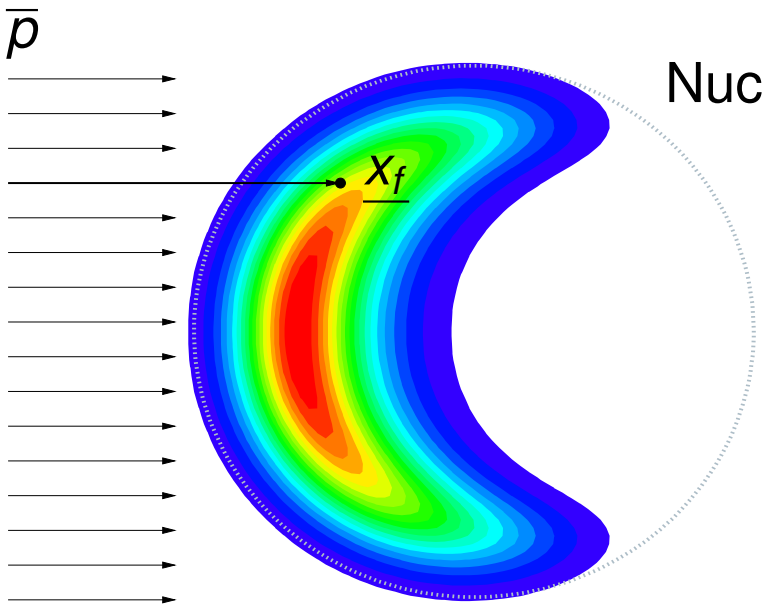


$$P_F \propto \rho^{1/3}$$





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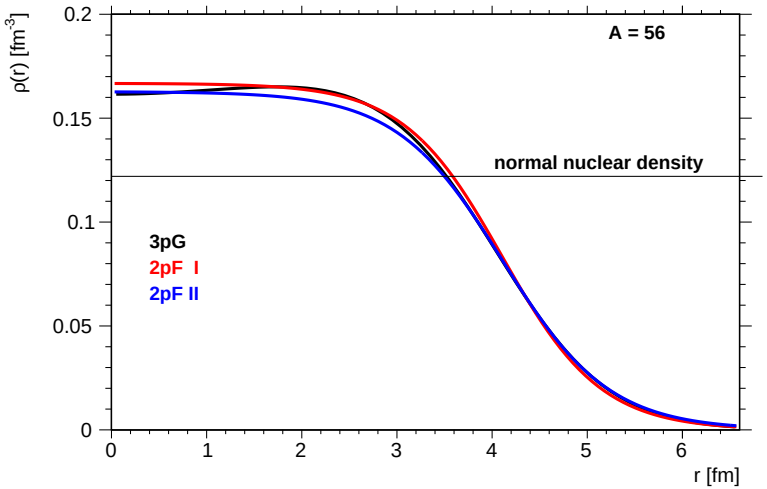

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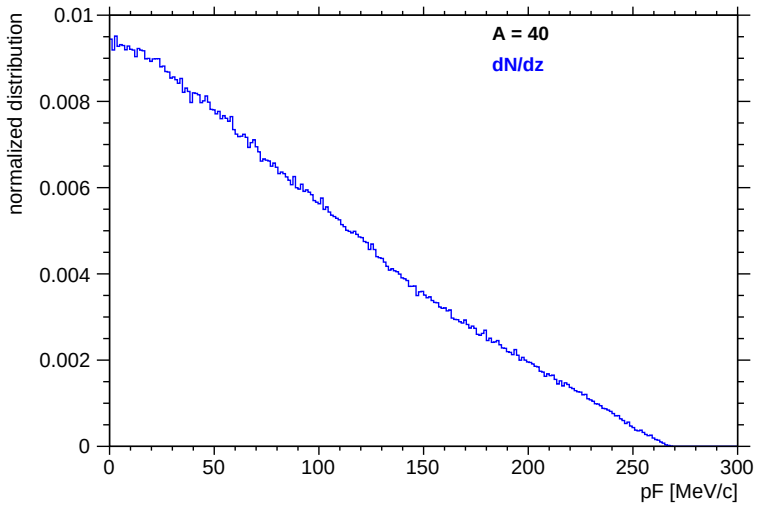
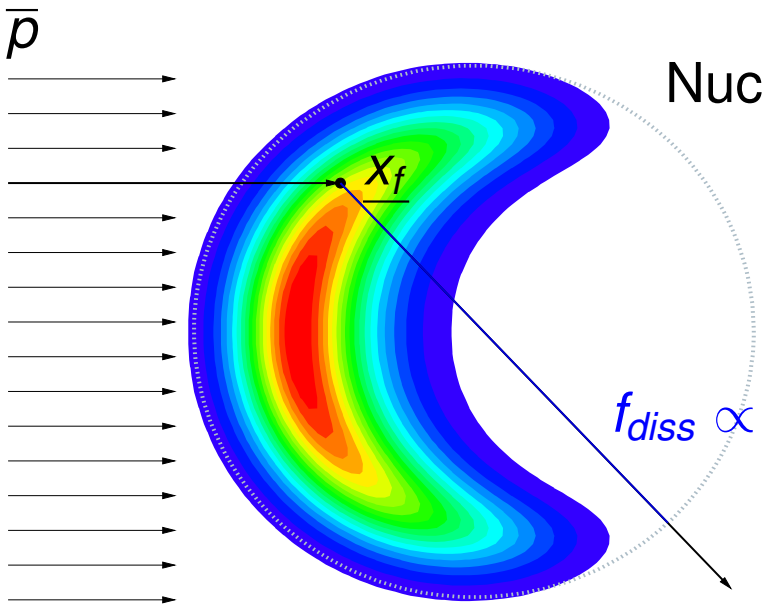


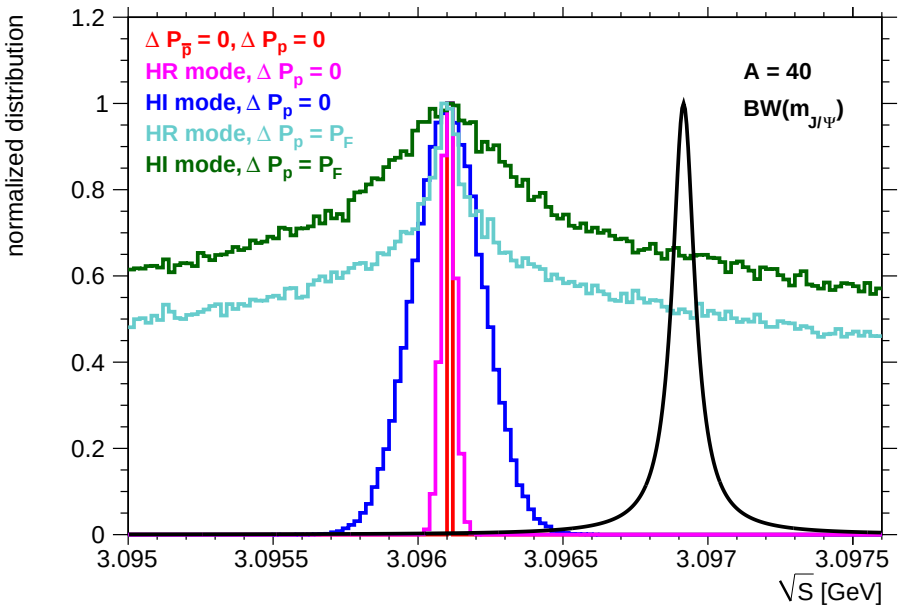


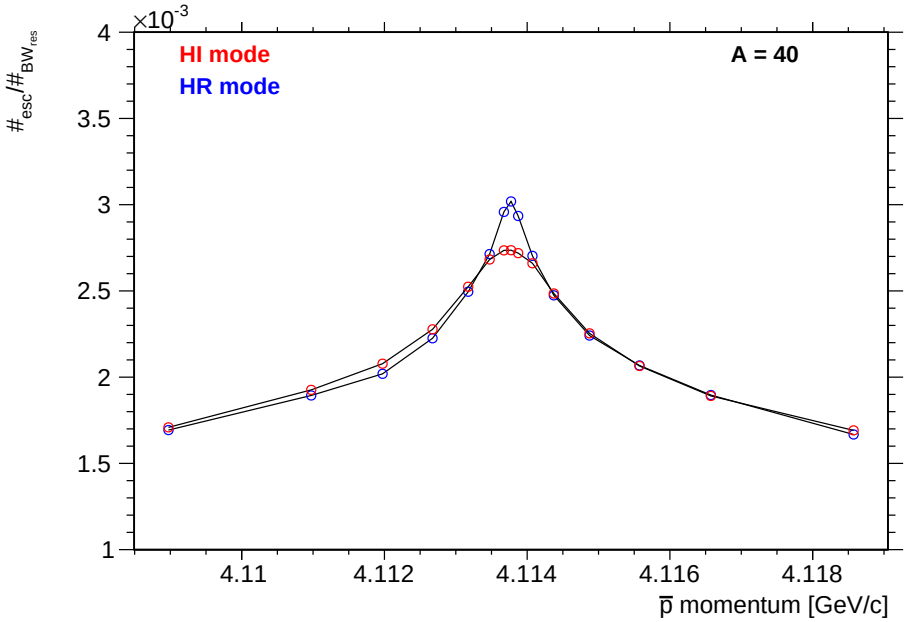
$$f_{diss} \propto \int_{x_f}^{r_A} \rho(l)\,dl$$

$$P_{J/\psi} = P_{\overline{p}} + P_F$$

$$dx_f \propto dN/dz$$

Computation of $\#_{form}$





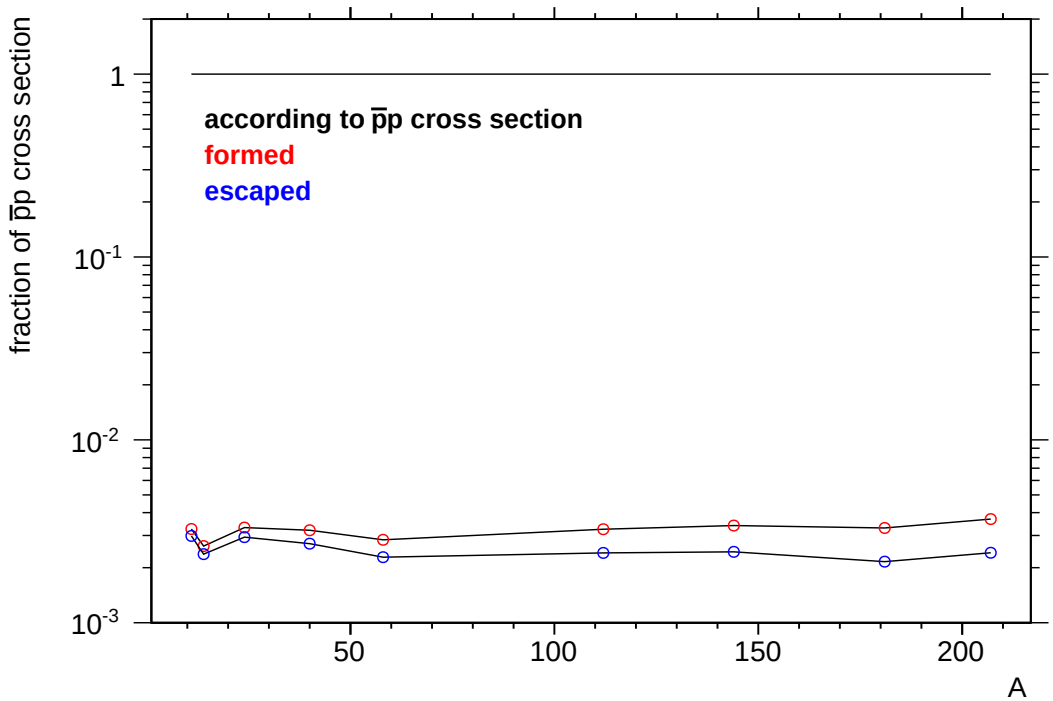
- First step in simulations
- more sophisticated models required

Computation of $\langle \rho L \rangle$

$$\sigma_{diss} = \frac{1}{\langle \rho L \rangle} \cdot \left[1 - \frac{\#_{esc}}{\#_{form}} \right]$$

modeling

measurement

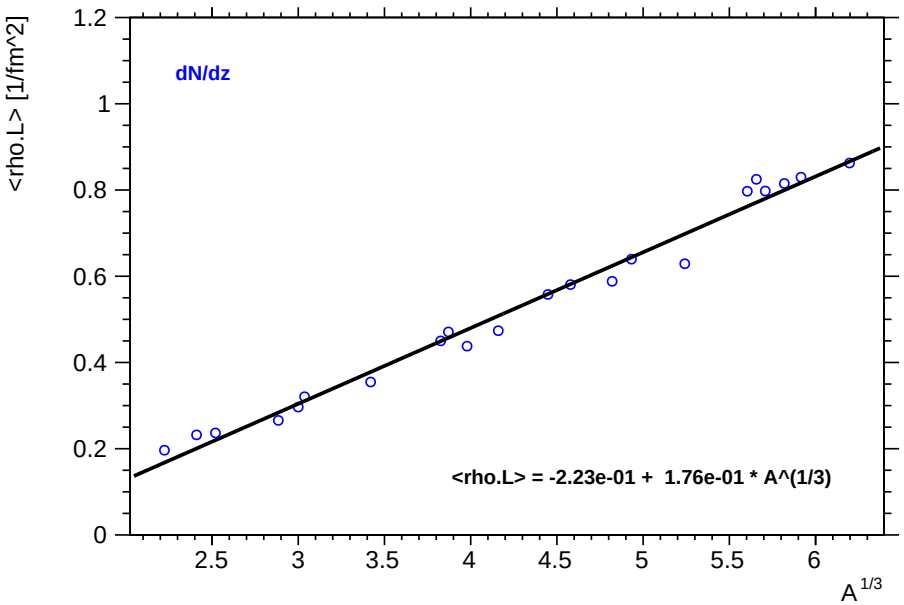


Computation of $\langle \rho L \rangle$

- $\langle \rho L \rangle = \left\langle \int_{\underline{x}_f}^{\infty} \rho(\underline{l}) d\underline{l} \right\rangle$
- depends on
  - $\rho(r)$
  - distribution of formation points, d($\underline{x}_f$)
  - Fermi-momentum distribution
- compute by MC with high statistics

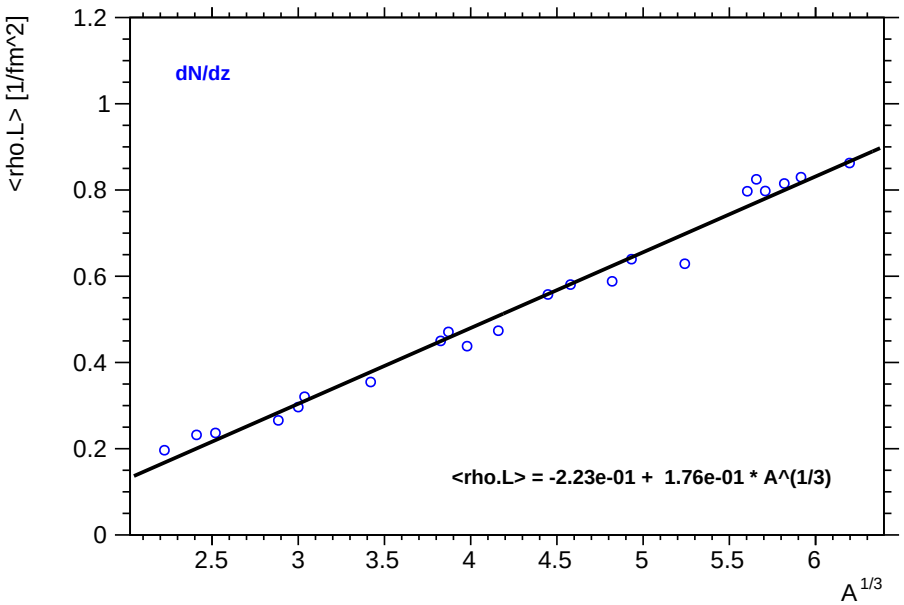
Computation of $\langle \rho L \rangle$

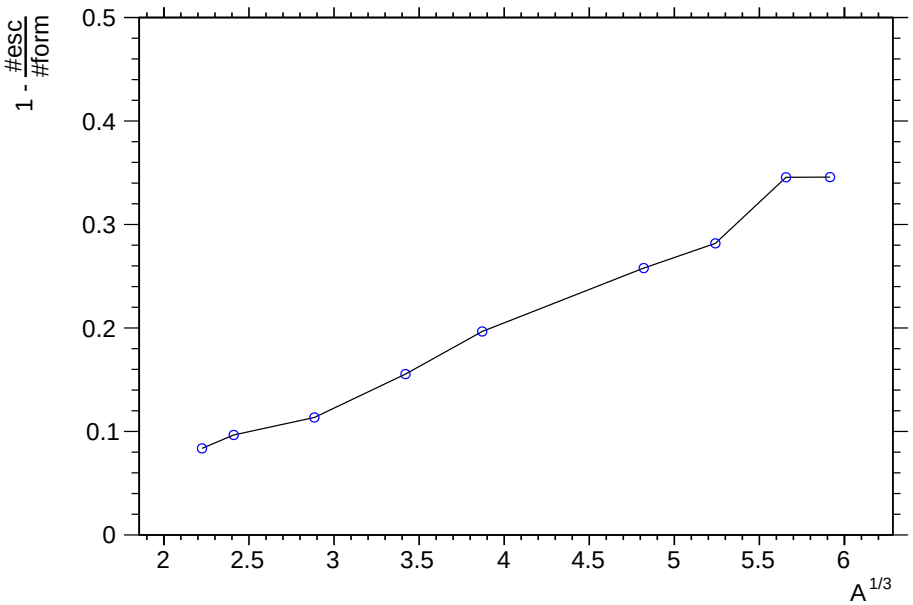
$$\sigma_{diss} = \frac{1}{\langle \rho L \rangle} \cdot \left[1 - \frac{\#_{esc}}{\#_{form}} \right]$$



Computation of $\langle \rho L \rangle$

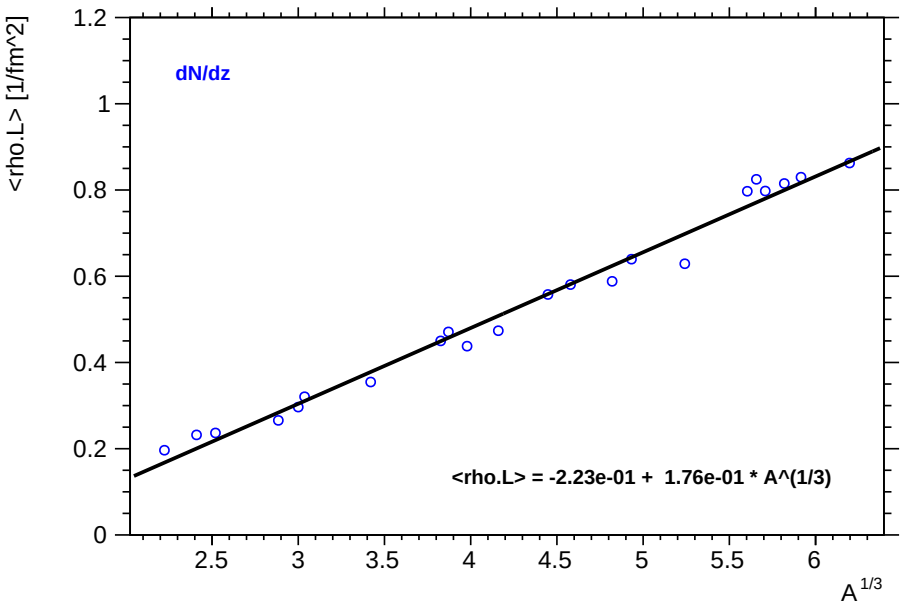
$$\sigma_{diss} \cdot \langle \rho L \rangle = \left[1 - \frac{\#esc}{\#form} \right]$$

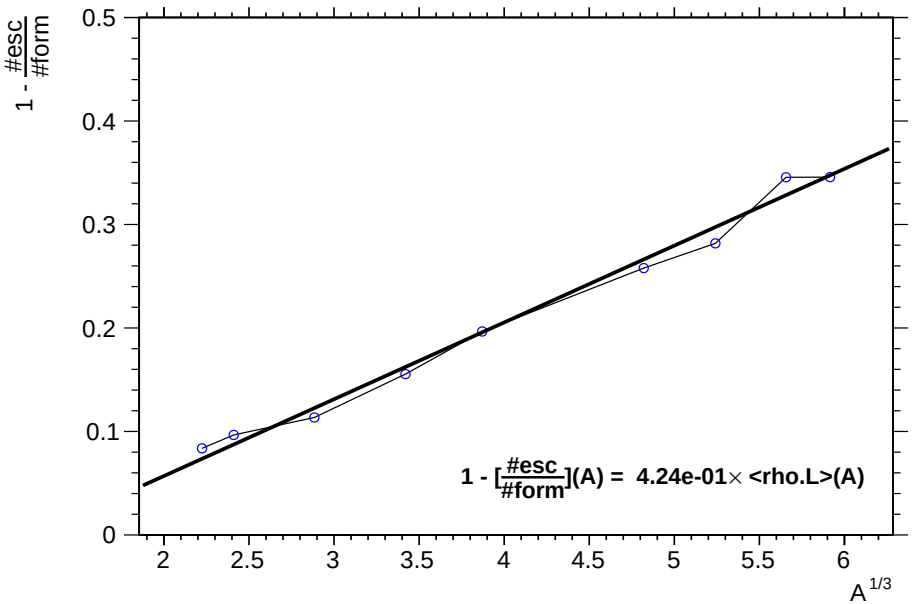




Computation of $\langle \rho L \rangle$

$$\sigma_{diss} \cdot \langle \rho L \rangle \quad = \quad \left[1 - \frac{\#esc}{\#form} \right]$$





$\longrightarrow \sigma_{diss} = 4.2$ mb

Summary

- With PANDA $\bar{p}A \rightarrow J/\Psi \rightarrow l^+ + l^-$ can be efficiently measured
  $\approx$ a few J/Ψ per day
- To determine σ_{diss} one needs to
  - Scan resonance and determine shape and number of J/Ψ ($\#_{esc}$)
  - Compute number of formed J/Ψ ($\#_{form}$)
  - Fit $\left[1 - \frac{\#_{esc}}{\#_{form}}\right](A)$ with $\langle \rho L \rangle (A)$

Parameters to select	$\{P_{\bar{p}_i}\}$, HR/HI, $\{(A,Z)_j\}$
Parameters to measure	$\#_{in}$, $\#_{esc}$
Parameters to model	$\#_{form}$