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Hadrons in Nuclei: What can be Done Early?

Mar 11, 2014 | Albrecht Gillitzer, IKP Forschungszentrum Jülich

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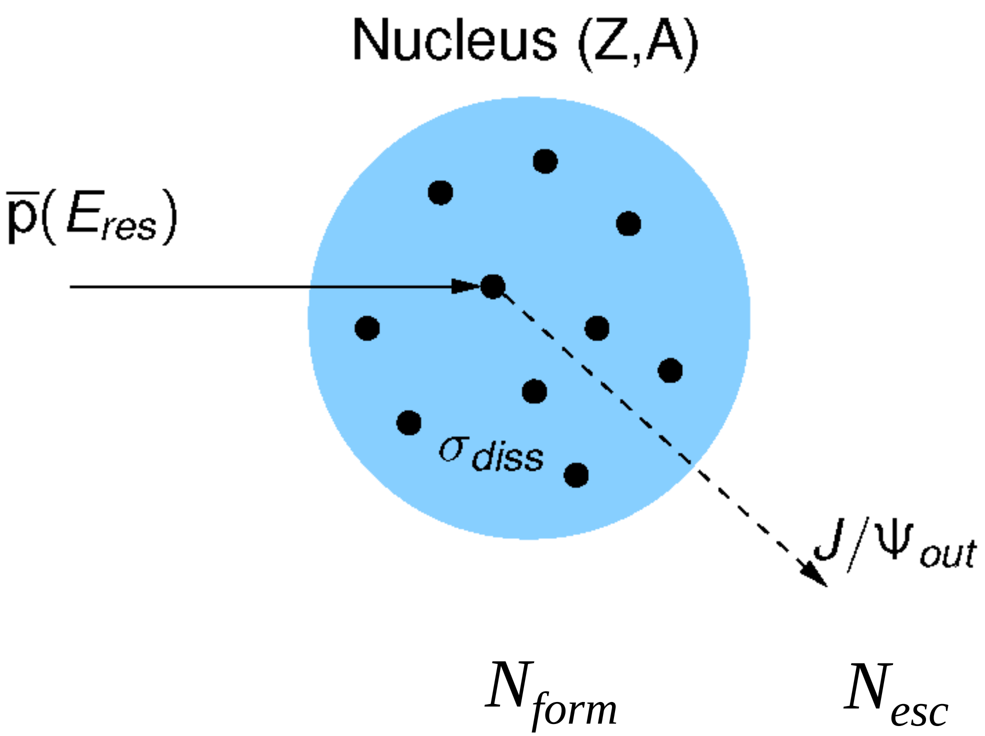
Physics topics in antiproton-nucleus collisions

Full program:

- Charmonium interaction with nucleons
- Nuclear potential of charmed hadrons
- Nuclear potential of light hadrons
- Hard QCD reactions inside the nuclear environment
- Few-body systems

J/ψ N dissociation cross section with $\bar{p}$



$$\sigma_{J/\psi N} = \frac{1}{\langle \rho L \rangle} \left(1 - \frac{N_{esc}}{N_{form}}\right)$$

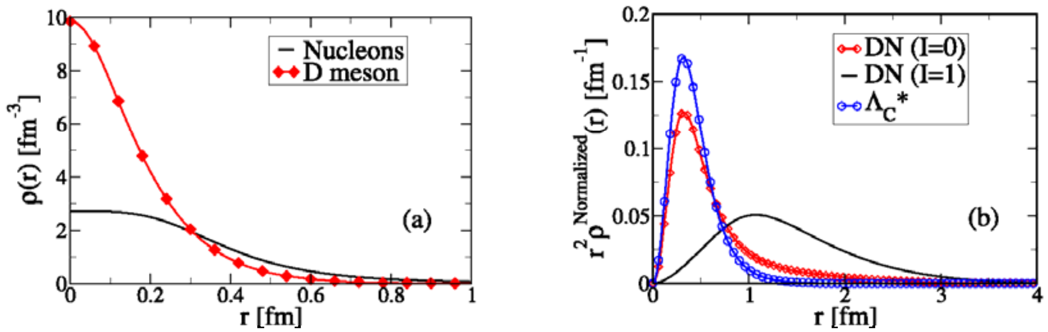
- **S.J. Brodsky, A.H. Müller, PLB 206 (1988) 685**
- G.R. Farrar et al., NPB 345 (1990) 125
- K. Seth, 629 (1998) 358

- well-defined conditions: exclusive resonant J/ψ formation on target proton at rest at 4.05 GeV/c
- no ambiguities due to feed-down, co-movers, …
- antiproton mean free path sufficiently known

→ **PANDA is unique !**

Nuclear Bound States of Charmed Hadrons?

Predicted bound DNN state A. Dote *et al.*, NPA 914 (2013) 499



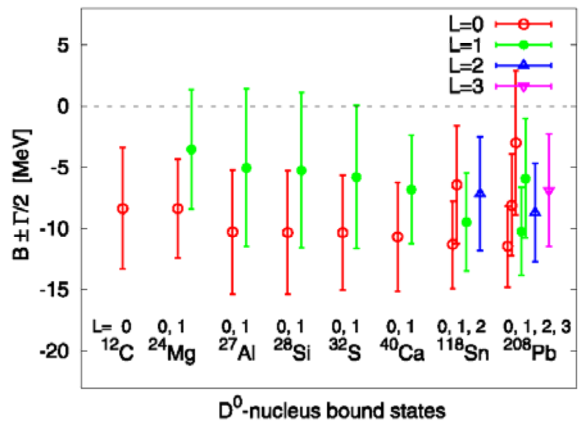


Fig. 5. D^0-nucleus bound states.

Predicted nuclear bound D and $\bar{\mathrm{D}}$ states

L. Tolos, NPA 914 (2013) 499 + refs therein

no slow D in nuclei →

3rd generation experiments!

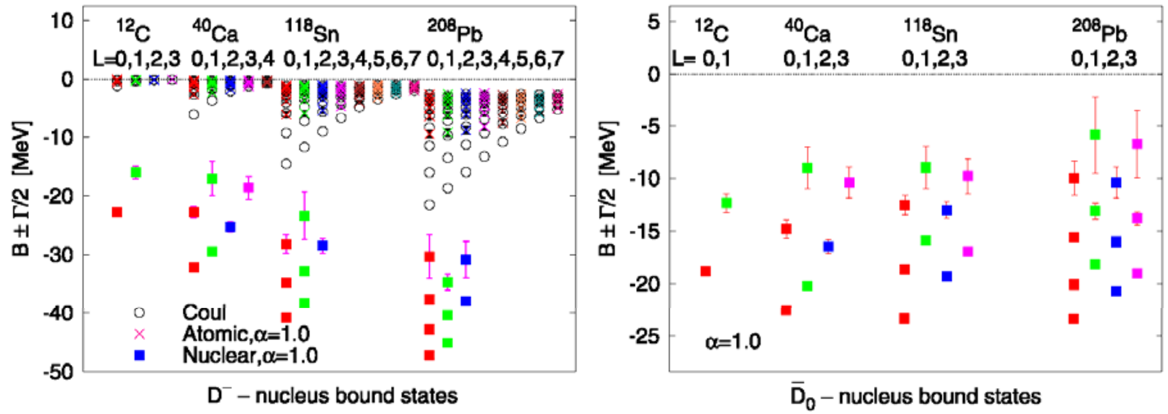
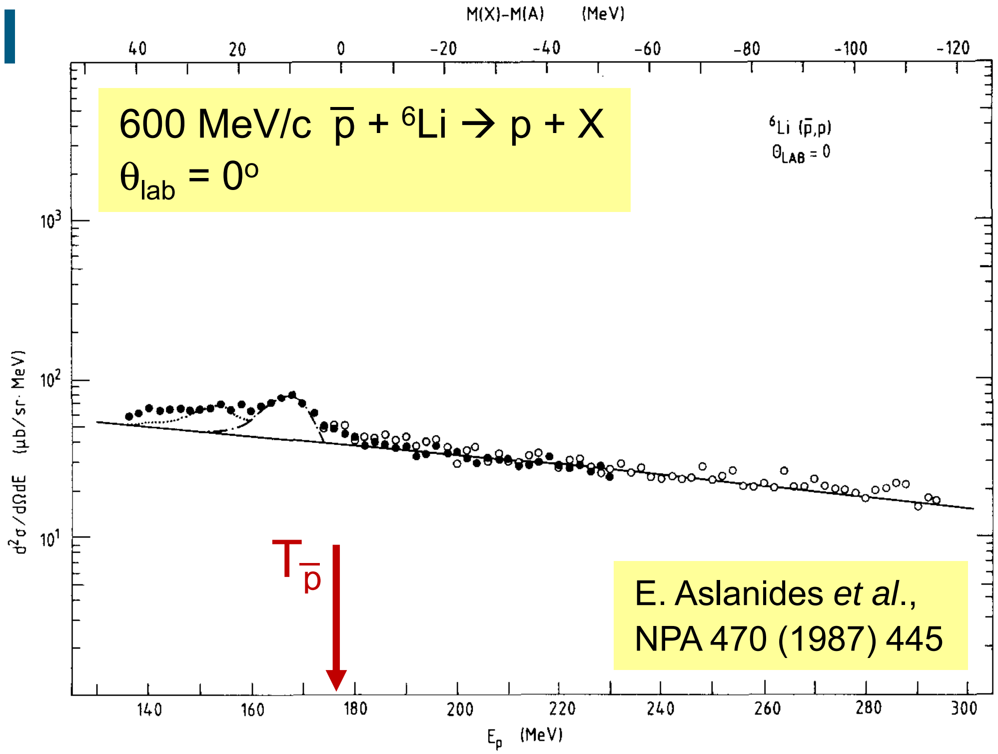
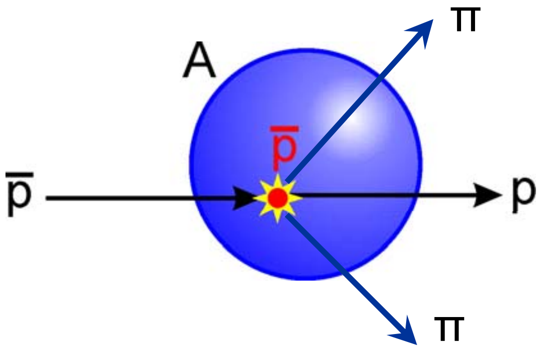


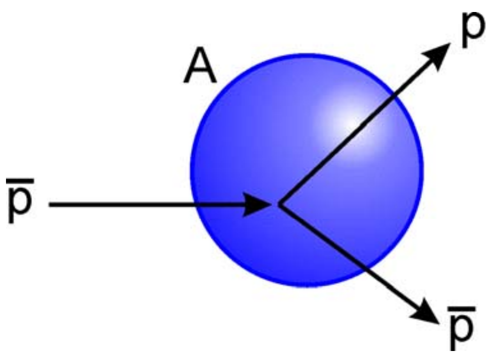
Fig. 6. D^- and $\bar{D}^0$-nucleus bound states.

Antiproton nuclear potential

- low energy measurements are not sensitive to Re $U_{\bar{p}}$
- G parity transformation gives very deep potential
  I.N. Mishustin *et al.*, PRC 71 (2005) 035201,
  A.B. Larionov *et al.*, PRC 78 (2008) 014604
- do p knock-out experiment at high energy with PANDA







$M_{(A-1)\bar{p}}$ from MM_p

$M_{(A-1)}$ from $MM_{\bar{p}p}$

- method should also work for $\bar{\Lambda}$, K^-, K^* …

Can we measure the potential for $\bar{Y}$?

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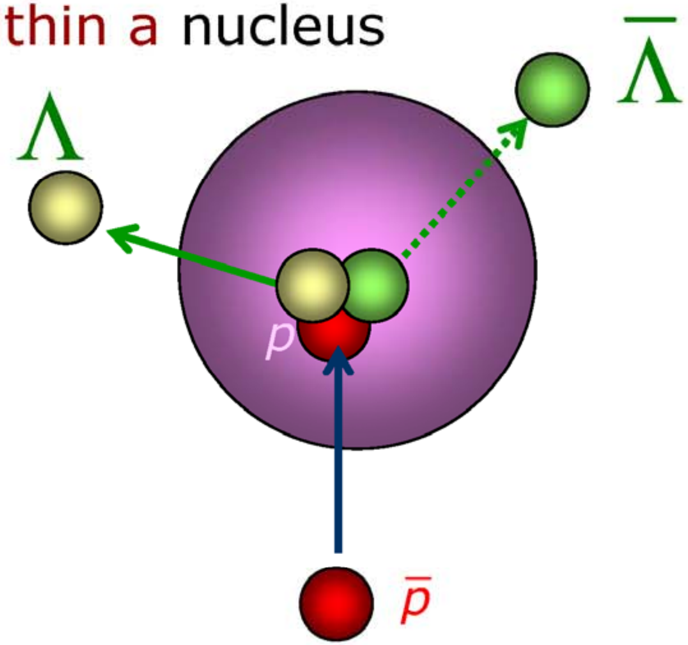
- antiprotons are optimal for the production of mass without large momenta
- consider $p+\bar{p} \rightarrow Y+\bar{Y}$ close to threshold within a nucleus
- Λ and $\bar{\Lambda}$ that leave the nucleus will have different asymptotic momenta depending on the respective potential

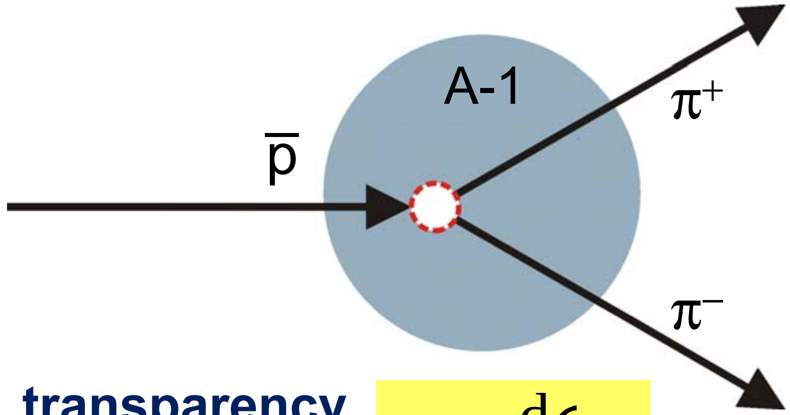


- experimental complications
  - Avoid annihilation
  - Fermi motion of struck proton
  - Non-isotropic production
  - Density distribution U(ρ)
  - Exclusiveness
  - Momentum dependence of potential

need to look at average *transverse* momentum close to threshold of *coincident* $Y\bar{Y}$ pairs

J. Pochodzalla, Dec 09, 2012

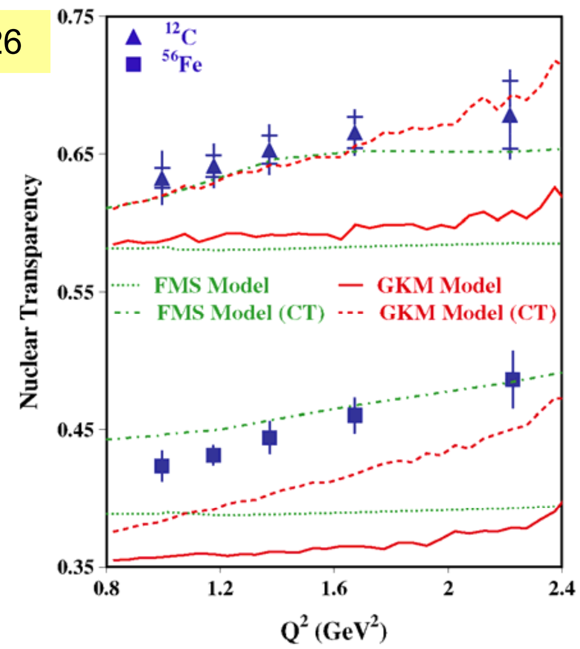
Color Transparency at PANDA: $\bar{p}\,A \rightarrow \pi^+\pi^-\,(A\text{-}1)$



- small-size color-neutral objects have reduced cross section → should be seen at large momentum transfer
- CT established at high energies, evidence at intermediate energies:
  JLAB: $(e,e'\pi^+)$ — B. Clasie *et al.*, PRL 99 (2007) 242502
  and $\gamma^*A \rightarrow \rho^0X$ — L. El Fassi *et al.*, [CLAS] PLB 712 (2012) 326
- proposal: study CT with $\bar{p}$ at PANDA in two-body reactions, e.g. in $\pi^+\pi^-$ annihilation (B. Pire, M. Strikman, …)
- CT conditions should be achieved at p ~ 8 … 15 GeV/c

transparency ratio:

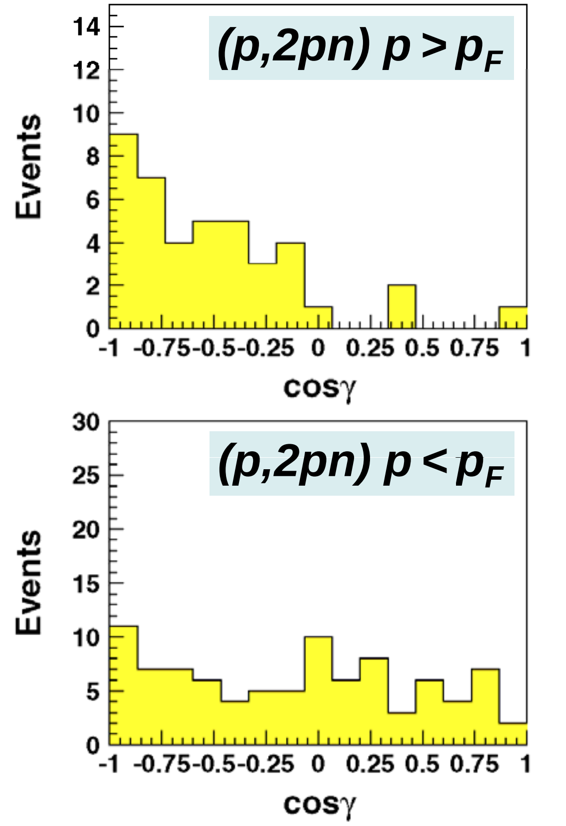
$$T = \frac{d\sigma_A}{A\,d\sigma_p}$$



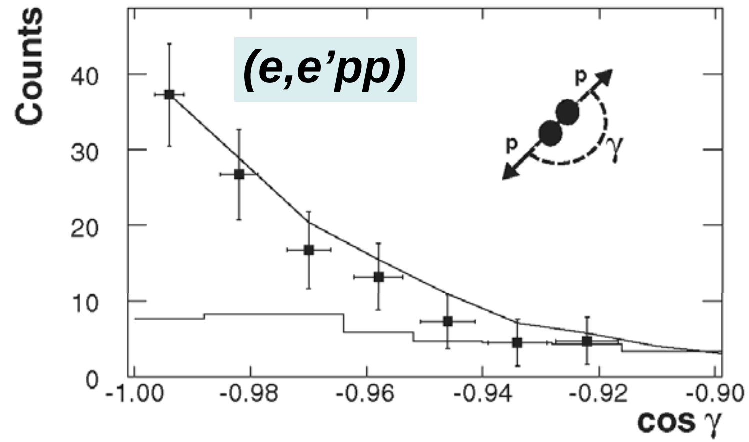
Study of Short Range Correlations

- understanding of high momentum components / high density behavior of nuclear matter
- high momentum nucleons are paired
- recent observation at BNL and JLAB
- most nucleons with $p > p_F$ are paired
- most pairs are pn
- pp pairs are rare but particularly interesting since directly related to high density matter in neutron stars
- PANDA can observe both pp and pn correlations

A. Tang *et al.*, PRL 90 (2003) 042301

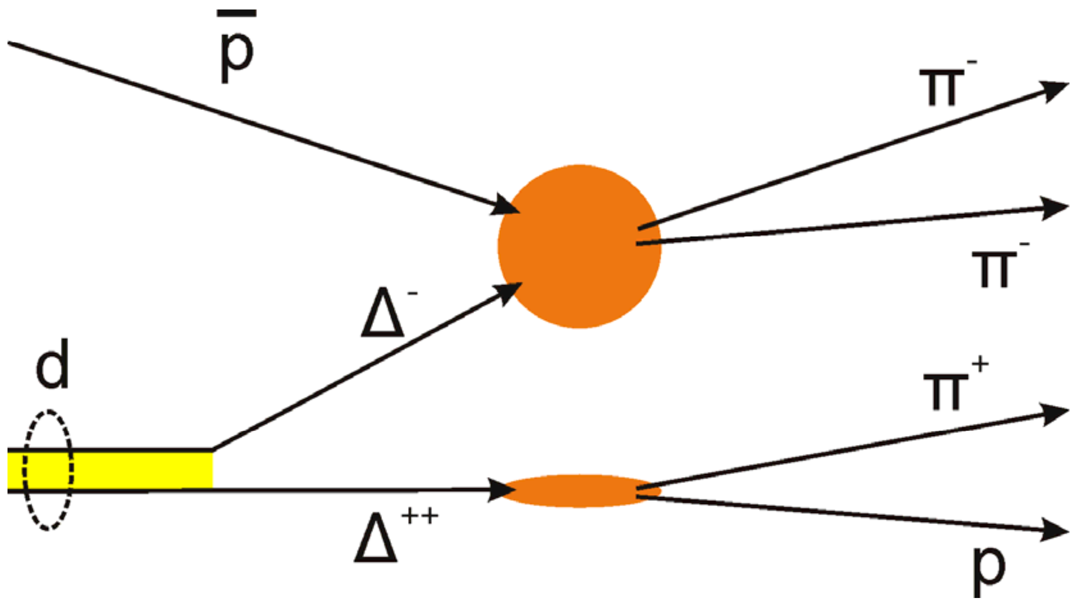


R. Shneor *et al.*, PRL 99 (2007) 072501



Hard collisions on bound nucleons: Hidden color and the ΔΔ component in the deuteron

- possible experiment at PANDA: search for $\bar{p}d \rightarrow p\pi^+ \pi^-\pi^-$ with
  - $M(p\pi^+) = M(\Delta^{++})$
  - $p_L(p\pi^+) \sim 0$
  - $p_L(\pi^-\pi^-) \sim p_{\bar{p}}$
- PANDA should have good acceptance for the complete final state
- need appropriate event generator (→ M. Sargsian)



Requirements I

Goal	Reaction	High Lumi	Tracking	EMC	PID	Forward
$\sigma(J/\psi N)$	$\bar{p}A \rightarrow e^+e^-X$	X	X	X	X	
	$\bar{p}A \rightarrow \bar{D}Y_cX$	X	X		X	
	$\bar{p}d \rightarrow D^-\Lambda_c^+$	X	X		X	
$\bar{p}$ potential	$\bar{p}A \rightarrow p_{fwd}X$		X	?		X
	$\bar{p}A \rightarrow p\bar{p}X$		X			
$\sigma(\bar{p}A)$	$\bar{p}A \rightarrow n\pi X, p\bar{p}X$		X			
$\bar{\Lambda}$ potential	$\bar{p}A \rightarrow \Lambda_{fwd}X$		X	X		X
	$\bar{p}A \rightarrow \Lambda\bar{\Lambda}X$		X	?		
$\bar{K}$ potential	$\bar{p}A \rightarrow \Phi_{fwd}K^+X$		X	?	X	X
$\bar{K}^*$ potential	$\bar{p}A \rightarrow K\bar{K}^*X$		X		X	

Requirements II

Goal	Reaction	High Lumi	Tracking	EMC	PID	Forward
CT	$\bar{p}A \rightarrow \pi^+\pi^- X$		X	?		
	$\bar{p}A \rightarrow K^+K^- X$		X	?	X	
	$\bar{p}A \rightarrow \bar{p}pX$		X	?		
SRC	$\bar{p}A \rightarrow \bar{p}ppX$		X	?		
	$\bar{p}A \rightarrow \bar{p}pnX$		X	X		
	$\bar{p}A \rightarrow p\pi^-\pi^0 X$		X	X		
ΔΔ comp.	$\bar{p}d \rightarrow p\pi^+\pi^-\pi^-$		X			
	$\bar{p}d \rightarrow p\pi^0 pp\pi^-$		X	X		
	$\bar{p}d \rightarrow p\pi^- pp\pi^0$		X	X		

Conclusion

- Tracking is needed for all parts of the program
- In addition most subtopics need EMC, PID and/or Forward Spectrometer
- Some options exist for a "Low Lumi & TS tracking only" scenario:
  - deuteron $\Delta\Delta$ component
  - $\bar{p}$A reaction cross section
  - $K^*/\bar{K}^*$ transparency measurement
  - nuclear potential from $\langle p_T \rangle$ distribution of $\bar{p}/p$, $\bar{\Lambda}/\Lambda$, … pairs