Momentum Dependent Mean-Fields for (Anti-)Hyperons

Th. Gaitanos, A. Chorozidou

ΤΜΗΜΑ ΦΥΣΙΚΗΣ
ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ

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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Gaitanos & Kaskulov, NPA 940 (2015) 181, NPA 899 (2013) 133
Gaitanos & Chorozidou, NPA (2021) in press

Momentum Dependent Mean-Fields for (Anti-)Hyperons

- Introduction
- The Non-Linear Derivative (NLD) model
- Basic properties: nuclear EoS & $p,\bar{p}$-optical potentials
- Y properties: density & momentum dependent optical potentials
- $\bar{Y}$ properties: density & momentum dependent optical potentials

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RMF + MDI

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RMF + MDI

Re & Im parts

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Re & Im parts

Comp to χ-EFT & LQCD

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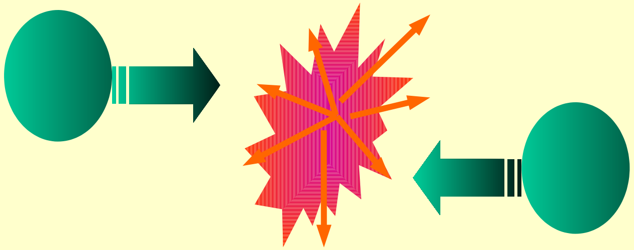
Introduction…

Important for astrophysics

explore EoS far beyond saturation (high ρ, high τ-asymm, Λ/Σ/Ξ/Ω)

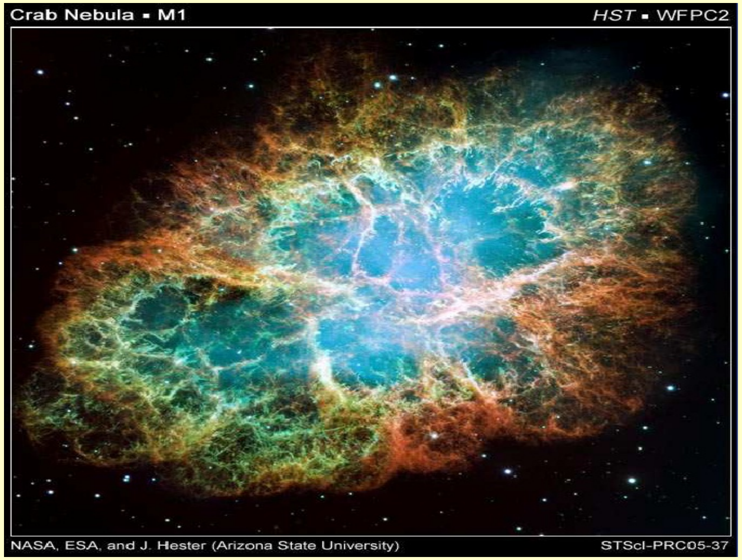
Heavy-ion collisions

(collective flow, meson production)



Densities of fireball for HIC@SIS: $\rho \sim (2\text{-}3)\rho_0$

Neutron stars (mass & radius)



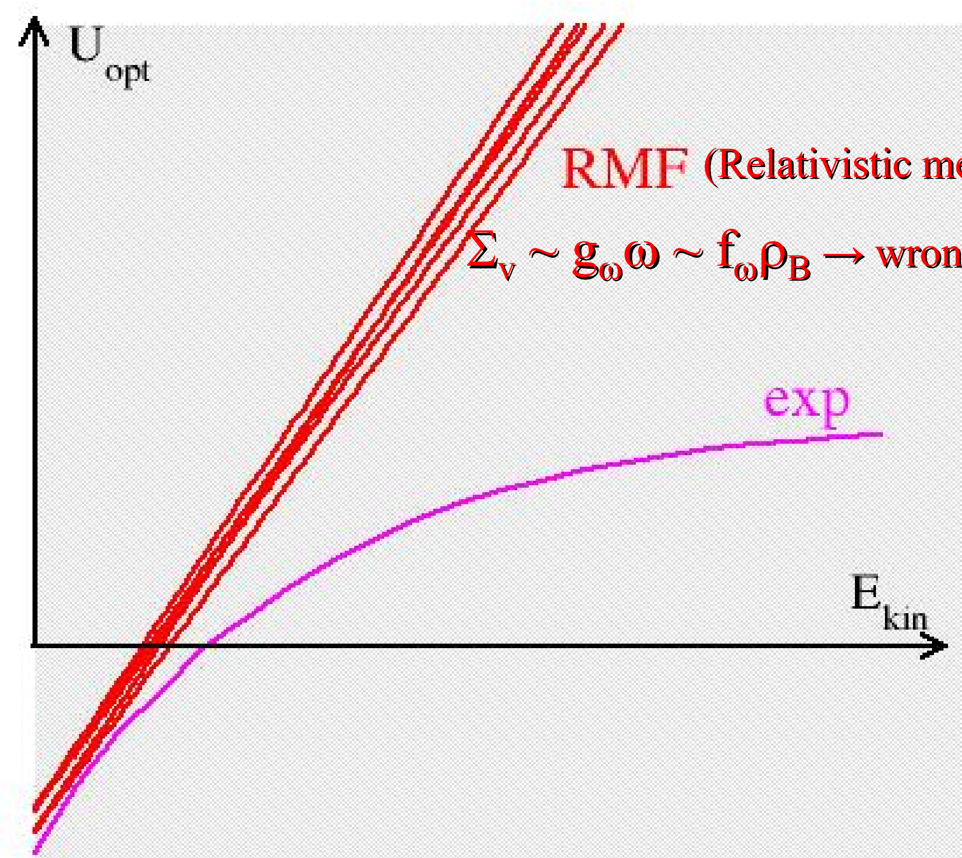
Densities in static NS: $\rho \sim (8\text{-}10)\rho_0$

- In high-density matter (+kinematics) → particles with high-momenta p
- Not only density dependence, but also **momentum dependence (MD)** essential
- Not only nucleon-EoS, but also hyperon-EoS essential
- Not only hyperon-density dependence, but also hyperon-momentum dependence essential

Introduction…

In-medium proton Schrödinger-equivalent $\mathrm{Re}(U_{opt})$

$$U_{\mathrm{opt}} = \frac{E}{m}\Sigma_v - \Sigma_s + \frac{1}{2m}\left(\Sigma_s^2 - \Sigma_v^2\right)$$



RMF (Relativistic mean-field)

$\Sigma_v \sim g_\omega \omega \sim f_\omega \rho_B \rightarrow$ wrong divergent MD at high ρ_B rsp. high momenta

DBHF & Dirac-phenomenology for nucleons:
Proton-opt. pot. well known
saturating fields (particular vector) with rising p

Solutions so far:

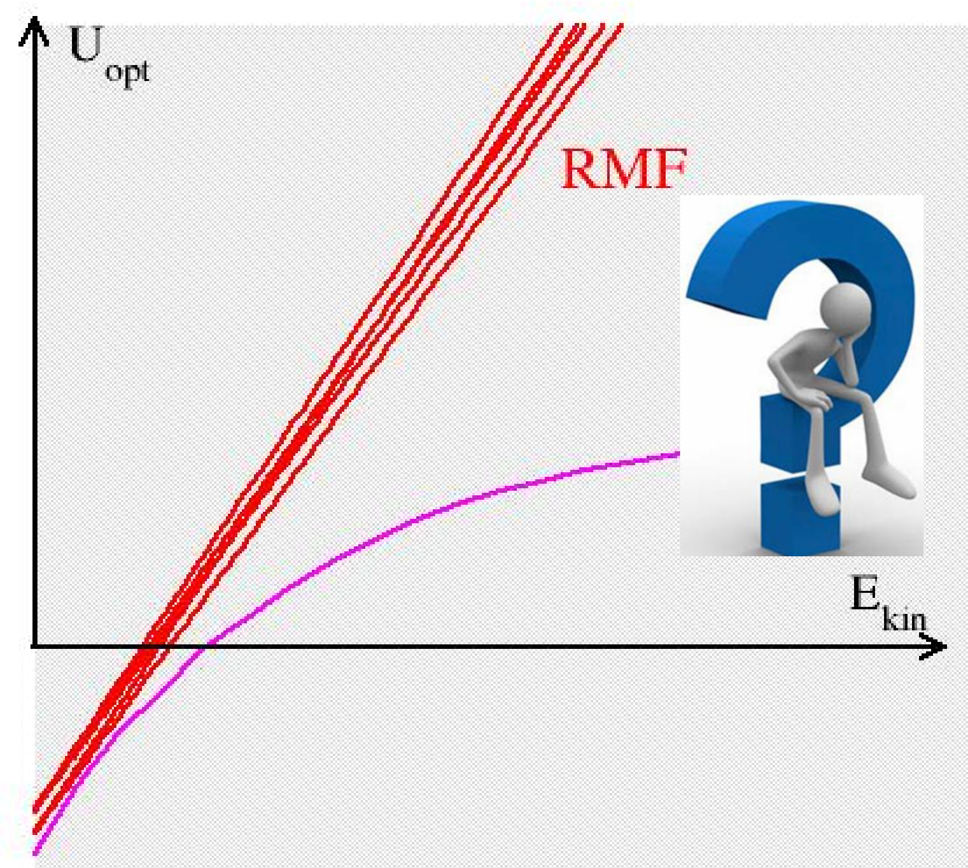
→ non-local (Hartree-Fock) contributions to RMF (Hartree) mean-field
Weber, Blättel, Cassing et al., Nucl. Phys. A539 (1992) 713

→ first-order derivative coupling terms into the interaction Lagrangian
S. Typel, Phys. Rev. C71, 064301 (2005)

Introduction...

In-medium **hyperon** Schrödinger-equivalent Re(U_{opt})

$$U_{\mathrm{opt}} = \frac{E}{m}\Sigma_v - \Sigma_s + \frac{1}{2m}\left(\Sigma_s^2 - \Sigma_v^2\right)$$



Dirac-phenomenology for **hyperons**:

?

rare experimental scattering data so far

The Non-Linear Derivative (NLD) model…

NLD Lagrangian : as in conventional Relativistic Hadrodynamics (RHD)

$$\mathcal{L} = \frac{1}{2}\sum_B \left[\overline{\Psi}_B \gamma_\mu i \overrightarrow{\partial}^\mu \Psi_B - \overline{\Psi}_B i \overleftarrow{\partial}^\mu \gamma_\mu \Psi_B\right] - \sum_B m_B \overline{\Psi}_B \Psi_B + \sum_{m=\sigma,\omega,\rho} \mathcal{L}^m_{int} .$$

For the baryon octet: $\Psi_B = \left(\Psi_N, \Psi_\Lambda, \Psi_\Sigma, \Psi_\Xi\right)^T$

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Interaction Lagrangian : as in conventional RHD

$$\mathcal{L}_{int}^m = \sum_B \frac{g_{mB}}{2} \left[\overline{\Psi}_B \Gamma_m \Psi_B \varphi_m + \varphi_m \overline{\Psi}_B \Gamma_m \Psi_B\right] ,$$

For (φ_m = σ,ω,ρ)-baryon interaction with corresponding vertices $\Gamma_m = \mathbb{1}, \gamma^\mu, \ldots$

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Non-linear derivative operators : Taylor expansion of partial derivatives ξ

$$\overrightarrow{\mathcal{D}}_B := \mathcal{D}\left(\overrightarrow{\xi}_B\right), \; \overleftarrow{\mathcal{D}}_B := \mathcal{D}\left(\overleftarrow{\xi}_B\right) \text{ with } \overrightarrow{\xi}_B = -\frac{v^\alpha i \overrightarrow{\partial}_\alpha}{\Lambda_B}, \; \overleftarrow{\xi}_B = \frac{i \overleftarrow{\partial}_\alpha v^\alpha}{\Lambda_B}$$

v^α auxiliarly 4-vector choosen such to get p-dependence

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cut-off, will regulate the high-momentum tail of RMF fields

The Non-Linear Derivative (NLD) model...

NLD Lagrangian: contains higher field derivatives: $\mathcal{L}\left(\varphi_r,\, \partial_{\alpha_1}\varphi_r,\, \partial_{\alpha_1\alpha_2}\varphi_r, \cdots, \partial_{\alpha_1\cdots\alpha_n}\varphi_r\right)$

→ Generalized Euler-Lagrange equations:

$$\frac{\partial \mathcal{L}}{\partial \varphi_r} + \sum_{i=1}^{n} (-)^i \partial_{\alpha_1\cdots\alpha_i} \frac{\partial \mathcal{L}}{\partial(\partial_{\alpha_1\cdots\alpha_i}\varphi_r)} = 0$$

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→ Generalized Noether-Theorem: conserved current

$$J^\mu = -i\left[\mathcal{K}_r^\mu\varphi_r + \mathcal{K}_r^{\mu\sigma_1}\partial_{\sigma_1}\varphi_r + \mathcal{K}_r^{\mu\sigma_1\sigma_2}\partial_{\sigma_1\sigma_2}\varphi_r + \cdots + \mathcal{K}_r^{\mu\sigma_1\cdots\sigma_n}\partial_{\sigma_1\cdots\sigma_n}\varphi_r\right]$$

with the following tensors

$$\mathcal{K}_r^{\mu\sigma_1\cdots\sigma_m} = \sum_{i=1}^{n}(-)^{i+1}\prod_{j=1}^{i-1}\partial_{\alpha_j}\frac{\partial\mathcal{L}}{\partial(\partial_{\mu\alpha_j\sigma_1\cdots\sigma_m}\varphi_r)}\;.$$

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infinite series rsp. to higher-order field derivatives, but...

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All infinite series can be resummed to compact expressions

The Non-Linear Derivative (NLD) model...

→ Dirac equation for nucleons $\left[\gamma_\mu(i\partial^\mu - \Sigma^\mu) - (m - \Sigma_s)\right]\Psi = 0$ with selfenergies

$$\Sigma^\mu = g_\omega \omega^\mu \overrightarrow{\mathcal{D}} + g_\rho \vec{\tau} \cdot \vec{\rho}^{\,\mu} \overrightarrow{\mathcal{D}} + \cdots$$

$$\Sigma_s = g_\sigma \sigma \overrightarrow{\mathcal{D}} + \cdots$$

(up to terms containing derivatives of the meson fields)

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→ Meson field equations:

$$\partial_\alpha\partial^\alpha\sigma + m_\sigma^2\sigma + \frac{\partial U}{\partial\sigma} = \frac{1}{2}g_\sigma\left[\overline{\Psi}\,\overleftarrow{\mathcal{D}}\,\Psi + \overline{\Psi}\overrightarrow{\mathcal{D}}\,\Psi\right],$$

$$\partial_\mu F^{\mu\nu} + m_\omega^2\omega^\nu = \frac{1}{2}g_\omega\left[\overline{\Psi}\,\overleftarrow{\mathcal{D}}\gamma^\nu\Psi + \overline{\Psi}\gamma^\nu\overrightarrow{\mathcal{D}}\,\Psi\right],$$

$$\partial_\mu\vec{G}^{\,\mu\nu} + m_\rho^2\vec{\rho}^{\,\nu} = \frac{1}{2}g_\rho\left[\overline{\Psi}\,\overleftarrow{\mathcal{D}}\gamma^\nu\vec{\tau}\,\Psi + \overline{\Psi}\vec{\tau}\,\gamma^\nu\overrightarrow{\mathcal{D}}\,\Psi\right]$$

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→ Energy-momentum tensor:

$$T^{\mu\nu} = \frac{1}{2} \overline{\Psi} \gamma^\mu\, i \overrightarrow{\partial}^{\,\nu} \Psi - \frac{1}{2} \overline{\Psi}\, i \overleftarrow{\partial}^{\,\nu} \gamma^\mu \Psi$$
$$+ \frac{1}{2} \sum_m g_m \left[\overline{\Psi}\, \Gamma_m\, \overrightarrow{\Omega}^\mu\, i \overrightarrow{\partial}^{\,\nu}\, \Psi + \overline{\Psi}\, i \overleftarrow{\partial}^{\,\nu} \overleftarrow{\Omega}^\mu\, \Gamma_m\, \Psi \right] \varphi_m - g^{\mu\nu} \mathcal{L} + \cdots .$$

The NLD model: RMF approach to INM…

→ Plane wave *Ansatz* for Ψ and $\overline{\Psi}$ with $\mathcal{D} = \mathcal{D}(p)$

$$\Sigma_{vi}^{\mu} = g_\omega \omega^\mu \mathcal{D} + g_\rho \tau_i \rho^\mu \mathcal{D} \ , \ \Sigma_{si} = g_\sigma \sigma \mathcal{D}$$

$$m_\sigma^2 \sigma + \frac{\partial U}{\partial \sigma} = g_\sigma \sum_{i=p,n} \left\langle \overline{\Psi}_i \mathcal{D} \Psi_i \right\rangle = g_\sigma \rho_s$$

$$m_\omega^2 \omega = g_\omega \sum_{i=p,n} \left\langle \overline{\Psi}_i \gamma^0 \mathcal{D} \Psi_i \right\rangle = g_\omega \rho_0$$

$$m_\rho^2 \rho = g_\rho \sum_{i=p,n} \tau_i \left\langle \overline{\Psi}_i \gamma^0 \mathcal{D} \Psi_i \right\rangle = g_\rho \rho_I \ .$$

$$T^{\mu\nu} = \sum_{i=p,n} \frac{\kappa}{(2\pi)^3} \int_{|\vec{p}\,| \leq p_{F_i}} d^3p \, \frac{\Pi_i^\mu p^\nu}{\Pi_i^0} - g^{\mu\nu} \langle \mathcal{L} \rangle$$

$$\Pi_i^\mu = p_i^{*\mu} + m_i^* \left(\partial_p^\mu \Sigma_{si} \right) - \left(\partial_p^\mu \Sigma_{vi}^\beta \right) p_{i\beta}^*$$

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meson-field equations

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Equation of State (EoS)

$$\varepsilon = \sum_{i=p,n} \frac{\kappa}{(2\pi)^3} \int\limits_{|\vec{p}|\leq p_{F_i}} d^3p\, E(\vec{p}) - \langle \mathcal{L} \rangle$$

$$P = \frac{1}{3} \sum_{i=p,n} \frac{\kappa}{(2\pi)^3} \int\limits_{|\vec{p}|\leq p_{F_i}} d^3p\, \frac{\vec{\Pi}_i \cdot \vec{p}}{\Pi_i^0} + \langle \mathcal{L} \rangle$$

Features of NLD...

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cut-off Λ regulates:

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1) DD & MD of selfenergies

2) DD of meson-field sources

(particularly for ω-field)

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1) DD & MD of selfenergies

2) DD of meson-field sources (particularly for ω-field)

3) fully thermodynamic consistent

Basic properties: nuclear EoS & opt. potentials...

Parameters

	$\vec{\mathcal{D}}$	cut-off	Λ_s [GeV]	Λ_v [GeV]	g_σ	g_ω	g_ρ	b [fm^{-1}]	c	m_σ [GeV]	m_ω [GeV]	m_ρ [GeV]
NLD	$\frac{1}{1+\sum_{j=1}^{4}\left(\zeta_j^\alpha i\vec{\partial}_\alpha\right)^2}$	$\frac{\Lambda^2}{\Lambda^2+\vec{p}^2}$	0.95	1.125	10.08	10.13	3.50	15.341	-14.735	0.592	0.782	0.763

Comparison with other models

Model	ρ_{sat} [fm^{-3}]	E_b [MeV/A]	K [MeV]	a_{sym} [MeV]	L [MeV]	K_{sym} [MeV]	K_{asy} [MeV]	
NLD	0.156	-15.30	251	30	81	-28	-514	
NL3*	0.150	-16.31	258	38.68	125.7	104.08	-650.12	→ Lalazissis
DD	0.149	-16.02	240	31.60	56	-95.30	-431.30	→ Typel
D^{3}C	0.151	-15.98	232.5	31.90	59.30	-74.7	-430.50	
DBHF	0.185	-15.60	290	33.35	71.10	-27.1	-453.70	→ Li, Machleidt, Brockmann
	0.181	-16.15	230	34.20	71	87.36	-340	→ Fuchs
empirical	0.167 ± 0.019	-16 ± 1	230 ± 10	31.1 ± 1.9	88 ± 25	–	-550 ± 100	

Basic properties: nuclear EoS & opt. potentials...

Parameters

	$\vec{\mathcal{D}}$	cut-off	[GeV]				g_ρ	b [fm^{-1}]	c	m_σ [GeV]	m_ω [GeV]	m_ρ [GeV]
NLD	$\frac{1}{1+\sum_{j=1}^{4}\left(\zeta_j^\alpha i \vec{\partial}_\alpha\right)^2}$	$\frac{\Lambda^2}{\Lambda^2+\vec{p}^2}$	0.95	1.125	10.08	10.13	3.50	15.341	−14.735	0.592	0.782	0.763

monopole form

Comparison with other models

Model	ρ_{sat} [fm^{-3}]	E_b [MeV/A]	K [MeV]	a_{sym} [MeV]	L [MeV]	K_{sym} [MeV]	K_{asy} [MeV]	
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Basic properties: nuclear EoS & opt. potentials...

Parameters

	$\vec{\mathcal{D}}$	cut-off	Λ_s [GeV]	Λ_v [GeV]	g_σ	g_ω	g_ρ	b [fm^{-1}]	c	m_σ [GeV]	m_ω [GeV]	m_ρ [GeV]
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	0.181	−16.15	230	34.20	71	87.36	−340
empirical	0.167 ± 0.019	-16 ± 1	230 ± 10	31.1 ± 1.9	88 ± 25	–	-550 ± 100

soft EoS at ρ_{sat},
but stiff at high ρ relevant for NS!

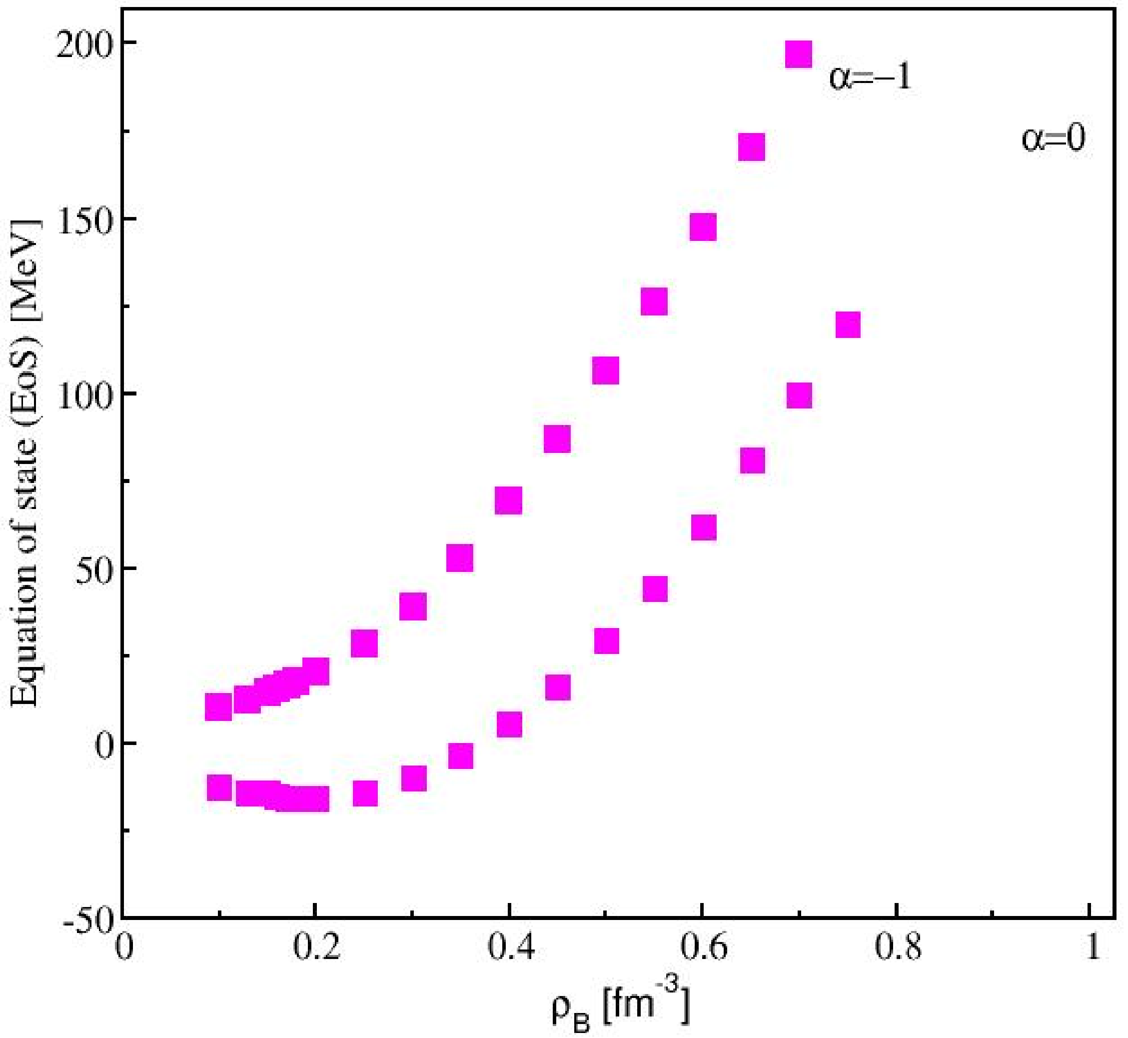
→ Lalazissis

→ Typel

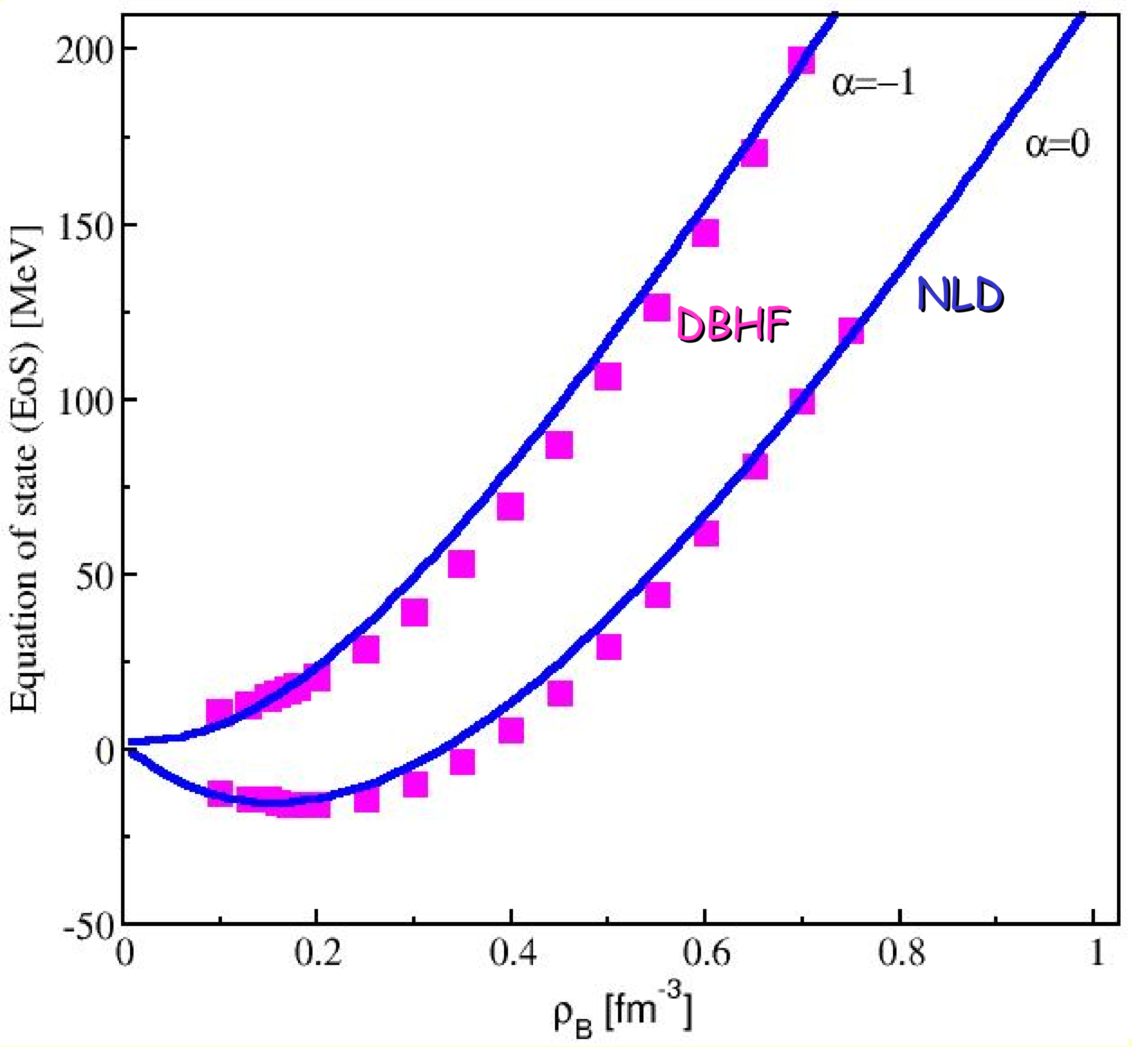
→ Li, Machleidt, Brockmann

→ Fuchs

Basic properties: nuclear EoS & opt. potentials...



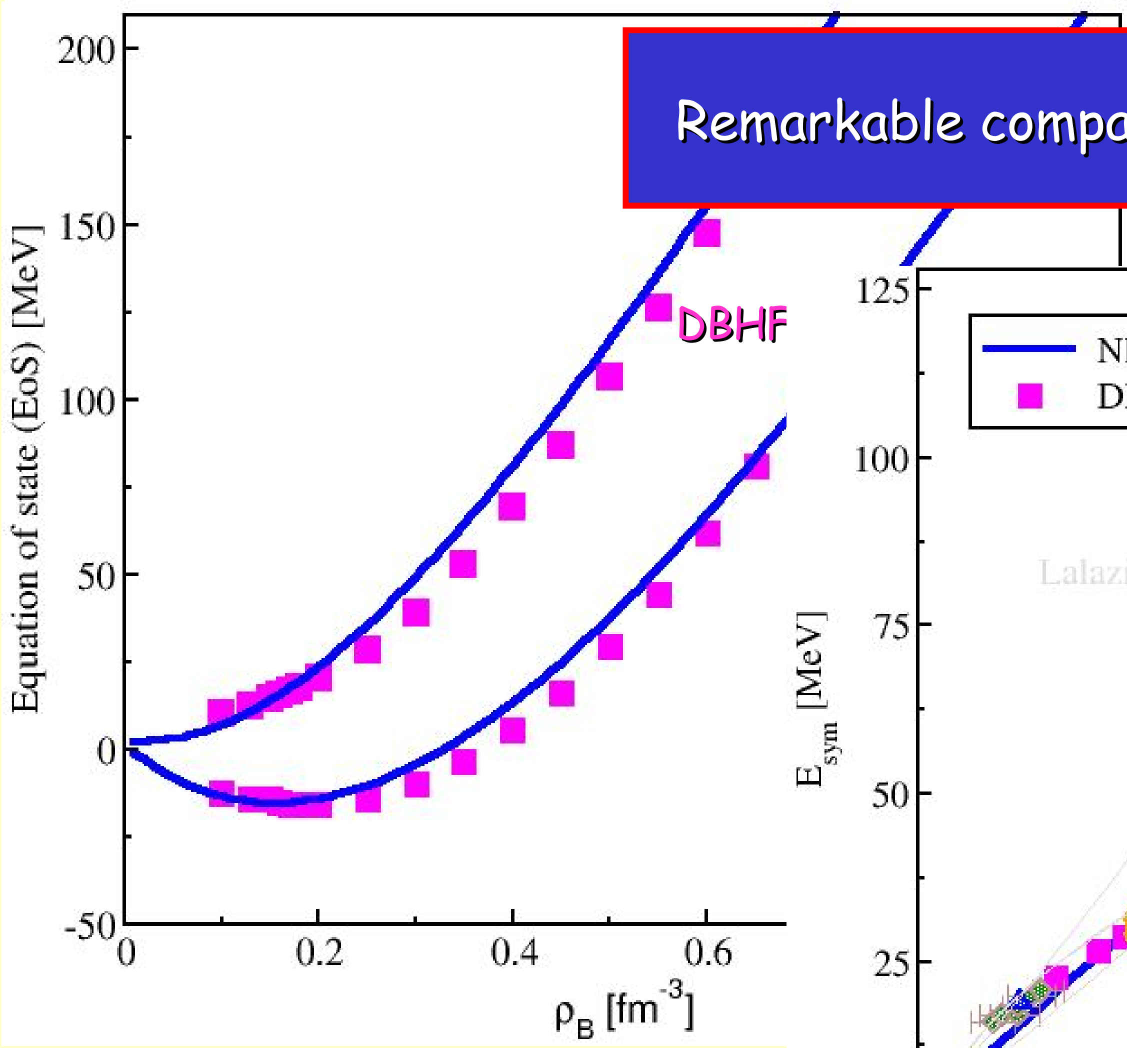
Basic properties: nuclear EoS & opt. potentials...

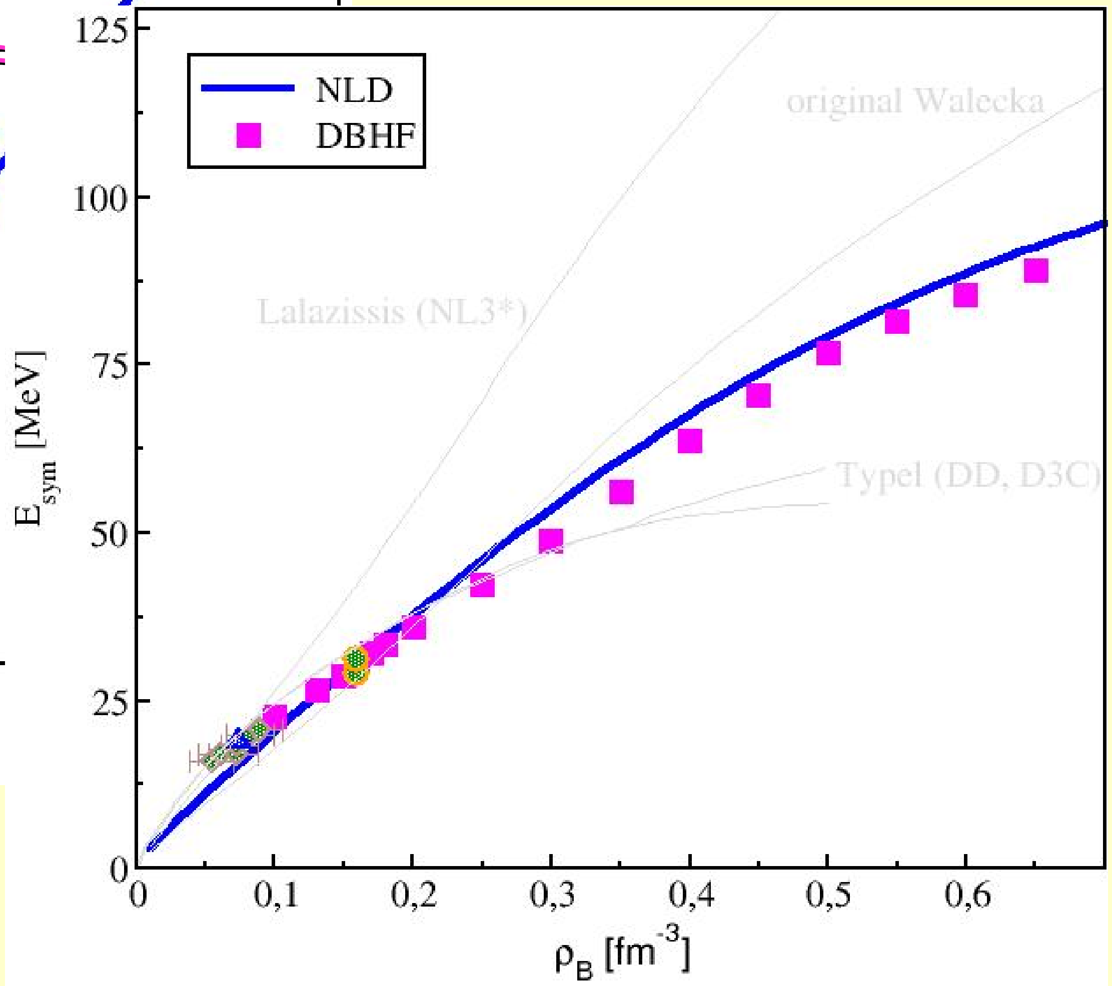


Remarkable comparison with microscopic DBHF!

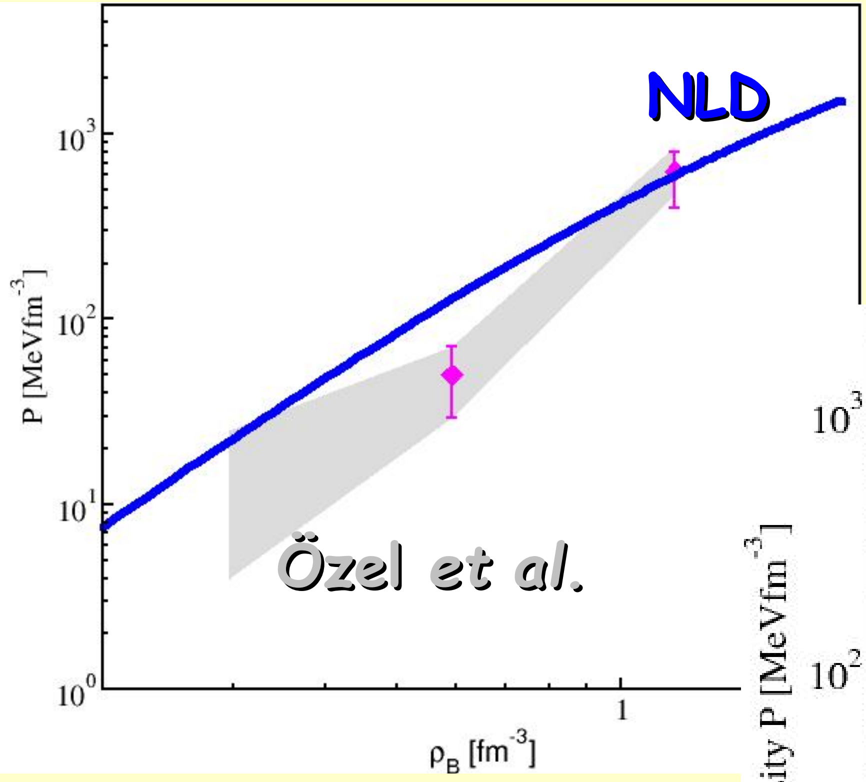
Basic properties: nuclear EoS & opt. potentials…

Remarkable comparison with microscopic DBHF !



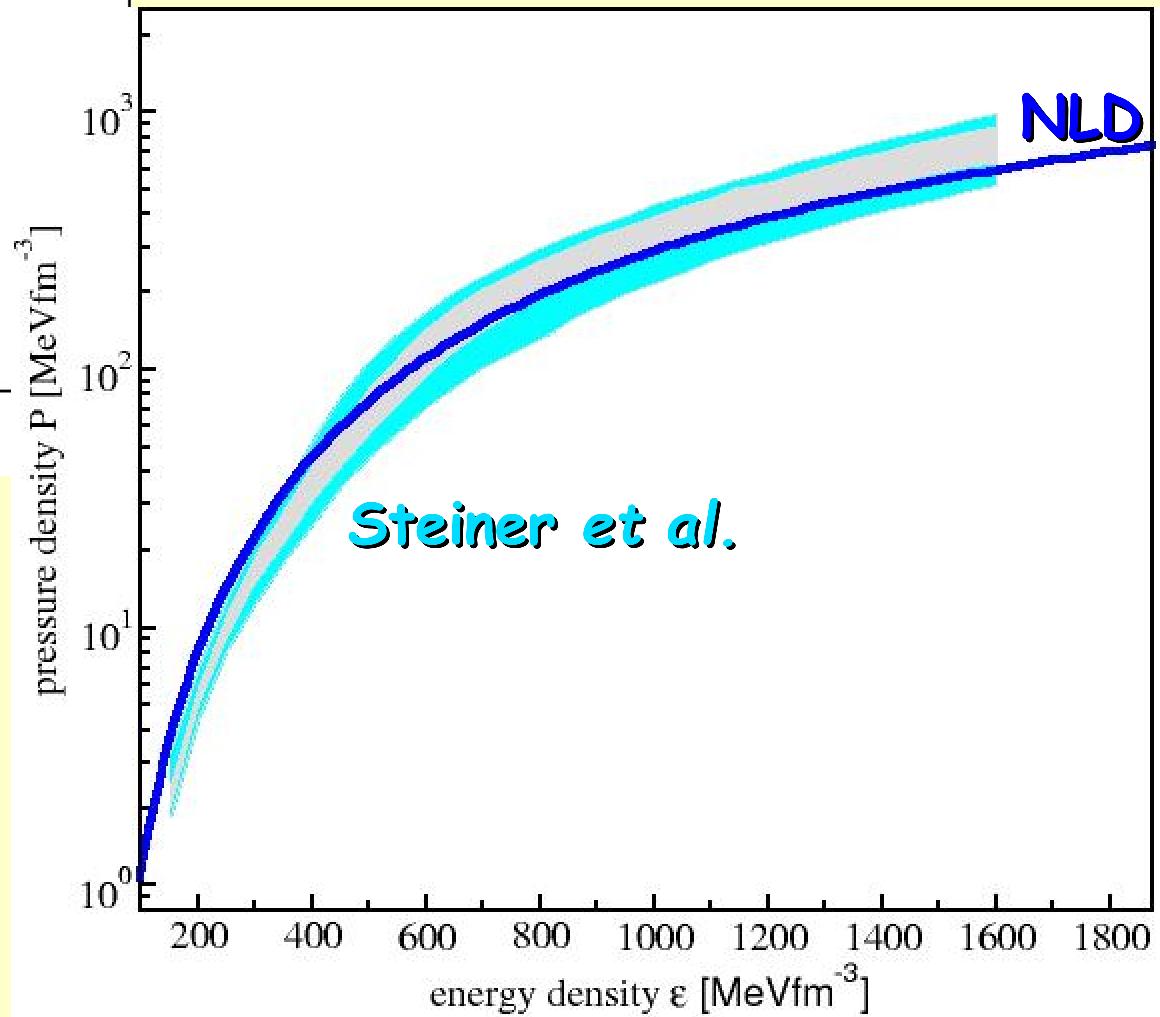


Basic properties: nuclear EoS & opt. potentials...



Consistent with analyses of F. Özel..!

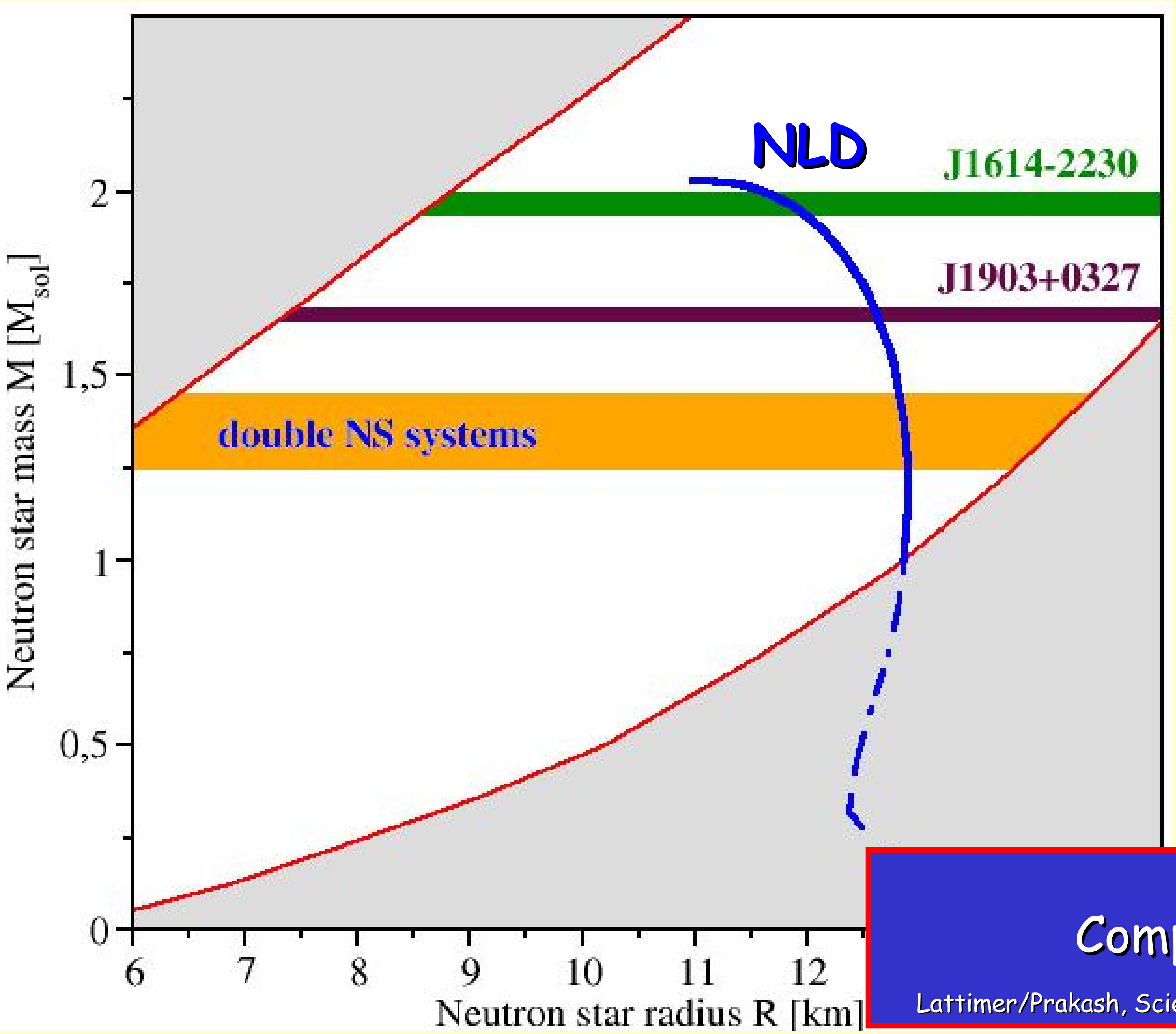
Phys. Rev. D82, 101301 (2010).



... and A.W. Steiner !

Astrophys. J. 722, 33 (2010).

Basic properties: nuclear EoS & opt. potentials...

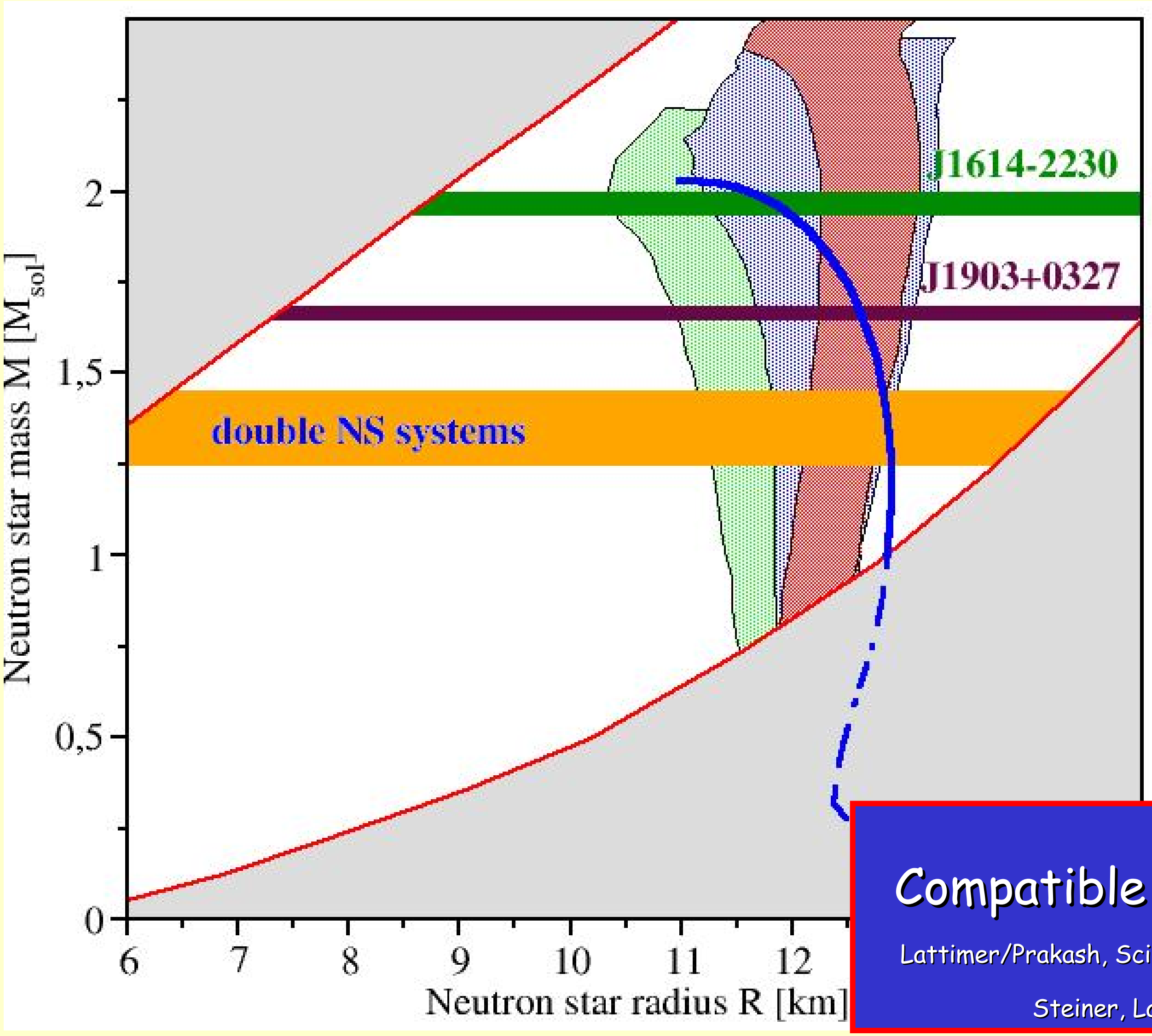


Compatible with ...

Lattimer/Prakash, Science 304 ('04) 536, Phys. Rep. 442 ('07) 109

Nucl. Phys. A899 (2013) 133

Basic properties: nuclear EoS & opt. potentials...



Compatible with all observations !

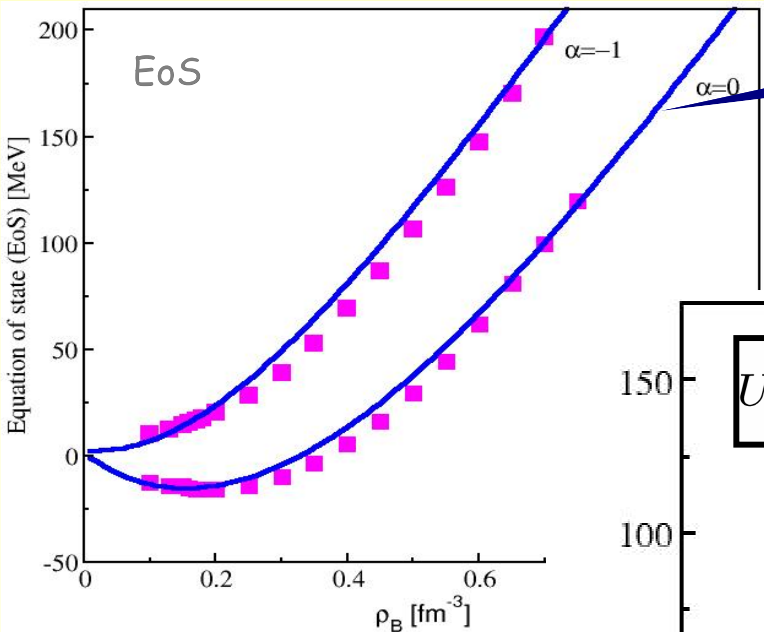
Lattimer/Prakash, Science 304 ('04) 536, Phys. Rep. 442 ('07) 109

Steiner, Lattimer, Brown, arXiv: 1205.6871

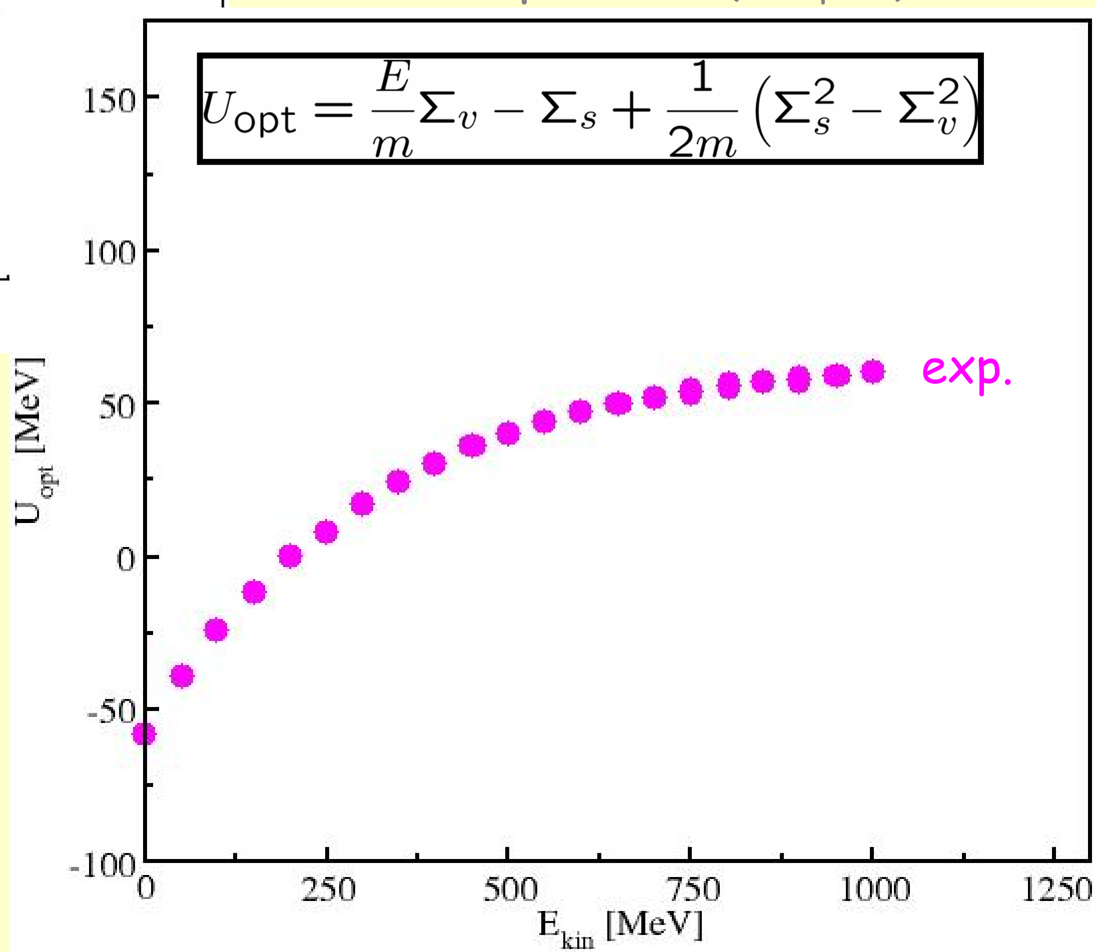
Nucl. Phys. A899 (2013) 133

Basic properties: nuclear EoS & opt. potentials…

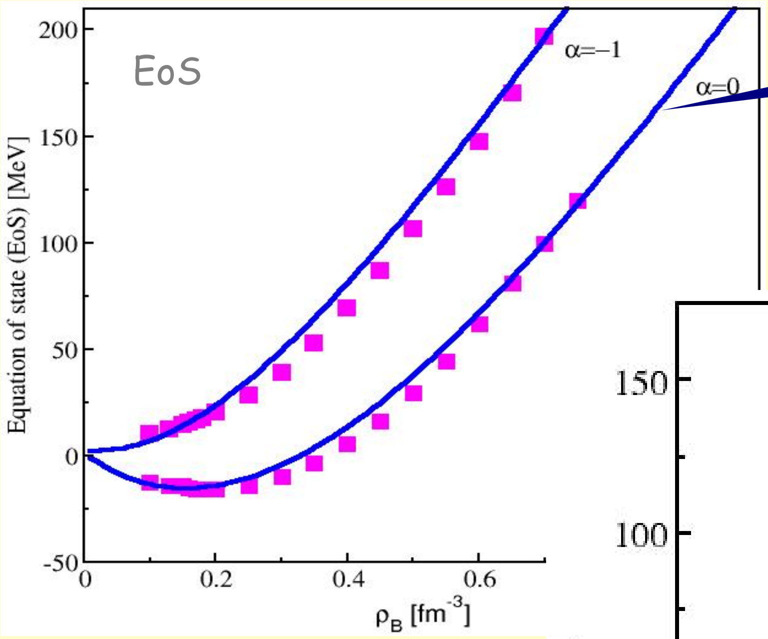
high ρ → high momenta



In-medium **proton** SEP (real part)

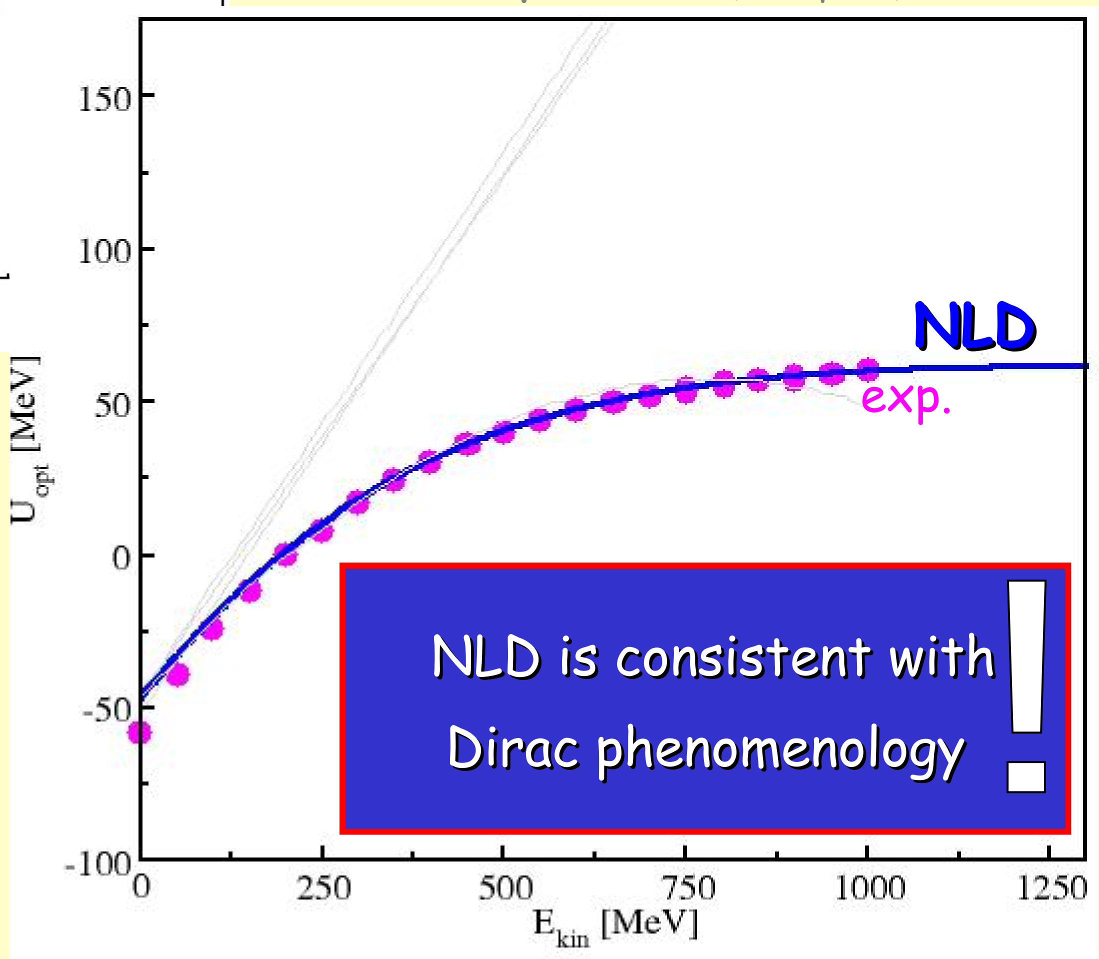


Basic properties: nuclear EoS & opt. potentials...



high ρ → high momenta

In-medium **proton** SEP (real part)

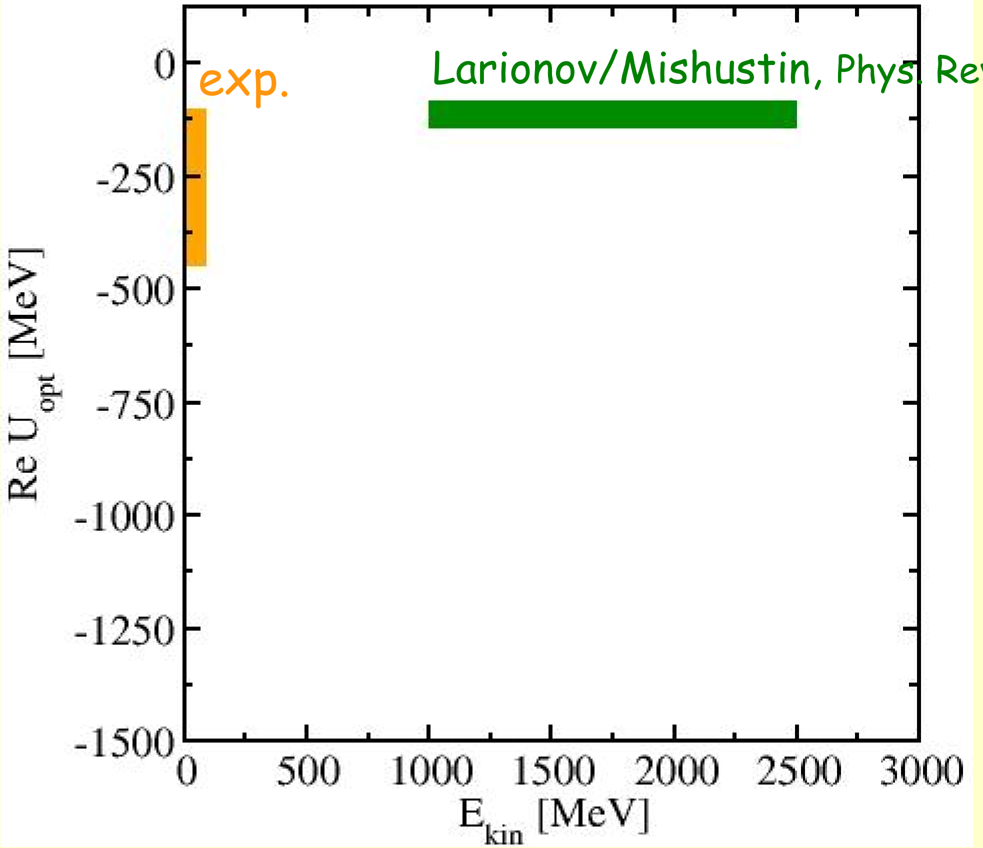


NLD is consistent with Dirac phenomenology !

Nucl. Phys. A899 (2013) 133

Basic properties: nuclear EoS & opt. potentials...

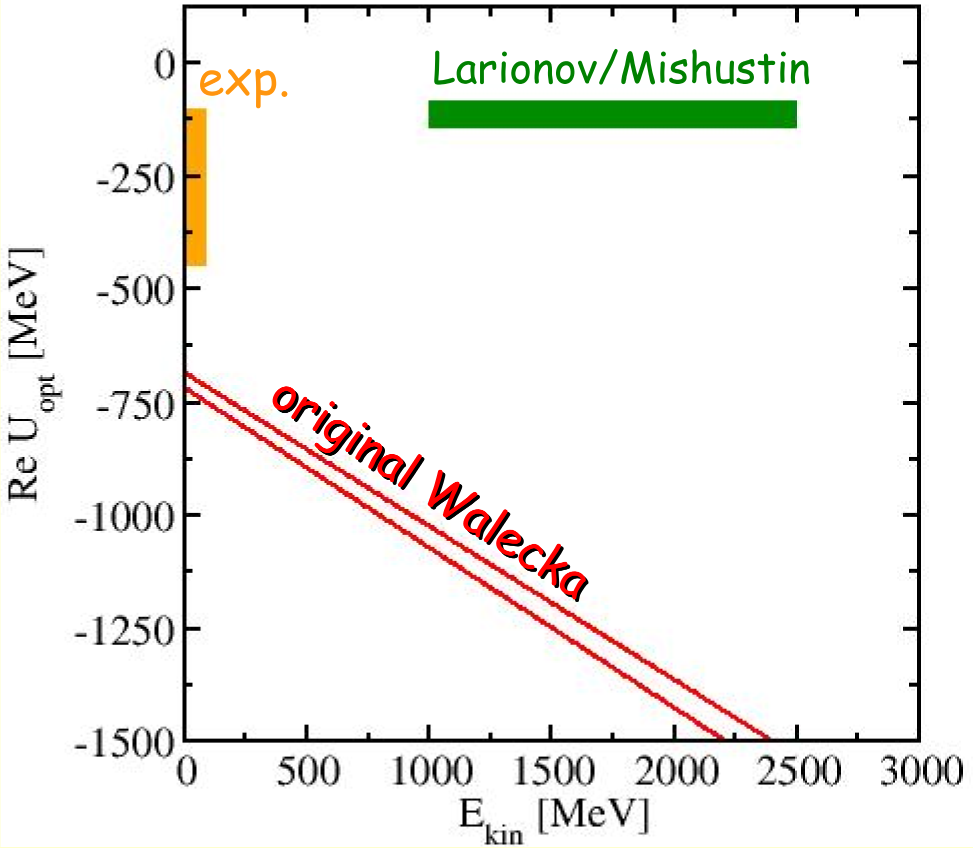
In-medium **anti-proton** SEP (real part)



Larionov/Mishustin, Phys. Rev. C80 ('09) 021601(R).

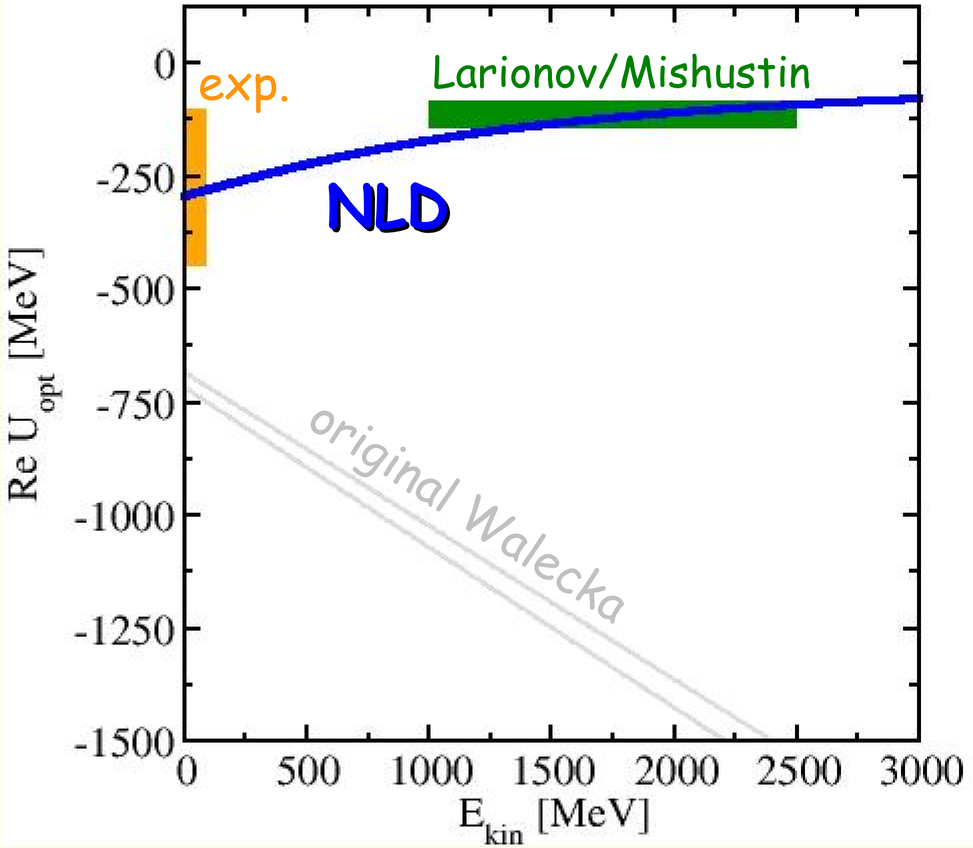
Basic properties: nuclear EoS & opt. potentials…

In-medium **anti-proton** SEP (real part)



Basic properties: nuclear EoS & opt. potentials...

In-medium **anti-proton** SEP (real part)

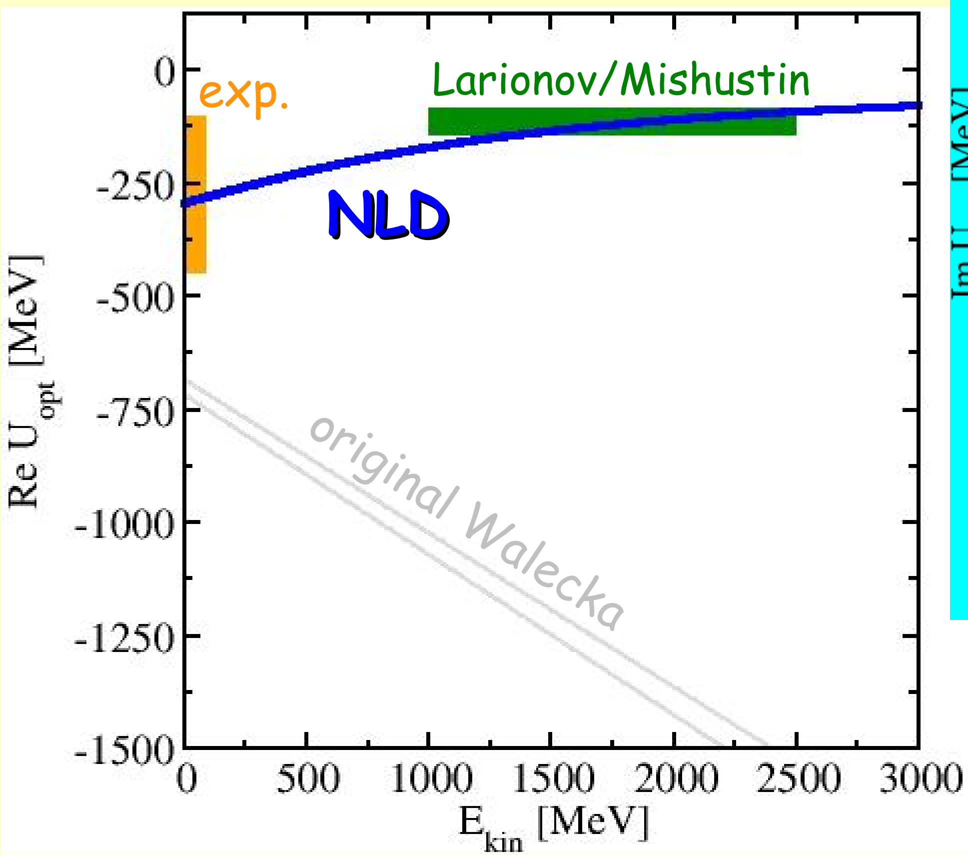


Also: NLD provides the imaginary part of SEP for anti-proton in-medium interactions using dispersion relation (without subtractions)

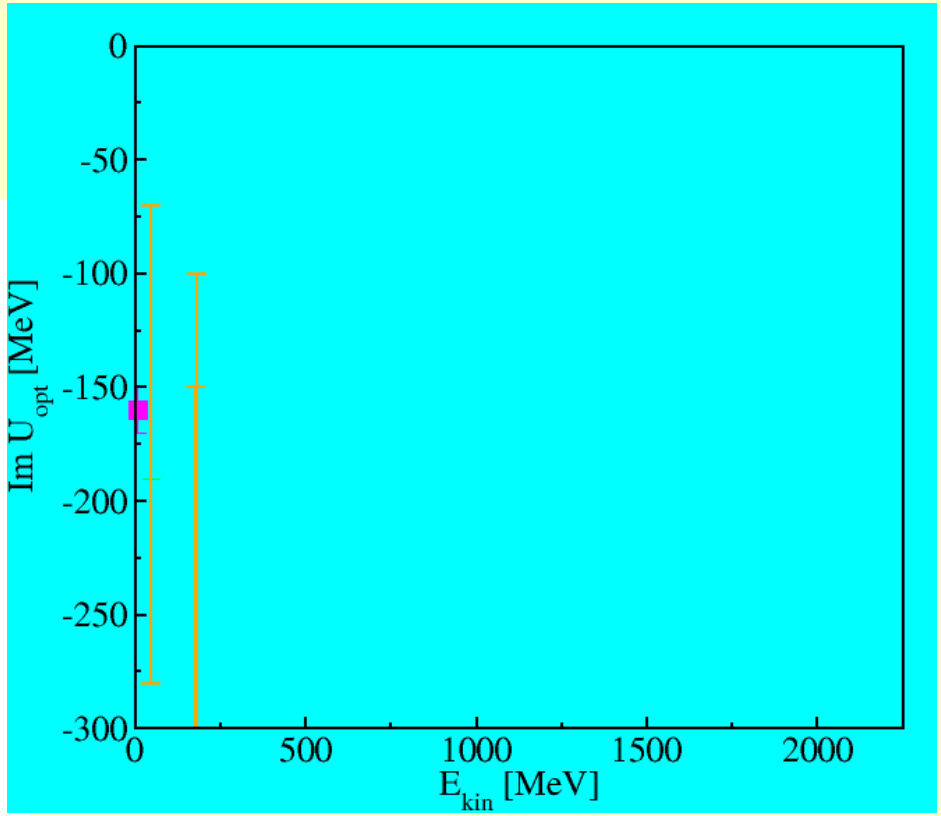
Nucl. Phys. A940 (2015) 181

Basic properties: nuclear EoS & opt. potentials…

In-medium **anti-proton** SEP (real part)



In-medium **anti-proton** SEP (imag. part)



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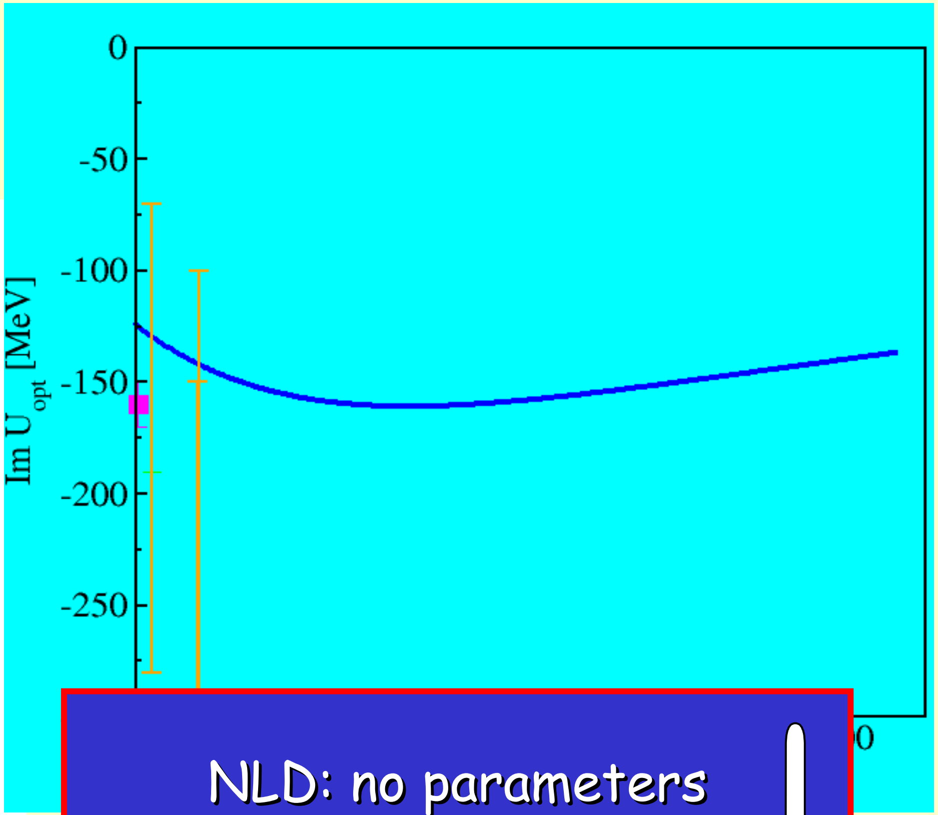
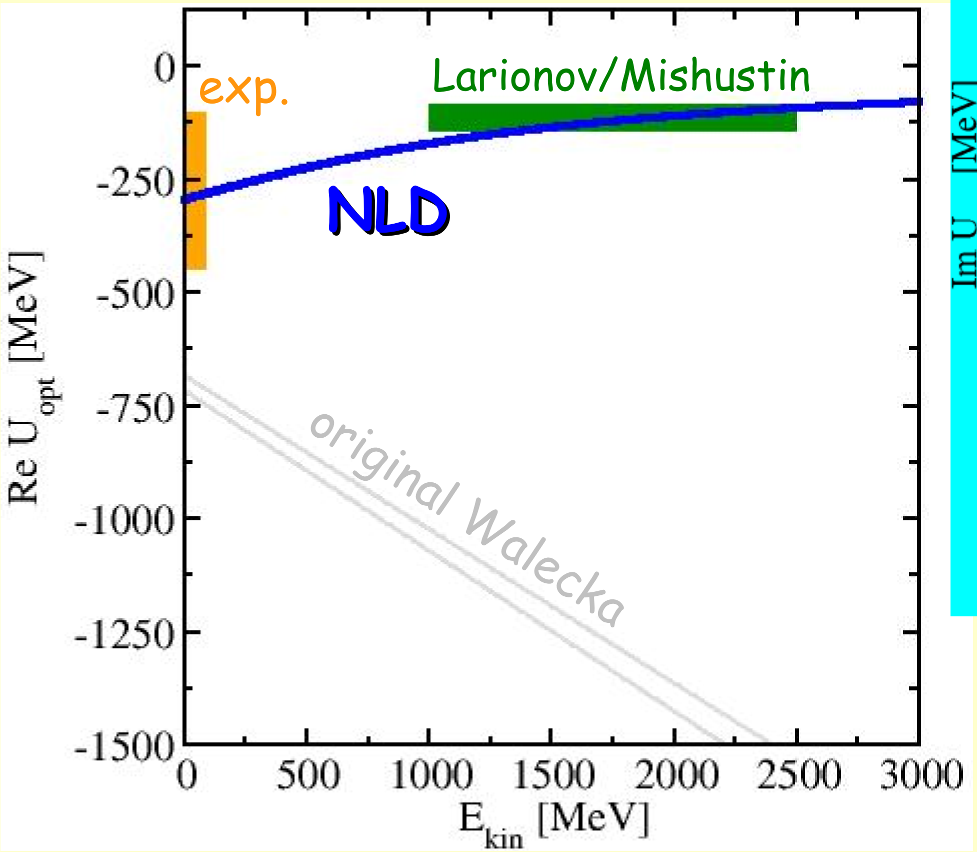
Nucl. Phys. A940 (2015) 181

Basic properties: nuclear EoS & opt. potentials...

In-medium **anti-proton** SEP (imag. part)



In-medium **anti-proton** SEP (real part)



NLD: no parameters

good description of phenomenology

also for in-medium

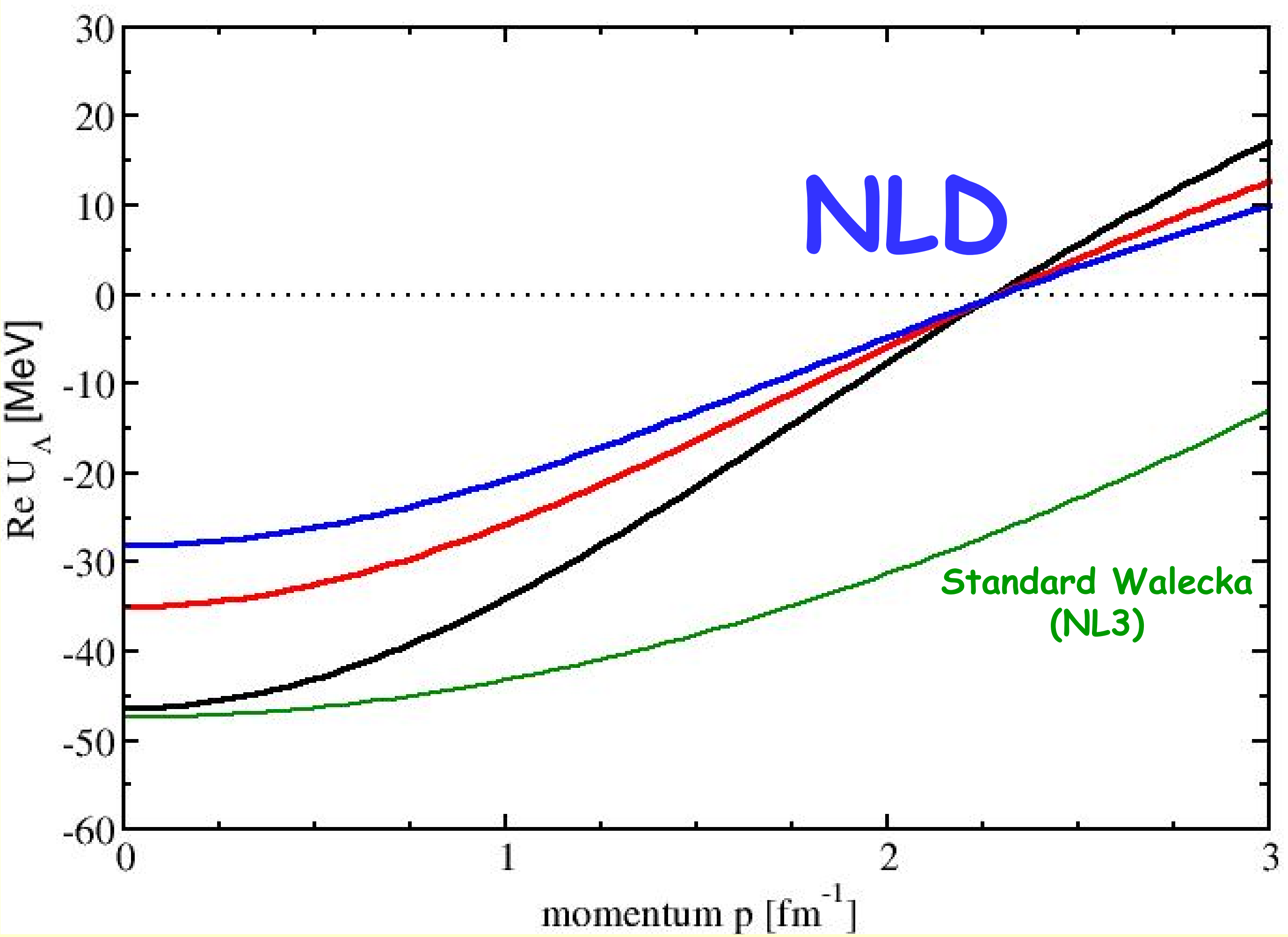
anti-proton interaction

Also: NLD provides the imaginary part of SEP for anti-p
using dispersion relation (without subtractions)

Hyperon properties: optical potentials...

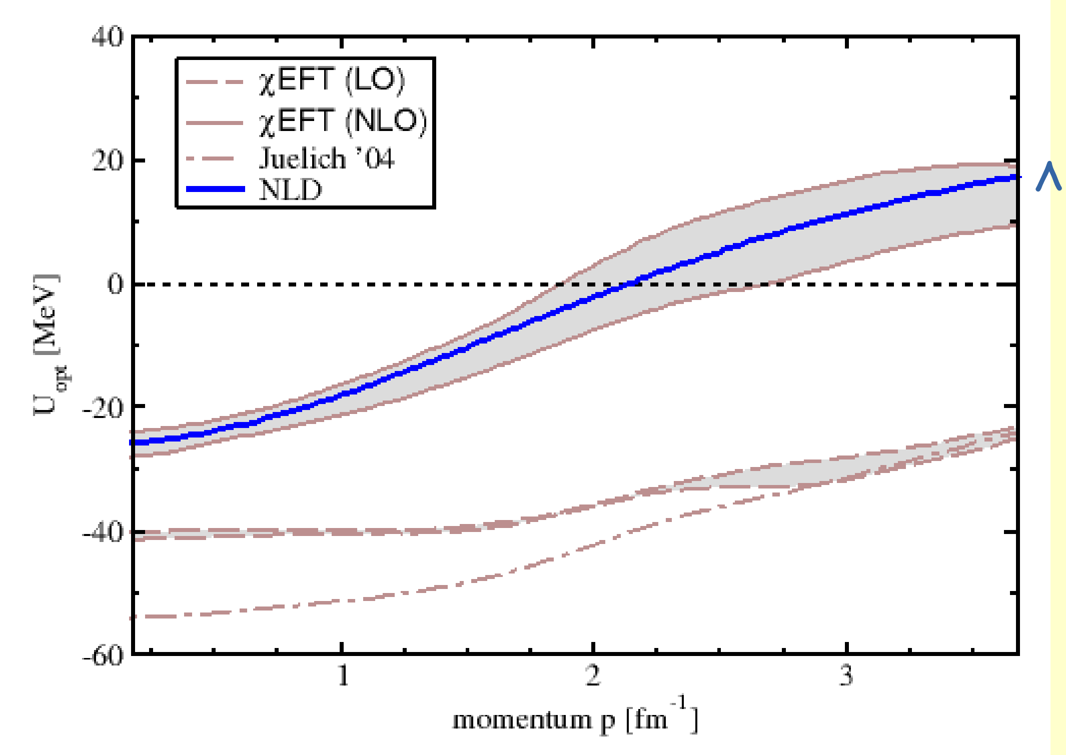
NLD + SU(6) for standard meson-nucleon couplings

Hyperon cut-off regulates MDI



Hyperon properties: Λ-optical potentials...

SU(6) for standard meson-nucleon couplings + NLD (monopole forms)
SNM, saturation density, adjust to χEFT

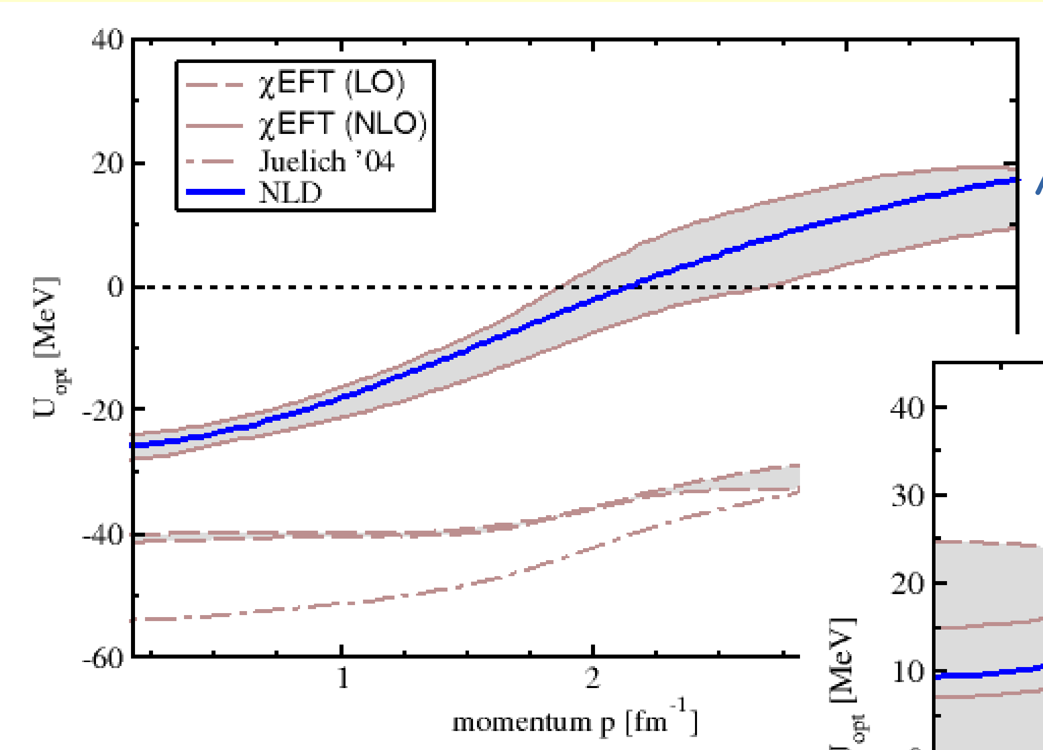


Λ Uopt: cut-offs ~ 0.75 GeV

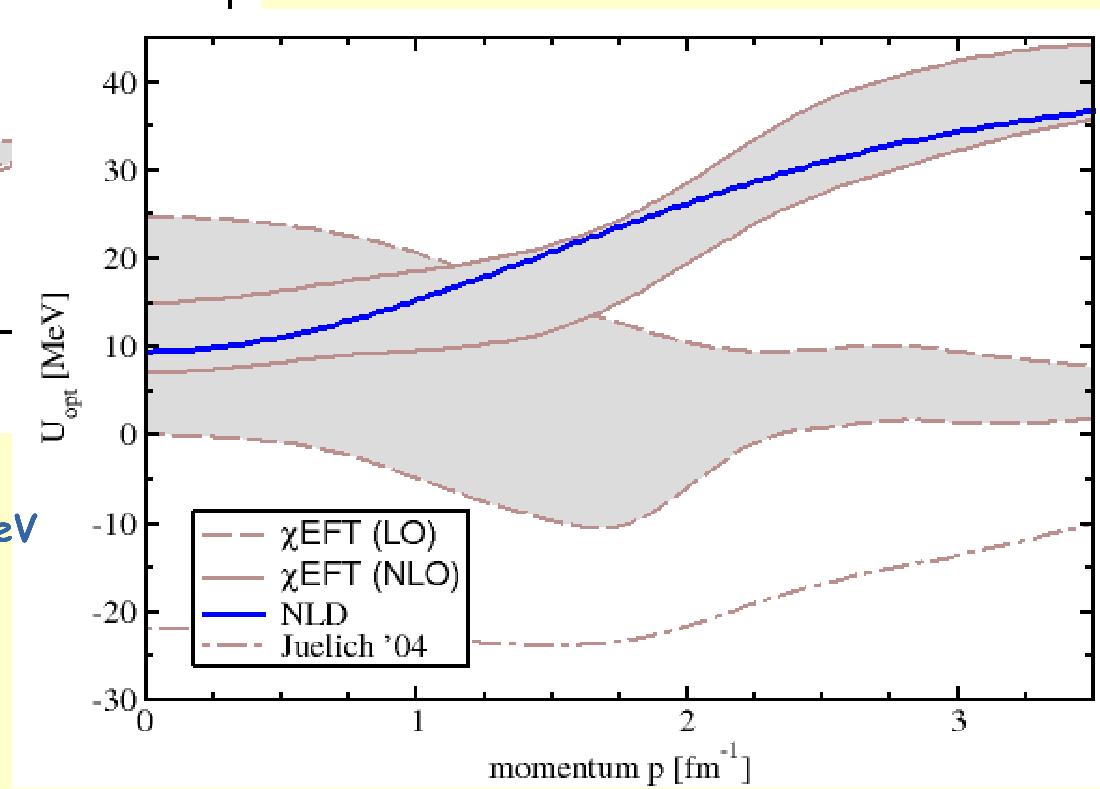
Hyperon properties: Λ,Σ-optical potentials...

SU(6) for standard meson-nucleon couplings + NLD (monopole forms)
SNM, saturation density, adjust to χEFT

χEFT: EPJA52 (2016) 15



Λ Uopt: cut-offs ~ 0.78 GeV



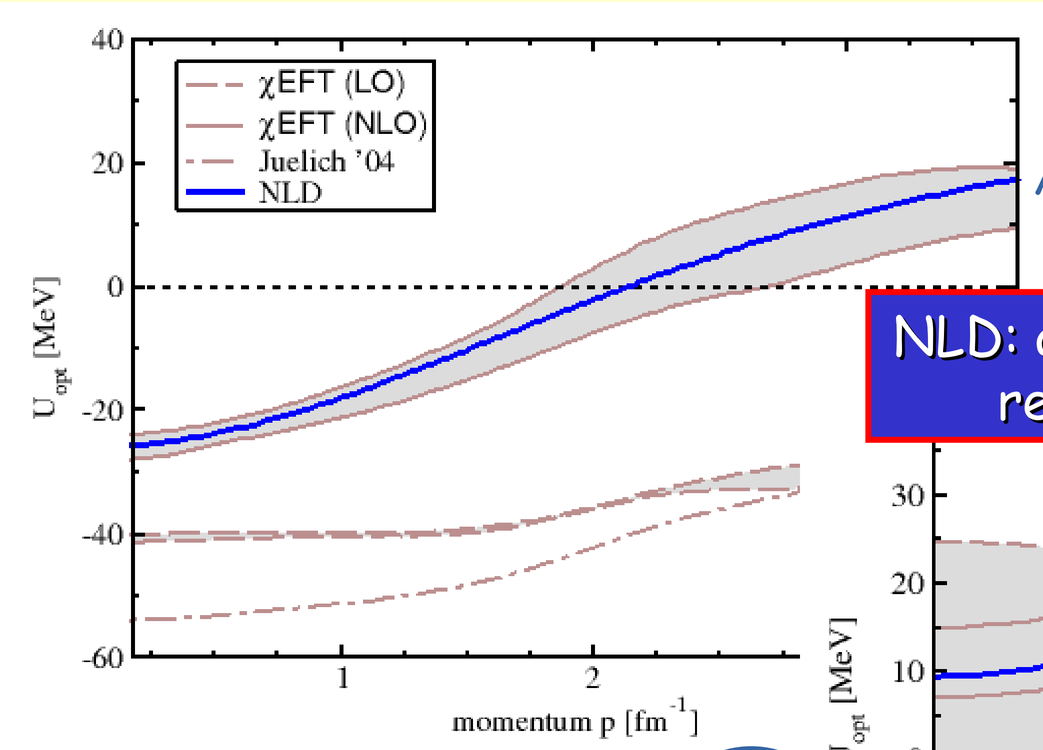
Σ Uopt: cut-offs ~ 0.8 GeV

Nucl. Phys. (2021) in press

Hyperon properties: Λ,Σ-optical potentials...

SU(6) for standard meson-nucleon couplings + NLD (monopole forms)
SNM, saturation density, adjust to χEFT

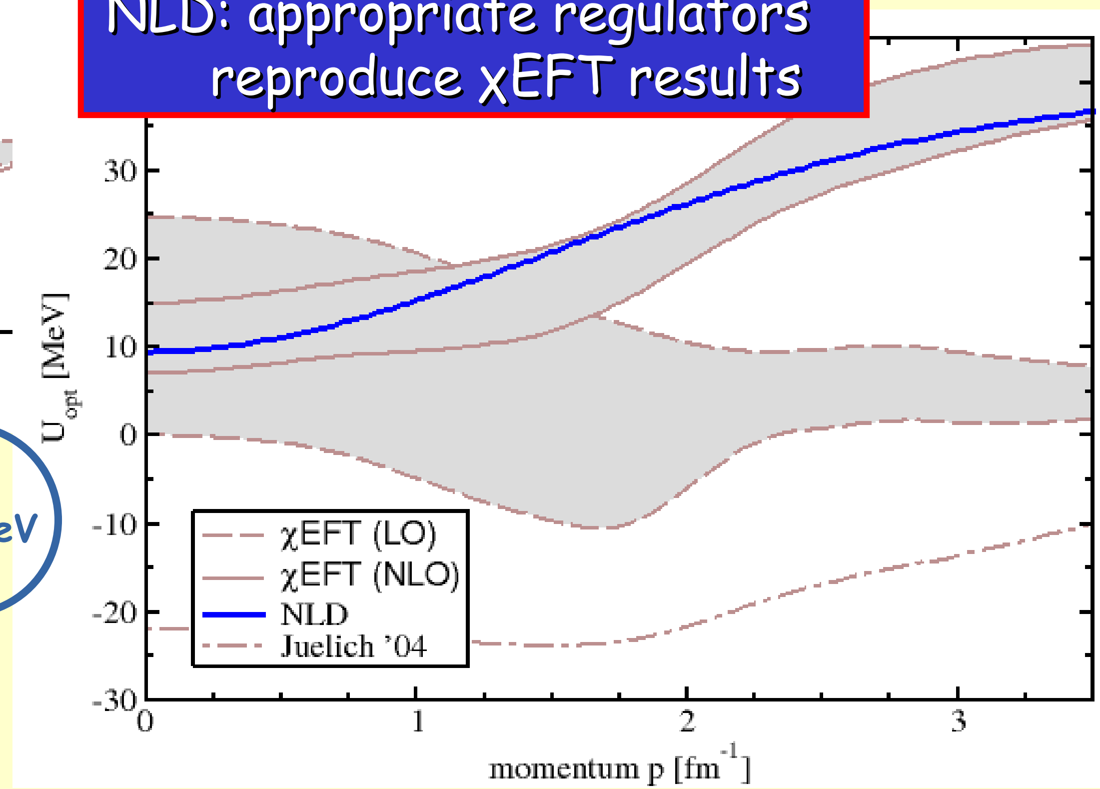
χEFT: EPJA52 (2016) 15



Λ Uopt: cut-offs ~ 0.78 GeV

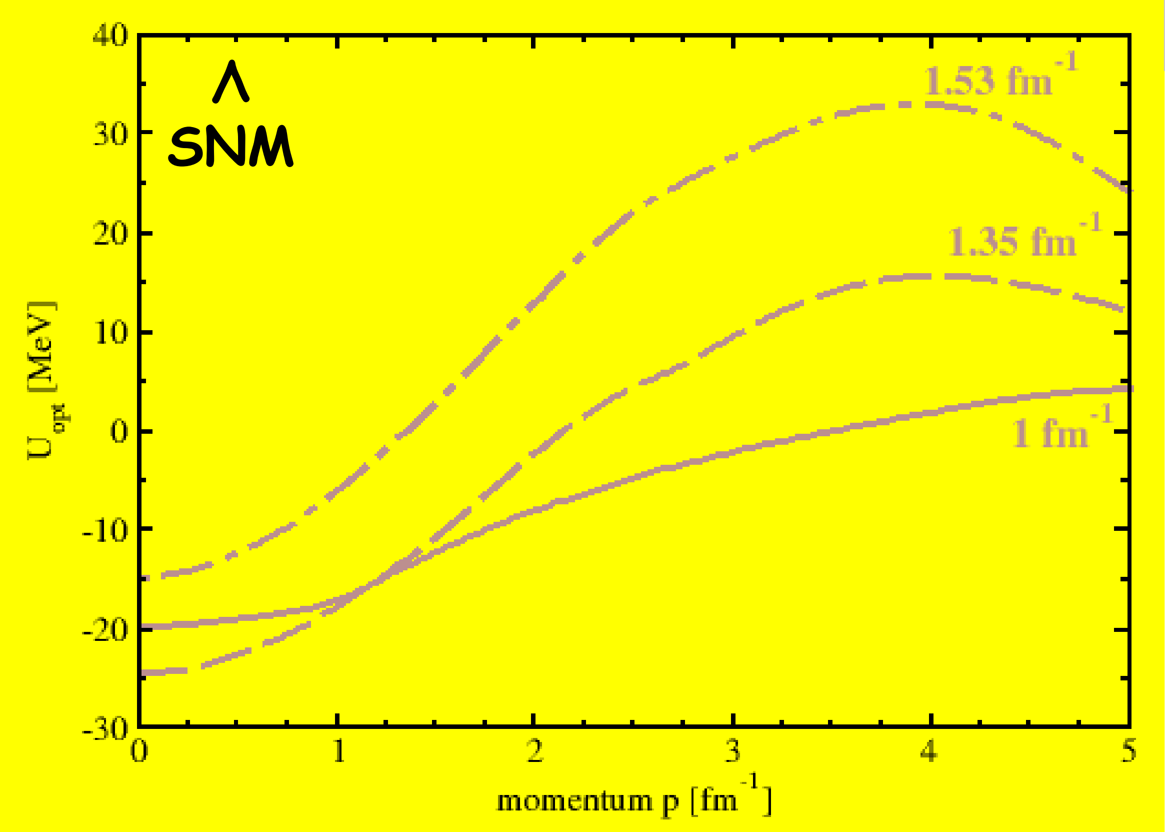
NLD: appropriate regulators reproduce χEFT results

Σ Uopt: cut-offs ~ 0.8 GeV



Hyperon properties: Λ-optical potentials...

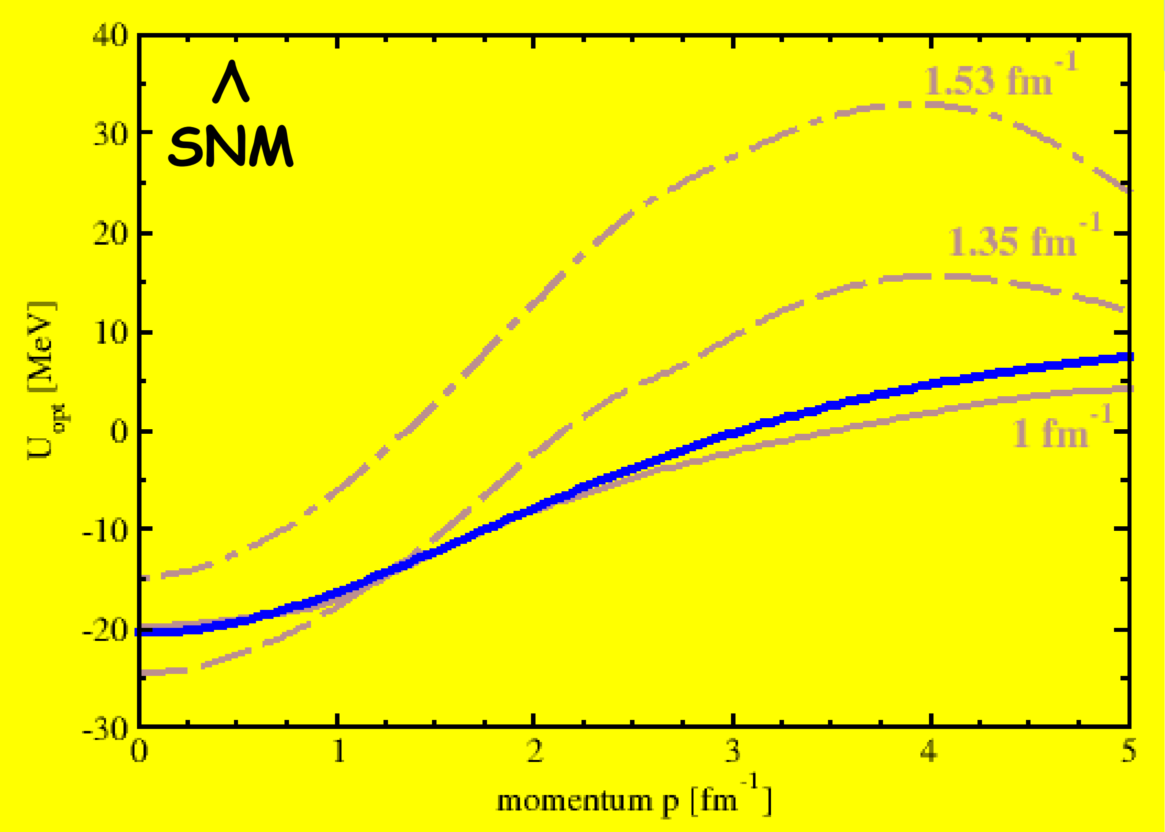
NLD predictions: density & momentum dependence



χEFT: EPJA52 (2016) 15

Hyperon properties: Λ-optical potentials...

NLD predictions: density & momentum dependence

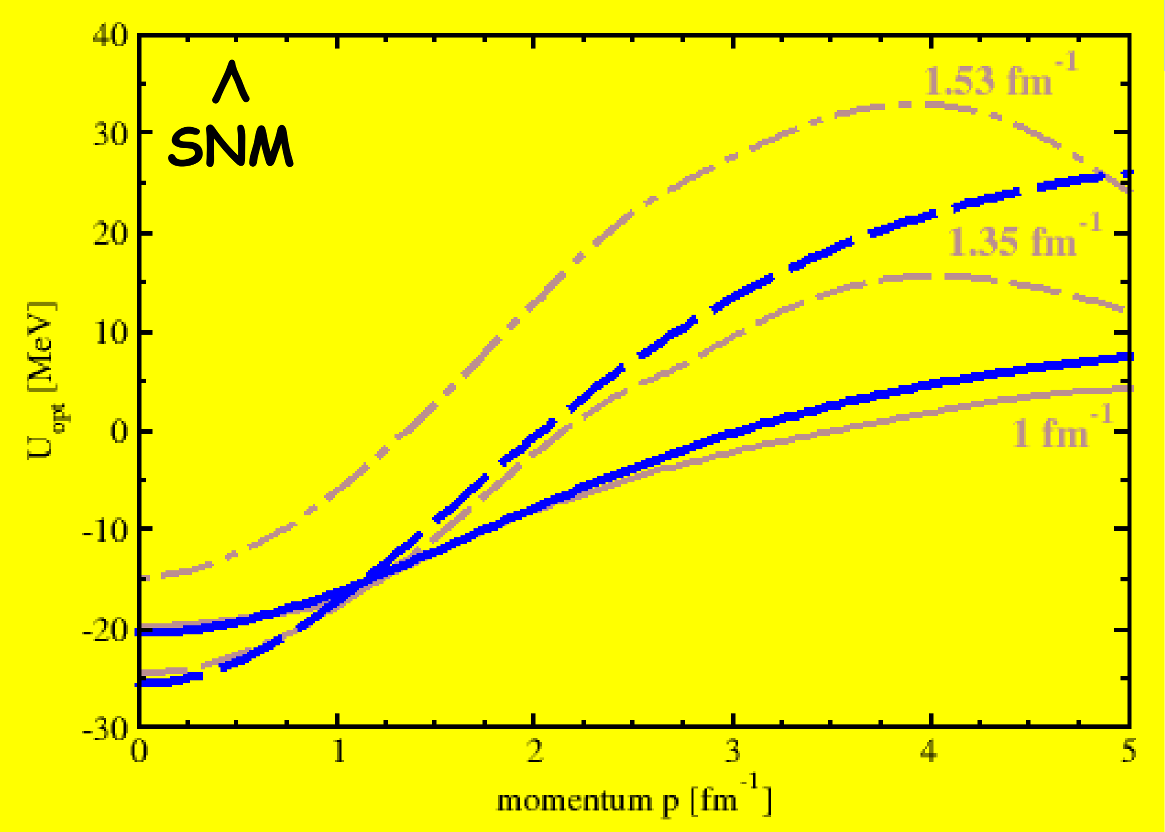


χEFT: EPJA52 (2016) 15

NLD results

Hyperon properties: Λ-optical potentials...

NLD predictions: density & momentum dependence



χEFT: EPJA52 (2016) 15

NLD results

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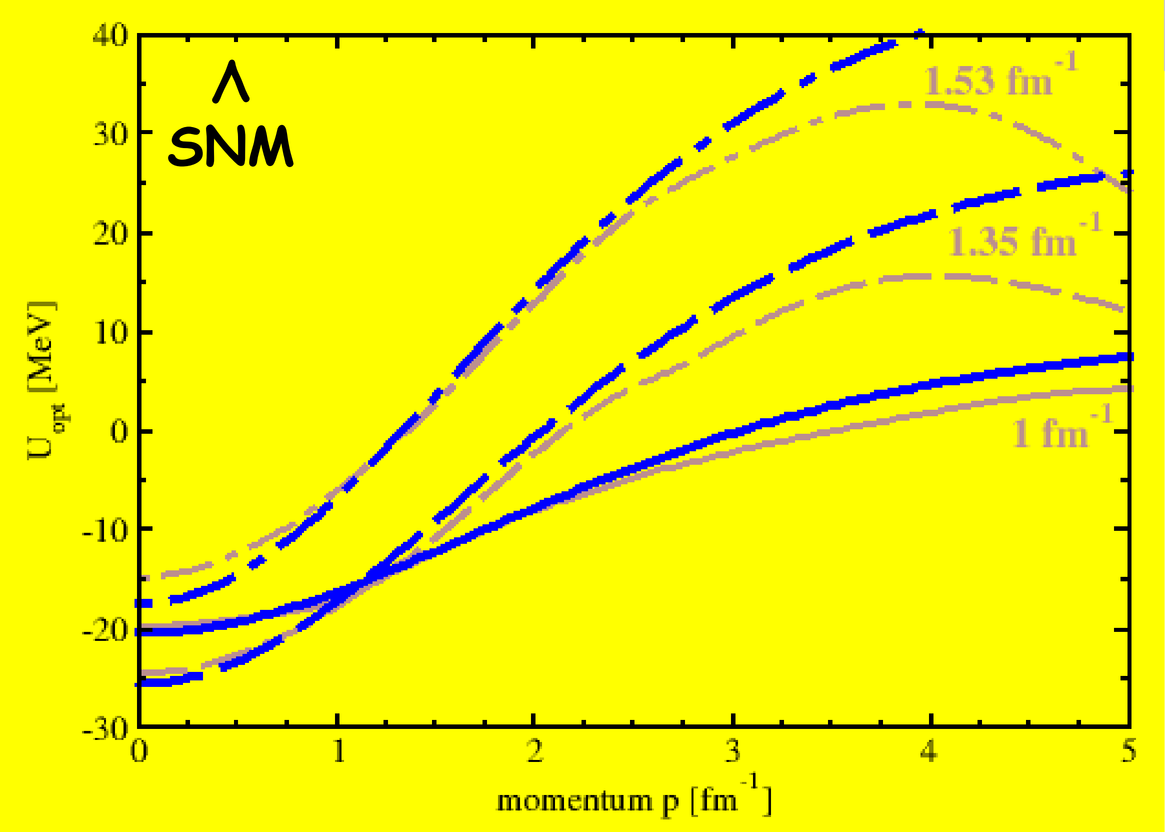
NLD predictions: density & momentum dependence



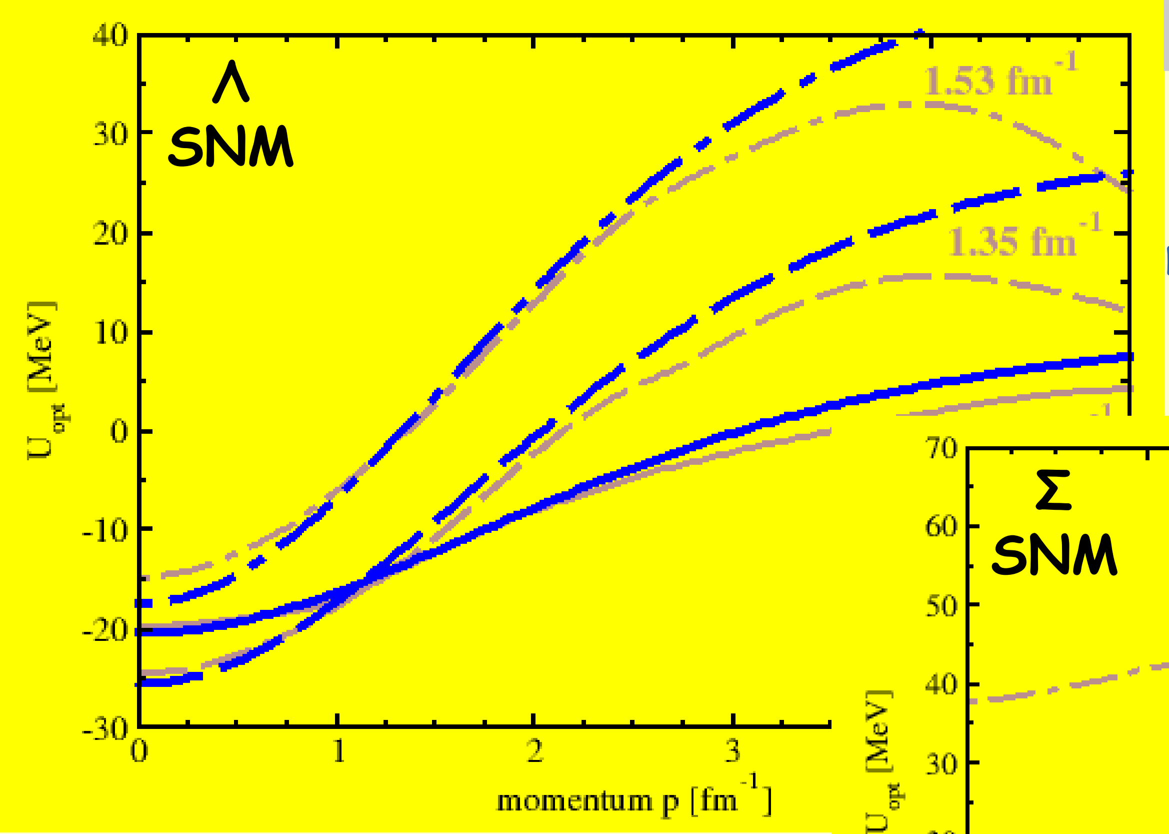
χEFT: EPJA52 (2016) 15

NLD results

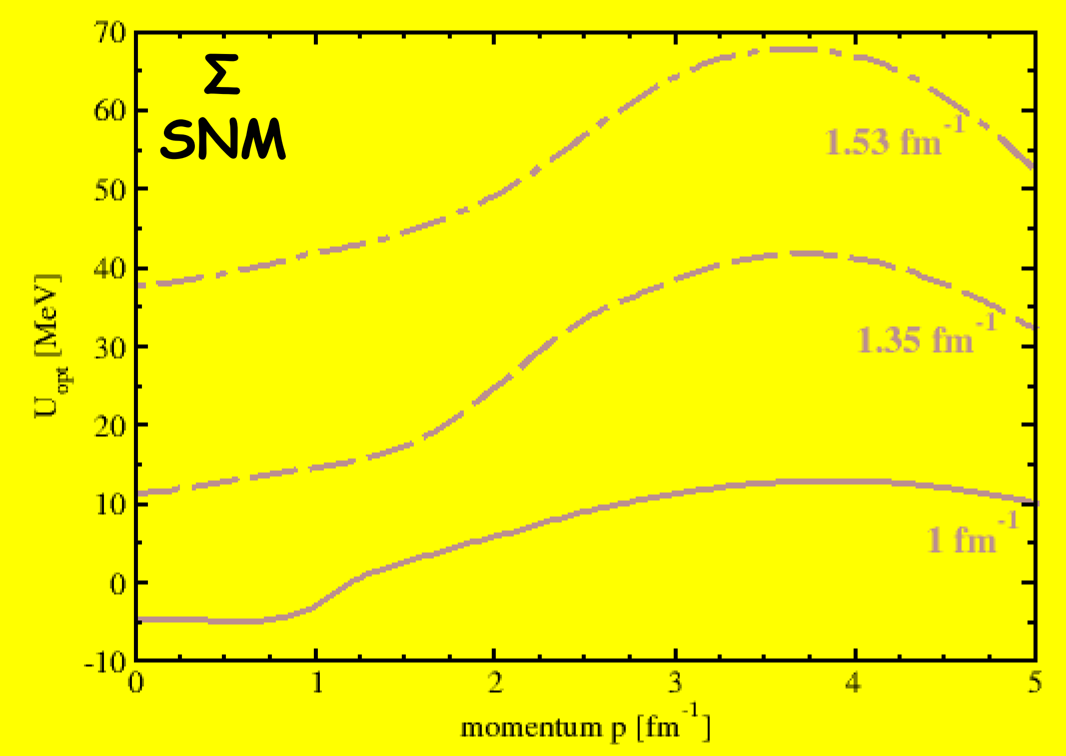
Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence

χEFT: EPJA52 (2016) 15



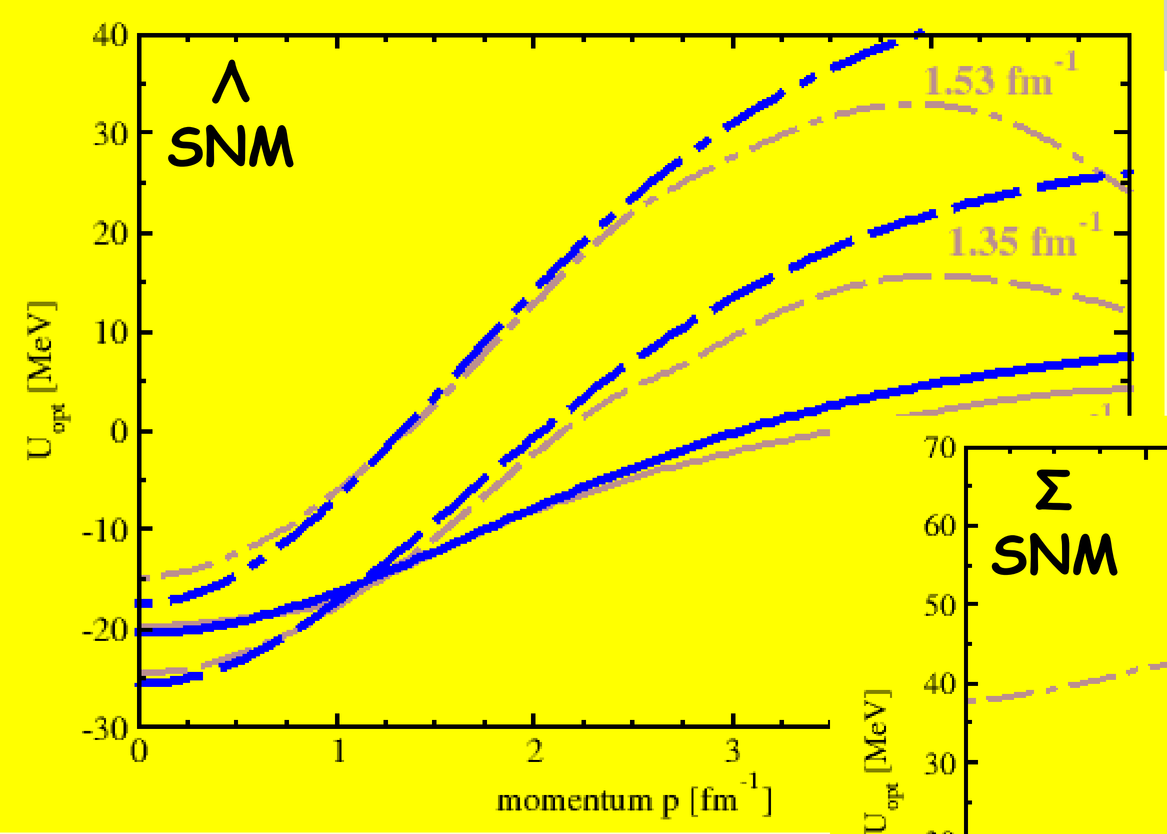
NLD results



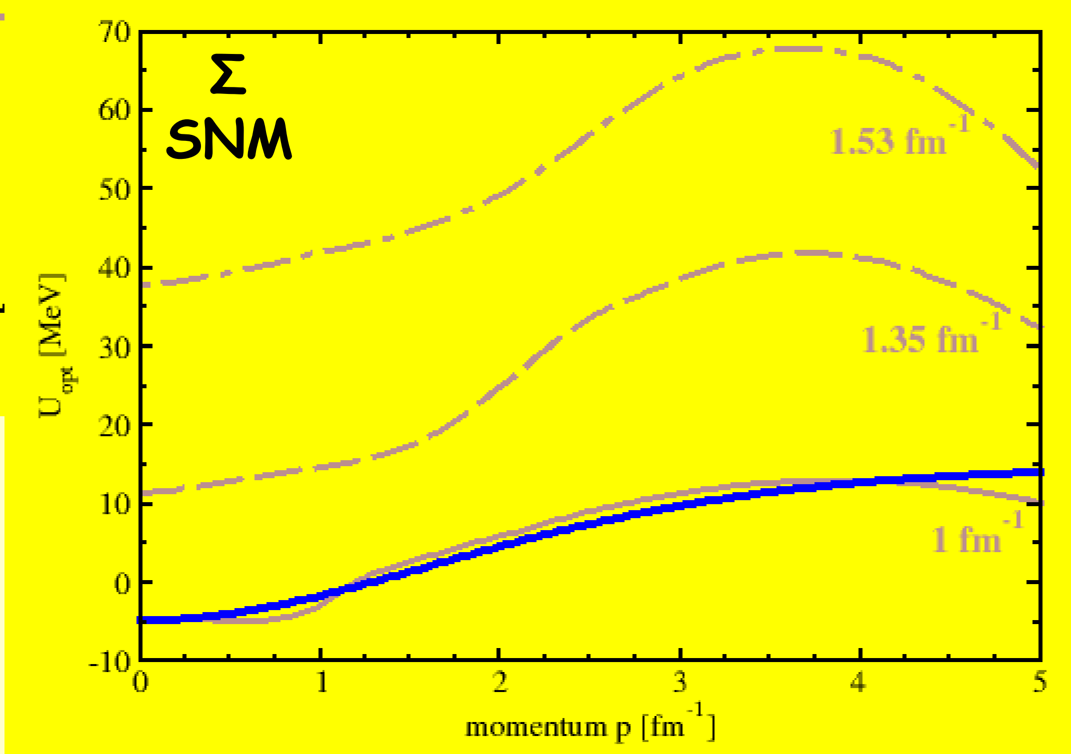
Hyperon properties: Λ,Σ-optical potentials…

NLD predictions: density & momentum dependence

χEFT: EPJA52 (2016) 15



NLD results

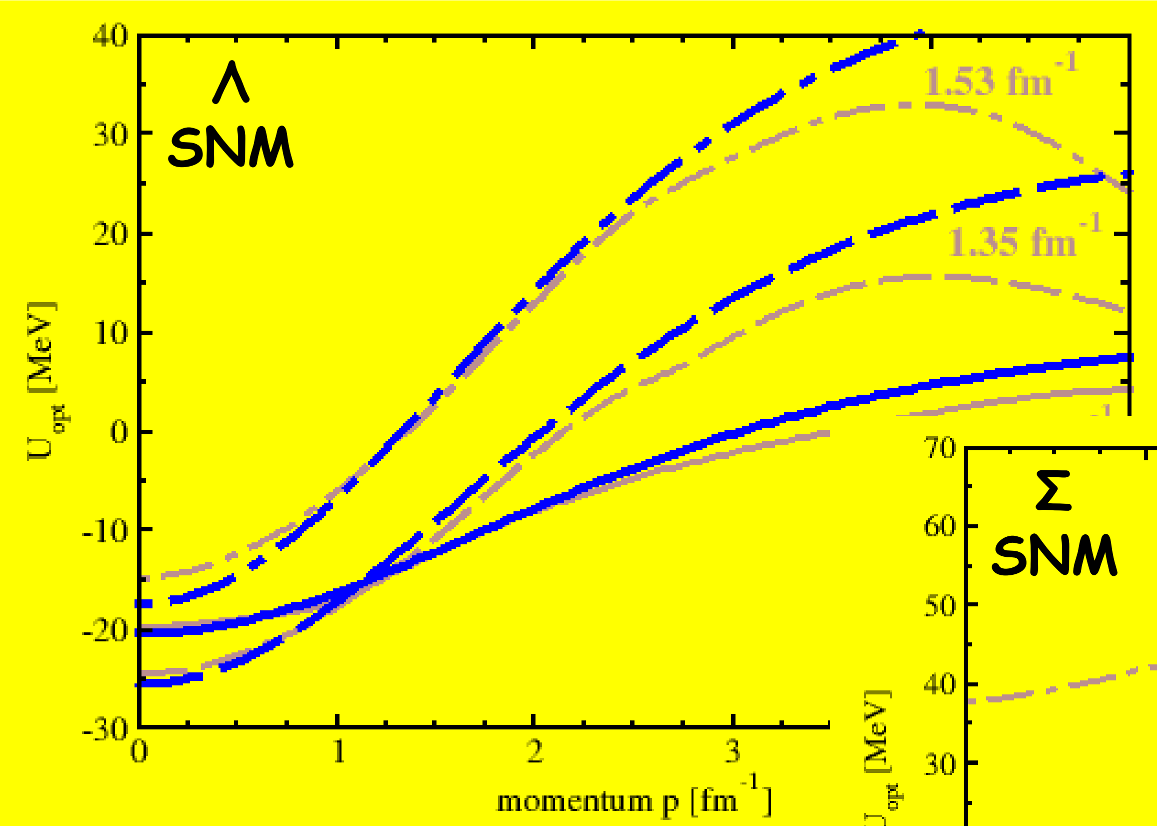


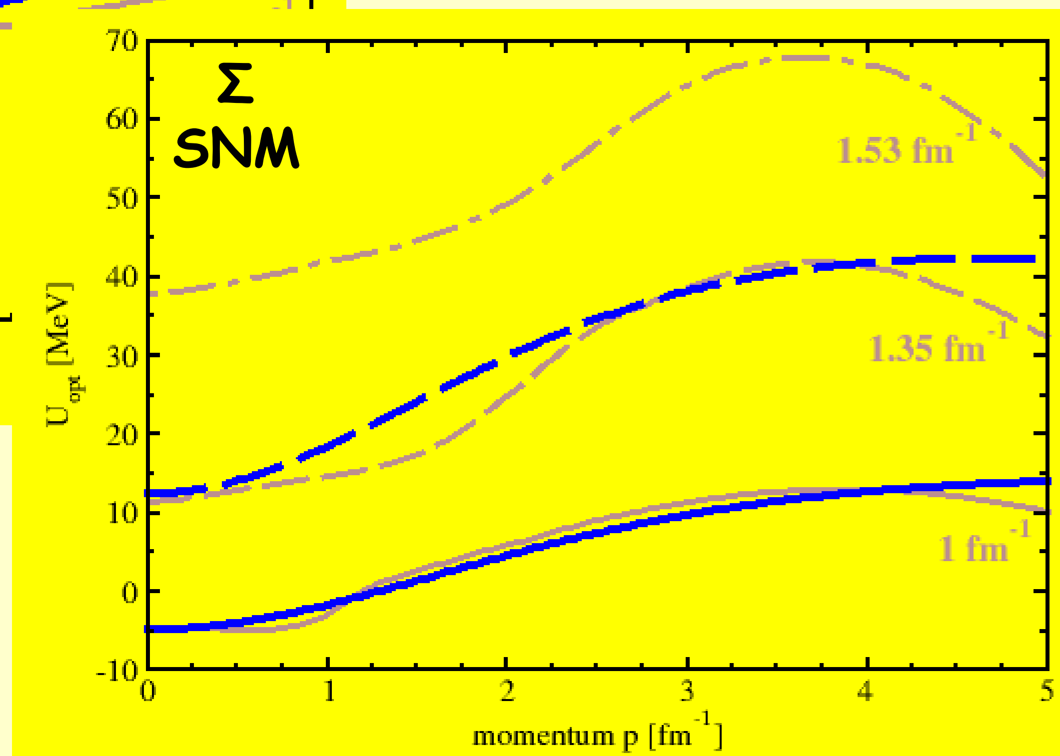
Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence

χEFT: EPJA52 (2016) 15

NLD results

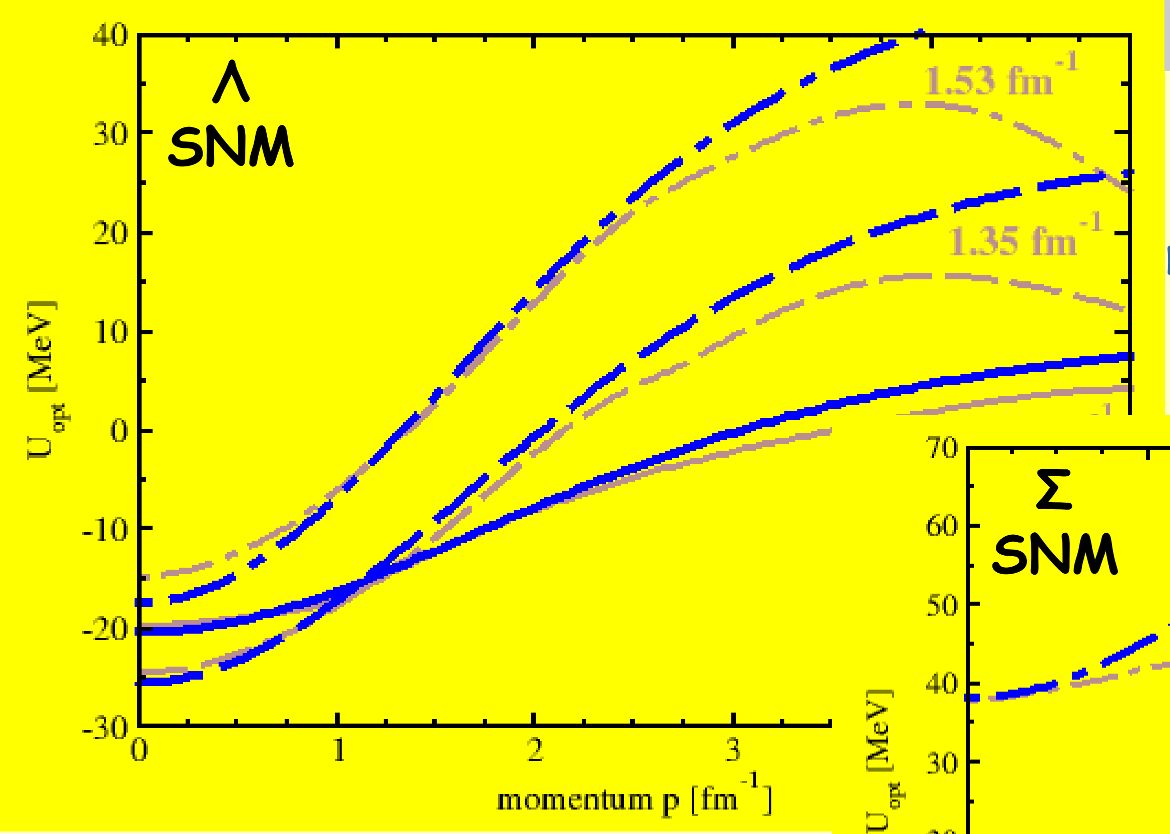




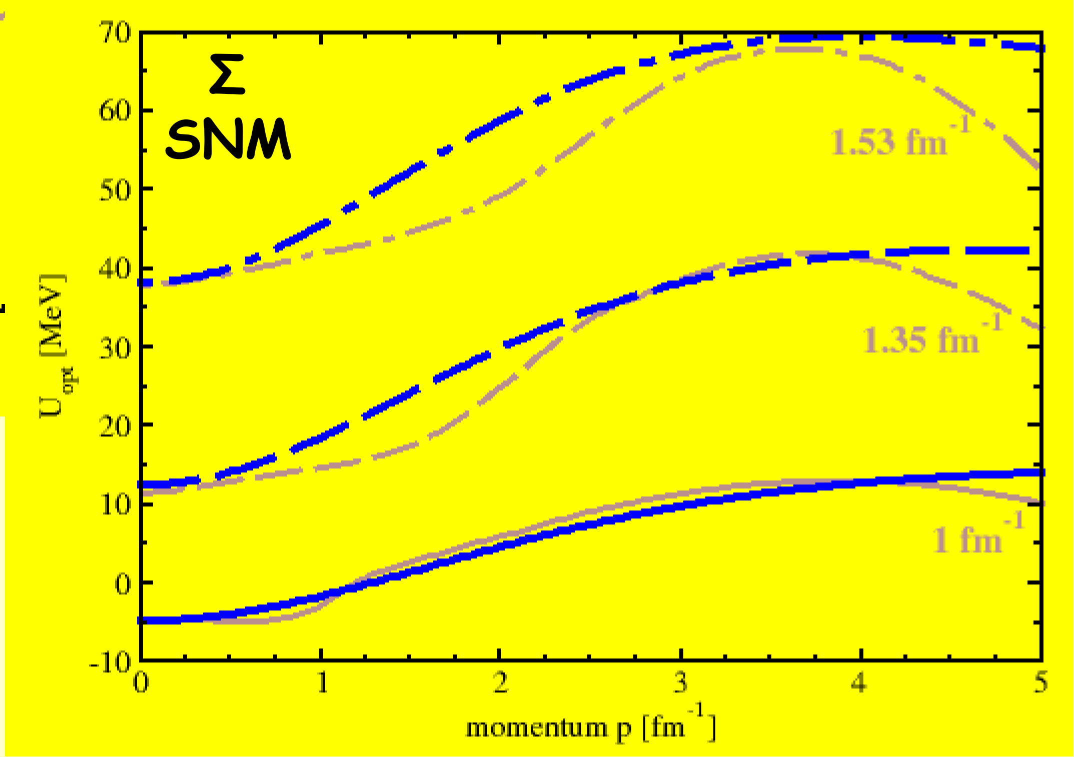
Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence

χEFT: EPJA52 (2016) 15



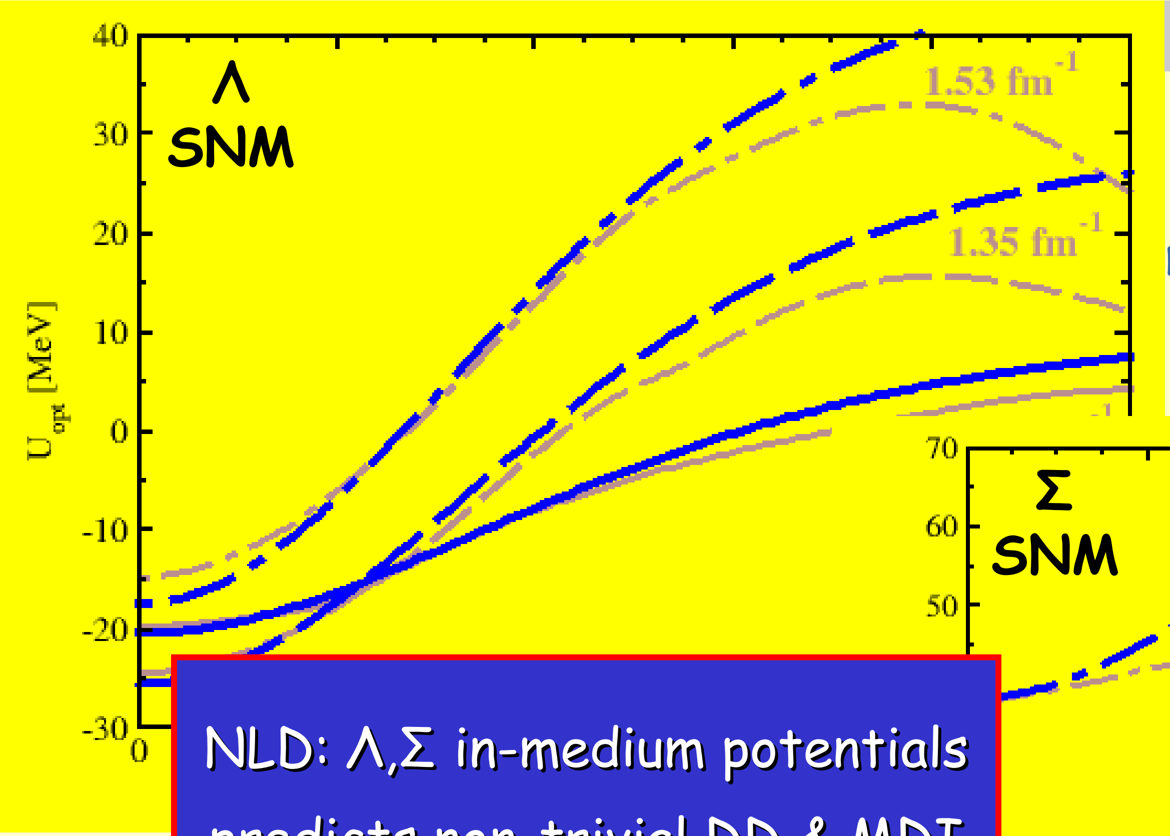
NLD results



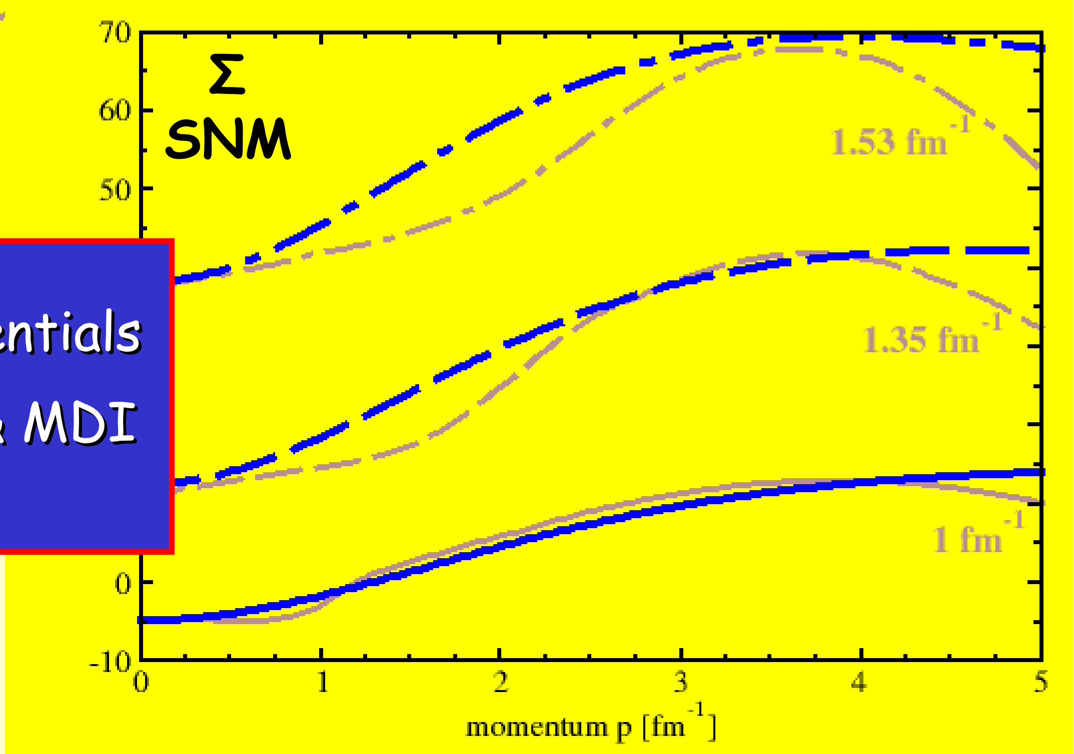
Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence

χEFT: EPJA52 (2016) 15



NLD results

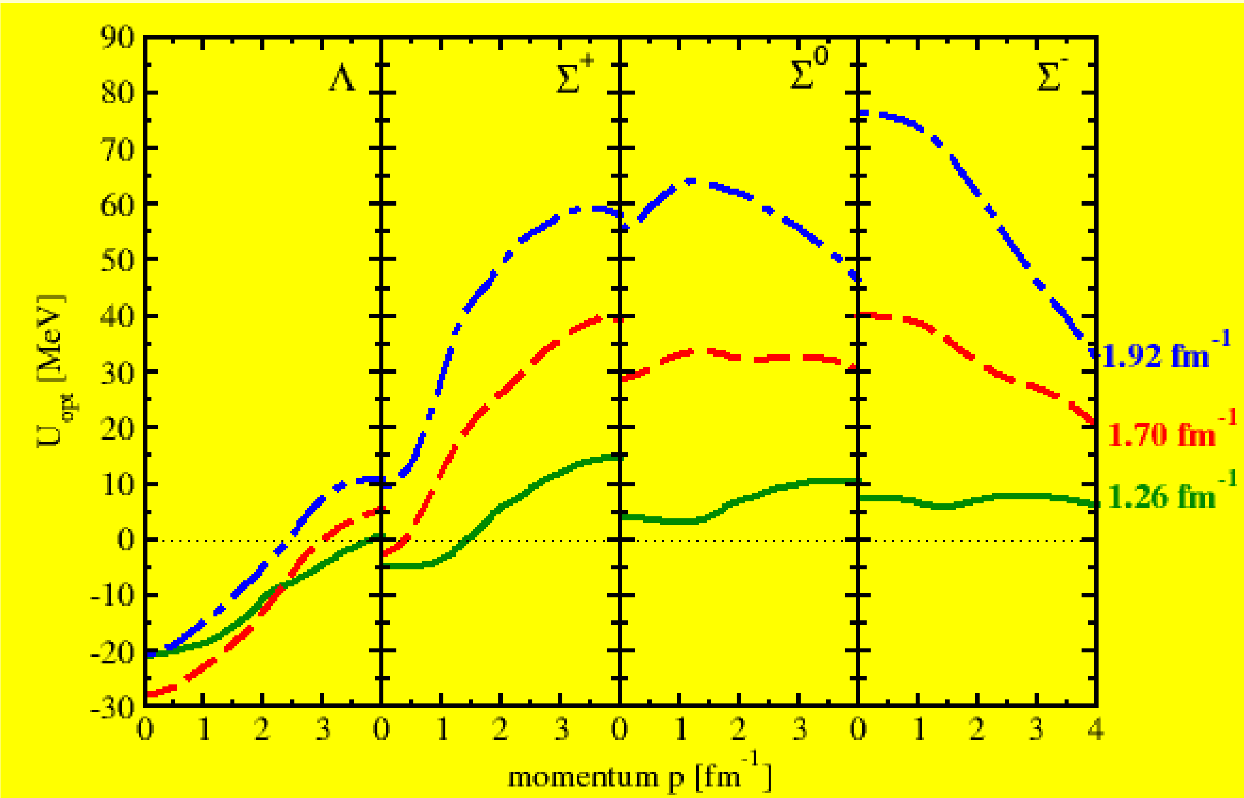


NLD: Λ,Σ in-medium potentials predicts non-trivial DD & MDI according χ-EFT

Nucl. Phys. (2021) in press

Hyperon properties: Λ,Σ-optical potentials…

NLD predictions: density & momentum dependence
pure neutron matter



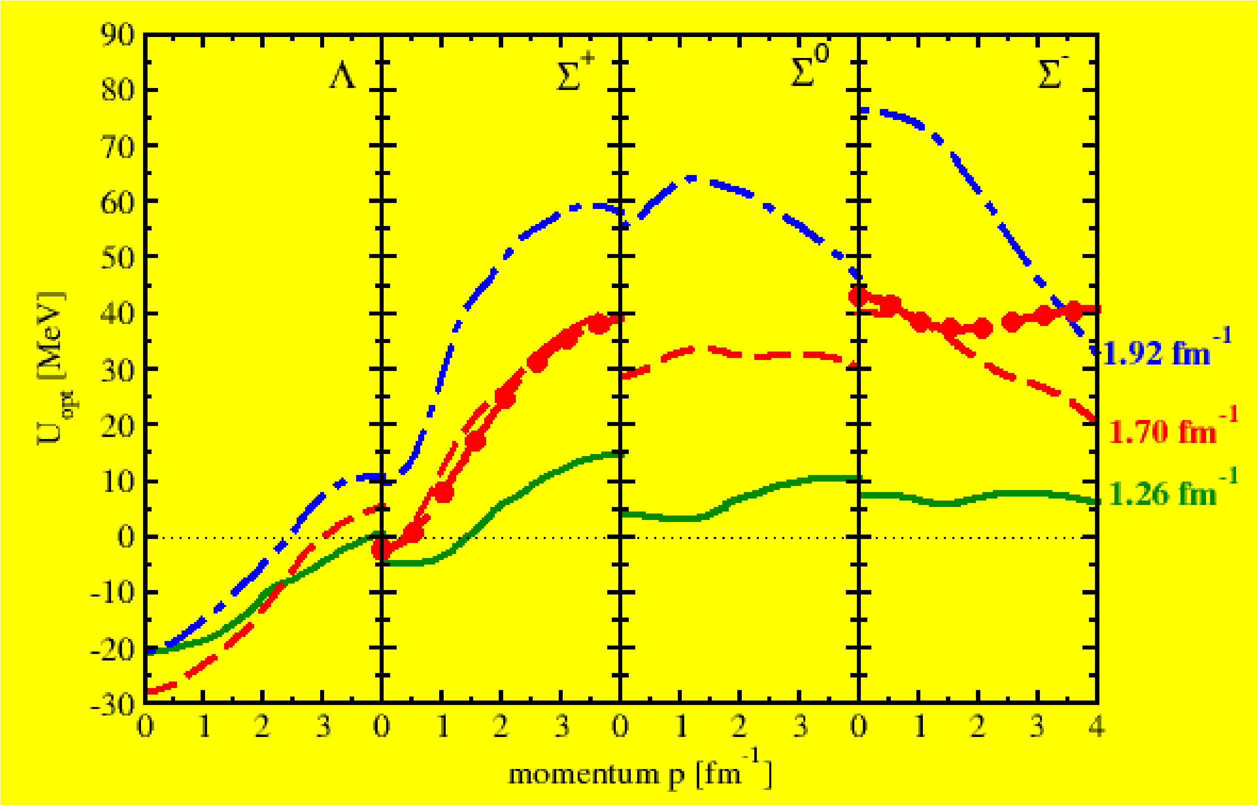
χEFT: EPJA52 (2016) 15

χ-EFT: non-trivial MDI

Hyperon properties: Λ,Σ-optical potentials...

NLD fit:

density & momentum dependence
pure neutron matter

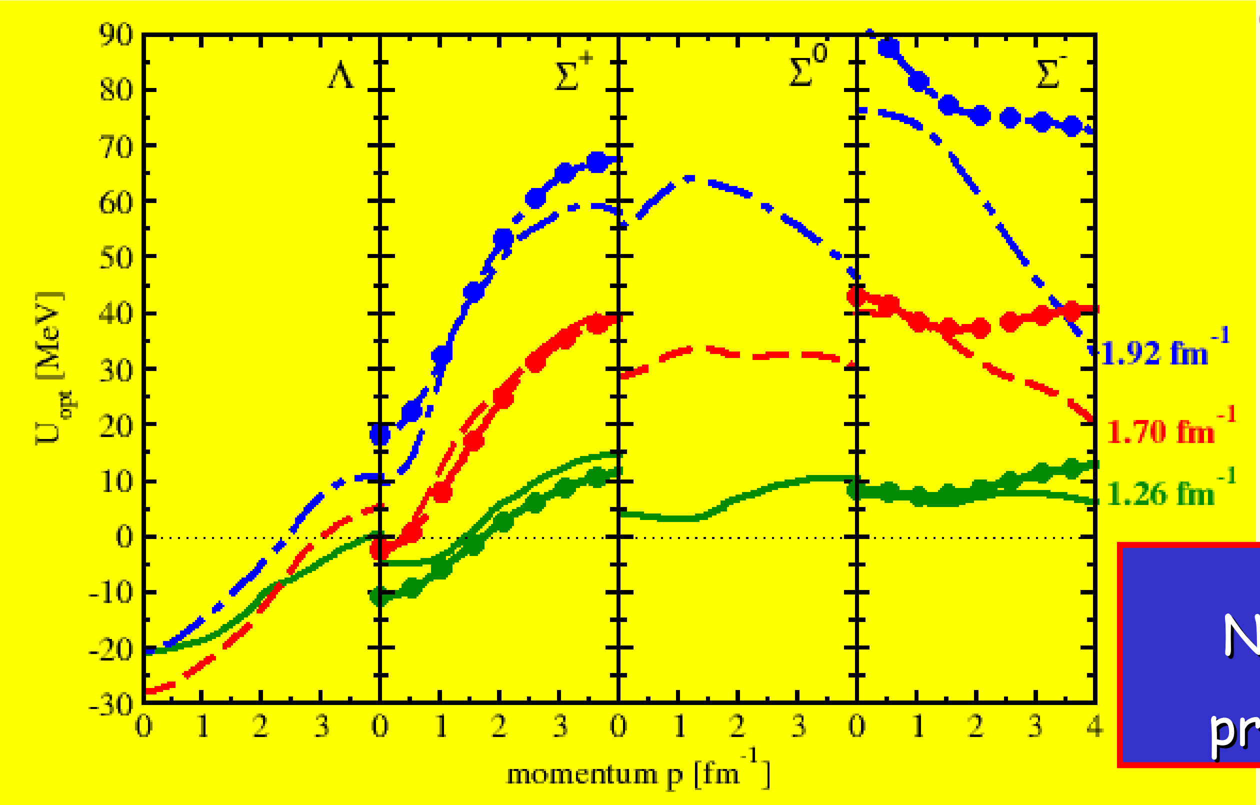


Curves: x-EFT
symbols: NLD

x-EFT: non-trivial MDI

Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence
pure neutron matter



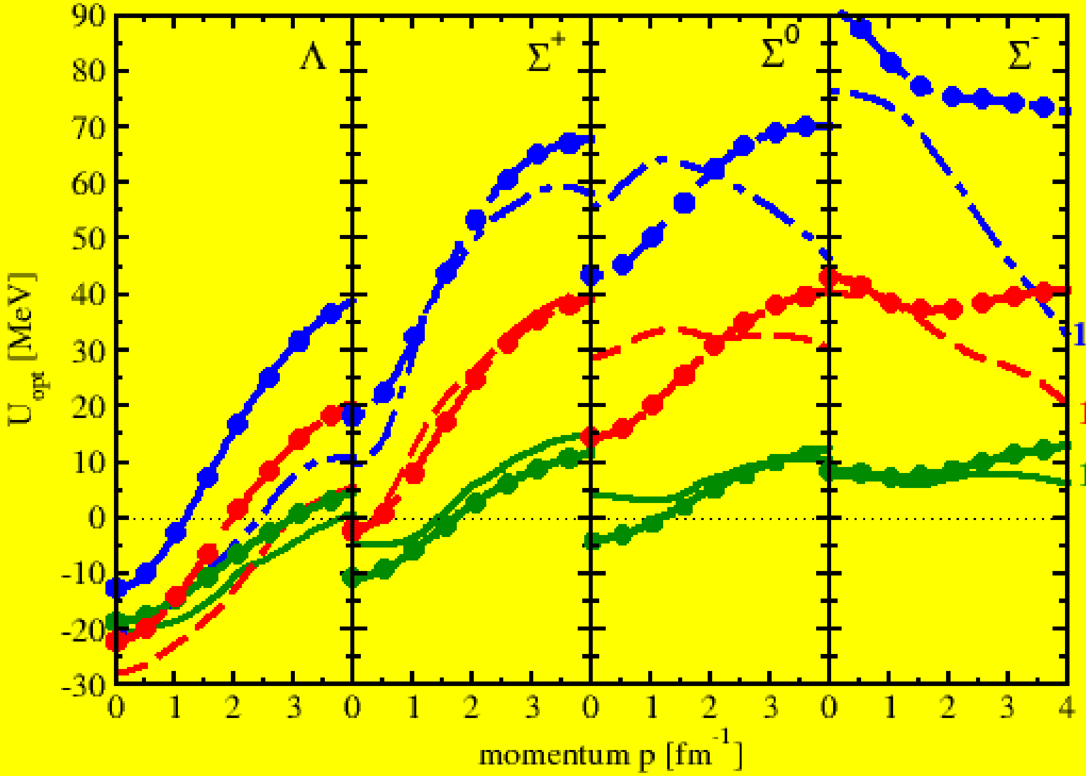
Curves: x-EFT
symbols: NLD

x-EFT: non-trivial MDI

NLD: charged hyperons predicts non-trivial MDI

Hyperon properties: Λ,Σ-optical potentials...

NLD predictions: density & momentum dependence
pure neutron matter



Curves: x-EFT
symbols: NLD

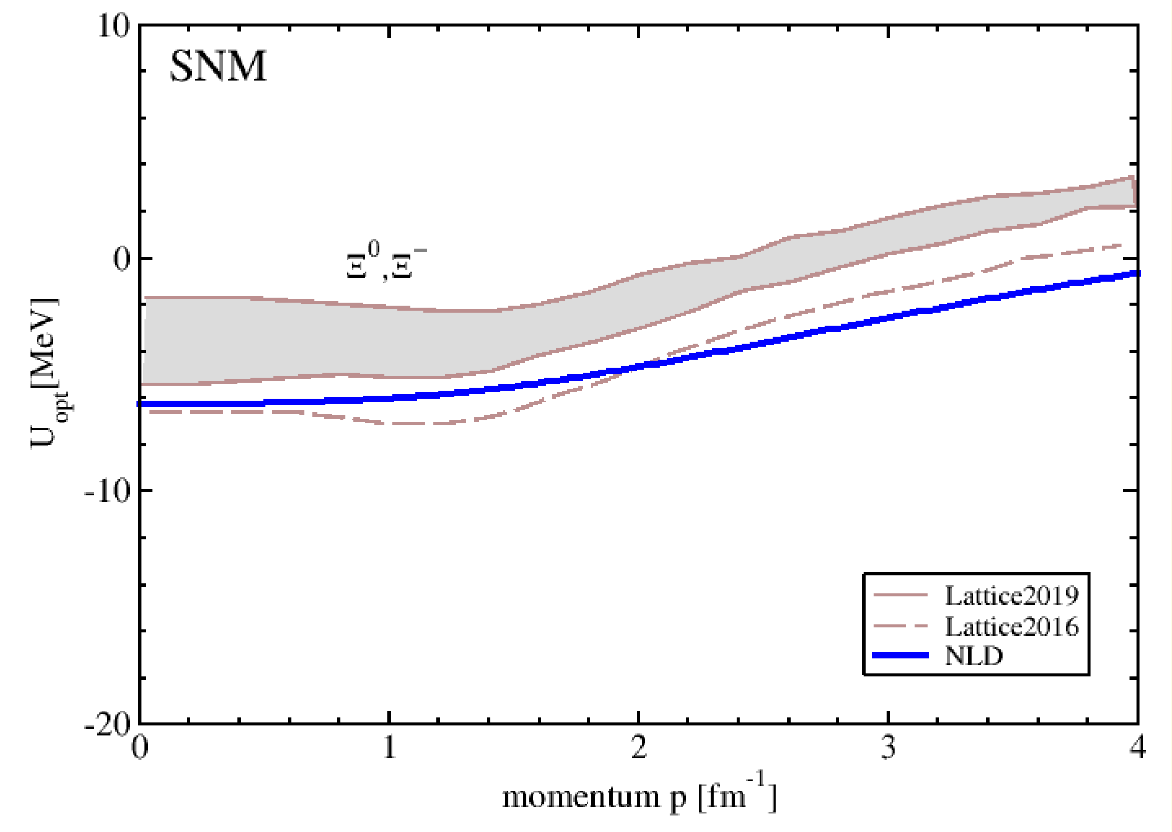
x-EFT: non-trivial MDI

NLD: all hyperons
predicts non-trivial MDI
adequate description

Nucl. Phys. (2021) in press

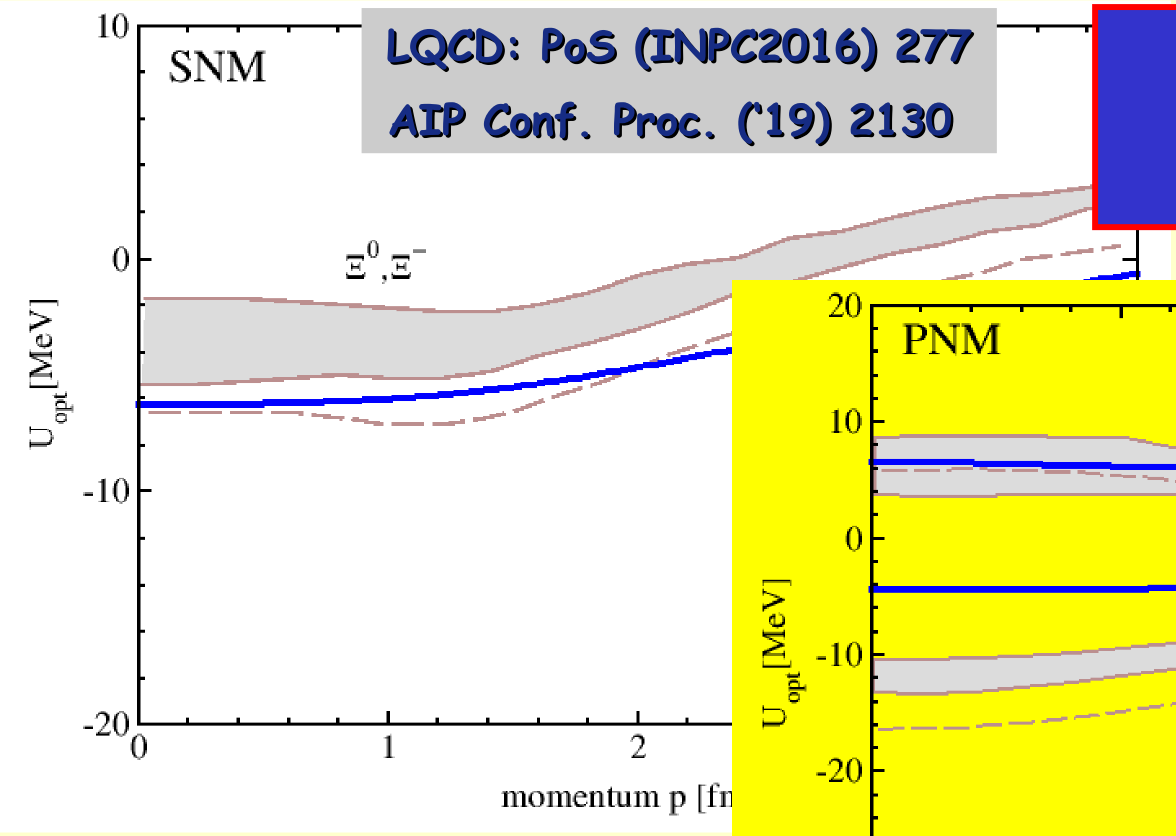
Hyperon properties: Ξ-optical potentials...

NLD fit: density & momentum dependence
symmetric NM



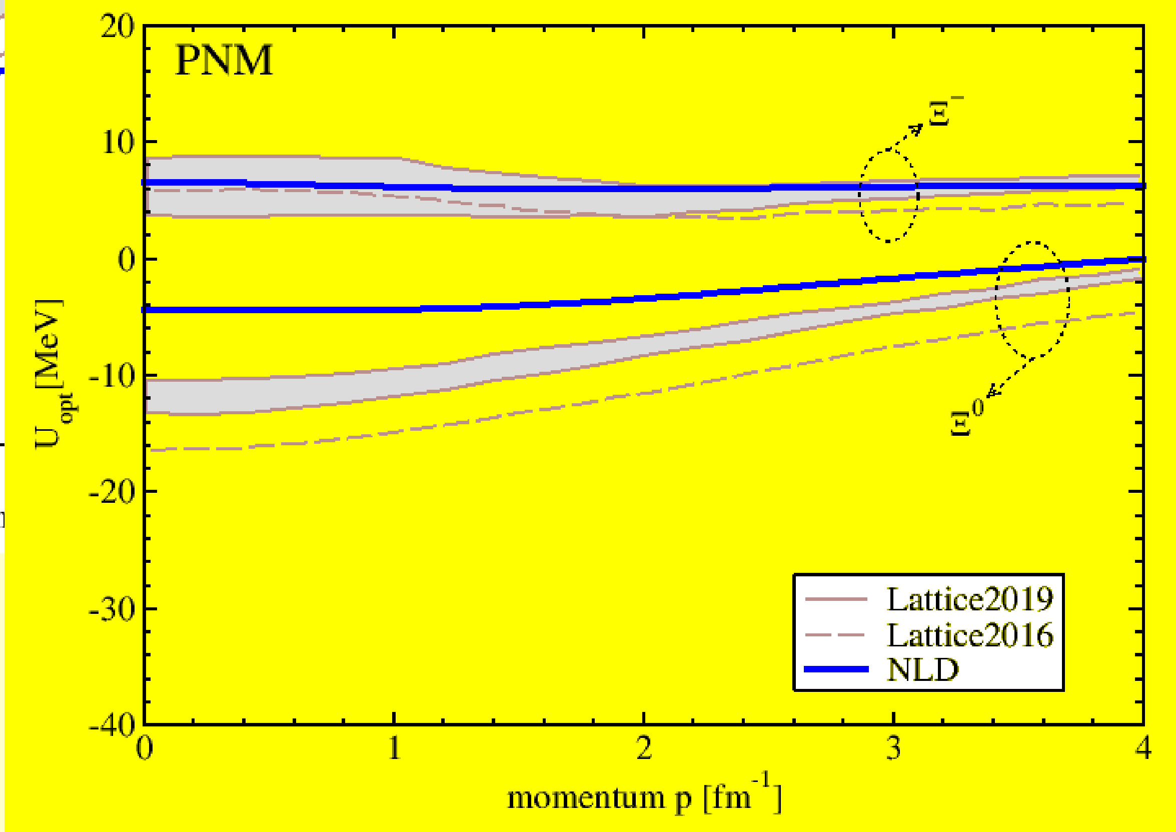
Hyperon properties: Ξ-optical potentials...

NLD predictions: density & momentum dependence
SNM & pure neutron matter



LQCD: PoS (INPC2016) 277
AIP Conf. Proc. ('19) 2130

NLD: Ξ hyperons
predicts weak MD



Nucl. Phys. (2021) in press

Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
G-parity

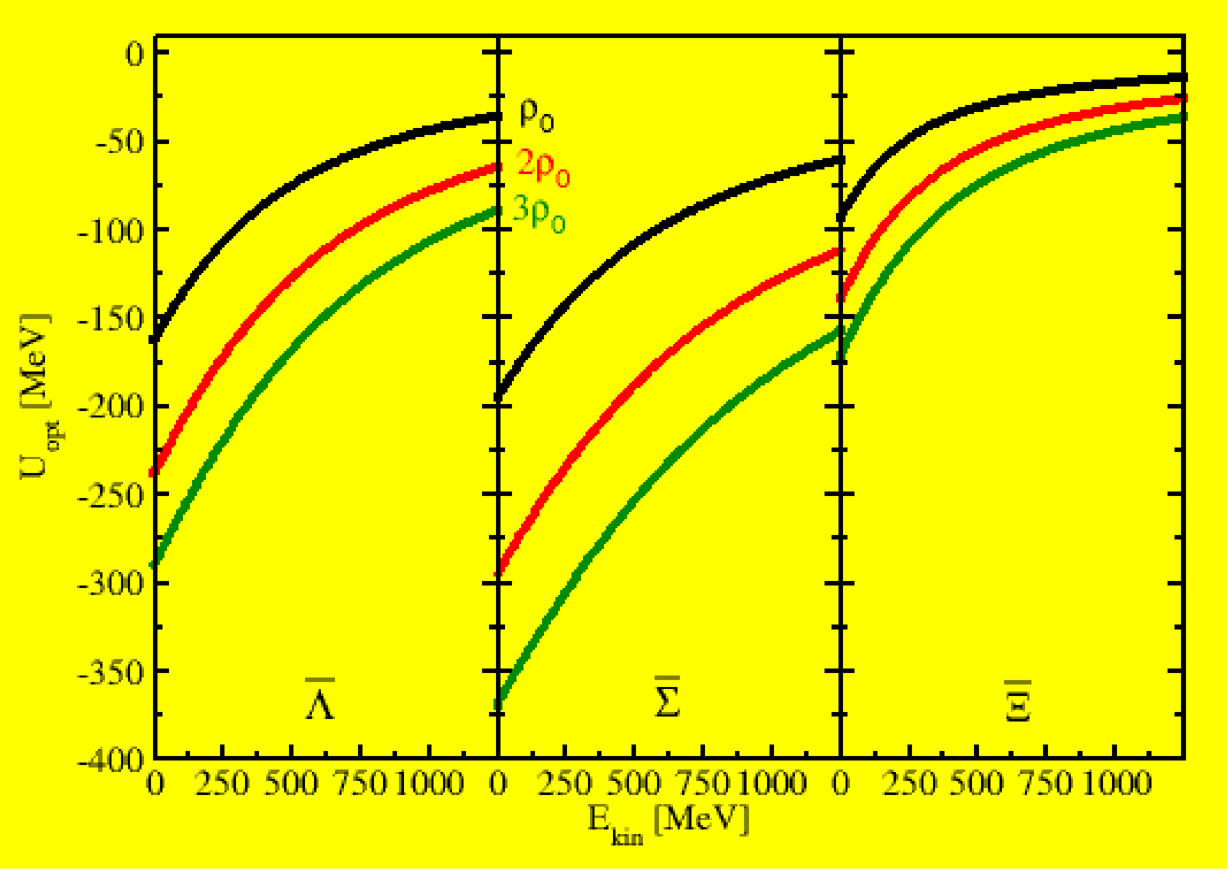
Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
G-parity, **no parameters**

Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
G-parity, **no parameters**

real part



Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
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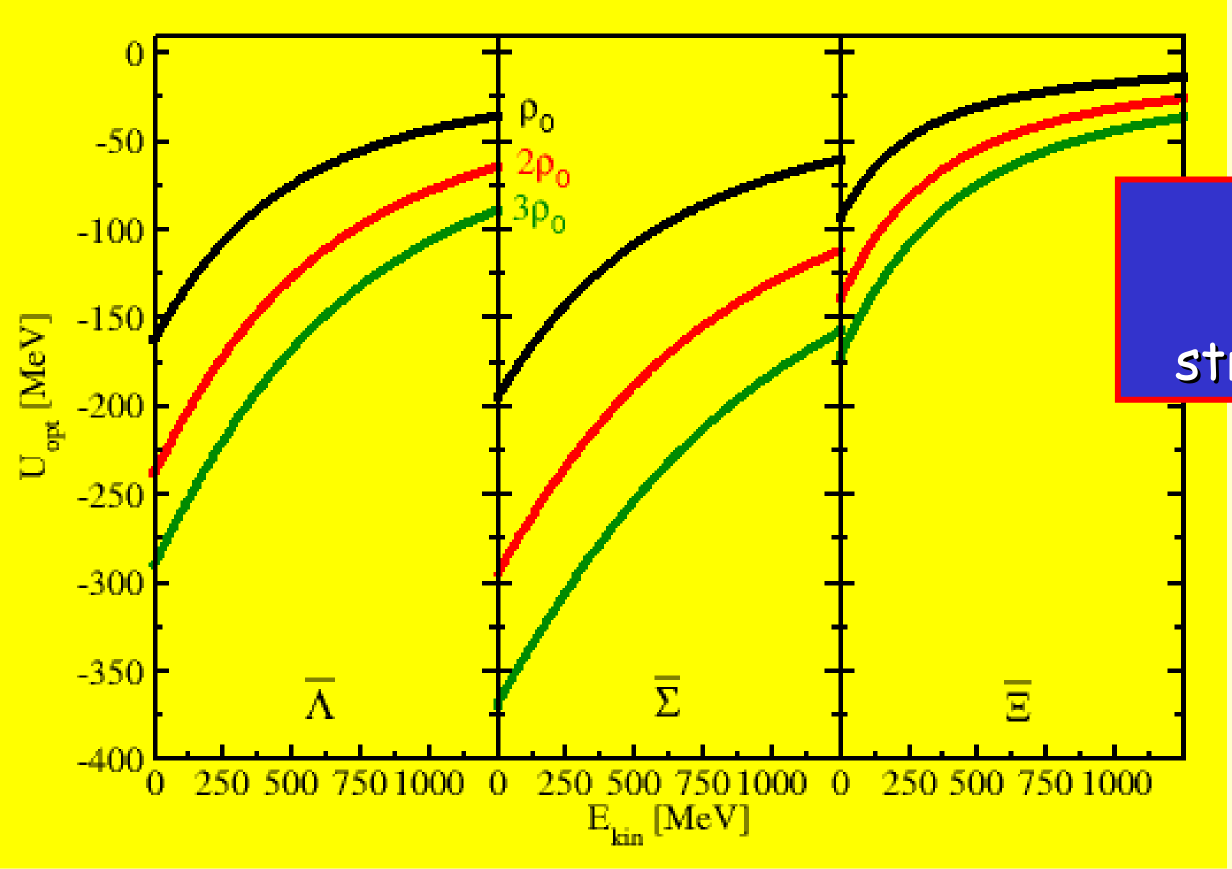
real part

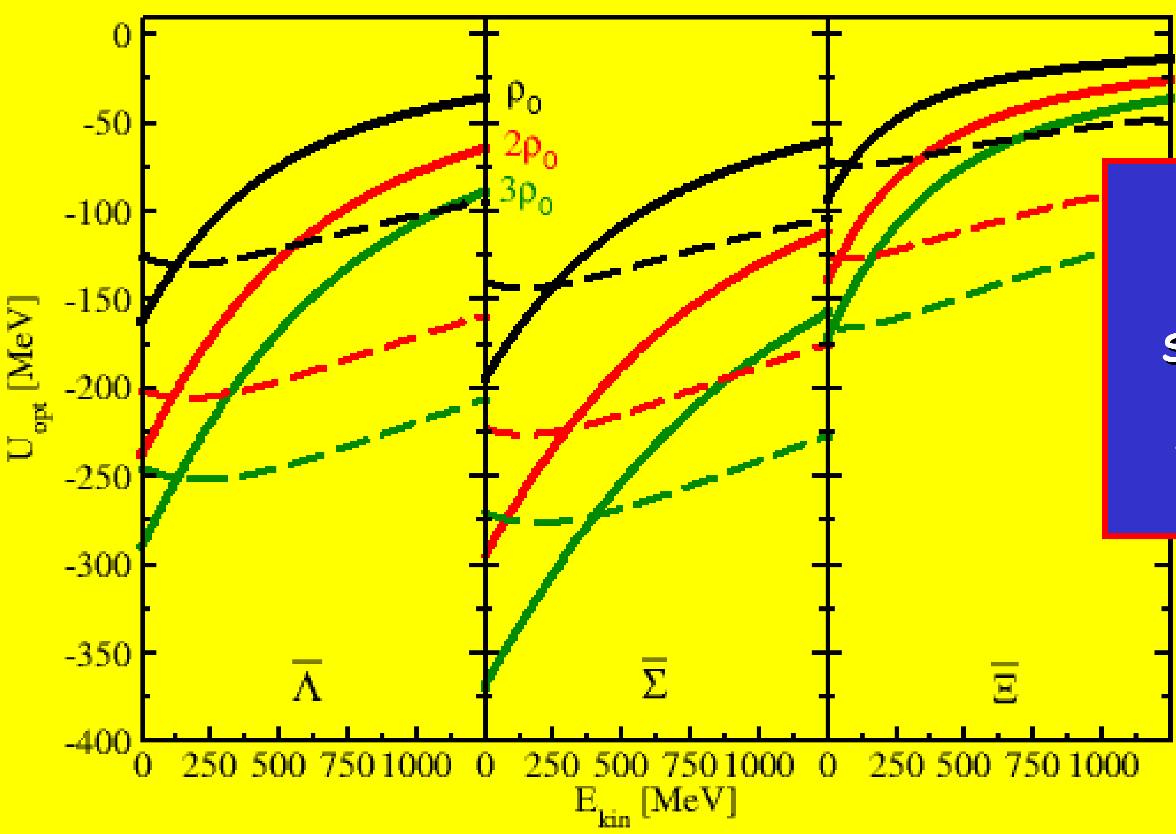


NLD: anti-hyperons
strong potential (real part)

Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
G-parity, **no parameters**

real part & imag part



NLD: anti-hyperons

strong potential (real part)

strong contributions from imaginary part

Nucl. Phys. (2021) in press

Final remarks & outlook...

NLD model

→ keeping simplicity (RMF) to describe complexity (**non-linear ρ & p dependences)**

→ realized by covariant introduction of regulators on a Lagrangian level

→ in RMF: cut-off Λ regulates high ρ- & p-components of mean-fields

→ cut-off Λ regulates also p-dependence of hyperon opt. pot.!

NLD Results

→ EoS soft at low ρ (K~250 MeV), but stiff at high ρ
compatible with all recent observations of EoS & NS

→ Correct MD for in-medium proton **(!) and (!)** antiproton interactions

→ compatible with recent results from χ-EFT for hyperons in matter

→ strong potentials for anti-Y & strong contributions from imag. parts

Under progress developments: include NLD mean-fields in...

→ transport model for HADES (π+A induced reactions)

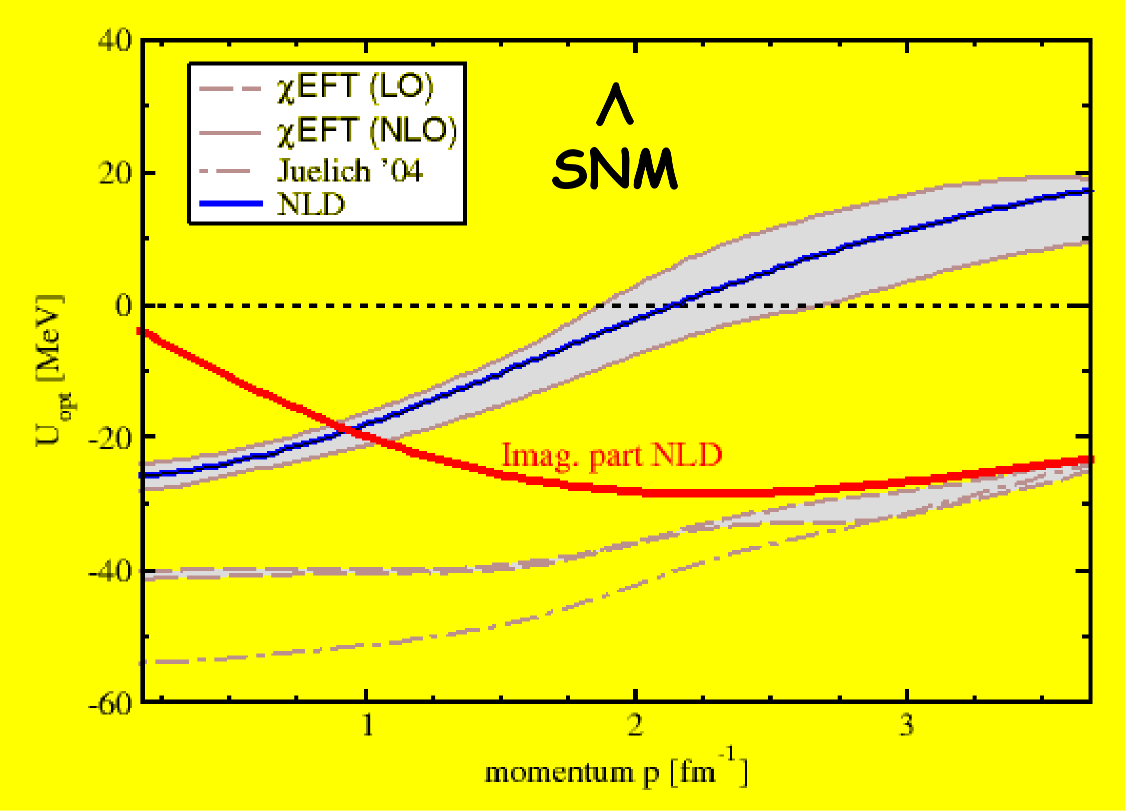
→ transport model for PANDA ($\bar{p}$-A & Ξ-A induced reactions)

→ application to β-equilibrated matter for NS

Back up slides

Anti-Hyperon properties: optical potentials...

NLD predictions: density & momentum dependence
G-parity, **no parameters**



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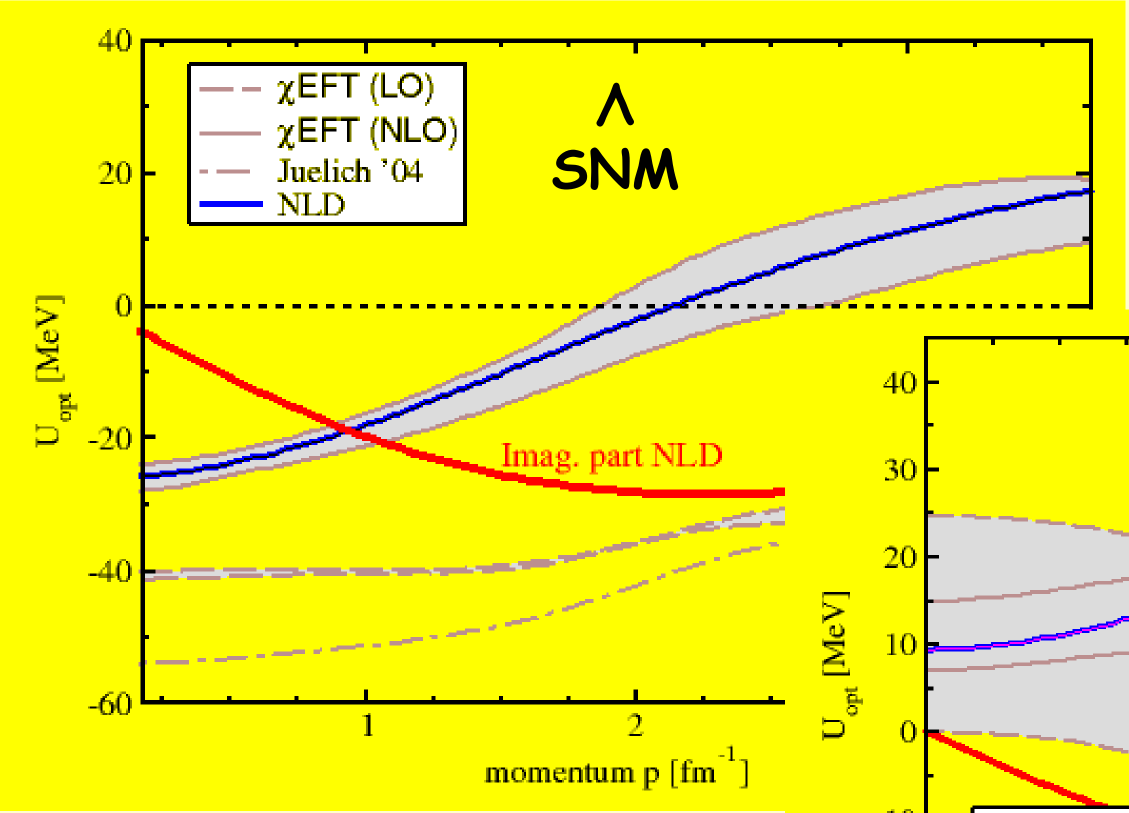
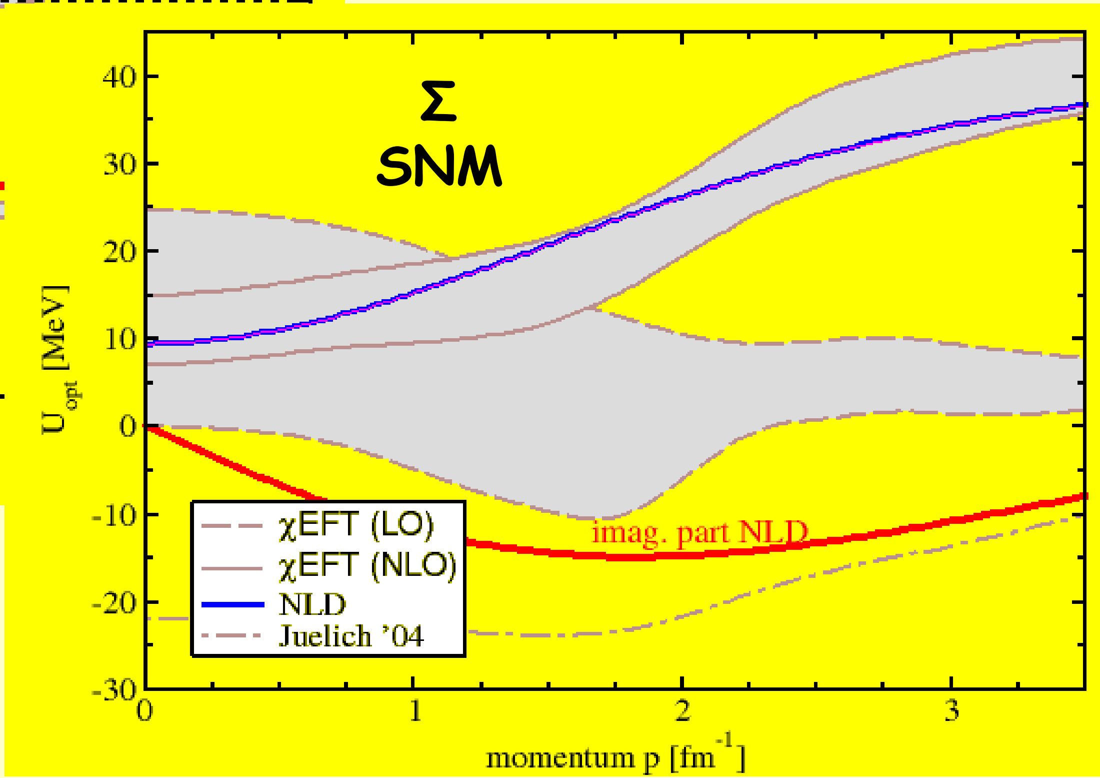




Explore in-medium Λ-pot: HADES experiment...

Key Information

- HADES Spectrometer at GSI
- Secondary π^--beam 1.7 GeV/c

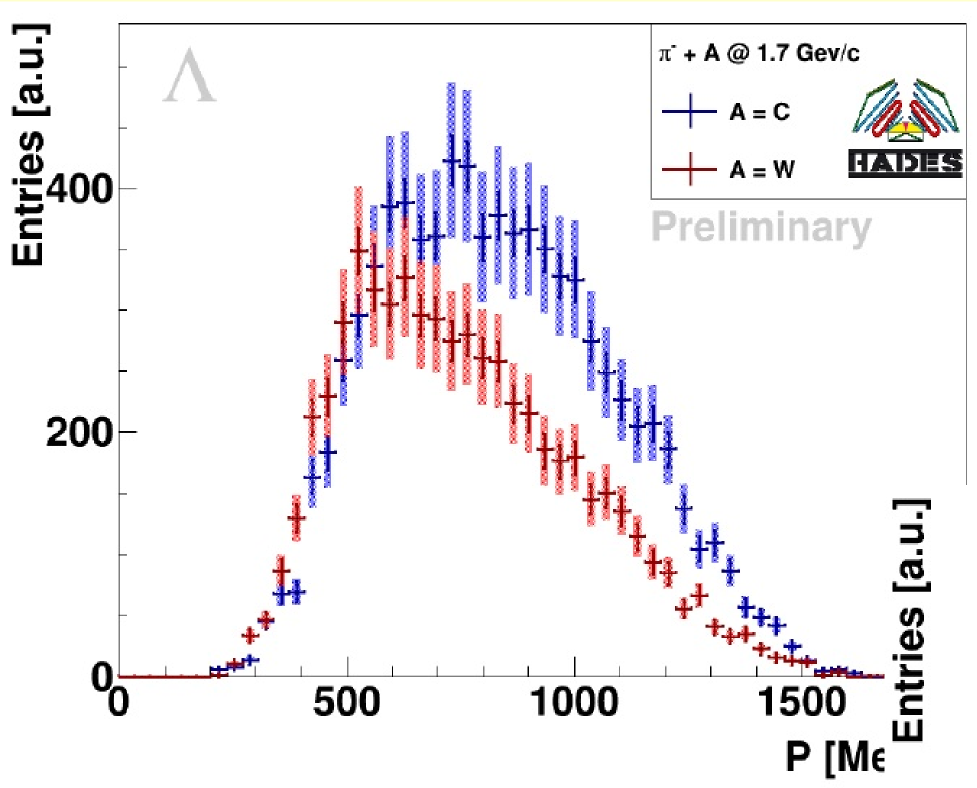
Target	W	C
Segment Length [mm]	2.4	7.2
ρ [g/cm^3]	19.3	1.85
A	183.84	12.011
Statistics [$x10^8$]	1.69	2.00

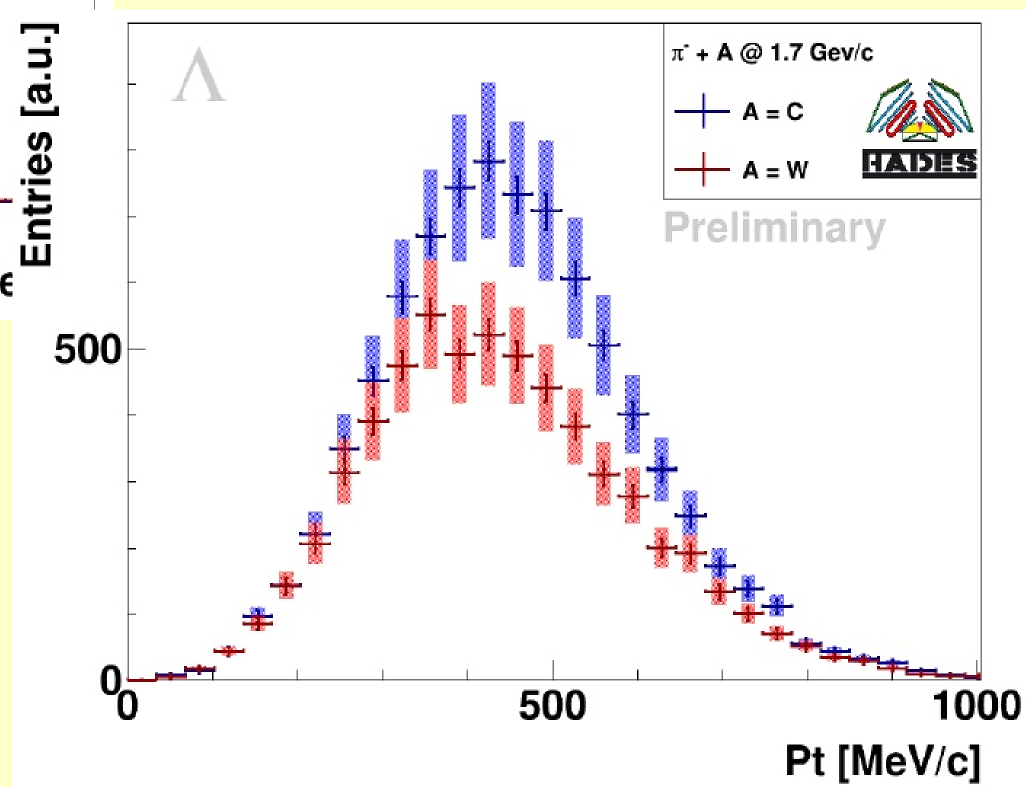
Idea:

- Search for Charge Pattern 2+ 2- ($\Lambda \to p + \pi^-, K^0 \to \pi^+ + \pi^-$)
- Make best assignment of bouble π^- occurence by minimizing:
  $\Delta M_\Lambda = M_{INV}(p + \pi^-) - M(\Lambda)_{PDG}$
  $\Delta M_{K0} = M_{INV}(\pi^+ + \pi^-) - M(K0)_{PDG}$
  For all π^- Combination
- Cut on 2D ΔM_Λ vs. ΔM_{K0}

Icons from: https://www.flaticon.com/

Explore in-medium Λ-pot: HADES new data...





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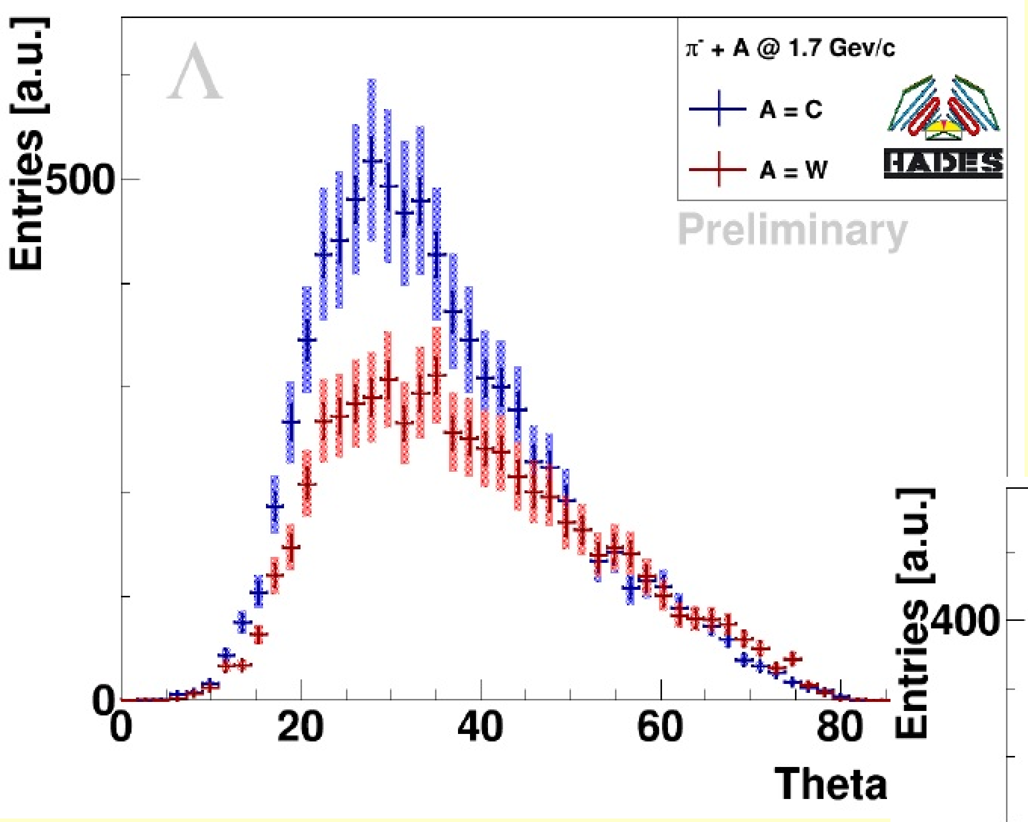
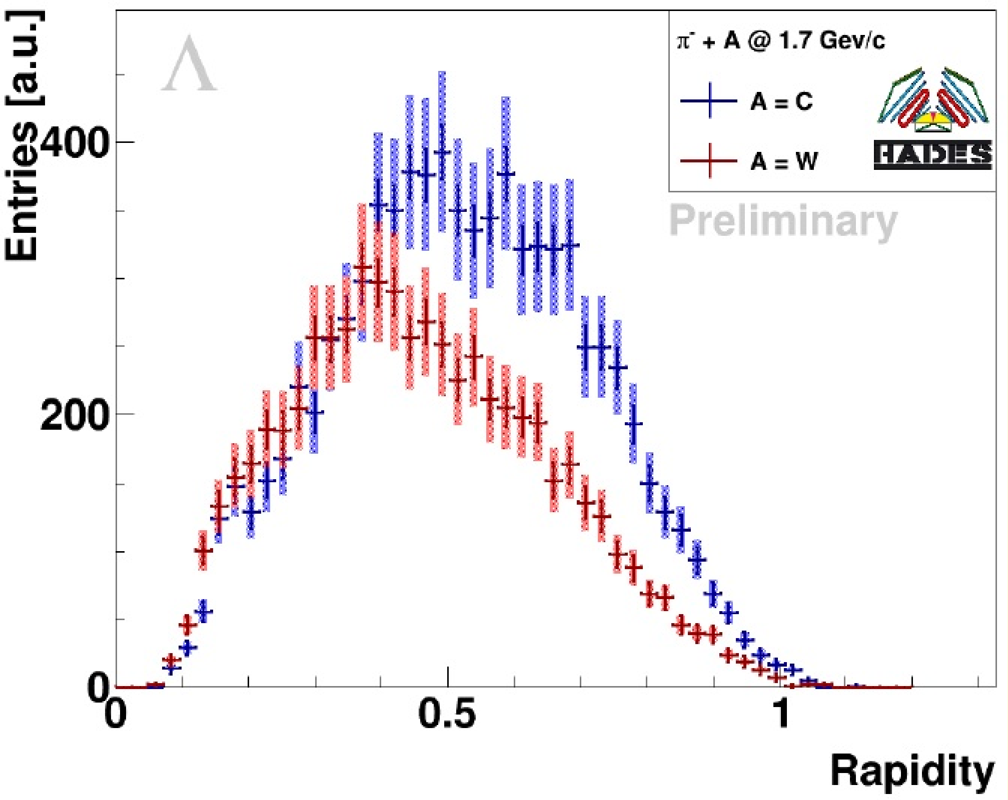
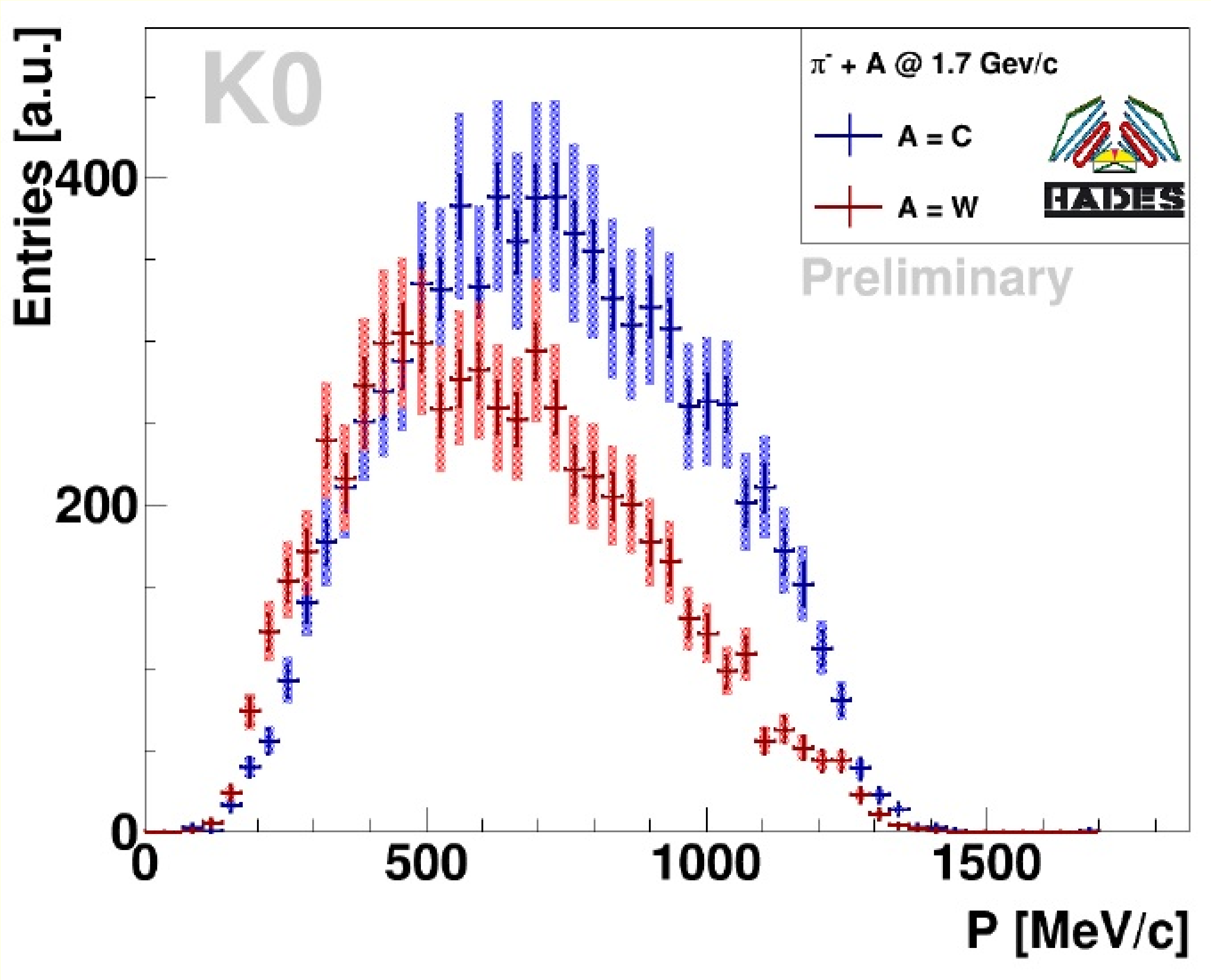




Explore in-medium K-pot: HADES new data...



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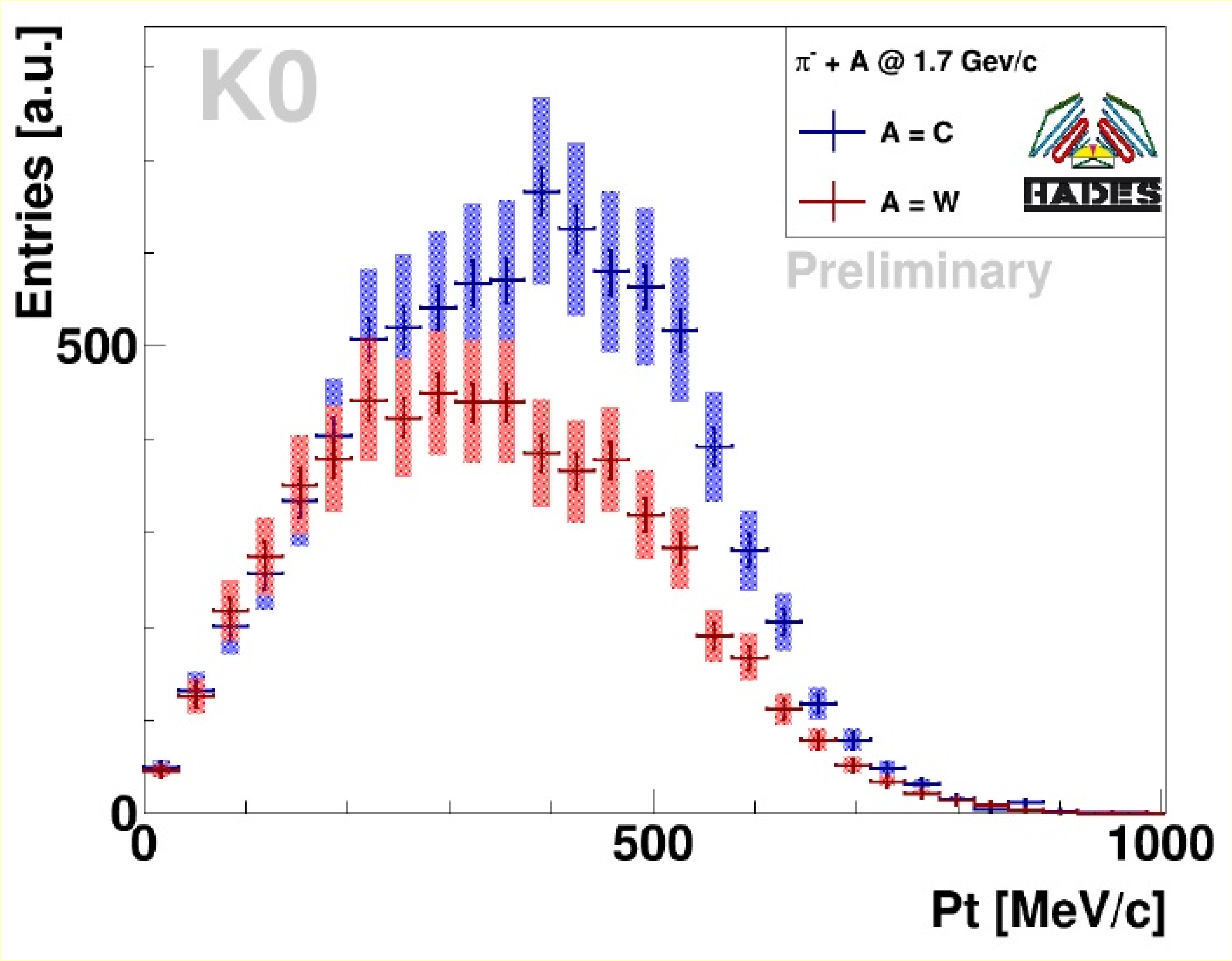

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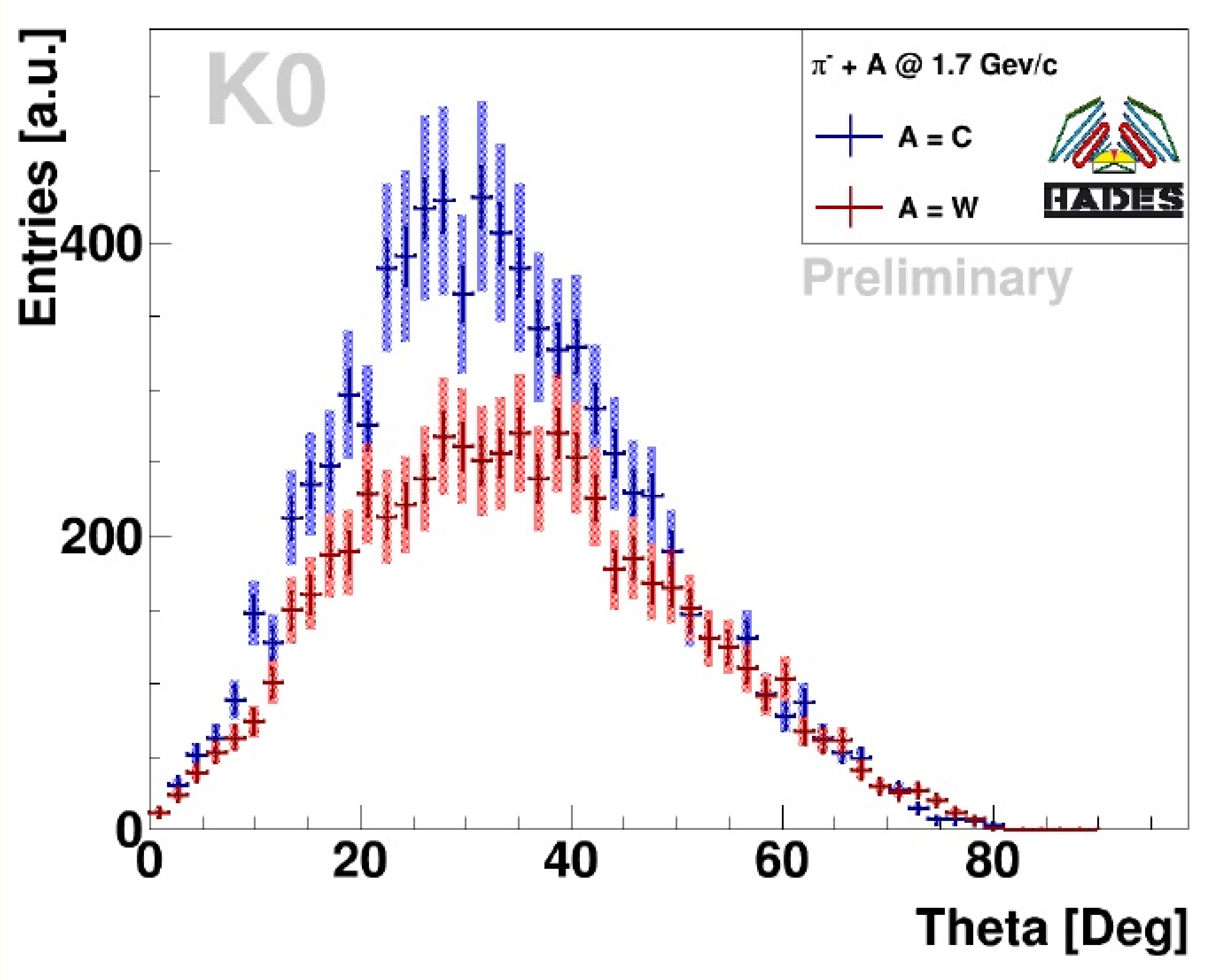

Explore in-medium K-pot: HADES new data...