HYP2003

Parallel Session 1

KEK
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for the E438 Collaboration

Σ-Nucleus Potentials in Medium to Heavy Nuclei

Physics Motivation

How is the Σ-Nucleus (U_Σ) Potential?

○Isospin dependent U_Σ in light systems
- a bound state in A=4 (PRL80(`98)1605)
- systematics of (K^-,π^E) in A=4,6,9 (PRL83(`99)5238)

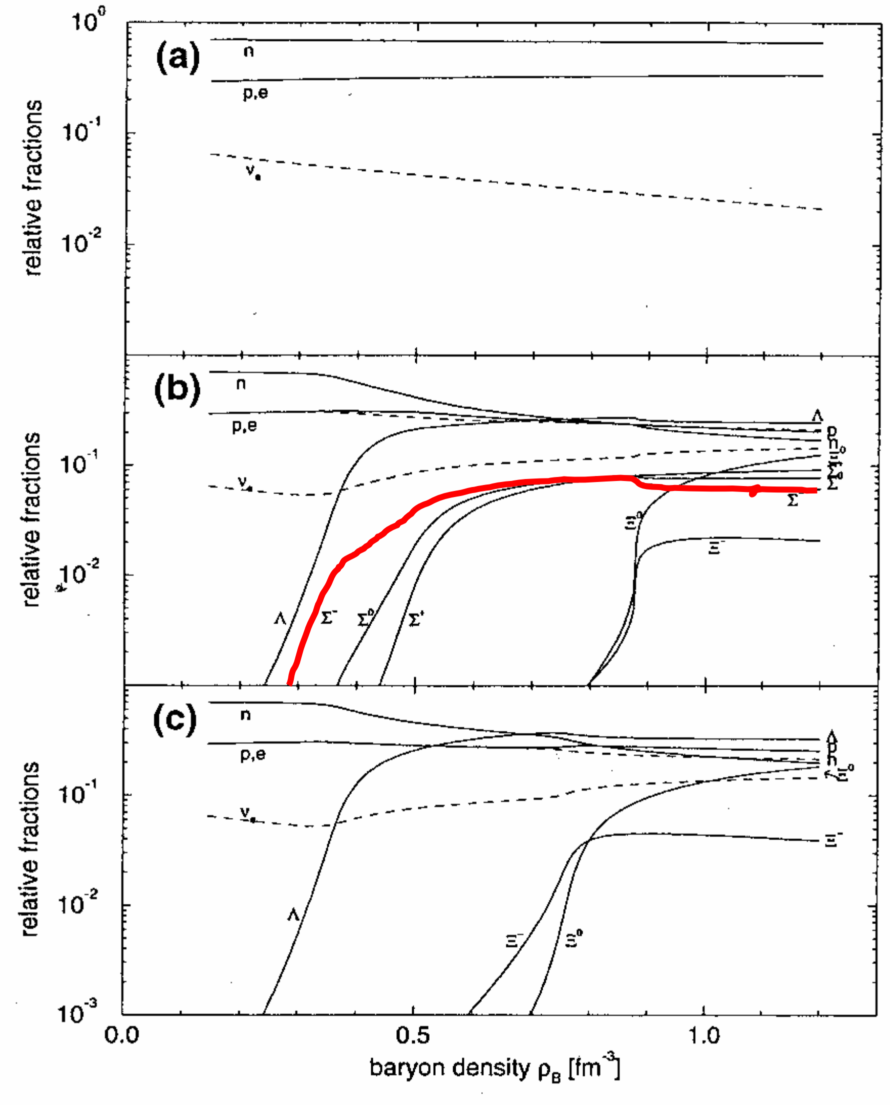
○Σ^-- atomic X ray data suggest that…
- attractive/m. absorptive in tρ-potential
- repulsive/s. absorptive in DD-potential (PTP117(`94)227)

○No other data is available…
- Poor YN Scattering Data
  M.E.P.: ESC02←→ESC03
  QM: repulsive in ΣN(I=3/2)?
- (K^-,π^E) spectra on AO16
  V_Σ(Re U_Σ)>-10 MeV from ^{12}C(stopped K^-,π^+)

by M. Iwasaki

Role of Σ^- in Neutron Star

S. Balberg and A. Gal, NPA625(1997)435



Normal

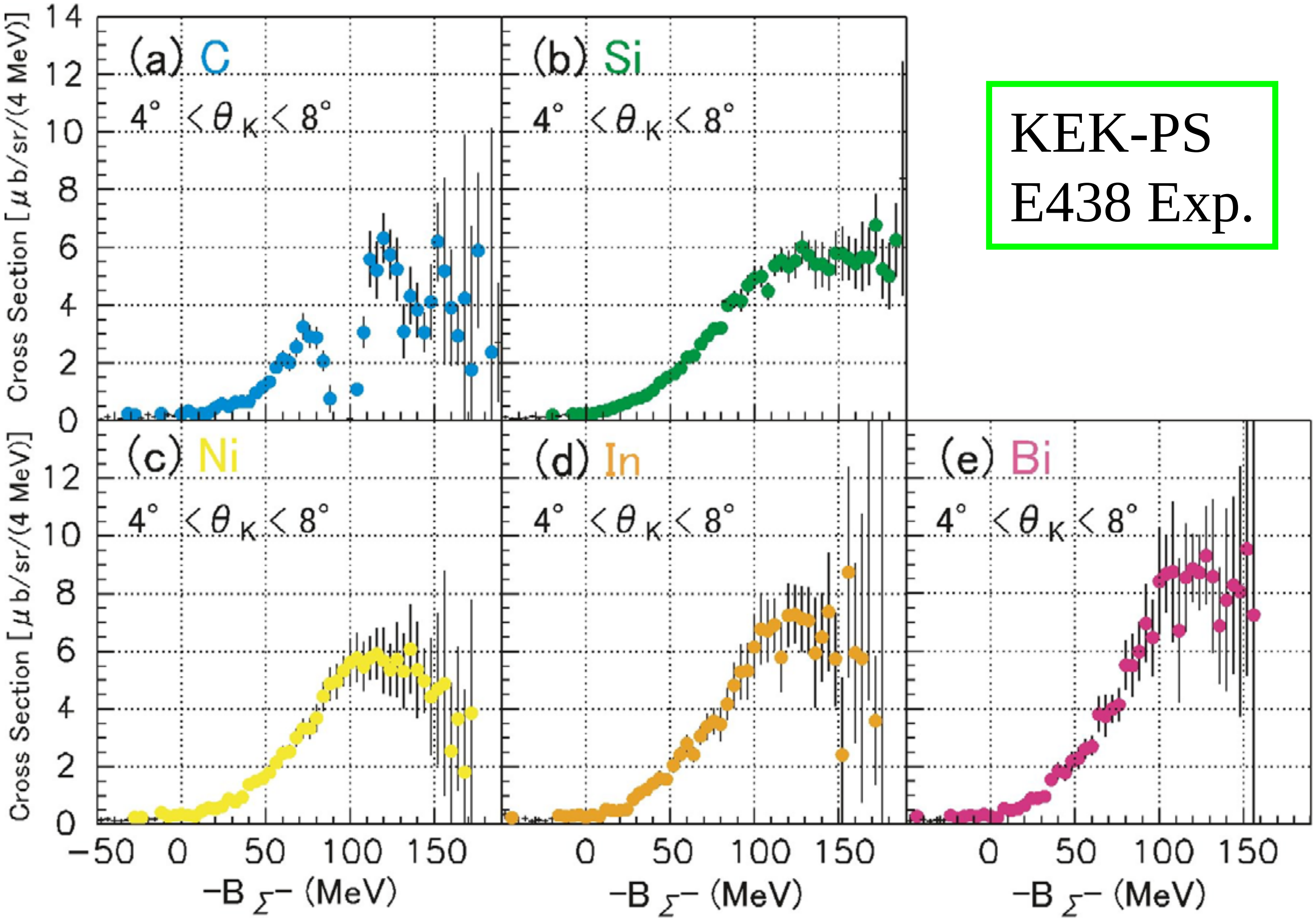
$V_\Lambda \sim V_\Sigma$

No Sigma Appears

V_Σ : repulsive

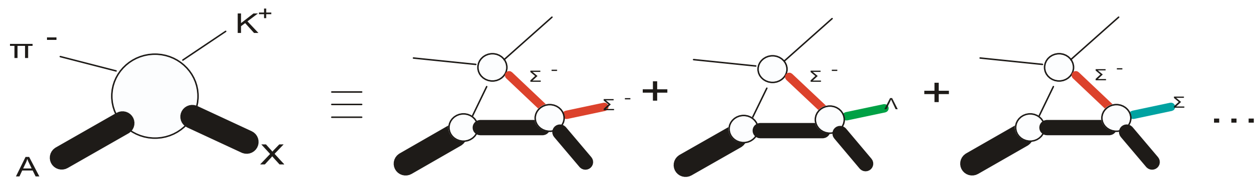
Inclusive (π,K^+) Spectra on C, Si, Ni, In, & Bi

P. K. Saha, PhD thesis, KEK-Rep.2001-17



KEK-PS
E438 Exp.

Spectrum Analysis based on DWIA



Inclusive (π^-,K^+) Spectrum

$$d^2\sigma/d\Omega dE = \beta \cdot \overline{d\sigma/d\Omega}_{elem} \cdot S(E)$$

Strength Function:

$$S(E) = -1/\pi \; Im \sum_{\alpha\alpha'} \int dr dr' \{ f^{+}_{\alpha}(r') G_{\alpha\alpha'}(E;r',r) f_{\alpha'}(r) \}$$

$$f_{\alpha}(r) = \chi^{(-)*}(R) \chi^{(+)}(R) \langle \alpha | \psi_N(r) | i \rangle, \; R=(M_c/M_{hy})r$$

Green's Function:

$$G_{\alpha\alpha'}(E;r',r) = \langle \alpha | \psi_{\Sigma}(r) \frac{1}{E - H + i\eta} \psi^{+}_{\Sigma}(r') | \alpha' \rangle$$

$$\rightarrow \left(\frac{\hbar^2}{2\mu} \Delta + E - U_{\Sigma} \right) G(E;r',r) = -\delta(r'-r)$$

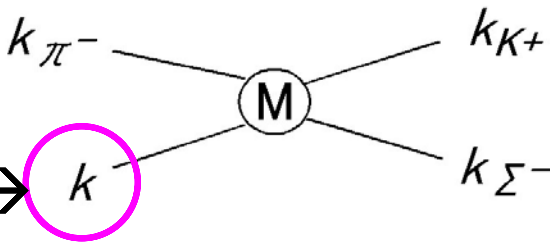
One Body Potential Parameters: *Woods-Saxon Type*

$$U_x(r)=(V_x+iW_x)f(r) + V_{SO}(h/m_\pi c)^2 r^{-1} df/dr(l.\sigma)+V_{Coulomb}(r)$$

$$x=\Sigma \text{ or } TGT, \quad f(r)=1/[1+\exp\{(r-c)/z\}]$$

Fermi-averaging of the Elementary Cross Section

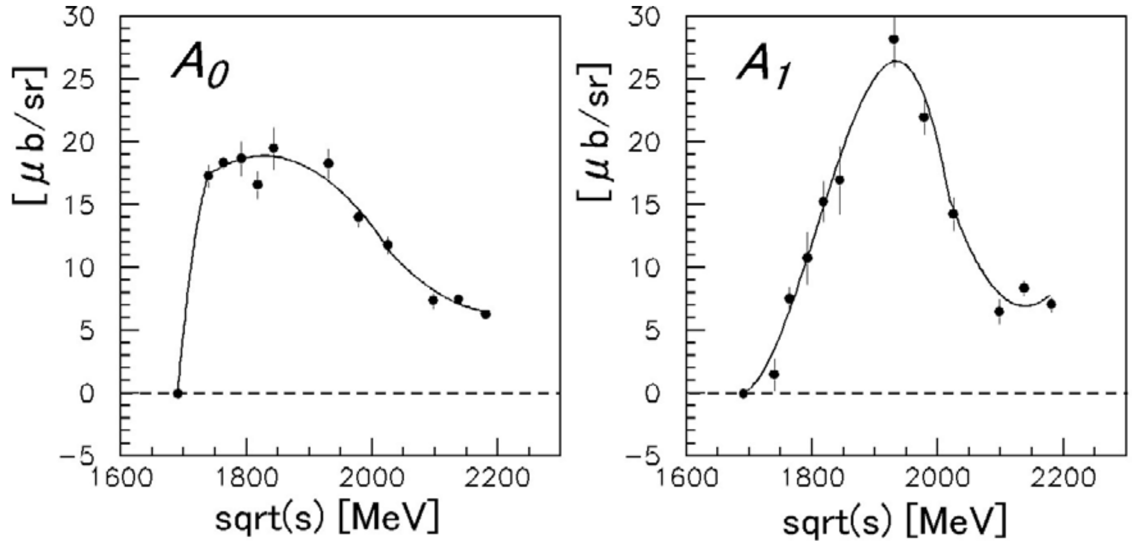
Fermi motion of a proton →

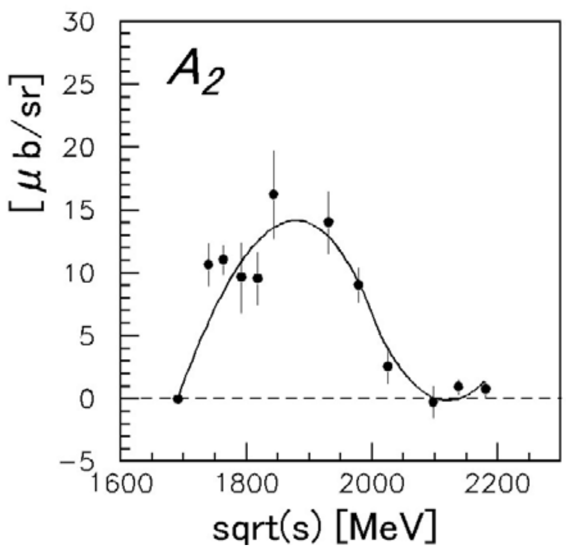


$$\overline{d\sigma/d\Omega}_{elem}(E) = \frac{\int \rho(\mathbf{k})[d\sigma/d\Omega(s,t)]\,\delta(\mathbf{k}-\mathbf{P})d\mathbf{k}}{\int \rho(\mathbf{k})\,\delta(\mathbf{k}-\mathbf{P})d\mathbf{k}}$$

$$P = k_{K+} + k_{\Sigma^-} - k_{\pi^-}$$

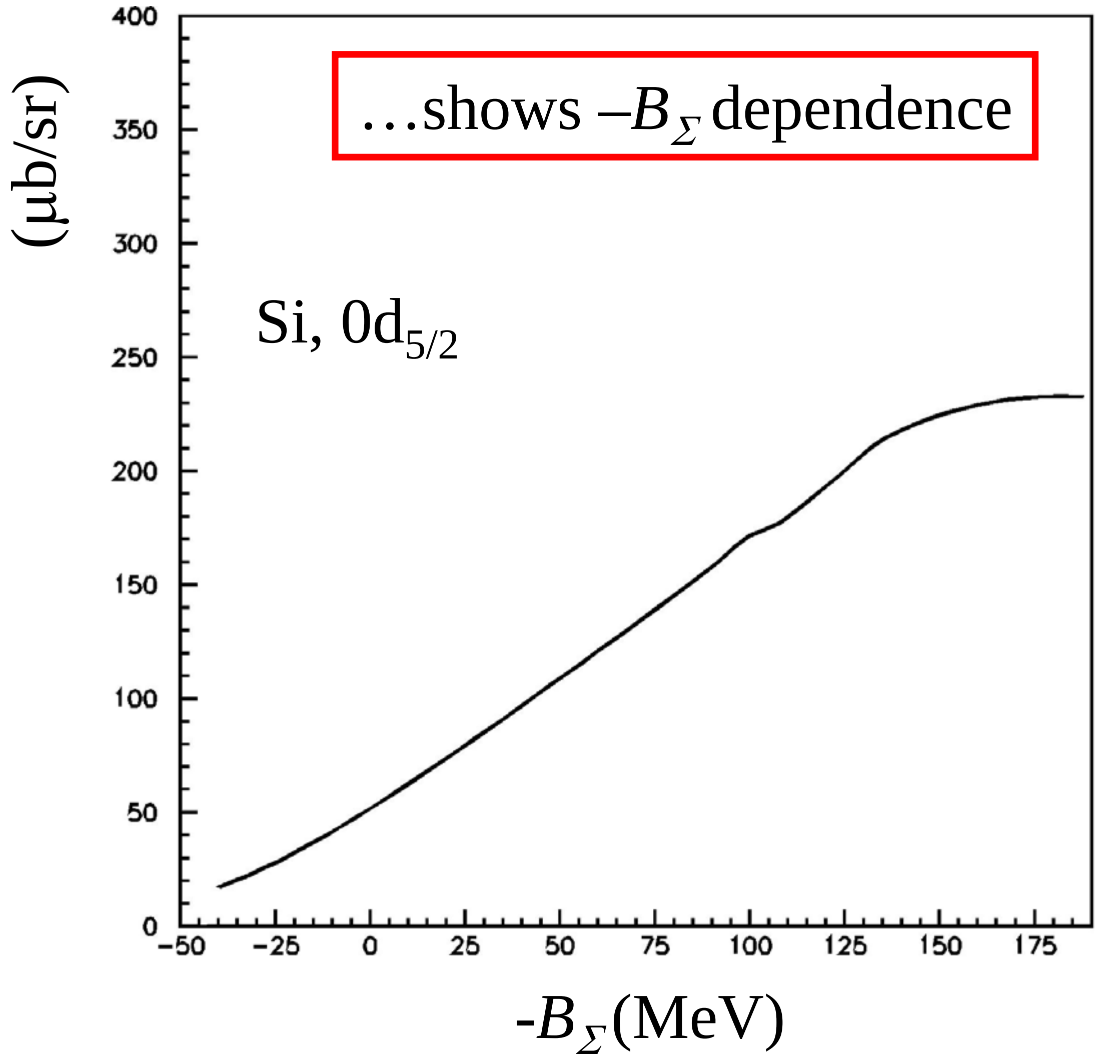
$$d\sigma/d\Omega_{\Sigma^-}(s,t) = \sum_n A_n P_n(\cos\theta_{K^+}) \text{ in CM}$$





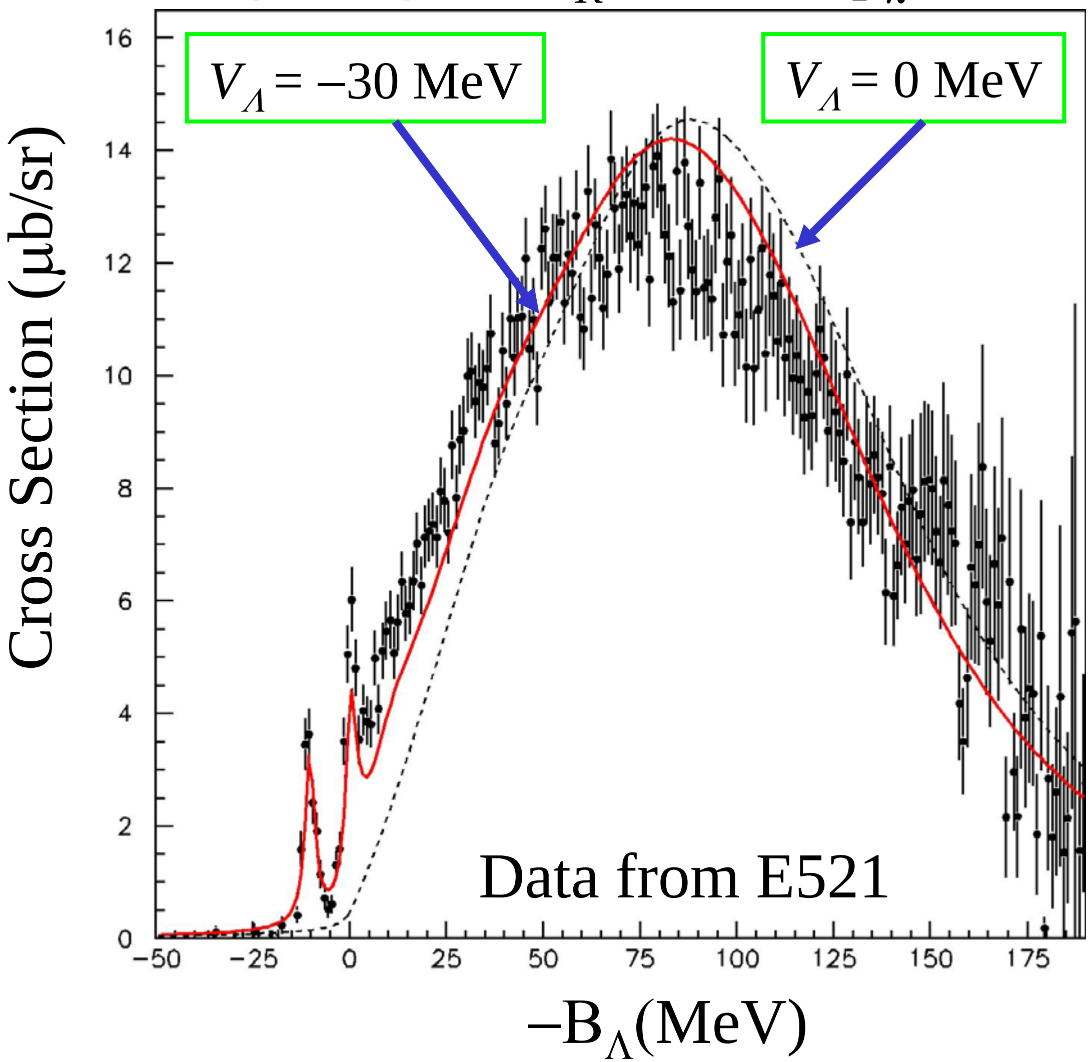
M.L. Good et al., PR183, 1142(1969)
J.C. Doyle et al., PR165, 1483(1968)
O.I. Dahl et al., PR163, 1430(1967)

Fermi-averaged $d\sigma/d\Omega_{elem}$ in Lab



DWIA application to the (π^+,K^+) spectrum

^{12}C (π^+,K^+) at θ_K = 6°K2°, p_π=1.2 GeV/c



Note:
The vertical scale
is adjusted
arbitrarily
in calculated spectra.

Fitting Results of the (π^-,K$^+$) spectra

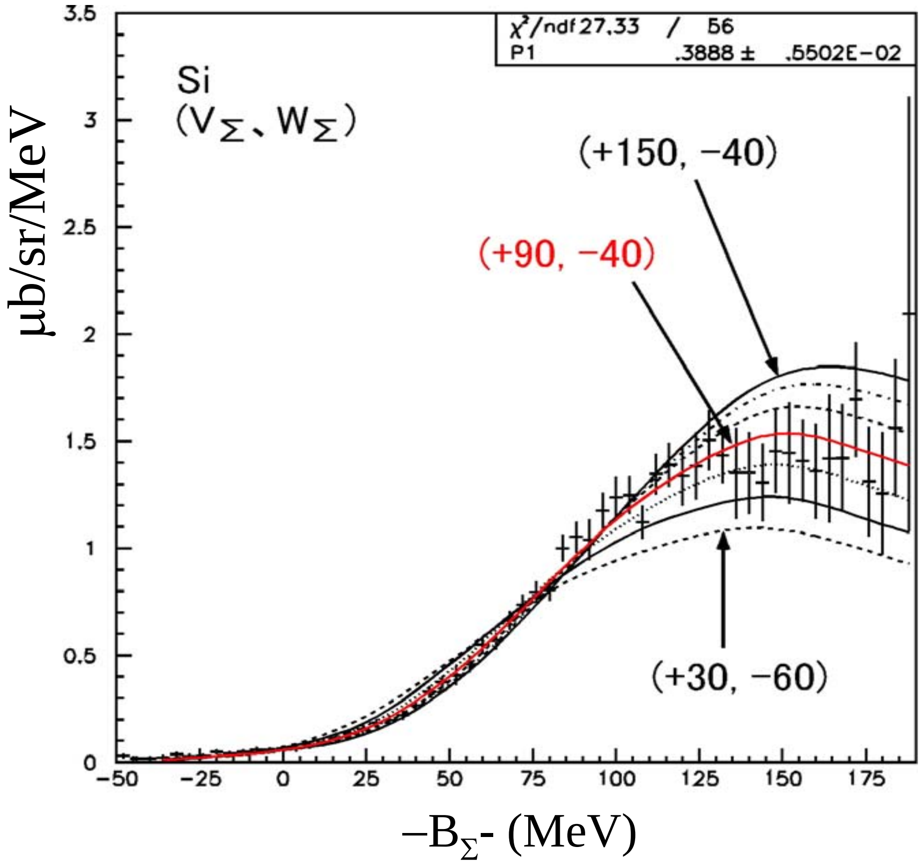
Surveying $U_\Sigma = (V_\Sigma + iW_\Sigma) f(\boldsymbol{r})$

with choice of

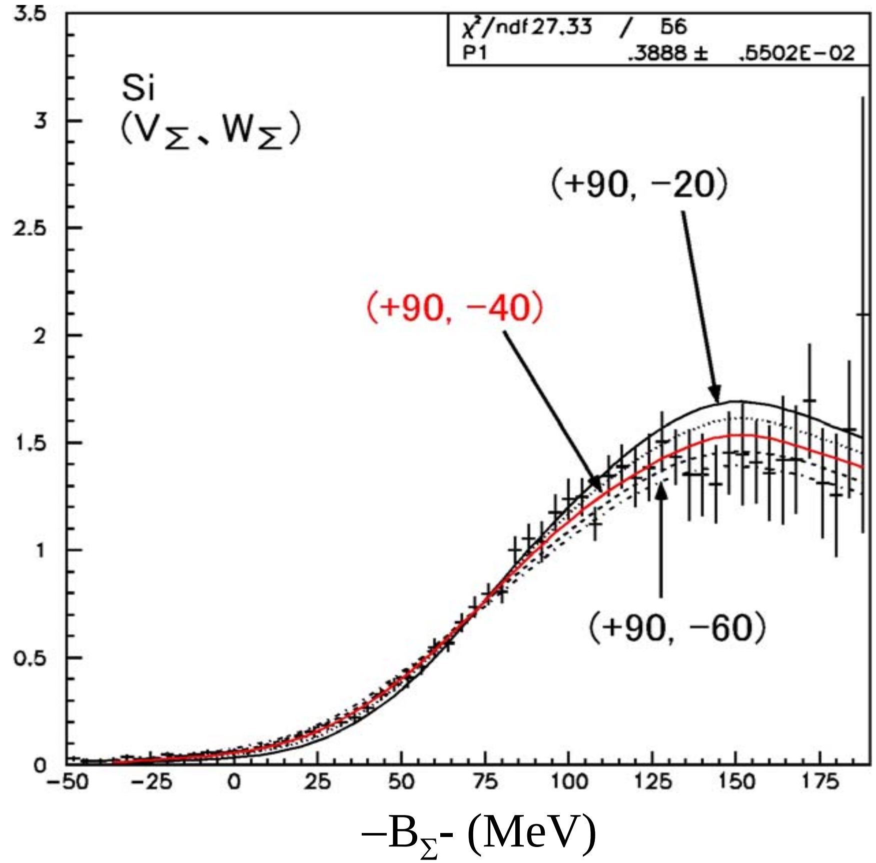
$z_\Sigma = 0.67$ fm and $c_\Sigma = 1.1(A\text{-}1)^{1/3}$ fm

Free parameter: the magnitude of the spectrum

Re U_Σ dependence



Im U_Σ dependence

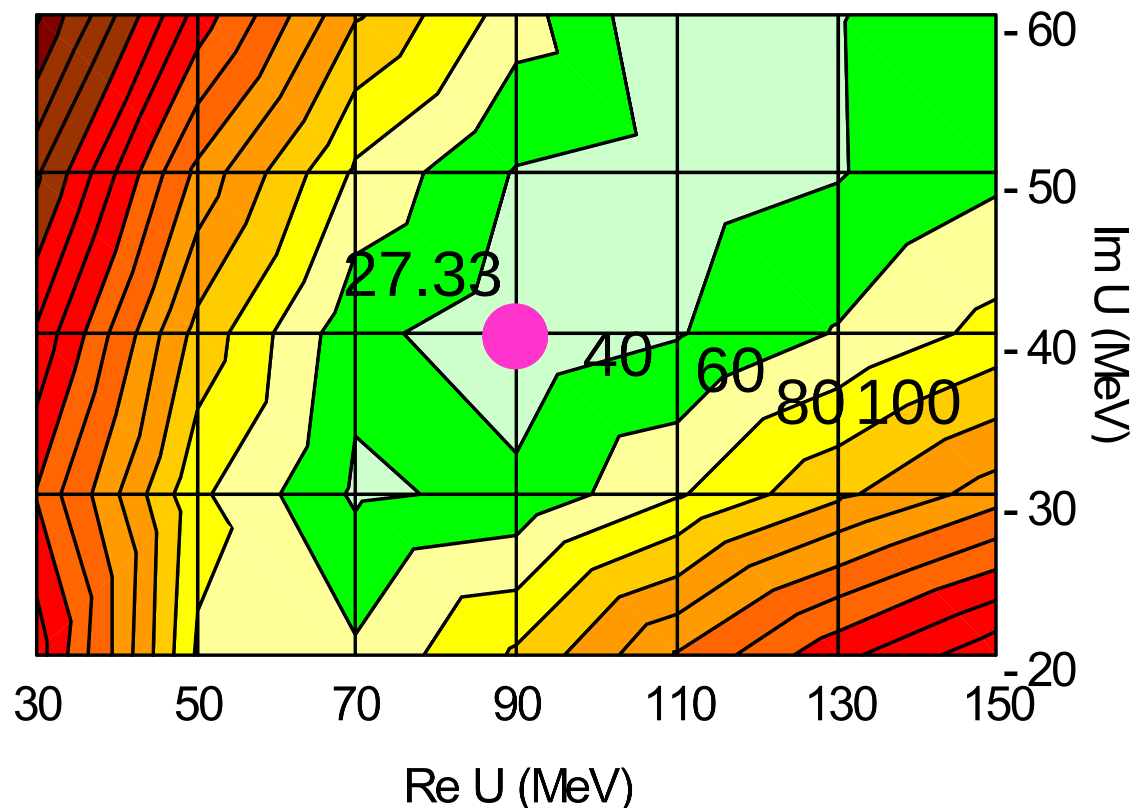


Si

W.S. Potential Parameters →

	U_Σ	U_{Si}
z(fm)	0.67	0.537
c(fm)	3.3	3.82
V0(MeV)		-54.5

Si(π^-,K^+)



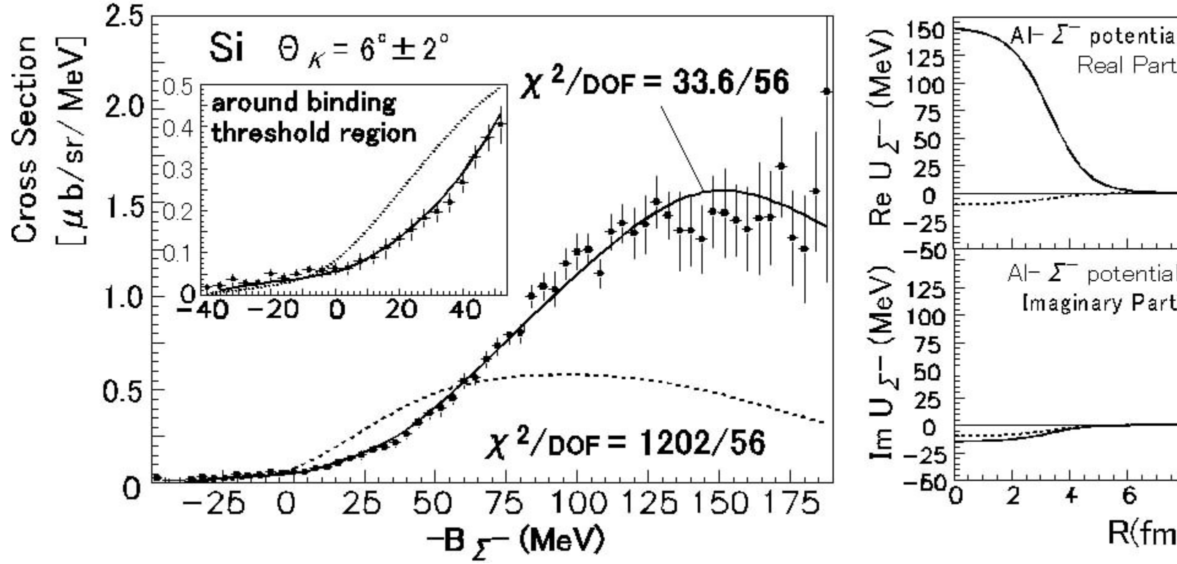
ndf = 56

CL~99.9% for ●

CL = 1.93% for χ^2 = 80

(~0.03%) (100)

In PRL89, 072301(2002),



In the Present Work,

took c~3.8 (~1.25*$A^{1/3}$) fm of Si (…was 4.09 fm)

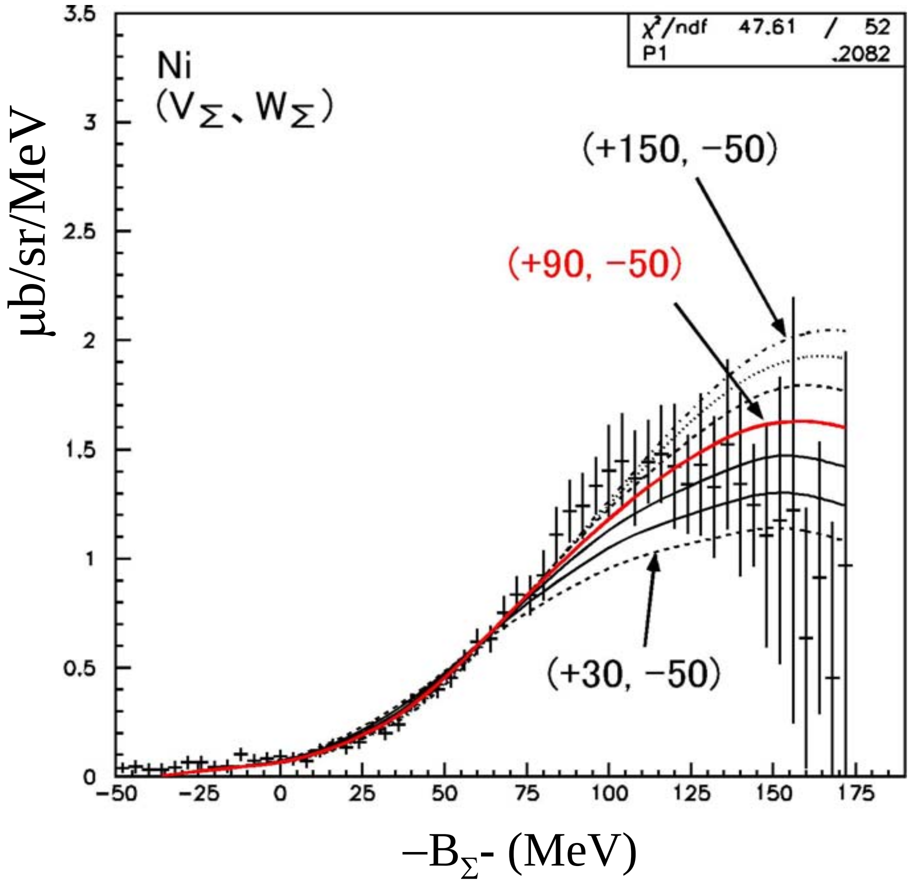
considered ΔL in (π^-,K^+) up to 21 (…was 8)

Best Fit (V_Σ, W_Σ)=(90, -40) in MeV (…was (150,-15))

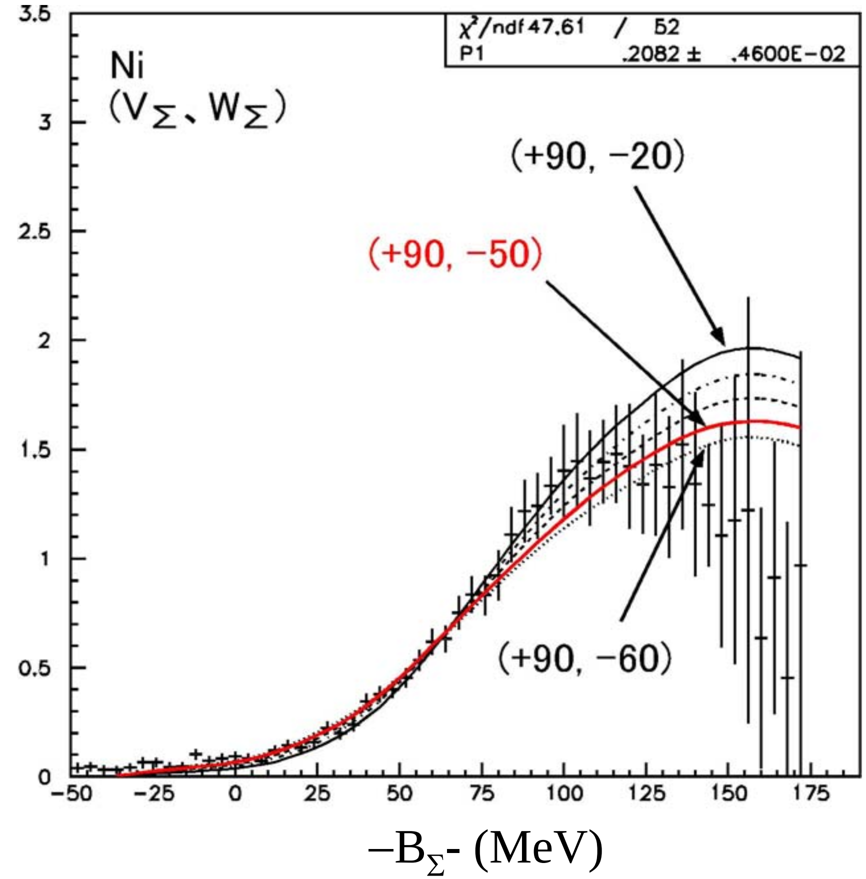
Favor a repulsive V_Σ >50 MeV, (…was >70 MeV)

Weaker sensitivity for W_Σ , (…was <–30 MeV)

Re U_Σ dependence



Im U_Σ dependence

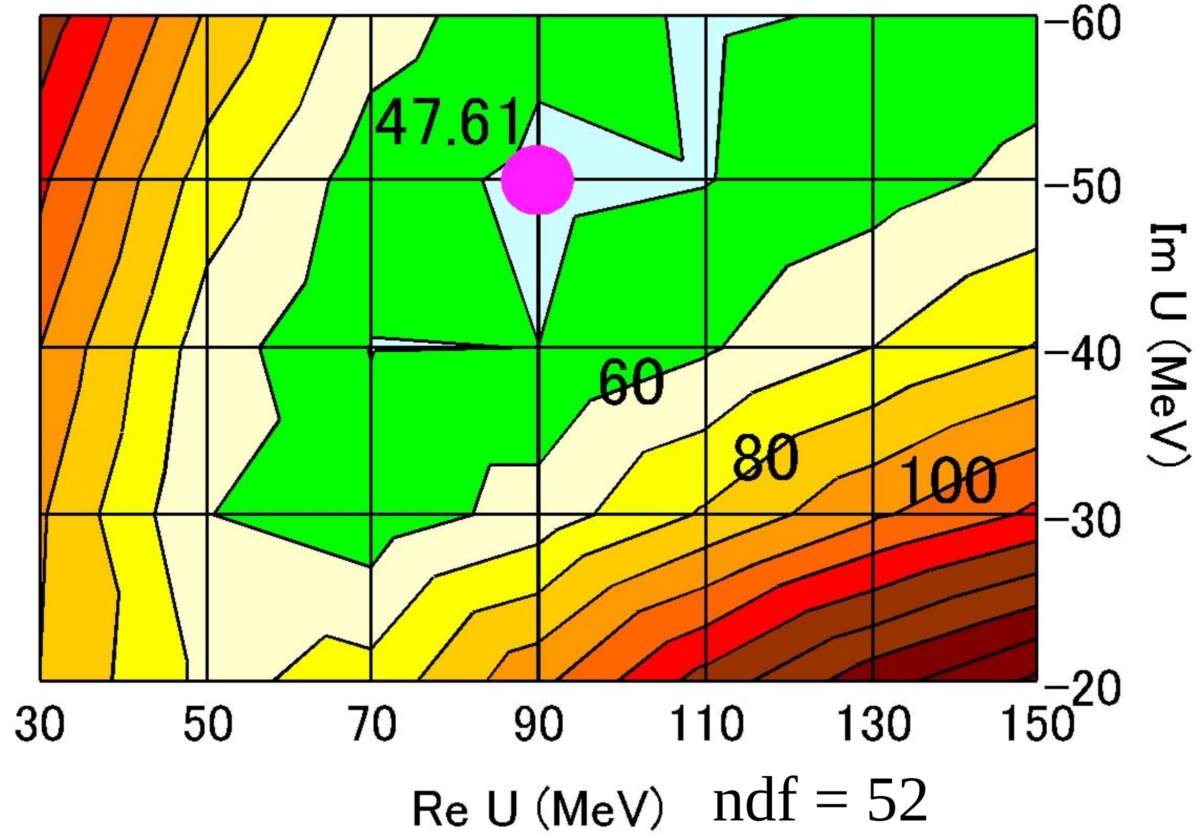


Ni

W.S. Potential Parameters

	U_Σ	U_{Ni}
z(fm)	0.67	0.517
c(fm)	4.26	4.95
V0(MeV)		-51.6

Ni(π⁻、K⁺)



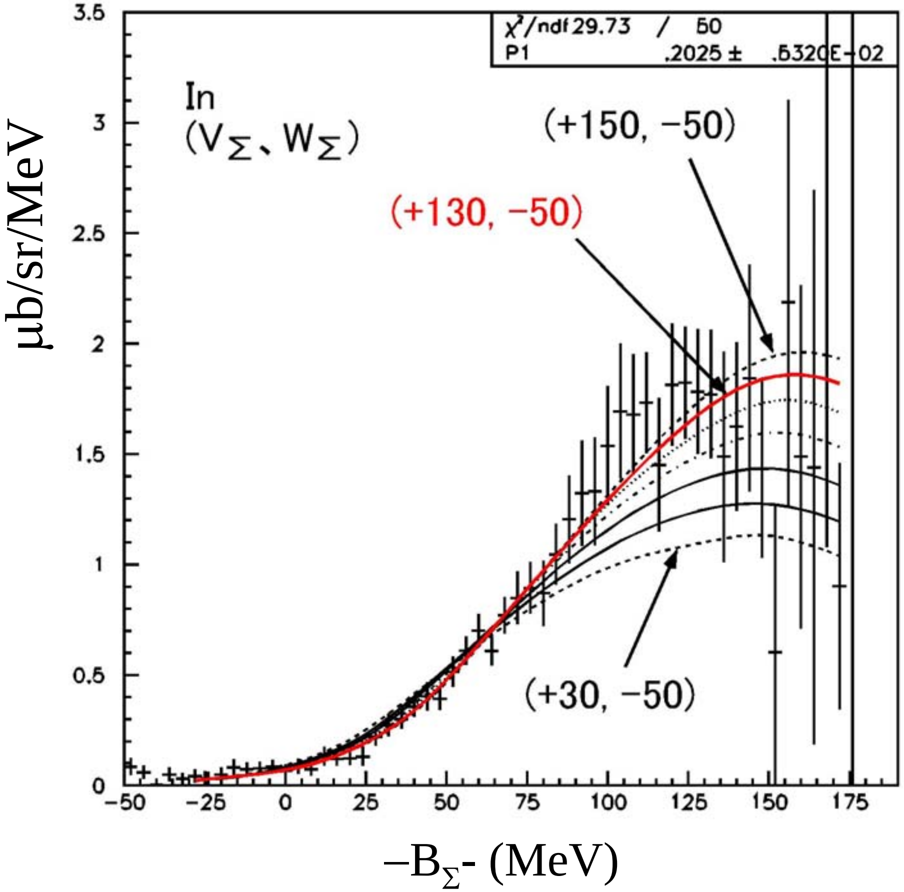
ndf = 52

CL~64% for ●

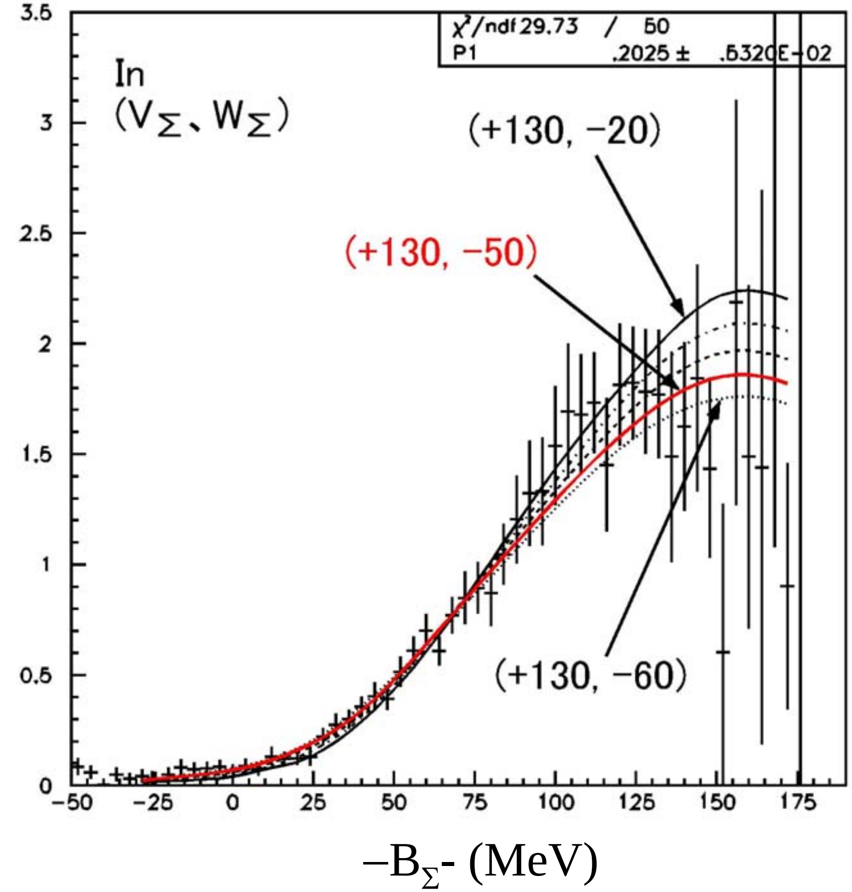
CL = 0.75% for χ^2 = 80

(>0.01%) (100)

Re U_Σ dependence



Im U_Σ dependence

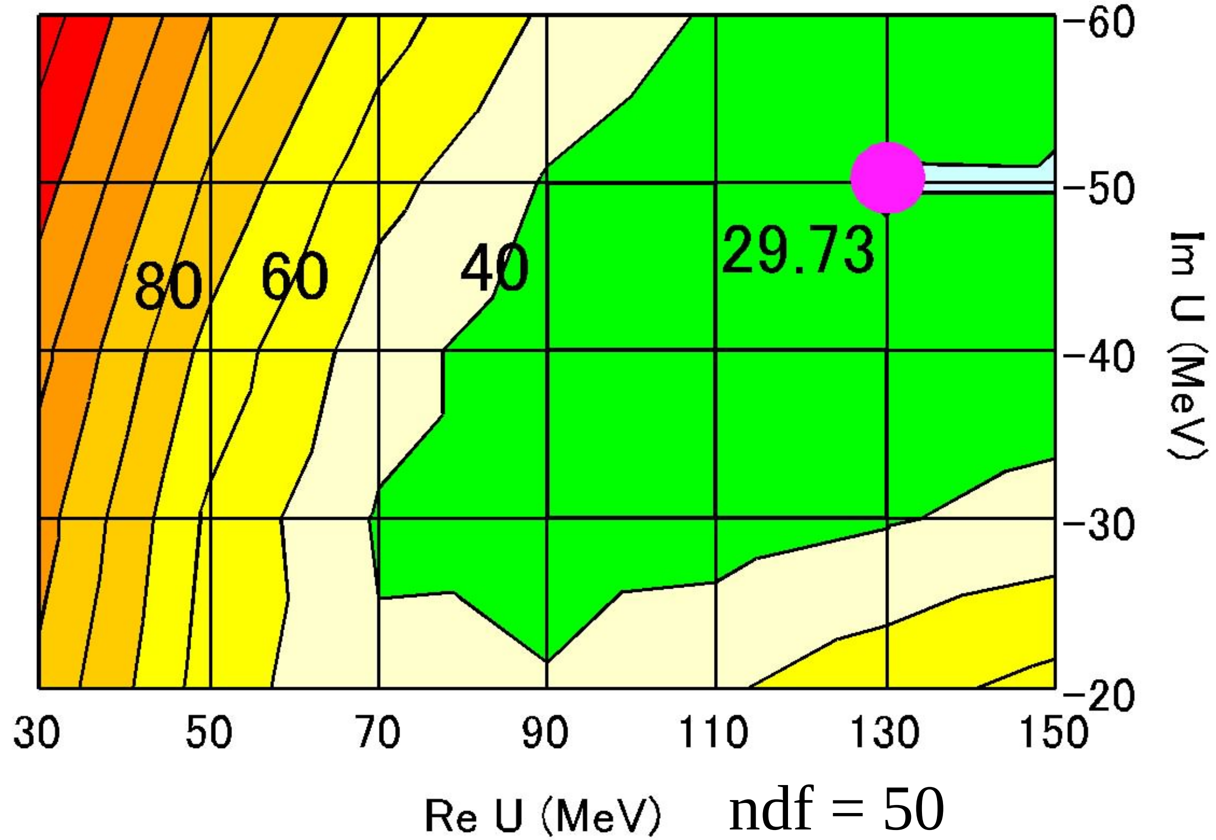


In

W.S. Potential Parameters

	U_Σ	U_{In}
z(fm)	0.67	0.563
c(fm)	5.35	6.24
V0(MeV)		-51.4

In(π^-、K^+)



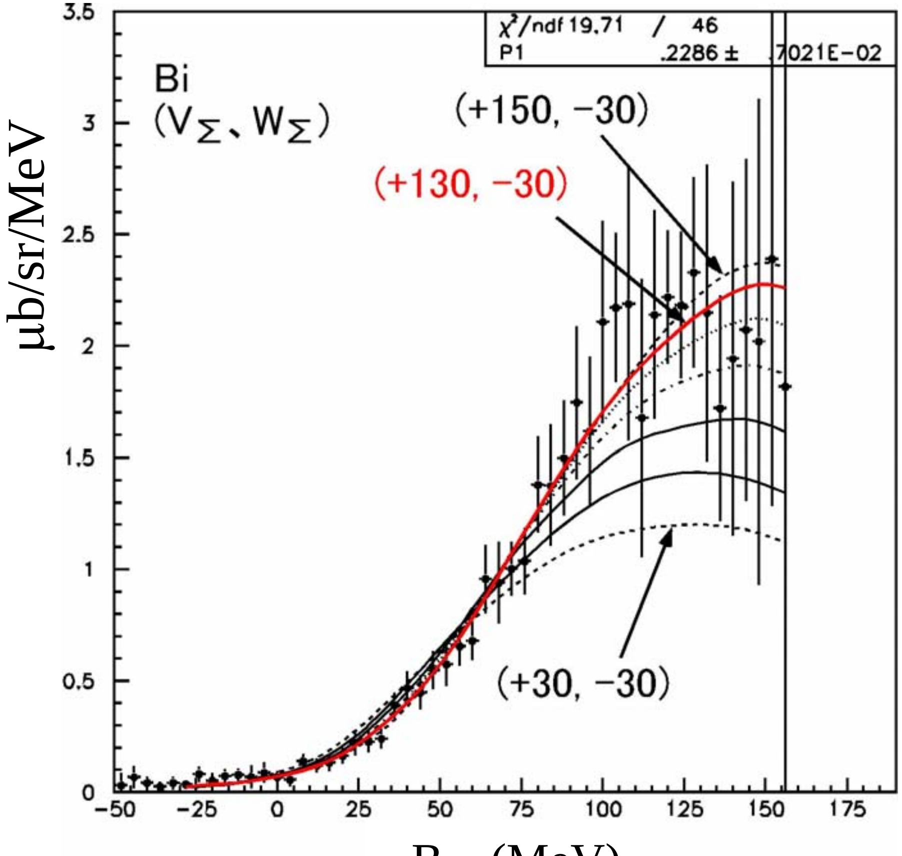
ndf = 50

CL~99% for ●

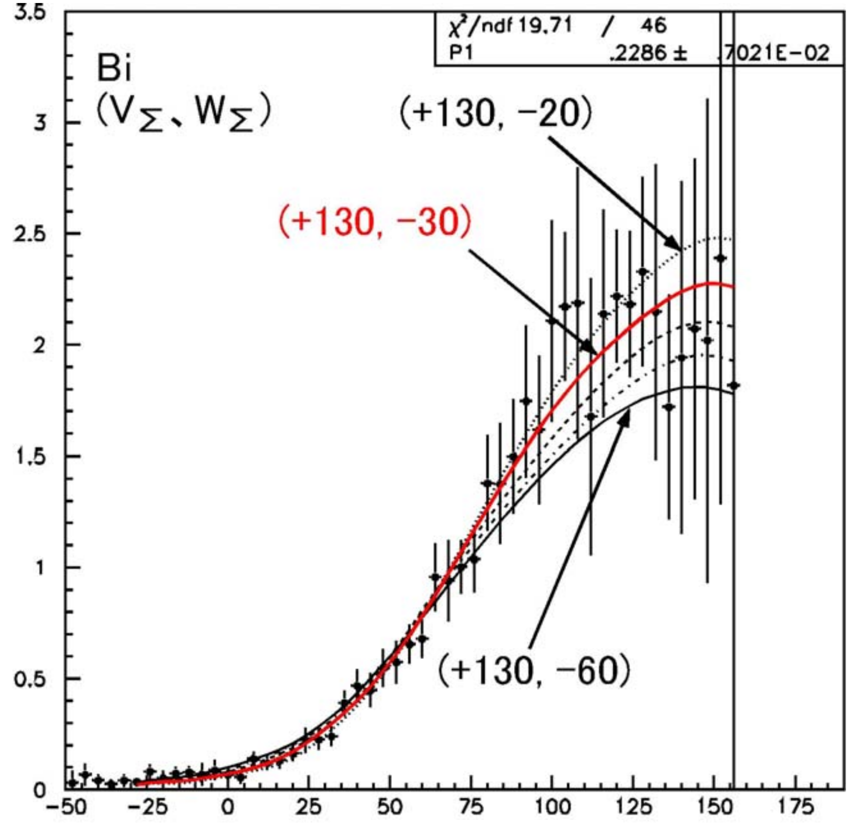
CL = 15.7% for χ^2 = 60

(~0.4%) (80)

Re U_Σ dependence



Im U_Σ dependence

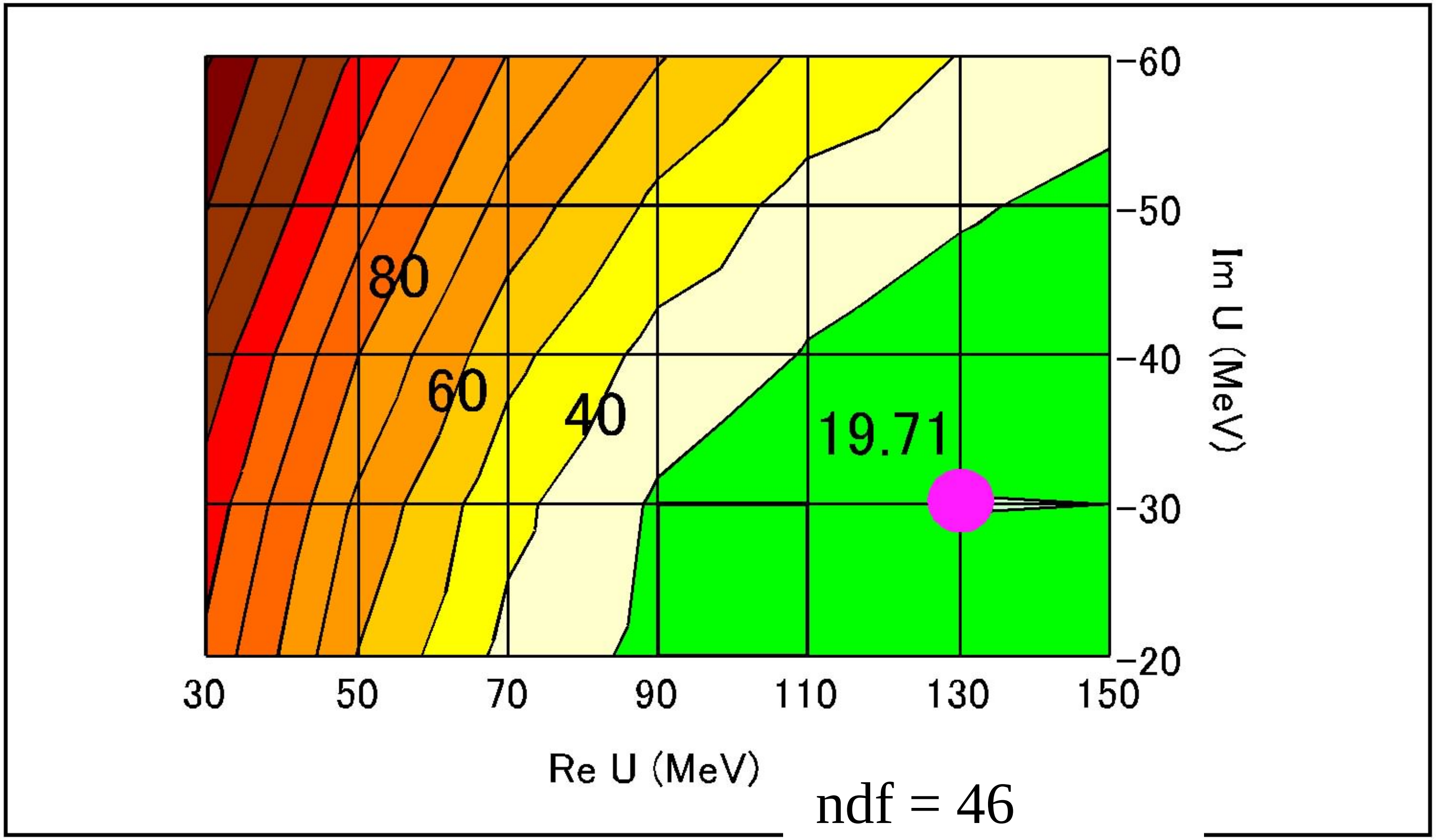


Bi

W.S. Potential Parameters

	U_Σ	U_{Bi}
z(fm)	0.67	0.468
c(fm)	5.35	7.42
V0(MeV)		-55.5

Bi(π^-、K^+)



ndf = 46

CL~99.98% for

CL = 8.1% for χ^2 = 60

(~0.1%) (80)

Summary

1. Inclusive (π^-,K^+) spectra on Si, Ni, In, & Bi were analyzed to extract U_Σ by the DWIA calculations.
   → This framework was successfully applied to reproduce the (π^+,K^+) spectrum on C
2. Repulsive Σ^--nucleus potentials seem to be favored to reproduce the (π^-,K^+) spectra in all targets.
3. The best fit potential parameters were obtained in the surveyed region, V_Σ: 30~150 MeV, W_Σ: -20~-60 MeV, as listed below:

	V_Σ(MeV)	W_Σ(MeV)
Si	+90	-40
Ni	+90	-50
In	+130	-50
Bi	+130	-30

Questions arise after the present demonstration…

1. How is the shape of U_Σ(r)?

   : combined analysis/test with the other data

   → Σ^- atomic data/YN potential

   : detailed structure at around $-B_\Sigma = 0$ MeV

   : $\Sigma^{+/0}$ -Nucleus Potential?

   → high resolution spectroscopy hopefully done in J-PARC

2. Is really U_Σ strongly repulsive?

   : examine the analysis with different framework/people

   : choice of c_Σ / z_Σ

   Is c of $U_Y = 1.1(A-1)^{1/3}$ a common sense?