Σ^+ hyperon in Gamov states

poor men hypernucleus

Sławomir Wycech - Warsaw

Kristian. Pischiccia, Alessandr.Scordo - Frascati

Experiments : FINUDA, AMADEUS

Description of Gamov states : S.W.

Related physics: open

Σ Hyperon momenta from K^- ^6Li

FINUDA

Low momentum peak, only with Σ^+

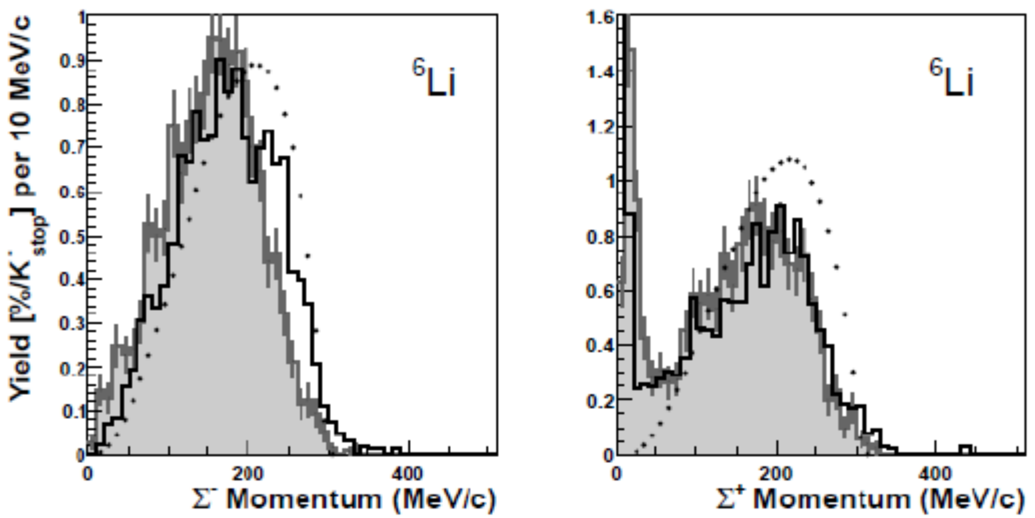


Fig. 5. Momentum distributions of sigmas from the $^6Li(K^-_{stop}, \pi^{\pm}\Sigma^{\mp})A'$ reactions. The grey-filled histograms are the measured distributions. The distributions of Monte-Carlo generated sigmas are depicted by full dots, and with open diagrams are represented the M-C generated sigmas being reconstructed by FINUDA.

The origin of lower peak ?

* Initial FINUDA interpretation - stopping in the target

** AMADEUS - thin targets

Trapping of Σ^+ into Gamov states

Low Peak versus Main Peak

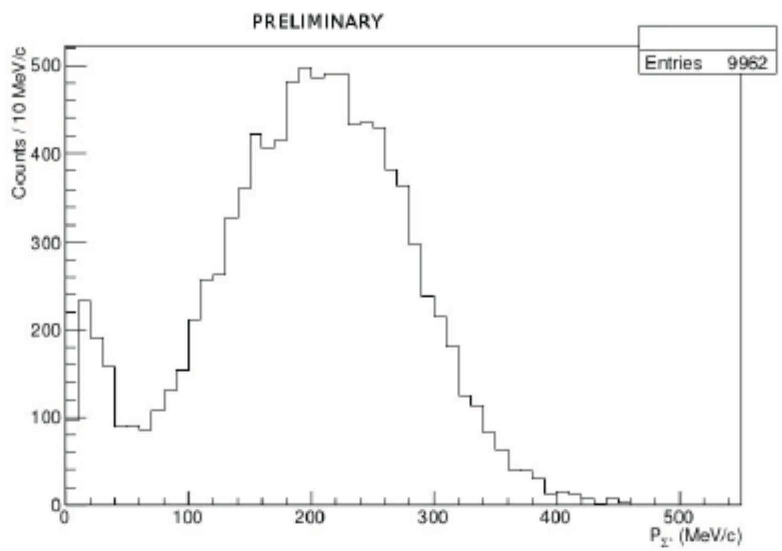
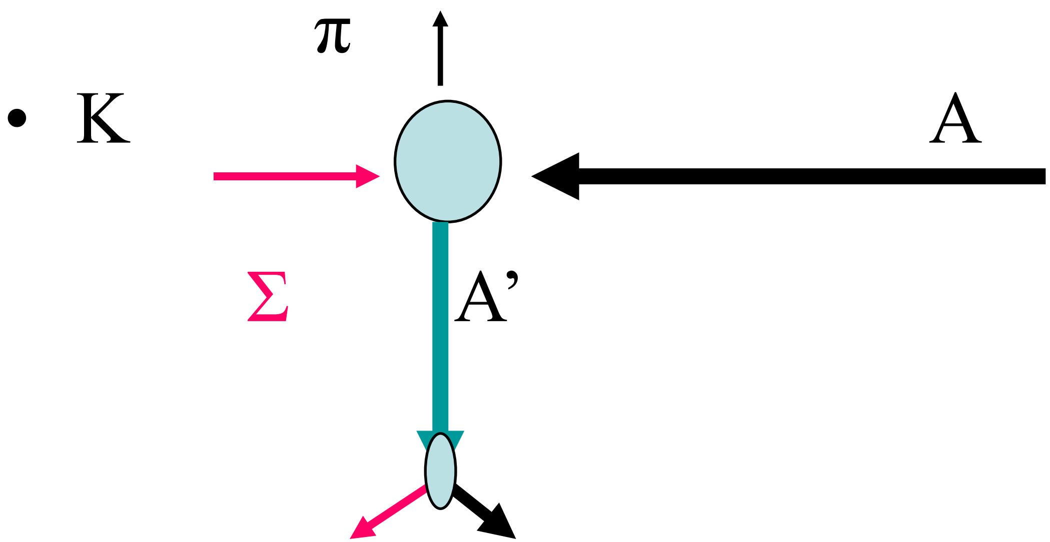


Figure 4. *Σ^+ momentum distribution, from K^- captures in ^{12}C giving rise to $\Sigma^+\pi^-$ formation.*

AMADEUS peaks seen in K^- meson capture at rest and also in-flight

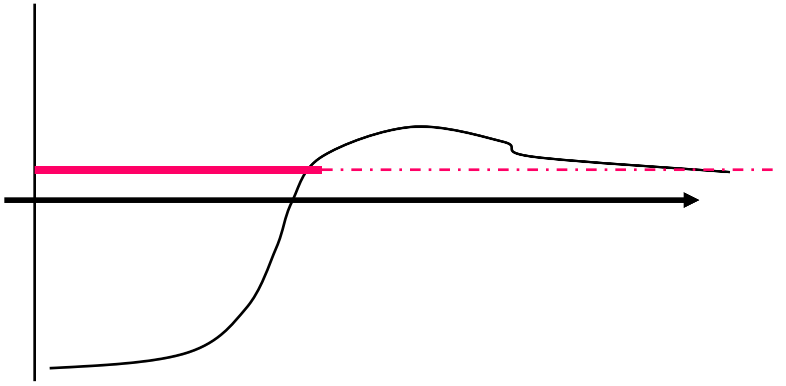
Expectation



Σ^{+} +A’ = quasi bound large object decays with „zero” momentum,propagates large distance

Gamov state

Nuclear +Coulomb potential



A quasi -discrete decaying state in the continuum

– outgoing wave conditions

Gamov states of Σ^+

In light nuclei - exist if Σ^+ is almost bound

$$\Phi = \frac{R(r)}{r}$$

$$-\frac{1}{2M}\,\frac{dR}{d^2r} + (V_c + V_n)R = ER$$

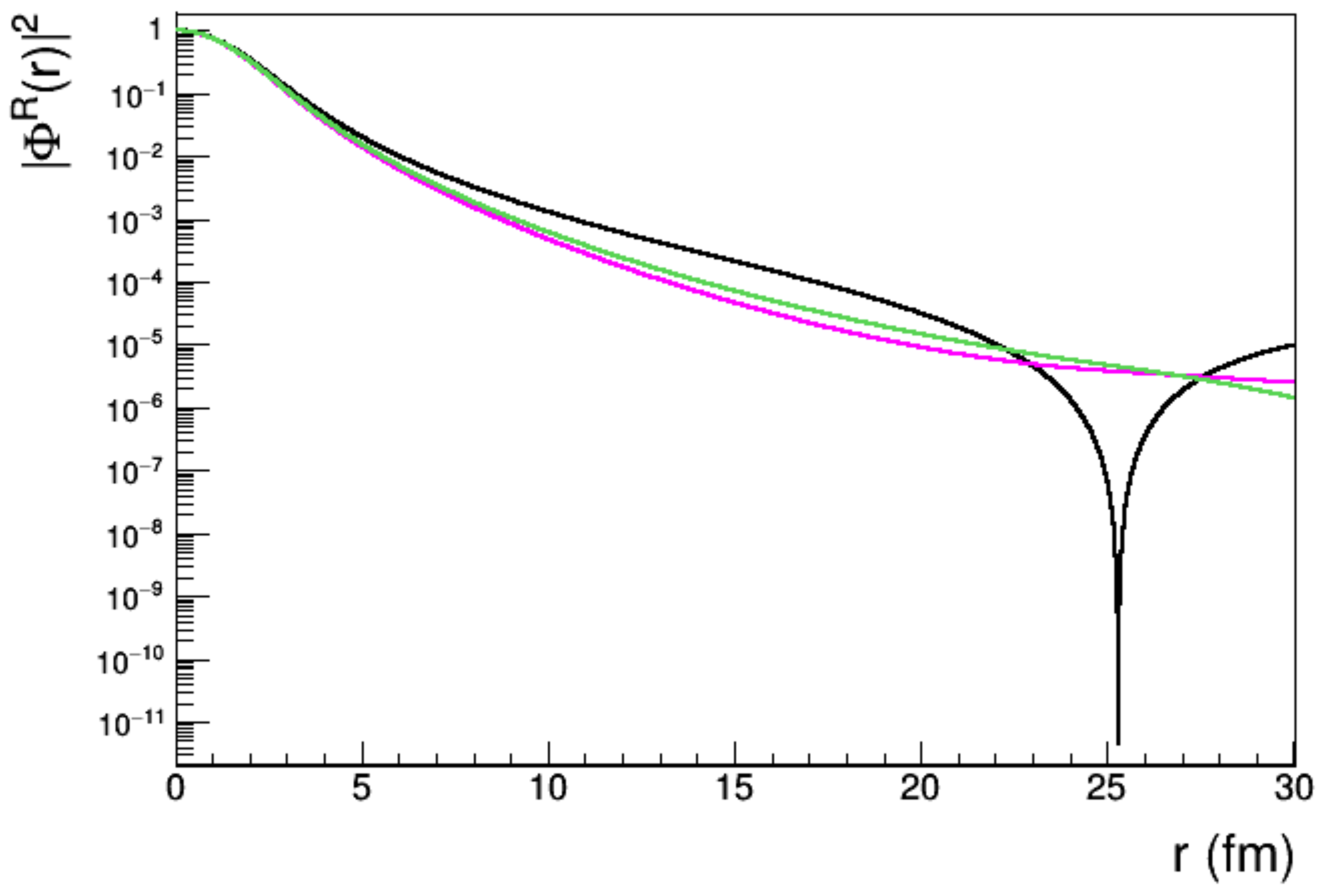
Solutions for real potential Vculomb + Vnucl

Densities in Gamov states, examples

C

B

He



K^- Capture in ^{12}C
Gamov states in ^{11}B :examples

E [MeV]	R_{ms} [fm]	Γ [keV]
0.013	5.1	0.49
0.38	9.1	17

Limits Σ potential well depth to +/- 0.4 MeV

Trapping time ~ 10^4 • Σ formation time

Technical description of Gamov states

DESCRIPTION OF GAMOV STATE

TWO POTENTIALS

$$V_{LONG} = V^{CULOMB} + V^{NUCLEAR}$$

$iW_{SHORT} \qquad \Sigma \to \Lambda$

GREEN'S FUNCTION FOR V_{LONG}

$$G_L = \Phi^R(r_<)\,\Phi^+(r_>)\,\frac{1}{W[\Phi^R\,\Phi^+]}$$

REGULAR OUTGOING WRONSKI

NEAR SINGULARITIES = GAMOV STATES

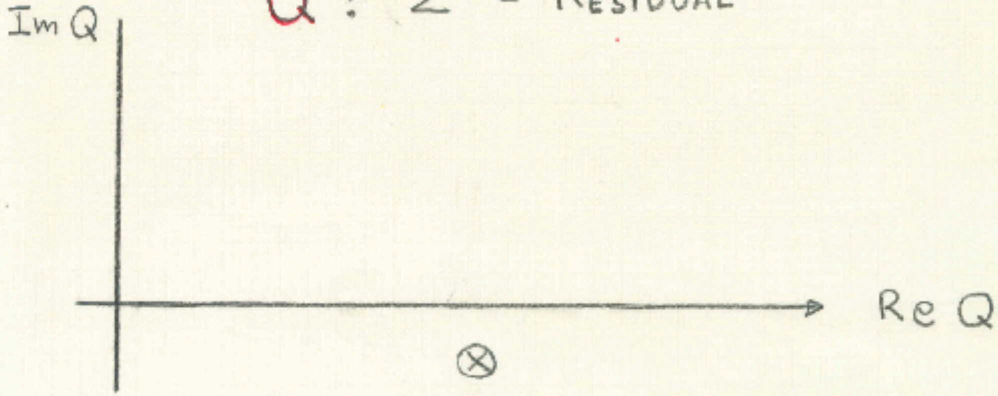
FULL

$$G = G_L + G\,iW\,G_L$$

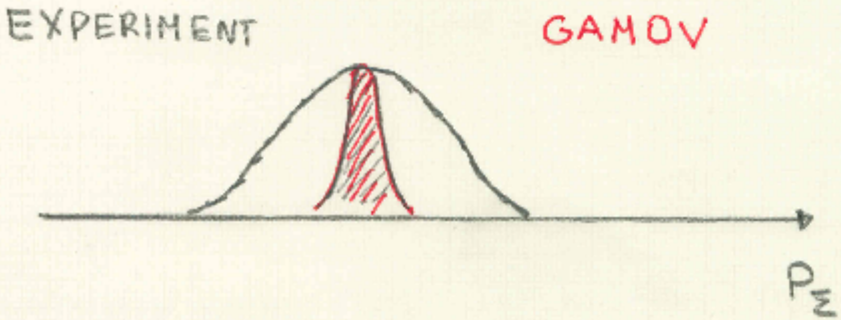
$\uparrow$

COMPLEX MOMENTUM PLANE

Q : Σ^+ - RESIDUAL



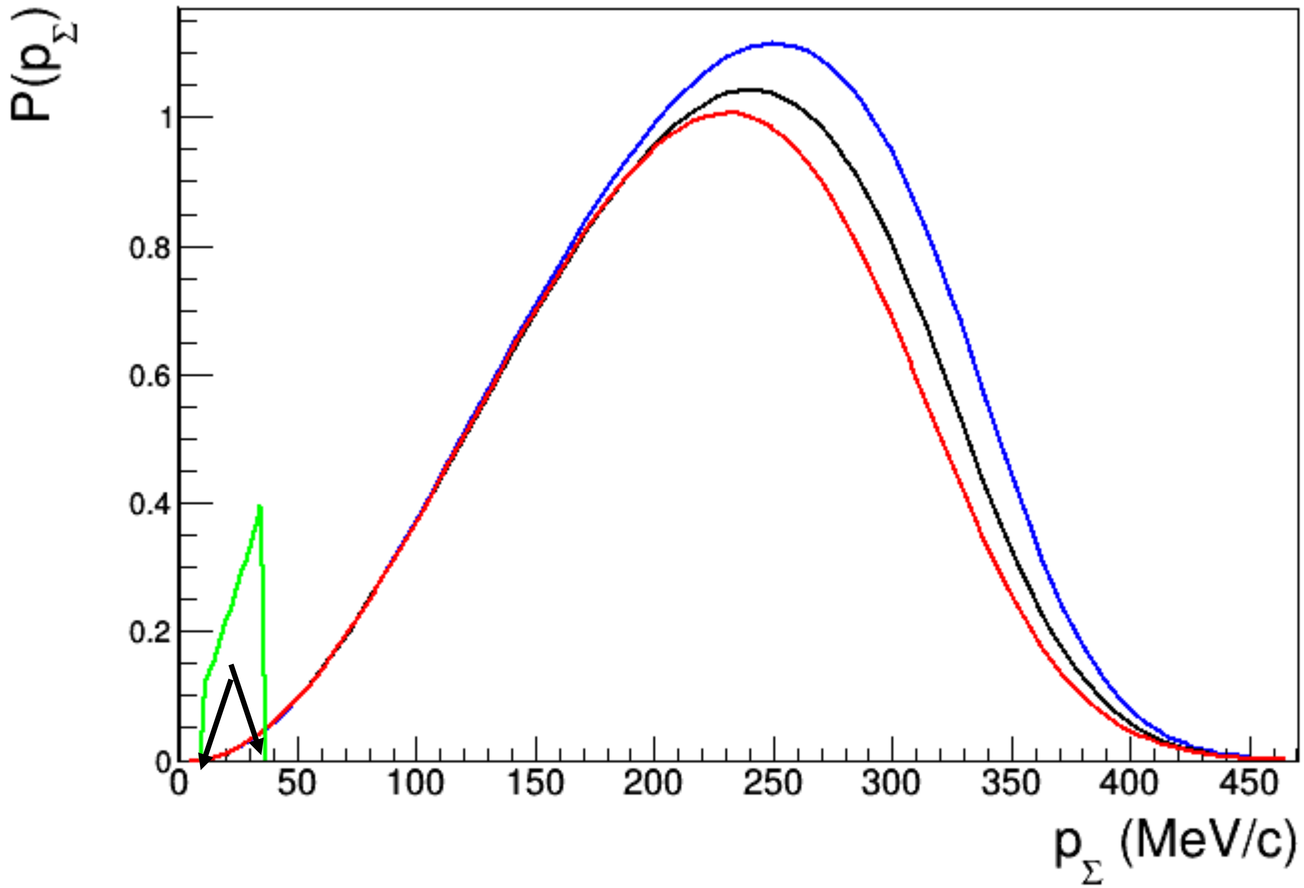
$$W(Q_G - iQ_I) = 0$$



$$\vec{P}_\Sigma \sim \vec{Q}_G + \frac{m_\Sigma}{m_\Sigma + m_R}\vec{P}_\pi$$

Hyperon momentum spectra

delayed fast processes



What is learned from Gamov peak

Energy level → depth of Σ potential well

precisely $2M \int dr\, r\, V(r) \approx \pi/2$

widths → level

strengths → K, Σ absorption parameters

difficult to extract

Extraction of nuclear parameters

The existence of the peak determines

If simple potential well : if $V = V_o \rho(r)$

^{12}Carbon (^{11}B) $V_o \sim -18.6 \pm 0.4$ MeV

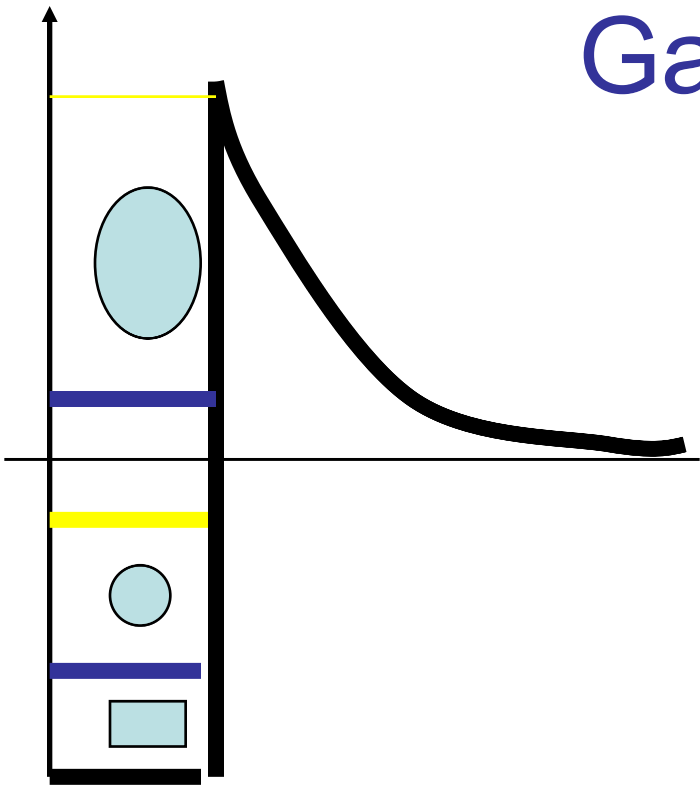
^{6}Lithium (^{5}He) $V_o \sim -26 \pm 0.5$ MeV

But potential is strongly nonlinear in ρ

Relation to Σ Hypernuclei

Hypernuclear region

Gamov region



Optical potential for Σ

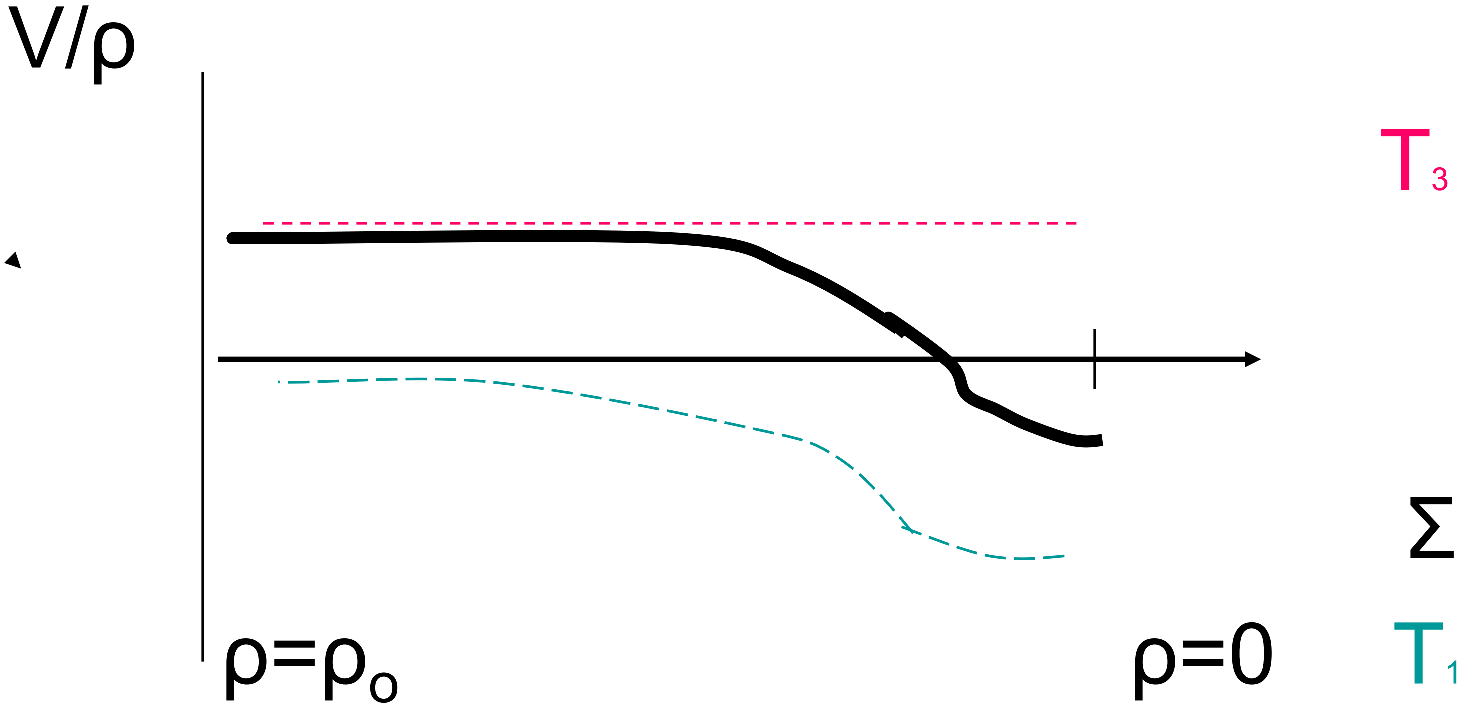
Scattering amplitudes : isospin 3/2,1/2

$$T(\Sigma^- p) = T(\Sigma^+ n) \qquad = \frac{1}{3}T_3 + \frac{2}{3}T_1$$

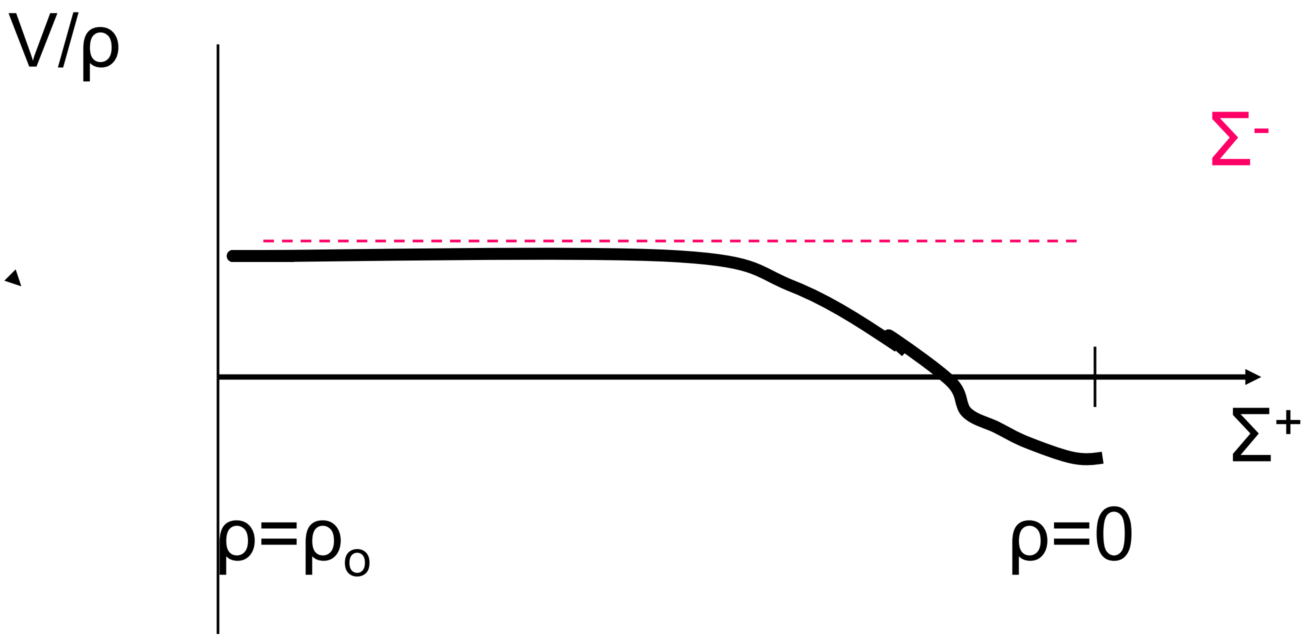
$$T(\Sigma^- n) = T(\Sigma^+ p) = T_3$$

T_1 attractive (virtual state, changes in nuclear matter)
T_3 repulsive

Symmetric N=Z nuclei



Hypothetical nuclei made of neutrons only



Fair chances for Σ^+ Gamov states (or Hypernuclei) in neutron excess nuclei , but A > 16 not tested

outlook

Nuclei with strong neutron tails and small or medium Z may attract Σ^+ hyperons in Gamov (or hypernuclear) states

Thank you

References:

M. Agnello et al., Phys. Lett. B704 (2011) 474, FINUDA

K. Piscicchia et al., EPJ Web Conf. 137 (2017) 09005 AMADEUS –preliminary

T.Nagae et.al. Phys.Rev. Lett.80(1998)1605 He-Σ hypernucleus

S. Bart, et al., Phys. Rev. Lett. 83 (1999) 5238. no heavier Σ (-) hypernuclei

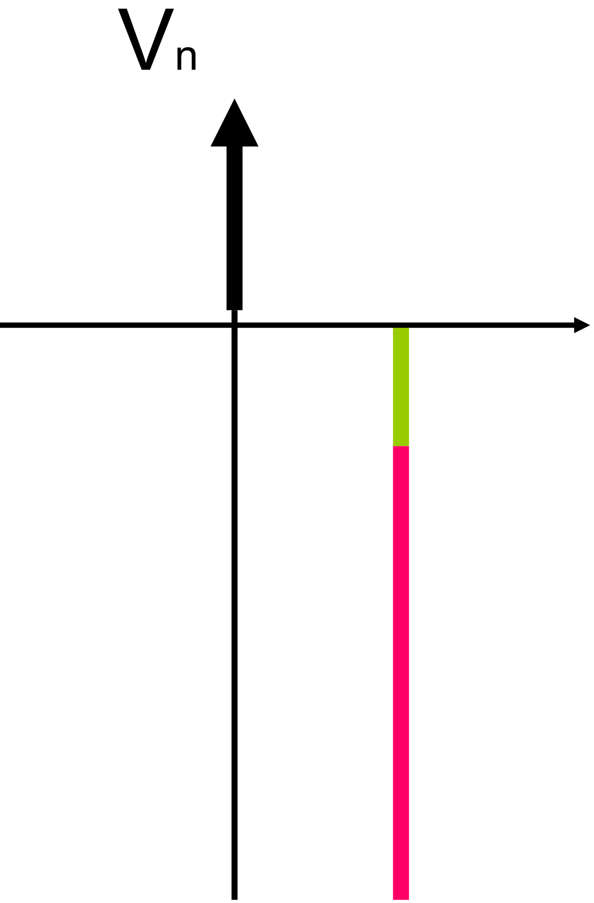
P.K. Saha, et al., Phys. Rev. C 70 (2004) 044613 no Σ (+) hypernuclei for A<16

K. Piscicchia , S. W. Acta Phys Pol. 48(2017)1869 description of the Σ (+) Gamov state

T.Harada et al. Phys. Lett. B 740 (2015) 312–316 $_{\Sigma}$He P wave expected

Appendices

Nuclear well depths in B



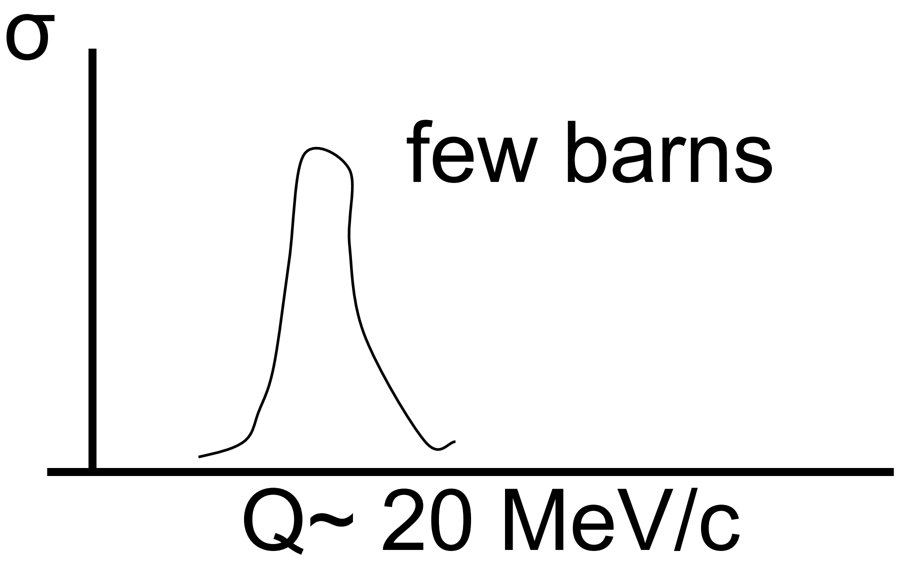
onset of hypernucleus 19 MeV

Gamov states possible ~1 MeV

no significant Coulomb effects

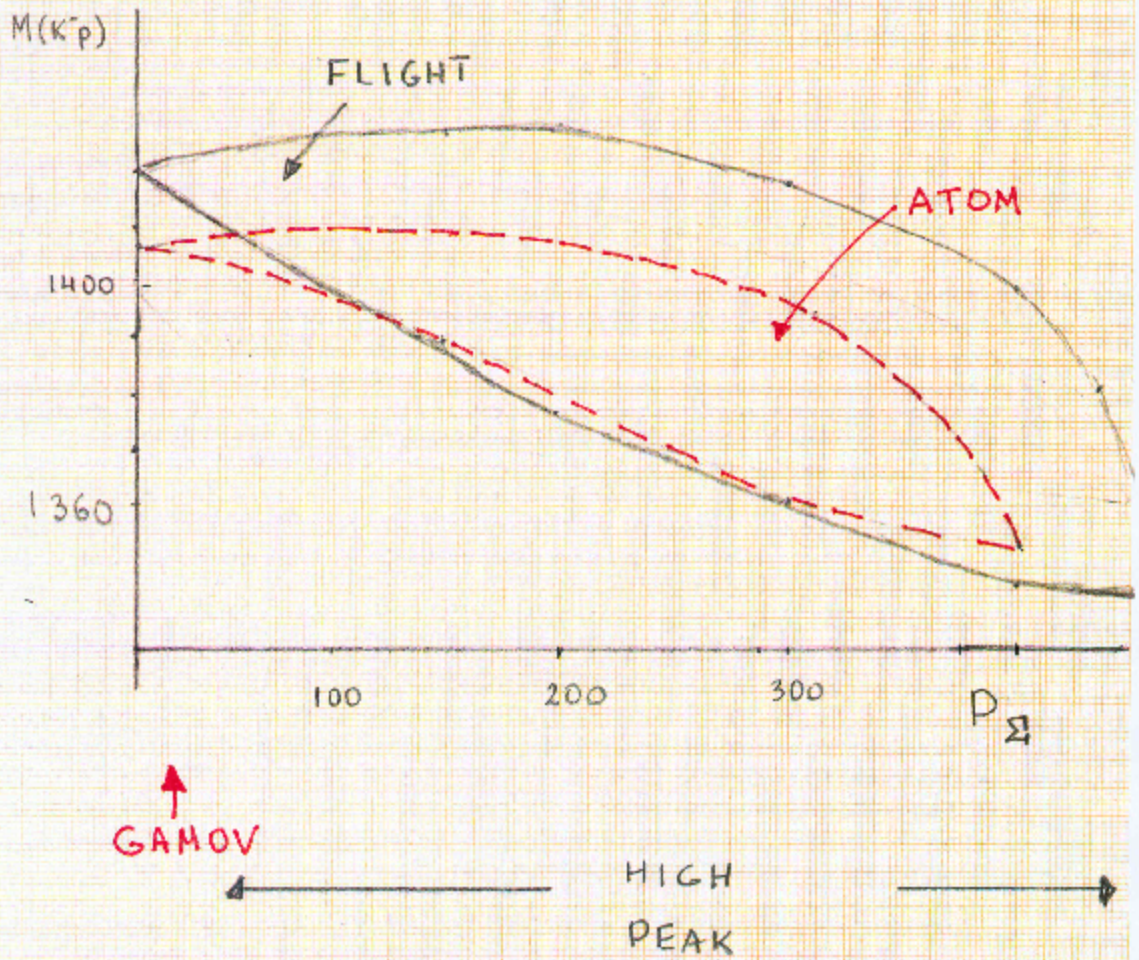
no good localization

Σ^+ nucleus scattering at low momenta



No Σ^+ beams , only intermediate Kp → Σπ

Complicates description $\phi(r) \rightarrow G(r,r')$



PHASE SPACE

Gamov Peak versus Main Peak

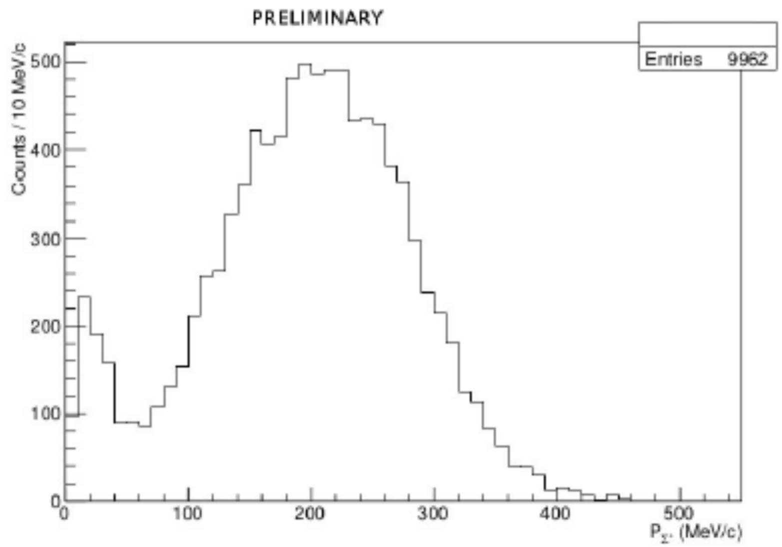


Figure 4. *Σ^+ momentum distribution, from K^- captures in ^{12}C giving rise to $\Sigma^+\pi^-$ formation.*

AMADEUS Gamov peaks seen in K capture at rest and in-flight