NUFRA 2013

September 29th – October 6th 2013

Kemer Turkey

Joint SPHERE & JSPS meeting

HadronPhysicsHORIZON

The first EU Calls for the Program Horizon 2020 will be issued early 2014 with the instrument of Integrating Activities.

three key priorities of the Programme: Excellence science, Industrial leadership, Societal challenges

The HadronPhysics3 Management Board, together with the selected coordinator for the HadronPhysics project in Horizon 2020, will serve as Steering Committee to prepare the new proposal to be submitted to the European Commission in the upcoming calls.

Following the strategy adopted in the previous HadronPhysics projects, the Steering Committee has launched an internal call for work packages to be included in the future

"A horizon for Hadron Physics:
mastering challenges in a globalized world"

HadronPhysicsHorizon (HPH)

Stratigical Framework

- The overall EC contribution is expected to be of the order of that of HadronPhysics3 for a duration of three years. Therefore the budgets of the new work packages cannot exceed on average the actual HadronPhysics3 budgets.
- Main challenges
  - Mastering the high-tech challenge
  - Mastering the precision challenge
  - Mastering the complexity challenge
  - Mastering the data challenge
  - Mastering the international collaboration challenge
  - Mastering the outreach challenge
  - Mastering the application challenge

- We started work on a proposal for a networking activity continuing the SPHERE activity

Global Networking Activity Exploring
Baryonic Structures with Exotic Flavor

- Acronym: BASE-NET (*better ideas are welcome*)
- Deadline: October 31st 2013

Physics Opportunities with Antihyperons at PANDA

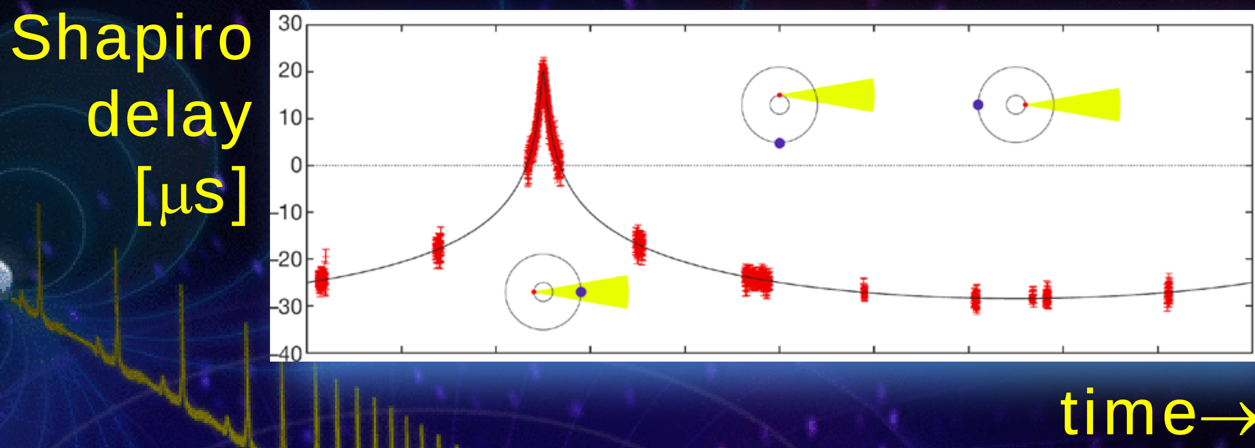
Alicia Sanchez Lorente & Josef Pochodzalla

Production Rates (1-2 $(fb)^{-1}/y$)

Final State	cross section	# reconstr. events/y
Meson resonance + anything	100µb	10^{10}
$\Lambda\bar{\Lambda}$	50µb	10^{10}
$\Xi\bar{\Xi}$ ($\rightarrow {}_{\Lambda\Lambda}A$)	2µb	10^{8} (10^{5})

NUFRA 2013
Kemer , September 29th -October 5th 2013

Heavy Neutron Stars



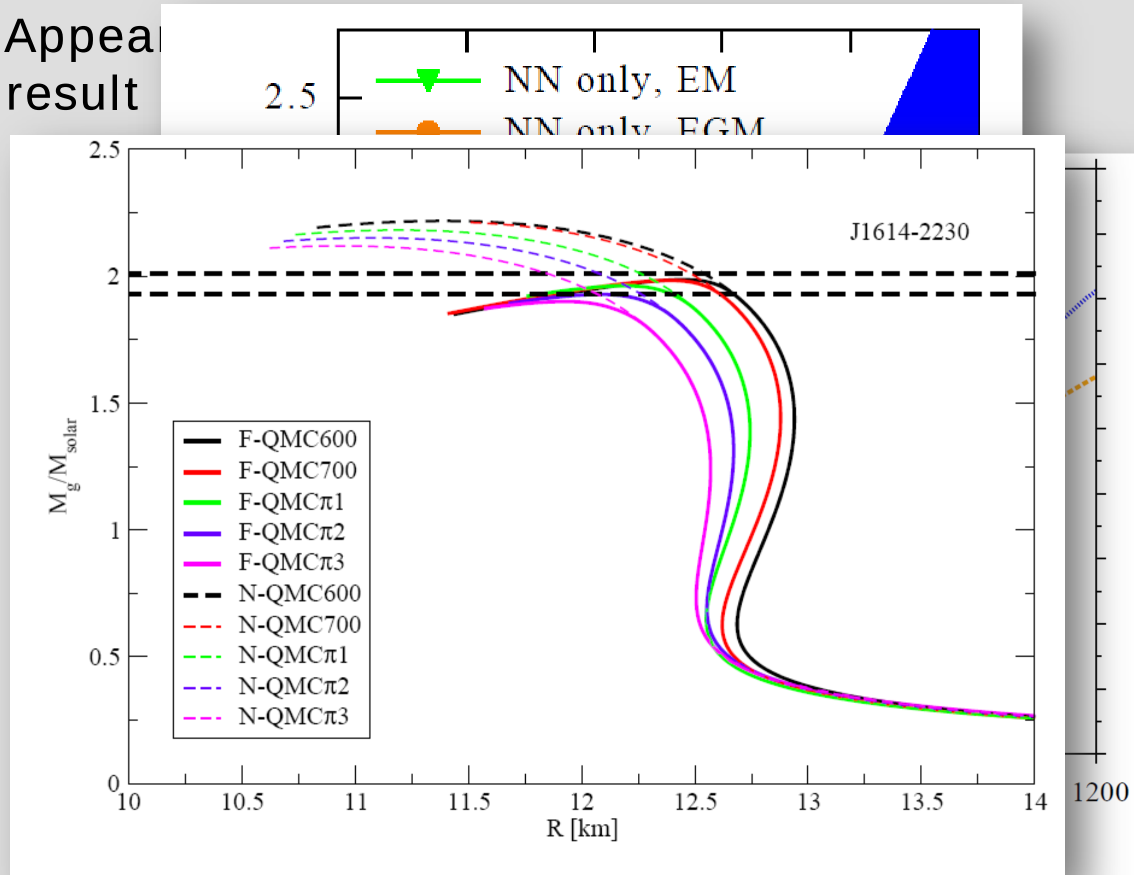
$M(\text{PSR J1614-2230}) = 1.97 \pm 0.04\ M_\odot$

$M(\text{PSR J0348+0432}) = 2.01 \pm 0.04\ M_\odot$

P. B. Demorest, T. Pennucci, S. M. Ransom, M. S. E. Roberts and J. W. T. Hessels, Nature 467 (2010)
John Antoniadis et al., Science 340 (2013)

The Hyperon Puzzle in Neutron Stars

- Also three (and four) baryon forces are essential for understanding the EOS at high density
- Appea[r]
  result



J. R. Stone et al.,
arXiv:1012.2919v1

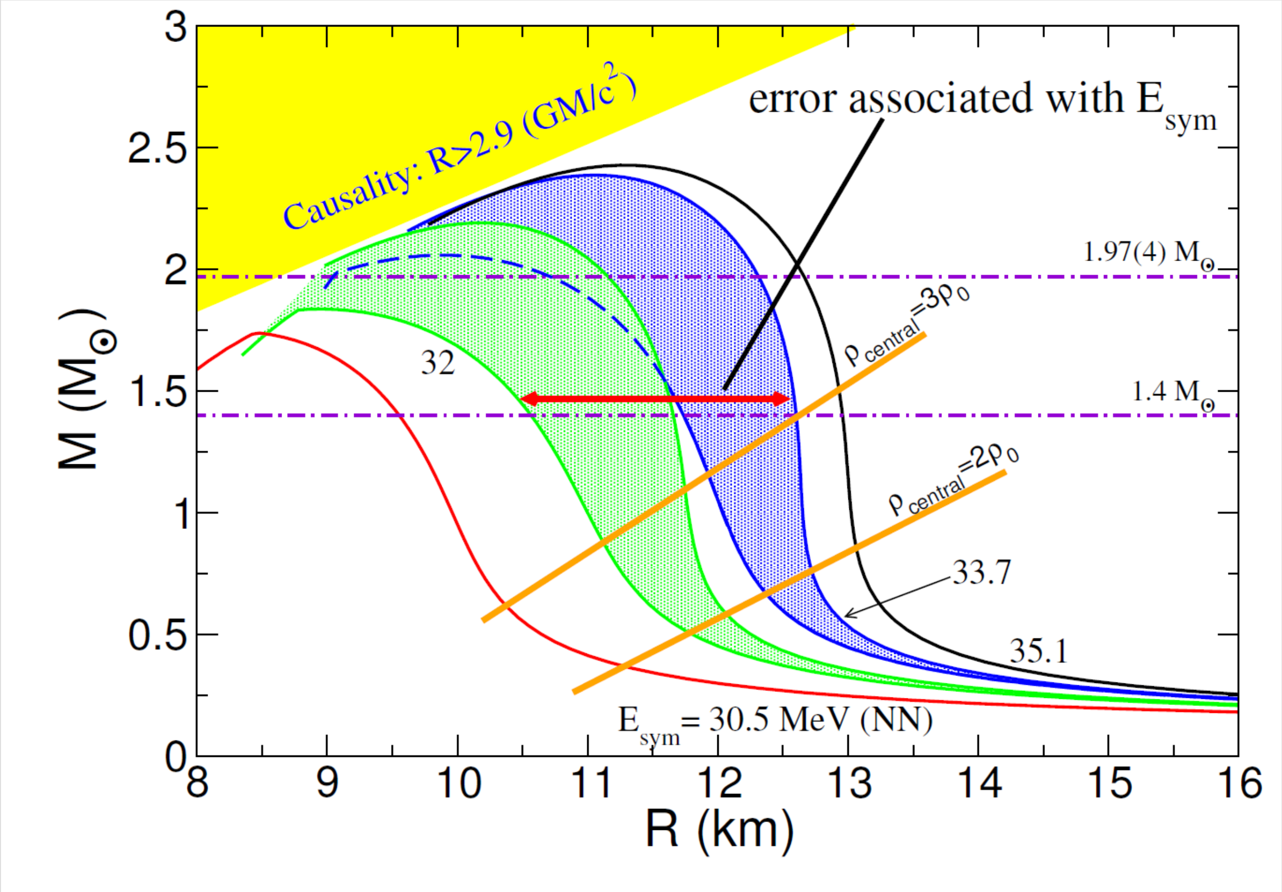
D.L.Whittenbury et *al.*, arXiv:1204.2614

- This causes a dilemma for many EOS but a two solar mass neutron star may still be compatible with the presence of hyperons

But even if hyperons do *not* appear in neutrons stars, why so ?
⇒ Need a precise understand Y-N, Y-Y, Y-N-N, … interactions !

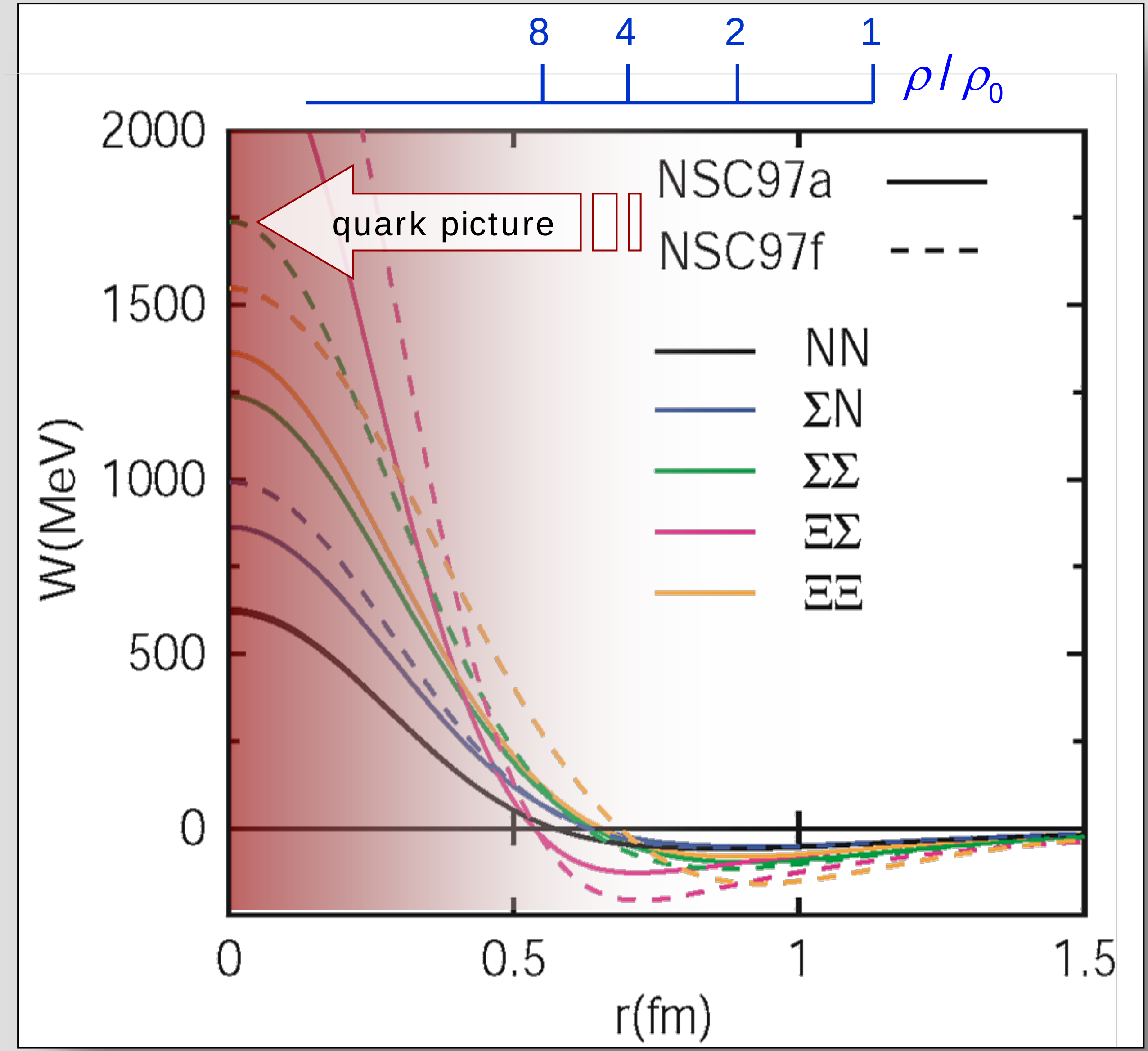
The short distance challenge

- Comprehensive description of strange nuclei in terms of basic principles (QCD) to allow quantitative predictions in regions not directly accessible by experiments



Stefano Gandolfi and Andrew W. Steiner arXiv:1308.6002

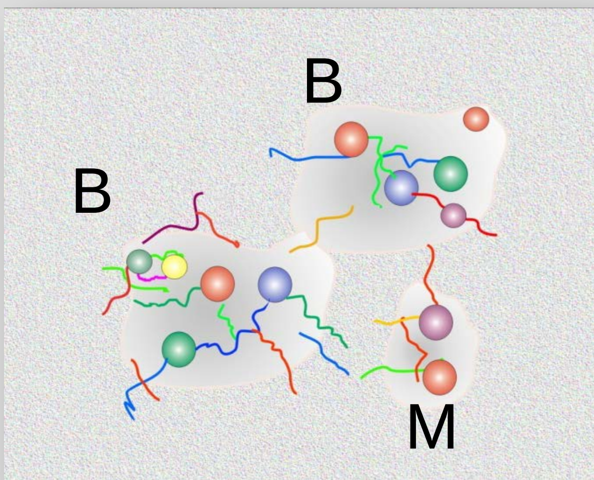
Interpolation vs. extrapolation

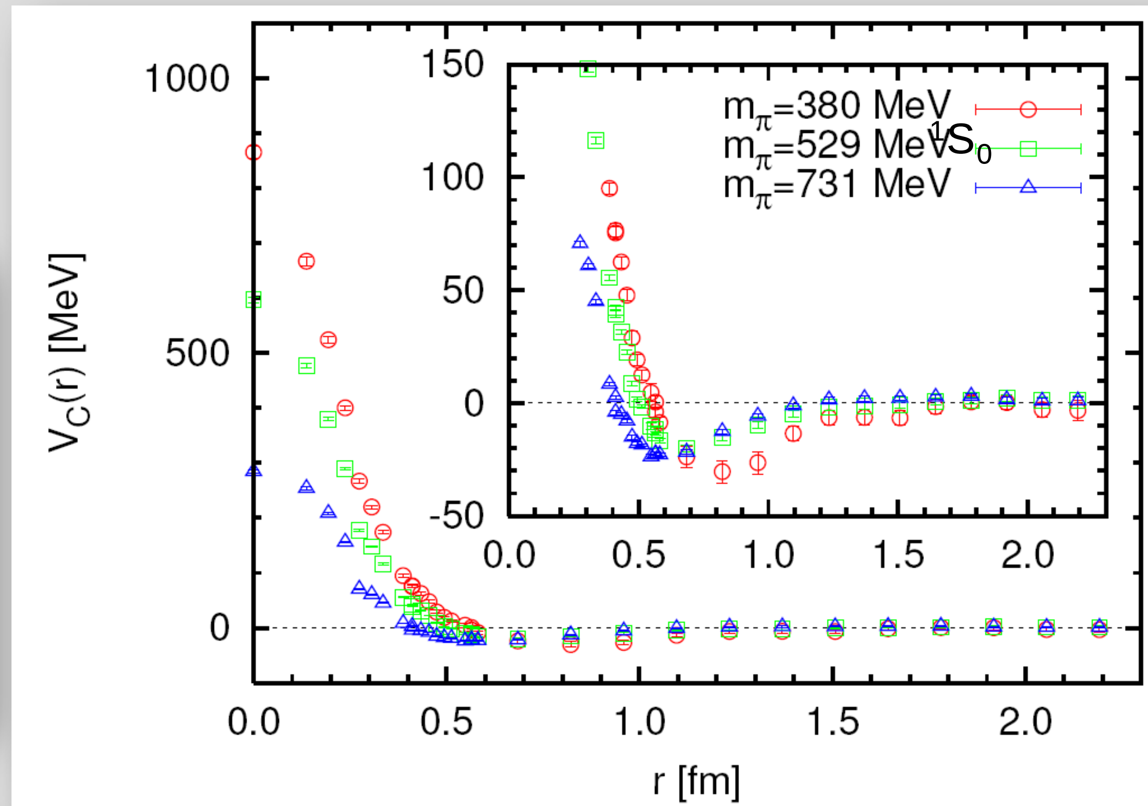


Modern Version of B-B Interaction

- Nuclear Forces from Lattice QCD
- Pauli Principle not essential for repulsive core: Spin □ flavor □ color
- Understanding baryons and their mutual interactions is a complex, quantum-fieldtheoretical, non-perturbative many-body problem

Rudolf Fiebig





S. Aoki, T. Hatsuda and N. Ishii, Prog. Theor. Phys. 123 (2010) 89

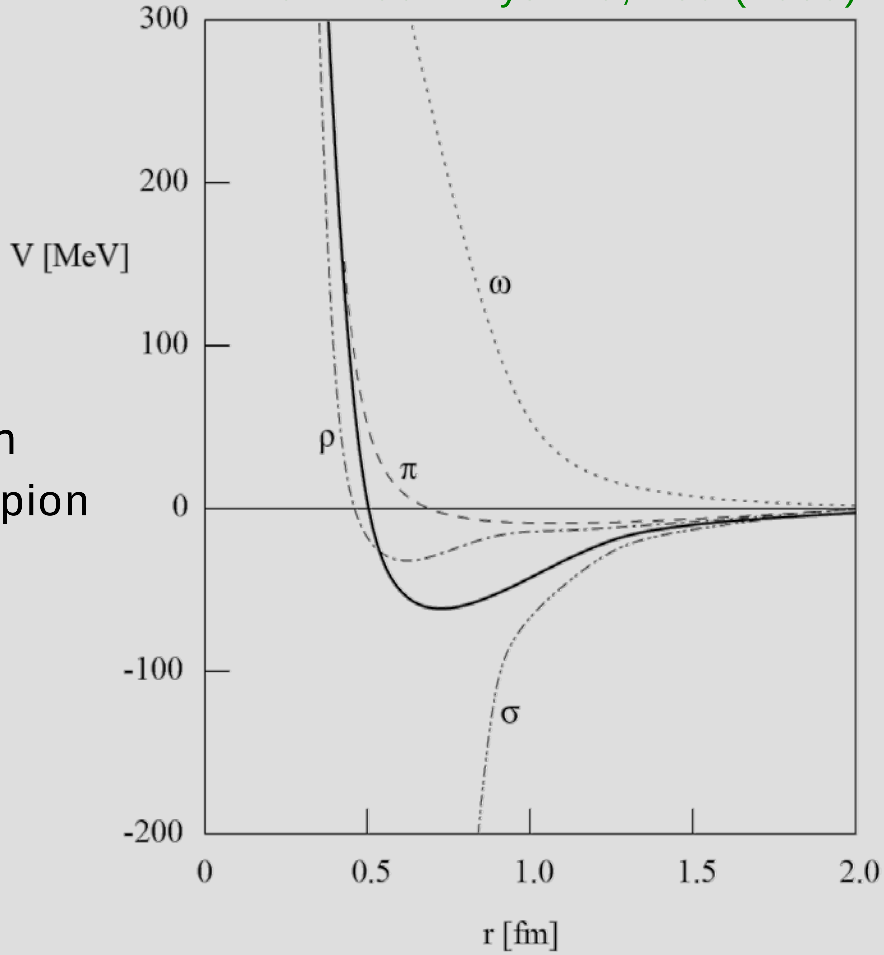
Traditional View of the N-N Interaction

- Experimental observation
  - short range (r<0.5fm) repulsion
  - intermediate (r≈1fm) strong attraction
  - long range (r>1.5fm) attraction
- Boson exchange model
  - Yukawa (1935)
  - Klein-Gordon equation

$$\left(\partial^2 + m^2\right)\varphi(x) = g\bar{\psi}\psi$$

  - range of N-N interaction R≈2fm
  - $R=\hbar c/mc^2 \Rightarrow m\approx 100 MeV/c^2 \Rightarrow$ pion

R. Machleidt,
Adv. Nucl. Phys. **19**, 189 (1989)



G-Parity and N$\bar{\text{N}}$ Potential

- G=charge conjugation + 180° rotation around 2nd axis in isospin (Lee und Yang 1956, L. Michel 1952 „Isoparität") $G = C \cdot e^{i\pi I_2}$
- G-parity of particle-antiparticle multipletts

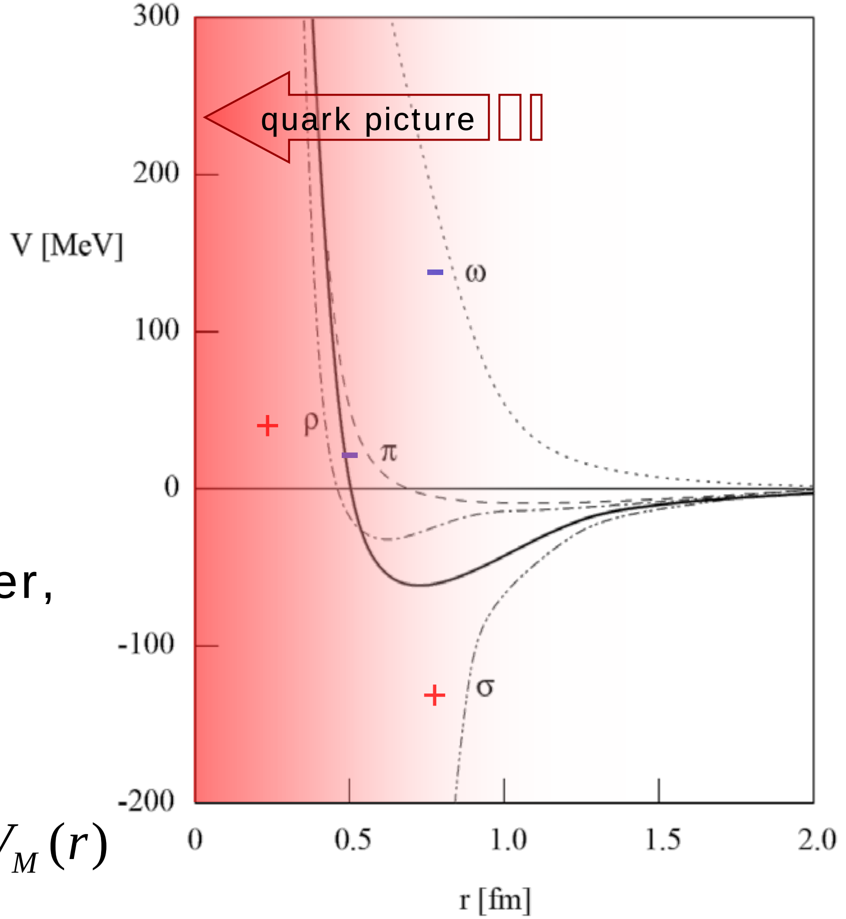
$$G\left|f\bar{f}\right\rangle = (-1)^{I} C\left|f\bar{f}\right\rangle = (-1)^{I+L+S}\left|f\bar{f}\right\rangle$$

$$G\left|\pi^{\pm 0}\right\rangle = (-1)^{1} C\left|\pi^{\pm 0}\right\rangle = -\left|\pi^{\pm 0}\right\rangle$$

$$G\left|\rho\right\rangle = (-1)^{1} C\left|\rho\right\rangle = +\left|\rho\right\rangle$$

$$G\left|\omega\right\rangle = (-1)^{0} C\left|\omega\right\rangle = -\left|\omega\right\rangle$$

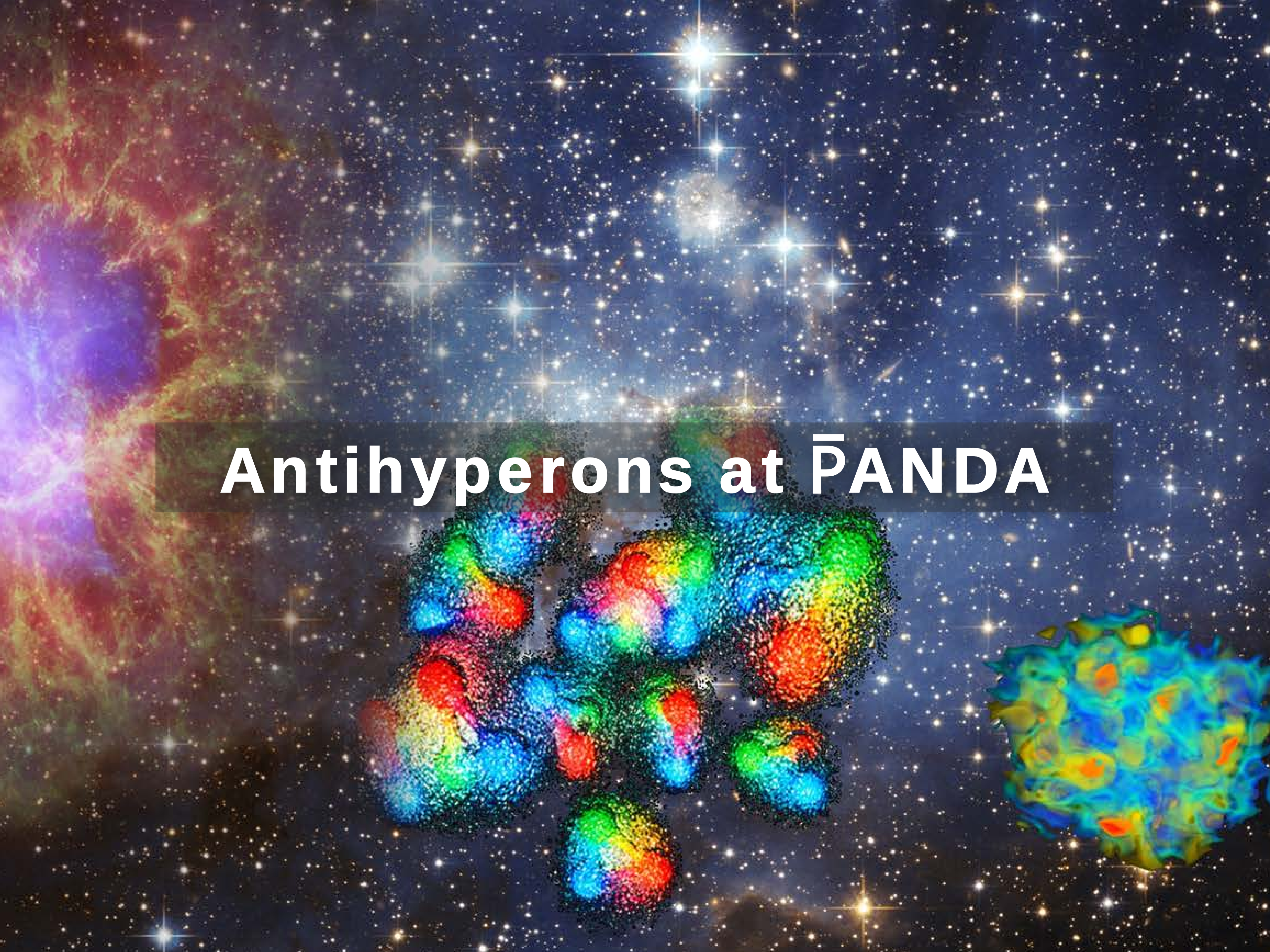
$$G\left|\sigma\right\rangle = (-1)^{0} C\left|\sigma\right\rangle = +\left|\sigma\right\rangle$$



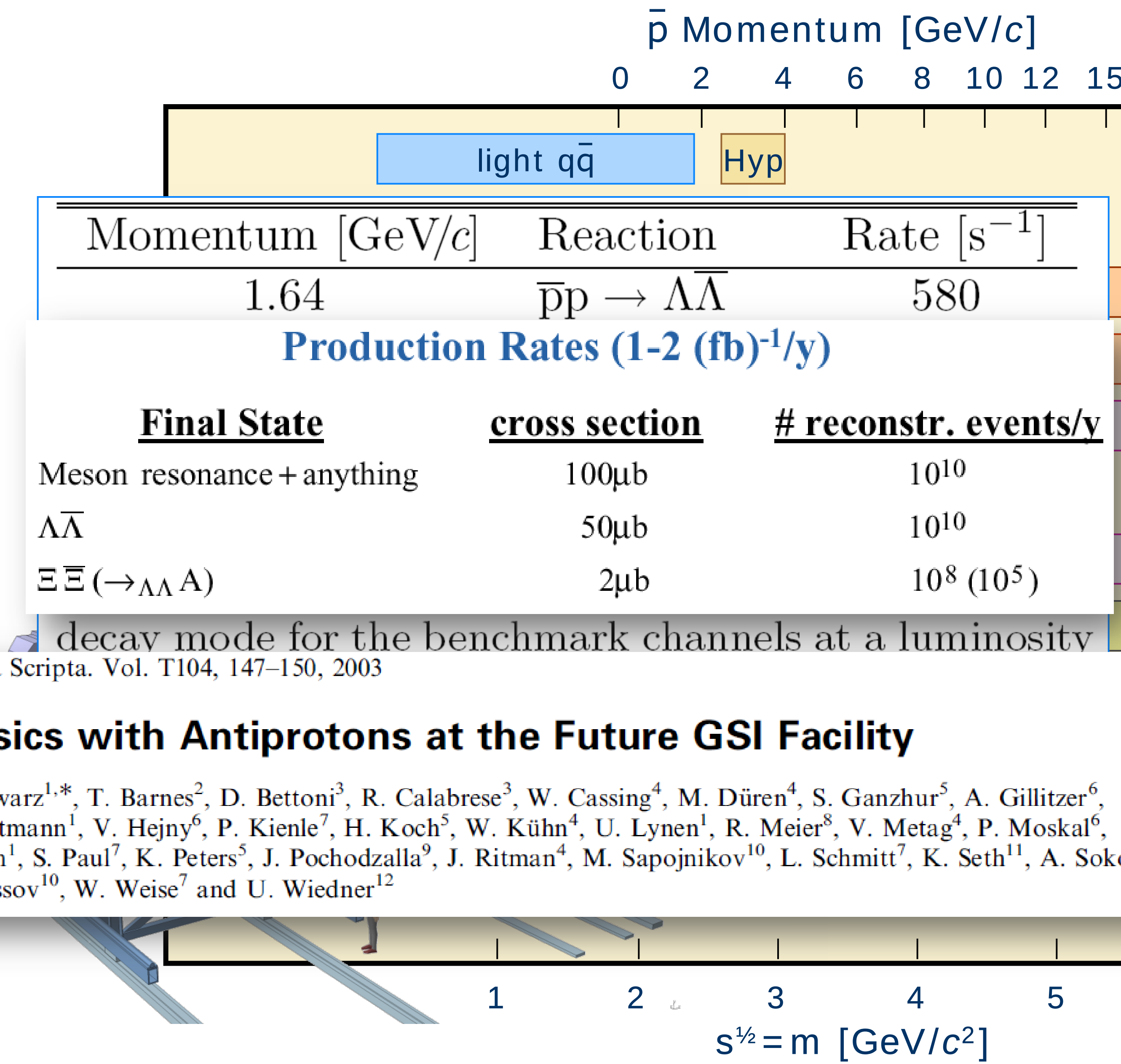
- Hans-Peter Dürr and Edward Teller, Phys. Rev. **101**, 494 (1956)
  - sign change in coupling constant when going from NN to N$\bar{\text{N}}$

$$V(NN)(r) = \sum_M V_M(r) \rightarrow V(N\bar{N})(r) = \sum_M G_M V_M(r)$$

- Caveat: meson picture will probably not work at small distance
- Chance to study transition from meson to quark-gluon regime


Antihyperons at $\bar{\text{P}}$ANDA

$Y\bar{Y}$ at PANDA



Momentum [GeV/c]	Reaction	Rate [s^{-1}]
1.64	$\bar{p}p \to \Lambda\bar{\Lambda}$	580

decay mode for the benchmark channels at a luminosity

Production Rates (1-2 $(fb)^{-1}/y$)

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Physica Scripta. Vol. T104, 147–150, 2003

Physics with Antiprotons at the Future GSI Facility

C. Schwarz[1,*], T. Barnes[2], D. Bettoni[3], R. Calabrese[3], W. Cassing[4], M. Düren[4], S. Ganzhur[5], A. Gillitzer[6], O. Hartmann[1], V. Hejny[6], P. Kienle[7], H. Koch[5], W. Kühn[4], U. Lynen[1], R. Meier[8], V. Metag[4], P. Moskal[6], H. Orth[1], S. Paul[7], K. Peters[5], J. Pochodzalla[9], J. Ritman[4], M. Sapojnikov[10], L. Schmitt[7], K. Seth[11], A. Sokolov[1], N. Vlassov[10], W. Weise[7] and U. Wiedner[12]

Possibilities for studying YN, YNN,YY

- Hypernuclei !
  - Advantage: YN,YNN,...,YY interaction accessible

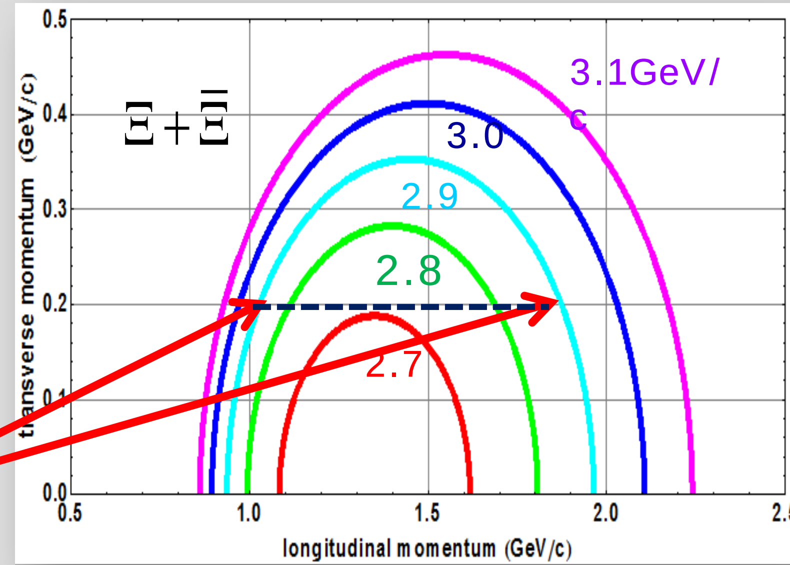
  →talk of Alicia Sanchez

Can we do a scattering experiment with low momentum (anti)hyperons?

In principle Yes !

Low momentum $\bar{p}$-p collider

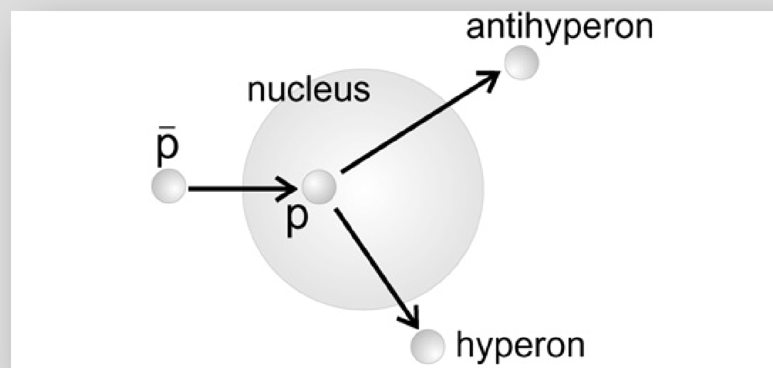
HESR + HESR



- $\bar{p}$+A→ $\bar{Y}$+Y+X: (anti)hyperon nuclear potentials from $\bar{Y}$+Y pair correlations

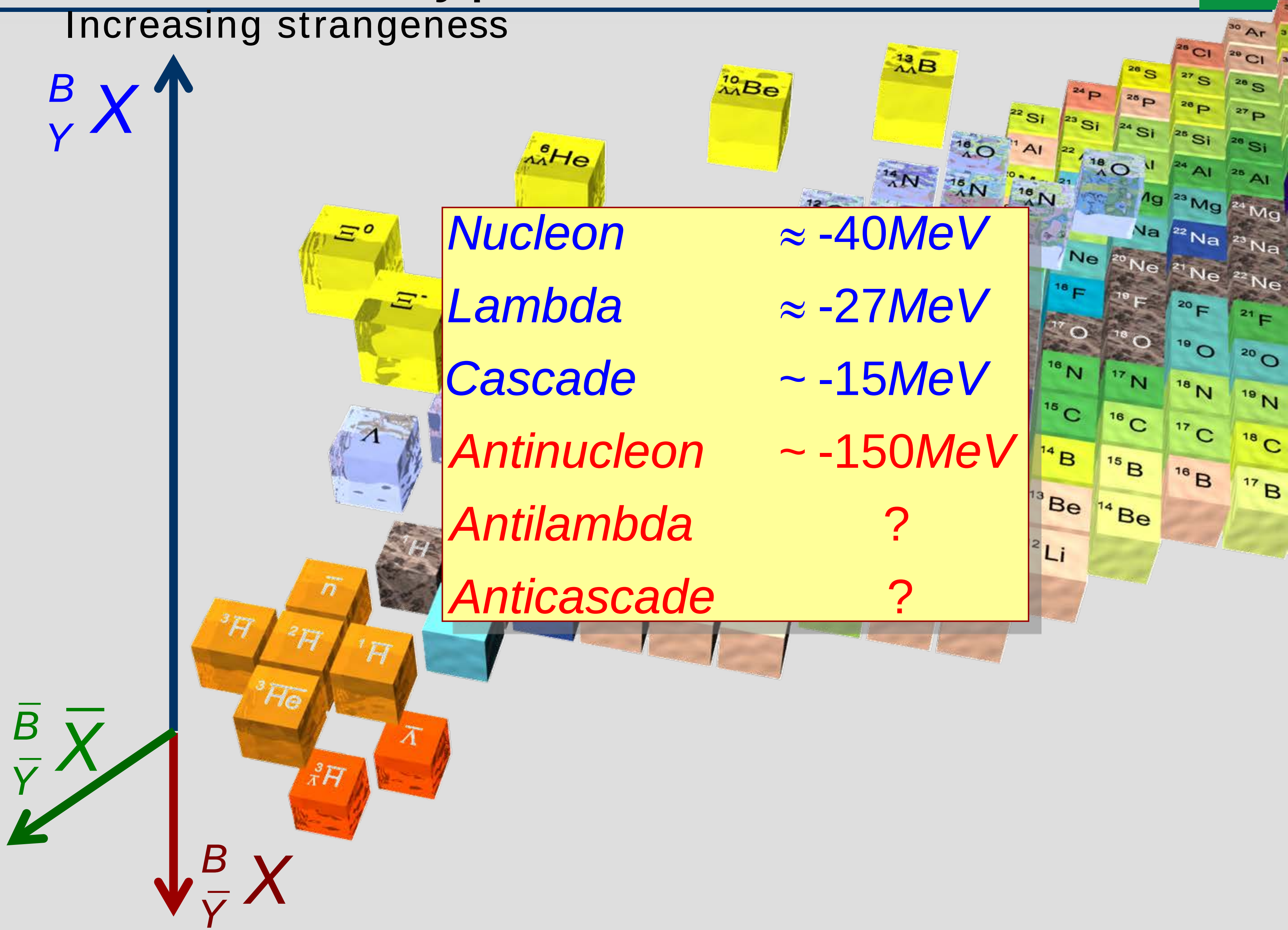
  → PANDA

  see e.g. PLB 669 (2008) 306



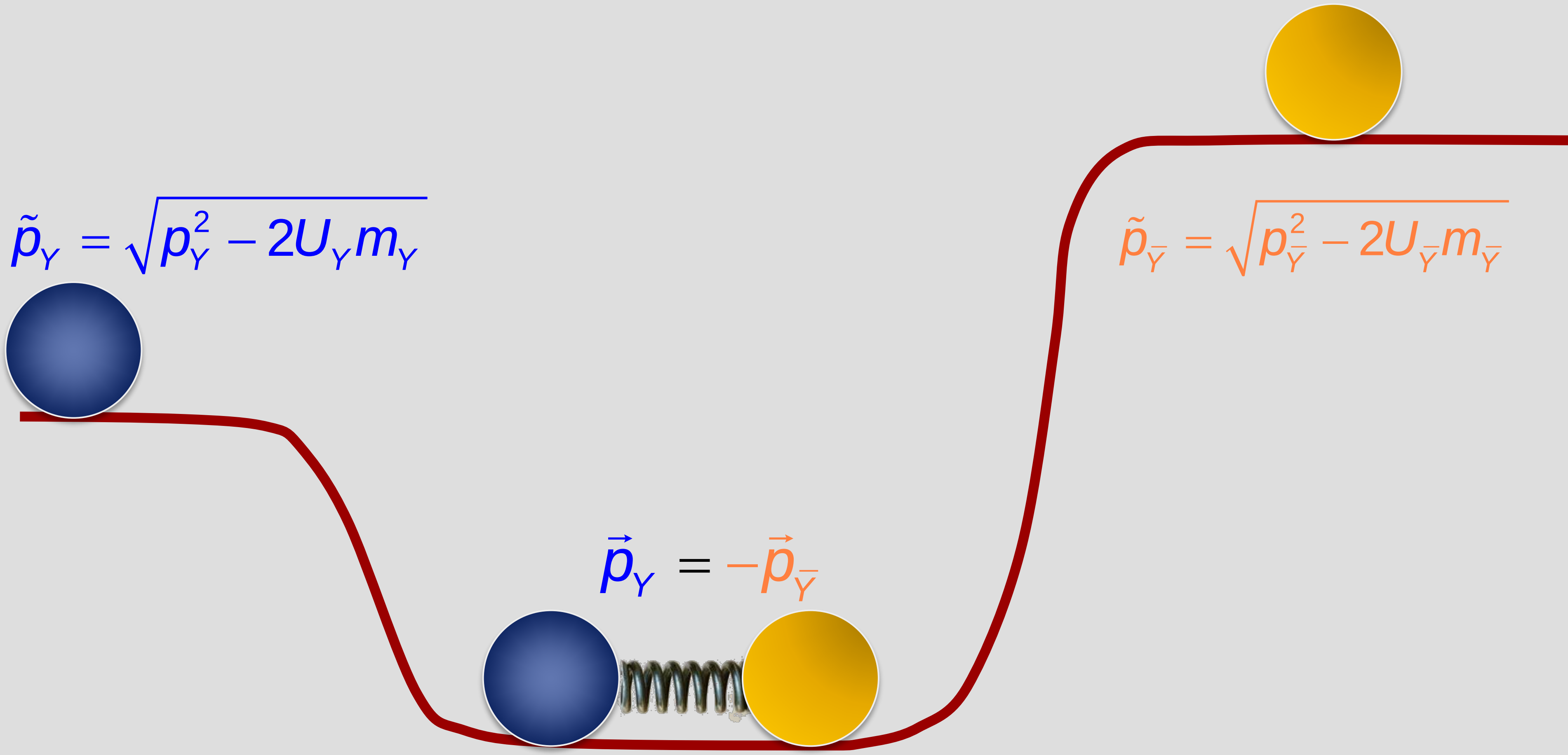
This topics are part of the "Update on the Physics Perspectives of $\bar{P}$ANDA"

Nuclei with hyperons



Nucleon	≈ -40*MeV*
Lambda	≈ -27*MeV*
Cascade	~ -15*MeV*
Antinucleon	~ -150*MeV*
Antilambda	?
Anticascade	?

How to measure a potential (difference)

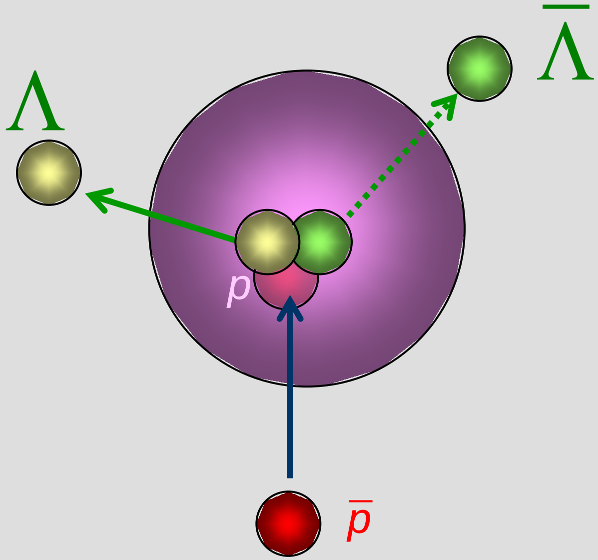


- If $m_Y \approx m_{\bar{Y}} \approx m$ and $U_Y \approx U_{\bar{Y}} \approx U \Rightarrow$

$$\alpha = \frac{\tilde{p}_Y - \tilde{p}_{\bar{Y}}}{\tilde{p}_Y + \tilde{p}_{\bar{Y}}} = \frac{\sqrt{p_0^2 - 2m_Y U_Y} - \sqrt{p_0^2 - 2m_{\bar{Y}} U_{\bar{Y}}}}{\sqrt{p_0^2 - 2m_Y U_Y} + \sqrt{p_0^2 - 2m_{\bar{Y}} U_{\bar{Y}}}} \approx \frac{U_{\bar{Y}} - U_Y}{4\left(\frac{p_0^2}{2m} - U\right)} \approx \frac{U_{\bar{Y}} - U_Y}{4E_{kin}}$$

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

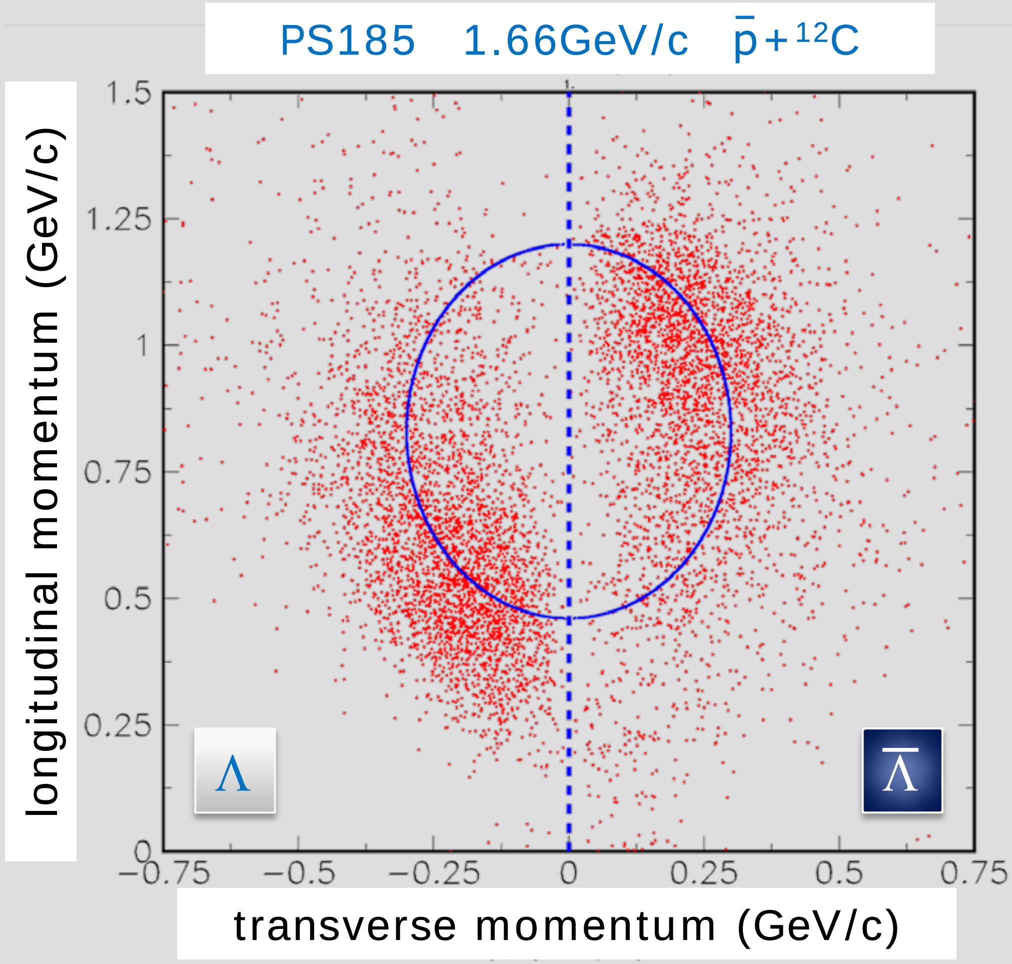
- antiprotons are optimal for the production of mass without large momenta
- consider exclusive $\bar{p}$+p(A) → Y+$\bar{Y}$ close to threshold within a nucleus
- Λ and $\bar{\Lambda}$ that leave the nucleus will have different asymptotic momenta depending on the respective potential



- experimental complications
  - Fermi motion of struck proton
  - Non-isotropic production
  - Density distribution U(ρ)
  - Exclusiveness

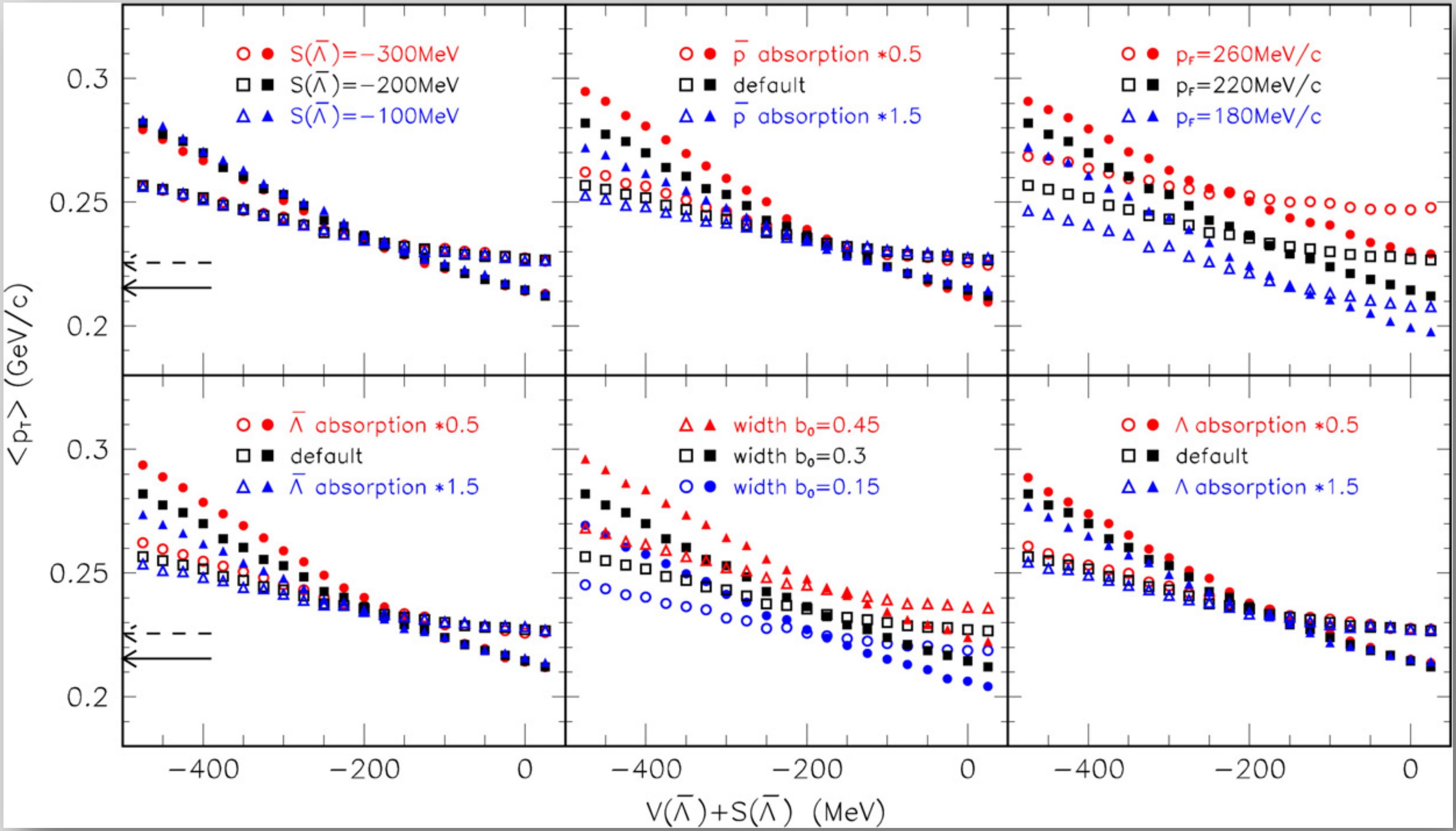
⇒ need to look at average *transverse* momentum close to threshold of *coincident* $Y\bar{Y}$ pairs

PS185: 1.66 GeV/c $\bar{p} + {}^{12}C \rightarrow \Lambda\bar{\Lambda}$



Sensitivity of p_t to model parameters

- Major sensitivity to assumed Fermi motion and angular distribution
- $\langle p_t \rangle$ of inclusive distributions is not sufficient to determine the potential parameters unambiguously



PLB 669 (2008) 306

Parameter Scan for transverse Asymmetry

- Parameter variation by ±50%
  - Other potentials (p,$\bar{p}$,Λ)
  - absorption cross sections
  - angular distribution
  - diffuseness
- Transverse asymmetry mainly determined by total potential
- Effect largest for backward emitted $\bar{\Lambda}$
- α_T non-zero even if V+S=0

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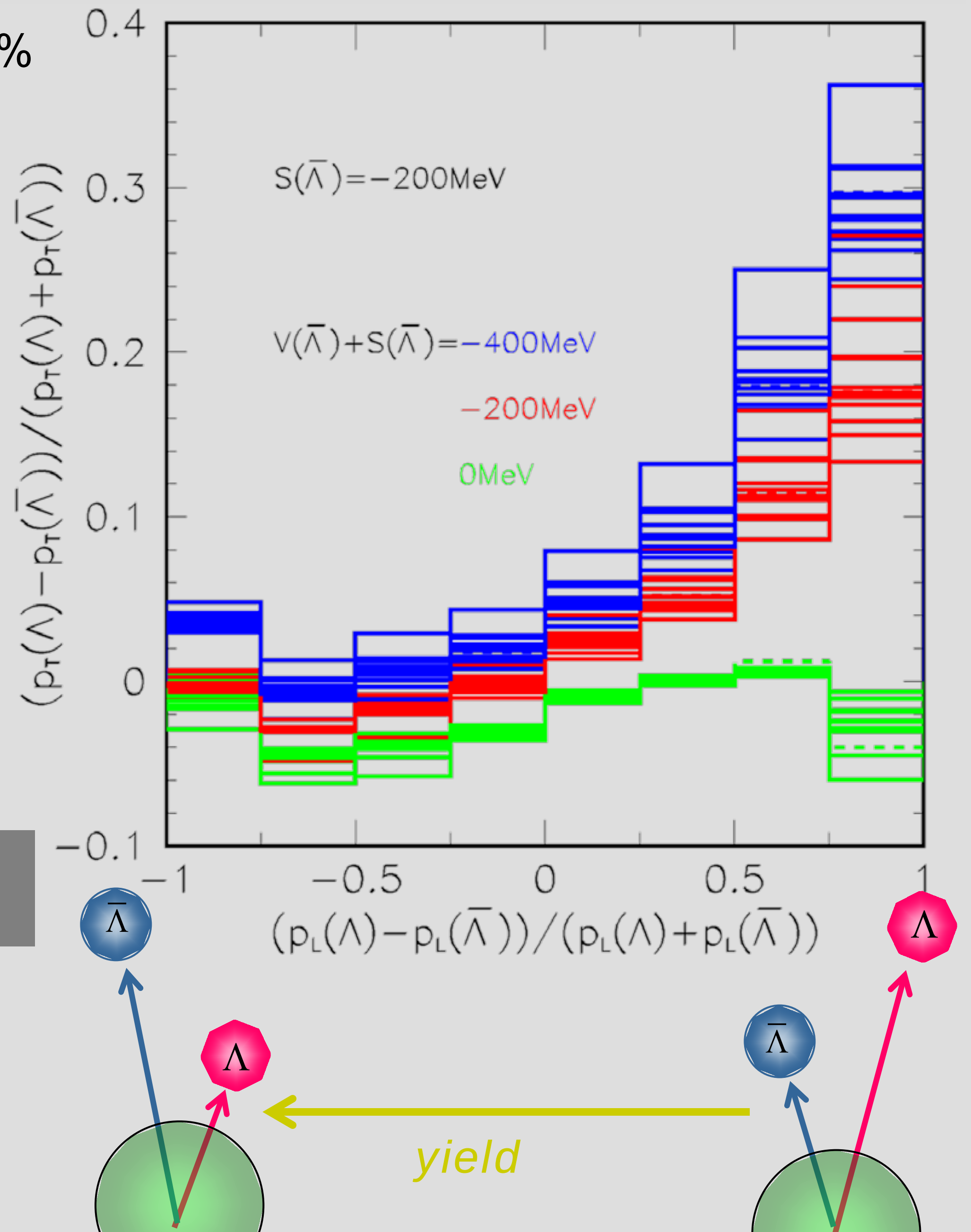
What about state-of-the-art transport calculations?

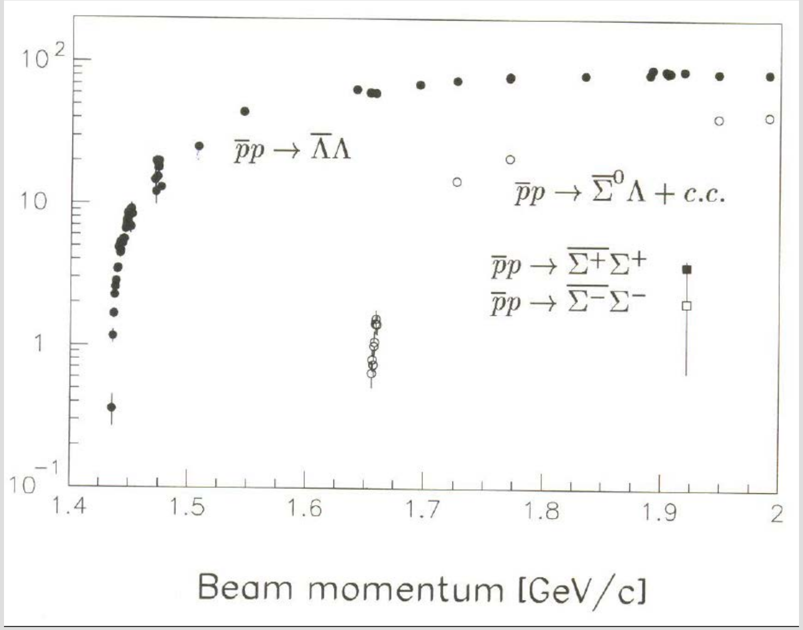


GiBUU

- https://gibuu.hepforge.org/trac/wiki

- Reactions studied $\bar{p}+{}^{20}\text{Ne} \rightarrow \Lambda\bar{\Lambda}+X$
- Threshold 1435MeV/c
- 27M inclusive events for each data set calculated at HIMster
- Approximately 10k exclusive $\Lambda\bar{\Lambda}$ pairs in each set

Energy (MeV)	Momentum (MeV/c)	Excess energy (MeV)
850	1522	30.6
900	1581	51.2
1000	1696	92.0



p_t distributions

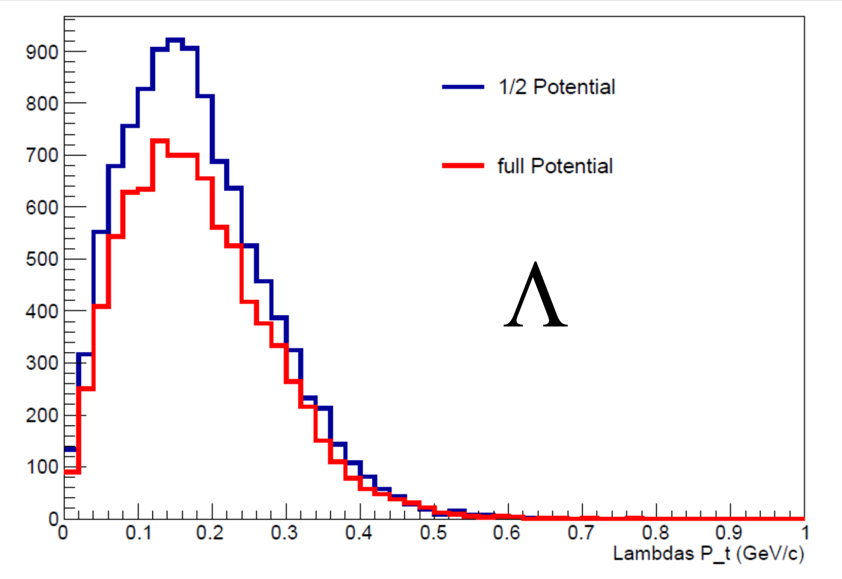
- Default parameters for RMF
  - V(N) = -46MeV
  - V(Λ) = 38MeV
  - V($\bar{N}$) = -150MeV
  - V($\bar{\Lambda}$) = -449MeV

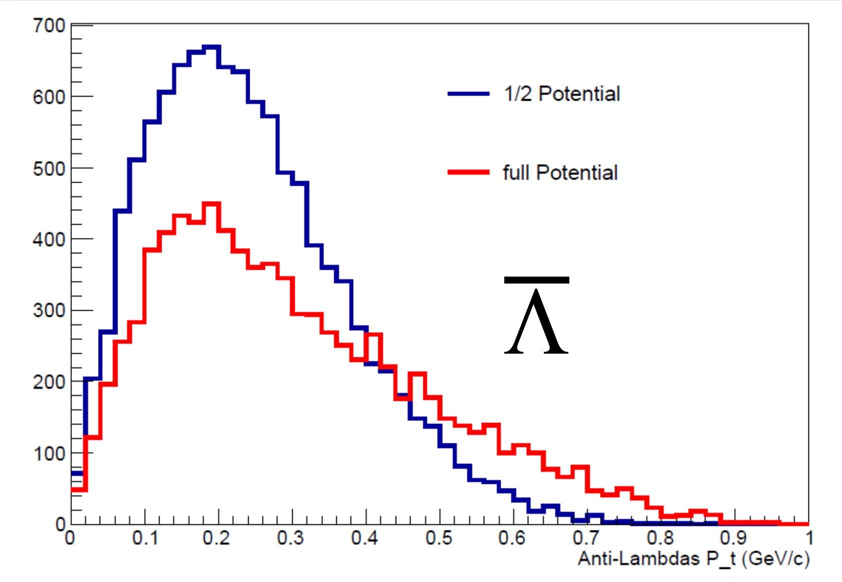
- Full potential

$$\frac{\langle p_t(\Lambda)\rangle}{\langle p_t(\bar{\Lambda})\rangle} \approx \frac{0.18}{0.30} = 0.6$$

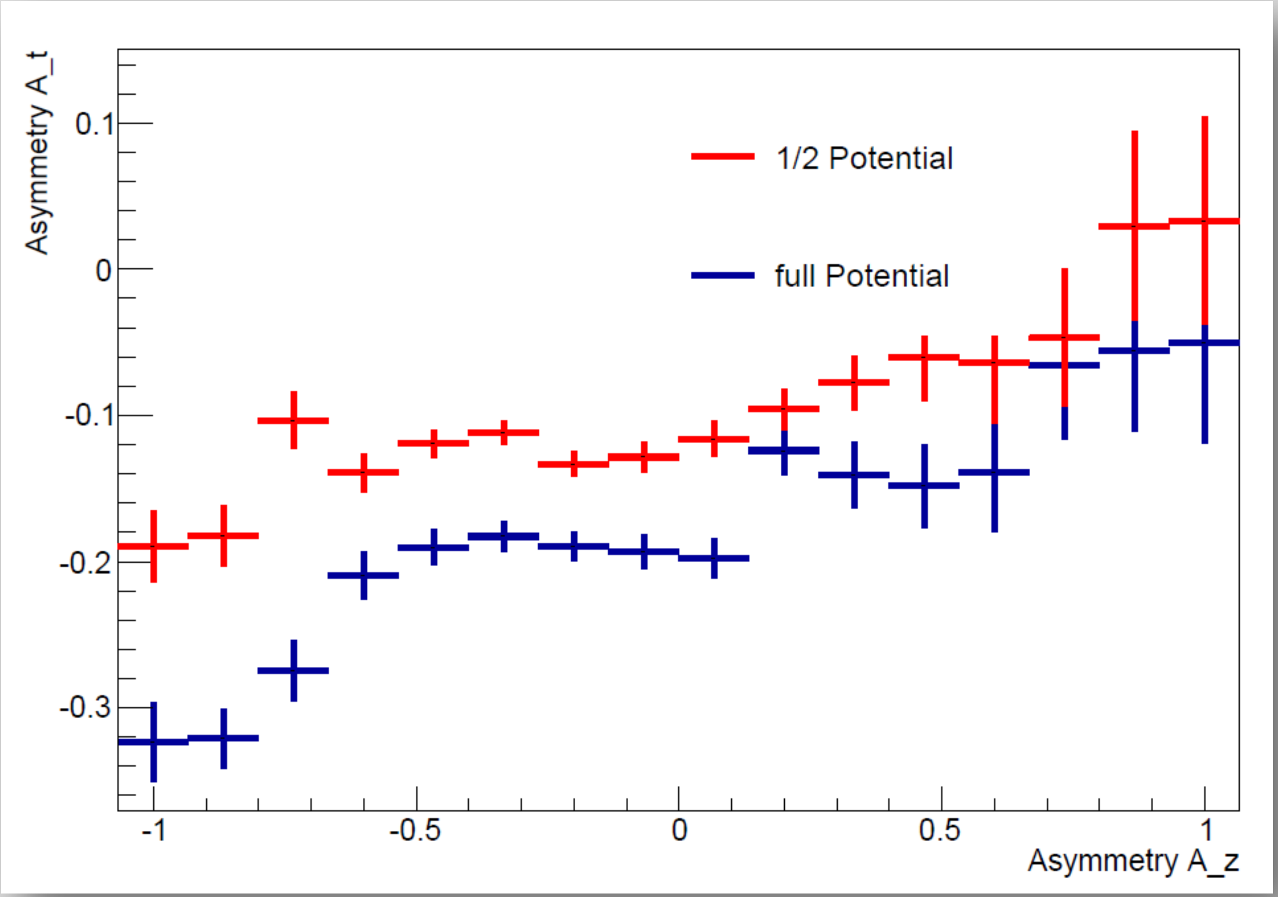
- Half $\bar{\Lambda}$ potential

$$\frac{\langle p_t(\Lambda)\rangle}{\langle p_t(\bar{\Lambda})\rangle} \approx \frac{0.18}{0.24} = 0.74$$



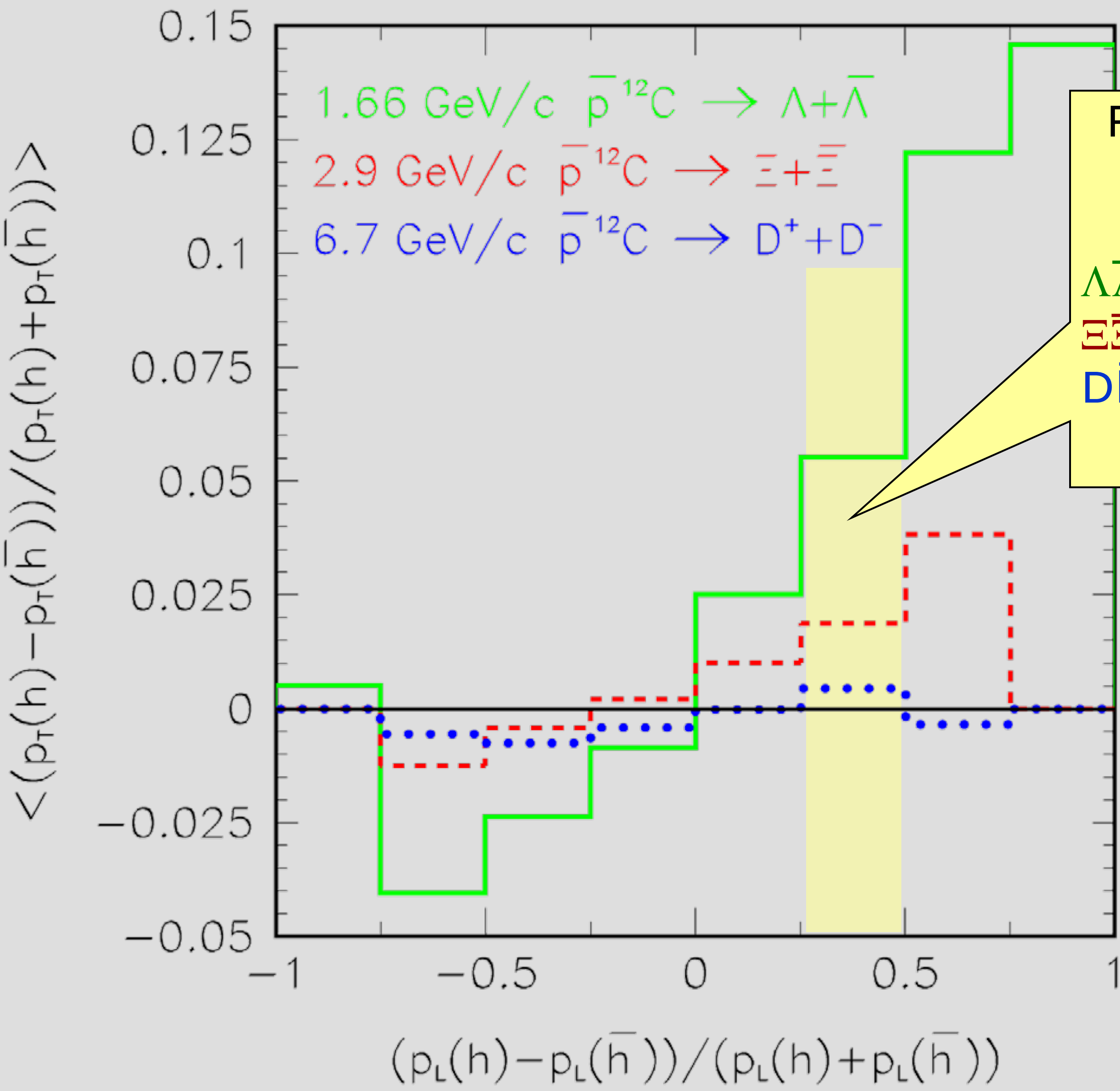


GiBUU 1.52 GeV/c $\bar{p}+{}^{20}Ne$



- What‘s next?
  - statistics
  - further parameter scan
  - energy scan
  - Other $Y\bar{Y}$ pairs ($\Xi\bar{\Xi}$,...)

Other hadron-antihadron pairs



Required running time for $\delta a/a = 10\%$:

$\Lambda\bar{\Lambda}$: few minutes
$\Xi\bar{\Xi}$: several h
$D\bar{D}$: several months

at PANDA

Stored antiproton beams offer several unique opportunities to study the interactions of hyperons and antihyperons in nuclear systems

THANK YOU

Production of hyperon-antihyperon pairs in antiproton-proton collisions provides momentum tagged (anti)hyperon beams with moderate momenta of a few hundrets of MeV/c