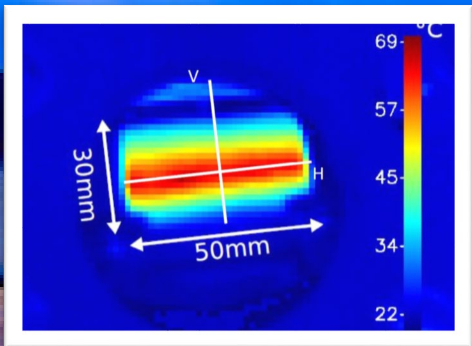
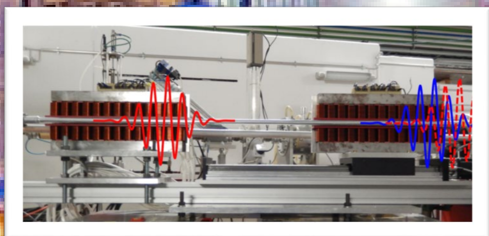
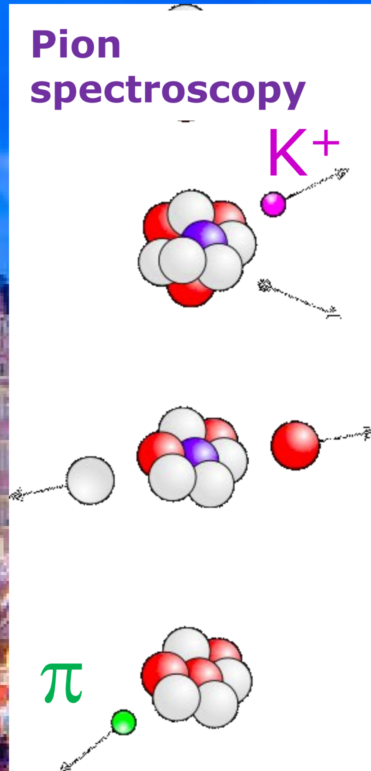
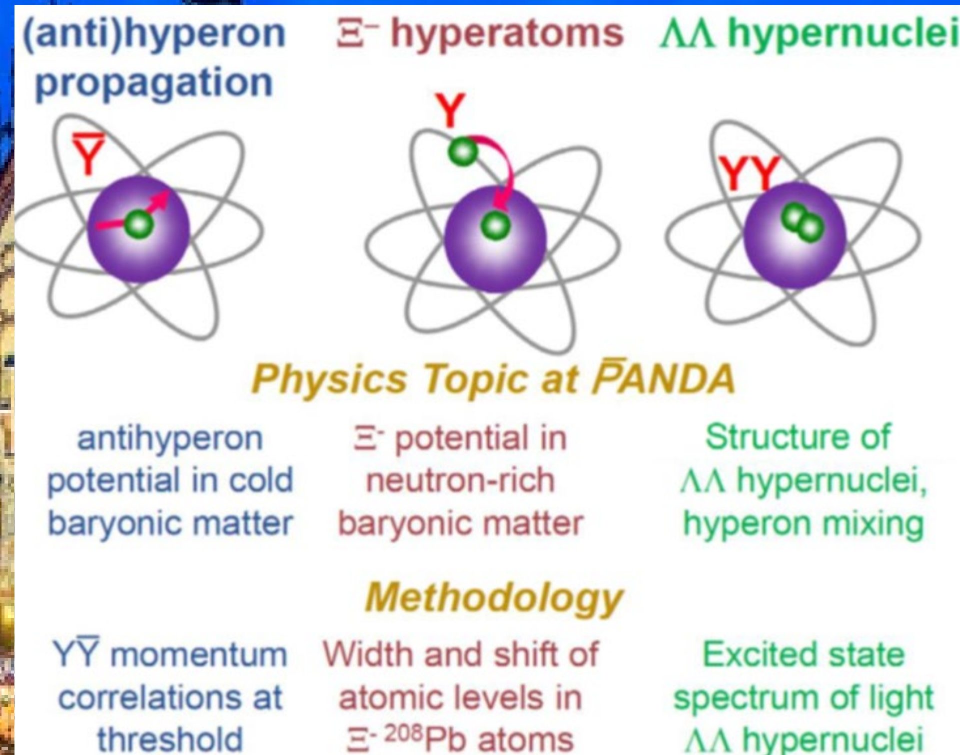
MAMI

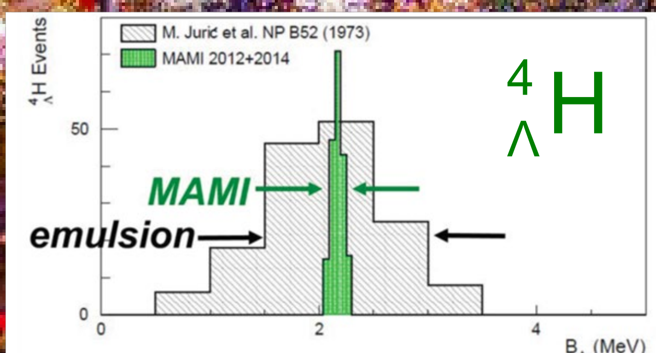
$\bar{P}$ANDA

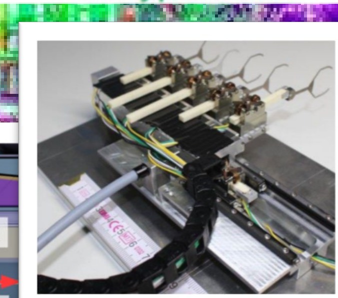


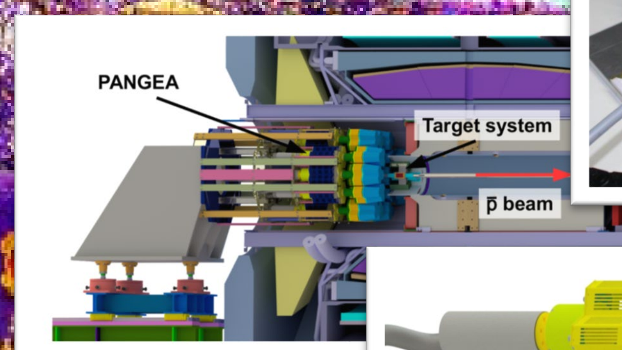












This work receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Deutsche Forschungsgemeinschaft
German Research Foundation

3rd EMMI Workshop
Anti-matter, hyper-matter and exotica production at the LHC

Antihyperons in nuclei at PANDA

- Motivation
- PANDA Phase1
- Status

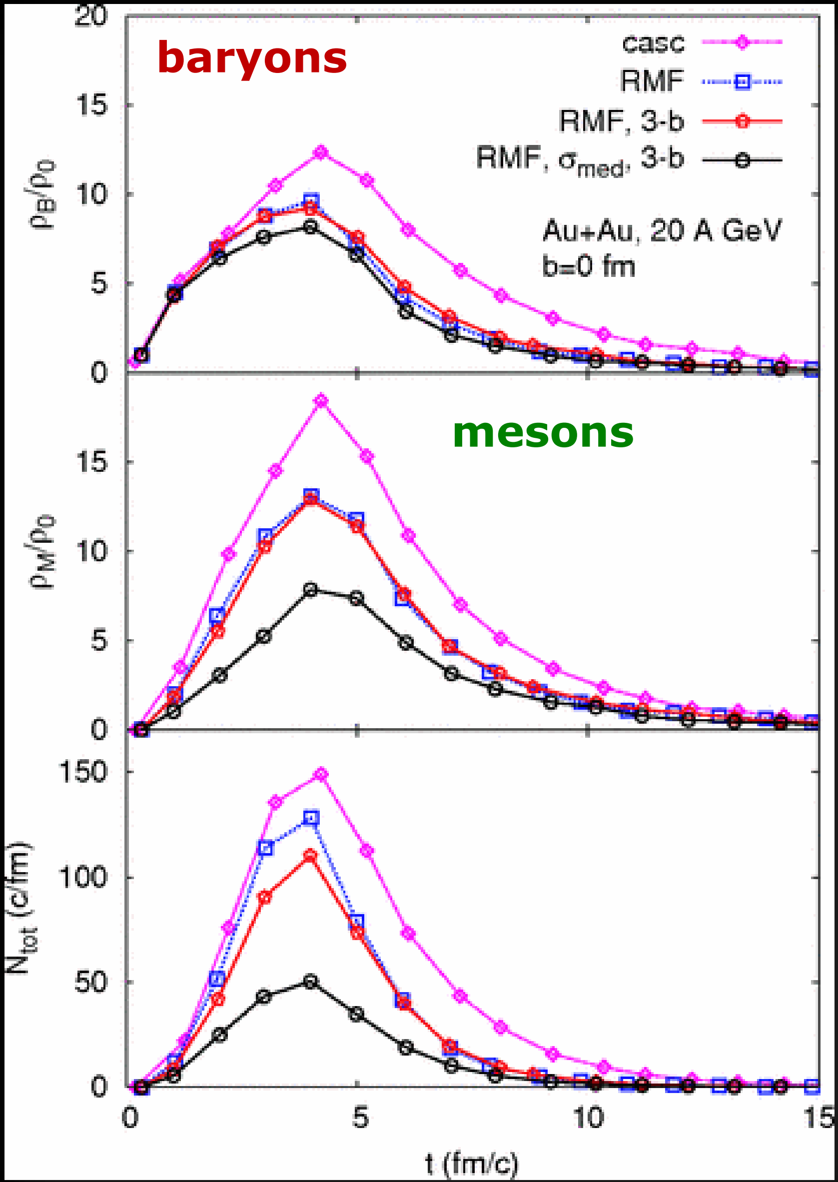
2-6 December 2019
University of Wroclaw

Josef Pochodzalla
JGU & HI Mainz
European Union

The Short Distance Challenge

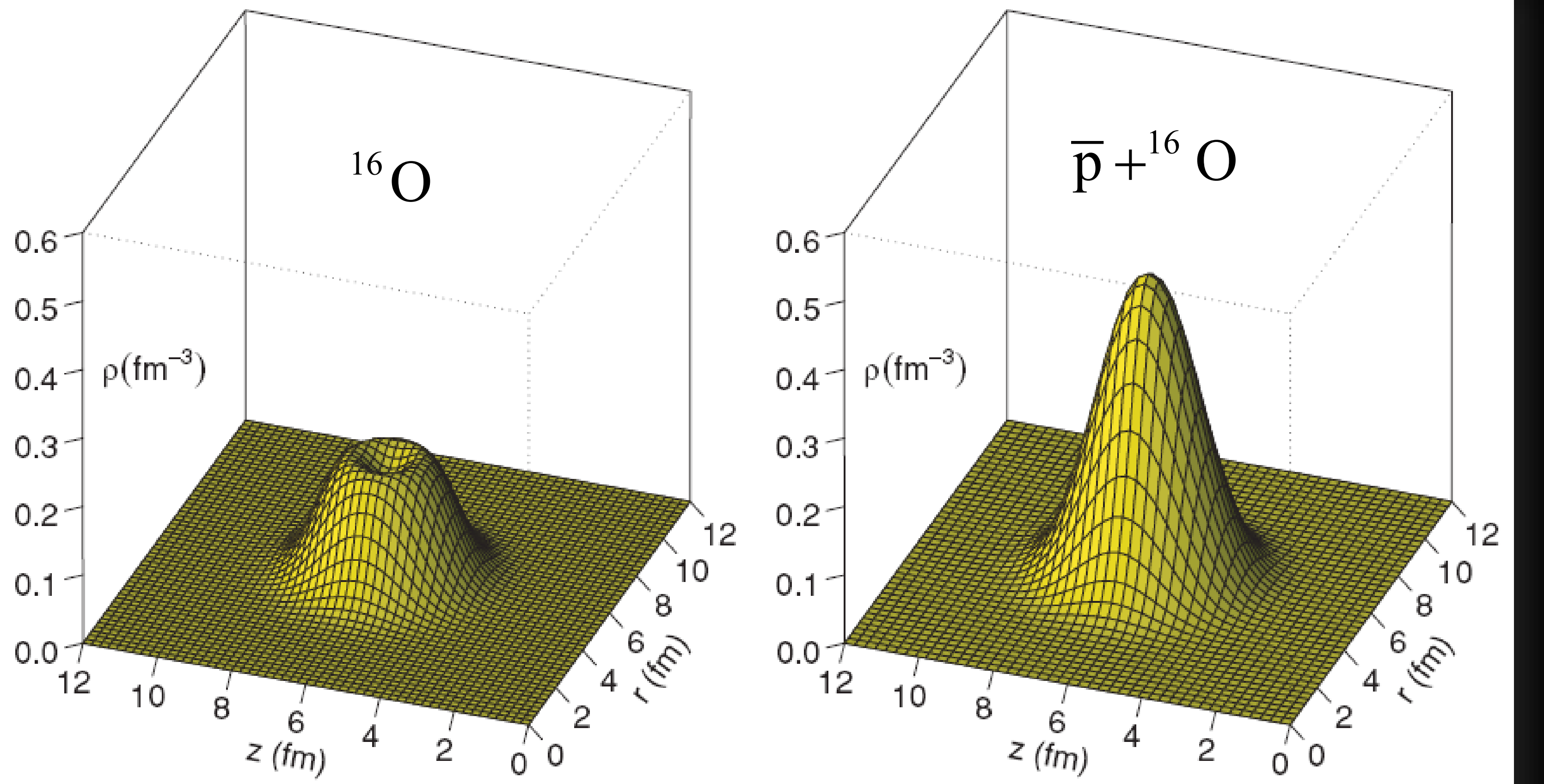
- Central heavy ion collisions are the conventional tool to probe high hadronic/partonic densities
- But…
  - Central collisions → hot hadronic finite matter with mesons and baryons
  - Neutron stars → Cold baryonic infinite matter

⇒ Let us try an complementary approach to dense baryonic matter



A.B. Larionov, O. Buss, K. Gallmeister, and U. Mosel
Phys. Rev. C 76, 044909 (2007)

Cold compression by antibaryons ?



nucleon density in the ^{16}O nucleus (left) and in the bound $\overline{p}$ + ^{16}O system (right)

I. N. Mishustin, L. M. Satarov, T. J. Bürvenich, H. Stöcker, and W. Greiner

PHYSICAL REVIEW C **71**, 035201 (2005)

$\bar{p}$ Scattering (in nuclear emulsion)

Elastic Scattering of Antiprotons from Complex Nuclei*

GERSON GOLDHABER† AND JACK SANDWEISS‡

Physics Department and Radiation Laboratory, University of California, Berkeley, California

(Received May 5, 1958)

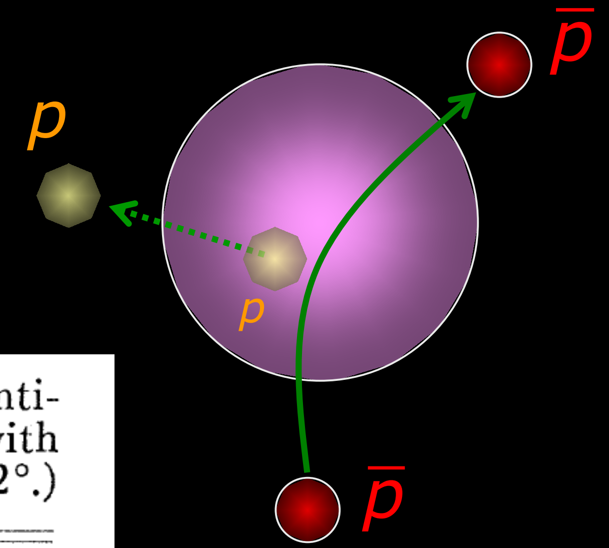
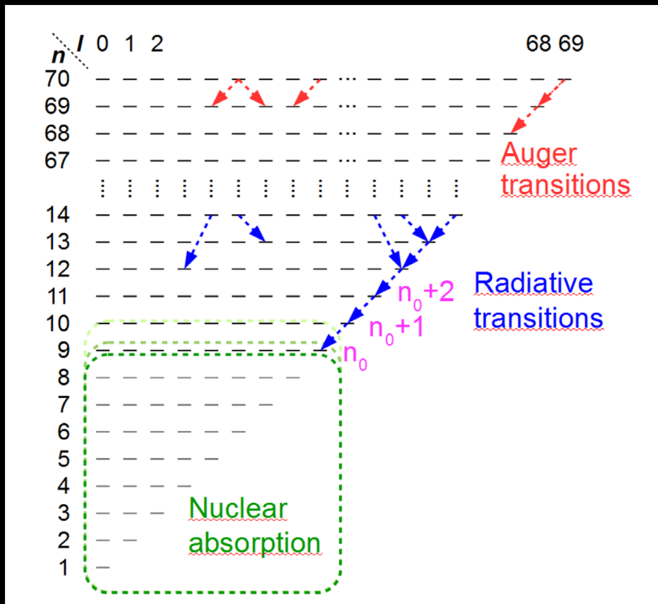


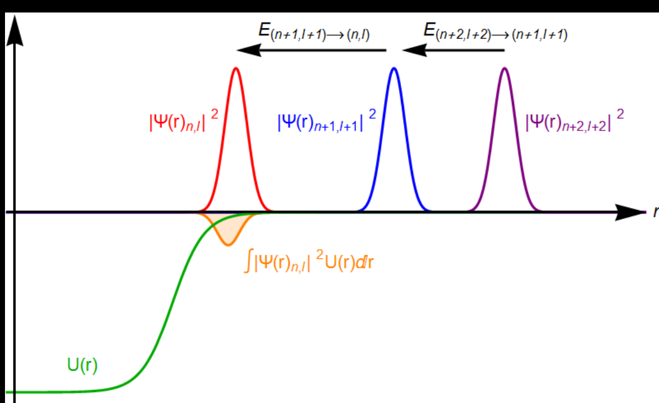
TABLE III. Comparison of experimental data for elastic antiproton-nucleus scattering of energy $T_{\bar{p}}=80$ to 200 Mev with Glassgold's calculations at $T_{\bar{p}}=140$ Mev. (Projected angle $\geqslant 2°$.)

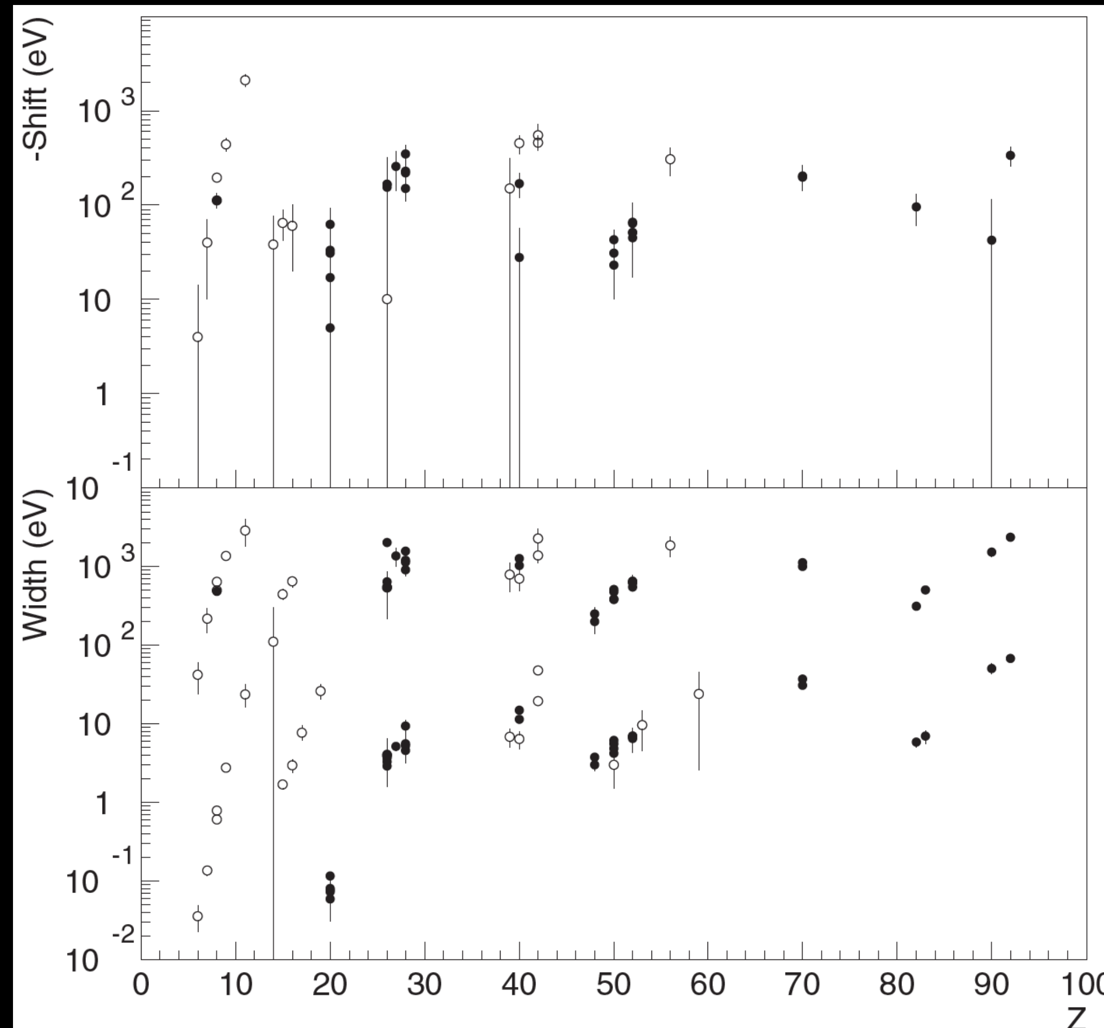
Angular interval (degrees)	Experimental ($T_{\bar{p}}=80$ to 200 Mev)	Number of events: Calculated for potential[a] $V=-15$ Mev $W=-50$ Mev	Calculated for potential[a] $V=-528$ Mev $W=-50$ Mev
2–6	54	56	71
6–12	20	17.1	24
12–24	5	4.3	10
24–180	1	1.4	9.5
2–180	80	78.8	114.5

…but scattering experiment with antihyperons very difficult.

Antiprotonic atoms







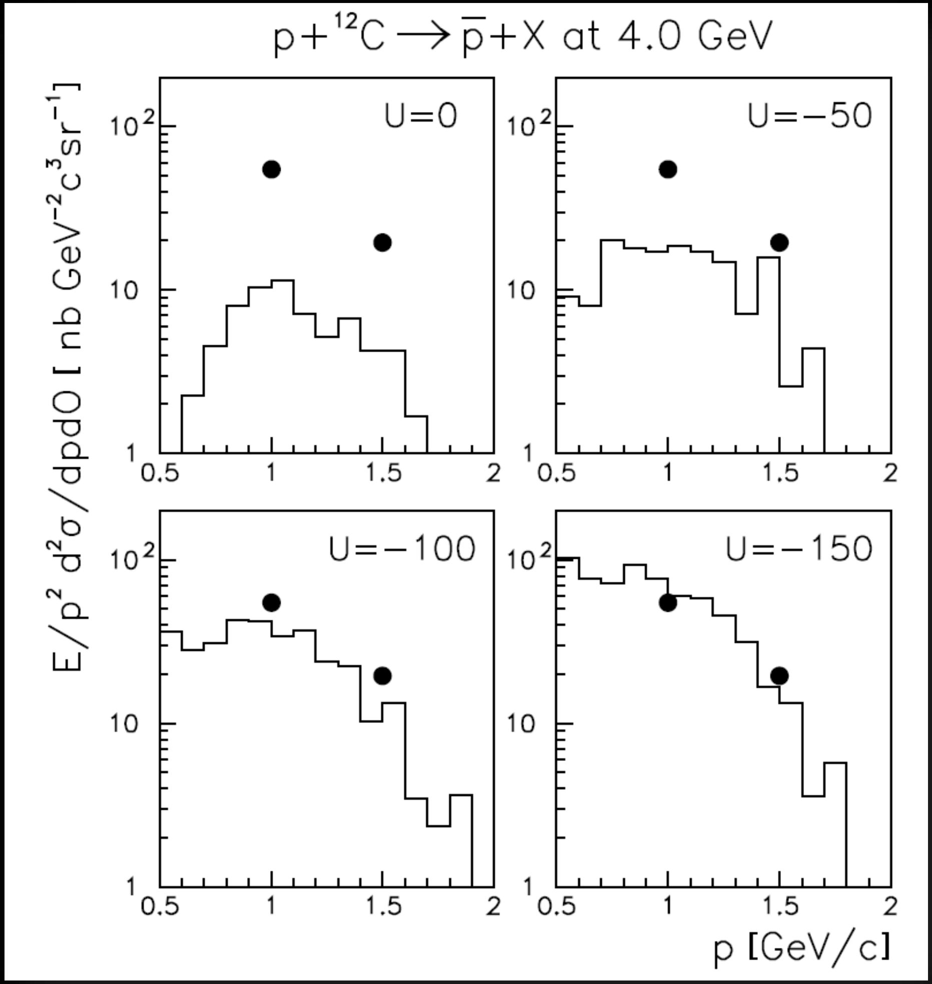
...Friedmann, Gal,...

Need a negative particle

...slow $\bar{\Sigma}^-$ difficult to produce; $\bar{p}p \rightarrow \Sigma^+ \bar{\Sigma}^-$?

Antiproton production in HI Collisions

..close to threshold



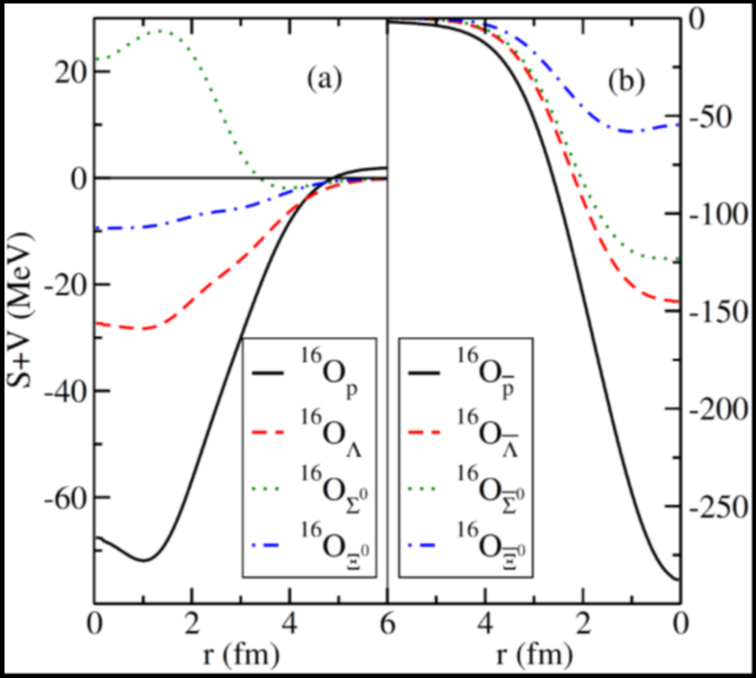
Nucleon	≈ –40*MeV*
Lambda	≈ –27*MeV*
Antinucleon	~ –150*MeV*
Antilambda	?
…	

A. Sibirtsev, W. Cassing *et al.*, Nucl. Phys. A **632**, 131 (1998)
C. Spieles *et al.*, Phys. Rev. C **53**, 2011-2013 (1996)

Antihyperons in Nuclei

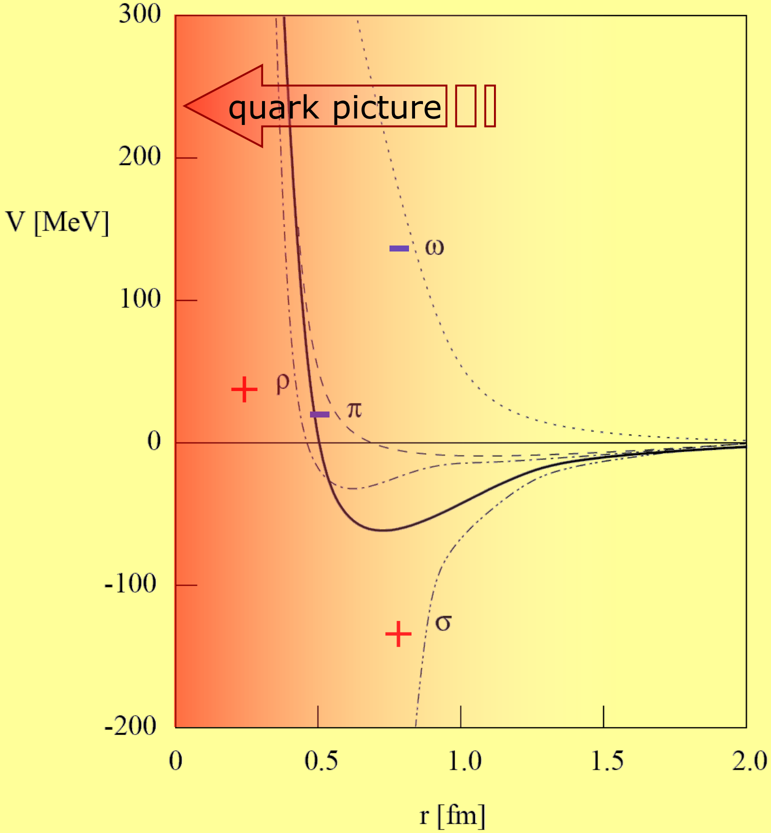
- How is g-parity broken? $U(\bar{p})$=-150MeV

$$G|\pi^{\pm 0}\rangle = (-1)^1 C|\pi^{\pm 0}\rangle = -|\pi^{\pm 0}\rangle$$
$$G|\rho\rangle = (-1)^1 C|\rho\rangle = +|\rho\rangle$$
$$G|\omega\rangle = (-1)^0 C|\omega\rangle = -|\omega\rangle$$
$$G|\sigma\rangle = (-1)^0 C|\sigma\rangle = +|\sigma\rangle$$



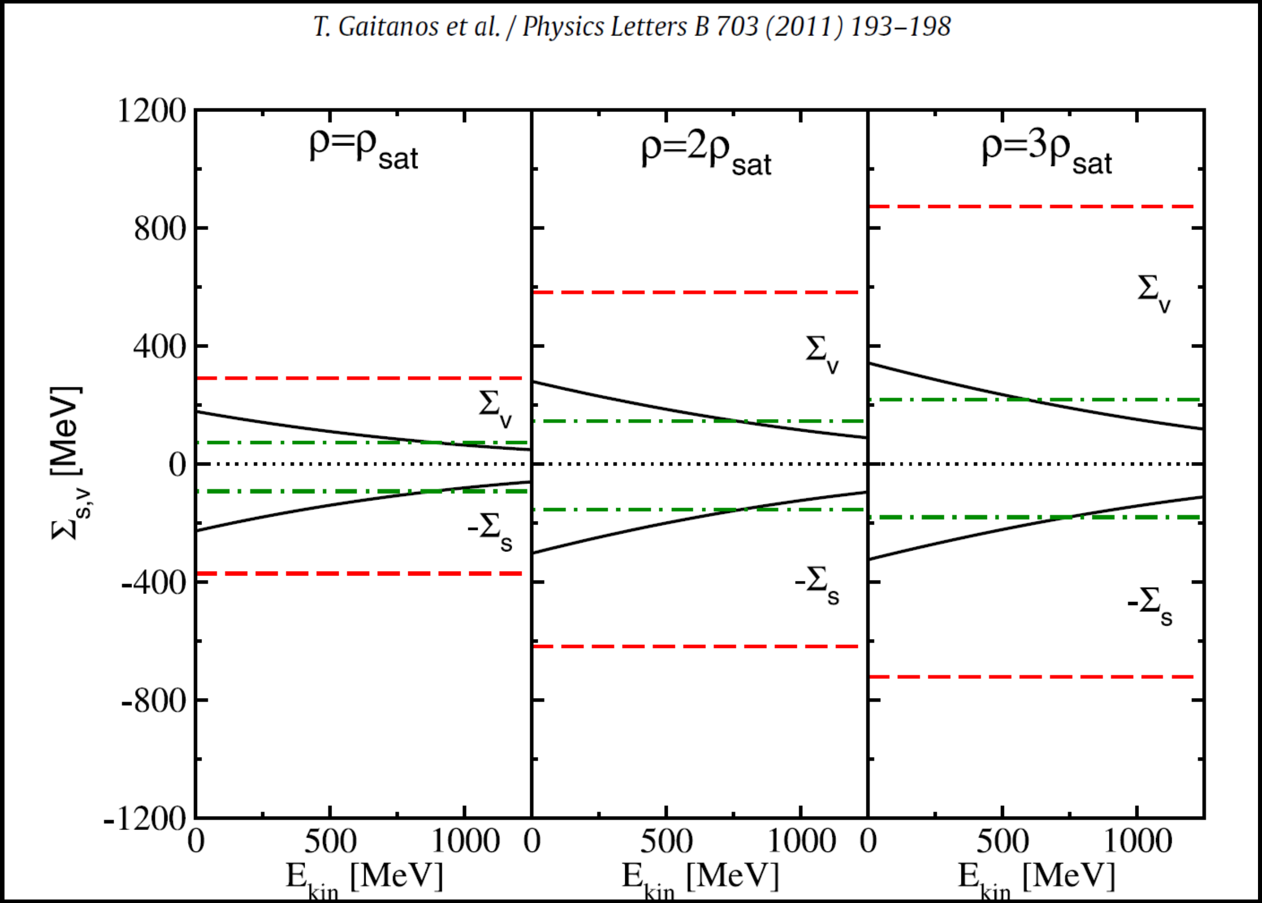
Jaroslava Hrtankova et al.

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



Beyond RMF

- Issue resolved in the framework of the nonlinear derivative model which describes consistently bulk properties of nuclear matter and Dirac phenomenology of nucleon–nucleus interactions.
- Key point: energy dependence of p-nucleus potential



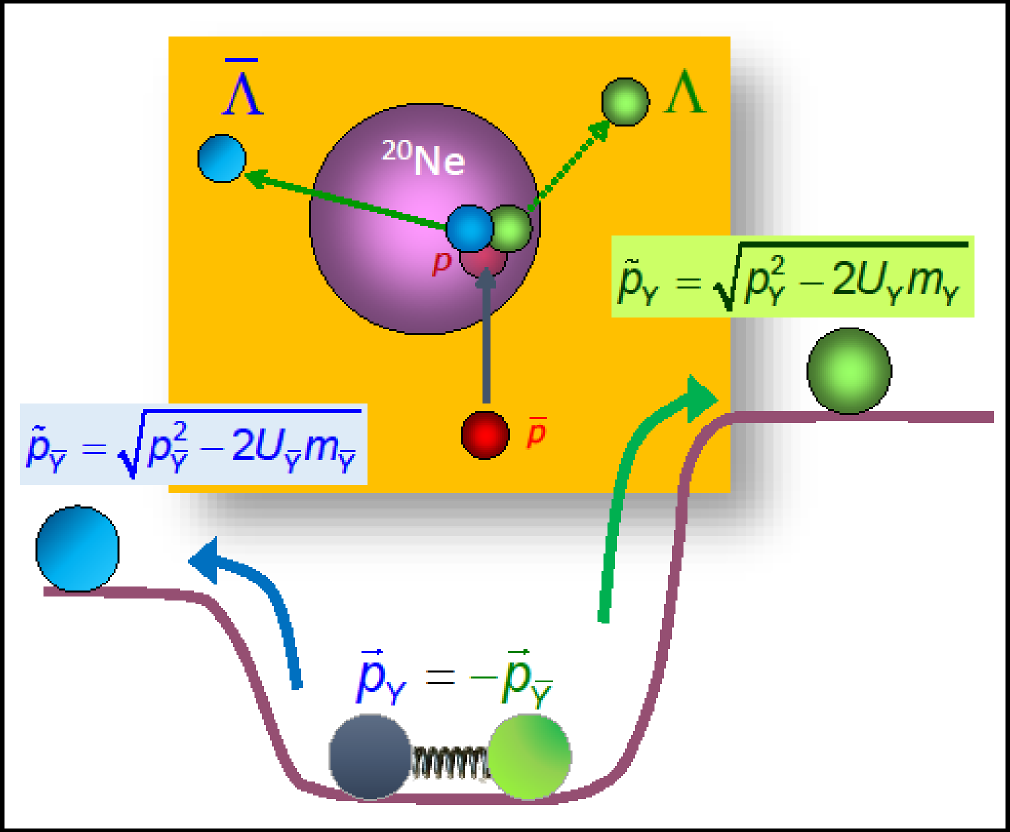
Antihyperons in Nuclei ?

Curiosity
- Antiprotons in (cold) nuclei reasonably well known
  BUT: Nothing is known about antihyperons in nuclei
- (Only) PANDA can do it
- Simple experiment

Antibaryon production important probe for RHIC
- Transport models important tool
- Antibaryons are usually treated superficially

Probe of short-range multi-body interaction
- Complements baryon-antibaryon FSI studies
- Baryonic environment (no pions)
- Possibly neutron rich

$\bar{\Lambda}$ Potential in Nuclei



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

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

Physics Letters B 669 (2008) 306–310

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Exploring the potential of antihyperons in nuclei with antiprotons

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Johannes Gutenberg-Universität Mainz, Institut für Kernphysik, D-55099 Mainz, Germany

Physics Letters B 749 (2015) 421–424

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Antihyperon potentials in nuclei via exclusive antiproton–nucleus reactions

CrossMark

Alicia Sanchez Lorente[a], Sebastian Bleser[a], Marcell Steinen[a], Josef Pochodzalla[a,b,*]

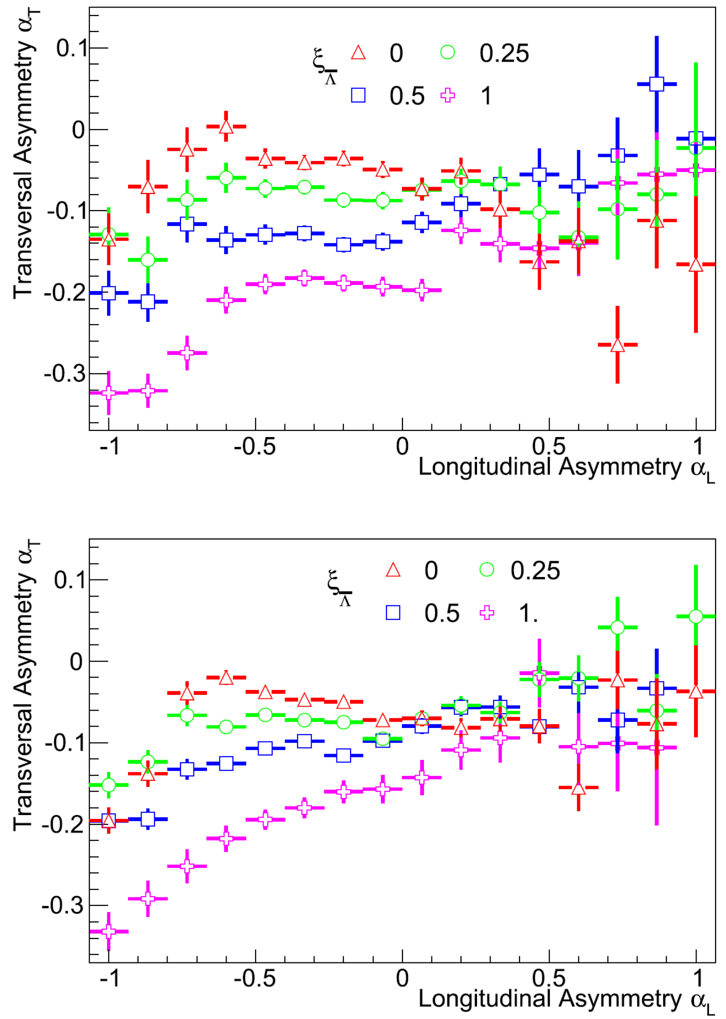
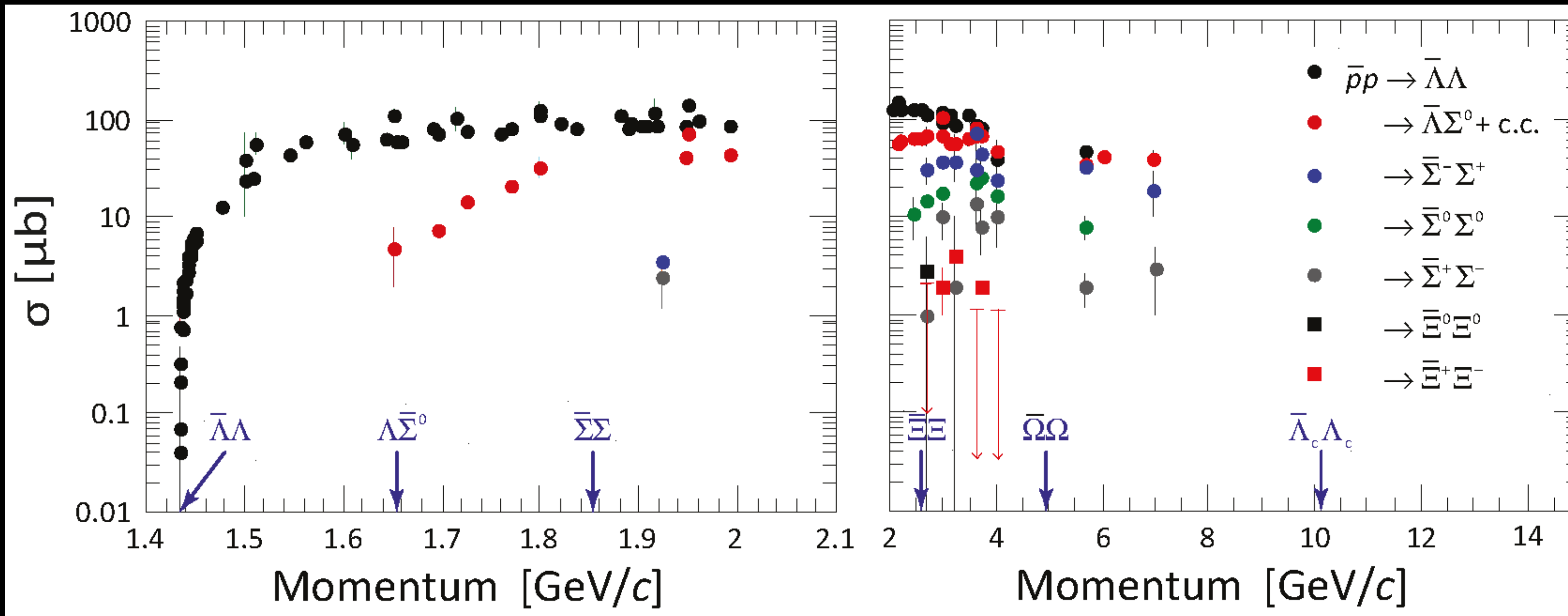


Fig. 4. Average transverse momentum asymmetry as a function of the longitudinal momentum asymmetry for $\Lambda\bar{\Lambda}$-pairs produced exclusively in 0.85 GeV (top) and 1 GeV (bottom) $\bar{p}^{20}$Ne interactions. The different symbols show the GiBUU predictions for different scaling factor $\xi_{\bar{\Lambda}}$ of the $\bar{\Lambda}$-potentials.

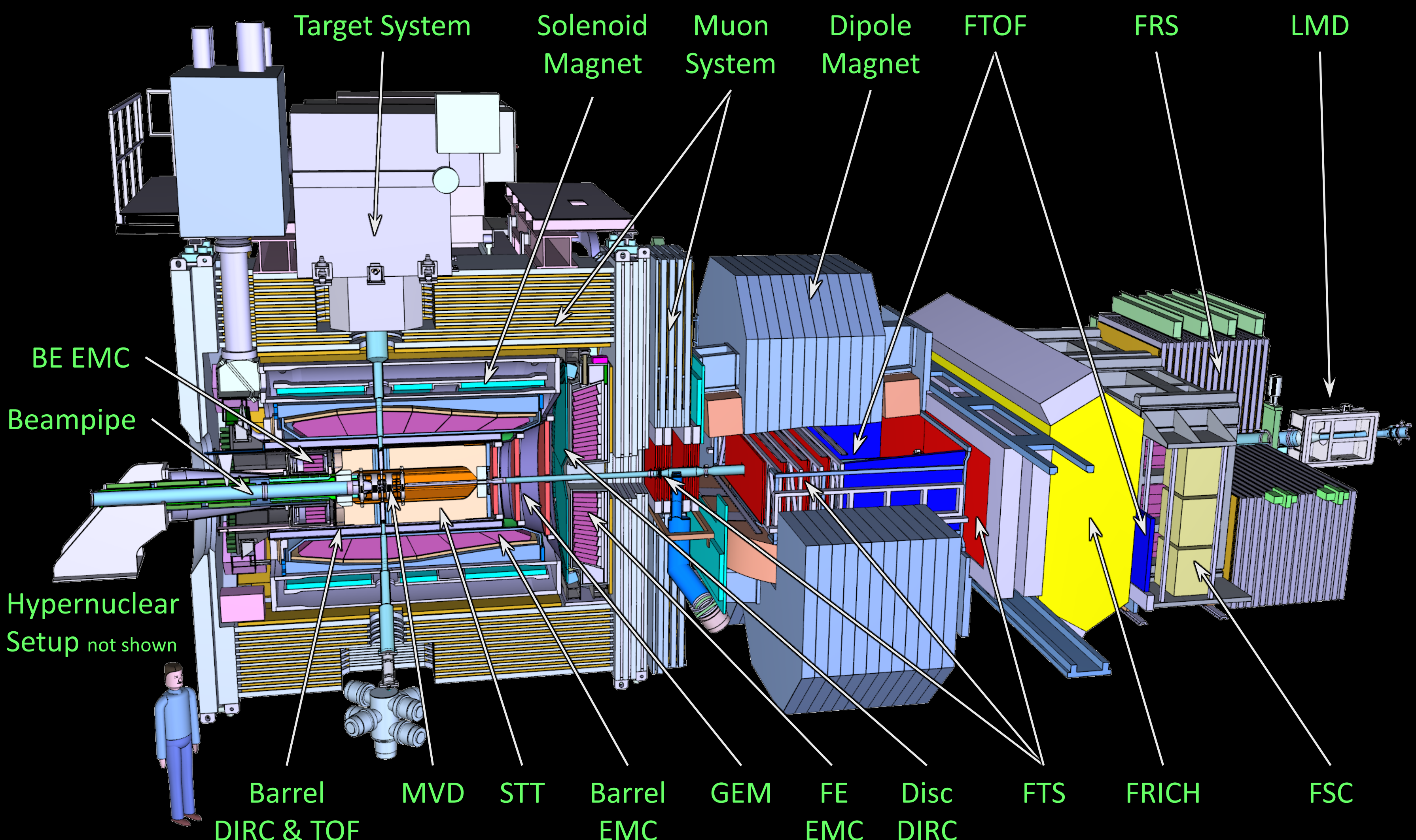
Factory for strange *and* charmed $Y\bar{Y}$-Pairs



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}
$\Xi\bar{\Xi}$ ($\to_{\Lambda\Lambda}$ A)	2μb	10^8 (10^5)
$D\bar{D}$	250nb	10^7
J/ψ ($\to e^+e^-, \mu^+\mu^-$)	630nb	10^9
χ_2 ($\to J/\psi + \gamma$)	3.7nb	10^7
$\Lambda_c\bar{\Lambda}_c$	20nb	10^7
$\Omega_c\bar{\Omega}_c$	0.1nb	10^5

PANDA Detector



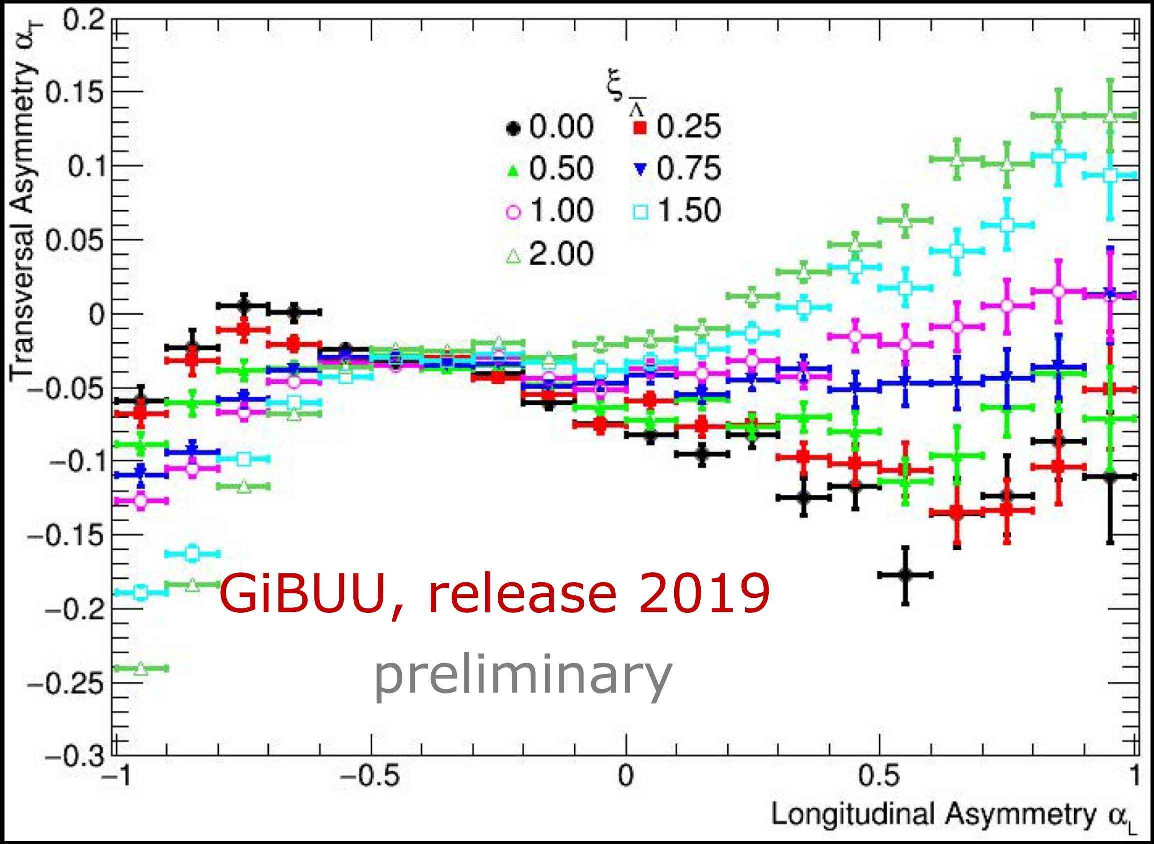
Work in Progress

- “High statistics” event samples generated with GiBUU
- Integration in PANDA reconstruction software started
- PANDA Phase One paper under internal review by collaboration

$\bar{\Lambda}$ in Nuclei

- 1.54GeV/c $\bar{p}+{}^{20}Ne$
- $135 \cdot 10^6$ events each ~ 10 PANDA minutes ($\Lambda\bar{\Lambda}$ enhanced by 10)

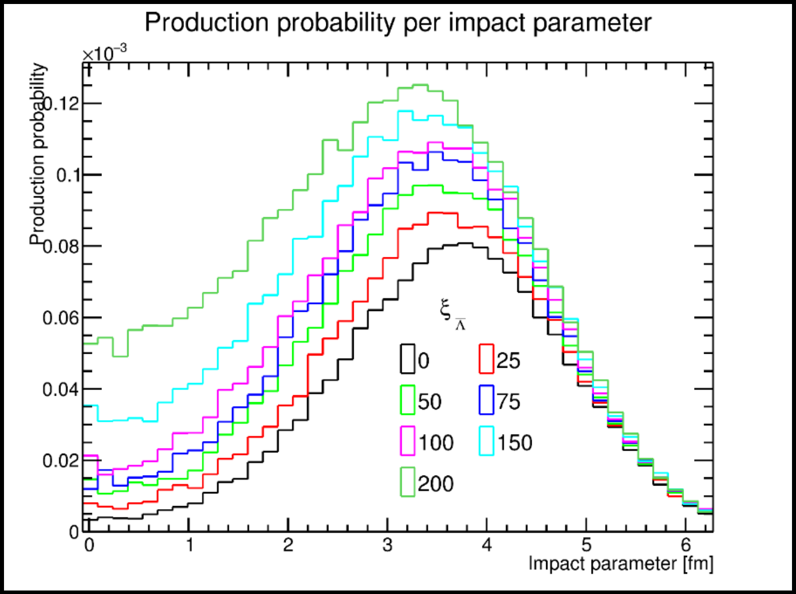
$$\alpha_\perp = \left\langle \frac{p_\perp(\Lambda) - p_\perp(\bar{\Lambda})}{p_\perp(\Lambda) + p_\perp(\bar{\Lambda})} \right\rangle$$



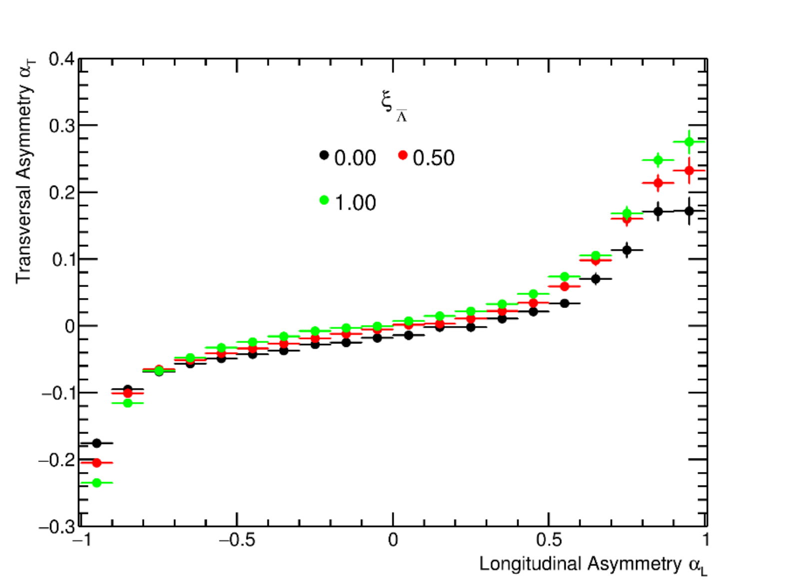
- Need to understand difference between GiBUU 1.5 and 2019
- Use other transport models (xQMD,…)
- Anyway - large production yield at PANDA ⇒ DAY-ONE experiment

Annihilation in periphery

- Annihilation in periphery



- $\Lambda\bar{\Lambda} : \Sigma^0\bar{\Lambda} : \Lambda\bar{\Sigma} \sim 4 : 1 : 2$



- At higher momenta (e.g. 2.9GeV/c) smaller sensitivity

Status

- PANDA-day1 is not the complete detector
  - Running strategy: comparison to $\bar{p}p \rightarrow \Lambda\Lambda$
- Reconstruction in PANDA has just started (*plots to be released*)
  - Full coverage of α_T-α_L plane
  - First qualitative results indicate efficiencies for $\bar{\Lambda}\Lambda$ ~10^{-2}
- If verified in coming months previous statistics corresponds to ~1 day running
  - Ideal experiment for start-up phase

PANDA Phase One

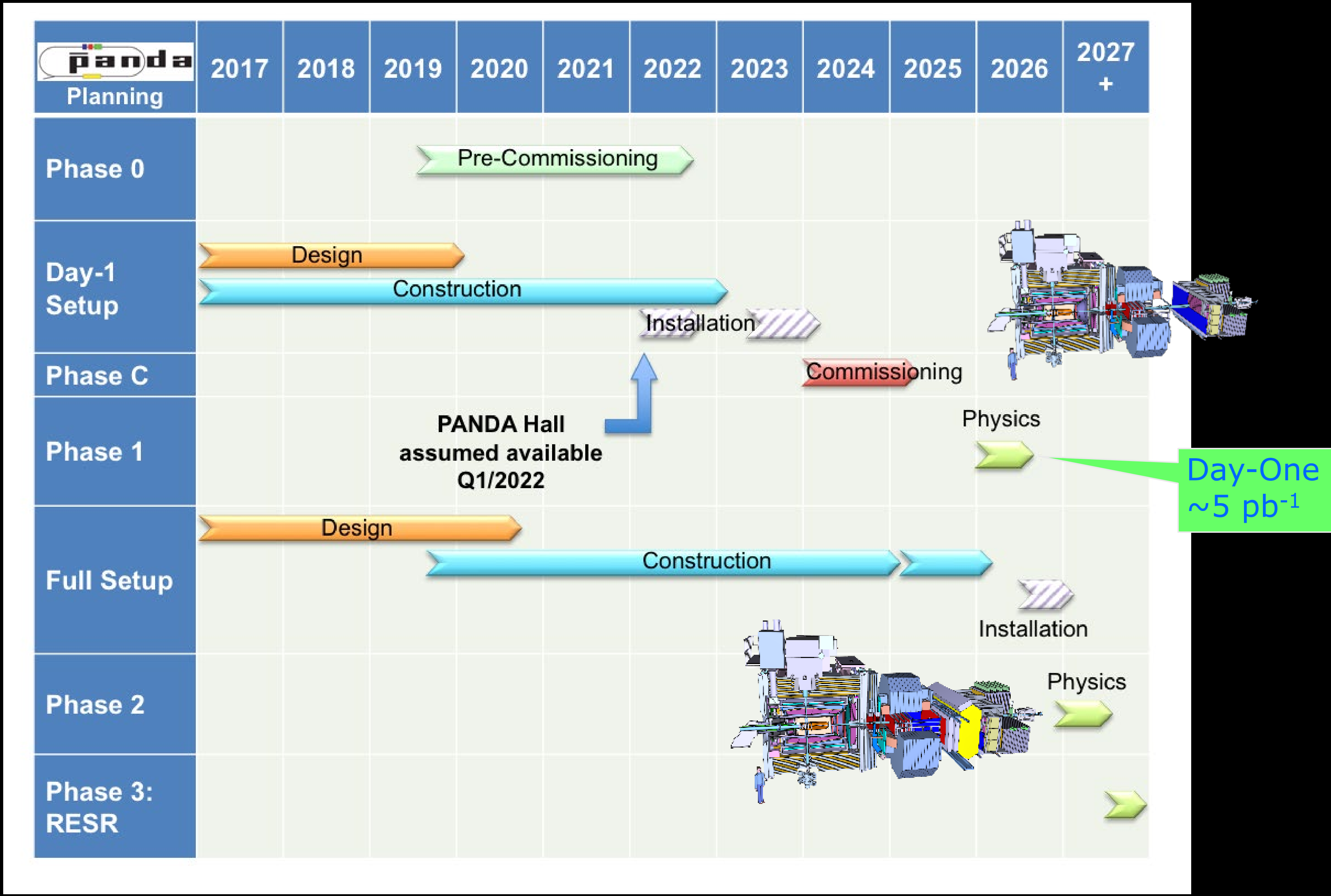
The PANDA collaboration

July 23, 2019

Abstract

The Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, provides unique possibilities for a new generation of hadron-, nuclear- and atomic physics experiments. The future PANDA experiment at FAIR will offer a broad physics programme with emphasis on different aspects of hadron physics. Understanding the strong interaction in the perturbative regime remains one of the greatest challenges in contemporary physics and for this, hadrons provide several important keys. Furthermore, the high-intensity, low-energy domain of PANDA will be suitable for Standard Model tests on the high-precision frontier. However, financial and technical constraints enforce a staged approach to the detector setup and the luminosity. In this document, we will present the setup available at the time of the first antiproton beam from the HESR, *i.e.* the *Phase One* setup and outline the physics programme.

PANDA planing

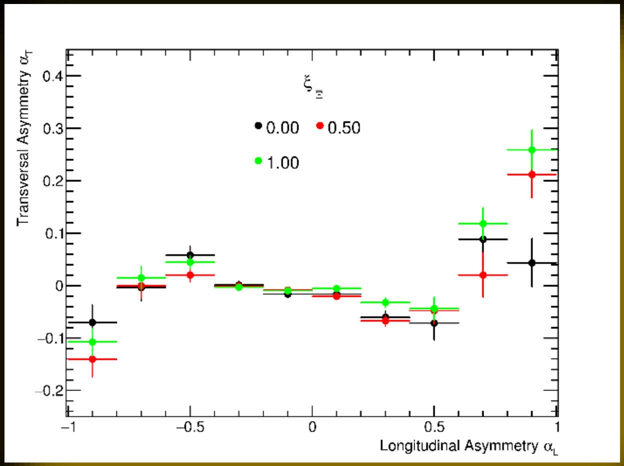


Take-home message

- Antihyperon-hyperon pair production in nuclei in p̄A collisions are a novel instrument to study the behaviour of antihyperons in nuclei

- The high production rate at PANDA makes this measurement an ideal topic for day-one of PANDA

- Extension to other $\bar{Y}Y$ pairs possible: $\bar{\Sigma}\Lambda$,..,$\bar{\Xi}\Xi$




Thank you
for your attention