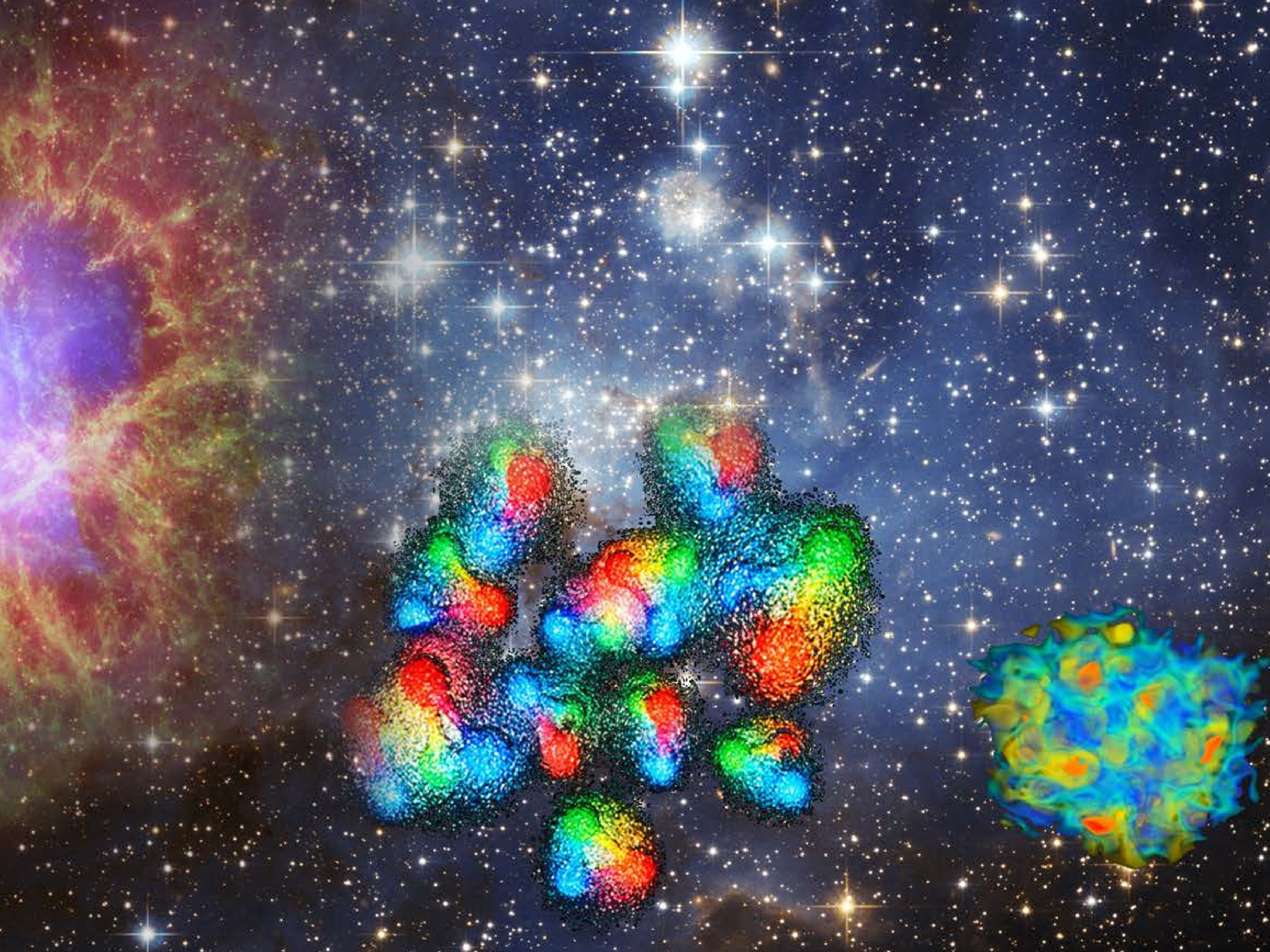


2nd international Symposium on Science at J-PARC July 2014

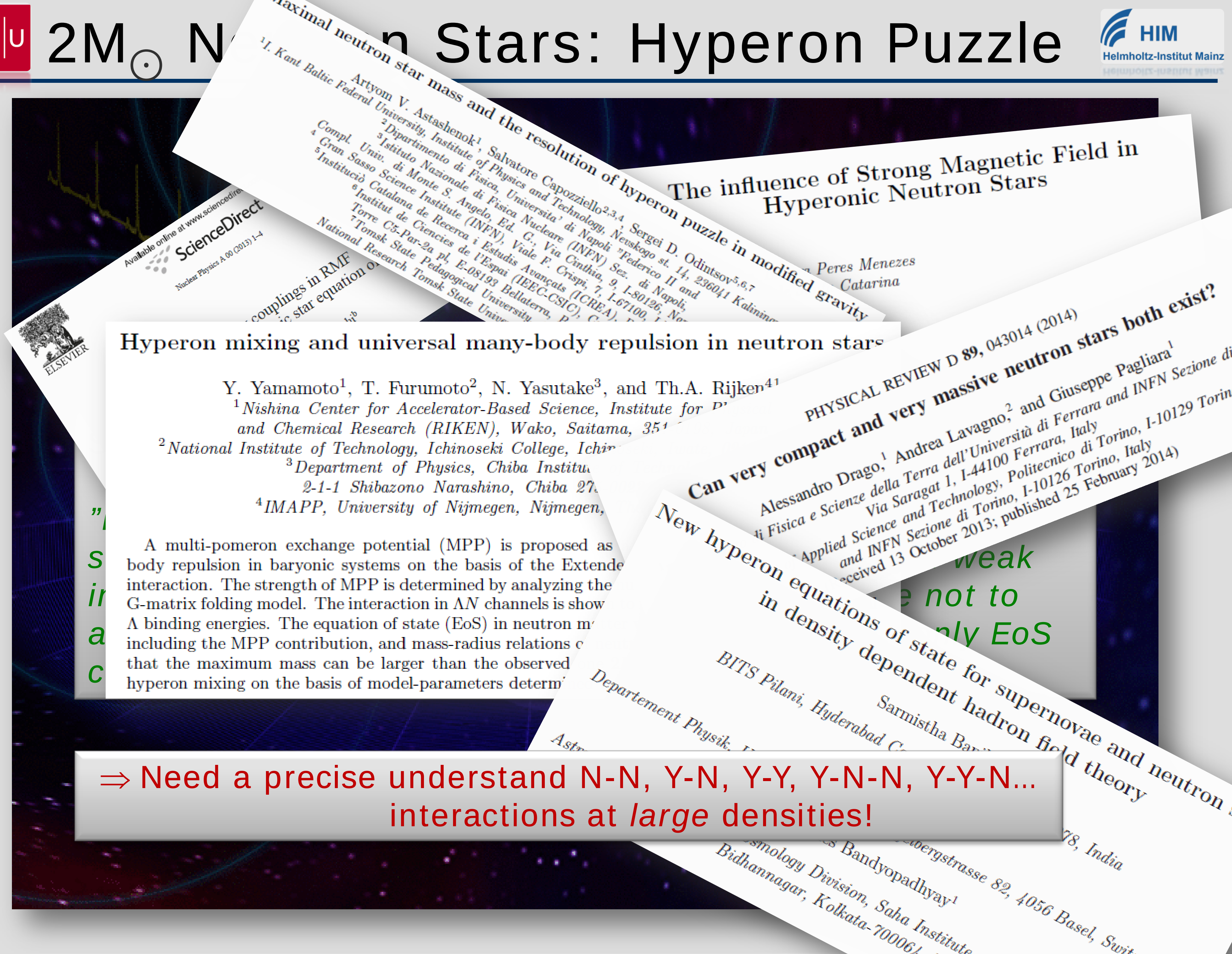
Strange baryons and antibaryons in nuclei: unique opportunities for $\bar{\text{P}}$ANDA@FAIR

Josef Pochodzalla & Alicia Sanchez Lorente

on behalf of the $\bar{\text{P}}$ANDA Collaboration

- **Motivation**
- **The $\bar{\text{P}}$ANDA experiment**
- **Antihyperons in nuclei at $\bar{\text{P}}$ANDA**
- **Status of the Simulations**
- **Future options**

2M$_\odot$ N… n Stars: Hyperon Puzzle



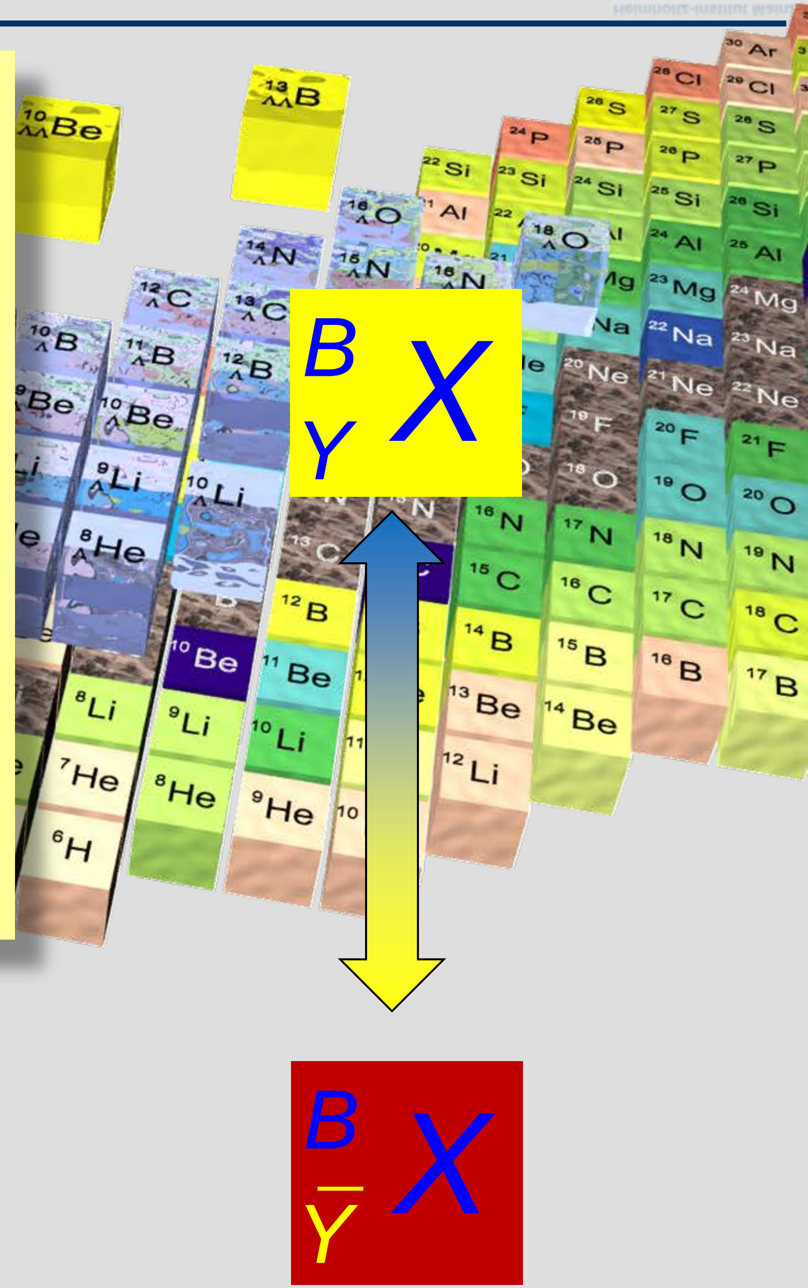
"… s… i… a… c…

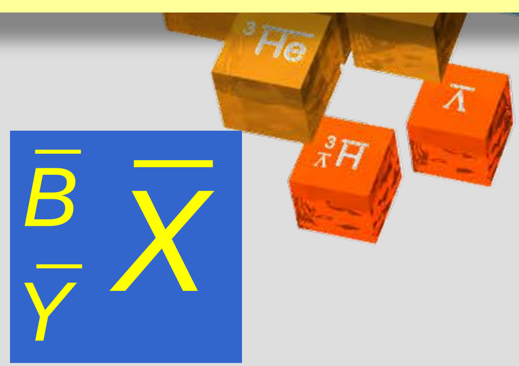
… weak
… e not to
… nly EoS

⇒ Need a precise understand N-N, Y-N, Y-Y, Y-N-N, Y-Y-N… interactions at *large* densities!

Nuclei with (Anti)hyperons

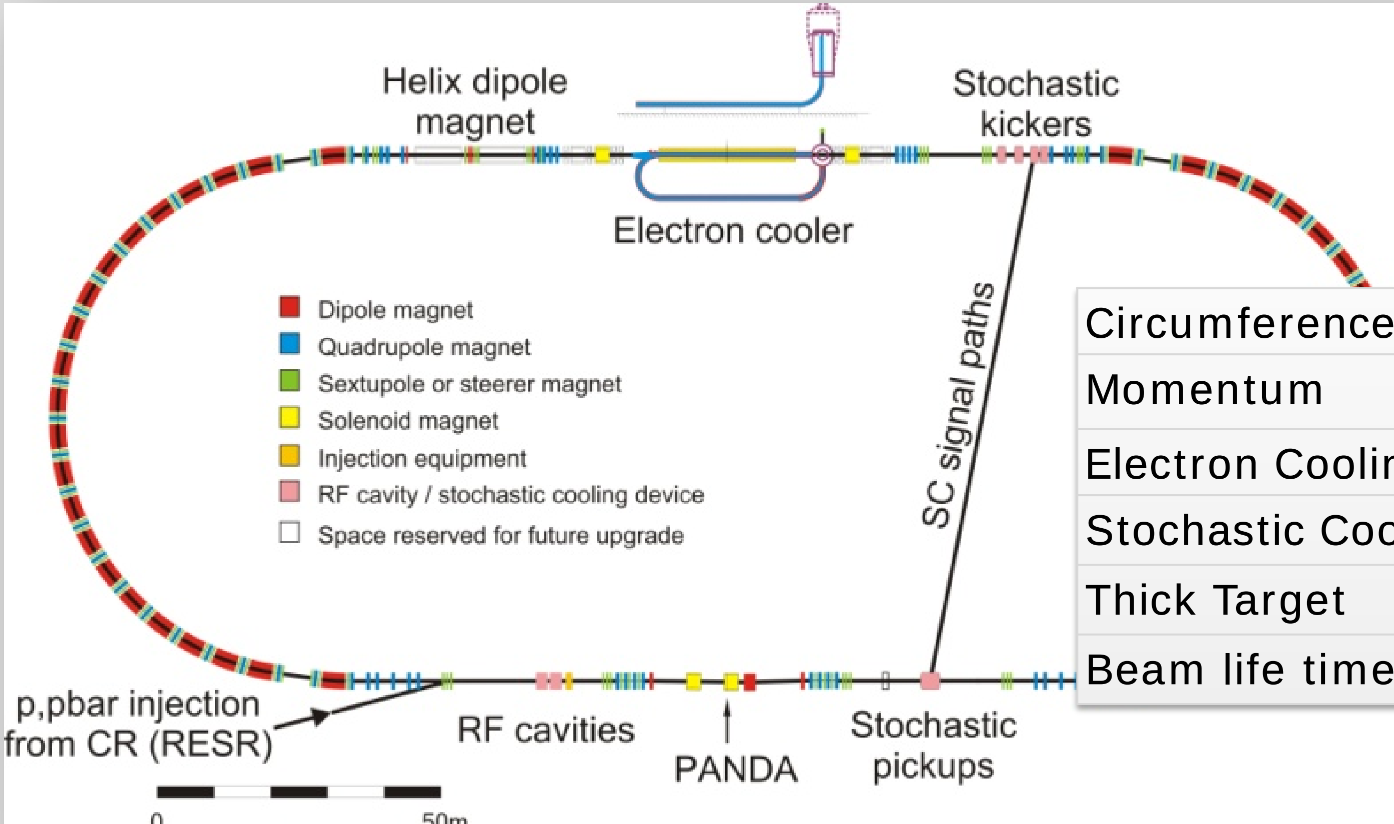
- G-parity relates NN with $N\bar{N}$ interaction (Dürr & Teller 1956)
- Coupling of baryons or antibaryons in nuclei could be related
- But: G-parity is broken for nucleons (V~-150MeV)
- To what extent is G-parity broken with strange quarks ?
- Antibaryons in nuclei are a novel probe for short range interactions of strange baryons in nuclei





THE $\bar{\text{P}}$ANDA EXPERIMENT in a NUTSHELL

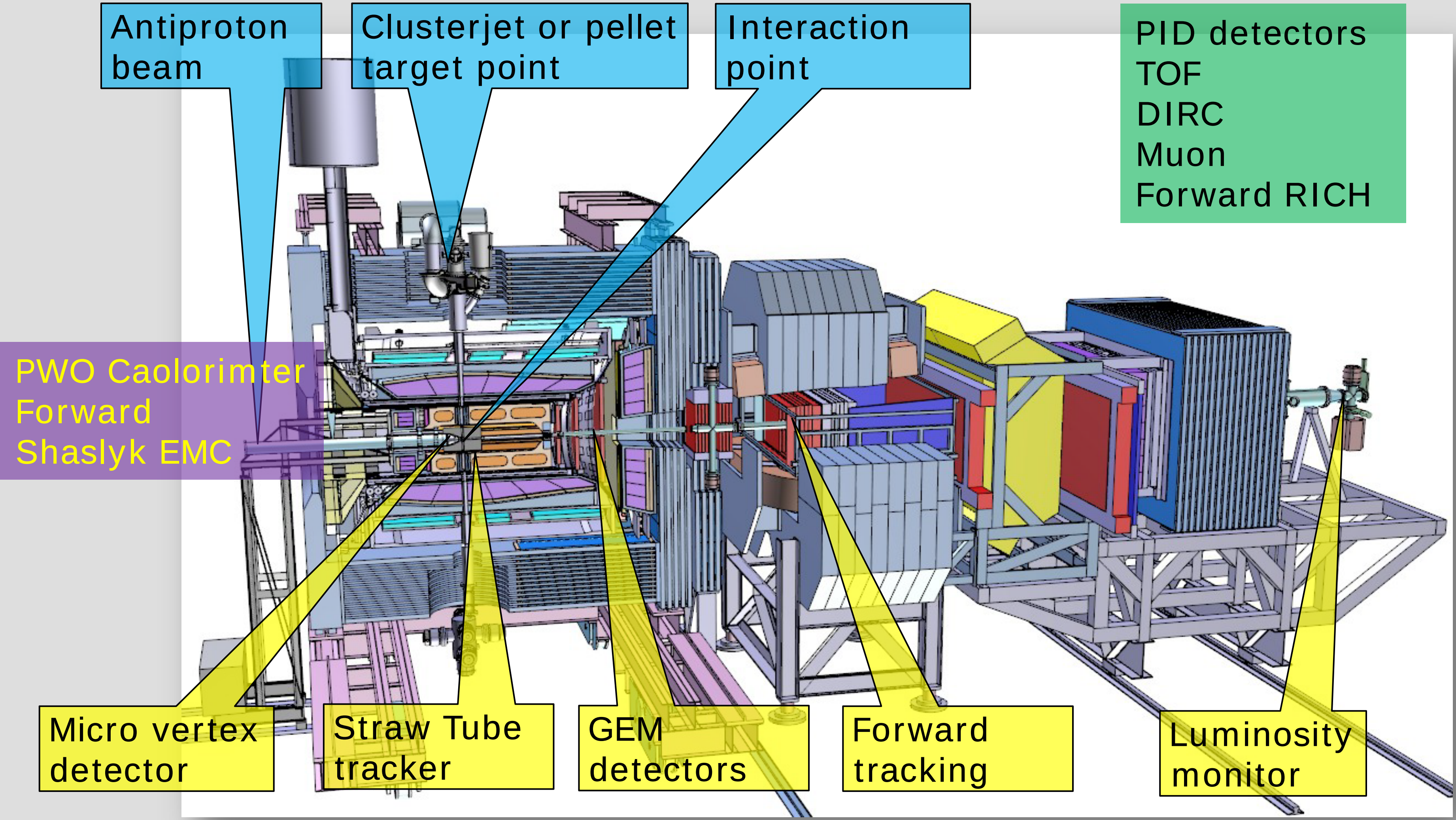
HESR with PANDA and Electron Cooler



Circumference	575 m
Momentum	1.5 – 15 GeV/c
Electron Cooling	up to 9 GeV/c
Stochastic Cool.	Full range
Thick Target	$4 \cdot 10^{15}$ cm^{-2}
Beam life time	>30 min

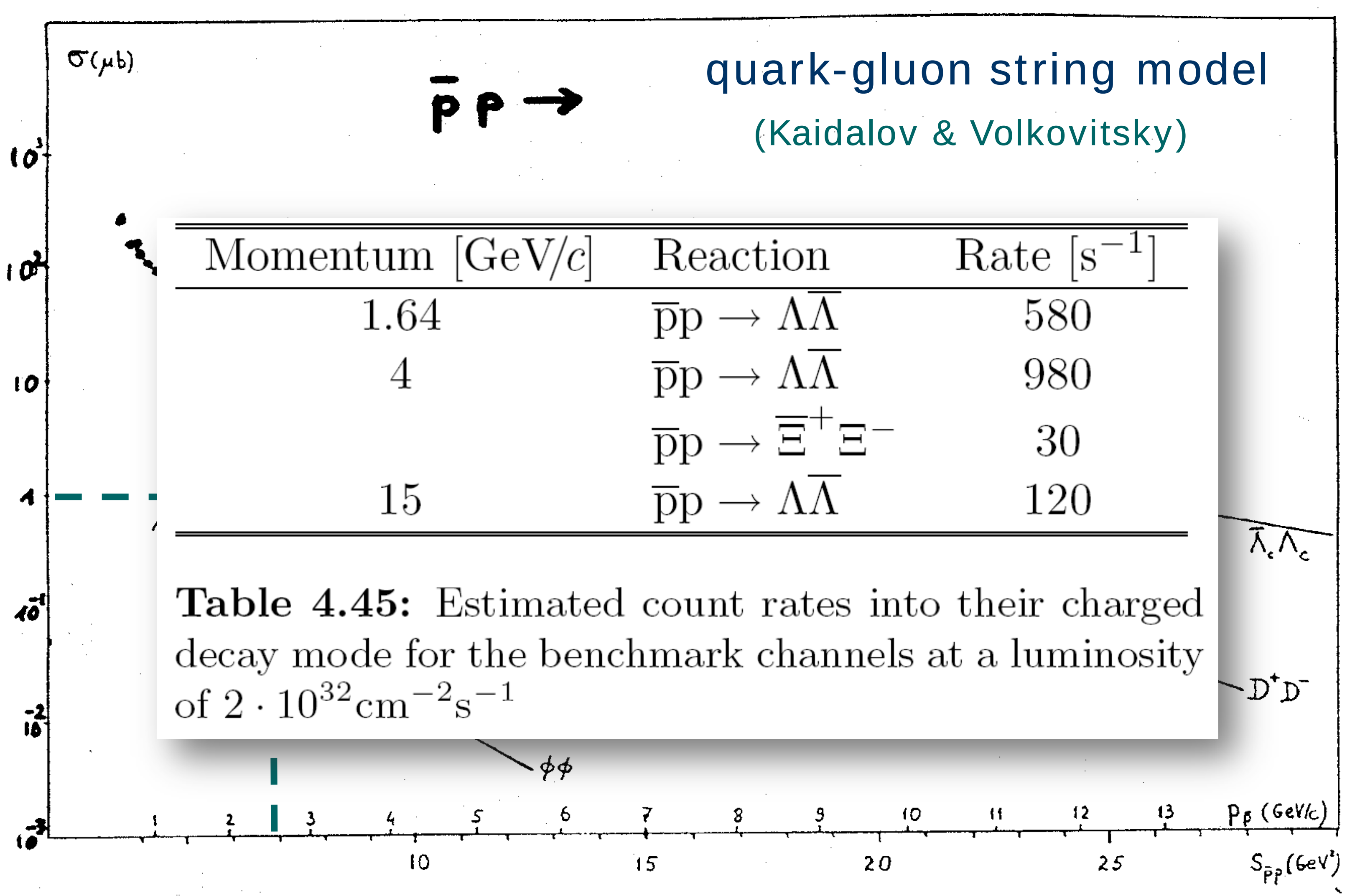
- High resolution mode
  - e^- cooling $1.5 \le p \le 8.9$ GeV/c
  - 10^{10} antiprotons stored
  - Luminosity up to $2 \cdot 10^{31}$ cm^{-2}s^{-1}
  - $\Delta p/p \le 4 \cdot 10^{-5}$
- High luminosity mode
  - Stochastic cooling $p \ge 3.8$ GeV/c
  - 10^{11} antiprotons stored
  - Luminosity up to $2 \cdot 10^{32}$ cm^{-2}s^{-1}
  - $\Delta p/p \le 2 \cdot 10^{-4}$

The P̄ANDA detector



- Official timeline
  - 2013-2017: (partial) pre-assembling at COSY, Jülich
  - ≥2018: first beam expected at FAIR

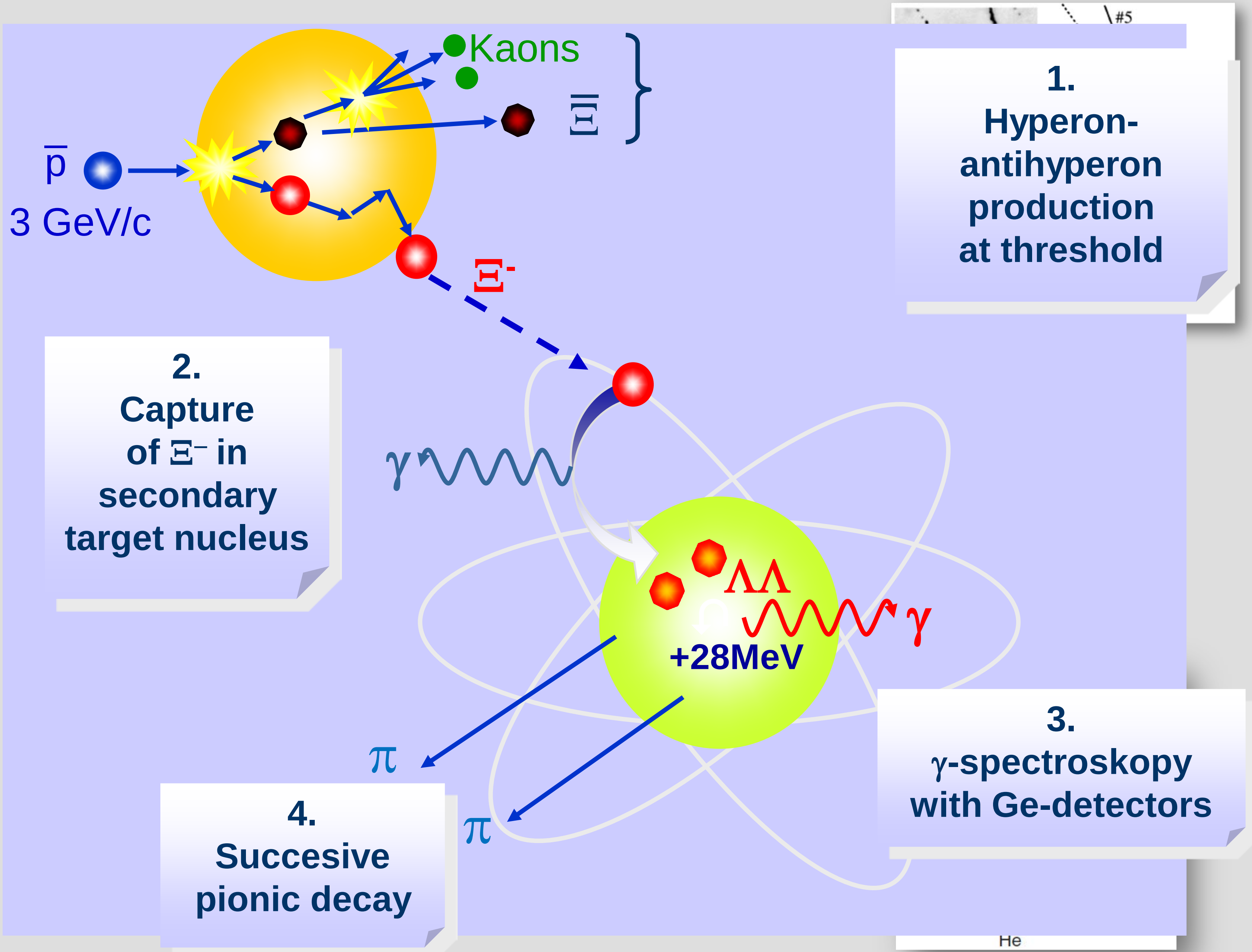
$\overline{\text{P}}$ANDA – a Factory for strange *and* charmed $Y\overline{Y}$-Pairs



Momentum [GeV/c]	Reaction	Rate [s^{-1}]
1.64	$\overline{p}p \rightarrow \Lambda\overline{\Lambda}$	580
4	$\overline{p}p \rightarrow \Lambda\overline{\Lambda}$	980
	$\overline{p}p \rightarrow \overline{\Xi}^{+}\Xi^{-}$	30
15	$\overline{p}p \rightarrow \Lambda\overline{\Lambda}$	120

Table 4.45: Estimated count rates into their charged decay mode for the benchmark channels at a luminosity of $2 \cdot 10^{32} cm^{-2}s^{-1}$

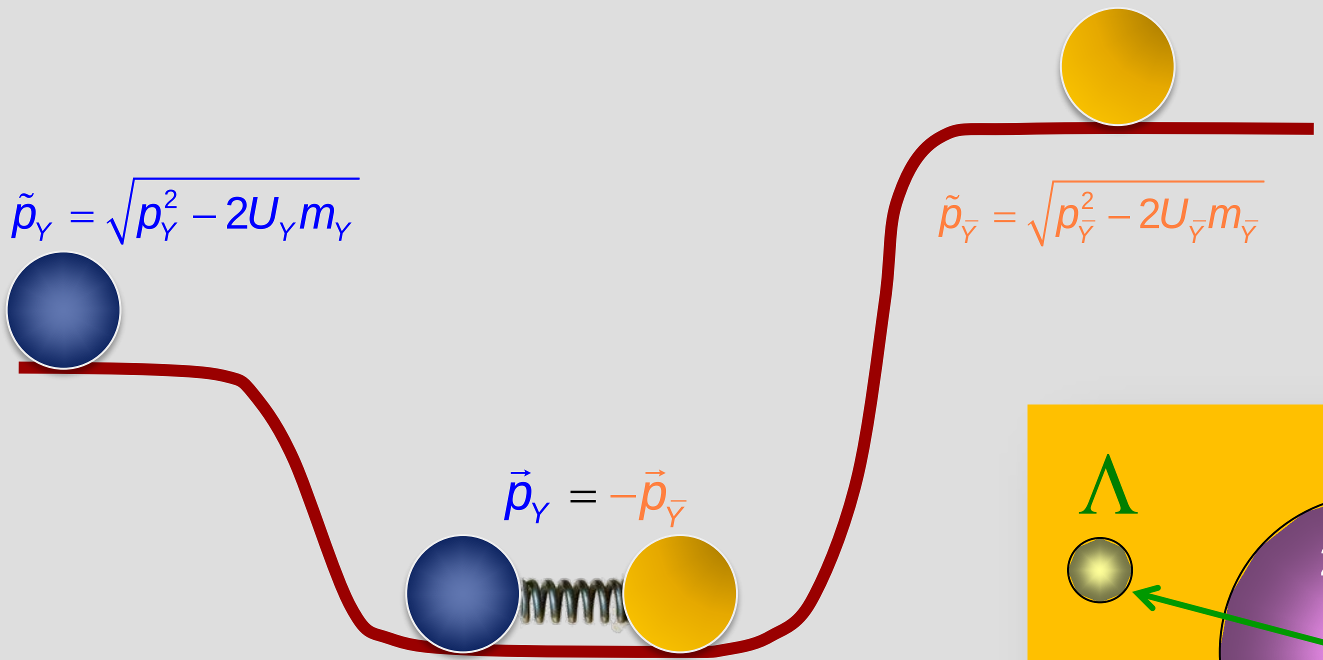
Many Roads to Double Hypernuclei




reaching for the unthinkable
ANTIHYPRONS IN NUCLEI
AT PANDA

$\bar{\Lambda}$ Potential (in Neutron Matter)

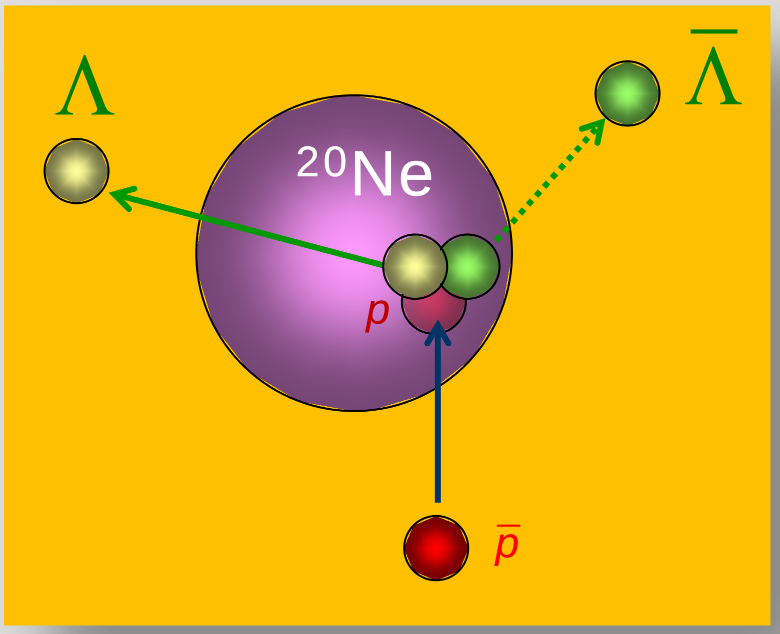
- exclusive $\bar{p}+p(A) \rightarrow Y+\bar{Y}$ close to threshold within a nucleus
- Λ and $\bar{\Lambda}$ that leave the nucleus will have different asymptotic momenta depending on the respective potential



- $\Rightarrow$ *transverse* momentum close to threshold of *coincident* $Y\bar{Y}$ pairs

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

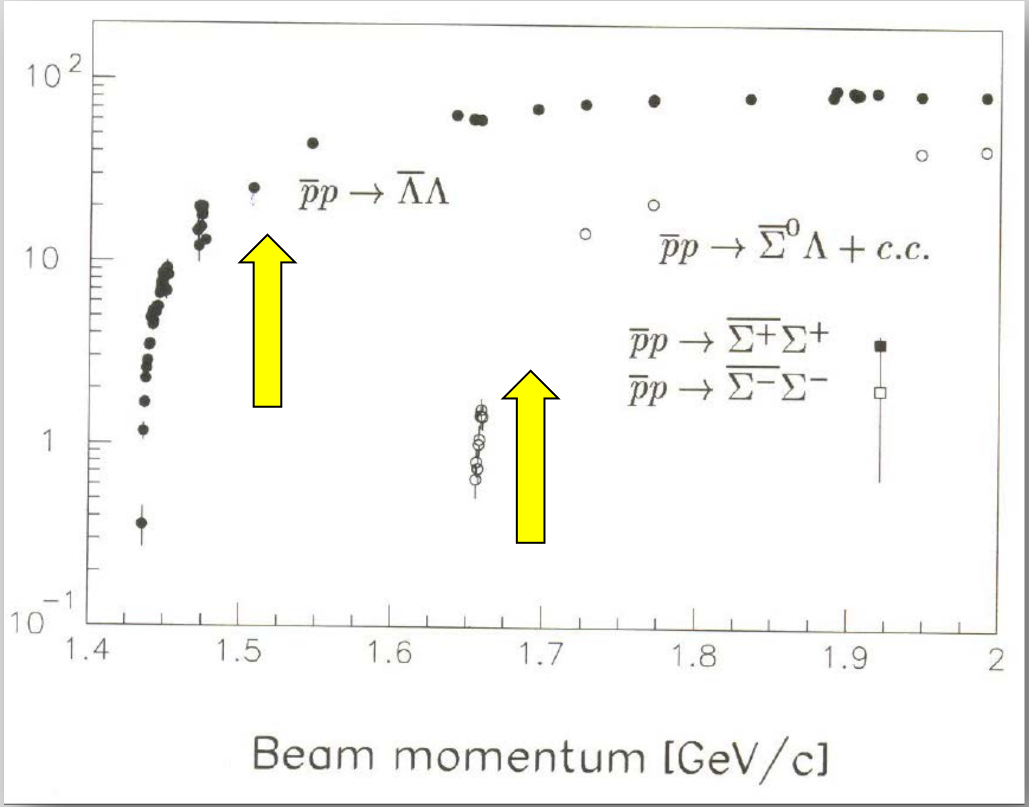
J.P., PLB **669** (2008) 306



GiBUU Simulations $\bar{p}+{}^{20}\mathrm{Ne} \rightarrow \Lambda\bar{\Lambda}+X$

- GiBUU
  - G-parity used to estimate anti-baryon potentials except for $\bar{N}$
  - Approximately 15k exclusive $\Lambda\bar{\Lambda}$ pairs in each set
    corresponds to < 10 min P̄ANDA incl. efficiency

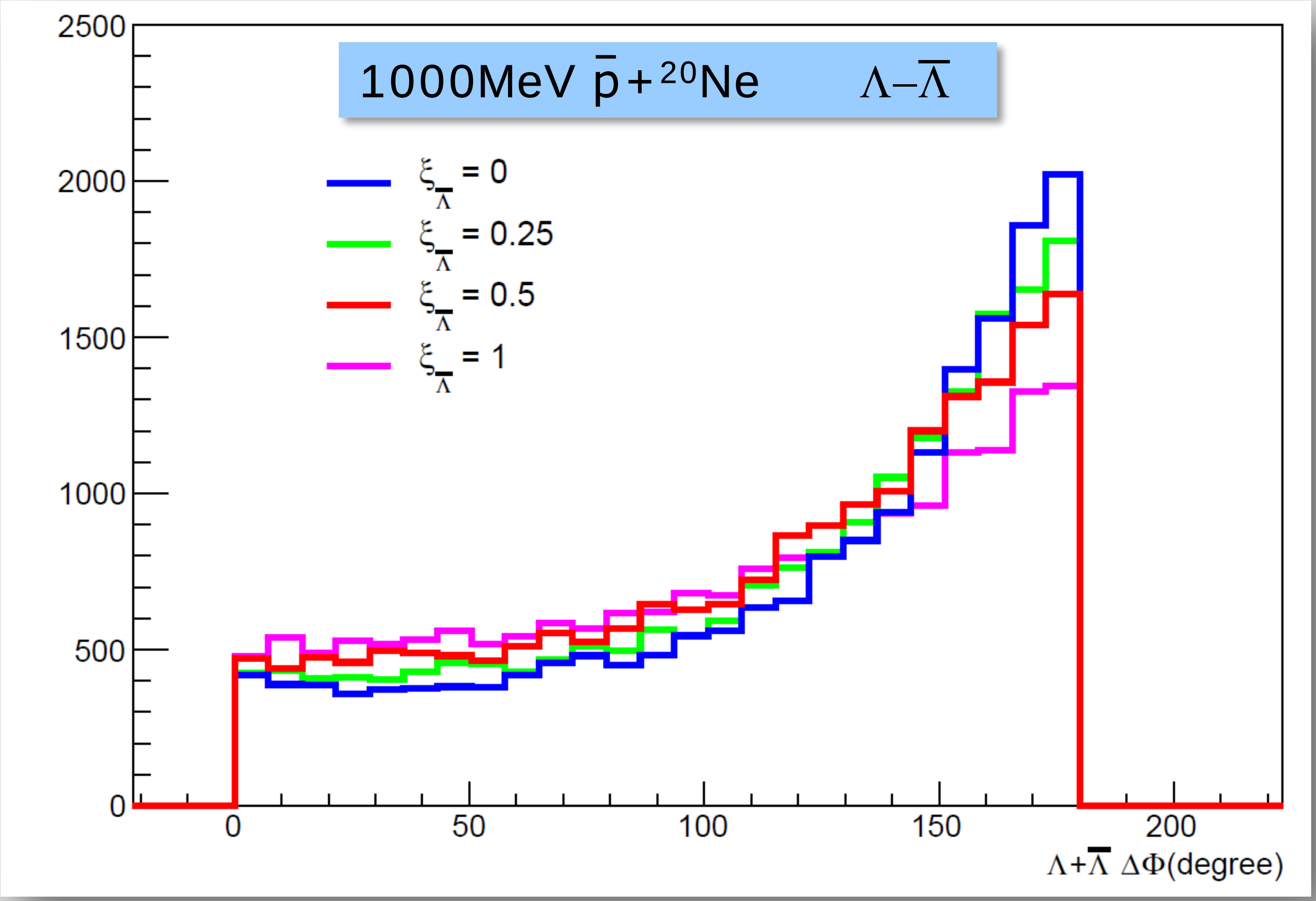
Energy (MeV)	Momentum (MeV/c)	Excess energy (MeV)
850	1522	30.6
1000	1696	92.0



- Aim of the present work
  - Explore sensitivity of α_T to a scaling of the real $\bar{Y}$ potential
  - Proof the feasibility of a measurement at P̄ANDA
  - Trigger a fully self-consistent dynamical treatment of antihyperons in nuclei

Rescattering effects

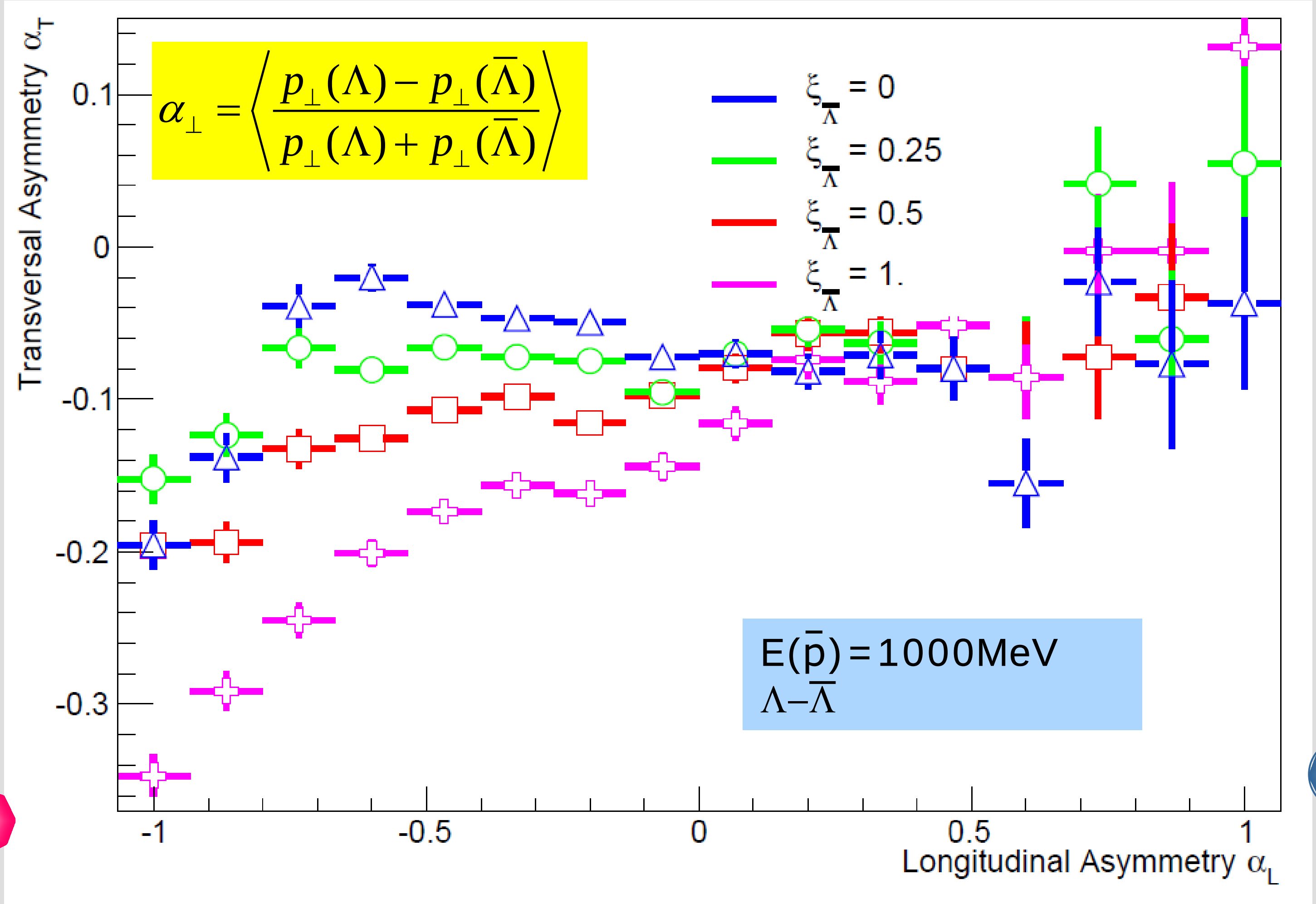
- Typical 15000 $\bar{\Lambda}\Lambda$ pairs produced

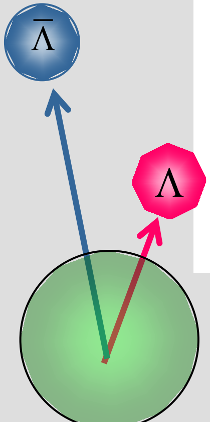


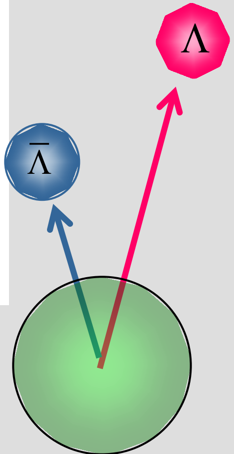
- Coplanarity distorted $\Rightarrow$ strong refractive and/or rescattering effects

Scan of $\bar{\Lambda}$ Potential

- $U(\bar{\Lambda})$ = -449MeV, -225MeV, -112MeV, 0MeV
- All other potentials unchanged



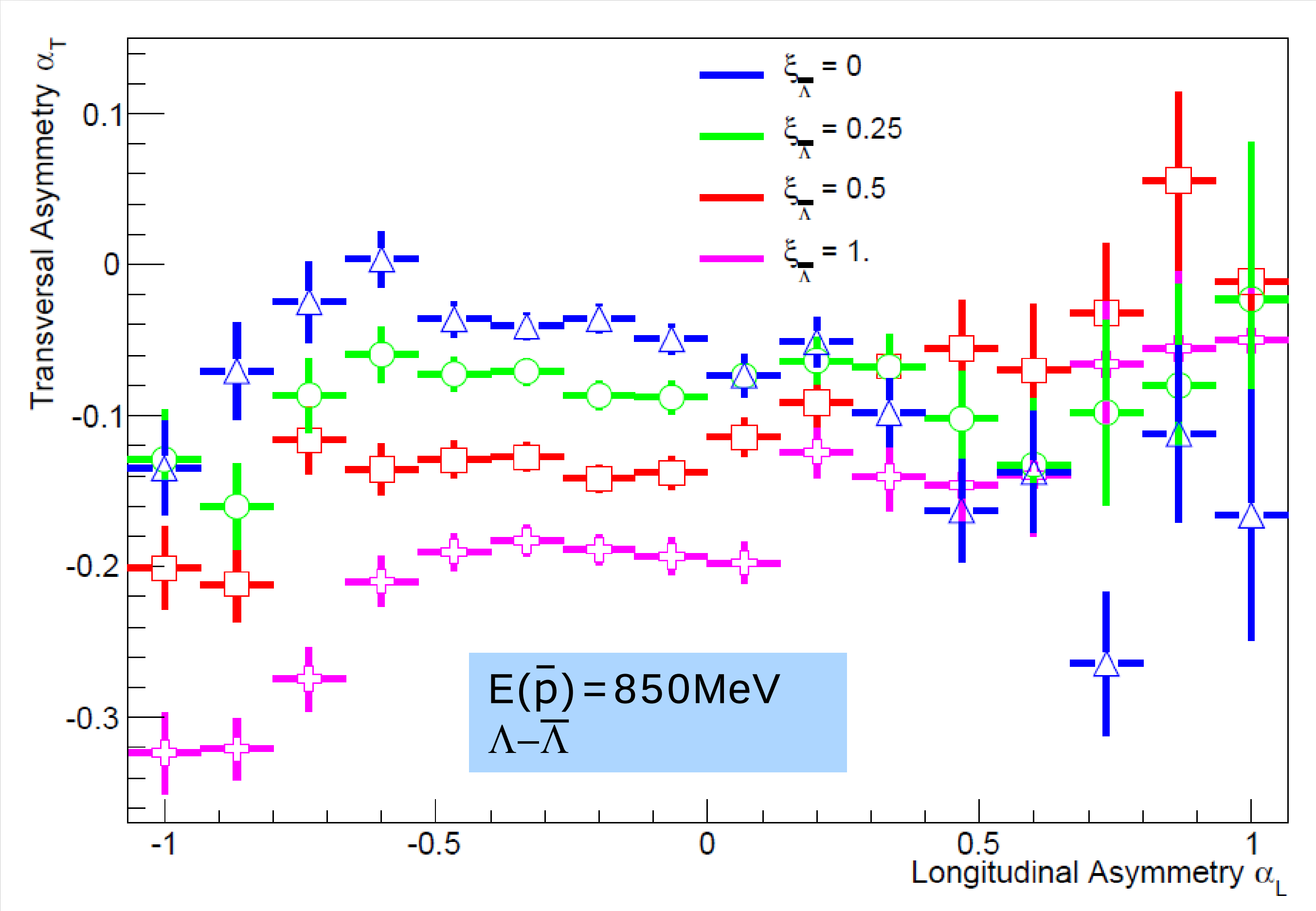


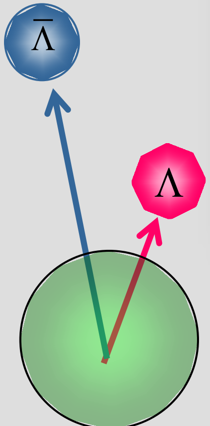


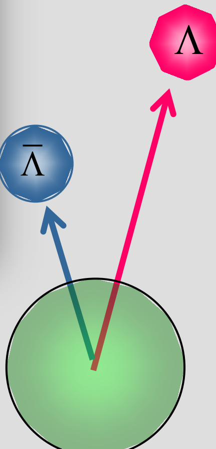
$$\alpha_L = \frac{p_L(\Lambda) - p_L(\bar{\Lambda})}{p_L(\Lambda) + p_L(\bar{\Lambda})}$$

Scan of $\overline{\Lambda}$ Potential

- $U(\overline{\Lambda})$ = -449MeV, -225MeV, -112MeV, 0MeV
- All other potentials unchanged



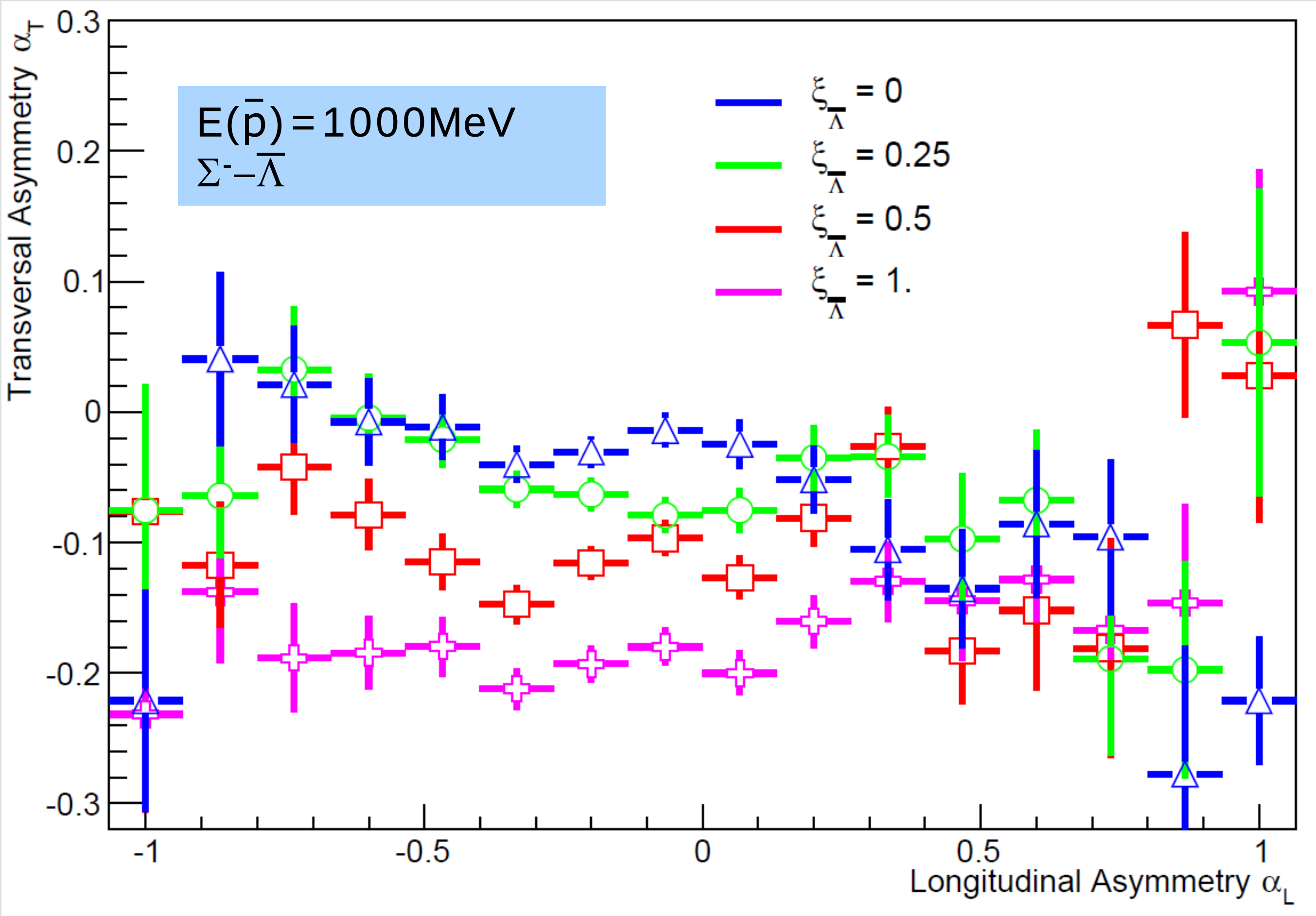


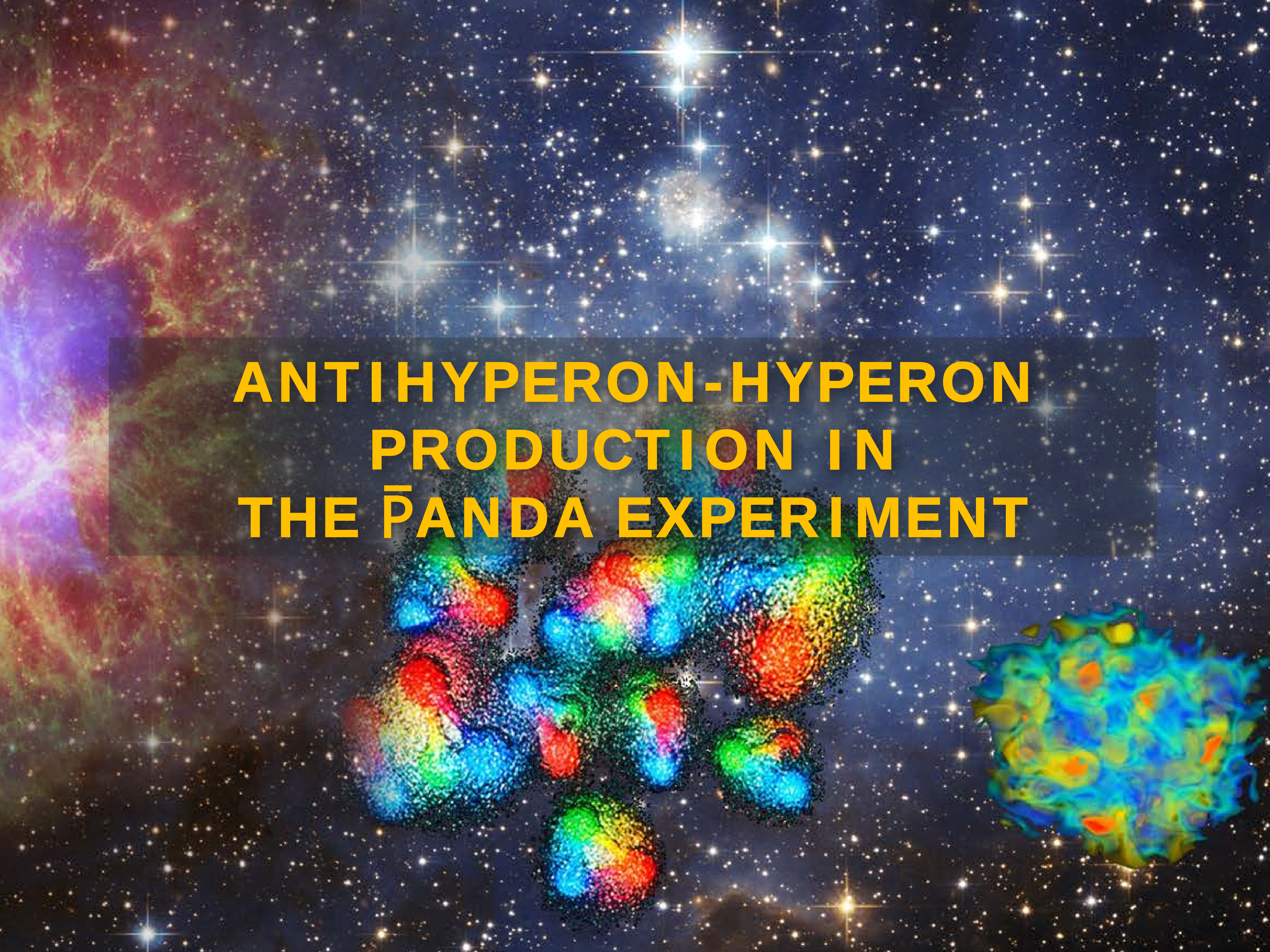


$$\alpha_L = \frac{p_L(\Lambda) - p_L(\overline{\Lambda})}{p_L(\Lambda) + p_L(\overline{\Lambda})}$$

Other |s|=1 channels @ 1000MeV

- $\bar{p}+p\rightarrow\bar{\Lambda}+\Lambda$ $\bar{p}+p\rightarrow\bar{\Sigma}^0+\Lambda$
- $\bar{p}+n\rightarrow\bar{\Lambda}+\Sigma^-$ $\bar{p}+n\rightarrow\bar{\Sigma}^++\Lambda$
- all antihyperon potentials scaled by same factor

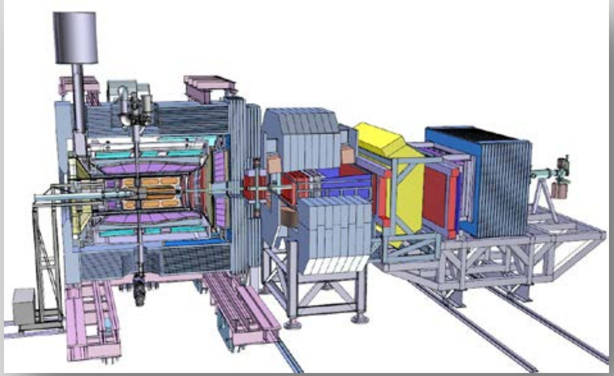



ANTIHYPERON-HYPERON
PRODUCTION IN
THE P̄ANDA EXPERIMENT

Antihyperon-Hyperon Pairs in $\bar{\text{P}}$ANDA

- 2018 first beam in $\bar{\text{P}}$ANDA expected → commissioning phase
- We are right now exploring different scenarios
  - Different detector availability
  - Different solenoid fields (1T, 0.5T,...)

  and other important aspects like
  - Luminosity
  - Length of typical running period



- Typical (*preliminary*) $\bar{\Lambda}\Lambda$ pair efficiency ≈ 3-5% (better at higher momenta)
- $\bar{\Lambda}+\Lambda$
  - ^{nat}Ne target, H for calibration
  - only charged particle detection *easy*
  - Assume average interactions rate $10^5 s^{-1}$ i.e. *~1% of default luminosity*
  - Moderate data taking period *~ 30 days*

    ⇒ $2.6 \cdot 10^{11}$ detected interactions
  - pair reconstruction efficiency 4%

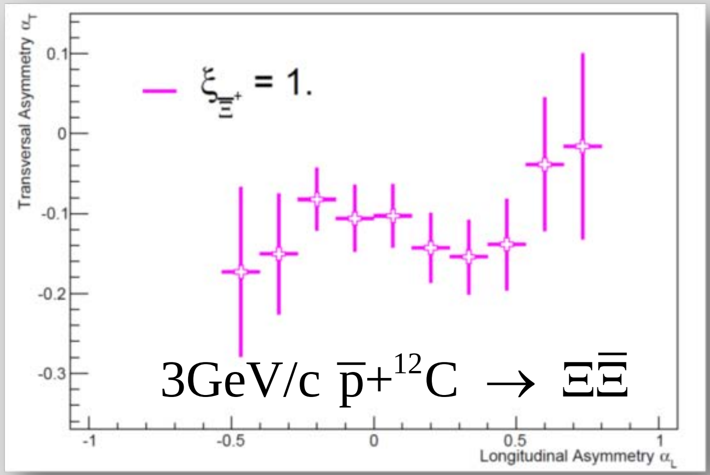
    ⇒ 0.5M events detected $\bar{\Lambda}+\Lambda$ pairs

40 × present GiBUU simulations

Further Options

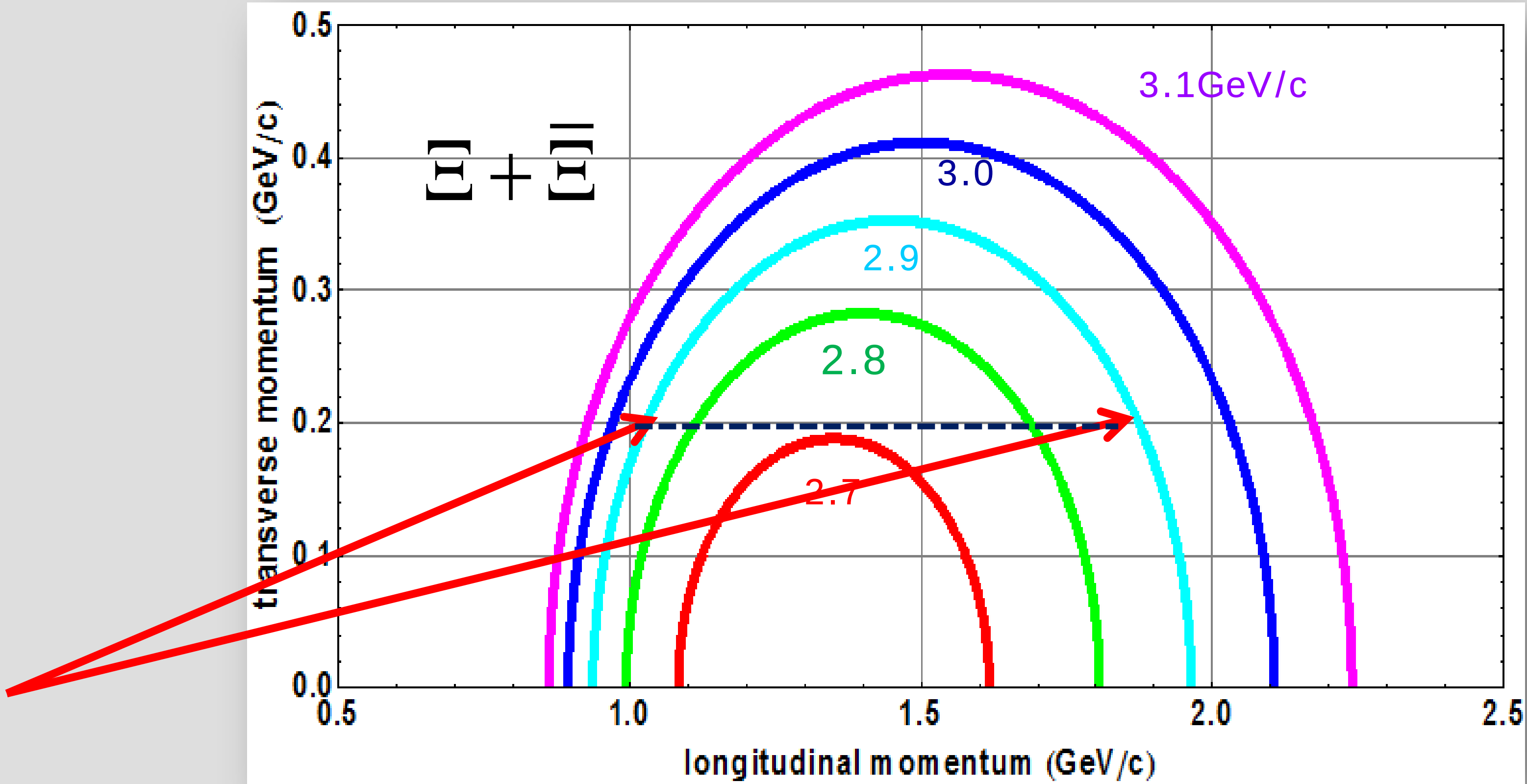
- $\overline{\Lambda}+\Sigma^-$
  - Ideal probe for interactions in the neutron skin
  - ^{20}Ne; ^{22}Ne, H for calibration; later: ^{86}Kr (36 Protons, 50 Neutrons)
  - Σ^- tracking, $\Sigma^- \rightarrow n\pi^-$
  - similar production rate (at least in light nuclei)

- Further options:
  - Any other pair: Σ-$\overline{\Sigma}$, Ξ-$\overline{\Xi}$, $\Lambda_c\overline{\Lambda}_c$
  - long lived resonances in nuclei
    - Λ(1520) (Γ= 15.6 MeV)
    - Ξ(1530) (Γ=9.9 MeV)
    - Λ_c(2880) (Γ=5.8MeV)



- Unique change to study charmed baryons in nuclear systems

Beyond $\bar{P}$ANDA: YN, $\bar{Y}$N scattering



- $\bar{p}+p\rightarrow \bar{Y}+Y$ provides momentum tagged low momentum, polarized hyperon *or* antihyperon beams
- scattering experiment with low momentum (anti)hyperons possible
- Optimal: Low momentum asymmetric $\bar{p}$-p collider HESR + HESR

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

$\bar{\text{P}}$ANDA is a unique factory for strange and charmed $\bar{Y}Y$ pairs

The $\bar{\Lambda}$-Λ production is an ideal experiment for the commissioning phase of $\bar{\text{P}}$ANDA