Measuring the Potential of antihyperons in nuclei with antiprotons at PANDA

,
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Nuclei with (anti)hyperons

- Link between NN $\Rightarrow$ N$\bar{\text{N}}$
- G-Parity $G = C \cdot e^{i\pi I_2}$

  G=charge conjugation + 180°

  rotation around 2nd axis in isospin

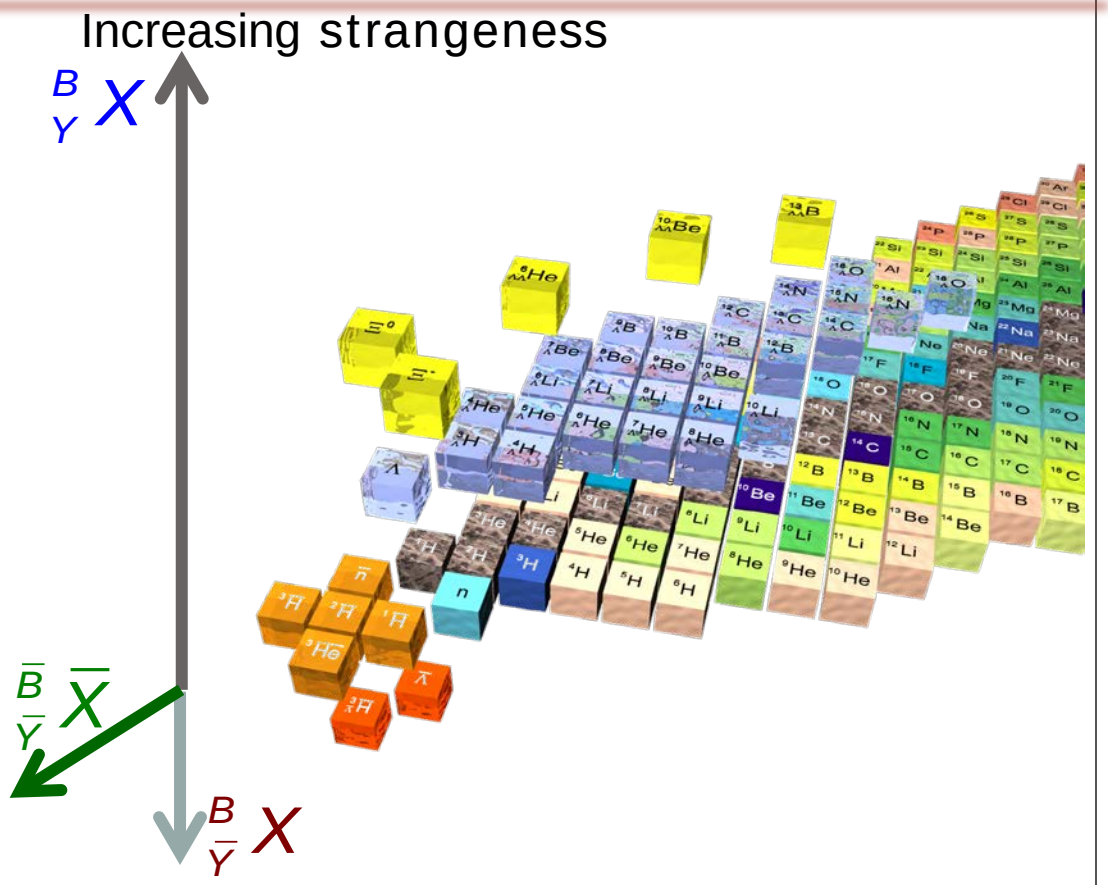
  (Lee und Yang 1956, L. Michel 1952)

- Hans Peter Dürr and E. Teller

  *(Phys. Rev. **101**, 494 (1956))*

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

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



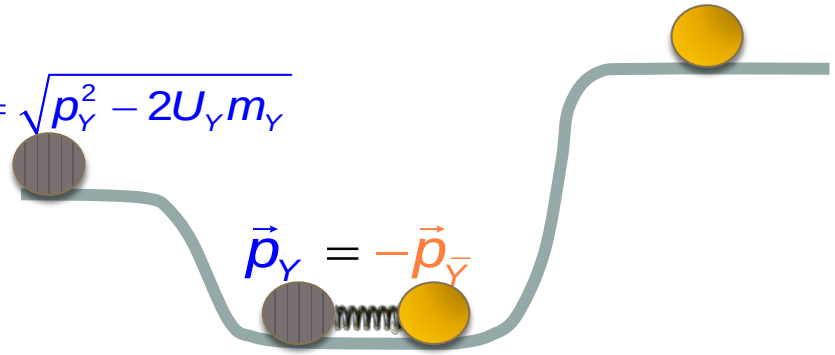
Nucleon	*≈ -40MeV*
Lambda	*≈ -27MeV*
Cascade	*~ -15MeV*
Antinucleon	*~ -150MeV*
Antilambda	*?*
Anticascade	*?*

Antibaryons in nuclei are a novel probe
for short range interactions of strange baryons in nuclei
No exp. info on nuclear potential of antihyperons exists so far

$\overline{\Lambda}$ Potential (in nucleon Matter)

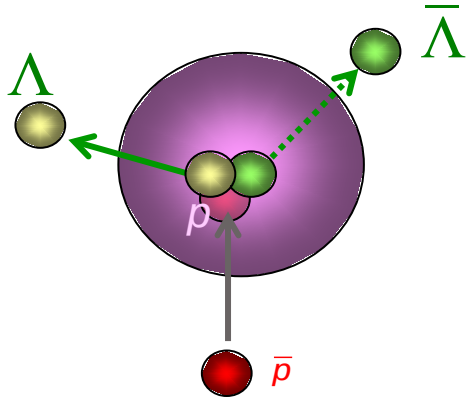
- antiprotons are optimal for the production of mass without large momenta
- consider exclusive $\overline{p}$ +p(A) $\Rightarrow$ Y+ $\overline{Y}$ close to threshold within a nucleus
- Λ and $\overline{\Lambda}$ that leave the nucleus will
  have different asymptotic momenta
  depending on the respective potential $\tilde{p}_Y = \sqrt{p_Y^2 - 2U_Y m_Y}$

$\tilde{p}_{\overline{Y}} = \sqrt{p_{\overline{Y}}^2 - 2U_{\overline{Y}} m_{\overline{Y}}}$



A. Gal ,Phys. Rev. Lett. **64B**, 2 (1976)
J.P., PLB **669** (2008) 306

$\Rightarrow$ Advantage: well defined geometry , kinematics determined by energy and momentum conservation of a (nearly) two-body reactions



$\Rightarrow$ need to look at transverse momentum close to threshold of coincident $Y\overline{Y}$ pairs

$\Rightarrow$ But, studying only the average transverse momentum separately does not allow to extract unambiguous information

(Nearly) two-body kinematics

- Distribution of the produced baryon-antibaryon, not isotropic
- Absorption of antibaryon in the periphery
- Rescattering

⇒ A difference between tranverse momenta of the coincident $Y\bar{Y}$ reflects the different potentials

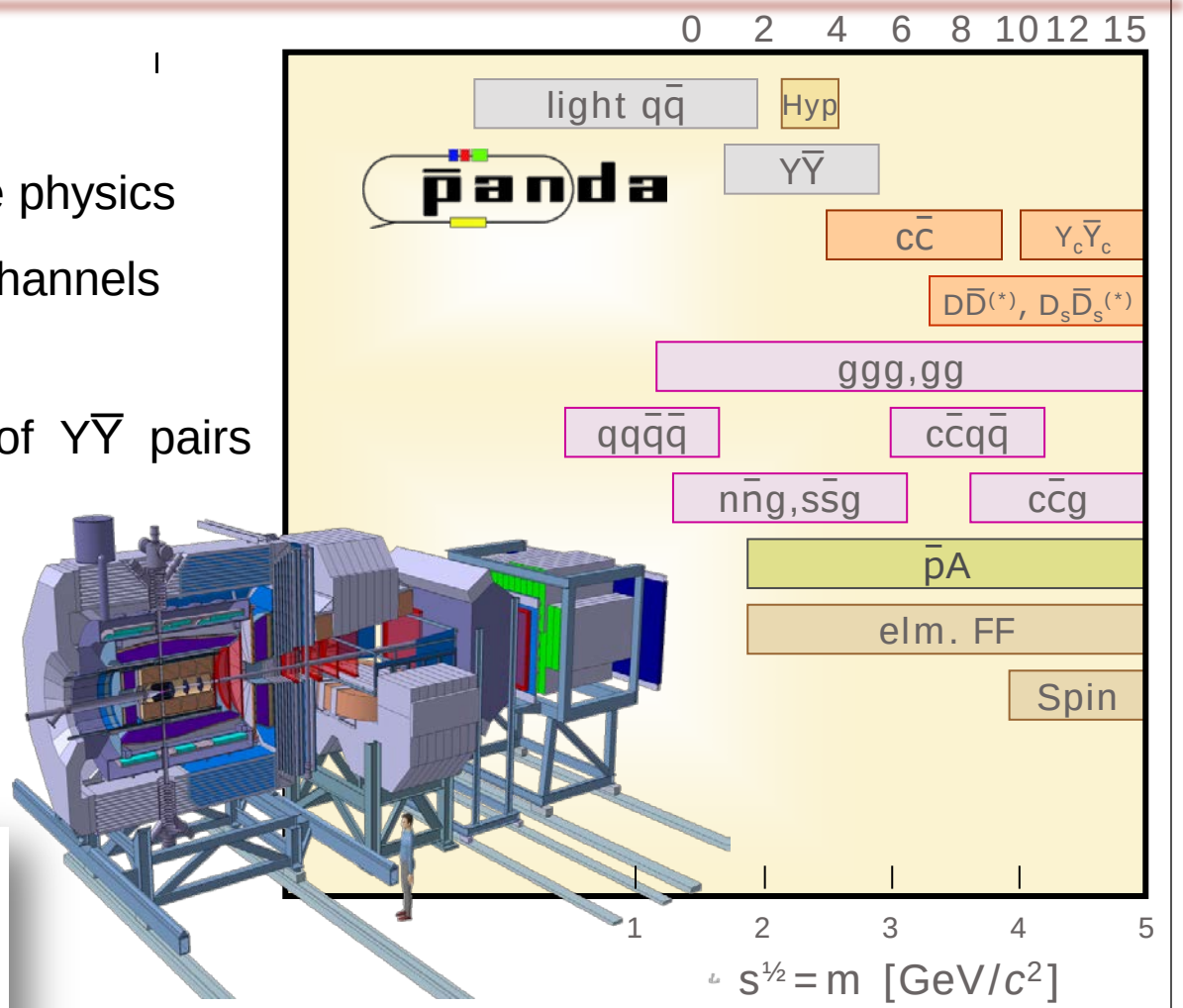
Studying their correlation and to reduce the influence of the cm. anisotropy by exploring the tranverse asymmetry as a function of the longitudinal asymmetry

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

$Y\bar{Y}$ pairs production at PANDA

PANDA can provide solid and unique physics for the $\bar{p}+p \Rightarrow Y+\bar{Y}$ in strangeness channels

- significant elementary production of $Y\bar{Y}$ pairs
- low background



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

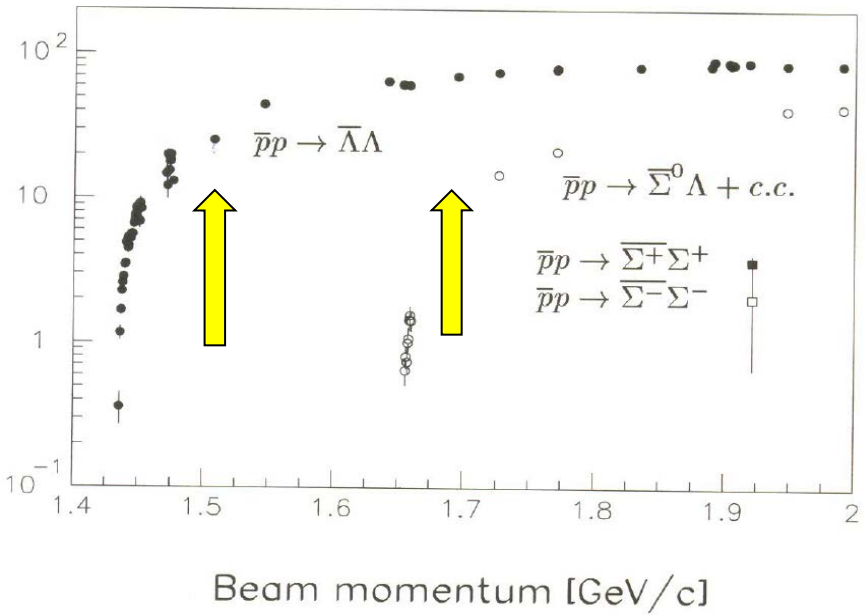
Table 4.45: Estimated count rates into their charged decay mode for the benchmark channels at a luminosity of $2 \cdot 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

GiBUU Simulations

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

- GIBUU: *Phys. Rev. C 85, 024614 (2012)*
- G-parity used to estimate anti-baryons potential
- Approximately 10k exclusive $\Lambda\bar{\Lambda}$ pairs in each set

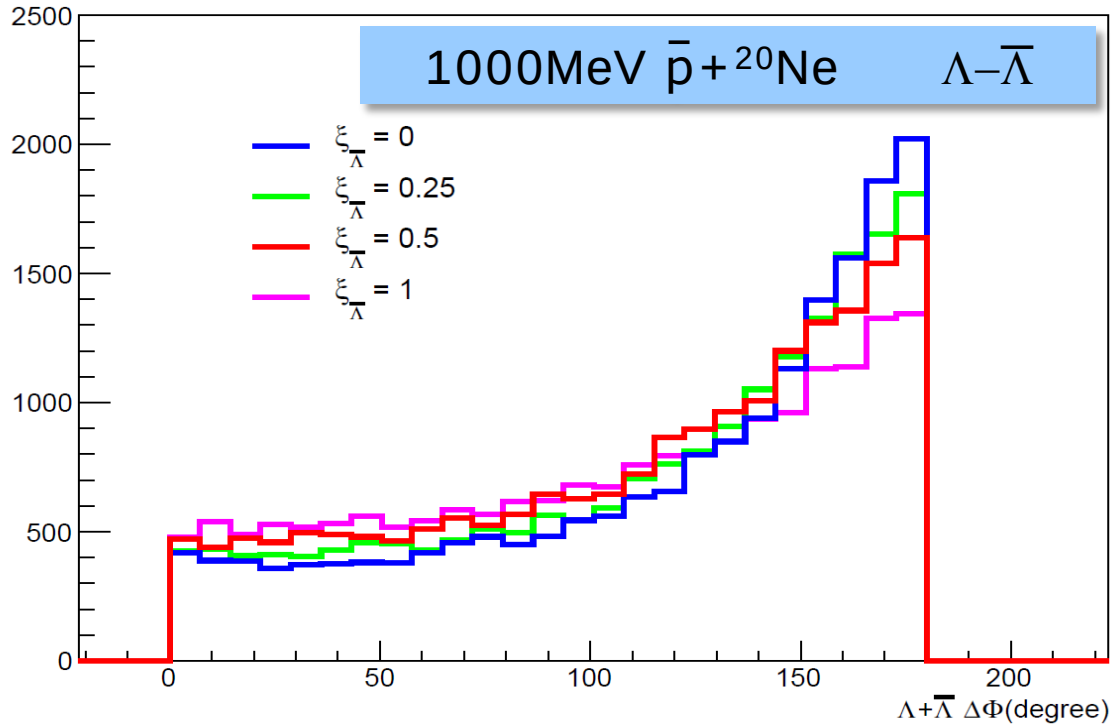
Energy (MeV)	Momentum (MeV/c)	Excess energy (MeV)
850	1522	30.6
1000	1696	92.0

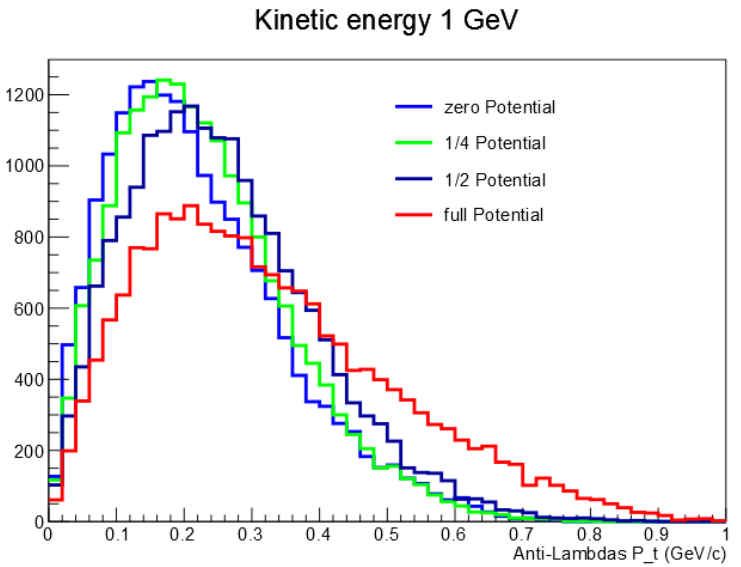


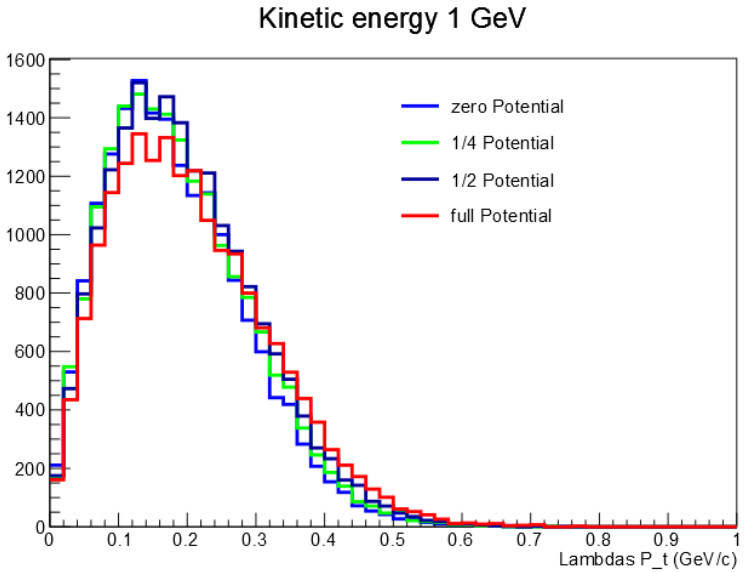
- Aim of the present work
  - Explore sensitivity of α_T to a scaling of the real $\bar{Y}$ potential
  - Proof the feasibility of a measurement at PANDA
  - Trigger a fully self-consistent dynamical treatment of antihyperons in nuclei

Rescattering effects

- Typical 15000 $\overline{\Lambda}\Lambda$ pairs produced
- U($\overline{\Lambda}$)= -449MeV, -225MeV, -112MeV, 0MeV
- $\xi_{\overline{\Lambda}}$ scaling factor
- All other potentials unchanged





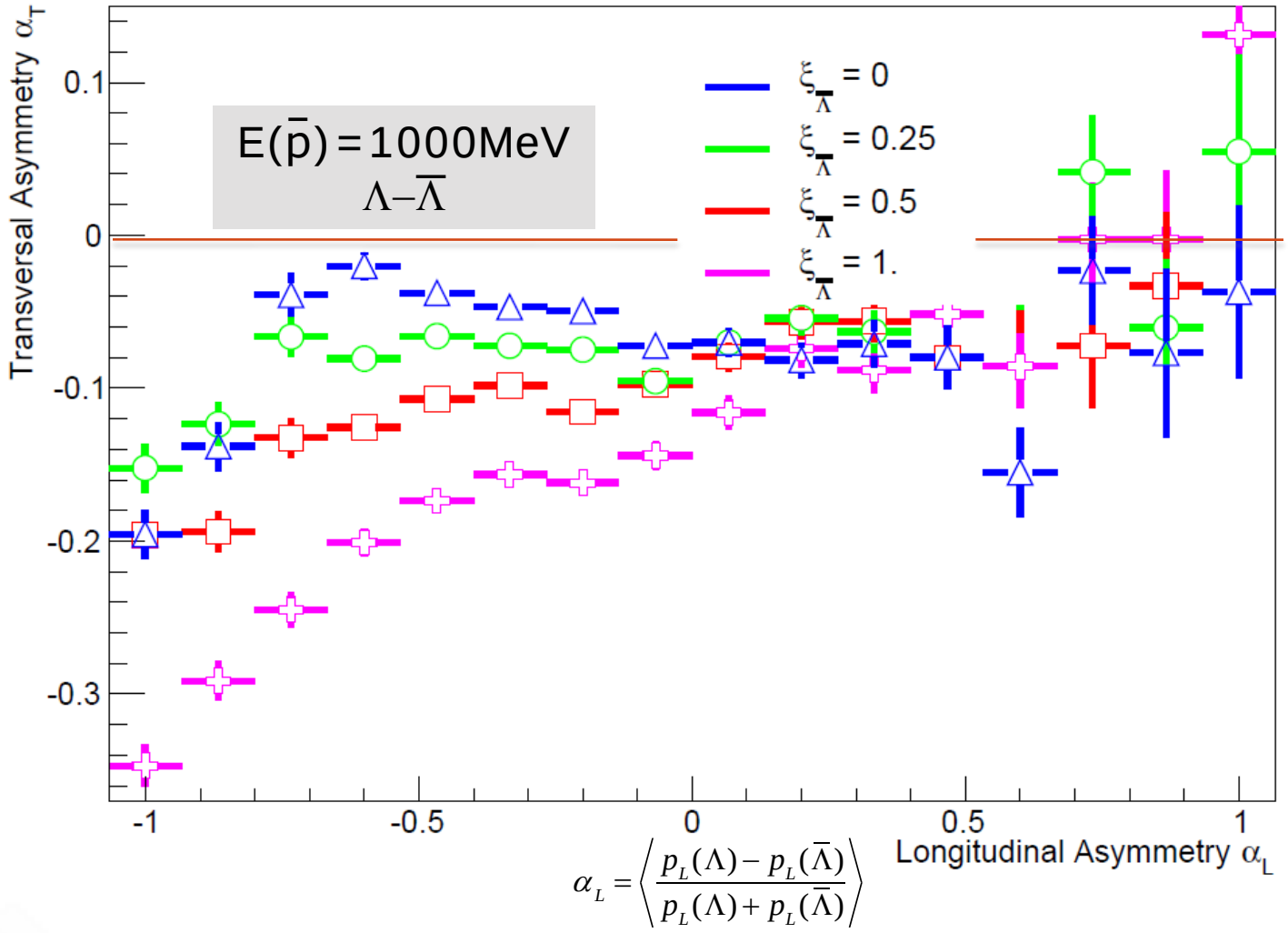


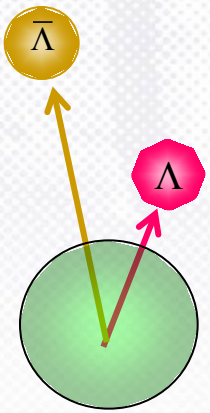
- Coplanarity distorted ⇒ strong rescattering effects

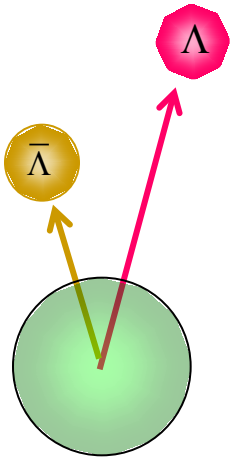
Scan of $\overline{\Lambda}$ potential

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

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

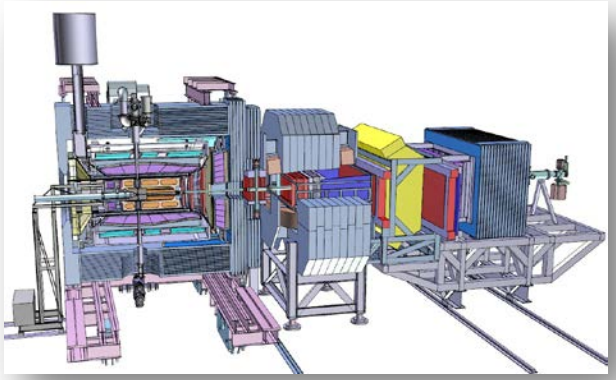






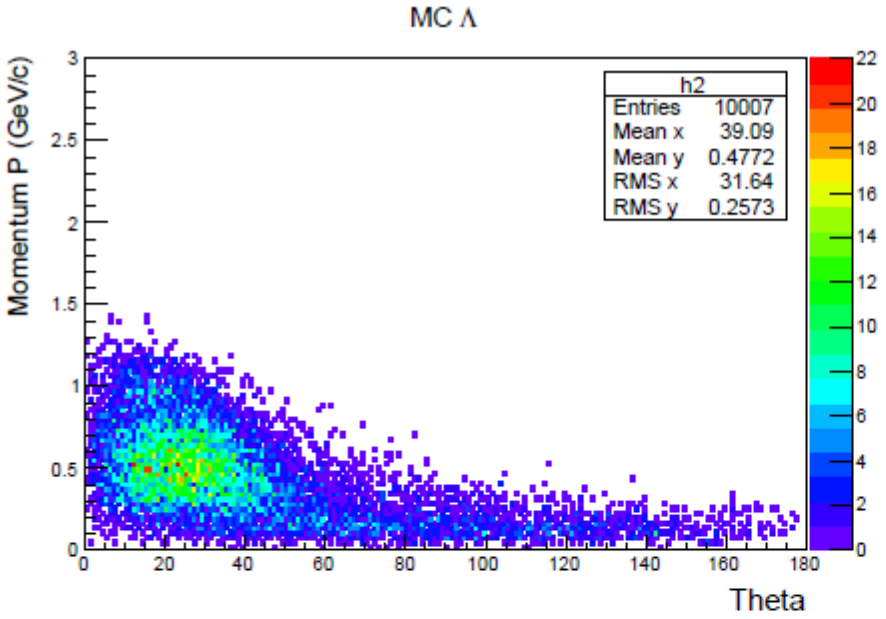
Antihyperon-Hyperon Pairs at PANDA

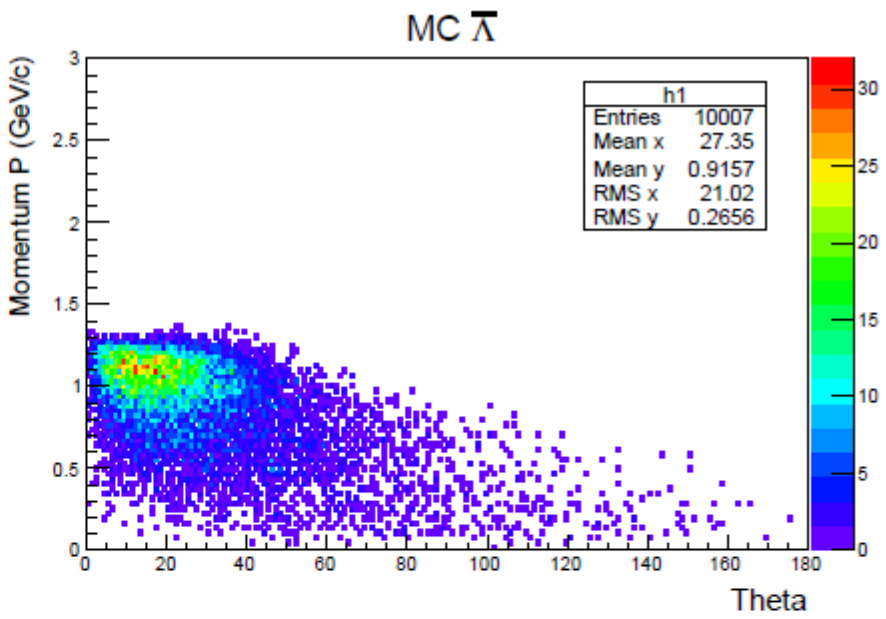
- We are right now exploring different scenarios
  - Different detector availability
  - Different solenoid fields (1T, 0.5T,…)

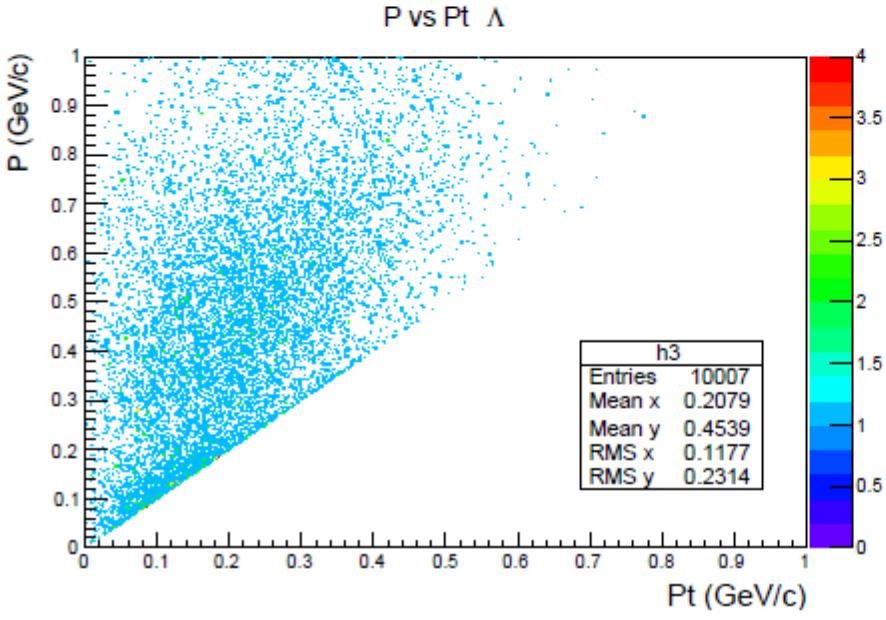


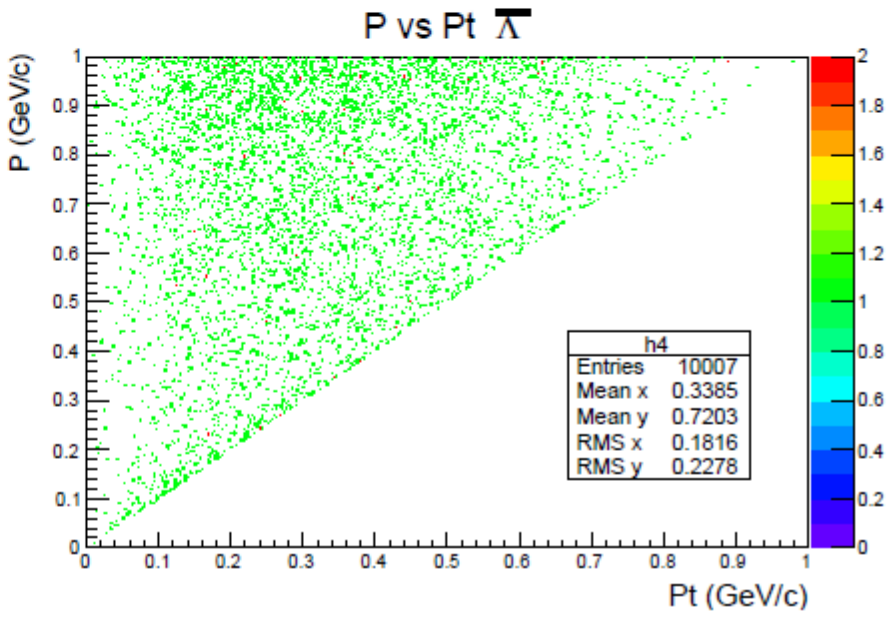
- MC Simulation Procedure:
  - Generation of 10 K $\Lambda + \overline{\Lambda}$ at 1 GeV ($\overline{p}$), $\overline{B}$ = 1 T, GiBUU-based events
  - Transport of particles through entire spectrometer
  - Generation of detector signal, digitization
  - Ideal Pattern Recogn./Tracking of charged particles
  - Particle Identification, particle mass assigment
  - Λ / $\overline{\Lambda}$ reconstruction from particles cand. Lists.
  - Fitting, No 4Cfitter, Mass constraint / Vertex filter, need further evaluation
  - Looking for $\Lambda + \overline{\Lambda}$ pairs event-by event, need further evaluation
  - Asymmetries

MC Events Generation









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- 2018 first beam in PANDA expected → commissioning phase
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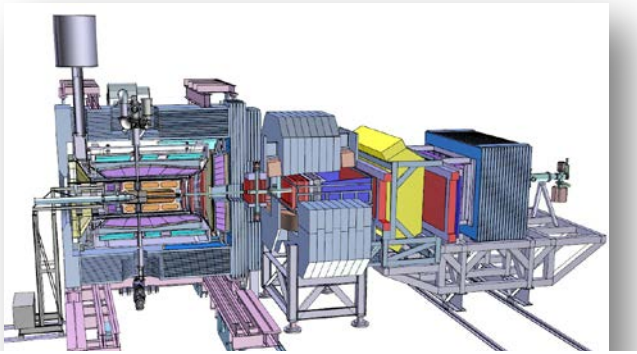
and other important aspects like

  - Luminosity
  - Length of typical running period



	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Efficiency Llbar	1,41	4,31	1,48	2,17
Efficiency L	11,23	18,12	11,95	15,98
Effiency Lbar	10,41	16,73	10,55	14,2

Scenario 1 : Full Setup (no Lambda discs) + full Mag. field, 2 T

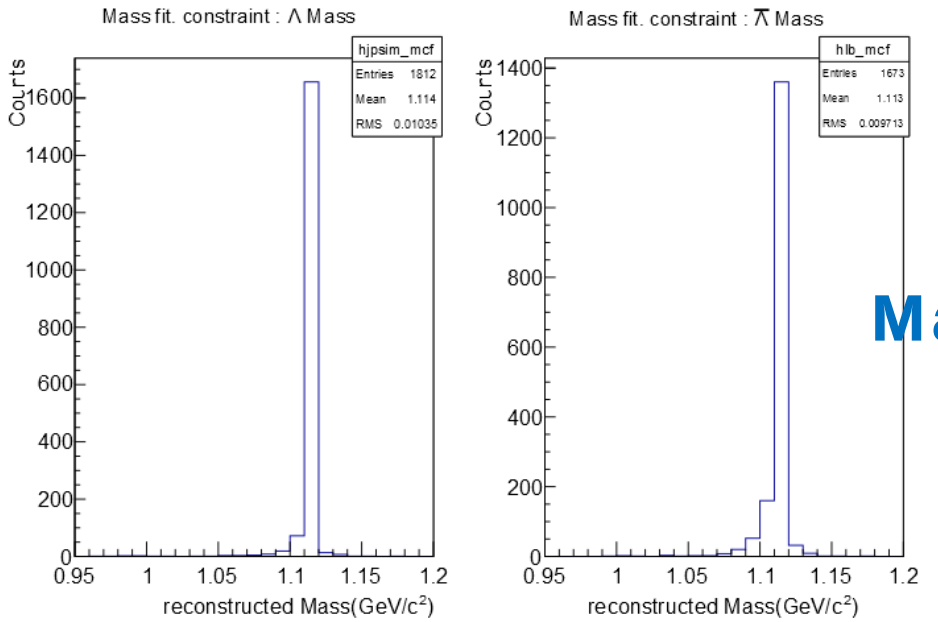
Scenario 2 : Full Setup (no Lambda discs) + half Mag. field, 1 T

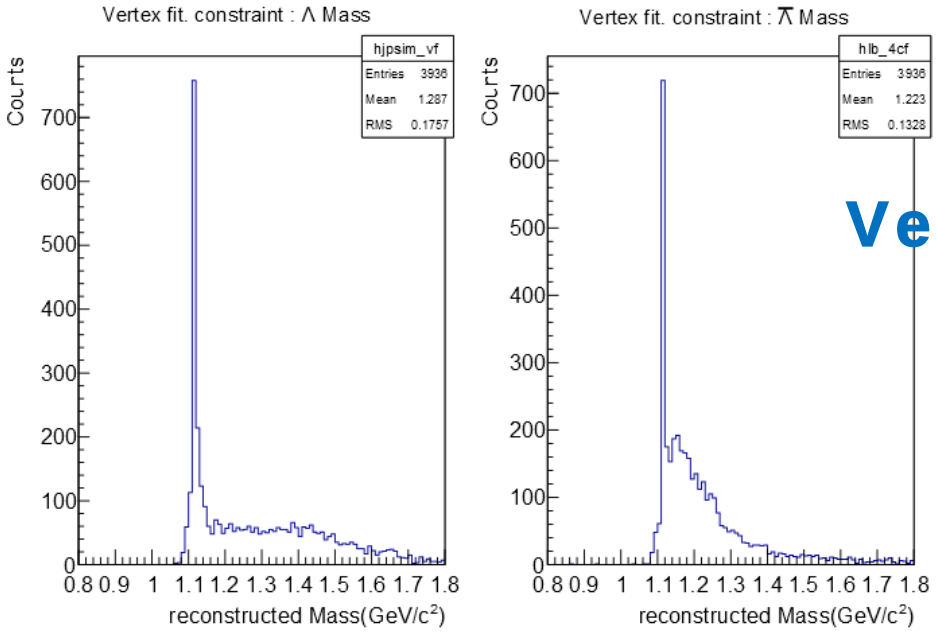
Scenario 3 : Reduced Setup (no Emc, no Fwd Spec, no Lambda discs) + full Mag. field

Scenario 4 : Reduced Setup (no Emc, no Fwd Spec, no Lambda discs) + half Mag. field

All : Realistic Tracking , PID, Mass Constraint Filter

Λ / $\bar{\Lambda}$ Reconstruction





- Full PANDA set up.
- 1T Solenoid Magnetic field.

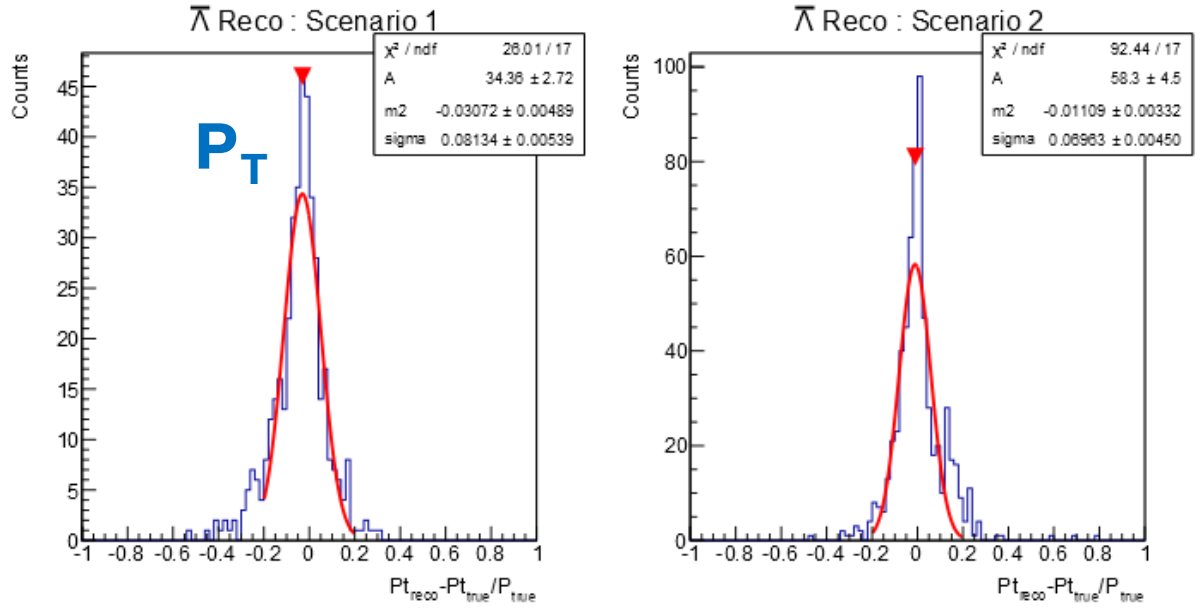
Mass CF

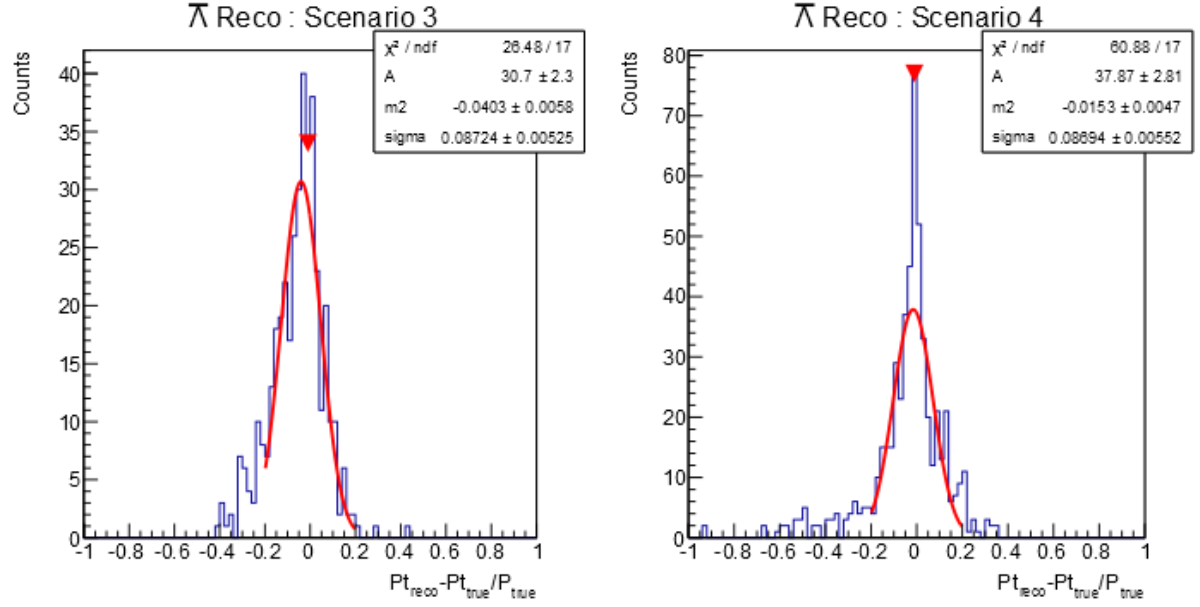
- Mass Filter constraint
- Good performance

Vertex CF

- Vertex filter constraint
- Not so good performance
  - Not able to reconstruct decay products properly

Building Asymmetries: Pull P_T and P_z





- 4 scenarios of the PANDA set up.
- 1T Solenoid Magnetic field.
  - Λ / $\overline{\Lambda}$ Candidates selected which fulfill Mass Filter const.
  - Poor tracking efficiency for P_T
  - Better behavior for P_Z
  - Improvement are needed.

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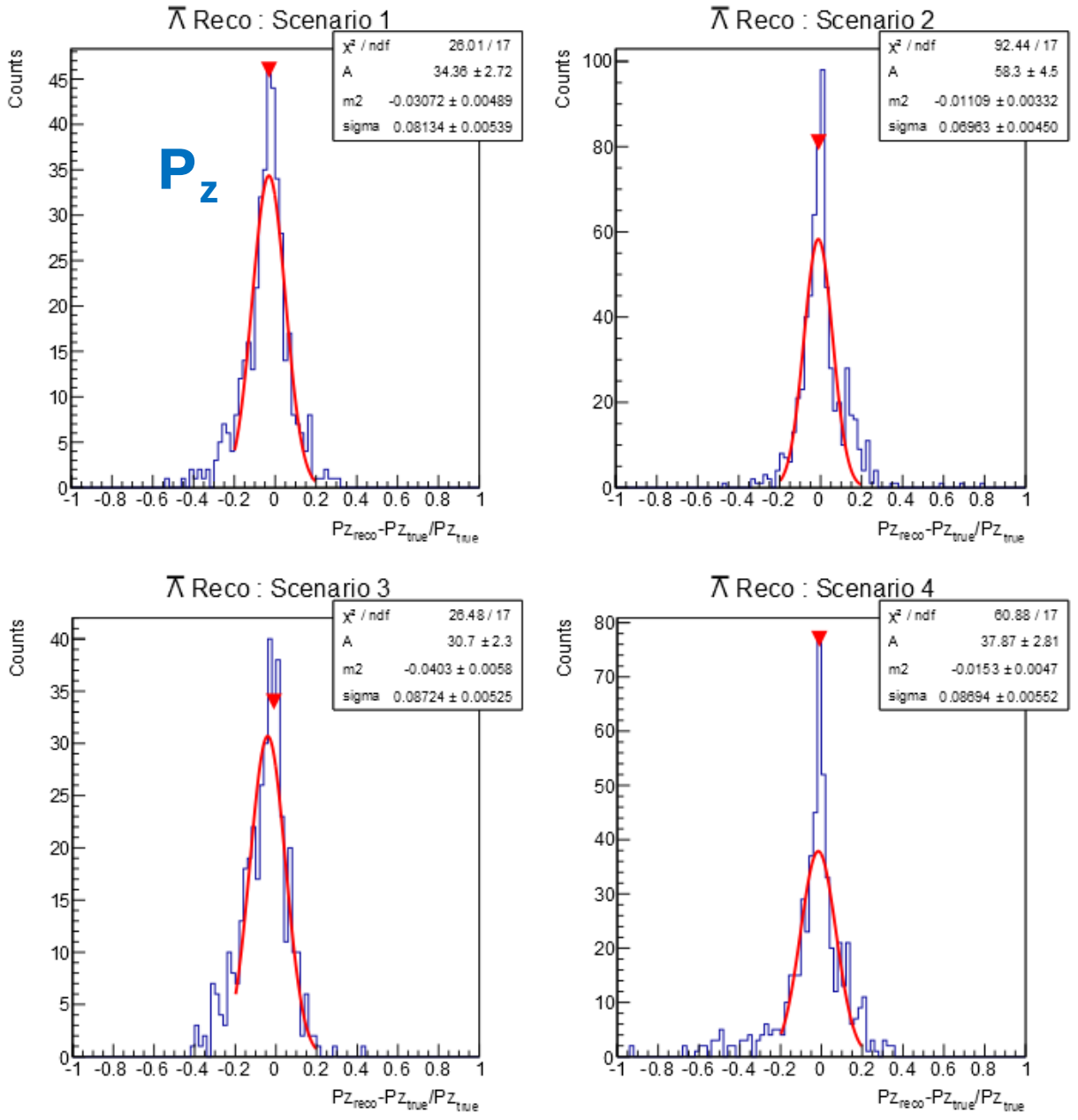

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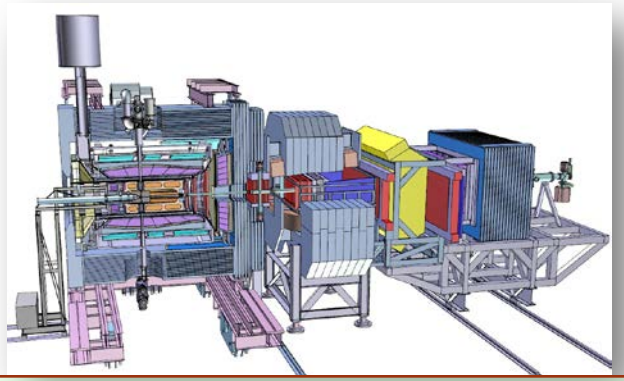

- Typical (*preliminary*) $\Lambda\overline{\Lambda}$ pair efficiency ≈ 3-5% (better at higher momenta)
- $\Lambda+\overline{\Lambda}$
  - ^{nat}Ne target, H for calibration
  - only charged particle detection *easy*
  - Assume average interactions rate $10^5 s^{-1}$ i.e. *~1% of default luminosity*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

  ⇒ $2.6 \cdot 10^{11}$ detected interactions

  - pair reconstruction efficiency 4%

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

40 × present GiBUU simulations

Summary and conclusion

- Analysis procedure in good shape
- Further studies considering
  0.5 T and E = 850 MeV (threshold) are in preparation
- Improvement of analysis filters in Pandaroot
- Finding a solution to the wrong true MC Match

THANK YOU FOR YOUR ATTENTION