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Time-based reconstruction of hyperons at the PANDA experiment at FAIR

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Start seminar of Jenny Regina

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Outline

- Prologue
- Why hyperons?
- Hyperon physics with PANDA
- Challenges with hyperons
- PANDA@HADES
- Summary and outlook

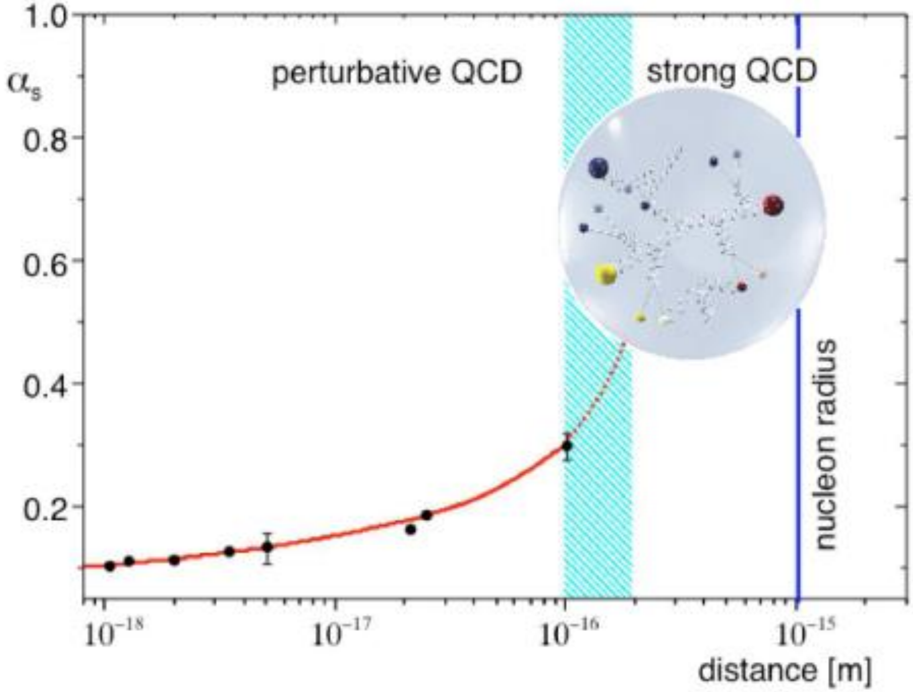
Prologue

Missing in the Standard Model of particle physics:

A complete understanding of the strong interaction.

- Short distances / high energies: pQCD rigorously and successfully tested.

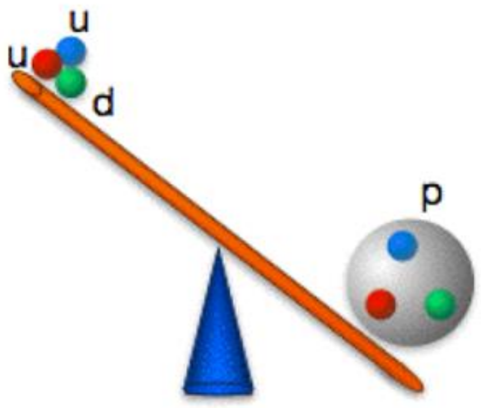
- Charm scale and below: pQCD fails, no analytical solution possible.

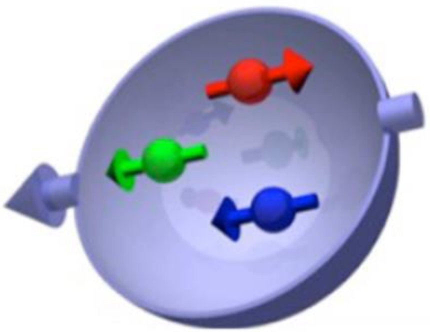


Prologue

Many fundamental puzzles manifest in the **nucleon:**

- Discovered a century ago.
- Still, we don’t understand
  - Its abundance
  - Its mass
  - Its spin
  - It radius
  - Its inner structure





Prologue

Abundance: matter-antimatter / nucleon-antinucleon asymmetry of the Universe.

Equal amounts in Big Bang (?)
→ Where did the anti-nucleons go?

Baryogenesis*: possible if

- Baryon number violation
- CP violation
- Processes outside thermal equilibrium.

Picture from Virginia Tech

*A. D. Sakharov, JETP 5 (1967) 24-27

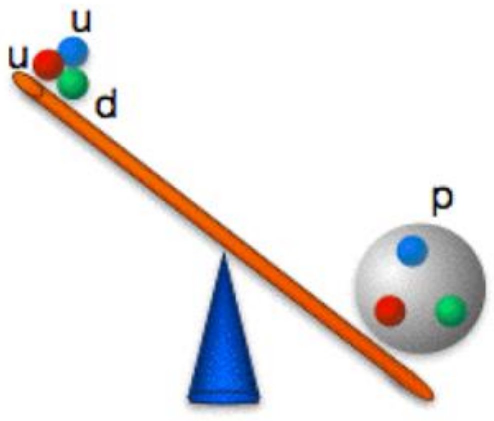
Prologue

Mass:

- Summing quark masses: 1% of total proton mass.

→ 99% of the visible mass in the Universe is dynamically generated by the strong interaction!

But how?

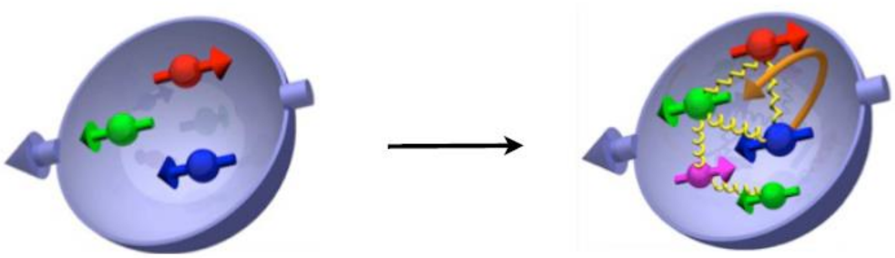


Prologue

Spin:

- Valence quark spin only cause ~1/2 of the total nucleon spin*.

- Proposed solution to *spin crisis:*
  - Sea quarks?
  - Gluons?
  - Relative angular momentum?



*C. A. Aidala *et al.*, RMP 85 (2013) 655-691.

Prologue

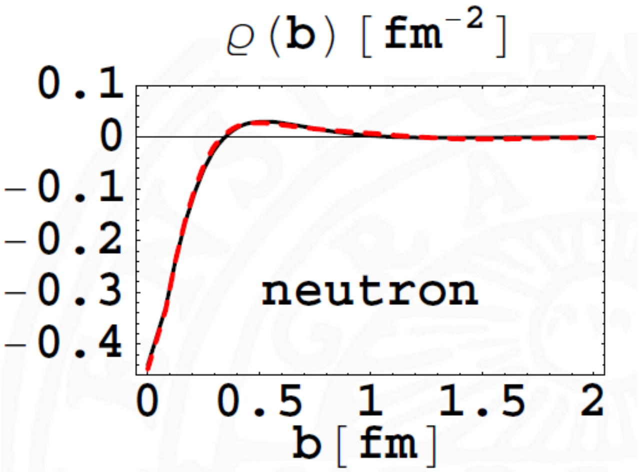
Radius: measured in

- Electron-nucleon scattering
- Electronic hydrogen spectrum
- Muonic hydrogen spectrum.

Results disagree.*

Inner structure:

- Neutron charge distribution intruguing.**



*R. Pohl, *Nature* 466 (2010)7303, 213-216.
** G. A. Miller, PRL 99 (2007) 112001.

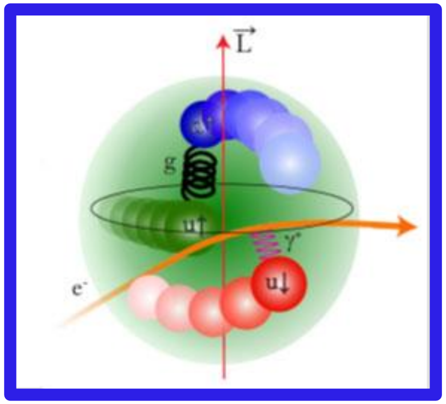
Approaches

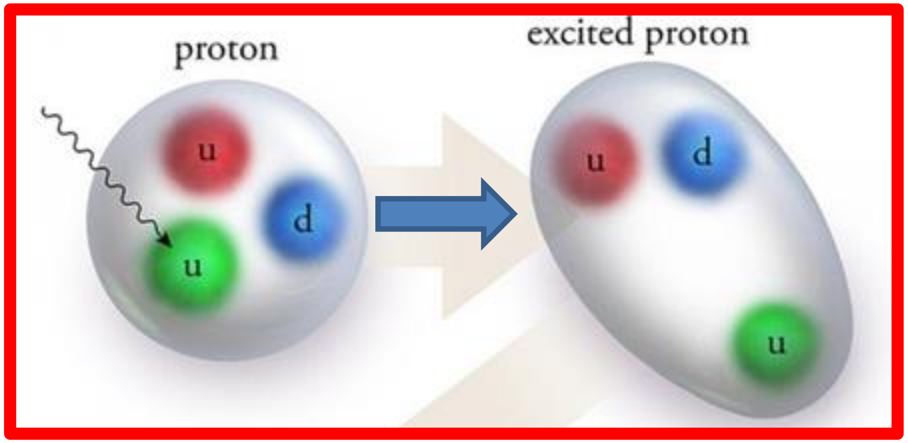
When you don’t understand a system, you can*

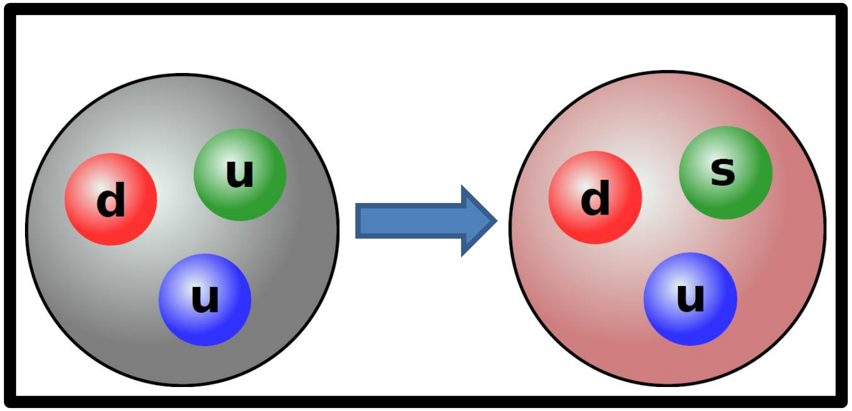
– Scatter on it

– Excite it

– Replace one of the building blocks



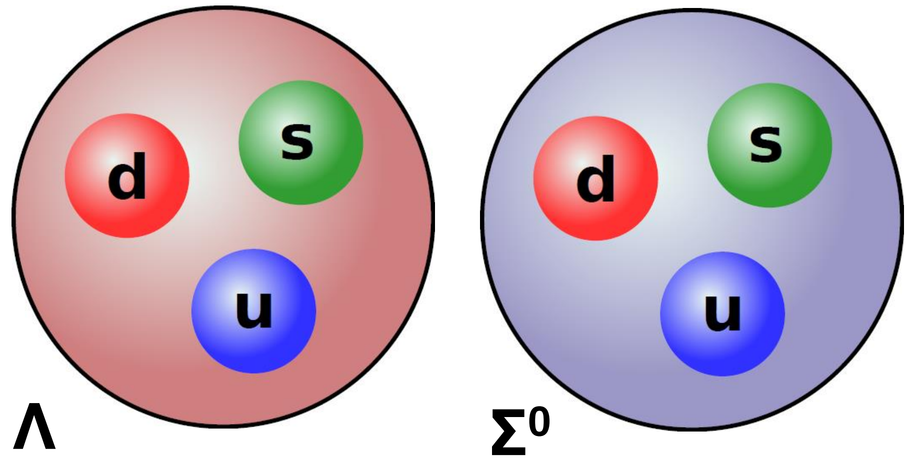


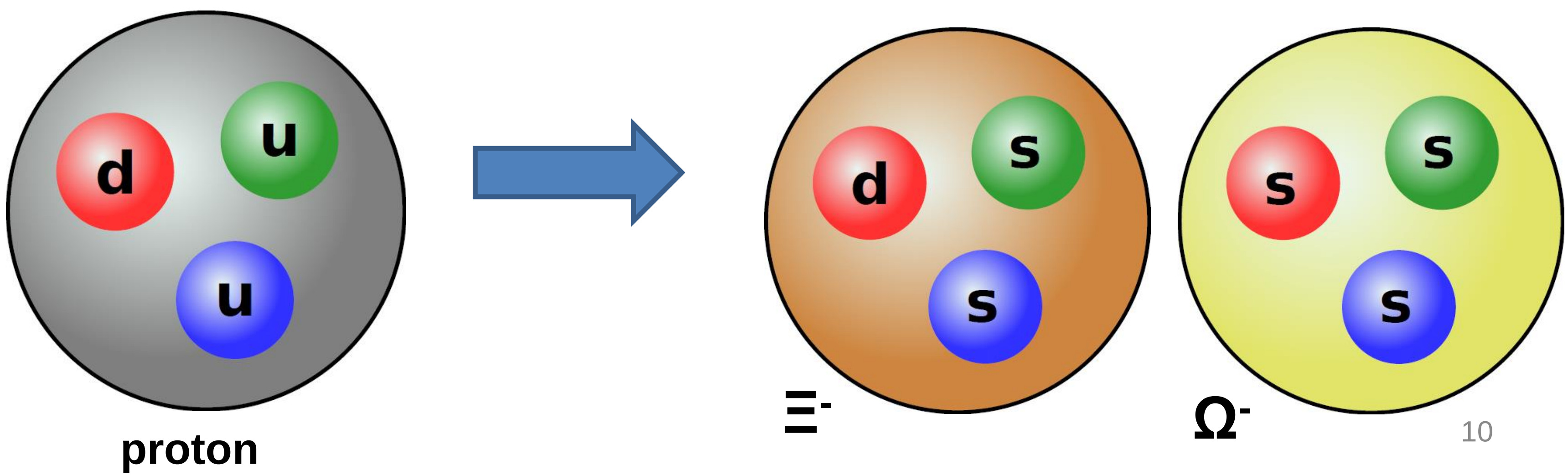


*C. Granados *et al.*, EPJA 53 (2017) 117

Why hyperons?

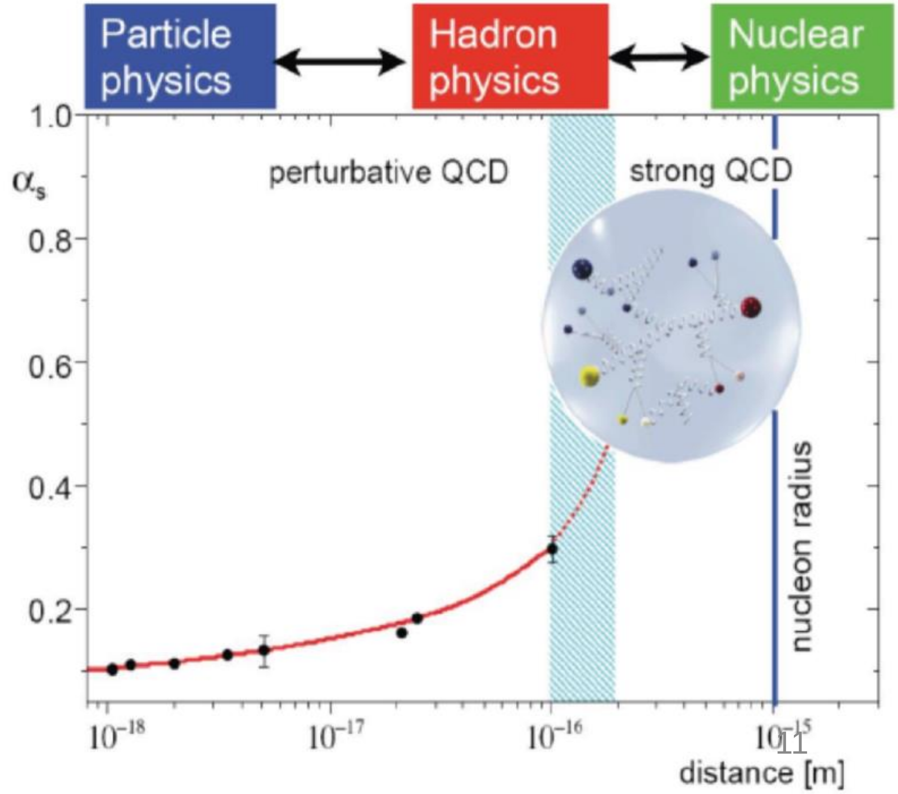
What happens if we replace one of the light quarks in the proton with one - or many - heavier quark(s)?





Why hyperons?

- Systems with strangeness
  - Scale: $m_s \approx 100$ MeV ~ $\Lambda_{QCD} \approx 200$ MeV.
  - Relevant degrees of freedom?
  - **Probes QCD in the confinement domain.**
- Systems with charm
  - Scale: $m_c \approx 1300$ MeV.
  - Quarks and gluons more relevant.
  - **Probes QCD just below pQCD.**



Why hyperons?

Traceable spin:

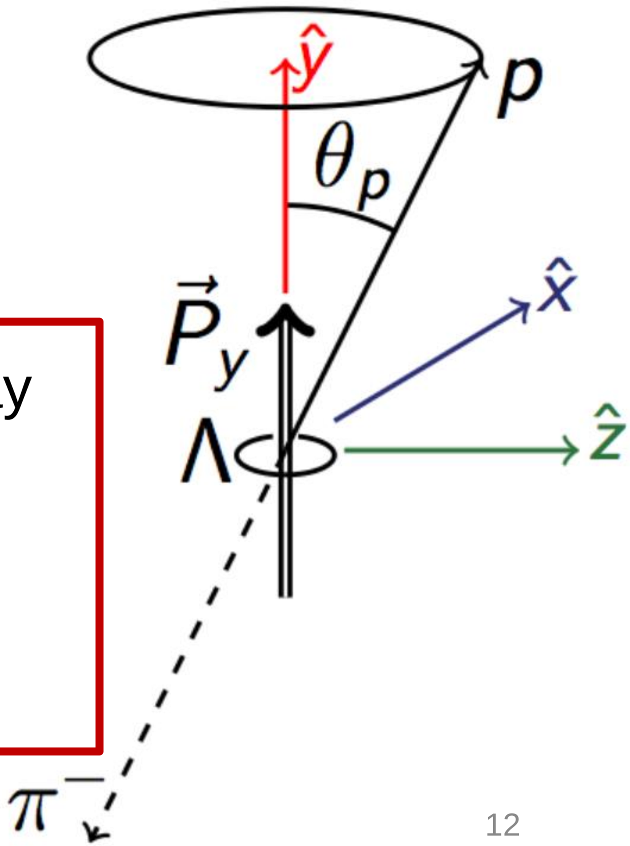
Polarization experimentally accessible by the weak, parity violating decay:

Example: Angular distribution of $\Lambda \to p\pi^-$ decay

$$I(\cos\theta_p) = N(1+\alpha P_\Lambda \cos\theta_p)$$

P_Λ : polarisation

α = 0.64 asymmetry parameter



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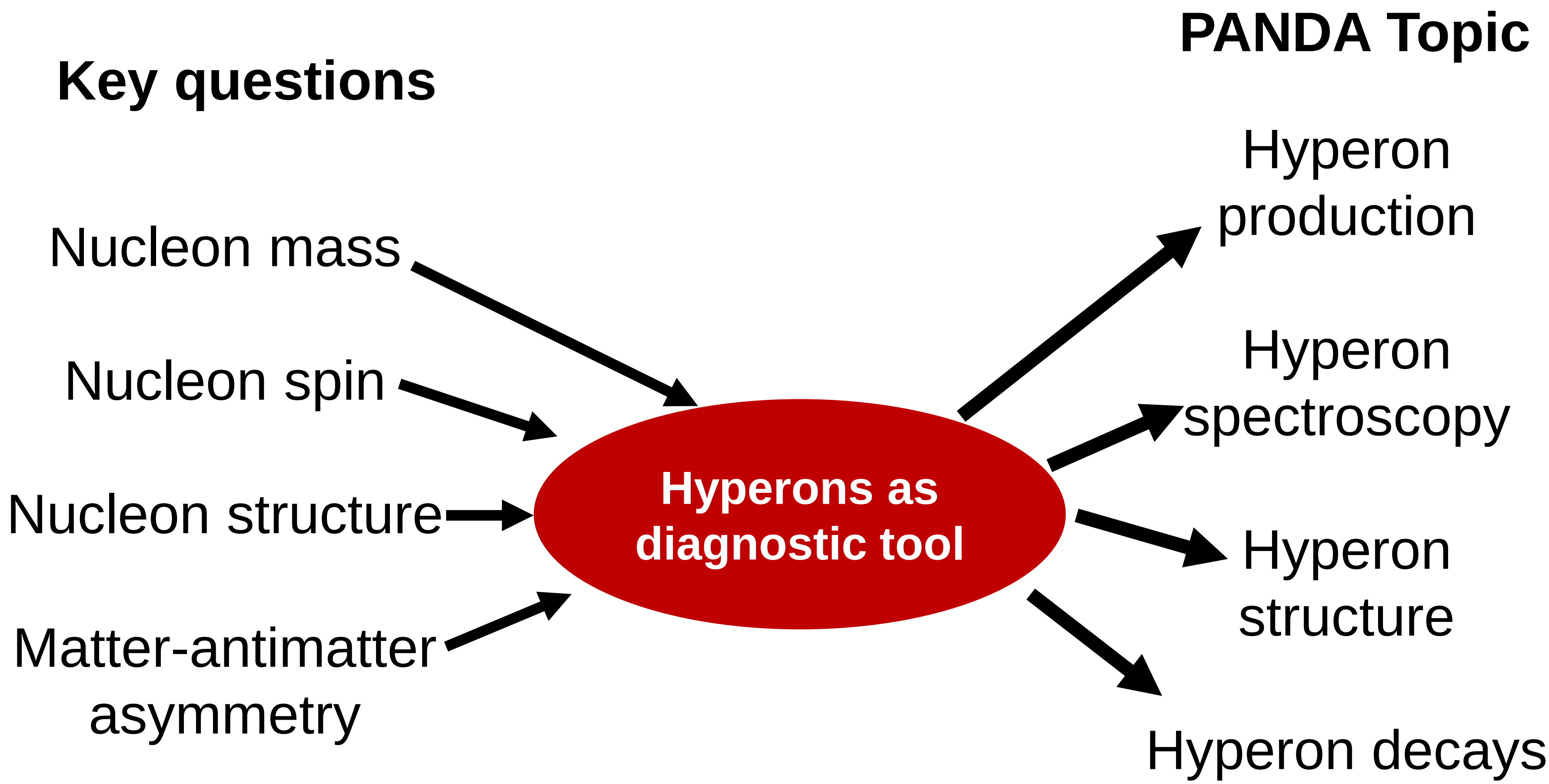
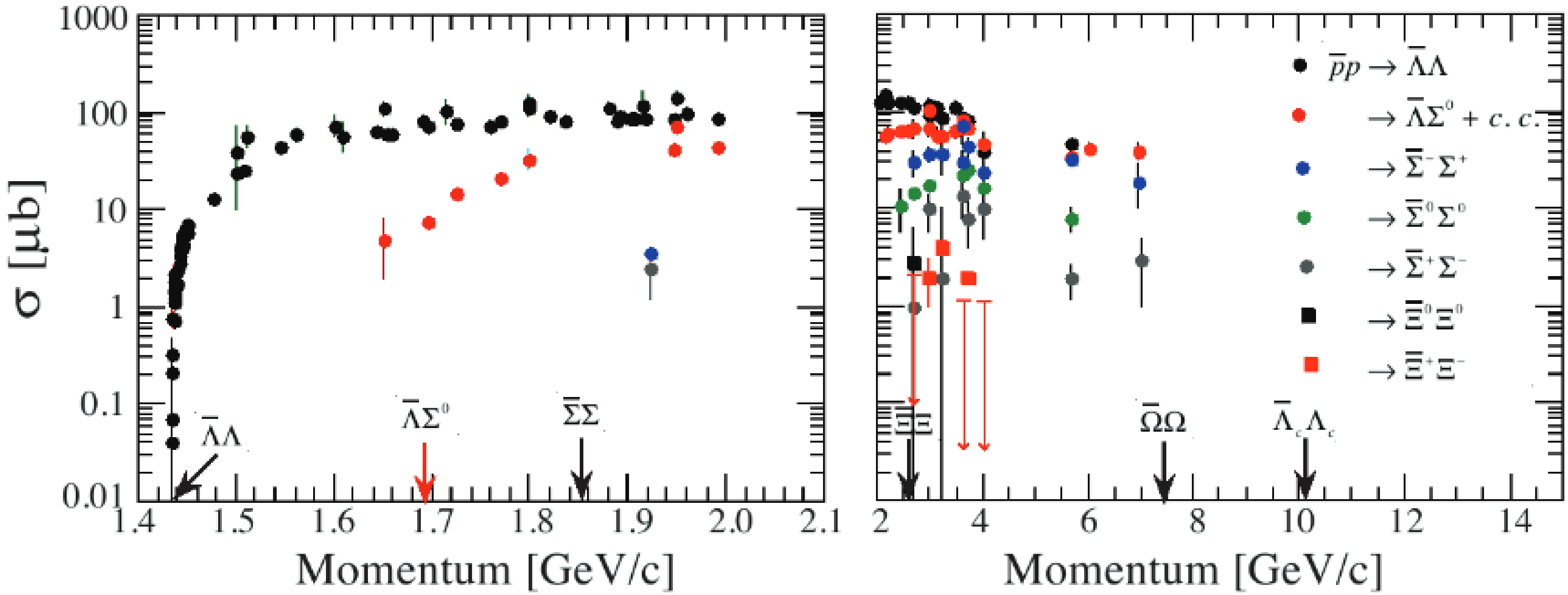
Hyperon Physics with PANDA



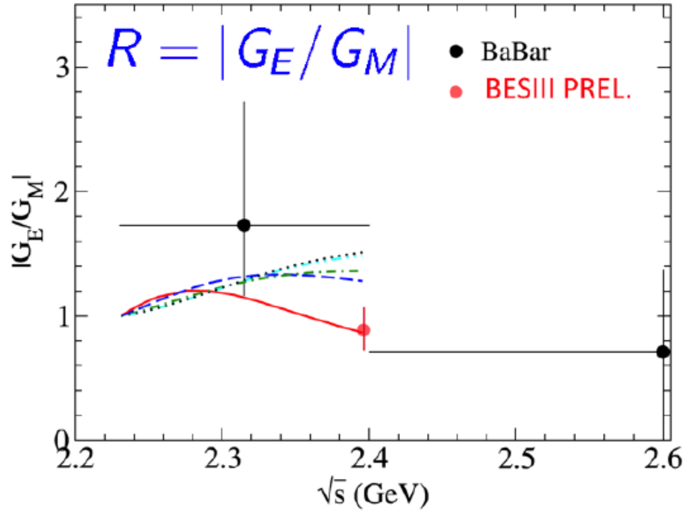
Hyperon production in $\bar{p}p$ annihilations

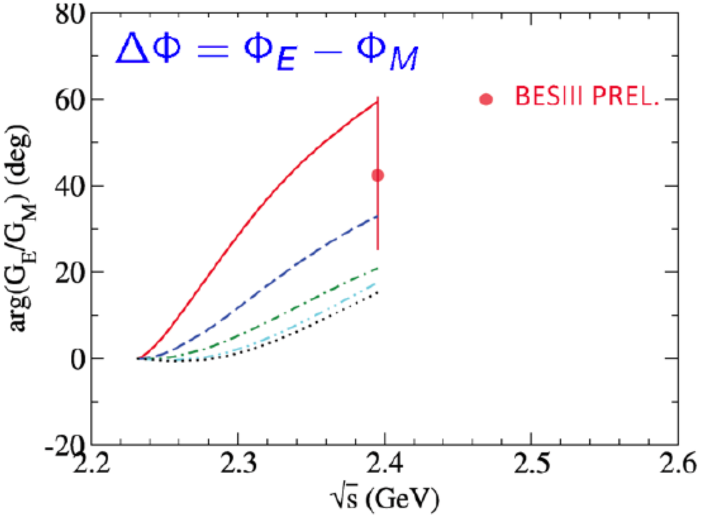


- Mainly single-strange data.
- Scarce data bank above 4 GeV.
- No data on Ω or Λ_c.

T. Johansson, AIP Conf. Proc. of LEAP 2003, p. 95.

Hyperon production





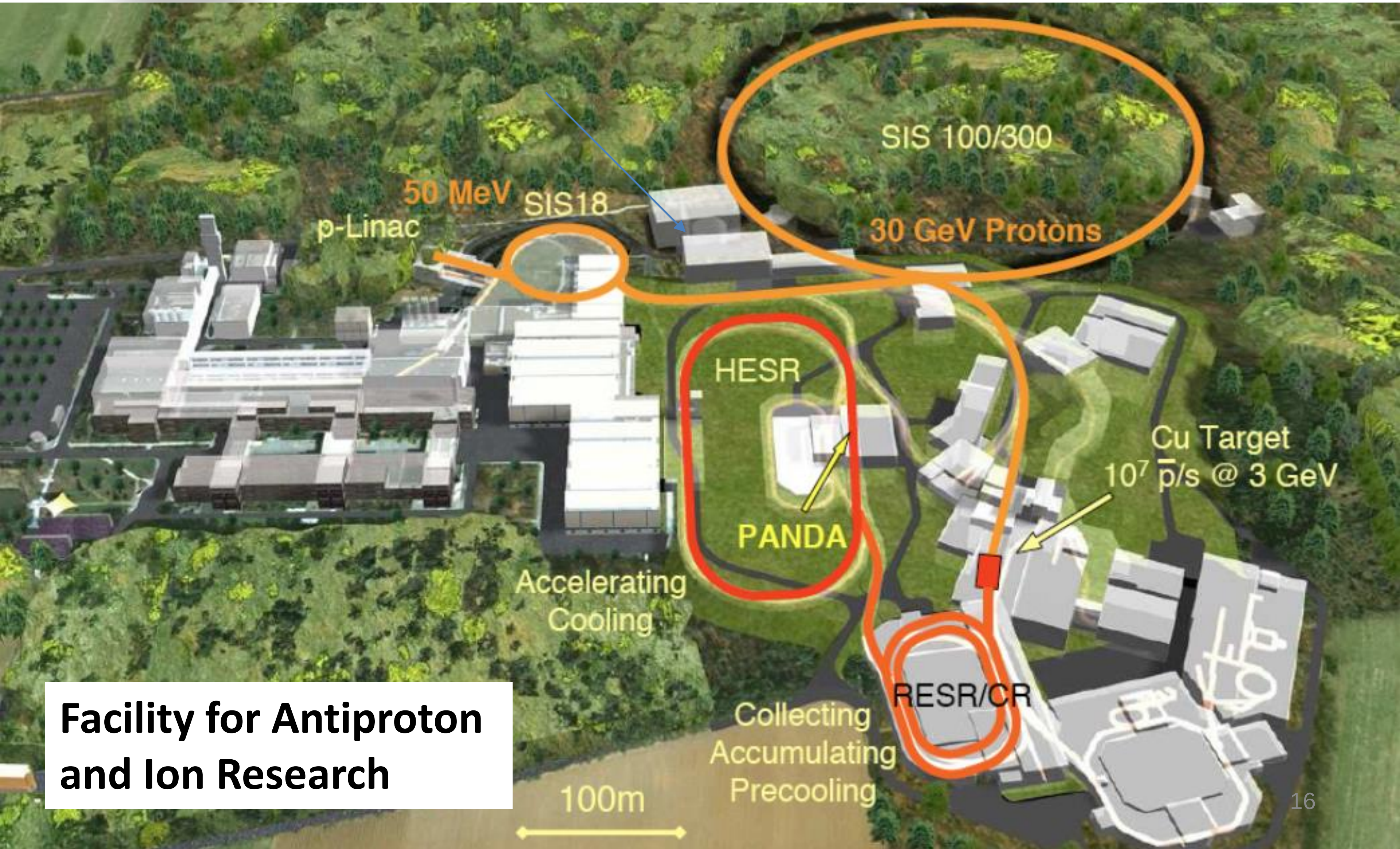
Spin observables sensitive to the interaction process.

- Prediction for $e^+e^- \to \bar{Y}Y$ based on potential models obtained with $\bar{p}p \to \bar{Y}Y$ data.*
- New data from BESIII on hyperon structure.**

  $\to$ Understanding $\bar{Y}Y$ interaction important!

*PLB 761(2016) 456
BaBar: PRD 76 (2007) 092006
***BES III: Talk by C. Li, BEACH2018

The PANDA experiment at FAIR



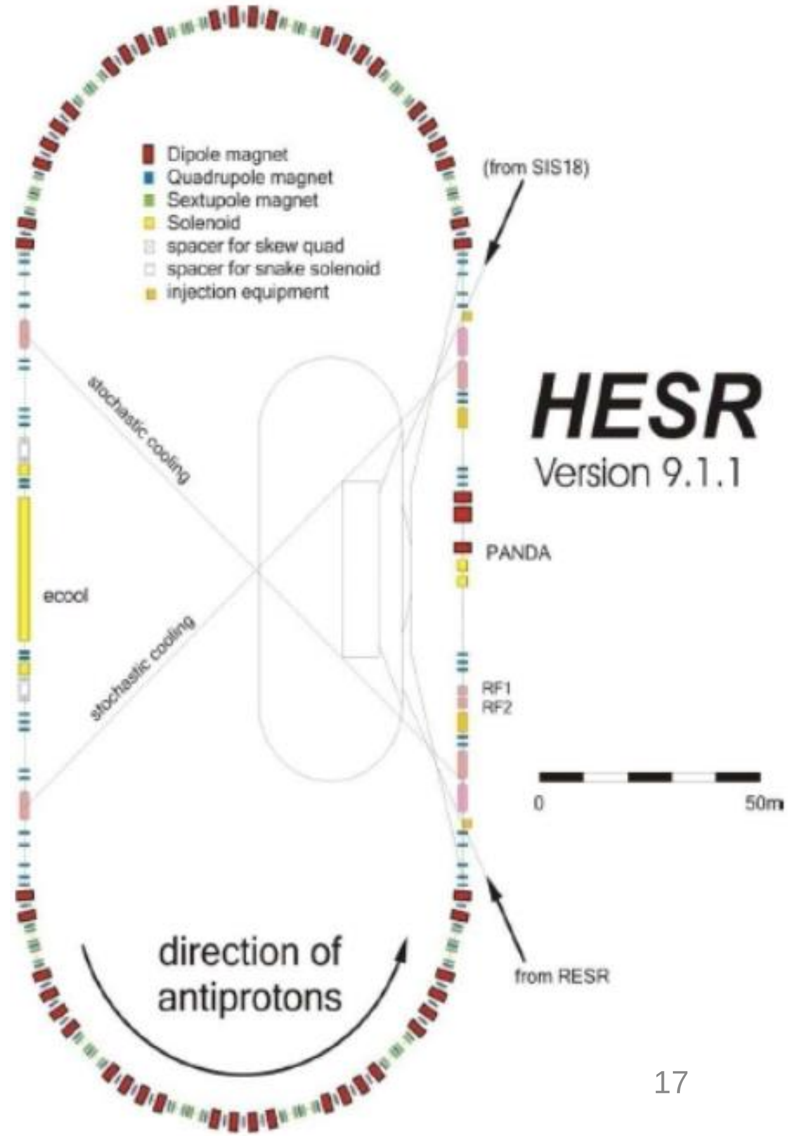
Facility for Antiproton and Ion Research

The PANDA experiment at FAIR

The High Energy Storage Ring (HESR)

- Anti-protons within

  1.5 GeV/c < p_{pbar} < 15 GeV/c
- Internal targets
  - Cluster jet and pellet ($\bar{p}p$)
  - Foils ($\bar{p}A$)



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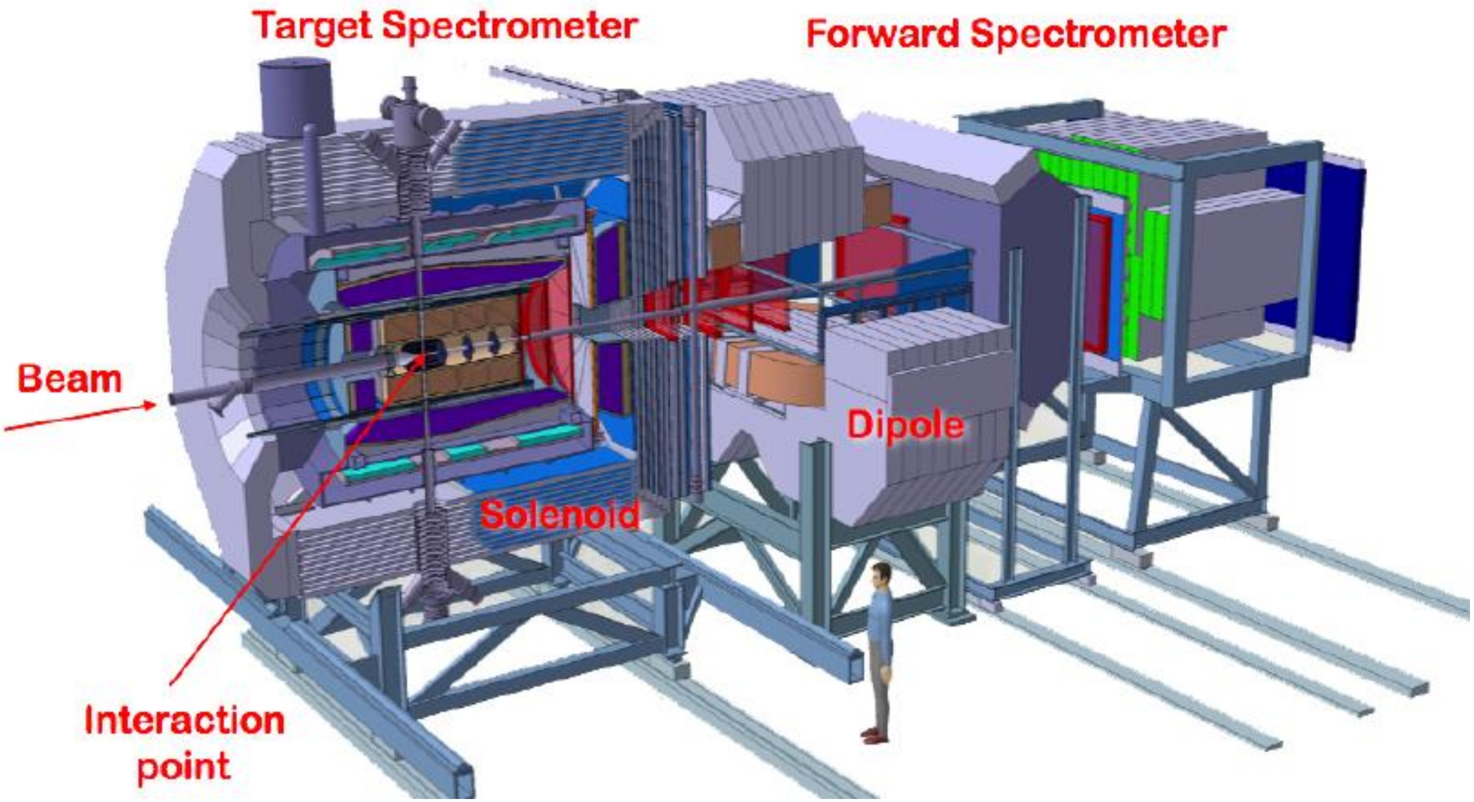
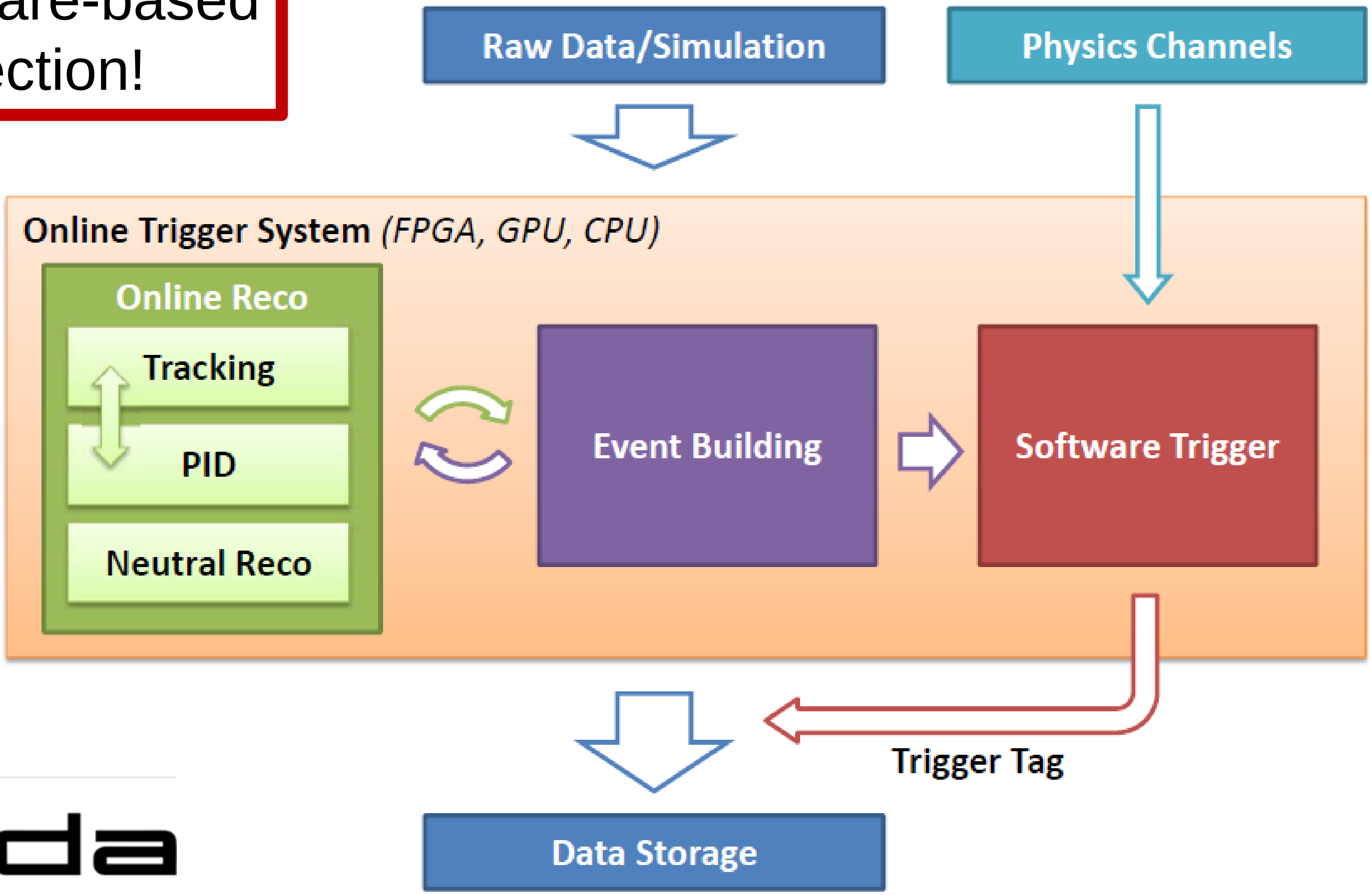
The PANDA experiment at FAIR



- 4π coverage
- Precise tracking
- PID
- Calorimetry
- Vertex detector
- Modular design
- Time-based data acquisition with software trigger

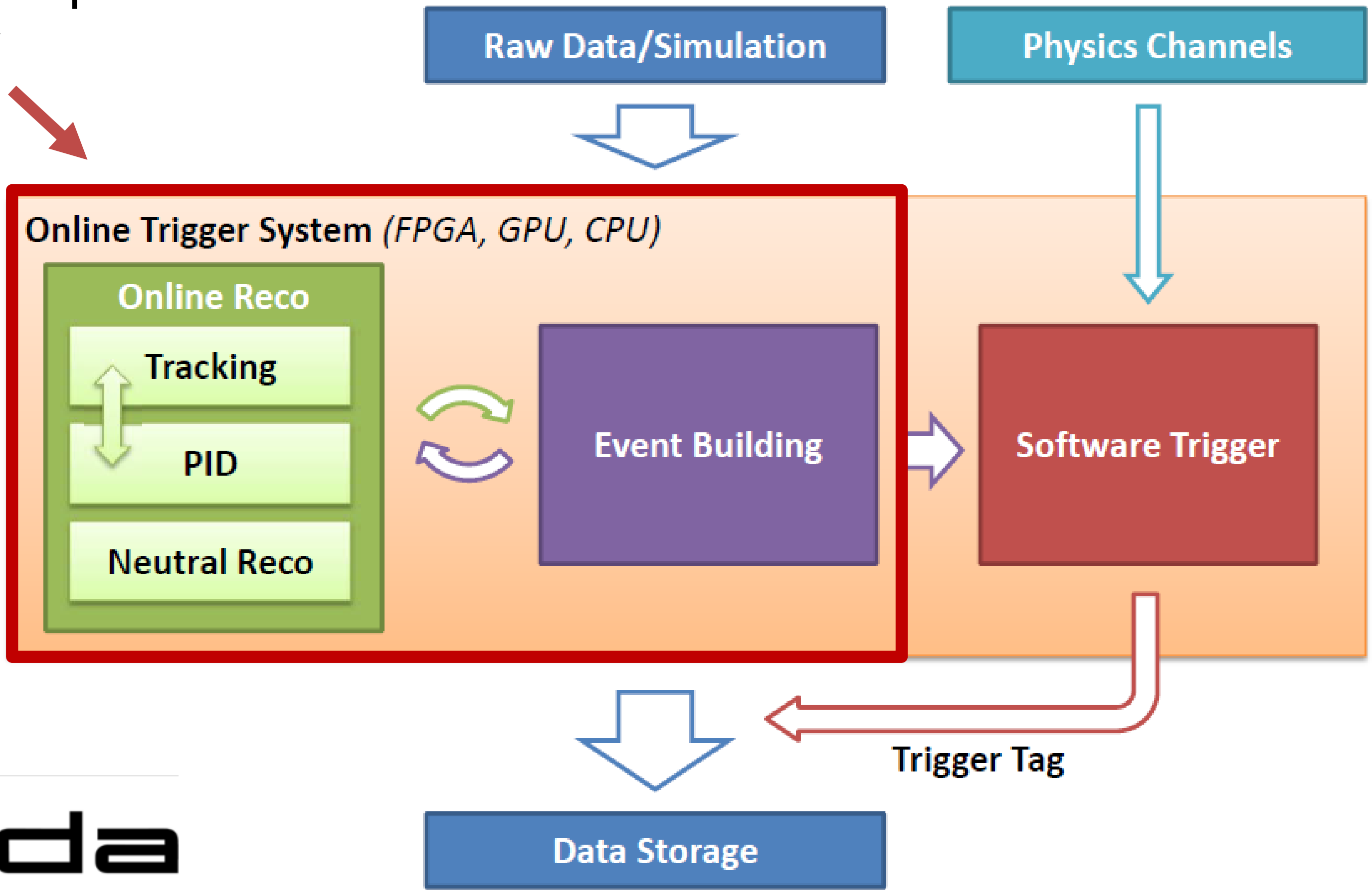
Online reconstruction and filtering

PANDA will use an entirely software-based data selection!



Online reconstruction and filtering

Algorithms will depend on event topology



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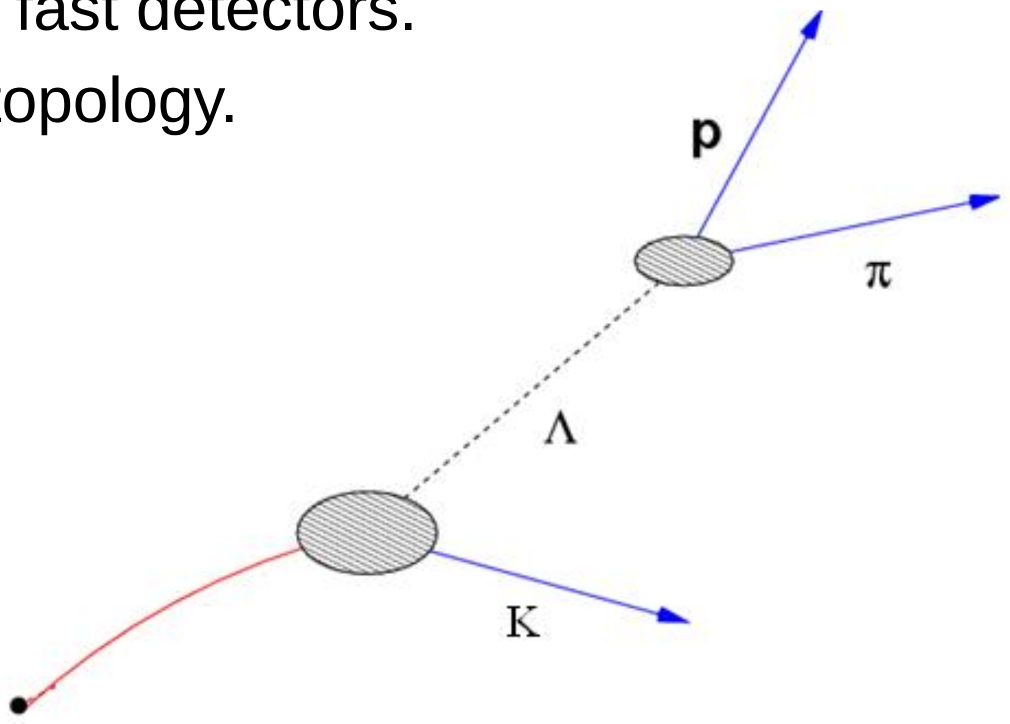
Challenges in hyperon reconstruction

Weak decays → displaced vertices

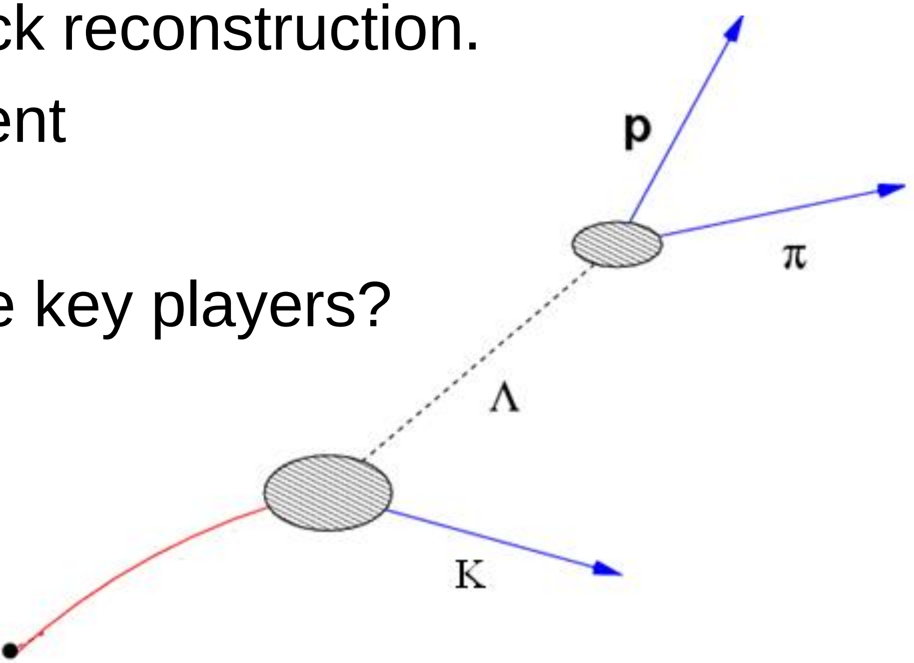
- Tracks do not come from the interaction point.
- Hyperons may miss fast detectors.
- Complicated event topology.



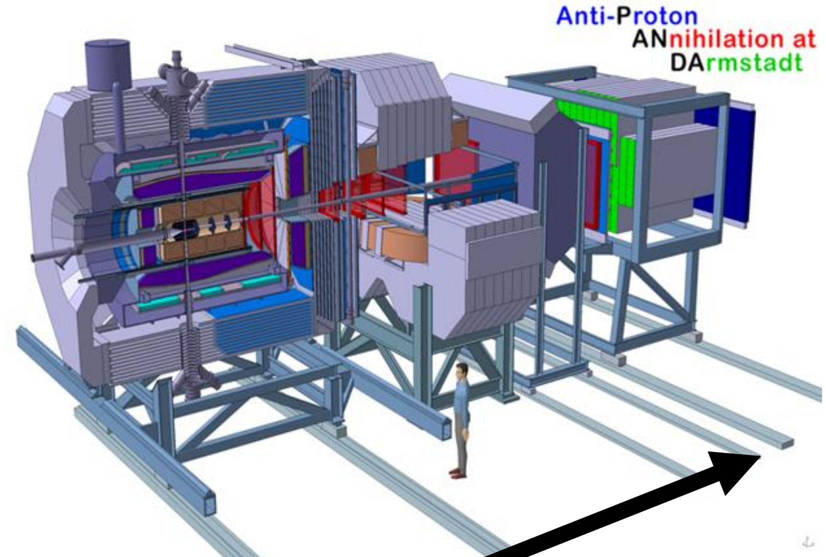
Challenges in hyperon reconstruction

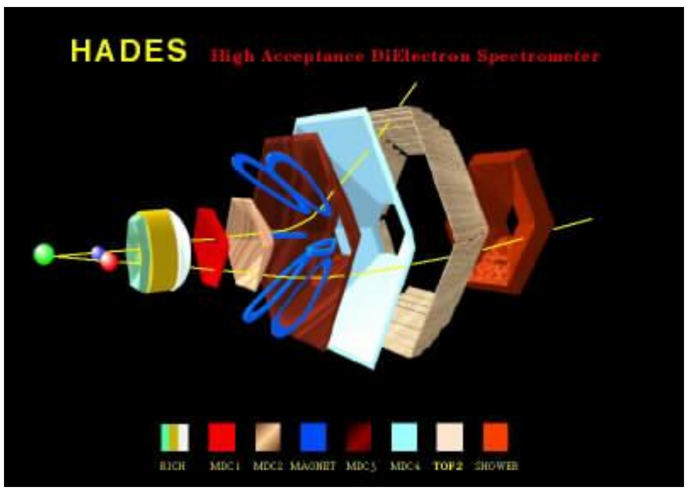
Need a data selection scheme compatible with the complex hyperon topology

– Independent of track origin.
– Dynamic event and track reconstruction.
– Paradigm changing event filter concept.
– Which detectors are the key players?



PANDA @ HADES



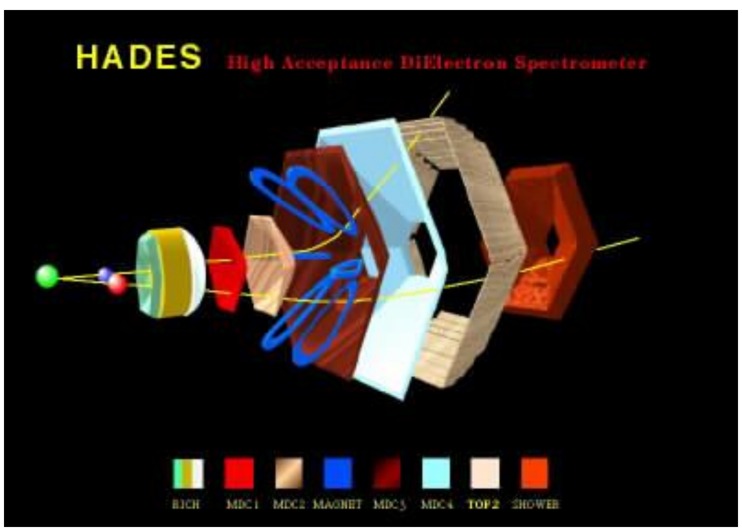


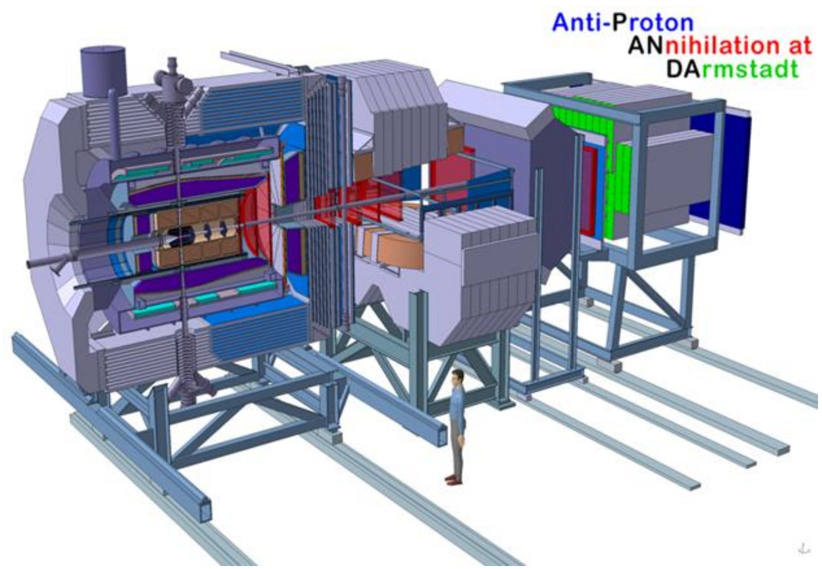
New Memorandum of Understanding between PANDA and HADES!

- Possible to test tools and methods on real data!
- Possible to do hyperon physics in Europe before PANDA@FAIR!

Interesting questions for HADES/PANDA

- Electromagnetic transitions of octet- and decuplet hyperons
  - $Y_A \rightarrow Y_B \gamma$ (mainly $\gamma\Lambda$ quasi-final states)
  - $Y_A \rightarrow Y_B e^+ e^-$ (mainly $e^+ e^- \Lambda$ quasi-final states)
  - $Y_A \rightarrow Y_B \gamma \pi$





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Summary

- Many fundamental questions manifest themselves in our (lack of) understanding of the nucleon.
- Strategy: replace one of the building blocks → hyperons!
- Hyperons of different flavour probe different scales of the strong interaction.
- Self-analyzing decay → help pinpointing the role of spin.

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Outlook

- Collecting and reconstructing hyperon events is a challenging task!
- Need detailed knowledge of hyperon signals in the PANDA detector.
- Need a track reconstruction method that
  - Can be used online.
  - Is independent of the interaction point.
- PANDA@HADES opens up new possibilities:
  - Test tools and methods developed for PANDA
  - Do interesting hyperon physics before PANDA@FAIR.

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Thanks for your attention!