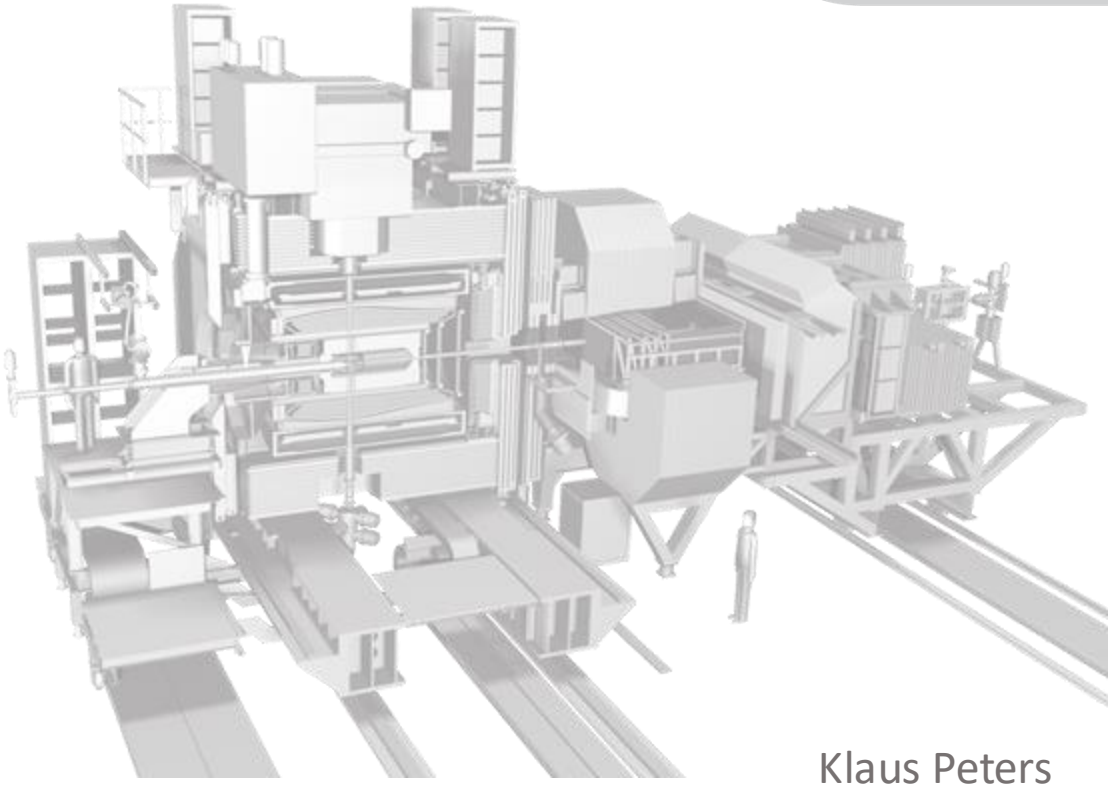
Antiprotons in COSY at FAIR

an opportunity for a stepwise approach towards PANDA

QCD at FAIR

GSI, Nov 13, 2024



Klaus Peters

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PANDA @ HESR FAIR

Status Quo

The ultimate goal is PANDA @ FAIR in MSV3/5

- No doubt that this is and remains the final solution !

Full MSVc after FS++ is difficult to accomplish
as a single additional step

- Thus, we need to take into account the resource situation and realistic timelines

At shorter timescales and with fewer resources needed, one could speculate about FS++(+)

- First experiments with Antiprotons at FAIR prior to MSVc

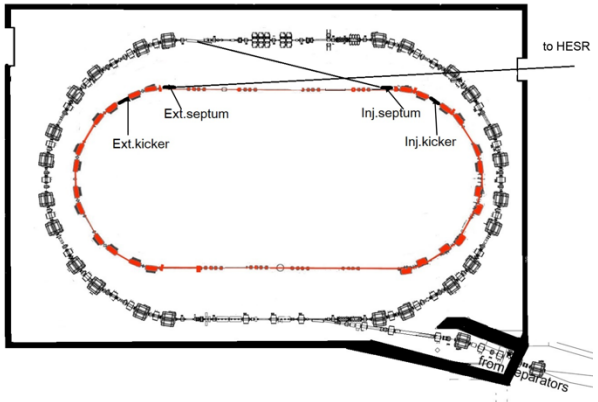
First Step : Conservation of COSY

- MSVc study group (lead by L. Schmitt) has presented to the committees (ECE and JSC) the results concerning COSY

- in a nutshell: dismantling costs 38-42 M€
  and conserving it for later use needs about +10% (must ~4 M€)

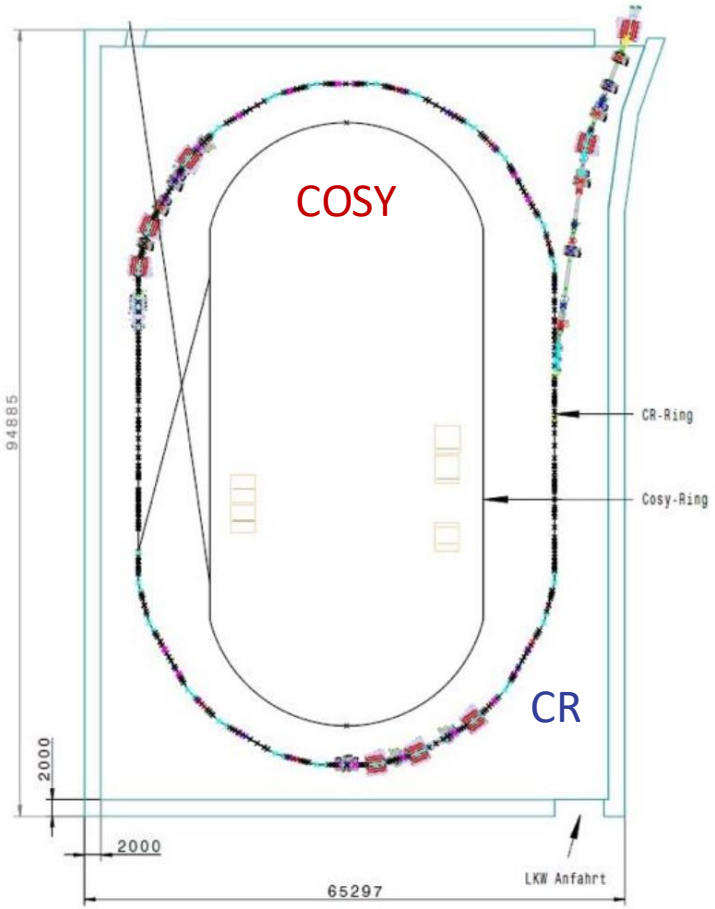
- an important aspect is, that the new CR hall layout
  with COSY may leave space for experiments with COSY

The decision to save COSY
must be taken very soon

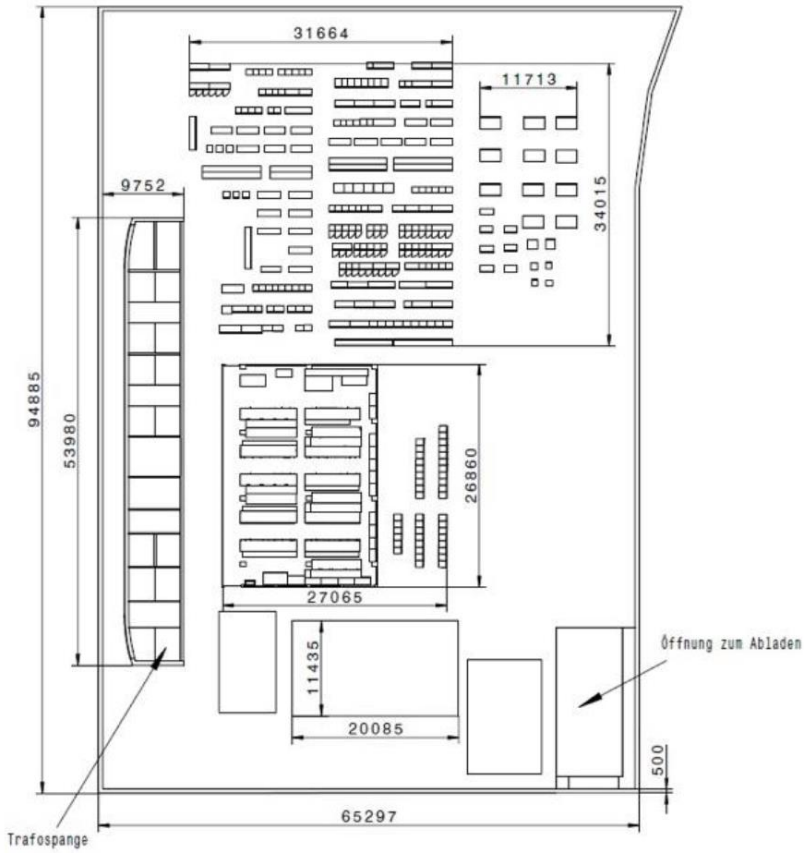


CR Hall Layout w/ COSY inside CR

Ground floor



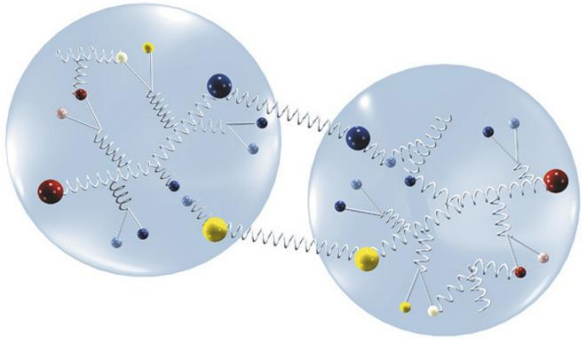
Upper floor



Physics in FS++(+)

COSY energy : $p_{\bar{p}} < 3.5$ GeV/c & $m_{CMS} < 2.92$ GeV/c^2

- Starting point Review 2022 / Highlights Reviewers
  - Glueballs
  - High Precision Scans of Charm
- Plus: Highlights from our Report to the Review 2022
  - $\Lambda\bar{\Lambda}$ CP-Violation
  - Double Λ-Hypernuclei

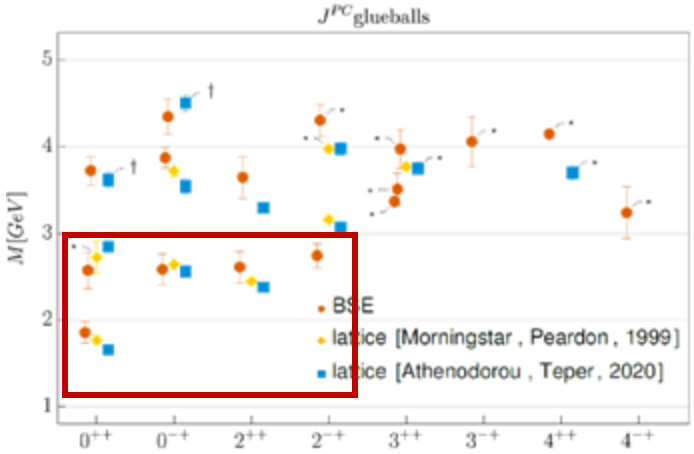


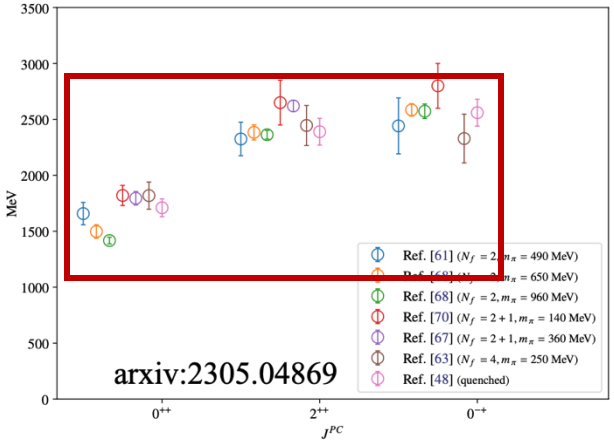
Physics in FS++(+)

COSY energy : $p_{\bar{p}} < 3.5$ GeV/c & $m_{CMS} < 2.92$ GeV/c^2

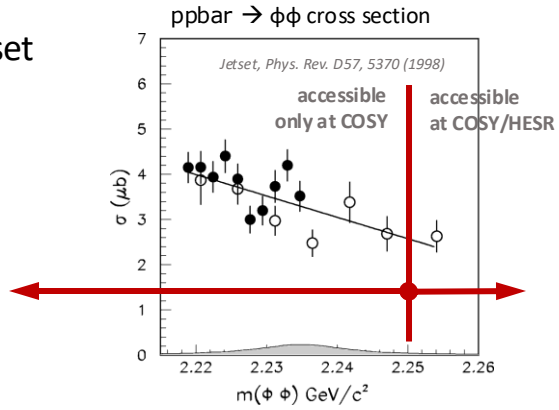
- Starting point Review 2022 / Highlights Reviewers
  - Glueballs (partly possible)
  - Energy too low: ~~High Precision Scans of Charm~~
- Plus: Highlights from our Report to the Review 2022
  - $\Lambda\bar{\Lambda}$ CP-Violation
  - Double Λ-Hypernuclei
- Plus: many other topics from our Physics book
- Plus: topics which require momenta below 1.5 GeV/c

Glueballs

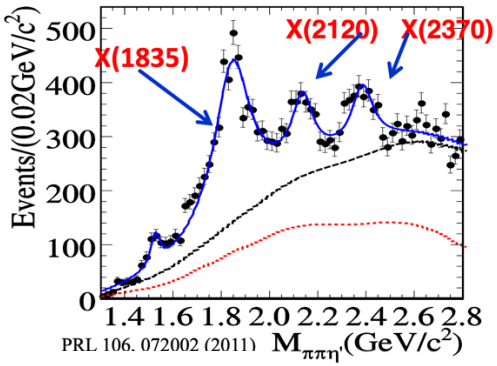




Jetset



BESIII



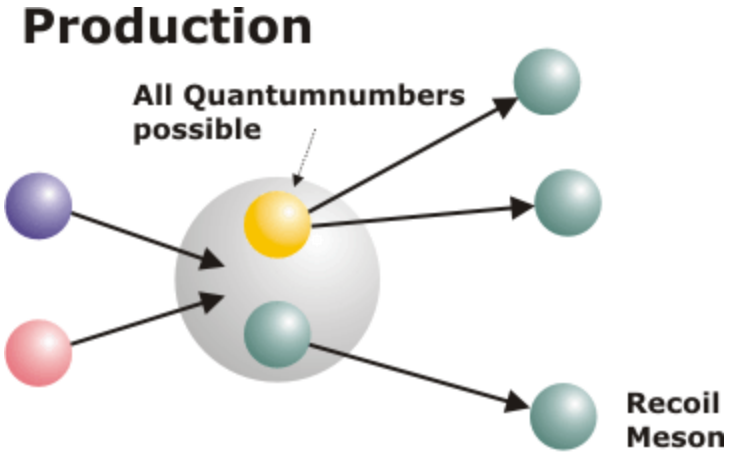
- can be studied in Formation and Production

Modes of Operation

Antiproton-Proton Annihilation is

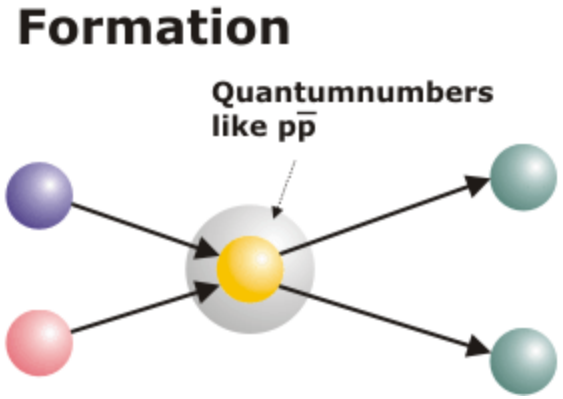
- a gluonrich process
- an antiquark-quark rich process

Thus, it is extremely versatile



main modes of operation

- Production : which has the least restrictions for the final state
- Formation : which has the highest precision and yields the smallest ambiguities



Formation Mode Experiment

Energy scan (first coarse, then fine)
Trigger on specific channels and Minimum Bias
Luminosity detection and monitoring
Mass independent Partial Wave decomposition of final states

- well constrained 2-body formation reactions can be decomposed model-independent bin-by-bin
  - like e.g. Vector+Pseduoscalar, 2 Vectors, 2 Tensors, Tensor+Pseudoscaler, Tensor, Vector etc.
- 3-body formation reactions still need modelling of intermediate states
  - but the analysis bias is much smaller compared to (3+1)-body production

Main Targets (tbc.)

- 0^{++}, 0^{-+}, 2^{++}, 2^{-+} glueballs
- Single and double strange tetraquarks
- Strangeonium Hybrids
- Strange Hexaquarks

Trade-off: no exotic Quantum-Numbers

Other modes

- Production is the only possibility to identify states with exotic Quantum numbers
  - the statistics at COSY at FAIR would superseede the statistics of Crystal Barrel and Obelix by several orders of magnitude
  - the analysis is extremely difficult, quite model dependent and ambiguous
  - IMHO: Should be done nonetheless, but it may be not the first experiment to perform
- Antihyperon-Nucleon Annihilation
  - one example are Anti-Ξ-Proton reactions to create double Λ-Hypernuclei in a secondary target
  - or a "Λ beam" to create final states with open strangeness in a secondary target ("Kaon facility")

PANDA Physics $p_{\bar{p}} < 3.5$ GeV/c / $m_{CMS} < 2.92$ GeV/c^2

Highlights / Flagship Experiments

- Glueballs (Tensor, Scalar, Pseudoscalar and Pseudotensor)
- Double Λ-Hypernuclei
- ΛΛ̄ CP-Violation

as well as

- Other Light Exotics (e.g. Hybrids, Multiquarks from uds)
- Strange Meson Physics
- Strangeness in Nuclei (hyperon-N physics)
- Hyperon Physics (S=1[,2] Dynamics and Spectroscopy)

plus

- Λ̄ beam for secondary reactions : Kaon production
- Physics with momenta below HESR range (Pontecorvo a.o.m.)

It is evident that a lower energy region could only be a first step

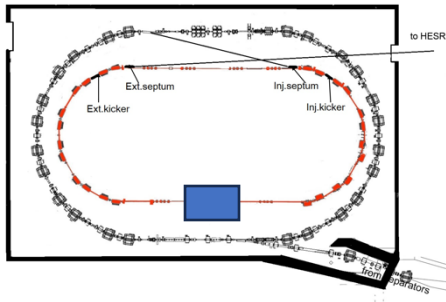
Idea of a Lower-Energy Antiproton Expt

Due to lower energies and lower multiplicities
the necessary detector layout could benefit from

- already completed PANDA components
- reused detectors and magnets from elsewhere
- very few new (or copied) detectors

which would result in low residual costs compared to MSVc

Lower-Energy Antiproton Experiment



- all previous simulations have been done with HESR properties and the PANDA Detector
- simulation studies must be redone with COSY properties and a Low Energy Experiment
  - studies would start with the flagship expts
  - Toy MC to optimize basic properties of a detector setup
  - investigate COSY operation parameters
- Detector Workshop at GSI (2025, March 5-7)
- Physics Workshop on High and Low Energy Antiproton Physics in Uppsala in (2025, June 16-20)
  - jointly organized together with our Theory Advisory Group
  - revisit our physics case for the low and high energy range
  - identification of new topics for the low and high energy range
  - collect material for an LoI
- “Antiprotons @ FAIR” Workshop at GSI in Summer 2026

and what about PANDA @ HESR ?

PANDA @ HESR remains our goal

The Science Review from 2022 clearly indicates
the uniqueness of our scientific program
and MSV Completion is mandatory to realize it

just to mention a few things

Exotic Glueballs, Exotic Charm(onium) and scanning, S>1 Hyperon Spectroscopy and Dynamics and most Electromagnetic Physics are only possible with the HESR beam !

and with an active Antiproton-Community at FAIR there is
a good probability to realize PANDA eventually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FAIR
Thank you