1st Physics Questionnaire
Requirements for the (sub)systems from the physics case of the PANDA Detector

1. Physics Group: **Baryon Spectroscopy**

2. Physics Group Convener(s):
   Albrecht Gillitzer

3. List of groups involved:
   Univ. Basel, Univ. Bonn, Univ. Giessen, KVI Groningen, JCHP / FZ Jülich, IHEP Protvino

   List of relevant TAG members:
   Ch. Fischer, M. Lutz, S. Ryan

4. List of physics subtopics:
   Example: ccbar Hybrids, ccbar Molecule (XYZ), Light Exotics, Glueballs

   Study of excited states of:
   - Double-strange hyperons (Ξ^*)
   - Triple-strange hyperons (Ω^*)
   - Charmed hyperons (Λ_c^*, Σ_c^*)
   - Hidden charm hyperons ($N_{c\bar{c}}^*$), other non-qqq baryon states

   Note that charmed baryons are also discussed in the “Open Charm” physics working group.

   Except for first studies of Ξ excited states, the sequence of the subtopics in the above list does not directly reflect the time planning of the experiments. In expectation of a possibly extended start-up phase of PANDA with reduced luminosity and only partially equipped detector we propose to also include as additional subtopics studies of non-strange and single-strange baryons ($N^*, \Delta^*, \Lambda^*, \Sigma^*$). Excited states of these species can be produced with large cross sections and will certainly be already observable in the start-up phase of PANDA. These states can of course also be observed at any later stage with improved or full performance if the selected antiproton momentum is appropriate and additional trigger conditions are set accordingly. However, it is probably realistic to expect that then all activities will be focused on the analysis of more ambitious channels.
   We are convinced that important and interesting physics aspects are addressed in the study of non-strange and single-strange baryons in antiproton-proton collisions that are complementary to studies at other facilities using different probes. We therefore propose to add:

   Study of excited states of:
   - Non-strange baryons (N^*, Δ^*)
   - Single-strange hyperons (Λ^*, Σ^*).

   Details should be discussed with the theory advisory group in order to find out particular aspects not or not at the same quality accessible in other experiments. Therefore we postpone a detailed discussion of the selected channels as well as the related parameters and requirements after clarification of this issue.

5. Importance/Impact:
   should involve the PANDA TAG members
   a) Please give a short summary (< ½ page) for the motivation of this topic.

Understanding the internal degrees of freedom of baryons and thus their excitation modes is mandatory for any deeper understanding of the strong interaction. Along this motivation, since several years an intense worldwide experimental program on nucleon spectroscopy using photo-excitation is being carried on, thus extending earlier studies based on pion-induced reactions. Although these studies have delivered many valuable results, several basic issues concerning the nucleon spectrum such as the energies of the first radial excitation or the lowest negative parity state, or the so-called "missing resonance" problem deserve further clarification also from the theoretical side. The latter term denotes the phenomenon that the number of observed states is much smaller than predicted by the quark model. Various possible explanations of this puzzle are being discussed such as the dominant contribution of meson-baryon dynamics ("dynamically generated resonances") as compared to excitations of a three-quark system, a underlying quark-diquark structure with frozen degrees of freedom, or the idea that photons in contrast to hadronic probes do not excite modes involving the degrees of freedom of all three quarks. Therefore both the use of antiprotons and the extension up to the multi-strange and charmed baryon sector is an important complementation to on-going or planned photo-excitation studies of the nucleon. To gain more insight in the contribution of three-quark, quark-diquark or meson-baryon degrees of freedom responsible for the excitation pattern, a comparative study and the observation of similarities or deviations in the different baryon species will be of enormous help. Based on the quark model the known nucleon and Δ states should have partner states in the heavier baryon species. Due to the different masses of the quarks involved, some of the degeneracies in the N^*/Δ^* spectrum should be removed. The role of meson-baryon degrees of freedom could be seen by comparing the effect of meson-baryon thresholds on the spectrum in the different baryon species (see e.g. the $\Lambda(1405)$ and the $\Lambda_c(2595)$ states).

In addition, non-qqq states such as hidden charm baryons, which are not forbidden by QCD and predicted in some theoretical models, should be searched for. Other exotic baryonic states carrying anti-strange or anti-charm quantum numbers could also be accessible at PANDA, and the question of their existence should be clarified.

Comparing the experimental information collected so far in the different baryon species on energy levels, quantum numbers and decay properties, one observes a strong decrease of knowledge with increasing s-quark content. In the Ξ spectrum the only 4-star resonance is the $\Xi(1530)$ state being the decuplet ground state in analogy to the Δ resonance, whereas the relation of experimentally observed "bumps" in the Ξ spectrum to quark model states is unclear in most cases. In the Ω spectrum essentially nothing is known. In the charmed baryon sector the situation is slightly better than for double-strange hyperons but the character of several states is still unclear.

Antiproton-proton collisions are well-suited to populate (anti-)baryon excited states, and except for triple-strange or charmed hyperons the expected cross sections are large enough to allow collecting large statistics samples within relatively short running time, given the design luminosity at the PANDA experiment. A particular advantage of the $\bar{p}p$ entrance channel is in the option to control systematic errors, as excited baryons and antibaryons in the final state should exhibit the identical pattern. Due to its large acceptance for both charged particles and photons, and due to its particle identification capability, PANDA allows measuring differential observables for nearly all decay modes.

b) Please summarize the originality of the measurements.
can only PANDA do that, is PANDA the first to do that, why is PANDA in a better position

Obviously excited states of multi-strange and charmed baryons can also be populated in other reactions than in antiproton-proton collisions. We are however convinced that the combination of the $\bar{p}p$ entrance channel with its intrinsic option to control systematic errors and with its comparably large cross sections, together with the high PANDA detector performance allows collecting large statistics samples for a variety of decay modes across the complete phase space, which is difficult to be obtained in other experiments. Considering the presently available data and the expected production cross sections, the discovery potential seems particularly high in the study of excited Ξ states, which therefore should be started as soon as the luminosity and the detector performance allow doing this. Partial wave analyses, mandatory for the identification of the quantum number of observed states, require both large statistics samples and full acceptance for the final state to be studied, both offered at PANDA.

c) Please indicate competition in the goals, the methods and the reaction channels involved.
competition on the narrow and wider physics case

Baryon resonances can and will be studied also at other facilities. Experiments at JLAB using quasi-real photons will be focused on the nucleon spectrum. The population of Ξ states in photon or electron induced reaction requires the production of two kaons and has rather small cross section at the order of nb, which does not allow studies competitive to the options given at PANDA.
Experiments aiming at large samples of B decays (Belle II, LHCb) can in principle also do spectroscopic studies of baryons in all species up to charmed baryons. Baryon spectroscopy is however not in the main focus of these experiments, and it is not clear how much time and effort can be devoted to these studies. The decay branch to Ω^* states and thus the count rates for these species will be extremely small.
BES III can study baryons in charmonium decays, but count rates expected for states with more than single strangeness are expected to be very small.
J-PARC using a high momentum secondary hadron beam has plans for a baryon spectroscopic study of charmed hyperons in (π^-, D^{*-}) reactions with estimated count rates of a few hundred per Λ_c^* or Σ_c^* state per year. Using the double strangeness exchange reaction $p(K^-, K^+)$ also the population of excited Ξ states seems to be accessible.
In summary, we are thus convinced that, concerning baryon spectroscopy, PANDA will be competitive to other experiments, particularly in the multi-strange baryon sector and in the search for non-qqq states.

d) Is there a unique selling point? Please explain this (< ¼ page)
what can we do, what others can't and how important is it?

Antiproton-proton collisions are particularly well-suited to populate excited states of (anti-)baryons with single- or multiple-strangeness or with charm at cross sections higher than with other entrance channels.
Strangeness or charm in the baryon can be balanced by the respective antiquarks in the antibaryon, and consequently no extra mesons need to be created. The charge conjugation symmetry in the populated final states provides an intrinsic control of systematic errors, uniquely related to the $\bar{p}p$ entrance channel.
Considering the combination of the $\bar{p}p$ entrance channel, the achievable production rates, and acceptance for both charged and neutral species and particle identification capabilities of PANDA, the potential of PANDA to explore the (multi-)strange and charmed (anti-)baryon spectrum is unique in the world. The highest discovery potential is in the study of the double-strange Ξ hyperon spectrum, which on the one hand exhibits a dramatically poor level of knowledge and on the other hand rather only requires moderate if not low luminosities. We are convinced that the study of the Ξ spectrum (and that of the other species) will take us a big step forward in understanding

the excitation pattern of baryons.

e) Short executive summaries
can be written after the physics group has done most of the homework

i. Which of those statements (impact, uniqueness, etc.) made before hold still for 1/100 and 1/10 of the nominal instantaneous luminosity?

ii. What could be done with 1/100 and 1/10 of the nominal instantaneous luminosity and how long would it take in terms of beam-time?

A combined answer to i. and ii. Is given.
Even at strongly reduced luminosities excited states of non-strange and single-strange baryons $(N^*, \Delta^*, \Lambda^*, \Sigma^*)$ can be investigated in a reasonable running time. This has however not been in the focus of the baryon spectroscopy program of PANDA presented so far. The scientific impact of such a study, in particular of aspects that are uniquely related to the $\bar{p}p$ entrance channel, still deserves further exploration and discussion.
Within the subtopics listed in answer to question 4.) first studies of Ξ^* states can be started already at reduced luminosity for specific decay modes. With the order of µb, the expected cross sections are reasonably large, and in addition the in general much smaller width of Ξ^* states as compared to that of N^* and Δ^* states facilitates their observation. We estimate that a reasonable measurement can be done within 4 weeks, as discussed below.
Studies of triple-strange as well as open or hidden charm states will certainly require the full luminosity.

6. Details for each subtopic listed above
Example: ccbar Molecule (XYZ)

a) What are the required momentum(-range) settings?

In the study of each baryon species several momentum settings are required. The selected momentum needs to be high enough for sufficient phase space to populate the excited baryonic state, on the other hand an unnecessarily high momentum should be avoided in order to constrain the number of contributing partial waves, which is determined by the available phase space for the selected final state.
The range of excitation energies worthwhile being studied may extend up to 1.5 GeV above the respective ground state or even higher, as indicated by the fact that in the nucleon sector the highest N^* state identified with its spin-parity quantum numbers is the $N^*(2700)$ state, roughly at 1.75 GeV excitation energy. In the study of charmed hyperons the maximum antiproton momentum of 15 GeV/c limits the accessible excitation energy to 0.9 GeV for Λ_c^+ or 0.73 GeV for Σ_c, respectively.

Double-strange hyperons (Ξ^*)

To cover a reasonable excitation energy range, the momentum ranges from 3.4 GeV/c up to 8.9 GeV/c. The number of required separate momentum settings in total is estimated to be around 5.

Triple-strange hyperons (Ω^*)

It is unclear whether the state seen at 2.25 GeV is the lowest excited state, therefore the study should include lower excitation energies. The selected $\bar{p}$ momentum should cover values from 5.3 GeV/c up to 12 GeV/c.

Charmed hyperons (Λ_c^*, Σ_c^*)

The threshold for charmed hyperon production on a proton target is at antiproton beam momentum of 10.2 GeV/c. The whole momentum range from values close to the threshold up to 15 GeV/c should be covered.

Hidden charm hyperons ($N_{c\bar{c}}^*$)

Theory models predict rather narrow states above the $J/\psi\, N$ threshold. However the study should also include the case of a bound $c\bar{c}$ pair below the charmonium-nucleon threshold. Consequently this study requires $\bar{p}$ momenta between 10 GeV/c and 15 GeV/c.

subtopic	p_{min} [GeV/c]	p_{max} [GeV/c]	remarks
Ξ baryons	3.4	8.9	~5 settings
Ω baryons	5.3	12	~5 settings
Λ_c, Σ_c baryons	10.5	15	~3 settings
$N_{c\bar{c}}$ baryons	10	15	~3 settings

b) What is the required integrated luminosity?
sometimes this can only be guessed, since production cross sections are unknown.
Please then give a guestimate and explicitly list all input variables,
like signal and background assumptions (e.g. 1 nb cross section, 10.000 rec. events, S/B=1:1)

Double-strange hyperons (Ξ^*)

For both Ξ charge states a cross section between 2 µb and 4 µb in the reaction $\bar{p}p \to \bar{\Xi}\Xi$ has been measured. For excited states there are no data, but the comparison of the reactions $\bar{p}p \to \bar{\Lambda}\Lambda$ with $\bar{p}p \to \bar{\Lambda}\Lambda^*$, and of $\bar{p}p \to \bar{\Sigma}\Sigma$ with $\bar{p}p \to \bar{\Sigma}\Sigma^*$ demonstrates that excited states are populated with similar cross sections with a reduction of at most a factor two to three, given the same center-of-mass energies above the respective thresholds. Therefore we assume $\sigma(\bar{p}p \to \bar{\Xi}\Xi^*) = 1\,\mu b$. This cross section is high enough for a study of this reaction at reduced luminosity during the startup phase of PANDA. For first considerations we assume a reduction of 1/100 with respect to the design luminosity, equivalent to 10^5 $\bar{p}p$ collisions per second. Assuming further a 10% decay branch for the selected meson-baryon final state of the excited Ξ state and 20% reconstruction efficiency for reconstructable final states, and taking into account the branching fraction of $\Lambda \to p\pi^-$ squared, a 1 month run results in $4{\times}10^4$ events in a Dalitz plot to be analyzed with respect to the contribution of excited Ξ states. This is sufficient for first measurements and the goal to identify states with a typical width of a few tens of MeV, much smaller than those of N^* or Δ^* states, and to deduce angular distributions of their decay particles. In terms of integrated luminosity this corresponds to 5 pb^{-1}.

Triple-strange hyperons (Ω^*)

No data exist on the reaction $\bar{p}p \to \bar{\Omega}\Omega$. Within a quark-gluon string model a cross section of only ~2 nb has been predicted which seems to be too strong a reduction as compared to the $\bar{p}p \to \bar{\Xi}\Xi$ cross section. Considering in contrast the typical strangeness "penalty" factor in measured cross sections or in hadronic model predictions (e.g. $\sigma(\bar{p}p \to D^+D^-)$ and $\sigma(\bar{p}p \to D_s^+D_s^-)$ only differ by a factor ~3), we use as a basis for the required beam time estimate $\sigma(\bar{p}p \to \bar{\Omega}\Omega^*) = 30\,nb$. Using the full luminosity with 10^7 $\bar{p}p$ collisions per second and equivalent numbers for branching fraction and reconstruction efficiency as given above for $\bar{\Xi}\Xi^*$, and taking into account the squared branching fractions for the $\Omega^- \rightarrow \Lambda K^-$ and $\Lambda \rightarrow p\pi^-$ decays, one obtains 6×10^4 reconstructed final states to be analyzed for the contribution of Ω^* states within one month of running time, or equivalently within an integrated luminosity of 500 pb^{-1}.

Charmed hyperons (Λ_c^*, Σ_c^*)

No data exist for exclusive charmed hyperon antihyperon production in antiproton-proton collisions. The predicted cross sections cover an extremely large range from 1 nb up to a few µb. Based on the expectation that complete annihilation of $\bar{p}p$ into three $\bar{s}s$ pairs is more unlikely than creation of a single $\bar{c}c$ pair, we use the cross section estimate $\sigma(\bar{p}p \rightarrow \overline{\Lambda}_c^- \Lambda_c^+) = 100\, nb$ and a factor of 2 reduction for population of excited Λ_c or Σ_c states. The exclusive reconstruction of both charmed hyperon and antihyperon is very difficult due to their large number of decay branches with branching fractions on the percent level each. Therefore it seems necessary to add up all characteristic decay modes for either Λ_c^+ or $\overline{\Lambda}_c^-$, and to identify the other one based on 4-momentum balance. The fraction of final states reconstructable in this way amounts to 24.5%. It needs to be proven that this approach is feasible in view of a probably high background level.
Assuming further full luminosity, a 10% branching fraction of the excited charmed hyperon into Λ_c, a reconstruction efficiency of 20%, and one month running time (500 pb^{-1}), one obtains 1.2×10^5 events to be analyzed for contributions of excited charmed hyperon states. However this estimate may be too optimistic, not only due to a possibly smaller production cross section but also due to the fact that sufficient background suppression might only be achieved at the expense of lower signal reconstruction efficiency.

Hidden charm hyperons ($N_{c\bar{c}}^*$)

The existence of these states has been predicted in theoretical models but has not been substantiated by experimental observation so far. We are also not aware of any theoretical work on the dynamics related to their production in antiproton-proton collisions. The cross section could be similar to that of charmed hyperon production. Depending on their mass and on their quantum numbers, different final states will be relevant for their identification. Above the charmonium-nucleon threshold this will be the $\bar{p}p\, J/\psi$ and the $\bar{p}p\eta_c$ final states. Below this threshold the case is more difficult, and a hidden charm N^* state could decay into many different multi-meson nucleon states. There are indications that nature in case of large available phase space prefers heavy daughter particles in the decay chain, thus looking for η', ϕ or $K^*/\overline{K}^*$ could be a good strategy, combined with a study of the $\bar{p}/p$ missing mass spectrum in correlation with $p/\bar{p}$ – (multi-)meson invariant mass spectra containing these heavy meson species. As a maybe indicative example it should be noted that the $\eta_c \rightarrow \eta'\pi\pi$ decay has a branching as large as 4%.

Assuming 100% $N_{c\bar{c}}^* \rightarrow N\, J/\psi$ decay, a cross section $\sigma(\bar{p}p \rightarrow \bar{p}N_{c\bar{c}}^{*+} + c.c.) = 50\, nb$, and 20% reconstruction efficiency, a full luminosity run of 2 weeks (250 pb^{-1}) will allow to detect 1.5×10^5 $\bar{p}p\, J/\psi$ events based on the $J/\psi \rightarrow e^+e^-/\mu^+\mu^-$ decay. The statistical significance corresponding to such a number of events depends on the continuum cross section and the width of the state, which are both unknown quantities. Also the production cross section could be smaller. To give a meaningful estimate for the case of a hidden charm N^* state below the charmonium-nucleon threshold, theoretical guidance helping to select the most promising final states is very welcome.

subtopic	integrated L [pb^{-1}]	remarks
Ξ baryons	5-10	per momentum setting
Ω baryons	500	"
Λ_c, Σ_c baryons	500	"
$N_{c\bar{c}}$ baryons	250	"

c) List "all" channels of interest

List either in a generic or in an explicit list (if possible) all or the kind of reactions which need to be investigated.

Double-strange hyperons (Ξ^*)

- $\bar{p}p \rightarrow \bar{\Xi}^+\Xi^{*-} + c.c.$
- $\Xi^{*-} \rightarrow \Xi^-\pi^0,\ \Xi^-\pi^+\pi^-,\ \Xi^-\pi^0\pi^0,\ \Xi^-\eta,\ \Xi^-\omega,\ \Lambda K^-, \ldots$
- $\Xi^- \rightarrow \Lambda\pi^-;\ \Lambda \rightarrow p\pi^-$

Triple-strange hyperons (Ω^*)

- $\bar{p}p \rightarrow \bar{\Omega}^+\Omega^{*-} + c.c.$
- $\Omega^{*-} \rightarrow \Omega^-\pi^+\pi^-,\ \Omega^-\pi^0\pi^0,\ \Omega^-\eta,\ \Omega^-\omega,\ \Xi^-\bar{K}^0, \ldots$
- $\Omega^- \rightarrow \Lambda K^-,\ \Xi^-\pi^0,\ \Xi^0\pi^-(?);\ \Xi^- \rightarrow \Lambda\pi^-;\ \Xi^0 \rightarrow \Lambda\pi^0;\ \Lambda \rightarrow p\pi^-$

Charmed hyperons (Λ_c^*, Σ_c^*)

- $\bar{p}p \rightarrow \bar{\Lambda}_c^-\Lambda_c^{*+} + c.c.$
- $\bar{p}p \rightarrow \bar{\Lambda}_c^-\Sigma_c^{*+} + c.c.$
- $\Lambda_c^{*+} \rightarrow \Lambda_c^+\pi^+\pi^-,\ \Lambda_c^+\pi^0\pi^0,\ \Sigma_c^+\pi^0,\ \Sigma_c^0\pi^+,\ pD^+, \ldots$
- $\Sigma_c^{*+} \rightarrow \Lambda_c^+\pi^0,\ \Lambda_c^+\pi^+\pi^-,\ \Sigma_c^+\pi^0,\ \Sigma_c^0\pi^+,\ pD^+, \ldots$
- $\Sigma_c^+ \rightarrow \Lambda_c^+\pi^0$
- $\Sigma_c^0 \rightarrow \Lambda_c^+\pi^-$
- $\Lambda_c^+ \rightarrow pK^-\pi^+,\ pK^-\pi^+\pi^0,\ \Lambda\pi^+,\ \Lambda\pi^+\pi^0,\ \Lambda\pi^+\pi^+\pi^-$
- $\Lambda \rightarrow p\pi^-$

Hidden charm hyperons ($N_{c\bar{c}}^*$), other non-qqq baryon states

$N_{c\bar{c}}^*$ above the charmonium-nucleon threshold:
- $\bar{p}p \rightarrow \bar{p}pJ/\psi$
- $\bar{p}p \rightarrow \bar{p}p\eta_c$
- $J/\psi \rightarrow e^+e^-,\ \mu^+\mu^-$
- $\eta_c \rightarrow K\bar{K}\pi,\ K\bar{K}\pi\pi,\ K\bar{K}3\pi,\ \eta'\pi\pi,\ \eta\pi\pi$

$N_{c\bar{c}}^*$ below the charmonium-nucleon threshold:
- $\bar{p}p \rightarrow \bar{p}p\eta',\ \bar{p}p\eta'\pi\pi, \ldots$

d) Which (non-)exclusive channels pose as role models (e.g. for simulations)

Example: J/psi pipi eta, J/psi pipi scan

Partial wave analysis programs for baryon antibaryon plus meson final states need to be developed.
As long as decay chains with complex topology and displaced vertices cannot be simulated on short time scale, final states with $\Lambda\bar{\Lambda}$ can be used to obtain coarse information on detector requirements which are also valid for Ξ^* spectroscopy. Similarly,

this also holds for $\bar{\Lambda}_c^-\Lambda_c^+$ as benchmark for studies of charmed baryon excited states. Simulation of J/ψ, η_c, or η' production ($\bar{p}p$ + meson final states) may help to better understand the requirements for studies of hidden charm baryons.

e) What are typical potential trigger scenarios (guestimates!)?

subtopic	trigger conditions	remarks
Ξ baryons	3/4 displaced decay vertices	depending on Ξ^*decay mode
Ω baryons	≥4 displaced decay vertices	depending on Ω decay mode
Λ_c, Σ_c baryons	"open charm" trigger	complex "OR" for different decay modes, needs detailed study
$N_{c\bar{c}}$ baryons	$J/\psi \to e^+e^-/\mu^+\mu^-$ trigger, η_c, η' or η (+mesons) + $\bar{p}p$ in final state	depends on $N_{c\bar{c}}$ mass, needs further study

f) What are the main background channels and which are the most important filter steps and which detectors are involved to deliver this information?

subtopic	main background channels	remarks
Ξ baryons	same final state without $\Xi\bar{\Xi}$	suppressed by delayed vertices
Ω baryons	same final state without $\Omega\bar{\Omega}$	suppressed by delayed vertices
Λ_c, Σ_c baryons	same final state without charmed hyperon antihyperon	ambitious, needs detailed studies
$N_{c\bar{c}}$ baryons	same final state from non-resonant continuum production	main issue: good mass resolution and reconstruction efficiency

g) Minimal setup required for this subtopic

i. What is the figure of merit for the reactions for this subtopic?
e.g. S/B, efficiency,… t.b.d. by the subgroup

ii. What is the minimal setup for full performance at nominal instantaneous luminosity
full performance means, that the performance with this setup differs insignificantly (t.b.d. by the individual subgroup, but a guide might be efficiency within 20% and background within a 20%) from the full blown detector

iii. What is minimal setup for full performance in the startup phase (1/100 and 1/10 nom. inst. lum.)?
s. above

iv. What is the minimal setup for reasonable performance at nominal instantaneous luminosity?
reasonable performance (t.b.d. by the individual subgroup, but a guide might be efficiency within factor of 2 and background within a factor of 2), but may involve leaving out detectors with marginal correlation to the full performance

v. What is the minimal setup for reasonable performance in the startup phase (1/100 and 1/10 nom. inst. lum.)?
s. above

At this stage only a preliminary and qualitative answer can be given in summary to questions i.-v., based on the list of subtopics and reaction channels given above.

In the start-up phase with low luminosity and incomplete detector spectroscopic studies of the non-strange and single-strange baryon spectrum are possible. The minimum set-up must include functioning of the tracking detectors of the Target Spectrometer (MVD, STT, GEM), where, concerning the MVD performance, certain compromises may be acceptable in case of N^* or Δ^* spectroscopy. Since purely charged final states in both mesons and baryons/antibaryons are only a small sub-set of all populated final states, photon detection in the EMC is mandatory. In Λ^* and Σ^* spectroscopy the performance of the MVD is more important since the inner hit points are required to reconstruct the delayed $\Lambda/\bar{\Lambda}$ decay vertices. Due to their relatively high mass, the final state baryons are emitted within relatively small polar angles. To which extent the Forward Spectrometer is required for these measurements, still needs to be explored.

Ξ^* spectroscopy is more demanding than that of non-strange or single-strange baryons, however with cross sections at the µb level this part of the program does not require full luminosity. Due to the more complex decay topology the inner hit points in the MVD are important for the reconstruction of the $\Lambda/\bar{\Lambda}$ and $\Xi/\bar{\Xi}$ decay vertices. The requirement for full performance of the Forward Spectrometer needs to be verified.

The investigation of all other subtopics of the program (triple-strange baryons, charmed baryons, hidden-charm baryons) is so ambitious that it will require both full luminosity and the full detector performance. In particular, we are convinced that even with the present design parameters of the full PANDA detection system the study of charmed hyperons will be very demanding, and that any significant reduction in the performance parameters would force us to abandon this part of the program.

7. Options for lower detector performance (short survey)
   - What resolution/thresholds is actually needed for the key components of the minimal setups. Please summarize the performance indicators needed for the (sub)systems of the minimal setup
     try playing with the parameters to find out, at what point the physics case becomes meaningless. T.b.d. by the individual subgroup what the criterion is for that
     What would be the consequences of these changes?
     Please explain all known scientific consequences and risks

     See answer to question 6g), a more detailed answer requires further studies.

8. Room for add. information from the physics group not listed above
   comments, caveats, whatever might be interesting

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