PANDA Scrutiny Group (SG) **March/June 2014**

1st Physics Questionnaire

Requirements for the (sub)systems from the physics case of the PANDA Detector

1. Physics Group: **Hadrons in Nuclei**

2. Physics Group Convener(s):
   Albrecht Gillitzer, Volker Metag

3. List of groups involved:
   Univ. Giessen, JCHP / FZ Jülich, Univ. Mainz, HIM, Politecnico Torino, SMI Wien

   List of relevant TAG members:
   A. Larionov, N. Brambilla, M. Strikman

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

   - properties of hadrons in nuclei: nuclear potential of non-charm (anti-)baryons and mesons and charmonium-nucleon interaction
   - hard QCD reactions inside nuclei
   - exclusive studies in $\overline{p}d$ collisions

   The sequence of subtopics in the list does not reflect any time order in experiment planning.

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

      We see a three-fold impact in the study of antiproton-nucleus collisions with PANDA.

      The first aspect focuses on the properties of produced hadrons embedded inside the nuclear environment, or in a microscopic view, to the interaction of hadrons with nucleons. The possible modification of hadrons due to finite baryonic density is of fundamental interest related to the mass generation mechanism by the spontaneous breaking of chiral symmetry in QCD and its predicted restoration at finite density or temperature. Another fundamental problem is to understand the deviations of baryon-nucleon and antibaryon-nucleon interactions from the relation that is determined by G-parity transformation. Beyond the importance that any information on the potentials and widths of hadrons in the nuclear medium has in the field of hadron, nuclear and astrophysics, an observation of strongly coupled hadron-nucleus systems (antikaon-, D-meson-, antibaryon-nucleus) would be the most spectacular finding within hadron-nuclear interaction studies.
      Antiprotons as beam particles are unique in delivering an energy release of nearly 2 GeV in annihilation processes on nucleons, which allows studying hadrons at comparably low momentum inside nuclei where the sensitivity to nuclear potentials is large.
      Studies of cold nuclear matter effects on hadron properties are also indispensable for a better understanding of signals of deconfinement in ultra-relativistic heavy ion collisions at LHC, RHIC, SPS and FAIR.

      The second aspect focuses on using the nucleus as a laboratory to determine the distance and time scale of hard QCD reactions. The goal is to observe the formation process of hadrons, based on the prediction that hadrons produced in reactions at large momentum transfer evolve from small size configurations with reduced interaction cross section. This phenomenon is known as “Color Transparency (CT)”, and is established at high energies, but its onset at intermediate energies deserves further experimental clarification.

The third aspect is related to the short-distance structure of the nucleus itself. Hard collisions of antiprotons inside the nucleus can be used as a probe to reveal pairing or higher correlation effects of high momentum nucleons and non-nucleonic components of the nuclear wave function (usually labeled “Short Range Correlations (SRC)”). Due to the locally very high density the study of SRC may also shed light on the properties of compressed cold nuclear matter like in neutron stars.

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

The largest fraction of the program can only be carried out with PANDA. This is due to the required combination of antiprotons as beam particles, high luminosity and the availability of a high performance and large acceptance detector (e.g. direct charmonium formation at defined momentum). For some subtopics the luminosity requirement is somewhat relaxed, but these still rely on the antiproton beam and a powerful large acceptance detector (e.g. slow non-charm hadrons inside nuclei, in particular the antiproton itself and anti-hyperons). In both cases the originality of PANDA is unreachable in other experiments. A small fraction of the program, such as the study of short range nuclear correlations involving *quasi-elastic* antiproton-nucleon scattering could be done with other probes such as electrons (with much smaller cross sections for the same momentum transfer) or protons but still needs a large acceptance detection system. However, antiprotons as different probes deliver valuable complementary information. This also holds for part of color transparency studies.

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

Studies of reactions on nuclear targets are planned at JLAB and at J-PARC, thus having potential overlap with the antiproton-nucleus program at PANDA, which will be discussed in more detail below. Other experiments competing with the future PANDA physics program like BES-III and BELLE-II - working at e^+e^- colliders - will not be able to do experiments on nuclear targets.
The nuclear physics program of JLAB is focused on the nuclear modification of parton distributions, or more generally, on the nucleon structure inside the nuclear medium. This program has so far no direct counterpart at PANDA (the EMP working group might consider an extension to nuclear targets if feasible). In the past JLAB has investigated color transparency and short range correlations in electron-nucleus collisions, and plans further experiments after the 12 GeV upgrade. Hence in these subtopics PANDA and JLAB have some overlap concerning the physics objectives, and concerning the method to the extent that large momentum transfer reactions are to be studied. However, with antiprotons PANDA will use different probes and different final states, and thus provide complementary information. This may help to separate effects due to different interplay of soft and hard QCD dynamics in the used reaction channels and the nuclear short-distance structure. In addition, due to its large acceptance, PANDA is also suited to investigate final states with a larger number of particles. This will be important in the study of non-nucleonic degrees of freedom like ΔΔ components or of higher order nucleon correlations. The measurement of quasi-free annihilation channels into mixed

charged and neutral final state with PANDA allows directly identifying the struck nucleon without the need of neutron detection.

J-PARC can study collisions on nuclear targets induced by a high-energy proton beam and by secondary K±, and π± beams. The secondary negative hadron beam also includes a small fraction of antiprotons which can be tagged and used as projectiles, but both intensity and quality are by far not competitive to that of the HESR antiproton beam. Proton, pion or kaon beams don't produce heavier hadrons at low momenta inside the nucleus, in particular no antibaryons. Therefore, except for a possible nuclear transparency measurement of $K^*/\overline{K}^*$ mesons using K^+/K^- beams, we do not anticipate competitive experiments at J-PARC having overlap with the antiproton-nucleus program at PANDA.

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?

PANDA is a unique factory for coincident antihyperon-hyperon pairs – even at moderate luminosities. Exclusive antihyperon-hyperon pairs produced in nuclei with antiprotons at FAIR will therefore for the first time ever allow us to study the interaction of low momentum anti-hyperons as well as hyperons in nuclei in a quantitative way. These processes may shed light on e.g. the short-range structure of the residual baryon-baryon force and the momentum dependence of anti-baryon potentials. During the commissioning phase of PANDA one should focus on $\Lambda\overline{\Lambda}$ production at beam momenta around 1.6 GeV/c. Once established for $\Lambda\overline{\Lambda}$ pairs, this method can be extended to $\Xi\overline{\Xi}$ and $\Omega\overline{\Omega}$ pairs and possibly even the production of long-lived resonances (e.g. $\Xi(1530)$) in nuclei, once PANDA reaches its full luminosity and detection capabilities.

With full luminosity and detector performance, PANDA is unique in producing J/ψ (and possibly higher charmonium and charmonium-like XYZ states) via resonant formation with antiprotons on protons inside a nucleus. This will allow determining the J/ψ-nucleon dissociation cross section in a clean, almost model-independent way at well-defined conditions not accessible in other experiments.

The knowledge of J/ψ absorption in cold nuclear matter is a prerequisite for interpreting a reduced J/ψ yield in high-energy nucleus-nucleus collisions as signal of deconfinement. Furthermore, the study of charmonium-nucleon interactions may provide an additional test of charmonium structure models and of the QCD factorization theorem.

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 preliminary summarized answer to i. and ii. can be given already without availability of detailed simulation results. First one should not forget that the usage of nuclear targets already reduces the effective mean luminosity as compared to a hydrogen target, since the total hadronic cross section and thus the antiproton consumption rate is higher by roughly a factor $A^{2/3}$. Single Coulomb scattering, particularly for higher Z targets, results in a further reduction. A reduction of the HESR filling rate by one or two orders of magnitude will clearly reduce the impact of an antiproton-nucleus program at PANDA, and exclude the investigation of most of the listed subtopics, as e.g. charmed hadrons in nuclei, which is ambitious and requires full luminosity. Facing a reduction in luminosity by a factor 1/100, the following experiments still seem to be feasible and competitive:

- Investigation of the Λ and $\overline{\Lambda}$ nuclear potential by coincident measurement of their transverse momentum distributions
- search for a $\Delta\Delta$ component in the deuteron
- study of color transparency and short range correlations in few selected reaction channels

Program	*Hyperons and antihyperons in nuclei*	*J/ψN interaction*	*ΔΔ component in deuteron*	*Color transparency*
New – not part of original proposal	*yes*	*original proposal*	*yes*	*yes*
Uniqueness – no competition	*yes*	*yes*	*yes (in parts)*	*yes (in parts)*
Required running period at 10% luminosity	*few days (preliminary)*	*not possible*	*few days (preliminary)*	*few days/target (preliminary)*
Feasibility at 1% luminosity	*1 month (preliminary)*	*not possible*	*1 month (preliminary)*	*few weeks/target (preliminary)*
Detector requirements	*no high resolution mode* *hyperon vertexing* *0.5 T field*	*full performance EMC & MUO*	*MVD for low-momentum proton needed*	*EMC as veto probably needed*
Additional requirements	*nuclear target (Ne)* $\bar{p}p \rightarrow \Lambda\overline{\Lambda}$ *as calibration*	*all gaseous nucl. targets D – Xe*	*d target, high momentum*	*all gaseous nucl. targets D - Xe*

6. Details for each subtopic listed above

Example: ccbar Molecule (XYZ)

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

Nuclear potential of (non-charm) hadrons:

Antiprotons as projectiles allow to probe the effect of the nuclear potential on various hadrons at low momenta such as $\overline{\Lambda}$, $\bar{p}$, $\overline{K}$, $K^*/\overline{K}^*$, both in coincident particle-antiparticle transverse momentum distributions and in missing mass spectra obtained in recoilfree quasi-two-body reactions. In all these cases the typical $\bar{p}$ momentum is 2 GeV/c. In the measurement of the $\overline{\Lambda}/\Lambda$ nuclear potential, which we propose to be done as one of the first experiments in the startup phase of PANDA, the optimum momentum is close to 1.52 GeV/c. This momentum is low enough to exclude the production of additional pions, on the other hand the phase space in the elementary reaction $\bar{p}p \to \bar{\Lambda}/\Lambda$ is already large enough for a sufficient cross section.

Charmonium-nucleon interaction:

Scan with antiproton beam momentum around 4 GeV for resonant formation of J/ψ with nuclear protons at rest or low momenta. These experiments can only be started when the luminosity is close to the design value. The variation of both target nucleus (d, N_2, Ne, Ar, Kr, Xe) and of the antiproton momentum will require a long total running time, since the peak cross section including the e^+e^- / $\mu^+\mu^-$ branching fraction is of the order of 1 nb. With d target the inclusive measurement of the J/ψ yield can in parallel be combined with the exclusive study of the Pontecorvo reaction $\bar{p}d \to \Lambda_c^+ D^-$ which provides complementary information on the J/ψN dissociation cross section.

Hard QCD reactions inside nuclei:

Both the study of color transparency and of short range correlations requires minimum $\bar{p}$ momenta of about 6 GeV/c.

Exclusive studies of $\bar{p}d$ collisions:

The momentum depends on the final state to be studied. Due to the many different aspects within this subtopic the full momentum range of the HESR from 1.5 GeV/c up to 15 GeV/c may be relevant.

The optimum momentum to study ΔΔ components in the deuteron is in the range from 8 GeV/c to 15 GeV/c, depending on the energy dependence of the cross section for the selected final state and of the signal-to-background ratio.

Studies of J/ψ dissociation on the spectator neutron $J/\psi\, n \to \Lambda_c^+ D^-$ require a momentum scan around a $\bar{p}$ momentum of 4 GeV/c which is time consuming due to the small cross section (the predicted value is around 20 pb).

Search for a DNN bound state in $\bar{p}d \to \bar{\Lambda}_c^- [DNN]^+$ requires the highest $\bar{p}$ momenta up to 15 GeV/c.

subtopic	p_{min} [GeV/c]	p_{max} [GeV/c]	remarks
$\bar{\Lambda}/\Lambda$ potential	1.52	1.7	
J/ψN interaction	3.5	4.5	scan, ≥ 5 points
color transparency	~10	15	
ΔΔ in deuteron	~8	15	
$\bar{p}d \to \Lambda_c^+ D^-$	3.5	4.5	parallel to J/ψN int.

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)

Nuclear potential of (non-charm) hadrons:

At antiproton momenta around 2 GeV/c the total $\bar{p}p \to \bar{\Lambda}\Lambda$ cross section is of the order of 100 µb. Thus high statistics measurements of $\bar{\Lambda}\Lambda$ production on nuclei are possible even if the luminosity is reduced by a factor 100 as compared to the design value. A rate of 10^5/s antiproton-nucleus collisions corresponds to more than a million $\bar{\Lambda}\Lambda$ pairs produced per day. A significant result on the $\bar{\Lambda}\Lambda$ nuclear potential based on a sufficient statistics in differential observables should be achieved in a run with 0.3 pb^{-1} integrated luminosity. For 10^5 $\bar{p}$ + ^{20}Ne collisions per second this corresponds to a running time of about 12 days. For studies of the nuclear potential of other non-charm hadrons ($\bar{p}$, $\bar{K}$, $K^*/\bar{K}^*$) the estimated required integrated luminosity is also below 1 pb^{-1}.

Charmonium-nucleon interaction:

Based on 1 nb assumed average peak cross section for J/ψ production with di-leptonic decay, 30% reconstruction efficiency, S/B = 1:1 and 3% required statistical error a measurement of the A dependence of the peak cross section for the 6 targets listed above would require an integrated luminosity of about 50 pb^{-1}. This has to be multiplied by the number of scan points that one wants to take in order to determine the width of the excitation function. To do this, a number of 5 scan points seems to be the absolute minimum.

Hard QCD reactions inside nuclei:

As an example for the study of color transparency the reaction 10 GeV/c $\bar{p}A \rightarrow \pi^+\pi^-(A-1)$ at large transverse pion momenta is discussed. Based on data at p = 8.8 GeV/c the total cross section for the elementary annihilation reaction on a proton at p = 10 GeV/c is expected to be a few µb. For a nuclear target, pion center-of-mass angles around 90° (e.g.$|\cos\theta_{cm} < 0.3|$), and the residual (A-1) nucleus in the ground state or at low excitation energy we assume the cross section to be 0.1 µb. This is sufficiently large to be already studied at reduced luminosity, e.g. at a total antiproton-nucleus collision rate of 10^5/s. In a run of 2 weeks, corresponding to about 0.3 pb^{-1} integrated luminosity, a sufficient number of $\pi^+\pi^-$ pairs can be collected per target nucleus to observe a 5% reduction of the pion absorption probability, if the A dependence of the $\pi^+\pi^-$ yield for all 6 gaseous targets is measured.

The requirements for the study of short range nucleon-nucleon correlations in terms of integrated luminosity are estimated to be similar. A study of ΔΔ correlation with equivalent statistical uncertainty will roughly require a factor 100 higher integrated luminosity due to the lower probability of finding ΔΔ components in the nucleus.

Exclusive studies of $\bar{p}d$ collisions:

The study of the ΔΔ component in the deuteron seems already feasible at reduced luminosity. Assuming a $\bar{p}d$ collision rate of 10^5/s, 5×10^{-3} probability of a $\Delta^{++}\Delta^-$ ($\Delta^0\Delta^+$) component, 1 µb cross section for $\bar{p}\Delta^- \rightarrow \pi^-\pi^-$ ($\bar{p}\Delta^+ \rightarrow \pi^+\pi^-$), and 30% reconstruction efficiency for the $p\pi^+\pi^-\pi^-$ final state, a run of 3 weeks (equivalent to ~2 pb^{-1}) results in ~3000 detected events, and thus in a statistical uncertainty of ~3% at a signal to background ratio of 1:1.

For the Pontecorvo reaction $\bar{p}d \rightarrow \Lambda_c^+ D^-$ at 4 GeV/c momentum, corresponding to maximum J/ψ formation on the proton and thus testing J/ψ dissociation on the neutron, the predicted cross section is only 20 pb. To detect this final state with sufficient statistical accuracy is very ambitious and requires full luminosity and detector performance. Since the charmed hadron decays are spread across a large number of modes with only few characteristic ones, only one of either Λ_c^+ or D^- can be reconstructed while the other one needs to be identified from 4-momentum balance. Based on 2×10^7 $\bar{p}d$ collisions per second, 25% summed branching fraction for characteristic decay modes, and 30% reconstruction efficiency a 1 month run (equivalent to ~500 pb^{-1}) allows collecting ~800 $\Lambda_c^+ D^-$ events, corresponding to a statistical uncertainty of ~6% at S/B = 1. However, in order to unambiguously relate the detected $\Lambda_c^+ D^-$ final states to $J/\psi\, n$ dissociation processes requires measuring the excitation function of this reaction and thus at least four additional measurements e.g. at 50% and at 10% of the peak cross section both below and above $p_{\bar{p}} = 4\,\mathrm{GeV}/c$, corresponding to maximum J/ψ formation.

To discuss the requirements for searching a DNN nuclear bound state, further theoretical work on the dynamics of reactions populating such a state, e.g. the reaction mentioned above, is needed. Any statement on the required integrated luminosity would not be meaningful at this stage.

subtopic	integrated L [pb^{-1}]	remarks
$\bar{\Lambda}/\Lambda$ potential	0.3	Ne target
J/ψN interaction	50	/momentum /target
color transparency	0.3	/target
ΔΔ in deuteron	2	
$\bar{p}d \to \Lambda_c^+ D^-$	500	

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.

Nuclear potential of (non-charm) hadrons:

- $\bar{p}\,A \to \bar{\Lambda}\Lambda\,X$: coincident measurement of transverse momentum
- $\bar{p}\,A \to \Lambda\,X$: measure missing mass from Λ at small forward angles
- $\bar{p}\,A \to p\,X$: measure missing mass from p at small forward angles
- $\bar{p}\,A \to \bar{p}p\,X$: comparative measurement of nuclear excitation spectrum
- $\bar{p}\,A \to \phi K^+\,X$: measure missing mass to deduce K$^-$ potential
- $\bar{p}\,A \to K^*\bar{K}^*\,X$: coincident transverse momentum and yield (ReU, ImU)

The determination of the nuclear potential does not directly involve the A dependence as a relevant observable. A selection of e.g. three target nuclei (light, medium, heavy) seems to be sufficient.

Charmonium-nucleon interaction:

- $\bar{p}d \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, and the exclusive channel $\bar{p}d \to \Lambda_c^+ D^-$
- $\bar{p}\,{}^{14}\mathrm{N} \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, $\bar{p}\,{}^{14}\mathrm{N} \to \Lambda_c^+ D^-\,X$
- $\bar{p}\,{}^{20}\mathrm{Ne} \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, $\bar{p}\,{}^{20}\mathrm{Ne} \to \Lambda_c^+ D^-\,X$
- $\bar{p}\,{}^{40}\mathrm{Ar} \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, $\bar{p}\,{}^{40}\mathrm{Ar} \to \Lambda_c^+ D^-\,X$
- $\bar{p}\,{}^{nat}\mathrm{Kr} \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, $\bar{p}\,{}^{nat}\mathrm{Kr} \to \Lambda_c^+ D^-\,X$
- $\bar{p}\,{}^{nat}\mathrm{Xe} \to J/\psi\,X \to e^+e^-\,X, \mu^+\mu^-\,X$, $\bar{p}\,{}^{nat}\mathrm{Xe} \to \Lambda_c^+ D^-\,X$

If possible, enriched Kr and Xe isotopes should be used in order to avoid systematic uncertainties due to the effect of the neutron skin on J/ψ absorption. In addition to the Λ_c charmed hyperon in the final state also Σ_c hyperons may be searched for.

Hard QCD reactions inside nuclei:

- $\bar{p}\,A \to \pi^+\pi^-\,(A-1)$: large transverse pion momentum, all gaseous target nuclei
- $\bar{p}\,A \to K^+K^-\,(A-1)$: large transverse kaon momenta, all gaseous target nuclei
- $\bar{p}\,A \to \bar{p}p\,(A-1)$: large transverse momenta, all gaseous target nuclei
- $\bar{p}\,A \to \bar{p}pp\,(A-2), \bar{p}\,A \to \bar{p}pn\,(A-2), \bar{p}\,A \to \pi^+\pi^-p\,(A-2), \bar{p}\,A \to \pi^-\pi^0p\,(A-2)$: recoil nucleon with momentum opposite to struck nucleon, at least three target nuclei (light, medium, heavy)

Exclusive studies of $\bar{p}d$ collisions:

- $\bar{p}d \to p\pi^+\,\pi^-\pi^-$, $\bar{p}\,d \to p\pi^+\,\pi^-\pi^-\pi^0$, $\bar{p}\,d \to p\pi^+\,\pi^+3\pi^-$: slow $p\pi^+$ $(p\pi^-)$ with $M_{p\pi} = M_\Delta$, fast doubly negative 2-,3- or 4-pion system
- $\bar{p}d \to p\pi^-\,\bar{p}p\pi^0$: slow $p\pi^-$ with $M_{p\pi} = M_\Delta$, fast $\bar{p}p\pi^0$ system
- $\bar{p}d \to \Lambda_c^+ D^-$: scan around p = 4 GeV/c for intermediate J/ψ formation
- $\bar{p}d \to \bar{\Lambda}_c^-\,[DNN]^+$: fast forward $\bar{\Lambda}_c^-$

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

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

Event generators for specific reactions on nuclei require further development, at this stage reactions on proton target resulting in final state containing the relevant particles can serve as benchmark channels.

- $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$
- $\bar{p}p \rightarrow \bar{p}p$ (elastic scattering up to $\theta_{cm} = 180^o$)
- $\bar{p}p \rightarrow \pi^+\pi^-$
- $\bar{p}d \rightarrow p\pi^+\pi^-\pi^-$
- $\bar{p}p \rightarrow J/\psi$
- $\bar{p}p \rightarrow D^+D^-$
- $\bar{p}p \rightarrow \bar{\Lambda}_c^-\Lambda_c^+$

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

subtopic	trigger conditions	remarks
$\bar{\Lambda}/\Lambda$ potential	delayed decay vertices, $\bar{p}\pi^+p\pi^-$ final state	MVD-STT-GEM combined online tracking
J/ψN interaction	co-planarity, e^+e^- / $\mu^+\mu^-$ PID, high-energy particle multiplicity = 2, $p_T(ll) \cong 0,\ p_L(ll) \cong p_{\bar{p}}$	very ambitious: need to study online background suppression efficiency
color transparency	$\pi^+\pi^-$ PID (2 opposite charge particle final states), approximate co-planarity, no neutrals, no other high-energy particles	to be extended to final states other than $\pi^+\pi^-$
ΔΔ in deuteron	$M_{charged} = 4$, $M_{neutral} = 0$, $p\pi^+\pi^-\pi^-$ final state (PID), $p_T(p\pi^+) \cong 0,\ p_L(p\pi^+) \cong 0,$ $p_T(\pi^-\pi^-) \cong 0,\ p_L(\pi^-\pi^-) \cong p_{\bar{p}}$	MVD particularly important for low energy proton
$\bar{p}d \rightarrow \Lambda_c^+D^-$	“open charm” trigger for either of Λ_c^+ or D^-	very ambitious, complex combination (“OR”) of valid trigger conditions, efficiency and background suppression need detailed studies

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
$\bar{\Lambda}/\Lambda$ potential	$\pi^+\pi^-$ production: $\bar{p}p\pi^+\pi^-$	will be efficiently suppressed by displaced decay vertices
J/ψN interaction	$\bar{p}A \to \pi^+\pi^- X$ with same topology	good e/μ PID extremely important
color transparency	no severe background, additional undetected particles	main issue: residual nucleus must be at low excitation energy, missing mass resol.
ΔΔ in deuteron	same $p\pi^+\pi^-\pi^-$ final state with different kinematical topology	main issue: proton has low energy and may have only few hits in MVD
$\bar{p}d \to \Lambda_c^+ D^-$	all final states populated in selected decay modes	S/B needs detailed studies

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

A combined preliminary answer is given to questions i.-v. based on the list of subtopics and reaction channels given above. Considering a scenario with a 1/100 fraction of the design luminosity and incomplete PANDA detector however with full tracking in the Target Spectrometer available, only studies of the transverse $\bar{\Lambda}\Lambda$ momentum distribution to determine the $\bar{\Lambda}$ nuclear potential, and of the $p\pi^+ \pi^-\pi^-$ and $p\pi^+ \pi^+ 3\pi^-$ final states in search for a ΔΔ component in $\bar{p}d$ collisions seem feasible.

Studies of hidden and open charm on nuclear targets are very demanding and require both full luminosity and a complete Target Spectrometer (EMC, DIRC,MUO in addition to full tracking in MVD, STT, GEM). The search for a bound DNN state in addition requires full tracking and PID in the Forward Spectrometer.

Studies of color transparency and short range nucleon correlations do not need full luminosity, but they require information on the excitation energy of the residual nuclear system based on the EMC as veto detector which therefore needs to be complete.

Missing mass studies in (nearly) recoil-free kinematics to study the nuclear potential of non-charmed hadrons (e.g. $\bar{p}, \bar{\Lambda}, K^-$) also do not require the full luminosity but full tracking and PID in the Forward Spectrometer.

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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