PRESPEC-AGATA Campaign 2013

General recommendations for preparing (pre)proposals (7/2012)

Introduction

These notes try to provide a useful overview for a basic cross-check of the feasibility of an anticipated experiment to be proposed for the second round of the PRESPEC-AGATA campaign at GSI. Planning such an experiment is for sure a multi-variable optimization, while good starting points are existing LISE, MOCADI, and/or AGATA simulation files and codes for the accepted proposals or, even better, secondary fragment settings of the commissioning runs earlier this year. More precise empirical numbers and features of the set-up are going to arise from running the first round of experiments during the second half of 2012. These will be presented at the workshop `PRESPEC-AGATA: Status and Future Ideas', to be held near GSI Darmstadt on December 10th and 11th, 2012.

Besides the scientific merit of the (newly) proposed experiments also the international competition is to be considered. Always find a good answer to the question: "Why is the experiment unique for the PRESPEC-AGATA campaign at GSI?". Feasibility is the next step, i.e. for any physics idea reliable rate estimates must be evaluated at an early stage, which is why in the following some guidelines for rate estimates are given. More (detailed) information on procedures and estimates can often be found at, for example, the PRESPEC and/or the FRS websites at:
http://web-docs.gsi.de/~wolle/PreSPEC/index.html
http://www-wnt.gsi.de/frs/index.htm

For possible (or realistic) primary beam intensities the pages regularly updated by the accelerator people (http://www.gsi.de/start/beschleuniger/service.htm) might also be useful. Below we list primary intensities `per spill', which at typical best corresponds to a 2-second cycle of 1 second ramping/acceleration and 1 second extraction. Heavy beams (U,Pb) require a somewhat longer (1.5-2.0 s) acceleration phase. Note that the extraction time can be shortened, but that in this case the time profile of the extracted beam is less homogenous. Therefore the instantaneous rate on the detectors could strongly increase. This mode is therefore only recommended if the S2 and S4 rates (see below) are well below the anticipated PRESPEC-AGATA limits. For a rather realistic first-order `Hz' rate estimate, divide the following numbers by 2.

^{238}U: $2\cdot10^{9}$
^{208}Pb: $2\cdot10^{9}$
^{144}Sm: $2\cdot10^{9}$ (no standard beam, used once)
^{136}Xe: 10^{10}
^{124}Xe: 10^{10} (requires enriched material)
^{112}Sn: $\sim10^{8}$ (requires enriched material)
^{107}Ag: $4\cdot10^{9}$
^{86}Kr: $2\cdot10^{10}$
^{78}Kr: $2\cdot10^{10}$ (requires enriched material)
^{76}Ge: $3\cdot10^{8}$ (no standard beam, needs to be developed)
^{64}Ni: $5\cdot10^{9}$ (requires enriched material)
^{58}Ni: $5\cdot10^{9}$
^{48}Ca: $3\cdot10^{7}$ (low intensity from the ECR source when used for pulsed beams for SIS. Or very very expensive …)

Primary beam energy and FRS operation

In principle the highest primary beam energy will lead to the highest production rates and transmission through the FRS. This scenario has to compromised due to the fact that typically best secondary beam energies for, e.g., relativistic Coulomb excitation (at GSI) are some 100-150 MeV/u *at the secondary target*, i.e. in the S4 area. This accounts for, e.g., Bremsstrahlung's and other gamma-ray related background or the achievable energy resolution due to Doppler effects. This 100-150 MeV energy range can be achieved by a combination of lowering the primary beam energy, a rather thick primary target, or a rather thick wedge at S2 in the FRS, thereby somewhat compromising the separation quality and transmission in the (second half of the) FRS. An energy degrader with variable thickness (including zero!) is installed at S4 as well. However, using that one implies increased gamma radiation background hence unwanted particle-gamma trigger rate – which may or may not be acceptable for a given experiment. Note also that the identification detectors at S4, both FRS- and LYCCA-related, also induce a considerable slowing down of the secondary beam energy before arriving at the secondary target.

Primary target thickness

Common RISING or PRESPEC primary targets are ^{9}Be, some 1, 2, or 4 g/cm^2, or Pb, about 2 g/cm^2. These usually allow for an optimal production at the primary target (for beam energies above 500 MeV/u) and proper transmission through the FRS. Note that for optimal rejection in the FRS a thinner target may be preferred, and that there is a whole suite of targets on the standard FRS target ladder (see, e.g, http://www-w2k.gsi.de/frs-setup/ →Target 2 →TS2ET2 drive position). Full LISE or MOCADI simulations can provide fine-tuning opportunities.

Secondary target thickness

For *Coulomb excitation* ^{208}Pb or ^{197}Au targets with a thickness of ~0.4 g/cm^2 are proposed. This value should not be exceeded in view of the beam dispersion (~10 mrad at 100 MeV/u). Otherwise a separation from nuclear excitation processes will become impossible. Note that for higher beam energies the Coulomb excitation cross section will drop (typically by 1/3 when going from 100 to 150 MeV/u). At β~0.5 the time-of-flight through the Au target (0.2 mm) is ~1 ps. Therefore, only gamma decays with a half-life exceeding ~1ps will decay predominantly after the target and lead to "sharp" gamma-ray lines. For shorter half-lifes this effect could be used to determine it -- if *sufficient statistics* can be achieved.

For *secondary fragmentation* or *knock-out* experiments ^{9}Be targets of 0.2-0.5g/cm^2 exist, likewise a liquid hydrogen target (LH$_2$). Here, the maximum target thickness is determined by the energy resolution in particular for "short-lived" transitions which decay within the target and, in case of the LH$_2$ target, the spatial uncertainty of the event-by-event reaction spot. A 1 g/cm^2 Be target is ~5 mm thick which corresponds to a travel time of ~45 ps! In order to make best use of the resolution of AGATA the target should be chosen as thin as possible, unless the effect of the target thickness will be exploited to measure lifetimes by a line-shape analysis. This requires, of course, *sufficient statistics*. Similar arguments are valid for the LH$_2$ target, but the limitations are stronger due to the much larger spatial extension (0.6 g/cm^2 = 60 mm thickness).

Rate limitations

The current and anticipated 2013 PRESPEC detector set-up allows for maximum total rates (i.e. all contaminants included!!) of $3 \cdot 10^6$ Hz at S2 and $1 \cdot 10^4$ Hz at S4 for proper event-by-event *A* and *Z* identification of secondary beam particles. The rates at both S2 and S4 can be determined with properly constructed LISE or MOCADI simulations. The standard set-up includes an existing and working finger detector at S2 while digital readout of the S4 MUSIC detectors has not yet been reliably established. Rates of some $5 \cdot 10^4$ Hz at S4 are tolerable by the (S4 and LYCCA) detectors but should not be considered by experiments (or settings) depending on a clean *Z*-identification of the incoming beam. Finally, the total trigger rate (typically particle-gamma coincidences) should not exceed 2-3 kHz. Experience shows that some 20% of these triggers relate to physically useful triggers; this depends, of course, on trigger-signal threshold and can (and will) be improved by including more (LYCCA) detectors in the trigger scheme. This issue concerns in particular experiments relying on low-energy (< 400 keV) transitions, which suffer from worse peak-to-background ratios and, associated, a reduced ratio of physics triggers.

LYCCA set up

In order to have an optimal *Z* and *A* resolution from LYCCA a minimum energy of the fragments of 80-100 MeV/u after the secondary target is recommended. Make sure that the final fragments come to rest in the CsI full-energy detector elements of LYCCA. Note that all uncertainties, i.e. velocity (spread) or the travel distance (interaction point in an extended LH^2 target) will enter into the ToF- and hence mass resolution. $\Delta Z/Z \leq 0.5\%$ and $\Delta A/A \leq 1.0\%$ are proven numbers for LYCCA-0 from the first PRESPEC experiments, without making use of all fine-tuning offline analysis features possible. The 2012 and 2013 LYCCA-1 set-up comprises a total of 16 $\Delta E/E$ modules (in rows of 2-4-4-4-2) and has an additional 12-PMT Target-TOF detector inside the new AGATA target chamber. This should allow for more precise measurements of incoming and outgoing velocities hence mass resolution.

AGATA set-up

In 2013 the AGATA set-up will realistically consist of 5 triple clusters and 5 double clusters. This leads to these recommended values for the photo-peak efficiencies:

Target-to-Detector distance of 8.5 cm (closest possible)
Efficiency: 13.6% at 0.5 MeV, 11.3% at 1 MeV and 8.2 % at 2 MeV
Target-to-Detector distance of 23.5 cm (nominal)
Efficiency: 7.4% at 0.5 MeV, 6.0% at 1 MeV and 4.5 % at 2 MeV

For short lived transitions (τ < 10 ps for a 0.2 g/cm^2 Be target) the effect of the gamma-decay in the secondary target should be taken into account in the simulation since it can lead to a large broadening of the gamma lines. More details can be obtained via a draft of a PRESPEC-AGATA GEANT4 simulation paper (C. Domingo-Pardo *et al.*, to be submitted).

In 2013 **8 MINIBALL** triples can be accommodated at 90º, thereby replacing the respective **HECTOR** crystals at these positions. (The 2012 standard set-up comprises in total 12-14 BaF_2 or $LaBr_3$ HECTOR detectors at 90º and further backwards.) The MINIBALL detectors are expected to add some 2-3% efficiency at 1 MeV.

Experimental statistics

For Coulomb excitation experiments a 10% statistical error seems a reasonable goal, taking into account that systematic effects for this type of experiment are also of that order (normalisation, nuclear interaction, etc.). As the peak-to-background in the gamma spectra is expected to be of the order of 1:1 (at energies above ~ 600keV!) this would require a statistics of ~300 counts. Beam time requests that exceed this limit should argue precisely why higher statistics is needed. This may, for example, be the case for heavier nuclei where the limited mass resolution of LYCCA does not allow for an unambiguous mass determination. Another example is the line-shape analysis where depending on the peak width 10^3 or more counts may be needed. For spectroscopic studies using knock-out or secondary fragmentation experiments a lower limit of 80-100 counts seems realistic (depending on the achievable line width and the expected peak-to-background).

Other PRESPEC equipment:

Plunger:

A Cologne plunger built for GSI / PRESPEC purposes has been built and a commissioning run was performed Spring 2011. Results are to be presented in the December workshop. Groups interested in plunger experiments should get in contact with the Cologne group (C. Fransen *et al.*).

LH_2 target:

The LH_2 target has been built and (successfully) commissioned Spring 2011. Details will be presented during the December workshop. Groups interested in using it should get in contact with the Saclay group (A. Obertelli *et al.*) to discuss details.