Design ideas for pellet tracking systems for PANDA and WASA

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I. Introduction

The pellet target concept was originally developed for the CELSIUS/WASA experiments [1,2,3] at TSL in Uppsala. The use of cryogenic hydrogen pellets have made it possible to have bare high density hydrogen targets without any enclosing and disturbing material in internal-target storage-ring experiments like WASA and PANDA. The pellets can be brought to the interaction region through meter-long thin pipes. This arrangement provides the necessary space to put the $4\pi$ detection system around the interaction region. Pellet target area densities of up to $3 \times 10^{15}$ atoms/cm$^2$ gives acceptable half-lives of the circulating ion beam as well as acceptable vacuum conditions in WASA. This target system is used regularly with high availability (>90%) in several weeks long experimental runs, since 2006 at COSY and provides 25-30 micrometer sized pellets of hydrogen or deuterium. A new generation of pellet target systems is now being developed at FZJ, Jülich and at ITEP/MPEI, Moscow [4].

The pellet target concept also gives the possibility to have very well defined spatial parameters of individual target particles by using optical position measurements. An optical pellet tracking system (PTR) that would allow to fully exploit the pellet concept has still not been realized. Our project aims to such a PTR that could be used in the future PANDA experiment at FAIR and in WASA at COSY. This requires efficient detection and identification of individual pellets in a pellet stream of high intensity, typically 10k-20k pellets/s. The final goal is to be able to reconstruct the position (3d xyz) for pellets that are in the accelerator beam region at the time of a hadronic interaction event with an accuracy of a few tenths of a mm.

II. Pellet target

The presently operating pellet target systems have a similar basic design. The main components of the WASA system are shown in figure II.1. The heart of the setup is the pellet generator where a jet of liquid hydrogen is broken up into droplets with a diameter of about 30 µm by a vibrating nozzle. The droplets are generated with an exact frequency in the range 40-80 kHz and have a velocity of 10-20 m/s. They freeze by evaporation in a droplet chamber and form a beam of pellets that pass a 7 cm long vacuum-injection capillary (VIC). During vacuum injection, the pellets are accelerated to a velocity around 60 m/s. A useful intensity of 5k-20k pellets/second and beam diameter around 1 mm is obtained by collimation. After collimation, the pellets are directed through a thin 2 m long pipe into the scattering chamber and further down to a pellet beam dump. The inner diameter of the pipe is 5 mm at the entrance to the scattering chamber. The pellet beam has then a diameter around 3 mm and it takes about 70 µs for the pellets to pass through an accelerator beam with 4 mm diameter.

The pellets have very little spread in velocity and direction in the droplet chamber. A significant spread in velocity and direction arise in connection with the injection into vacuum through the VIC. At WASA the time distribution of pellets at the interaction region has turned out to be stochastic and this causes large variations in effective target thickness on a time scale from 10 microseconds to a few milliseconds. This variation should be much reduced with the new generation of pellet target systems.
III. Tracked pellets

Already when the idea of using hydrogen pellets as targets in CELSIUS was first presented [5] there was a simple optical system for pellet detection included. Then studies in the mid 1990ties at a pellet target test setup at CELSIUS showed that it is possible to detect single pellets using a laser and a photodiode array [6]. Later it was shown that it is also possible to detect individual pellets using a commercial “fast” line-scan (LS) CCD camera [7,8] and some pellet stream parameters could be measured at the TSL pellet test station (UTPS). With a LS-camera like with an ordinary camera one makes an exposure and gets a picture, but with LS-cameras the picture only consist of a sub-millimeter thin line of pixels. With the presently fastest LS-cameras the repetition frequency of the exposures is around 100 kHz. The UPTS has now been upgraded with improved alignment mechanics and diagnostics and was after three years of shut down brought into operation again in beginning of November 2008. The measurements with a single LS-camera have been repeated and at present a system of two synchronized LS-cameras is being developed and tested. Some of the results from the tests form the basis of this report.

Precision and effectiveness constitute criteria for how the tracking system will be designed. Different configurations of measurement points and algorithms for different pellet beam intensities and other parameters must be studied for optimization of the system. The geometric conditions for the design study are given by the PANDA and the WASA setups. The accelerator beam is in the horizontal plane and the pellet beam is directed vertically from up to down. In the following description a coordinate system where the y-axis is directed parallel to the pellet beam and the z-axis along the accelerator beam is used. The origin lies in the nominal crossing point between the beams. Pellet detectors can be placed in two sections of the pellet pipe, one at the pellet generator and one at the dump, both at a distance of 1.5 m (WASA) or 2 m (PANDA) from the interaction region. The pellet trajectories must then be
extrapolated to the interaction region using the knowledge of pellet velocity and direction. The determination of velocity and direction can be done over a distance of a few hundred mm at the two sections. The goal for the precision in interaction position is some tenths of a mm. In order to get a feeling for what performance would be required one can do some simplified estimates:

Assuming that we have two perfectly aligned measurement positions (for x and z) separated with 200 mm (in y) on 2000 mm distance from the interaction region. We ignore any correlations between the measurement errors. For a resolution sigma = 0.15 mm in the interaction position coordinates, x and z are then required to have a sigma = 11 micron (i.e. corresponding to a 40 micron pixel size) in measurement positions. In the same way for a sigma = 0.15 mm in the interaction position coordinate, y is then required to have a sigma = 0.12 µs (i.e. 0.4 µs LS-camera exposure time bin) in measurement time for a pellet velocity of 60 m/s. For a pellet velocity of 40 m/s a sigma = 0.18 µs is required (i.e. 0.6 µs LS-camera exposure time bin).

High total effectiveness for pellet tracking means that the tracking system gives correct information for a vast majority of the interaction events and moreover a big proportion applicable position information. In general, the position information is applicable if there is one and only one pellet in the interaction region at the time of interaction. This is achieved by minimizing the spread in velocity in the pellet beam and by choosing an appropriate combination of velocity and pellet intensity. In order for the tracking system to give correct information, the used measurement information must originate from the right pellet. The biggest problem is the spread in velocity in the pellet beam. E.g. if the spread in velocity is +/- 5% and the measurement positions are separated by 200 mm the uncertainty in arrival time to the second measurement position becomes +/- 0.17 ms for a velocity of 60 m/s. For a pellet intensity of 10 k/s 3.4 pellets arrives on the average during that time and it is impossible to know which signal originates from which pellet. The solution is to decrease the distance between the measurement points and to increase the number of measurement points. This could mean that for an initial determination of the velocity of a pellet, the separation between some measurement positions should be around 50 mm.

The velocity spread in the presently operating pellet target systems has not been measured directly with good accuracy but indirect studies points to a spread of some per cent in relative velocity. This would mean that a pellet being in the interaction region at the time of a certain event could have passed the pellet detectors during a time interval of some milliseconds. Thus, to have an even time distribution and small velocity spread is not only important for avoiding large variations in the effective target thickness but obviously also crucial for the possibility of efficient pellet tracking. The time distribution of pellets at the interaction region has turned out to be stochastic in WASA. In this case there are pellets in the interaction region only during 50% of the time for a pellet intensity of 10k pellets/s. In about 50% of those cases there is more than one pellet in the interaction region and in general it is not possible to find out in which pellet an interaction occurred. The tracking system should be designed in a way that it can cope with such a time distribution i.e. it must be able to tell with high reliability how many pellets were in the interaction region at a certain time. This requires a very high efficiency for detecting all individual pellets and a sufficient resolution in the extrapolated y coordinate at the interaction region. The latter means that the sigma must be small in comparison with the accelerator beam size (and also in comparison with the average pellet-pellet distance). In this design study an accelerator beam diameter of 4 mm is considered.
IV. Tracking system

IV.a Layout

A full system as planned for the PANDA setup could be based on a large number of LS-cameras. Two 0.4 m long sections of the pellet beam pipe are planned for lasers and tracking detectors. One section is placed at the pellet generator and one at the dump. Each sector could contain four levels with four ports of quartz glass windows. The levels can be separated by 50-100 mm. Two levels could be for x position and two for z position determination or each level could have both x and z. In the latter case additional ports are needed. The velocity and direction determination can then be done over a path length of 150-225 mm. At each level there would be a laser and positions for LS-cameras and for “normal” CCD cameras, the latter for additional monitoring of the pellet stream. To have two tracking sections gives redundancy with extended possibilities for tuning and checking. Important checks concern efficiency and alignment.

A smaller prototype system with a few LS-cameras could be tested with accelerator beam in WASA at COSY. Such a system might have reduced efficiency and only measure z positions accurately. The resolution in the y-position must be good enough to determine whether a pellet was in the interaction region or not. This means that the resolution sigma must be reasonably small in comparison with the accelerator beam size (and also in comparison with the average pellet-pellet distance), i.e. a few mm at WASA.

Presently a first prototype system with two LS-cameras is being developed at the UPTS for investigation of pellet detection and basic LS-camera performance. Some results are presented in the following sections and form the basis of further design and development work discussed in chapter V.

IV.b LS-camera

The LS-camera model, tested so far, is a commercially available CCD line camera. It has a CCD with one line of 512 pixels, each 14 µm squared. During readout of a line image, the collected charge is transferred to two analog shift registers one for even and one for odd pixels, as shown in figure IV.1. The two sets of pixels can then be processed in parallel chains in the camera by correlated double sampling, dark level correction, gain and offset correction and 12 bit analog to digital conversion. The camera can be read out and controlled via a camera link connection (figure IV.1). The model is called AViiVA M2 CL, and was originally manufactured by the company ATMEL, later acquired by the E2V company. It is claimed to have a maximum line scan rate of 98 kHz and a maximum data rate of 60 Mpixels/s.

During each line scan the CCD is exposed for a period of minimum 5 µs, then follows a dead time of at least 1 µs according to specifications when the charge is transferred from the CCD. After that a new cycle could start in principle. However, the maximum rate is also limited by the readout which starts automatically after 1 µs, and thus will overlap with the next exposure. The maximum line scan rate actually corresponds to a minimum cycle time of 10.2 µs. The readout time should be 8.5 µs. In our tests we could reach a maximum rate of 92 kHz but only with severe readout problems. For proper performance the cycle time had to be set longer than 13 µs and the exposure time could at maximum be 3-4 µs shorter. In addition we found minor interference effects when the readout time and the exposure time overlapped. The cycle can be programmed into the camera or transmitted from the frame grabber via the camera link. Figure IV.2 shows an example of such a control signal from the frame grabber.
Figure IV.1 The AViiVA M2 CL signal processing. Picture from the AViiVA M2 CL product sheet.

Figure IV.2 Timing diagram for the readout of one line. Picture from the AViiVA M2 CL product sheet.

It can either be generated by the frame grabber or passed from an external signal. Using an external signal it is possible to synchronize several cameras so that the lines are exposed simultaneously.

The data sent via the camera link connection is collected by a frame grabber, a PCI board in the DAQ computer. Our frame grabber is mvTITAN-CL made by the company Matrix vision. It acquires the lines from the camera link and stores them in an internal memory. Usually a set of lines e.g. ~5000 is stored at a time. This set, called a frame, is then transferred by DMA into the computer’s memory where it can be retrieved by an online program and e.g. searched for signals coming from pellets. The lines in the frame are then analyzed one by one, individual pedestals are subtracted and a cut is applied for each pixel. A pellet signal is identified if one or more consecutive pixel signals are above the cut.

**Camera optics**

A convenient work distance for pellet detection is about 250 mm to the focal plane. This distance was chosen from mechanical and optical considerations. The cameras have been tested with lenses of focal lengths 50 mm and 25 mm. For the 50 mm lens the image seen by
each pixel corresponds to \(\sim 40 \mu m\) square and for the 25 mm lens to \(\sim 100 \mu m\) square at the working distance. The length of the line corresponds to 20 mm and 50 mm respectively. The depth of field (DOF) is a few mm only.

It should be noted that a 25 \(\mu m\) pellet with velocity 60 m/s can be seen by the camera only during 1 \(\mu s\) (2 \(\mu s\)) when using the 50 mm (25 mm) lens. This means that the light pulses from the pellets are much shorter that the dead time of 3-4 \(\mu s\) in the camera cycle and that this causes a detection inefficiency that must be handled. How this could be done is discussed in chapter V.

**IV.c Illumination**

To see the pellets a sufficiently intense light source needs to illuminate the region where the pellets are expected to pass in the camera’s field of view. This means that the laser light should be focused to a line with a height matching the field of view of the camera and allowing for some small misalignment. For the \(f = 50\) mm lens this means a height in the region 50-100 \(\mu m\). The width of the line to be illuminated is given by the diameter of the pellet stream i.e. 1-10 mm depending on exactly where along the pellet stream the camera would be positioned. The light should also be emitted at a wavelength where the camera is most sensitive (see figure IV.3).

**Laser-camera alignment.**

For efficient detection of pellets in an extended pellet stream it is necessary that the plane defined by the laser line and the plane seen by the camera are very well aligned. At the UPTS the position of the cameras can be adjusted by micrometers with a relative accuracy slightly better than 5 \(\mu m\). The inclination cannot be adjusted in a smooth way in the present setup. The laser position and inclination is adjusted to give a beam in the horizontal plane in a quite rough way with positioning screws. The alignment is optimized by maximizing the pellet rate seen by the camera(s) by tuning the camera y-position. When scanning over y-position, a pellet rate distribution with a fwhm of 100 \(\mu m\) and a full width of 200 \(\mu m\) was obtained with
the MFL and a distribution with a fwhm of 150 µm and a full width of 300 µm with the SNF in typical runs. This indicates that the camera plane and laser plane were not in perfect agreement.

![Figure IV.4](image1.png)

**Figure IV.4** Distribution of integrated pellet signals for the SNF laser at a) 45° and b) 135° angle.

With pellets, three illumination geometries with different opening angle between the camera and the laser beam (45, 90 and 135 degrees) have been tested. The 90 and 45 degree cases give about the same light yield while the 135 degree case gives more than the double. Amplitude spectra from pellets illuminated by the SNF laser are shown in figure IV.4. The size of the pellets in the images is mostly one or two pixels.

![Figure IV.5](image2.png)

**Figure IV.5** Tabletop camera test stand.
IV.d Camera test stand and calibration

A tabletop test setup for studying and developing camera performance has been prepared (figure IV.5) where thin wires ($\Phi = 30 - 100 \mu m$) can be used as objects instead of pellets. There are different possibilities for illumination e.g. laser and light emitting diode (LED). Basic optical performance like magnification and depth of field (DOF) has been studied in this setup. By using a LED powered by a pulse generator as light source it was possible to check basic camera parameters like exposure time, dead time and other effects for different camera settings. In these studies, a set of different LED pulse lengths, amplitudes, frequency settings was used and the camera response was then compared with expectations/simulations. In figure IV.6 are shown examples of signal responses for a certain camera period and exposure time with different LED pulse lengths. If the LED pulse length is different from the exposure time a maximum signal peak is seen. If they are equal no peak is seen (lower right plot). In this way the exposure times were measured.

Figure IV.6 Tabletop camera test. Examples of signal response for a particular camera period and exposure time and some different signal lengths. In red expectations from simulations.

Top line: Response of a neighbor pixel, left with pedestal, right without, to a 2 µs diode pulse.
2nd line: Response of the central pixel. The red line shows the result of a simulation.
3rd line: Response of the central pixel to an 8 and 14 µs long pulse. Note the flat distribution obtained when the signal length equals the exposure time.
Figure IV.7  Number of lines since last signal for 14 µs exposure time, 20 µs cycle time and 8 µs LED signal length at 9.2 kHz frequency. The right plot shows the expectation from simulation.

In a similar way one looked for the appearance/disappearance of cases with missing signals or with signals in neighboring lines versus LED pulse length and got a measure of the dead time (figure IV.7). Other studies concerned signal linearity versus LED pulse length and amplitude. An important parameter is the signal resolution. The width of the pedestals (due to noise) and the width of the maximum signal peaks were about 10 units (for 12 bit readout). This means that the signals from pellets should be at least a few times higher than the noise level for fully efficient detection.

The setup was also used to investigate the previously mentioned (sect. IV.b) interference effects in the camera cycle. An evenly illuminated white screen as object was used to make (check) signal calibration for the individual pixels. Basic synchronization tests were done in a configuration with two cameras looking at a wire that was illuminated by short LED pulses (figure IV.5).

IV.e  Synchronized operation of LS-cameras

The first tests with pellets and two synchronized cameras were carried out at the UPTS in November 2009. Figure IV.8 shows a two-dimensional profile of the pellet beam obtained in this way. The two cameras view the pellet stream from the x and z direction at the same height, y-coordinate. The alignment in y is assured by the narrow line profile of the laser beam. The pellets are illuminated from behind, with the laser at 135 degrees relative to the cameras (figure IV.9). An external signal triggers the line scans of the cameras to ensure that the lines are simultaneous with high accuracy. However, since the lines are read in frames of several 1000 lines, there is a risk that the frames are shifted relative to each other. One way to
check that the frames are synchronized is illustrated in figure IV.10. When a pellet is found on a line in the second camera it is checked on which line a pellet was last found in the first camera and the difference in the line numbers are plotted as a function of time (in units of lines). Zero means that there was a “pellet signal” in both cameras at the same time and a number greater than zero means that one signal was missing e.g. due to inefficiency, noise or that camera synchronization was lost. At time \( 500 \times 10^3 \) lines the synchronization was switched off and a more random distribution is seen. This gives some confidence that the synchronized cameras are actually seeing the same pellet. The cross section of the pellet beam shown in figure IV.8 agrees fairly well with what was obtained from other diagnostics in the same run.

Figure IV.9. Two-camera setup at the UPTS.

Figure IV.10. Monitoring of the line synchronization with pellets for two cameras in an x-z configuration.
With cameras at different positions along the pellet stream, different $y$, the method in figure IV.10 cannot be used since the pellets arrive at different times. One idea how to check the alignment of the frames in this case, is to use synchronized LEDs providing short light flashes with low frequency. White screens placed at the edge of the field of view of the cameras, reflects the LED light into the lens, creating occasional lines with a bright signal in the peripheral part of the line. An example of a test with this method is show in figure IV.11.

![Figure IV.11](image)

**Figure IV.11.** A frame of 5000 consecutive lines where some pellets can be seen and two flashes of the synchronization diod. With cameras at different positions along the pellet stream synchronized flashes in both cameras could allow the lines to be synchronized in time.

V. Tracking system design plan

The steps planned for the process of design and preparation of a final full system for PANDA (“PTR-panda”) were discussed in section IV.a. Further basic tests and developments are needed using the prototype system at the UPTS (“PTR-upts”) in order to find a design that could work and be tested at WASA (“PTR-wasa”).

V.a Considerations for PTR-upts/wasa/panda

**Detection efficiency**

Important for a high pellet detection efficiency are good illumination conditions and to have minimal inefficiencies due to dead times in the camera cycle. Development work on this will continue at the UPTS.

The illumination conditions obtainable with the present equipment may be acceptable but there is room for improvements. For example, the laser beam intensity can be increased by using more optimal laser optics. There also exist lasers of suitable type with slightly higher power that could be used. The illumination geometry cannot be improved very much with the present equipment due to geometrical constraints. Ways to further optimize the alignment between the laser beam and the camera will be investigated. The shape of the amplitude spectra for pellets must also be better understood. In measurements with one laser and two synchronized cameras looking at the same $y$-level and with symmetric illumination geometry
we plan to study correlations between amplitudes and between amplitude and position. This would give valuable information for finding the cause for the wide amplitude spectra seen so far (e.g. as shown in figure IV.4).

In a useful tracking system one can only allow very small inefficiencies caused by camera dead times. One way is to make sure that the light signal from a pellet is sufficiently long to bridge over the dead time in the camera cycle. Since the specified minimum dead time is 1 µs for the present cameras, the signals from the pellets should be about 2 µs long. This could be achieved e.g. with the f = 25 mm lens (and modified laser beam profile), but with a loss of resolution. To have much longer light pulses does not make sense. This means also that the presently achieved minimum dead times of 3 - 4 µs must be understood and reduced. Another way, which should be more effective, is to have two cameras at the same y-level synchronized with their cycles shifted half a period so that always at least one camera sees the pellets. With the present equipment the only possible geometry is that the cameras sit on opposite sides of the pellet beam. One could then use one laser at 90 degrees (or two lasers at 135 degrees).

It must be possible to monitor and optimize the detection efficiency in a convenient way. This can be done quite straightforward in a configuration with one laser and two synchronized cameras looking at the same y-level and with a symmetric illumination geometry. Then one just checks the time correlation between signals from the two cameras. If the cameras measure the same coordinate one can also compare the obtained pellet positions. Another possibility is to use a “standard” pellet counter based on a laser and a PM tube and compare pellet rates and signals from that system with what is seen by the LS-cameras.

**Time resolution**

The time resolution for a single camera is given by the exposure time duration. With the present cameras the specified shortest exposure time is 5 µs but it has turned out that shorter times down to 2 µs also work. For a final system this may still be too long if one aims at a sigma-y of 0.15 mm in interaction position precision. Another major problem is the long dead time, for the present cameras at least 8 µs in this case. This is due to the readout time which is about 8.5 µs, depending on the number of pixels to be read out.

![Diagram](image-url)

Figure V.1. An example is shown how the measuring cycles (white part = exposure, dark part = dead time) of two cameras can be shifted by half a cycle relative to each other, in order to minimize the overall dead time and increase the time resolution. The response of the two cameras can be compared so as to divide the cycle in to 4 bins.
With the current camera technology but specially designed with only 100 pixels the readout time would decrease to 2 μs. Then the minimum camera period time could be 3 μs and the dead time fraction would still be significant.

With two specially designed cameras measuring the same coordinate at the same y-level and synchronized with their cycles shifted half a period time one would then have a time bin of 0.5-1 μs i.e. a sigma of 0.25 μs which is in the region of the final goal for PTR-panda. This is illustrated in figure V.1. With such an arrangement one would also get rid of inefficiencies due to the dead times as discussed above. With the present camera performance of 14 μs period and 10 μs exposure time (see sect. IV.b) one would get a sigma of 1.5 μs which could give an interaction position y-coordinate sigma around 1.5 mm i.e. what is required for PTR-wasa (from time resolution point of view).

In the initial PTR-upts there will be only one camera at each level and this would give a time resolution sigma of 3-5 μs and a dead time fraction of around 30-20% for camera periods of 14-20 μs.

Laser-camera alignment

For efficient detection of pellets in a pellet stream of 1-6 mm in diameter at WASA and PANDA, it is necessary that the plane defined by the laser line(s) and the plane seen by the cameras are well aligned within ≈10 μm over the whole extension of the stream. This requires an accurate and flexible system for alignment.

Global alignment adjustment and check

The accuracy of the absolute alignment between the measuring positions within the tracking sections should be ≤ 0.01 mm and the accuracy of the absolute alignment of the tracking sections relative to the interaction region must be ≤ 0.1 mm in order not to limit the resolution in interaction position determination. This needs accurate mechanical machining of the tracking sections and accurate survey of the complete target setup. Also other elements, like VIC exit, skimmer and other aperture limitations that should be taken into account in the tracking must be carefully aligned. The alignment parameters can finally be tuned by using suitable beam particle – pellet interactions. The tracking section at the pellet dump should be very useful for checking alignment and tuning the tracking procedure (also without accelerator beam). The information from all tracking detector positions should finally be used in the tracking for best accuracy.

Multi-camera operation and data processing

The PTR-upts will initially consist of two cameras. A PTR-wasa would minimum consist of 3-4 cameras but probably the double would be needed for a useful (efficient) system. A PTR-panda would have even more cameras.

To process this amount of data online, is probably not feasible using a normal computer with readout of the individual cameras but requires the use of a dedicated electronics board. A board that could be suitable for the task has recently been developed within the WASA group in Uppsala. The board is intended as an intelligent trigger for the WASA experiment. ADC data are collected directly from the frontend modules via serial optical links. The data can be calibrated and complex trigger conditions can be calculated. The board, which is presently being commissioned, is equipped to receive data from up-to 16 optical links with a maximum speed of 1.6 Gbytes/s. A VIRTEX 5 FPGA receives the data from all links and can be programmed to perform any desired calculations e.g. to find the time and position of
detected pellets. To use the board in the PTR system an adapter which converts the serial data from the camera to a suitable format for the optical links needs to be developed. Each camera can produce up to about 120 Mbytes/s of data giving a total of ~2 Gbyte/s for a 16 camera system. The FPGA should also provide all signals to synchronize the different cameras to each other. Such a system which handles all cameras in parallel should avoid all the previously discussed synchronization issues. The board could also receive the experiment time stamp to avoid any timing issues and record the experiment trigger number for use in the analysis. Finally the time and positions for pellet passages at each camera and triggers, amounting to a few Mbytes/s, can be stored in memory also available on the board. Readout is provided via VME or the specially developed LVDS bus available in WASA. Eventually the pellet position in the interaction area at the time of a particular trigger can be calculated in the offline data analysis.

V.b Simulations

The discussion in this report concerning performance of the pellet tracking systems was mainly based on rough calculations and simple simulations. More extensive simulations are being prepared in order to make an optimal design. In the simulations individual pellets are traced through a setup (WASA and PANDA) consisting of a “pellet generator” (VIC exit), a skimmer, some measurement positions, the interaction region and additional measurement positions at the dump. Different configurations of measurement points and parameters and different possible pellet stream properties will be studied. The simulations are also needed in the development of tracking algorithms. From the simulations one should be able to answer the following questions:

- What is the number of pellets in the interacting region at a particular time?
  Several situations are possible: none, one pellet or several pellets in the interacting region at a certain time. One and only one pellet is desired. It is interesting to know how good information one can get from the tracking system in this respect.

- What are the effectiveness in tracking and the quality of the tracking information?
  Due to the spread in velocity, limited measurement accuracy and inefficiencies, (and other things) the information from tracking can be uncertain. For an interaction event the information can be missing, be correct and more or less accurate or simply incorrect.

- Accuracy in the reconstructed interaction position?
  The measurement accuracy and efficiencies, the alignment of the detector system and the performance of the tracking algorithm are important factors.

More extensive simulations are also needed for the design of the PTR-ups, for choosing the measurement conditions and for the interpretation of the measurement results. One of the first studies will concern the effect of pellet stream intensity and camera dead time on the possibility to identify a certain pellet at two y-levels at a given distance and with certain pellet stream parameters.
V.c Status and plans

Status (December 2009):

- A reasonable understanding and verification of the operation of the LS-cameras have been reached.
- A procedure of signal calibration for individual pixels has been developed
- Synchronized r/o of 2 LS-cameras has been demonstrated.
- The conditions for illumination of the pellets have been improved.
- The design of a few-camera tracking system has started.

Plan for 2010:

- To continue basic performance studies/optimizations.
- To prepare a first prototype PTR system at a section to be placed below the pellet stream collimator (UPTS) for measurements of pellet target parameters dt, dx, dz
- To begin preparations for a simple tracking system based on at least 3-4 LS-cameras (that could be tested at WASA).
- To start the simulations for the design of a full scale system (for PANDA).

Goal for 2011-12:

- To make full performance simulations of possible tracking system configurations and algorithms using realistic pellet stream parameters.
- To design the full scale system including mechanics, detectors, lasers, readout, software etc and eventually start prototyping.

References