1. Physics at PANDA

a) collisions:
- Hadron spectroscopy
- Charmonium
- Glueballs, hybrids, tetraquarks, molecules
- D mesons
- Strange and charmed baryons
- Non-perturbative QCD dynamics
- Baryon-Antibaryon production
Large angle annihilation into two-mesons
b) collisions:
- Λ hypernuclei
- Hadrons in the nuclear medium

2. Experimental conditions

Requirements on experimental conditions:
- High luminosity
- High detection acceptance and efficiency
- Low "nonphysical background"
- Reliable determination of event topology

Important features of the PANDA target design:
- Possible target thicknesses
- Size of interaction region
- Space and time structure of interactions
- Info for vertex position reconstruction
- Improve track reconstruction
- Background suppression
- Identify secondary vertices (cτ = 0.1 - 100 nm)

3. Target variants

Clusters – cold aggregates of hydrogen molecules
- Sizes ≈ 10^{10} atoms, diameter < 1 μm
- Cluster jet size ≈ 3 x 15 μm
- Max target thickness ≈ 1 x 10^{15} atoms/cm²
Pellets – frozen microdroplets of hydrogen
- Sizes: 10^{12} − 10^{14} atoms, diameter: 10-25 μm
- Pellet stream size: ≈ 3 mm
- Max target thickness: ≈ 5 x 10^{15} atoms/cm²

Usually
The interaction region is given only by an estimate of the overlap of the target and the accelerator beams
→ an extension of ≈ 3 - 12 mm

To know the interaction point more precisely:
- Gives better possibility to reconstruct the particle tracks coming from the interaction point.
- Gives suppression of background events that do not come from the target, but e.g. may occur in rest-gas, present in the beam pipe.

4. Basic Concept

To measure pellet position and time in a few planes along the pellet stream...

... and extrapolate the pellet tracks to the interaction region.

5. Pellet detection

Measurements done with fast line-scan CCD cameras (≈ 10 μs cycle, 25 μm pixels)
Pellets illuminated by lasers.

6. Multi-camera readout development

CamLink FPGA board is used for readout of 2-4 cameras.

Software:
- Camera link readout and pellet recognition
- Communication with camera and VME board

VME FPGA board (developed for the WASA trigger) is used for readout of up to 8 CamLink FPGA boards.

Software:
- Control and readout of camera link board
- VME readout

7. UPTS

Uppsala Pellet Test Station

Prototype of a pellet tracking system is being tested at UPTS.

8. Design simulations

Various aspects of pellet stream behavior and the measurement process are taken into account in the simulations.

Pellet behavior
- Generation frequency
- Mean velocity in the stream
- Velocity spread
- Direction and position spread
- Loss at generation and during the way
- Fluctuation of the rate

Measurements
- Pellet size and camera sensor shape and size
- Camera cycle structure (period and exposure time)
- Illumination
- Effects of optics - apparent pellet size, its center of brightness

The simulations are well reproducing the results of experiments with pellets at the Uppsala Pellet Test Station. They are used in further design work.

Extrapolated transversal positions of pellet tracks from experimental data taken at UPTS (left) and the result of the simulation (right).

9. Pellet track reconstruction

For each pellet recorded at the first measurement level we want to collect all information needed to reconstruct the time and position of this pellet at the interaction region.

- The mean velocity of pellets is used to get the expected pellet time at the second measurement level.
- The measurement closest to the expected time is assumed to be the measurement of the correct pellet.
- This time is used to calculate a new, improved velocity.
- The velocity is then used to search for the pellet at the next measurement level.
- This is continued until the last measurement level.

Having information from all measurement levels, one can fit pellet tracks.

The pellet position at generation may also be used as an additional point in the track fitting.

10. Tracking resolution

Tracking resolution obtained in the simulations, by comparing reconstructed and true pellet position at the interaction region.

Transverse resolution
Depending on the position measurement resolution and on the distance between the measurement levels.

Longitudinal resolution
Depends on the time resolution from the cameras and the distance between first and last level in the measurement section.

11. Tracking performance

The tracking system should provide useful i.e. correct tracking information for as many as possible of hadronic events.

To evaluate the performance one compares the number of true and reconstructed pellets in the beam region.

Questions:
- What number of pellets is found by the tracking, if a certain number of pellets is in the beam?
- What is the true number of pellets, when the tracking gives a certain number?

For 5 mm accelerator beam diameter and 50% position information at the beam centre:
- About 70% of the hadronic events would have correct information from the tracking system.
- For about 50% of the events there would be unambiguous position information.

12. Long Range TDC at WASA

A suppression of events from rest-gas, one of the advantages given by the pellet tracking, may be demonstrated with another system using standalone information similar to the pellet tracking.

- Pellets are in the beam only during a fraction of the time
- Events from rest-gas happen all the time
- When a pellet is in the beam it’s much more probable, that the event came from the pellet.

One can exploit an alternative method, based on the integrated event rate of interactions, to check when pellets are in the beam.

When a pellet passes through the beam, there are more interactions.

Further reading


Acknowledgements

This project is supported by Forschungszentrum Jülich, COSY-FFE, European Commission Framework Program 7, Swedish Research Council and Foundation for Polish Science (MPD programs).