Implementation of pellet tracking in physics experiments – initial studies at WASA

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Small **frozen hydrogen pellets**, generated far from the interaction region, are used as targets in hadron physics experiments.

- **Goal:** improving the accuracy of event analysis by precise knowledge of the primary interaction vertex
- **Method:** measuring positions and times of the pellets
- **Means of measurement:** lasers and line scan CCD cameras
Measurements at Uppsala Pellet Test Station (UPTS) with the Pellet Tracking (PTR) prototype

Windows center
vert. dist. (mm)

-76.5    DC
0        VIC exit
271.5    PTR gen

1513.0 Skimmer
Φ=2 mm

1860.2    PTR up
1939.7    PTR low

(2690 Cosy beam)
(3500? HESR beam)
Pellet tracking for Panda

Panda with two sections for pellet tracking

Tracking section design idea

PTR section – Interaction region ≈ 2 meters

Laser

Cameras
A **tracking system** based on the upper tracking section (at the pellet generator) has been designed*

- **Various aspects** of pellets behavior and detection are **simulated**
- **Realistic parameter** distributions are taken from **UPTS experiments**
- Required **transverse** position **resolution of** $\sigma \approx 100 \, \mu m$ can be reached
- Required **efficiency can be achieved**; i.e. useful information for $>70 \, \%$ hadronic events is expected
- **Further optimization** work **in progress**, both for equipment and procedures

*) See talk at SFAIR meeting 2012: [http://www.physics.uu.se/np/panda/pub](http://www.physics.uu.se/np/panda/pub) (Presentations and Conference Contributions)
Simple demonstration of one possibility with pellet tracking

With Pellet Tracking, the number of pellets in the accelerator beam region at the time of an interaction, can be reconstructed in the offline event analysis.

This allows suppression of events not originating from accelerator beam - pellet interactions in two ways:

- **Event-by-event**: reject events occurring when no pellet was present.
- **In kinematic distributions**: save the no-pellet event sample to be used in background subtraction (continuous empty target correction).

Check feasibility of using a standalone system for suppression of rest-gas events.

- There are pellets in the beam only for some fraction of the time
- Events from rest-gas happen all the time
- When a pellet is in the beam, it is most probable, that the event came from the pellet.

Exploit the integrated rate of interactions, to know when there are pellets in the beam.

When a pellet passes through the beam, there are more interactions.
Studies of "pellet" Long-Range (LR) TDC spectra

Rate of WASA “elastic” trigger

- A pellet crosses the COSY beam at its center in \( \approx 70\mu s \)
- Structures of such duration are visible in the time spectra

Most straight-forward use of the LR TDC information

Select time intervals when single “well sized” pellets pass the central part of the COSY beam

The LR TDC system operates with a similar time scale as pellet tracking (between some microseconds and several seconds).

This is very different from the time scale of the WASA data acquisition (parts of nanoseconds to a few microseconds).

The work on the LR TDC data together with the WASA DAQ data gives experience of how to synchronize and use PTR information in a hadron experiment data analysis.

The synchronization was achieved by writing a common time stamp (and event number) to both DAQ systems.

Example 10 ms sample:
- Pellet rate \( \approx 8 \text{ k/s} \)
Events classification

Non-Pellet class
Small instantaneous event rate ⇔ Small probability of a pellet in the beam region
0 – 20 events in a 25 $\mu$s bin

Pellet class
High instantaneous event rate ⇔ High probability of a pellet in the beam region
21+ events in a 25 $\mu$s bin

Ranges adjusted to correct for accelerator beam decaying during the cycle
(At the end, the beam intensity $\approx$ 50 % of initial intensity)
Test reaction: $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$

$P_{\text{beam}} = 1.023 \text{ GeV/c} \leftrightarrow E_{\text{kin}} = 0.45\text{GeV}$
The measurement of $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$ events is simulated with the WASA Monte-Carlo (WMC).

The simulated WMC events (right plot) are with realistic detector resolutions but without taking rest-gas into account.
**Reconstructed angles** of gamma particles depend on the **assumption**, that the **interaction** vertex was in its nominal position \((0, 0, 0)\).

If the **interaction** occurred in **rest-gas**, the reconstructed **angle** will be **incorrect**.

*Distribution of theta angles of gammas:*

Theta angle of lower energetic gamma
Theta angle of higher energetic gamma

Theta angle of first neutral particle track in CD
Theta angle of second neutral particle track in CD
Missing and invariant mass for different angles

Angle of higher energetic $\gamma$

[27, 40) deg  [40, 107) deg  [107, 169) deg

Angle of lower energetic $\gamma$

[107, 169) deg  [40, 107) deg  [27, 40) deg

WMC with 0% rest-gas  WMC with 23% rest-gas

Influenced by rest-gas contribution:
- Shape of the 2-dim distribution
- Width and position of the $\pi^0$ peak
- Distribution of events between the 9 angle combinations
Simulations of the rest-gas influence

Comparison between **exp. data** and **23% rest-gas WMC** for **small angles of both gammas** ($\Theta < 40^\circ$) i.e. the sample in the lower left plot of the 3x3 MM-IM-plots. – angle range where the **rest-gas influence is the most visible**

- **WMC** with 23% rest-gas reproduces the **rest-gas** influence in the exp. data
- In the **exp. data** there are also present structures not coming from rest gas or pellets - **other kind of background** events resulting e.g. from event pile-up or accelerator beam halo interactions in the pipe walls.
Results of the LR TDC "tracking" (1)

Comparison between two LR TDC classes in the exp. data – for small angles of the gammas (\( \Theta < 40^\circ \))

- **additional peak** clearly visible in the \( IM_{\gamma\gamma} \) spectrum for the Non-Pellet class
- \( MM_{pp} \) spectrum sharper for the Pellet class
Comparison of **LR TDC classes** with suitable **WMC** simulations – for small angles of the gammas ($\Theta < 40^\circ$)

**Exp. data LR TDC** Non-Pellet class and WMC with 48% rest-gas events

(events from pellets might occur also with small LR TDC rate)

**Exp. data LR TDC** Pellet class and WMC with 10% rest-gas events

(events from rest-gas present also when pellet is in the beam region)

- **LR TDC Pellet class** exp. data is in agreement with WMC with low rest-gas contrib.
- **LR TDC Non-Pellet class** exp. data contains events from rest-gas and other background not coming from the nominal interaction region.
Pellet tracking

A system for PANDA, based on lasers and fast line-scan cameras, has been designed.

- The requirements on position resolution and efficiency can be fulfilled.

Initial studies, on how to synchronize and implement pellet tracking information in a hadron physics experiment, have been done at WASA.

- The procedure works according to expectations.