A Pellet Tracking System for the PANDA Experiment

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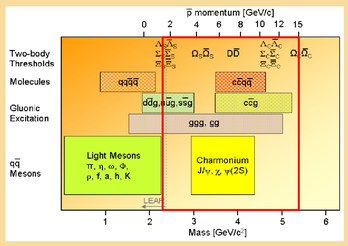
1. Physics at PANDA

$\bar{p}p$ **collisions:**

- **Hadron spectroscopy**
  - Charmonium
  - Glueballs, hybrids, tetraquarks, molecules
  - D mesons
  - Strange and charmed baryons
- **Non-pertubative QCD dynamics**
  - Baryon-Antibaryon production
  - Large angle annihilation into two-mesons



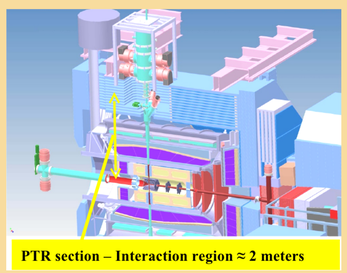
$\bar{p}A$ **collisions:**

- $\Lambda\Lambda$ **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** ($c\tau$ = 0.1 – 100 mm)

Some particles with $c\tau$ = .1–100 mm	
$D^{+/-}(1869)$	0.3 mm
$\Lambda(1116)$	79 mm
$\Sigma^{+}(1189)$, $\Sigma^{-}(1197)$	24, 44 mm
$\Theta^{0}(1315)$, $\Theta^{-}(1321)$	87, 49 mm
$\Omega^{-}(1672)$	25

3. Target variants

Clusters = cold aggregates of hydrogen molecules
- **Size:** $\approx 10^5$ atoms, diameter $< 1\ \mu m$
- **Cluster jet size:** ≈ 3 x 15 mm^2
- **Max target thickness:** $\approx 1 \times 10^{15} atoms/cm^2$

Pellets = frozen microspheres of hydrogen
- **Size:** $10^{13} - 10^{14} atoms$, diameter: 10-25 μm
- **Pellet stream size:** $\phi \approx 3mm$
- **Max target thickness:** $\approx 5 \times 10^{15} atoms/cm^2$
- **Distance between pellets:** a few millimeters

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**;

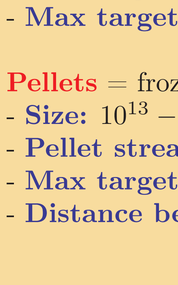
Goal

To know the interaction point more precisely:

– Gives **better** possibility to **reconstruct** the particle **tracks** coming from the interaction point.

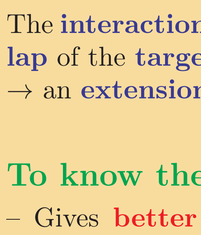
– Gives **suppression** of **background** events that do not come from the target, but e.g. may occur in rest-gas, present in the beam pipe.

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

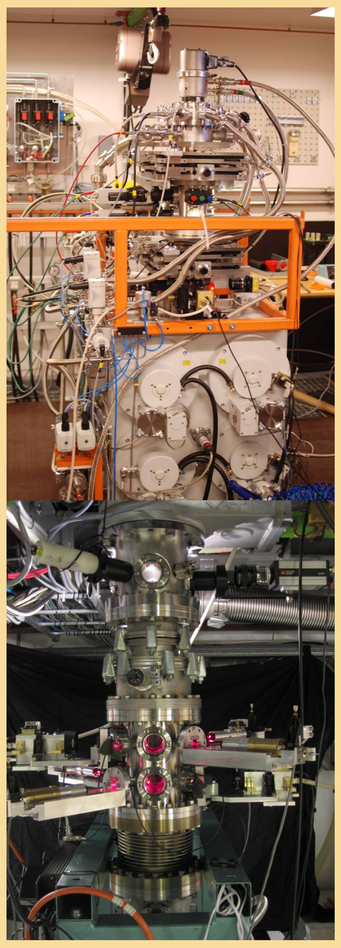


VME FPGA board (developed for the WASA trigger) is used for readout of up to 8 CamLink FPGA boards.

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

7. UPTS

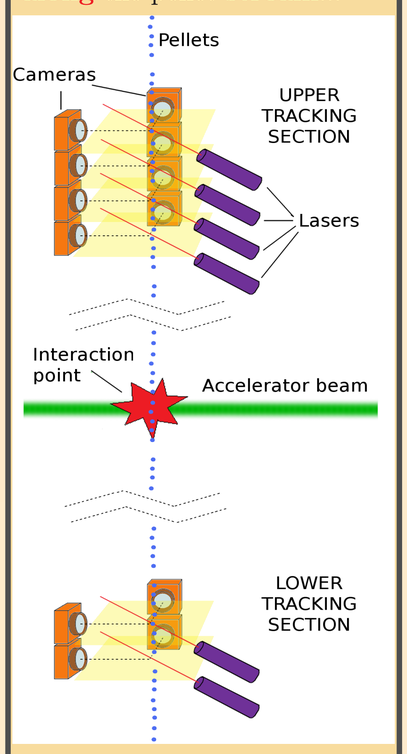
Uppsala Pellet Test Station



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

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**.

***

Design of a tracking section:

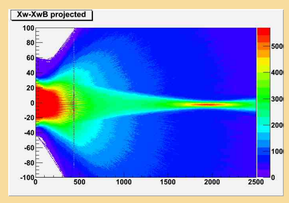
8. Design simulations

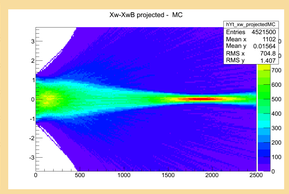
Various aspects of pellet stream behavior and the measurement process are taken into account in the simulations:

Pellet behavior
- Generation **frequency**
- Mean **velocity** in the stream
- **Velocity spread**
- **Direction** and **position** spread
- **Loss** at **generation** and during the **way**
- **Fluctuations** 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 transverse positions of pellet tracks from experimental data taken at UPTS (left) and the result of the simulation (right). The scale on the x-axis is in millimeters. A focus is seen at about 2000 mm which is the position of generation.

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.

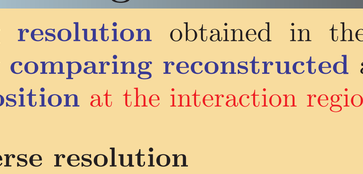
Transverse resolution

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

→ Resolution $\sigma \approx$ **250** μm
→ $\sigma \approx$ **70** μm when the nominal pellet **generation** point is an **additional point** in the track **fitting**.

Longitudinal resolution

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

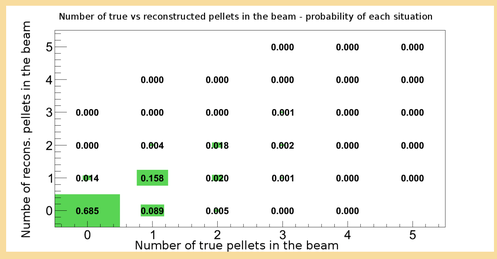


→ Resolution $\sigma \approx$ **0.8 mm** for 4 μs effective measurement resolution.

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 **pellet rate 5k** 1/s:

- 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**.

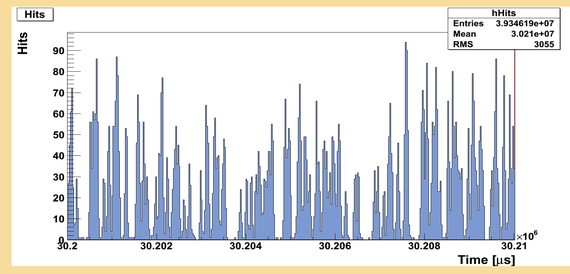
12. Long Range TDC at WASA

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 similarly 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**.



The study at WASA-at-COSY is in progress...

Further reading

Simulation studies for design of pellet tracking systems, A. Pyszniak et al., January 2013, Project report, *http://www.physics.uu.se/en/np/panda/pub/*

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