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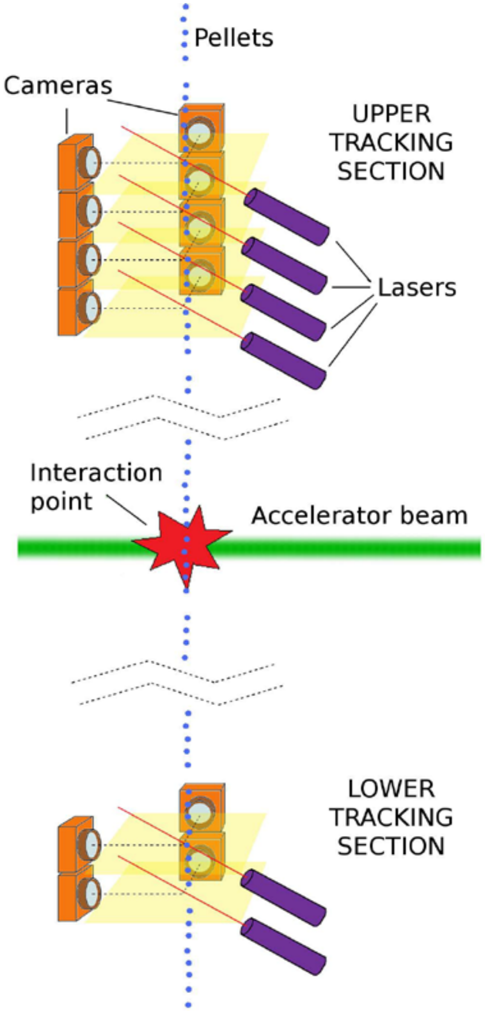
Status of Pellet Tracking

Work during the autumn:

- **Tracking system design … cont.**
  (Andrzej Pyszniak: Lower section, algorithms ….)
- **High efficiency pellet detection.**
  (Analysis of UPTS studies. Miriam Kümmel and others ….)
- **Multi-camera readout system.**
- **Implementation of pellet tracking in physics experiments – initial studies at WASA**
  (Andrzej Pyszniak talk at Swedish Nuclear Physicist Meeting Stockholm 4-6.11.2013)
- **Vacuum studies at WASA (COSY).**
  (Added PEG vacuum gauges in February 2012….
  Johan Löfgren does the vacuum calculations)



UPPSALA team

Senior researchers:	Hans Calén, Kjell Fransson, Pawel Marciniewski
PhD student:	Andrzej Pyszniak
Engineers:	Carl-Johan Fridén, Elin Hellbeck
Erasmus / Project work	Miriam Kümmel (Bochum), Johan Löfgren

Project supported by JCHP-FFE, EC FP7, FNP(eu-MPD) and SRC

Tracking system design status (December 2013)

A pellet tracking system for PANDA, based on the **upper tracking section** (generator), **was designed:**

- **Various aspects** of pellet behavior and detection were **simulated** using **realistic parameter** distributions from **UPTS tests.**
- A first version of **pellet tracking algorithm** was **implemented**.
- The **simulations** were used to determine **resolution and efficiency**.

→ **Transverse** position **resolution is σ ≈ 100 μm**

→ **Vertical resolution is σ ≈ 800 μm**, with 10 μs cycle cameras. (**May be sufficient**, **but it would be better** with 5 μs cycle … (camera type commercially available))

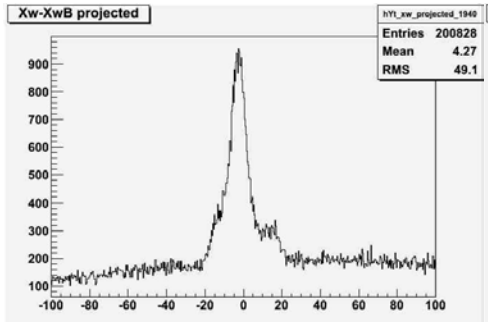
→ **Efficiencies >70 %** as specified **in Panda Target TDR can be achieved**; i.e. useful info for a proper combination of pellet rate (around 10 k/s) and beam size (5-10 mm)

A design for the lower section (dump), mainly for tuning and checks, but also for improvement of vertical position resolution, **is in progress**

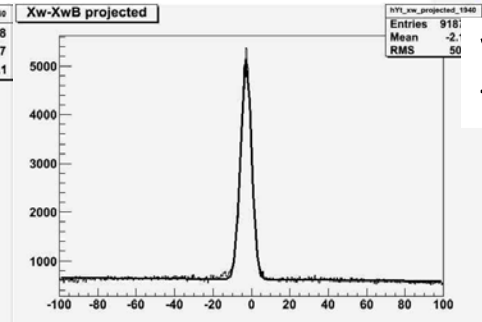
Further optimizations are ongoing and planned
both for equipment and procedures

DOF study (May 2013). Camera optics f=50mm, bl.=1.4, d(pelletstream – focalplane) ≈250mm.

Pellet beam a few mm out of camera focus ….



Pellet beam in camera focus



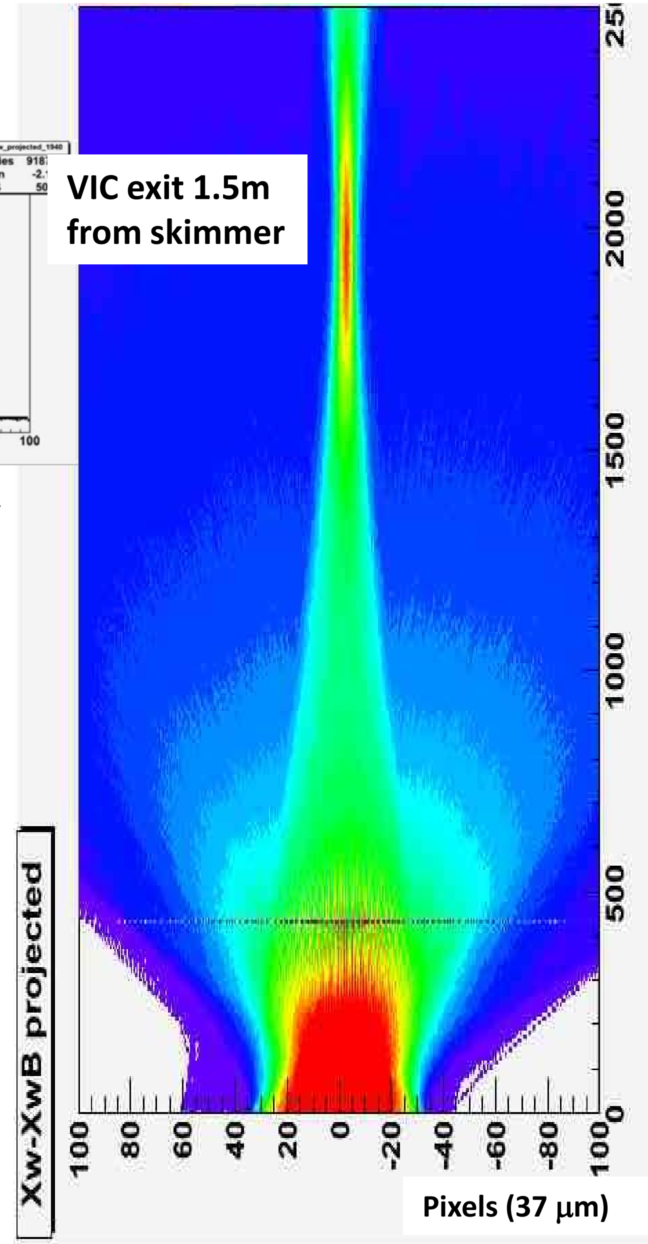
Out of field effects may be severe outside +/- 2 mm of focus

Extrapolated track positions at VIC : σ≈ 100 μm

This causes problems when measuring a pellet stream with bigger diameter than 3-4 mm e.g. at the dump at PANDA where the pellet stream diameter would be about 7 mm.

Tests of camera optics with f=25mm have been done to investigate the tracking performance. The DOF (in measurement conditions) has been verified to be about the double compared to optics with f=50mm.

Pellet track x-distribution versus vertical position



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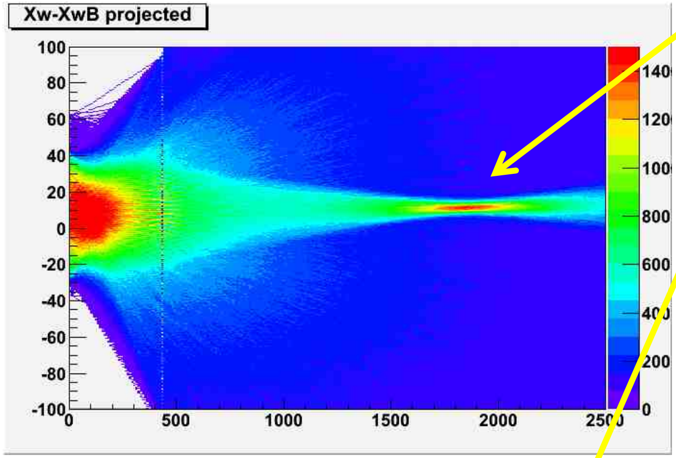
Studies with different camera optics bl.=1.4, d(pelletstream – focalplane) ≈250mm.

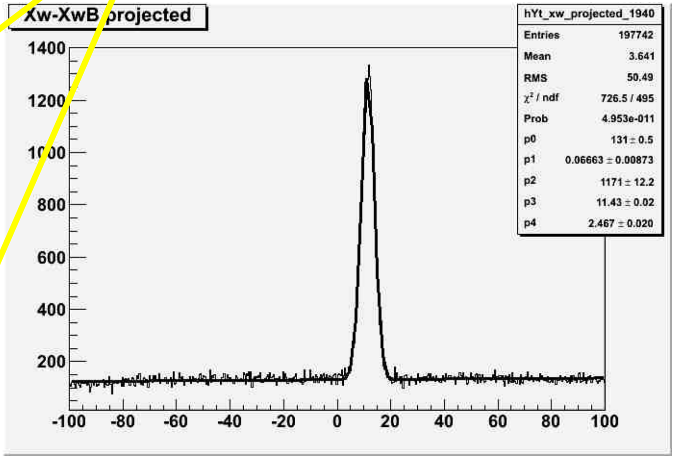
High efficiency pellet detection

At VIC exit 1.5m above the skimmer

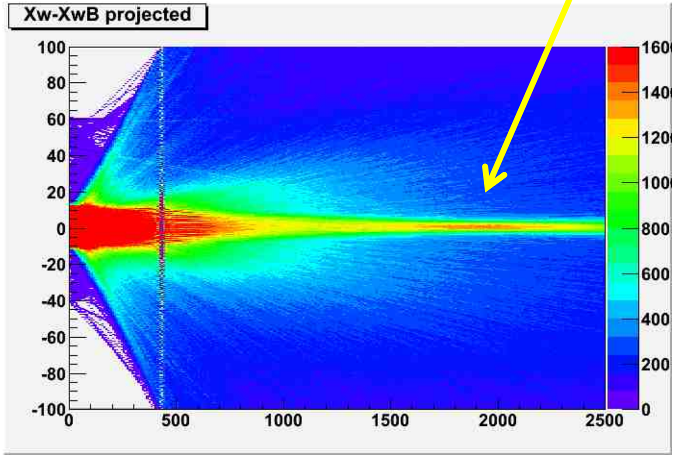
Pellet track x-distribution versus vertical position

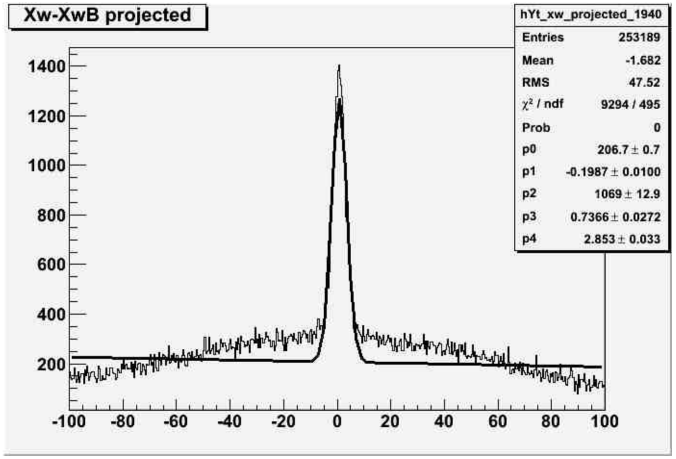
f=50mm





f=25mm





Unit of Pixels

PTR status

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GSI, December 2013
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A lower tracking section with 3 levels…

Cameras with f = 25 mm optics
and 10 µs exposure cycle

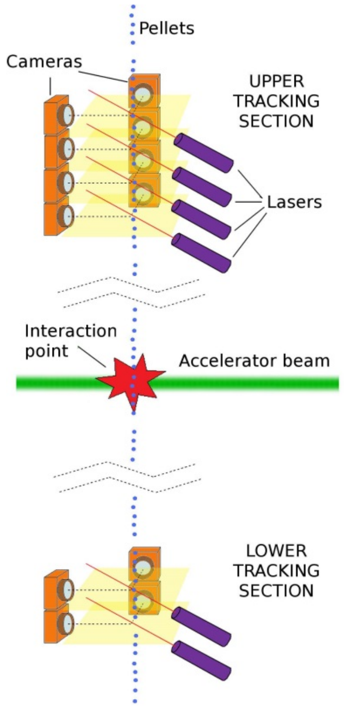
IMPROVES vertical position resolution
from $\sigma \approx 800\ \mu m$ **to $\sigma \approx 100\ \mu m$**

with an efficiency ≈ 80% for a PR=5k/s

…. but efficiency drops to ≈ 55 % at PR=15k/s

NOTE !
These are preliminary results obtained with the first version of pellet tracking algorithm.

The **pellet tracking algorithm** is being developed and will give increased efficiency numbers.



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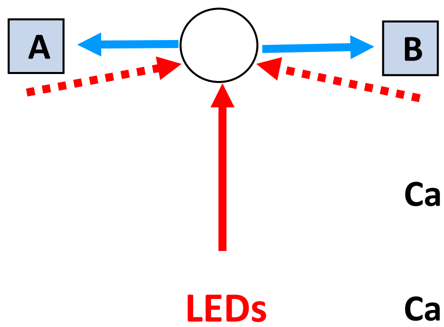
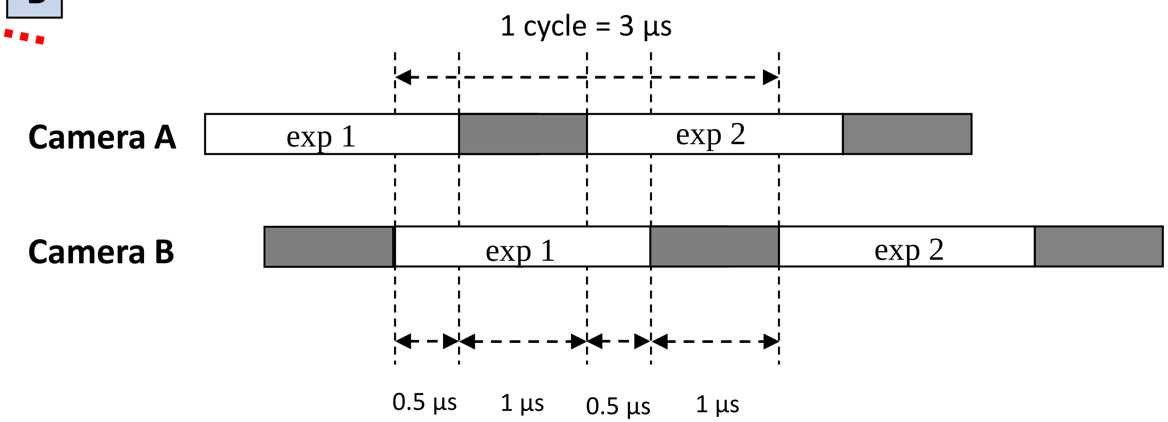
Time resolution & measurement dead time

High efficiency pellet detection

Cameras



Camera exposure cycles



Test bench setup including camera holders with reference LEDs and vacuum windows .

Two cameras look on a fishing-line illuminated by a LED.

(Erasmus work M. Kümmel).

PTR status

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Time resolution & measurement dead time

Some studies in the test bench:

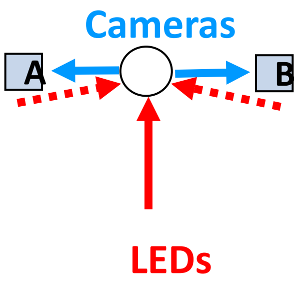
+ **Effects of misalignments of the cameras** (the idea is to develop an algorithm for aligning the cameras, with automation in mind).

+ How to optimize the placement and mounting of the synchronization-monitoring diodes.

+ Interference of objects in the window with the pellet detection (masks of paper with a circular hole was used) and how to get a good monitoring signal without disturbing the pellet detection.

+ How noise ("pellets" at wrong positions) could be suppressed by choosing proper camera parameters e.g. for the offset balance between even and odd pixels for each camera.

+ **Delayed cycle operation with simulated pellets from a diode, to get an idea of the achievable resolution and tune the length of time bins.**



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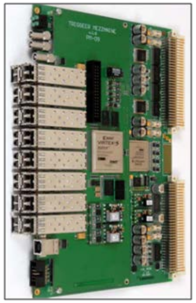
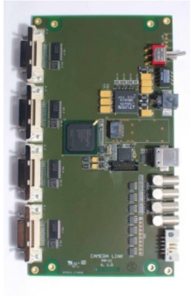
Multi camera readout development: status

Multi-camera system

Software: Project works by Malte Albrecht, Madhu Thelajala and Geng Xiaoxiu



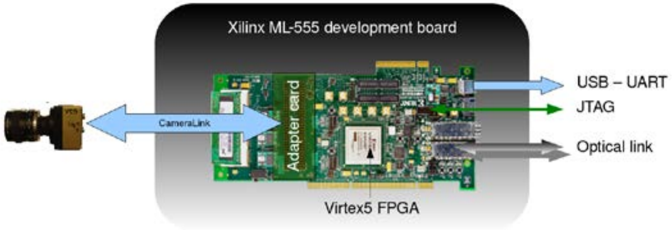
VME FPGA board (developed for WASA trigger) is used for readout of up to 8 CamLink FPGA boards.
FPGA Software:
- Control and readout of camera link board ready
- VME readout ready



CamLink FPGA board is used for readout of 2-4 cameras:
1’st prototype board debugged and software developed
2 boards of a modified version were produced and tested
FPGA Software:
- Camera link readout and pellet recognition implemented
- Communication with camera and VME board works

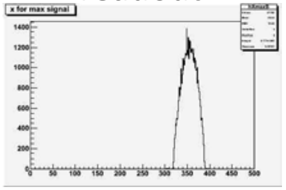
Remaining tasks
- More work on synchronization of boards and cameras
- Implementation in the PTR readout system
- (Camera link readout for 200 kHz cameras)

Tests with pellets on development board

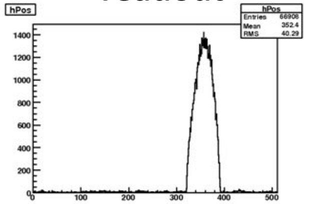


Pellet position in the PTR chamber

Frame grabber readout



FPGA readout



PTR status

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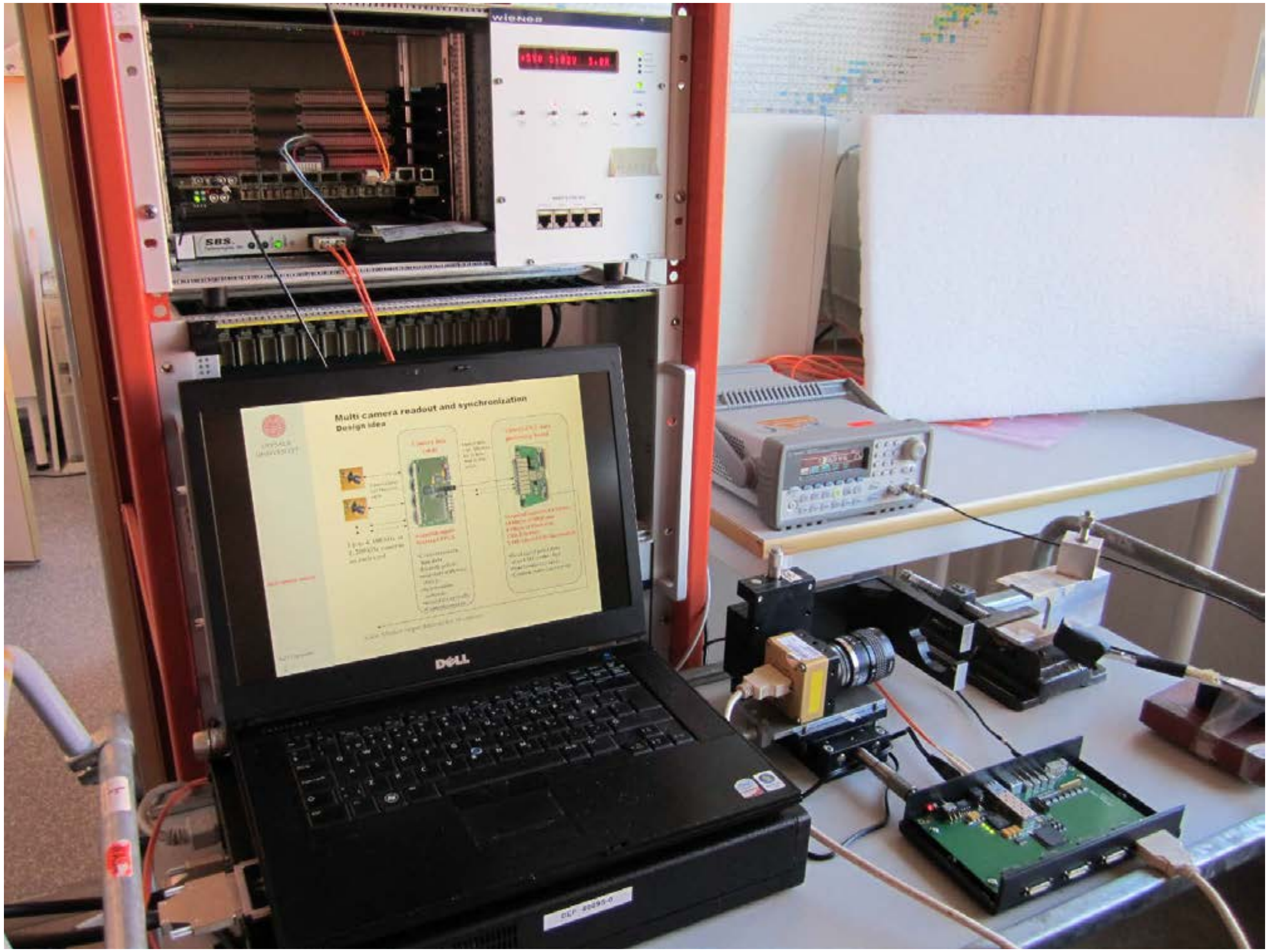
Work since last summer:

Communication with camera and VME board



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.

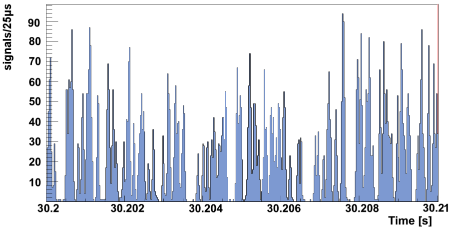
- There are **pellets** in the **beam** only for some **fraction** of the **time**
- Events from **rest-gas** happen **all** the **time**
- When a **pellet** is in the **beam**, it is **most probable**, that the **event** came **from** the **pellet**.

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



example 10 ms sample
pellet rate ≈ 8 k/s

- A **pellet** crosses the COSY **beam** at its center in ≈ 70μs
- **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.

Events classification

Non-Pellet class

Small instantaneous event rate ⇔ Small probability of a pellet in the beam region

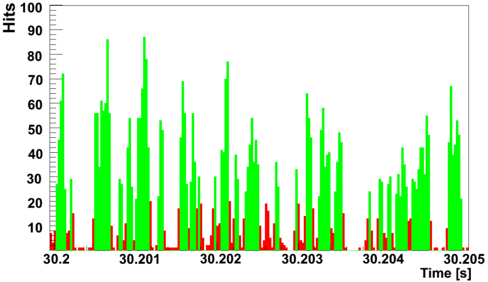
0 – 20 events in a 25 μs bin

Pellet class

High instantaneous event rate ⇔ High probability of a pellet in the beam region

21+ events in a 25 μs bin

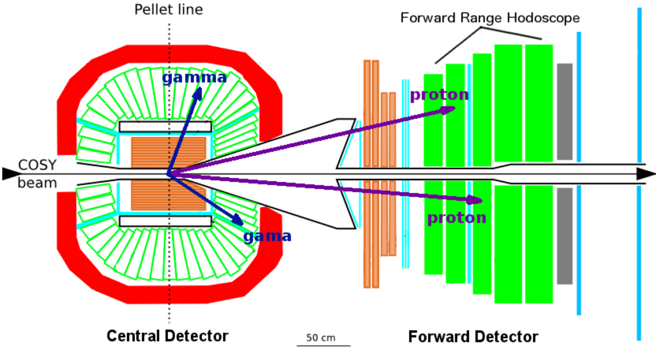
Ranges adjusted to correct for accelerator beam decaying during the cycle
(At the end, the beam intensity ≈ 50 % of initial intensity)



Check of rest-gas event suppression

Test reaction: $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$

Pbeam = 1.023 GeV/c $\Leftrightarrow$ $Ekin = 0.45GeV$



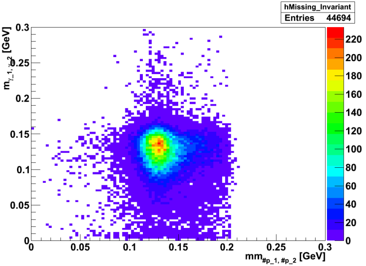
Missing Mass and Invariant Mass

The **measurement** of $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$ events is **simulated** with the **WASA Monte-Carlo** (**WMC**).

$IM_{\gamma\gamma}$

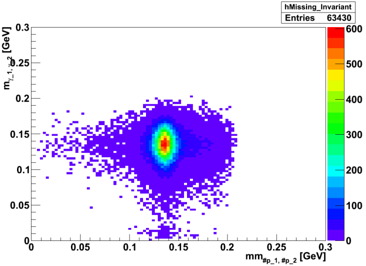
Peak at π^0 mass

Exp



MM_{pp}

WMC



MM_{pp}

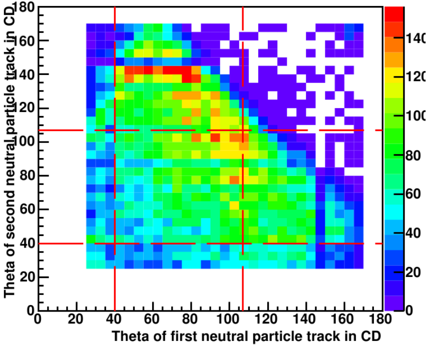
The simulated WMC events (right plot) are with realistic detector resolutions but without taking rest-gas into account.

Theta angles of gammas

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

Missing and invariant mass for different angles

Angle of higher energetic γ

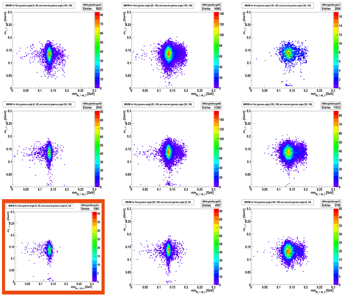
[27, 40) deg | [40, 107) deg | [107, 169) deg | [27, 40) deg | [40, 107) deg | [107, 169) deg

Angle of lower energetic γ

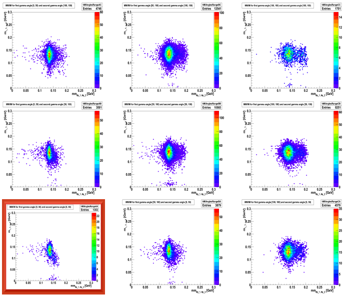
[107, 169) deg

[40, 107) deg

[27, 40) deg



WMC with 0% rest-gas



WMC with 23% rest-gas

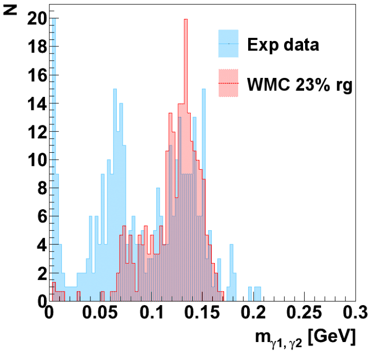
Influenced by rest-gas contribution:

- Shape of the 2-dim distribution
- Width and position of the π^0 peak
- Distribution of events between the 9 angle combinations

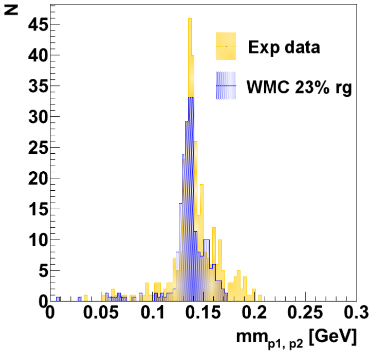
Simulations of the rest-gas influence

Comparison between **exp. data** and **23% rest-gas WMC** for **small angles of both gammas** ($\Theta < 40°$) 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**

Invariant mass



Missing mass

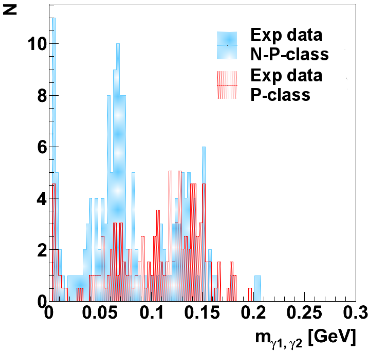


- **WMC** with 23% rest-gas **reproduces** the **rest-gas** influence in the exp. data
- In the **exp. data** there are also present structures not coming from rest gas or pellets - **other kind of background** events resulting e.g. from event pile-up or accelerator beam halo interactions in the pipe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

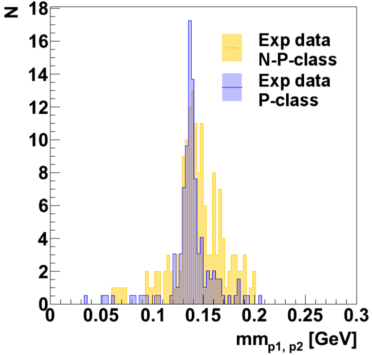
Results of the LR TDC "tracking" (1)

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

Invariant mass



Missing mass



- **additional peak** clearly visible in the $IM_{\gamma\gamma}$ spectrum for the Non-Pellet class
- MM_{pp} **spectrum sharper** for the Pellet class

Results of the LR TDC ”tracking” (2)

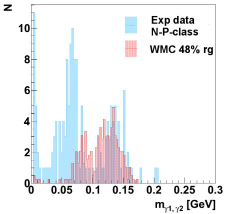
Comparison of **LR TDC classes** with **suitable WMC** simulations – for small angles of the gammas ($\Theta < 40°$)

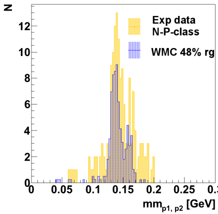
Invariant mass

Missing mass

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

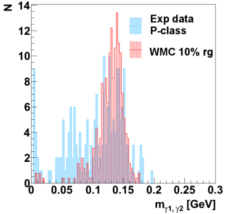
(events from pellets might occur also with small LR TDC rate)

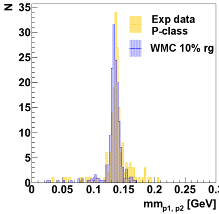




Exp. data LR TDC **Pellet class** and
WMC with **10 % rest-gas events**

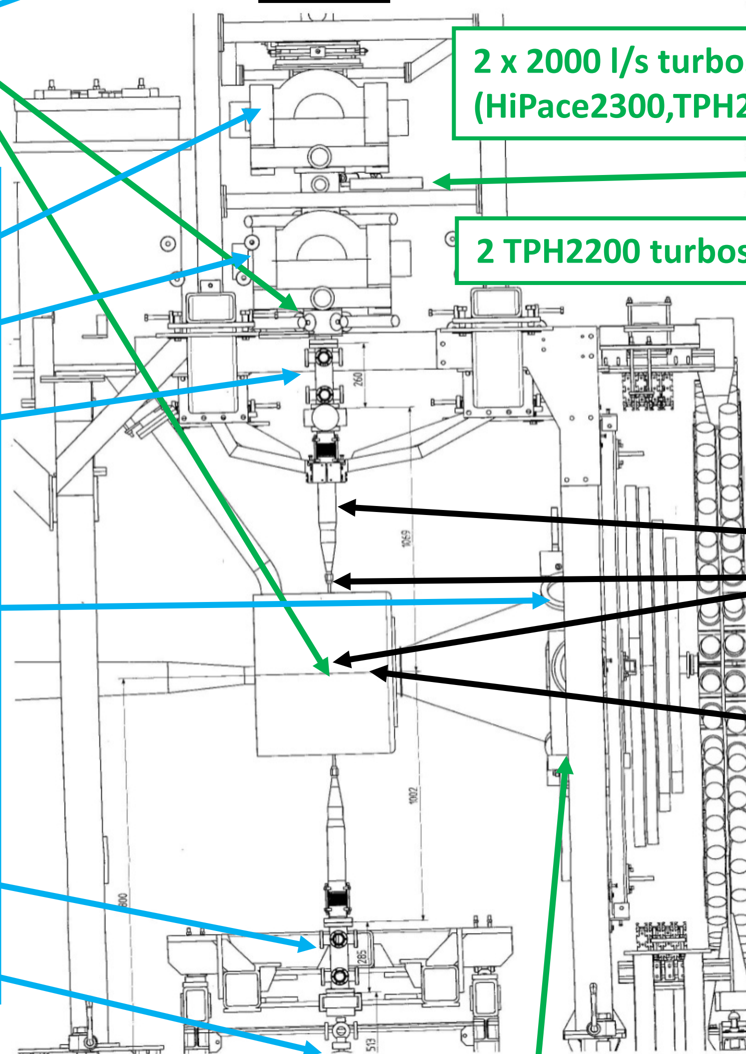
(events from rest-gas present also when pellet is in the beam region)





- **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.

Pressures with (w/o) pellets at WASA 13/7-13



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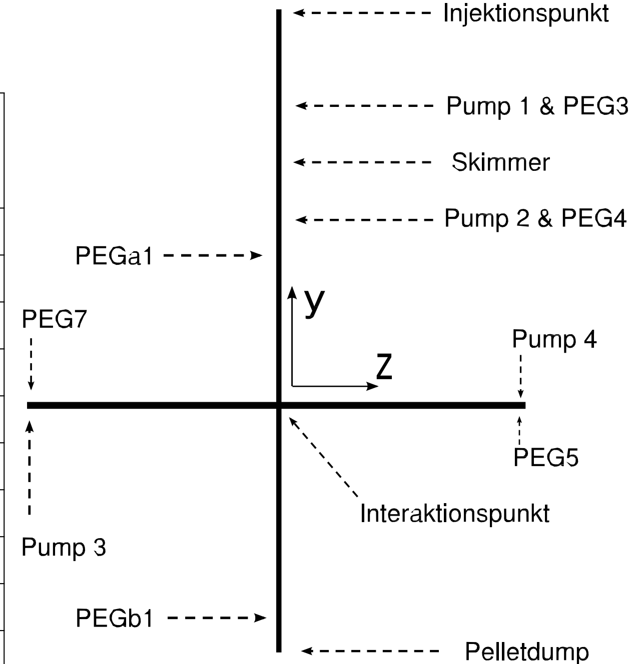
Calculated pressures w/o (with) pellets at WASA

WaC Pellet vacuum

Parameters for gas load and pumping

Parameter	*Outgasing [mbarl/s]*	*Pump speed [l/s]*
Kollisioner	**517×10^{-6}**	**-**
Vakuuminjektionen	**483×10^{-3}**	**-**
Skimmern	**32.8×10^{-3}**	**-**
Interaktionspunkten	**346×10^{-6}**	**-**
Pelletdumpen	**60.0×10^{-3}**	**-**
Pump 1	**-**	**2640 (66%)**
Pump 2	**-**	**2640 (66%)**
Pelletdumpen	**-**	**500 (50%)**
Pump 3	**-**	**1000 (66%)**
Pump 4	**-**	**500 (16%)**



Closed shutter (P_s = *measured*)

Mätpunkt	***P [mbar]***	***P_s/P***
PEG3	**200×10^{-6}**	**0.998**
PEG4	**11.1×10^{-6}**	**1.08**
PEGa1	**10.9×10^{-6}**	**0.921**
PEG5	**43.0×10^{-9}**	**1.16**
PEGb1	**1.61×10^{-6}**	**0.931**
PEG7	**14.9×10^{-9}**	**-**
Int.	**45.8×10^{-9}**	**-**

Open shutter (P_o = *measured*)

Mätpunkt	***P [mbar]***	***P_o/P***
PEG3	**180×10^{-6}**	**1.000**
PEG4	**13.5×10^{-6}**	**1.000**
PEGa1	**15.0×10^{-6}**	**0.999**
PEG5	**740×10^{-9}**	**0.810**
PEGb1	**125×10^{-6}**	**0.957**
PEG7	**227×10^{-9}**	**-**
Int.	**1.21×10^{-6}**	**-**

Fig. 9.2 from Targets TDR (february 2012)

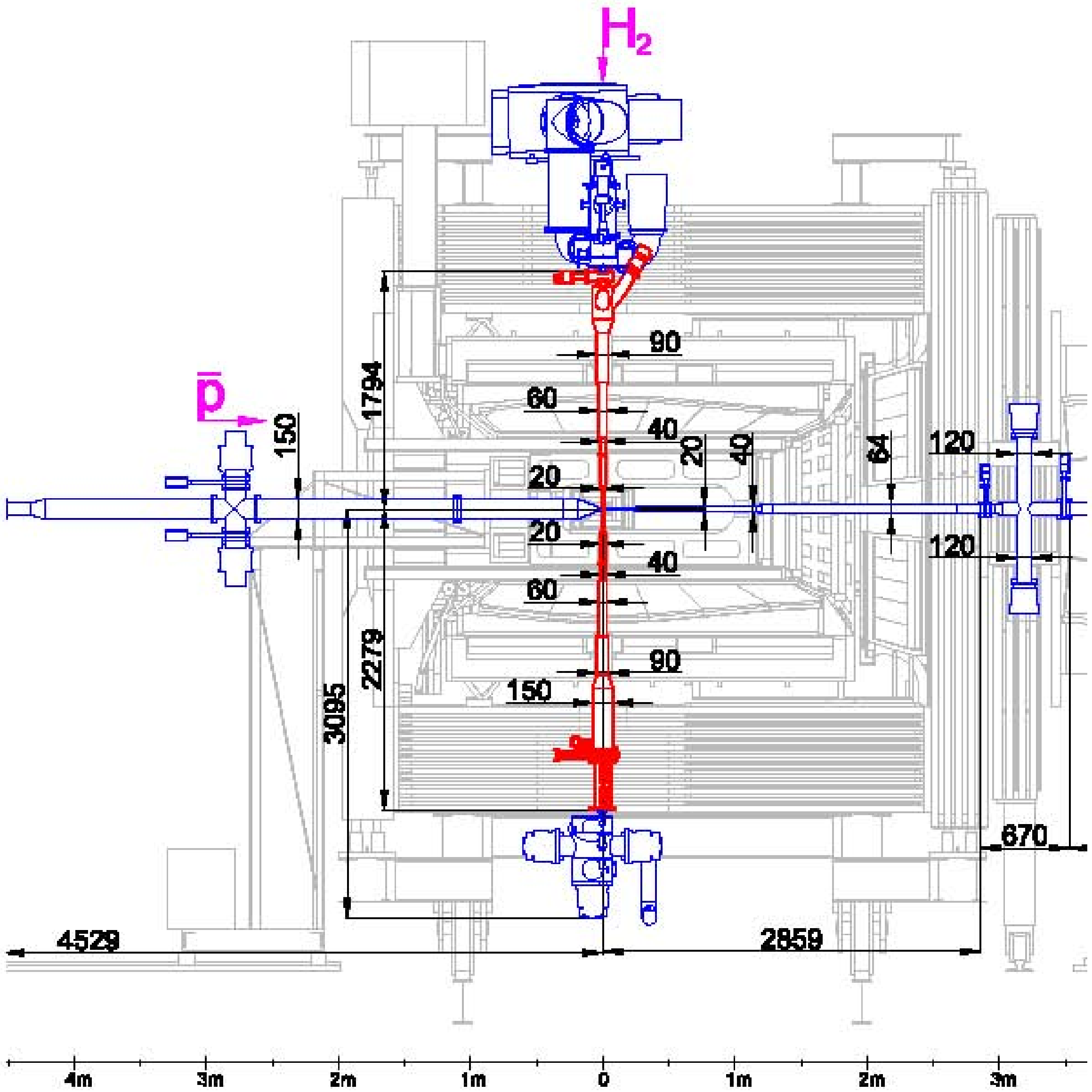


Figure 9.2: Cross section of the Target Spectrometer with detector components in light gray. The target and dump lines are marked in red. The antiproton beam line, as well as the cluster-jet target and the target beam dump, is marked in blue. The dimensions are given in mm. The diameters refer to inner diameters of the tubes.

Calculated pressures with pellets at PANDA

PANDA Pellet vacuum

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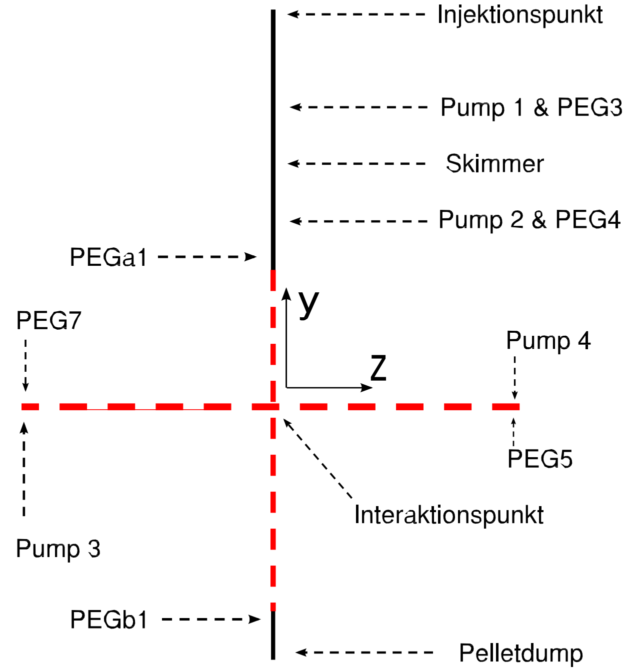
WaC pump configuration and performance

Mätpunkt	P [mbar]
PEG3	180×10^{-6}
PEG4	14.6×10^{-6}
PEGa1	20.6×10^{-6}
PEG5	154×10^{-9}
PEGb1	122×10^{-6}
PEG7	2.97×10^{-6}
Int.	16.4×10^{-6}

WaC pump configuration and nominal capacity

Mätpunkt	P [mbar]
PEG3	119×10^{-6}
PEG4	9.88×10^{-6}
PEGa1	15.8×10^{-6}
PEG5	17.8×10^{-9}
PEGb1	62.2×10^{-6}
PEG7	1.42×10^{-6}
Int.	10.7×10^{-6}



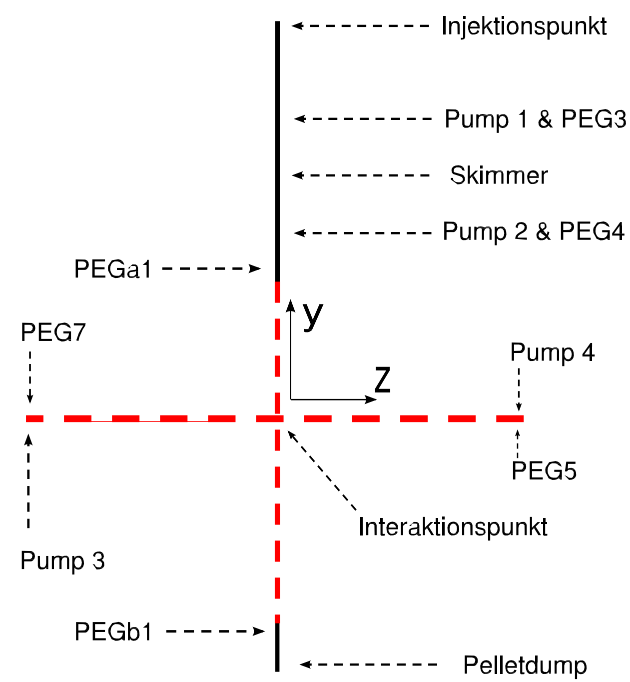
The red cross
= PANDA piping
(The rest are WASA components)

Calculated pressures with pellets at PANDA

PANDA Pellet vacuum

PANDA pump configuration

Pumps	*TDR (AG)*	*Wasa (JL)*
Generator	**2x360 l/s**	**4000 l/s**
Dump	**-**	**1000 l/s**
Upstream	**2x1000 l/s**	**1500 l/s**
Downstream	**2x700 l/s**	**3000 l/s**



PANDA vacuum (Pellets ON)

Pressure (mbar)	**TDR (AG)**	**Wasa (JL)**
Generator	**2.e-5**	**2.e-5**
Dump	**2.e-4**	**6.e-5**
Int.point	**4.e-5**	**1.e-5**
Upstream	**2.e-6**	**1.5e-6**
Downstream	**4.e-7**	**2.e-8**

The red cross
= PANDA piping
(The rest are WASA components)

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PTR status

PANDA CM
GSI, December 2013
Hans Calén

Summary (December 2013)

Status of tasks connected to FP7 HP3 FutureJet:

3.6 Pellet track processing and optimization of pellet detection points

- **Detailed design simulations, based on the tracking section at the generator, for PANDA has been done (Milestone 13 report …) .**

  Design of the lower section at the dump is in progress…

3.5 High efficiency pellet detection

- **Camera cycle operation conditions … being studied.**

3.7 Multi-camera readout system

h-w: 2nd version of CamLink FPGA board works...

s-w: Complete readout chain (camera-to-computer) works.

Preparing for operation with 4 cameras under real conditions.

Status of other tasks:

- **Initial studies, on how to synchronize and implement pellet tracking information in a hadron physics experiment, have been done at WASA.**
  The procedure works (nicely) according to expectations.

- **Results of vacuum measurements at WASA (COSY) are analyzed for use in vacuum system design for PANDA, e.g. need for “extra” pumps and estimates of different (target on/off) vacuum situations.**

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