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FP7-Futurejet Pellet Tracking in Uppsala

Main HP2 WP19 activities 2009 - 2011:

- **Synchronized readout of LS-cameras.**
- **Pellet tracking system design ideas (task 3.15, milestone 10).**
- **Time and position correlation studies. Velocity measurements (task 3.17).**
- **Tracking system prototype at UPTS (task 3.16 deliverable 10).**
- **Pellet tracking studies (task 3.17).**

Goals for HP3 WP20 activities 2012 - 2014:

- **Close to 100% efficiency pellet detection (task 3.5, milestone 12, Dec13).**
- **Pellet track processing and optimization of pellet detection points (task 3.6, milestone 13, Dec14).**
- **Multi-camera readout system (task 3.7, milestone 14, Dec14).**
- **Feasibility of laser-induced droplet production (task 3.8, milestone 15, Dec14).**

(- Preparation of one tracking section for PANDA.)

Senior researchers:	Hans Calén, Kjell Fransson, Pawel Marciniewski
PhD student:	Andrzej Pyszniak
Engineers:	Carl-Johan Fridén, Elin Hellbeck
Mechanics:	Lars-Olof Andersson, Masih Noor (design)
Exam/Project worker:	Malte Albrecht (Spring 2011)

Project supported by JCHP-FFE, EC FP7 and SRC

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Development of Pellet Tracking Systems for PANDA and WASA

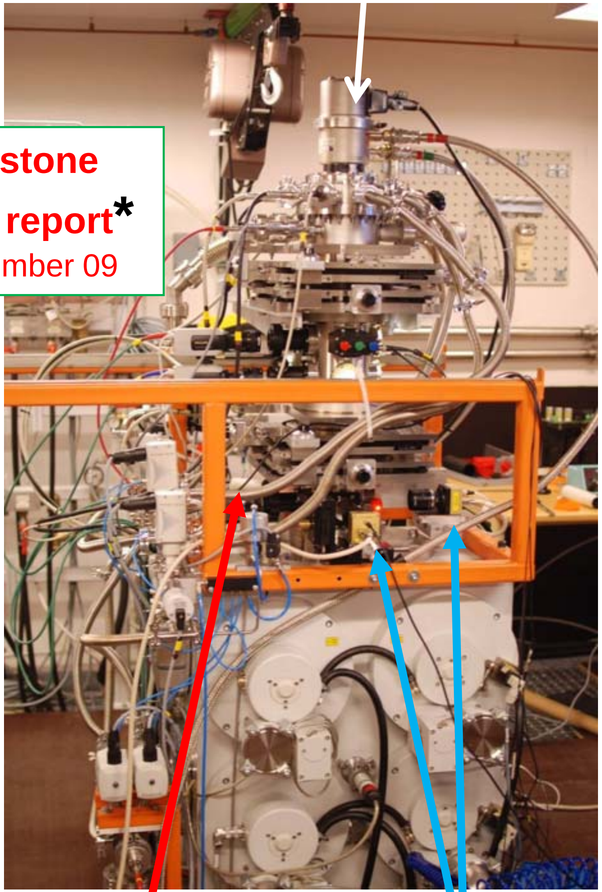
Uppsala activities 2009:

- Pellet diagnostics with single LS camera
- Understand LS camera performance …..
- Improve light yield from pellets …..
- Develop synchronized r/o for 2 cameras
- Time and position correlation studies

Milestone
FP7 report*
December 09

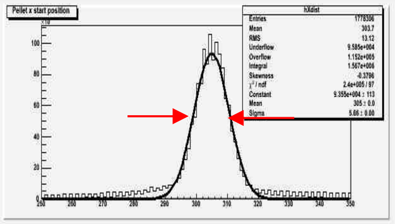
*) Design ideas for pellet tracking systems for PANDA and WASA

Uppsala Pellet Test Station, UPTS

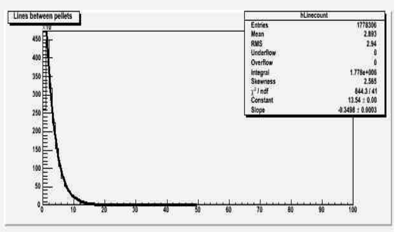


Example of pellet beam diagnostics with one LS camera

Beam profile



Time between pellets



Develop synchronized r/o for 2 cameras

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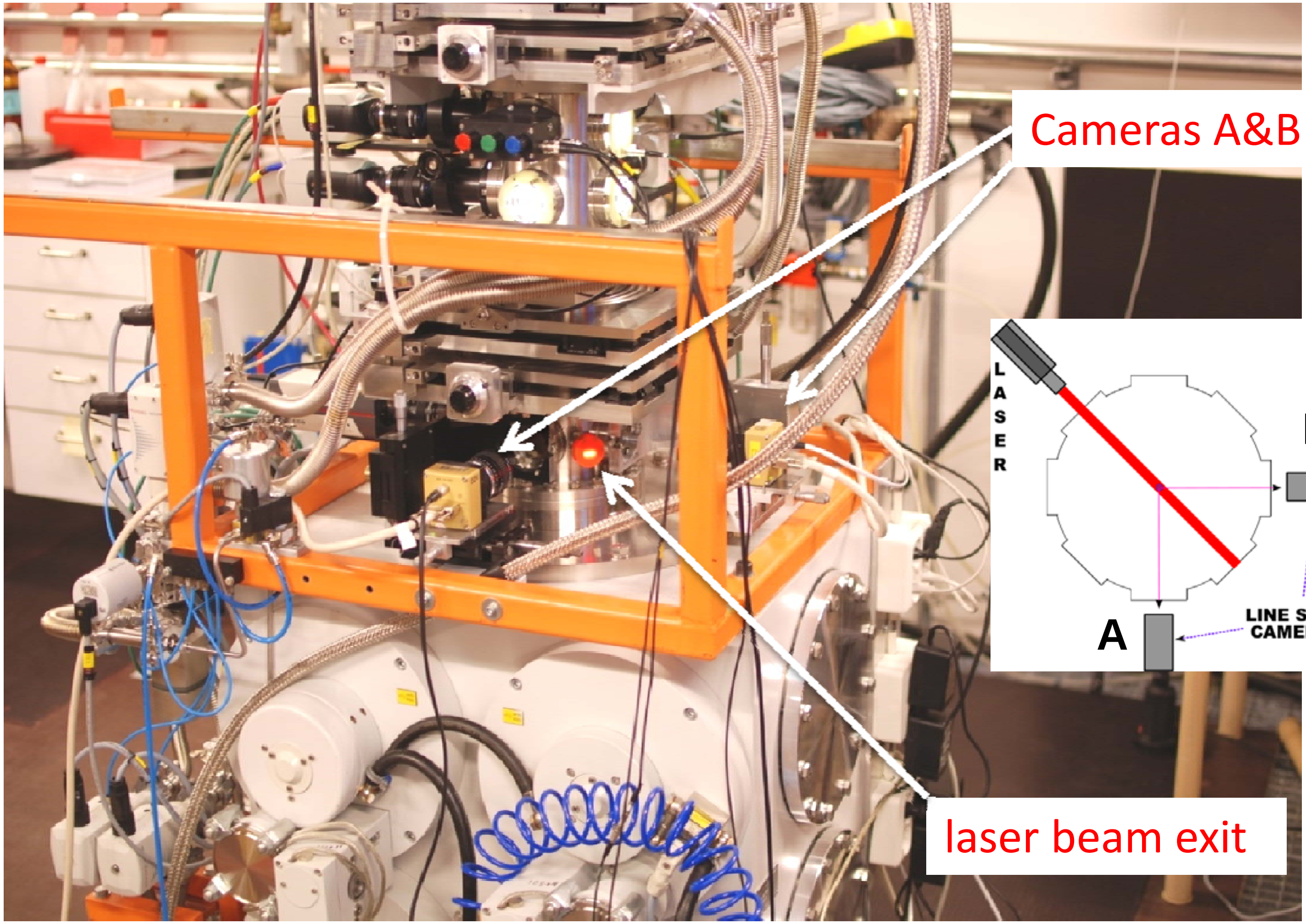
Two-cameras setup. Synchronized measurement of x and z



135 degrees laser illumination geometry (refraction)

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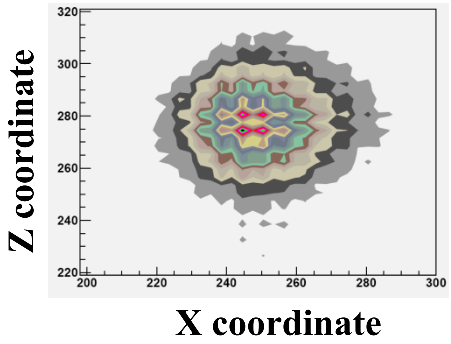
GSI 2011-11-03
Hans Calén

Develop synchronized r/o for 2 cameras

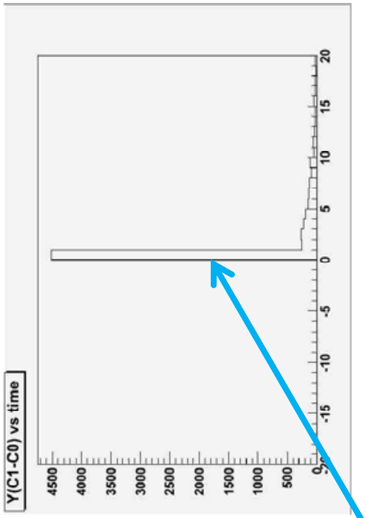
Two camera synchronization with pellets

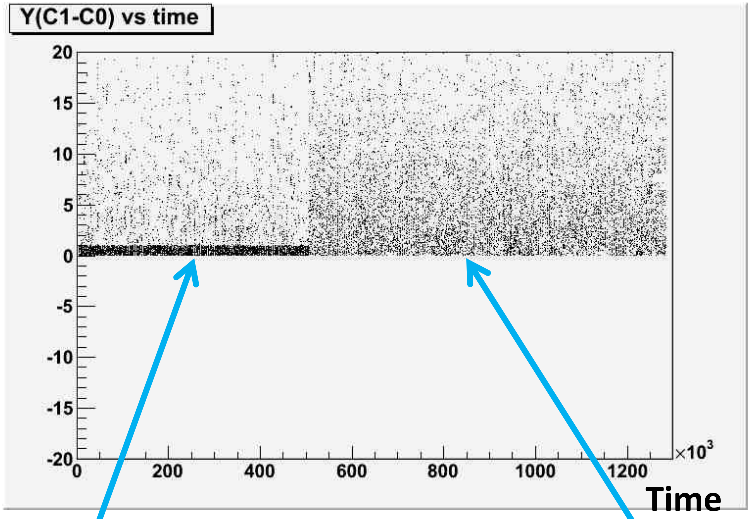
- Line scans triggered from external pulse generator
- Frames of 5000 lines each, analyzed in real time

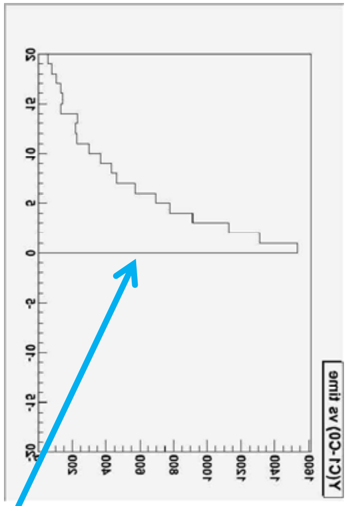
2d profile of the pellet beam



Lines between signals in camera A & B vs time (during 25 s)







Same pellet seen by both cameras?

Frames out of synch

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Milestone report for FP7 HadronPhysics2 WP19 (Futurejet), December 2009.

Design ideas for pellet tracking systems for PANDA and WASA

Hans Calén, Kjell Fransson, Elin Hellbeck

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Carl-Johan Fridén

The Svedberg Laboratory, Uppsala, Sweden

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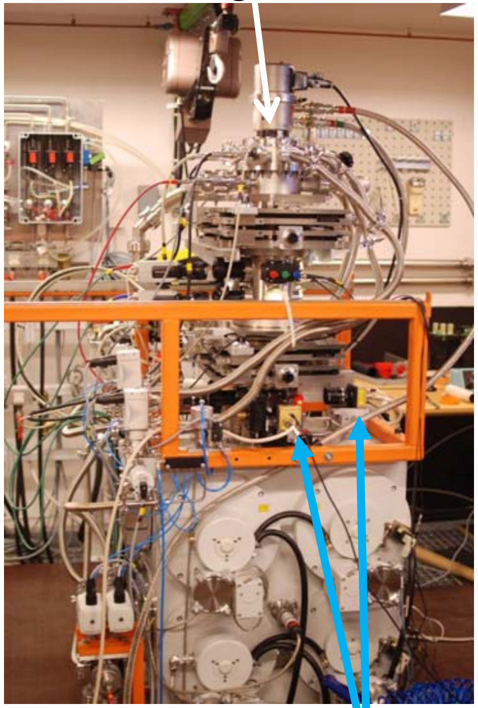

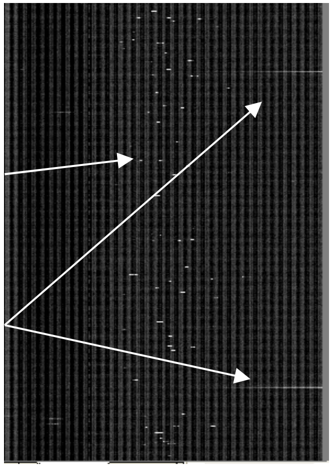

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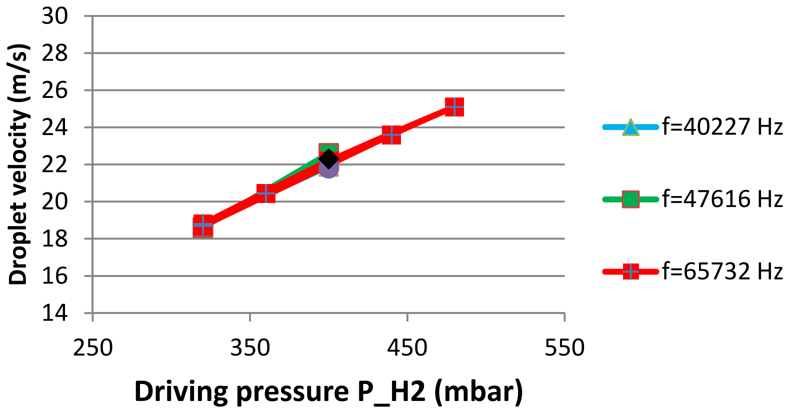
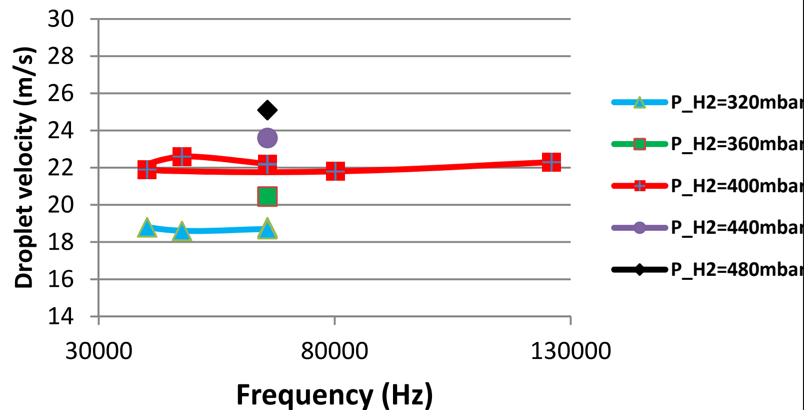
Measurements at UPTS September 2010

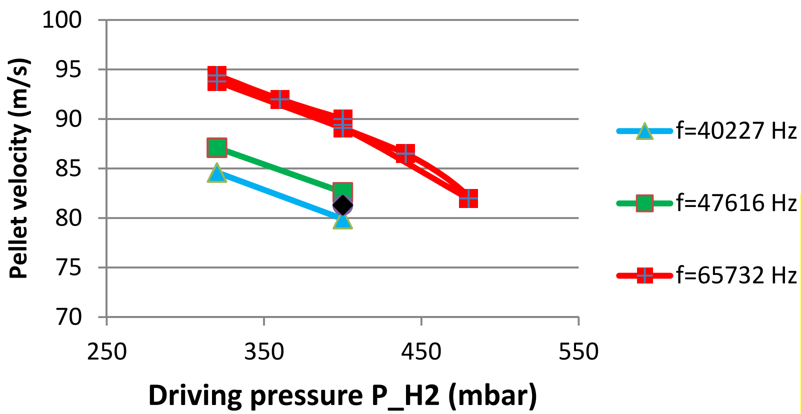
Droplet velocity vs driving pressure and generation frequency

Pellet generation conditions
p(droplet.ch.) ≈ 25mbar
pellet diameter 25-35 micron (guess)





Pellet velocity from LS-camera measurement



Higher driving pressure
⇒ faster (and bigger droplets)
⇒ slower pellets

$\Delta\phi/\phi \approx 1\% \Leftrightarrow \Delta v/v \approx 1.5\%$

(at these conditions)

PTR system prototype FP7 HP2 deliverable WP19.10

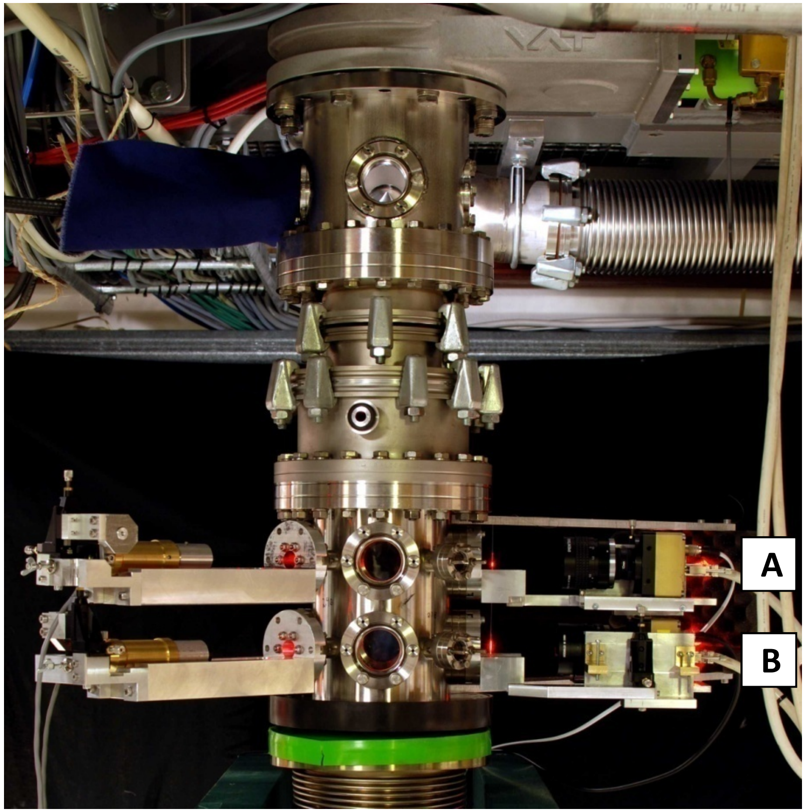
Pellet tracking system prototype

Camera system

Two line scan cameras
Model AViiVA M2 CL manufacturer e2v
512 pixel line-CCD, dual tap
Pixels: 14 μm squared, 12 bit resolution
Maximum line rate: 98 kHz (claimed)
Maximum readout rate of 60 Mpixels/s via cameralink
Optics
Focal length 50 mm
Working distance: 250 mm to the focal plane corresponding to ~40 μm pixel size
Maximum aperture: 1.4 f.

Lasers

Two Lasiris™ , type SNF, structured light, diode laser module, single line beam profile
Power 40 mW at 656 nm
Working distance: 185 mm
Fan angle of 1 degree (line length of ~3 mm at the focus).
Line thicknesses 40-60 μm at a DOF of 15 mm



Mechanics

Tracking chamber (130 mm diameter)
A total of 16 observation ports in 2 levels (A and B) separated by 80 mm
8 camera ports (35 mm windows)
8 laser ports (16 mm) windows

Camera support with 3d linear adjustment
Laser support with 3d linear + angle adjustment

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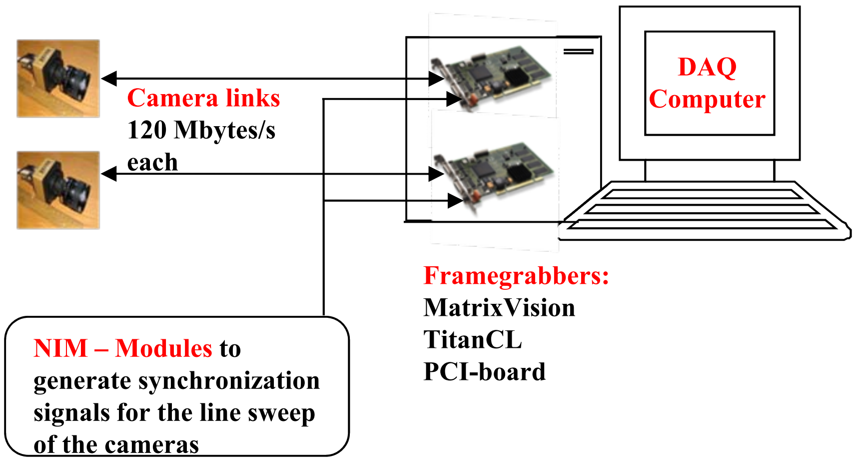
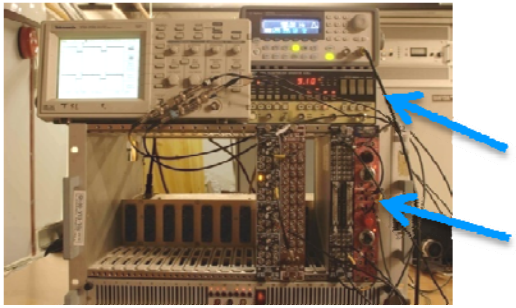
Readout

2 frame grabbers, model mvTITAN-CL, PCI card, manufacturer: Matrix vision.
Line synchronization and trigger by external gate generator in NIM
Maximum line rate with continuous readout: ~50 kHz, limited by pci bus capacity
With triggered frames ~80 kHz

Software

Monitoring and control software from manufactures.
Readout C++ software based on Matrix vision software development kit and root.





Pulse generators:

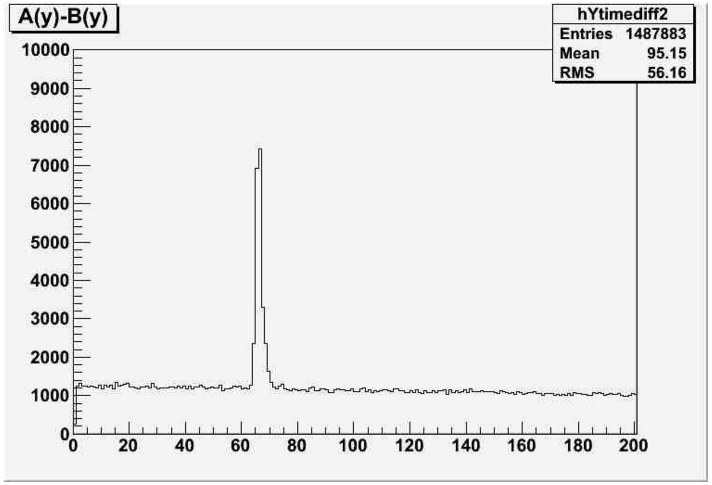
for LEDs (for control and monitoring of camera synchronization)

for Camera cycle

Example of measurements

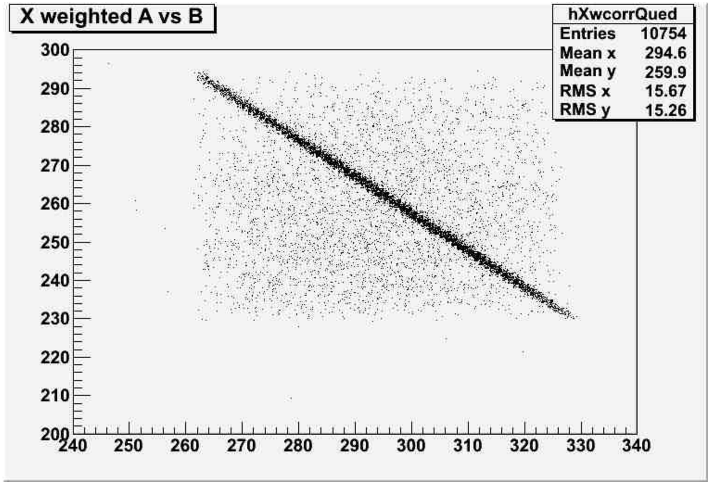
PTR system prototype FP7 HP2 deliverable WP19.10

Time difference between signals in the upper and lower PTR chamber level



The peak is due to the signals from the same pellet at both levels. Its width corresponds to a small velocity spread in the pellet beam.

Pixel position correlation between signals in the upper and lower level



The dark line is due to straight pellet tracks pointing to the pellet generator (1.5 m above the PTR chamber).

Further details can be found in references:

- Design ideas for pellet tracking systems for PANDA and WASA, Hans Calén, Kjell Fransson, Elin Hellbeck and Carl-Johan Fridén, December 2009, Milestone report for EC FP7 Hadron Physics2 WP19 , www5.tsl.uu.se/panda/pub

- Simulations for design of a pellet tracking system for PANDA and WASA, Marek Jacewicz, January 2011, Project report, www5.tsl.uu.se/panda/pub

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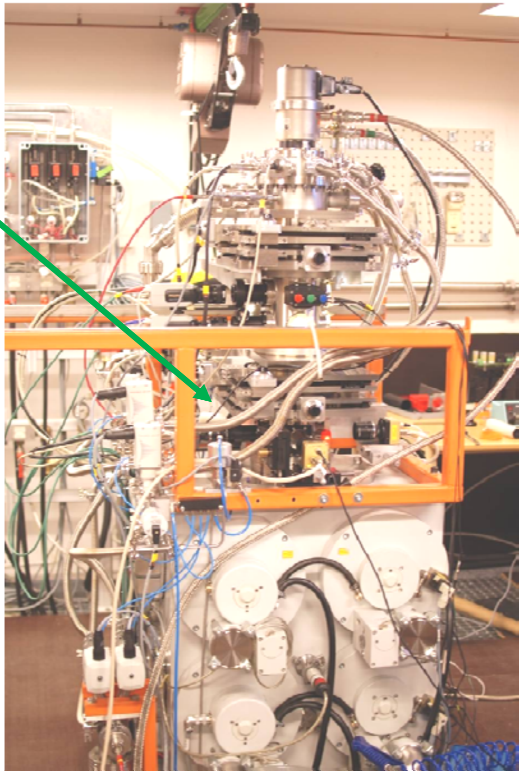
PTR at UPTS 2010 - 2011

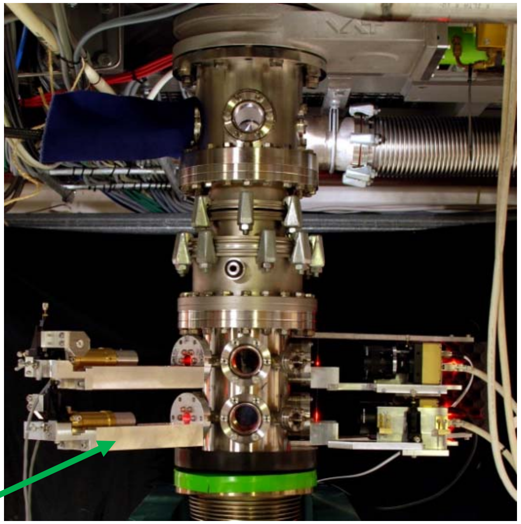
Generator floor with one level for 2 cams (x,y) and one laser at 135 deg.

Pellet beam diam. (mm)

		Skimmed beam
VIC exit :	< 0.07	
PTR gen:	2.2	
Skimmer:	2.9	2
PTR up:	3.5	2.45
PTR lo:	3.7	2.55
(Cosy beam:	5.1	3.6)

Dump floor with two levels for 2-4 cams (x,y) with lasers at 135 deg.

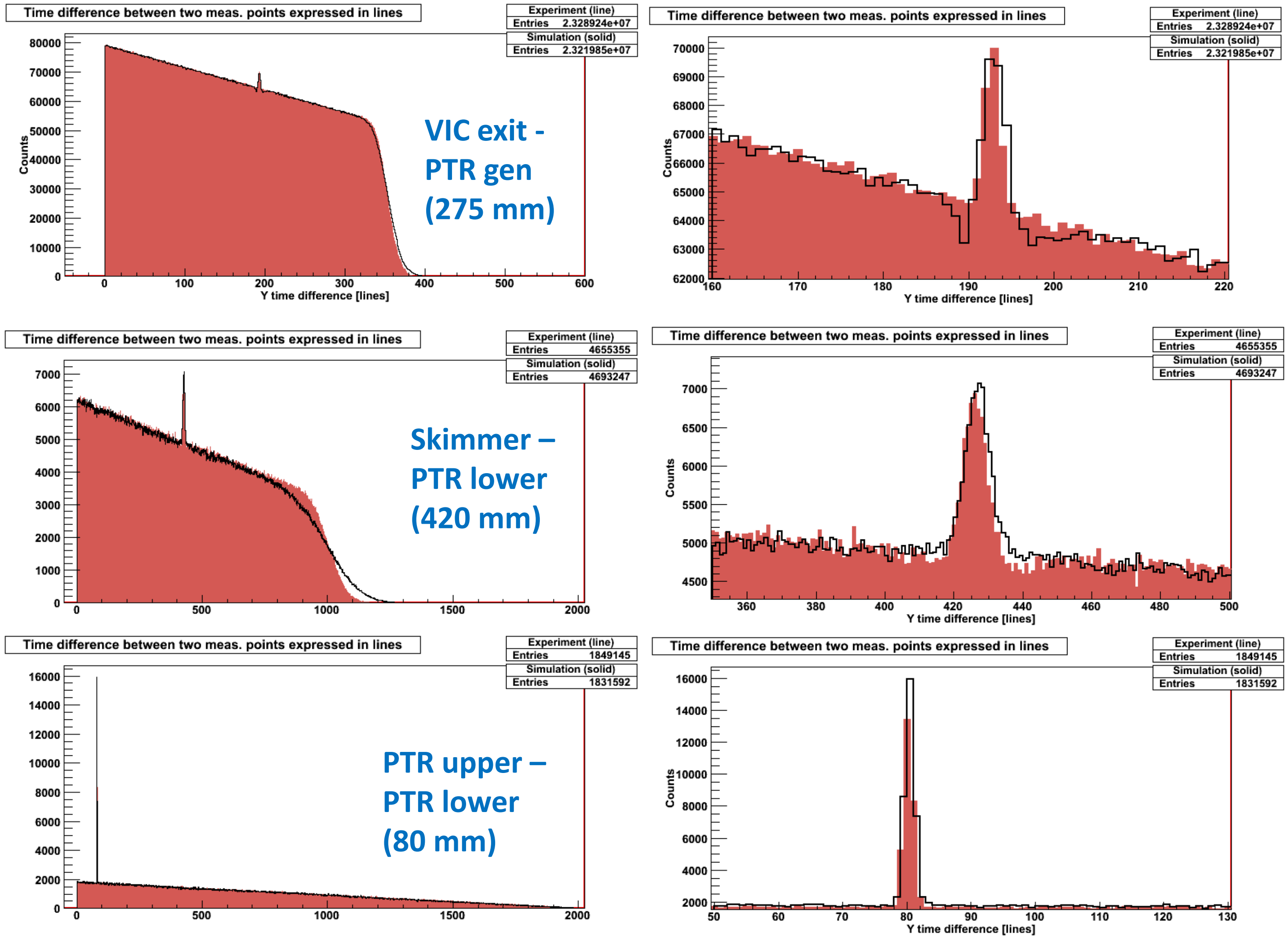




Windows center position vertical distance (mm)

-76.5	DC	
0	VIC exit	
273.5	PTR gen	
1503.5	Skimmer	0
1843.5	PTR upper	340
1923	PTR lower	419.5
(2690	Cosy beam	1166.5)

Measurements since March 2011: Signal time differences lower-upper camera



What has to be simulated?
Direction smearing
Generation position smearing
Loss at generation (in VIC)
Stream collimation at the skimmer
Generation frequency and time smearing
Velocity and velocity smearing
Acceleration due to gravity
Loss/disturbance on the way
Camera cycle and dead time
Detection inefficiency caused by insufficient illumination conditions ….. etc

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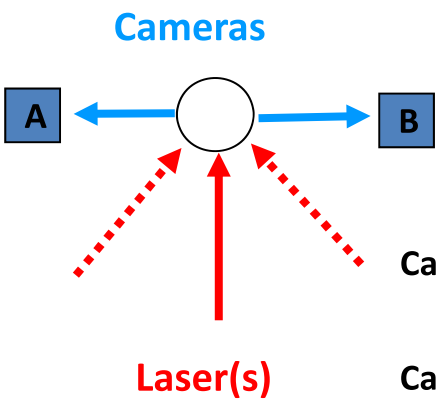
Time resolution, efficiency & measurement dead time

Two specially designed cameras (3 μs period time), measuring same coordinate at the same y-level being synchronized with cycles shifted half a period time, would give a time bin of 0.5 - 1 μs (σ ≈ 0.25 μs) which is in the region of the final goal for PANDA.

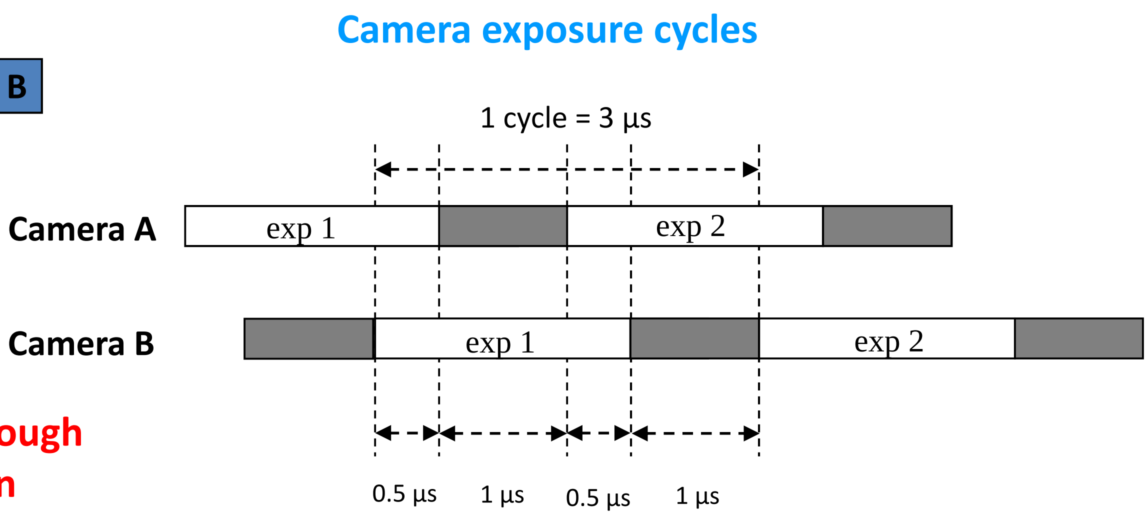
The present (M2) camera performance of 12 μs period and 9 μs exposure time gives a σ ≈ 1 μs would give an interaction position vertical (y) coordinate σ ≈ 1 mm.

We plan to test a new camera model (EM4) which has a shortest period of 5 μs.

With a two-camera arrangement one would also get rid of inefficiencies due to the camera cycle dead times.



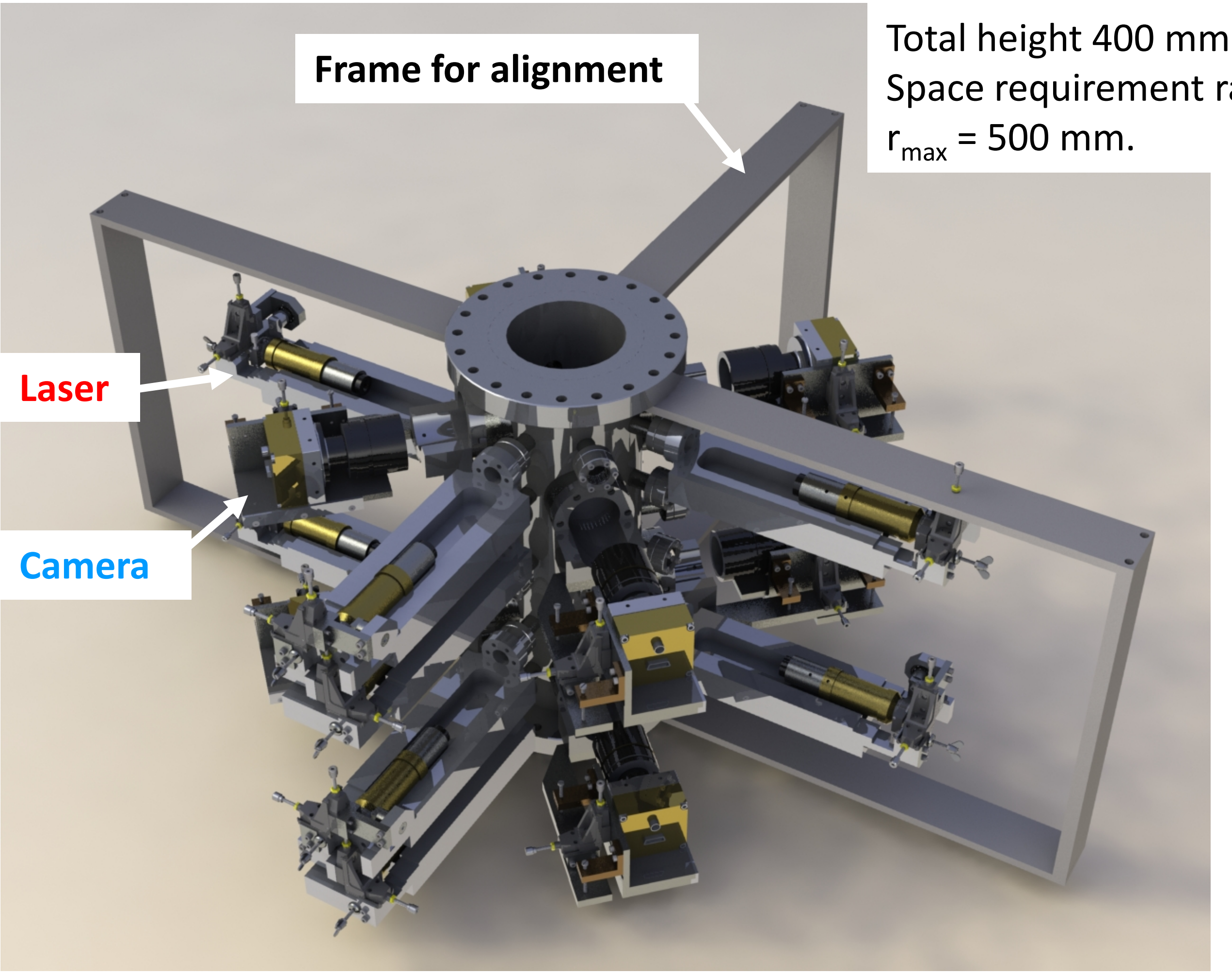
... strong / many enough to give full detection possibility.



Design idea: Multi-camera pellet tracking section for determination of velocity and 3-d direction for individual pellets

Four levels for measurements, each with two lasers and two LS-cameras.
- Distance for velocity determination 60 – 260 mm.
- Distance for direction determination 200 mm (…internally… one can use VIC exit also).

Total height 400 mm.
Space requirement radially:
r_{max} = 500 mm.



Design Masih Noor, CAI (Center for Accelerator and Instrument Development), Uppsala University

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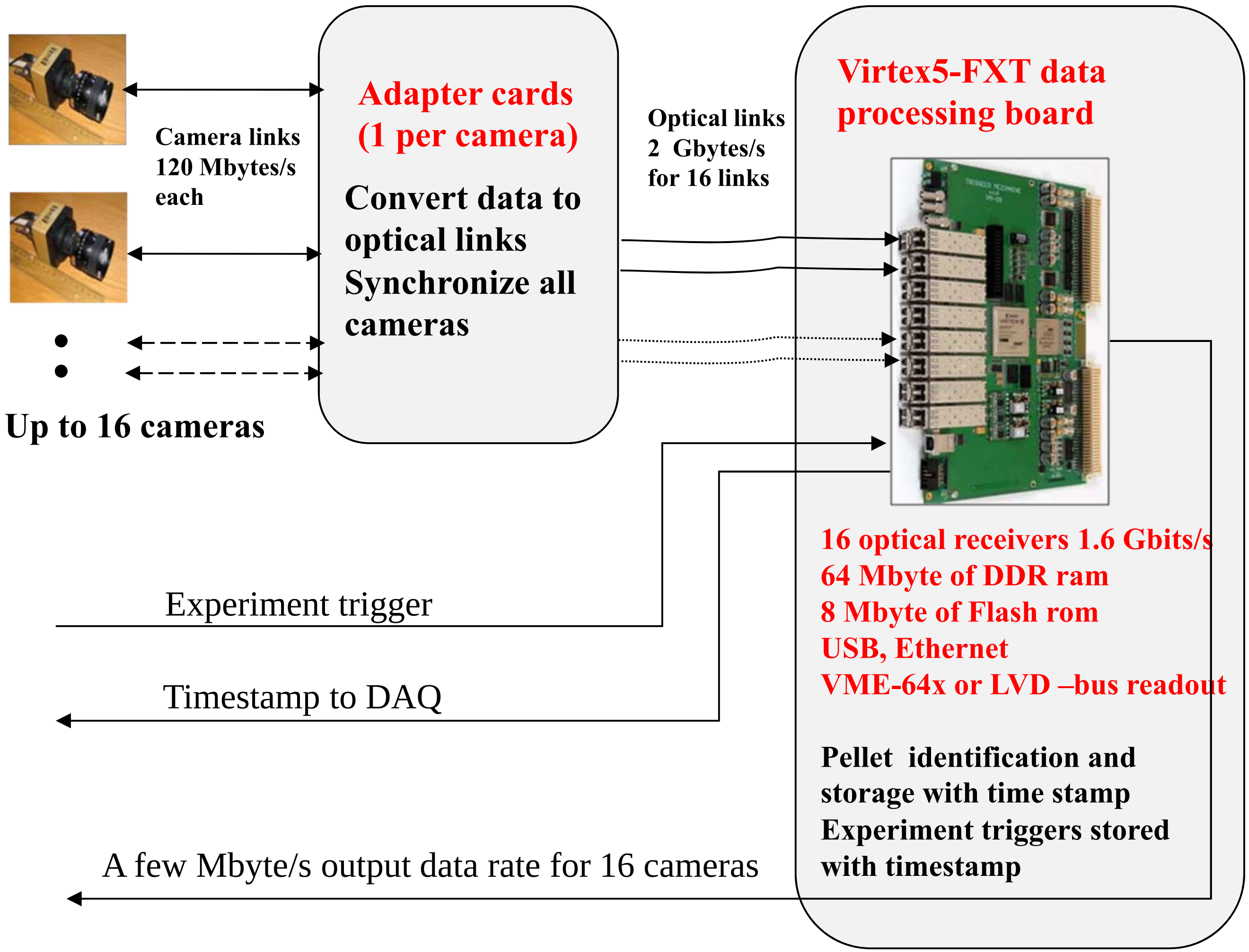
Multi camera readout and synchronization



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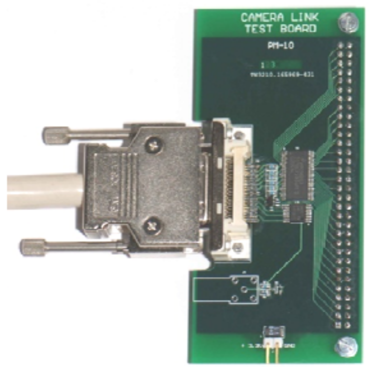
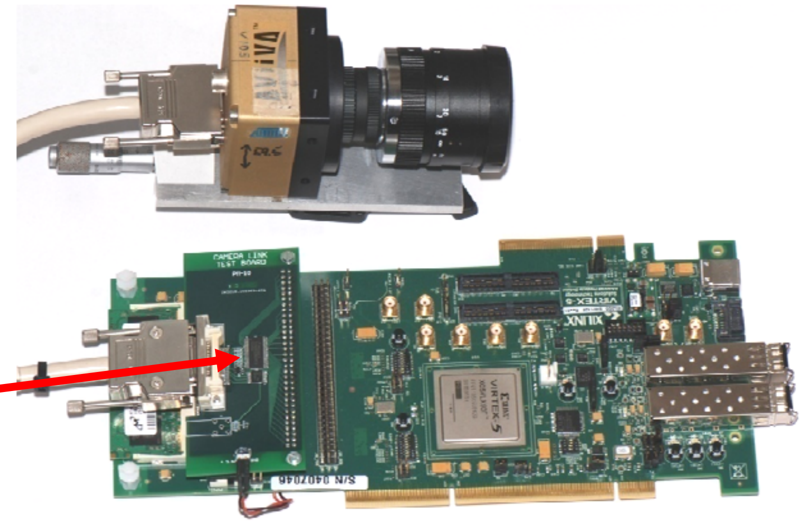
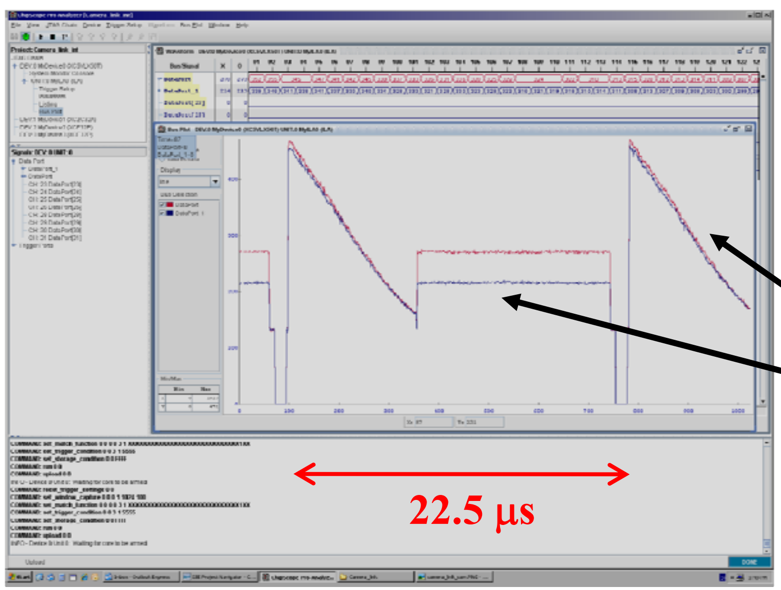
Multi camera readout development prestudies





CameraLink bus
Signal converter card
"Serial" ⇒ parallel bus

Virtex-5 development board
Study of camera signal behavior



Pixel signal monitoring for 22.5 µs camera cycle
Signal amplitudes 2 x 256 pixels
Readout idle time (exposure)

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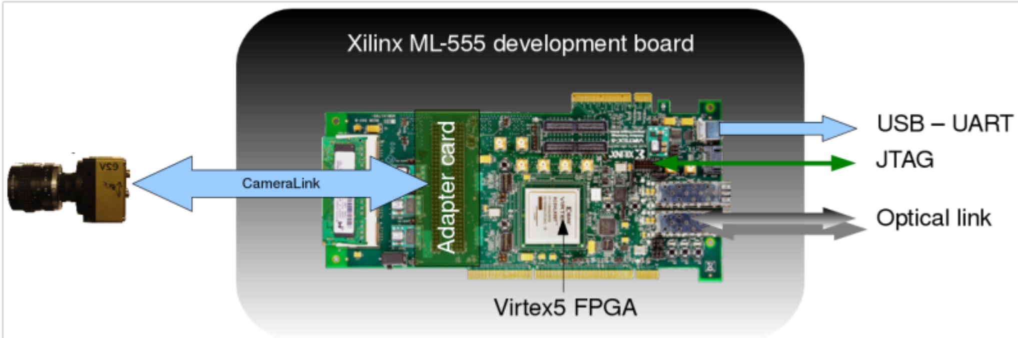
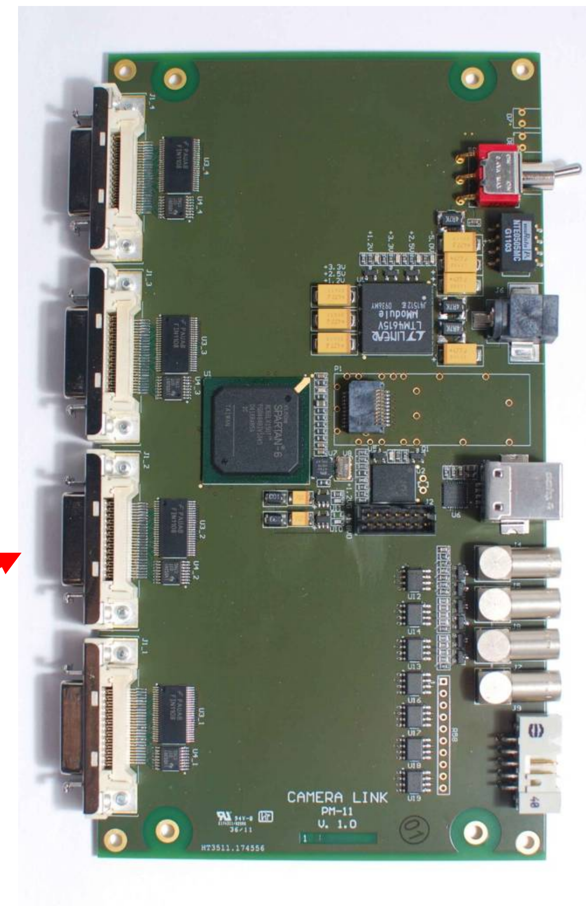
Multi camera readout development prestudies



Erasmus work by M. Albrecht.
FPGA code for pellet detection:
- Automatic pedestal correction
- Pellet detection with position amplitude and timestamp output
- Data output via USB for tests

Prototype board with four CameraLink inputs and one FPGA (SPARTAN-6) ….
…being debugged …..
… for further development work during 2012 …..



Status and Conclusions November 2011:

- **LS camera performance basically understood ….**
- **Synchronized operation with two cameras works (12 μs cycle)**
- **Illumination/detection conditions good … but should be improved**
- **Required transverse position resolution reachable with present cameras. Solution for good time (⇒ y position) resolution and high camera efficiency exists.**
- **Pellet velocity spread σ_v/v <<1% should be possible to obtain**

- **A first prototype PTR system for UPTS is in operation since March:**
  - **Tracking chamber with two levels of pellet detection**
  - **2-3 LS-cameras with lasers**

- **Development of a new readout system in progress.**
- **Design & preparation of tracking systems with more LS-cameras started.**
- **Preparing simulations for the design of a full scale system for PANDA.**

Goals for 2012 - 2014:

- **Close to 100% efficiency pellet detection**
- **Pellet track processing and optimization of pellet detection points**
- **Multi-camera readout system**
- **A tracking section for PANDA/WASA (hopefully tested at UPTS).**
- **Feasibility of laser-induced droplet production.**

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