Experiment Control System at Petra III

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- Introduction
- Tango
- Sardana
- Hardware synchronized scans
- Data transfer and storage
- Conclusions

LCWS
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Herzlich willkommen!

Introduction: Petra III

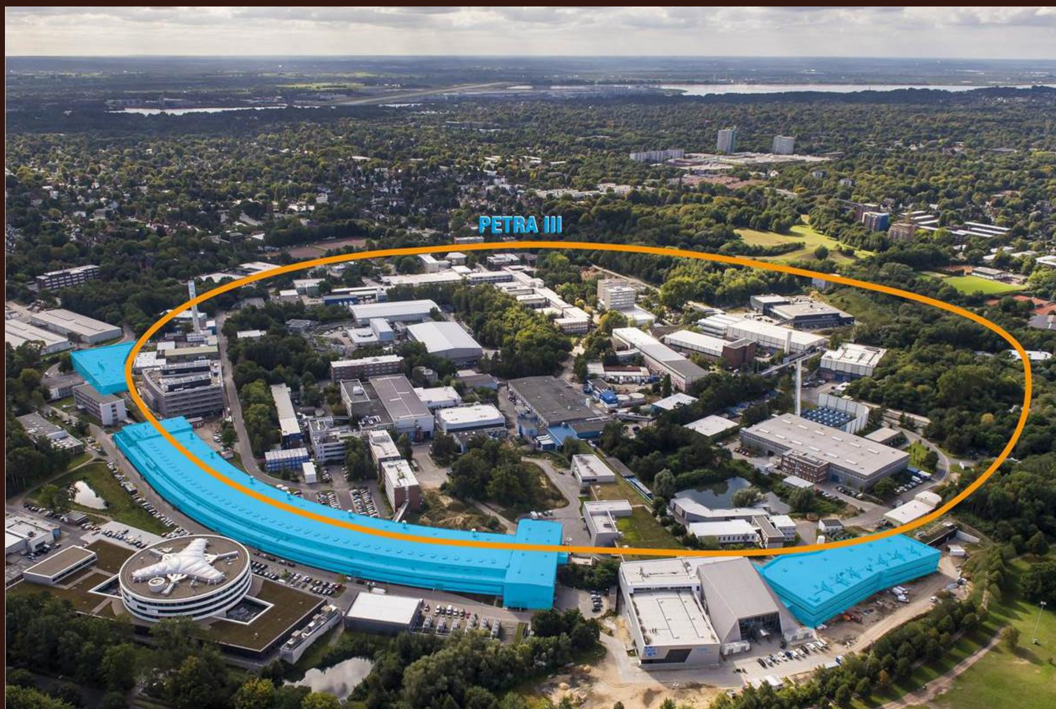
The high brilliance Synchrotron Radiation Source at DESY

PETRA:

- 1978-1986: High Energy Physics accelerator
- 1986-2005: Pre-accelerator for HERA (PETRA II)
- 2007: upgraded as high intensity Synchrotron radiation source (PETRA III)
- 2009: started user operation

Introduction (ctd.)

Petra III



P01 High Resoultion Dynamics
P02.1 Power Diffraction and Total Scattering
P02.2 Extreme Conditions
P03 Micro- and Nanofocus X-ray Scattering
P04 Variable polarization XUV
P05 Imaging (HZG)
P06 Hard X-Ray Micro/Nano Probe
P07 High Energy Material Science (partly HZG)
P08 High Resolution Diffraction
P09 Resonant Scattering and Diffraction
P10 Coherence Applications
P11 Bio-Imaging and Diffraction
P12 BioSAXS (EMBL)
P13 Macromolecular Cryst. (EMBL)
P14 Macromolecular Cryst. (EMBL)
P21 High Energy Material Science
P22 Hard X-Ray Photo Emission
P23 Insitu and Nano Difraction
P24 Chemical Crystallography
P64 TimeResolved and Bio EXAFS
P65 EXAFS

(FLASH)

Energy: 6 GeV
Circumference: 2304 m
Current: 100 mA
Hor. emittance: 1 nmrad
X-ray energy : 150eV-200KeV
Experiment stations: 35

5000 h/year user operation
2400 users/years
Everybody can apply for beamtime
Beamtime 1-2 days/user

Introduction (ctd.)

Experiment Control System Issues

- Flexibility: support different experimental techniques
- User friendliness
- Modularity: enable collaborative work
- Customizability: prepare discipline-specific applications
- Client-server structure, multi-client access
- Widely-accepted scripting language
- Performance, reliability
- Gateways: TINE, DOOCS, EPICS
- International community: collaboration, communication, standarized user environment

Tango chosen as control system

Tango

Software tool kit for building high performance and high quality distributed control systems for small or large installations

- Implements distributed objects called devices as layer between clients and hardware
- Uses CORBA and ZeroMQ for device/clients communication
- APIs: c++, python, Java
- OS: Linux, Windows
- Used by a large community ensuring maintenance and continuous improvement
- Core and Servers code shared in common open source repository
- Provides set of tools for developing, managing and monitoring

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Tango: institutions

Softwareschneiderei

Universitas Scientiarum Szegediensis – Szegedi Tudományegyetem

AKKA Technologies

THALES Services

LAL – Laboratoire de l'Accélérateur Linéaire

DESY

École Polytechnique – Université Paris-Saclay

3Controls

THEOSIS

NEXEYA

SKA – Square Kilometre Array

ESRF – The European Synchrotron

SOLARIS – National Synchrotron Radiation Centre

ANKA

iK

Atos

INAF – Istituto Nazionale di Astrofisica

HYTEC ELECTRONICS LTD

Instrumentation Technologies

COSYLAB – Control System Lab

MAX IV

National Research Centre «Kurchatov Institute»

Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II)

bertin Technologies

NanGenex – Member of the DRGT Group

ScandiNova – Excellence in Pulsed Power

TATA – Tata Consultancy Services

Codra

eli beamlines

eli Nuclear Physics

eli attosecond

Helmholtz-Zentrum Geesthacht – Centre for Materials and Coastal Research

ALBA

Elettra Sincrotrone Trieste

Observatory Sciences

The Italian Mars Society – MARS CITY – European Mars Analog Center

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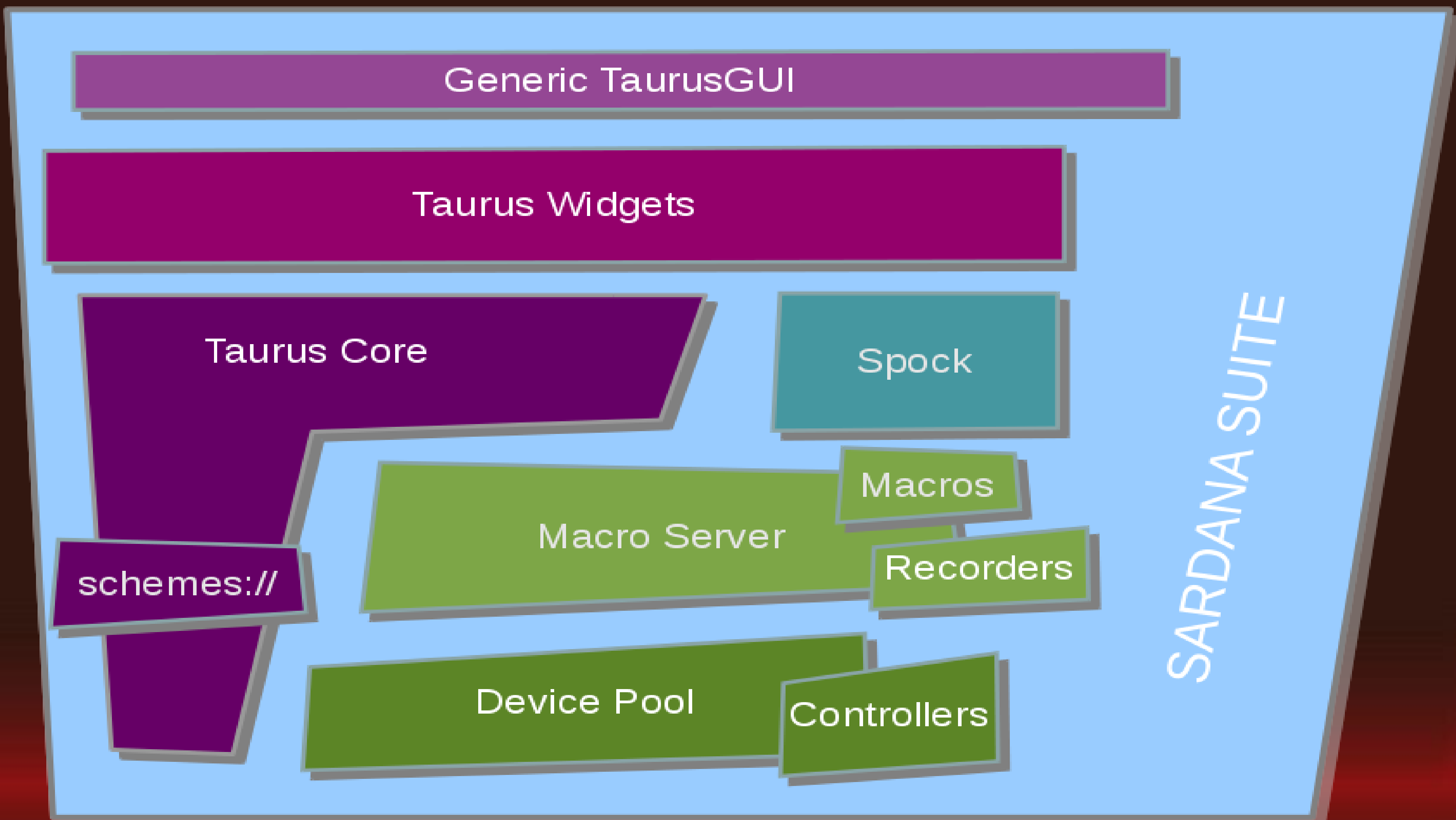
Tango: Petra III

Layer between experiment control and hardware

- More than 250 Tango classes developed
- Devices are instantiations of classes, distinguished by properties
- Device API: properties, commands, attributes

Sardana

Software suite for Supervision, Control and Data acquisition in small or large scientific installations



Taurus & Sardana Communities

Sardana (ctd.)

- Automatize procedures, ex. hardware and software synchronized continuous scans, diffractometer control
- Provides CLI and GUIs
- Data visualization and storage

- High flexibility and customization: implementation of new procedures, insertion of new devices
- Easy to configure

Hardware Synchronized Scans: Pi Logic Controller

Multifunctional and customizable module for fast signal processing

- Data processing power, speed, synchronicity -> FPGA
- Configurable input/outputs -> NIM/TTL I/O, ADC, DAC and temperature (PT sensor) cards
- High-level user-friendly interface -> Raspberry Pi 2

Scope of applications only limited by the FPGA functionality

Developed at DESY (FS-EC group) and
implemented in Tango

Hardware Synchronized Scans: Pi Logic Controller (ctd.)

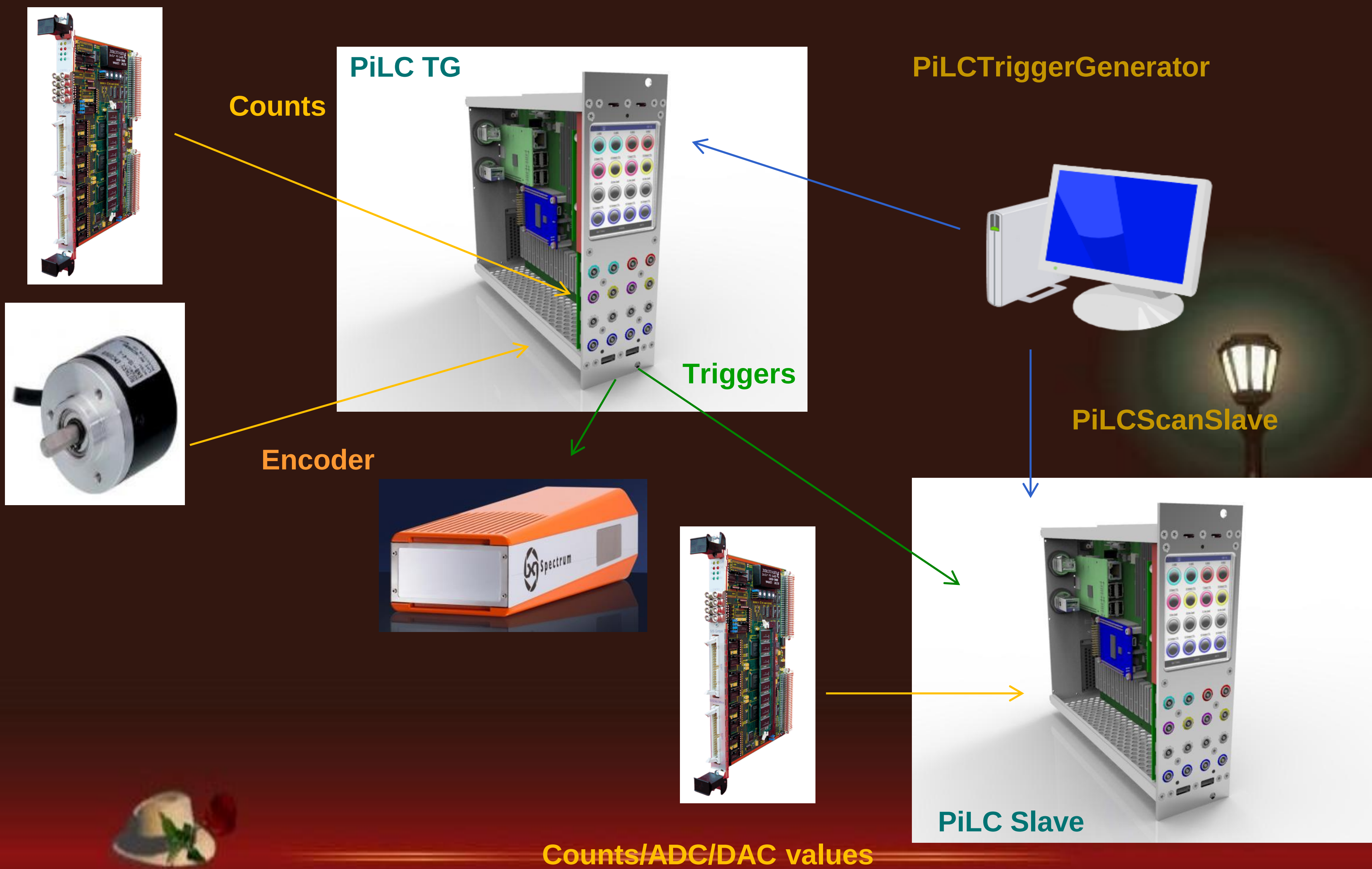
Three PiLC firmwares dedicated to hardware continuos scans

- Generation of equidistant triggers and data storage:
  - PiLCTriggerGenerator: trigger generation and data storage
  - PiLCScanSlave: trigger listener and data storage
- Generation of up to 4 not equidistant shifted triggers:
  - PiLCArrayBasedTG: generate user defined trigger pattern

Herzlich willkommen!

Hardware Continuous Scans: Pi Logic Controller (ctd.)

Equidistant continuous scans triggered by PiLC



Hardware Continuous Scans: Pi Logic Controller (ctd.)

PiLCTriggerGenerator:

Generate triggers and store data

– Seven trigger modes: based on time and/or position (start and frequency, 'zig-zag' in defined window) or external signal.

– Up to five encoder and one counter values (extensible) stored in circular buffer (32 MB depth) during scans

– Selectable encoder triggering

– Data (encoders/counter readings) accessible during scan

– Scans can be paused and resumed

– Maximum trigger rate depends on stored data and requested number of triggers (limited by buffer full): up to 11.2 kHz in worst scenario

– Output written in nexus files (pni-libraries)

Hardware Continuous Scans: Pi Logic Controller (ctd.)

PiLCScanSlave:

Listen triggers and store data

- Up to five values from counter, ADC or DAC cards (selectable)
- Data accessible during scan
- Working in manual or automatic mode (arm by itself or by TriggerGenerator)
- Output written in NeXus files (pni-libraries)

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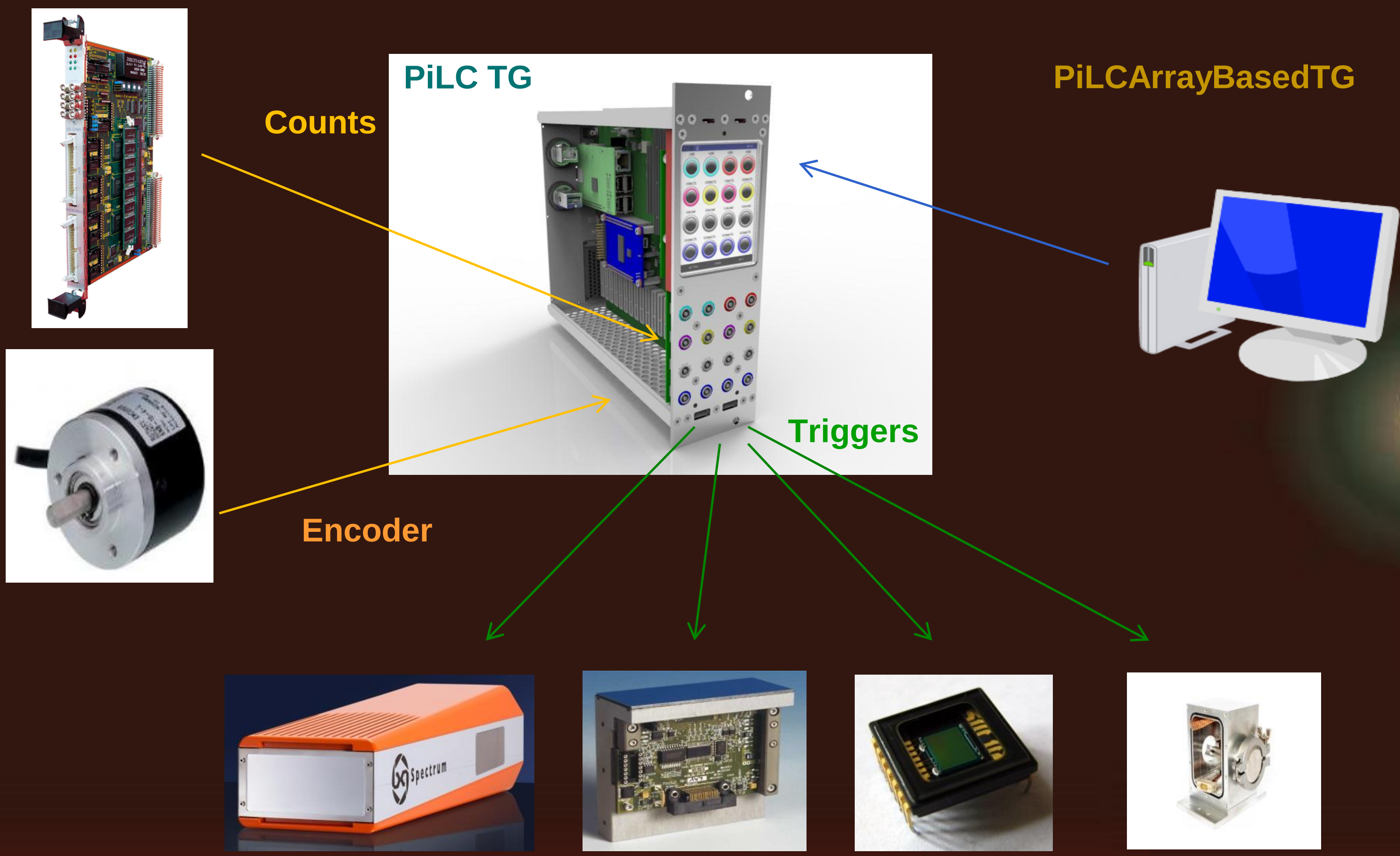
Hardware Continuous Scans: Pi Logic Controller (ctd.)

Not equidistant shifted triggers generator



Hardware Continuous Scans: Pi Logic Controller (ctd.)

PiLCArrayBasedTG:

Generate shifted triggers

- Array-based defined pattern
- Two modes: counter or encoder input signals
- Up to four different triggers (two outputs for each trigger)
- Trigger information loaded from input file: trigger-channel, trigger-value, trigger-level
- Take care of detector after-glow
- Ex. Control Perkin Elmer and shutter

Data Transfer and Storage

Handle massive data production at the experiments

- Cope with data rates
- Accept data from ‘everywhere’
- Implement authorization
- Provide long term storage
- Support data processing

Common initiative of DESY-CC and IBM (Speed):
PETRA GPFS storage system

Data Transfer and Storage (ctd.)

Data production for 2D detectors at Petra III experiments

	Data Rate [GB/s]	fps	fSize [MB] / frame	Transfer	Viewer	LaVue
Lambda (12b) HDF5	2.6	2000	1.5	NFS,HiDRA	ATK,Taurus, Onda	TS
Lambda2M HDF5	7.8	2000	4.5	NFS	ATK, Taurus, Onda	TS
AGIPD HDF5	0.6	3520	0.131	HiDRA	ATK, Taurus, Onda	TS
AGIPD1M HDF5	10	3520	2.1	n.a.	ATK, Taurus	TS
Jungfrau, HDF5, BIN	0.5	500	1	HiDRA	P11-Onda	
PCO Fr.Grabber, TIF(PCO), HDF5	0.8	100	8	NFS, HiDRA	ATK	TS, HiDRA
PCO USB (P11), TIF	0.8	100	8	SMB, (HiDRA)	Vendor SW	(HiDRA)
Eiger4M, HDF5 (LZ4, external filter)	1	750	9/18	HDF/http	Albula (low speed)	
Pilatus2 6M, CBF/TIF	0.15/0.6	25	6	NFS, HiDRA	TVX, Albula	HiDRA
Pilatus3 2M, CBF/TIF	0.6/ 2	250	2.5 /11	NFS, HiDRA		HiDRA
Pilatus2 1M, CBF/TIF	0.05/0.2	50	1	NFS, HiDRA		HiDRA
Pilatus2 300k, CBF/TIF	0.05/0.2	200	0.3	NFS, HiDRA		HiDRA
Perkin Elmer XS 1621	0.25	15	16 (+ 950 Byte)	SMB, (HiDRA)	QXRD	(HiDRA)

Data Transfer and Storage (ctd.)

Two gpfs servers installed at Computer Center:

- Beamline FS: optimized for ingestion of data at high speed bursts
- Core FS: optimized for capacity and concurrent parallel access

Several protocols for data transfer to storage system:

- ZMQ:
  - ✓ high throughput
  - ✓ decouples operating systems
  - ✓ reduces disk I/O
  - ✓ not necessarily site-specific
- NFS-3, SMB

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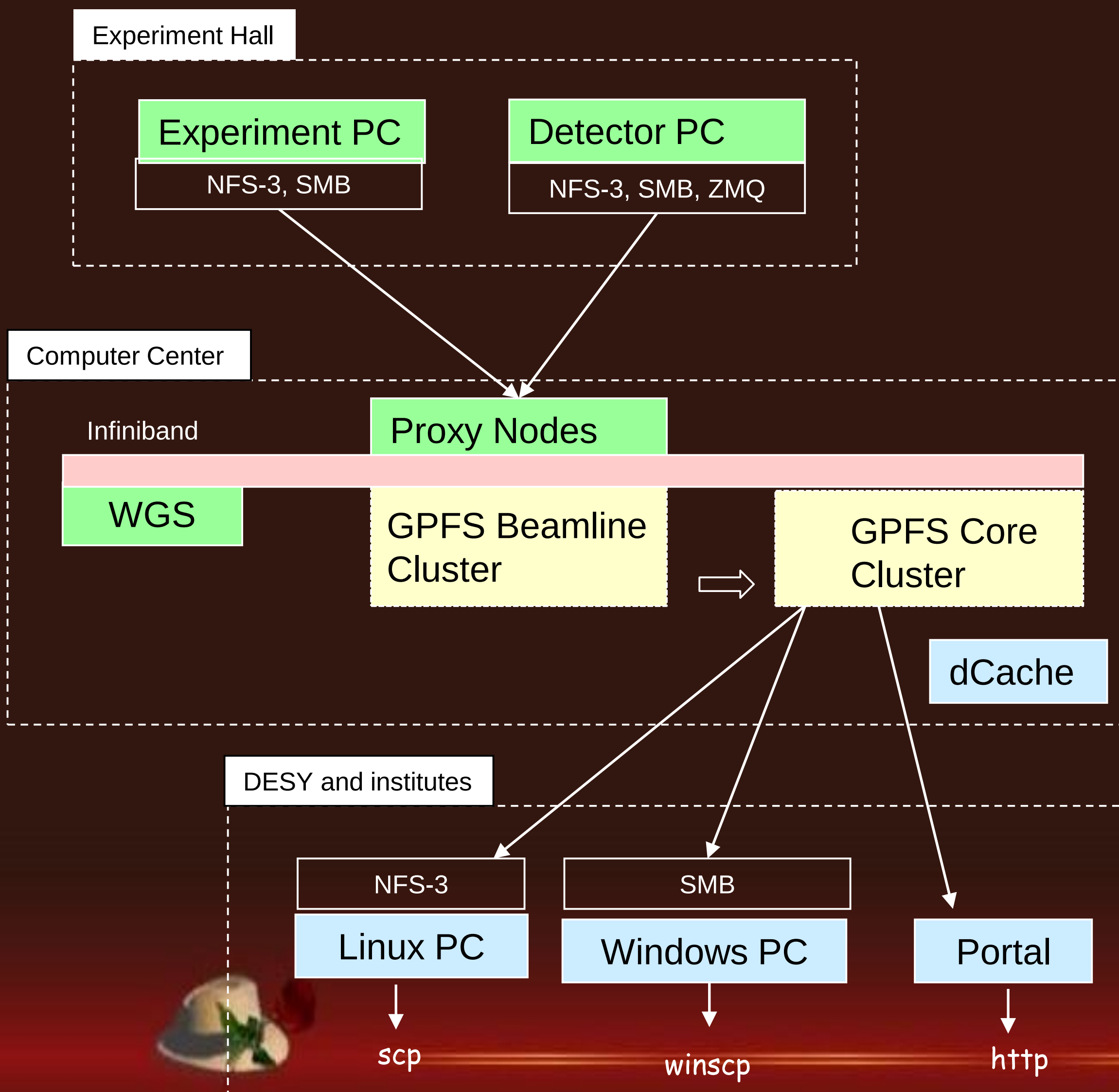
Data Transfer and Storage (ctd.)



GPFS – General Parallel File System (IBM)
- PETRA III, in-house and derived data

Proxy nodes
- Are installed when new detectors arrive

BL Cluster
- Optimized for high data rates
- Data transfer: nfs, smb, zmq
- Supports generic BL and detector users
- Data are copied to the Core cluster within minutes
- Data visible within a beamtime only

Core Cluster:
- Optimized for parallel access
- ACLs based on Door information

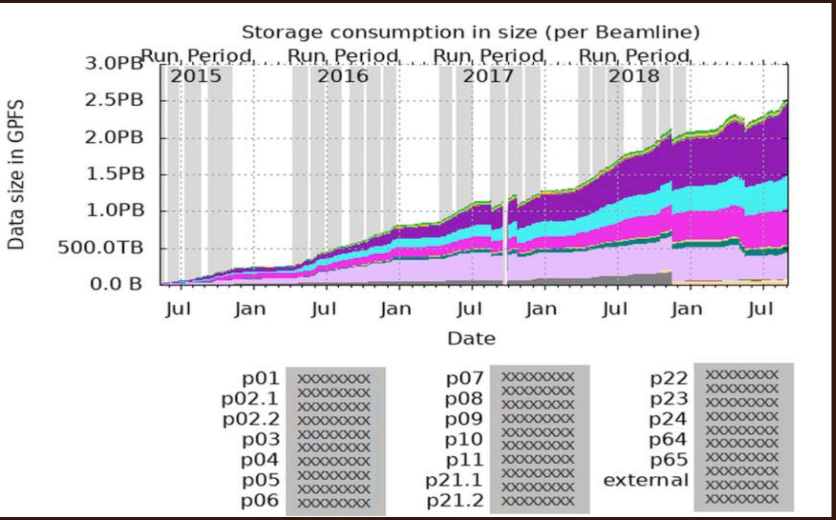
WGS: Analysis, NRTA

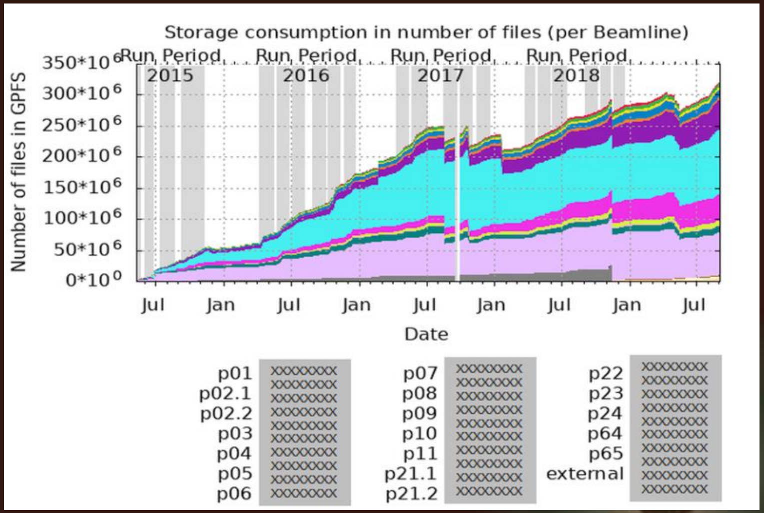
dCache: Tape archive

Portal: File discovery, downloads

Data Transfer and Storage (ctd.)

GPFS usage





- Produced 2015: ~200 TB total (30 TB/month)
- Produced 2016: ~460 TB (55 TB/month)
- Produced 2017: ~580 TB (75 TB/month)
- Produced 2018: ~750 TB (90 TB/month) [+ 250 TB FLASH+Ext.] ~ 1PB
- Produced 2019: as of 2.9. ~690 TB (120 TB/month) [+75 TB FLASH+Ext] ~ 765 TB

- Currently ca. 300+ million files in total (2015/2016 ~ 1, doubled in 2017)
  - new detectors resulting larger files
  - Partially NeXus/HSF5 files (Lambda, Eiger, [AGIPD])
  - Partially compressed data

- (Start to) delete data from GPFS permanent disk storage in 2017

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Conclusions

Petra III experiment control system implemented from scratch with

- High modularity
- High flexibility
- Easy to use and configure
- Capable to transfer/storage/handle/visualize large amounts of data
- Common interfaces with other synchrotron sources
- Easy to adapt/extend for new hardware and procedures

… being developed and extended every day …