Highlights from CARE-N3-HHH-ABI

Hermann Schmickler, 24.11.2008

layout

- The CARE-N3-HHH-ABI-network:
  - general strategy
  - work packages
  - contributing institutes
  - workshops
- Highlights
  - digital orbit system for proton machines
  - remote diagnostics, network security
  - RT feedback on beam parameters

N3-HHH-ABI network (1/4)

- LHC: LHC upgrade options do not demand significant changes to the LHC beam instrumentation: The bunch spacing is preserved, the dynamic range is slightly increased, but still within the range of the present (BPM) electronics.
- FAIR project: Enormous multitude of instrumentation systems, but for most of them a solution exists; only some R&D needed concerning the very high dynamic range in beam intensity.
- Other HHH projects including US projects: (Linac4, project X): no significant R&D on beam instrumentation needed

→ General Strategy:

Use the ABI network to stimulate necessary progress on all general purpose beam instrumentation fields and integrate newcomers into the field.

N3-HHH-ABI network (2/4)

- 8 workpackages

ABI1: Studying tools and diagnostic systems for luminosity monitoring and steering
ABI2: Studies on the applicability of a wire compensation for long range beam beam interactions
ABI3: Studies on advanced transverse beam diagnostics
ABI4: Implementation of fast feedback loops for orbit, coupling and chromaticity control
ABI5: Studies on advanced beam halo diagnostics
ABI6: Studies leading to remote diagnostics and maintenance of instrumentation devices
ABI7: Studying tools for diagnostic systems for high intense preaccelerators; preservation of emittance in the accelerator chain
ABI8: Requirements of diagnostic tools for machine protection systems (MPS)

N3-HHH-ABI network (3/4)

- Participating Institutes / Work packages Matrix

Institute	ABI1	ABI2	ABI3	ABI4	ABI5	ABI6	ABI 7	ABI 8
CERN	H. Schmickler	J.P. Koutchouk	A. Burns	J. Wenninger	E. Bravin	H. Schmickler		R. Schmidt
GSI			P. Forck	A. Galatis	P. Forck	A. Peters	P. Forck	H.Reeg
DESY			S. Herb	J. Klute	K. Wittenburg	R. Bacher	K. Wittenburg	M. Werner
PSI				V. Schlott				
ESRF					K. Scheidt	K. Scheidt		
UPSA			V. Ziemann			V. Ziemann		
BNL	A. Drees		P. Cameron	P. Cameron		S. Peggs		
LBNL	B. Turner				B. Turner	P. Denes		
FNAL	J. Marriner	V. Shiltsev	D. McGinnis	J. Marriner		J. Marriner		

N3-HHH-ABI network (4/4)

- Major events: 6 Workshops (one per year)

WS1: Trajectory and Beam position measurements using digital techniques, Aumuehle (Hamburg), 2003
WS2: DC current transformers and beam-lifetime evaluations Lyon (F), 2004
WS3: Remote Diagnostics and maintenance of beam instrumentation devices, Hirschberg (Darmstadt), 2005
WS4: Simulation of BPM front-end electronics and Special Mechanical Designs, Lueneburg (Hamburg), 2006
WS5: Schottky, Tune and Chromaticity Diagnostics (with Real-Time Feedback), Chamonix 2007
WS6: Transverse and Longitudinal Emittance Measurements in Hadron (Pre-) Accelerators, Bad Kreuznach (Darmstadt), 2008

Summary of Workpackages completion

ABI1: Studying tools and diagnostic systems for luminosity monitoring and steering

Not done

ABI2: Studies on the applicability of a wire compensation for long range beam beam interactions

Well covered in US-LARP collaboration

ABI3:

5th ABI Workshop

ABI4: Implementation of fast feedback loops for orbit, coupling and chromaticity control

5th and 1st ABI Workshop

ABI5:

Covered in Halo03 workshop

ABI6: Studies leading to remote diagnostics and maintenance of instrumentation devices

3rd ABI workshop

ABI7: Studying tools for diagnostic systems for high intense p c

In planned 6th ABI workshop (Dec.2008)

ABI8:

ABI network has stimulated a bilateral collaboration of CERN and DESY with many meetings and workshops

Highlights

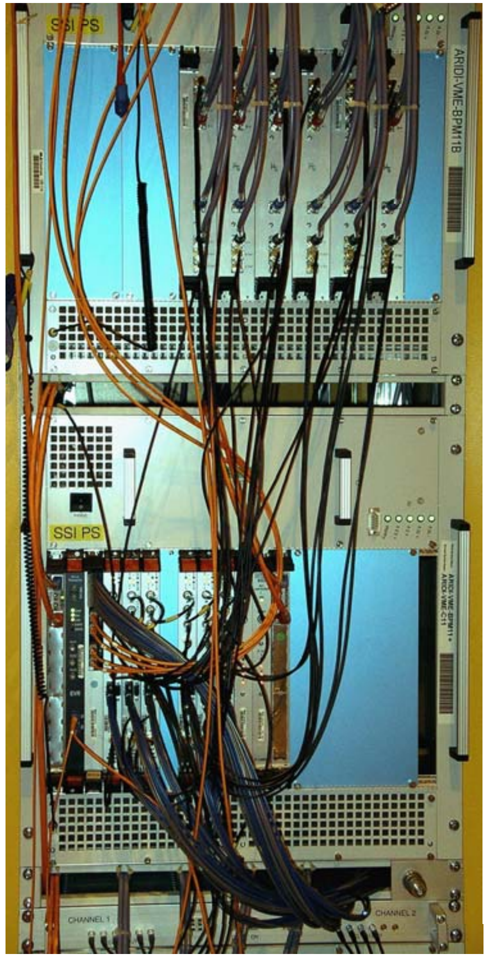
- …a personal selection for…
  - high technical level
  - for a highly collaborative realization

- Digital Orbit System for CERN-PS and GSI SIS machines
- RBAC = Role Based Access Control
- LHC Tune and Chromaticity Control and RT feedback

SLS Digital Beam Position Monitoring System

Care-N3-ABE Networking Workshop

June 2004



Outlines

- **System overview**
- **System elements**
- **Run modes**
- **Problems and solutions?**
- **Future developements**

BPMs in SLS Accelerators

- linac / linac to booster transfer line:	6	BPMs
- booster:	54	BPMs
- tune BPM in booster:	1	BPM
- booster to storage ring transfer line:	3	BPMs
- storage ring:	72	BPMs
- tune BPM in storage ring:	1	BPM

Total Number of BPMs: 137 BPMs

Strategy

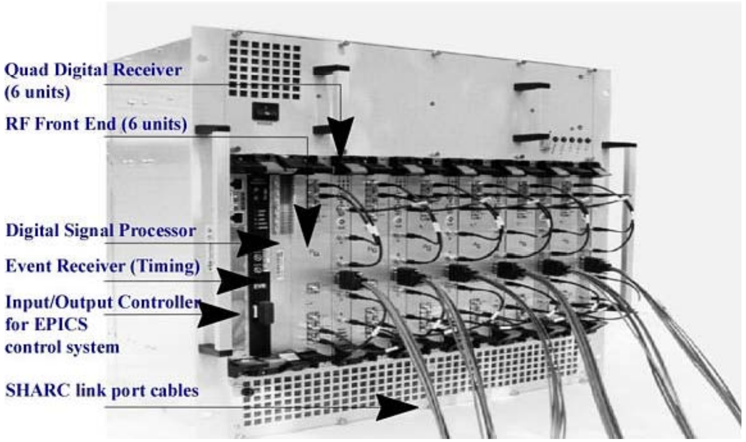
Use one type of BPM electronics for all sections of the machine

➡ **Digital BPM System with reprogrammable digital down converters**

Development

Collaboration between

ELETTRA (Trieste, Italy)
SLS
R. Uršič (Consultant)



Concept

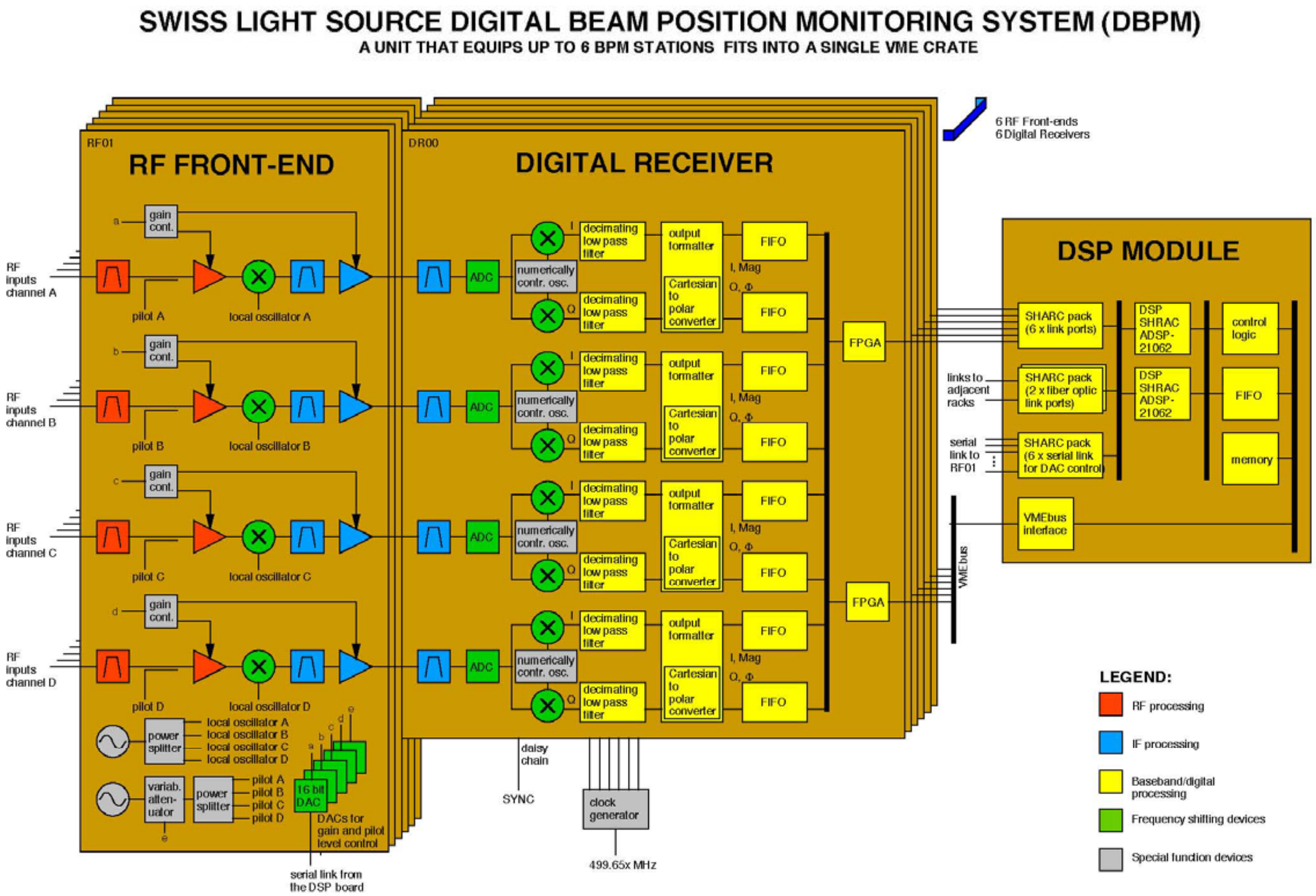
- 4 channel system
- modular system (VME technology)
  - RF front end (down conversion to IF)
  - Quad Digital Receiver (digital down conversion to base band)
  - Digital Signal Processing (position calculation)
- pilot signal in all four channels
  → calibration of electronics by individual gain settings

Development Milestones

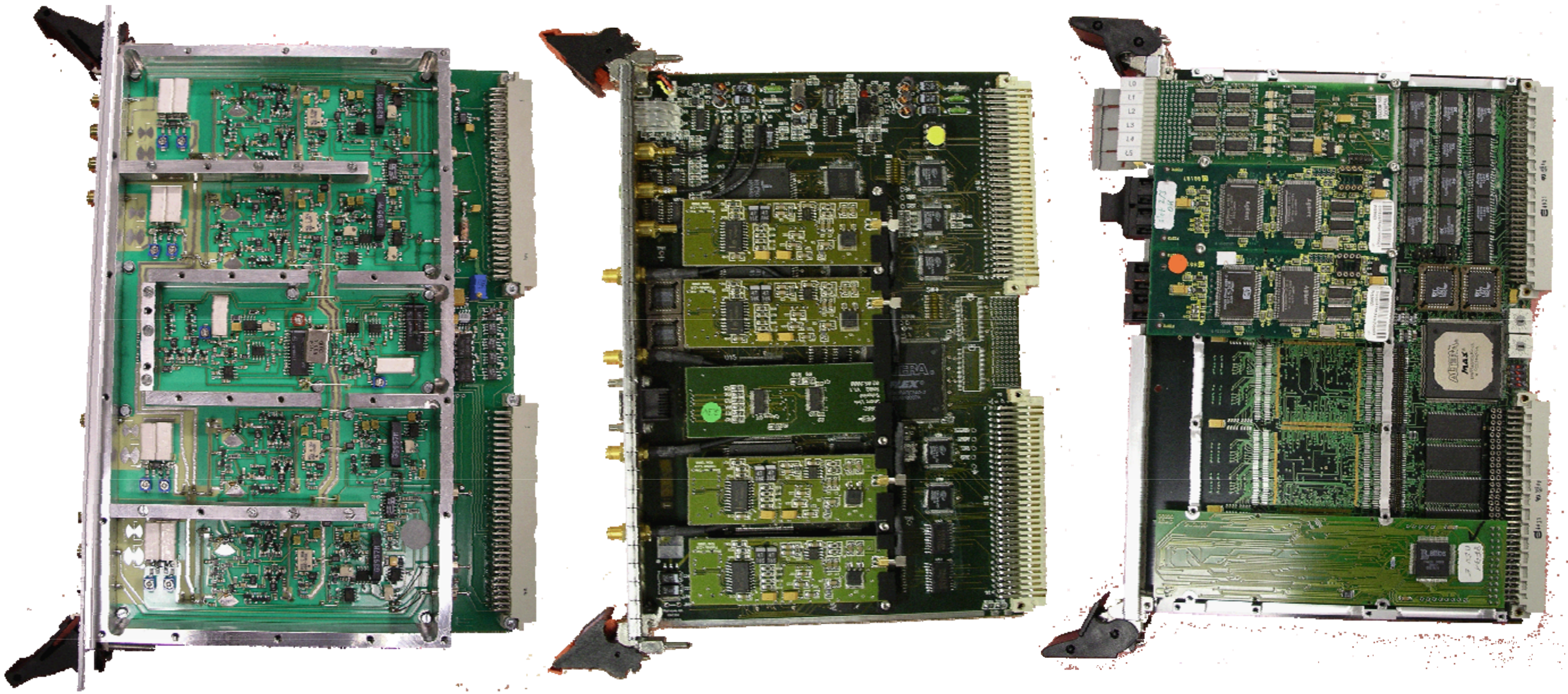
- **June 1998**: Concept and proposal.
- **October 1998**: Start evaluation of commercials digital receiver systems and in parallel start developement studies for a custom solution.
- **January 1999**: Decision for custom developement.
- **July 1999**: First prototype works @ Elettra, proof of principle.
- **June 2000**: SLS linac & transfer lines commissioning with DBPM serie 1.0.
- **August 2000**: SLS booster commissionning with DPBM serie 1.1.
- **December 2000**: SLS Storage ring commissionning with DBPM serie 1.2.

No significant hardware changes made since january 2001 !!!

SLS Digital BPM System



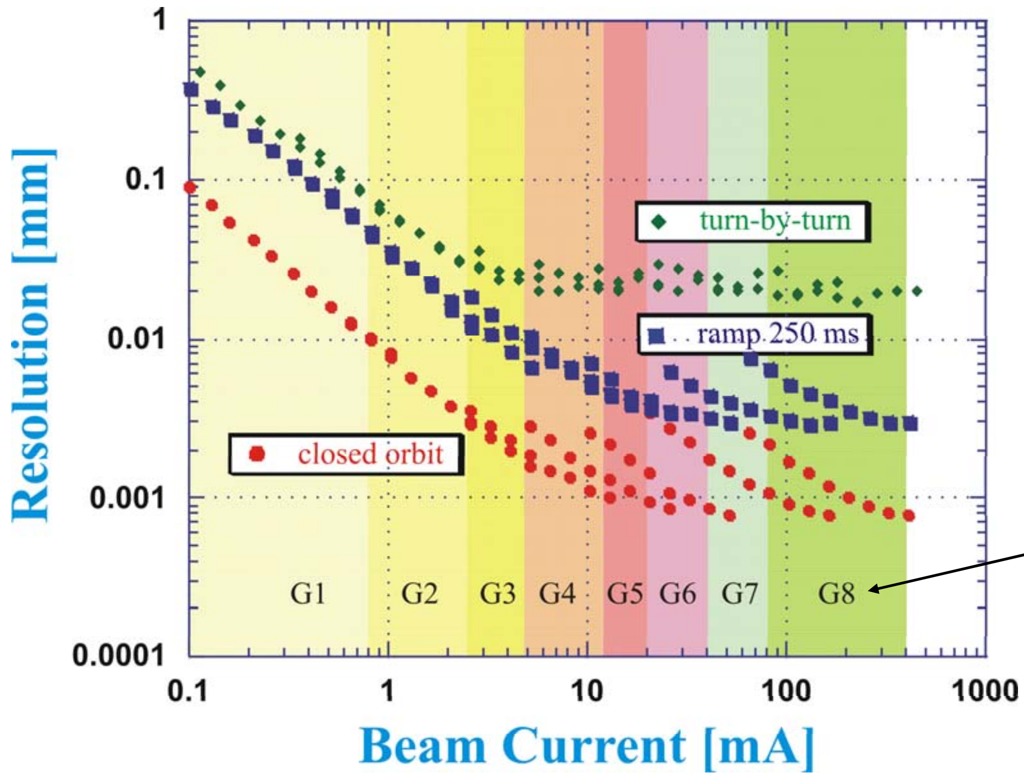
Hardware modularity



RF Frontend **Quad Digital Receiver** **DSP**

Parameter	CO and Feedback	Pulsed and TBT
Dynamic Range	1-500 mA	1-20 mA
Beam Current Dependence		
full range	< 100 µm	-
relative 1 to 5 range	< 5 µm	-
Position Measuring Radius	5 mm	10 mm
Resolution	< 1 µm	20 µm
Bandwidth	> 2 kHz	0.5 MHz
RF and IF Frequencies		
Carrier RF	500 MHz	500 MHz
Carrier IF	36 MHz	36 MHz
Pilot RF	498.5 MHz	498.5 MHz
Pilot IF	34.5 MHz	34.5 MHz

Resolution

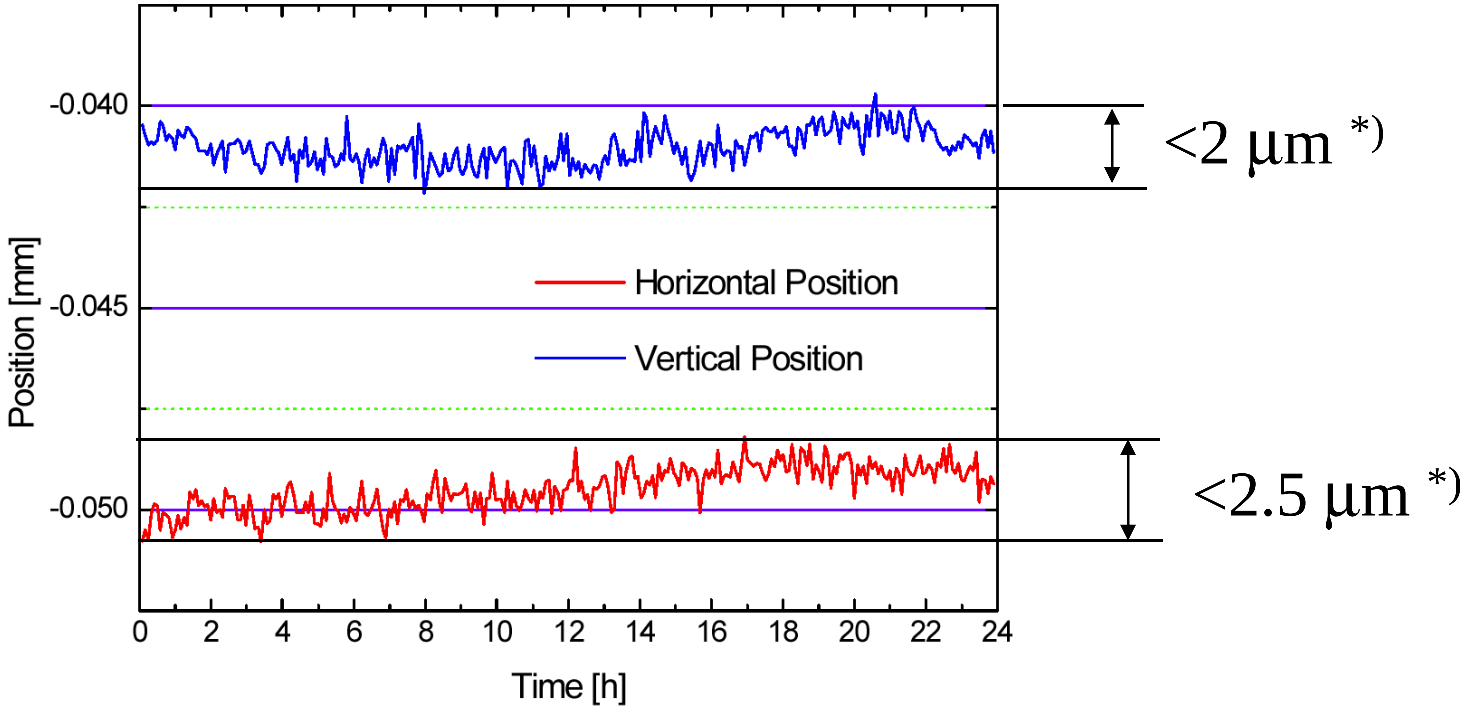


gain ranges
(80% filling pattern)

Mode	DDC Output Rate [kHz]	Passband BW [kHz]	Resolution [µm]
Turn-by-turn	1041	416	< 20
Ramp 250ms	32	11	3
Closed orbit / feedback	4	0.2	0.8

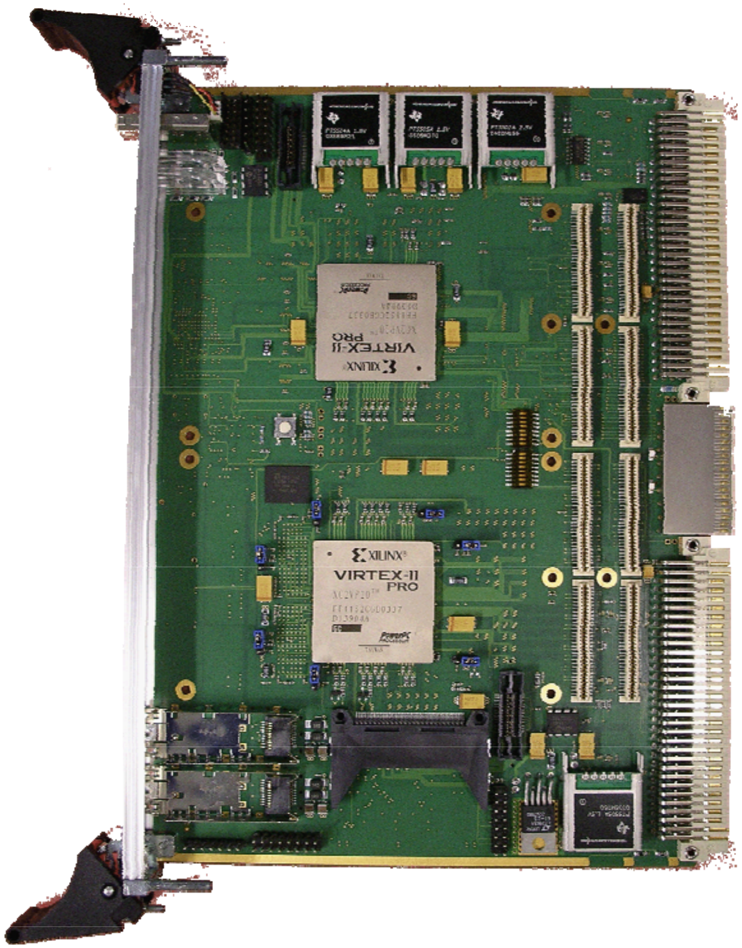
Stability

long term stability measurement in technical gallery (with RF signal generator):



*) hall temperature (technical gallery) regulated < ±1 ºC (spec)

The future …



- **VPC Generic PMC carrier Board.**

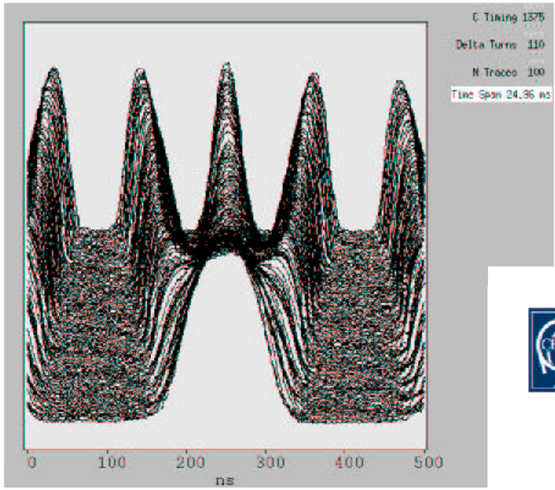
Specific requirements for hadron machines

Trajectory measurement for the CERN PS

RF gymnastics

During LHC cycles, each bunch is split into three equal bunchlets in about 25ms.

This is done on the injection plateau at 1.4GeV, by gradually increasing the RF at h=21, while at the same time reducing the RF at h=7.



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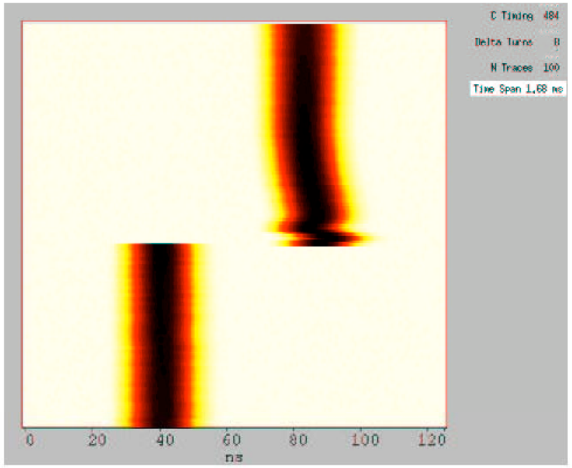
Bunch splitting

Transition crossing

Trajectory measurement for the CERN PS

In the PS, a p^+ beam goes through transition at a kinetic energy of 4.8 GeV (γ_{tr}=6.08). The phase of the cavity RF is changed abruptly to maintain longitudinal stability.

This picture has been taken on a SFTPRO cycle. The phase change due to γ–transition is about 120°.



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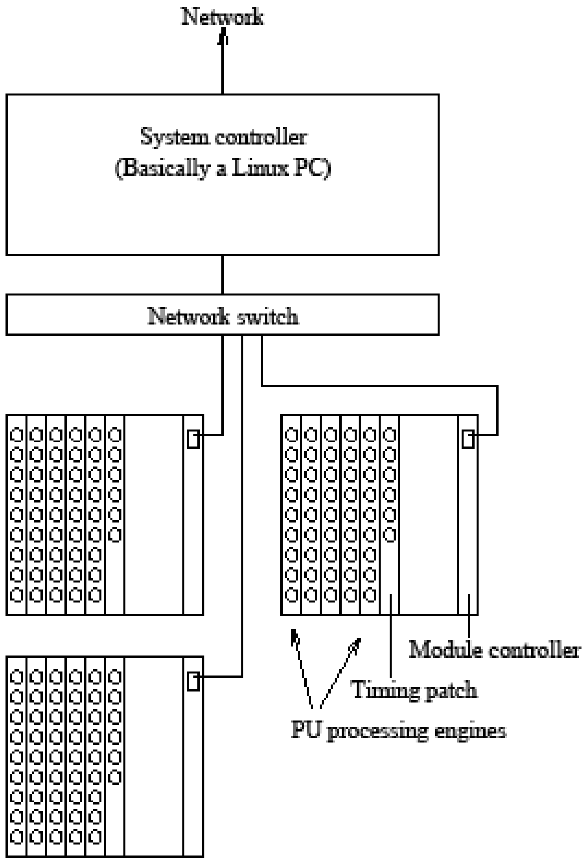
Jeroen Belleman

Evolution after 1st workshop

- Instrumentation technologies (R.Ursic et al.) developed a digital BPM system based on the SLS experience, which today is used in almost all European lightsources (LIBERA)
- The requirements of a digital orbit system for hadron machines became finalized and documented
  - variable revolution frequency tracking
  - bunch manipulations (change of harmonic number, bunch splitting)
  - transition crossing
- CERN, GSI and instrumentation technologies conclude in the FP6 framework a collaboration for the prototyping of such a digital orbit system for hadron machines.
- After the prototyping CERN procures a complete system for the PS; not from instrumentation technologies but from a concurrent company in GB → final commissioning in 2009.

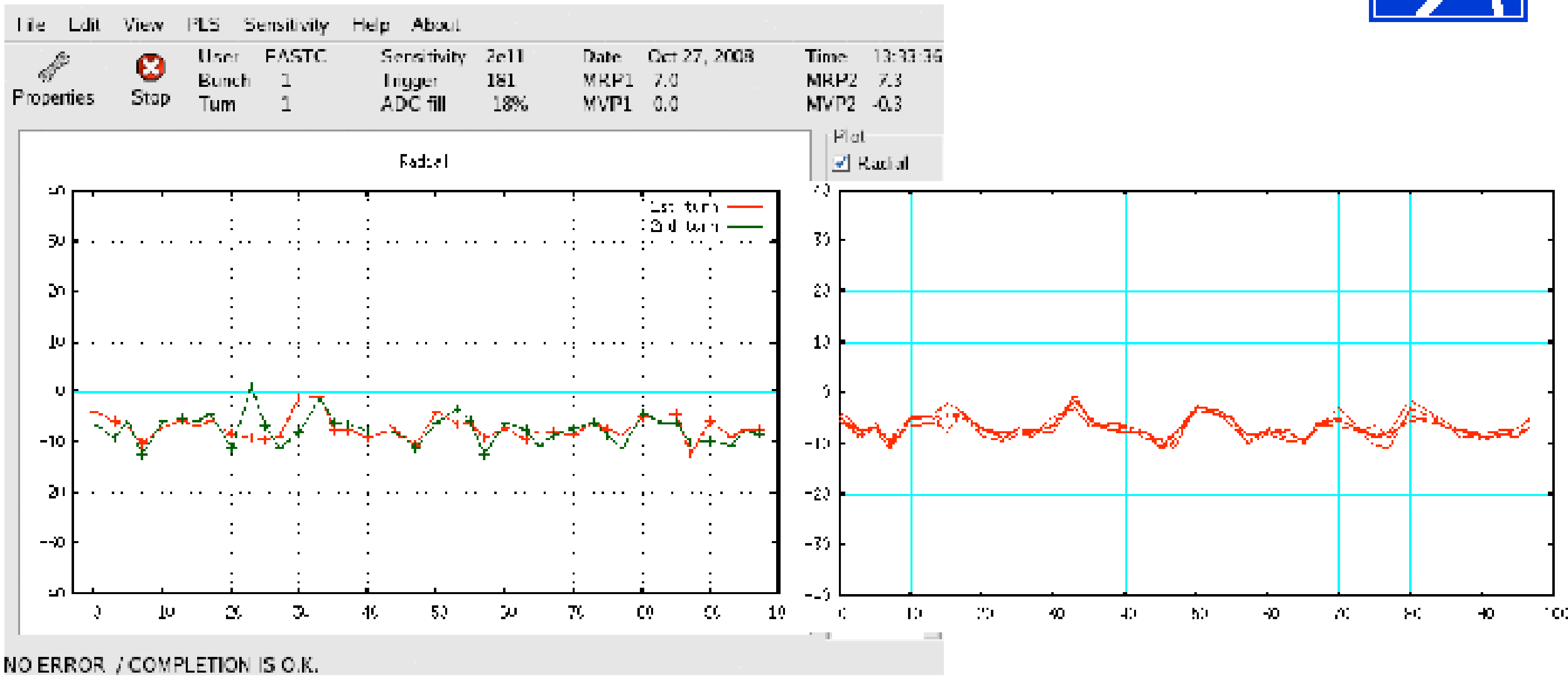
New PS orbit system; J.Belleman et al.



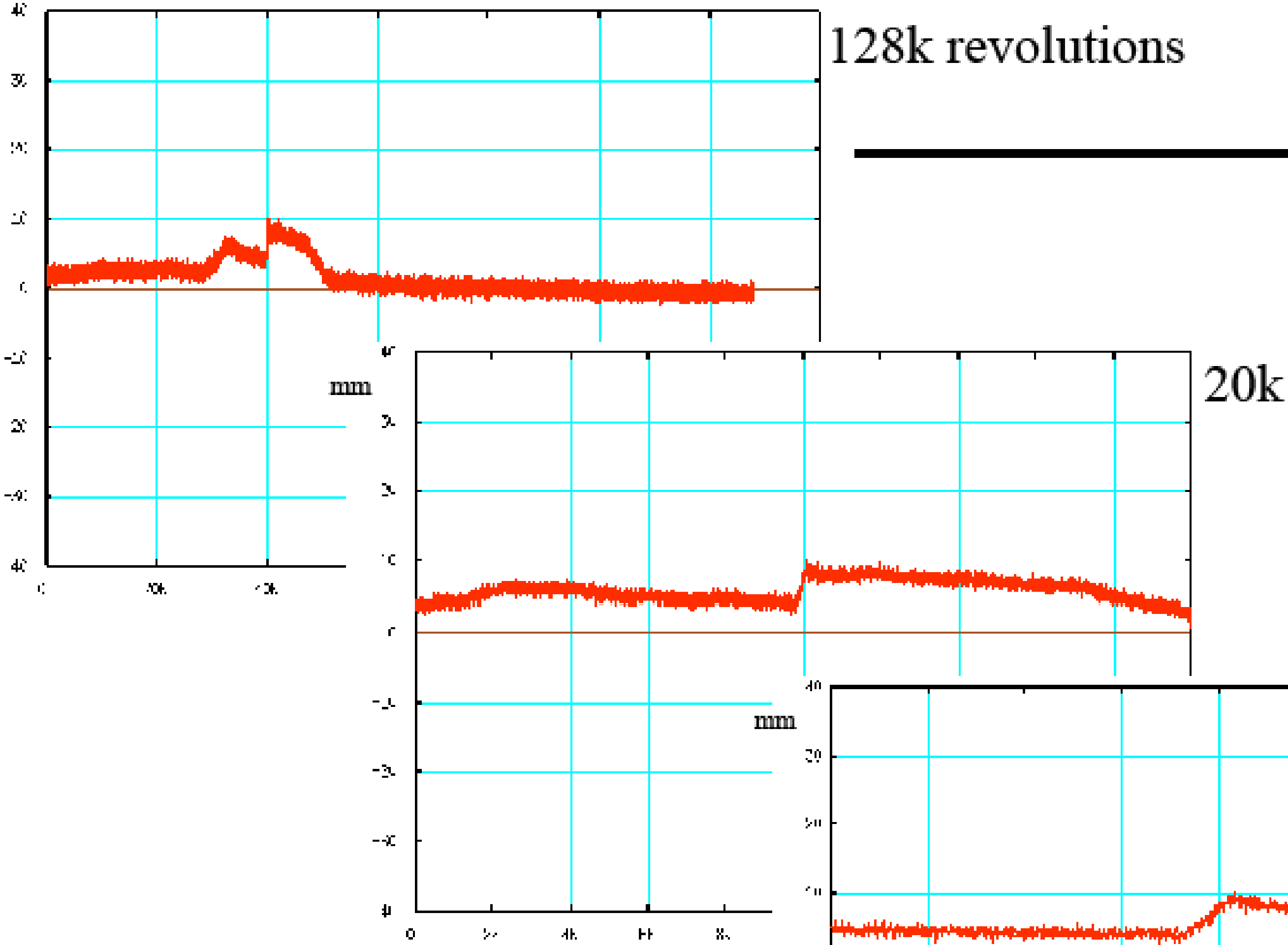
- 14 PU Processing Engines
- Treating 3 PUs each
- 3 cPCI crates
- One system controller

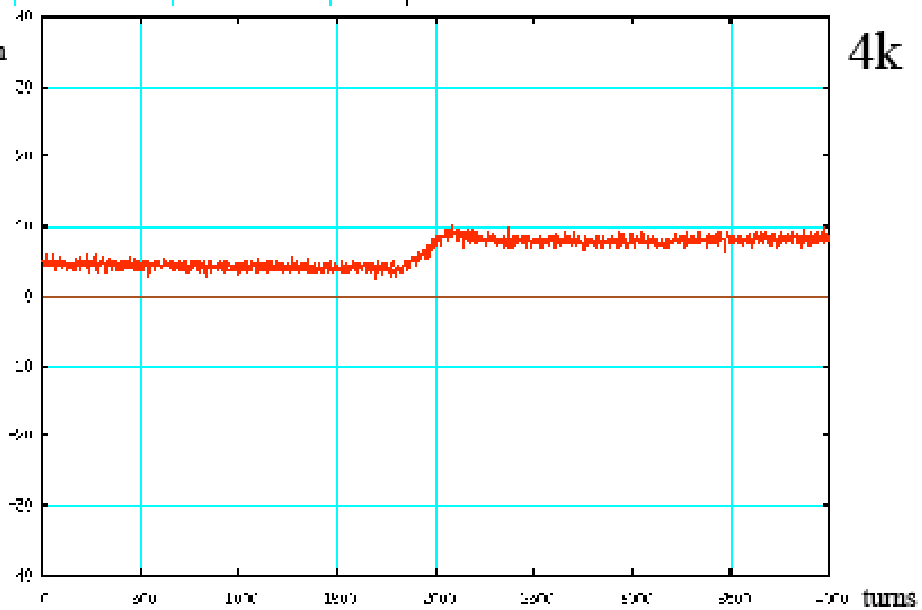
The cPCI crate processors are connected to the system controller using Gbit Ethernet.
The system controller connects to the TN using a 2nd network interface.

Side-by-side comparison of CODD and TMS



EASTC at C181
(Single-bunch 37e10ppb)





SFTPRO Transition crossing seen at PU33

Highlights

- …a personal selection for…
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- Digital Orbit System for CERN-PS and GSI SIS machines
- RBAC = Role Based Access Control
- LHC Tune and Chromaticity Control and RT feedback

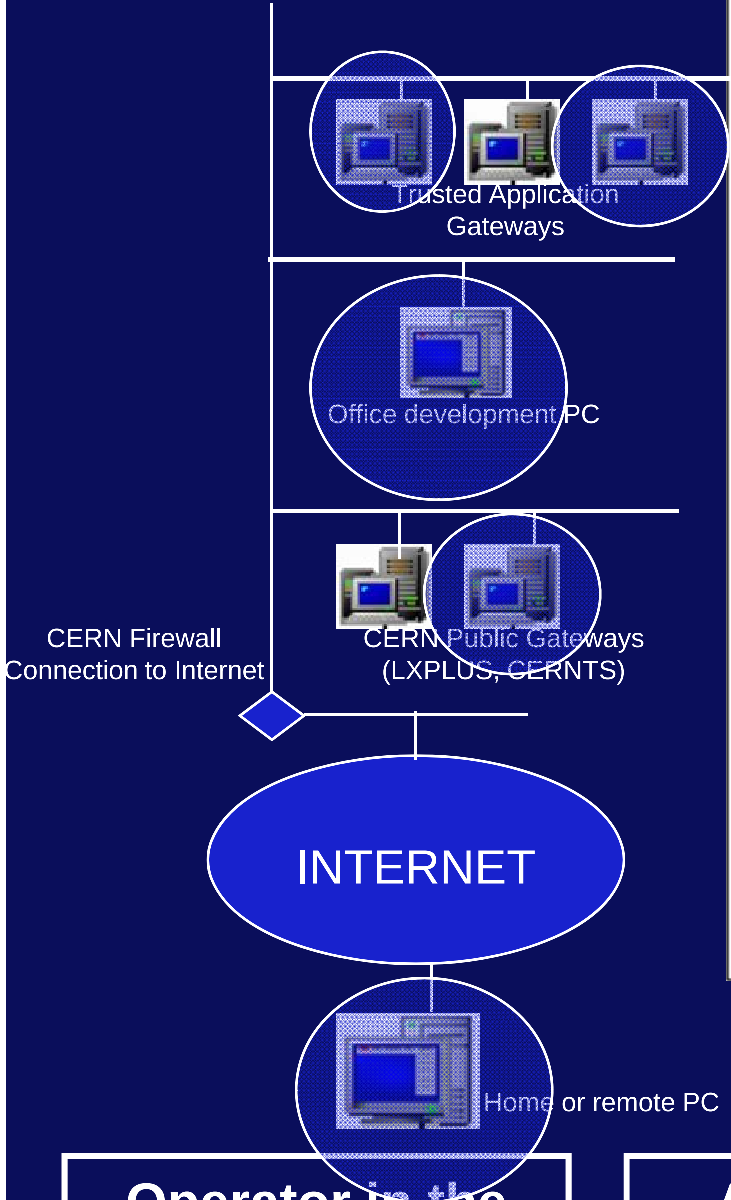
3rd workshop (→ RBAC)

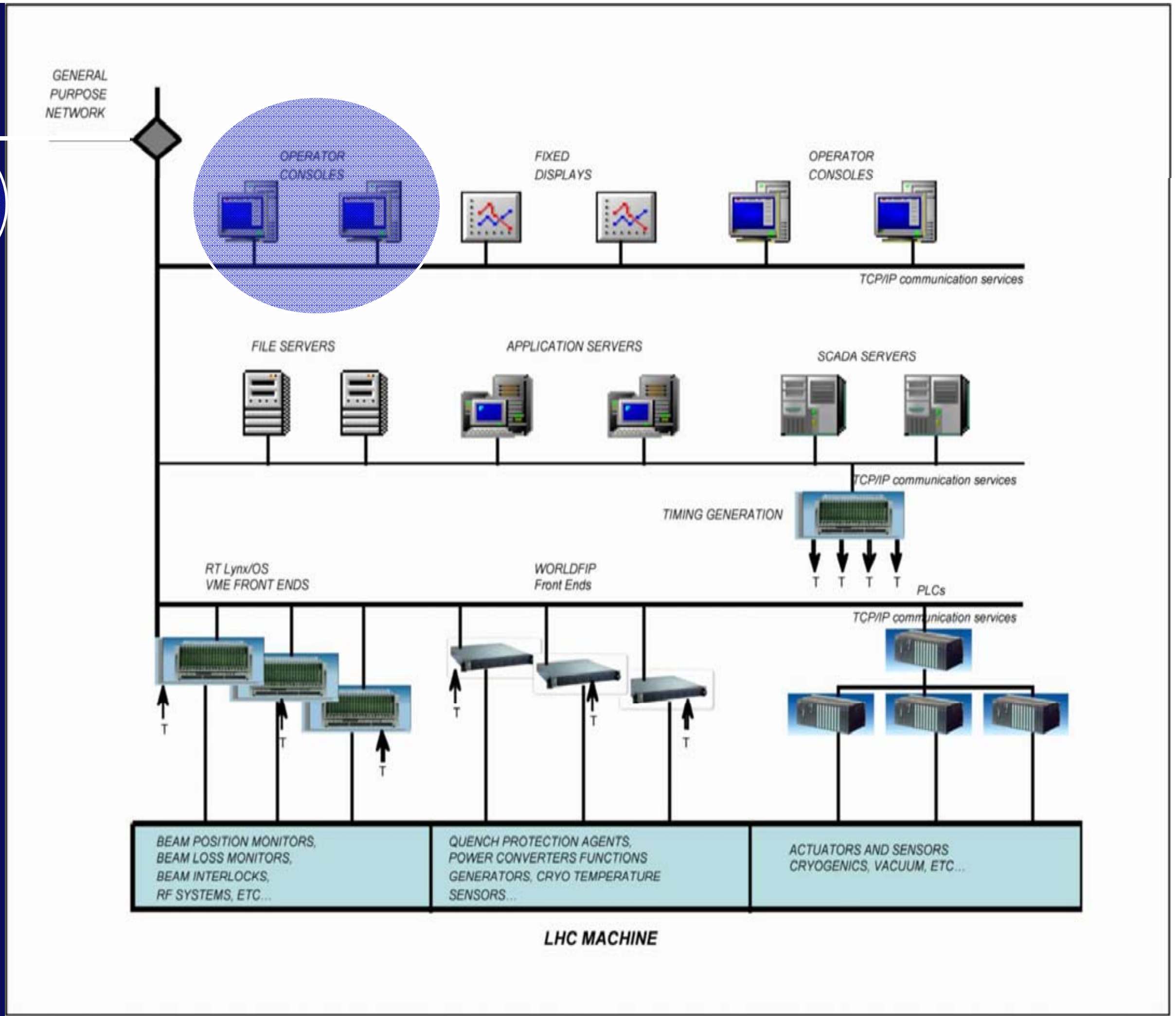
- Subject od the workshop was remote diagnostics and remote instrumentation maintenance
- Remote diagnostics: Discussed in the framework of GAN efforts (= Global Accelerator Network) and the FP6 supported MVL development (= Multipurpose Virtual Lab)
- Remote Instrumentation Maintenance: Special demand in the view that instrumentation components get completely developed by collaboration partners and the remote maintenance would enable them to stay responsible after commissioning.
- A concrete proposal from FNAL was on the table for LHC@FNAL, i.e. a remote operation room for the LHC in the FNAL highrise building

- Predominant discussion factor: network security
This stimulated the CERN – FNAL collaboration on RBAC =
Role Based Access Control

What is RBAC

- RBAC stands for Role Based Access Control
- RBAC is an infrastructure to prevent:
  - A well meaning person from doing the wrong thing at the wrong time.
  - An ignorant person from doing anything, at anytime.
- It is a suite of software components that provides
  - AUTHENTICATION (A1) on the client level
  - AUTHORIZATION (A2) on the server level
- RBAC website : <http://wikis/display/LAFS/Role-



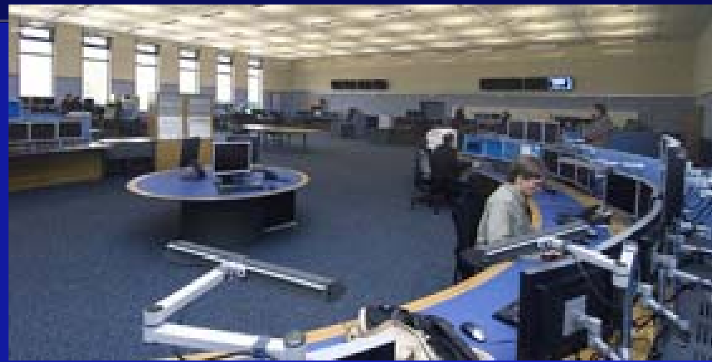


3 typical Use Cases

Operator in the CCC	Access from the office inside CERN	Specialist access from home

RBAC definitions

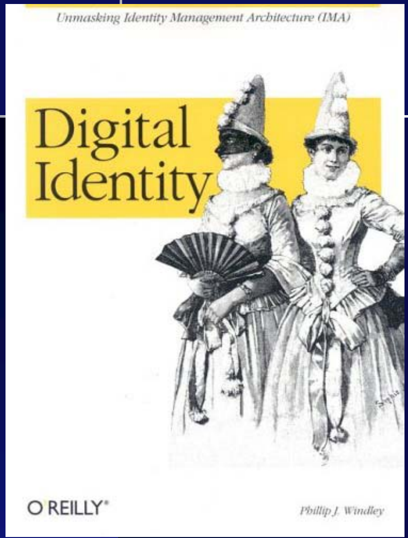
- What is a ROLE?
  - A role is a job function within an organization.
    Examples: LHC Operator, SPS Operator, RF Expert, BPM Developer …
  - Roles are defined by the security policy.
  - A user may have several roles



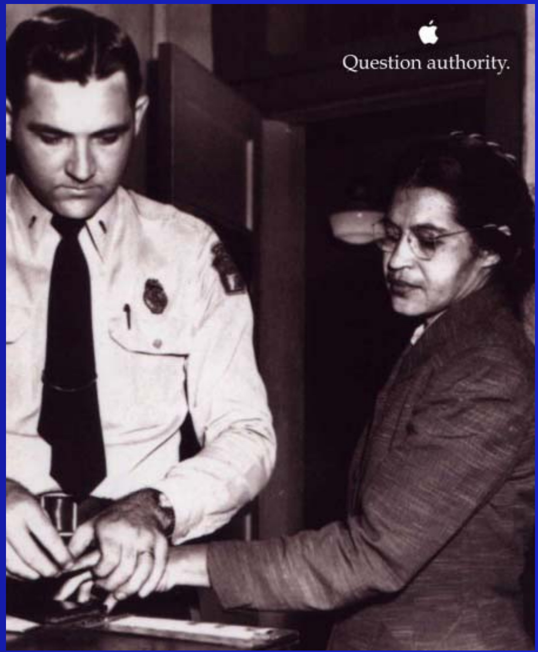
- What is being ACCESSED?
  - Real devices which map to physical devices (power converters, collimators, kickers, etc.)
  - High-level pseudo devices (Tune, Chromaticity, …)

- What TYPE of access?
  - get: the value of a property once
  - monitor: the property continuously
  - set: the value of a property

Authentication and Authorization



- Authentication (A1)
  – verifying a person's identity
  - mainly implemented on the GUI level
  - or authentication by location



•Authorization (A2) – verifying that a known person has the authority to perform a certain operation.

- implemented at CERN into the CMW communications layer and on the front-end computers

RBAC summary

- RBAC is a common development between CERN and FNAL
- RBAC is an integral part of CERN's control security effort (CNIC)
- RBAC has been deployed for the LHC start-up by AB-CO on all LHC equipment.

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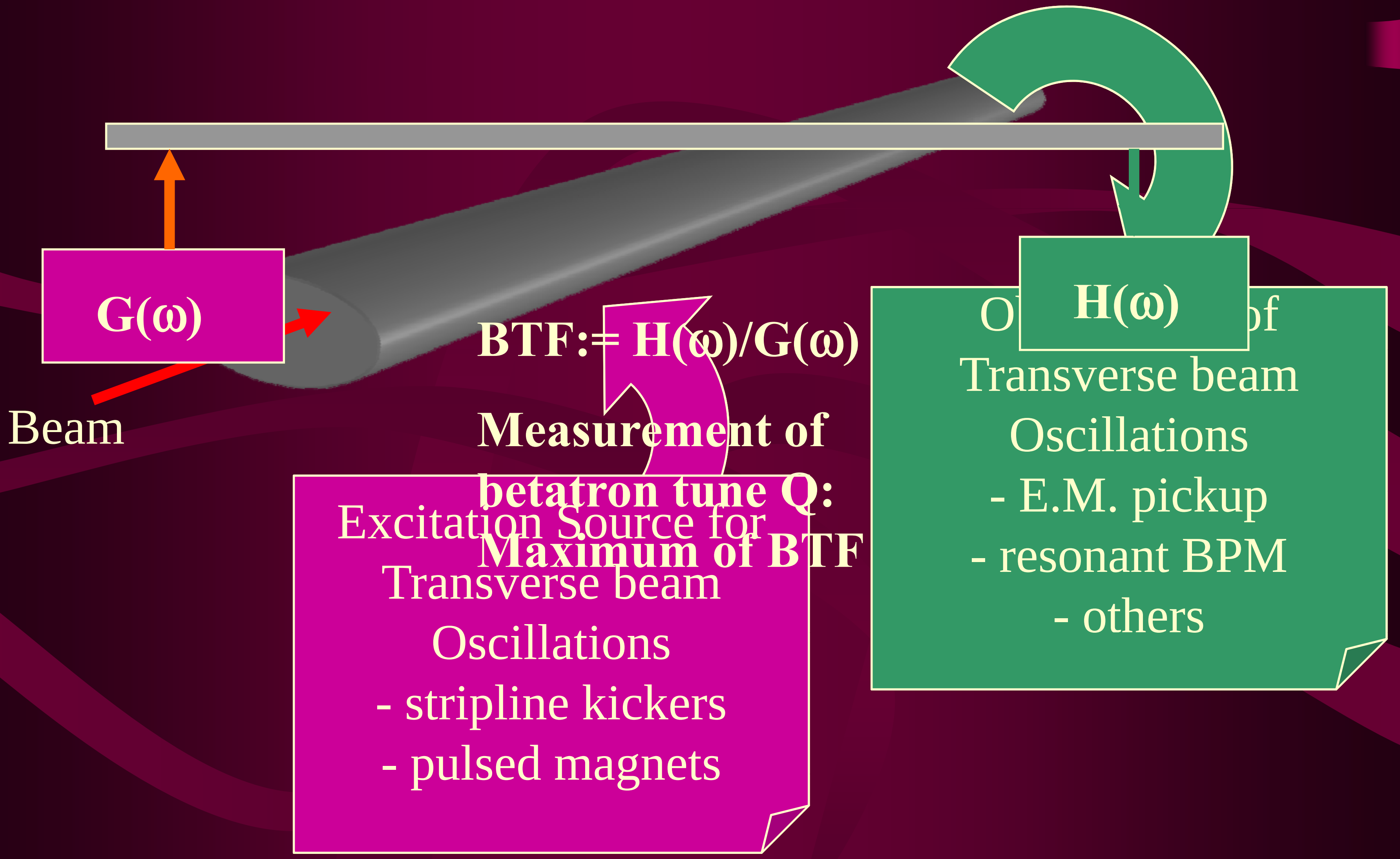
Tune and Chromaticity Diagnostics and RT control

- Well documented and almost identical Requirements in all new projects on tune, coupling and chromaticty diagnostics
- RT feedback requested at least during critical machine transitions (energy ramp, lowering of beta* in the insertions = squeeze)
- Additional requirement for hadron machines: Emittance preservation of beams → continuous beam excitations for measurements have to be well below the percent level of the beam sigma.

- Major focus of 5th workshop:

Time resolved Tune, Coupling and Chromaticity measurements at low excitation levels

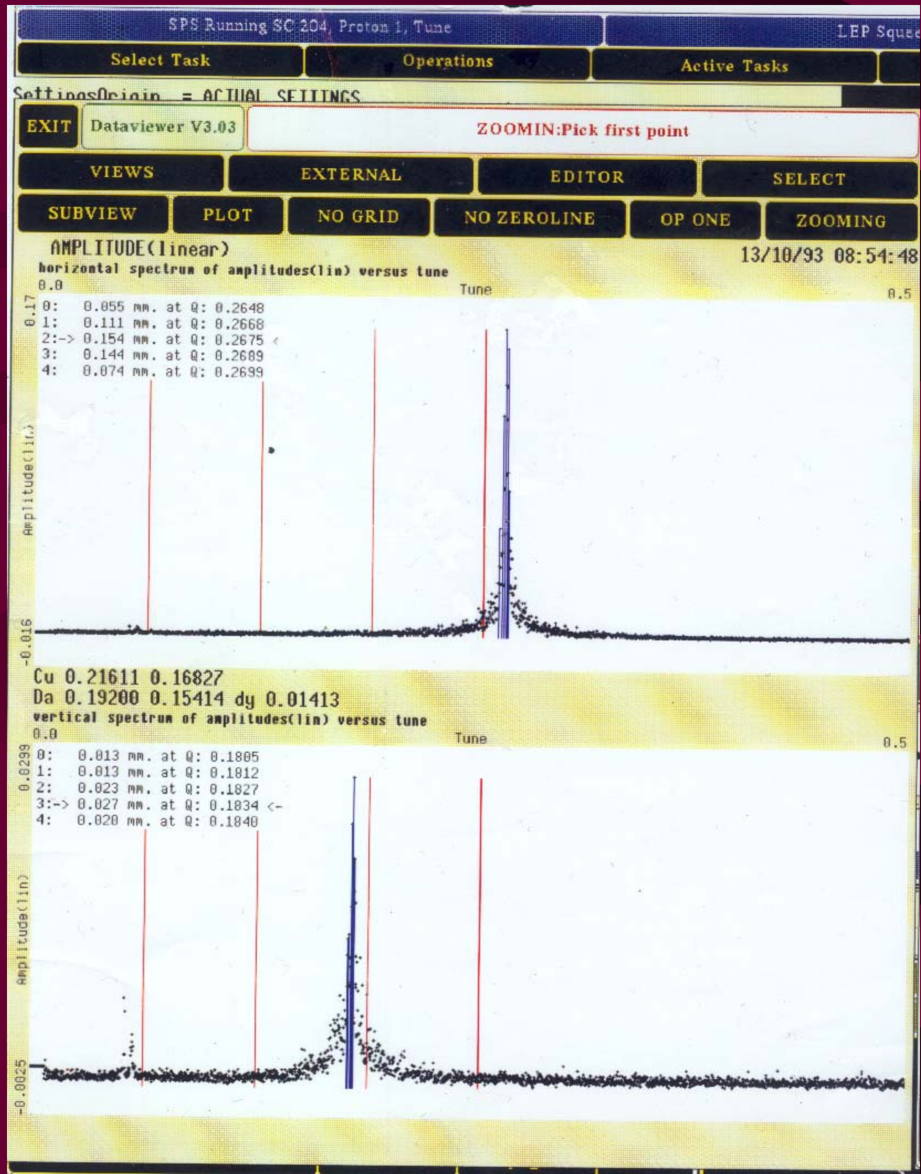
Principle of any Q-measurement



Simple example: FFT analysis

G(ω) == flat
(i.e. excite all frequencies)

Made with random noise kicks



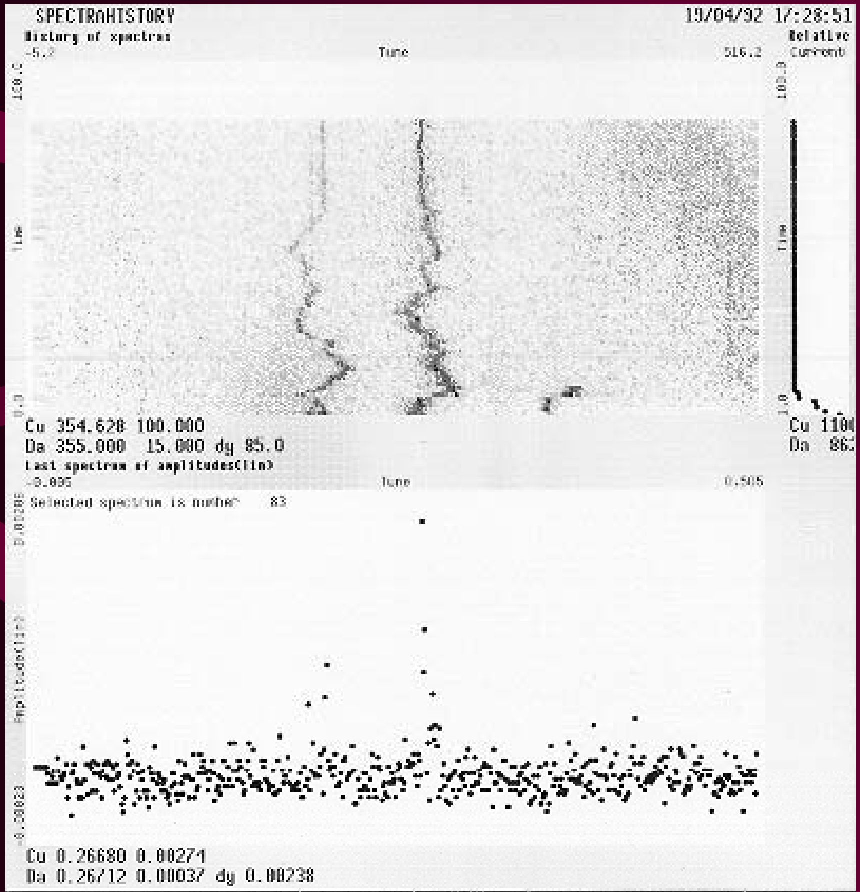
Measure beam position over many consecutives turns

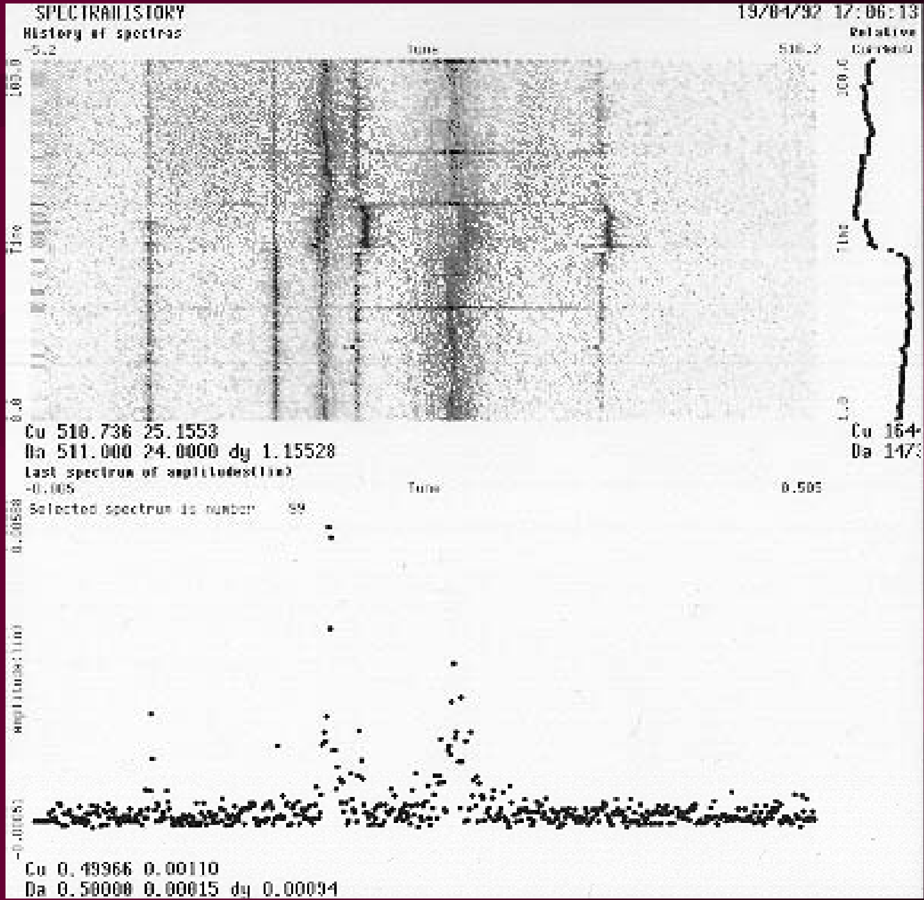
apply FFT → H(ω)

BTF = H(ω)

Time Resolved Measurements

- To follow betatron tunes during machine transitions we need time resolved measurements. Simplest example:
  - → repeated FFT spectra as before (spectrograms)





Principle of PLL tune measurements

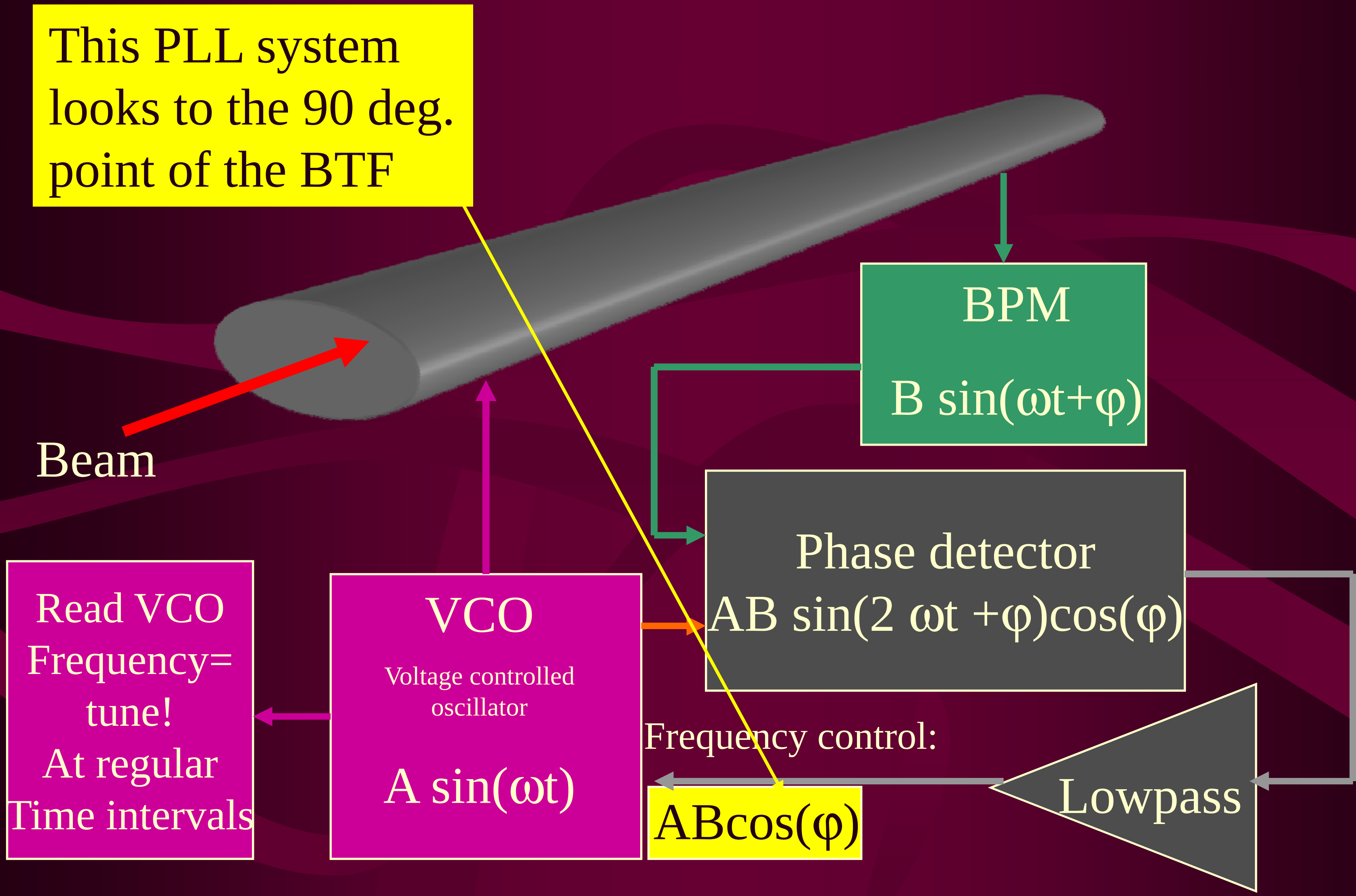
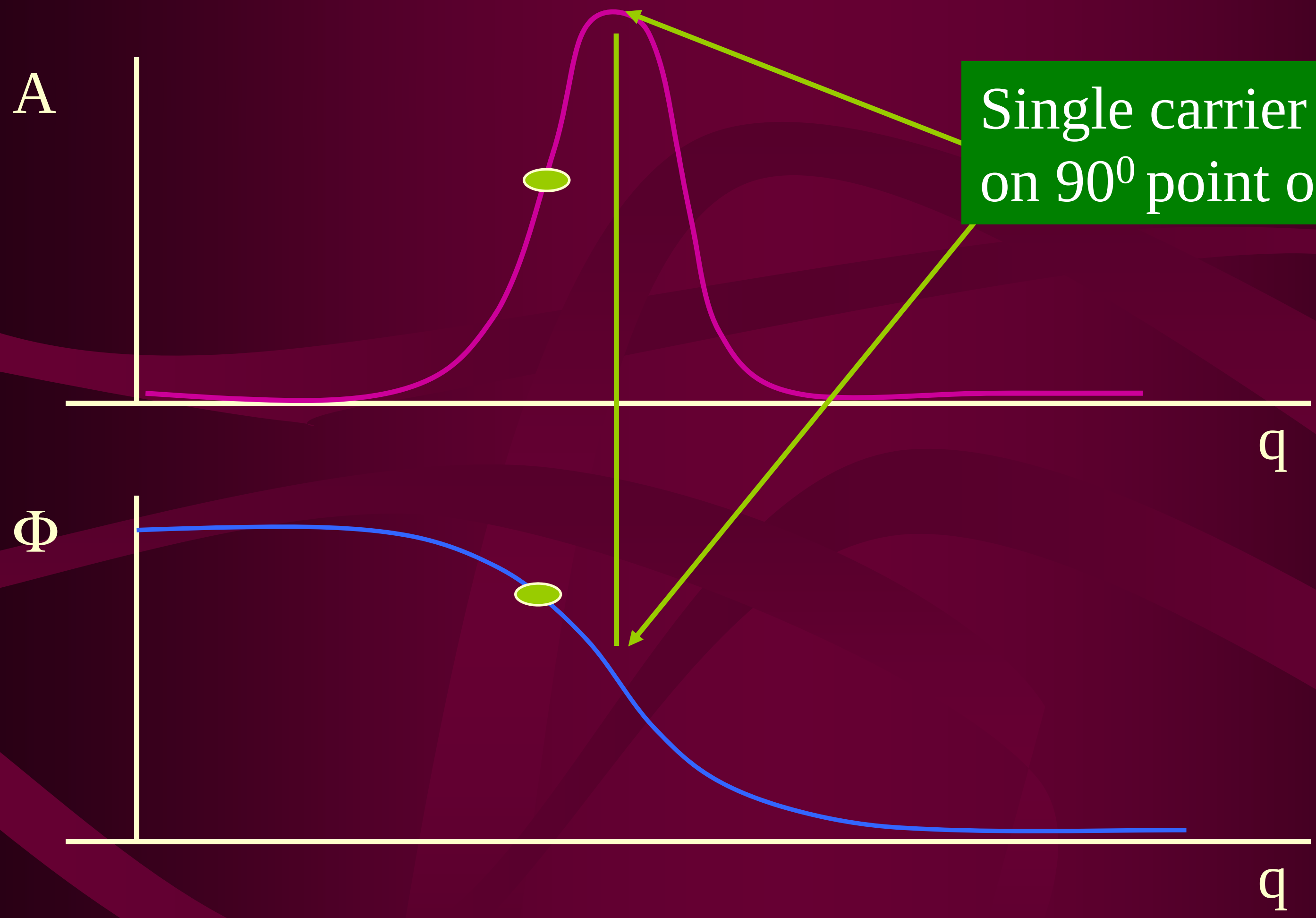
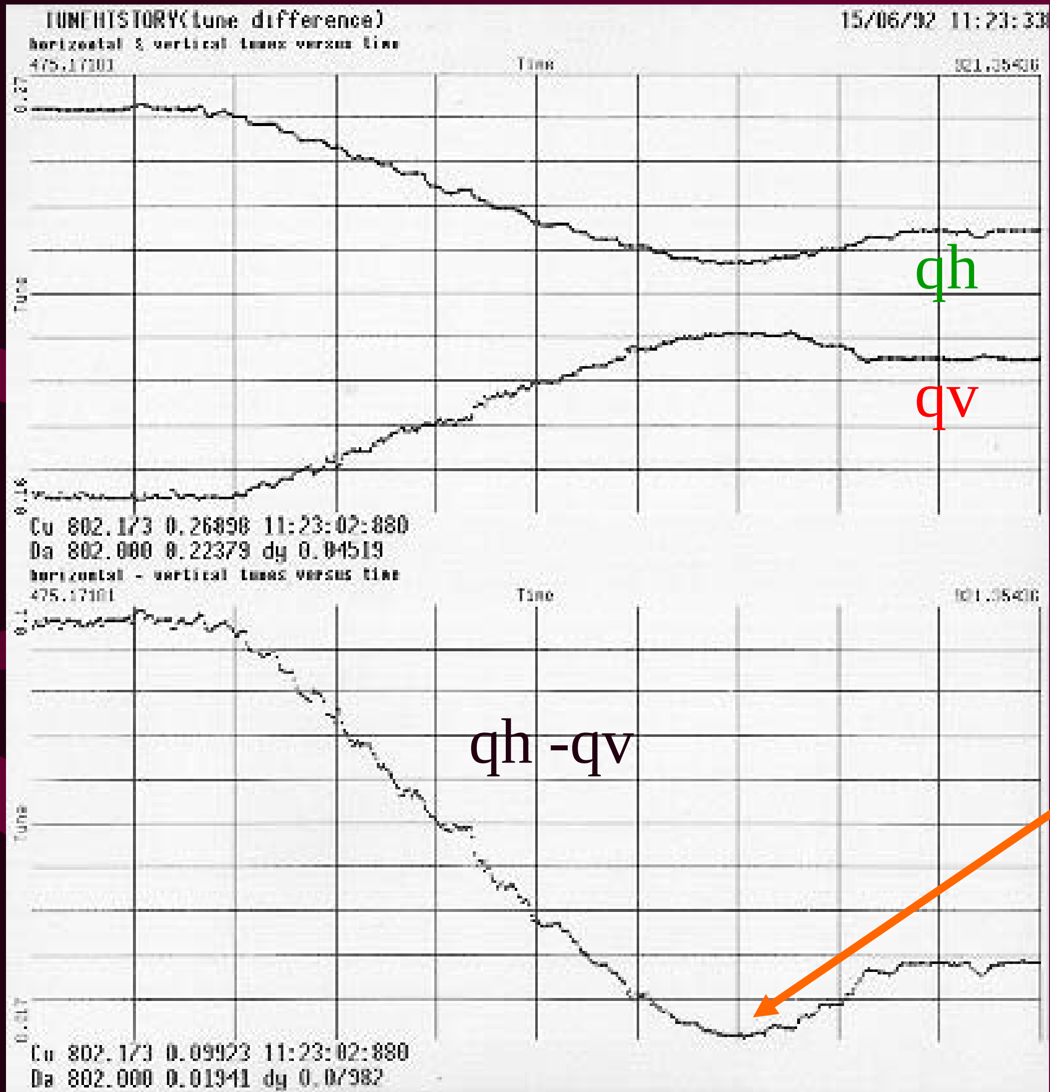


Illustration of PLL tune tracking



Single carrier PLL locks on 90^0 point of BTF;

Example of PLL tune measurement

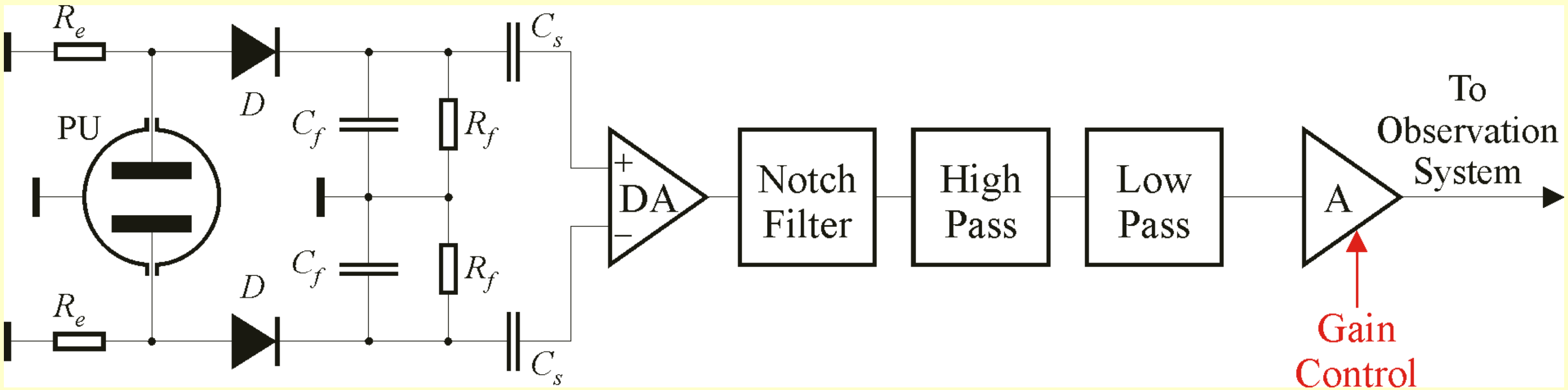


In this case continuous tune tracking was used whilst crossing the horizontal and vertical tunes with a power converter ramp.

Closest tune approach is a measure of coupling

Tune Measurement Systems

- Standard Tune Measurement (FFT) and PLL tune tracker will use a new BaseBand Tune (BBQ) system developed at CERN using Direct Diode Detection (3D)



3D Method Advantages / Disadvantages

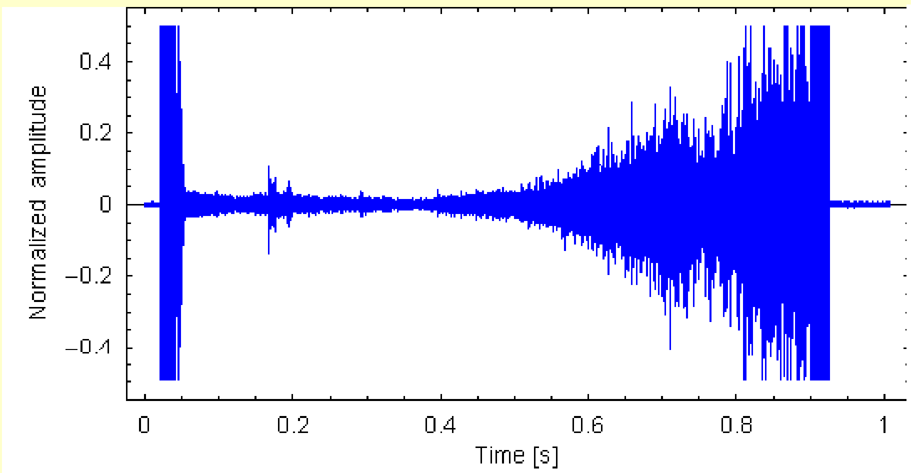
Advantages

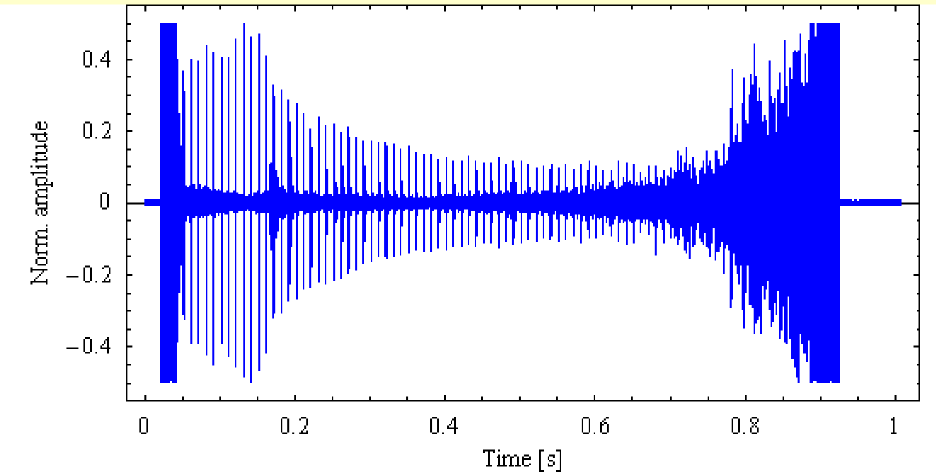
- Sensitivity (noise floor measured at RHIC in the 10 nm range!!)
- Virtually impossible to saturate
  → large Frev suppression already at the detectors + large dynamic range
- Simplicity and low cost
  → no resonant PU, no movable PU, no hybrid, no mixers, it can work with any PU
- Base band operation
  → excellent 24 bit audio ADCs available
- Signal conditioning / processing is easy
  → powerful components for low frequencies
- Independence from the machine filling pattern guaranteed
- Flattening out the beam dynamic range (small sensitivity to number of bunches)

Disadvantages

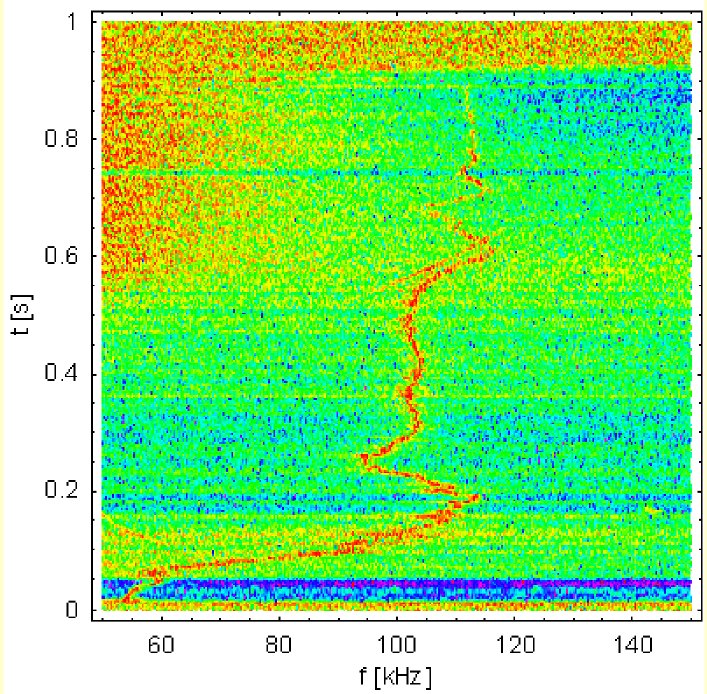
- Operation in the low frequency range
  → More susceptible to EMC
- It is sensitive to the “bunch majority”
  → gating needed to measure individual bunches

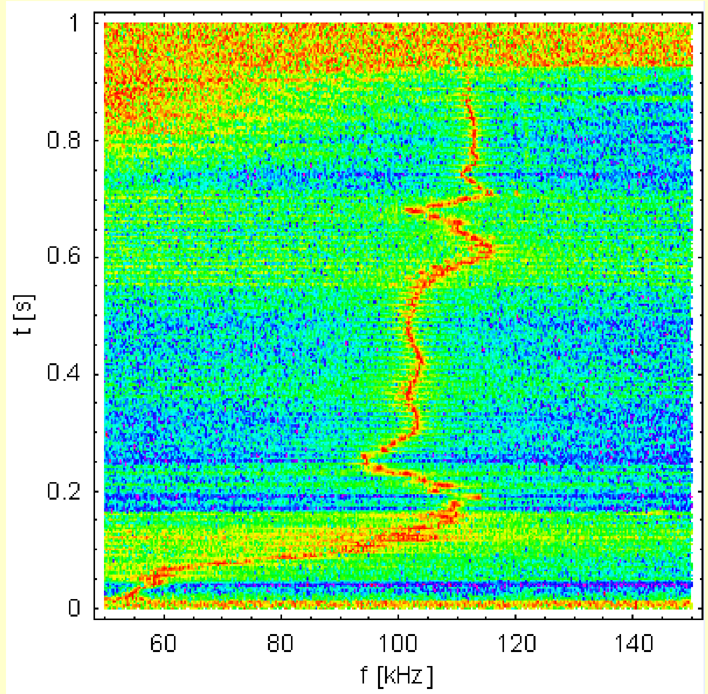
Results from the PS (AD cycle)





No explicit beam excitation



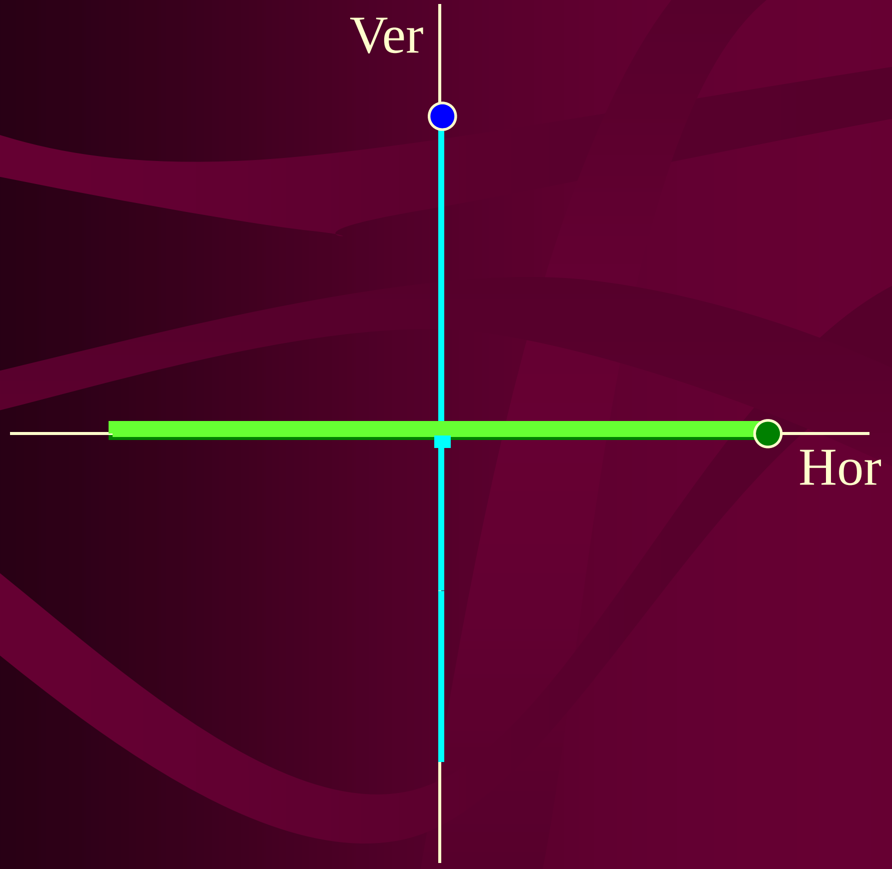


Q Kicker set to minimum

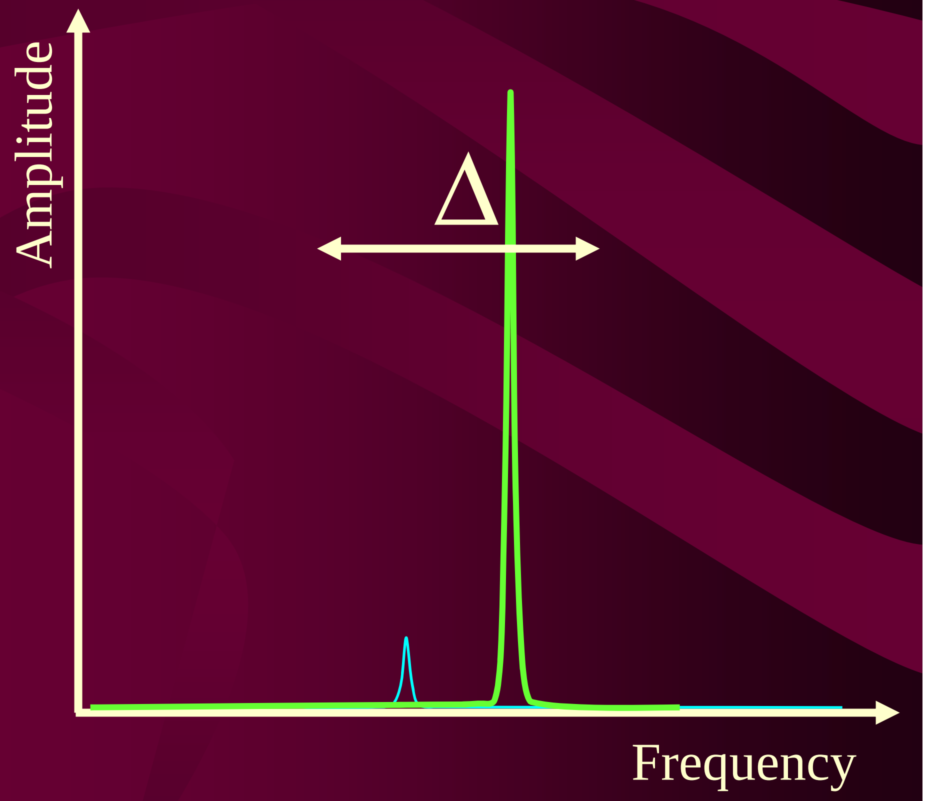
Measurement of Coupling using a PLL Tune Tracker

Start with decoupled machine ➡ Only horizontal tune shows up in horizontal FFT
Gradually increase coupling ➡ Vertical mode shows up & frequencies shift

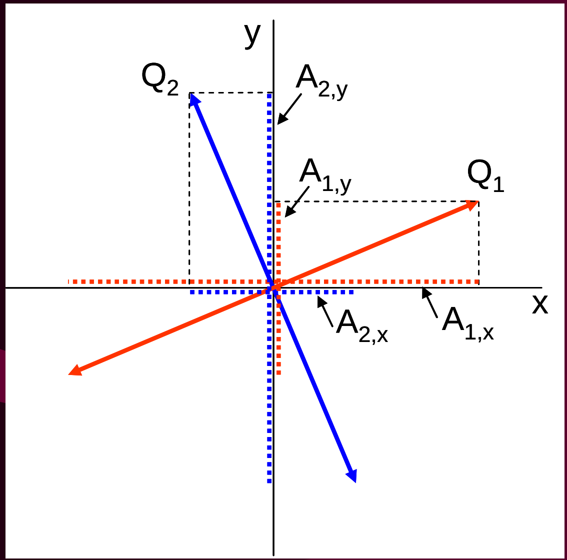
Fully coupled machine: $\Delta = |C^{-}|$

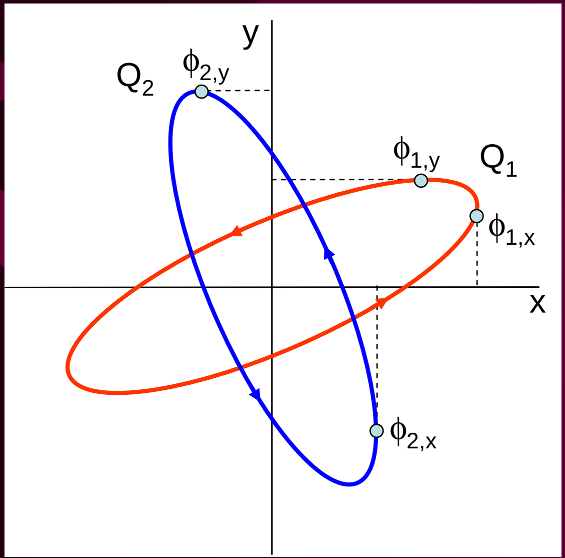


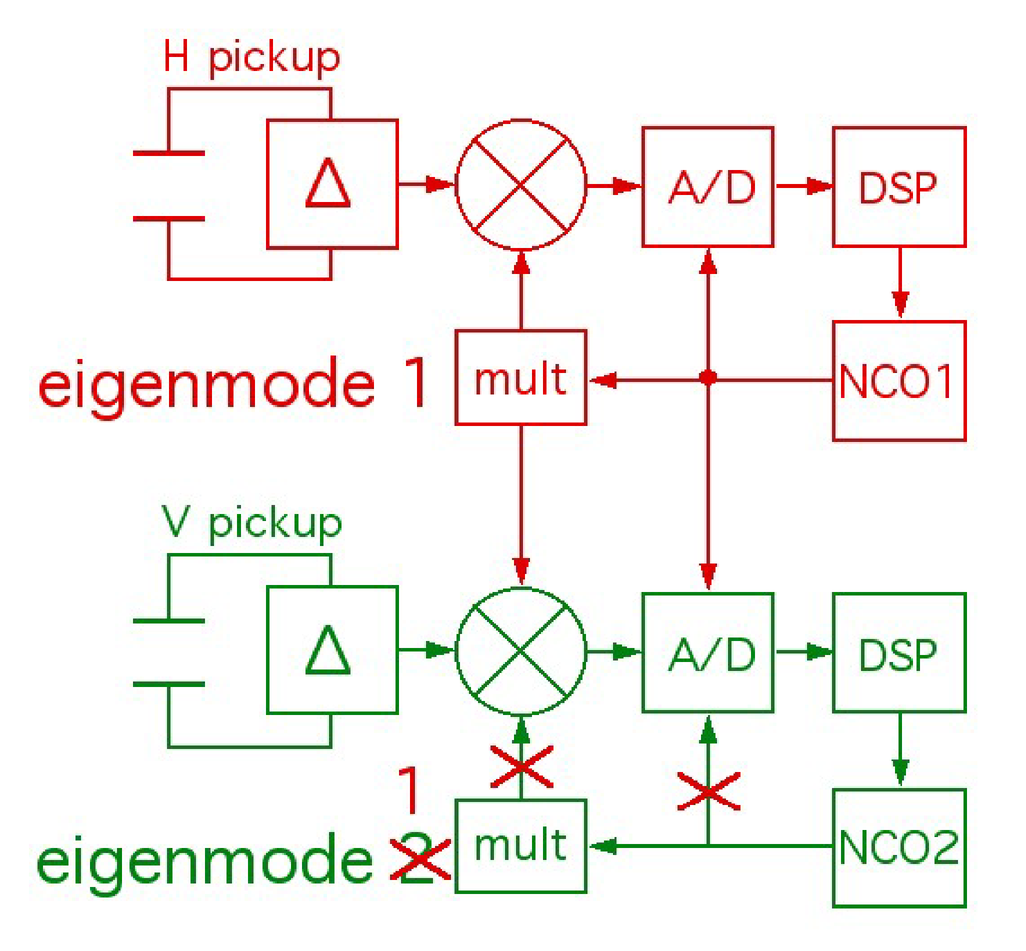
FFT of Horizontal Acquisition Plane



Measurement of Coupling using a PLL Tune Tracker

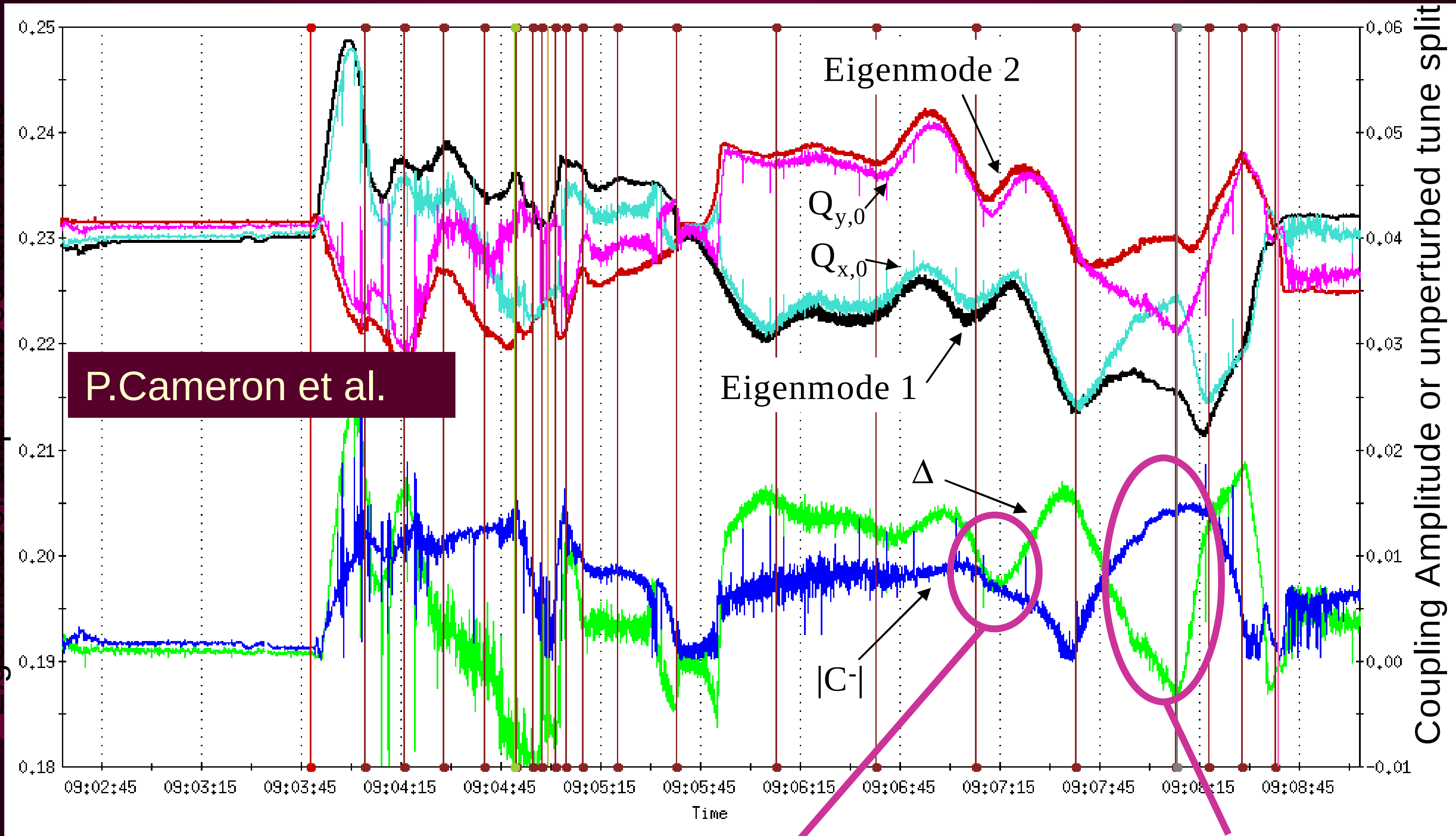






Tracking the vertical mode in the horizontal plane & vice-versa allows the coupling parameters to be calculated

Measurement of Coupling using a PLL Tune Tracker (RHIC Example)

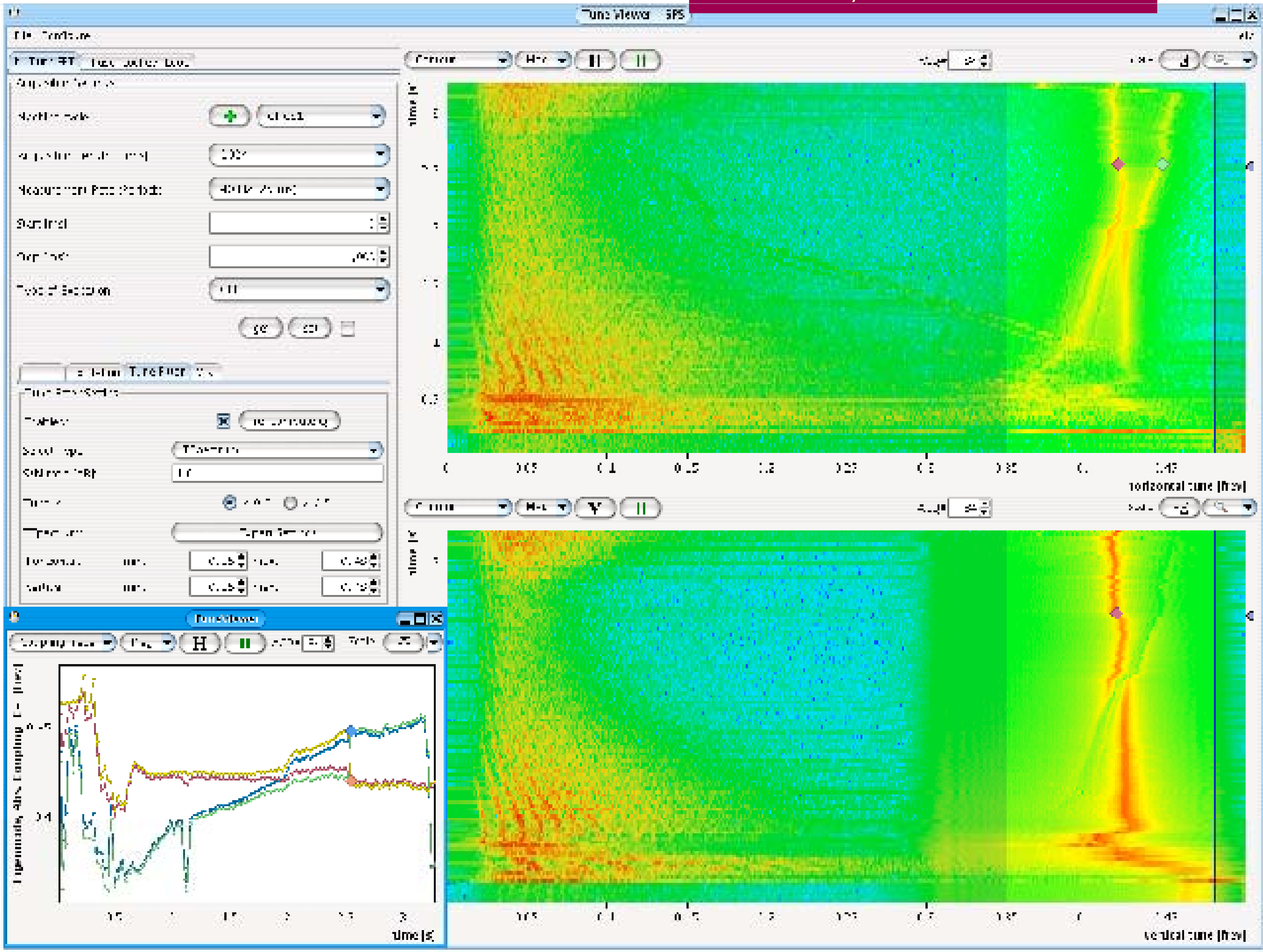


Fully coupled

Tunes entirely defined by coupling

Example: BBQ based Betatron-Coupling Measurement Real-Beam Data

M.Gasior, R.Jones et al.

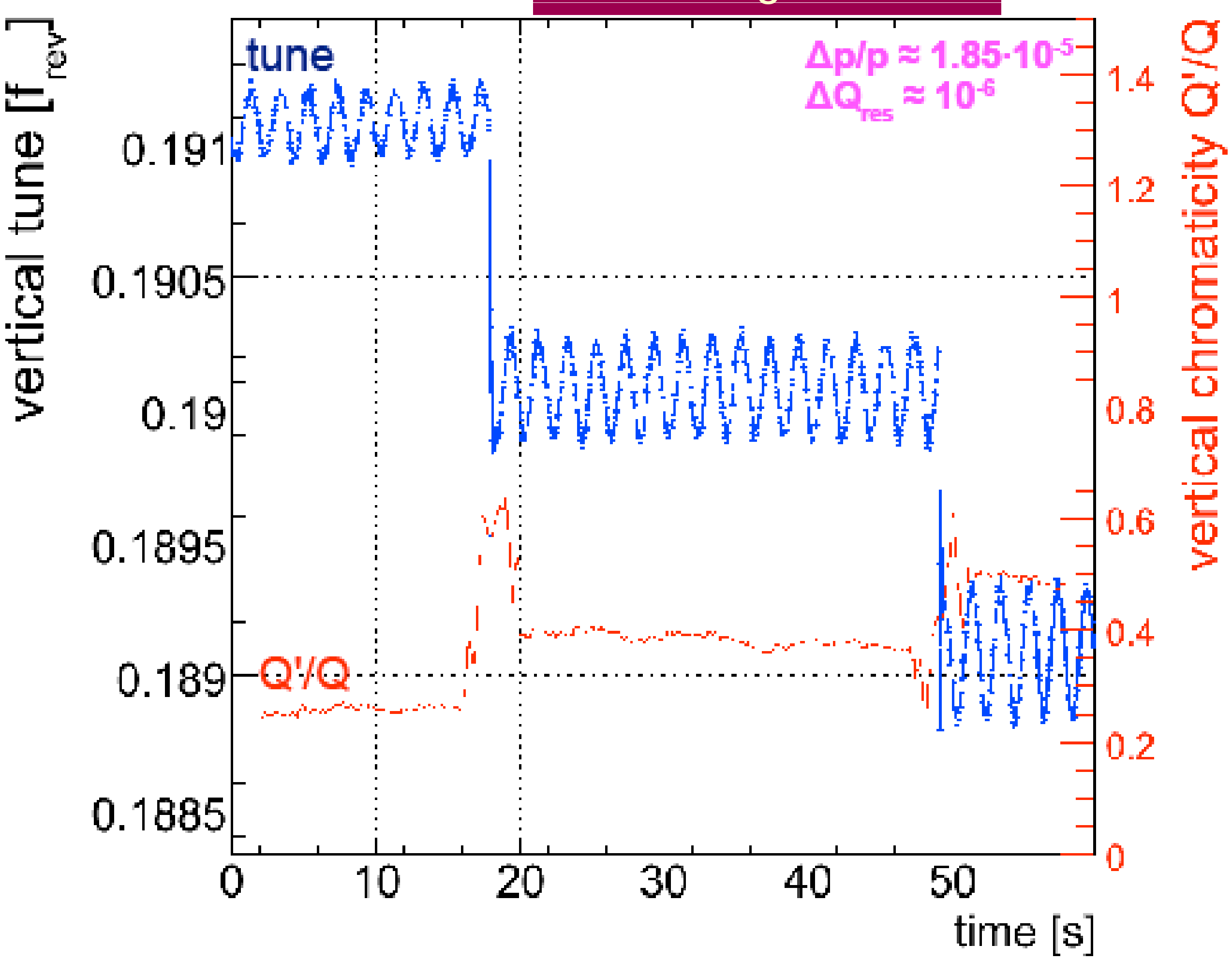


Chromaticity - What observable to choose?

Tune Difference for different beam momenta	⟺	used at HERA, LEP, RHIC in combination with PLL tune tracking

Example: LHC Chromaticity Tracker at the SPS Real-Beam Data

R.Steinhagen et al.

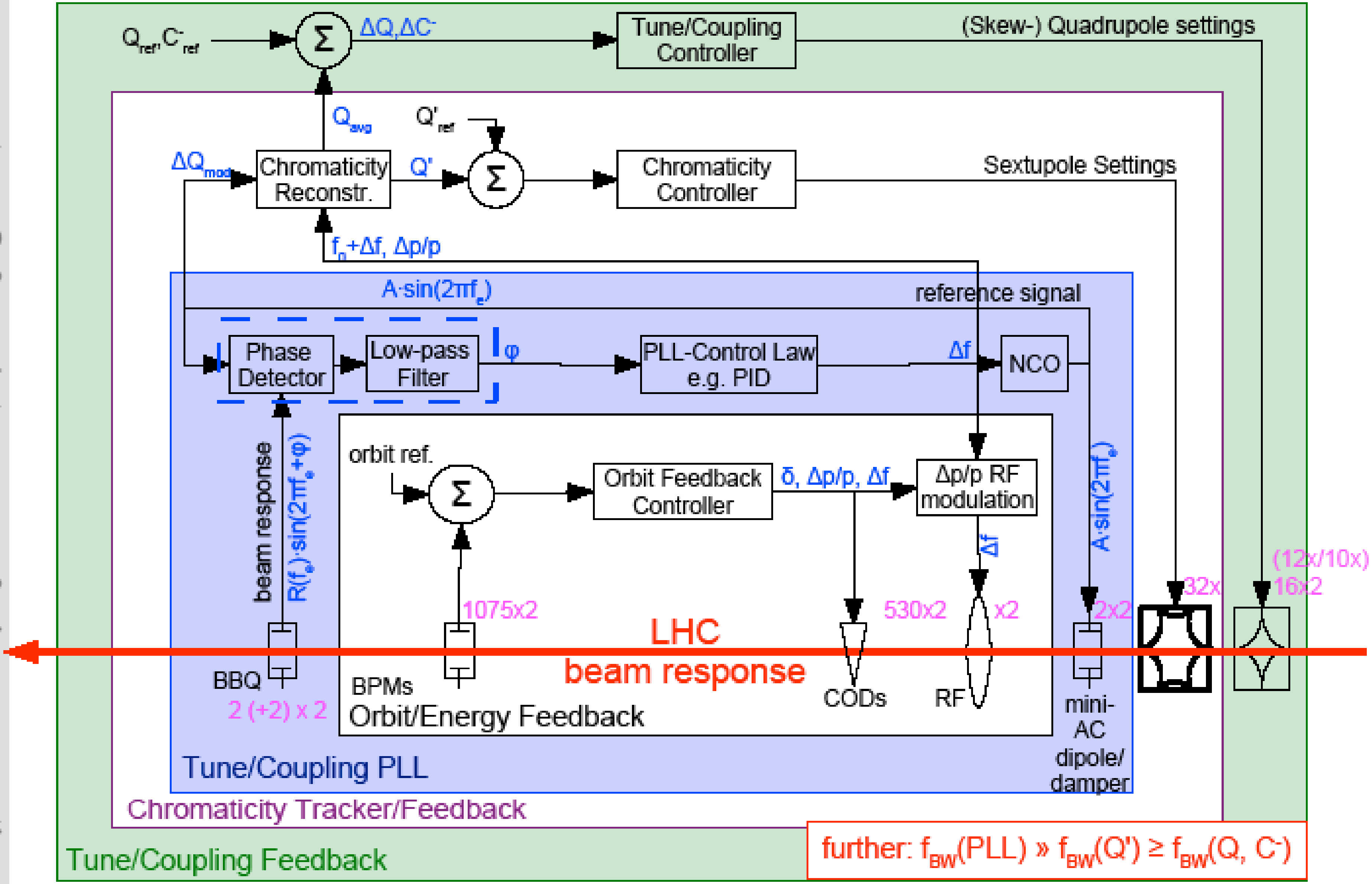


- real-time Q' detection algorithm (agrees with SPS cross-calibration):
  - Q' resolution better than 1 unit (nominal performance)

details:
→ Andrea's presentation

...Conquer: Cascading between individual Feedbacks

R.Steinhagen et al.



LHC FBs: 2158 input devices, 1136 output devices → total: ~3300 devices!