Grahame Blair & Thibaut Lefevre

Summary of the Instrumentation working group

CERN, 14-17 October 2008


Baggage

CLIC 3TeV – Numbers of devices

Instrument	How many?
Intensity	356
Position	**45008**
Beam Size / Emittance/Energy spread	**784**
Energy	205
Energy Spread	205
Bunch Length	302
Beam Loss	0
Beam Halo	0
Beam Phase	96

Drive Beam

46956 devices

Instrument	*How many?*
Intensity	205
Position	**7278**
Beam Size / Emittance/Energy spread	203
Energy	73
Energy Spread	20
Bunch Length	10
Beam Loss	1
Beam Halo	0
Beam Phase	52
Beam Polarization	8
Luminosity	6
Wakefield monitor	**142812**

Main Beam

150668 devices

Instrumentation requirements

<u>Feasibility issues to be studied for the CDR</u>

- Need to study the **Machine Protection System** for both the Drive and Main beams and to develop a Beam loss monitoring system along the CLIC linac (both beams)

- **Very tight requirements** for measuring micrometer **beam size**, 40-75microns short **bunch length** and **beam position** with a 50nm resolution, (achievable in principle)

- **Reliability and availability** of roughly 5000 high resolution (50nm) BPMs and 150000 wake field monitors with 5μm resolution
    - Impact on performance : Does the tuning procedure require all instruments to work simultaneously ?
    - Industrial series production : study the Impact on cost

- Beam **synchronization** implies a **0.1deg at 12GHz phase measurement** with an adequate feed-forward system and a **stability of the Drive Beam energy and intensity of 3.10^{-5}**

Intro: ILC Beam Instruments

- ~ 2000 Button/stripline BPM's (10-30 / 0.5 µm resolution)
- ~ 1800 Cavity BPM's (warm, 0.1-0.5 µm resolution)
- par
- s (0
- ition
- vitie
- ~ 1600 BLM's
- Other beam monitors, e.g. toroids, bunch arrival / beam phase monitors, wall current monitors, faraday cups, OTR & other screen monitors, sync light monitors, streak cameras, feedback systems, etc.
- Read-out & control electronics for all beam monitors

ILC
~ 6000 Devices

CLIC@500GeV
~32000 Devices

Introduction to LHC Beam Instrumentation

- Budget
  - Total budget of ~40 MCHF (~ 5000 devices)
    - Original estimate in 1995 was for 40 MCHF!
    - Many instruments were added & others dropped along the way
  - Main Systems account for 65%
    - BPM – 18.5 MCHF
    - BLM – 7 MCHF
  - Cabling accounts for 28%
    - 5 MCHF : fibre-optic cabling (single contract by TS/EL)
    - 3.7 MCHF : semi-rigid cryogenic coaxial cables (single contract)
    - 2.5 MCHF : cabling (contract by TS/EL)
  - Choice of fibre-optics was instrumental in
    - Reducing the overall cabling cost
    - Enabling most acquisition electronics to be located on the surface
      - No radiation concerns
      - Access possible

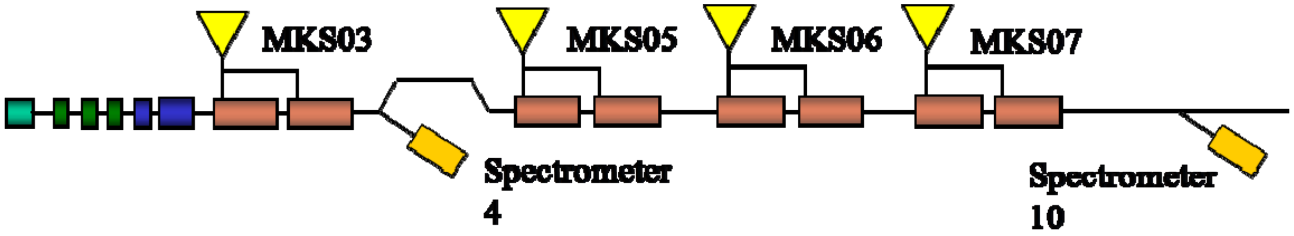
Preparation – Design Aspects

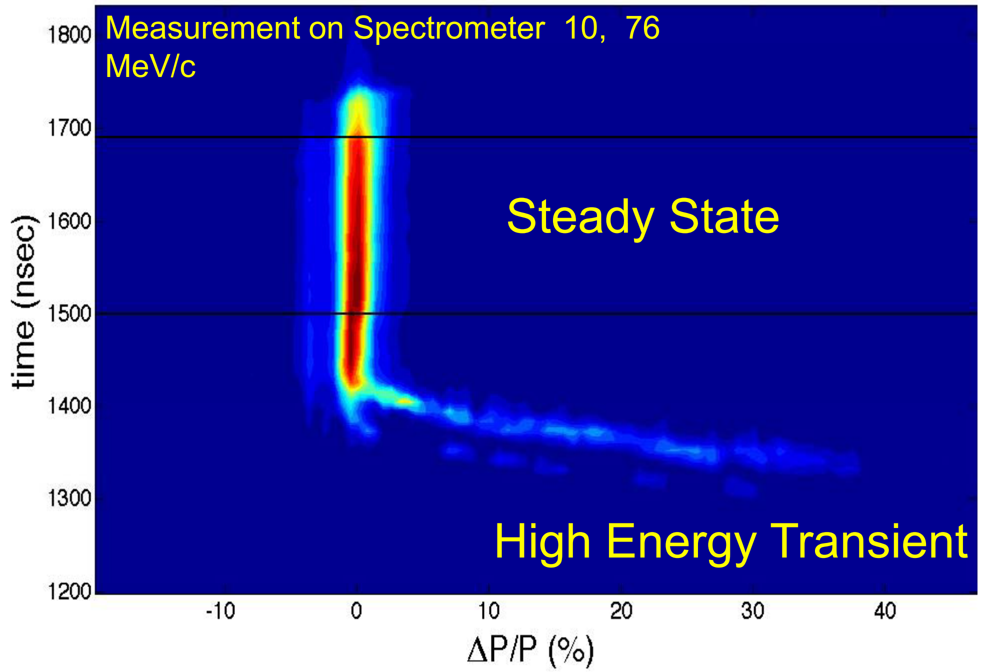
- For large scale distributed systems
  - Simplicity where possible
  - Robustness
  - Standardisation
  - Value for money
  - Final working environment

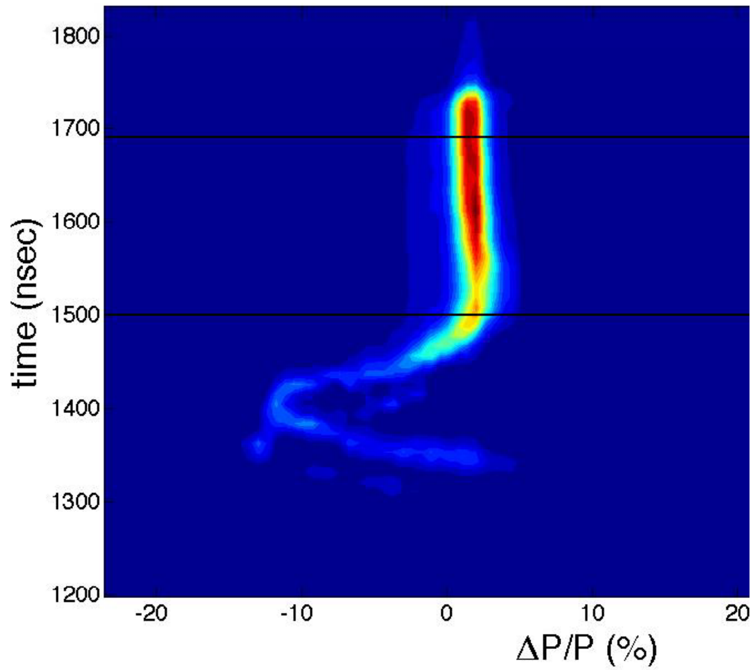
- The following complicate things
  - Integration
    - Equipment co-habiting with other systems
  - Radiation
  - Multiplicity - small changes can have
    - Large budgetary effects
    - A big influence on planning


Instrumentation @ CTF3

Beam loading compensation @ CTF3







Double target system as a new CDR generator for short bunch measurement

Location of CDR setup

- CDR setup in the CRM line after the vacuum pump and in front of the OTR screen

1st Test foreseen by the end of this year

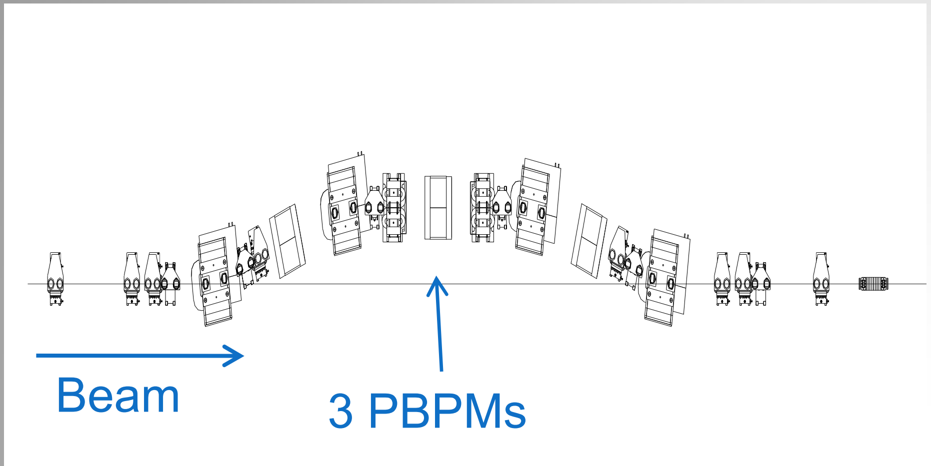
- CRM line (before & after installation of CDR):

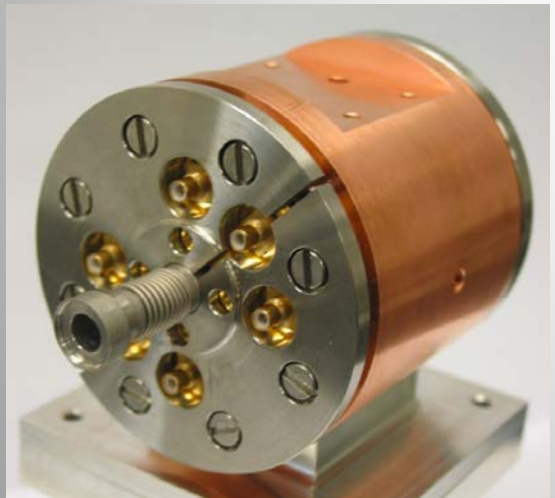
coherent
background
(wakes, SR)

beam
line

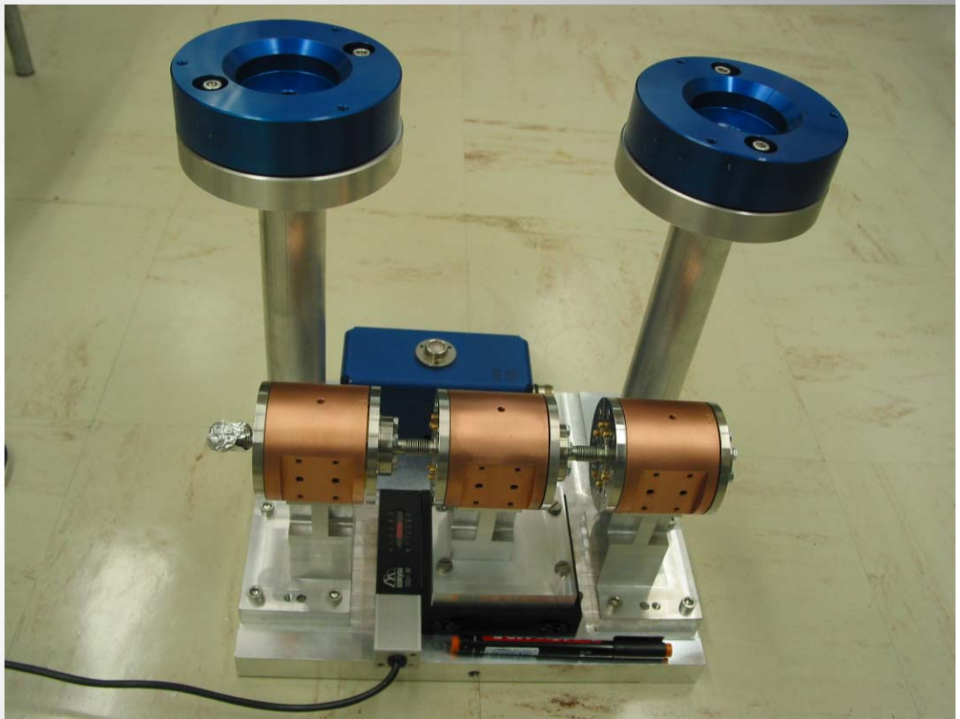
Precision Beam Position Monitor

Magnetic chicane CTF3 Linac

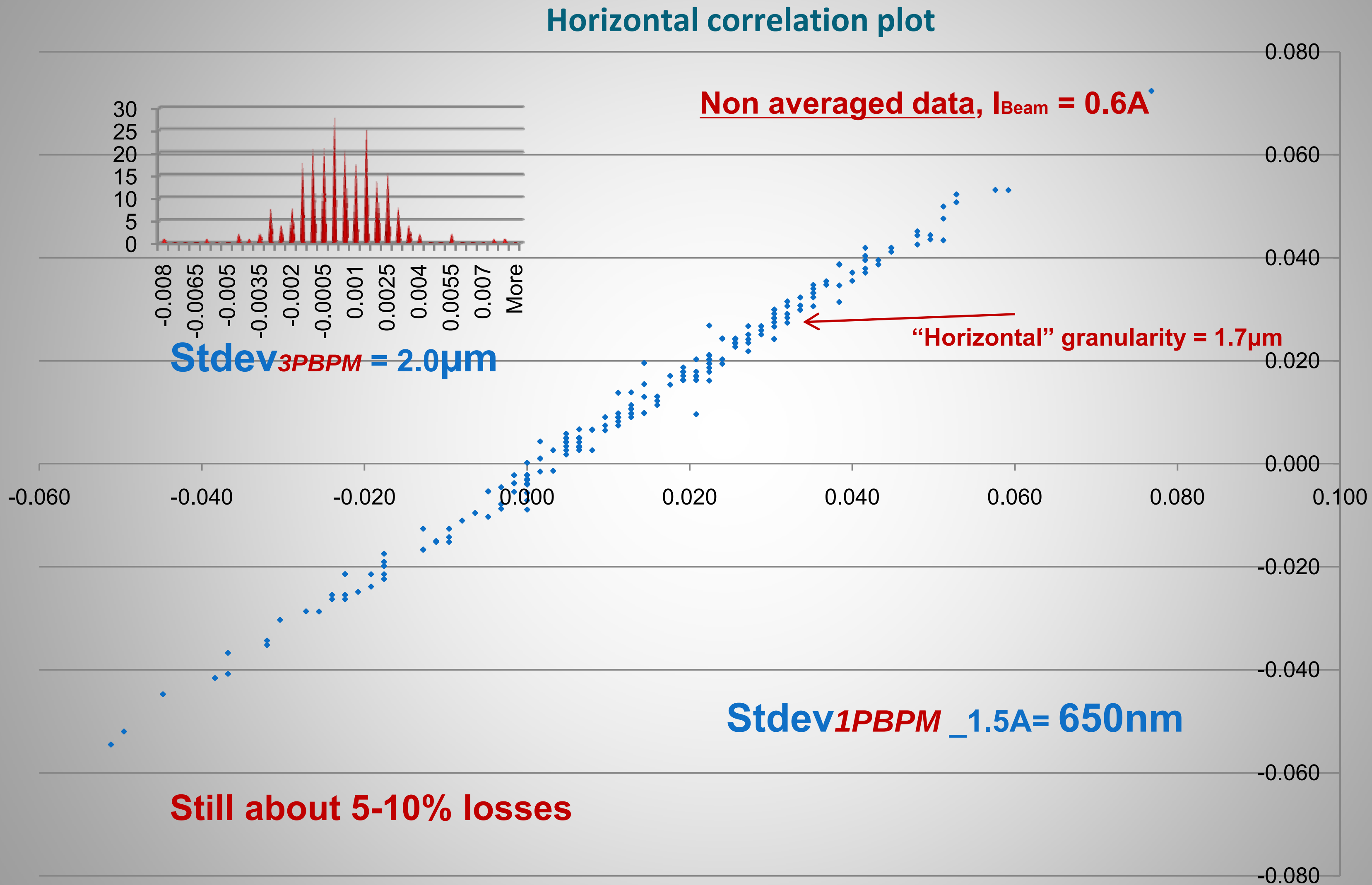




Installation of 3 PBPM in CTF3
November 2007



Beam tests September 2008



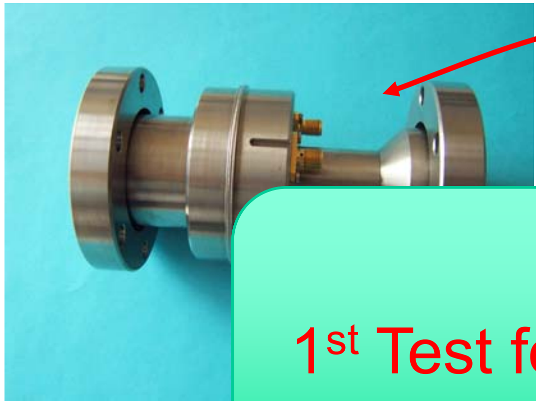
The first prototype of the BPS + rad-hard amplifier has been installed in the TBL (July 2008)

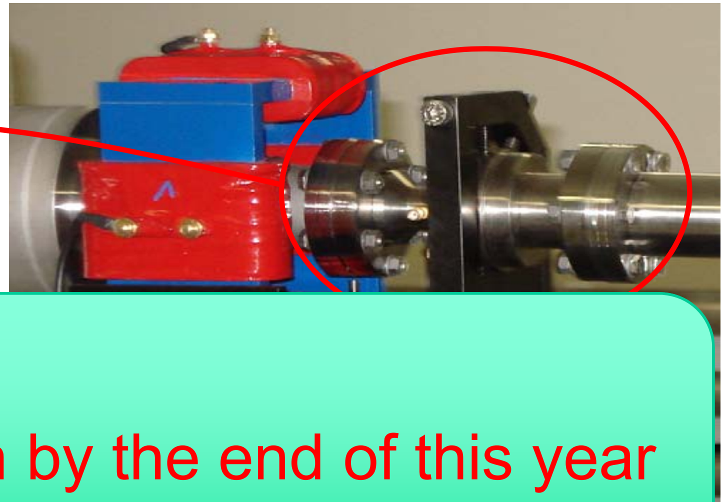
1st Test foreseen by the end of this year

BPM Parameters	
Analog bandwidth	10 kHz-100 MHz
Beam position range	±5 mm (H/V)
Beam aperture diameter	24 mm
Overall mechanical length	126 mm
Number of BPM's in TBL	16
Resolution at maximum current	$\leq 5\,\mu$m
Overall precision	$\leq 50\,\mu$m

Reentrant Cavity BPM at CALIFES

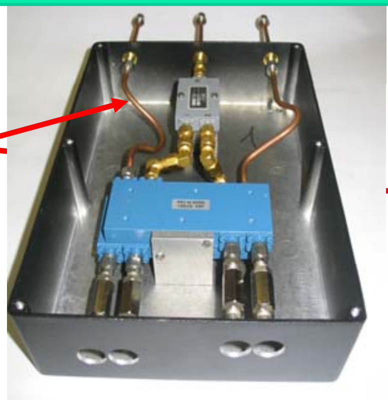
6 BPMs are installed on the CTF3 probe beam

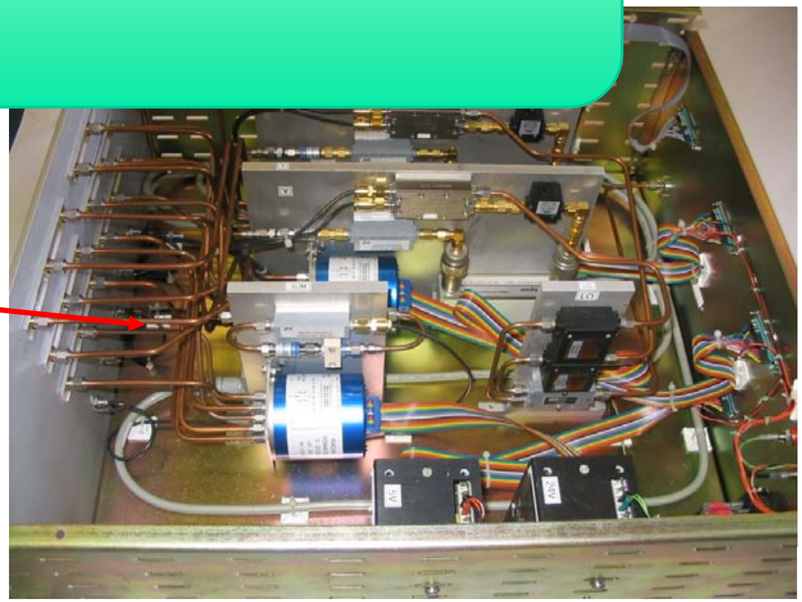




1[st] Test foreseen by the end of this year

Signal processing electronics of the re-entrant BPM





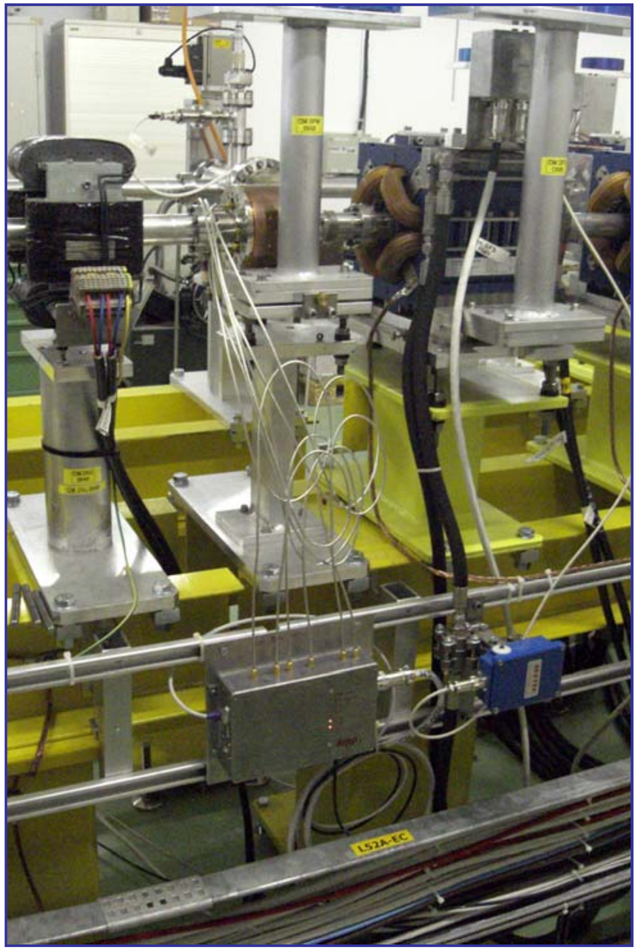
LAPP BPM Read-out electronics in CTF3

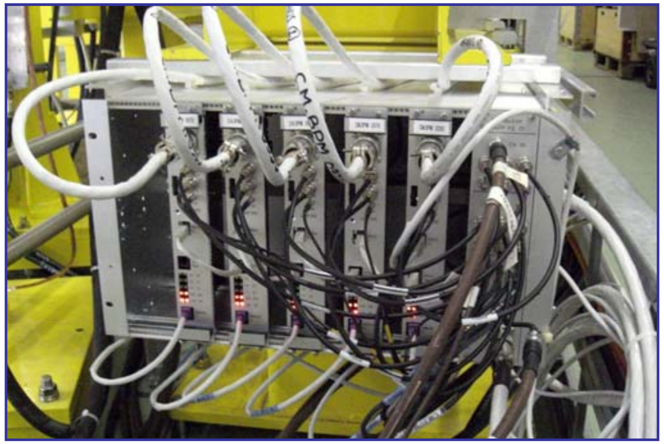
Jean Jacquemier, Yannis Karyotakis, Jean-Marc Nappa,
Pierre Poulier, Jean Tassan, Sébastien Vilalte.

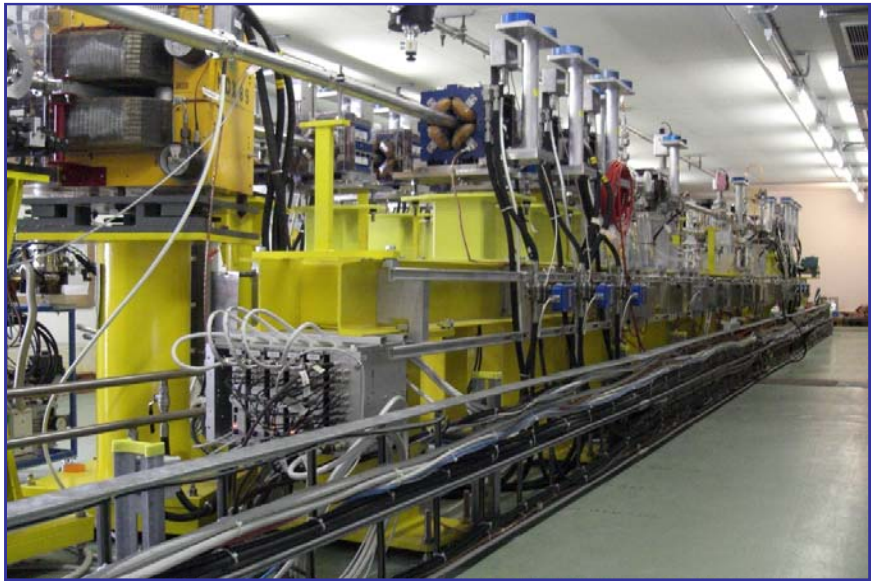
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE ET DE PHYSIQUE DES PARTICULES
haute savoie
Conseil Général

WS CLIC 14-17/10/2008

8 crates in TL2-CLEX







Future : acquisition for CLIC

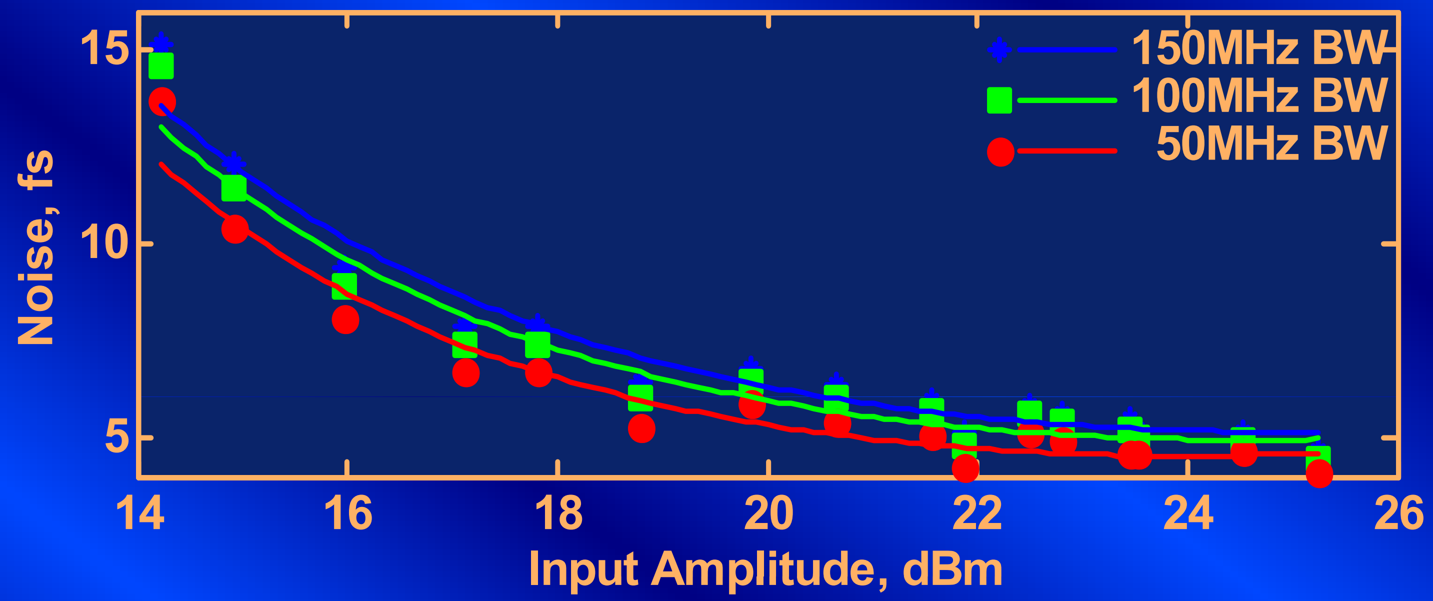
The logical evolution of this system is to be dedicated to a larger accelerator as CLIC:

Rare acces from surface, high number of channels, rad-hard, low-cost, low consumption…

Most important points to develop: ***elimination of cables***

- ***Power supplies:*** *autonomous (220V sector, DC-DC converters…).*
- ***Local calibration****.*
- ***Network :*** *flexible data collection, repetition crates…*
- ***Acquisition architecture:*** *faster ADC, direct bpm read-out, continuous sampling…*
- ***FPGA processing:*** *raw data, processed data…*
- ***Radiations.***

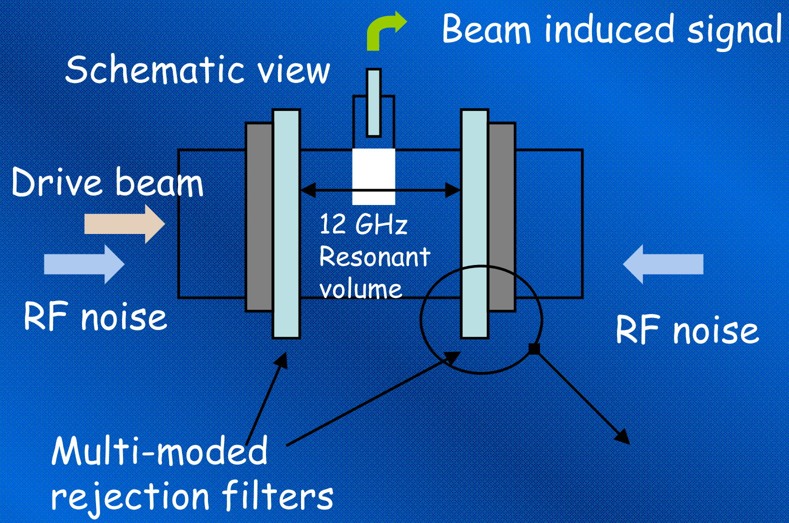
Femtosecond phase monitor @CTF3



CTF3 results – Noise

Future development: FP7 plans

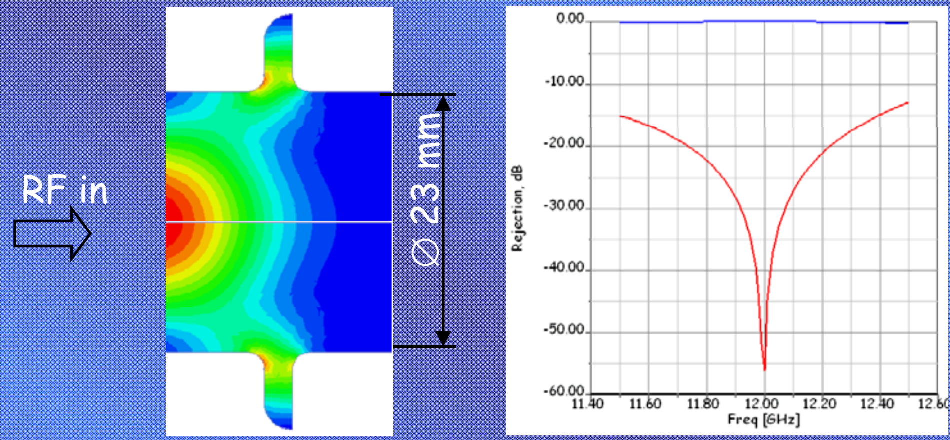
Monitor proposal by Igor Syratchev:



Special requirements

- Low impedance
- Immune to RF noise in beam pipe

Example: TM01 choke-type rejection filter

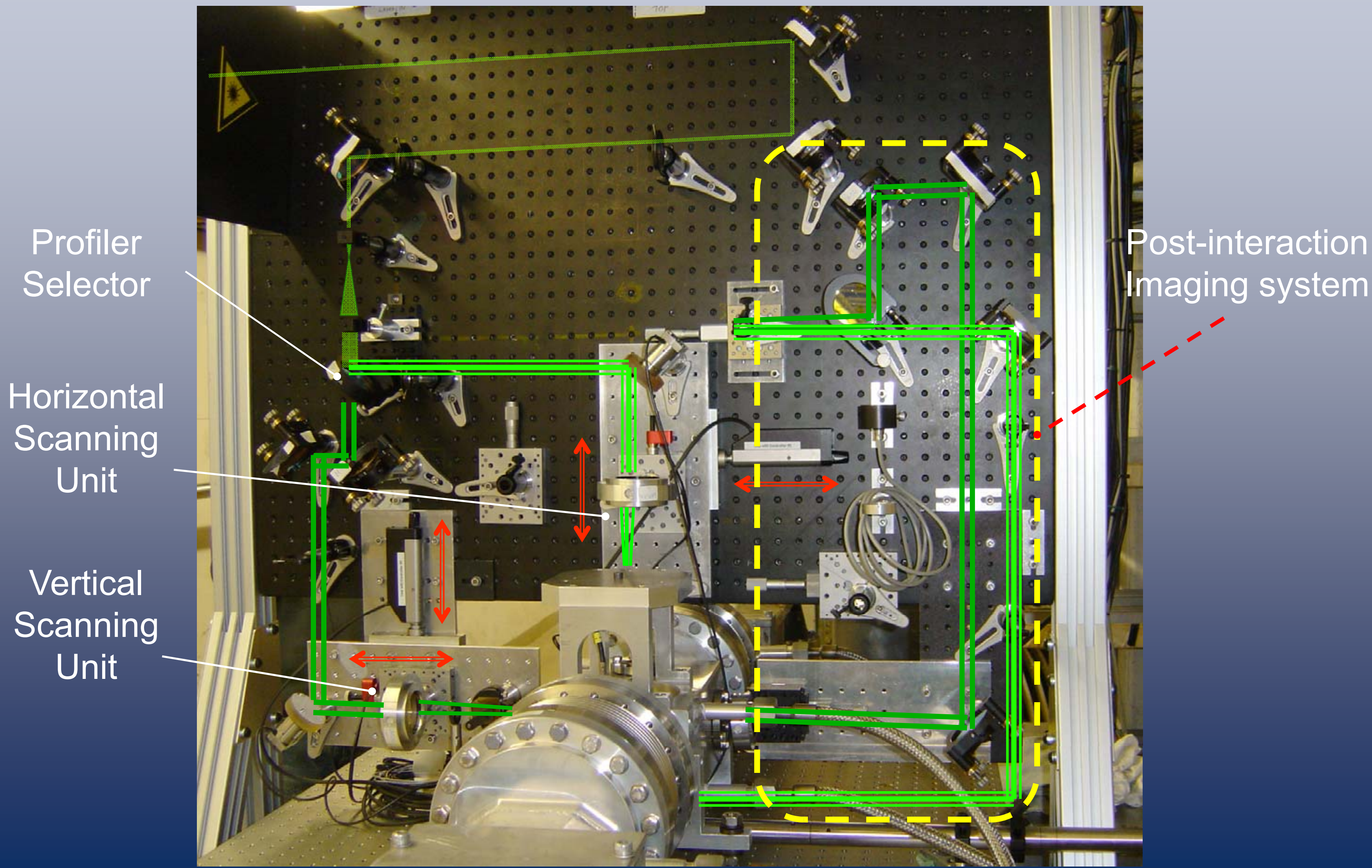


FP7

- Design and build monitors
- Convert electronics to 12 GHz and make improvements
- Test in CTF3

Progress on Laser wire Scanner

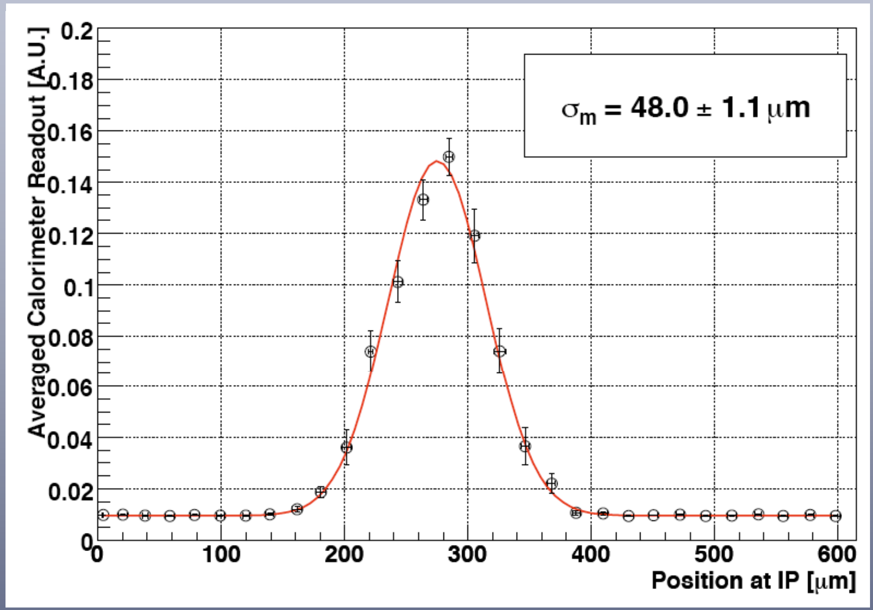
2D Laser-wire @ PETRA II



On the scan speed…

Laser rep. rate: 20 Hz (50 ms pulse spacing)
# of points: 30
# of pulses/point: 30

Total scan time ~ 45 s



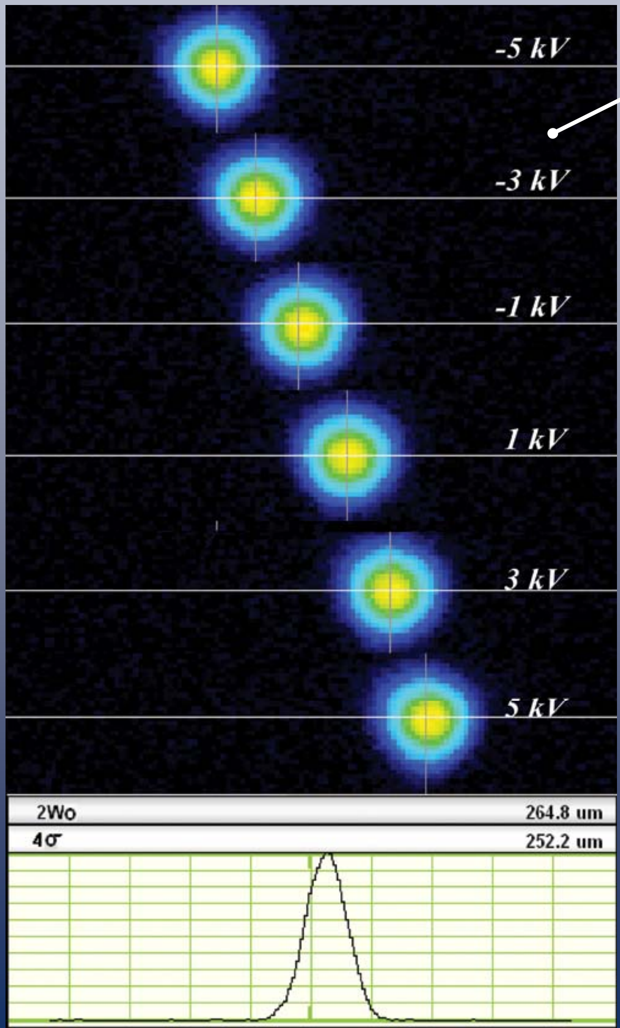
PETRA ring revolution time: 7.8 μs (130 kHz revolution frequency)

With this laser we have 1 impact every 6500 round trips

A new scanning technique using a mode-locked laser with 130 kHz Repetition rate is currently under study

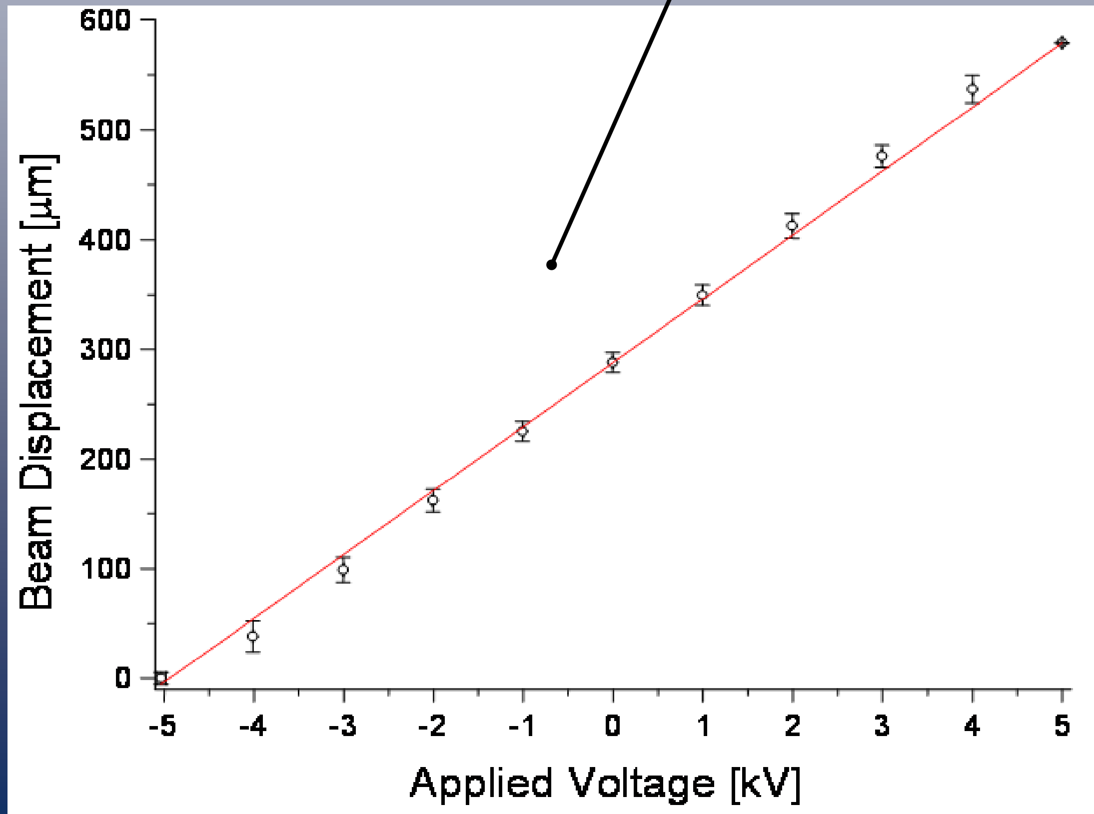
Experimental results: Deflection strength

Driving Voltage ramp time ~ 7 ms (e.g. 30 scan points) using electo-optic crystal



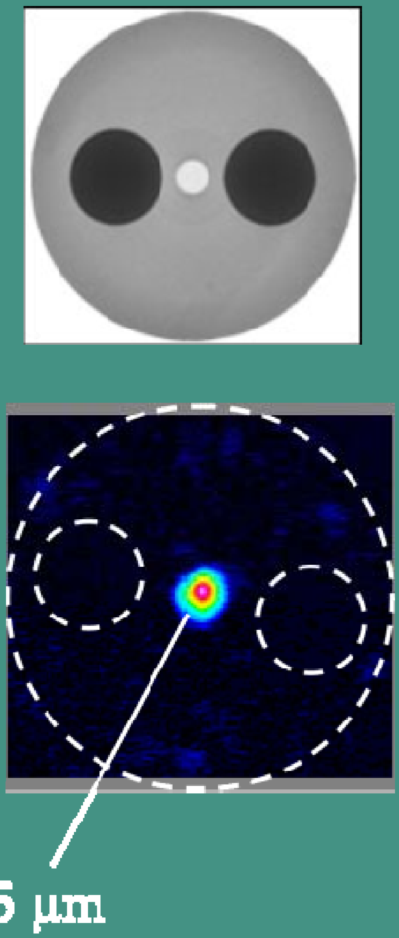
Beam profile perfectly circular and gaussian

Scan range linear with applied voltage

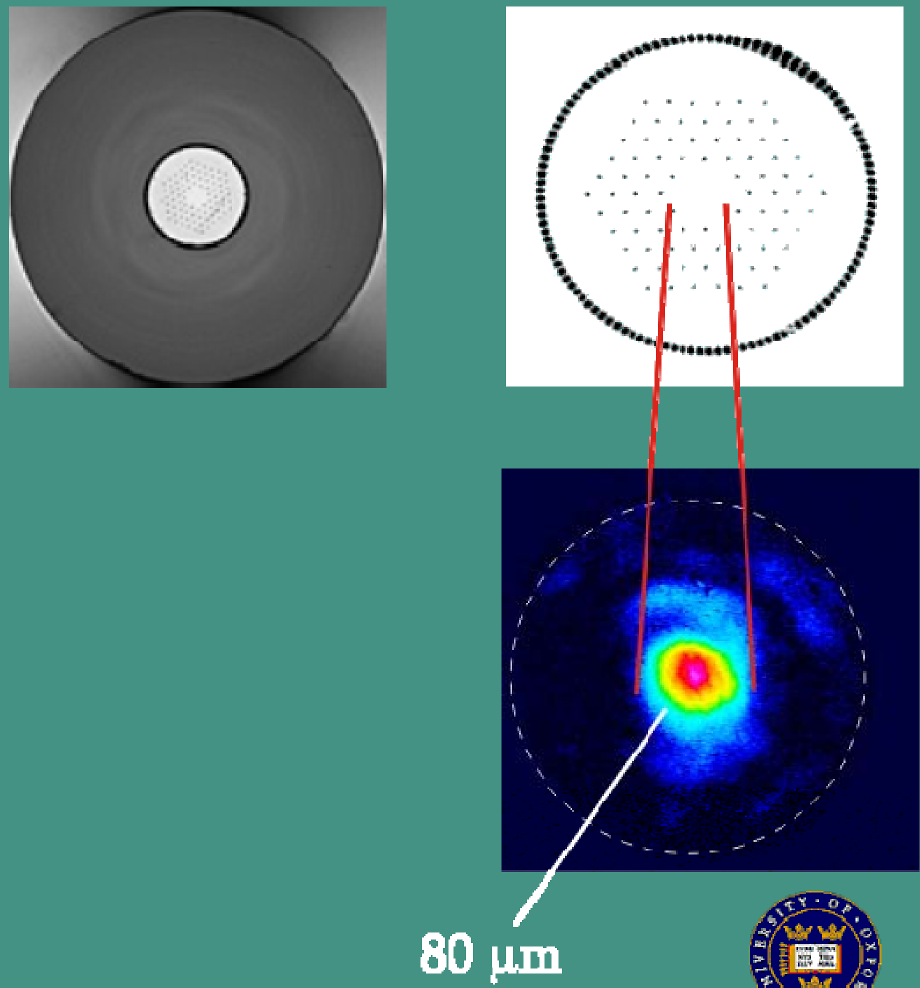


Investigation on optical fibre laser to produce high peak po

Double clad conventional fibre

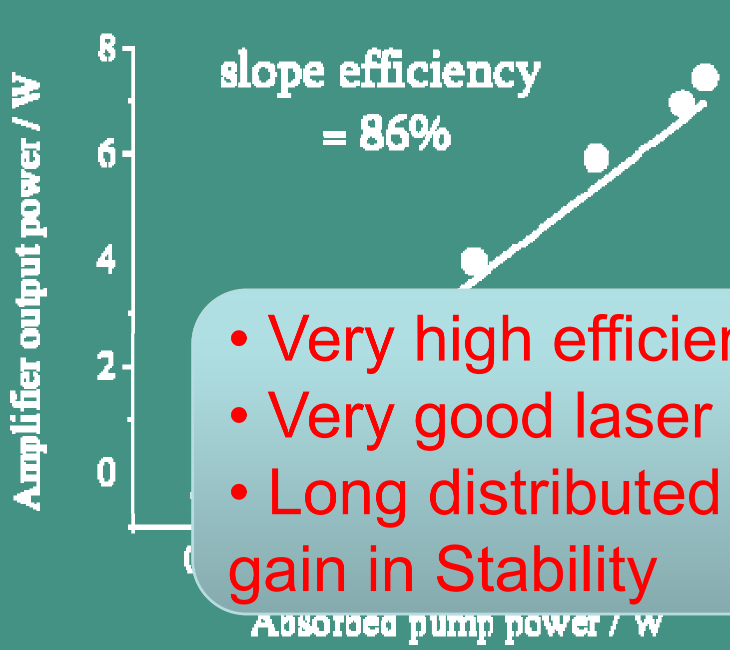


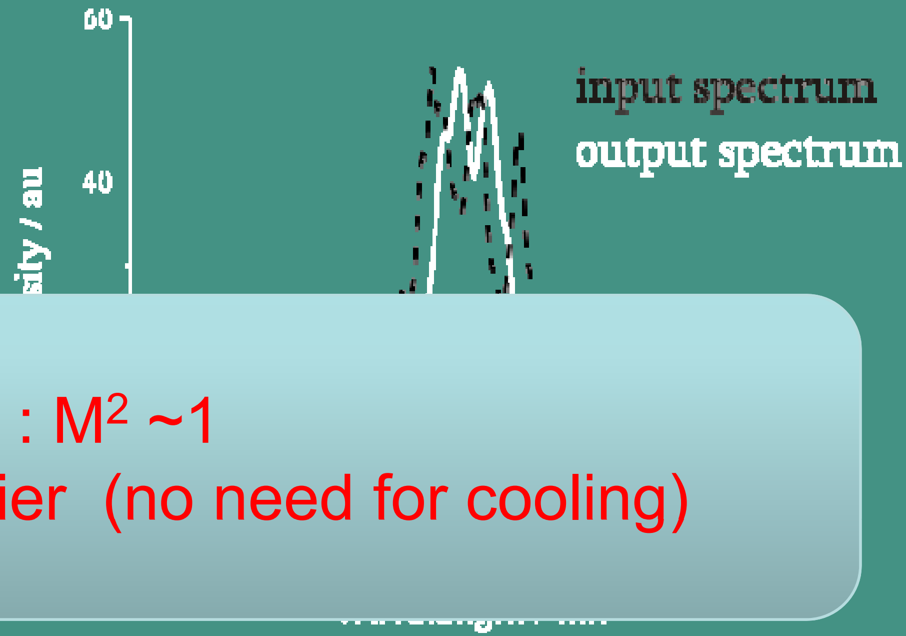
Photonic crystal fibre



John Adams Institute for Accelerator Science

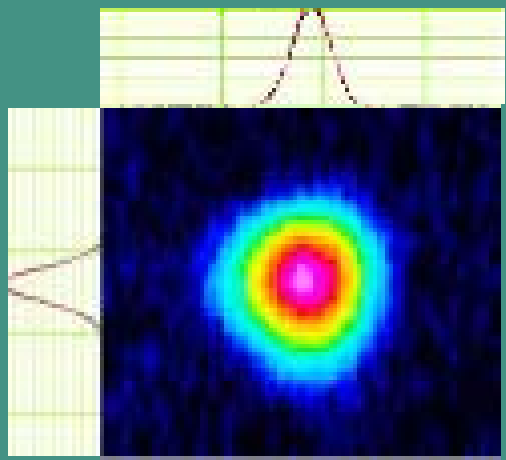
Results





- Very high efficiency
- Very good laser quality : M^2 ~1
- Long distributed amplifier (no need for cooling)

gain in Stability



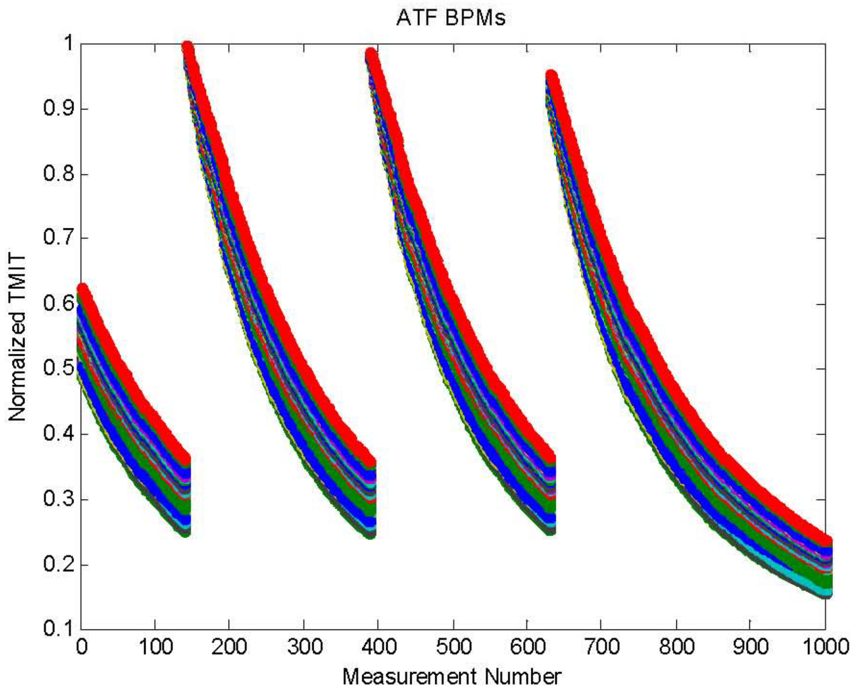
Damping rings activities

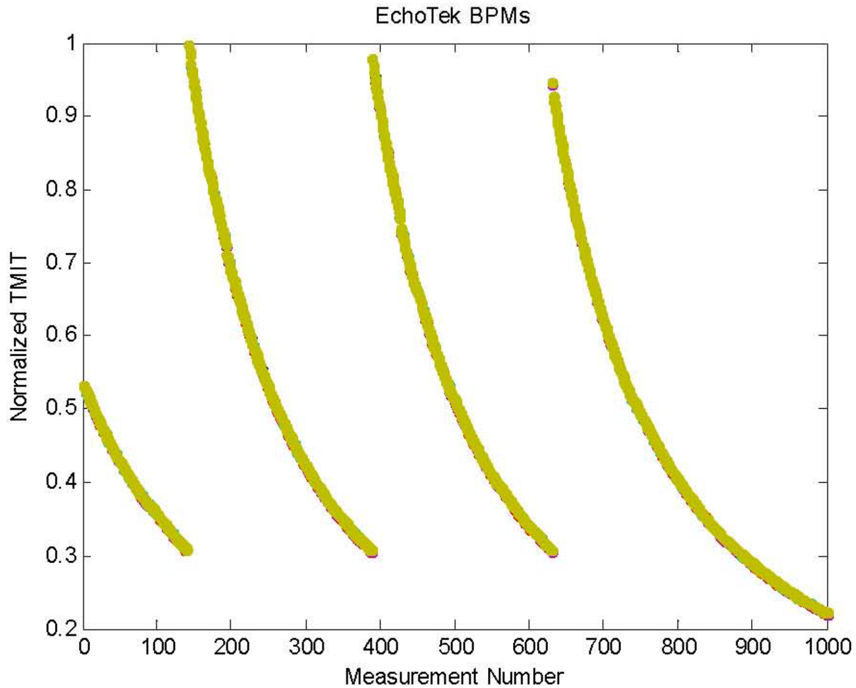
Motivation

- ILC damping ring R&D at KEK's Accelerator Test Facility (ATF):
  – Investigation of the beam damping process (damping wiggler, minimization of the damping time, etc.)
  – Goal: generation and extraction of a low emittance beam (ε_{vert} < 2 pm) at the nominal ILC bunch charge
- A major tool for low emittance corrections:
  a high resolution BPM system
  – Optimization of the closed-orbit, beam-based alignment (BBA) studies to investigate BPM offsets and calibration.
  – Correction of non-linear field effects, i.e. coupling, chromaticity,…
  – Fast global orbit feedback(?)
  – Necessary: a state-or-the-art BPM system, utilizing
    - a broadband turn-by-turn mode (< 10 µm resolution)
    - a narrowband mode with high resolution (~ 100 nm range)

Scrubbing Mode, Intensities
070518

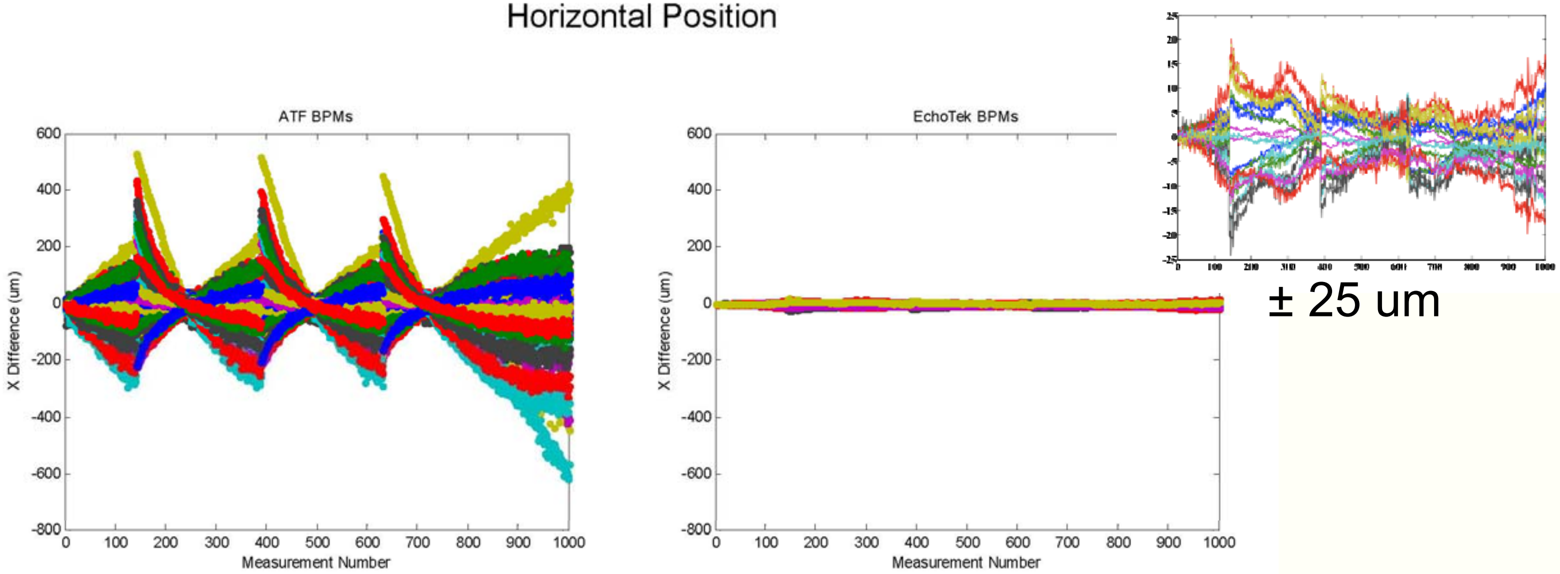
Normalized Intensities





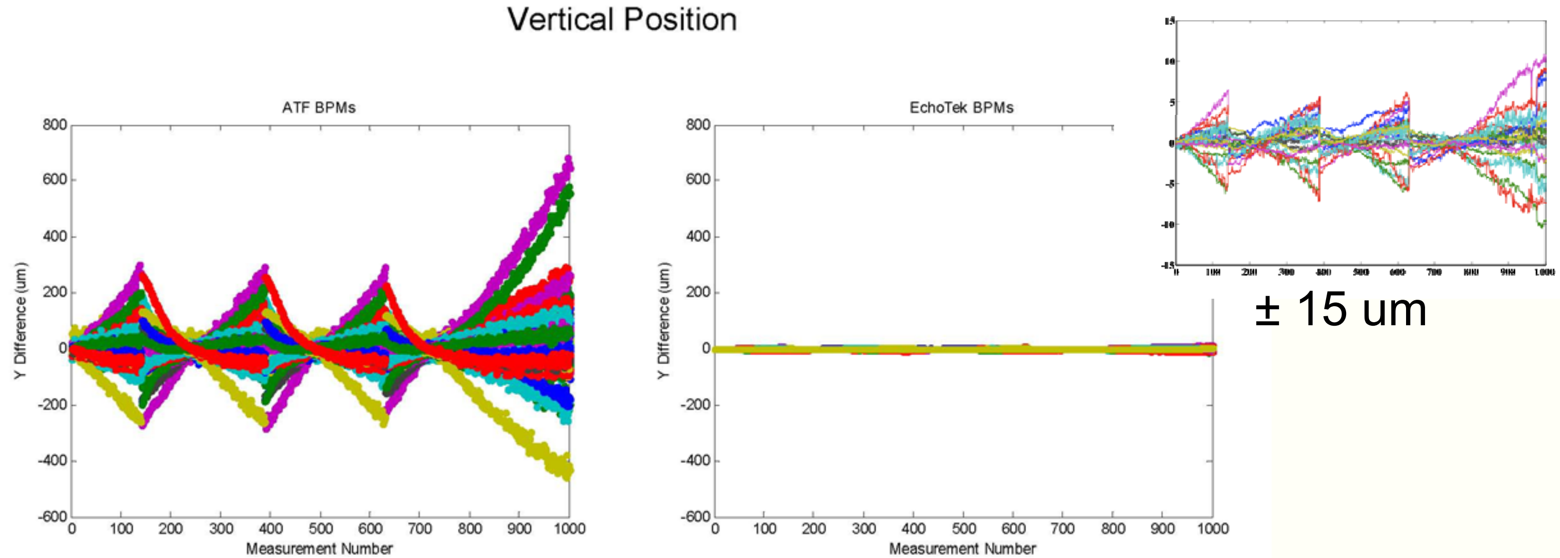
Scrubbing Mode, Positions
070518

± 700 um



± 25 um

± 700 um

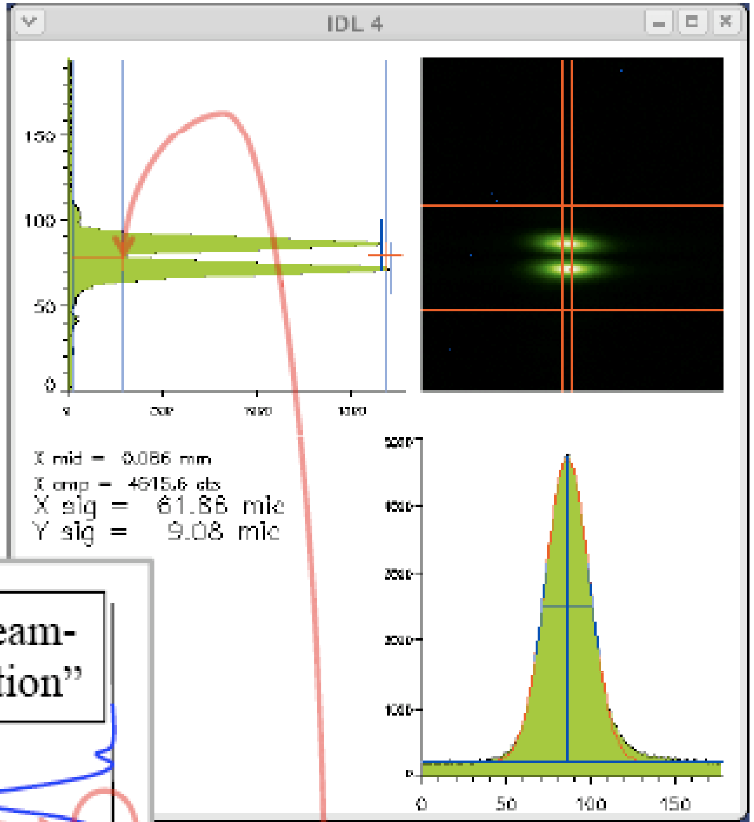


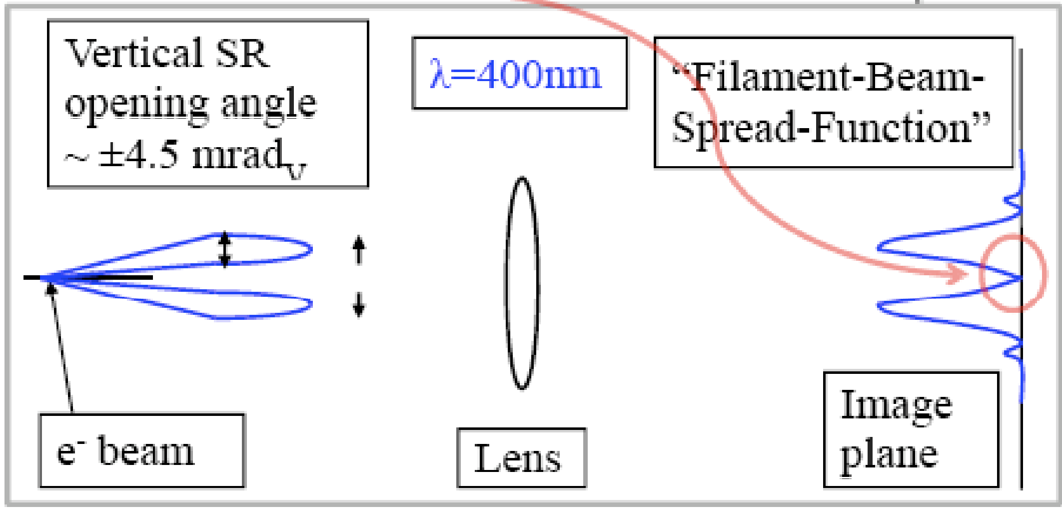
± 15 um

Beam size measurement

The π-polarization method(*):
An image of the beam is formed from vertically polarized visible-UV synchrotron radiation.

A π phase shift between the two radiation lobes ==> $I_{y=0}=0$ in "FBSF"





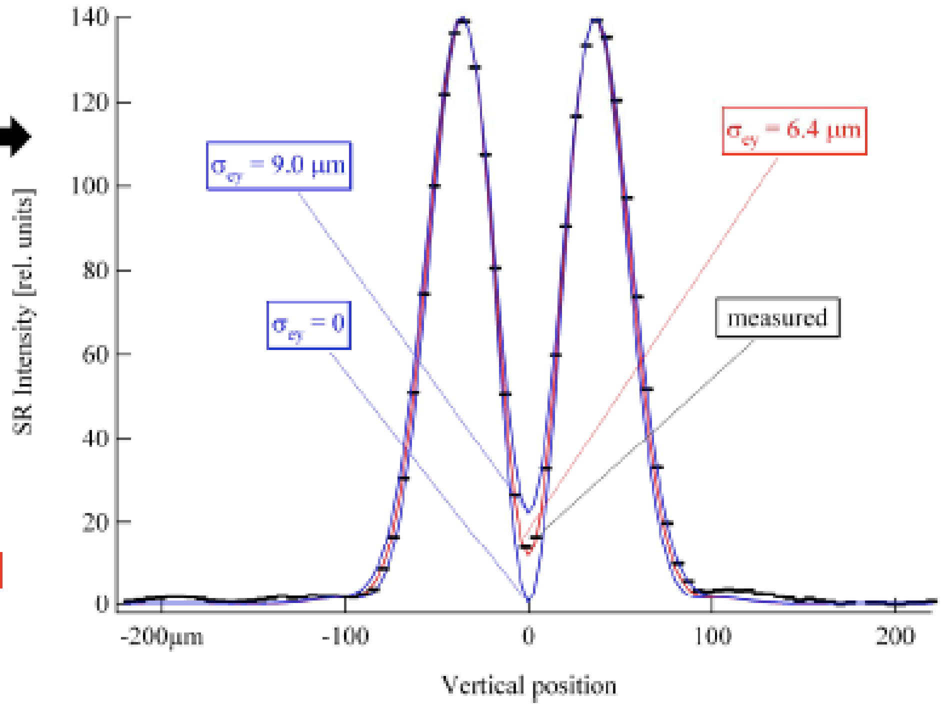
Finite vert. beam size ==>

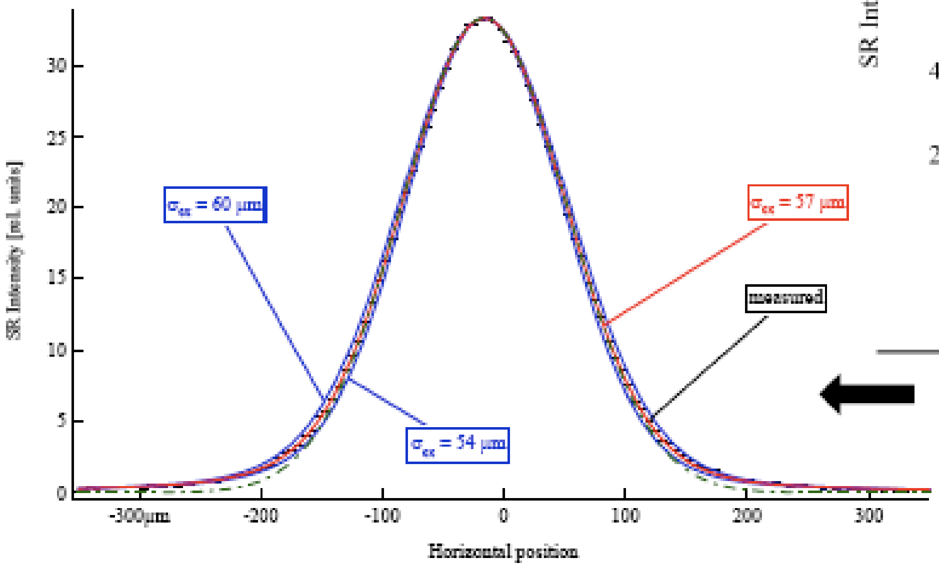
Non-zero central intensity

*) Old idea springing from MAX-lab, see EPAC'96 Andersson, Eriksson, Chubar

Beam size measurement: precision

Vertical: Predicted profiles (SRW*) for beam height values 0, 6.4, 9.0 µm, and measured.
Statistical rms error = 0.1µm



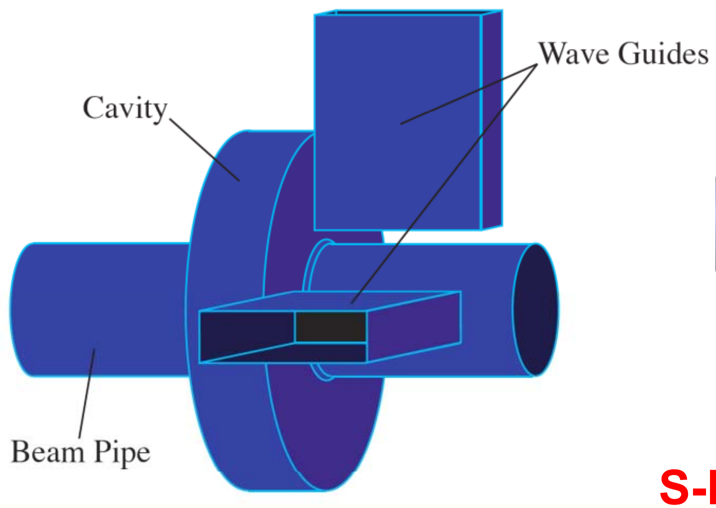


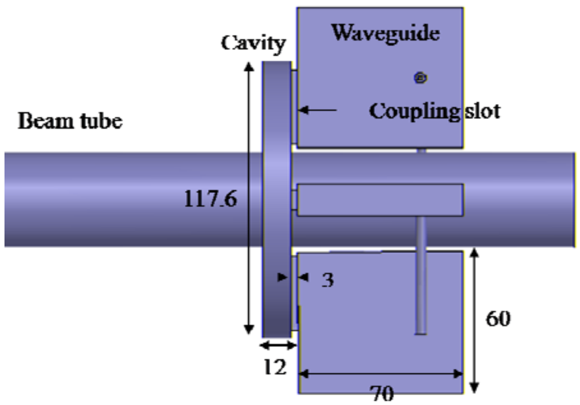
Horizontal: Predicted profiles (SRW) for beam width values 54, 57, 60 µm, and measured.
Statistical rms error = 0.3µm

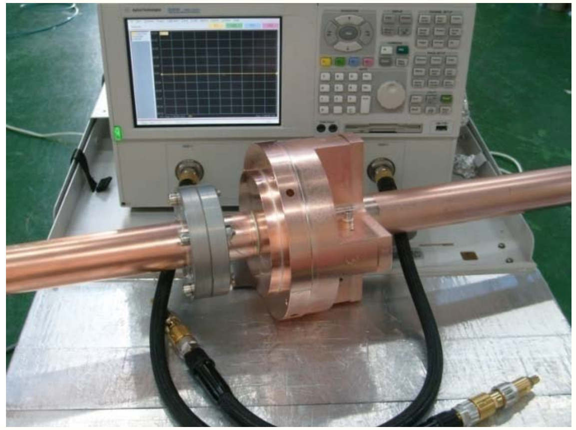
*) Synchrotron Radiation Workshop, see EPAC'98 Chubar, Ellaume

High resolution BPM's and Wake field monitors

CM-"free" Cavity BPM

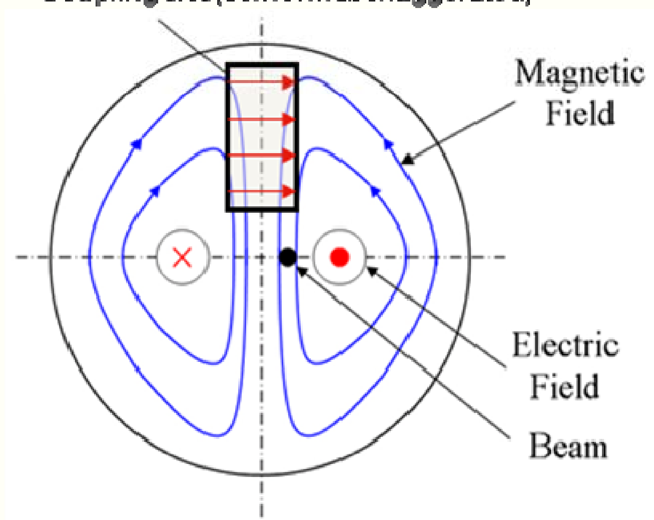






S-Band cavity BPM for ATF2 (KNU-LAPP-RHUL-KEK)

Coupling slot (somewhat exaggerated)



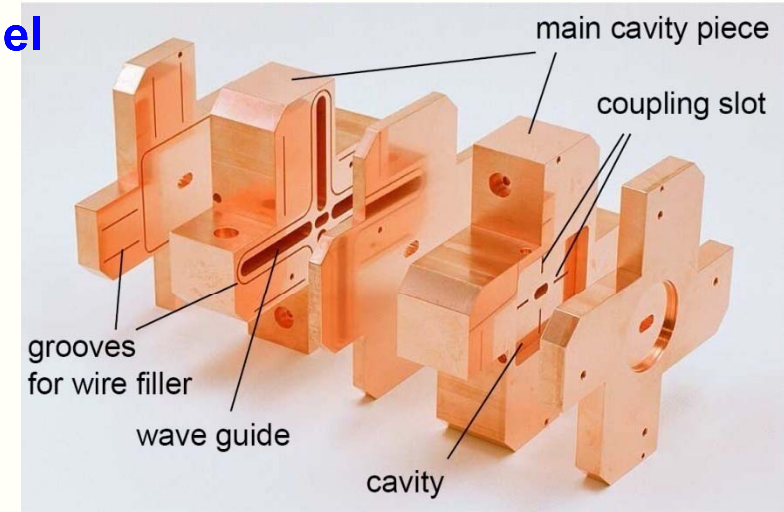
- **Waveguide TE_{01}-mode HP-filter**

  $$f_{010} < f_{10} = \frac{1}{2a\sqrt{\varepsilon\mu}} < f_{110}$$

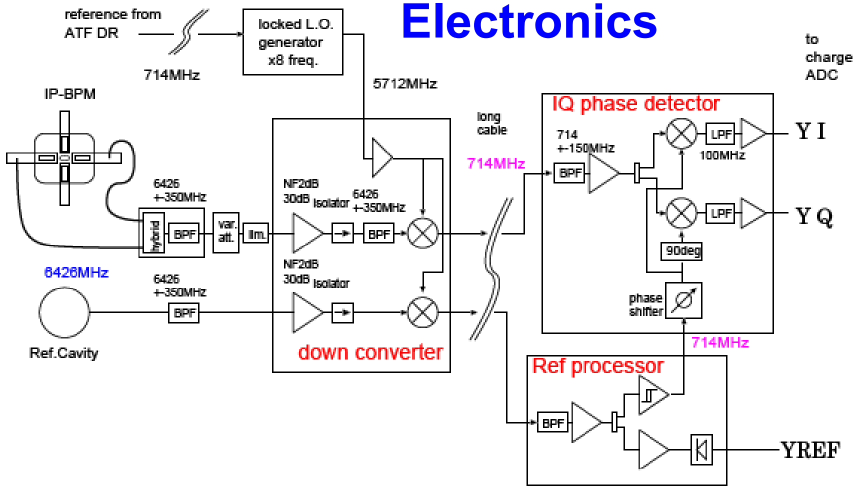
  between cavity and coaxial output port
- **Finite *Q* of TM_{010} still pollutes the TM_{110} dipole mode!**

Example: KEK C-Band IP-BPM

Model



Electronics



Characteristics

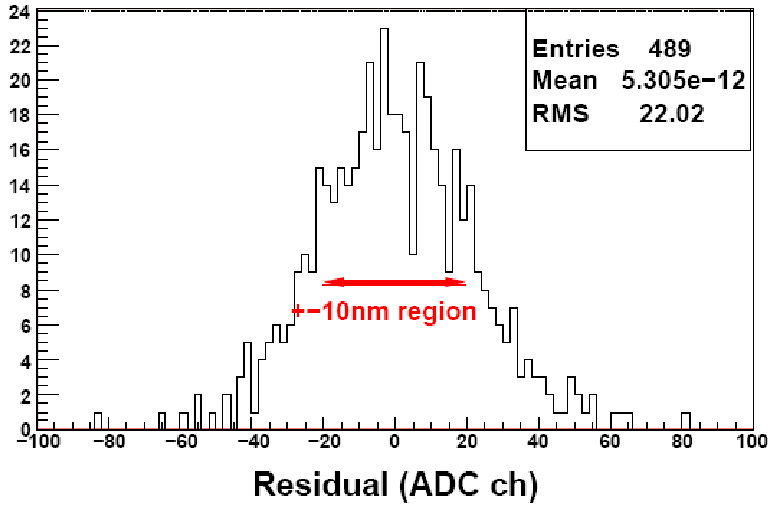
- Narrow gap to be insensitive to the beam angle.
- Small aperture (beam tube) to keep the sensitivity.
- Separation of x and y signal. (Rectangular cavity)
- Double stage homodyne down converter.

Design parameters

Port	f (GHz)	β	Q_0	Q_{ext}
X	5.712	1.4	5300	3901
Y	6.426	2	4900	2442

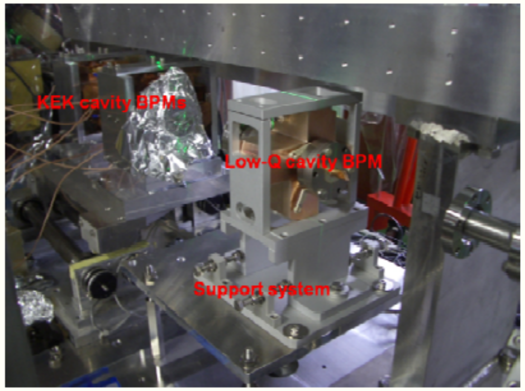
Results

8.7 nm position resolution!

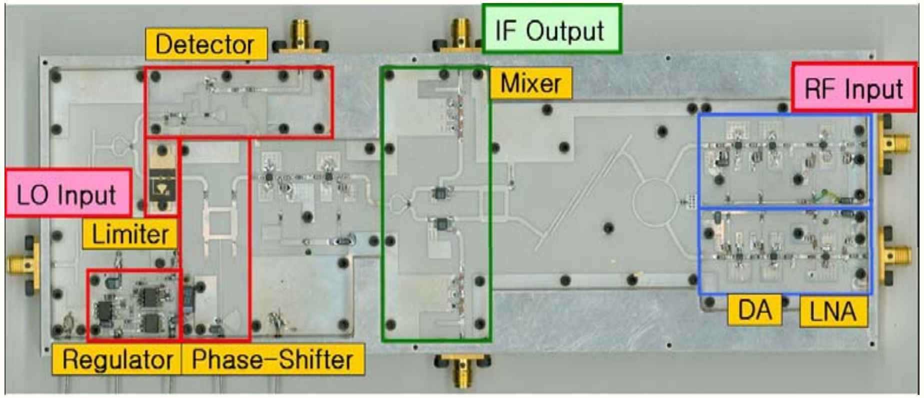


Example: KNU-KEK Low-Q BPM

Model



Electronics



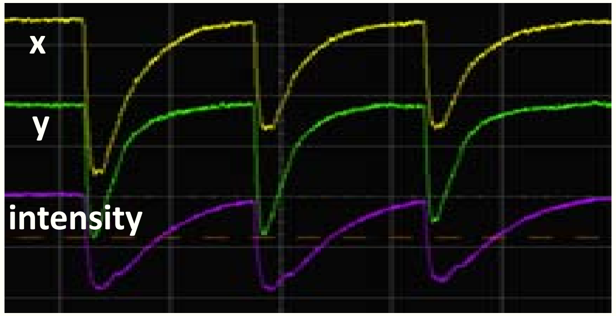
Characteristics

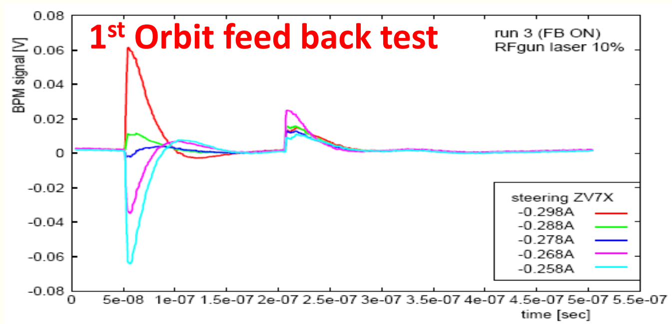
- Sam basic idea as the KEK IP-BPM.
- Short decay time, 20 ns for x and y signals.
- Short decay time (30 ns) for the reference signal.
- Single stage homodyne down-converter.
- LO-signal from reference cavity.

Design parameters

Port	f (GHz)	β	Q_0	Q_{ext}
X	5.712	8	5900	730
Y	6.426	9	6020	670
Reference	6.426	0.0117	1170	100250

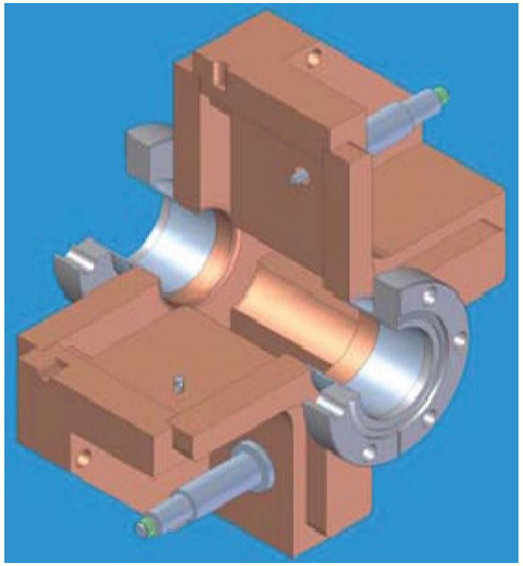
Results

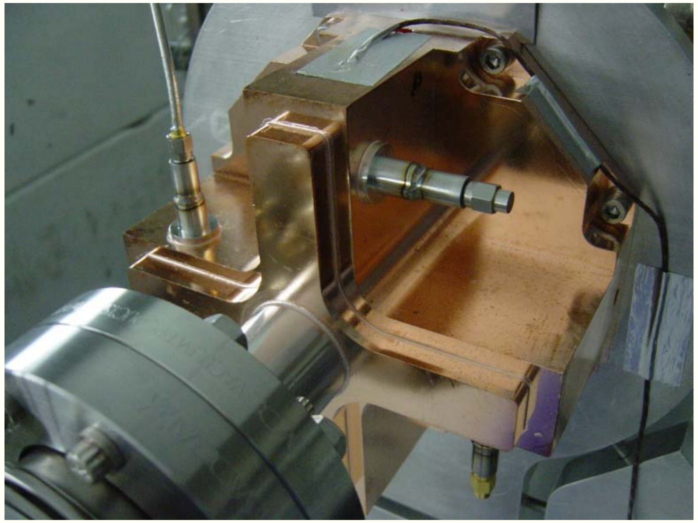


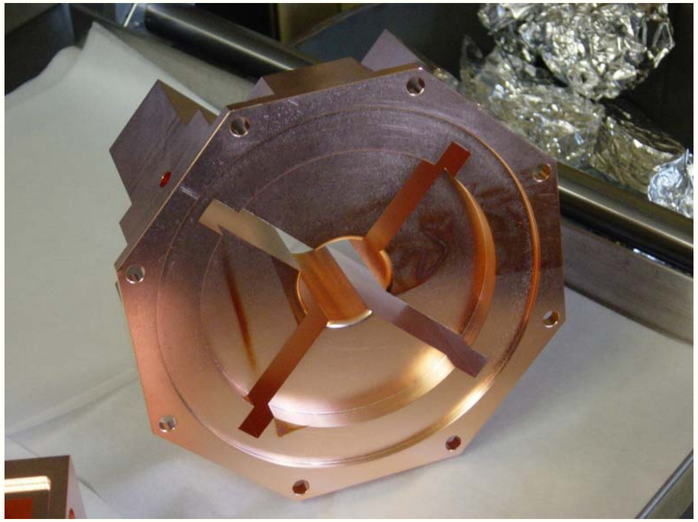


ILC Cryomodule Cavity BPM

- **SLAC approach:**
  - **S-Band design with reduced aperture (35 mm)**
  - **Waveguide is open towards the beam pipe for better cleaning**
  - **Successful beam measurements at SLAC-ESA, ~0.8 µm resolution**
  - **No cryogenic tests or installation**
  - **Reference signal from a dedicated cavity or source**



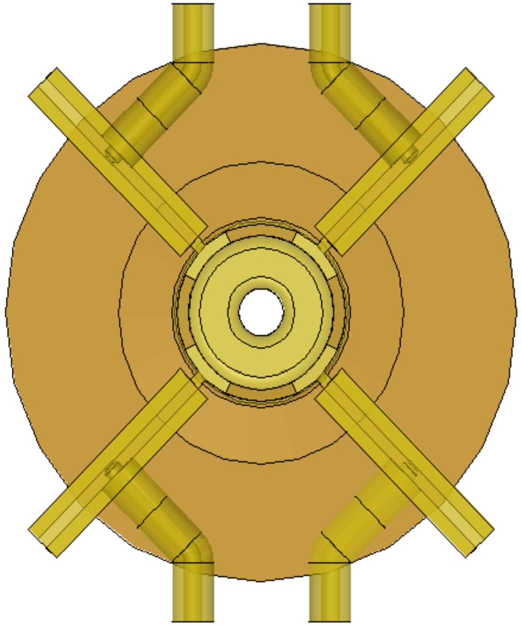


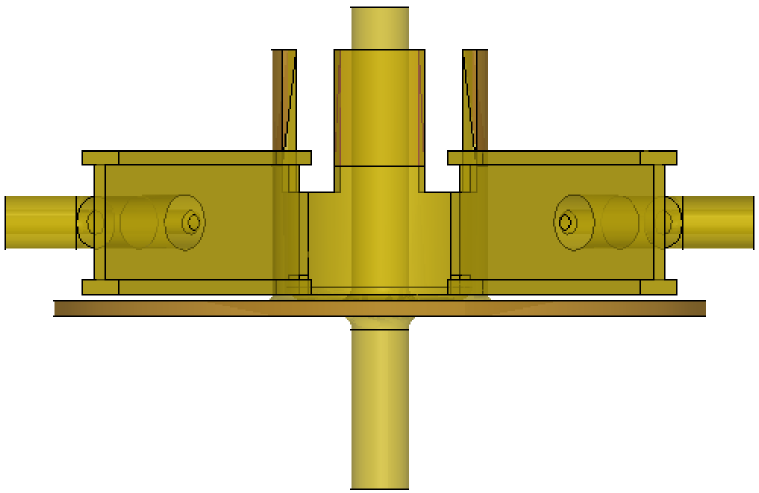


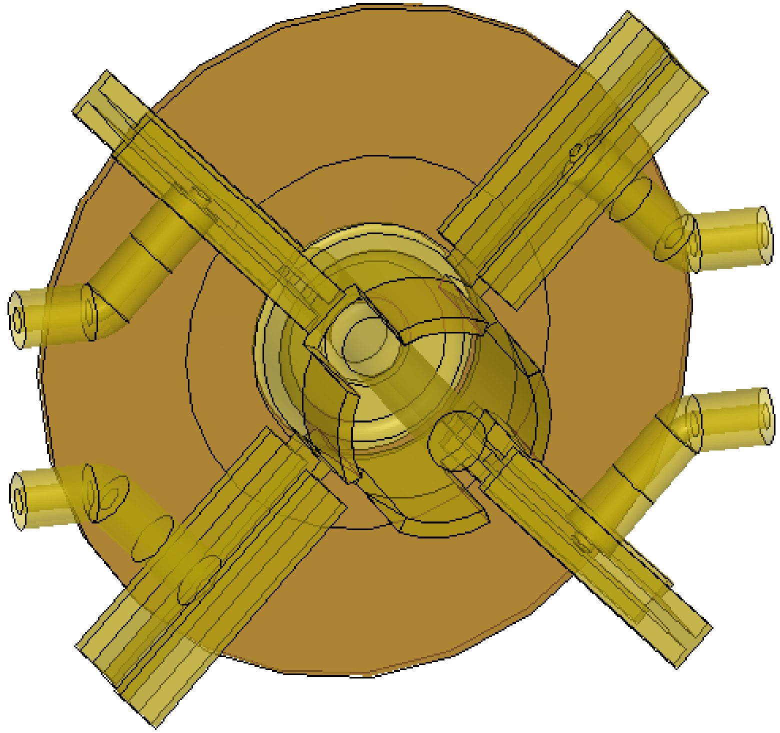
Conclusions

- Resonant BPMs with waveguide-based CM suppression achieved <10 nm resolution (C-Band, $Q_{load} \approx 3000$).
- A cold L-Band cavity BPM prototype with 78 mm aperture, $Q_{load} \approx 600$, resolution < 1 µm, is in fabrication.
- A cold 1.3 GHz cavity BPM for operation at the NML test accelerator is in an early design stage.
- A personal remark to the CLIC BPM requirements:
  - Large quantities require an as simple as possible approach!
  - A cavity BPM solution is in reach, when relaxing on the time resolution (i.e. averaging over the entire macropulse).
  - Read-out and calibration electronics need to be pushed towards digital signal processing to reduce costs and simplify DAQ.

'yet another high resolution BPM'

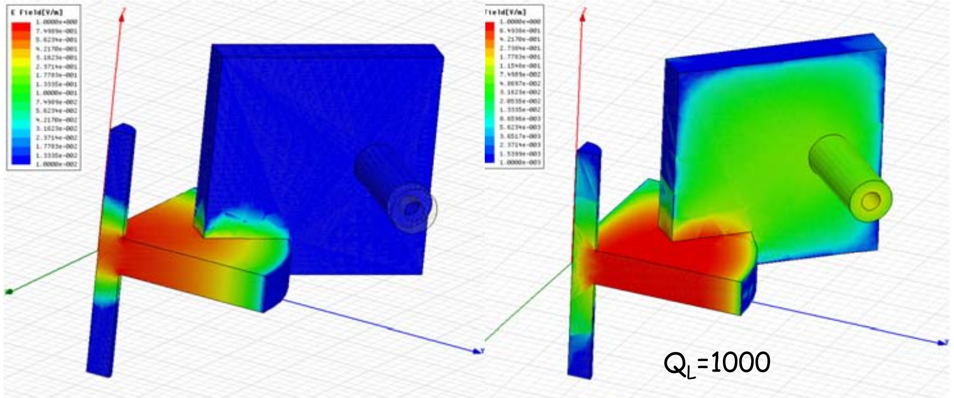




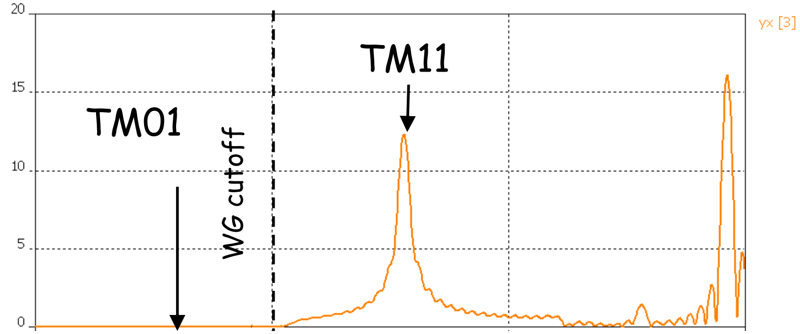


The New Choke BPM

TM01 TM11

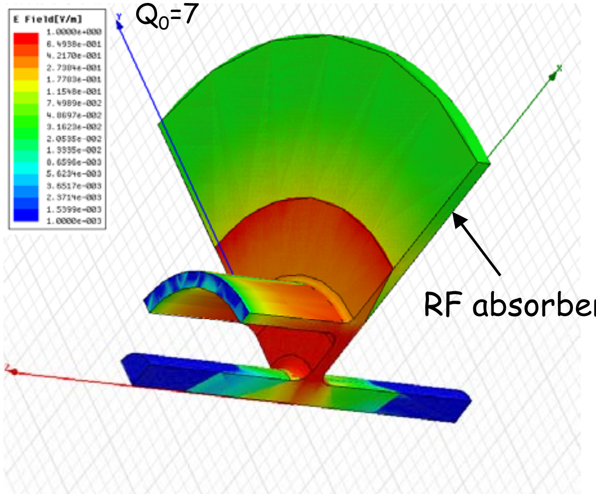


Spectrum of the port signal (single bunch)

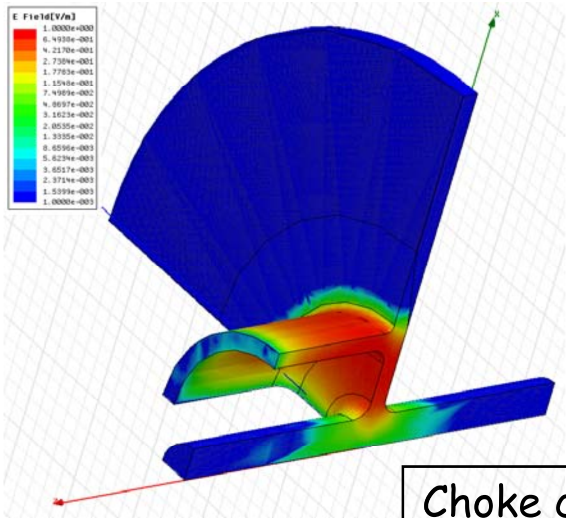


Slotted cavity

Monopole mode TM01
f=7.8GHz
Q_0=7



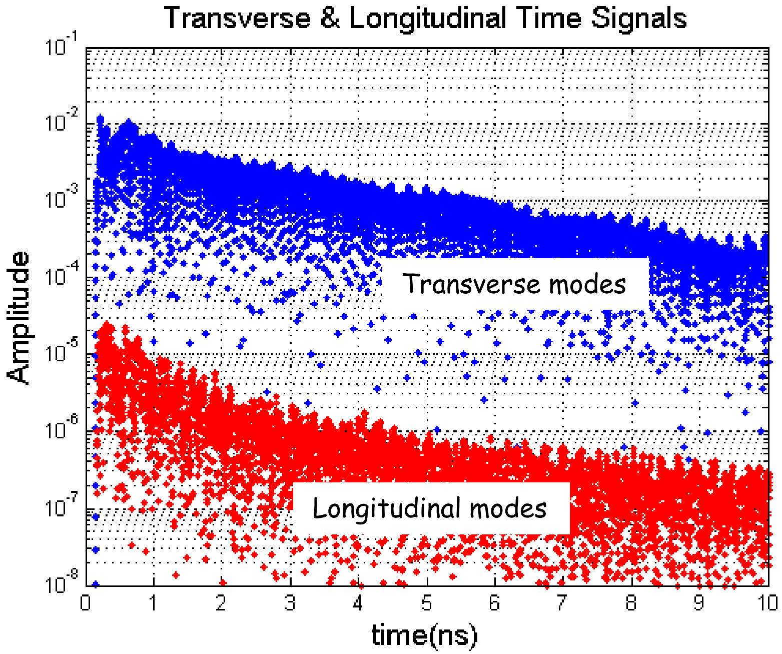
Dipole mode TM11
f=12GHz
Q_0=1600 (Copper)



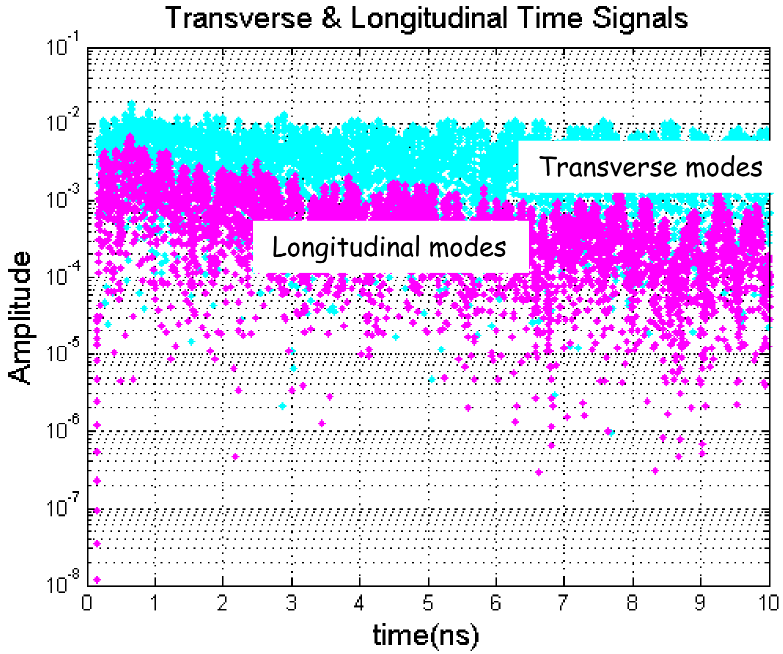
Choke cavity

GDFIDL Simulation Results #1. Port signals

New choke BPM



Slotted cavity BPM



~ 1 micron ⇦ Internal single bunch resolution ⇨ 500 micron

⇩

The two port pairs combination through the hybrid normally reduces the signals induced by the longitudinal modes by at least 20 dB

⇩

~ 10 nm ⇦ Single bunch resolution without post processing ⇨ 5 micron

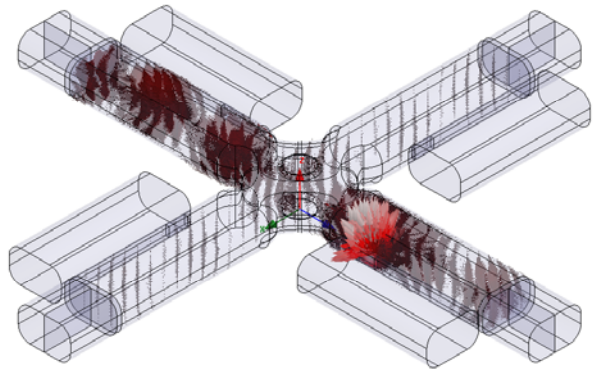
Objectives and development plan

Technical objectives:

1) Accelerating structure (ACS) alignment on girder using probe beam

2) Wakefield monitor (WFM) performance in low and high power conditions (and after a breakdown)

WFM specifications:
- *Resolution = 1 µm*
- *Precision = 10 µm*



Development plan:

1. **WFM prototype**

   -TBTS, Phase 2: 04 – 07 / 2010

   - Add WFM capability to a structure already in testing pipeline

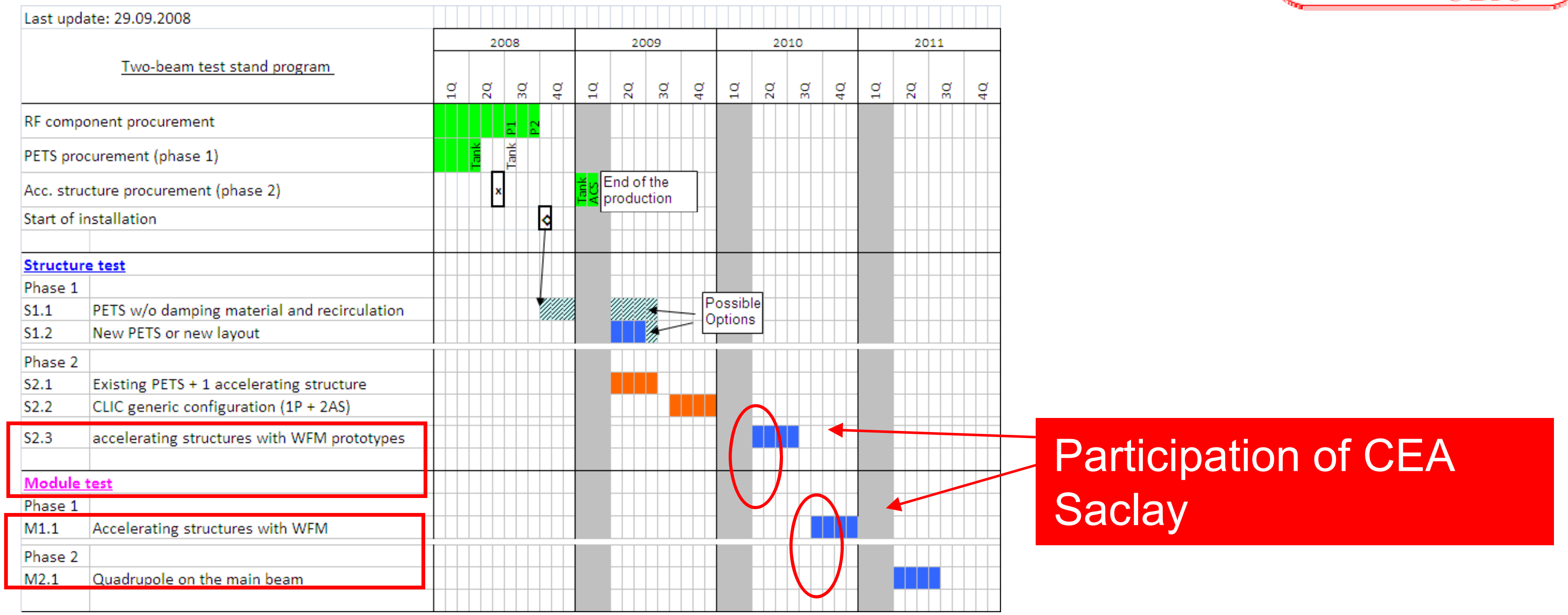
2. Complete ACS with WFM

   - TEST MODULE, Phase 1: 09 -12 / 2010

   - Full integrated module/system test

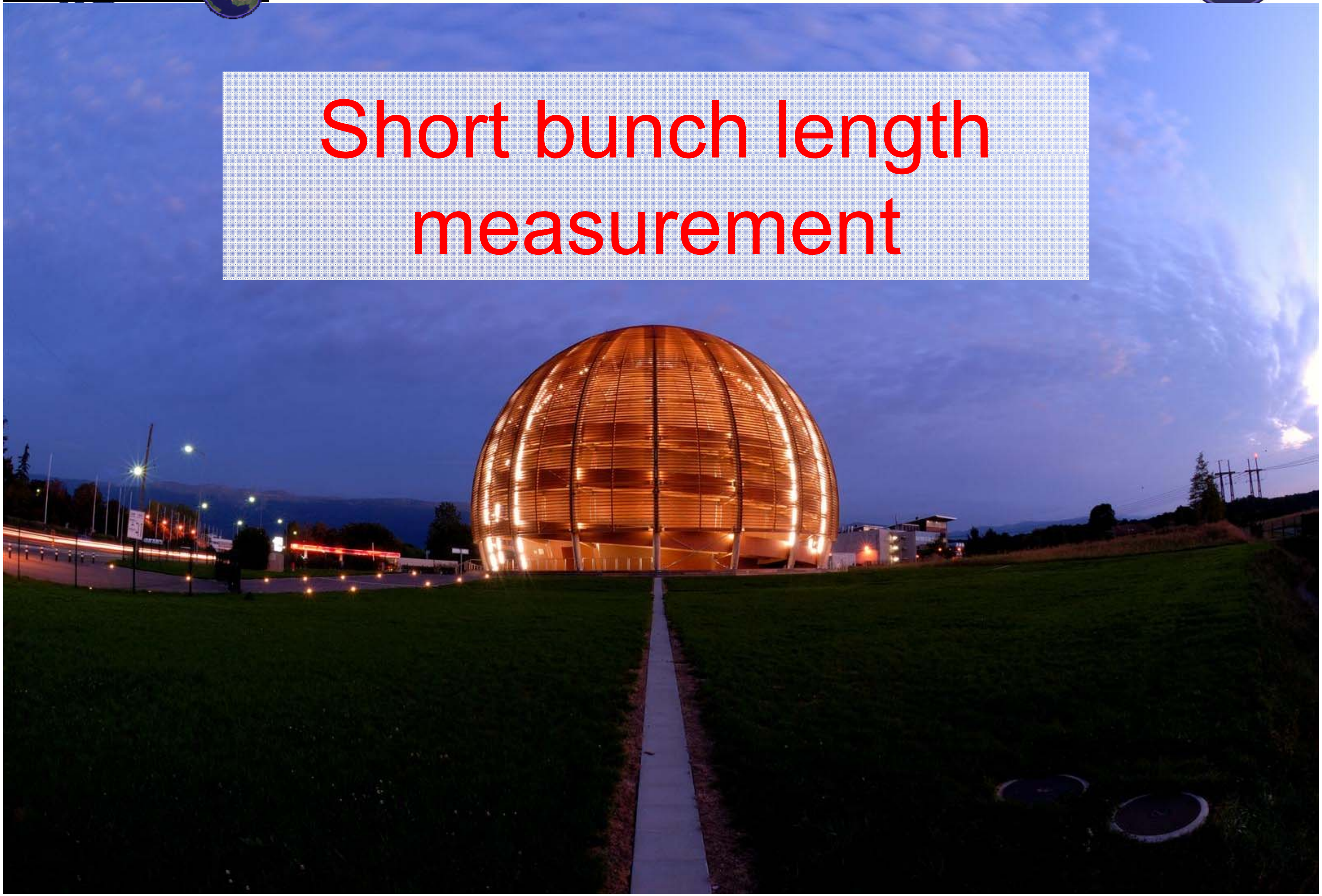
In the framework of exceptional contribution of France to CERN

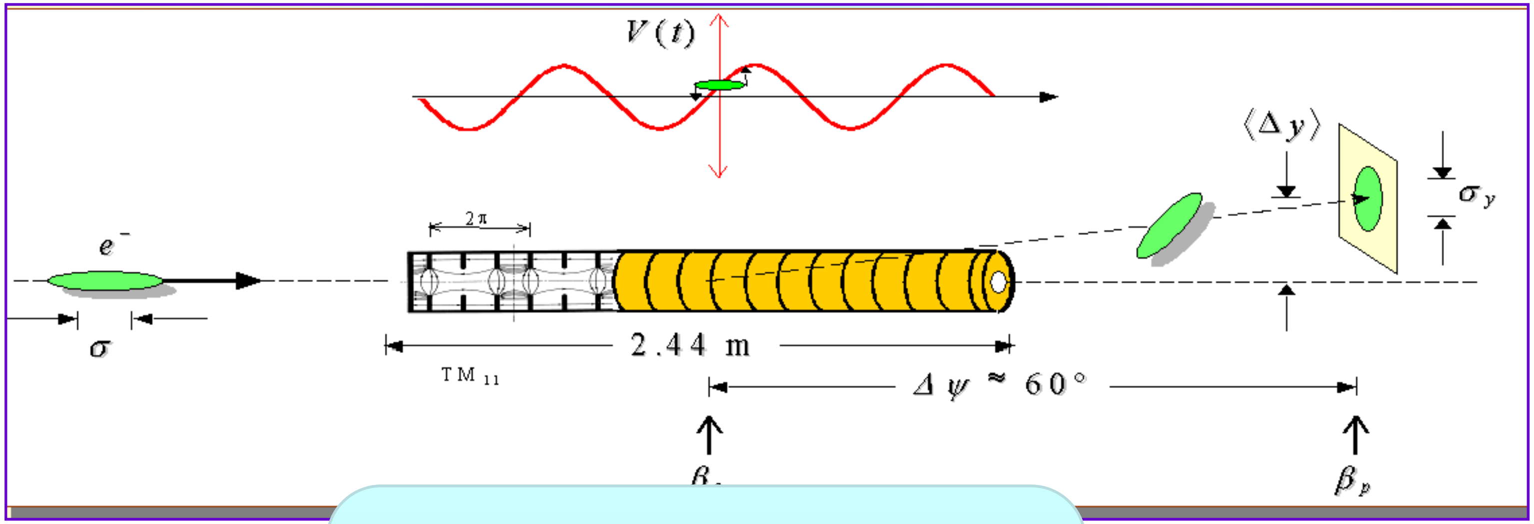
Milestones and deliverables



• Kick-off meeting:	Nov 2008
• WFM design review:	March 2009
• WFM procurement:	June 2009
• Complete ACS final design review:	Sep 2009
• Complete ACS procurement:	Mar 2010
• Complete 150000 devices	**Mar 2025**

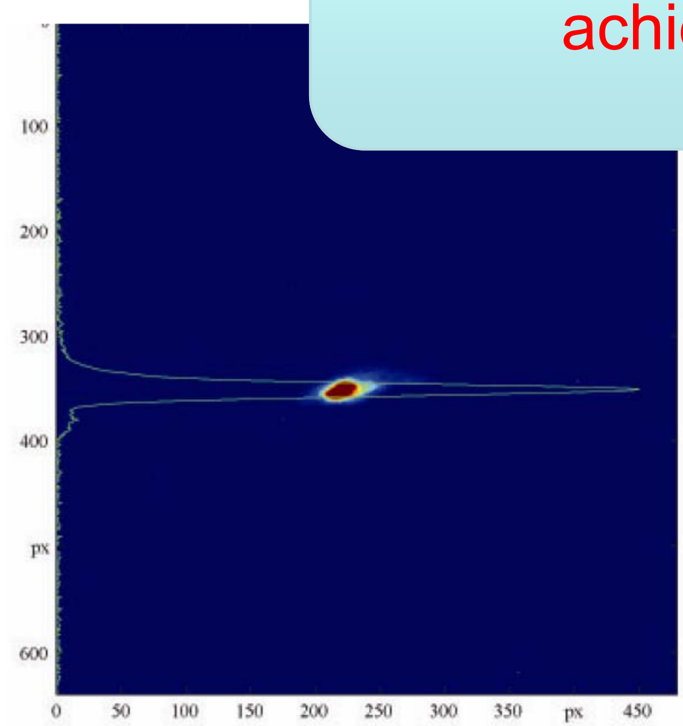
Short bunch length measurement

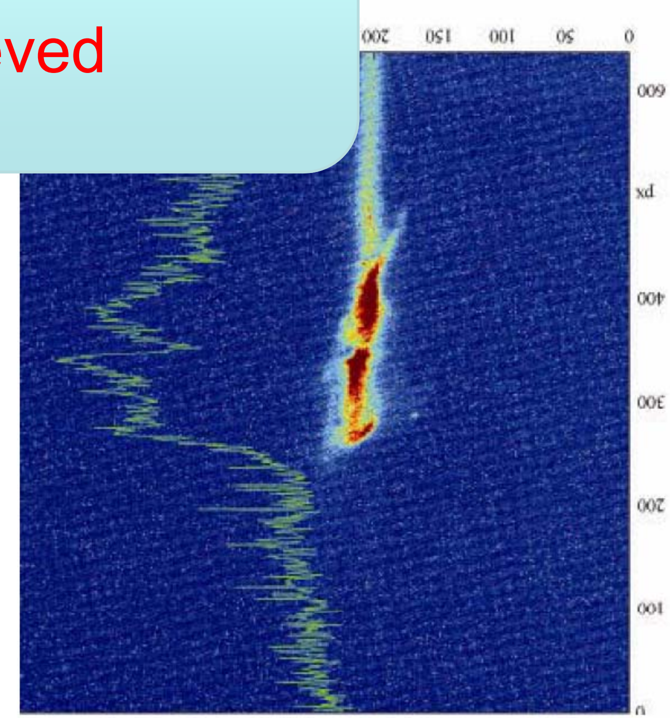




10fs resolution achieved

ff



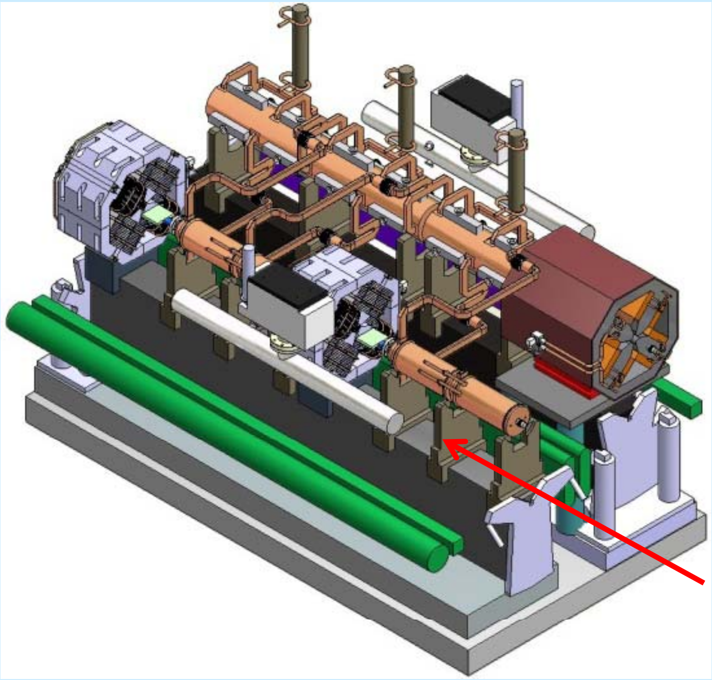


Beam Diagnostics Developments for CLIC in the QUASAR Group

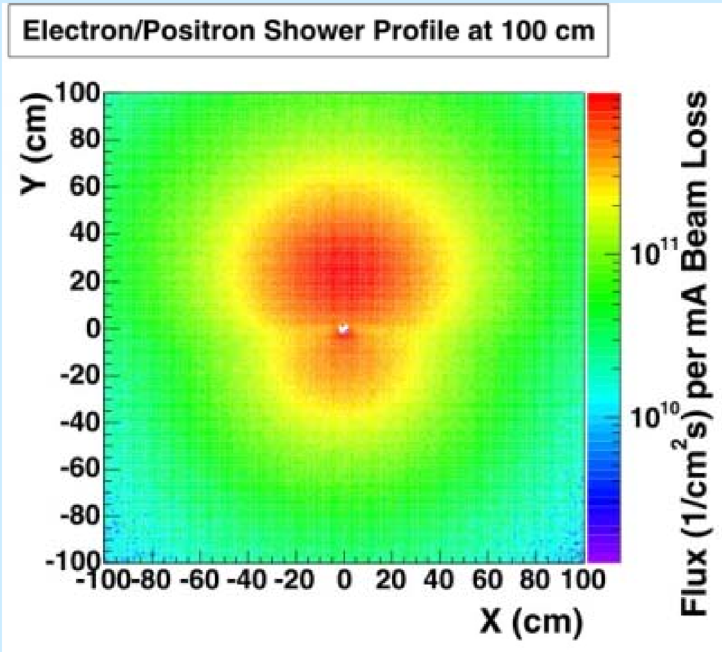
Carsten P. Welsch

Beam loss monitoring

Major complication:



100 A, 2.4GeV



M. Wood, T. Lefevre

A. Intermite

Instrumentation requirements

Feasibility issues to be studied for the CDR

- Need to study the **Machine Protection System** for both the Drive and Main beams and to develop a Beam loss monitoring system along the CLIC linac (both beams)

- **Very tight requirements** for measuring micrometer **beam size**, 40-75microns short **bunch length** and **beam position** with a 50nm resolution, (achievable in principle)

- **Reliability and availability** of roughly 5000 high resolution (50nm) BPMs and 150000 wake field monitors with 5μm resolution
    - Impact on performance : Does the tuning procedure require all instruments to work simultaneously ?
    - Industrial series production : study the Impact on cost

- Beam **synchronization** implies a **0.1deg at 12GHz phase measurement** with an adequate feed-forward system and a **stability of the Drive Beam energy and intensity of 3.10^{-5}**

Thanks all the participants