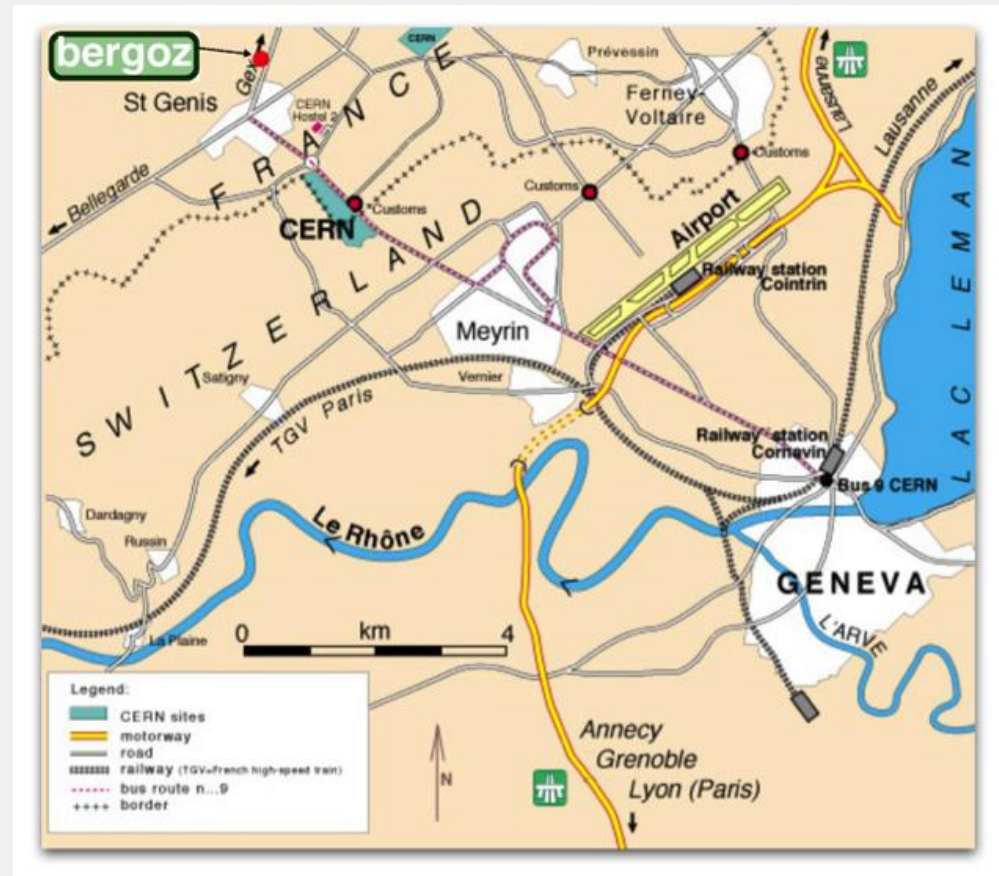


Joint University Accelerator School 2014

Welcome to Bergoz Instrumentation



- ❑ Legal form: SAS
- ❑ Founded in 1981 by Julien Bergoz & Klaus Unser
- ❑ Paid-up capital 152 K€
- ❑ President : Julien Bergoz
- ❑ Number of employees: 11
- ❑ Turnover : 1.5 MEuros



Distribution network

Beam Instrumentation products

USA: GMW Associates, California

Japan: REPIC Corporation, Tokyo

India: Geebee International, New Delhi

Other countries : direct sales

Industrial products:

USA: GMW Associates, California

Japan: REPIC Corporation, Tokyo

India: Geebee International, New Delhi

Other countries : direct sales

Our customers:

The World of Synchrotron Radiation



More than 80 synchrotron light sources in the world
Each of them uses our instruments

Our customers:

Neutron Spallation Sources

Most if not all spallation neutron sources worldwide use our beam instruments:

SNS, Oakridge TN, U.S.A.

SINQ, PSI Villigen Switzerland

PEFP, Taejon, Korea

CSNS, Chengdu, Sichuan, China

J-PARC, Tokai Mura, Japan

Our customers:



Instrumentation

Laser-plasma wakefield accelerators

All laser-plasma use our Integrating Current Transformer and Beam Charge Monitor to measure the charge of their femtosecond-long bunches

Integrated Parametric Current Transformer (IPCT)

To measure:

- Low current at very-high voltage
- Return ground current, DC and AC
- Leakage current, DC and AC
- Sum of low currents
- Power tube grid current
- Electrostatic corona discharge
- Electrochemically-induced current
- Standby battery charging current



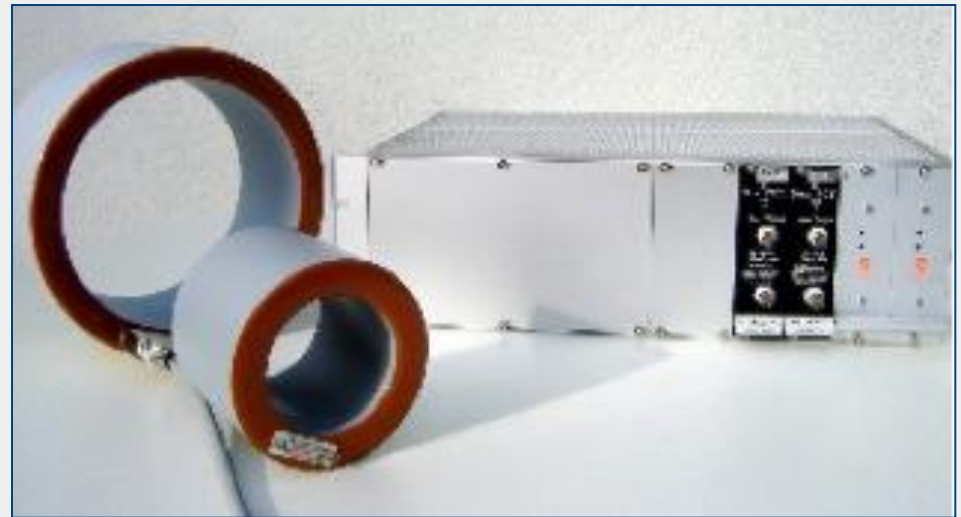
DC current monitoring

New Parametric Current Transformer

Less than 0.5 μA resolution

10 kHz bandwidth

20 mA-20A range



Based on DCCT operating principle invented at CERN by Klaus Unser in 1966 for the ISR, known as Flux-gate, second-harmonic detection, also Zero-fluxTM transformer

Waveform monitoring



High Resolution version

Bandwidth up to 300 kHz

Noise down to 1 μ Arms

Lower cutoff (-3dB) < 3 Hz

AC Current Transformer

Wide Band version

Bandwidth up to 1 MHz

Noise down to 5 μ Arms

Lower cutoff (-3dB) < 3 Hz



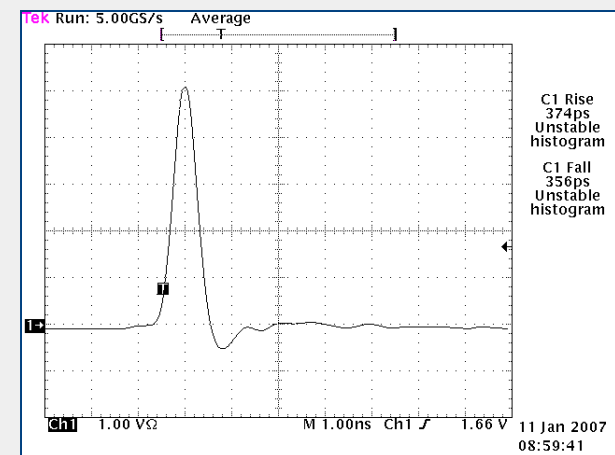
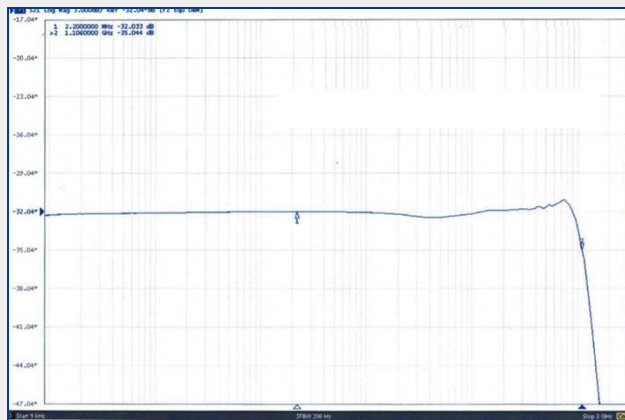
Waveform monitoring

Fast Current Transformer

Bandwidth up to 1.75 GHz

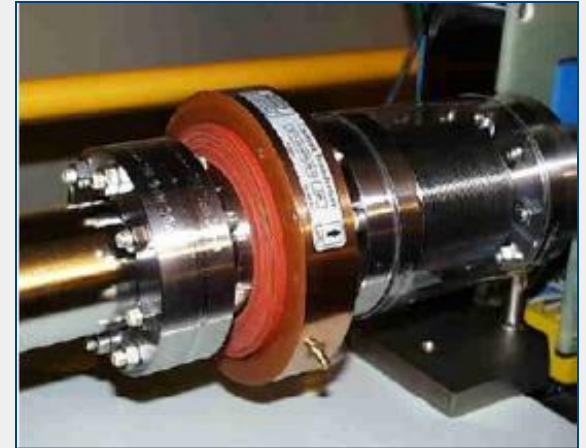
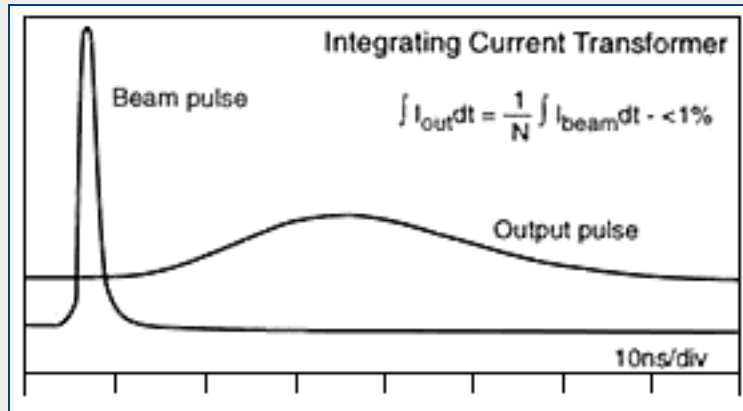
200 ps risetime

Sensitivity up to 5V/A



Charge monitoring

Integrating Current Transformer

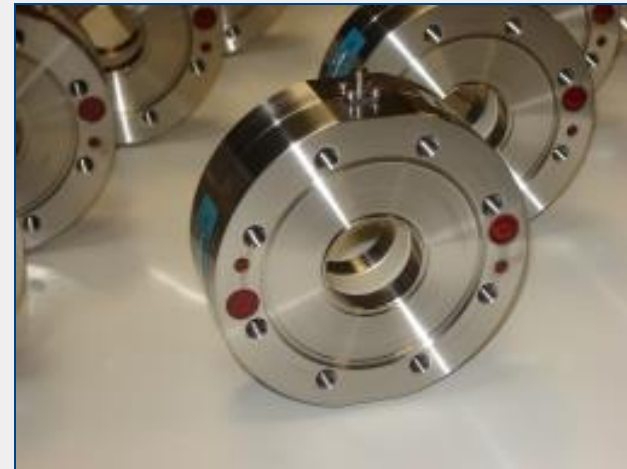
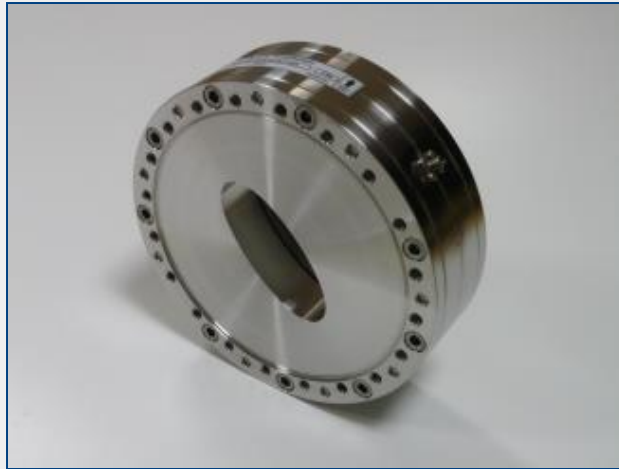


Beam Charge Monitor

Measures single pulses with 1pC resolution and stored beam current with 10 nA res.

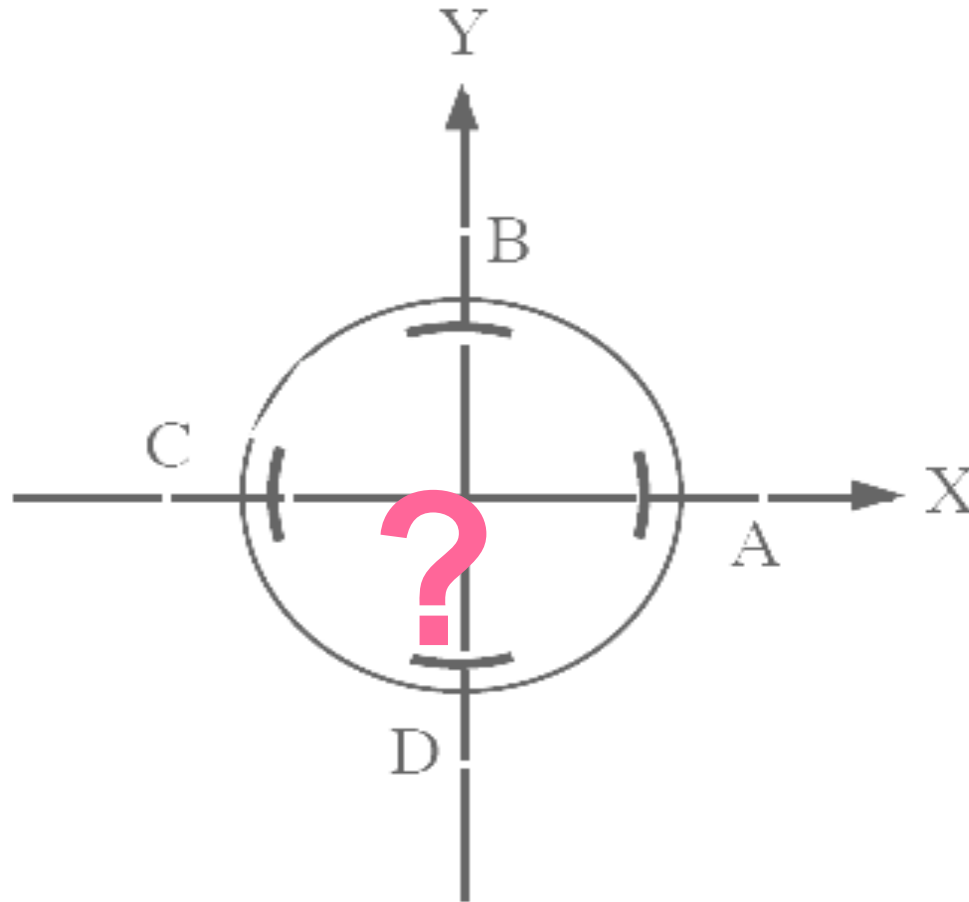


In-flange.FCT, ICT, ACCT, NPCT

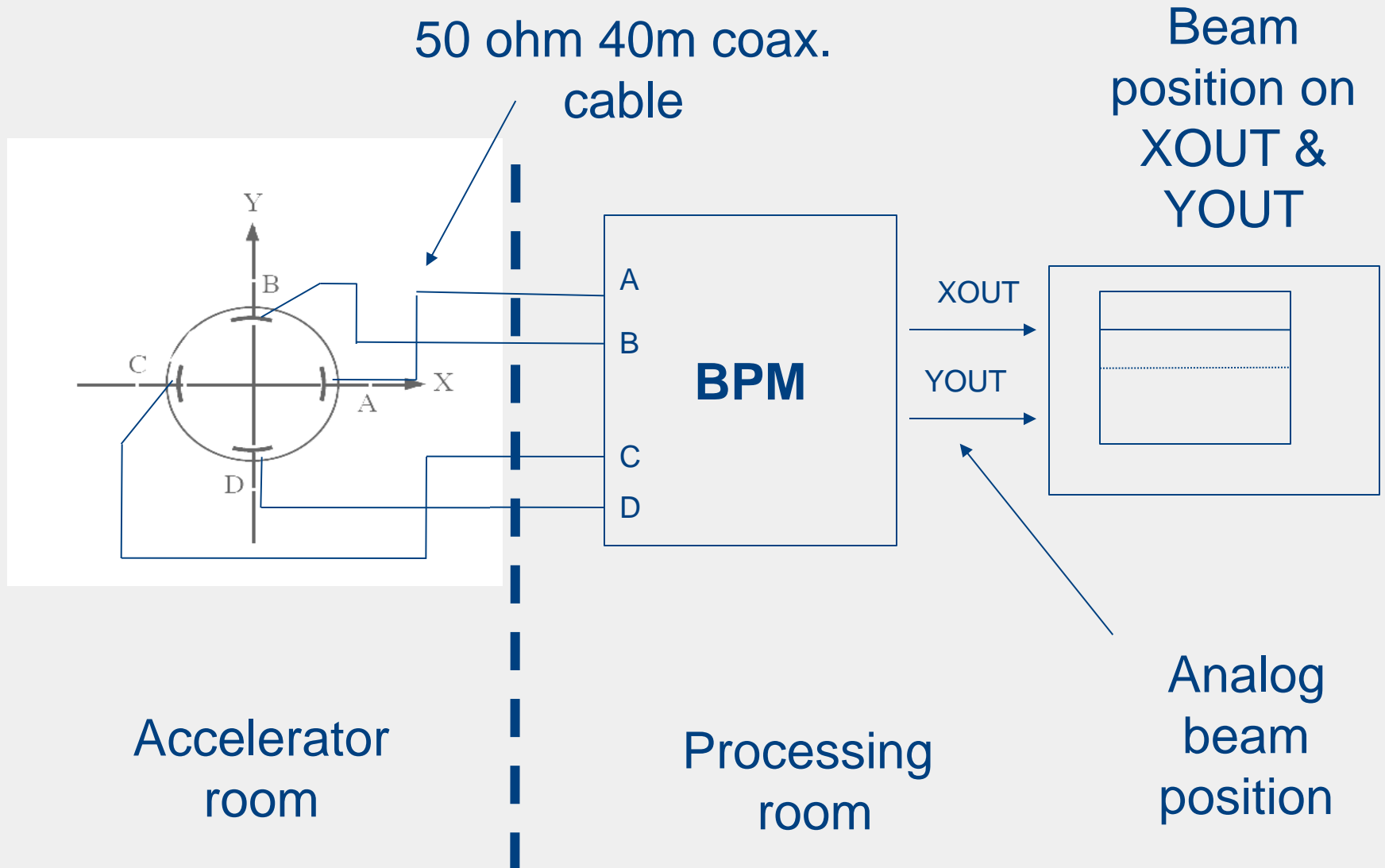


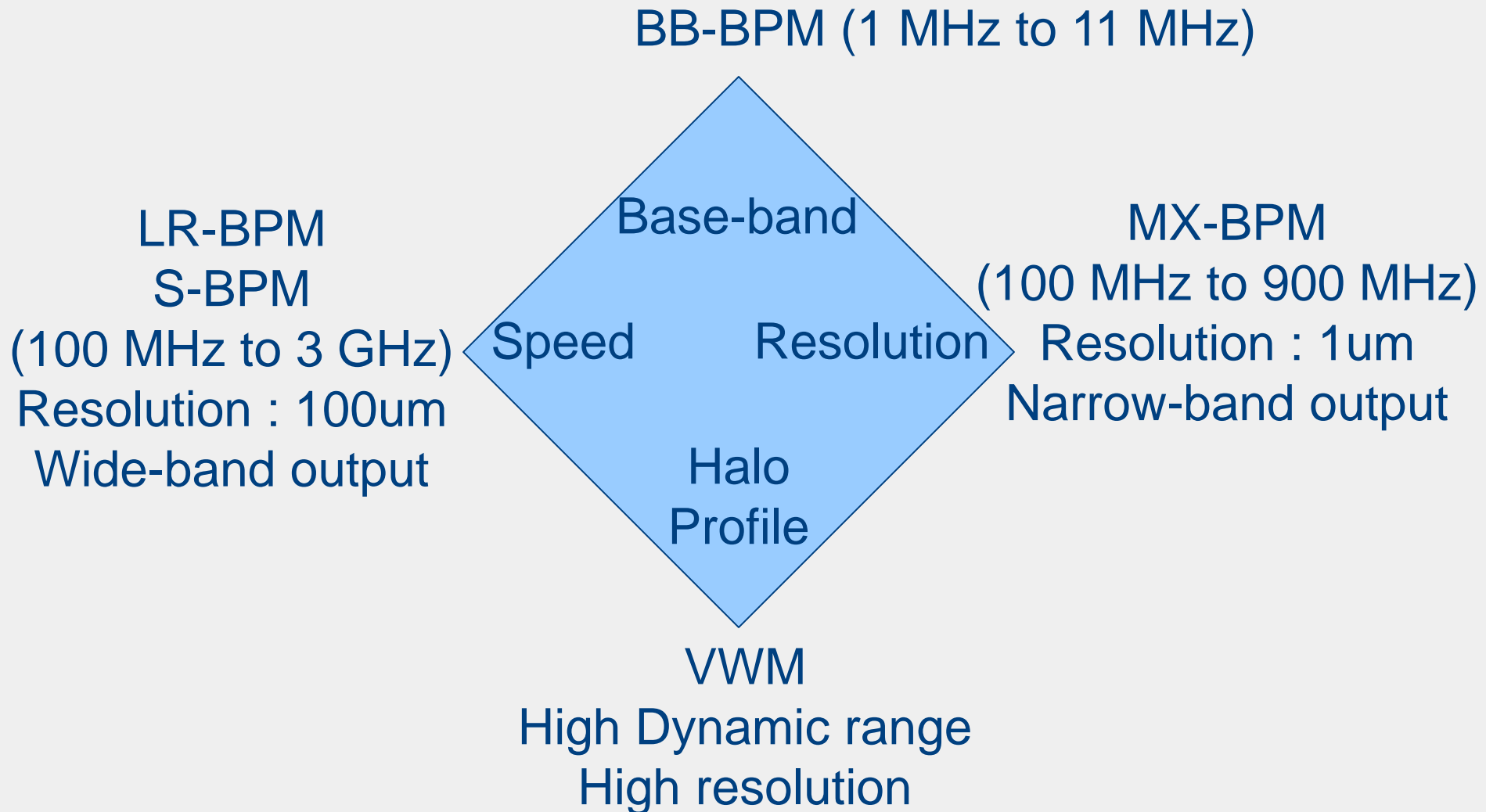
Simple installation
Ceramic break integrated
Vacuum down to 10^{-10} mbar

Beam Position Monitoring - BPM



Beam Position Monitoring - BPM





Multiplexed Beam Position Monitor



Instrumentation

MX-BPM

Multiplexed input BPM processor for Synchrotron close orbit measurement

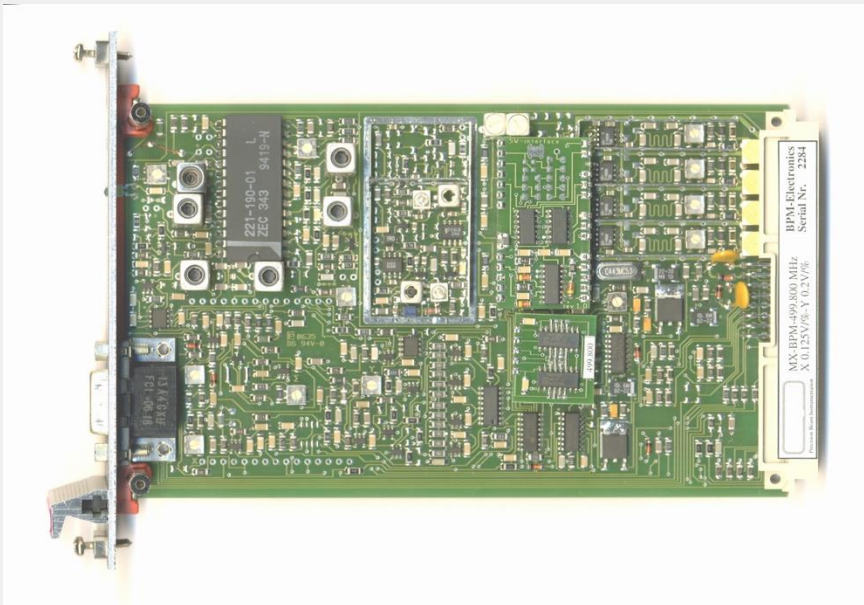
1 μm rms noise in 34-mm BPM pickups

8-kHz beam position sampling rate

Pre-calibrated

No software: X and Y voltage outputs ready to use

Compact: 16 processors in 19" x 3U chassis



Simple to install, simple to use, reliable

>3000 units used world-wide

Most used BPM processor?

EPICS / TANGO microIOC integration by Cosylab

Log-ratio Beam Position Monitor



Instrumentation

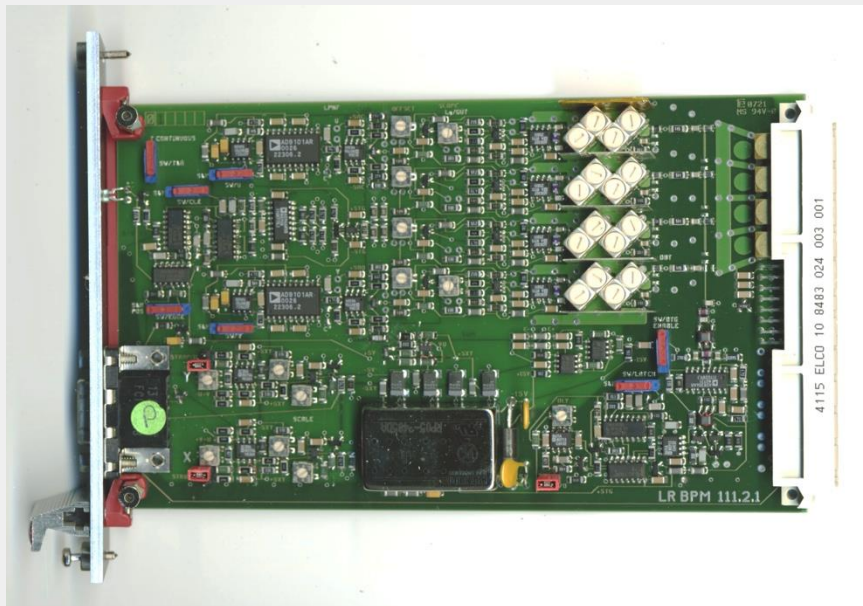
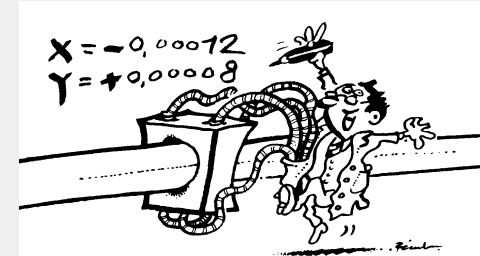
LR-BPM (100 MHz to 800 MHz)

S-BPM (1,56 GHz, 2,856 GHz and 2,999 GHz)

Parallel, simultaneous processing of four BPM inputs
for Linacs, Transfer lines

Measures single pass of bunch or macropulse, holds X and Y voltages until
next bunch with ~100um resolution

X and Y output are voltages tracking beam lateral movement with 5 MHz
bandwidth



Simple to install, simple to use, reliable
Compact: 16 modules in 19" x 3U chassis
>400 units used world-wide

EPICS / TANGO microIOC integration by Cosylab

Beam Loss Monitor (BLM)

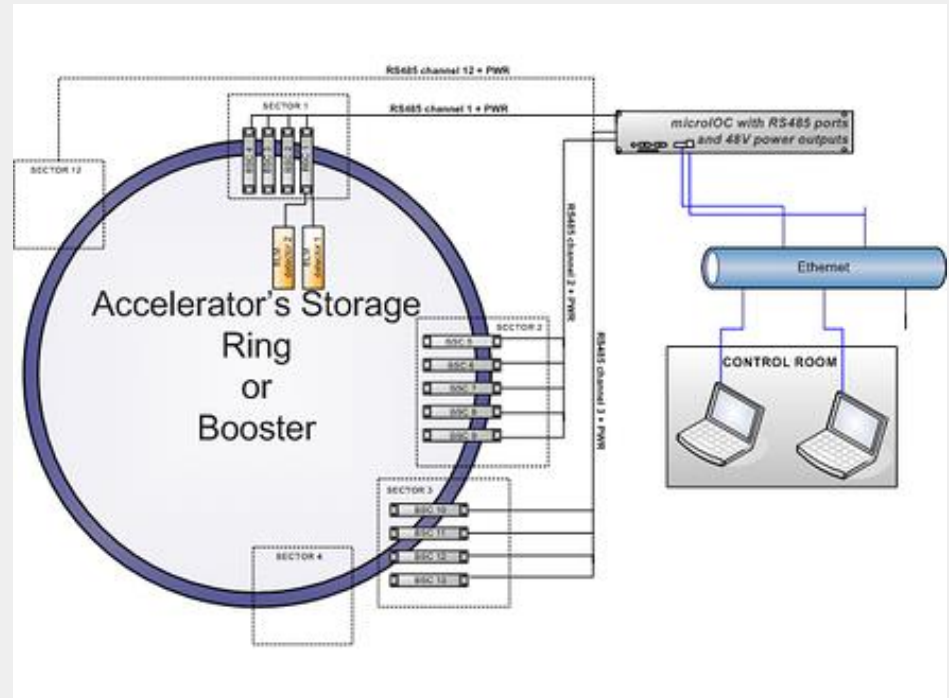


Measure & localise beam losses.

PIN photodiodes mounted face to face detect charged particles

Insensitive to synchrotron radiation photon

Up to 10 MHz counting



Vibrating Wire Monitor (VWM)



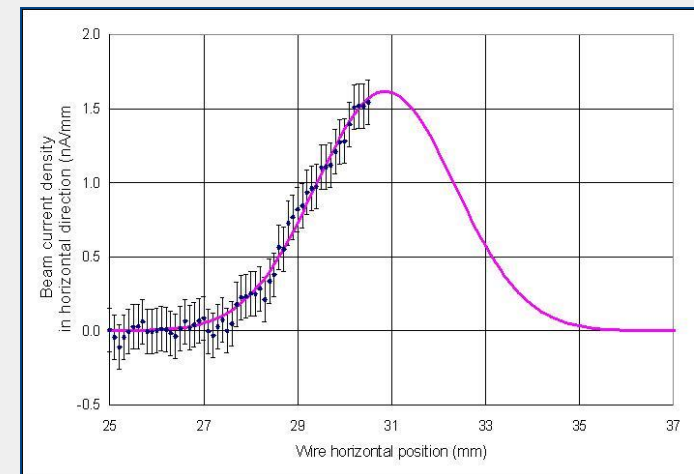
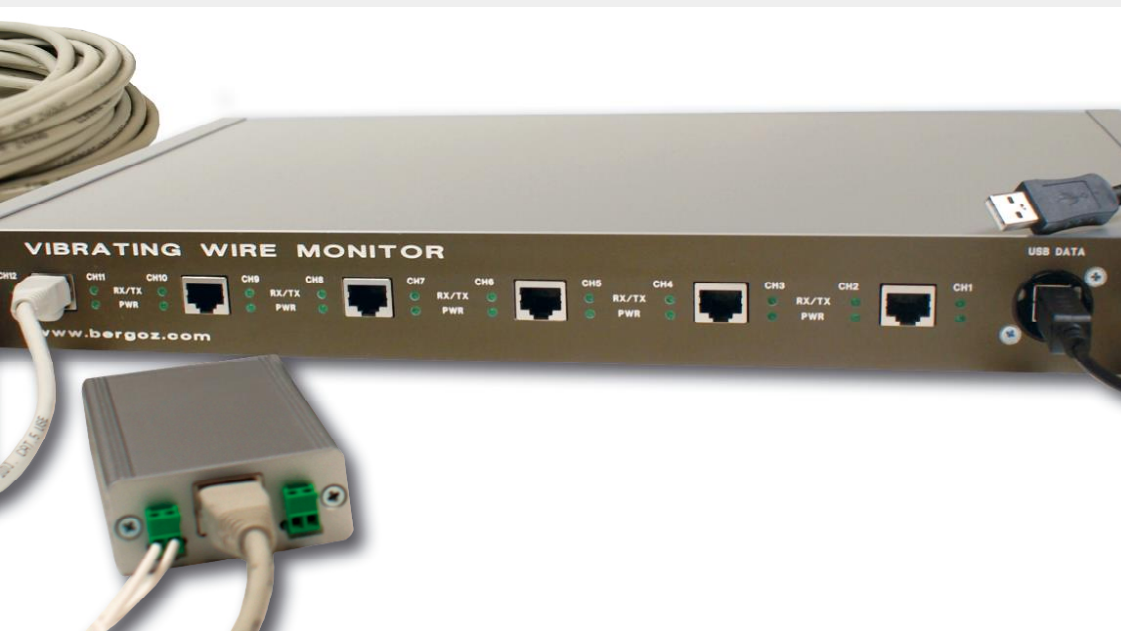
Instrumentation

To measure beam transverse profile and HALO

Protons, ions, electrons, photons, neutrons

Thermal resolution : 1 mK (for tungsten wire)

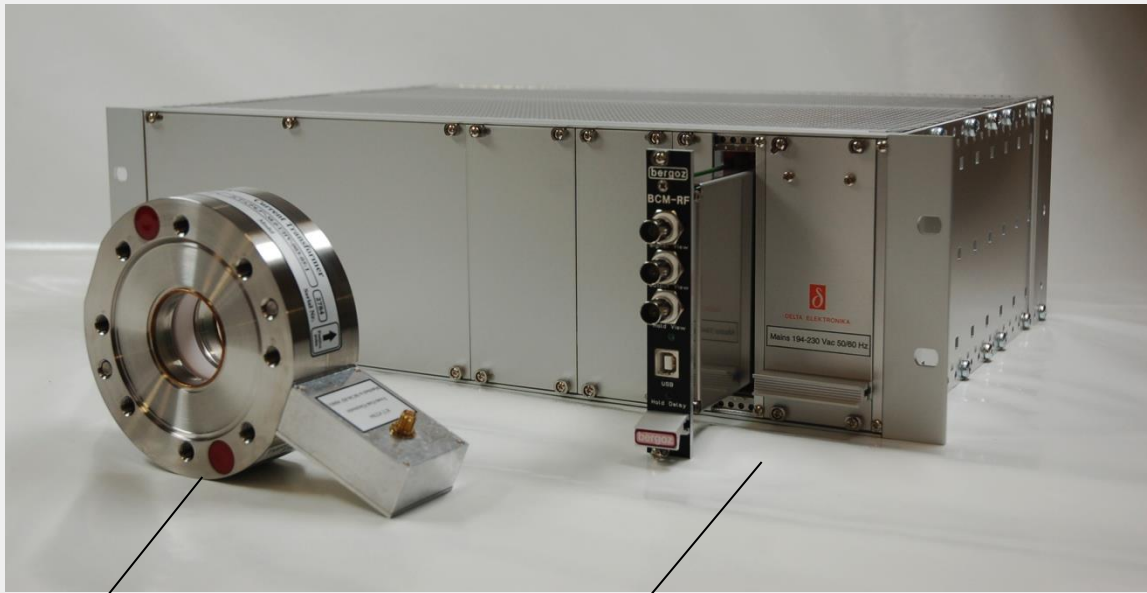
Dynamic range : 10^6



Turbo-ICT and BCM-RF electronics

Low single-bunch charge measurement :

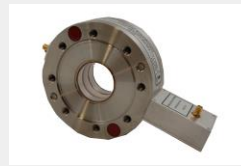
- $< 5 \text{ pC}$ @ 1% resolution « already measured at PSI with beam »
- 2 MHz repetition rate
- 66 dB dynamic range, from 0.1 pC to 200 pC
- could also measured current form CW beam (10 uArms @ 1% resolution)



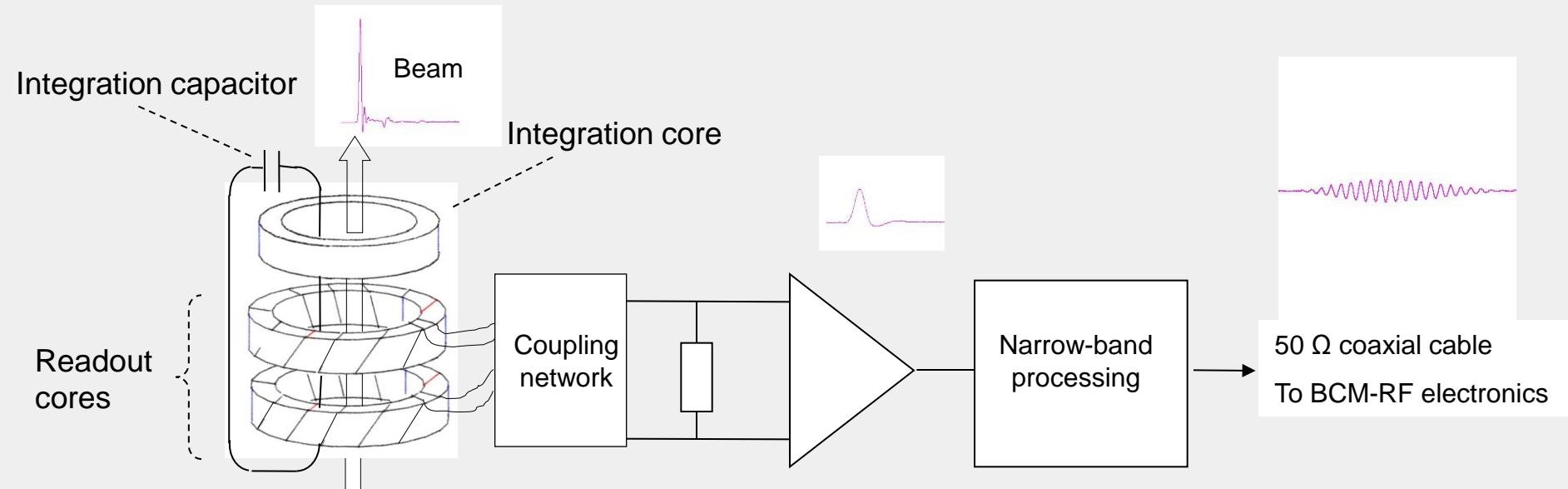
Turbo-ICT with its front-end
(Integrating current transformer)

BCM-RF electronics in chassis
(Beam charge monitor)

Turbo-ICT principle



Instrumentation



- Integration time is reduced by 25 compared to traditional ICT.

\Rightarrow Signal increases by 25 and noise by $\sqrt{25}$.

- Multiple cores (*) could be used to catch more signal from beam.

***Patent INPI 12/00667 March 6, 2012**

- Readout cores are coupled to a low noise amplifier.

- Narrow-band processing. The wide-band signal from the amplifier is converted to a 180 MHz single tone resonance. Apex amplitude is proportional to the bunch charge.

\Rightarrow increases noise immunity.

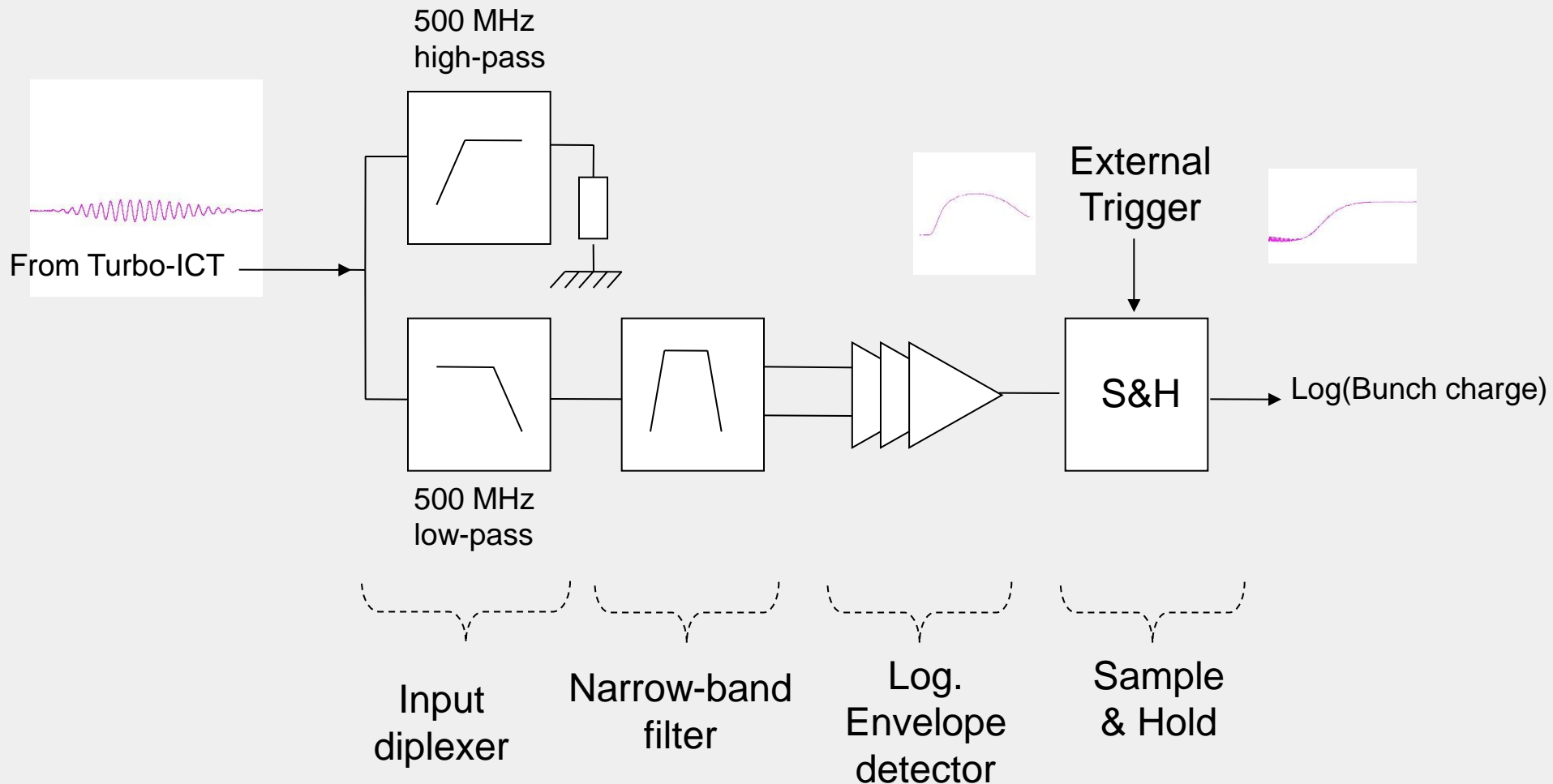
\Rightarrow decreases insertion losses in cable.

\Rightarrow improves impedance matching.

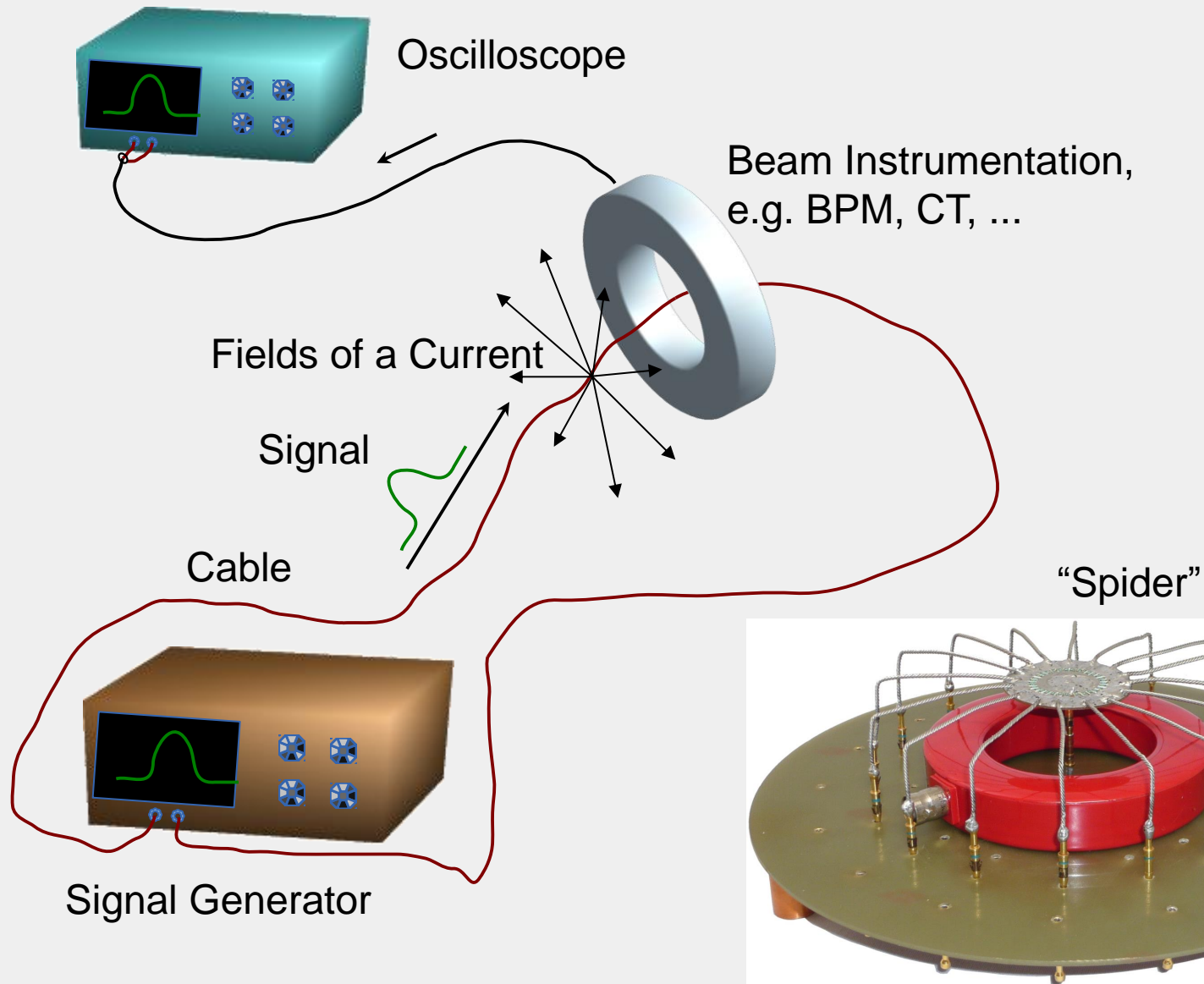
BCM-RF electronics



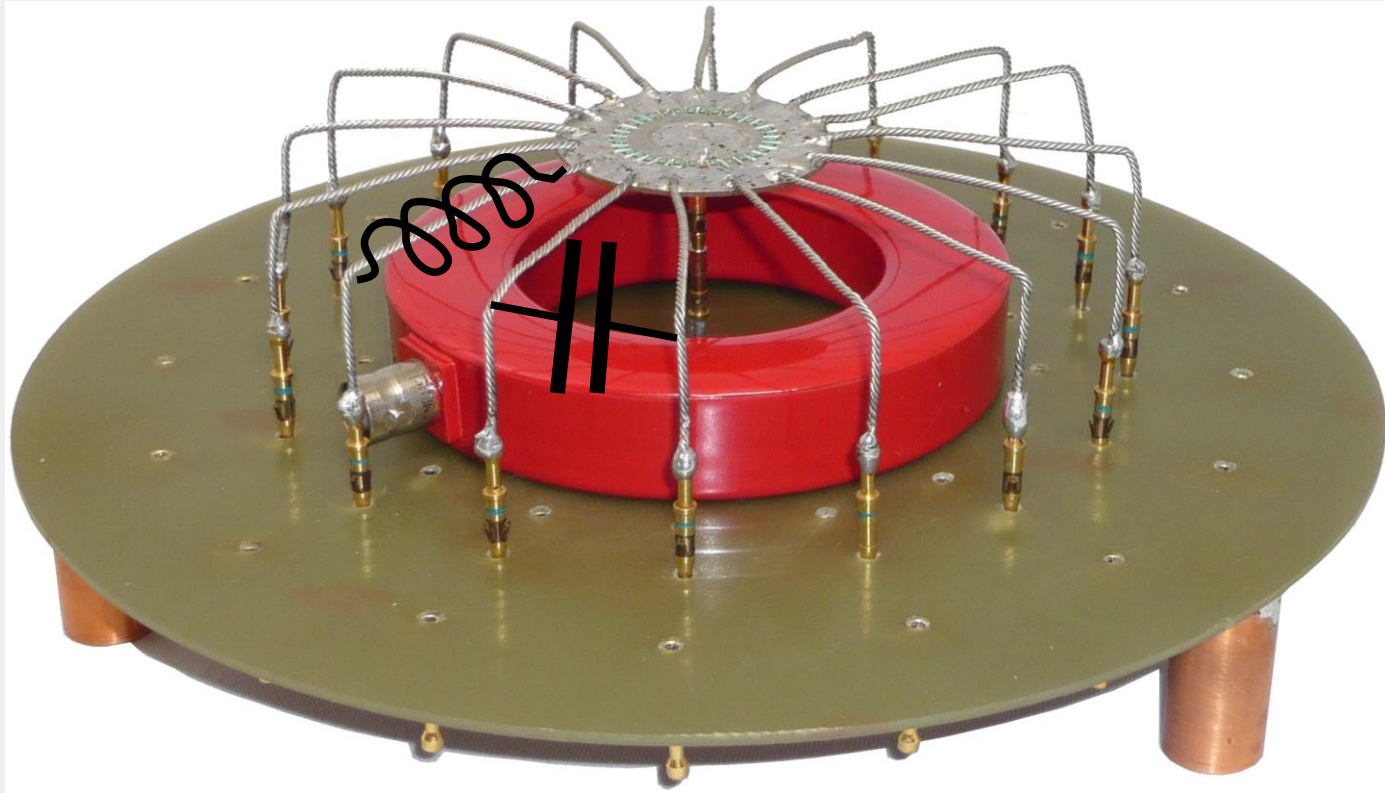
Instrumentation



Bench Testing in the Lab

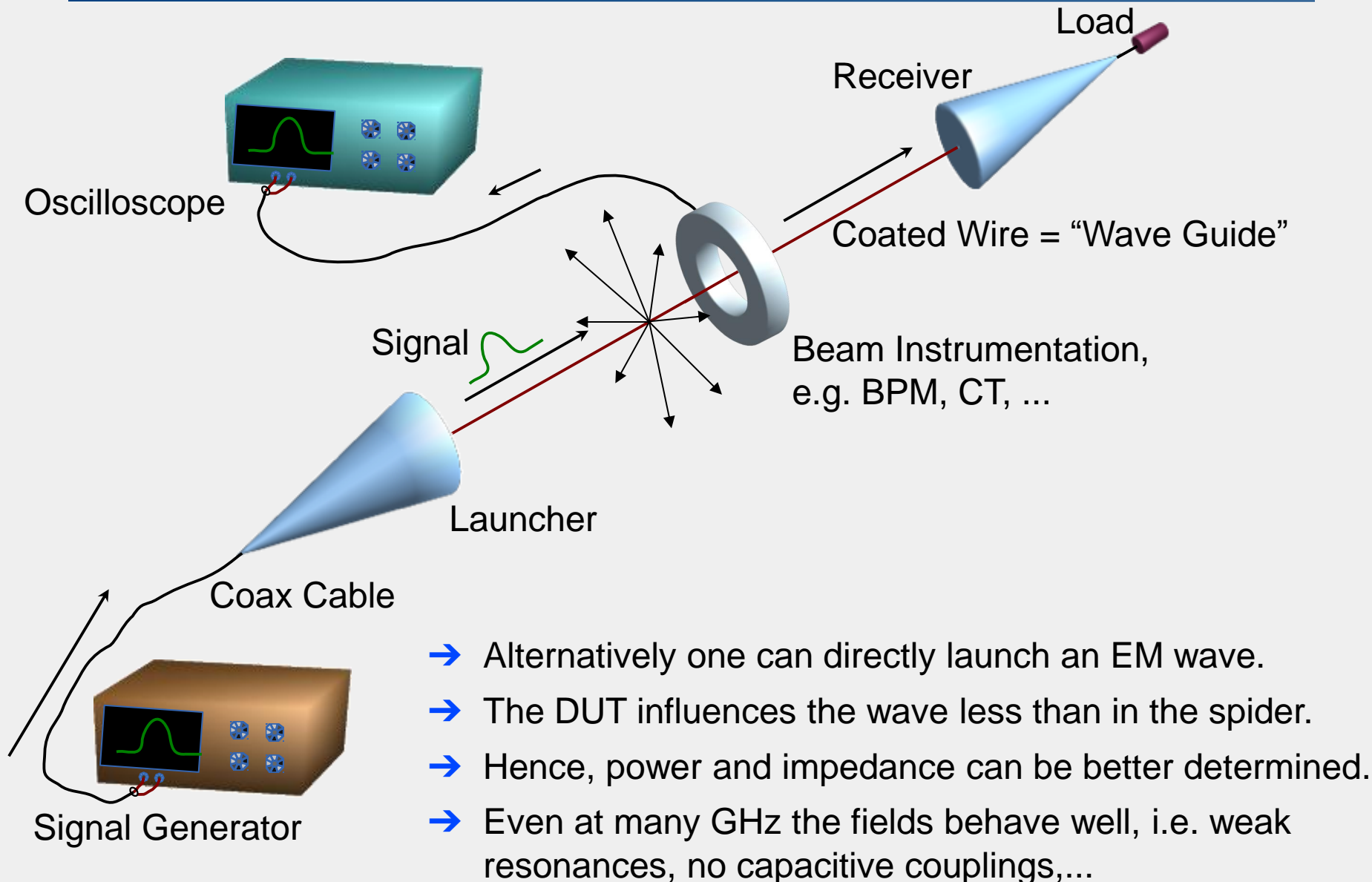


The Spider



- Works well up to some 100 MHz.
- At higher frequencies the impedance is not matched.
- Hence, it gets harder and harder to properly know the current.
- Above 1GHz resonance start to dominate and it is basically impossible to make accurate measurements.

The Goubau Line



EM Field around a realistic Wire

- Solution of Telegraph Equation taking into account imperfections (Sommerfeld 1899, Goubau 1950).
- A fundamental TM mode outside a wire of radius r_w ($r > r_w$) :

radial electric field:

$$E_r = \frac{I e^{i(\omega t - hz)}}{2\pi r_w} \frac{h}{\omega \epsilon} \frac{H_1^{(1)}(gr)}{H_1^{(1)}(gr_w)}$$

like fields around beam of charged particles!

azimuthal magnetic field:

$$H_j = \frac{B_j}{\mu} = \frac{I e^{i(\omega t - hz)}}{2\pi r_w} \frac{H_1^{(1)}(gr)}{H_1^{(1)}(gr_w)}$$

Hankel Functions, i.e. Bessel Functions

longitudinal electric field:

$$E_z = \frac{I e^{i(\omega t - hz - \rho/2)}}{2\pi r_w} \frac{g}{\omega \epsilon} \frac{H_0^{(1)}(gr)}{H_1^{(1)}(gr_w)}$$

Linac:

Waveform observation with FCT / ACCT

Beam position monitoring with Log-ratio BPM

Charge measurement with ICT and BCM / Turbo-ICT and BCM-RF

Linac-to-booster transfer line:

Waveform observation with FCT

Beam position monitoring with Log-ratio BPM

Charge measurement with ICT and BCM/ Turbo-ICT and BCM-RF

On the Booster:

Stored beam current with NPCT, injection efficiency

Beam position monitoring with MX-BPM or LR-BPM

Beam Loss monitoring with BLMs

On the Booster-to-storage ring Transfer Line:

Charge extracted from the booster and injection into storage ring
with ICT and BCM / Turbo-ICT and BCM-RF or NPCT

Beam position monitoring with Log-ratio BPM

On the storage ring:

Stored beam current and lifetime measurement with NPCT

Closed orbit position measurement with MX-BPM

First turn position measurement with LR-BPM

Beam loss monitoring with BLMs.....

End of Presentation