EMI Effects at TTF
(ElectroMagnetic Interference)

Tatsiana Klimkovich
DESY

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Content

- What is EMI?
- EMI influence on Machine side
- Possible influence on ILC Detector
- Next steps

Resources

- LCWS 05 at Stanford
- MDI Workshop 2005 at SLAC
- Meeting „EMI Improvements at TTF“
- Talking to machine people
- Talking to VTX detector people

EMI Definition

- (From Holger Schlarb and Peter Göttlicher)
- **EMI = Electromagnetic Interference**

Unwanted electromagnetic emissions, generated by electronic or electrical devices, that degrade the performance of another electronic device.

The interference is produced by a source emitter and is detected by a susceptible victim via coupling path. The coupling path may involve one or more of the following coupling mechanisms:

- **Conduction (electric current)**
- **Radiation (electromagnetic field)**
- **Capacitive coupling (electric field)**
- **Inductive coupling (magnetic field)**

Maximum acceptable levels of EMI from electronic devices are detailed i.e. by the FCC = Federal communications commission (US)

EMC Definition

- EMC = Electromagnetic compatibility

The ability of a device, unit of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

Common methods of noise reduction:

proper equipment circuit design, shielding, grounding, filtering, isolation, separation and orientation, circuit impedance level control, cable design, cable distribution, and noise cancellation techniques.

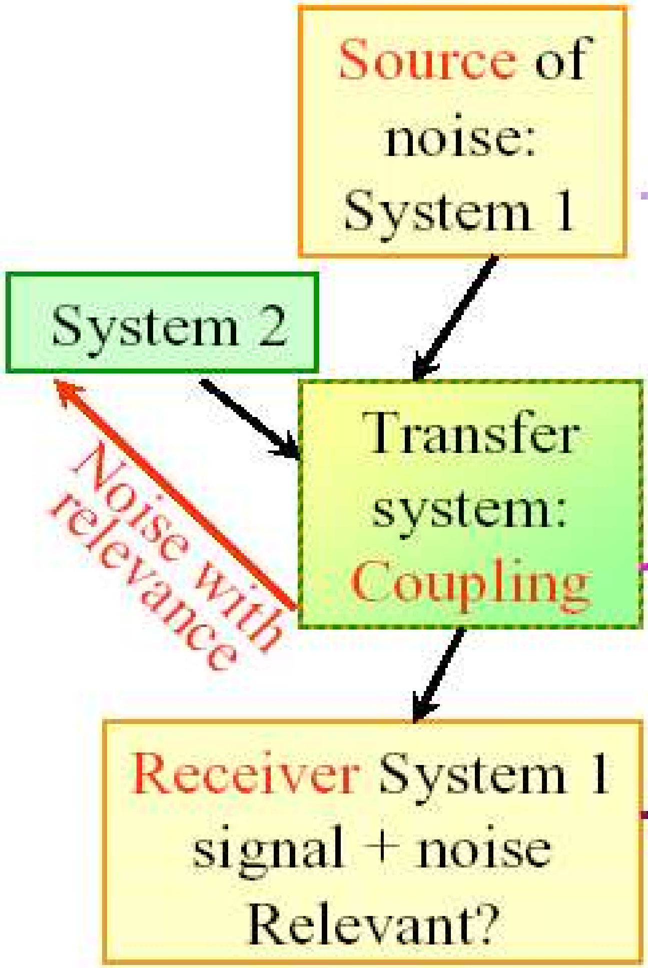
EMC at DESY

EMC is regulated in EU: legal character,
but DESY as self-user of developments needs not to certify!
Requirements on devices might be even more stringent as legal!

Motivation for EMC

- System-Integrity: Function of large system only successful if the perturbation of the sub-systems to each other is small.

Motivation for EMC



Digital electronics
Switching power supplies
DC/DC converters
Malfunction of analog electronic
⇨ Electronic design,
⇨ Choose of commercial products

Protection ground (PE)
Parallel cables
Current loops
Radio waves, not seen since long
⇨ Infrastructure
⇨ Electronic design

Current through receiver
Voltage level shifts
⇨ Electronic design

No system is perfect: Neither:
Source, Coupling, Receivers
⇨ Do your best/adequate at each

Normally: Technique for
low emission⇆low sensitivity

Courtesies: P. Göttlicher

EMI Sources at DESY

- **Pulsed operation:** The combination of
  - high pulsed currents and voltage sources (source emitter) and
  - the need of high precision measurements with sensitive equipment (susceptible victim)

is especially critical (transient effects).

DC & pulsed systems:

- **DC:** magnets, cryogenics, vacuum, interlocks (most), PS general, controls, synchronization, laser systems for diagnostics

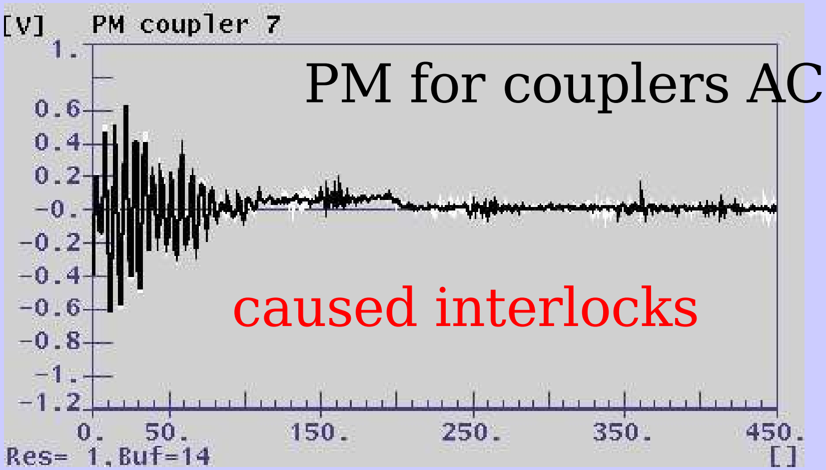
- **Pulsed:** RF, beam, beam measurements, interlock, laser (photo-cathode, pump-probe)

Observed EMI frequency range at TTF: hundreds kHz – tens MHz

Example: EMI in PMs due to pulsed power cables (modulator to klystron)

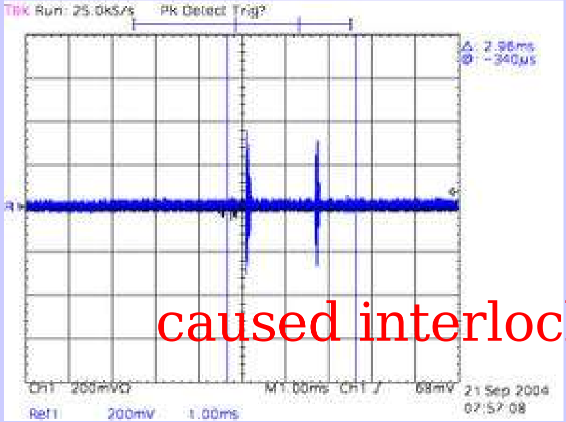
- when first time connected to klystron 5 (operating ACC2&ACC3)

PM for couplers ACC4



caused interlocks

PM for gun coupler



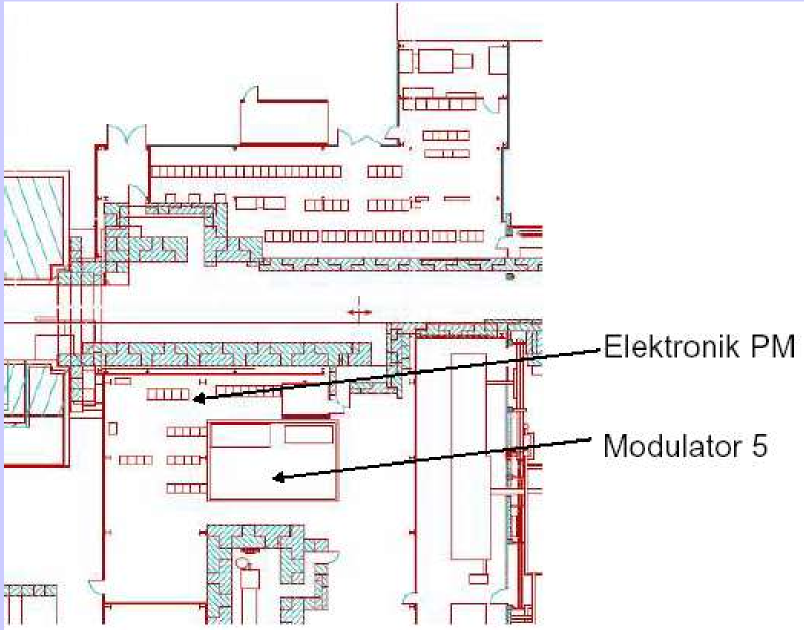
caused interlocks

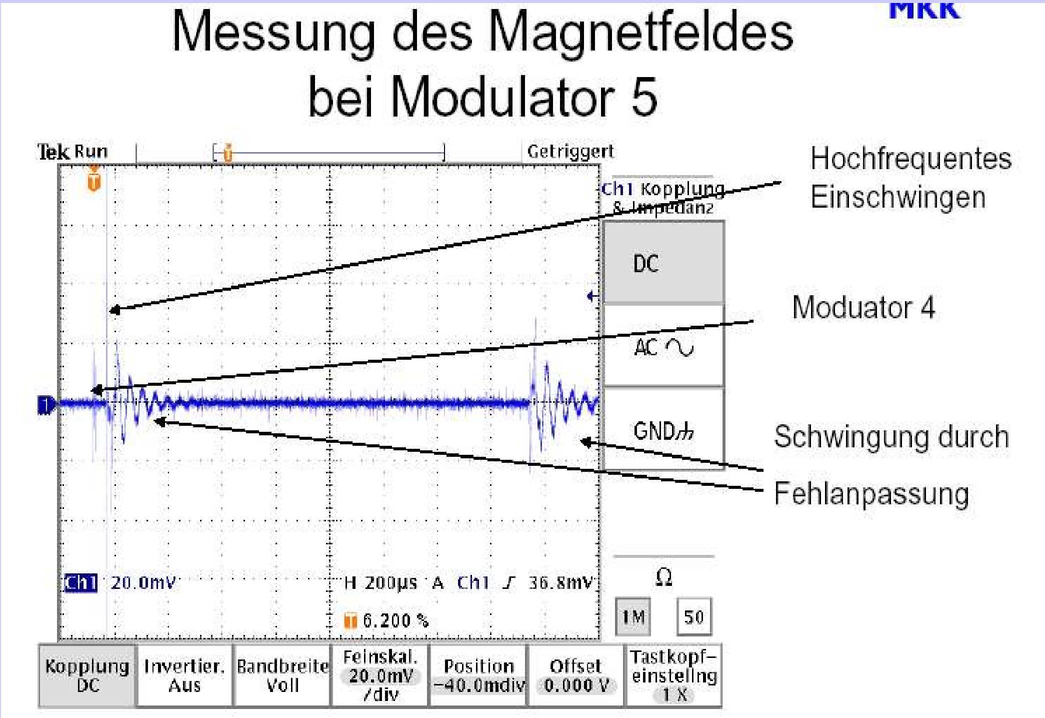
Logbook entry: 17.09.2004 13:41
O.Hensler
Subject: Pulsed cables of modulator 5: During the puls cable tests some weeks ago, we had problems to connect our VME to the CANbus readout. The VME crates went to overtemperature and switched off. Was ok the last two days, after we connected the VME chassis to rack ground
When the Modulator 5 is running, the use of walkie-talkie is impossible ! (C.Mueller)

Example: Investigations pulsed power cables

- lower noise signal due to improved grounding
- some investigations on radiation from cables done
- improved adaptation network required
- still too high current flow on outer cable shield

Location:





Goals and projects
(from EMI TTF meeting)

Goals (need to be defined):

- voltage or currents on ground < … i.e. 1V/1A
- ADC noise level < 1mV
- no impact of other machine operations … PETRA
- EM radiation reduction to … outside/inside tunnel
- effective shielding and protections against EMI

Projects:

- online monitor system of EMI (e.g. 20 represent channels, DAQ)
- certification standards for XFEL
- HV redistribution
- pulsed cable investigation and impact studies for ILC
- ground scheme for the XFEL
- documentation of devices, source

EMI Influence on Detector

- Not investigated yet
- Till now RF pickup was not observed at TTF (only kHz-MHz)

Except pyroelectrical detector people (bunch length measurements)

Possible reason for not seeing RF pickup: no detectors close to the beam pipe

Possible source of RF pickup: wakefields at the IP

➔ Proper beam pipe design at the IP

➔ Smooth charge flow in the pipe (careful with beam diagnostics etc.)

Beam RF Effects Summary
From MDI Workshop, Jan. 2005

Significant impact on:
- RF shielding for beamline and detector components
- Detector design
- Signal Processing and DAQ architecture

Beam rf effects have had a significant effect at previous colliders:

ex. SLC, PEP-II, HERA, UA1
beampipe heating and EMI from HOMs

Detector physicists MUST study this seriously together with the accelerator experts

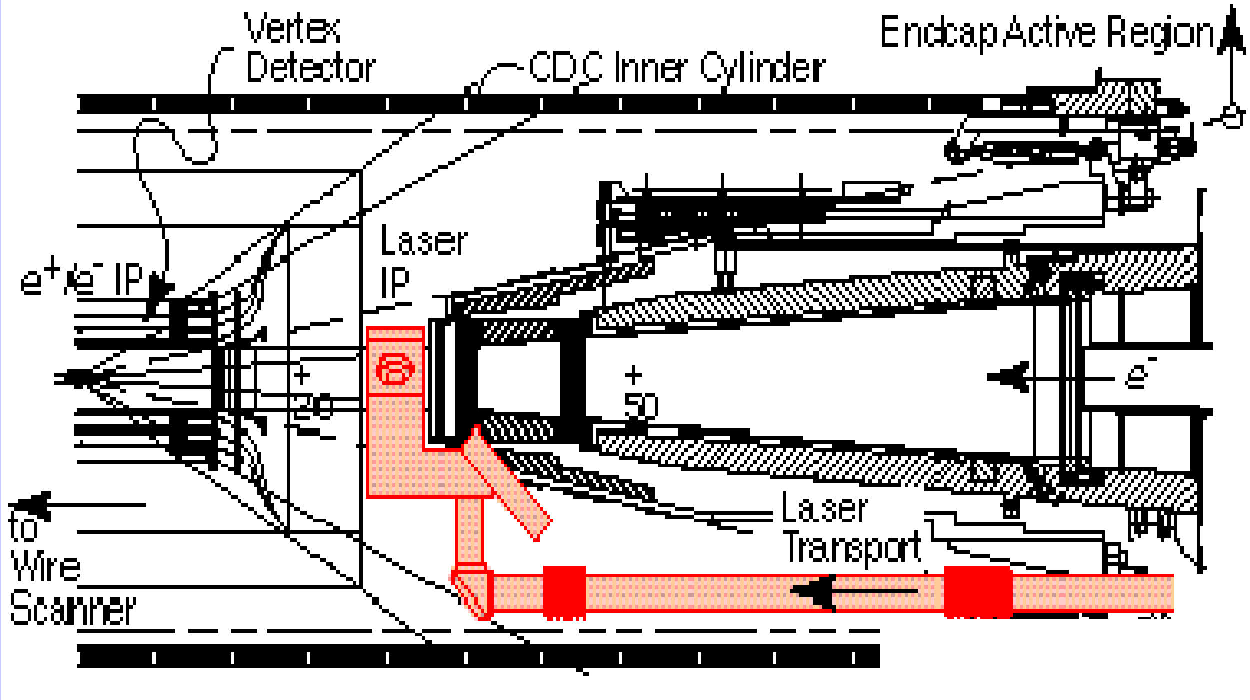
Beam Test at SLAC ESA to further investigate this is proceeding:
- with SLD's VXD3 and with simpler beampipe
- strong desire for this from international vertex community
- can provide important information for VXD design and for signal processing/DAQ for all LC Detector systems

Beam RF effects at Colliders (M. Woods)

SLC

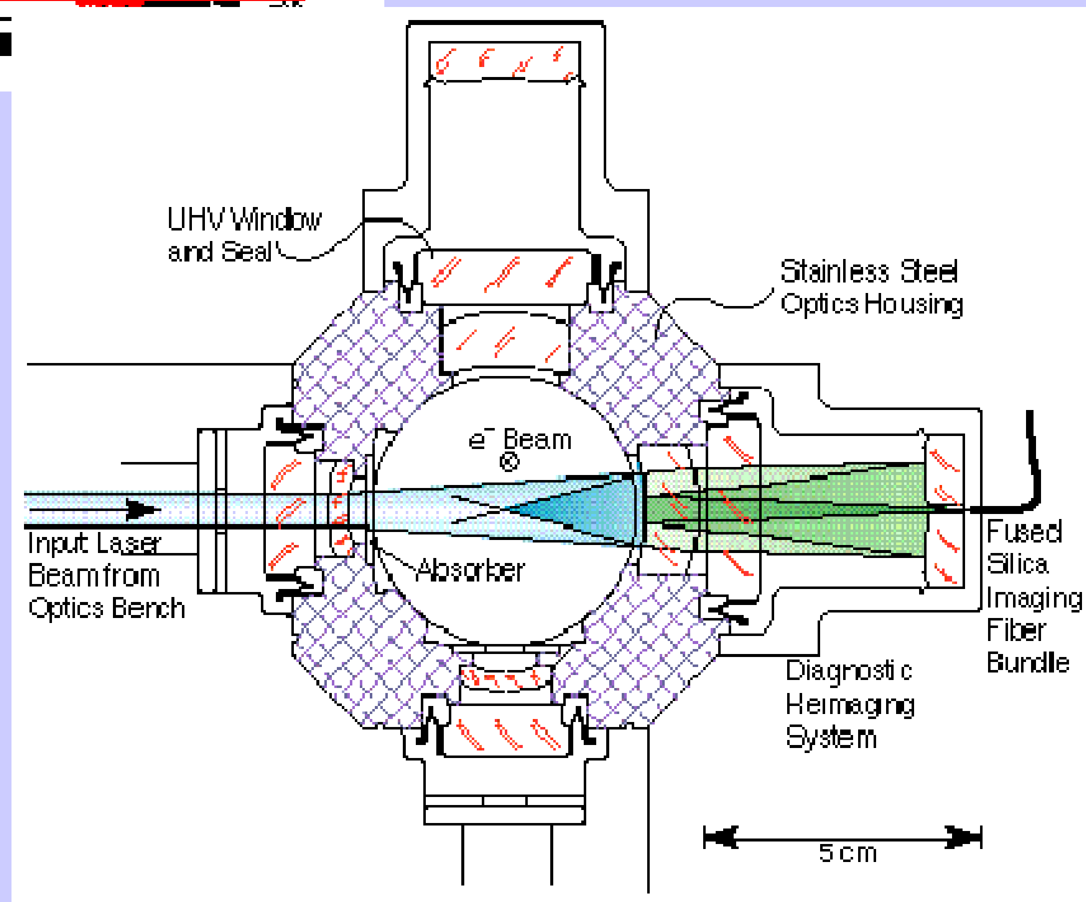
Problem for SLD VXD3 Detector

- Loss of lock between front end boards and DAQ boards
- Solved with 10 μsec blanking around beam-time – front end boards, ignore commands during this period
- with VXD2 had access to analog signals; observed saturation for some μs after each bunch crossing
- Will not be able to do such trick with ILC, as we need continuous reedout during bunch train



SLD

What can be the possible source?



Solutions for RF pickup? (Machine)

An RF shield in the IR was included in the NLC ZDR

The RF shield and septum were proposed to reduce possible wakefield effects in the IR including RF heating as well as beam deflections.
But: the RF shield is a significant source of backgrounds due to the scattering of the e+/e- pairs from the IP

If the IR beampipe were a smooth hermetic gun barrel, there would be no issue. But the IR geometry is complex with a crossing angle geometry, BPMs, pumps, …

It was revisited and concluded it was not needed to reduce RF heating and wakefield kick effects

Solutions ? (Detector)

Impact of Beam RF Effects on Detector Design and DAQ Architecture?

Do EMI worries necessitate storing signals locally for readout to DAQ during (quiet) inter-train period?

VXD

- **CCD small signals; 20-micron pixels nead readout 20X per train to have acceptable occupancy/pixel**

To avoid RF pickup:

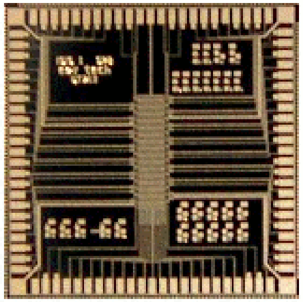
- **ISIS proposal: CCD Image Sensor with In-Situ Storage**
  - **800M pixel detector → 800M (image) x 20 (storage) pixels!**
  (see talk by C. Damerell at LCWS 2004)
- **FPCCD proposal: 5-micron CCD pixels → 13 Giga-pixels!**
  (see talk by Y. Sugimoto at ACFA Nov. 2004 Workshop)

Other Systems sensitivity and DAQ architecture

- **in particular for forward region detectors with large occupancy**
- **SiD electronics design (see Marty's talk) does local storage of signals for inter-train readout**

ISIS R&D

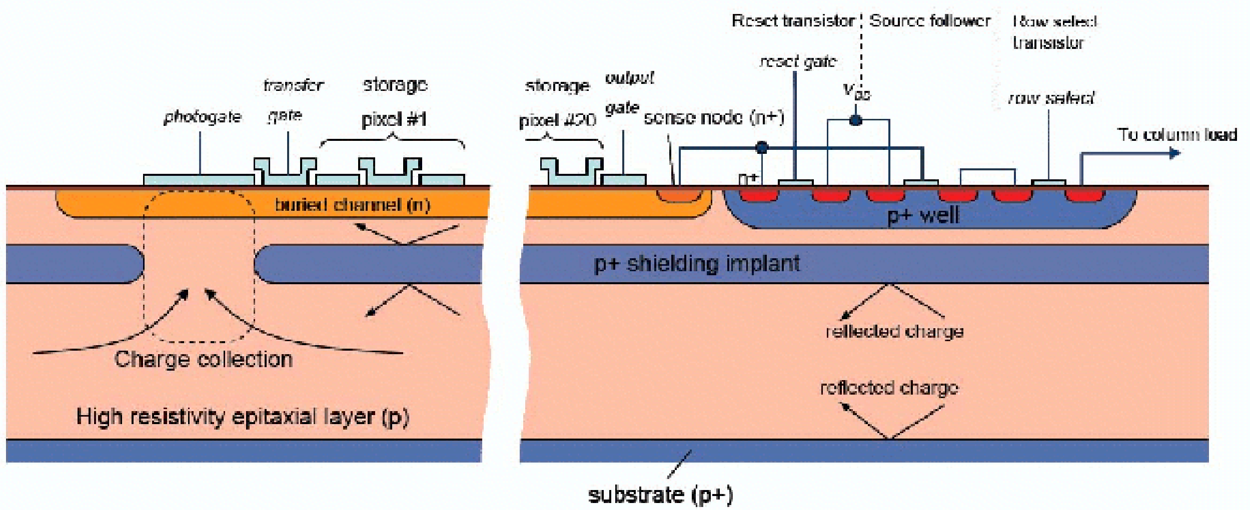
- **Additional ISIS advantages:**
  - **~100 times more radiation hard than normal CCDs – less charge transfers**
  - **Easier to drive because of the low clock frequency**
- **ISIS combines CCDs, active pixel transistors and edge electronics in one device: specialised process**
- **Development and design of ISIS is more ambitious goal than CPCCD**



Edge logic for row selection and clock gating not shown

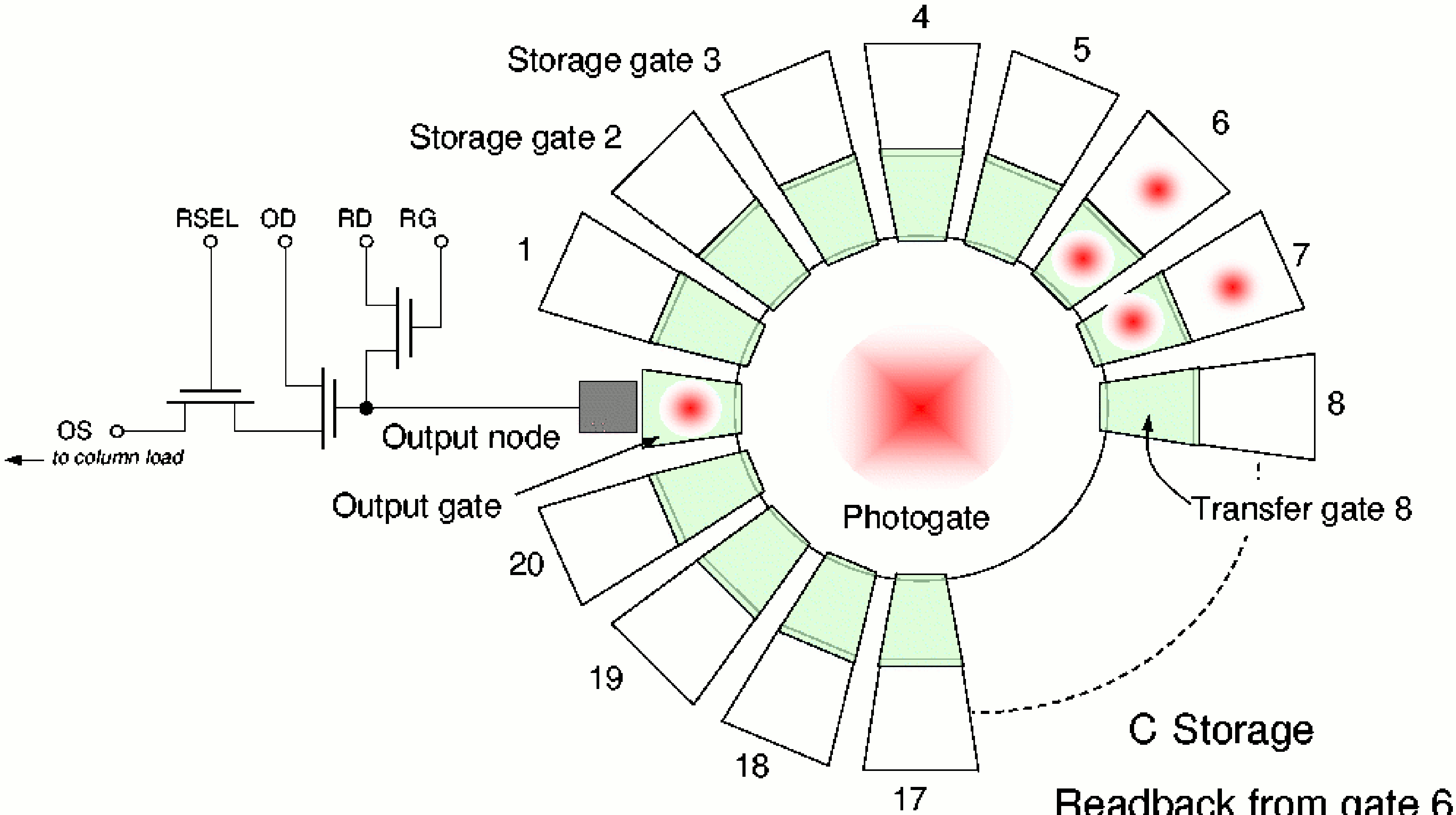
- **"Proof of principle" device (ISIS1) designed by E2V:**
- **16×16 array of ISIS cells with 5-pixel buried channel CCD storage register each;**
- **Cell pitch 40 μm × 160 μm, no edge logic (CCD process)**

ISIS R&D



- **RF pickup is a concern for all sensors converting charge into voltage during the bunch train;**
- **The In-situ Storage Image Sensor (ISIS) eliminates this source of EMI:**
  - ❖ **Charge collected under a photogate;**
  - ❖ **Charge is transferred to 20-pixel storage CCD in situ, 20 times during the 1 ms-long train;**
  - ❖ **Conversion to voltage and readout in the 200 ms-long quiet period after the train, RF pickup is avoided;**
  - ❖ **1 MHz column-parallel readout is sufficient;**

Revolver ISIS



Idea by D. Burt and R. Bell (E2V)

Tools

- SLD VXD3 and R20 module still available
  - Have a system that we know suffered from beam related EMI
    - Use it as a test to attempt to understand origin of EMI that affected it
- Also need to understand effects such as bunch length/charge
  - Points to using SLAC testbeams

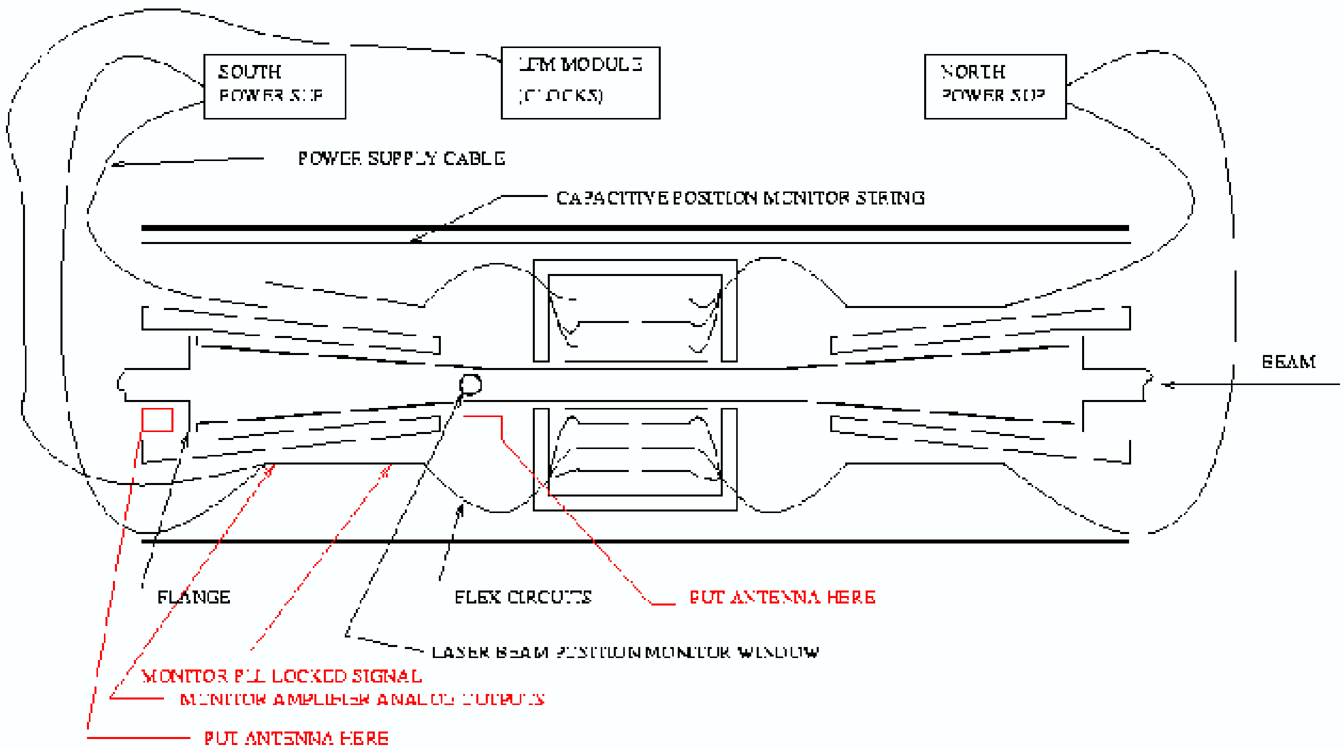
What can we measure

- First, we can try to reproduce failure mode of VXD3 front end electronics. We need to monitor lock signal from PLL. We can put scope probe on the PLL output, or just watch LFM "Link error" red LED.
- We also can put antennas in suspected leak locations and watch signals on them.
- If we are lucky to reproduce failure of VXD3 link, we can try to find out what modification of the shielding / grounding can eliminate such effect. In any case we can measure antennas signal dependence on bunch length and charge and such things as additional beam pipe shielding. And of course we can understand interference signal dependence on the distance from beam pipe. Can it be the problem for another front end electronics, or is it only Vertex Detector concern?

What can we measure - continue

- The measurements with real SLD R20 module will give us confidence, that we can reproduce EMI effect. But the module has too complex geometry for calculations or simulations. So, we may want to try to do comprehensive measurements of EMI with simpler beampipe, in which case we can compare results with calculations and validate our model of EMI effects. From practical point of view we may want to begin measurements with plain beampipe, and use R20 as next step.

Equipment - continue

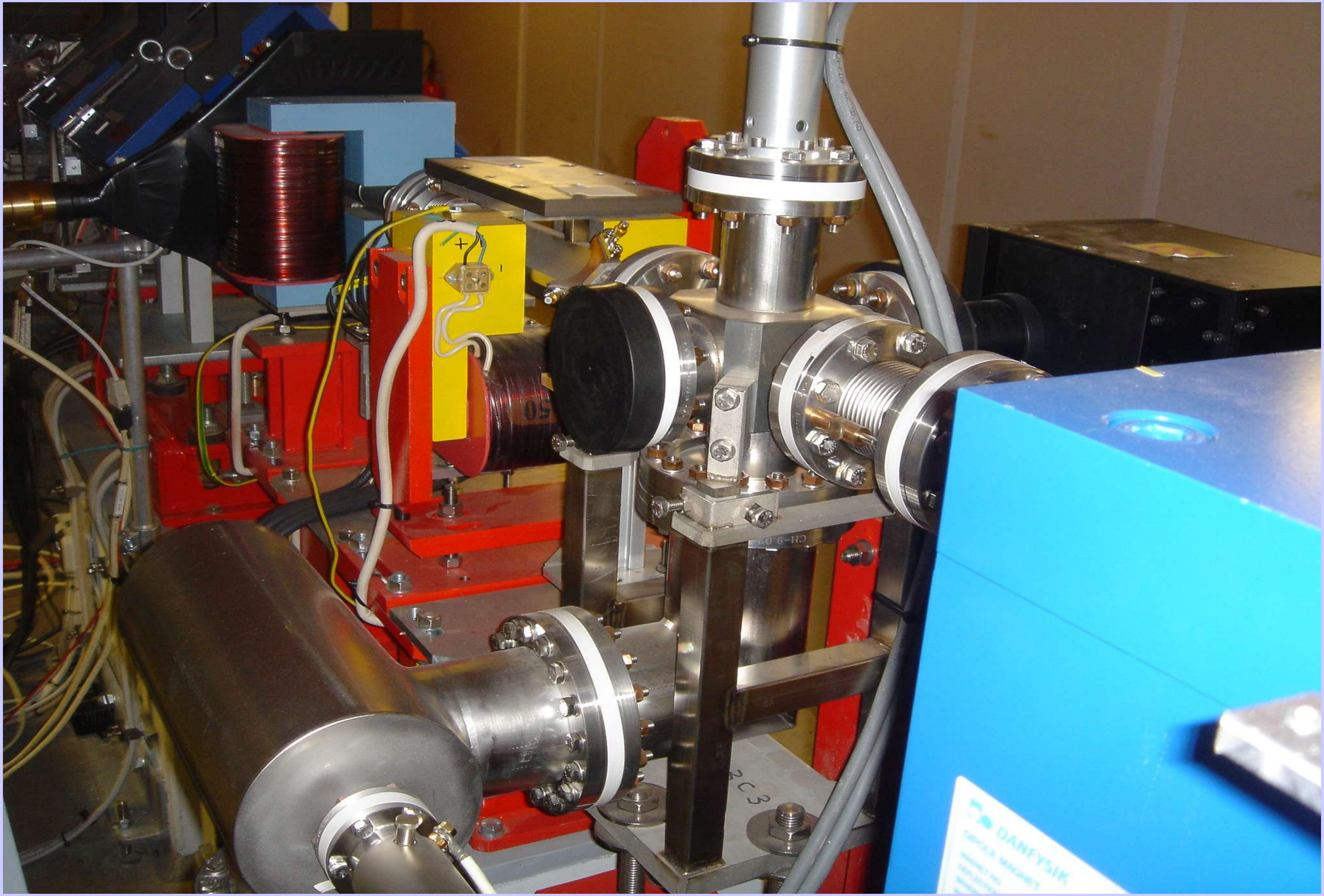


- What can we monitor

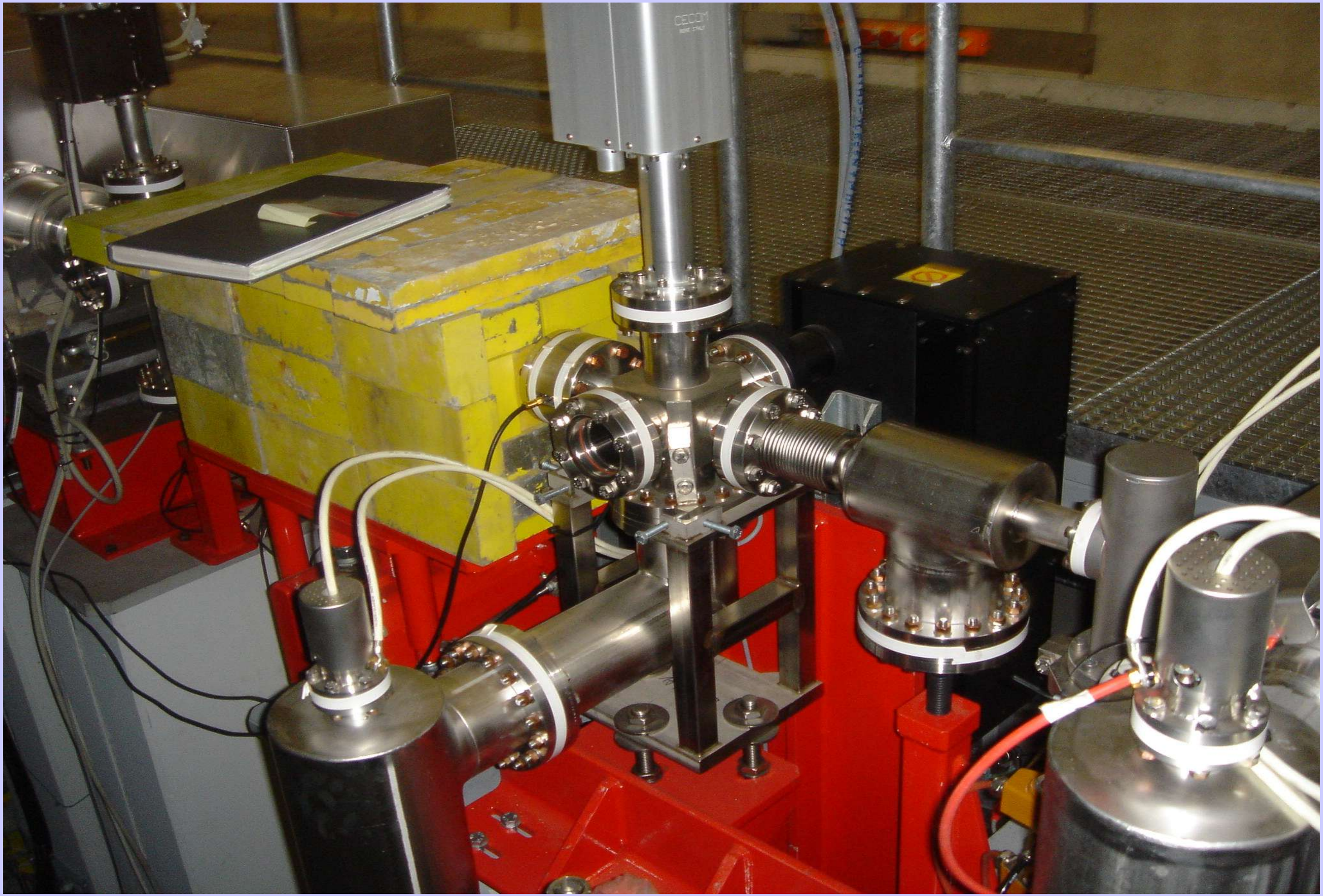
RF Pickup Tests at TTF ?

- We can check RF pickup at TTF
- Can start with putting antenna and wat-ching signal on it
- Need antenna limited up to 2 GHz
- Not a trivial task to do it
- Not easy to operate it in pulsed regime
- Mafia calculations of the electromagnetic fields (not easy with short bunches)
- Try to put vertex prototype close to the beam?
- Interesting for almost all VTX technologies!

Possible test locations at TTF: OTR Stations



Possible test locations at TTF: OTR Stations



Summary (Machine)

EMI can critical influence on the performance and the cost of the machine

- has big impact on the machine commissioning time!
- Complex subject since:

spans large range in power i.e. from 10kV …. 100 uV
spans large range in frequencies DC …. ~100 MHz
many different groups involved (MKK,MHV-p, LLRF, …)

- Requires:
  - Systematic study of EMI occurrence at TTF2
  - Needs assessment of the various subsystem (TTF2/XFEL/ILC)
  - Development of cost efficient solutions (TTF2/XFEL/ILC)

Summary (Detector)

- Significant impact of EMI on:
  - RF shielding for beamline and detector components
  - Detector design
  - Signal Processing and DAQ architecture
- Detector physicists MUST study this seriously together with the accelerator experts
- Need experimental check
- Possible measurements can be done with TTF beam
- Next steps?

Many thanks for the information and good ideas to
Nicolo de Groot, Uli Kötz, Peter Göttlicher, Holger Schlarb, Nicoleta-Ionela Baboi, ...