Damping Ring and Beam Delivery System Test Facilities

Junji Urakawa (KEK)

for

Mark Palmer (Cornell University), Andrei Seryi (SLAC), Mauro Pivi (SLAC), Yusuke Suetsugu (KEK),
John Flanagan (KEK), Philip Burrows (Oxford),
Grahame Blair (RHUL), Pavel Karataev (RHUL),
Takashi Naito (KEK), Yosuke Honda (KEK),
Susanna Guiducci (INFN-LNF), Andy Wolski (CI),
Janice Nelson (SLAC), Manfred Wendt (FNAL) and so on.

Test Facilities

- **There are possibilities for several test facilities that could play an important role in damping rings and BDS R&D:**
  - **KEK-ATF: in operation for many years. Has already made many important contributions: low-emittance tuning, development of instrumentation and diagnostics, test of fast kickers, fast ion instability studies…**
  - **KEKB: planned R&D programs for the damping rings, including electron cloud studies and so on.**
  - **PEP-II: now being used for electron cloud studies.**
  - **DAΦNE rings: now being used for several R&D's.**
  - **CESR-TA: proposed test facility. Could study a range of beam dynamics issues in wiggler-dominated regime, including low-emittance tuning, electron cloud…**
  - **SLAC-ESA: now being used for device development for BDS.**
  - **KEK-ATF2 project: constructing test facility. Could study ILC-BDS.**
- **The developing R&D plans must take full account of the possibilities afforded by these facilities to address critical issues.**

ATF
Accelerator Test Facility

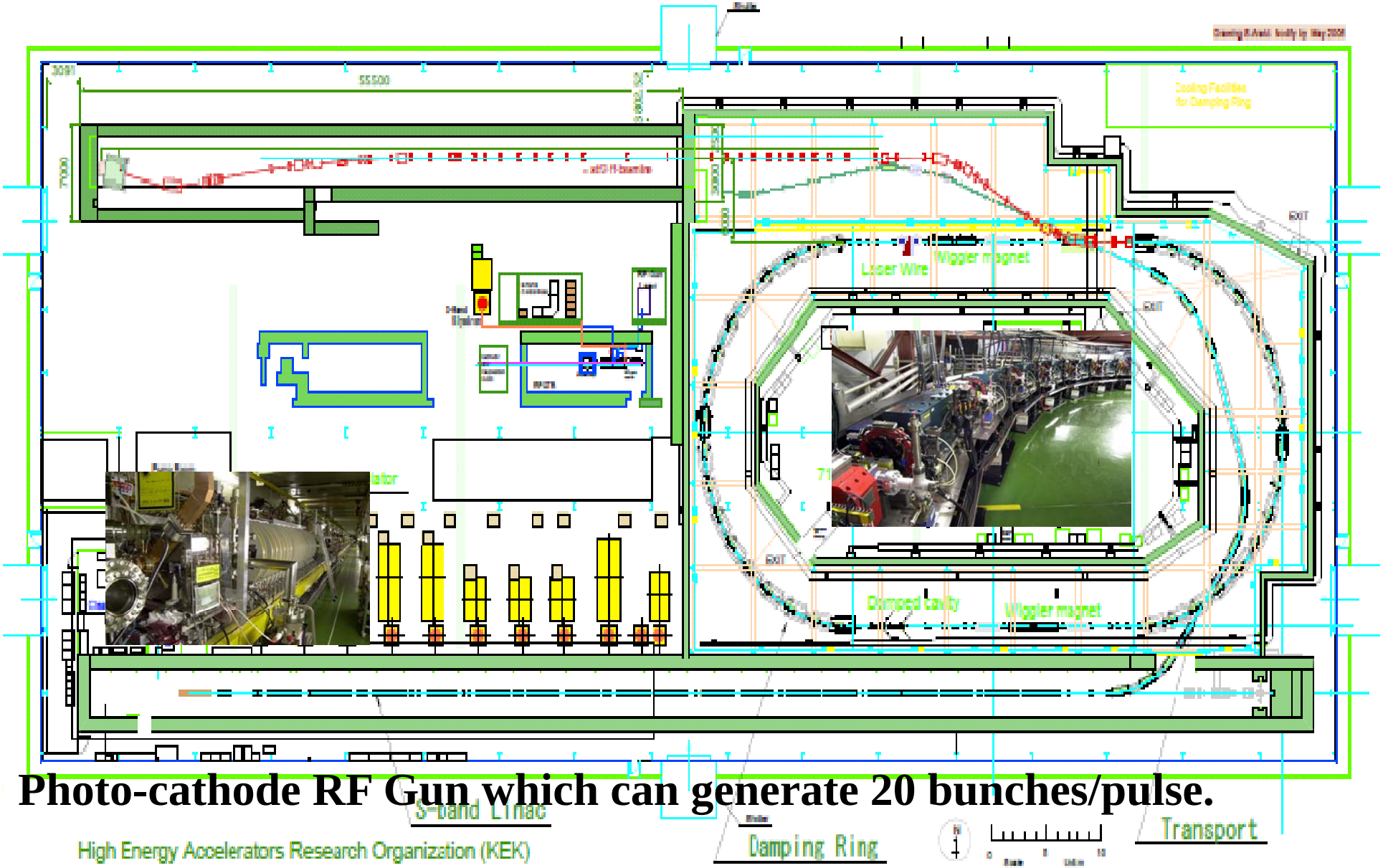
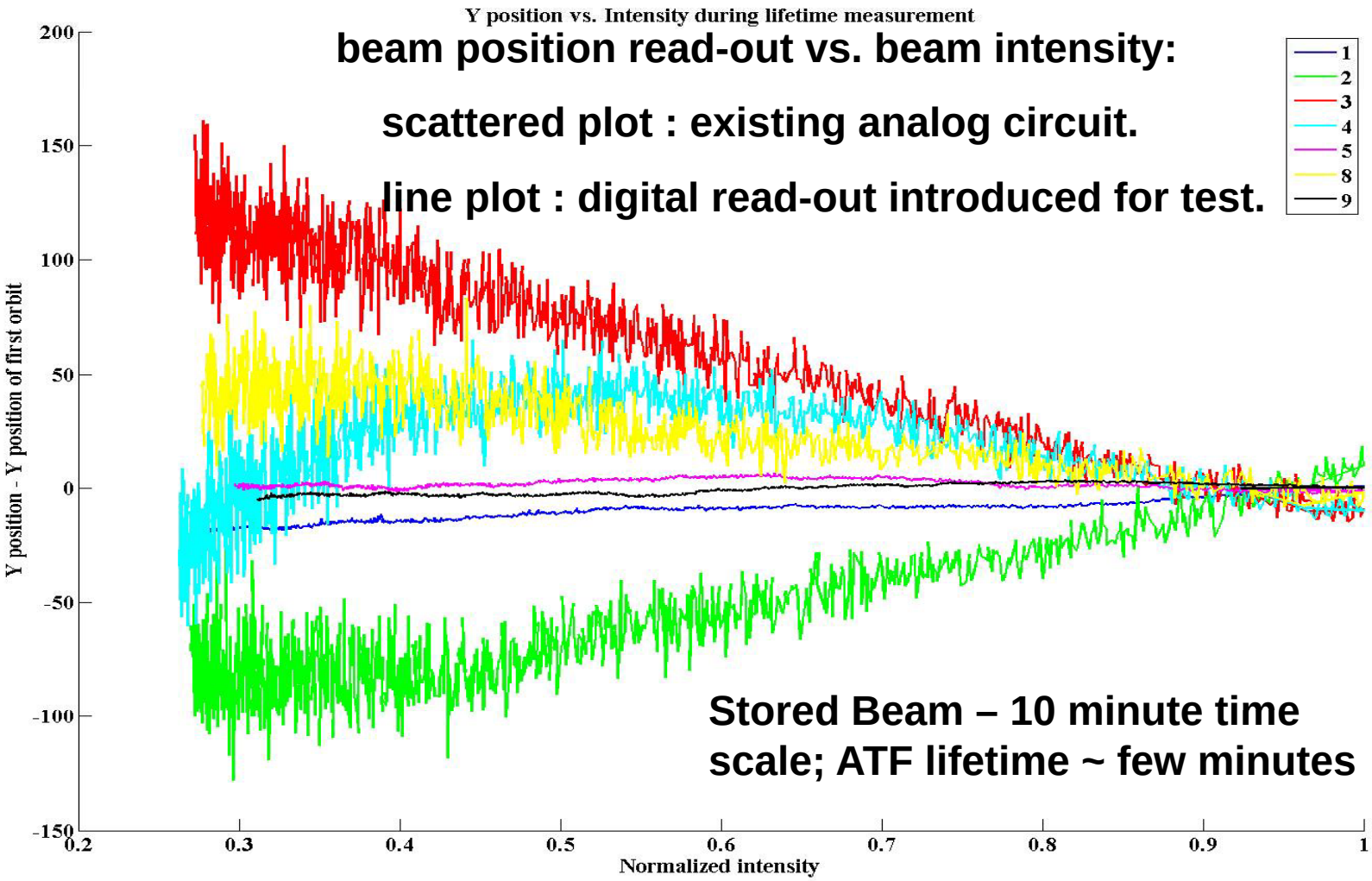


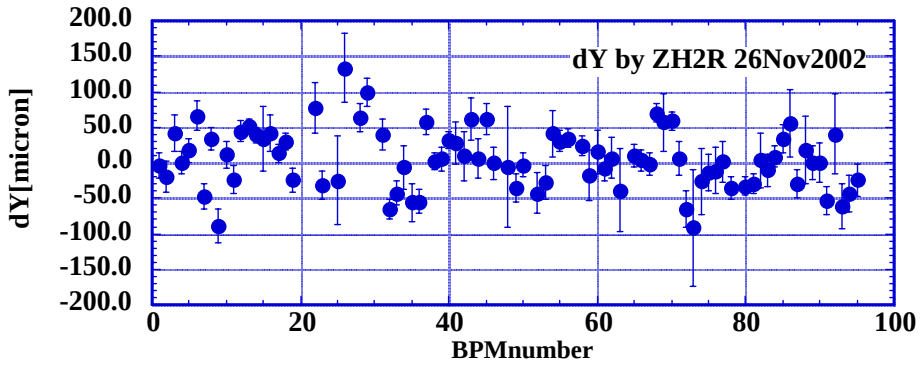
Photo-cathode RF Gun which can generate 20 bunches/pulse.

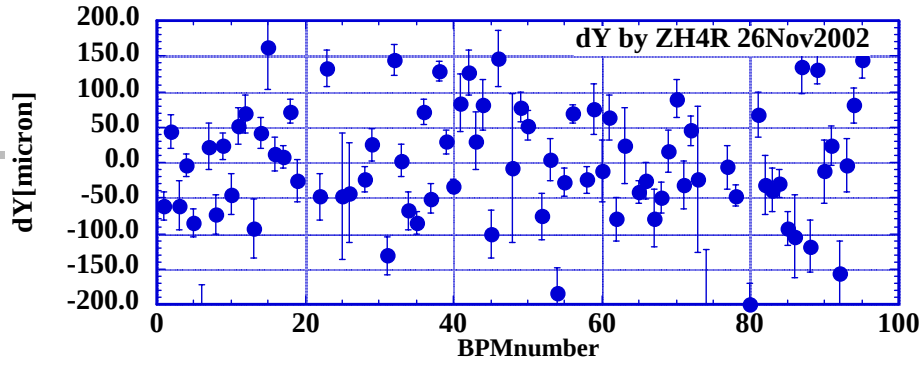
DR BPM resolution improvement by digital read-out system (SLAC, FNAL, KEK)



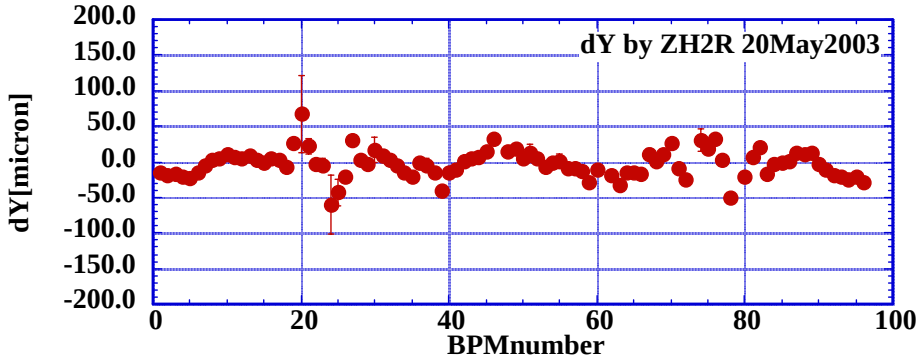
X to Y coupling Improvement

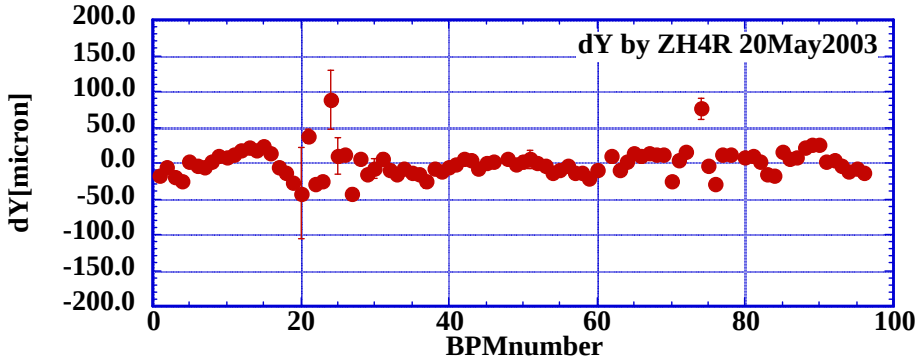
20μm BPM Resolution with old circuit





3μm BPM Resolution with present circuit

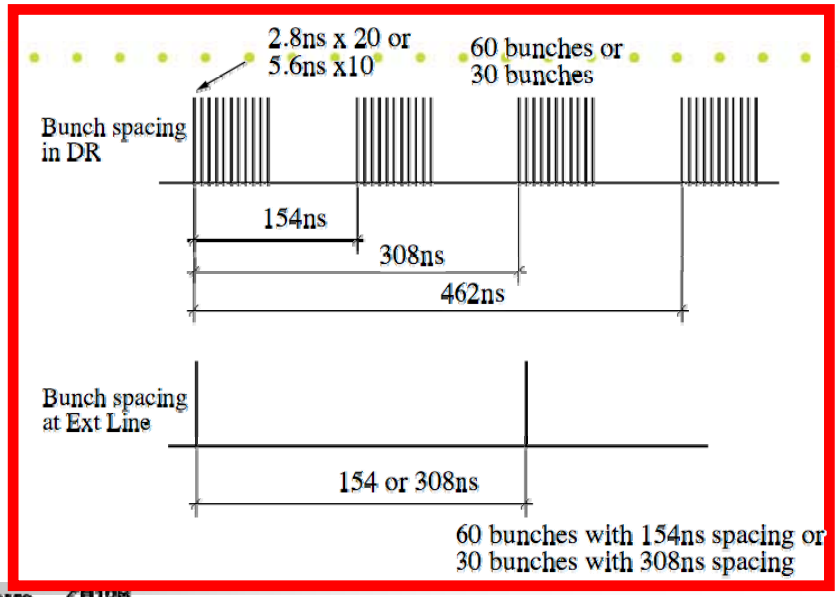


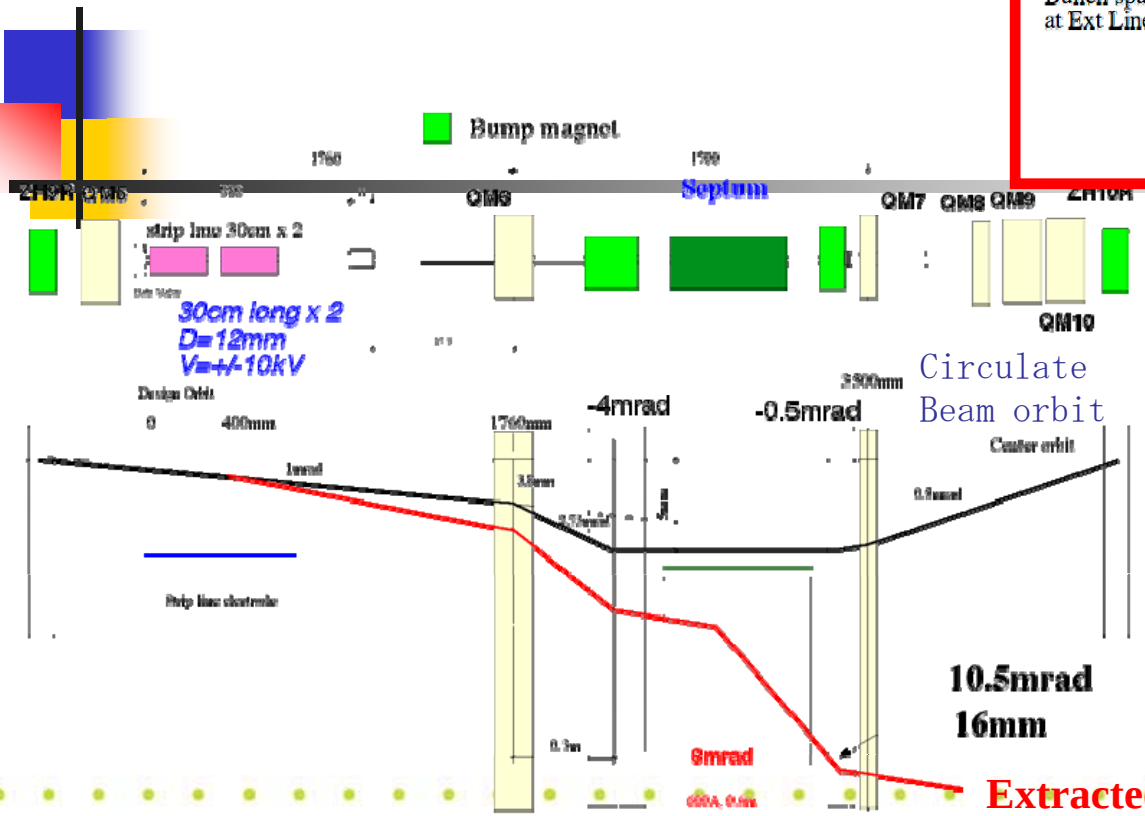


Upgrade of BPM Resolution (~ 0.1μm) with new circuit by SLAC and FNAL. Surely, we will achieve 2pm-rad.

Multi-bunch Beam extraction design for ATF

Multi-bunch Beam extraction by using strip-line kickers and pulse bump orbit system was designed, which can extract up to 60 bunches with 154ns bunch spacing. The space for installation of the strip-line kicker is not enough at the ATF septum region. So the kick angle of the strip-line kicker is not enough to make the beam extraction orbit.





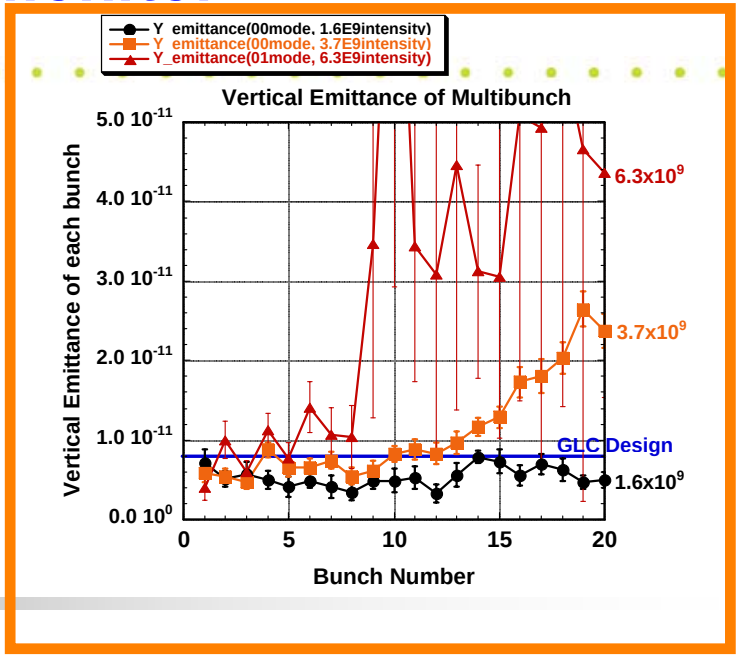
A new design uses pulse bump magnets and a thin septum magnet to help making the extraction orbit. This design makes a bump orbit after the beam damping, then each beam is extracted bunch-by-bunch by the strip-line kicker.

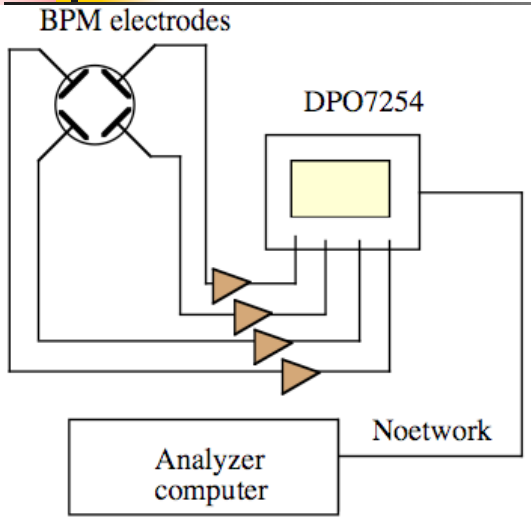
Designed by
T.Nato(KEK)

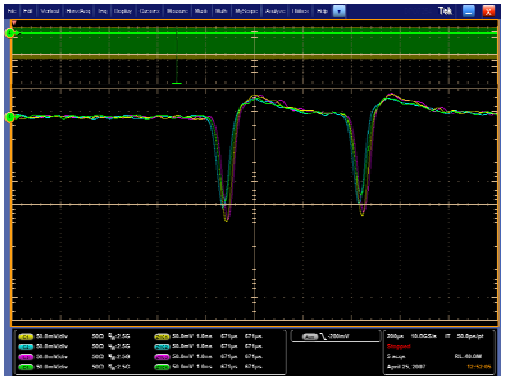
Multi-bunch Turn-by-turn monitor

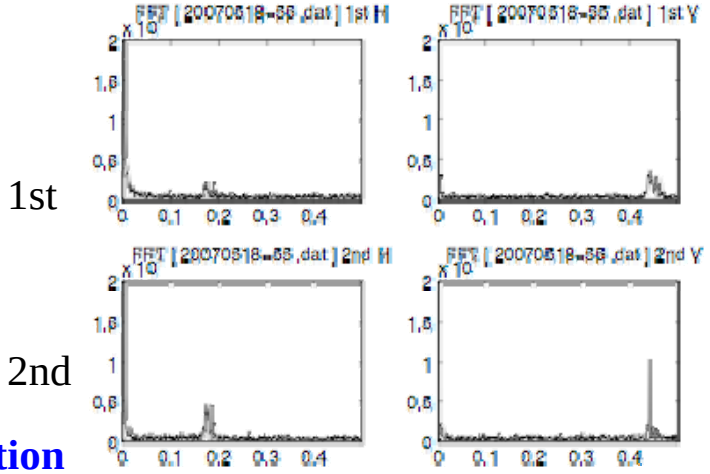
T.Nato(KEK)

The beam blowup at tail bunches was measured by the laser wire in ATF, which is assumed come from FII effect. In order to observe the individual beam oscillation in the multi-bunch beam, multi-bunch turn-by-turn monitor is developing. This monitor consists of front end circuits(amplifier and filter) and DPO7254 scope. The scope can store the waveform up to 2ms with 100ps time resolution.









The preliminary results shows the different oscillation amplitude of the tune-X and the tune-Y for the 1st and 2nd bunches at just after injection.

Diffraction radiation diagnostics

By Pavel Karataev (RHUL)

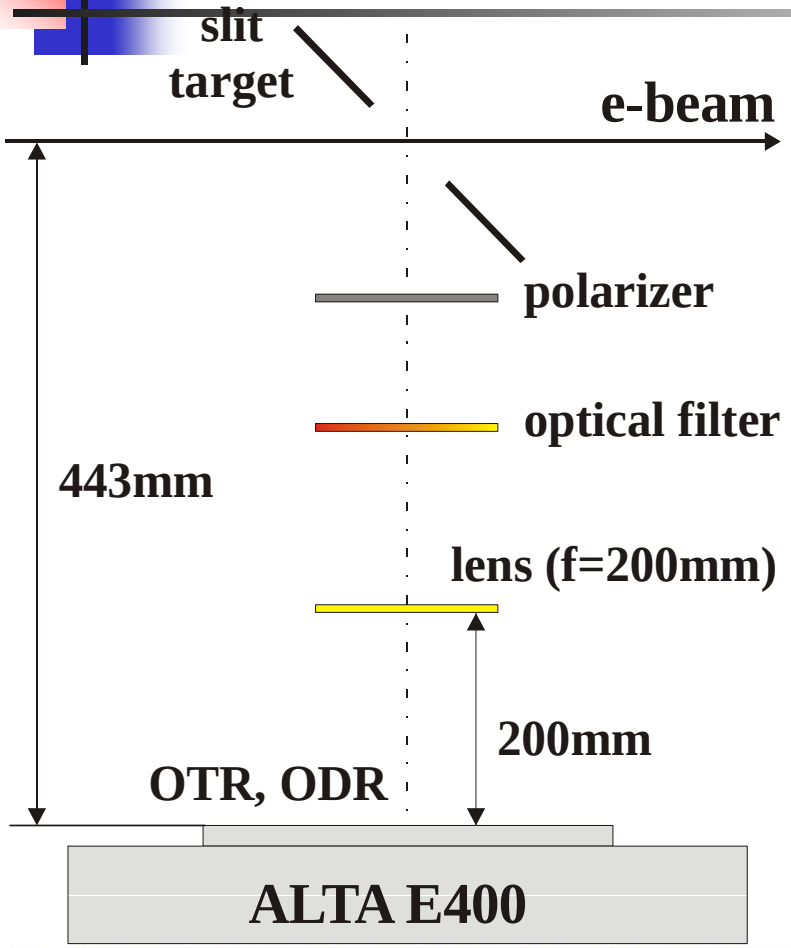
- Non-invasive method - no beam perturbation or target destruction)
- Instantaneous emission - quick measurements
- Single shot measurements - no additional error from shot-by-shot instabilities
- Large emission angles - good background conditions
- High resolution
- Easy to use
- Relatively inexpensive

ODR achievements

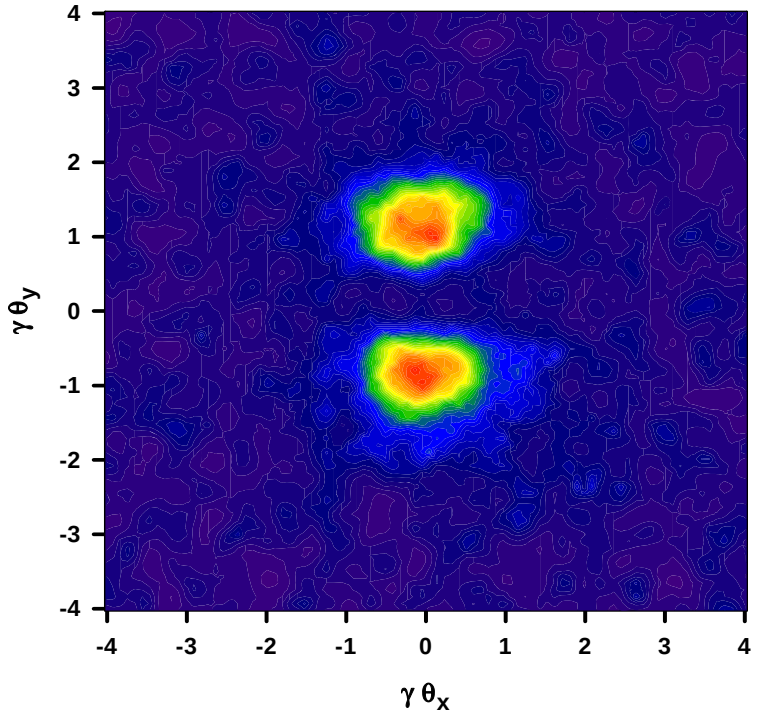
1. We have designed and constructed a beam size monitor based on optical diffraction radiation at KEK-ATF.
2. The first beam size measurements were performed and the sensitivity to a beam size as small 14μm was achieved.
3. A new highly sensitive cooled CCD camera system was successfully applied for single shot ODR measurements.

Optical Diffraction Radiation (ODR) beam size monitor at KEK-ATF

Experimental layout



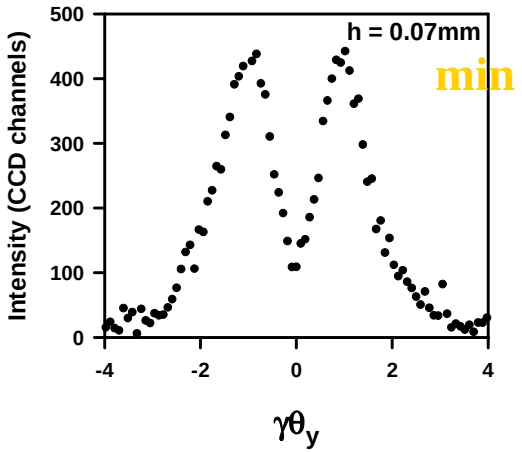
Typical CCD image of ODR vertical polarization component

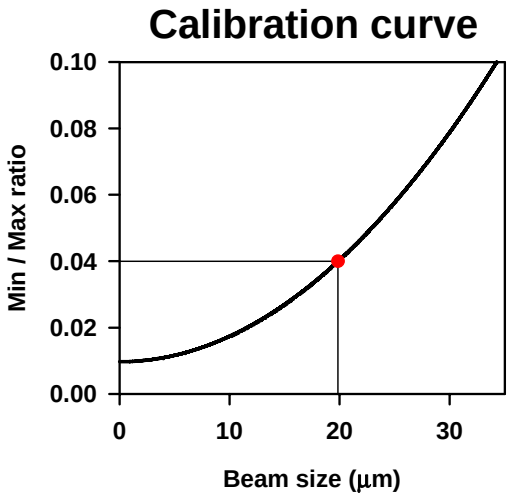


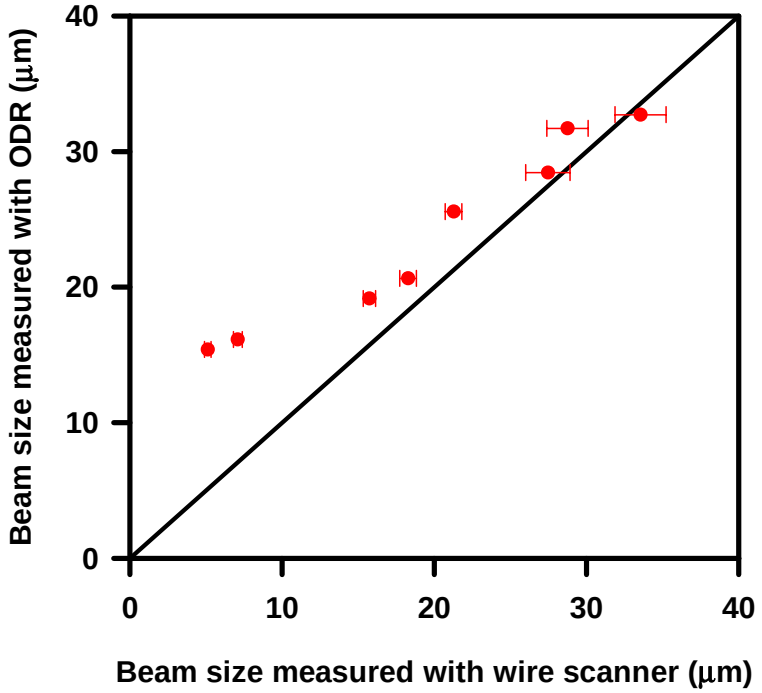
Single-short beam size measurements using ODR

max

Beam size was changed by a quadruple magnet







Plans

In the future we plan to integrate the ODR monitor into the Laser Wire chamber at the ATF2 in order to cover the beam sizes in the range 15-100μm. We also consider synchronization of the ODR measurements with ATF main control system to be able to acquire Beam Position Monitor and current data. In this case a real single shot beam size measurement with ODR will be possible.

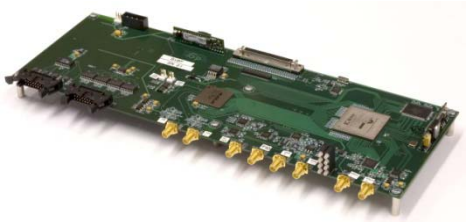
Development of next-generation digital filter system for bunch-by-bunch feedback.

By John Flanagan (KEK)

- **Collaboration among KEK, SLAC and INFN.**
- Fabricated 1st stage system (iGp) at KEK and SLAC, tuned, and improved.
- Feedback experiments conducted at several accelerators (**KEKB, SPEAR3, PEP-II, ATF, DAFNE**) using previous version (Gproto).
- Starting simulations for 2nd stage systems.
- Design and evaluation of general purpose feedback detection circuit.
  - Including feedback modulation circuit for longitudinal use.

iGp for SLAC:

(with small /slow FPGA (3M gates) and ADC (500MSPS) for PEP-II and DAFNE)



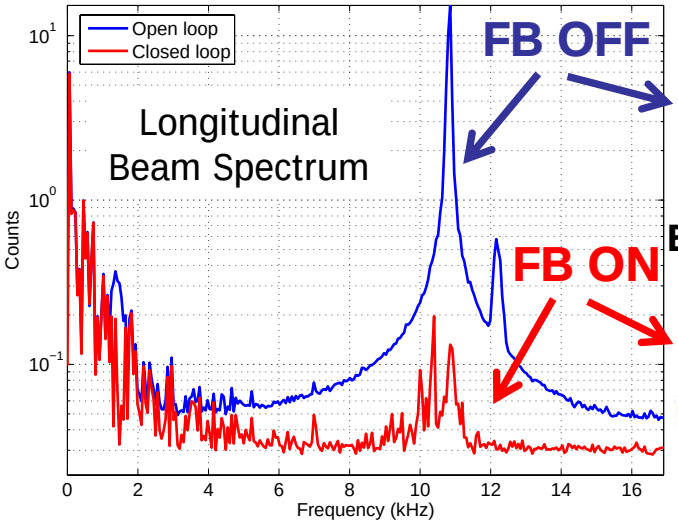
iGp for KEK:

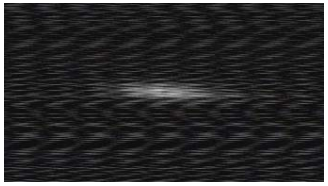
Dense (6M) and high speed FPGA and ADC for larger ring.

Built-in mini-ITX board for EPICS IOC

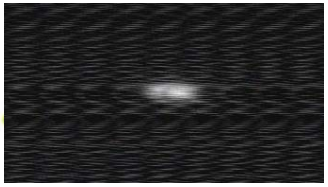
Longitudinal feedback experiment at KEK-ATF with Gproto:

Succeeded in suppressing the longitudinal instabilty, though observed vertical beam blowup.





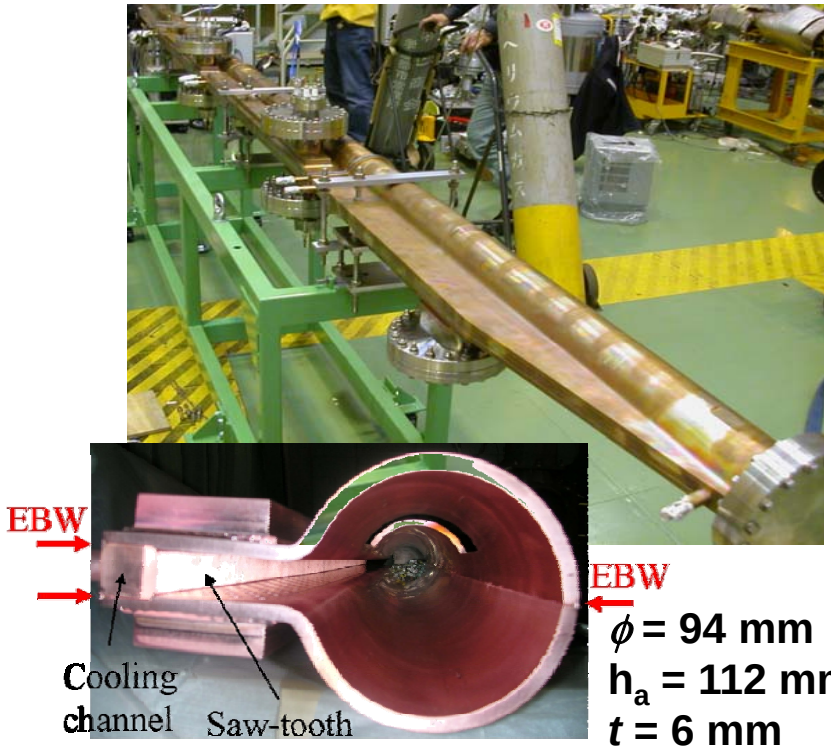
Beam X-Y profile



Study on Beam Duct with Ante-chamber

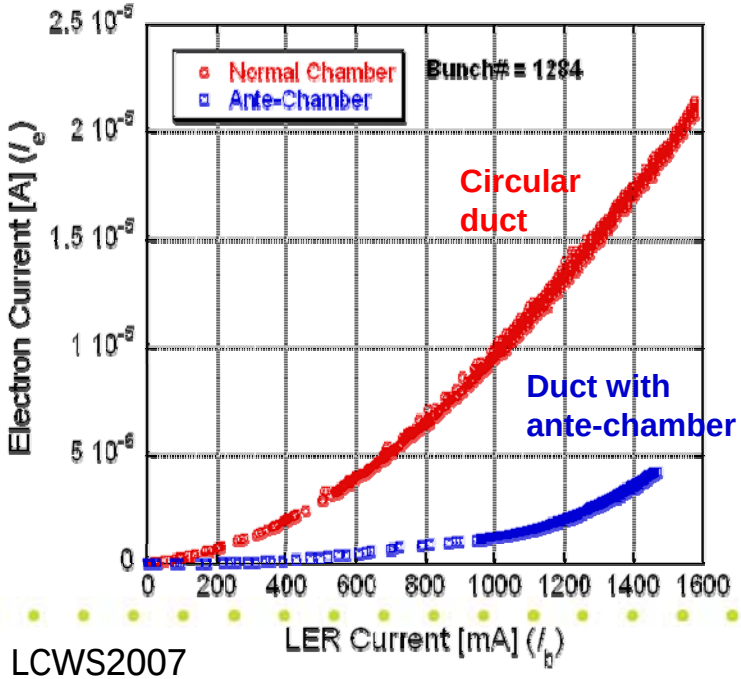
- **Copper chambers** with antechambers were manufactured for test, and installed in the KEKB positron ring.
- Electron density was measured and compared to that in a circular chamber.

By Yusuke Suetsugu (KEK),



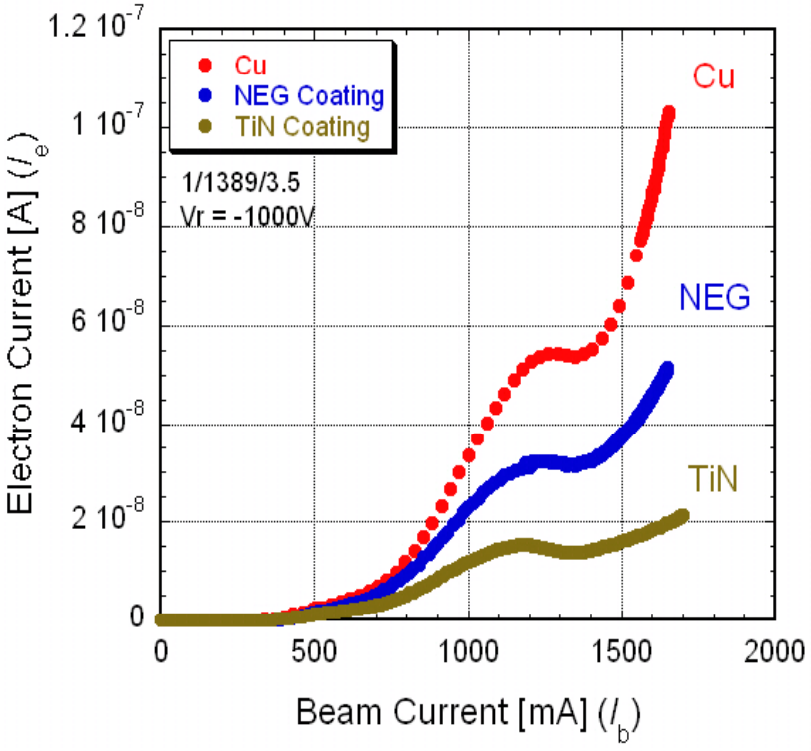
ϕ = 94 mm
h_a = 112 mm
t = 6 mm

- **Photoelectrons (electrons at low beam current) are well suppressed.**
- **Reduction rate is less than 1/100.**



Study on Low SEY Coating

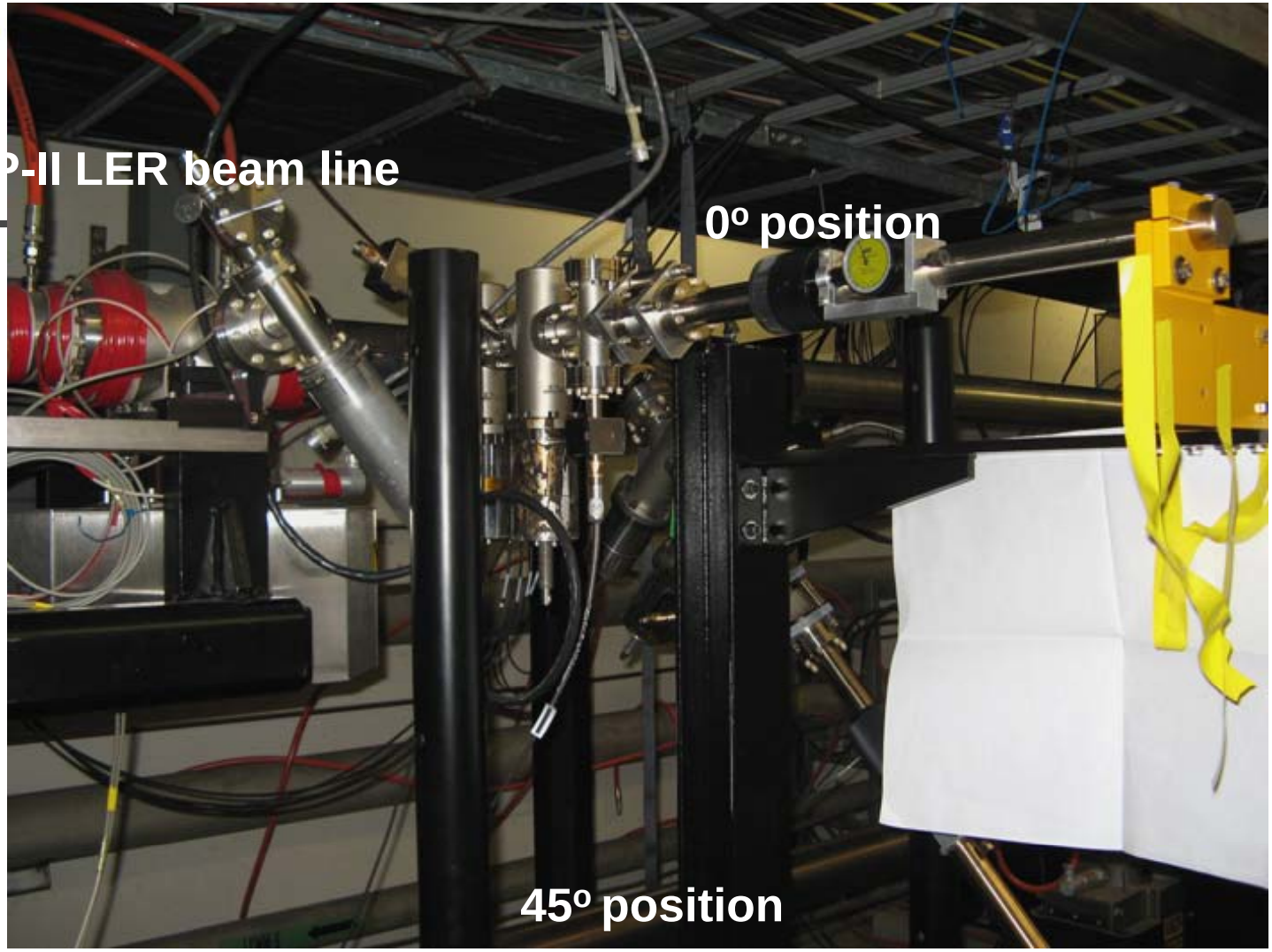
- Study of the effect of surfaces with a low SEY on the electron cloud formation.
- Focused are TiN coating and NEG coating.
- Electron densities in copper test chambers with and without coatings were measured and compared.



- Electron density for the case of TiN coating is 1/3 - 1/4 of copper, and ~1/2 of NEG coating.
- Estimated photoelectron yield (η_e) and the maximum SEY (δ_{max})

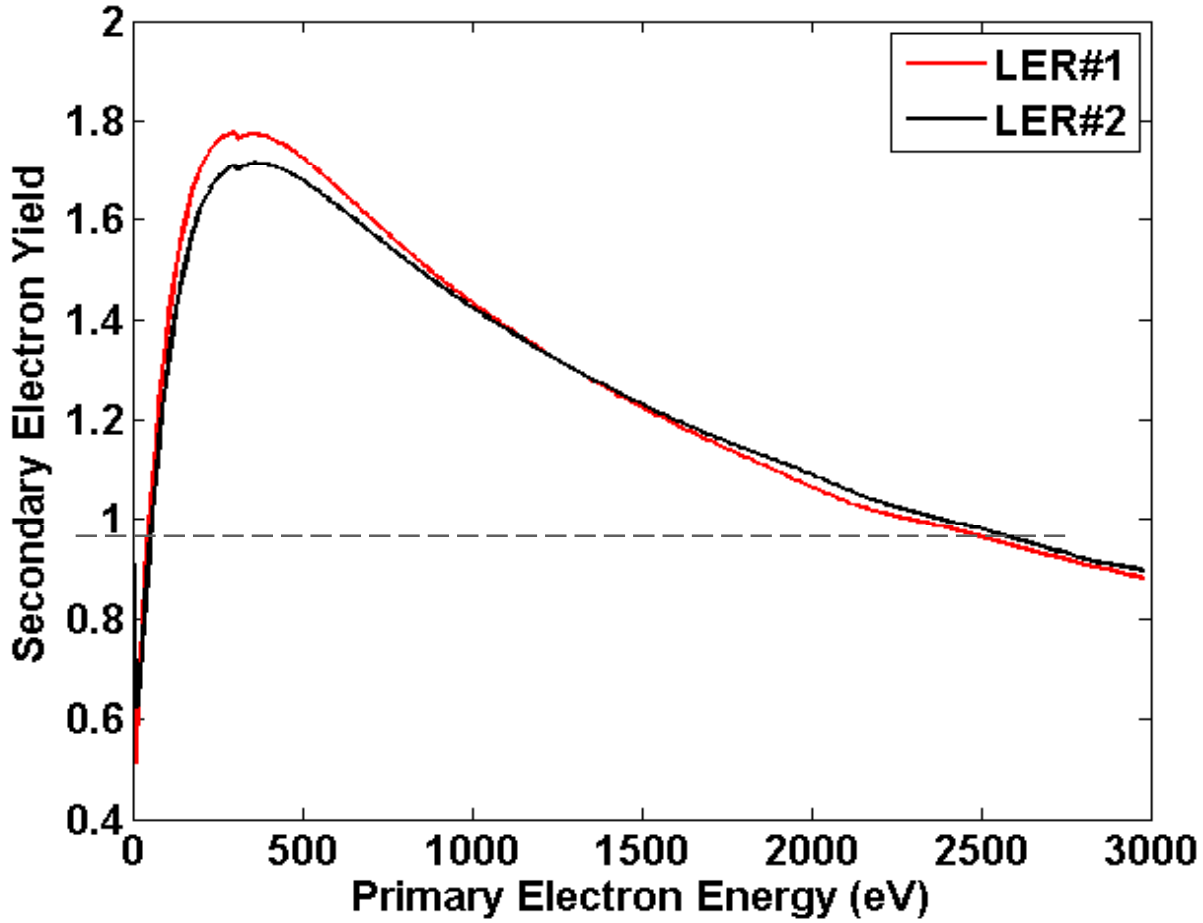
	η_e	δ_{max}
Cu	0.27-0.30	1.1-1.25
NEG	0.22-0.24	1.0-1.15
TiN	0.11-0.14	0.8-1.0

SEY station and electron cloud tests at SLAC



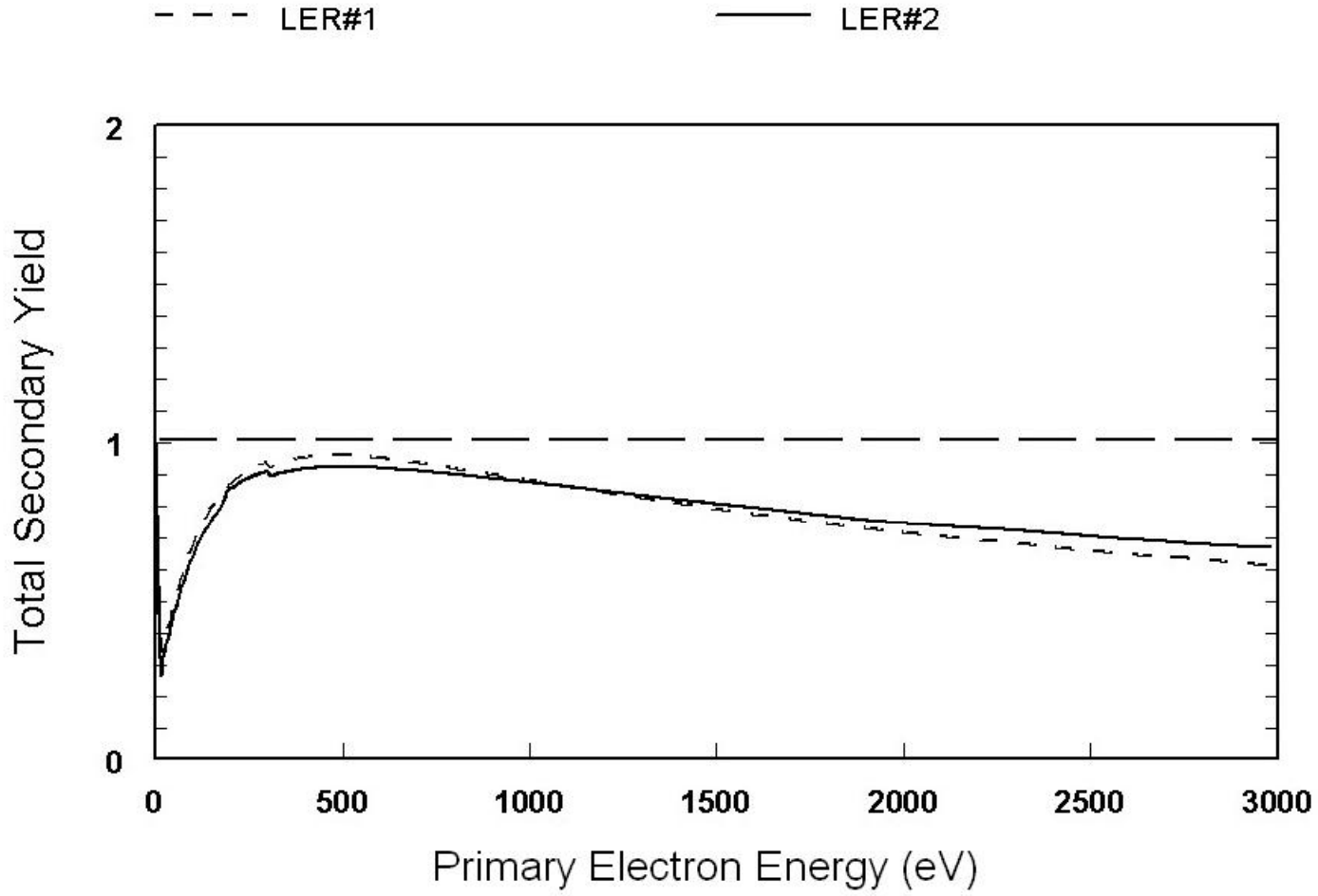
First measurements of this type. Surface Secondary Electron Yield (SEY) measurements of materials exposed to conditioning of synchrotron radiation and electrons in an accelerator beam line, PEP-II LER. Samples are initially positioned at 0 and 45 deg position with respect to fan of radiation. After conditioning, the samples are transferred under vacuum to laboratory setup for measurement of the SEY.

SEY before installation in PEP-II



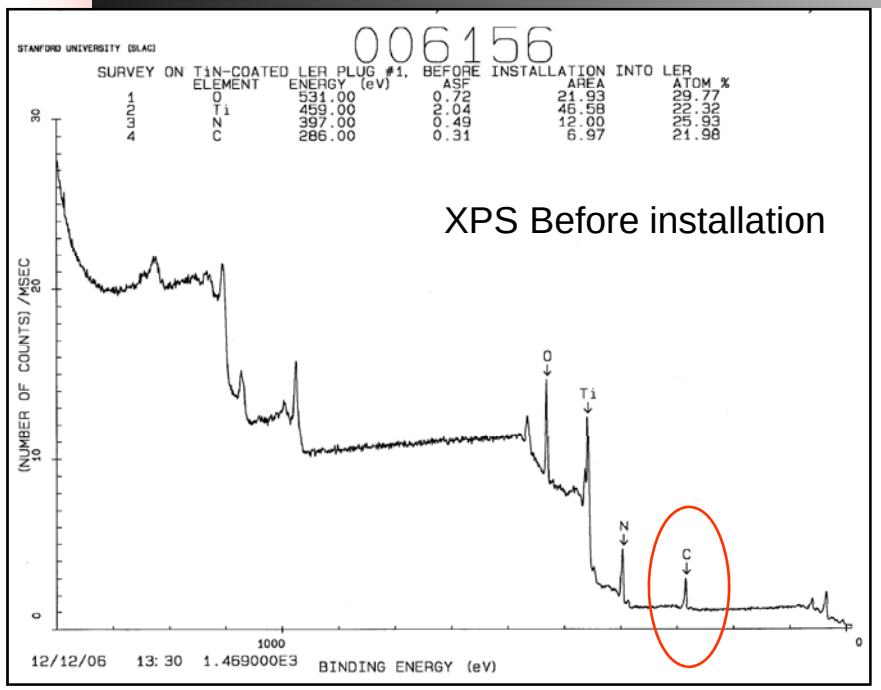
TiN samples are measured before installation in the PEP-II LER stainless steel chamber respectively in the plane of the synchrotron radiation fan (0^{o} position, sample #1) and out of this plane (45^{o} position, sample #2)

Secondary Yields after two months in PEP-II LER

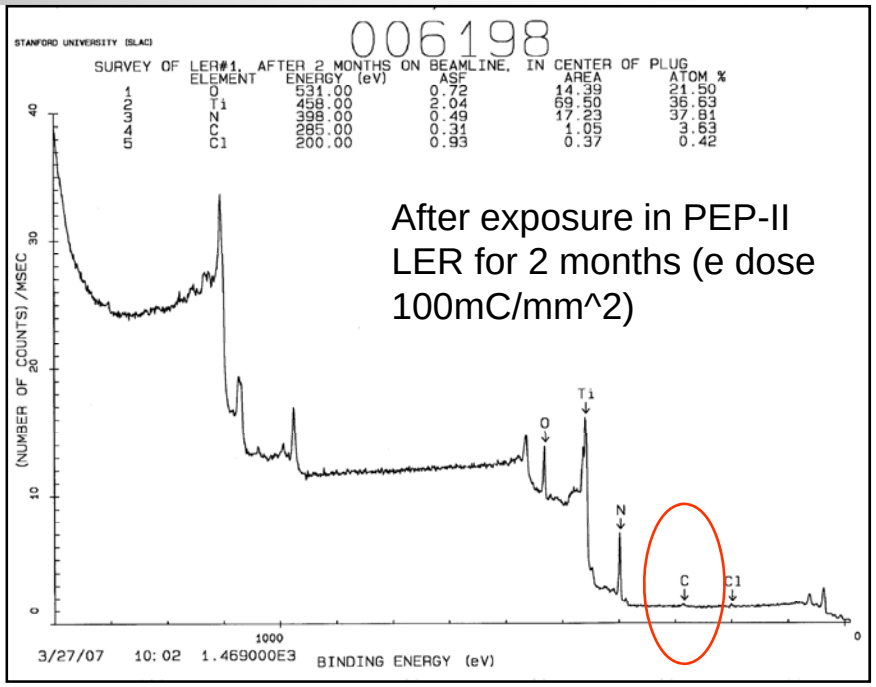


Secondary electron yield of TiN samples after the conditioning period. If the SEY~1, the build-up of an electron cloud is considerably reduced in the ILC DR. (Note: in this experiment, the TiN/Al samples have been installed in the stainless steel chamber)

Surface analysis: Carbon content decreases

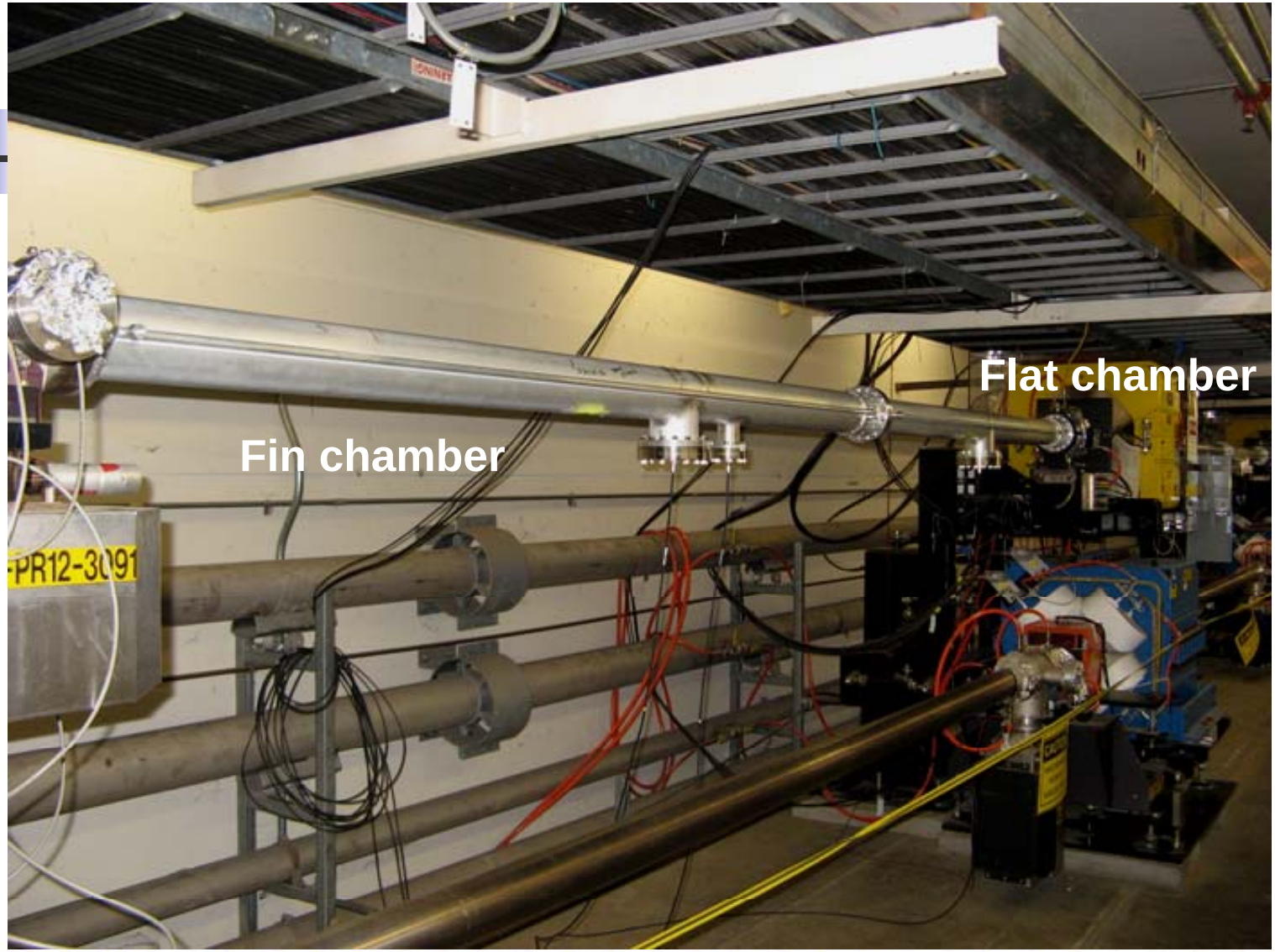


LER#1



In the accelerator beam line, the content of carbon is strongly reduced after exposure to the beam environment, differently from electron conditioning in laboratory setup where a growth of carbon is observed. Samples #1 and #2 similar results.

Installation in PEP-II LER



Work in progress - SLAC

- The electron signal recorded in flat & fin TiN-chambers is much lower than in the Stainless Steel chamber.

- Electron signal in Flat TiN-chambers is lower than in Fin TiN-chambers.
  - Appear to have higher photo e- rate in fin chambers
  - Photoelectron dominant in fins?

- Initial simulations: consistent with high SEY in Stainless steel chamber and low SEY in Flat & Fin TiN-chambers
  - Systematic simulation effort ongoing to parameterize fin & flat chambers results
  - Low SEY in flat & fin chambers between 0.9~1.2

- Preliminary results in favor of coating (TiN) and flat chambers. TiZrV getter, Al, Cu and stainless under study. Additional mitigation techniques as clearing electrodes, triangular fins or slots in magnets under study.

Damping ring R&D activity at LNF

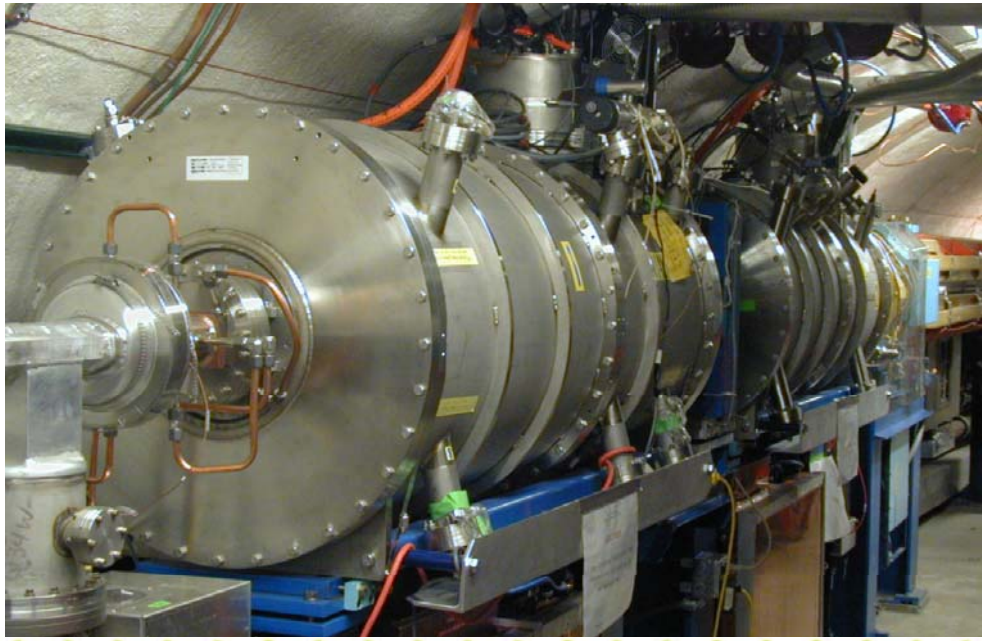
By Susanna Guiducci (INFN-LNF)

- Fast kickers
  - **Pulse duration < 12 ns** (2670 bunches, 6 ns bunch distance)
    - Strip-line prototype under test with high voltage feedthrough (up to 50 kV)
    - The kickers will be installed in DAΦNE during the shutdown for the luminosity upgrade with the “crab waist” IR (beam tests expected in fall)
  - **Pulse duration < 6 ns** (5340 bunches, 3 ns bunch distance)
    - Design and realization of a short strip-line kicker to test new fast pulsers
- e-cloud
  - Installation of e-cloud diagnostics in the DAΦNE rings
  - Benchmarking of e-cloud simulation codes with beam observations
- Beam dynamics with wigglers
  - Modification of the poles of the DAΦNE wiggler to reduce the nonlinear field components on the beam trajectory
- R&D activity on fast feedback systems

CesrTA Proposal

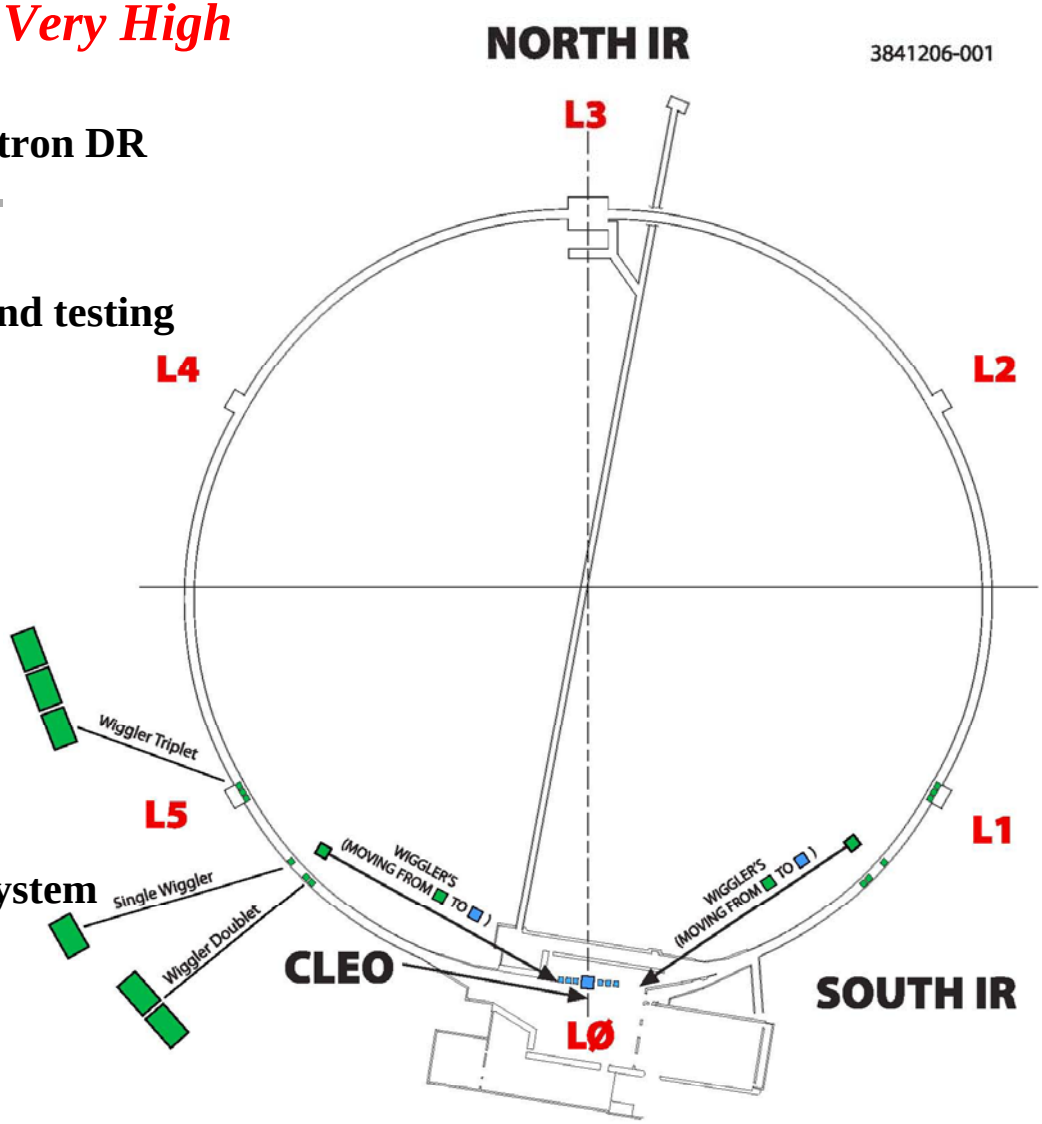
By Mark Palmer (Cornell University)

- Propose a dedicated program of damping rings R&D starting in April 2008
  - Builds upon the ongoing ILC R&D program at CESR.
- Goals:
  - Support critical damping rings R&D for an EDR in 2010.
  - Provide dedicated experimental runs to enable key R&D.
  - Provide a complementary program to work elsewhere (*eg*, KEK-ATF).
- Offers:
  - An operating wiggler-dominated storage ring
  - R&D with the CESR-c damping wigglers
  - Flexible operation with positrons and electrons in a single ring
  - Flexible energy range (1.5 GeV – 5.5 GeV)
  - Dedicated experimental runs for ILC R&D starting in 2008



CESR a CesrTA

- Contributions to several *High* and *Very High* priority S3 R&D areas
  - Electron cloud (EC) issues for the positron DR
  - Ion issues for the electron DR
  - Ultra low emittance operation
  - System and component development and testing
- CesrTA Configuration:
  - 12 damping wigglers located in zero dispersion regions for ultra low emittance operation
  - Diagnostic vacuum chambers with EC suppression methods
  - Designated sections available for installation of test devices
  - Precision instrumentation
    - Multi-bunch turn-by-turn BPM system
    - Fast X-ray beam profile monitors
  - 4 ns bunch train operation



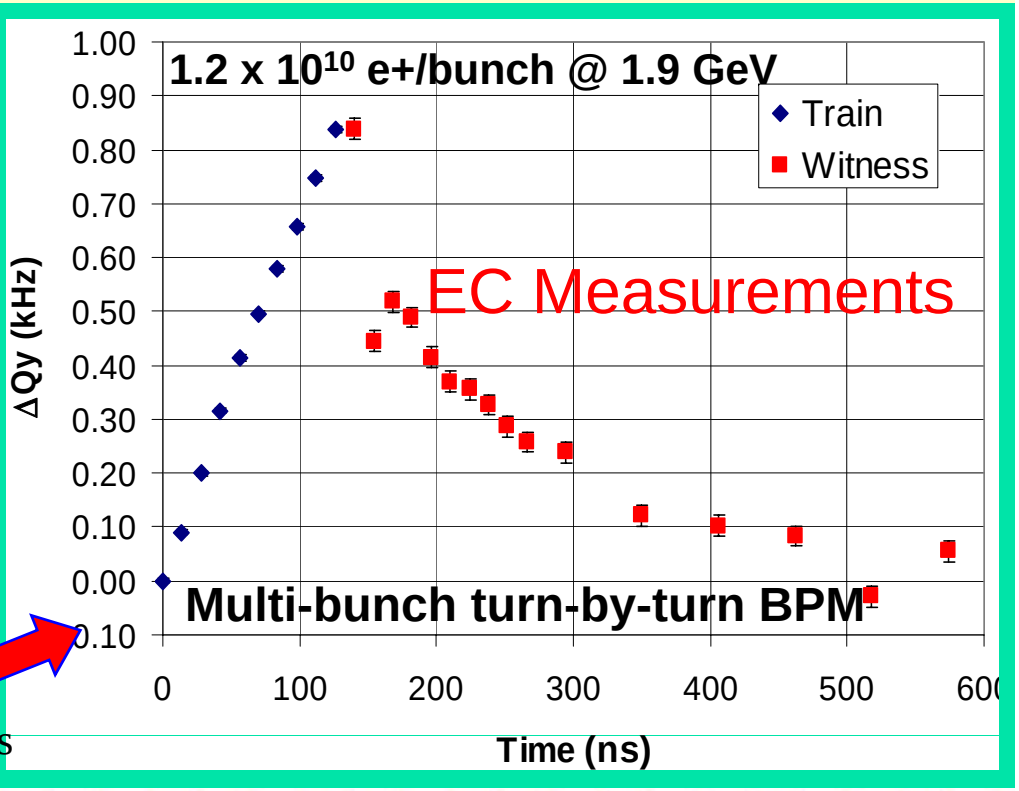
CesrTA Parameters & Capabilities

Baseline Configuration

Parameter	Value
No. of Wigglers	12
Wiggler Field	2.1 T
Beam Energy	2.0 GeV
Energy Spread ($\Delta E/E$)	8.6×10^{-4}
Target Vertical Emittance	5 – 10 pm (or better)
Horizontal Emittance	~2 nm
Damping Time	47 ms
Bunch Spacing	4 ns
Bunch Length	9 mm

- Parameters:
  - Baseline optics at 2 GeV for ultra low emittance studies
  - Energy flexibility will allow EC growth studies at 5 GeV as specified for the ILC DR

- EC Measurements:
  - Multi-bunch turn-by-turn instrumentation has been commissioned
  - Measured vertical tune shift along a train generating the electron cloud and for witness bunches trailing the train at various intervals

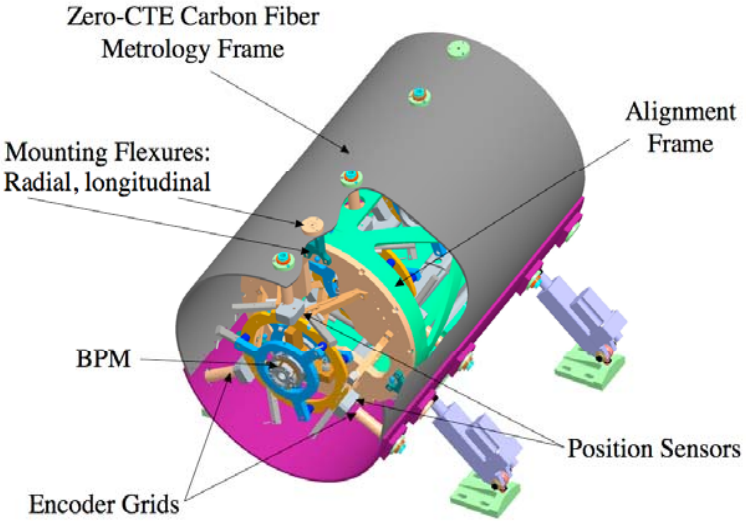


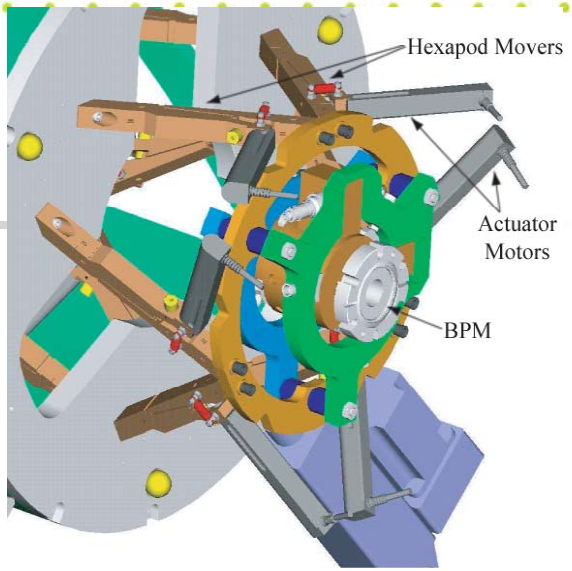
CesrTA Experimental Program

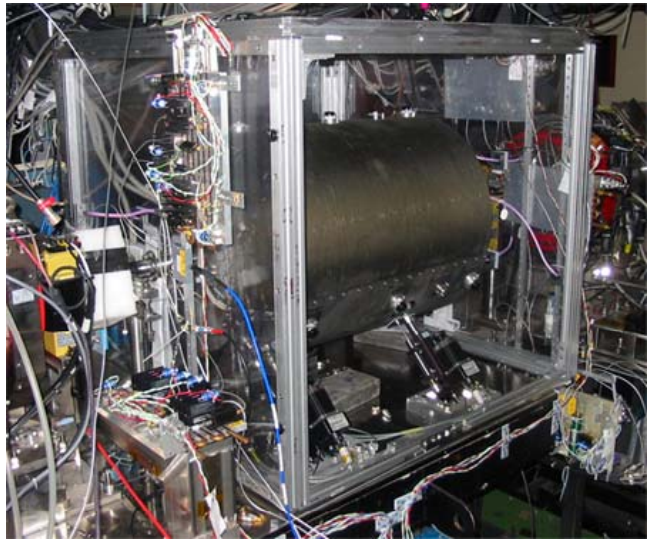
- Schedule:
  - **Primary conversion shutdown scheduled for mid-2008**
  - **2 CesrTA experimental runs during 2008**
  - **2009 onwards:**
    - 3 CesrTA experimental runs/yr totaling ~1/3rd of each year
    - 3 High Energy Synchrotron Source (CHESS) runs/yr totaling ~1/3rd of each year
    - Remainder of year scheduled as down and commissioning time for hardware installation and experimental setup
    - Provides flexible scheduling of collaborator experiments
- Experimental Focus:
  - **EC Growth and Mitigation Studies – particularly in the damping wigglers**
    - Bunch trains similar to those in the ILC DR
    - Instrumented vacuum chambers to quantify performance of EC suppression methods
  - **Ultra Low Emittance Operation**
    - Validation of correction algorithms
    - Measuring, tuning for, and maintaining ultra low emittance
  - **Beam Dynamics Studies**
    - Detailed inter-species comparisons (distinguish EC, ion and wake field effects)
    - Characterize emittance growth in ultra low emittance beams (EC, ion effects, IBS,…)
    - Demonstrate ultra low emittance operation with a positron beam
  - **Test and Demonstrate Key Damping Ring Technologies**
    - Wiggler vacuum chambers, optimized ILC wiggler, diagnostics, …

nm resolution BPM

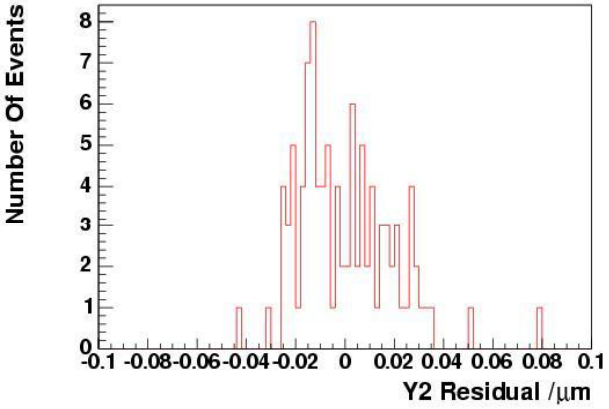
(SLAC, LLNL, UK-University, KEK)







ATF single bunch beam test

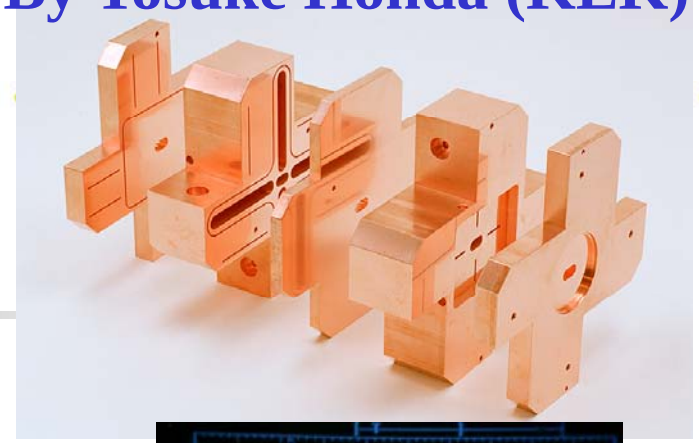


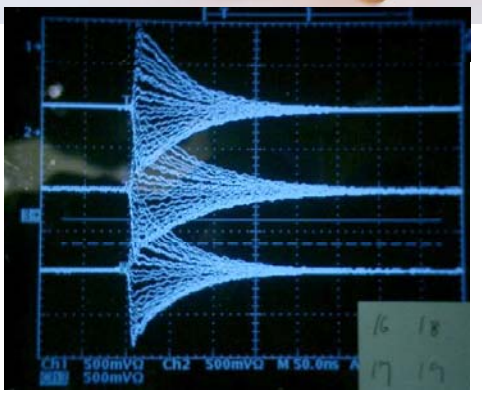
17nm resolution achieved

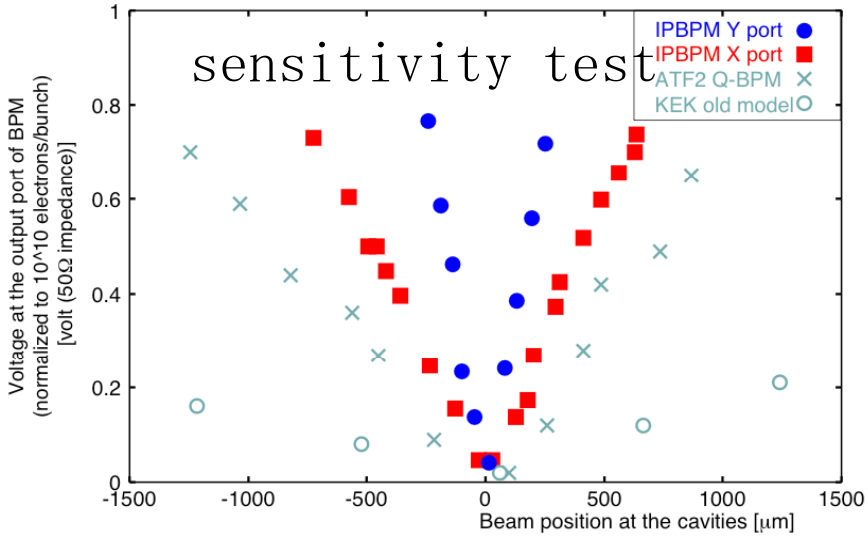
ATF2 IP-BPM

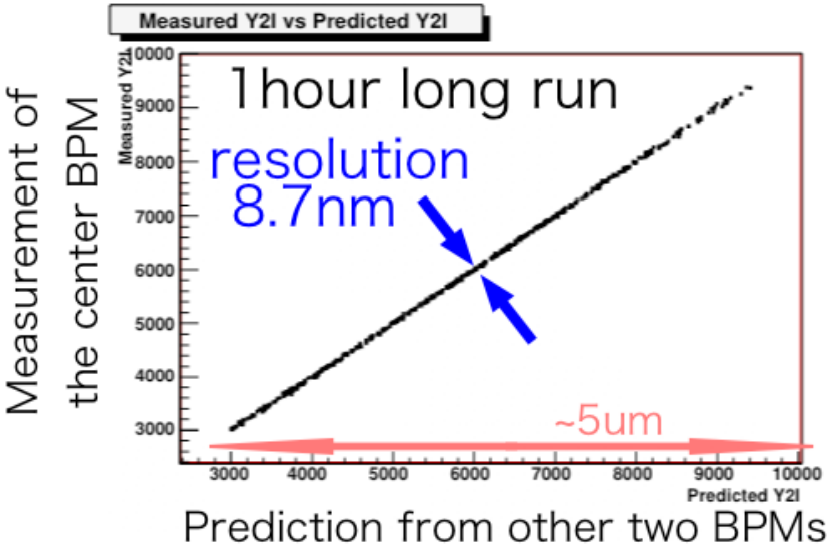
By Yosuke Honda (KEK)

- goal
  - measure beam jitter at the focal point of ATF2
  - produce a feedback signal for beam stabilization
- requirements
  - ultimate high resolution (a few nm)
  - less sensitivity for beam angle
- special cavity BPM
  - rectangular shape (X:5.7GHz, Y:6.4GHz)
  - thin cavity for angle signal reduction
  - small beam tube for high sensitivity
- status
  - various properties were checked with beam (position sensitivity, angle sensitivity, etc.)
  - 8.7nm reslution was achieved by 3-bpm measurement







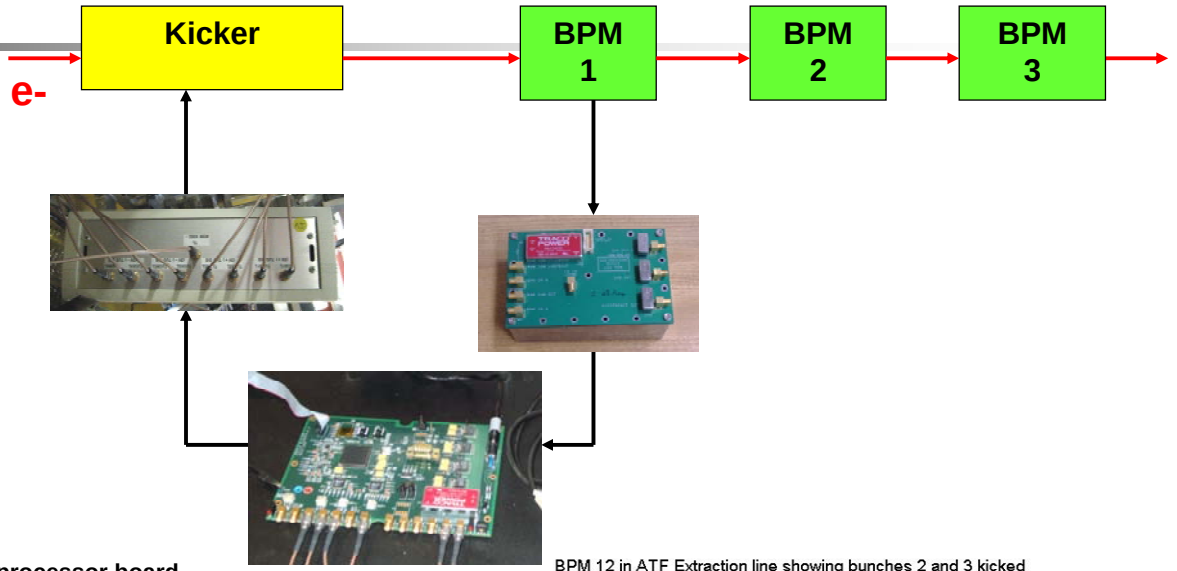


FONT4 ILC intra-train FB prototype

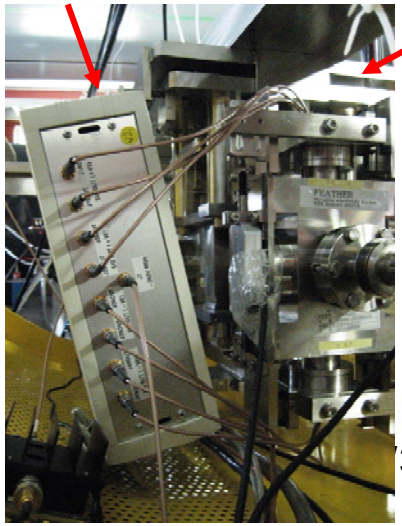
Oxford University, Daresbury Lab., KEK, SLAC

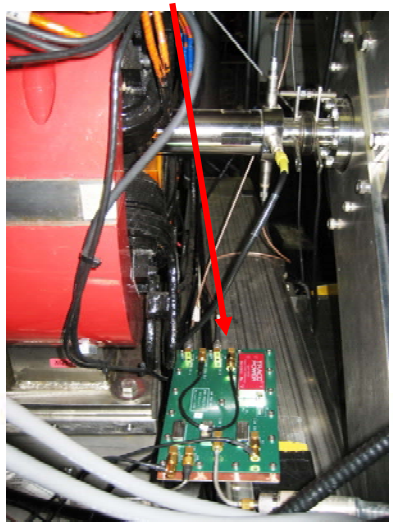
By Philip Burrows (Oxford)

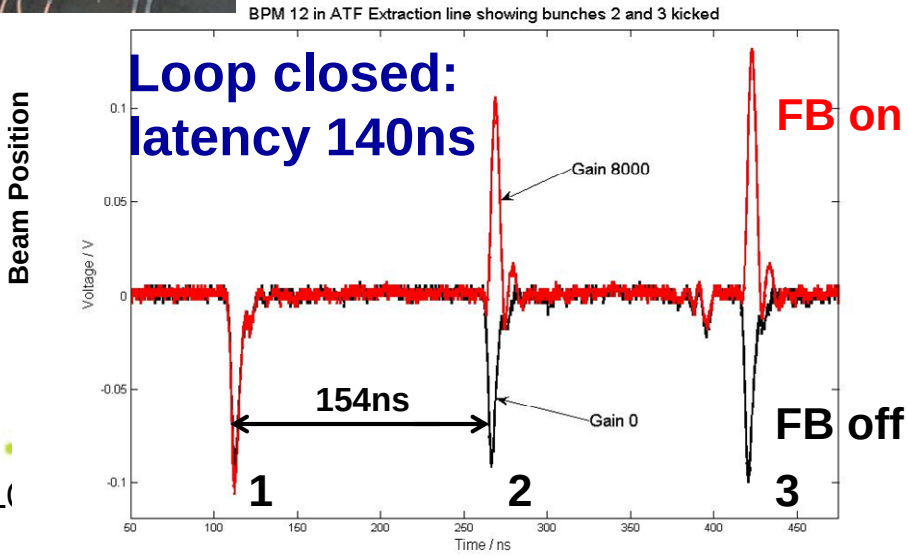
Prototype components of intra-train FB and test with beam at ATF:
bunch spacing c. 150ns



Components designed and built in UK: installed in ATF extraction line:



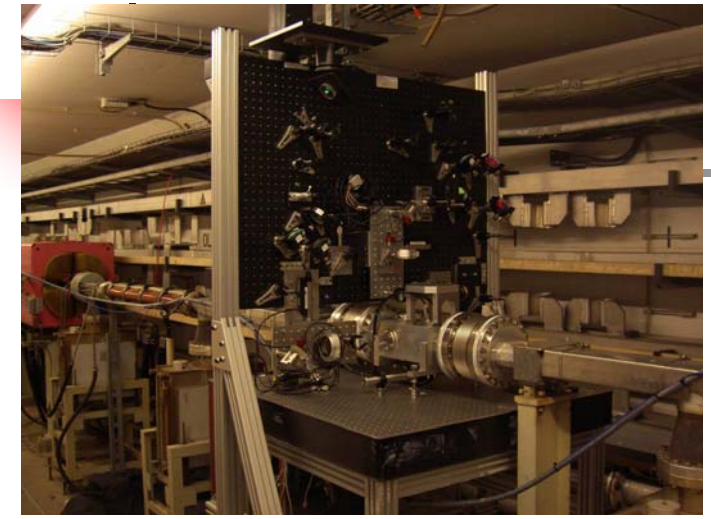


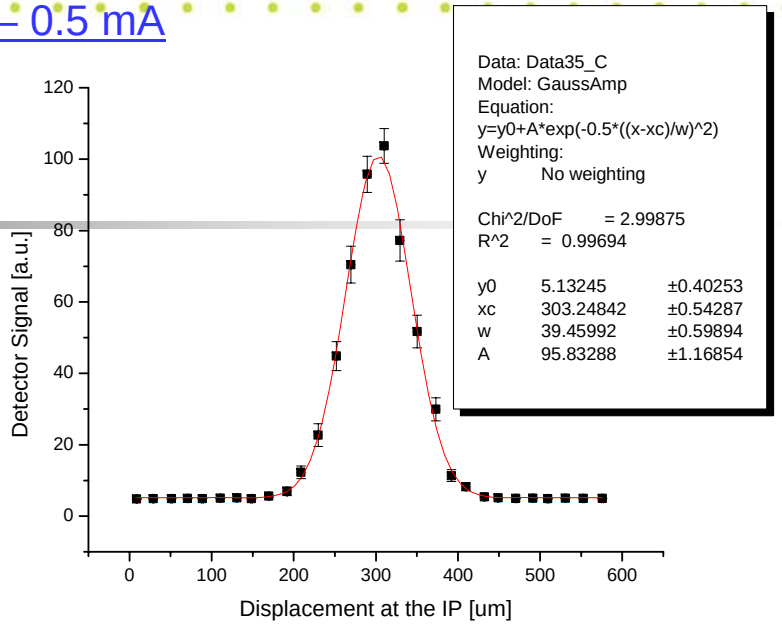


Laser-wire By Grahame Blair (RHUL)

2-D system at PETRA

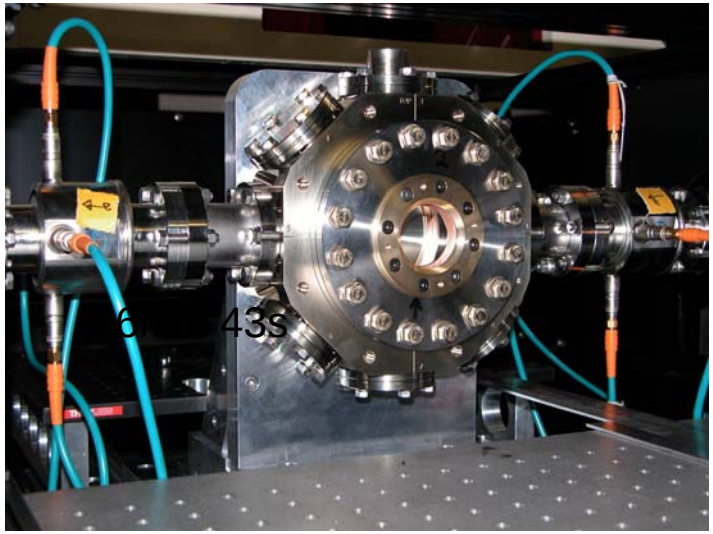
29 steps 35 points per step = **1000 point (50 sec)**
6 GeV – 0.5 mA

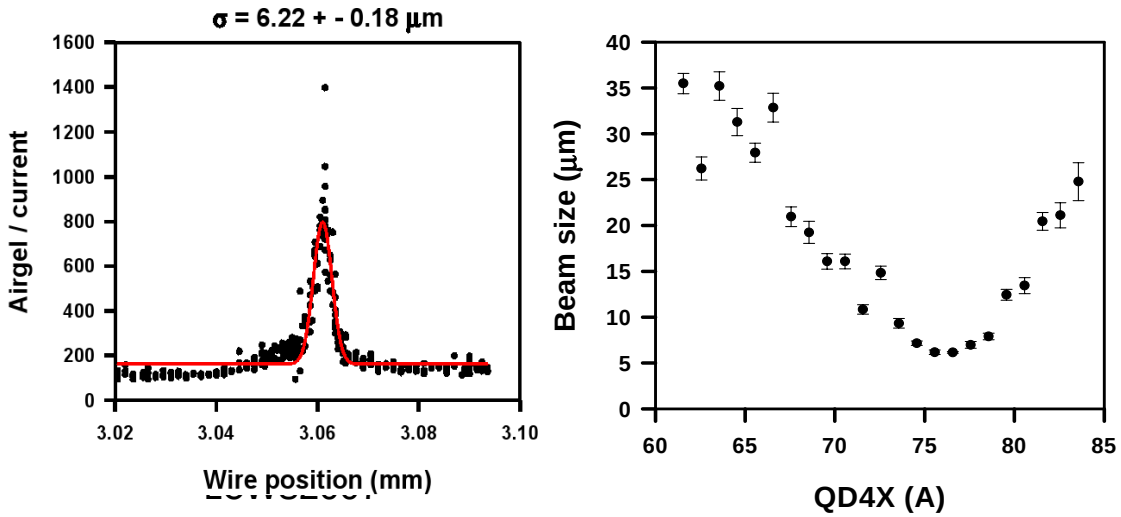




ATF-EXT

6min 43s

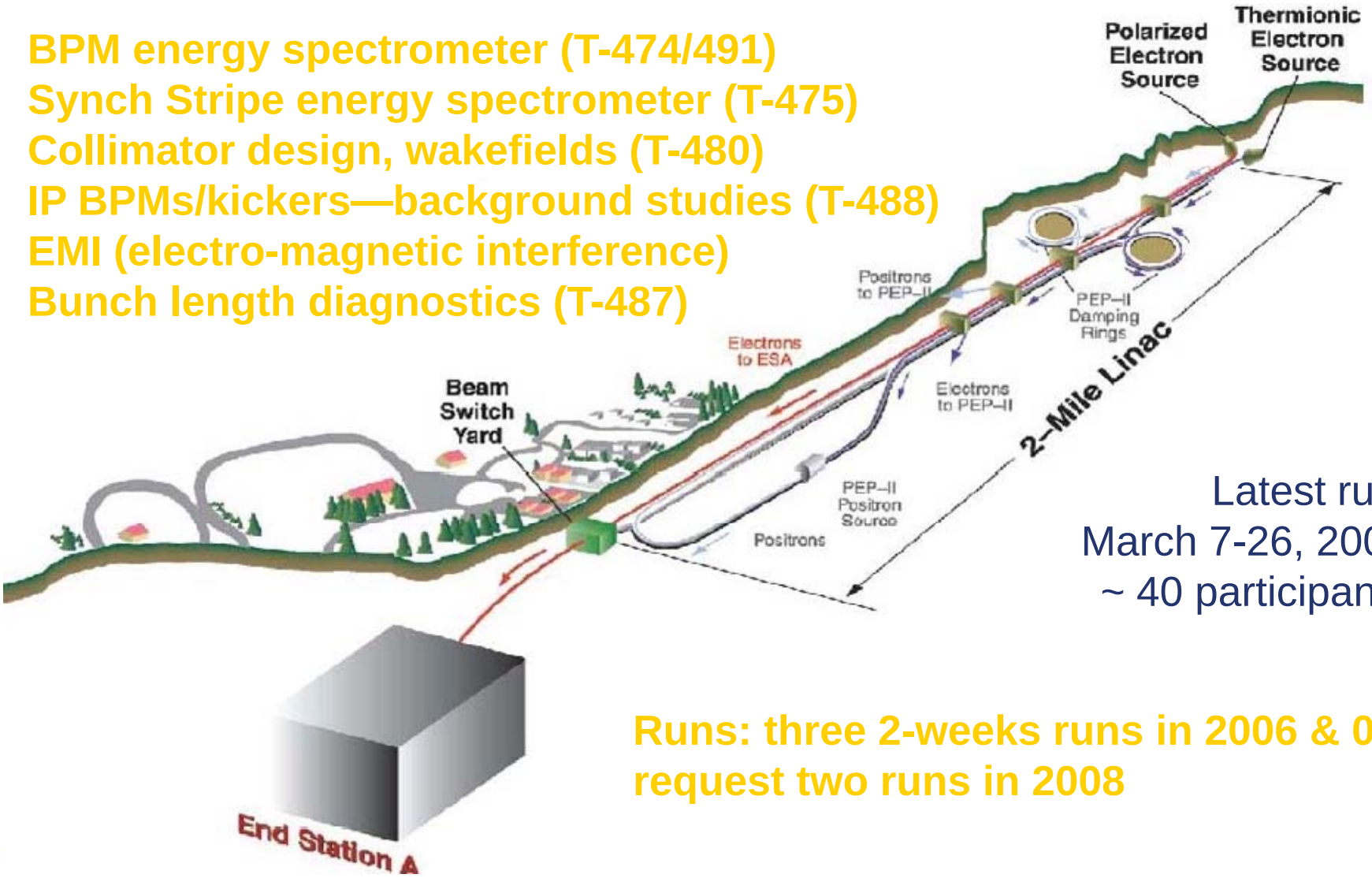




BDS beam tests at ESA

By Andrei Seryi (SLAC)

BPM energy spectrometer (T-474/491)
Synch Stripe energy spectrometer (T-475)
Collimator design, wakefields (T-480)
IP BPMs/kickers—background studies (T-488)
EMI (electro-magnetic interference)
Bunch length diagnostics (T-487)

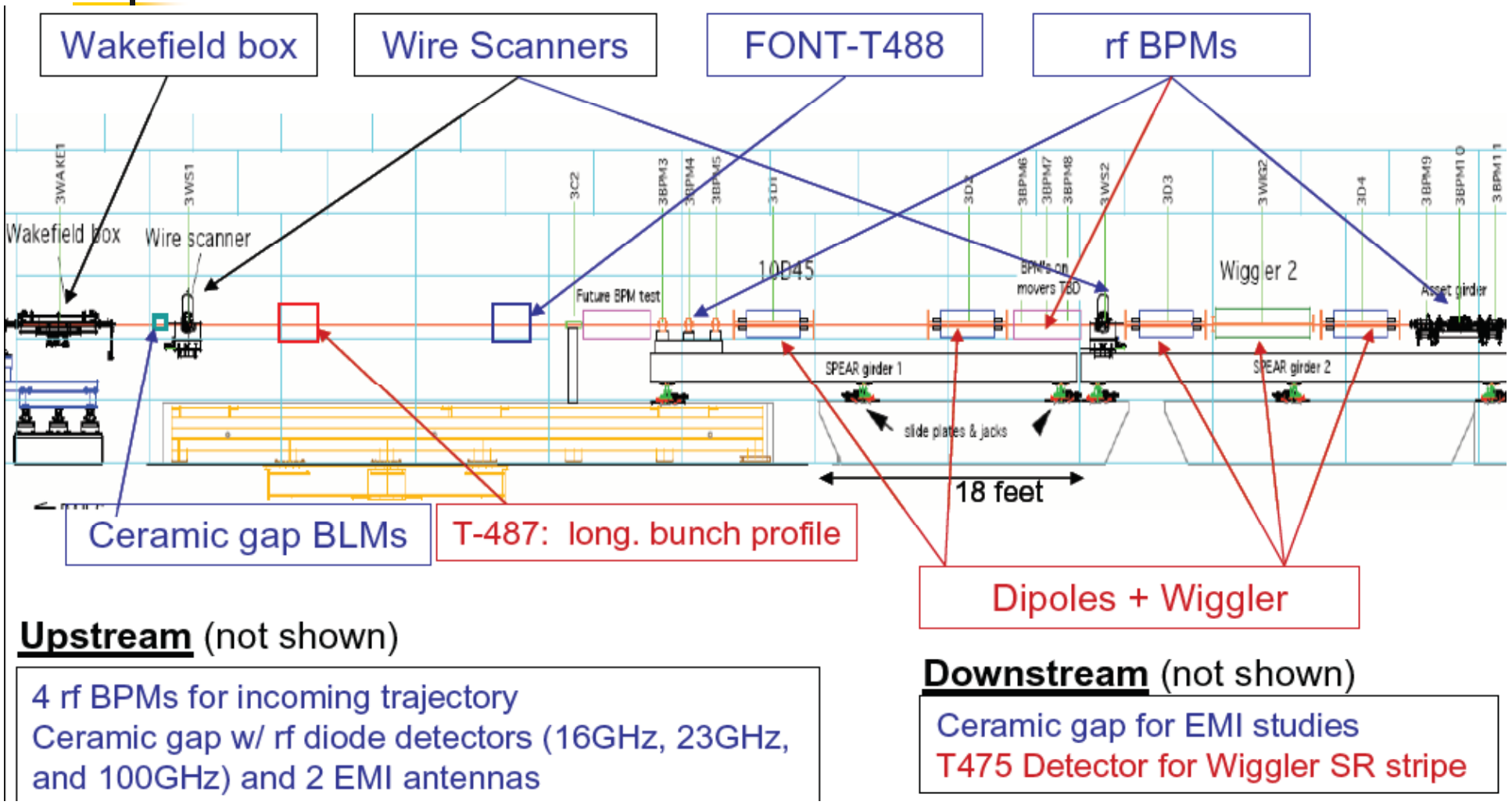


Latest run:
March 7-26, 2007
~ 40 participants

Runs: three 2-weeks runs in 2006 & 07;
request two runs in 2008

ESA in May 2007

blue=FY06
red=new in FY07



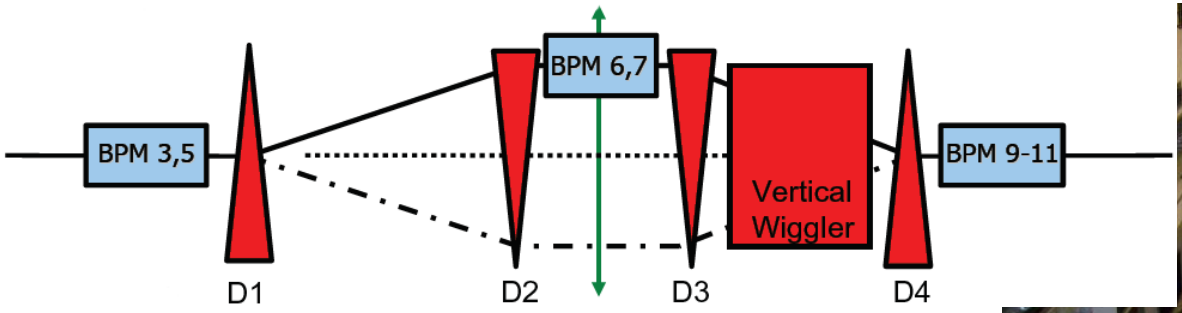
Upstream (not shown)

4 rf BPMs for incoming trajectory
Ceramic gap w/ rf diode detectors (16GHz, 23GHz, and 100GHz) and 2 EMI antennas

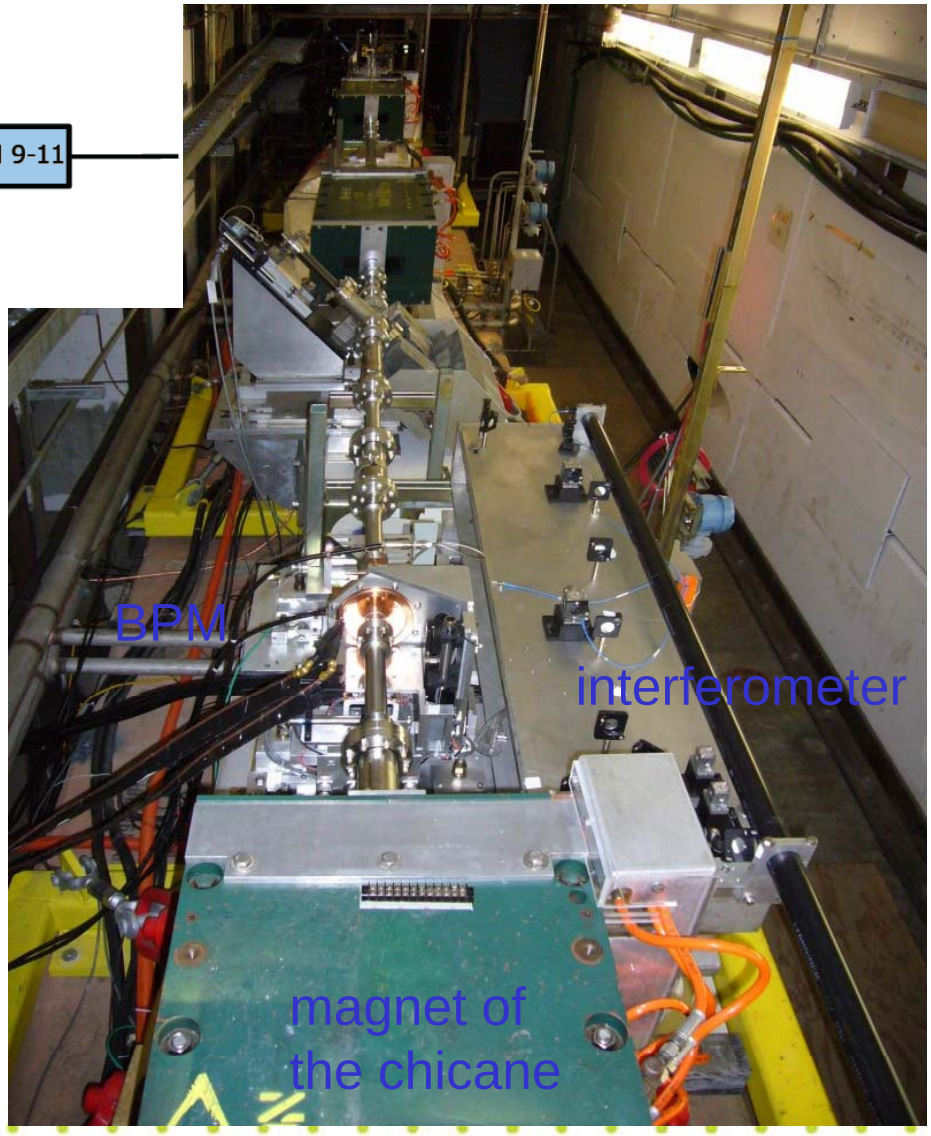
Downstream (not shown)

Ceramic gap for EMI studies
T475 Detector for Wiggler SR stripe

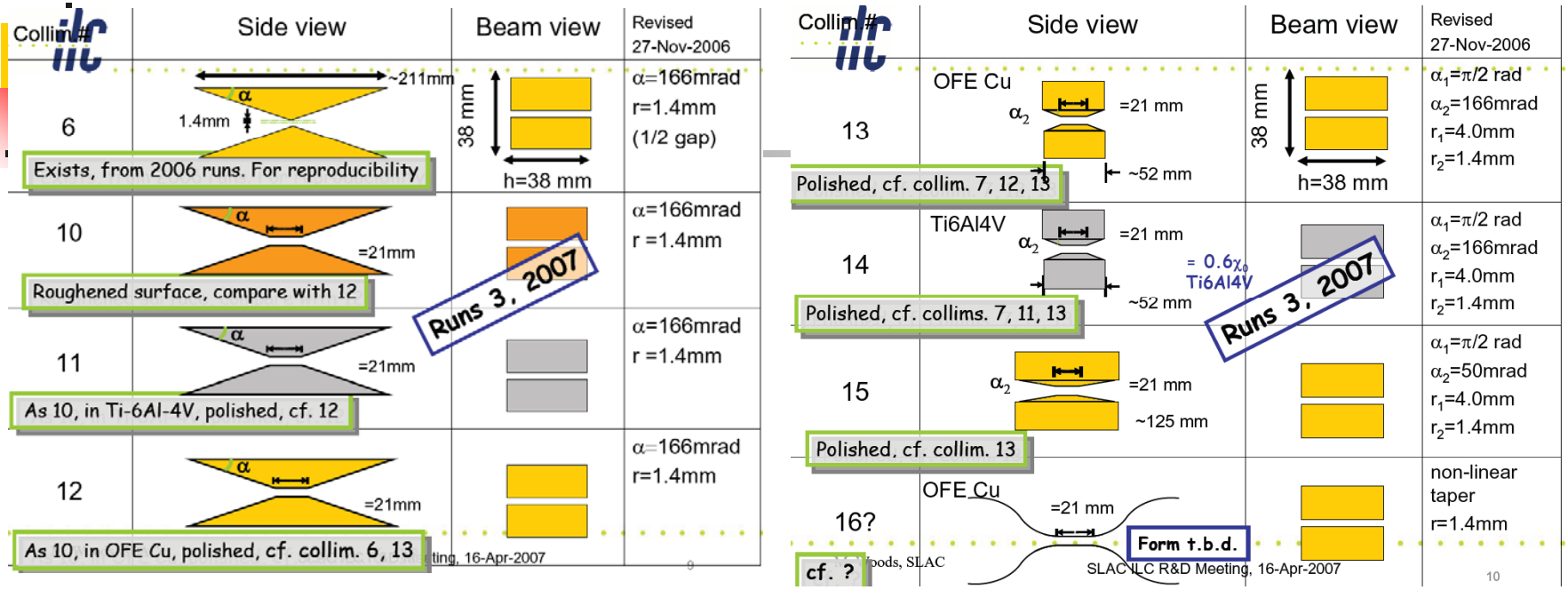
Energy spectrometer at ESA



- BPM & SR based
- Interferometer metrology grid for BPMs
- NMR probes in magnets
- 0.5um BPMs with h=5mm => 1e-4 energy resolution
- Study calibrations, systematics, stability
- SR version with quartz fiber detector will be used next run

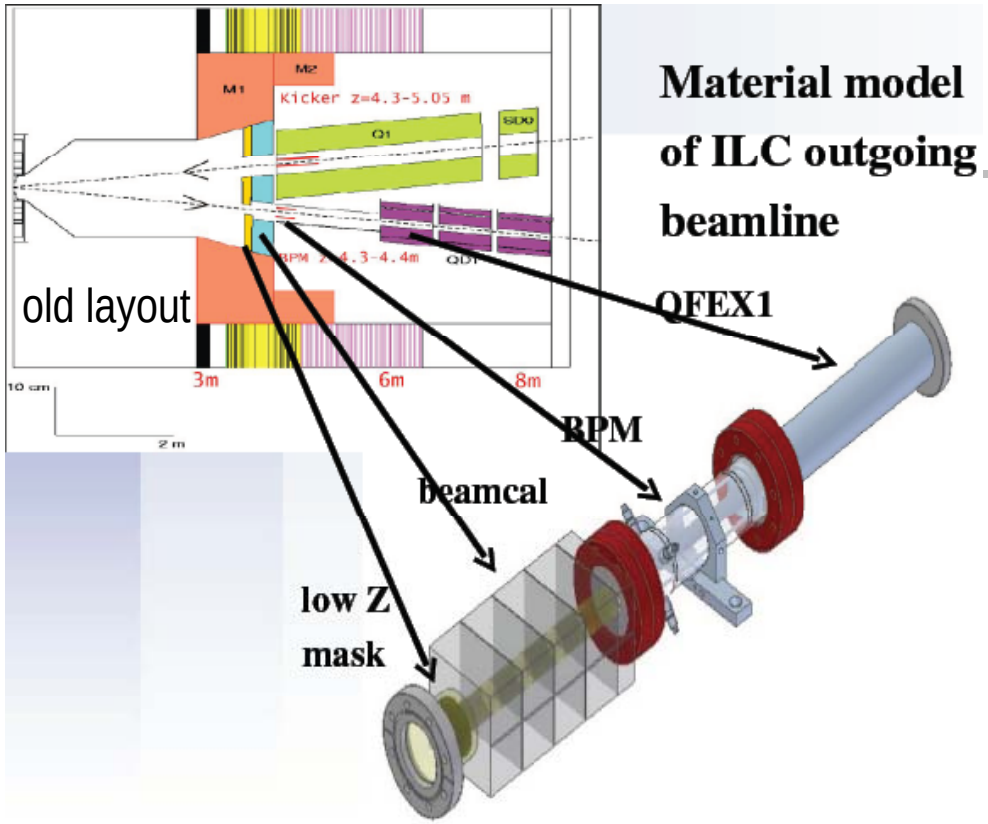


Collimation wakefield study in ESA



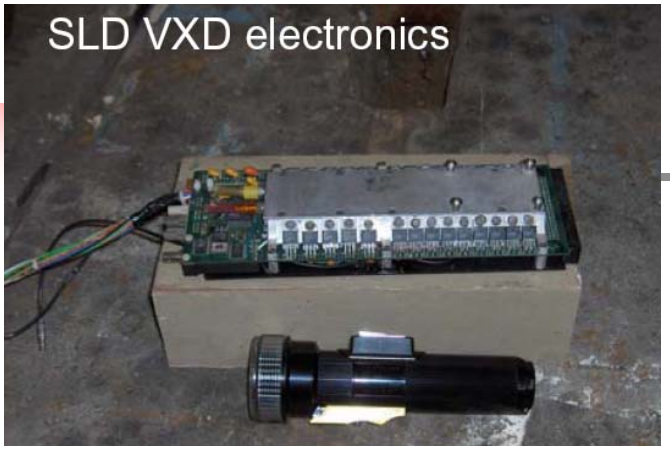
- Results from 2006 run:
  - measurements, analytics & 3d modeling differ by up to factor of 2
- March 2007 run was focused on tests of
  - importance of tapers in region away from gap center
  - tapers with shallow part only near beam axis
  - explicit tests of surface roughness
  - non-linear exponential form taper
- Results are being analyzed

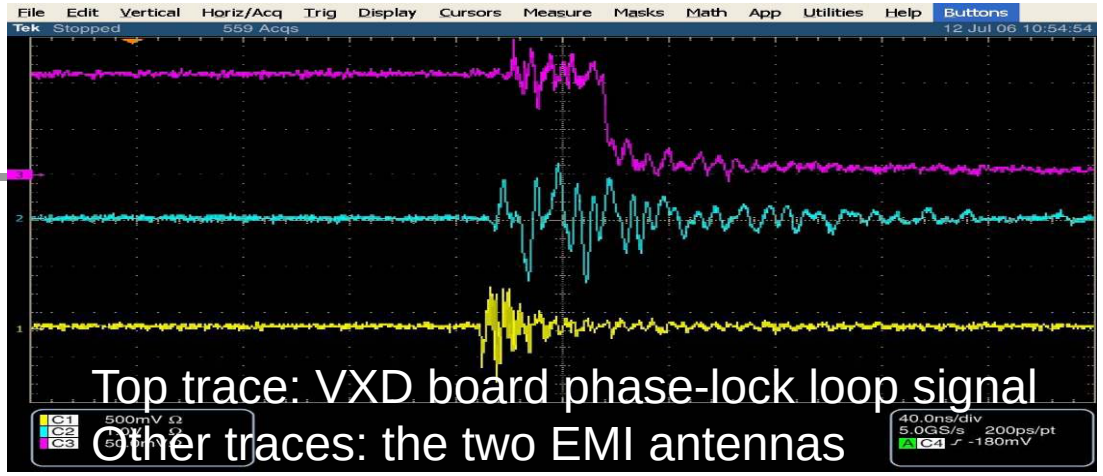
Fast feedback BPMs test in ESA



- Goal is to recreate ILC-like background hits on feedback BPM
- And to learn to make simulation predictions
- At ESA use thin upstream radiators to produce spay impinging on low Z mask
- 2006 run: put beam into low Z mask
- 2007 run: put beam through 1-5% Al foil 1m upstream
- Results are being analyzed

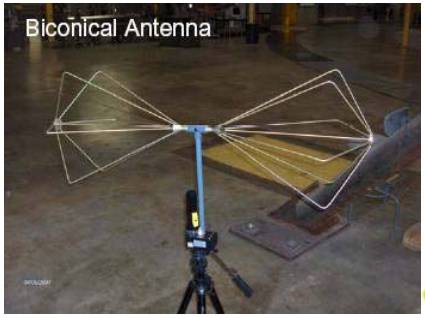
Electromagnetic interference & VX, ESA tests





N.Sinev

- VXD failure rate 85% for 20V/m, 5% for 1V/m
- Al foil over VXD or over ceramic gap stop failures
- 1cm^2 hole in Al foil over ceramic => 50% failures at 1m
- Hole 0.6*0.6cm => no failures



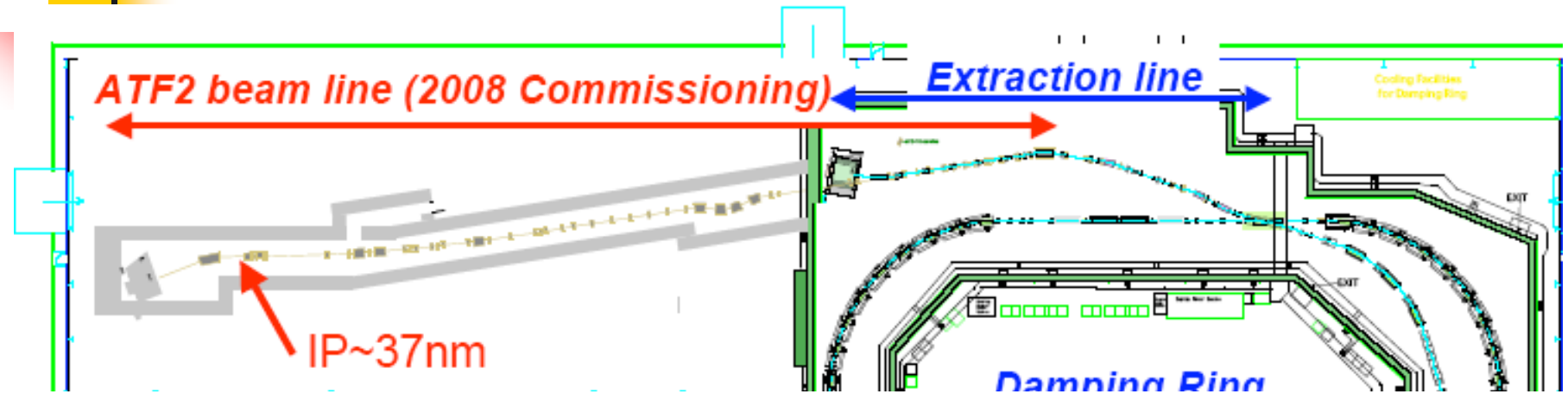
ATF2 Status for BDS R&D

ATF2 Project (37nm Final Focus beam line)

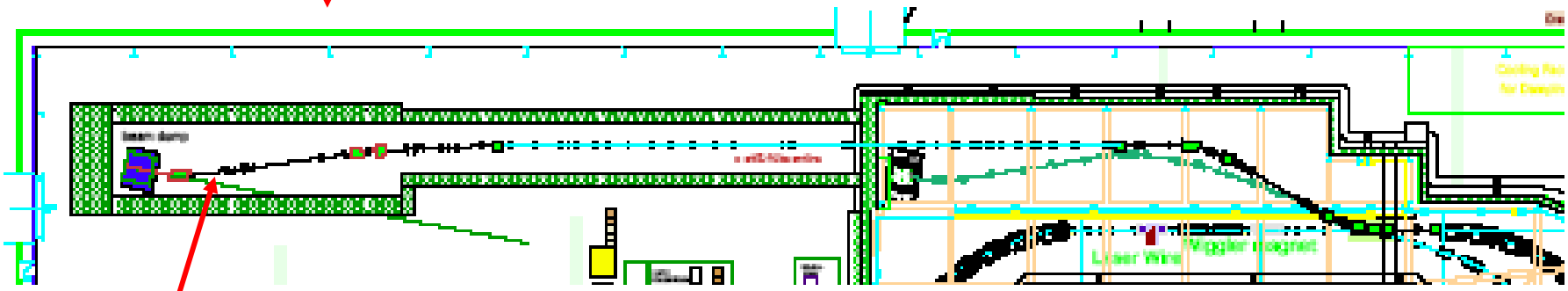
Status

- **Optics&beam line design fixed.**
- **Construction Schedule re-planed.**
- **Q-magnet from IHEP.**
- **Q-BPM from PAL.**
- **Electronics for QBPM from SLAC**
- **High Availability power supply for magnet from SLAC**
- **IP-BPM under beam test. (KEK, KNU)**
- **Laser Interference monitor upgraded. (Tokyo-Univ)**

ATF2 Beam line layout

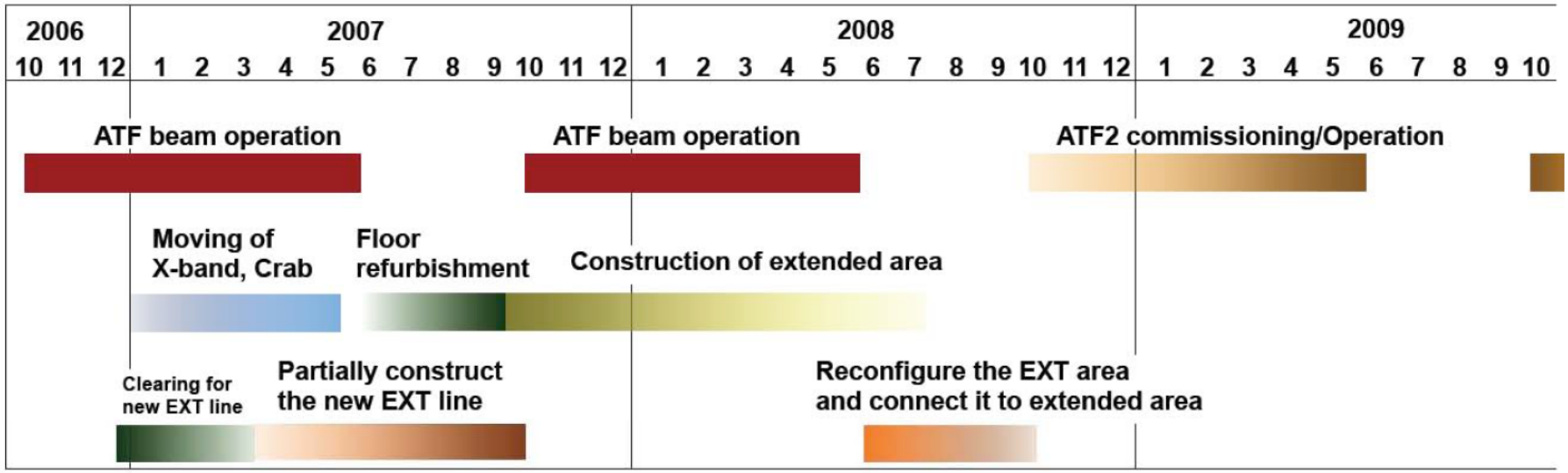


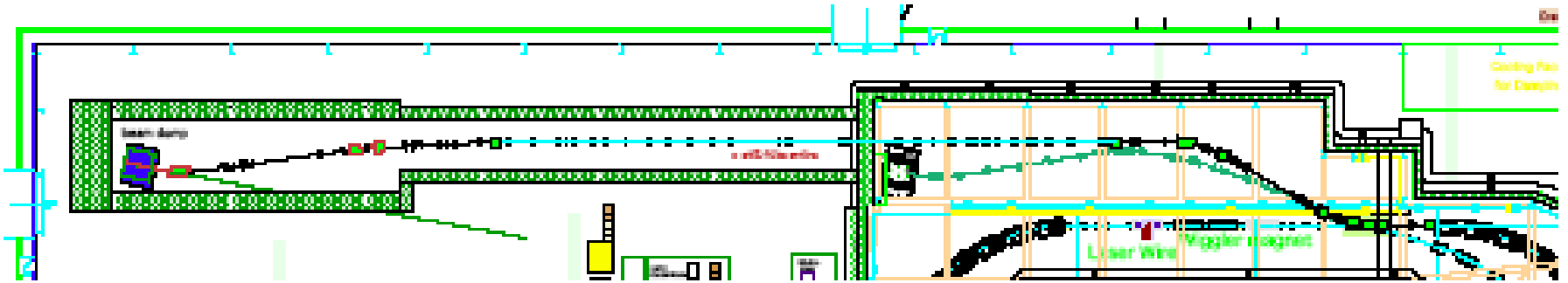
Optics & Lattice Design was fixed in June 2006.



IP ~37nm vertical size

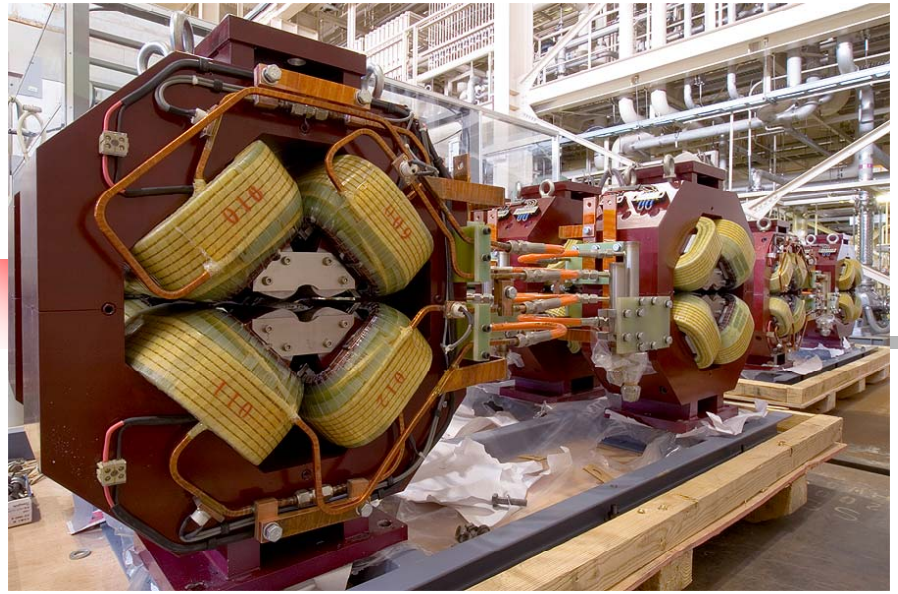
ATF2 construction schedule





- **ATF2 beam will come in October, 2008.**

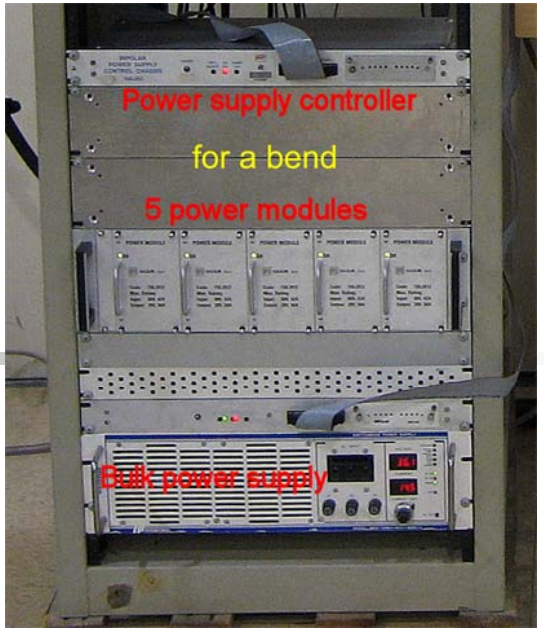
ATF2 development Highlights



Q-magnet from IHEP
(IHEP, SLAC, KEK)
~ 30 magnets were delivered.

Cavity-BPM for Q-magnet
from PAL (PAL, KEK)
~ 40 BPMs were delivered.

ATF2 development Highlights

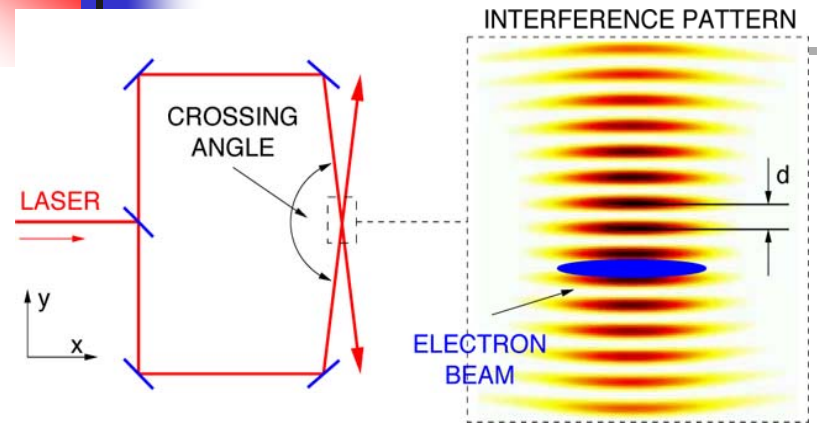


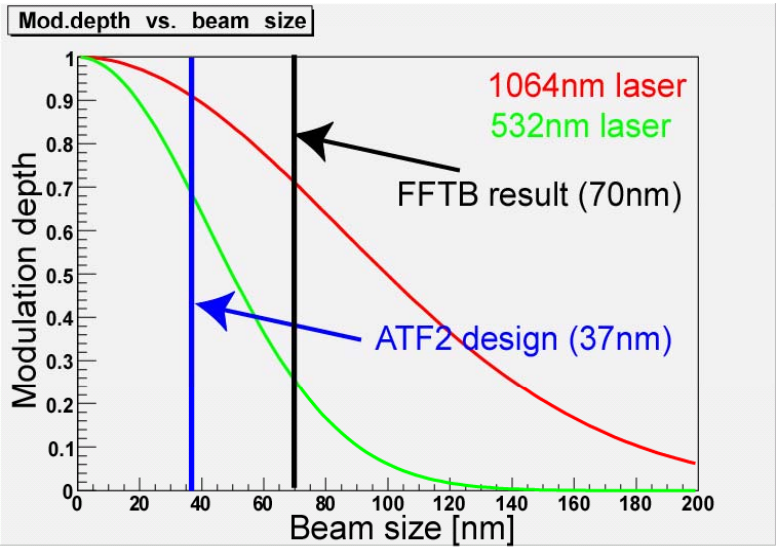
BPM electronics for cavity-BPM (SLAC)
Unit was tested in ATF.
Delivery in 2007.

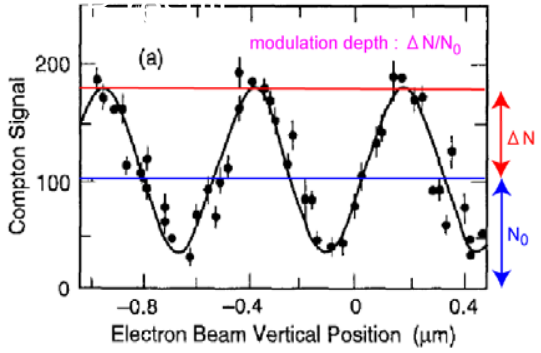
High Availability P.S. for Q-mag (SLAC)
1 unit was tested.
Delivery in 2007.

ATF2 development Highlights

Laser Interference Monitor at ATF2 IP(Tokyo Univ.)







Shintake-monitor result in FFTB

Shintake-monitor from FFTB

FFTB ~70nm -> ATF2 37nm
modification : Laser wavelength
fringe stabilization FB
new gamma detector

R&D Points for EDR of DR and BDS (from my view points)

- First, we have to select the lattice design which satisfies many constraints, especially dynamic aperture of positron DR and β function at beam injection/extraction to make enough kick angle.
- Consider the BPM turn-by-turn resolution (1μm (r.m.s.)) to make 2pm-rad vertical emittance beam.
- Consider the impedance and electron cloud issues to make the stable flat multi-bunch beam.
- Super Conducting 650MHz RF system to make 9mm bunch length beam and Super Conducting Wiggler system to make small damping time (20msec).
- Confirm beam quality by a lot of beam simulation.
- Confirm the tuning method for new final focus lattice.
- Develop necessary beam instrumentation (laser-wire, FONT, Cavity BPM,---).
- Confirm stable 37nm beam focus for long period.