The ILC Beam Delivery System Design and R&D Programme

T. Tauchi,

EPAC 2008, Genoa, Italy, 26 June 2008

International Linear Collider (ILC)

Acceleration with superconducting cavities and ~ 31 km total length

Aug. 2004 Choice of super-conducting technology

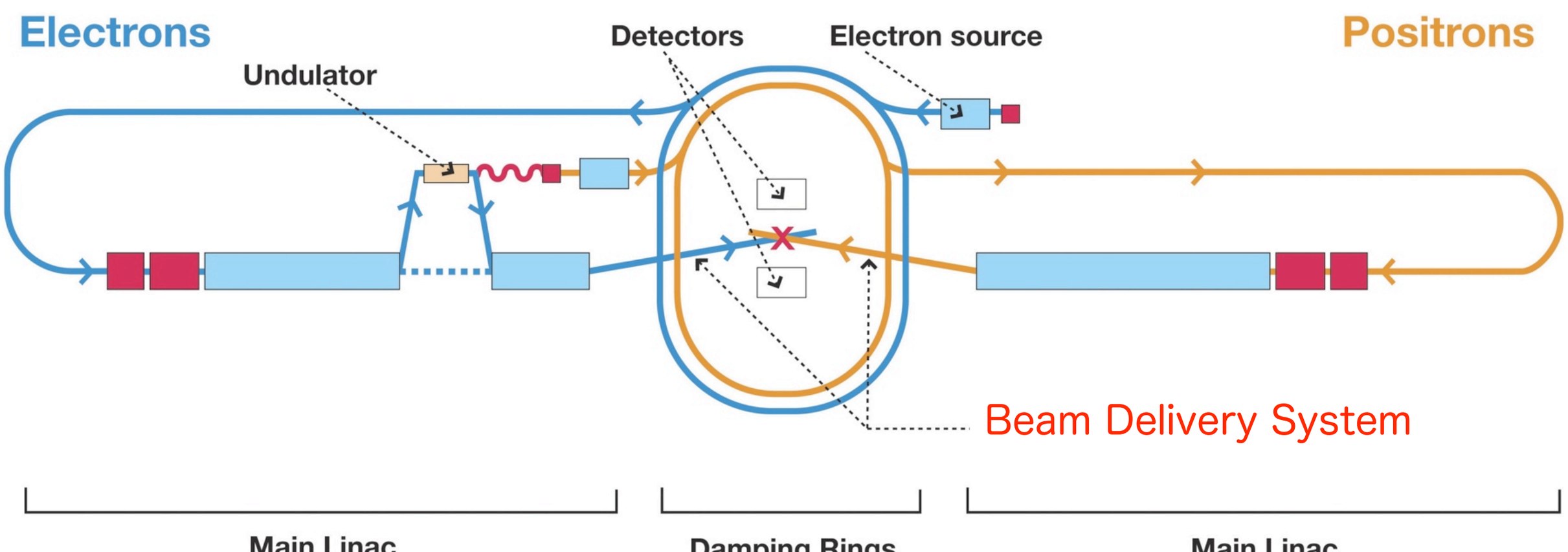
Mar. 2005 ILC GDE (Global Design Effort) established

Mar. 2006 BCD (Baseline Configuration Document) published

Aug. 2007 RDR (Reference Design Report) published

2008-2010 Technical Design Phase 1 (TDP1) - Interim report

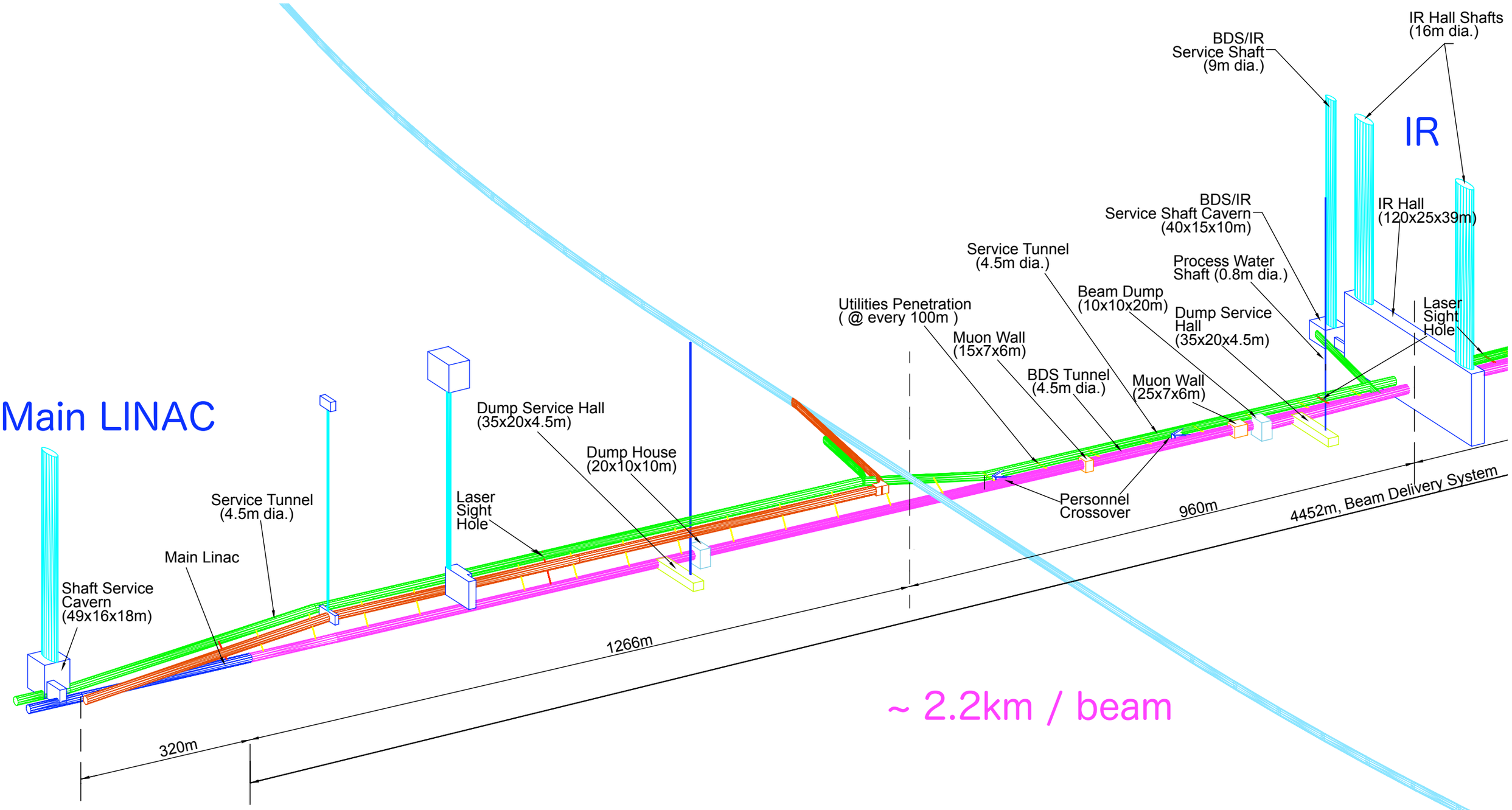
2010-2012 TDP2 - final report (the new baseline reference design)



Layout of BDS tunnels

Single IR for 2 detectors with push-pull scheme at E_{cm}=500GeV
Upgradable to E_{cm}=1TeV in the same layout

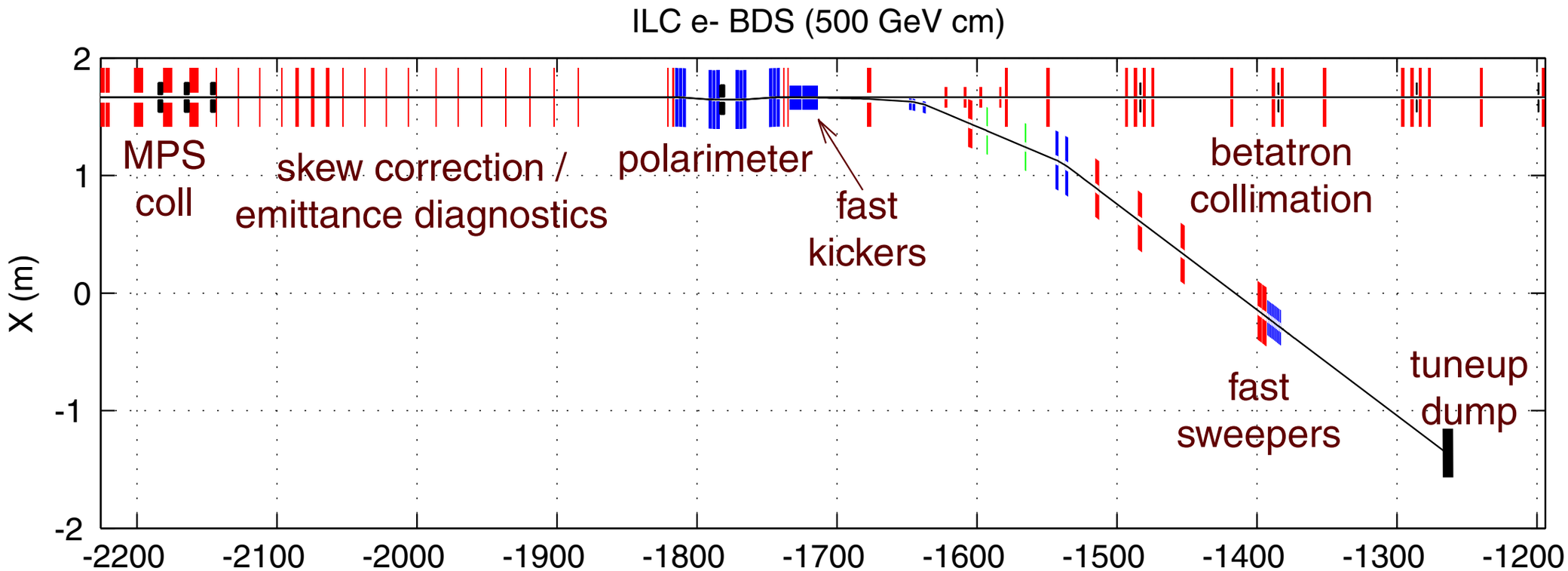
MOPP004, -031 (IR - pushpull - MDI)



BDS parameters

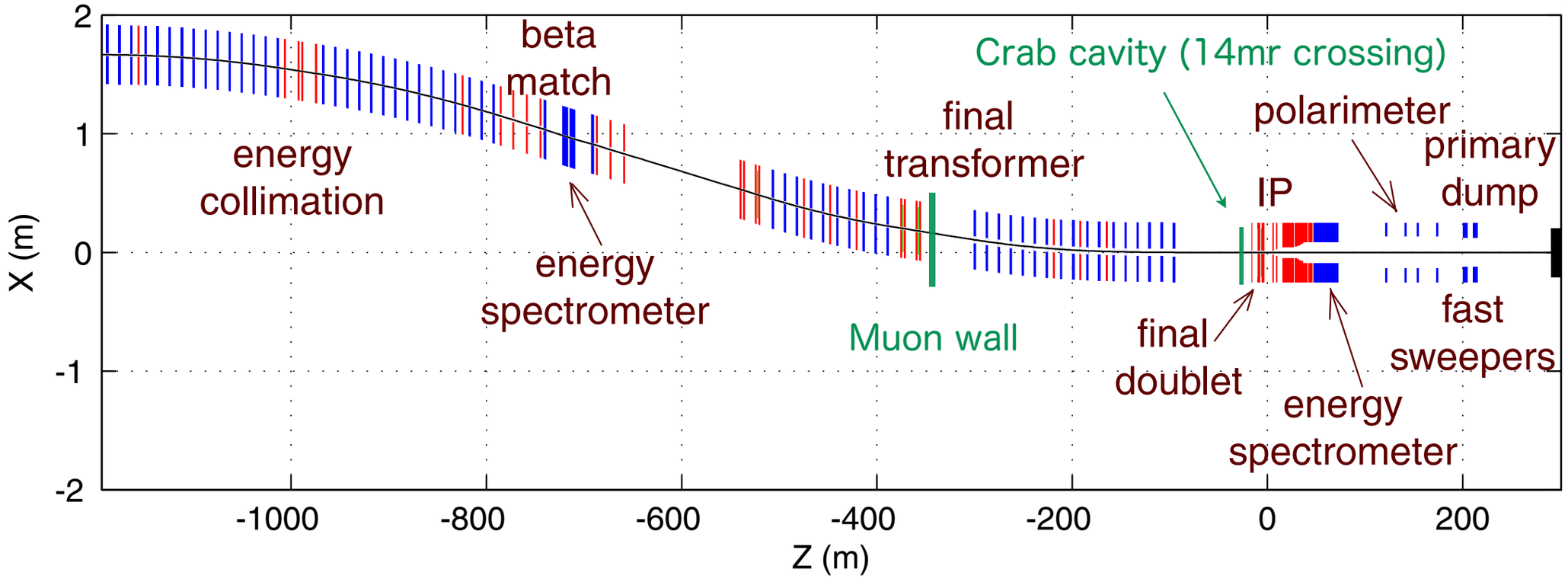
Length (linac exit to IP distance)/side	m	2226
Length of main (tune-up) extraction line	m	300 (467)
Max Energy/beam (with more magnets)	GeV	250 (500)
Distance from IP to first quad, L*	m	3.5-(4.5)
Crossing angle at the IP	mrad	14
Nominal beam size at IP, σ^*, x/y	nm	639/5.7
Nominal beam divergence at IP, θ^*, x/y	μrad	32/14
Nominal beta-function at IP, β^*, x/y	mm	20/0.4
Nominal bunch length, σ_z	μm	300
Nominal disruption parameters, x/y		0.17/19.4
Nominal bunch population, N		2.05×10^{10}
Beam power in each beam	MW	11.3
Preferred entrance train to train jitter	σ	< 0.5
Preferred entrance bunch to bunch jitter	σ	< 0.1
Typical nominal collimation depth, x/y		8–10/60
Vacuum pressure level, near/far from IP	nTorr	1/50

Functional subsystems in BDS



Z (m)

IR - Machine Detector Interface (MDI)



Major Issues in BDS

1. Chromaticity correction of final doublet

   chromaticity (ξ) : $\Delta\sigma^* = \xi\delta\sigma^*$, $\delta=(E-E_0)/E_0$

   $\xi \sim L^*/\beta^*_y \sim 10{,}000$ corrected by sextupoles

2. Beam diagnostic and tuning MOPP027 (fast feedback)

   beam size, energy, polarization measurements

   MOPP021

3. Beam-beam effect in interaction point (IP)

   MOPP024 (de-polarization)

   background (e^+e^- pairs) - flat beam

   extraction of disrupted beam to dump - crossing

   MOPP032, -033 MOPP005 (2mr)

4. Beam halo from main LINAC

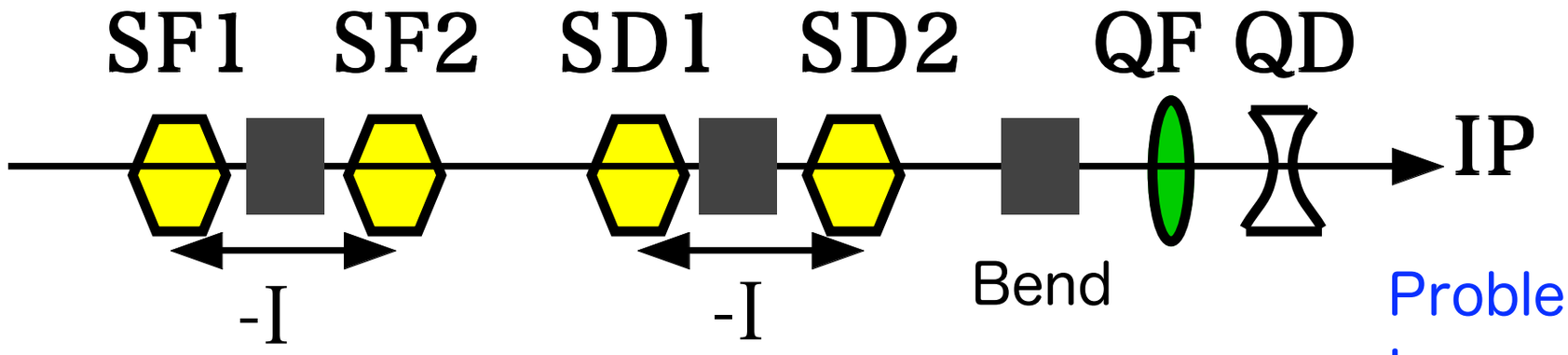
   robust collimation for synchrotron radiations

   MOPP007, -016

   muon wall (spoiler) for created muons

Optics design choice

(1) Non-local correction ; Conventional and tested at FFTB/SLAC

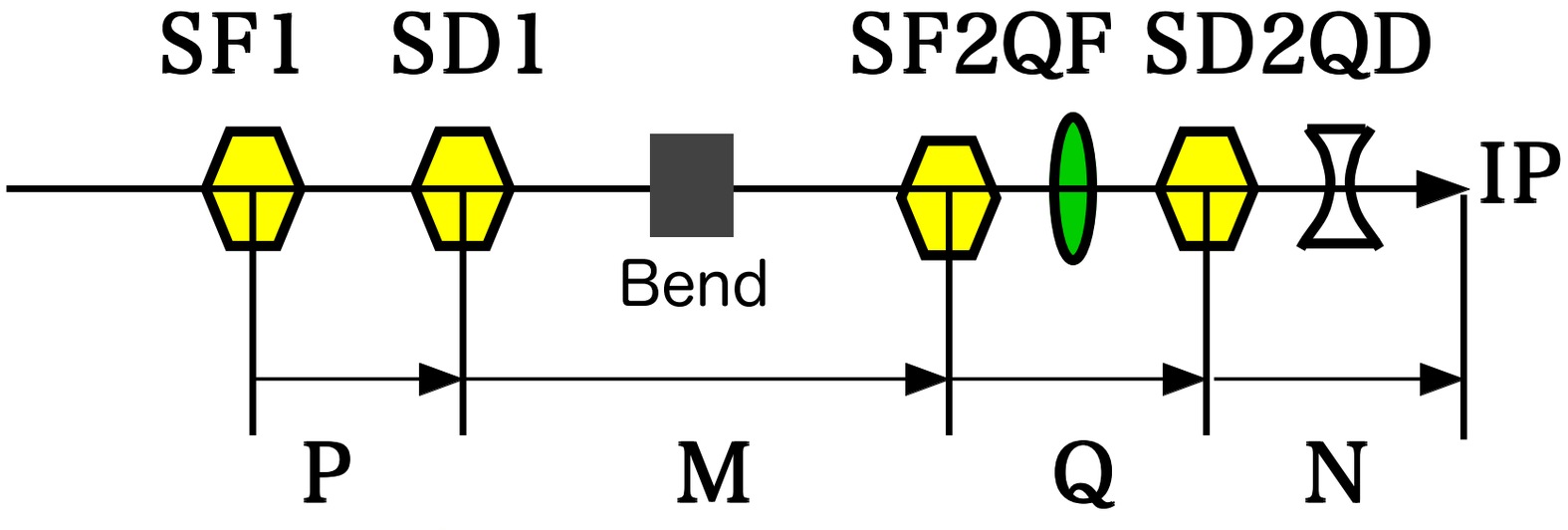


geometric aberration cancellation
and ξ correction at far upstream
in exclusive sections

Problem :
Large aberrations
for off-momentum
particles (beam halo)

(2) Local correction ; ILC choice and to be tested at ATF2/KEK

P.Raimondi and A.Seryi, Phys. Rev. Lett. 86 3779 (2001)



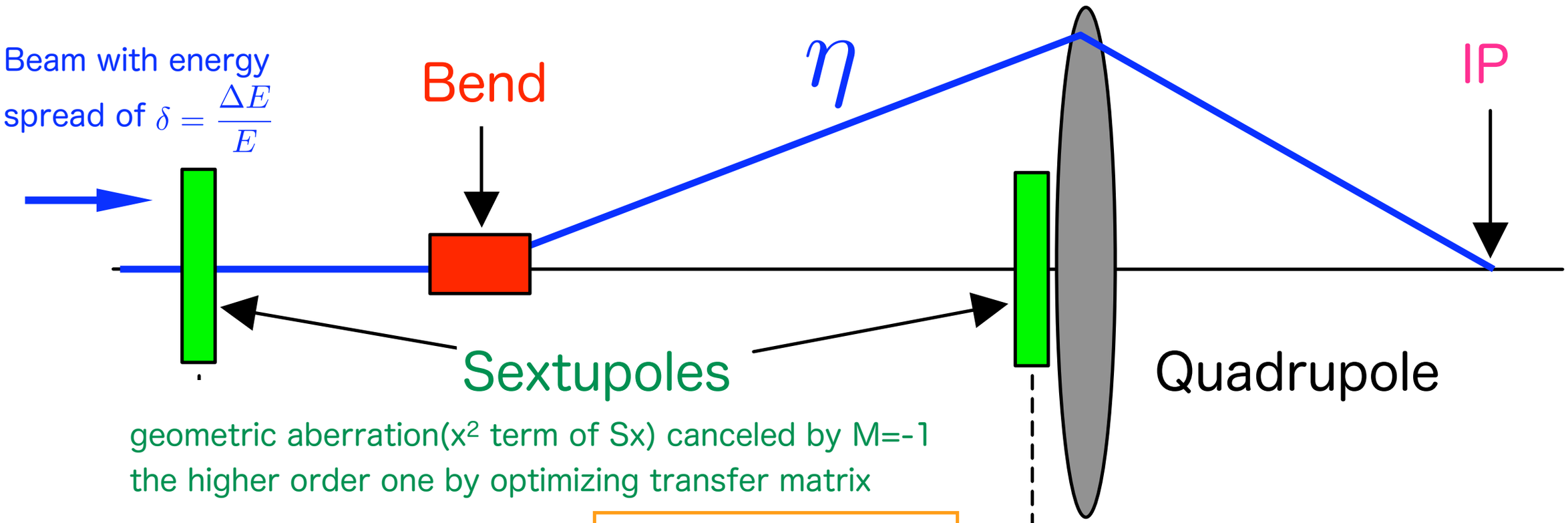
geometric aberration cancellation

higher order aberration cancellation

ξ correction at FD

Compact
Large IP bandwidth
Small aberration
for beam halo

Horizontal Chromaticity, 2nd Order Dispersion Correction



geometric aberration(x^2 term of Sx) canceled by M=-1
the higher order one by optimizing transfer matrix

Quadrupole: $$\Delta x' = \frac{K_1}{(1+\delta)}(x+\eta\delta) \rightarrow K_1(-\delta x - \eta\delta^2)$$

Sexupole: $$\Delta x' = \frac{K_2}{2}(x+\eta\delta)^2 \rightarrow K_2\eta(\delta x + \frac{\eta\delta^2}{2})$$

chromaticity

2nd order dispersion

Quadrupole pair: $$\Delta x' = \frac{K_1}{(1+\delta)}(x+\eta\delta) + \frac{K_{\beta-\mathrm{match}}}{(1+\delta)}x \rightarrow 2K_1(-\delta x - \frac{\eta\delta^2}{2})$$

$$K_{\beta-\mathrm{match}} = K_1 \qquad K_2 = \frac{2K_1}{\eta}$$

Test Facilities

1. ESA at SLAC , for 2006 - 2008

   ILC-BDS instrumentation experiments

2. ATF2 as scaled-down model of LC-BDS final focus

   All the elements will be developed and tested.

3. Proposed facility of FACET at SLAC

“Facilities for Accelerator Science and Experimental Test Beams”

- Accelerator Science Facility (ASF) , 24GeV and focused beam
  plasma wakefield accelerators (PWFA)
- ESA (12GeV) and ASF
  ILC-BDS instrumentation and ILC/LHC detector R&Ds

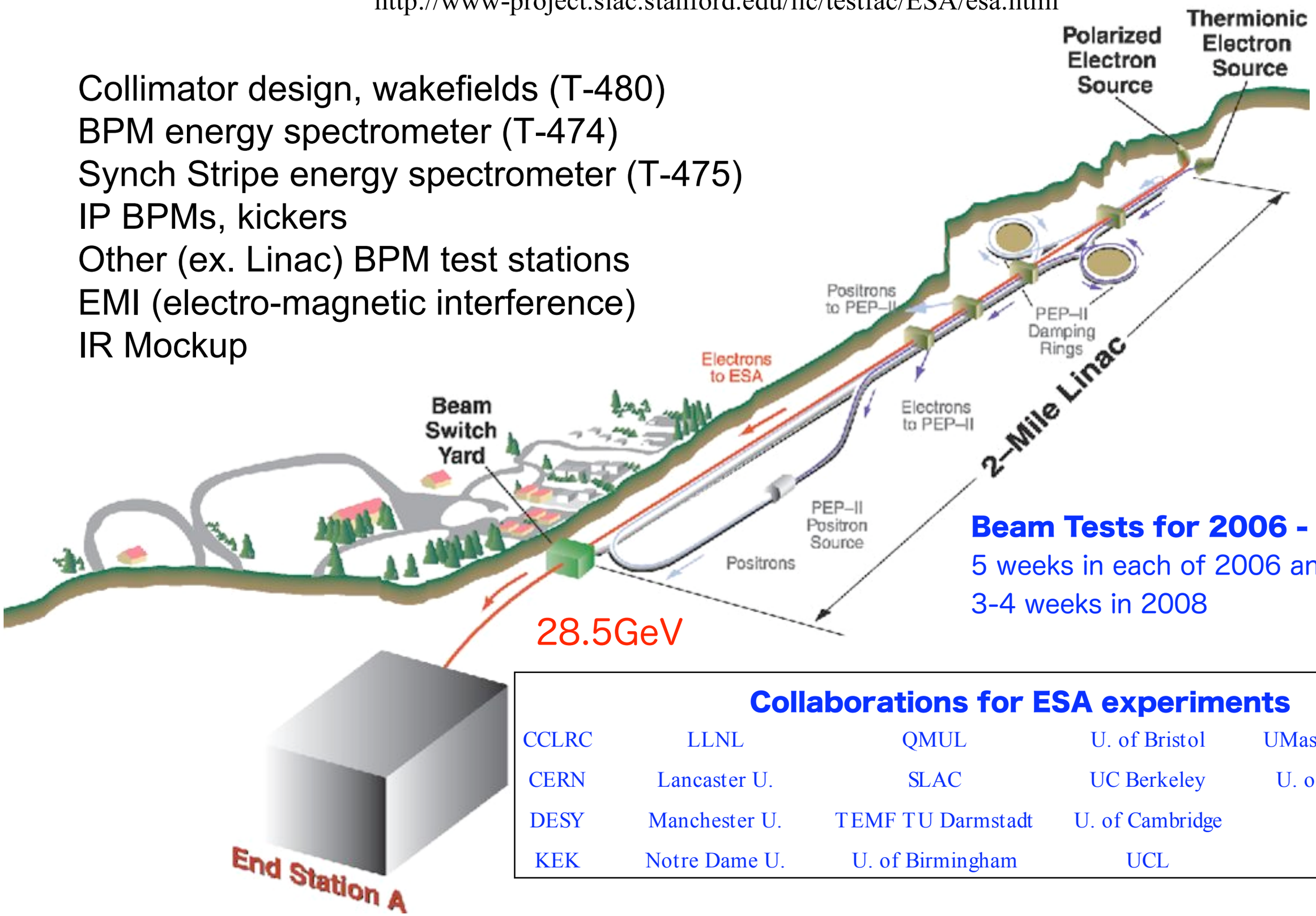
M. Woods (SLAC)

End Station A Test Facility

For Prototypes of Beam Delivery and IR Components

http://www-project.slac.stanford.edu/ilc/testfac/ESA/esa.html

Collimator design, wakefields (T-480)
BPM energy spectrometer (T-474)
Synch Stripe energy spectrometer (T-475)
IP BPMs, kickers
Other (ex. Linac) BPM test stations
EMI (electro-magnetic interference)
IR Mockup



Beam Tests for 2006 - 2008
5 weeks in each of 2006 and 2007
3-4 weeks in 2008

Collaborations for ESA experiments

CCLRC	LLNL	QMUL	U. of Bristol	UMass Amherst
CERN	Lancaster U.	SLAC	UC Berkeley	U. of Oregon
DESY	Manchester U.	TEMF TU Darmstadt	U. of Cambridge	
KEK	Notre Dame U.	U. of Birmingham	UCL	

Energy spectrometer R&D at ESA/SLAC

Goal : 100ppm -resolution ; MOPP021

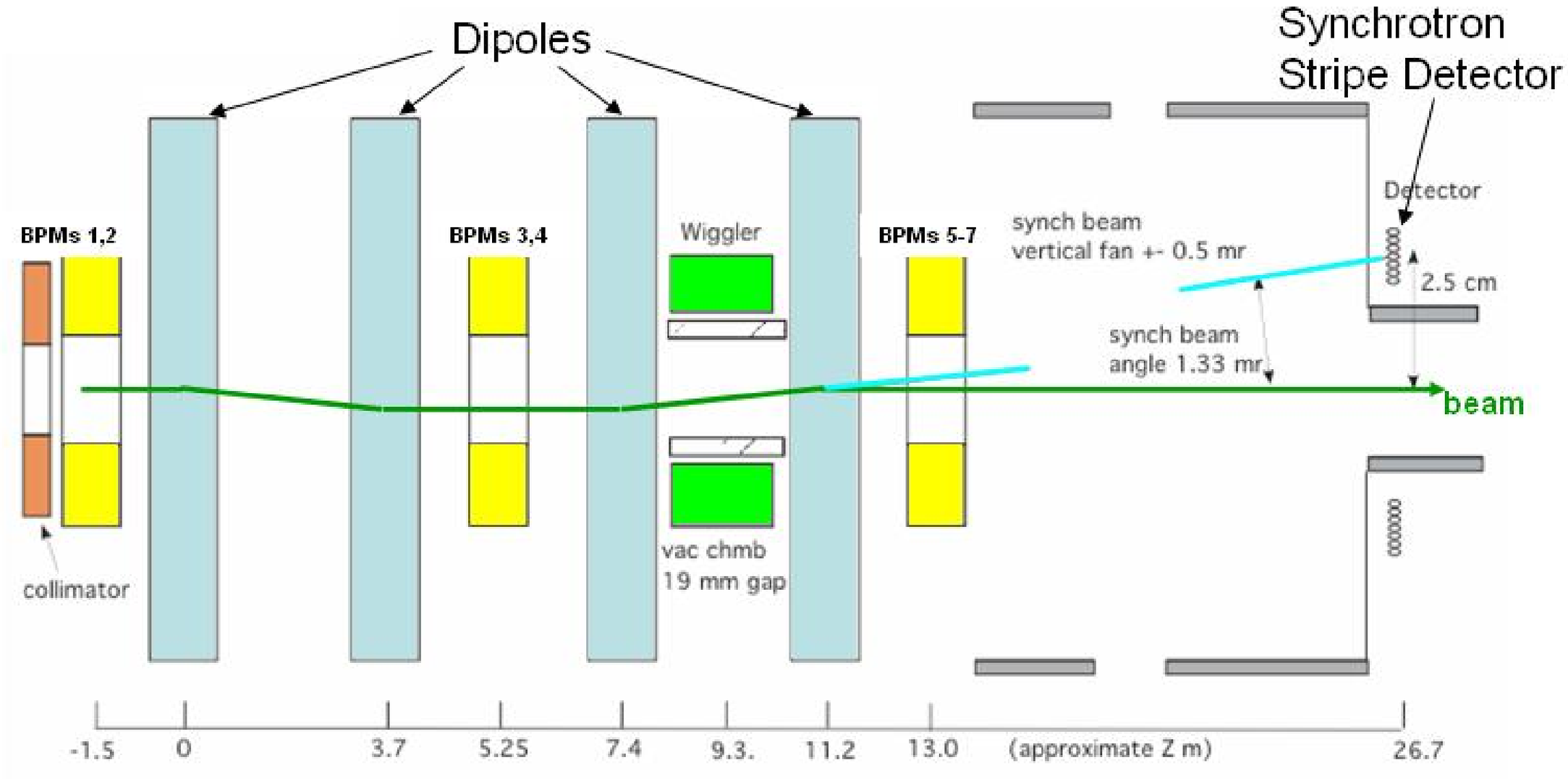


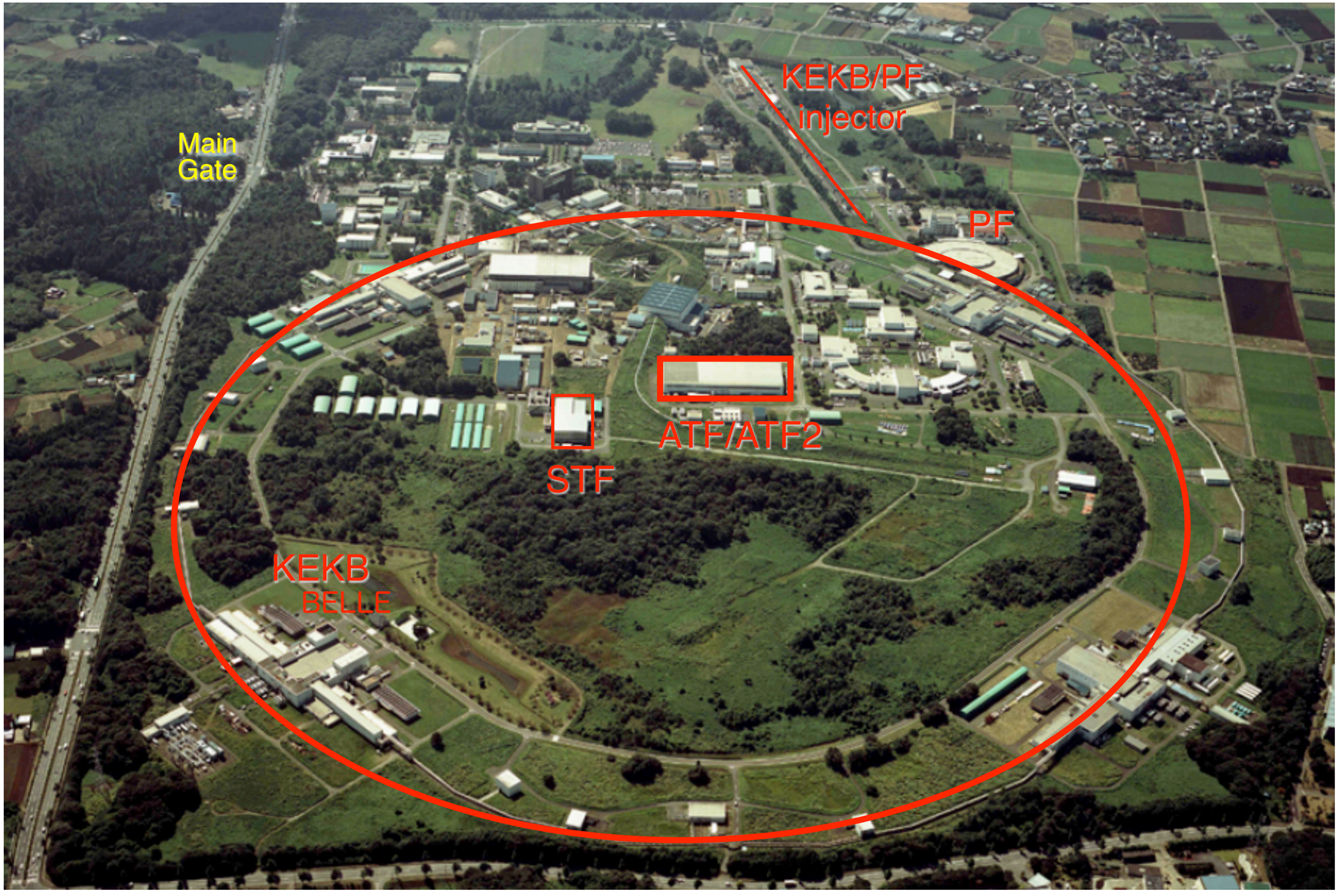
Figure 3-1. Plan view of 4-dipole chicane with vertical wiggler magnet for energy spectrometer studies. Two additional BPM doublets are 10 meters and 50 meters upstream of BPMs1, 2 respectively. Not shown is an interferometer system measuring horizontal offsets and stability of BPMs 1-4.

Position monitoring system (laser interferometer) at μm level

Wakefields box at ~8m upstream of first BPM for collimator damage

KEK High Energy Accelerator Research Organization

in Tsukuba site, Japan



ATF International Collaboration

with MOU since Aug.2005

CERN
DESY
IN2P3 (LAL, LAPP, LLR)
Tomsk Polytechnic Univ.
INFN, Frascati
University College London
John Adams Ins., Oxford Univ.
Royal Holloway Univ. of London

KEK
Waseda Univ.
Nagoya Univ.
Tokyo Univ.
Kyoto Univ.
Hiroshima Univ.
PAL (Korea)
IHEP (China)

SLAC
LBNL
FNAL
Cornell Univ.

Foreign Researchers visiting KEK (2006/4~2007/7)
23 institutes,71 people, total 2085 people・day
(full-year researchers are excluded)

N.Ternuma, LC project committee, 7 Aug.2007

ATF Accelerator Test Facility, KEK

1997-2008

Extraction line :utilization of low emittance beam
beam instrumentation, collimator damage

Cavity BPM
nanometer res.

FONT
fast feedback (ns)

Pulsed Laser Wire Scanner
for beam size monitor (μm)

Collimation damage
phase-1

ODR, OTR
single shot meas.

Beam Dynamics
MOPP003, - 047

CSR

LW, Cavity Compton

Damping Ring
ultra low emittance beam (2pm)
dynamics -fast ion instability
beam instrumentation(BPM,LW)

MOPP018, -066

Fast kicker
rise time < 3ns

MOPP024

XSR

Energy: 1.28 GeV
Electron bunch:
$2x10^{10}$ e/bunch
1 ~ 20 bunches/train
3 trains/ring
1.56 Hz

RF Gun
multi-bunch beam

S-band Linac (70m)
multi-bunch acceleration

ATF2 Proposal Vol.1 and 2
110 authors (25 research institutes)

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ATF2 Project in the ATF collaboration

MOPP030, - 039, TUPP016 (tuning, BBA, flight simulation)

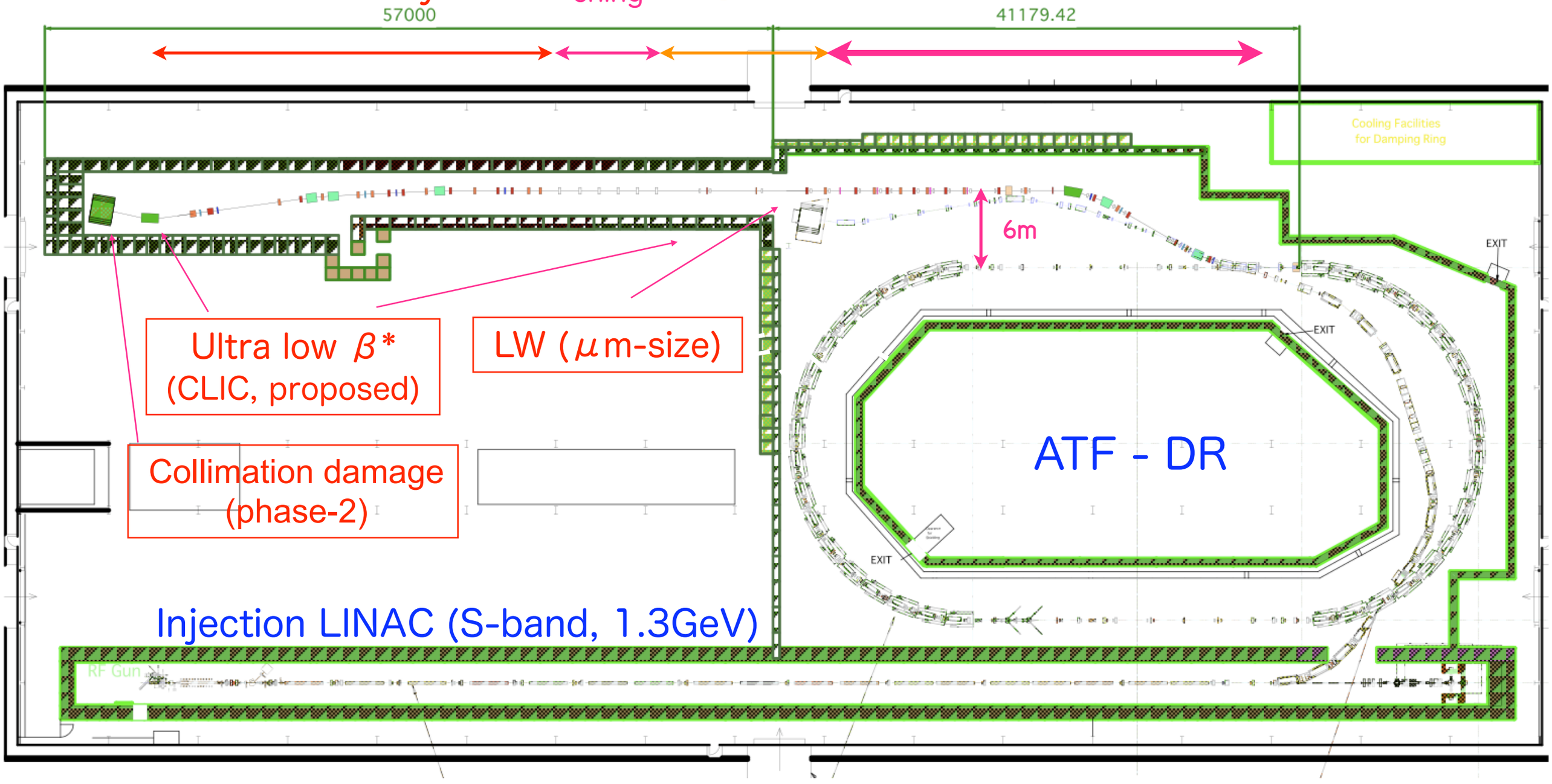
ATF2 beam line

Reconfiguration of extraction line
for reduction of dispersion

Final Focus System

β mat-ching

Diagnostic



params	ATF2	ILC
Beam Energy [GeV]	1.3	250
L* [m] (f*)	1	3.5 – 4.2
$\gamma\,\epsilon_x$ [m-rad]	5 e-6	1e-5
$\gamma\,\epsilon_y$ [m-rad]	3e-8	4e-8
β_x^* [mm]	4.0	21
β_y^* [mm]	0.1	0.4
η' (DDX) [rad]	0.14	0.094
σ_E [%]	~0.1	~0.1
Chromaticity W_y	$\sim 10^4$	$\sim 10^4$
$\sigma_x(\mu\mathrm{m})$	2.8	0.655
$\sigma_y(\mathrm{nm})$	34	5.7
σ_x/σ_y	82	115

$\sim \mathbf{L}^*/\beta_{\mathbf{y}}^*$

Mode-I

A. Achievement of 34nm beam size

A1) Demonstration of a new compact final focus system;
proposed by P.Raimondi and A.Seryi in 2000,

A2) Maintenance of the small beam size
(several hours at the FFTB/SLAC)

Mode-II

B. Control of the beam position

B1) Demonstration of beam orbit stabilization with
nano-meter precision at IP.
(The beam jitter at FFTB/SLAC was about 40nm.)

B2) Establishment of beam jitter controlling technique
at nano-meter level with ILC-like beam (2008 -?)

ILC-FF (660m)

electron beam

$\sqrt{\beta_x}, \sqrt{\beta_y}\ (\sqrt{\mathrm{m}})$

$\eta_x, \eta_y\ (\mathrm{m})$

SD0 SF1 B1 B2 SD4 SF5 B5 SF6 QM11 QM16

ATF2-FF (30m)

electron beam

IP

F

D

m

ATF2 Features

- The same number of magnets as the ILC-FF.
- The tuning knob, methods are the same,too.
- Beam instrumentation has been developed with the ILC specifications; BPMs, BSMs, movers, magnet support, laserwires, HA power supplies, FONT-feedback system etc. .
- International participation in the commissioning and operation

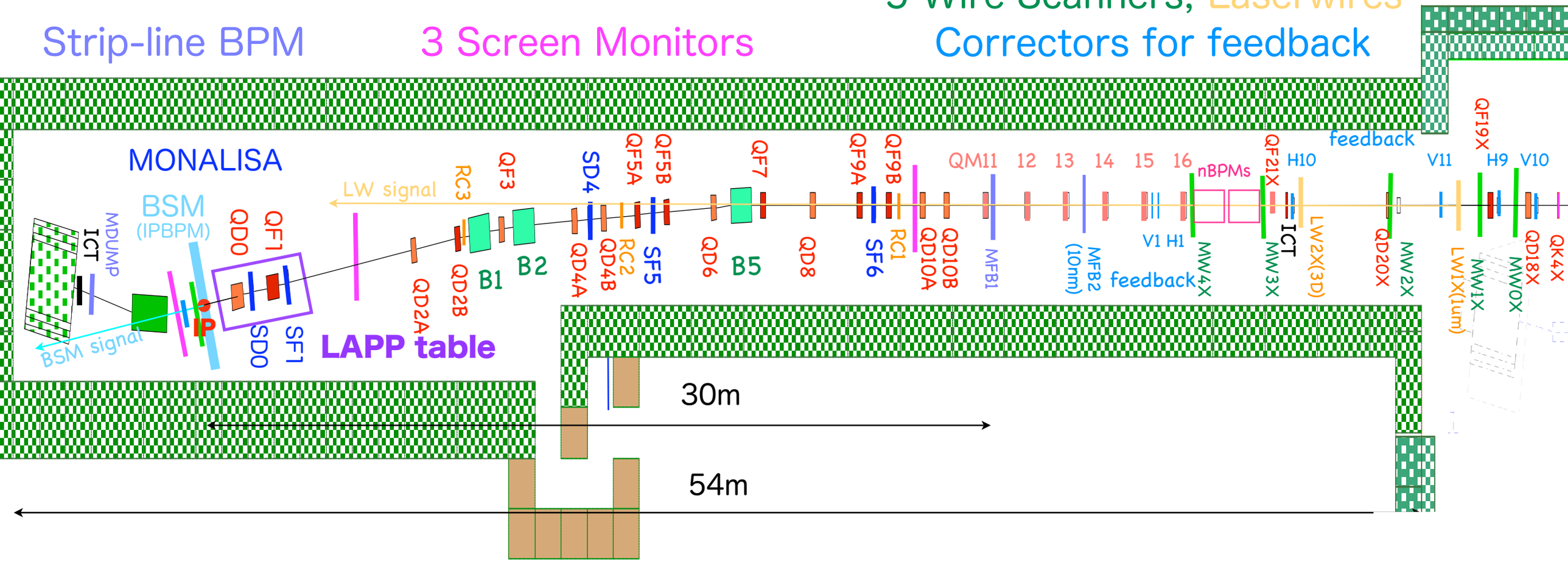
Hardware System at ATF2

22 **Q**uadrupoles, 5 **S**extupoles, 3 **B**ends in downstream of QM16
(IHEP, China, MOPP014) (SLAC) (SLAC, IHEP)

All Q- and S-magnets have cavity-type beam position monitors(QBPM, 100nm).
(PAL, Korea)

5 Wire Scanners, Laserwires

Strip-line BPM 3 Screen Monitors Correctors for feedback

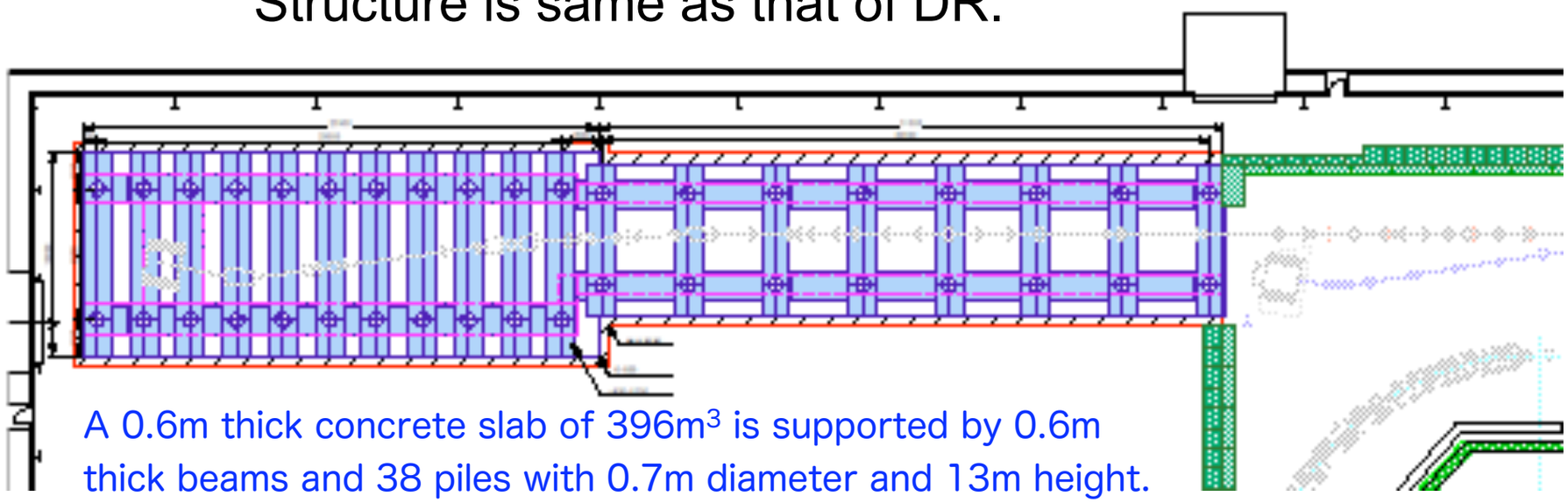


Shintake Monitor (beam size monitor, BSM with laser interferometer):Tokyo univ.
MONALISA (nanometer alignment monitor with laser interferometer):Oxford univ.
Laserwire (beam size monitor with laser beam for 1 μm beam size, 3 axies):RHUL
IP intra-train feedback system with latency of less than 150ns (FONT):Oxford univ.
Magnet movers for Beam Based Alignment (BBA):SLAC - MOPP039
High Available Power Supply (HA-PS) system for magnets:SLAC - THPP127

Floor structure for ATF2 beam line

Refurbishment from Jun to Sep 2007

Structure is same as that of DR.




29th November 2007


Q-manets installation, 10th January 2008


Beam Dump, 31st March 2008


Shintake mon. optics start, 14th May 2008

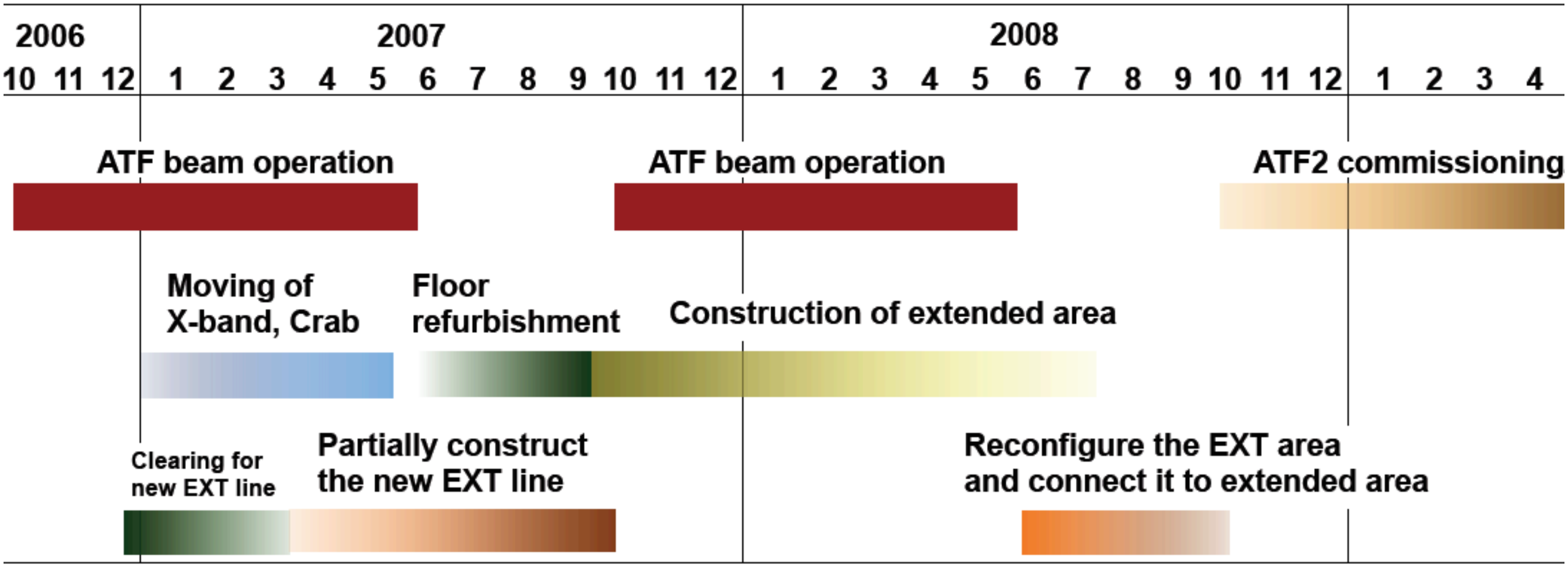
cabling and piping, 14th May 2008

HA-PS installation, 14th May 2008

Laser hut construction(LW), 14th May 2008

QBPM phase fine-adjustment, 21st May 2008

ATF2 Schedule



ATF2 will be commissioning in this October.

Conclusion

- ILC BDS has been designed by large international collaboration in framework of ILC-GDE since 2005.
- There are R&Ds of critical subsystems such as final doublet, crab cavity, laser wire, collimation etc.
- Close collaboration between machine and physics people is essential in the design, and it has been successful; i.e. IR Interface Document.
- Test facilities (ESA, ATF2 and FACET) will assure stable collisions of nanometer beams at future linear colliders.