Reminder of FONT IP Feedback system: hardware in MDI

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Feedback On Nanosecond Timescales (FONT) Group:

Robert Apsimon, Neven Blaskovic Kraljevic, Douglas Bett, Ryan Bodenstein, Talitha Bromwich, Philip Burrows, Glenn Christian, Christine Clarke, Ben Constance, Michael Davis, Tony Hartin, Young Im Kim, Simon Jolly, Steve Molloy, Gavin Nesom, Colin Perry, Rebecca Ramjiawan, Javier Resta Lopez, Jack Roberts, Christina Swinson

Outline

- Reminder of IP Feedback system concept
- TDR design
- Comments on status and technical issues

All engineering drawings shown here are from TDR era:

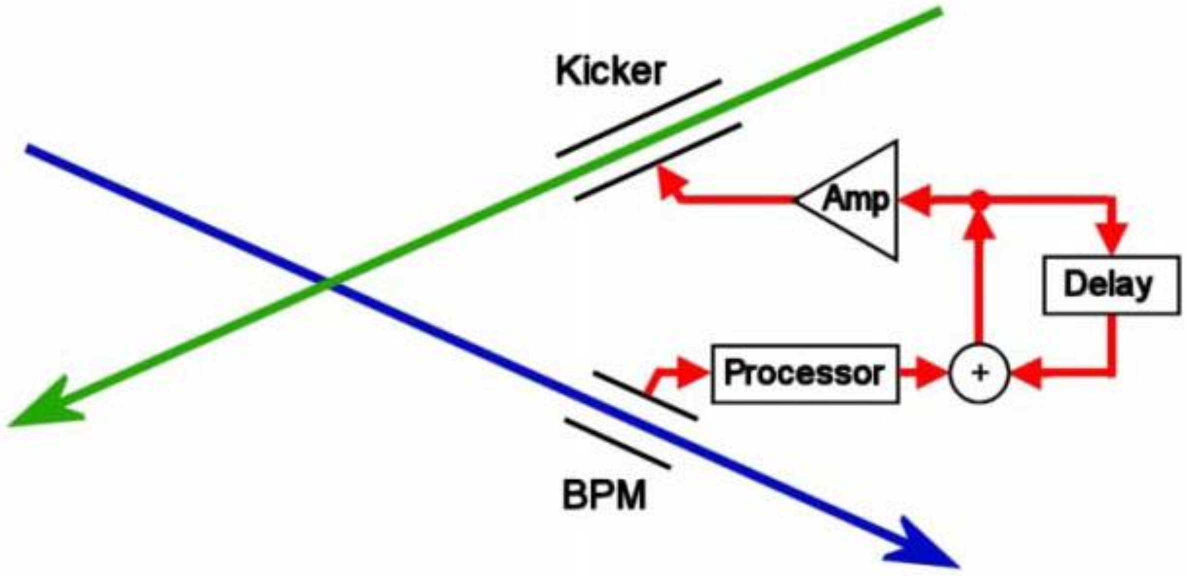
For SiD, L* has since changed from 3.5m to ~4m,

but this has no major consequences for IPFB.

For ILD, IP FB system is conceptually identical.

IP beam collision feedback

- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR



Beam parameters (TDR era)

	ILC 500	1000	CLIC 3 TeV	
Electrons/bunch	2	2	0.37	10**10
Bunches/train	1312	2450	312	
Bunch separation	554	366	0.5	ns
Train length	727	897	0.156	us
Train repetition rate	5	4	50	Hz
Horizontal IP beam size	474	335	40	nm
Vertical IP beam size	6	3	1	nm
Longitudinal IP beam size	300	224	44	um
Luminosity	2	5	6	10**34

General considerations

Time structure of bunch train:

ILC (500 GeV): c. 1300 bunches w. c. 500 ns separation

CLIC (3 TeV): c. 300 bunches w. c. 0.5 ns separation

Feedback latency:

ILC: O(100ns) latency budget allows digital approach

CLIC: O(10ns) latency requires analogue approach

Recall speed of light: c = 30 cm / ns:

FB hardware should be close to IP (especially for CLIC!)

Two systems, one on each side of IP, allow for redundancy

ILC IP FB Design Status

Engineering design documented in ILC TDR (2013):

1. IP beam position feedback:

beam position correction up to +- 300 nm vertical at IP

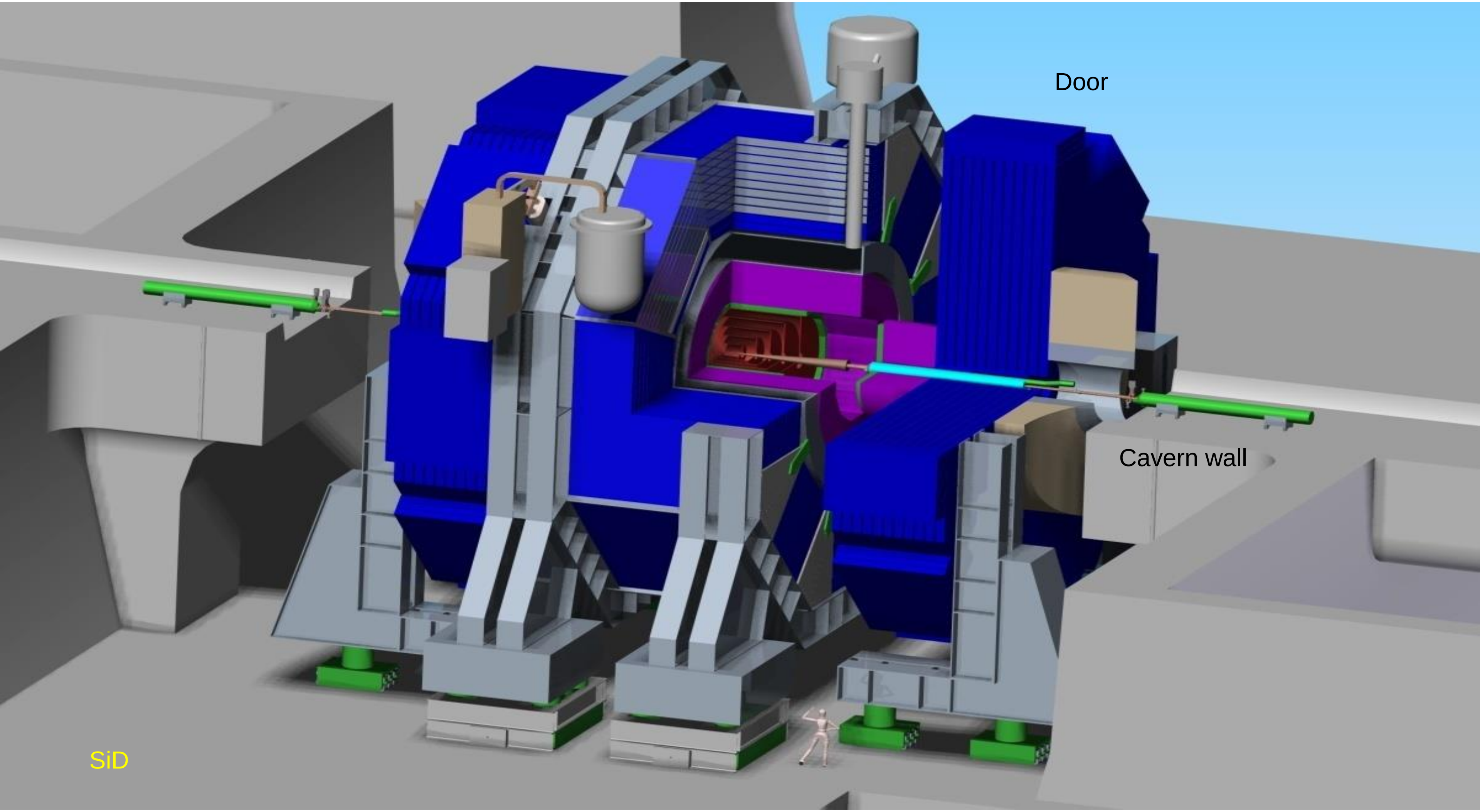
2. IP beam angle feedback: hardware located few 100 metres upstream

conceptually very similar to position FB, less critical

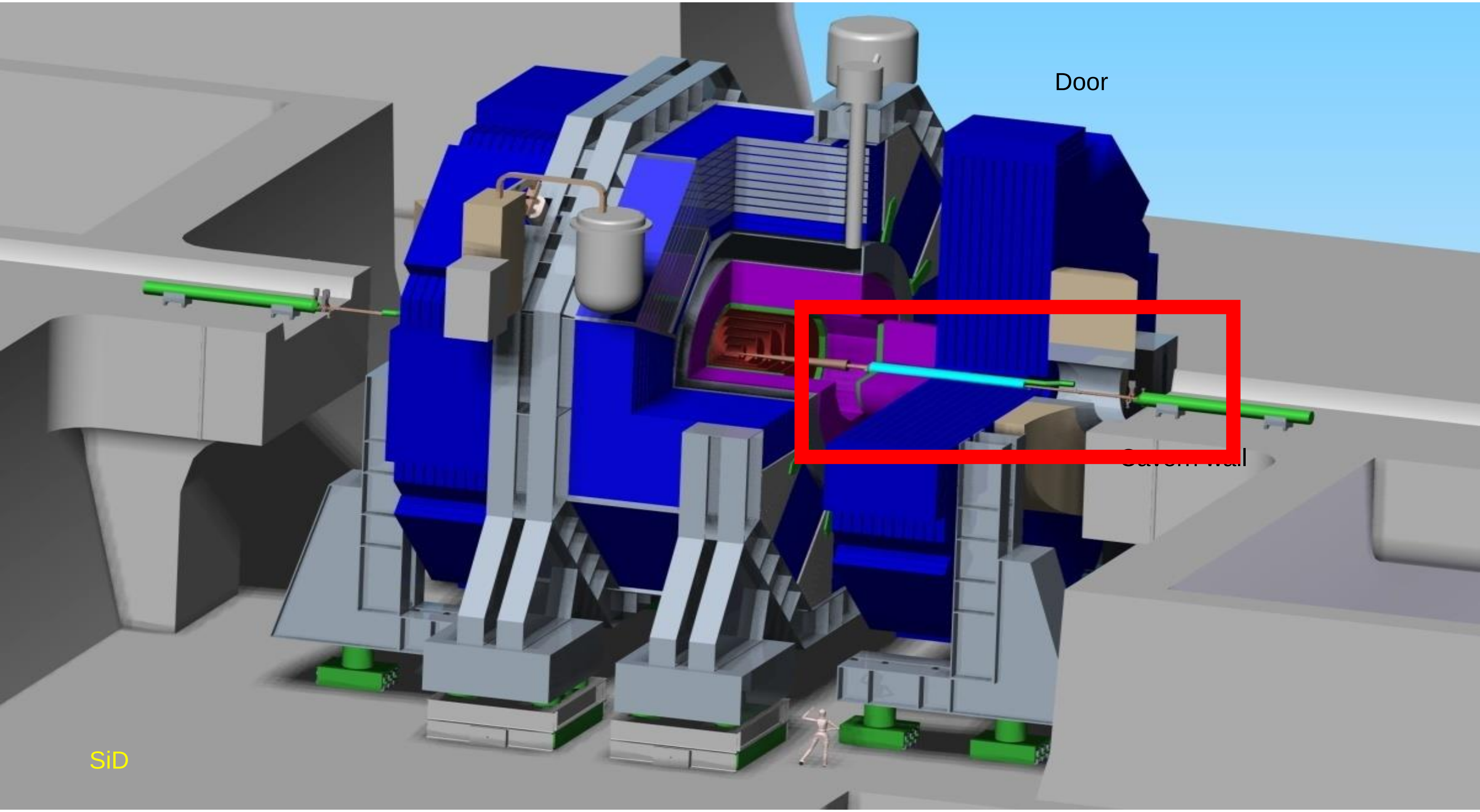
3. Bunch-by-bunch luminosity signal (from ‘BEAMCAL’)

‘special’ systems requiring dedicated hardware + data links

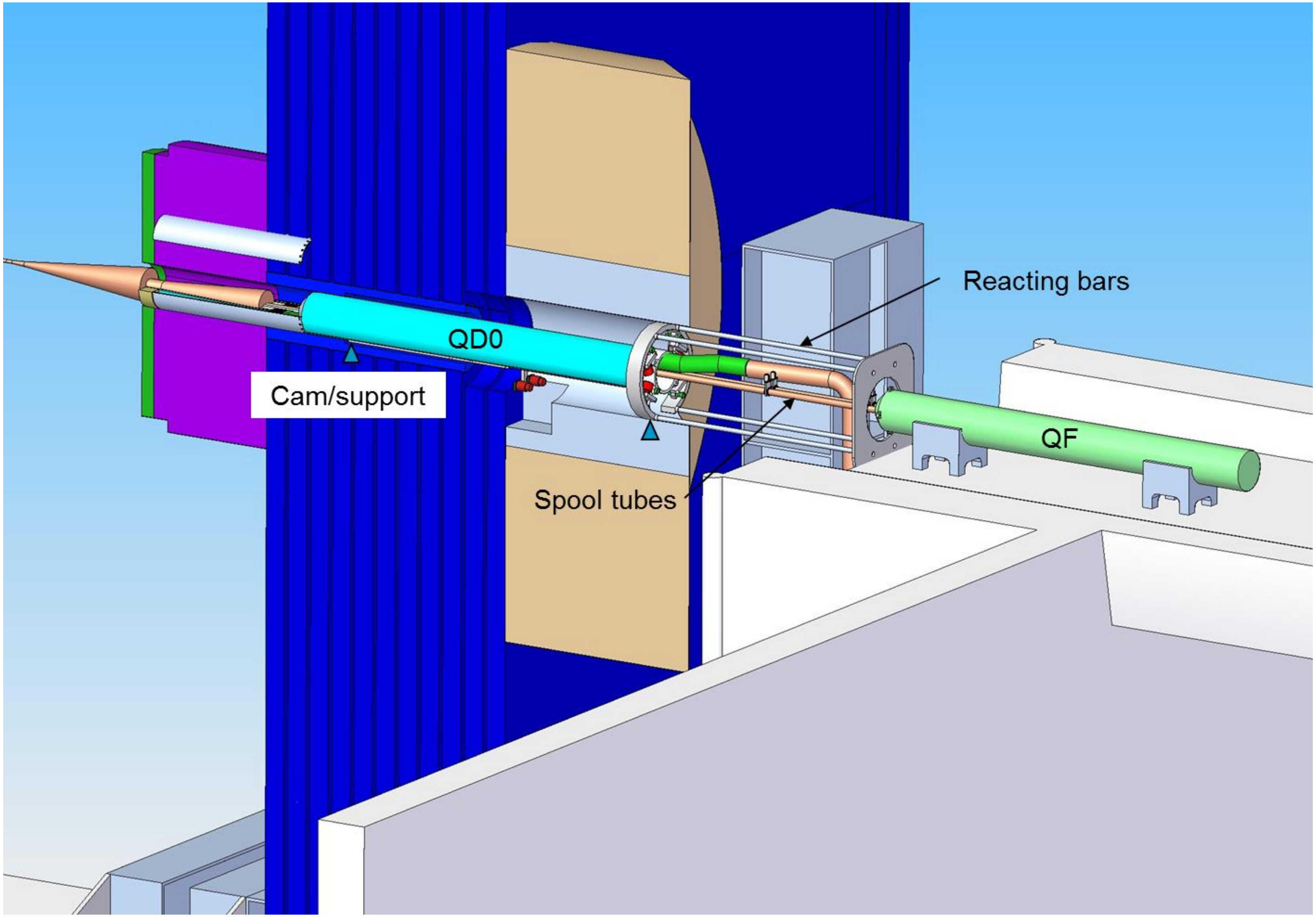
ILC IR: SiD for illustration



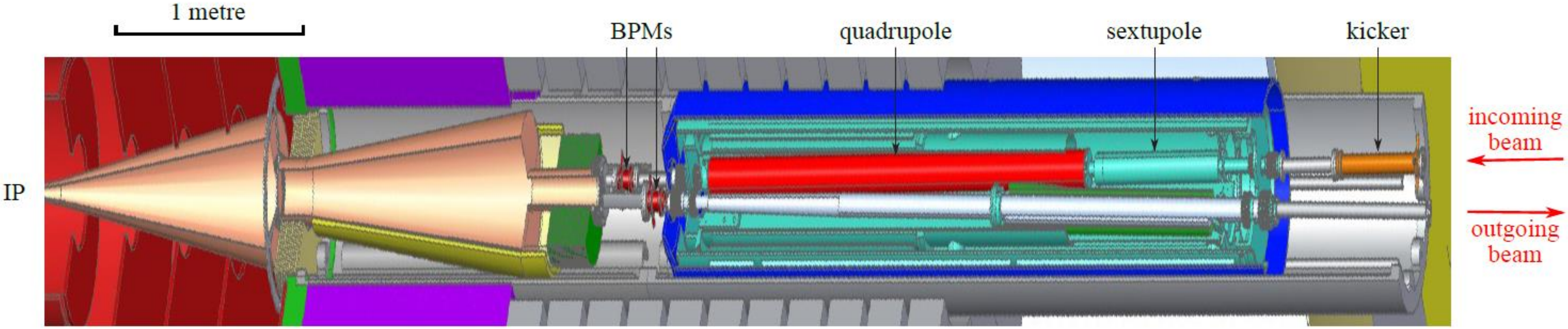
ILC IR: SiD for illustration



Final Doublet Region (SiD)

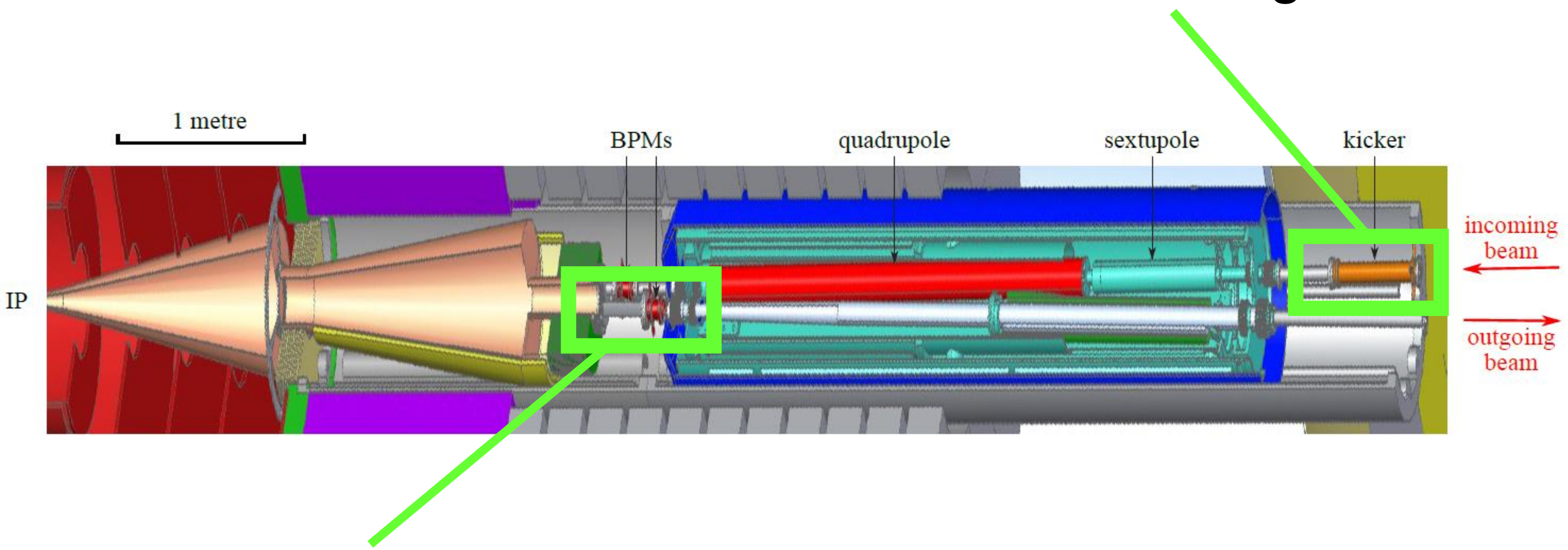


SiD QD0 region



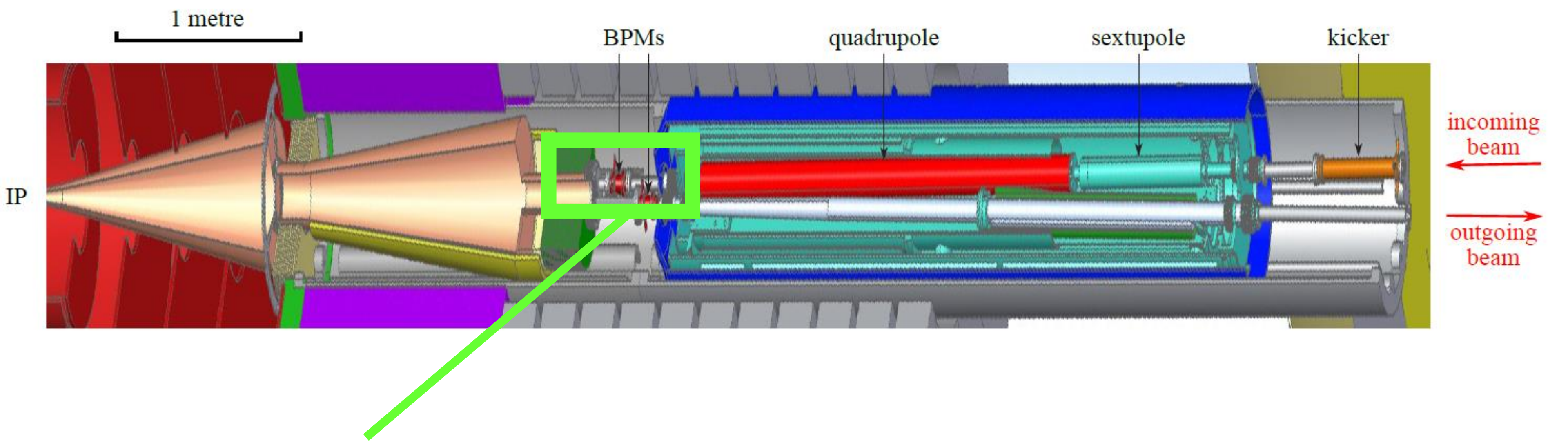
SiD QD0 region

feedback kicker on incoming beamline



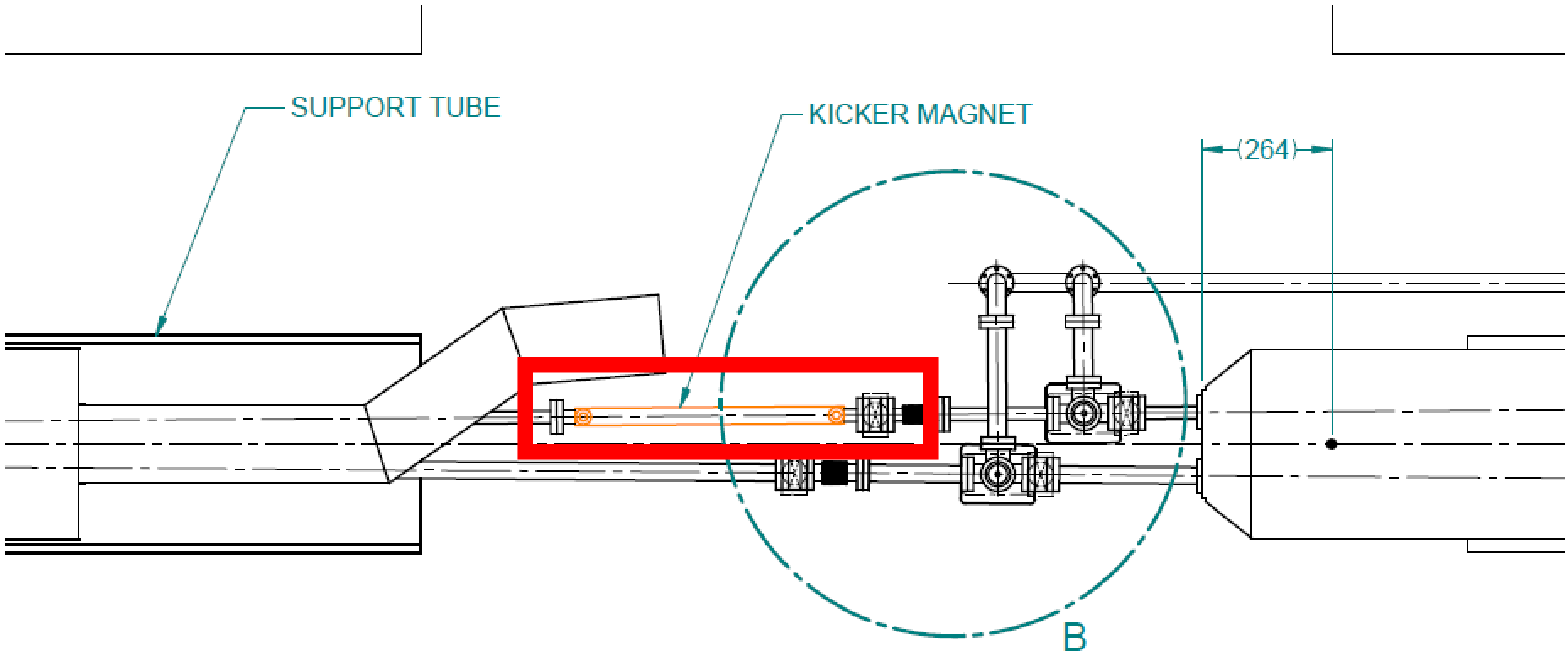
feedback BPM on outgoing beamline

SiD QD0 region

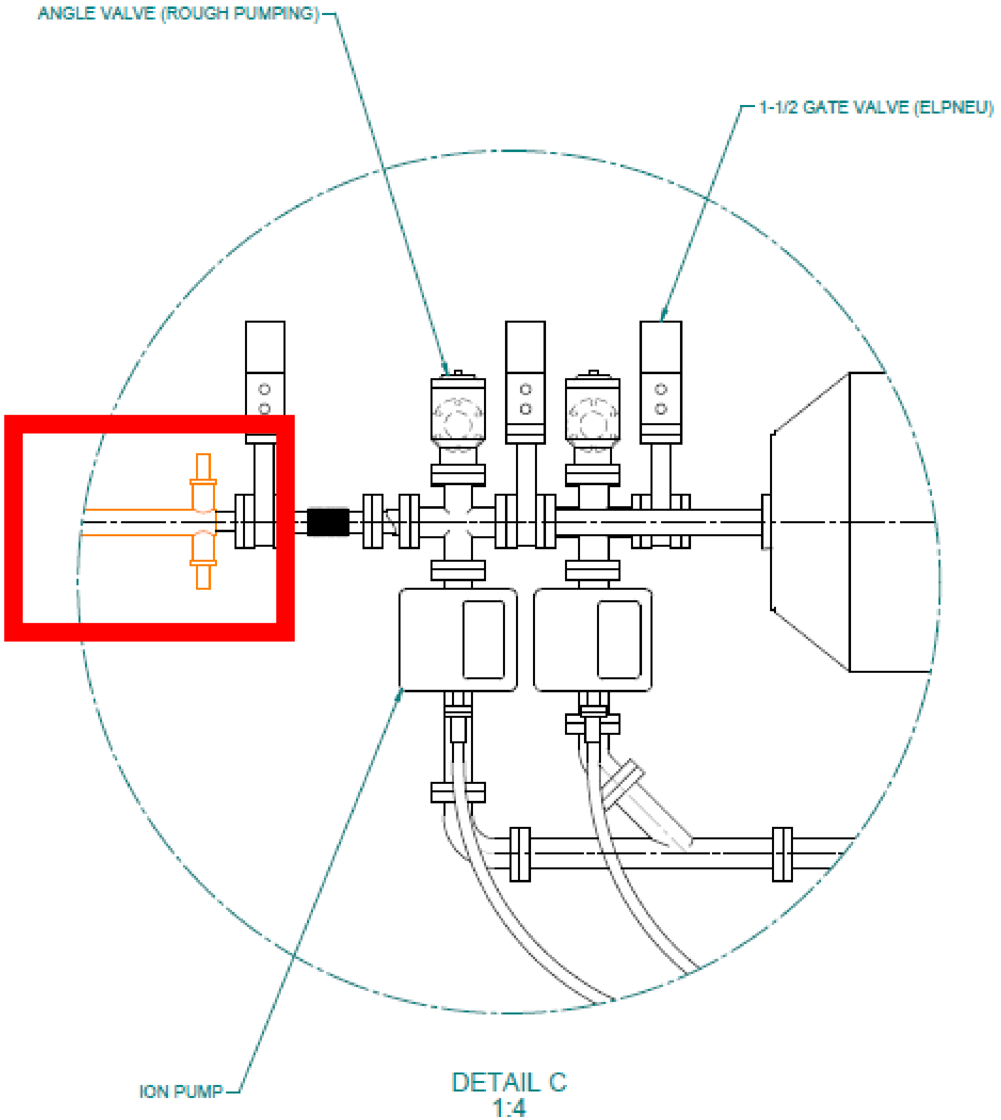


monitoring BPM on incoming beamline

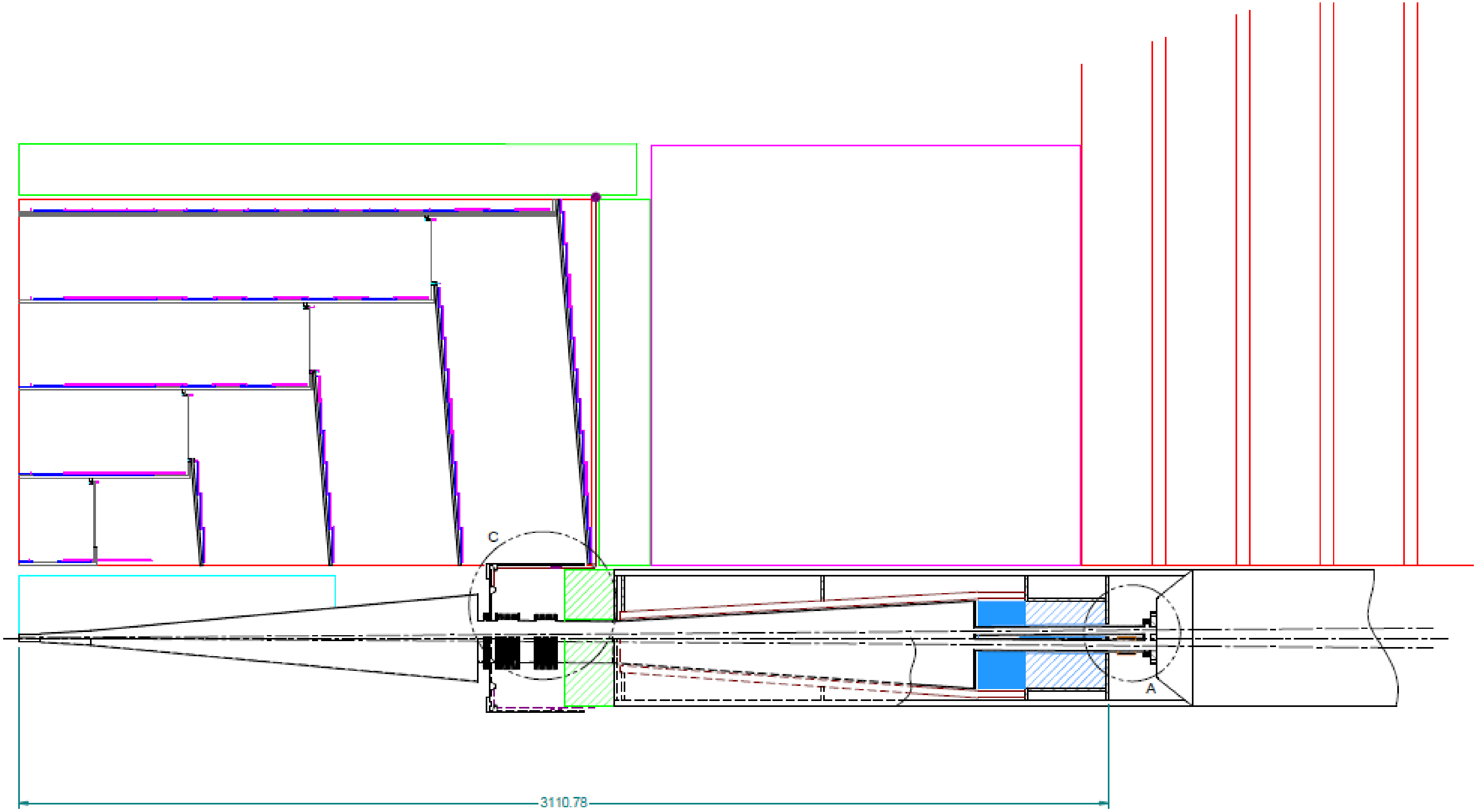
Plan view of kicker



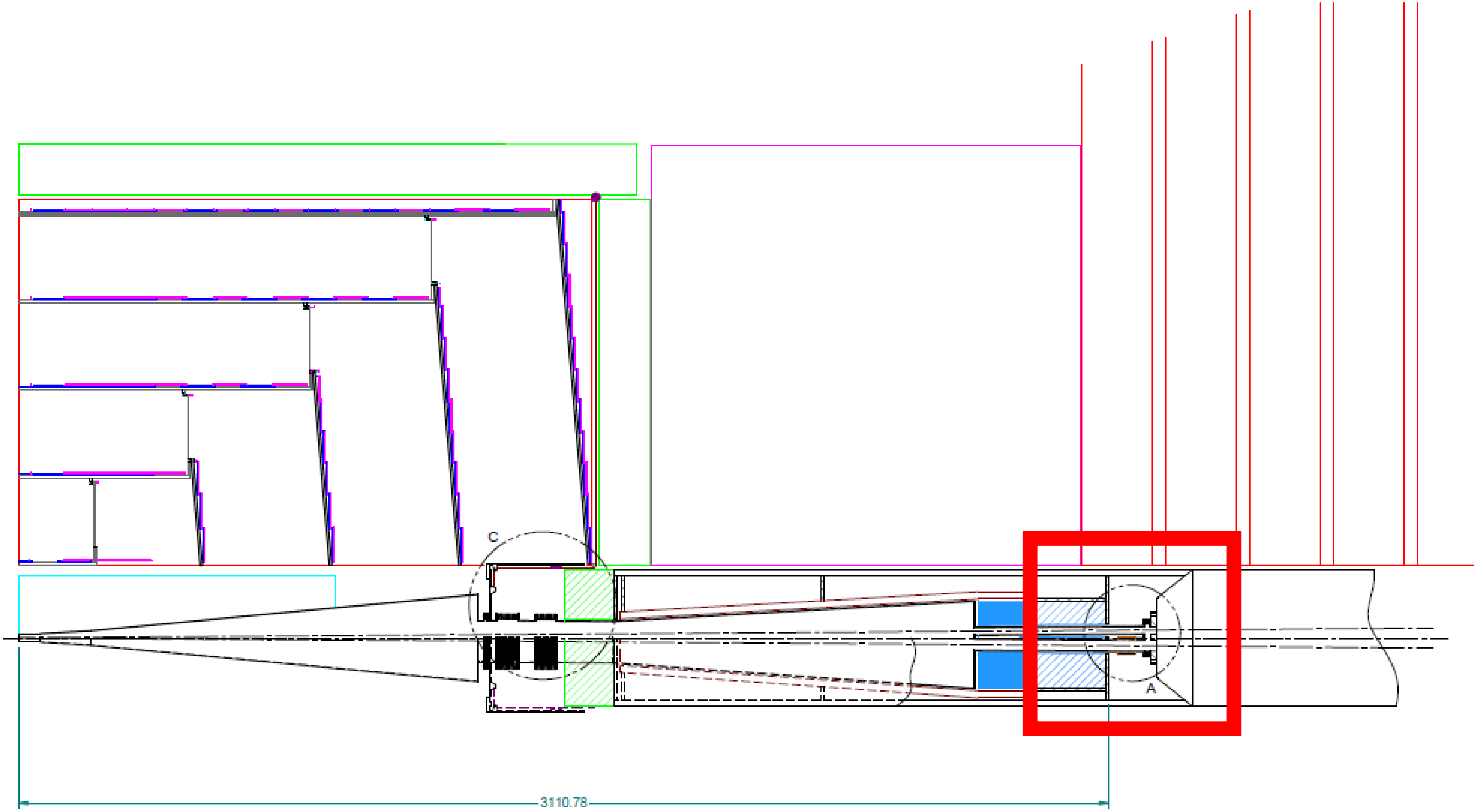
Side view of kicker



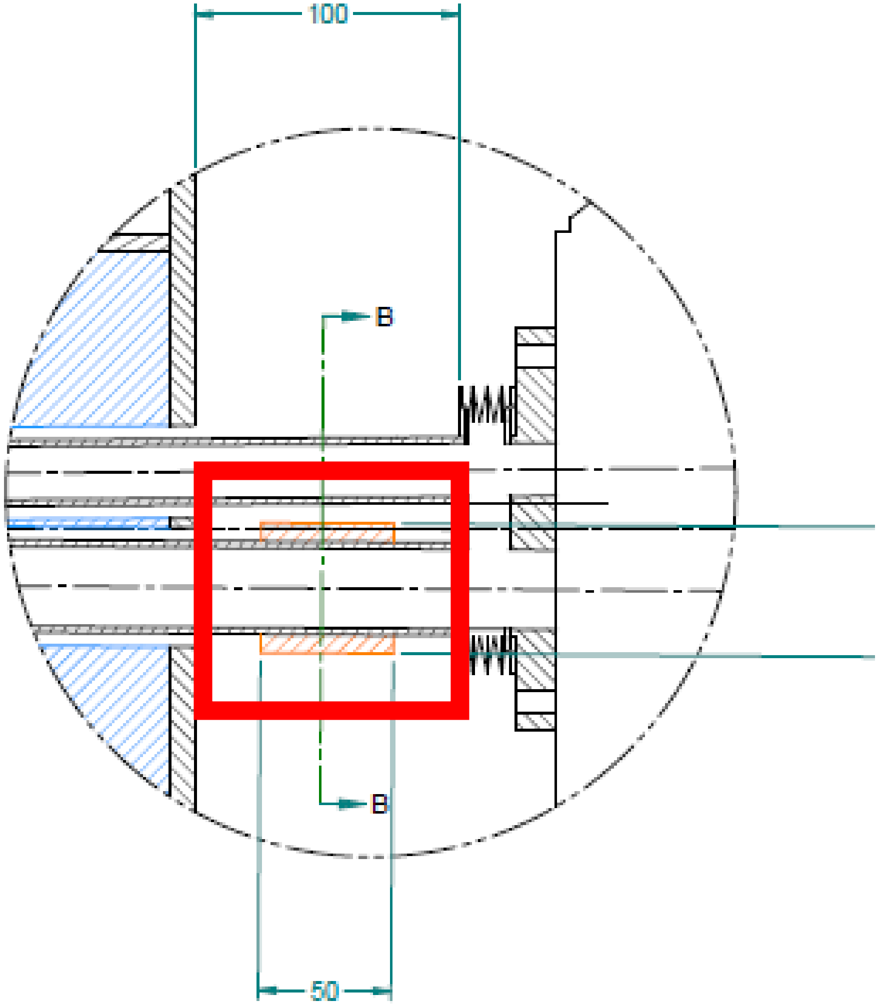
IP Region (SiD)



IP Region (SiD)

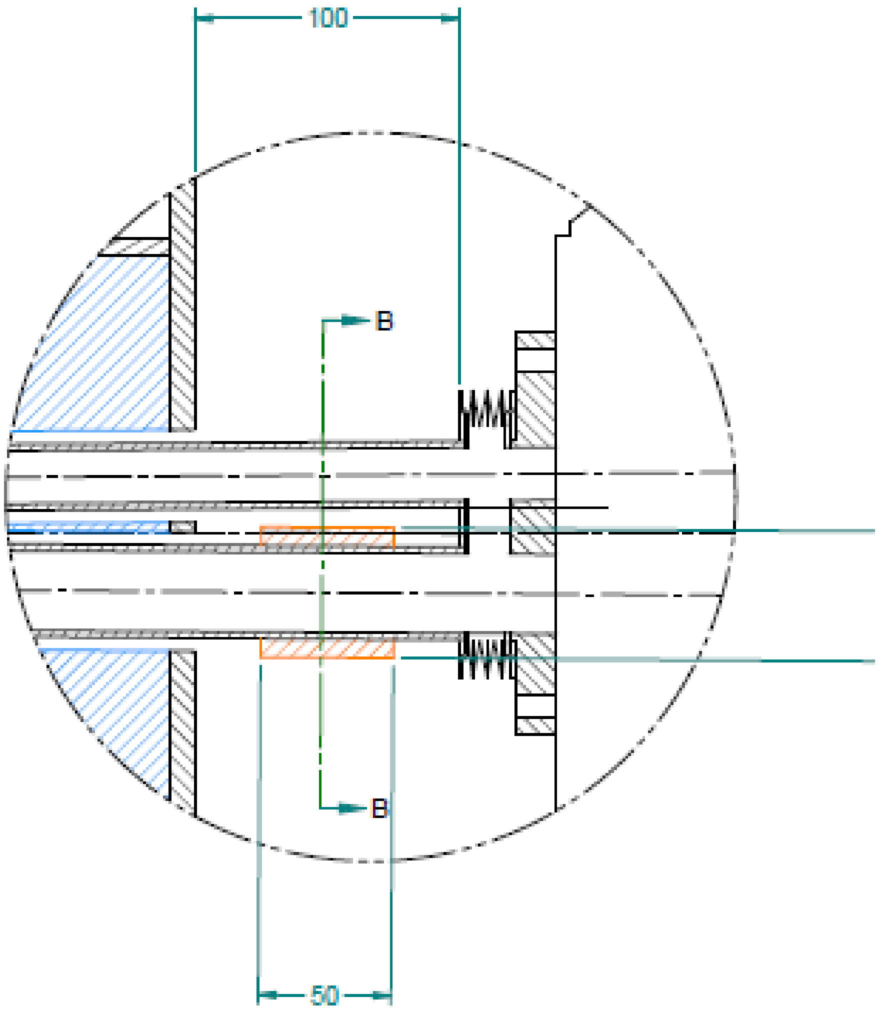


Plan view of BPM

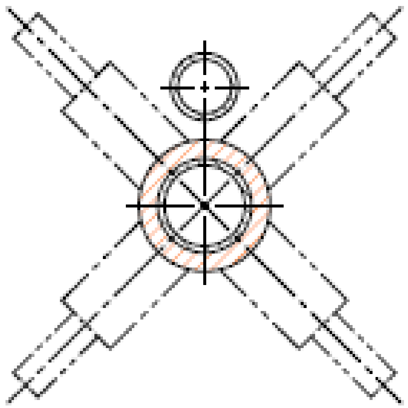


DETAIL A
SCALE 4:1

Section view of BPM



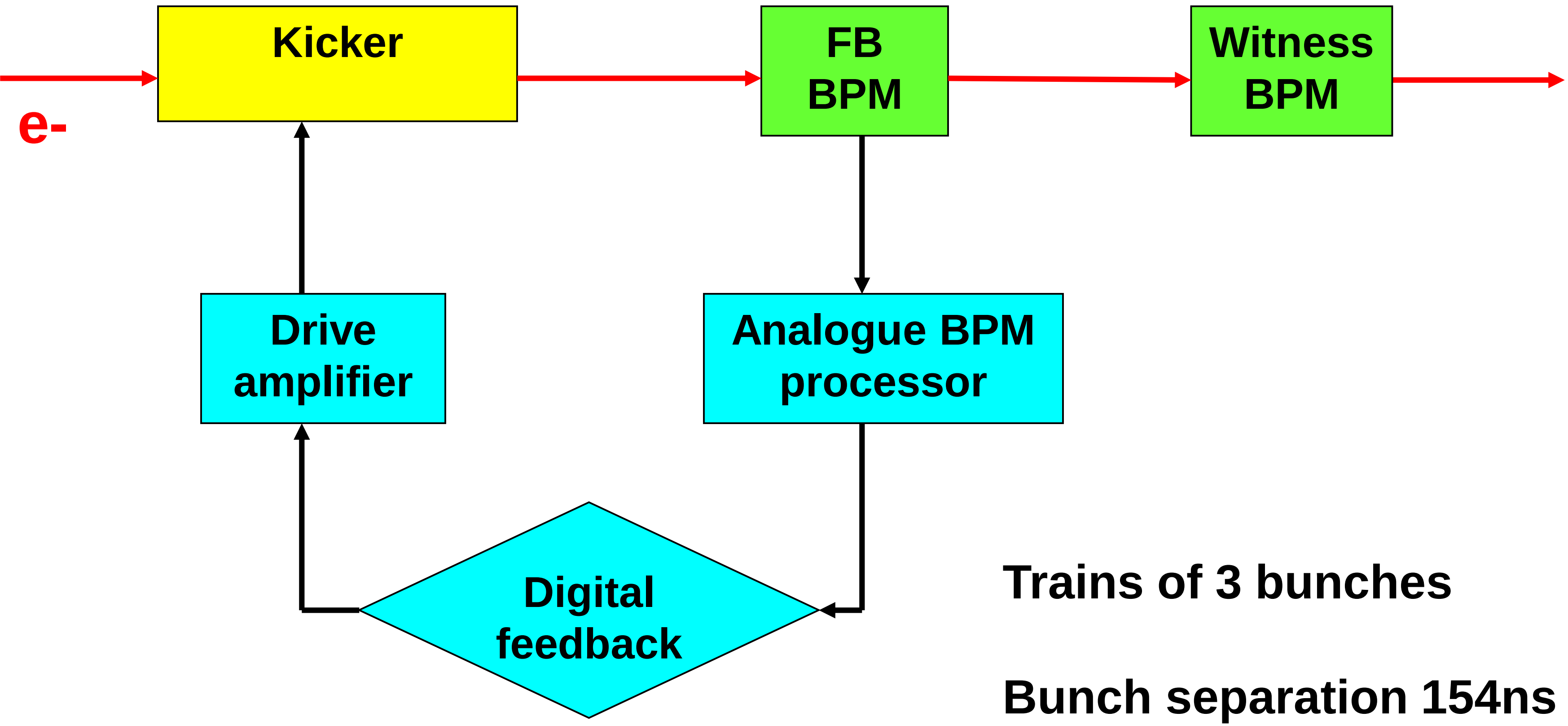
DETAIL A
SCALE 4:1



SECTION B-B
SCALE 4:1

Tom Markiewicz, Marco Oriunno, Steve Smith

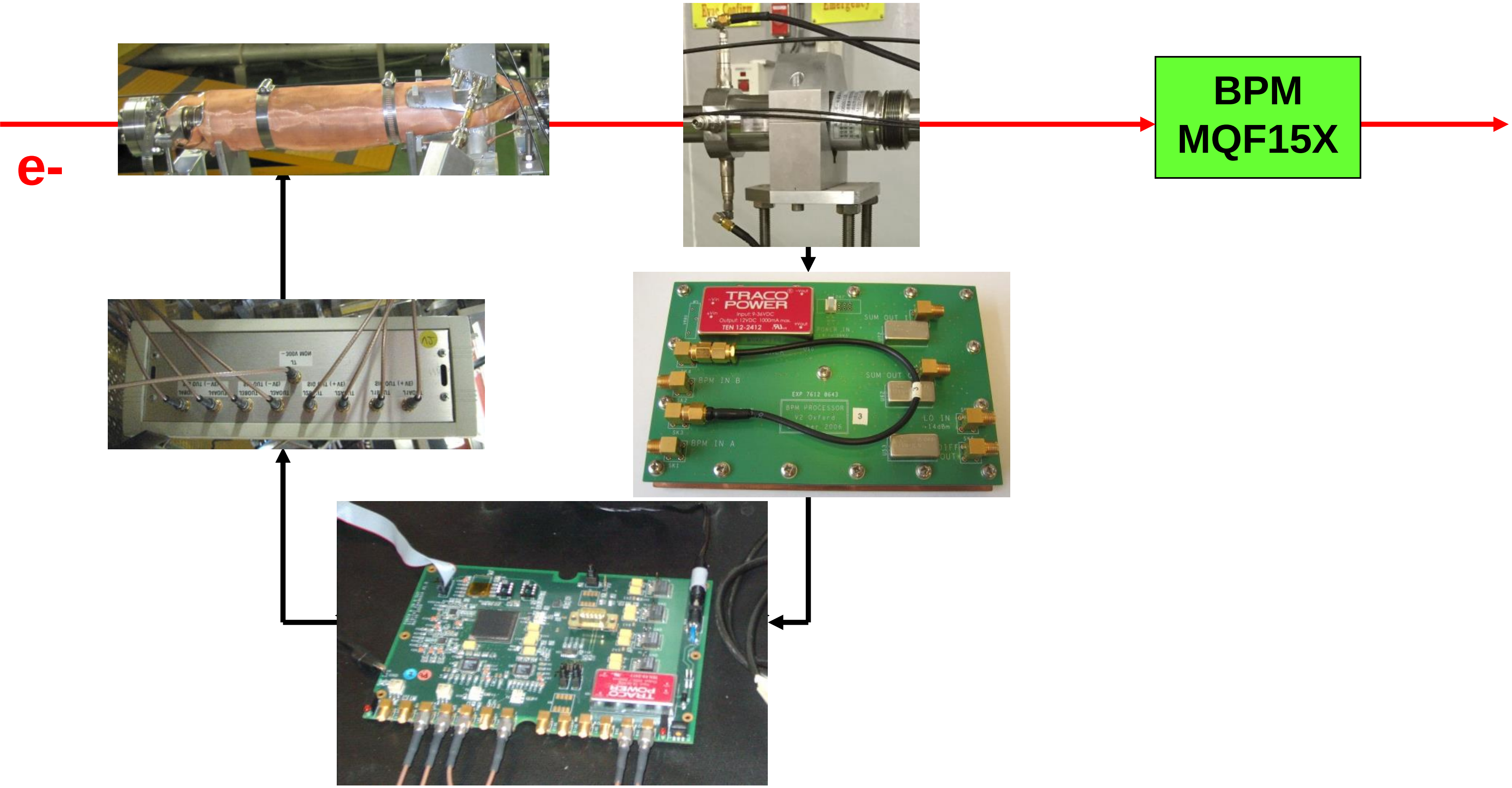
ILC IP FB prototype: FONT4 at ATF2



Trains of 3 bunches

Bunch separation 154ns

ILC IP FB prototype: FONT4 at ATF2



Stripline BPM paper

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **18,** 032803 (2015)

Design and performance of a high resolution, low latency stripline beam position monitor system

R. J. Apsimon,[*] D. R. Bett,[†] N. Blaskovic Kraljevic, P. N. Burrows, G. B. Christian,[‡] C. I. Clarke,[§] B. D. Constance, H. Dabiri Khah, M. R. Davis, C. Perry, J. Resta López,[‖] and C. J. Swinson[¶]

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(Received 1 October 2014; published 19 March 2015)

A high-resolution, low-latency beam position monitor (BPM) system has been developed for use in particle accelerators and beam lines that operate with trains of particle bunches with bunch separations as low as several tens of nanoseconds, such as future linear electron-positron colliders and free-electron lasers. The system was tested with electron beams in the extraction line of the Accelerator Test Facility at the High Energy Accelerator Research Organization (KEK) in Japan. It consists of three stripline BPMs instrumented with analogue signal-processing electronics and a custom digitizer for logging the data. The design of the analogue processor units is presented in detail, along with measurements of the system performance. The processor latency is 15.6 ± 0.1 ns. A single-pass beam position resolution of 291 ± 10 nm has been achieved, using a beam with a bunch charge of approximately 1 nC.

DOI: 10.1103/PhysRevSTAB.18.032803 PACS numbers: 29.27.Fh, 41.85.Qg, 41.75.Ht, 29.20.db

ILC IP feedback prototype paper

PHYSICAL REVIEW ACCELERATORS AND BEAMS **21**, 122802 (2018)

Design and operation of a prototype interaction point beam collision feedback system for the International Linear Collider

R. J. Apsimon,* D. R. Bett, N. Blaskovic Kraljevic,† R. M. Bodenstein, T. Bromwich, P. N. Burrows, G. B. Christian,‡ B. D. Constance, M. R. Davis, C. Perry, and R. Ramjiawan

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(Received 13 December 2017; published 17 December 2018)

A high-resolution, intratrain position feedback system has been developed to achieve and maintain collisions at the proposed future electron-positron International Linear Collider (ILC). A prototype has been commissioned and tested with a beam in the extraction line of the Accelerator Test Facility at the High Energy Accelerator Research Organization in Japan. It consists of a stripline beam position monitor (BPM) with analogue signal-processing electronics, a custom digital board to perform the feedback calculation, and a stripline kicker driven by a high-current amplifier. The closed-loop feedback latency is 148 ns. For a three-bunch train with 154 ns bunch spacing, the feedback system has been used to stabilize the third bunch to 450 nm. The kicker response is linear, and the feedback performance is maintained, over a correction range of over ± 60 μm. The propagation of the correction has been confirmed by using an independent stripline BPM located downstream of the feedback system. The system has been demonstrated to meet the BPM resolution, beam kick, and latency requirements for the ILC.

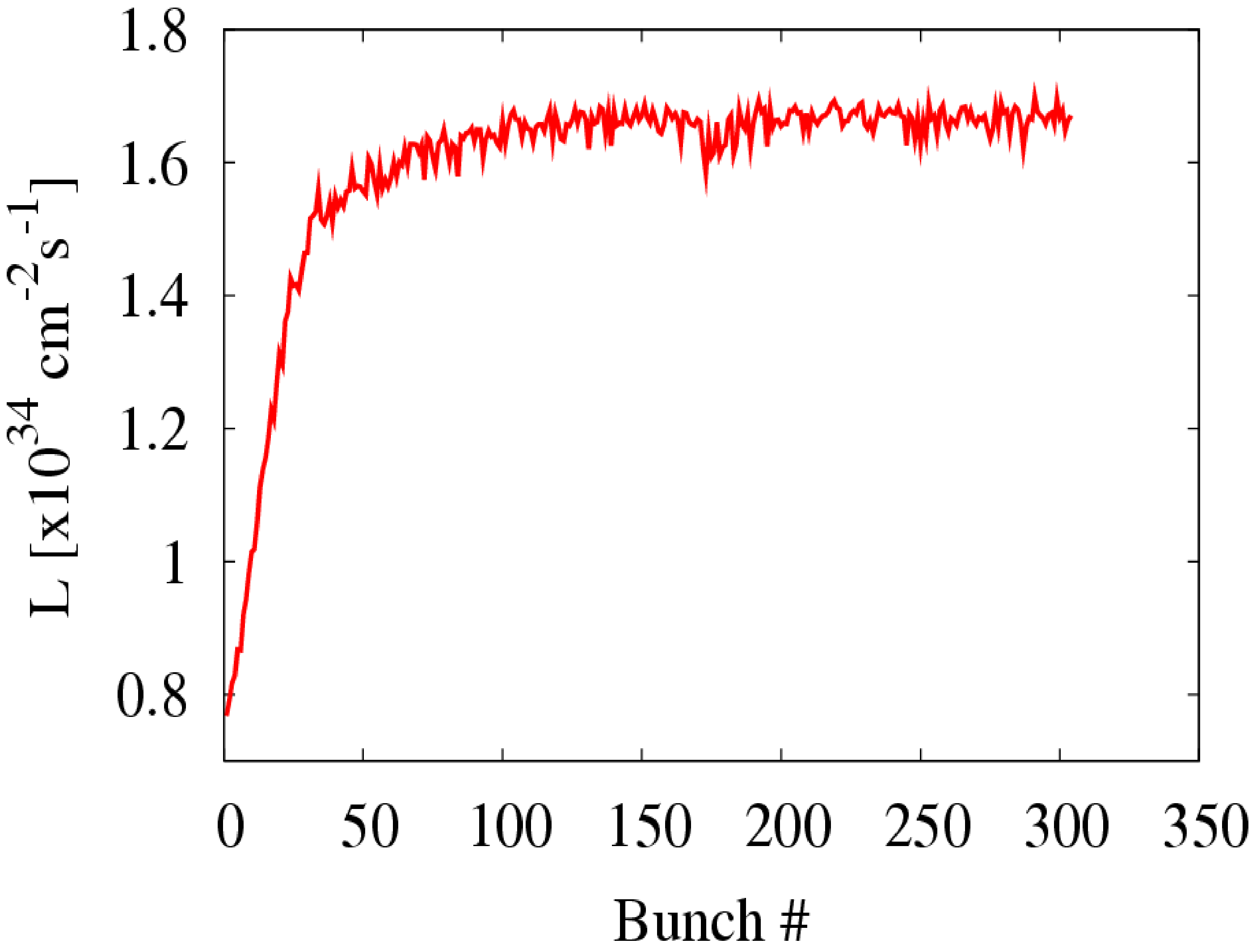
FONT4 performance summary

TABLE IV. Comparison of the IP feedback performance required at the ILC with that achieved by the FONT feedback system at ATF.

		ILC	ATF
Energy per beam	GeV	250	1.3
IP feedback latency	ns	554	148
BPM dynamic range	μm	± 1400	± 1500
BPM resolution	μm	~ 50	~ 1
Beam angle correction range	nrad	$\sim \pm 60$	$\sim \pm 180^{\dagger}$

† scaled by the ATF/ILC beam energy ratio

ILC IP FB performance (500 GeV)



Comments/issues

- Update engineering drawings to reflect L* change to ~4m
  - more major revision needed if QD0 → tunnel
- Re-visit 'functional requirements' of IR systems to reflect ILC 250 vs. 500 GeV, L* etc:
  - beam rigidity x2 lower
  - vertical beam size 30% larger (IP FB spec. was '50 sigma')

SLAC-PUB-13657
June 2009

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors*

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J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford),
T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

Abstract

The Interaction Region of the International Linear Collider [1] is based on two experimental detectors working in a push-pull mode. A time efficient implementation of this model sets specific requirements and challenges for many detector and machine systems, in particular the IR magnets, the cryogenics and the alignment system, the beamline shielding, the detector design and the overall integration. This paper attempts to separate the functional requirements of a push pull interaction region and machine detector interface from any particular conceptual or technical solution that might have been proposed to date by either the ILC Beam Delivery Group or any of the three detector concepts [2]. As such, we hope that it provides a set of ground rules for interpreting and evaluating the MDI parts of the proposed detector concept's Letters of Intent, due March 2009. The authors of the present paper are the leaders of the IR Integration Working Group within Global Design Effort Beam Delivery System and the representatives from each detector concept submitting the Letters Of Intent with the design of the IR. These are the authors of this report.

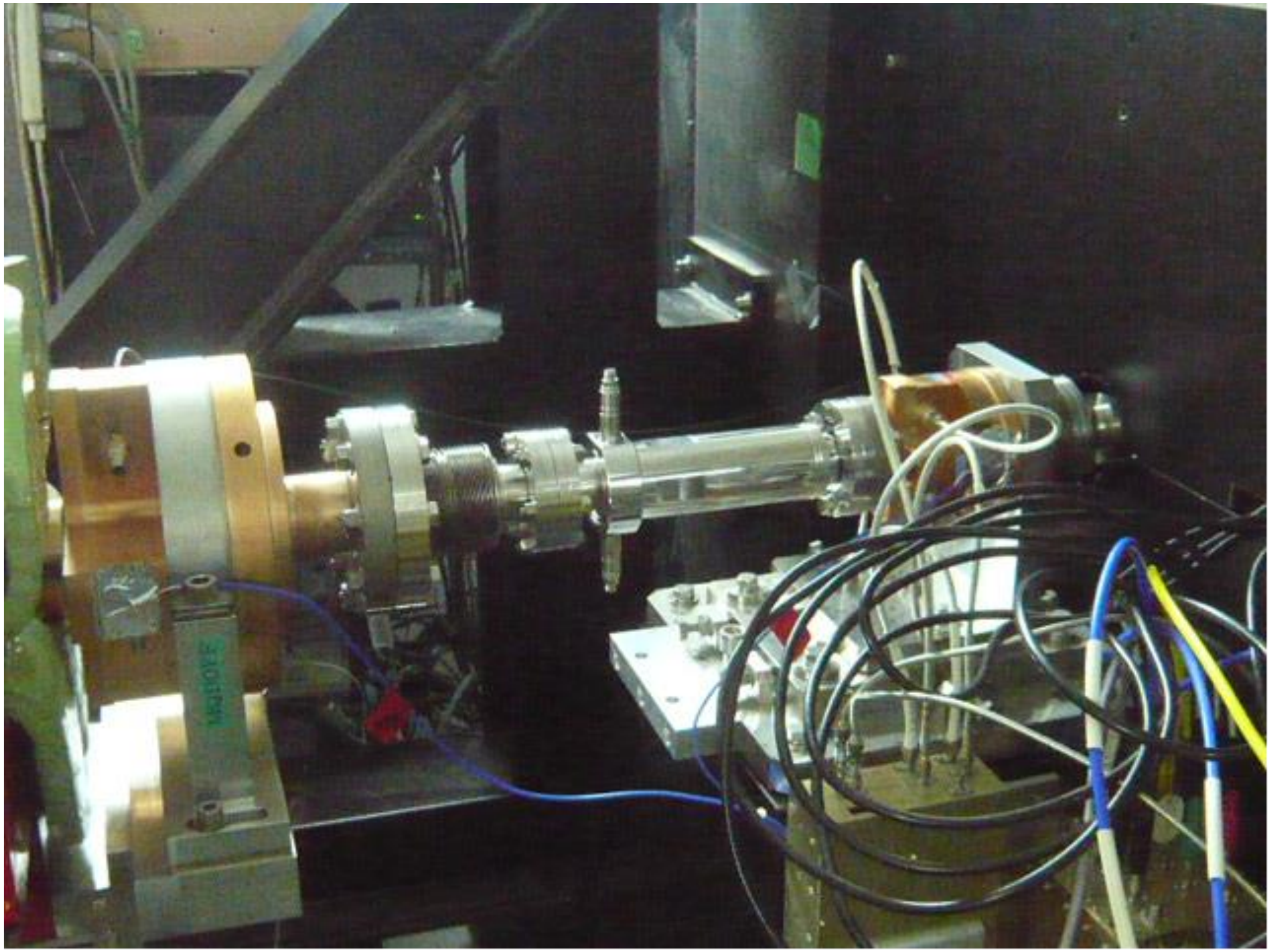
This document is meant to be the mechanism by which the four groups involved mutually define the MDI and Detector-to-Detector Interface (DDI) requirements by which the relevant parts of their respective LOIs can be evaluated. While the unknowns mentioned above, as well as the lack of engineering resources to date, preclude any definitive decisions, all parties involved see the merit in having the current set of agreed-to assumptions, goals and requirements documented. These should be as minimal as possible. It is neither the purpose of this report to prescribe the technology to be used [2] to achieve the requirements nor to list the myriad site-dependent safety requirements (O_2 deficiency, adequate emergency egress, non-flammable materials, etc.) to which the detectors must conform. Collaboratively developed technical solutions and interfaces between the final two detectors will be developed in the post-LOI time frame.

FUNCTIONAL REQUREMENTS

Comments/issues

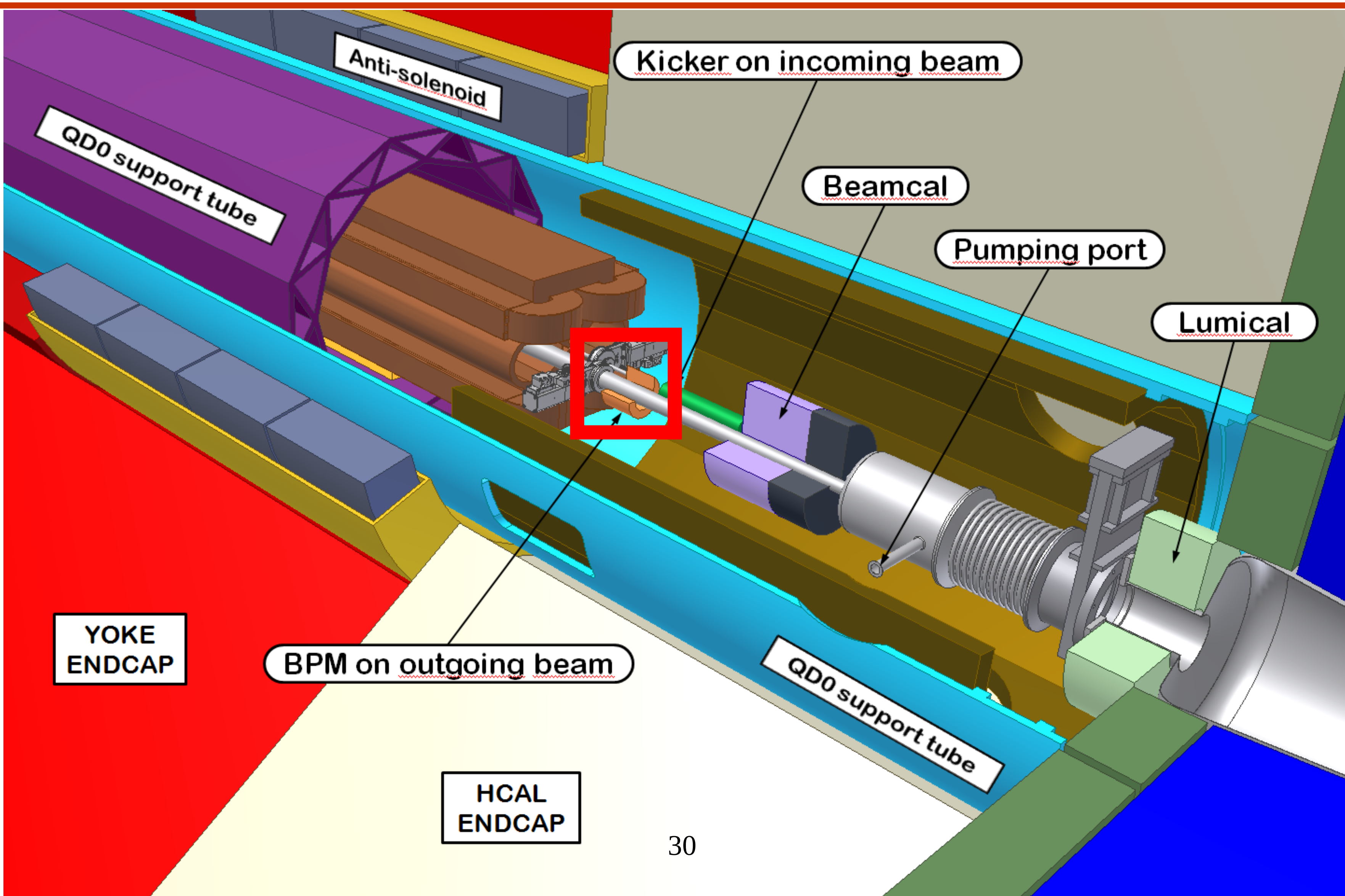
- Update engineering drawings to reflect L* change to ~4m
  - more major revision needed if QD0 → tunnel
- Re-visit 'functional requirements' of IR systems to reflect ILC 250 vs. 500 GeV, L* etc:
  - beam rigidity x2 lower
  - vertical beam size 30% larger (IP FB spec. was '50 sigma')
- Final designs of BPM + kicker + electronics can be tuned for global optimisation of MDI systems
- Location of cabling + electronics needs serious thought:
  - radiation considerations
  - ferrites don't like magnetic fields
  - RF interference
- Dither luminosity FB using BEAMCAL input needs detailed design
  - C. Grah did excellent job on conceptual design

Example: ATF2 IP kicker



Extra material

CLIC Final Doublet Region



CLIC Final Doublet Region