Fast Beam Collision Feedbacks

for luminosity optimisation at next-generation lepton colliders

Philip Burrows

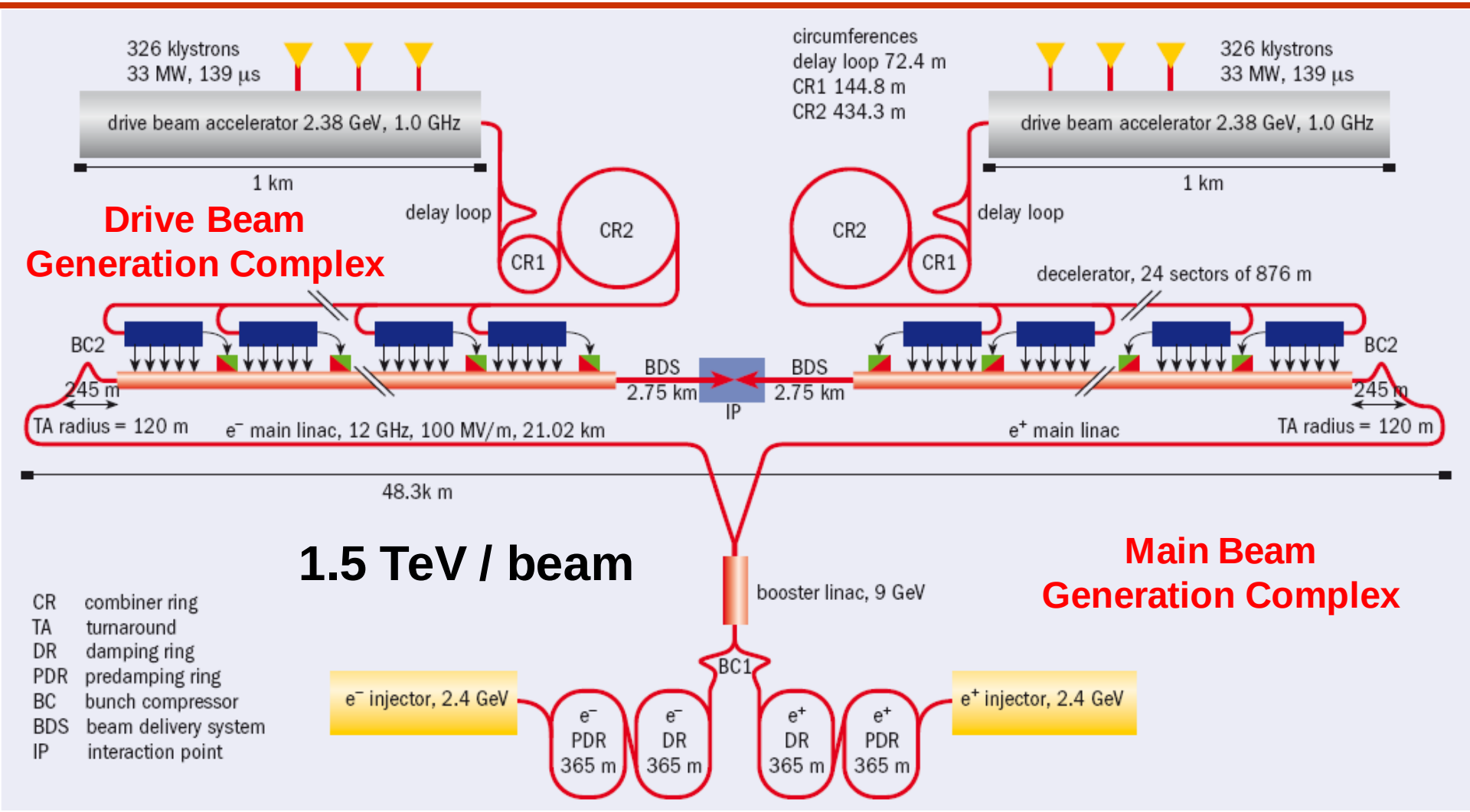
John Adams Institute

Oxford University

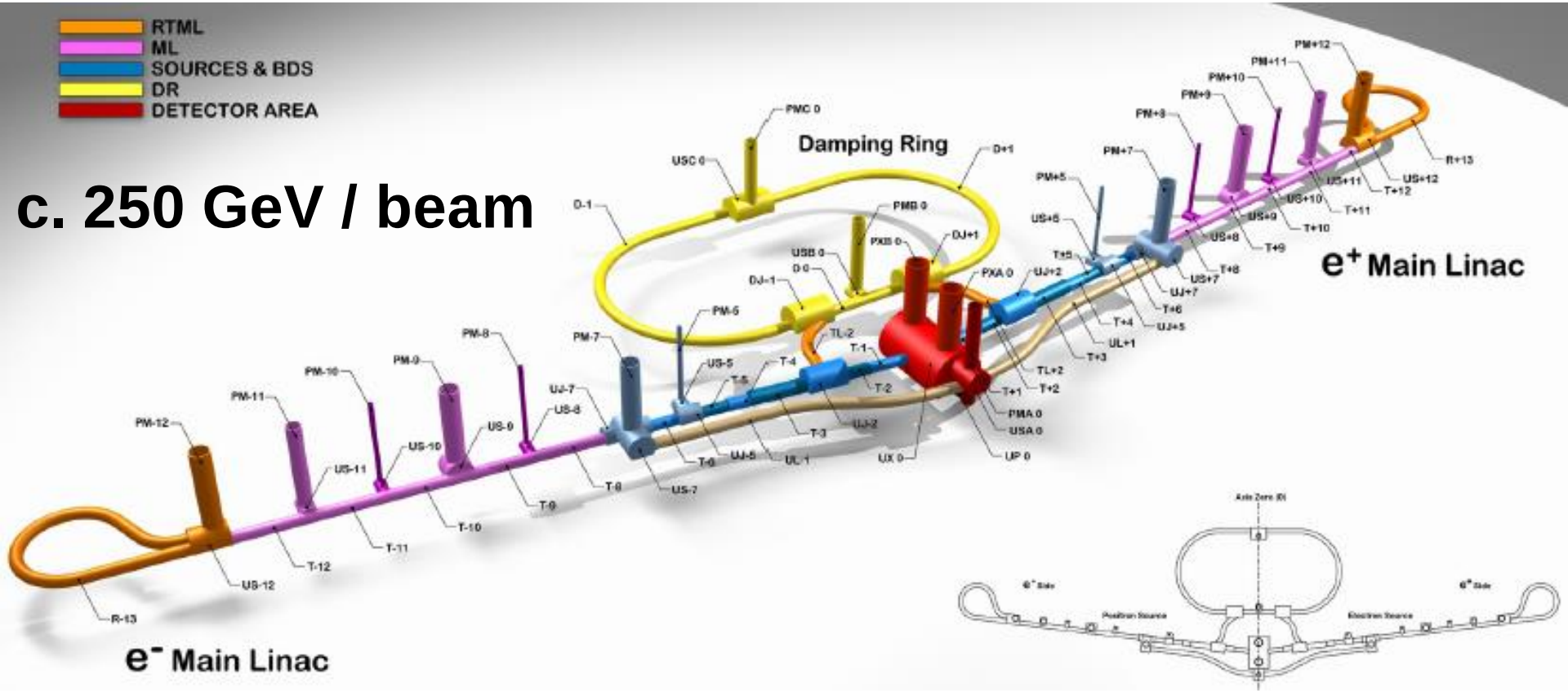
Outline

- Introduction and system concept
- ILC design status
- CLIC design status
- FONT prototype systems performance
- Outstanding technical issues
- Summary

Compact Linear Collider (CLIC)



International Linear Collider



Beam parameters

ILC 500 **CLIC 3 TeV**

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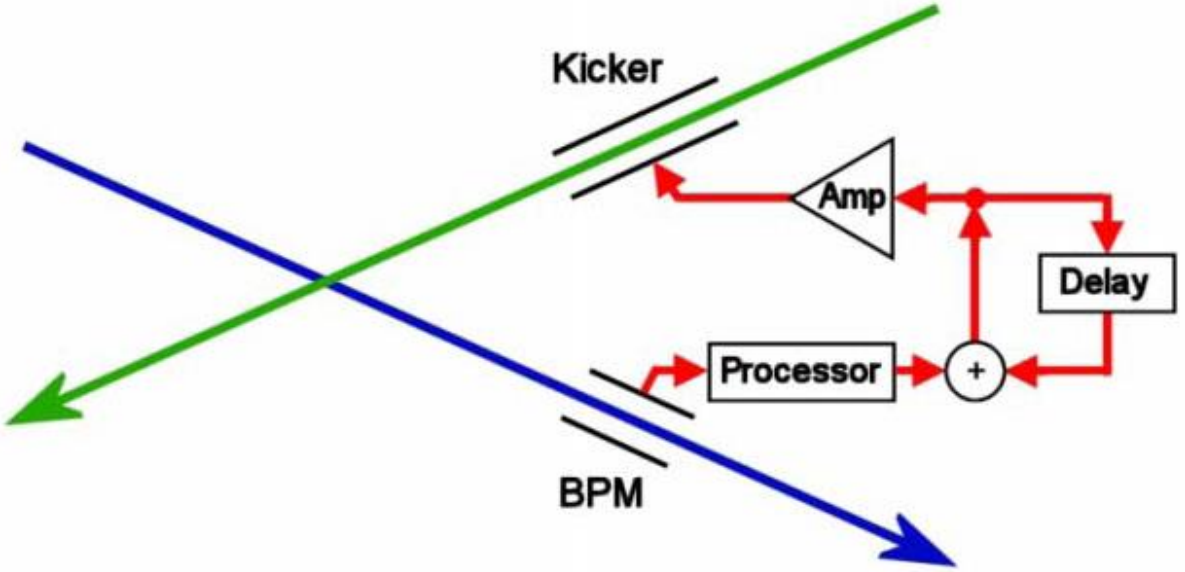
IP beam feedback concept

- 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



FONT – Feedback On Nanosecond Timescales

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

IP FB Design Status: ILC

Engineering design documented in ILC TDR (2013):

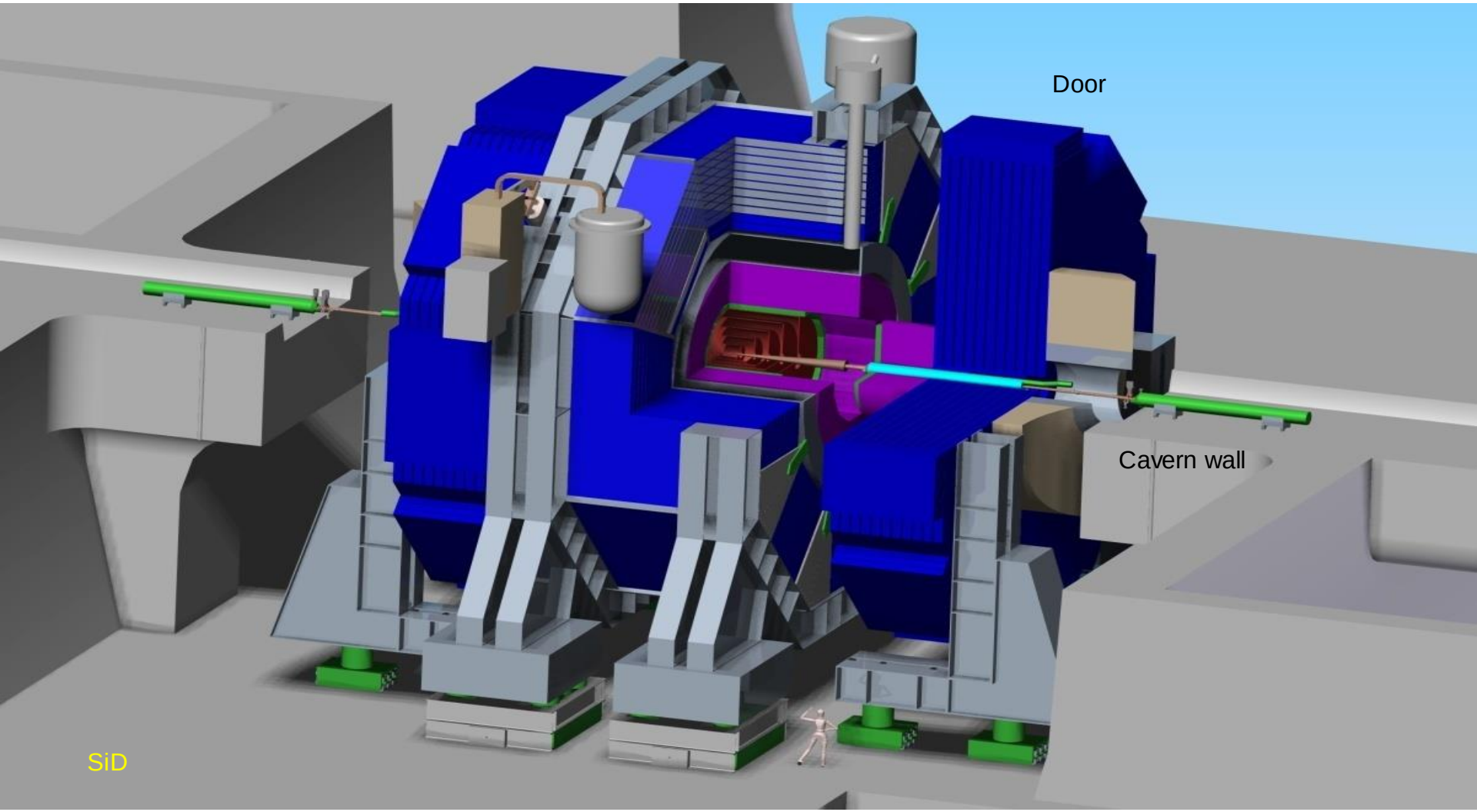
1. IP beam position feedback:
beam position correction up to +- 300 nm vertical at IP

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



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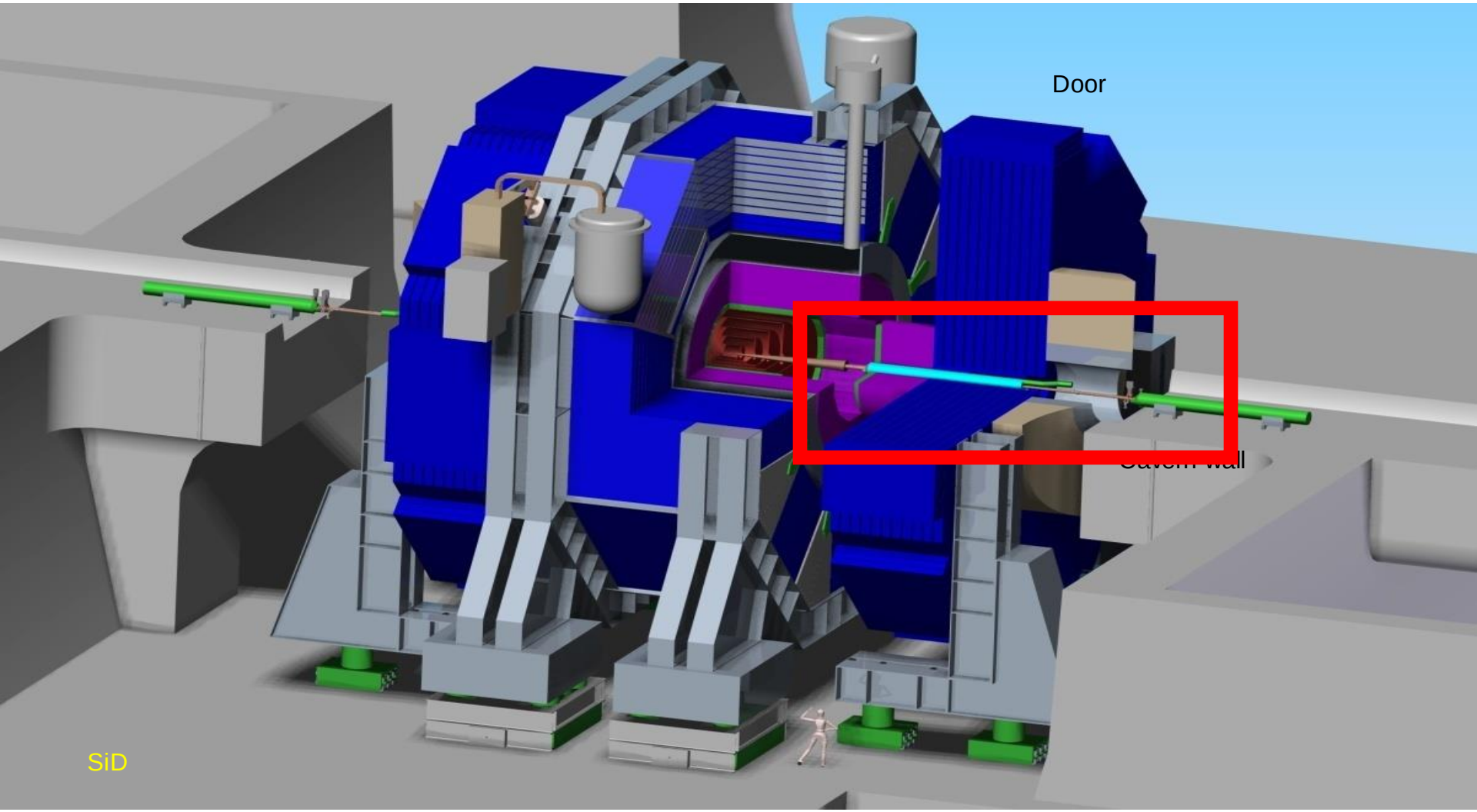
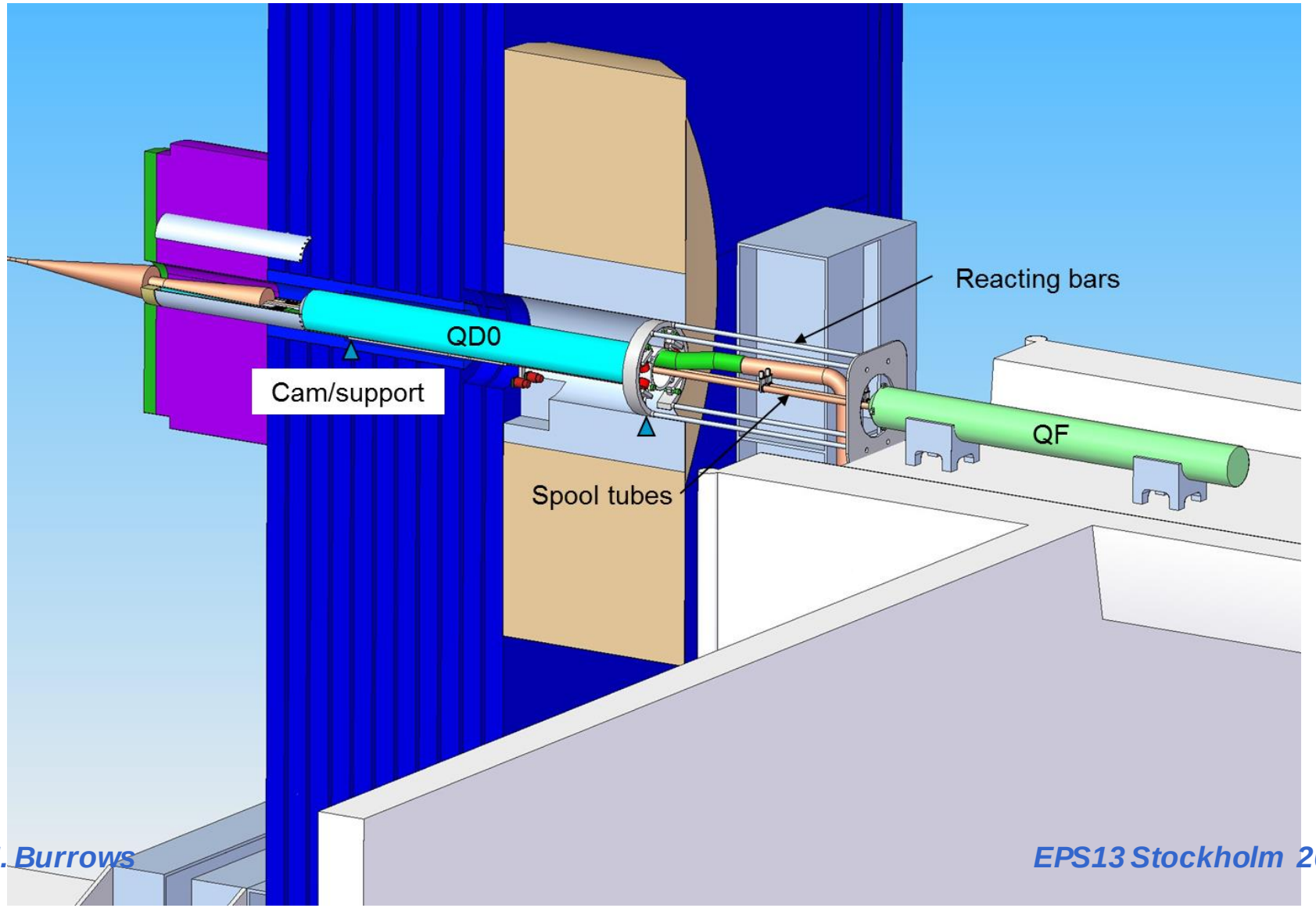


Final Doublet Region (SiD)



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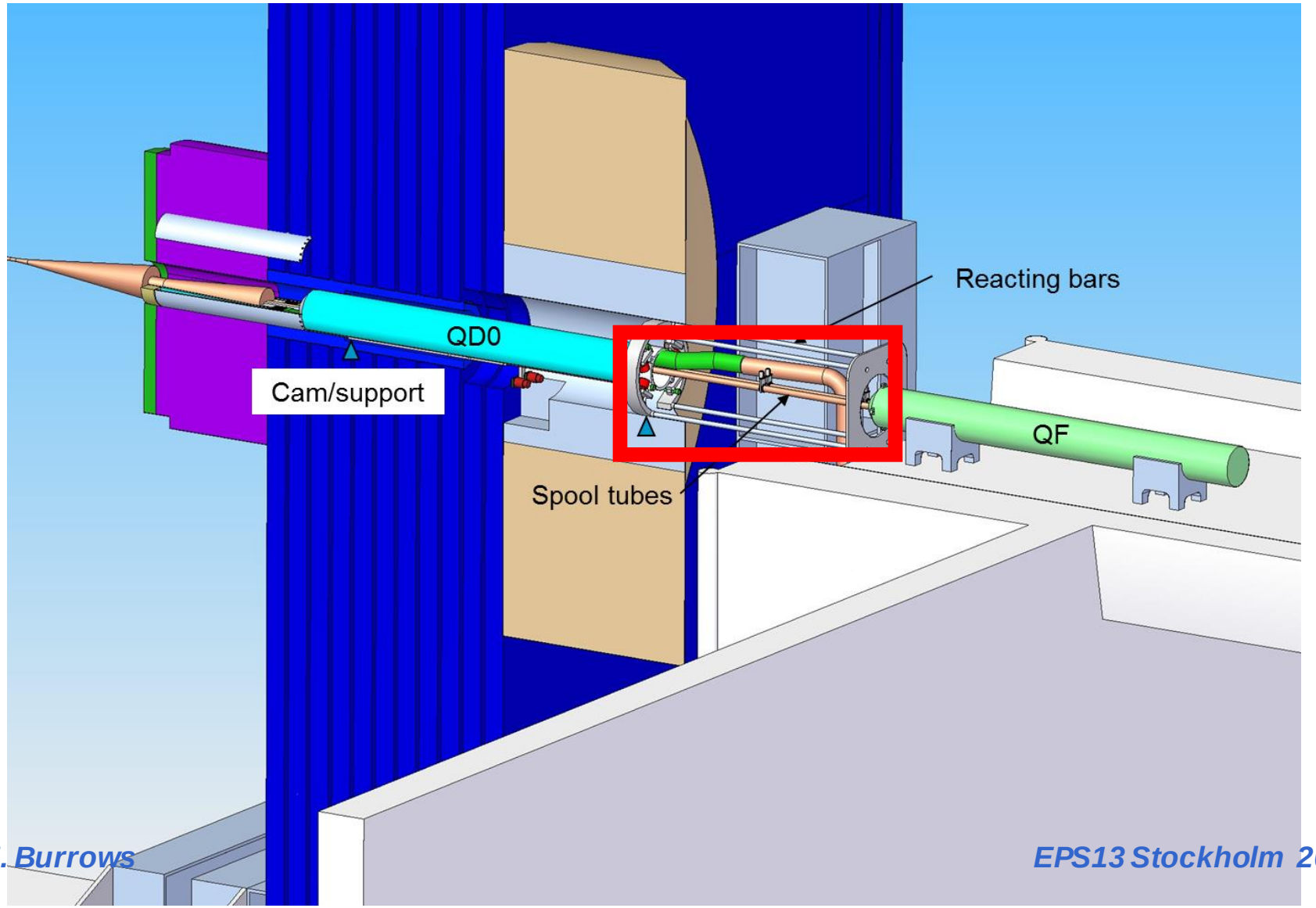
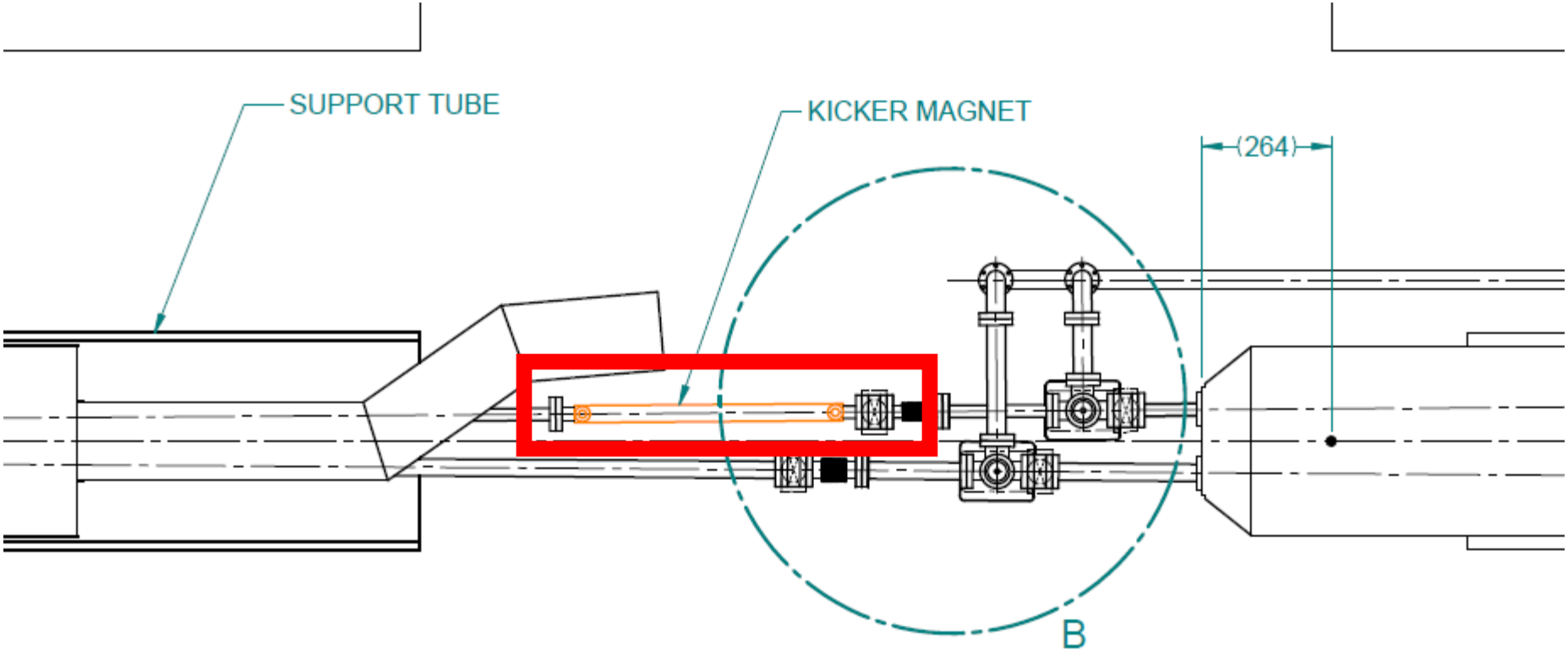


QD0 – QF1 Region (SiD)



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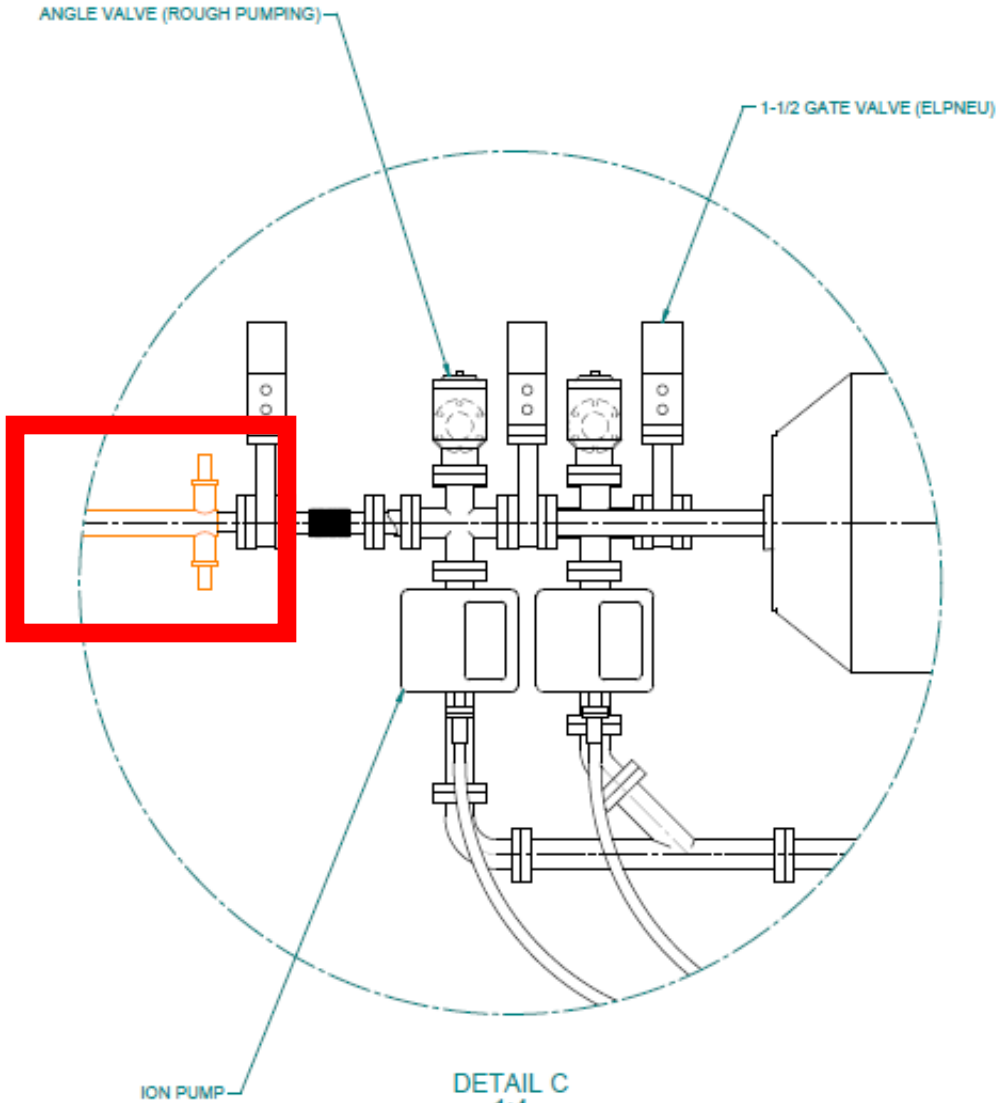

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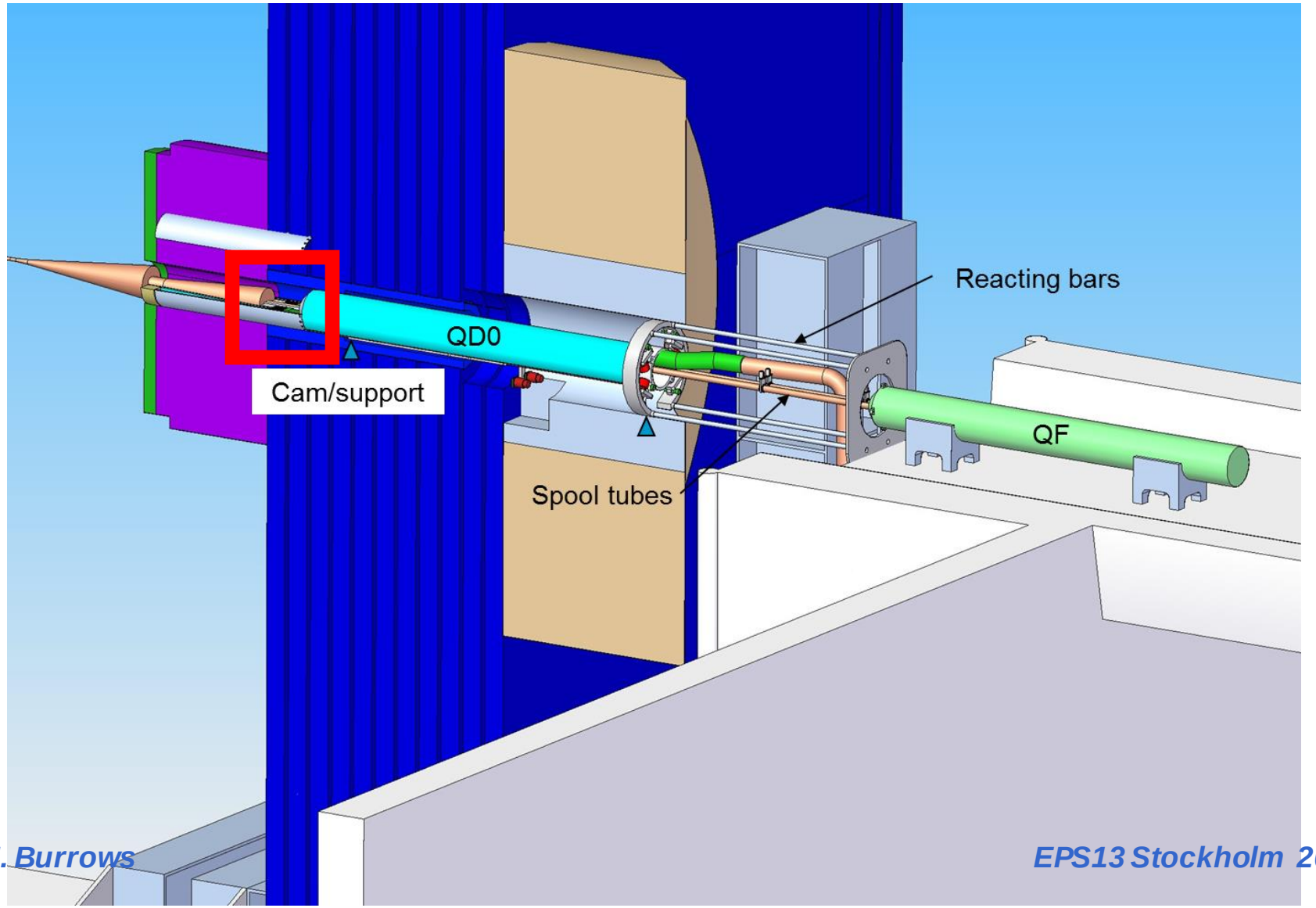
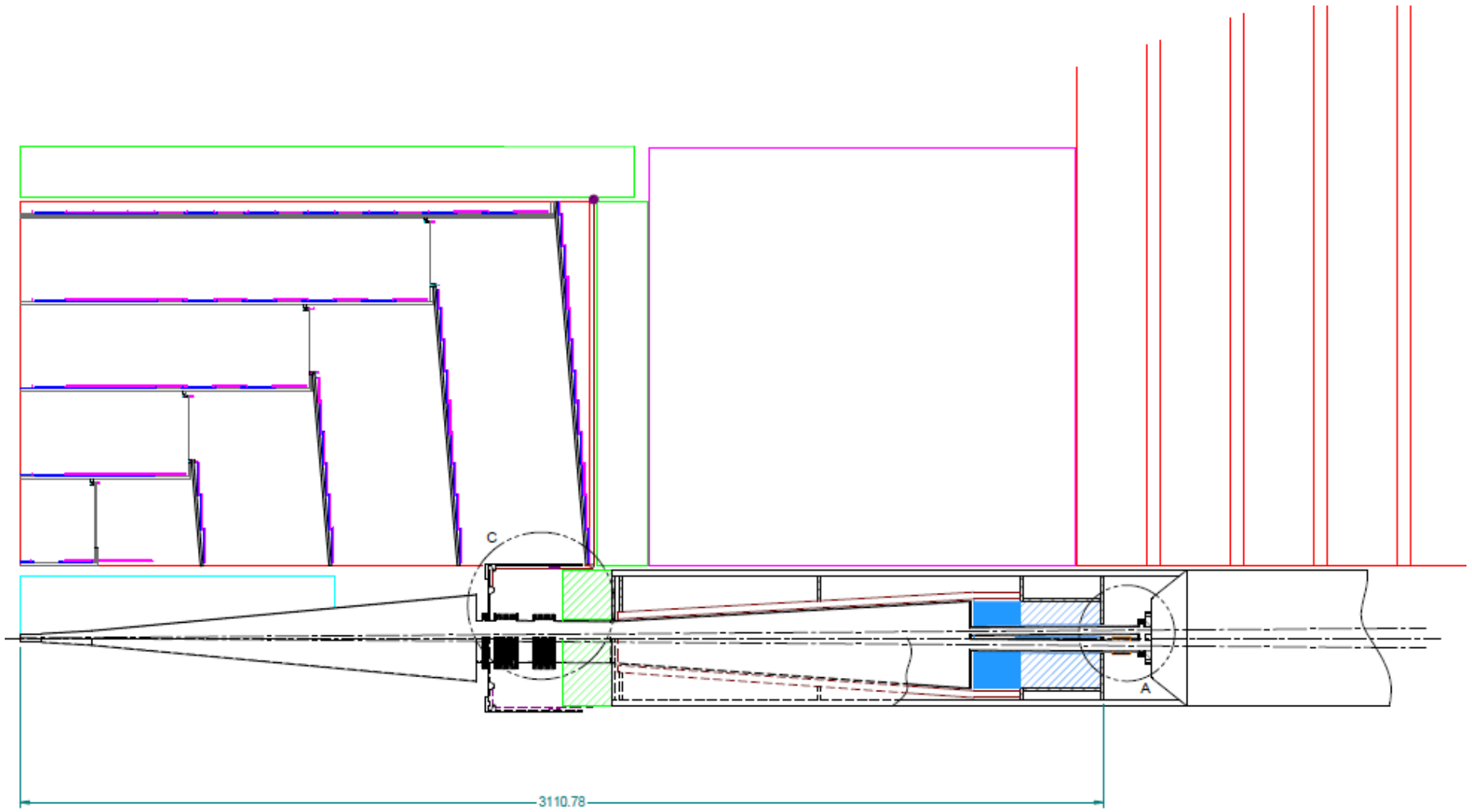


IP Region (SiD)



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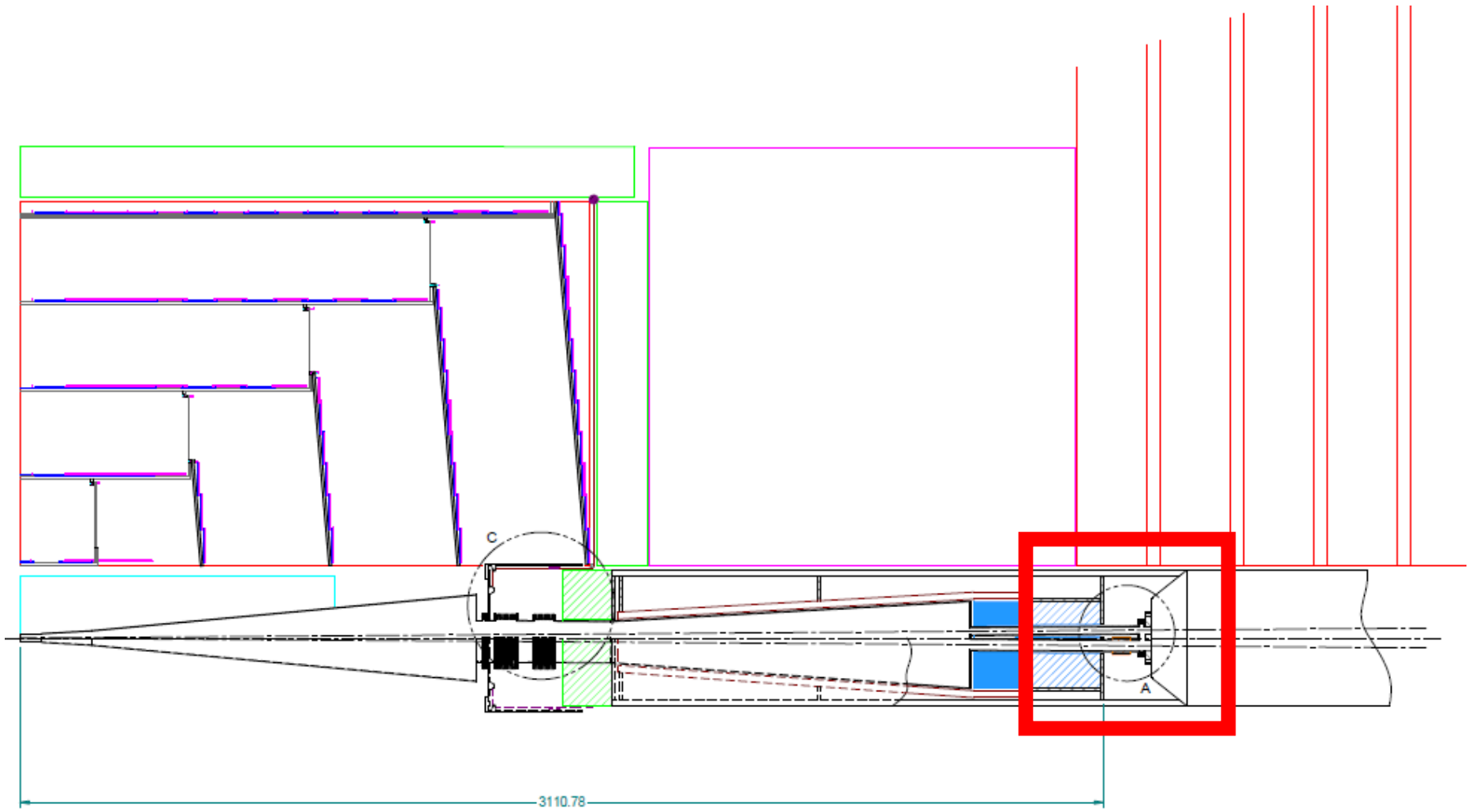
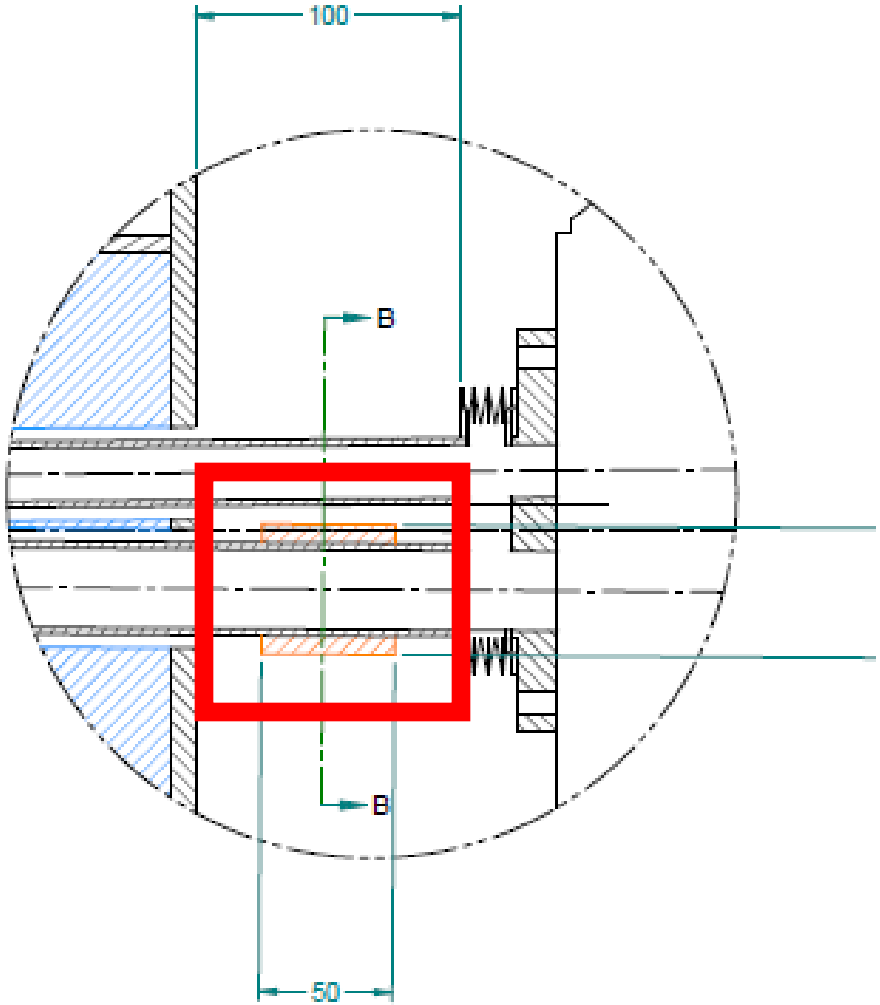
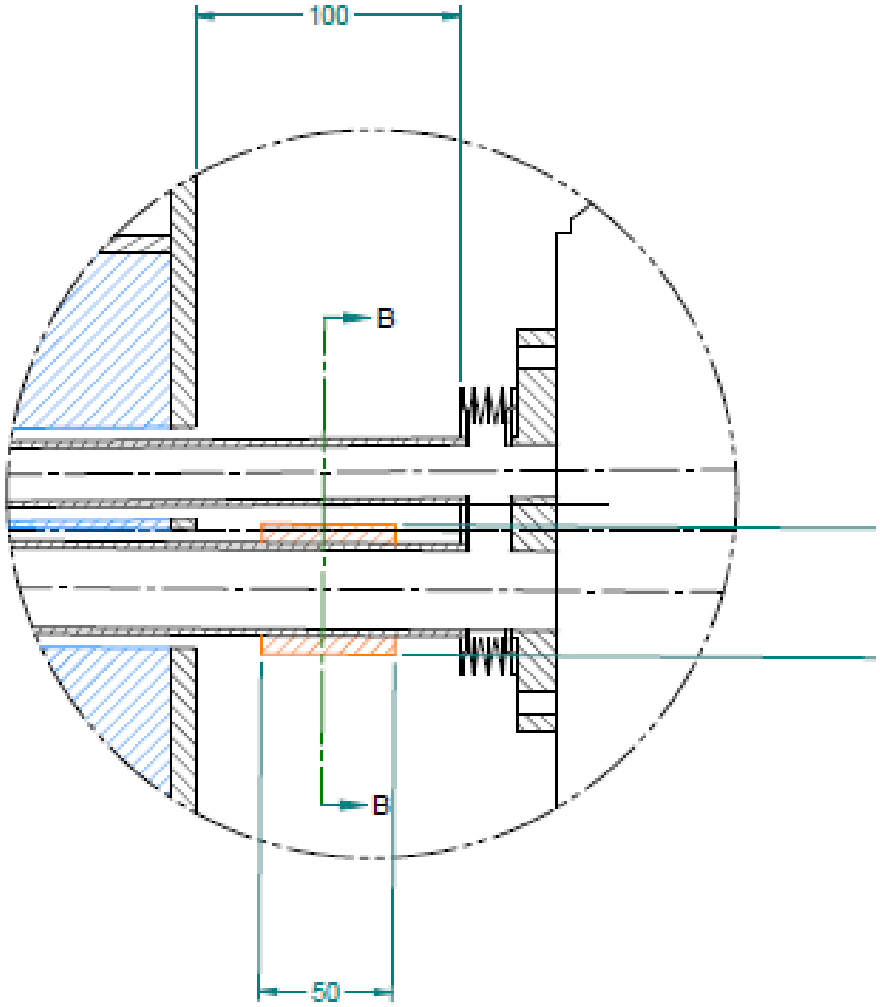


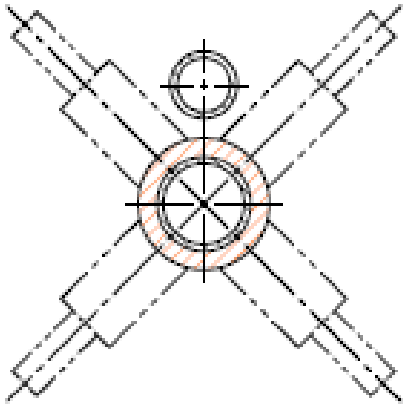
Beamcal – QD0 Region (SiD)



IP FB BPM Detail (SiD)

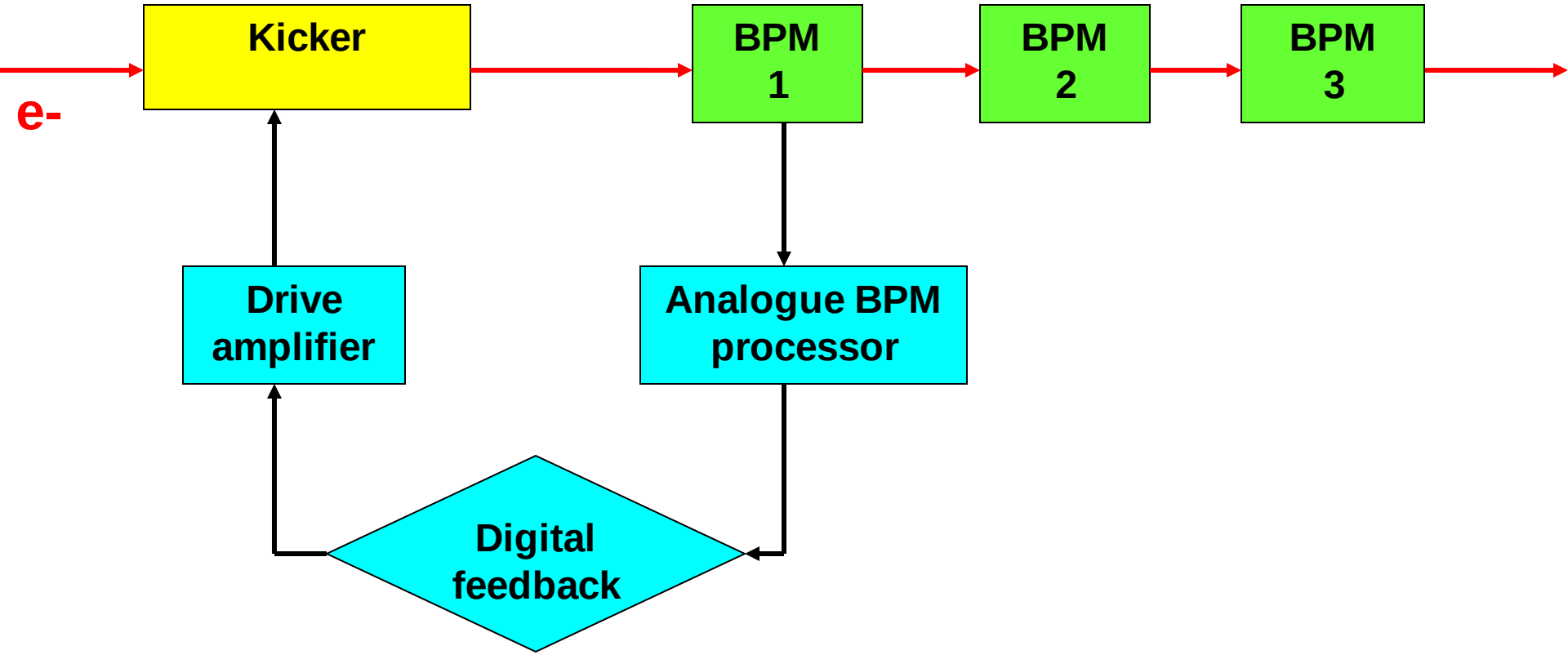


DETAIL A
SCALE 4:1

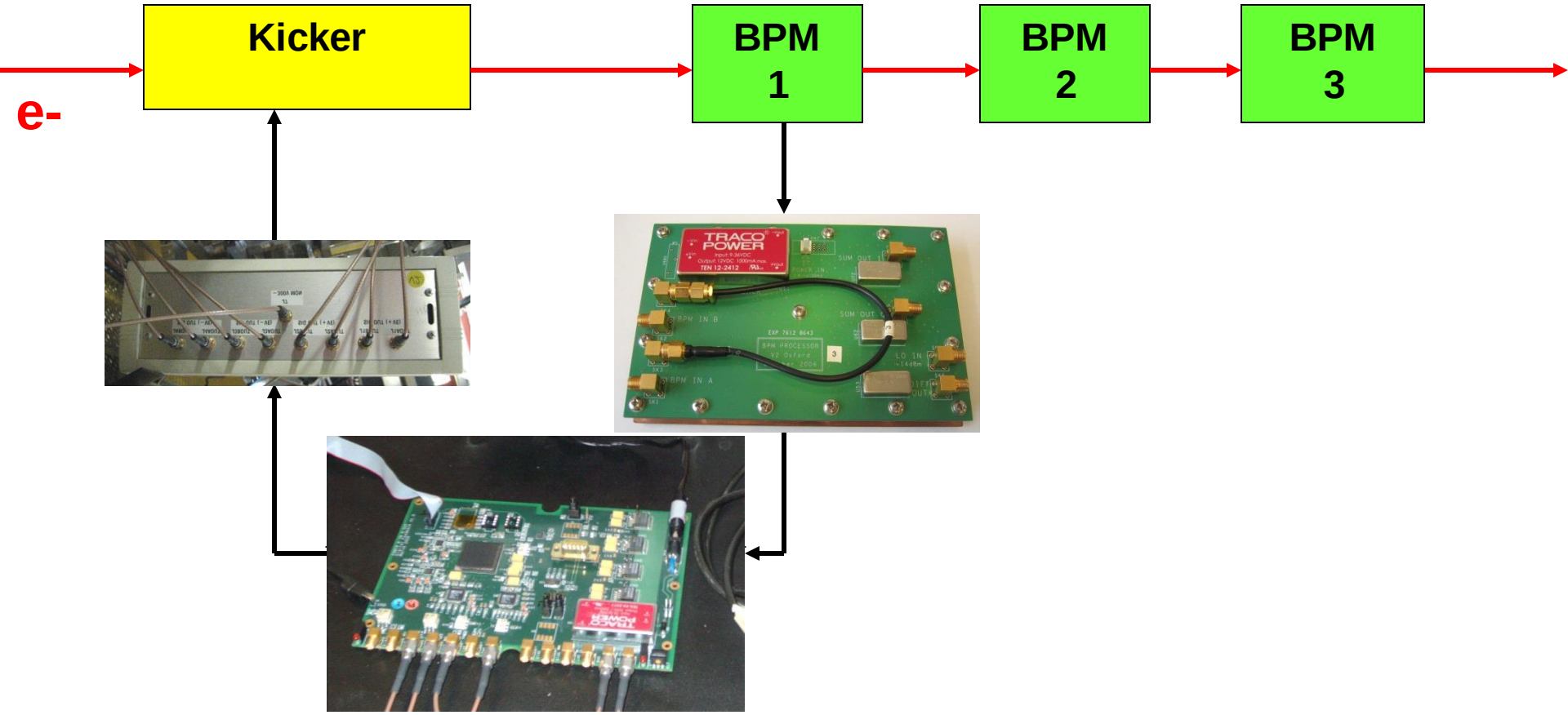


SECTION B-B
SCALE 4:1

ILC FB prototype: FONT at KEK/ATF



ILC prototype: FONT4 at KEK/ATF



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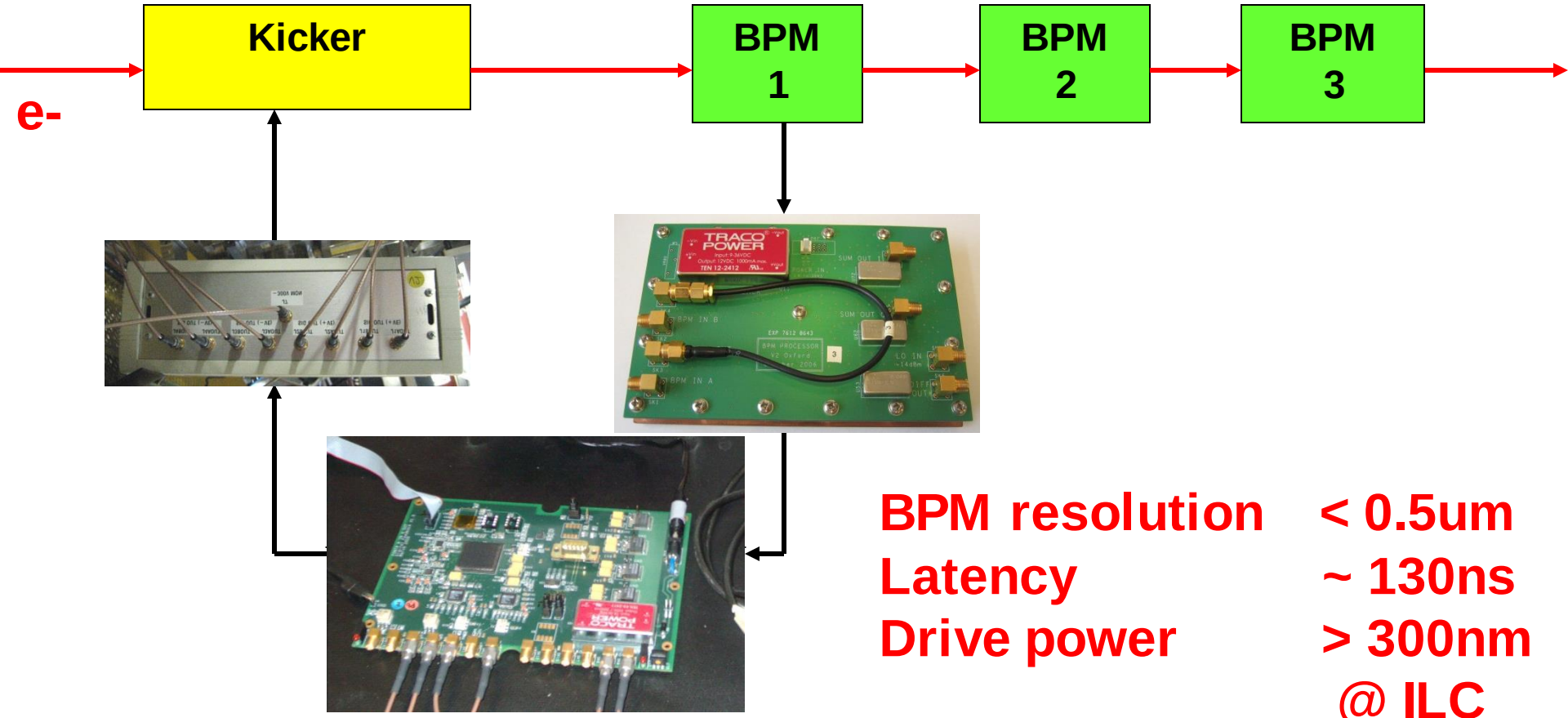


BPM resolution **< 0.5um**
Latency **~ 130ns**
Drive power **> 300nm @ ILC**

Latency

- Time of flight kicker – BPM: 12ns
- Signal return time BPM – kicker: 32ns

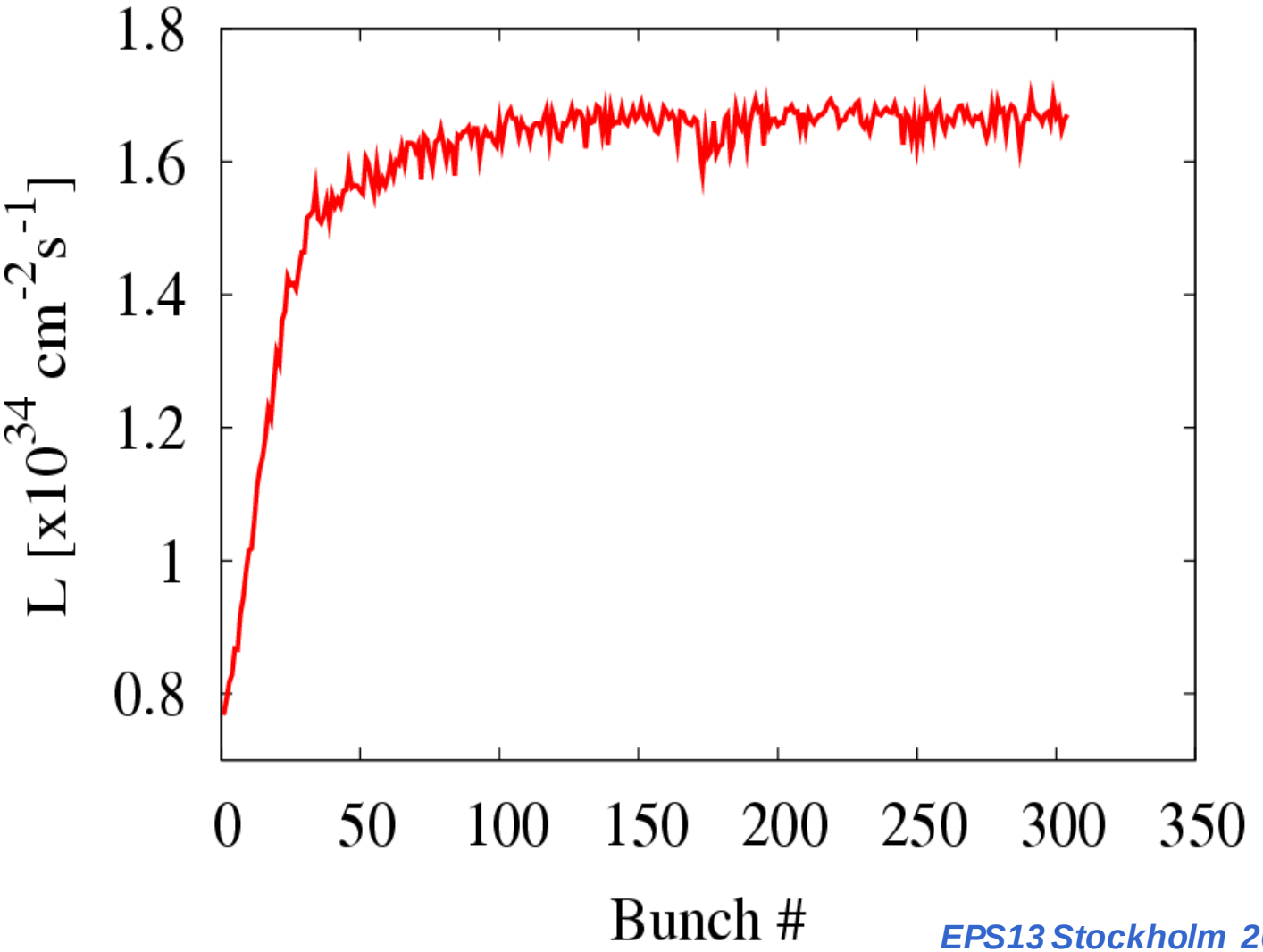
  Irreducible latency: 44ns

- BPM processor: 10ns
- ADC/DAC (4.5 357 MHz cycles) 14ns
- Signal processing (8 357 MHz cycles) 22ns
- FPGA i/o 3ns
- Amplifier 35ns
- Kicker fill time 3ns

  Electronics latency: 87ns

- Total latency budget: 131ns

ILC IP FB performance



Resta Lopez

P.N. Burrows

IP FB Design Status: CLIC

Conceptual design developed and documented in CLIC CDR (2012)

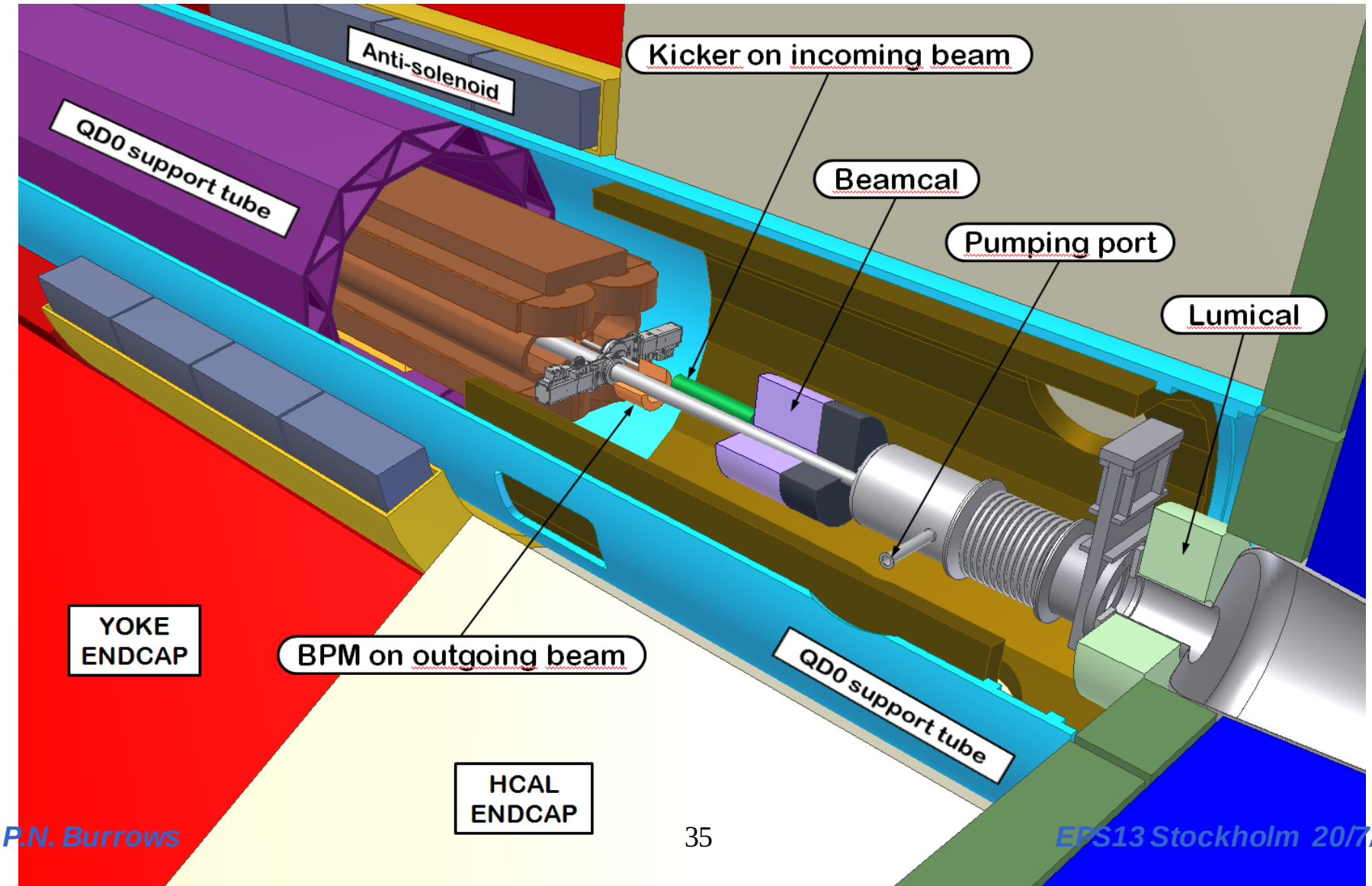
NB primary method for control of beam collision overlap is via vibration isolation of the FF magnets, and dynamic correction of residual component motions

IP position feedback:

beam position correction up to +- 50 nm vertical at IP

More realistic engineering design can be developed in next project phase

CLIC Final Doublet Region



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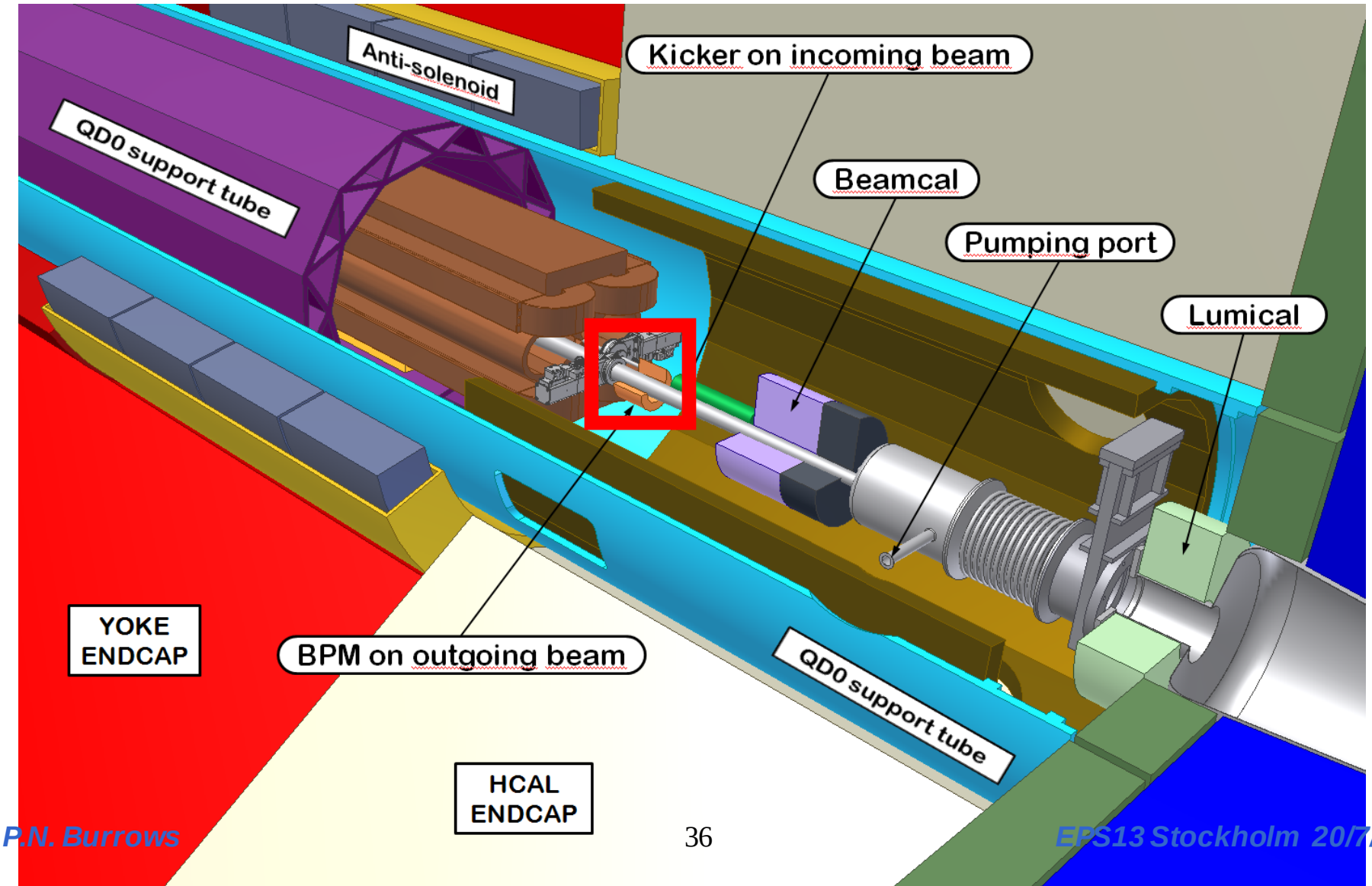

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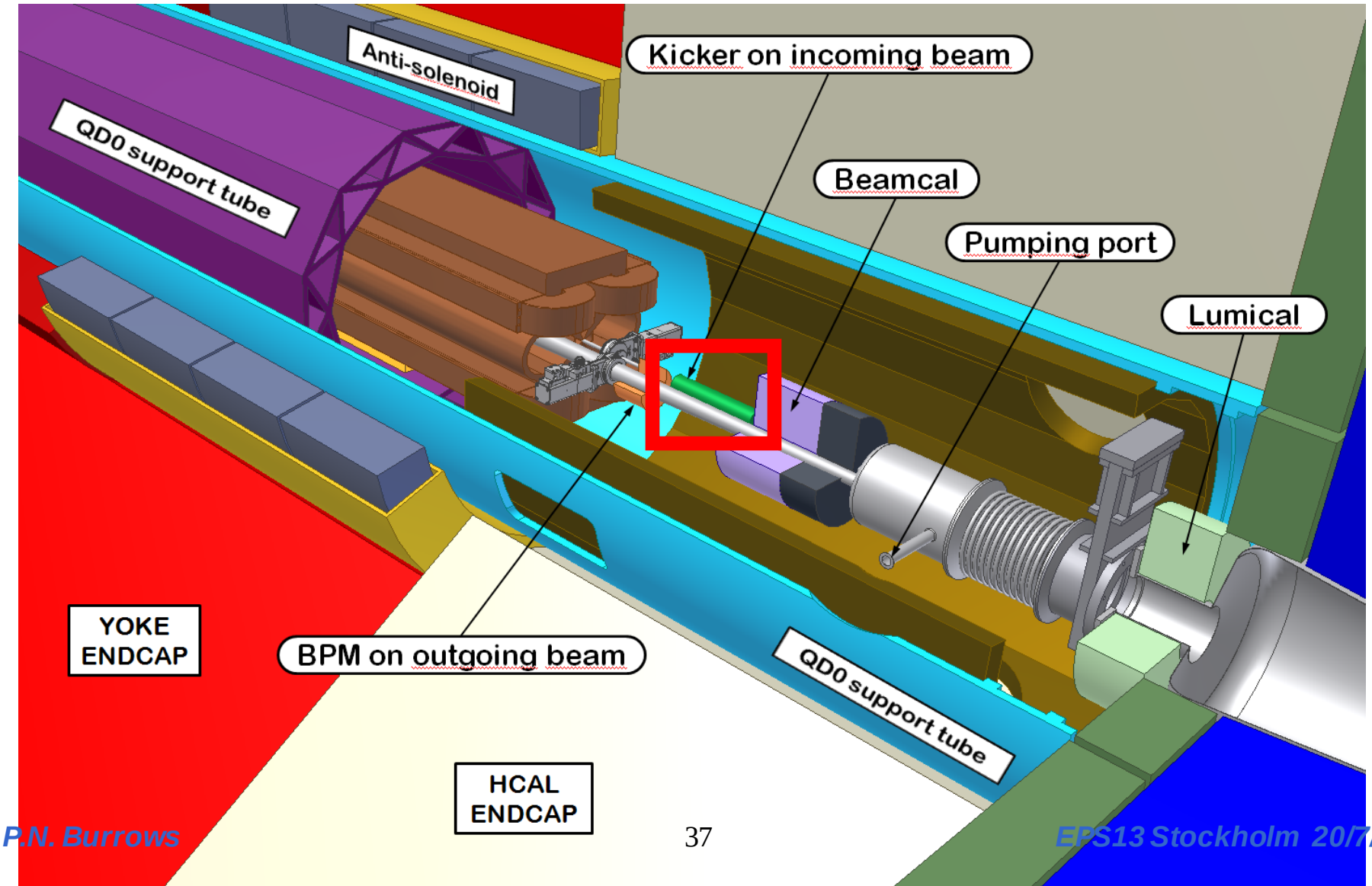

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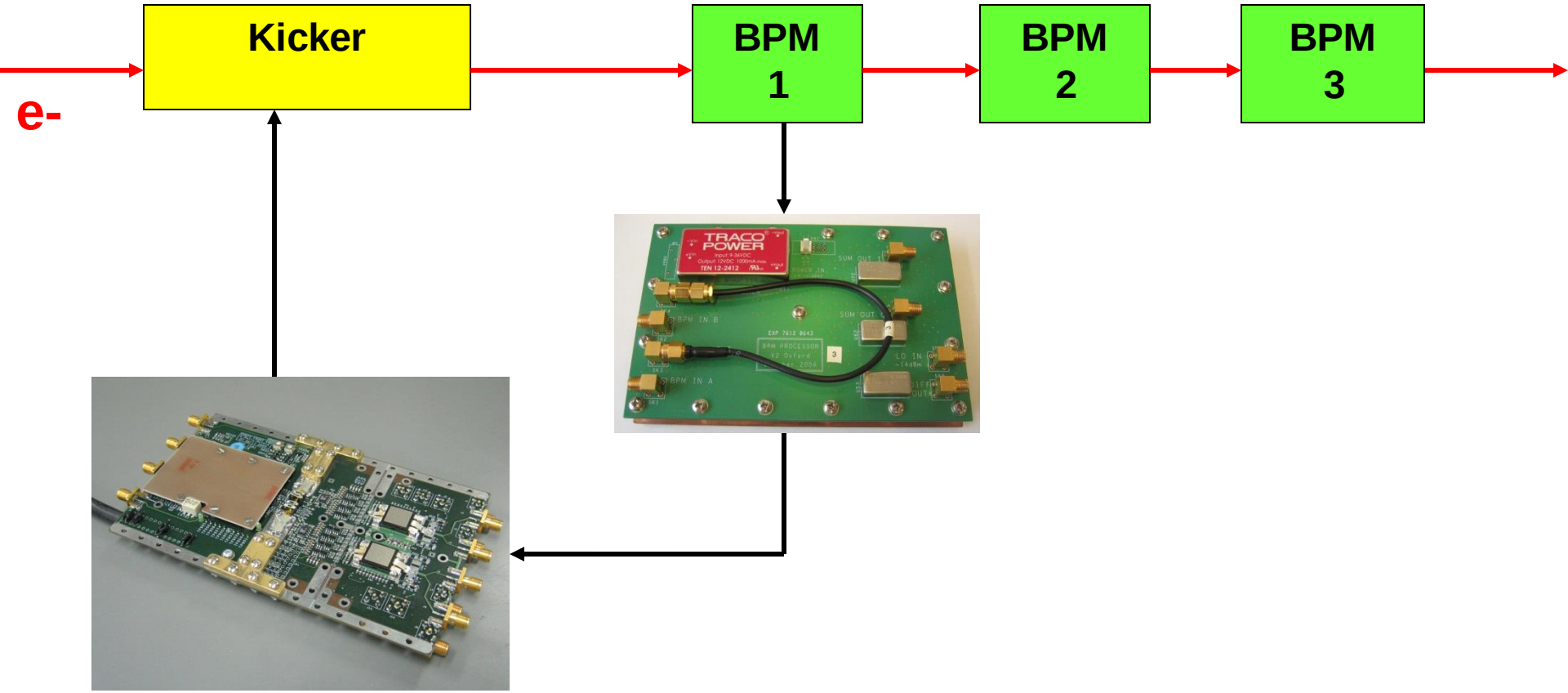

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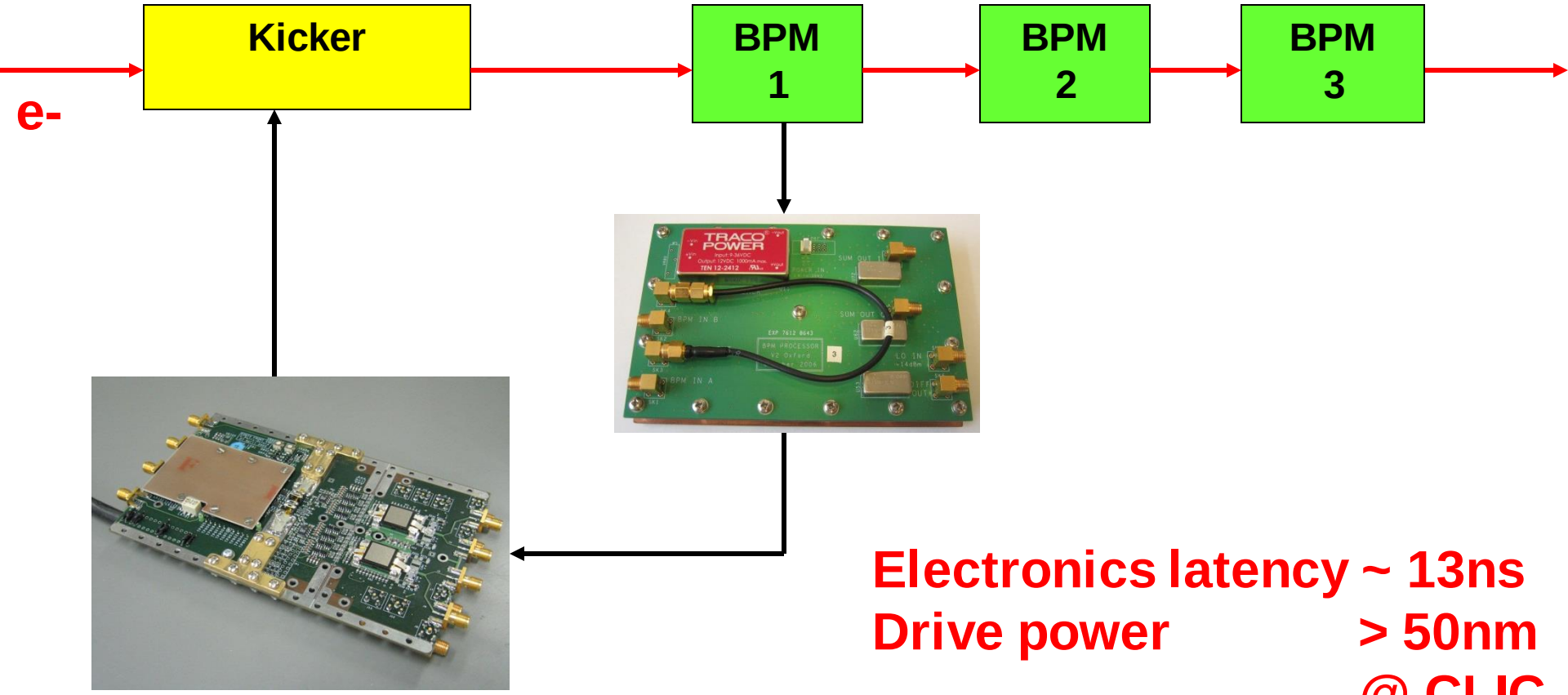
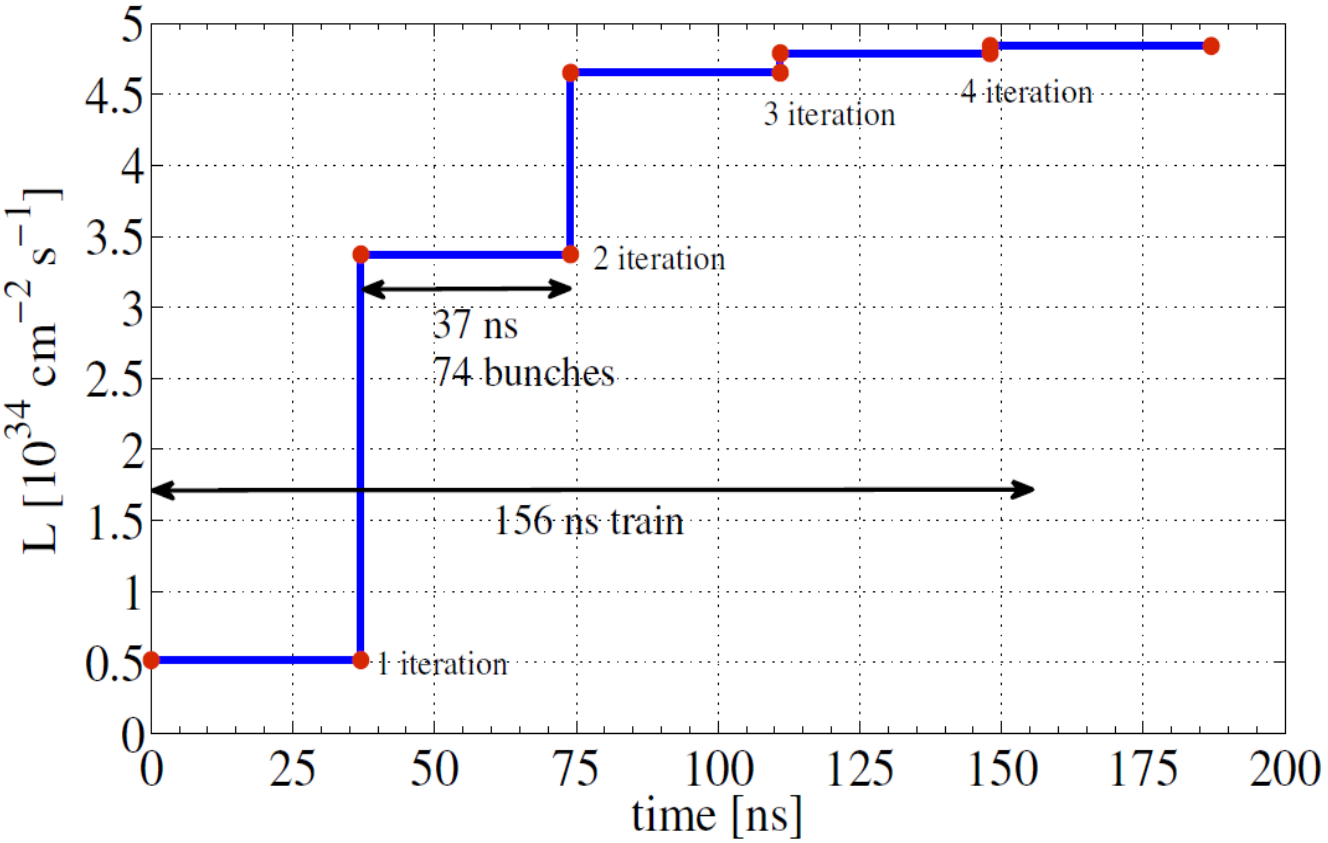


Electronics latency ~ 13ns
Drive power > 50nm @ CLIC

CLIC IP FB performance

Single random seed of GM C



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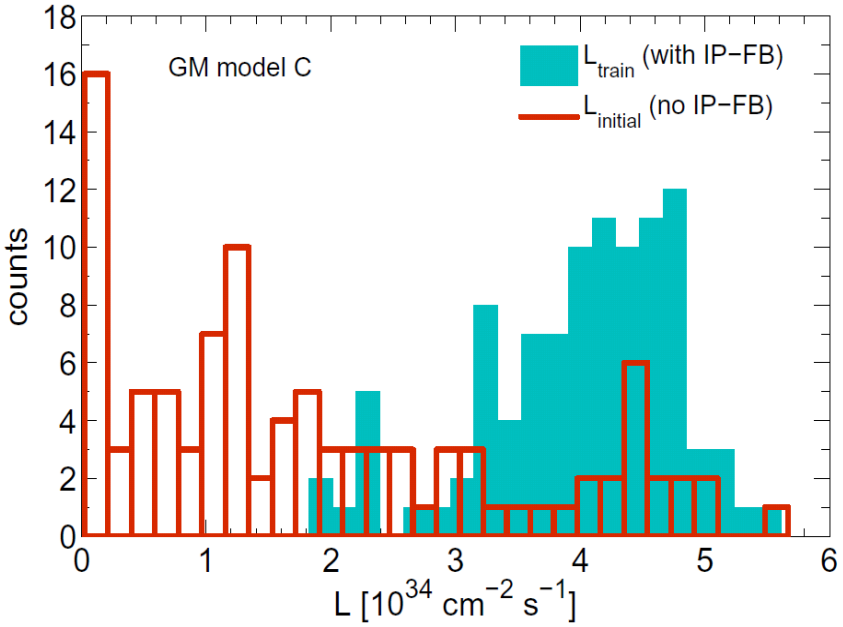
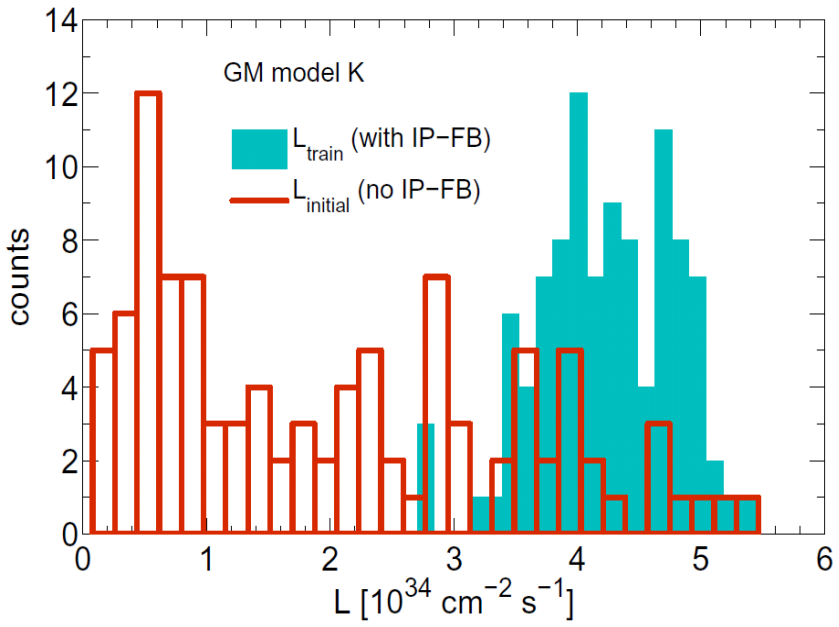
CLIC IP FB performance

For noisy sites:





→ **factor 2 - 3 improvement**

Outstanding Technical Issues

- **Component designs need to be optimised for tight spatial environments**
- **Routing of cables**
- **Operation of (ferrite) devices in large, spatially-varying B-field**
- **Further studies of radiation environment**
- **Electronics location, rad hardness, shielding**
- **RF interference: beam ←→ FB electronics**

  kicker ←→ detector

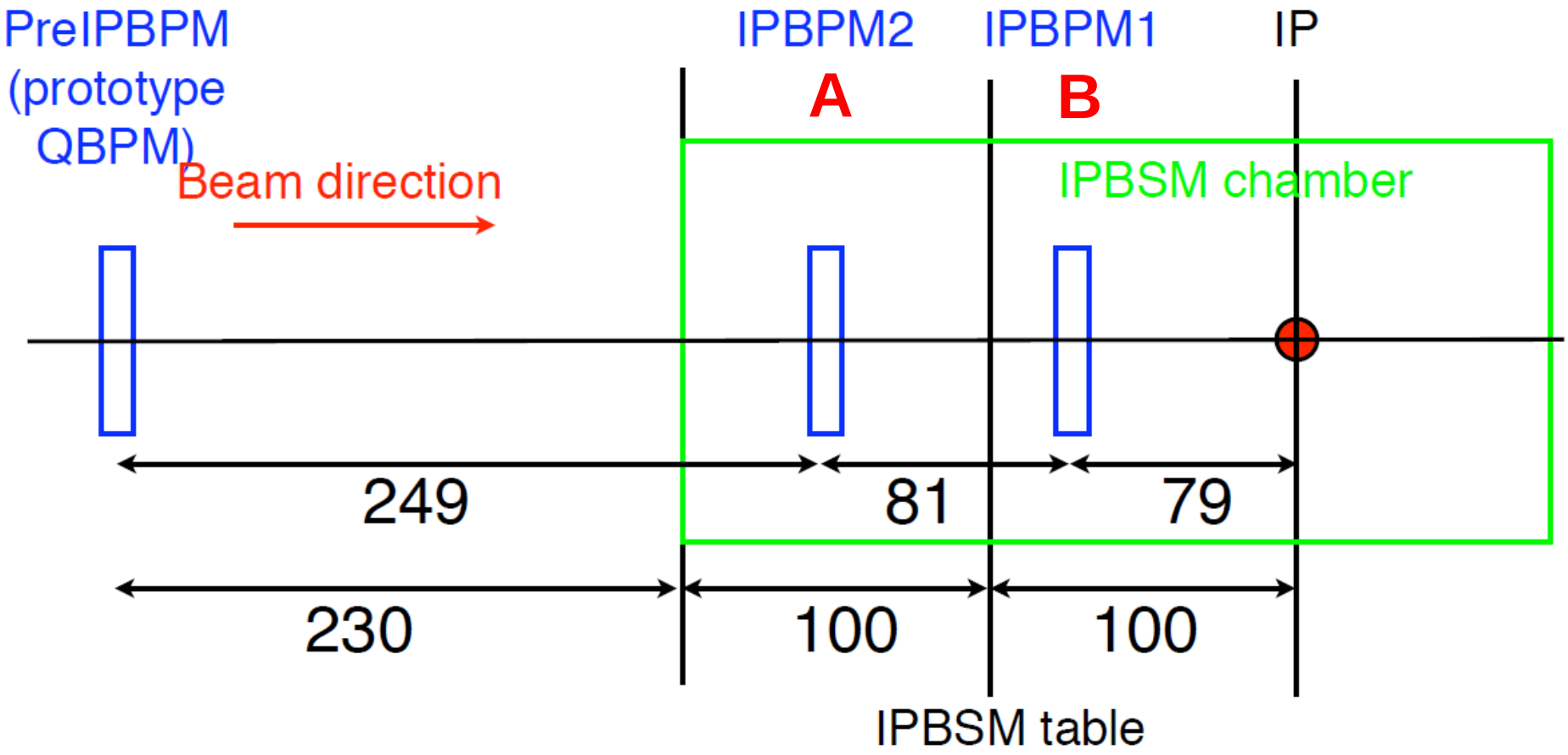
Summary

- **Well developed IP collision FB system designs for both ILC and CLIC**
- **Simulations demonstrate luminosity recovery capability**
- **Demonstrated prototypes with required performance parameters**
- **Progress on designing customised beamline components + optimising layout**
- **Ideas applicable at XFELs + rings**

NEWSFLASH from ATF2

- **Beam size ~ 65 nm achieved**
- **First attempts at stabilisation of small beam at nm level**

ATF2 IP region layout

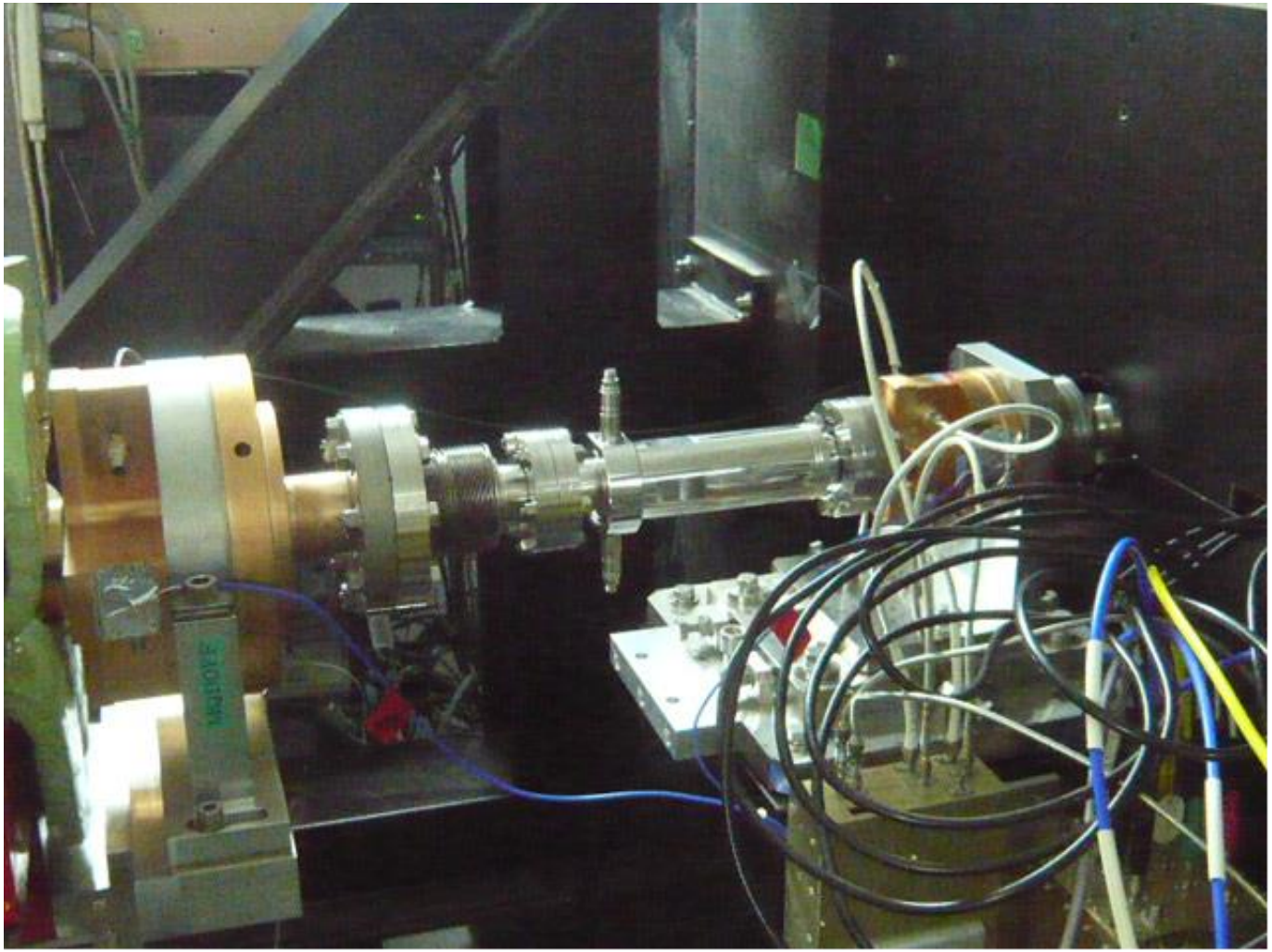


Layout with new IP kicker

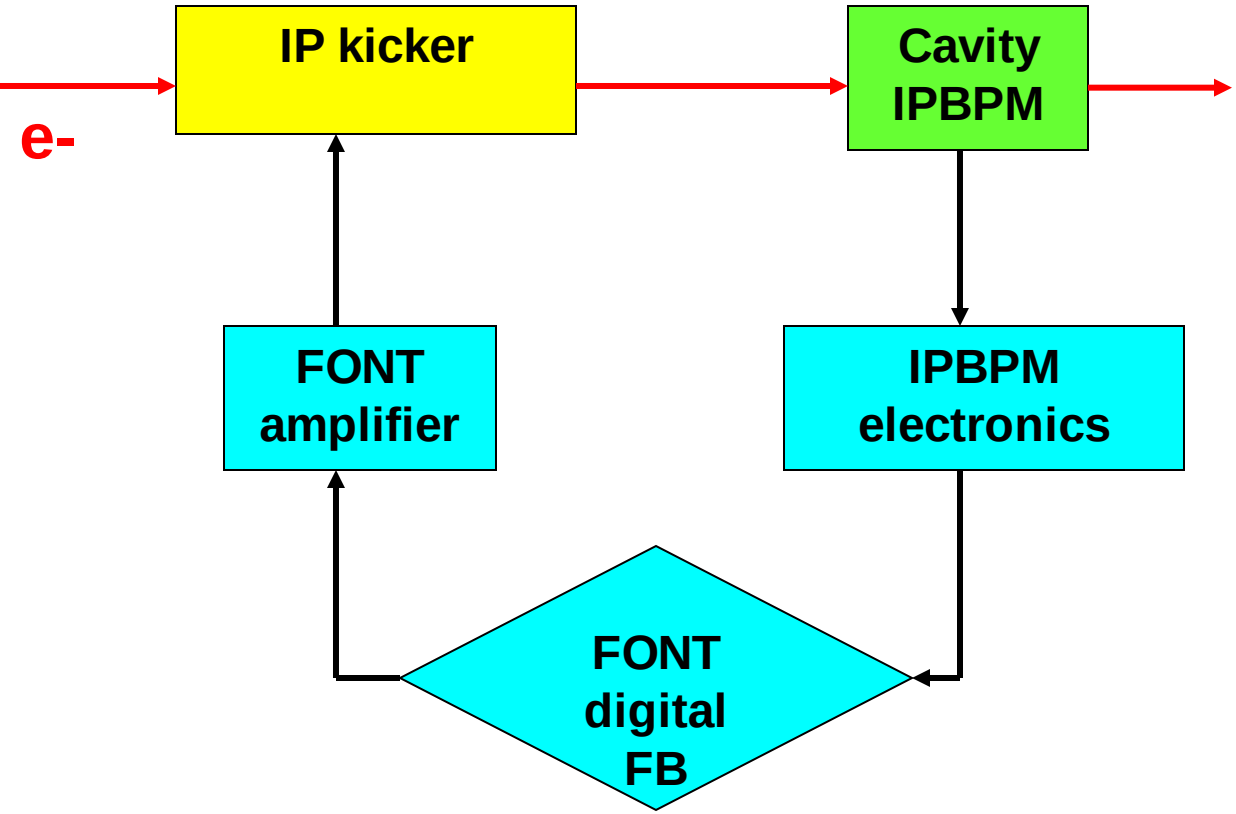
Designed by Oxford

Fabrication arranged by KEK

Installed May 2012

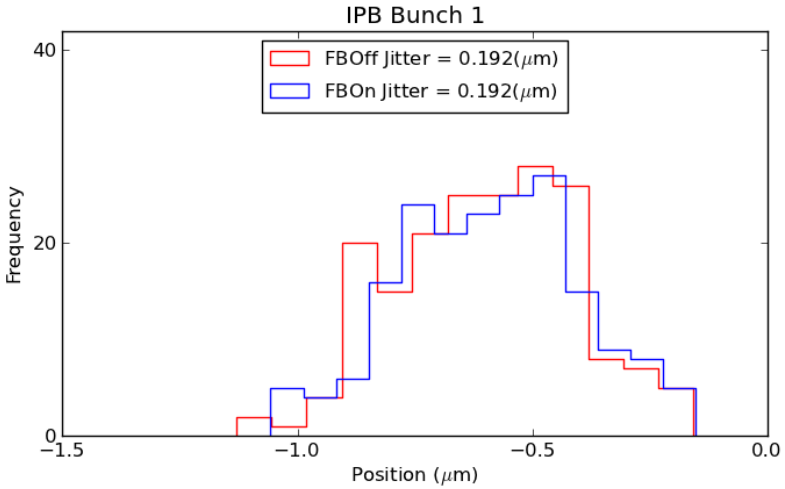


ATF2 IPFB tests June 2013



ATF2 IP FB results (June 2013)

Bunch 1:
Not corrected by FB
Incoming position jitter
~ 200nm



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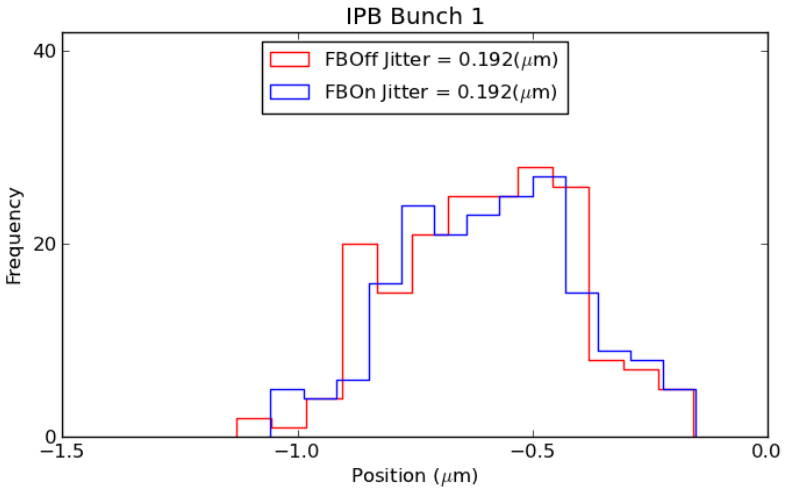
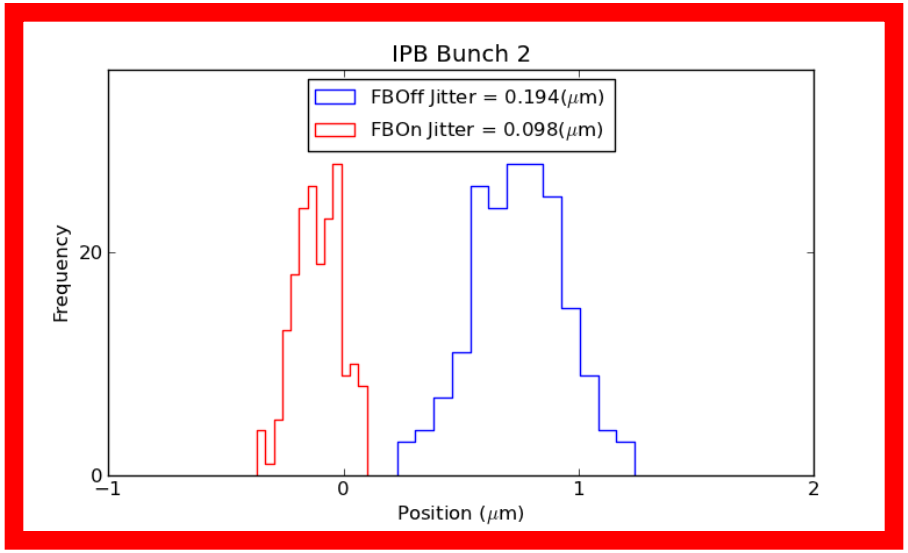


Bunch 2:
FB off jitter ~ 200nm

FB on:
beam zeroed
jitter reduced ~ 100nm



PRELIMINARY