BDS Instrumentation

Philip Burrows

John Adams Institute, Oxford University

Mike Woods

SLAC

Thanks to: Manfred Wendt (FNAL)

Draft BDS Instrumentation WBS

1. BPMs
2. Emittance: transverse
3. Emittance: longitudinal
4. Beam current monitors
5. Beam phase monitors
6. Beam loss monitors
7. Beam feedback systems
8. Beam energy measurements
9. Beam polarisation measurement
10. Background monitors
11. Collision diagnostics

Draft BDS Instrumentation WBS

1. BPMs
    - 1.1 Buttons
    - 1.2 Striplines
    - 1.3 Warm C-band cavities
    - 1.4 Warm S-band cavities
    - 1.5 Warm L-band cavities
2. Emittance diagnostics: transverse
    - 2.1 Laserwires
    - 2.2 Optical monitors (ODR, OTR, X-ray SR)
3. Emittance diagnostics: longitudinal
    - 3.1 Deflecting-mode (cold) cavities
    - 3.2 Other: electro-optic, diodes, Smith-Purcell …

Draft BDS Instrumentation WBS

4. **Beam current monitors**

5. **Beam phase monitors**

6. **Beam loss monitors:**

    6.1 PMT

    6.2 Ion chambers

7. **Feedback systems:**

    7.1 IP position, angle, luminosity (intra-train + 5Hz)

    7.2 Upstream trajectory (5Hz)

    7.3 BDS entrance intra-train

    7.4 Integration and interface to global system

Draft BDS Instrumentation WBS

8. Beam energy measurements:

- **8.1 Upstream spectrometer**
- **8.2 Extraction-line system**
- **8.3 Energy spread**
- **8.4 E-z correlations**

9. Polarimetry:

- **9.1 Upstream**
- **9.2 Extraction-line**

Draft BDS Instrumentation WBS

10. Background monitors:

- **10.1 BSR pairs/photons**
- **10.2 SR photons**
- **10.3 muons**
- **10.4 neutrons**
- **10.5 beam halo**
- **10.6 EMI?**

Draft BDS Instrumentation WBS

11. Collision diagnostics:

11.1 Luminosity

11.2 Beam offsets

11.3 Beam divergence angles

11.4 Beamcal

11.5 Gamcal

11.6 Beam waists

11.7 Dispersion

11.8 Bunch tilts

'Standard diagnostics': alignment, B-field monitors, vibrations …

Work package outline

- scope
- goals
- schedule
- milestones
- deliverables
- resources (personnel, materials, infrastructure)
- co-ordinator

ILC Project Management expects an MOU for each Work Package

Generalised scope of each task

Review of performance requirements

Document listing specifications

resolution, timing, dynamic range, linearity …

Review of state of the art / technologies

Specification of baseline / alternate technology

Conceptual engineering specification

Drawing / manufacturer's part number …

Specification of R&D programme with deliverables

Revised cost estimate

Expressions of interest

Button, stripline, cavity BPMs	**FNAL**
Laserwire	**UK**
Bunch length (also beam phase)	**UK, FNAL**
OTR/ODR monitors	**UK, FNAL**
Toroids	**FNAL**
Feedback systems	**UK, FNAL**
E-spectrometer	**UK, UCB, JINR, DESY, SLAC, Notre Dame, Oregon**
Polarimeter	**Iowa, INFN, SLAC, Tufts**
Gamcal	**BNL, Yale, DESY**
BDS/IR alignment	***UK***
Shintake Monitor (ATF2)	***Tokyo***

BDS Instrumentation Meetings & Reviews

- start monthly meetings in November
- updates from the Work Package co-ordinators
- detailed review/discussion for one system each month

Proposed system reviews

- November – transverse spotsize/emittance: laser wire + other proposals
  (OTR, ODR, Shintake)
- December – beam position monitors
- January – bunch length: XCAV/LOLA, electro-optic + other proposals
  (Smith-Purcell, diodes)
- February – collision diagnostics: BeamCAL, GamCAL + other
- March – beam loss, backgrounds and beam halo
- April – polarization and energy (during workshop at DESY-Zeuthen)

Following slides

Talk given at BDS kick-off meeting

Outline

- **Reminder of RDR**
- **EDR instrumentation issues**
- **Updated instrumentation list**
- **Expressions of interest**
- **Development of WBS**

Reminder of RDR

- **Instrumentation was ‘technical system’ with pan-machine view**
- **Purview: meas. of *beam-related* parameters:**

  eg. beam position, charge, size …

  NOT

  RF control, temperature, pressure, flow, currents …
- **Boundary with Controls defined (NB feedbacks)**
- **Luminosity, energy, polarimetry explicitly excluded**
- **Did not consider monitors for beam-related backgrounds**

RDR instrumentation master table

INSTRUMENT	AREA					
requirements (e.g. resolution)	e^- source	e^+ source	DR	RTML	ML	BDS
Button/stripline BPM	69	400	2 × 747			120
resolution (μm)	10-30	10-30	<0.5			<100
C-Band Cavity BPM (warm)		109		2 × 649		262
resolution (μm)		<0.1-0.5		<0.1-0.5		<0.1-0.5
S-Band Cavity BPM (warm)						14
resolution (μm)						< 0.1-0.5
L-Band Cavity BPM (warm)				2 × 27		42
resolution (μm)				<1-5		<1-5
L-Band Cavity BPM (cold)				2 × 28	2 × 280	
resolution (μm)				~0.5-2	~0.5-2	
Laser-wire IP	8	20	2 × 1	2 × 12	2 × 3	8
resolution (μm)	<0.5-5	<0.5-5	<0.5-5	<0.5-5	<0.5-5	<0.5-5
Wirescanner	12	8				
Optical Monitors	6	17	2 × 2	2 × 8		11
DMC	3	4		2 × 2		2 (cold)
resolution ΔE ~0.1% / s_z ~100 μm						
Beam Current Monitors	7	11	2 × 1	2 × 2	2 × 3	10
Beam Phase Monitor	4	2		2 × 3		2
BLM (PMT/IC)	60/2	400/20	2 × 40/4	2 × 75/2	2 × 325/10	100/10
Feedback System	5	10	2 × 2	2 × 1	2 × 10	12

RDR instrumentation master table

INSTRUMENT	AREA					
requirements (e.g. resolution)	e^- source	e^+ source	DR	RTML	ML	BDS
Button/stripline BPM	69	400	2 × 747			120
resolution (μm)	10-30	10-30	<0.5			<100
C-Band Cavity BPM (warm)		109		2 × 649		262
resolution (μm)		<0.1-0.5		<0.1-0.5		<0.1-0.5
S-Band Cavity BPM (warm)						14
resolution (μm)						< 0.1-0.5
L-Band Cavity BPM (warm)				2 × 27		42
resolution (μm)				<1-5		<1-5
L-Band Cavity BPM (cold)				2 × 28	2 × 280	
resolution (μm)				∼0.5-2	∼0.5-2	
Laser-wire IP	8	20	2 × 1	2 × 12	2 × 3	8
resolution (μm)	<0.5-5	<0.5-5	<0.5-5	<0.5-5	<0.5-5	<0.5-5
Wirescanner	12	8				
Optical Monitors	6	17	2 × 2	2 × 8		11
DMC	3	4		2 × 2		2 (cold)
resolution ΔE ∼0.1% / s_z ∼100 μm						
Beam Current Monitors	7	11	2 × 1	2 × 2	2 × 3	10
Beam Phase Monitor	4	2		2 × 3		2
BLM (PMT/IC)	60/2	400/20	2 × 40/4	2 × 75/2	2 × 325/10	100/10
Feedback System	5	10	2 × 2	2 × 1	2 × 10	12

RDR BDS Instrumentation List

• Button / stripline BPMs	120	< 100 um
• Warm C-band cavity BPMs	262	0.1 - 0.5 um
• Warm S-band cavity BPMs	14	0.1 - 0.5 um
• Warm L-band cavity BPMs	42	1 – 5 um
• Laserwire IPs	8	0.5 - 5um
• Optical monitors (bunch size)	11	
• Deflecting-mode (cold) cavities	2	100 um
• Beam current monitors	10	
• Beam phase monitors	2	
• Beam loss monitors (PMT/IC)	100/10	
• Feedback systems	12	

RDR BDS Instrumentation List

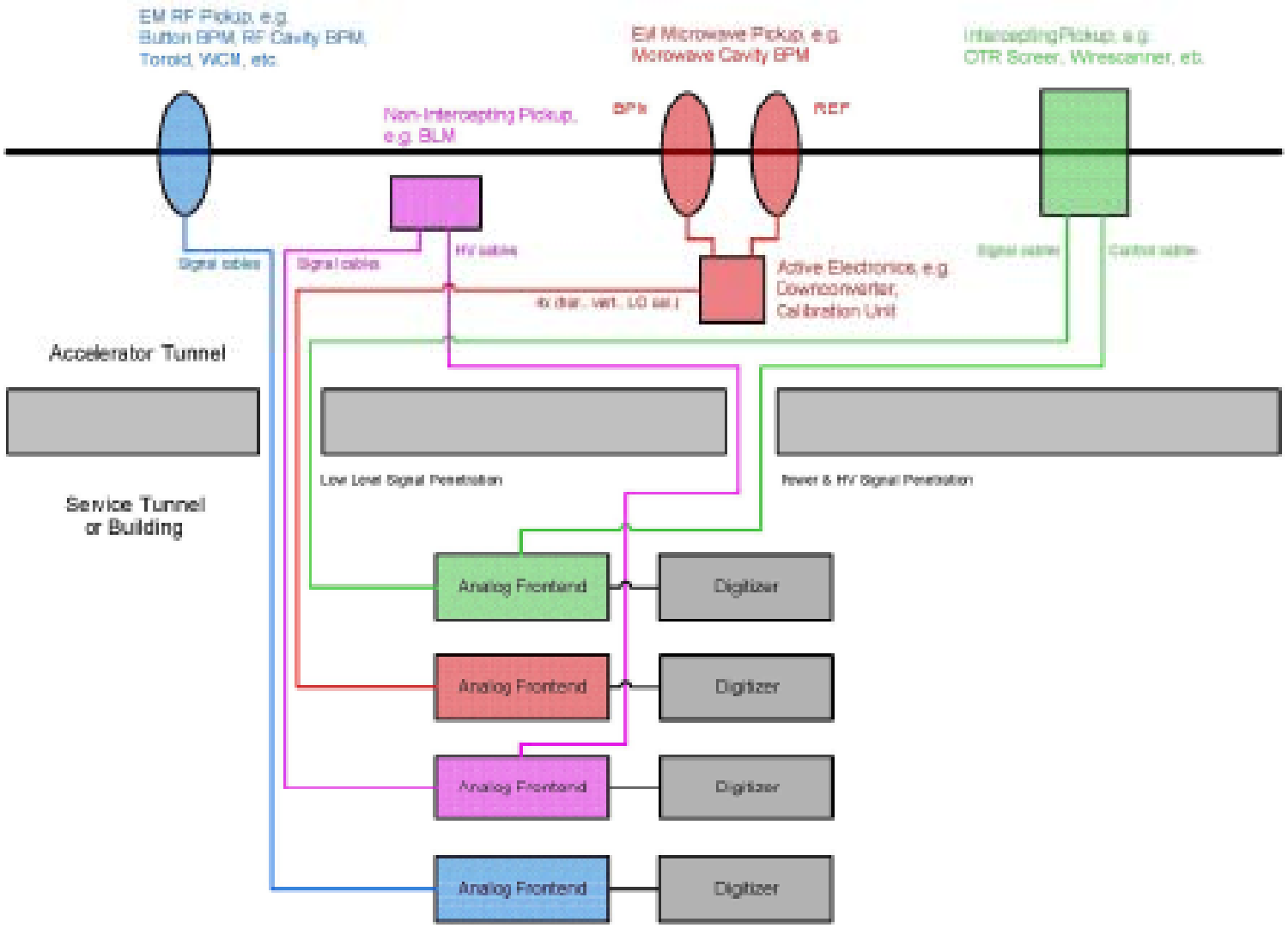
• Button / stripline BPMs	120	< 100 um
• Warm C-band cavity BPMs	262	0.1 - 0.5 um
• Warm S-band cavity BPMs	14	0.1 - 0.5 um
• Warm L-band cavity BPMs	42	1 – 5 um
• Laserwire IPs	8	0.5 - 5um
• Optical monitors (bunch size)	11	
• Deflecting-mode (cold) cavities	2	100 um
• Beam current monitors	10	
• Beam phase monitors	2	
• Beam loss monitors (PMT/IC)	100/10	
• Feedback systems	12	

NO SPARES!

What was costed

- Pickup station (typically part of vacuum system)
- ‘Detectors’: PMTs, scintillators, lasers, calib. systems
- RF system + infrastructure for DMCs
- Mechanical setup, incl. motors, switches …
- Signal + control cables, connectors, patch panels
- Dedicated readout electronics (analogue + digital)
- Control, timing, calibration electronics
- Local software + firmware
- Intra-train feedbacks: dedicated DAQ

Boundary with Controls



BDS Feedbacks

- **Train-to-train trajectory 5 Hz**
- **IP collision: intra-train (3 MHz) + 5 Hz**
- ***IP luminosity: intra-train***

NB upstream feedbacks:

- **End-of-linac trajectory: intra-train**
- **RTML feed-forward: intra-train**
- **Linac cascaded trajectory 5 Hz**

RDR costs / cost drivers

Machine-wide:

- **Value: c. XX MILCU**
- **Labour:**

  Prototyping + testing: 257 person-years

  NB: installation labour covered elsewhere
- **Biggest + costliest systems:**

  4500 BPMs (47%) , 68 laserwire IPs (22%)

BDS:

- **3.4% BDS cost – Andrei, 40 person-years**

EDR Instrumentation: issues

Instrumentation divided among areas; need to:

- **Ensure coordinate design of common devices**

  (BPMs, toroids, bunch length, laserwire …)
- **Avoid duplication of effort**
- **Keep track of interfaces w. Controls**
- **Work closely w. Accelerator Physics group**
- **Define interface with detectors:**

  ‘MDI’ instrumentation: L, E, P, backgrounds?

Comments

Some devices are high-volume, with ‘low’ unit cost:

toroids, BPMs …

Some devices are (unique) complex systems:

laserwires, energy spectrometers, polarimeters,

LOLA bunch-length monitor, feedback systems …

Vast majority of effort will go into complex systems!

EDR BDS Instrumentation: plan

- **Reviewing instruments list:**
  - **Is it consistent / correct?**
  - **Missing items?**
- **Collecting EoIs**
- **Need to review/define:**
  - **Scope of work for EDR**
  - **Priorities for effort: design + R&D**
- **Develop WBS in more detail**

For each device

- **Review required performance specifications**

  iteration with Accelerator Physics
- **Review RDR technologies:**

  ‘state of the art’ devices: good enough, or R&D needed?

  simpler/cheaper technologies?

  baselines/alternatives?

  fewer (or more!) devices?
- **Refine EDR work plan + deliverables:**

  Specification of ‘off-shelf’ devices?

  Engineering design of (pre-industrial) prototype?

  Significant R&D for complex devices/systems?

PRELIMINARY guess of status

• Button / stripline BPMs	off-shelf / engineering
• Warm C-band cavity BPMs	engineering / R&D
• Warm S-band cavity BPMs	engineering / R&D
• Warm L-band cavity BPMs	engineering / R&D
• Laserwire IPs	R&D / engineering
• Optical monitors (bunch size)	R&D / engineering
• Deflecting-mode (cold) cavities	engineering
• Beam current monitors	off-shelf
• Beam phase monitors	R&D / engineering
• Beam loss monitors (PMT/IC)	engineering
• Feedback systems	R&D / engineering

Comment

- **In some cases (cavity BPMs, toroids …) required performance may have been achieved for SINGLE-bunch mode**
- **Further R&D may be required to demonstrate TIME-RESOLVED performance bunch-by-bunch**

‘Physics’ instrumentation

- **Upstream + downstream**

  energy + energy spread measurement

  polarimeters
- **Luminosity monitoring:**

  Beamcal, Gamcal, rad. Bhabhas …
- **Beam correlations: y-z, x-z, E-z?**
- **IP collision parameters: x, x’, y, y’, offsets, spot sizes, coupling …**
- **Disrupted beam parameters**
- **Beam halo, beam loss monitoring**
- **Background monitoring:**

  muons, neutrons, photons, e+e-

Commissioning strategy

- **If commissioning of BDS and/or IR is anticipated BEFORE the detector(s) are rolled on beamline**

  it may be prudent to plan for appropriate instrumentation at the Machine Detector Interface

- **NOT included so far**

Expressions of interest

Button, stripline, cavity BPMs	**FNAL**
Laserwire	**UK**
Bunch length (also beam phase)	**UK, FNAL**
OTR/ODR monitors	**UK, FNAL**
Toroids	**FNAL**
Feedback systems	**UK, FNAL**
E-spectrometer	**UK, UCB, JINR, DESY, SLAC, Notre Dame, Oregon**
Polarimeter	**Iowa, INFN, SLAC, Tufts**
Gamcal	**BNL, Yale, DESY**
BDS/IR alignment	***UK***
Shintake Monitor (ATF2)	***Tokyo***

Comments on EoIs

- **Not all bases covered by EoIs**
- **Scope of EoIs varies considerably**
- **Levels of resources vary greatly**
- **Not yet ‘unpacked’ EoIs**
- **Vastly more worldwide expertise than in submitted EoIs**

Towards a WBS

- **Draft WBS for WP9 …**
- **Laundry-list of instrumentation!**

NB: **Overlap with WP2: ATF2**

Coupling with WP3: accelerator physics design

Coupling with WP4: IR + IR integration

Interface with WP10: vacuum system

Interface with Controls

Global approach needed for feedback

→ is a ‘systems’ approach more desirable?

MDI 'Diagnostics'

- Electromagnetic interference antennae?
- Radiation damage monitors?
- Crab cavity phase
- Magnet vibrations
- Alignment
- Vacuum
- Temperatures
- Magnetic fields
- Power supply currents