EXPERIENCES OF WORKING ON
MACHINE R&D:

FEEDBACK ON NANOSECOND
TIMESCALES (FONT)

Philip Burrows
University of Oxford

• Personal introduction/background
• The LC luminosity challenge
• The FONT programme
• Observations/lessons/suggestions
• 1985-88: Ph.D. student at Oxford
  TASSO experiment at PETRA at DESY
e^+e^- annihilations \(14 \leq \sqrt{s} \leq 46\) GeV
  multijet events + jet fragmentation

• 1989-98: postdoc → staff scientist at MIT
  SLD experiment at SLC at SLAC
e^+e^- annihilations \(\sim 91\) GeV
  Warm Iron Calorimeter + VXD alignment
  Shift Expert + Run Coordinator
  co-led SLD QCD Group

• 1998-2002: Advanced Fellow at Oxford
  SLD data analysis
  LC CCD vertex detector R&D
  Lumi optimisation and fast feedback
THE LC LUMINOSITY CHALLENGE

<table>
<thead>
<tr>
<th>Machine</th>
<th>$E$ (GeV)</th>
<th>$\mathcal{L}$ ($/\text{cm}^2$/s)</th>
<th>$x$ size (nm)</th>
<th>$y$ size (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLC</td>
<td>100</td>
<td>$10^{30}$</td>
<td>1400</td>
<td>600</td>
</tr>
<tr>
<td>TESLA</td>
<td>500</td>
<td>$3 \times 10^{34}$</td>
<td>500</td>
<td>5</td>
</tr>
<tr>
<td>N/JLC</td>
<td>500</td>
<td>$2 \times 10^{34}$</td>
<td>300</td>
<td>5</td>
</tr>
<tr>
<td>CLIC</td>
<td>3000</td>
<td>$10^{35}$</td>
<td>40</td>
<td>1</td>
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</table>

⇒ Next-generation machines need nm-scale vertical beam sizes
GROUND MOTION

Relative Motion of two final lenses

SLC ground motion data:
LUMINOSITY LOSS
DUE TO BEAM OFFSET

Oxford ‘GUINEA PIG’ simulations:
FAST IP FEEDBACK

• Useful ⇒ intra-train

• Bunch separation $\Delta t$:

<table>
<thead>
<tr>
<th>Machine</th>
<th>$\Delta t$ (ns)</th>
<th># bunches</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESLA</td>
<td>337</td>
<td>2820</td>
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<tr>
<td>NLC</td>
<td>1.4</td>
<td>190</td>
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<tr>
<td>CLIC</td>
<td>0.67</td>
<td>154</td>
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</table>

⇒ Feedback On Nanosecond Timescales (FONT)

• 1ns ≡ 1 foot

⇒ compact system very close to IP analogue electronics (J/NLC, CLIC)
EFFECT OF FEEDBACK ON LUMI

TESLA case (N. Walker/A. Wolski):

![Graph showing the effect of feedback on luminosity over time.]
CONCEPTUAL FONT LAYOUT: IR WITH CROSSING ANGLE (JLC, NLC, CLIC)

(M. Breidenbach, G. Haller, S. Smith)
SIMULATIONS

Set up powerful simulation infrastructure:

- Linac beam transport: **PLACET/LIAR**
- Beam del system xport: **MERLIN/LIAR**
- Beam-beam dynamics/EM backgrounds: **GUINEA PIG**
- Feedback model: **SIMULINK/MATLAB**
- IR material/knock-on EM backgrounds: **GEANT**
- neutron backgrounds: **FLUKA**
FEEDBACK MODEL

Includes:

- Signal propagation delays
- BPM parameters + response time
- Kicker parameters + response time
Choice of gain ‘delicate’:

⇒ feed-forward from linac?
⇒ adaptive algorithms?
⇒ robust algorithms
‘Simulate’ NLC/JLC/CLIC beam using NLCTA 150ns bunchtrain

‘Simulate’ ground motion with dipole magnet

Measure offset of leading bunches in fast X-band BPM

Feedback correction to upstream kicker

Kick trailing bunches towards nominal

Check with downstream BPM

Adjust kicker correction + repeat

Aim to close loop within 30 ns
DIPOLE OFFSET MAGNET

Reclaimed SLC ‘type-4’ linac corrector
6A peak current $\rightarrow$ 5 mm @ BPM
NEW FAST BEAM POSITION MONITOR

Built new X-band ‘button’ BPM:
resolution $\sim 10 \, \mu m$

Built prototype BPM processor circuit:
risetime $\sim 3 \, \text{ns}$
FAST KICKER

Reclaimed SLC kicker:

Designed and built kicker driver amplifier:

3-stage tube amplifier
Y690 planar triode tubes
Power $\leq 5$ kW
• Logistics non-trivial!

2 grad students @ SLAC c. 2 years
others @ SLAC frequently
weekly phone/www meetings

• UK funding not entirely straightforward:

2 students, 1 RA, 0.4 engineer, 0.7 faculty
LTA support for 2 students $40k/yr
Travel budget $25k/yr
Hardware/consumables $15k

• SLAC contributing significantly:

Beampipe fab, vacuum installations, BPM
Refurbished dipole, kicker, cables …

Accelerator physics input
NLCTA beamtime and operations

• ‘Future projects’ OK for UK students/RAs
FONT COLLABORATORS

Oxford:  SLAC:
Philip Burrows  Joe Frisch
Simon Jolly  Keith Jobe
Gerald Myatt  Tom Markiewicz
Gavin Nesom  Janice Nelson
Colin Perry  Marc Ross
Glen White  Steve Smith

DESY:  KEK:
Nick Walker  Taka Matsui
Manfred Wendt  Toshi Tauchi

CERN:
Ralph Assman
Daniel Schulte

Frank Zimmermann