Aims

Multi-bunch simulations for TESLA

Future plans
Aims

• Study performance of accelerators with multi-bunch tracking Linac-IP.
• Integrated test environment- all technologies/ all simulation environments.
• Provide database of IP parameters resulting from simulations for Particle/Accelerator Physics community (Lumi, Backgrounds etc).
Performance of TESLA with Angle + IP Fast Feedback

• Look at luminosity performance of TESLA model with multi-bunch tracking through LINAC and BDS (currently TDR BDS).

• Include short+long range wakes in Linac structures, and therefore effects of systematic bunch distortions (bananas) at IP beam-beam interaction.

• Study effectiveness of IP and Angle fast beam-based feedback systems.
Beam-Beam Interaction

- Beam-beam EM interactions at IP provide detectable FB signal.
- Beam-beam interactions modelled with GUINEA-PIG or CAIN.
- Kick angle and percentage luminosity loss for different vertical beam offsets shown.
TESLA Fast Feedback Systems: IP Feedback

- Detect beam-beam kick with BPM(s) 1 or either side of IP.
- Feed signal through digital feedback controller to fast strip-line kickers either side of IP.
TESLA Fast Feedback Systems: Angle Feedback

• Normalised RMS vertical orbit in TESLA BDS due to 70nm RMS quadrupole vibrations.
• Correct IP angle crossing at IP by kicking beam at entrance of FFS (~1000m).
• No significant sources of angle jitter beyond this point as all subsequent quads at same IP phase.
TESLA Fast Feedback Systems: Angle Feedback

- Place kicker at point with relatively high $\beta$ function and at IP phase.
- Can correct $\sim 130 \, \mu\text{rad}$ at IP ($>10\sigma_y$) with 3x1m kickers.
- BPM at phase $90^\circ$ downstream from kicker.
- To cancel angular offset at IP to $0.1\sigma_y$, level:
  - BPM 1: required resolution $\sim 0.7\mu\text{m}$, FB latency $\sim 4$ bunches.
  - BPM 2: required resolution $\sim 2\mu\text{m}$, FB latency $\sim 10$ bunches.
Banana Bunches

• Short-range wakefields acting back on bunches cause systematic shape distortions:
  • Z-Y plane of a sample bunch:

• Only small increase in vertical emittance, but large loss in luminosity performance with head-on collisions due to strong beam-beam interaction.

• Change in beam-beam dynamics from gaussian bunches.
Banana Bunch Dynamics

- Luminosity of a sample bunch over range of position and angle offsets.
- Wait for IP and ANG FB systems to ‘zero’ – then fine tune by stepping in y then y’ using LUMI monitor to find optimum collision conditions.
Fast Lumi monitor allows bunch-bunch readout of e+e- pair hits which are at Max at Max lumi
Multi-Bunch Simulations at QMUL

• Track >500 bunches through Linac, BDS and IP to observe dynamics of fast feedback correction and determine estimate of train luminosity.

• Typical simulation times on modern PC 40 hours+ depending on simulation parameters (per seed).

• To gauge performance for a variety of parameters/sim environments/machines need many cpu hours.

  • QMUL high-throughput cluster: GRID cluster development. Currently 32 * Dual Athlon2400+ (64 CPUs).

  • Currently being upgraded to ~320 CPUs with addition of 2.8 GHz P4 Xeon Processors.
QMUL High-Throughput Cluster

- QMUL Test GRID cluster - [http://194.36.10.1/cluster](http://194.36.10.1/cluster)
- Boxes run Redhat 9 Linux – have 100 Unix Matlab licenses.
Linac Simulation

PLACET:

• Structure Misalignment: 0.5mm RMS y, 0.3mrad y’ error.
• BPM misalignment: 25μm (y).
• Apply 1-1 steering algorithm.
• Choose lattice that gives approx. 50% vertical emittance growth. (single bunch tracking).
• Injection: 0.2, 0.5, 1.0σ RMS error.
• Misalign Quads 100nm RMS in y.
• Detune structures.
• Generate 500 bunches (multiple random seeds).
• Electron beam at LINAC exit
  • $y$ (left), emittance (right).
• Long-range wakes have strong effect on bunch train.
• Need to perform steering on plateaux not first bunch- slow.
BDS/IP Simulation

MATMERLIN:

• Random jitter on quads = 35nm RMS.
• Add 1.4ppm energy jitter on e⁻ bunches (simulates passage of e⁻’s through undulator).
• Track 80,000 macro-particles per bunch.

Feedback (Simulink model in Matlab):

• BPM error: 2μm (ANG FB) 5μm (IP FB)
• Kicker errors: 0.1% RMS bunch-bunch.

IP (Guinea-Pig):

• Input macro-beam from MatMerlin BDS (non-gaussian).
• Calculates Lumi & Beam-Beam kick.
• Produces e⁺e⁻ pairs -> track through solenoid field and count number hitting LCAL first layer for Lumi FB signal.
IP Feedback

- Corrects < 10 bunches.
- Corrects to finite $\Delta y$ due to banana bunch effect.
- Vertical Beam-Beam scan @ bunch 150.
IP Feedback

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5 Bunch $e^+e^-$ Int. Signal
• Angle scan after 250 bunches when position scan complete.
• Noisy for first \( \sim 100 \) bunches (HOM’s).
• FB corrects to \(<0.1 \sigma_y\).
Luminosity

- Luminosity through bunch train showing effects of position/angle scans (small).
- Total luminosity estimate: \( L(1-500) + L(450-500) \times (2820-500) \)
Multiple Seed Run (No HOMs)

- No GM
  \[ \mu = 1.0 \pm 0.005 \]

- GM (35nm BDS, 100nm Linac)
  \[ \mu = 0.95 \pm 0.1 \]

- GM + 0.2\( \sigma \) Inj. Jit
  \[ \mu = 0.92 \pm 0.1 \]

- Luminosity fraction compared with mean no-Ground Motion case.
Multiple Seed Run

- **No GM**
  \[ \mu = 10.4 \pm 0.02 \]

- **GM (35nm BDS, 100nm Linac)**
  \[ \mu = 10.6 \pm 0.3 \]

- **GM + 0.2σ Inj. Jit**
  \[ \mu = 10.7 \pm 0.4 \]

• Sum of Vertical IP Bunch Spot Sizes.
Extent of Banana Effect?

- Lumi proportional to $1/x$ if no banana (and offset), or optimised banana.

- No correlation -> lumi loss effects due to bunch shapes?
Effect of Lumi-Scan

- Effect of Pos & Ang Lumi scans compared with start of pulse with FB only.

- GM + 0.2 σ RMS Injection error data.

- After position scan

- After position and angle scan
LC Simulation Web Page

• Store all beam data from simulation runs online

• http://hepwww.ph.qmul.ac.uk/lcdata
Summary and Future Plans

• Facility for parallel processing of accelerator codes set-up.
• Used to test TESLA performance with Fast-Feedback.
  • Need to understand lumi performance & optimise.
  • Include bba in linac (&BDS- add BDS alignment errors).
  • Incorporate other feedbacks in linac and BDS.
  • New BDS lattice(s).
• Similar tests with NLC (&CLIC)…
• New people at QMUL to work on simulations:
  • Tony Hartin (Phys. Programmer).
  • Shah Hussain (PhD Student).